XII International Workshop on Ring Imaging Cherenkov Detectors - RICH2025

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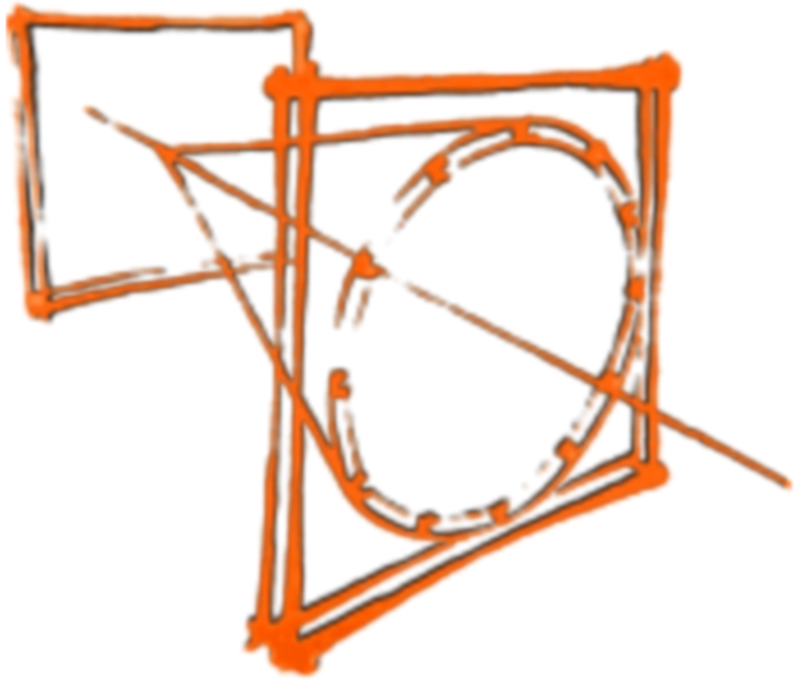

Book of Abstracts

RICH 2025
XII International Workshop on Ring Imaging Cherenkov Detectors
Mainz, Germany 15-19 September 2025
Topics
Cherenkov light imaging in current particle and nuclear physics experiments
Cherenkov light imaging in neutrino and astroparticle physics experiments
Pattern recognition and data analysis
R&D on Cherenkov light imaging systems for future experiments
Photon sensor techniques for Cherenkov imaging counters
Technological aspects and applications of Cherenkov light detectors
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Cherenkov light imaging in neutrino and astroparticle physics experiments

LACT: Status and Future Plans

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In 2024, the Large High Altitude Air Shower Observatory (LHAASO) released its first catalog of ultra-high-energy (UHE) gamma-ray sources, identifying over 40 such sources. This marked a significant advancement in UHE gamma-ray astronomy. Many of these sources exhibit extended features, necessitating next-generation Imaging Atmospheric Cherenkov Telescopes (IACTs) with higher angular resolution and sufficient sensitivity for detailed morphology studies. To address this need, we propose the Large Array of Imaging Atmospheric Cherenkov Telescopes (LACT), comprising 32 telescopes capable of achieving an angular resolution better than 0.05° for energies higher than 10 TeV. For gamma rays around 100 TeV, a 500-hour exposure on a single source will yield sensitivity comparable to one year of observations with LHAASO. These telescopes will be set up into the LHAASO detector array, taking advantage of LHAASO unique muon detector system to improve gamma-proton discrimination at ultra-high energies. This enhancement will significantly increase the detection sensitivity for gamma rays above 10 TeV, providing a substantial advantage over other IACT experiments worldwide. This presentation will give an overview of the performance and properties of LACT, the progress of the LACT project, and future construction plans.

R&D on Cherenkov light imaging systems for future experiments

A DIRC-like TOF detector for PID at STCF

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A DIRC-like TOF (DTOF) detector is chosen for particle identification (PID) at the super tau-charm facility (STCF) in the endcap region. A total timing precision of 50 ps (DTOF intrinsic ~30 ps) is required to achieve 4σ separation of π/K up to 2 GeV/c momentum, by combining both the TOF measurement and the multi-dimensional (timing-positional) information of Cherenkov photons. In this presentation the overall progress of DTOF study will be introduced.
A full-size endcap DTOF prototype has been developed and tested using cosmic ray. The prototype utilizes a large-size (0.56 m2) high-quality fused silica plate (surface roughness below 1 nm) as the Cherenkov radiator and 42 MCP-PMTs (Hamamatsu R10754) as photon sensor. A raw light yield of about 38 photons per cosmic-ray track was observed, and a single-track intrinsic time resolution of ~21 ps was achieved, both agreed well with the Monte Carlo simulation.
In the view of cost and difficulty in transportation, a smaller endcap DTOF prototype (1/3 of the full-size one) underwent beam tests for PID capability validation at CERN's PS T9 line, in mid-2024. This prototype achieves a 50 ps time resolution (including T0 ~44 ps) for hadron beams and a separation performance of 4.4σ for π/p at 4 GeV/c (equivalent to π/K separation at 2 GeV/c) , which is consistent with the cosmic ray results and fulfills the requirements of STCF
Given the excellent performance of the endcap DTOF, we plan to apply this scheme to the barrel region as back up of the barrel PID detector for STCF. The difficulty of this scheme lie in the higher ambiguity in reconstruction due to multiple lateral reflections, which is also the main difference compared to the endcap DTOF. Preliminary simulations indicate that this scheme is feasible. Therefore, a full-size barrel DTOF prototype is developed to validate its feasibility. Its construction and cosmic-ray test are planned in the near future (~May to July) and most-recent results will be presented.

Cherenkov light imaging in neutrino and astroparticle physics experiments

KM3NeT: an Infrastructure for Underwater Cherenkov Neutrino Telescopes

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The KM3NeT Collaboration is incrementally building two underwater Cherenkov neutrino telescopes in the Mediterranean Sea. Both telescopes share the same technology for neutrino detection, by studying Cherenkov radiation from secondary charged particles produced in neutrino interactions. Photomultipliers are a common choice for the detection of Cherenkov radiation, but the hostile underwater environment, affected by sea currents and bioluminescence demands innovative solutions in KM3NeT.

The distinctive technological features of KM3NeT will be discussed, such as its sub-nanosecond timing accuracy and the few-centimetre accurate acoustic positioning of the detector elements. This results in a neutrino pointing accuracy of the order of 0.1° at very high neutrino energies for track-like events. The KM3NeT design is modular and allows for data taking with the telescope still in the construction stage. Early technical and scientific results are enticing. In particular, KM3NeT recently discovered a neutrino of unprecedented energy from outer space.

The speaker will cover KM3NeT telescope design and operation, as well as readout techniques, time synchronization, data flow and event reconstruction, highlighting both technical and scientific aspects.

Cherenkov light imaging in neutrino and astroparticle physics experiments

JUNO's Water Cherenkov Detector

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The Jiangmen Underground Neutrino Observatory (JUNO) is a state-of-the-art neutrino physics experiment located in South China. With 20 ktons of ultra-pure Liquid Scintillator, JUNO aims to achieve groundbreaking measurements, including the determination of Neutrino Mass Ordering and the precise measurement of three neutrino oscillation parameters with sub-percent precision. The central detector is immersed in a Water Cherenkov Detector (WCD), which contains 40 ktons of ultrapure water and 2,400 microchannel plate photomultipliers (MCP-PMTs), serving dual purposes of radioactive background suppression from surrounding rock and cosmic muon tagging. The inner surface of the water pool's wall is covered by 5 mm HDPE to prevent the rock emanated radon from diffusing into the water. Tyvek reflectors cover both the HDPE surface and the stainless lattice steel structure to enhance the light collection efficiency. A 100t/h ultra-pure water system, which could reduce radon to mBq/m3 level and radium to μBq/m3 level, maintains high water quality and ensures optimal detector performance. The 32-coil magnetic shielding system effectively mitigates geomagnetic field effects on PMT operation. The WCD demonstrates exceptional cosmic muon detection efficiency, exceeding 99% while suppressing muon-induced fast neutron backgrounds to ~0.1 events per day. This talk will provide an overview of the design and current status of JUNO's Water Cherenkov detector.

Technological aspects and applications of Cherenkov light detectors

Nuova Officina Assergi: the inNOvAtive facility for the production of large area Silicon photodetectors

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Nuova Officina Assergi (NOA) is a novel semiconductor facility located at INFN Laboratori Nazionali del Gran Sasso (LNGS) and operational since the beginning of 2023. According to the ISO-14644-1 standard, it has been classified an ISO-6 clean room and it extends over a surface of 420 m2. The infrastructure is divided in two experimental areas with a reduced radon concentration. A larger portion of 350 m2 has been conceived to assemble and test large arrays of Silicon-based devices operated down to cryogenic temperature. A smaller area of 70 m2 but with a more sided ceiling has been devoted to the integration of large volume detectors. The assembly area houses cutting-edge technology packaging machines: an automatic cryogenic wafer probe station, a semi-automatic dicing system with a set of semiconductor assembly tools, a high-speed dual head die flip-chip bonder and a fully automatic fine wire bonder. Furthermore several dedicated customized set ups and instrumentation for testing and qualifying the photosensor modules with the related electronics are a significant part of the equipment. Currently NOA is fully committed to the mass production of 600 Photo Detection Units (20 cm x 20 cm) for the DarkSide-20k experiment that will be documented in this context. This achievement would represent an important milestone for the DarkSide-20k collaboration but also would open new frontiers for future synergies between LNGS and other collaborations interested to adoperate such technologies.
The NOA clean room has been also designed to be compatible with the installation of a Radon abatement system that in perspective would provide the opportunity to perform the packaging and test operations in a Radon free environment.

Photon sensor techniques for Cherenkov imaging counters

Experiences with series produced Microchannel-Plate PMTs

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The PANDA experiment at FAIR will use two DIRC detectors for charged particle identification via Cherenkov light. Given the harsh radiation environment and the placement of the photosensors in magnetic fields of ~1 Tesla, Microchannel Plate Photomultiplier Tubes (MCP-PMTs) were selected as the designated sensors to fulfill the stringent requirements for the DIRCs. For the Barrel DIRC, 155 MCP-PMTs of type XP85112-S-BA were ordered from PHOTONIS. These sensors feature a $2{\times}2\,\text{inch}^2$ active area and MCPs with $10\,\mu$m pore diameter. To meet the experiment's lifetime requirement of about $5\,\text{C/cm}^2$ integrated anode charge over ten years, all MCPs were treated with atomic layer deposition (ALD) coatings of Al_2O_3 and MgO to improve their lifetime.

Before deployment of the sensors in PANDA a comprehensive and systematic quality control program is conducted at the University of Erlangen. It includes a wavelength scan of the quantum efficiency (QE) and the measurement of the gain curve, as well as scans of the spatial homogeneity of QE and gain. The collection efficiency, the time resolution and the rate capability are also

measured. Using the DiRICH/TRB DAQ system from GSI additional parameters such as the dark count rate (DCR), afterpulse probability (AP) and its time-of-flight (TOF) distribution, and crosstalk are assessed as a function of the active area. The large amount of tested MCP-PMTs allows insights in the quality of the production and provides a high statistics sample of the various performance parameters.

While the complex process of ALD coating enhances the lifetime of MCP-PMTs, it also introduces unwanted side effects regarding some key parameters in a fraction of the sensors. Some MCP-PMTs show characteristic peaks in AP TOF spectra most likely corresponding to Mg and Al ions, suggesting that the AP ions originate from the ALD layers. Furthermore, a subset of tubes exhibits a phenomenon referred to as "escalation", where massive photon rates are emitted from within the MCP. In some cases, escalation occurs only in local regions of the sensor. Tubes with higher DCR and AP levels tend to enter escalation at lower gain values, suggesting a correlation between ALD-induced impurities and this behavior.

Despite the observed issues, the large dataset from more than 90 tested sensors enables a detailed analysis of correlations among sensor parameters, such as the MCP resistance and rate capability. Tubes with lower MCP resistance generally perform better under high-rate conditions, maintaining stable gain at photon rates up to 10^6 photoelectrons/s/cm^2. However, no direct correlation was found between MCP resistance and the occurrence of escalation.
These and more findings will be presented.

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Poster Session

Conceptual Design of PID Detectors for the EicC Spectrometer

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The Electron-ion collider in China (EicC) is a proposed future electron-ion collider with a high luminosity above 2.0 × 10^33 cm^2·s^−1 and center-of-mass energy ranging from 15 to 20 GeV. Excellent particle identification (PID) with large momentum coverage is crucial for investigating exclusive and semi-inclusive processes, as well as enabling precise 3D imaging of the nucleon structure in the EicC experiment. To meet its PID requirement, the EicC Collaboration has proposed the conceptual design of various Cherenkov detectors, including: DIRC in the barrel region, dRICH in the ion-endcap region, and mRICH in the electron-endcap region. In order to study and optimize their performance, GEANT4 simulation involving advanced optical transmission and image reconstruction algorithms has been conducted.

Photon sensor techniques for Cherenkov imaging counters

The SiPM readout plane for the ePIC-dRICH photodetector at the EIC: overview and beam test results

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The dual-radiator Ring Imaging Cherenkov (dRICH) detector of the ePIC experiment at the future Electron-Ion Collider (EIC) will make use of SiPM sensors for the detection of the emitted Cherenkov light. The photodetector will cover ~ 3 m^2 with 3×3 mm^2 pixels, for a total of more than 300000 readout channels and will be the first application of SiPMs for single-photon detection in a collider experiment. SiPMs are chosen for their low cost and high photon detection efficiency, which remains unaffected even in the presence of a significant magnetic field (~ 1 T at the dRICH location). However, since they are not radiation-hard, careful attention is required to preserve their single-photon counting capabilities and to keep the dark count rate (DCR) under control throughout the years of operation of the ePIC experiment. DCR control can be achieved by operating SiPMs at low temperatures and by recovering radiation damage through high-temperature annealing cycles. The exploitation of the precise timing of SiPMs with fast TDC electronics further helps to reduce the impact of DCR as background noise and to improve the signal-to-noise ratio.

In this talk, we present an overview of the ePIC-dRICH photodetector system with highlights from the R&D performed for the operation of the SiPM optical readout in the ePIC experiment. Special focus will be given to development and beam test results of a large-area prototype SiPM readout plane consisting of a total of up to 2048 3×3 mm^2 sensors. The photodetector prototype is modular and based on a novel EIC-driven photodetection unit (PDU) developed by INFN, which integrates 256 SiPM pixel sensors, cooling and TDC electronics in a volume of $\sim 5\times5\times14$ cm^3. Several PDU modules have been built and successfully tested with particle beams at CERN-PS in October 2023 and in May 2024. The data have been collected with a complete chain of front-end and readout electronics based on the ALCOR chip, developed by INFN Torino.

Poster Session

The AdvCam project: Designing the future cameras for the Large-Sized Telescopes of the Cherenkov Telescope Array Observatory

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An international collaboration composed of Italian, Japanese, Spanish and Swiss institutes, is developing the advanced camera (AdvCam), the next-generation camera for Imaging Atmospheric Cherenkov Telescopes (IACTs), designed specifically for the Large-Sized Telescopes (LSTs) of the Cherenkov Telescope Array Observatory (CTAO). AdvCam incorporates cutting-edge Silicon photomultipliers and a fully digital readout system, setting new standards for performance and efficiency.

The AdvCam will feature four times more channels than the existing PMT-based camera installed at LST-1. Covering the same field of view, this upgraded camera design enables finer image resolution and significantly improves the angular precision and background noise rejection. To cope with the increase in number of channels, many technological challenges are being tackled, from low-power and high-speed integrated chip design to real-time data processing on hardware accelerators.

This technological leap will lower the energy threshold by allowing telescopes to operate at a lower minimum signal level and providing brighter images. The increase in effective area, angular resolution and energy resolution of this new-generation of IACTs will enhance CTAO's sensitivity, unlocking new potential for gamma-ray astronomy. In this work, we present the performance of the AdvCam's core building blocks and its innovative architecture capable of enabling unprecedented

triggering capabilities. We also showcase the latest performance results based on Monte Carlo simulations that have been tuned to reflect the latest stages of the on-going technological developments, highlighting the transformative capabilities of this next-generation IACT camera.

Photon sensor techniques for Cherenkov imaging counters

Long-term performance of non-ALD MCP-PMTs in the high-radiation environment of ALICE

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The Fast Interaction Trigger (FIT) detector of the ALICE apparatus at LHC includes a Cherenkov subsystem utilizing 52 Planacon XP85002/FIT-Q microchannel plate-based photomultiplier tubes (MCP-PMTs). Operating in the forward rapidity region of ALICE since 2021, these devices sustain radiation load equivalent to ~10^12 1-MeV n_eqv/cm^2 hadron fluence and ~100 kRad total ionizing dose. Moreover, under the most intense flux of Pb-Pb ion collision products, the innermost photosensors detect 3x10^8 photoelectrons per second, resulting in 0.6 μA/cm^2 average anode current. The lifetime-extended version of the Planacon MCP-PMT with atomic layer deposition (ALD) cannot handle such a large anode current. Non-ALD MCP-PMTs are therefore used in ALICE FIT. Ageing trends exceeding 1.5 C/cm^2 have been collected to monitor changes in MCP-PMT response, and both the precise timing and counting performance of the Cherenkov detector remain unaffected so far. The detector will stay in operation until the end of LHC Run 4 in 2033.

This talk gives an overview of our experience of operating non-ALD Planacon MCP-PMTs in the harsh environment of the ALICE experiment's forward region: results of ageing and radiation damage monitoring, the newly observed self-recovery effect of aged photosensors, response variation and anode current saturation in strong magnetic fields.

Poster Session

RICH Detector for the STCF Barrel PID

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The Super Tau-Charm Facility (STCF) is a next-generation electron–positron collider currently under development in China. It is designed to operate at center-of-mass energies from 2 to 7 GeV, with a peak luminosity exceeding 0.5×10^{35} cm^{-2} s^{-1}. The particle identification (PID) detector in the barrel region is required to achieve π/K separation at 2 GeV with an identification efficiency above 97% and a misidentification rate below 2%. To meet these requirements, a Ring Imaging Cherenkov (RICH) detector has been adopted as the baseline solution.

The RICH detector at STCF uses perfluorohexane, enclosed in a quartz container, as the Cherenkov radiator. A CsI-coated Thick Gas Electron Multiplier (THGEM) is used as the photocathode, while the amplification of photoelectrons is achieved jointly by the THGEM and a subsequent Micromegas (MM) layer. An alternative design is also under investigation, in which the CsI photocathode is directly deposited onto a double micro-mesh gaseous structure (DMM).

The performance of the RICH detector has been studied using the STCF Offline Software System (OSCAR), which is built on the SNiPER framework and incorporates external packages such as ROOT and Geant4. In this framework, we have developed a full simulation and reconstruction chain for the RICH detector, including geometry, simulation, digitization, reconstruction algorithms, and performance evaluation. The geometry and simulation are primarily based on Geant4. Two reconstruction algorithms, a 2D probability density function (PDF) method and a θ_c fitting algorithm, are used to derive the PID performance. The RICH detector achieves a π/K identification efficiency above 97% and a misidentification rate below 2% in most of the kinematic region below 2 GeV/c.

A large-area prototype with a size of 300 mm × 300 mm has been built and tested with the THGEM+MM configuration, achieving a gain above 1×10^5. To meet the requirements for high integration and high rate capability in the readout electronics, a dedicated ASIC chip has been developed. In addition, a water and oxygen purification system has been designed for the liquid radiator, increasing the transmission at 180 nm from 35% to 96% (for a 1 cm path length). CsI photocathode coating has also been completed.

Currently, cosmic ray tests with the prototype are underway. The cosmic ray system has been successfully commissioned, and Cherenkov rings from cosmic muons have been observed. A beam test is planned for October this year to further investigate the detector performance.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Antarctic Ice and Ocean Water as Cherenkov Neutrino Detectors

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The concept of using the neutrino as an astronomical messenger is as old as the neutrino itself, and the challenge to open this new window on the high-energy universe has been technological in nature. We will describe how the IceCube Neutrino Observatory transformed a cubic kilometer of natural ice at the geographic South Pole into a neutrino telescope as well as discuss the technologies that have pioneered the deployment of similar instrumentation in deep lakes and ocean waters. We will highlight some of the main results of neutrino astronomy, including the discovery of a diffuse flux of high-energy neutrinos reaching us from the cosmos, the observation of the first extragalactic high-energy neutrino sources, and the discovery that our own Galaxy shines in neutrinos. We will also describe the unexpected observation of a neutrino event of 220,000 TeV energy.

Technological aspects and applications of Cherenkov light detectors

Front-End electronics for RICH detectors: general requirements, design criteria and examples of current projects

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This talk will give an overview of the electronics requirements for today's and future RICH detectors. Key challenges in the design of RICH detectors are reviewed along with their impact on front-end electronics designs. This includes requirements for resolution in space and time, signal coupling to single-photon sensors and front-end data processing. Additional detector integration aspects are

considered such as power consumption, geometry, data throughput and radiation hardness. Different designs are explored to seek a common ground for RICH detectors and to highlight where additional constraints lead to more application-specific developments

Photon sensor techniques for Cherenkov imaging counters

Status and Perspectives of CMOS SPAD-based single photon detectors

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CMOS-based individual SPAD detectors and arrays have seen a host of applications being explored and industrialised in the past years, relying on their single-photon detection capability, combined with excellent photon-timing precision and noiseless read-out (in the digital flavour). Manufactured in standard CMOS technologies, their sensitivity spans the entire spectrum, from NUV to NIR.
We will start by looking at some of the recent commercial developments, technology trends and general manufacturing options, with emphasis on manufacturing bottlenecks and opportunities. This will be followed by a review of representative CMOS SPAD arrays and digital SiPM (dSiPM) designs, as well as hybrid architectures, for high-energy physics and the nuclear science community in the large sense (e.g. including Positron Emission Tomography). Digital SiPMs are one of the array flavours, where the intrinsically digital nature of the SPAD response is preserved and exploited as close as possible to the SPAD itself, without necessarily reaching the granularity of true imagers.
We will also highlight how the target applications drive high level architectural choices and the ultimate system performance, be it for synchronous, high data rate scenarios such as RICH detectors (spadRICH project), or event-driven, low data rate experiments such as neutrino tracking.

Photon sensor techniques for Cherenkov imaging counters

SiPM radiation hardness and perspectives for new developments

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Invited review talk

Photon sensor techniques for Cherenkov imaging counters

Status and Perspectives of MCP-based photodetectors

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Finely pixelated Micro-Channel Plate Photomultipliers (MCP-PMTs) are vacuum photosensors often used in Imaging Cherenkov detectors, such as Belle II TOP, future LHCb TORCH and PANDA DIRC detectors, as well as ePIC pfRICH and hpDIRC. This type of PMTs can have gain up to 10^7 and higher, timing resolution below 50 ps and sub-mm position resolution in a single photon mode, as well as peak quantum efficiency exceeding 30% in a wavelength range suitable for aerogel and fused silica radiators. MCP-PMTs exist in both capacitively coupled and DC-coupled implementations, and allow quite some flexibility in adjusting their anode pixellation to the needs of a particular detector. Being equipped with 10 mm or smaller diameter pore MCPs, these photosensors exhibit a sufficiently high resilience to magnetic fields up to ~2 T. Atomic Layer Deposition (ALD) coating applied to MCPs allow them to survive integrated photon fluence equivalent to dozens of C/cm^2 of extracted anode charge at a nominal bias voltage, before photocathode starts showing signs of a substantial degradation.

The talk will provide a state of the art overview of this technology, use cases in presently running and future experiments, as well as discuss perspectives of MCP-PMT performance improvements, illustrated in particular by recent evaluation results of the first so-called High Rate Picosecond Photo Detectors (HRPPD) by Incom Inc.

R&D on Cherenkov light imaging systems for future experiments

R&D Developments in Cherenkov Imaging Technologies for Particle Identification Systems in Future Experiments

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Cherenkov light imaging is expected to play a critical role in charged particle identification across a wide kinematic phase space in many upcoming particle and nuclear physics experiments worldwide, in particular in the filed of hadronic physics, flavor physics and for electron-positron colliders.

Extensive R&D efforts are underway on multiple fronts of Cherenkov imaging technology, including the optimization of radiator material selection, advancements in photon sensor technologies, the development of fast and reliable readout electronics, and system-level integration. The synergies between novel ideas emerging from future experimental needs and the knowledge gained from operating Cherenkov detectors, together with a broad spectrum of R&D contributions from various collaborations, are shaping the next generation of Cherenkov imaging systems.

Experiments at the Large Hadron Collider (LHC) and the Electron-Ion Collider (EIC) are among the major contributors to these R&D activities. These efforts are driven by the need to meet increasingly demanding physics requirements, which call for both innovative technological solutions and the refinement of established designs. The challenging experimental conditions play a critical role in detector design; factors such as strong magnetic fields, high radiation levels, and limited available space are key considerations.

In order to maintain the precision of Cherenkov emission angle measurements, R&D studies are focused on developing radiator materials with improved optical quality, and, most importantly, photon sensors with high photon detection efficiency and fine granularity. To effectively suppress background, accurate measurement of the Time-of-Arrival (ToA) of the detected photons is essential, which in turn requires a large number of detected photons to ensure statistical precision.

As a result, in recent years, particular attention has been directed toward sensor technologies that enable the combination of Cherenkov photon timing information with high quantum efficiency, high gain, high rate capability, and fine spatial granularity. Photon detectors capable of achieving time resolutions below 100 picoseconds for single-photon detection have therefore emerged as a focal point in detector development. These technologies hold the potential to significantly enhance the

performance of particle identification systems in the challenging environments anticipated in future high-energy physics experiments.

Moreover, these fast photon sensors open the possibility of using them as Time-of-Flight (TOF) detectors by exploiting the timing properties of Cherenkov photons generated by particles passing through the detector window.

In this talk, I will present an overview of the current R&D landscape dedicated to Cherenkov imaging detectors, with a focus on the efforts from various experimental collaborations aiming to implement this technology in coming and future experimental efforts. Special emphasis will be placed on recent developments in photon sensor technologies, which are central to meeting the performance goals of the upcoming experiments.

Technological aspects and applications of Cherenkov light detectors

The DRD4 Collaboration for research and development on photon detectors and particle identification techniques

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The DRD4 international Collaboration has been formed at the beginning of 2024 following the ECFA Detector R&D Roadmap. The scope of the Collaboration, which is anchored at CERN, is to bundle and boost R&D activities in photodetector technology and particle identification techniques for building future high-energy physics (HEP) experiments and facilities. DRD4 also covers scintillating fibre tracking as well as transition radiation detectors based on solid state X-ray detectors. An overview of the scientific scope and organisation of DRD4 will be presented, with particular focus on the strategic role of the Collaboration for the future of HEP, and the main technological challenges will be discussed.

Cherenkov light imaging in current particle and nuclear physics experiments

Cherenkov light imaging detectors in current particle and nuclear physics experiments

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Cherenkov radiation has characteristics that enable us to measure the velocity of the parent charged particle by means of the number of photons, the specific polar angle of the photon emission, and the timing of the photon detection. The precision of the velocity measurement depends on how well such information can be exploited. In fact, innovative developments of radiators, photosensors and readout electronics led to the excellent Cherenkov light imaging detectors working at ongoing experiments. In this review talk, such developments of the detector components will be digested, and the performance of the detectors will be summarized.

Cherenkov light imaging in neutrino and astroparticle physics experiments

The AMS-02 RICH detector: status, latest results, and physics prospects

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The Ring Imaging Cherenkov (RICH) detector aboard the Alpha Magnetic Spectrometer (AMS-02) has been operating successfully on the International Space Station since 2011. The RICH detector, based on a proximity focusing design, features a dual-radiator configuration with sodium fluoride tiles at the center surrounded by silica aero gel tiles, and a matrix of 680 multi-anode photomultiplier tubes. It achieves a velocity resolution of $\Delta\beta/\beta \approx 1.2$ per-mil for protons with a charge resolution of ~0.3 units. The velocity resolution improves with increasing charge.

In this contribution, we present the latest AMS results on light cosmic-ray isotope measurements obtained with RICH detector, with highlights on the recently published Li-6 and Li-7 spectra.

We will also present preliminary studies on beryllium isotopes, where the radioactive Be-10 can probe cosmic-ray confinement time. The extension of the isotopic separation to heavier species requires an improved mass resolution. In this physics context, current advancements in the RICH reconstruction algorithms and detector response calibration will be discussed.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Overcoming the physical limits of Cherenkov telescopes

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Imaging with Cherenkov telescopes was a breakthrough for gamma ray astronomy. However, by pushing Cherenkov telescopes to ever higher precision and ever larger sizes our upcoming generation of telescopes has reached the intrinsic limits of imaging itself. Aberrations limit our field-of-view and our possible angular resolution in the gamma-ray sky. The square-cube-law escalates the costs to construct rigid structures for the optics of ever larger telescopes. A narrowing depth-of-field in larger telescopes prevents us from lowering the energy threshold for cosmic gamma rays as it blurs the images irrecoverably. While aberrations can be mitigated by more complex and costly optical surfaces, and while the square-cube-law can be mitigated by spending disproportionately more resources and engineering, the narrowing depth-of-field is a physical limitation of imaging and the telescope itself which can not be overcome by spending resources. We will show that all these limitations can be overcome by not only measuring the direction of a photon, as the telescope does it, but by additionally measuring the position where the same photon is reflected on the telescope's mirror. With a groundbreaking optics, our proposed Cherenkov plenoscope does exactly this without blocking or losing any light. The plenoscope can tolerate deformations of its mirror and misalignments of its camera what postpones the square-cube-law and lowers the costs. The plenoscope can compensate aberrations of its mirror what widens its field-of-view and sharpens the images. And the plenoscope turns the telescope's narrow depth-of-field into the perception of this depth giving the plenoscope intrinsic stereoscopic reconstruction power. Plenoptic perception has far reaching consequences for gamma- and cosmic-ray astronomy. We will present one possible consequence

which is a Cherenkov plenoscope that aims for an energy threshold of one giga electronvolt for cosmic gamma rays. The plenoscope allows for the first time the high-resolution imaging of low energy gamma ray air showers using a huge (71m) mirror. For the first time we might be able to collect the more abundant low energetic gamma rays, for which the universe is still transparent up to high red shifts, in the large collecting areas of the atmospheric Cherenkov method. With astronomy pivoting towards the time domain, the Cherenkov plenoscope might become the next generation's timing explorer in the gamma ray sky to clock the emission from gravitational mergers, bursts, recurring novas, flaring jets, pulsars, and many more.

Poster Session

Performance Evaluation of a Ring Imaging Cherenkov Detector with High-Momentum hadron beams at J-PARC

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We are preparing a spectroscopy experiment of Ξ and Ω baryons at the $\pi20$ beamline, a secondary particle beamline of the high-momentum beamline at J-PARC. We utilize negatived kaons as incident particles with momenta ranging from 5.0 to 8.5 GeV/c. An unseparated secondary beam contains, however, approximately 100 times the amount of pions as a background, and the number of secondary particles arrived is 6.0×10^7/spill. Therefore, a beam particle identification detector with a π misidentification probability below 0.03% is required. For this purpose, we use a Ring Imaging Cherenkov detector (beam-RICH).

The beam-RICH detector is composed of an aerogel radiator, a spherical mirror, and photon detectors based on Silicon Photomultipliers (SiPMs). The optical performance was evaluated using a positron beams, achieving an angular resolution of 4.57 mrad for a single photoelectron. For particle identification, we adopted the "Global likelihood approach," which is a method originally introduced in the LHCb collaboration, which assumes several particle hypotheses and calculates the expected number of detected photons for each. Particle identification is performed based on the differences in the log-likelihood values derived from these expectations. Simulation results demonstrate that a K^- detection efficiency exceeding 96% at 5.0 GeV/c has been achieved while keeping a misidentification rate below 0.03%.

In January 2025, we performed a beam test at the J-PARC high-momentum beamline using secondary hadron beams with momenta of 3, 5, and 10 GeV/c. The measurements were complemented by tracking information from tracking detectors and low-momentum particle identification using threshold-type Cherenkov detectors.

We present the detector design and construction, the evaluation results from two kind of beam tests. Additionally, we report the secondary particle composition of at the J-PARC high-p beamline, with particular emphasis on the evaluation of the K fraction.

Poster Session

Aerogel characterization for RICH applications

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Silica aerogel has gained increasing popularity over the past few decades as a Cherenkov radiator, thanks to its exceptional properties. One of its most distinctive features is the ability to finely tune its refractive index to meet the specific requirements of various RICH detectors for future HEP experiments, such as the ALICE 3-RICH and the ePIC-dRICH detectors. At the INFN Bari laboratories, a detailed optical characterization of hydrophobic silica aerogel tiles is currently underway, using an Agilent Cary 4000 spectrophotometer. The study involves aerogel tiles of varying thicknesses and sizes. The measured physical quantities include total and diffuse transmittance, total reflectance, as well as derived linear transmittance and specular reflectance. Results indicate that intensive use and surface degradation significantly affect the optical performance of the tiles, reducing both linear transmittance and transmission length. High-precision refractive index measurements were carried out using both the dispersion law and the minimum deviation angle method, with an experimental uncertainty of approximately 0.01 percent. This level of accuracy enables the detection of possible refractive index gradients across the tile thickness, a feature beneficial for Cherenkov photon focusing. This optical characterization lays the groundwork for further studies aimed at optimizing tile configurations and enhancing the overall performance of future RICH detector systems. The results obtained will be presented and discussed.

R&D on Cherenkov light imaging systems for future experiments

Status of the PANDA DIRC Detectors

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Among other physics goals, the PANDA experiment at the FAIR facility at GSI will perform charmonium spectroscopy and search for gluonic excitations using high luminosity antiproton beams from 1.5 to 15 GeV/c. To achieve these scientific objectives, a high performance particle identification (PID) system is required, in particular a kaon/pion separation up to 4 GeV/c. Because of space limitations the main components of the PID system will consist of DIRC (Detection of Internally Reflected Cherenkov light) detectors located in a magnetic field of about 1 Tesla. A barrel DIRC with fused silica radiator bars will surround the target at a radial distance of about 50 cm and cover a polar angle range of 22 to 140 degrees; an endcap DIRC, consisting of a four-fold segmented fused silica disk with a diameter of about 2.1 m, will be installed in the forward region to cover polar angles from 5 to 22 degrees.

During the R&D phase, the PANDA DIRCs had to overcome several challenges, which will be discussed in this presentation: the photon rates can reach MHz/cm^2 and photon detection with high spatial and temporal resolution is required within the magnetic field. The limited space available for both DIRCs forced the development of specialized optics to focus the Cherenkov photons onto a compact readout area that allows a straightforward and efficient reconstruction of the Cherenkov angle. Design and testing of the specific optical elements are discussed. High rate and magnetic field capable multi-anode microchannel-plate (MCP) PMTs were selected as photon sensors to read out the ultrafast signals using specially designed frontend boards.

The different design and readout options for both DIRCs were investigated with small-scale prototypes using particle beams in different laboratories. Important results of these test runs will be presented and compared with simulations. While further development of the endcap DIRC is currently paused, the construction of the barrel DIRC is underway. The components such as radiator bars and MCP-PMTs are already available or are currently being delivered and quality-tested. Other components such as lenses, expansion prism, bar boxes and readout electronics are still in an optimisation phase.

The current status of both the endcap DIRC and the barrel DIRC will be reviewed in this contribution.

Technological aspects and applications of Cherenkov light detectors

Perspectives for the "green"use of fluorocarbons in Cherenkov gas radiators.

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Saturated fluorocarbons (SFCs: CnF(2n+2)) are chosen for their optical properties as Cherenkov radiators, with C4F10 and CF4 currently used at CERN in the COMPASS and LHCb RICH detectors. New RICH detectors are being considered, which might again use C2F6 as a radiator gas, possibly blended with CO2.
Non-toxicity, nonconductivity, non-flammability and radiation resistance has also made SFCs ideal coolants: C6F14 liquid cooling is used in all LHC experiments, while C3F8 evaporatively cools the ATLAS silicon tracker using compressors or a thermosiphon recirculator exploiting the hydrostatic advantage of the 92m cavern depth.
These fluids, however, have high GWPs (5000–10000*CO2), and represented around 37% of CERN's CO2-equivalent emissions in 2022. There is thus an impetus to reduce their use through improved monitoring and circulation system design.
Spur-oxygenated fluoro-ketones, with CnF2nO structures, can offer similar performance to SFCs with but with very low, or zero GWP. These fluids do not exist in large quantities over the full CnF2n "matrix", but the radiation tolerance and thermal performance of 3M NOVEC 649® (C6F12O) was sufficiently promising for it to be considered as a C6F14 replacement for cooling photomultipliers. Additionally, subject to optical and further material compatibility testing, C5F10O could (if blended with N2, Ar or CO2) replace both C4F10 and CF4 in Cherenkov detectors for a lower overall radiator GWP 'load'. The thermodynamics of C5F10O (mw 266) circulation is likely to be very similar to C5F12 (mw 288), for which there is heritage experience from the DELPHI RICH and SLD CRID as well as crossover from evaporative cooling experience at CERN.
Improvements in leak reduction around large gas volume radiator volumes should be considered. through the use of thin (5-10 cm) containment plenums purged with a light gas - which can be the same as the light component of the radiator itself - with gas continuously aspirated from the plenum for analysis.
Ultrasonic gas mixture analysis is very sensitive to concentration changes of a heavy vapour in a light carrier, and is used for real-time monitoring of C3F8 coolant leaks from the ATLAS SCT silicon tracker into N2-flushed environmental volumes. A typical C3F8 sensitivity of better than 10−5 is achieved.
This presentation outlines various approaches to GWP reduction in Cherenkov gas radiators using saturated fluorocarbons and fluoro-ketones. Different approaches to monitoring, kinetic and thermodynamic circulation are discussed.

Poster Session

R&D of Fast Timing MCP-PMT with PbF2 Window

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The timing performance of photodetector is a critical parameter for the development of Radiation Imaging Detectors based on Time Of Flight (TOF) technique, notably in applications like TOF Positron Emission Tomography (TOF-PET). The small size Microchannel Plate Photomultiplier (MCP-PMT), also referred to as Fast timing MCP-PMT (FPMT), is a popular candidate photodetector of TOF-PET for its high gain, good detection efficiency, single photon detect ability, magnetic field resistance, ultimately its good time resolution.
Using the Cherenkov radiator as the light window directly can eliminate the optical interface between the radiator and conventional MCP-PMT, and Cherenkov light will be directly converted into photoelectrons, thus improving the CTR of Cherenkov TOF-PET.
PbF2 is a favoured Cherenkov radiator for its high refractive index, high density and pure Cherenkov radiation. Starting from 2020, the MCP-PMT workgroup has completed the development of FPMT from Glass window FPMT (Glass-FPMT) to Pb Glass window FPMT (Pb-FPMT), and ultimately advanced to PbF2 window FPMT (PbF-FPMT). The structure of the PbF-FPMT was optimized to achieve a Rise Time (RT) less than 300 ps and a Transit Time Spread (TTS) of 30 ps under single photon mode. The direct use of PbF2 as the optical window eliminate the optical interface between the radiator and the detector, significantly enhances the number of Cherenkov photons and the multi-anode structure enables a great spatial resolution. The CTR of the first version of PbF-FPMT prototypes can reach 129.2±1.6 ps, and the improved ones will be used for this test later.

Cherenkov light imaging in neutrino and astroparticle physics experiments

The Design and Performance of Multi-PMT Modules for the Hyper-Kamiokande Experiment

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The Hyper-Kamiokande experiment is a next-generation underground water Cherenkov detector designed to explore CP violation, proton decay, and astrophysical neutrino sources with unprecedented sensitivity. To enhance photodetection capabilities, both the far detector (FD) and the Intermediate Water Cherenkov Detector (IWCD) incorporate novel multi-PMT modules. Each module integrates nineteen 3-inch PMTs and dedicated front-end electronics within a waterproof pressure vessel, offering improved directional sensitivity and timing resolution. The Hyper-Kamiokande FD employs 800 modules, 200 of which are equipped with in-situ calibration LEDs. The IWCD, located 1 km from the J-PARC neutrino beam, uses 400 modules as its primary photosensor system. The FD modules prioritize ultra-low power operation, while the IWCD electronics are optimized for higher event rates.
We present the design, production, and testing of the multi-PMT system, highlighting differences in electronics architectures, assembly and QA procedures, and recent results from the Water Cherenkov Test Experiment (WCTE) at CERN. These developments mark a significant step forward in photodetection technology for large-scale neutrino experiments.

Poster Session

Research on High-Precision Time-Resolved Detectors Coupled with fast Scintillation Crystals and fast PMTs

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High-precision time-resolved detectors are core technologies in fields such as particle physics, nuclear physics, and medical imaging, with their performance critically depending on the decay time, light yield of ultrafast scintillation crystals, and the temporal response characteristics of fast photomultiplier tubes (PMTs). Traditional materials like LYSO and BGO, which suffer from slow response speeds or insufficient light yields, are unable to meet the demands of ultrafast imaging. In recent years, novel fast-decay crystals such as BaF_2, GAGG:Ce, and the perovskite $Cs_3Cu_2I_5$:Mn have shown potential, but their environmental stability and detector compatibility still need to be optimized.
Ultrafast PMTs have demonstrated excellent single-photon detection capabilities, providing strong support for high-precision time measurements. The MCP-PMT collaboration has developed a series of fast PMTs (FPMTs) with single-photon detection capabilities, featuring a rise time (RT) of less than 300 ps and a transit time spread (TTS) of less than 30 ps.
Coupling ultrafast scintillation crystals with FPMTs is expected to achieve higher-precision coincidence time resolution, breaking through the sub-100 picosecond time resolution bottleneck. Experimental tests were conducted on the time performance of BaF_2 crystals with different doping concentrations (1%, 3%, 5%, and 10%) coupled with FPMTs, focusing on their rise time (RT), fall time (FT), and pulse width. The results show that as the doping concentration increases, the detector's counting rate and peak voltage change, and the rise and fall times exhibit different characteristics. These data indicate that doping concentration significantly affects the time resolution performance of the detector, providing important experimental evidence for optimizing the doping concentration of ultrafast scintillation crystals to enhance detector performance. Further experiments coupling more ultrafast crystals with FPMTs are ongoing, with results being analyzed progressively. The complete findings will be presented in formal reports or publications.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Status of the Pierre Auger Observatory

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The Pierre Auger Observatory is the world's largest cosmic-ray observatory, dedicated to the study of ultra-high-energy (UHE) cosmic rays with energies above 10¹⁷ eV. This overview talk presents recent results and ongoing research across a wide range of topics aimed at elucidating the origin, composition, and interactions of these enigmatic particles. Key highlights include measurements of the energy spectrum—featuring the second knee and the suppression at the highest energies—as well as studies of mass composition derived from the depth of shower maximum and the muon content of inclined air showers. Recent progress in understanding the number of muons and discrepancies with hadronic interaction models has provided new constraints on proton–proton cross sections at centre-of-mass energies beyond those accessible at colliders.

We discuss anisotropy searches in arrival directions, including efforts to identify potential sources through correlations and harmonic analyses, and the ongoing search for UHE photons and neutrinos as signatures of exotic physics and cosmogenic processes. The capability of the Observatory to detect upward-going air showers enables complementary searches for beyond-standard-model particles. Atmospheric monitoring—using lidar scans, the XY-scanner, and aerosol attenuation models—

ensures high-precision energy and composition reconstruction, while the inter-calibration of the fluorescence detectors, the surface detectors, and the high-elevation telescopes enhances longitudinal shower profiling.

Additional topics include observations of atmospheric transient phenomena such as elves, halos, and terrestrial gamma-ray flashes, and searches for high-energy neutrons from Galactic sources. Advances in radio detection using the Auger Engineering Radio Array, including interferometric techniques and calibration efforts, have further expanded the multi-hybrid capabilities of the Observatory. Finally, the ongoing AugerPrime upgrade aims to enhance mass composition sensitivity at the highest energies through the addition of radio antennas and surface scintillator detectors, improved electronics, and underground muon detectors. These enhancements will allow the Pierre Auger Observatory to address open questions in cosmic-ray astrophysics and probe new physics at the highest energies accessible in nature.

Poster Session

First results from a full-scale TORCH prototype

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The TORCH time-of-flight detector is part of a proposed upgrade of the LHCb detector foreseen for the high-luminosity phase of the LHC. The detector comprises an array of modules each comprising a fused-silica radiator plate of size 66 cm-by-250 cm-by-1 cm. The modules are designed to have a minimal depth and are supported using a light-weight carbon-fibre structure, designed to minimise the amount of material in the LHCb detector acceptance. A full-sized prototype module has been assembled and will be tested in a charged particle beam at the CERN PS in July this year. First results from this prototype will be presented.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Direct comparison of SiPM and PMT operation under bright background and perspectives of using truly digital sensors

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The maximum photon detection efficiency (PDE) of silicon photomultipliers (SiPMs) can be comparable to or even exceed that of photomultiplier tubes (PMTs). There are experiments where the signal is measured in the presence of strong background light. Considering PDE alone can lead to wrong conclusions and results, one needs to accurately assess the signal-to-noise ratio. Imaging atmospheric Cherenkov telescopes (IACTs) observe in the presence of strong light of the night sky. It is interesting to directly compare SiPM performance in IACTs with that of PMTs, without any assumptions. For this purpose, we performed long-term tests by using the 17m diameter MAGIC IACT. For completeness, we used SiPMs from well-known companies EXCELITAS, SensL, and Hamamatsu and compared these with two PMT types from Hamamatsu. From today's perspective, SiPMs are relatively outdated –they are used as classic PMTs, i.e. small signals are amplified and fed into digitizers. SiPM is essentially a digital sensor, but its design does not allow one to benefit from this basic feature. A sensible alternative is the use of purely digital sensors. In this presentation we would like to show the results of comparison as well as address the above- mentioned issue.

R&D on Cherenkov light imaging systems for future experiments

TORCH detector concept and design

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The TORCH time-of-flight detector is part of a proposed upgrade of the LHCb experiment, foreseen for the high-luminosity phase of the LHC. The TORCH detector aims to provide particle identification of hadrons in the sub-10 GeV/c momentum range, exploiting the prompt production of Cherenkov photons in an array of fused-silica plates. Photons are propagated to the periphery of the detector via total internal reflection, where they are focused by a cylindrical mirror onto an array of fast-timing photon detectors. In order to achieve the design goals of TORCH, individual photons must be timed to better than 100 ps precision. Progress on R&D activities, the detector design, and performance studies since the last RICH conference will be discussed. This includes updates to the design that have evolved from a scoping process for the whole LHCb experiment.

Pattern recognition and data analysis

The ARC compact RICH detector: reconstruction and performance

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Particle Identification (PID) will be crucial in Future Circular Colliders (FCC-ee) or other Higgs Factory experiments for precision studies involving heavy-flavour particles in Z decays, as well as jet flavour tagging in the decays of Higgs, W, and top particles.
In this context, a novel Ring Imaging Cherenkov (RICH) detector concept, named ARC (Array of RICH Cells), has been proposed.
The ARC detector is designed to provide charged hadron separation over a momentum range of 1-40 GeV, using both C_4F_{10} gas (or an environmentally friendly alternative) and aerogel as radiators.
The ARC detector features a modular design composed of identical cells, each equipped with radiators, a spherical mirror, and a Silicon PhotoMultiplier (SiPM) photodetection plane. Simulations demonstrate excellent hadron separation capabilities across the target momentum range. Reconstruction algorithms have been developed and integrated into the simulation framework, allowing detailed studies of photon yield and Cherenkov angle resolution. Current efforts focus on implementing advanced pattern recognition algorithms and developing a detailed simulation framework that includes magnetic field effects for accurate performance evaluation. Scenarios involving multiple tracks crossing the same cell are also under investigation to assess the detector's reconstruction capabilities in cases with increased pattern complexity.
The latest simulation results and performance assessments of the ARC detector will be presented, highlighting its potential for high-precision PID at FCC-ee.

Photon sensor techniques for Cherenkov imaging counters

Exploring New Avenues for Particle Detection with LAPPDs and WbLS in ANNIE: Milestones and Firsts

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The Accelerator Neutrino Neutron Experiment (ANNIE) is a 26-ton Fermilab-based effort studying neutrino cross-section physics on a water target, with particular attention to final-state neutron yields. The goal of ANNIE's physics program is to better understand and constrain key systematic uncertainties on next-generation neutrino oscillation experiments. ANNIE is also a leading R&D platform studying next generation technologies for hybrid Cherenkov/scintillation neutrino detectors, with recent achievements including the first detection of neutrinos in water-based Liquid Scintillator (wbLS) and the first detection of neutrinos with Large Area Picosecond Photodetectors (LAPPDs). In this talk we present on the newest developments from ANNIE, with particular focus on the milestones achieved in making LAPPDs and wbLS application-ready for large future neutrino experiments.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Status of the Cherenkov Telescope Array Observatory

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The Cherenkov Telescope Array Observatory (CTAO) is a project whose objective is to advance knowledge of the gamma-ray sky with the largest gamma-ray observatory ever built. The CTAO will consist of two Imaging Atmospheric Cherenkov Telescope (IACT) arrays, with more than 60 telescopes. One of them is under construction in the northern hemisphere, at the Roque de los Muchachos Observatory (ORM) on the Canary Island of La Palma. The other will be installed in the southern hemisphere, in Paranal, Chile.
The CTAO will use IACTs of three different sizes to cover a wide energy range (from 20 GeV to 300 TeV). The construction of the CTAO is progressing, with the commissioning of large-sized telescopes (LSTs) at the ORM. In parallel, infrastructure work and telescope deployment will soon begin at the CTAO's southern site.
The CTAO team is developing the science and technical operations plan that will allow it to meet the scientific requirements. For each CTAO array, the Array Control and Data Acquisition (ACADA) software will allow for the operations of several functional units (subarrays) simultaneously. An automatic scheduler within ACADA will plan and adapt on the fly the desired operations, creating, merging, and splitting subarrays to carry them out. These operations will consist of both observation and calibration activities. A set of calibration and environmental monitoring instruments, such as laser imaging detection and ranging (LIDAR) instruments and weather stations, will operate together with the IACTs under the supervision of ACADA. These instruments will provide detailed atmospheric characterization, which is important for telescope operations and subsequent data analysis, as well as external light sources for the calibration of the IACT cameras. In addition, CTAO will incorporate the capacity for fast science alert processing, together with the rapid movement of CTAO telescopes, which makes CTAO an excellent instrument for studying high-impact astronomical transient phenomena such as gamma-ray bursts or gravitational waves.
This contribution outlines the status of the construction of the CTAO and the planned science and calibration operation schemes.

Poster Session

Performance degradation of SiPM sensors under various irradiation fields and recovery via high-temperature annealing

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Silicon Photomultipliers (SiPMs) are widespread photon detectors in high-energy physics. Their performance degrades significantly when exposed to radiation, particularly high-energy hadrons (neutrons or protons) that induce defects in the silicon lattice. A moderate level of radiation causes damage in SiPMs, leading to an increase in dark current and dark count rate (DCR) and potentially affecting the single-photon detection capability due to pile-up and limitations in the readout electronics. At very high doses, radiation damage can also modify operational parameters (breakdown voltage, gain) and decrease photon detection efficiency (PDE). Nevertheless, several studies show that high-temperature annealing can significantly accelerate the recovery of radiation-induced defects, thereby lowering dark current and DCR.
In this talk, we report on the studies performed in the context of the R&D for the dual-radiator RICH (dRICH) detector at the future Electron-Ion Collider (EIC), where a large number of SiPMs were tested for usability in single-photon applications in a moderate radiation environment. Proton irradiation was performed at the Trento Proton Therapy Centre, delivering integrated fluences up to 1011 1-MeV neq/cm2 to the SiPMs and studying different proton energies from 18 to 138 MeV. Neutron irradiation was conducted at the CN accelerator of the INFN Legnaro National Laboratories

at integrated fluences up to 1010 1-MeV neq/cm2. Gamma irradiation was performed at the CERN GIF++ facility up to 1 krad. All sensors were characterised before and after irradiation, with special focus on their low-temperature performance at -30 ℃. Irradiated SiPMs underwent various annealing procedures to test their recovery capability from radiation damage. Particular attention was given to an annealing procedure exploiting the Joule effect, where high temperatures were achieved via self-heating of the sensor. Repeated irradiation and annealing cycles were performed to simulate a realistic experimental scenario and to assess the robustness of the sensors against such procedures. A summary of the studies and the main results will be presented in this talk.

Poster Session

High-Precision Timing Characterization of MCP-PMT Using Front-End ASIC and TDC ASIC

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This study presents the development of a high-precision time measurement system for Micro-Channel Plate Photomultiplier Tubes, combining a custom front-end electronics ASIC and a Time-to-Digital Converter (TDC) ASIC. The system aims to improve the time resolution of current photon detector, enabling critical applications in high-energy physics experiments, such as particle identification and precise time-of-flight reconstruction.

The TDC ASIC adopts a differential delay-loop architecture (inspired by a 0.18 μm SMIC CMOS process-based design), featuring dynamic delay calibration and dual-loop structures to mitigate process variations. The FEE ASIC incorporates a low-noise transimpedance amplifier (TIA) and a threshold discriminator to minimize timing jitter in the signal chain, ensuring robust signal conditioning for the fast response of MCP-PMTs
The ASICs have been successfully fabricated and functionally verified. The TDC ASIC achieve a l LSB of 12.04 ps, with differential nonlinearity (DNL) < ±0.5 LSB and integral nonlinearity (INL) < ±1.0 LSB. Future work will focus on system-level integration of the ASICs with MCP-PMTs, followed by experimental validation under real-world physics scenarios to evaluate performance boundaries. This work paves the way for practical deployment of sub-10 ps timing systems in next-generation particle detectors and quantum optics research.

Poster Session

CBM RICH ring reconstruction using machine learning

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The Compressed Baryonic Matter experiment (CBM) at FAIR is designed to explore the QCD phase diagram at high baryon densities with interaction rates up to 10 MHz using triggerless free-streaming data acquisition. The CBM Ring Imaging Cherenkov detector (RICH) contributes to the overall PID by identification of electrons from the lowest momenta up to 6-8 GeV/c, with a pion suppression factor of more than 100. The RICH reconstruction combines a local Cherenkov ring-finding with

a ring-track matching of extrapolated tracks from the Silicon Tracking System (STS) by closest distance.

The existing conventional algorithm for standalone ring-finding based on the Hough transform was revised and optimized. A method based on a Convolutional Neural Network (CNN) architecture was developed for noise suppression while taking into account the latency and data format (space and time, i.e. 3+1) constraints of the triggerless free-streaming readout. The method was tested and validated on simulations taking into account the time data stream and on data from the prototype mini-RICH (mRICH) in the mini-CBM (mCBM) experiment, which shares the same free-streaming readout concept as the future CBM experiment.

An alternative standalone ring-finder based on a Graph Neural Network (GNN) is investigated for its viability for the CBM RICH. It is designed as an end-to-end pipeline for ring-finding, optionally including noise classification as an auxiliary downstream task.

R&D on Cherenkov light imaging systems for future experiments

Designing the ALICE 3 bRICH detector: simulation studies and beam test results

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The ALICE Collaboration is proposing a completely new apparatus, ALICE 3, for the LHC Run 5 and beyond. The design target of the ALICE 3 charged particle identification (PID) system is to ensure a better than 3σ e/π, π/K and K/p separation for momenta up to 2 GeV/c, 10 GeV/c and 16 GeV/c, respectively. A key PID subsystem in the barrel region (|⊠|<2) will be a proximity-focusing Ring-Imaging Cherenkov detector, the bRICH, using aerogel (n = 1.03 at 400 nm) as radiator and silicon photomultipliers (SiPMs) as photon sensors. The system must be optimized to ensure efficient particle identification in the high-multiplicity environment of Pb-Pb collisions. Dedicated reconstruction machine-learning based algorithms were developed to prove the bRICH physics reach. Various small-scale prototypes instrumented with aerogel tiles by Aerogel Factory Co., Ltd., different Hamamatsu SiPM arrays readout by custom boards equipped with front-end Petiroc 2A or Radioroc 2 coupled with PicoTDC ASICs, were successfully tested in beam test campaigns at the CERN PS T10 beam line between 2022 and 2024. Our measurements allowed us to validate both the bRICH geometry and the expected performance in terms of photon yield, angular resolution and the resulting separation power. With a measured single photon angular resolution at saturation of about 4.2 mrad and 6 detected photons with about 25% ring acceptance at the operation conditions, the target larger than 3σ π/K separation up to 10 GeV/c has been achieved. We also studied the contribution of uncorrelated and correlated background sources with respect to the signal and proved the effectiveness of time matching between charged tracks and photon hits to achieve efficient suppression of the SiPM dark count rate (DCR) background. Finally, we proved the stability of the reconstruction performance with the increasing DCR expected during ALICE 3 operation. In this talk, the bRICH concept, the expected performance from simulations and the main beam test results will be reported.

R&D on Cherenkov light imaging systems for future experiments

Status of the CBM RICH detector towards first beam in 2028

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The Compressed Baryonic Matter experiment (CBM) is a main scientific pillar of FAIR, the Facility for Antiproton and Ion Research, currently being constructed in Darmstadt, Germany. CBM will study the phase diagram of baryonic matter in regions of moderate temperature and large baryonic chemical potential, reaching net baryon densities several times larger than ordinary nuclear matter.

Dileptons are an important part of the CBM physics program, giving access to the early, high density phase of the evolution of the fireball created by heavy ion collisions.

The CBM RICH detector is a key CBM subdetector for providing efficient electron identification and suppression of pion background up to 6-8 GeV/c momentum range.
The RICH will be using a CO_2 gas radiator (pion threshold 4.65~GeV/c) and a 13m^2 segmented spherical mirror. Hamamatsu H12700 multianode photomultipliers will be used for Cherenkov photon detection in combination with the newly developed FPGA-TDC based DIRICH readout chain, which aims for exceptional timing precision limited only by a transient time spread of 350~ps of the MAPMTs.

With first beam for CBM being expected for 2028, and CBM RICH being part of the CBM day-1 detector setup, the RICH project has now fully shifted from the design- towards construction phase.
Major components, like the two photon cameras, or large parts (60\%) of the frontend readout electronic modules have been already built.

Cooling of the readout electronics inside the camera volumes, enclosed by magnetic shielding boxes, will be achieved using a unique closed-loop air-cooling approach. In this concept, the cooling air and heat flow is channeled away from the sensitive photon sensors, using CNC-milled aluminum parts for air distribution.
A prototype of the cooling system (including a large air/water heat exchanger and blower system) has been put into operation, and temperature measurements operating a fully equipped camera module are currently being carried out.

The free streaming readout concept of CBM - and CBM RICH in particular - has been successfully demonstrated in the mRICH detector, a small-scale aerogel proximity-focusing RICH detector using the same PMT and electronic DIRICH readout as the CBM RICH, routinely operated during several mCBM beam campaigns over the last years.

In the presentation we intend to present the latest status of constructing the CBM RICH detector, and report on results of the ongoing prototype tests, in particular of the RICH cooling system.\\

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Poster Session

SiPM-based RICH detector at an upgraded Compressed Baryonic Matter experiment

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In recent years, Ring Imaging Cherenkov (RICH) detectors have explored new photon detection technologies to improve timing, spatial, and amplitude resolutions. Silicon photomultipliers (SiPMs) fulfill the requirements for future experiments in high-energy physics, such as single-photon resolution, picosecond timing precision, and high photon detection efficiency. However, they suffer from high dark-count rates and low radiation hardness. The Compressed Baryonic Matter (CBM) experiment aims to study the phase diagram of strongly interacting matter at high densities and moderate temperatures. We performed a feasibility study of upgrading the photon cameras of the CBM's RICH from Multi-Anode Photomultipliers to SiPMs. CBM RICH will run without an external trigger in a high-radiation environment with a dose of up to 1×10^{11}\,n$_{eq}$/cm^{2} when assuming a running scenario with 2 months per year of Au+Au collisions at 35\,AGeV. The combination of SiPM weaknesses and the CBM operations conditions make the implementation of SiPMs in the CBM RICH challenging. In this work, we present the design and characterization of a prototype of SiPM array adapted to the readout electronics of the CBM RICH. We evaluated the performance of the three SiPMs: Broadcom AFBR-S4N66P024M, Hamamatsu S14160-6050HS, and OnSemi MICROFC-60035. We analyze the dark current, dark count rate, crosstalk, afterpulses, and photon resolution, after neutron irradiation (from 3×10^{8}\,n$_{eq}$/cm^{2} to 1×10^{11}\,n$_{eq}$/cm^{2}) and electrical annealing (up to 250\,°C during 30\,min). In addition, we implemented a novel triggering system based on signal thresholding within a narrow coincidence window ($\sim$ns). This approach minimizes the impact of dark counts caused by thermal emission or radiation damage.

Poster Session

Mirror System and Mirror Alignment Monitoring of the CBM RICH Detector

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Sven Peter for the CBM-RICH collaboration

This poster presents the progress of the mechanical design, mirror properties and mirror alignment monitoring system of the Ring Imaging Cherenkov (RICH) detector for the Compressed Baryonic Matter (CBM) experiment at FAIR.

CBM is designed to explore the phase structure of strongly interacting matter at high net-baryon densities and moderate temperatures via heavy-ion collisions in the energy range $\sqrt{S_{NN}}$ = 2.9–4.9 GeV. A key observable for the anticipated first order phase transition or even critical point is the electromagnetic radiation from the dense system. Electron identification will be performed in day-1 setup of CBM with a large RICH detector followed by a transition radiation detector (TRD). The RICH detector will use CO2 as radiator gas allowing for electron-pion separation up to 6-8 GeV/c.

The mirror system consists of 80 individual mirror tiles mounted onto an aluminum structure. A simulation was conducted to verify the mechanical stability of the mirror wall. Additionally, a full-scale pillar prototype was constructed and tested. Furthermore, the optical quality and reflectivity of mirror tiles with various coatings were measured. Silicone glue is used to attach circular plates to the back of the mirrors to connect them to the frame. Measurements confirmed that this technique does not introduce measurable mirror deformations.

The RICH is planned to be regularly exchanged with the MUCH detector using a crane. This carries the risk of mirror misalignment. This misalignment must be detected and accounted for during reconstruction to ensure correct ring diameters, locations and thus ring-track matching. Simulation and beam studies have shown that a misalignment of 1 mrad can be tolerated; beyond that value, the RICH-STS track matching quality deteriorates. We intend to use the CLAM (Continuous Line Alignment and Monitoring) method, originally developed for the COMPASS RICH-1.

The CLAM system consists of a grid of reflective stripes, cameras and LEDs for illumination. By observing the mirror image of the reflective grid using cameras, the misalignment of individual tiles can be detected and measured. An optical simulation of the CLAM system is used to determine suitable locations for the components within the CBM-RICH. The mirror tile rotations are determined by simulating the image with misalignment and optimizing for maximum overlap between the measured image and the simulation. The performance of the method is investigated with a focus on the permissible tolerances of component locations and camera intrinsics.

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Photon sensor techniques for Cherenkov imaging counters

Development and characterization of hybrid MCP-PMT with embedded Timepix4 ASIC

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We introduce a novel single-photon detector that incorporates a vacuum tube design featuring a photocathode, a microchannel plate (MCP), and a Timepix4 CMOS ASIC serving as the readout anode. Designed to handle detection rates of up to 10^9 photons per second over a 7 cm^2 active area, the system achieves spatial resolution between 5-10 μm and timing resolution better than 100 ps. The Timepix4 ASIC contains approximately 230{,}000 pixels and integrated analog and digital front-end electronics, it operates in a data-driven acquisition mode with data transmission rates reaching a maximum of 160 Gb/s.
Control and readout of the Timepix4 are executed via FPGA-based external electronics. Initial experimental validation was performed using a prototype coupled to a 100 μm thick n-on-p silicon sensor and exposed to a pulsed infrared picosecond laser. This setup yielded a timing resolution of 110 ps per individual pixel hit, which improved to below 50 ps when analyzing clusters of pixels, with the silicon layer contribution taken into account.
Hamamatsu Photonics produced six prototype detectors featuring different MCP stack configurations and varying end-spoiling depths. These were characterized through measurements of gain, dark count rate, spatial and timing resolution, both in laboratory settings and in a test-beam environment at CERN's SPS facility. The results of these activities will be presented.

Technological aspects and applications of Cherenkov light detectors

Efficient and precise Cherenkov-based charged particle timing using SiPMs

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In the framework of the DRD4 Collaboration, work package 4.4, dedicated R&Ds are ongoing on the coupling of a thin Cherenkov radiator to Silicon Photomultiplier (SiPM) arrays for precise charged particle Time-of-Flight (TOF) measurements. Cherenkov prompt radiation emission is indeed ideal for ultimate timing performance for a TOF detector. A thin radiation with high refractive index as synthetic quartz (fused silica) is able to provide a fast signal for charged particles which are above the Cherenkov threshold. A crucial requirement to approach the target time resolution is the optimization of both the radiator material and thickness, as well as the optical coupling with the SiPMs. We assembled small-scale prototypes instrumented with various Hamamatsu SiPM arrays sensors

with pitches ranging from 1.3 to 3 mm coupled with various window materials, such as fused silica and MgF_2, featuring different thickness values. The prototypes were successfully tested in beam test campaigns at the CERN PS T10 beam line between 2022 and 2024. The data were collected with a complete chain of front-end and readout electronics based on the Petiroc 2A and Radioroc 2 together with a picoTDC to measure charges and times. By comparing the time measurements with two of such arrays we were able to measure a time resolution better than 50 ps at the full system level with a charged particle detection efficiency above 99%. We have also measured the time performance of similar SiPM arrays without the thin radiator resulting in both a worse efficiency and a time resolution worse than 200 ps. The present technology makes the proposed SiPM-based PID system attractive also for future high-energy physics experiments and for space applications. In this talk the results achieved in our beam test campaigns will be reported. The perspectives of the proposed TOF layout and its optimization will be also discussed.

Cherenkov light imaging in current particle and nuclear physics experiments

Performance of the High Momentum Particle IDentification (HMPID) detector during LHC Run 3

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The ALICE experiment is designed to collect pp, p–A, and A–A collision data provided by the LHC, to investigate the properties of strongly interacting matter under extreme conditions of temperature and energy density. Among the ALICE particle identification (PID) detectors, the High Momentum Particle Identification Detector (HMPID) is dedicated to the identification of charged hadrons. It consists of seven identical Ring Imaging Cherenkov (RICH) counters, using liquid C6F14 as the Cherenkov radiator ($n \approx 1.298$ at $\lambda = 175$ nm). Cherenkov photons and charged particles are detected by a Multi-Wire Proportional Chamber (MWPC), coupled to a pad-segmented CsI-coated photocathode.
The HMPID successfully contributed to the ALICE physics program during LHC Run 1 (2009–2013) and Run 2 (2015–2018). In the ongoing LHC Run 3 (2022–2026), the HMPID has been fully integrated into the new ALICE computing framework (O2) and trigger environment. The detector performance based on Run 3 data will be presented and discussed.

R&D on Cherenkov light imaging systems for future experiments

hpDIRC Detector Development for the ePIC Experiment at the Electron-Ion Collider

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The high-performance DIRC (hpDIRC) detector for the ePIC experiment at the future Electron-Ion Collider (EIC) has progressed into an advanced development stage, transitioning from simulation-driven design to component validation and integration testing.
The baseline design, optimized through detailed and test-beam-validated Geant4 simulations, features a novel 3-layer spherical lens, small pixel sensors, and fast readout. It plans to leverage repurposed BaBar DIRC radiator bars. Construction of a modular hpDIRC prototype is nearing completion, with validation

underway at the Cosmic Ray Telescope (CRT) facility at Stony Brook University. These efforts include the reuse and quality assurance of legacy DIRC components and the gradual replacement of interim hardware with ePIC-specific systems. The project is on track toward a full Technical Design Report (TDR) by late 2026. This talk will present the current status of the hpDIRC development, the integration, and reuse strategy for key optical components, and performance studies from ongoing CRT-based testing.

Poster Session

The "xpDIRC" Concept for the Next-Generation DIRC Detector

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We present the concept of the next-generation DIRC (xpDIRC), a novel detector geometry under development for next-generation particle Identification systems. Building upon the high-performance DIRC (hpDIRC) designed for the ePIC detector at the Electron-Ion Collider (EIC), the xpDIRC introduces a hybrid optical architecture featuring enhanced focusing optics, a wide-plate light guide, and compatibility with alternative photosensors, including promising SiPM technologies. This contribution summarizes recent, highly encouraging simulation results and outlines the planned R&D program for experimental validation of the concept.

Poster Session

Water Cherenkov Detectors in Precision Agriculture: A Novel Approach for High-Resolution Soil Moisture Monitoring

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Water Cherenkov Detectors (WCDs), traditionally employed in particle physics to detect cosmic rays, are now being repurposed for a groundbreaking application: precision soil moisture monitoring via neutron sensing. This method offers distinct advantages over conventional neutron probes, including possible enhanced sensitivity to low moisture levels and the ability to cover larger soil volumes without direct subsurface intrusion.

This study evaluates the feasibility of WCDs for agricultural neutron hydrometry, addressing key challenges such as background noise suppression and data interpretation in heterogeneous soils. We present experimental results from controlled condition measurements in an environment that emulates wet and dry soil conditions, and, on the other hand, a Monte Carlo simulation using a model in

Geant 4 with an atmospheric neutron spectrum to relate the change in the signal due to soil moisture differences.
By bridging particle physics and agronomy, WCDs could improve the current state of soil moisture monitoring, offering a non-invasive, scalable, and highly accurate alternative for optimizing water use in crops. Further research is needed to refine cost efficiency and adaptability to diverse soil types, but the preliminary findings suggest a transformative role for this technology in sustainable farming.

Poster Session

Two-Stage Gamma-Neutron Source Classification in Water Cherenkov Detectors: Energy Threshold Screening and Machine Learning Pulse Analysis

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Water Cherenkov detectors (WCDs) provide a durable and cost-effective solution for real-time radiation monitoring by exploiting Cherenkov light emitted when charged particles exceed the speed of light in water. This work introduces a two-stage classification framework for gamma-neutron source discrimination: a physics-driven energy threshold filters out unambiguous low-energy gamma sources, while a machine learning (ML) ensemble resolves ambiguities at higher energies, balancing interpretability and accuracy.

The detector response was characterized using controlled sources: ^{60}Co (1.17/1.33 MeV), ^{137}Cs (0.66 MeV), and a shielded ^{241}AmBe source (neutrons/gammas). Lead, paraffin, and cadmium isolated neutron and gamma interactions, generating enriched datasets. Charge spectra (analog-to-digital units, ADUs) were calibrated against known gamma energies, yielding a linear ADU-to-MeV conversion ($R^2 = 0.966$). A 3σ significance cutoff defined a neutron threshold at 2.62 ± 0.77 MeV, corresponding to the 2.22 MeV neutron-capture gamma in water. Stage one classifies sources as pure gamma (below threshold) or neutron-emitting (at threshold). To resolve the ambiguous region above the threshold, we assembled a machine learning pipeline centered on pulse-shape analysis. A soft-voting ensemble (combining Bagging, CatBoost, and a Multilayer Perceptron) achieved 81.6% accuracy and an area under the receiver-operating-characteristic curve (AUC) of 0.921.

This hybrid "traffic light" scheme (red/green/yellow classification) filters low-energy gamma sources via physics-based cuts, reserving ML for ambiguous cases. Future work will integrate deep-learning architectures for waveform analysis and advanced statistical models for low-energy spectra. The framework's interpretability and scalability make it ideal for nuclear security, nonproliferation monitoring, and fundamental radiation research.

Poster Session

High-Count-Rate Saturation Behavior in MCP-PMT: An Experimental Study

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As the core photoelectric conversion device in Ring Imaging Cherenkov (RICH) detectors, the microchannel plate photomultiplier tube (MCP-PMT) exhibits dynamic response characteristics that critically determine the spatial resolution accuracy of particle trajectory reconstruction. Under high-flux detection conditions, the nonlinear gain attenuation caused by electron cloud saturation effects within microchannels has become a key bottleneck limiting the beam tolerance of these devices. Although atomic layer deposition (ALD) technology has been proven effective in extending the lifetime of MCP-PMTs, ALD MCP-PMTs exhibit slow saturation recovery [Kuinian Li, et al, NIMA 1074(2025)170323] and the influence of ALD coatings on their saturation characteristics remains to be thoroughly investigated.
To elucidate the factors affecting the saturation behavior of MCP-PMTs, this study established a test system based on a nanosecond-pulsed laser source. A systematic control variable approach was employed to investigate the response characteristics of single-anode MCP-PMTs with different ALD coating thicknesses (0-6 nm) under three operational modes:
(1) Constant gain mode (gain maintained at 1E4 or 1E6 levels),
(2) Constant charge output mode (single-pulse output charge stabilized at 10 pC/cm2),
(3) Constant photon flux mode (incident photon count fixed at 1700 ph/ cm2·pulse).
Saturation characteristic curves were obtained through frequency-sweep testing (10 Hz to 10 MHz), and a quantitative evaluation model based on average anode current was established.
Experimental results demonstrate that ALD coatings with thicknesses below 6 nm show no significant impact on the saturation characteristics of MCP-PMTs. Notably, the normalized saturation curves obtained under all three testing modes exhibit remarkable self-consistency, confirming that average anode current serves as a universal evaluation metric independent of specific operational conditions. Under constant photon flux mode, the lower the gain of the MCP-PMT, the higher the tolerable count rate. The established evaluation framework provides quantitative criteria for MCP-PMT selection in high-count-rate applications.
In this report, we will present the latest research findings on the lifetime study, saturation recovery characteristics, and saturation characteristics of ALD MCP-PMTs.

Cherenkov light imaging in current particle and nuclear physics experiments

Operation and performance of the Belle II TOP counter

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At the Belle II experiment a Time-of-Propagation (TOP) counter is used for particle identification in the barrel region. This novel type of particle identification device combines the Cherenkov ring imaging technique with the time-of-flight. An overview of the operation and performance status of the TOP counter will be presented. We will discuss also a Geant-4 based Monte Carlo simulation, which is used for the production of Belle II Monte Carlo samples, and show a comparison with the experimental data.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Status of the Southern Wide-field Gamma-Ray Observatory

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The Southern Wide-field Gamma-Ray Observatory (SWGO) will be a next-generation gamma-ray observatory located in the Southern Hemisphere. Building upon the experience of previous and current ground-based particle array observatories, SWGO will feature a large detection area, a high-altitude site, and a southern location to explore the gamma-ray sky up to PeV energies. Following the recent site selection at Pampa la Bola in Chile, located at an altitude of 4770 meters above sea level, the collaboration is now focusing on developing an on-site pathfinder. In this contribution, we present the current status of SWGO, highlight recent progress in R&D activities, and outline the future plans for the observatory.

Poster Session

A compact Cherenkov detector for measurement of the high energy anti deuteron flux in cosmic rays

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The measurement of the antideuteron flux in cosmic rays has been proposed as a probe towards the discovery of exotic sources, due to a smaller background from more ordinary process with respect to the antiproton flux in the low energy region of the spectrum. This comes from the higher mass of the antideuteron with respect to the antiproton, which leads to the suppression of its production from interaction between cosmic rays and the interstellar medium.

No antideuteron in cosmic rays has been detected yet and the best current limits on the flux comes in the energy region from 0.163 and 1.1 GeV/n comes from BESS-Polar II. Although the lowest energetic region of the spectrum is the most interesting one for exotic searches, measurement of antidueteron flux at higher energy is paramount to constrain the current models for ordinary production.
Here we present our design for a ring imaging Cherenkov detector that could provide PID between a proton and antideuteron hypothesis in a high momentum range.
The overall design of the detector is quite simple and consists of a rectangular plate of fused silica of dimension 500mm x 500mm x 18mm, which acts both as a Cherenkov radiator (with n_r around 1.5) for the incoming particle and as light guide via internal reflection for the photons emitted, in a similar fashion to the DIRC and TOP modules (from the BaBar and Belle II experiments respectively). The lateral faces of the crystal would be instrumented with an array of Silicon Photo Multiplier (SiPM) able to detect single photons and provide the 2D position information alongside with their timing with a resolution of the order of 100 ps. Suitable sensors are available from Hamamatsu photonics, for example the MPPC S1336 series, that would provide good quantum efficiency and satisfying position resolution.

A simulation using the GEANT4 tool was also developed to study the propagation of the photon inside the plate and to extimate the discrimination power between proton and antideuteron candidates. Some initial results we obtained with the simulation are presented in the additional material. We find that our setup offers good discrimination in the 5 GeV region. The simulations will be compared with a laboratory setup where a partially-instrumented prototype is explosed to cosmic muons.

The design we present is not limited to applications in astroparticle physics, but could also be implemented as a module for a segmented detector in the forward direction for collider experiments.

Poster Session

MANTRA: Measuring anti-neutron energy with the TOP counter of Belle II

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The MANTRA project is an inter-university effort to develop an algorithm to measure anti-neutron momentum using existing detectors installed in the BESIII and Belle II experiments. Both experiments are equipped with CsI electromagnetic calorimeters: these provide a loose measurement of the anti-neutron energy, which is heavily affected by shower containment. This can be mitigated by using the timing information of a high resolution particle identification detector installed in front of the calorimeter.
Such is the case for the Time of Flight system at BESIII and the Time of Propagation (TOP) counter at Belle II.

This talk will focus on the latter; the TOP allows precise measurement of the time of propagation of the Cherenkov photons emitted and trapped within a fused silica bar by incoming charged particles. This timing is function of the Cherenkov angle and the time of flight the incoming particle, allowing for a measurement of it velocity
A Cherenkov signal, however, can also be induced by neutral particles annihilating in or nearby the TOP radiator. This talk will outline a technique for anti-neutron detection using the timing information of the Belle II TOP counter. We will show how the TOP can both function as a target for anti-neutrons allowing for a measurement of their time of flight, and provide precise timing for hadronic showers originating inside the calorimeter.
We will show the timing signature left by the anti-neutron, as a function of their energy and their annihilation position, and how this information correlates with calorimetric measurements.
This study therefore paves the way towards precise measurement of the anti-neutrons produced in e^+e^- collisions, and provides useful information on the backgrounds due to neutral hadron interactions in the TOP counter.

Poster Session

The LS3 Enhancement of the RICH detectors

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The readout electronics chain of the LHCb RICH sub-detectors will be upgraded during LS3 Enhancements program scheduled for the 3rd LHC long shutdown. A novel front-end application-specific integrated circuit (ASIC) has been custom designed as the main core of the future RICH readout electronics. The FastRICH is implemented by using TSMC's 65 nm CMOS technology node together with several radiation hardness techniques including triplication for the digital logic. It provides sensor-agnostic readout capabilities, which are tunned according to the RICH specifications and would allow timing measurements with several picosecond precision. The ASIC has been designed to meet the requirements for the 4th LHC RUN, as well as for the 5th and 6th during HL-LHC phase, when the LHCb will operate as a 4D-precision spectrometer. Large efforts are dedicated to prepare the testing and a validation campaign. This work presents the design of the new opto-electronics chain for the RICH LS3 Enhancement, the testbeam campaigns performed to validate the new concept, the validation setup and the testing routines which were prepared for the FastRICH prototype validation. The plan for the radiation campaign, with ions and X-rays during this fall, and ultimately a comprehensive radiation testing at the CHARM facility at CERN will be presented as well.

R&D on Cherenkov light imaging systems for future experiments

A Proximity-Focusing RICH Detector for the ePIC Experiment at the EIC

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The Electron-Proton/Ion Collider Experiment (ePIC) will be a large, multi-purpose detector to be installed at the Electron-Ion Collider (EIC) being built at Brookhaven National Laboratory. As robust particle identification (PID) capabilities are essential for fully realizing the EIC science program, ePIC contains several PID subsystems spanning different angular ranges. PID capability in the electron-going endcap is provided by a proximity-focusing Ring Imaging Cherenkov detector (pfRICH) designed to deliver 3-sigma separation between pions and kaons for momenta up to 7 GeV/c. It will also aid with electron-hadron discrimination at low momentum and assist in the determination of the collision time (t_0).

The pfRICH design consists of a cylindrical vessel 130 cm in diameter and approximately 49 cm in length. The face closest to the interaction point holds aerogel tiles (n = 1.04) which serve as the radiator, while the opposite face contains the photosensors. The baseline photosensors are the High-Rate Picosecond Photon Detectors (HRPPDs) by Incom, which combine a large, finely pixelated, active area (104x104 mm^2, 32x32 pixels), high quantum efficiency (peak values greater than 30%), low dark count rate (hundreds to several thousand Hz/cm^2), and very good spatial and temporal resolution. In particular, single photon timing resolutions of 15 to 20 ps will enable a precise t_0 measurement and aid in extending hadron PID capabilities to lower momenta.

This contribution will summarize the design of the pfRICH as well as ongoing fabrication and component testing efforts. GEANT-based performance simulations and integration into the ePIC geometry and reconstruction framework will also be discussed.

Poster Session

Simulation Study for Particle Identification with the dRICH of the ePIC Experiment at the EIC

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Particle identification plays a critical role in the core physics program of the Electron-Ion Collider (EIC). A dual-radiator Ring Imaging Cherenkov detector (dRICH) will provide hadron identification over a momentum range from a 3 GeV/c up to 50 GeV/c in the forward region of the ePIC experiment. The ePIC dRICH will also perform pion rejection to identify electrons in order to reconstruct DIS events.
The detector employs aerogel and C_2F_6 radiators to produce Cherenkov photons, which are focused by six spherical mirrors and subsequently detected by six matrixes of SiPM (Silicon Photomultiplier) sensors. Advanced simulation studies are central to the optimization of the dRICH design.
Currently, significant effort is being dedicated to ensuring a realistic geometrical description of the detector, including the mechanical constraints and integration within the overall detector system. Additionally, realistic parameterizations of the optical components and photo-sensors are being implemented.

A particular challenge arises from the intrinsic dark count rate of SiPMs, which can impact the particle identification capabilities of the detector. Therefore, extensive simulation studies have been conducted to evaluate the identification limits under varying dark count conditions.
In this contribution, we present the simulation framework, the reconstruction algorithm, and the performance evaluation of the dRICH under different SiPM noise rates. The impact on the dRICH performance when applying timing cuts to mitigate noise effects has also been studied.

R&D on Cherenkov light imaging systems for future experiments

A RICH detector for the ALADDIN experiment

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ALADDIN is a proposed fixed-target experiment at the LHC (Letter of Intent submitted and reviewed by the LHCC; Technical Design Report in preparation) designed to measure the electromagnetic dipole moments of the Λ_c^+ and Ξ_c^+ baryons. Protons from the LHC beam halo are deflected onto a fixed solid target, producing highly boosted charm baryons. These baryons are then channeled through a bent crystal, where the intense electric field between the atomic planes of the crystal induces a measurable spin precession.The Λ_c^+ and Ξ_c^+ baryons predominantly decay into protons, kaons, and pions, with average momenta exceeding 500 GeV/c. To achieve efficient particle identification up to 1 TeV, a gaseous RICH detector with unprecedented angular resolution is required. This contribution presents the latest developments in the detector design, focusing on two alternative technologies for Cherenkov photon detection: one based on MPPCs/SIPMs and the other on MCP-PMTs.

Cherenkov light imaging in current particle and nuclear physics experiments

The Ring Imaging Cherenkov Detector of the NA62 experiment at CERN: basic performance and aging effects

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The NA62 experiment is designed to measure the extremely rare kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$ at the CERN SPS. This decay mode is highly sensitive to indirect effects of new physics at energy scales beyond the reach of current accelerators, and its branching ratio is predicted with high precision by

the Standard Model to be below 10^{-10}. One of the main experimental challenges in NA62 is the suppression of background decay channels with branching ratios up to ten orders of magnitude larger than the signal and exhibiting similar experimental signatures. A dominant background arises from the decay $K^+ \to \mu^+\nu$, making highly efficient pion/muon separation essential. A key component of particle identification (PID) in NA62 is the Ring Imaging Cherenkov (RICH) detector, which distinguishes μ^+ from π^+ in the momentum range between 15 and 35 GeV/c with a muon rejection factor of 10^{-2}. It also measures the arrival time of charged particles with a precision better than 100 ps and plays a central role in the NA62 trigger system. Since the start of data collection in 2016, the RICH detector has been operating successfully, ultimately allowing the first observation of the decay $K^+ \to \pi^+\nu\bar{\nu}$ with a significance exceeding 5σ, based on data from the period 2016–2022. This contribution presents the evolution of the RICH detector's basic performance parameters as well as recent studies on aging effects.

Poster Session

Performance evaluation in different environments of the MCP-PMT for the TOP counter in the Belle II experiment

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The Belle II experiment produces large numbers of B mesons by colliding electrons and positrons at the Υ(4S) resonance ($\sqrt{s}$ = 10.58 GeV). It aims to validate the Standard Model precisely, search for new physics, and elucidate the internal structure of hadrons. The target integrated luminosity is 50 ab-1, fifty times larger than the previous B-factory experiment.
The Time-of-Propagation (TOP) counter is a ring-imaging Cherenkov detector consisting of a quartz radiator and a photodetector, Micro-Channel-Plate (MCP)-PMT, which distinguishes charged K and π mesons produced by the decay of hadrons. The MCP-PMT has a good timing resolution of σ ~34 ps, which satisfies the requirements for K/π mesons separation. On the other hand, the MCP-PMT shows a gradual decrease in quantum efficiency (QE) with integrated output charge, which results in a deterioration of particle identification performance. Based on the collision data, the evaluated relative QE shows a more rapid drop than expected from the test bench results. It is therefore essential to identify the cause of the unexpectedly rapid QE degradation and to take effective measures to prevent it.
In this study, we performed a series of measurements using MCP-PMTs removed from the TOP counter during the long-term shutdown in 2022-2023. First, to confirm the QE degradation in the detector, we conducted laboratory measurements, which showed good linearity with those obtained in the TOP counter. Second, we investigated the temperature dependence of QE degradation. This is because the temperature during the lifetime measurements (room temperature, 25 ℃) is significantly lower than the actual operating temperature (40 – 50 ℃), which is expected to affect the amount of outgassing. Therefore, we carried out the lifetime measurements at room temperature (25 ℃) and under heated conditions (40 ℃ and 50 ℃) using the PMTs removed from the TOP counter. The results showed that no QE degradation comparable to that observed during beam operation was seen. Third, we investigated the effect of applying to a magnetic field. The lifetime measurement in the laboratory was conducted under a magnetic field of 0 T, while the actual operation occurs in a magnetic field of 1.5 T, which may affect the ionization process. Since lifetime measurements need a long time, we performed after-pulse measurements beforehand. After-pulses can be detected by a delayed pulse. They are expected to be directly associated with the presence of ions, making their measurement important for investigating potential QE degradation. As a result, we observed that the number of light ions reaching the photocathode was higher under a magnetic field than in the no-field condition. Subsequently, we evaluated the lifetime of the same PMTs. The results showed that the QE drop was observed 1.3 to 2.3 times faster at 1.5 T than at 0 T. However, the QE drop was not large enough to explain the reduction observed during the experiment.
In this presentation, we demonstrated that the presence of a magnetic field contributes to the degradation of QE. These findings provide valuable insights for improving MCP-PMTs and optimizing their operational conditions in the future.

Photon sensor techniques for Cherenkov imaging counters

Characterisation of LAPPD

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This study presents a comprehensive characterization of Large Area Picosecond Photodetectors (LAPPD) of Generation II, developed by Incom Inc., with a focus on their applicability in high-performance timing and imaging systems such as RICH detectors (e.g., Belle II ARICH, LHCb RICH) and time-of-flight PET imaging. LAPPDs combine single-photon sensitivity, ~30 ps time resolution, millimeter-scale spatial resolution, and a large active area (20×20 cm²), making them suitable for advanced particle detection applications.

The investigation centers on the effects of capacitive coupling between the monolithic ground-plane anode and the external readout pads, particularly examining how signal spread and timing performance depend on geometrical factors and pad segmentation. Using a pulsed diode laser system, spatial and timing characteristics were probed with fine granularity. Measurements confirm that signal distribution is dominantly governed by induced charge spread rather than electron diffusion, with signal confinement significantly affected by pad size and MCP-to-anode and anode-to-pad distances. A model was used to understand the observed signal spread and to find optimal system parameters.

Time resolution analyses show a primary timing peak ($\sigma \approx 27$ ps) and secondary structures consistent with backscattering effects, with resolution improving with increased photocathode-to-MCP potential, all in agreement with a simple model. The study also evaluates integration with two readout systems: PETSYS TOFPET2 ASIC, which showed effective photon detection and spatial clustering, and FastIC ASIC, which delivered excellent timing precision with low-power consumption and integrated TDC/ADC features.

Pattern recognition and data analysis

Recent advances and trends in pattern recognition and data analysis for RICH detectors

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As RICH detector technologies evolve and data volumes increase, innovative pattern recognition and data analysis methods have become essential to fully exploit the capabilities of RICH systems. This talk presents an overview of recent developments in this domain, highlighting both methodological advancements and practical implementations across current and next-generation experiments. We discuss progress in traditional likelihood-based reconstruction methods, the integration of machine learning techniques - including deep neural networks and graph-based algorithms - and their performance in challenging high-volume and high-occupancy environments.

Pattern recognition and data analysis

High level performance of the NA62 RICH detector

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NA62 is the last generation kaon experiment at the CERN SPS aiming to study the ultra-rare $K^+ \to \pi^+\nu\overline{\nu}$ decay, measuring its branching ratio with a precision better than 20%.
One of the challenging aspect of NA62 is the suppression of background decay channels with branching ratios up to 10 orders of magnitude higher than the signal and with a similar experimental signature, such as $K^+ \to \mu^+\nu$.
To this purpose, the NA62 experimental strategy requires, among other conditions, good charged particle identification (PID) capability. A key element of PID is the Ring-Imaging Cherenkov detector (RICH) that, according to the NA62 requirements, identifies μ^+ and π^+ in the momentum range between 15 and 35 GeV/c with a muon rejection factor larger than 100. The latest performance of the RICH on PID for the $K^+ \to \pi^+\nu\overline{\nu}$ measurement and for other key analyses in NA62 will be presented.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Probing the MeV Frontier with IceCube: Supernovae, Transients, and Future Directions

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The IceCube Neutrino Observatory, though primarily designed for high-energy neutrinos, has become a powerful tool for studying MeV-scale neutrino bursts from astrophysical transients. This talk will provide an overview of recent efforts and developments aimed at enhancing IceCube's capabilities in this energy regime, including searches for core-collapse supernovae, gamma-ray bursts, and compact object mergers. Key improvements in the real-time supernova data acquisition system will be highlighted, alongside ongoing efforts to probe new physics scenarios, such as axion-like particles produced in supernovae. The talk will conclude with a look ahead to the deployment of the IceCube Upgrade and the potential of IceCube-Gen2 to expand MeV-scale neutrino science, including efforts toward energy reconstruction from supernova neutrinos.

Poster Session

Development of a Gas/Aerogel Dual-Radiator RICH Detector for the J-PARC MARQ Spectrometer Using Sipm Technology

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Abstract content is in the attached summary file: RICH2025abstract-ksuzuki.pdf

Cherenkov light imaging in current particle and nuclear physics experiments

The LHCb RICH detectors: operations and performance

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During the second LHC long shutdown (2019 – 2021), the LHCb experiment underwent a major upgrade in order to be able to operate at the instantaneous luminosity of $2 \times 10^{33}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, and remove the hardware trigger reading out every LHC bunch crossing. This instantaneous luminosity corresponds to illumination rates up to $100\ \mathrm{MHz/cm}^2$ on the photon detection plane of the RICH system. In order to provide charged hadron identification in a wide range of momentum between approximately 3 and 100 GeV/c in a such challenging environment, the RICH detectors of LHCb has been completely refurbished and are operated at the LHC since 2022. The overview of operations, including the calibration procedures of the photon detection chain, is presented, together with the figures of merit used to assess the performance of the upgraded RICH detectors.

Poster Session

Optimized optical design of the LHCb RICH detectors for Upgrade-II

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The design of the LHCb/RICH optical systems operating during the current Run-3 data-taking period of the LHC, will be presented with its full characterisation, to set the realistic reference for the similar designs begin developed for the envisaged Upgrade-II, which requires more stringent requirements. Designs for Upgrade-II are then presented and analytically compared with the reference one (the Run-3 one), based on performance indicators specifically tailored to a RICH detector.
The optical designs are optimised using the OpticaEM© optical CAD, a fully flexible and customisable framework for optical (geometric and wave) calculations based on an approach very close to standard HEP codes and built on top of WOLFRAM MATHEMATICA©. Several examples of the optimization and performance reporting capabilities are shown.

The performance in terms of Cherenkov angle precision and photo-detection yield is validated through full simulation, which incorporates realistic detector conditions. We will present results obtained using a full simulation framework based on DD4hep for the detector geometry and interfaces to GEANT4 for simulating detector response and optical processes in the RICH detector.
Finally, the performance of the current RICH optics for Run-3 is compared to the expected performance of the optics for Upgrade-II, which is showed to fulfill the requirements imposed by physics.

Poster Session

Studies for the Upgrade of Belle II Aerogel RICH

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The Aerogel Ring Imaging CHerenkov (ARICH) counter of the Belle II spectrometer performs particle identification by detecting Cherenkov ring images from the aerogel radiator using Hybrid Avalanche Photo Detectors (HAPDs). Belle II will operate into the 2040s targeting 50 /ab integrated luminosity. To support extended operation and improve particle identification efficiency, an ARICH upgrade is planned during the long shutdown in the early 2030s.
HAPDs are expected to perform well for about 10 years despite radiation damage but are not suited for longer-term use, and their production has ended. Therefore, we are evaluating alternative photodetectors, such as Multi-Pixel Photon Counters (MPPCs) and Large Area Picosecond Photo Detectors (LAPPDs), for their tolerance to magnetic fields and to high levels of neutron irradiation.
Various MPPC types from Hamamatsu Photonics were assessed, particularly for operation under Belle II's high-background environment, which increases dark pulses. We irradiated samples and tested them under cooling and annealing, both of which significantly reduced dark count rates. We developed a dedicated readout ASIC, "TF01A64,"for MPPCs and evaluated its performance using

MPPC signals. A 64-channel readout system incorporating TF01A64 was constructed, and its basic functionality was confirmed in preparation for an upcoming beam test using Cherenkov ring imaging at an electron beam facility.
LAPPDs from Incom are also under evaluation. Their performance was tested with a TOFPET2 ASIC-based readout, and we are developing a system compatible with LAPPDs for further testing with particle beams and in magnetic fields.
In this presentation, we will introduce the ARICH upgrade plan and report the status of the photodetector and readout system developments toward upcoming beam and magnetic field tests.

Poster Session

CalAliMon: In-Situ Rayleigh-Scattering based Calibration Alignmnent and Monitoring system for the future LHCb RICH upgrades

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Detector-related systematics effects will become increasingly critical in the planned ''LS3-enhancements" and ''Upgrade-II" phases for the RICH detectors of the LHCb experiments at CERN LHC, due to the large photo-detector occupancy caused by the large particle flux in the high-luminosity environment.
Therefore, the requirements for calibration, alignment and monitoring will be even more stringent than for the current Run-3 detector, requiring new specialized systems to control and mitigate systematics effects.
Therefore, a system, called ''CalAliMon", has been designed,
to exploit the Rayleigh scattered light from pulsed laser beams traveling in front of and parallel to the photo-detector assembly plane.
The minimally invasive system, after taking into account for the simple geometry and kinematics of photon transport, will allow time alignment and relative pixel-to-pixel calibration, in a first phase, and,
after an upgrade during LS4, the measurement of absolute photo-detection efficiency.
The design, the first simulation results and first laboratory tests will be presented.

Cherenkov light imaging in current particle and nuclear physics experiments

The CLAS12 RICH detector

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The RICH detector of the CLAS12 experiment at Jefferson Lab has been designated to separate kaons from pions and protons in the momentum range between 3 and 8 GeV/c.
The detector geometry is based on an innovative hybrid optics design, with Cherenkov photons that can be detected either directly or after one or more reflections on a mirror system.
Its main components are: i) high transparency, large dimension blocks of aerogel radiator with refractive index n=1.05; ii) planar mirrors made by thin glass skins, never used before in nuclear physics; iii) light carbon fiber spherical mirrors; iv) large-area multianode photomultipliers for the photon detection with modular binary readout.
The detector is composed by two identical modules positioned in CLAS12 at opposite polar angles.
The first module has been installed in January 2018, just on time for the beginning of the CLAS12 data taking with the new 12 GeV energy beam.
The second module has been completed in June 2022, when the data taking with polarized targets has been started.
In this presentation we will discuss the status of the detector after several years of operation.
We will discuss the monitoring tools, the calibration and alignment procedures, the reconstruction and particle identification algorithms.
Finally, we will show select example of physics results demonstrating the PID performance of the detector.

Poster Session

Characterization of SiPMs for the LHCb RICH Detectors Upgrade-II

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The LHCb experiment is planning a major detector upgrade for the LHC RUN5 (2035) to cope with the foreseen instantaneous peak luminosity of ~ 1.0 − 1.5 × 1034 $cm^{-2}s^{-1}$. For the RICH Upgrade-II detectors, new photo-sensors are under study since the present MaPMTs cannot stand the high particle flux in the central high occupancy region in a very harsh environment.

Silicon Photo Multiplier (SiPM) is the candidate technology, given the fast time response, small dimensions and high photo-detection efficiency. Their main drawback is the radiation damage which provokes a massive DCR increase and could require mitigation strategies, namely neutron shielding, in-situ annealing, cooling to low temperatures and replacing periodically the devices.

An extensive irradiation campaign is ongoing to measure the variation of their performances with increasing 1MeV equivalent neutron fluences, up to the maximum expected value of few × 10^{13}n/cm^2.

Results of I-V curves, Gain, DCR and Time Resolution, as a function of the over-voltage, temperature and for few irradiation steps, will be presented.

Pattern recognition and data analysis

Primary vertex time reconstruction using the LHCb RICH detectors

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The LHCb RICH detectors will introduce timing information $\mathcal{O}(100\,\mathrm{ps})$ for every detected photon during the LHC Run 4. Using the RICH time information, the primary vertex time (PV t_0) can be estimated for the first time in LHCb, which is a key input parameter for exploiting fast-timing techniques in the experiment. In the RICH reconstruction algorithm, an object called a photon object (PO) is created for each combination of a detector hit and particle track that passes a set of initial spatial constraints. Using the LHCb tracking systems, tracks can be associated with different PVs. The multitude of POs (on average, hundreds of signal photons are detected per PV) in the RICH detectors allows the PV t_0 to be determined with high precision. The key challenge is to determine, out of all generated POs and in the presence of signal pile-up and background hits, which PO has a correct association from detector hit to track to PV. Simulation studies show that approximately 20% of the initial POs have a correct association to the PV. Therefore, new techniques in the reconstruction algorithm have been explored to identify a subset of POs with the highest probability to have a correct PV association. New results, generated using the LHCb experiment simulation framework, will be presented. The proposed techniques provide a 85±2 ps (FWHM) time resolution for 94% of the PVs, starting from an initial PV time spread of 450 ps (FWHM) at the simulated bunch crossings. Additionally, the use of additional information from a first iteration of the RICH reconstruction likelihood-maximisation algorithm is being explored. The benefit of such a likelihood iteration and other techniques will be weighed against the cost in extra computation.

Poster Session

Development of a Gaseous Photomultiplication Based Cherenkov Detector Targeting Picosecond Time Resolution

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To meet the growing demand for photosensors with high time resolution, large photocoverage, and low cost in Cherenkov imaging detectors, we have developed a gaseous photomultiplier (GasPM). It has a photocathode and a simple electron multiplication mechanism similar to that of resistive plate chambers. Using a picosecond pulse laser, we have already demonstrated that the GasPM with a LaB_6 photocathode and a mixture of R134a and SF_6 gas has a single-photon time resolution of $\sigma = 25 \pm 1.1$ ps at a gain of 3.3×10^6. The next milestone of the R&D is to detect Cherenkov photons with that excellent time resolution.
The photocathode was replaced with CsI deposited on a MgF_2 window, which can detect Cherenkov photons at wavelengths below 200 nm generated in the window. We performed beam tests of this detector with a 5 GeV electron beam at the PF-AR test beamline at KEK. We achieved a time resolution of $\sigma = 73.0 \pm 2.4$ ps with a gap electric field of 140 kV/cm. To improve the time resolution, the thickness of the MgF_2 window and the gap electric field were increased to 187 kV/cm. In addition, a digitizer with a higher sampling rate of 10 Gsamples/sec was used to distinguish between overlapping initial signal pulse and subsequent ones due to photon feedback.
The results of these beam tests will be discussed in this presentation.

Poster Session

Rate capability and transient gain drop of an single photon timing detector

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Multi-anode Microchannel Plate (MCP) detectors offer distinct advantages, including timing resolutions below 30 ps, single-photon sensitivity, and a modular architecture. Advancements in High-Energy Physics experiments—such as the TORCH project—are driving the need for increased photon rate capability and higher spatial resolution granularity of detector designs. This study presents measurements of the rate capability of multi-anode photomultiplier tubes (MAPMT), including an MAPMT with higher granularity custom readout for the TORCH project of 16 x 96 pixels (0.55 mm pitch), building on this, aims to quantify the lateral spread of the transient gain drop.

When a photoelectron strikes a microchannel plate (MCP), it can trigger an electron avalanche that rapidly drains charge from the microchannel walls. This sudden discharge causes a noticeable drop in gain, which does not recover instantaneously. Instead, the affected regions experience a temporary "dead" period during which their ability to amplify subsequent signals in this channel is significantly reduced. Studies demonstrate that this gain suppression isn't limited to the directly impacted channels—neighbouring channels also exhibit reduced sensitivity, suggesting a lateral spread of the effect. This phenomenon plays a key role in determining the MCP's local rate capability, as the local charge depletion extends the effective dead time across multiple channels.

Quantitatively characterizing the lateral extent of the gain drop is essential for applications like particle physics, where higher photon rates are required. This measurement can guide the optimization of MCP detector designs, including pixel pitch in multi-anode configurations.

Pattern recognition and data analysis

Online AI-based distributed data reduction for the dual-radiator RICH detector in the ePIC experiment

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The ePIC experiment at EIC integrates a dual-radiator RICH (dRICH) detector for particle identification in the forward region. The detector will use silicon photomul tipliers (SiPMs) to detect Cherenkov radiation with single-photon sensitivity over a surface of ~3 m2. The ~320k detector channels will be readout by 4,992 Front End Boards (FEBs); each of the 1,248 Readout Boards (RDOs) will collect data from four FEBs and forward them via a VRTX+ optical link to a Data Aggregation and Manipulation Board (DAM) supporting up to 48 ports. DAMs will be implemented by FPGA-based FELIX-155 cards designed for the ATLAS experiment. They will collect and merge data from 42 RDOs, forwading them through 100 GbE channels to the ePIC data buffering system (Echelon 0). To mitigate the potential risk of an excessive dRICH output bandwidth demand due to the increasing SiPM Dark Current Rate(DCR), expected to reach a maximum of 300 KHz during the experiment lifetime, we designed a real-time data reduction system that will reduce the detector output bandwidth by an order of magnitude at least. This will be accomplished by implementing a distributed data-flow processing scheme on the DAMs and on an additional Felix-155 card that will act as a Trigger Processor (TP), selecting and discarding online the DCR noise only events. Current design is characterized by a distributed Multi-Layer Perceptron Neural Network performing the Noise-Only event discrimination, with 30 separate sub-network replicas deployed on each DAM which processes its event fragment to extract a set of features that are passed to the TP using a direct low-latency communication channel. The TP implements a different sub-network that, having in input the full set of features extracted by each DAM, performs the classification task and generates the corresponding trigger signal to keep or discard the event, respectively, in the case of a physics (including background) signal plus DCR noise and DCR noise only. The main EIC clock will be at 100 MHz, corresponding to ~10 ns election-ion bunch crossing: this will be the main challenge in the implementation of the system. We will outline our approach to this issue, covering both the FPGA computing pipelines and communication, along with the current implementation status.

Poster Session

The FastRICH ASIC for next-generation RICH detectors

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A novel ASIC, called the FastRICH, is designed and produced for the front-end electronics of single-photon detectors in future RICH detectors. Owing to the prompt Cherenkov radiation and precise optical arrangement of RICH detectors, the Cherenkov photon time-of-arrival can be used to improve the particle identification performance. The 24.4 ps detector hit timestamps provided by the FastRICH will equip the detector for such fast-timing reconstruction techniques. The addition of time information, especially when combined with the increased particle multiplicity in High-Luminosity LHC experiments, requires advanced data-compression techniques to limit the front-end bandwidth requirements. Dedicated design features therefore include constant-fraction discrimination, an on-chip time gate to remove out-of-time background and an optimised data-driven output format. In order to deal with the typically non-uniform hit rates in different regions of the RICH detectors, the 16-channel FastRICH has a configurable output data rate between 320 Mb/s and 5.12 Gb/s. The ASIC has a wide input signal dynamic range allowing it to be flexibly coupled to different types of fast single-photon sensors including silicon photomultiplier arrays and vacuum-based sensors. A strong design effort was made to minimise the power consumption (simulated to be less than 16 mW/channel at 1.2 V) for integration into compact future detectors with high channel densities. The FastRICH is produced in 65 nm CMOS technology with triplication of sensitive logic for tolerance against single-event effects due to radiation in high-energy physics applications. The FastRICH is developed in the context of the LHCb experiment and compliant with the 40 MHz event rate and experiment timing and control system. The ASIC can be coupled directly to the next-generation CERN front-end optical link chipset for data transfer. The FastRICH ASICs were produced in May 2025. A detailed measurement campaign is launched to validate the design at the single-chip level as well as a full module for beam tests at the CERN PS/SPS facilities. In this contribution, the key features and the first test results of the FastRICH ASIC are reported.

Poster Session

Large Area Picosecond Photodetector for the Upgrade II of the LHCb RICH

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The Large Area Picosecond Photodetector (LAPPD) is a commercially available photon detector based on microchannel plate technology (MCP), which has garnered significant attention from the scientific community due to its large size, outstanding timing resolution, high gain, and low dark count rate. With a large sensitive area of 200×200 mm^2, the LAPPD is particularly appealing for Ring Imaging Cherenkov (RICH) detectors in particle colliders, neutrino experiments, as well as applications in medical imaging and nuclear non-proliferation. The LAPPD 97 generation-II model purchased from INCOM (US) uses a capacitively coupled array of 64 (8×8) square pixels with a granularity of 24×24 mm^2 to readout the photon signal. A custom backplane, designed to improve the spatial resolution, uses pixel size of 2.9×2.9 mm^2 and covers a limited area of the detector. The LAPPD coupled to the LHCb RICH fast electronics readout chain was tested at CERN SPS across several test beam campaigns. The results will be presented together with the first quantum efficiency and the rate capability measurements for the LAPPD 97. Further tests are planned to explore the limits of this device in rate and timing capabilities.

Photon sensor techniques for Cherenkov imaging counters

Transmission Dynodes: Enhancing Vacuum Photodetectors

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Microchannel Plate Photomultiplier Tubes (MCP-PMT) devices represent the state-of-the-art in terms of picosecond timing resolution combined with low noise, high gain, and radiation hardness. However, with experiment upgrades producing higher luminosities, there are concerns over the ability of the existing technologies to achieve sufficiently high rates and longer tube lifetime in terms of extracted charge. To overcome these limitations, we are developing a hybrid diamond/MCP photomultiplier consisting of a transmission dynode followed by an MCP.
The transmission dynode, a diamond-based composite material comprising a single crystal diamond membrane on a high open area support structure, operates at a gain of 10-20, followed by further gain in the MCP. This high first gain stage produces a low gain variance which allows operation at a lower overall gain while maintaining the tight pulse height distribution necessary for single photon counting. Since the maximum MCP signal is current-limited due to the MCP resistance, a lower overall gain allows higher maximum photon count rate to be achieved. In addition, the diamond membrane acts as an impermeable barrier to ion feedback from the MCP, a major cause of photocathode degradation which limits the effective lifetime of conventional tubes.
In the longer term, a complete replacement of MCPs with transmission dynodes is an attractive prospect. These devices would have an excellent single-photon spectrum, higher collection efficiency than MCP-PMTs and their linear geometry will give much improved timing precision over the ~30 ps of conventional MCP-PMTs.

High photocoverage and time resolution are of great importance for modern water Cherenkov neutrino detectors, but this leads to high costs. This work presents a lower-cost alternative to classical large area hemispherical PMTs, namely the Hamamatsu R7801 based on SiPMs coupled to wavelength shifting plates, the FRANCIS. Two generations of prototypes of these detectors were tested with a picosecond laser and digitiser readout, and it was seen that the system could provide arrival time spreads in the region of 1.17 ns in the case of a 250×250 mm^2 which is better than that quoted for the Hamamatsu R7801 at 3.4 ns.

Poster Session

A cryogenic RICH detector demonstrator for SiPM operation with integrated flex-PCB electronics

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Silicon photomultiplier (SiPM) arrays are strong photodetector candidates for future RICH detectors owing to their excellent single-photon detection efficiency, time resolution and fine granularity. The main challenge in operating SiPM arrays is the dark-count rate (DCR), especially after irradiation damage. Operation at cryogenic temperature effectively mitigates the DCR. The design and integration of a cryostat in a RICH detector pose a technical challenge. A modular cryostat demonstrator is being developed at CERN to characterise SiPM arrays at liquid-nitrogen temperatures ($\sim$ 80 K) under different experimental conditions. The design of the demonstrator addresses critical technical aspects such as the coupling of SiPM arrays to a cold block, the operation of multi-channel readout electronics in vacuum and the transmission of the SiPM array analogue signals over distances of several centimetres. This demonstrator will provide valuable insights for the scalability of the system to large photodetector areas. A flex-PCB solution has been adopted for the transmission of analogue signals from the cryogenic-cooled SiPM arrays to the readout electronics at room temperature. A prototype of the flex-PCB has been designed and produced to evaluate the effect of 15cm-long high-density traces on signal integrity and time resolution. The results demonstrate that signal integrity is well preserved. A single-photon time resolution of 107ps (σ) was measured using a picosecond-pulsed laser setup. These results represent an important step in the development of the cryostat demonstrator.

R&D on Cherenkov light imaging systems for future experiments

The Upgrade II of the LHCb RICH system

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The High-Luminosity LHC (HL-LHC) will present unprecedented opportunities for precision flavour physics, along with new challenges for detector performance in extreme conditions. As part of the LHCb Upgrade II program, the Ring Imaging Cherenkov (RICH) detectors are undergoing a comprehensive redesign to meet the demands of increased luminosity, higher track multiplicities, and tighter timing constraints with occupancies approaching those of general-purpose detectors in the forward region. This contribution outlines the conceptual design and ongoing R&D efforts for the RICH Upgrade II system. The upgraded detectors will feature ultra-fast photon sensors with improved spatial granularity and picosecond-level time resolution, enhanced optics to mitigate occupancy effects, and fully integrated front-end electronics capable of precision time stamping, enabling 4D particle identification, using the timing information to disentangle high-density event topologies. We will present the current status of sensor and optics development, simulation studies guiding design choices, and initial results from testbeam campaigns, demonstrating how these unprecedented technological advances are essential to realizing LHCb's physics ambitions in the HL-LHC era.

Poster Session

spadRICH: Developing Digital Analog SiPMs as Candidate Photodetectors for Future RICH Detectors

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In the next generation of experiments in high energy particle physics a large increase in beam interaction density will necessitate upgrades of particle detectors. Examples are the Ring imaging Cherenkov detectors (RICH) in the planned upgrades of the LHCb, Belle II and ALICE 3 experiments. The upgraded RICH detectors will need photo detectors capable of detecting rings of Cherenkov photons at high rates of true and background events as well as large background radiation. Silicon photomultipliers (SiPMs) are an attractive photodetector candidate, with the main remaining technological challenge being the resistance to neutron radiation damage - during the whole experiment run time, the photodetectors are expected to receive accumulated dose of a couple 10^{13} 1-MeV neutron equivalent/cm^2. To achieve the targeted radiation tolerance, as well as other RICH detector requirements, dedicated developments and a combination of radiation damage reduction and mitigation techniques, such as cryogenic cooling, are needed. The spadRICH project is developing a CMOS single-photon avalanche diode (SPAD) based photodetector optimized for the application of the planned RICH detectors, with SPADs designed specifically for radiation hardness and cryogenic operation. SPADs designed by the AQUA Lab in 55 nm BCD technology, 110 nm CMOS image sensor technology and 180 nm CMOS technology were characterized at temperatures between room and liquid nitrogen, before and after irradiation with neutrons up to 10^{12} 1-MeV neutron equivalent/cm^2. We report on the results of measurements of dark count rates, afterpulsing probability and response of SPADs to low-level light illumination.

R&D on Cherenkov light imaging systems for future experiments

The ePIC dual-radiator RICH detector

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The dual radiator Ring Imaging Cherenkov (dRICH) detector is part of the particle identification system in the forward (ion-side) end-cap of the ePIC detector and complements the forward time-of-flight system and calorimetry.

The dRICH is required to provide continuous hadron identification from ~3 GeV/c to ~50 GeV/c, and to supplement electron and positron identification from a few hundred MeV/c up to about 15 GeV/c. Such an extended momentum range imposes the use of two radiators, gas and aerogel, with a common imaging system to ensure compactness and cost-effectiveness. The selected reference gas radiator is hexafluoroethane (C2F6), which matches the requirements being characterized by refractive index n = 1.00086 at STP and excellent chromatic dispersion. The aerogel radiator is a amorphous solid network of SiO2 nanocrystals whose density is tuned to get a refractive index of n = 1.026 at 400 nm wavelenght.

The dRICH has to provide open acceptance in the ePIC forward pseudo-rapidity range 1.5 - 3.5. To achieve proper light focalization within the due volume, the dRICH active area is curved and located behind the shadow of the barrel detector support, close to the ePIC solenoid coils. In this region, the ~1T strong and not-uniform ePIC magnetic field imposes the use of unprecedented detectors (SiPM). The dRICH is a ring-shaped detector, with a length of 1.27 m and a diameter of 3.6 m. In order to minimize the material budget, both the structure and the mirrors are made of composite materials.

During the R&D phase, the dual radiator principle and the single component performance have been validated. In this presentation, the status of the project will be presented. The design and technological choices will be discussed together with the results obtained by laboratory characterization of the component demonstrators and beam tests of the evolving prototypes.

Poster Session

Muon Decay as a Robust Long-Term Calibration Method for Water Cherenkov Detectors

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Water Cherenkov detectors (WCDs) are widely used in gamma-ray astronomy. At high altitudes (>4000 m a.s.l.), where detectors such as those in the LAGO network, HAWC, and the upcoming SWGO operate, gamma-induced air showers can be detected more efficiently due to reduced atmospheric absorption. However, the harsh conditions at these sites make regular maintenance and calibration extremely challenging, highlighting the need for remote and reliable calibration methods.
At these elevations, the atmospheric background is dominated by its electromagnetic component, significantly suppressing the muon flux and rendering the traditional muonic hump in the charge spectrum nearly undetectable. This feature, typically used for energy calibration, becomes unusable.
In this work, we apply a previously developed method that exploits the detection of Michel electrons —emitted from muon decays within the detector volume—to calibrate WCDs without requiring complementary instrumentation. The method is robust against variations in altitude, meteorological conditions, and solar activity, and provides a stable calibration reference independent of the features of the total charge spectrum.
We demonstrate the feasibility of this approach by analyzing long-term calibration periods for prototype LAGO detectors, and compare the measured Michel spectra with detailed simulations. Our results confirm that this technique enables consistent and remote energy calibration in WCDs, even under extreme high-altitude conditions.

Photon sensor techniques for Cherenkov imaging counters

Studies of LAPPD and HRPPD photodetectors for Cherenkov imaging application

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Large Area Picosecond Photon Detectors (LAPPDs) and High Rate Picosecond Photon Detectors (HRPPDs) are large area Micro-Channel Plate-PMTs (MCP-PMTs) resulting from a long-lasting collaboration between academy and industry. The atomic layer deposition technique that improves the MCP-PMT lifetime has been introduced within this development. These photosensors have a very good time resolution typical for MCP-PMTs, down to 15-20 ps for single photon detection. They have high Quantum Efficiency (QE) with peak values larger than 30% and low Dark Count Rates ($\sim$few kHz/cm^2). A distinguishing feature of LAPPDs and HRPPDs is a large sensitive area of about 20×20 cm^2 and 10×10 cm^2, respectively. HRPPDs have fine granularity with 3.25×3.25 mm^2 anode pads DC coupled to external readout electrodes. In the case of HRPPDs, the two MCP stages have 10 μm diameter capillaries and can provide a gain above 10^7 at a bias voltage not larger than 800 V across each of them. HRPPDs are the baseline photosensor of a proximity focusing RICH (pfRICH) of the Electron-Proton/Ion Collider (ePIC) experiment at Elecron Ion Collider (EIC). They are also considered for a high performance DIRC (hpDIRC) of the same experiment.

In this contribution, we first present the timing resolution of an LAPPD photosensor detecting Cherenkov light produced in a quartz radiator at a CERN PS hadron test beam performed in 2022. Results show a Single Photo-Electron (SPE) time resolution of 87 ps rms. We then present the performance of an LAPPD in a magnetic field up to $\sim$1.5 T. The measurements were performed at CERN using MNP-17 and M113 vertical dipole magnets in 2023 and 2024, respectively. Exponential gain drop as a function of a magnetic field strength, with a rather moderate dependence on the field line orientation with respect to the photosensor window normal direction has been observed. The relative Photon Detection Efficiency (PDE) in the magnetic field is also affected. However, both the gain and the efficiency can be partially recovered by increasing the bias voltages across the two MCPs. We also present the results of aging studies performed with an HRPPD photosensor in 2025. The strategy of these measurements is to expose a small area of the photocathode to substantial light illumination and monitor a degradation of the effective PDE as a function of the integrated photon flux as well as the charge generated in the electron multiplication process. The aging effect on the gain will also be reported. All these studies are performed by the INFN Genova and INFN Trieste groups.

Cherenkov light imaging in neutrino and astroparticle physics experiments

From a Network to a Networking: The Evolution of the Latin American Giant Observatory

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The Latin American Giant Observatory (LAGO) is a collaborative initiative that deploys a network of low-cost, autonomous Water Cherenkov Detectors (WCDs) across Latin America and Spain. Initially focused on detecting gamma-ray bursts at high-altitude sites, LAGO has evolved into a multidisciplinary platform for astroparticle physics, space weather studies, and environmental monitoring. Its detectors operate from sea level to over 4300 meters above sea level in diverse geomagnetic and atmospheric conditions. The ARTI-MEIGA simulation framework is a key development that models the complete cosmic ray interaction chain and enables site-specific simulations to be integrated into FAIR-compliant workflows. These tools support a range of applications, including muography, radiation dose modelling, and a new method for soil moisture estimation via cosmic neutron detection. Calibration of WCDs is achieved using both Michel electrons from muon decays, and the VEM (Vertical Equivalent Muon) a direct product of the WCD measurement, ensuring robust performance without external instruments. LAGO also plays a significant role in regional education and training through partnerships with ERASMUS+ projects LA-CoNGA and EL-BONGÓ Physics, positioning itself as a hub for research capacity building. New contributions to the collaboration include neutron hydrometry for precision agriculture and space weather monitoring in the South Atlantic Magnetic Anomaly. LAGO demonstrates how Cherenkov-based detection and open science can drive scientific discovery and practical innovation.

Technological aspects and applications of Cherenkov light detectors

An integrated housing with active cooling for Silicon Photomultipliers arrays in next generation of Ring Imaging Cherenkov Detectors

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The next generation of Ring Imaging Cherenkov (RICH) detectors imposes stringent requirements on photon detection technologies.
Silicon Photo-Multipliers (present on the market with different brand names, including SiPM and MPPC), offering
high photon detection efficiency (
$gtrsim0.5$) in the near-UV,
fine granularity down to one mm pixel size,
excellent timing performance of the order of tens of ps,
extensive flexibility in the design with mechanical robustness and
relatively cheap costs,
have emerged as the solution.

However, their integration into large-scale RICH systems requires attention to dark count rate, which can be influenced by various factors such as irradiation and operating temperature. Mitigating this effect requires a combination of shielding, annealing, and cooling, with the specific approach depending on the experimental environment.

We present the design and development of a compact, integrated housing module for SiPM arrays that combines mechanical support, active thermal management, and readout electronics into a scalable autonomous unit.

Building upon the modular Elementary Cell (EC) concept adopted in the LHCb RICH Upgrade I, the new solution is tailored to meet the demanding requirements of future Cherenkov detectors.

Different active cooling strategies are being explored. The most promising approach employs a multilayer ceramic PCB substrate with embedded fluidic channels for cooling, offering excellent thermal conductivity, mechanical robustness, and high-density signal routing within a compact footprint.

We will present results from validation studies, including thermal simulations and functional tests, demonstrating the system's ability to maintain the SiPMs at operating temperatures well below 0 °C, thereby suppressing dark count rate while preserving signal integrity.

This development represents a significant step toward the large-scale deployment of high-density, low-noise SiPM arrays in next-generation Cherenkov detectors, and provides a concrete path toward future 2.5D and 3D integration of sensors, electronics and cooling into a unified, compact architecture.

Cherenkov light imaging in current particle and nuclear physics experiments

Operation and performance of the Belle II Aerogel RICH detector

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The Aerogel Ring Imaging CHerenkov (ARICH) detector is a key component of the Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, designed to provide excellent charged particle identification in the forward region. The experiment aims to accumulate 50 times more data than its predecessor to enable precise studies of rare B and D meson decays, as well as tau lepton processes. The ARICH system, utilizing silica aerogel radiators and 420 Hybrid Avalanche Photo Detectors (HAPDs), is optimized to distinguish between charged kaons and pions up to momenta of 4 GeV/c.

Since the start of full physics runs in 2019, Belle II has collected over 500 fb−1 of data. The 2024a-b run posed significant challenges for ARICH due to increased accelerator background and a partial failure in the cooling system. A comprehensive realignment was conducted using high-momentum dimuon events and a novel calibration procedure. Despite concerns over neutron-induced damage to the HAPDs, their performance remains within expectations, aided by close monitoring of leakage currents.

In light of these operational difficulties, the ARICH detector continues to deliver reliable and precise kaon-pion separation. This report presents an overview of the detector's performance, recent challenges, and the measures implemented to maintain optimal operation.

Poster Session

iactsim: a CUDA-accelerated simulation framework for IACTs

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Analyzing data from Imaging Atmospheric Cherenkov Telescopes (IACTs) requires large-scale Monte Carlo simulations of air showers and the detailed simulation of telescope optics and Cherenkov camera. Within the simulation of the telescope response, optical ray-tracing and camera electronics are the most time-consuming parts. Fortunately, these tasks involve many independent calculations (photon propagation and pixel response) that can be run concurrently. This makes them ideal candidates for acceleration using Graphics Processing Units, which have become widespread in both High Performance Computing systems and consumer hardware over the past decade due to their high parallel processing power and energy efficiency.

We have developed *iactsim*, a Python simulation framework, using CUDA to parallelize these specific tasks. *iactsim* is designed as a user-friendly and adaptable set of tools to support IACT performance evaluation, instrument design and data analysis. We have validated the framework capabilities by simulating the ASTRI dual-mirror optical system and its SiPM-based camera, confirming its effectiveness even in its early development stage.

Although it has been designed for IACT simulations, a key feature of *iactsim* is the separation between the optical ray-tracing and the camera electronics simulation. This modularity allows users to simulate the pixel response independently, using photon propagation results generated by external software (such as Geant4). As a specific application, we have used it to simulate the detection of Cherenkov photons induced by muons passing through the ASTRI camera protective window.

Here we present these ASTRI-specific use case studies, performance analysis and comparison with existing software.

Poster Session

Characterization of Aerogel Radiators for RICH Detectors Using Optical Coherence Tomography

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The High Energy Light Isotope eXperiment (HELIX), a balloon-borne detector targeting 3% mass resolution for cosmic-ray isotope composition, uses a Ring Imaging Cherenkov (RICH) with aerogel radiators (n=1.155, 1 cm thick) for velocity measurements above 1 GeV/n. Achieving the mass resolution requires a velocity resolution of 0.1%, necessitating characterization of the aerogel radiator's refractive index and thickness. We introduce an independent method to characterize the refractive index and thickness of aerogel radiators simultaneously: Spectral Domain Optical Coherence Tomography (SD-OCT). SD-OCT relies on changes in optical path length to simultaneously extract the group refractive index and thickness. This work demonstrates the feasibility of OCT for these direct group refractive index and thickness measurements, from which the phase refractive index at 405 nm is then derived. The aerogel thickness varies between 9.45 mm and 9.65 mm, with refractive index values at 405 nm ranging from 1.155 to 1.159, each determined to within an order of 10^{-3} mm and 10^{-4} respectively.

Technological aspects and applications of Cherenkov light detectors

Developing hydrophobic silica aerogels for Cherenkov detectors

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The latest research results on developing hydrophobic silica aerogel as a Cherenkov radiator are reported. Previously, our benchmark for the aerogel's optical property was a transmission length of 40 mm at a 400-nm wavelength for a refractive index of 1.05. The maximum size of a single tile with no mechanical cracking was 18 cm × 18 cm × 2 cm while ensuring hydrophobic quality. These characteristics were obtained during the construction of an aerogel-based RICH (ARICH) detector for the Belle II experiment being performed at KEK, Japan. We have recently been focusing on increasing the volume of a single aerogel tile in terms of area and thickness (e.g., 20 cm × 20 cm × 3 cm and beyond). Larger tiles enable us to construct a boundary-reduced radiator module for large detector systems. The key to producing a large tile with no internal cracking is a drying technology to extract solvents from a synthesized alcogel. Moreover, improving the optical transparency is crucial for utilizing aerogels with lower refractive indices in RICH detectors (e.g., ranging from 1.025 to 1.04), given the limited number of Cherenkov photons emitted in low-index aerogels. Specific applications of the above aerogels in planned worldwide high-energy physics experiments are also discussed.

Technological aspects and applications of Cherenkov light detectors

The ePIC dRICH rdiator gas

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Excellent PID is an essential requirement of the ePIC experiment at the EIC, where hadron identification in the forward region will be provided by the dRICH detector, using as radiators both aerogel and gas.
The motivation for the choice of hexafluoroethane (C2F6) as dRICH radiator gas is illustrated and the challenges related to this choice are discussed.
The main requirements on the dRICH gas system and the characteristics of the proposed components are presented.
The option to perform separation of the gas mixture using selective permeability membranes as an alternative to distillation is illustrated.
The possibility of minimizing the environmental impact of the system operation is discussed.
The tools and techniques for qualifying and continuously monitoring the radiator gas are presented.
The use of modified Jamin interferometer for precise determination of the refractive index value and for very accurate monitoring is illustrated, presenting results from a prototype instrument.
Alternative options to hexafluoroethane, including the use of pressurized argon radiator, have been considered, and prototype tests and being prepared.

Silicon photomultipliers (SiPMs) are being considered as candidates for photon detectors in the Ring Imaging Cherenkov (RICH) systems of high-luminosity experiments, such as EIC, Belle II, and the upgraded LHCb. Their small size, high photon detection efficiency, sub-100 ps time resolution, and compatibility with magnetic fields make them attractive for Cherenkov imaging. However, their vulnerability to neutron-induced radiation damage, particularly the dramatic increase in dark count rate (DCR), poses a challenge for sustained operation in environments with expected fluences up to 10^{13} neq/cm^2. This work investigates the performance of SiPMs of different producers, irradiated to various neutron fluences and characterised over a wide temperature range from +20 ℃ down to -180 ℃. We show that although room-temperature operation becomes unfeasible at high fluences, adequate cooling enables recovery of single-photon sensitivity and timing resolution. The results demonstrate that cooling is essential to retain the timing capabilities of SiPMs in next-generation RICH detectors and provide benchmarks for future design and integration.

Poster Session

ALCOR: a SiPM readout chip for the ePIC-dRICH detector at the EIC

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ALCOR (A Low-power Chip for Optical sensor Readout) is a mixed-signal ASIC designed for the readout of silicon photomultiplier (SiPM) sensors and developed in the framework of the ePIC dual-radiator RICH (dRICH) detector at the future Electron-Ion Collider (EIC). The current version of ALCOR integrates 32 channels, arranged in an 8×4 matrix, to provide a precise time measurement with single-photon sensitivity and a fully-digital output. Each channel features a low-impedance current conveyor input stage, based on a regulated common-gate topology, supporting both positive and negative polarity inputs. The analogue front-end offers four programmable gain settings and incorporates two discriminators with independent 6-bit DAC thresholds. Quad-buffered, low-power TDCs with analog interpolation are deployed in each channel to provide precise timestamping with a 25-50 ps time bin. The ASIC also includes time-over-threshold and slew-rate operating modes, providing an indirect measurement of signal amplitude to correct time-walk effects. Designed in 110 nm CMOS technology, ALCOR operates with less than 12 mW power consumption per channel. ALCOR has been thoroughly tested both standalone and coupled with different SiPM models and its performance has been validated in beam tests using a dRICH prototype with a 2048 3×3 mm^2 SiPM readout plane. A new version of the chip (ALCOR-64), designed to meet specific EIC-driven requirements, has been sent for fabrication in April 2025. In this version, the number of channels has been extended to 64 and the chip is integrated inside a BGA package. A hardware shutter with programmable width has been implemented to filter SiPM dark-count signals that are out-of-time with respect to the 10.2 ns EIC bunch crossing period. The presentation will outline the main blocks

of the ALCOR ASIC, summarize the key performance results from the chip electrical characterization and beam test campaigns, and discuss the new features implemented in the novel version for the ePIC dRICH detector.

Poster Session

The mRICH detector for the mCBM prototype Experiment

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The CBM (Compressed Baryonic Matter) experiment to be built at the future FAIR facility in Darmstadt, Germany aims to investigate the QCD phase diagram at high-net baryon densities and moderate temperatures. The FAIR accelerator will provide high-intensity heavy-ion beams for this fixed target experiment. To ensure the best operability of CBM at day one, a prototype of CBM has been set up, including scaled-down versions of almost all the detectors later to be employed in the final CBM setup. One main goal of this prototype, called mini-CBM (mCBM), is to establish the free-streaming readout scheme envisioned for CBM. To test this scheme,
several beam times were carried out during 2024. This contribution will focus on the mRICH detector, being part of mCBM. The mRICH is a proximity-focusing RICH detector that employs the same readout electronics as the planned RICH detector for the final CBM experiment. Particular emphasis is placed on the mRICH performance observed during the recent campaigns. Furthermore, this discussion covers the status of buffer studies currently underway to mitigate the risk of data loss due to buffer overflow on the free-streaming readout setup.
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Cherenkov light imaging in neutrino and astroparticle physics experiments

HUNT : An ultra-large-scale neutrino astronomy telescope

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In 2021, LHAASO observed a large number of PeV cosmic ray candidates in the Milky Way. We proposed to build a telescope with at least 30 times the sensitive volume of the IceCube detector, so as to observe those LHAAASO sources. In order to realize this project, we innovatively put forward a photosensitive detector unit based on a photomultiplier tube with a maximum photosensitive area of 20 inches. We have already started the prototype work in Lake Baikal and South China Sea respectively. It is estimated that within three years, we will complete the R&D work of the project.

Cherenkov light imaging in current particle and nuclear physics experiments

Status and Performance of the GlueX DIRC

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The GlueX experiment is located in experimental Hall D at Jefferson Lab (JLab) and provides a unique capability to search for hybrid mesons in high-energy photoproduction, utilizing a ~9 GeV linearly polarized photon beam. Since 2020 a Detector of Internally Reflected Cherenkov light (DIRC) has been in use at GlueX, utilizing components from the decommissioned BaBar DIRC. In this contribution we will discuss the status and performance of the GlueX DIRC with the data collected to date, including recent developments in the use of machine learning for particle identification.

Cherenkov light imaging in neutrino and astroparticle physics experiments

Cherenkov Detector Arrays in LHAASO and Updated Physics Results

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LHAASO using large area water Cherenkov for CR air shower detection in the energy range from 0.5 to 20 TeV for gamma ray astronomic observation of mainly extragalactic objects. The water cherenkov detectors are burried 2.5 m beneath the surface to measure muons in showers in LHAASO. The largest muon detector array with the active area of 40k square meters in the CR detction history provides most powerful supression of CR background in detection of gamma rays at energies above 10 TeV up to 10 PeV. This permits discovery of many PeVatrons widely existing in the Milky Way. In LHAASO 18 imaging air Cherenkov telespoces used to measure shower developments for both shower energy and shower maximum, which allow the attempts of identification of protons, helium and even iron nuclei at energies above 0.1 PeV up to 100 PeV in which the knees of individual species spectra are expected. Now, the proton and helium spectra are measured with high purity samples.

Poster Session

Characterisation of a Novel Photodetector Configuration for Water Cherenkov Detectors

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We present the development and experimental characterisation of a novel photodetector configuration designed for water Cherenkov detectors, aimed at future use in high-energy gamma-ray observatories. The design consists of a small-area photomultiplier tube (PMT) coupled with a wavelength-shifting (WLS) plate, which aims to increase the effective light collection area by converting and guiding absorbed Cherenkov photons toward the PMT's photocathode edge. This approach offers a cost-effective alternative to large-area PMTs traditionally used in water Cherenkov detectors, as a means for background hadronic rejection.
To evaluate its performance, the detector was installed in a dedicated water tank at the University of Leicester and paired with a custom-built muon telescope to measure coincident triggers from atmospheric muons. The response of the WLS plates was measured and compared to that of a stand-alone 3-inch PMT. We report on the light yield, time response, and detection efficiency of the PMT with WLS plates. These results demonstrate the feasibility of using WLS-enhanced compact

photodetectors in large-scale Cherenkov arrays and their potential integration into next-generation high-energy gamma-ray observatories.

Poster Session

MCP-PMT Innovations at Incom

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Innovations to reduce afterpulsing, develop MCP-PMTs with 6 um microchannel plates for improved time resolution and rate capacity and a compact position sensitive MCP-PMT are in progress at Incom. A hydrophobic ALD film has been developed for use on top of an MgO secondary electron emission film. It is intended to reject water layers from air exposure, thereby reducing the load of adsorbed water load in the microchannels that leads to afterpulsing and photocathode degradation. Using a technique that combines aluminosilicate glass microchannel substrates with ALD films for resistance and secondary electron emission, Incom is reducing the diameter of the microchannels to 6 um. A 33 mm diameter size is in development, to be followed by scaleup to a 10 cm square size. A compact, 43 mm diameter MCP-PMT with a position sensitive, capacitively-coupled anode has been constructed to serve as both a test device for 6 um microchannel plates and as a routinely manufactured product. Finally, a square format 56 mm MCP-PMT is in development to have a scintillator with as a window. It is intended for use with PET medical imaging, where timing and position sensitivity may be degraded by a thick window. A barrier is required between the photocathode and scintillator to prevent unwanted diffusion and compositional changes. A thin fused silica window may also be used on this device.