The RICH detector for the CBM experiment at FAIR

T. Mahmoud for the CBM collaboration

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Justus-Liebig-Universität Giessen
Germany
Tariq.Mahmoud@exp2.physik.uni-giessen.de

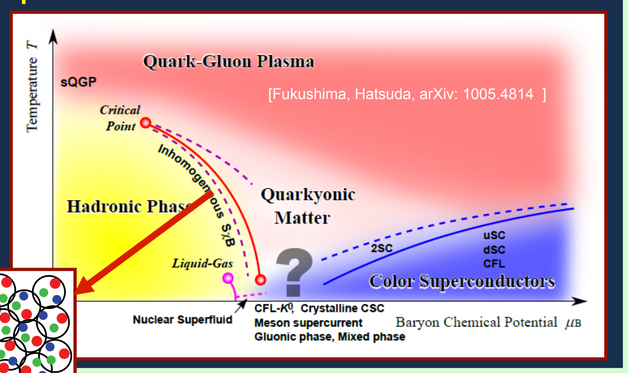
Compressed Baryonic Matter @ FAIR – high μ_B, moderate T

QCD Phase diagram at high μ_B :
- Quarkyonic phase?
- Phase transition(s)?
- Critical point/ triple point?

Need for high precision data including rare probes

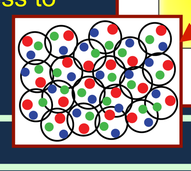
Field driven by experimental data!

Need: ~ 2-40 AGeV beam energies at high intensities



Electromagnetic probes

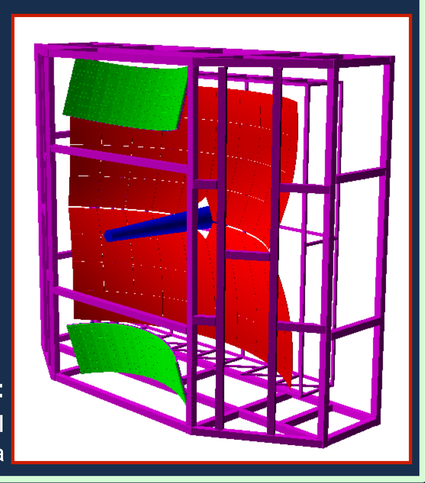
- **Photons**: access to early temperatures
- **Di-leptons (inv.-mass):**
  - **Low-mass vector mesons**: in-medium properties of ρ-meson
  - **$1 \le m_{inv} \le 2$ GeV range**: access to fireball radiation
  - **J/ψ**: charm as a probe for dense baryonic matter



Concept of the CBM RICH detector

Gaseous RICH detector for electron identification (p<8GeV/c):

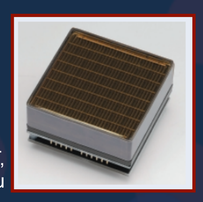
- **Radiator**: CO_2 as radiator gas ($p_{\pi,th}$=4.65 GeV/c)
- **Photodetector**: 2 photodetector planes (MAPMTs, Hamamatsu H12700) with approx. 55,000 channels
- **Mirror**: 2 large spherical mirrors (R=3m) as focussing optics, Al+MgF_2 reflective coating
- Vertical splitting of RICH geometry because CBM dipole magnet is located in front of the RICH



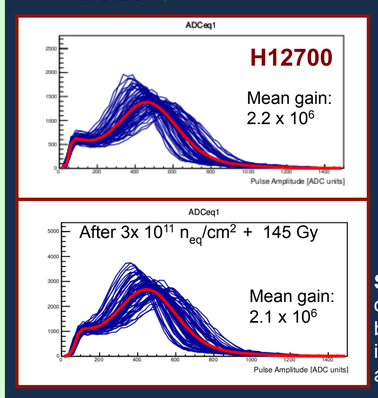
CBM-RICH collaboration:
University Giessen, University Wuppertal, GSI, PNPI Gatchina St. Petersburg, ITEP Moscow, JINR-LIT Dubna

Photodetector

Hamamatsu H12700 MAPMT (successor of H8500) has been selected after extensive R&D phase:
- Pixel resolution ✓
- Single photon response ✓
- Quantum efficiency ✓
- Enhanced Q.E. with WLS coverage* ✓
- Radiation hardness, activation ✓
- Noise ✓

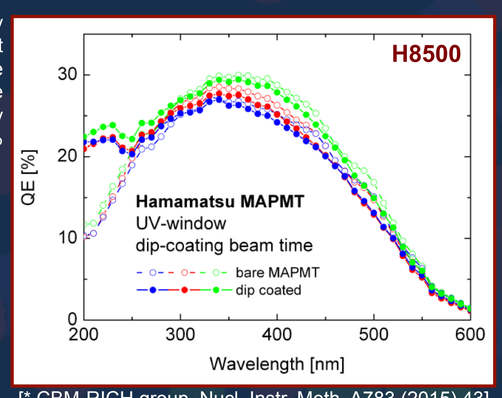


H12700 MAPMT, Hamamatsu



Single photon spectra of all individual pixels before and after irradiation; Red line: average over all pixels

Quantum efficiency with and without WLS coverage; the latter increases the final hit multiplicity by up to 20%



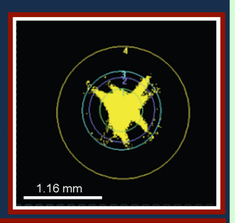
[* CBM-RICH group, Nucl. Instr. Meth. A783 (2015) 43]

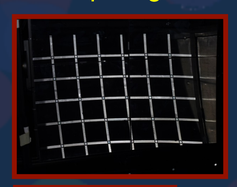
Mirror

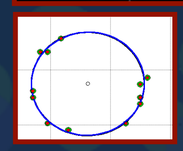
SIMAX glass mirrors, thickness 6 mm, R = 3m, Al+MgF_2 coating from JLO Olomouc:
High reflectivity and very good surface homogeneity (D_0=2-3 mm)

Mirror alignment control system:
- CLAM* method: retroreflective grid at entrance, illuminated by LED, reflection seen via mirror
- Method based on online and offline data analysis comparing fitted and extrapolated ring center$

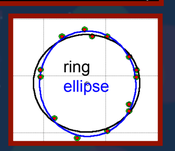
D_0 is diameter of the reflected spot from a point source which contains 95% of the light intensity

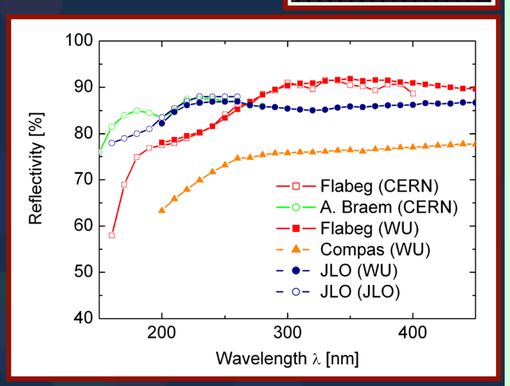






Test of CLAM method in prototype:
Mirror aligned → ring
… misaligned → ellipse



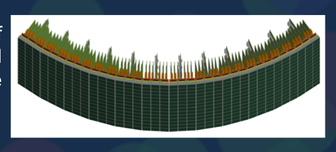


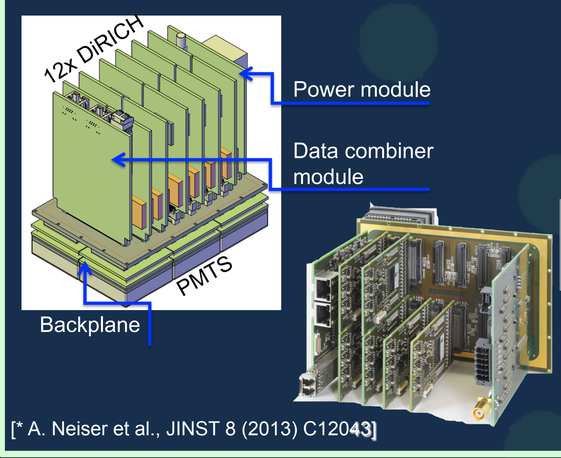
[* COMPASS experiment, Nucl. Instr. Meth. Phys. Res. A 553 (2005) 135]
[$ HERA experiment, Nucl. Instr. Meth. Phys. Res. A 433 (1999) 408]

Readout electronics

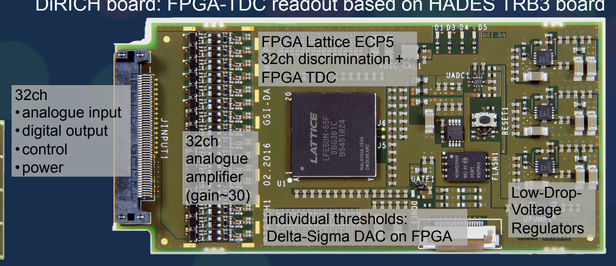
- Development of **DiRICH board**: combine PADIWA* functionality (discrimination) and TRB* (TDC, data handling) on a single board
  joint development of PANDA-DIRC, CBM-RICH and HADES-RICH
- Make use of new Lattice ECP5-85F FPGA: 32 channels ToT, ~10 ps precision TDC
- Small units for flexible photodetector setup:
  - 3x2 MAPMT readout module with: 2 DiRICH boards per MAPMT, data combiner module and power board
- Gas tight mounting on carrier plane (steel) resembling shape of focal plane

Sketch of cylindrical PMT plane





DiRICH board: FPGA-TDC readout based on HADES TRB3 board



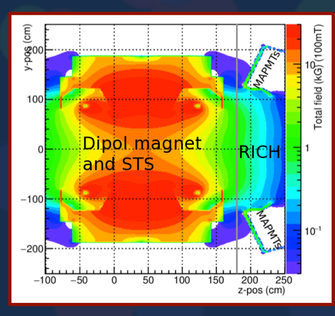
Photos by G. Otto, GSI: modules are being tested in laboratory and in COSY beamtime in May 2017

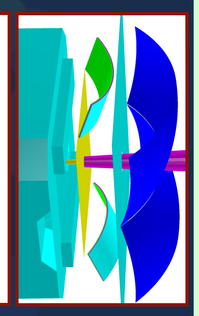
[* A. Neiser et al., JINST 8 (2013) C12043]

Geometry and technical design

Photodetector plane

- Cylindrical shape → well focused rings with barely elliptical distortion
- Rotated (with mirrors) by 10°up-/downwards the beam axis → move it out of
  - magnetic stray field of dipole magnet
  - high radiation level environment
- Enclosed with appropriate shielding boxes made of iron → reduce stray field below 1 mT

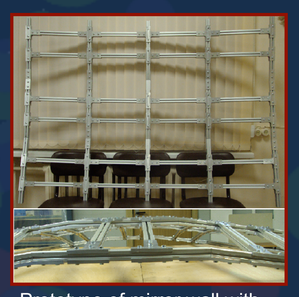




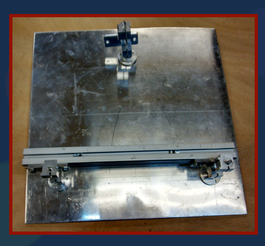
CBM dipole field with various PMT positions

Mirror mounting structure

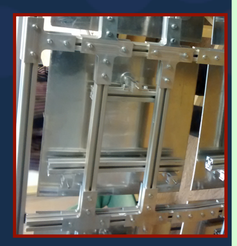
Optimized to reduce the material budget in the detector volume while keeping high mechanical stability:
Measurements with proto-types show deviations of few µm only



Prototype of mirror wall with mirror mounting scheme



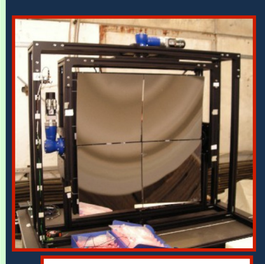
Use three point mount for mirror tiles in order to reduce material budget

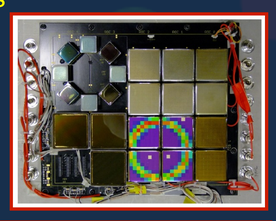


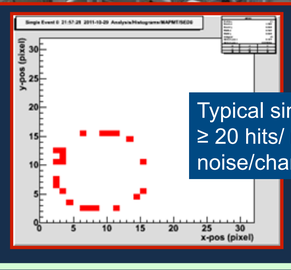
Actuators allow for full alignment flexibility

CBM RICH prototype tests

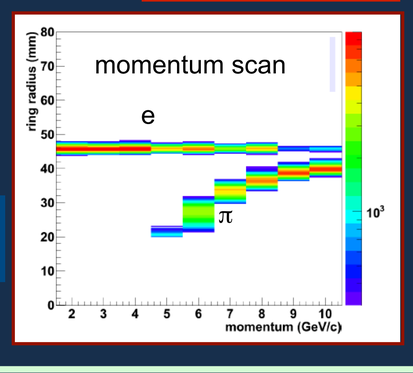
- Real dimension prototype succesfully tested in mixed e-µ-π testbeam at CERN PS from 2-10 GeV.
- Investigate:
  - Various photosensors, WLS coverage,
  - Electronics developments,
  - Gas system and required gas purity,
  - Mirror misalignment limits, mirror alignment controls







Typical single event display!
≥ 20 hits/ ring
noise/channel ~10Hz

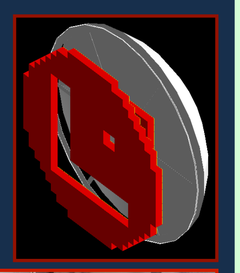


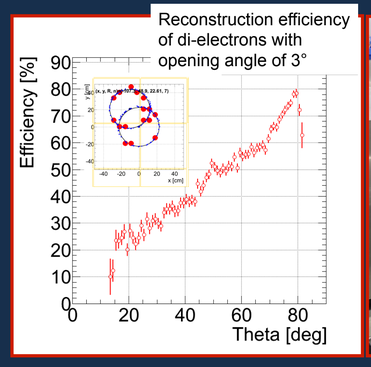
- 7-13 hits per ring depending on polar angle θ
- 96% reconstruction efficiency for single rings ≥ 5 hits

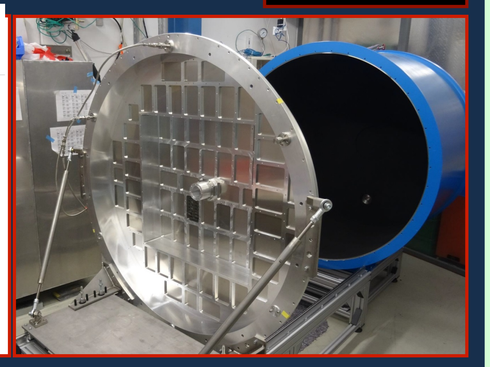
Upgrade of HADES RICH detector

- HADES RICH successfully in operation since more than 10 years
- In cooperation with TU Munich: Replace existing CsI photocathode with MAPMTs from CBM in order to significantly enhance the e+/e- identification capability
- Be ready asap for next HADES π+A, A+A beamtime at GSI

→ Data taking and physics analysis: checks performance of MAPMTs, electronics, ring finding and calibration routines for CBM







[Realization of test stand: Mike Faul (GSI), Jürgen Friese und Tobias Kunz (TU München)]

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