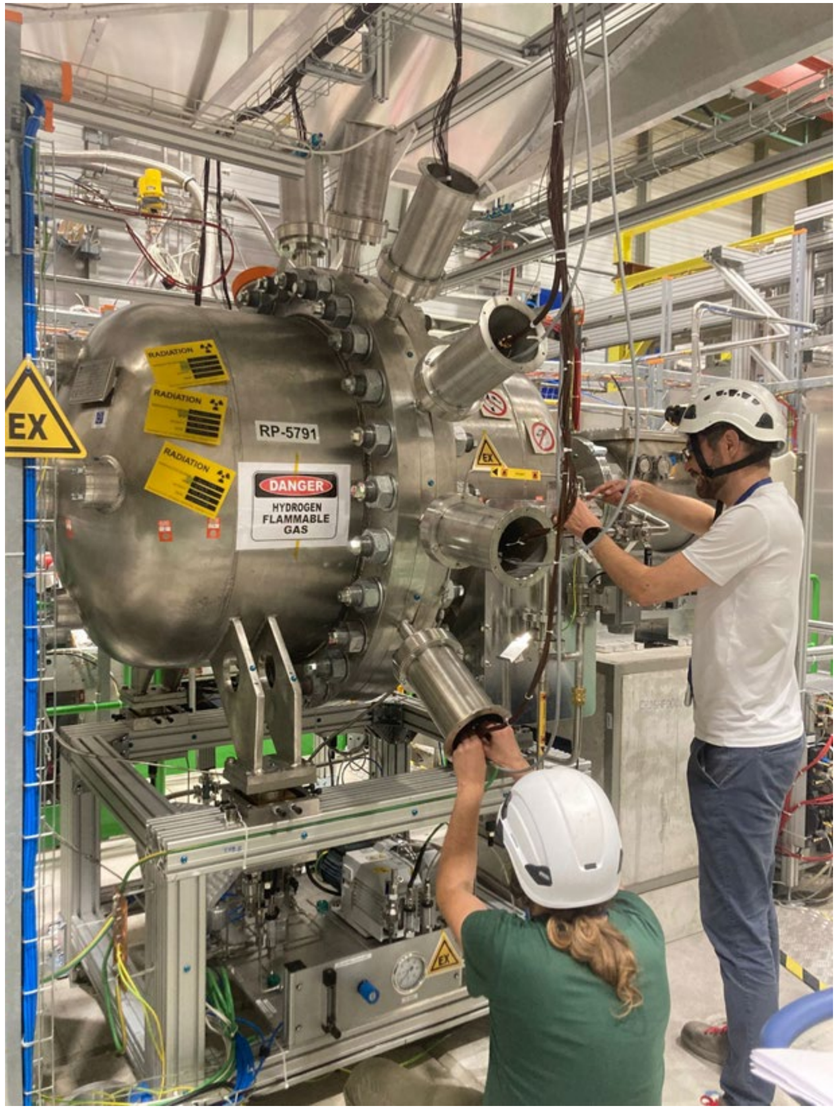
AMBER
Apparatus for Meson and Baryon
Experimental Research

A Strong-Interaction Facility at CERN

Bernhard Ketzer

GSI-FAIR Colloquium

05 May 2026



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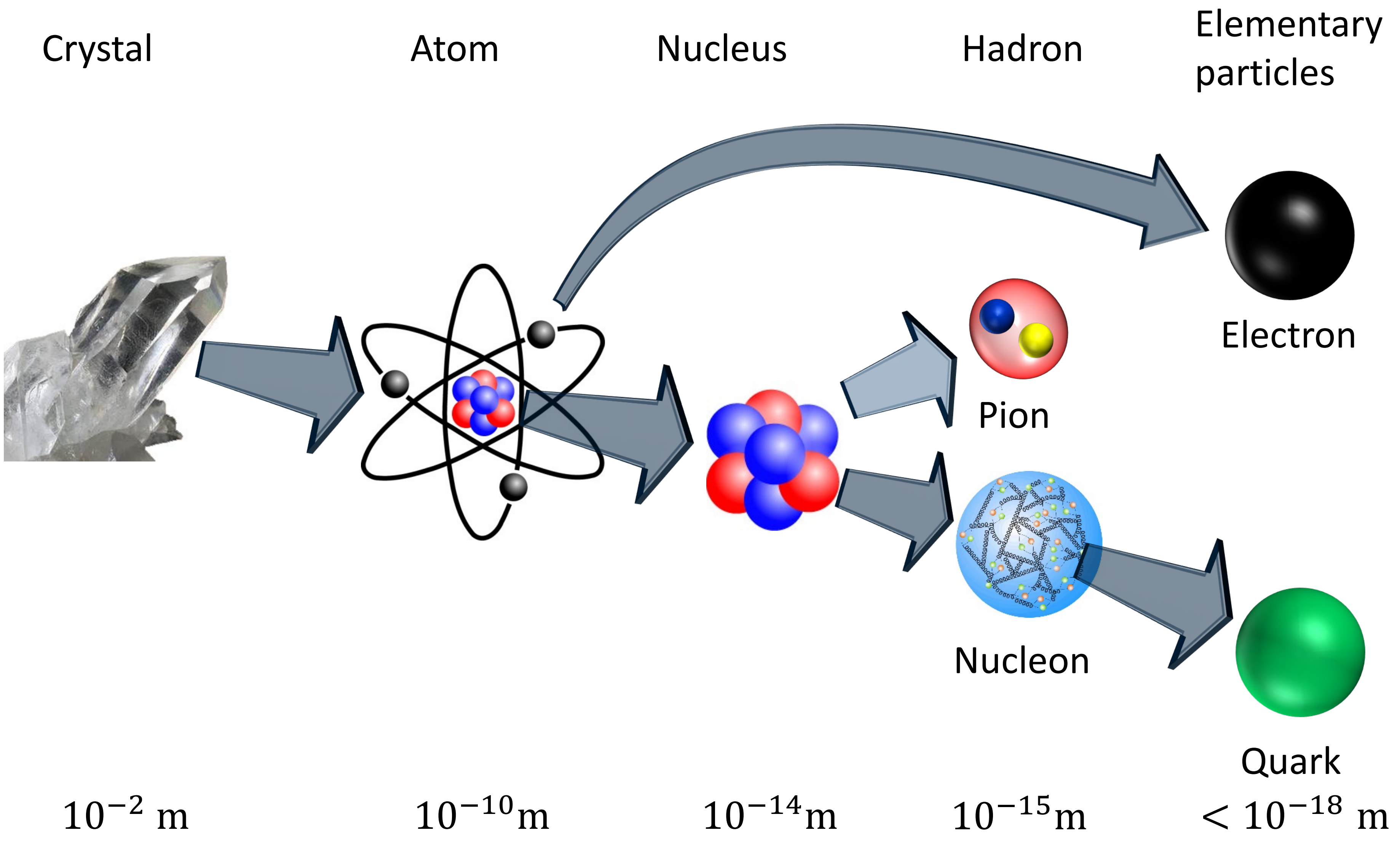
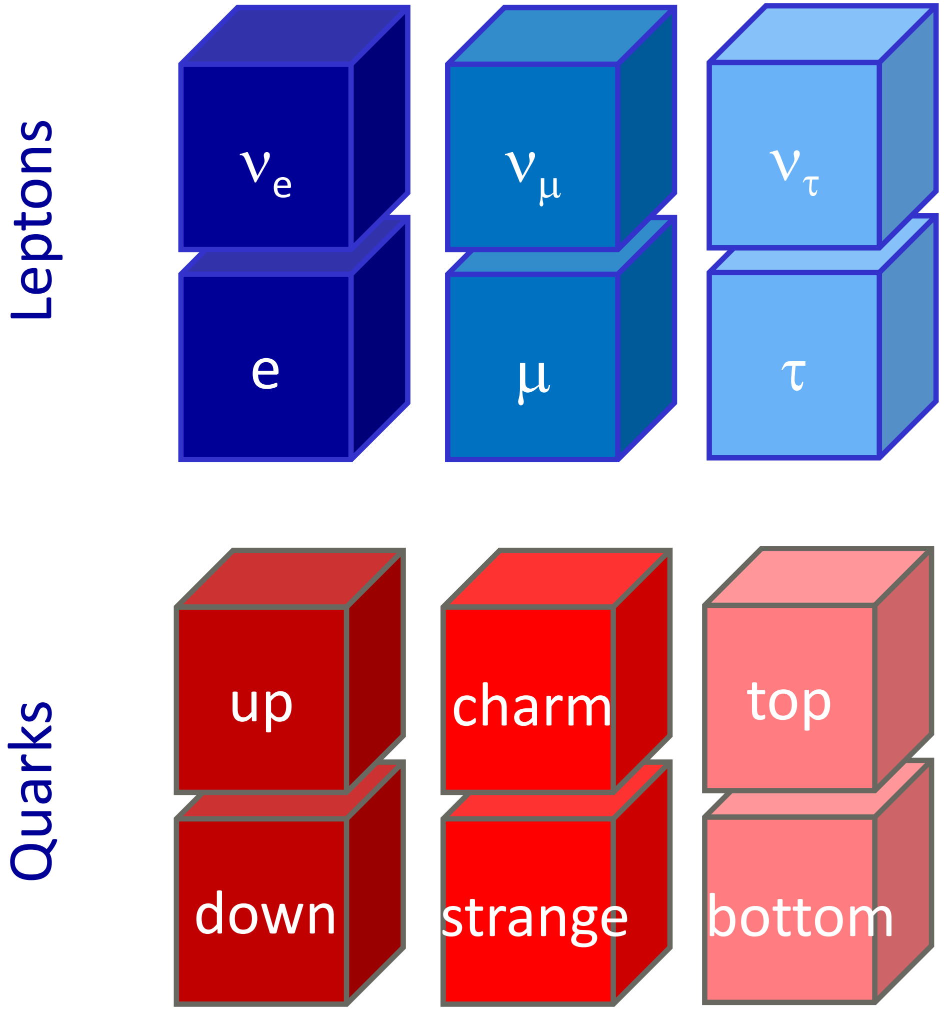
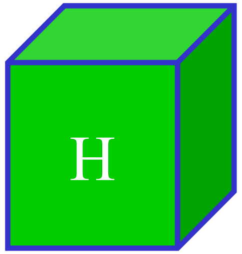
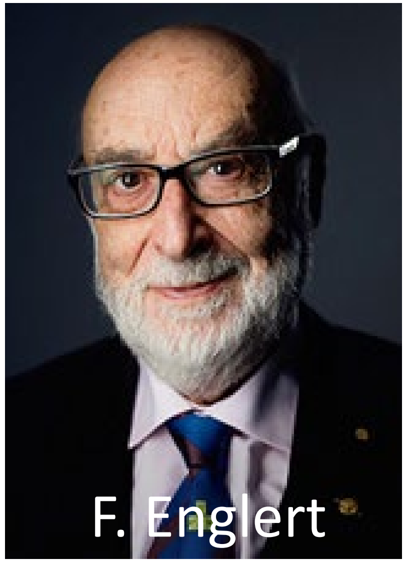
STRUCTURE OF MATTER

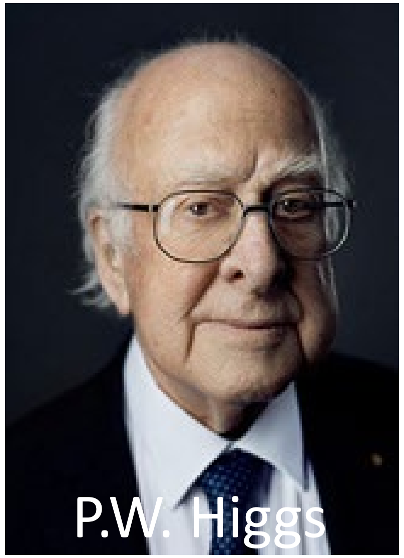


FUNDAMENTAL MATTER CONSTITUENTS



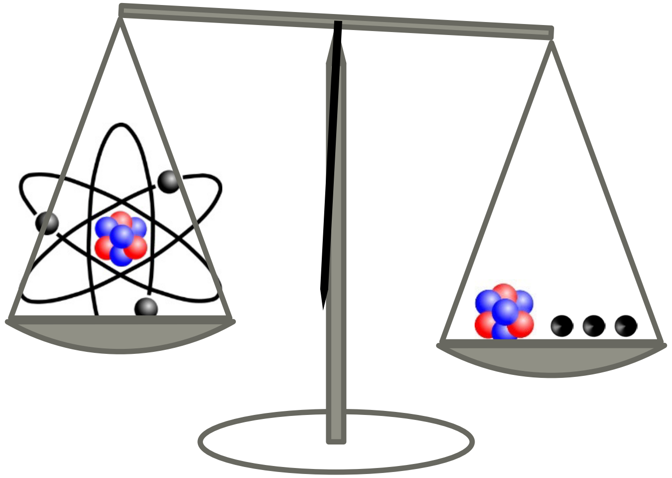




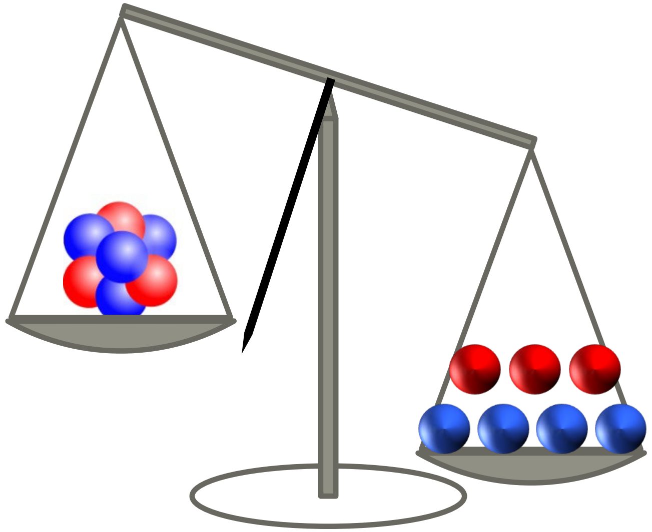


COMPOSITE OBJECTS

Atom $M \lessapprox \sum m_i$



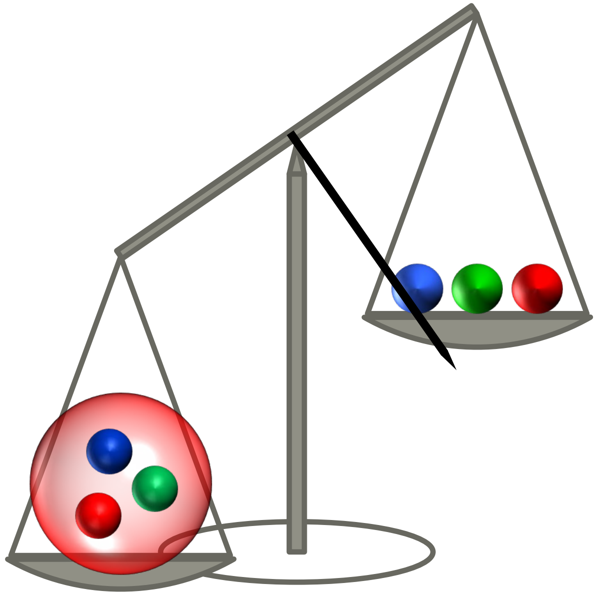
Nucleus $M < \sum m_i$



$$E = mc^2$$

Nucleon

$M \gg \sum m_i$



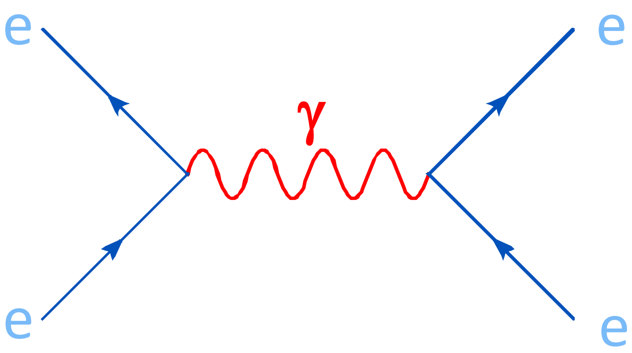
Higgs mechanism does NOT explain most of the visible mass in the universe!

INTERACTIONS

Apparatus for Meson and Baryon Experimental Research

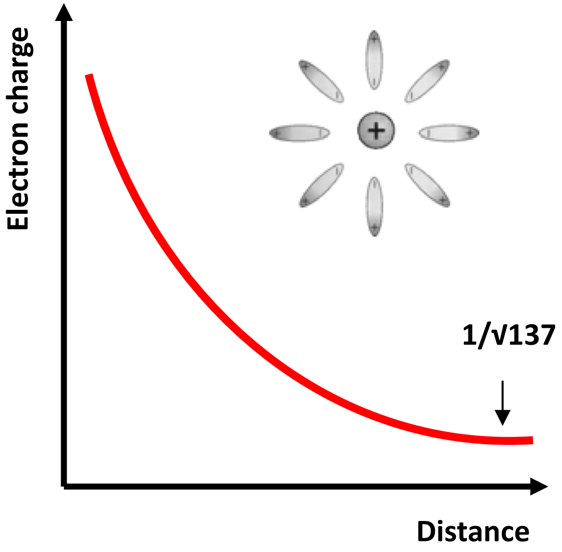
Electromagn. interaction

acts on electric charge



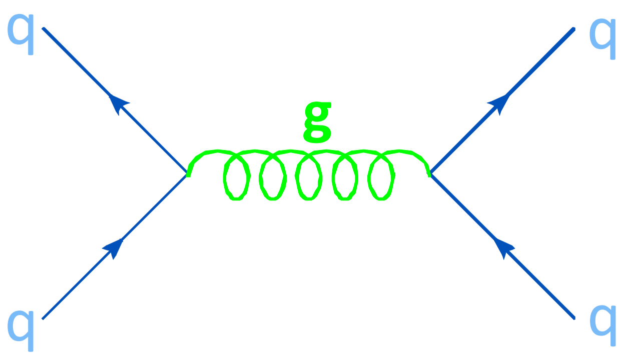
Force carrier

- photon
- carries no charge
- can fluctuate in e^+e^- (vacuum polarization)



Strong interaction

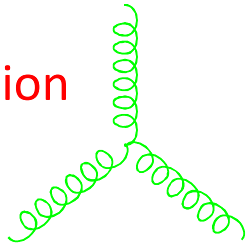
acts on color charges

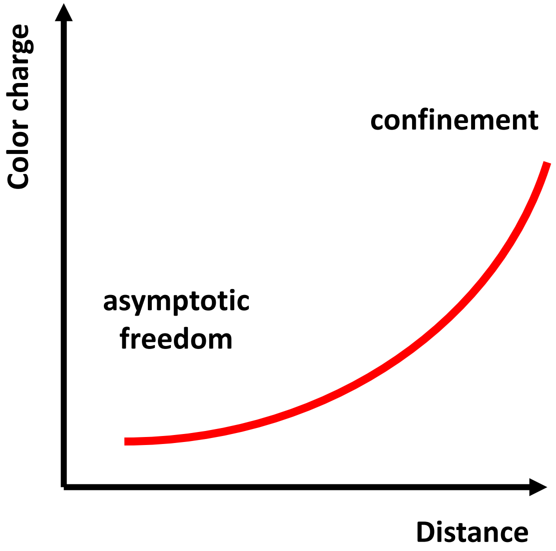


Force carrier

- gluon
- carries color charge

⇨self-interaction





THE STRONG COUPLING "CONSTANT"

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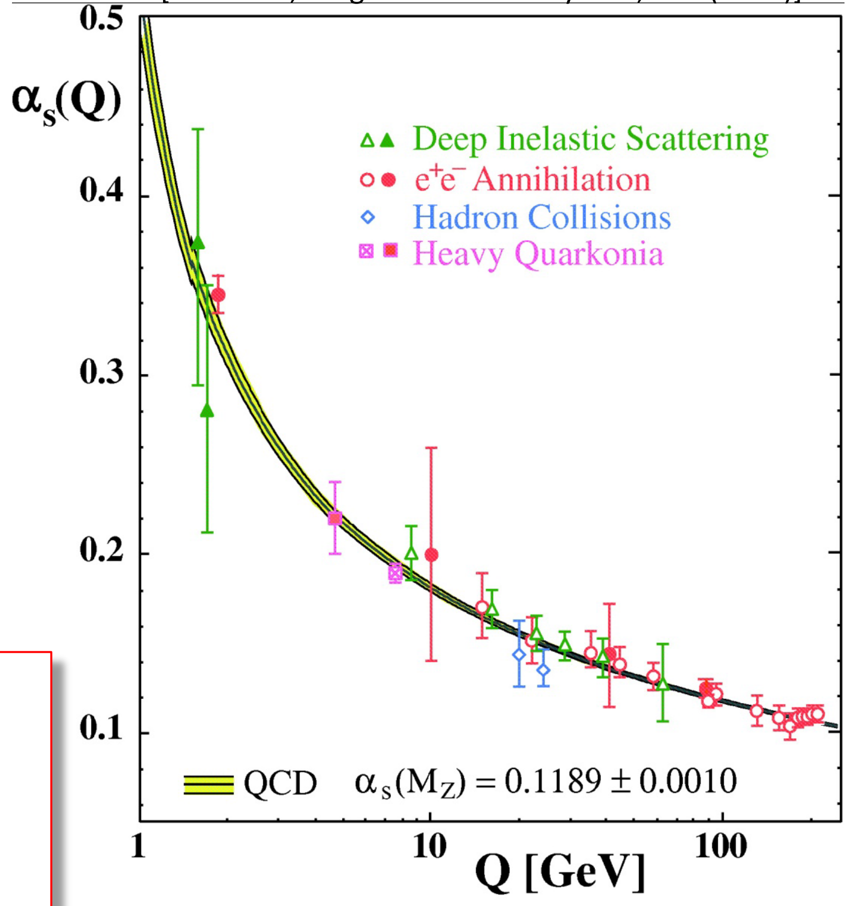
[S. Bethke, Progr. Part. Nucl. Phys. 58, 351 (2007)]



Distance

Small momentum transfer (large distances)

- α_s large
- non-perturbative regime $\Rightarrow$ hadron physics, i.e. world we live in

Large momentum transfer (small distances)

- α_s small
- perturbation theory can be applied

FUNDAMENTAL QUESTIONS

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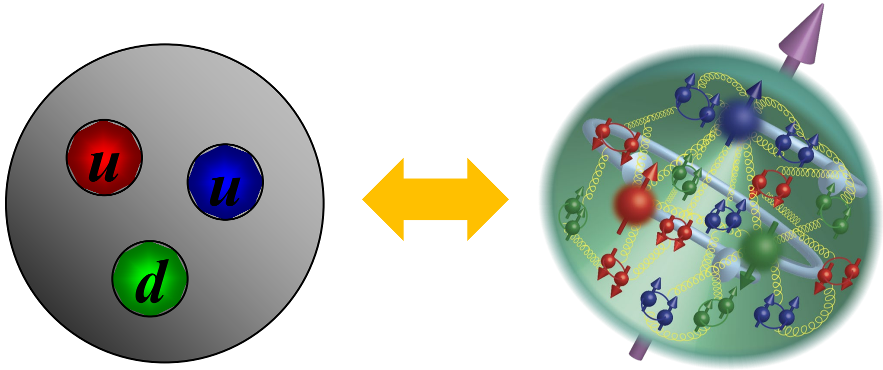
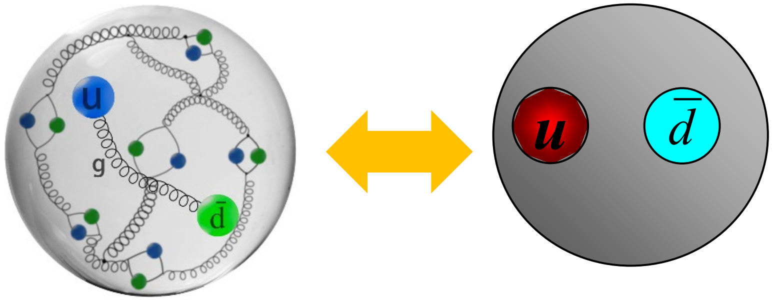
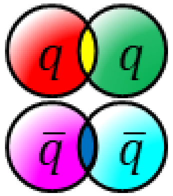


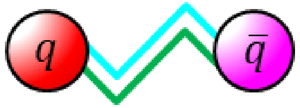
Proton



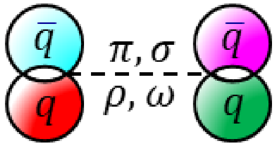
Pion



Tetraquark



Hybrid



Quark molecule

- What is the origin of mass? Why are hadrons so much heavier than the bare quarks?
- Why don't we observe free quarks?
- What is the internal structure of hadrons?
- What are the effective degrees of freedom?
- Are there other forms of hadronic or quark matter?
- What happens to quarks and gluons at extreme densitites?

QCD IN THE STRONG COUPLING REGIME

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- Understand hadron properties in terms of quarks, gluons
  - emergence of hadronic and nuclear d.o.f.
  - confinement
  - masses: proton vs pion and kaon
- Experiment:
  - quark and gluon PDFs of pion, kaon, proton
  - excitation spectrum of hadrons
  - form factors, hadron radii
  - input to SM tests at colliders, BSM searches
- Quantitative theoretical approaches:
  - effective field theories
  - lattice QCD
  - continuum methods

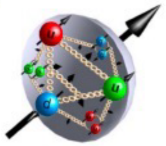
Pion

- $M_\pi \sim 140$MeV
- Spin 0
- 2 light valence quarks

Kaon

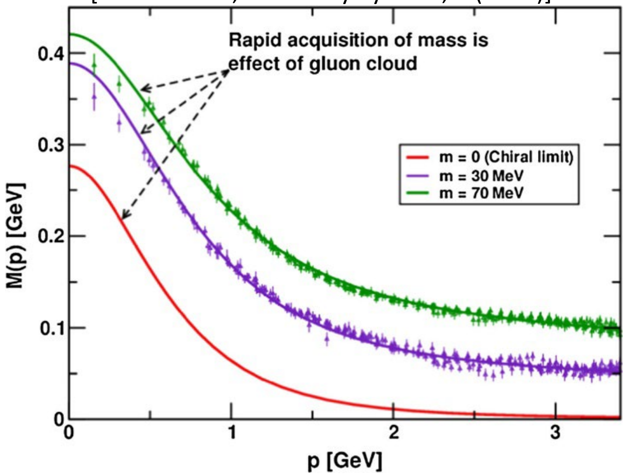
- $M_K \sim 490$MeV
- Spin 0
- 1 light and 1 “heavy” valence quarks

Proton

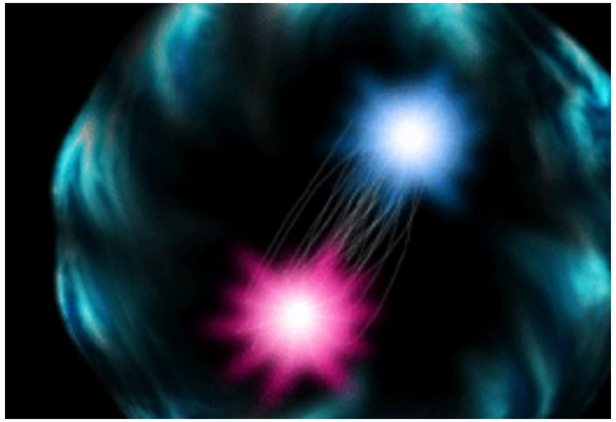


- $M_p \sim 940$MeV
- Spin 1/2
- 3 light valence quarks

[C.D. Roberts, Few-Body Syst. 58, 1 (2017)]



Plot: dressed-quark mass function
curves: DSE [Bhagwat et al., 2003/2006]
data: LQCD [Bowman et al., 2005]



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AMBER @ CERN SPS

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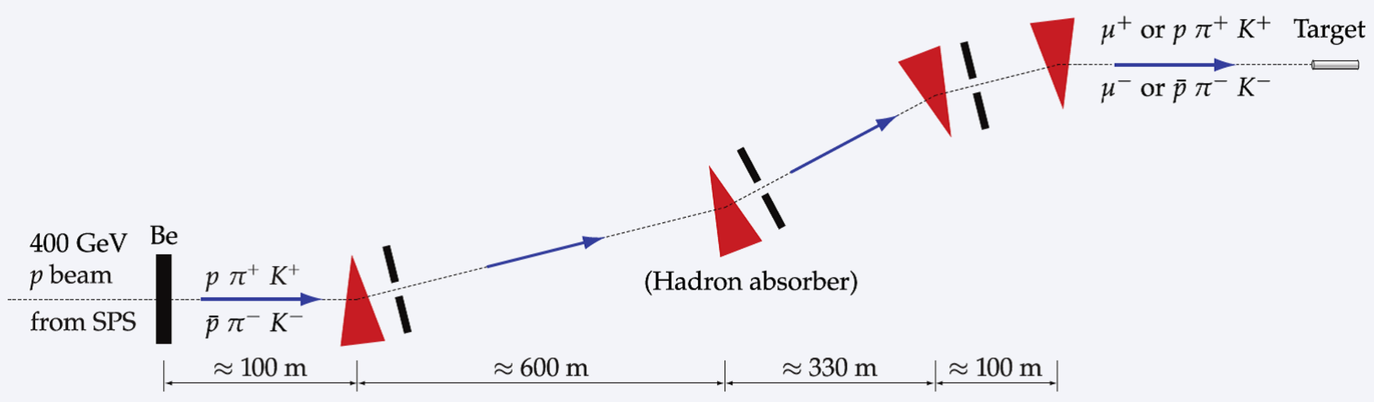
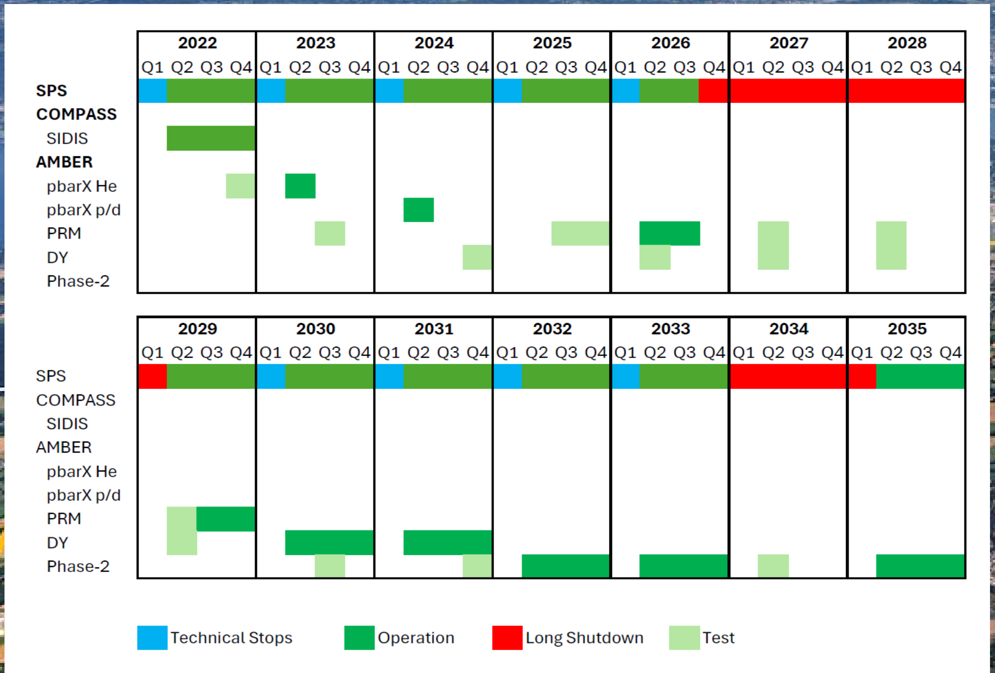




M2 beamline (EHN2):

- most versatile beamline at CERN
- high-intensity beams of $\mu^\pm, \pi^\pm, K^\pm, p, \bar{p}$
  - $\mu^\pm$: 90-180 GeV, up to $5 \cdot 10^7\ \mathrm{s}^{-1}$
  - $h^\pm$: 60-250 GeV, up to $1.5 \cdot 10^7\ \mathrm{s}^{-1}$
    up to $10^9\ \mathrm{s}^{-1}$ w/ absorber
- intensity limited by radioprotection
- North Area Consolidation ongoing

LHCb
CERN Prévessin
SUISSE
FRANCE

Phase-1: 2023 → 2031 (conventional beams)

- approved by CERN RB in 2020
- conventional h/μ beams

Phase-2: 2031 → 2041 (high-intensity kaon beam)

- proposal in drafting stage
- to be submitted in 2027
- high-intensity h beams (K, $\bar{p}$,…)

AMBER PHYSICS PROGRAM

CERN Physics Beyond Colliders

AMBER Apparatus for Meson and Baryon Experimental Research

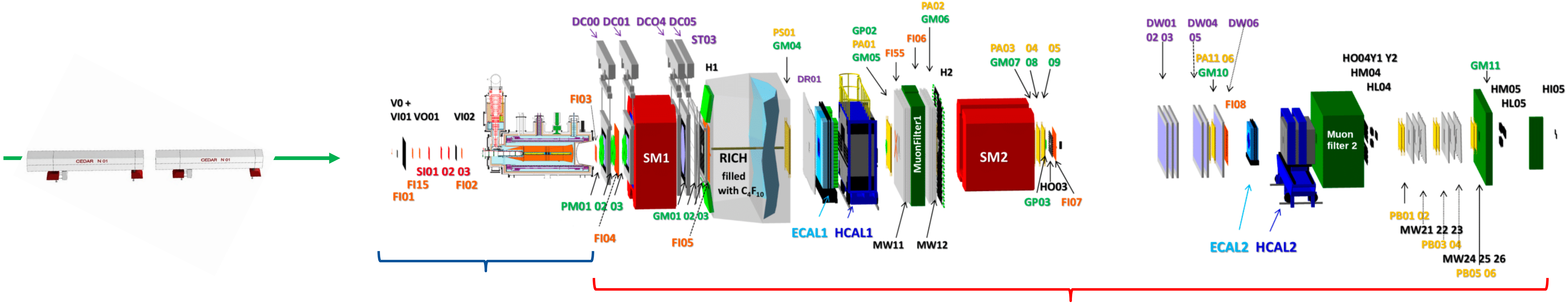
Phase-1: 2023 → 2031 (conventional beams)

- $\bar{p}$ production cross section measurements for DM searches (pbarX)
- Proton radius: high-energy μ-p elastic scattering (PRM)
- Pion and kaon quark PDFs: Drell-Yan processes (DY)

Phase-2: 2031 → 2041 (high-intensity kaon beam)

AMBER EXPERIMENTAL SETUP

Apparatus for Meson and Baryon Experimental Research



Beam: p, μ, π, K, (e)

Target region: program-specific

Spectrometer: common for all measurements

- pbarX: 60 – 250 GeV p
- PRM: 100 GeV $\mu^{\pm}$
- DY: 190 GeV $\pi^{\pm}, K^{\pm}$
- upgrade of CEDARs for PID

- pbarX: lHe/lH/lD target
- PRM: **H_2 TPC + Si pixel + fiber**
- DY: C, W target, absorber + beam + **vertex detector**

- new **free running DAQ**
- upgrades of several detector systems: FI, ECAL
- new large-area **GEM** detectors

- **beam line upgrade** for high-intensity K beam

- DY: active absorber/vertex detector
- Spectroscopy: lH target + RPD

- ECAL0
- MWPC replaced by **large-area MPGD**
- final-state PID

AMBER PHYSICS PROGRAM

CERN Physics Beyond Colliders

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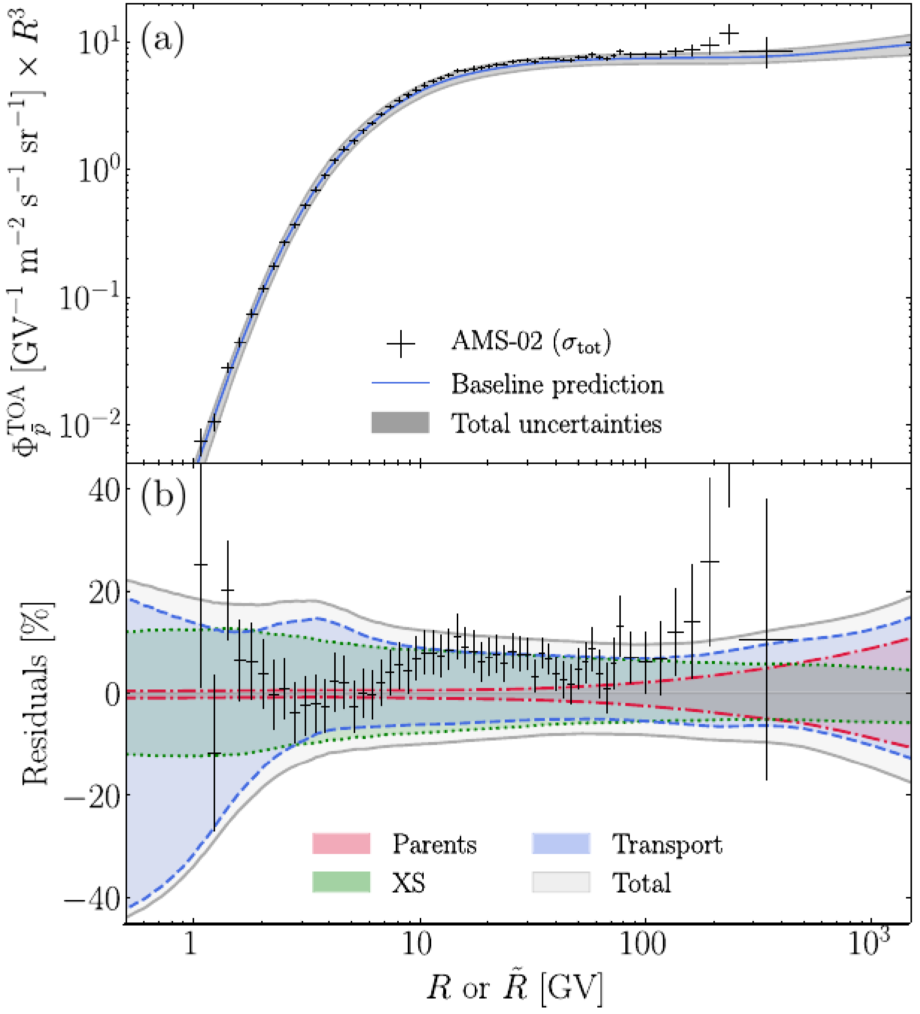
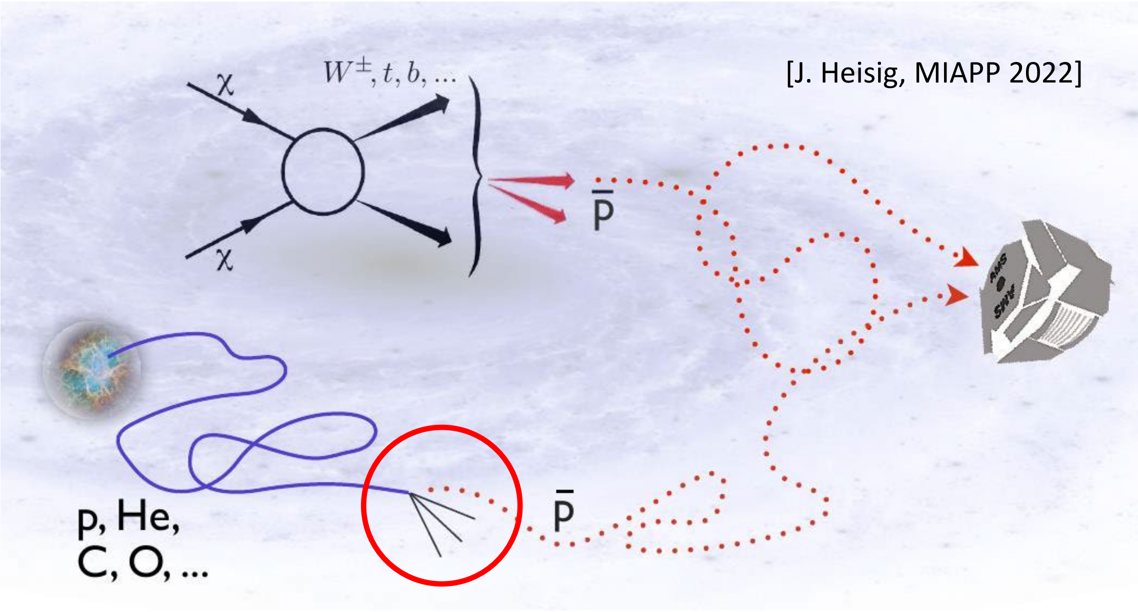
Phase-2: 2031 → 2041 (high-intensity kaon beam)

DARK MATTER SEARCHES

AMS-02: Precise data on cosmic antiparticle flux



[M. Boudaud et al., Phys. Rev. Res. 2, 023022 (2020)]



- **Limiting factor:** $\bar{p}$ production cross section uncertainties from collisions involving p and He (currently 30-50%!)
- **Common program** for the next decade: arXiv:2503.16173v1

  Precision cross sections for advancing cosmic-ray physics
- Main facilities:
  - AMBER, NA61/SHINE (SPS)
  - ALICE, LHCb (LHC)
- Input to the 2026 ESPPU

ANTIPROTON PRODUCTION IN GALAXY

- Dominant part of $\bar{p}$ in galaxy from inelastic scattering of cosmic rays (CR) off interstellar medium nuclei
- Excess could be due to exotic contributions from dark matter annihilation
- Required for interpretation of data:
  - Realistic modeling of CR sources and CR propagation (diffusion, galactic wind, energy loss)
  - Turbulence spectrum of galactic magnetic field
  - Reliable knowledge of inelastic cross sections for $\bar{p}$ production

Important quantity: **secondary CR source term** (e.g. $\bar{p}$)

= integral of diff. cross section over all possible energies of incident particle

$$q_{ij}\left(T_s\right) = \int_{T_{\text{th}}}^{\infty} dT_i \, 4\pi \, n_{\text{ISM},j} \, \phi_i\left(T_i\right) \frac{d\sigma_{ij}}{dT_s}\left(T_i, T_s\right)$$

i primary CR component, e.g. p

j ISM component, e.g. He

s secondary component, e.g. $\bar{p}$

$n_{ISM,j}$ density of ISM component j

$\phi_i(T_i)$ energy differential flux of primary CR component

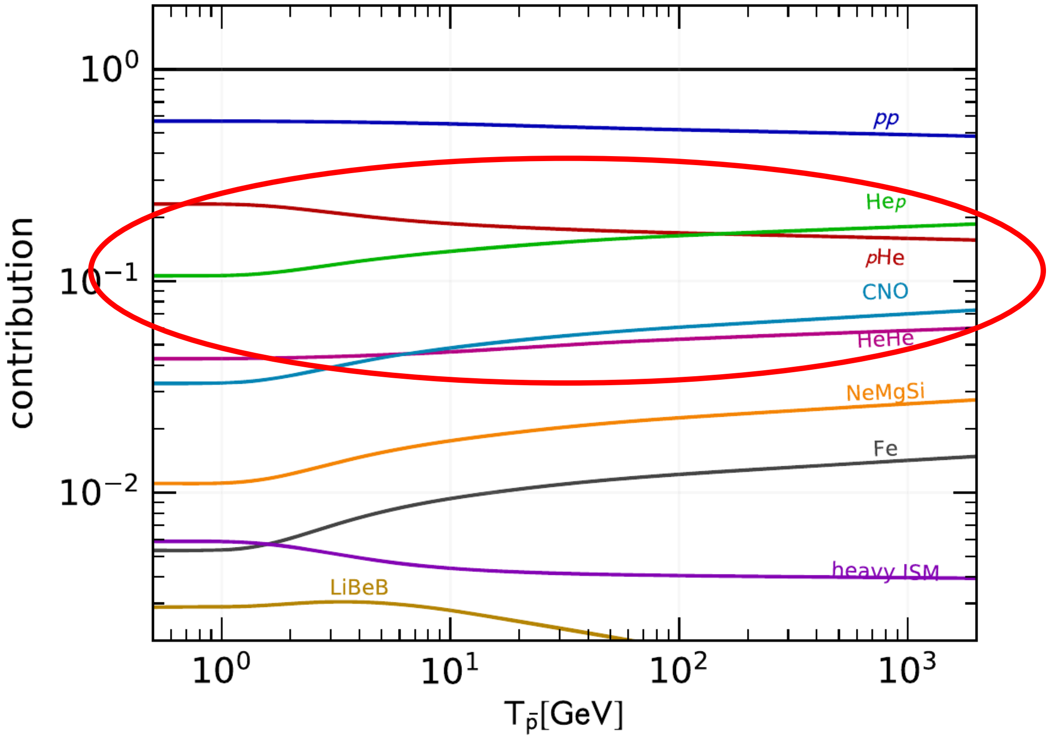
$\frac{d\sigma_{ij}}{dT_s}$ differential cross secction for reaction $i + j \rightarrow s + X$

ANTIPROTON PRODUCTION AT AMBER

Apparatus for Meson and Baryon Experimental Research

Reactions contributing to $\overline{p}$ production

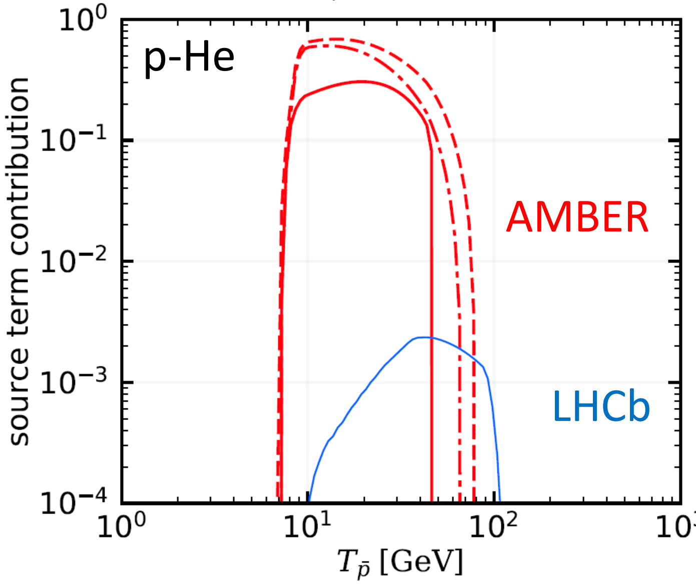
[Di Mauro et al., Phys. Rev. D 97, 103019 (2018)]



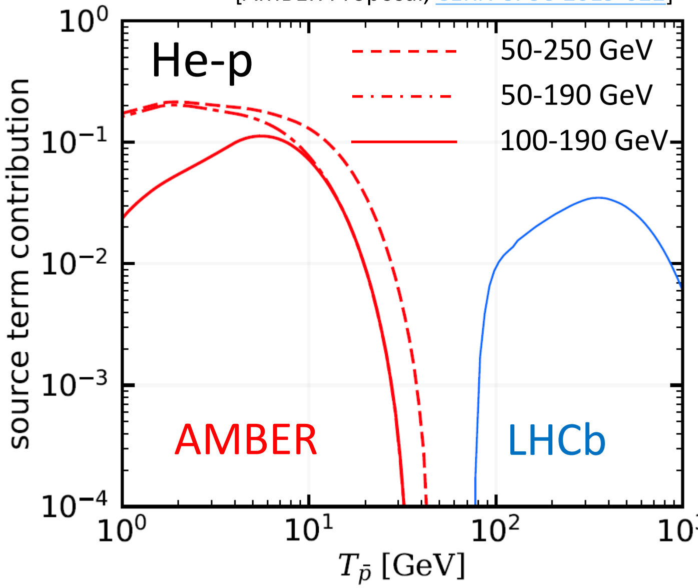
- 90% of the reactions involve p and He (ISM)
- $p + p \rightarrow \bar{p} + X$ some measurements (NA49, NA61)
- $p +^4 \mathrm{He} \rightarrow \bar{p} + X$ no data at relevant energies

  only LHCb at 4 TeV and 6.5 TeV

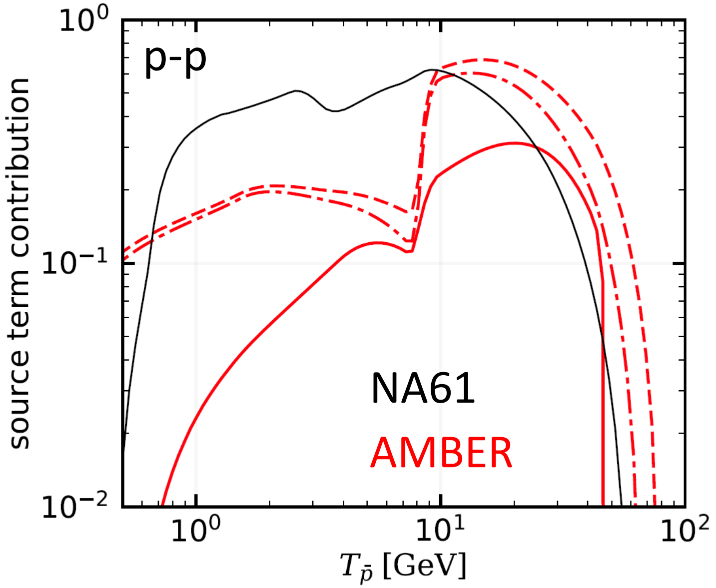
[M. Korsmeier, priv. comm.]



[AMBER Proposal, CERN-SPSC-2019-022]



Impact of measurements on constraining the production of $\bar{p}$ (fraction of total source term constrained by phase space of experiment)



MEASUREMENTS BY AMBER

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2023: $p + \mathrm{He} \rightarrow \bar{p} + X$

- 6 different collision energies:

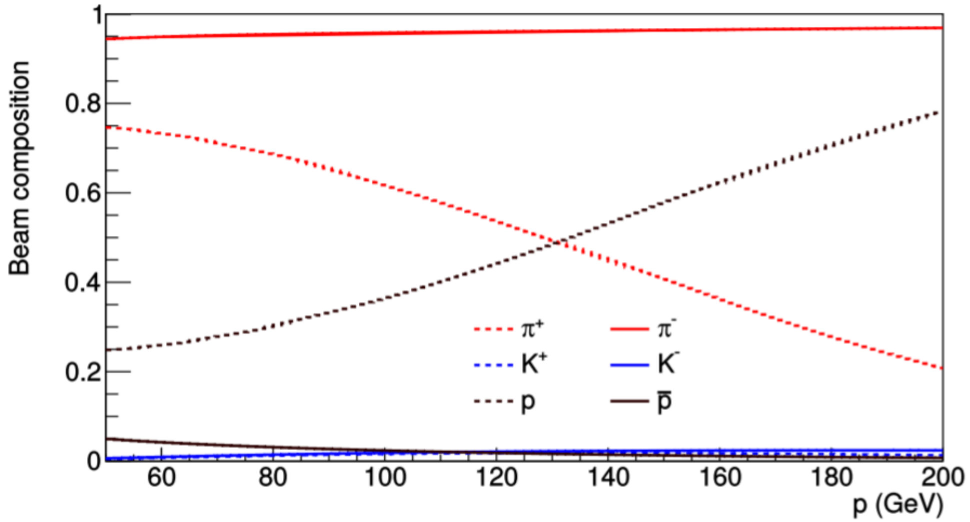
Period name	Beam mom. [GeV/c]	Collision energy $\sqrt{s_{NN}}$ [GeV]	Target	# of spills
W01	190	18.9	LHe	11000
W02-W03	60	10.7	LHe	37000
W04	100	13.8	LHe	13700
W05	250	21.7	LHe	7300
W06	160	17.3	LHe	8500
W07	80	12.3	LHe	13400

2024: $p + \mathrm{H} \rightarrow \bar{p} + X, p + D \rightarrow \bar{p} + X$

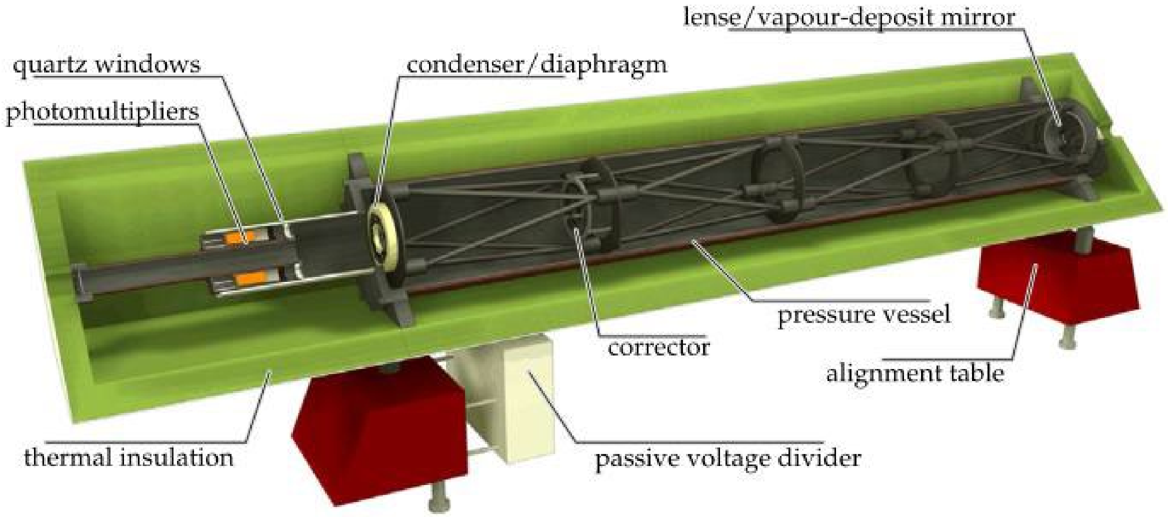
- 3 different collision energies, H and D target
- Extract possible difference in $\bar{p}$ production on p and n

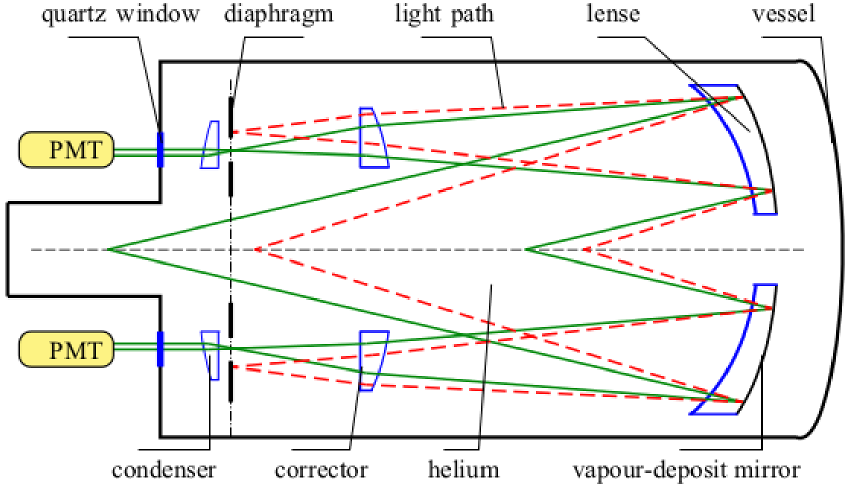
Period name	Beam mom. [GeV/c]	Collision energy $\sqrt{s_{NN}}$ [GeV]	Target	# of spills
W01	250	21.7	LH	8600
W02	80	12.3	LH	16500
W03	160	17.3	LH	12500
W04	160	17.3	LD	13000
W05	80	12.3	LD	16500
W06	250	21.7	LD	9100

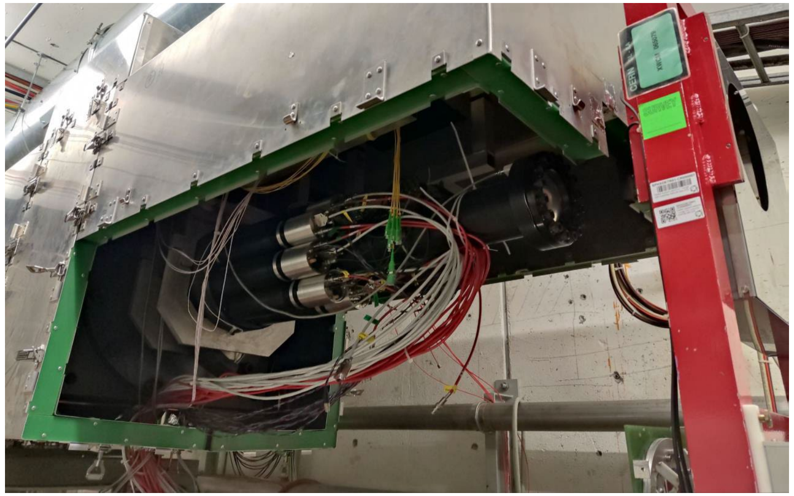
- Secondary p beam with 60 - 250 GeV/c, intensity $5 \cdot 10^5\ \mathrm{s}^{-1}$
- Minimum bias trigger $25 \cdot 10^3\ \mathrm{s}^{-1}$
- Liquid H_2, D_2, and He target
- Proton ID in CEDARs, antiproton ID in RICH
- Measure differential cross section in 10 bins in $\bar{p}$ momentum and pseudo-rapidity $2.4 < \eta < 5.6$
- Statistical uncertainty $\approx 0.5 - 1\%$ per data point
- Total systematic uncertainty $\approx 5\%$ (efficiencies, dead time)



BEAM PID – CEDAR DETECTORS







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BEAM PID – CEDAR DETECTORS

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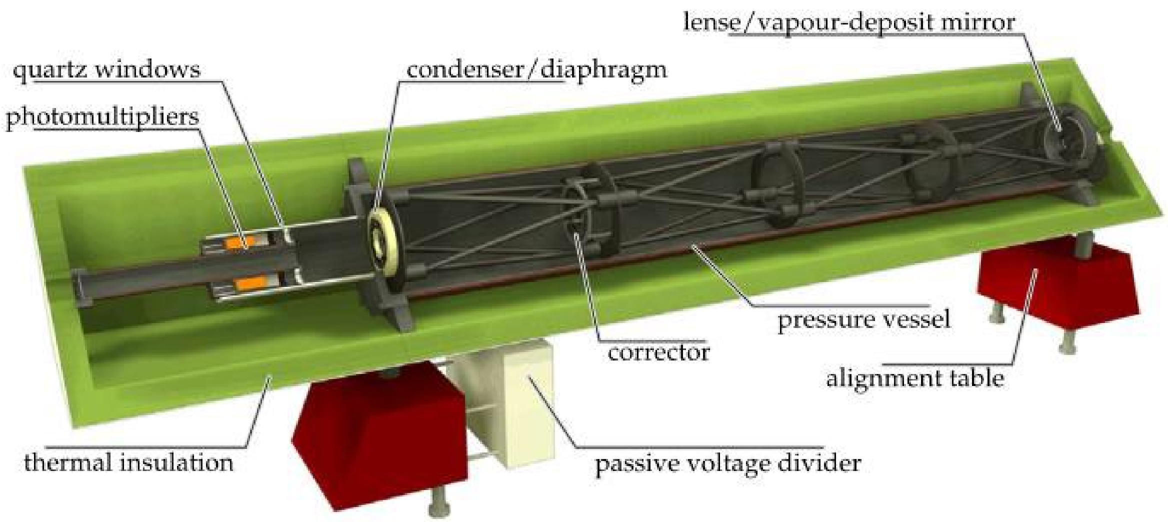
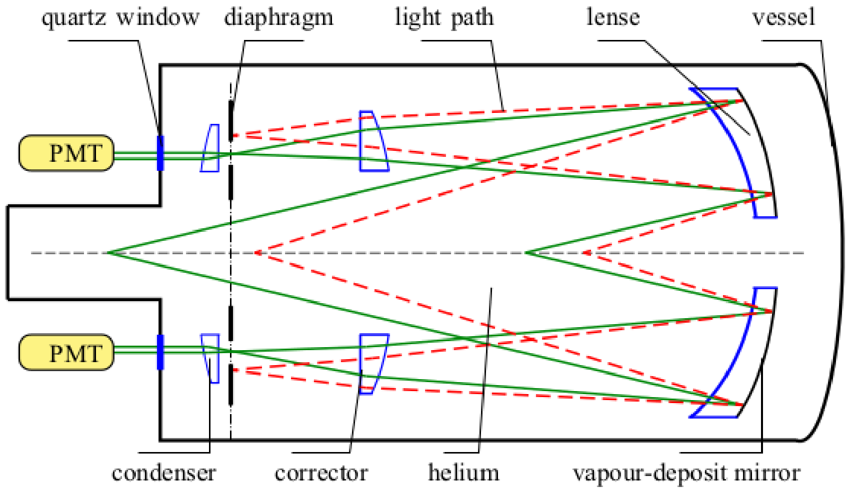
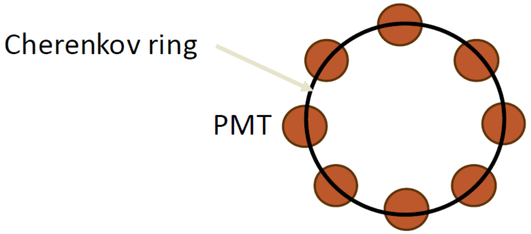
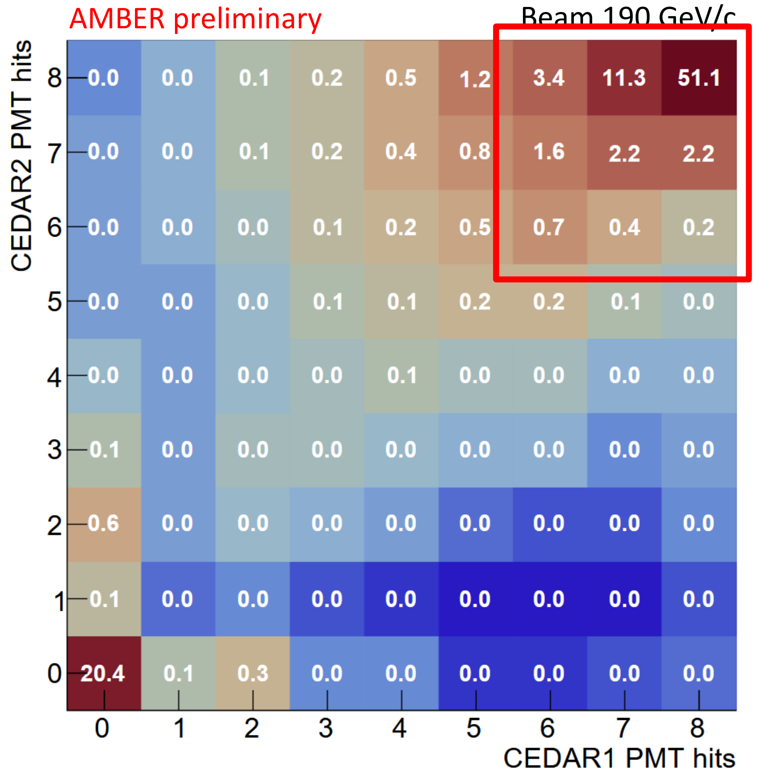


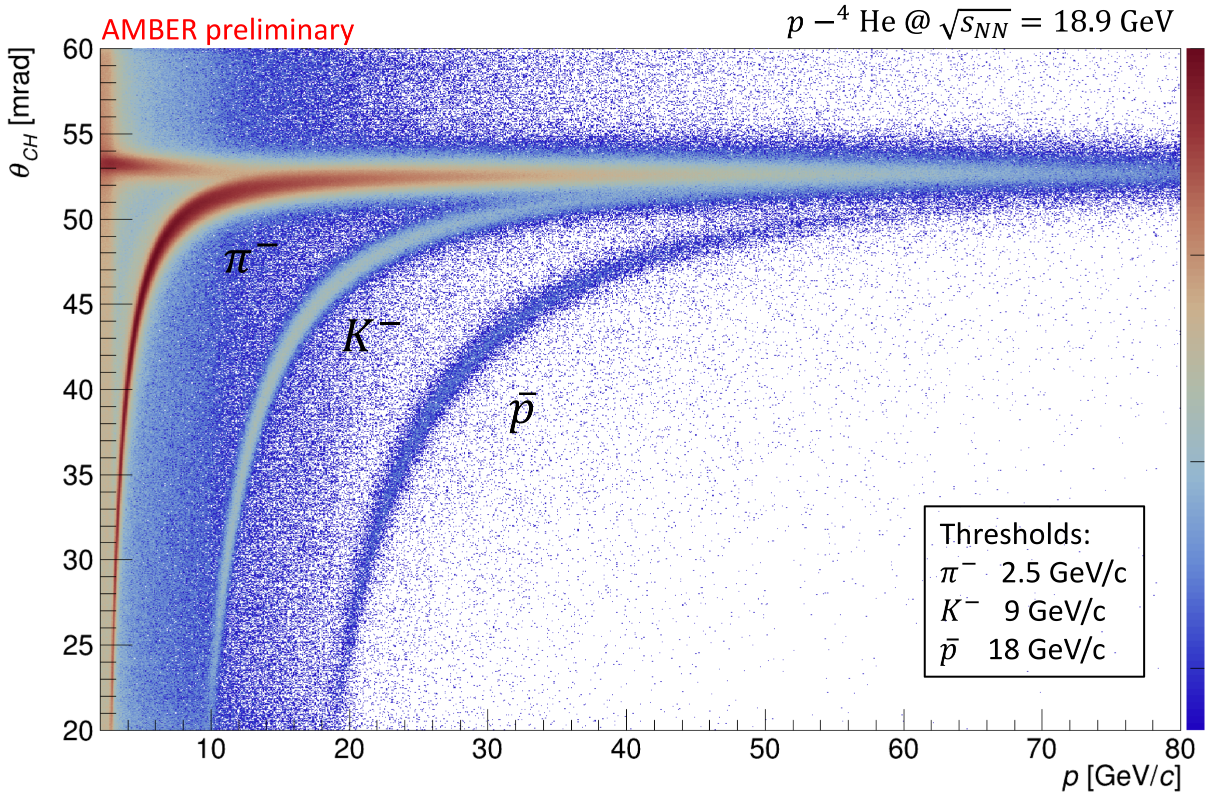


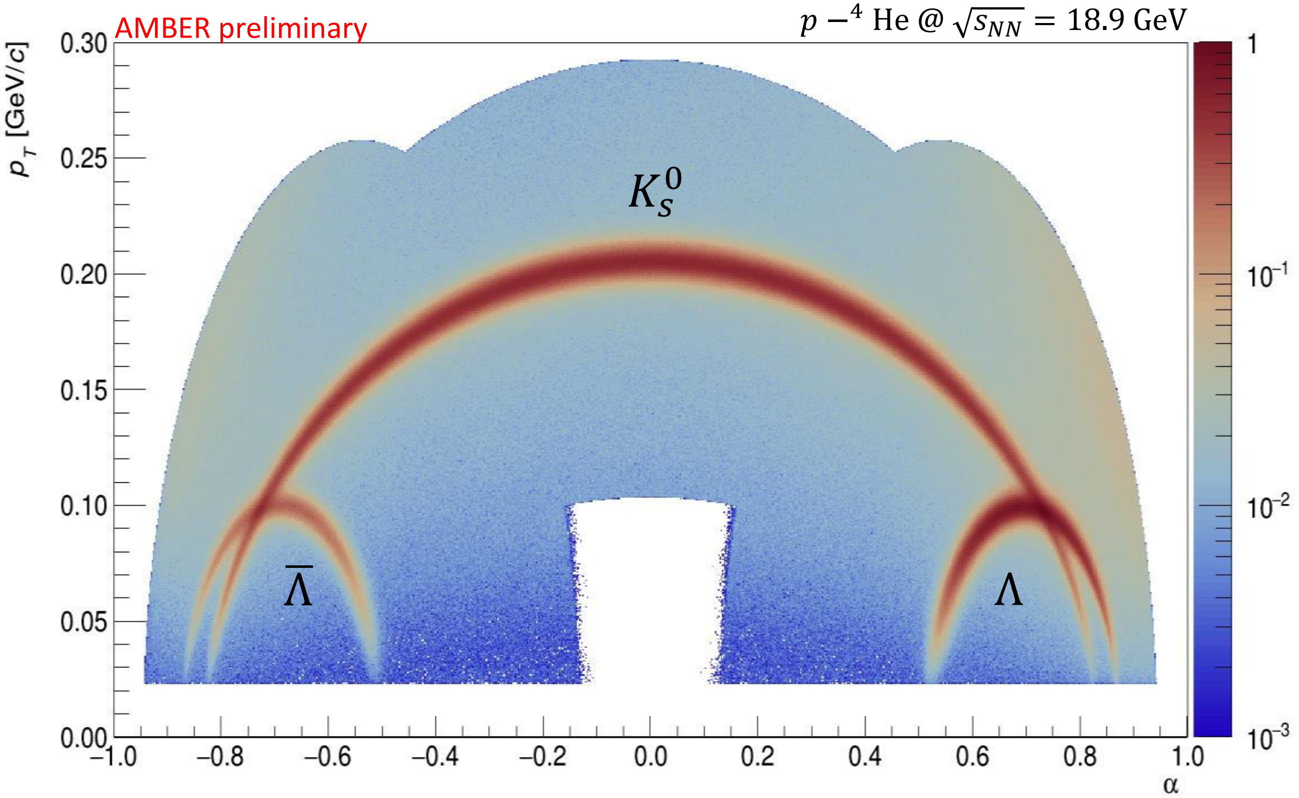




- Proton signal well separated from pions
- By requiring $\geq$ 6 PMT hits in CEDAR1/2, we get 73% p in beam
- Expect 76% p $\Rightarrow$ tagging efficiency 96% @ 190 GeV
- R&D: convert CEDAR to RICH

FINAL-STATE HADRON PID – RICH





- PID: extended maximum likelihood method
- RICH PID matrix estimated from real data using V0 decays
- After unfolding: ~ 6 M identified protons in 2023 data

$$\alpha = \frac{p_l^+ - p_l^-}{p_l^+ + p_l^-}$$

$$p_l = p\cos\theta$$

$$p_T = p\sin\theta$$

FIRST RESULTS

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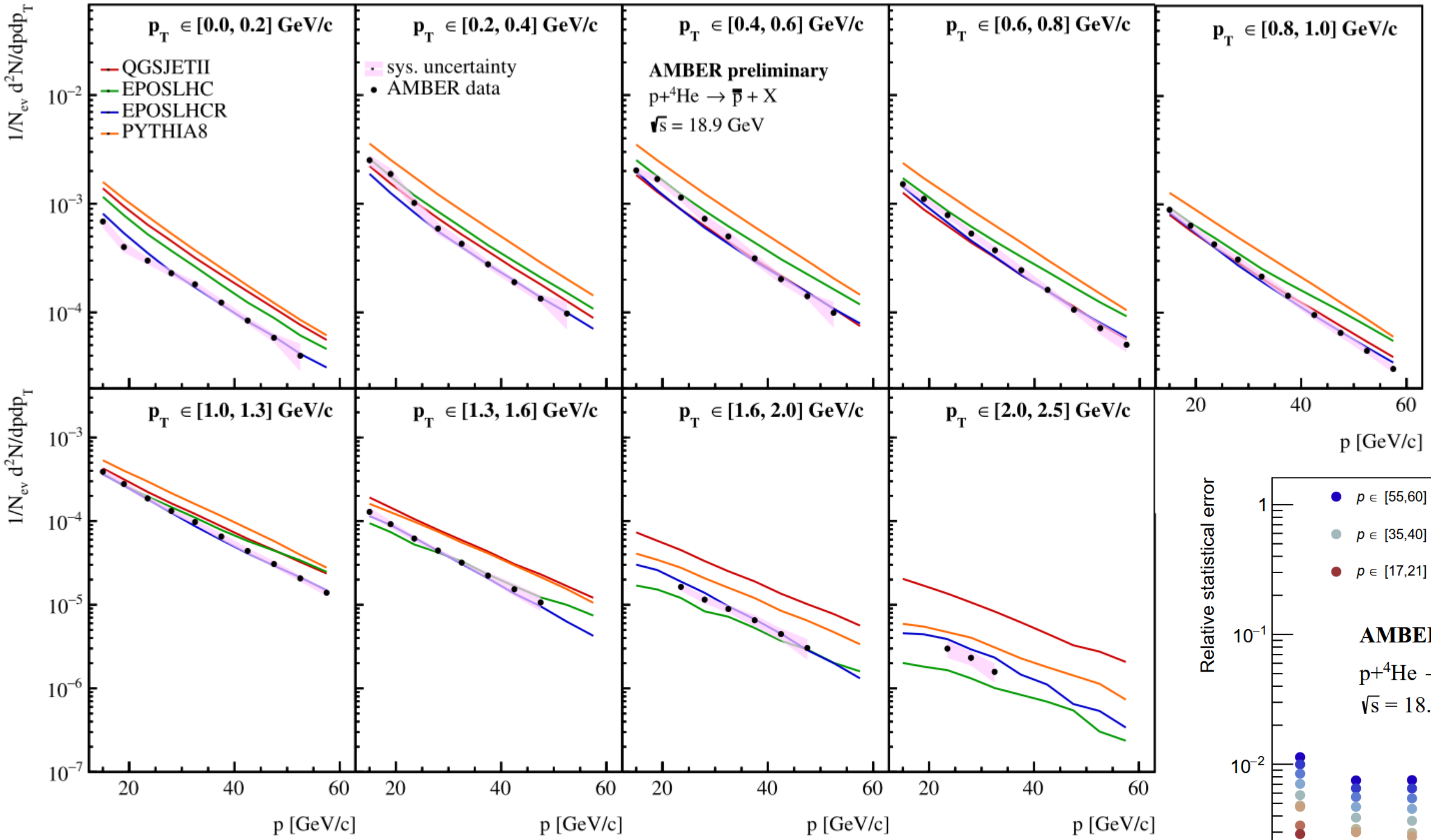

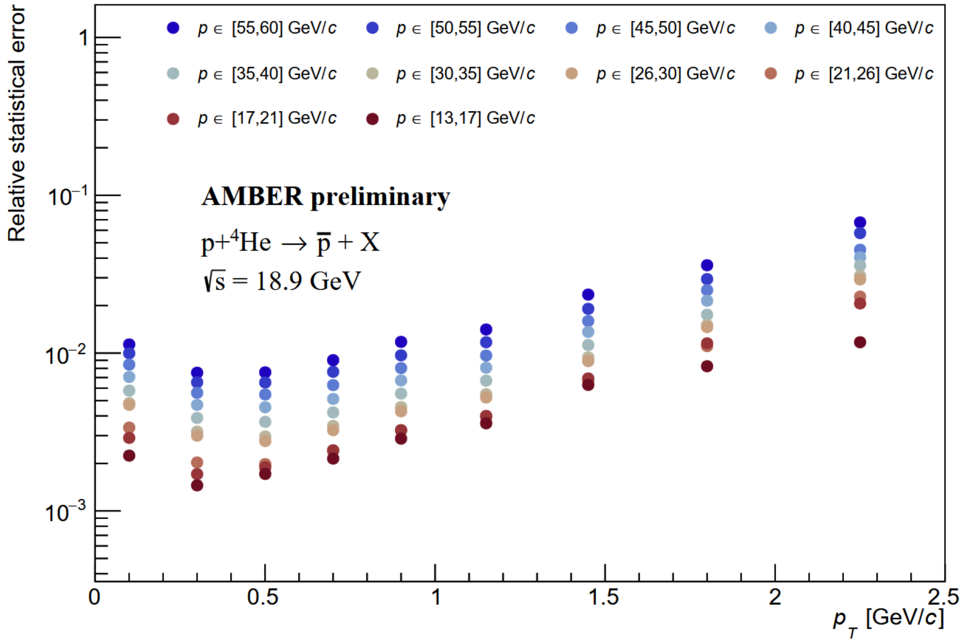

Statistical uncertainties mostly < 1% for p-He data

ISOSPIN ASYMMETRY

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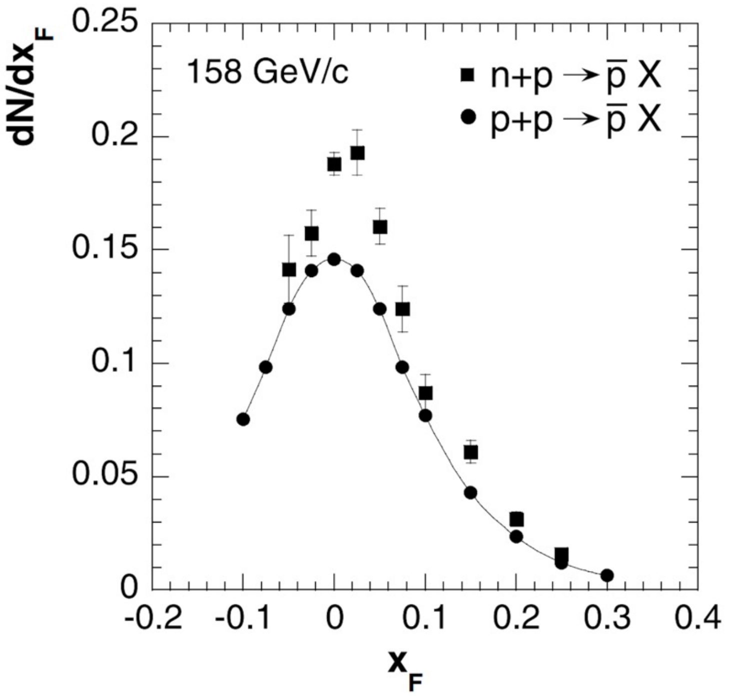
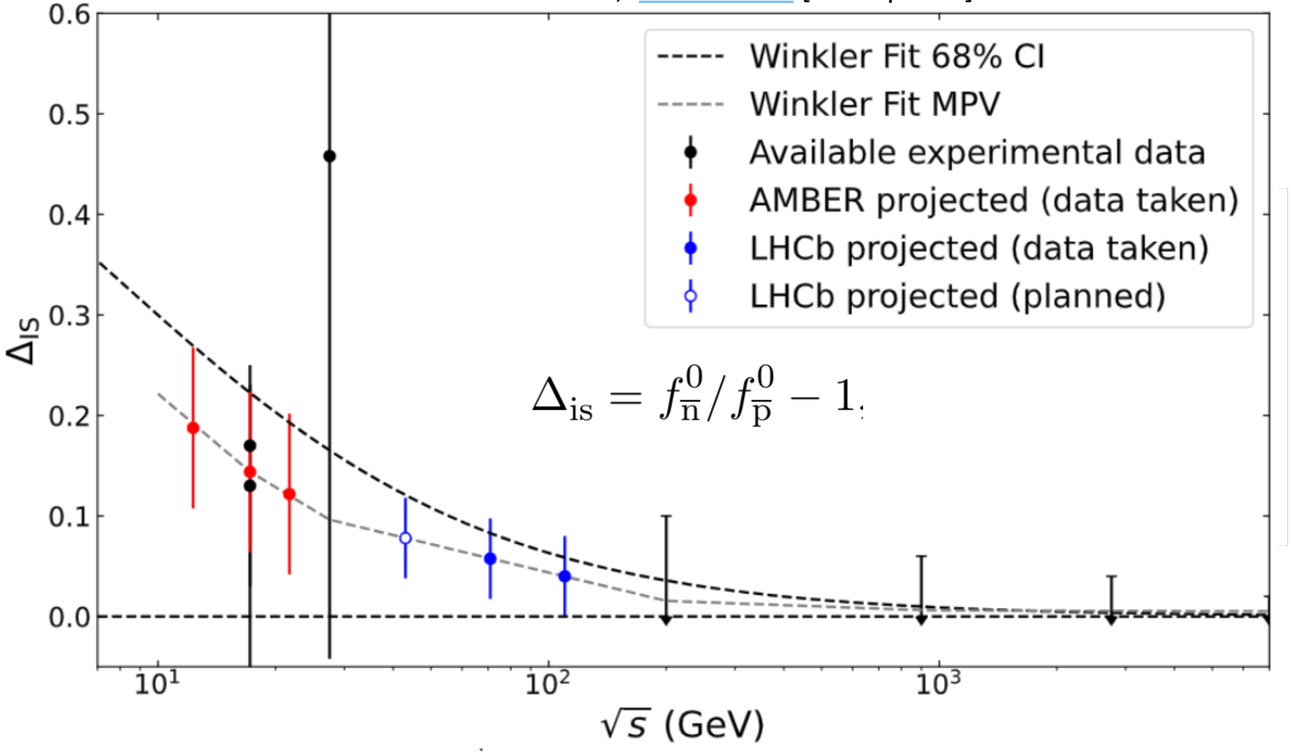
Asymmetry of $\overline{p}$ / $\overline{n}$ production?

[NA49, Acta Phys. Hun. A 17, 369 (2003)]



D. Maurin et al., 2503.16173 [astro-ph.HE]



- Hints by NA49 for production asymmetry of $\bar{p}n$ and $\bar{n}p$
- Can be verified by AMBER via $p + p \to \bar{p} + X$ vs $p + d \to \bar{p} + X$: data taken at 80, 160, 250 GeV/c
- Expected precision of recorded p-H / p-D data will help to solve question of isospin asymmetry in $\bar{p}$ / $\bar{n}$ production

AMBER PHYSICS PROGRAM

Phase-1: 2023 $\rightarrow$ 2031 (conventional beams)

- $\bar{p}$ production cross section measurements for DM searches (pbarX)
- Proton radius: high-energy μ-p elastic scattering (PRM)
- Pion and kaon quark PDFs: Drell-Yan processes (DY)

Phase-2: 2031 $\rightarrow$ 2041 (high-intensity kaon beam)

HOW TO MEASURE THE SIZE OF THE PROTON?

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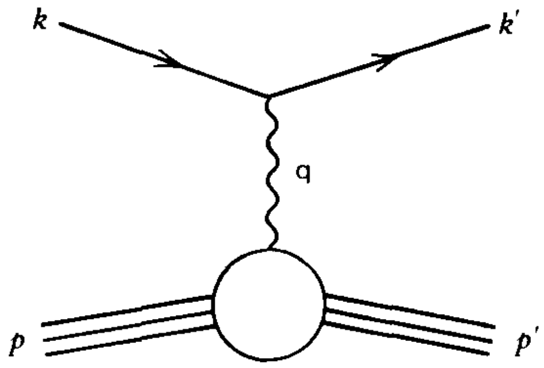
Elastic lepton – proton scattering

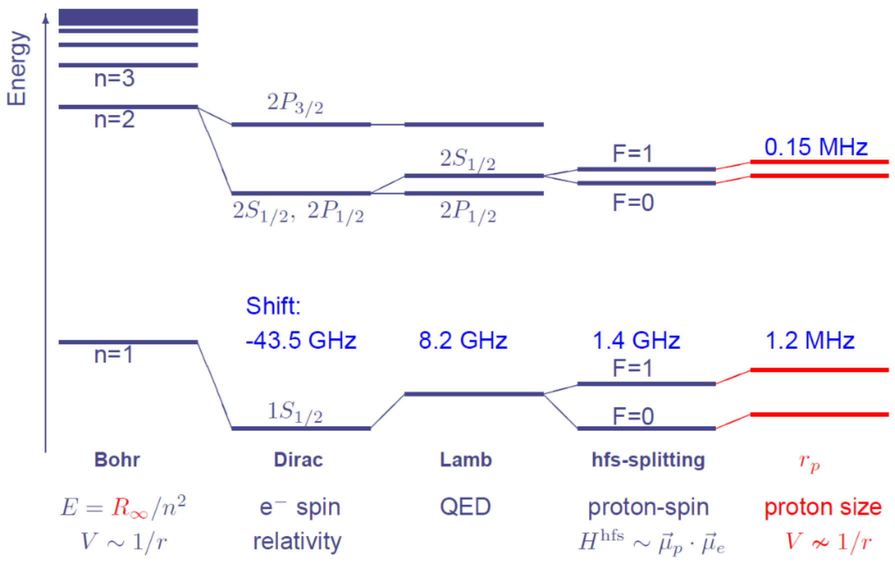


$$\left(\frac{d\sigma}{d\Omega}\right)_{\rm red} \equiv \frac{d\sigma/d\Omega}{(d\sigma/d\Omega)_{\rm Mott}}\frac{E}{E'} = \frac{1}{\epsilon(1+\tau)}\left(\epsilon G_{\rm E}^2(Q^2) + \tau G_{\rm M}^2(Q^2)\right)$$

$$\langle r_p^2\rangle = -6\left.\frac{dG_E(Q^2)}{dQ^2}\right|_{Q^2=0}$$

Spectroscopy of H

[R. Pohl, The Size of the Proton, Hadron 2011]



$$E(nS) = -\frac{R_\infty}{n^2} + \frac{L_{1S}}{n^3}$$

$$L_{1S}(r_p) = (8171.636(4) + 1.5645\langle r_p^2\rangle/(\text{fm}^2))\ \text{MHz}$$

PROTON CHARGE RADIUS - STATUS

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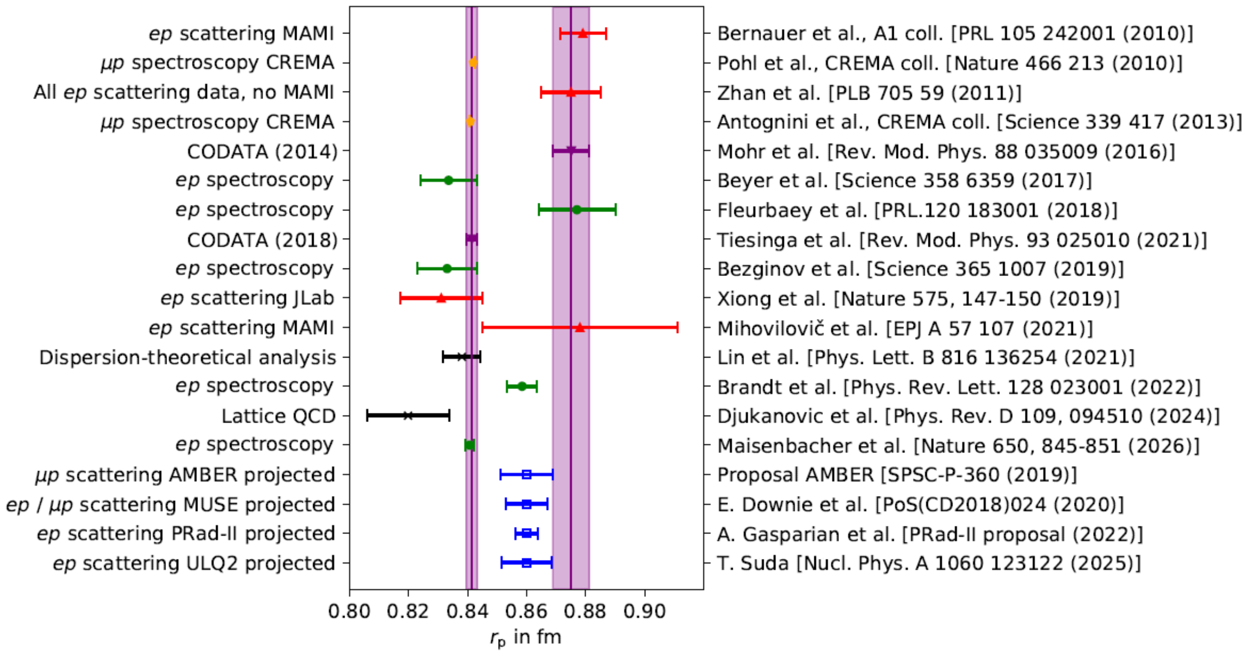
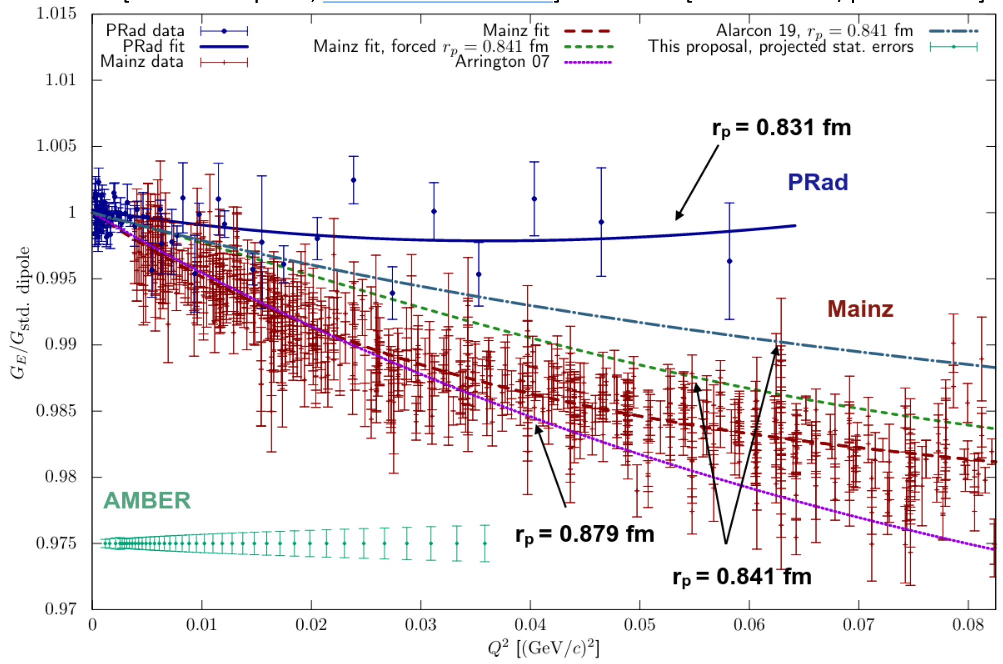


[AMBER Proposal, CERN-SPSC-2019-022] [M. Hoffmann, priv. comm.]

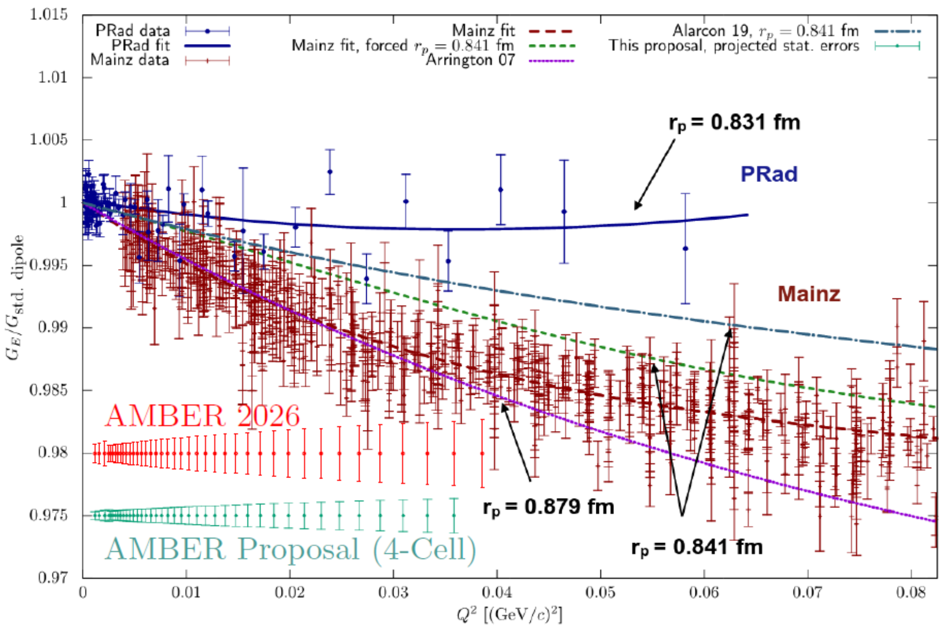


	ep	μp
Scattering	New measurements: • Lower systematics • Lower Q^2	Not measured yet • MUSE @ PSI • AMBER @ CERN
Spectroscopy	New measurements: • Lower systematics • New transitions	Done (CREMA)

Why high-energy μp scattering?

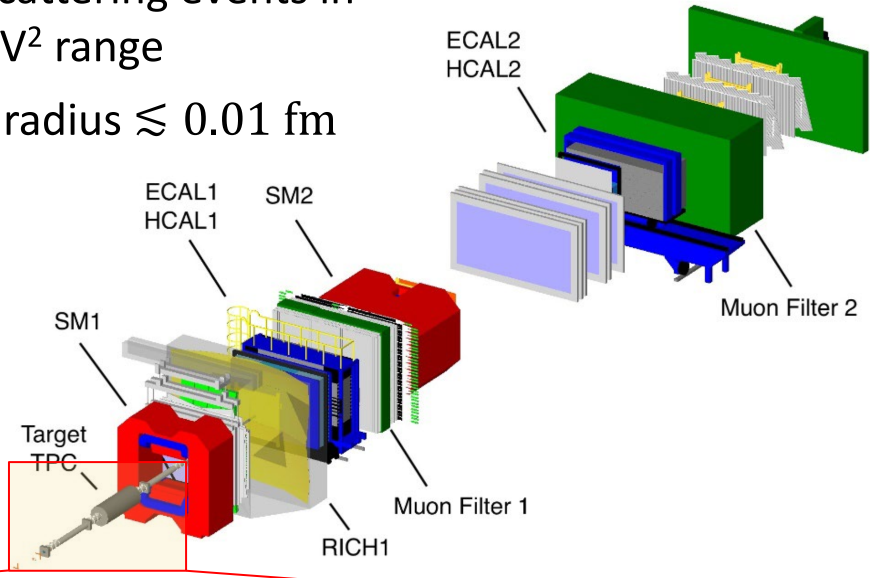
- different leptonic probe
- different systematic uncertainties
- >10 × smaller radiative corrections than *ep*
- provide precise data for global fit
- test lepton universality

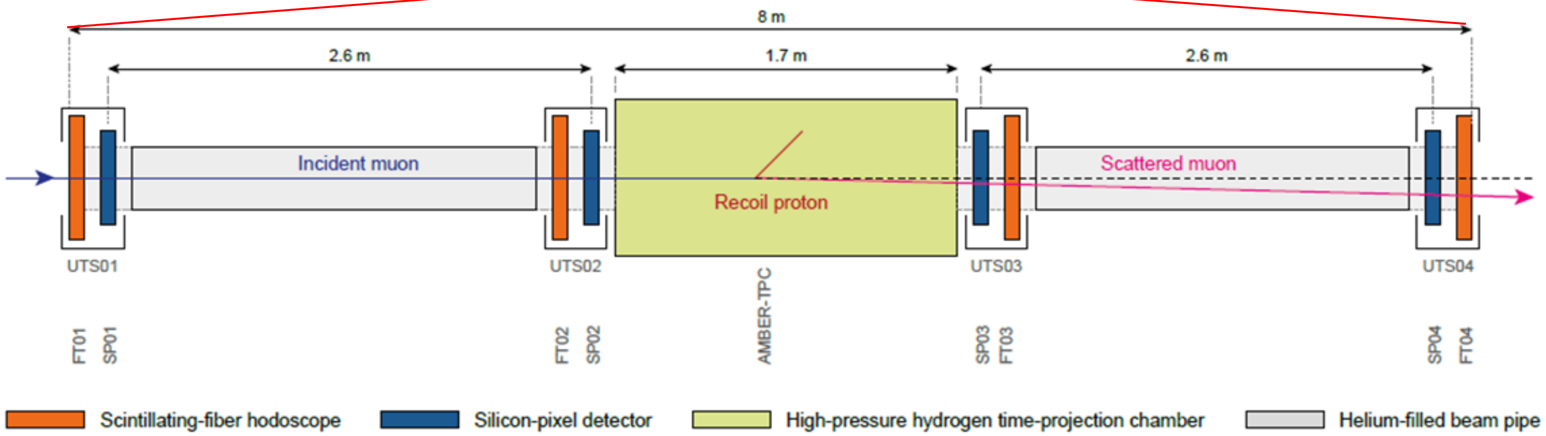
PROTON RADIUS MEASUREMENT AT AMBER



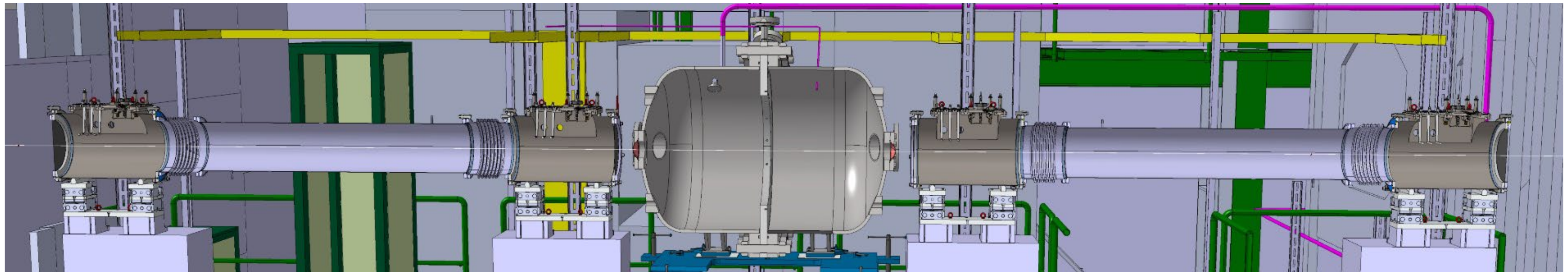
Unique measurement: high-energy $\mu^{\pm}$ (100 GeV/c)

- goal: 70 million elastic scattering events in the $10^{-3} < Q^2 < 4 \cdot 10^{-2}$ GeV^2 range
- precision on the proton radius $\lesssim 0.01$ fm



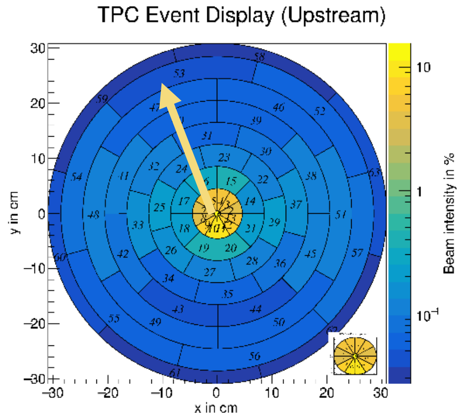


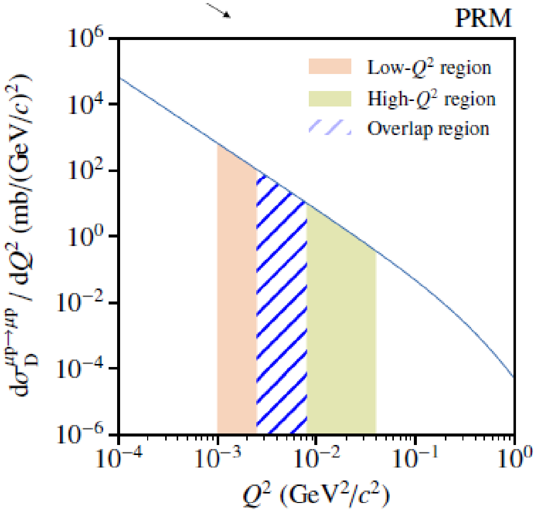
TARGET REGION FOR PRM

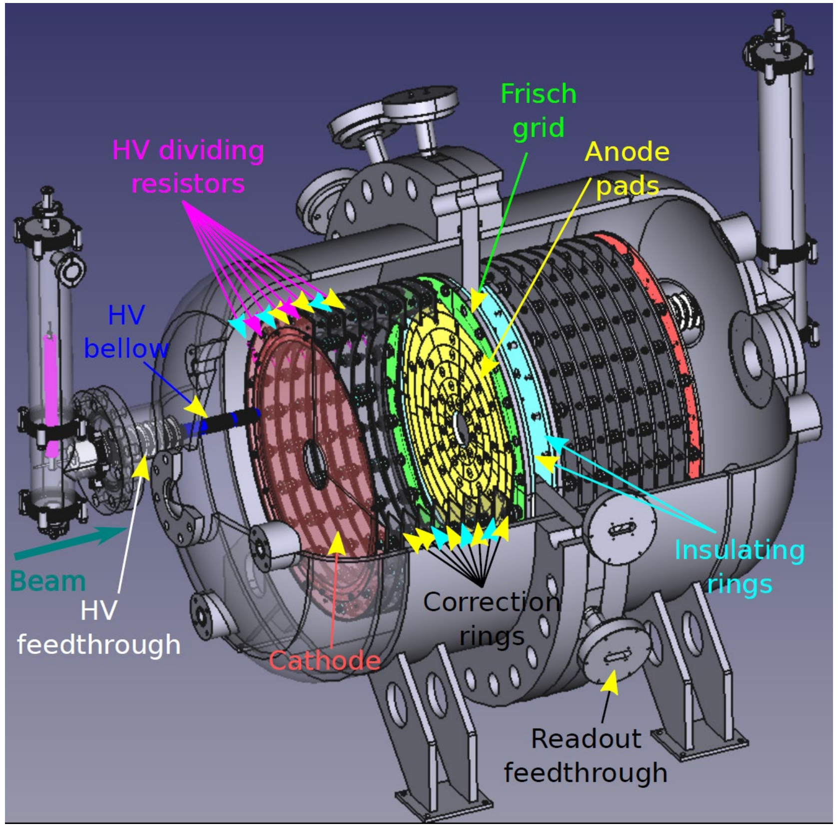


TPC: Direct measurement of recoil proton energy

- pure high-pressure H_2 as target and detector gas
- 2×40 cm drift cells, drift time $\sim 150\ \mu s$
- energy resolution $< 6\%$ required for desired precision
- segmented readout planes $\Rightarrow$ reconstruction of p track
- 2 different pressure settings: 4 bar, 20 bar to cover Q^2 range







TARGET REGION FOR PRM

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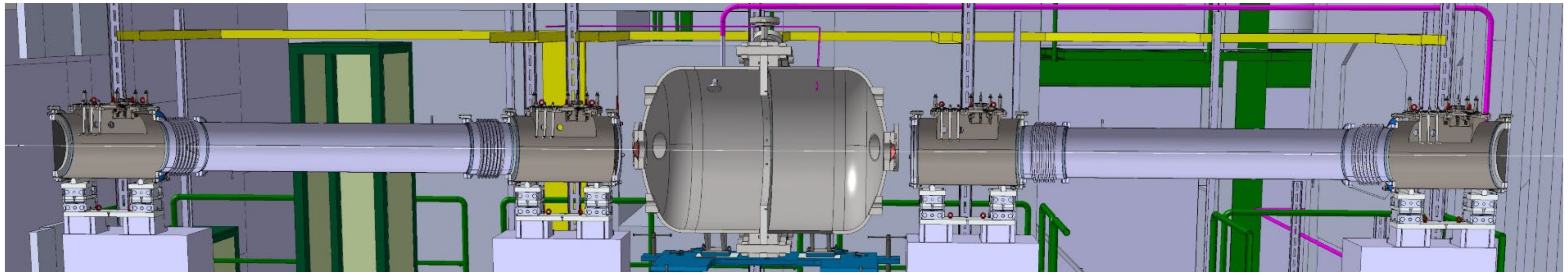

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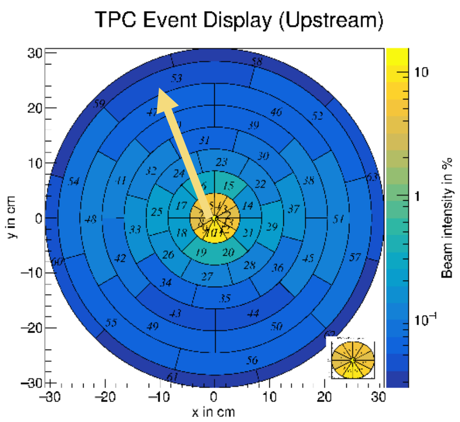
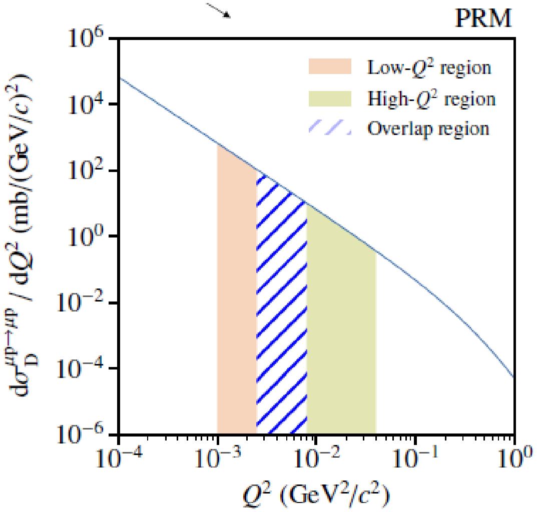
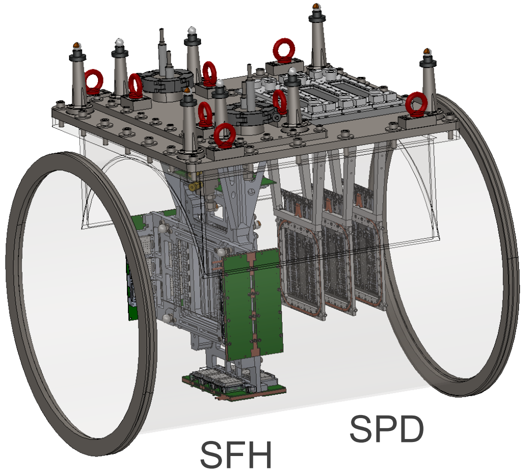




High-precision muon tracking system

- μ scattering angle $\sim 300\ \mu rad$, resolution $\sim 30\ \mu rad$
- Low material budget and high rate capability (2 MHz beam rate)
- 4 stations of MAPS (SPD) and scintillating-fiber hodoscope (SFH), size $\sim 9 \times 9\ \mathrm{cm}^2$



TARGET REGION FOR PRM – 22.04.2026

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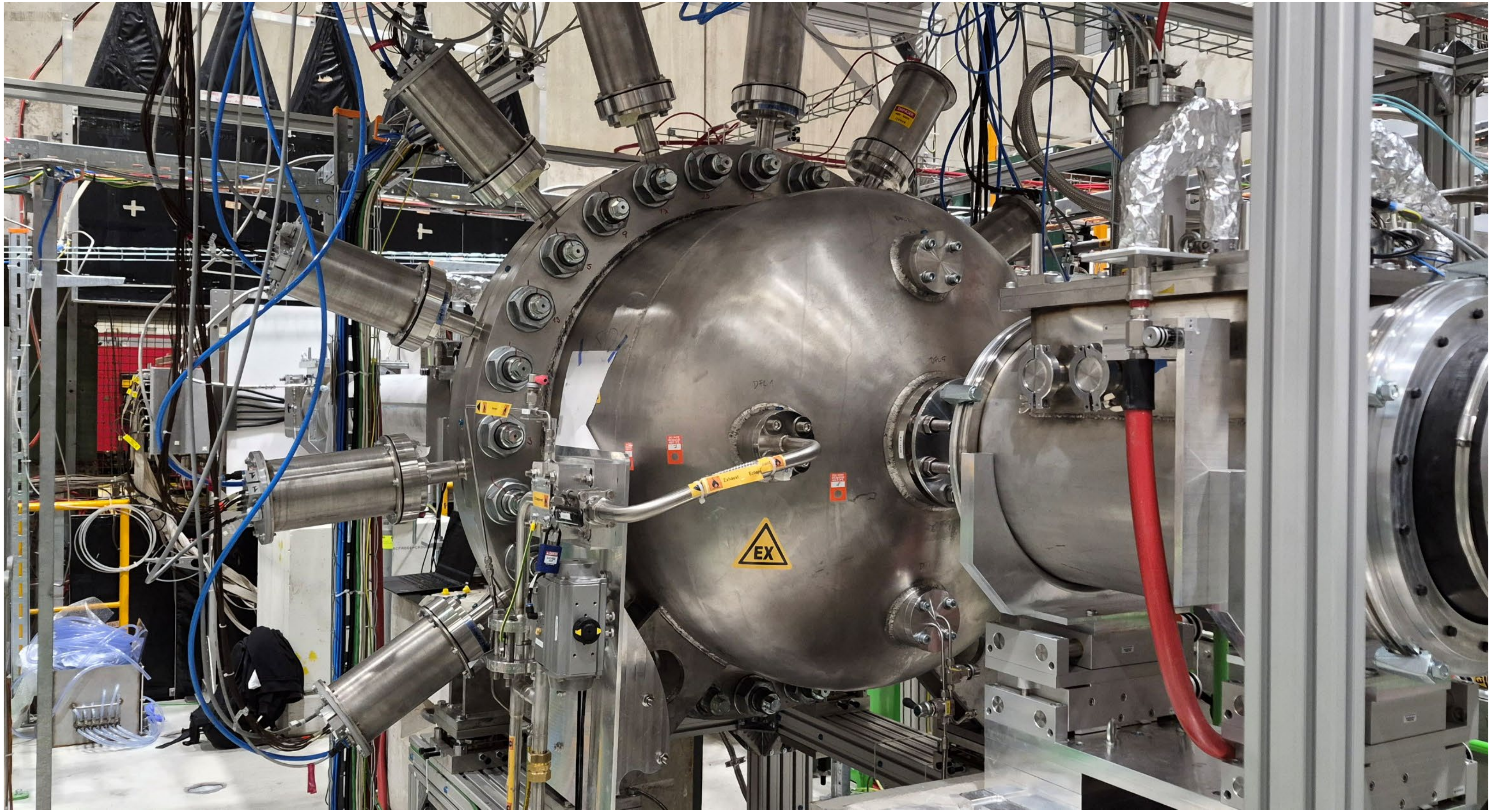
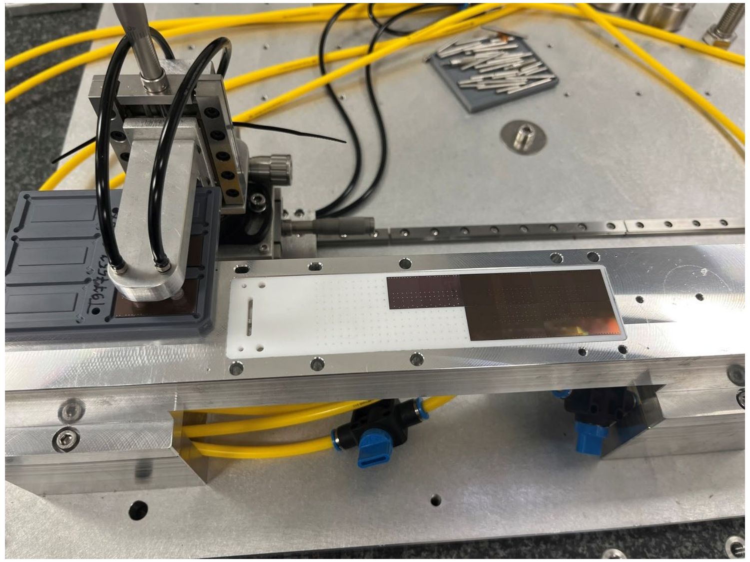


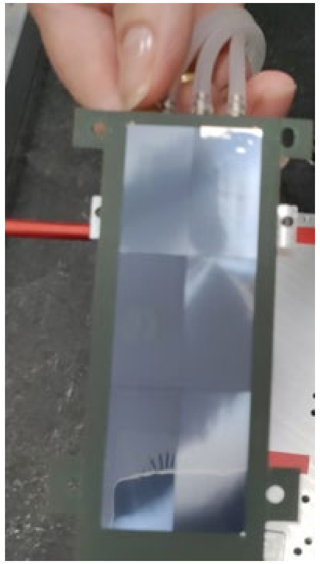
HIGH-PRESSURE TPC

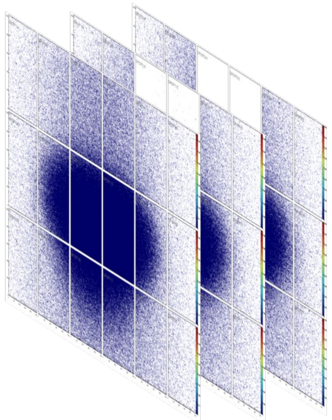
SILICON PIXEL DETECTOR - SPD

AMBER
Apparatus for Meson and Baryon Experimental Research

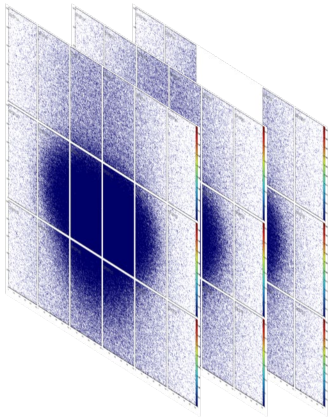
- Monolithic active pixel sensors (MAPS): ALPIDE
- 29 µm x 27 µm pixel size, ~8 µm spatial resolution
- 15 mm (Y) × 30 mm (X) sensor, 512 x 1024 pixels
- Thickness 50 µm
- 3 planes (18 sensors each) per station
- ~ 2 µs time resolution with integration window up to 30 µs







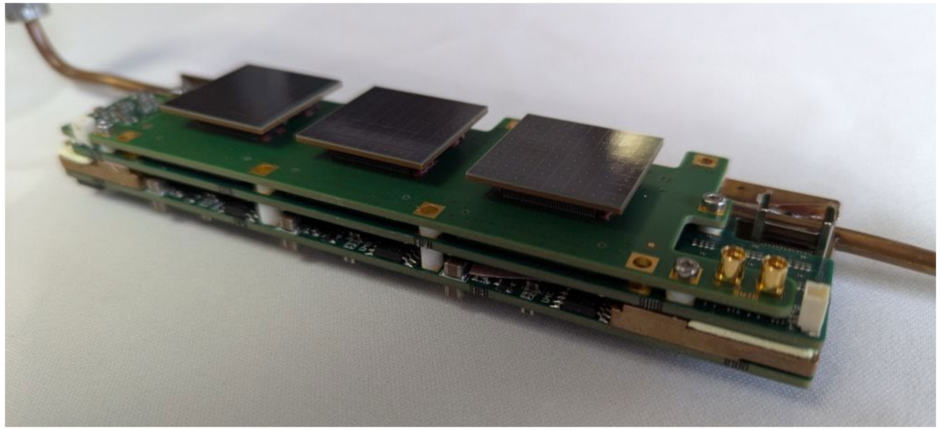
UTS2

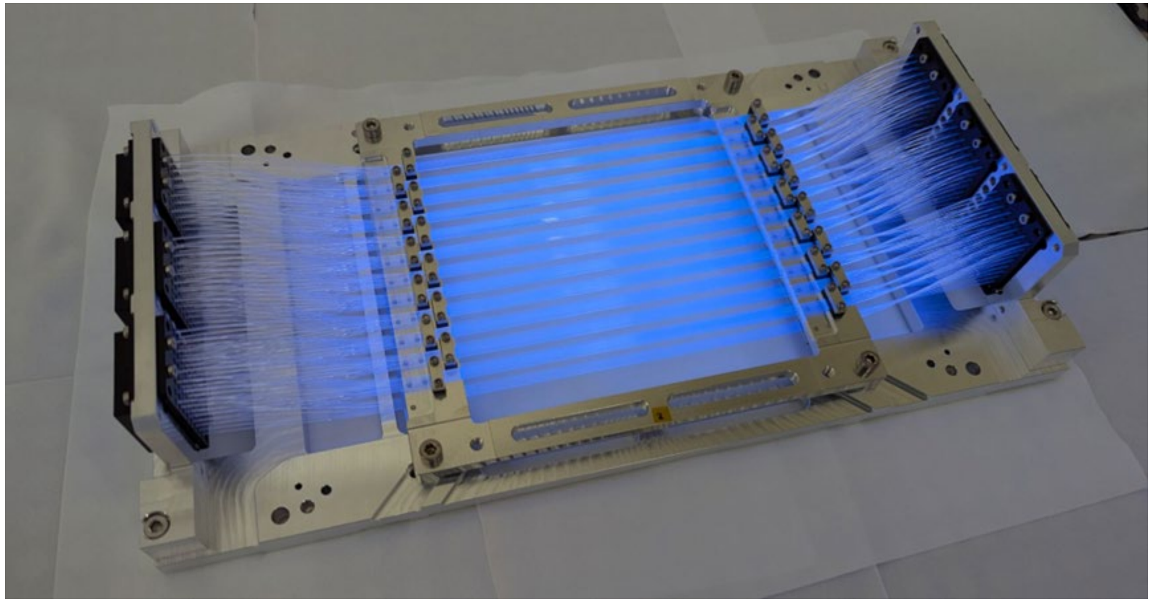


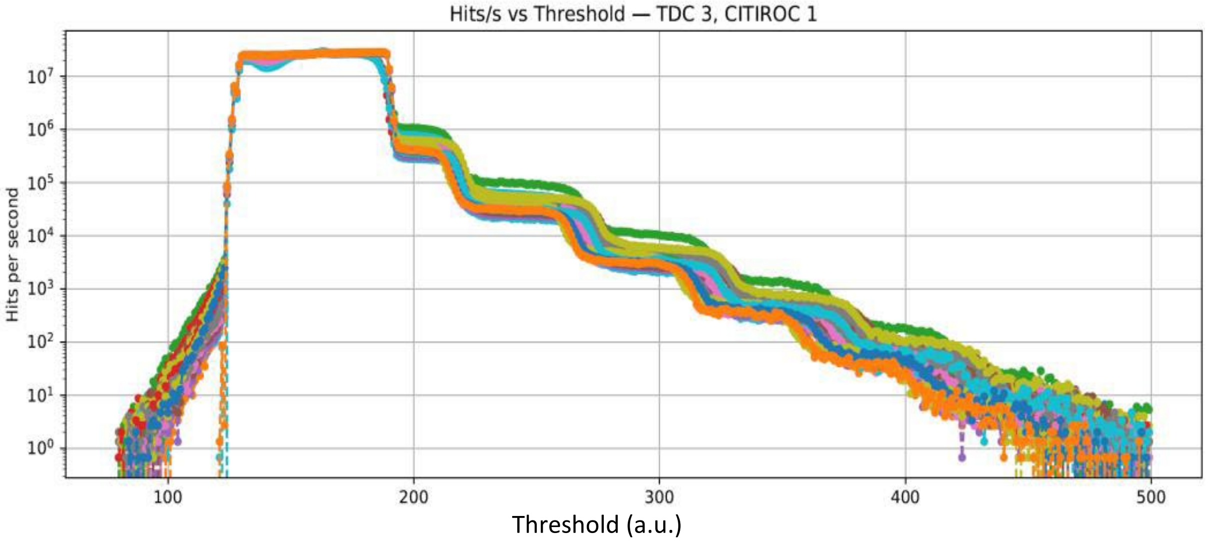
UTS3

SCINTILLATING FIBER HODOSCOPE - SFH

- 4 planes (2 X, 2 Y) of square scintillating fibers (Kuraray SCSF-78, 500 µm thickness)
- 192 fibers per plane, arranged in packages of eight
- SiPM readout of individual fibers (Hamamatsu S13360-3050AE-08)
- Citiroc 1A ASIC, TDC readout
- Threshold scan demonstrates single-photon detection capability







STREAMING DAQ

Apparatus for Meson and Baryon Experimental Research

Challenge:

Combination of slow and fast detectors with a continuous readout and software trigger logic for data reduction.

- Data stream sorted in time slices
- Detector data ordered in time images according to detector resolution and rates
- Hardware event builder stores data

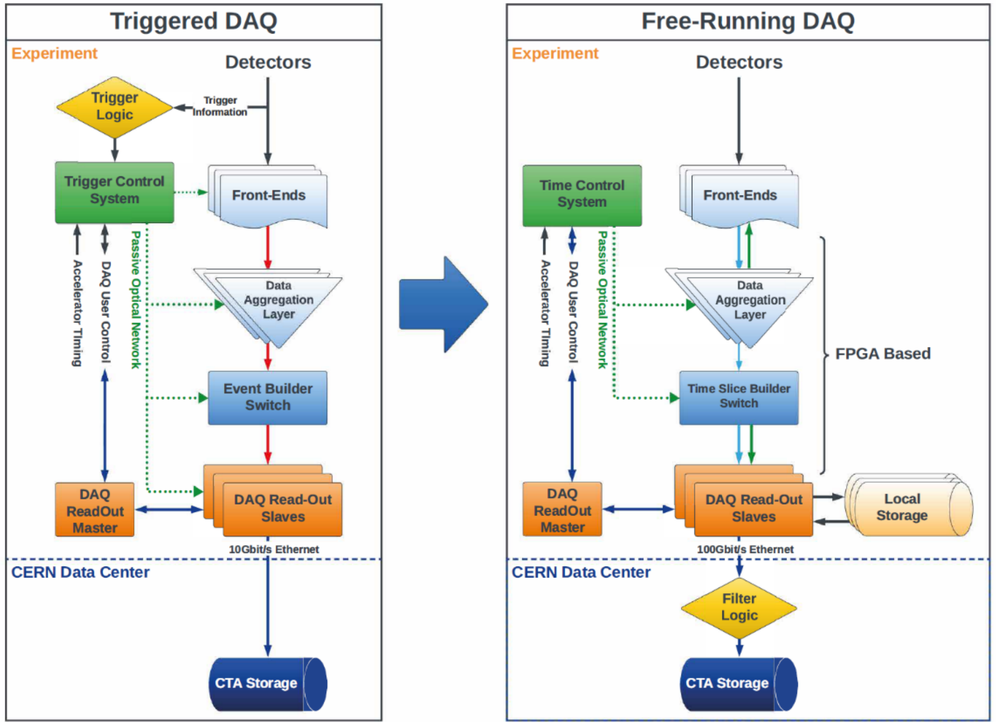
FPGA

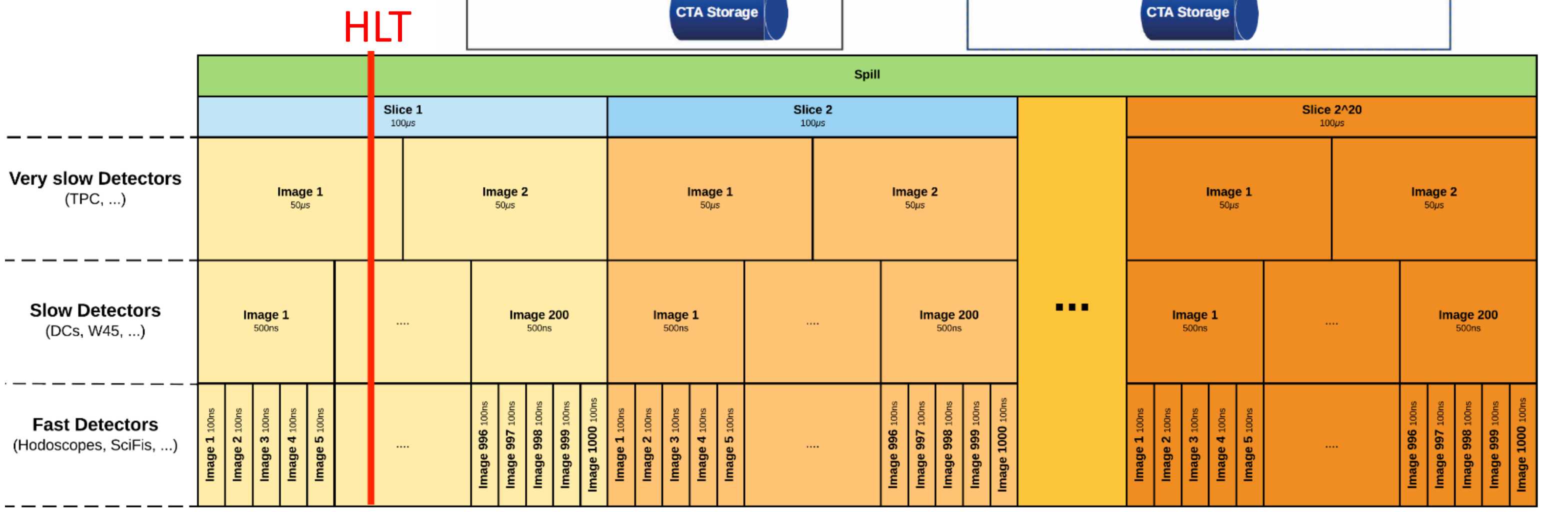
- High-level trigger selects time slices + images

software

Status:

- ➢ New DAQ hardware installed
- ➢ tests are ongoing





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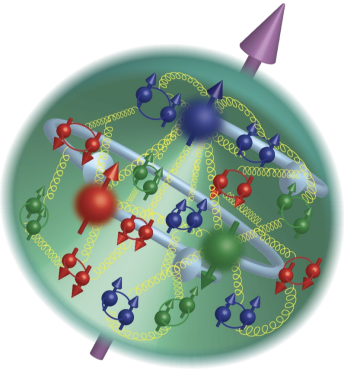
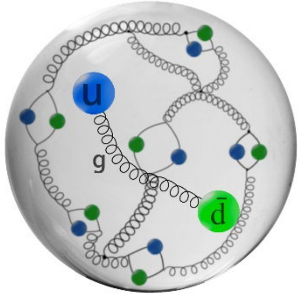
HADRON STRUCTURE

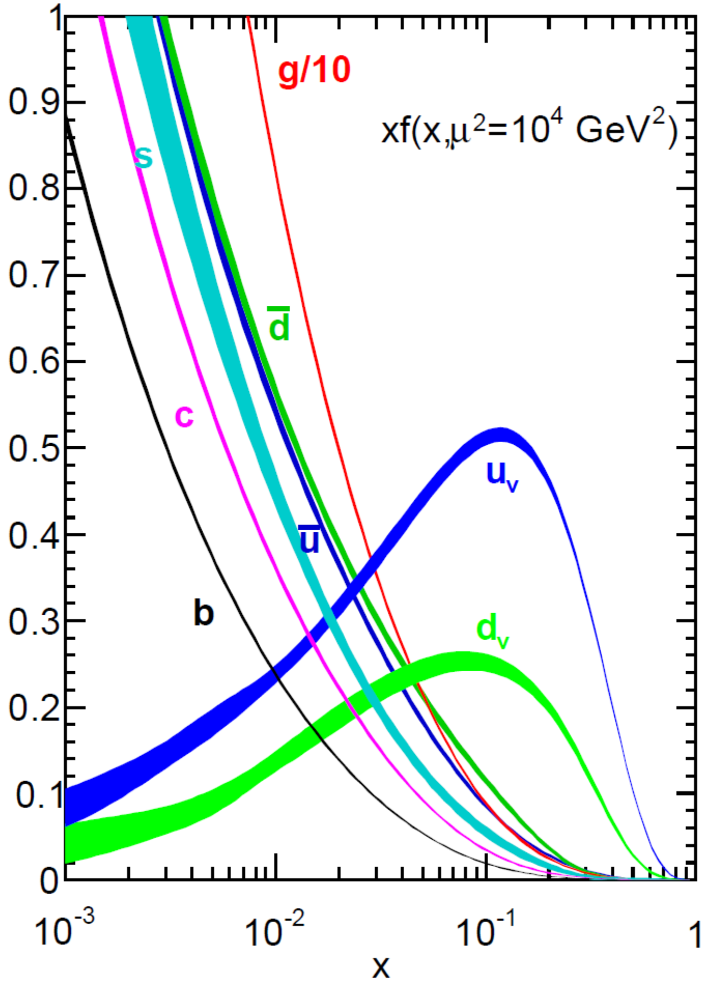
Proton:
- $M_p \sim 940\ MeV$
- Spin ½
- 3 light valence quarks
- Internal structure (PDF) well constrained by abundant experimental data



Pion:
- $M_\pi \sim 140\ MeV$
- Spin 0
- 2 light valence quarks
- Internal structure (PDF) nor well constrained
- Related to emergence of hadron mass (EHM)



Kaon?

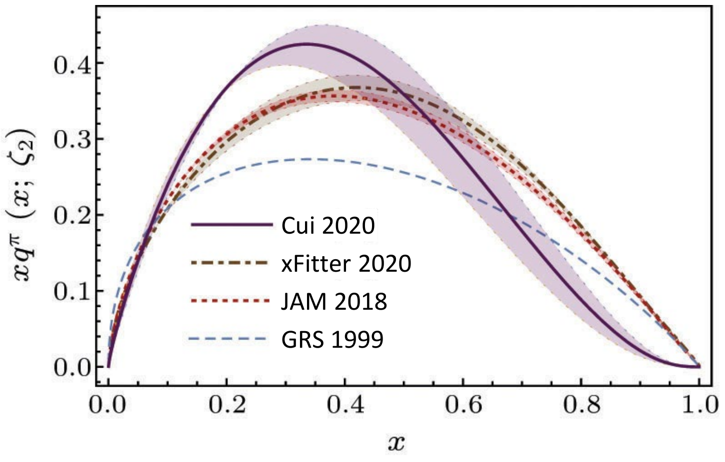


[K.A. Olive *et al.* (Particle Data Group), Chin. Phys. C, **38**, 090001 (2014)]

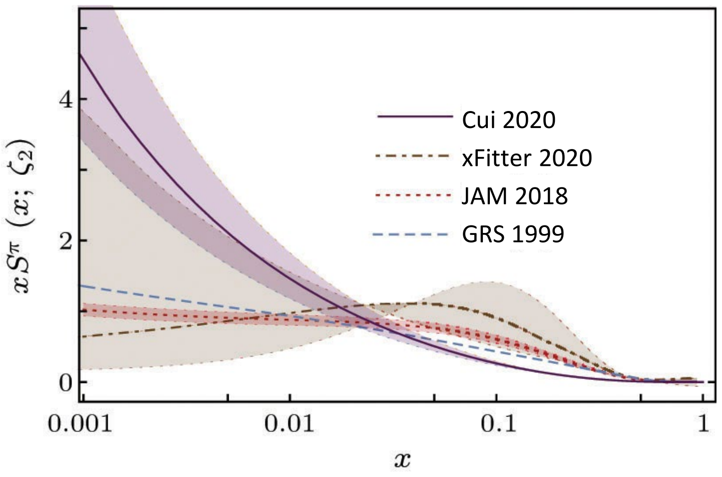
PION STRUCTURE – CURRENT STATUS

Apparatus for Meson and Baryon Experimental Research

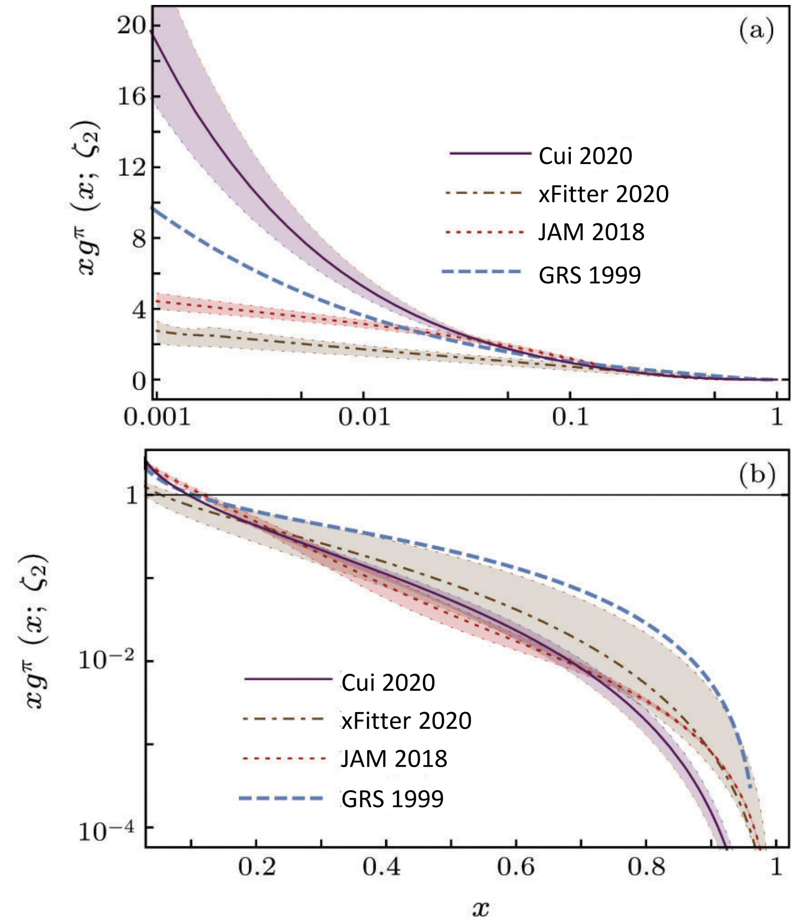
Valence quarks



Sea quarks



Gluons

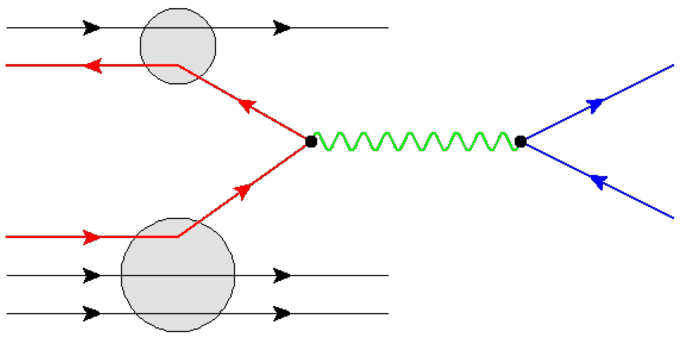


- Scarce / old data: E615, NA3, NA10,…
- Valence PDF poorly constrained
- Sea and gluon PDFs basically unknown
- Mostly heavy nuclear targets (Pt, W) $\Rightarrow$ large nuclear effects
- Discrepancy between experiments
- More and precise data urgently needed

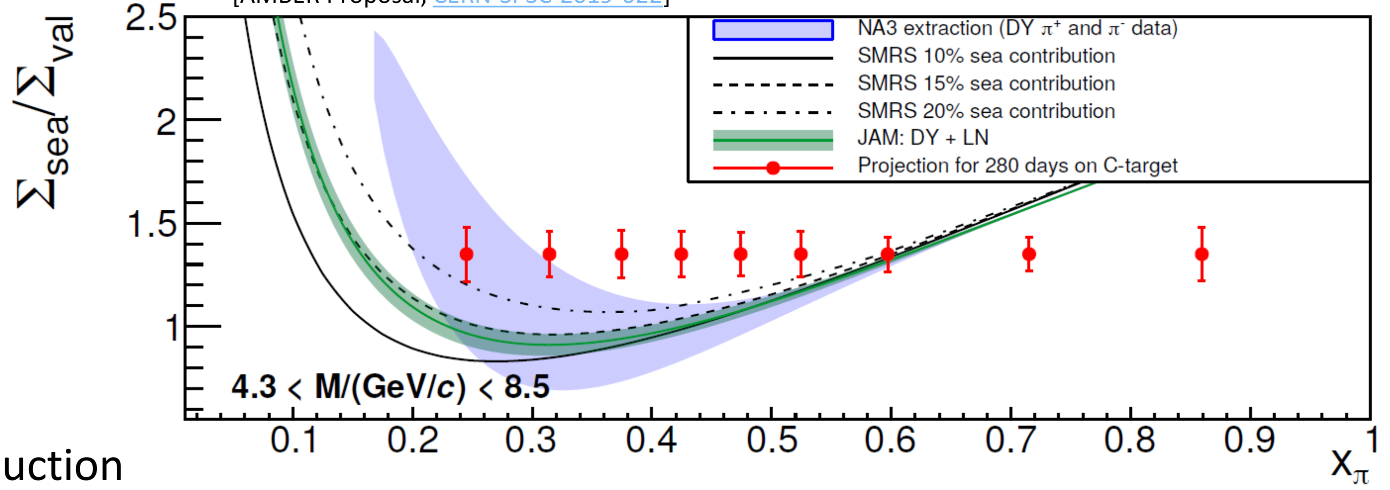
[Chang et al., Chin. Phys. Lett. 38 (2021) 081101]

PION/KAON VALENCE AND SEA QUARK PDFS AT AMBER

AMBER — Apparatus for Meson and Baryon Experimental Research



[AMBER Proposal, CERN-SPSC-2019-022]



- Pion- and kaon-induced Drell-Yan dimuon production
- Isoscalar ^{12}C target ⇒ minimize nuclear effects
- Pos. and neg. beams ⇒ separate valence and sea

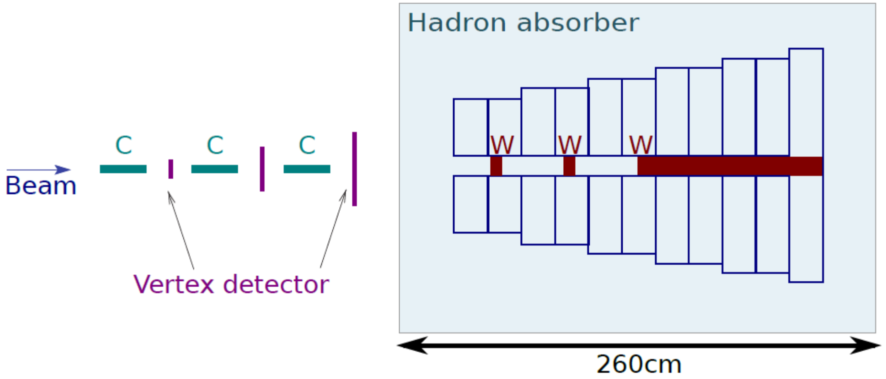
$$\sigma_{\rm DY}^{\pi^+ A} \propto \sum_i (e_i)^2 \left[\bar{q}_i^{\pi^+} q_i^A + q_i^{\pi^+} \bar{q}_i^A\right]$$

$\Sigma_{\rm val} = \sigma^{\pi^-} - \sigma^{\pi^+}$ only valence-valence

$\Sigma_{\rm sea} = 4\sigma^{\pi^+} - \sigma^{\pi^-}$ sea-valence / valence-sea

Goals:

- 10× more data than currently available
- First precise and direct measurement of the sea quark distribution in the pion



Setup:

- High-energy π/K beam only available at CERN
- Dedicated target, vertex detector, hadron absorber
- Dimuon mass resolution ~ 100 MeV

PION GLUON PDF AT AMBER

In parallel: study of $\boldsymbol{J/\psi}$ **production**: $\pi + A \to J/\psi + X$

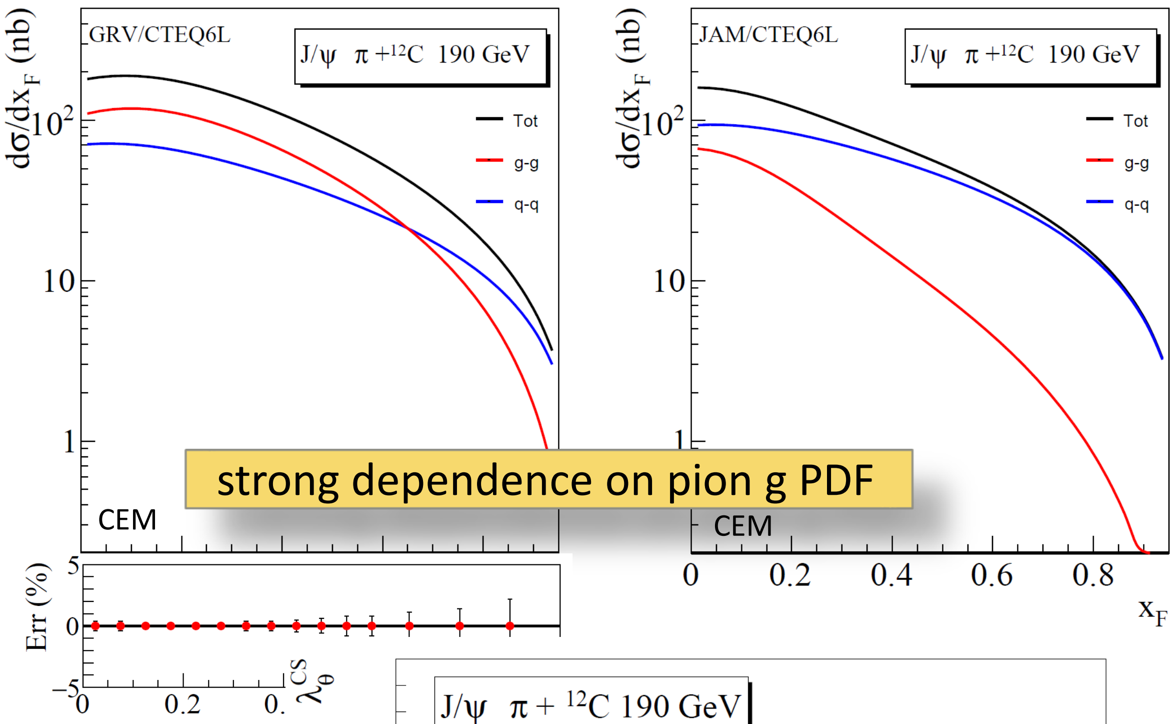
- Dominated by $q\bar{q}, gg \to J/\psi$ at low $p_T < M(J/\psi)$
  $\Rightarrow$ access to gluon PDF of pion
- Cross section 30-50 × larger than DY

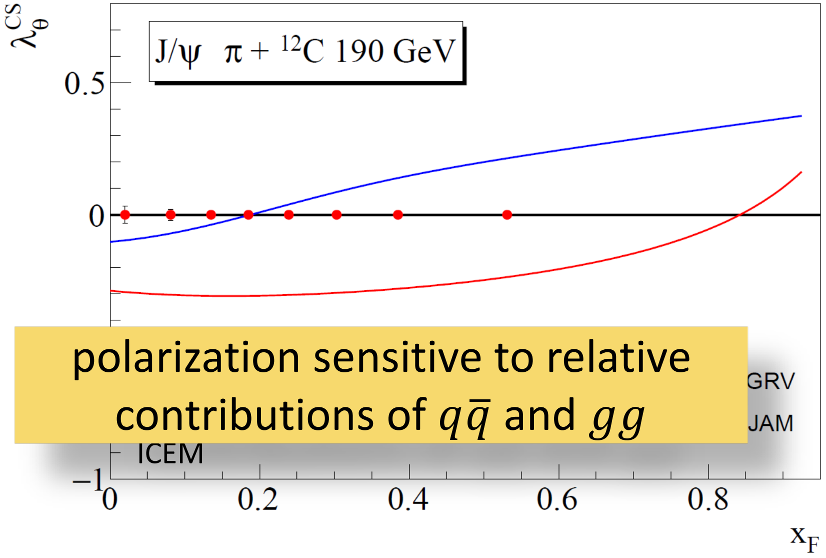
  $\Rightarrow$ measure differential distributions with >1M ev.
- Measurement of (π^+, p) and π^-
- But: J/ψ production mechanism not well known at low p_T (CEM vs NRQCD)

Additional observable: $\boldsymbol{J/\psi}$ **polarization**

- $J^{PC} = 1^{--}, J_z = -1, 0, +1$
- Angular distribution $$\frac{d\sigma}{d\cos\theta} \propto 1 + \lambda\cos^2\theta$$
  - $\lambda = +1 \Leftrightarrow J_z = \pm 1$ $\quad q\bar{q} \to J/\psi$
  - $\lambda = 0 \quad \Leftrightarrow$ unpolarized
  - $\lambda = -1 \Leftrightarrow J_z = 0$ $\quad gg \to J/\psi$

[V. Cheung et al., PRD 98 (2018) 114029]





VERTEX DETECTOR FOR DRELL-YAN

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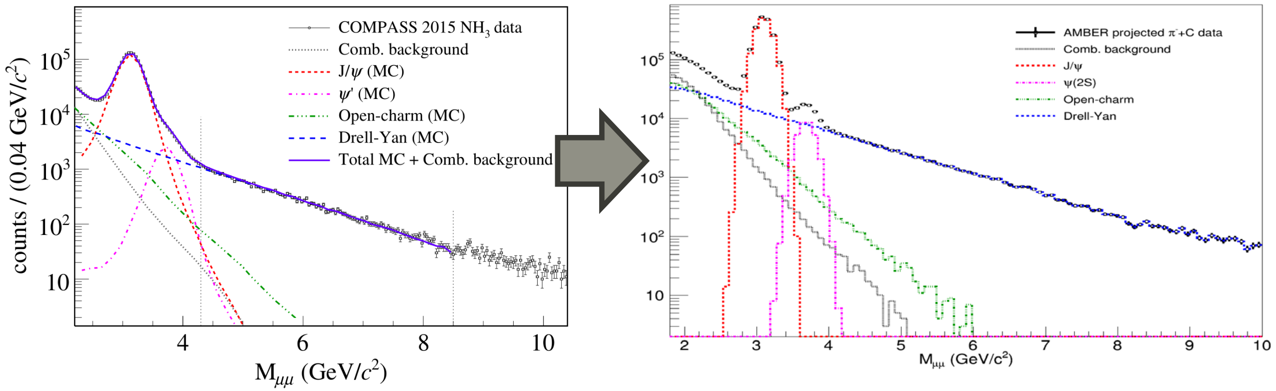
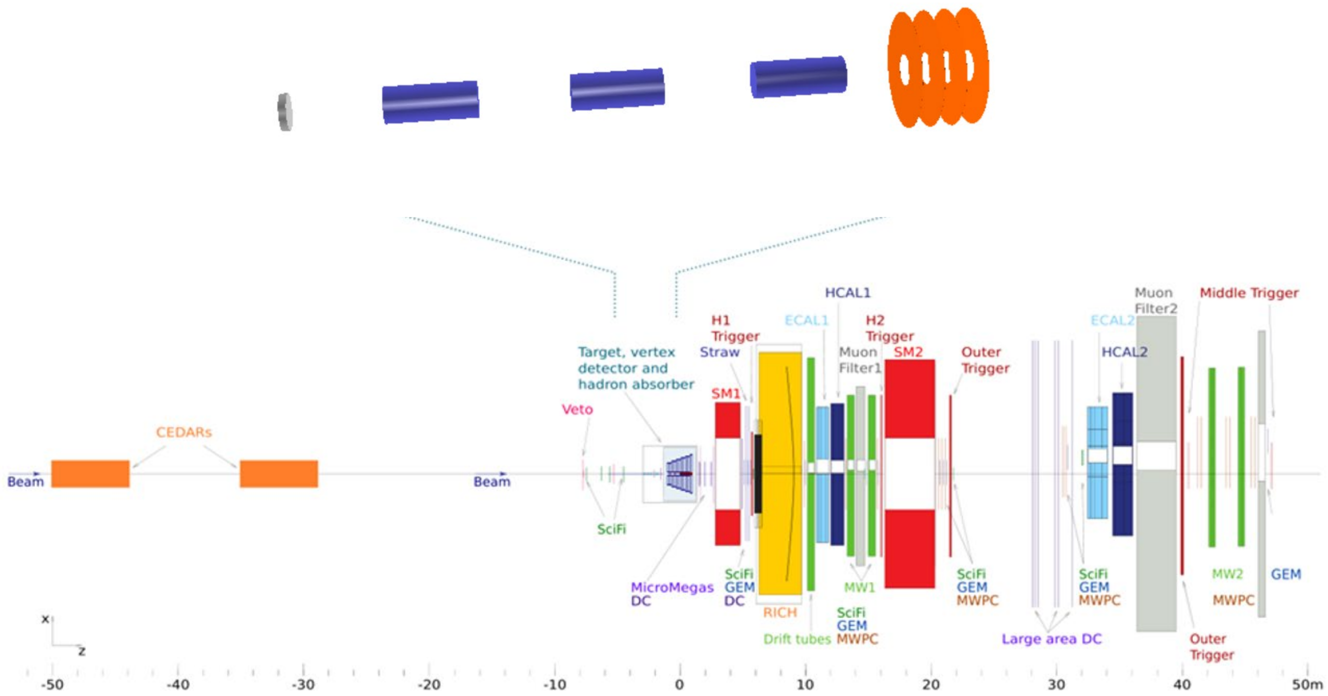
Apparatus for Meson and Baryon Experimental Research

DY program: $\pi + N \rightarrow \mu^{+}\mu^{-} + X$

- 3 carbon targets + hadron absorber
- add silicon vertex detector after last C target
- based on the FVTX detector built for the PHENIX experiment
- new beam telescope for backtracking to CEDARs





MC simulations:

- improves the mass resolution from ~200 MeV down to 100-150 MeV, the vertex resolution from ~12 cm down to <3 cm
- allows a lower mass cut for DY (4.3 GeV -> 4 GeV)
- suppresses the combinatorial background through tighter vertex cut
- enables clean access to ψ'
- might even allow us to access low-mass DY events

AMBER PHYSICS PROGRAM

Phase-1: 2023 $\rightarrow$ 2031 (conventional beams)

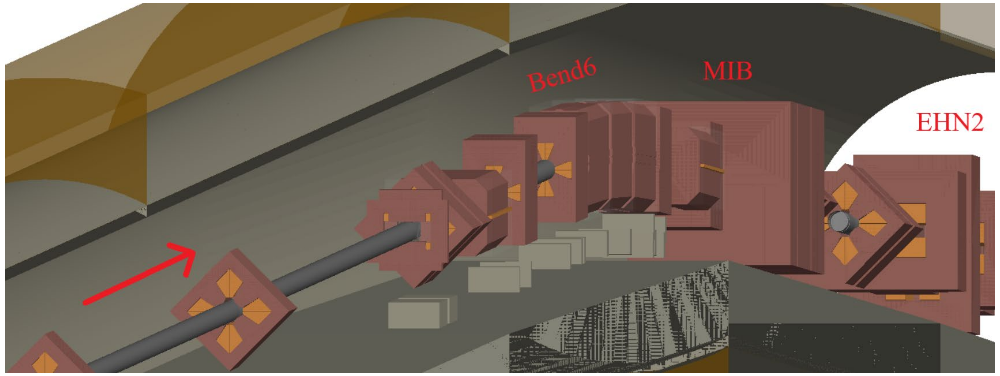
Phase-2: 2031 $\rightarrow$ 2041 (high-intensity kaon beam)

- K quark and gluon PDFs (DY, prompt photons)
- Strange meson spectroscopy
- Meson charge radii
- Meson-photon reactions in Primakoff kinematics
- New ideas

HIGH-INTENSITY KAON BEAM FOR PHASE-2

Worldwide unique experiments:

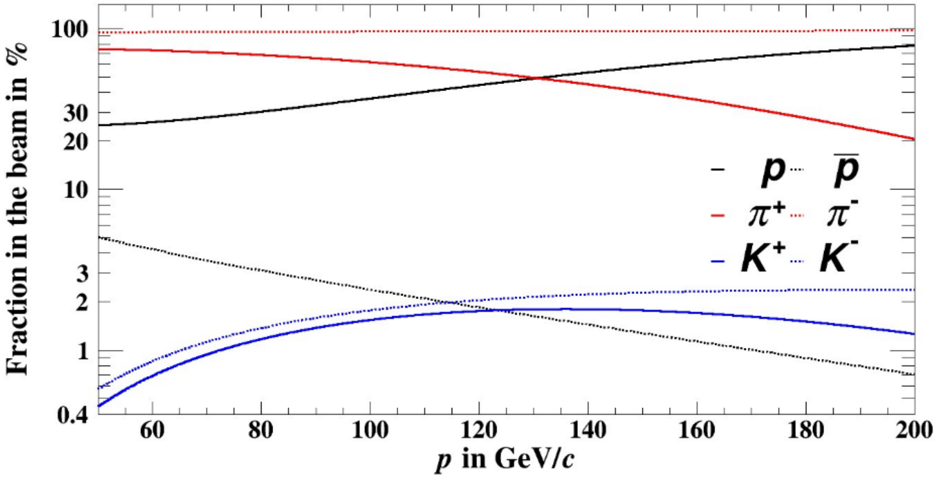
- spectroscopy of K_J, K_J^* in diffractive production
- measure kaon quark and gluon PDF (DY, prompt photons)
- electromagnetic/Primakoff reactions with kaons
- kaon charge radius in inverse kinematics



Requirements:

- Highest possible intensity of K in secondary beam
  - complete beam-line vacuum: remove 100m air sections, except XTAX (5m), replace wire chambers by SciFi (XBPF)
  - improve transport: reduce beam divergence at CEDARs
- High-efficiency / high-purity beam particle identification

  $\Rightarrow$ reduce beam momentum, choose positive polarity



Atherton parameterization

HIGH-INTENSITY KAON BEAM FOR PHASE-2

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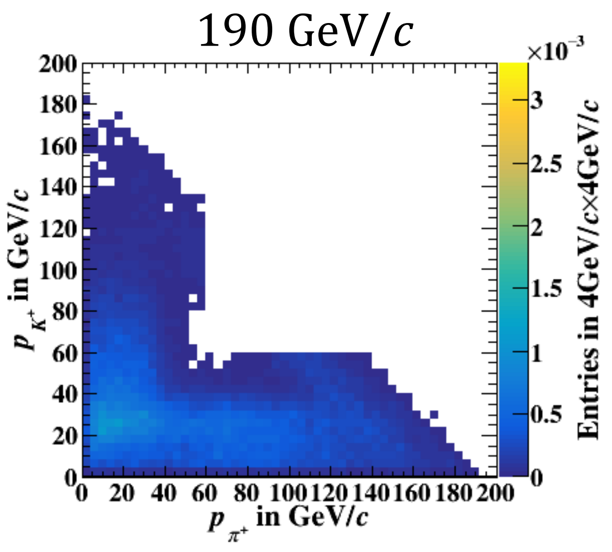
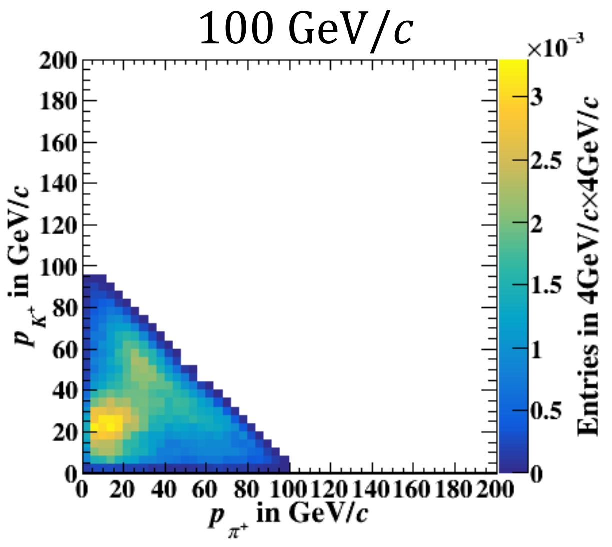
  - improve transport: reduce beam divergence at CEDARs
- High-efficiency / high-purity beam particle identification
  $\Rightarrow$ CEDAR upgrade
- Close acceptance hole in final-state PID
  $\Rightarrow$ extend RICH acceptance, adjust beam momentum

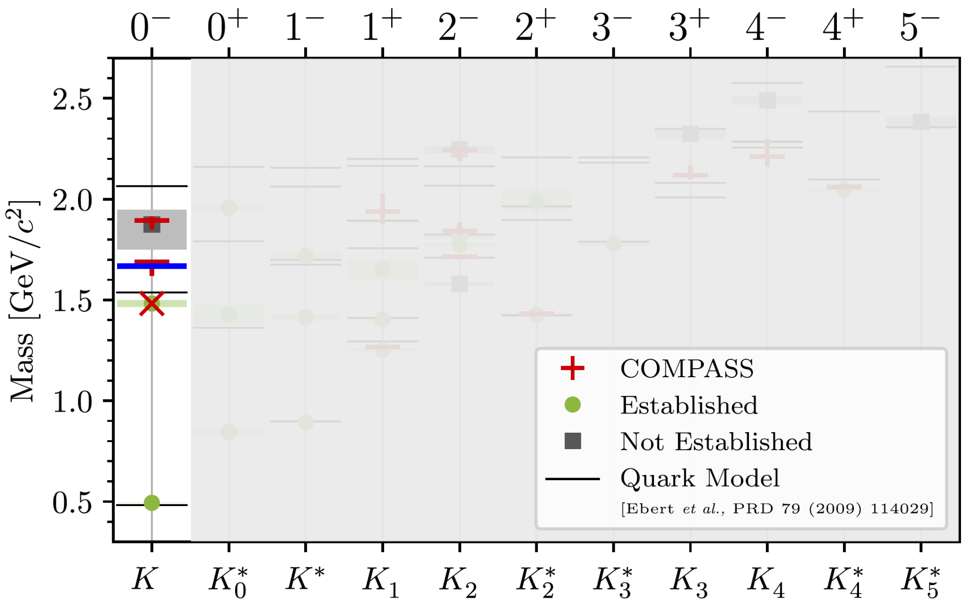


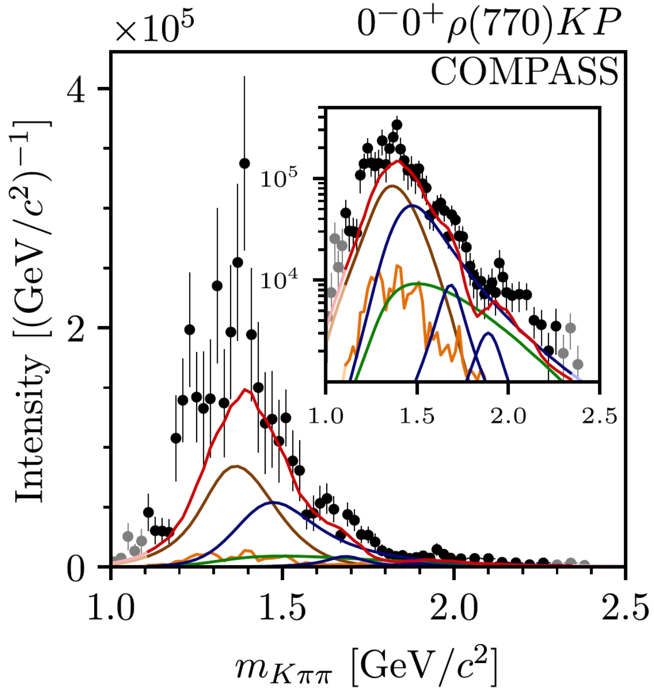


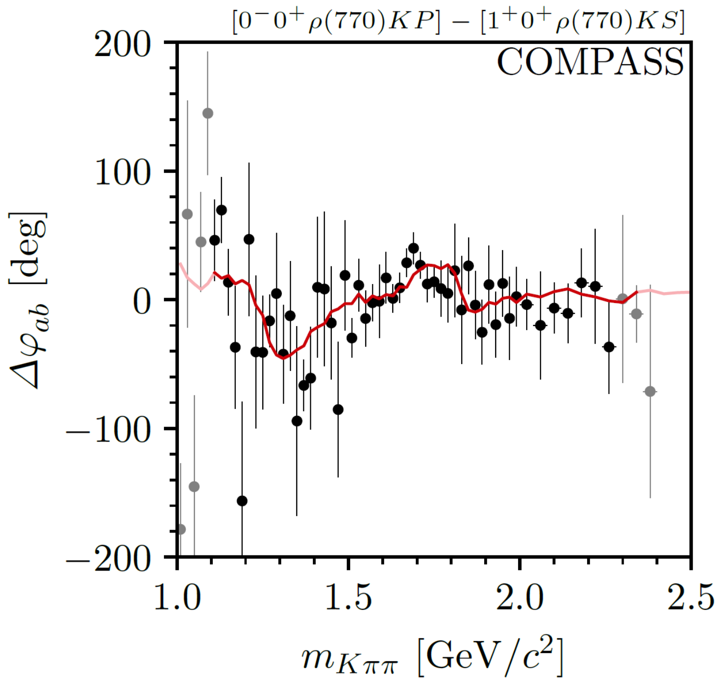
STRANGE MESON SPECTROSCOPY

Apparatus for Meson and Baryon Experimental Research

[COMPASS, arXiv:2504.09470]







COMPASS:

- Studying $K^- p \to K^-\pi^-\pi^+ p$ (parasistic to π^- beam)
- Evidence for 3 excited K states in $0^-0^+\rho K$ P wave
- Quark model only predicts 2: $K(1460), K(1830)$?
- $K(1690)$ supernumerary $\Rightarrow$ candidate for crypto-exotic strange meson
- statistically and systematically limited: 720k ev., PID

AMBER Phase-2:

- Beamline upgrade (NA-CONS)
- Improved beam K identification
- Improved final-state K identification
- Full solid-angle coverage for photons / electrons
- Goal: 20×10^6 exclusive $K^-\pi^-\pi^+$ events

CONCLUSIONS

AMBER
Apparatus for Meson and Baryon Experimental Research

- **NA66/AMBER** is a **new and unique facility** at CERN dedicated to study fundamental questions related to the emergence of hadron properties from QCD with high-energy h and μ beams
- **Phase-1: started in 2023**
  - Antiproton-production cross sections for DM searches
  - Proton radius with high-intensity muon beam
  - Pion and kaon valence / sea PDFs in Drell-Yan processes
- **Phase-2: measurements with high-intensity hadron/K beam**
  - Strange meson spectroscopy
  - Kaon and pion gluon PDFs
  - Primakoff reactions, charge radii, etc.
- **Opportunities for cooperation:**
  - Important contributions to instrumentation & software: tracking, calorimetry, PID, DAQ, reconstruction
  - Shaping physics program for Phase-2

New
The exp
provide
A few
confere
results

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CERN Physics Beyond Colliders

CERN-PBC Report-2025-003

Summary Report of the Physics Beyond Colliders Study at CERN

arXiv > hep-ex > arXiv:2601.06570 *Nuclear Physics News*, Vol. 36, No. 1, 2026

High Energy Physics - Experiment

[Submitted on 10 Jan 2026]

AMBER - A Strong-Interaction Facility at CERN

Bernhard Ketzer, Michela Chiosso (for the AMBER Collaboration)

AMBER (NA66) is a fixed-target facility at the M2 beam line of CERN SPS, which performs worldwide unique research on the internal s
The approved first phase of the experiment focuses on three main physics topics: (i) the measurement of the production cross section o
over a wide energy range; (ii) the precise measurement of the electric form factor of protons at small momentum transfers using a high-
pion and kaon quark PDFs through Drell-Yan and charmonium production measurements with negative and positive meson beams. Ph
intense kaon beam. The high-energy muon, pion and kaon beams required for these measurements are only available at CERN.

Comments: Submitted to Nuclear Physics News
Subjects: **High Energy Physics - Experiment (hep-ex)**; High Energy Physics - Phenomenology (hep-ph); Nuclear Experiment (nucl-ex)
Cite as: arXiv:2601.06570 **[hep-ex]**
(or arXiv:2601.06570v1 **[hep-ex]** for this version)
https://doi.org/10.48550/arXiv.2601.06570
Related DOI: https://doi.org/10.1080/10619127.2026.2614257