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AMBER

Apparatus for Meson and Baryon Experimental Research

AMBER: a new QCD facility at the CERN SPS M2 beam line

Bjoern Seitz
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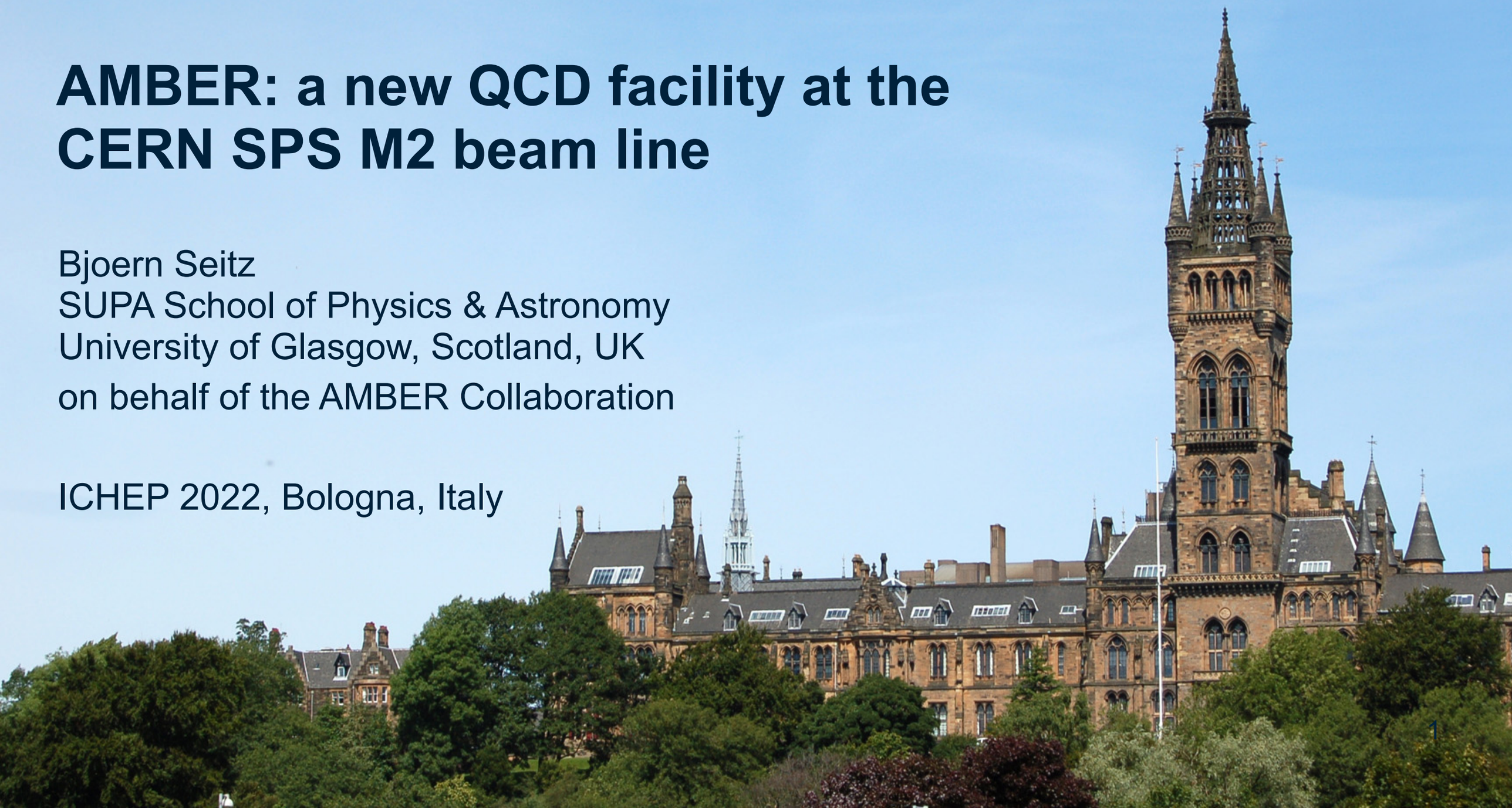
University of Glasgow, Scotland, UK
on behalf of the AMBER Collaboration

ICHEP 2022, Bologna, Italy



Physics beyond Colliders - Emergent Phenomena

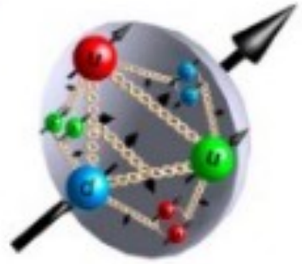
Pion

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

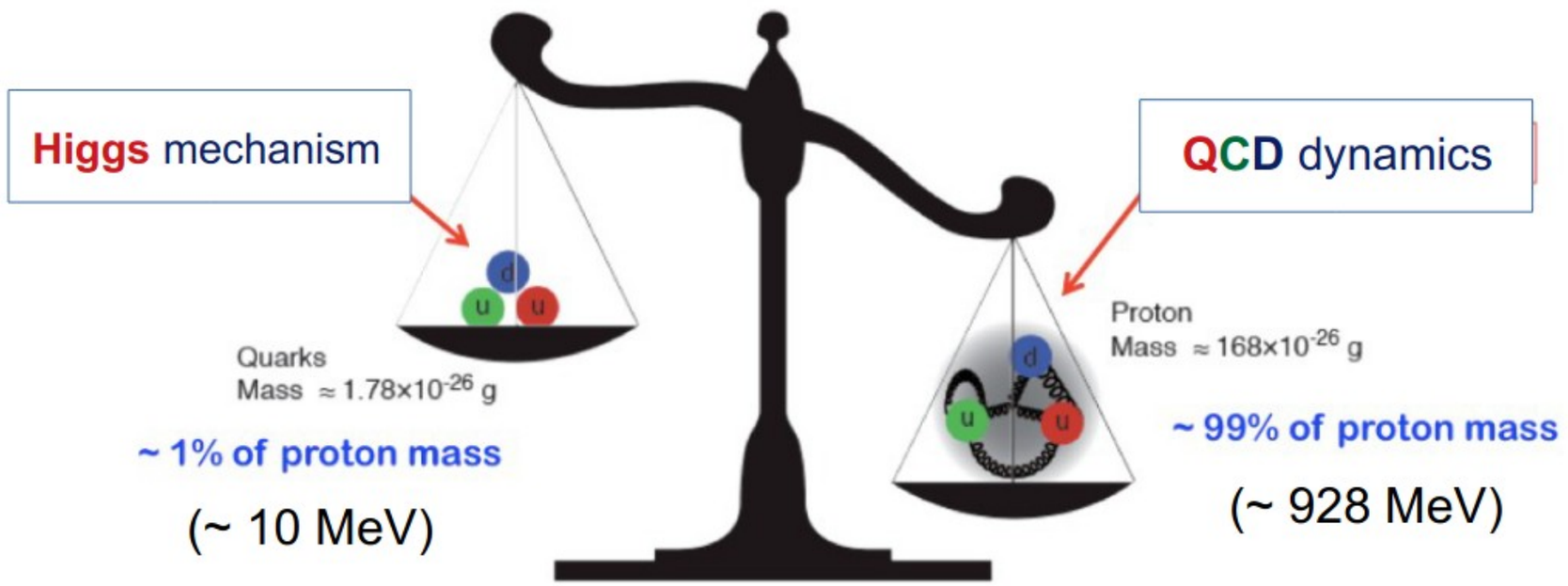
Kaon

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

Proton



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



Explore QCD in detail to understand emergent phenomena

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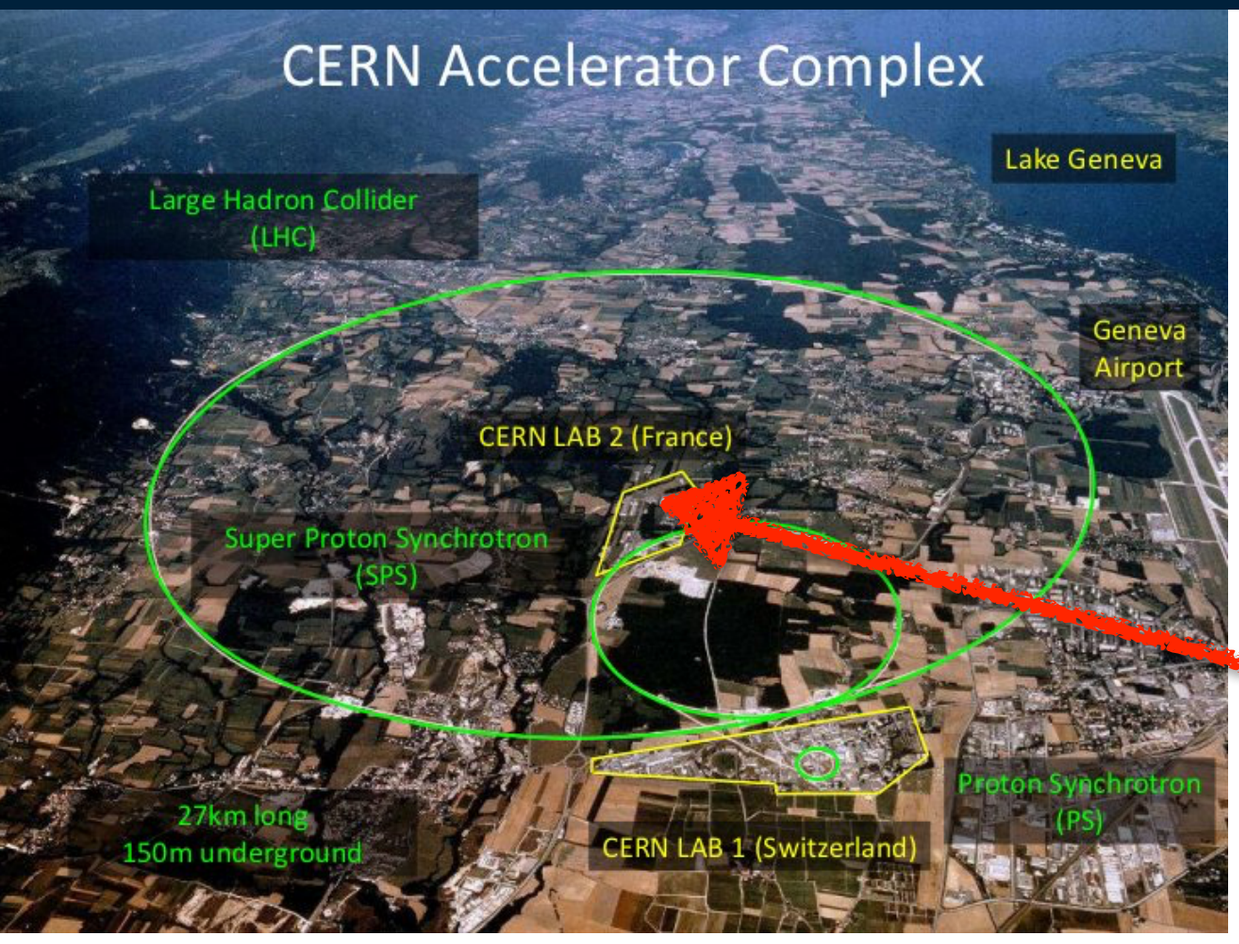

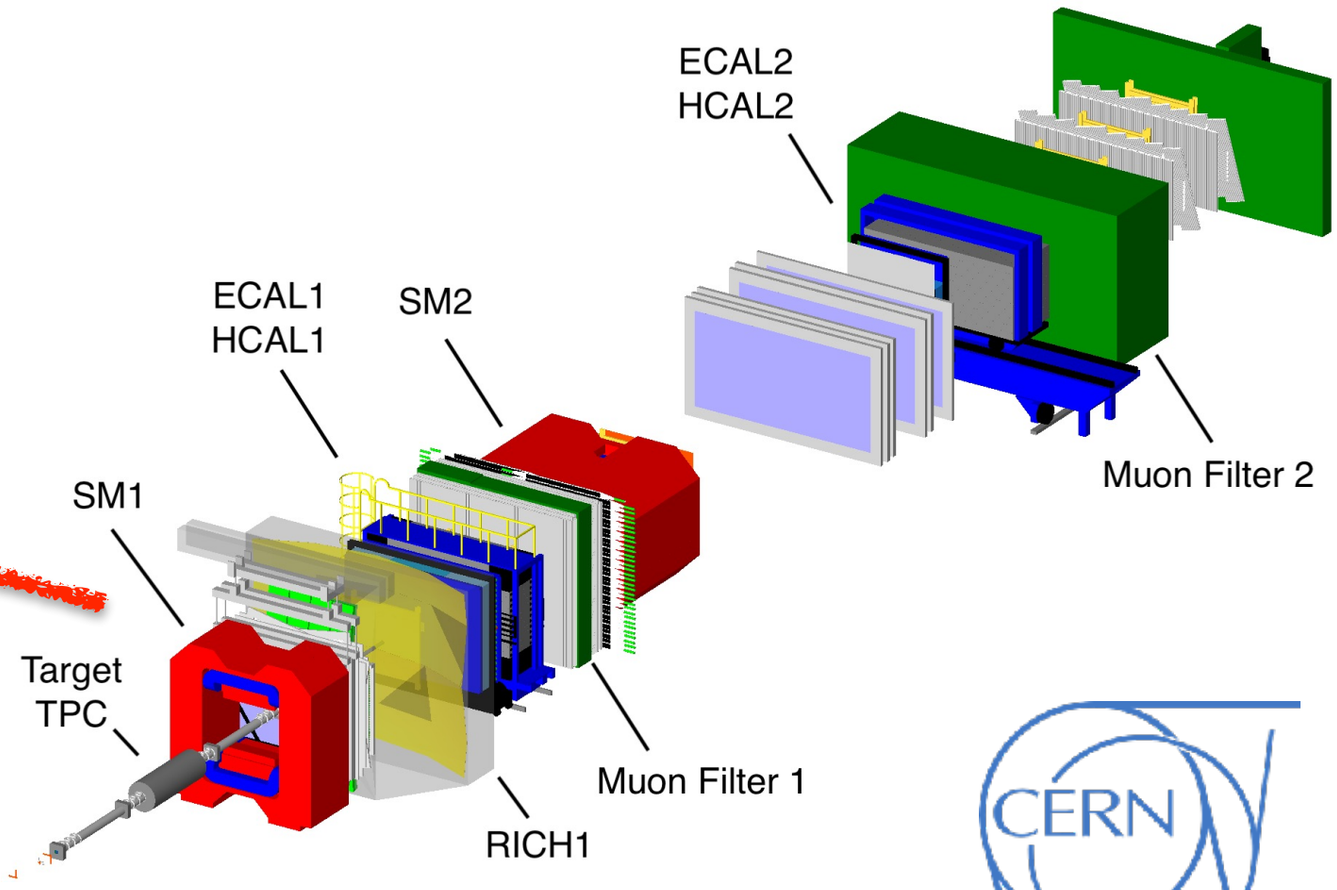

CERN

Use M2 beam in the CERN/SPS North Area
Versatile beams (muons and hadrons of both charges)
Beam momenta from 50 - 280 GeV/c
Intensity limited by radiation protection

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	Beam	Target	Additional Hardware	
Proton radius measurement	*100 GeV muons*	*high pressure Hydrogen*	*active target TPC, tracking stations (SciFi, Silicon)*	Phase 1 (approved)
Antiproton production cross section	*50 GeV - 280 GeV protons*	*LH_2, LHe*	*Liquid He target*	
Drell-Yan measurements with pions	*190 GeV charged pions*	*Carbon, Tungsten*		
Drell-Yan measurements with Kaons	*~100 GeV charged Kaons*	*Carbon, Tungsten*	*vertex detectors, 'active absorber'*	Phase 2 (in preparation)
Prompt photon measurements	*> 100 GeV charged Kaon/pion beams*	*LH_2, Nickel*	*hodoscopes*	
K-induced spectroscopy	*50 GeV - 100 GeV charged Kaons*	*LH_2*	*recoil ToF, forward PID*	

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A problem of size - proton radius

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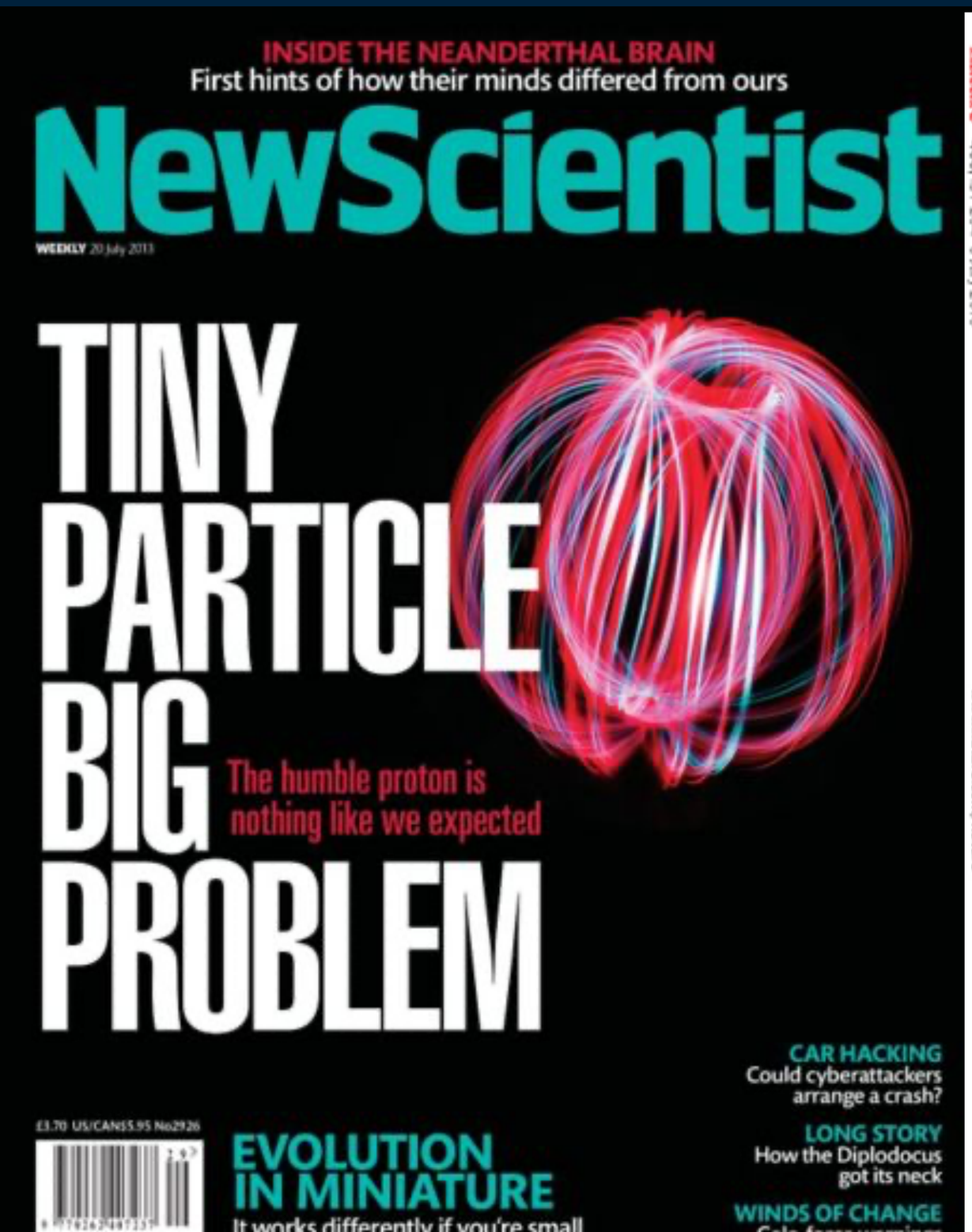

A problem of size - proton radius

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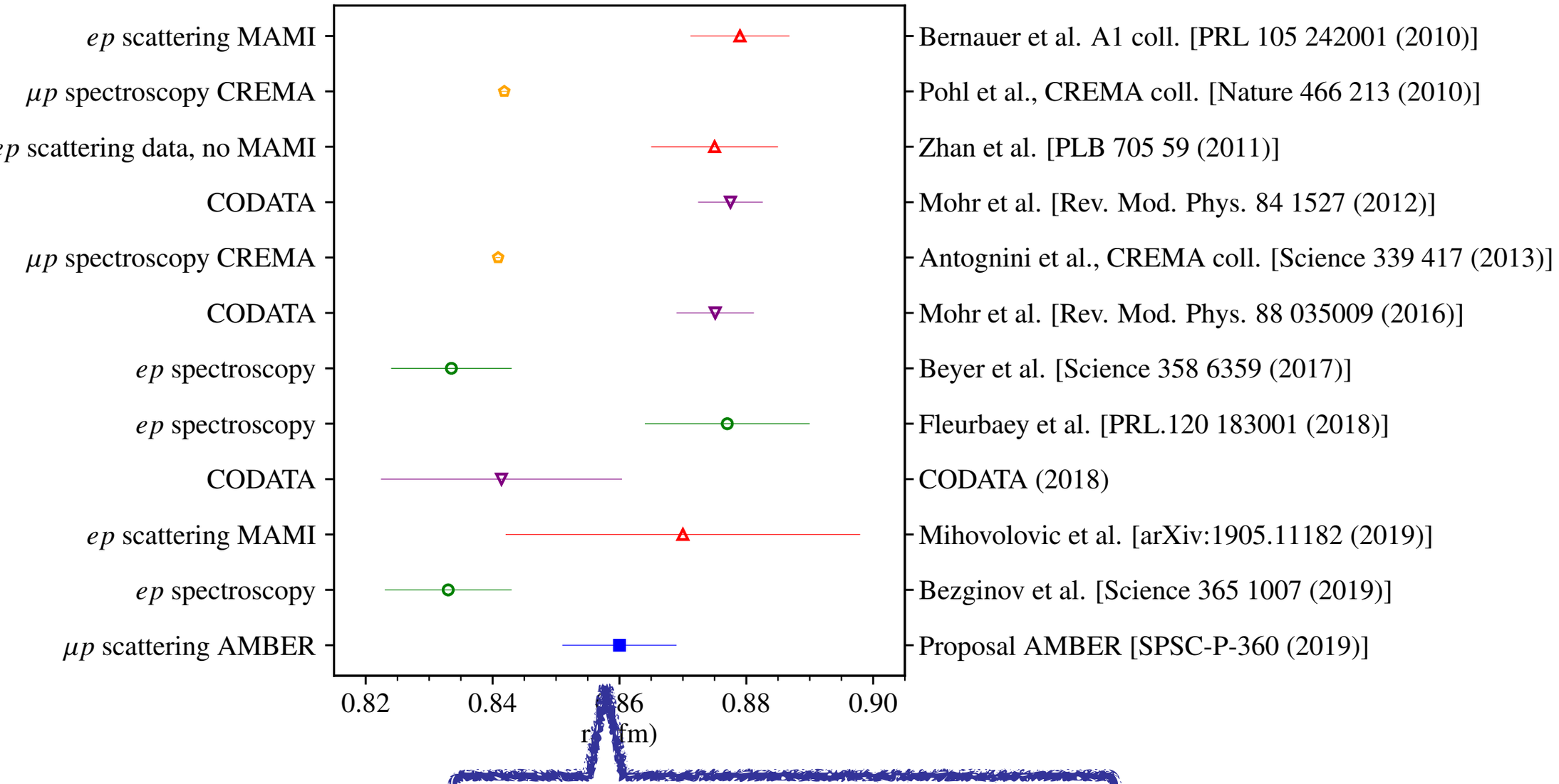

AMBER arbitrary value indicating precision

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Proton Radius Measurement

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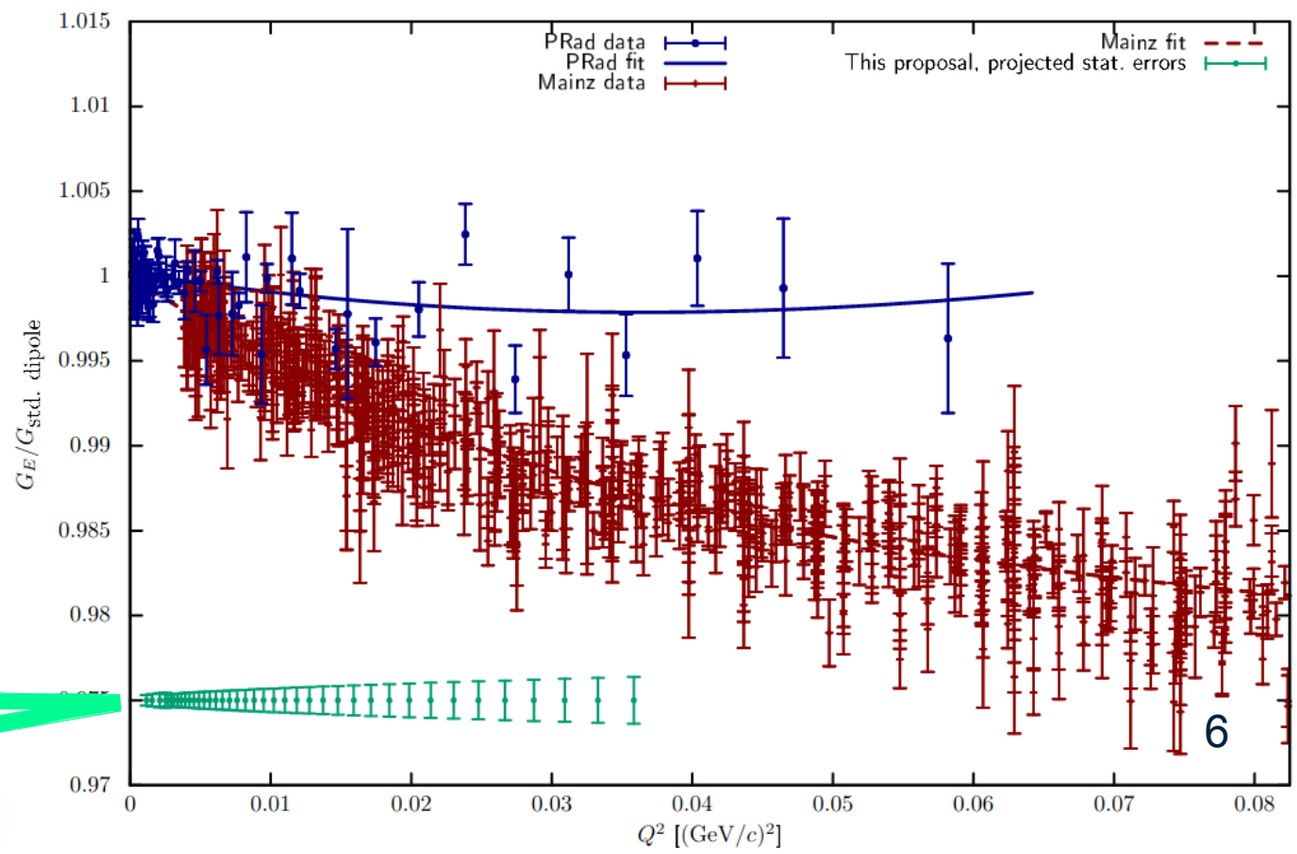
$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2}{Q^4} R \left(\epsilon G_E^2 + \tau G_M^2\right)$$

- 100 GeV muon beam
- Active-target TPC with high-pressure H_2 (20 bar)
- $10^{-3} < Q^2 < 4 \times 10^{-2}$ GeV^2
- Expected precision on the proton radius ~0.01 fm

AMBER projection



Proton Radius Measurement

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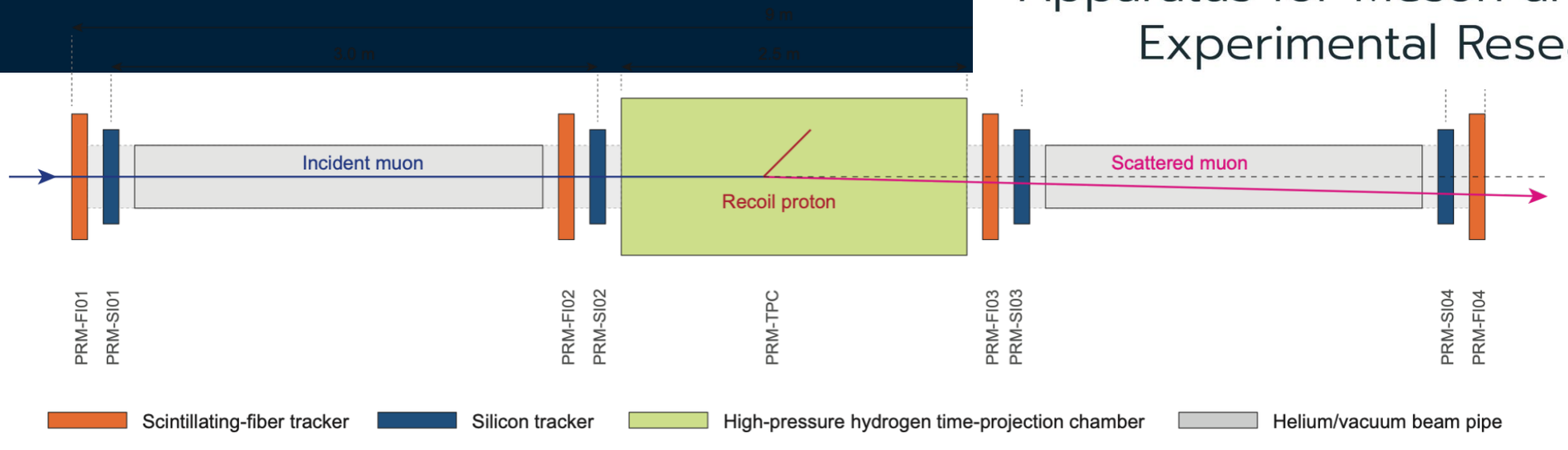

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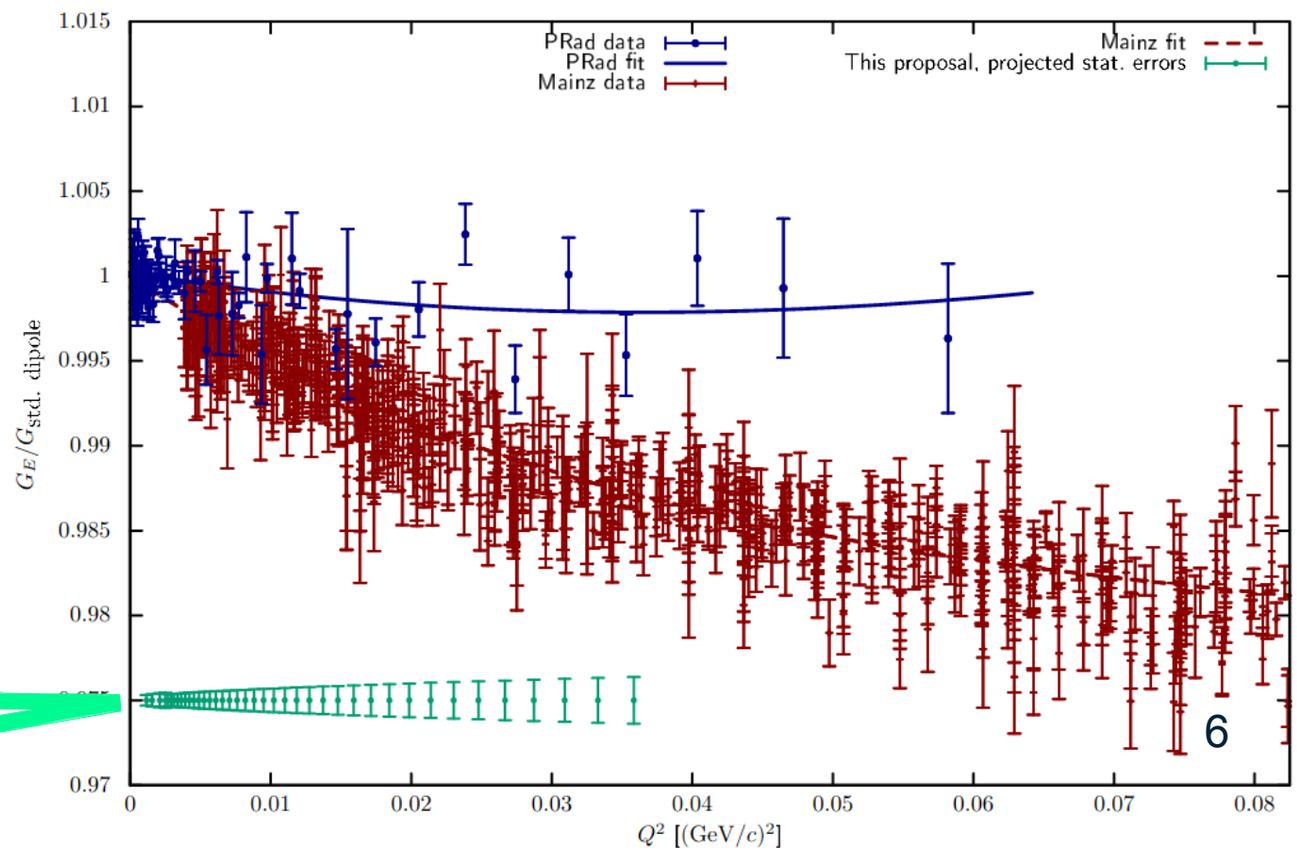

AMBER projection

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And now for something completely different

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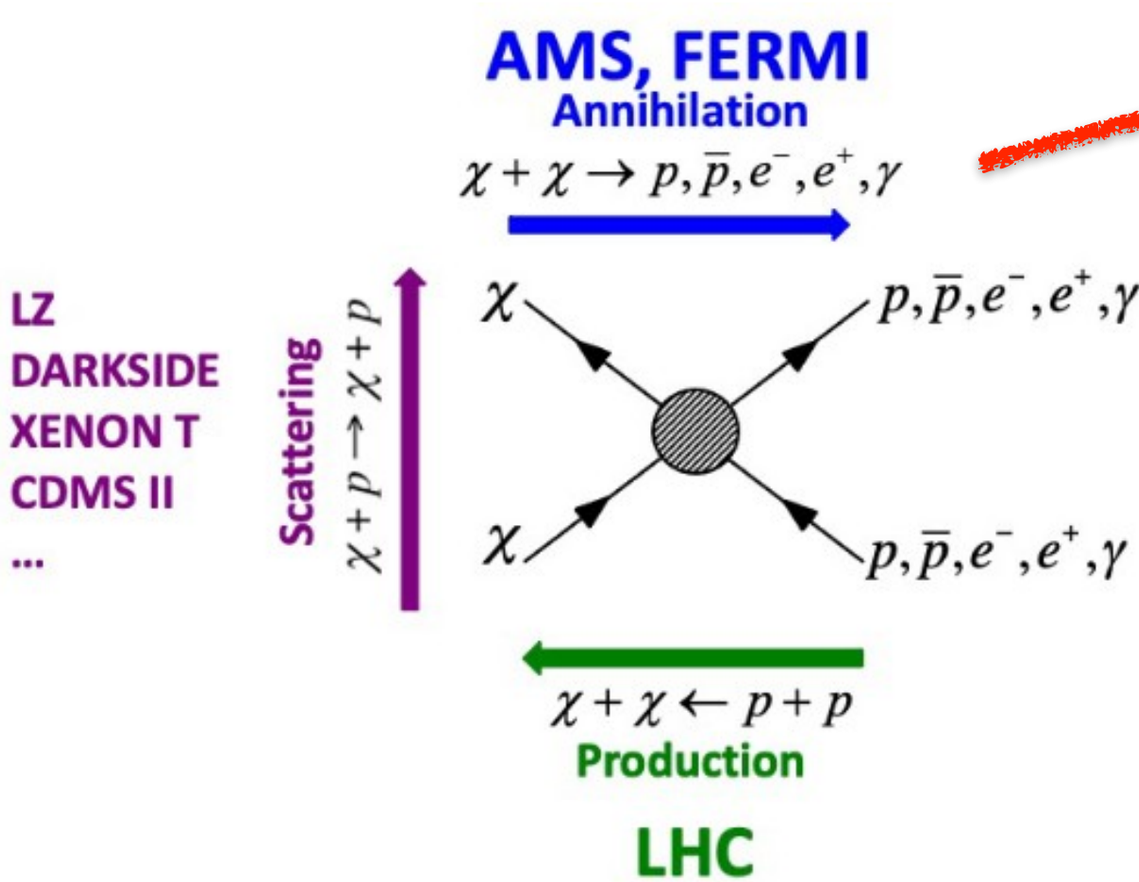

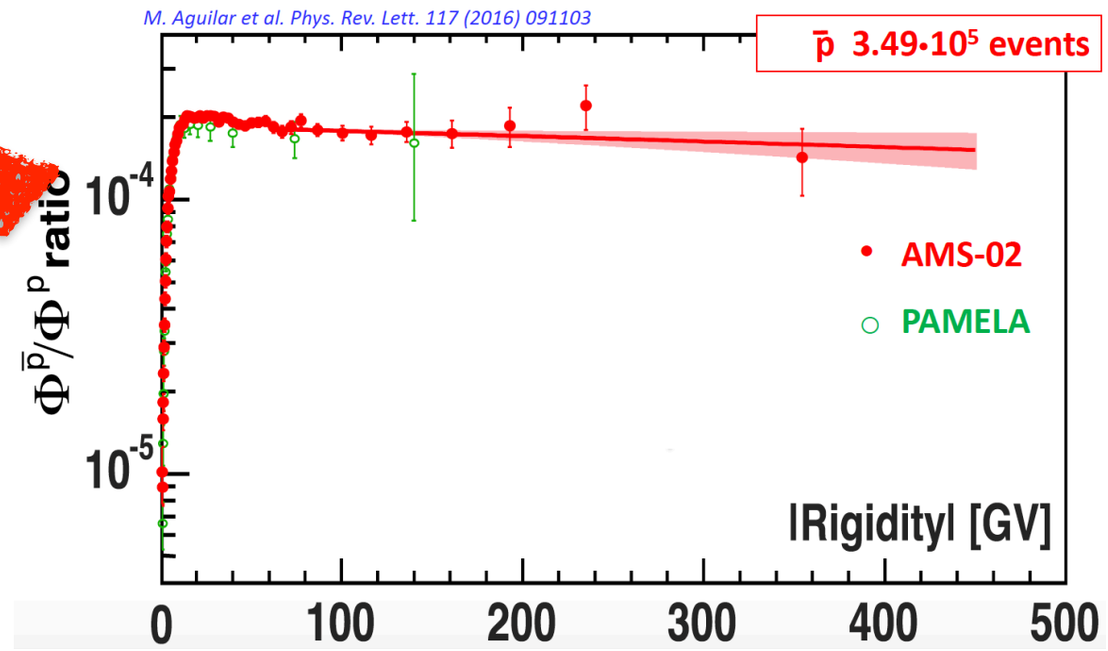

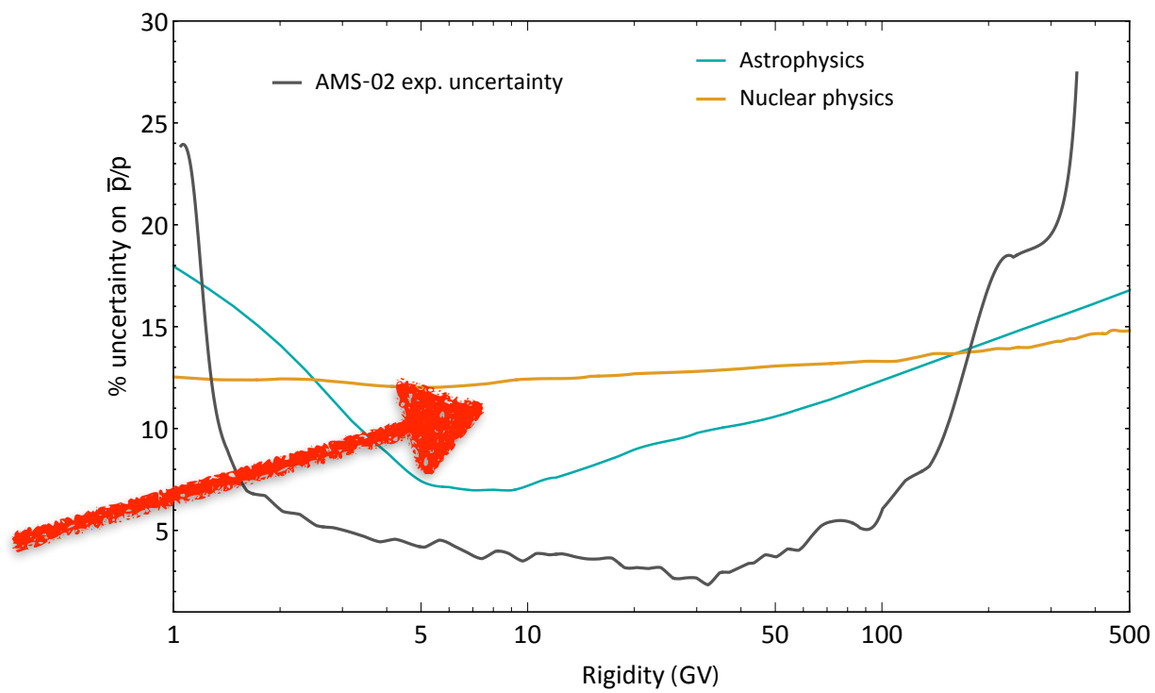

Nuclear Physics (i.e. cross sections) dominant uncertainty in region of interest

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AMBER - antiproton production

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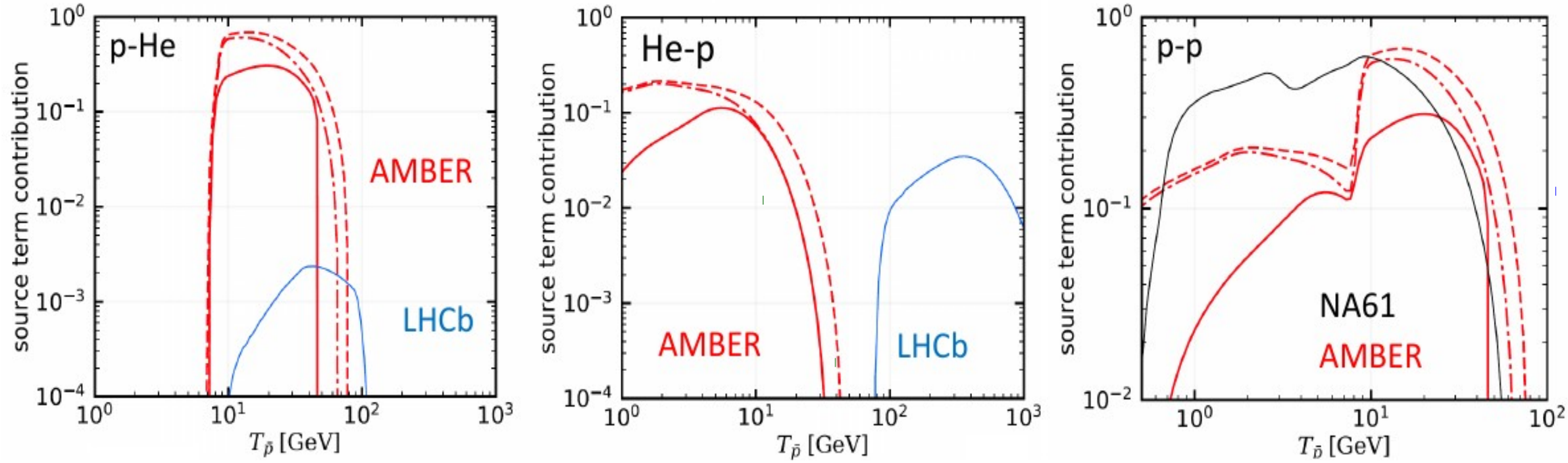

- Secondary p beam with 50, 100, 150, 200, 280 GeV
- Liquid H_2 and He target
- Minimum bias trigger allowing beam intensity of $5 \cdot 10^5$ s^{-1}
- Beam-proton ID in CEDARs, produced antiproton ID in RICH
- Measure differential cross section in 10 bins in p momentum & pseudo-rapidity $2.4 < \eta < 5.6$
- Statistical uncertainty ≈ 0.5 – 1% per data point
- Total systematic uncertainty ≈ 5% (efficiencies, dead time)

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Drell-Yan measurements

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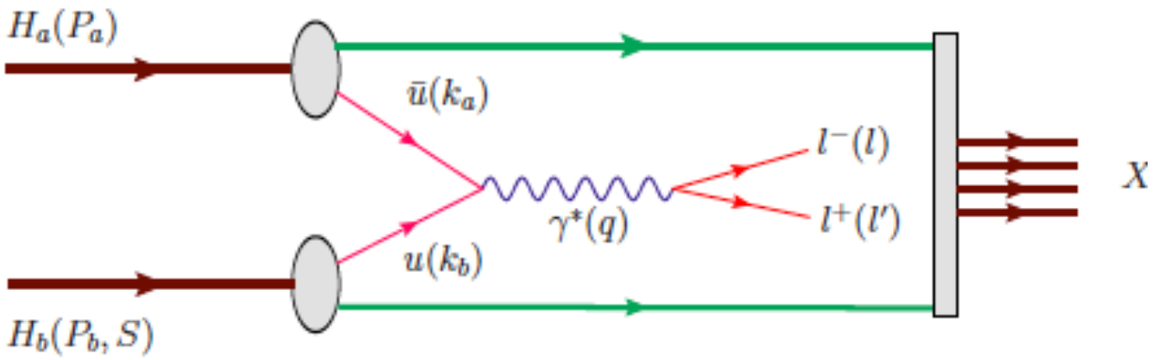
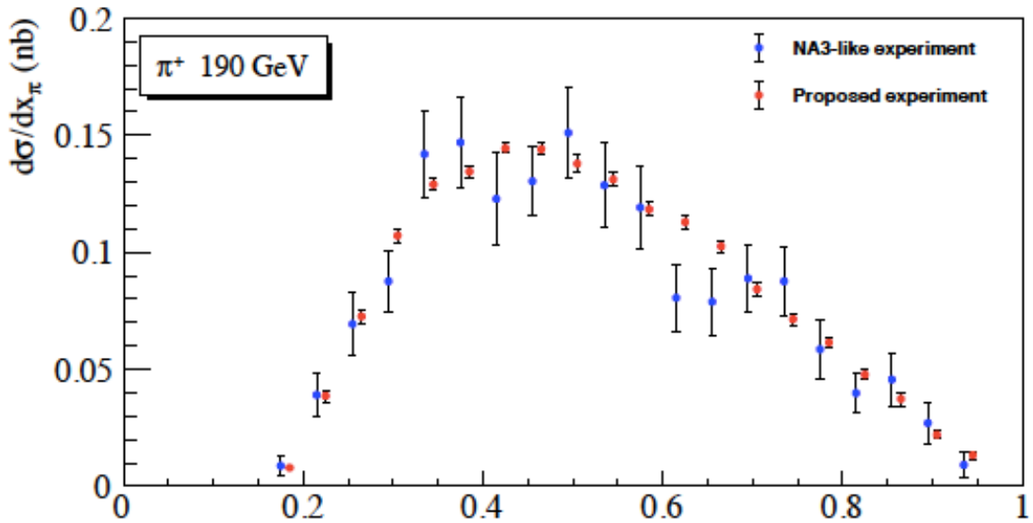
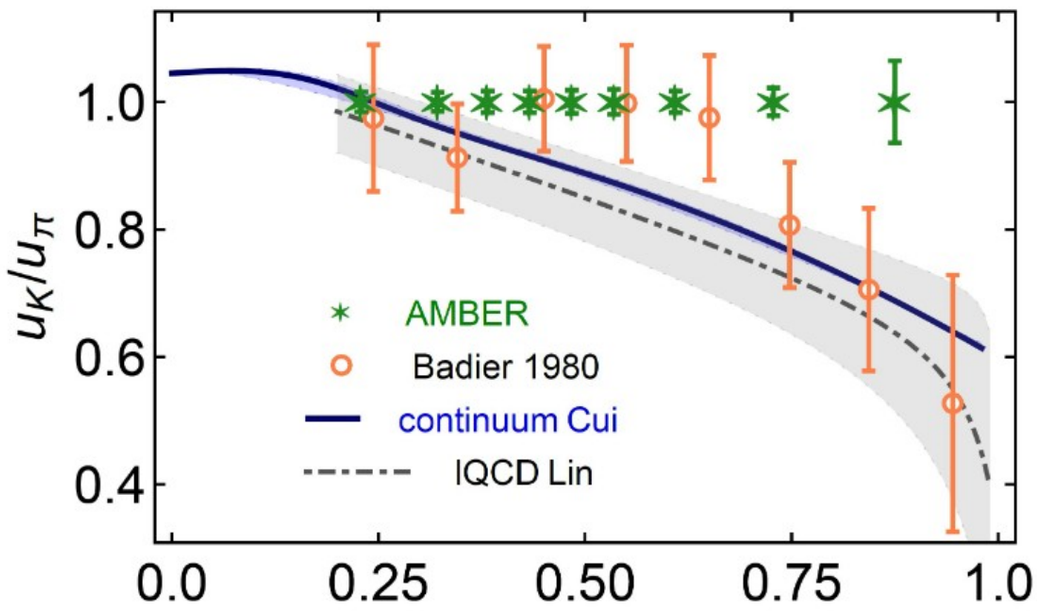




- charged K/π beams (190 GeV/c)
- inclusive measurement of lepton pair
- access to quark/gluon content of mesons
- high statistics runs

Z-F. Cui, *et al.* EPJC80(2020)1064, H-W. Lin *et al.*, PRD103(2021)014516



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Drell-Yan setup

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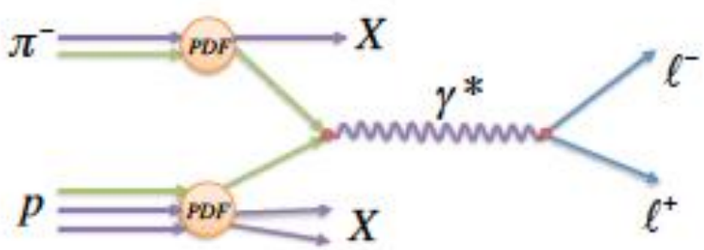
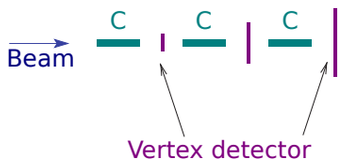
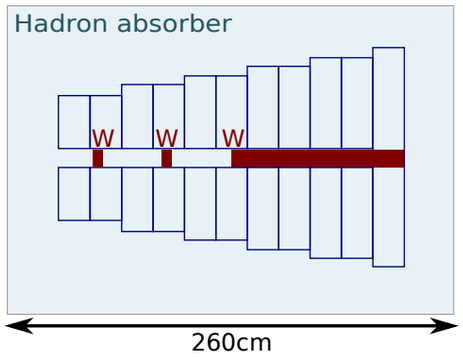


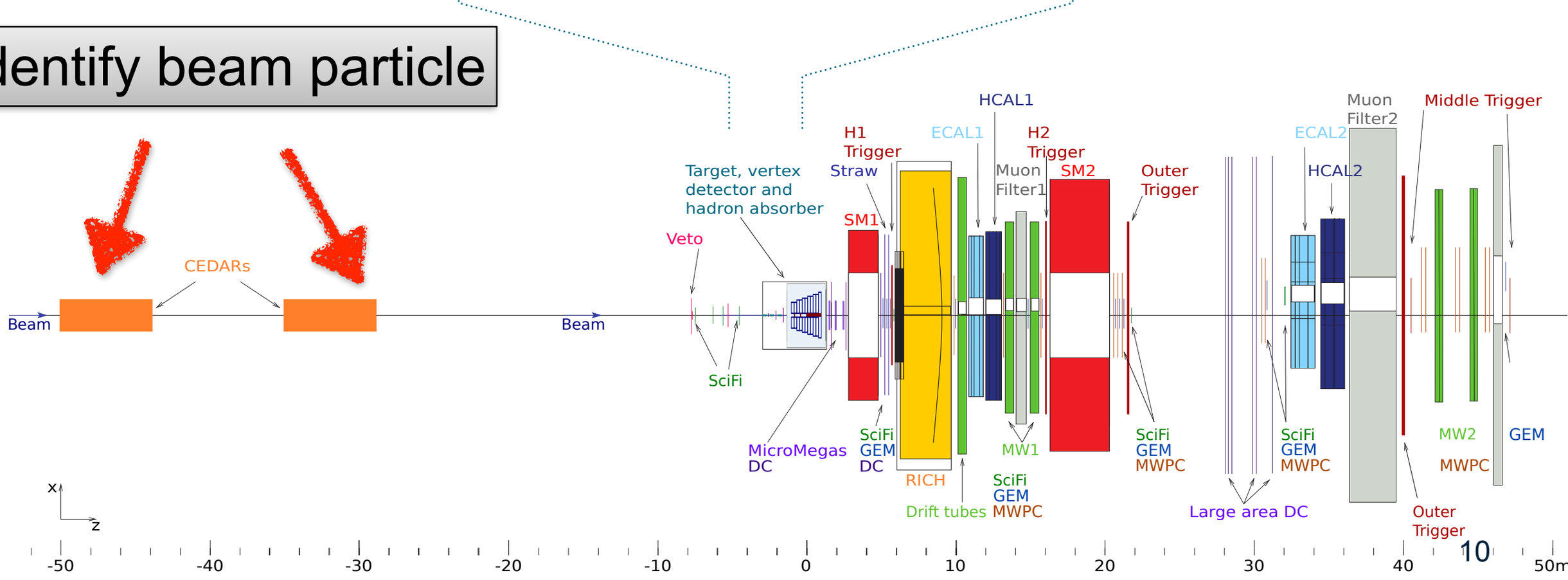




- Isoscalar target(s)
- 190 GeV/c beam

identify beam particle

2024 Drell-Yan setup



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Pion Structure

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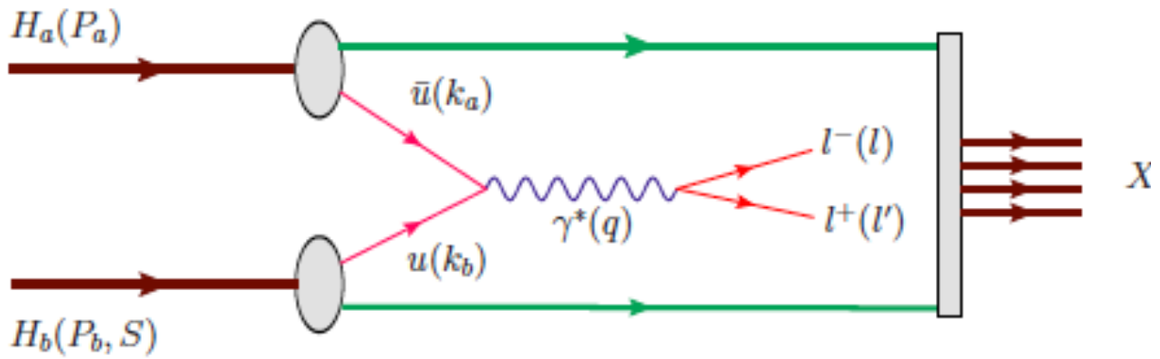
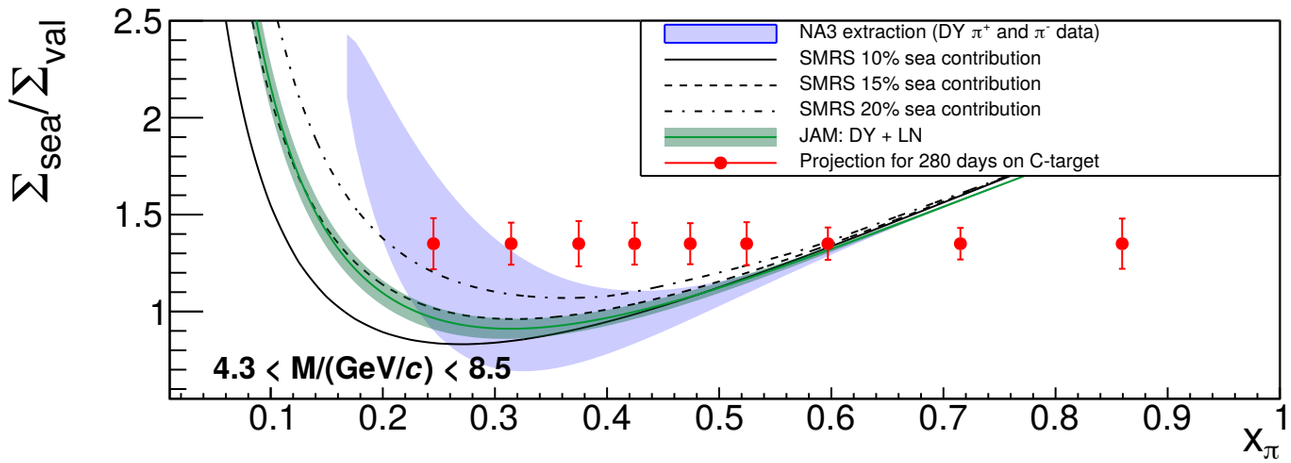
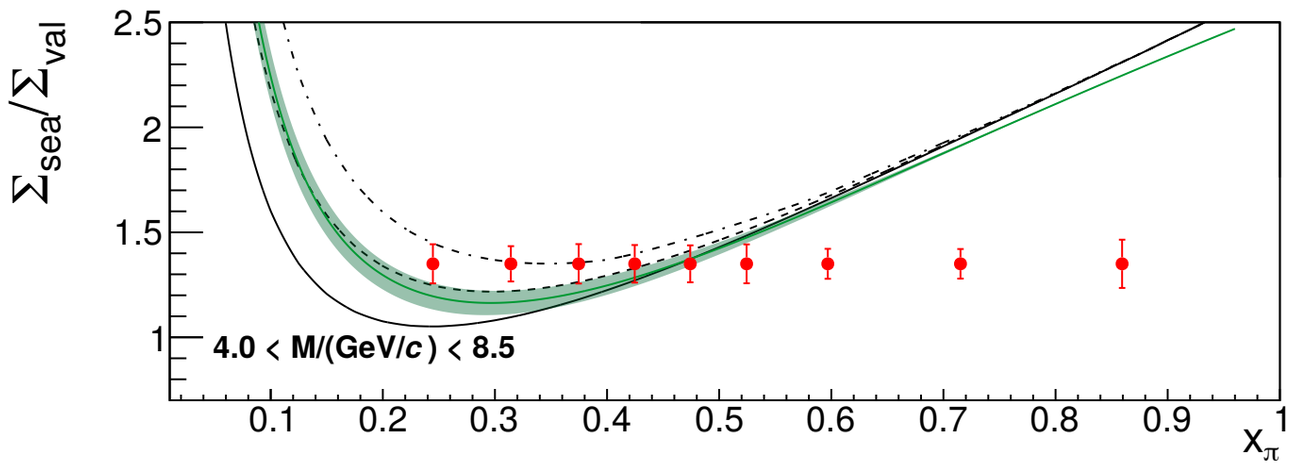


$$u^{\pi^+}_{val} = u^{\pi^+} - \bar{u}^{\pi^+} \quad d^{\pi^-}_{val} = d^{\pi^-} - \bar{d}^{\pi^-}$$

assuming isospin symmetry:

$$\frac{\Sigma_{sea}}{\Sigma_{val}} = \frac{4\sigma^{\pi^+C} - \sigma^{\pi^-C}}{-\sigma^{\pi^+C} + \sigma^{\pi^-C}}$$





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Looking to the future - AMBER phase 2

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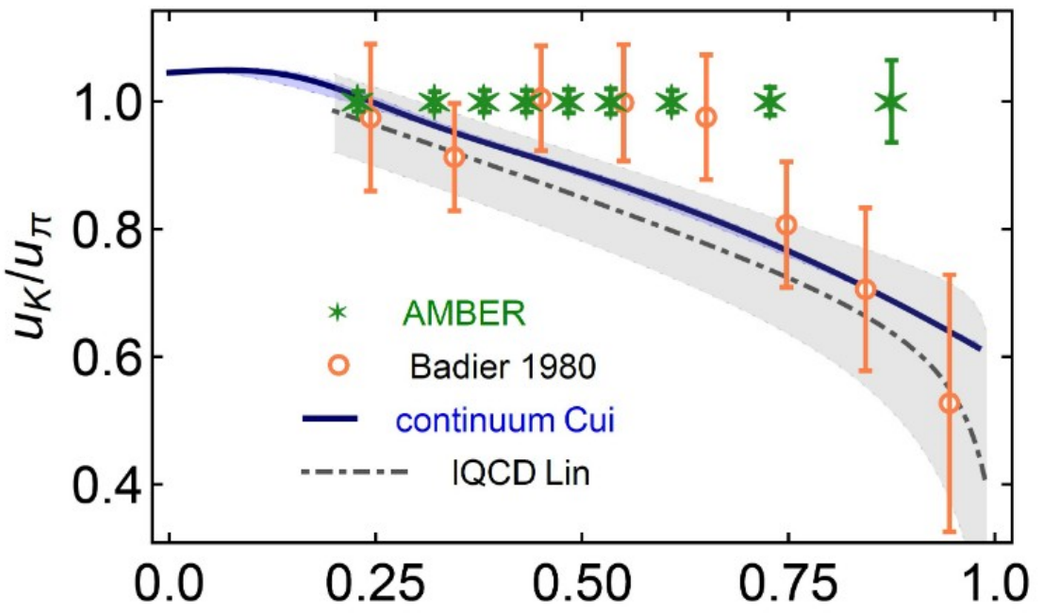
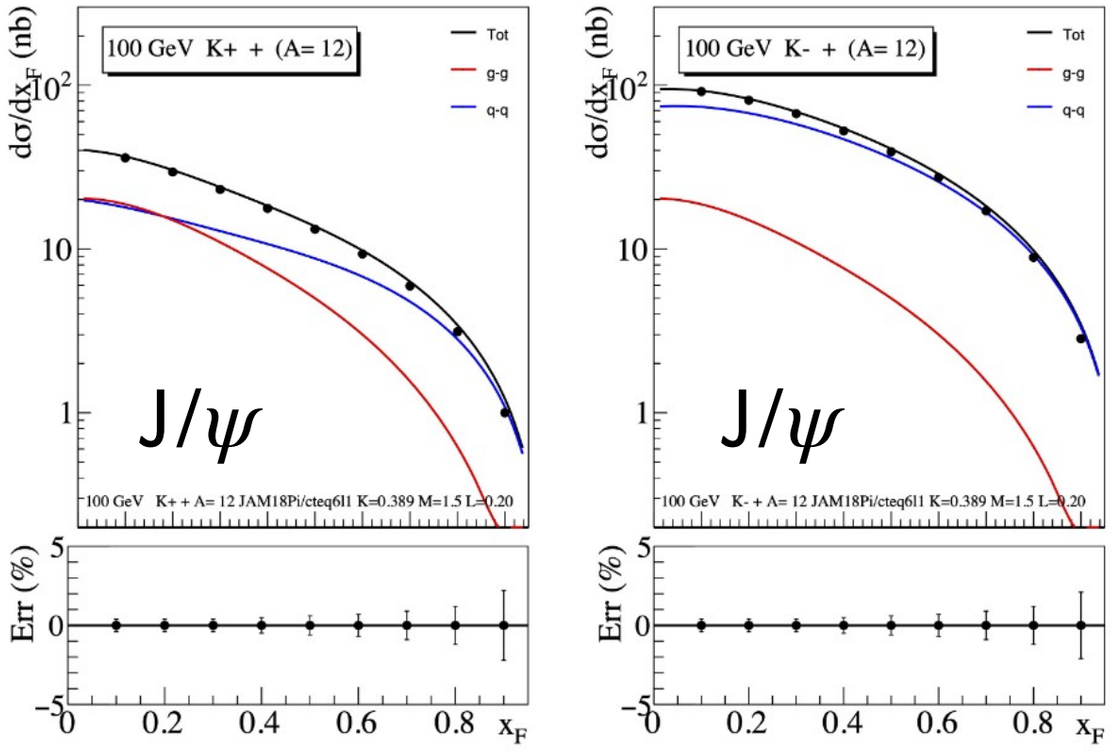
Z-F. Cui, *et al.* EPJC80(2020)1064, H-W. Lin *et al.*, PRD103(2021)014516





High purity Kaon beams are being proposed for a Phase 2 of AMBER:

- Kaon structure from Kaon-induced Drell-Yan and Charmonium production
- Gluon content in the Kaon from direct-photon production
- Light meson spectroscopy using Kaon beams
- Kaon charge radius from elastic Kaon-electron scattering

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Summary

AMBER
Apparatus for Meson and Baryon Experimental Research

- **AMBER (NA66) is a new QCD fixed target facility at CERN (Physics Beyond Colliders)**
- **Wide range of beam energies and particles**
- **Three main measurement aims in Phase 1 (approved):**
  - **Proton radius measurement with high energy muons**
  - **Anti-proton cross section measurement to constrain dark matter searches**
  - **Meson structure using Drell-Yan process (mostly pions)**
- **Extension of physics programme in Phase 2 (in preparation)**

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http://amber.web.cern.ch