AMBER
Apparatus for Meson and Baryon Experimental Research

Measurement of the reactions with light nuclei by AMBER experiment at CERN

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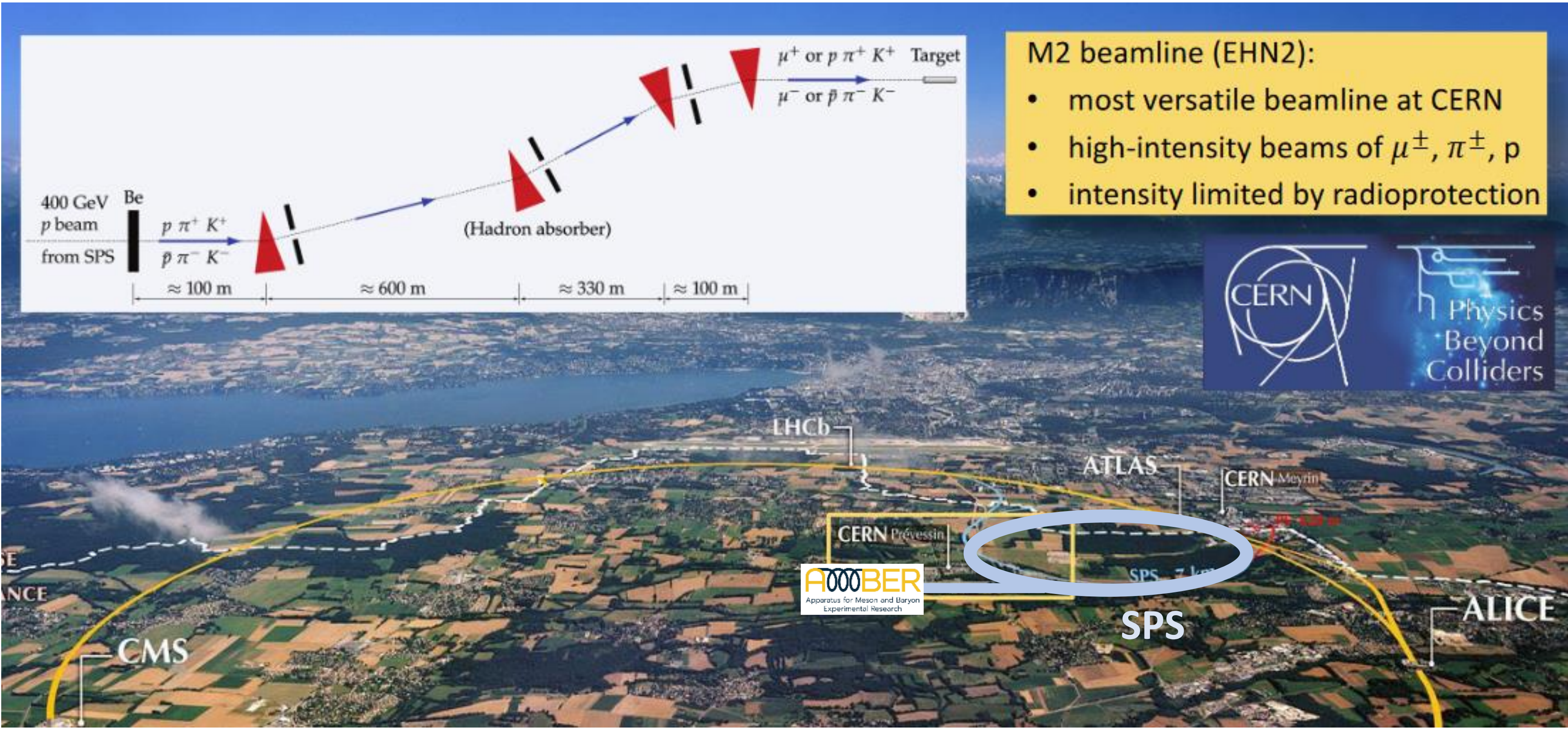
50 лет на пике науки

CERN SPS



M2 beamline (EHN2):

- most versatile beamline at CERN
- high-intensity beams of $\mu^{\pm}$, $\pi^{\pm}$, p
- intensity limited by radioprotection

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Apparatus for Meson and Baryon Experimental Research

- Successor experiment of COMPASS, but a lot of new groups
- Letter of Intent 2018: arXiv:1808.00848
- Extension and upgrade of spectrometer
- Will use both conventional and RF-separated beams
- **Phase-1** proposal (CERN-SPSC-2019-022) is approved in 2020 as NA66

Discussed today in details

	Targets
1. Measurement of proton charge radius	*p*
2. Antiproton production XS measurement for Dark Matter searches	He
3. Drell-Yan and J/ψ production using conventional M2 beam	C

- **Phase-2** proposal is planned to be submitted in 2022
    - Kaon and meson gluon parton distribution functions
    - Strange sector spectroscopy using RF-separated beams
    - Meson charge radii

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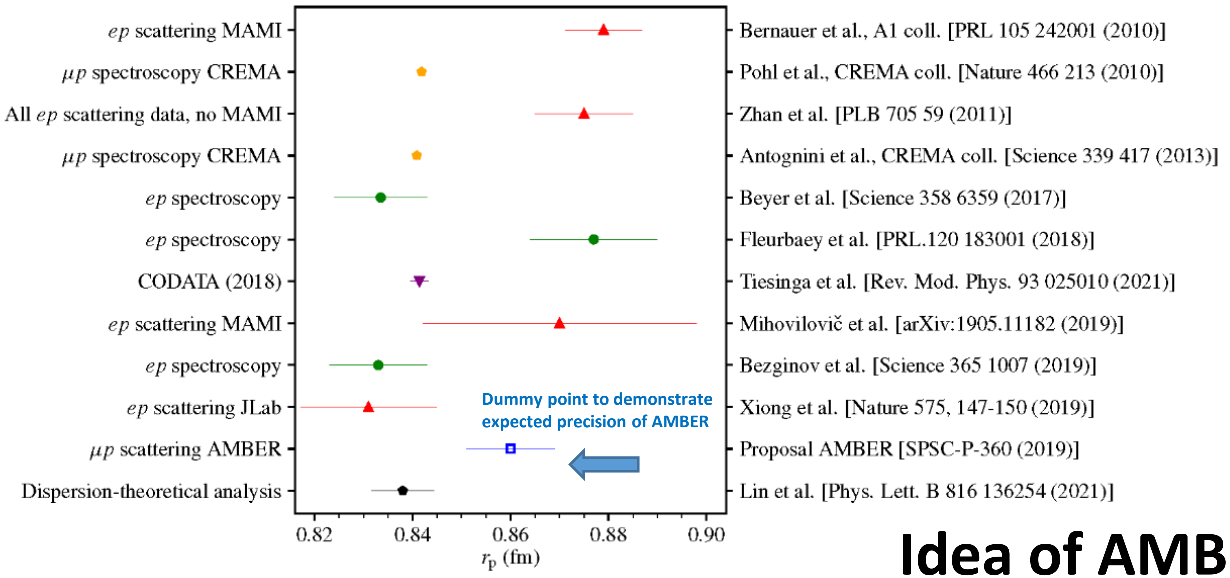
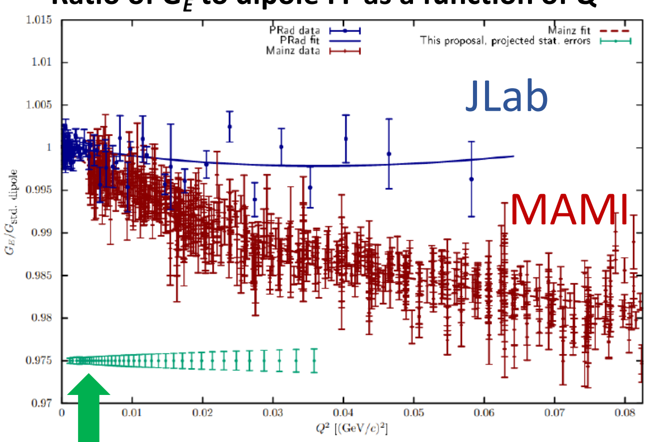
Topic 1: Addressing proton radius puzzle



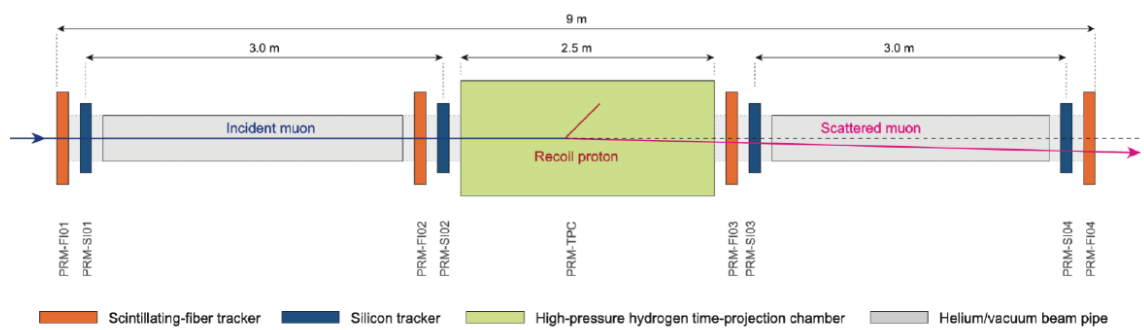
- μp scattering is different leptonic probe, which is not measured yet
- It provides different systematics, as well as low radiative corrections (wrt. *ep* case)

Idea of AMBER measurement

Ratio of G_E to dipole FF as a function of Q^2



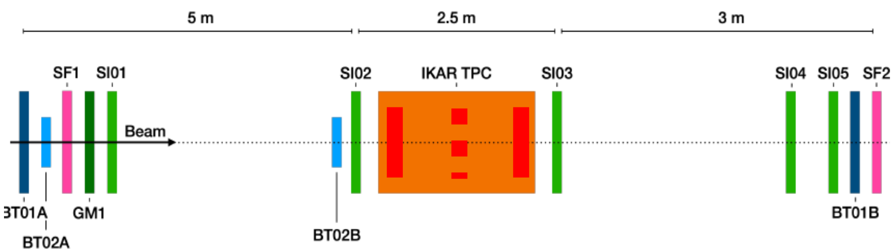
Expected precision of AMBER

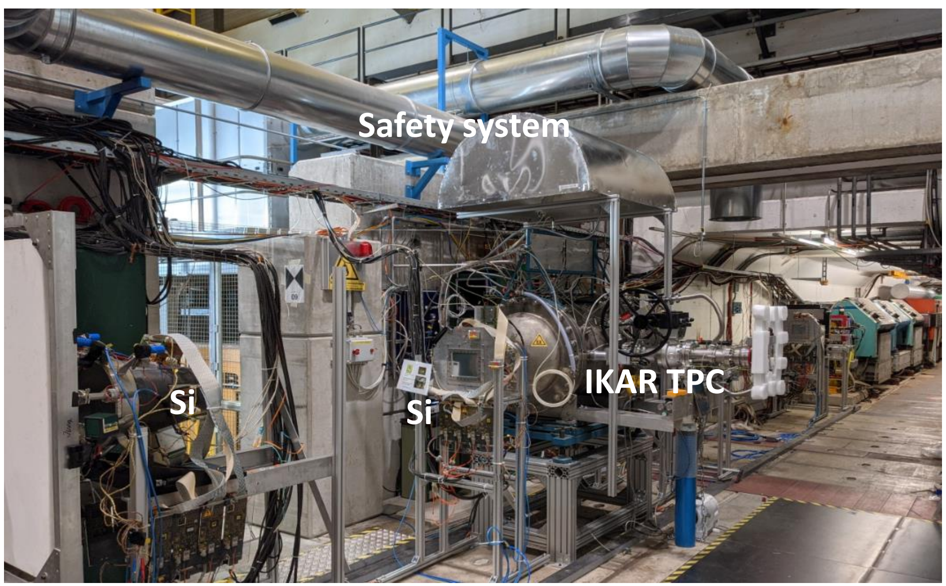


100 GeV muons; 20 bar H_2 TPC as active target

$10^{-3} < Q^2 < 4 \times 10^{-2}$ GeV^2

Pilot run in 2021 to prove the idea

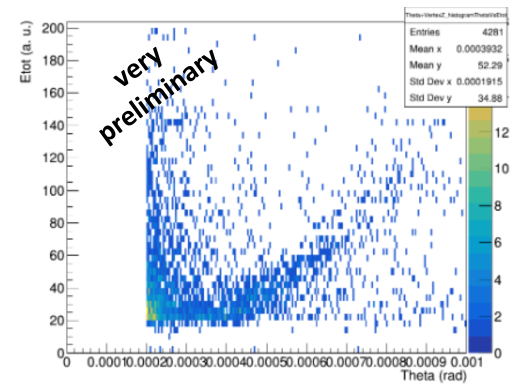




Many successful tests. Among them:

- high-pressure (8 bar) 2-cell TPC prototype (IKAR) with high-intensity μ beam: beam noise, p/T effects, new anode structure
- muon momentum reconstruction (only SM2)
- target tracking system (Silicon strip + SciFi) / match muon and recoil proton tracks

Recoil energy from IKAR TPC



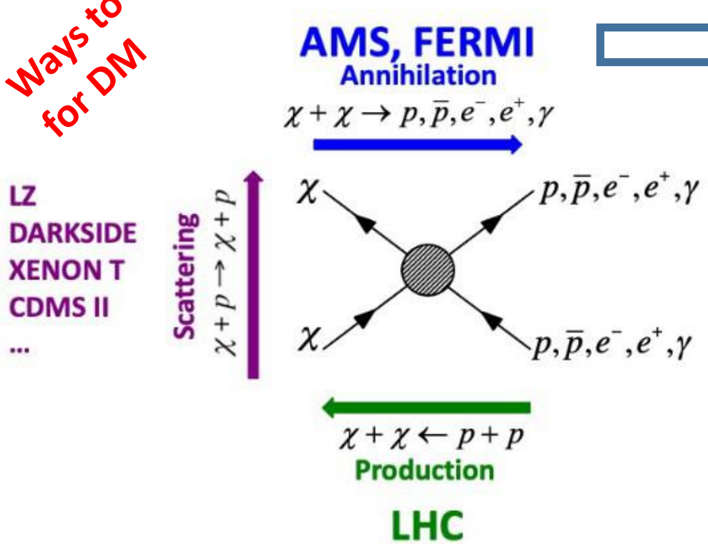
Angle reconstructed by tracker

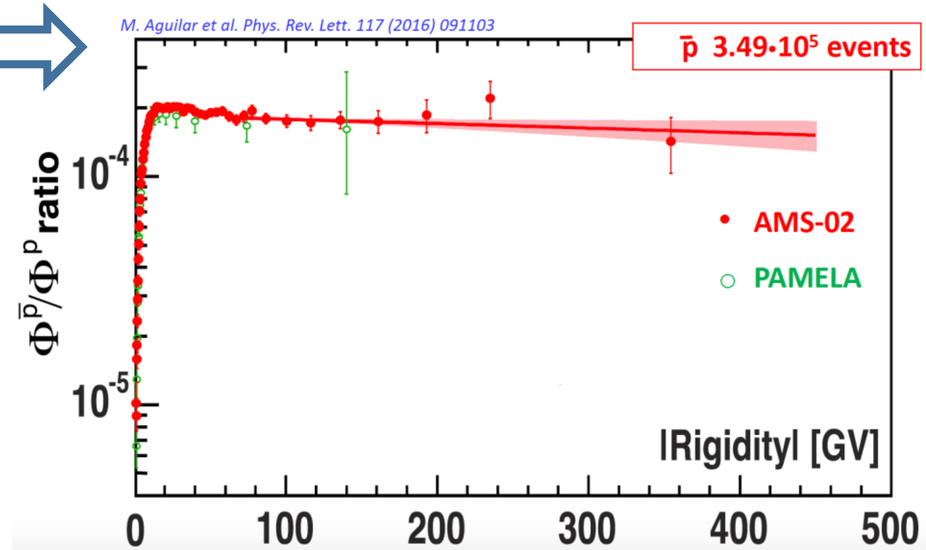
Next steps:

- Production of 20 bar TPC
- Final tests with ALPIDE + SciFi tracker
- Measurements in 2023-24

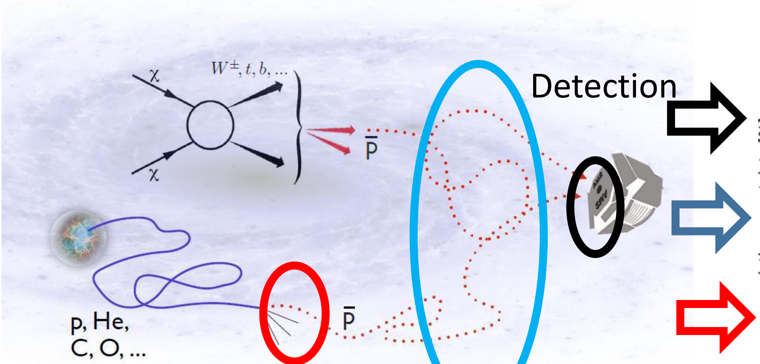
Topic 2: antiproton production cross section

Ways to search for DM



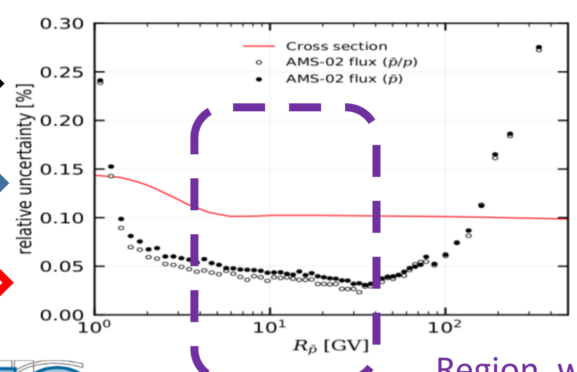


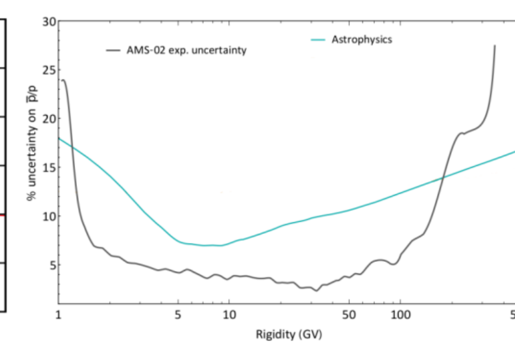
Uncertainty budget



Cross section

Propagation





Region, where XS uncertainty dominates

Plot by M. Korsmeier

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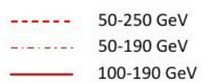
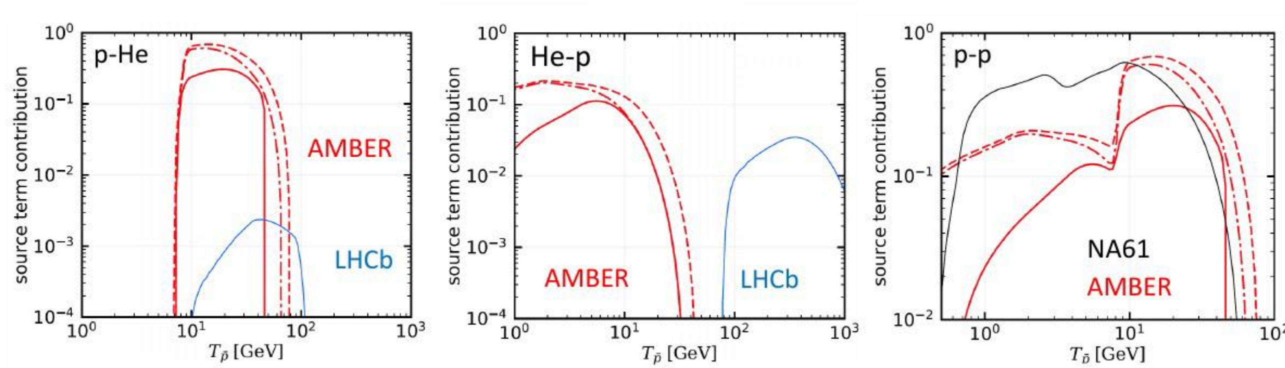
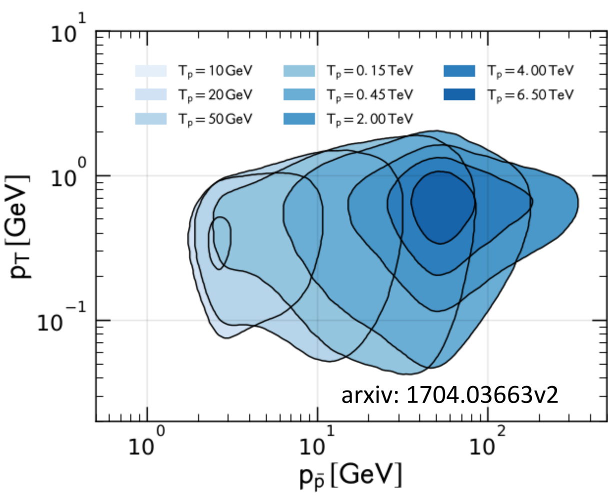
Antiproton production at AMBER

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







- **Parameter space for the pHe channel corresponding to an exemplary fixed target experiment.**
- **3% relative uncertainty within the blue regions (30% outside)**

- 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, antiproton ID in RICH
- Measure differential cross section in 10 bins in p_p & η
- $2.4 < \eta < 5.6$
- Statistical uncertainty ≈ 0.5 – 1% per data point
- Total systematic uncertainty ≈ 5% (efficiencies, dead time)

- AMBER pilot run for antiproton production measurements is scheduled in the end of 2022

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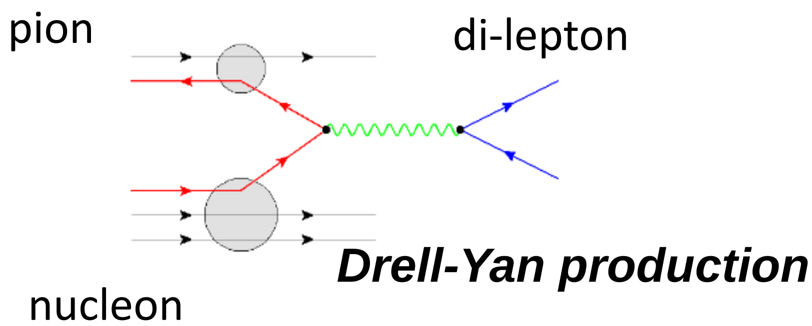
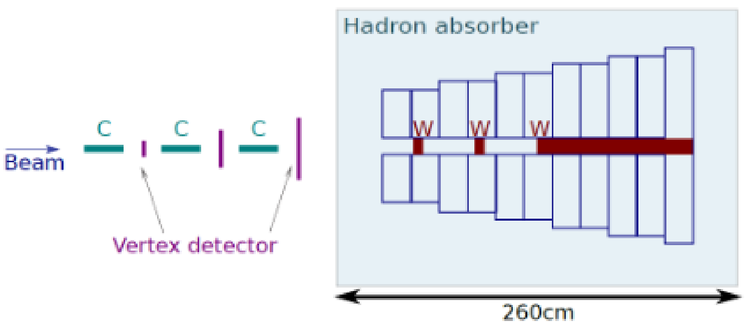
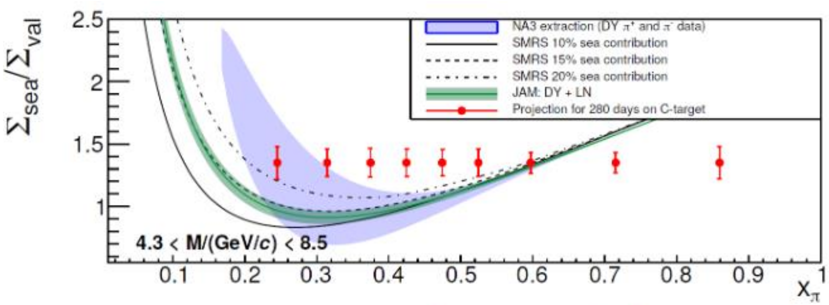
<u>Topic3:</u> Pion PDFs at AMBER (*via* DY)







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

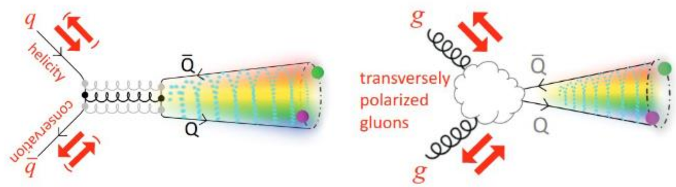
- Isoscalar target (^{12}C) to minimize nuclear effects
- Beams of positively and negatively charged pions to separate valence and sea contribution:

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

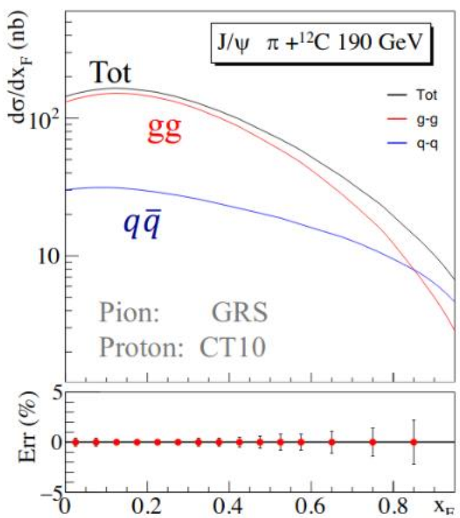
- 250k DY events expected (current available statistics 25k events)
- First precise and direct measurement of the sea quark distribution in the pion

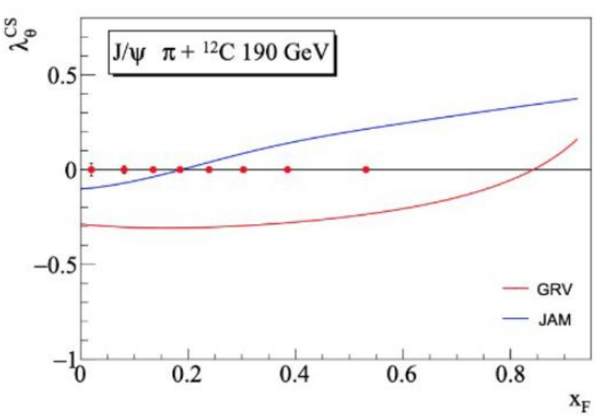
- 190 GeV pion beam
- Target / vertex detector / hadron absorber
- Radiation protection
- Di-muon mass resolution of 100 MeV

Possible mechanisms



Strong dependence on pion PDFs





J/ψ production

- Large statistics on J/ψ production at dimuon channel (30-50 times wrt. DY)
- Inclusive measurements: due to the hadron absorber prompt production from the rest can't be separated
- Expected significant feed-down: $\psi(2S)$, χ_{c1}, χ_{c2}
- Expected to have dominant contribution from 2→1 processes
- Use J/ψ polarization to distinguish production mechanism (polarization is sensitive to relative contributions of quark- and gluon-induced productions)
  - Angular distribution $$\frac{d\sigma}{d\cos\theta} \propto 1 + \lambda \cos^2\theta$$
    - $\lambda = +1 \Leftrightarrow J_z = \pm 1$ $\quad q\bar{q} \to J/\psi$
    - $\lambda = 0$ ⇔ unpolarized
    - $\lambda = -1 \Leftrightarrow J_z = 0$ $\quad gg \to J/\psi$

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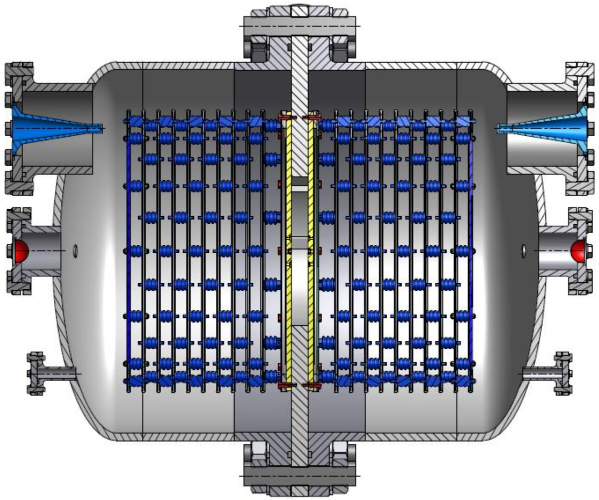
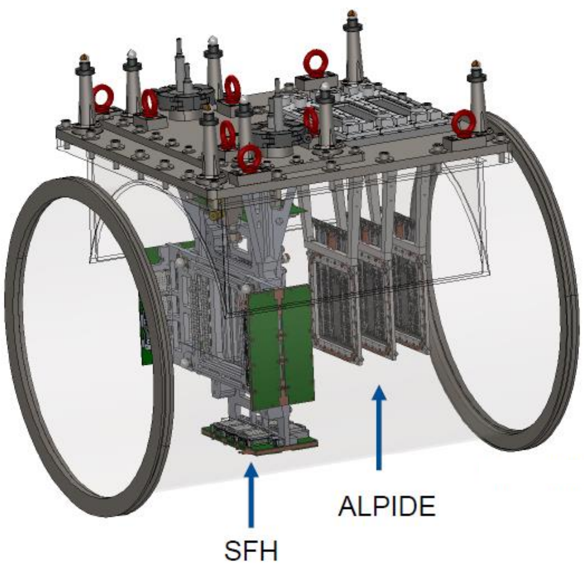
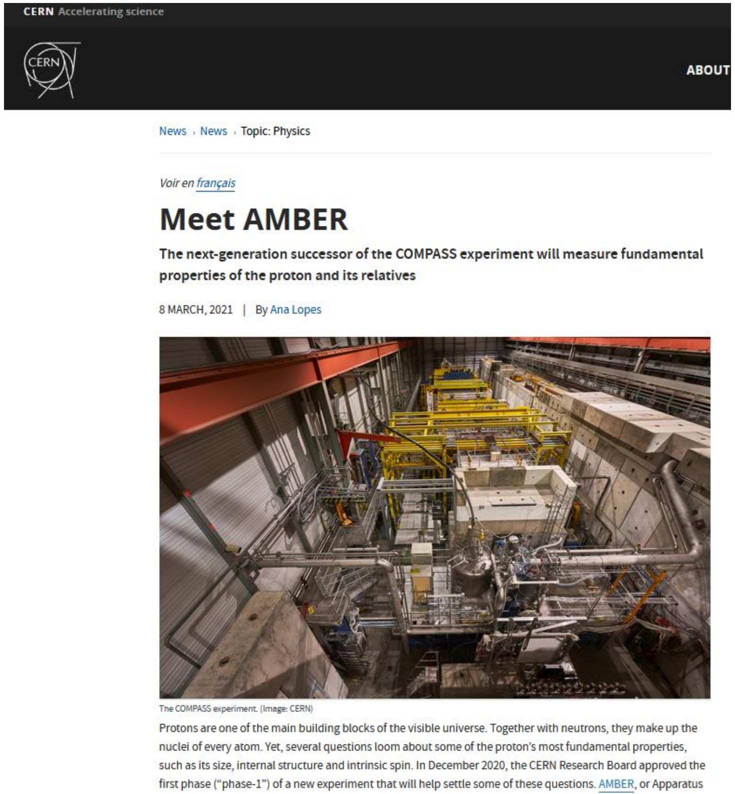
New equipment for AMBER Phase-1





- High-pressure hydrogen TPC
- SciFi/Silicon Pixel tracking stations
- C/W, LH2, LHe target
- DY vertex detector
- Large-area MPGD detectors with self-triggering readout
- Self-triggered electronics for ECAL
- Upgrade CEDAR electronics for high rates
- Triggerless DAQ and HLT


CERN Accelerating science

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Voir en français

Meet AMBER

The next-generation successor of the COMPASS experiment will measure fundamental properties of the proton and its relatives

8 MARCH, 2021 | By Ana Lopes

The COMPASS experiment. (Image: CERN)

Protons are one of the main building blocks of the visible universe. Together with neutrons, they make up the nuclei of every atom. Yet, several questions loom about some of the proton's most fundamental properties, such as its size, internal structure and intrinsic spin. In December 2020, the CERN Research Board approved the first phase ("phase-1") of a new experiment that will help settle some of these questions. AMBER, or Apparatus

https://home.cern/news/news/physics/meet-amber

Summary

NA66/AMBER is a new experiment at CERN dedicated to study fundamental questions related to the emergence of hadron properties from QCD

Phase-1 approved by CERN

- Proton radius with high-intensity muon beam
- Pion PDFs in Drell-Yan processes
- Antiproton-production cross sections for DM searches

Phase-2 being studied in the framework of Physics Beyond Colliders at CERN

- Kaon and meson gluon PDFs
- Strange spectroscopy
- Meson charge radii
- Unique RF-separated beams to M2