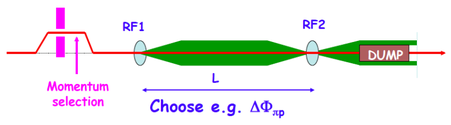
Measurement of antiproton production cross sections for dark matter search @AMBER (CERN)

Davide Giordano on behalf of the AMBER collaboration

AMBER Collaboration:
> 200 members,
41 participating institute, 14 countries.

AMBER
Apparatus for Meson and Baryon Experimental Research



$\Delta\Phi = 2\pi\ (L\ f\ /\ c)\ (\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$

RF- separated beam

Conventional muon/hadron M2 beams

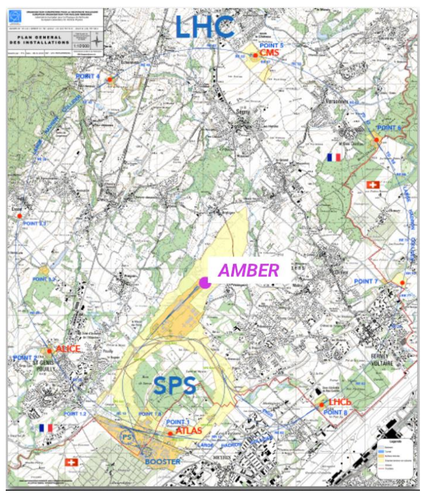
Run 3 → Run 4

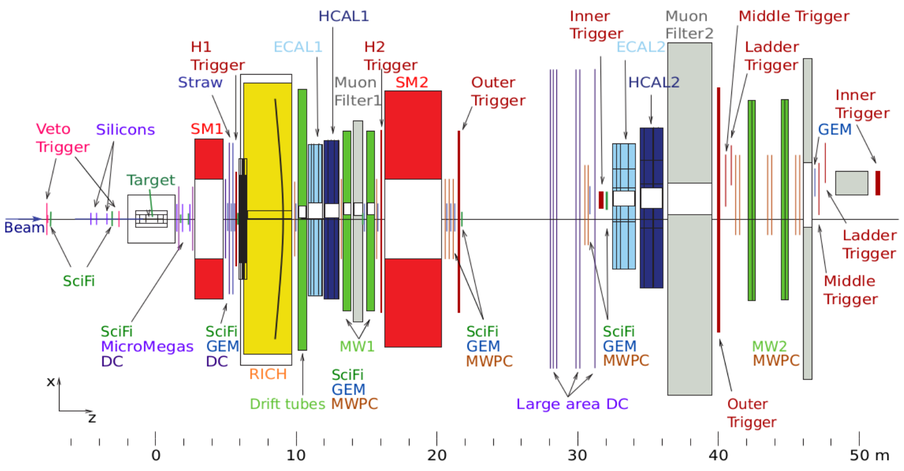
Phase-1 ✓

Proton Radius Measurement
Antiproton production cross section
Pion structure (PDFs) via DY and charmonia

Phase-2

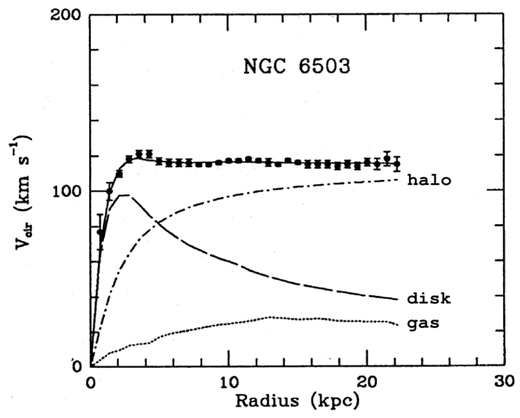
Kaon and pion structure
High precision strange-meson spectrum
Kaon and pion charge radii
Kaon induced Primakoff reaction





Phase-1: Proposal approved by RB on 02/12/2020 Phase-2 Proposal submission in 2022

DARK MATTER



M. KAMIONKOWSKI, WIMP AND AXION DARK MATTER, CU-TP-866, CAL648, hep-ph/9710467

Rotation curve for the spiral galaxy NGC6503

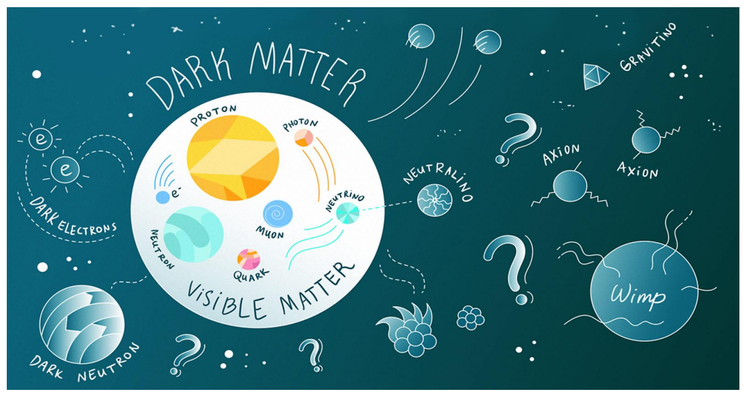
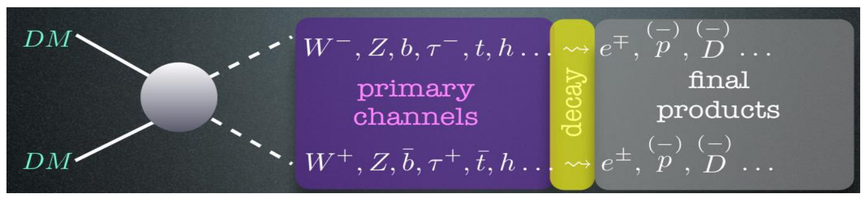


Illustration by Sandbox Studio, Chicago with Ana Kova. https://www.symmetrymagazine.org/article/december-2013/four-things-you-might-not-know-about-dark-matter

WIMP: dark matter particle candidate interacts with ordinary matter through weak-interaction



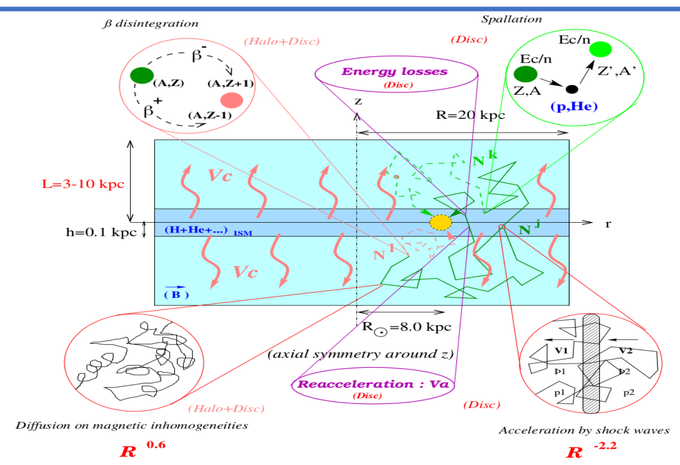
Indirect detection: search of products of DM annihilation or decay as excesses in the spectra of rare cosmic ray (CR) components like positrons, antiprotons.

Most of antiprotons at Earth are secondaries.
Necessity to better validate models: need of higher accuracy of the predicted flux

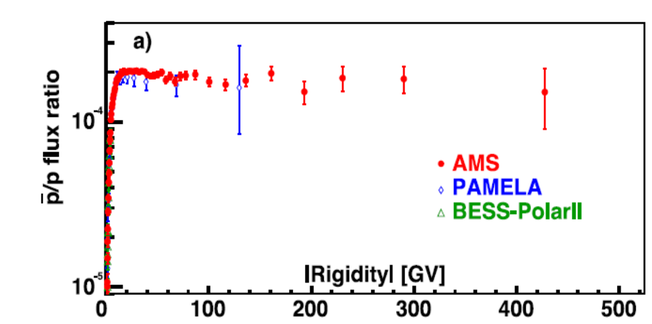
CR PROPAGATION EQUATION – SOURCE TERM

$$\frac{\partial\psi(\vec{r},p,t)}{\partial t} = q(\vec{r},p,t) + \vec{\nabla}\cdot(D_{xx}\vec{\nabla}\psi - \vec{V}\psi) + \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{1}{p^2}\psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\vec{\nabla}\cdot\vec{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

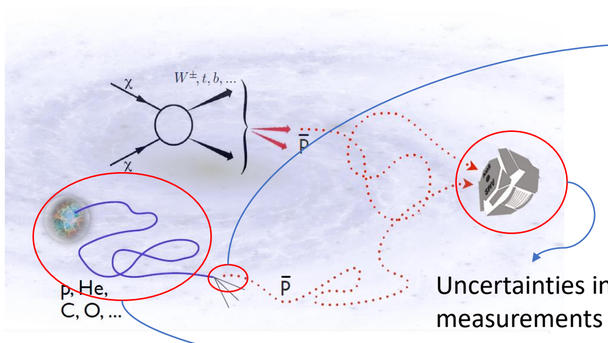
$$q_{ij}(T_{\bar{p}}) = \int_{T_{\rm th}}^{\infty} dT_i\ 4\pi\ n_{{\rm ISM},j}\ \phi_i(T_i)\ \frac{d\sigma_{ij}}{dT_{\bar{p}}}(T_i, T_{\bar{p}})$$



Maurin D. et al. Galactic Cosmic Ray Nuclei as a Tool for Astroparticle Physics, arXiv:astro-ph/0212111

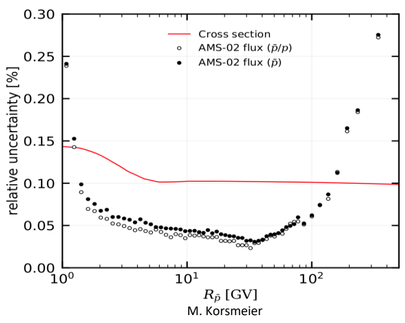


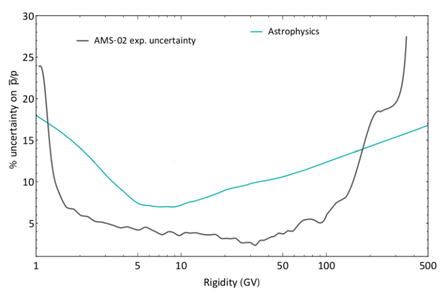
AMS collaboration, Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station, PRL 117, 091103 (2016)



Uncertainties in measurements

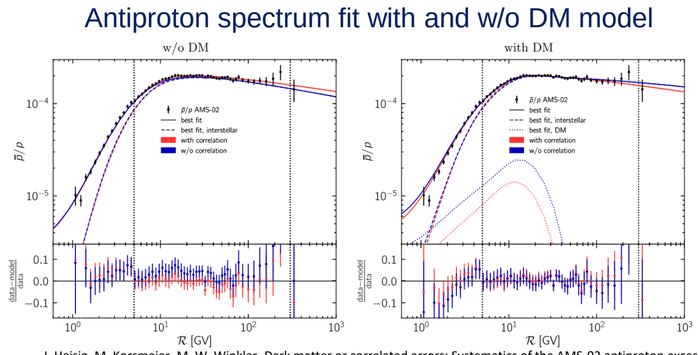
Antiproton production cross sections





Cosmic-ray propagation uncertainties

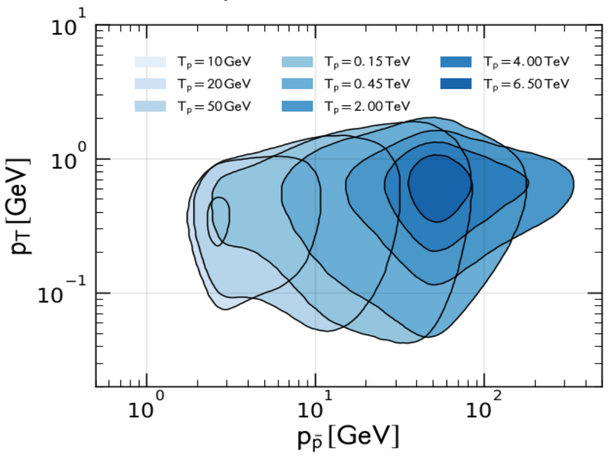
Antiproton spectrum fit with and w/o DM model



J. Heisig, M. Korsmeier, M. W. Winkler, Dark matter or correlated errors: Systematics of the AMS-02 antiproton excess, PHYSICAL REVIEW RESEARCH 2, 043017 (2020)

AMBER - EXPERIMENTAL REQUIREMENTS

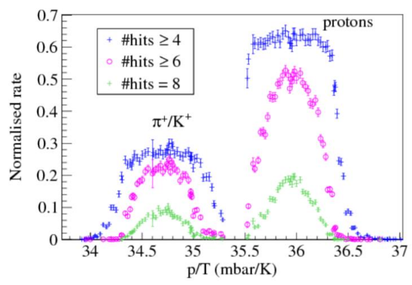
p+He channel

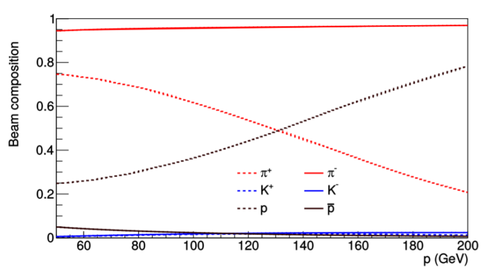


F. Donato, M. Korsmeier and M. Di Mauro,Prescriptions on antiproton cross section data for precise theoretical antiproton flux predictions,arXiv: 1704.03663v2[astro-ph.HE] 4 Jun 2018

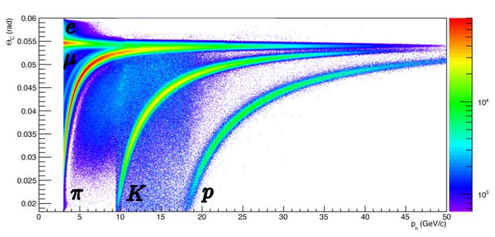
- Parameter space for the pHe channel corresponding to an exemplary fixed target experiment.
- 3% relative uncertainty within the blue regions (30% outside)

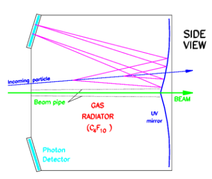
- @M2 beamline: 400 GeV/c proton beam on a 500 mm thick primary Beryllium production target (T6) -> Secondary beam 60-280 GeV/c
- beam PID: two CEDAR detectors installed 30 m upstream the target region
- beam intensity 5 * 10^5 p/s.

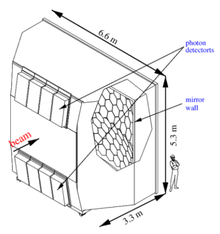




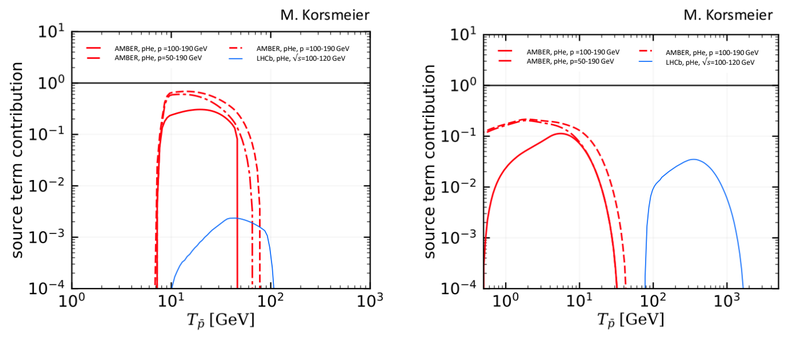
Antiproton PID performed by RICH detector



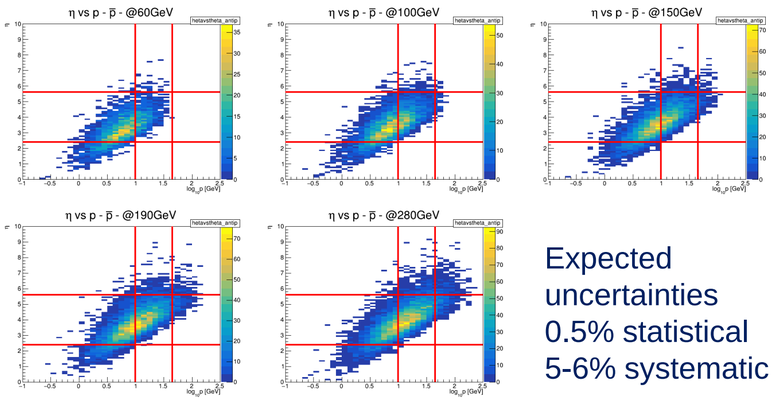




Projected contribution to the source term



Antiproton phase space covered



Expected uncertainties
0.5% statistical
5-6% systematic