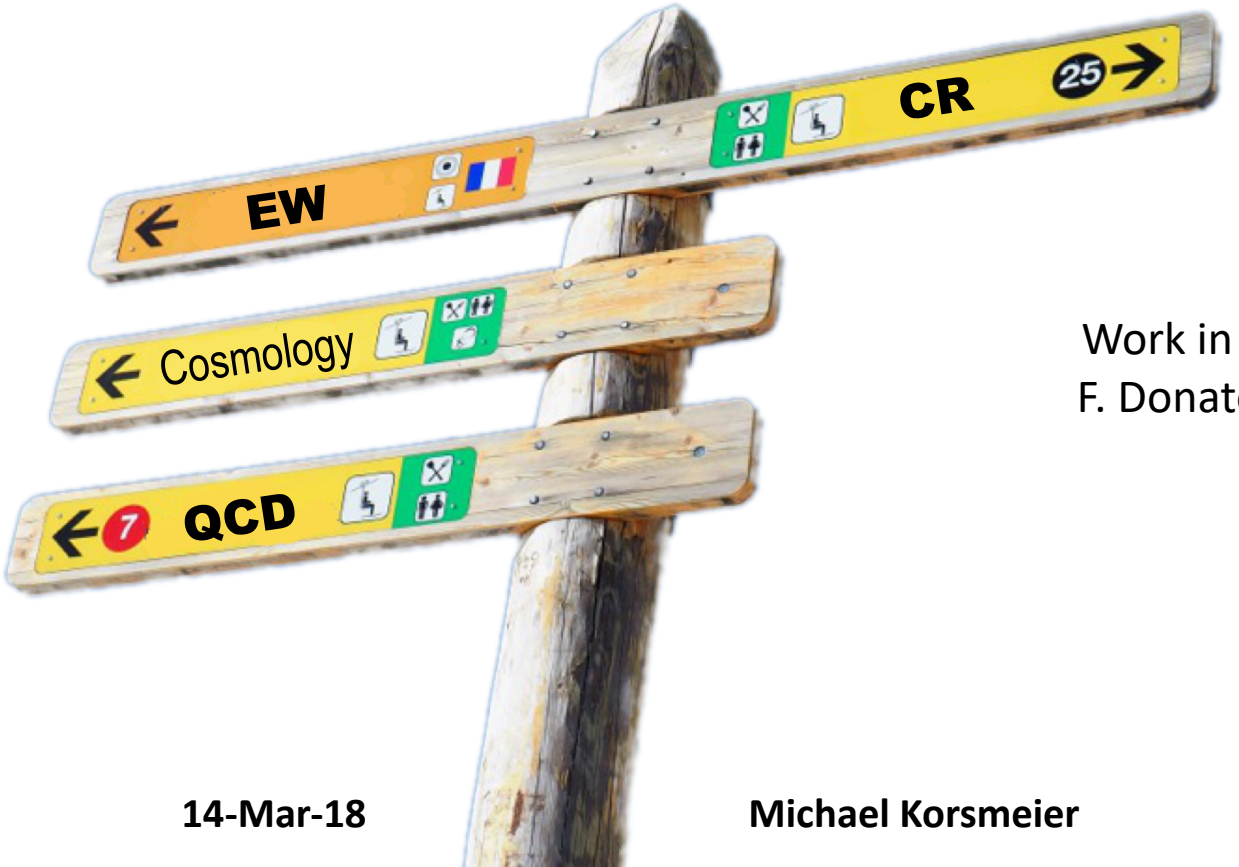
UNIVERSITY of TURIN and INFN
Department of Physics
INFN Istituto Nazionale di Fisica Nucleare
TTK Institute for Theoretical Particle Physics and Cosmology
RWTH AACHEN UNIVERSITY

Production cross sections for cosmic-ray antiprotons

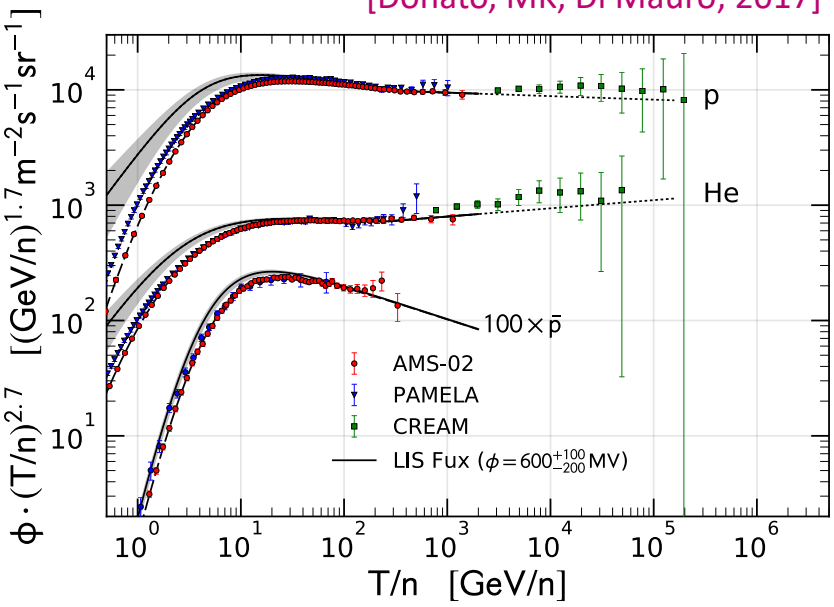


Work in collaboration with
F. Donato and M. Di Mauro

Cosmic rays in the precision era

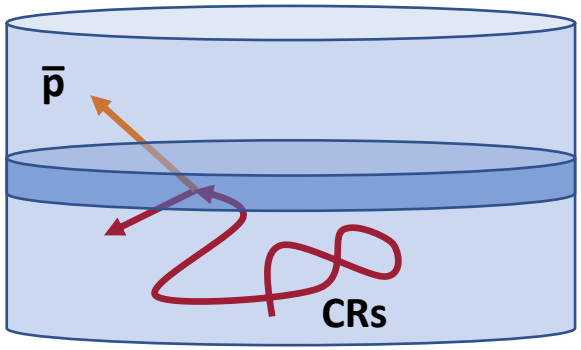
- Space-based experiments PAMELA and AMS-02 determine cosmic-ray spectra with increasing precision
- Interpretation the CR data requires understanding of:
  - Production
  - Propagation in the Galaxy
  - Solar Modulation
- AMS-02 measures the antiproton flux at about 5% precision between 1 and 400 GeV

[Donato, MK, Di Mauro; 2017]



Source term for cosmic-ray $\bar{p}$

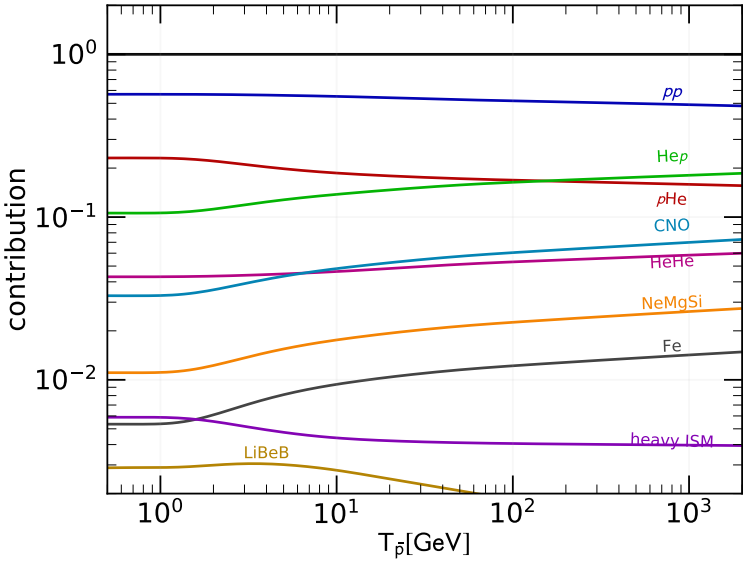
Antiprotons are produced by interaction of CR p and He with the ISM of mostly H and He.



$$\mathrm{CR}_i + \mathrm{ISM}_j \rightarrow \bar{p} + X$$

Or by dark matter?

[MK, Donato, Di Mauro; 2018]



Main production channels:

- *pp* 50%-60%
- *p*He 15%-20%
- He*p* 15%-20%

Fit of cross section parametrization

- Reevaluation of two parametrizations for

$$E\frac{d^3\sigma}{dp^3}(\sqrt{s}, x_{\mathrm{R}}, p_{\mathrm{T}})$$

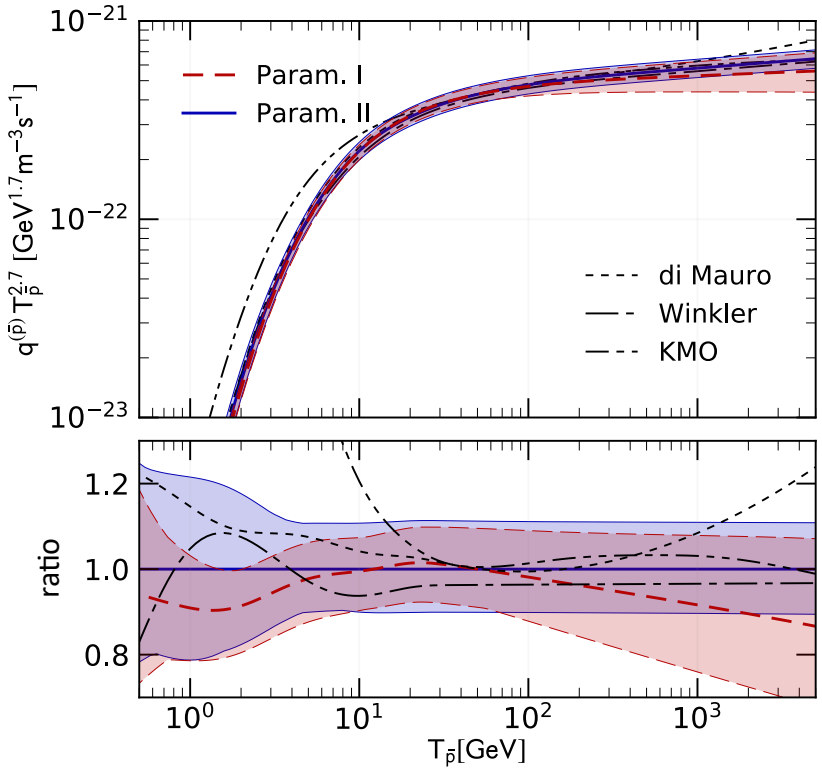
  - Param. I [Di Mauro, et al.; 2014]
  - Param. II [Winkler; 2017]

  for proton-proton and proton-nucleus collisions

- Focus on data from NA49, NA61, and the first-ever determination of the proton-He cross section by LHCb

- 10% to 20% uncertainty in $\bar{p}$ cosmic ray source term q in the energy range of AMS-02

[MK, Donato, Di Mauro; 2018]

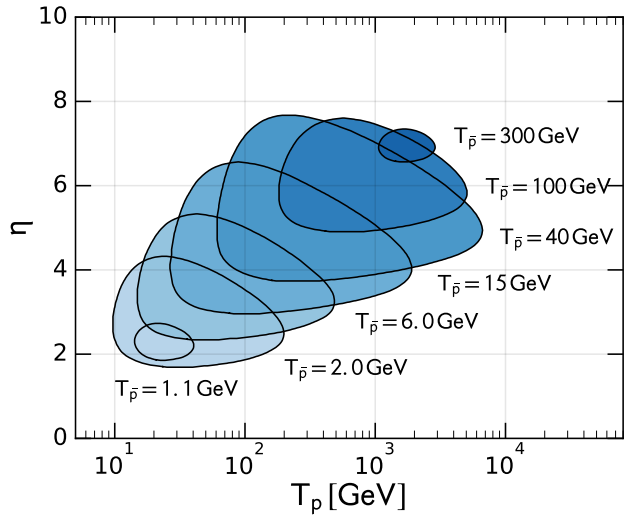


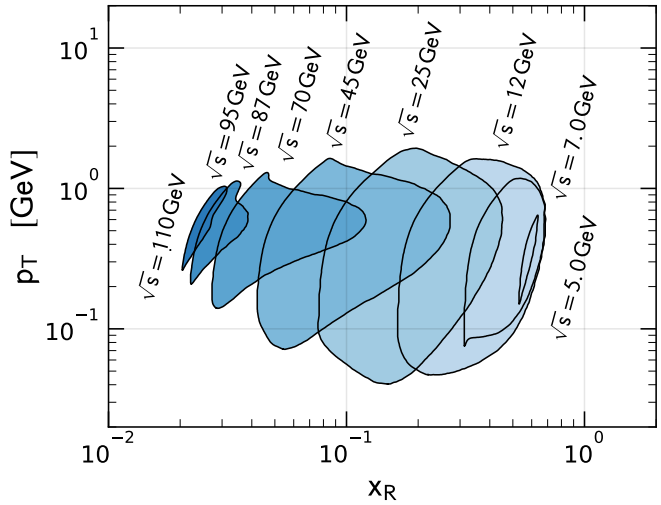
$$q_{ij}(T_{\bar{p}}) = \int_0^\infty dT_i \; 4\pi \, n_{\mathrm{ISM},j} \, \phi_i(T_i) \, \frac{d\sigma_{ij}}{dT_{\bar{p}}}(T_i, T_{\bar{p}})$$

Definition: $x_{\mathrm{R}} = E^*_{\bar{p}} / E^{\max *}_{\bar{p}}$ in the CM frame

Accuracy of AMS-02

- The particle spectrometer AMS-02 onboard the ISS measures the antiproton flux at 5% accuracy
- This requires a better measurement of the antiproton production cross section
- If the cross sections $E\frac{d^3\sigma}{dp^3}(\sqrt{s}, x_{\mathrm{R}}, p_{\mathrm{T}})$ are known by 3% inside the blue contours we reach AMS-02 accuracy



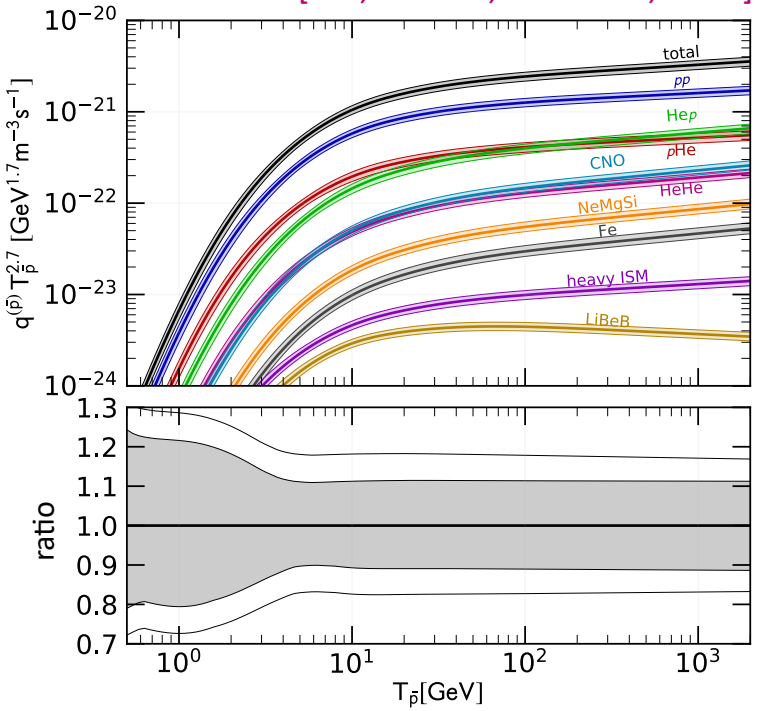


[Donato, MK, Di Mauro; 2017]

Conclusions

- We provide a description of cross sections and uncertainties for antiproton production in proton-proton and proton-nucleus collisions
- Further efforts are required to reach AMS-02 flux accuracy
- We determine the parameter space for future cross section measurements

[MK, Donato, Di Mauro; 2018]



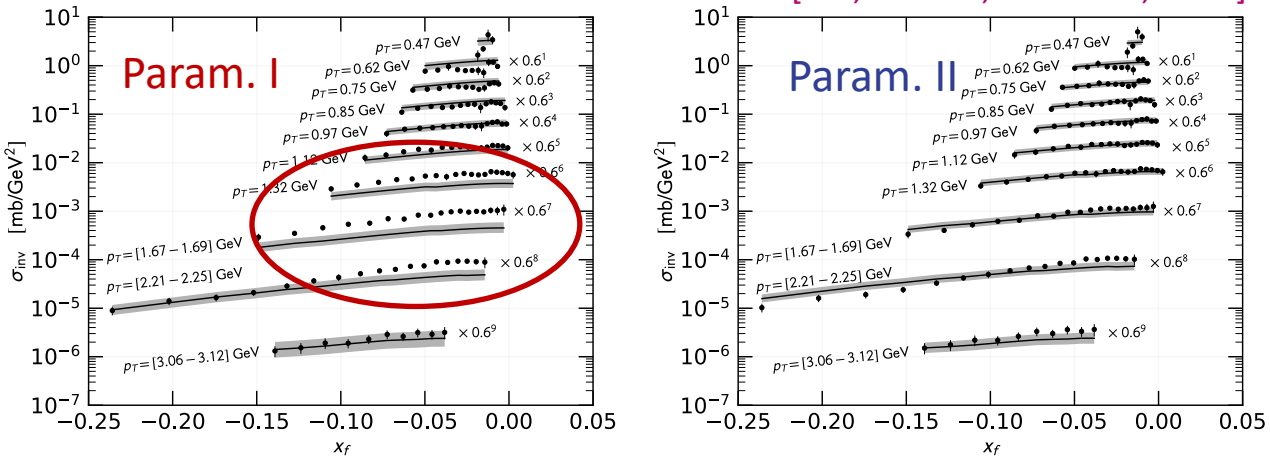
Thank you for your attention!

Backup

LHCb

- Provides the first ever measurement of antiproton production for a proton beam with T_p = 6.5 TeV on fix-target helium
- Gives preference to Param. II, but does not significantly shrink uncertainties

[MK, Donato, Di Mauro; 2018]



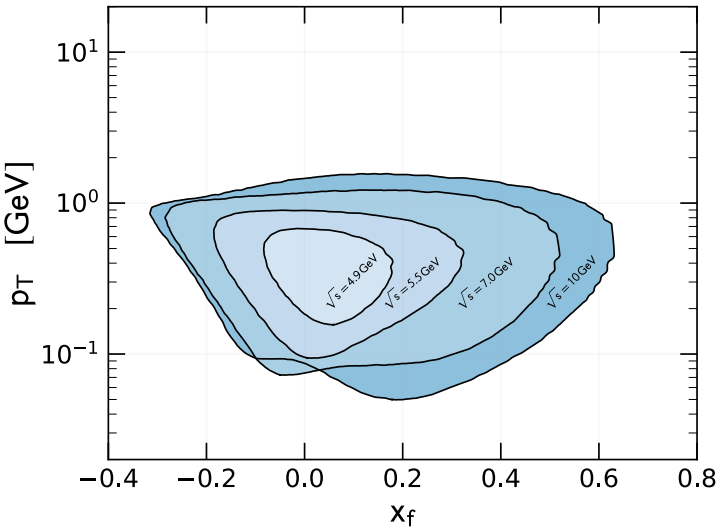
Parametrization II [Winkler; 2017]

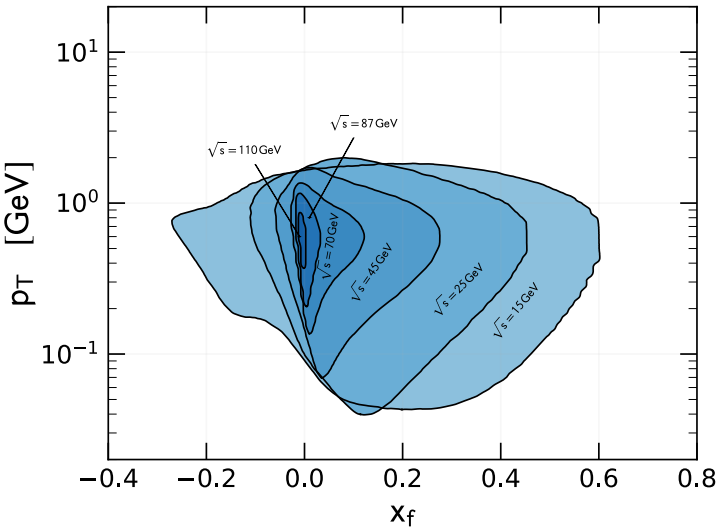
$$f_{\bar{p}}^{0} = R\,\sigma_{\text{in}}\,c_5\,(1-x_R)^{c_6}\left[1+X(m_{\text{T}}-m_p)\right]^{-\frac{1}{Xc_7}}$$

$$R = \begin{cases} \left[1+c_9\left(10-\frac{\sqrt{s}}{\text{GeV}}\right)^5\right]\exp\left[c_{10}\left(10-\frac{\sqrt{s}}{\text{GeV}}\right)(x_R-x_{R,\min})^2\right] & \sqrt{s}\le 10\ \text{GeV} \\ 1 & \sqrt{s} > 10\ \text{GeV} \end{cases}$$

$$X = c_8\,\log^2\left[\frac{\sqrt{s}}{\sqrt{s}_{\text{th}}}\right]$$

[MK, Donato, Di Mauro; 2018]





[MK, Donato, Di Mauro; 2018]