Hunting for WIMPs with Charged Cosmic Rays

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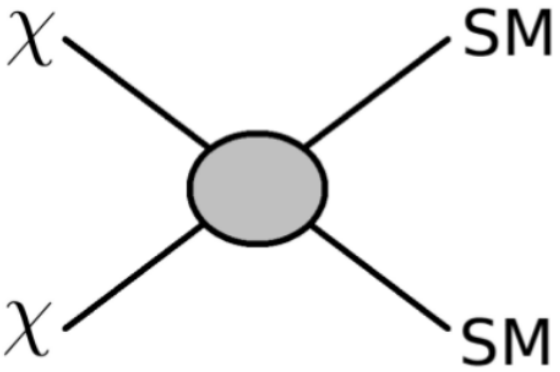
JCAP 02 (2017) M.W.
JCAP 01 (2018) A. Reinert, M.W.

UCLA
DARK MATTER 2018

Antimatter in Cosmic Rays

primary antimatter

- dark matter annihilation

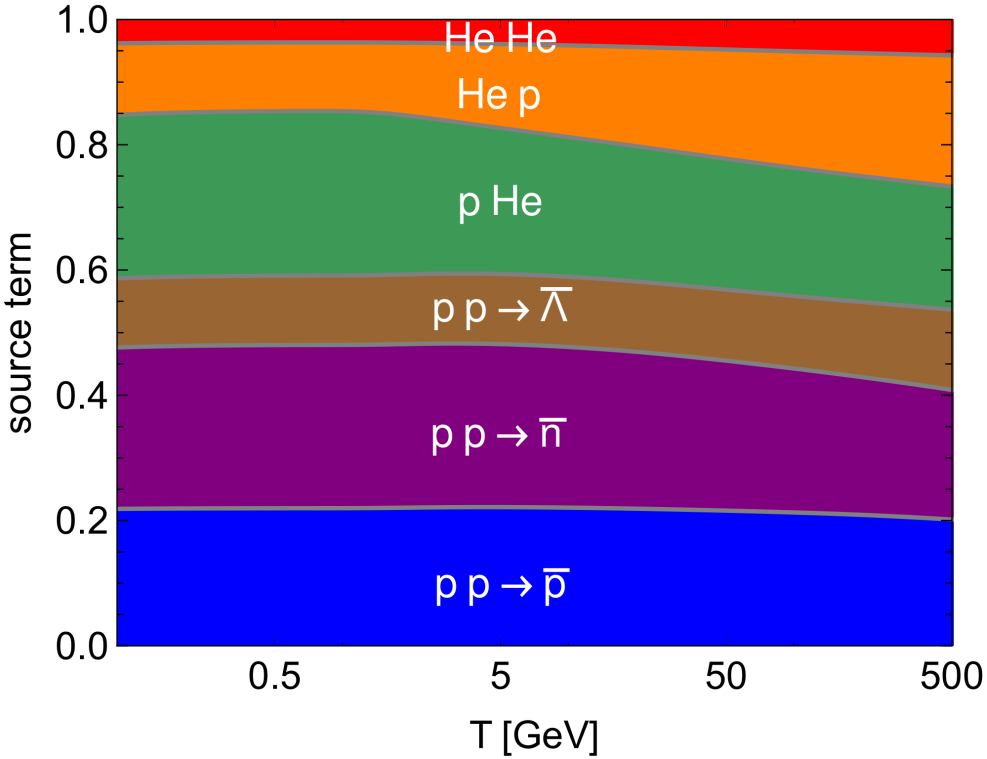


- smooth spectrum
- propagation washes out directional information

secondary antimatter

- primary cosmic rays (p,He) scatter on interstellar matter

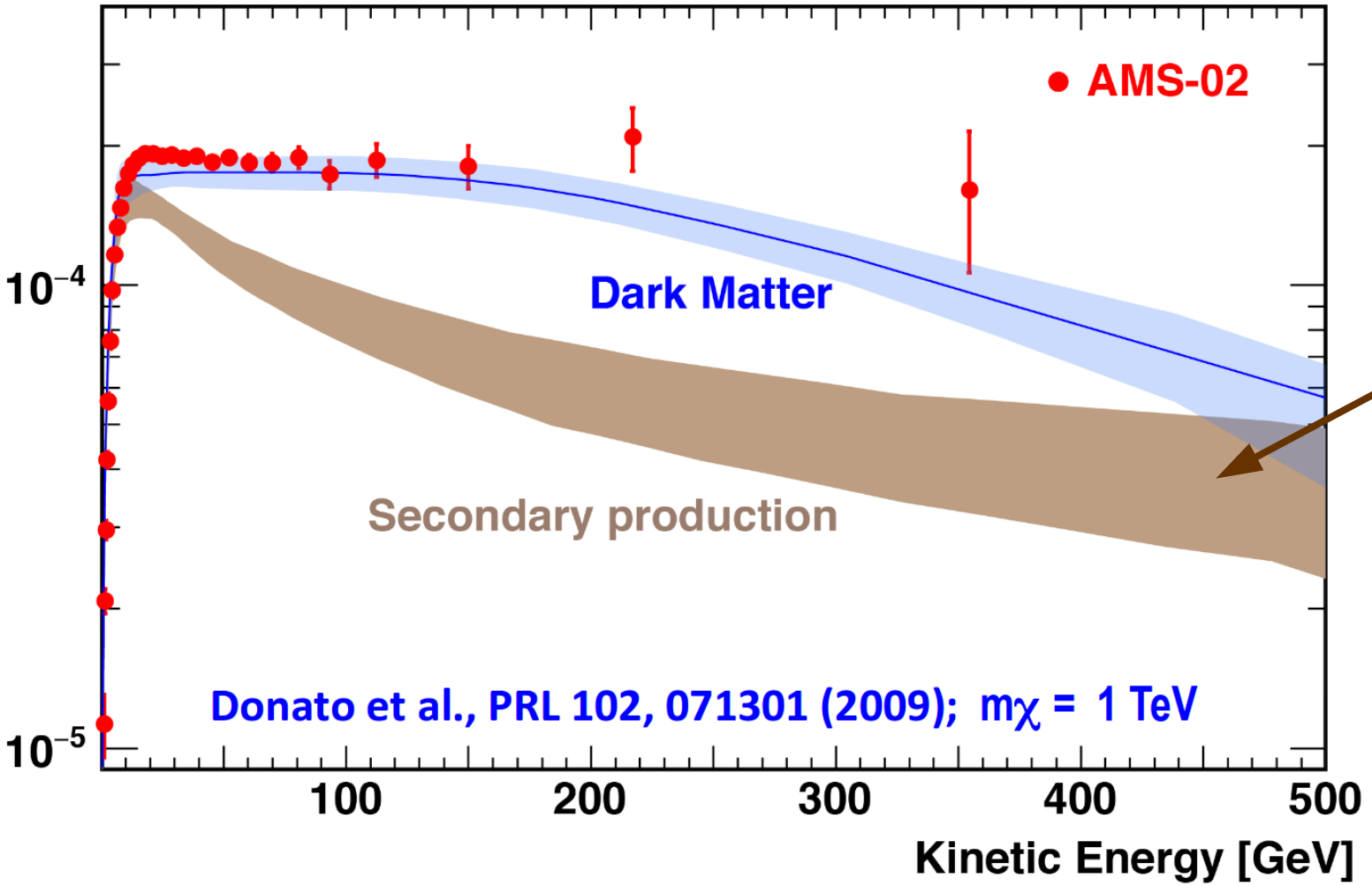
$$q^{\mathrm{sec}}(T) \sim \int dT' \left(\frac{d\sigma_{\bar{p}}}{dT}\right) \rho_{p,He}\, \Phi_{p,He}$$



AMS-02 Antiprotons

- AMS-02 in 2015: surprisingly hard $\bar{p}$ spectrum

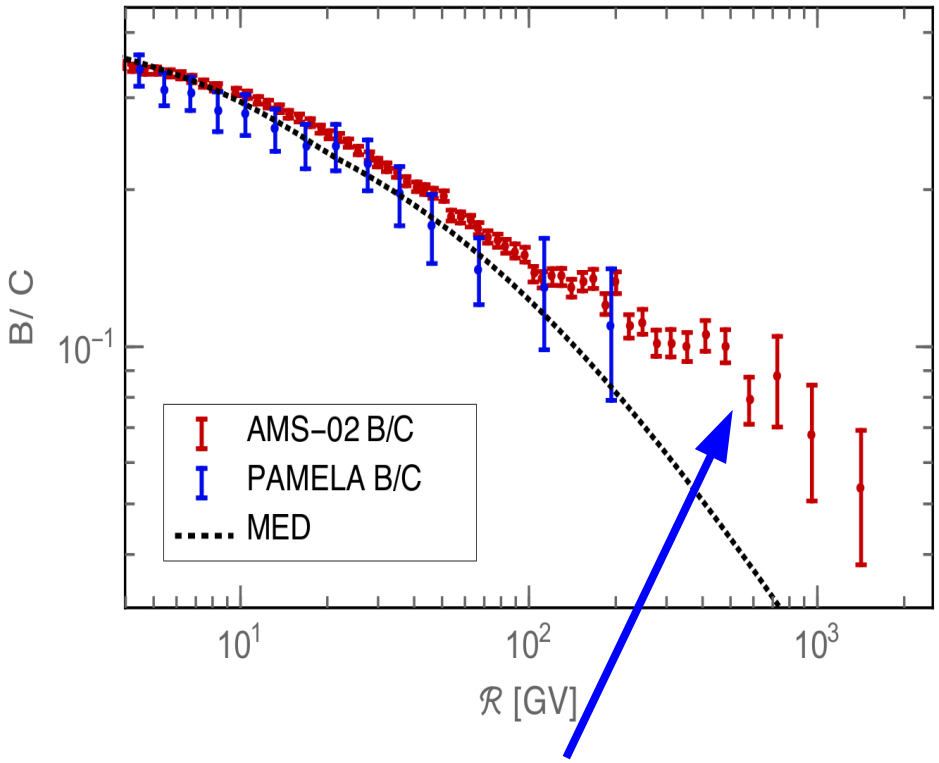
  S.Ting, A. Kounine, AMS Days at CERN (2015)

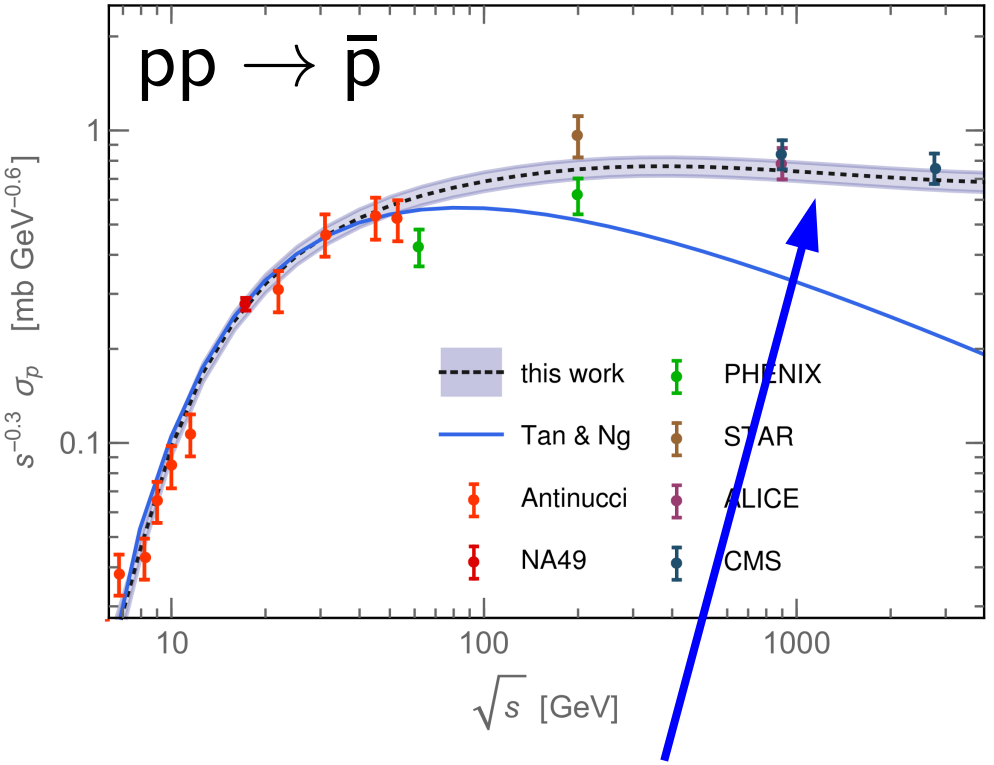


Uncertainties:
cross section,
propagation

Origin of High Energy Antiprotons

- background improvements





propagation update to fit B/C

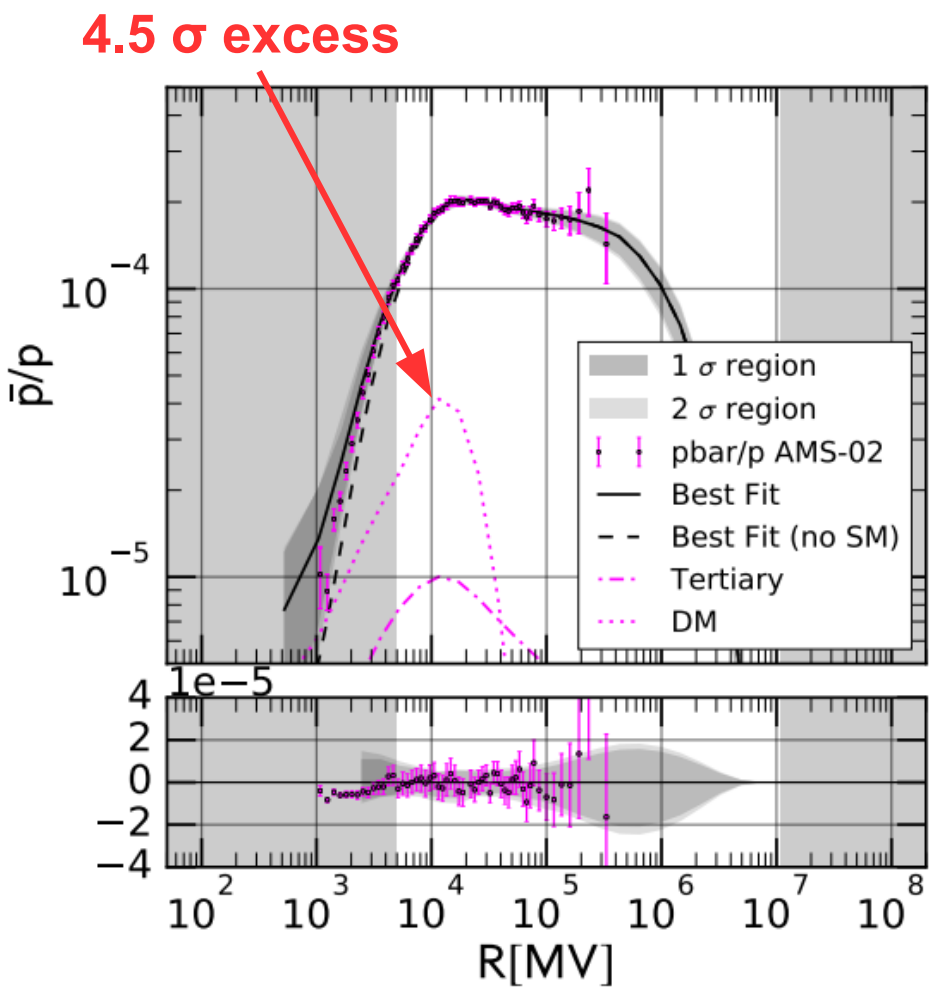
Giesen et al., Evoli et al.,
Kappl, Reinert, M.W., JCAP (2015)

cross section increase

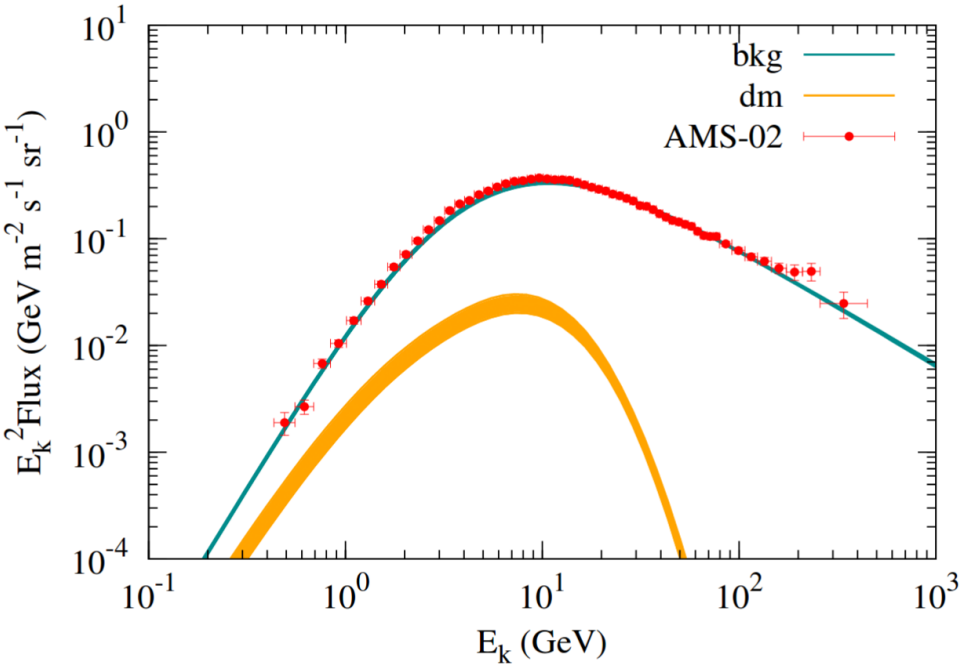
M.W., JCAP 02 (2017)

- no dark matter required for hard spectrum

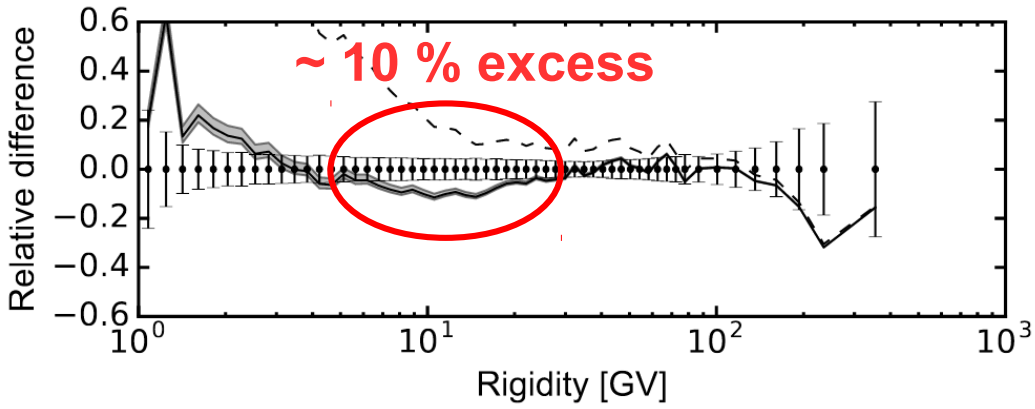
New Antiproton Excess



Cuoco, Krämer, Korsmeier, PRL 118 (2017)



Cui, Yuan, Tsai, Fan, PRL 118 (2017)

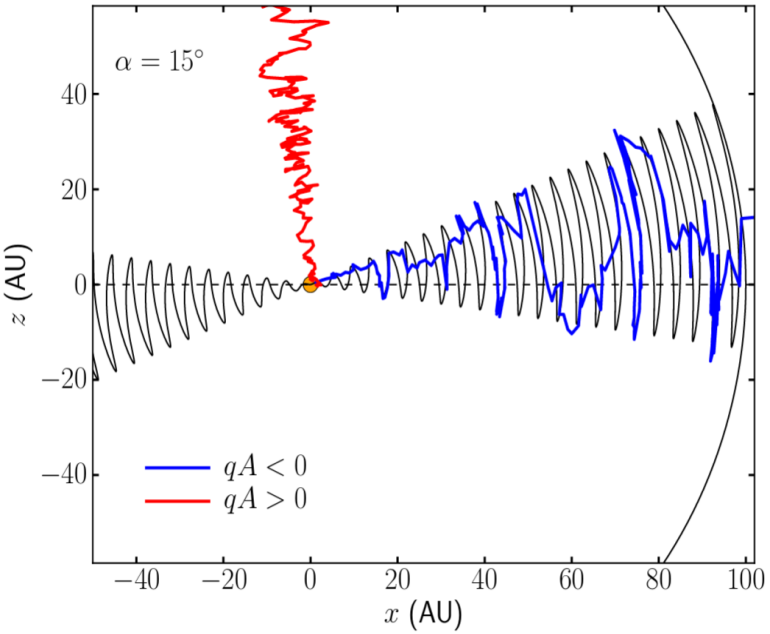


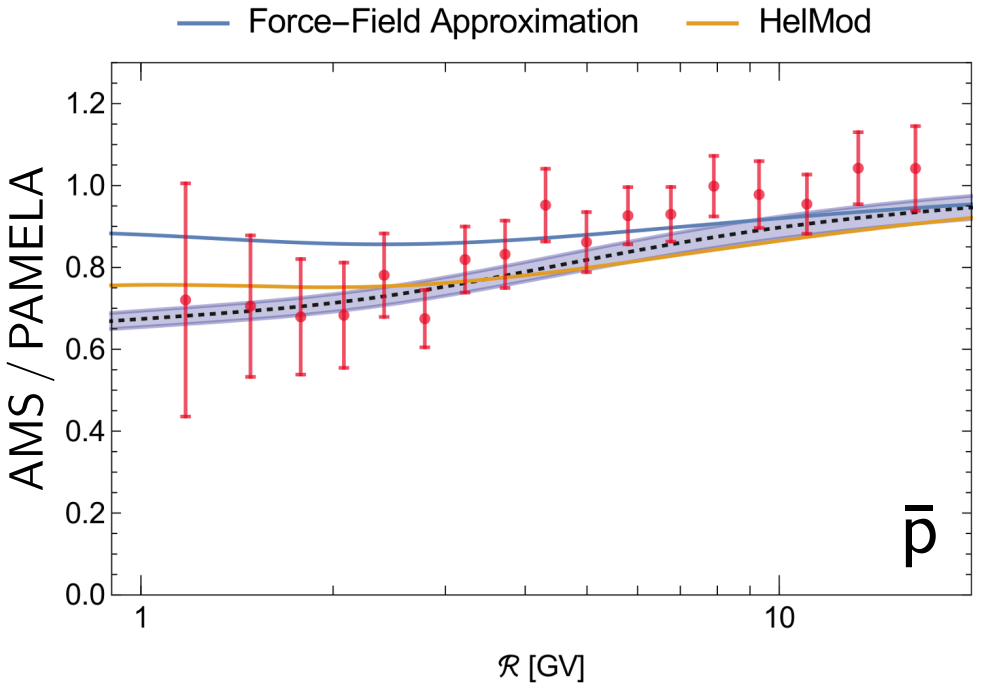
Boschini et al., Astrophys. J. 840 (2017)

Analysis Strategy

- simultaneous fit to B/C and $\bar{p}$
- low energy positrons used to fix diffusion zone

Lavalle, Maurin, Putze, Phys.Rev. D90 (2014), Boudaud et al., Astron. Astrophys. 605 (2017)



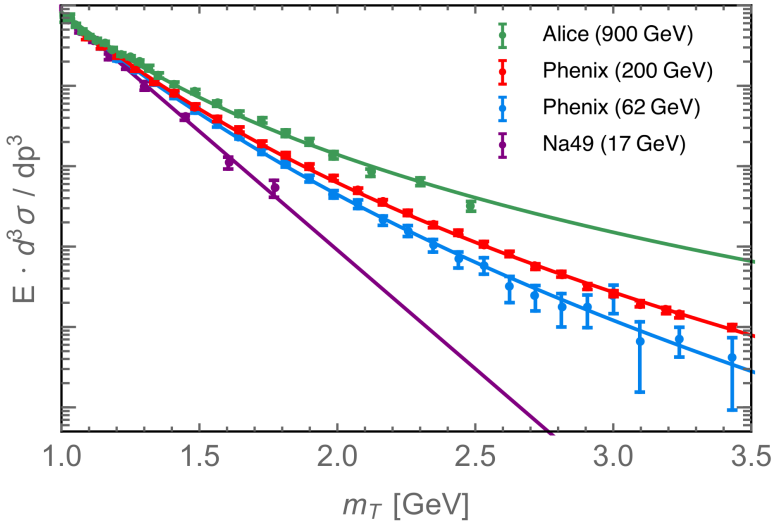


Cholis et al. Phys. Rev. D 93 (2016),
Jokipii, Thomas, Astrophys. J. 243 (1981)

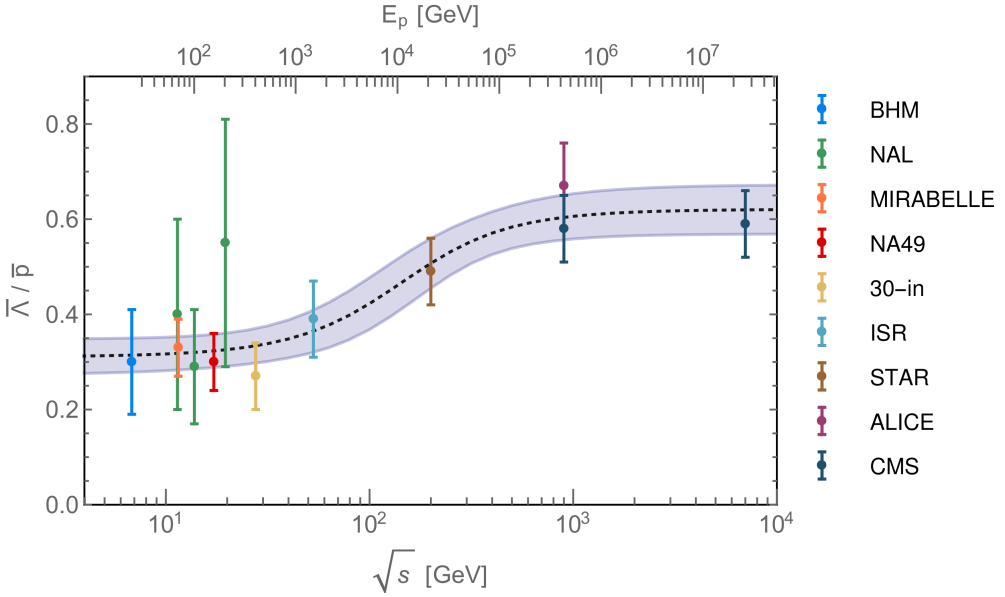
- charge-dependent solar modulation from $\bar{p}$(AMS) / $\bar{p}$(PAMELA)

Antiproton Cross Section

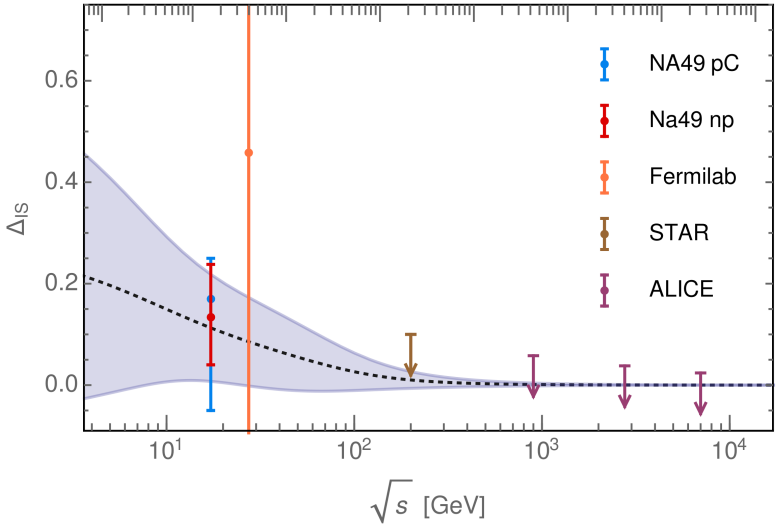
scaling violation



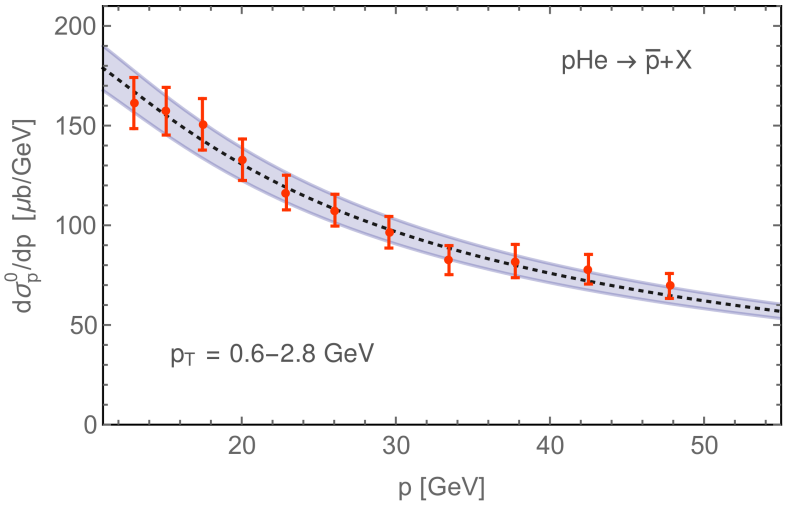
hyperons



antineutrons

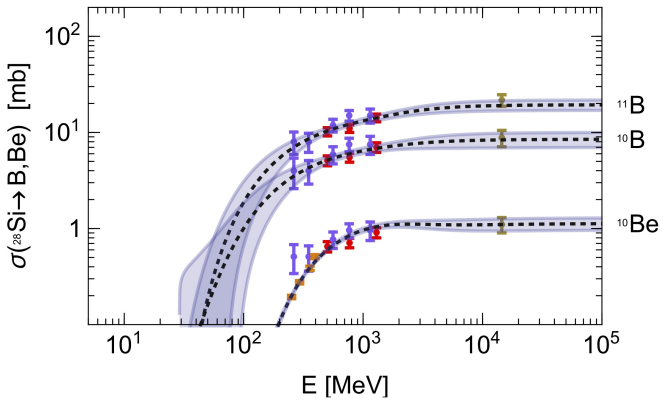


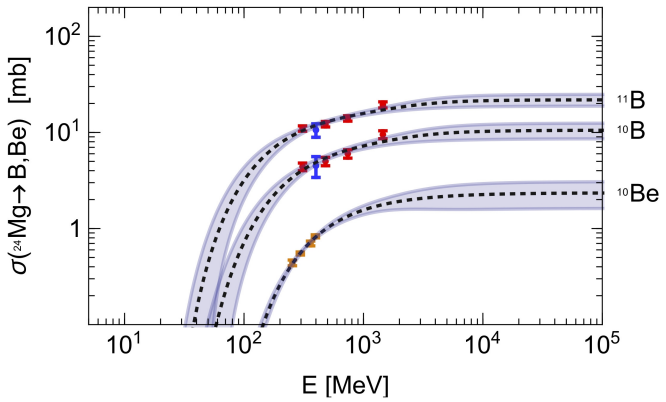
proton helium scattering

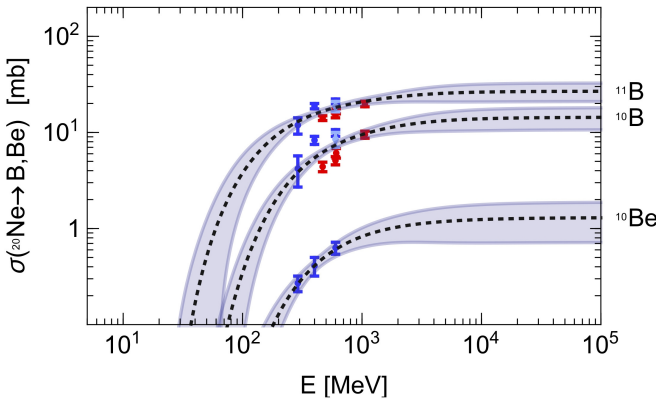


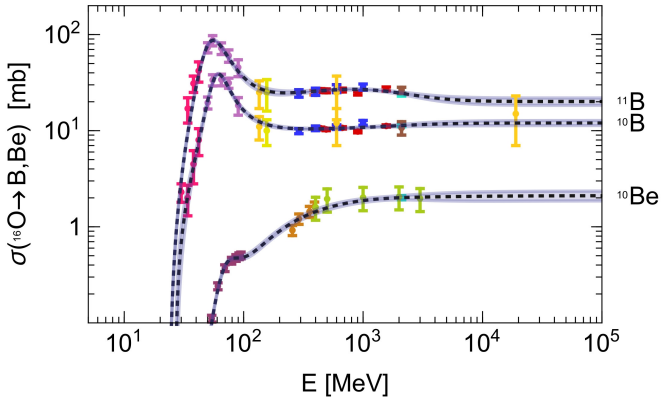
PHENIX, Phys. Rev. C83 (2011), ALICE, Eur. Phys. J. C71 (2011), CMS, Eur. Phys. J. C72 (2012), Blobel, Nucl. Phys. B69 (1974), Amaldi, Nucl. Phys. B86 (1975), Whitmore, Phys. Rept. 10 (1974), Kichimi, Phys. Rev. D20 (1979), Ammosov, Nucl. Phys. B115 (1976), Abelev, Phys. Rev. C75 (2007), Aamodt, Eur. Phys. J. C71 (2011), Khachatryan, JHEP 05 (2011), Antreasyan, Phys. Rev. D19 (1979), Fischer, Heavy Ion Phys. 17 (2003), Baatar, Eur. Phys. J. C73 (2013), Aamodt et al., Phys. Rev. Lett. 105 (2010), Abbas et al., Eur. Phys. J. C73 (2013)

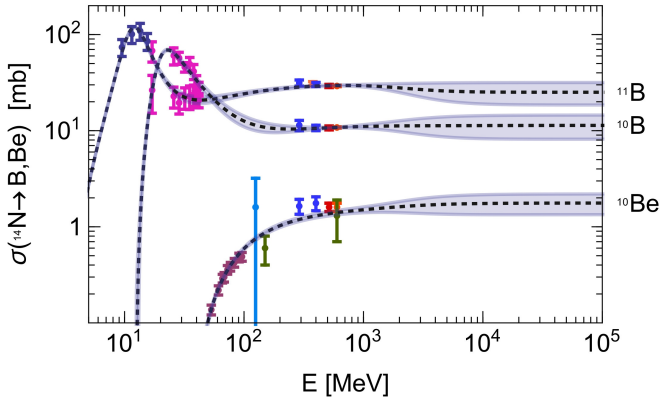
Boron Cross Section

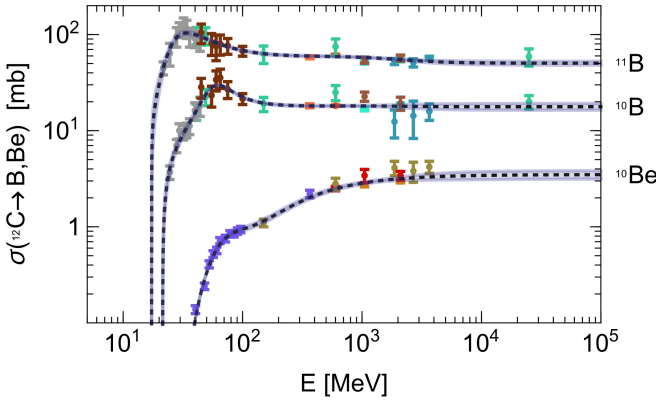


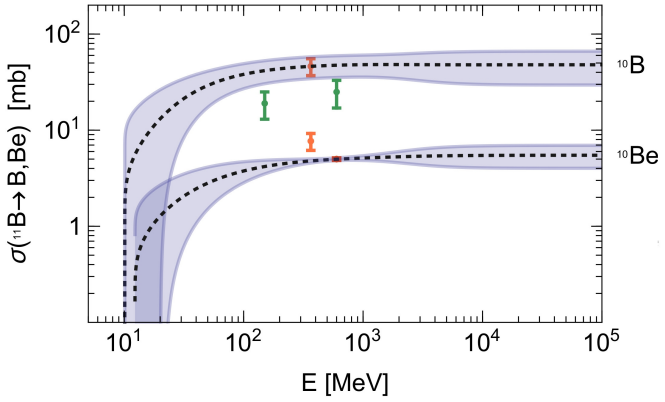










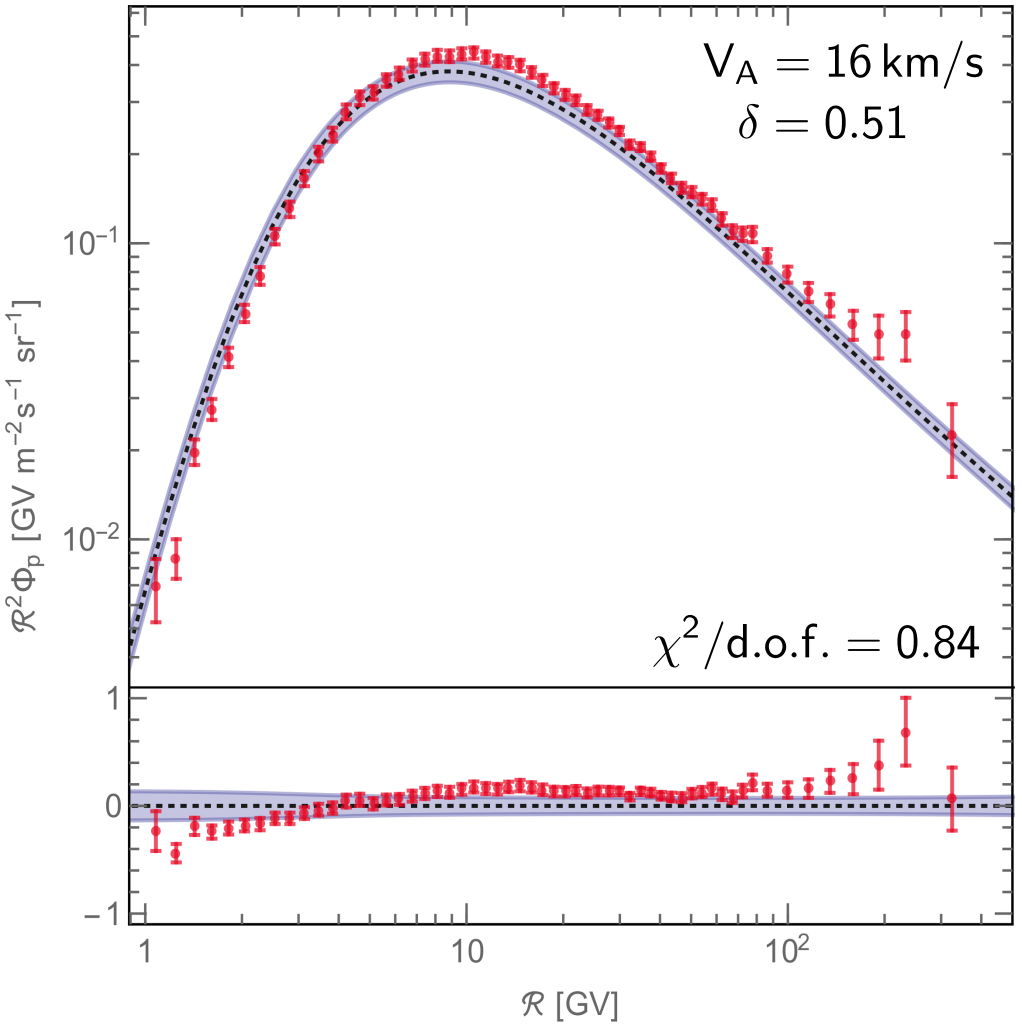


Fit to:

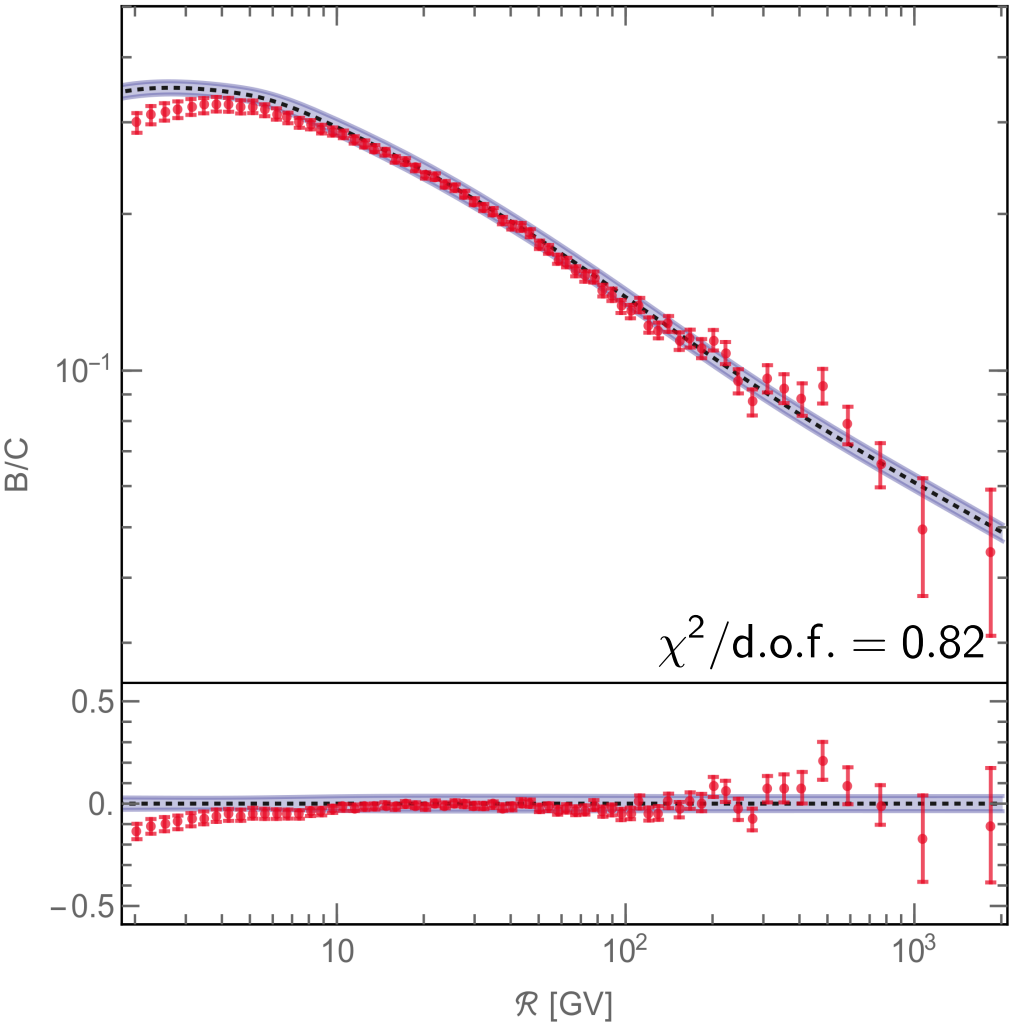
Bodansky et al., Astrophys. J. 202 (1975), Bodemann et al., Nucl. Instr. 82 (1993), Brechtmann et al. Phys.Rev. C39 (1989), Davids et al., Phys. Rev. C1 (1970), Epherre et al., Nucl. Phys. A139 (1969), Fontes et al.,Nucl. Phys. A165 (1971), Phys. Rev. C15 (1977), Goel et al., Nature 223 (1969), Jung et al., Phys. Rev. C1 (1970), Korejwo et al., J. Phys. G28 (2002), Laumer et al., Phys. Rev. C8 (1973), Phys. Rev. C10 (1974), Lindstrom et al., LBL-3650 (1975), Moyle et al., Phys. Rev. C19 (1979), Olson et al., Phys. Rev. C28 (1983), Raisbeck et al., Phys. Rev. C9 (1974), Raisbeck et al., PRL 27 (1971), Roche et al., Phys. Rev. C14 (1976), Schiekel et al., Nucl. Instr. 114 (1996), Webber et al. Phys. Rev. C41 (1990), Astrophys. J. 508 (1998), Yiou et al. J. of Geophy. Res. 74 (1969), Zeitlin et al. Nucl.Phys. A784 (2007), Phys.Rev. C83 (2011), Phys.Rev.C64 (2001)

Antiproton + B/C Fit

antiproton flux



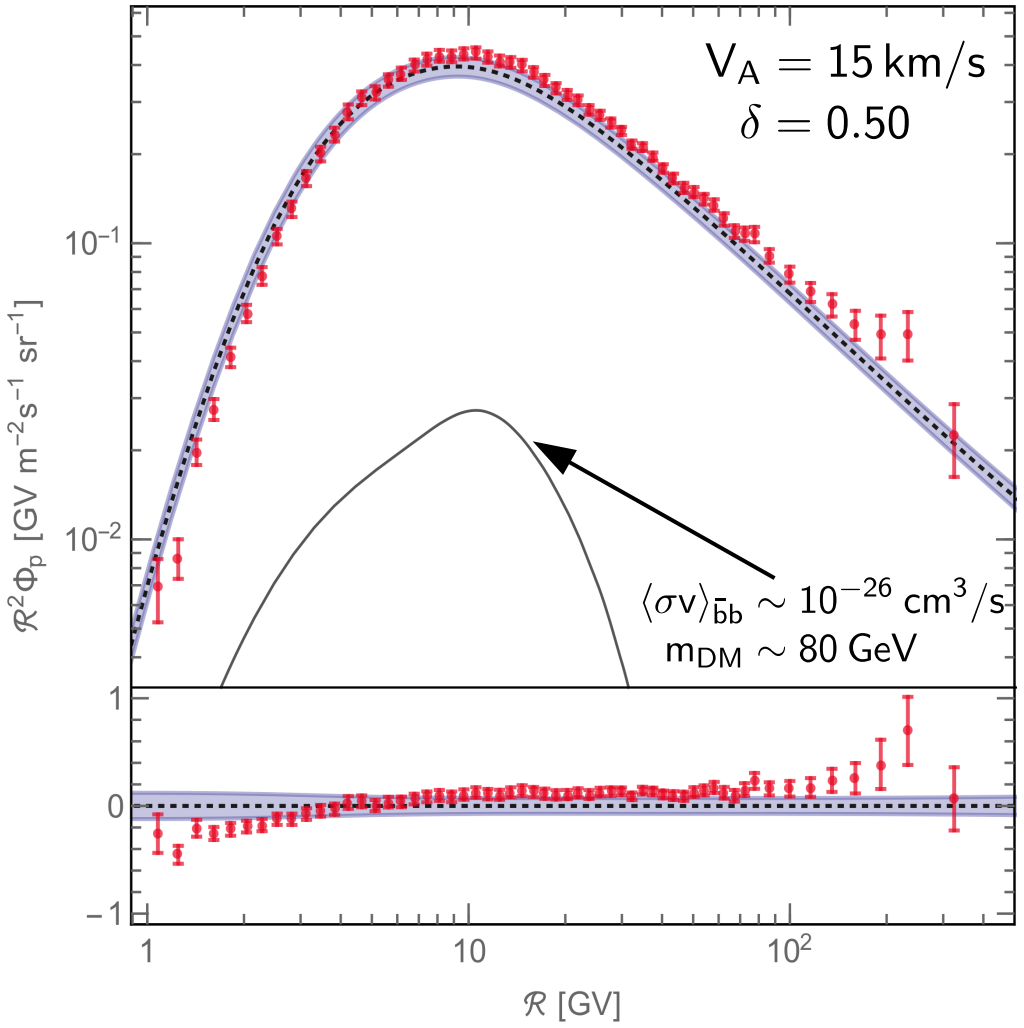
boron/carbon



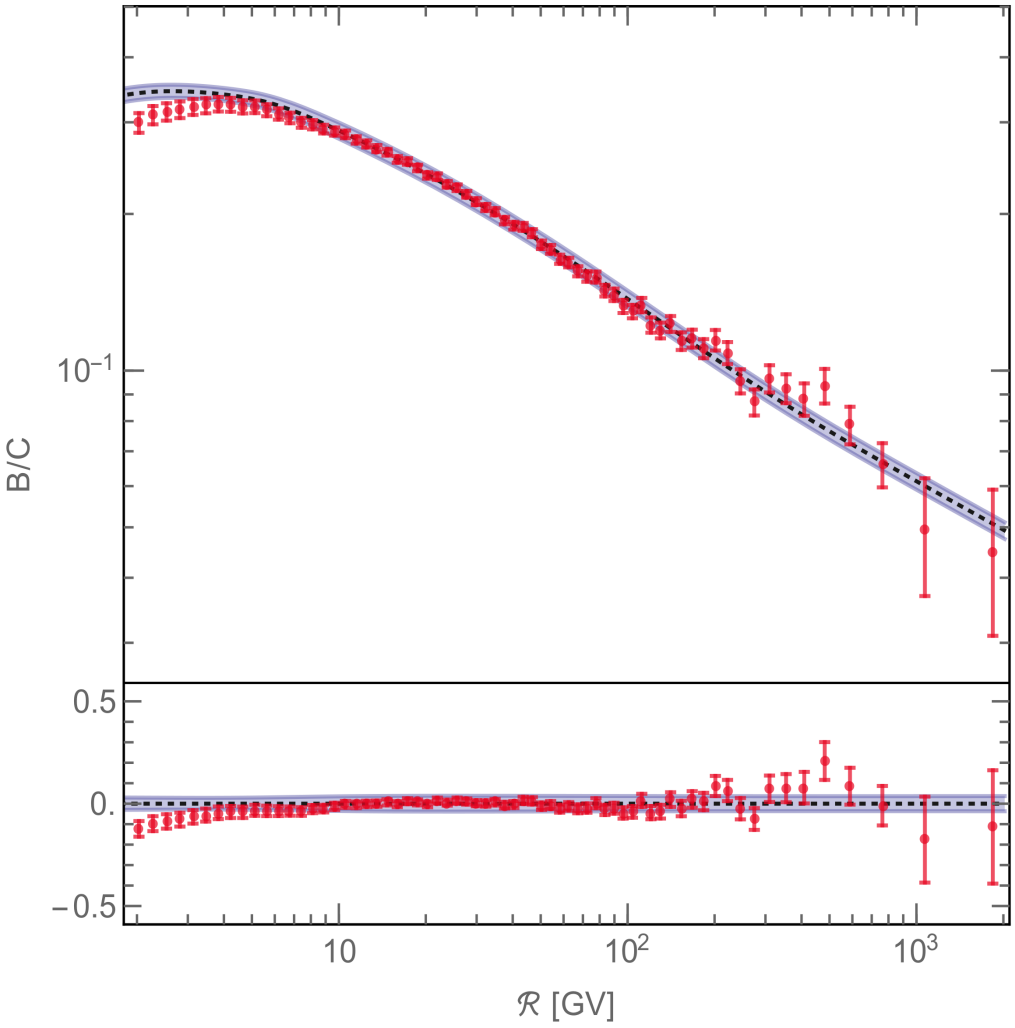
AMS-02 data: Aguilar et al., Phys. Rev. Lett. 117 (2016)

Fit with Dark Matter

antiproton flux

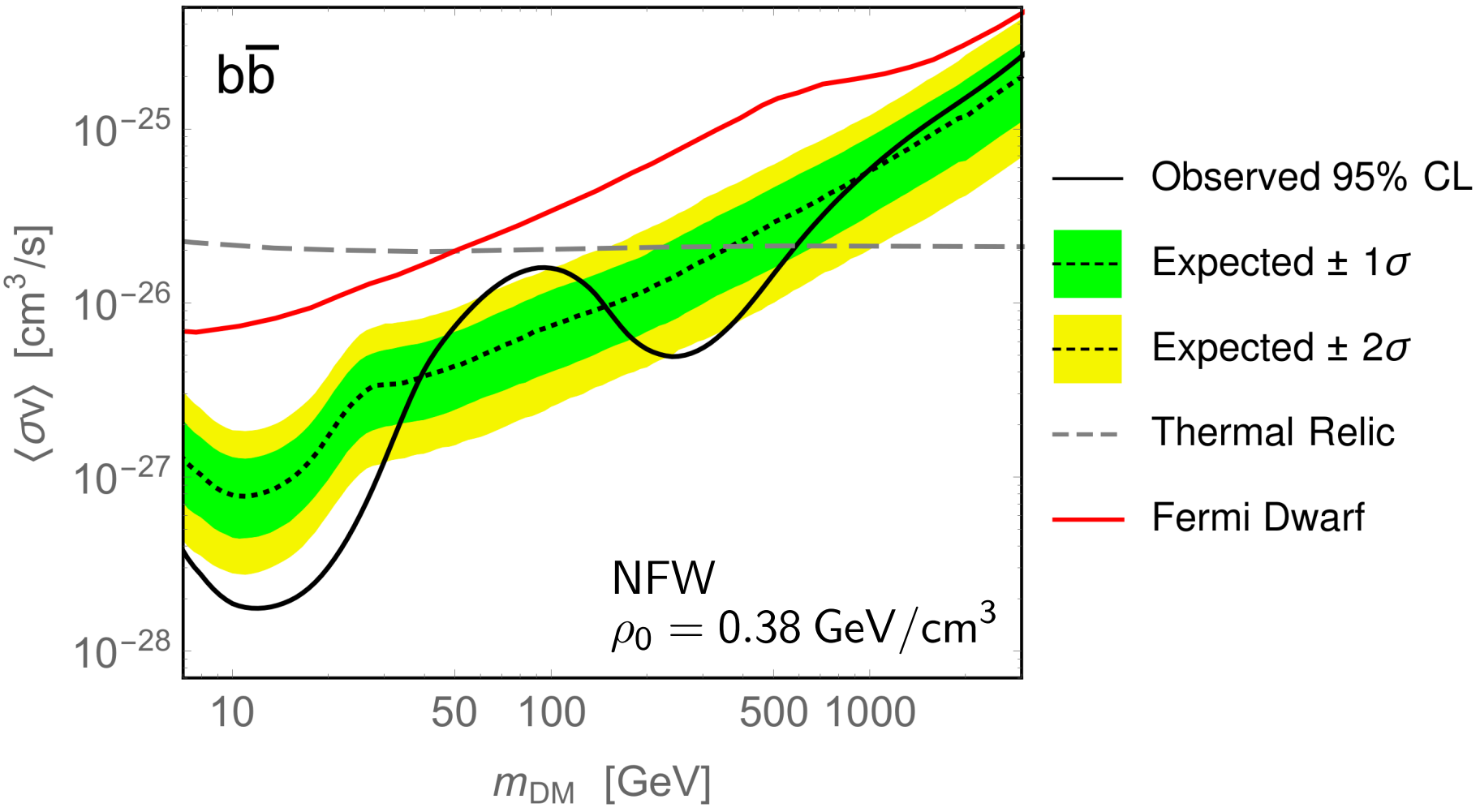


boron/carbon



local significance 2.2σ (look-elsewhere ▶ 1.1σ)

Constraints on Dark Matter

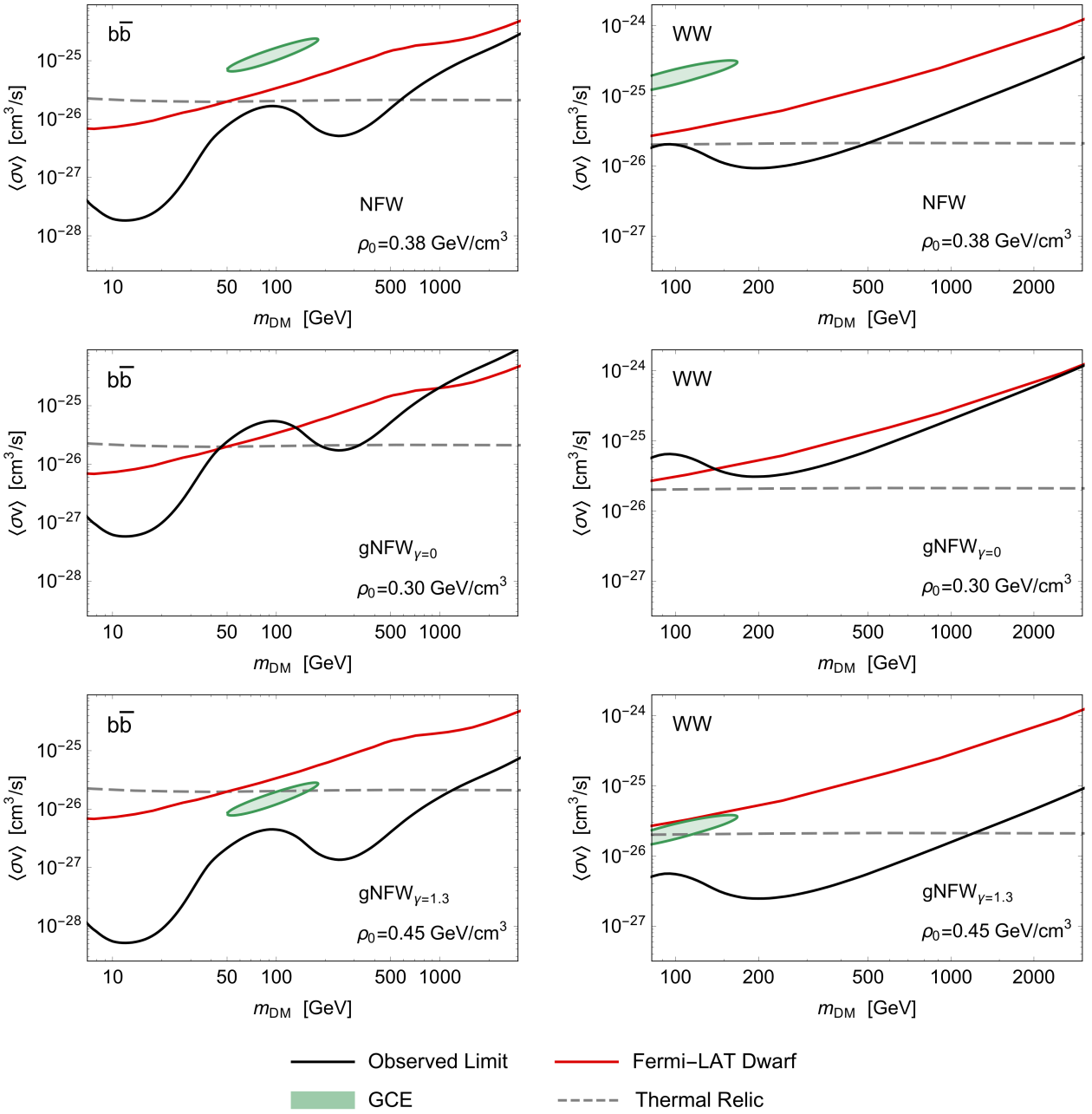


McMillan, Mon. Not. R. Astron. Soc. 465 (2017), Fermi-LAT, Astrophys.J. 834 (2017)

Conclusion

- uncertainties in $\bar{p}$ flux systematically addressed
- $\bar{p}$ set strongest constraints on hadronic WIMP annihilation
- a reported excess at R $\sim$ 10 GV is currently not significant

Backup


bb̄
WW
NFW
gNFW$_{\gamma=0}$
gNFW$_{\gamma=1.3}$
ρ_0=0.38 GeV/cm^3
ρ_0=0.30 GeV/cm^3
ρ_0=0.45 GeV/cm^3
$\langle\sigma v\rangle$ [cm^3/s]
$m_{\rm DM}$ [GeV]
Observed Limit
Fermi–LAT Dwarf
GCE
Thermal Relic