THE COSMIC ANTIPROTON PUZZLE

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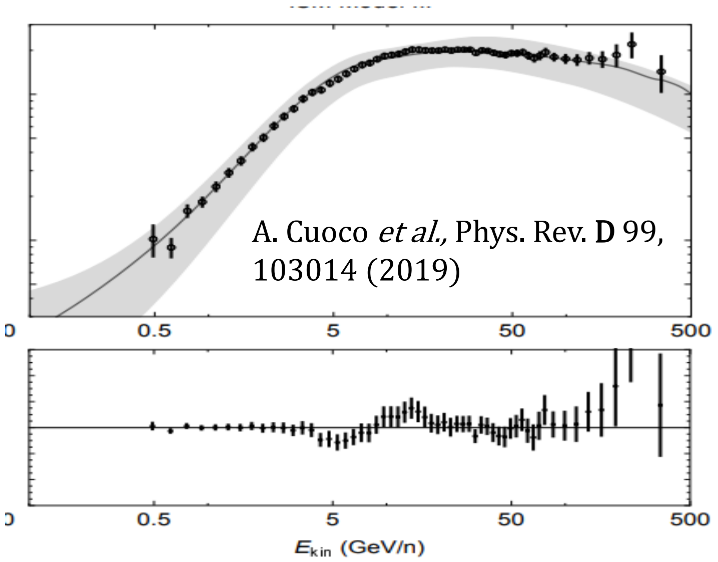
Possible excess in the AMS $\bar{p}$ data

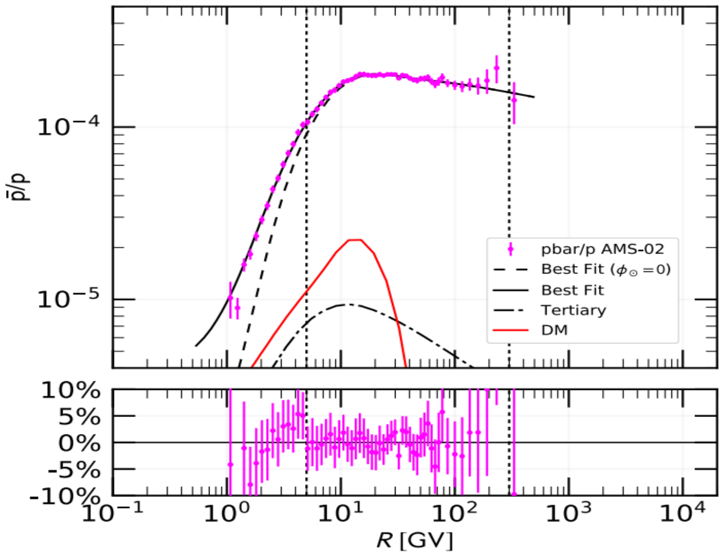
DM possible signal in literature:

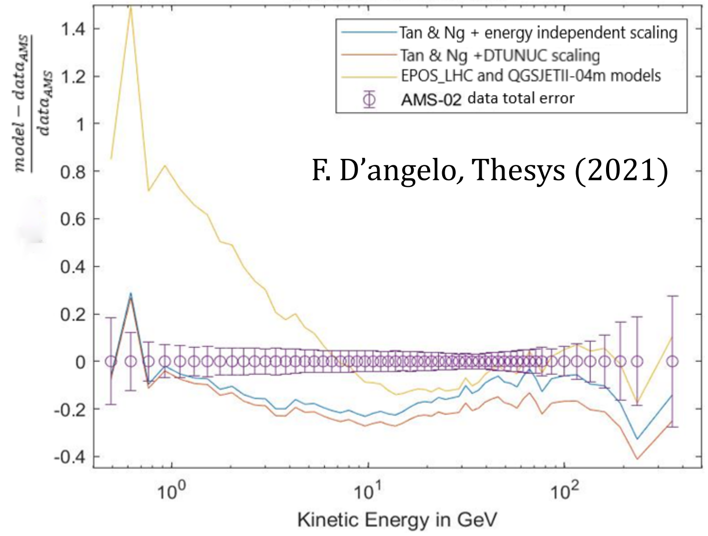
- Phys. Rev. D 99, 103026 (2019)
- Phys. Rev. D 99, 103014 (2019)
- Phys. Rev. D 100, 103014 (2019)
- arXiv:1712.00002
- Phys. Rev. Lett. 118, 191102 (2017)
- Phys. Rev. Lett. 118, 191101 (2017)
- Phys. Rev. D 93, 015015 (2016)
- JCAP 1710 053 (2017)
- PoS(EPS-HEP2017)065
- The Astrophysical Journal, 914:110 (2021)



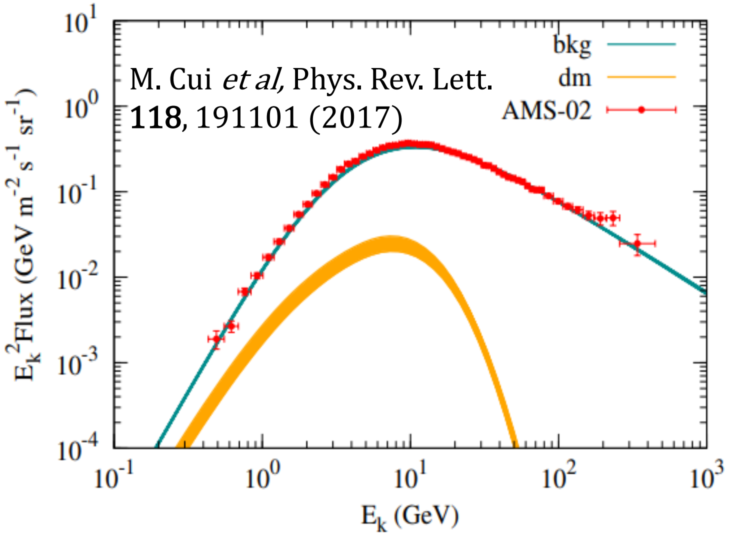
A. Cuoco *et al.*, Phys. Rev. **D** 99, 103014 (2019)

I. Cholis *et al*, Phys. Rev. D **99**, 103026 (2019)



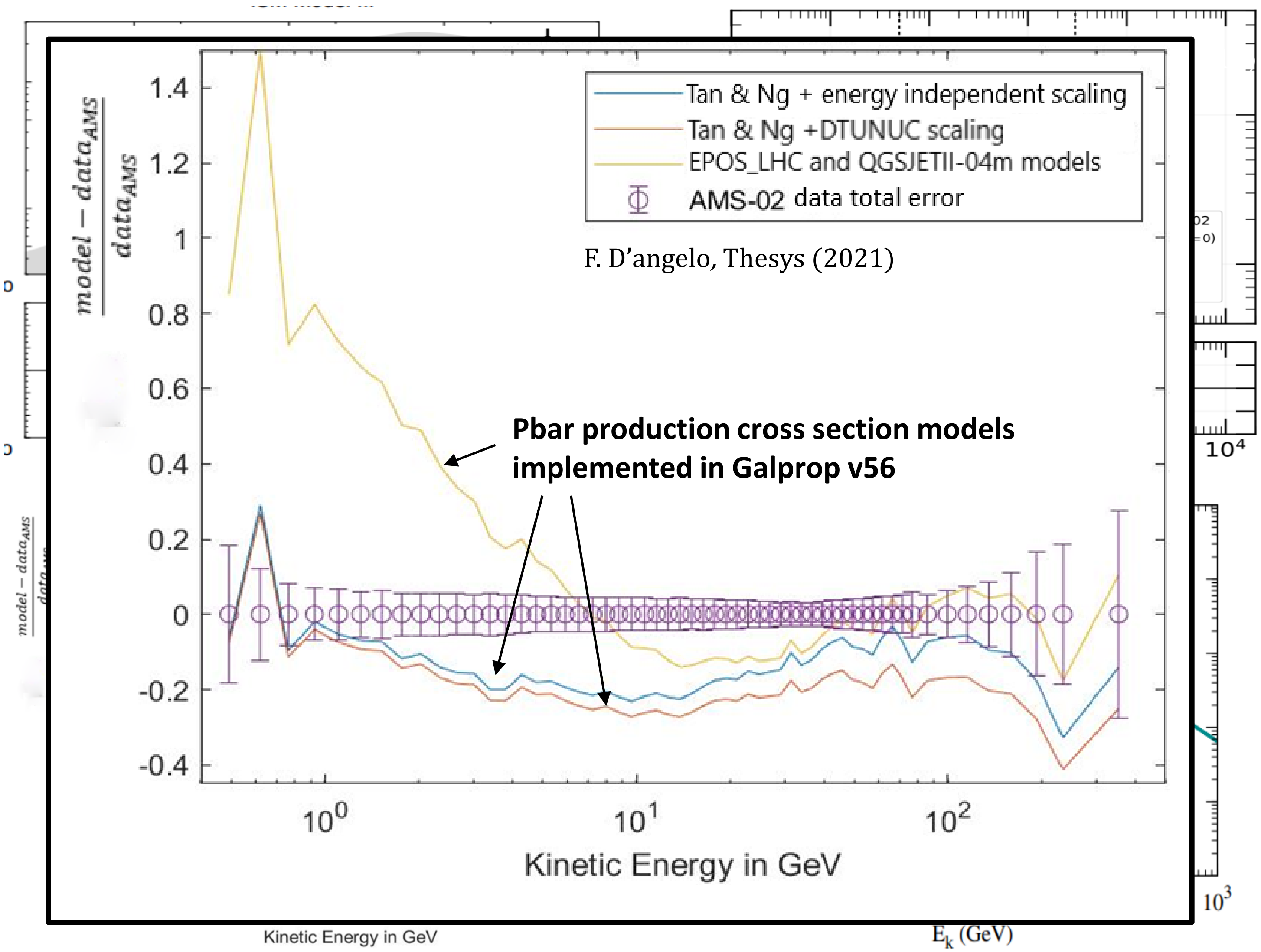


F. D'angelo, Thesys (2021)



M. Cui *et al*, Phys. Rev. Lett. **118**, 191101 (2017)

Possible excess in the AMS $\bar{p}$ data



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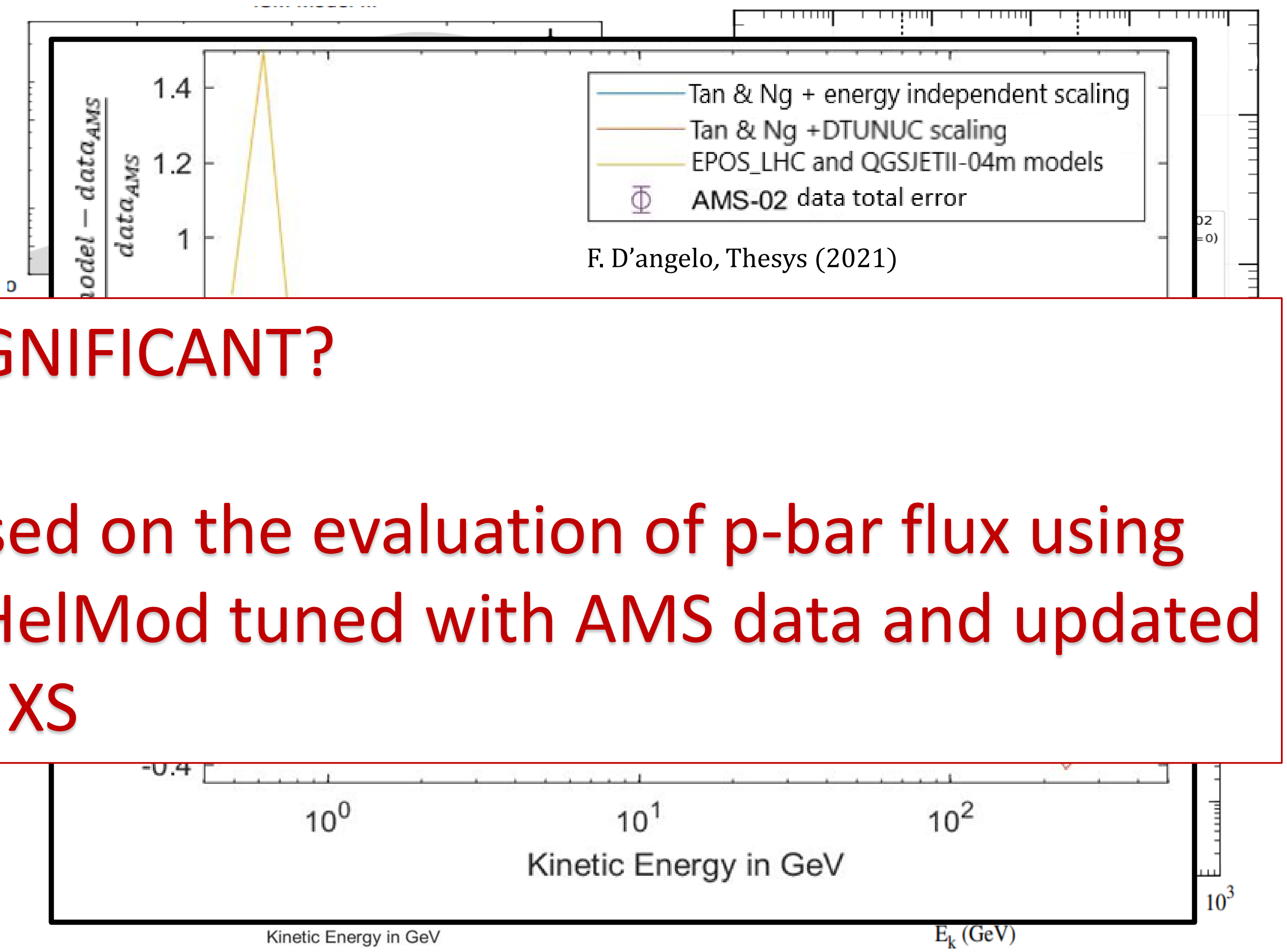

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- Phys. Rev. D 99, 103014 (2019)
- Phy
- arX
- Phy
- Phy
- Phy
- JCA
- PoS
- The (20

IS THE EXCESS SIGNIFICANT?

This topic is focused on the evaluation of p-bar flux using latest GALPROP-HelMod tuned with AMS data and updated p-bar production XS

Winkler parameterisation of $\bar{p}$ Production XS in pp channel

One of the most common parametrisation used in literature for the **pp channel** is the Winkler one (*JCAP02(2017)048)* that is composed by three parts:

1. A Tsallis distribution

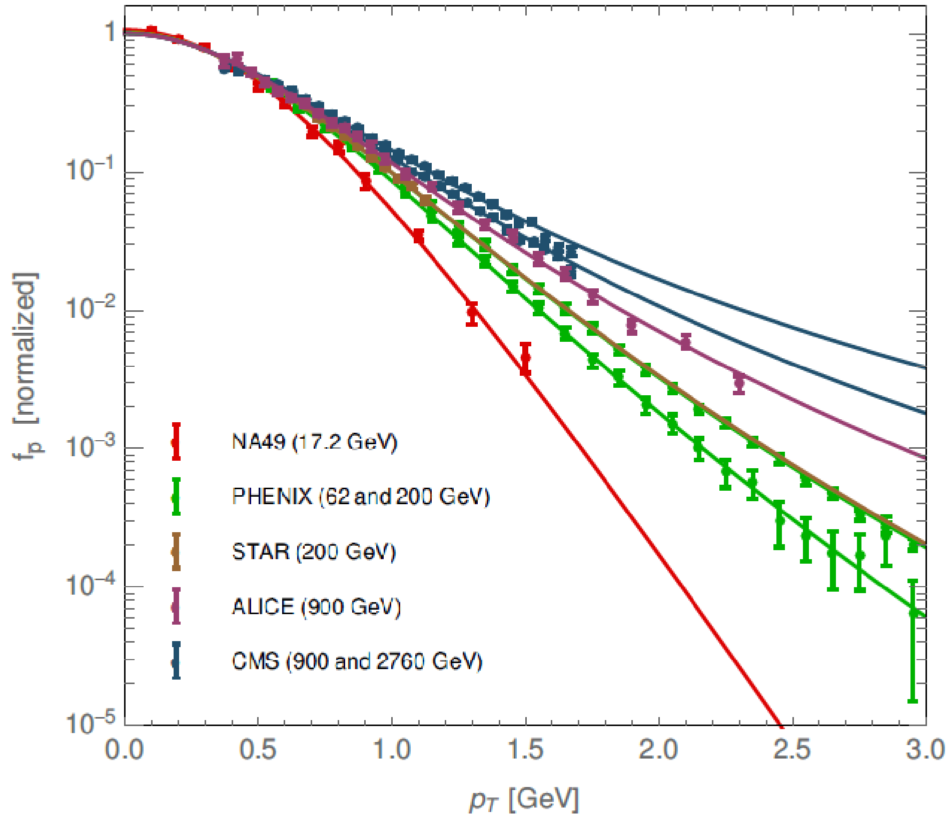
$$\sigma_{invariant}(\sqrt{s}, x_R, p_T) = \sigma_{inel} R \boldsymbol{C_1} (1 - x_R)^{\boldsymbol{C_2}} [1 + X(m_T - m_P)]^{-\frac{1}{\boldsymbol{C_3} X}}$$

2. A high energy modulation of the Tsallis distribution shape

$$X = \boldsymbol{C_4} log^2 \left(\frac{\sqrt{s}}{4m_p} \right)$$

3. A low energy scaling

$$R = \begin{cases} 1, & \sqrt{s} > 10\ GeV \\ [1 + \boldsymbol{C_5}(10 - \sqrt{s})^5] exp\left[\boldsymbol{C_6}(10 - \sqrt{s})(x_R - x_{R,min})^2\right], & \sqrt{s} < 10\ GeV \end{cases}$$



JCAP02(2017)048

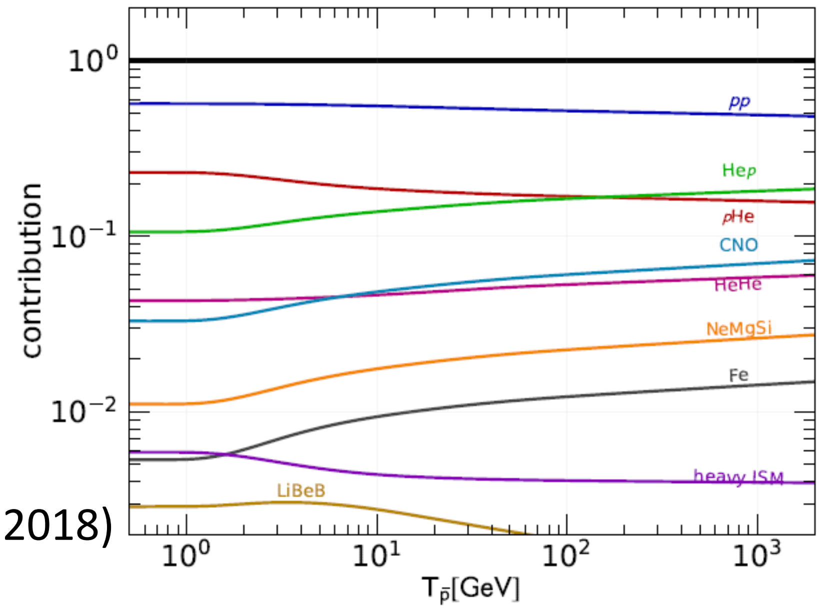
Winkler parameterisation extension to pA channel

Heavier channels are responsible of the 45% of the overall antiproton production.
The Winkler model has been extended to the general AA channel by Korsmeier-Donato-Di Mauro (KDD) (Phys. Rev. D 97, 103019 (2018)):

$$\sigma_{A_1 A_2} = f^{A_1 A_2} \sigma_{pp}$$

$$f^{A_1 A_2} = A_1^{D_1} A_2^{D_1} \left[A_1^{D_2} \left(1 + \frac{N_1}{A_1} \Delta_{iso} \right) F_{pro}(x_F) + A_2^{D_2} \left(1 + \frac{N_2}{A_2} \Delta_{iso} \right) F_{tar}(x_F) \right]$$

$A_1 = Number\ of\ nucleons\ in\ the\ projectile\ (CRs)$
$A_2 = Number\ of\ nucleons\ in\ the\ target\ (ISM)$
$N_1 = Number\ of\ neutrons\ in\ the\ projectile\ (CRs)$
$N_2 = Number\ of\ neutrons\ in\ the\ projectile\ (CRs)$
$\Delta_{iso} = Isospin\ Asymmetry\ in\ the\ \bar{p}$



Phys. Rev. D 97, 103019 (2018)

$\bar{p}$ cross section estimation

Previous work have been cross-checked.

A quite similar parameter set has been fitted with a new data strategy:

PARAMETER	WINKLER FIT	KDD FIT	THIS WORK
C1	0.047	0.0502 ± 0.0022	0.0527 ± 0.00155
C2	7.76	7.79 ± 0.077	7.918 ± 0.071
C3	0.168	0.1649 ± 0.0012	0.1668 ± 0.0012
C4	0.038 ± 0.00057	0.038 ± 0.00057(fixed)	0.0392 ± 0.000965
C5	0.001 ± 0.0004	0.000474 ± 0.000259	0.000474 ± 0.000259 (fixed)
C6	0.7 ± 0.04	3.70 ± 0.64	3.70 ± 0.64 (fixed)
Data used	Main: Na49 C4: Phenix, Star, Alice, Cms	Na49, Shine, Ps data	Na49, Shine, Star, Alice, Cms
D1	//	0.828 ± 0.012	0.838 ± 0.013
D2	//	0.145 ± 0.012	0.112 ± 0.013
Data used	//	SMOG (pHe), NA49 (pC)	SMOG (pHe), NA49 (pC)

$$\frac{\chi^2}{gdl} = 1.437$$

We used the KDD parameters

New data strategy

$$\frac{\chi^2}{gdl} = 1.644$$

The whole parameters have been fitted **together** on the NA49, NA61-SHINE, STAR, ALICE, SMOG and CMS data

$\bar{p}$ cross section estimation

The obtained correlation matrix is important for studying the impact of p-bar XS production on the p-bar measured flux:

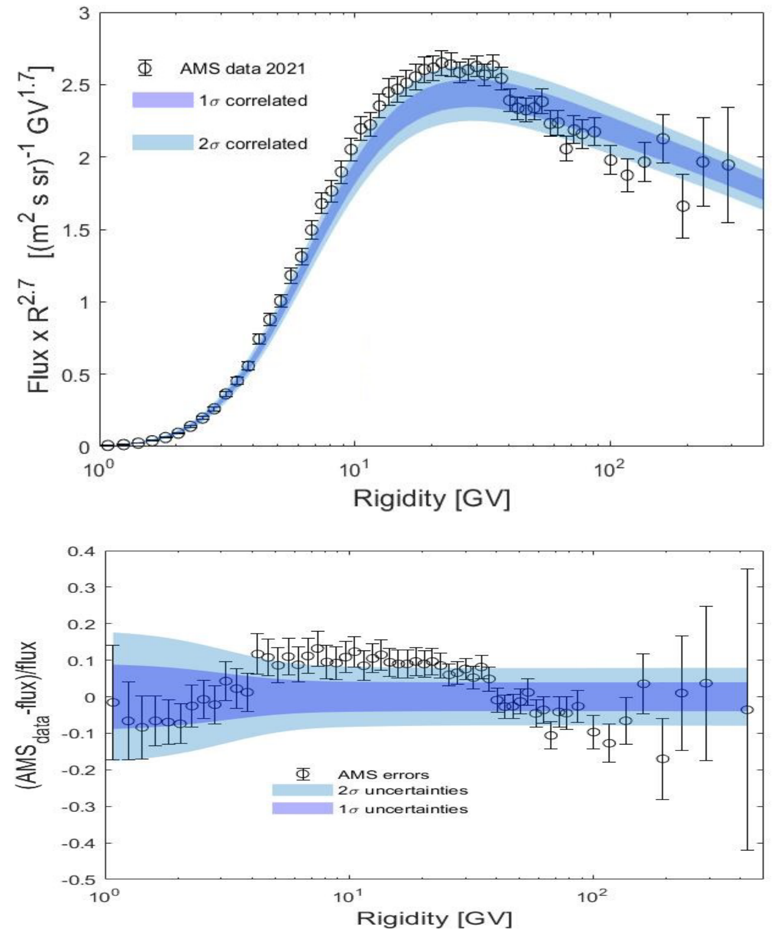
	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0.2	-0.19	0.051	0	0	0	0
C2	0.2	1	0.239	-0.216	0	0	0	0
C3	-0.19	0.239	1	-0.826	0	0	0	0
C4	0.051	-0.216	-0.826	1	0	0	0	0
C5	0	0	0	0	1	-0.127	0	0
C6	0	0	0	0	-0.127	1	0	0
C7	0	0	0	0	0	0	1	-0.526
C8	0	0	0	0	0	0	-0.526	1

Used the correlation found in the KDD paper

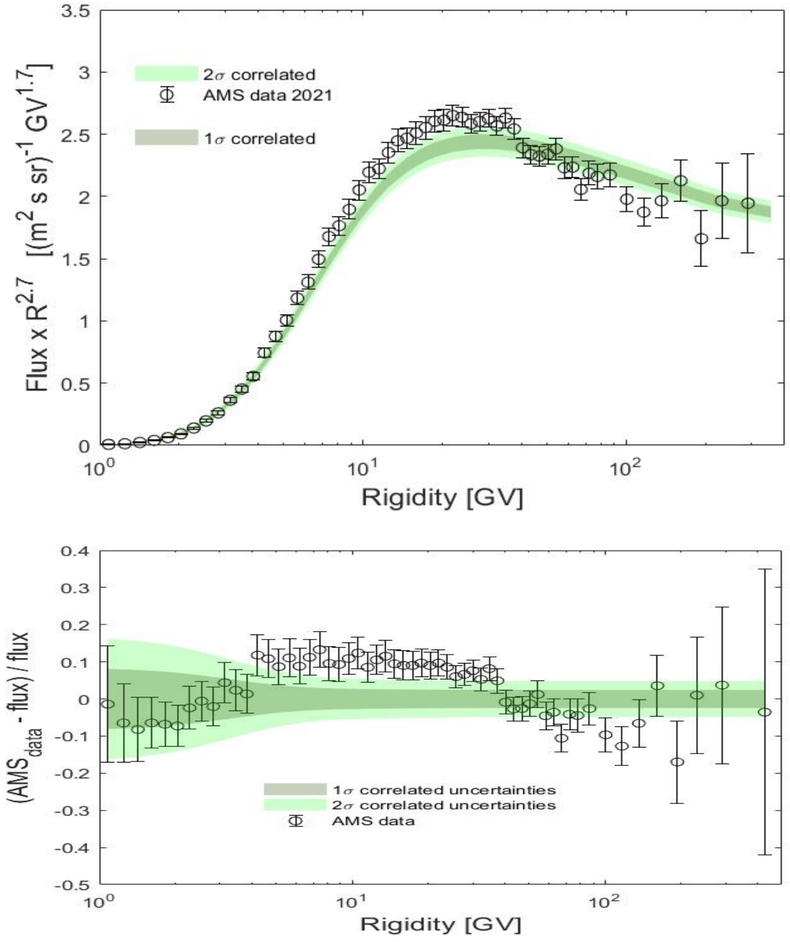
C5 and C6 are fixed in the fit procedure

Results

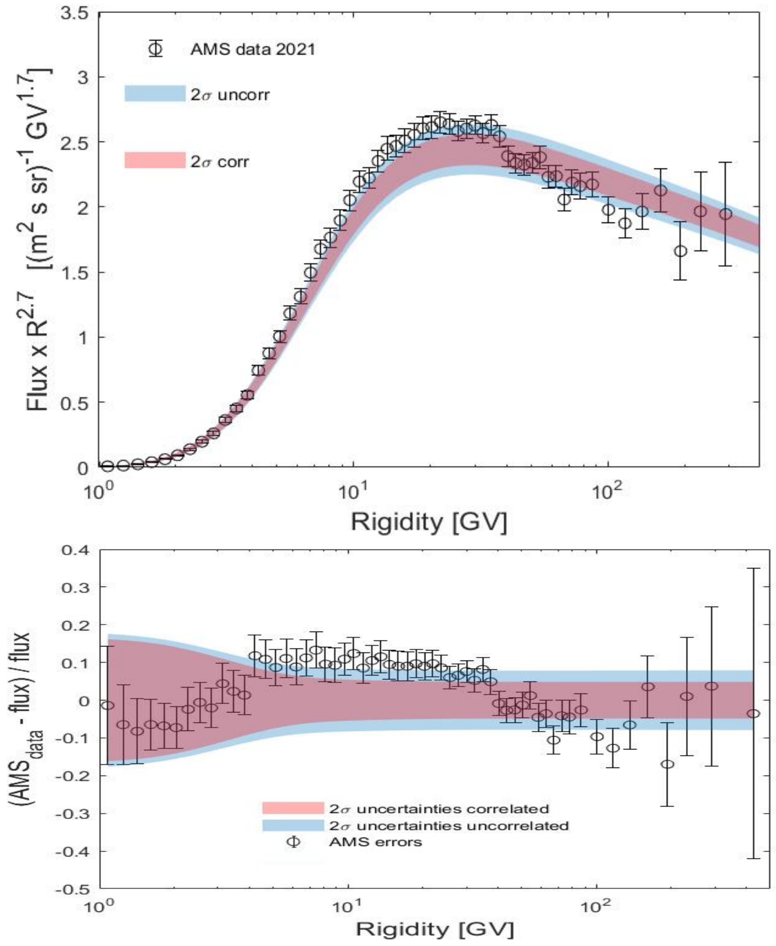
GALPROP/HelMod flux compared with AMS data. Uncertainties connected to GALPROP tuning are not considered in this work.



Uncorrelated nuclear uncertainties

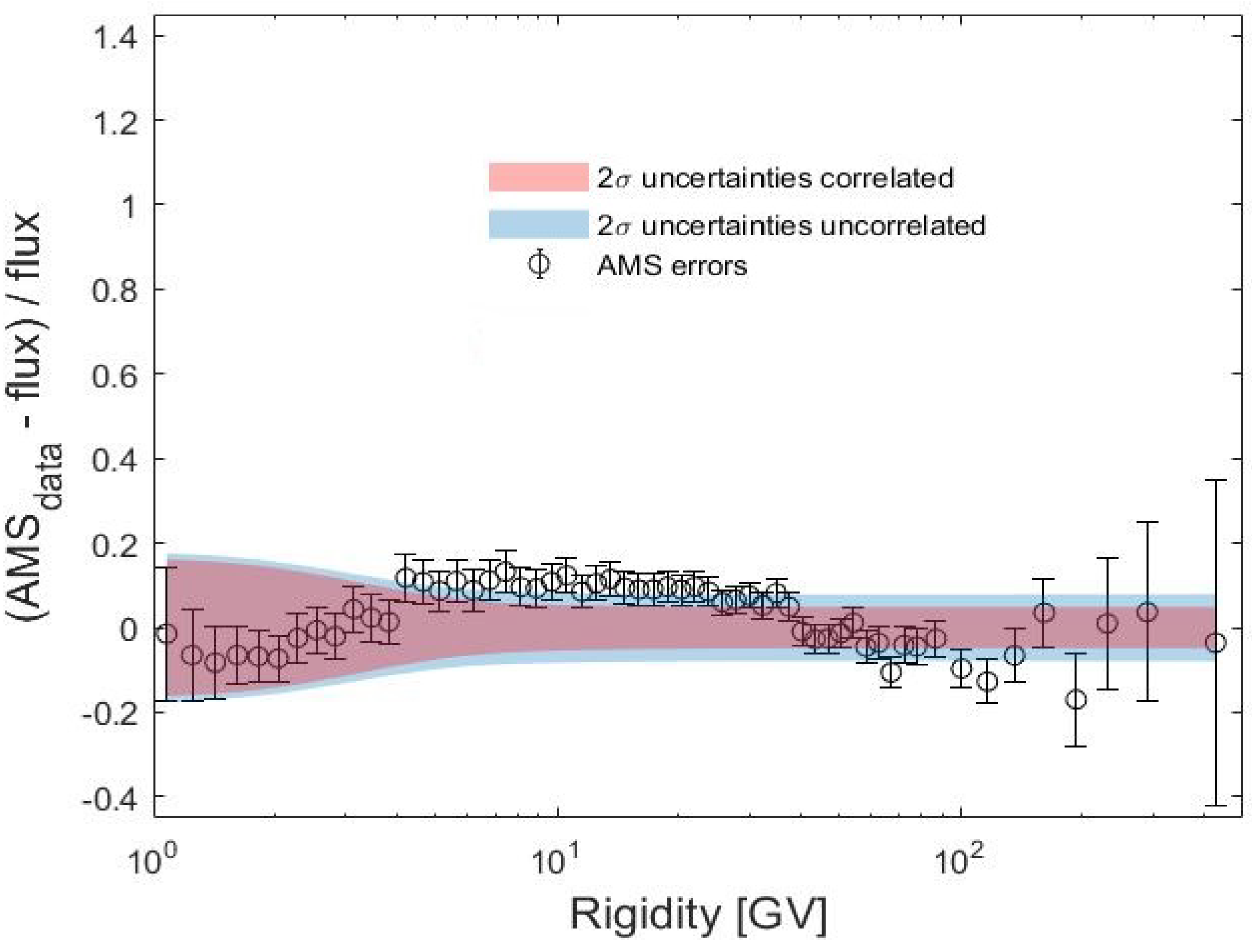


Correlated nuclear uncertainties

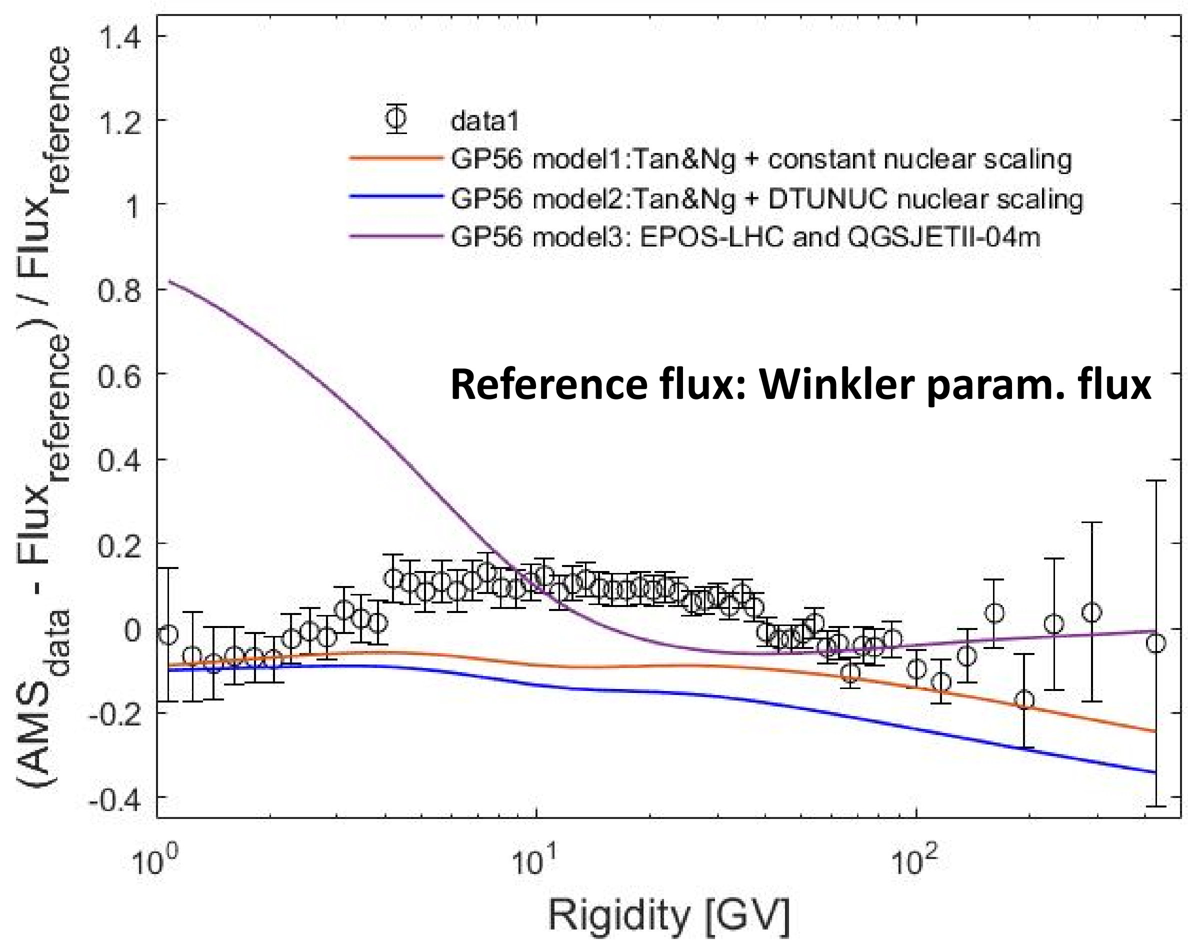


Correlated vs Uncorrelated

Results



2σ uncertainties correlated
2σ uncertainties uncorrelated
AMS errors
(AMS_data - flux) / flux
Rigidity [GV]



data1
GP56 model1:Tan&Ng + constant nuclear scaling
GP56 model2:Tan&Ng + DTUNUC nuclear scaling
GP56 model3: EPOS-LHC and QGSJETII-04m
Reference flux: Winkler param. flux
(AMS_data - Flux_reference) / Flux_reference
Rigidity [GV]

Conclusions

I. p-bar production cross section parameterisation studied and extended to a more complete dataset

II. correlations on the p-bar production cross section parameterisation have been propagated to the p-bar flux estimation using latest GALPROP-Helmod model tuned with AMS data.

III. a discrepancy has been observed at 10 GeV/n with a low significance.

Future Work:

❖ use p-bar model + coalescence to calculate anti-matter secondary production