The p-He cross section measurement: a physics case from cosmic rays Workshop
Torino, 6-7 July 2015

Proposal to use the LHCb-SMOG detector to measure the antiproton production in p-He at LHC

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Basic ideas

- Secondary anti-protons that we find in Cosmic Rays outside the Earth atmosphere are produced mainly in interactions between primary protons and α-particles and the inter-stellar gas (mainly H and He)
- The anti-proton energy of interest for current studies is of the order of 10-100 GeV
- The corresponding energy of the primary interacting protons which produce anti-protons in this energy range is roughly 10 times greater, i.e. up to a few TeV (interaction with H or He at rest)

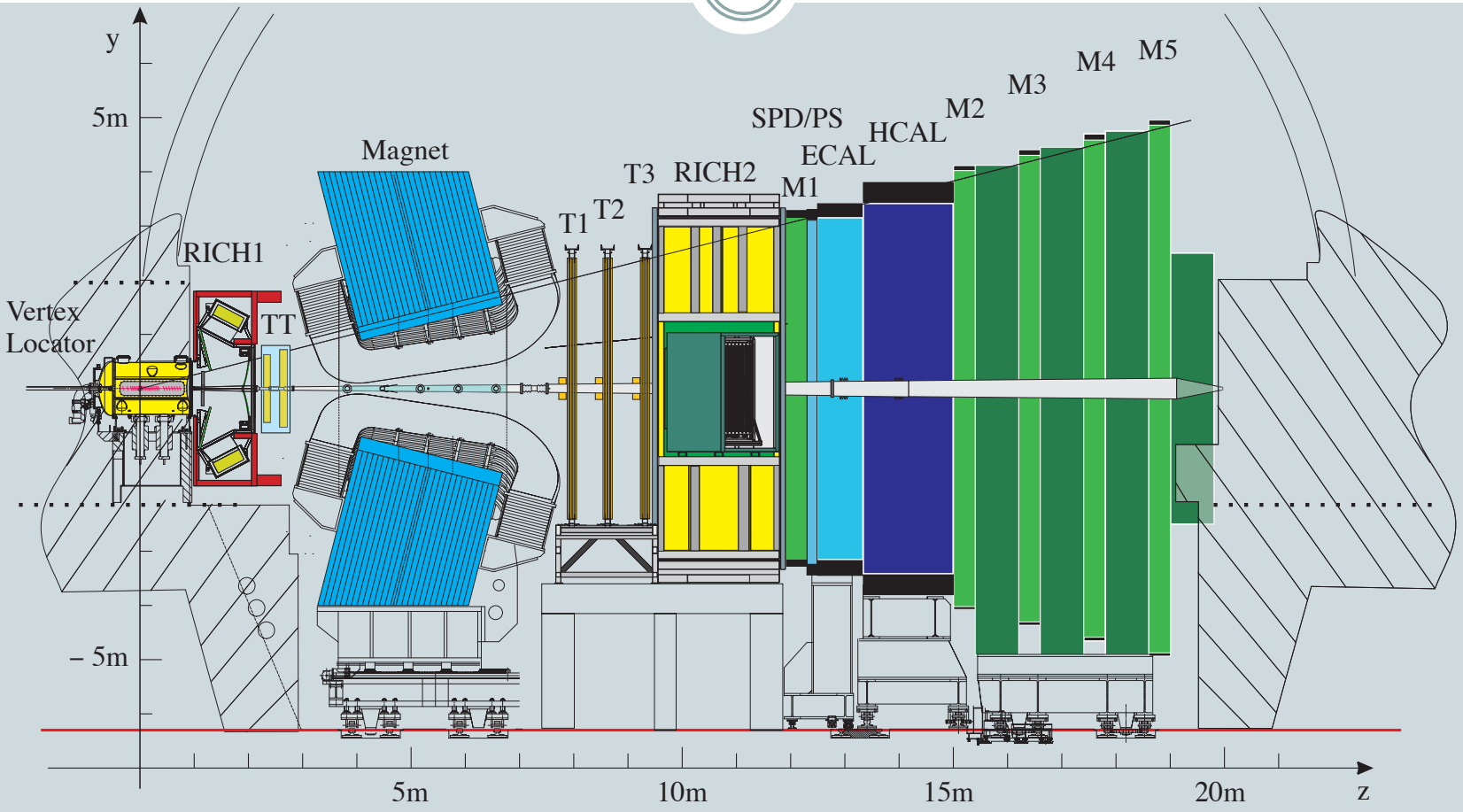
- Proposal: use the SMOG-LHCb system to inject He at rest at IP8 to measure the anti-proton production cross section for the

p(6.5TeV) – He(rest)

Disclaimer

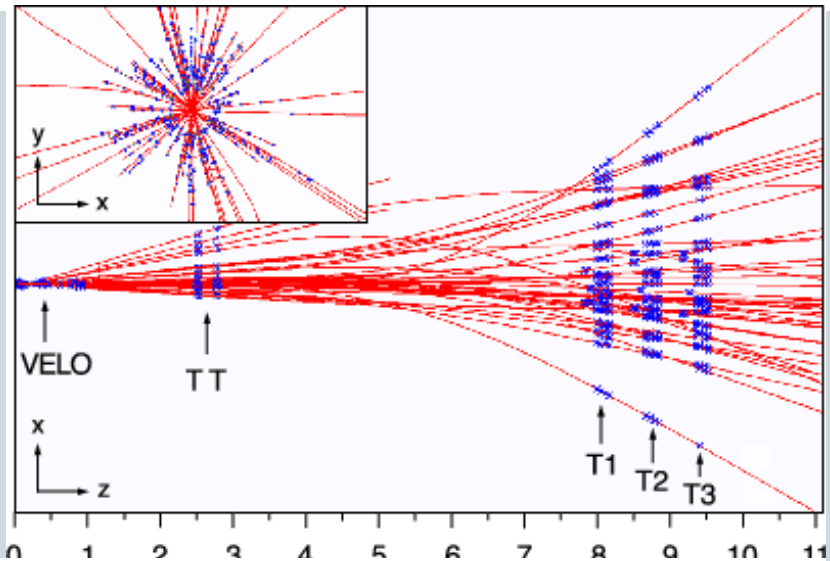
- We are not members of the LHCb Collaboration so information used in our simulations come from “private” discussion with LHCb people
- We have formally presented our proposal to the Collaboration and we are waiting feedback about feasibility from the LHCb Management

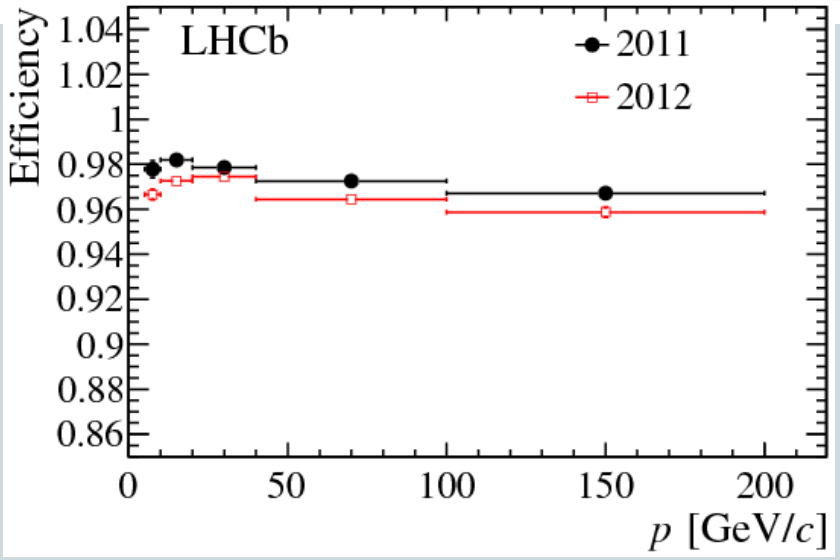
The LHCb detector

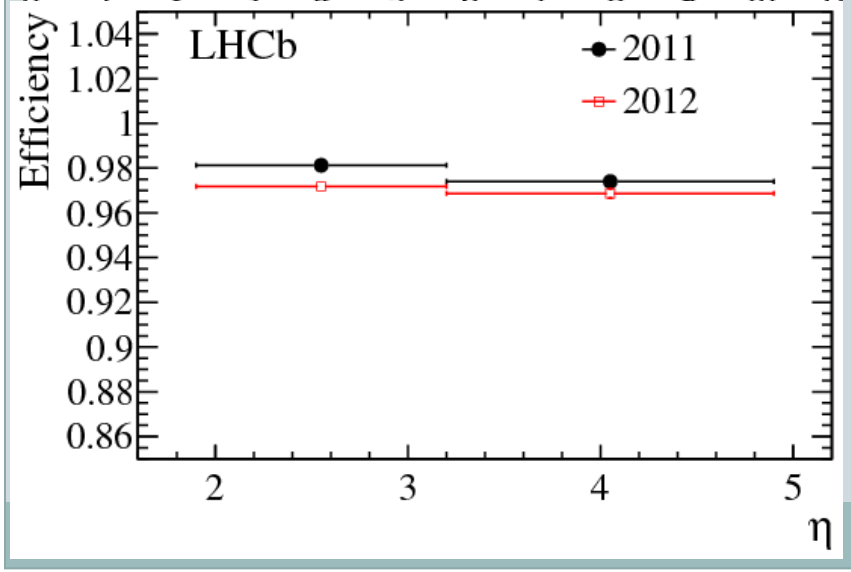


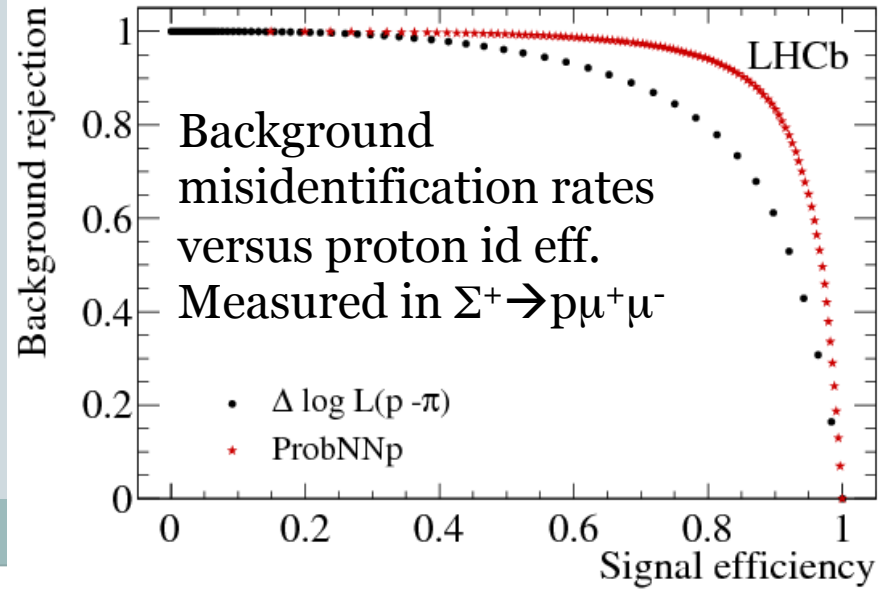
LHCb PID

Int. J. Mod. Phys. A 30 (2015) 1530022

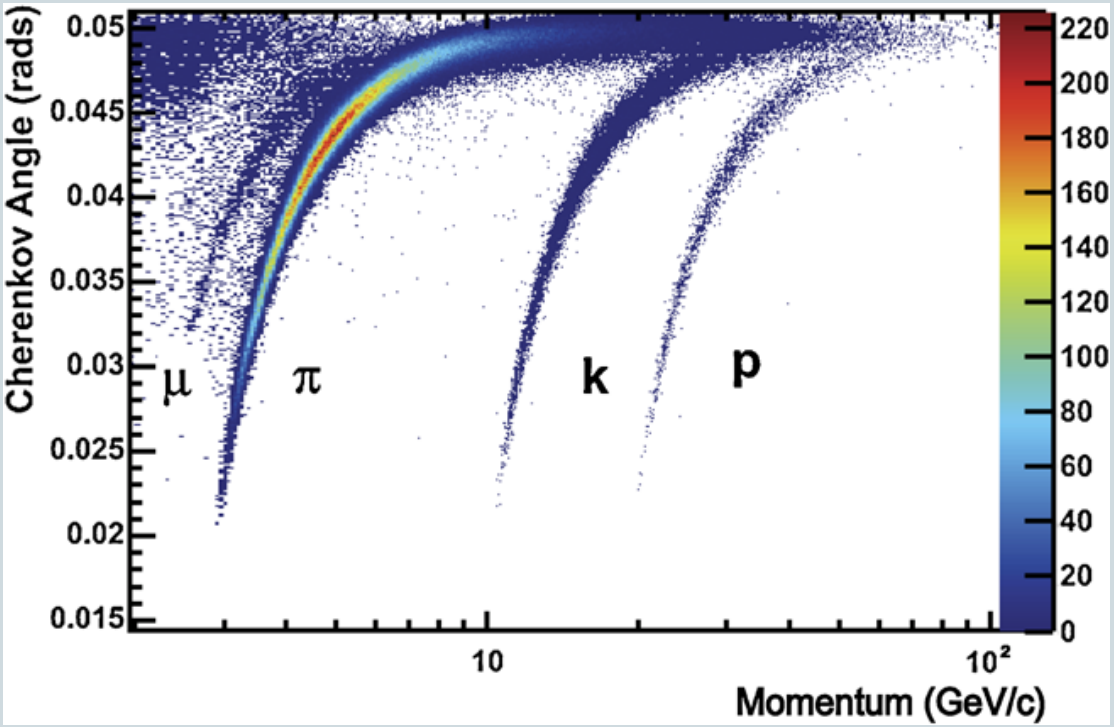


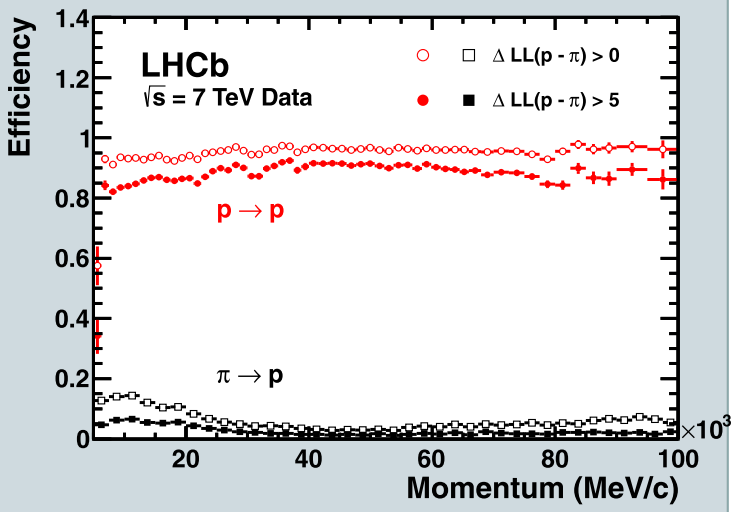


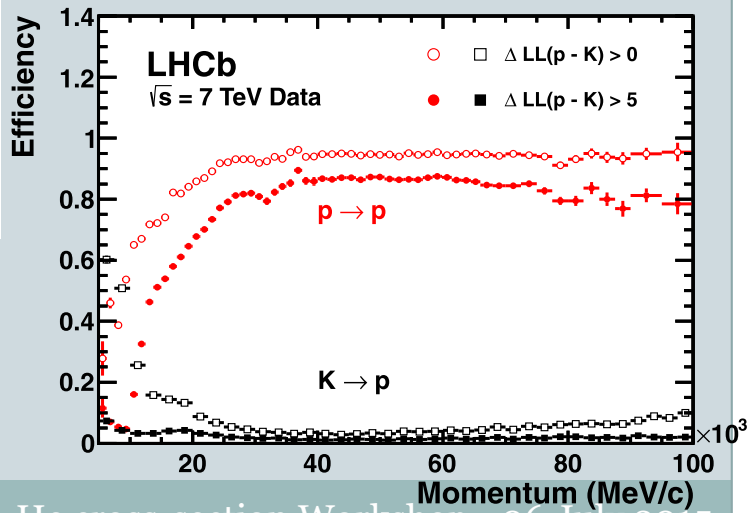




LHCb RICH performances



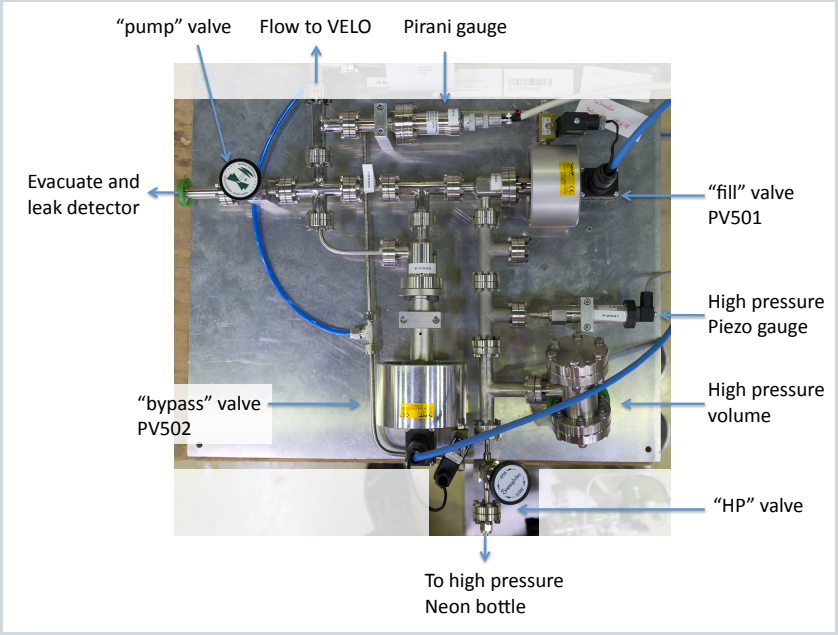




Eur. Phys. J. C (2013) 73:2431

The SMOG system

- SMOG: System to Measure the Overlap integral with Gas
  - It is part of the luminosity measuring system of LHCb
  - LHCb can measure the luminosity both with Van Der Meer scan and with the Beam Gas Imaging system
    - Measure interaction vertices between the circulating beam and the residual gas present at the interaction point
  - SMOG is a small system used to inject gas inside the beam pipe at IP8 to measure the luminosity with BGI method

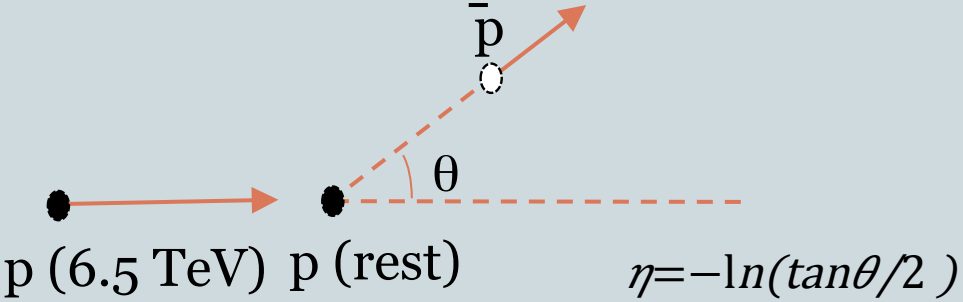


Proposal to use SMOG

- From the basic idea (O. Adriani, NPQCD 2015 Meeting, Cortona, 20-22 April 2015) to our proposal
  - use SMOG to inject He gas
    - Is it feasible? Can He be used?
  - use LHC p(6.5 TeV) beam to study p+He reaction
  - use high-performance particle ID by LHCb to study anti-proton production
    - Is the rate reasonable enough?
    - How much data taking should last?
    - Is the LHCb detector able to measure anti-p in the interesting range?
- *We started to address some question with a rough and preliminary simulation study*

Preliminary simulation studies

- Rough estimate of cross-section
- Is LHCb acceptance likely to be adequate?



- First studies done with Pythia 8.205
  - 10^7 p-p collision simulated with SoftQCD:All
  - $\sqrt{s}$ = 110.5 GeV
  - Detector acceptance cuts introduced according to information provided by G. Passaleva
    - $2.5 \leq \eta \leq 4.5$
    - p > 10 GeV/c (to allow PID)

Some numbers and global results

INPUT

$\sigma_{pp}^{tot} = 47\ mb$

$L = 6x10^{27}\ cm^{-2}\ s^{-1}$

is assumed (a better estimation can be provided by the LHCb collaboration)

$N_{int} = 10^7$ *(simulated)*

ESTIMATED

DAQ time (eff=1) ~ 10h

PYTHIA OUTPUT: TOTAL

$N_p\ (tot) = 3.4\ x\ 10^6$

$\sigma_{pp} \rightarrow p\ X(tot) = 0.27\ x\ 47\ mb \approx 13\ mb$

(Average multiplicity = 0.34 *p* / ev)

PYTHIA OUTPUT: AFTER CUTS

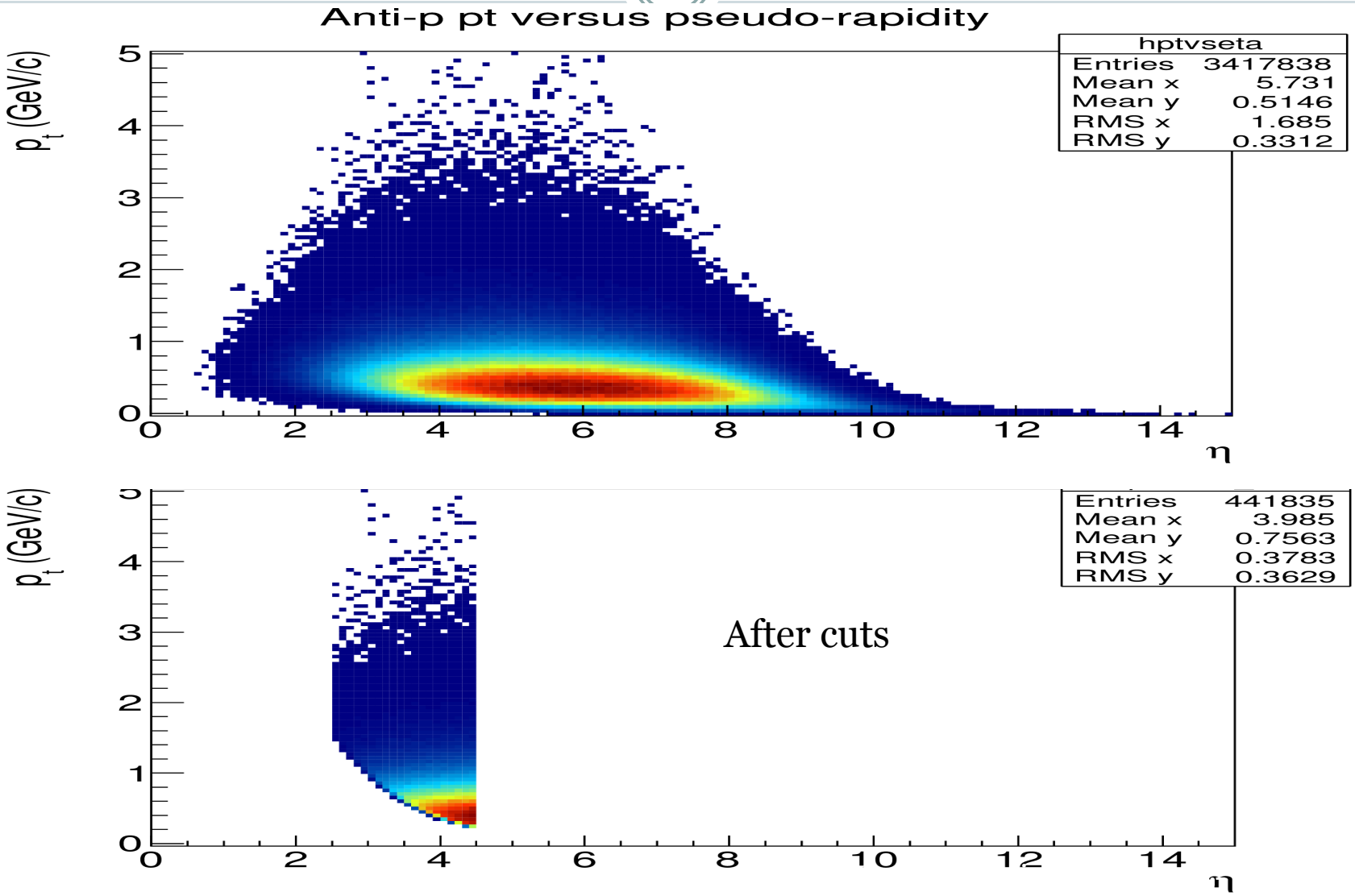
$N_p\ (acc) = 4.4\ x\ 10^5 \rightarrow$ Integral acceptance = 13 %

$\sigma_{pp} \rightarrow p\ X(acc) = 0.043\ x\ 47\ mb \approx 2\ mb$

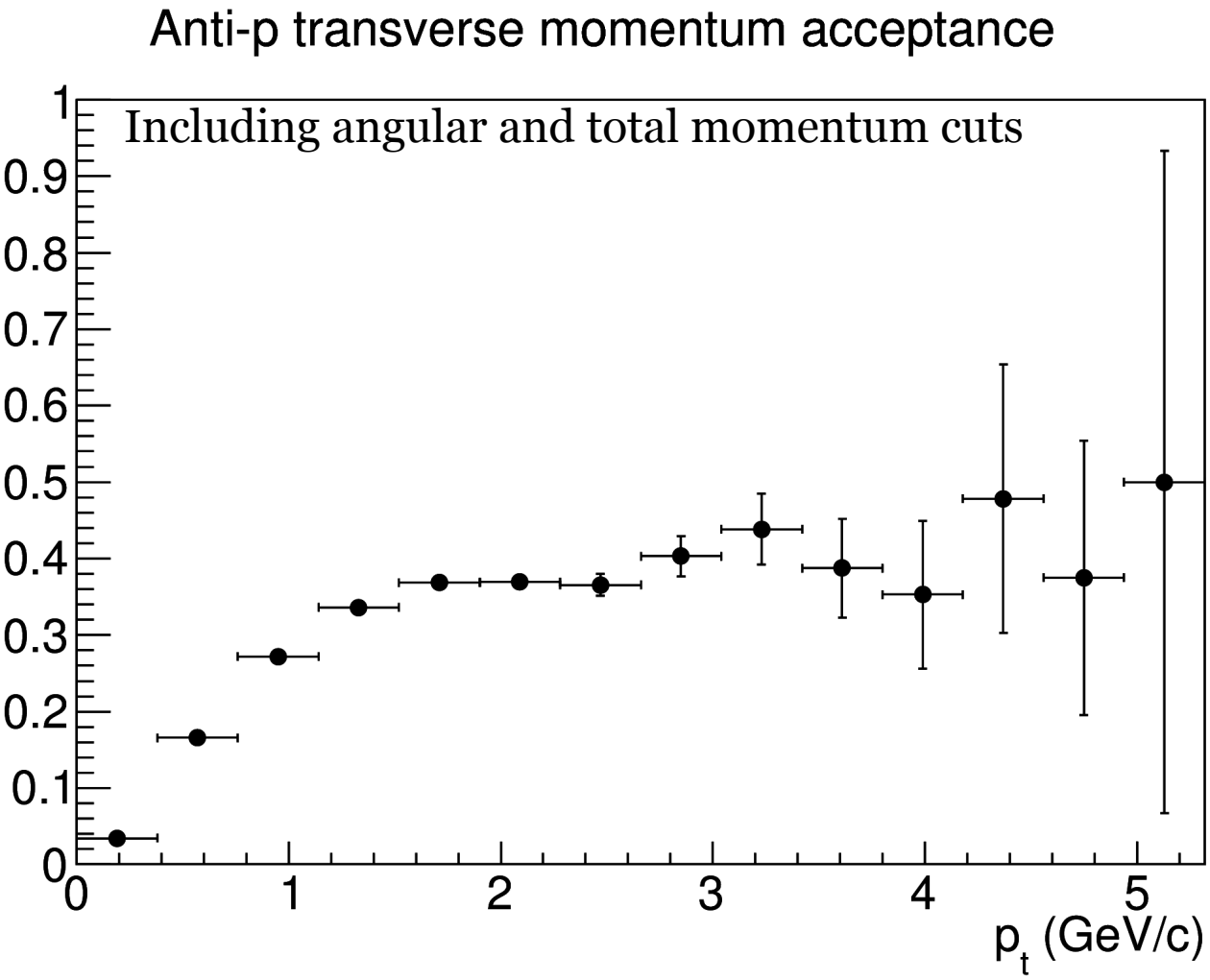
(Average multiplicity = 0.044 *p* passing cuts / ev)

Then we expect an increase of roughly a factor 4 in p-He with respect to p-p. Simulations for p-He will be implemented using other models.

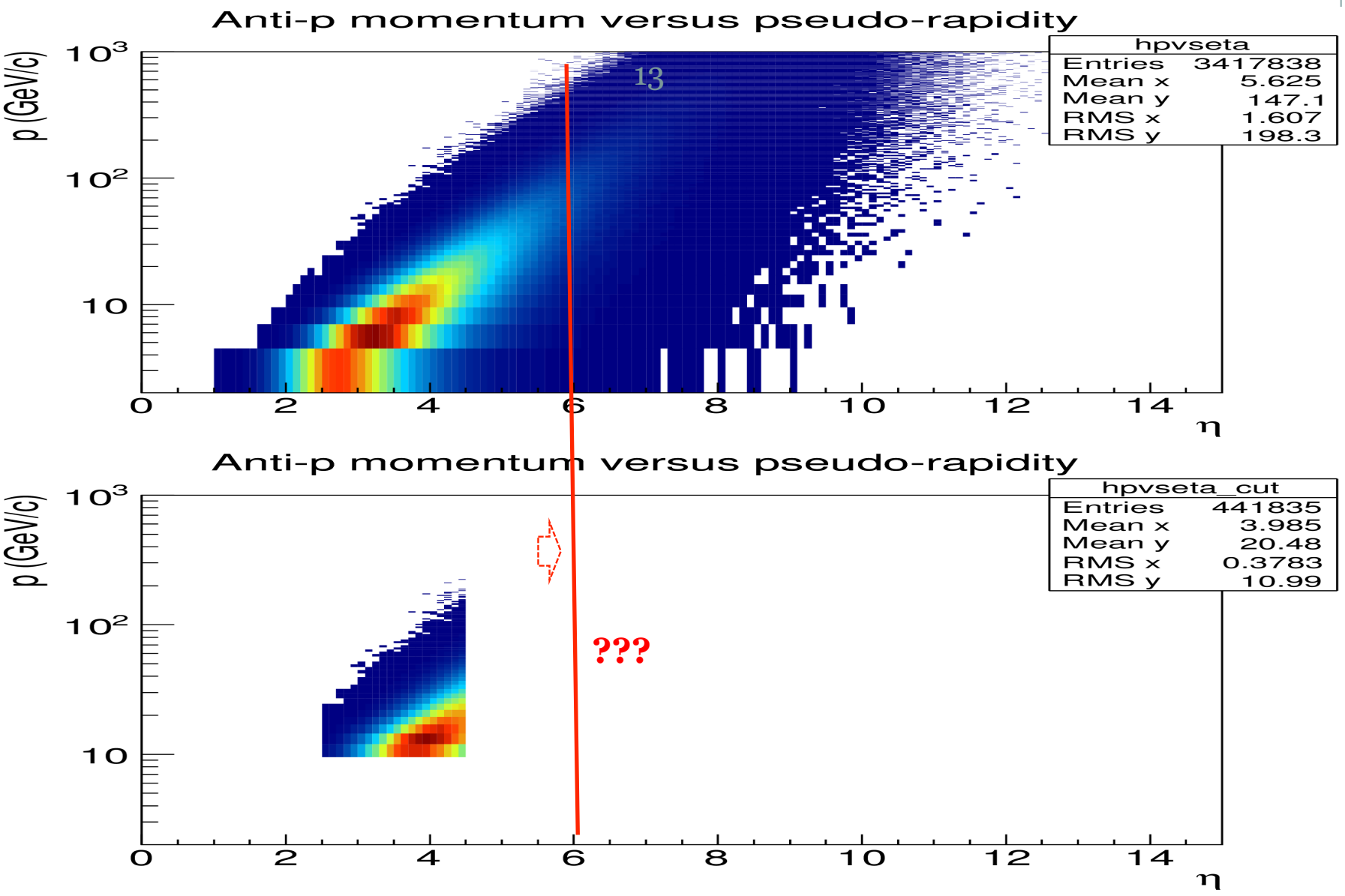
Detector acceptance (p_t vs η)



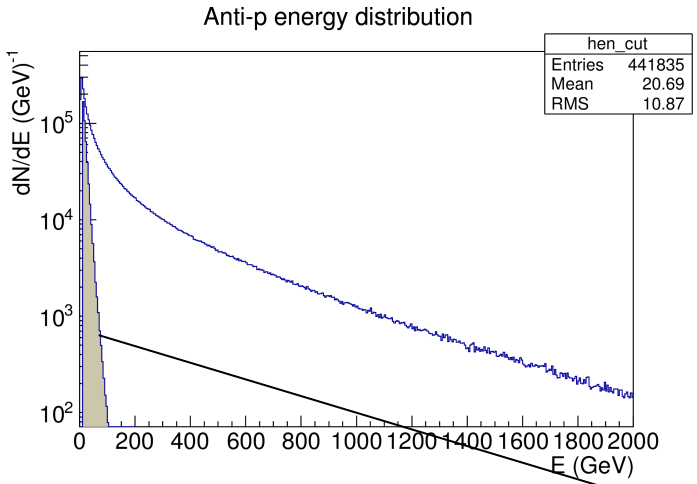
Acceptance in p_t

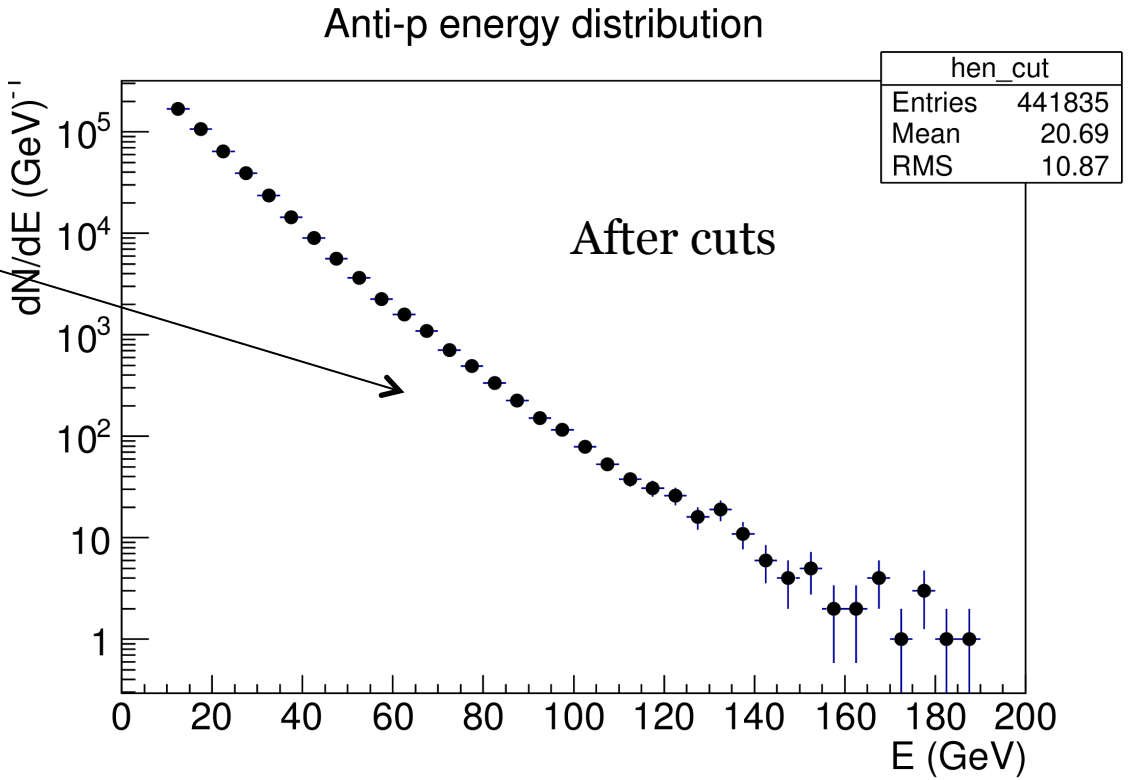


Detector acceptance (p vs η)

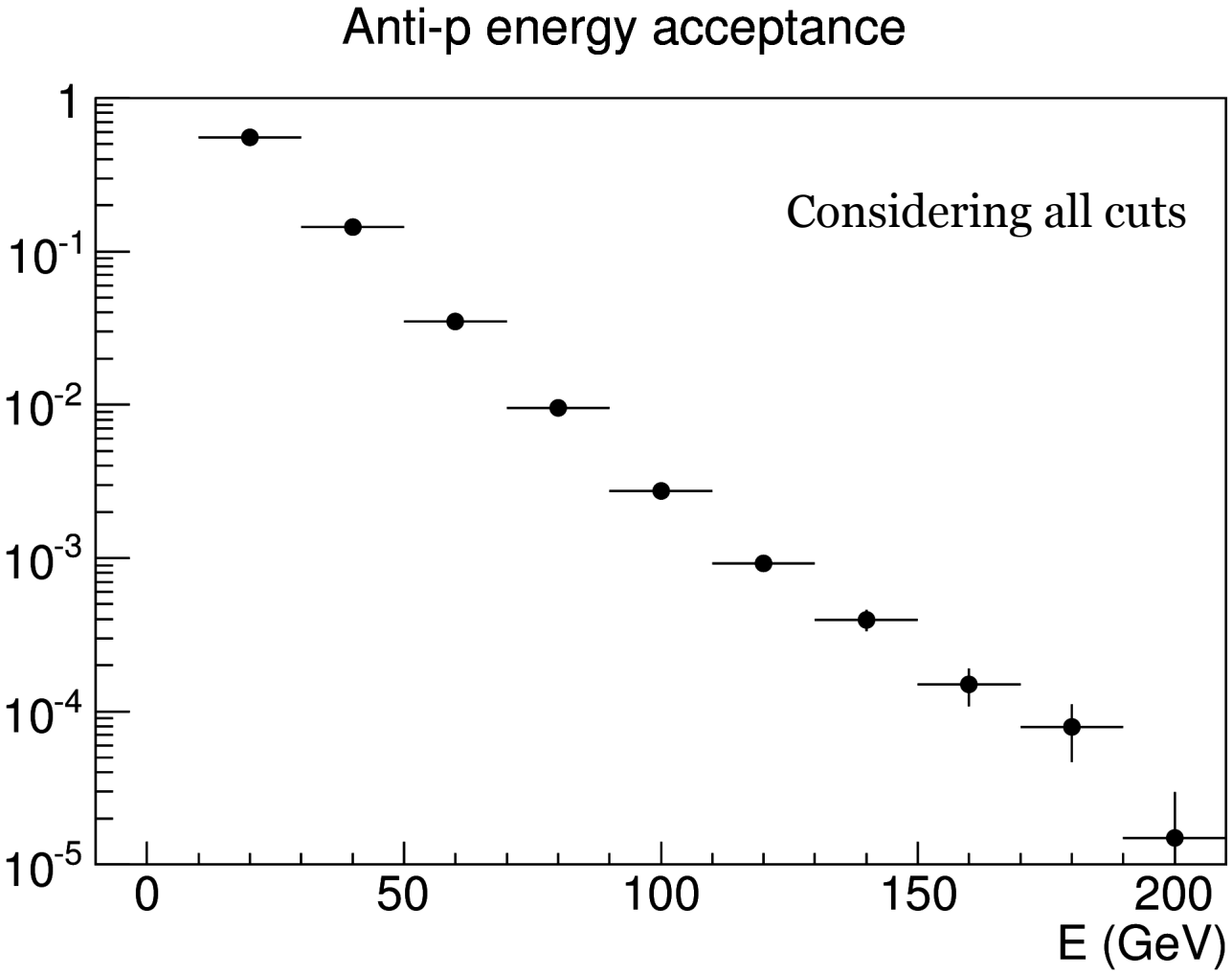


Pbar energy spectra

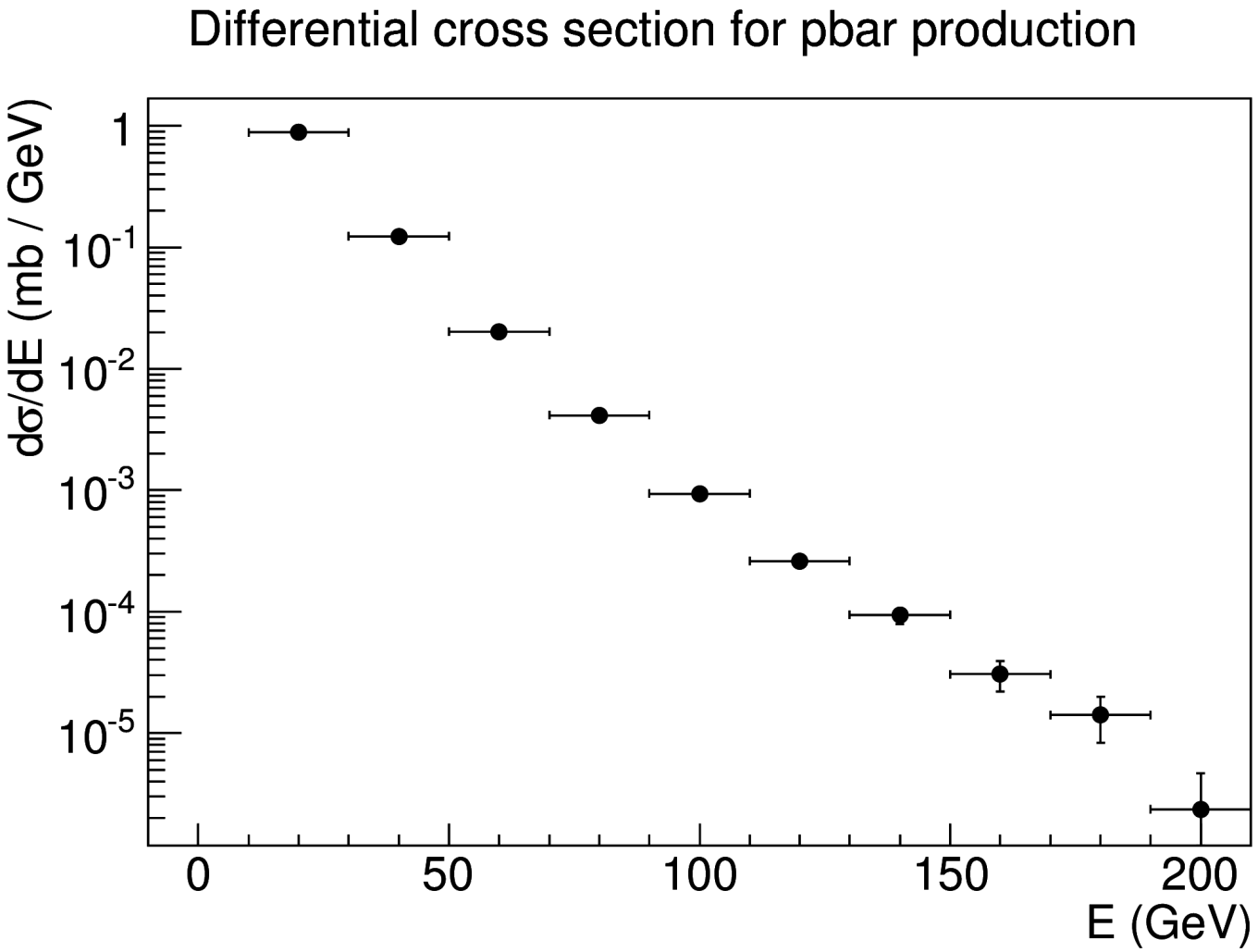




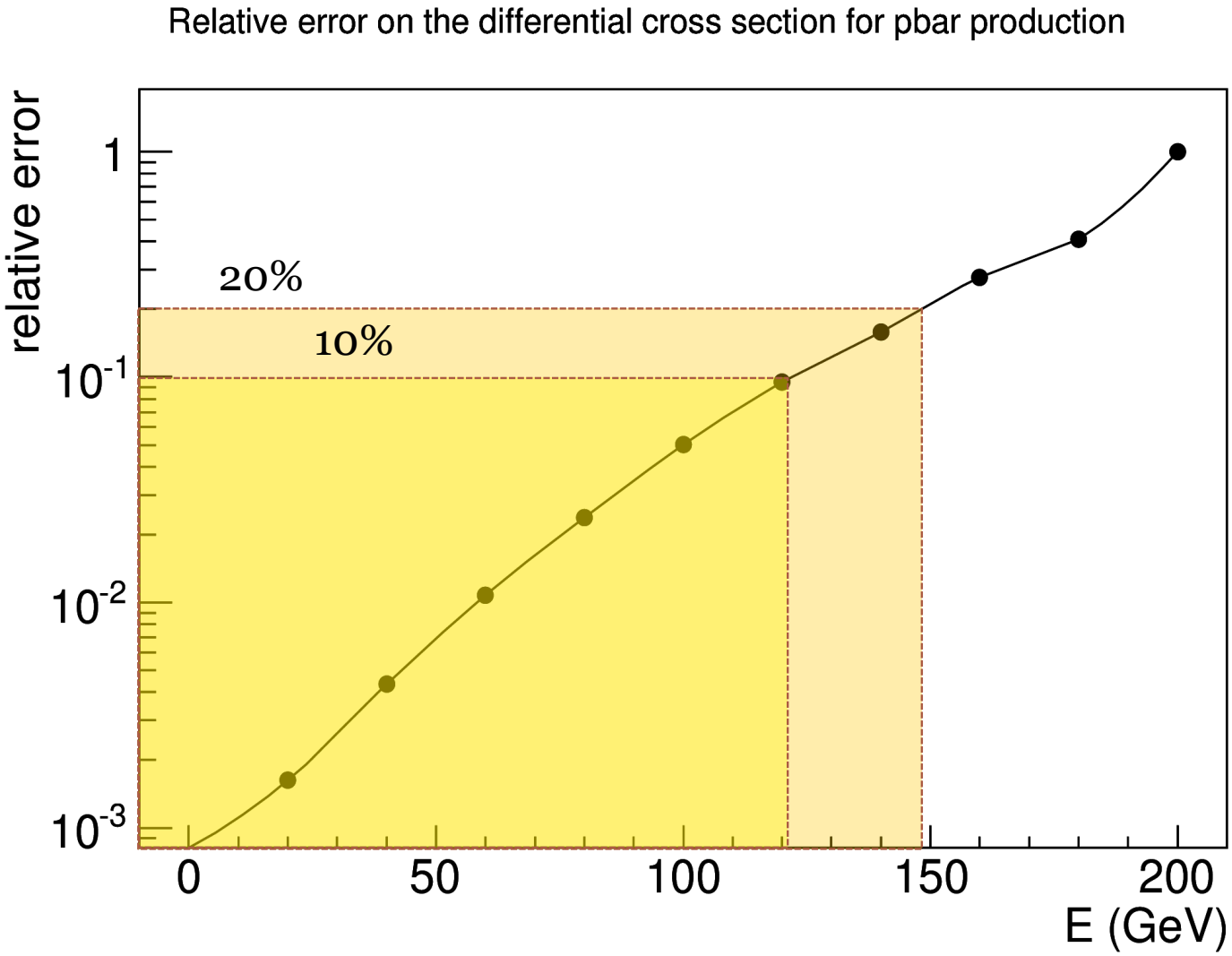
Antiproton detection efficiency (E)



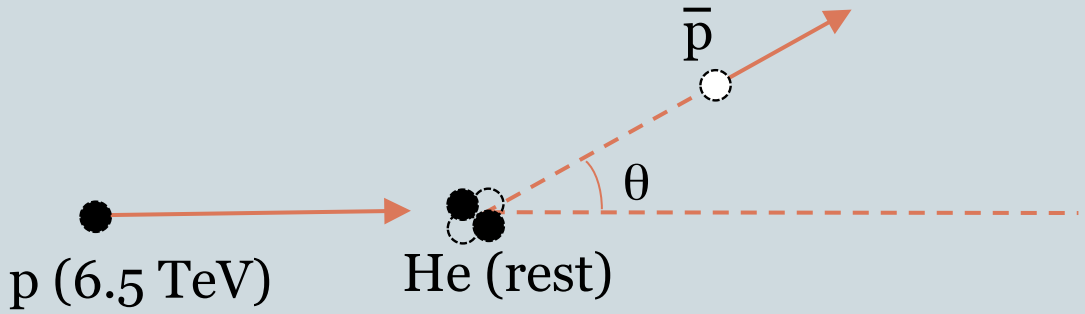
Measurement of differential cross section in E



Statistical uncertainties

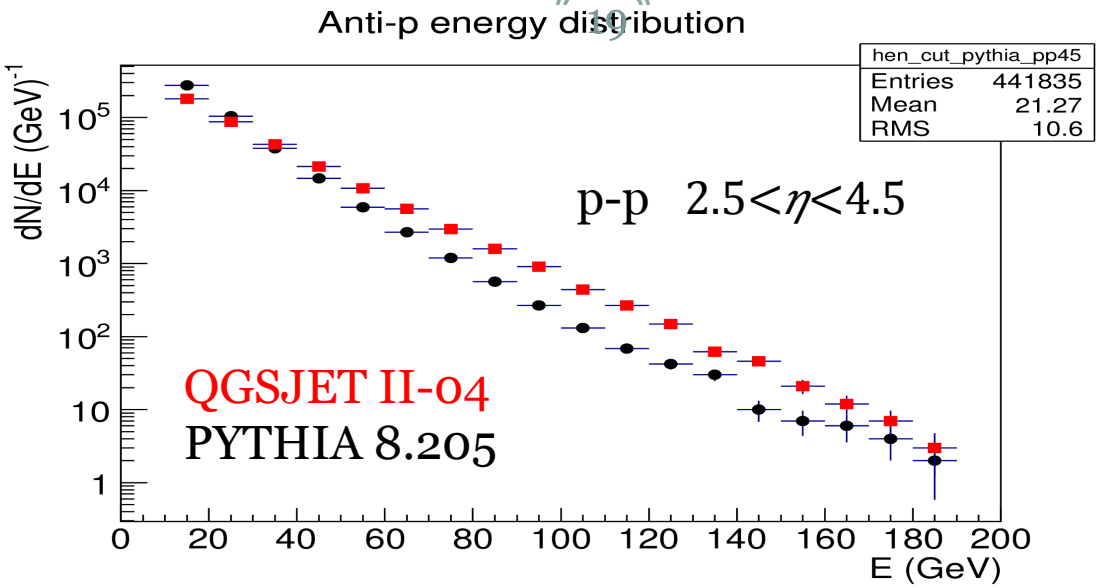


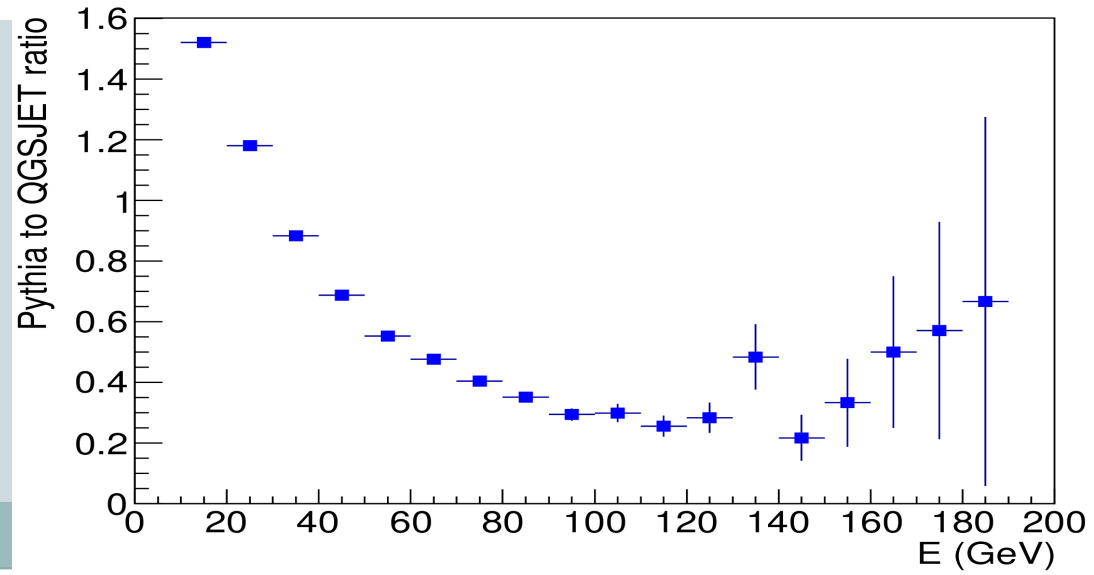
Preliminary simulation of p-He



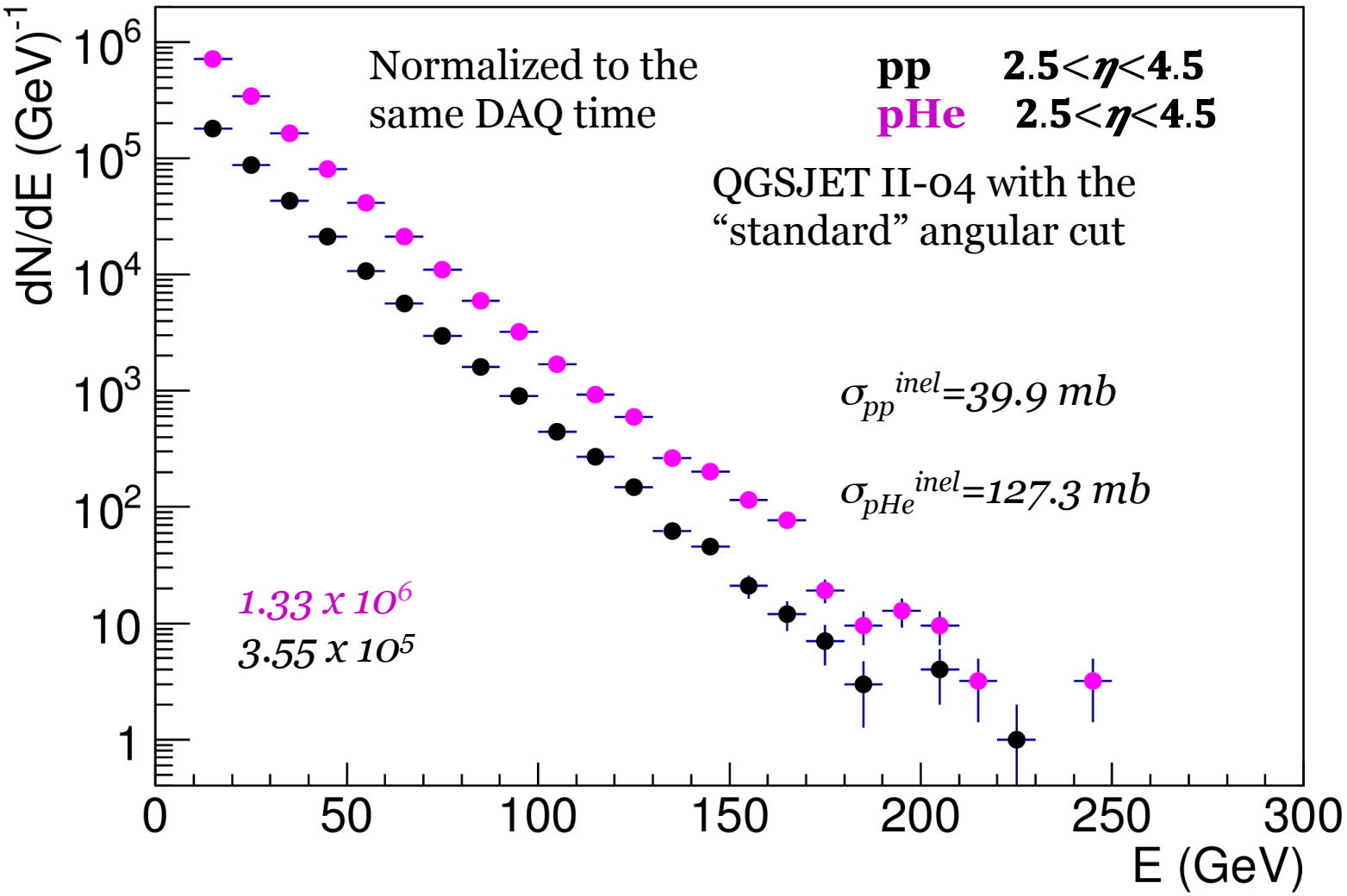
- First results based on QGSJET II-04 with CRMC 1.5.3
- No flags/cards modified: default simulation
- Simulated 10^7 interactions
- Same cuts?
  - Cut in acceptance: $2.5 \leq \eta \leq 4.5$ or maybe possible up to 6?
  - Cut in momentum: $p > 10$ GeV/c (to allow PID)

Comparison: Pythia 8.205 vs QGSJET II-04

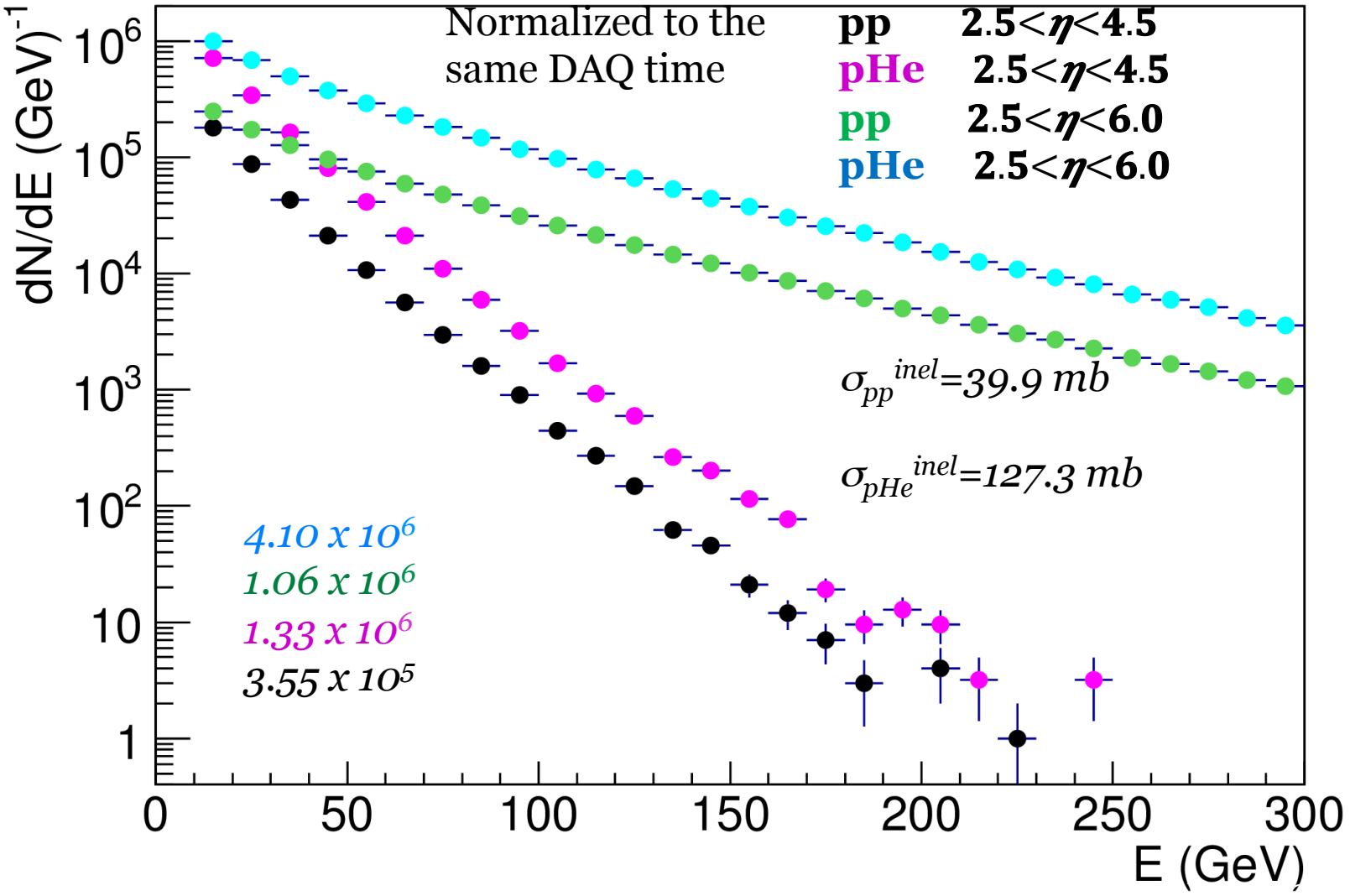




p-p vs p-He spectra



p-p vs p-He: possible extension of the pseudo-rapidity coverage (?)



Summary

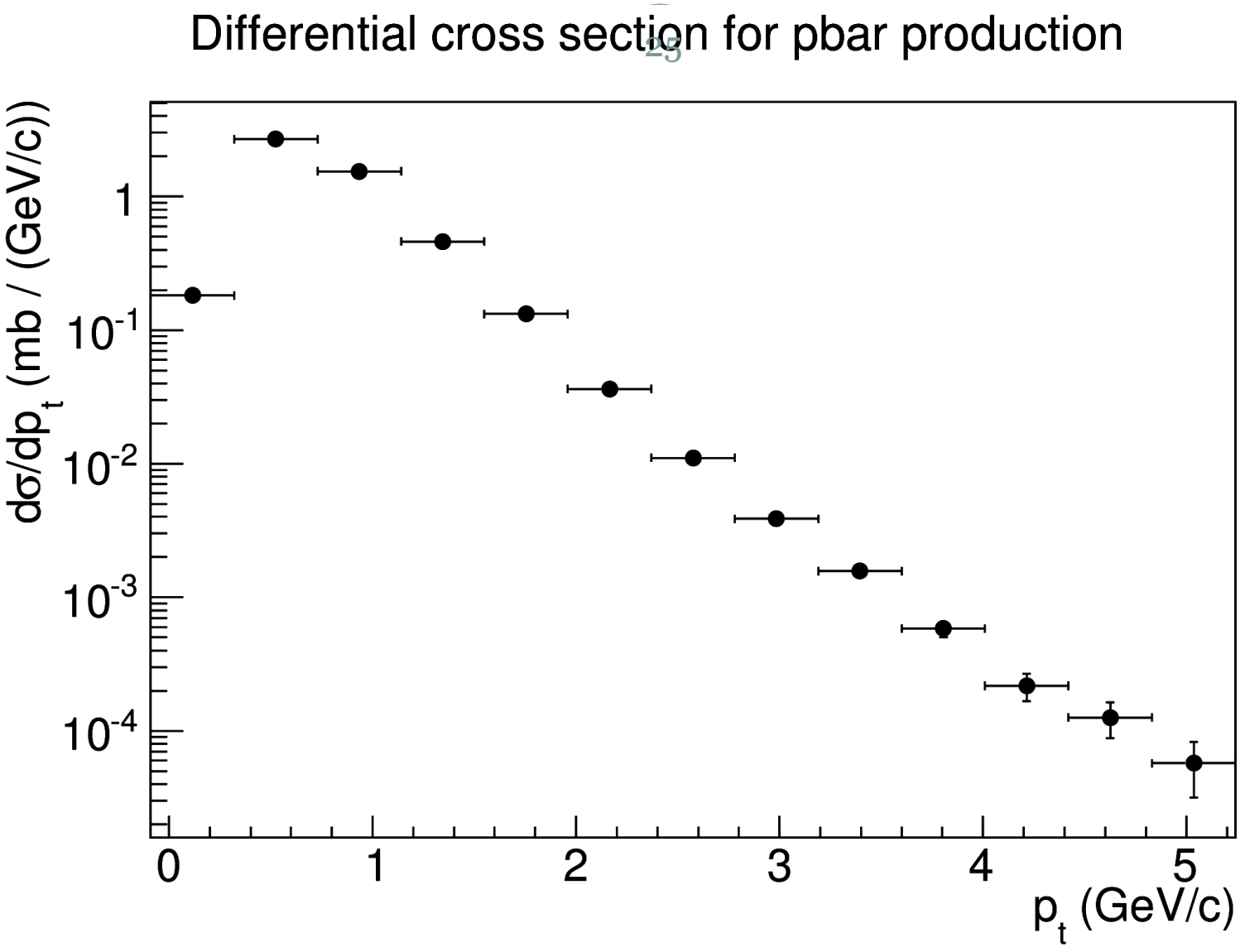
- The possibility to measure the p-He differential cross section with SMOG-LHCb is really an excellent chance to improve the precision of calculations of the expected secondary pbar spectra in CR
- The measurement looks to be feasible in a reasonable time from preliminary simulations using the Pythia 8.205 and QGSJET II-04 models
- Several technical items should be addressed by LHCb before final claiming of feasibility
  - Is He injectable?
  - How well the gas pressure can be measured? → this impact on the cross-section precision
- Possible additional or future measurements can be studied
  - Identification and measurements of gamma and positrons in the p-He collisions?
  - pbar production in the standard p-p collision?
  - pbar production in p-H collisions?

Some references

1. *A new evaluation of the antiproton production cross section for cosmic ray studies*, M. di Mauro, F. Donato, A. Goudelis, P.D.Serpico, **Phys.Rev. D90 (2014) 085017, arXiv:1408.0288 [hep-ph]**
2. *Antiprotons from spallations of cosmic rays on interstellar matter*, F. Donato, D. Maurin, P. Salati, A. Barrau, G. Boudoul, R. Taillet, THE ASTROPHYSICAL JOURNAL, 563 : 172-184, 2001 December 10 **arXiv:astro-ph/0103150**
3. *Parametrization of the antiproton inclusive production cross section on nuclei*, R.P. Duperray, C.-Y. Huang, K.V. Protasov, M. Buénerd, **Physical Review D, vol. 68, Issue 9, id. 094017**
4. F. Donato et al., **PRL 102, 071301 (2009)**
5. *AMS-02 antiprotons, at last! Secondary astrophysical component and immediate implications for Dark Matter,* G. Giesen et al., **http://arxiv.org/pdf/1504.04276.pdf**
6. *Secondary antiprotons as a Galactic Dark Matter probe*, C. Evoli, D. Gaggero, D. Grasso, **http://arxiv.org/pdf/1504.05175v1.pdf**

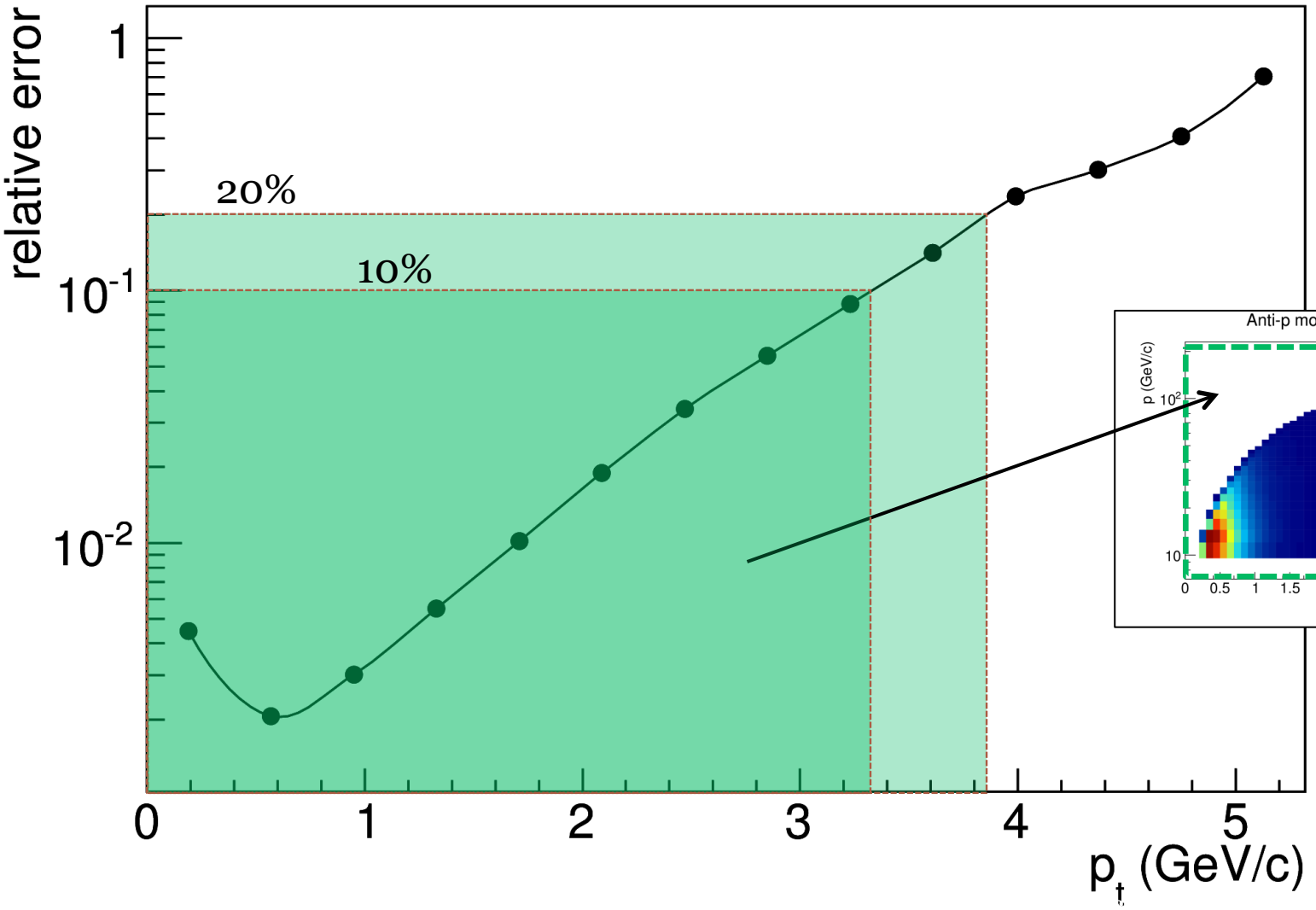
Backups

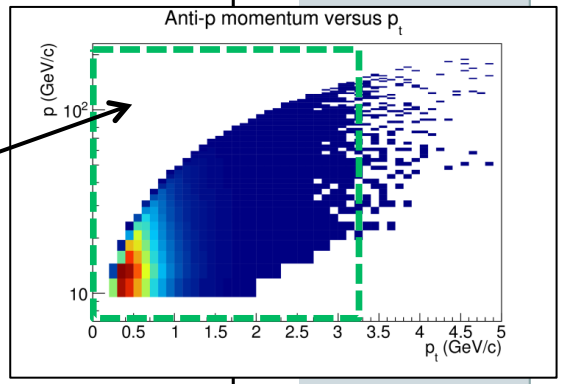
Measurement of differential cross section in p_t



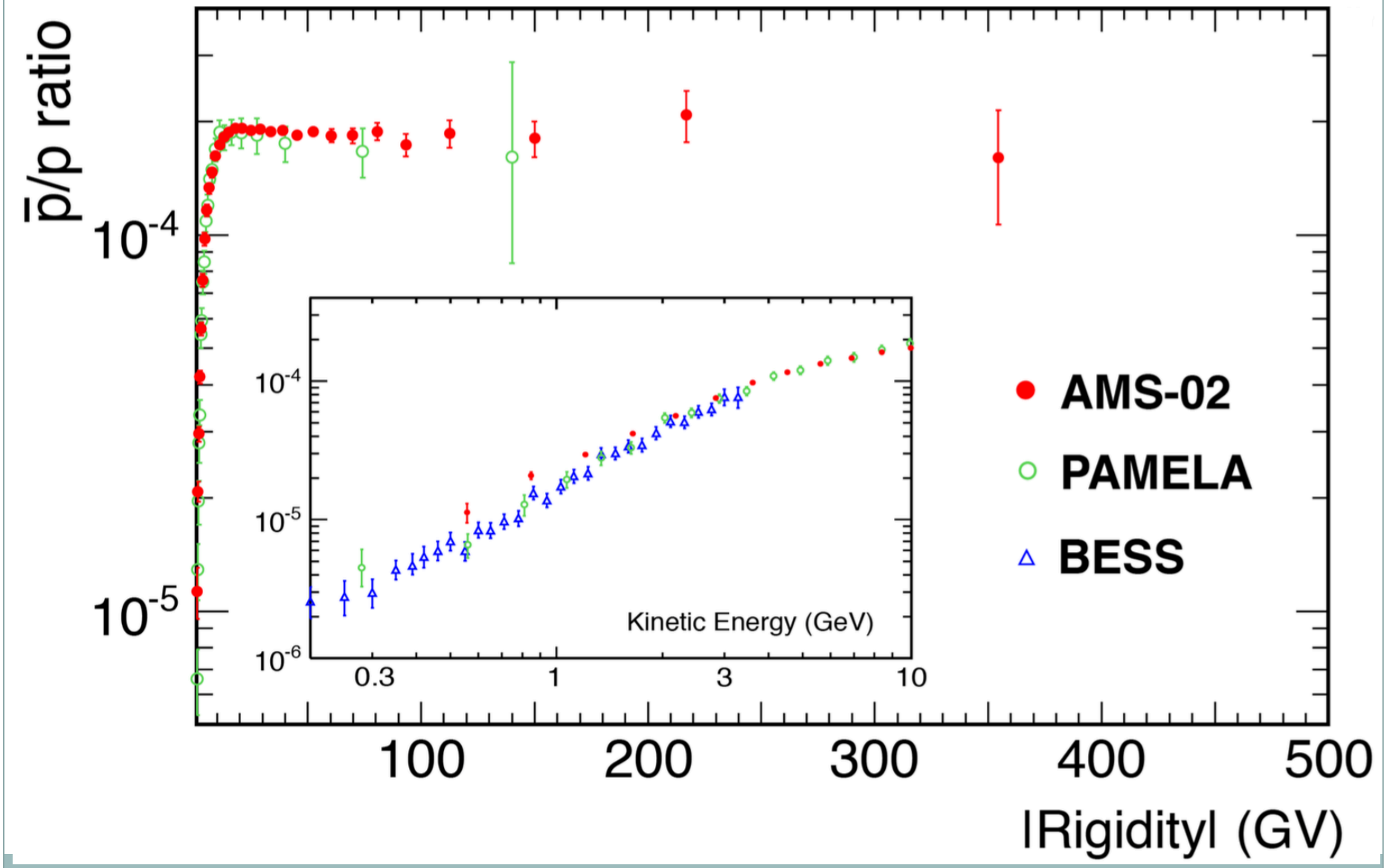
Statistical uncertainties

Relative error on the differential cross section for pbar production

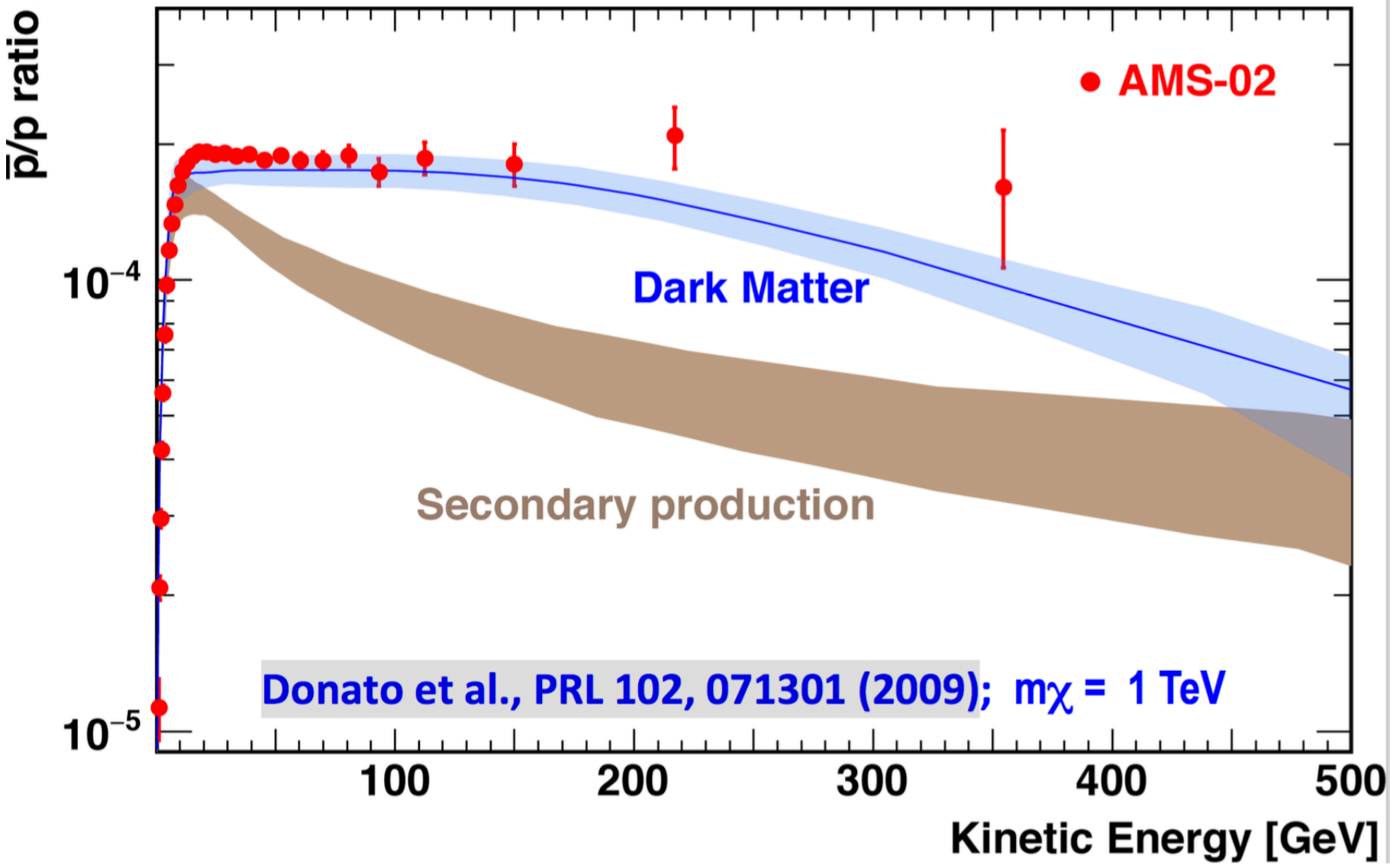




AMS $\bar{p}/p$ results



AMS $\bar{p}/p$ results and modeling



Most up-to-date calculations

http://arxiv.org/pdf/1504.05175v1.pdf

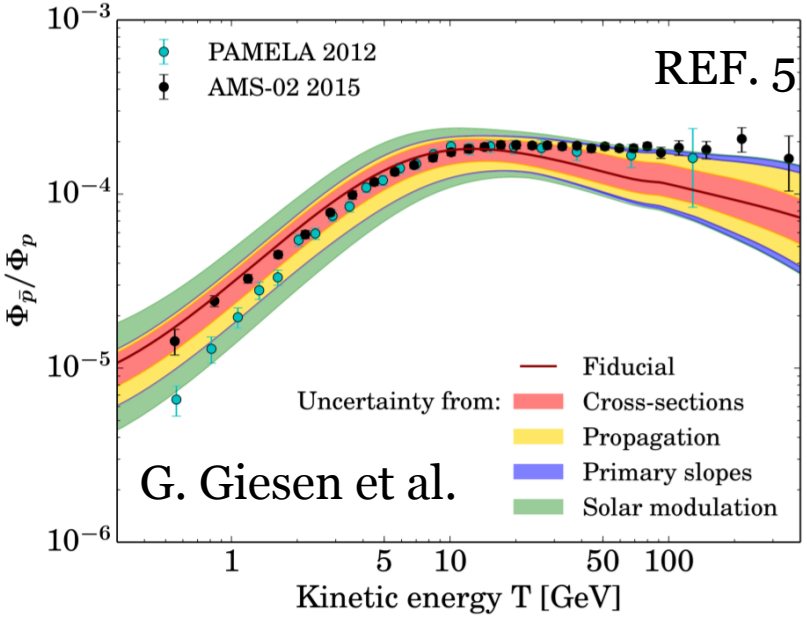


Fig. 2 constitutes our summary and best determination of the astrophysical pbar/p ratio and its combined uncertainties, compared to the new (preliminary) Ams-02 data. The crucial observation is that the astrophysical flux, with its cumulated uncertainties, can reasonably well explain the new datapoints. Thus, our first —and arguably most important— conclusion is that, contrarily to the leptonic case, there is no clear antiproton excess that can be identified in the first place, and thus, at this stage, no real need for primary sources.

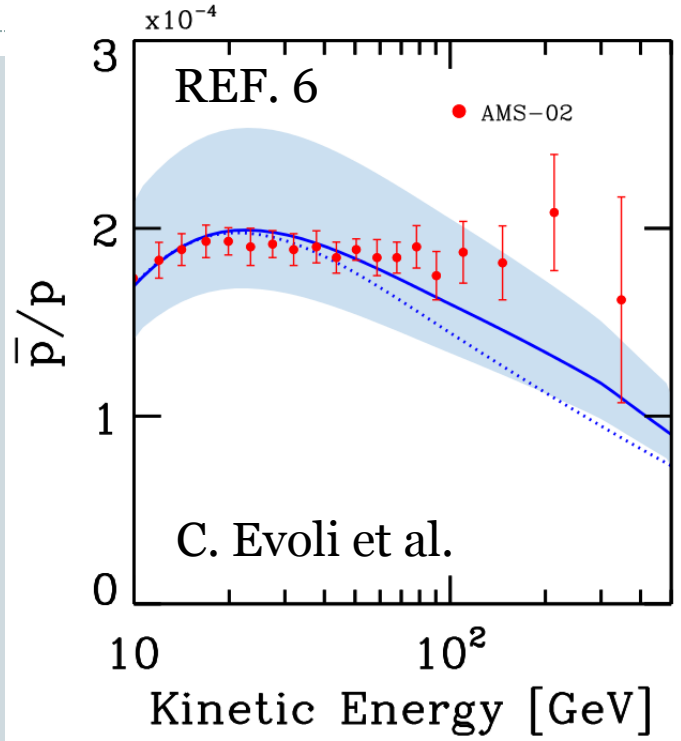


Figure 9. Our reference model compared to AMS preliminary pbar/p data. Blue solid (dashed) line: the pbar/p spectrum computed with the fiducial cross sections from [14], with (without) the hardening in the proton and helium injection spectra. The blue band reports the uncertainty associated to the production cross sections.