Detecting the cosmic antiduteron at AMS-02 and GAPS

Lin Sujie (林苏杰)

Institute of High Energy Physics, CAS

with Bi Xiaojun and Yin Pengfei

Hefei, Oct 23, 2016

Contents

- The purpose and advantage of considering $\bar{d}$
- How to estimate the flux of cosmic $\bar{d}$?
  - $\bar{d}$ in the Galaxy
  - estimation of $\bar{d}$ production
- Our improvements
  - abandoning the unsuitable approximations
  - avoiding overestimating the production by adopting the Monte Carlo simulation
- The $\bar{d}$ from dark matter
- Summary

Purpose and advantage

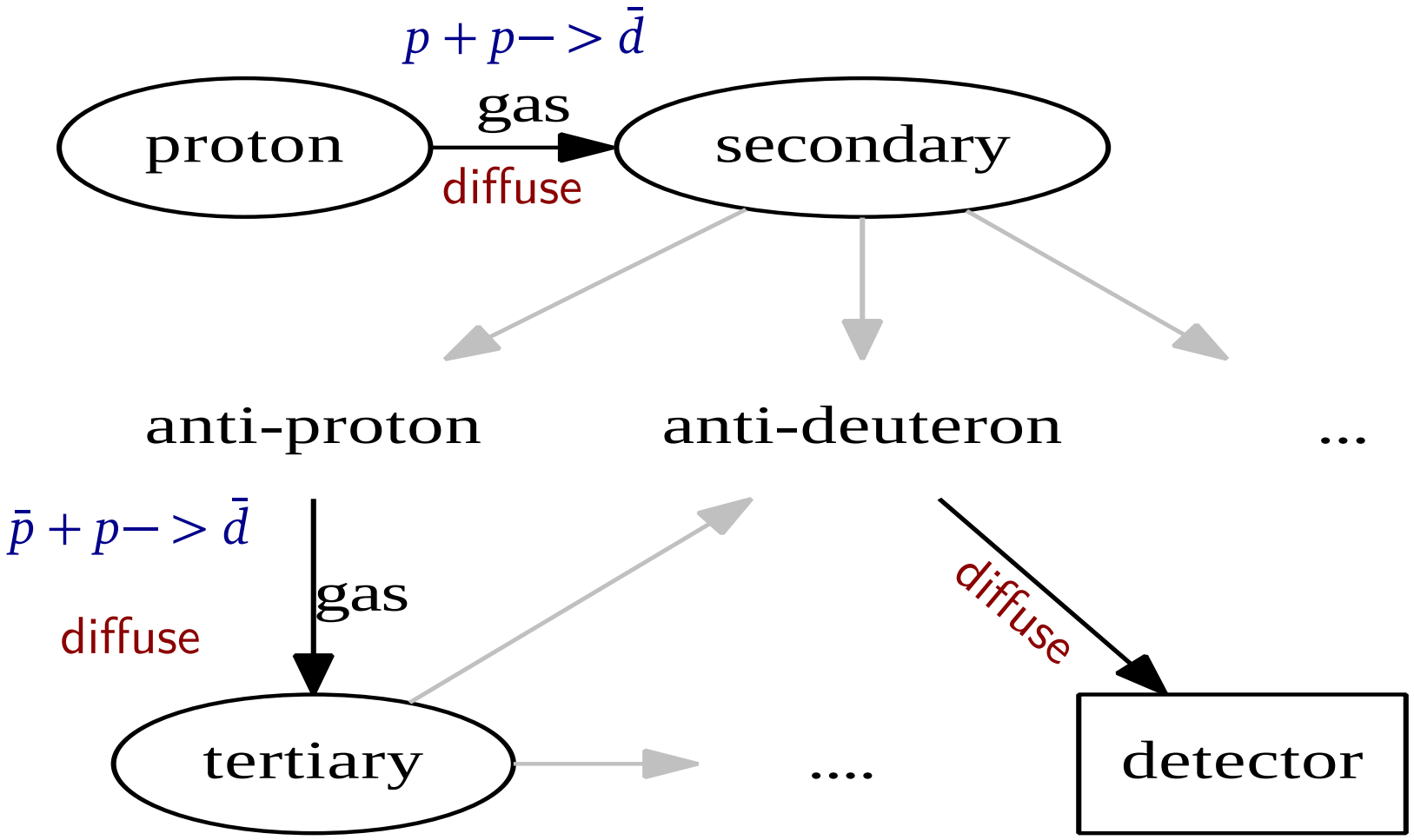
- $\bar{d}$ could be adopted as a probe of dark matter
- Advantage:
  - $\bar{d}$ flux inside cosmic ray is supposed to be low
  - if there is anomaly in $\bar{d}$ flux, it would not be mixed up with the background

No cosmic ray $\bar{d}$ have being detected yet

But what could we conclude if it were found?

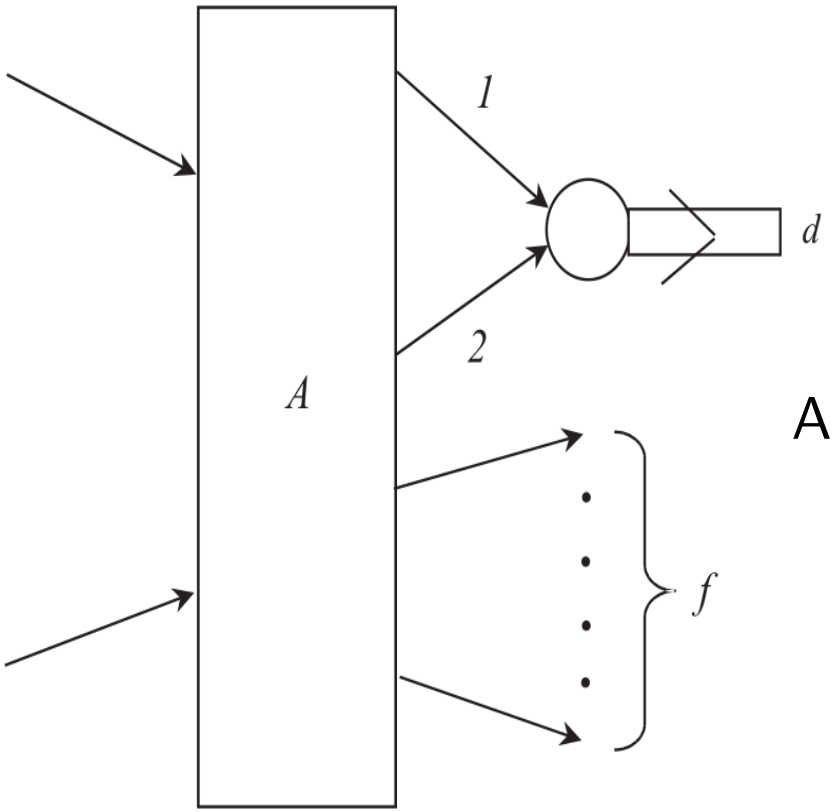
The production of background $\bar{d}$ inside Galaxy

The production of background $\bar{d}$ inside Galaxy



The coalescence model

The coalescence model



[arxiv:nucl-th/0209078]

particle 1 and 2 would coalesce if their momentum are close

A naive method:

- assume a certain value p_0
- $|\mathbf{p}_1 - \mathbf{p}_2| < p_0 \Rightarrow$ coalescence
- $|\mathbf{p}_1 - \mathbf{p}_2| > p_0 \Rightarrow$ no coalescence

value of p_0 would be defined by experiment

An approach to coalescence model for $p + p \rightarrow \bar{d}$

An approach to coalescence model for $p + p \to \bar{d}$

With current experiments, the momentum distribution of $\bar{p}$ from $p + p$ could be estimated in a parameterized way:

$$\frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{p}X} = \frac{1}{E}(1-x_R)^{D_1} e^{-D_2 x_n}\left[D_3(\sqrt{s})^{D_4} e^{-D_5 p_T} + D_6 e^{-D_7 p_T^2}\right]$$

[arxiv:astro-ph/0305274]

The distribution of $\bar{n}$ is unclear, but one could assume an approximation

$$\frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{n}X} \approx C \cdot \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{p}X}$$

$C \sim 1.1 - 1.5$ is a constant

Then the distribution of $\bar{d}$ is,

γ is Lorentz factor

$$\gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{d}X} = \frac{4\pi}{3} p_0^3 \left(\gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{n}X}\right)\left(\gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{p}X}\right)$$

For $p + \bar{p} \to \bar{d}$

No $p + \bar{p}$ collision data could be found, thus we need some assumption to reach $p\bar{p} \to \bar{p}X$ and $p\bar{p} \to \bar{n}X$ distribution

assuming [astro-ph/0503544]:

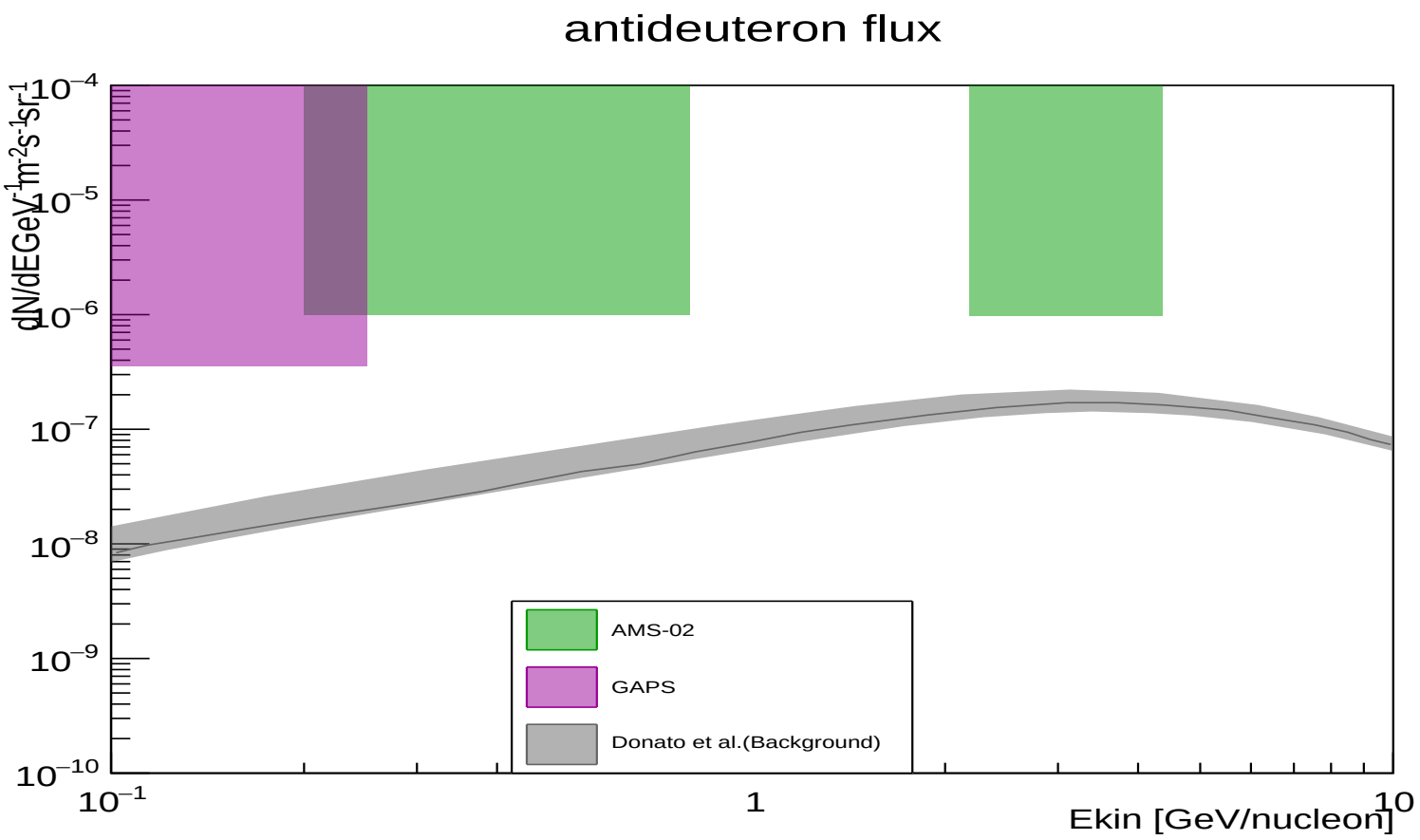
$$\frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{p\bar{p}\to\bar{n}X} \approx \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{p}X}$$

$$\frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{p\bar{p}\to\bar{p}X} \approx \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to pX} = CA^{b(p_T)} x'(1-x')^{\alpha p_T^2} (p_T^2 + \mu^2)^{-4.5}$$

[Kalinovski et al. 1989]

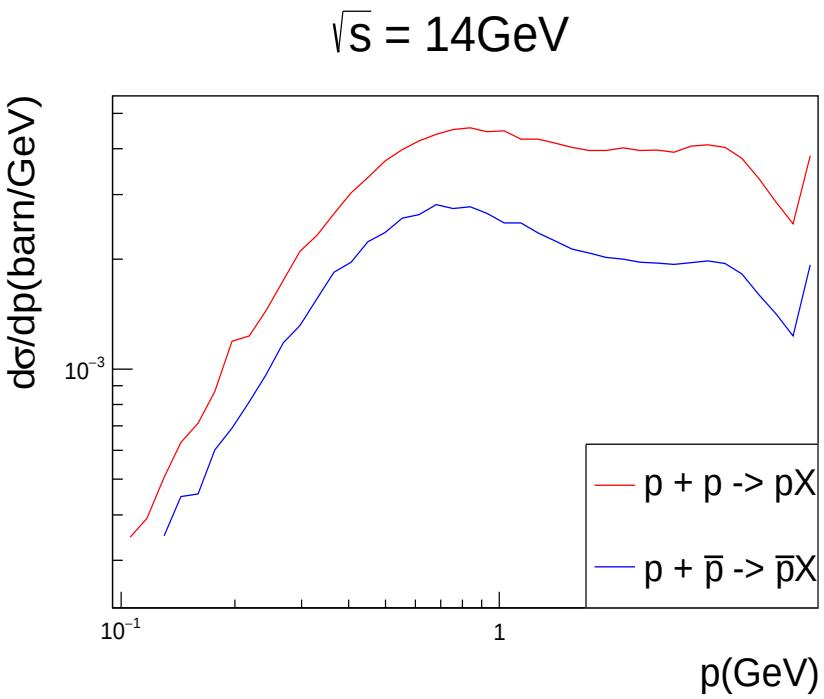
$$\Rightarrow \quad \gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{p\bar{p}\to\bar{d}X} \approx \frac{4\pi}{3} p_0^3 \left(\gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to\bar{p}X} \right) \left(\gamma \frac{\mathrm{d}^3 N}{\mathrm{d}\mathbf{p}^3}_{pp\to pX} \right)$$

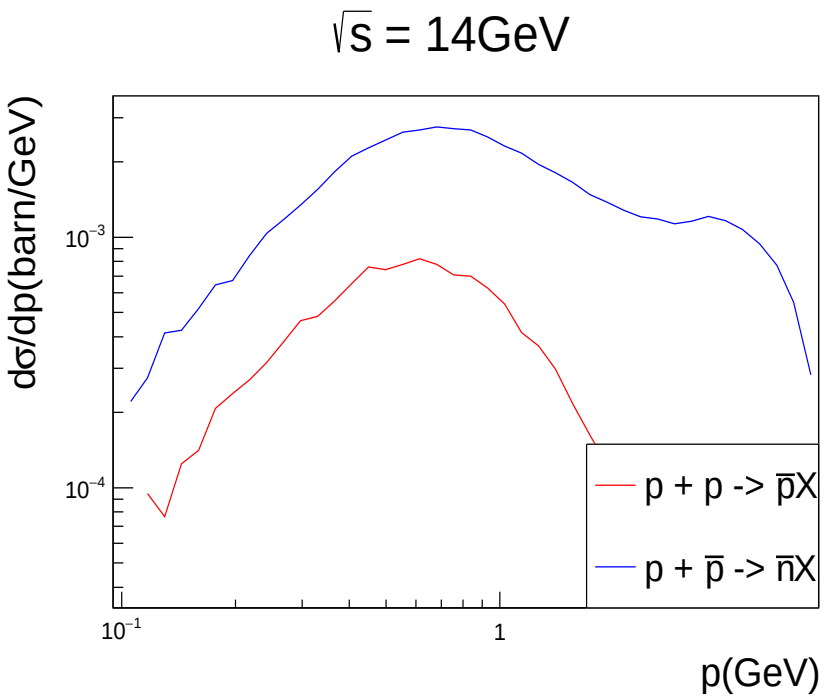
Result


antideuteron flux
dN/dEGeV^{-1}m^{-2}s^{-1}sr^{-1}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-1}
1
10
Ekin [GeV/nucleon]
AMS-02
GAPS
Donato et al.(Background)

The two approximations about $p + \bar{p}$ collision are not quite suitable

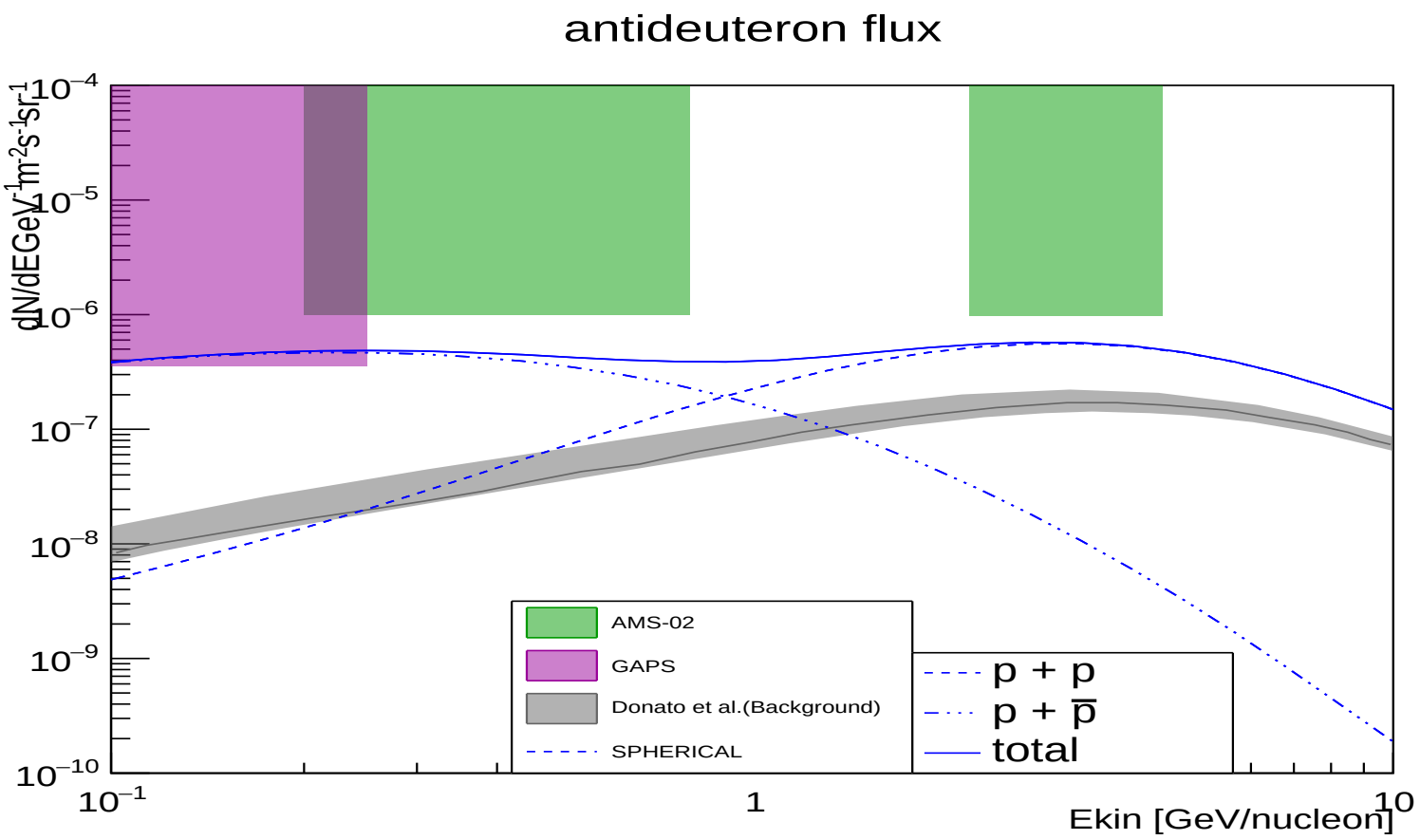
We adopt the generator EPOS LHC to simulate all the momentum distribution





Both the two approximation are not suitable

Result ($\bar{p}$, $\bar{n}$ simulated from EPOS LHC)



However, this is still not a suitable estimation

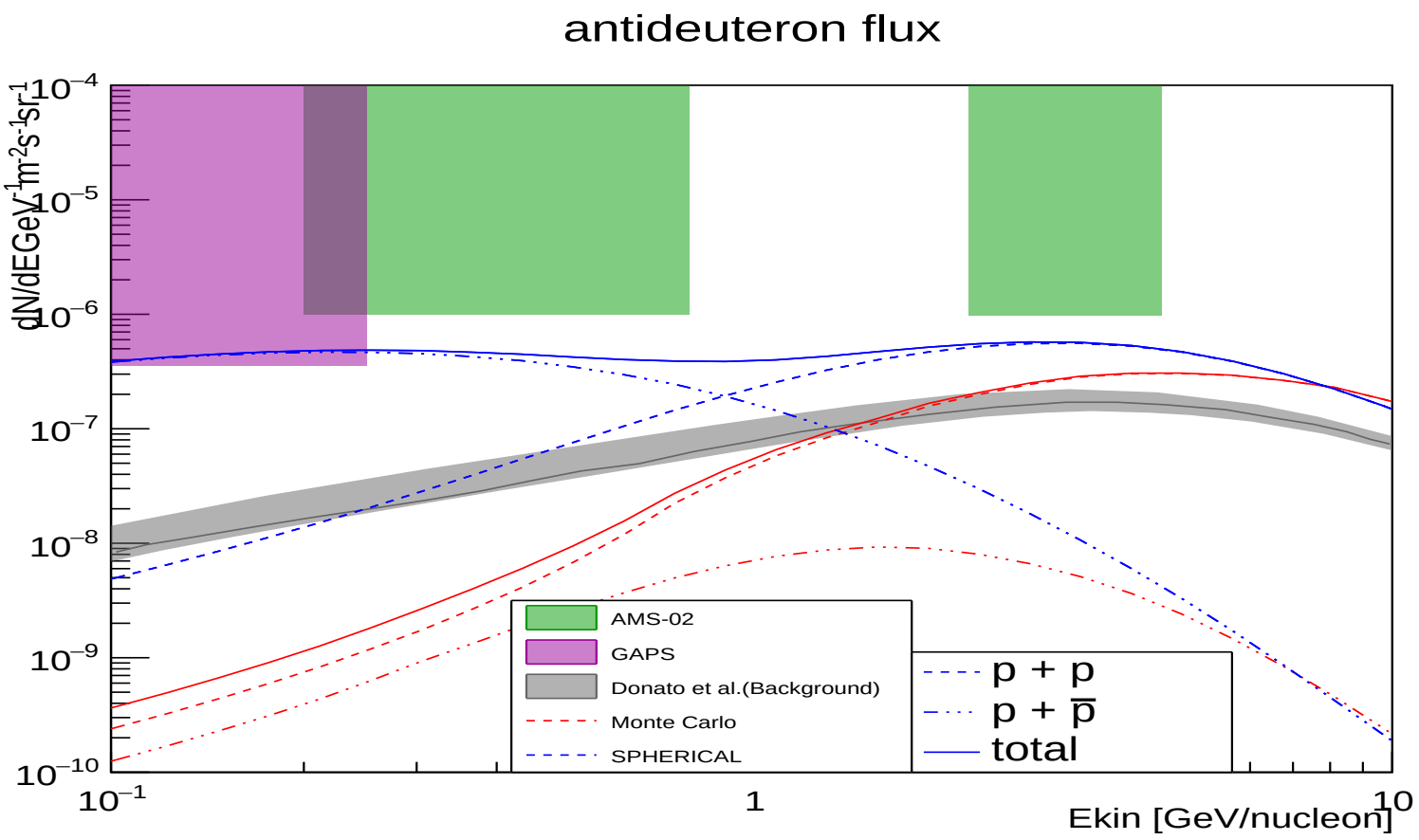
A more realistic Monte Carlo simulation

- The method shown before make the estimation with the distribution counted from many collisions.
- However, the coalescence should only arise for the particles from the same collision.
- The method shown before have overestimated the $\bar{d}$ flux as they counted the coalescence between different collisions, especially around the threshold.

Thus we have adopted a more realistic simulation

With generator EPOS LHC, we produce the $\bar{p}$ and $\bar{n}$, and judge if they would coalescence to $\bar{d}$ event by event

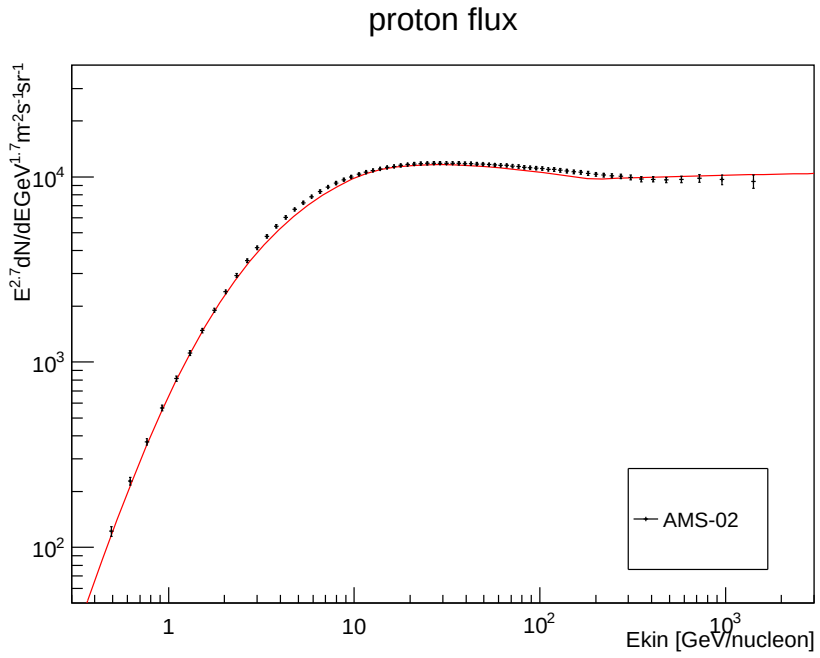
A more realistic Monte Carlo simulation



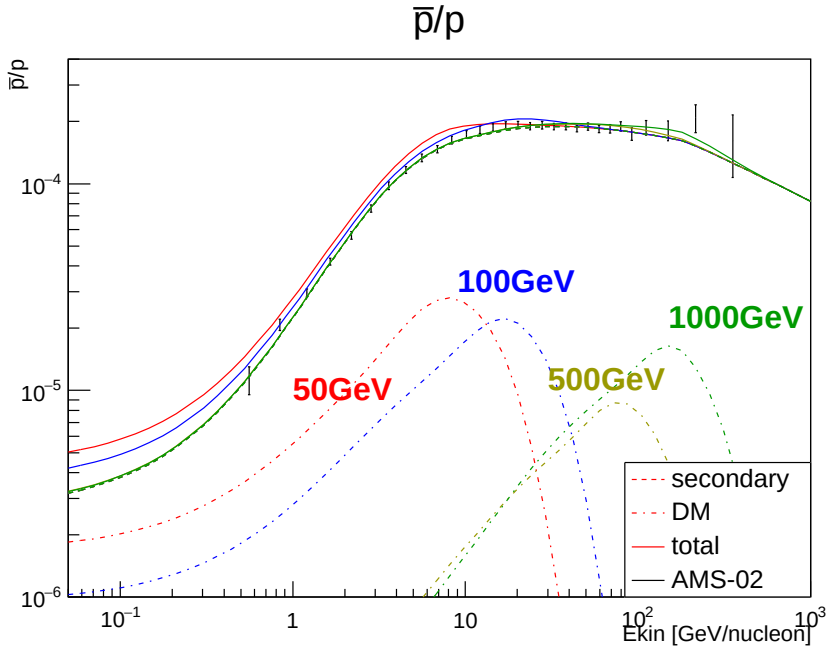
Constraint on DM

Constraint on DM

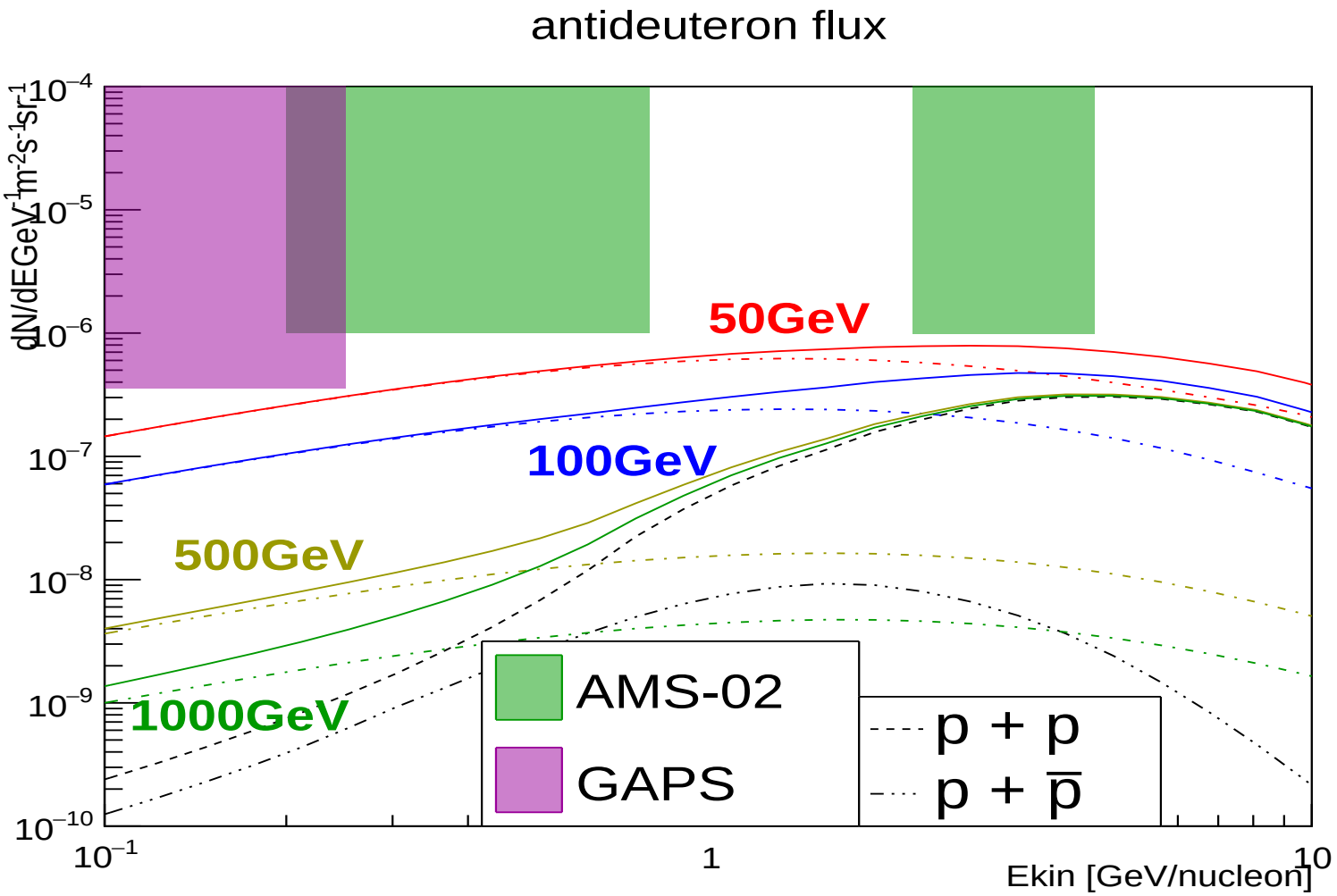
We adopt suitable propagation parameters to obtain the right proton flux



Such propagation parameters would lead to $\bar{p}/p$ ratio that match with the observed data. we then find the 95% C.L. up-bound for the DM annihilating cross section

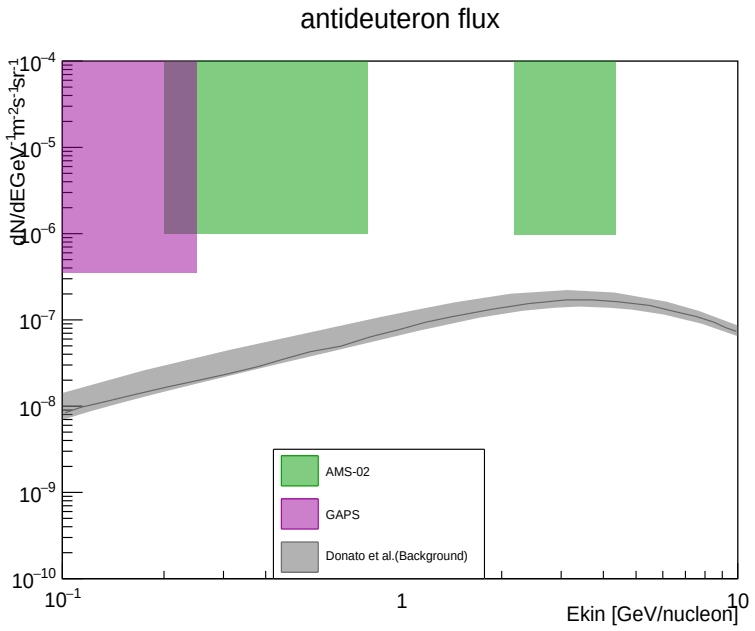


$\bar{d}$ from DM


antideuteron flux
dN/dEGeV⁻¹m⁻²s⁻¹sr⁻¹
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹
1
10
Ekin [GeV/nucleon]
50GeV
100GeV
500GeV
1000GeV
AMS-02
GAPS
p + p
p + p̄

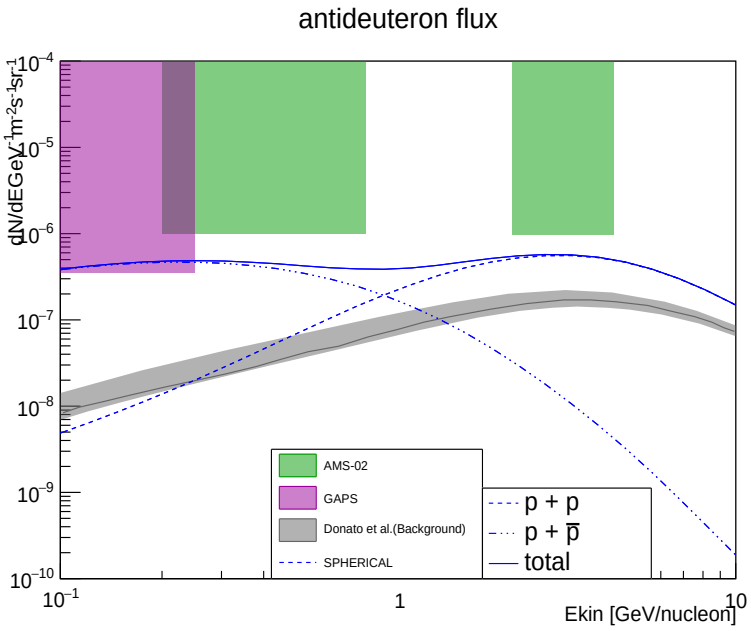
Summary

- The $\bar{d}$ flux in cosmic ray is supposed to be quite low. We want to ensure if the $\bar{d}$ from secondary CR or from DM is detectable for the current experiments.
- Instead of the parameterized function, we adopt the EPOS LHC generator to estimate the distribution of the $\bar{p}$ and $\bar{n}$.
- To avoid the overestimating around the threshold, we then choose a more realistic method to approach the coalescence model.
- With the new estimation on background $\bar{d}$, the we showed if $\bar{d}$ from dark matter could be detected by the current experiments.



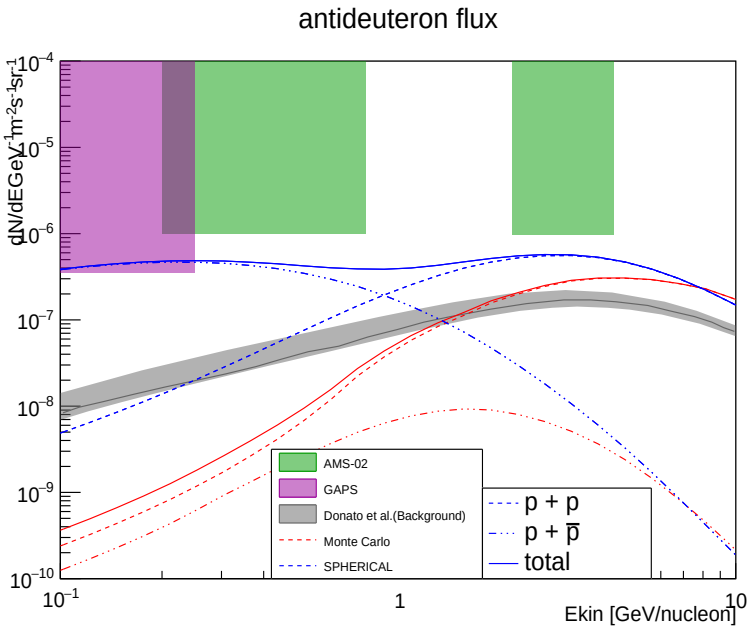
Summary

- The $\bar{d}$ flux in cosmic ray is supposed to be quite low. We want to ensure if the $\bar{d}$ from secondary CR or from DM is detectable for the current experiments.
- Instead of the parameterized function, we adopt the EPOS LHC generator to estimate the distribution of the $\bar{p}$ and $\bar{n}$.
- To avoid the overestimating around the threshold, we then choose a more realistic method to approach the coalescence model.
- With the new estimation on background $\bar{d}$, the we showed if $\bar{d}$ from dark matter could be detected by the current experiments.



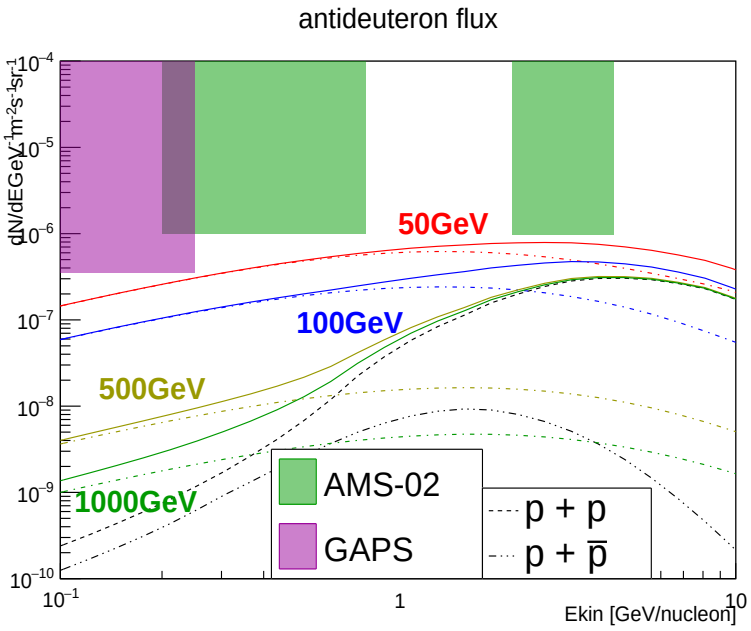
Summary

- The $\bar{d}$ flux in cosmic ray is supposed to be quite low. We want to ensure if the $\bar{d}$ from secondary CR or from DM is detectable for the current experiments.
- Instead of the parameterized function, we adopt the EPOS LHC generator to estimate the distribution of the $\bar{p}$ and $\bar{n}$.
- To avoid the overestimating around the threshold, we then choose a more realistic method to approach the coalescence model.
- With the new estimation on background $\bar{d}$, the we showed if $\bar{d}$ from dark matter could be detected by the current experiments.



Summary

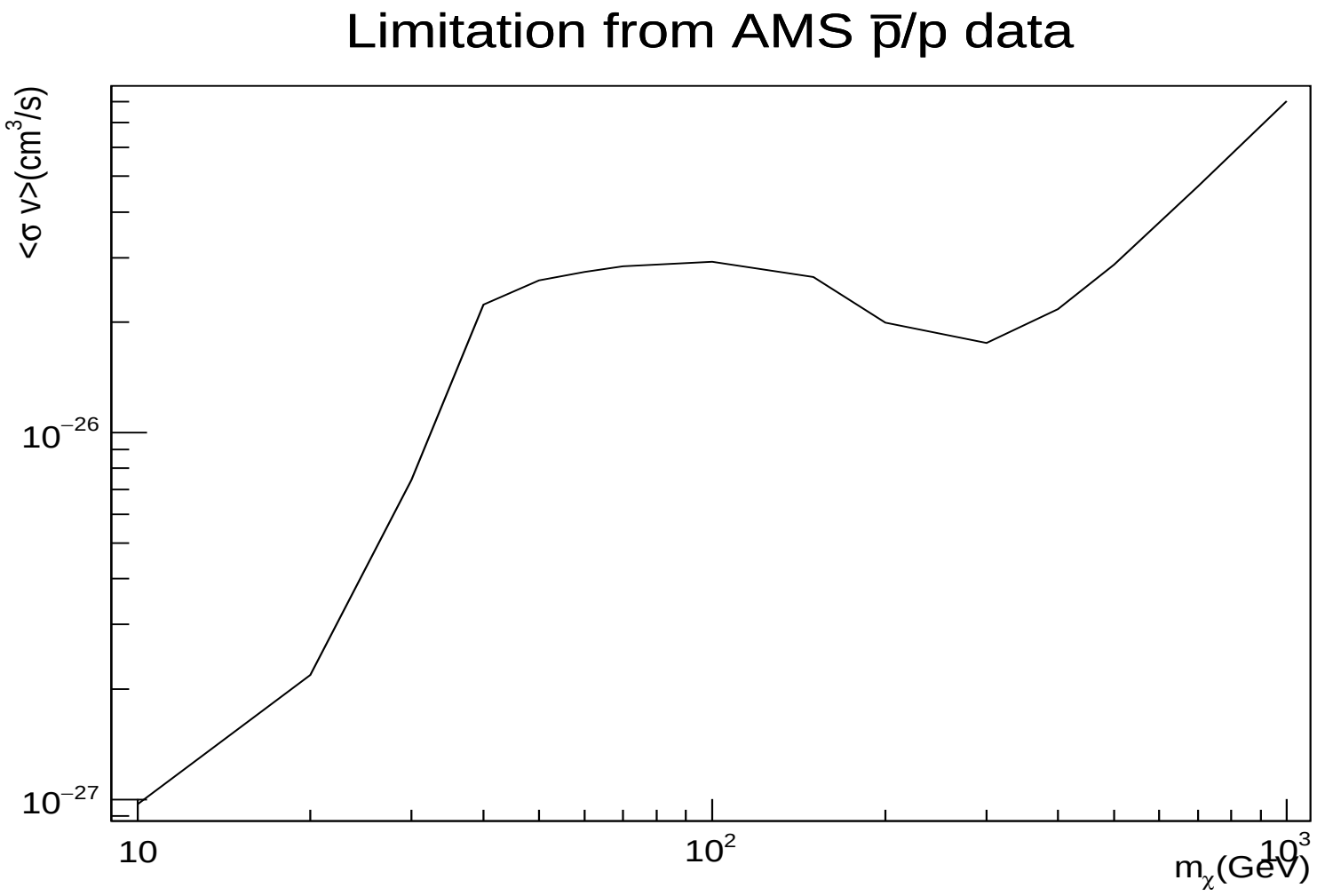
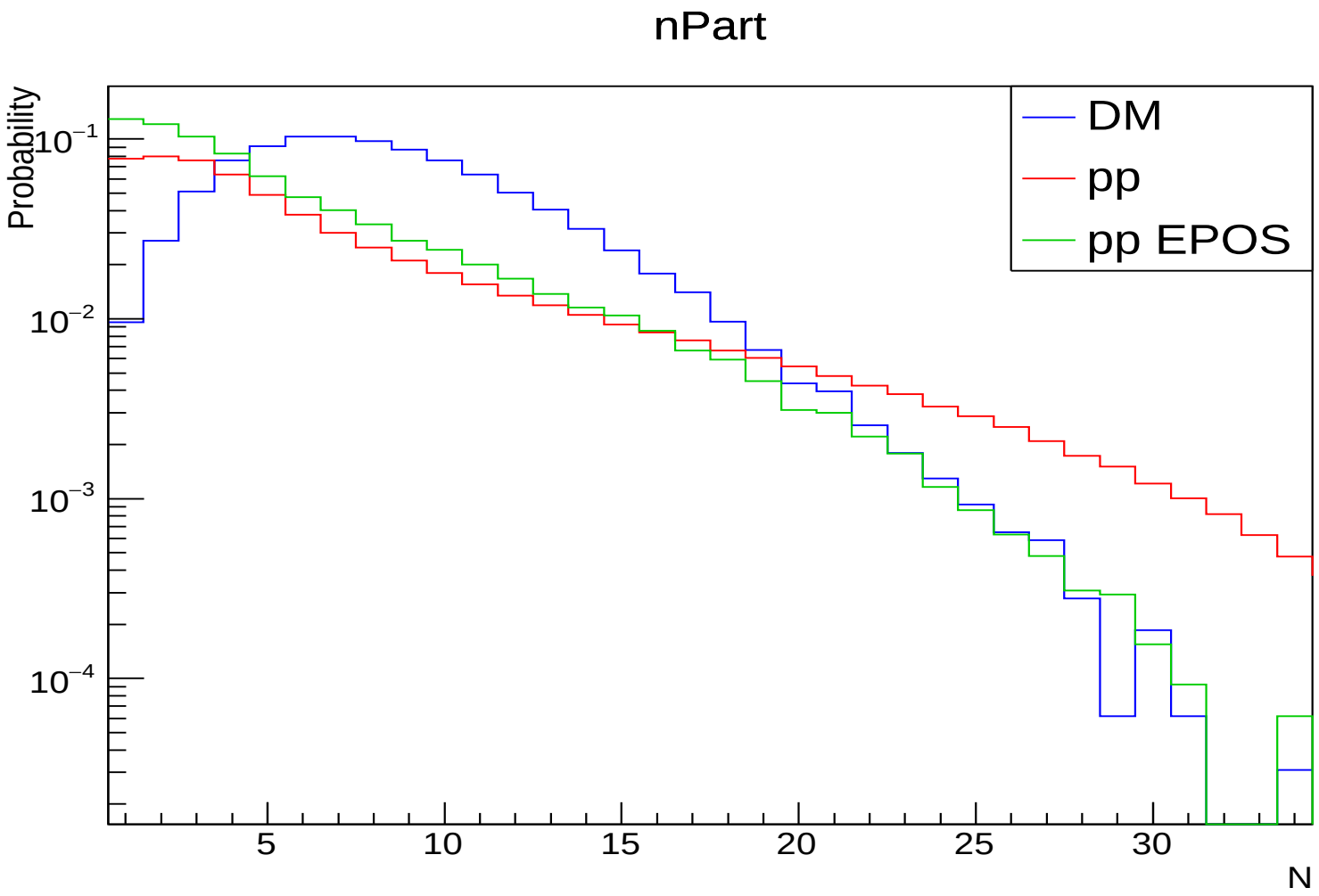
- The $\bar{d}$ flux in cosmic ray is supposed to be quite low. We want to ensure if the $\bar{d}$ from secondary CR or from DM is detectable for the current experiments.
- Instead of the parameterized function, we adopt the EPOS LHC generator to estimate the distribution of the $\bar{p}$ and $\bar{n}$.
- To avoid the overestimating around the threshold, we then choose a more realistic method to approach the coalescence model.
- With the new estimation on background $\bar{d}$, the we showed if $\bar{d}$ from dark matter could be detected by the current experiments.



Thanks for your attentions!

back up

Exclude line



N distribution