Antihelium-3 Fluxes near Earth using Data-Driven Estimates for Annihilation Cross Section

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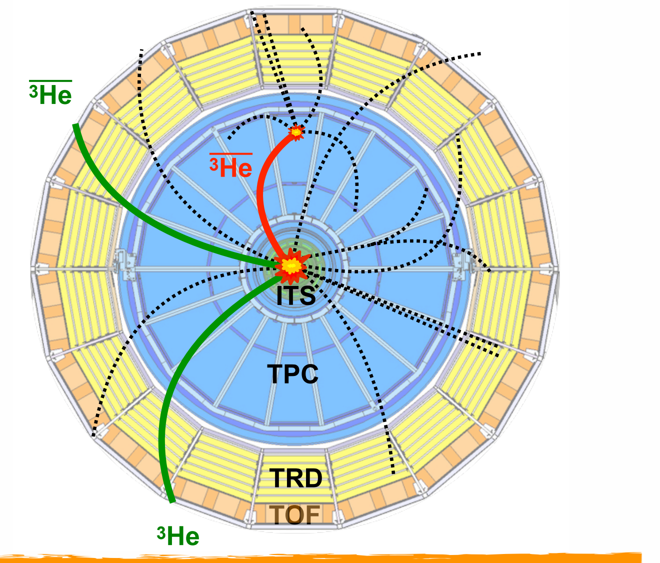


Antimatter Cosmic Rays and Indirect Dark Matter Search

- Antinuclei cosmic rays (CR) can provide a possible "smoking gun" signature of dark matter (DM).
- They are essentially free of the astrophysical background.
- Such study requires good understanding of antinuclei propagation, production and annihilation.
- The latter two must be studied in accelerator experiments on Earth.

Transport Equation

$$q(\vec{r},p) + \vec{\nabla}\cdot(D_{xx}\vec{\nabla}\psi - \vec{V}\psi) + \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{\psi}{p^2} - \frac{\partial}{\partial p}\left[\psi\frac{dp}{dt} - \frac{p}{3}(\vec{\nabla}\cdot\vec{V})\psi\right] - \frac{\psi}{\tau_f} = \frac{\partial\psi}{\partial t}$$

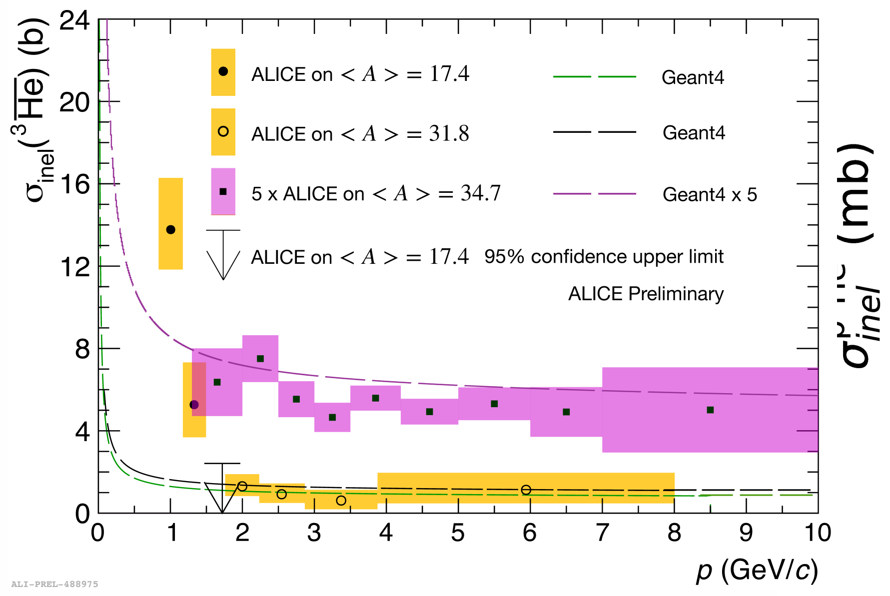
Propagation

- The transport equation was solved using public GALPROP code [4].
- The propagation parameters are expected to be the same for all (anti-)nuclei species.
- They can be constrained by fitting GALPROP to available CR data.
- Parameters from [5] were used here.

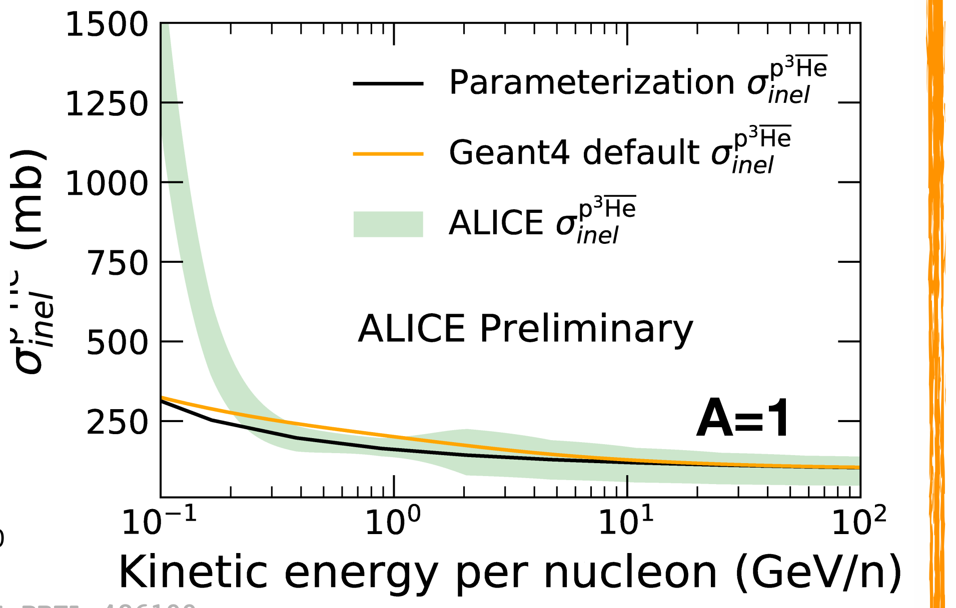
$^3\overline{\mathrm{He}}$ Annihilation Cross Section

- $^3\overline{\mathrm{He}}$ inelastic cross section (CS) measured using ALICE detector as a target material.
- The annihilation cross section on proton and helium-4 targets was estimated using Geant4.

ALICE: <A> = 17.4, 34.7



ISM: <A> = 1, 4

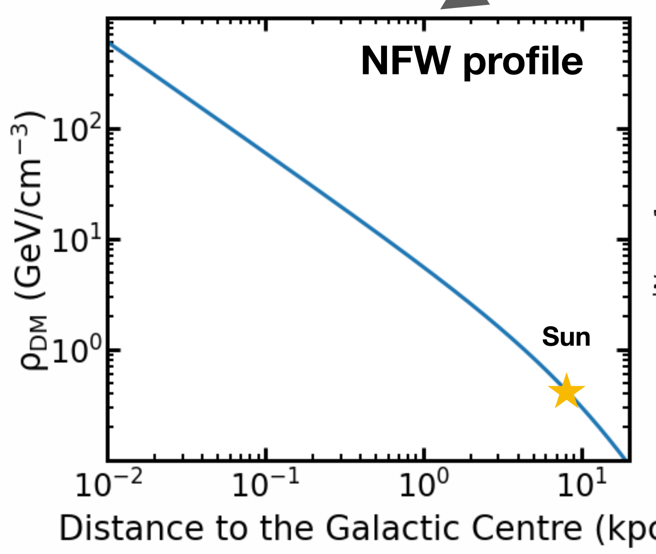


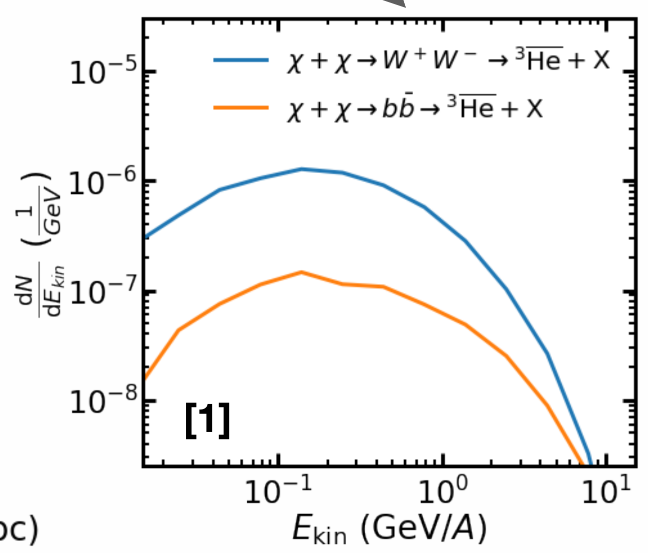
First $^3\overline{\mathrm{He}}$ inelastic cross section measurement ever!

$^3\overline{\mathrm{He}}$ Source Function from DM

- Annihilating dark matter can produce $^3\overline{\mathrm{He}}$.
- Navarro-Frenk-White profile was used to describe DM density distribution.
- $^3\overline{\mathrm{He}}$ spectra produced in 100 GeV mass DM particle annihilation via $b\bar{b}$ and W^+W^- channels taken from [1].

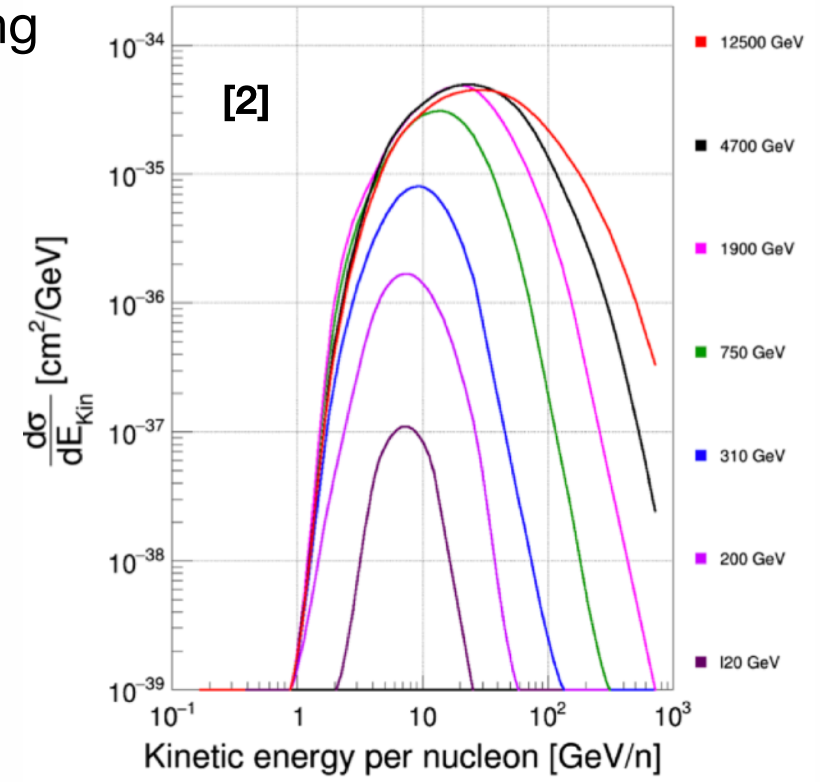
$$q(r,E_{kin}) = \frac{1}{2}\frac{\rho^2_{\mathrm{DM}}(r)}{m^2_\chi}\langle\sigma_{DM}v\rangle\frac{dN}{dE_{kin}}$$





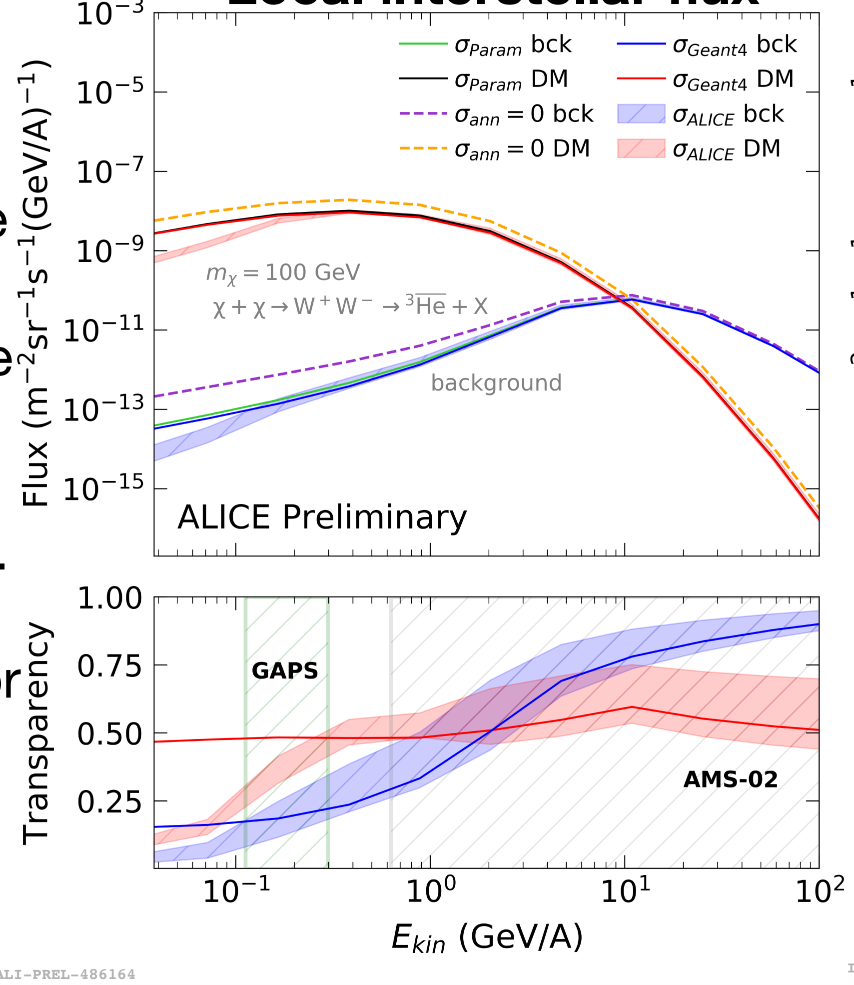
$^3\overline{\mathrm{He}}$ Source Function from CR

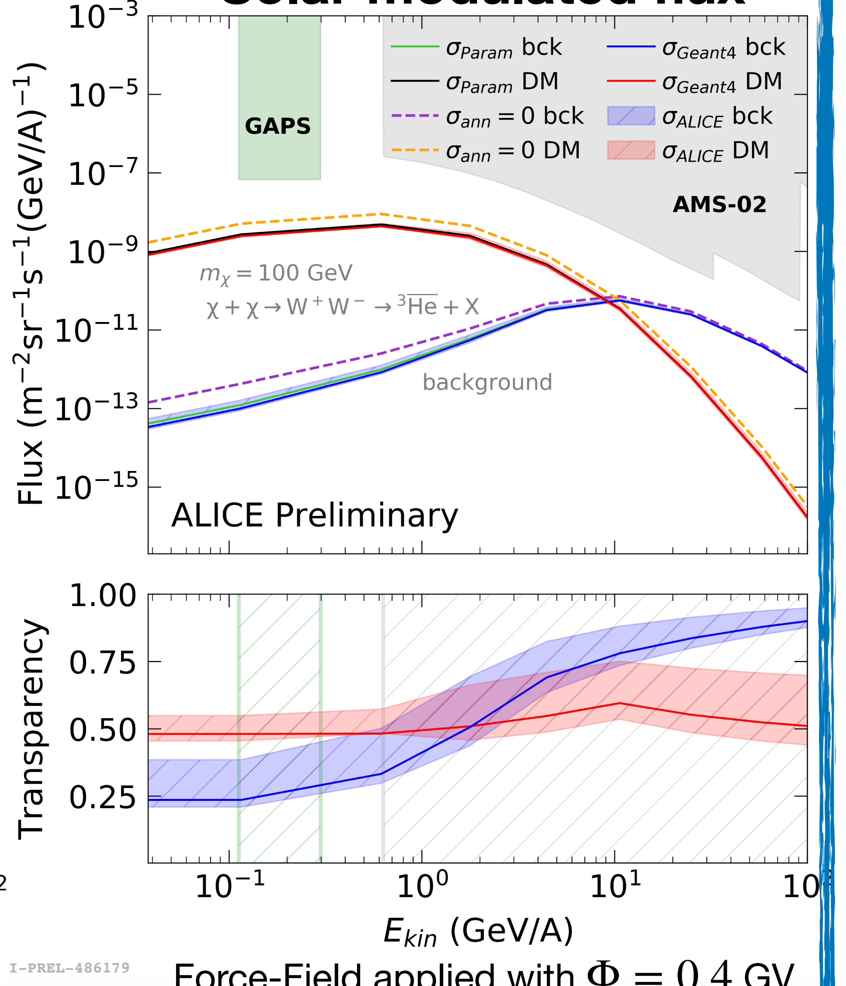
- $^3\overline{\mathrm{He}}$ can also be produced in CR collisions with the gas present in the interstellar medium.
- The gas and cosmic rays consist mainly of hydrogen (~90%) and helium (~9%).
- Collisions of interest are pp, p-He, He-p, He-He.
- The $^3\overline{\mathrm{He}}$ production cross section in pp collisions is taken from [2], while for heavier collisions the $(A_T A_P)^{2.2/3}$ scaling is used [2].
- The default hydrogen and helium gas distributions provided in GALPROP were used. [3]



Results

- ALICE measurement allows estimate of the $^3\overline{\mathrm{He}}$ CR annihilation in the Galaxy.
- The transparency of the Galaxy shows survival probability of $^3\overline{\mathrm{He}}$ in the interstellar medium.
- Uncertainty is shown only for annihilation CS.
- Rather constant transparency of 50% for DM scenario (similar results obtained for $b\bar{b}$) and 25-90% for background.





Force-Field applied with $\Phi = 0.4$ GV

First data-driven estimation of $^3\overline{\mathrm{He}}$ annihilation in the Galaxy!

[1] Carlson et al, Phys. Rev. D. 89, 076005 (2014)
[2] Shukla et al, Phys. Rev. D. 102, 063004 (2020)
[3] Moskalenko et al, ApJ 565 280 [2002]
[4] Strong et al, ApJ 509 212 [1998]
[5] Boschini *et al, ApJS* **250** 27 [2020]