Measurement of anti-helium nuclear absorption and impact on galaxy transparency

12th Course on Physics at the LHC 2023

International Doctorate Network in Particle Physics, Astrophysics and Cosmology (IDPASC)

LIP

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Measurement of 3He nuclei absorption in matter and impact on their propagation in the Galaxy

Introduction

Light antinuclei can be produced through high-energy cosmic-ray collisions with the interstellar médium...

Light antinuclei could originate from the annihilation of dark-matter particles that have not yet been discovered.

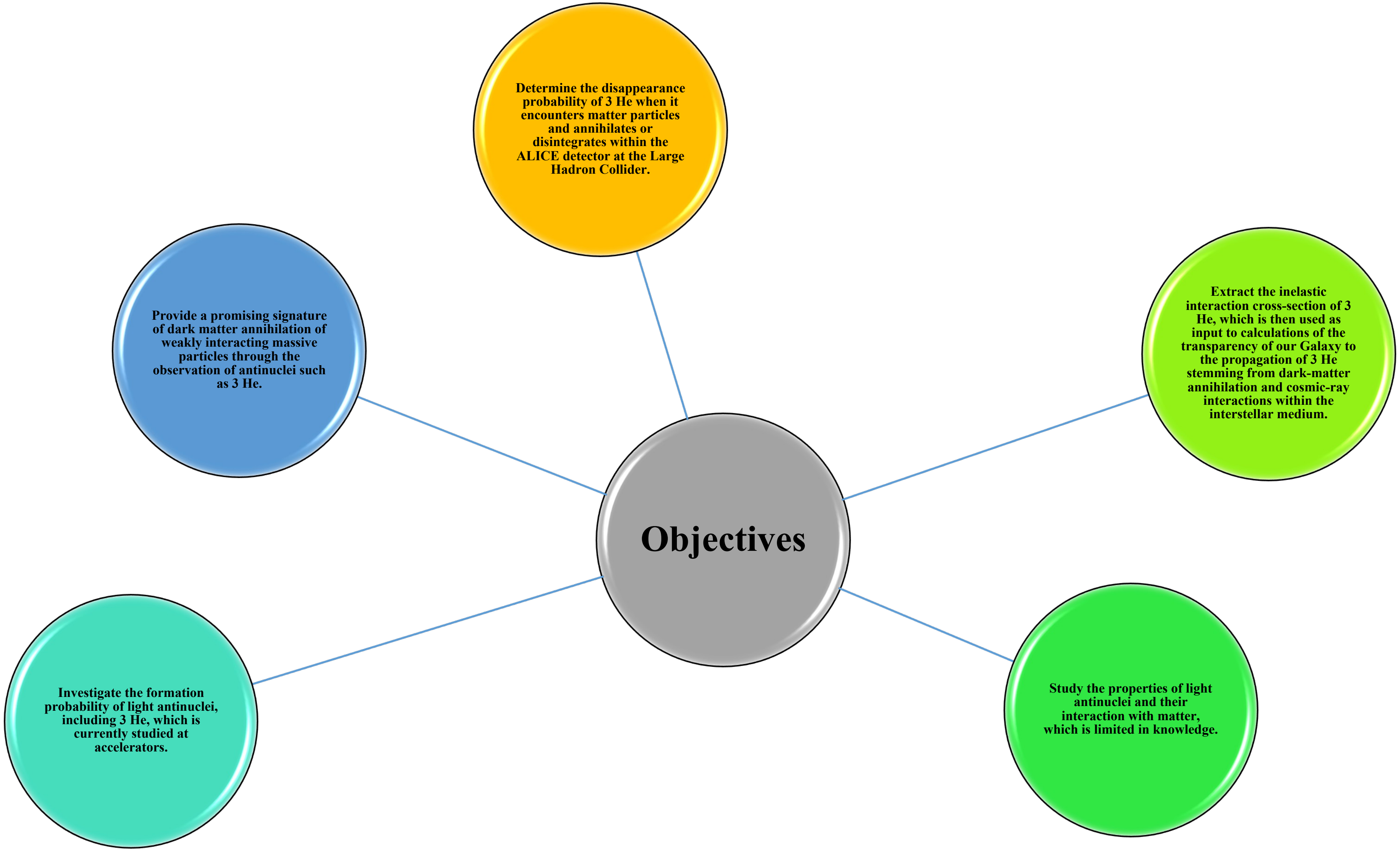
The only way to produce and study antinuclei is to create them at high-energy particle accelerators.

Although the properties of elementary antiparticles have been studied in detail, the knowledge of the interaction of light antinuclei with matter is limited.

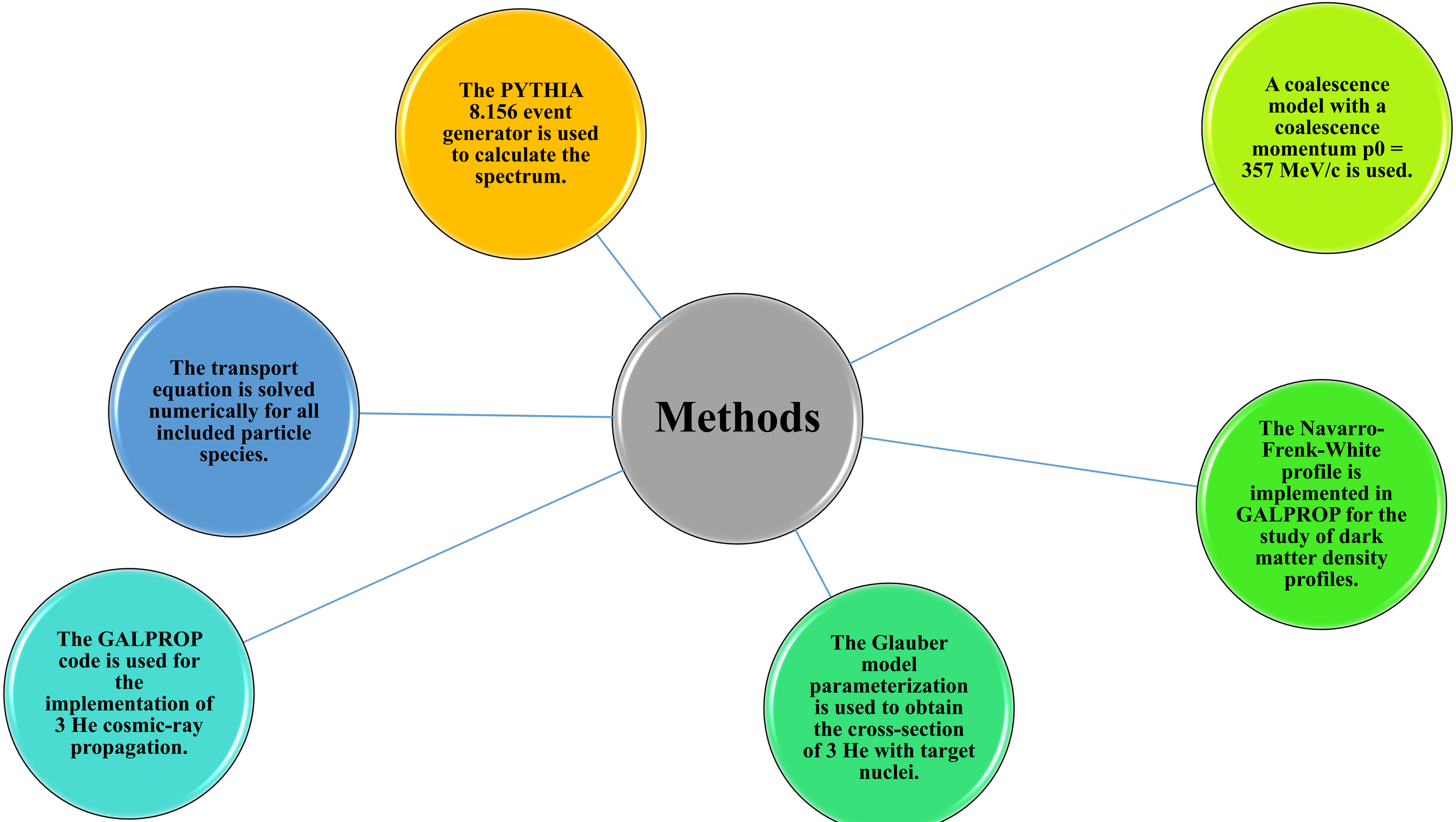
Input to calculations of the transparency of our Galaxy to the propagation of 3He stemming from dark-matter annihilation and cosmic-ray interactions within the interstellar medium.

- Estimate a transparency of about 50%
- Varies with increasing 3He momentum from 25% to 90% for cosmic-ray sources.
- 3He nuclei can travel long distances in the Galaxy
- 3He nuclei can be used to study cosmic-ray interactions and dark-matter annihilation.

Objectives


Determine the disappearance probability of 3 He when it encounters matter particles and annihilates or disintegrates within the ALICE detector at the Large Hadron Collider.
Provide a promising signature of dark matter annihilation of weakly interacting massive particles through the observation of antinuclei such as 3 He.
Extract the inelastic interaction cross-section of 3 He, which is then used as input to calculations of the transparency of our Galaxy to the propagation of 3 He stemming from dark-matter annihilation and cosmic-ray interactions within the interstellar medium.
Objectives
Investigate the formation probability of light antinuclei, including 3 He, which is currently studied at accelerators.
Study the properties of light antinuclei and their interaction with matter, which is limited in knowledge.

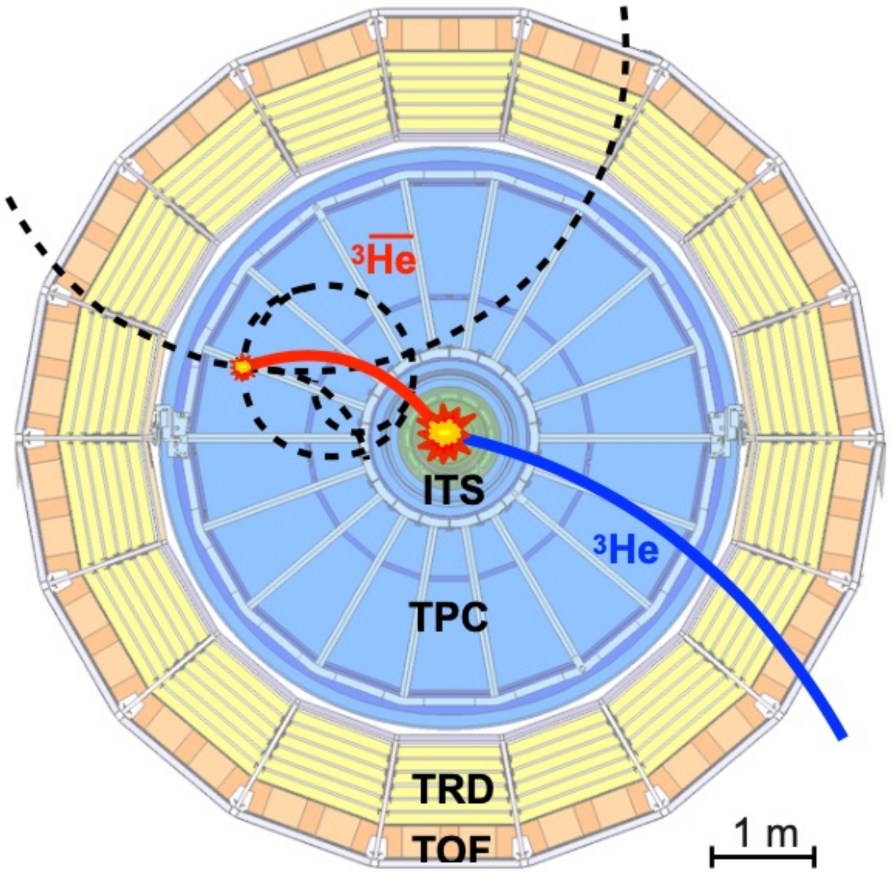
Methods


Methods
The PYTHIA 8.156 event generator is used to calculate the spectrum.
A coalescence model with a coalescence momentum p0 = 357 MeV/c is used.
The transport equation is solved numerically for all included particle species.
The Navarro-Frenk-White profile is implemented in GALPROP for the study of dark matter density profiles.
The GALPROP code is used for the implementation of 3 He cosmic-ray propagation.
The Glauber model parameterization is used to obtain the cross-section of 3 He with target nuclei.

Results

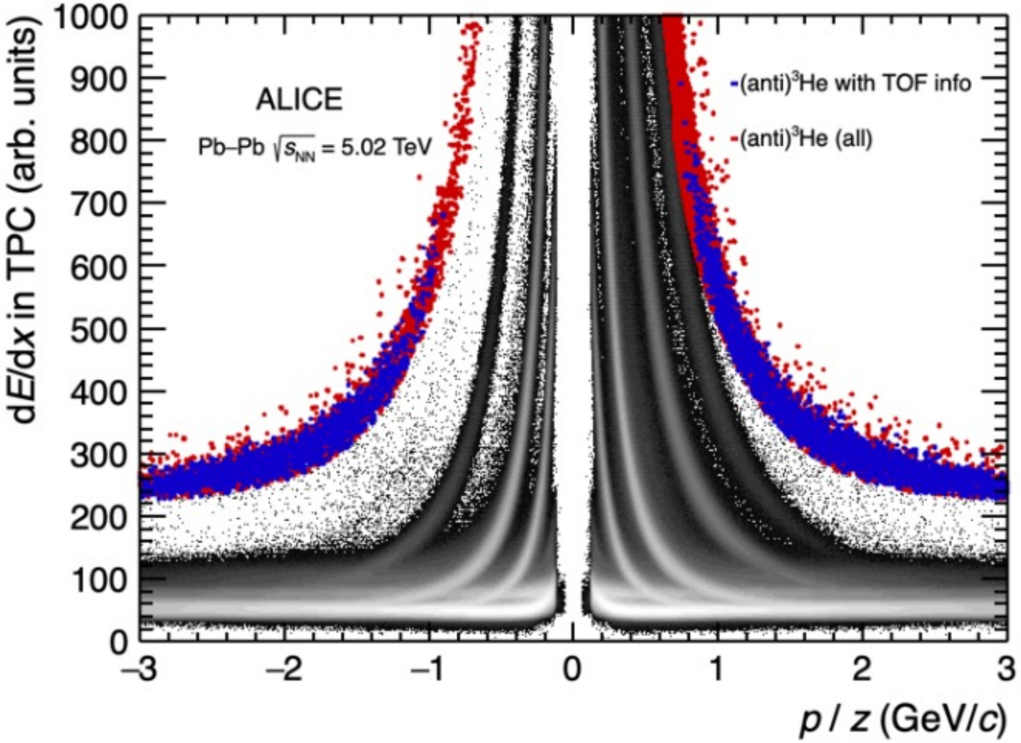
Determination of the inelastic cross section

(a)



$^{3}\overline{\mathrm{He}}$
ITS
^{3}He
TPC
TRD
TOF
1 m

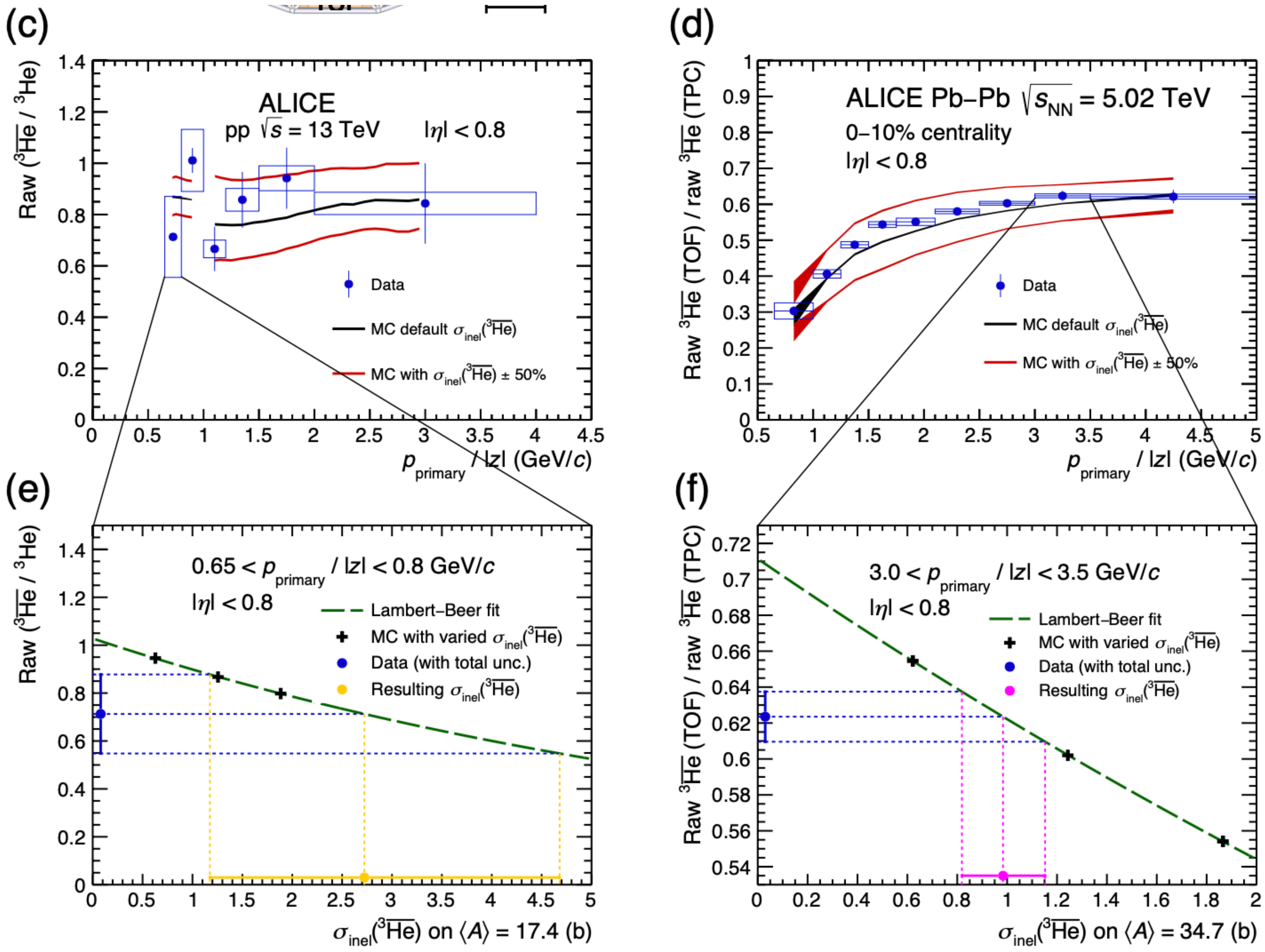
(b)



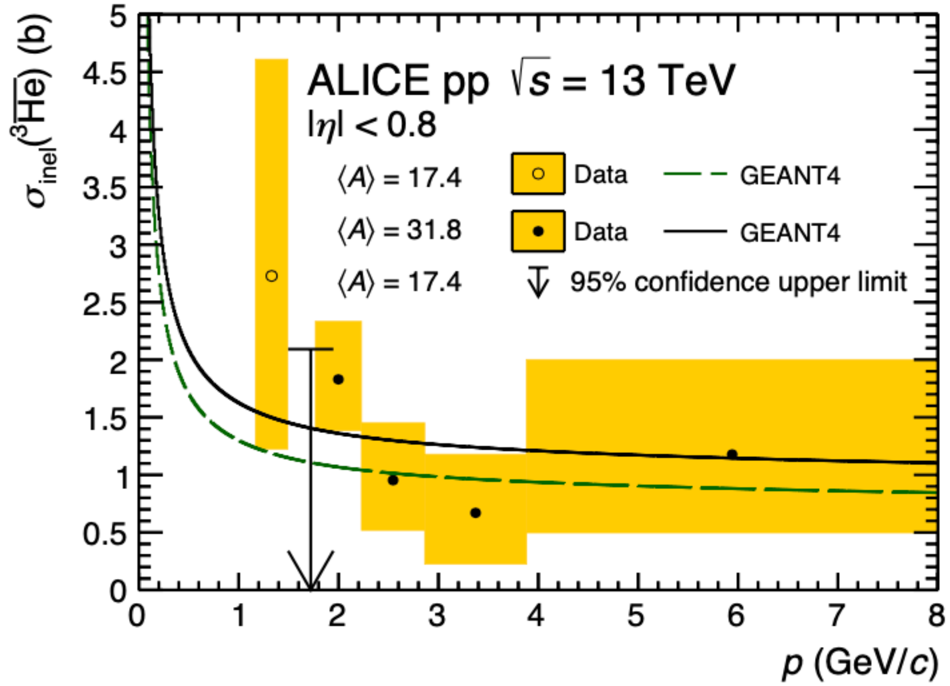
ALICE
Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV
(anti)^{3}He with TOF info
(anti)^{3}He (all)
dE/dx in TPC (arb. units)
p / z (GeV/c)
0
100
200
300
400
500
600
700
800
900
1000
−3
−2
−1
0
1
2
3

(c)

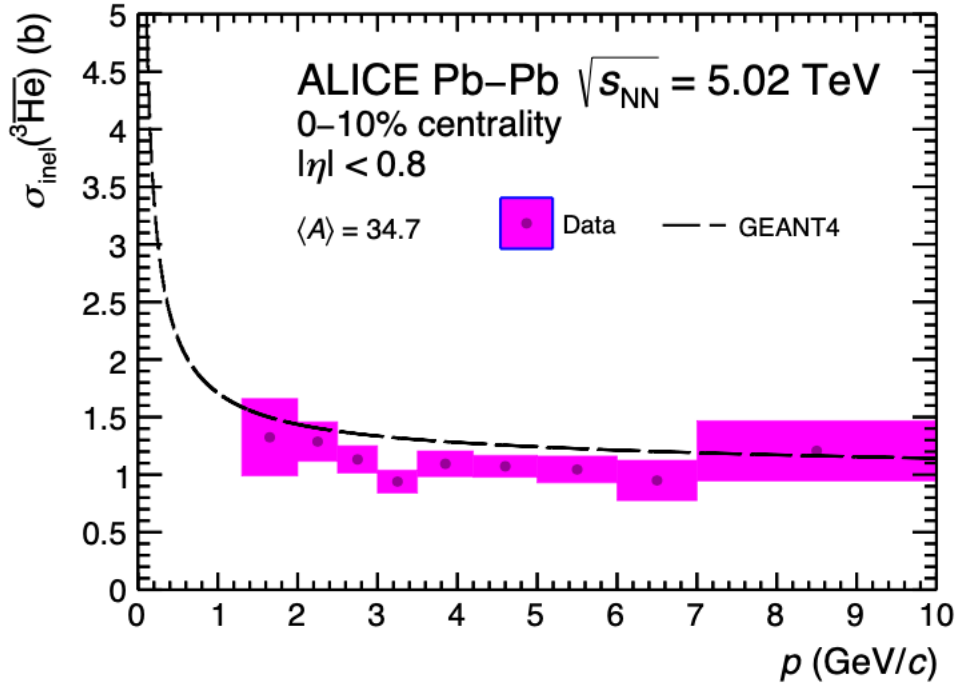
(d)


(c)
ALICE
pp $\sqrt{s}$ = 13 TeV
$|\eta| < 0.8$
Data
MC default $\sigma_{inel}(^3\overline{He})$
MC with $\sigma_{inel}(^3\overline{He})$ ± 50%
Raw ($^3\overline{He}$ / ^{3}He)
$p_{primary}$ / |z| (GeV/c)
(d)
ALICE Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV
0–10% centrality
$|\eta| < 0.8$
Data
MC default $\sigma_{inel}(^3\overline{He})$
MC with $\sigma_{inel}(^3\overline{He})$ ± 50%
Raw $^3\overline{He}$ (TOF) / raw $^3\overline{He}$ (TPC)
$p_{primary}$ / |z| (GeV/c)
(e)
0.65 < $p_{primary}$ / |z| < 0.8 GeV/c
$|\eta| < 0.8$
Lambert–Beer fit
MC with varied $\sigma_{inel}(^3\overline{He})$
Data (with total unc.)
Resulting $\sigma_{inel}(^3\overline{He})$
Raw ($^3\overline{He}$ / ^{3}He)
$\sigma_{inel}(^3\overline{He})$ on $\langle A \rangle$ = 17.4 (b)
(f)
3.0 < $p_{primary}$ / |z| < 3.5 GeV/c
$|\eta| < 0.8$
Lambert–Beer fit
MC with varied $\sigma_{inel}(^3\overline{He})$
Data (with total unc.)
Resulting $\sigma_{inel}(^3\overline{He})$
Raw $^3\overline{He}$ (TOF) / raw $^3\overline{He}$ (TPC)
$\sigma_{inel}(^3\overline{He})$ on $\langle A \rangle$ = 34.7 (b)

Results for σinel(3He) as a function of 3He momentum.



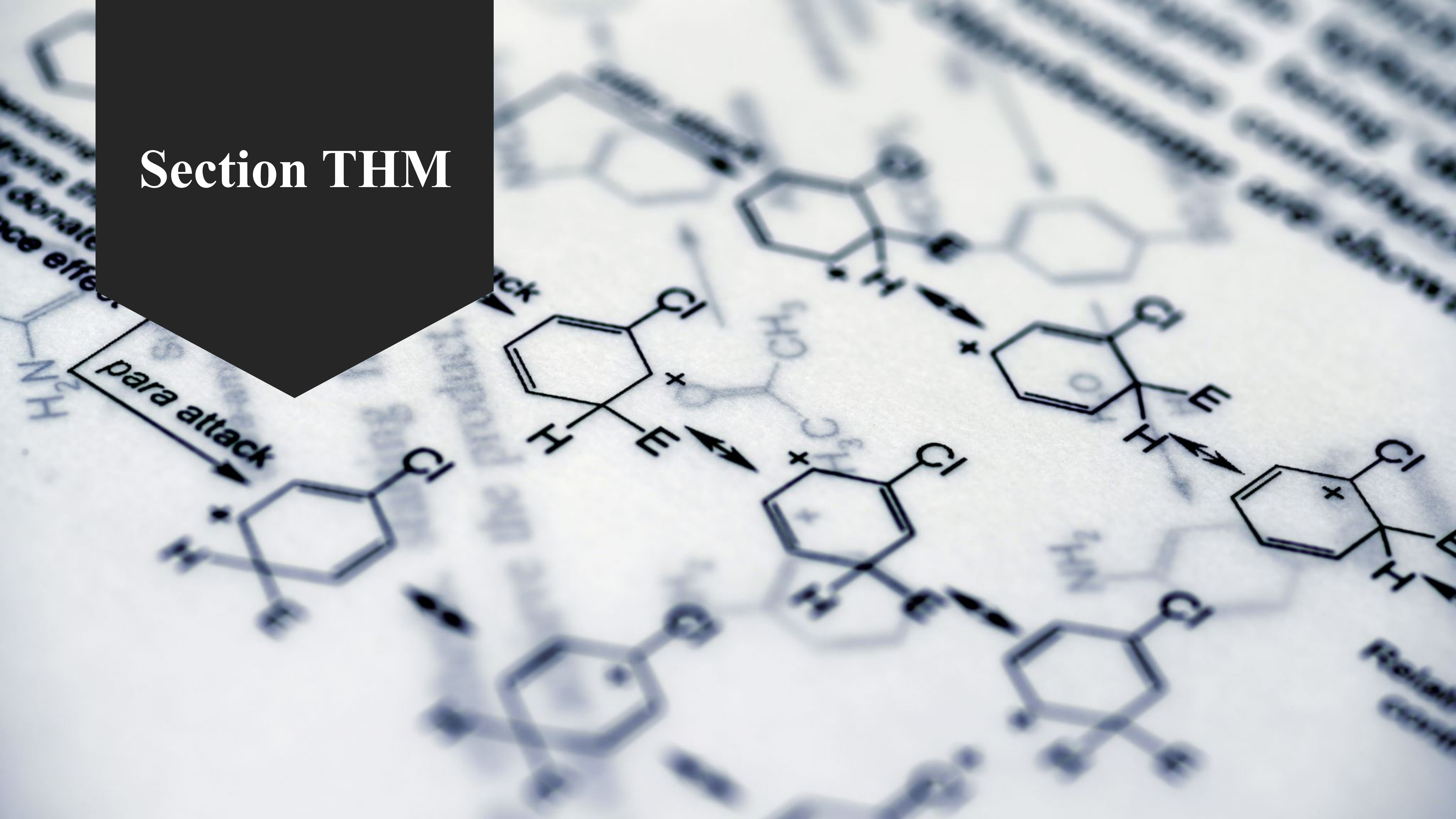
Results obtained from pp collisions at √s = 13 TeV



Results from the 10% most central Pb–Pb collisions at √sNN = 5.02 TeV

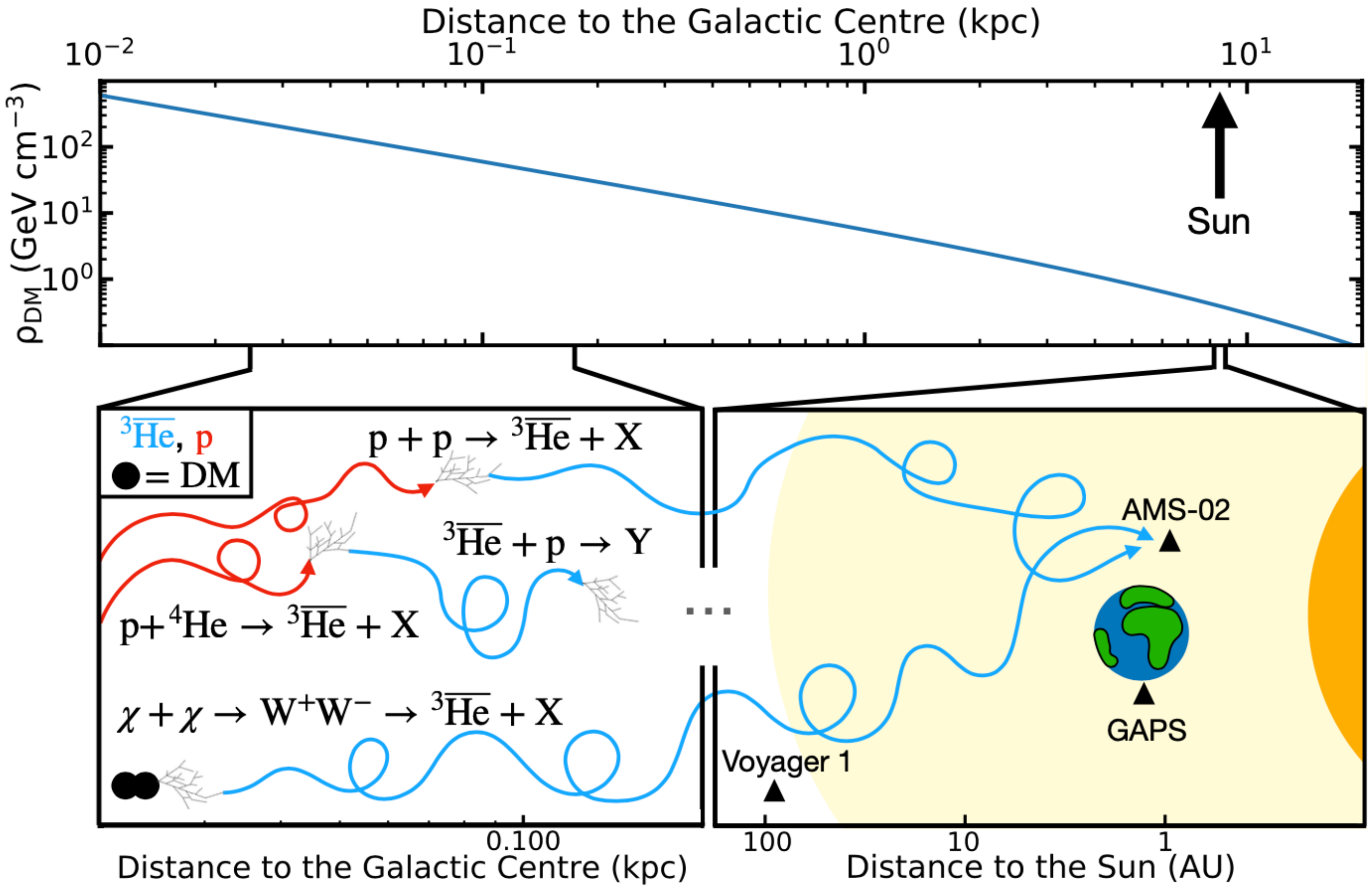
Results for σinel(3He) as a function of 3He momentum - THM

Section THM



Propagation of antinuclei in the interstellar medium

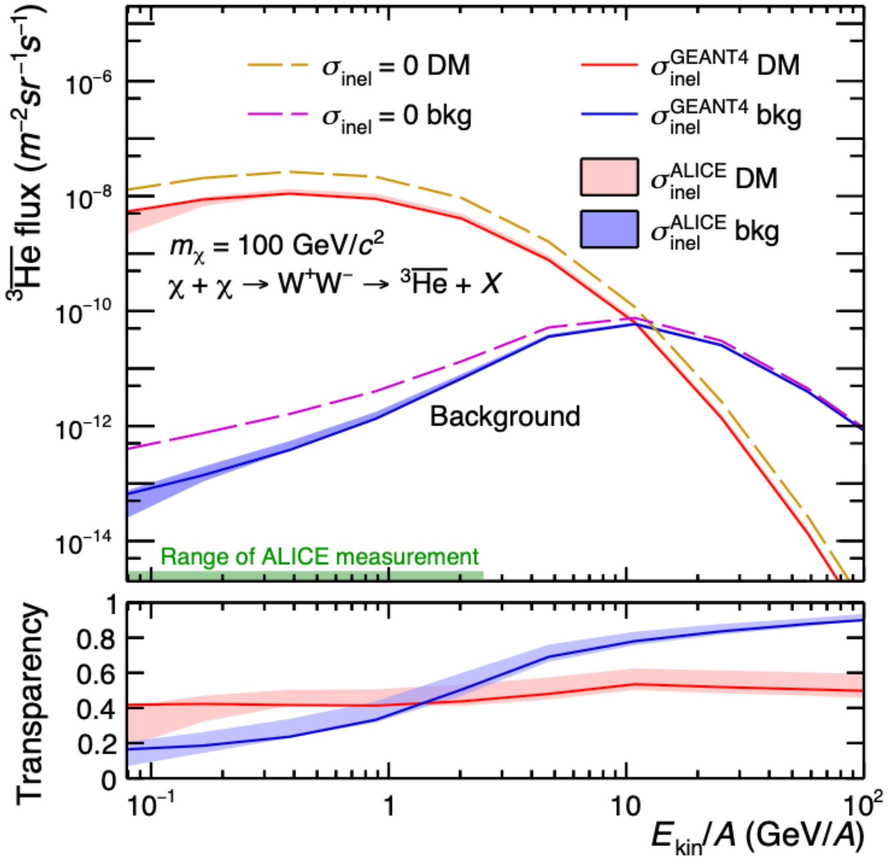
Schematic of 3He production and propagation in our Galaxy.



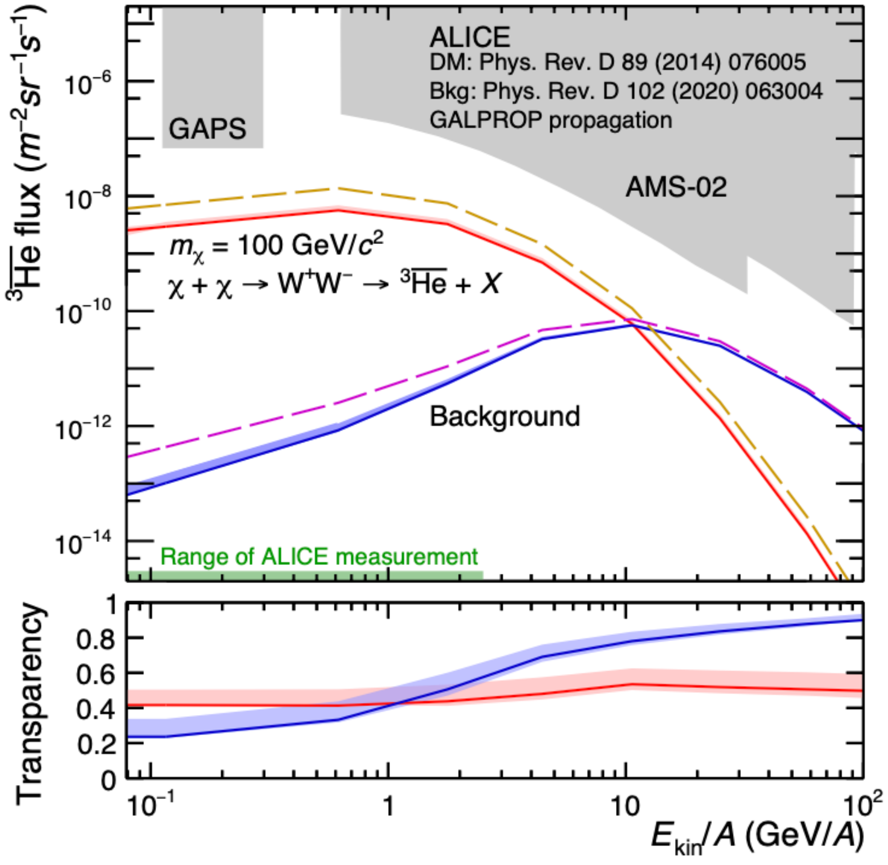
Expected 3He flux near Earth before and after solar modulation.

Transparency of our Galaxy to the propagation of 3He outside

The Solar System



Data before solar modulation



Data after solar modulation

Transparency of our Galaxy to the propagation of 3He inside

The Solar System

Section THM

Results general THM

Contributions and Conclusion

The paper discusses the production and study of light antinuclei, which are objects composed of antiprotons and antineutrons.

It explains that the only way to produce and study antinuclei with high precision is to create them at high-energy particle accelerators.

The paper highlights the limited knowledge of the interaction of light antinuclei with matter.

The paper determines the disappearance probability of 3 He when it encounters matter particles and annihilates or disintegrates within the ALICE detector at the Large Hadron Collider.

The paper extracts the inelastic interaction cross-section, which is then used as input to calculations of the transparency of our Galaxy to the propagation of 3 He stemming from dark-matter annihilation and cosmic-ray interactions within the interstellar medium.

The paper estimates a transparency of about 50% for a specific dark-matter profile, whereas it varies with increasing 3 He momentum from 25% to 90% for cosmic-ray sources.

The paper concludes that 3 He nuclei can travel long distances in the Galaxy and can be used to study cosmic-ray interactions and dark-matter annihilation.

Thanks / Obrigado

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