Day One Wrap Up

Alberto Calivà

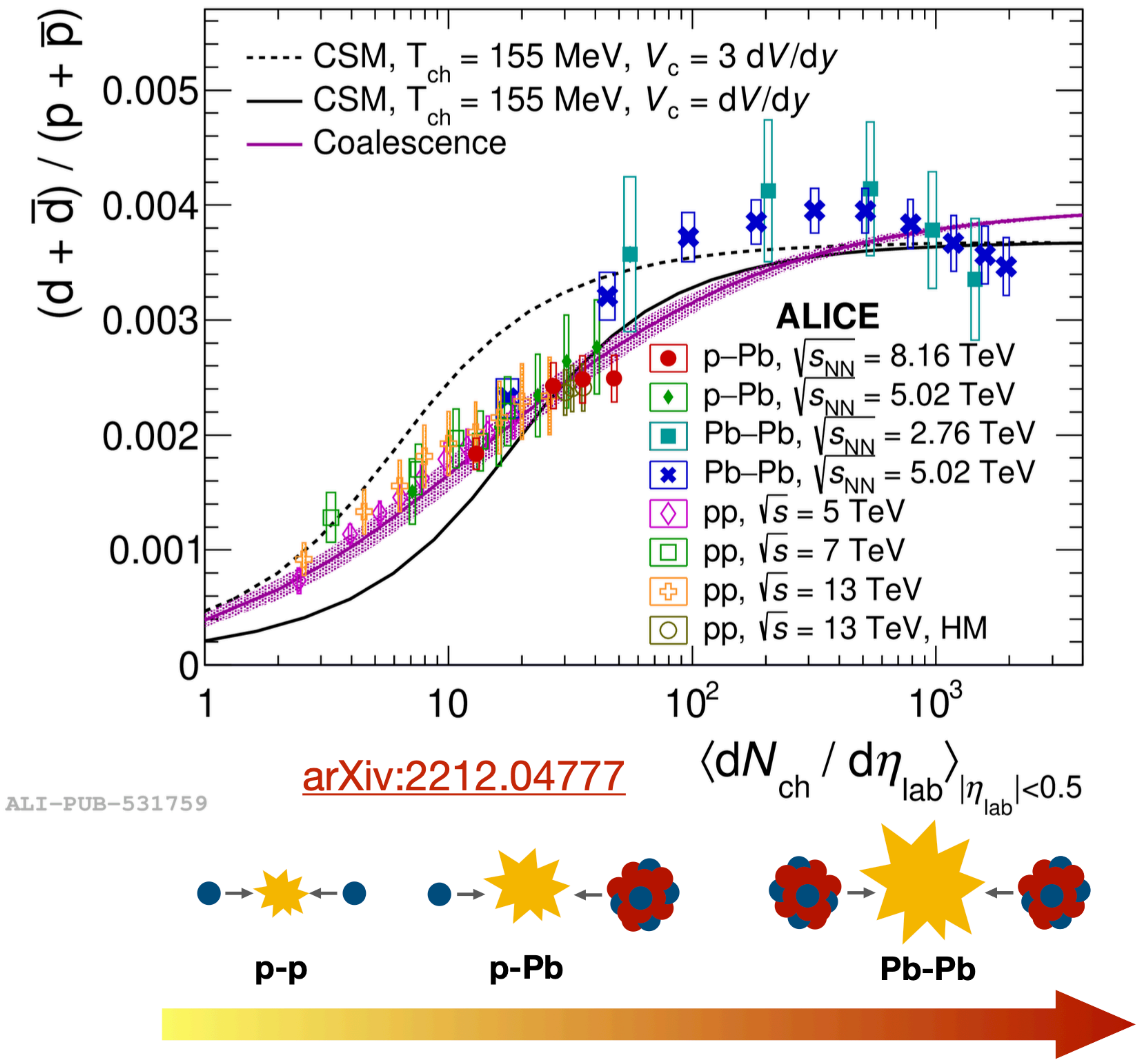
ExtreMe Matter Institute (EMMI)

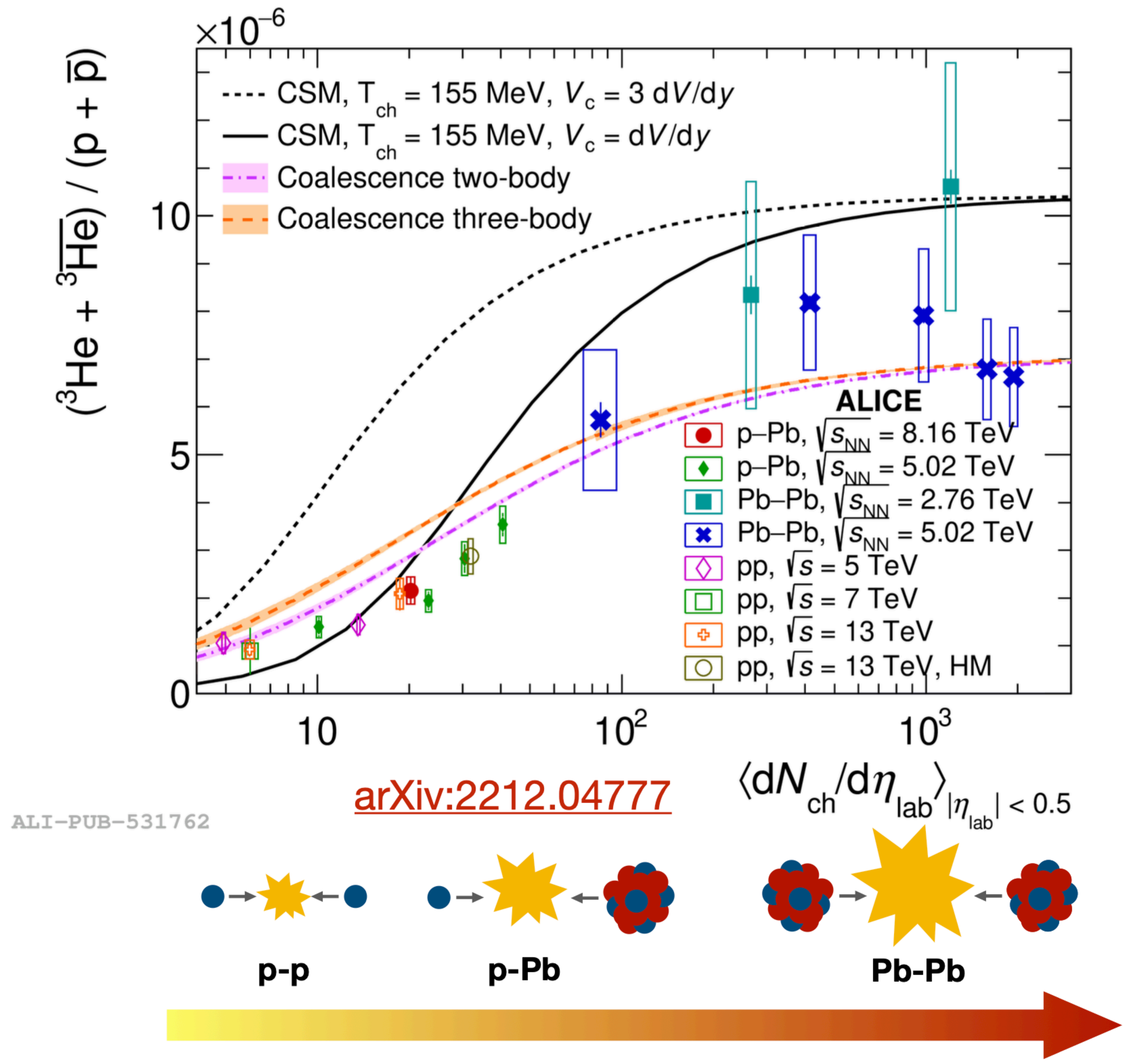
INFN

University of Bologna

ALICE results

L. Barioglio (University of Turin)

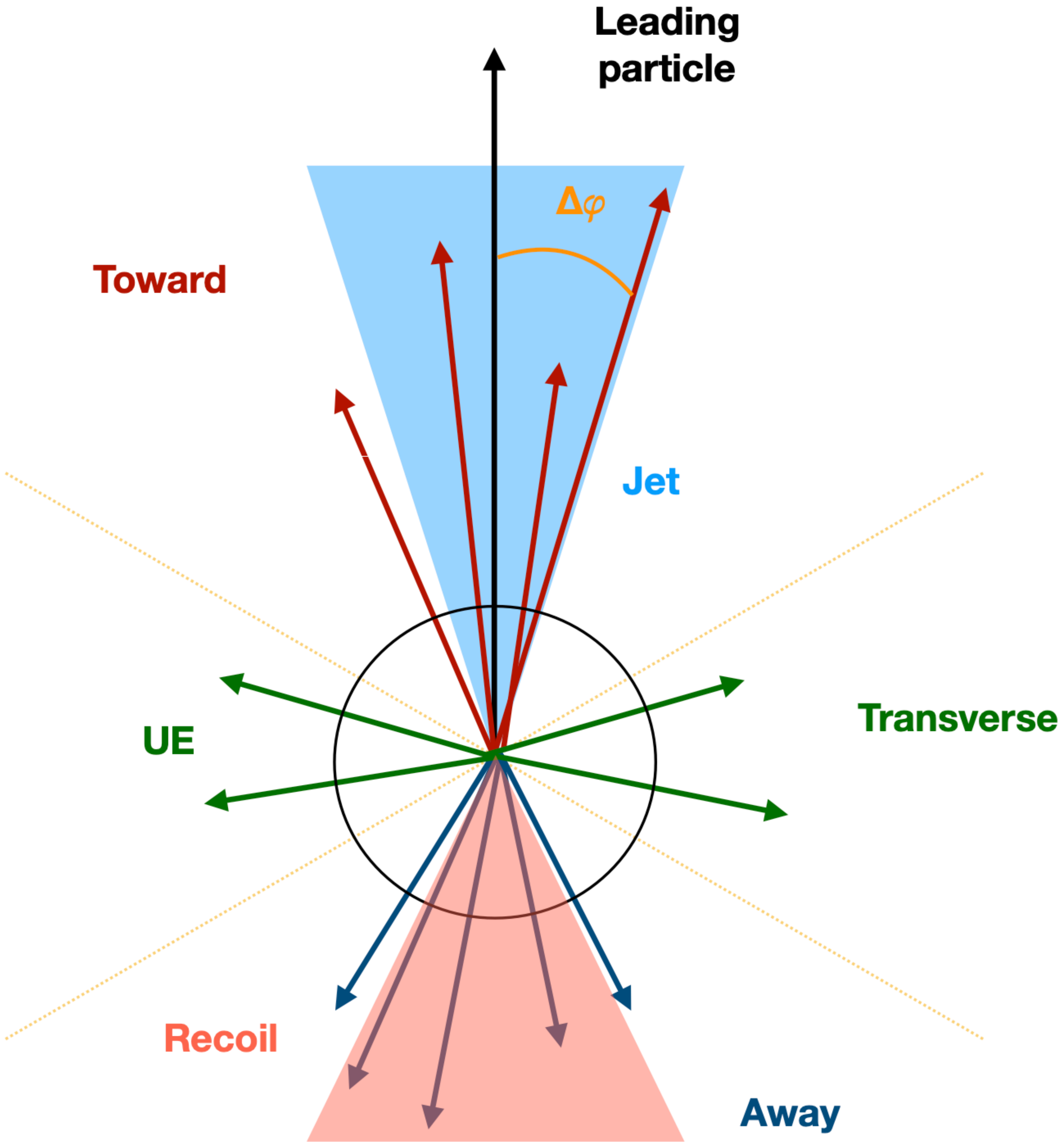


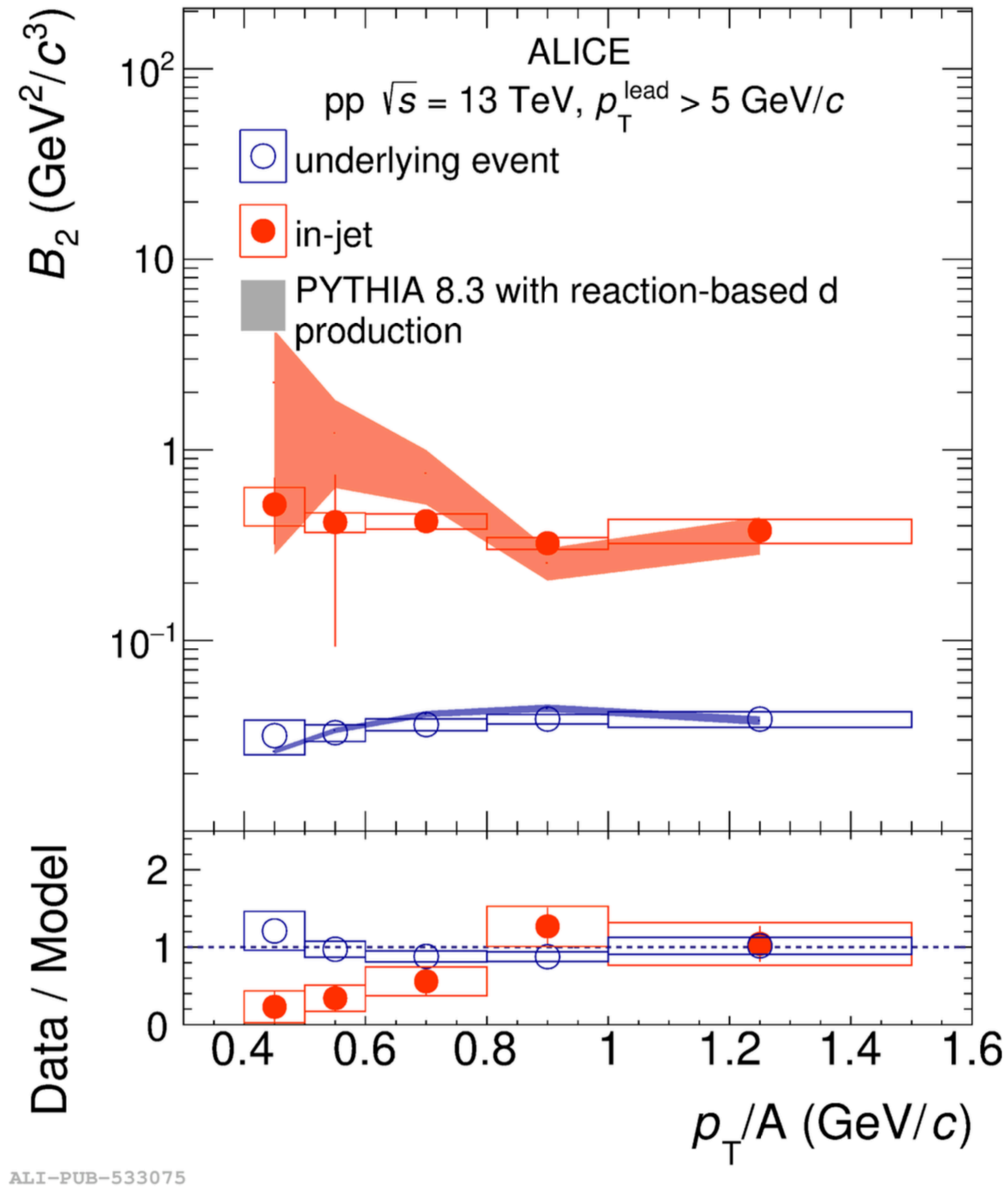


Discontinuity at $dN/d\eta \approx 80$: maybe the trend is not universal

ALICE results

L. Barioglio (University of Turin)

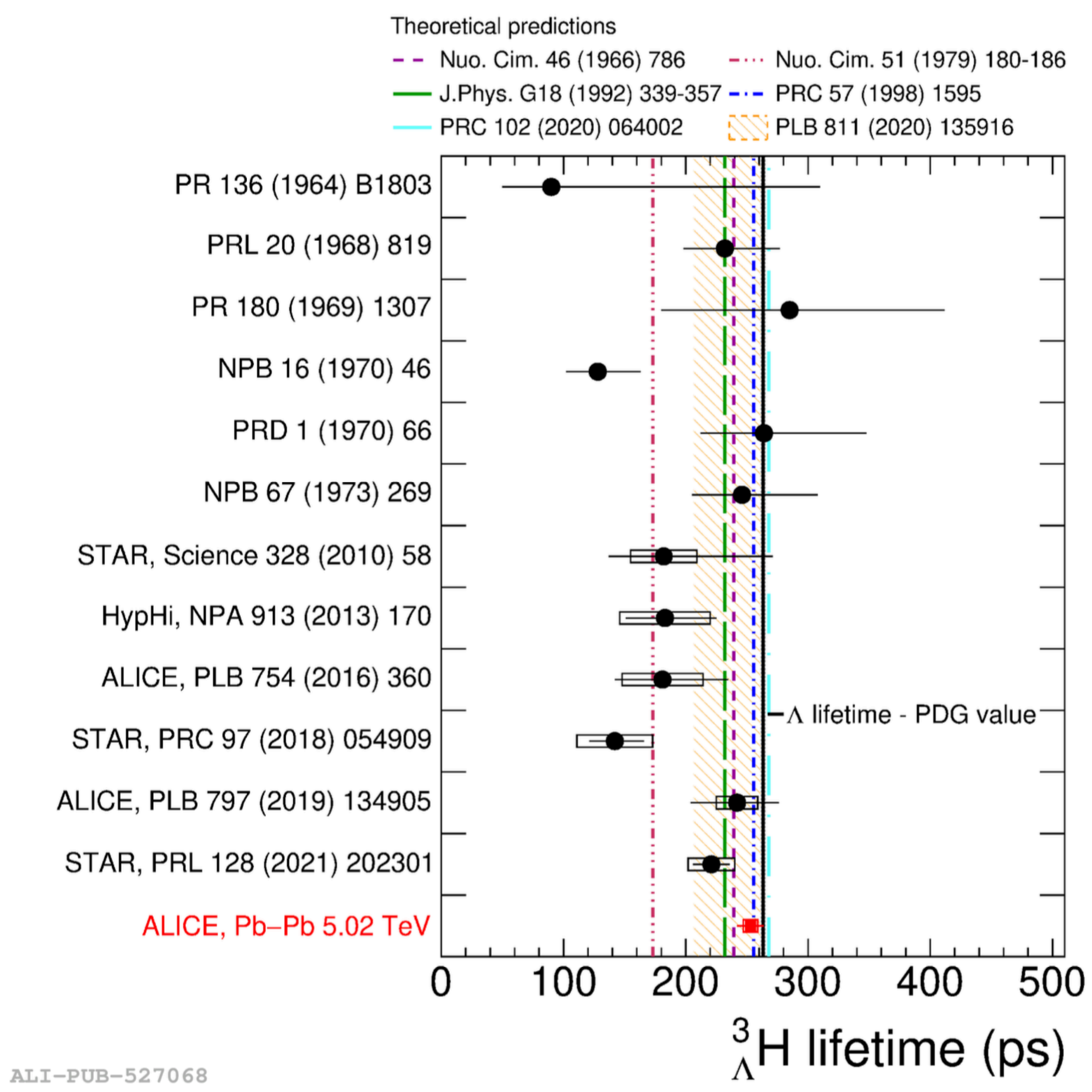




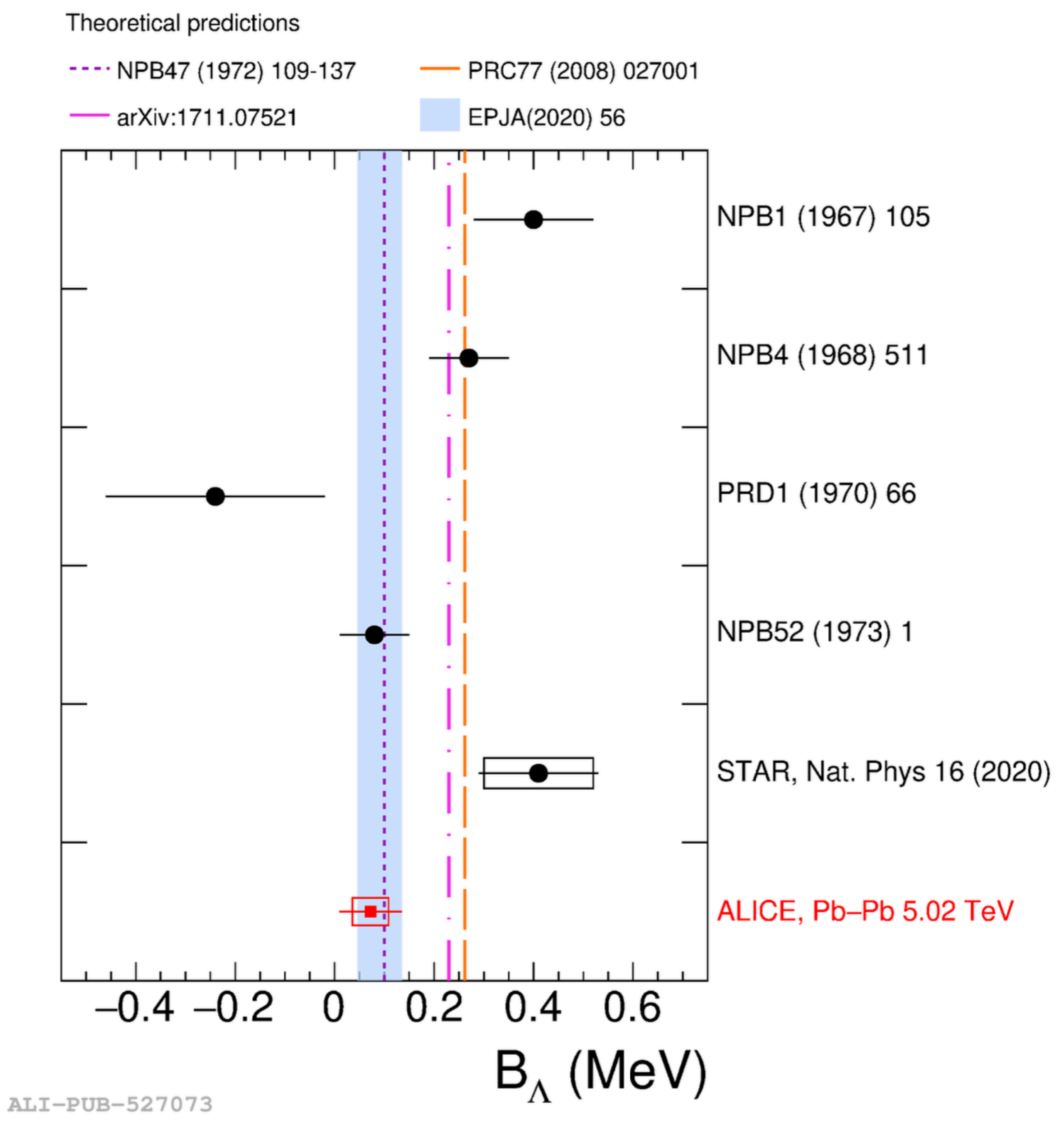
arXiv:2211.15204

ALICE results

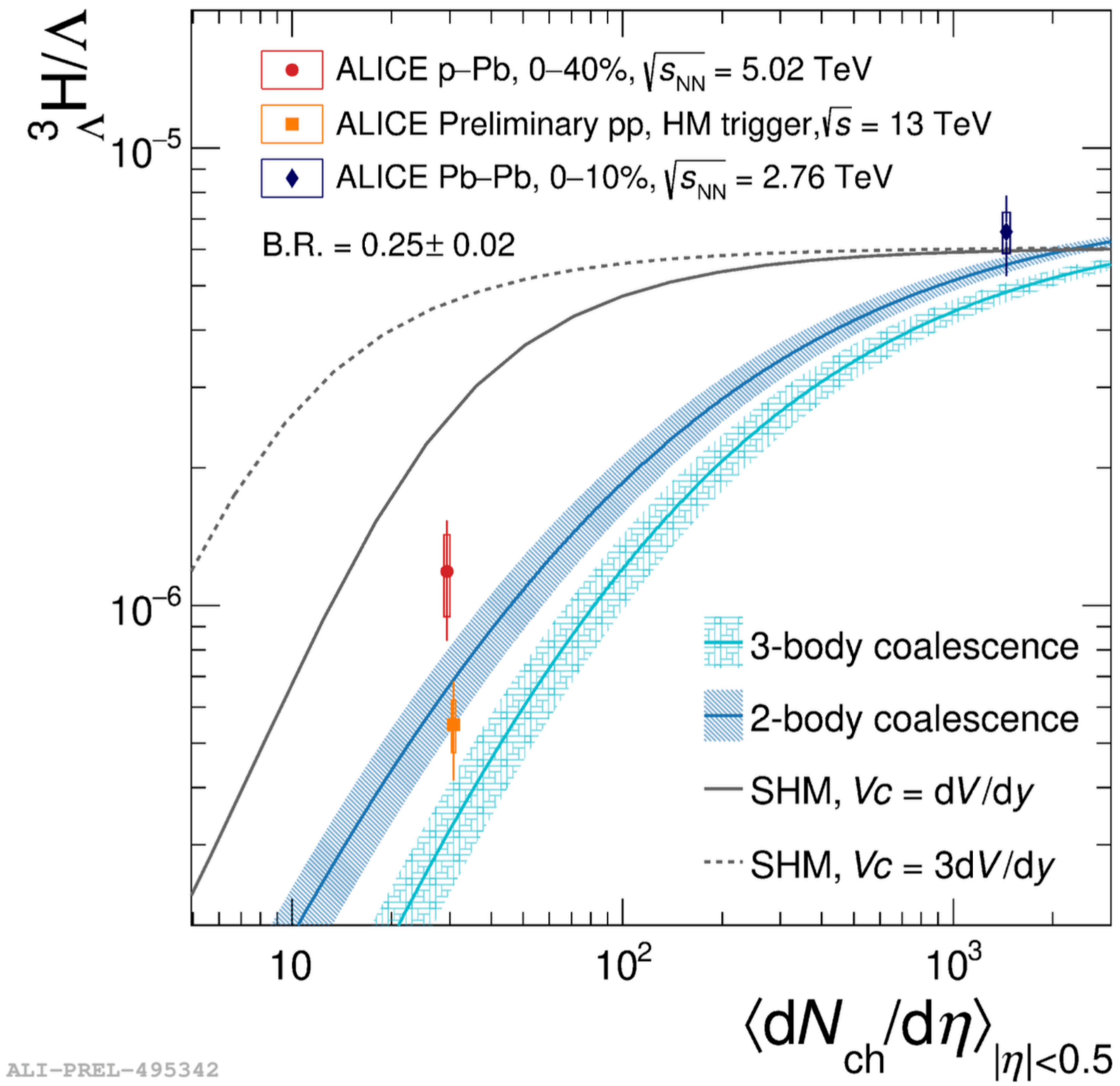
L. Barioglio (University of Turin)



arXiv:2107.10627



arXiv:2107.10627



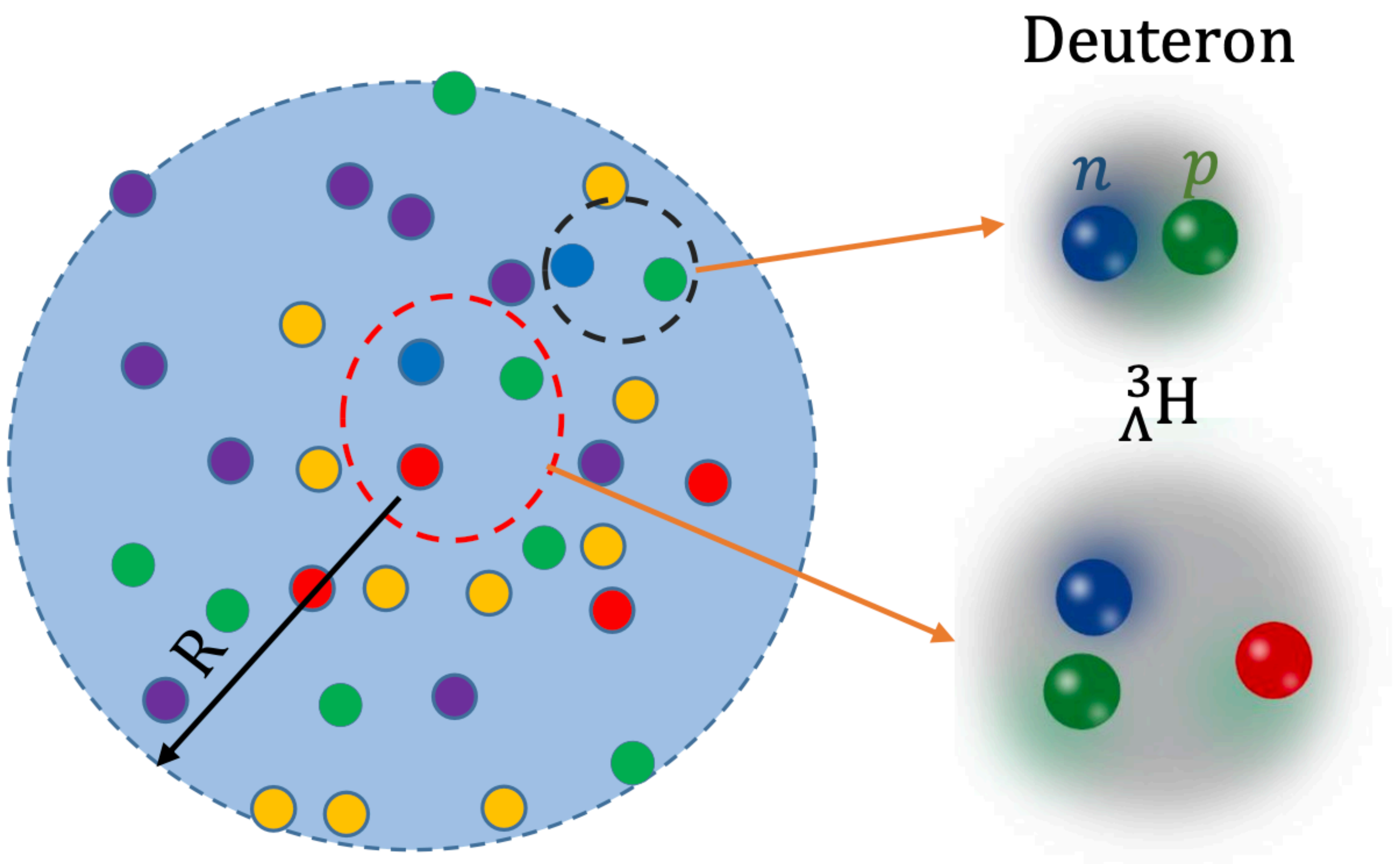
PRL 128 (2022) 252003

- More precise measurements in run 3
- 3-body decay will be measured → measurement of the BR

Latest developments on coalescence

K. J. Sun (Fudan University)

Coalescence Model



Quantum Correction (Size Effects)

K. J. Sun, C. M. Ko, and B. Dögnius, Phys. Lett. B792, 132-137(2019)

$$N_d \propto \frac{1}{\left[1+\left(\frac{2r_d^2}{3R^2}\right)\right]^{\frac{3}{2}}}$$

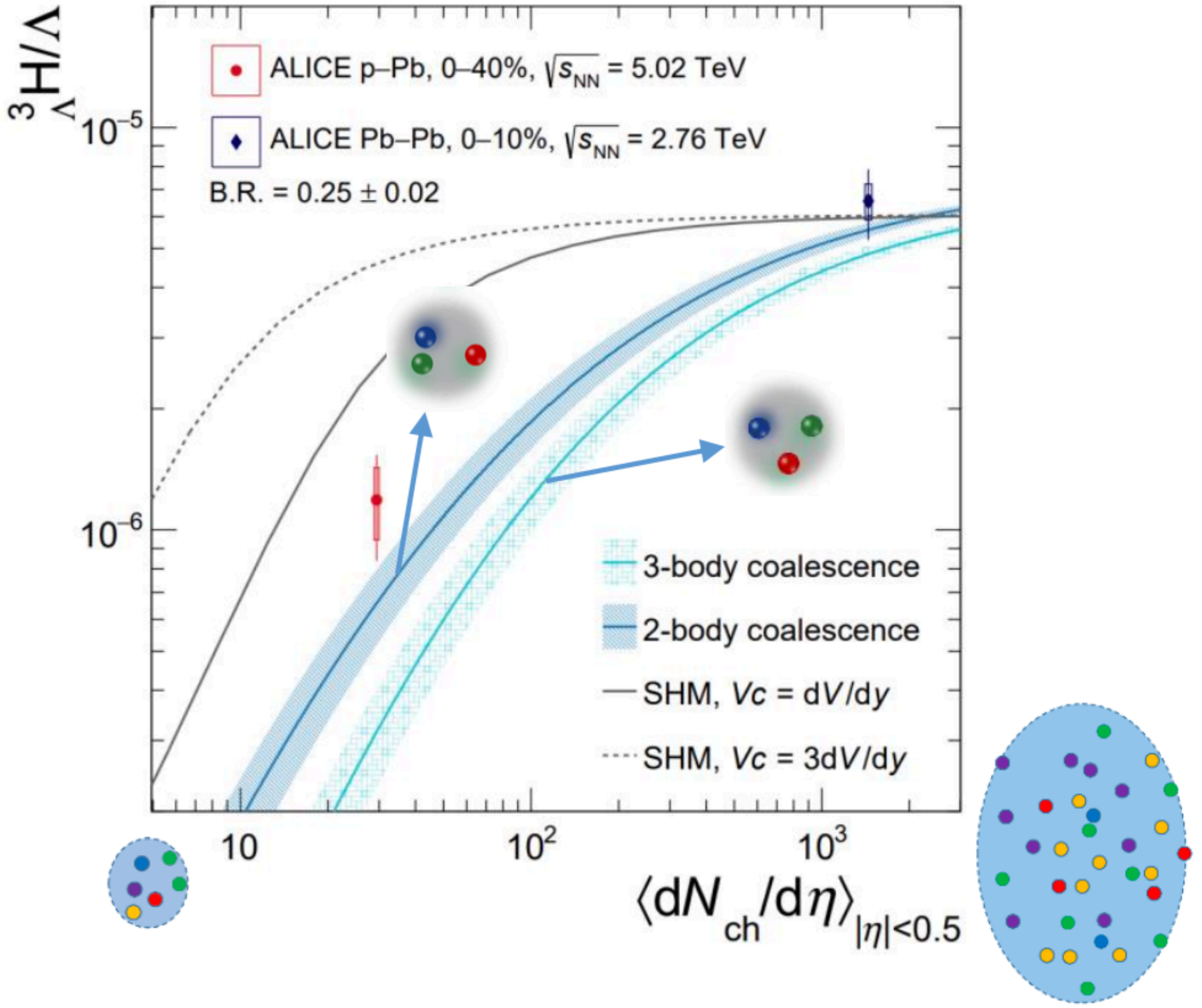
$$N_{^{3}_{\Lambda}\mathrm{H}} \propto \frac{1}{\left[1+\left(\frac{r^2_{^{3}_{\Lambda}\mathrm{H}}}{2R^2}\right)\right]^{3}}$$

Yield

Structure

ALICE Results（ $^{3}_{\Lambda}$H ）

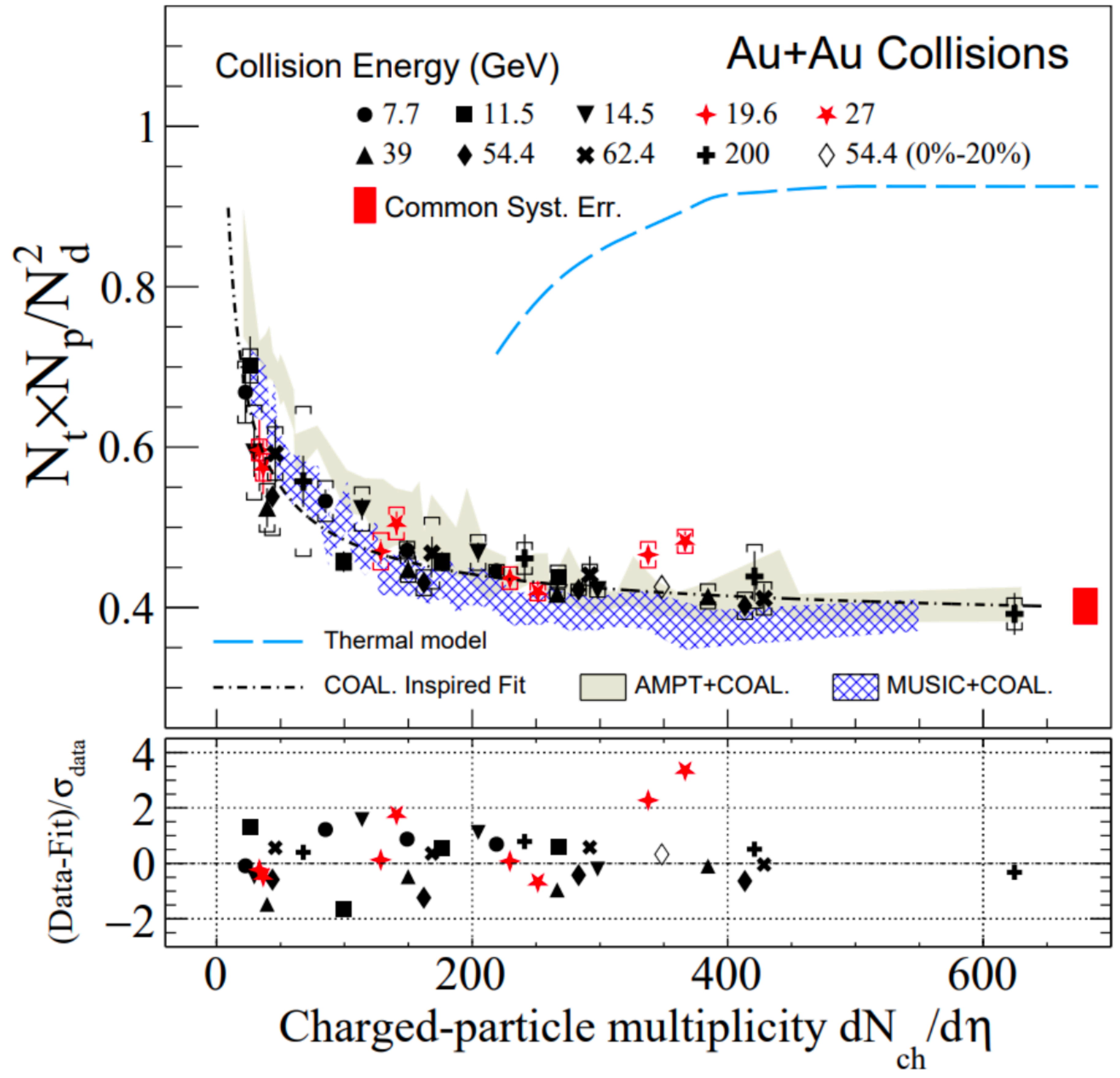
Phys. Rev. Lett. 128, 055203(2022)

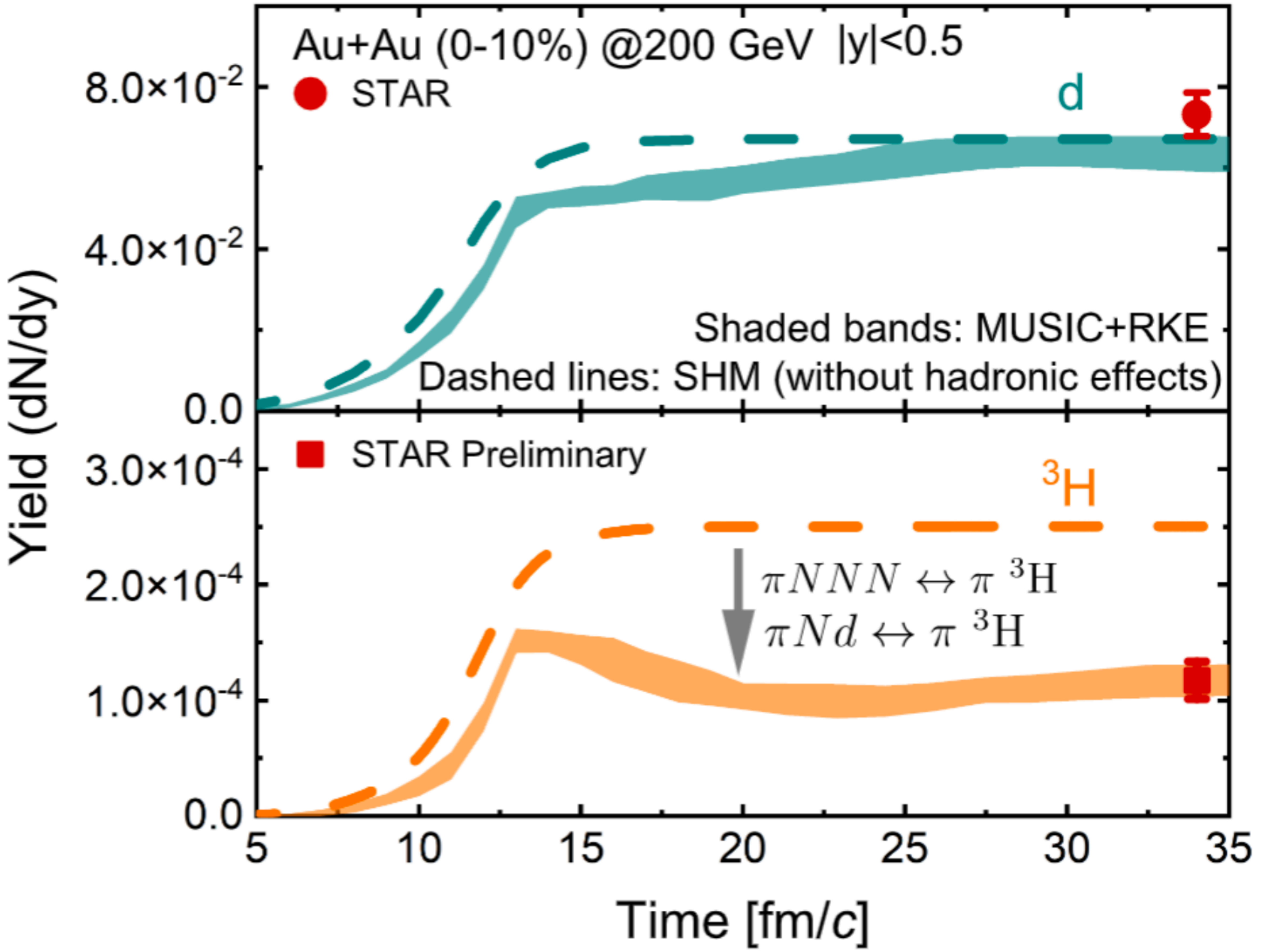


Quantum-mechanical corrections on light nuclei production due to finite nuclei sizes are observed at LHC and RHIC

Latest developments on coalescence

K. J. Sun (Fudan University)





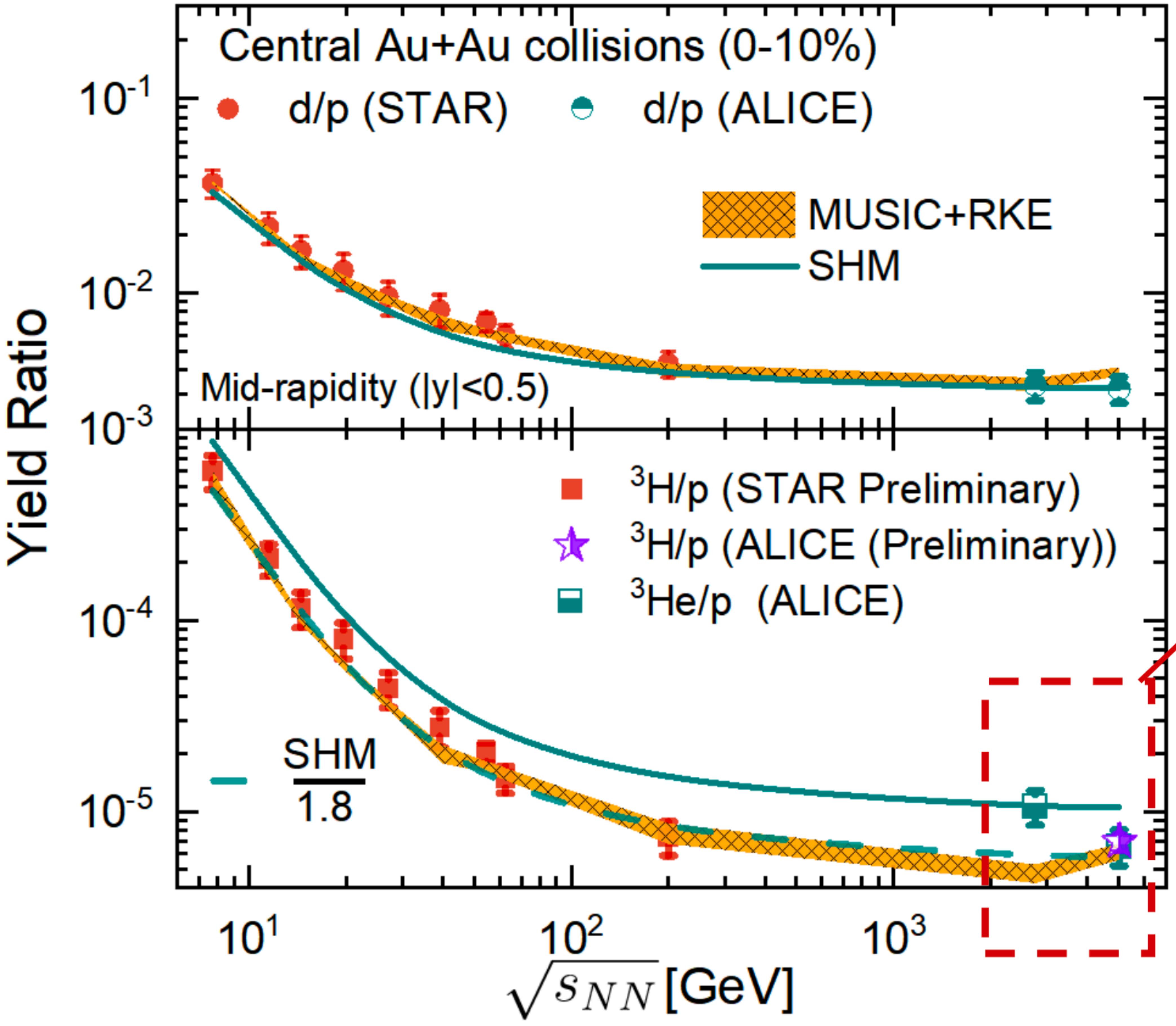
Hadronic re-scattering effects particularly relevant for the triton yield

→ Triton disintegration rate > regeneration rate

Latest developments on coalescence

K. J. Sun (Fudan University)

arXiv:2207.12532(2022)



Novel kinetic approach to light nuclei production in high-energy nuclear collisions, with the inclusion of many-body scatterings and finite nuclei sizes

Triton yield in Pb+Pb collisions at 5.02 TeV is consistent with the hadronic re-scattering effect. More statistics are needed

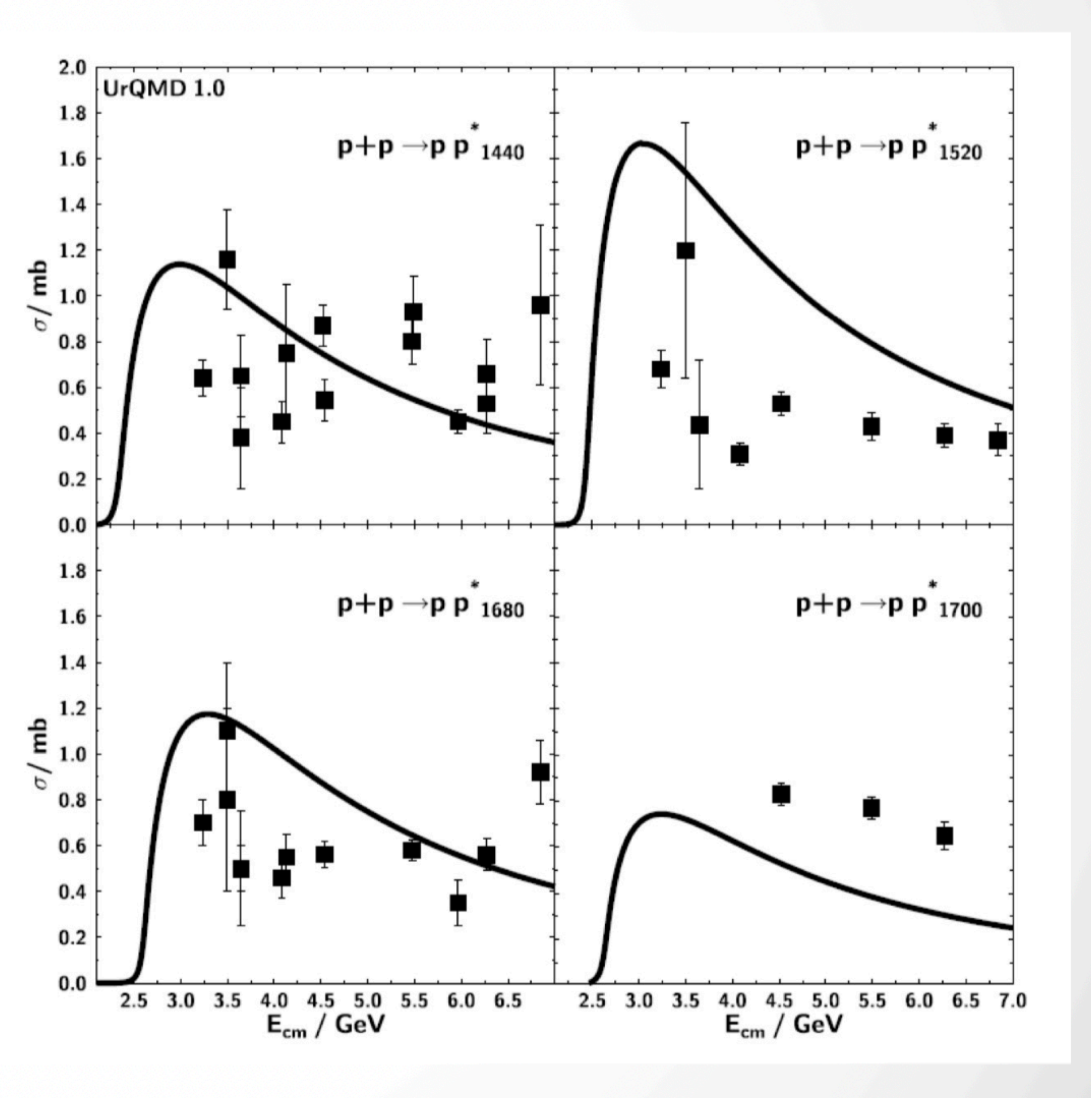
Through this approach, the overestimation on triton production in the thermal model can be resolved after taking into account the effect of hadronic re-scatterings.

The URQMD transport model

M. Bleicher (University of Frankfurt)

nucleon	Δ	Λ	Σ	Ξ	Ω
N_{938}	Δ_{1232}	Λ_{1116}	Σ_{1192}	Ξ_{1317}	Ω_{1672}
N_{1440}	Δ_{1600}	Λ_{1405}	Σ_{1385}	Ξ_{1530}	
N_{1520}	Δ_{1620}	Λ_{1520}	Σ_{1660}	Ξ_{1690}	
N_{1535}	Δ_{1700}	Λ_{1600}	Σ_{1670}	Ξ_{1820}	
N_{1650}	Δ_{1900}	Λ_{1670}	Σ_{1775}	Ξ_{1950}	
N_{1675}	Δ_{1905}	Λ_{1690}	Σ_{1790}	Ξ_{2025}	
N_{1680}	Δ_{1910}	Λ_{1800}	Σ_{1915}		
N_{1700}	Δ_{1920}	Λ_{1810}	Σ_{1940}		
N_{1710}	Δ_{1930}	Λ_{1820}	Σ_{2030}		
N_{1720}	Δ_{1950}	Λ_{1830}			
N_{1900}		Λ_{1890}			
N_{1990}		Λ_{2100}			
N_{2080}		Λ_{2110}			
N_{2190}					
N_{2200}					
N_{2250}					

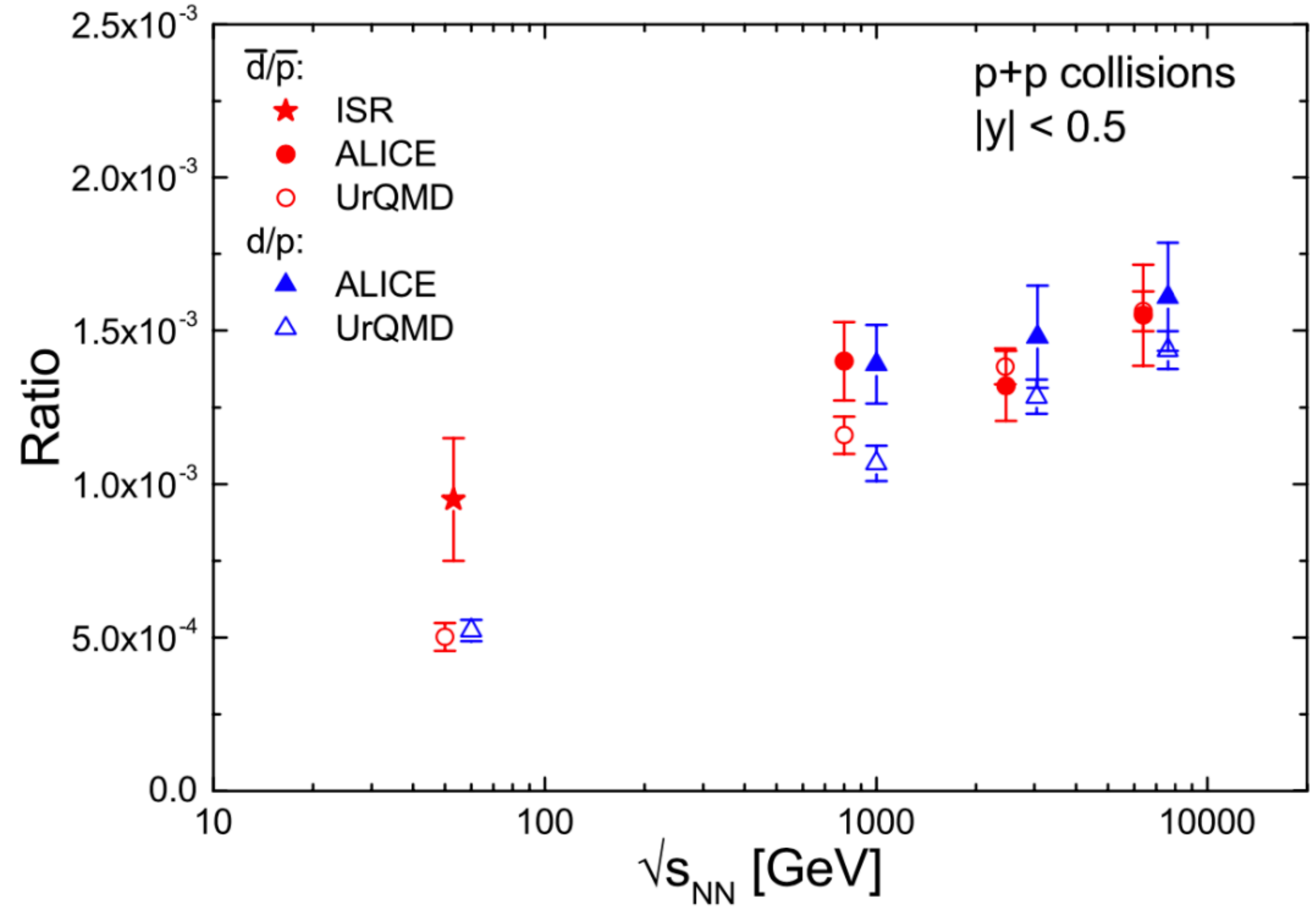
0^{-+}	1^{--}	0^{++}	1^{++}
π	ρ	a_0	a_1
K	K^*	K_0^*	K_1^*
η	ω	f_0	f_1
η'	ϕ	f_0^*	f_1'
1^{+-}	2^{++}	$(1^{--})^*$	$(1^{--})^{**}$
b_1	a_2	ρ_{1450}	ρ_{1700}
K_1	K_2^*	K_{1410}^*	K_{1680}^*
h_1	f_2	ω_{1420}	ω_{1662}
h_1'	f_2'	ϕ_{1680}	ϕ_{1900}

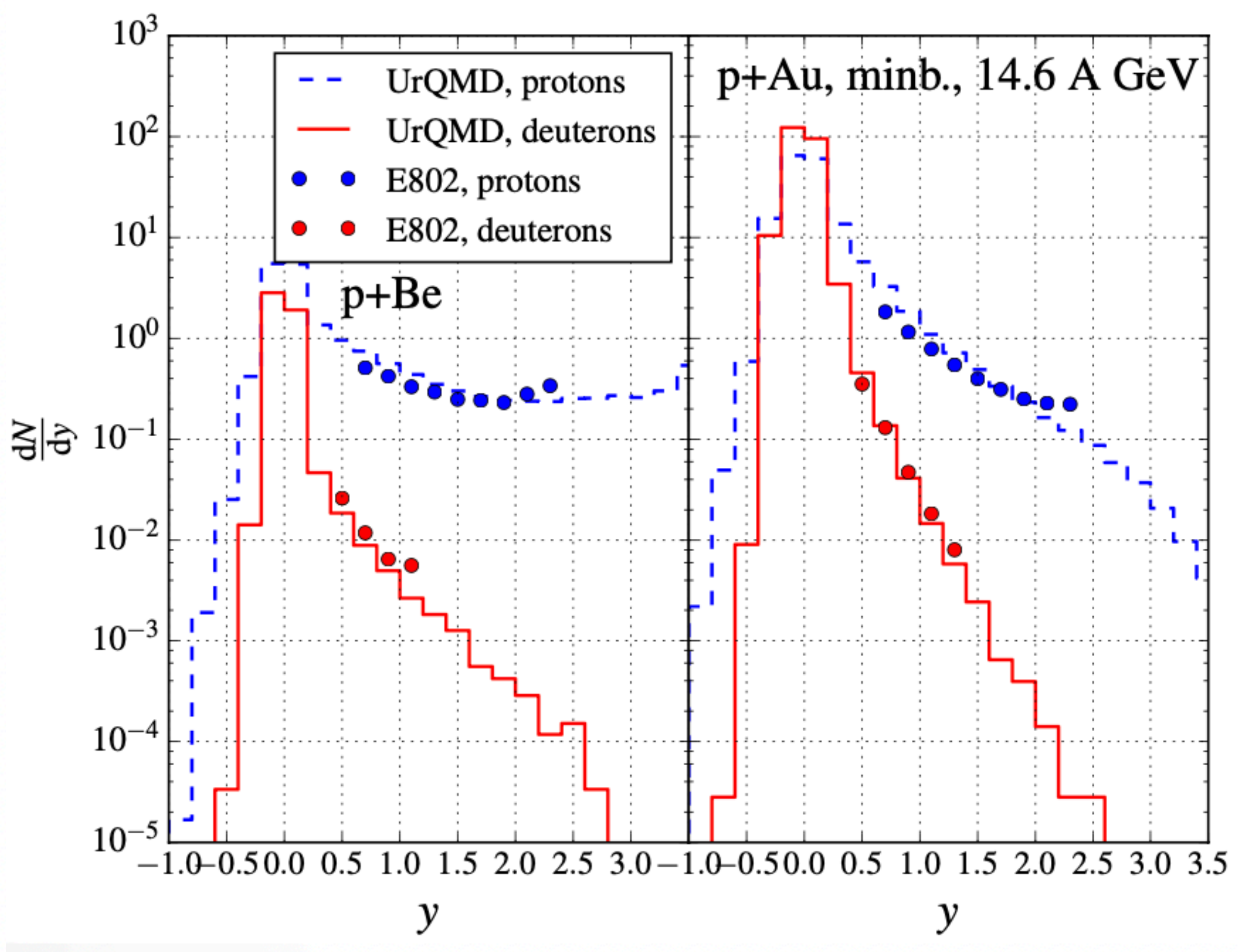


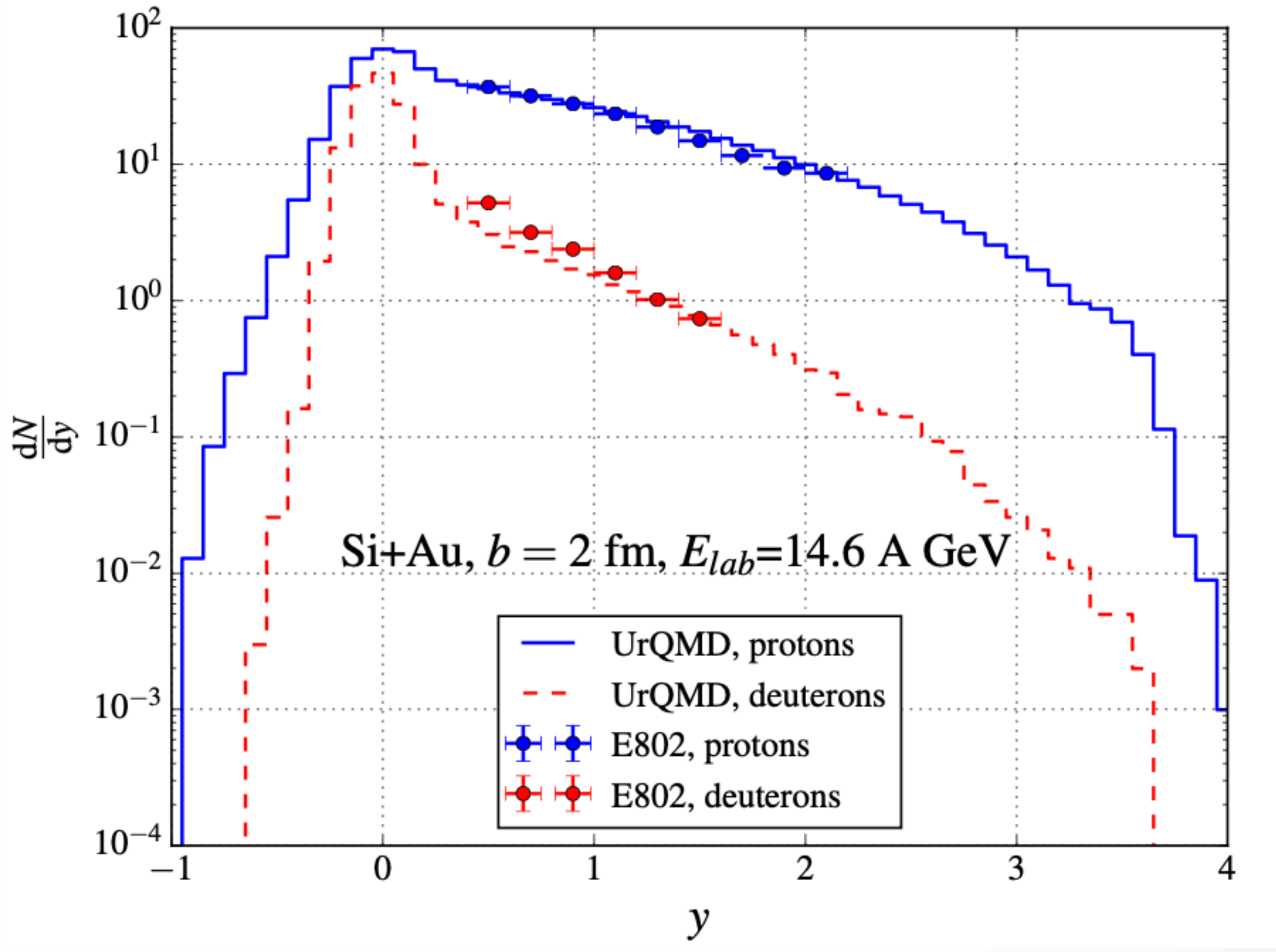
- Binary interactions between all implemented particles are treated
- Cross sections are taken from data or models
- Resonances are implemented in Breit-Wigner form
- No in-medium modifications
- Detailed balance

The URQMD transport model

M. Bleicher (University of Frankfurt)





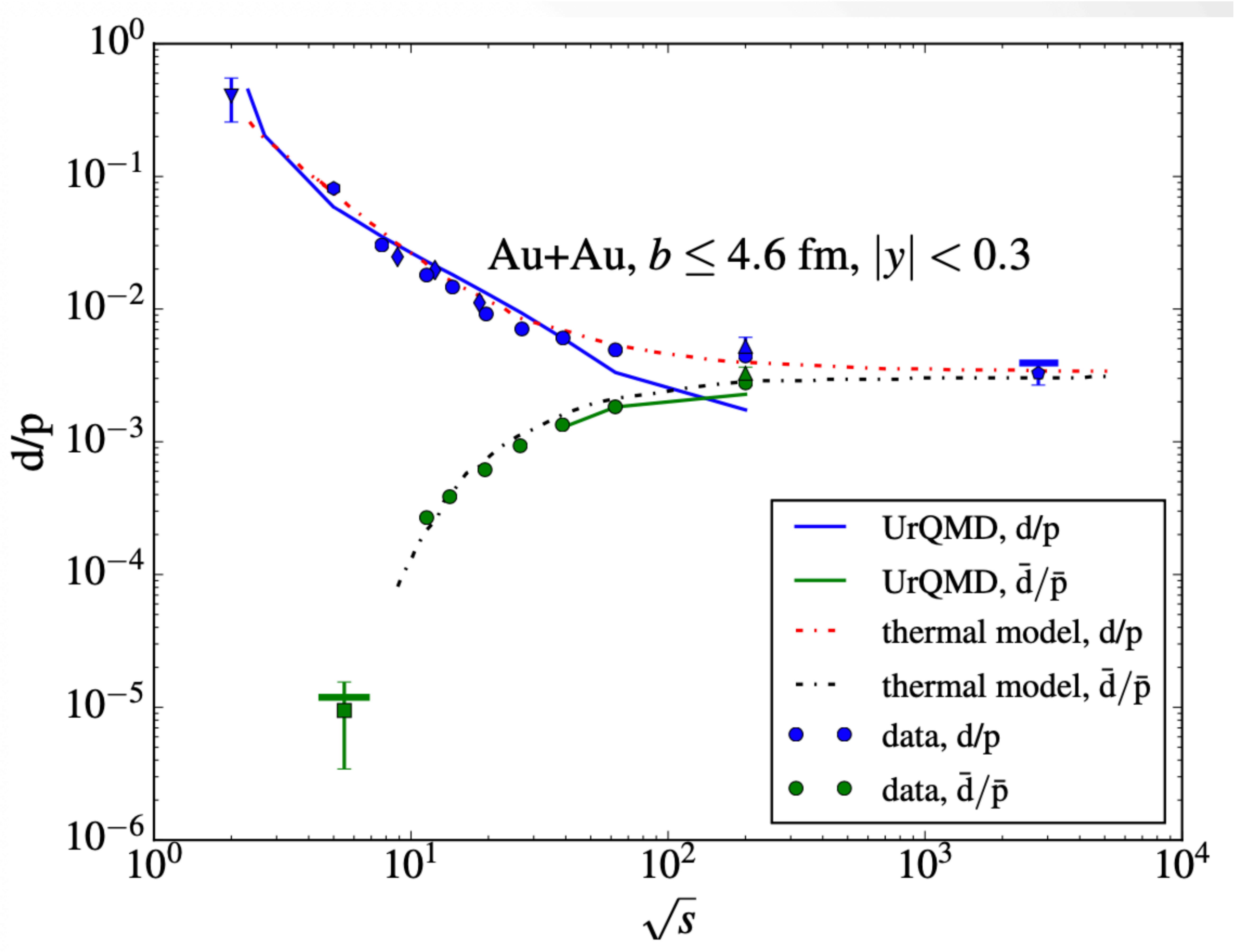


URQMD + coalescence hybrid model

> Good description of low energy data (small systems)

The URQMD transport model

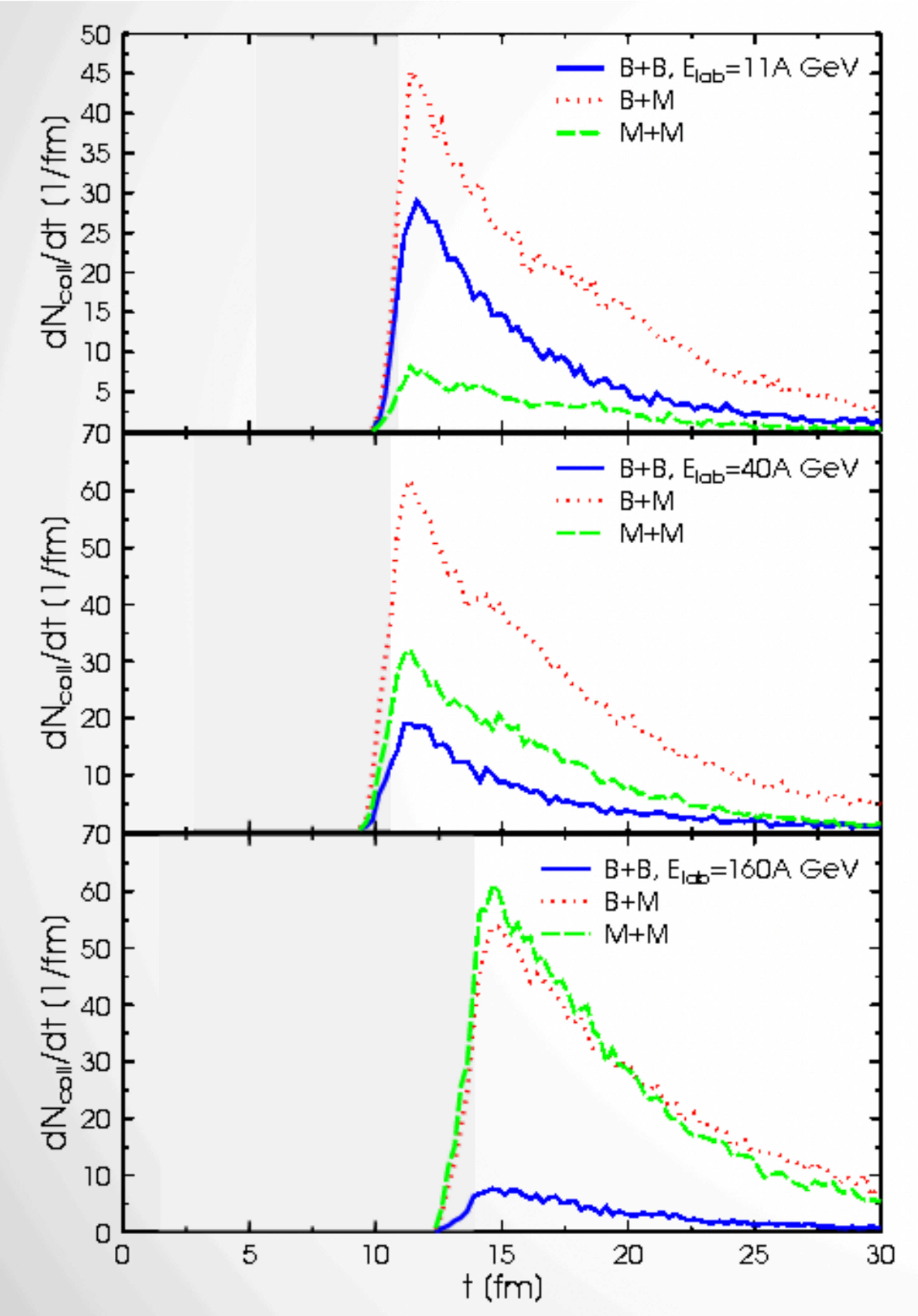
M. Bleicher (University of Frankfurt)

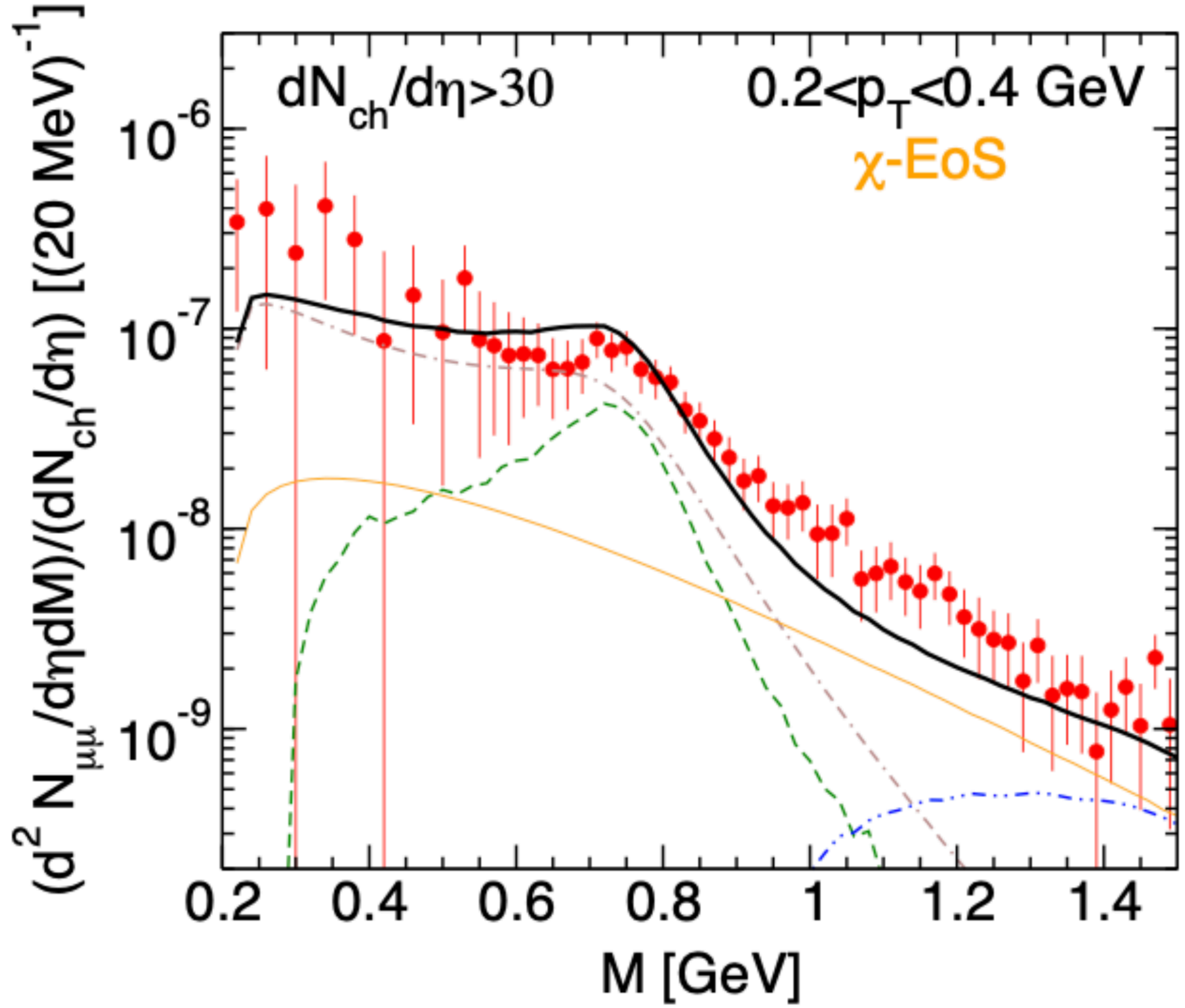


- URQMD + coalescence converge toward Thermal model (curves are missing hydro stage)
- Calculations for large energy
- μ_B = 0 at LHC: matter and antimatter are produced in equal amounts

The URQMD transport model

M. Bleicher (University of Frankfurt)

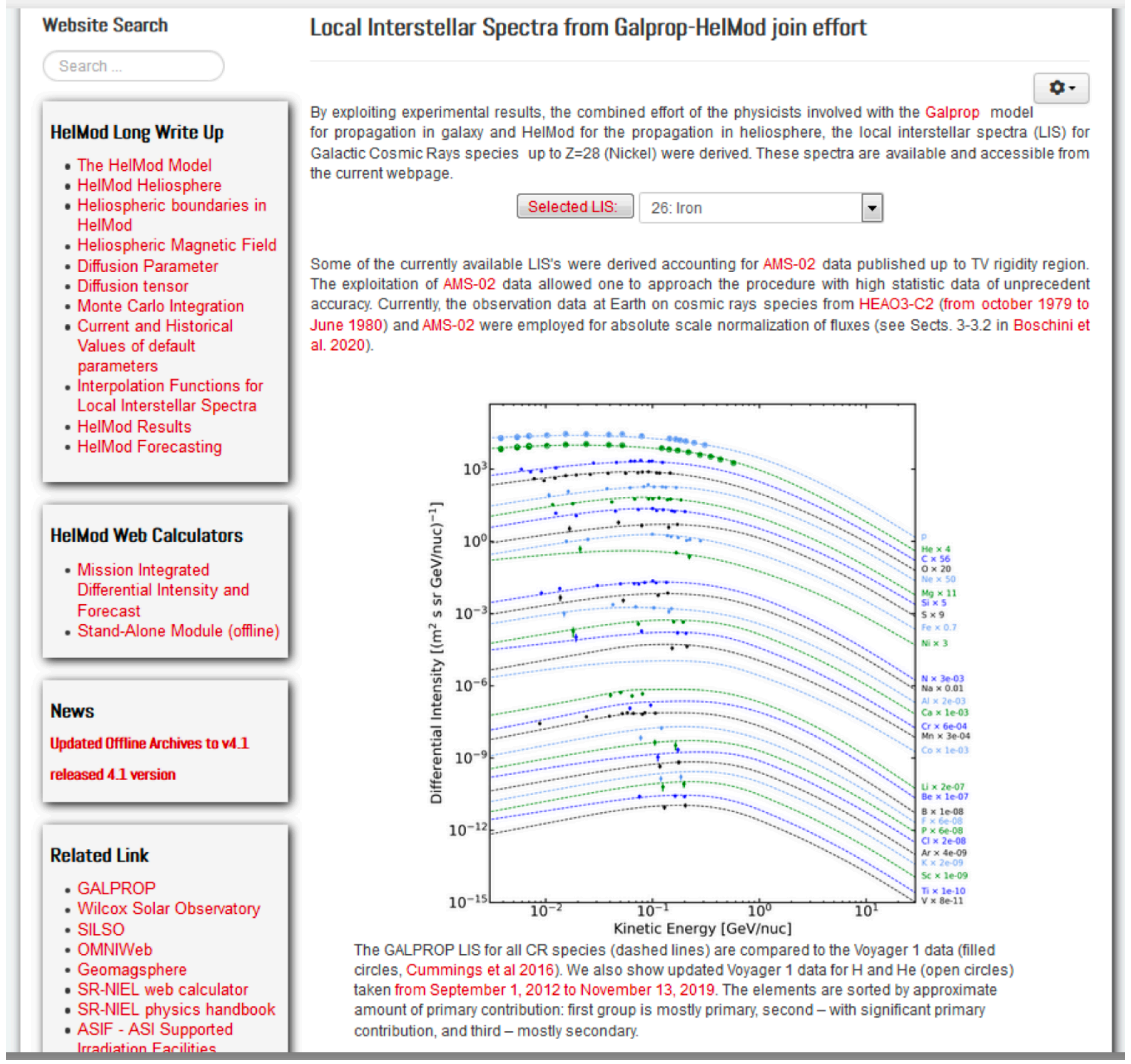




ρ^0 broadening effect is a measure of the lifetime of the hadronic phase

Antiprotons in our Galaxy and at colliders

Nicolò Masi (University of Bologna)



Website Search

Search ...

HelMod Long Write Up

- The HelMod Model
- HelMod Heliosphere
- Heliospheric boundaries in HelMod
- Heliospheric Magnetic Field
- Diffusion Parameter
- Diffusion tensor
- Monte Carlo Integration
- Current and Historical Values of default parameters
- Interpolation Functions for Local Interstellar Spectra
- HelMod Results
- HelMod Forecasting

HelMod Web Calculators

- Mission Integrated Differential Intensity and Forecast
- Stand-Alone Module (offline)

News

Updated Offline Archives to v4.1

released 4.1 version

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- GALPROP
- Wilcox Solar Observatory
- SILSO
- OMNIWeb
- Geomagsphere
- SR-NIEL web calculator
- SR-NIEL physics handbook
- ASIF - ASI Supported Irradiation Facilities

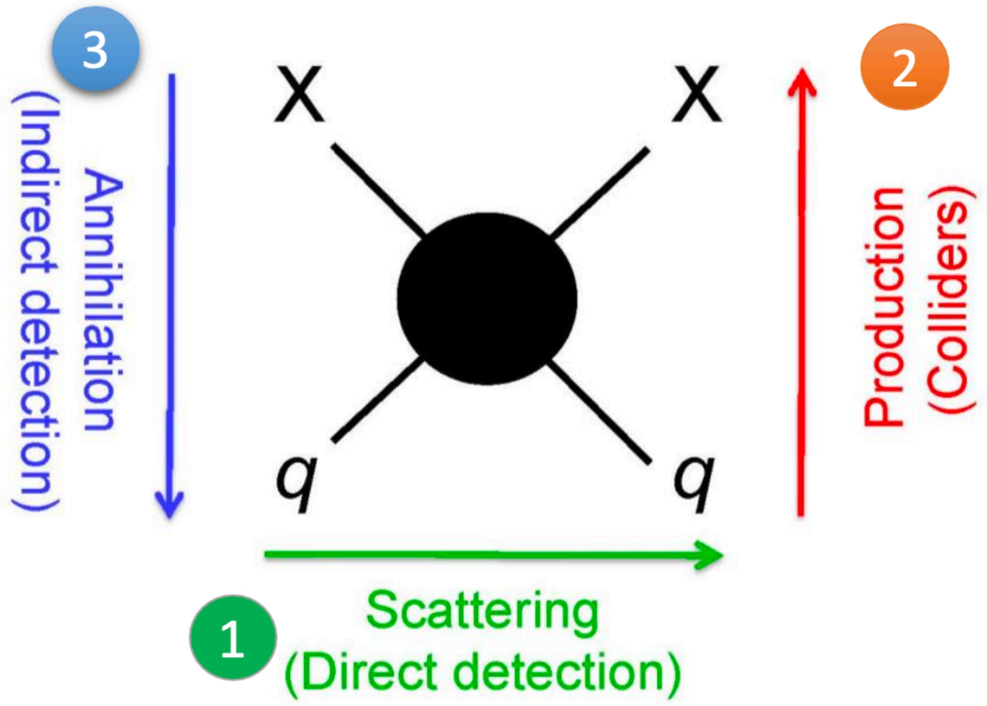
Local Interstellar Spectra from Galprop-HelMod join effort

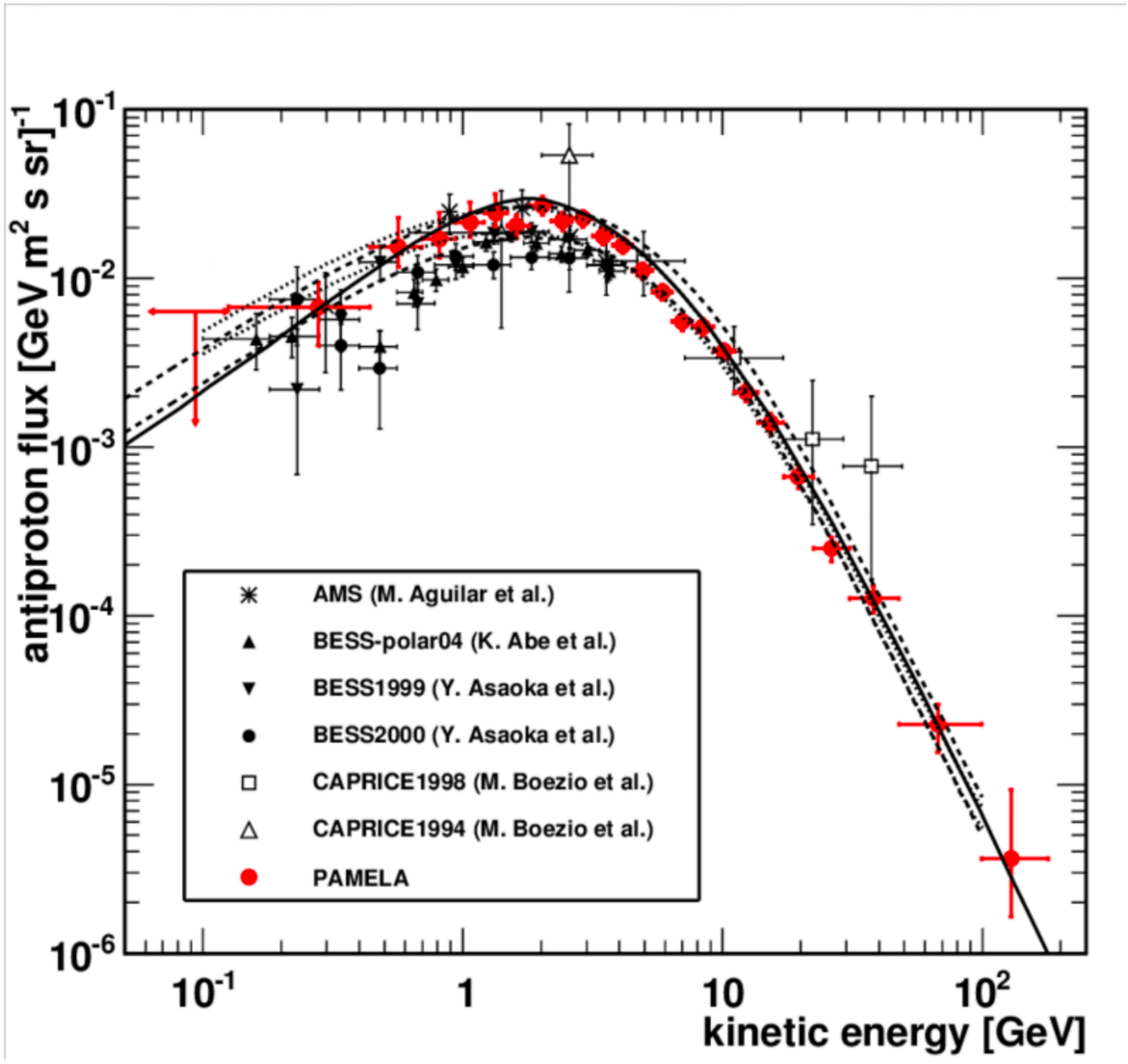
By exploiting experimental results, the combined effort of the physicists involved with the Galprop model for propagation in galaxy and HelMod for the propagation in heliosphere, the local interstellar spectra (LIS) for Galactic Cosmic Rays species up to Z=28 (Nickel) were derived. These spectra are available and accessible from the current webpage.

Selected LIS: 26: Iron

Some of the currently available LIS's were derived accounting for AMS-02 data published up to TV rigidity region. The exploitation of AMS-02 data allowed one to approach the procedure with high statistic data of unprecedent accuracy. Currently, the observation data at Earth on cosmic rays species from HEAO3-C2 (from october 1979 to June 1980) and AMS-02 were employed for absolute scale normalization of fluxes (see Sects. 3-3.2 in Boschini et al. 2020).

The GALPROP LIS for all CR species (dashed lines) are compared to the Voyager 1 data (filled circles, Cummings et al 2016). We also show updated Voyager 1 data for H and He (open circles) taken from September 1, 2012 to November 13, 2019. The elements are sorted by approximate amount of primary contribution: first group is mostly primary, second – with significant primary contribution, and third – mostly secondary.





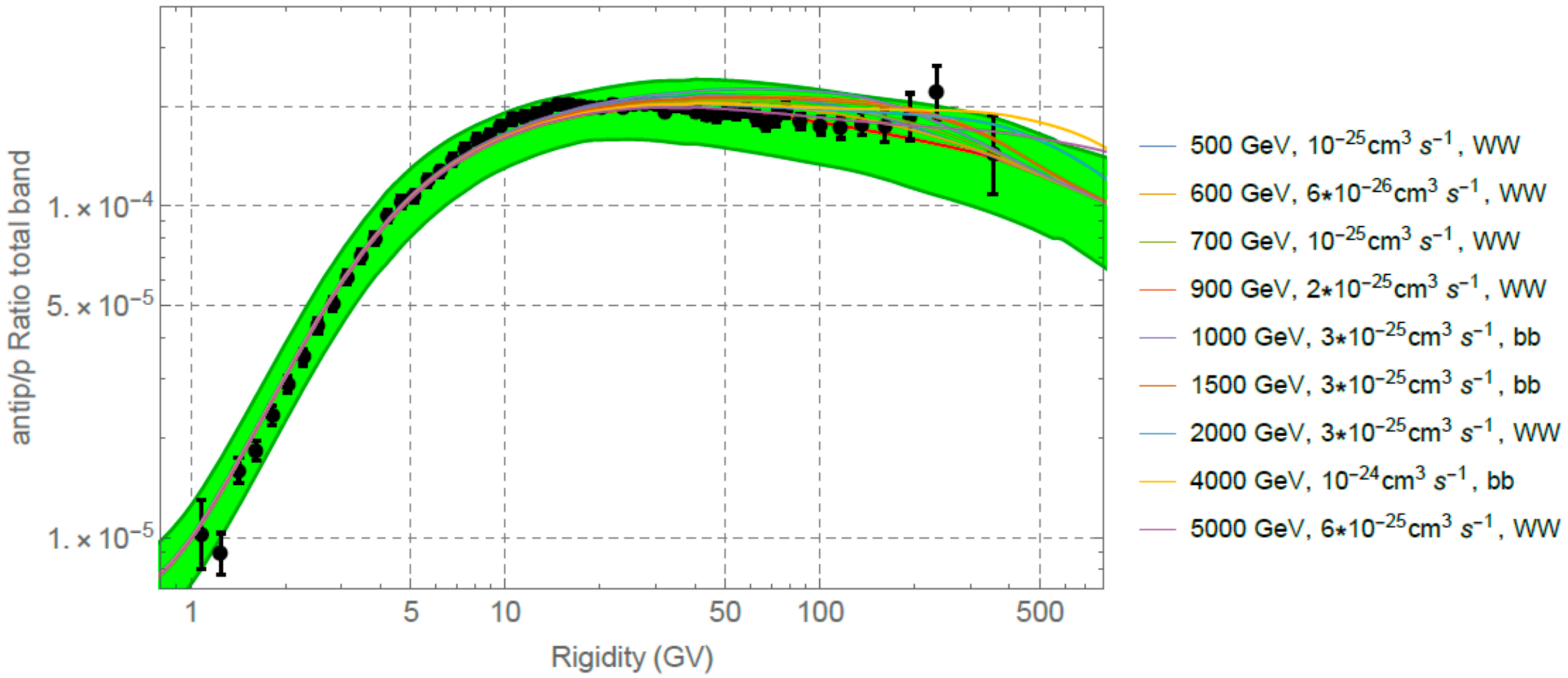
Indirect Cosmic Rays Anomalies:

WIMP-like Dark Matter self-annihilates in the galactic halo and injects into CRs detectable products: $\gamma, \nu, e^+, \bar{p}, \bar{d}$. They progate in the Milky Way, according to a Standard Model, and arrive at the top of Earth atmosphere, where they can be detected by space experiment, such as FERMI, PAMELA, AMS-02, DAMPE, CALET…

Antiprotons in our Galaxy and at colliders

Nicolò Masi (University of Bologna)

BETTER CANDIDATES: m > 1 TeV, 0.6 TeV < m < 1 TeV and $\langle \sigma v \rangle < 10^{-25} cm^3/s$



- **AMS-02 results are still compatible with a secondary production but DM signals could in principle still hide within the overall error band.**
- With the nuclear measurements effort we will be capable of extracting a possible DM signal.

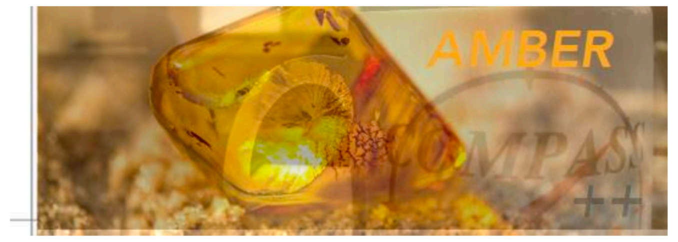
The COMPASS/AMBER experiment is a fixed-target experiment at located in the M2 beam-line of the SPS.

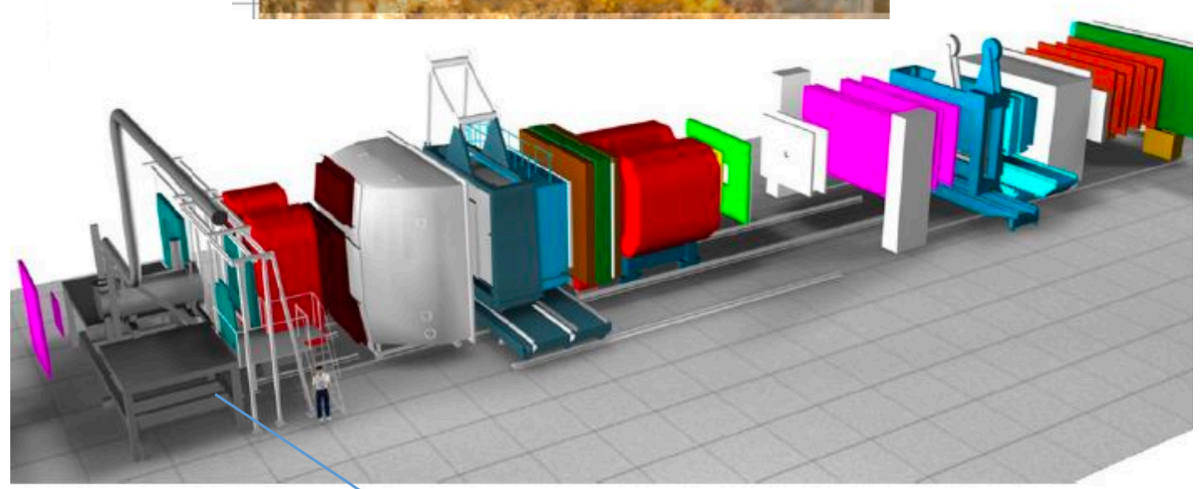
AMBER

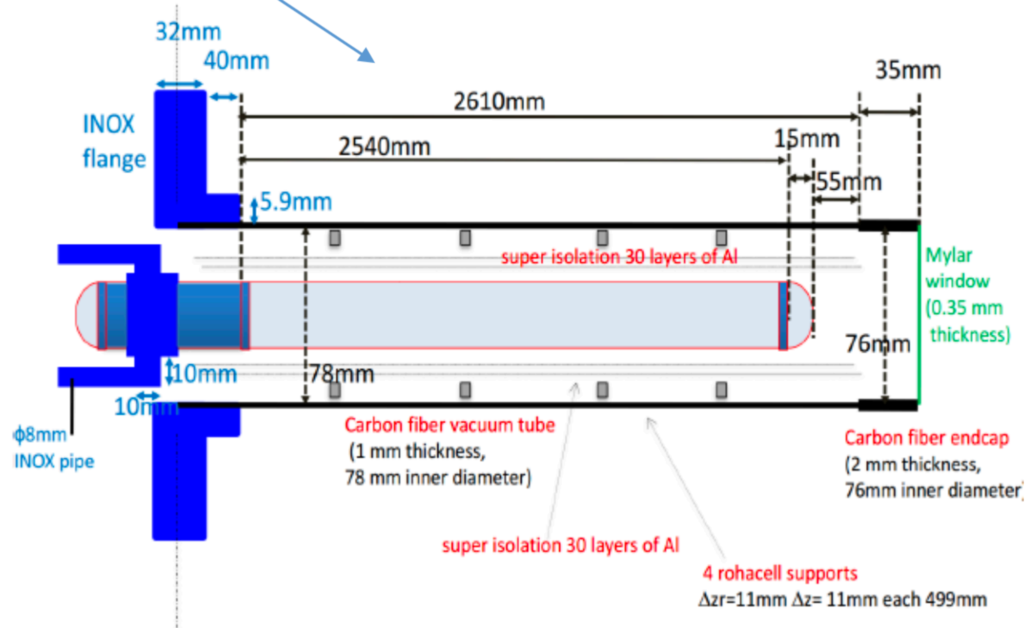
Apparatus for Meson and Baryon Experimental Research

AMBER proton beam: from a 60 GeV/c up to 250 GeV/c.
The goal is to measure the double differential (momentum and pseudo-rapidity) anti-p cross production from p+He (and p+H) at different proton momenta (60, 100, 150, 190, 250 GeV/c) on a fixed LHe (and LH2) target.

The calibration run occurred last May 2022 and the first test run in November. The first data taking is scheduled for May/June 2023.







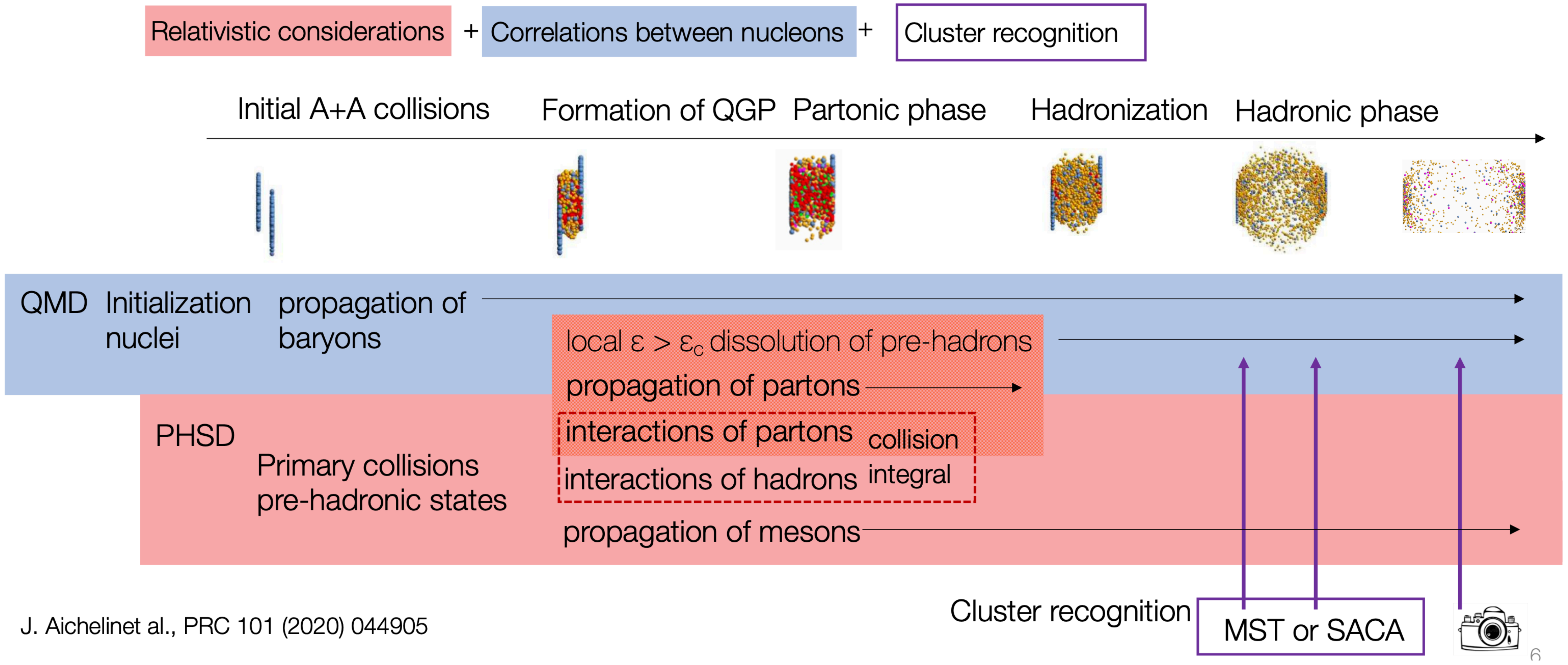
Profile of the COMPASS LH2 target

- Helium channels are responsible for almost 40% of the antiproton production
- AMBER will improve our knowledge of the production of cosmic antiprotons with kinetic energy up to 50 GeV with supposed 5% errors

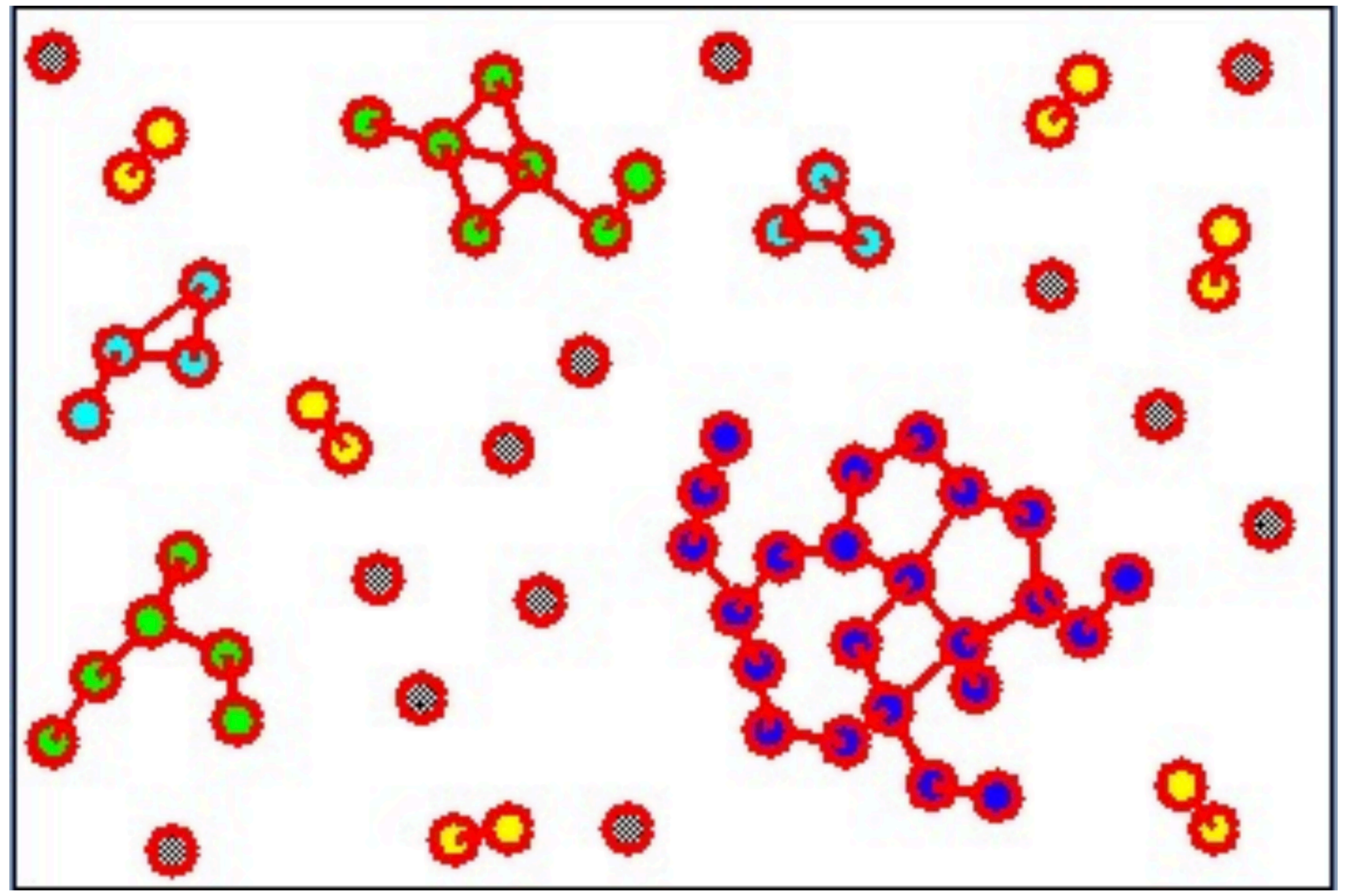
Latest developments of PHQMD

Susanne Glaessel (University of Frankfurt)

= n-body microscopic transport approach for the description of heavy-ion dynamics with dynamical cluster formation from low to ultra-relativistic energies



J. Aichelinet al., PRC 101 (2020) 044905



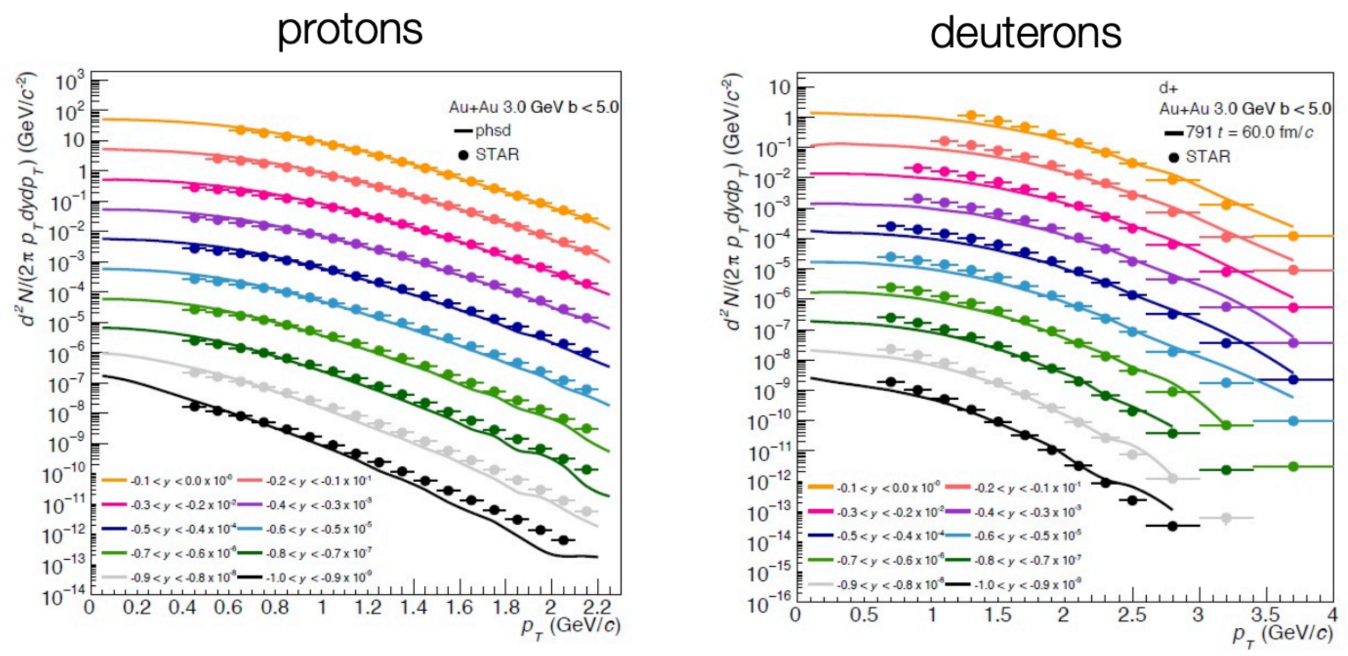
Cluster formation algorithm searches for accumulations of particles in coordinate space

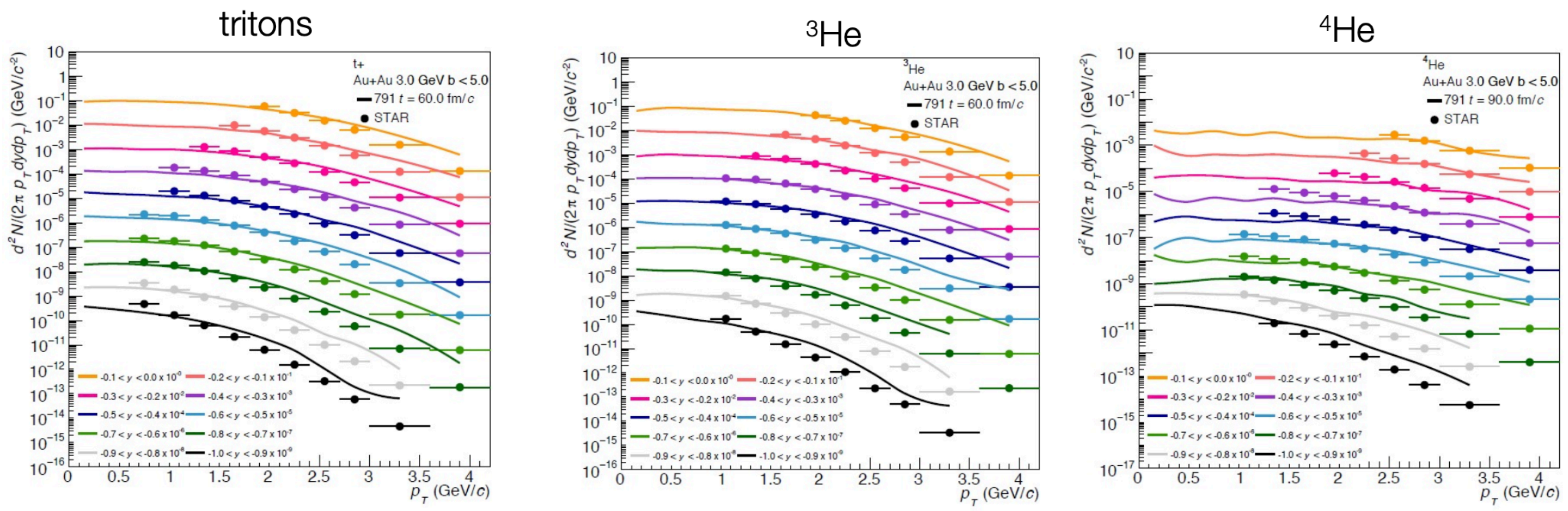
> Two particles i & j are bound if: $|r_i - r_j| < 4.0$ fm

Latest developments of PHQMD

Susanne Glaessel (University of Frankfurt)

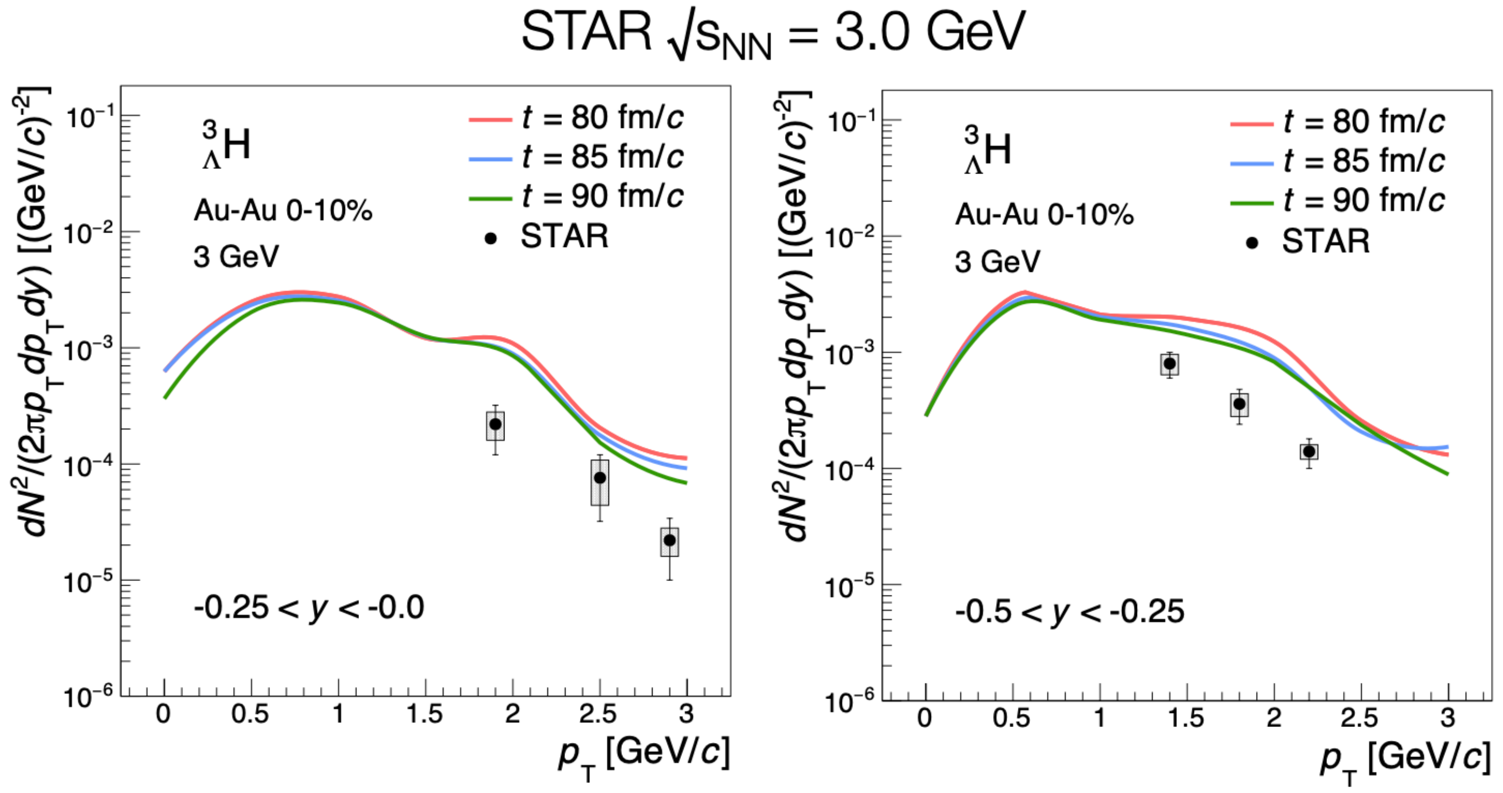
Light cluster production at $\sqrt{s_{NN}}$ = 3 GeV





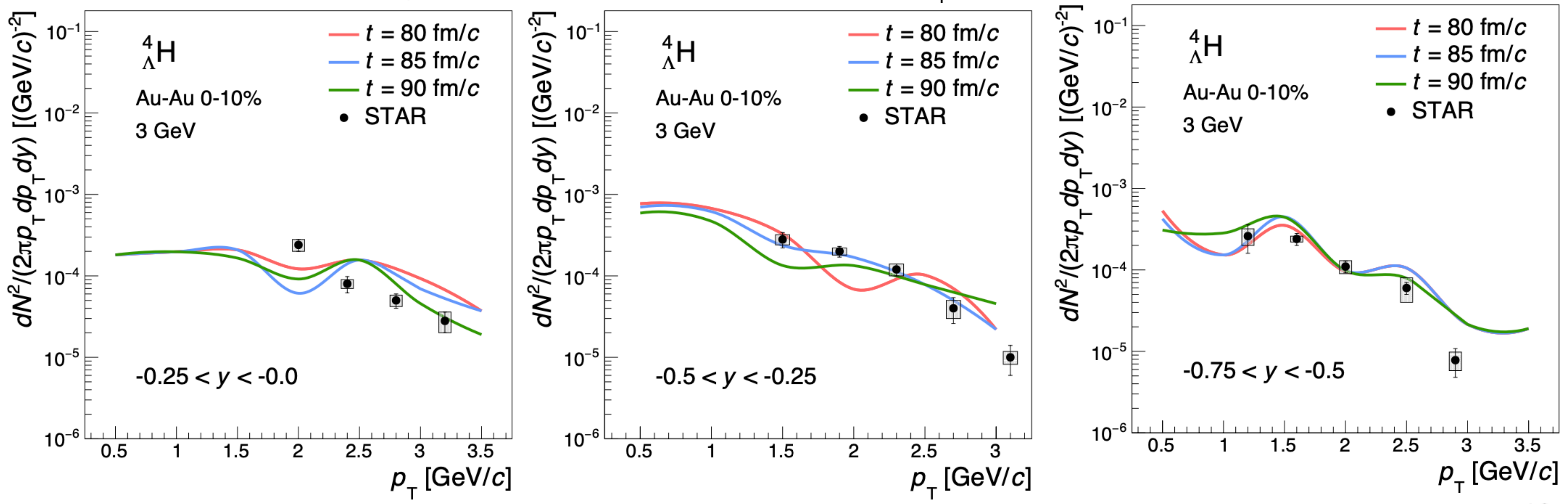
=> PHQMD reproduces STAR* p_T-spectra for protons, deuterons, tritions ^{3}He and ^{4}He.

* (preliminary) STAR data – talk by Hui Liu at QM'2022



=> Reasonable description of hypernuclei production at $\sqrt{s_{NN}}$ = 3.0 GeV

*Yue-Hang Leung: First results of H3L & H4L (dN/dy, c_τ, v_1) from 3 GeV Au+Au collisions with the STAR detector (CPOD2021)

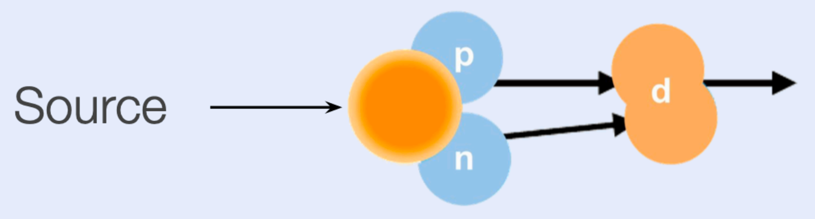


- No tuning to experimental data
- Good description of spectra, yields and particle ratios for different center-of-mass energies
- for hypernuclei the description is a bit worse

Advanced coalescence

M. Horst (Technical University of Munich)

What do we need for coalescence?



$q = (p_p - p_n)/2$
$r = r_p - r_n$

p,n-pair | deuteron

Quantum mechanics:

$d^3N/dP^3 = \mathrm{Tr}(\rho_d \rho_{Nucl})$

$d^3N/dP^3 = \int d^3q \int d^3r_p \int d^3r_n$ *Deuteron Density* *Nucleon Density*

$d^3N/dP^3 = S \int d^3q \int d^3r_p \int d^3r_n W(q,r)\; W_{pn}(p_p, p_n, r_p, r_n)/(2\pi)^6$

Spin-Isospin statistics factor (=⅜ for deuterons)

Wigner function of deuteron

Wigner function of p-n state

Kachelriess et al. EPJA 57 (5) 167, 2021

Two-nucleon Wigner function

$$W_{np}(\vec{P}/2+\vec{q}, \vec{P}/2-\vec{q}, r_n, r_p) = H_{np}(\vec{r}_n, \vec{r}_p) G_{np}(\vec{P}/2+\vec{q}, \vec{P}/2-\vec{q})$$

- ➢ G_{np} is the momentum distribution of nucleons
- ➢ H_{np} is the spatial distribution of nucleons. Assuming a **Gaussian source**

$$H_{np}(\vec{r}_n, \vec{r}_p) = h(\vec{r}_n) h(\vec{r}_p) = \frac{1}{(2\pi\sigma^2)^3} \exp\left(-\frac{\vec{r}_n^{\,2} + \vec{r}_p^{\,2}}{2\sigma^2}\right)$$

Some simple calculation later

$$\frac{d^3N_d}{dP_d^3} = \frac{3\zeta}{(2\pi)^6} \int d^3q\, e^{-q^2d^2} G_{np}(\vec{P}_d/2+\vec{q}, \vec{P}_d/2-\vec{q})$$

with

$$\zeta \equiv \left(\frac{d^2}{d^2+4\sigma^2}\right)^{3/2}$$

Constrained from data!

Kachelriess et al. EPJA 57 (5) 167, 2021
Kachelriess et al. EPJA 56 (1) 4, 2020

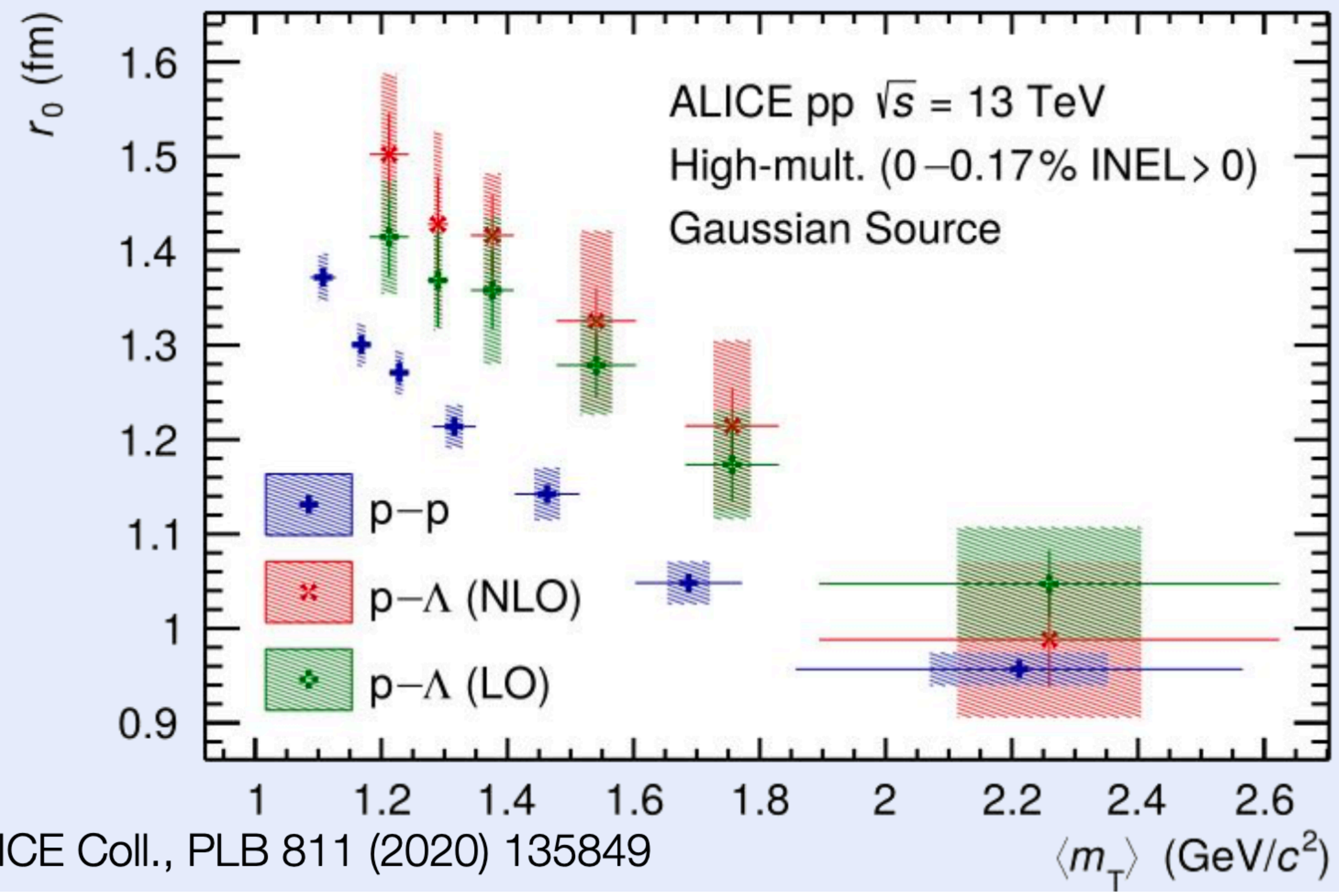
Deuteron coalescence depends on:

- particle-emitting source size (measured in HM pp)
- Deuteron wave function
- Imput nucleon spectra (measured)

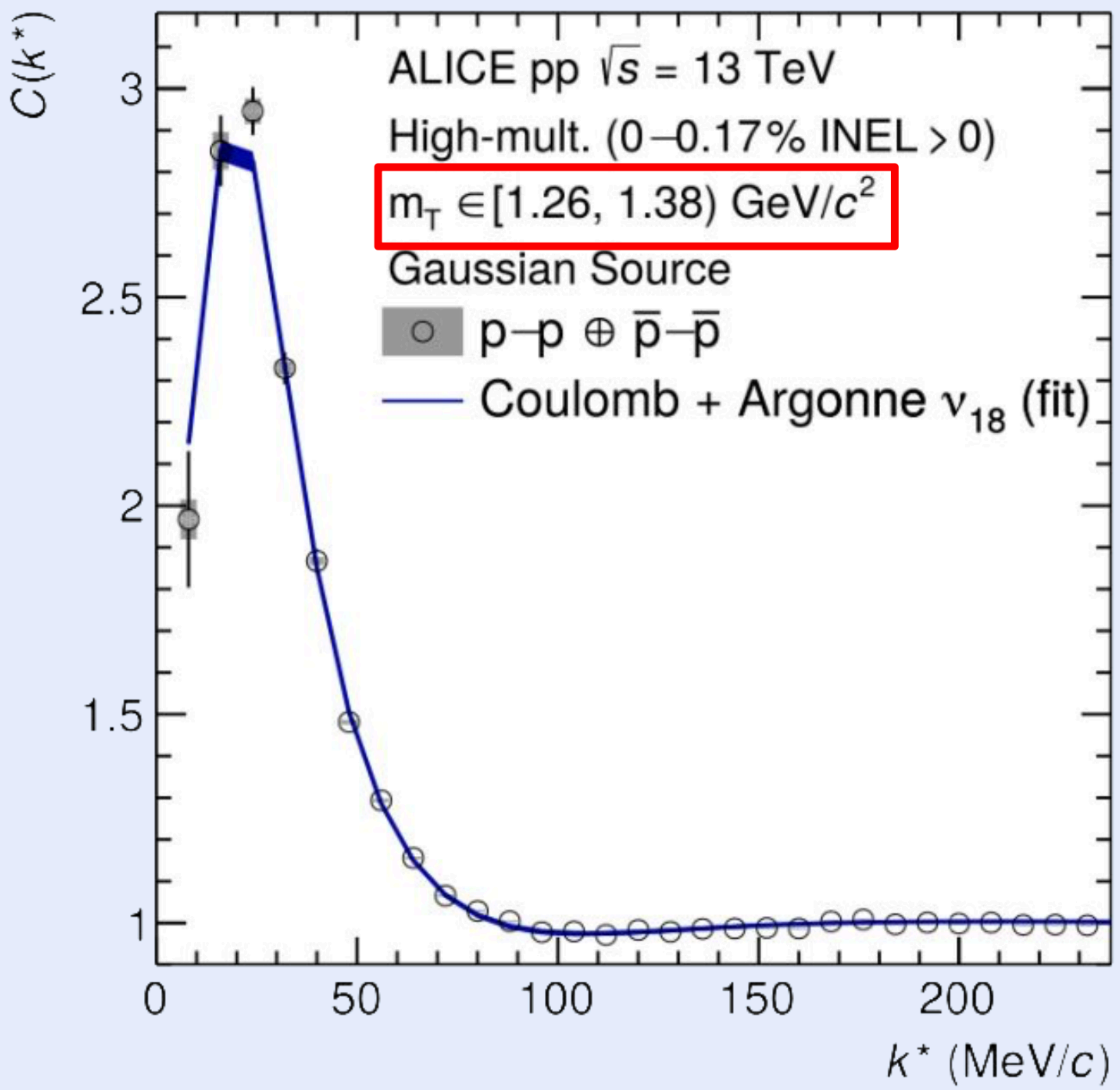
Advanced coalescence

M. Horst (Technical University of Munich)

- Good description of the interaction with Fermi-Dirac statistics, Coulomb and strong interaction (using v18)
- Only free parameter: the source size
- When done as a function of m_T



ALICE Coll., PLB 811 (2020) 135849

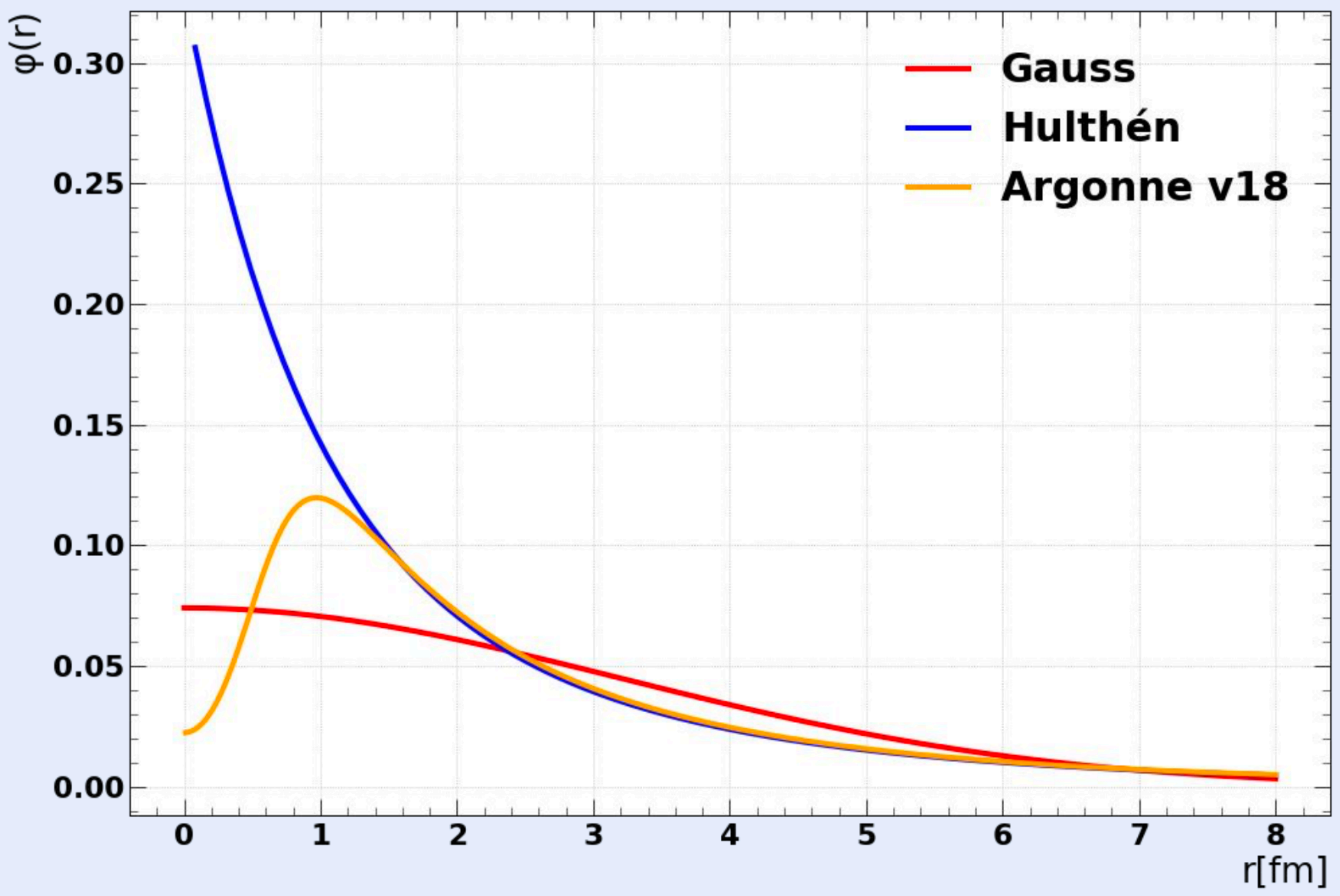


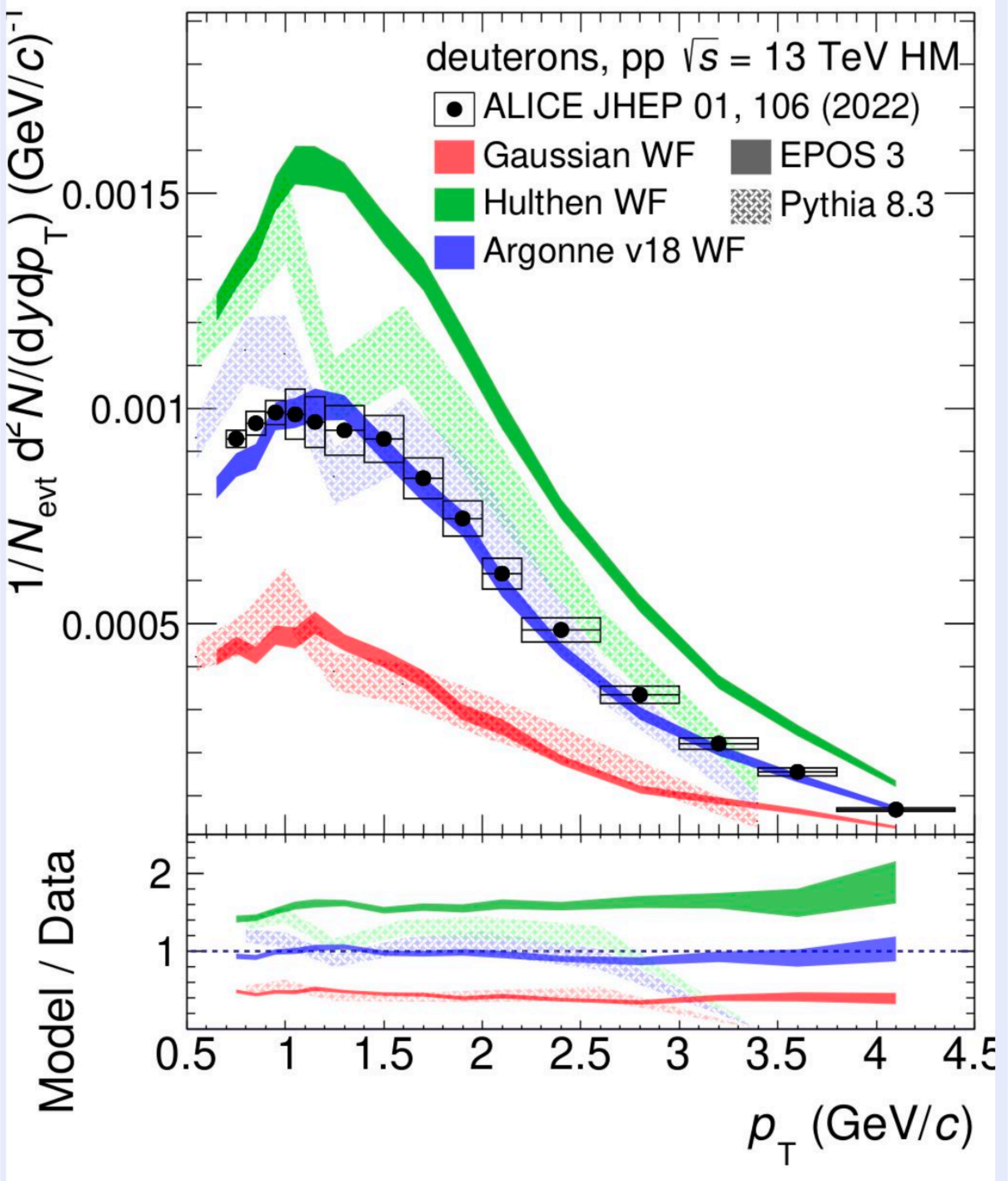
Advanced coalescence

M. Horst (Technical University of Munich)

There are multiple models for the deuteron wave function

- Simplistic:
  Single Gaussian
- From *pion field theory* (Yukawa-like potential) ('50s)*:
  Hulthén
- From pn scattering measurements**:
  Argonne v_{18}

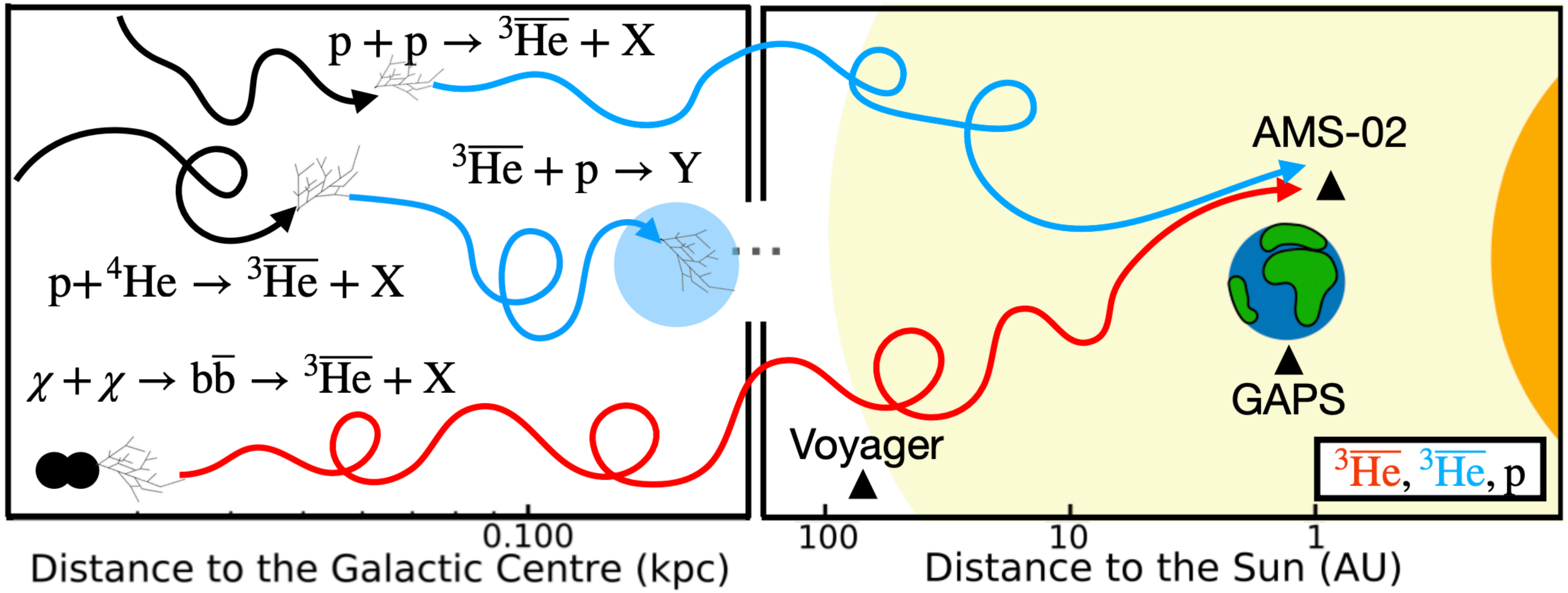


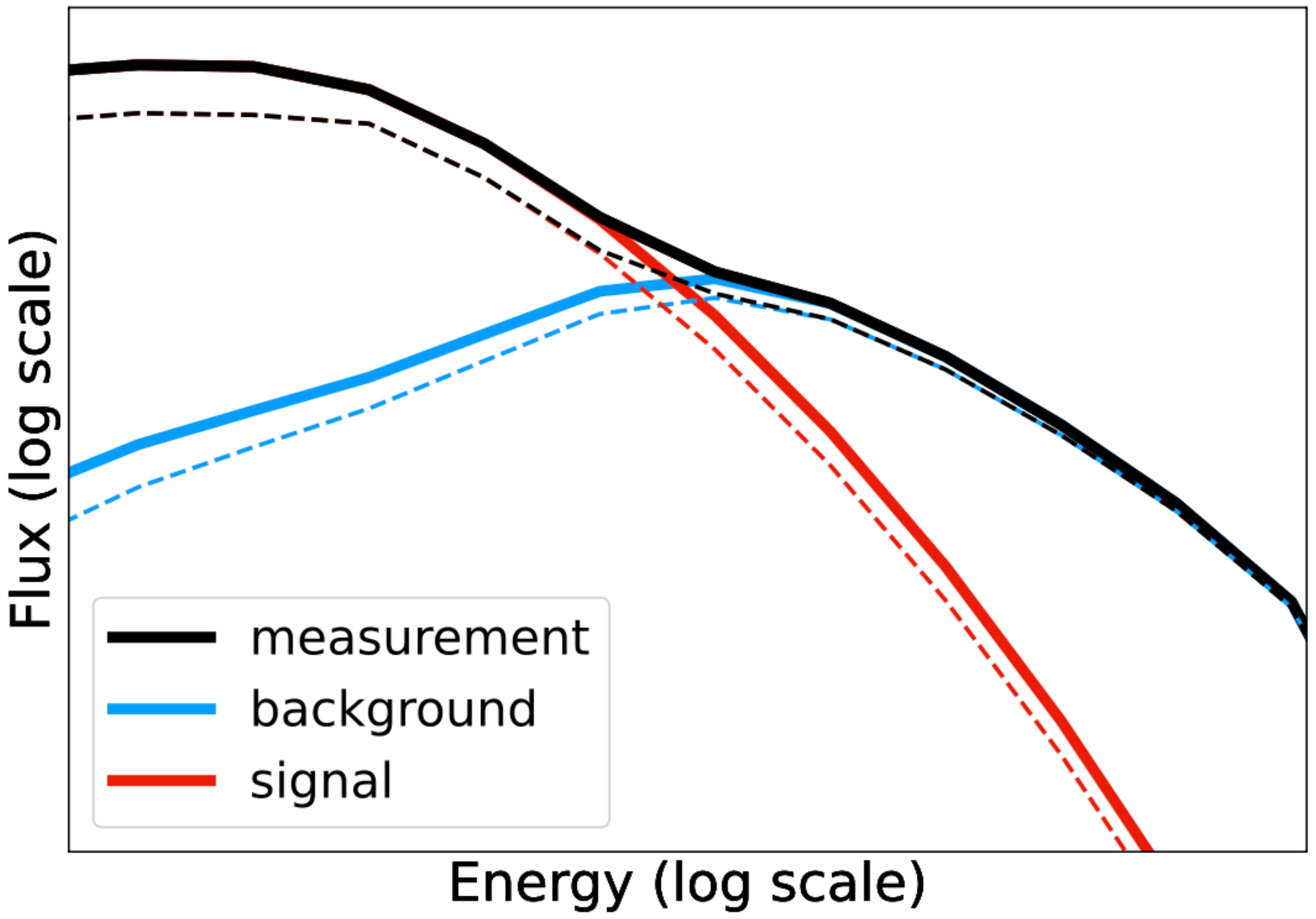


Model predicts measured deuteron spectrum with no free parameter

Antinuclei propagation and annihilation

L. Šerkšnytė (Technical University of Munich)



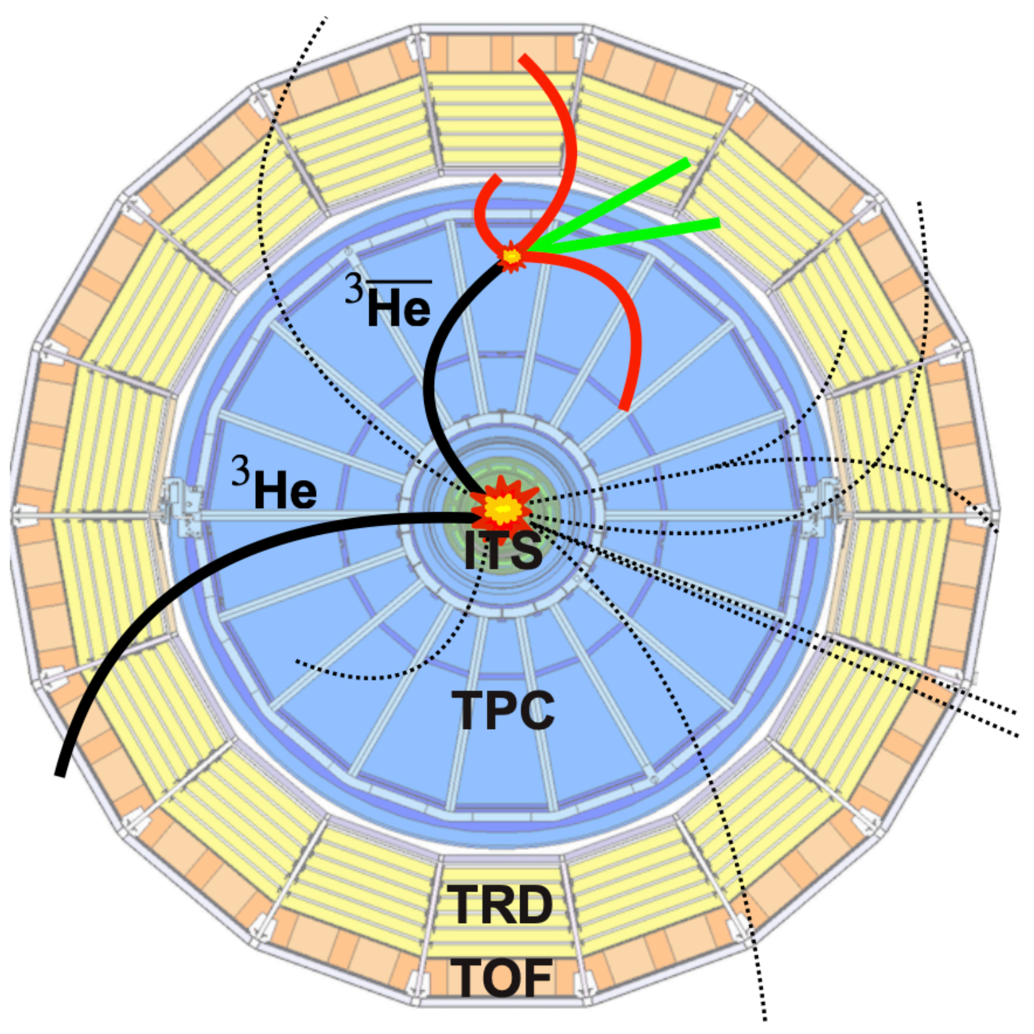


Antinuclei propagation and annihilation

L. Šerkšnytė (Technical University of Munich)

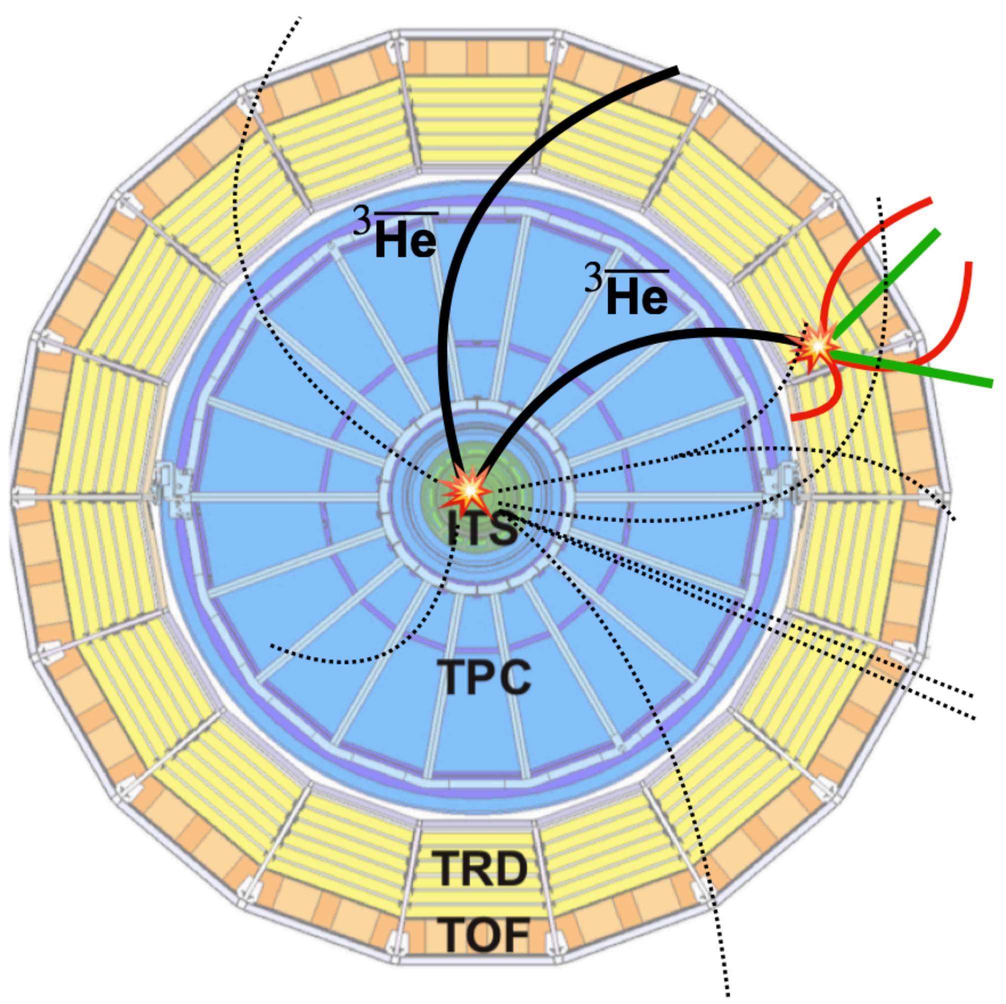
Antimatter-to-matter ratio

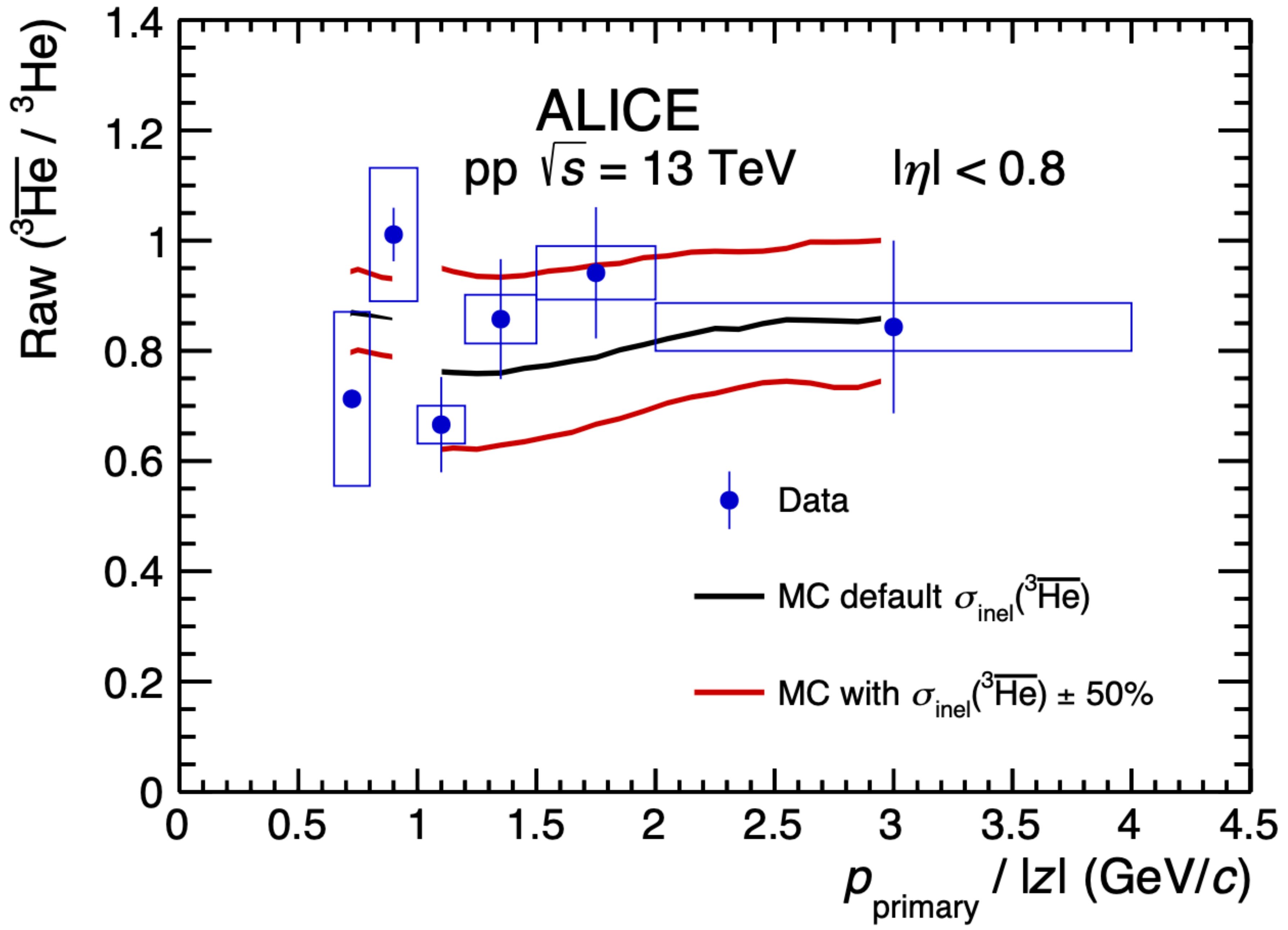
- Measure reconstructed $^{3}\overline{\text{He}}/^{3}\text{He}$ and compare with MC simulations



TOF-to-TPC-matching

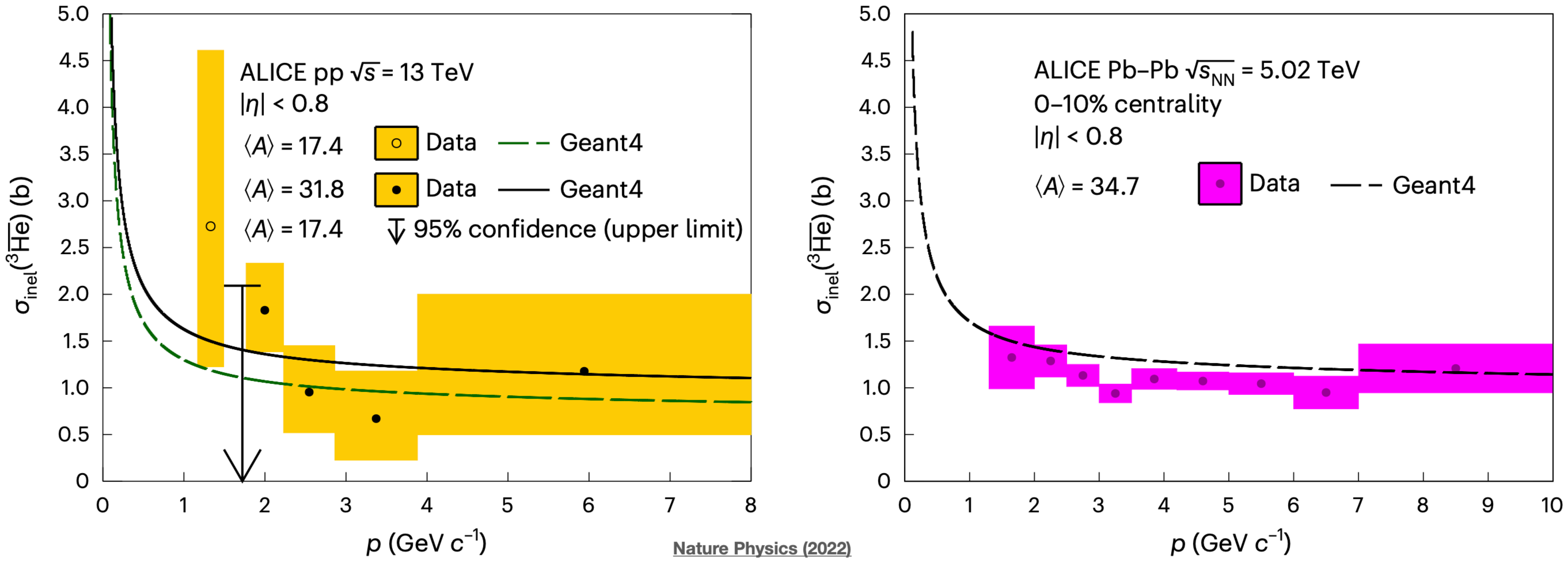
- Measure reconstructed $^{3}\overline{\text{He}}_{\text{TOF}}/^{3}\overline{\text{He}}_{\text{TPC}}$ and compare with MC simulations



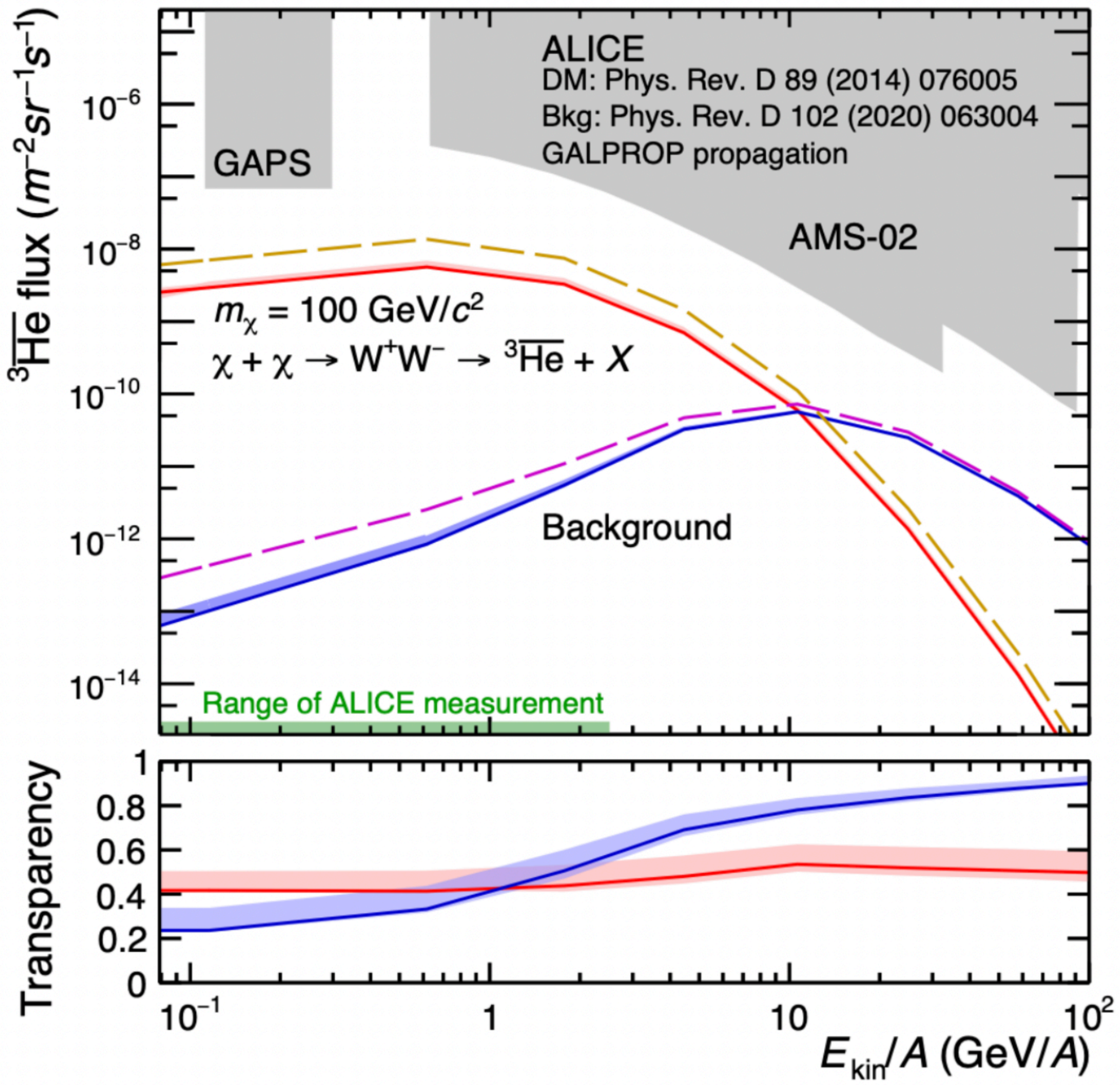


Antinuclei propagation and annihilation

L. Šerkšnytė (Technical University of Munich)



Nature Physics (2022)



Transport equation

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

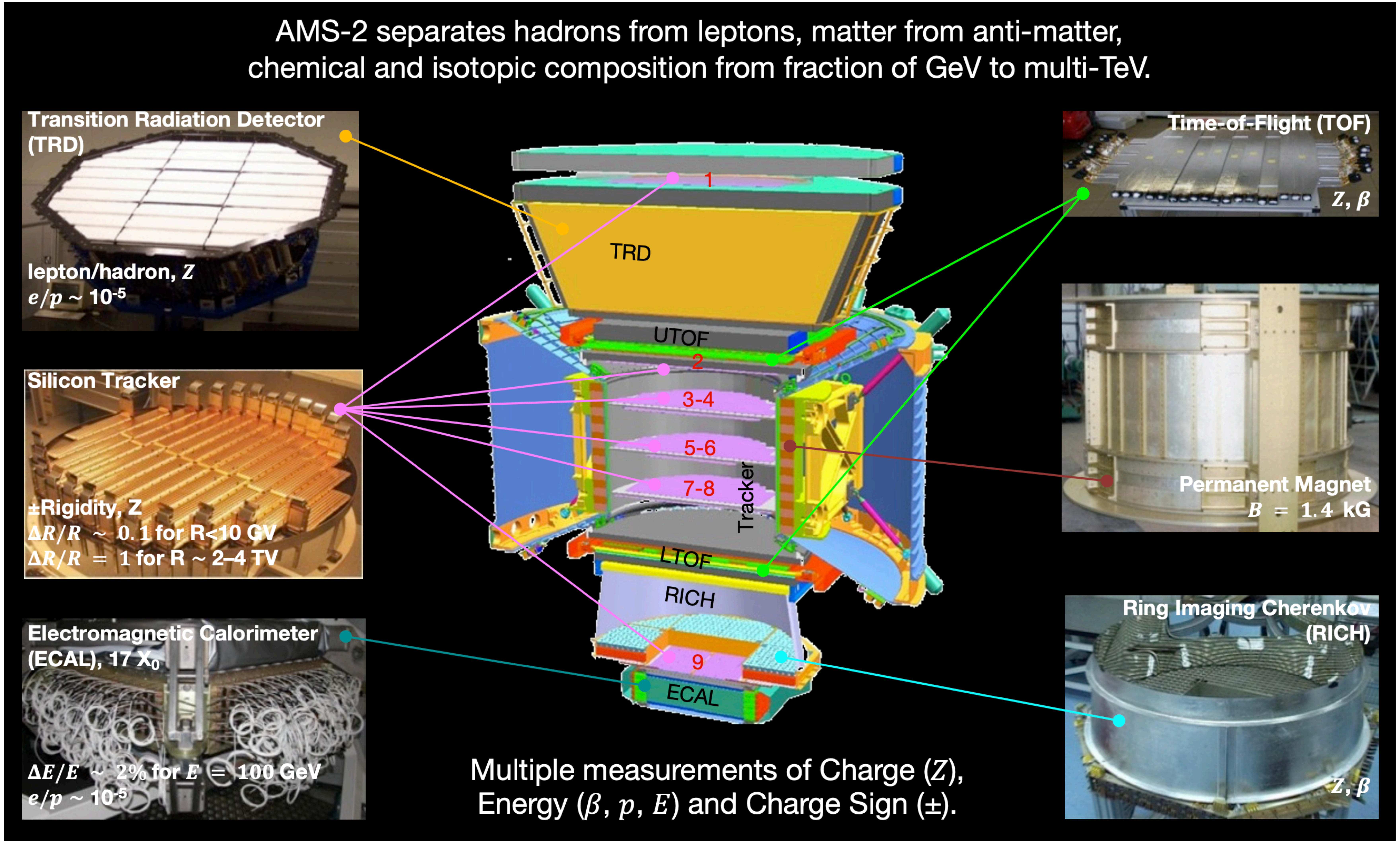
Source Function | Propagation: diffusion, convection... | Fragmentation, annihilation

$$\text{Transparency} = \frac{\text{Flux}(\sigma_{\text{inel}})}{\text{Flux}(\sigma_{\text{inel}} = 0)}$$

Can be numerically solved using the GALPROP code!
Publicly available at: https://galprop.stanford.edu.

Antinuclei with AMS-02

A. Oliva (INFN of Bologna)



Antinuclei with AMS-02

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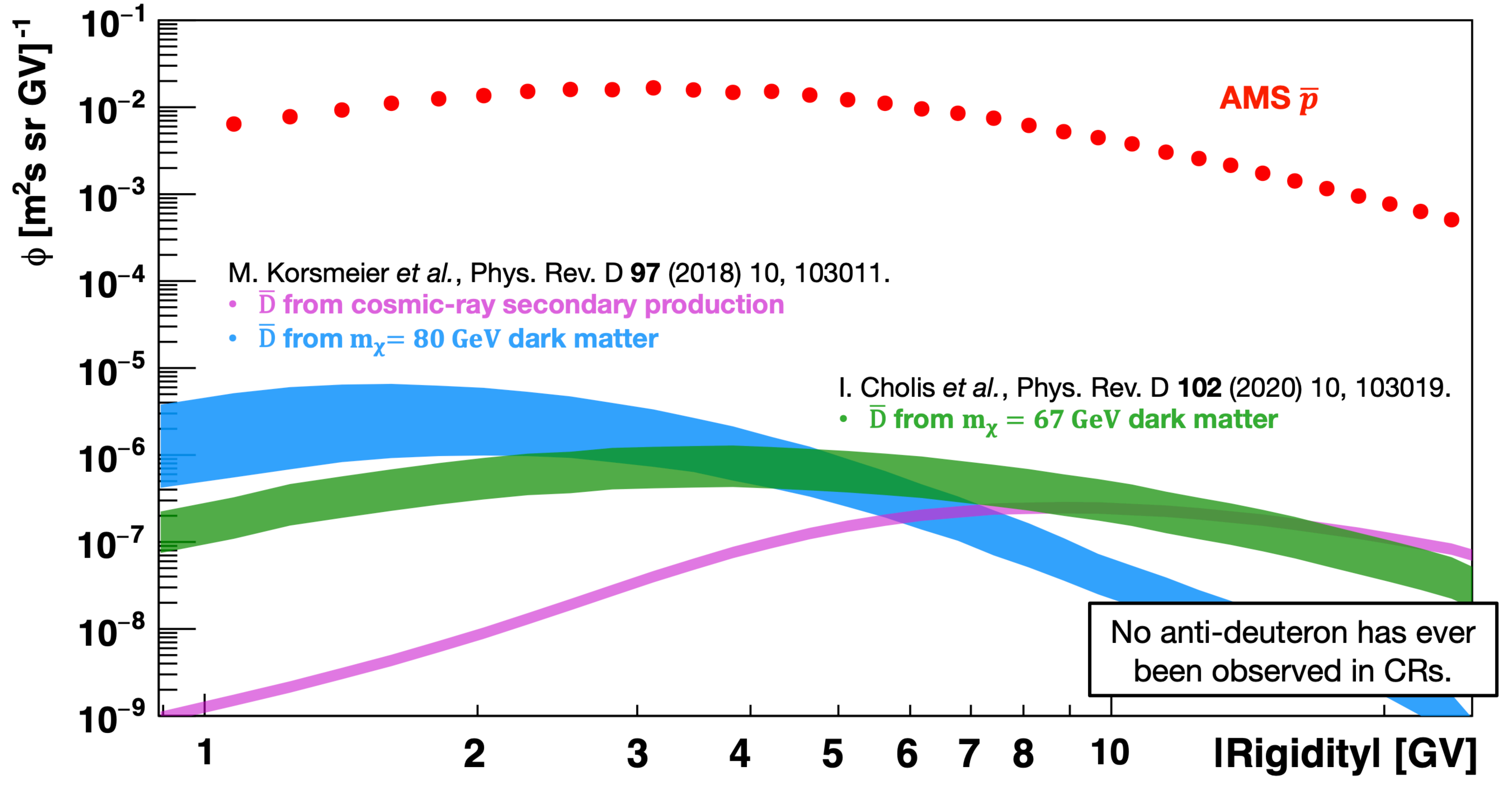
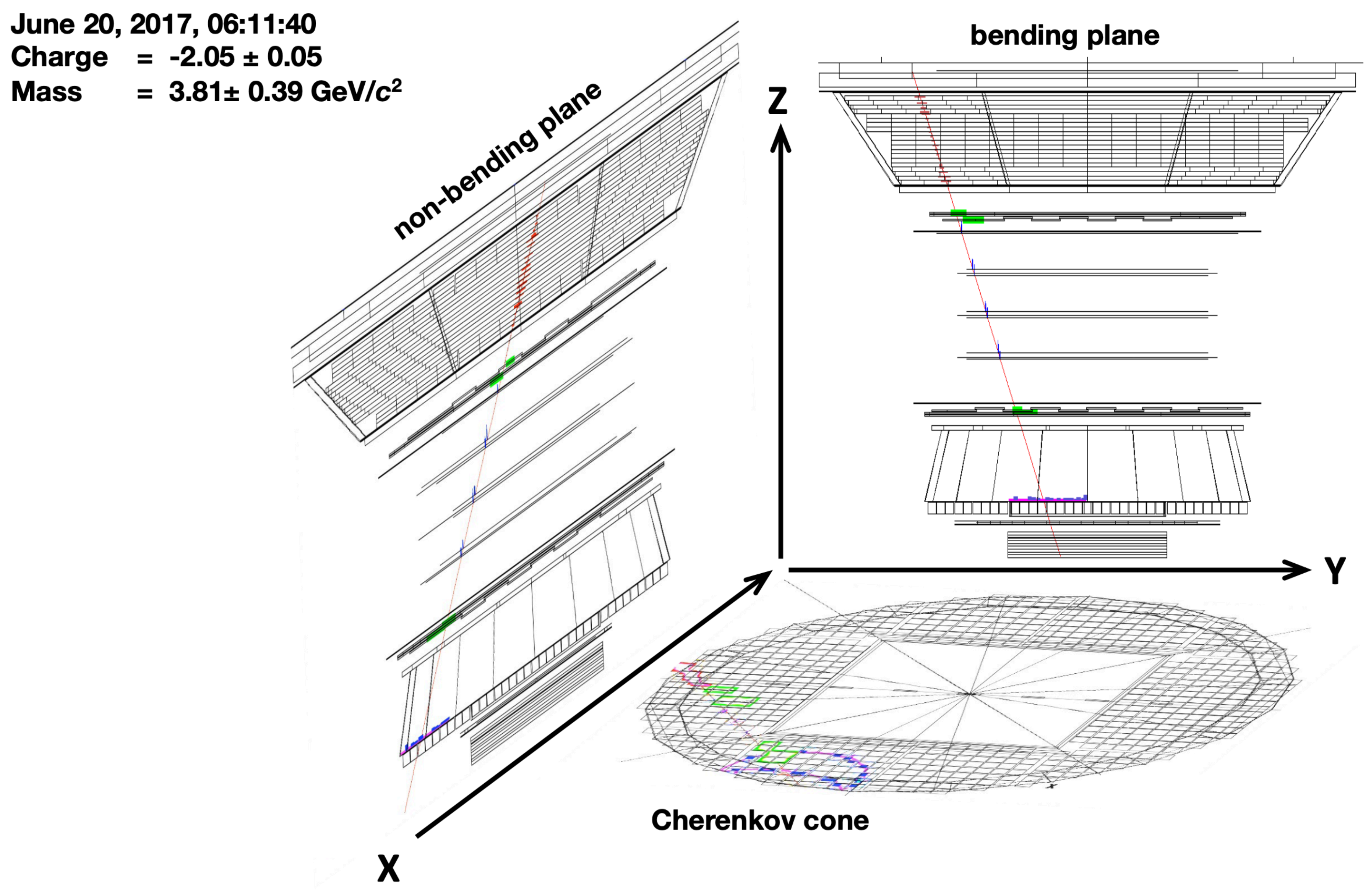
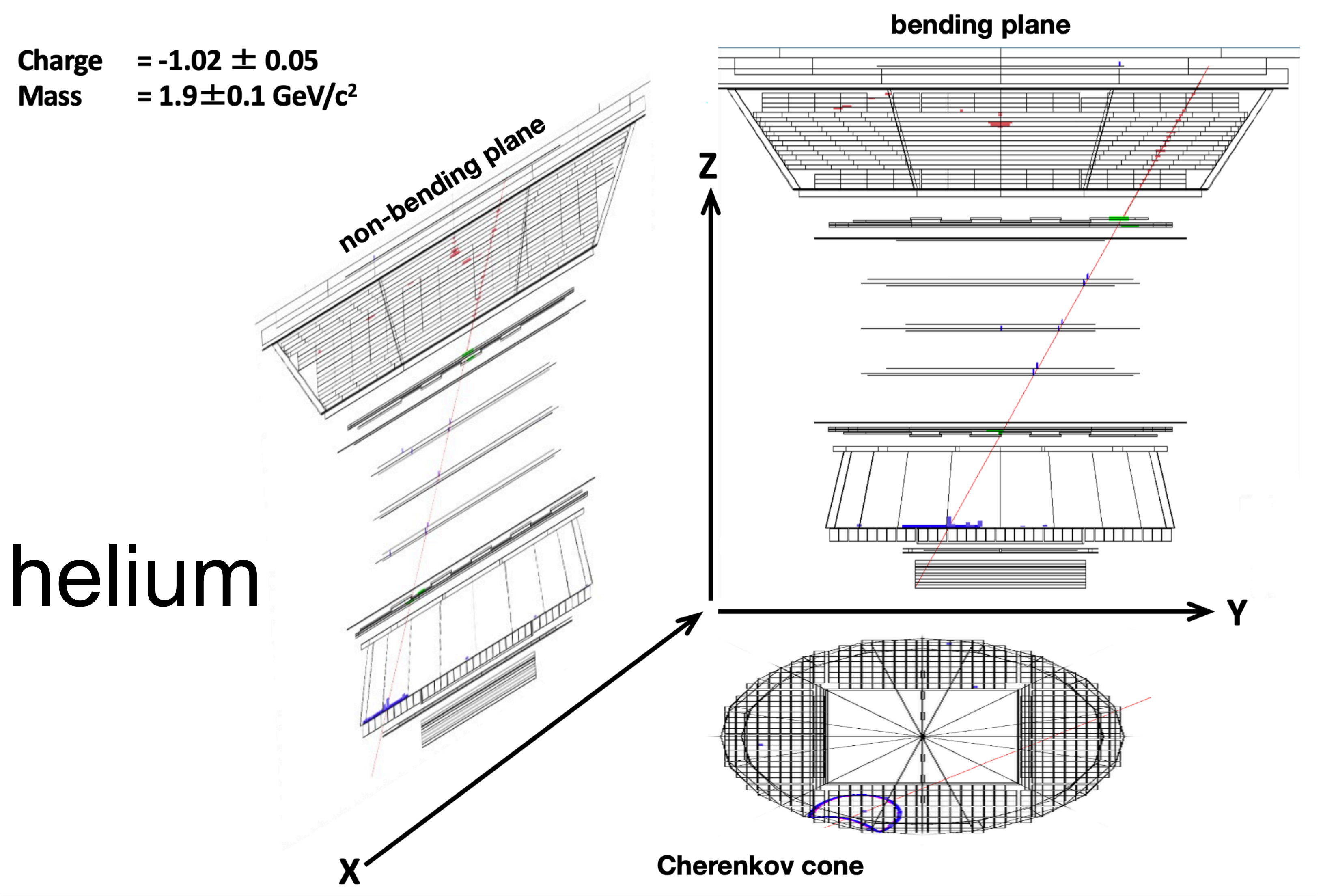






Spectrum of CR antideuterons not measured yet

For antihelium3: event rate is 1 anti-helium in ~100 million helium

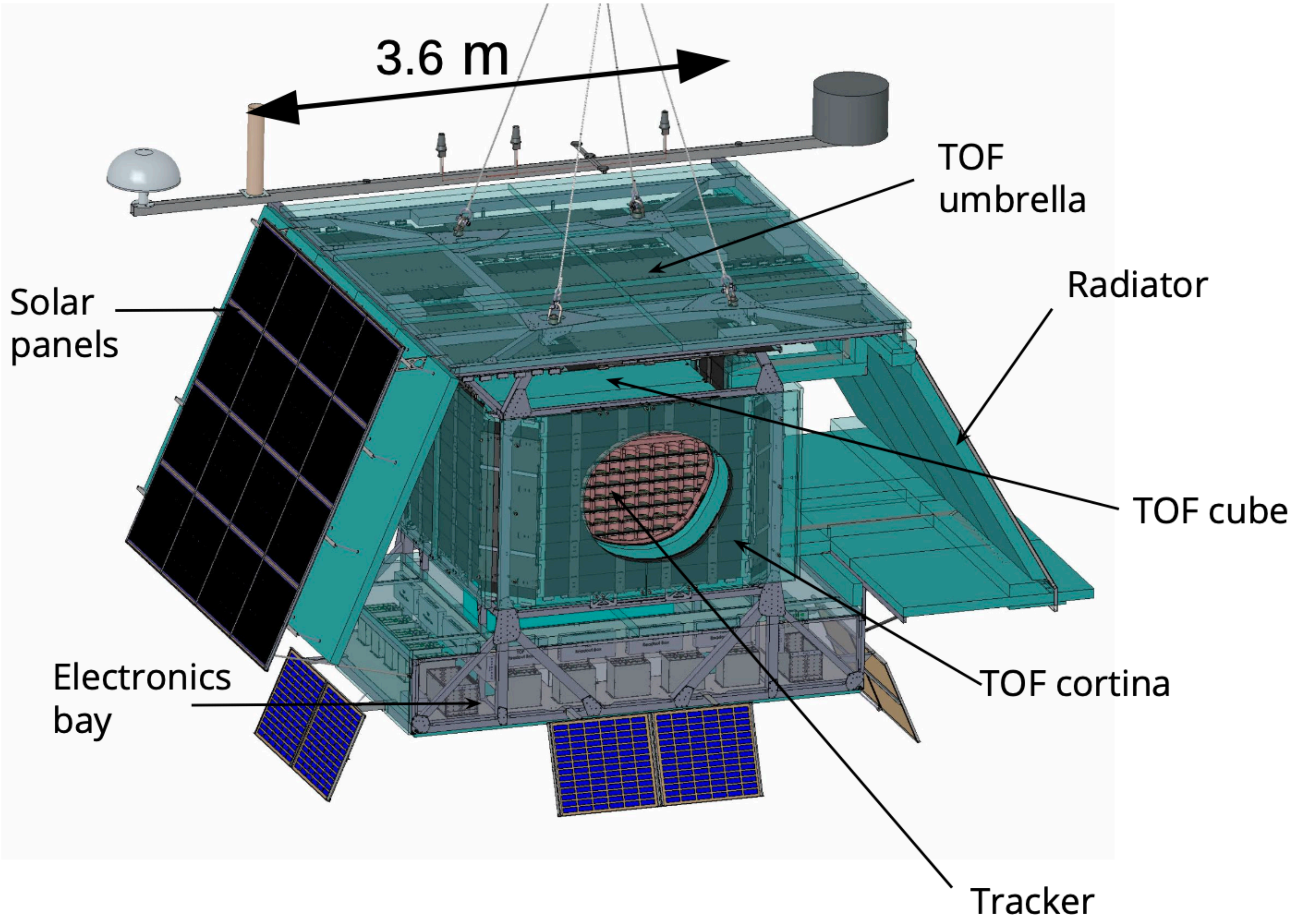
> very challenging measurements

Antinuclei with GAPS

Alessio Tiberio (INFN of Florence)

GAPS: Balloon-borne experiment designed to detect antideuteron and antihelium-3 below 250 MeV/n as evidence for DM

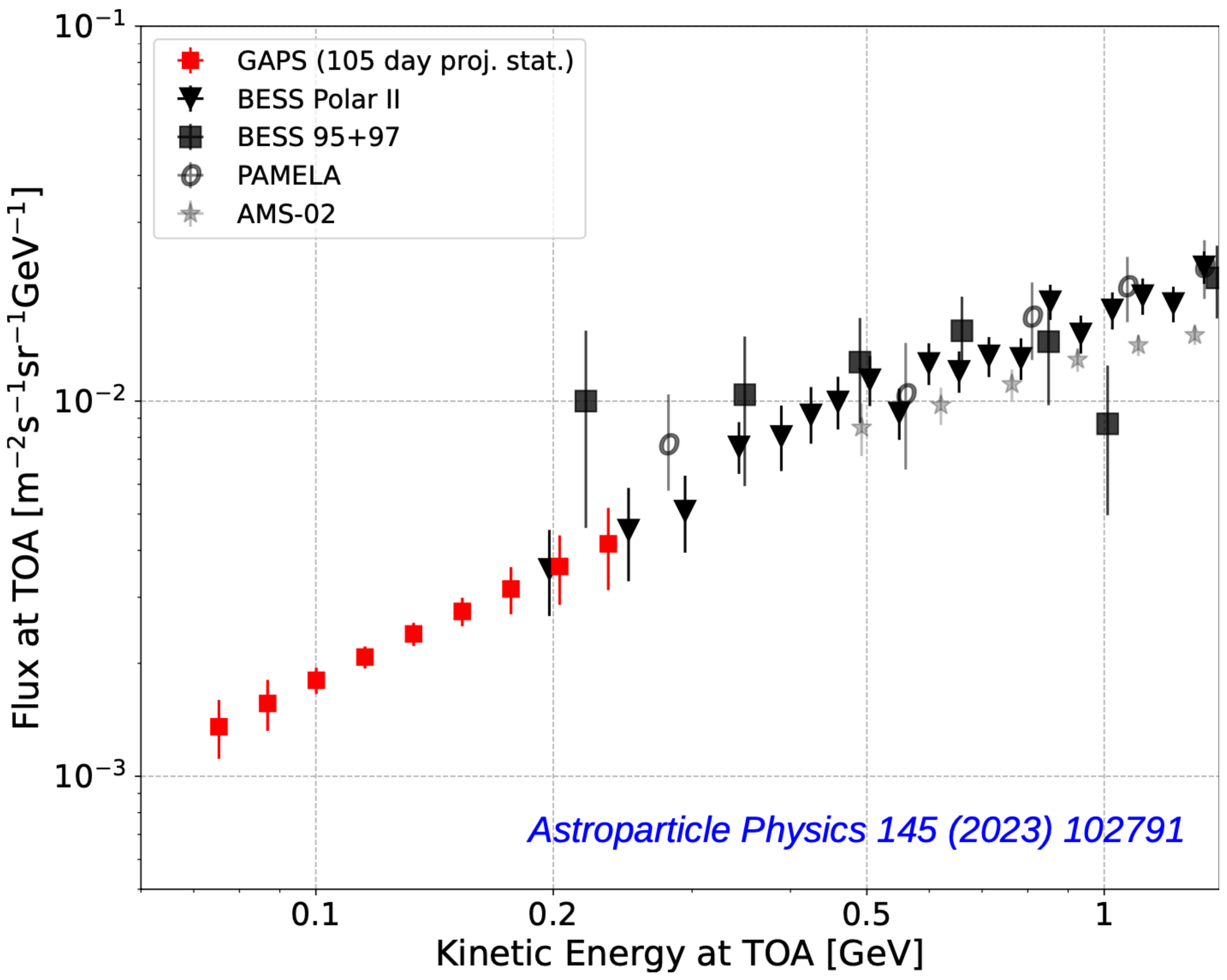
Experimental apparatus composed of a time-of-flight (ToF) system surrounding a tracker

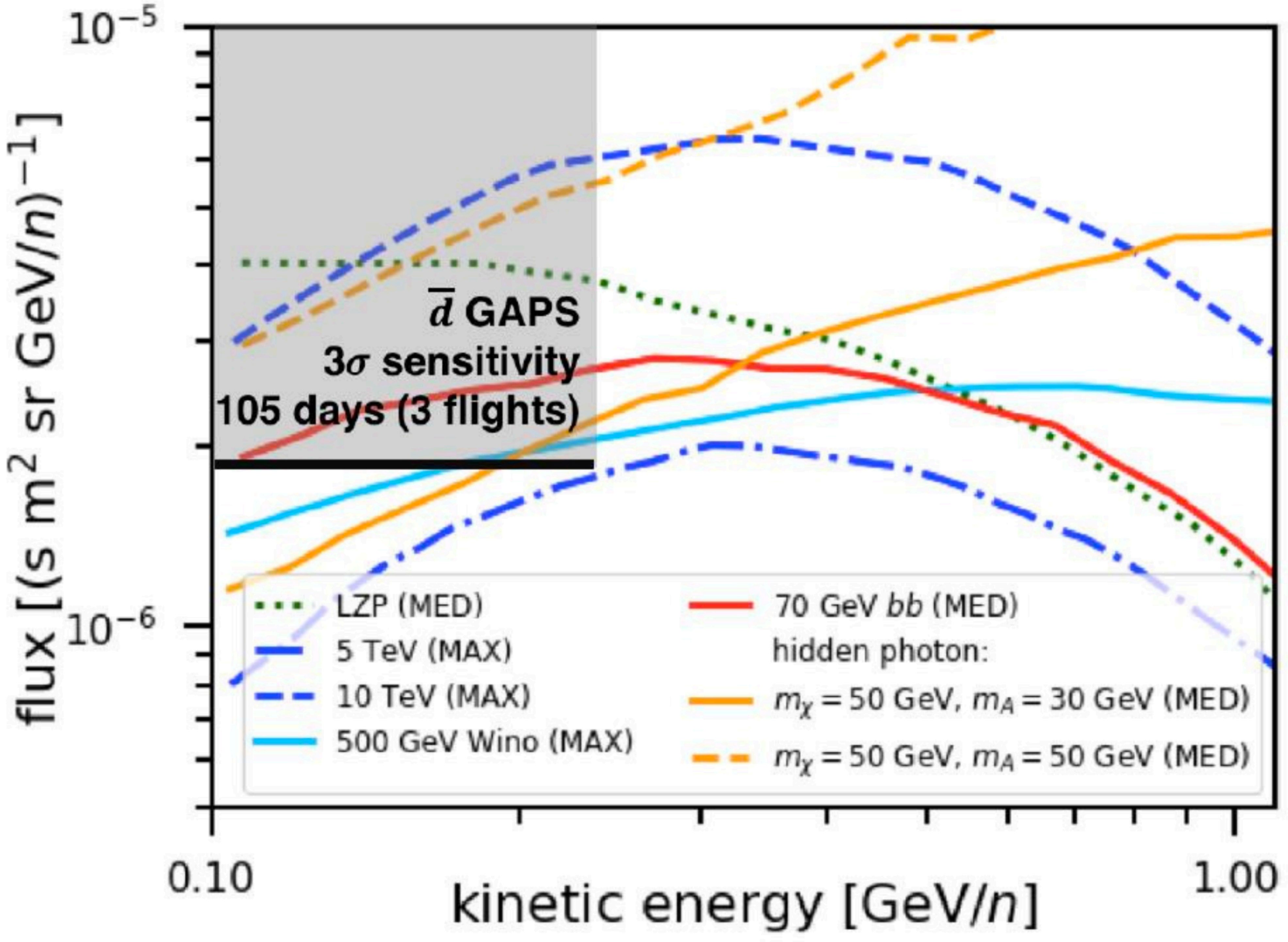


Antinuclei with GAPS

Alessio Tiberio (INFN of Florence)

Precision measurement of **antiproton** spectrum in an **unexplored low energy region**





GAPS will also measure antideuteron spectrum

> sensitive to a wide range of DM models

Antinuclei with GAPS

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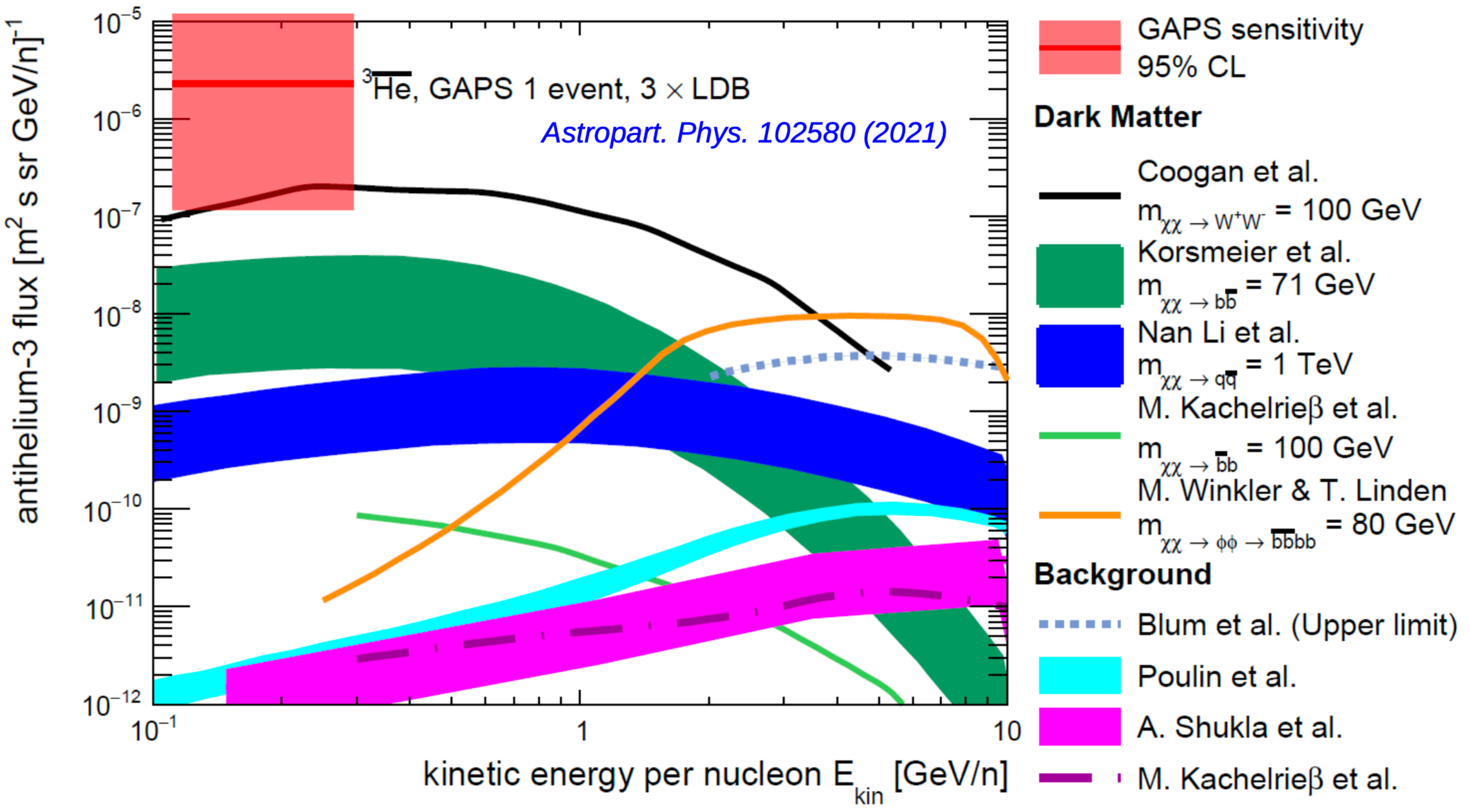

Sensitivity to antihelium-3

> 1 single antihelium-3 event at low energy would be a signature of new physics