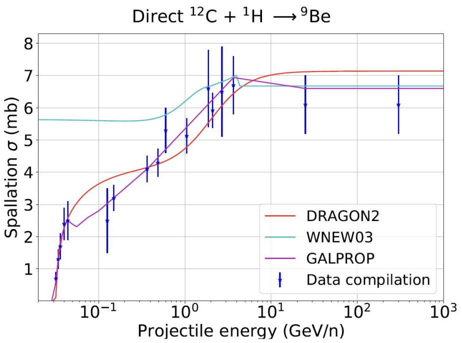
Wrap-up 20.08.2024

JENAA workshop on Nuclear Physics at the LHC and SPS and connection to astrophysics

Antiprotons

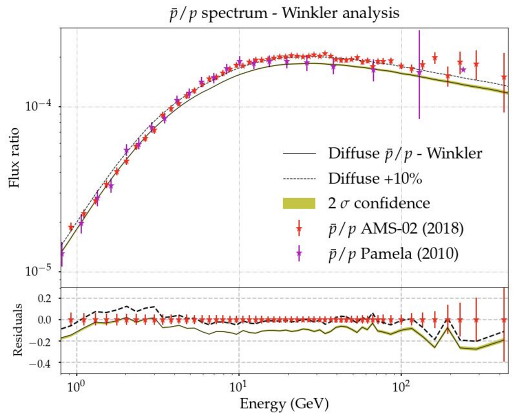
Dark Searches and cosmic ray antiprotons

P. Della Torre

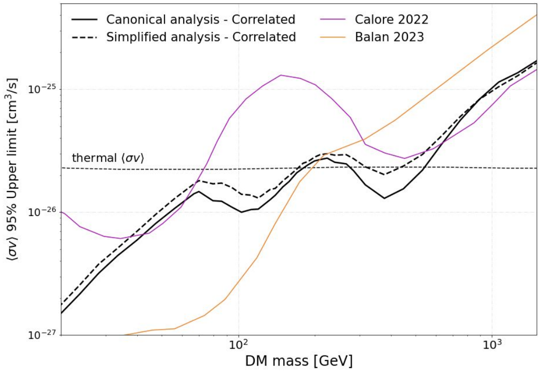


- C+H, O+H cross sections for secondary production very poorly constraint!
- Essential for antiprotons yield
- Grammage excess: Antiproton yields underestimated by 10-20%

Globally: antiproton yields compatible
With secondary origin



AMS-02 data: also compatible with this hypothesis but..
Covariance matrices need to be checked



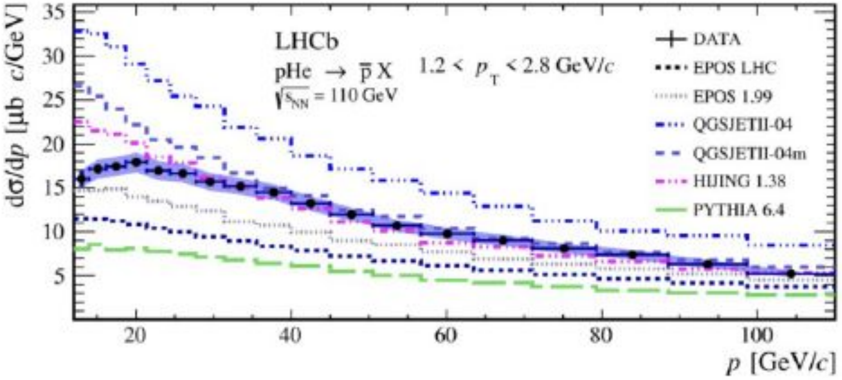
Current DM bounds from antiproton analysis

Dark matter searches with antiprotons would benefit from significantly improved production cross section measurements

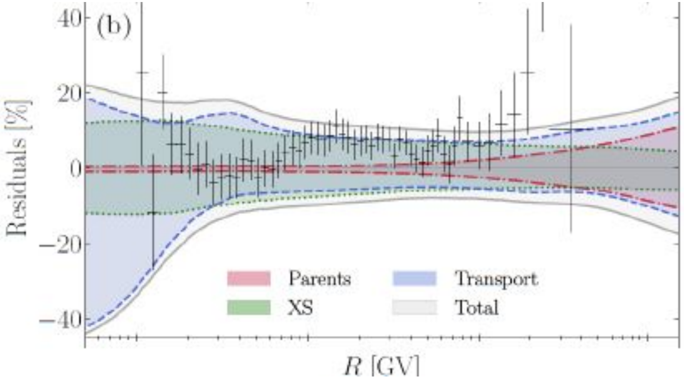
SMOG measurement of antiprotons

C. Lucarelli

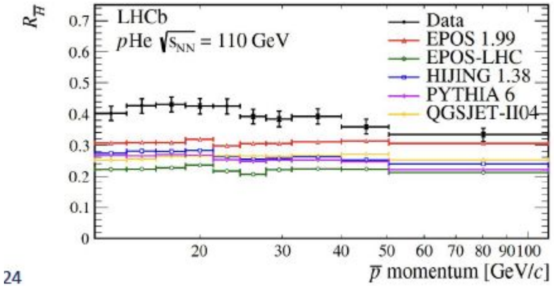
First measurement of $\sigma(pHe \longrightarrow \overline{p}_{prompt}X)$ at $\sqrt{s_{NN}} = 110\ GeV$:



Improved constraint on the production cross-section but still dominating uncertainty



-> Analysis of secondary to primary pbar ratio tagging weak decays



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More displaced antip than expected !!

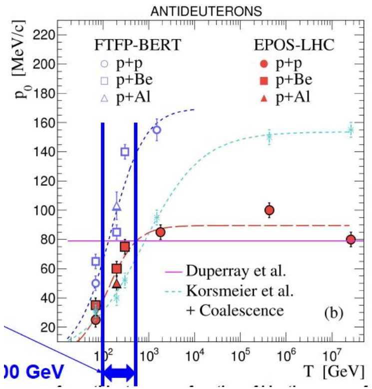
- SMOG2, pp and pA, including H2, D2 and pO2

- Is the study of the pbar-displaced also relevant at higher energies?

A. Shukla

NA61/Shine results

Simplistic coalescence with p0 parameter varying for different measurement at the same energy

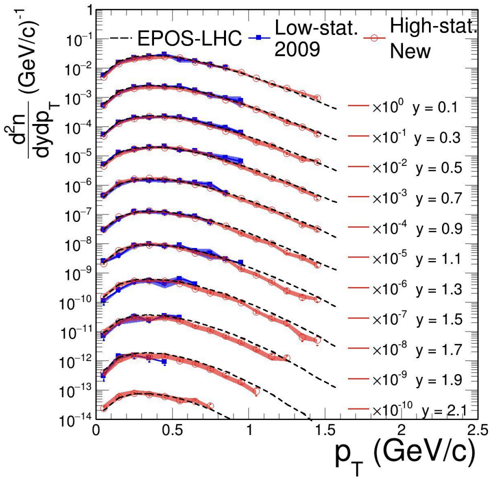


Energy range 50-100 GeV: mostly relevant for cosmic rays reactions
-> measure antiprotons, antideuterons in this energy range
-> measure femtscopy radii to employ **New coalescence models** (Wigner approach)

P+p collisions at 158 GeV

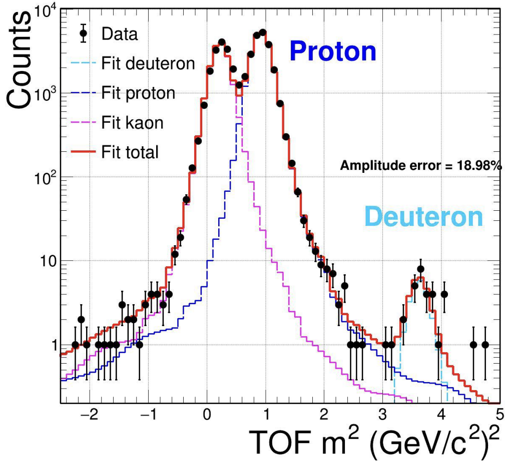
- π−π or K-p correlations can also be used to determine the radii (more statistics)
- For antiprotons: maybe combined analysis with AMBER?

New $\bar{p}$ *data*



New d *data*

Vol 3, +ve, [p, p_T] = [4.0 - 6.0, 0.0 - 0.5] (GeV/c)



A. Shukla

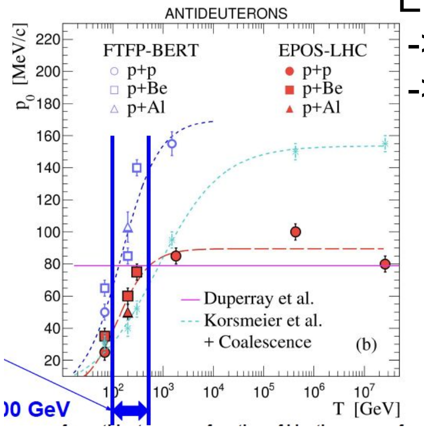
NA61/Shine results

Simplistic coalescence with p0 parameter varying for different measurement at the same energy

Energy range 50-100 GeV: mostly relevant for cosmic rays reactions

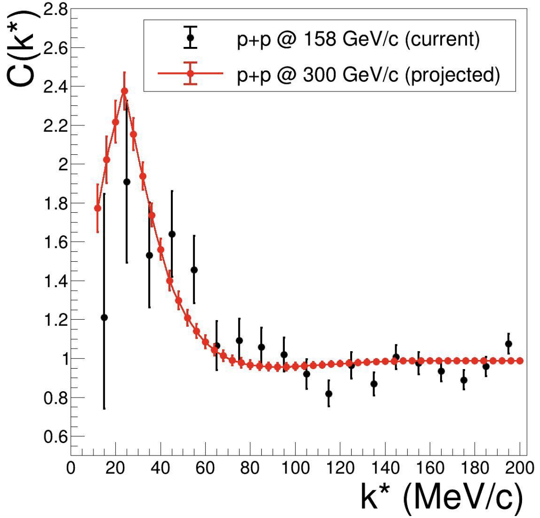
-> measure antiprotons, antideuterons in this energy range

-> measure femtoscopy radii to employ **New coalescence models** (Wigner approach)



P+p collisions at 158 GeV

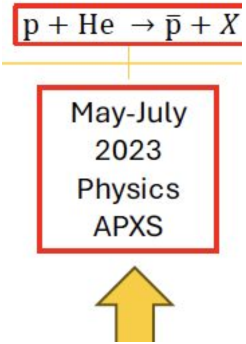
First femtoscopy function with pp pairs !!



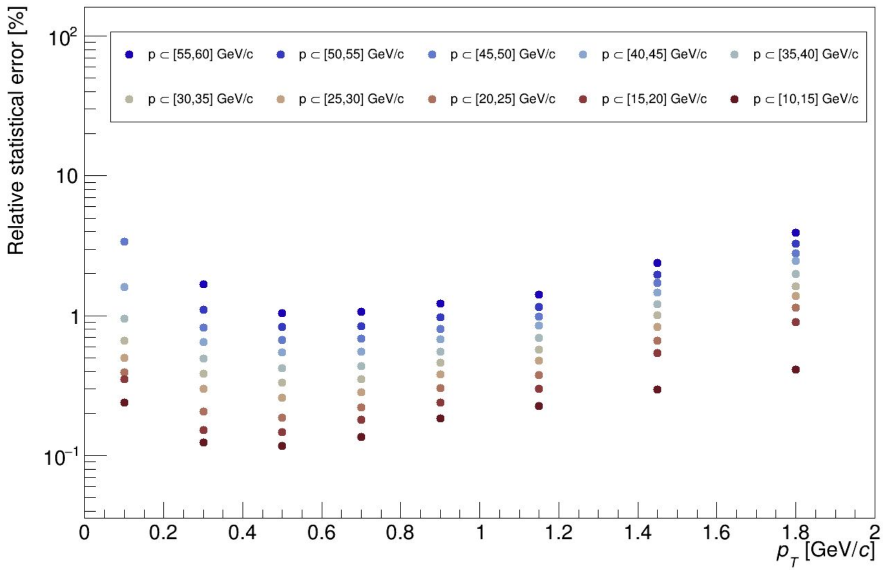
- π−π or K-p correlations can also be used to determine the radii (more statistics)
- For antiprotons: maybe combined analysis with AMBER ?
- Campaign in 2025!

D. Giordano

AMBER results on antiproton



60, 80, 100, 160, 190, 250 GeV/c

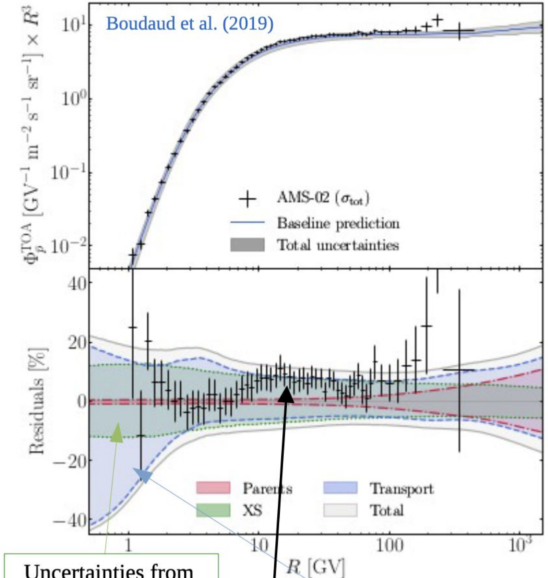


- Maybe femtoscopy measurements can also be carried out by AMBER?

D. Maurin

Cosmic ray propagation and key measurements

Background (astro. contrib.)

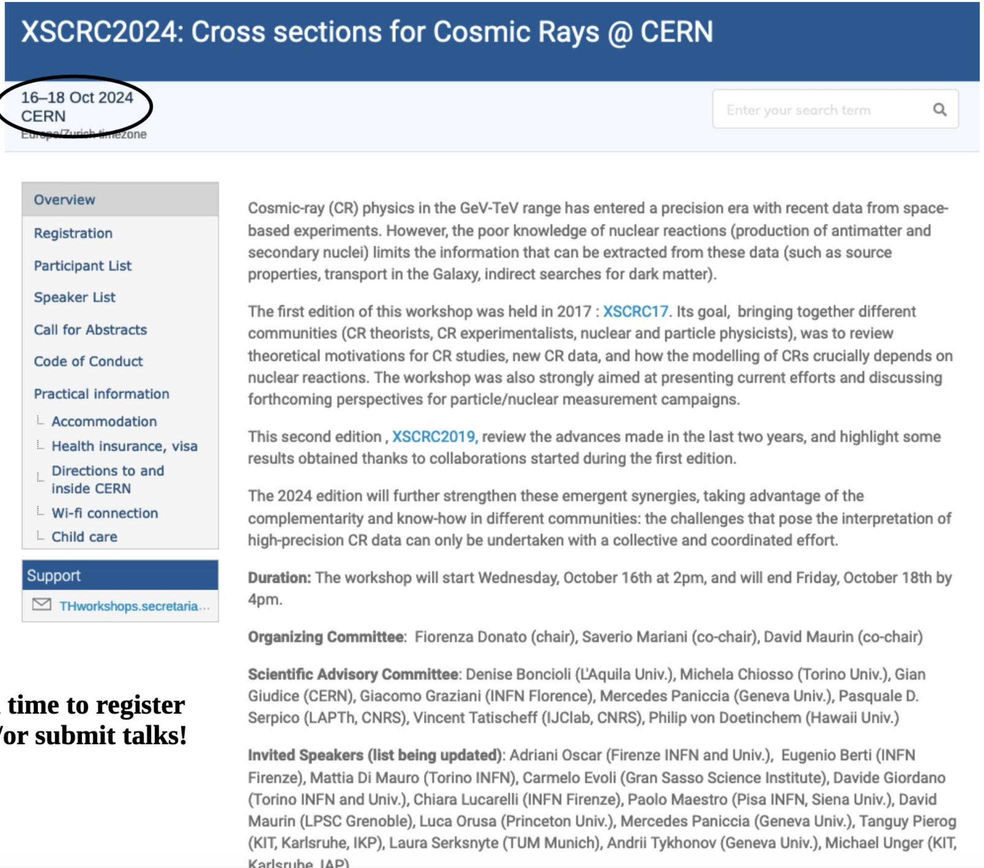


Uncertainties from pbar production $(p,He)_{CR}$ + $(H,He)_{ISM}$

Uncertainties from LiBeB nuclear XS

Cannot take full benefit of AMS-02 high-precision data

[N.B.: any future improvement on pbar data moot if no better XS!]



XSCRC2024: Cross sections for Cosmic Rays @ CERN

16–18 Oct 2024
CERN
Europe/Zurich timezone

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THworkshops.secretaria...

Cosmic-ray (CR) physics in the GeV-TeV range has entered a precision era with recent data from space-based experiments. However, the poor knowledge of nuclear reactions (production of antimatter and secondary nuclei) limits the information that can be extracted from these data (such as source properties, transport in the Galaxy, indirect searches for dark matter).

The first edition of this workshop was held in 2017 : XSCRC17. Its goal, bringing together different communities (CR theorists, CR experimentalists, nuclear and particle physicists), was to review theoretical motivations for CR studies, new CR data, and how the modelling of CRs crucially depends on nuclear reactions. The workshop was also strongly aimed at presenting current efforts and discussing forthcoming perspectives for particle/nuclear measurement campaigns.

This second edition , XSCRC2019, review the advances made in the last two years, and highlight some results obtained thanks to collaborations started during the first edition.

The 2024 edition will further strengthen these emergent synergies, taking advantage of the complementarity and know-how in different communities: the challenges that pose the interpretation of high-precision CR data can only be undertaken with a collective and coordinated effort.

Duration: The workshop will start Wednesday, October 16th at 2pm, and will end Friday, October 18th by 4pm.

Organizing Committee: Fiorenza Donato (chair), Saverio Mariani (co-chair), David Maurin (co-chair)

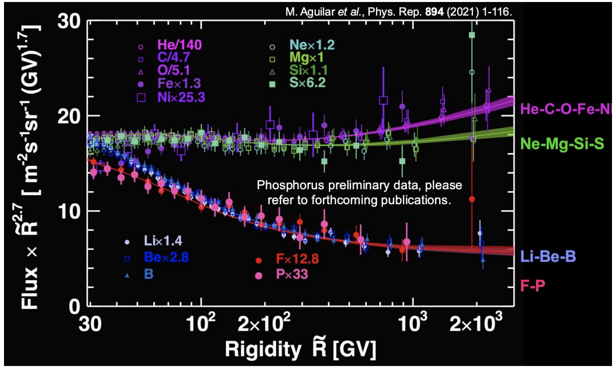
Scientific Advisory Committee: Denise Boncioli (L'Aquila Univ.), Michela Chiosso (Torino Univ.), Gian Giudice (CERN), Giacomo Graziani (INFN Florence), Mercedes Paniccia (Geneva Univ.), Pasquale D. Serpico (LAPTh, CNRS), Vincent Tatischeff (IJClab, CNRS), Philip von Doetinchem (Hawaii Univ.)

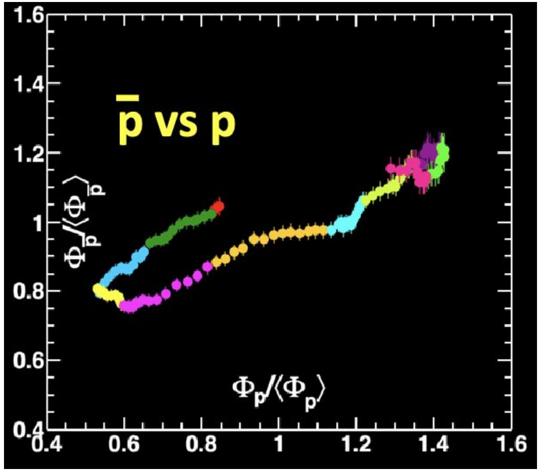
Invited Speakers (list being updated): Adriani Oscar (Firenze INFN and Univ.), Eugenio Berti (INFN Firenze), Mattia Di Mauro (Torino INFN), Carmelo Evoli (Gran Sasso Science Institute), Davide Giordano (Torino INFN and Univ.), Chiara Lucarelli (INFN Firenze), Paolo Maestro (Pisa INFN, Siena Univ.), David Maurin (LPSC Grenoble), Luca Orusa (Princeton Univ.), Mercedes Paniccia (Geneva Univ.), Tanguy Pierog (KIT, Karlsruhe, IKP), Laura Serksnyte (TUM Munich), Andrii Tykhonov (Geneva Univ.), Michael Unger (KIT, Karlsruhe, IAP)

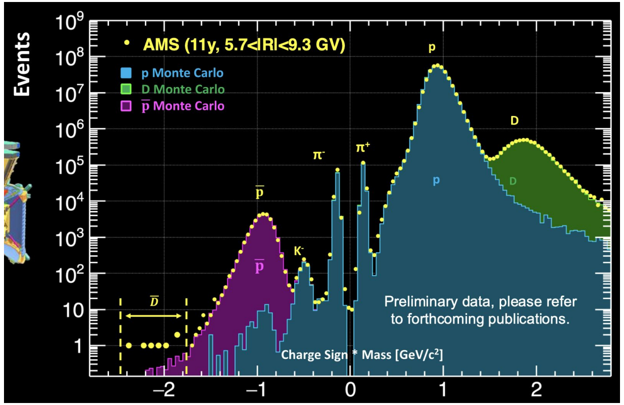
Still time to register and/or submit talks!

AMS-02

- Detailed measurements of cosmic-ray primaries and secondaries across a wide rigidity range.
- High cadence flux data allows for the generation of detailed solar modulation models.
- High-precision antiproton measurements and informs continued searches for dark matter excesses.
- Potential detection of antideuterium requires additional work







Antinuclei

P.Salati

Dark matter searches with cosmic Antideuterons and Antihelium

- Antideuteron events
  Antideuterium is expected to be detected in the cosmic radiation.
  Conventional processes yield a flux peaking at ~ 10 GeV.
  Events below ~ 1 GeV would point toward annihilating DM.

- Antihelium-3 events
  Unless CR propagation and coalescence are very different from expected, AMS-02 should not see secondary cosmic antihelium-3.
  Is the interesting possibility from DM annihilating into anti-Λ_b baryons ruled out?

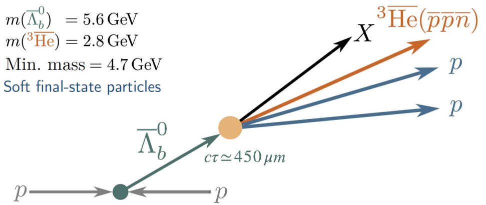
- Antihelium-4 events
  There is no hope to detect a single event from CR spallation.
  A detection would require an exotic explanation:
  A QCD dark sector for instance, or BSM fireballs all over the Milky Way?

LHCb (Anti)hypertriton and (Anti)helium

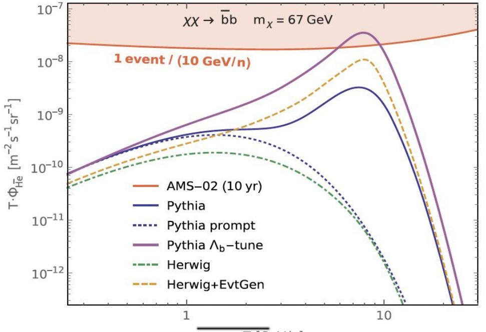
T.Pöschl

First ever measurement of (anti)hypertrion and (anti)Helium yields by LHCb (pp at 13 TeV, 5.5 fb-1)

- Hypetriton signal (~110 counts seems too small)
- $\overline{{}^3He}$ clear signal thanks to velo, but no cross section yet
- No signal for the $\Lambda_b \longrightarrow \overline{{}^3He}$ +X



PRL 126(2021)101101



$\mathcal{B}(\Lambda_b \longrightarrow \overline{{}^3He}$ +X) $\approx \mathcal{O}(10^{-6})$

$$\mathcal{B}(\overline{\Lambda}_b^0 \to {}^3\overline{\text{He}}pX) < 3.6 \times 10^{-8} \text{ at } 90\% \text{ CL}$$

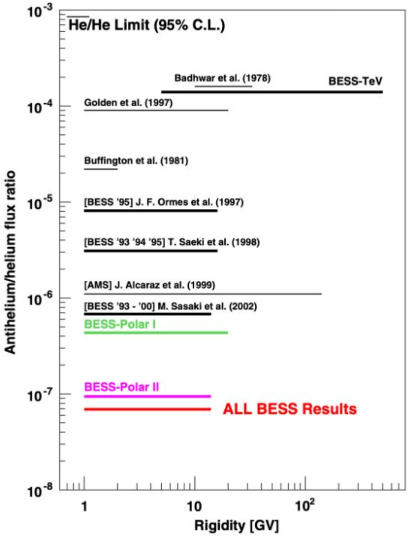
- $\overline{{}^3He}$ cross section measurements to be 'compared' to the ALICE data are necessary to verify the analysis
- Checks on Λ_b kinematics in LHCb
- Diplaced $\overline{{}^3He}$ measurements possible with ALICE
- $\bar{d}$ from Λ_b studies still open and very interesting

TIM

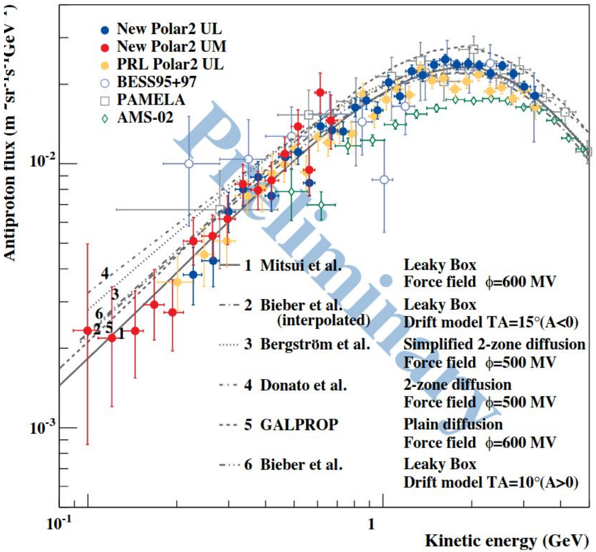
K Sakai

BESS antinuclei

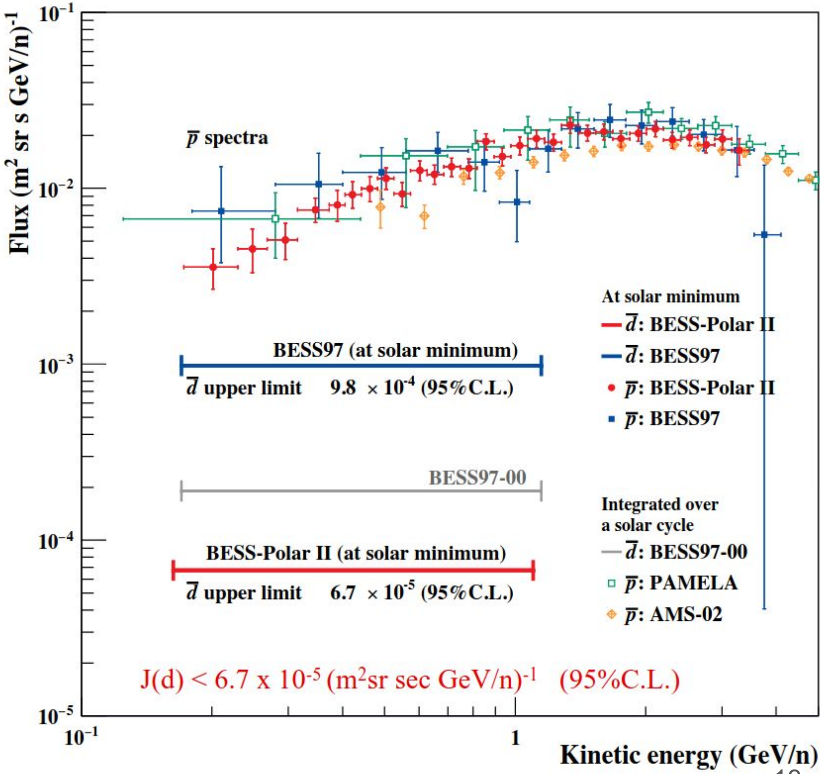
antihelium



new antiproton results

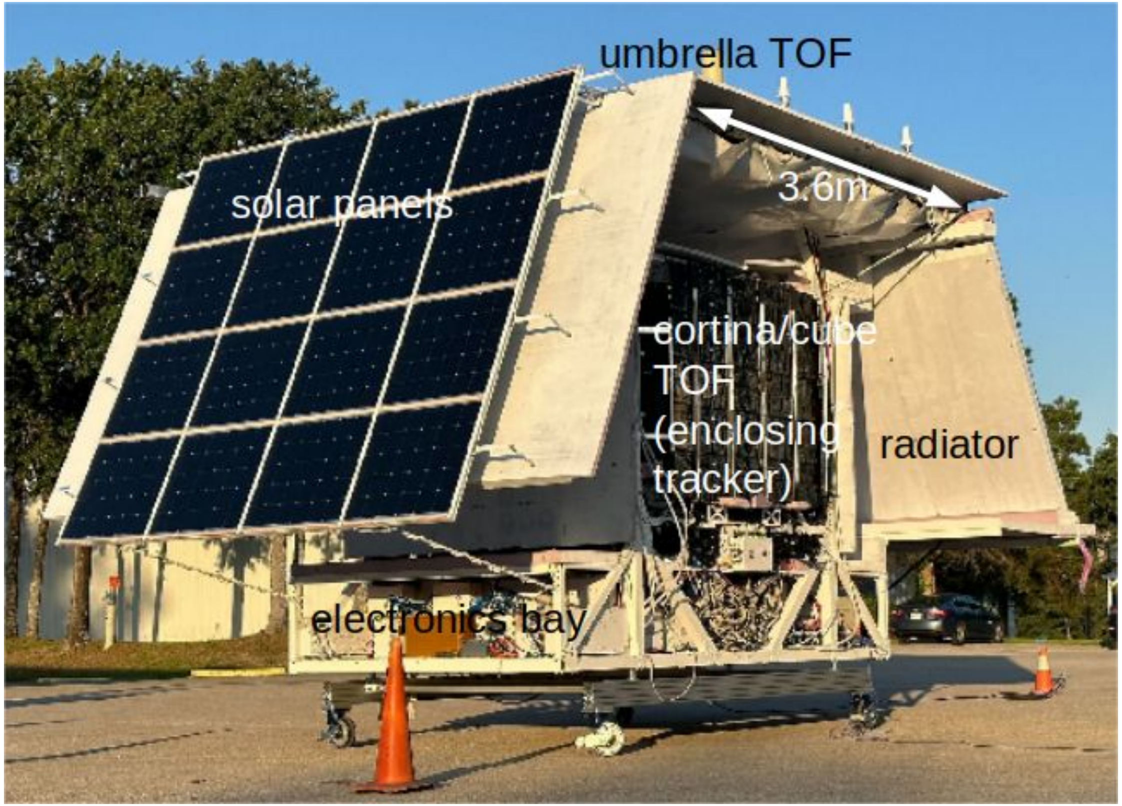


new antideuteron limits



new B10/B9 from BESS and HELIX are also coming

GAPS

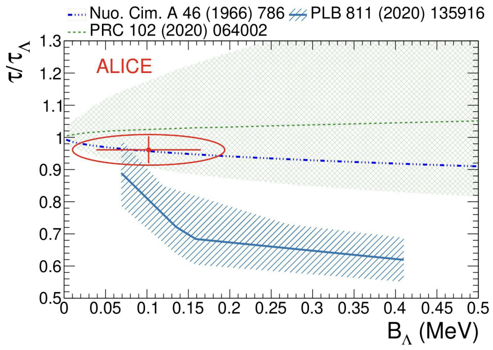


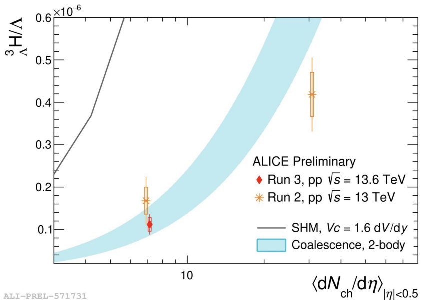
- The **G**eneral **A**nti**P**article **S**pectrometer is the first experiment dedicated and optimized for low-energy cosmic-ray antinuclei search
- Requirements: long flight time, large acceptance, large identification power, flight at low-geomagnetic cutoff location
- GAPS will deliver:
  - a precision antiproton measurement in an unexplored energy range <0.25 GeV/n
  - antideuteron sensitivity 2 orders of magnitude below the current best limits, probing a variety of DM models across a wide mass range
  - leading sensitivity to low-energy cosmic antihelium nuclei
- **GAPS is under construction, preparing for first Antarctic Long Duration Balloon flight in December 2024**

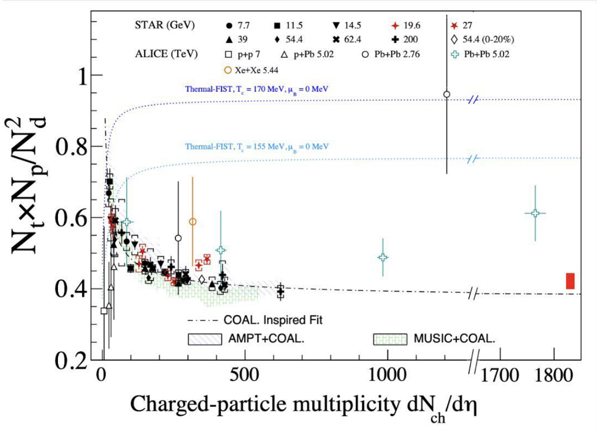
ALICE (hyper)nuclei

F. Mazzaschi

- Hypertriton binding energy and lifetime: most precise measurement at the LHC
- useful for Lambda-N interaction but also to study nuclei production mechanism (coalescence?)
- Antinuclei production and absorption measured by ALICE -> relevant parameters t interprete future observations
- A=4 (hyper)nuclei accessible and precision measurements coming in Run3





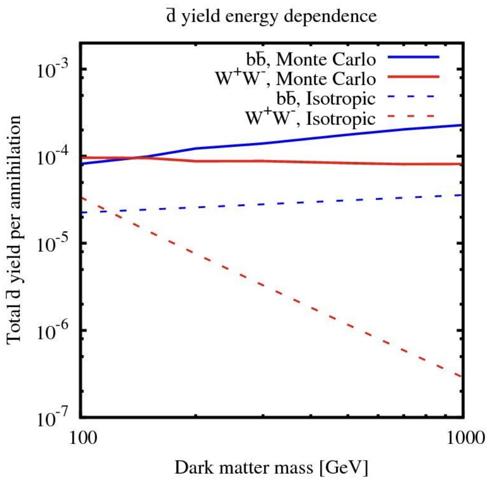


Coalescence

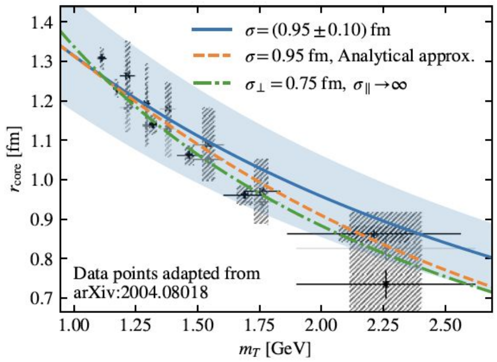
M. Kachelriess

Coalescence Models

Important of momentum correlations. Interplay between larger mass and more collimated events



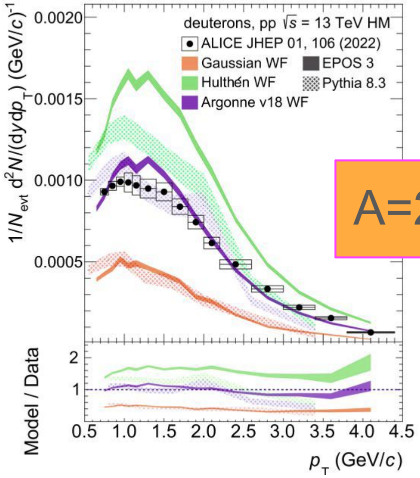
Formalism assuming a constant radius of 1fm
Equal-time approximation only 10%



- Phythia mT scaling due to kinematics.
- Collective effects in heavy ion collisions important for nuclei production?

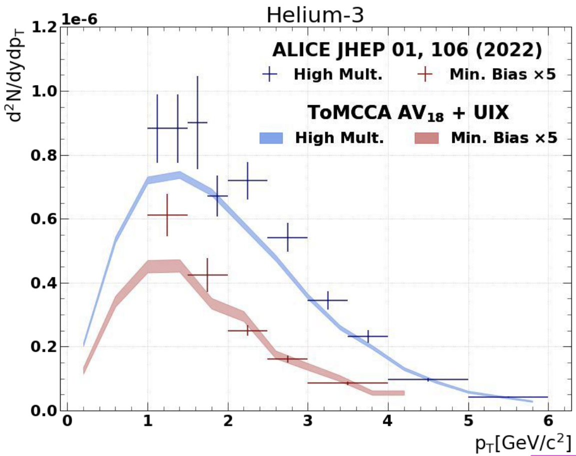
Coalescence Models

M. Mahlein



A=2

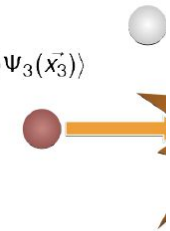
Sensitivity to deuteron wave function



Add 3rd particle to basic formalism

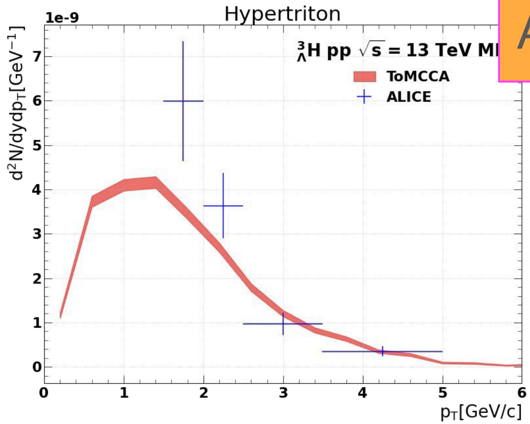
$$\frac{dN_{He}}{d^3P} = S_{He} \int d^3x_1 \int d^3x_2 \int d^3x_3 \int d^3x_1' \int d^3x_2' \int d^3x_3'$$

$$\times\ \Psi^*_{He}\left(\vec{x_1}', \vec{x_2}', \vec{x_3}'\right) \Psi_{He}\left(\vec{x_1}, \vec{x_2}, \vec{x_3}\right) \langle \Psi_3^\dagger(\vec{x_3}')\Psi_2^\dagger(\vec{x_2}')\Psi_1^\dagger(\vec{x_1}')\Psi_1(\vec{x_1})\Psi_2(\vec{x_2})\Psi_3(\vec{x_3})\rangle$$



Similarly the probability can be expressed as

$$\mathcal{P}(q_1, q_2, \sigma) = \frac{S_d}{(2\pi)^3 2^3 \sigma^6} \int d^3r_1 d^3r_2 \mathcal{D}(q_1, q_2, r_1, r_2) e^{-\frac{r_1^2+r_2^2}{4\sigma^2}}$$



A=3

Strange hadron interactions and EoS

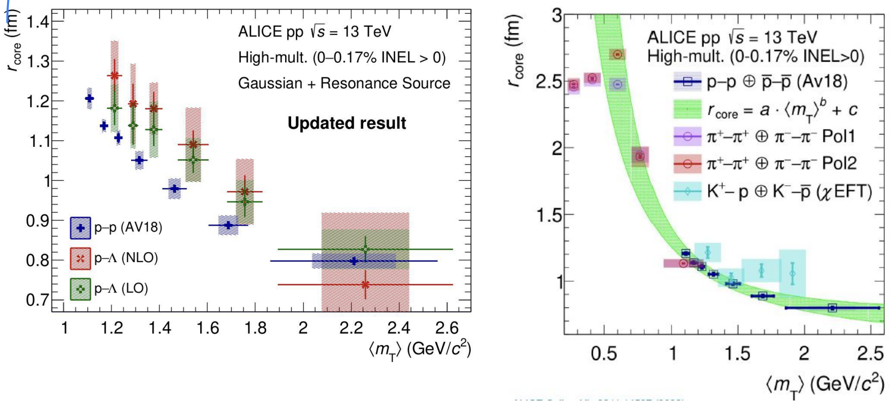
D. Mihaylov

Particle emitting Source

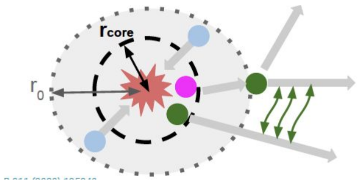
Essential ingredient for coalescence models and for interaction studies

$$C(k^*) = \frac{N_{\mathrm{SE}}(k^*)}{N_{\mathrm{ME}}(k^*)} = \int S(r^*) \left|\Psi(\vec{k}^*, \vec{r}^*)\right|^2 d^3r^* \xrightarrow{k^* \to \infty} 1$$

Common CORE source for particle emission at the LHC

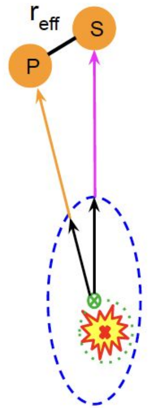


RSM Model



Works for pairs

CECA Model



Works for pairs and triplets..

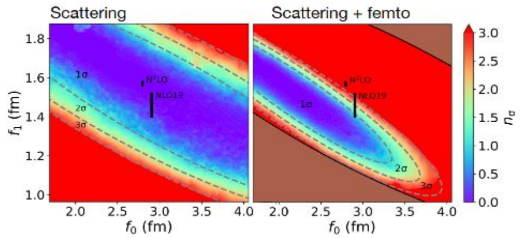
- Test of CECA on meson-baryon system
- Application to three body systems

L. Serksnyte

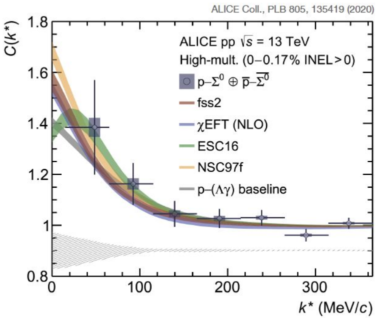
Two body interaction with strangeness

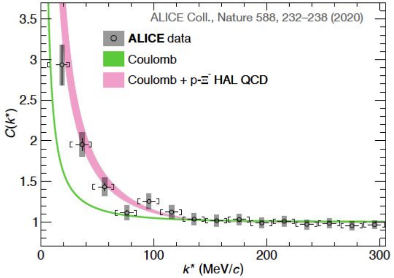
- Femtoscopy technique at the LHC can be used to study final state interactions including strange hadrons
- Two-body interactions are the back-bone for the calculation of EoS of dense nuclear matter

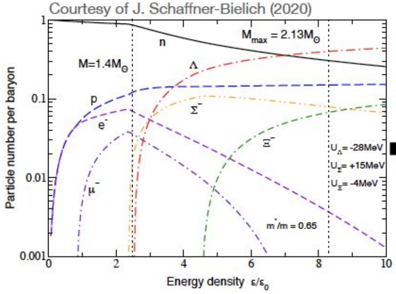
new constraints on p-Lambda scattering parameters

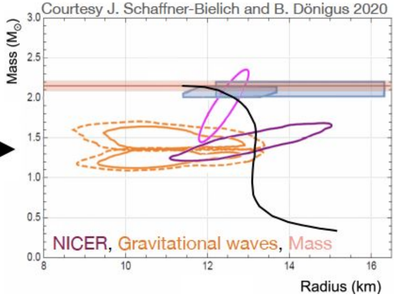


First measurement of p-Sigma0 and p-Xi- interaction









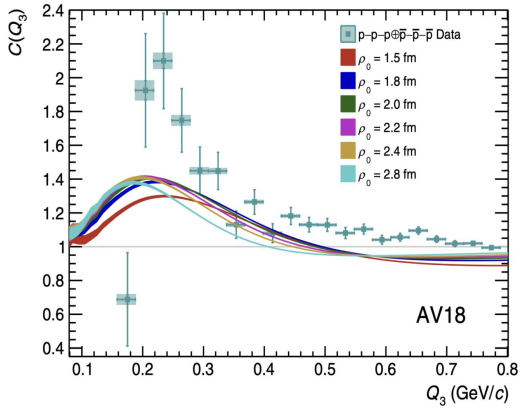
- Two-body interactions can be used to calculate single particle potentials and then EoS
- Example from 2020 shows a stiff EoS but without realistic nuclear forces and no three body interactions
- Errors need to be propagated

Three body interaction with strangeness

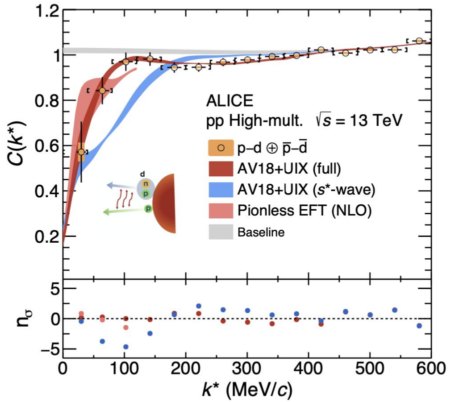
R. Del Grande

Since three body forces including hyperons are not known new measurements have been proposed at the LHC

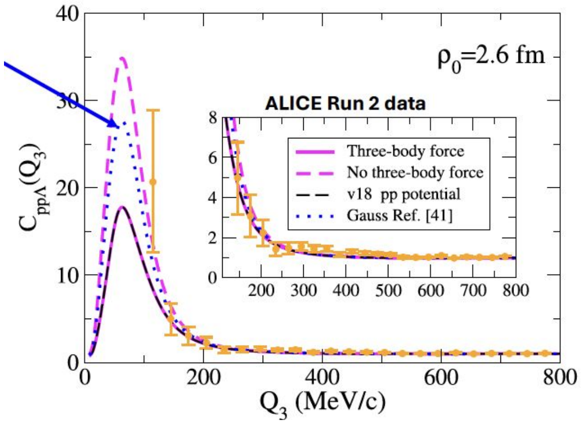
ppp: Benchmark for source and interaction



pd: benchmark and evidence



ppLambda : first measurement of the



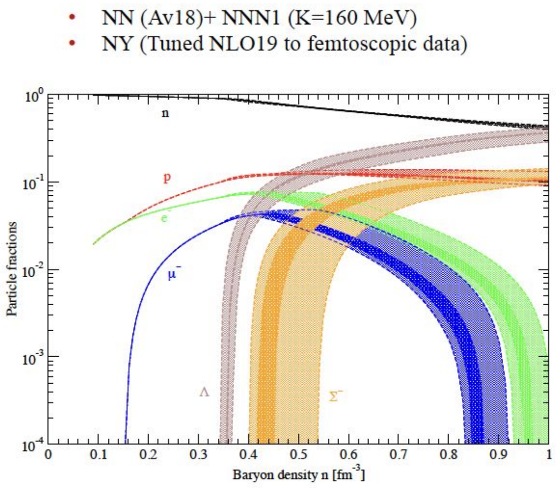
I. Vidana

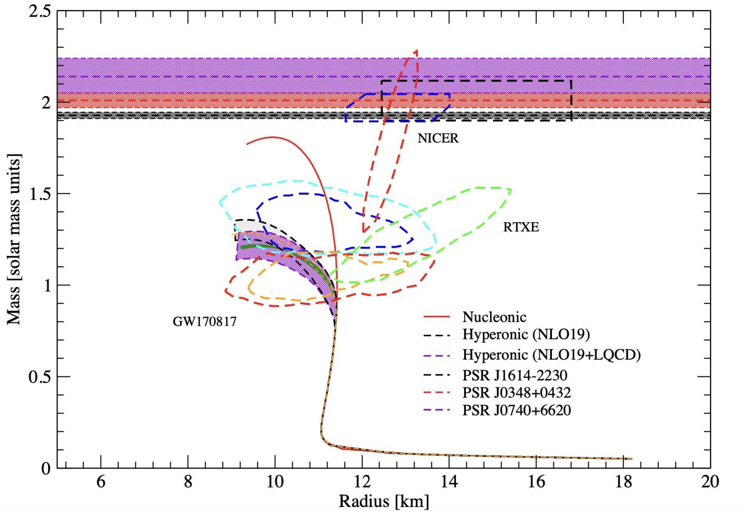
EoS for neutron stars with strangeness

Update of the EoS using the femtoscopy measurements for hyperon-nucleon interactions and realistic nuclear forces. Error progapation.

-> EoS with hyperons does not reach the two solar masses measurement

-> Three body interactions not included yet though!



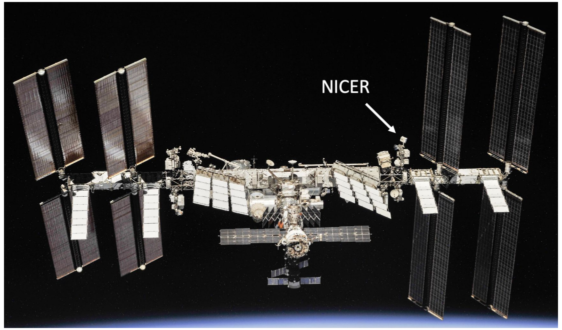


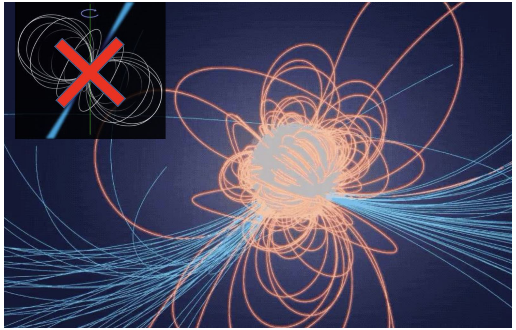
Neutron Stars

A. Watts

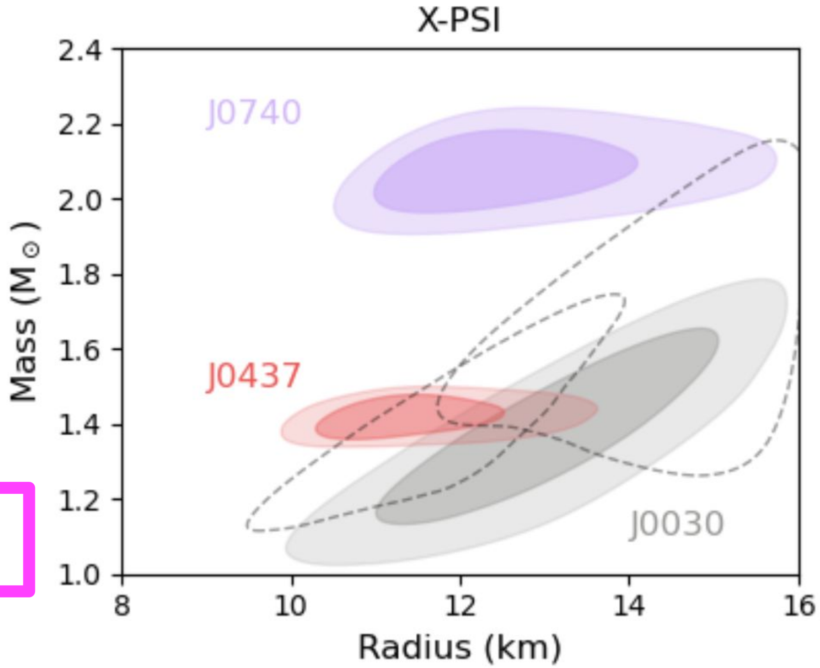
NICER

Our research depends a lot on the ISS: both AMS and NICER are located there!





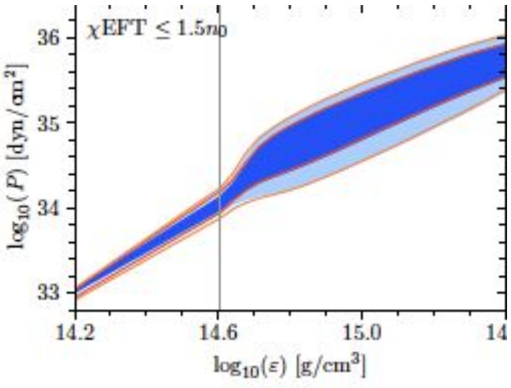
Necessity of constraining plausible radii region



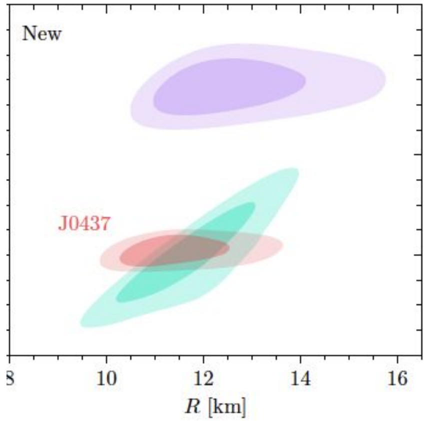
I. Svensson

Bayesian analysis of nuclear theory and astrophysics constraints

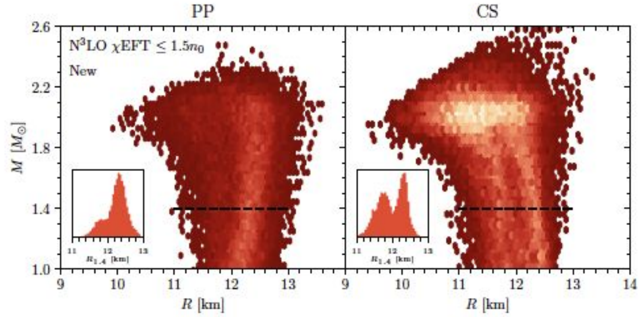
Nuclear EoS trusted till 1.5 rho0



New nicer data



Bimodal structure ??!!



New project to constrain low energy QCD constant for pion-Nucleon interaction from astrophysics data

- Maybe global analysis including pion-Nucleon and pion-Nucleon
- Important also for Axion properties in neutron stars

K. Springmann

Axions in neutron stars

QCD Axion coupling to nucleons in finite baryon density environments can strongly modify the EoS of neutron stars

Indeed light QCD axion couples similarly to the pion to nucleons

-> Axion fields induces a phase transition !!

- Need for better constraints of ci coupling constants of pion to nucleon coupling
- Multiparticle correlation could also access the coupling ‘in medium’

Let’s write a paper on our workshop:

Making Progress in Astrophysics with Nuclear Physics Measurements at CERN

August 20, 2024