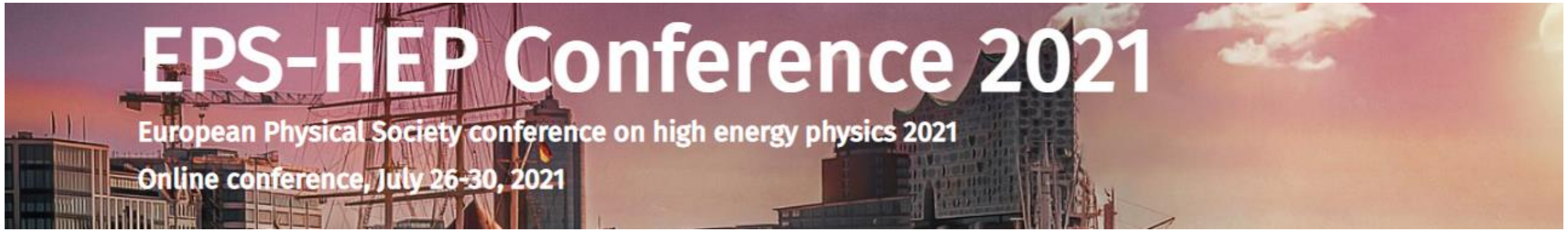
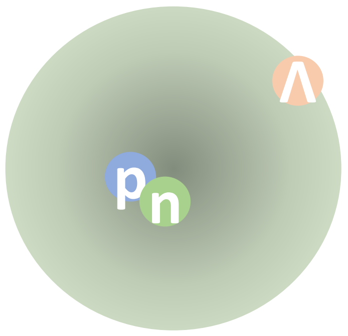
A large bound state in small systems: ALICE measurement of hypertriton production in pp and p-Pb collisions

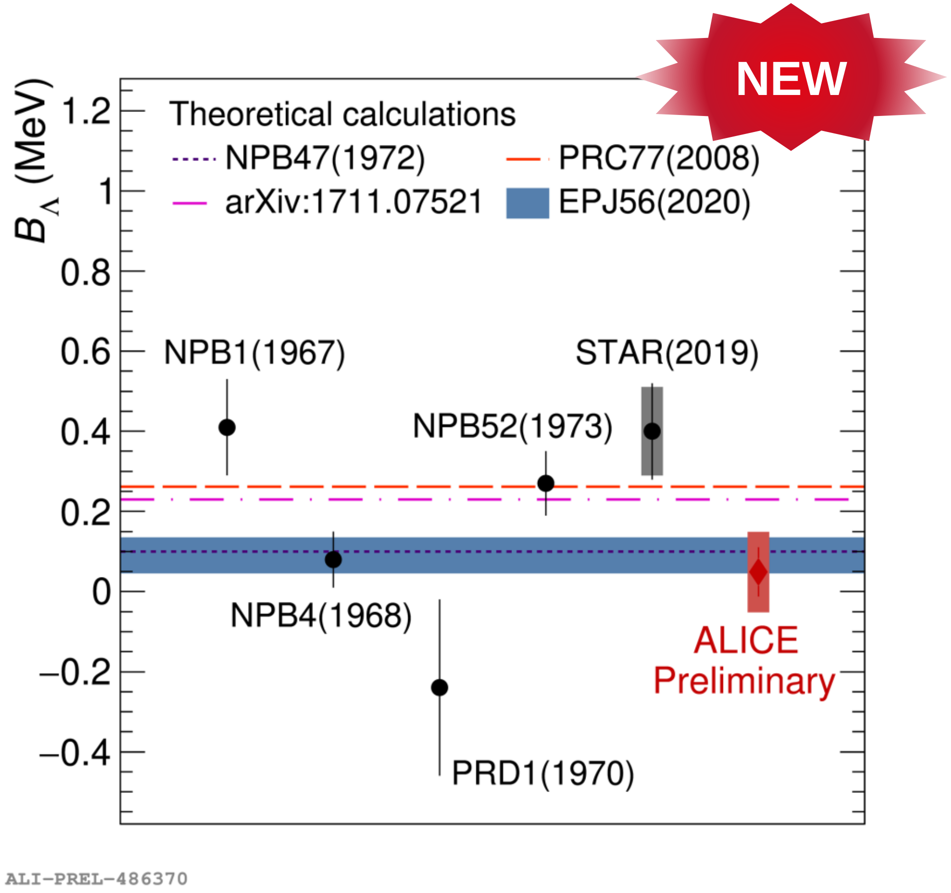


Janik Ditzel
on behalf of the ALICE Collaboration

Hypertriton

- Λ, p, n bound state
- Lightest known hypernucleus and very loosely bound
- Mass ≈ 2.991 GeV/c^2
- Λ separation energy ≈ 130 keV
- Recent calculations predict a large radius for the hypertriton wave function *[F. Hildenbrand, H.-W. Hammer, Phys. Rev. C 100, 034002]*





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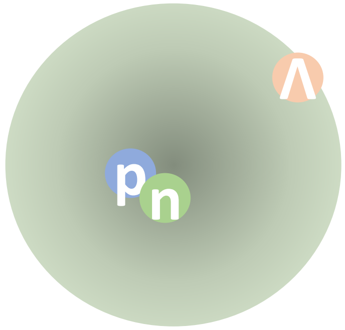
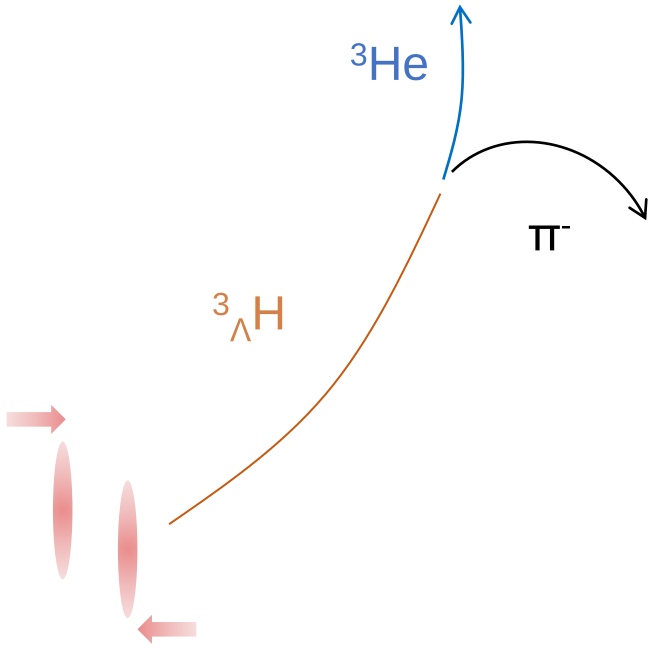


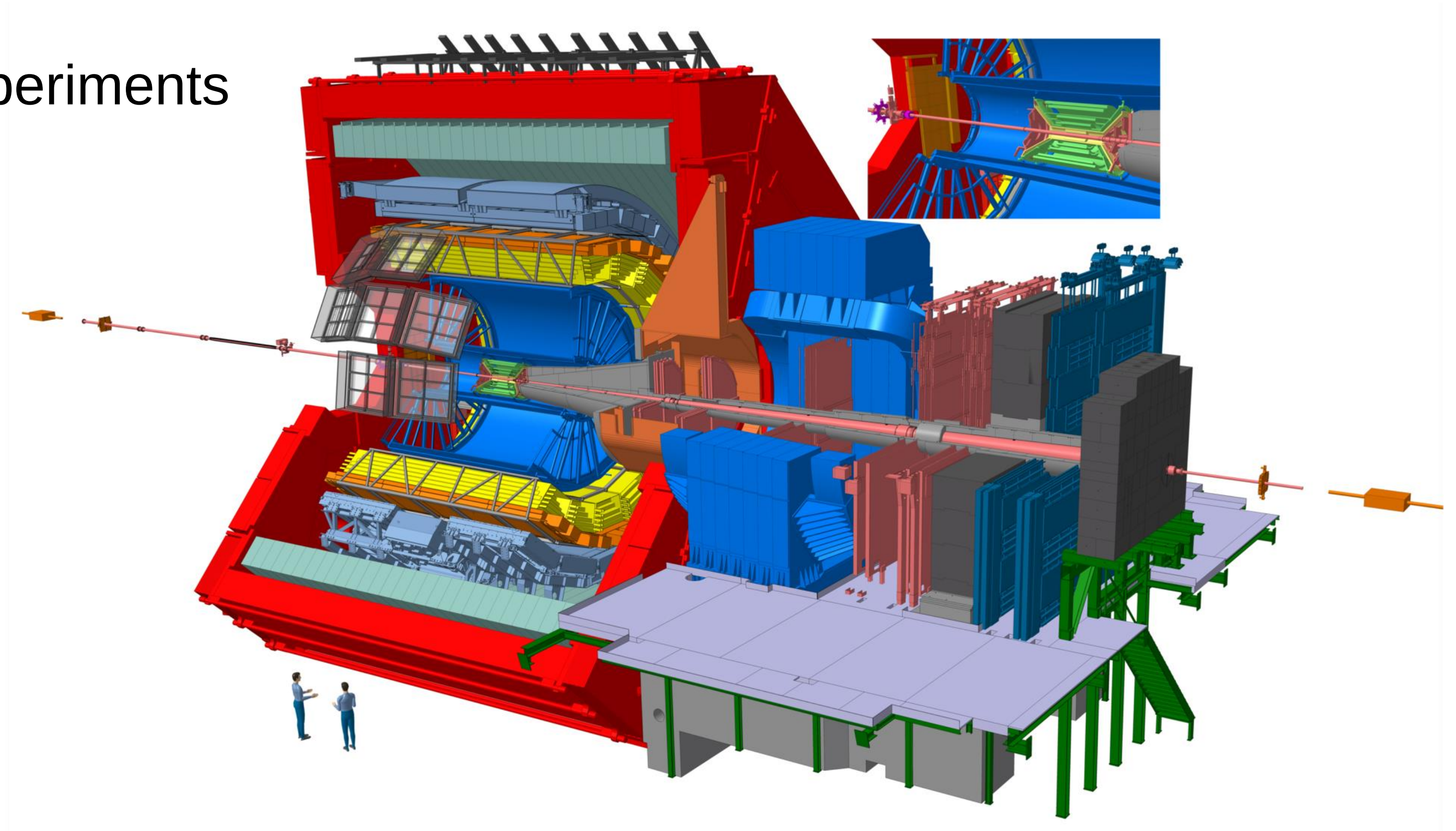
- Decay modes:

$^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$	$^{3}_{\Lambda}\mathrm{H} \rightarrow d + p + \pi^{-}$
$^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{0}$	$^{3}_{\Lambda}\mathrm{H} \rightarrow d + p + \pi^{0}$



ALICE detector

- One of the four major LHC experiments
- Specialized in tracking and particle identification from low to high momenta using different detector technologies



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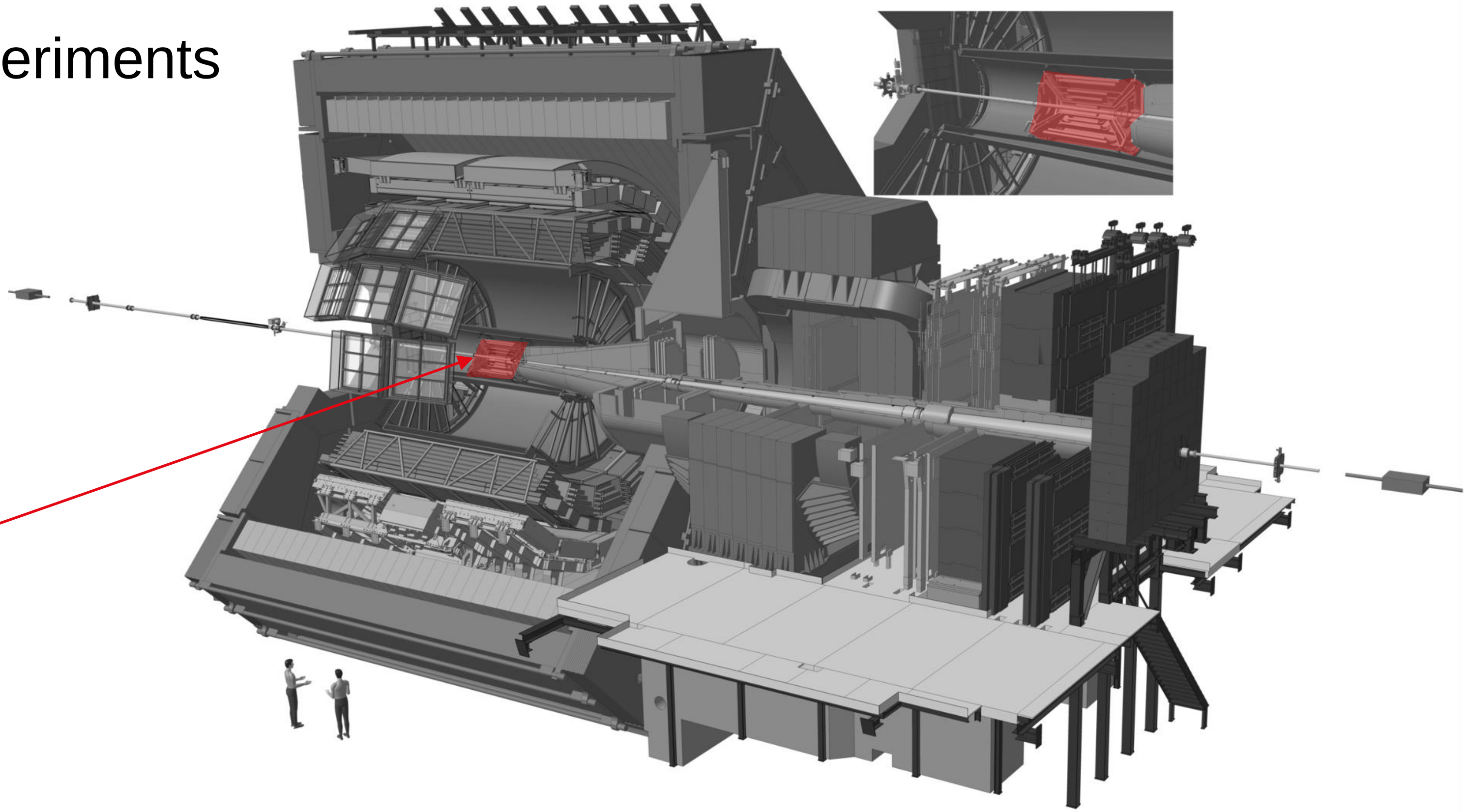
ITS (Inner Tracking System)
- Reconstruction of primary and decay vertices
- Track reconstruction
- Particle identification for low momentum particles



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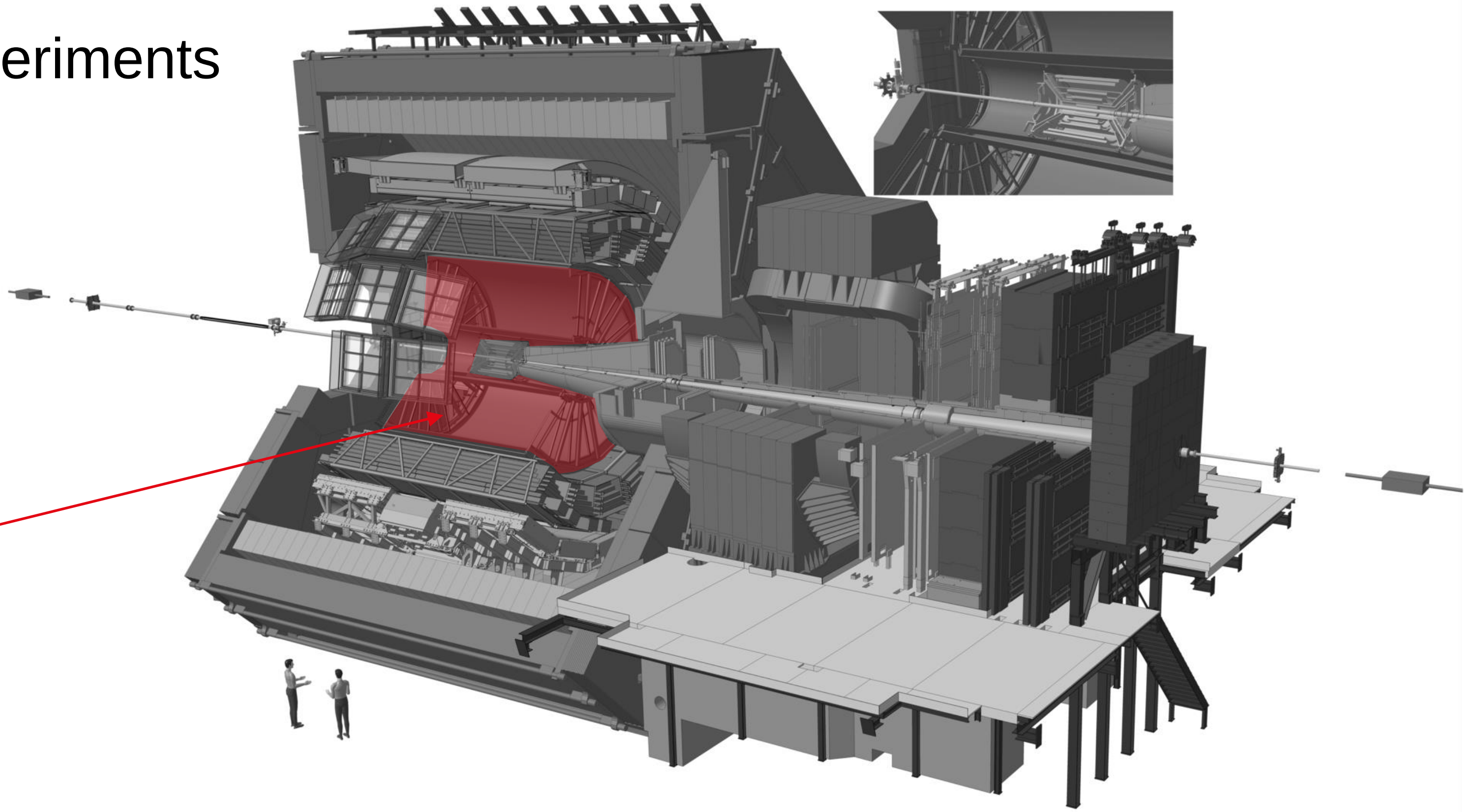

TPC (Time Projection Chamber)
- Tracking
- Particle identification via dE/dx measurement

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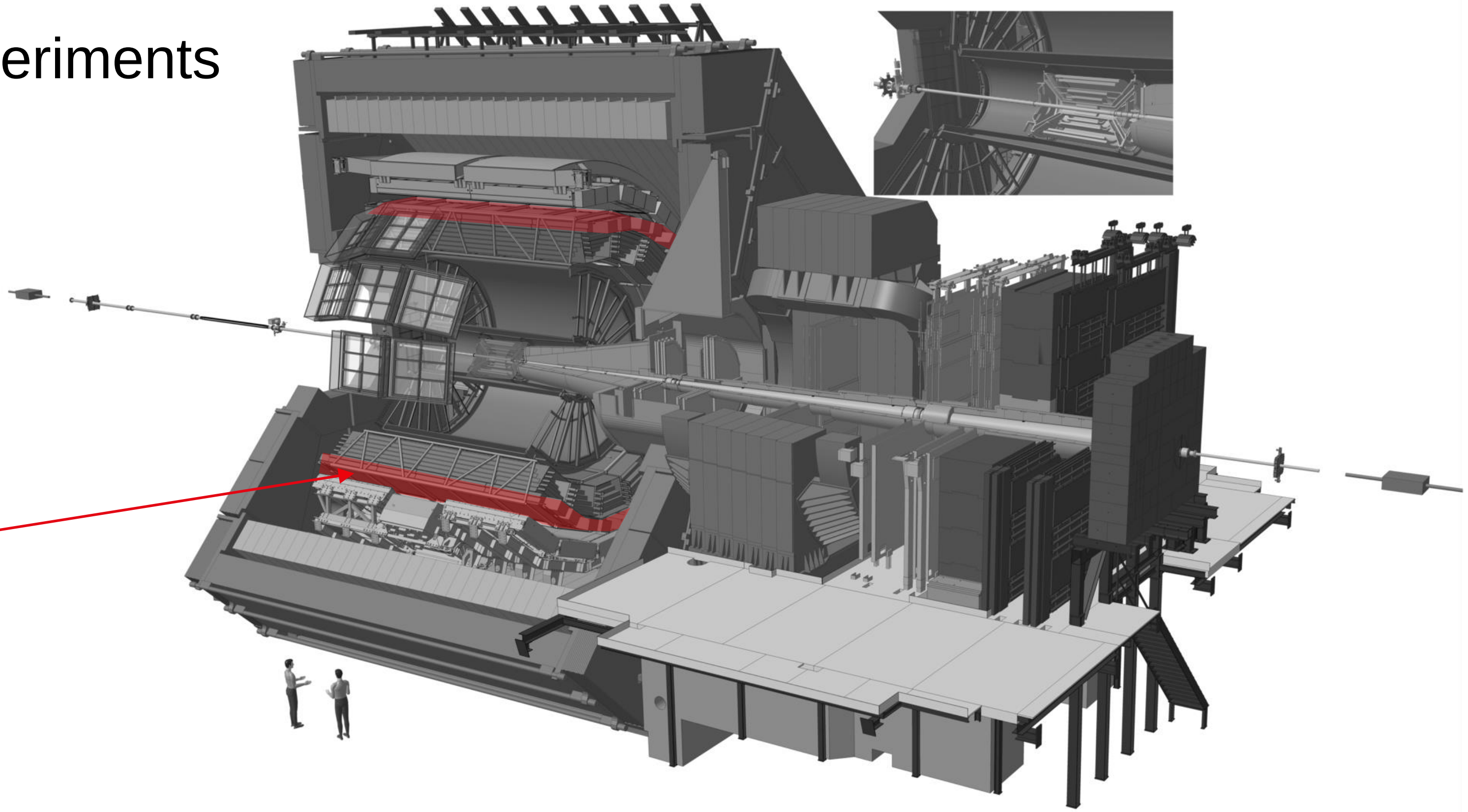

TOF detector (Time Of Flight)

- Particle identification with time-of-flight measurement

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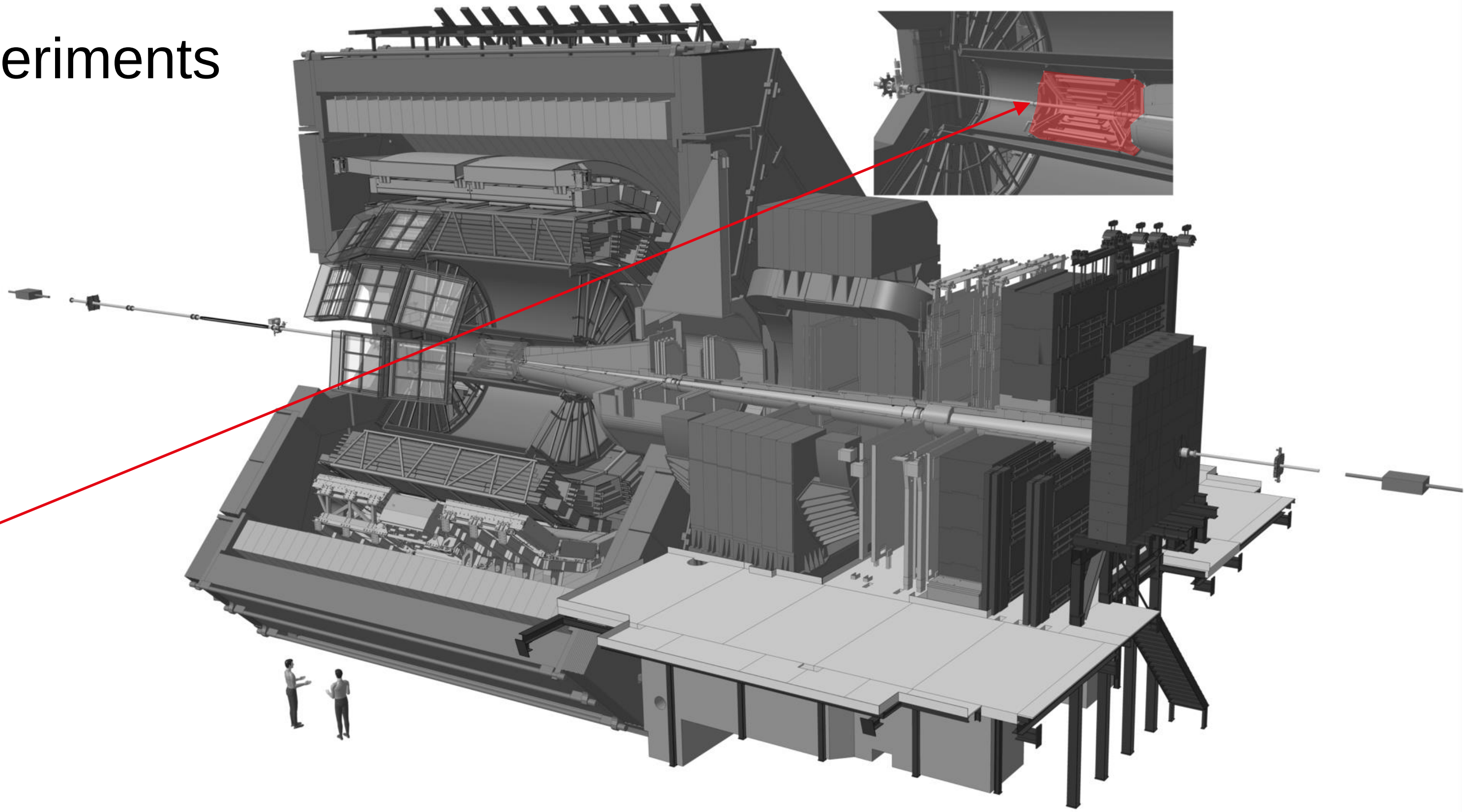
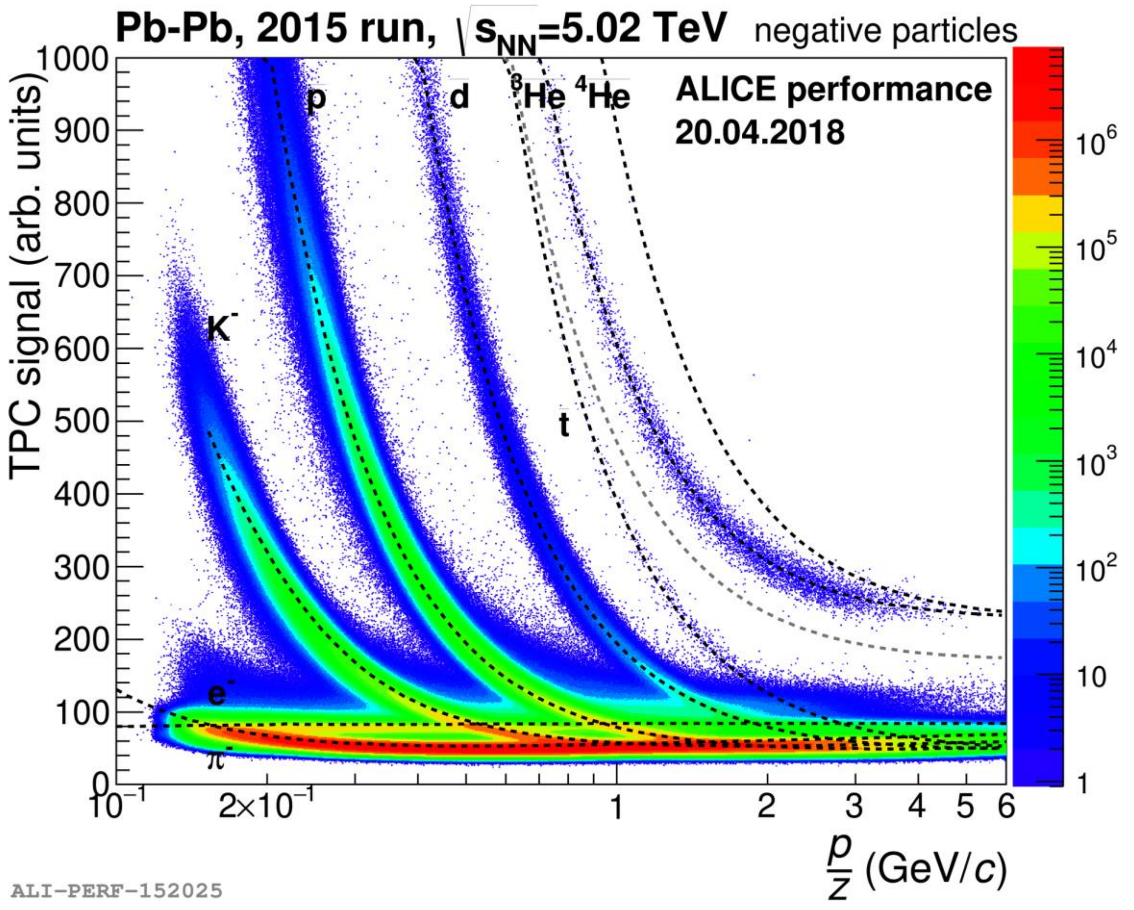


V0 detectors
- Centrality / multiplicity determination
- Trigger

Hypertriton reconstruction

- **Step 1**: find and identify the daughter particle tracks
    - Using the TPC PID via the specific energy loss
    - Excellent separation of different particle species

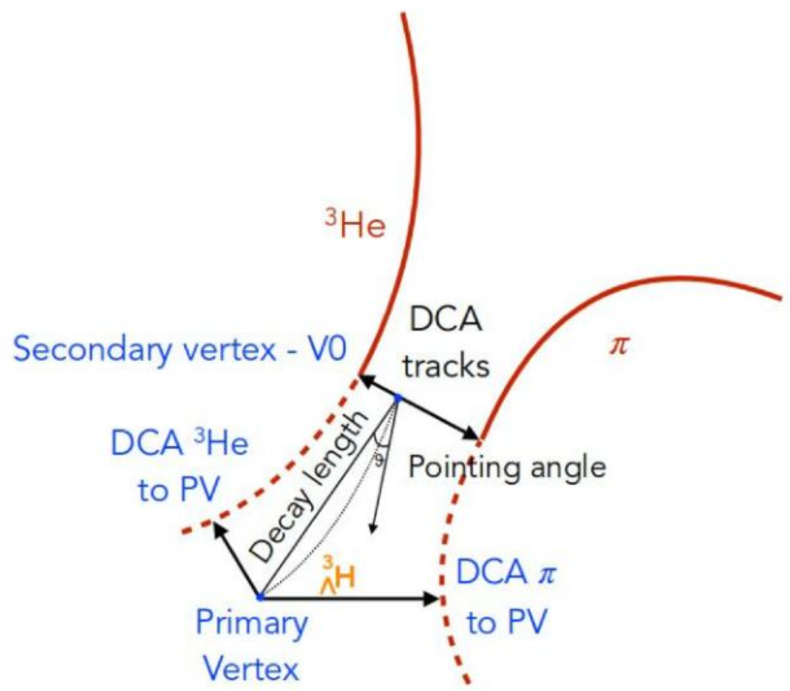


Hypertriton reconstruction

- **Step 1**: find and identify the daughter particle tracks
- **Step 2**: reconstruct the decay vertex of the hypertriton

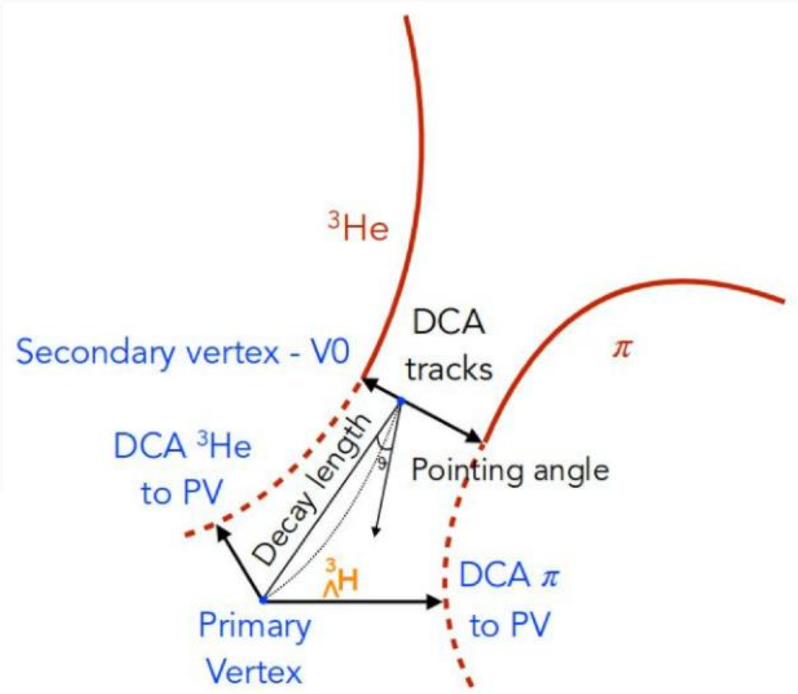
  - The identified daughters are assumed to come from a common vertex
  - Their tracks are matched by algorithms to find the best possible decay vertex

  - Problem: huge combinatorial background
  - Solution: topological and kinematical cuts or machine learning approach



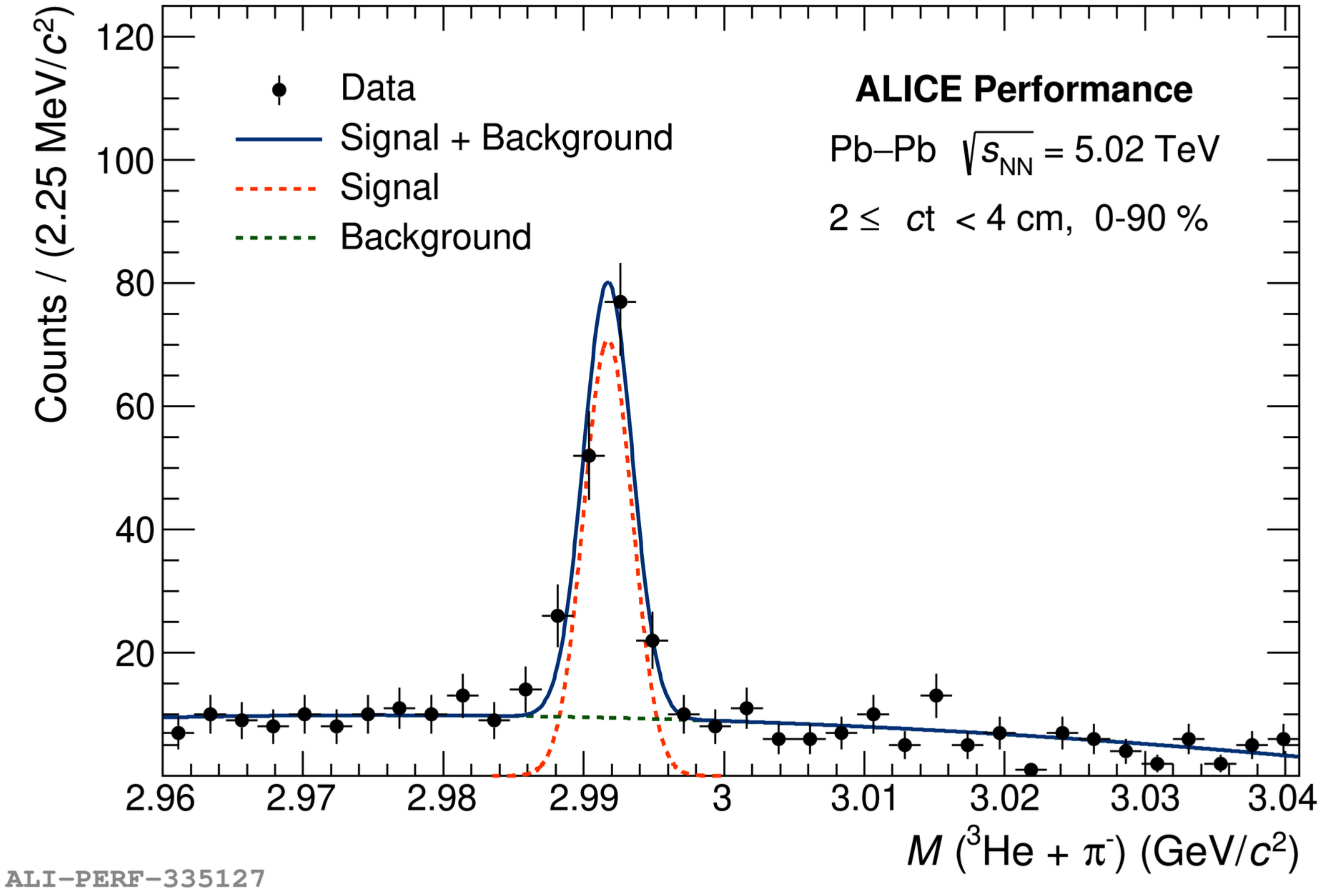
Hypertriton reconstruction

- **Step 1**: find and identify the daughter particle tracks
- **Step 2**: reconstruct the decay vertex of the hypertriton
- **Step 3**: applying corrections
  - Tracking efficiency and detector acceptance
  - Assuming a branching ratio of 25%



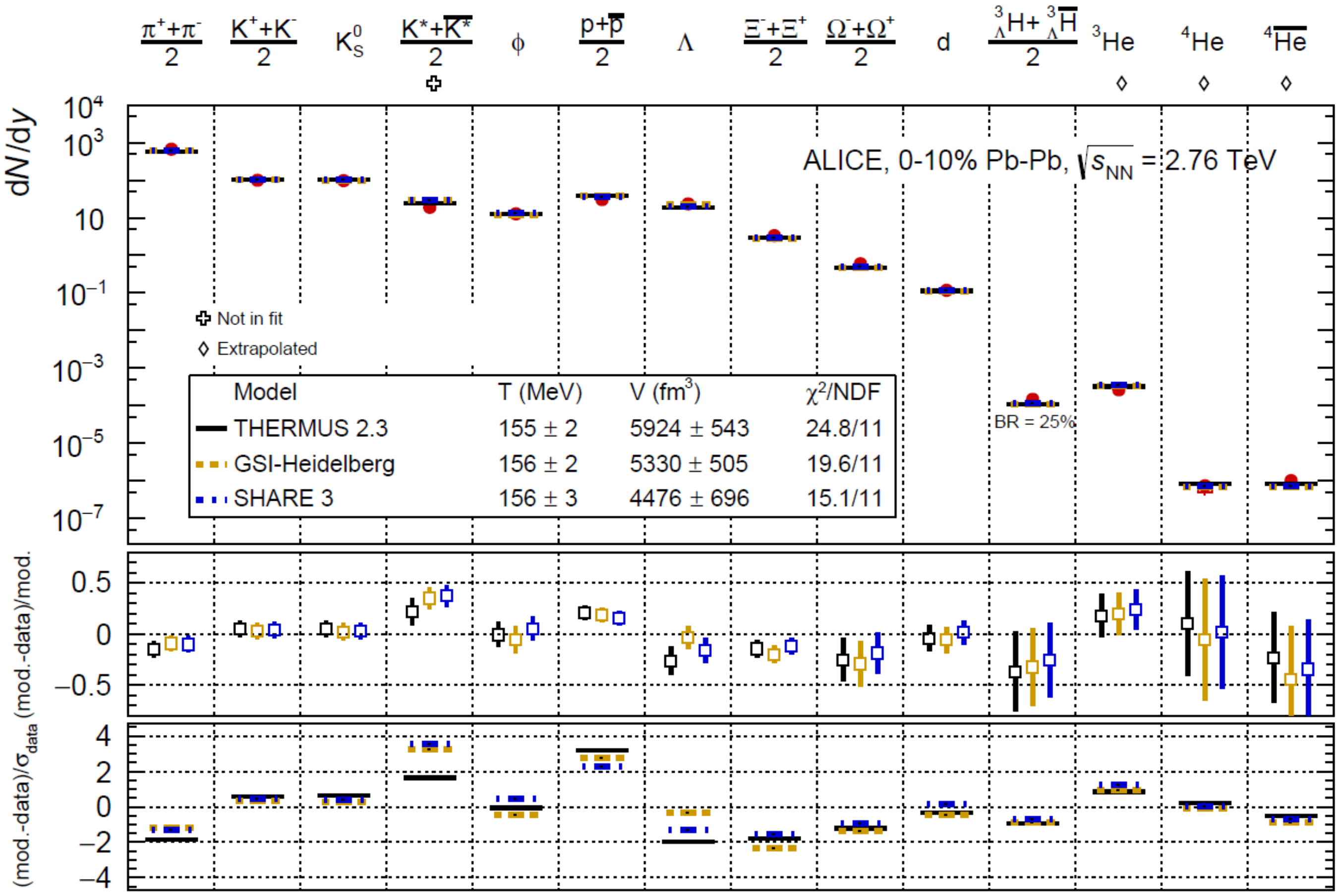
Hypertriton production

- Hypertriton production in heavy-ion collisions since LHC Run 1
- Recent measurement in Run 2 Pb-Pb collisions at 5.02 TeV
- Signal extraction by using a machine learning approach



Hypertriton production

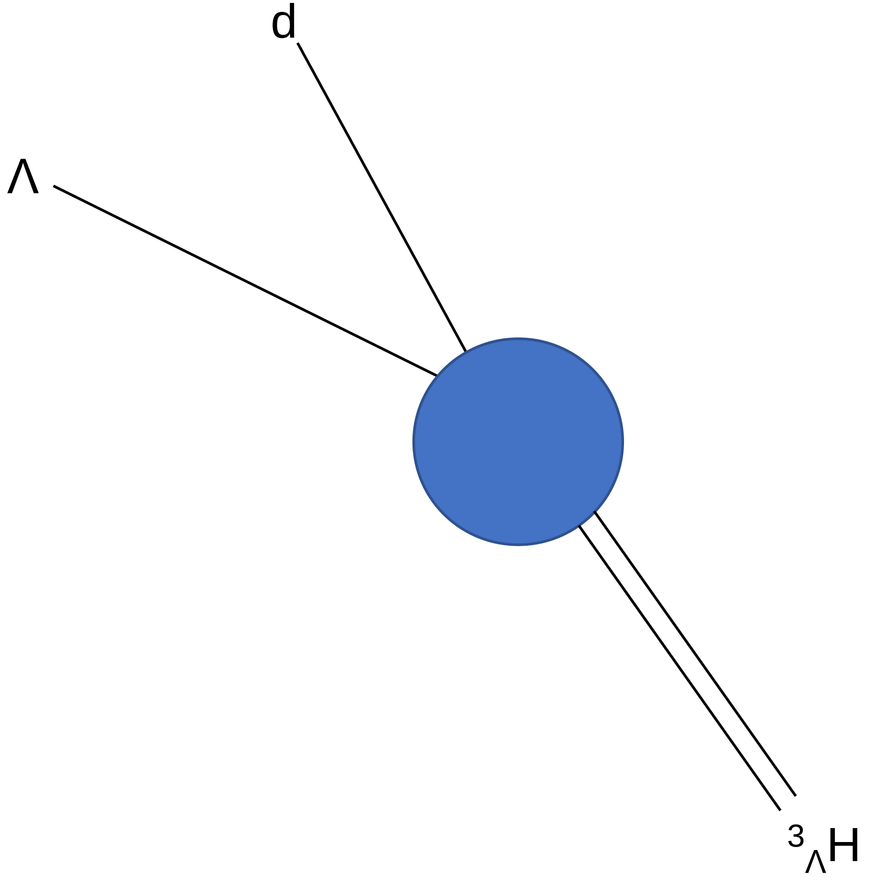
- Hypertriton production in heavy-ion collisions since LHC Run 1
- Integrated yield well described by the Statistical Hadronization Model (SHM)
- SHM assumes hadron abundances from statistical equilibrium at the common chemical freeze-out temperature T_{ch} = 156 MeV.
  How hypernuclei can survive in this environment is not clear.



ALICE Collaboration, S. Acharya et al., "Production of ^{4}He and $^4\overline{\text{He}}$ in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at the LHC", Nucl. Phys. A 971 (2018) 1–20, arXiv:1710.07531 [nucl-ex]

Hypertriton production

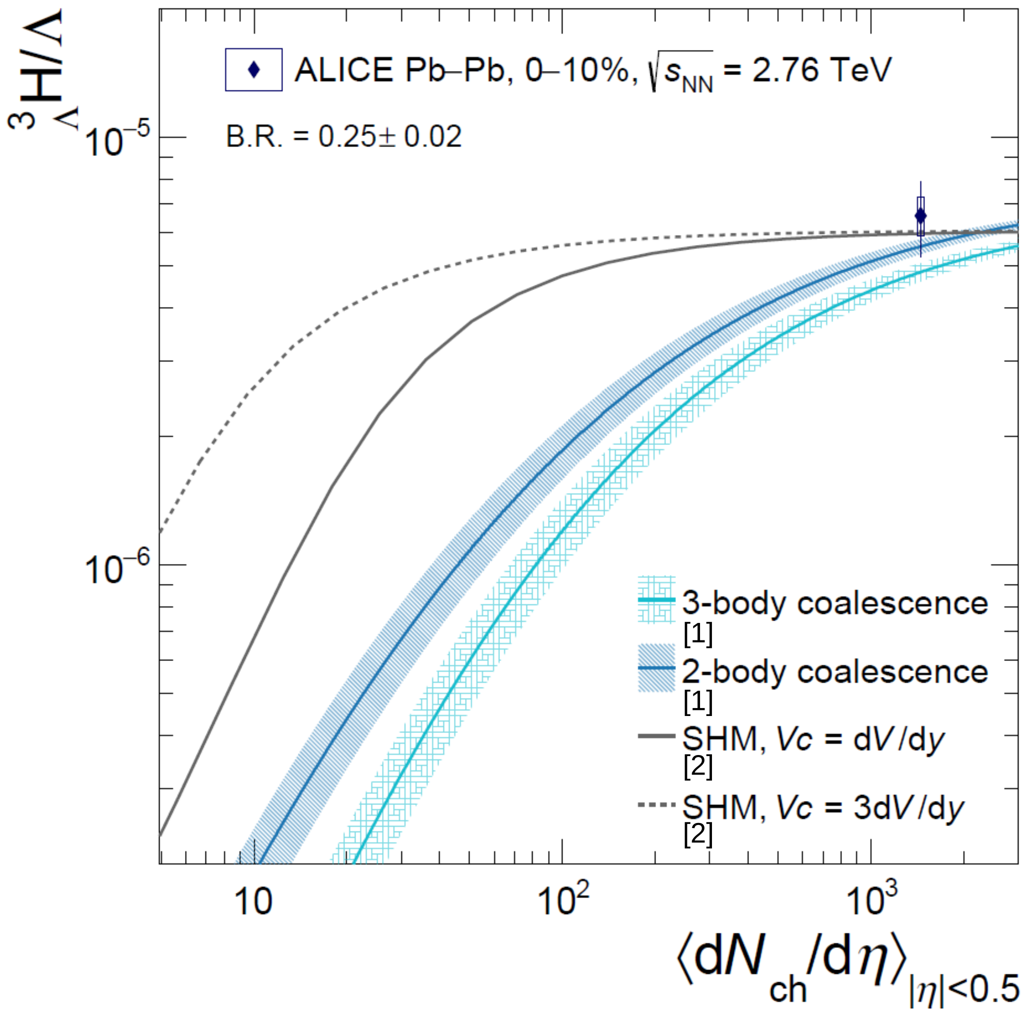
- Hypertriton production in heavy-ion collisions since LHC Run 1
- Coalescence Model:
  Nucleons that are close in phase space at the freeze-out can form a nucleus via coalescence.
  The key concept is the overlap between the nuclear wavefunctions and the phase space of the nucleons



Hypertriton production

- $^{3}_{\Lambda}H$ / Λ ratio vs multiplicity

- Extremely sensitive to the nuclei production mechanism:
  - In statistical hadronization models (SHM) the object size is not taken into account
  - In a coalescence picture large suppression of the production in small systems expected



Hypertriton production

- $S_3 = ({}^3_\Lambda H\ /\ {}^3He)\ /\ (\Lambda\ /\ p)$ vs multiplicity

- Strangeness population factor for the measurement of baryon-strangeness correlations
- Extremely sensitive to the nuclei production mechanism:
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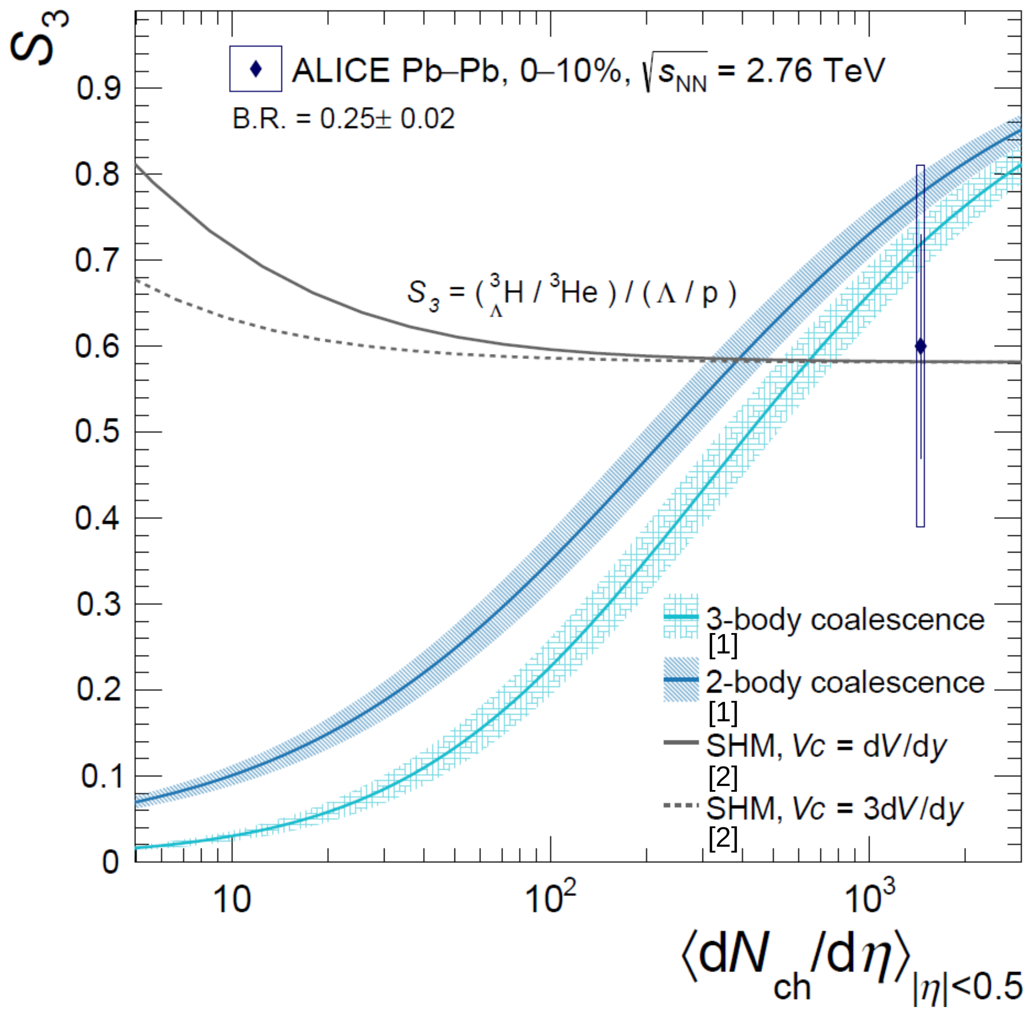
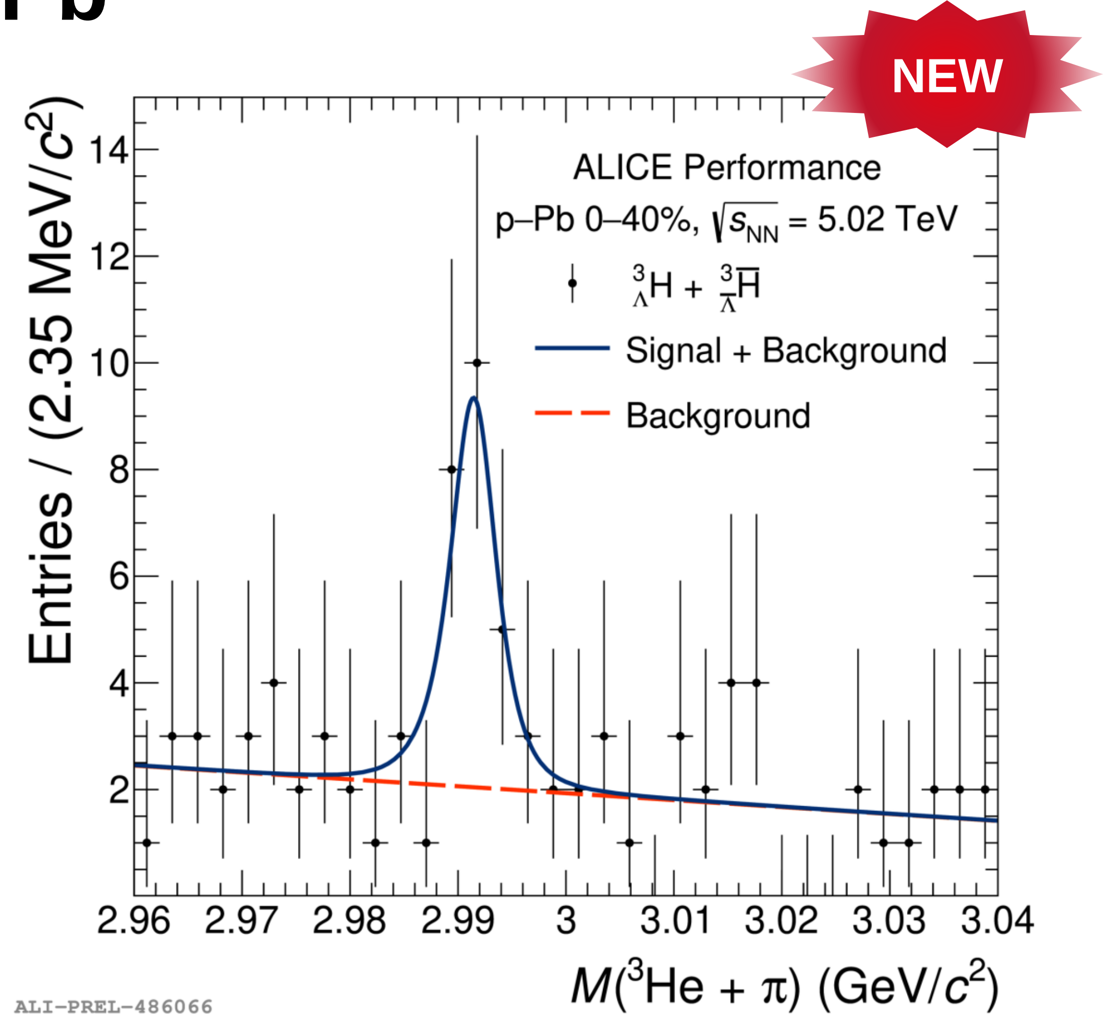
  - In a coalescence picture large suppression of the production in small systems expected



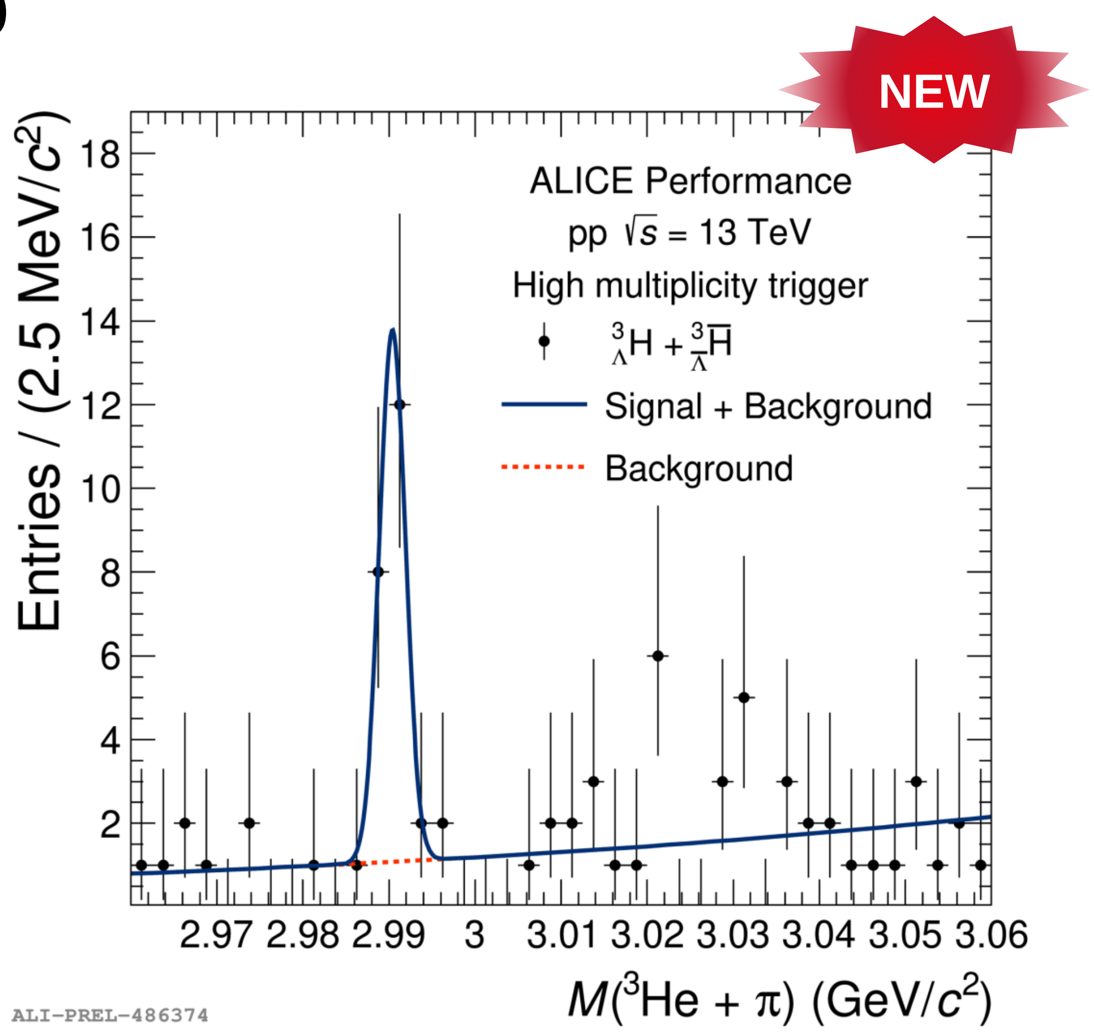
Hypertriton measurement in p-Pb

- First measurement of the hypertriton in Run 2 p-Pb collisions at 5.02 TeV
- Signal extraction by using a machine learning approach



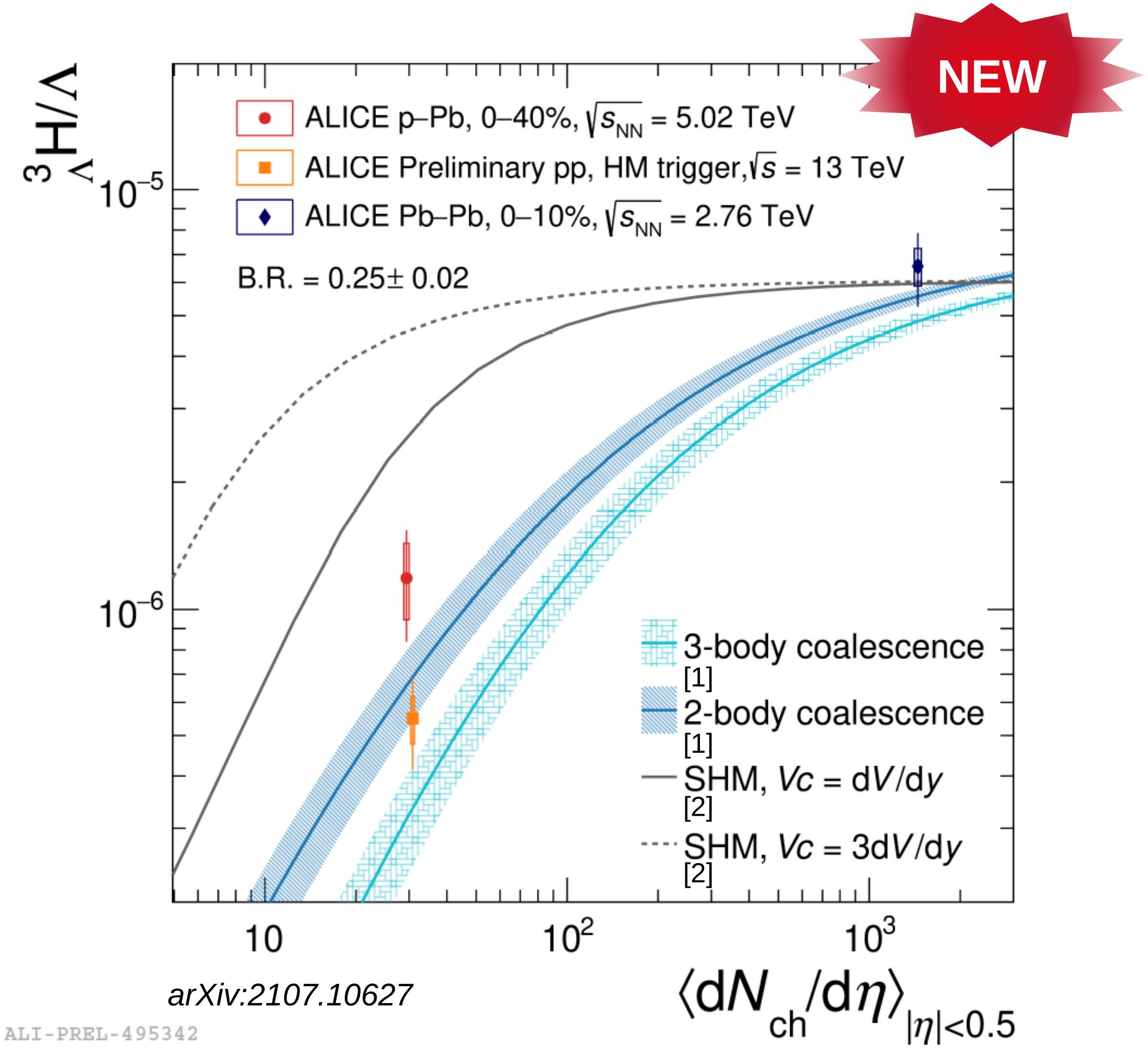
Hypertriton measurement in pp

- First measurement of the hypertriton in Run 2 pp collisions at 13 TeV
- Topological and kinematical cuts applied to optimize the signal-to-background ratio and improve the significance in a traditional analysis



$^{3}_{\Lambda}$H / Λ ratio

- Measurements in pp and p-Pb:
  Two new points at different multiplicities
- Points slightly favour the
  two-body coalescence
- But do not exclude
  three-body coalescence



arXiv:2107.10627

S_3

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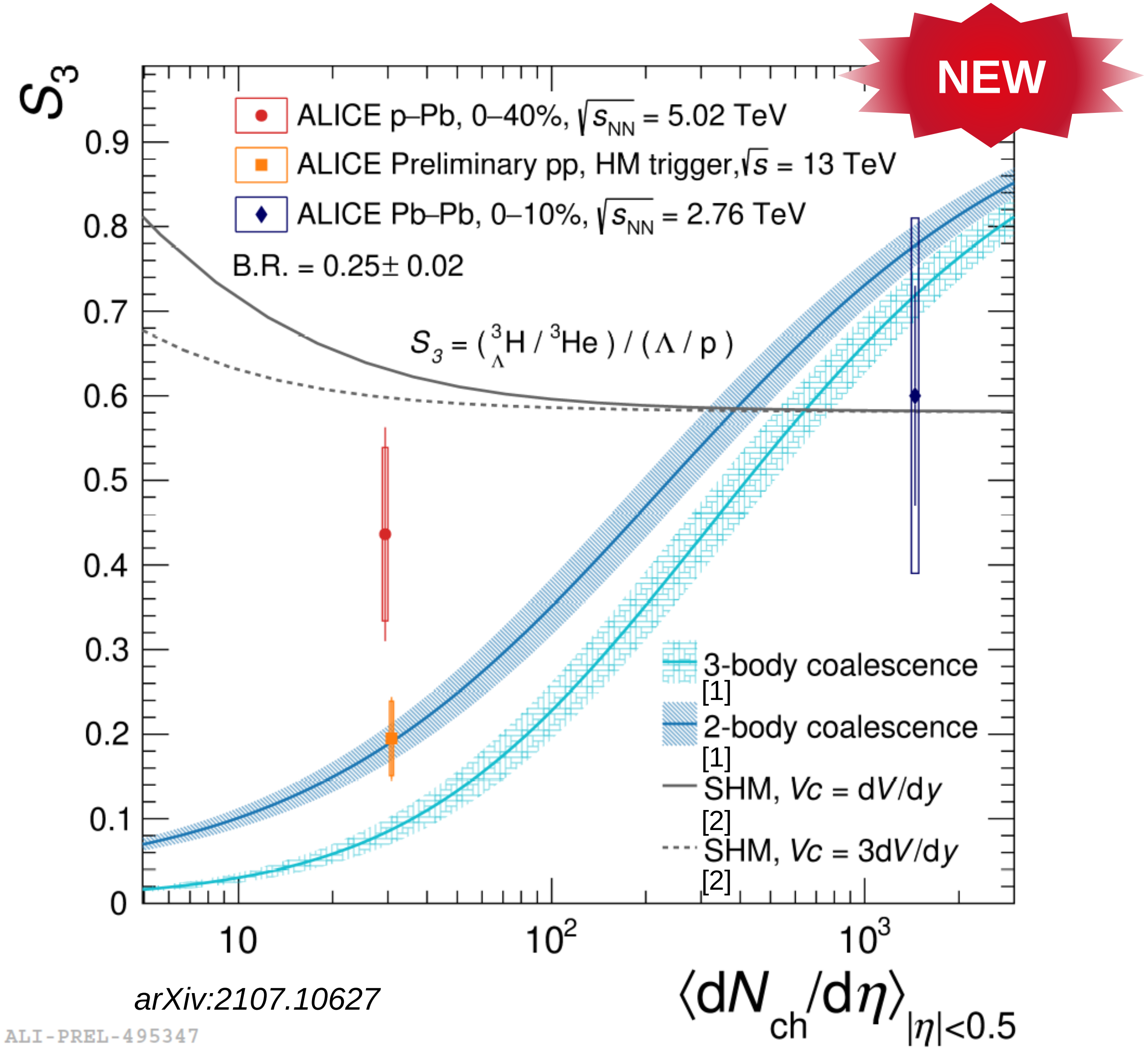

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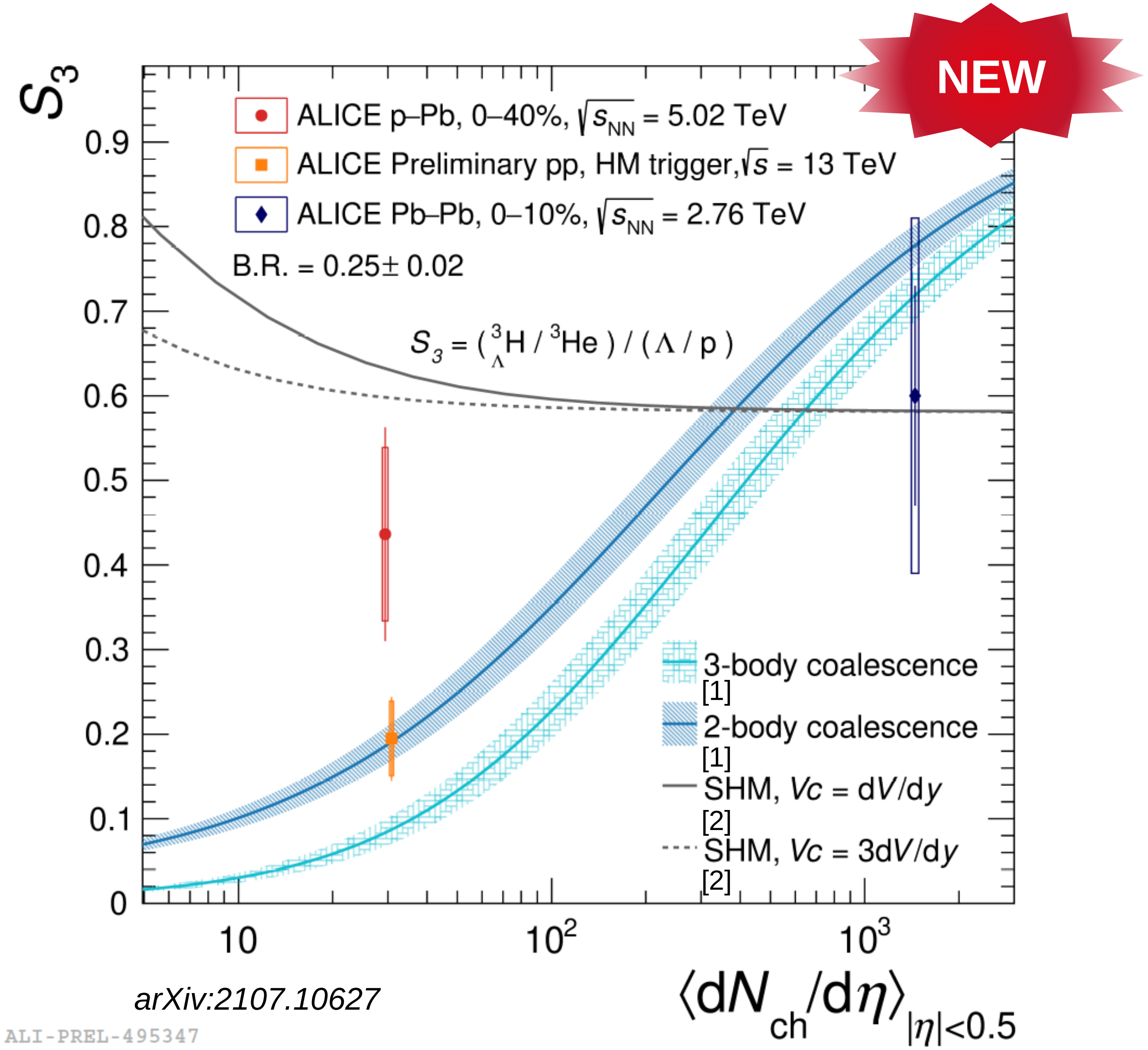
Outlook

- Studies of the hypertriton production in different multiplicities are the key to explore the formation mechanism
- The upcoming Run 3 of the LHC will add significantly more statistics also for small systems
- This may give the possibility of a conclusive answer to the question of the correct production model



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