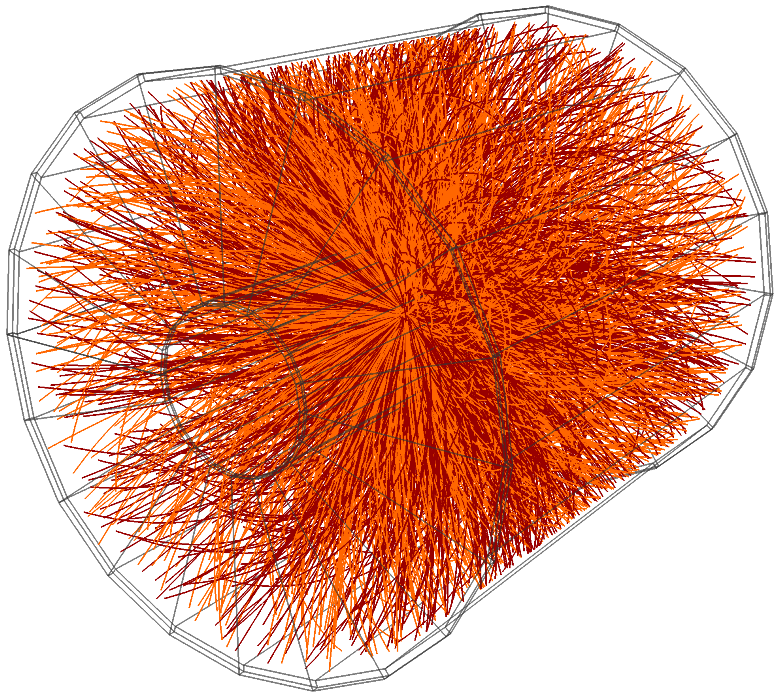
Recent results on strangeness from ALICE at LHC

KAON 2016
14-17 SEPTEMBER
UNIVERSITY OF BIRMINGHAM, UK



ALICE

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GOETHE UNIVERSITÄT FRANKFURT AM MAIN

IKF Institut für Kernphysik Frankfurt

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- Introduction
- Motivation
- ALICE experiment
- Results
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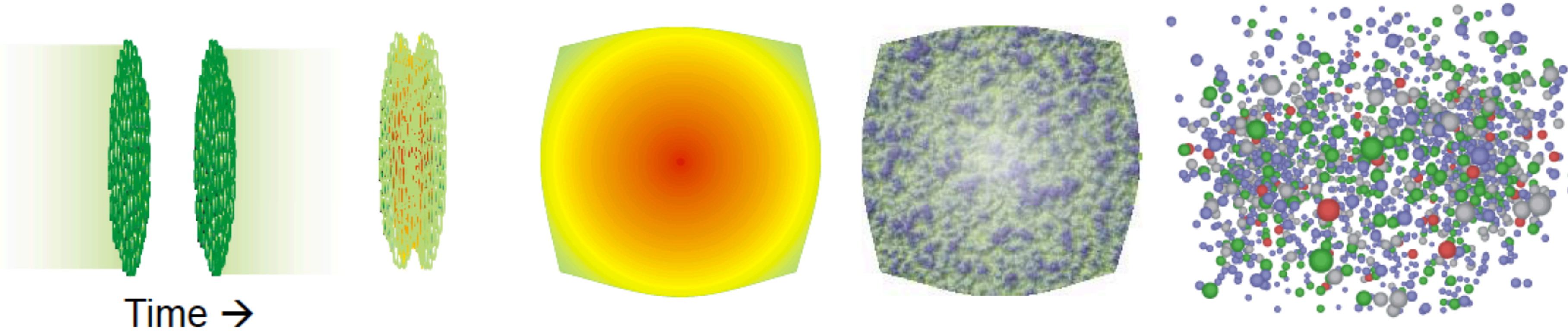
Introduction



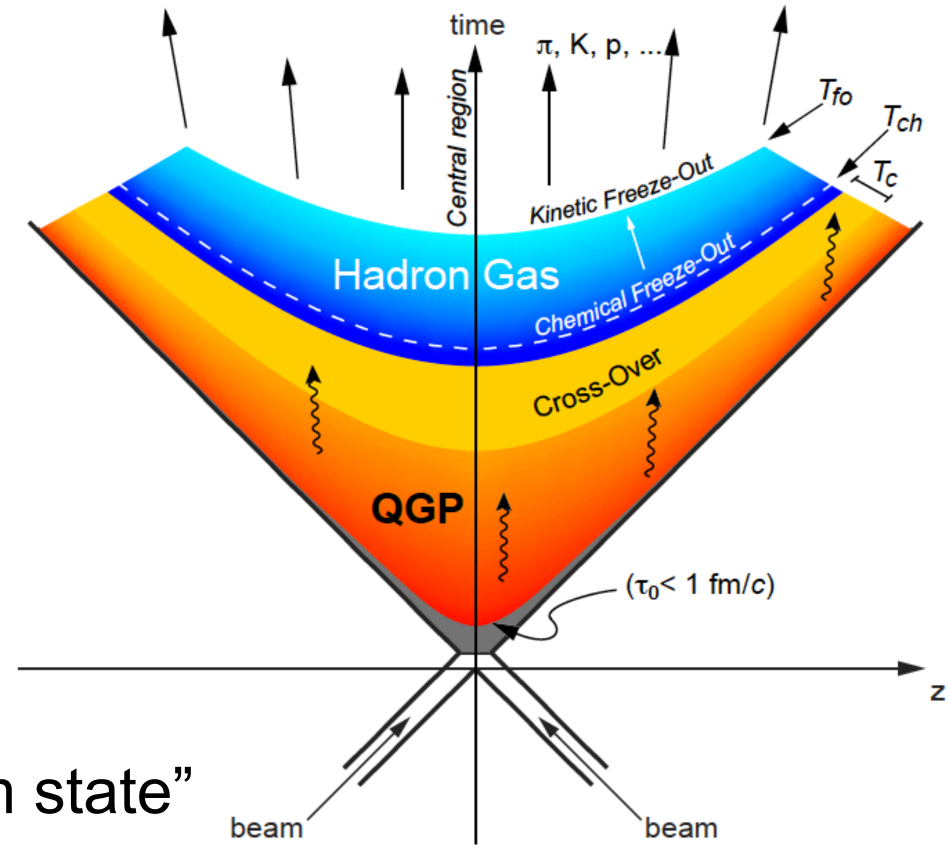
Cartoon of an ultra-relativistic heavy-ion collision

Left to right:

- the two Lorentz contracted nuclei approach,
- collide,
- form a Quark-Gluon Plasma (QGP),
- the QGP expands and hadronizes,
- finally hadrons rescatter and freeze

Plot by S. Bass, Duke University; http://www.phy.duke.edu/research/NPTheory/QGP/transport/evo.jpg

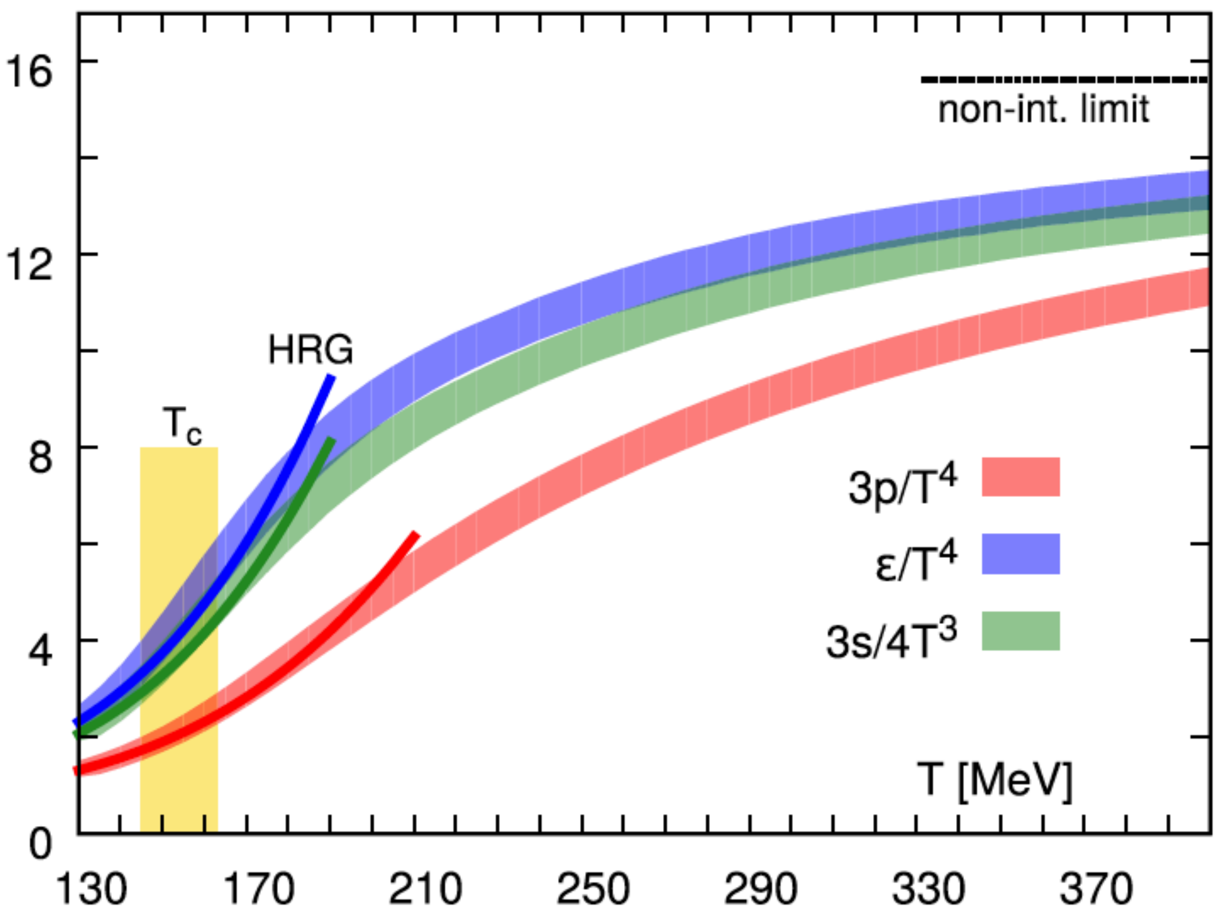
Introduction



The fireball evolution:

- Starts with a “pre-equilibrium state”
- Forms a Quark-Gluon Plasma phase (if T is larger than T_c)
- At *chemical freeze-out*, T_{ch}, *hadrons stop being produced*
- At *kinetic freeze-out*, T_{fo}, *hadrons stop scattering*

Lattice QCD results



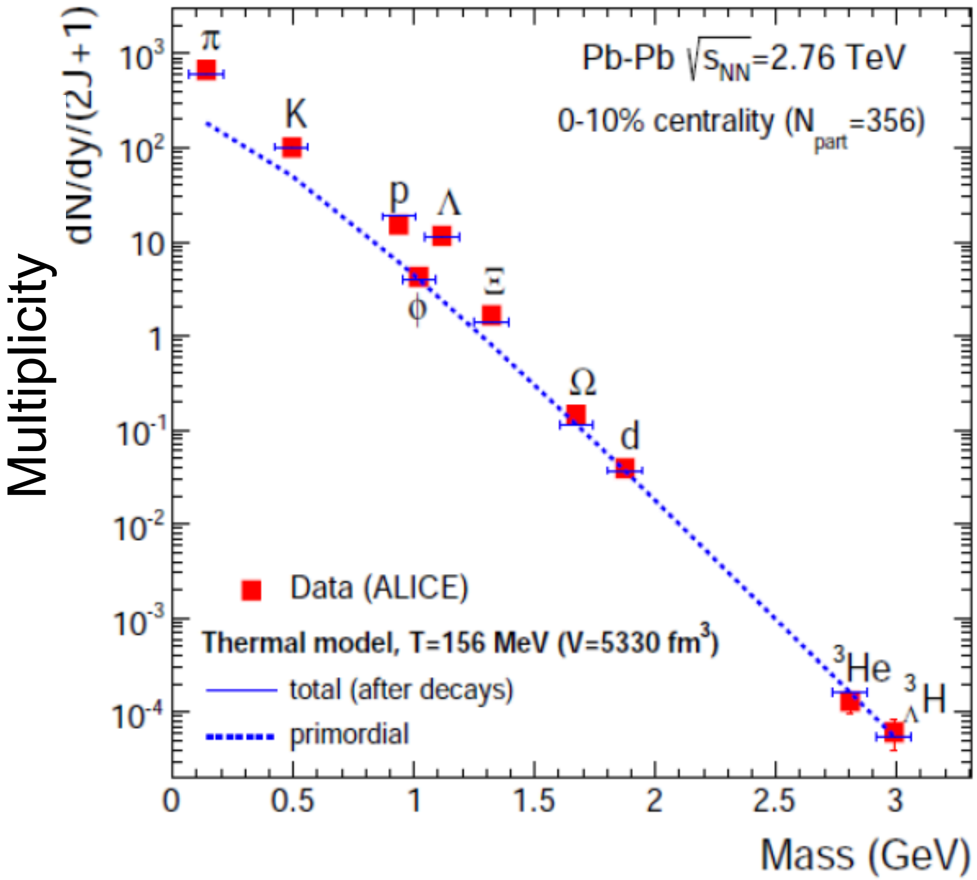
Lattice QCD tells us where to expect the phase transition

Critical energy density:
$\varepsilon_C = 0.34 \pm 0.16$ GeV/fm^3

Critical temperature
$T_C = (154 \pm 9)$ MeV

A. Bazavov et al. (hotQCD) Phys. Rev. D90 (2014) 094503
Similar results from Budapest-Wuppertal group: S. Borsányi et al. JHEP 09 (2010) 073

Temperature of the source



Plot by A. Andronic, GSI-Heidelberg group
arXiv:1407.5003 [nucl-ex]

Analogy:

Light source ⇒ particle source

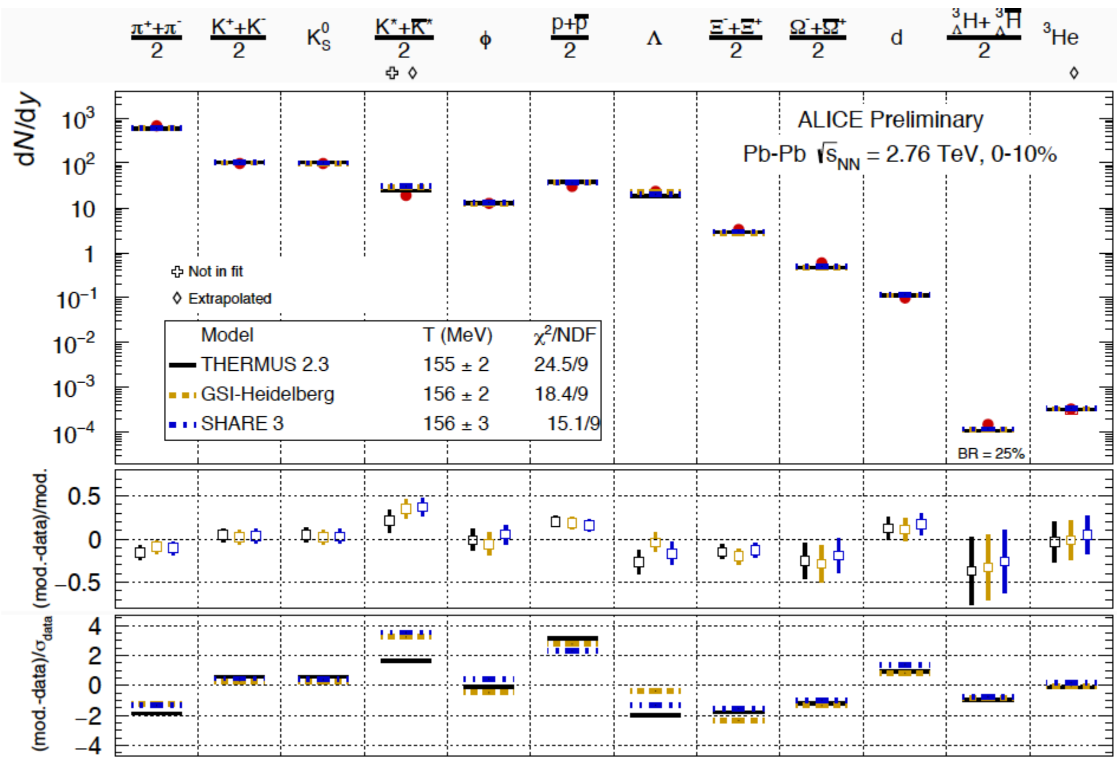
- Multiplicity described best with T = 1 900 000 000 000 ^{o}C (1.9 trillion degree centigrade)

⇒ 100 000 times hotter than in the interior of the sun!

1/40 eV = 20 ^{o}C

Thermal model

- Statistical (thermal) model with only three parameters able to describe particle yields (grand canonical ensemble)

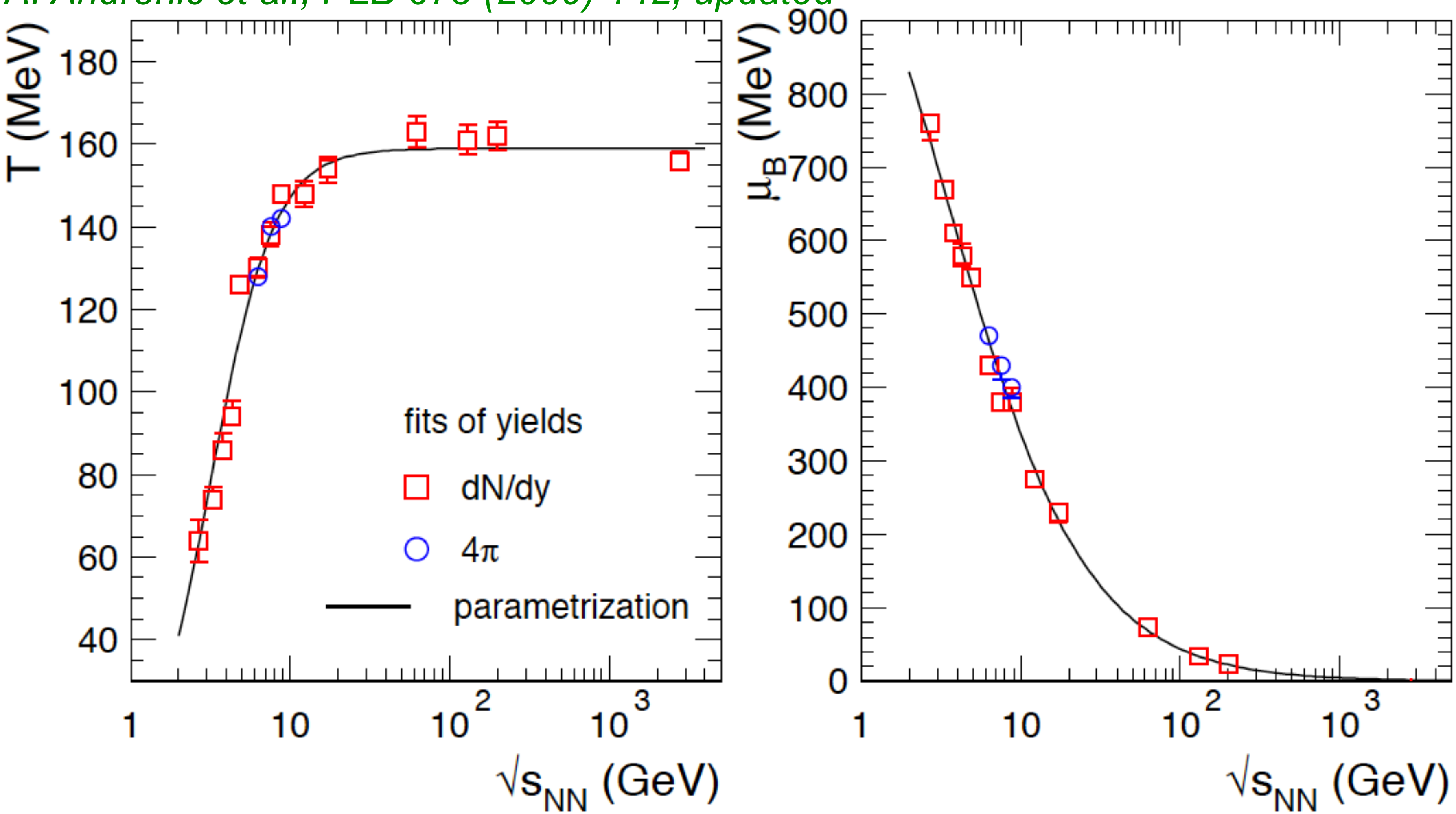


- chemical freeze-out temperature T_{ch}
- baryo-chemical potential μ_B
- Volume V

→ Using particle yields as input to extract parameters

Energy dependence

A. Andronic et al., PLB 673 (2009) 142, updated



Thermal model fits show limiting temperature: T_{lim} = (159 ± 2) MeV

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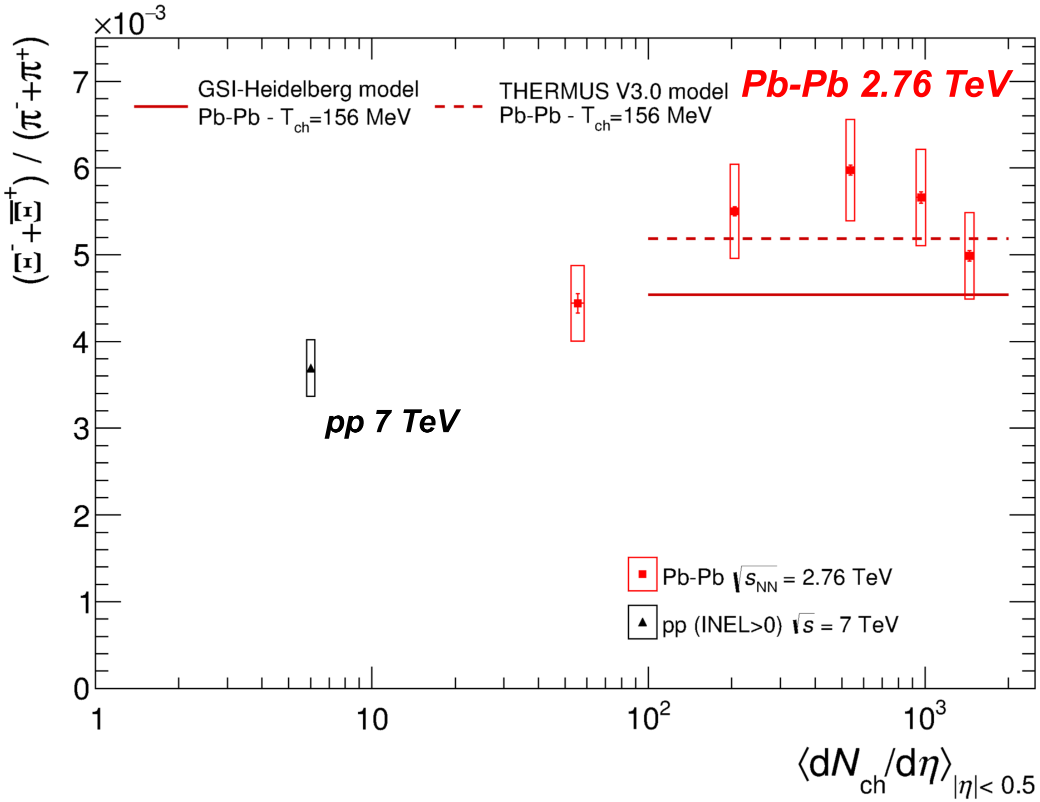
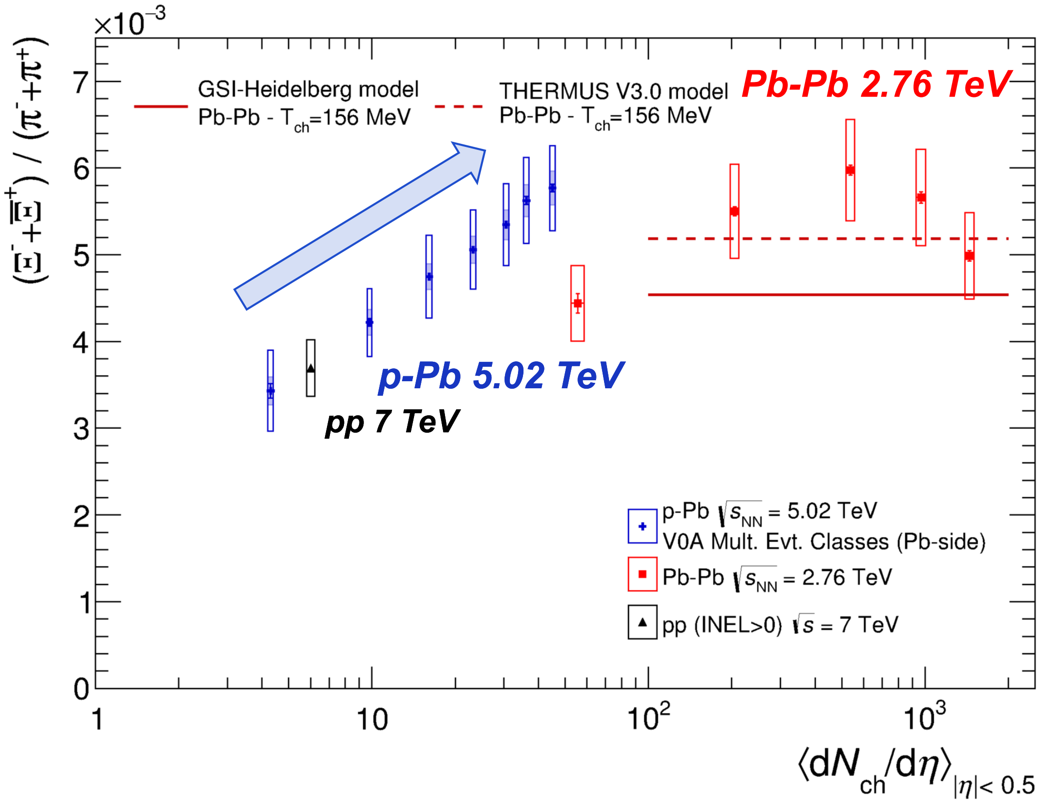


Hyperon-to-pion ratio as a function of the average charged multiplicity density $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ at midrapidity ($|\eta|<0.5$)

Strangeness production: historically related to the formation of a QGP

Motivation



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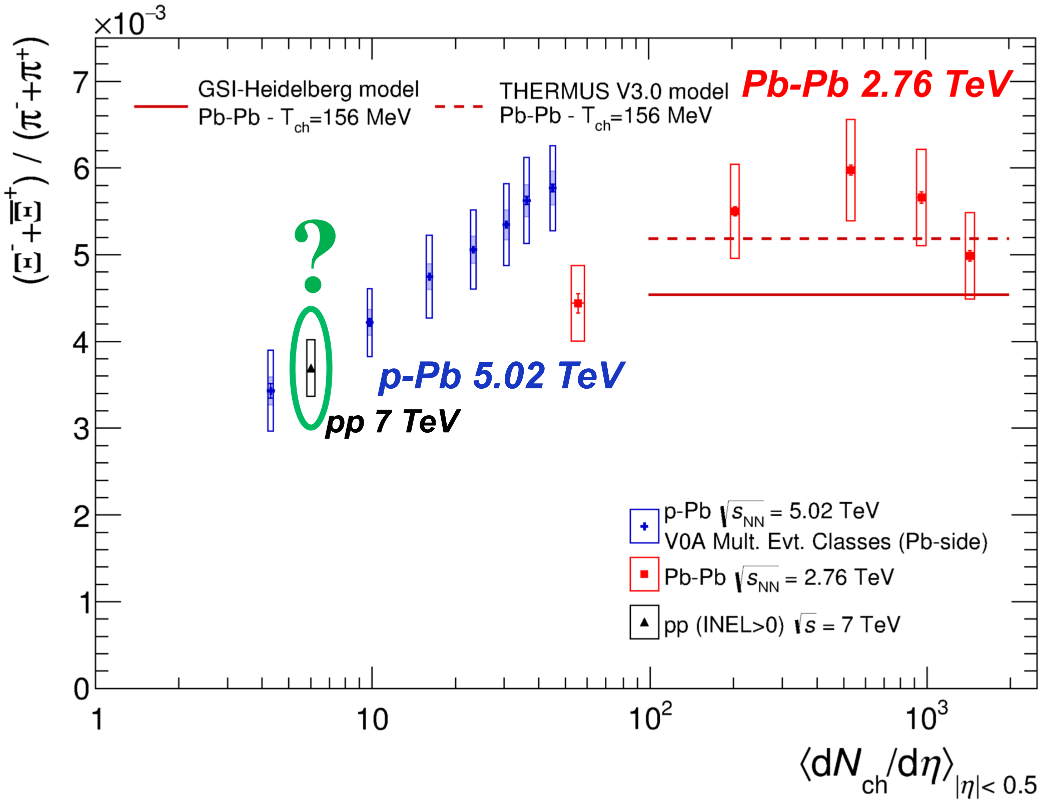
Strangeness production: historically related to the formation of a QGP

- **p-Pb results:**

  Phys. Lett. B 758 (2016) 389-401

  - *Consistent with **pp** at low multiplicities and with **central Pb-Pb** at high multiplicities*

Motivation



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What about multiplicity dependence in pp?

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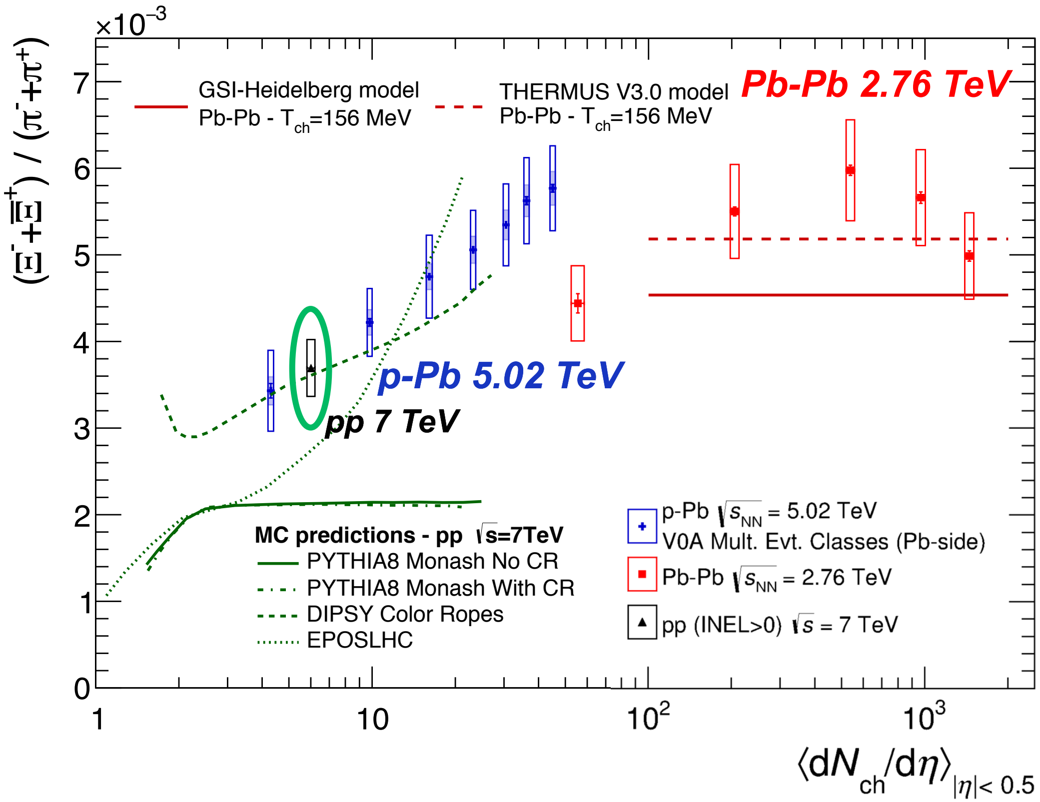

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Large Hadron Collider at CERN

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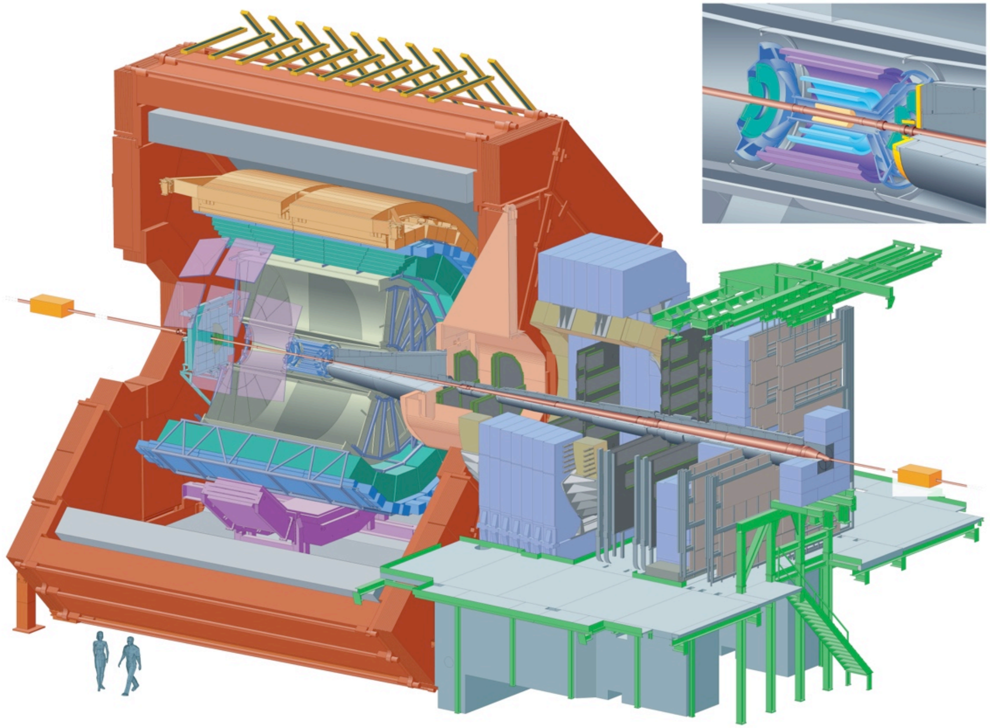
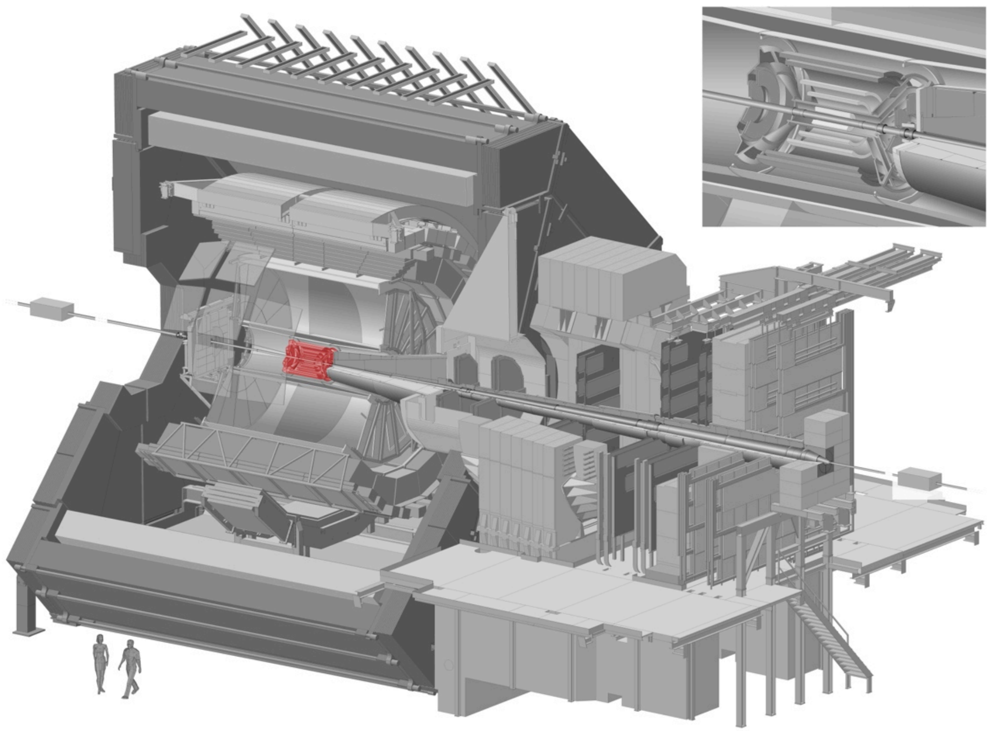
ALICE experiment



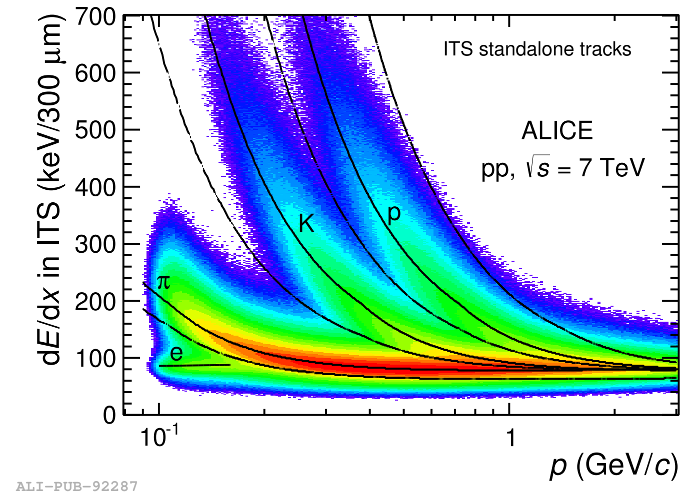
Specificity: low-momentum tracking and particle identification in a high-multiplicity environment

ALICE experiment



ITS (|η|<0.9)

- 6 Layers of silicon detectors
- Trigger, tracking, vertex, PID (dE/dx)



ITS dE/dx

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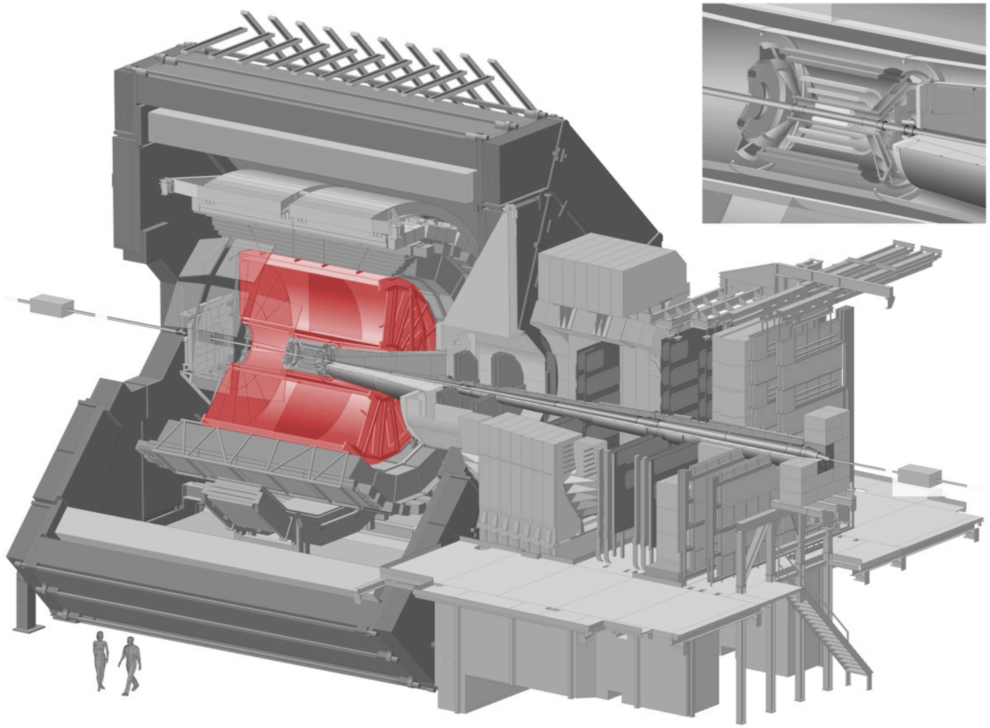

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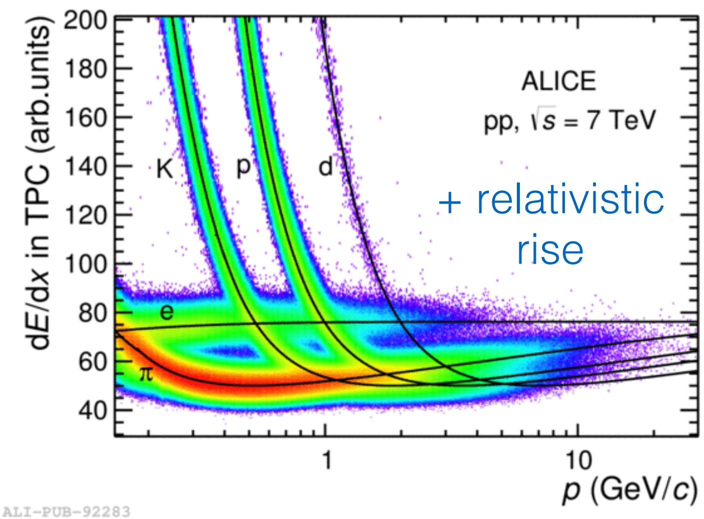
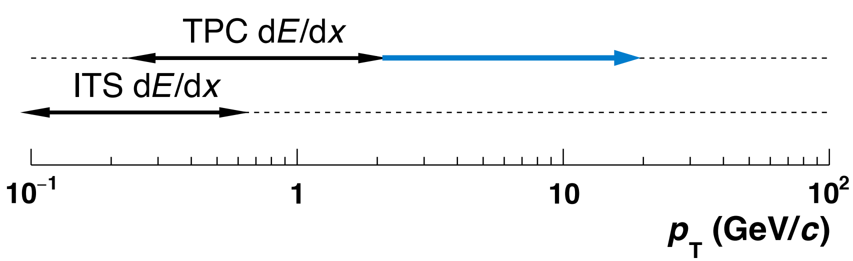
TPC (|η|<0.9)

- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)





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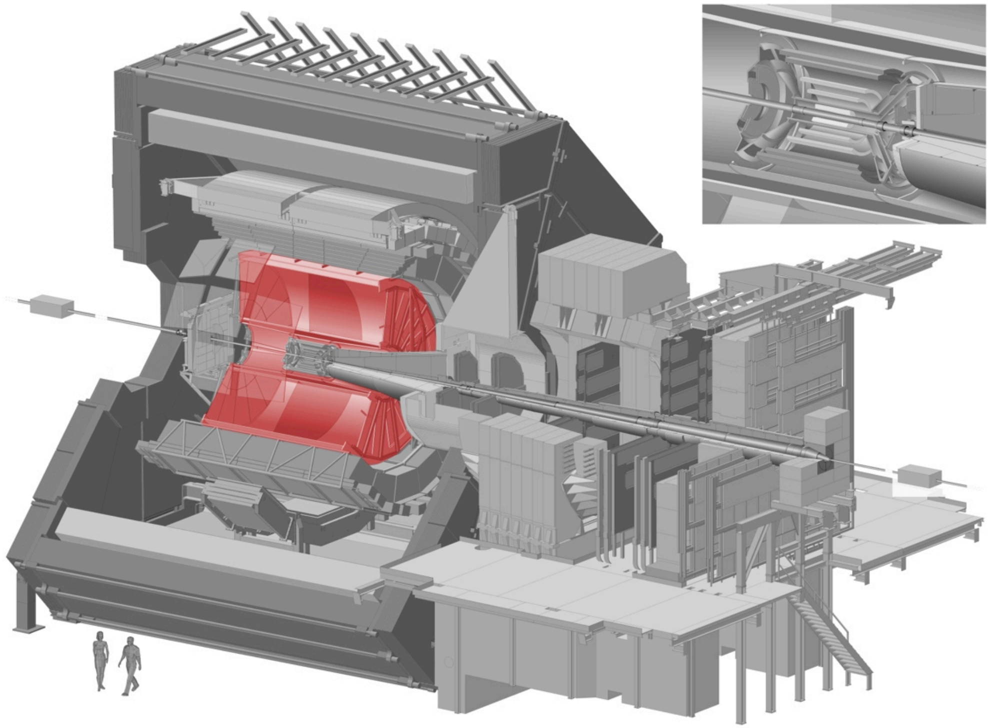

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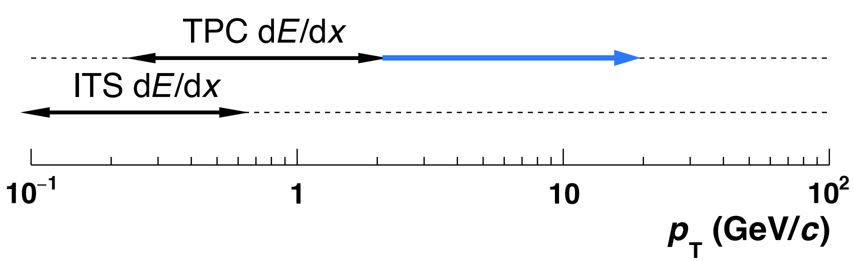
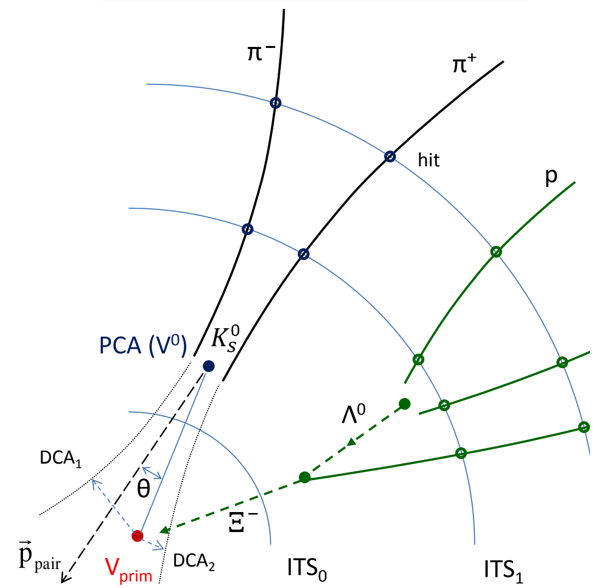
TPC (|η|<0.9)
- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)
- Weak decay reconstruction (topological)

$$\Xi^- \rightarrow \Lambda + \pi^-$$





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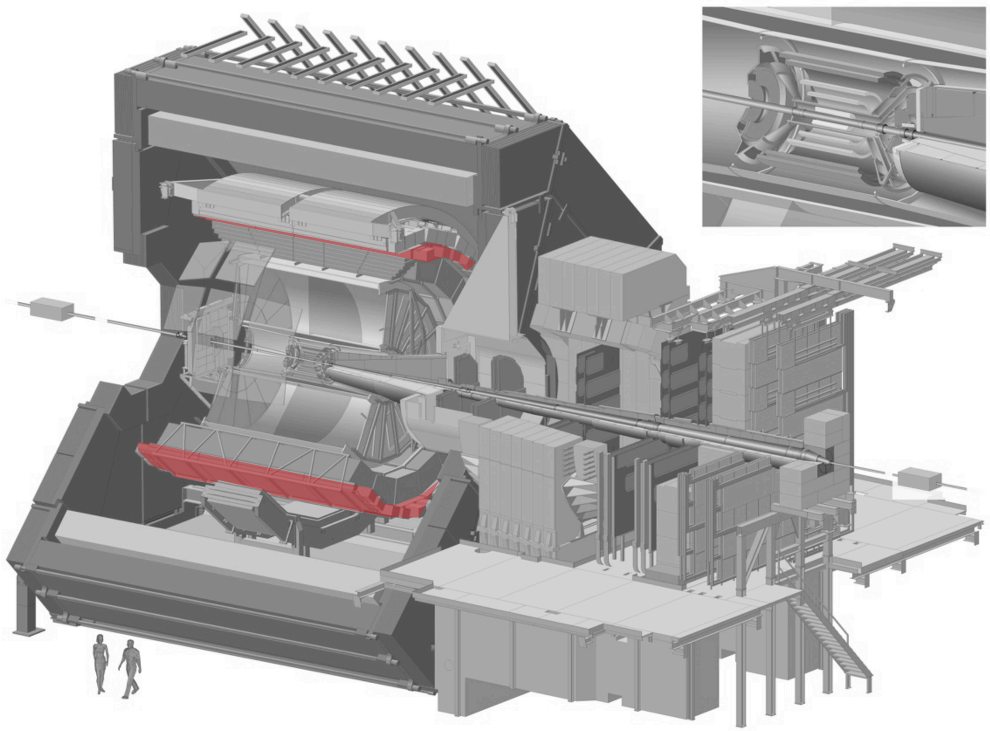

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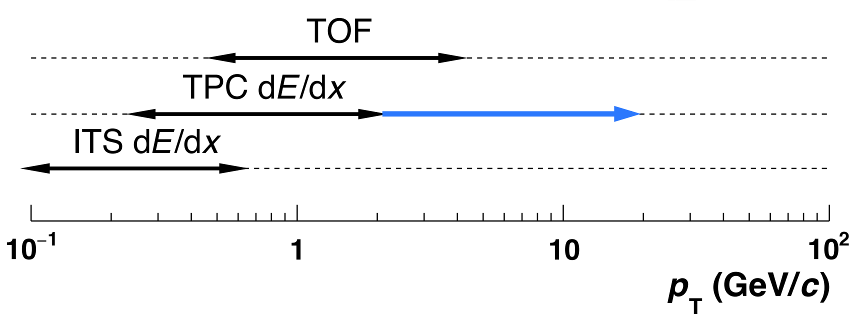
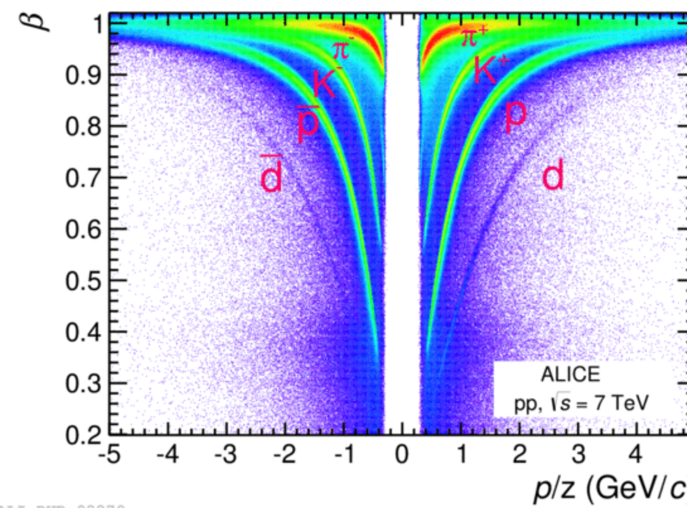
TOF (|η|<0.9)
- Multi-gap resistive plate chambers
- PID via velocity determination





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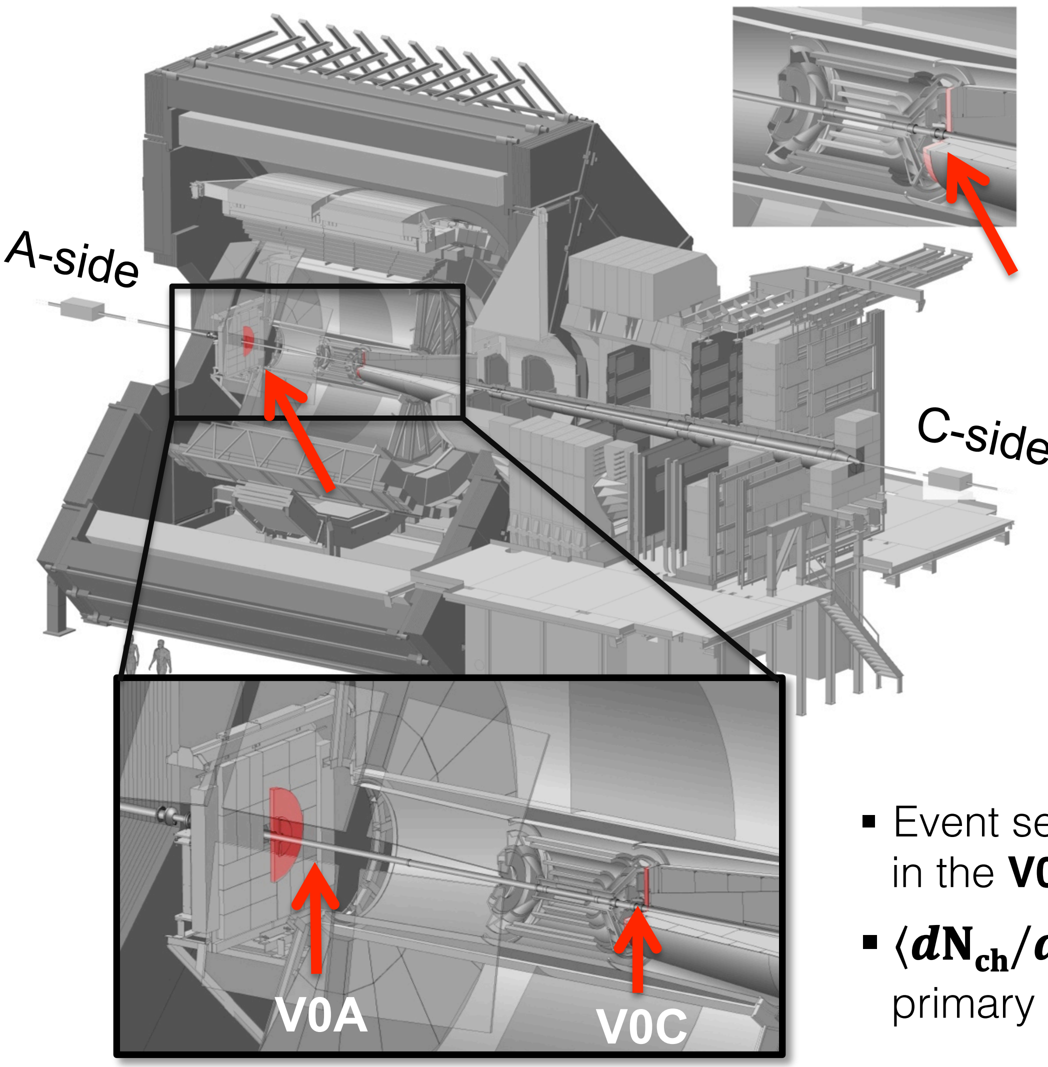

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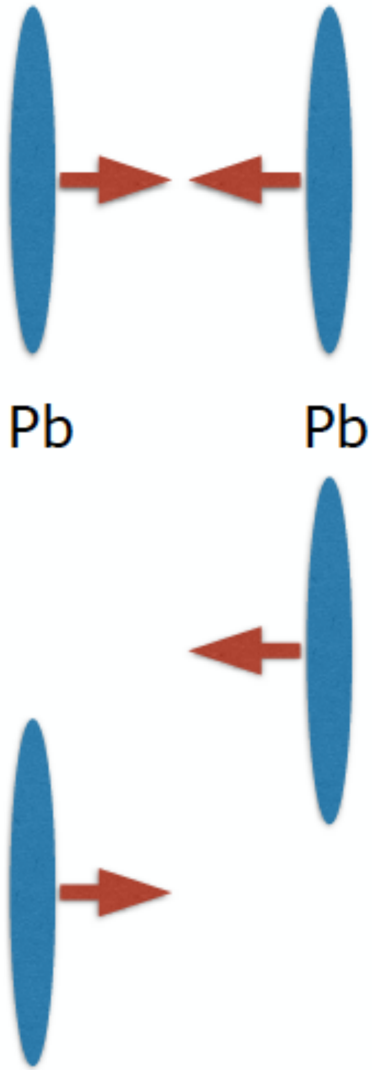
V0 [V0A ($2.8<\eta<5.1$) & V0C ($-3.7<\eta<-1.7$)]
- Forward arrays of scintillators
- Trigger, beam gas rejection
- Multiplicity estimator:

- Event selection based on total charge deposited in the **V0A** and **V0C** detectors ("V0M")
- $\langle d\mathrm{N}_{\mathrm{ch}}/d\eta \rangle$ estimated as the average number of primary charged tracks in $|\eta|<0.5$

Interlude: Centrality



Central Pb-Pb collision:

High multiplicity = large $\langle \mathrm{d}N/\mathrm{d}\eta \rangle$

High number of tracks

(more than 2000 tracks in the detector)

Peripheral Pb-Pb collision:

Low multiplicity = small $\langle \mathrm{d}N/\mathrm{d}\eta \rangle$

Low number of tracks

(less than 100 tracks in the detector)

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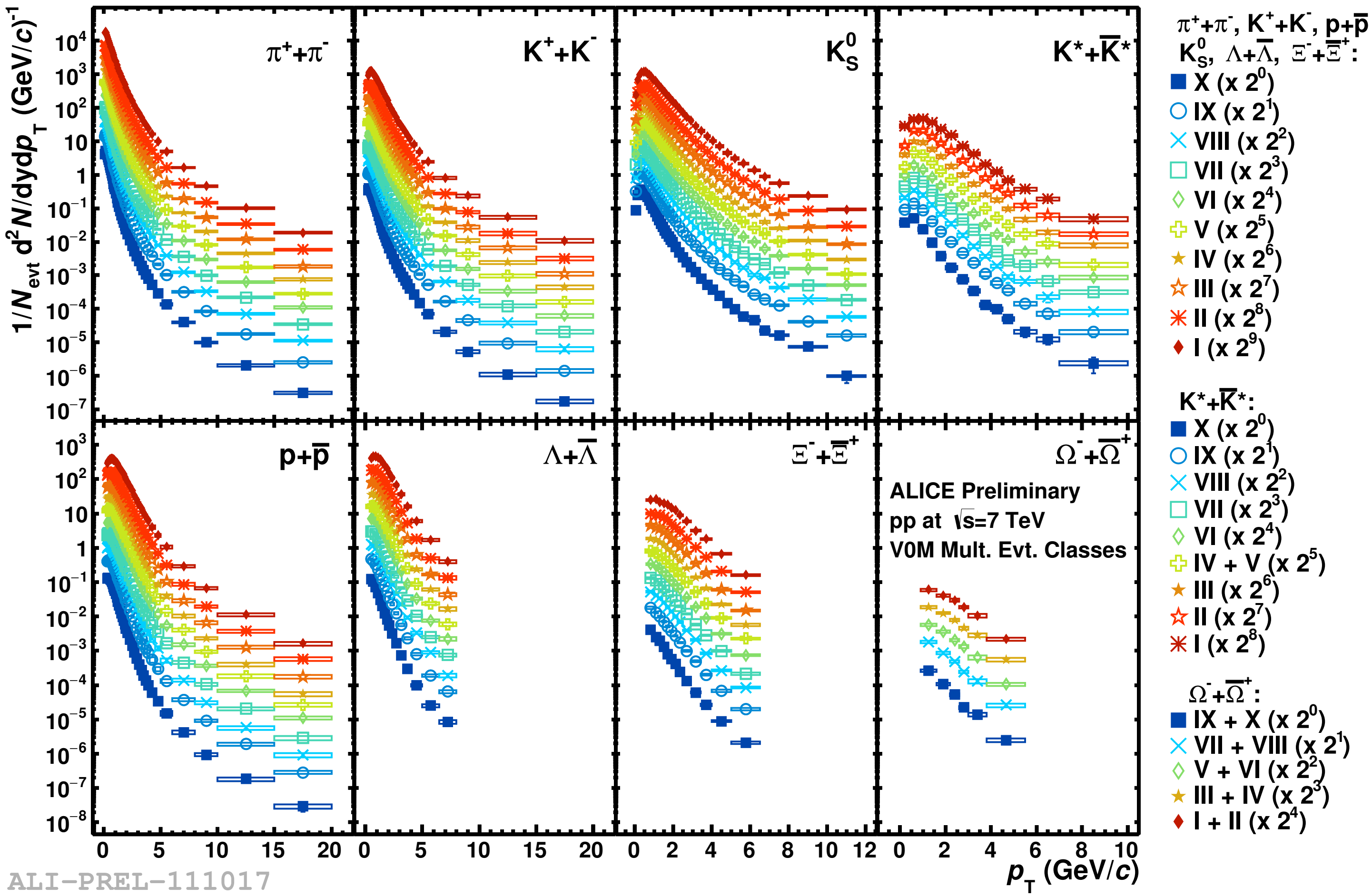
Transverse momentum spectra

- **V0M Multiplicity Classes:**

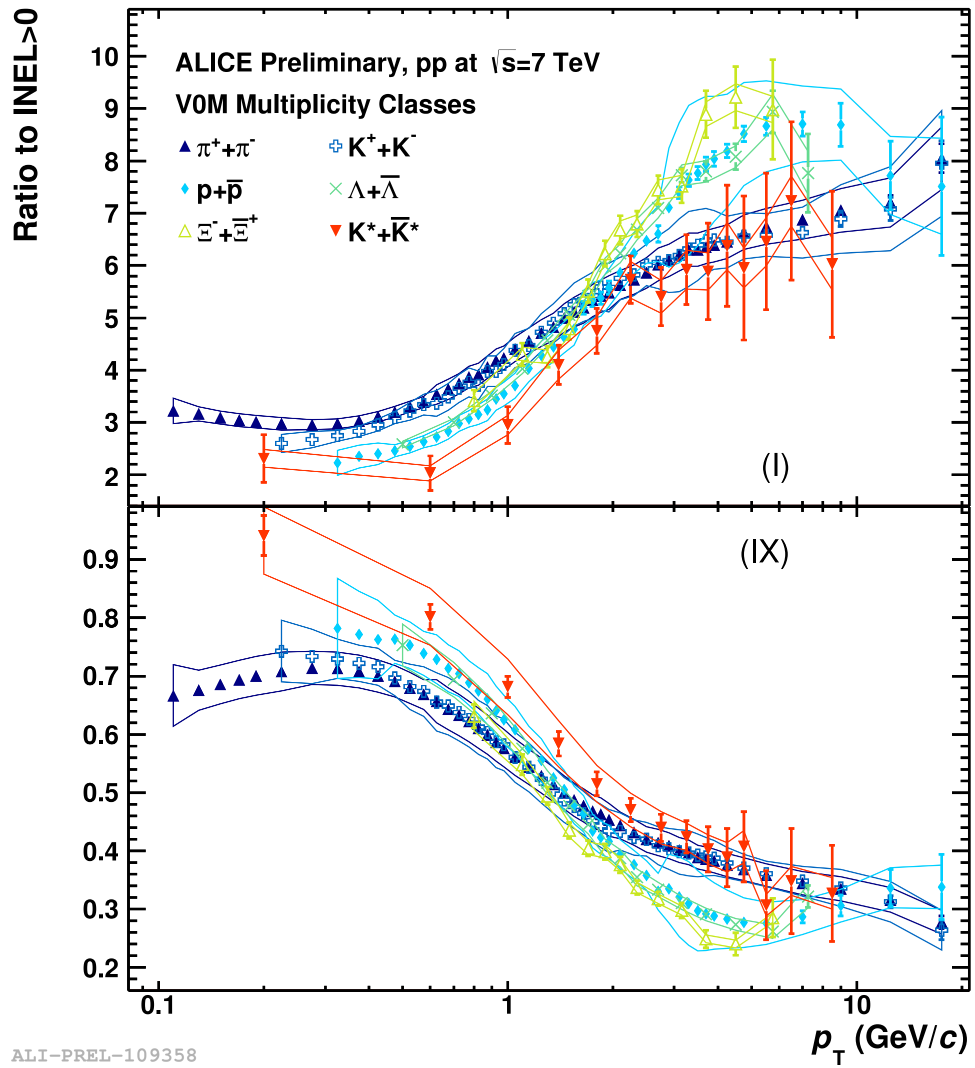
$$\left[\langle dN_{ch}/d\eta \rangle^{INEL>0} \approx 6.0 \right] \quad \begin{cases} I \rightarrow \langle dN_{ch}/d\eta \rangle \approx 3.5 \times \langle dN_{ch}/d\eta \rangle^{INEL>0} \\ \vdots \\ X \rightarrow \langle dN_{ch}/d\eta \rangle \approx 0.4 \times \langle dN_{ch}/d\eta \rangle^{INEL>0} \end{cases}$$

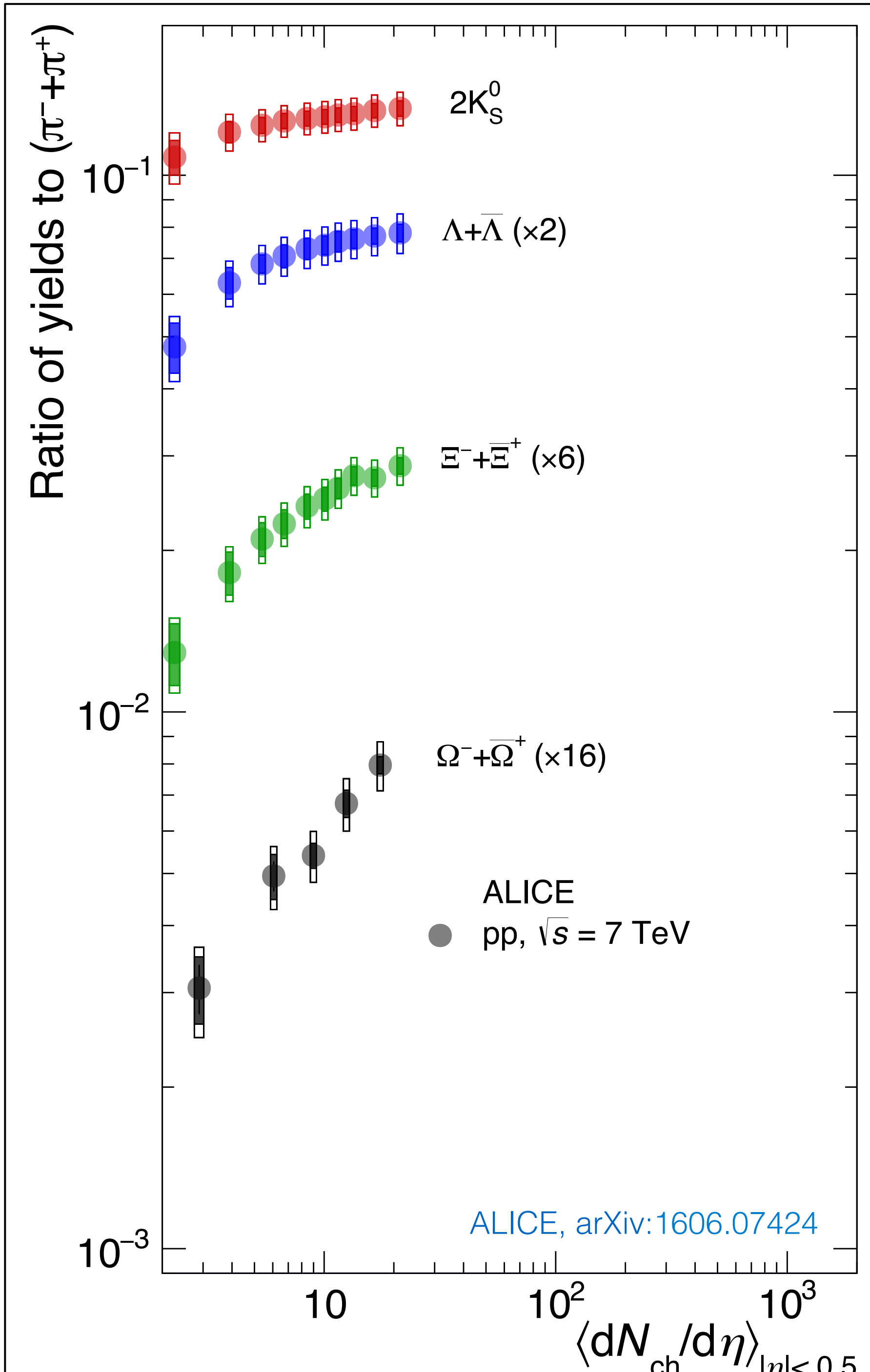


Modification of p_T spectra

- Spectra become harder at higher multiplicities
- The hardening is more pronounced for **baryons** than for **mesons**

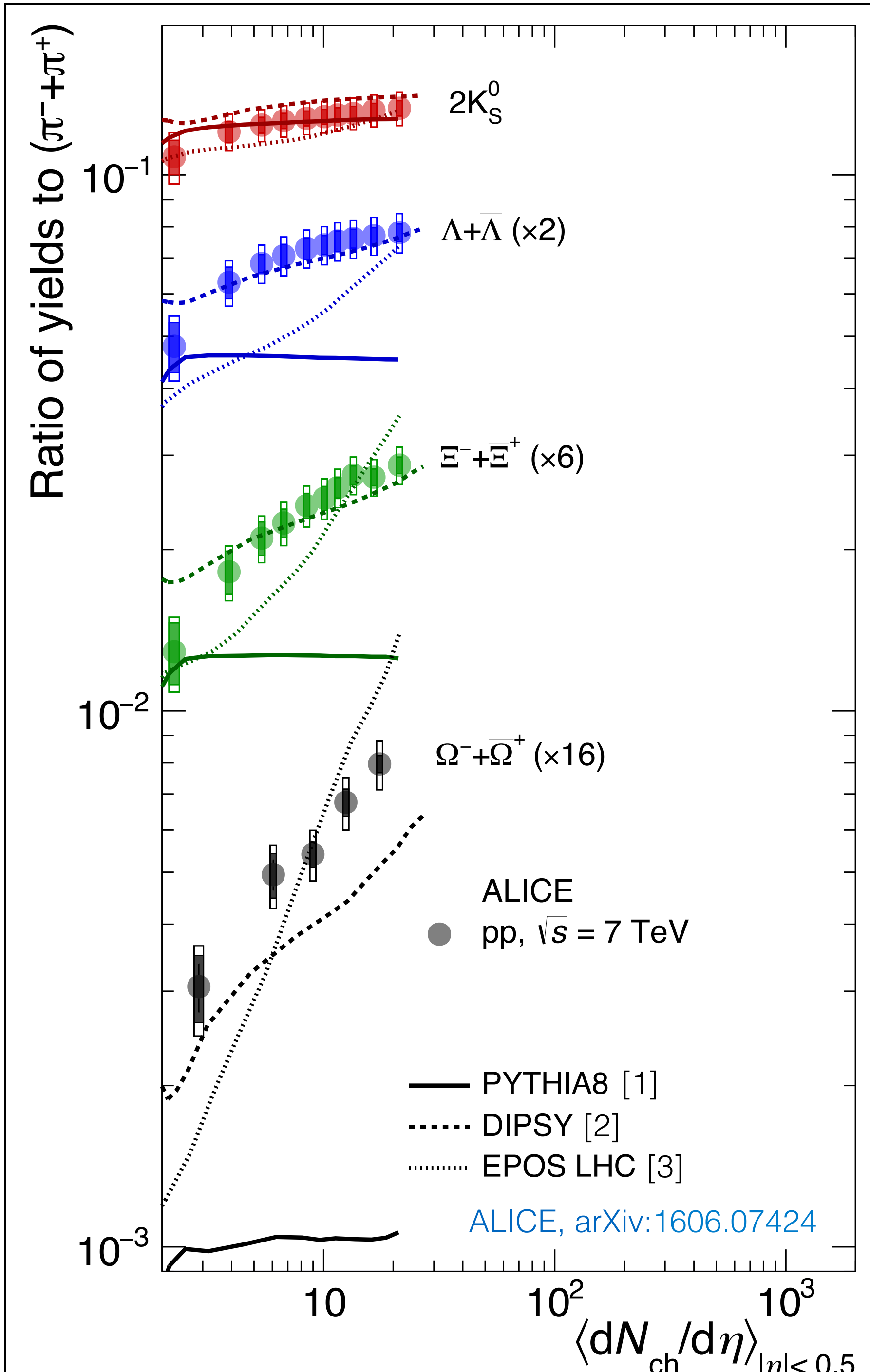
$$\langle dN_{ch}/d\eta \rangle^{INEL>0} \approx 6.0$$





Relative Strangeness Production

- Quantified via strange to non-strange integrated particle ratios vs. $\langle dN_{ch}/d\eta \rangle$
- Significant enhancement of strange and multi-strange particle production



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- MC predictions do not describe this observation satisfactorily

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[2] JHEP 08 (2011) 103
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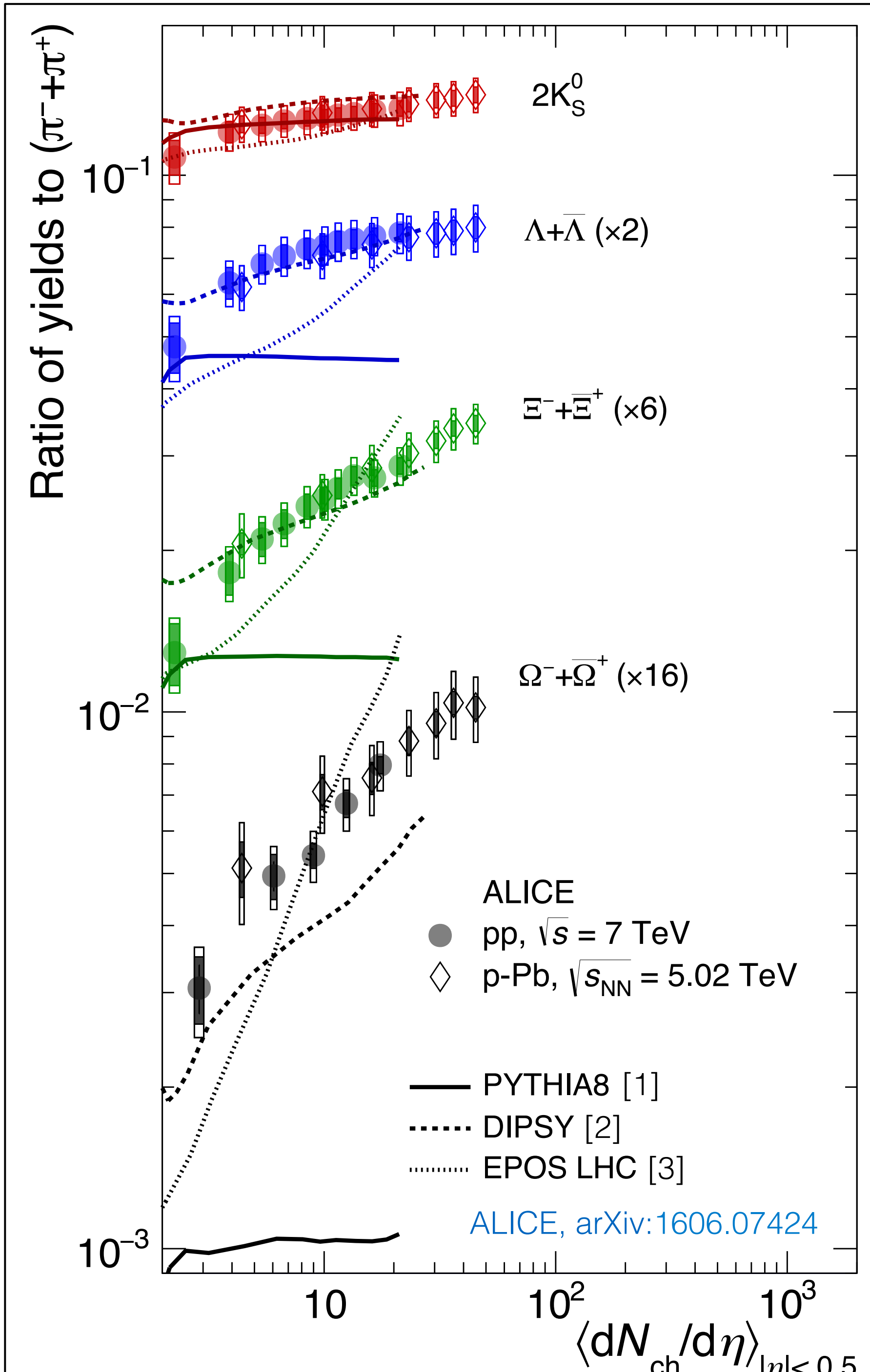

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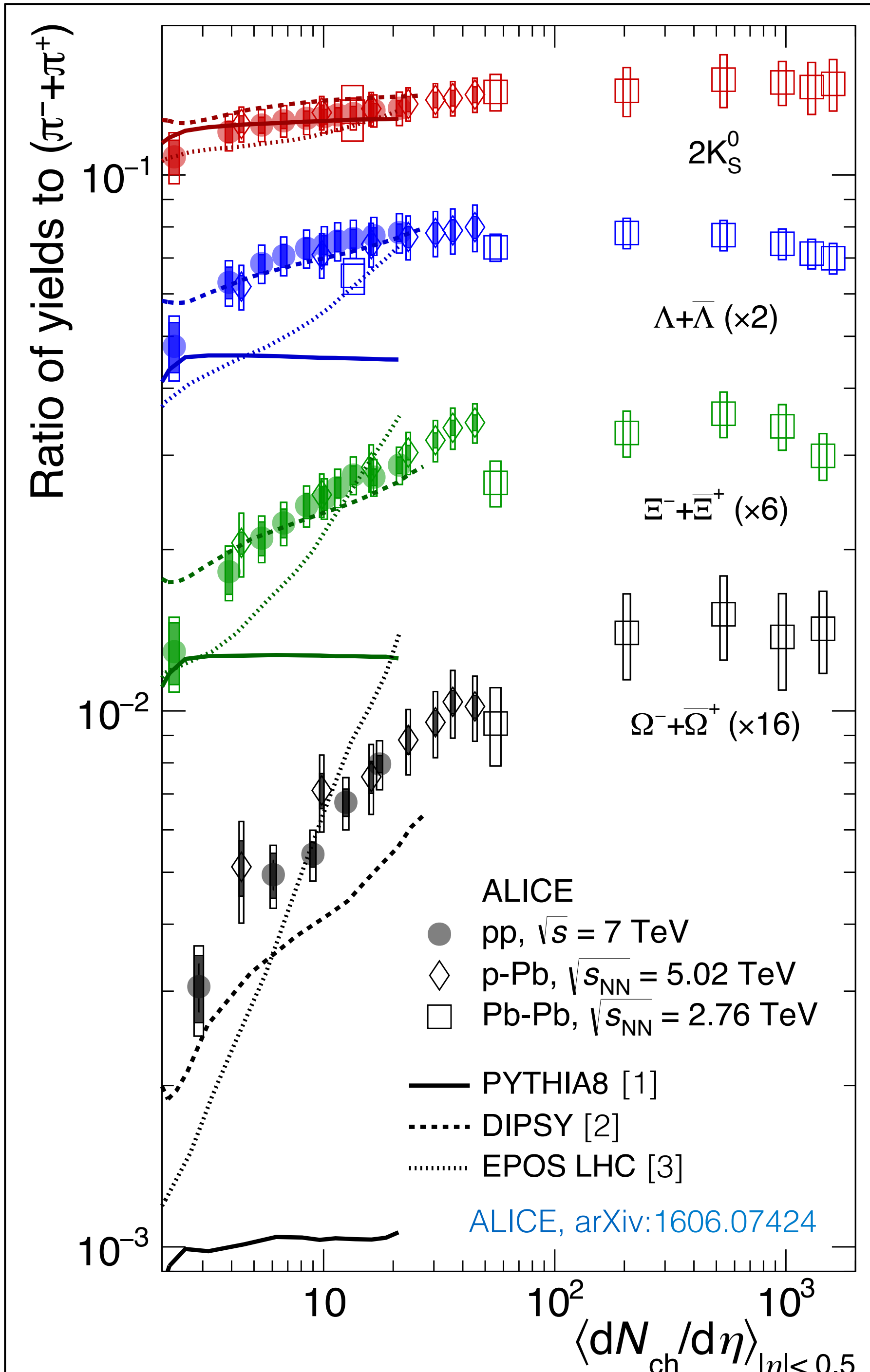

Relative Strangeness Production

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- Significant enhancement of strange and multi-strange particle production
- MC predictions do not describe this observation satisfactorily
- Follows the trend observed in p-Pb, despite differences in initial state
- Particle ratios reach values that are similar to those observed in central Pb-Pb collisions

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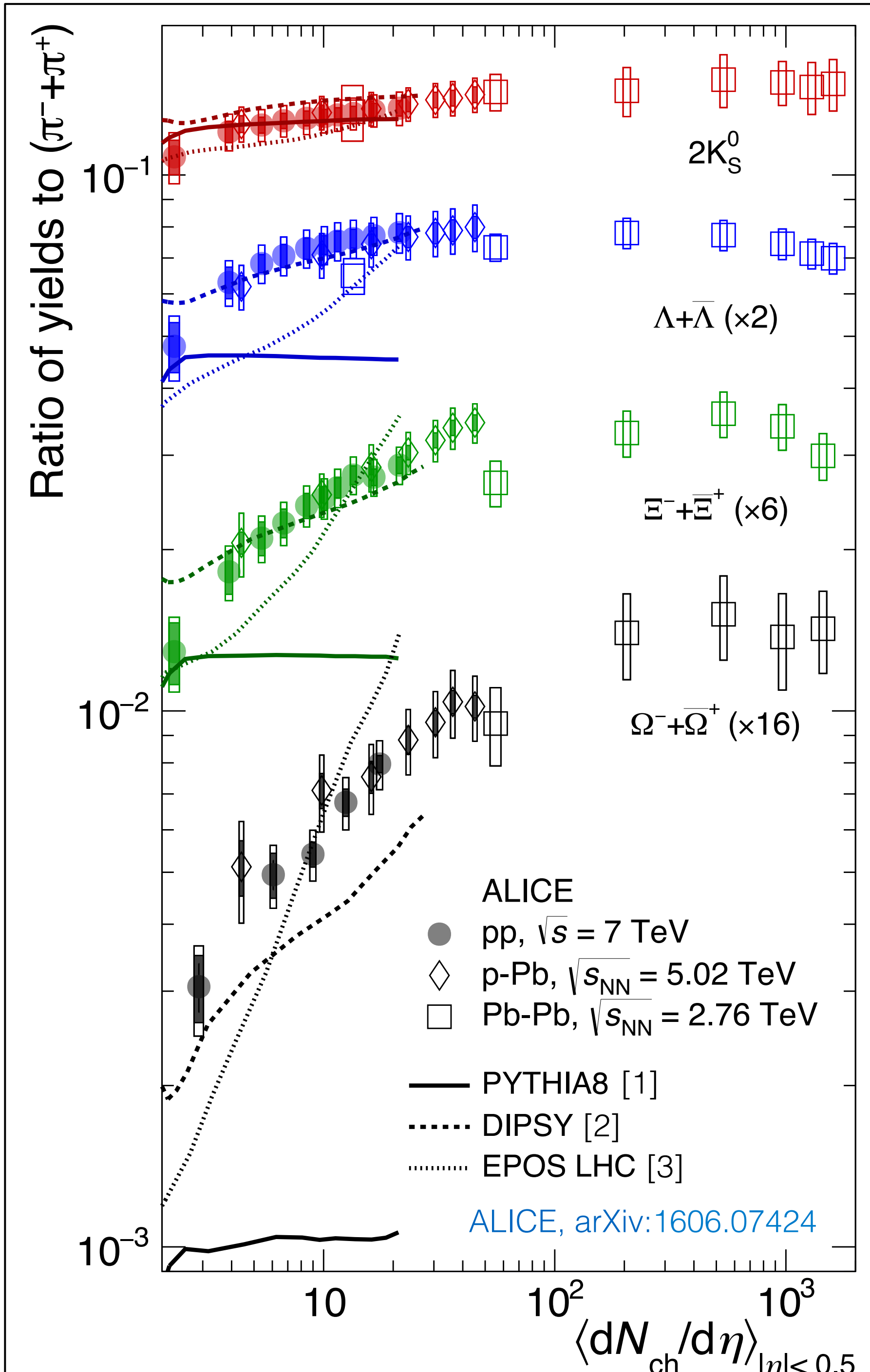

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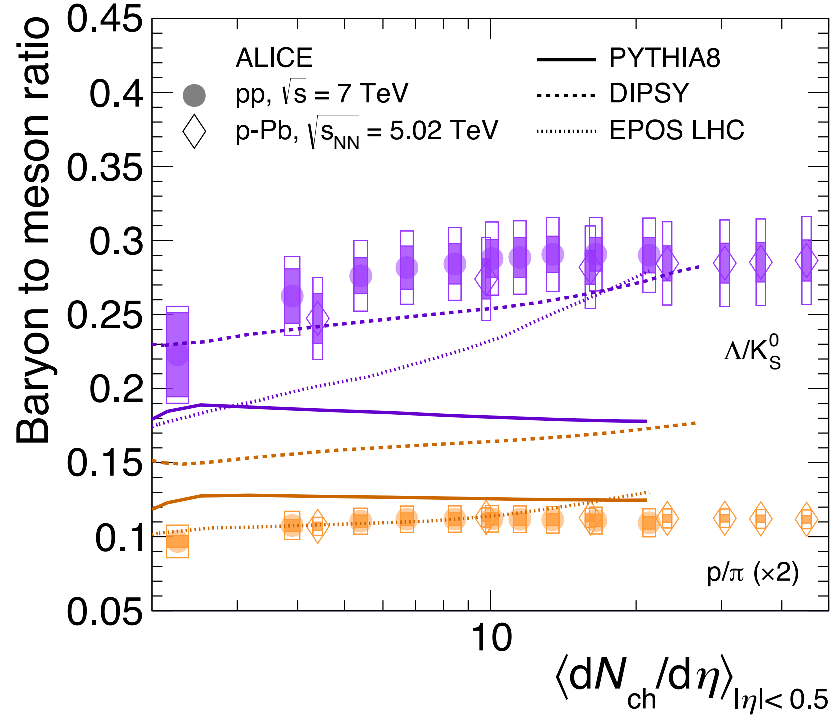

- No increase for protons (non-strange), contrary to models such as DIPSY

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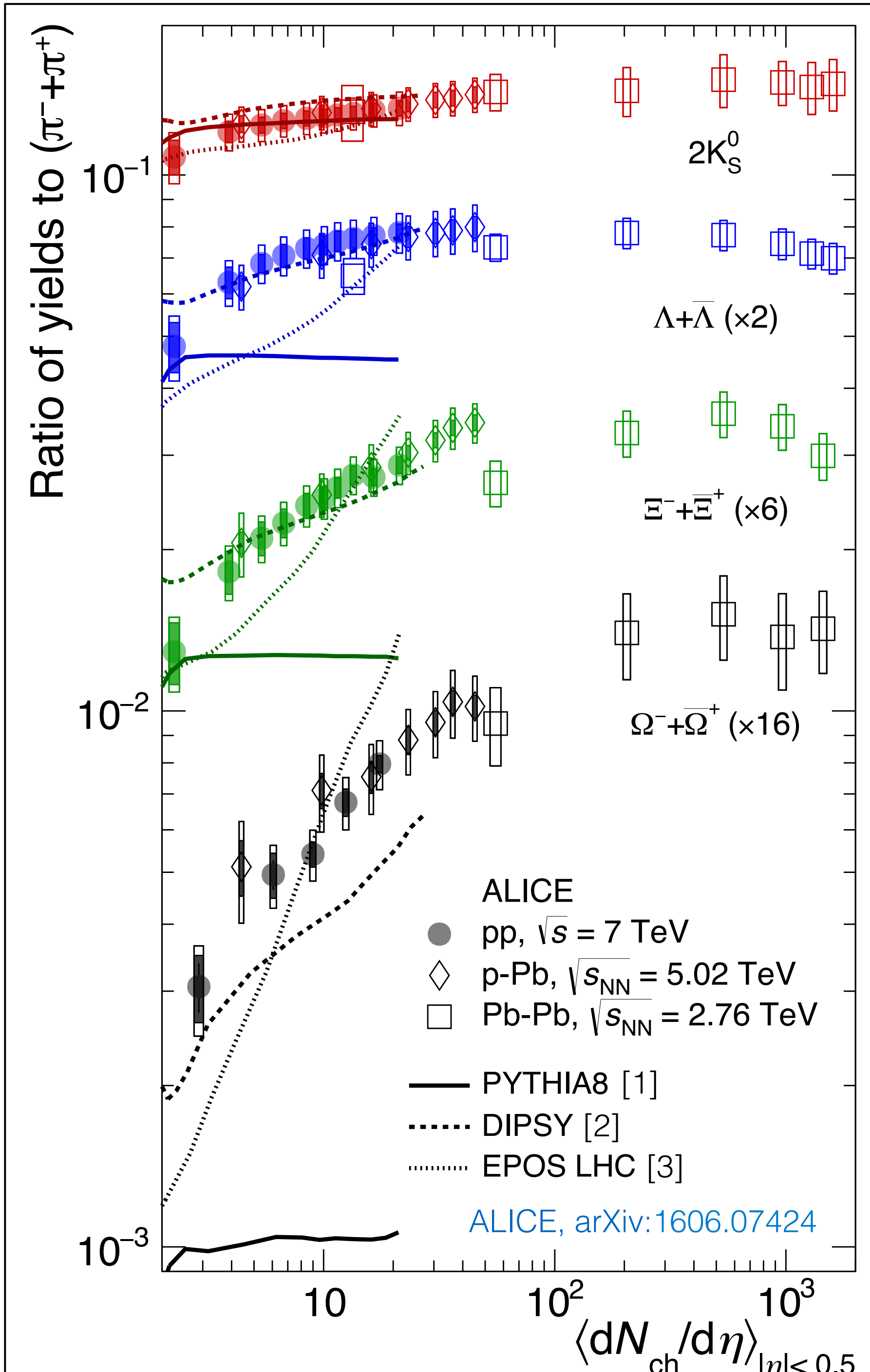

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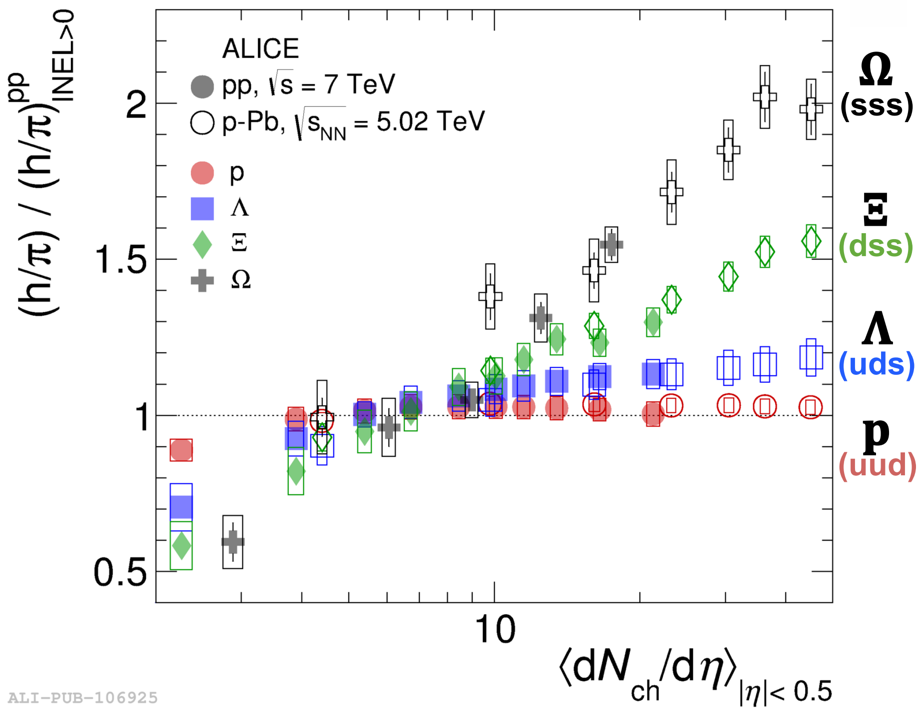
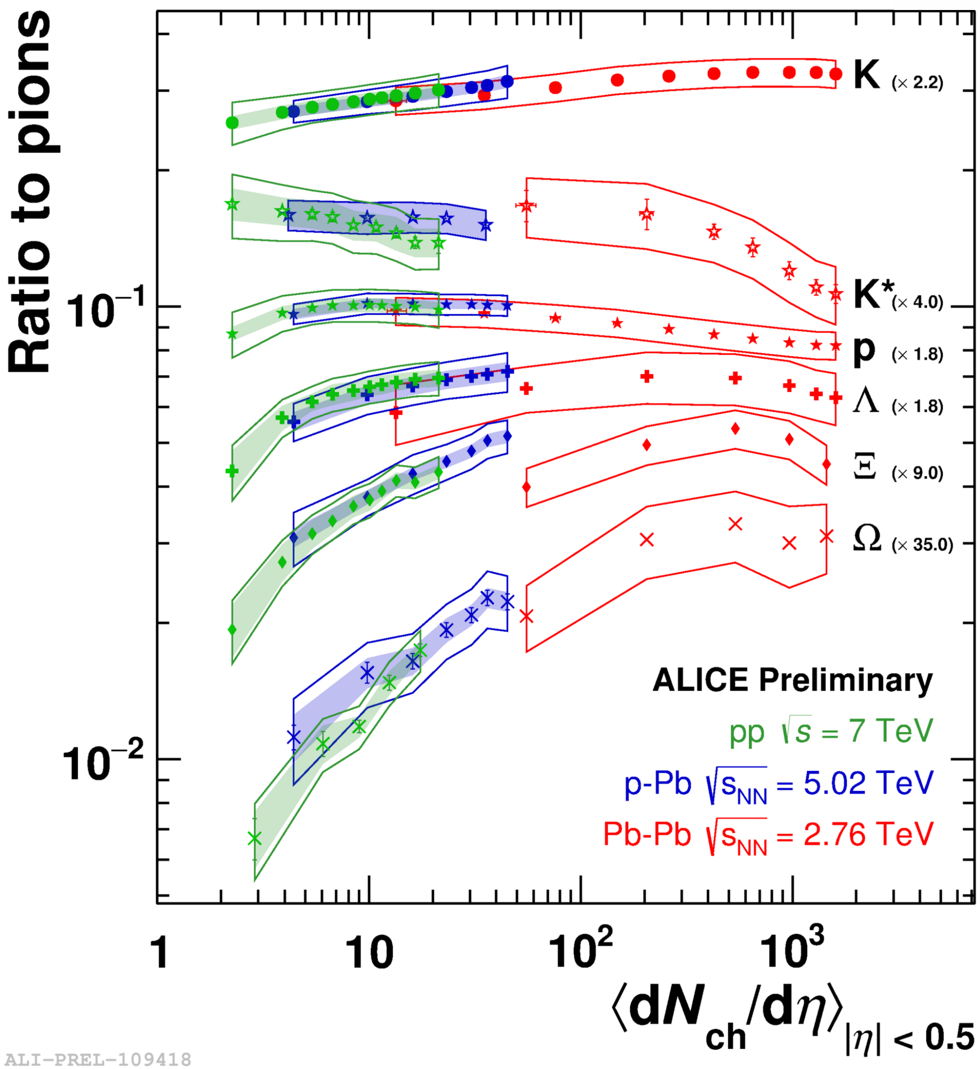


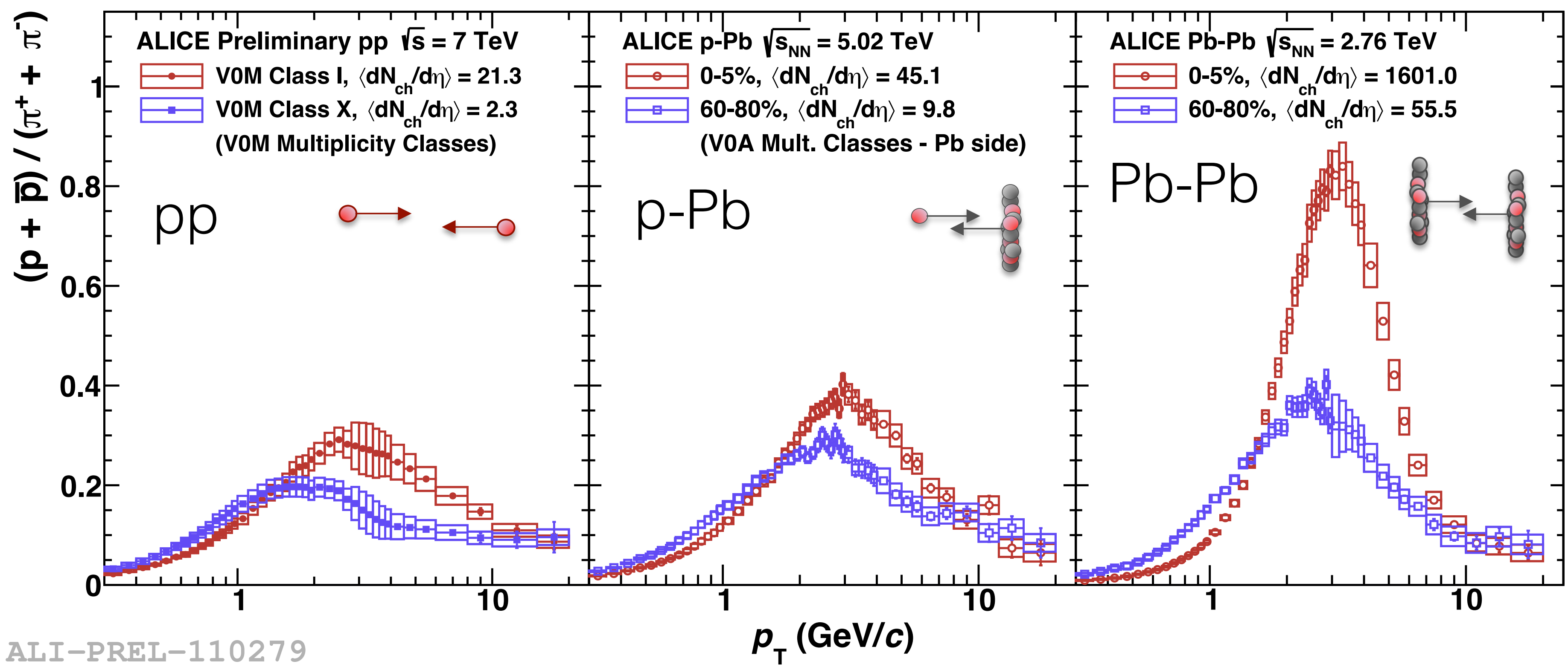
- No increase for protons (non-strange), contrary to models such as DIPSY
- Observed increase is more pronounced for baryons with higher strangeness content

Ratios in different systems

- Small systems:
  - Strangeness enhancement
  - Relative decrease of K^{*0}
  - No multiplicity dependence of baryon/meson ratio
- Towards central Pb-Pb:
  - Strangeness abundance constant
  - K^{*0} abundance decreases further
  - Baryon/meson decreases

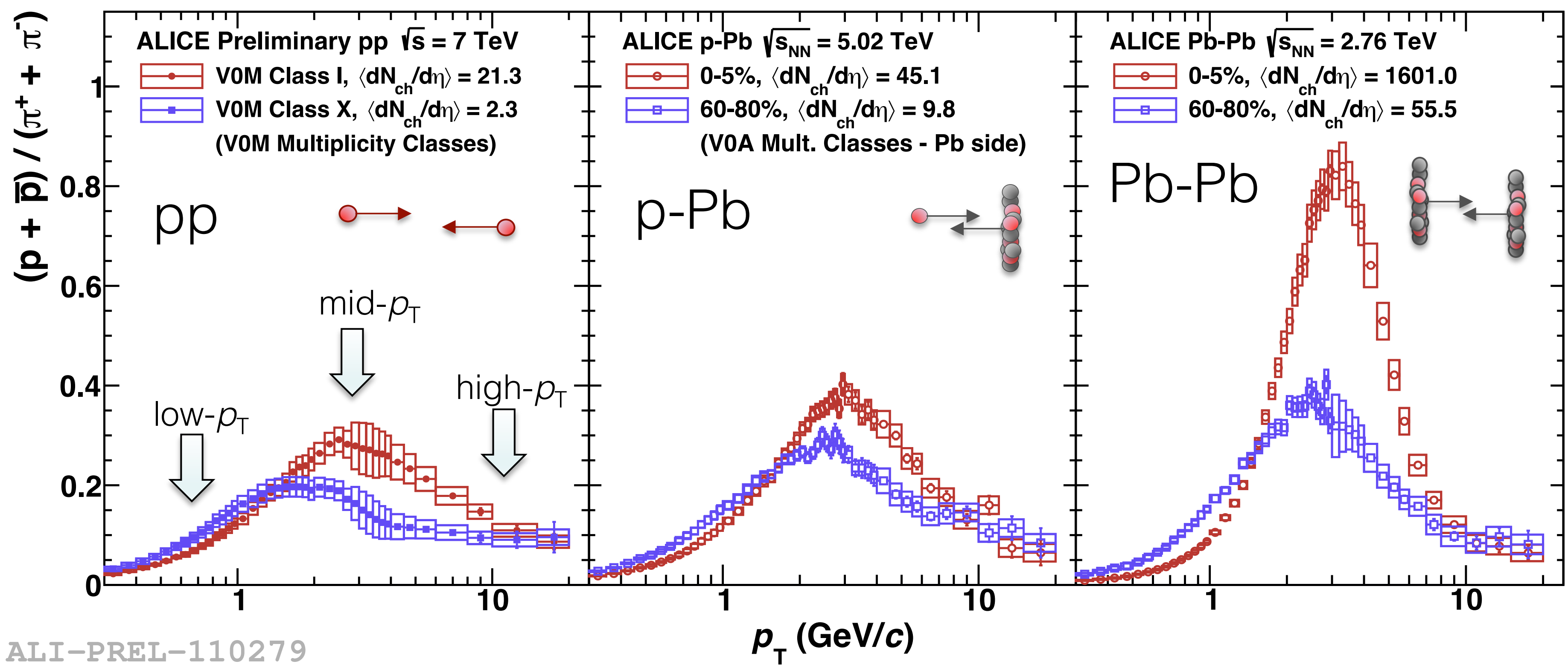


Baryon-to-meson ratio



Dependence with the event multiplicity in pp
qualitatively similar to p-Pb and Pb-Pb

Baryon-to-meson ratio



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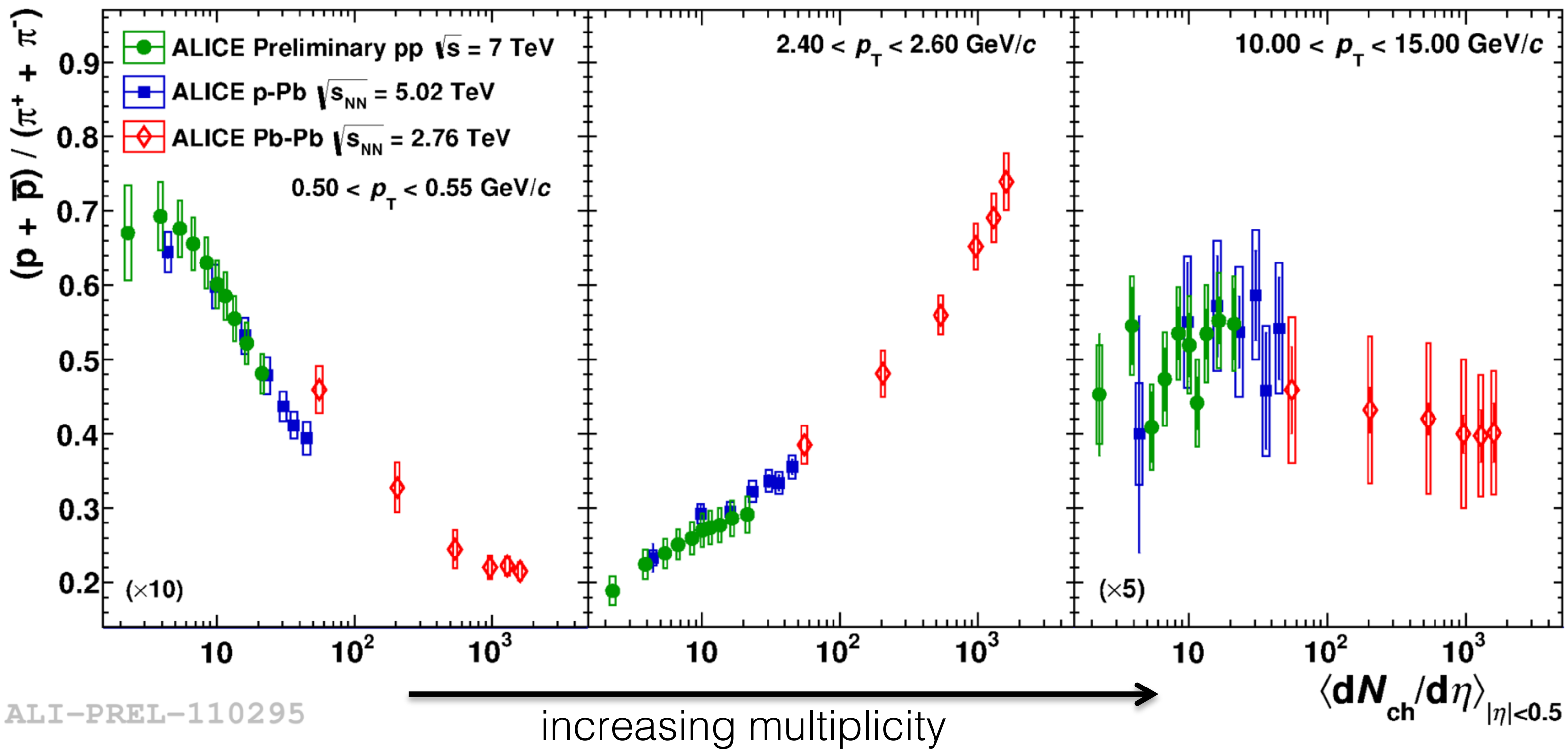

Remarkable consistency across systems as a function of multiplicity

Radial flow? Color reconnection?...

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Summary

- An enhanced production of strange and multi-strange particles has been observed in high-multiplicity pp collisions (arXiv:1606.07424)
- The multiplicity dependence of strangeness production is strikingly similar in pp and p-Pb, and approaches values similar to those in central Pb-Pb
- None of the current MC models are successful at fully describing these observations.
- **Open questions (stay tuned!)**:
  - Will the relative strangeness production in smaller systems eventually saturate?
  - Higher energy pp (13 TeV): how do charged-particle multiplicities and collision energy relate?

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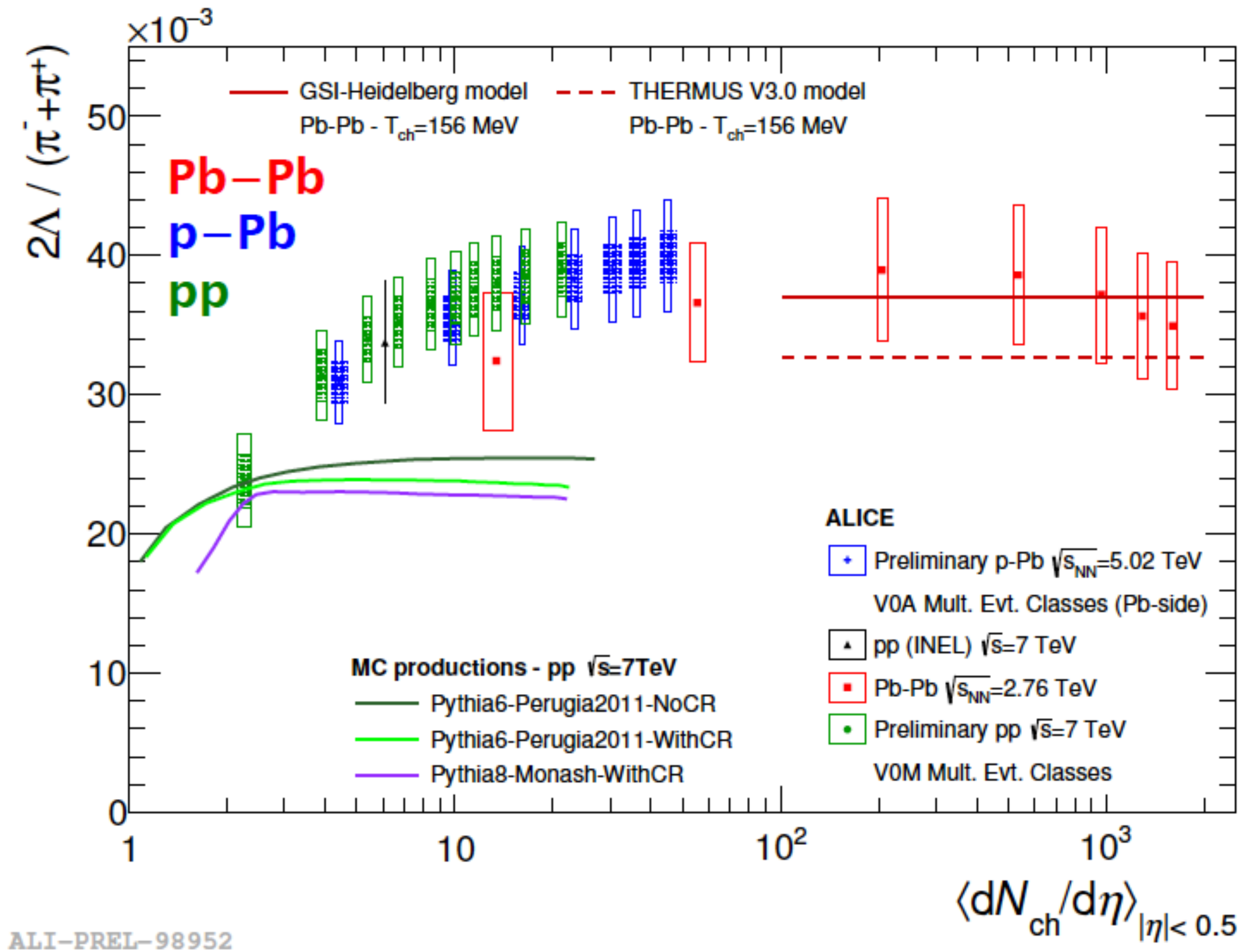
Thank you!

Backup

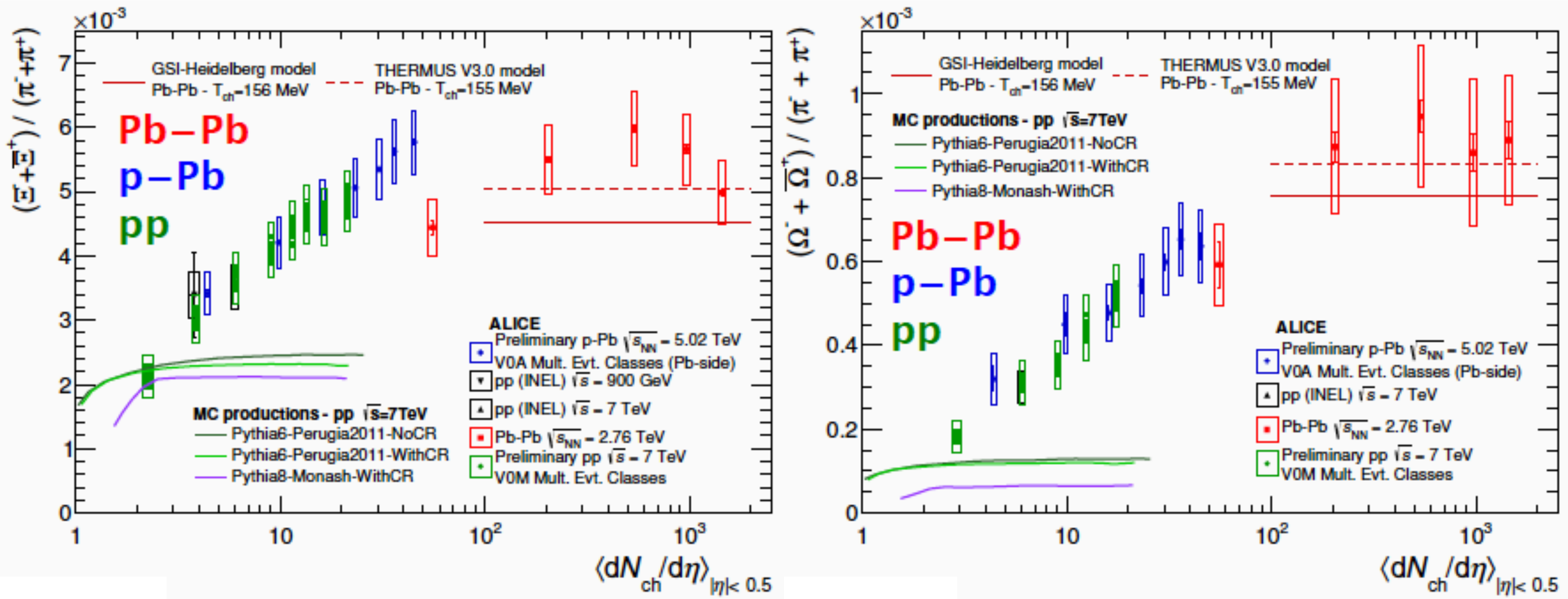
Strangeness: Λ/π

- Observation when Λ/π ratio is compared for different collision systems as function of multiplicity

→ Values approach thermal model expectation also in high-multiplicity pp and p-Pb events



Strangeness: Ξ/π & Ω/π



- Similar trend observed for the Ξ/π and Ω/π ratios

→ Saturation reached at the grand canonical limit in Pb-Pb collisions

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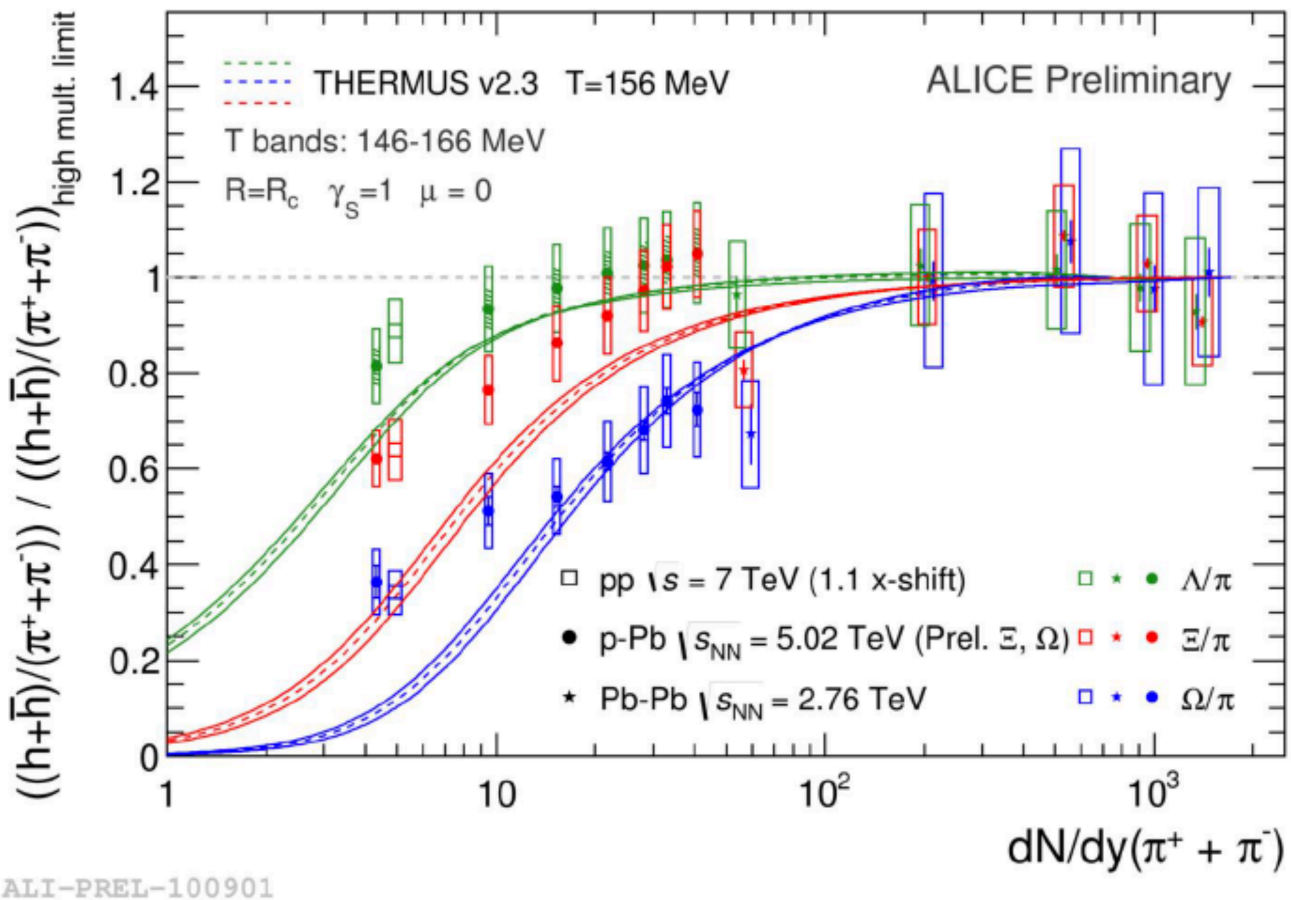
Canonical suppression

ALICE



- Can be interpreted as the lifting of the canonical suppression of strangeness

→ Trend qualitatively reproduced within a thermal model with additional local conservation of strangeness