Resonance measurement with ALICE at the LHC

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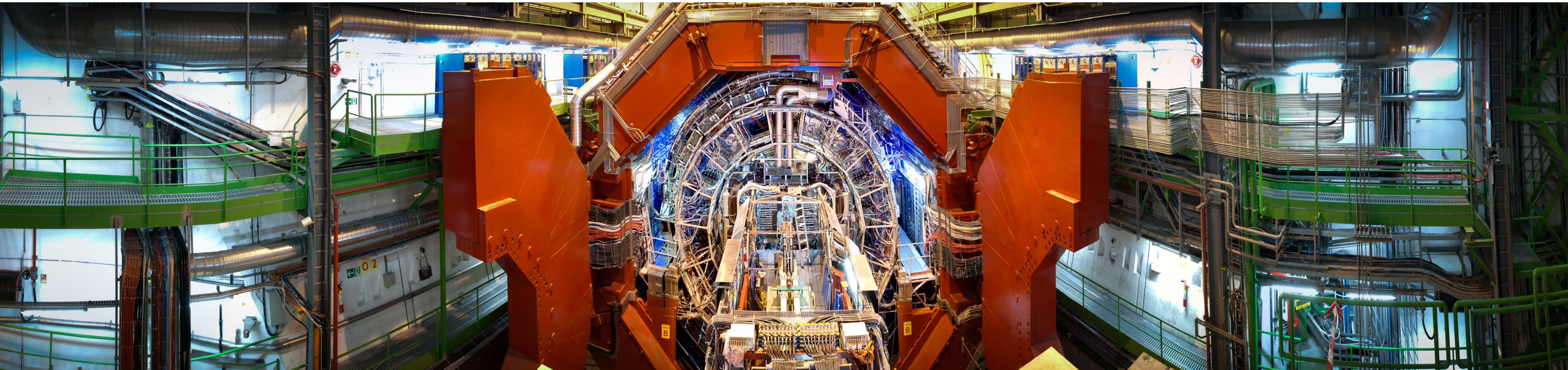


Outline

- Motivation
- The ALICE detector
- Resonance reconstruction
  - signal extraction
  - p_T-spectra
- Mean transverse momentum studies
- Integrated particle yield ratios
  - excited hyperons to ground-state hyperons
  - strangeness production to π vs. multiplicity
- Summary

Resonances in ALICE

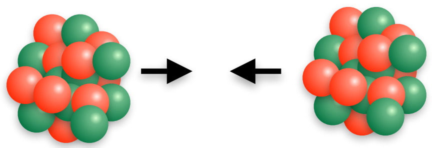
- Excited state of ground state particles with same quark content and higher mass

- Short lifetime on the order few fm/c ($\tau_{resonance} \sim \tau_{fireball}$)

particle	Mass (MeV/c²)	Width (MeV/c²)	cτ(fm)	Decay channel	quark contents	Branching ratio (%)
$\rho(770)^0$	770	150	1.3	ππ	$(u\bar{u}+d\bar{d})/\sqrt{2}$	100
$K^*(892)^0$	896	47.4	4.2	πK	$d\bar{s}$	66.7
$\Sigma^*(1385)^+$	1383	39.4	5.5	Λπ	uus	87
$\Sigma^*(1385)^-$	1387	36.0	5.0	Λπ	dds	87
$\Xi^*(1530)^0$	1532	9.1	21.7	πΞ	uss	66.7
Φ(1020)	1019	4.27	46.2	KK	$s\bar{s}$	48.9

- Resonance measured with ALICE detector in **pp** (0.9, 2.76, 7, 13 TeV), **p-Pb** (5.02 TeV) and **Pb-Pb** (2.76, 5.02 TeV) collisions

Motivation

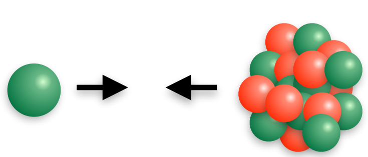


Pb-Pb collisions

- Properties of the **hadronic phase**
  - good tool to probe the interplay of particle re-scattering and regeneration due to **short lifetime**

- **Particle production mechanisms**
  - comparison of resonance with particles that differ by mass, baryon number, strangeness content

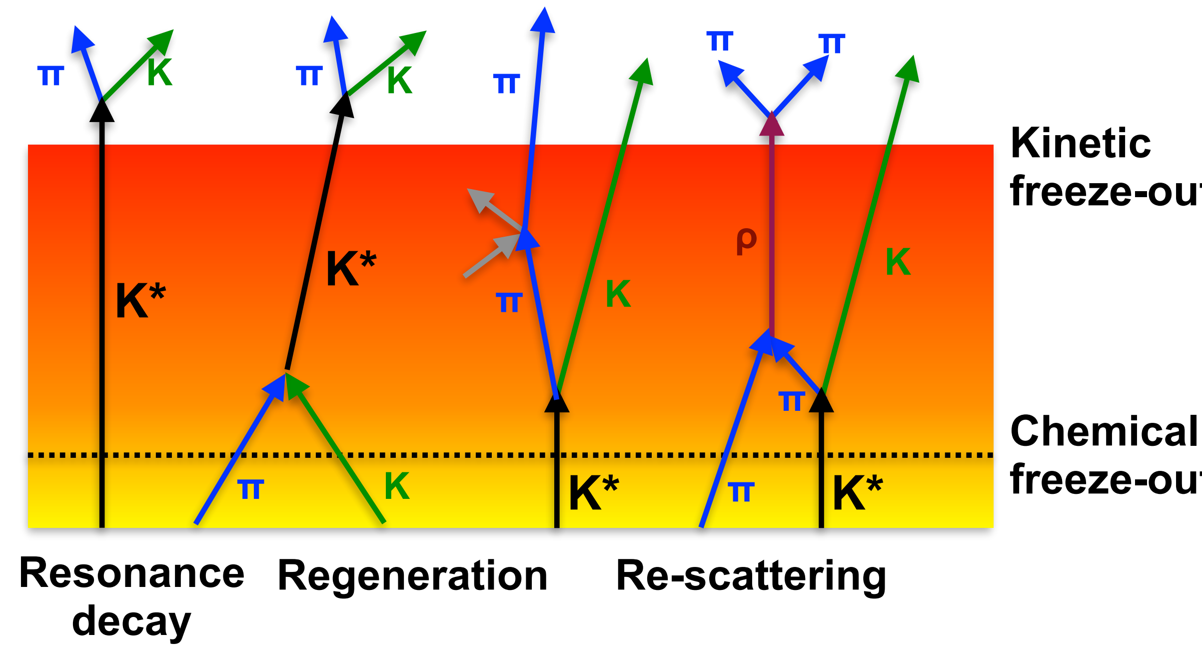
- Strange resonances
  - complement **strangeness enhancement**



p-Pb collisions

- helps to disentangle cold nuclear matter effects from genuine hot medium effects

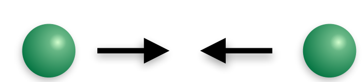
- Contribute to the study of the system size dependence of re-scattering



Regeneration: pseudo-elastic scattering of decay products

Re-scattering: resonance decay products undergo elastic scattering or pseudo-elastic scattering through a different resonance

→ Not reconstructed through invariant mass

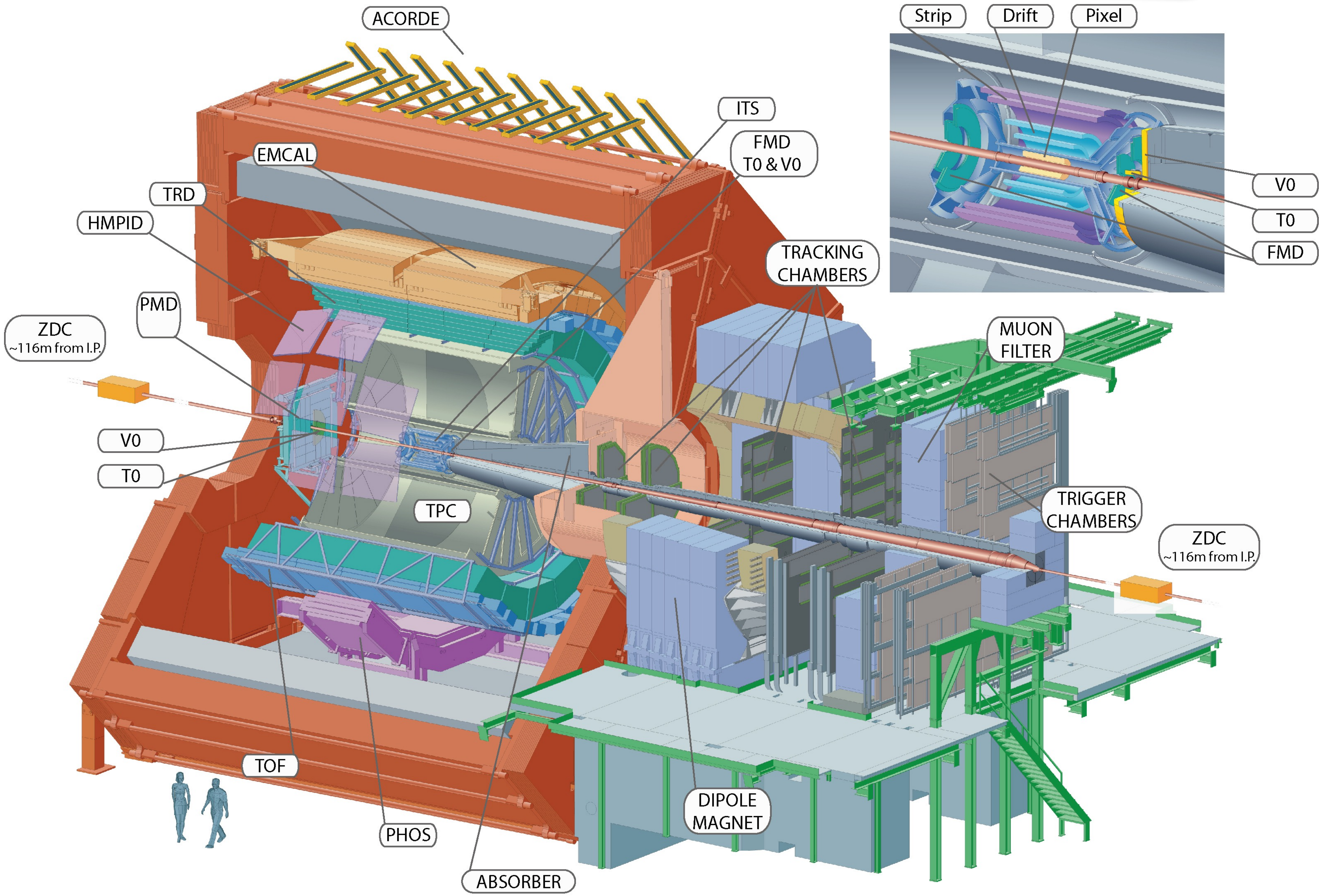


pp collisions

- Reference for ‘larger’ systems

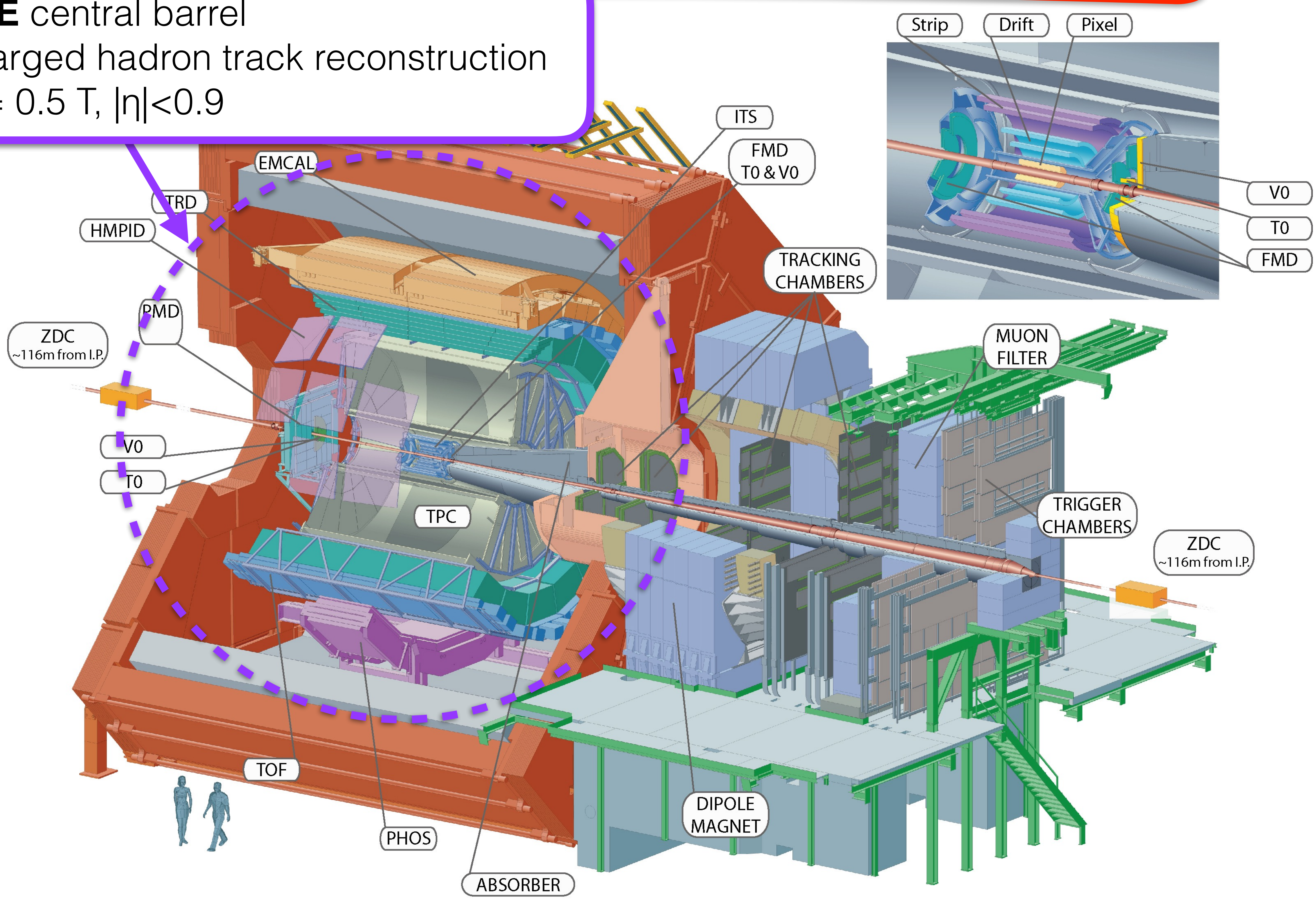
- Help tuning QCD-inspired event generators

The ALICE detector



The ALICE detector

ALICE central barrel
→Charged hadron track reconstruction
→B = 0.5 T, |η|<0.9



The ALICE detector

Inner **T**racking **S**ystem
→Tracking and vertexing

ALICE central barrel
→Charged hadron track reconstruction
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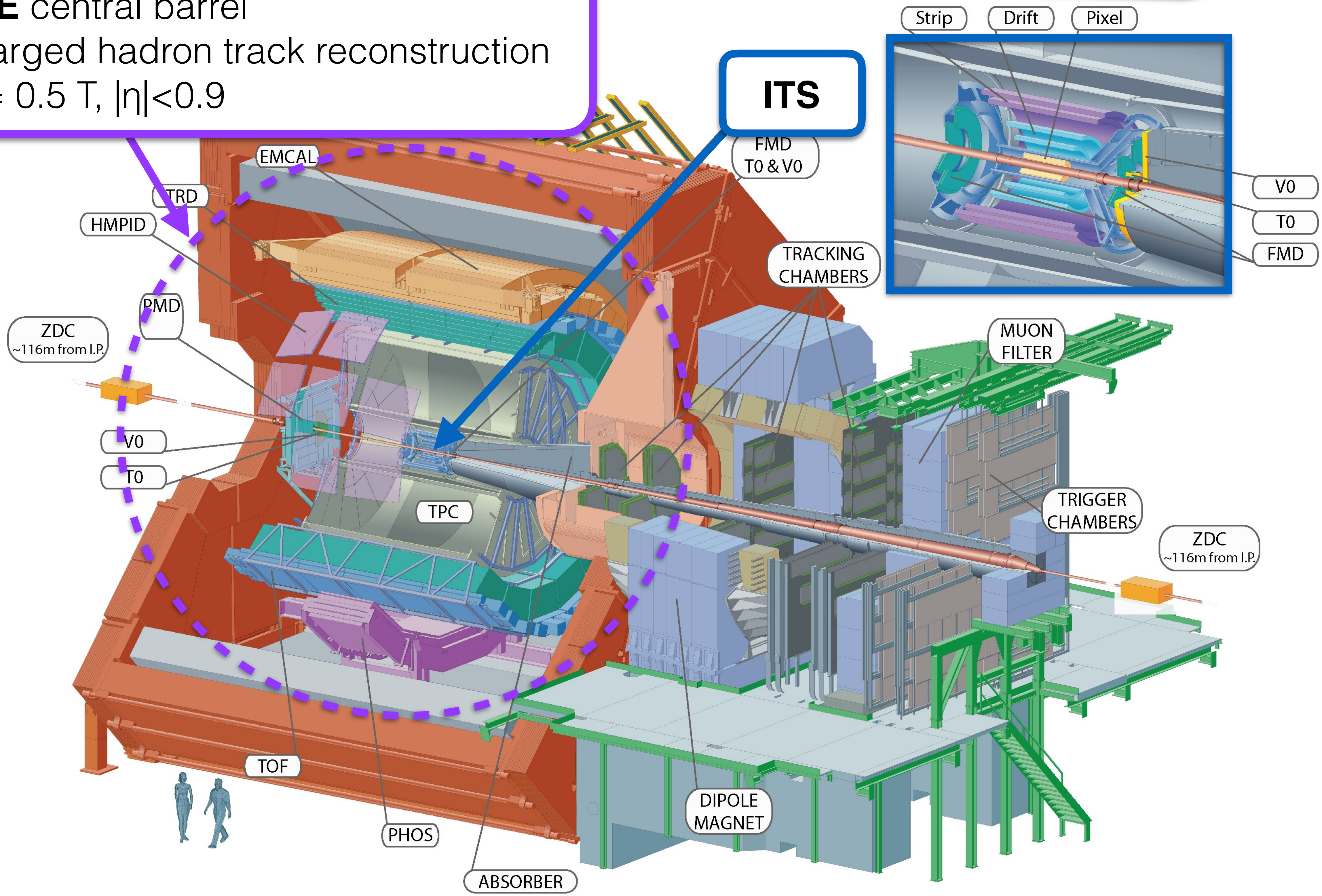

The ALICE detector

Inner Tracking System
→Tracking and vertexing

ALICE central barrel
→Charged hadron track reconstruction
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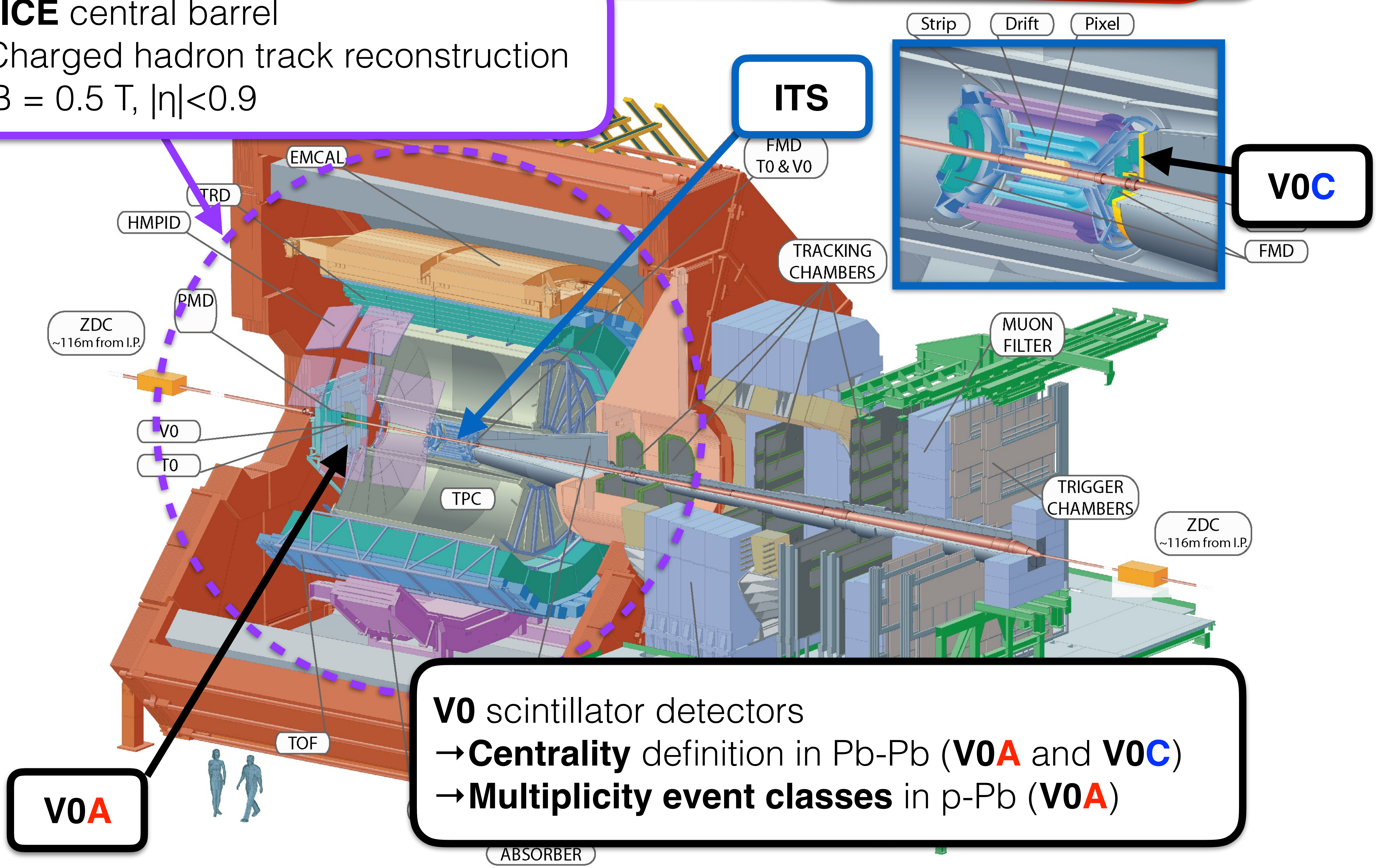
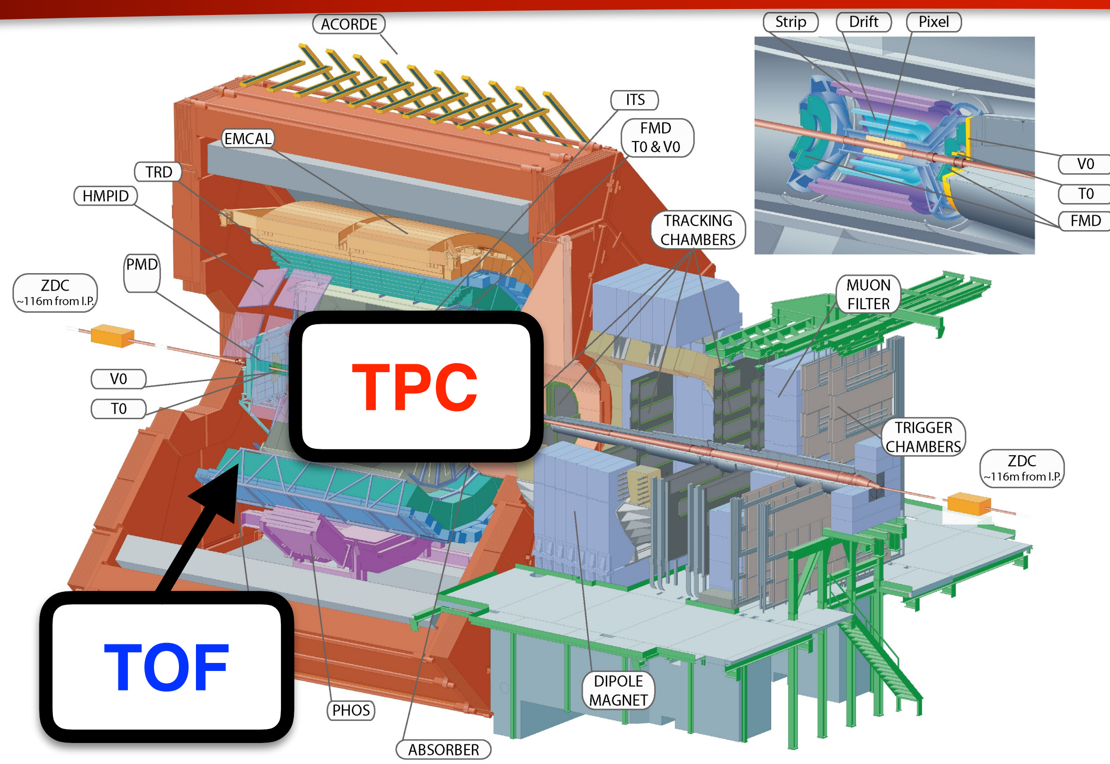
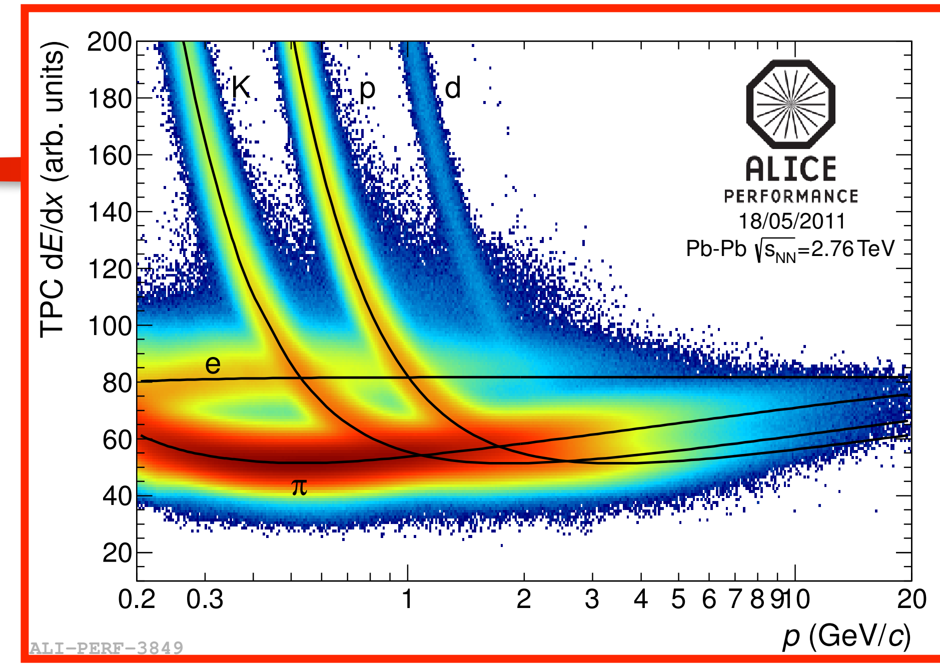


V0 scintillator detectors
→**Centrality** definition in Pb-Pb (**V0A** and **V0C**)
→**Multiplicity event classes** in p-Pb (**V0A**)

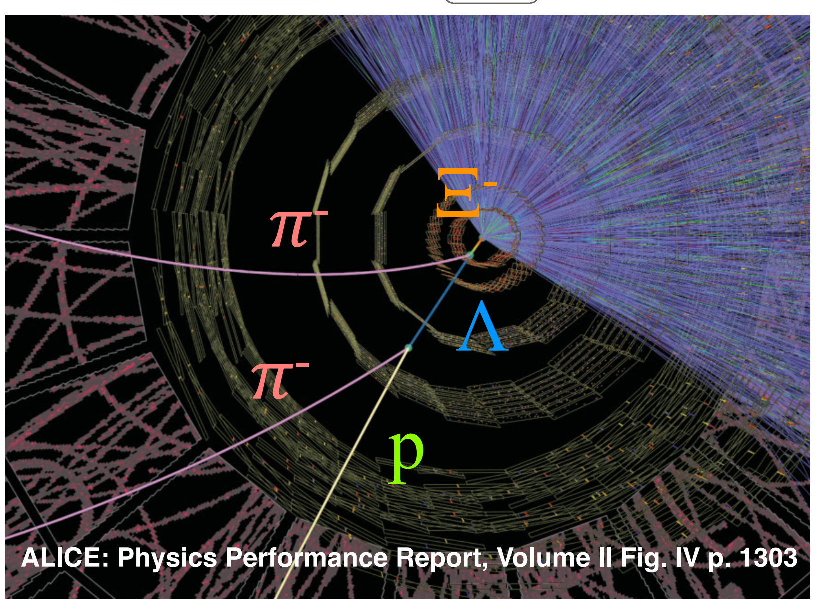
Particle identification





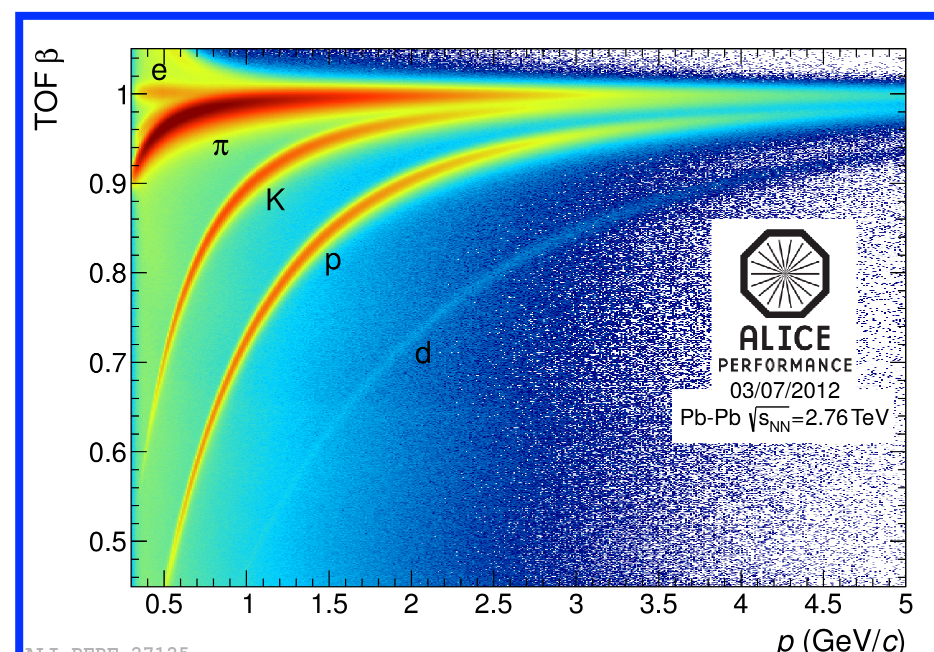
Time Projection Chamber (TPC)

- tracking in |η|<0.9
- Particle Identification via dE/dx in gas



Topological reconstruction of weak decays

- V-shaped topology for K^0_s and Λ
- cascade topology for Ξ and Ω

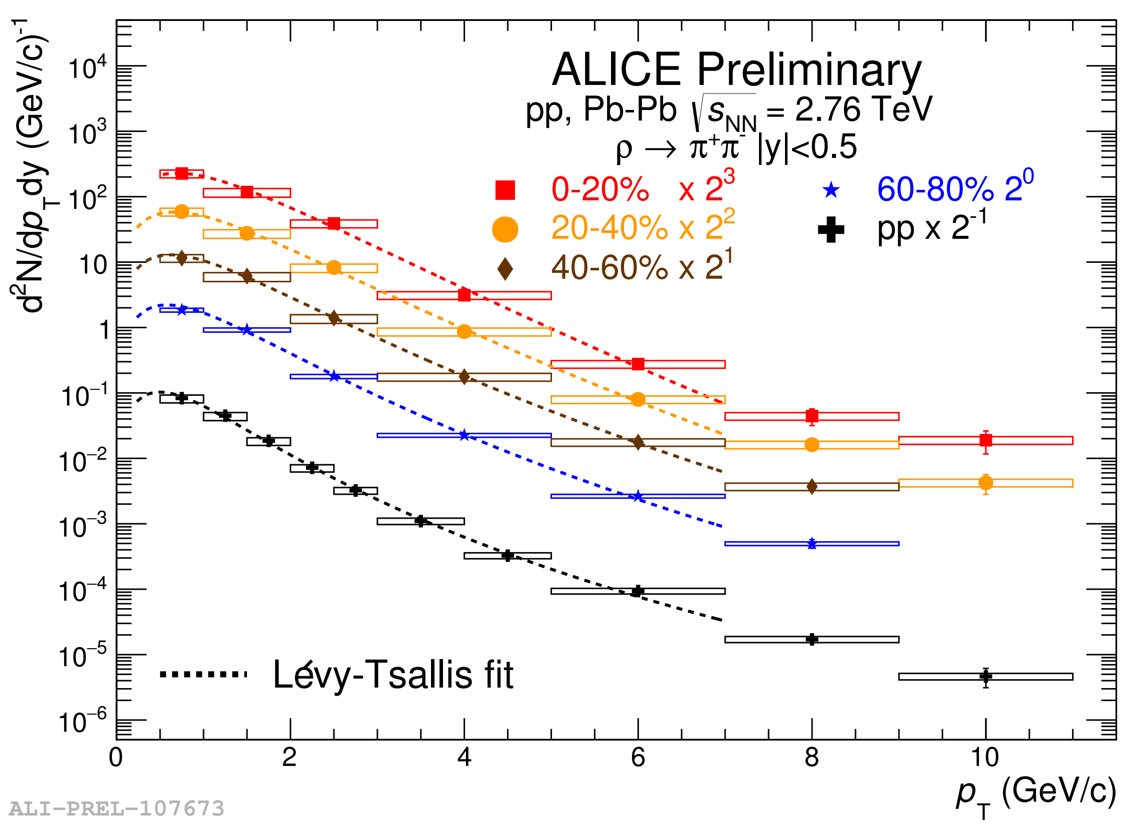


Time-**O**f-**F**light (**TOF**)

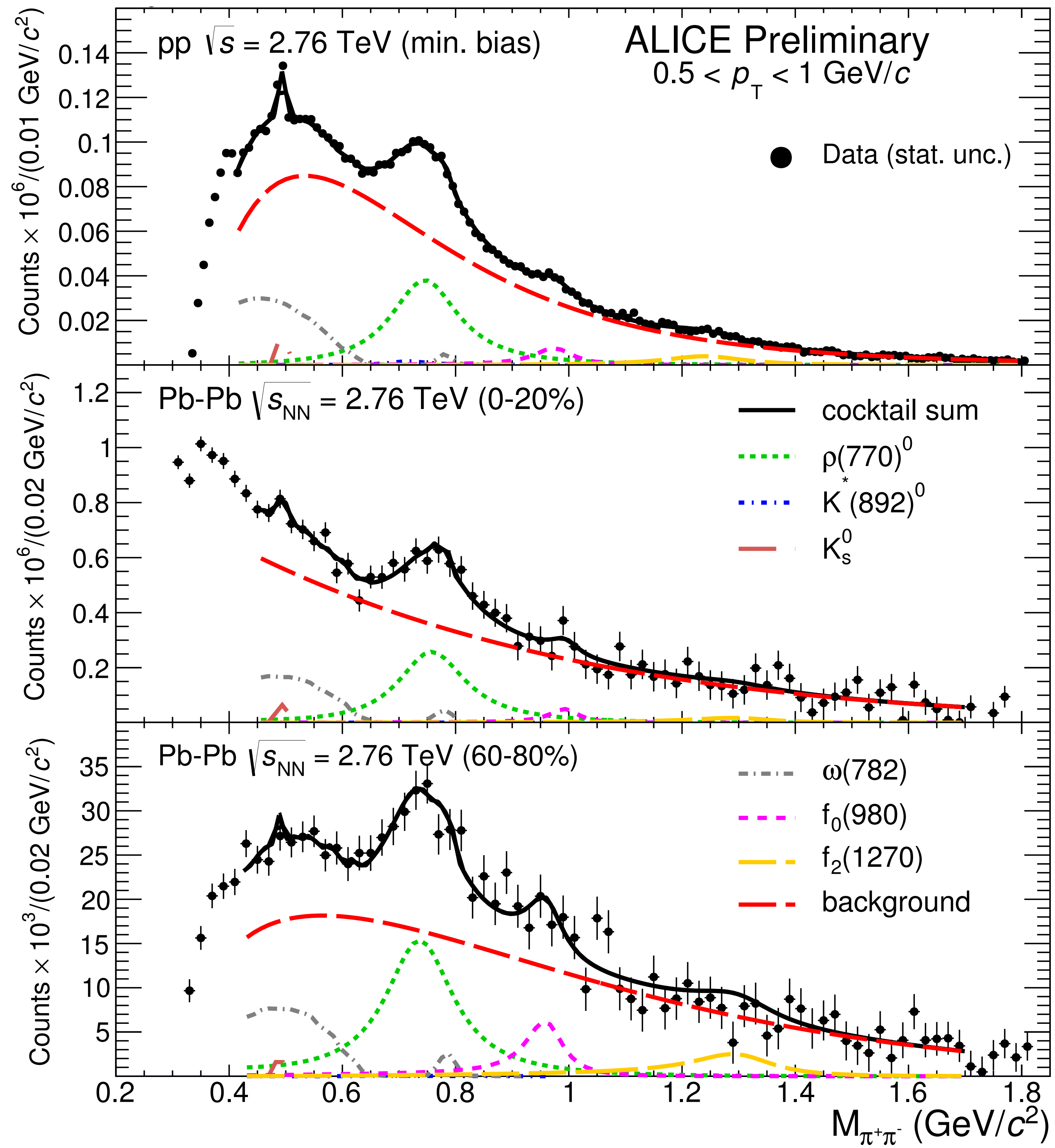
- PID via time-of-flight measurement

Reconstruction: $\rho(770)^0$

- Analysis in pp and Pb-Pb collisions at 2.76 TeV
- Subtract like-charge combinatorial background
- Fit with residua background + cocktail. (K^0_s, K^*0, ω, f_0, f_2)



ALI-PREL-107673

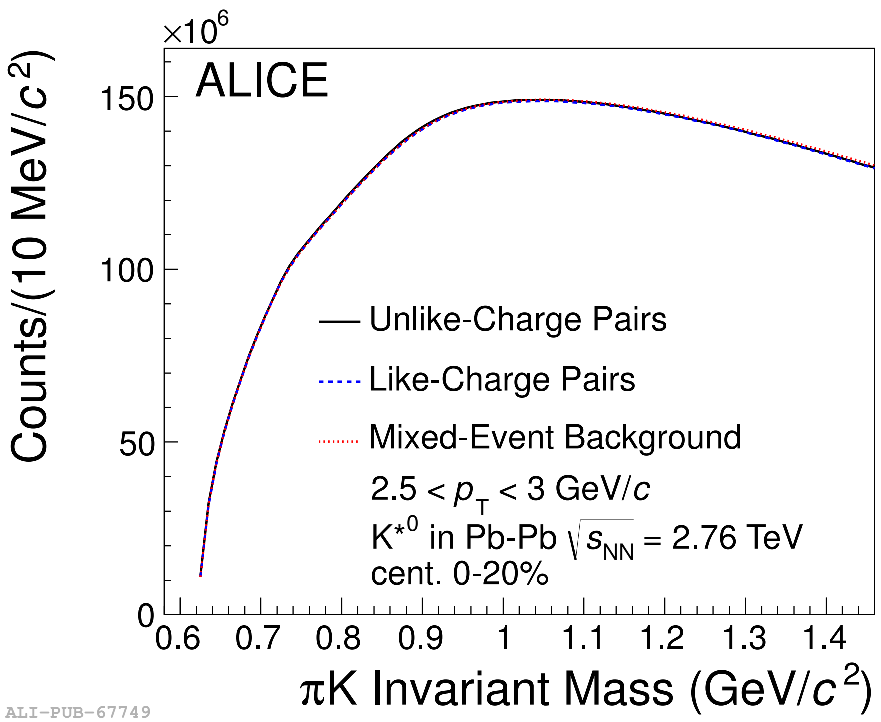


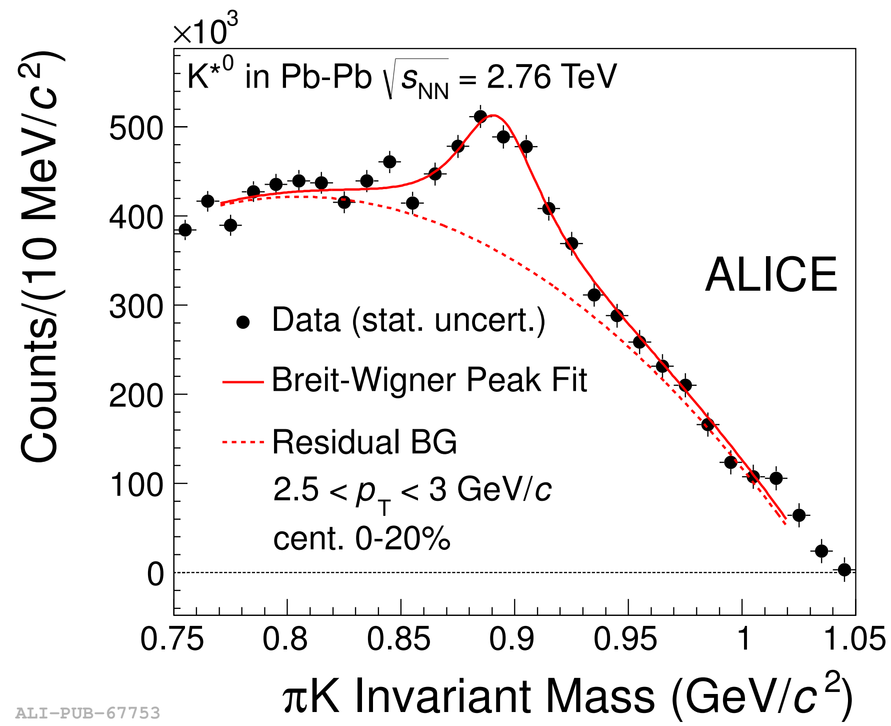
ALI-PREL-107636

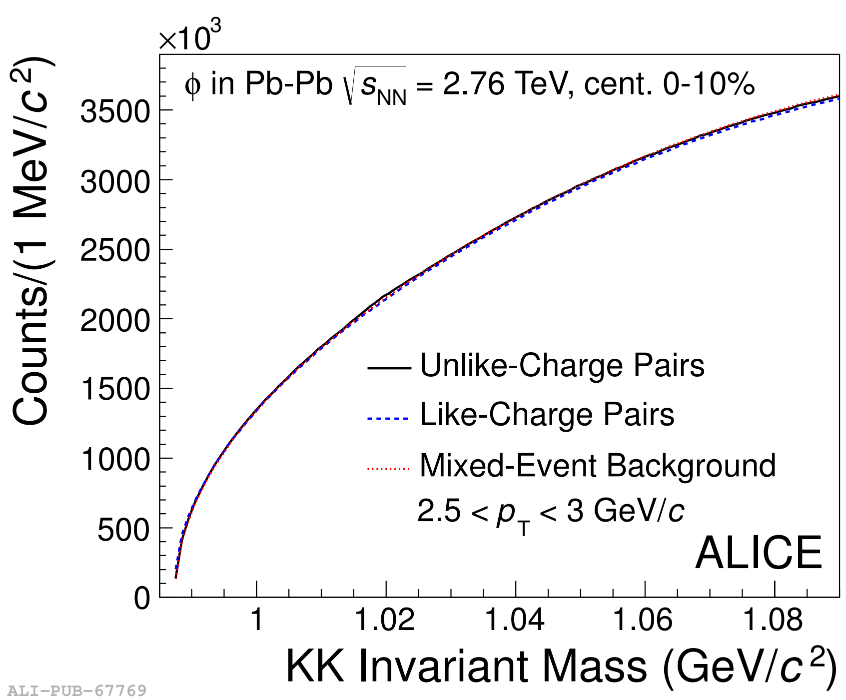
Reconstruction: K*(892)^0 and Φ(1020)

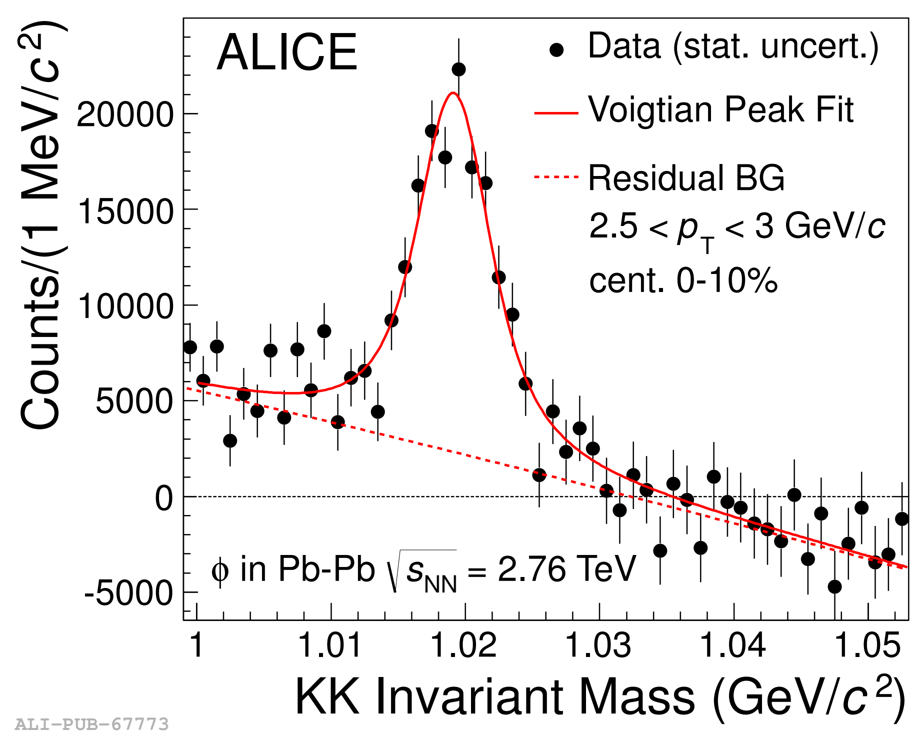
Before BG subtraction

After BG subtraction



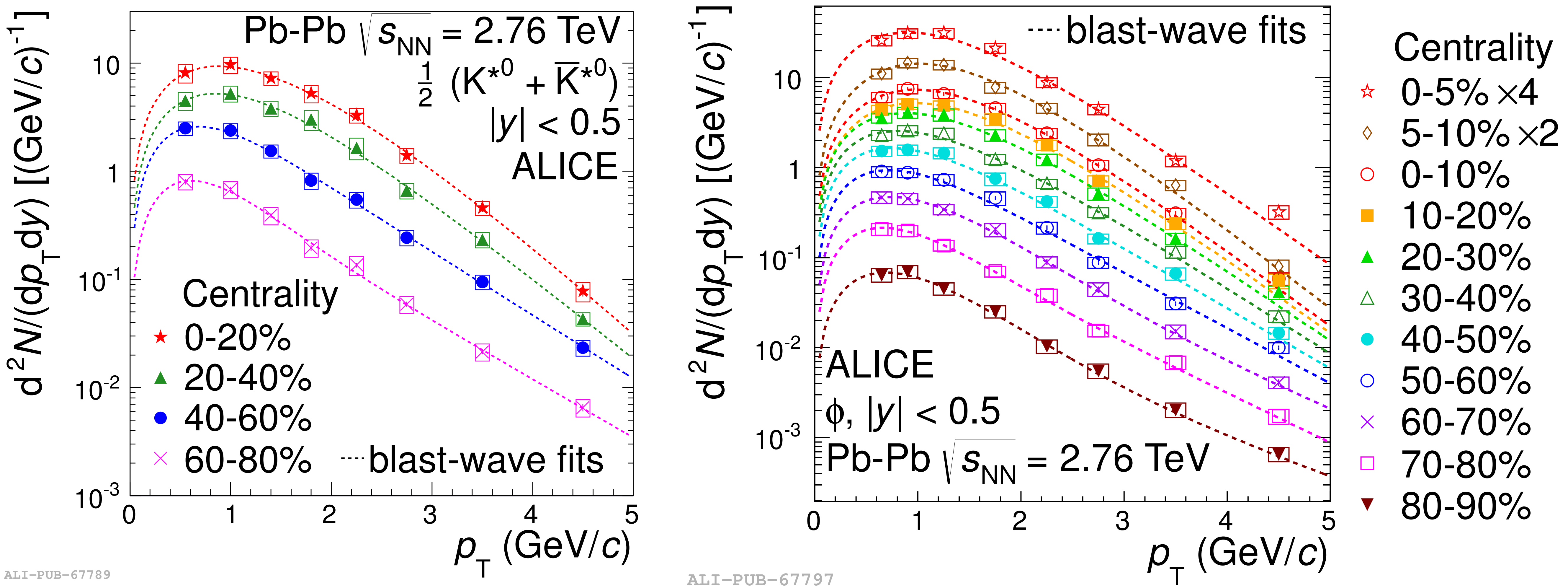






- Analysed in
  - pp at 0.9, 7 (vs. multiplicity), 13 TeV
  - p–Pb at 5.02 TeV
  - Pb–Pb at 2.76, 5.02 TeV
- Subtract mixed-event or like-charge combinatorial backgrounds
- Polynomial residual background
- Peak : Breit-Wigner (K*^{0}) or Voigtian (Φ)

Reconstruction: K*(892)^0 and Φ(1020)

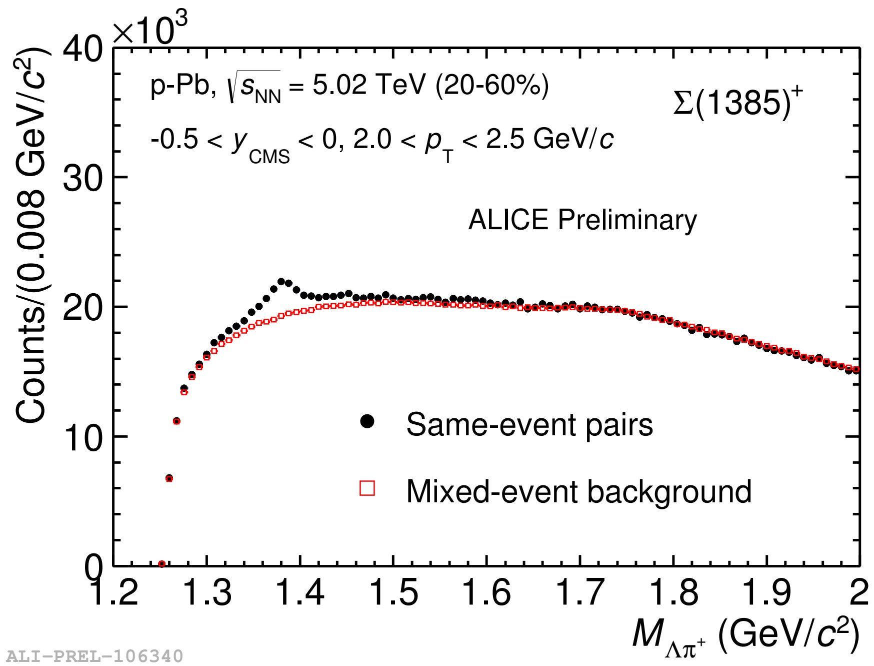


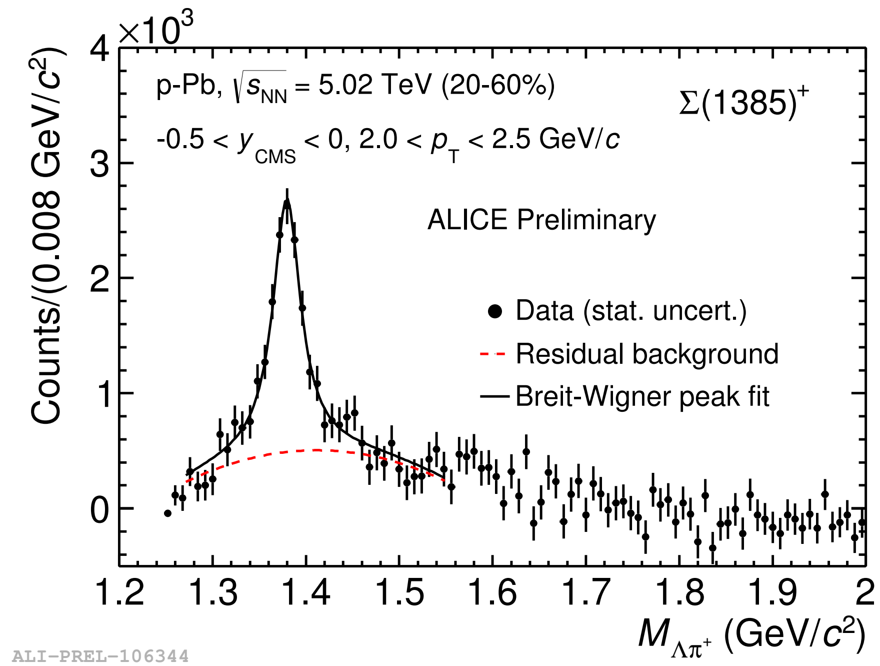
- Measurement performed in different V0M centrality (V0A multiplicity in p-Pb case) bins
- Spectra shape harder in central collision w.r.t. peripheral collisions

Reconstruction Σ(1385)$^{\pm}$ and Ξ(1530)^{0}

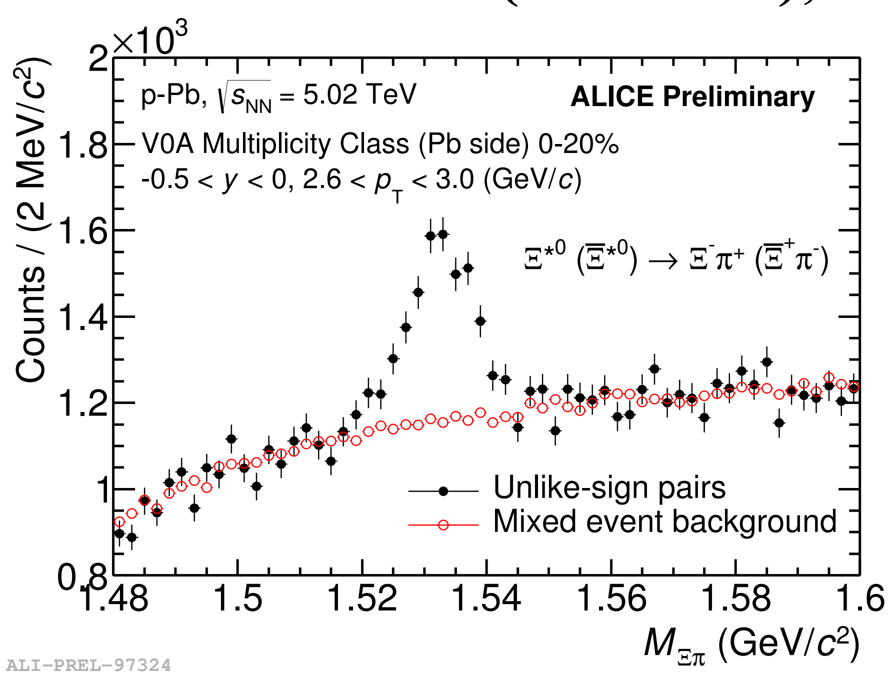
Before BG subtraction — After BG subtraction

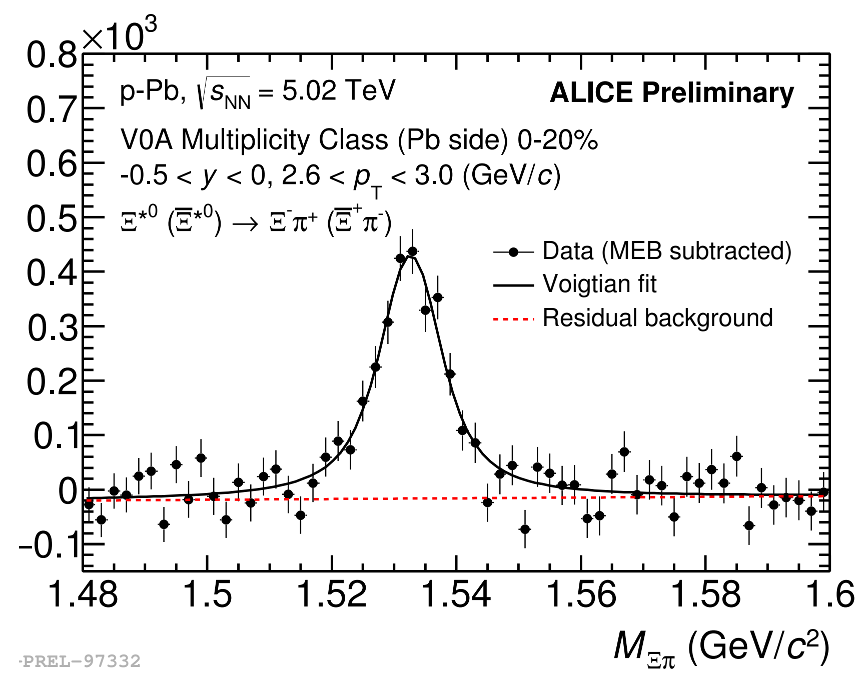
$\Sigma^{*+} \rightarrow \Lambda\pi^{+}$ (BR~87%), m = 1.382 GeV/c^2, Γ = 0.036 GeV/c^2





$\Xi^{*0} \rightarrow \Xi^{\pm}\pi^{\mp}$ (BR~67%), m = 1.532 GeV/c^2, Γ = 0.009 GeV/c^2

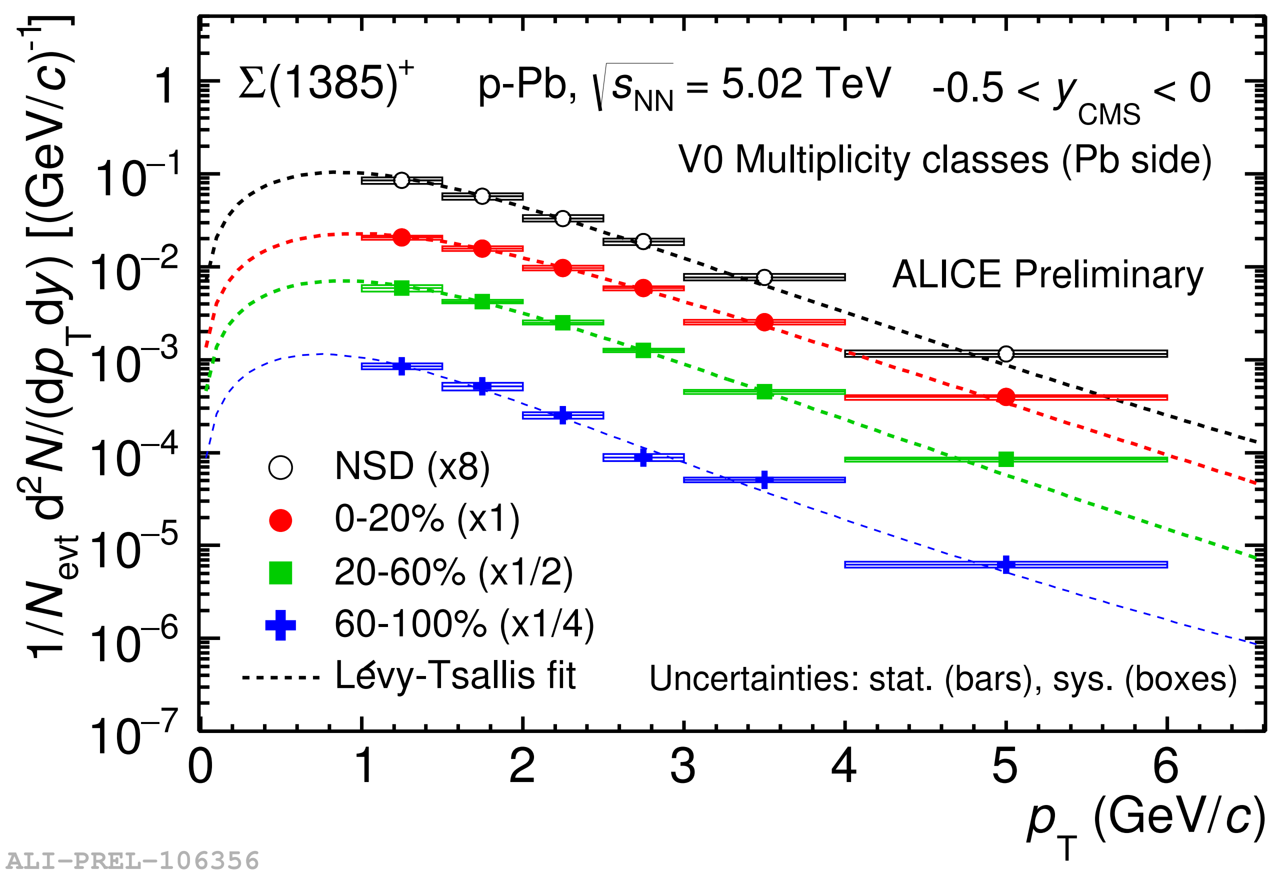




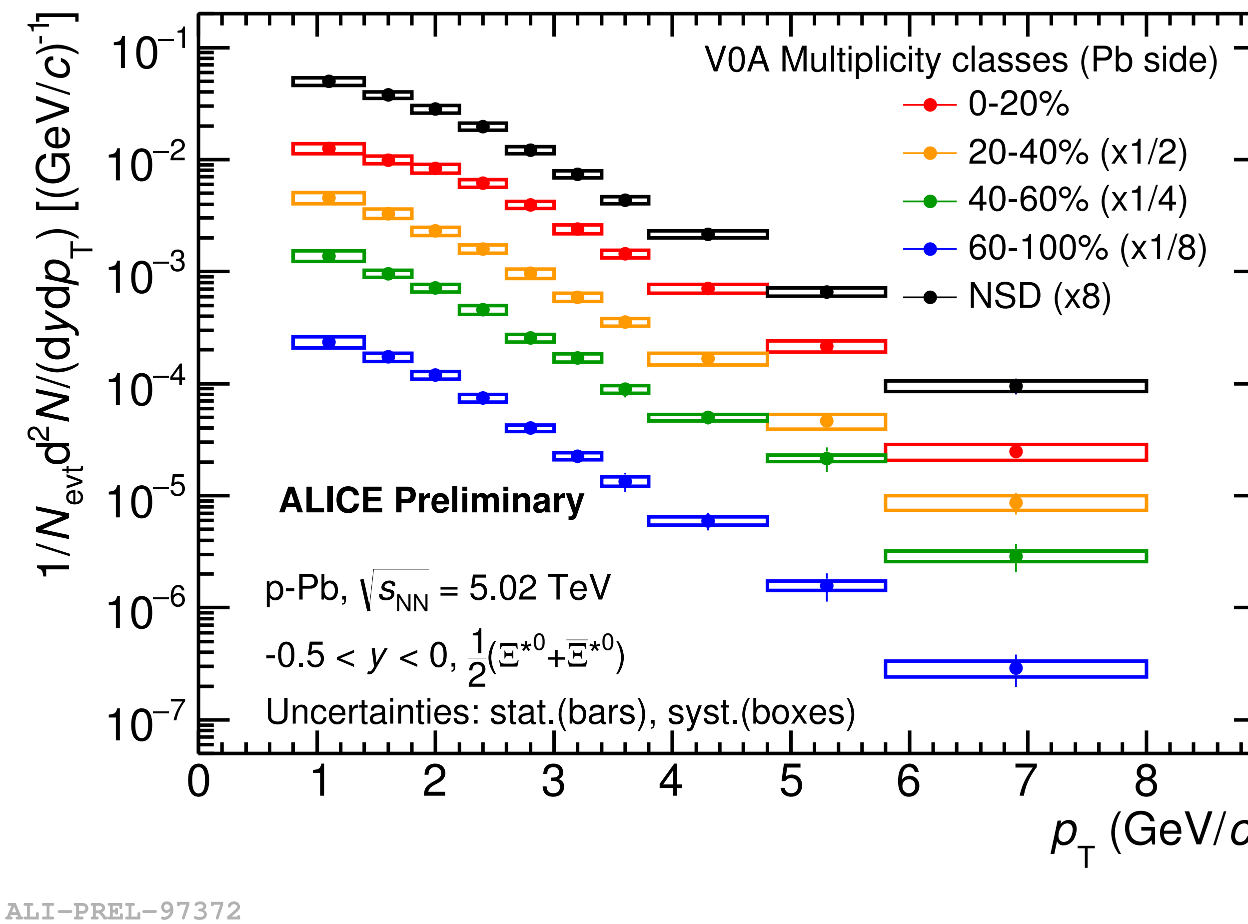
- Invariant mass analysis
- combinatorial background using event mixing technique
- Breit-Wigner($\Sigma^{*\pm}$) and Voigtian(Ξ^{*0}) fit functions for signal extraction
- Polynomial fit for residual background

Reconstruction Σ(1385)± and Ξ(1530)0

Σ*+



Ξ*0



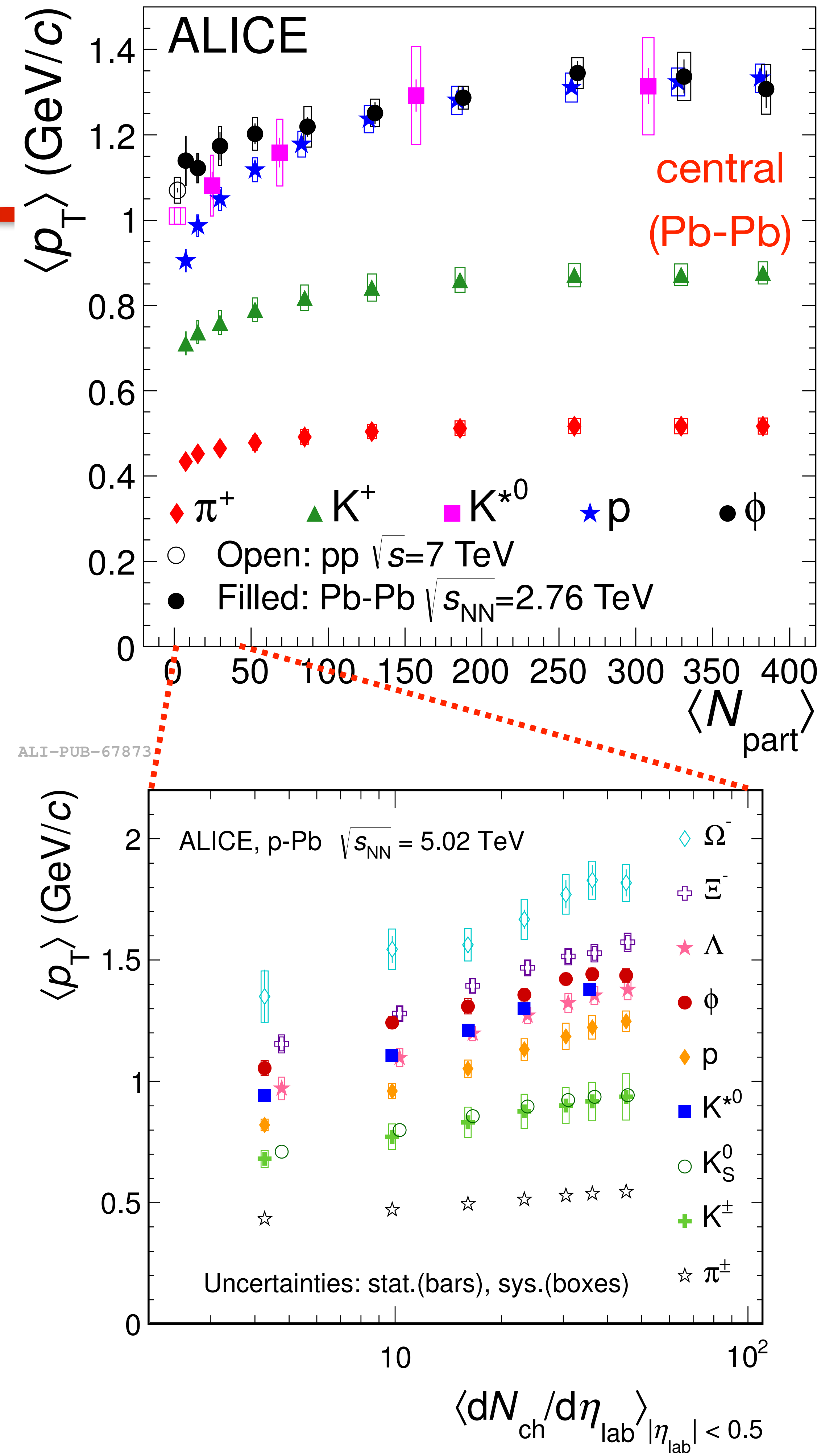
- Measurement performed in different V0A multiplicity bins
- Lévy-Tsallis function is used to extrapolate dN/dy at low p_T and obtain $\langle p_T \rangle$
  - percentages of yield in the extrapolated low p_T
    (36-47% for $\Sigma^{*\pm}$ 20-29% for Ξ^{*0})

Mean transverse momentum

$<p_{T}>$

peripheral Pb-Pb
(similar to pp)

- **Pb-Pb** collisions
  - **central**: K^{*0}, p and $\boldsymbol{\phi}$ follow mass ordering
  - **peripheral**: we observe a splitting of $\langle p_T \rangle$ for proton and $\boldsymbol{\phi}$
  - **peripheral→central**: the $\langle p_T \rangle$ of p exhibits a larger increase than other particles
- **p-Pb** collisions
  - increase from lowest to highest multiplicity event class
  - $\langle p_T \rangle_p < \langle p_T \rangle_\Lambda < \langle p_T \rangle_{K^{*0}} < \langle p_T \rangle_{\phi}$
- **pp** collisions
  - agreement with Pb-Pb (p-Pb) peripheral collisions



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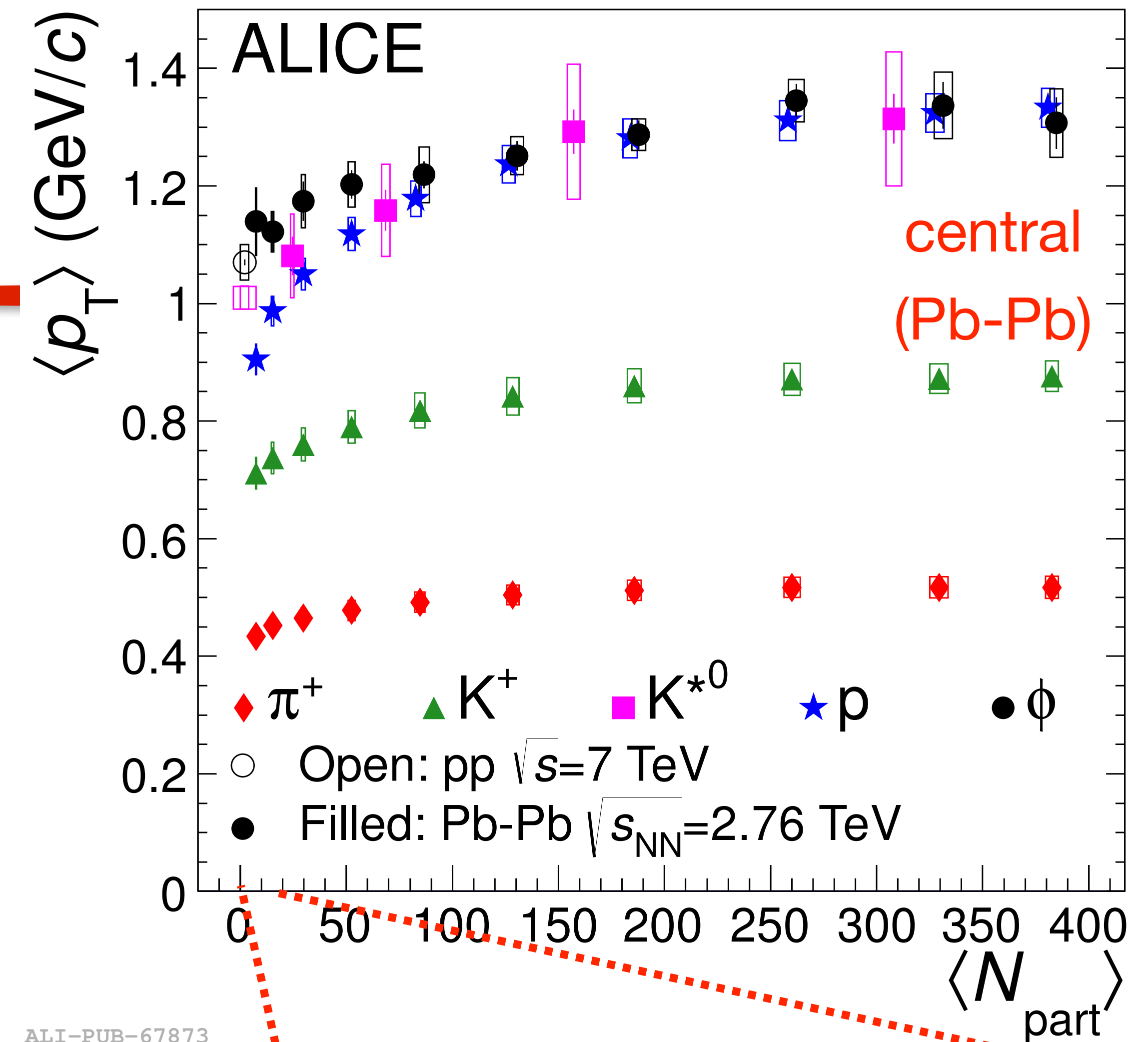
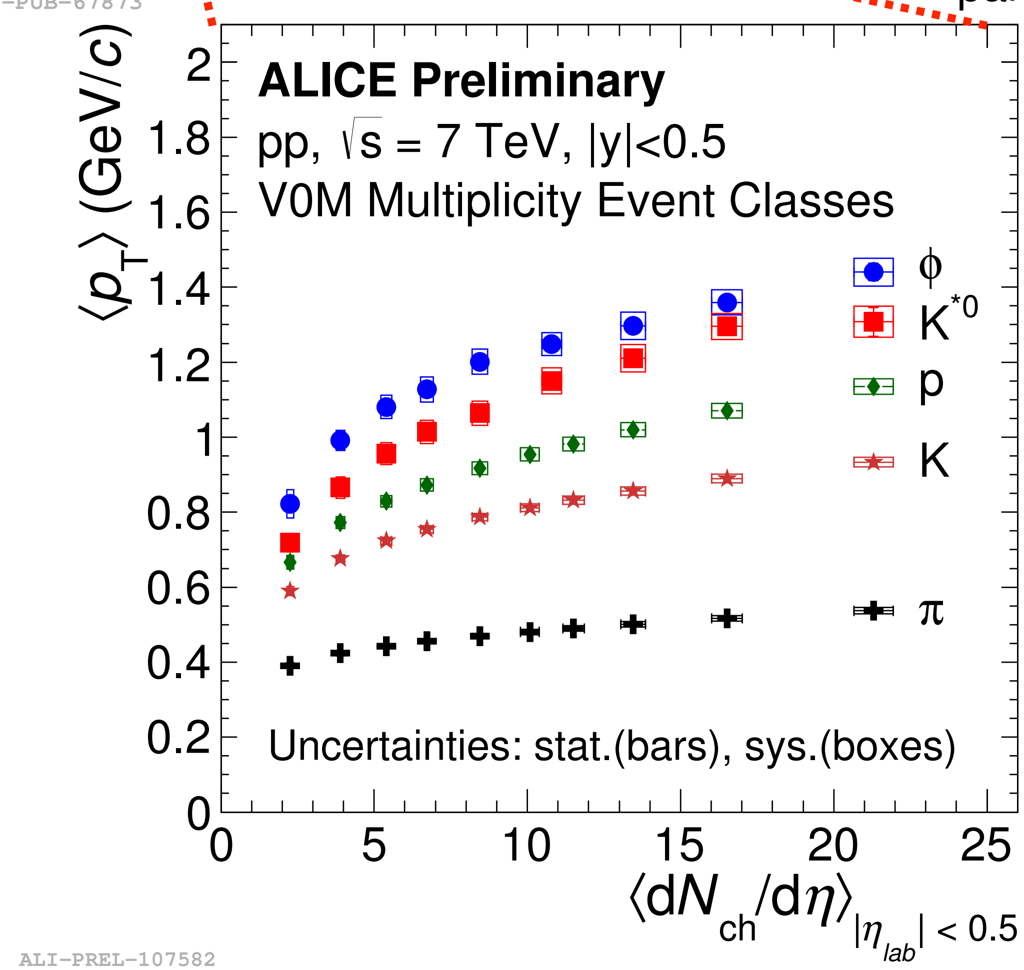
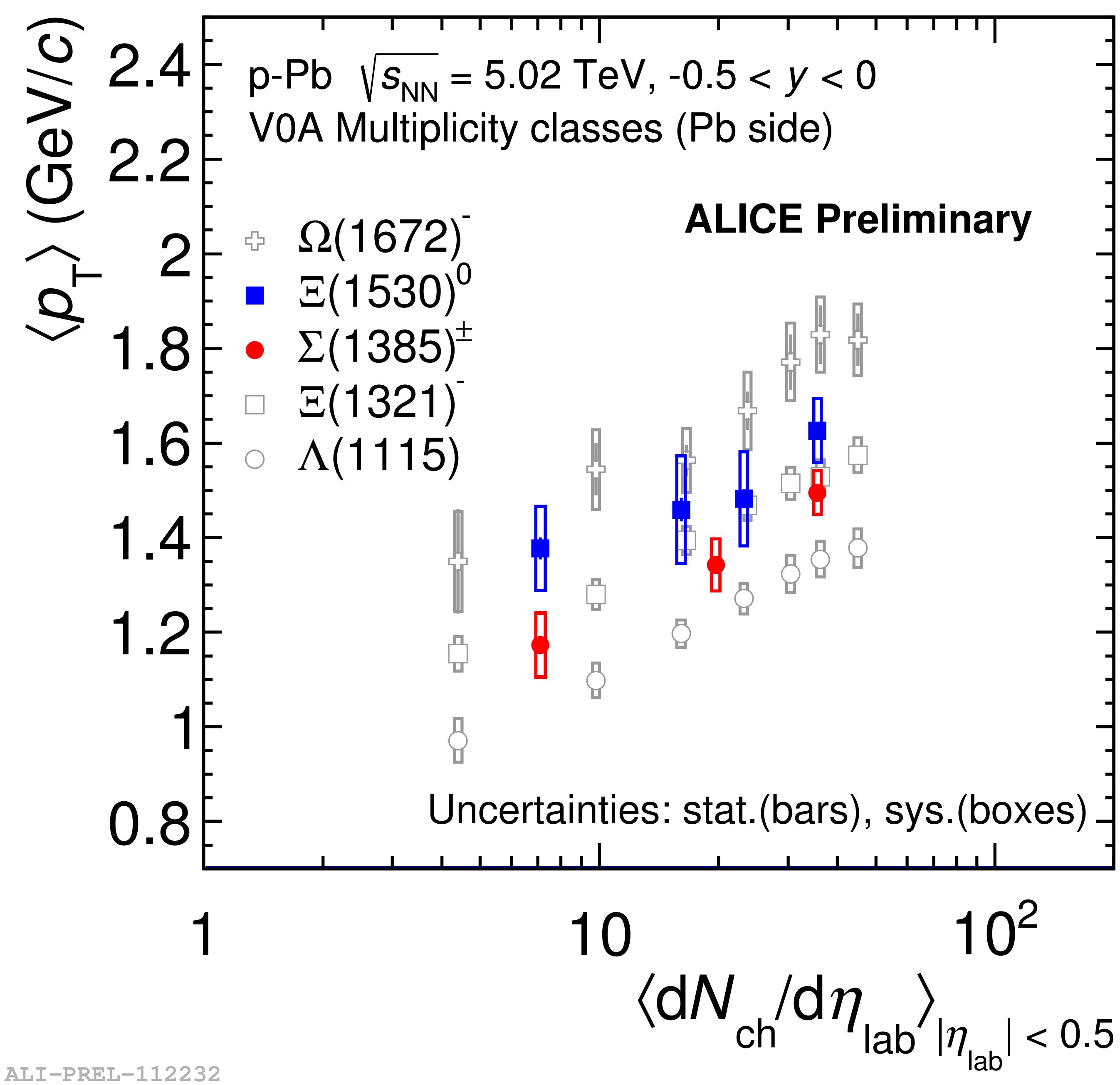
  - agreement with Pb-Pb (p-Pb) peripheral collisions
  - pp in **multiplicity dependent analysis** shows same results with p-Pb



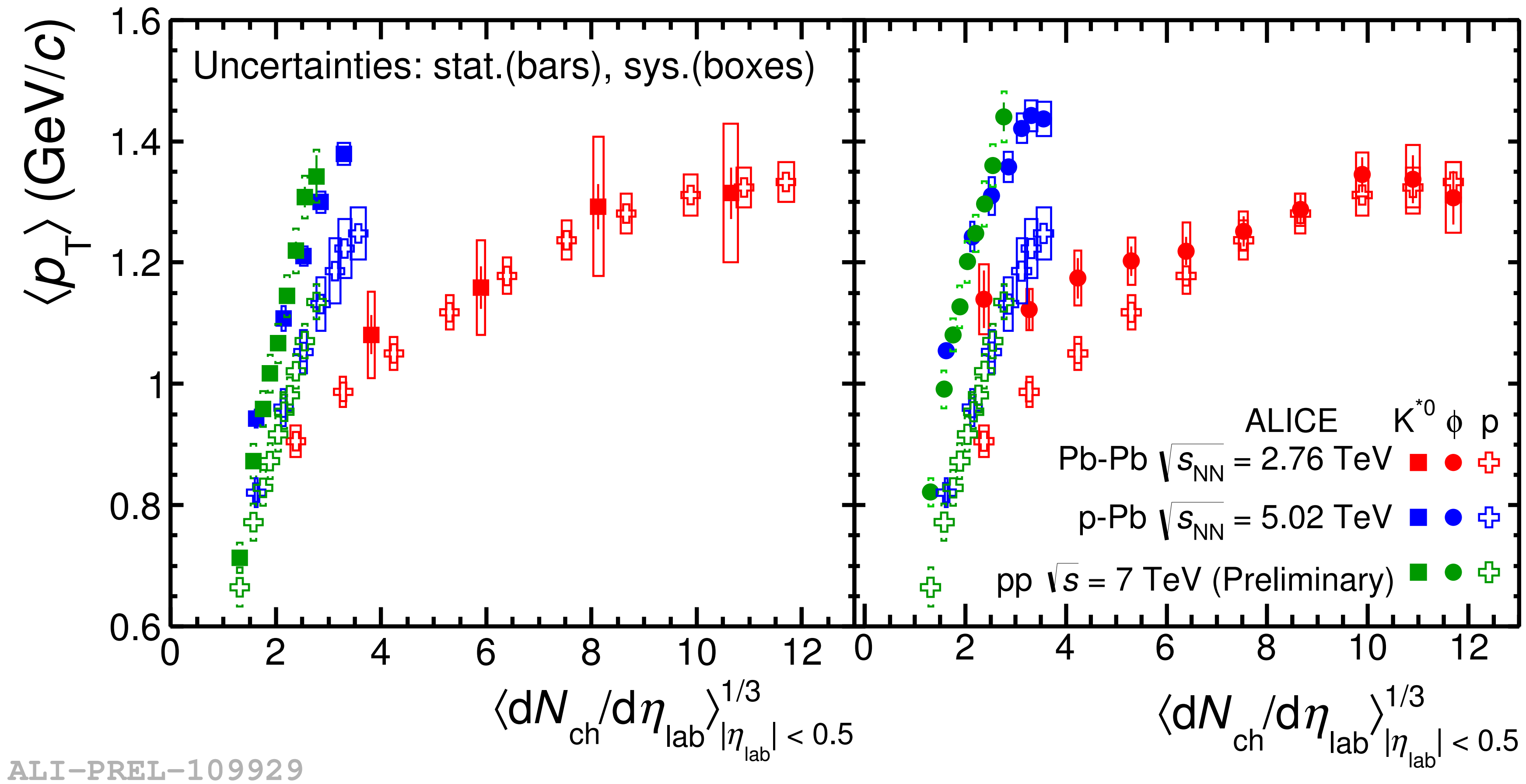


$<p_T>$ vs $<dN_{ch}/d\eta>$: hyperons



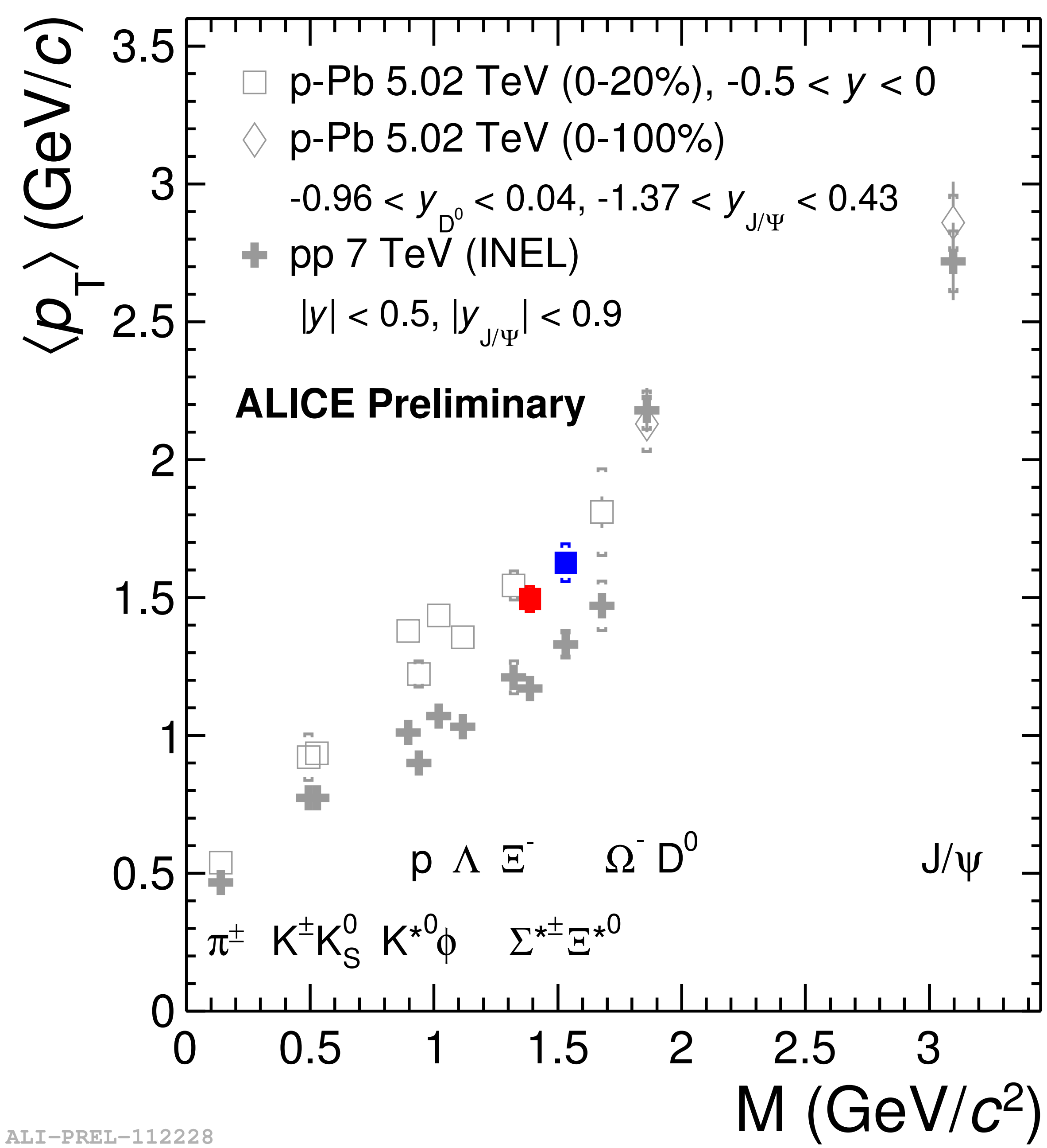
- $<p_T>$ of **Σ*±** & **Ξ*0** are compared with those for the other hyperons [1],[2]
- Increasing trend from low to high multiplicities for all hyperons
- In all multiplicity classes, $<p_T>$ follows **mass ordering**

<p_T> : system size dependence



- Central **Pb-Pb**: K^{*0}, p, *Φ* have similar <p_T>
  - consistent with hydrodynamics
- Small systems (**p-Pb** and **pp**)
  <p_T> values rise faster with multiplicity than Pb-Pb, reach similar values at high multiplicity as central Pb-Pb

$<p_T>$ vs Mass



- Mass dependence of $<p_T>$ of identified particles
  - 0-20% V0A multiplicity class in p-Pb (D^0 & J/Ψ is measured in 0-100% with different rapidity range in p-Pb)
  - MB in pp collisions

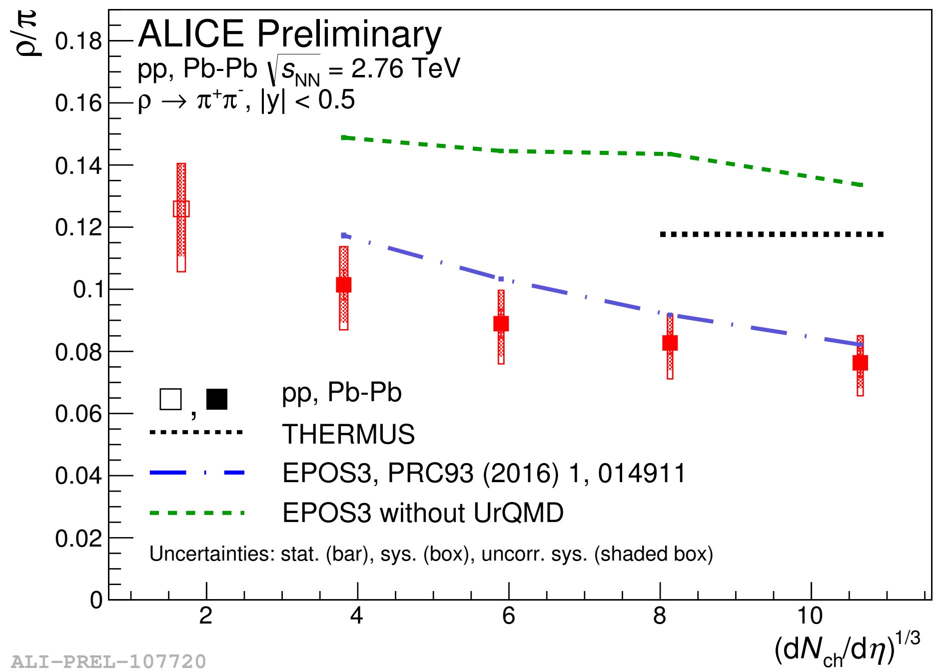
- Mass ordering :
  $\langle p_T \rangle_{\Lambda} < \langle p_T \rangle_{\Xi^-} \simeq \langle p_T \rangle_{\Sigma^{*\pm}} < \langle p_T \rangle_{\Xi^{*0}} < \langle p_T \rangle_{\Omega^-}$

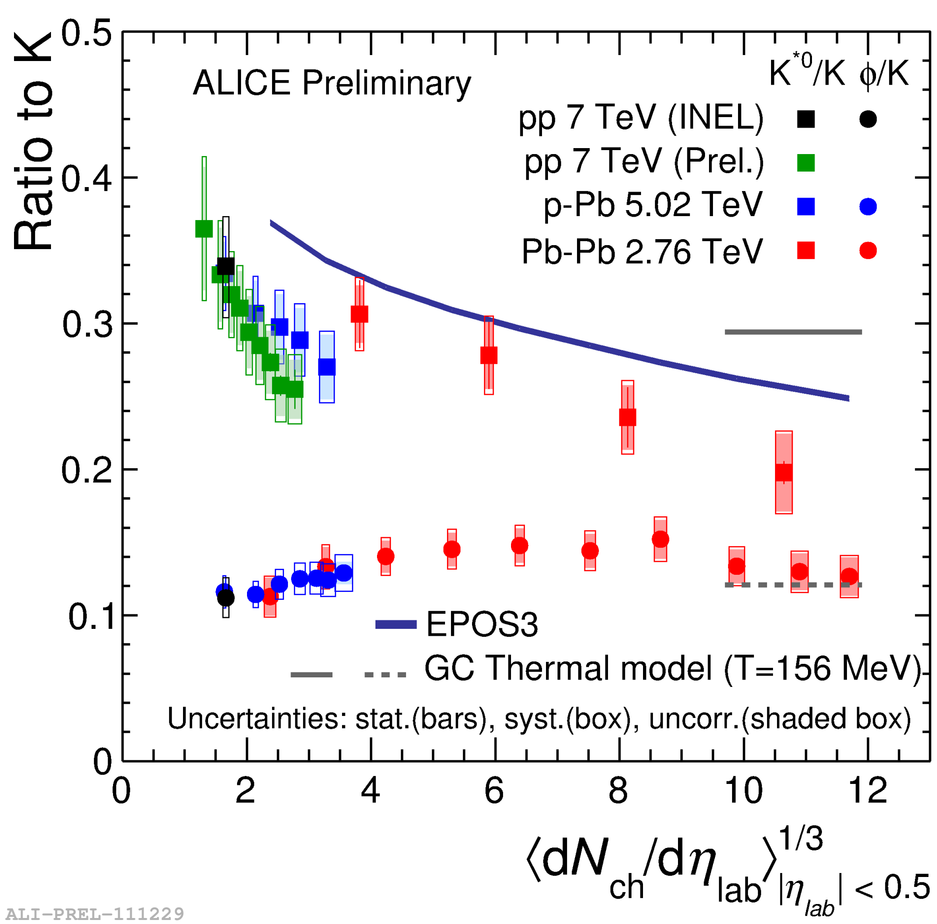
- Trend with mass is similar in **pp** and central **p-Pb**

Particle ratios

Particle yield ratios (Mesons)

particle	cτ(fm)
ρ^0	1.3
K^{*0}(892)	4.2
Φ(1020)	46.2





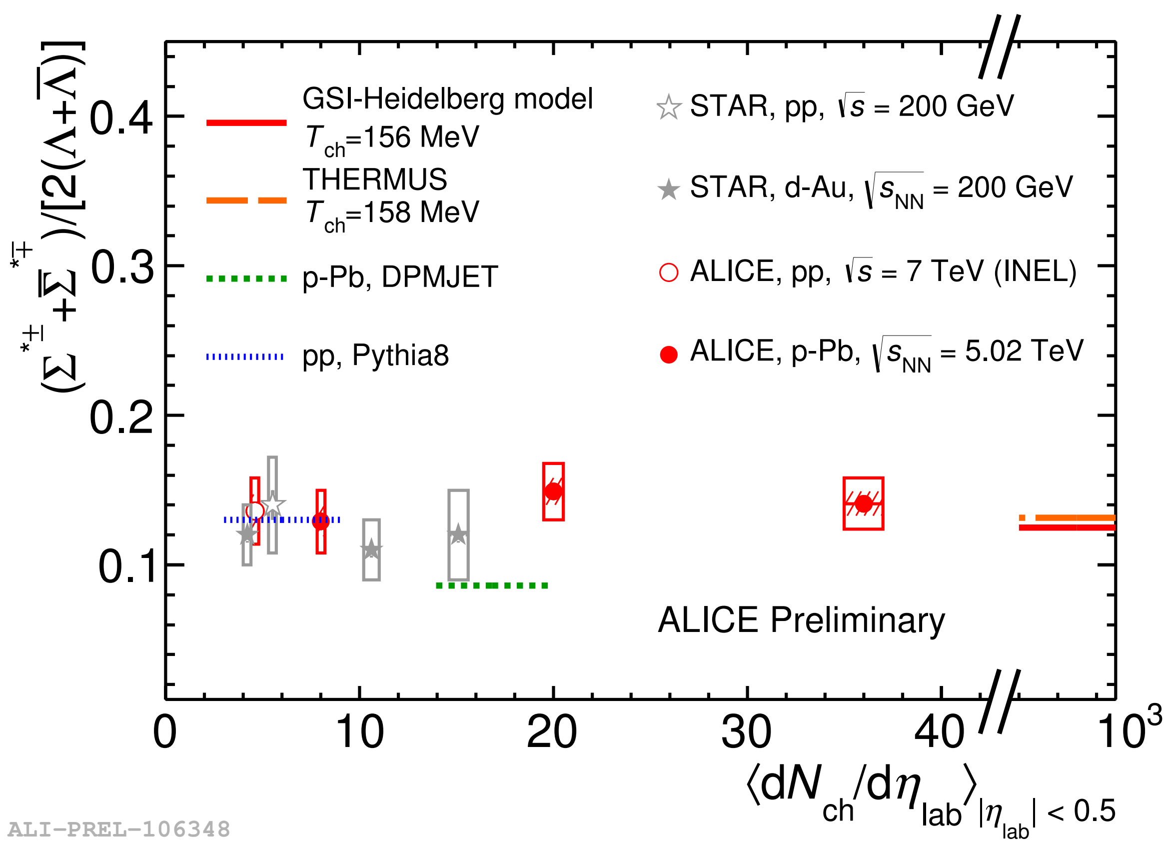
- Integrated particle ratios of **excited to ground-state hadron** with **same strangeness content** are shown as function of $\langle dN_{ch}/d\eta \rangle$

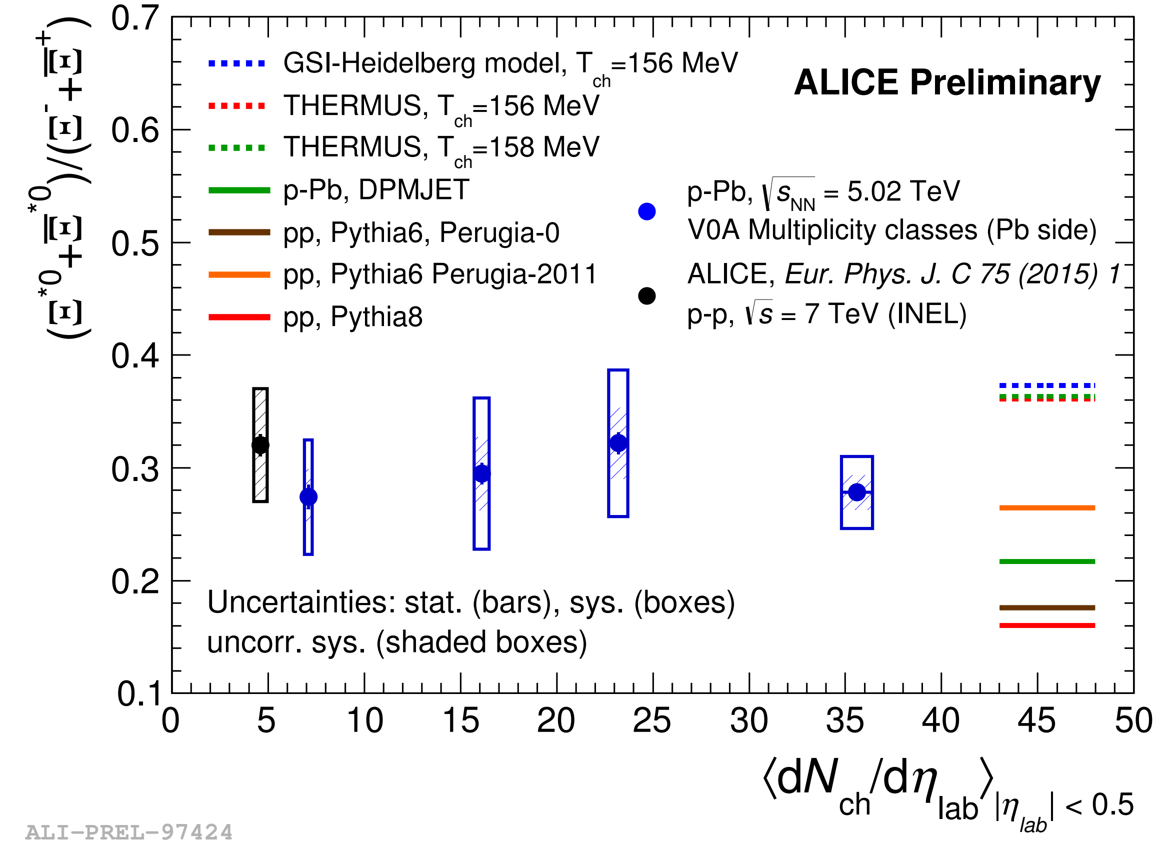
- **ρ^0/π**: suppression in central Pb-Pb, consistent with hypothesis that re-scattering is dominant over regeneration

- ***K^{*0}/K^-***
  - progressively larger suppression when going from pp to p-Pb and Pb-Pb
  - more re-scattering in larger collision system

- ***Φ/K*⁻**: no significant trend across systems

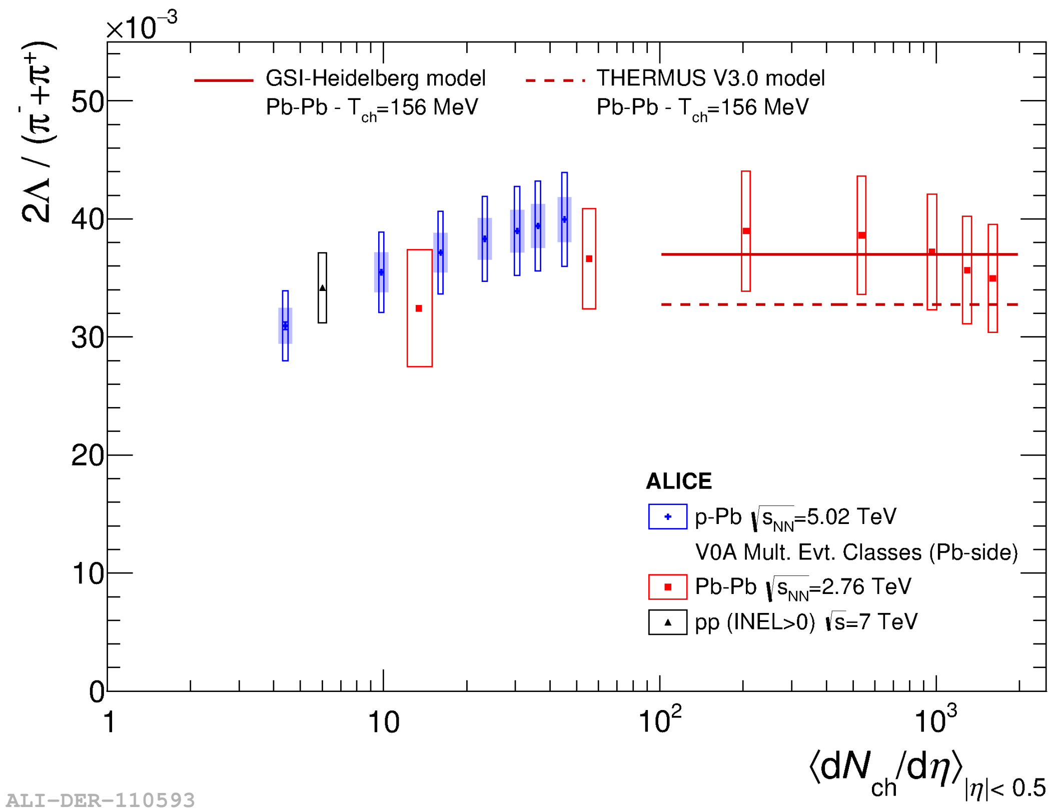
Particle yield ratios (Baryons)

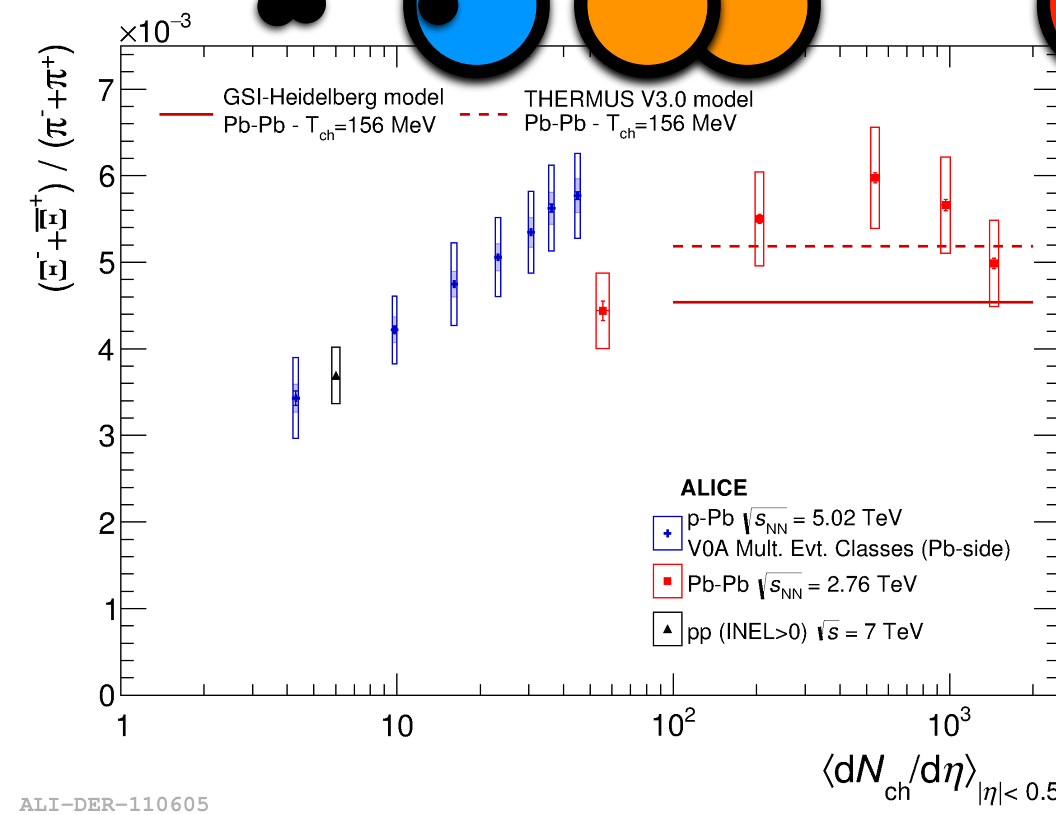


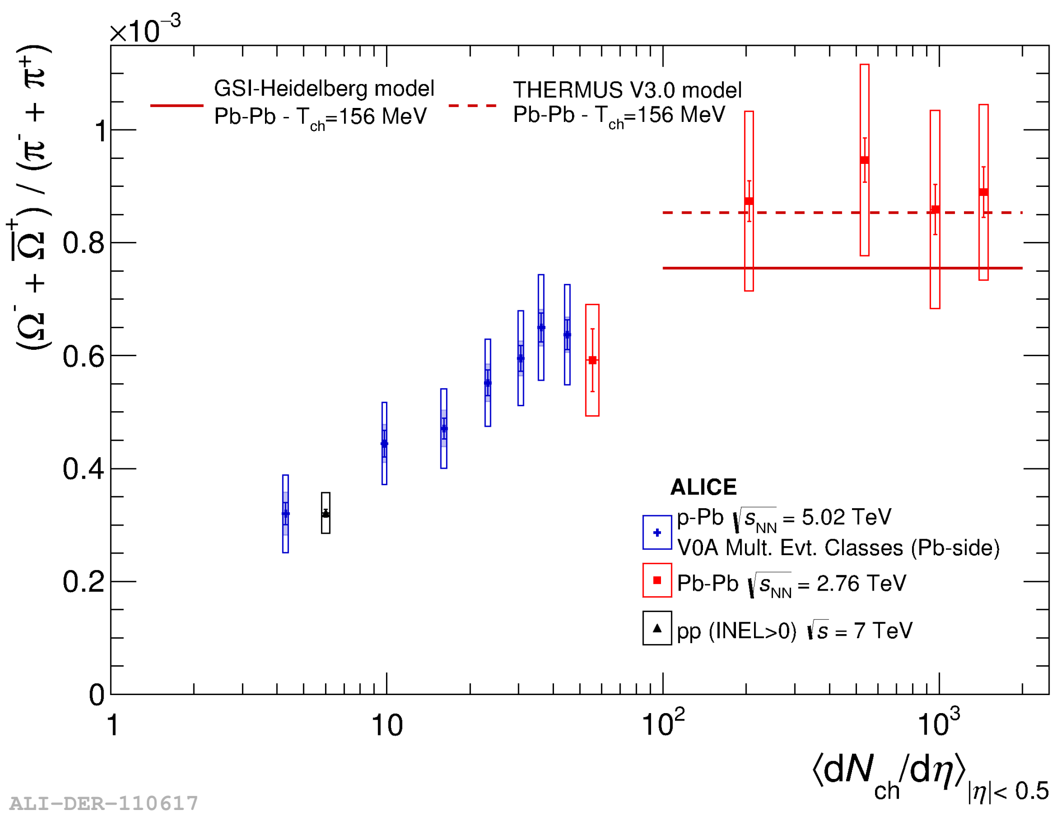


- Integrated particle ratios of **excited to ground-state hyperons** with **same strangeness content** are shown as function of <dN_{ch}/dη>
- Ratios are observed to be rather **independent** of the <dN_{ch}/dη>
- Results are compared with model predictions
  - **$\Sigma^{*\pm}/\Lambda$** : consistent with the values predicted by PYTHIA8
    DPMJET prediction is lower than experimental data
  - **Ξ^{*0}/Ξ**: higher than PYTHIA8 and DPMJET but lower than the thermal models

Strangeness production in **pp**, **p-Pb** and **Pb-Pb**



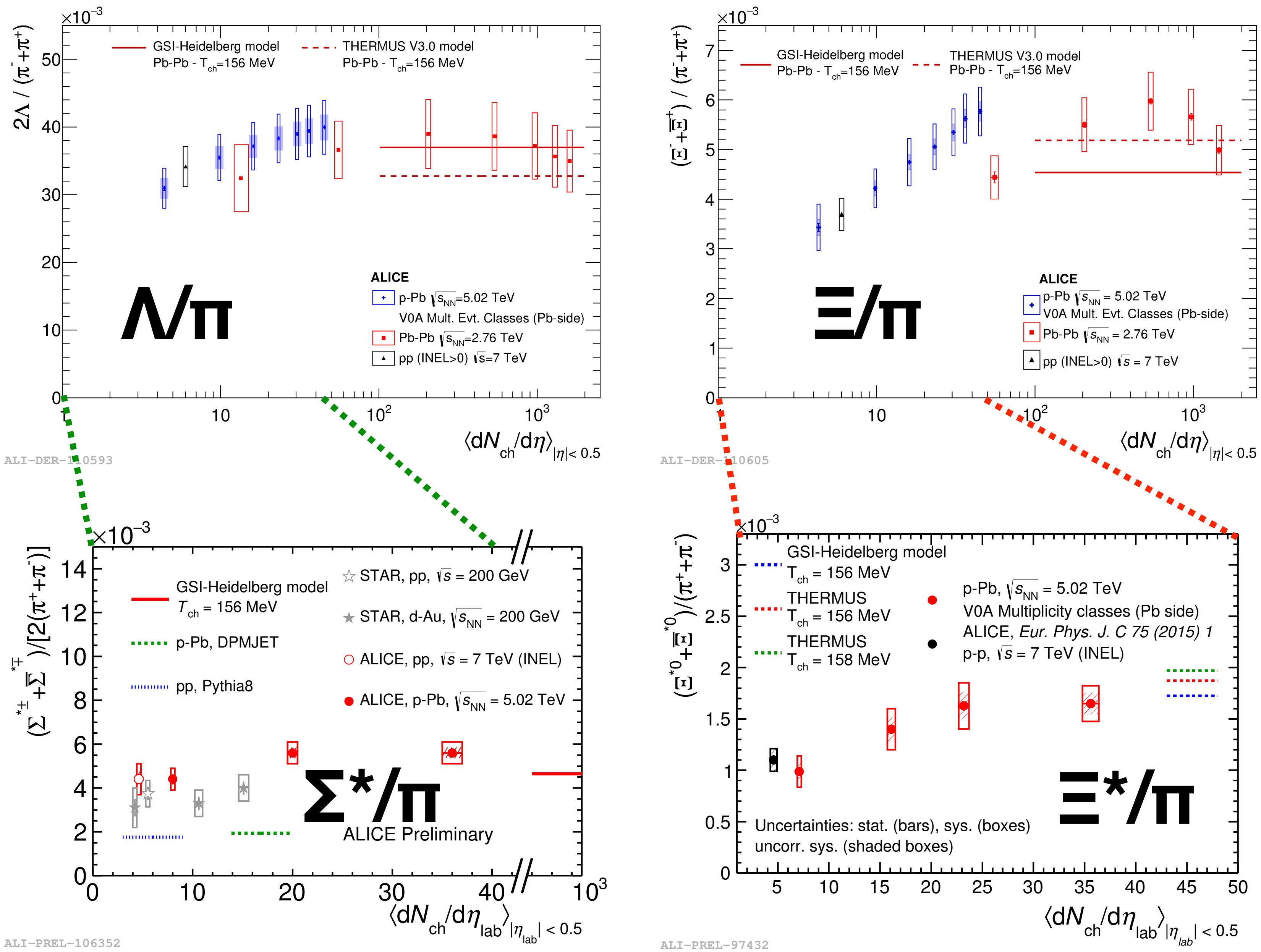




- **Strangeness enhancement**
  - one of the first proposed **QGP** signatures
- Clear **increase of strangeness production** from **pp** to **Pb-Pb**
- **p-Pb** results consistent with **pp** at low multiplicities and with central **Pb-Pb** at high multiplicities

Strangeness production in **pp** and **p-Pb**

Comparison with **Σ(1385)±** and **Ξ(1530)⁰** Resonance

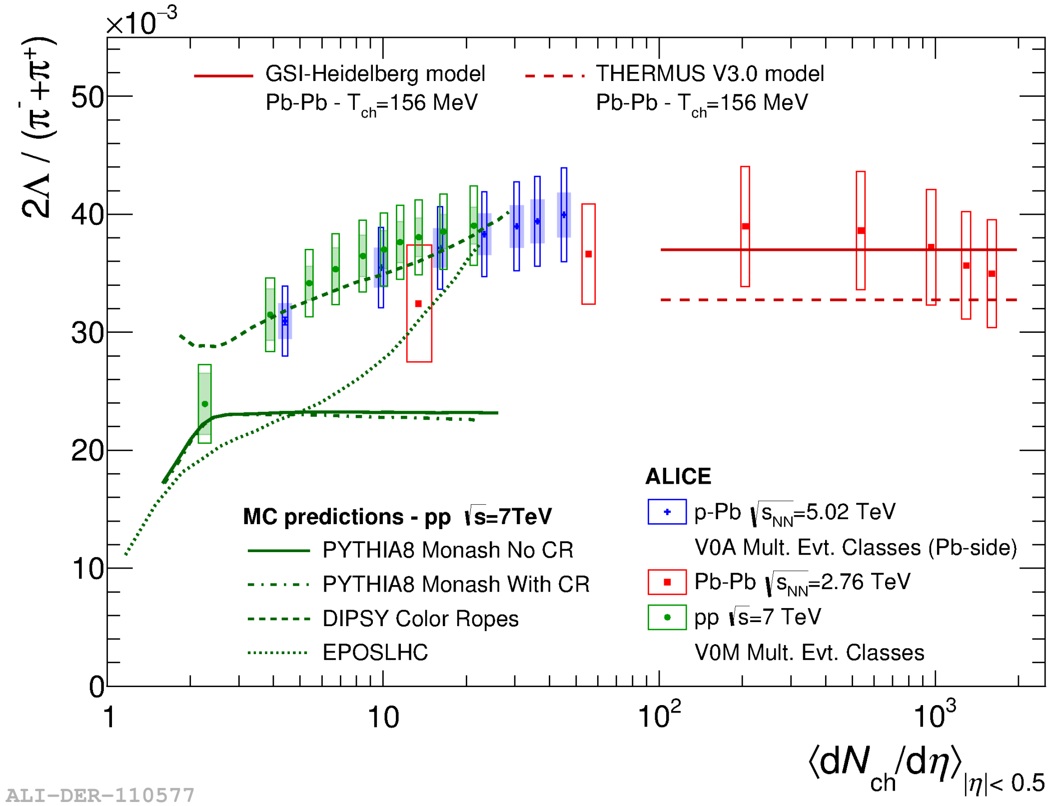


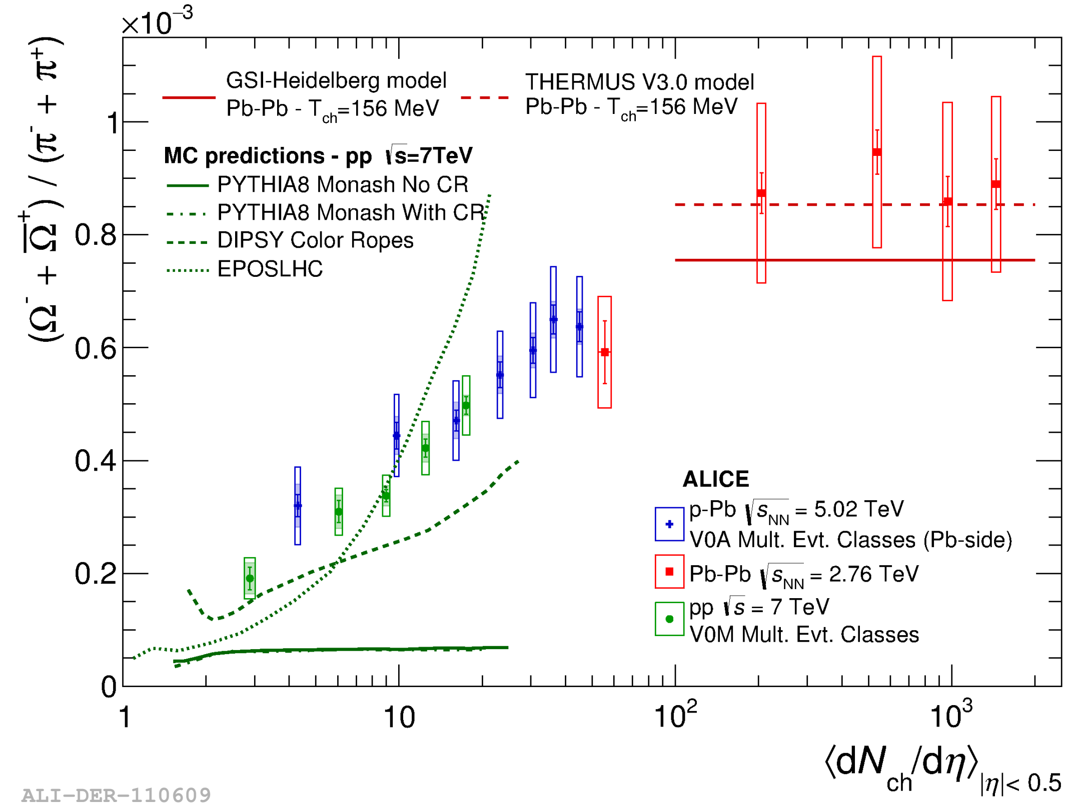
- Same strangeness contents
- Relative strangeness production increase with the multiplicity
- **$\Sigma^{*\pm}$**
  - similar mass with $\Xi(1320)^{\mp}$
  - Σ^*/π shows an increase compatible with Λ/π
- **Ξ^{*0}**
  - intermediate in mass between $\Xi(1320)^{\mp}$ and $\Omega(1680)^{\mp}$
  - Ξ^{*0}/π shows gradually increasing patterns

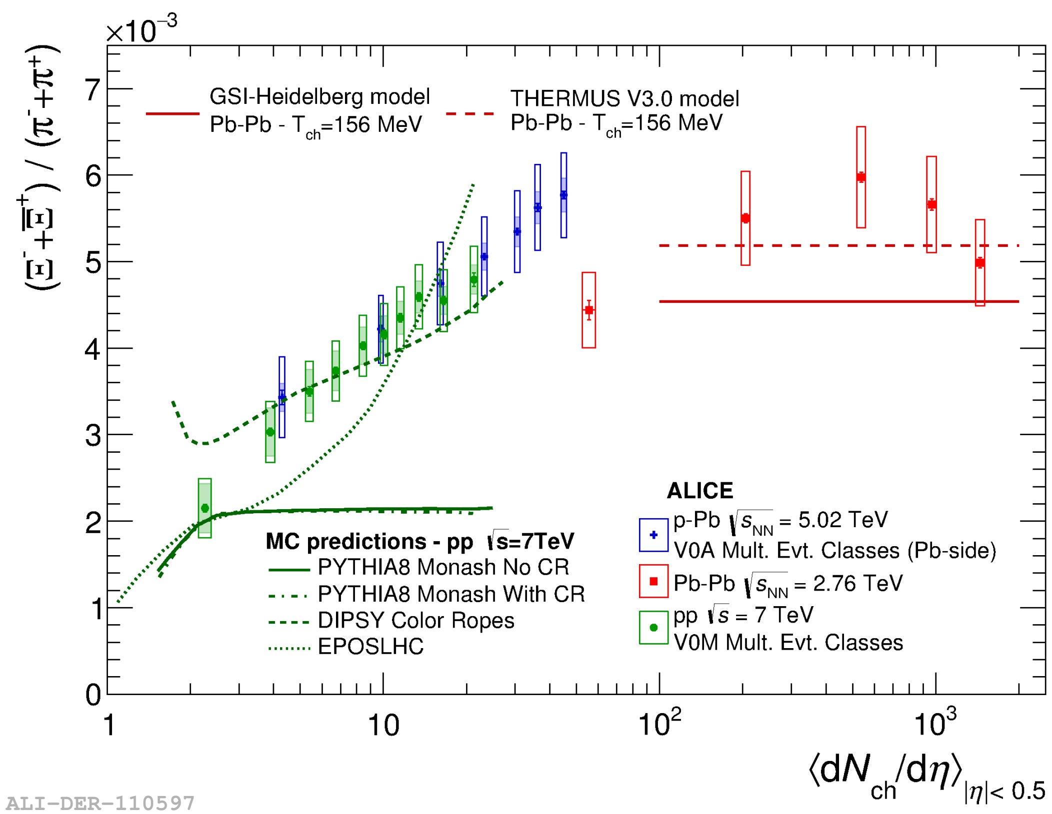
enhancement of hyperons is due to their strangeness content !

(not a mass effect)

Strangeness production in pp(multiplicity), p-Pb and Pb-Pb

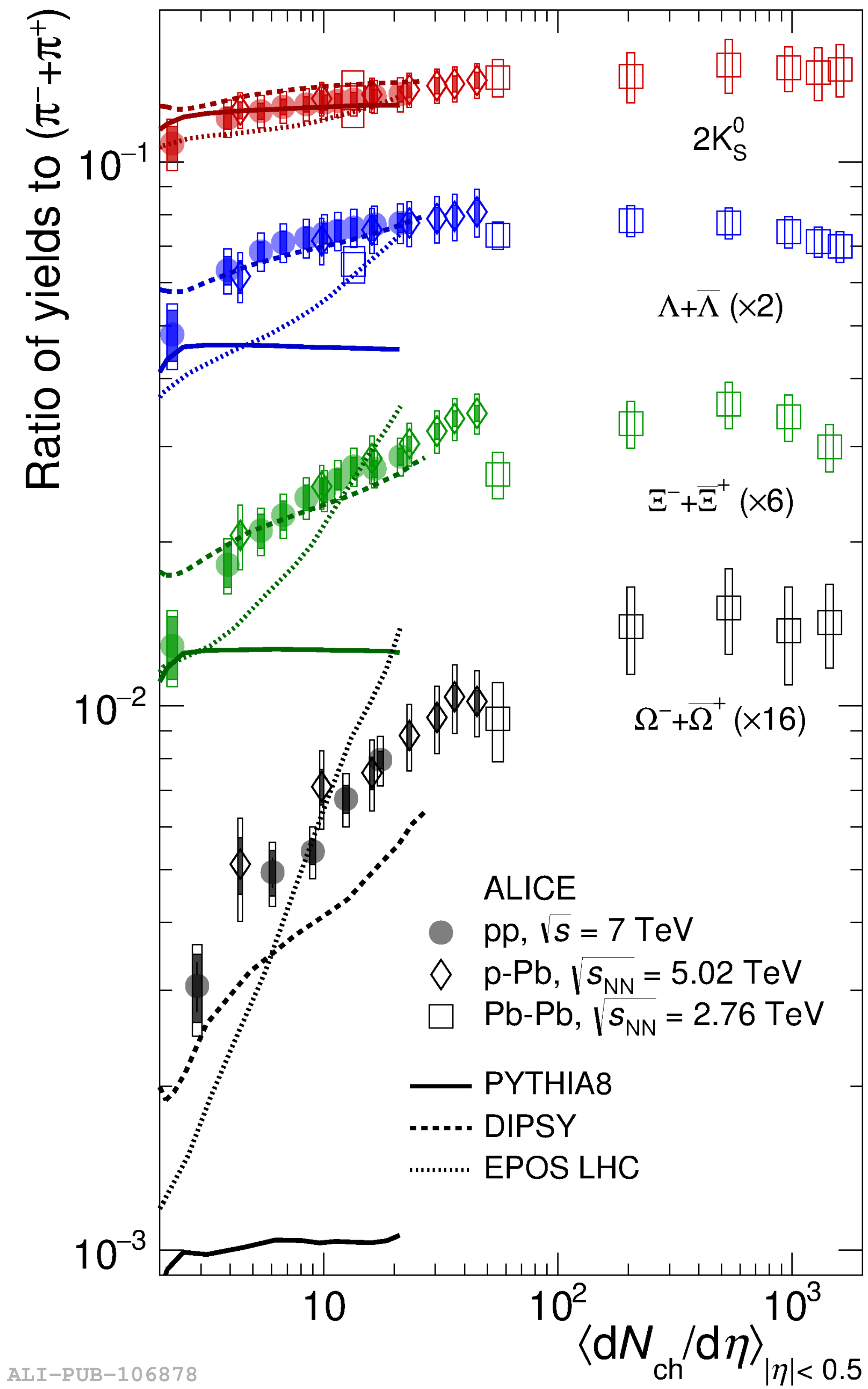






- Increase of (multi)strange production to π with **multiplicity in pp**
- **MC models** as DIPSY (colour ropes) and EPOS LHC exhibit a trend wth multiplicity but may still need tuning

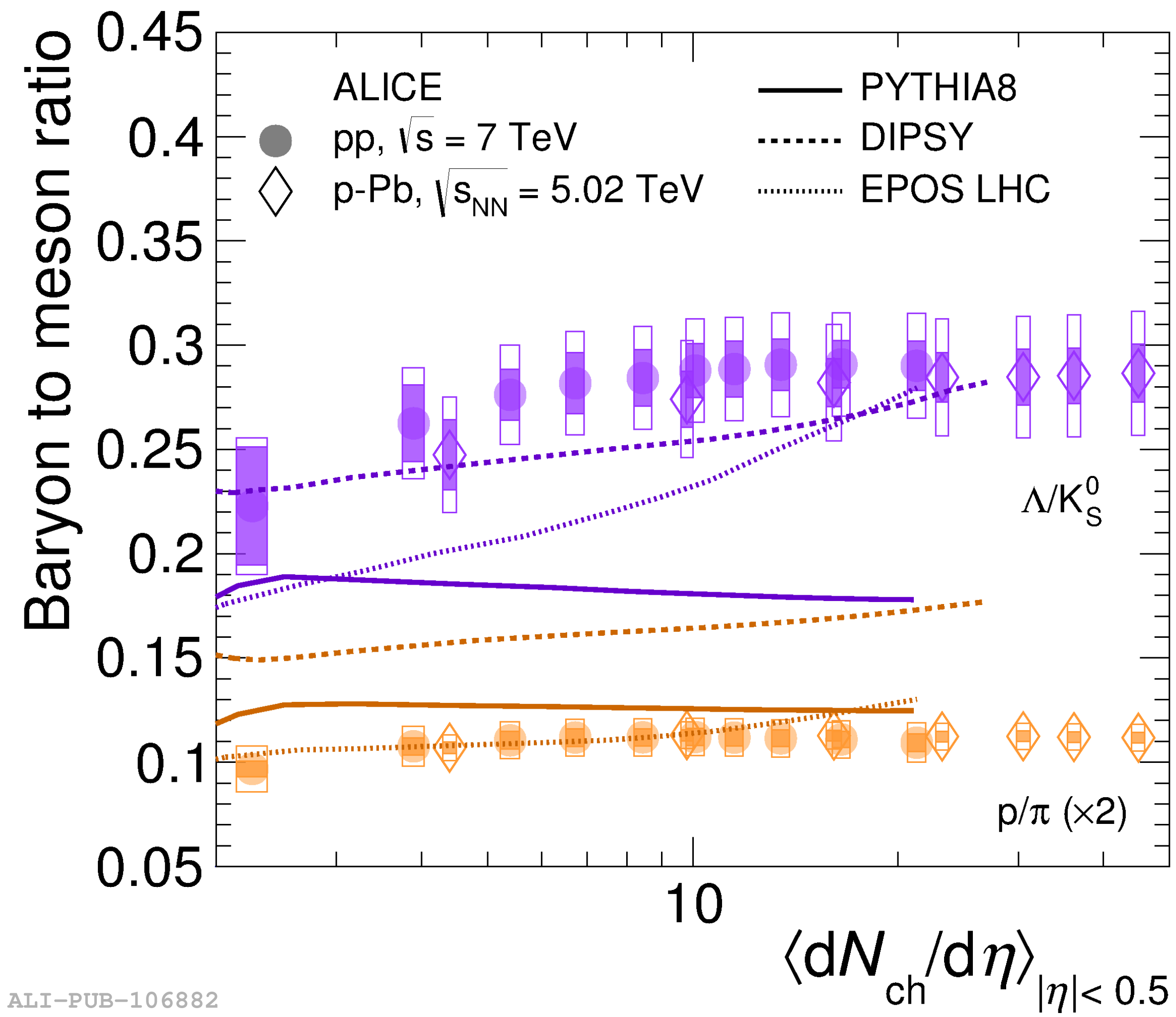
Strangeness production vs. multiplicity

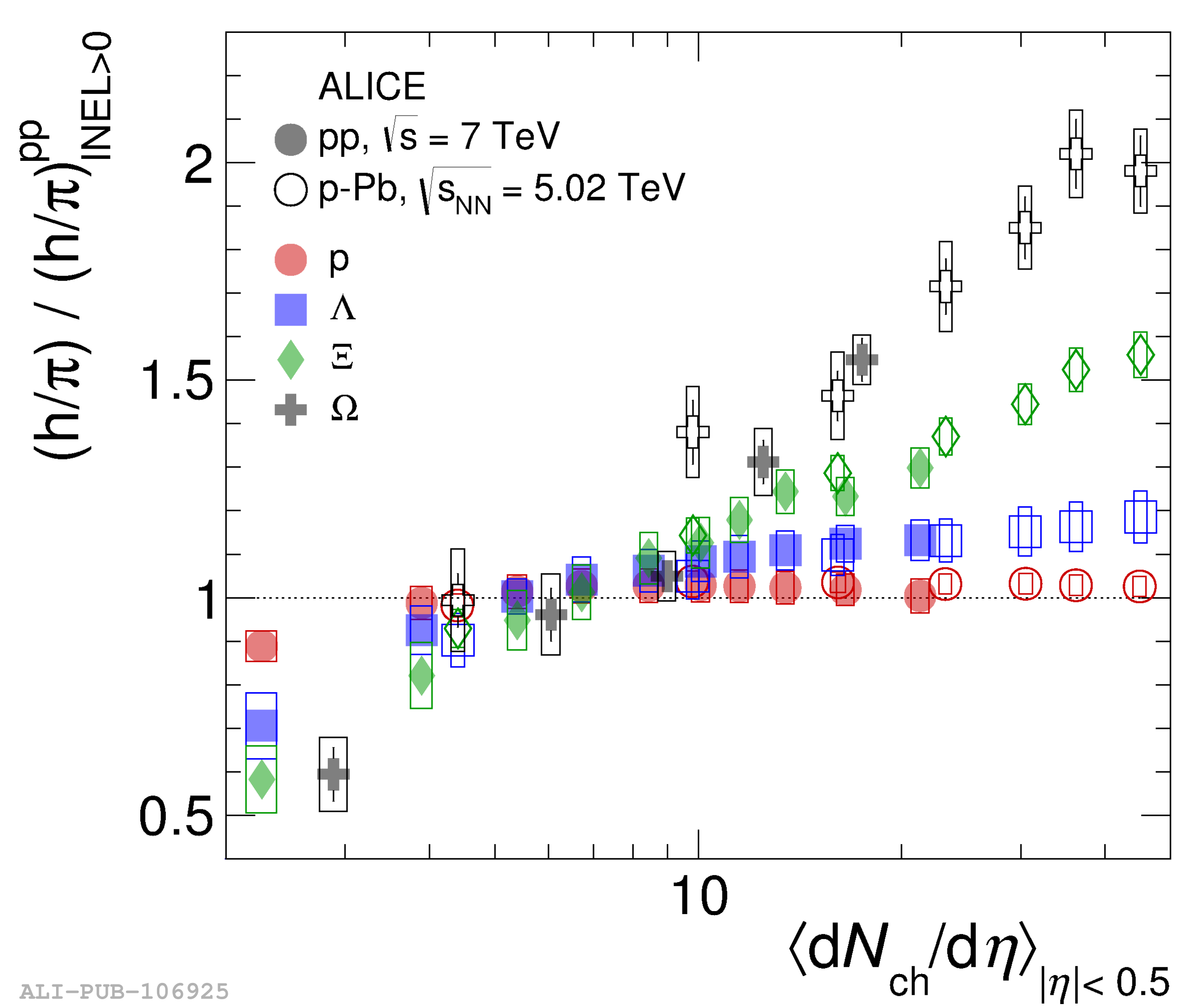


In pp collisions, **strange to non-strange integrated particle** ratios increasing the event multiplicity show

- Significant **enhancement** of strange and multi-strange particle production
- **Follow** the same trend observed in p-Pb collisions despite differences in initial state
- Particle ratios reach value **similar** to those observed in **central Pb-Pb** collisions
- MC predictions are **not able to** describe satisfactorily this behaviour

Strangeness production vs. multiplicity





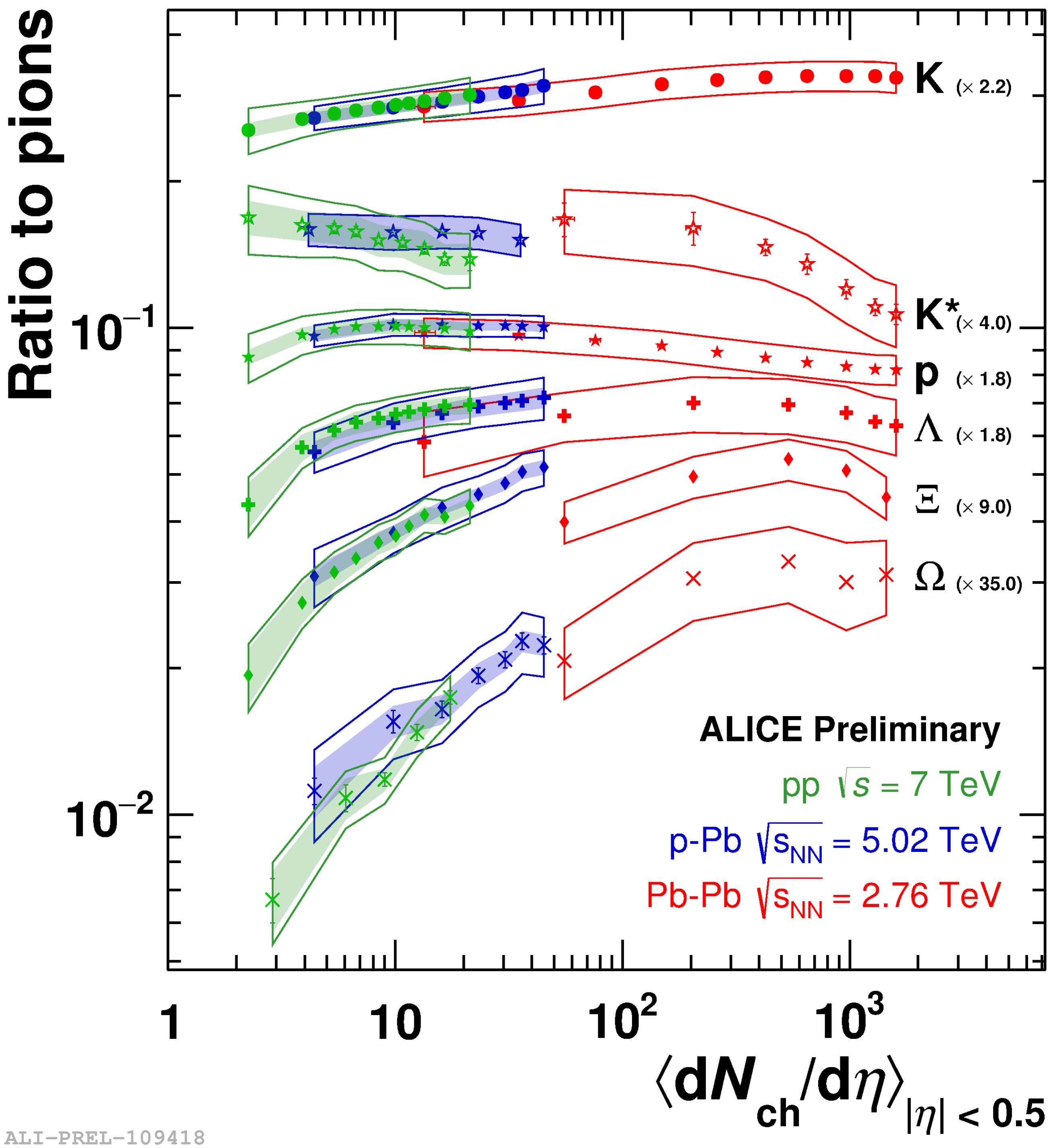
Λ/K^0_s and p/π rather constant vs. multiplicity

- No enhancement is observed for particles with same strange quark content
- Increase is not mass related but strangeness related

Normalised values to INEL>0 show

- No increase for p/π
- Hierarchy of the increase clearly associated with the strangeness content

K^{*0} production vs. multiplicity



Measurement of strange particle production in **pp**, **p-Pb** and **Pb-Pb** have revealed interesting and similar features across different systems

- **Small systems**
  - strangeness enhancement
  - relative decrease of K^{*0}
- **Toward central Pb-Pb**
  - strangeness abundance constant
  - relative decrease of K^{*0} in central collisions

Summary

Mean transverse momentum

- **Pb-Pb** collisions: K^{*0}, p, Φ have similar $<p_T>$
- **pp**,**p-Pb** collisions: hierarchy of mass ordering; rising faster with multiplicity than Pb-Pb, reach similar values at high multiplicity as central Pb-Pb

Integrated particle ratios

- Central **Pb-Pb**
  - suppression for ρ/π, K^{*0}/K (re-scattering is dominant effect)
  - Φ not suppressed
  - strangeness abundance constant

- **p-Pb** collisions
  - K^{*0}/K, Φ/K ratios follow trend from pp to peripheral Pb-Pb collisions
  - $\Sigma^{*\pm}/\Lambda$ and Ξ^{*0}/Ξ show flat behaviour over the multiplicity range covered by pp and p-Pb collisions (no dominant effect of re-scattering or regeneration)
  - hadron/π ratios : strangeness enhancement (strangeness content related)

- **pp** collisions
  - K^{*0}/K suppressed at high multiplicity

Backup

- INEL: inelastic events(Non+Single+DoubleDiffraction+CD…)
- NSD: ND+DD(to ignore large uncertainty from SD)
- INEL>0 : inelastic events with at least one charged particle in $|\eta| < 1$