Measurement of identified hadron production as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV with the ALICE experiment

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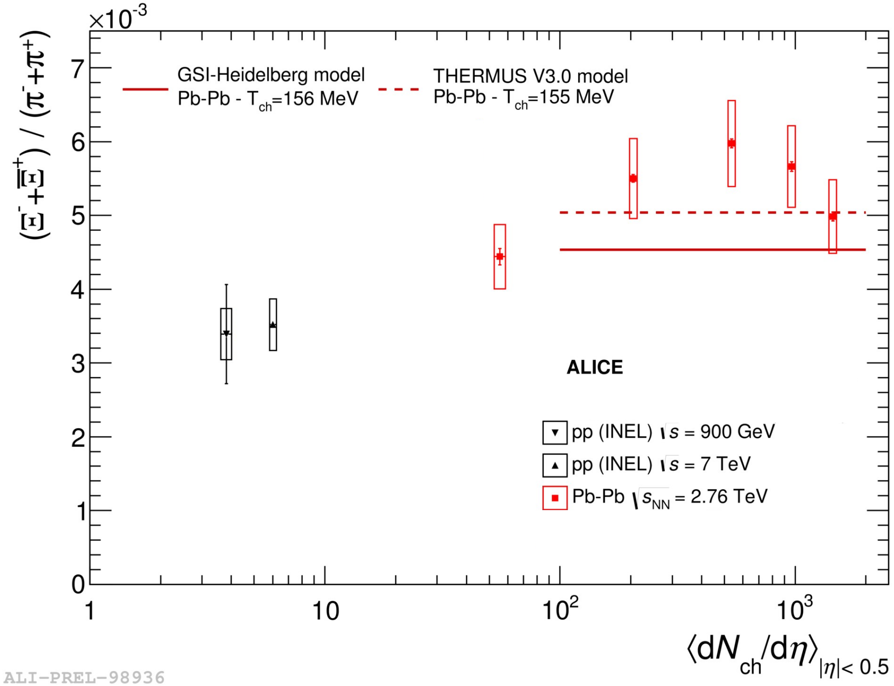


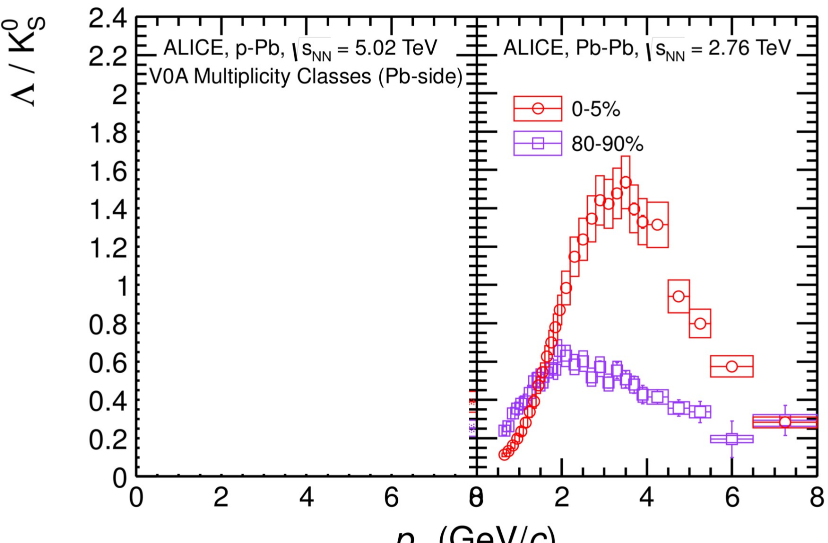
ALI-PREL-98936

pp: Eur. Phys. J. C (2011) 71: 1594;
Physics Letters B 712 (2012) 309–318

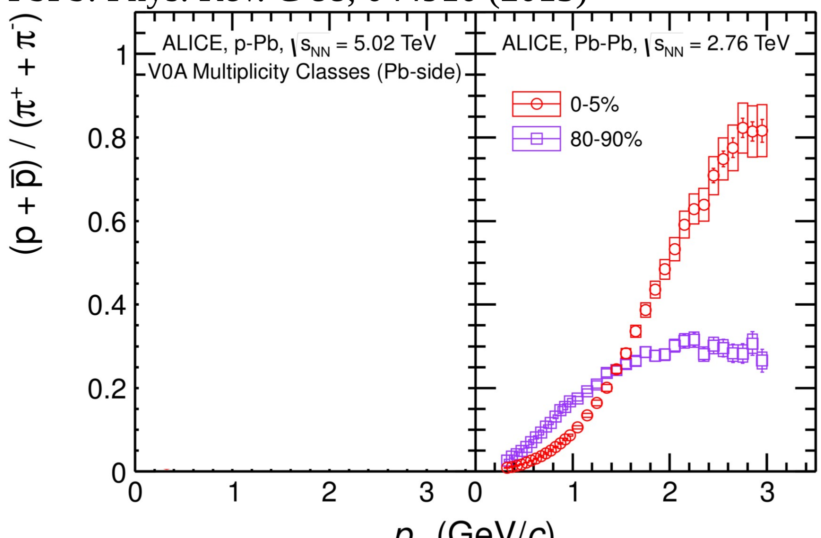
Detailed studies of particle production in A-A:

- Strangeness enhancement / canonical suppression in pp
- Baryon/meson ratio enhanced at intermediate p_T

PbPb: Phys. Rev. C 88, 044910 (2013)

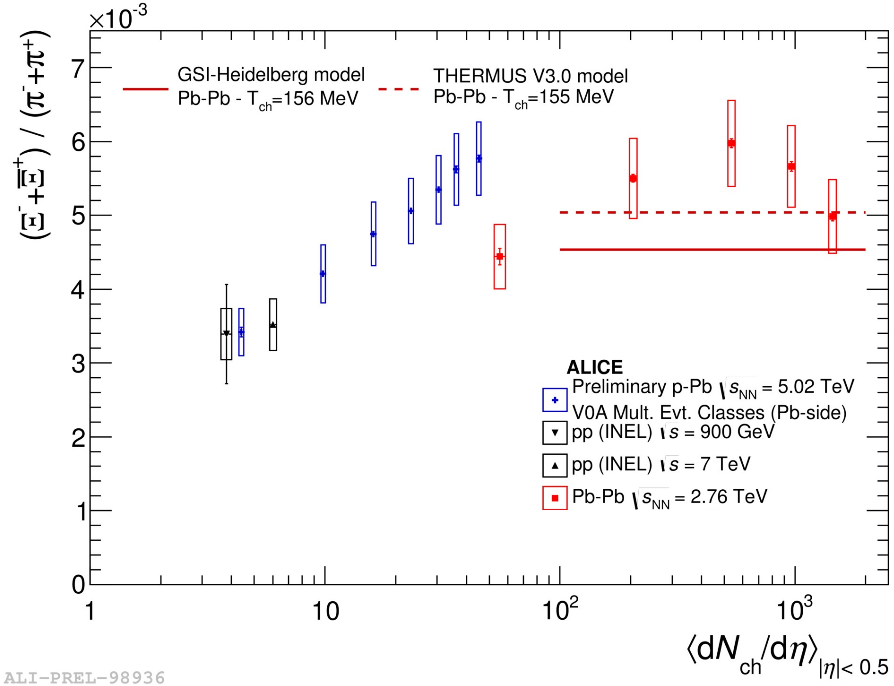


ALI-PUB-58065



ALI-PUB-58061

From Pb-Pb … via p-Pb ...



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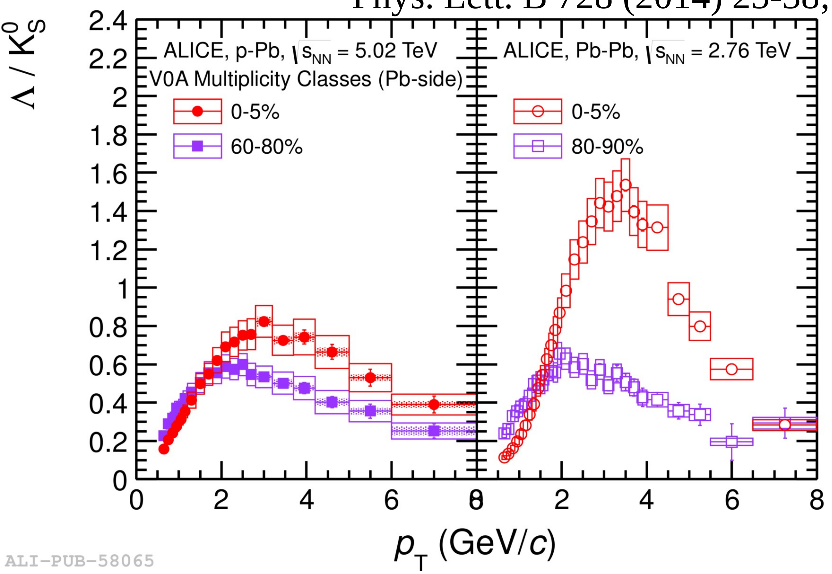
More recently similar studies in p-A:

- Progressive release of canonical suppression?
- Λ/K^0_S and p/π qualitatively similar to A-A

Phys. Lett. B 728 (2014) 25-38; PbPb: Phys. Rev. C 88, 044910 (2013)



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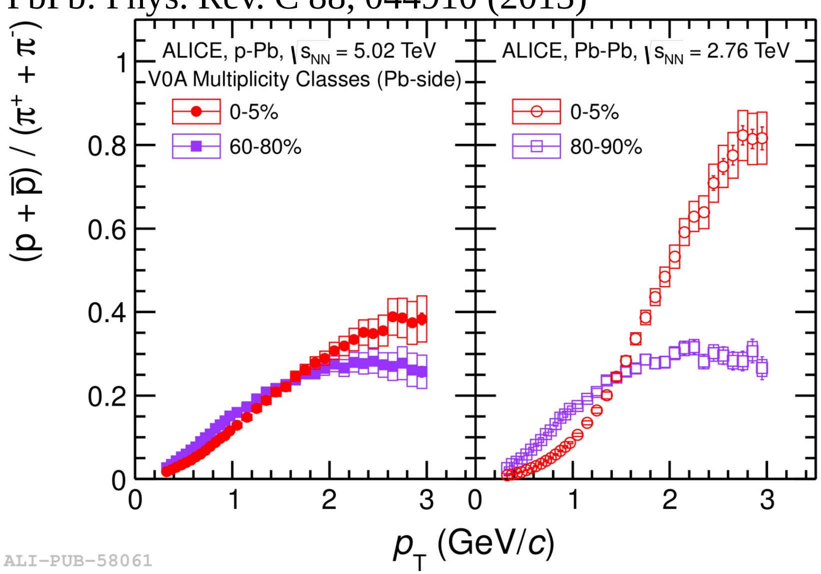
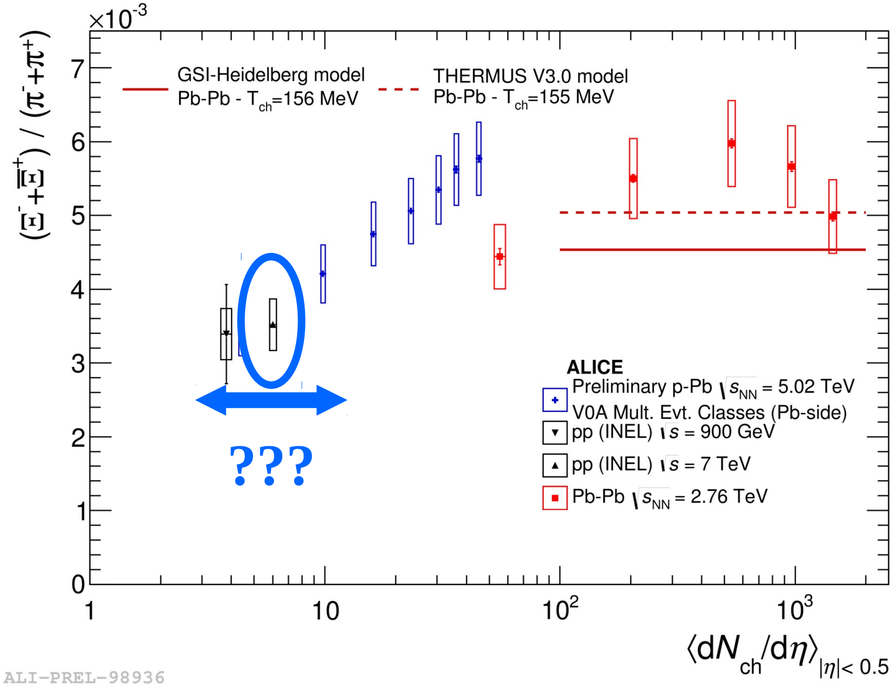


ALI-PUB-58061

From Pb-Pb … via p-Pb … back to the roots: pp



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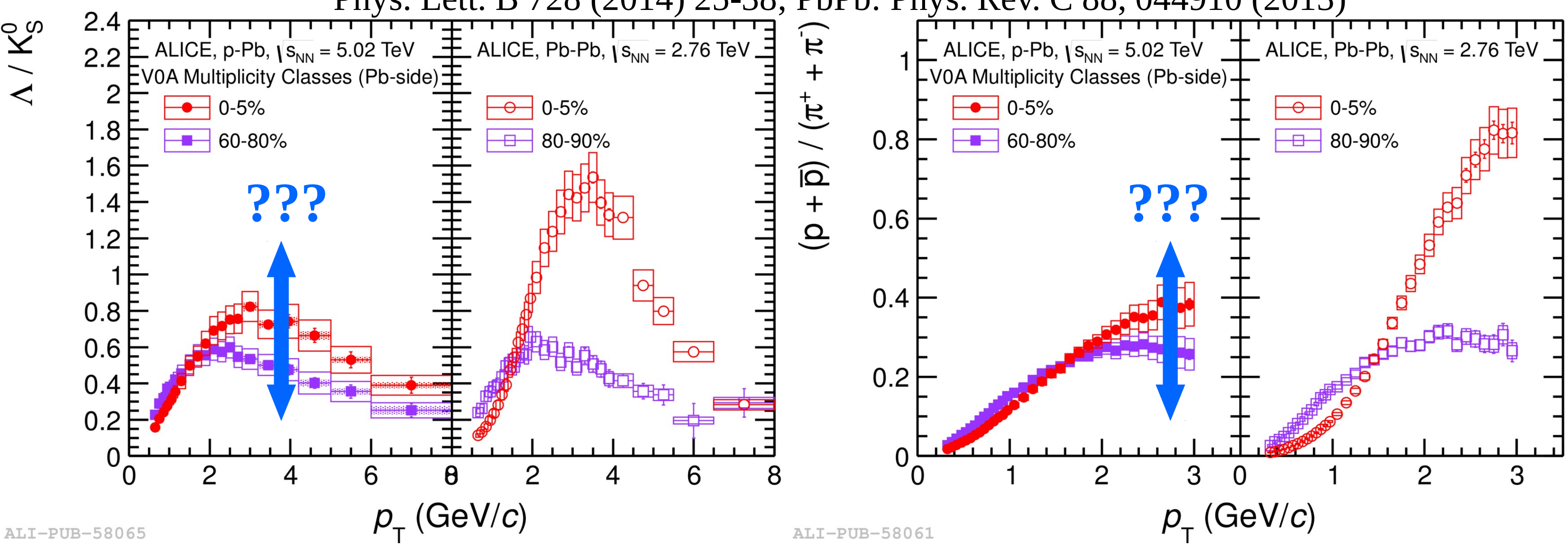
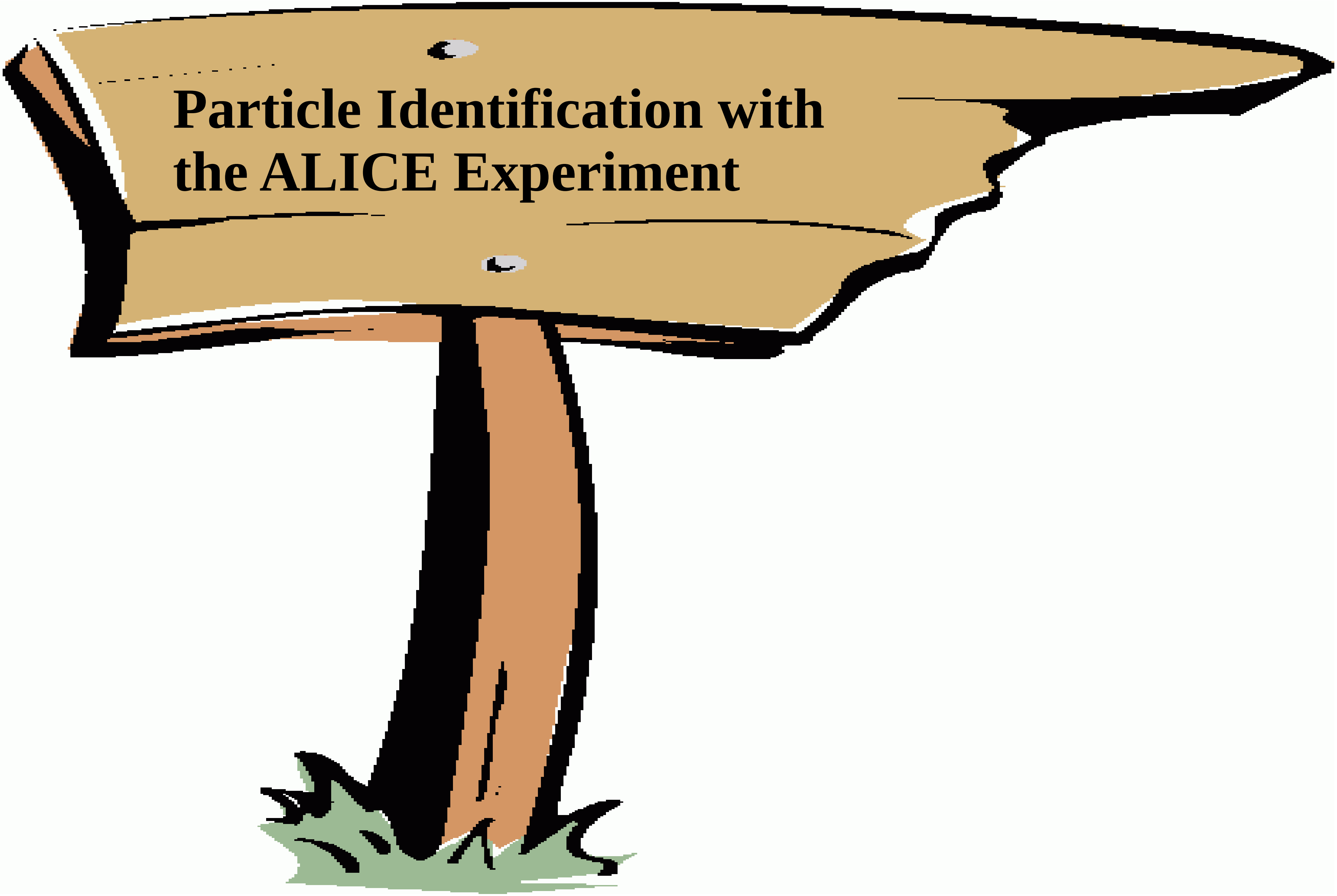


What happens in pp?


Particle Identification with
the ALICE Experiment

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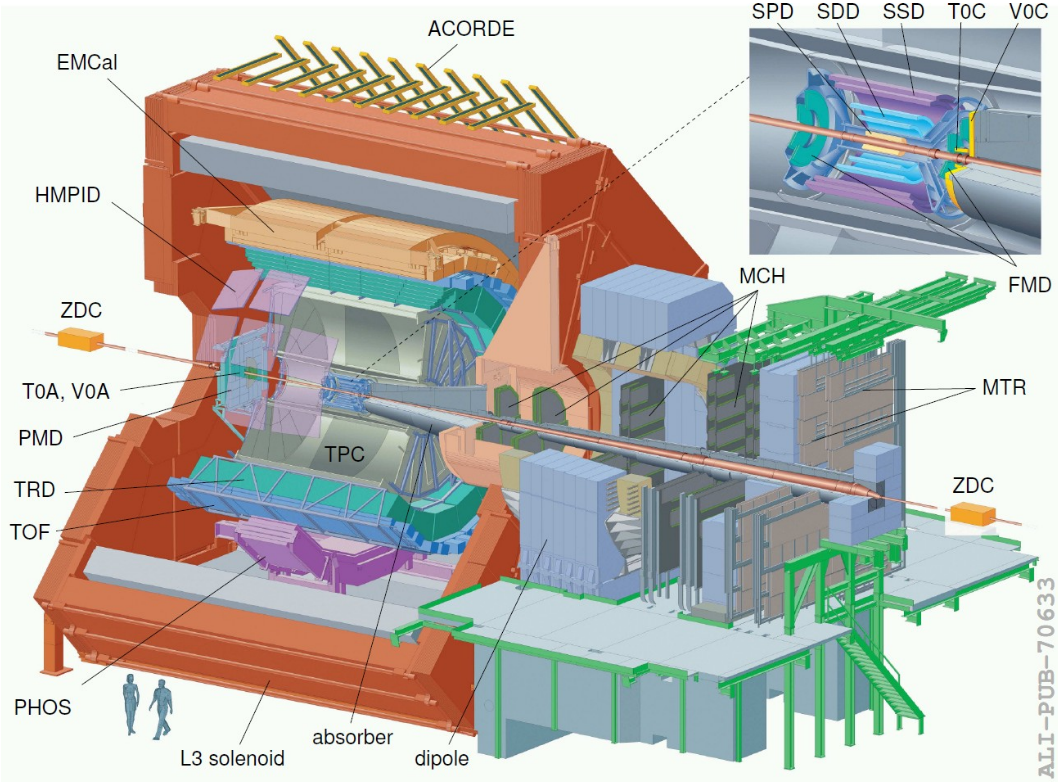

Detectors used in this analysis:

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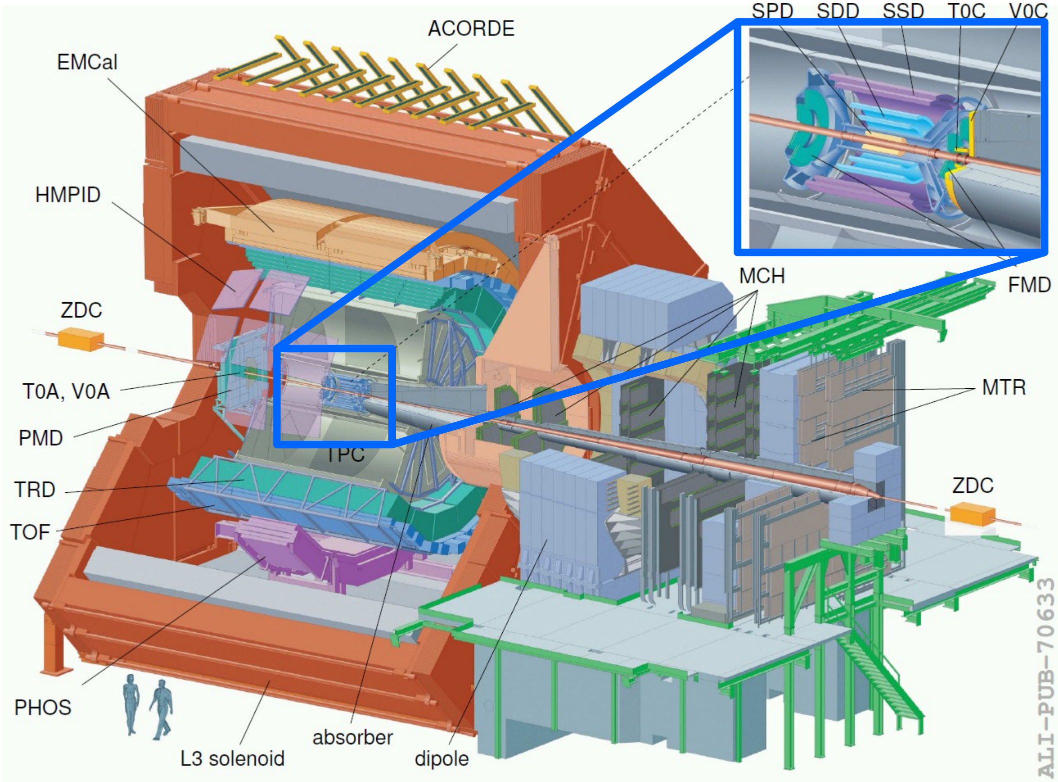

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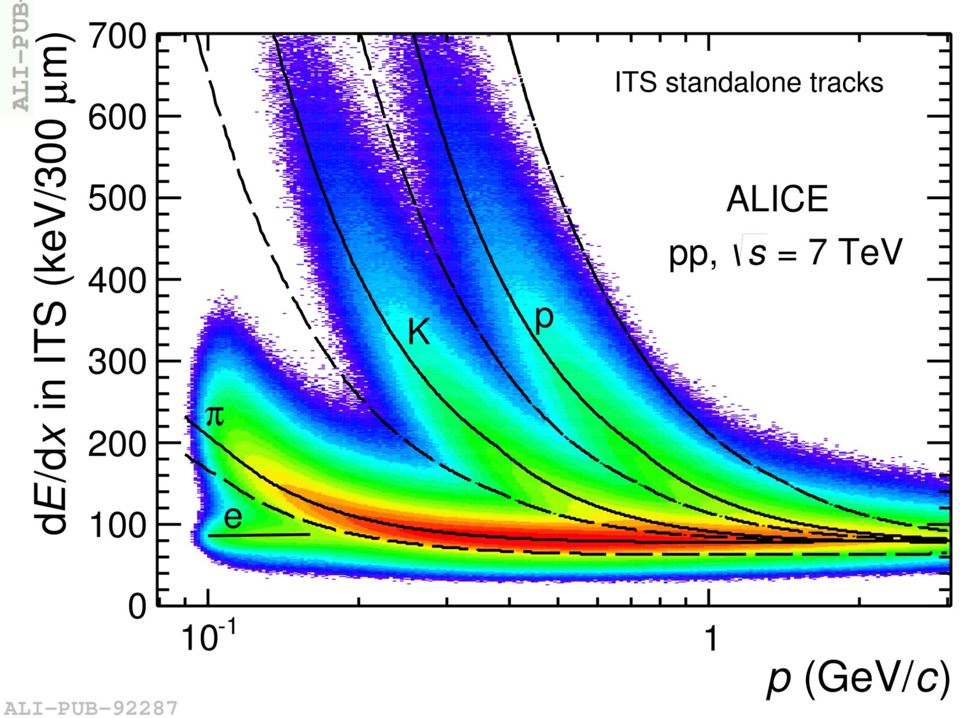
→ trigger, tracking, vertex, PID



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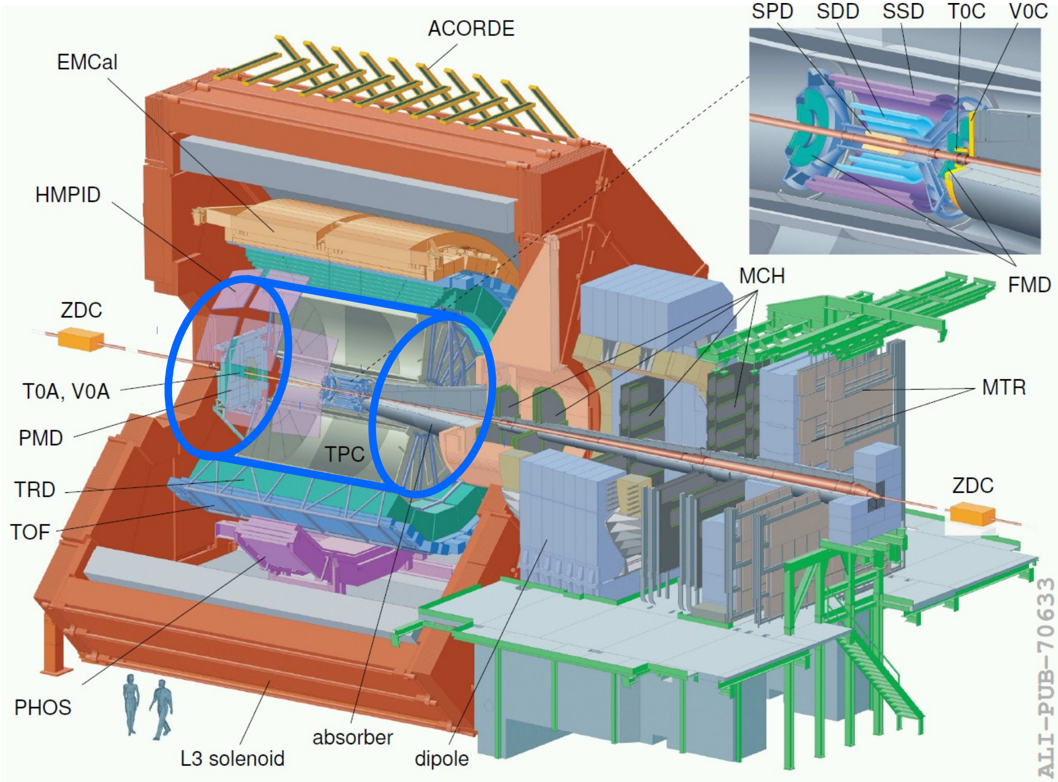

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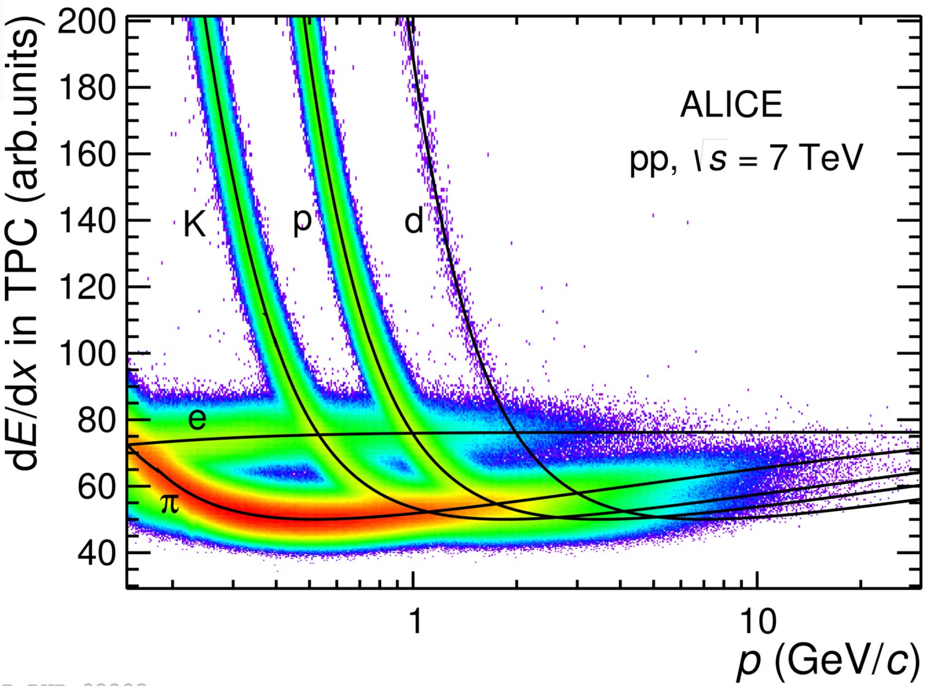

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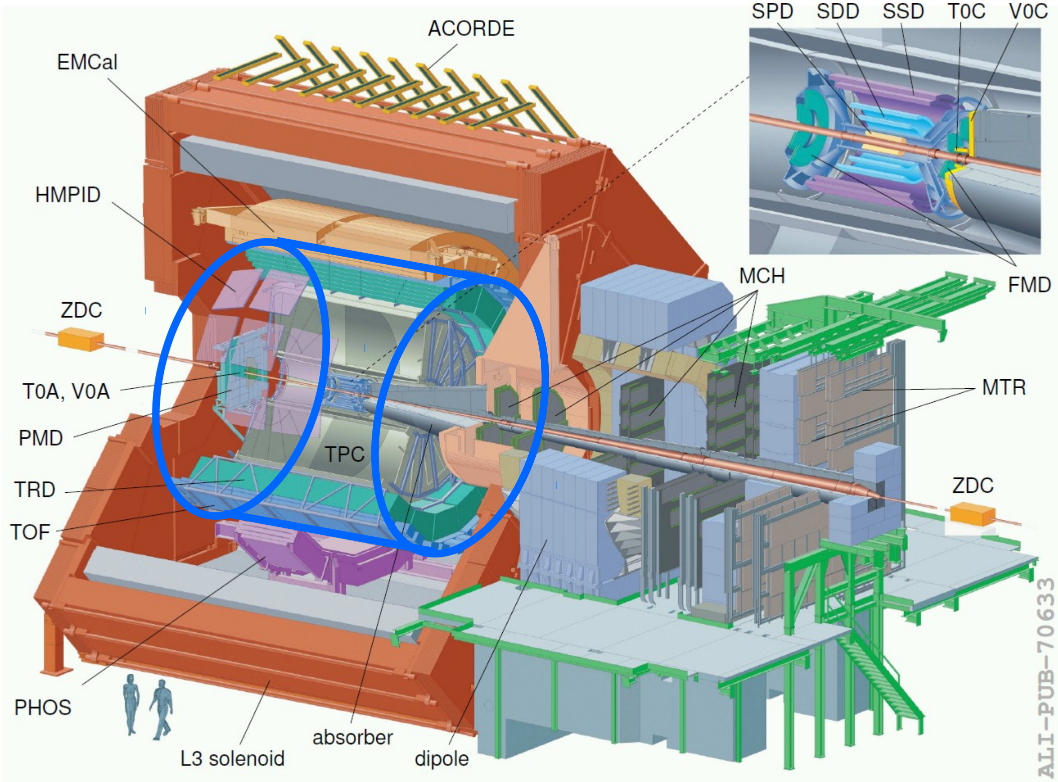

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<u>T</u>ime <u>O</u>f <u>F</u>light Detector (|η| < 0.9)
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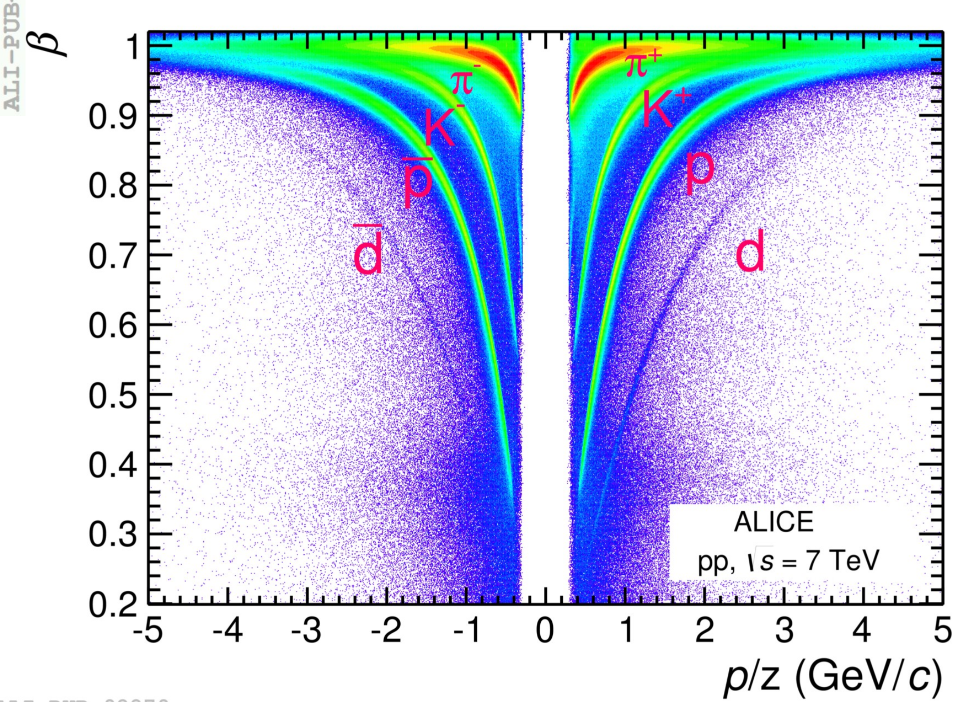
→ PID



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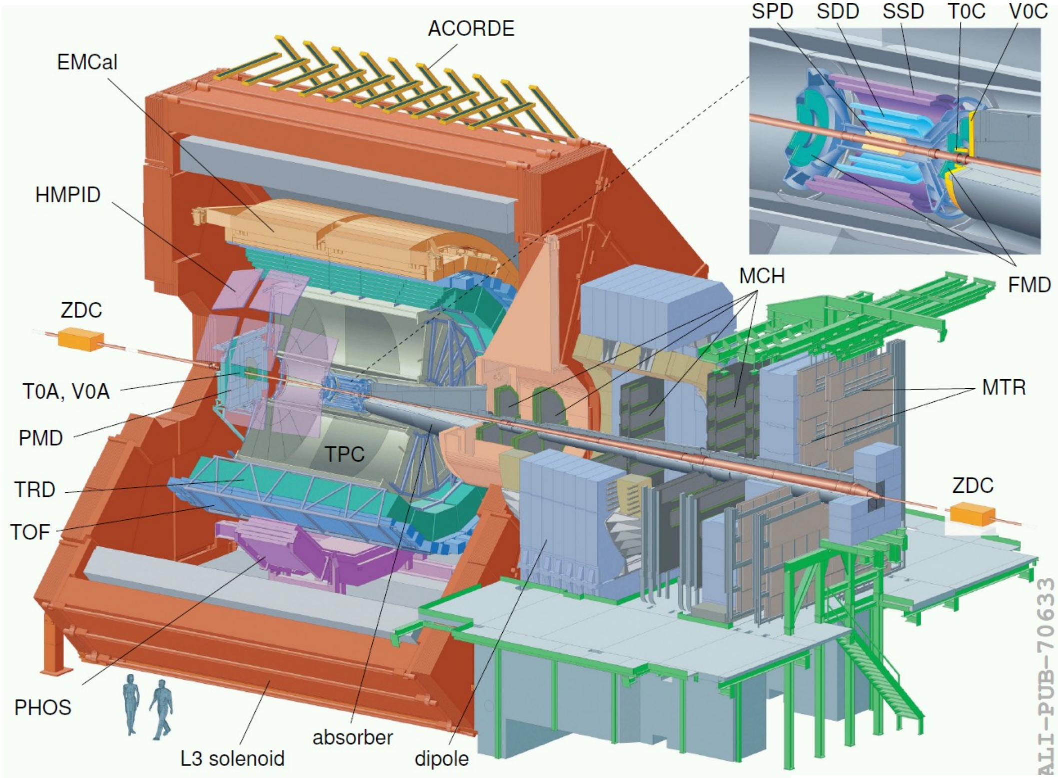

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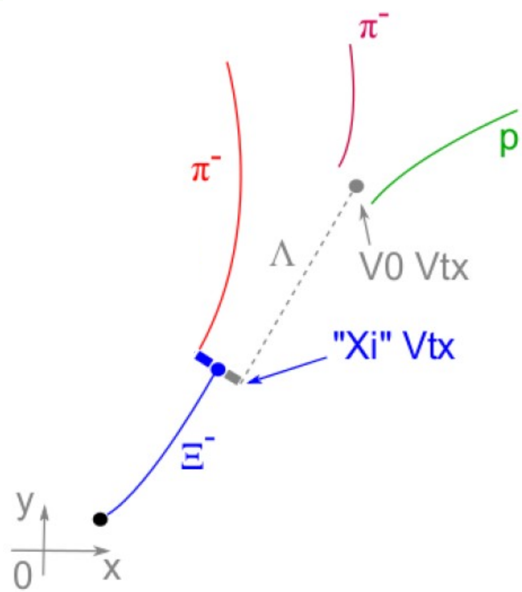
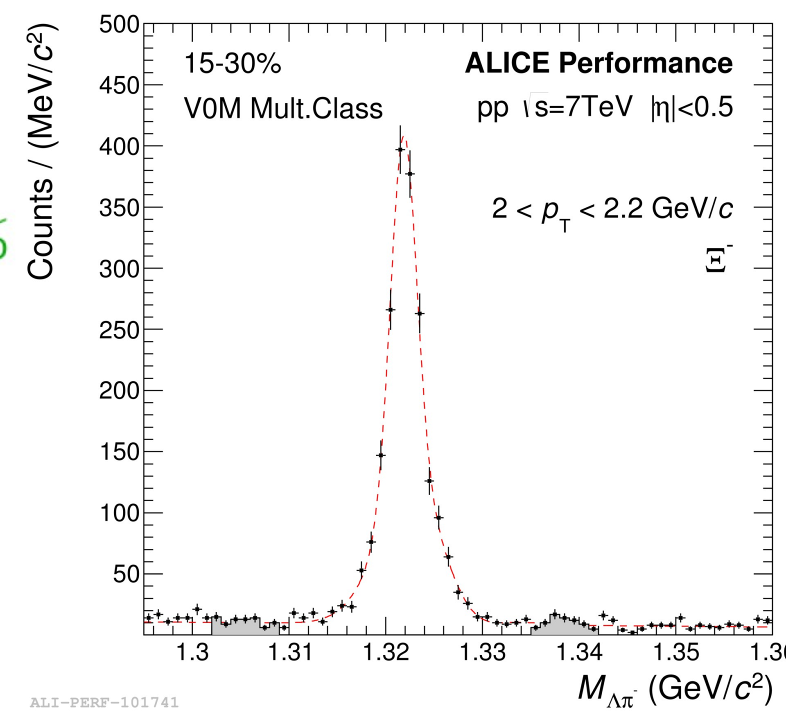
Strange particle identification:

- Topological cuts tuned for optimal S/B

- PID for all the 2 (3) V0 (cascade) daughters via TPC

- Yields extracted via bin-counting technique





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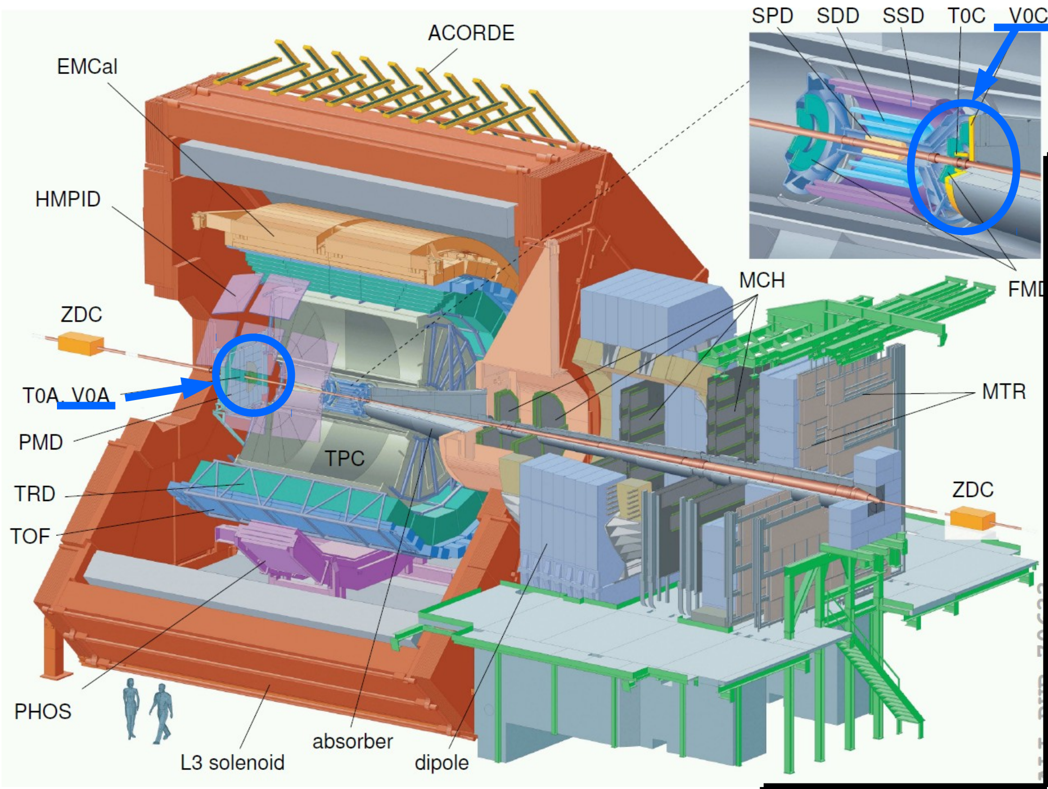

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V0 (2.8 < η < 5.1 (V0A) & -3.7 < η < -1.7 (V0C))
plastic scintillators
→ trigger, beam gas rejection, multiplicity estimate

Strange particle identification:

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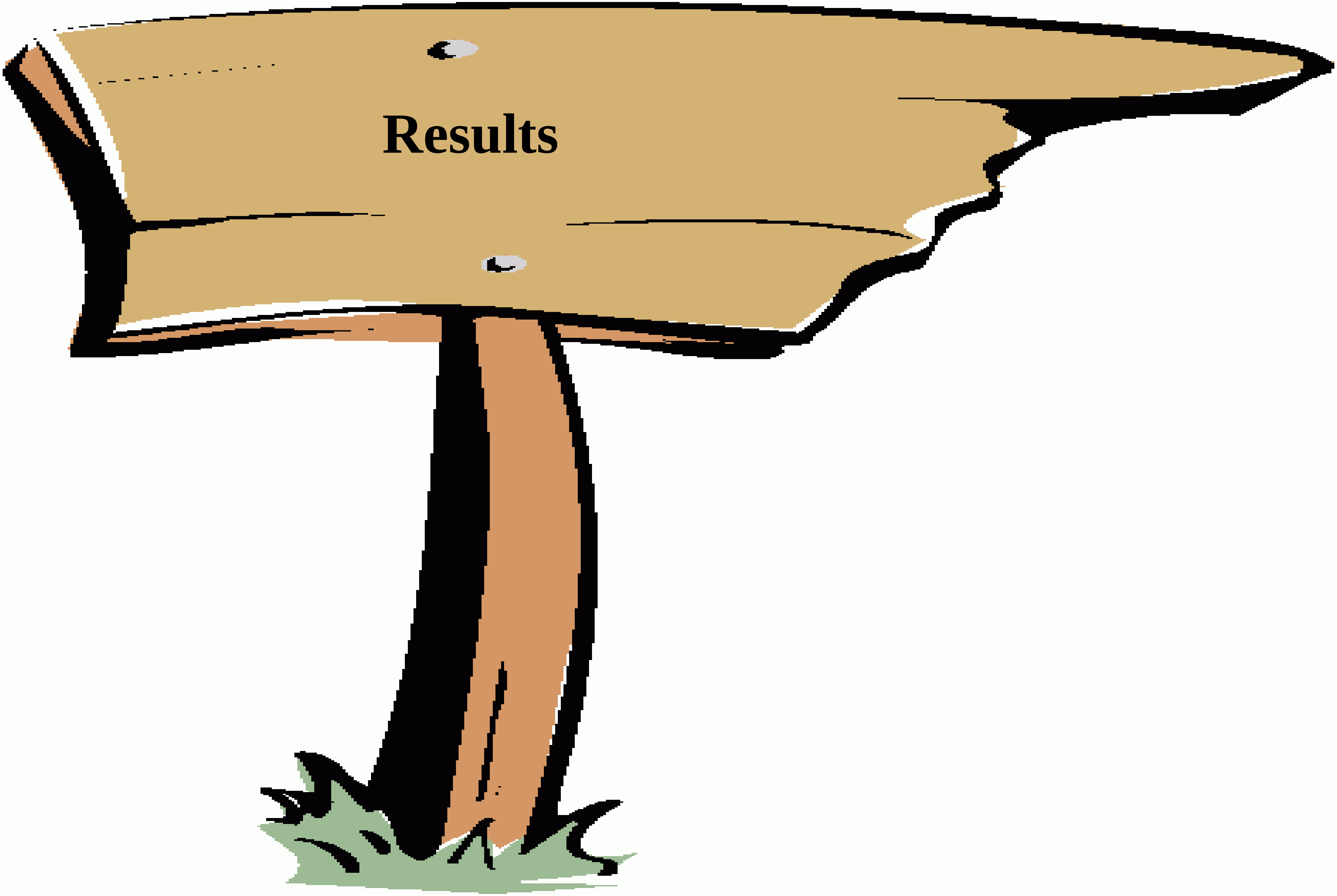
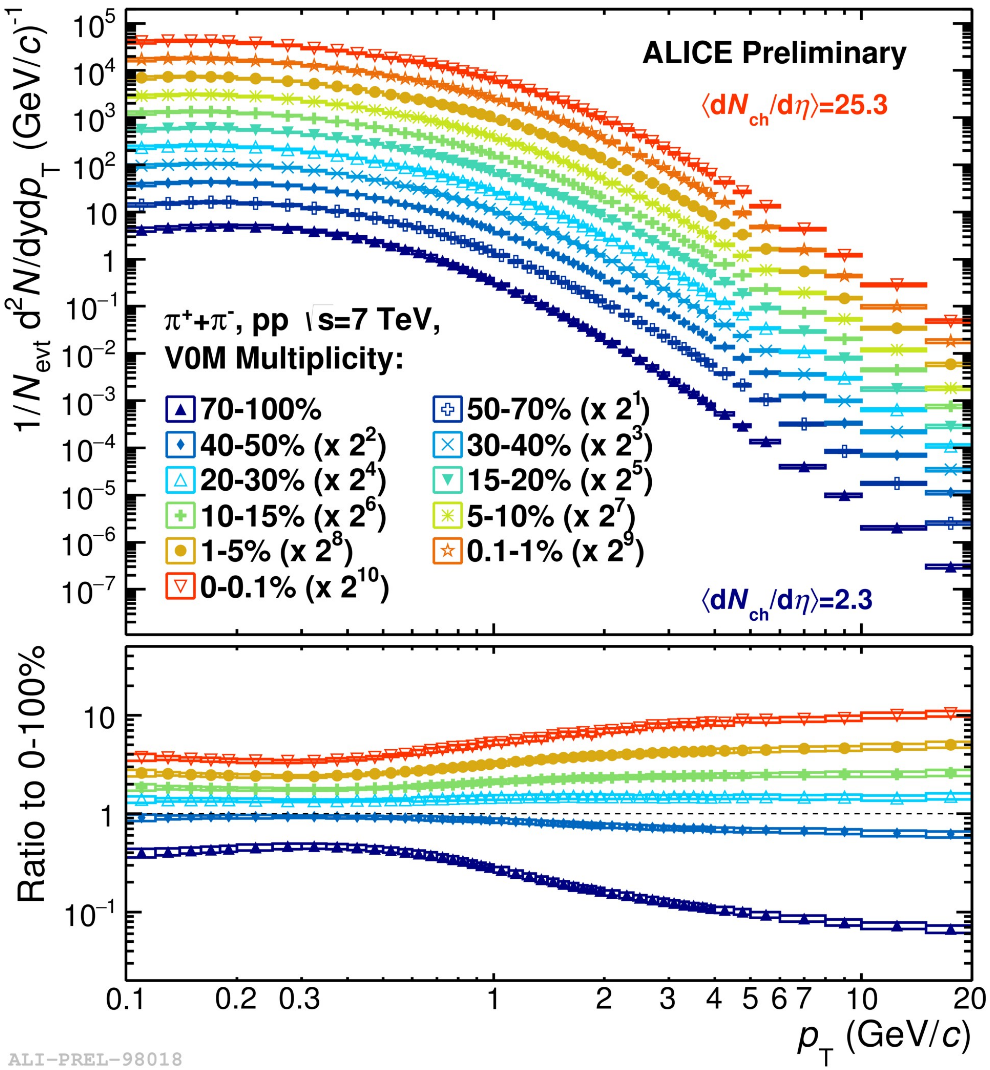
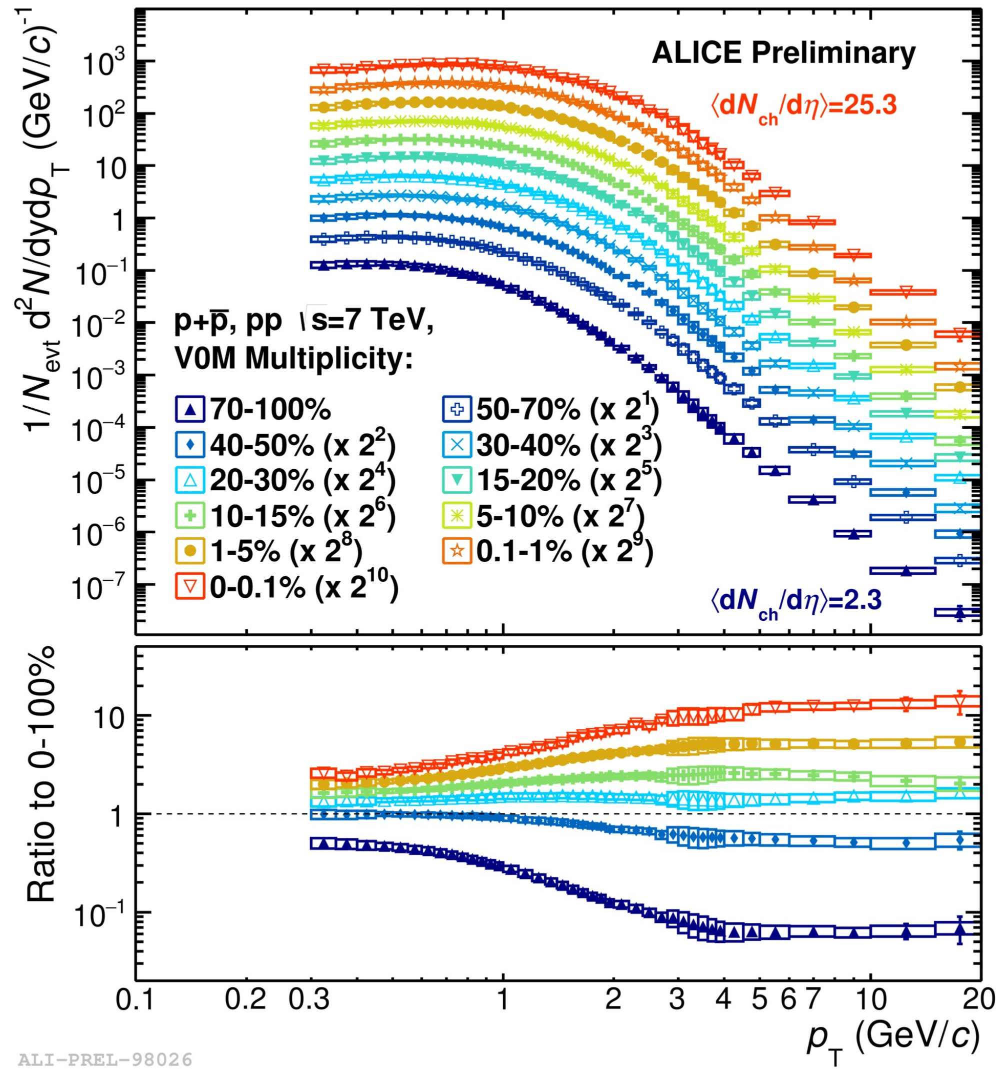
Multiplicity estimation procedure:

- Use forward rapidity estimator V0M (sum of amplitudes in V0A and V0C)
- Select multiplicity within INEL>0 event class
- Each V0M multiplicity class is related to the average of the charged track distribution in |η| < 0.5: $\langle dN_{ch}/d\eta \rangle$


Results

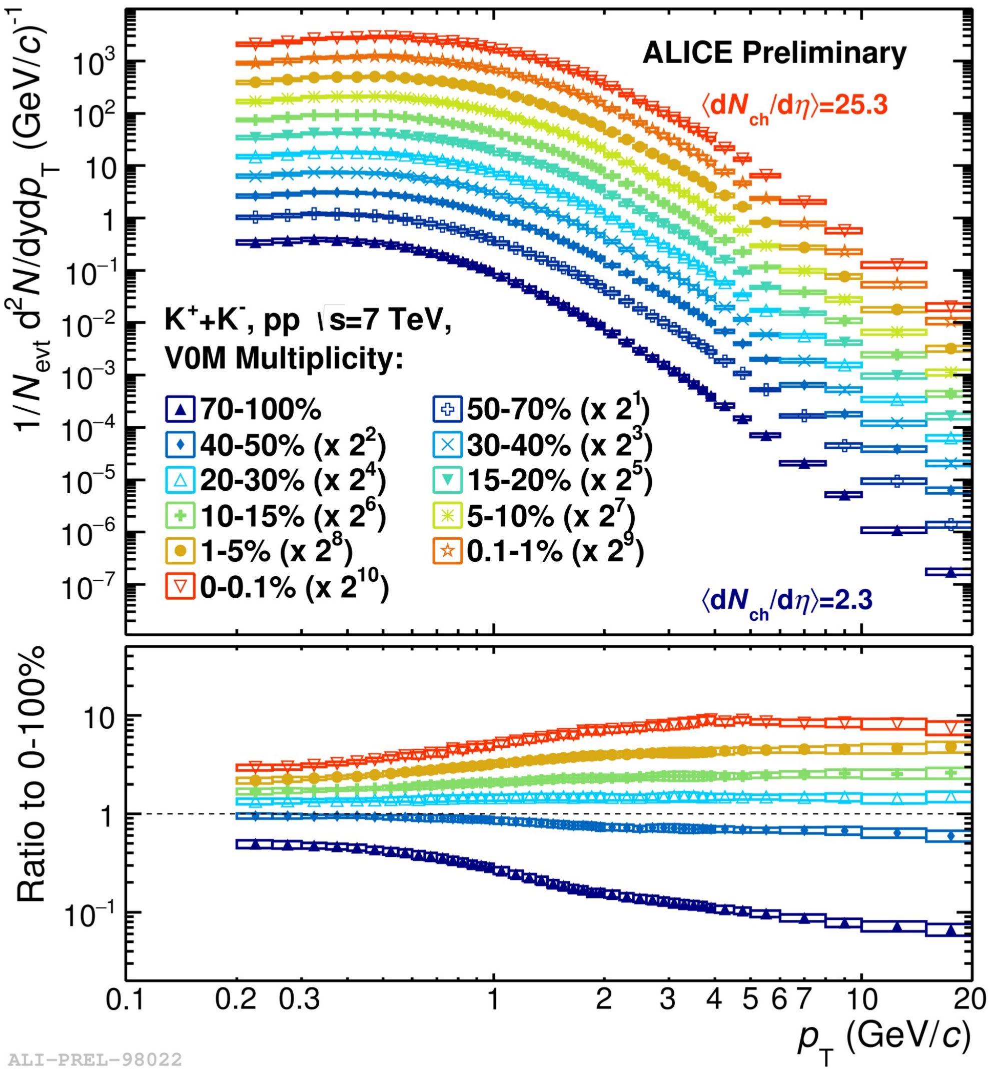
Tranverse Momentum Spectra (I): π and p

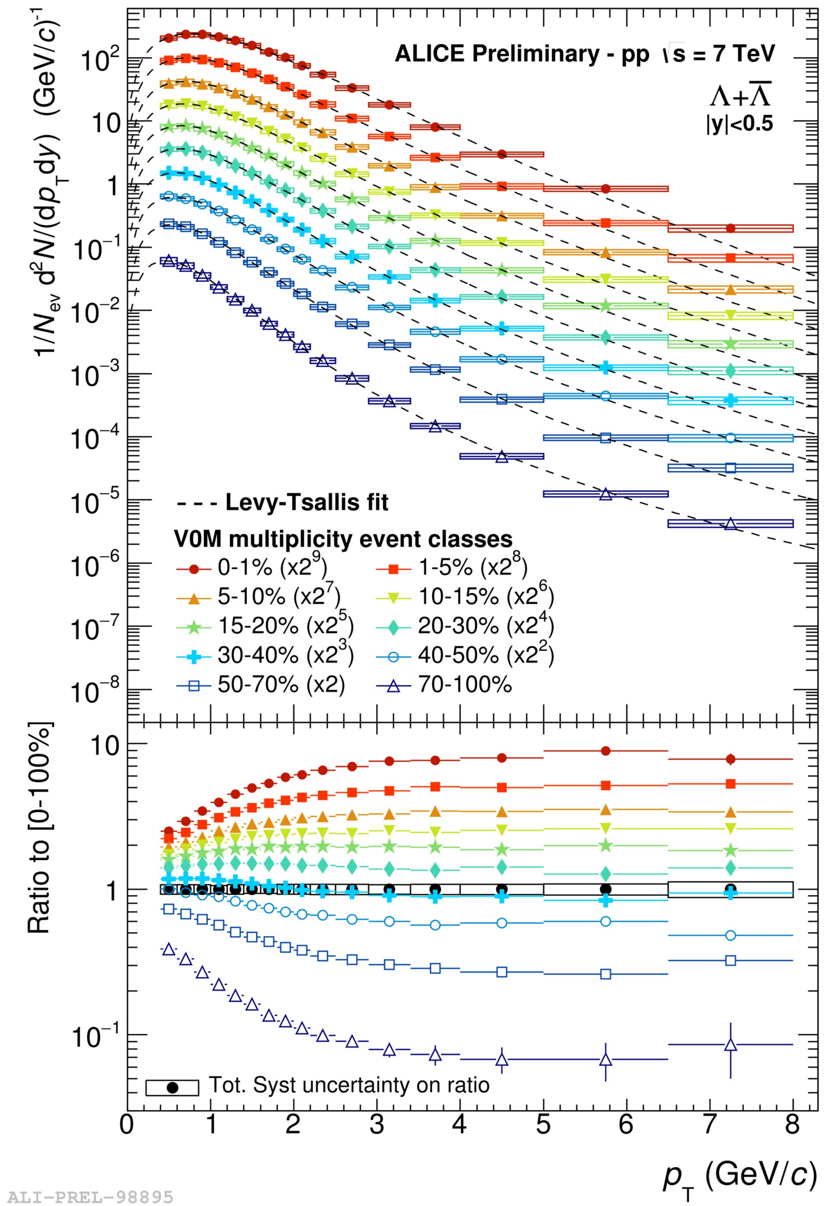




- Ratio panel compares to inclusive spectra (INEL > 0)
- Spectra become harder with increasing multiplicity
- Spectral shapes unaltered at high p_T → MPI / parton luminosity scaling?

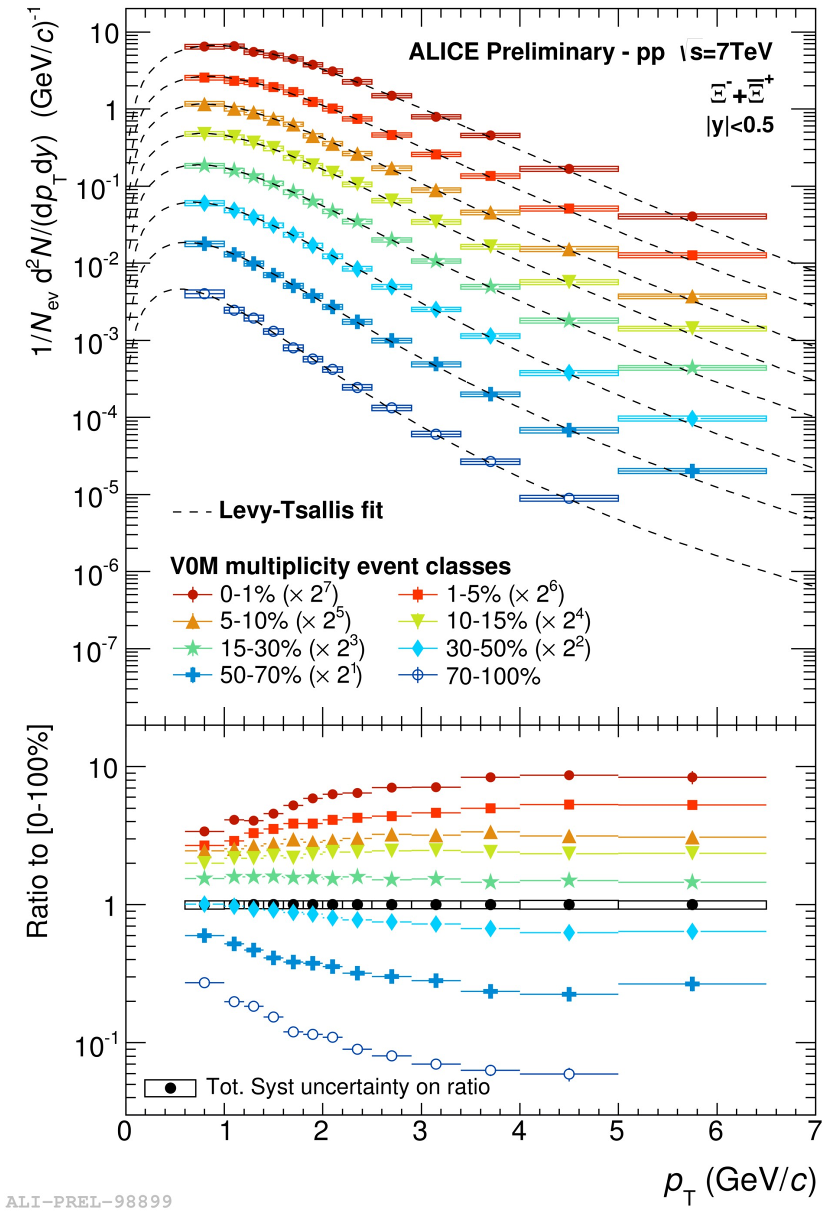
Tranverse Momentum Spectra (II): K and Λ

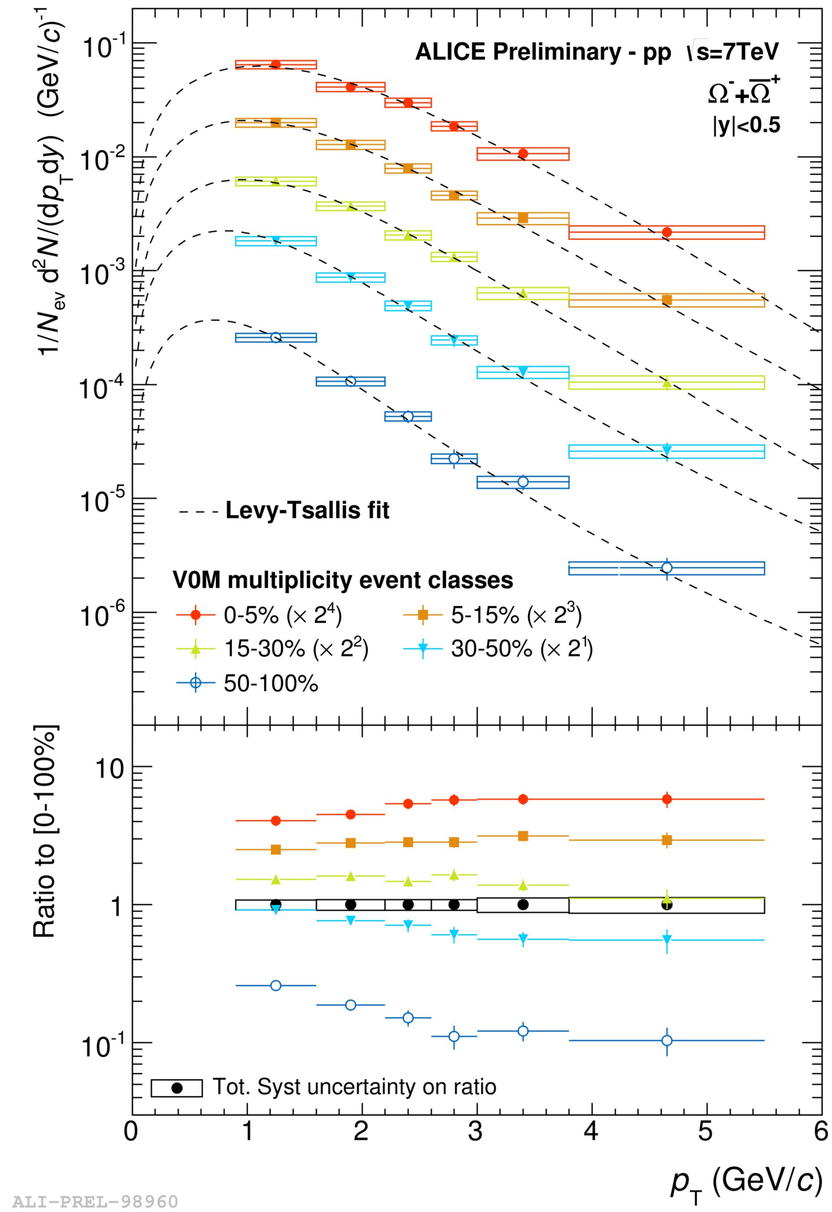




- Similar trends also for strange hadrons

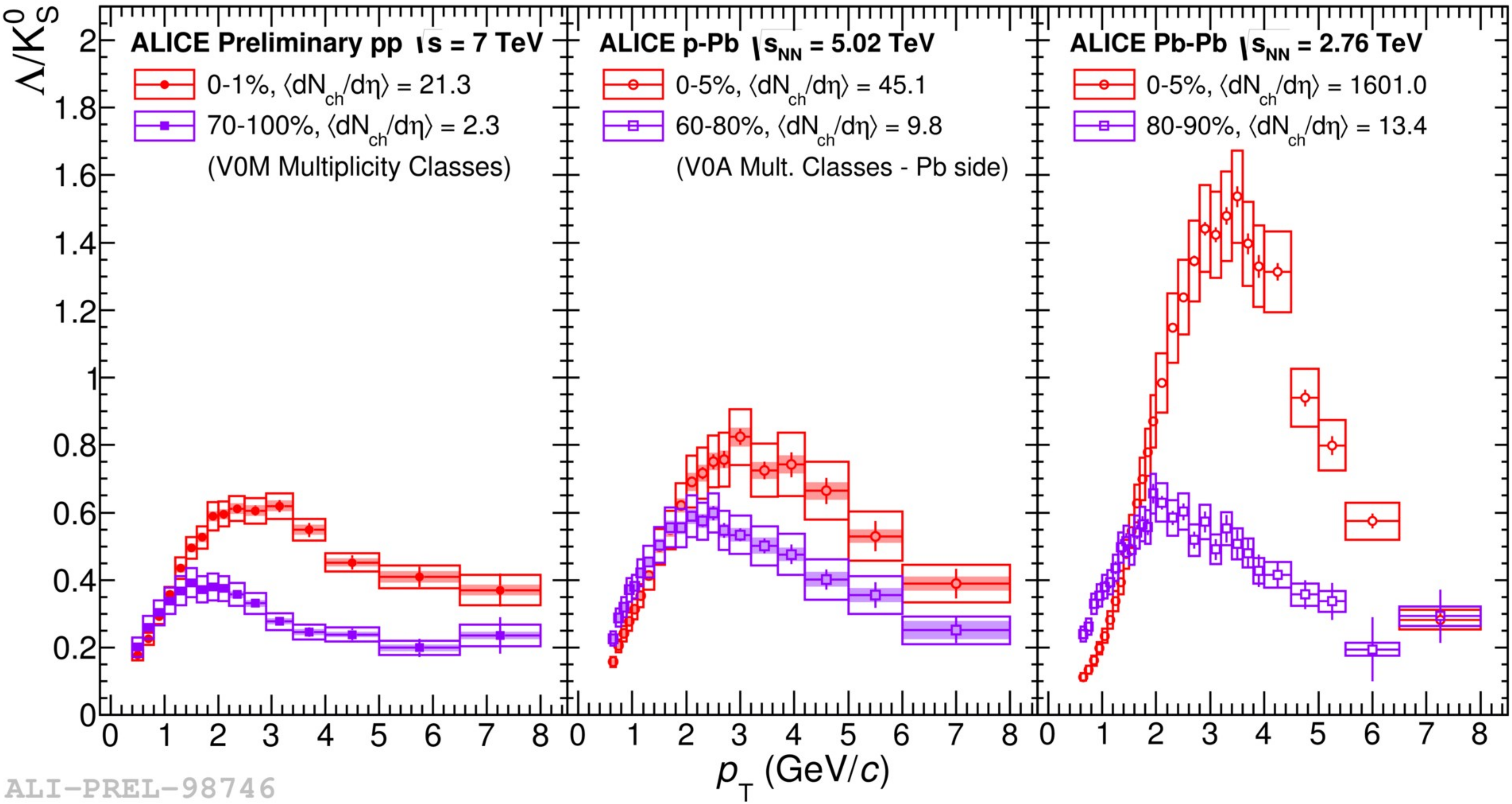
Tranverse Momentum Spectra (III): Ξ and Ω





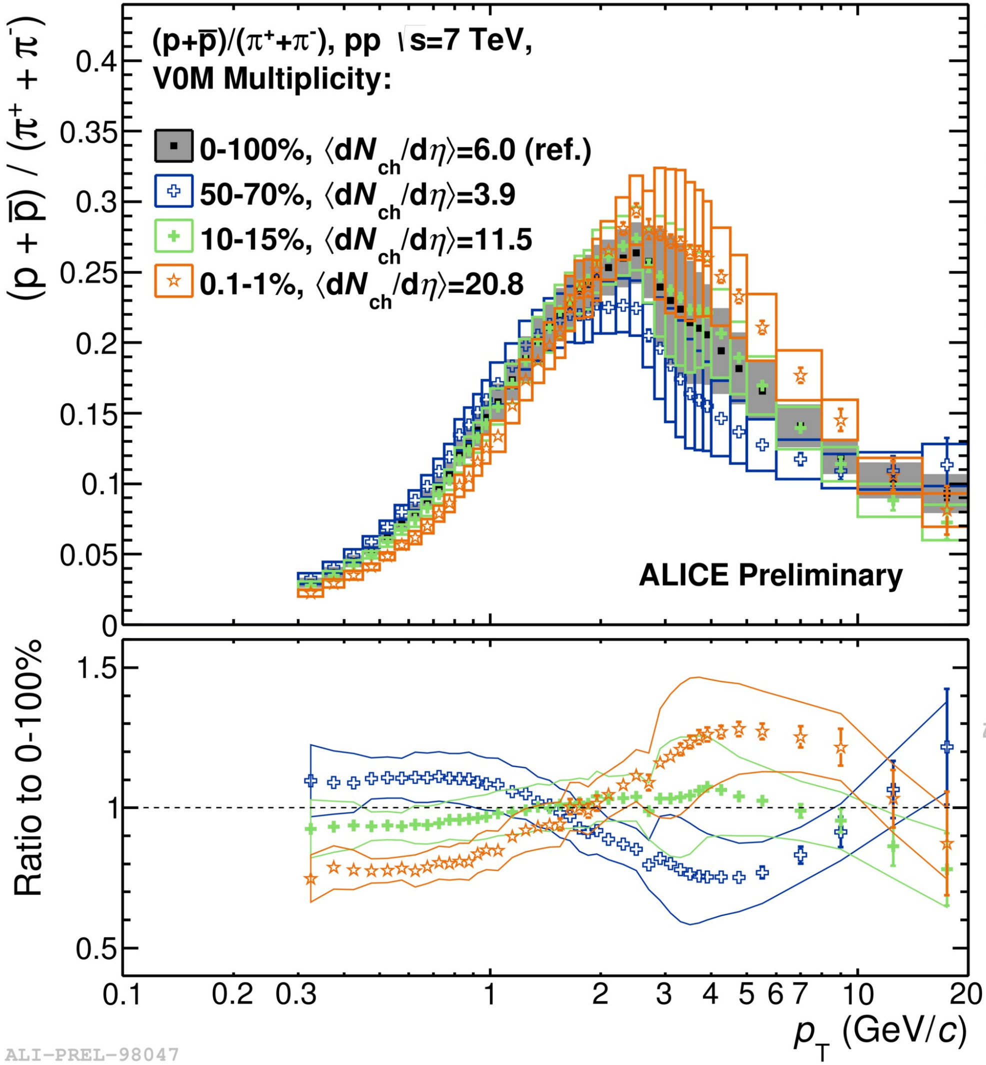
- … and for multi-strange hadrons as well

Spectral Ratios (I): Λ / K^0_S



- The ratio changes with multiplicity in a qualitatively similar way for pp, p-Pb and Pb-Pb
- The magnitude of the change is larger in Pb-Pb than in p-Pb and pp
  - ➔ However: note that similar percentiles correspond to very different <$dN_{ch}/d\eta$> for the three collisions systems

Spectral Ratios (II): p / π



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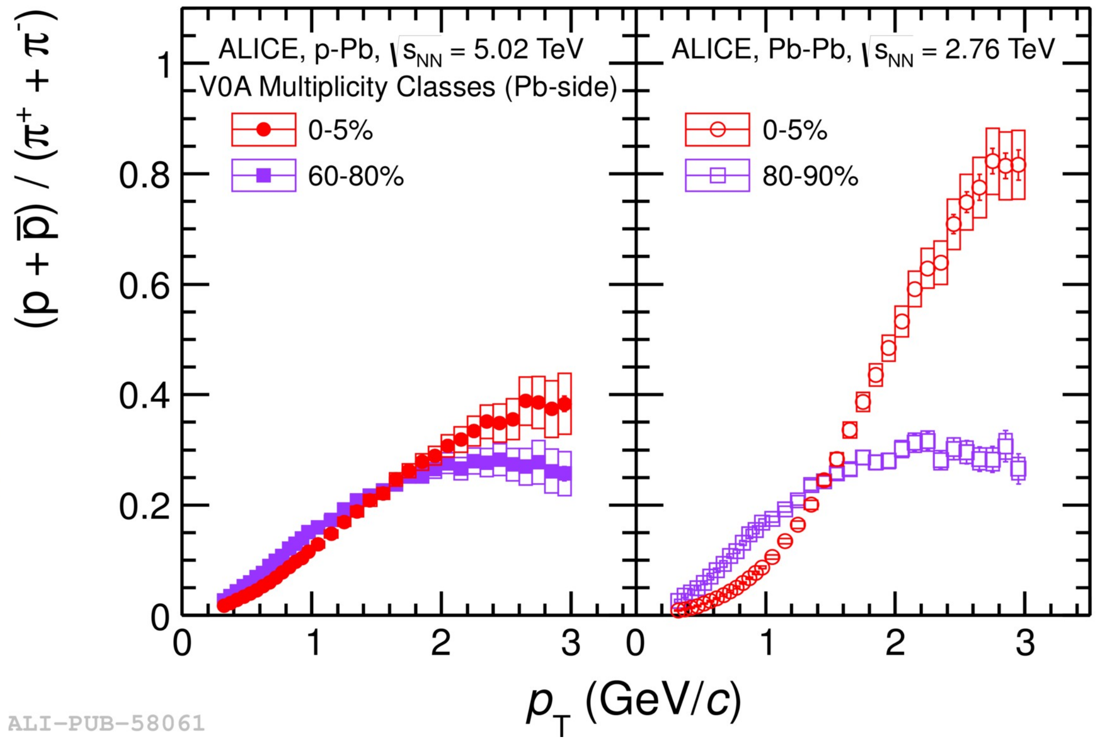


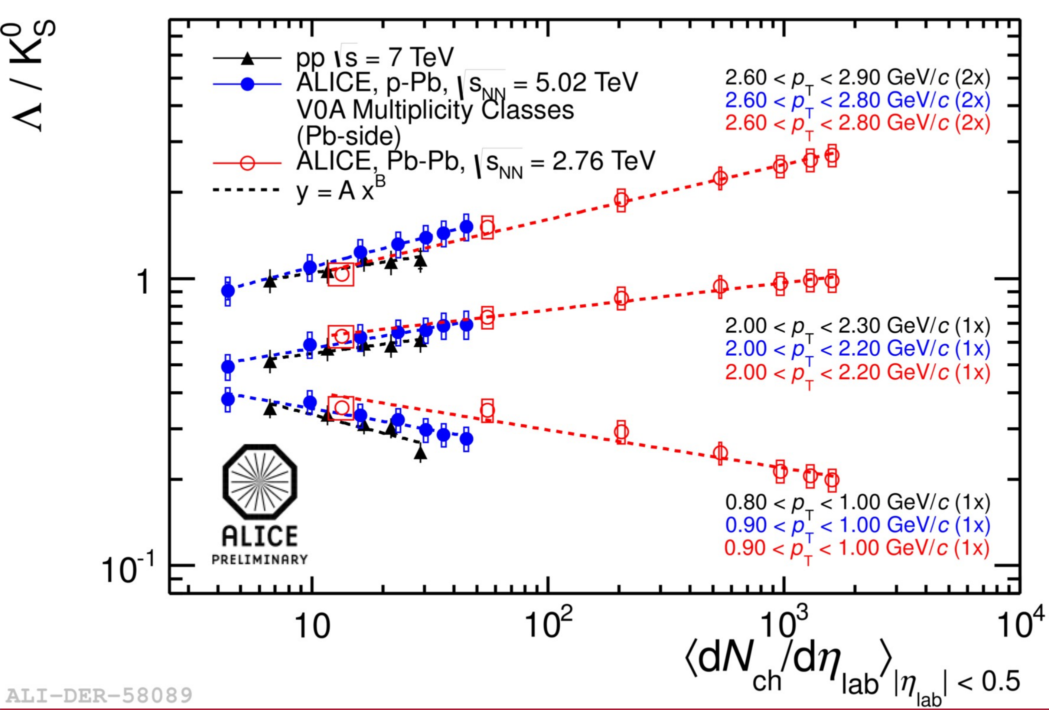
- Also for p/π: qualitatively similar multiplicity dependence of ratio in all 3 systems, but different magnitude

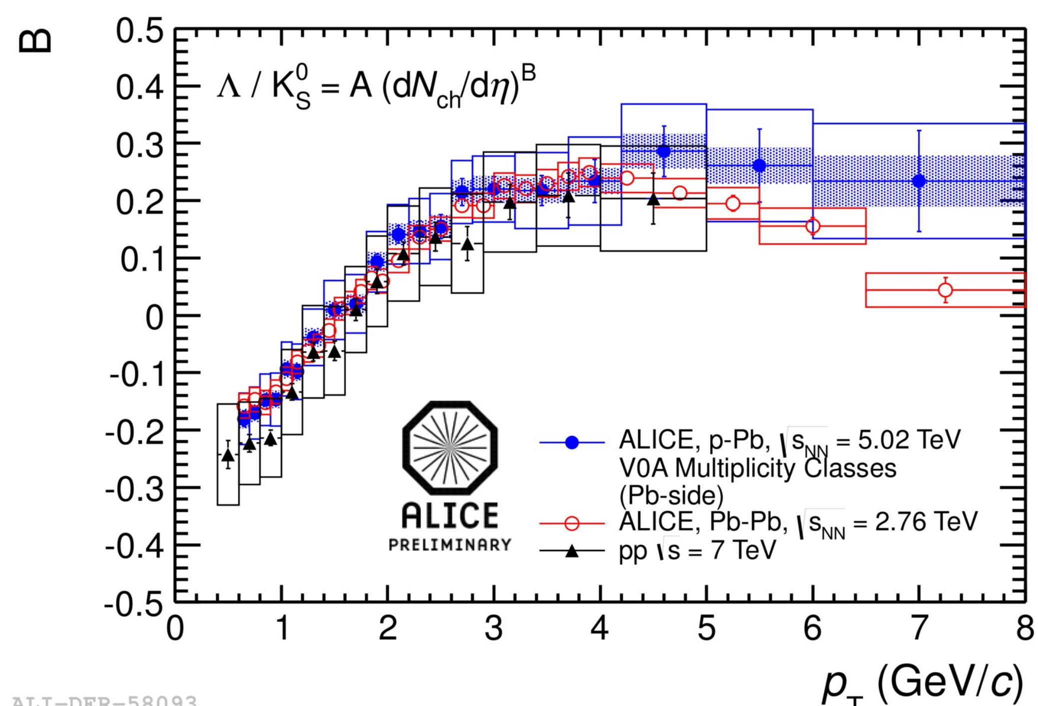
Multiplicity Scaling

Quantitative study: multiplicity dependence of particle ratios in fixed p_T interval

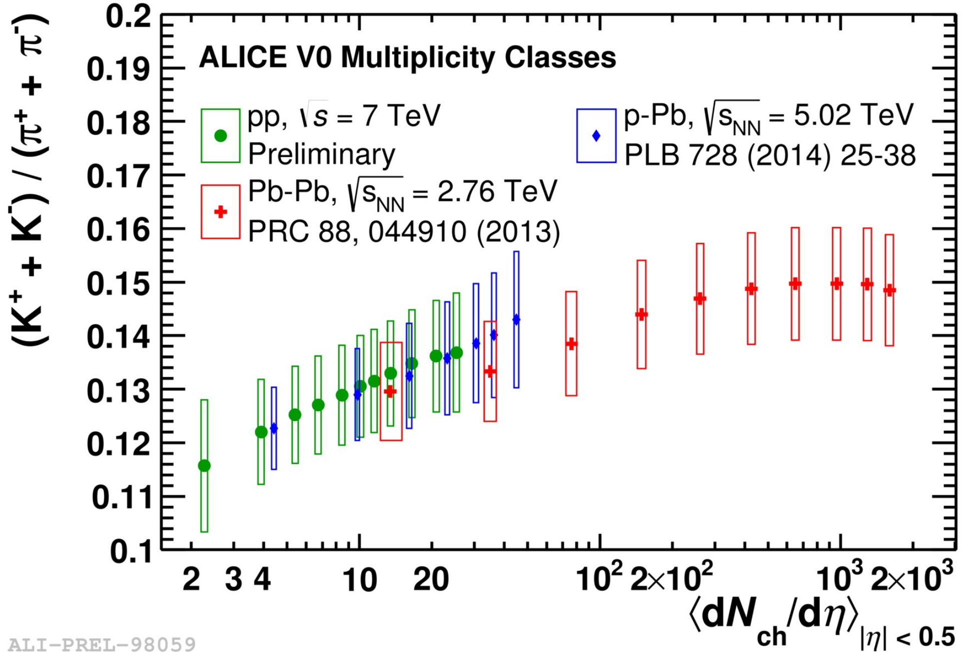
- Similar increase of Λ/K^0_S for similar increase of $<dN_{ch}/d\eta>$ in pp, p-Pb and Pb-Pb
  - Note: pp data points in plots via multiplicity estimator at mid-rapidity (potential bias!)
- Fit particle ratio (at given p_T) vs. $<dN_{ch}/d\eta>$ with power-law: $y = A*x^B$
- Same power-law scaling exponent (B) in all three collision systems
- Scaling holds also for p/π

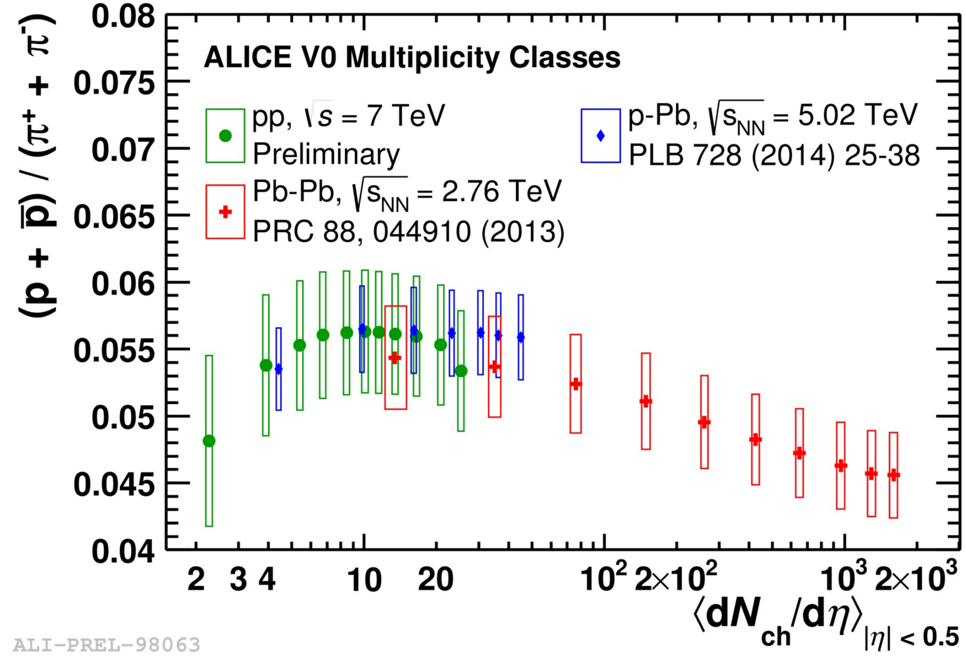
p-Pb and Pb-Pb from: Phys. Lett. B 728 (2014) 25-38





Yield Ratios (I)

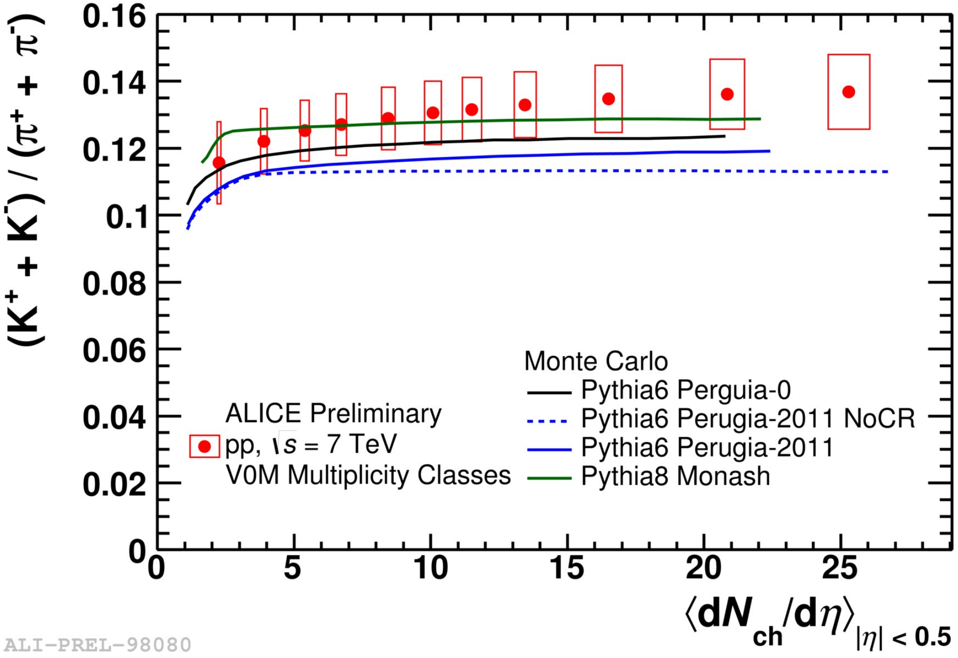


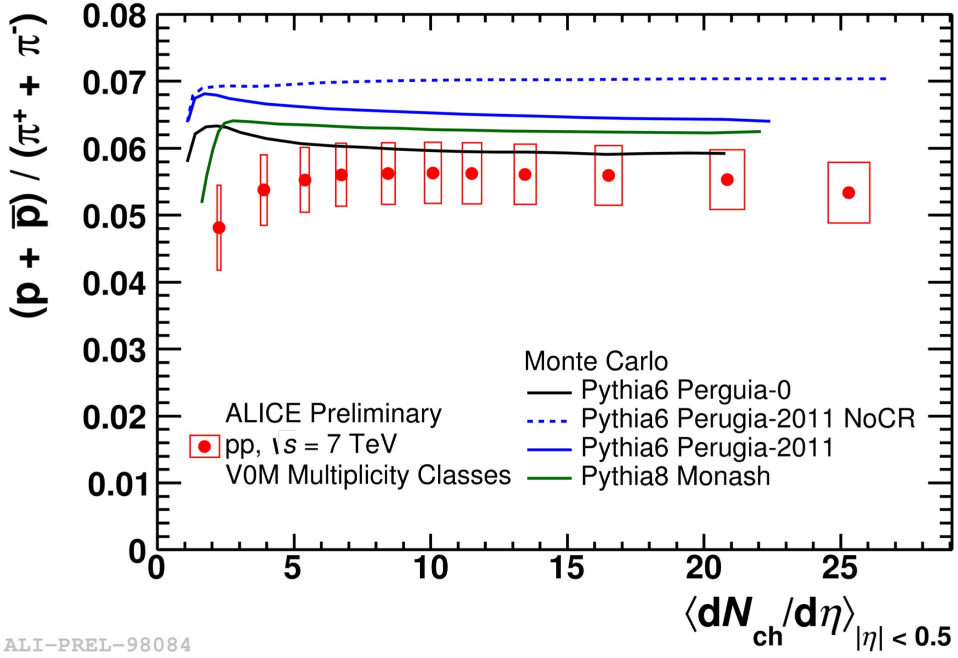


Used Levy-Tsallis fits to p_T spectra in order to extract yields (low-p_T extrapolation, contribution from extrapolation to infinite p_T negligible)

Same trends in pp and p-Pb

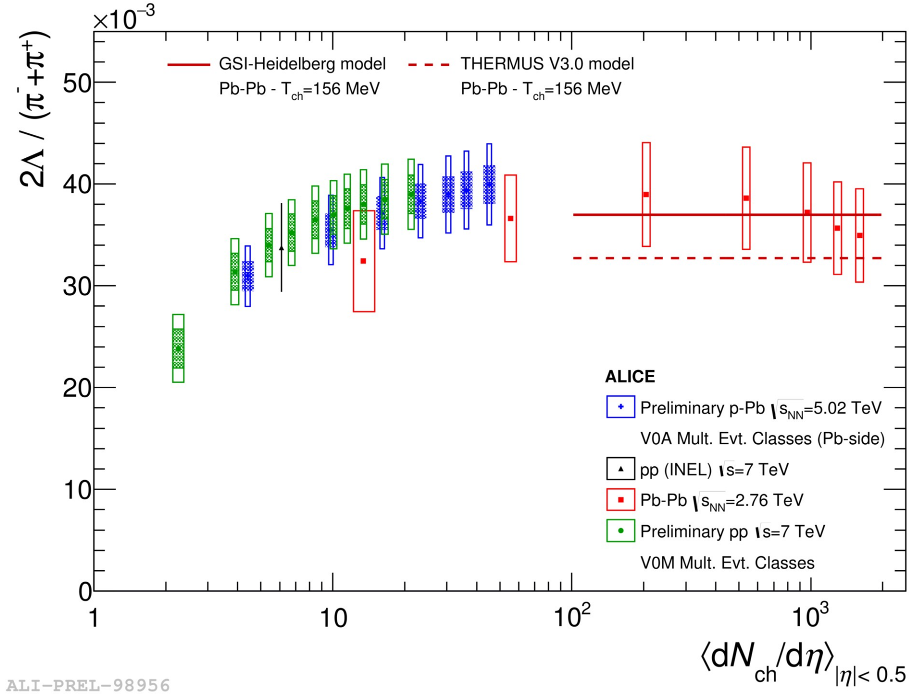
Yield Ratios (I) – Comparison to Models

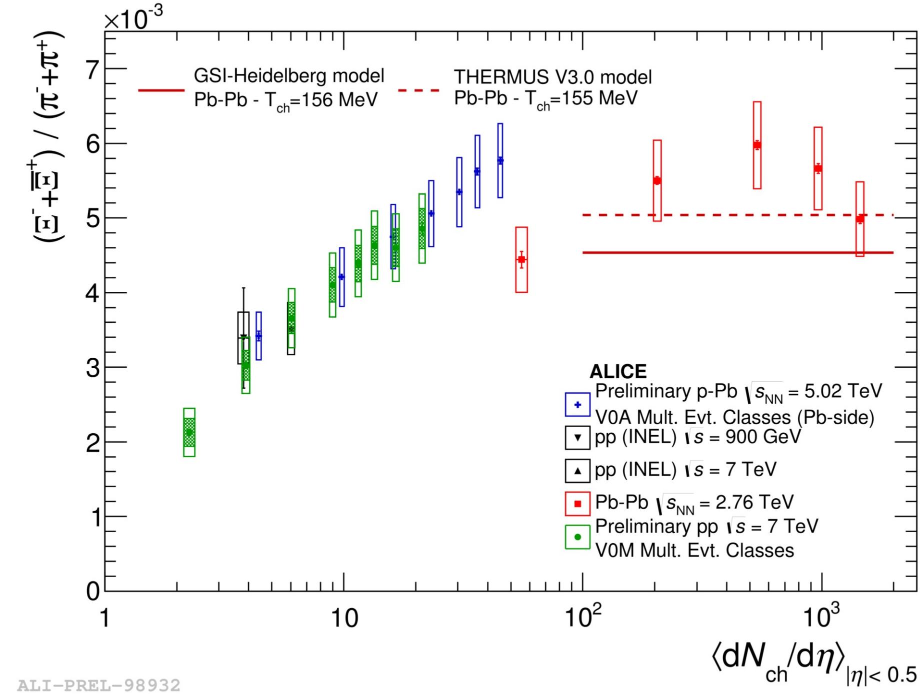


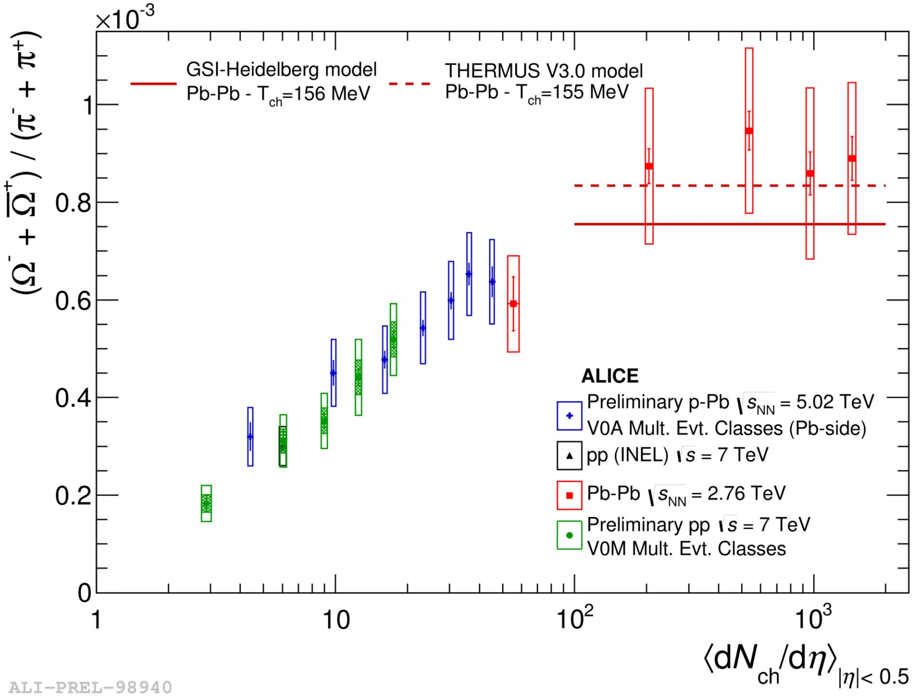


- Considered PYTHIA 6 and 8 with several tunes (P-0, P-2011, 4C, Monash)
- Colour Reconnection (CR) has similar impact on prediction for all tunes
- None of the tunes describes both yield ratios correctly

Yield Ratios (II)







Ratios as a function of multiplicity in pp:

- In very good agreement with INEL result
- Follow same trend as observed in p-Pb
- Λ/π and Ξ/π reach grand canonical saturation values as predicted by Heidelberg-GSI and THERMUS models, whereas Ω/π stays below.

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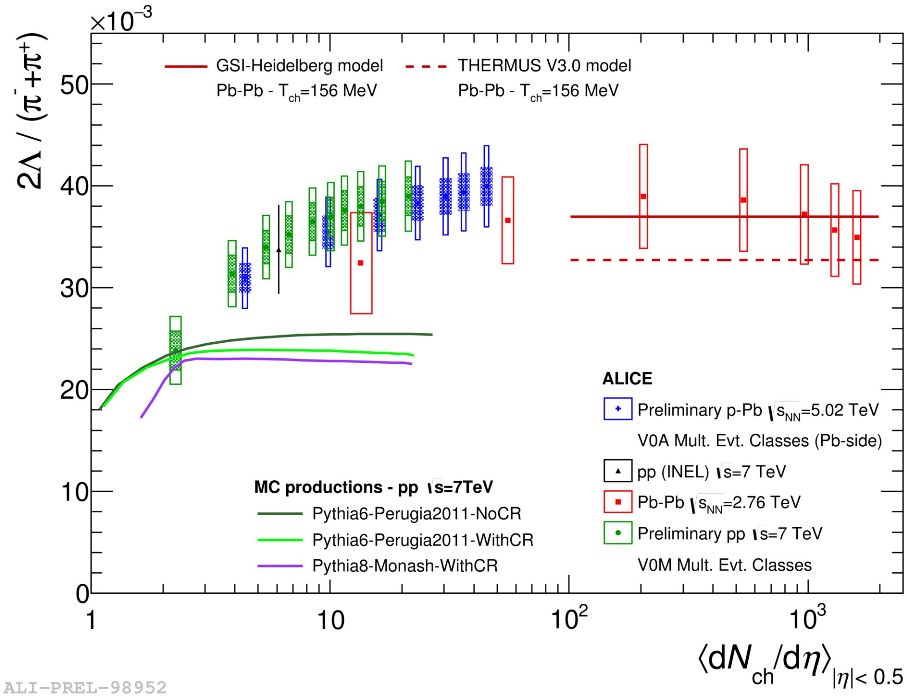

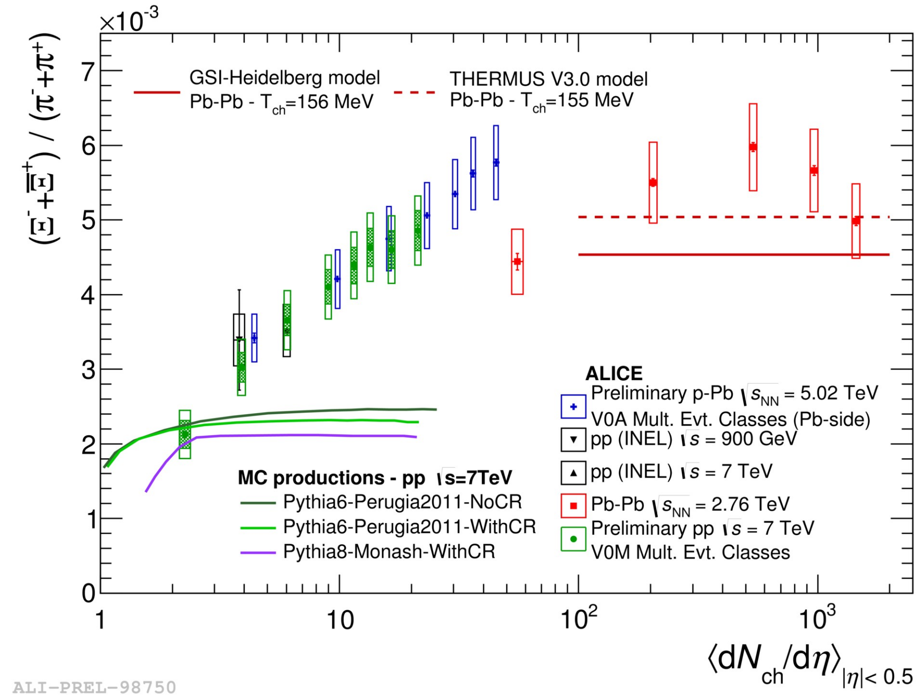

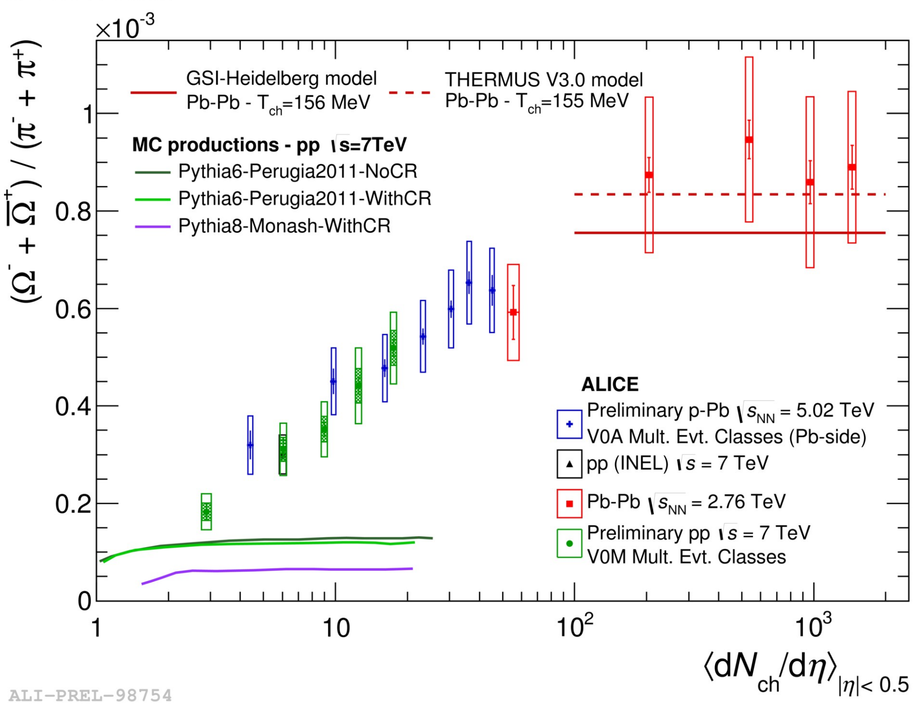

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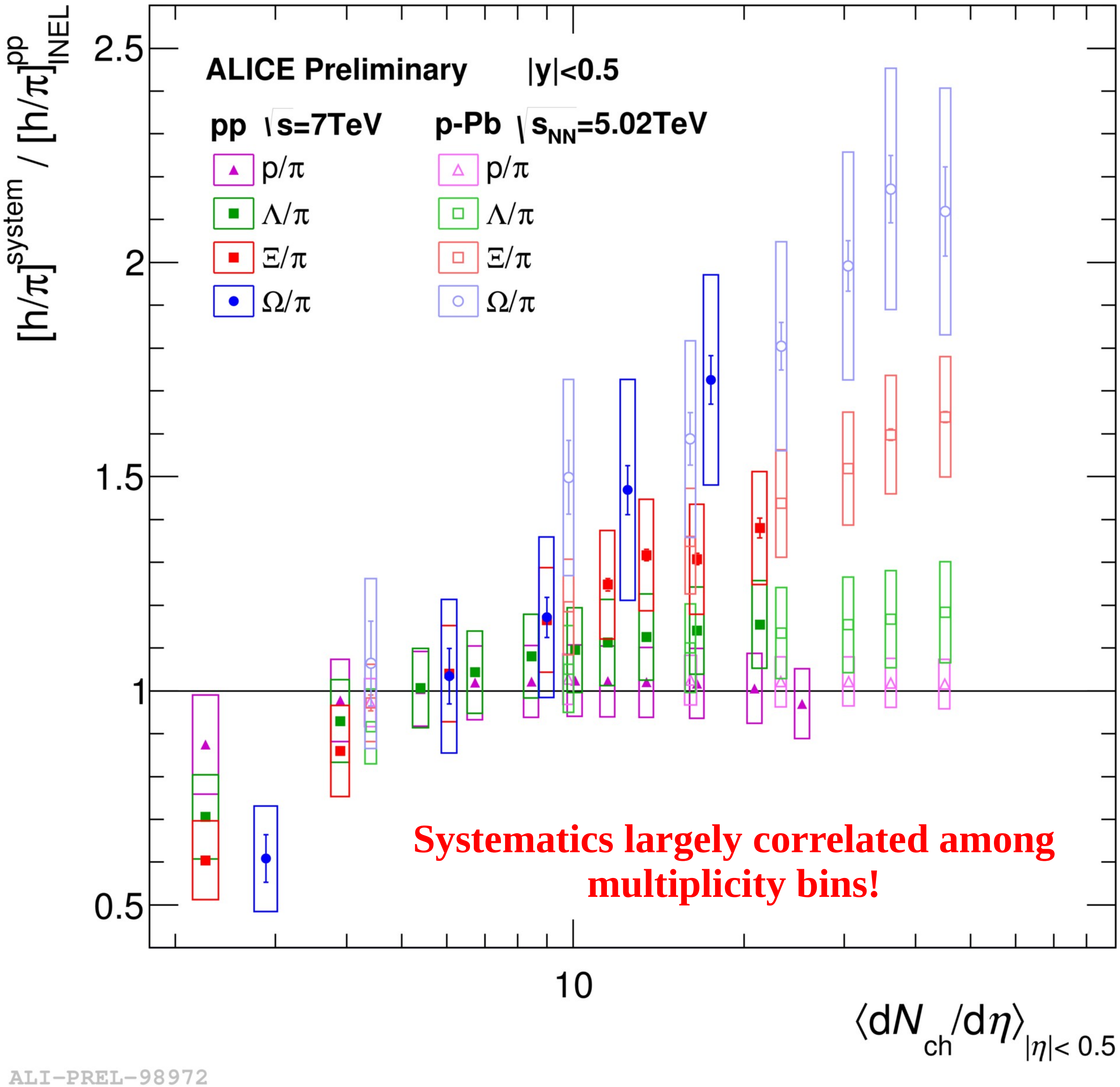
- Trends predicted by PYTHIA 6 and 8 strongly disagree with data
- CR has only little impact on predicted multiplicity dependence

pp and p-Pb normalised to pp_{INEL}



- To check how fast the h/π ratio increases with multiplicity for various species:
  - ➔ Plot $[h/\pi]^{species}/[h/\pi]^{pp}_{INEL}$
- Ratio stays at unity for protons in considered multiplicity range
- The higher the strangeness content of the baryons, the higher the relative rise with multiplicity

➤ **The increase is not baryon-related, but strangeness-related**

Canonical suppression of [Λ,Ξ,Ω]/π?

Indications:
(1) pp and p-Pb results exhibit the same functional dependence...
(2) … which is approaching the grand canonical saturation value.

Consistent with canonical suppression scenario??

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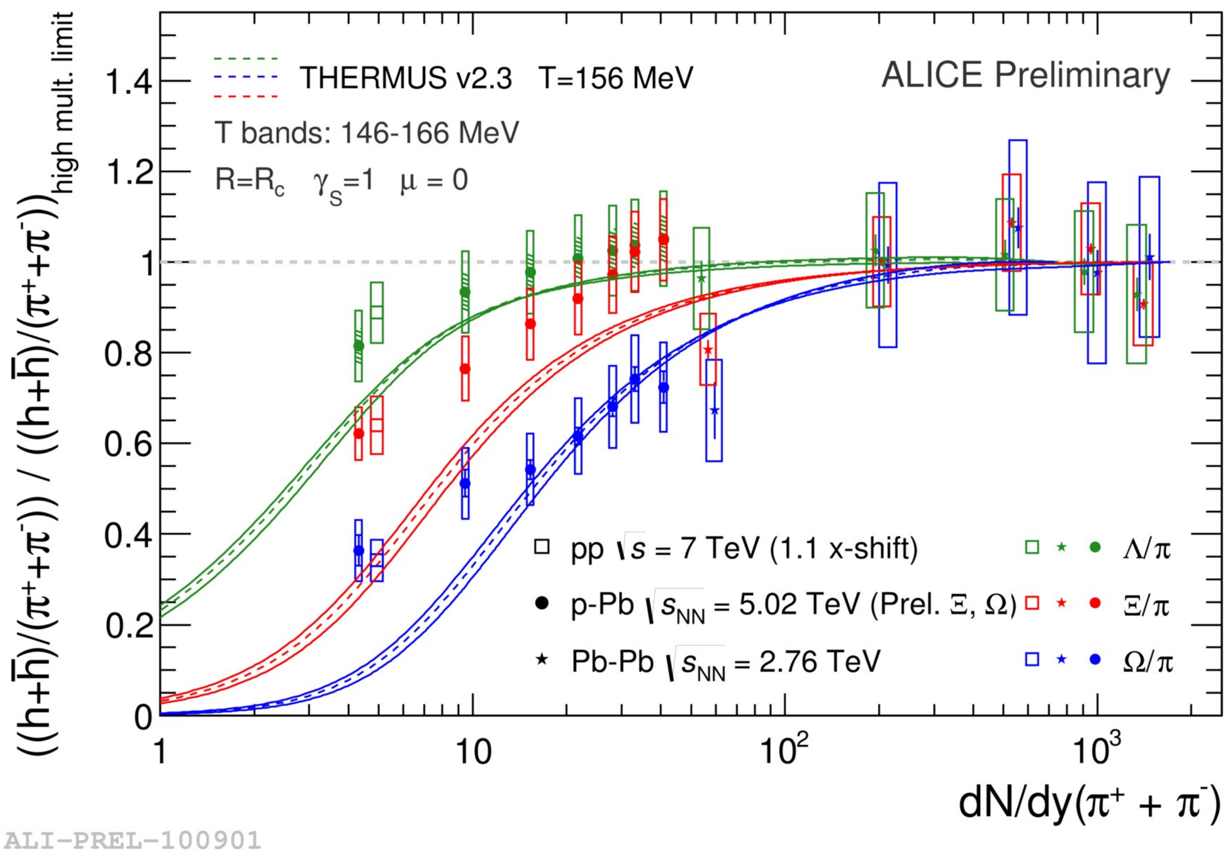

- Consider evolution of h/π normalised to value at high-multiplicity limit with charged pion multiplicity
- Trend for [Λ,Ξ,Ω]/π roughly described by THERMUS ($T=156\pm10$ MeV, $R=R_C$, $\gamma_S=1$, $\mu_B = \mu_Q = \mu_S = 0$; curves are for Pb-Pb only)

- Experimental data for Λ, Ξ, Ω in qualitative agreement with canonical suppression
- **BUT**: Φ seems not to fit into this picture

Summary

The ALICE Collaboration reported on the measurement of identified hadron production as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV

- p_{T} spectra of π, K, p, Λ, Ξ, Ω: hardening with multiplicity, shape at high p_{T} is unaltered
- p_{T}-differential baryon/meson ratios (p/π, $\Lambda/\mathrm{K}^0_{\mathrm{S}}$): qualitatively similar evolution with multiplicity in pp, p-Pb and Pb-Pb; with an enhanced production of baryons at mid-p_{T}
- h/π ratios:
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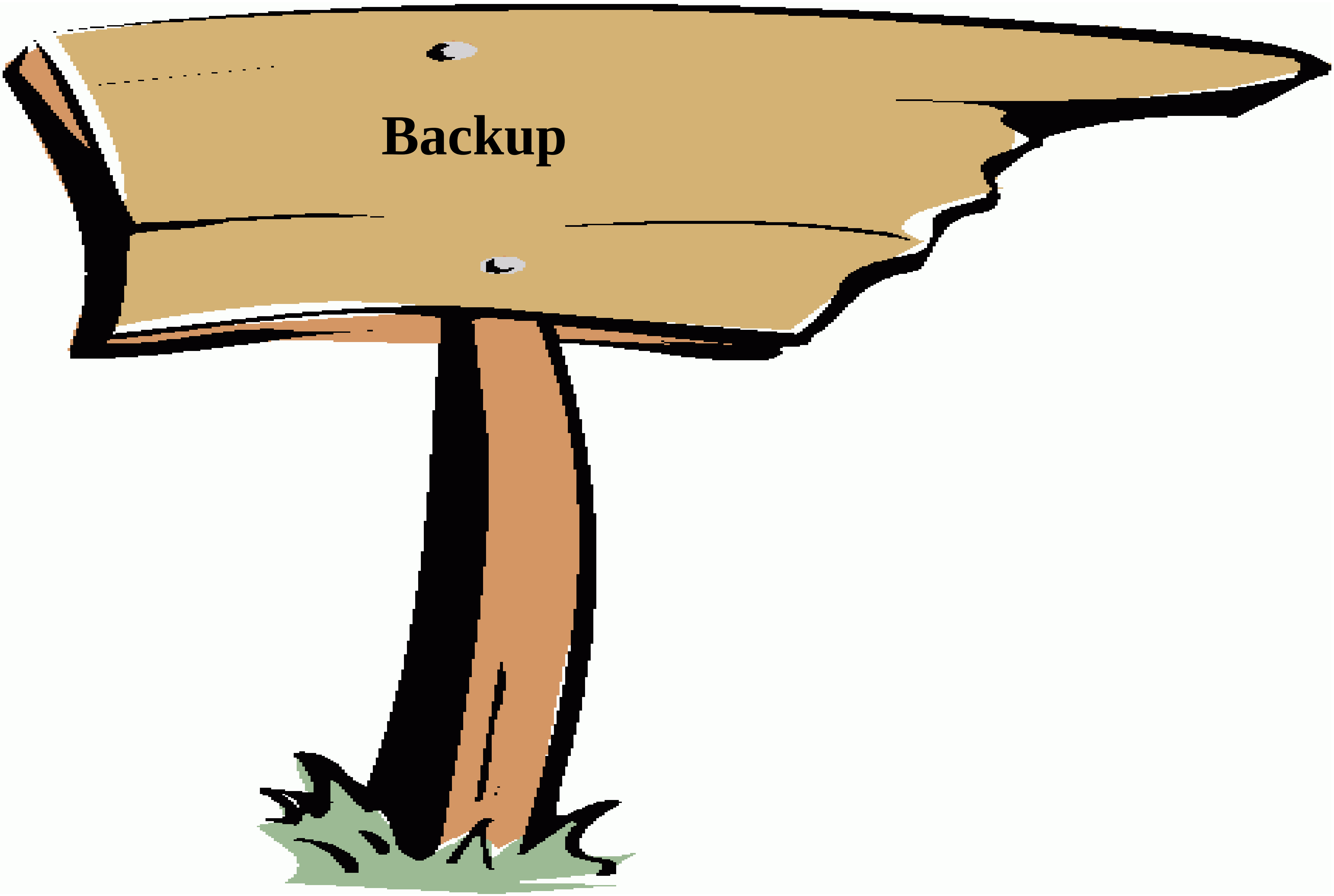
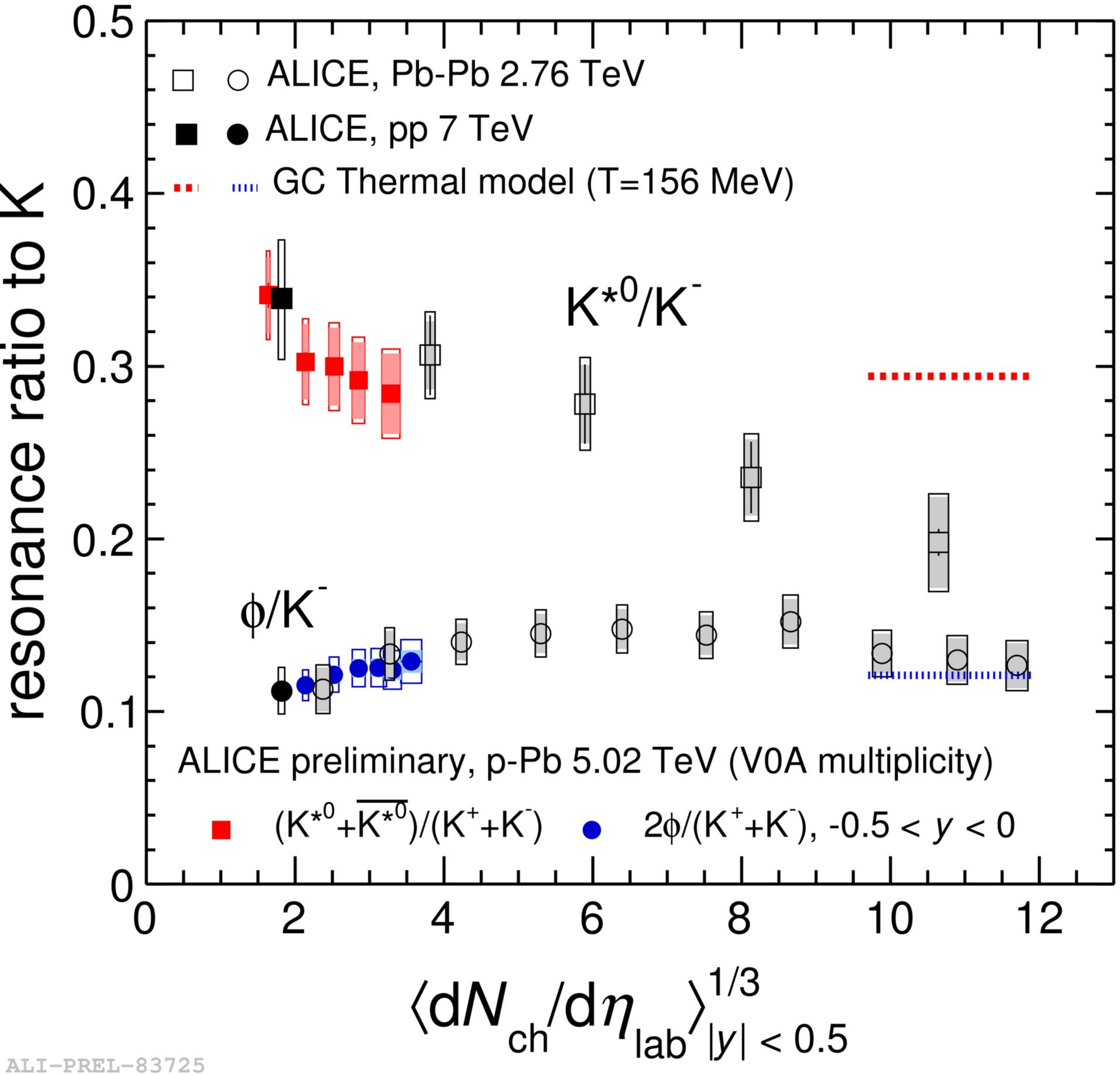
THANK YOU for your ATTENTION!


Backup

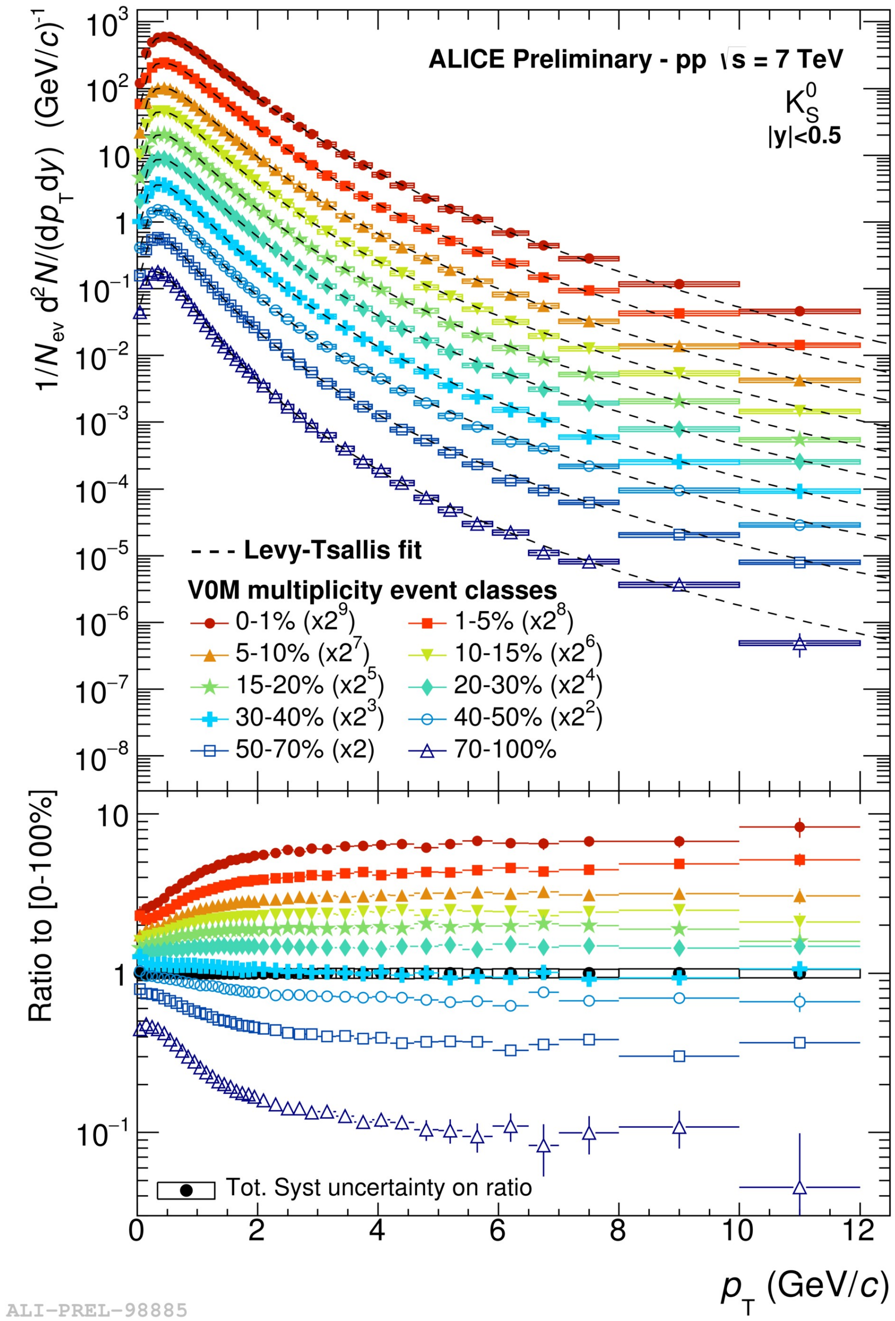
Resonance Ratios to K



- **Large uncorrelated uncertainties** (shaded boxes)!
- Φ/K ratio seems to be rather flat

➔ Φ might behave similar to K as a function of multiplicity

Tranverse Momentum Spectra (IV): K^0_S



- Similar trends as the other considered species

As for Λ/K^0_S, the p/π ratio at given p_T depends on <dN$_{ch}$/dη> in a similar way for p-Pb and Pb-Pb

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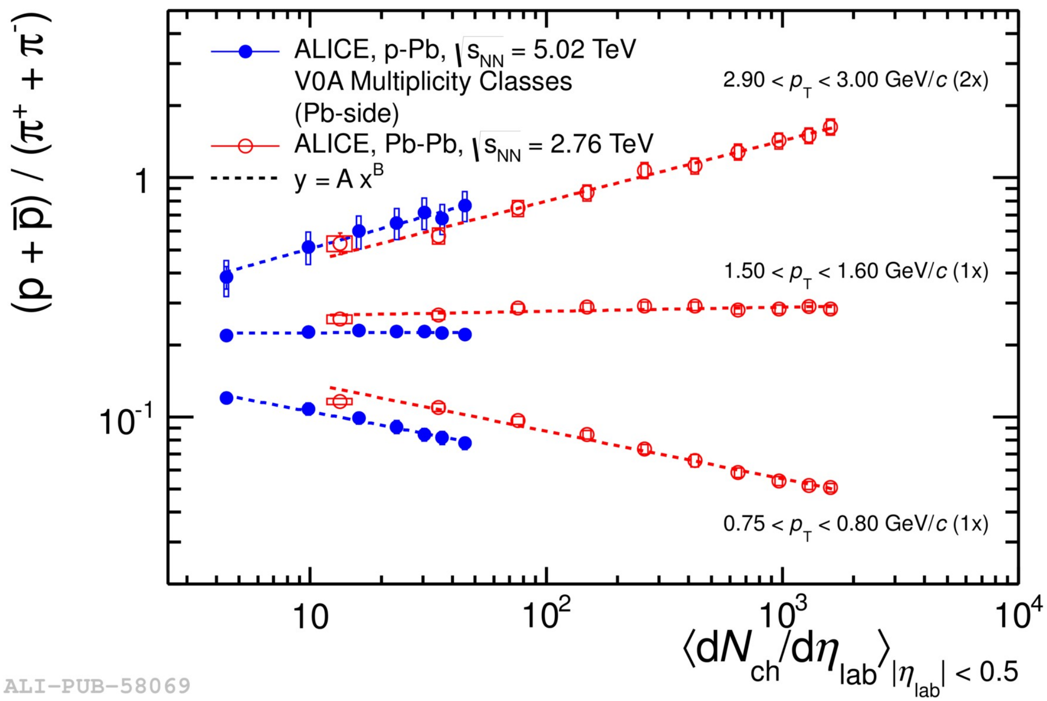
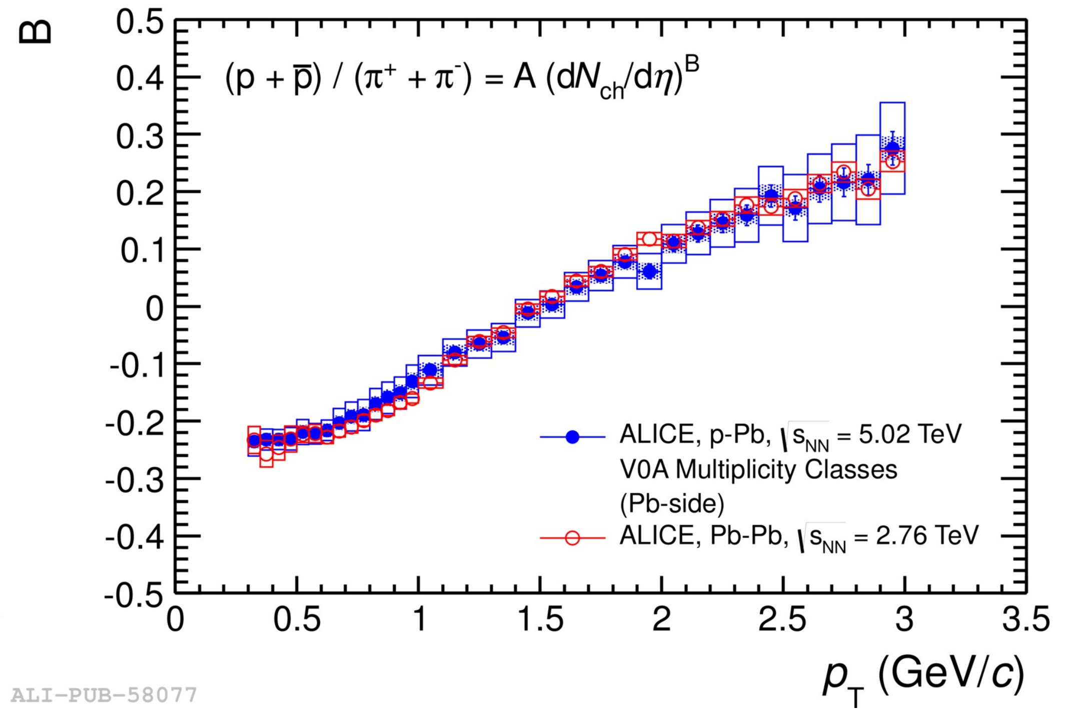




Combined PID Analysis of π/K/p

Overview of individual analyses contributing to the combined results for π/K/p.

The specified p_T ranges are those used for the combination of the results, somewhat broader ranges are possible in order to cross-check the individual results.

Analysis	PID Technique	p_T Range (GeV/c)			Analysis Region
		π	K	p	
ITS stand-alone	n-σ cuts on ITS	$0.1-0.6$	$0.2-0.6$	$0.3-0.6$	$\|y\| < 0.5$
Bayesian PID	Bayesian probability	$0.2-2.5$	$0.3-2.5$	$0.5-2.5$	$\|y\| < 0.5$
TPC-TOF	n-σ cuts on TPC and TOF	$0.25-1.2$	$0.3-1.2$	$0.45-2.0$	$\|y\| < 0.5$
TPC-TOF Fits	n-σ fits to TPC and TOF	$0.25-2.5$	$0.3-2.5$	$0.45-2.7$	$\|y\| < 0.5$ (TPC) $\|\eta\| < 0.2$ (TOF)
TPC Template Fits	TPC dE/dx Template Fits	> 2.0			$\|\eta\| < 0.8$

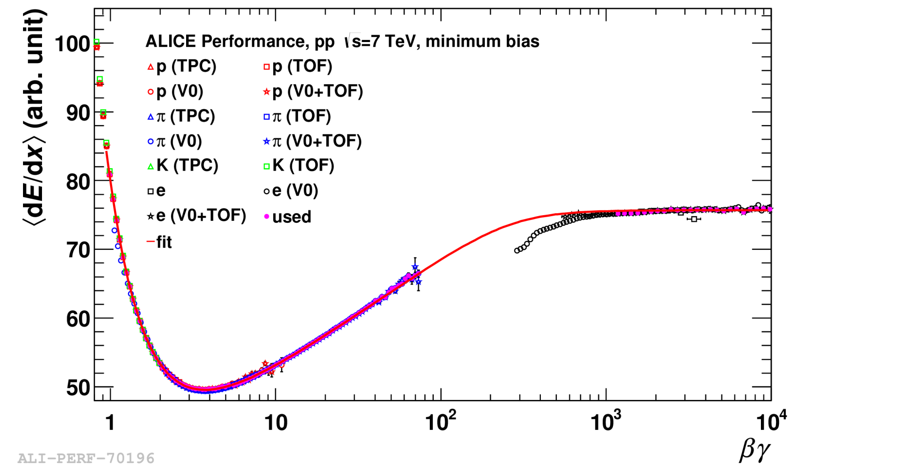
TPC Multi-template Fit – Modelling the TPC d*E*/dx Response

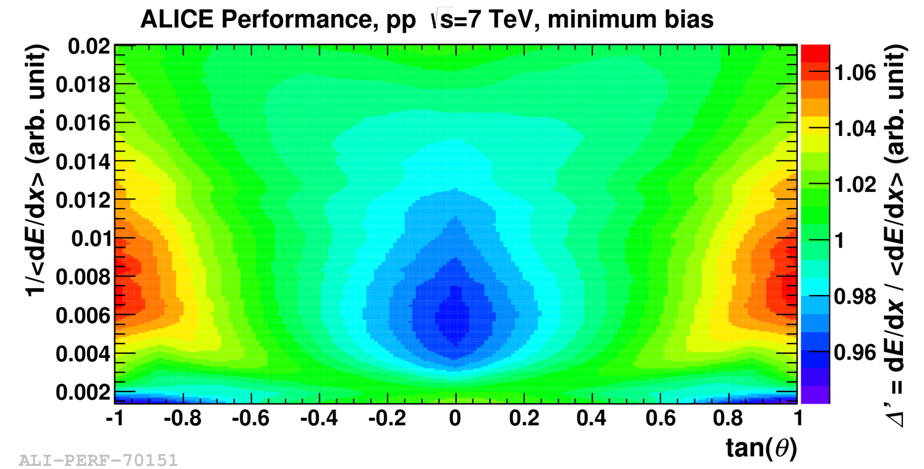
TPC d*E*/dx of track depends on: momentum, mass, θ, d*E*/dx, #PID clusters, shape asymmetry

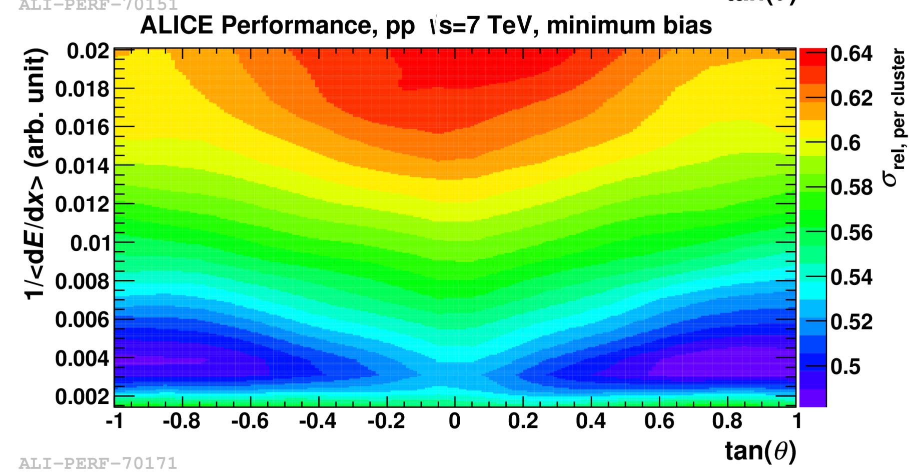
Extract dependencies with data driven methods:

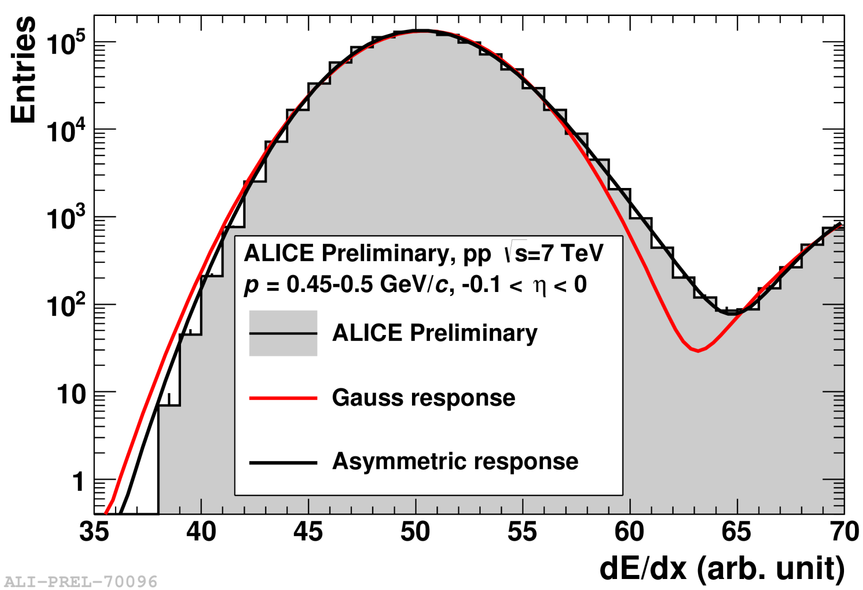
- Clean samples from TPC, TOF and V0's
- Fit <d*E*/dx> (*θ* averaged) with Bethe-Bloch model
- Extract dependence on *θ* (vs. 1/<d*E*/dx>)
- (Rel.) resolution map in (*θ*, 1/<d*E*/dx>)-bins as function of #PID cluster
- Parametrise asymmetric shape

Track parameters from sample of TPC tracks at given p_T to generate templates for each species





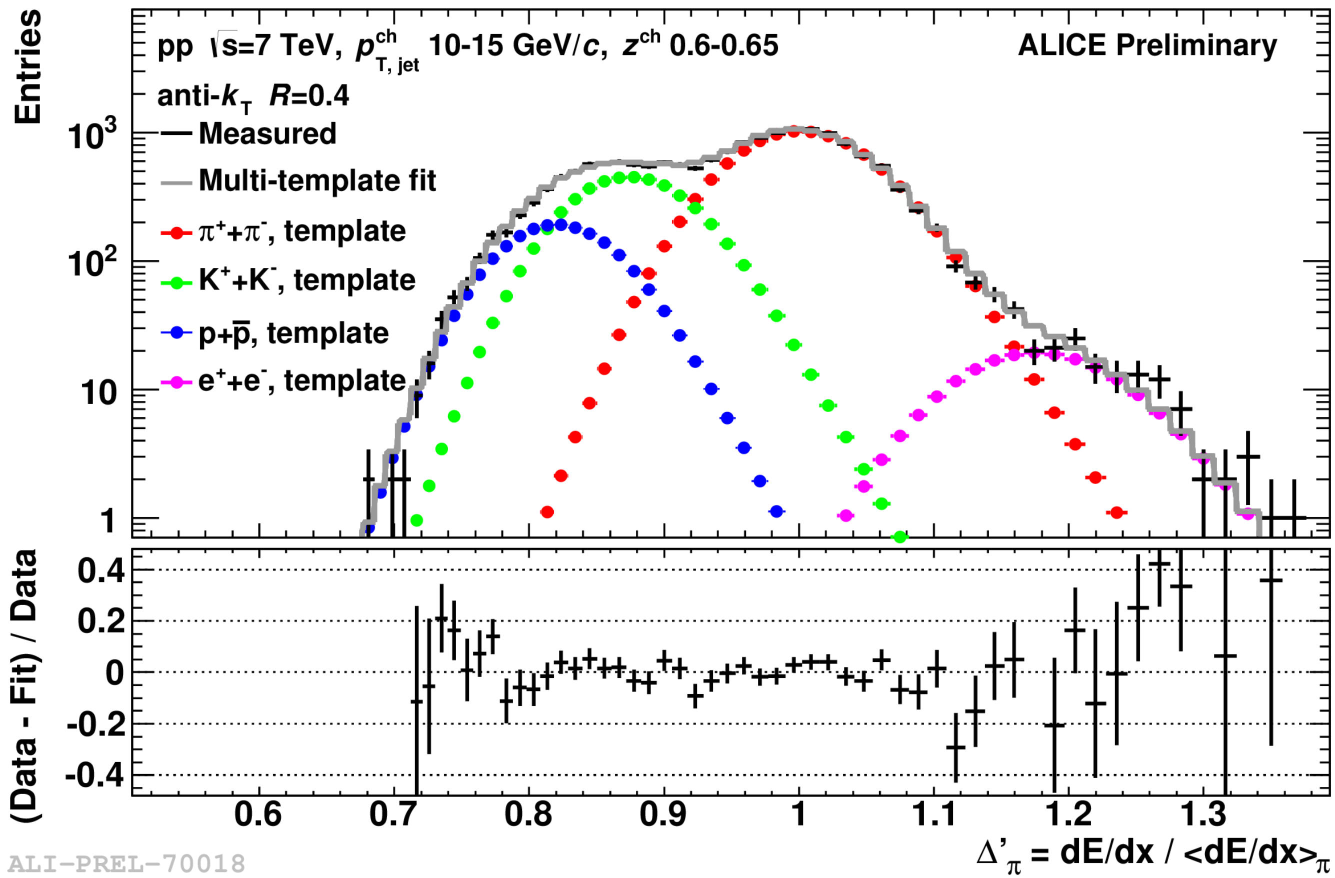




TPC Multi-template Fit – Overview

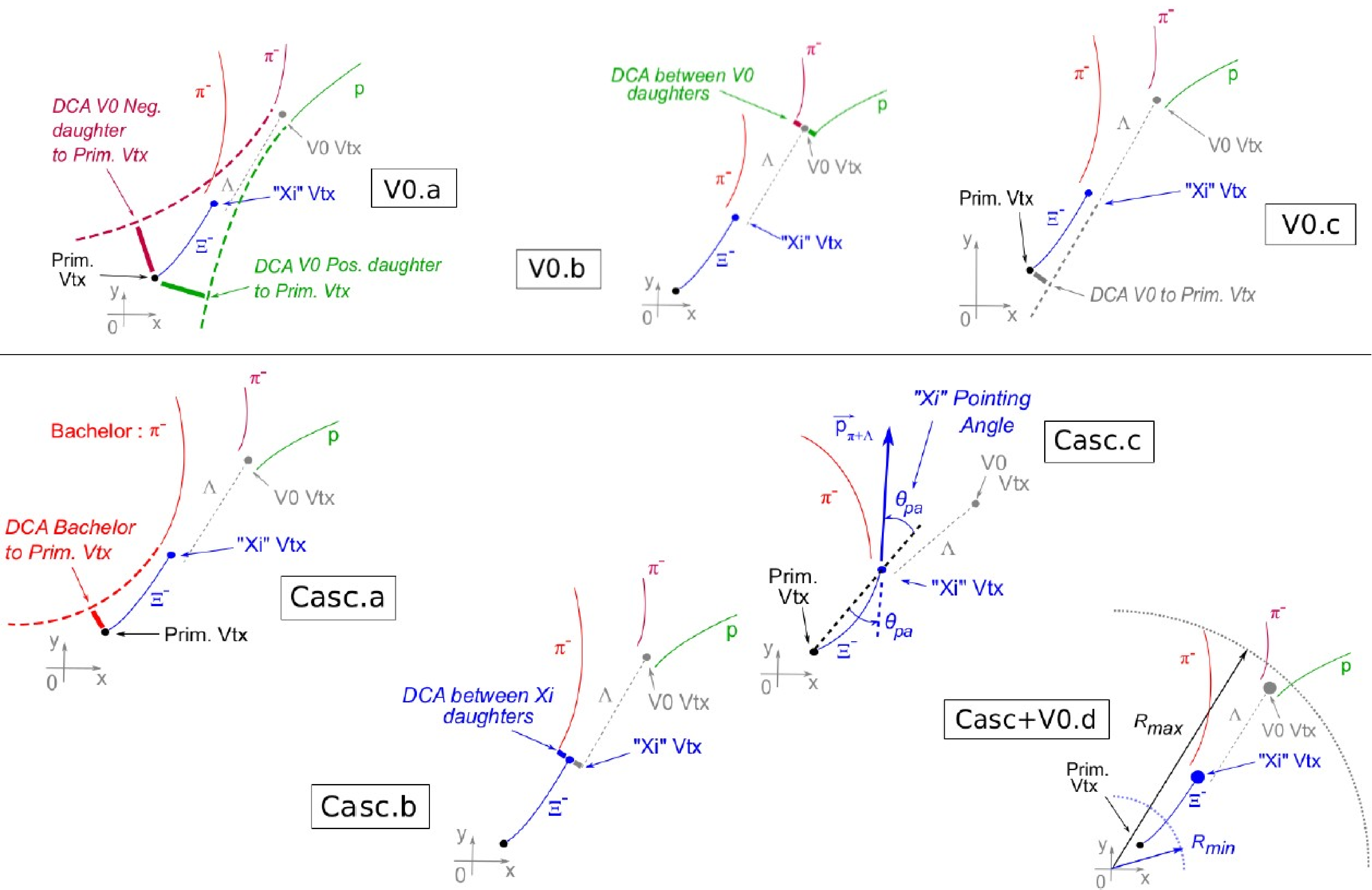
- *Binned log-likelihood fit*:
  Minimise difference between measured dE/dx distribution and template sum weighted by species fractions is
    → Fit parameters: Particle fractions as function of p_T

- Regularisation:
  Ensure continuity of fractions versus ln(p_T)

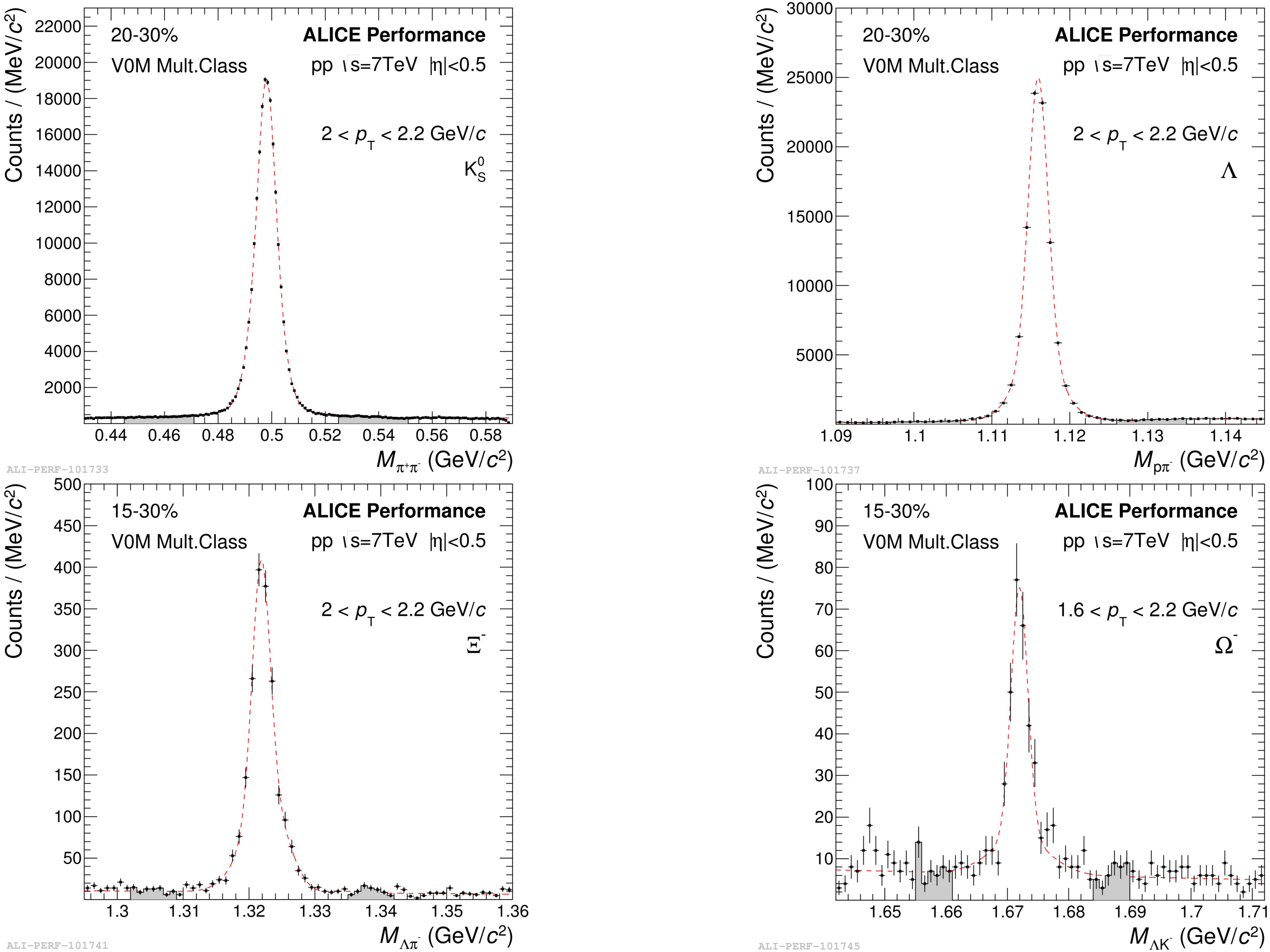


- Excellent description of data over 2-3 orders of magnitude

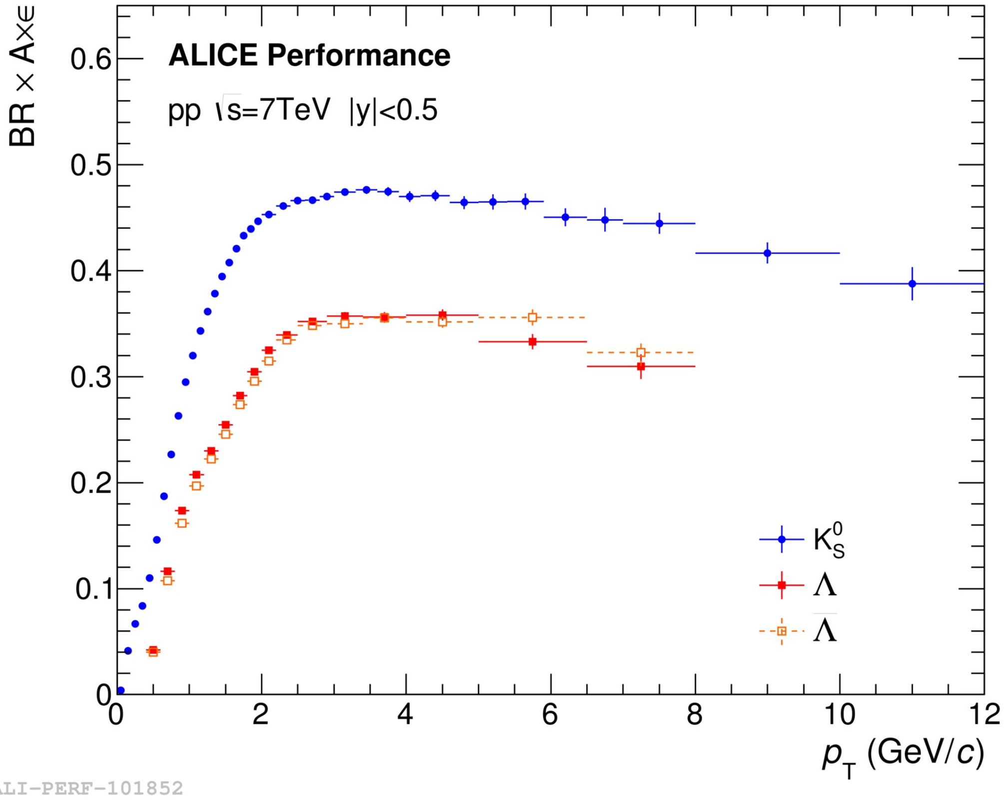
Topological Cuts for Strangeness Analysis

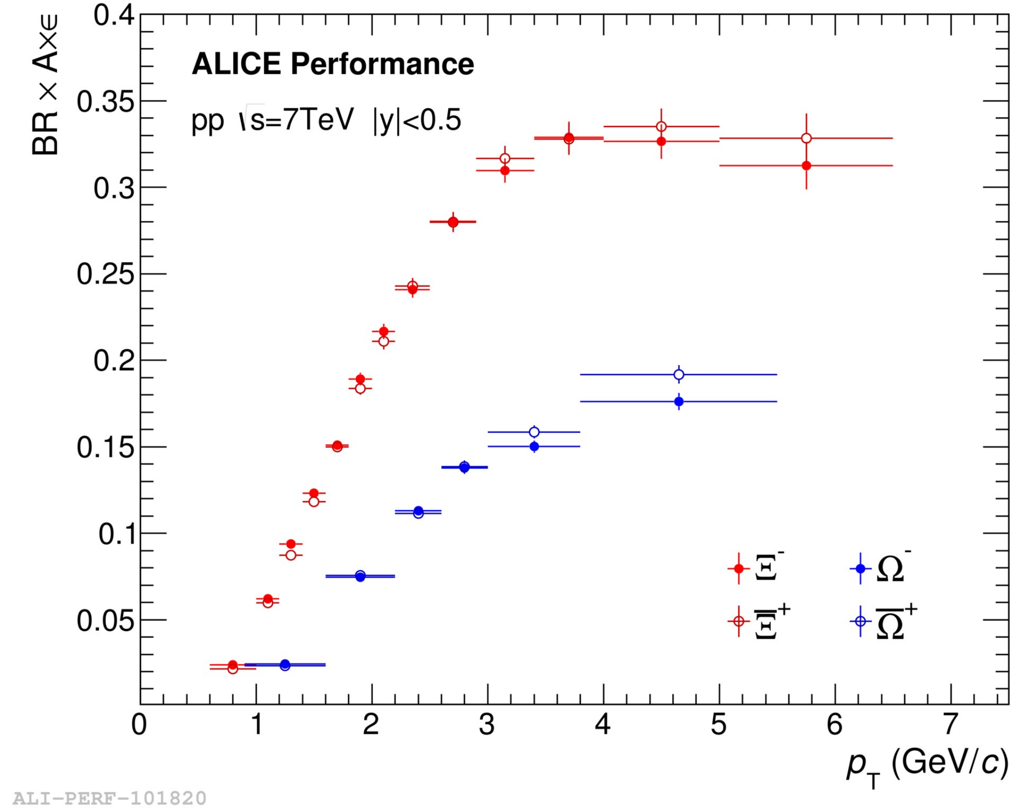


Invariant Mass Spectra (Strangeness Analysis)



Acceptance x Efficiency for Strangeness Analysis





- Acceptance x efficiency (Axε) estimated via PYTHIA-Perugia-0 simulation propagated through full ALICE geometry using Geant3
- Ξ and Ω values obtained using a Monte Carlo sample with enriched cascade content
- Axε verified to be independent of the charged particle multiplicity