Baryon to meson ratio in jets and underlying events in pp, p-Pb, Pb-Pb collisions measured in ALICE

Yonghong Zhang for the ALICE Collaboration

Central China Normal University

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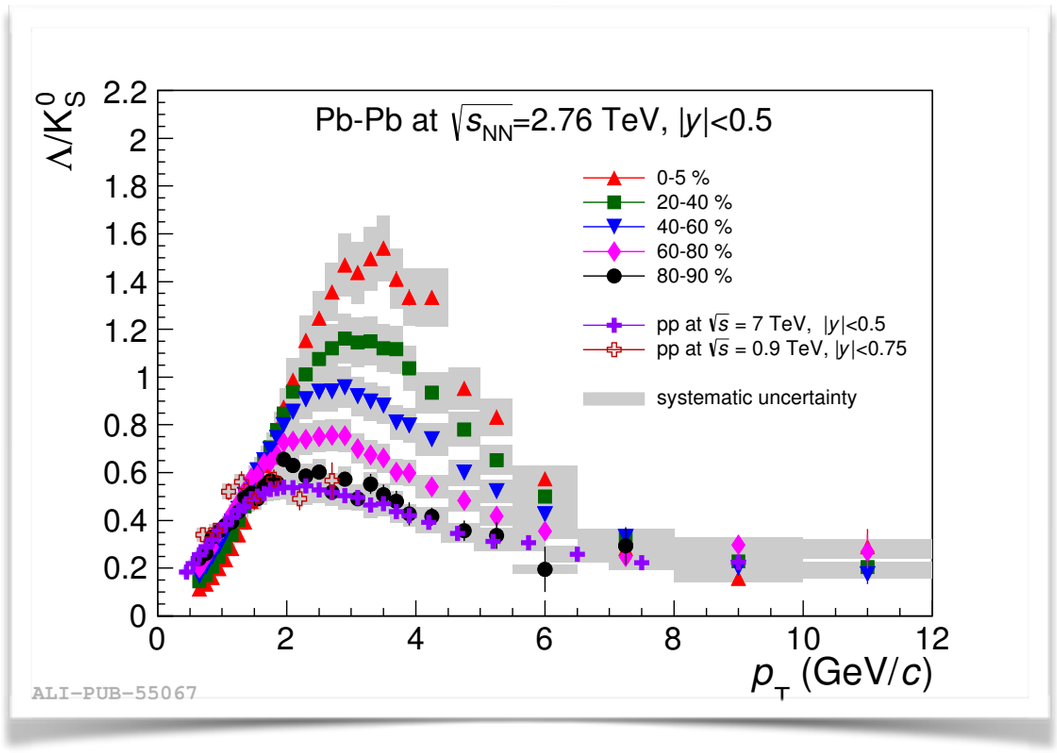
Outline

- **Physics motivation**
- **ALICE setup**
- **Analysis strategy**
- **Results and discussion**
- **Summary and outlook**

Physics Motivation

- **Baryon to meson enhancement in Pb-Pb and p-Pb observed w.r.t. pp collisions**
  - Involving several phenomena
    1. Bulk effect (radial flow, coalescence/recombination)?
    2. Jet fragmentation (?)
- **$\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets and underlying events**
  - Separation of soft and hard processes



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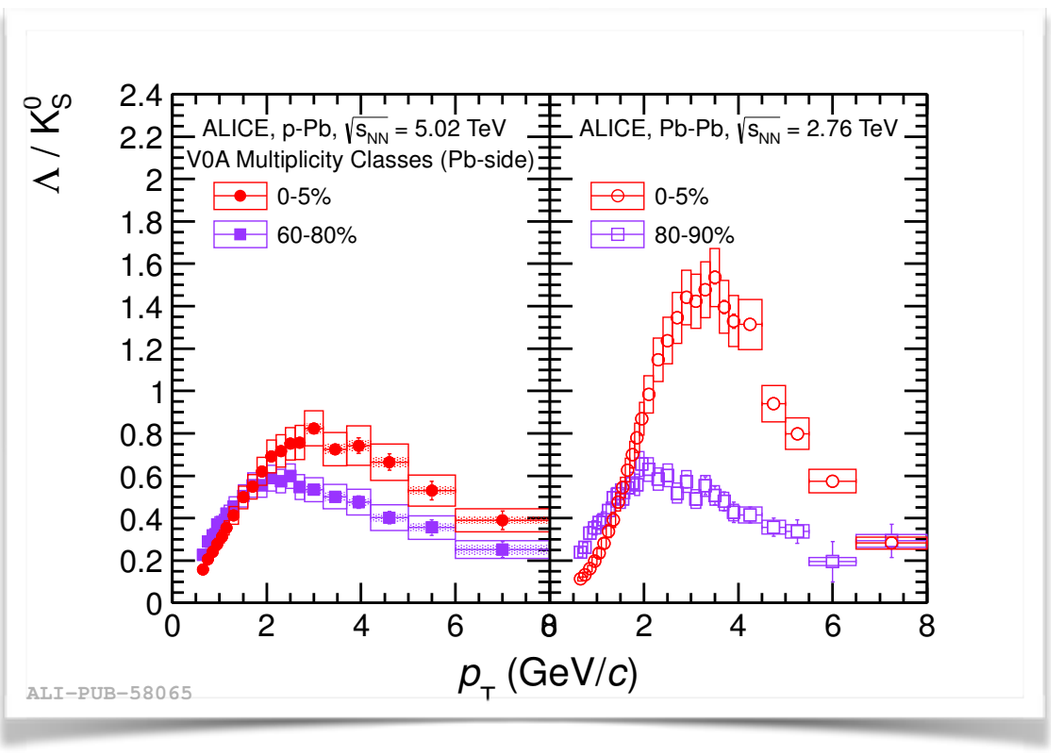

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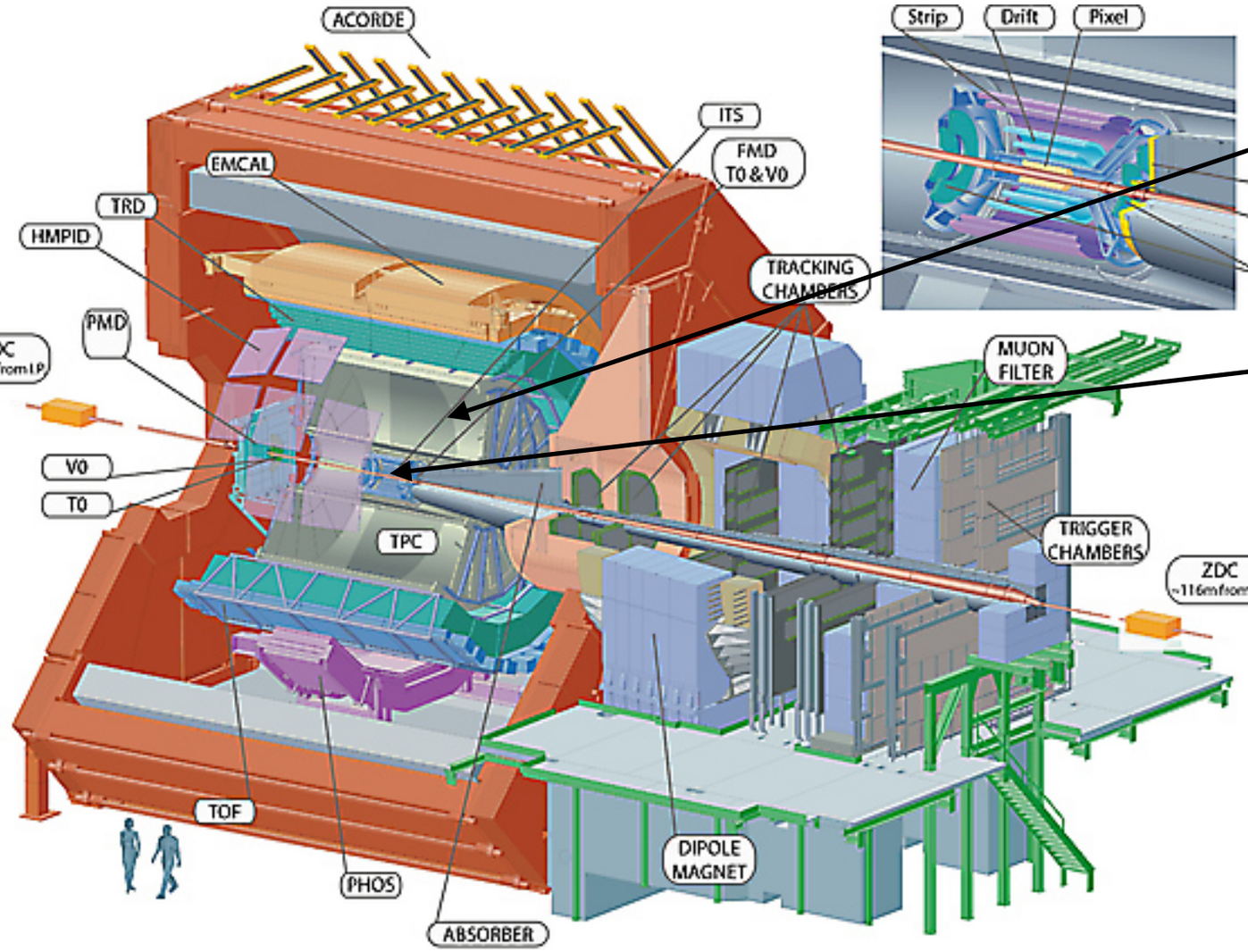
ALICE setup



Time projection Chamber(TPC)

- $|\eta| < 0.9$
- charged particle tracking and particle Identification

Inner Tracking System(ITS)

- $|\eta| < 0.9$
- vertex reconstruction
- event trigger

V0A(only for pPb) + V0C

- $2.8 < \eta < 5.1$ & $-3.7 < \eta < -1.7$
- event multiplicity class determination
- event trigger

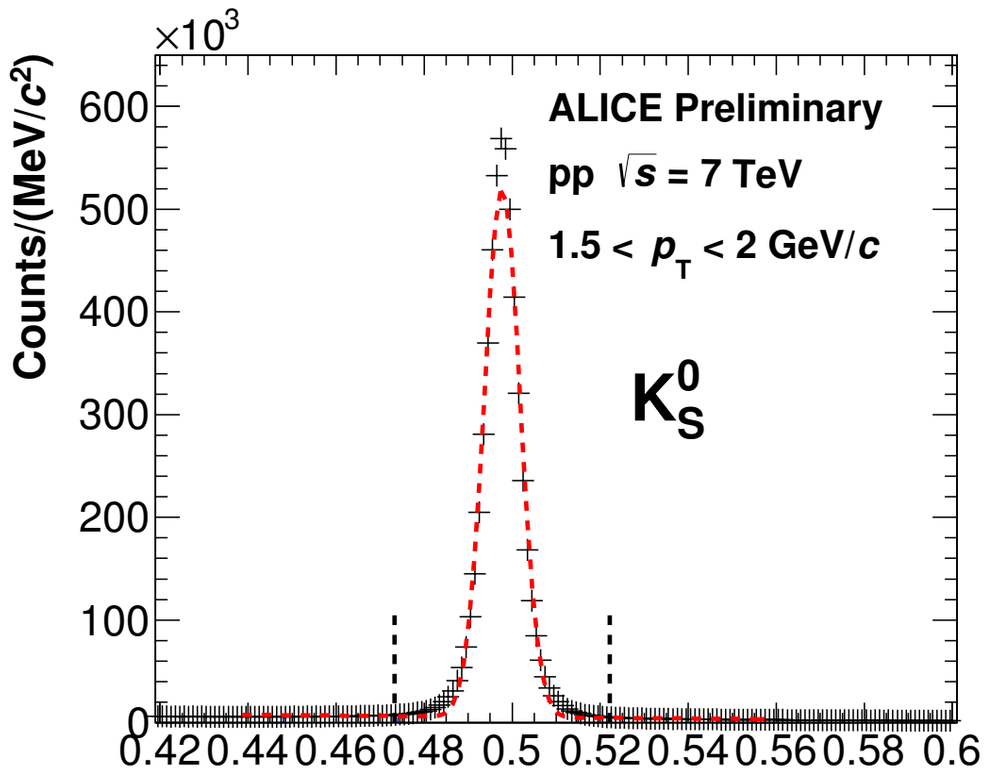
- **Advantage:** Particle Identification
- **Data sample:** pp collisions at 7 TeV, p-Pb collisions at 5.02 TeV, Pb-Pb collisions at 2.76 TeV
- pp collisions with 127 MB events, collected in 2010

Analysis strategy

- **V^0 candidate selection**
  - Select V^0 candidates by decay topology
  - Signal extract from invariant mass distribution
  - Acceptance: $|\eta| < 0.75$
- **Jet reconstruction**
  - Charged particles $|\eta| < 0.9$, $p_T > 150$ MeV/c
    - With excluding V^0 daughters
  - anti-k_t, $R = 0.4$ and 0.2, $|\eta_{jet}| < 0.35$
- **V^0s matched with jets (JC)**
  - V^0s and jets are reconstructed independently
  - Match V^0s with jets by angular distance between the jet axis and the V^0 direction

$$\sqrt{(\eta_{V^0} - \eta_{jet})^2 + (\varphi_{V^0} - \varphi_{jet})^2} < R_{matching}$$

- **V^0s in underlying events (UE)**
  - PC (default): V^0s in the perpendicular cone
  - NJ: V^0s in event without jet within $p_T > 5$ GeV/c
  - OC: V^0s outside the jet cone



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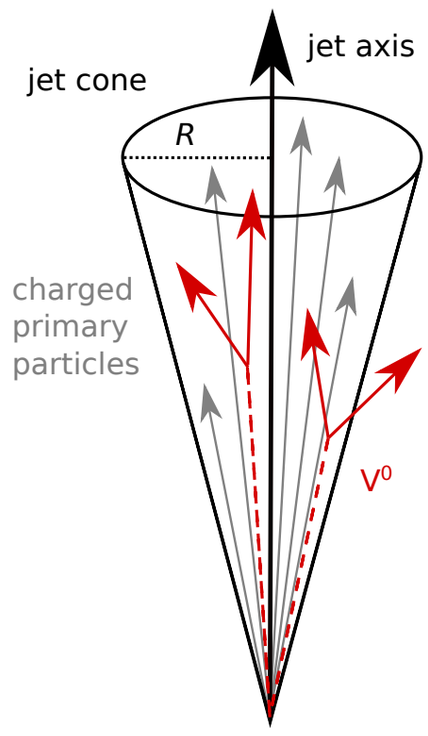
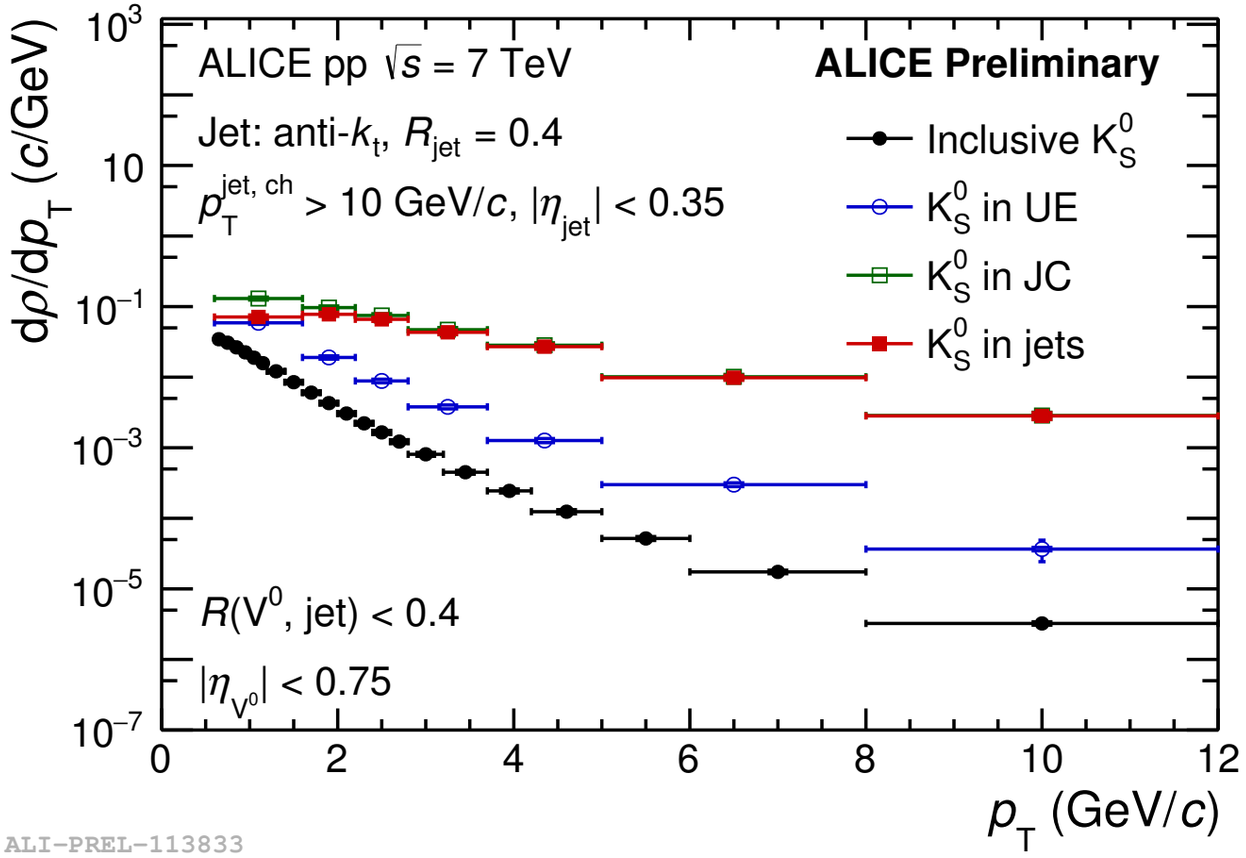


Corrected density of V^0s in jets with R_{jet} = 0.4

K^0_S



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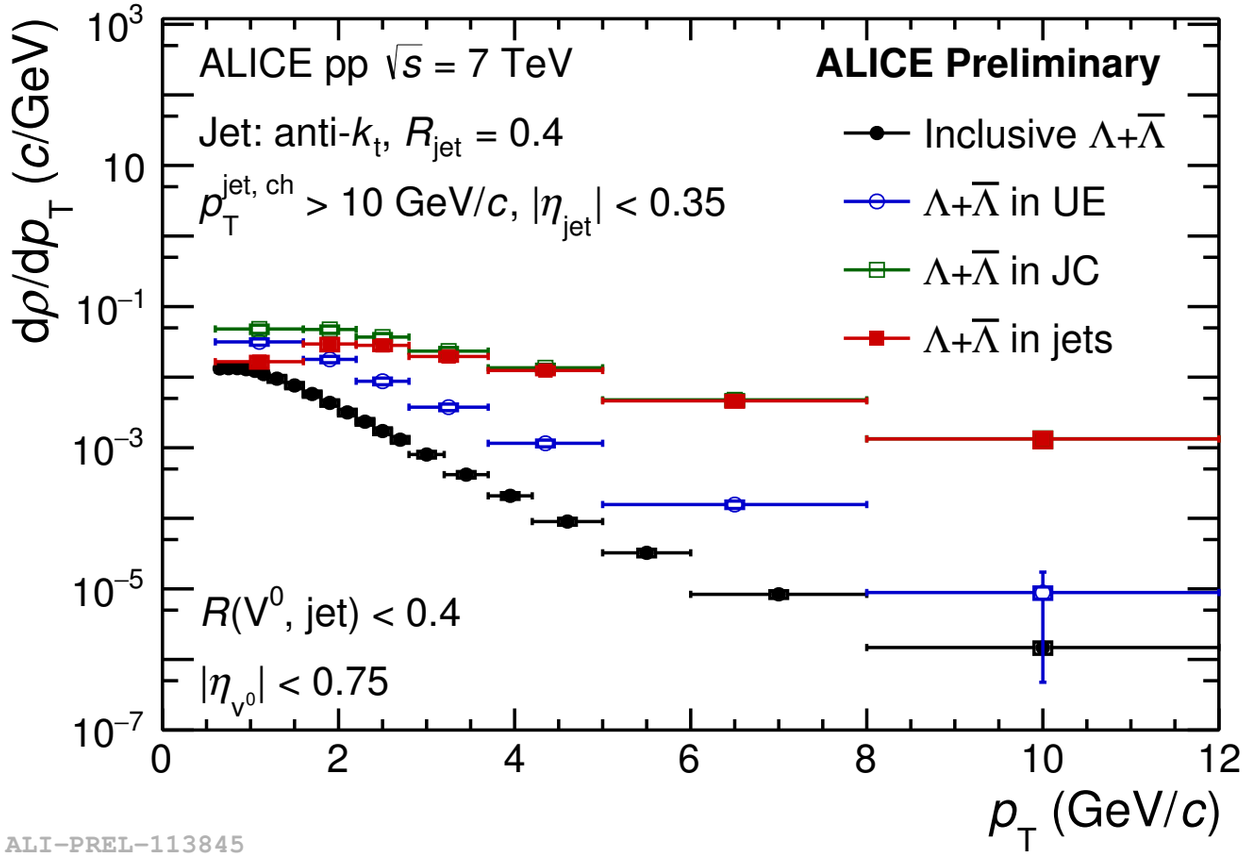
$\Lambda + \bar{\Lambda}$



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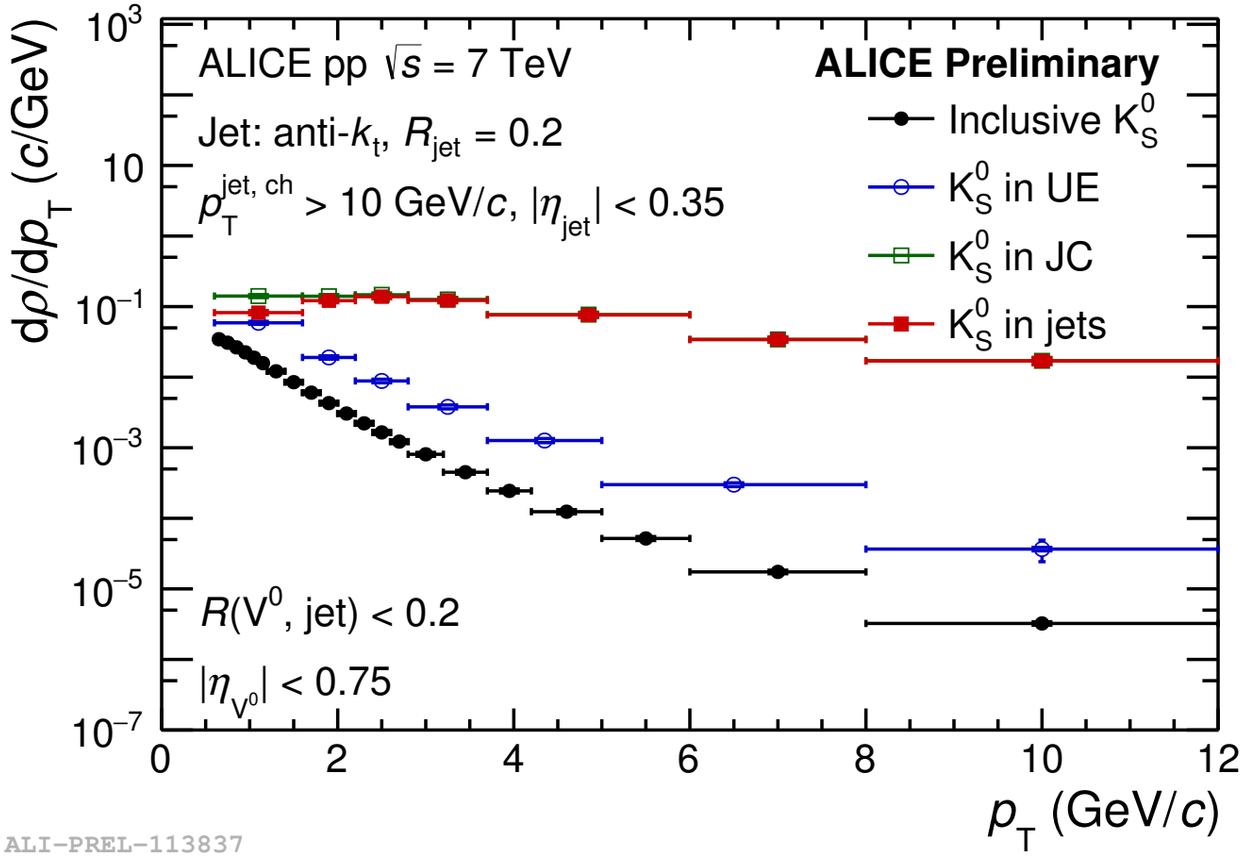
- The spectra normalised per area density and corrected by efficiency and feed down
- V^0s in jets: JC V^0s - UE V^0s
- Density of UE V^0s is smaller than that of JC V^0s, the effect is only relevant at low-p_T, overall the effect is small

Corrected density of V^0s in jets with R_{jet} = 0.2

K^0_S



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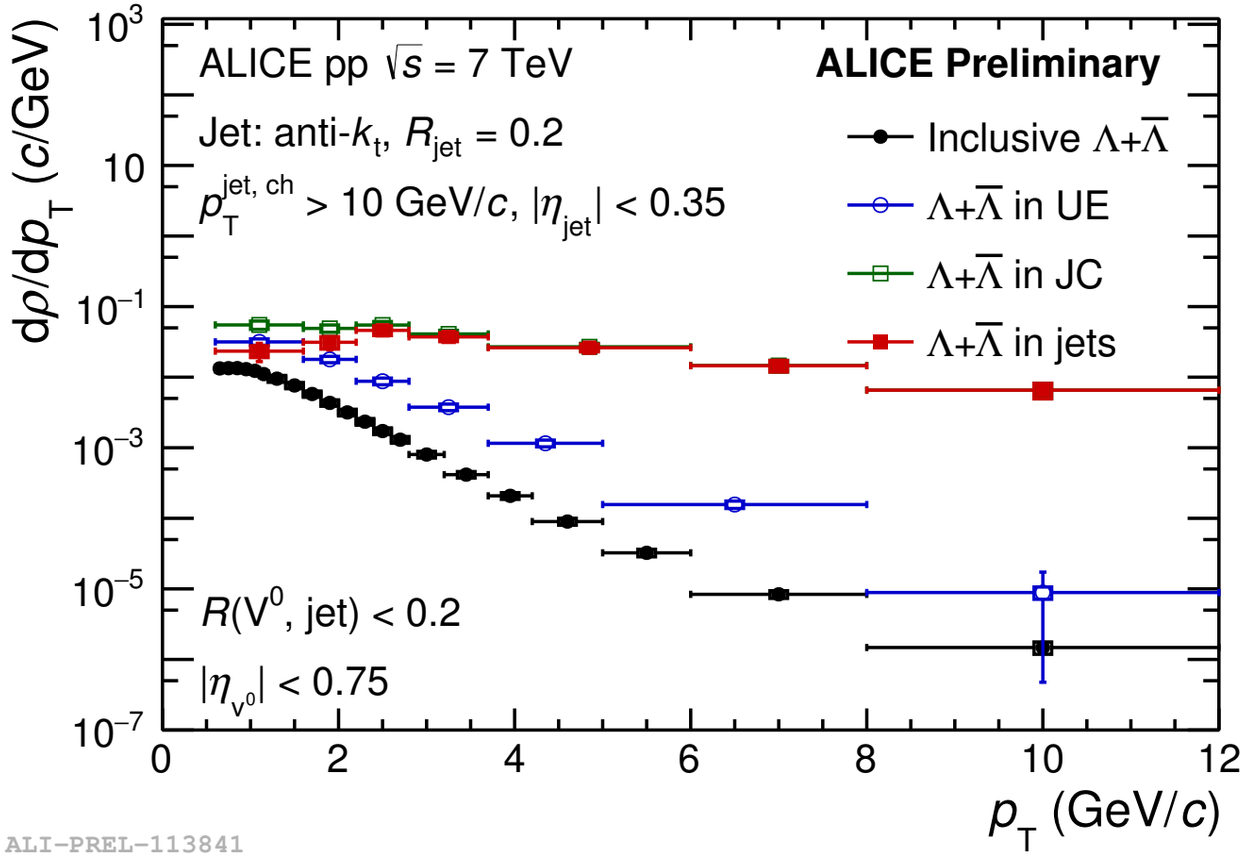
$\Lambda + \bar{\Lambda}$



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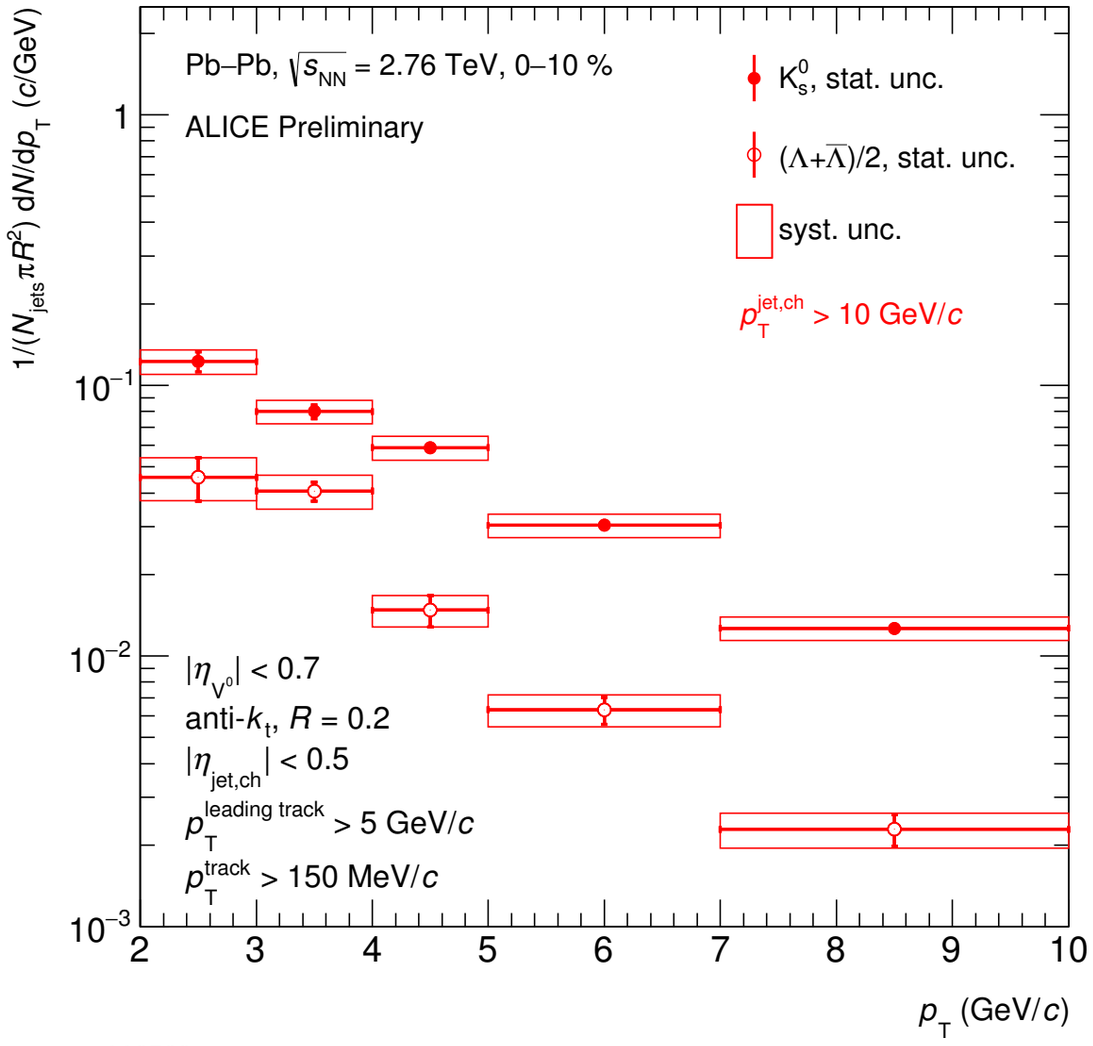
- Density of JC V^0s for R = 0.2 is higher than that for R = 0.4
  - V^0 transverse profile peaked around jet axis

Spectra of strange particles in charged jets in Pb-Pb collisions

$p_{\mathrm{T}}^{\mathrm{jet,ch}} > 10\ \mathrm{GeV}/c$ **Pb-Pb** $p_{\mathrm{T}}^{\mathrm{jet,ch}} > 20\ \mathrm{GeV}/c$



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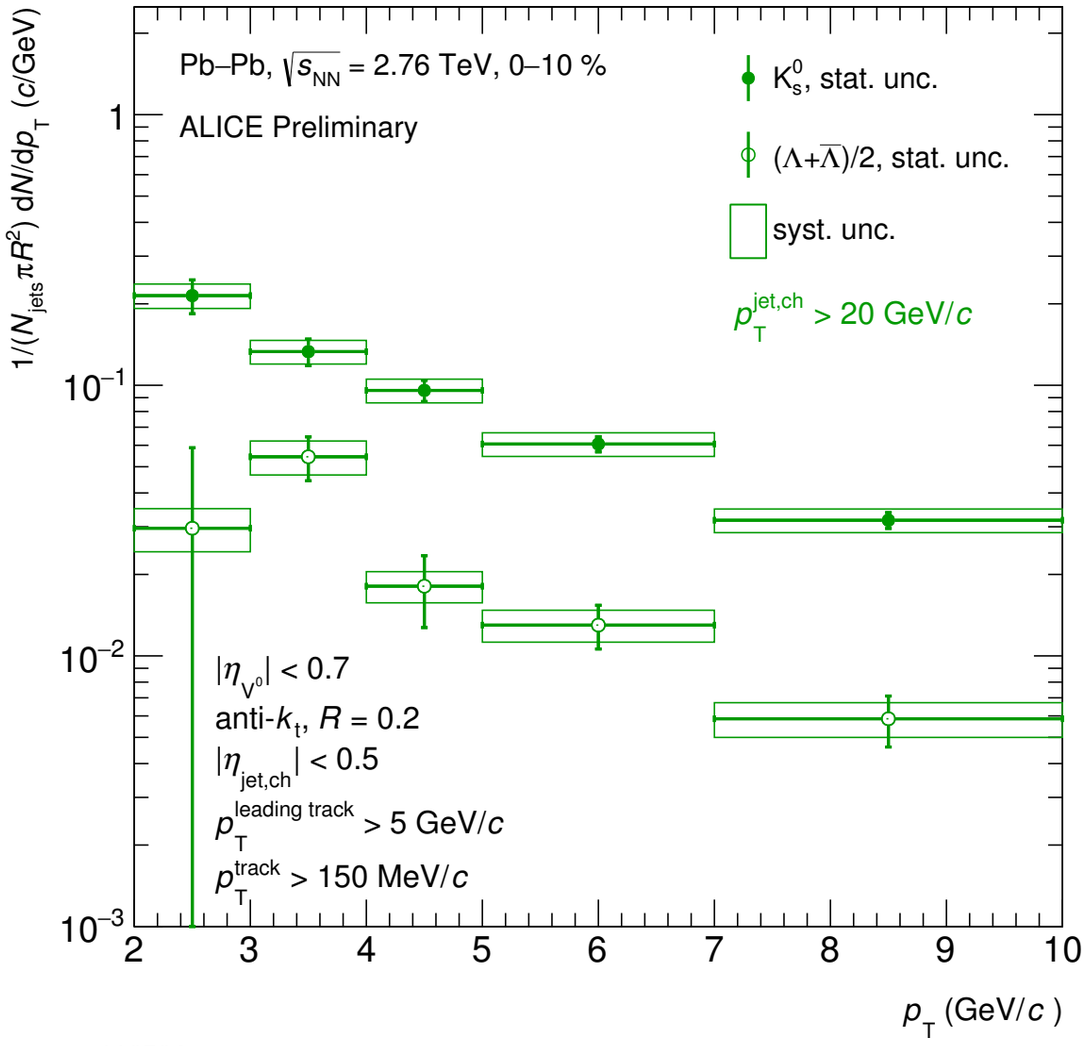

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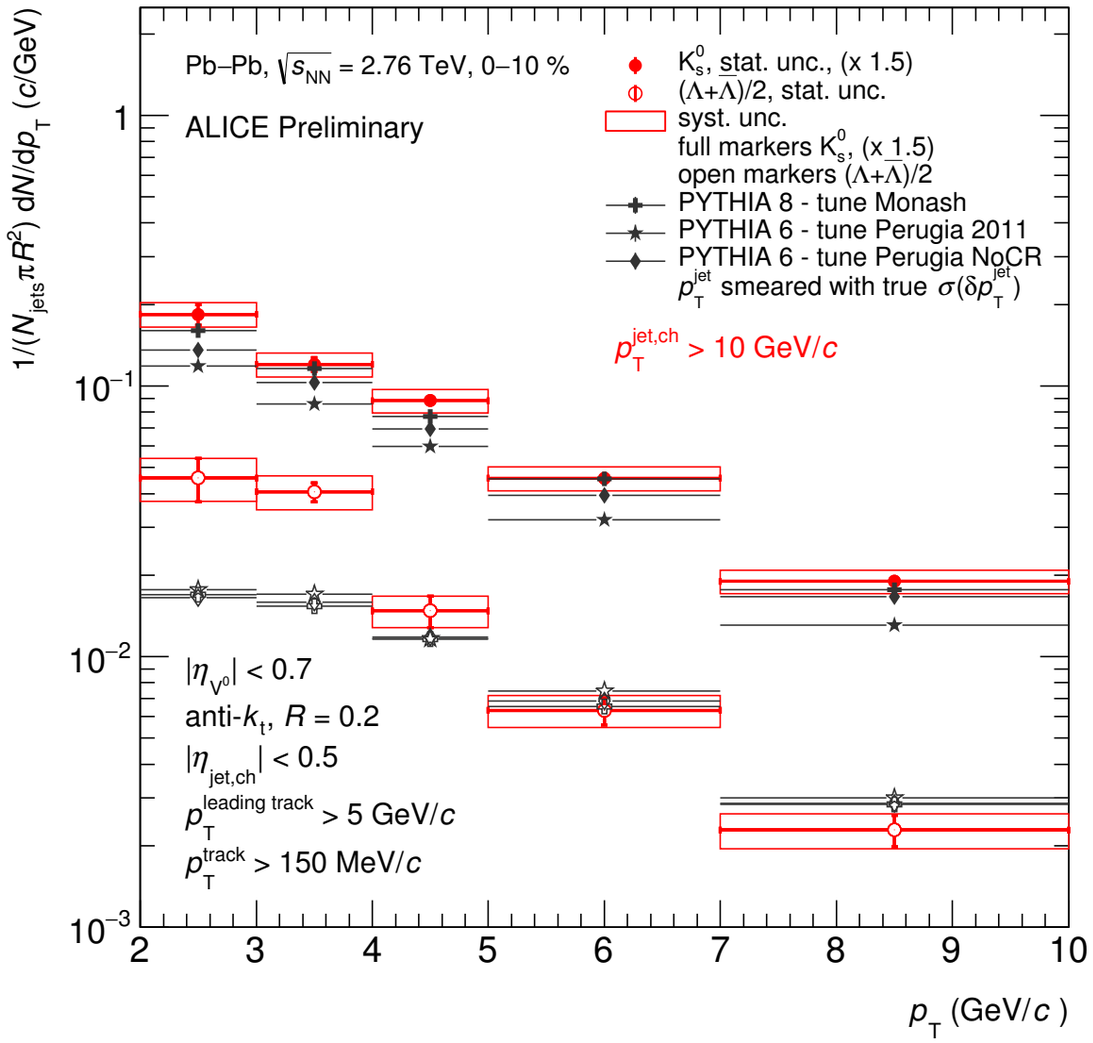
- V^0 p_{T} spectra are obtained with same method as that in pp analysis
  - Additional correction for impact of UE fluctuations applied

Comparison to PYTHIA simulations

$p_{\mathrm{T}}^{\mathrm{jet,ch}} > 10$ GeV/c **Pb-Pb** $p_{\mathrm{T}}^{\mathrm{jet,ch}} > 20$ GeV/c



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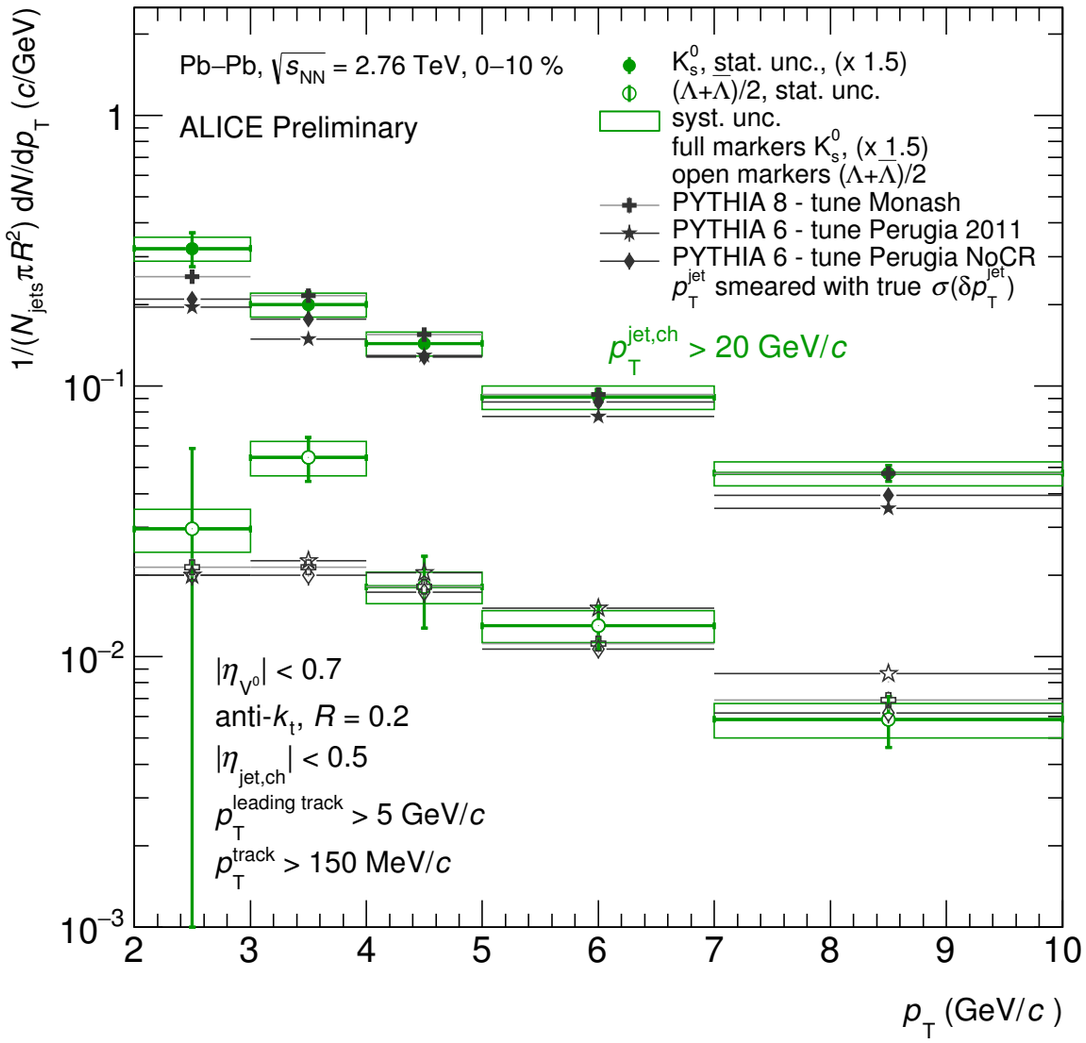

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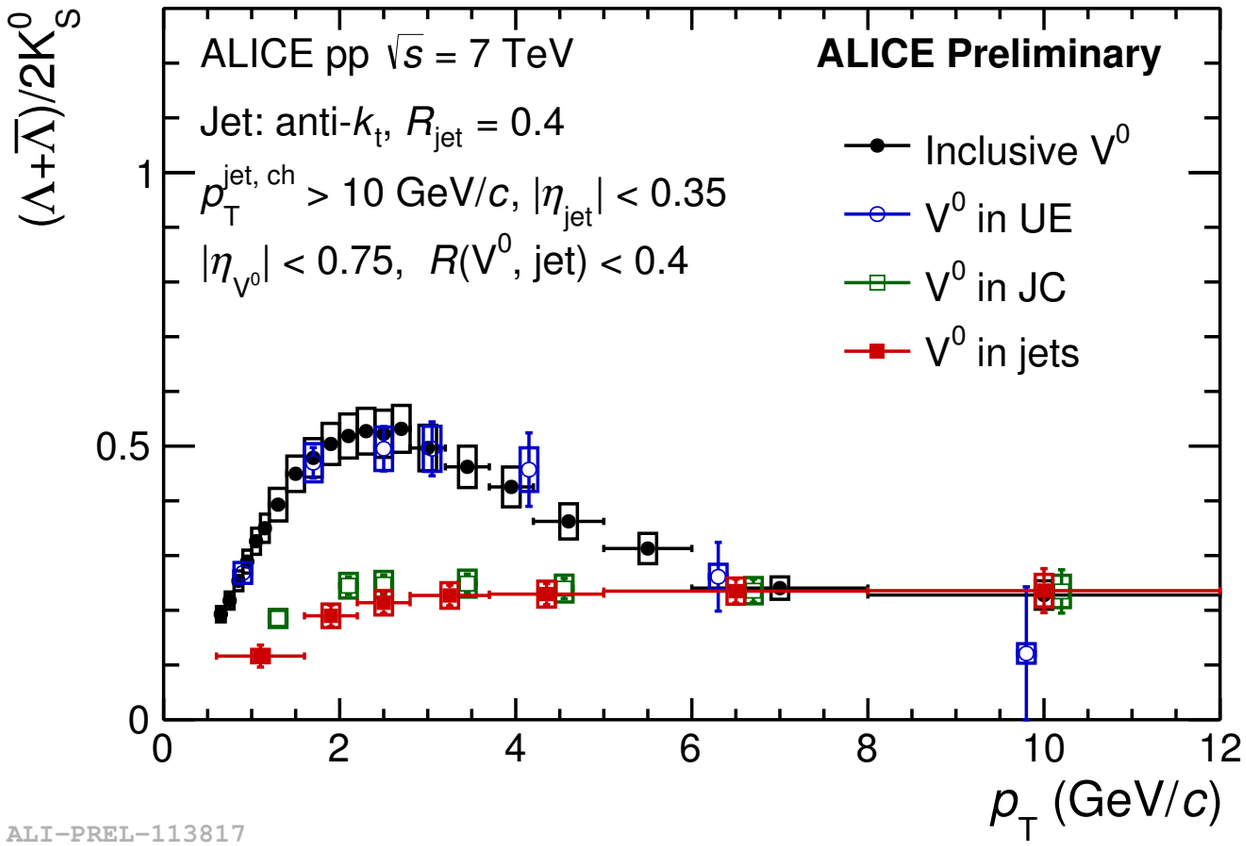
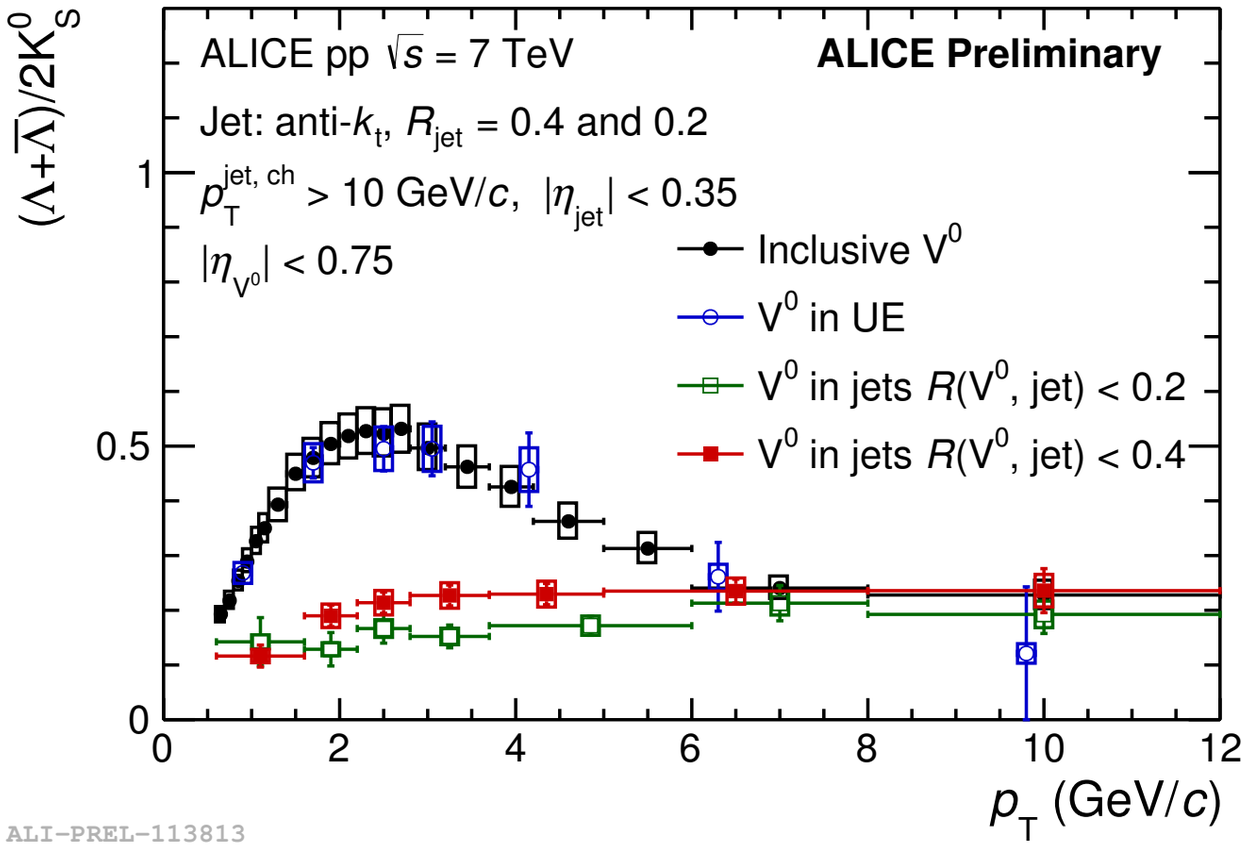
- V^0 p_{T} spectra in data follow similar slope as predicted by PYTHIA simulations
  - Λ - shows clear enhancement at low p_{T} (< 4 - 5 GeV/c)
  - Indication of that we need better reference measurements to become more quantitative

$\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in UE and Jets with different jet radius

pp

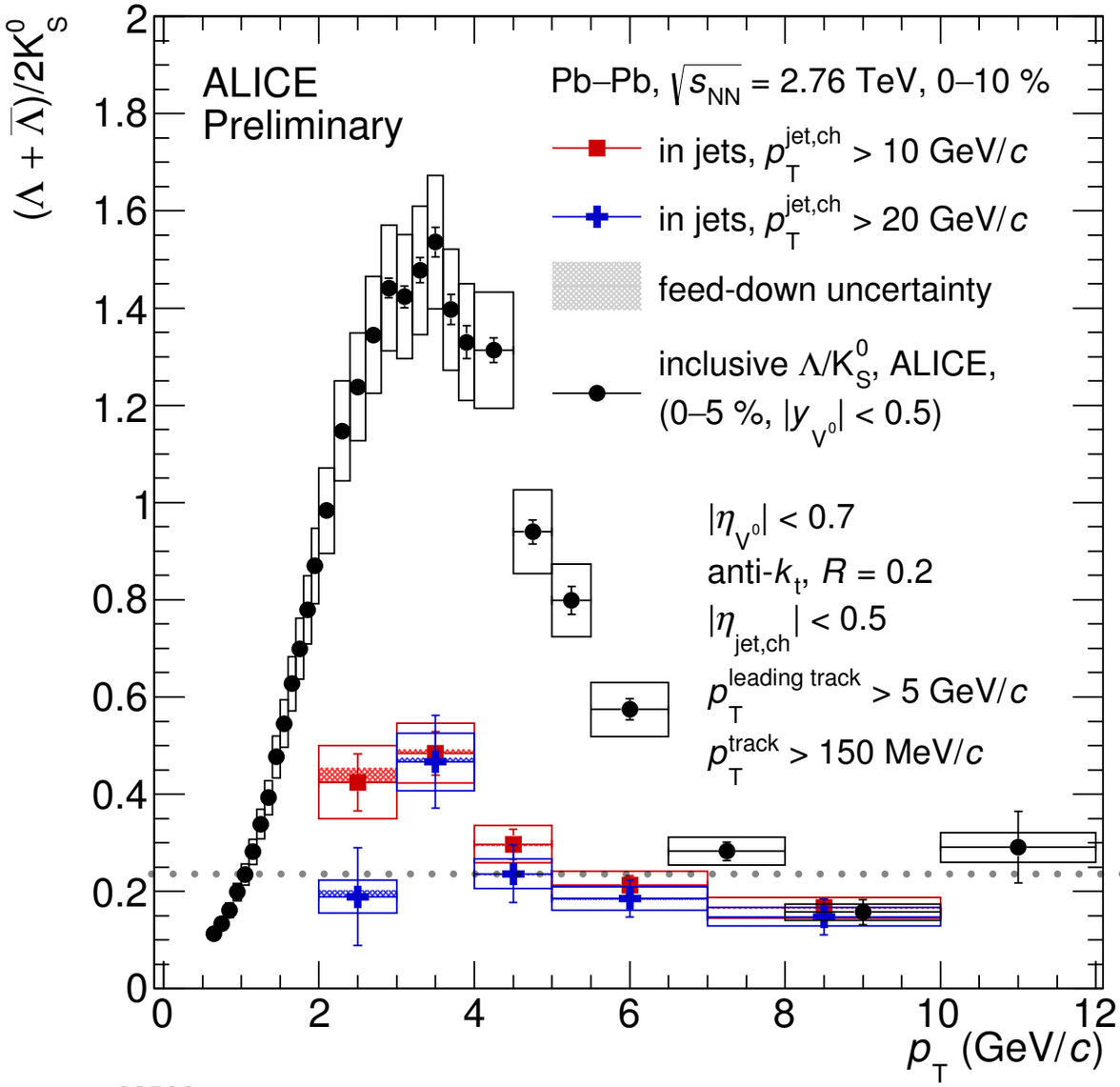




1. K^0_S and Λ in the UE region - consistent with inclusive measurements
2. $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets is unambiguously different from the UE (and inclusive)
3. UE subtraction most relevant at low-p_T
4. Slight decrease of the ratio with decreasing $R(V^0, jet)$
5. The ratio is flat with $p_{T,V^0} > 3$ GeV/c, and consistent with inclusive V^0s at high p_T

Comparison with Pb-Pb, p-Pb collisions

Pb-Pb



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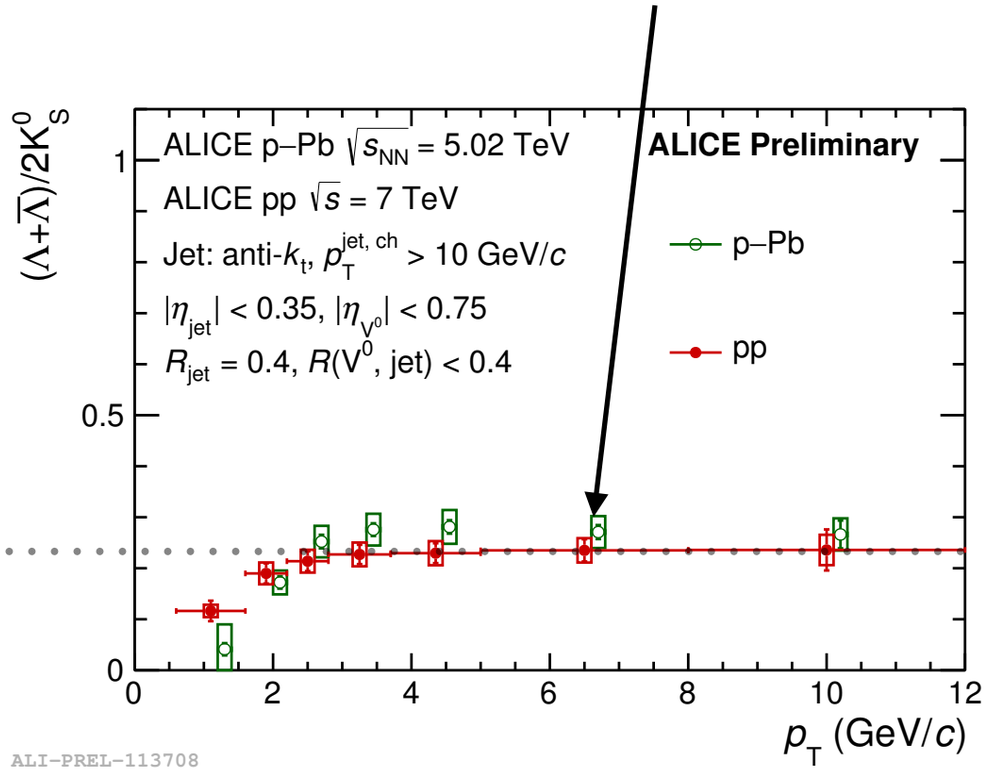
pp/p-Pb

- pp consistent with p-Pb within uncertainties in jet R = 0.4



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- Λ/K^0_S ratio in jets significantly lower than ratio for inclusive V^0s observed in different collision systems
- Λ/K^0_S ratio in jets are consistent with inclusive at high p_T in pp, p-Pb and Pb-Pb collisions
- The ratio has no significant $p_T^{jet,ch}$ dependence

Summary and outlook

- **Summary**
  - V⁰s in jets have been studied in pp, p-Pb and Pb-Pb in ALICE
  - $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets are in agreement among different collision systems within systematical uncertainties
  - Difference is found unambiguously between V⁰ in jets and in UE
  - Λ p_T spectra in jets in Pb-Pb collisions show an enhancement at low p_T (< 4-5 GeV/*c*) w.r.t. PYTHIA simulations while being consistent with PYTHIA at higher p_T (> 5 GeV/c)
  - Hint of medium modified jet fragmentation - effect differs between baryons and mesons
- **Outlook**
  - $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets with multiplicity dependence in pp and p-Pb
  - $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets with centrality dependence in Pb-Pb
  - $\Lambda/\mathrm{K}^0_\mathrm{S}$ ratio in jets with energy dependence with RUN II Pb-Pb at 5 TeV

Backup

Detail cuts

selection	value
Track Kink index	< 1
$\|\eta\|$	< 0.8
TPC refit flag	kTRUE
number of crossed rows in TPC	> 70
number of findable rows in TPC	> 0
crossed rows / findable rows ratio	> 0.8
TPC dE/dx	$< 5\ \sigma$

Table 4.1: Default selections for V^0 daughter tracks.

selection	value
V^0 2D decay radius	in [0.5,200] cm
negative track DCA to PV	$> 0.06cm$
positive track DCA to PV	$> 0.06cm$
DCA between V^0 Daughters	$< 1\sigma$
$\cos\theta_{pointing}$	> 0.97 (K^0_S), > 0.995 (Λ)

Table 4.2: Default cuts for V^0 decay topological selection

Normalisation

$$\frac{d\rho}{dp_{\mathrm{T}}}_{Inclusive} = \frac{1}{N_{event} * (acceptance)} * \frac{dN}{dp_{\mathrm{T}}}$$

$$\frac{d\rho}{dp_{\mathrm{T}}}_{JC} = \frac{1}{N_{jet}\pi r^2 * factor_{overlapped}} * \frac{dN}{dp_{\mathrm{T}}}$$

$$\frac{d\rho}{dp_{\mathrm{T}}}_{PCL} = \frac{1}{2 * N_{jet}\pi r^2 * factor_{overlapped}} * \frac{dN}{dp_{\mathrm{T}}}$$

$$\frac{d\rho}{dp_{\mathrm{T}}}_{PCU} = \frac{1}{2 * N_{jet}\pi r^2 * factor_{overlapped}} * \frac{dN}{dp_{\mathrm{T}}}$$

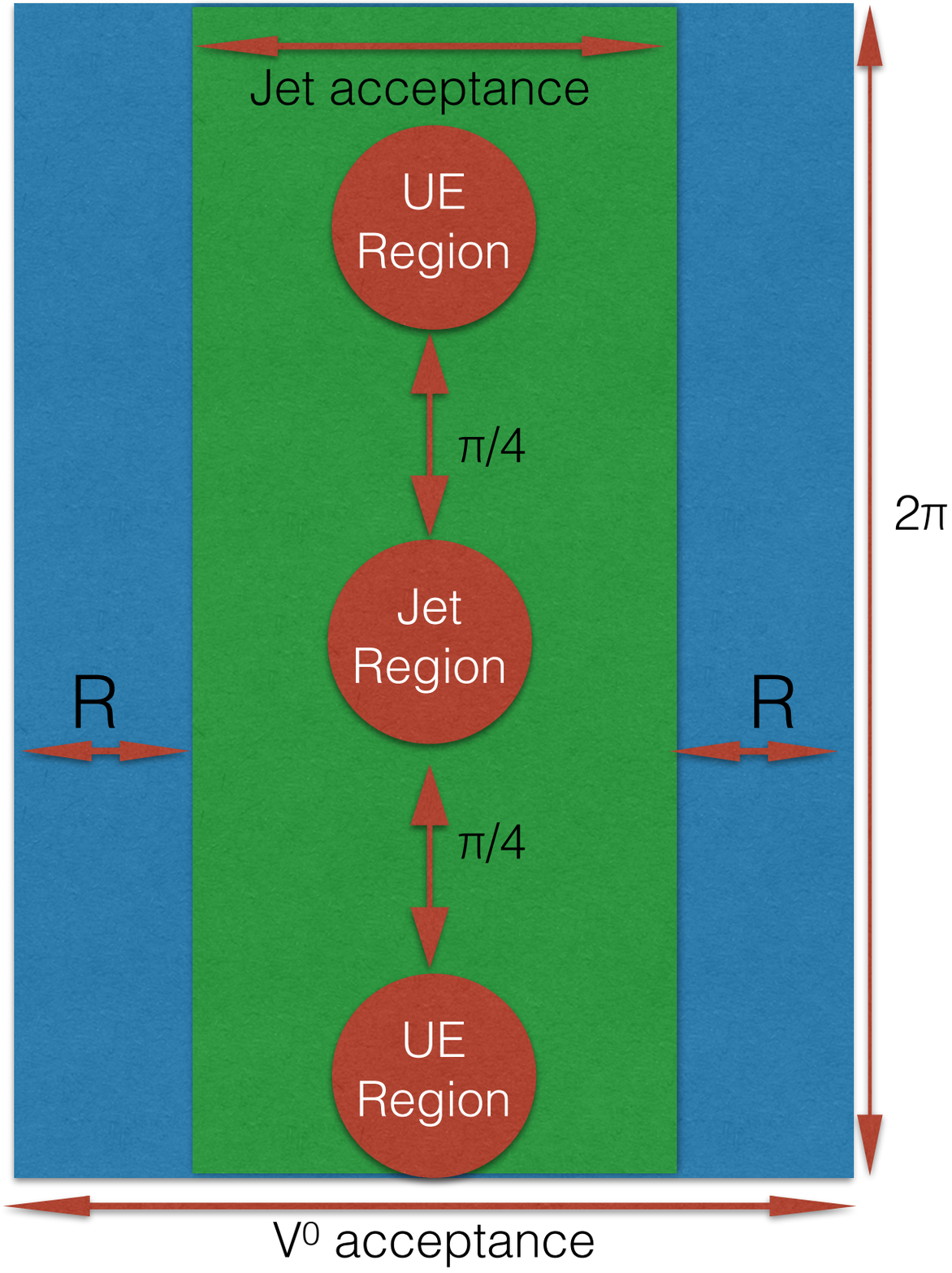
$$\frac{d\rho}{dp_{\mathrm{T}}}_{OC} = \frac{1}{N_{event} * (acceptance - (Njet/Nevent) * factor_{overlapped} * \pi r^2)} * \frac{dN}{dp_{\mathrm{T}}}$$

factor describe the overlap effect of multi-jets events

Analysis strategy

1. Tag hard scattering with charged particle jets (jet pt>10 GeV/c)
2. Reconstruct Λ and K_s^0 within “Jet Region”
3. Reconstruct Λ and K_s^0 within “UE Region”
4. Correct V0s in the Jet Region and UE Region.
5. Subtract the Λ and K_s^0 in “UE Region from Jet Region”
6. Correct V0s by Feeddown correction

→ Yield and ratio of Λ and K_s^0 in jets

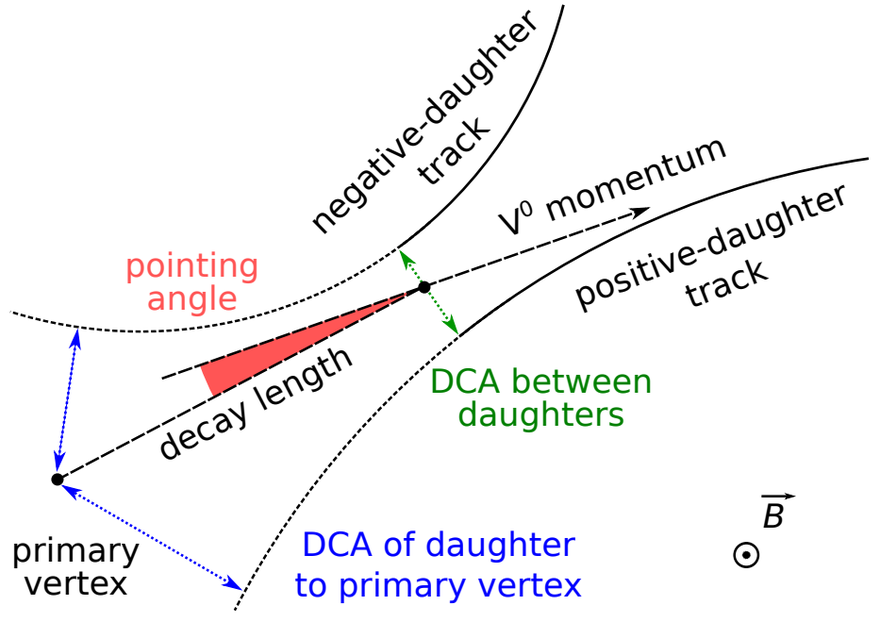


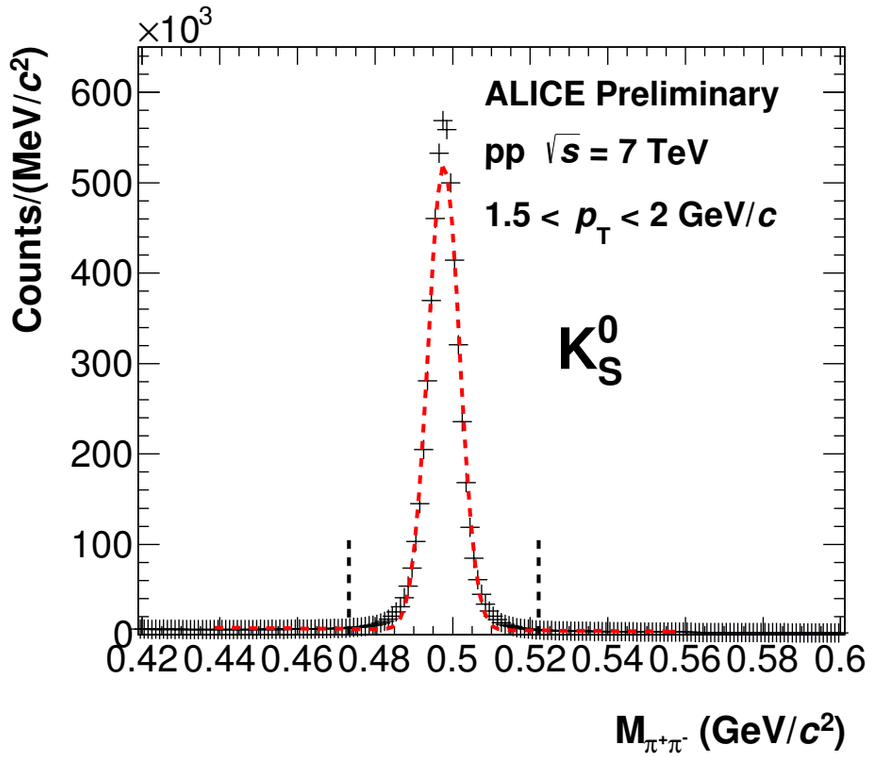
V⁰ candidate selection

- **V⁰ candidate selection**
  - Decay channels

$$K^0_S \to \pi^+\pi^- \ (\mathrm{BR} = 0.692) \text{ and } \Lambda \to p\pi^- \ (\mathrm{BR} = 0.639)$$

  - Decay topology based on five variables
  - Acceptance: |η|<0.75
  - Details: see in the backup
- **V⁰ signal extraction**
  - Fit invariant mass with gaussian plus a linear function in each p_T bin
    - extract the mean and sigma
  - Define the side bands and signal region
    - signal region: $|M_{inv} - M_{mean}| < N\,\sigma$, default N=6
    - side bands: $N\,\sigma < |M_{inv} - M_{mean}| < 2N\,\sigma$
  - Background subtraction - bin counting
    - fit with linear function from side bands and interpolate into signal region





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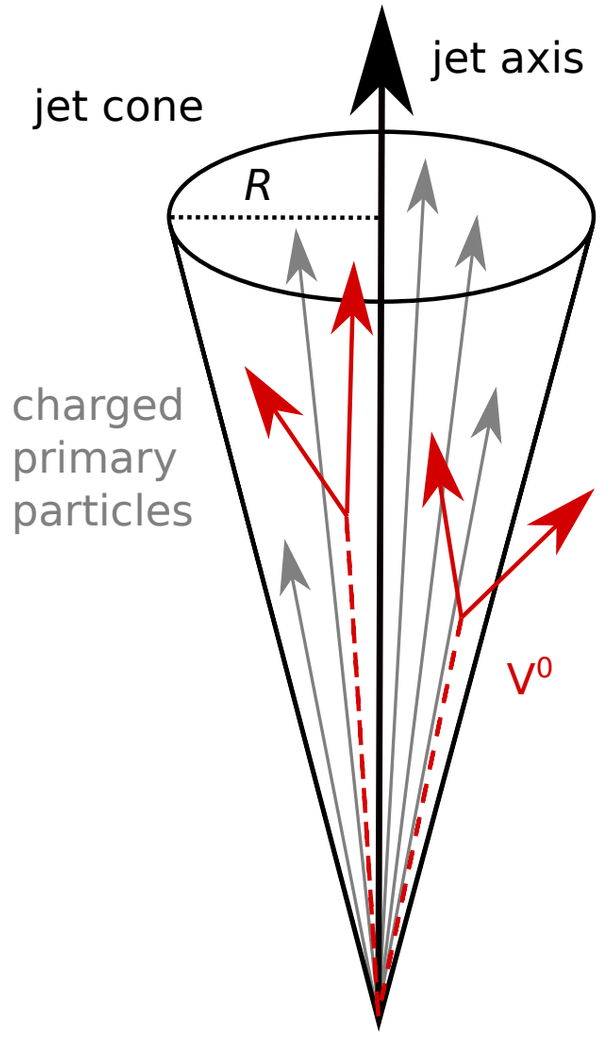
Jet reconstruction and V^0-jet matching

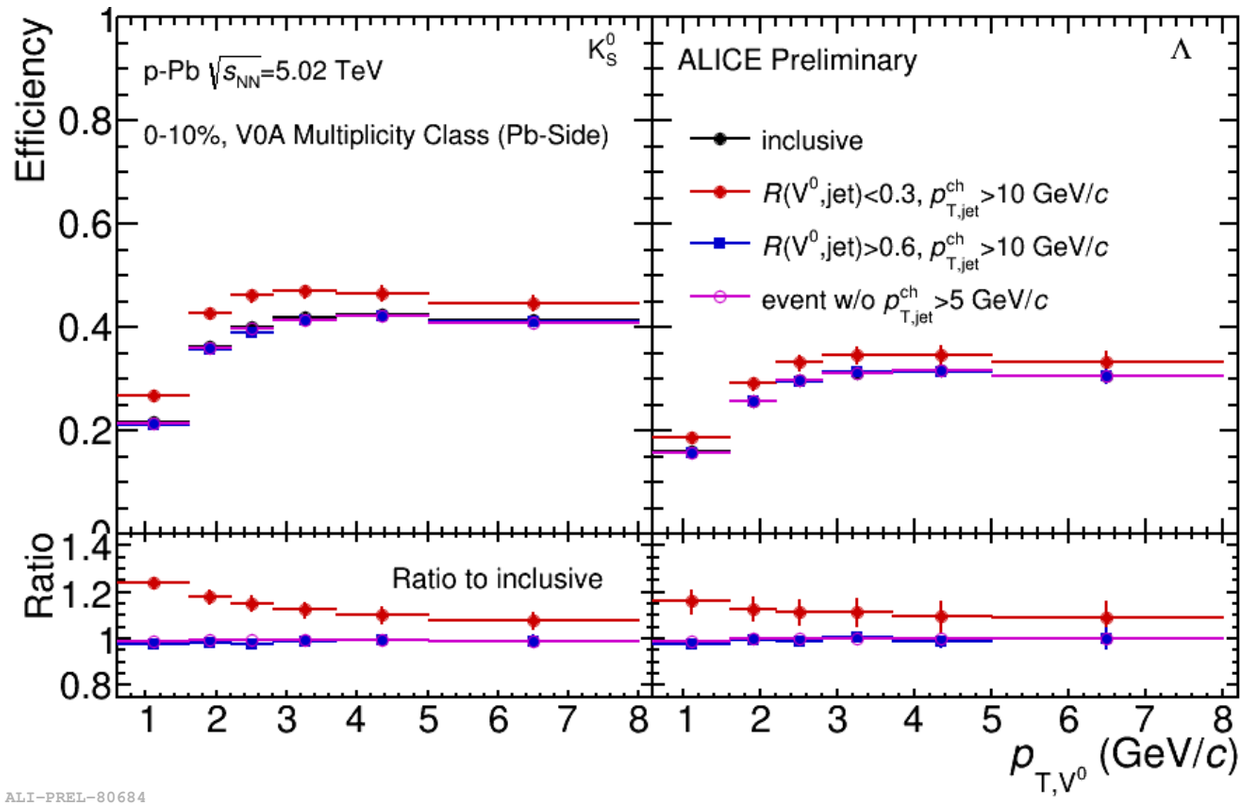
- **Jet reconstruction**
  - Charged particles $|\eta|<0.9$, $p_T>150$MeV
  - anti-k_T, R=0.4 and 0.2, $|\eta_{jet}|<0.35$
- **V^0-jet matching(JC)**
  - V^0s and Jets are reconstructed independently
  - Match V^0s and jets with a matching radius
- **Underlying V^0s(UE)**
  - PC: V^0s in perpendicular cones
  - NJ: V^0s in event w/o jet in $p_T > 5$ GeV/c
  - OC: V^0s outside matching cone
- **PC used as the default UE estimator, NJ and OC are used for estimating uncertainty on underlying event subtraction**



$$\sqrt{(\eta_{V^0}-\eta_{jet})^2+(\varphi_{V^0}-\varphi_{jet})^2}<R$$

Correction

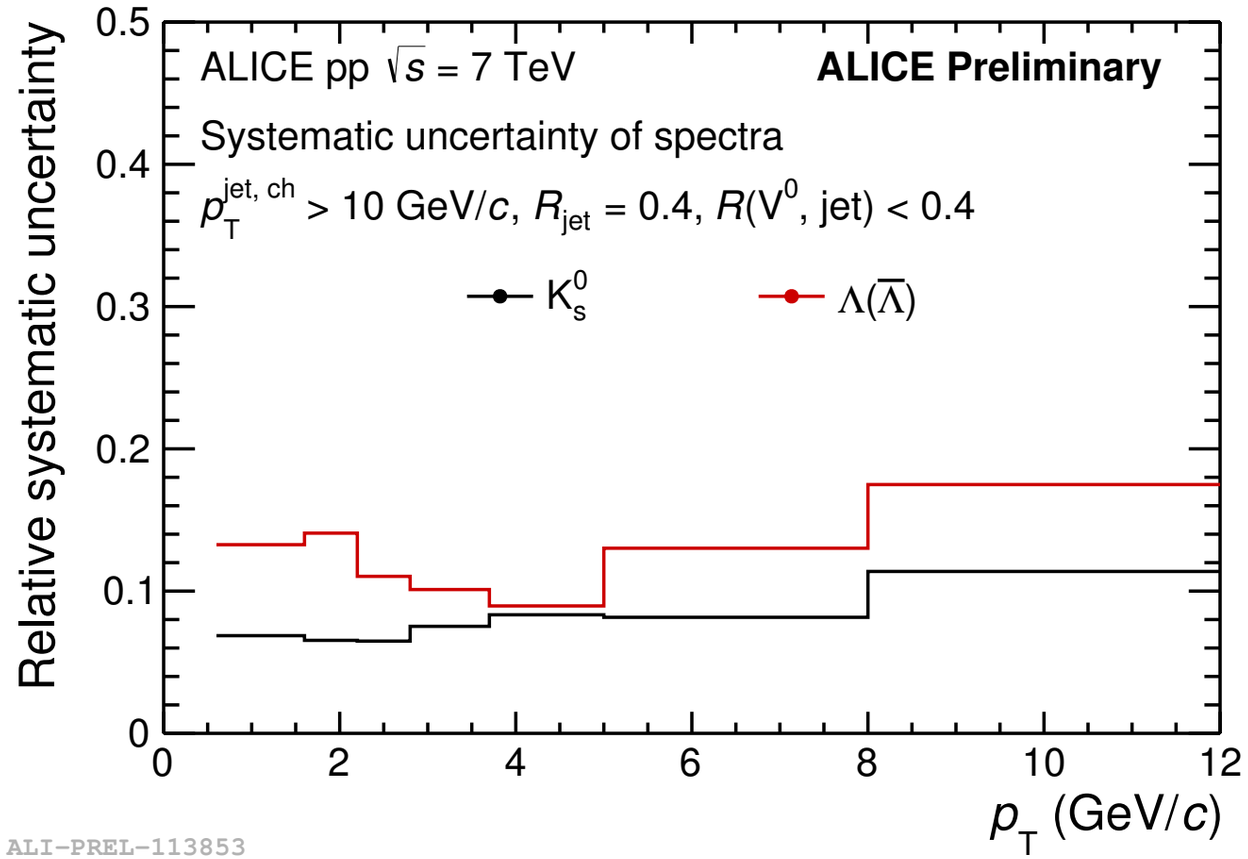
- **Efficiency of V^0s**
  - Efficiency depends on η
  - η distribution of V^0s in jets is different from that of inclusive V^0s

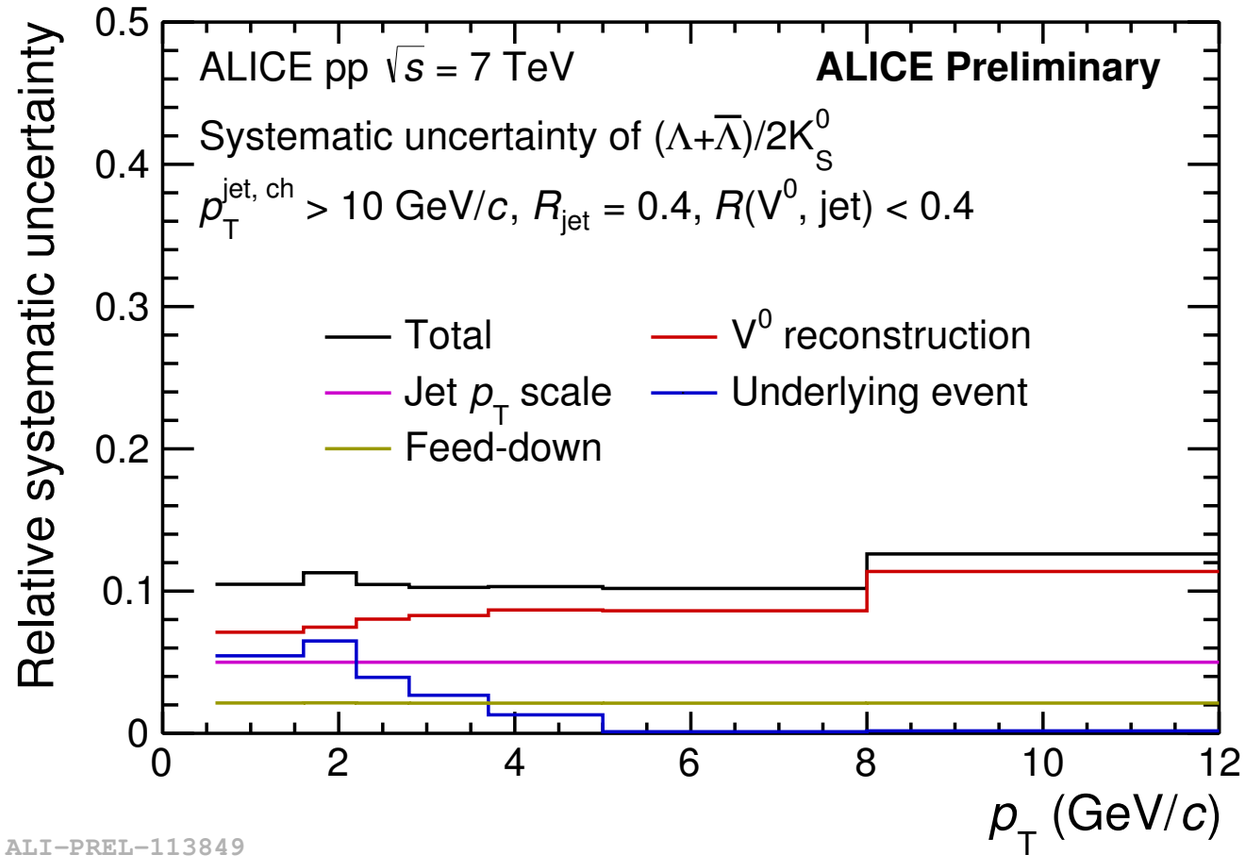


- An η weighted method used to correct the efficiency in jets and UE.
- The η weighted efficiency for V^0s in jets are higher than inclusive V^0s in lower p_T, and consistent in high p_T
- The η weighted efficiency or V^0s in UE is constant with Inclusive V^0s

- **Feeddown correction for Λ from Ξ**
  - Secondary V^0s in jet cone have been corrected after underlying event subtraction
  - The difference between the feed down fraction from Inclusive V^0s in data and that of V^0s in jets is taken as uncertainty(3%)

Systematic uncertainty estimation





- Uncertainty consists of V^0 reconstruction, jet p_T scale, Underlying subtraction and Feeddown subtraction
- Systematic uncertainties for V^0 yield in jets is less than 18%, UE subtraction dominates at lower p_T, V^0 reconstruction dominates at higher p_T
- The systematic uncertainty of L/K ratio is nearly 11%