Strangeness production in jets and the underlying event in pp, p-Pb and Pb-Pb collisions with ALICE

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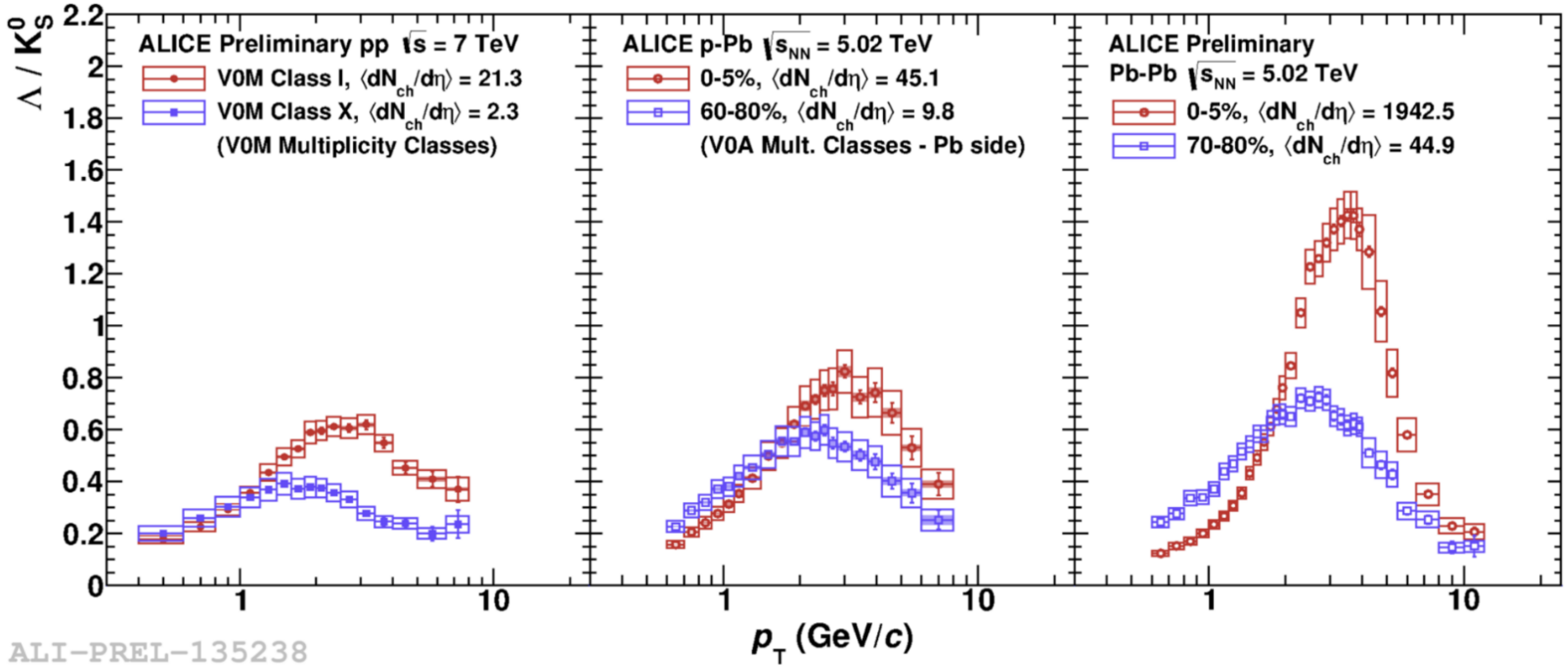
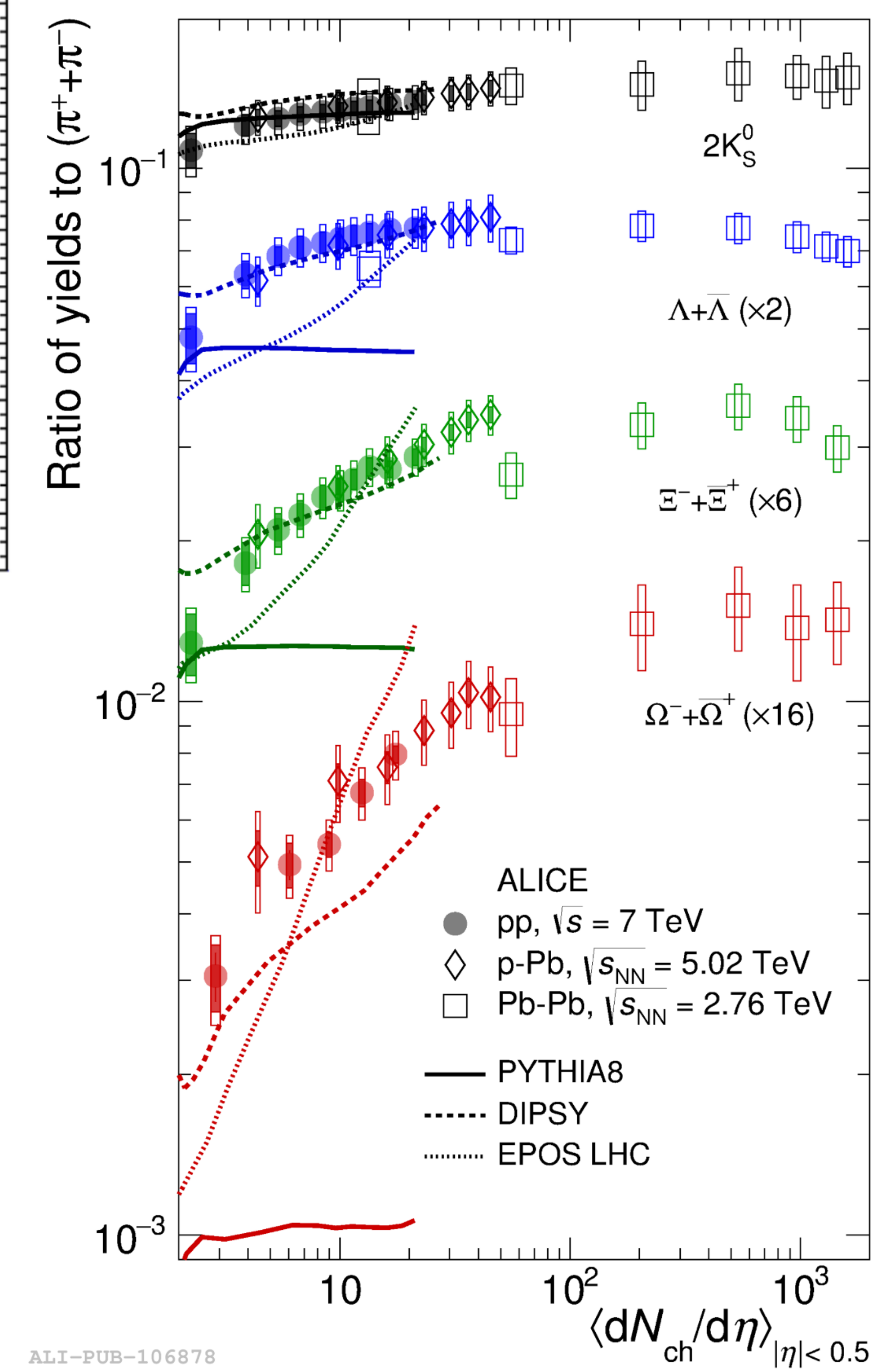
06/22/2018

中国物理学会高能物理分会第十届全国会员代表大会暨学术年会

Motivation



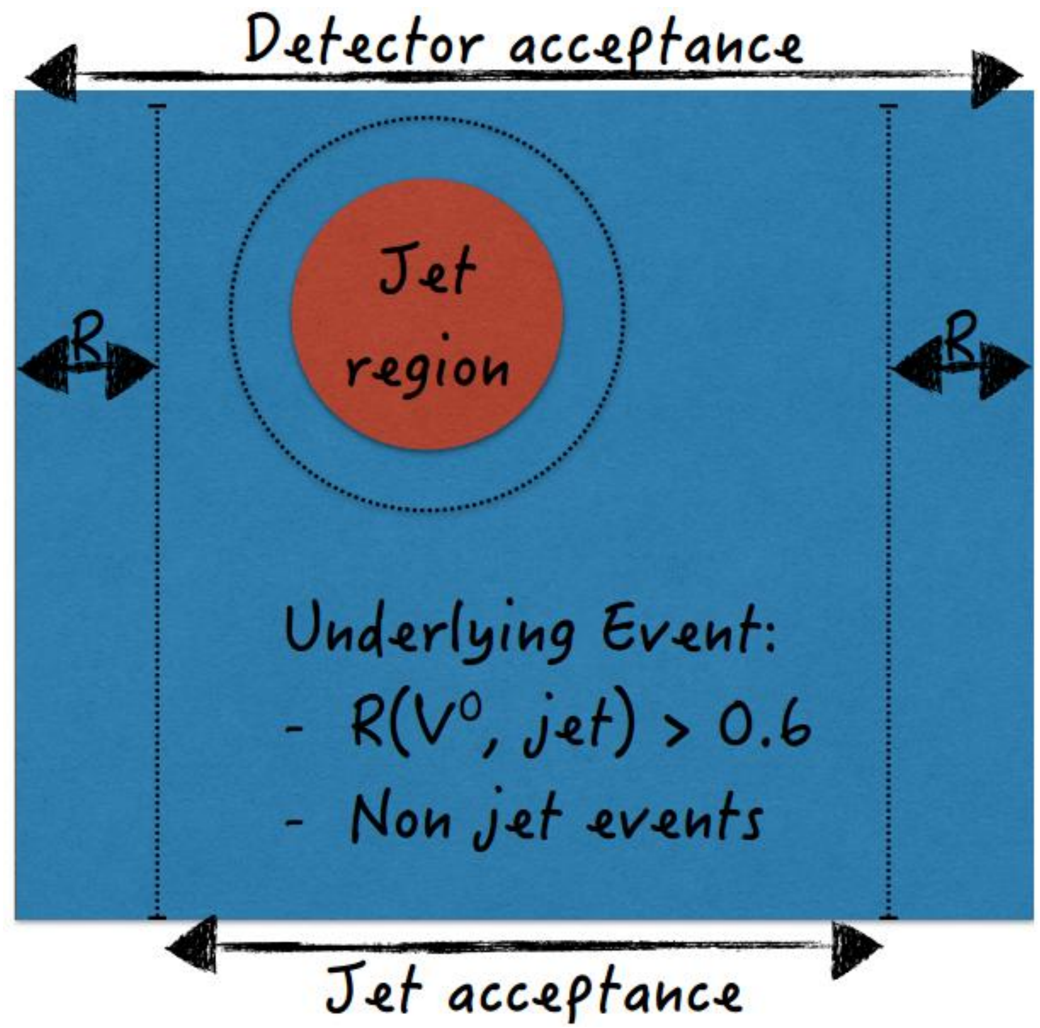
Nature Phys. 13 (2017) 535-539



- Enhancement of Λ/K^0_S ratio observed at intermediate p_T at high multiplicity in pp, p-Pb and Pb-Pb collisions w. r. t that at low multiplicity
- Production of multi-strange particle increases with multiplicity
  - ➢ The similarity behavior among different systems

This analysis

- Jets provide a nature reference to separate particles produced in hard processes and underlying events→**further constraints on particle production mechanisms in different systems**
  - **pp**
    - ✓ Study the jet fragmentation properties in vacuum
    - ✓ Provide reference for p-Pb and Pb-Pb systems
  - **p-Pb**
    - ✓ Have a new insight into understanding the origin of flow-like behavior observed at high multiplicity in small systems
  - **Pb-Pb**
    - ✓ Study medium modified jet fragmentation and potential constraint on jet-medium excitation

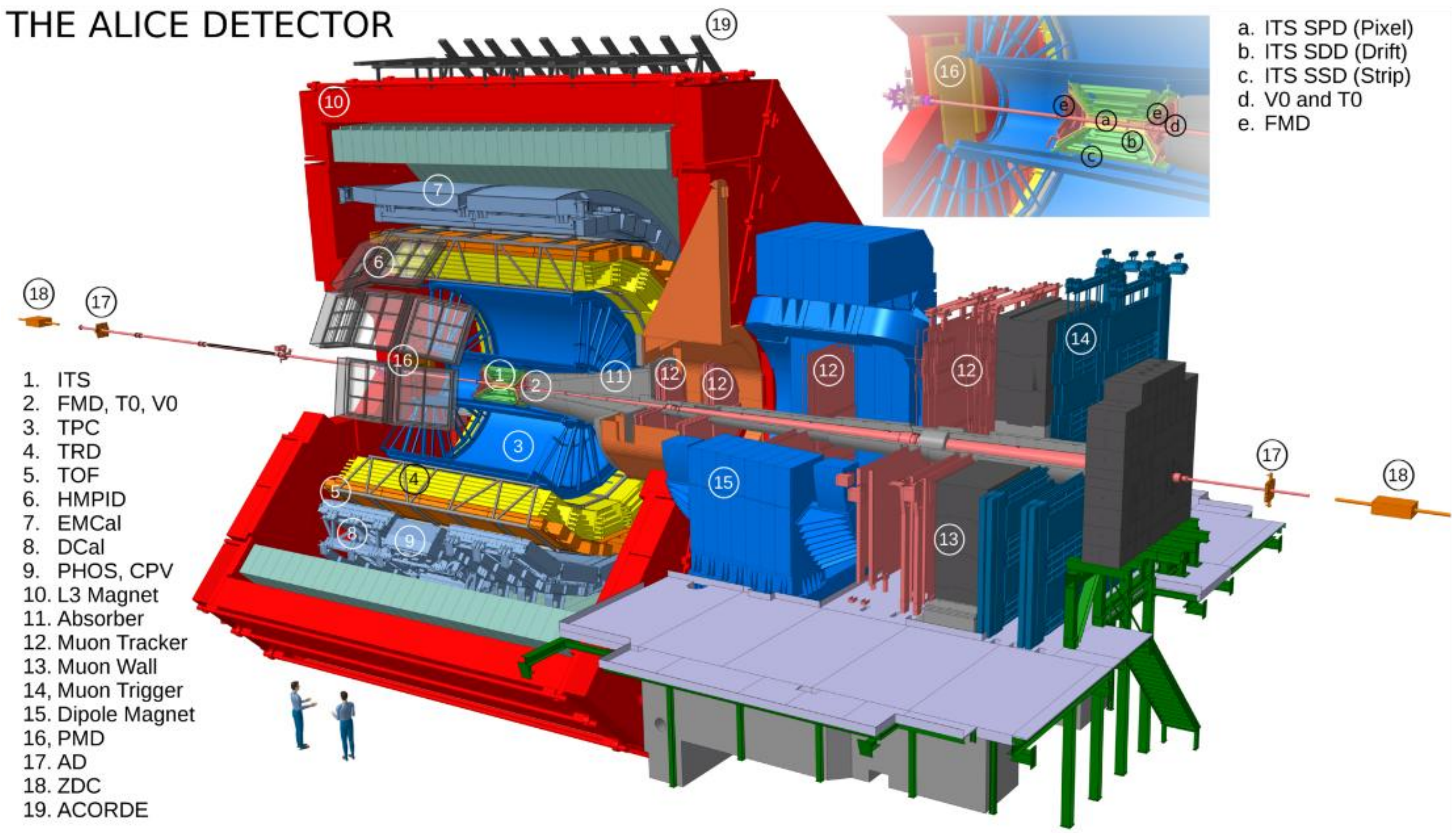


- **$V^0(\Xi)$-jets matching**
  - $R(V^0/\Xi, \mathrm{jet}) < 0.4$

JE = JC - UE

- **Underlying event**
  - **PC:** cone in perpendicular direction of jet axis
  - **OC:** out side the jet cone
  - **NJ :** events without jet in p_T larger than a given threshold

ALICE setup and data sample



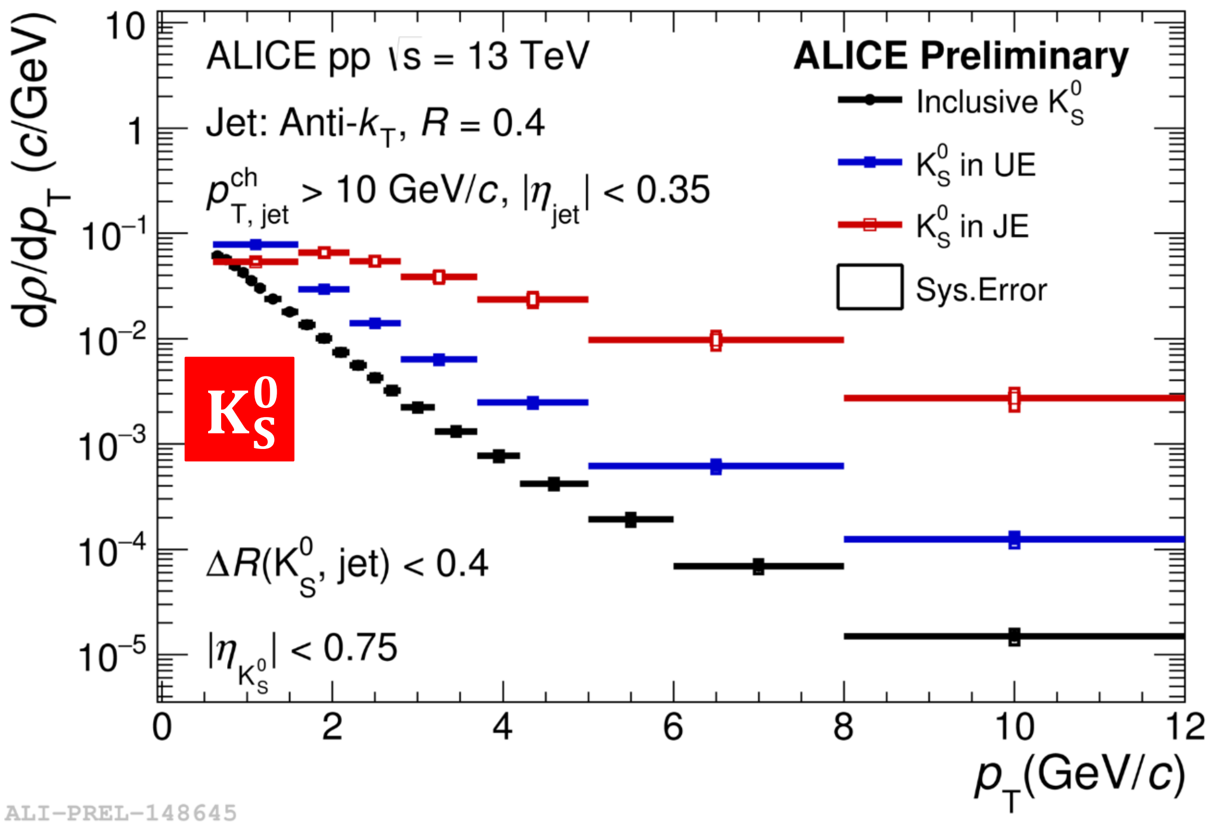
- **TPC(Time Projection Chamber)**
  - $|\eta|<0.9$
  - Charged particle tracking
  - Particle identification
- **ITS(Inner Tracking System)**
  - $|\eta|<0.9$
  - Vertex reconstruction
  - Event trigger
- **V0A + V0C**
  - $2.8<\eta<5.1$ and $-3.7<\eta<-1.7$
  - Event multiplicity class determination
  - Event trigger

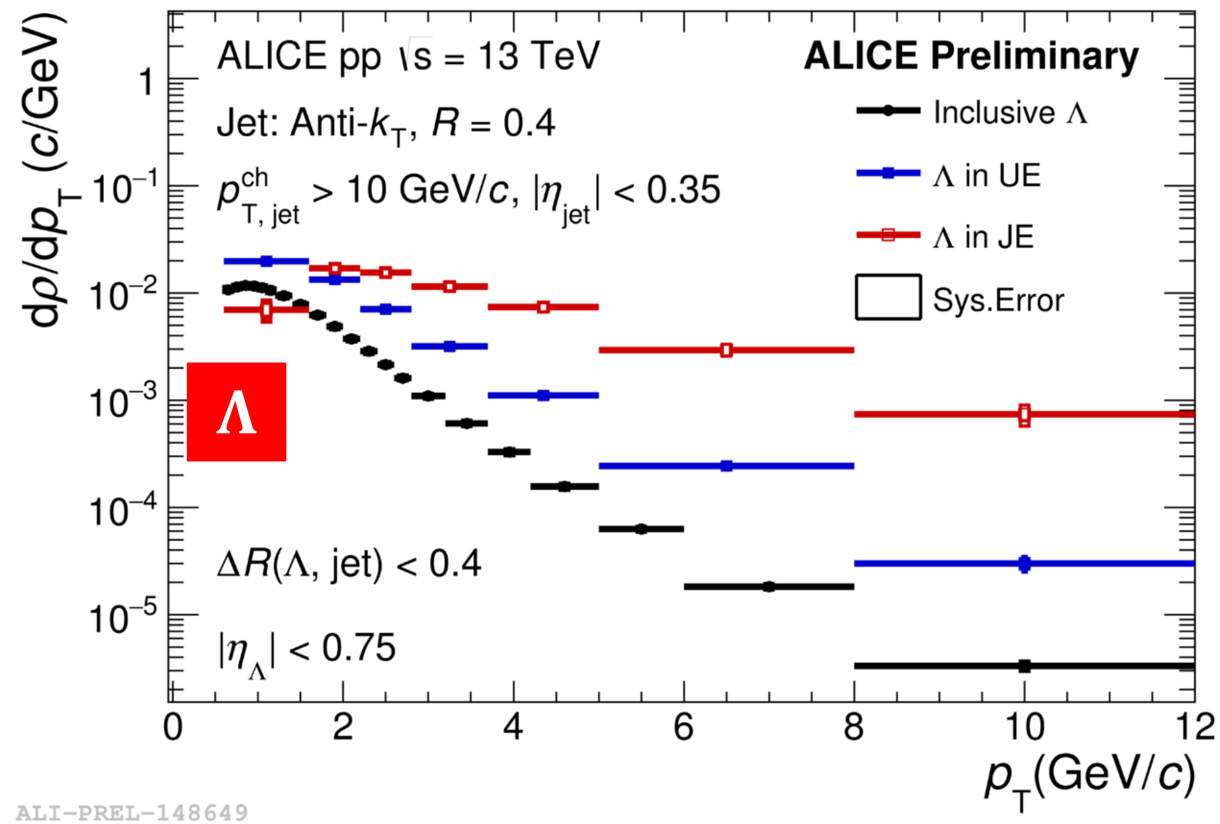
- **Data sample**
  - pp collisions at 13 TeV, p-Pb collisions at 5.02 TeV, and Pb-Pb collisions at 2.76 TeV

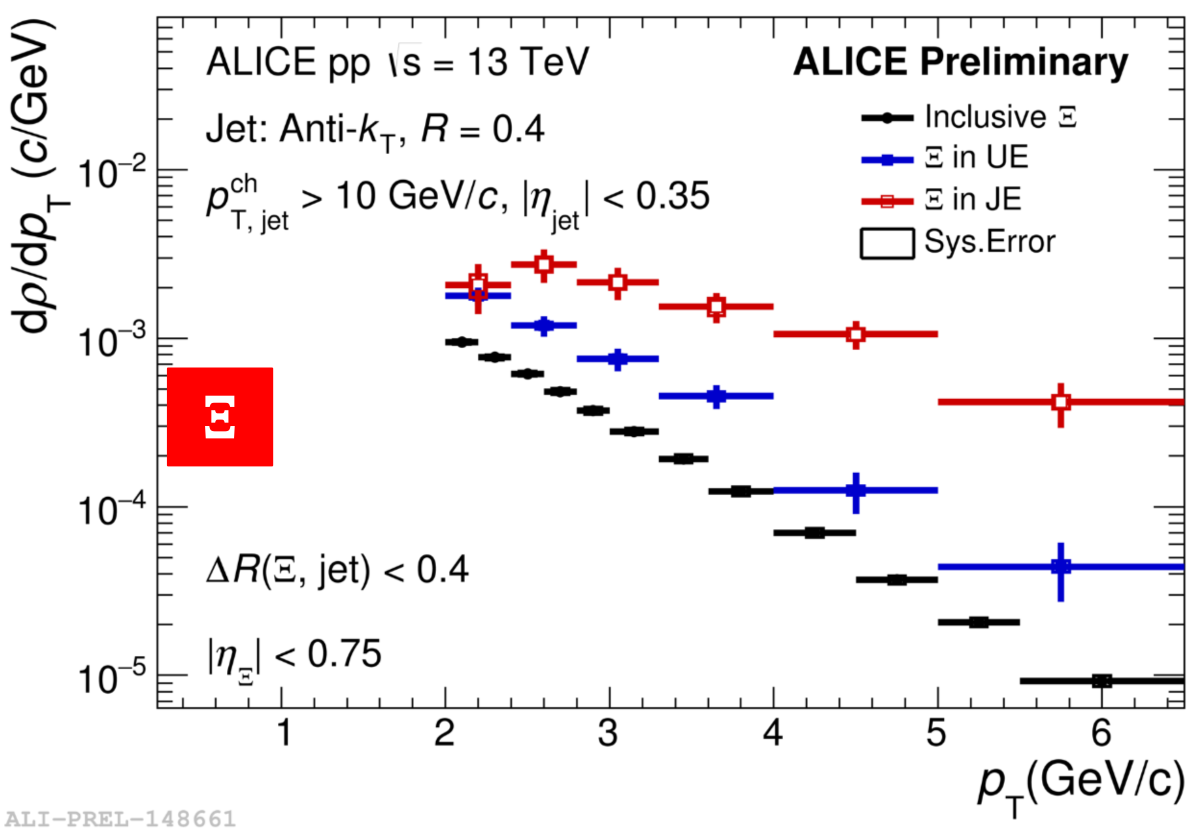
- **Strangeness reconstruction**
  - $K^0_S \rightarrow \pi^+ + \pi^-$ (BR 69.2%)
  - $\Lambda \rightarrow p + \pi^-$ (BR 63.9%)
  - $\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^-$ (BR 63.9%)

- **Jet reconstruction:**
  - Charged track selection: $|\eta| < 0.9,\ p_T > 0.15$ GeV/c
  - Jet finder: anti $- k_T,\ R = 0.4,\ |\eta_{jet}| < 0.35$

Results of pp collisions

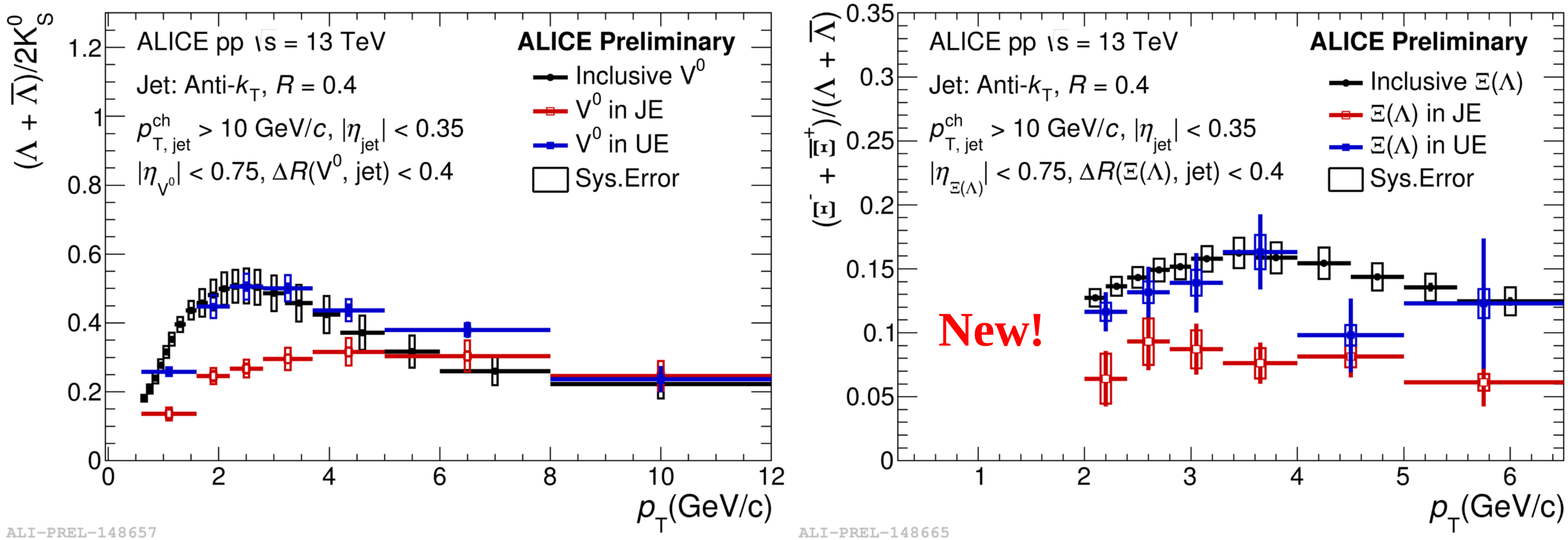






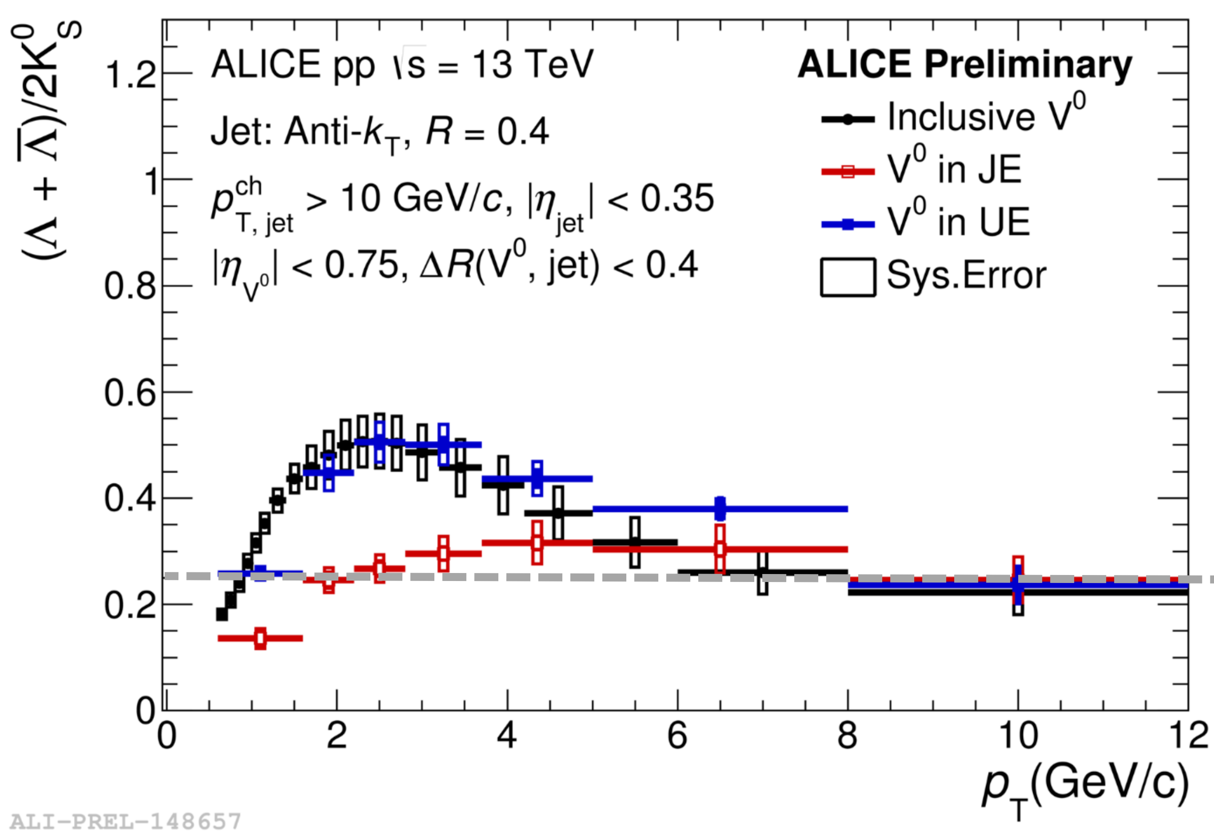
- The production density of strangeness in jets is harder than that in underlying events
- The UE is harder than inclusive distribution - the presence of the jet biases on UE

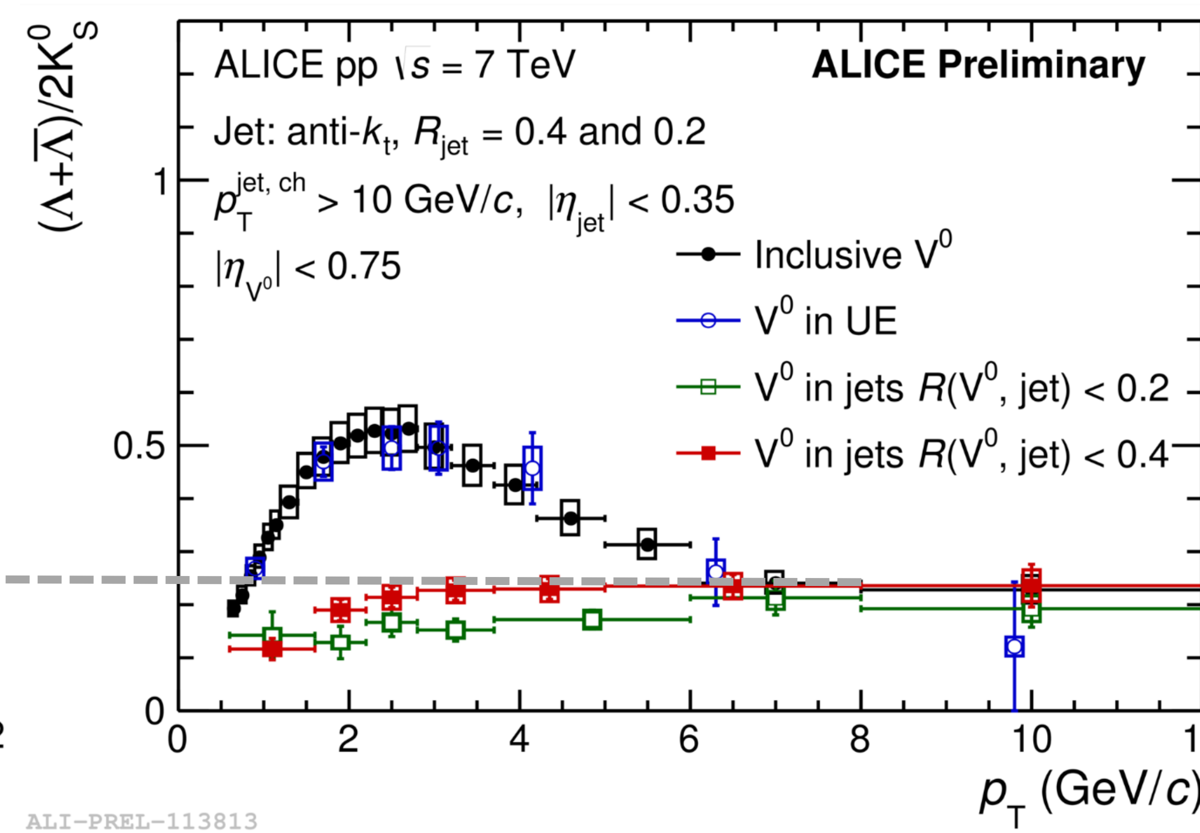
Results of pp collisions



- The Λ/K^0_S in UE is consistent with the inclusive ratio
- The ratio in jets is clearly different from the inclusive ratio at low and intermediate p_T
- Further constrain on particle production mechanism in jets and UE by extending the study to multi-strange particle sector
- Ξ/Λ is almost p_T independent in JE

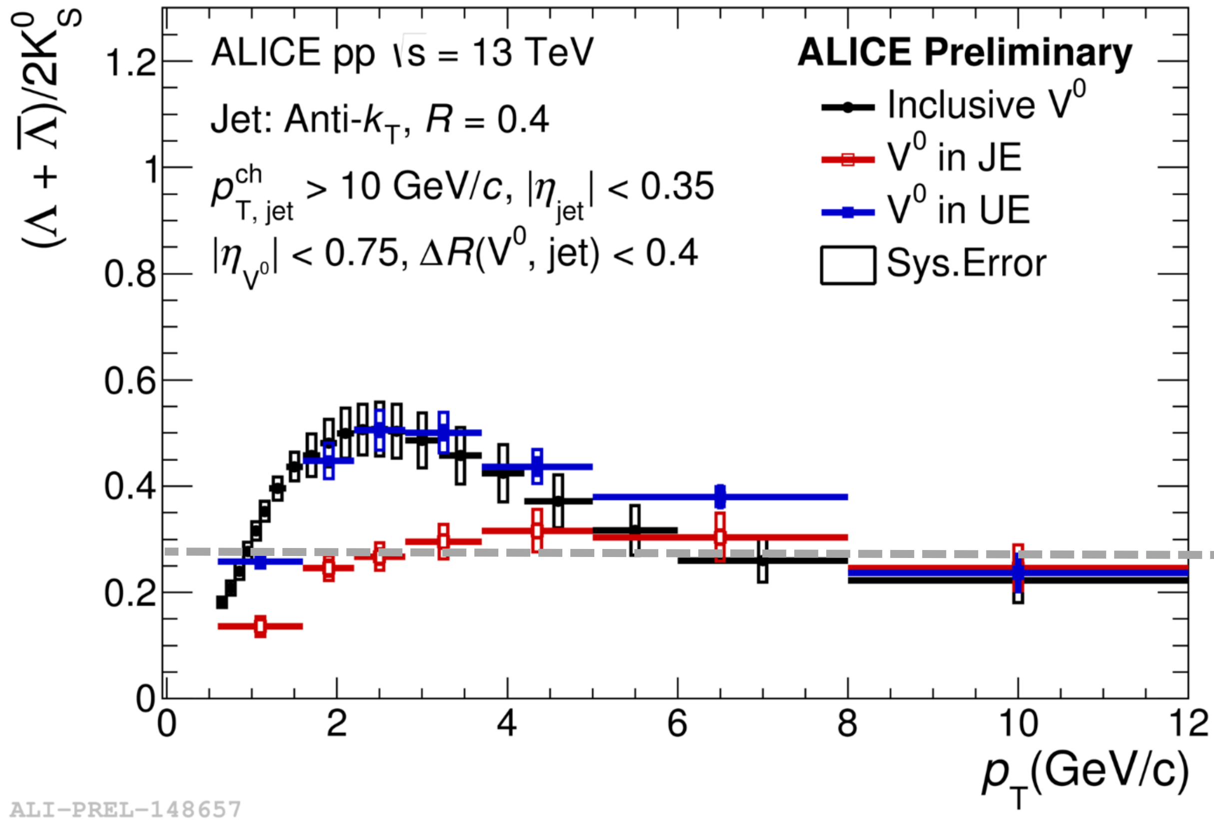
Results of pp collisions

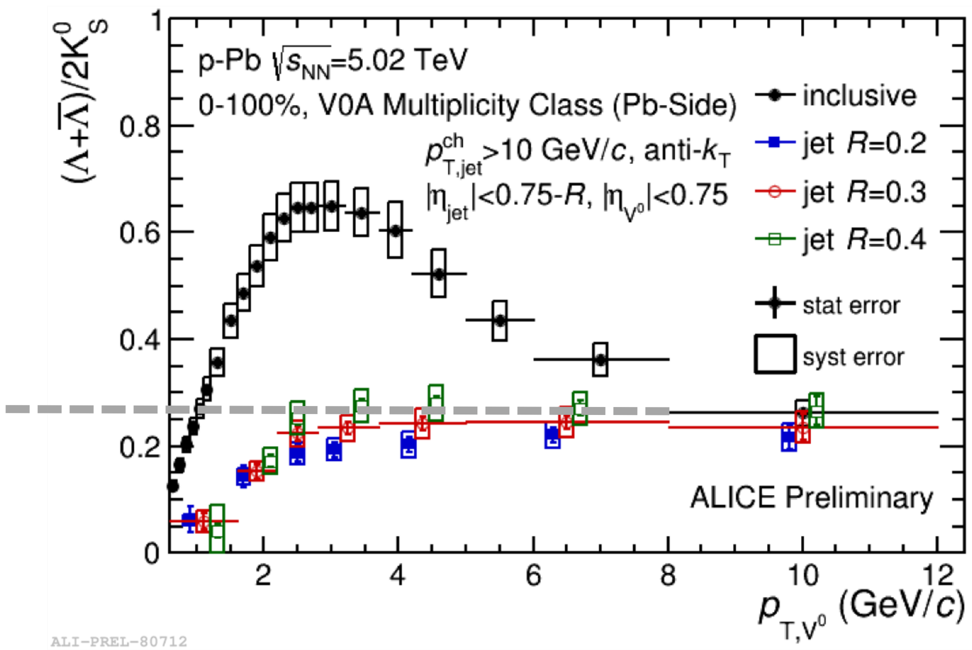




- The Λ/K^0_S in UE is consistent with the inclusive ratio
- The ratio in jets is clearly different from the inclusive ratio at low and intermediate p_T
- A slight increase of the ratio in jets with increasing R_{jet} and collision energy

Results of pp and p-Pb collisions

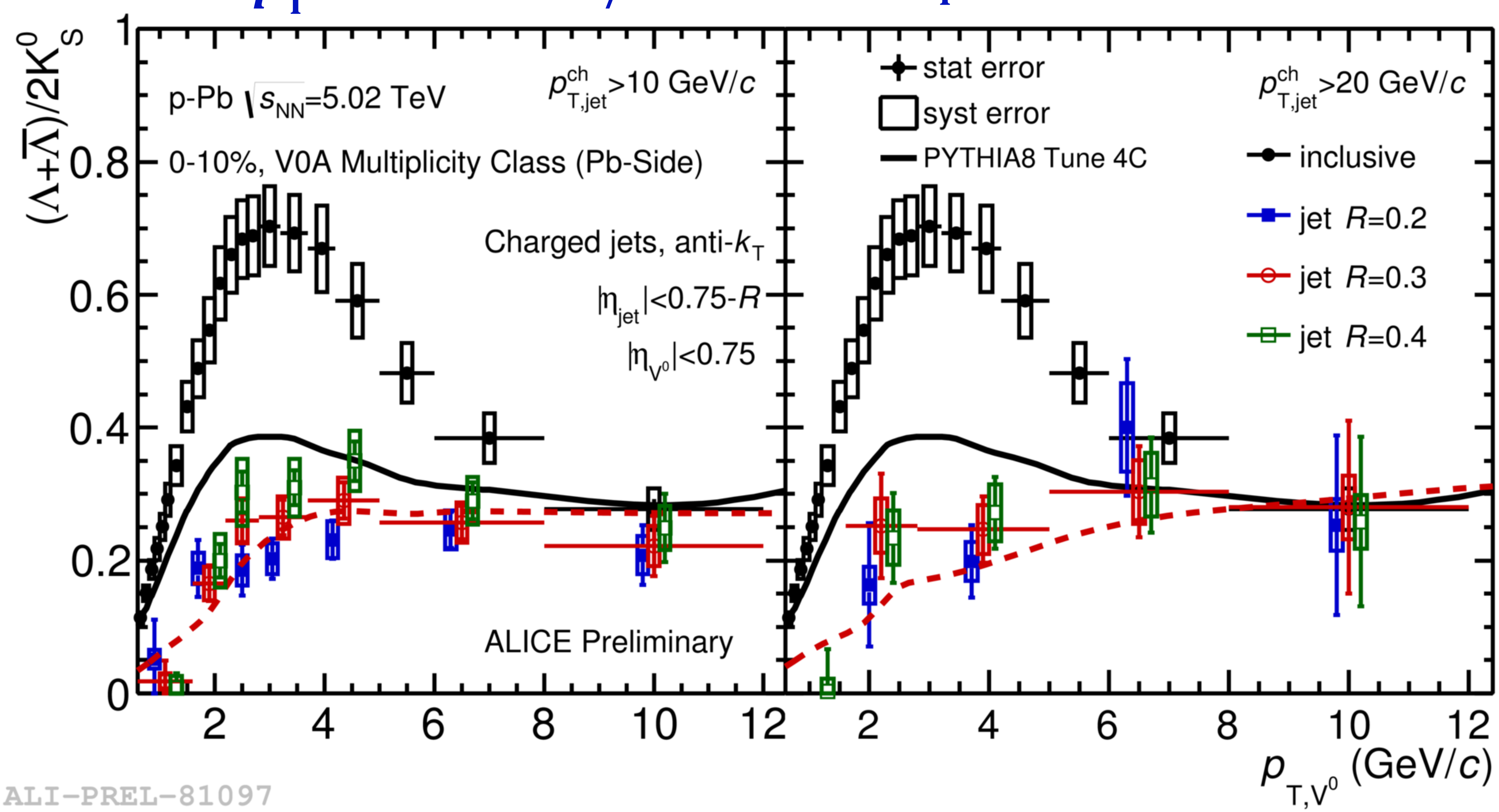




- The Λ/K^0_S in UE is consistent with the inclusive ratio
- The ratio in jets is clearly different from the inclusive ratio at low and intermediate p_T
- A slight increase of the ratio in jets with increasing R_{jet} and collision energy
- pp consistent with p-Pb within uncertainties in R = 0.4

Results of p-Pb collisions

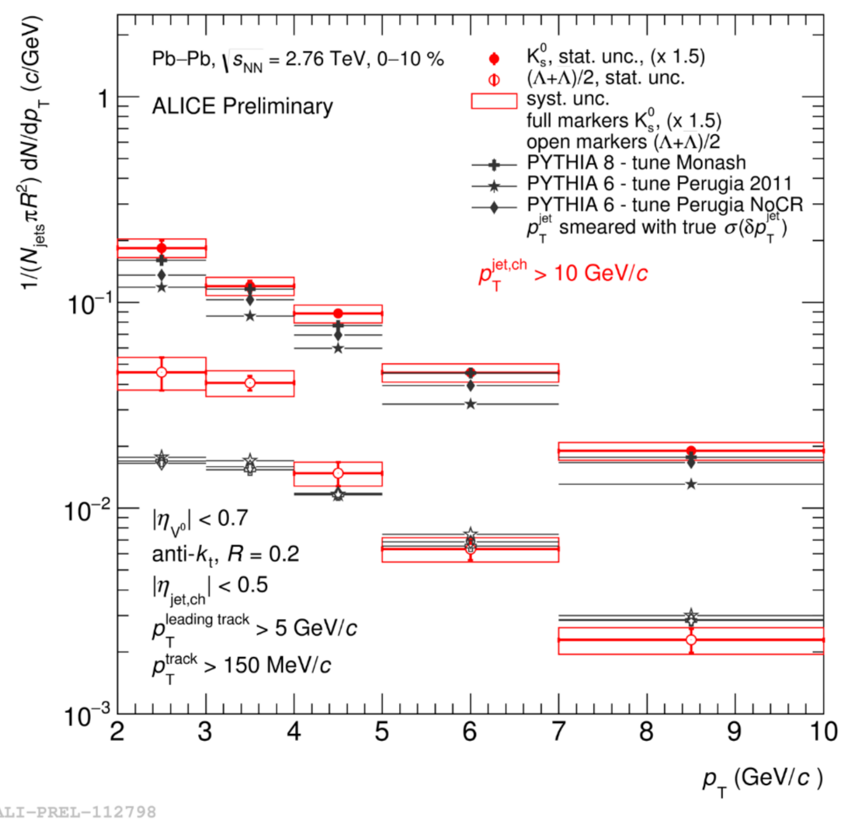
$p_{\mathrm{T}}^{\mathrm{jet,ch}} > 10\ \mathrm{GeV}/c$ $p_{\mathrm{T}}^{\mathrm{jet,ch}} > 20\ \mathrm{GeV}/c$

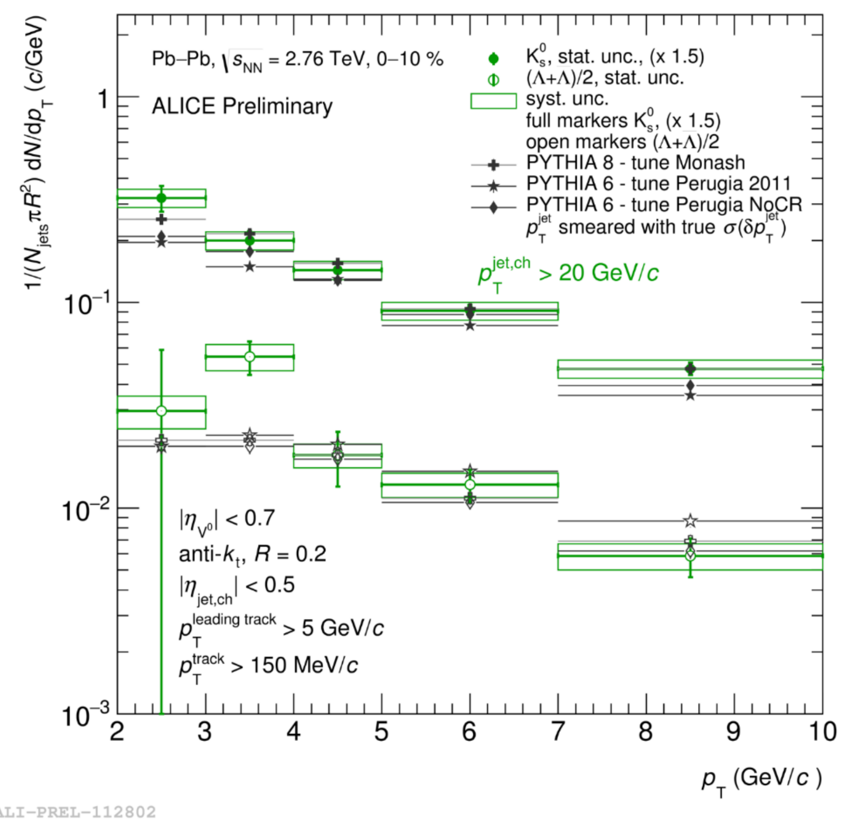


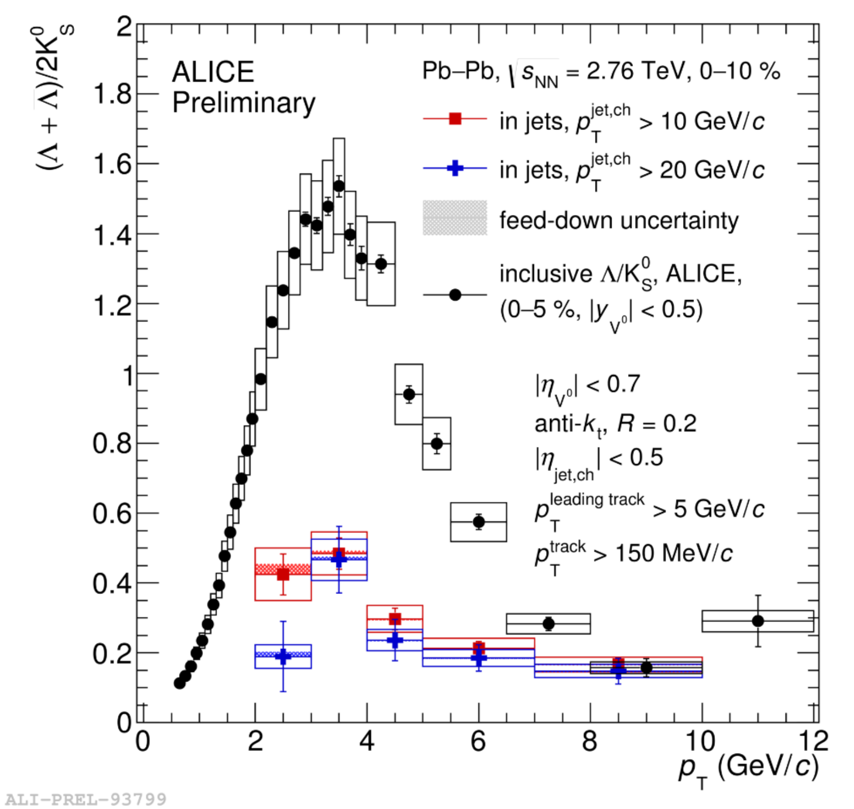
- The ratios depend only slightly on the jet resolution parameter R and do not vary with $p_{\mathrm{T}}^{\mathrm{jet,ch}}$
- They are compatible with PYTHIA8 predictions in pp collisions
- The data shown hints of the modification for baron to meson ratio

Results of Pb-Pb collisions

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







- Interesting aspects seen at low V^0 p_T in comparison with PYTHIA
- The ratio in jets is far below the inclusive ratio in Pb–Pb collisions
- The ratio in jets are similar to the pp collisions or predicted by PYTHIA8 calculations

Summary

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- Production of V^0s (K^0_S and Λ) and Ξ has been investigated in jets and the UE in pp collisions at 13 TeV
- The first look at $\Xi^-(\overline{\Xi}^+)$ production and the Ξ/Λ ratio in jet and the UE in pp collisions with ALICE
- Baryon to meson ratio enhancement not present when the particles are in coincidence within a jet in pp, p-Pb and Pb-Pb collisions systems

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Thanks

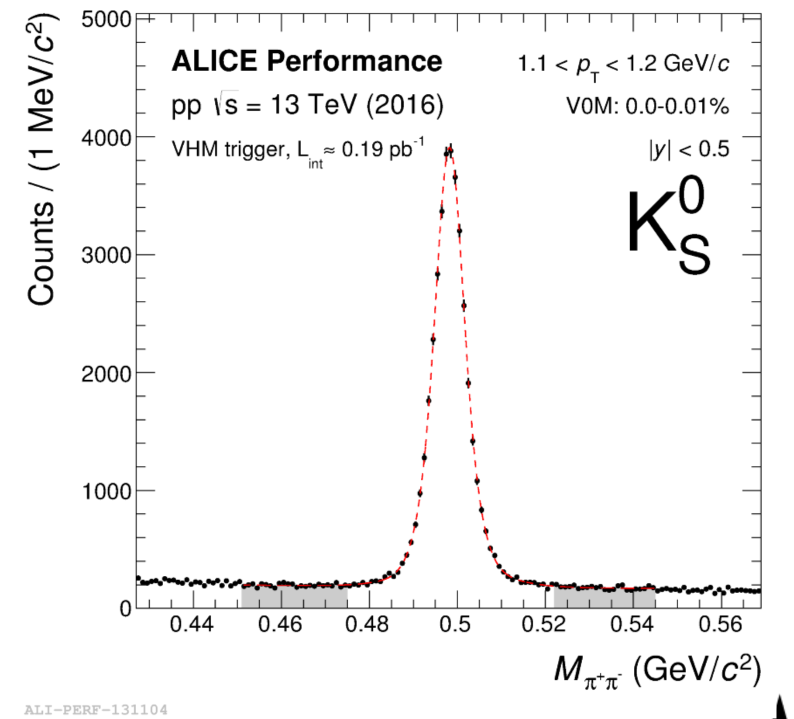
Backup

Analysis strategy

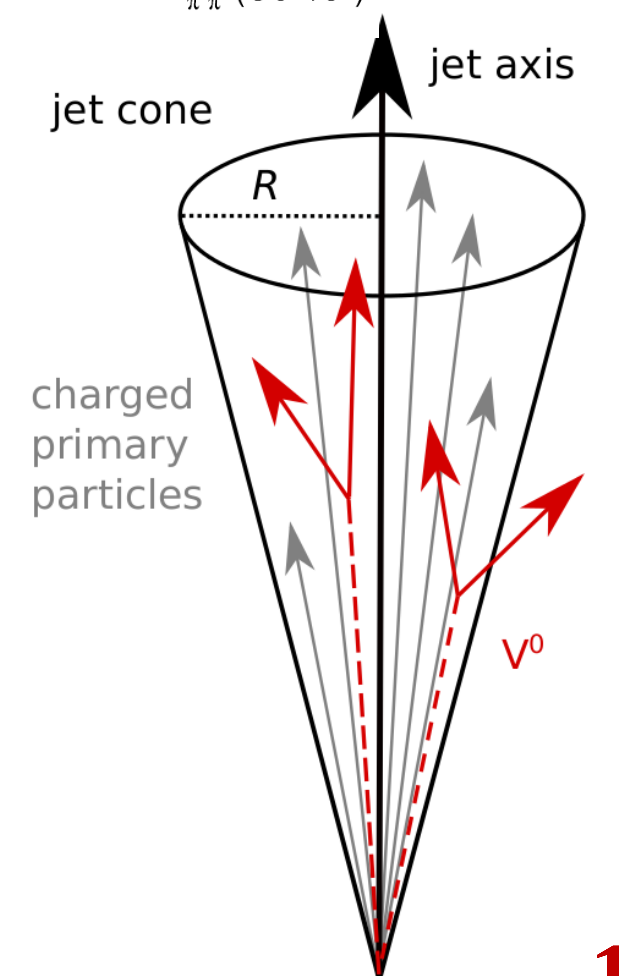
- **Tag the hard scattering with charged particle jets (in $p_{\mathrm{T}}^{\mathrm{jet}} > 10$ GeV/c)**
- **Reconstruct V^{0}s (Λ and K_S^0) and Ξ within the "jet region"**
  - $R(V^0/\Xi, \mathrm{jet}) < R_{\mathrm{match}}$
- **UE background: reconstruct V^{0}s and Ξ within the UE region**
  - PC: cone in perpendicular direction of jet axis
  - OC: out side the jet cone
  - NJ : events without jet in p_{T} larger than a given threshold
- **Normalization**

$$\frac{d\rho}{dp_{\mathrm{T}}} = \frac{1}{N_{ev}} \times \frac{1}{<\mathrm{Area}>} \times dN/dp_{\mathrm{T}}$$

- **Efficiency correction**
- **Feed-down correction (for $\Lambda(\overline{\Lambda})$)**

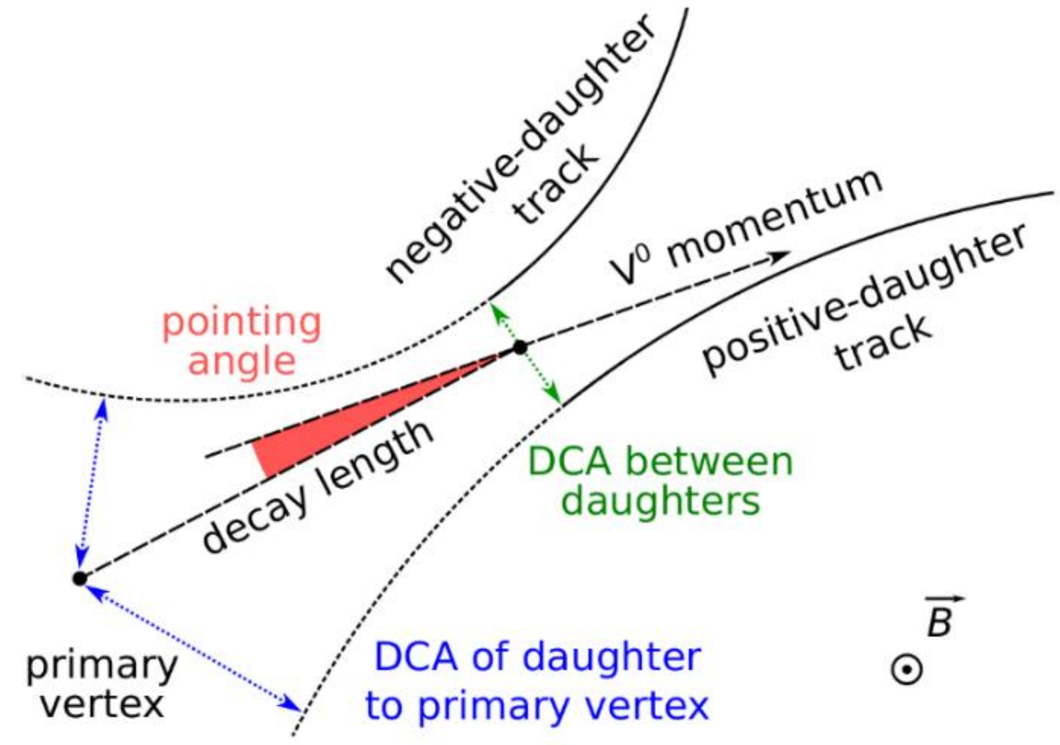


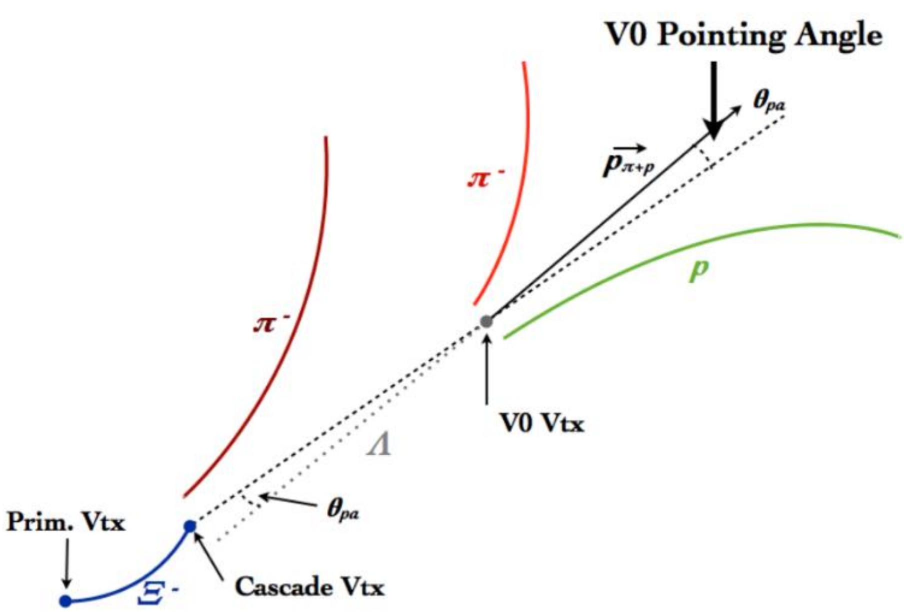
JE = JC - UE

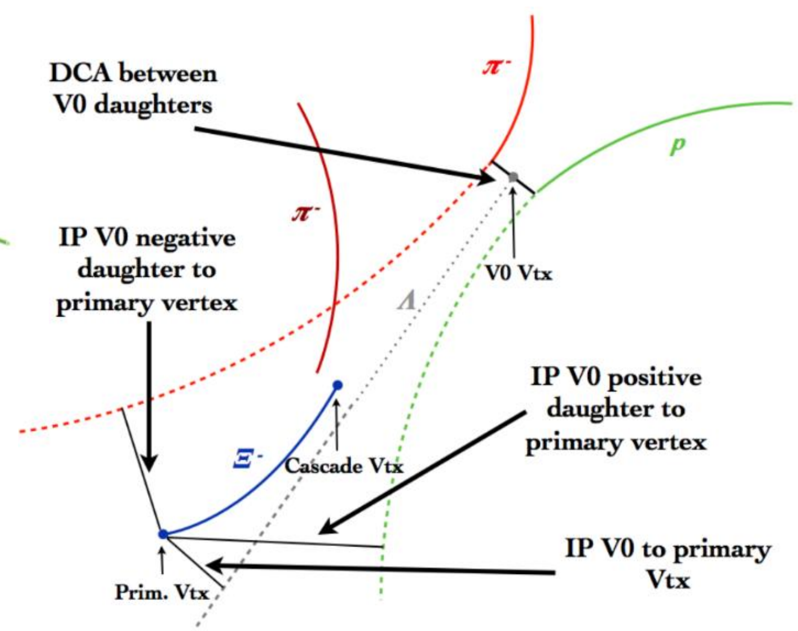


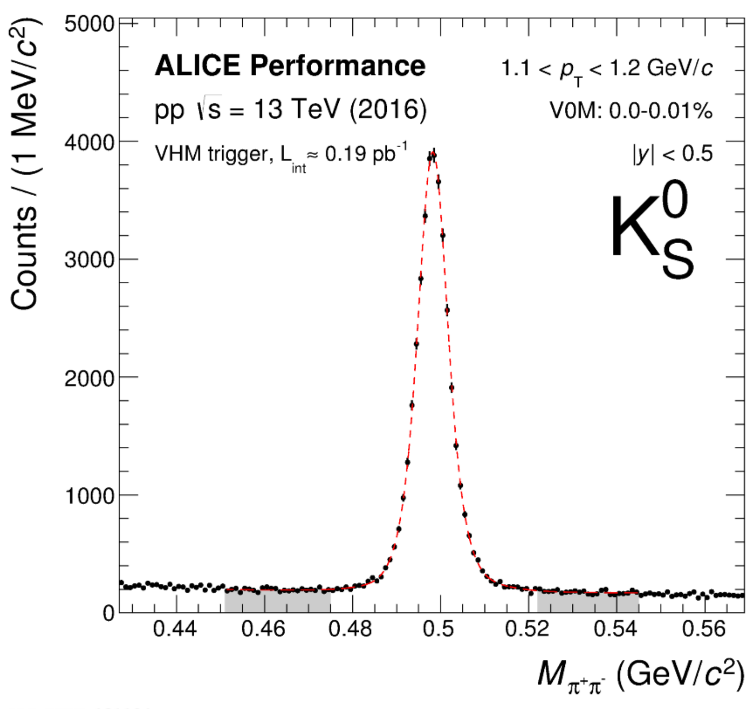
V^0s and Ξ reconstruction

- **Channels**
  - $K_S^0 \rightarrow \pi^+ + \pi^-$ (BR 69.2%)
  - $\Lambda \rightarrow p + \pi^-$ (BR 63.9%)
  - $\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^-$ (BR 63.9%)
- **Strategy: based on decay topology selections**
- **Acceptance:** $|\eta| < 0.75$









$V^0(\Xi)$ candidates selection

Selection	Value
Track Kink index	<1
$\|\eta\|$	<0.8
TPC refit flag	kTRUE
Number of findable cluster	>0
Number of TPC Crossed Rows	>70
TPC crossed rows/findable ratio	>0.8

Selection cuts for daughter tracks

Selection	**value**
V^0s 2D decay radius	in [0.5, 200] cm
Negative track DCA to PV	>0.05 cm
Positive track DCA to PV	>0.05 cm
DCA between V^0s daughters	<1.0 cm
$\cos\theta_{pointing}$	>0.97K^0_S, >0.995Λ
Competing V^0s rejection	$\|M_\Lambda - 1.115683\| > 0.003$ GeV/c(K^0_S) $\|M_{\bar{\Lambda}} - 1.115683\| > 0.003$ GeV/c(K^0_S) $\|M_{K^0_S} - 0.4968\| > 0.010$ GeV/c(Λ)

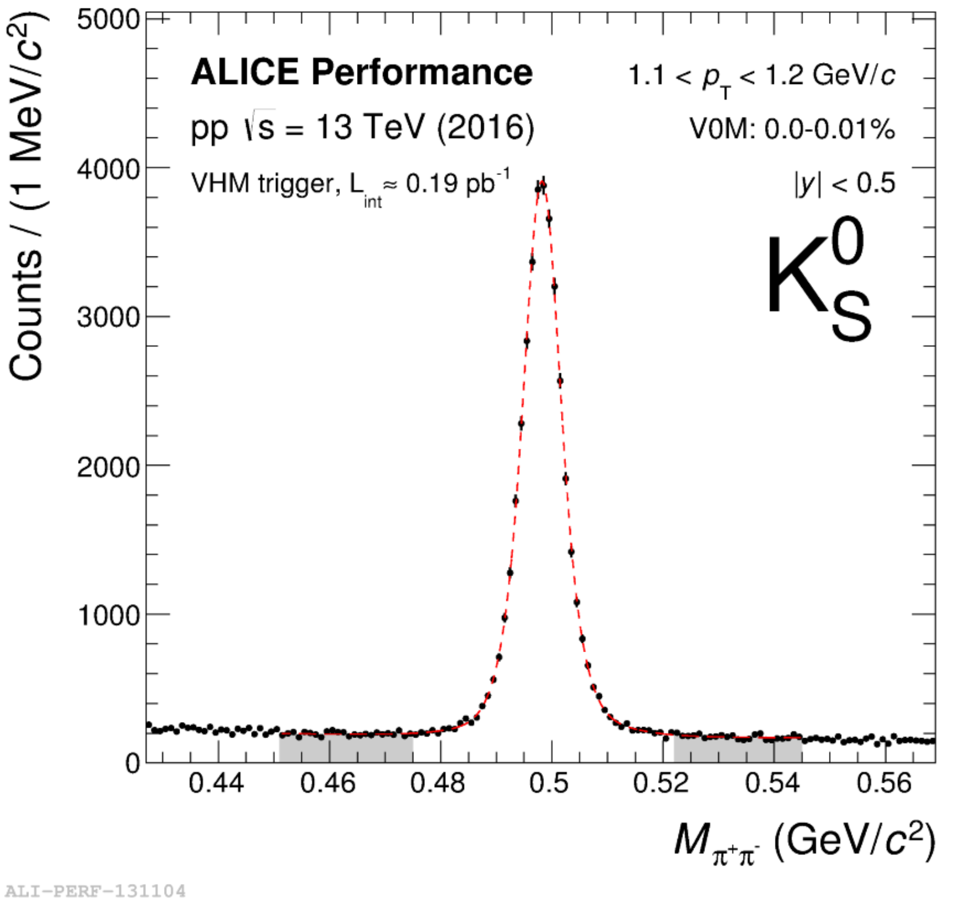
Selection cuts for V^0 candidates

Selections	Value
V0Radius	> 1.4
V0CPA	> 0.97
DCAV0Daus	< 1.6
DCAPosTrk	> 0.04
DCANegTrk	> 0.04
LaMassWind	< 0.006
XiRadius	> 0.8
XiCPA	> 0.98
DCAV0toBach	< 1.6
DCAV0toPV	> 0.07
DCABachTrk	> 0.05

Selection cuts for Ξ candidates

Bin counting method

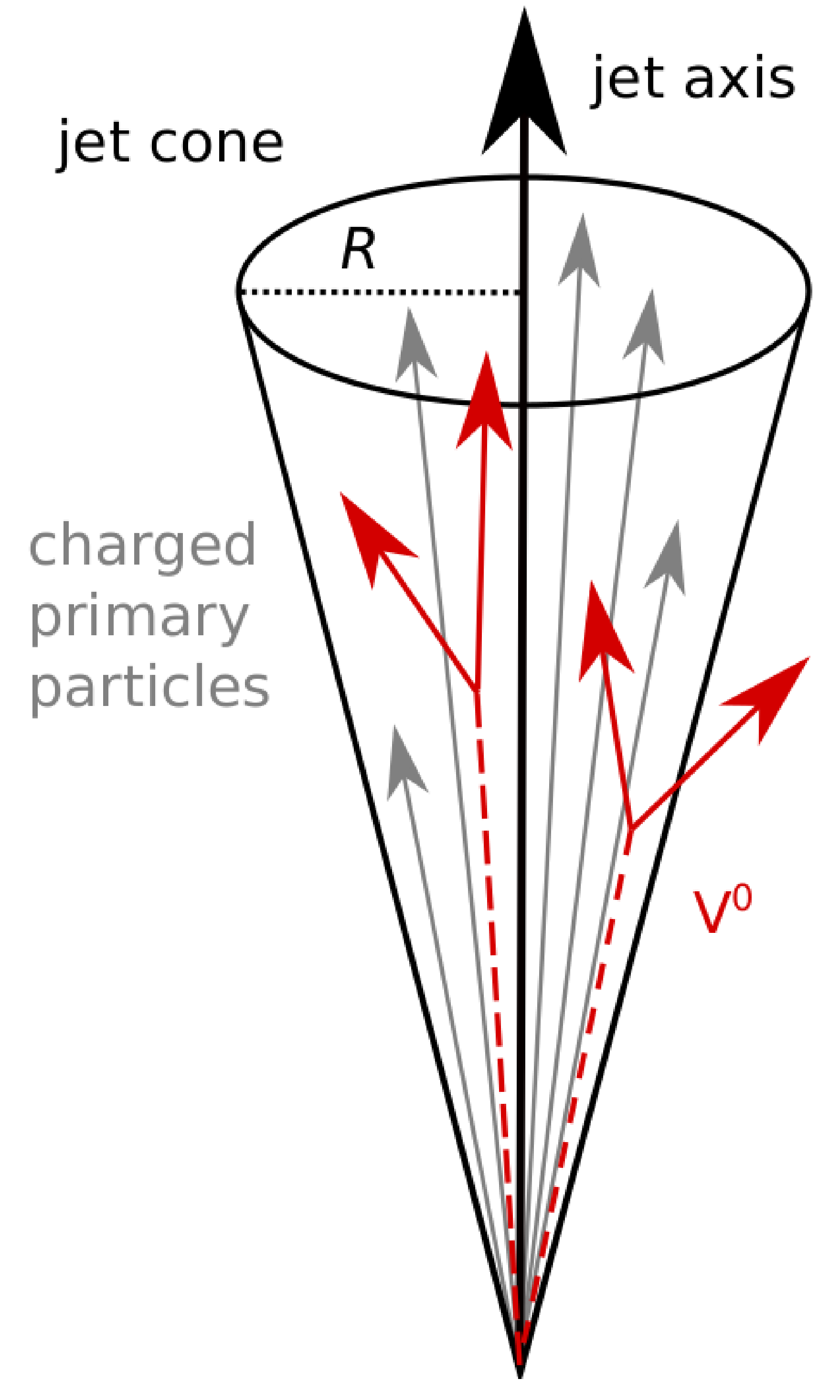
- **Raw yield of the $V^0(\Xi^{\pm})$ is extracted by using bin counting method**
  - Fit Inv.Mass distribution with Gaussian plus a liner function in each p_T bin
  - Extract the mean value(μ) and the σ of the Gaussian function
  - Define side bands and the signal region
  - Fit with liner function from side bands and interpolate into signal region
  - Subtract the background in the signal region



$V^0(\Xi)$ jets matching

- **Jet reconstruction:**
  - Charged track selection: $|\eta| < 0.9,\ \ p_{\mathrm{T}} > 0.15\ \mathrm{GeV}/c$
  - Jet finder: anti $- k_{\mathrm{T}},\ R = 0.4,\ |\eta_{\mathrm{jet}}| < 0.35,\ \ p_{\mathrm{T}}^{\mathrm{jet}} > 10\ \mathrm{GeV}/c$
- **$V^0(\Xi^{\pm})$-jets matching**
  - $\mathrm{R}(V^0/\Xi, \mathrm{jet}) < 0.4$
- **Normalization**
  - $\frac{d\rho}{dp_{\mathrm{T}}} = \frac{1}{N_{ev}} \times \frac{1}{\langle \mathrm{Area} \rangle} \times dN/dp_{\mathrm{T}}$
- **UE estimators**
  - PC : perpendicular cone
  - OC : $\mathrm{R}(V^0/\Xi, \mathrm{jet}) > 0.6$
  - NJ : events w/o jet in $p_{\mathrm{T}} > 5$ GeV/c

JE = JC - UE



Efficiency correction

- **Efficiency definition:**

$$\varepsilon = \frac{N_{reco+asso}}{N_{gen}}$$

  - The same signal extraction apart from PID cut as for real data has been used also for MC. The $V^0s(\Xi)$ and their daughters was identified by using MC truth information . The check for $IsPhysicalPrimary()$ has been also performed.
  - For the denominator all generated physical primary particles after event selection have been selected.

- **Efficiency of V^0s/Ξ inside and outside jets:** controlled by the jet modified η-distribution - accounted for by reweighing with η-distributions of V^0s/Ξ

Feed-down correction

We scaled MC production to the data measurement to estimate kinematics distribution of the feed-down Λ and then we implement the subtraction

- **Inclusive**
  - Subtract the feed-down V^0s according to the measured feed-down fraction before efficiency

$$\Lambda^{\mathrm{raw}}_{\mathrm{measured}} = \Lambda^{\mathrm{raw}}_{\mathrm{primary}} + \Lambda^{\mathrm{raw}}_{\mathrm{secondary}}$$

$$\Lambda^{\mathrm{raw}}_{\mathrm{sec}} = \sum_i F_{ij} \int_{p_{\mathrm{T}}(bin)} \frac{dN}{dp_{\mathrm{T}}}(\Xi) \left(F_{ij} = \frac{N_{reco}(\Lambda)^{in\ bin\ i}_{from\ \Xi\ bin\ j}}{N_{gen}(\Xi)_{\Xi\ bin\ j}} \right)$$

- **JC**
  - Apply the efficiency correction for both JC and UE V^0s
  - Subtract the normalized UE component form the JC V^0s
  - Subtract the feed-down V^0s matched with jets according to the measured feed-down fraction

$$\Lambda_{\mathrm{JC}} = \Lambda^{\mathrm{prim}}_{\mathrm{JE}} + \Lambda^{\mathrm{sec}}_{\mathrm{JE}} + \Lambda^{\mathrm{prim}}_{\mathrm{UE}} + \Lambda^{\mathrm{sec}}_{\mathrm{UE}}$$

$$\Lambda^{\mathrm{sec}}_{\mathrm{JE}} = \sum_j F_{ij} \int_{p_{\mathrm{T}}(bin)} \frac{dN}{dp_{\mathrm{T}}}(\Xi) \left(F_{ij} = \frac{N_{gen}(\Lambda)^{in\ bin\ i}_{from\ \Xi\ bin\ j}}{N_{gen}(\Xi)_{\Xi\ bin\ j}} \right)$$

Systematic uncertainty

- **Uncertainty on signal extract**
  - **Single V^0s/Ξ analysis:** varying the correlated selection cuts
  - **Feed-down correction:** obtained from the spectra of Ξ
- **Uncertainty on jet p_T scale and UE**
  - **Jet p_T threshold:**
    - Estimated from jet background fluctuations and detector response
    - Variation of the jet p_T threshold within 1 GeV/c
  - **UE background subtraction** (to be further studied and updated):
    - Central value: estimated from the PC background
    - Lower/upper limits: given by the OC/NJ backgrounds
- **Other sources of uncertainties: material budget — 4%**

Results of p-Pb collisions