Strangeness production in jets and in the UE vs multiplicity in Run 3 pp collisions

ALICE e-PIC Meeting - 29/01/2025

https://indico.cern.ch/event/1503581/

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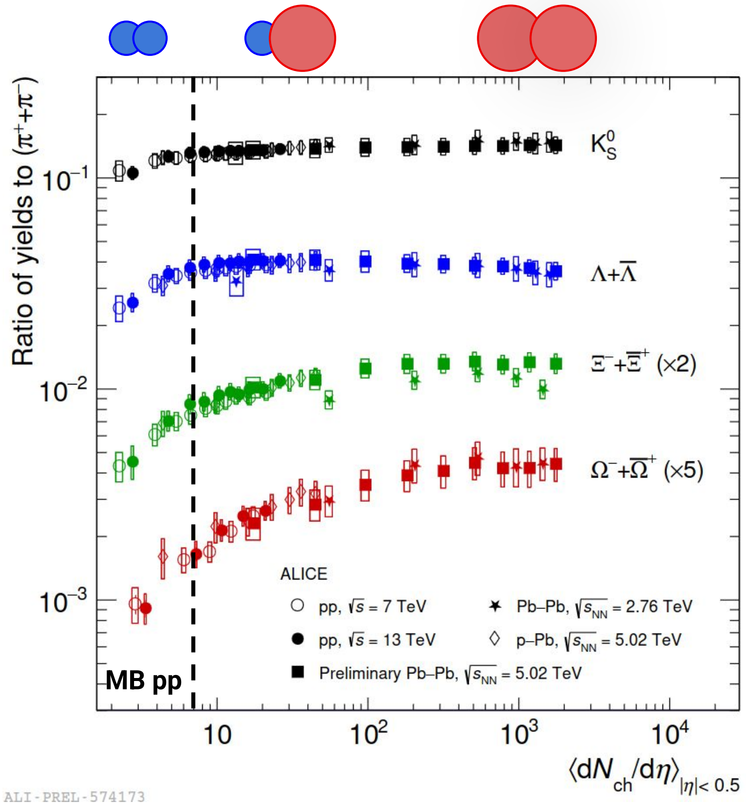
Physics Motivation



Continuous evolution of strange hadron yield ratios to pions **with the charged-particle multiplicity** observed at the LHC, smoothly connecting different systems and energies

Strangeness production **increases with** particle **multiplicity**, saturating for central Pb–Pb

Strange content **hierarchy**:

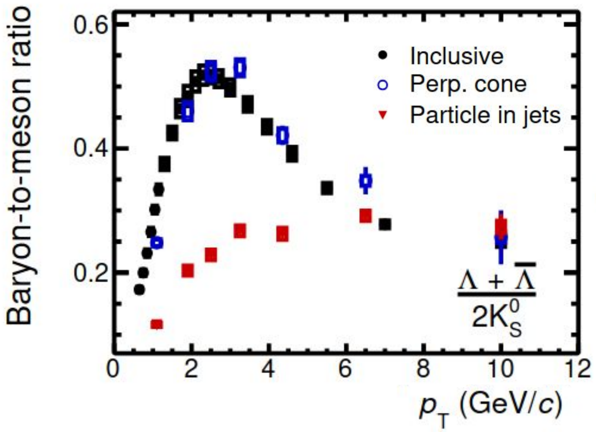
$$|S_{\Omega^\pm}| > |S_{\Xi^\pm}| > |S_\Lambda| \approx |S_{K^0_S}|$$

State of the Art

[1] Densities and baryon/meson ratios vs. p_T , full jet reconstruction (p_T(jet) > 10 GeV/c)

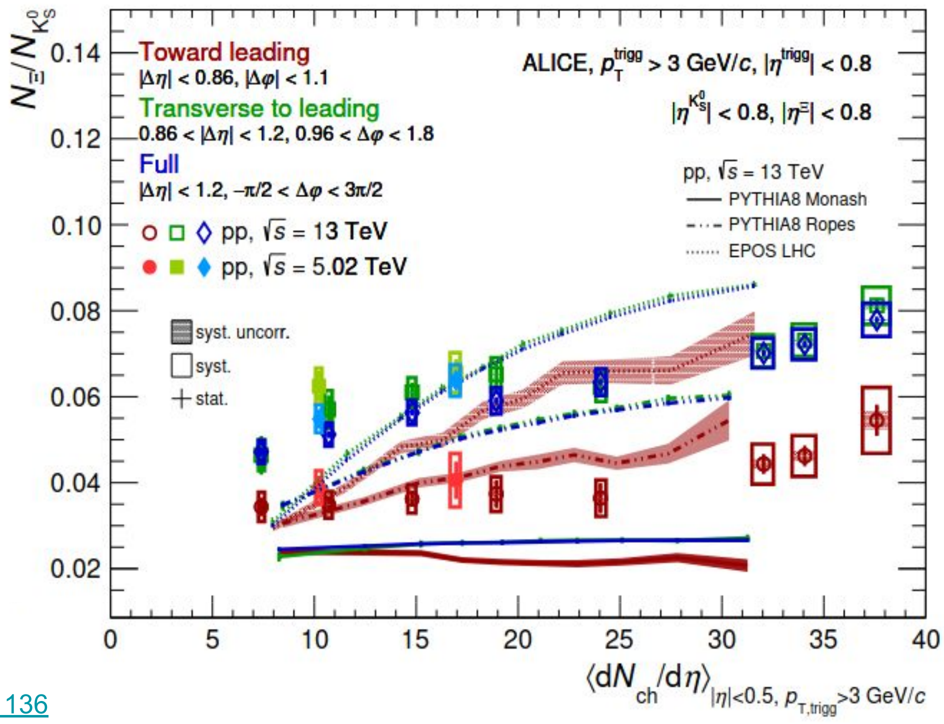
[2] Trigger particle as a proxy for the jet axis (p_T > 3 GeV/c) + angular correlation

Goal: Extend the study using full jet reconstruction as a function of multiplicity



[1] JHEP 07 (2023) 136

[2] JHEP 09 (2024) 204



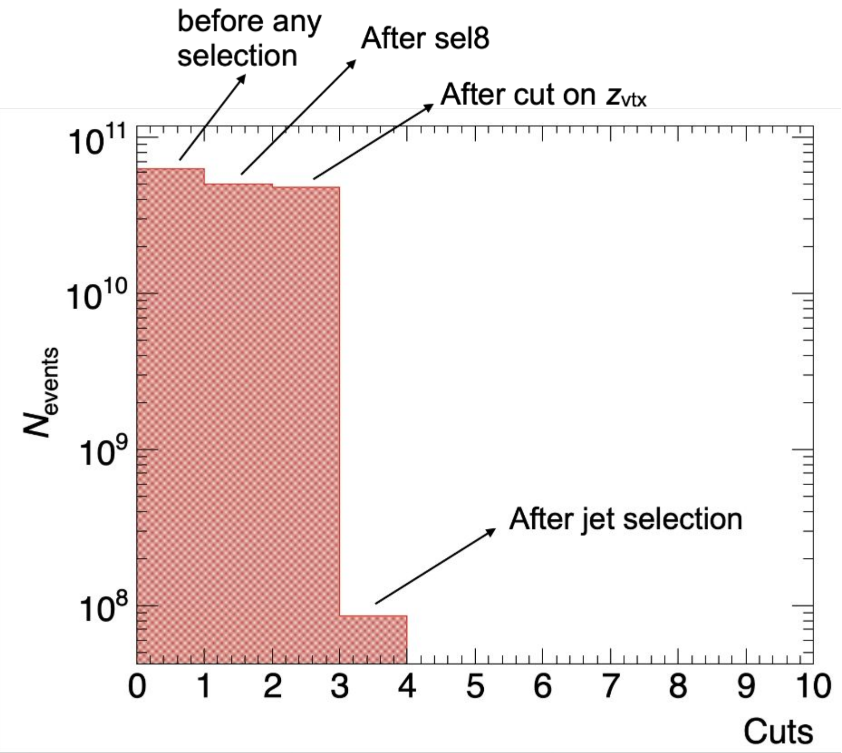
Data set and event selection

Dataset: LHC22o_pass7_minBias

Runs: 526641, 526964, 527041, 527057, 527109, 527240, 527850, 527871, 527895, 527899, 528292, 528461, 528531

Event selection
- Sel8
- $|z_{vtx}| < 10$ cm

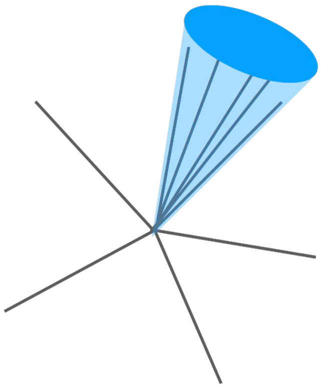
Selections	N_{events}
Before any selection	62.191×10^9
After sel8	49.590×10^9
After z-vertex cut	47.803×10^9
After jet selection	85.024×10^6



Analysis Task: https://github.com/AliceO2Group/O2Physics/blob/master/PWGLF/Tasks/Strangeness/strangeness_in_jets.cxx

Jet finder and track selection

Anti-KT jet clustering algorithm → Alberto's contribution at the past ALICE-ePIC meeting



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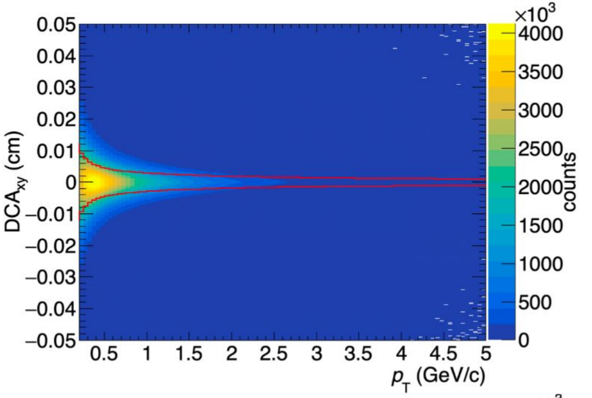
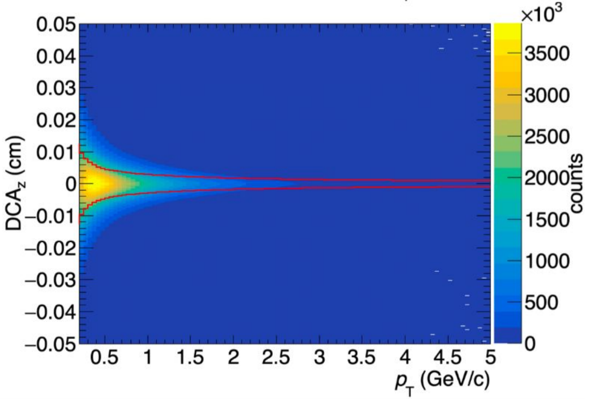
Variable	Requirement
hasITS	True
hasTPC	True
$N_{\rm ITS}$ clusters	≥ 3
$N_{\rm TPC}$ crossed rows	≥ 70
$\chi^2/N_{\rm TPC}$ clusters	< 4
$\chi^2/N_{\rm ITS}$ clusters	< 36
$\lvert{\rm DCA_{xy}}\rvert$	$< (0.00164 + 0.00231/p_{\rm T})$ cm
$\lvert{\rm DCA_{z}}\rvert$	$< (0.00177 + 0.00255/p_{\rm T})$ cm
Pseudorapidity (η)	$[-0.8, 0.8]$
$p_{\rm T}$	> 0.15 GeV/c

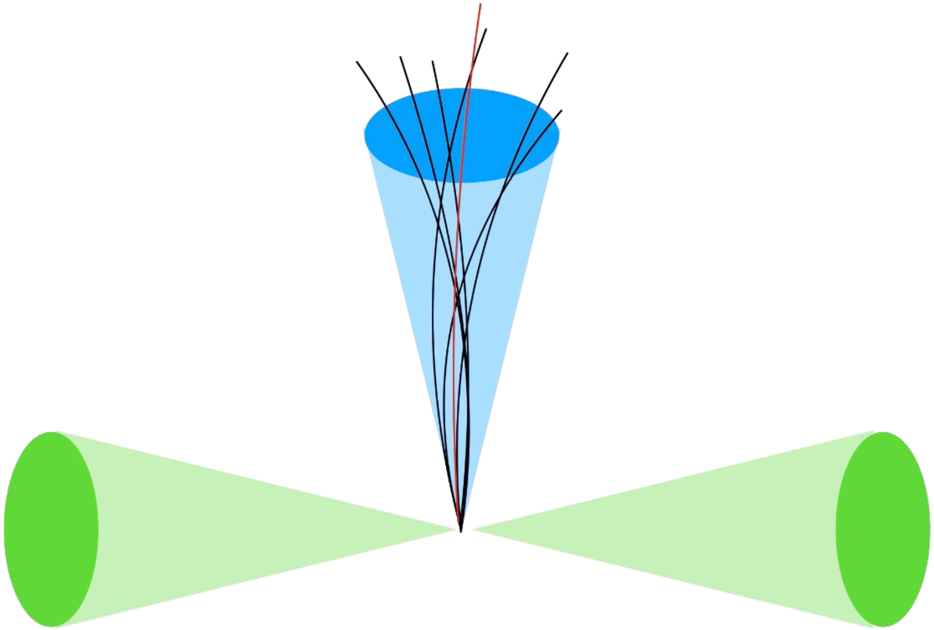
$p_{\rm T}$-dependent selections for both DCA_{xy} and DCA_z

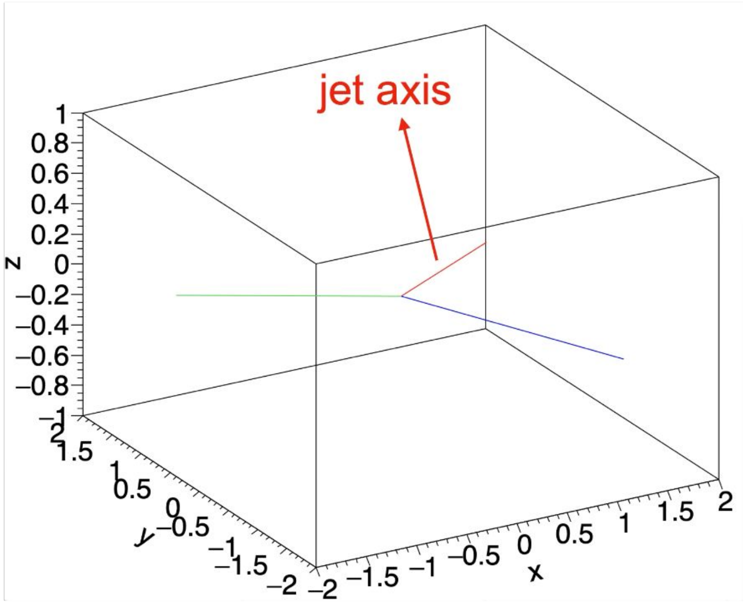
- Fit central core of the DCA distributions using a Gaussian
- Parametrizations correspond to the range $\pm 1\sigma$





Underlying event: perpendicular cone

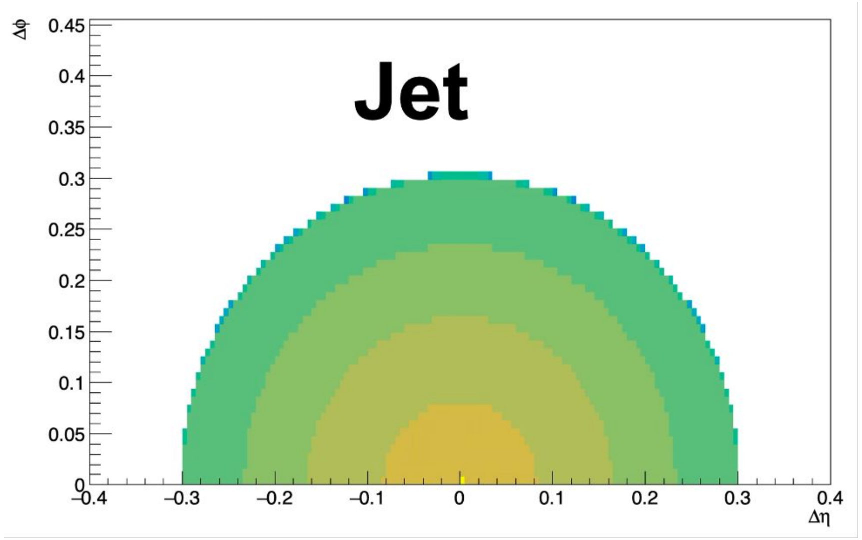


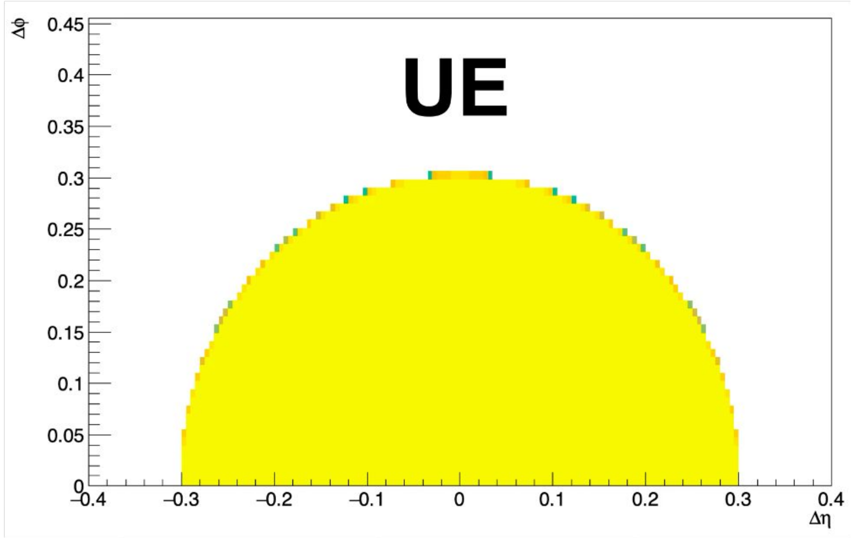


Underlying event estimated using two cones of radius R = 0.3

- perpendicular to the jet axis
- same η as the jet

$\Delta\eta - \Delta\phi$ correlation Motivation



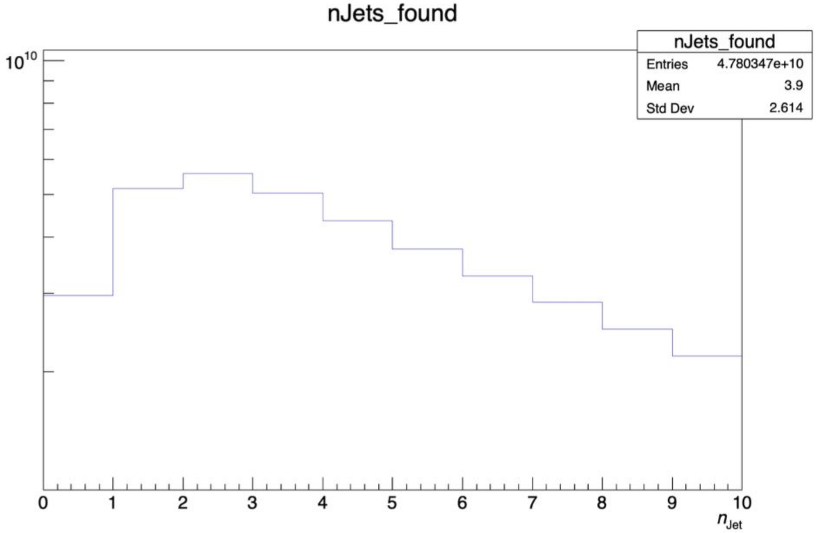


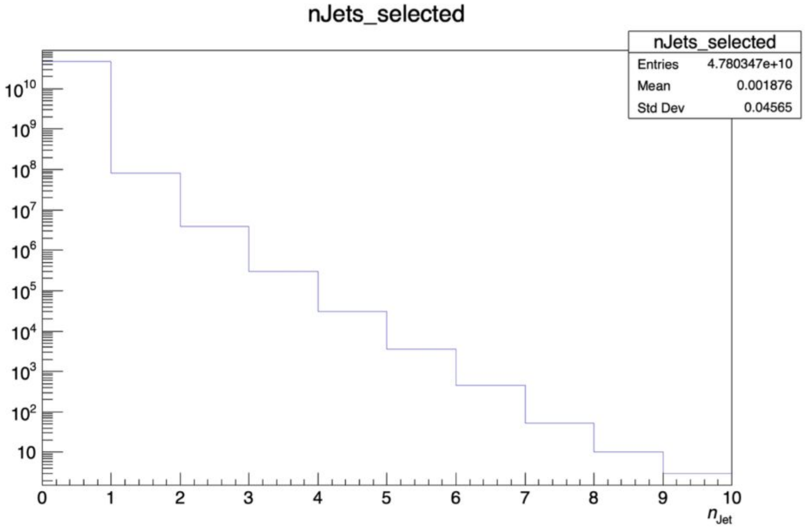
Area cut is applied for normalization: $\sqrt{(\eta_i - \eta_{\text{jet}})^2 + (\phi_i - \phi_{\text{jet}})^2} < 0.3$

- $\Delta\eta$—$\Delta\phi$ of charged particles found inside jet has a peak at (0,0) as expected
- Uniform distribution for the UE as expected

Jet selection

- Jet must be fully contained in the acceptance: $|\eta_{\text{jet}}| + R < 0.8$
- At least two charged particles
- $\sum p_{\mathrm{T}} > 10$ GeV/c (after event-by-event subtraction of the UE)
- No overlap between any pair jet-jet, jet-UE or UE-UE cones in events with multiple jets



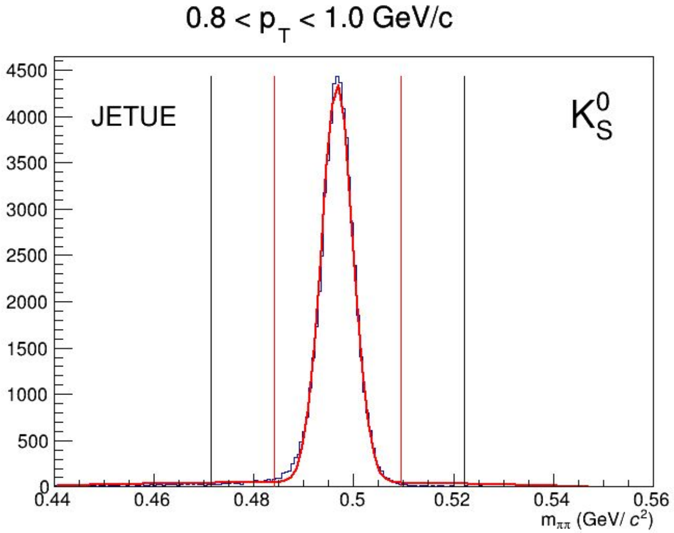


Analysis details

V0s	
Topological variable	**Cut K^0_S, Λ, $\bar{\Lambda}$**
V0 transv. decay radius	> 0.50 cm && < 40 cm
DCA Dau Track to PV	> 0.1 cm
V0 Cosine of Pointing Angle	> 0.99
DCA V0 Daughters	< 0.5 cm
N_{TPC} crossed rows	> 80
TPC χ^2	< 4
$p_T{}^{\pi}$ (K^0_S)	[0.3,10] GeV/c
$p_T{}^{\pi}$ (Λ)	[0.1,1.5] GeV/c
$p_T{}^{p}$ (Λ)	[0.3,10] GeV/c
Other selections	**Cut**
TPC dE/dx Selection (Real data only)	$< 3\sigma$
Primary Selection (MC Only)	AliStack::IsPhysicalPrimary()
MC Association (MC Only)	PDG code association V0
Daughter Track Pseudorapidity Interval	$\|\eta\| < 0.8$
N sigma signal extraction	$\pm 6\sigma$

Signal extraction

- fit data Gauss (sgn) + *pol2* (bkg)
- bin counting technique ±6σ

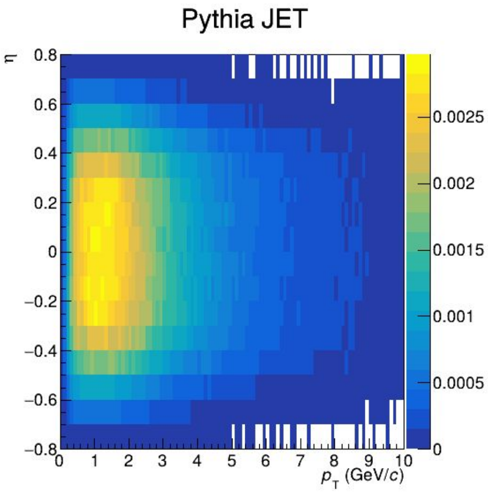


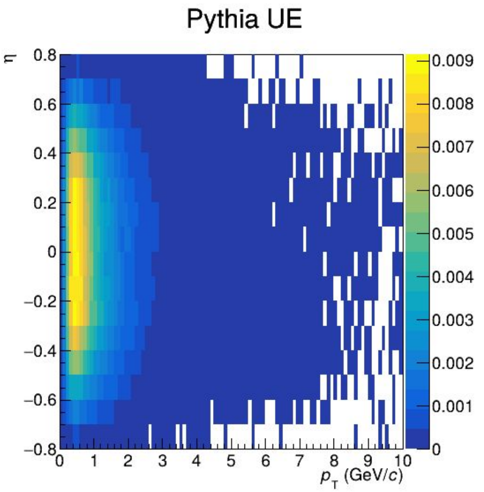
Efficiency correction

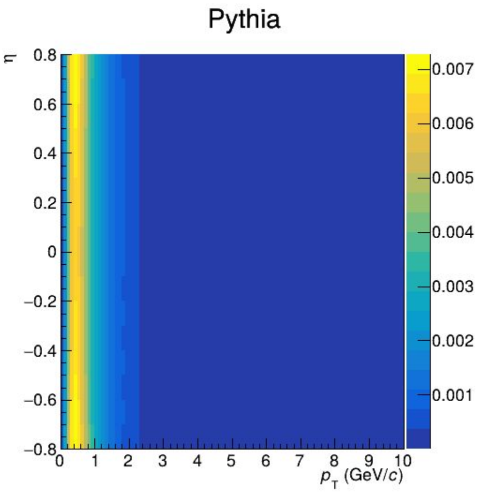
LHC24f3c General Purpose MC anchored to LHC22o apass7 13.6 TeV pp MB sample

$$\varepsilon = \frac{N(V0_{\mathrm{reco+assoc+primary}})}{N(V0_{\mathrm{gen\ primary}})} \text{ in reco events}$$

Efficiency inside jets and UE are different due to different kinematic distributions 2d (p_T, η) → reweighting comparing with the general pythia distribution





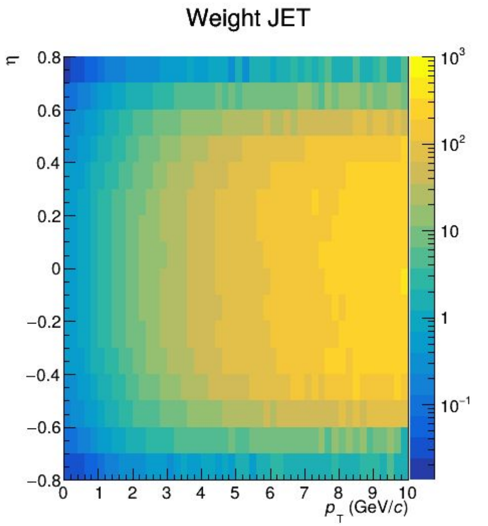


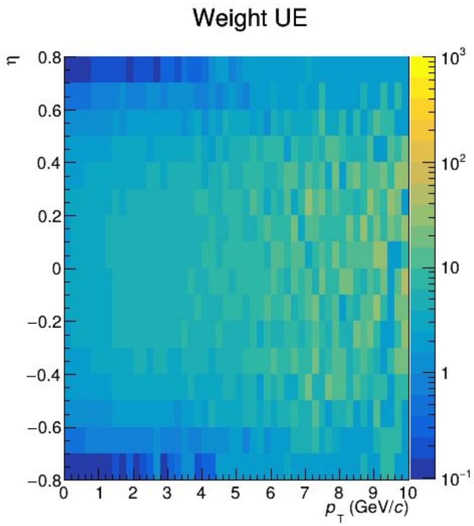
Efficiency re-weighting

1. The p_T-η distributions of V0s in jet, UE and in pythia are obtained
2. The p_T and η dependent weights are obtained as:

$$w_{\mathrm{jet}}(p_T,\eta) = \frac{\left[\mathrm{d}^2N/(\mathrm{d}\eta\mathrm{d}p_T)\right]_{\mathrm{jet}}}{\left[\mathrm{d}^2N/(\mathrm{d}\eta\mathrm{d}p_T)\right]_{\mathrm{Pythia}}} \qquad w_{\mathrm{ue}}(p_T,\eta) = \frac{\left[\mathrm{d}^2N/(\mathrm{d}\eta\mathrm{d}p_T)\right]_{\mathrm{ue}}}{\left[\mathrm{d}^2N/(\mathrm{d}\eta\mathrm{d}p_T)\right]_{\mathrm{Pythia}}}$$

3. These values are used to weight the candidates which fill the numerator and the denominator of the efficiency



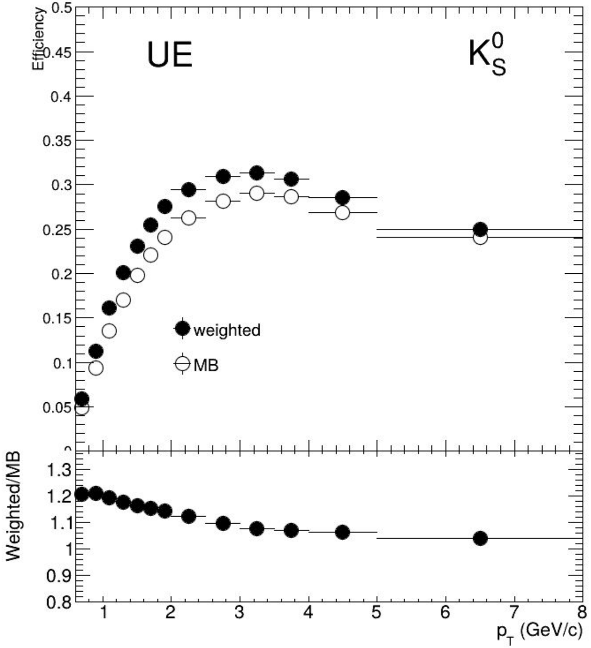


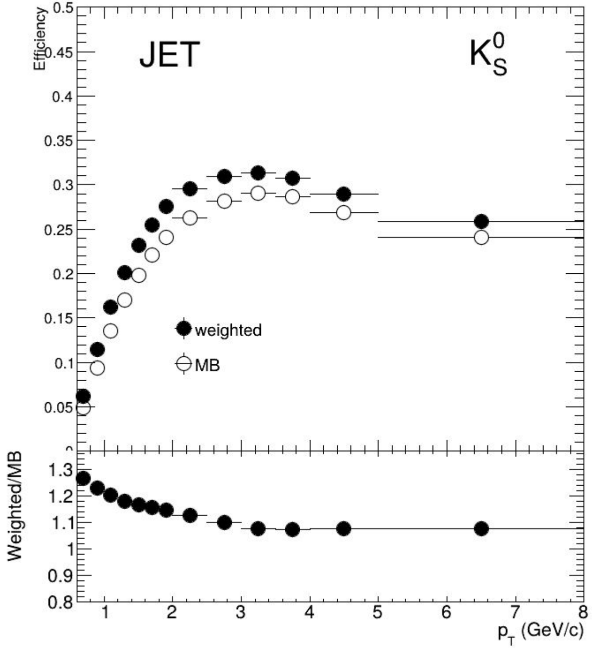
Efficiency correction: K0s

$$\varepsilon = \frac{N(V0_{\text{reco+assoc+primary}})}{N(V0_{\text{gen primary}})} \text{ in reco events}$$

The weights affect the K0s efficiency up to ~25% at low p_T and decreasing with momentum

Similar effect (~15%) observed for Λ and anti-Λ

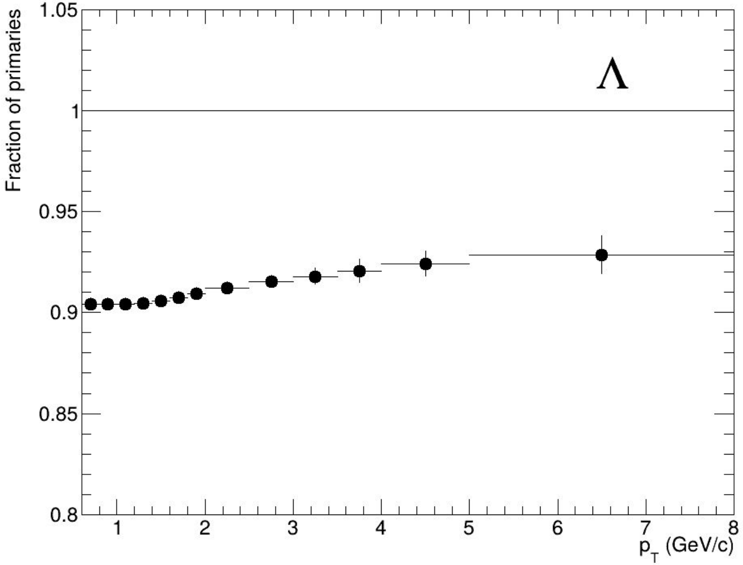


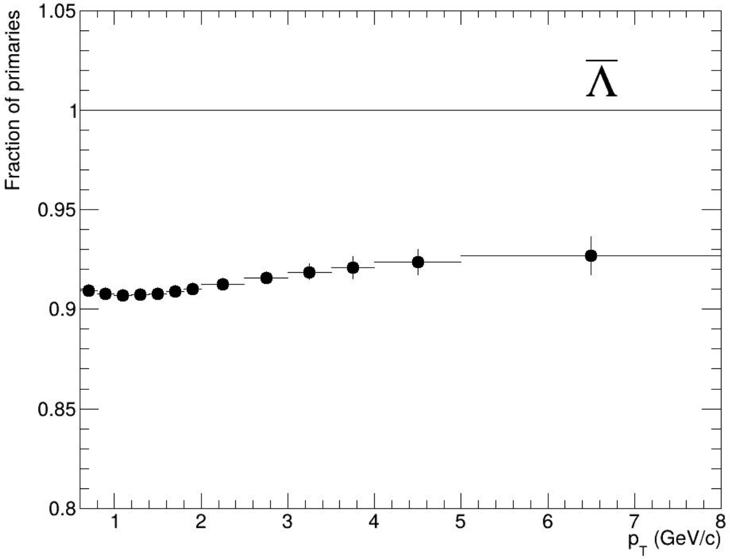


Feeddown correction

Primary Λ fraction is computed from the MC (no Ξ measurement foreseen for the preliminaries but planned for publication):

$$\text{Primary fraction} = \varepsilon_{\text{prim}} = \frac{\text{N}(\text{V0}_{\text{reco+assoc+primary}})}{\text{N}(\text{V0}_{\text{reco+assoc}})} \text{ in reco events}$$





Density distribution - MB

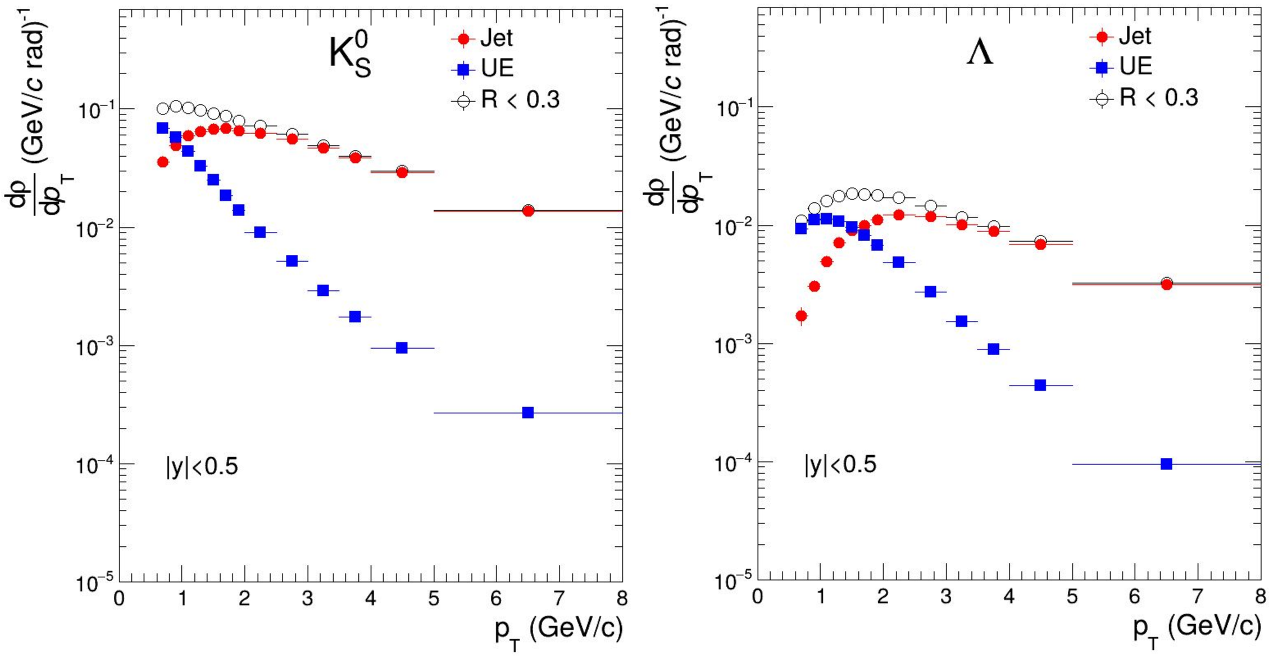
To subtract the UE from the JC, a density distribution is defined

$$\frac{\mathrm{d}\rho}{\mathrm{d}p_{\mathrm{T}}} = \frac{1}{N_{\mathrm{ev}}} \times \frac{1}{A_{\mathrm{acc}}} \times \frac{\mathrm{d}N^{\mathrm{raw}}}{\mathrm{d}p_{\mathrm{T}}} \times \frac{\varepsilon_{\mathrm{primary}}}{\varepsilon_{\mathrm{reco}}}$$

The **JE** density distribution is obtained by subtracting the one of particles in the **UE** selection from that with the **JC** selection

$$\frac{\mathrm{d}\rho^{\mathrm{JE}}}{\mathrm{d}p_{\mathrm{T}}} = \frac{\mathrm{d}\rho^{\mathrm{JC}}}{\mathrm{d}p_{\mathrm{T}}} - \frac{\mathrm{d}\rho^{\mathrm{UE}}}{\mathrm{d}p_{\mathrm{T}}}$$

$A_{\mathrm{acc}} = \pi R^2$, times 2 for the UE

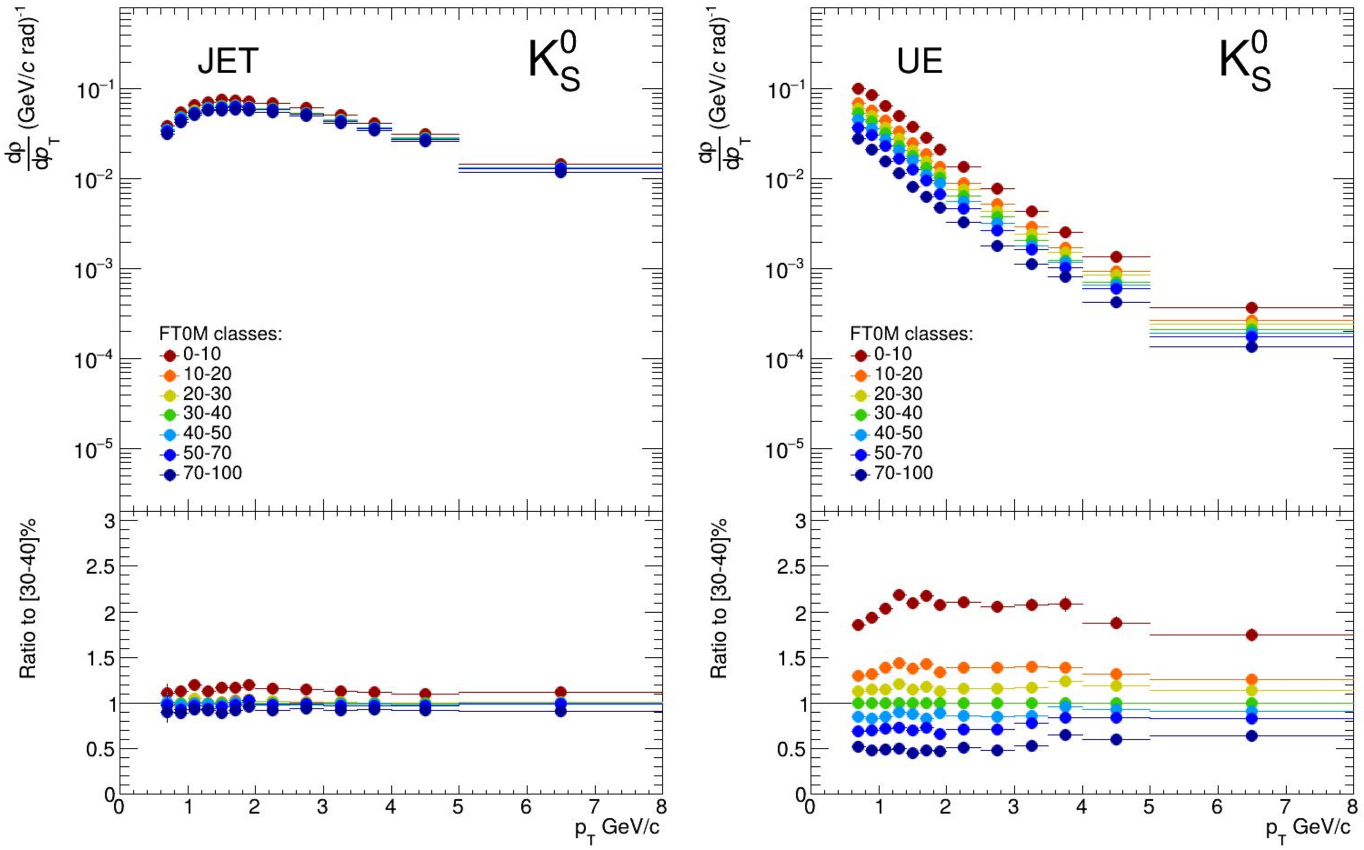


Density distribution - multiplicity

For all multiplicity classes the **JE** spectra are **harder** than the **UE** ones

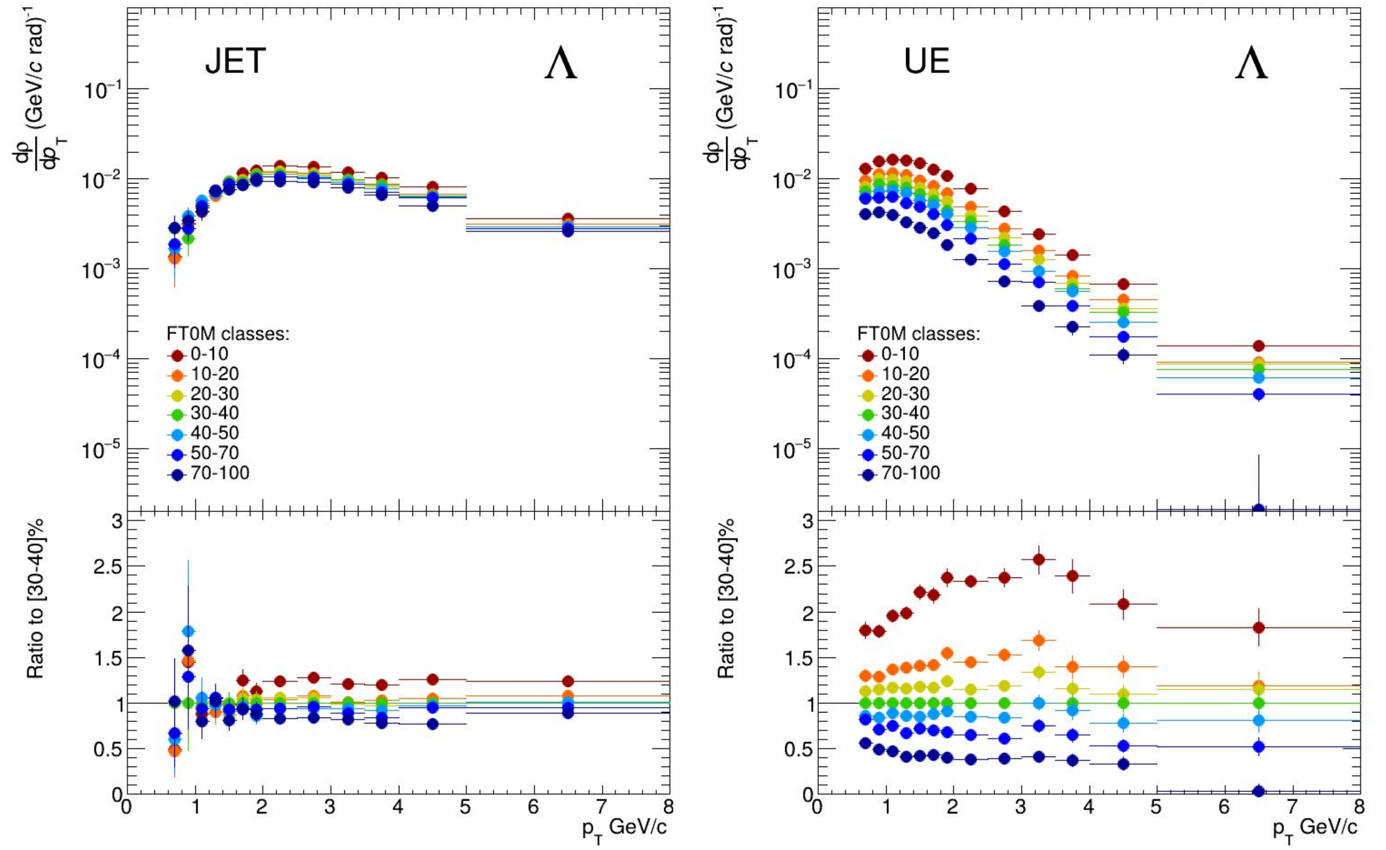
JE spectra have similar shapes for different multiplicity classes + yields vary only within ~10%

Mild **hardening** observed for **UE** spectra + **large yield variations** in different multiplicity classes



Density distribution - multiplicity

The same comments apply also to the Λ and anti-Λ spectra

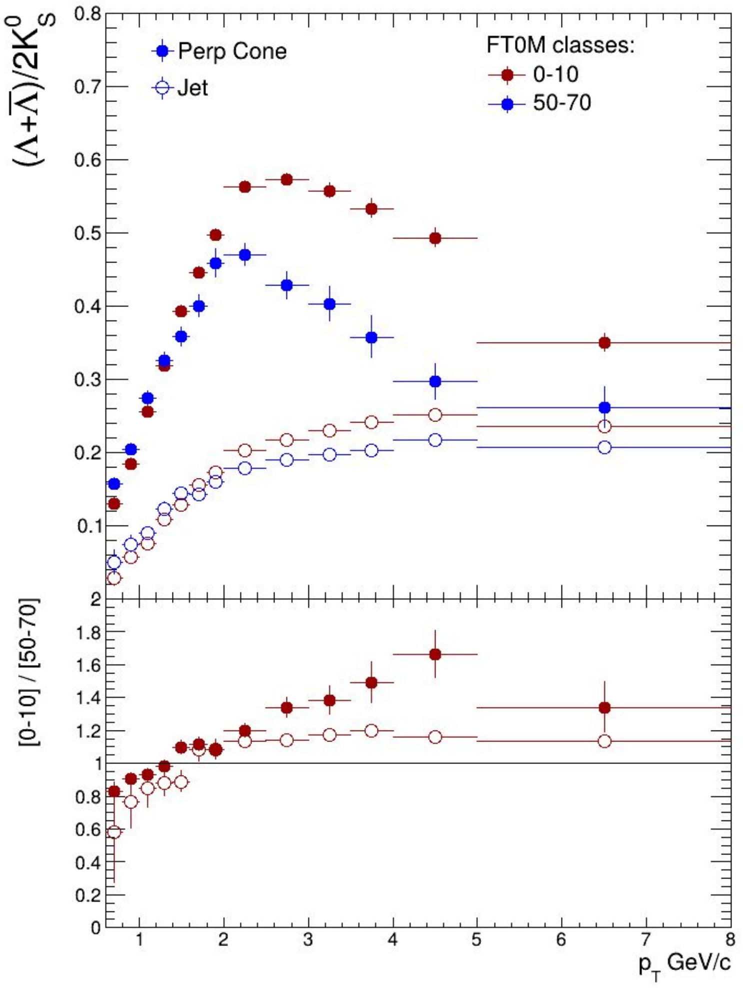


Λ/K0 vs multiplicity

Λ/K0 ratio shown for the highest and lowest (-1) multiplicity class measured

UE spectra exhibit the known enhancement in the mid p_T region, while no effect is observed for JE particles

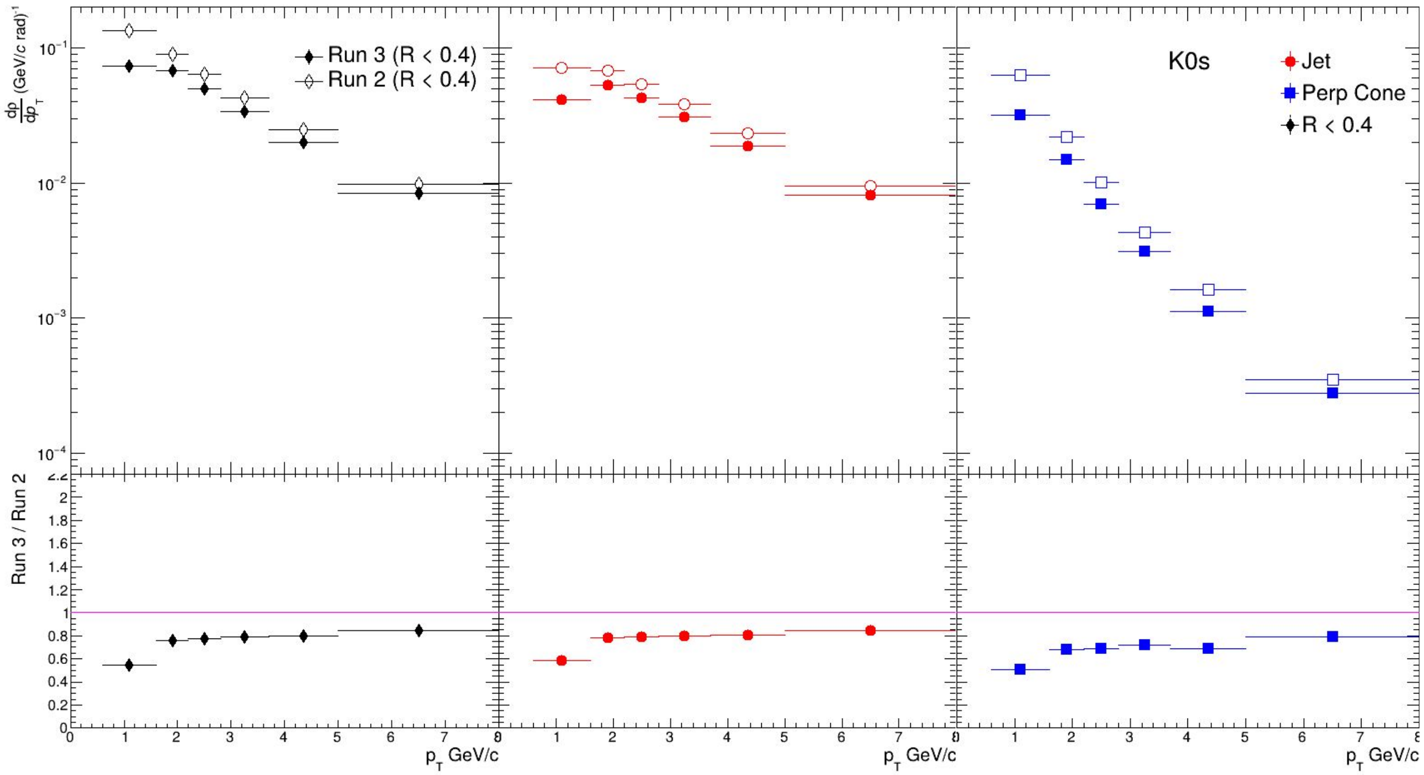
An **evolution with multiplicity** is observed for the **UE**, **mild but significant** effect seen for the **JE**



Comparison to Run 2 - K0s

Comparison with
JHEP 07 (2023) 136

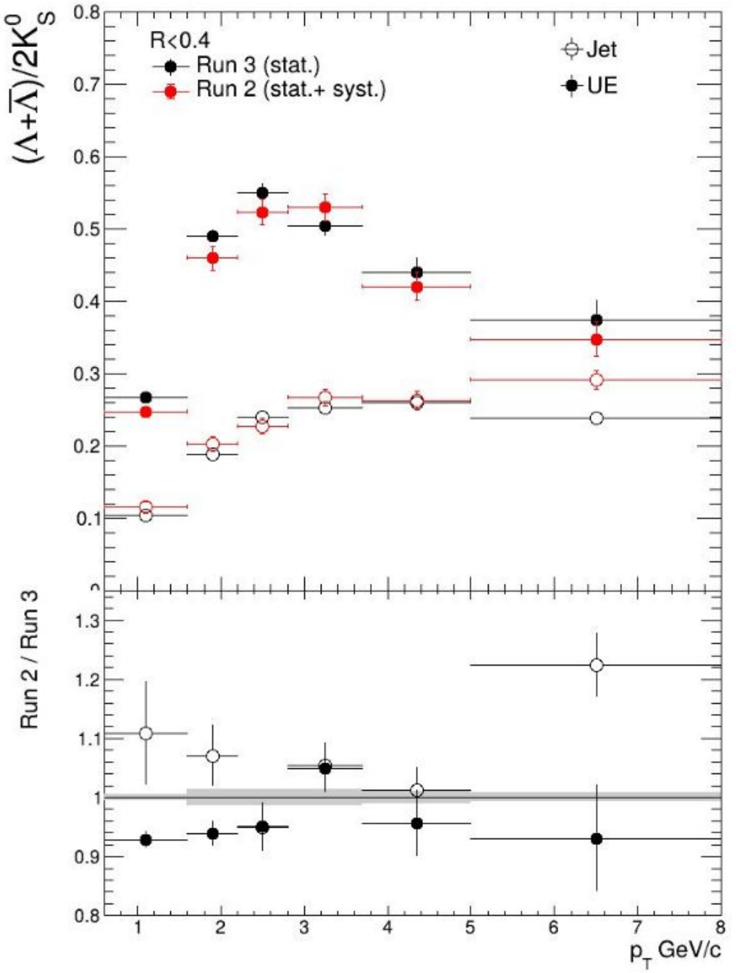
Run 3 is lower wrt Run 2 similarly for JE, UE and JC, of ~20% with a larger difference at low p_T



Comparison to Run 2

Comparison with JHEP 07 (2023) 136

Λ/K0 ratio is in better agreement with Run 2



Conclusions

Preliminary approvals ongoing → Monday Preview at the PWG-LF

Today:

- Jet and UE fully corrected spectra of K0s and Λ + anti-Λ measured for the first time as a function of multiplicity using full jet reconstruction with Run 3 pp collisions
- Deviations >~20% observed wrt Run 2 for the single particle spectra
- Λ/K0 ~ in agreement with Run 2

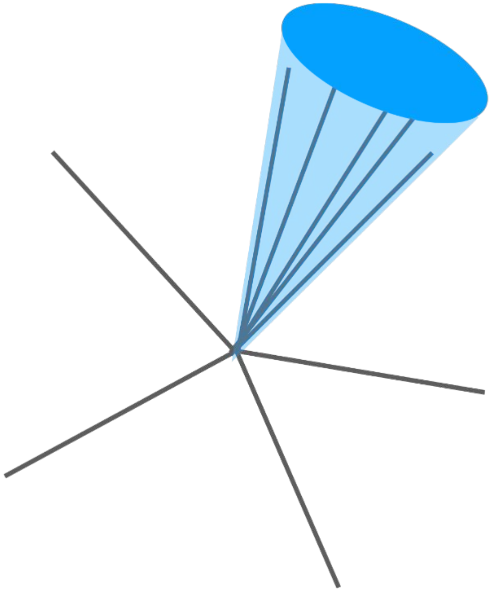
Next steps:

- Systematic uncertainty evaluation
- Understand deviations of single particle spectra from Run 2

For these preliminary results we plan to focus on V0s, but we started to have a look at **Cascades** and **pions** for the publication

Backup

The anti-KT jet clustering algorithm



$$d_{ij} = \min\left(k_{ti}^{-2}, k_{tj}^{-2}\right) \frac{\Delta_{ij}^2}{R^2}$$ → Distance between entities (particles, pseudo-jets) i and j

$$d_{iB} = k_{ti}^{-2}$$ → Distance between entity i and the beam (B)

$$\Delta_{ij}^2 = (\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2$$

$R = 0.3$ (jet resolution parameter)

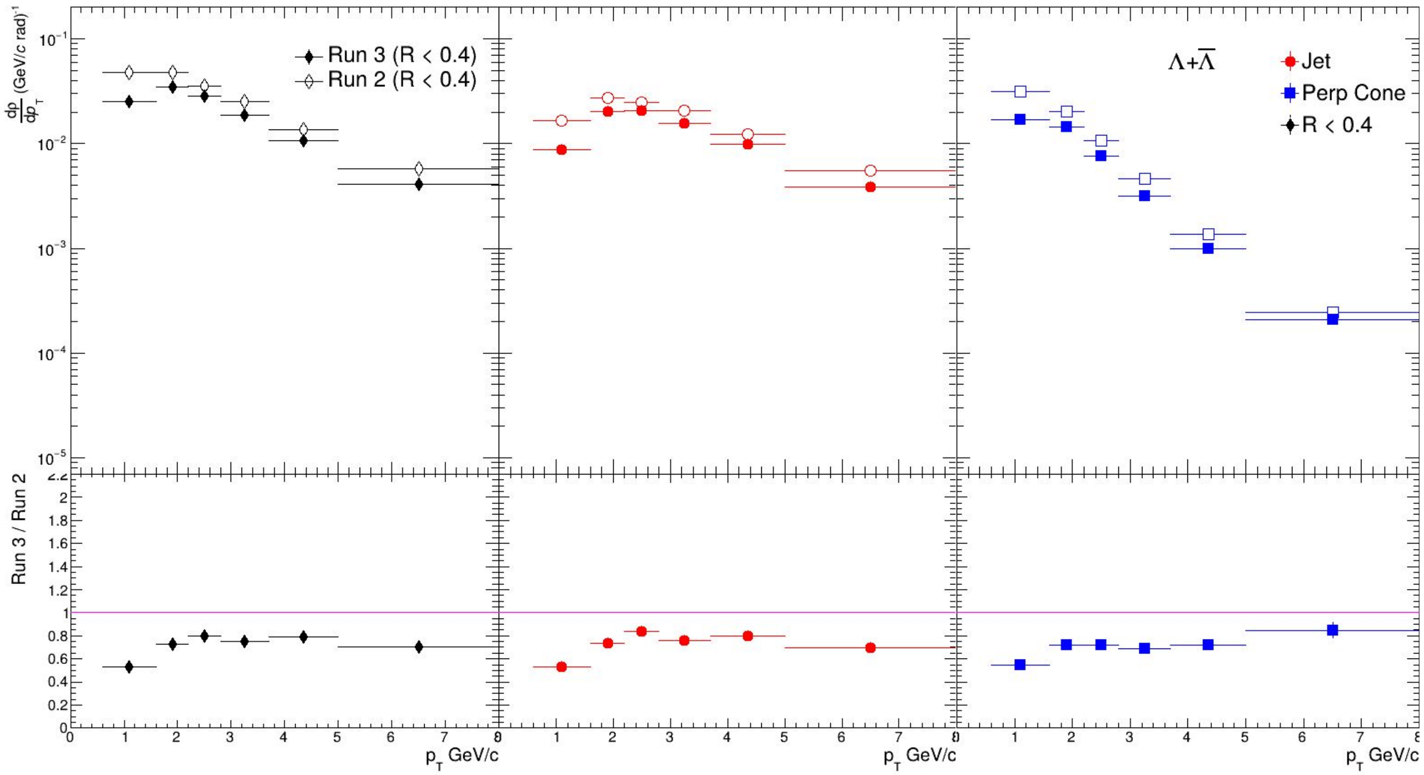
Algorithm: calculate the smallest distance

- If of type d_{ij}: recombine entities i and j (add their momenta) to form a pseudo-jet
- If of type d_{iB}: call i a jet and remove it from the list
- Continue until no entities are left

M. Cacciari and G. P. Salam
https://arxiv.org/pdf/0802.1189

Comparison to Run 2 - Λ

The same comments apply also to the Λ + anti-Λ spectra



Status of benchmark MB for V0s

Note that the fully corrected Run 3 MB spectrum of K0s is lower wrt Run 2 with a flat trend in p_T of ~ 15%

Likely part of the discrepancy in the jet analysis is related to this observation

Also other aspects are being investigated, e.g. the jet-p_T definition in the algorithm with respect to the Run 2 publication