Production of strange particles in charged jets in p–Pb and Pb–Pb collisions measured with ALICE at the LHC

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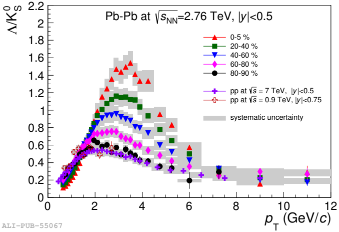
Overview

Motivation

- Baryon/meson ratio in p–Pb and Pb–Pb collisions enhanced compared to pp collisions
  Several scenarios:
  - collective effects like particle flow (mass dependent)
  - jet fragmentation
  - parton recombination and/or coalescence
- Ratio in most peripheral p–Pb events close to pp ratio
  → Is ratio in Pb–Pb and p–Pb jets like ratio in minimum bias pp or modified?
  → Measurement of identified particles in jets helps to constrain hadronisation and energy loss scenarios



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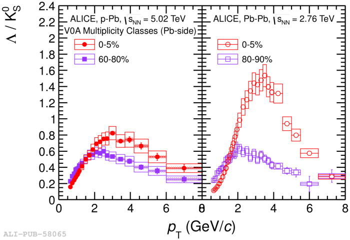

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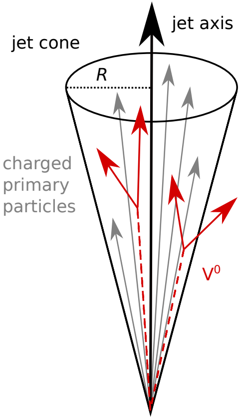
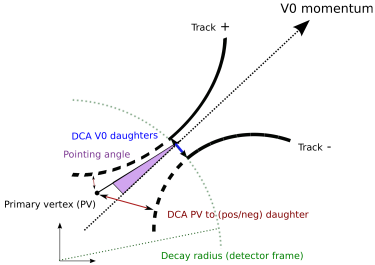
Analysis strategy

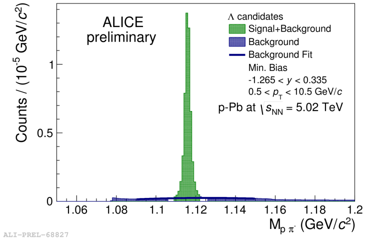
- V0 particles reconstructed down to very low p_{T} ($\geq$ 600 MeV/c)
- $\mathrm{K^0_S}$ and Λ p_{T} spectra measured in jet cone (JC) and Underlying Event (UE)
- $\Lambda/\mathrm{K^0_S}$ ratio in jets and UE
- Comparison of ratio in jets to ratio in inclusive analyses
- Comparison among different collision systems (pp, p–Pb, Pb–Pb)



V0 reconstruction

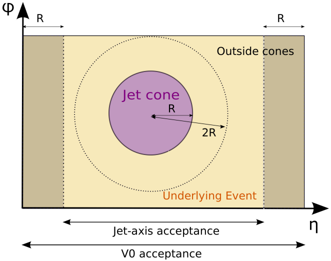
- Analysis of p–Pb data at $\sqrt{s_{NN}} = 5.02$ TeV and Pb–Pb data at $\sqrt{s_{NN}} = 2.76$ TeV
- Neutral strange particles reconstructed via V0 decay topology
  - $K^0_S \rightarrow \pi^+ + \pi^-$ (69.2%)
  - $\Lambda \rightarrow p + \pi^-$ (63.9%)
- V0 selection according to 5 different selection parameters (see cartoon below)
- Particle acceptance $|\eta^{V0}| < 0.7$
- Signal extraction via fit or bin counting procedure in invariant mass distributions
- Analysis performed in different intervals of p_T^{V0} and $p_{T,\,jet}^{ch}$





Jet reconstruction

- Anti-k_t algorithm, using charged primary tracks ($p_T > 150$ MeV/c)
- Jet resolution parameter ("cone size") $R = 0.2, 0.3$
- Jet-axis acceptance $|\eta^{\text{jet}}| < |\eta^{\text{V0}}| - R = 0.5$ (0.4), with $|\eta^{\text{V0}}| < 0.7$
- Leading constituent bias $p_T^{\text{leading track}} > 5$ GeV/c (suppression of combinatorial jets)
- Jet energy is corrected for average energy from UE

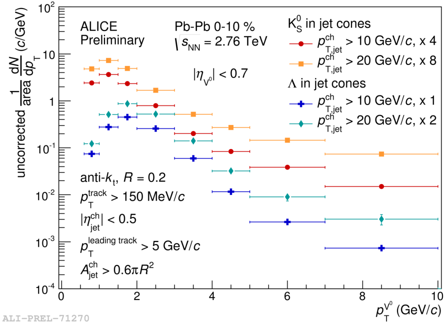


The excluded area $2R$ serves for estimating UE V0 spectrum outside the jet cone (OC method, see also slide 8)

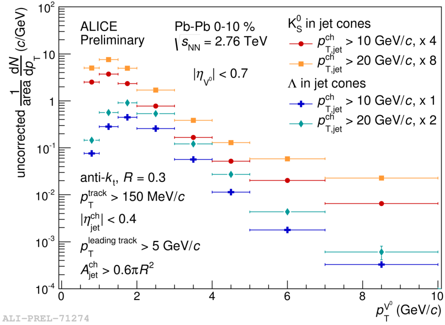
Raw V0 spectra in jet cone in Pb–Pb collisions

Uncorrected V0 spectra in jet cones (scaled for better visibility)

- Measured for two jet $p_{\mathrm{T,\,jet}}^{\mathrm{ch}}$ intervals ($p_{\mathrm{T,\,jet}}^{\mathrm{ch}} > 10$ GeV/c and $p_{\mathrm{T,\,jet}}^{\mathrm{ch}} > 20$ GeV/c)
- No UE subtraction applied in these plots



$R = 0.2$

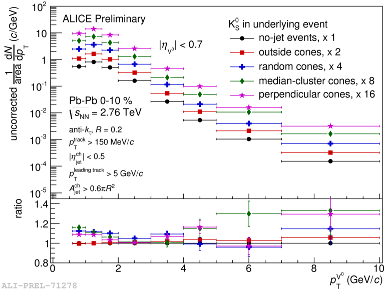


$R = 0.3$

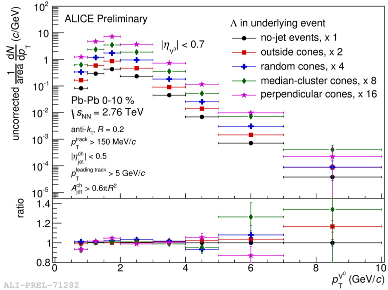
Contribution of V0s from Underlying Event (UE) in Pb–Pb collisions

UE estimation method	Definition
No-jet events (NJ)	V0s in events without selected jets
Outside Cone (OC)	V0s outside of $2R$ of selected jets
Random Cone (RC)	V0s in randomly placed cone (no overlap with selected jets)
Perpendicular Cone (PC)	Rotate jet axis $\pm 90^{\circ}$ in azimuthal direction
Median-Cluster Cone (MCC)	Uses median k_{t} cluster (similar to k_{t} alg. for average background estimation)

- Different methods serve to estimate systematic uncertainty of UE subtraction
- NJ V0 spectrum as default method for UE V0 subtraction
- Ratios (below spectra) represent UE-subtraction method divided by default UE V0 spectrum (NJ V0s)



K^0_S in UE



Λ in UE

→ Differences of UE estimation methods < 12 % (below 4 GeV/c)

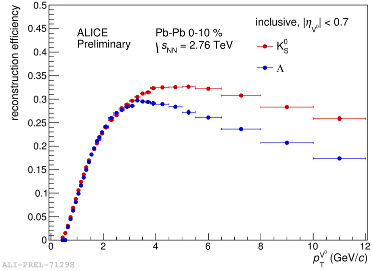
Efficiency and Feed-down (FD) estimation ($\Xi^{0,-} \to \Lambda$)

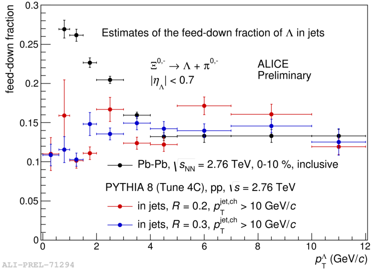
ALICE

- Reconstruction efficiency of single V0s in and outside of JC is equal (in Pb–Pb and p–Pb)
- Inclusive efficiency has higher statistics than V0 eff. in JC
- η dependence of V0s reconstructed in JC accounted for by reweighting (data)

Two approaches to estimate FD contributions to Λ spectrum, since there is no measurement of $\Xi^{0,-}$ available in jets

- FD estimated like in inclusive particle analysis
  (Phys. Rev. Lett. 111, 222301 (2013))
- FD from PYTHIA jets
  (pp, $\sqrt{s} = 2.76$ TeV)

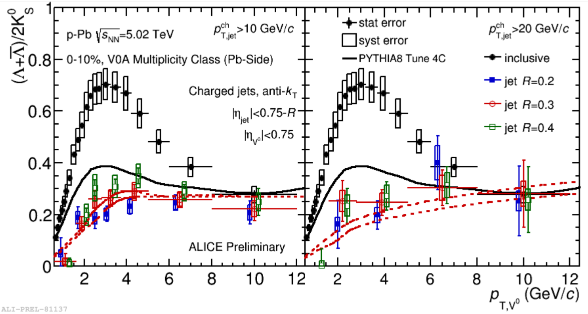




Λ/K^0_S ratio in jets in p–Pb collisions

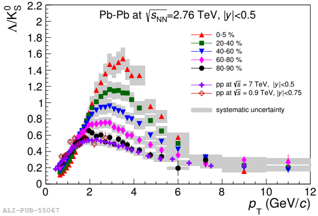
- Ratio in jets in p–Pb collisions in between MB PYTHIA8 simulation and jet PYTHIA8 simulations
- Slightly below inclusive pp measurement (see "dark purple" markers, small figure)
- Smaller than inclusive ratio in p–Pb collisions (see black markers)
- No dependence on jet resolution parameter R or on jet energy interval seen within our systematic uncertainties

$p^{\text{ch}}_{\text{T, jet}} > 10$ GeV/c $\quad$ $p^{\text{ch}}_{\text{T, jet}} > 20$ GeV/c



(black solid line - MB PYTHIA simulation of inclusive V0s,
red dotted line - PYTHIA8 simulation of V0s in jets
(for R = 0.2 and 0.4))

Incl. ratio in pp (dark purple) and Pb–Pb



(Phys. Rev. Lett. 111, 222301 (2013))

Summary and Outlook

- Measurement of V0 spectra in jet cones and UE in p–Pb collisions
- Λ/K^0_S ratio in p–Pb jets is in between pp collision PYTHIA8 simulations for MB and for jets
- Ratio is smaller than in inclusive p–Pb collisions in high-multiplicity events
  $+$ smaller than measured ratio of MB pp
  $+$ within the systematic uncertainties no modification of the ratio in jets in p–Pb collisions visible

- First measurement of uncorrected V0s spectra in jet cones and UE in Pb–Pb collisions
  $\rightarrow$ Λ/K^0_S ratio in jets in Pb–Pb will be reported soon

Thank you for your attention!

Appendix

Systematic uncertainties to be considered

Source of uncertainty	Method
V0s in UE	NJ, RC, PC, MCC, OC
Signal extraction	Bin counting, sideband-fit
V0 reconstruction efficiency	Cut variations[1]
Material budget	Estimate from inclusive particle analysis
FD fraction	Incl. FD and PYTHIA-FD

[1]Distance of Closest Approach between Daughters, Cosine of Pointing Angle,
Transverse Proper Lifetime

Efficiency calculation for V0 in jet and UE cones

- ϵ — reconstruction efficiency of inclusive particles
- ϵ_s — reconstruction efficiency of particles of interest
- a_s — yield of associated particles of interest
- g_s — yield of generated particles of interest
- m — uncorrected yield of measured particles (candidates) of interest
- t — yield of true (corrected) particles of interest
- P — signal purity

Signal extraction in JC, UE (assume that $P_{\text{inclusive}}(p_{\text{T}}^{\text{V0}}, \eta^{\text{V0}})$ is the same as for inclusive V0s):

$$m(p_{\text{T}}^{\text{V0}}, \eta^{\text{V0}}) = m_{\text{raw}}(p_{\text{T}}^{\text{V0}}, \eta^{\text{V0}})|_{\text{peak region}} \cdot P_{\text{inclusive}}(p_{\text{T}}^{\text{V0}}, \eta^{\text{V0}})|_{\text{peak region}}$$

Efficiency calculation:

$$a_s \equiv m, \quad \sigma_{a_s} \equiv 0, \qquad g_s = a_s/\epsilon$$

$$\frac{1}{\epsilon_s(p_{\text{T}}^{\text{V0}})} = \frac{\sum_{\eta_i^{\text{V0}}} g_s(\eta_i^{\text{V0}}, p_{\text{T}}^{\text{V0}})}{\sum_{\eta_j^{\text{V0}}} a_s(\eta_j^{\text{V0}}, p_{\text{T}}^{\text{V0}})} = \sum_{\eta_j^{\text{V0}}} \frac{a_s(\eta_j^{\text{V0}}, p_{\text{T}}^{\text{V0}})}{\sum_{\eta_i^{\text{V0}}} a_s(\eta_i^{\text{V0}}, p_{\text{T}}^{\text{V0}})} \frac{1}{\epsilon(\eta_j^{\text{V0}}, p_{\text{T}}^{\text{V0}})}$$

Spectra correction:

$$t = m/\epsilon_s$$

Cut selection for V0 particle reconstruction

Cut variable	Value
Daughter tracks	
TPC refit	`true`
type of production vertex	not `kKink`
DCA to the primary vertex	≥ 0.1 cm
DCA between daughters	$\leq 1\sigma_{\mathrm{TPC}}$
$\lvert\eta\rvert$	≤ 0.8
$\lvert\Delta(\mathrm{d}E/\mathrm{d}x)\rvert$ (p, $p_{\mathrm{T}} < 1$ GeV/c)	$\leq 3\sigma_{\mathrm{d}E/\mathrm{d}x}$
V0 candidate	
Reconstruction method	offline
Cosine of the pointing angle (CPA)	≥ 0.998
Radius of the decay vertex	5–100 cm
$\lvert\eta\rvert$	≤ 0.7
Transverse proper lifetime	$\leq 5\tau$
Armenteros–Podolanski cut (K^0_S)	$p_{\mathrm{T}}^{\mathrm{Arm.}} \geq 0.2\lvert\alpha^{\mathrm{Arm.}}\rvert$