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

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Hot Quarks 2014

ALICE

evropský sociální fond v ČR

EVROPSKÁ UNIE

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

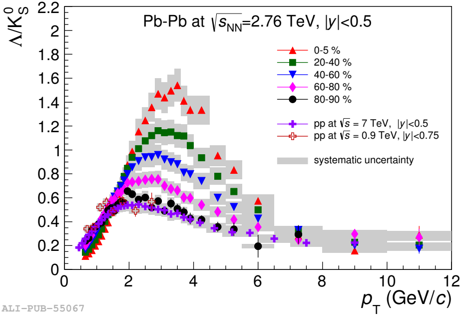
Outline

- Motivation for particle identification (PID) in jets
- Jet analysis in ALICE
- Analysis of neutral strange particles in jets
- Uncorrected spectra of strange particles in jets in Pb–Pb
- Correction techniques
- Sources of systematic uncertainties
- Corrected Λ/K^0_S ratios in p–Pb
- Summary and outlook

Motivation for PID in jets

- Baryon-to-meson ratio enhanced in Pb–Pb and p–Pb collisions.
- This phenomenon cannot be explained by fragmentation in vacuum.
- What is the effect of QGP on hadronisation mechanism(s) in jets?
- What mechanisms are they (parton recombination)?

Pb–Pb



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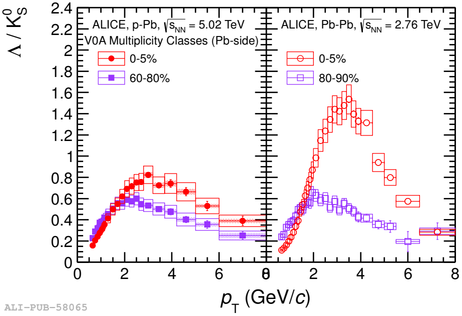
p–Pb Pb–Pb



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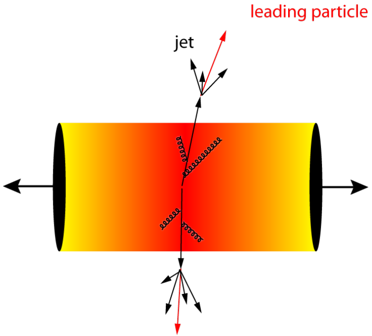
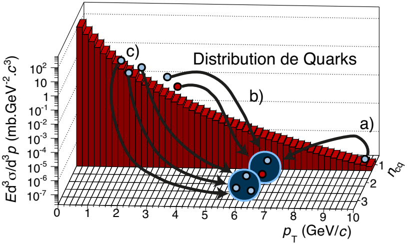
Motivation for PID in jets

We aim to understand the origin(s) of the Λ/K^0_S enhancement by separating hadrons produced in jets from hadrons produced in the thermalised bulk.



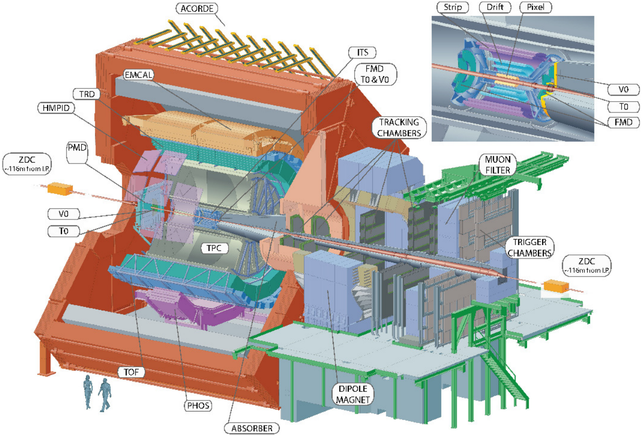
Is the baryon-to-meson ratio enhanced due to the bulk effects in the plasma (parton recombination, radial flow,. . .) or is it (also) due to a modification of the jet fragmentation in the medium?

- jet fragmentation
  In a hard scattering process, a high-p_T parton is produced which fragments into hadrons.
- parton recombination
  Multiple partons (close to each other in phase space) cluster together to form a hadron (meson if $q\bar{q}$, baryon if qqq).



ALICE

- data used in the analyses: Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV measured with ALICE
- tracking of charged particles by ITS & TPC in magnetic field of 0.5 T
- centrality estimated from the multiplicity of charged particles in the V0 detectors



Analysis of charged jets

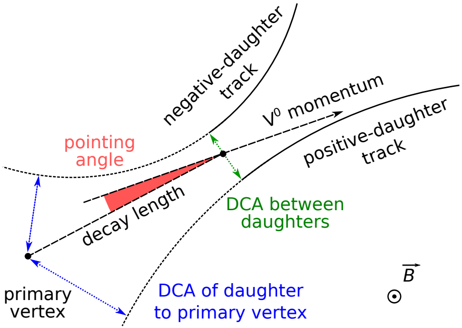
- track selection
  - charged primary particles
  - $p_{\mathrm{T}}^{\mathrm{track}} > 150\ \mathrm{MeV}/c$
  - uniform in $\varphi \times \eta$, $|\eta_{\mathrm{track}}| < 0.9$
- raw-jet reconstruction
  - anti-k_{t} algorithm
  - resolution parameter $R = 0.2, 0.3, (0.4)$
- subtraction of average soft background
  - average background density ρ estimated from the median k_{t} cluster
  - $\boldsymbol{p}_{\mathrm{jet,ch}}^{\mathrm{corr}} = \boldsymbol{p}_{\mathrm{jet,ch}}^{\mathrm{raw}} - \rho \boldsymbol{A}_{\mathrm{jet,ch}}$, (where $\boldsymbol{A}_{\mathrm{jet,ch}}$ is jet area)
- signal jet selection (good candidates for hard scattering)
  - $p_{\mathrm{T}}^{\mathrm{jet,ch}} > 5\ \mathrm{GeV}/c$
  - $p_{\mathrm{T}}^{\mathrm{leading\ track}} > 5\ \mathrm{GeV}/c$
  - $A_{\mathrm{jet,ch}} > 0.6\pi R^2$
- further $p_{\mathrm{T}}^{\mathrm{jet,ch}}$ corrections
  - background anisotropy (intra-event p_{T} fluctuations)
  - detector response

Analysis of neutral strange particles

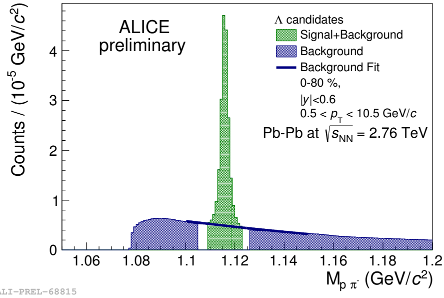
Strange neutral particles decaying into two charged daughter particles

- meson $K^0_S \to \pi^+ + \pi^-$ (BR 69 %)
- baryon $\Lambda \to p + \pi^-$ (BR 64 %)

Mother V^0 particle reconstructed using topology of its V-shaped decay.



Combinatorial background suppressed by cuts on decay parameters.
Signal yield extracted from the invariant-mass distribution.



Analysed ranges:

- $0.6\ \text{GeV}/c < p_T^{V^0} < 10\ \text{GeV}/c$
- $|\eta_{V^0}| < 0.7$

Strange particles in jets

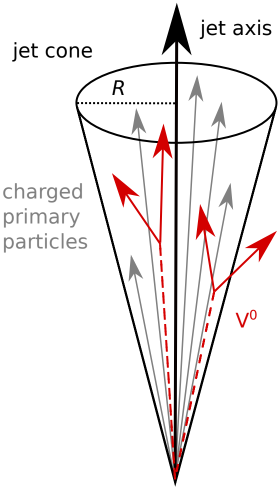
Analysis steps

- V^0 candidate selection
- candidate–jet matching (V^0s in jet cones)

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

$$|\eta_{\text{jet,ch}}|^{\max} < |\eta_{V^0}|^{\max} - R$$

- candidate–bulk matching (regions with V^0s from underlying event (UE) only)
- signal extraction (invariant-mass distribution)
- efficiency correction (inclusive, in jet cones, in UE)
- subtraction of V^0s in UE
- subtraction of V^0s coming from decays, i.e. "feed-down correction" (inclusive, in jets, in UE)

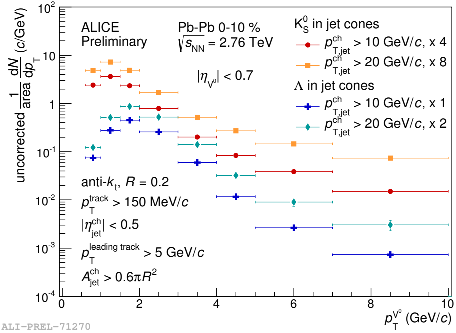


Uncorrected spectra of V^0s in jet cones in Pb–Pb

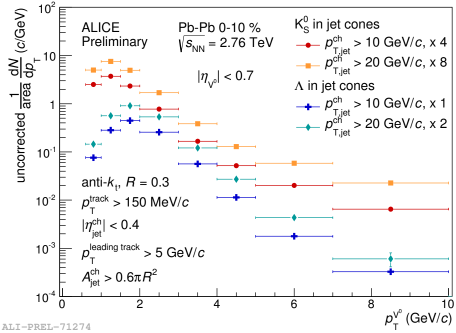
Analysis performed for:

- triggered central events (0–10 %, $7.3 \cdot 10^6$ events)
- jets in open p_T bins: $p_T^{\text{jet,ch}} > 10\ \text{GeV}/c, 20\ \text{GeV}/c$
- jets reconstructed with cone size: $R = 0.2, 0.3$

$R = 0.2$



$R = 0.3$

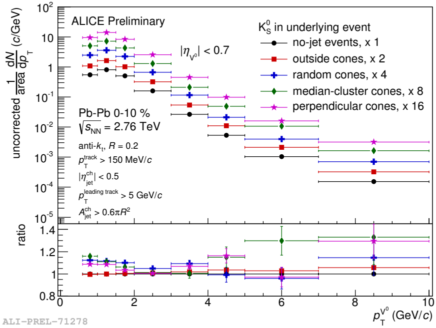


Estimation of V^0s in the underlying event in Pb–Pb

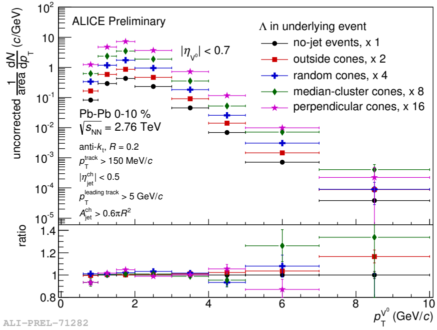
- no-jet events: V^0s in events with no selected jets
- outside cones: V^0s outside jet cones
- random cones: V^0s in a randomly oriented cone
- median-cluster cones: V^0s in the cone of the median k_t-cluster
- perpendicular cones: V^0s in cones perpendicular to the jet in azimuth

Methods differ in regions, events, statistics, efficiency.
Spectra after efficiency correction agree within 5 % at intermediate $p_T^{V^0}$.

K^0_S



Λ

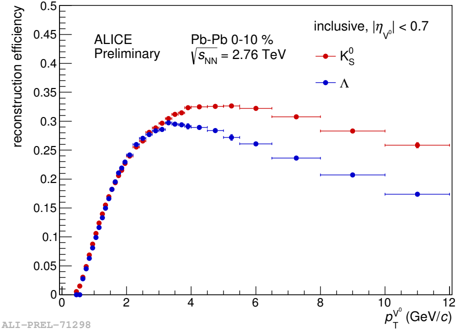


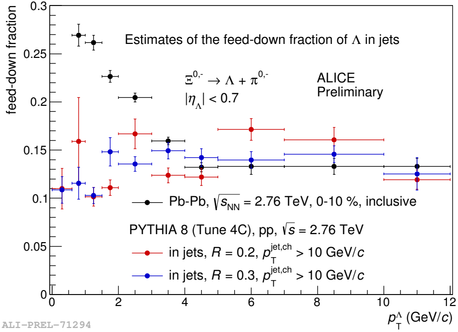
Reconstruction efficiency, feed-down in Pb–Pb

Reconstruction efficiency depends strongly on $p_{\mathrm{T}}^{\mathrm{V}^0}$, η_{V^0}.
Shape of the measured η_{V^0} distribution depends on the selection criteria.
Efficiency of inclusive V^0s is reweighted to get efficiency in jet cones and UE.

Feed-down fraction of Λ in jets estimated from:

- inclusive Λ (Pb–Pb-like),
- jets generated by PYTHIA 8 (pp-like).





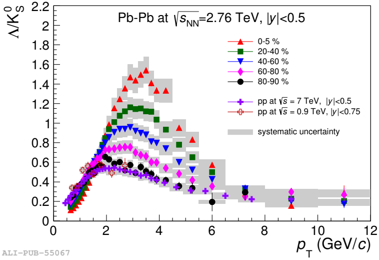
Sources of systematic uncertainties

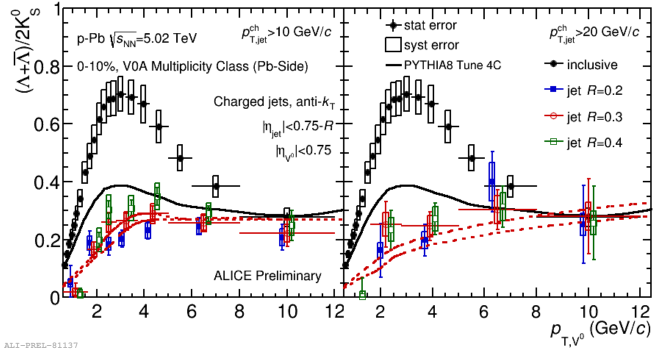
- choice of cuts for the selection of V^0 candidates (cuts varied)
- choice of a method to extract signal yields (multiple settings)
- choice of a method to estimate V^0s in the underlying event (multiple methods)
- estimation of material budget (taken from another analysis)
- choice of a method to estimate fraction of Λ baryons from feed-down in jets (extreme scenarios)
- correction of p_T^{jet} (embedding of simulated jets in real data)

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

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

- below the inclusive ratio in p–Pb (black circles), in pp (dark purple, right plot) and in PYTHIA (black line)
- similar to ratios in PYTHIA jets (red dashed lines)
- no significant dependence on R or $p_T^{\text{jet,ch}}$





Summary and outlook

- Pb–Pb
  - Extracted uncorrected spectra of Λ and K^0_S in charged jets in Pb–Pb collisions.
  - Ongoing investigation of corrections and uncertainties.
  - Fully corrected Λ/K^0_S ratio in charged jets in central Pb–Pb collisions will be reported soon.
- p–Pb
  - ALICE performed the first measurement of Λ and K^0_S in charged jets in p–Pb collisions at the LHC.
  - Λ/K^0_S ratio in charged jets close to the ratio in jets in PYTHIA 8.
  - No visible modification of strangeness production in charged jets in p–Pb.

Message: Λ/K^0_S enhancement is coming from the bulk effects.

Thank you for your attention.

Backup

V^0 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, $\overline{\mathrm{p}}$: $p_{\mathrm{T}} < 1$ GeV/c)	$\leq 3\sigma_{\mathrm{d}E/\mathrm{d}x}$
V0 candidate	
reconstruction method	offline (Vít), on-the-fly (Alice)
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)	$p_{\mathrm{T}}^{\mathrm{Arm.}} \geq 0.2\lvert\alpha^{\mathrm{Arm.}}\rvert$

Jet algorithms

A sequential recombination jet finder is defined according to this general scheme:

1. $\forall\, i, j$: calculate distances d_{ij} and d_{iB} (NB $k_t \equiv p_T$):

$$d_{ij} = \min\left(k_{t,i}^{2p}, k_{t,j}^{2p}\right) \frac{\Delta_{ij}^2}{R^2}, \quad \Delta_{ij}^2 = (y_i - y_j)^2 + (\varphi_i - \varphi_j)^2, \quad d_{iB} = k_{t,i}^{2p}$$

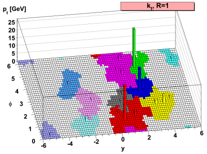
2. Find $d_{\min}$:

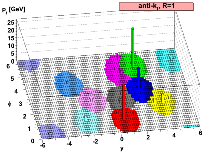
$$d_{\min} = \min\left(d_{ij}, d_{iB}\right).$$

- If $\exists\, i, j : d_{\min} = d_{ij}$, merge particles i and j into a single particle and combine their momenta.
- If $\exists\, i : d_{\min} = d_{iB}$, declare particle i to be a final jet and remove it from the list.

These steps are repeated until no particles are left.

$$p = \begin{cases} 1 & k_t \text{ (background estimation)} \\ 0 & \text{Cambridge/Aachen} \\ -1 & \text{anti-}k_t \text{ (signal jets)} \end{cases}$$





Reweighting of the reconstruction efficiency

- ϵ — reconstruction efficiency of inclusive particles
- ϵ_s — reconstruction efficiency of particles of interest (scaled ϵ)
- 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 $P_{\text{inclusive}}(p_{\text{T}}^{\text{V}^0}, \eta_{\text{V}^0})$ is the same as for V^0s of interest):

$$m(p_{\text{T}}^{\text{V}^0}, \eta_{\text{V}^0}) = m_{\text{raw}}(p_{\text{T}}^{\text{V}^0}, \eta_{\text{V}^0})|_{\text{peak region}} \cdot P_{\text{inclusive}}(p_{\text{T}}^{\text{V}^0}, \eta_{\text{V}^0})|_{\text{peak region}}$$

Efficiency calculation:

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

$$\frac{1}{\epsilon_s(p_{\text{T}}^{\text{V}^0})} = \frac{\sum_{\eta_{\text{V}^0 i}} g_s(\eta_{\text{V}^0 i}, p_{\text{T}}^{\text{V}^0})}{\sum_{\eta_{\text{V}^0 j}} a_s(\eta_{\text{V}^0 j}, p_{\text{T}}^{\text{V}^0})} = \sum_{\eta_{\text{V}^0 i}} \frac{a_s(\eta_{\text{V}^0 i}, p_{\text{T}}^{\text{V}^0})}{\sum_{\eta_{\text{V}^0 j}} a_s(\eta_{\text{V}^0 j}, p_{\text{T}}^{\text{V}^0})} \frac{1}{\epsilon(\eta_{\text{V}^0 i}, p_{\text{T}}^{\text{V}^0})}$$

Spectra correction:

$$t = m/\epsilon_s$$

Systematic uncertainties in p–Pb

source	uncertainty
selection cuts	2–5 % for K^0_S, 3–6 % for Λ
signal extraction	6 % (10 %) for $p_T^{jet,ch} > 10$ GeV/c (20 GeV/c)
V^0s in UE	10 % (2 %) at low (high) $p_T^{V^0}$
$p_T^{jet,ch}$ scale	1 % (10 %) at low (high) $p_T^{V^0}$
feed-down	5 %