Strangeness production in Xe-Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV with the ALICE experiment at the LHC

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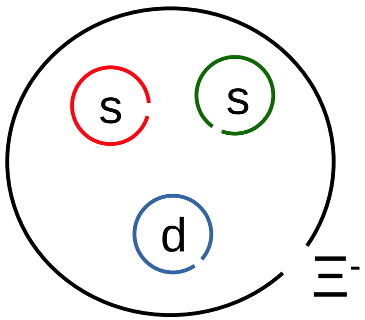
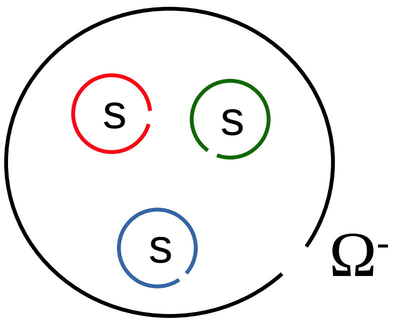
- Reaction threshold, equilibration time





Reaction Threshold

- Hadron gas – production of strangeness via interaction between abundant pions

  Strange particle and antiparticle produced jointly due to baryon and strange number conservation

  Threshold (two times the rest mass of the hadrons) 2642 MeV for the Ξ and 3344 MeV for the Ω

  Indirect production $\pi + N \rightarrow K + \Lambda$

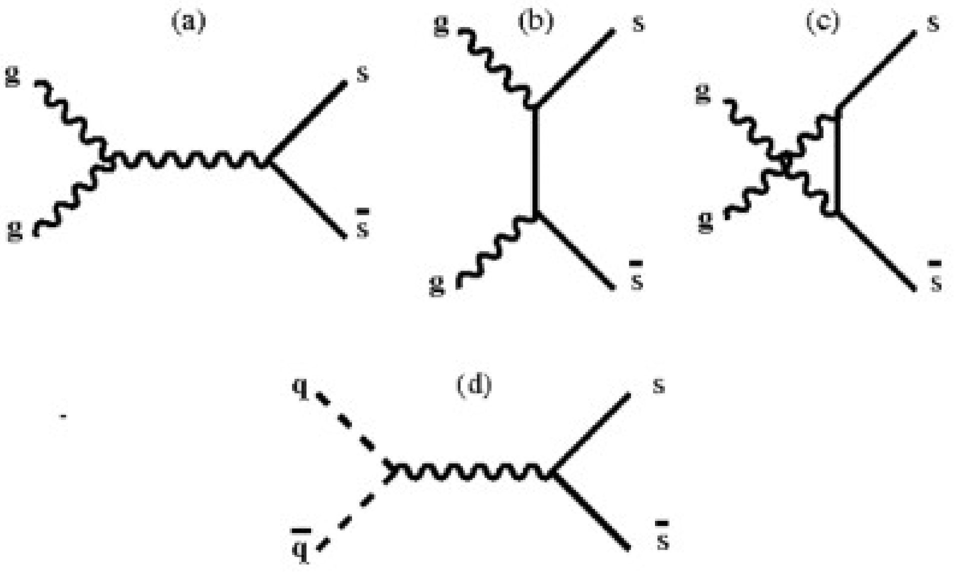
$$\pi + \Lambda \rightarrow K + \Xi \; (1100 \text{MeV})$$
$$\pi + \Xi \rightarrow K + \Omega \; (1810 \text{ MeV})$$

Reaction Threshold

- QGP – strangeness production via gluon fusion g g ➞ $s\bar{s}$ abreast quark pair annihilation

  gluon fussion – 80% of $s\bar{s}$ pairs

  reaction threshold – mass of the two strange quarks 200 MeV



Equilibration Time

- Equilibration times of partonic reactions due to gluon fussion processes are much shorter than the ones of hadronic reactions
- Low hadronic cross – sections if rare multi – strange baryons are considered

T_{QGP} = 10 fm/c – the order of the expected duration of a heavy ion reaction

– hadronization time negligible – hadrons have similar production times

T_{HG} = 100 fm/c – strongly dependent on strange particle specie

Strangeness Enhancement

- QGP production probability depends on the density of the strange quarks to the power of the number of strange quarks contained in the considered hadron

Ω / Ξ (QGP) $\approx$ Ξ / Λ (QGP)

Ω / Ξ (HG) $<$ Ξ / Λ (HG)

Ω / Ξ (QGP) $>$ Ω / Ξ (HG)

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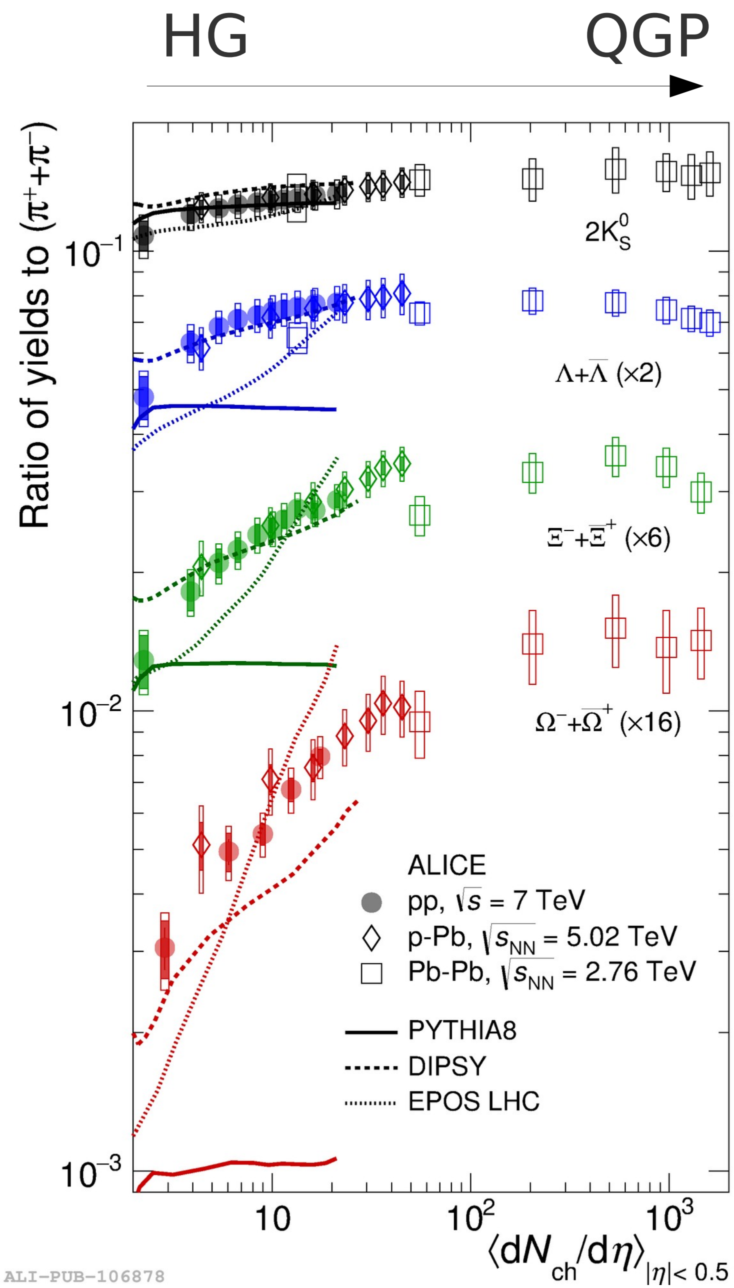
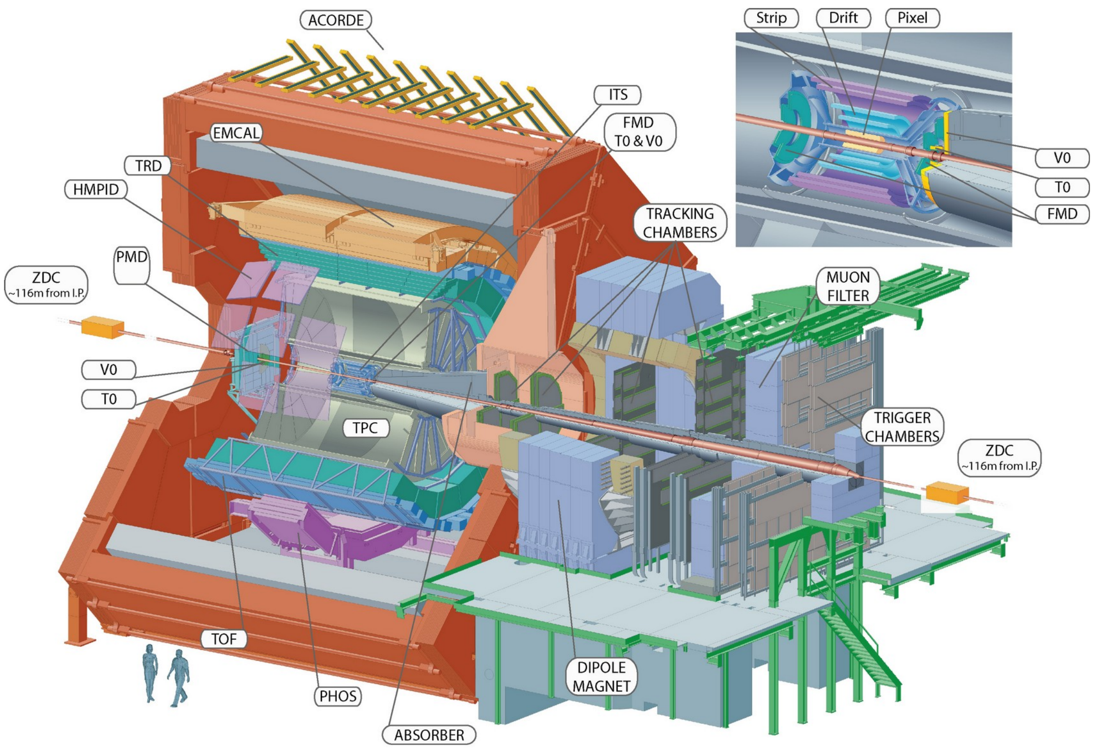
Strangeness enhancement – overabundance of strangeness production in a QGP with respect to a HG scenario

Strangeness Enhancement



- The ratio between (multi-)strange hadron yields and pion yields is enhanced in heavy-ion collisions
- Smooth evolution with the multiplicity of charged particles across different collision systems (pp, p-Pb, Pb-Pb)
- No dependence on the collision energy at the LHC
- The enhancement is larger for particles with larger strangeness content

A Large Ion Collider Experiment (ALICE)



- Tracking, vertexing and PID

  Inner Tracking System (ITS)

  - 6 cylindrical layers of Si detectors at radii between 4 – 43 cm

  Time Projection Chamber (TPC)

  - 5m drift chamber at radii between 85 - 250 cm

  - $Ne/CO_2/N_2$

  - 18 sectors in which MWPC are housed

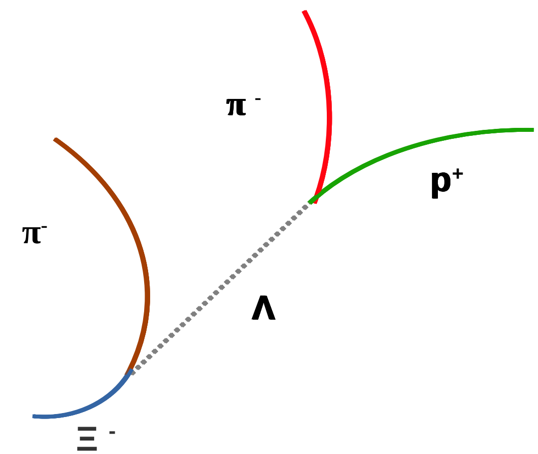
  - dE/dx measurements

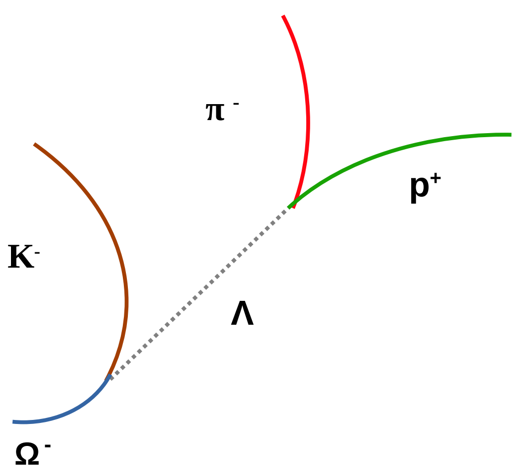
- Multiplicity estimation and triggering

  V0 detectors – two segmented arrays of plastic scintilator counters V0 – A and V0 – B

  - minimum bias trigger

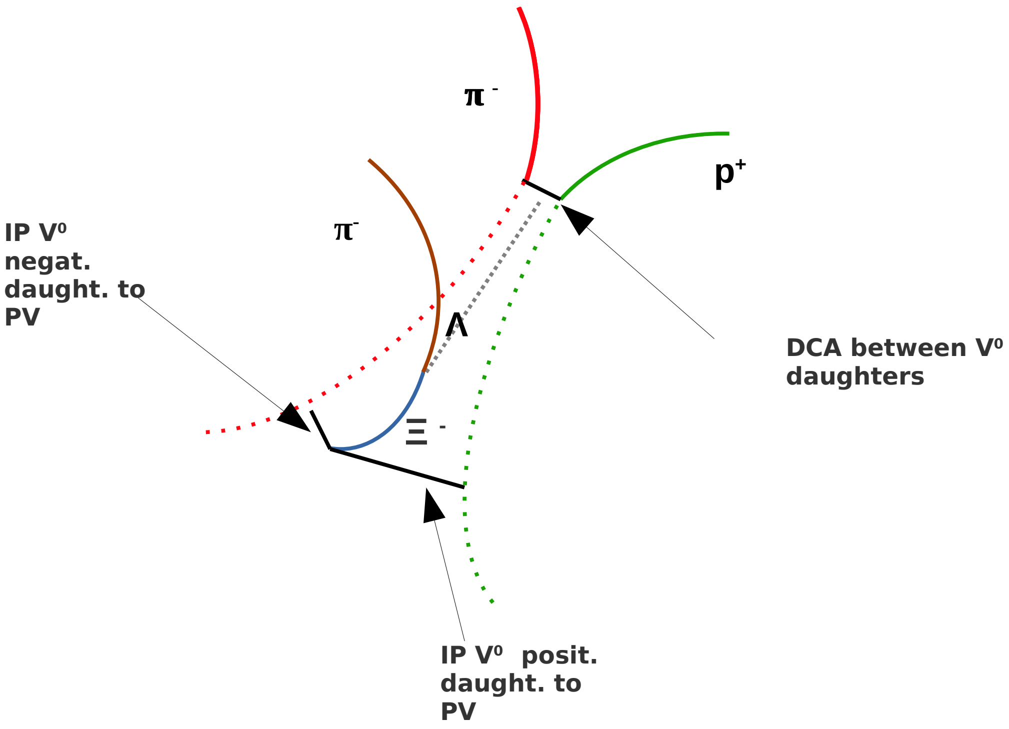
Cascade Identification





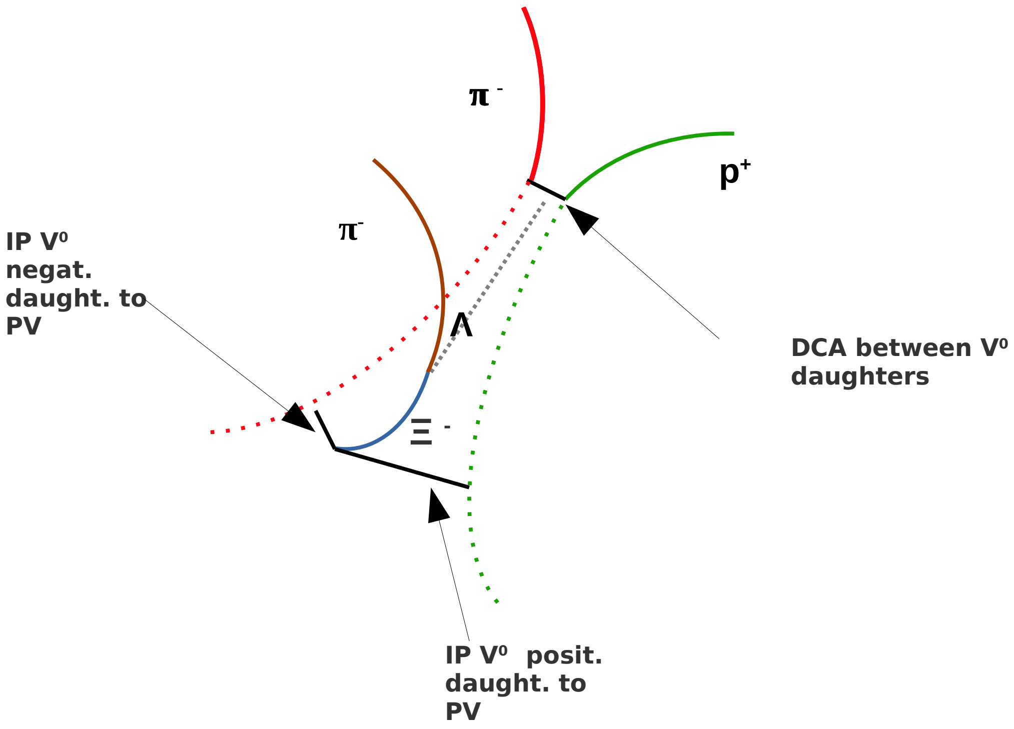
- Cascades Ξ and Ω
- Impossible to detect directly ➞ decay products detection
- Weak decay topology
- Reconstruction under assumption every charged particle can be identified

Topological Reconstruction



- Particle association is subject of fulfilling a set of geometrical and kinematic conditions

Topological Reconstruction



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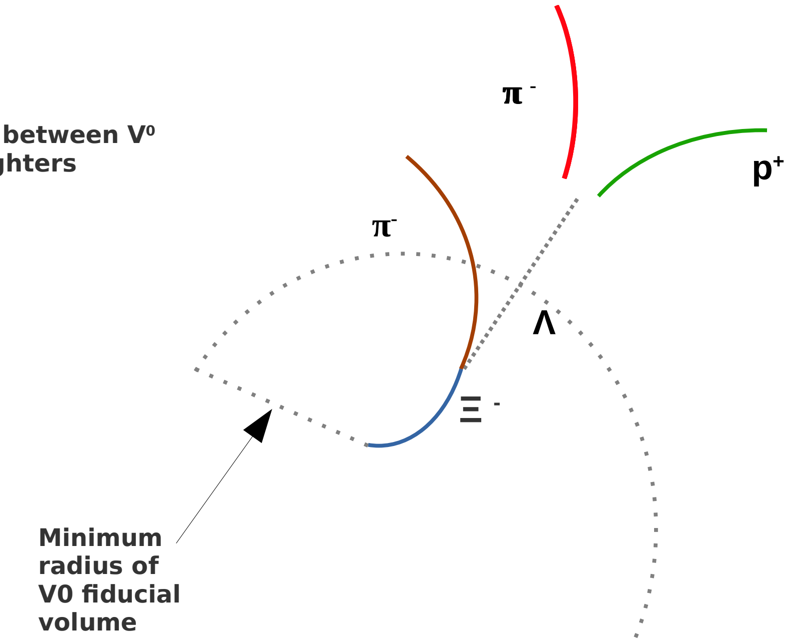

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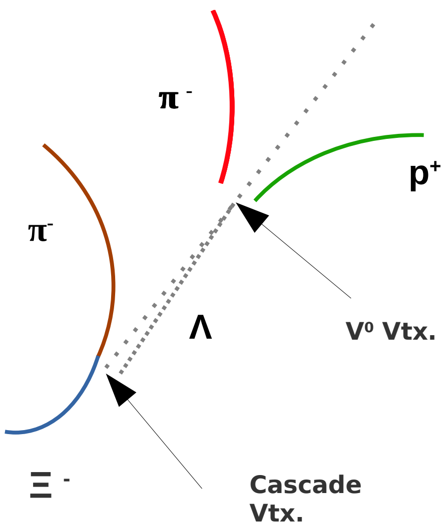

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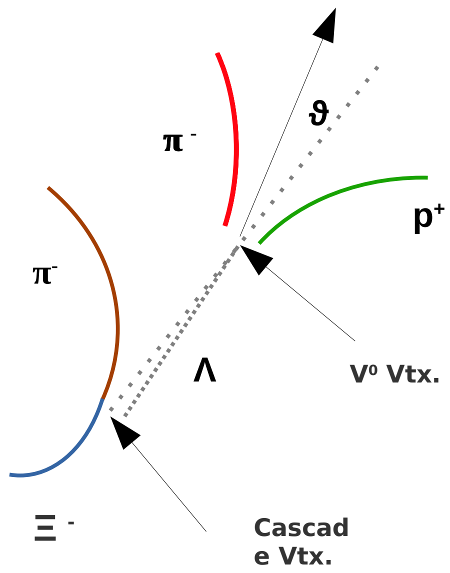

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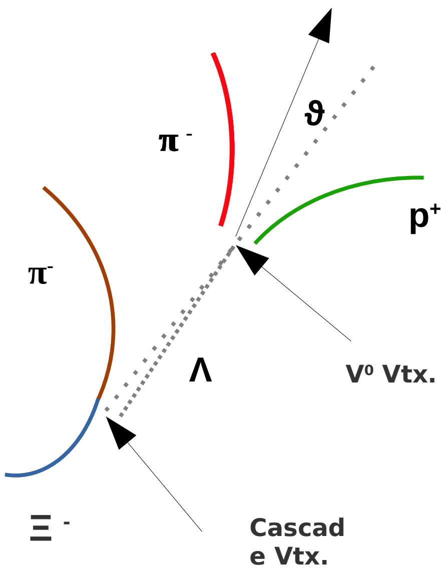

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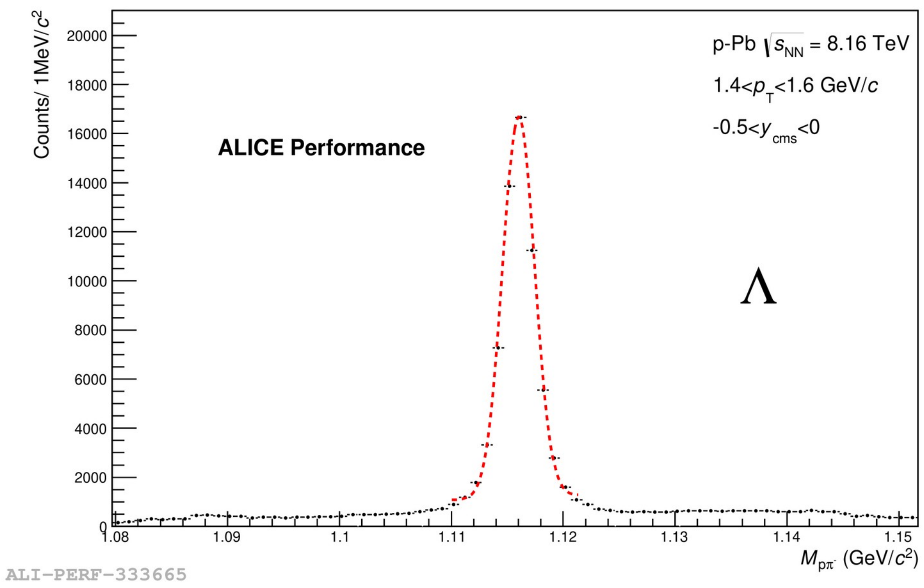


Signal extraction

- Data from Xe – Xe run
- Minimum bias trigger selection, centrality – V0 detector
- Location of PV $|z| < 10cm$
- p_T binning:

  Ξ : 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.4, 4.0, 5.0 GeV/c

  Ω : 1.0, 1.4, 1.8, 2.2, 2.6, 3.0, 3.6, 4.2, 5.0 GeV/c

- Centrality bins:

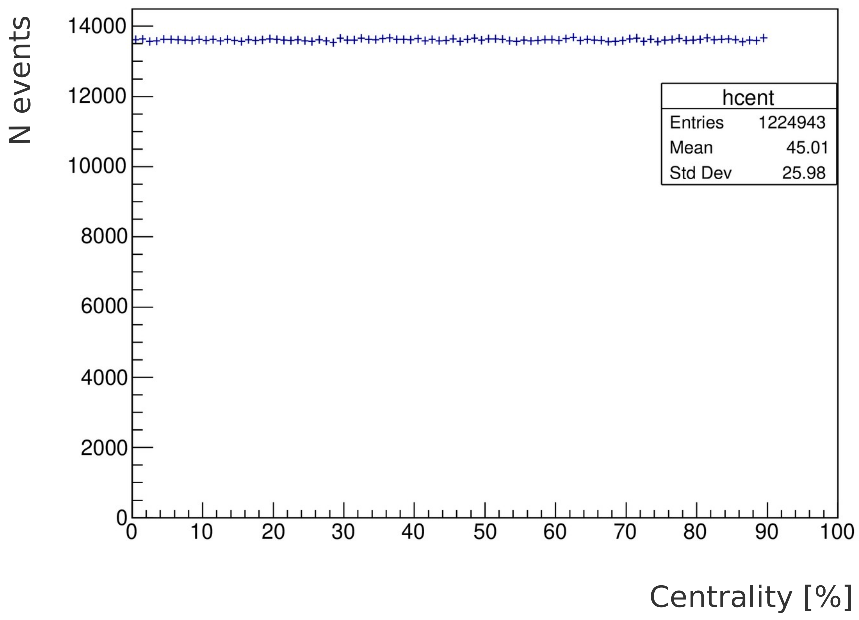
  Ξ : [0,10], [10,30], [30,60], [60,90]

  Ω : [0,90]

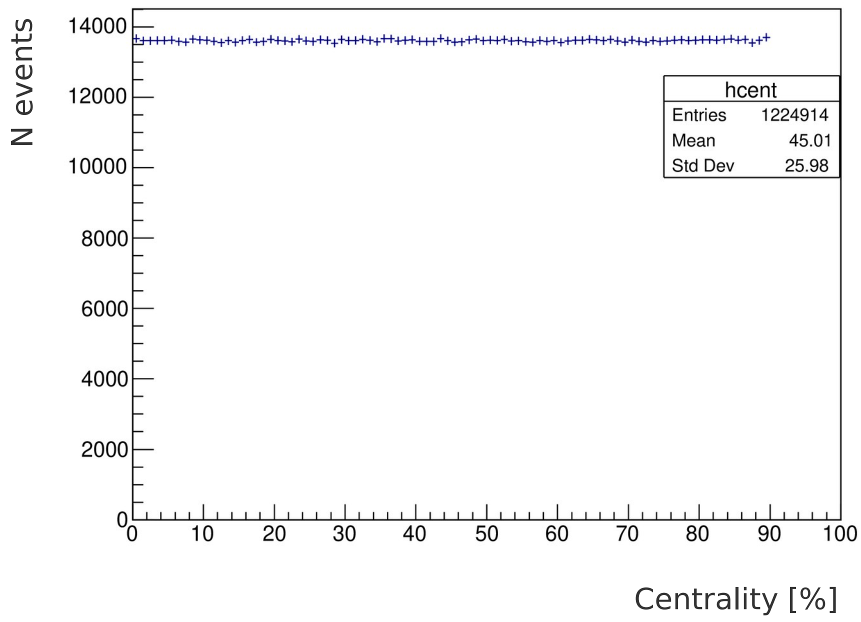
DCA (casc. daught.)	$< 1\sigma$
Cascade cos(PA)	> 0.98
Cascade radius	> 1cm
V0 inv. mass window	$\pm$ 0.005GeV/c ^{2}
DCA (V0 daught)	$< 1\sigma$
V0 cos(PA)	> 0.98
DCA (V0 - PV)	> 0.1cm
DCA (bach - PV)	> 0.1cm
Rapidity	$|y| < 0.5$
Prop. lifetime	$< 3\ c\tau$
$N_{TPCclusters}$	≥ 70
$N_{crossedrows}$	≥ 70
$N_{crossed/findable}$	≥ 0.8
TPC dE/dx selection	$< 4\sigma$

Data Samples

Ξ



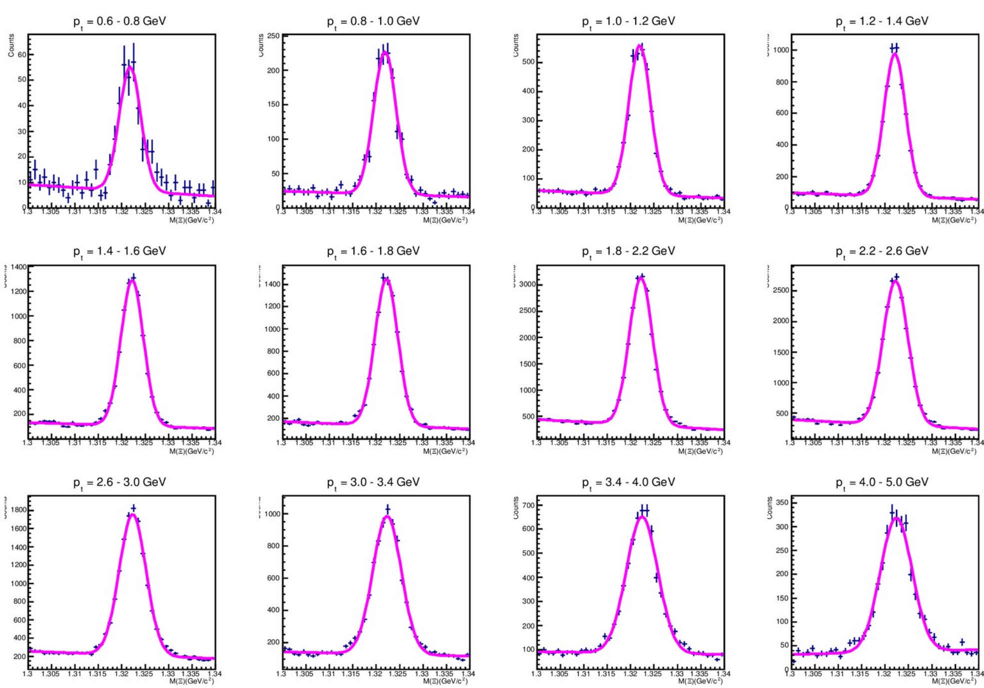
Ω



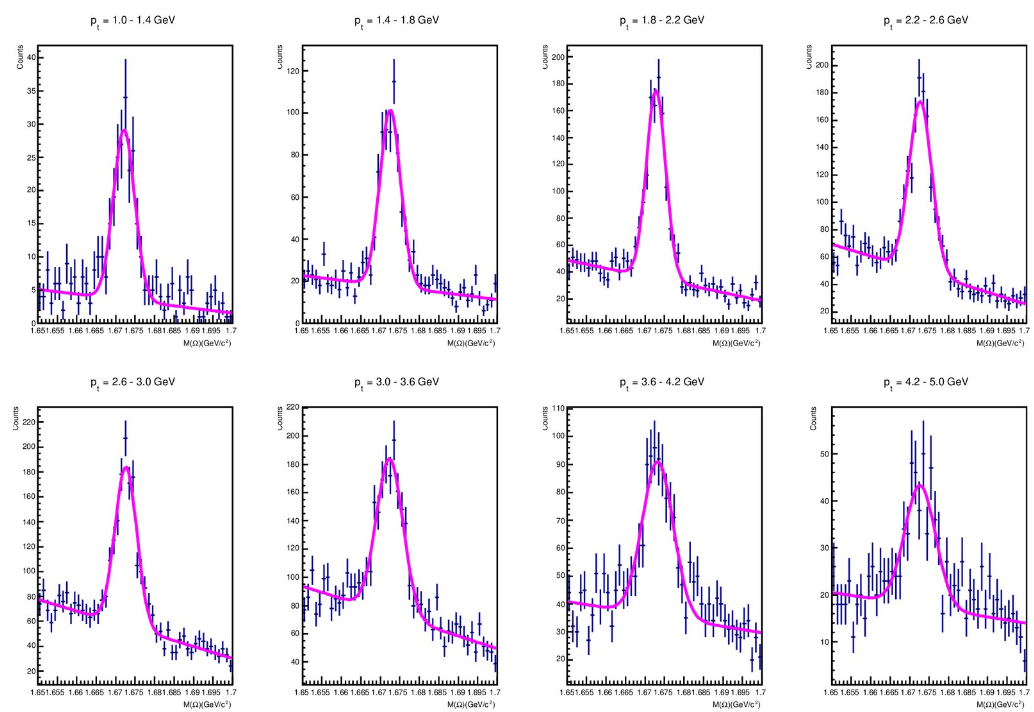
Invariant Mass Distributions

- 0 – 90% centrality interval
- Signal $\Xi^{-} + \Xi^{+}$ and $\Omega^{-} + \Omega^{+}$ candidates
- Gaussian peak and 2. order polynomial
- Yield extraction in $\mu \pm 4\sigma$

Ξ



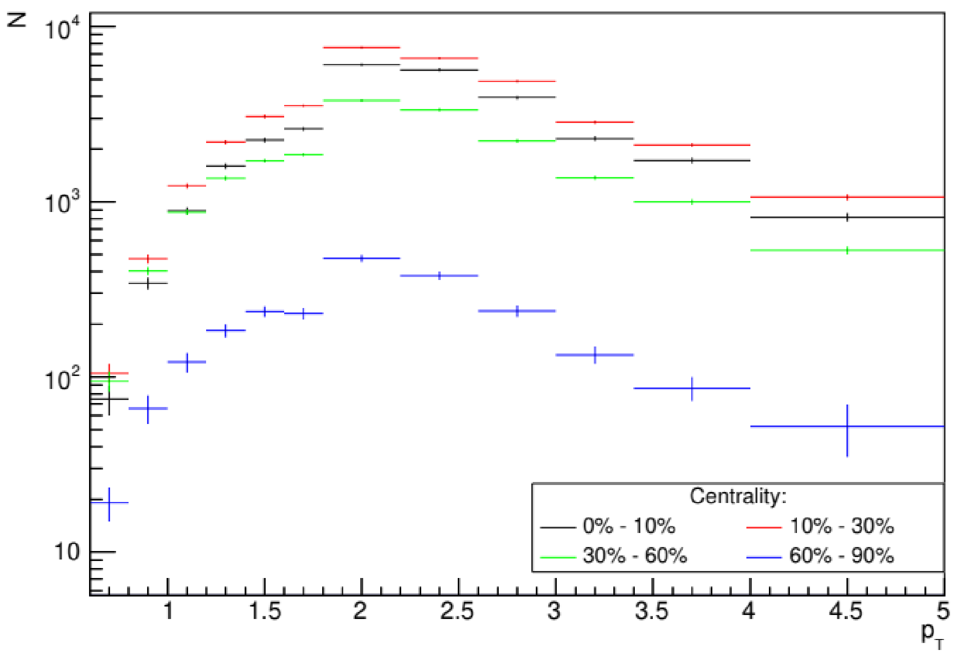
Ω



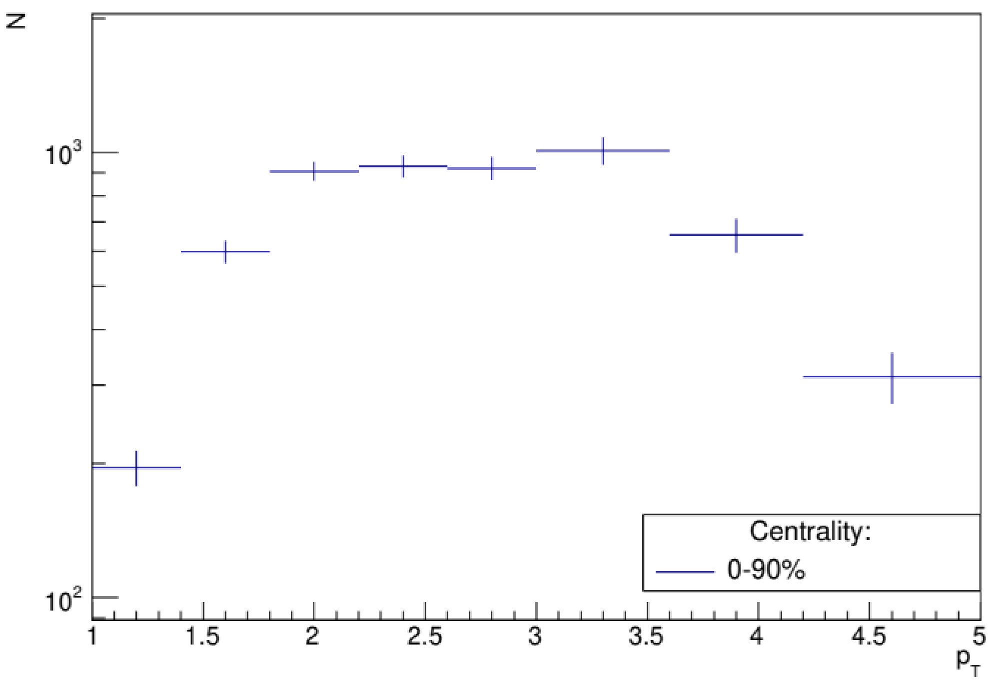
Raw Yields

- Raw yield obtained by bin counting in this window followed by background subtraction (from fit) in the same peak window
- Statistical uncertainty

Ξ



Ω



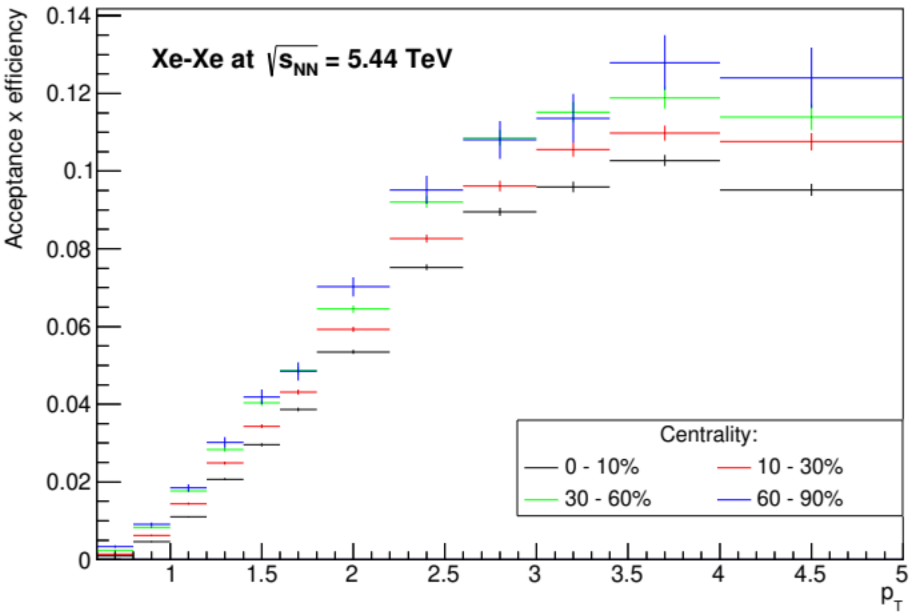
Correction factor

- Acceptance, efficiency
- MC with the same selection criteria
- $N_{recon+asoc}$ given by bin count in μ±4σ

- Weighted average for sum
- Uncertainties: binomial distribution

$$\epsilon = \frac{N_{recon+asoc}}{N_{generated}} \qquad \delta_\epsilon = \sqrt{\frac{\epsilon(1-\epsilon)}{N_{generated}}}$$

Ξ



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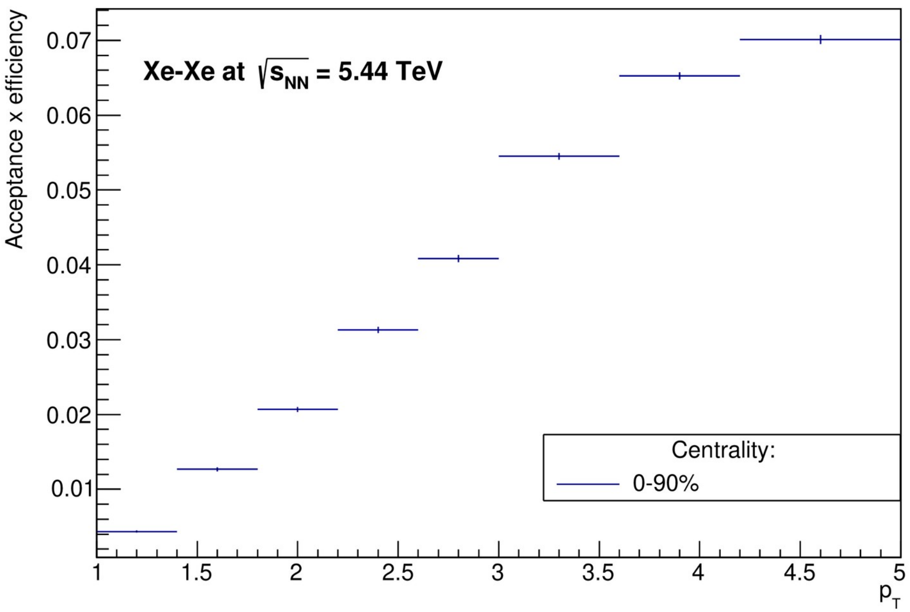
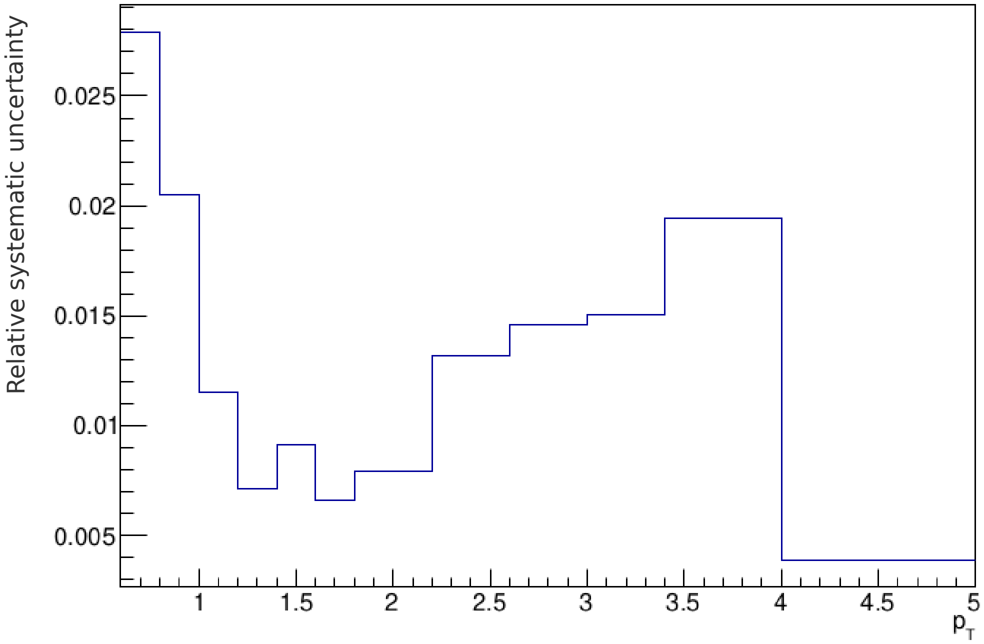


Systematic Uncertainties

- The choice of topological selection criteria
- 2% raw yield variation
- Integrated centrality
- Roger – Barlow 1σ cut

Ξ



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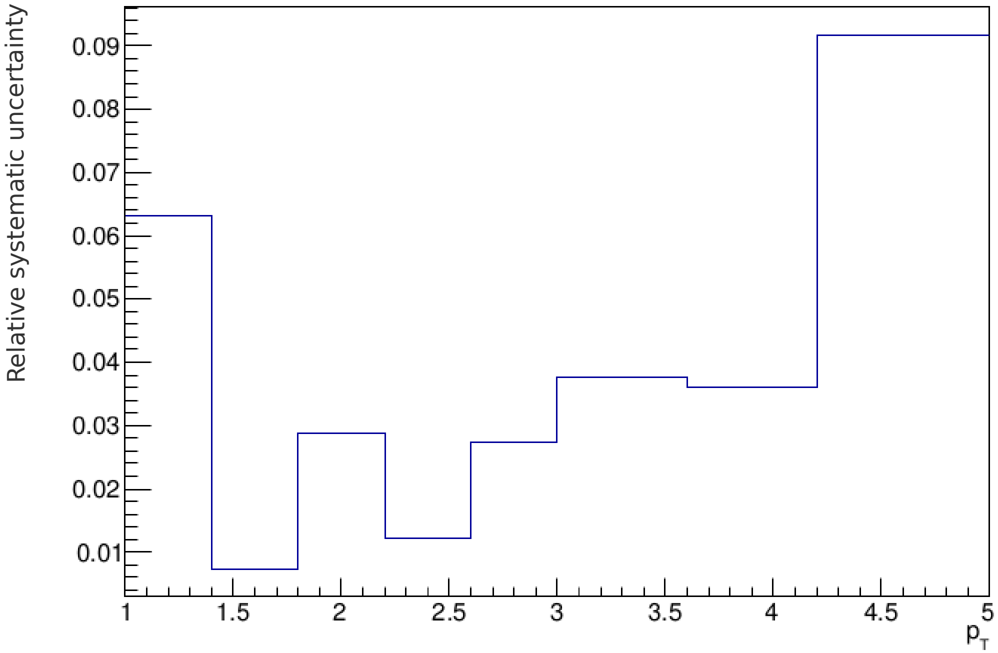
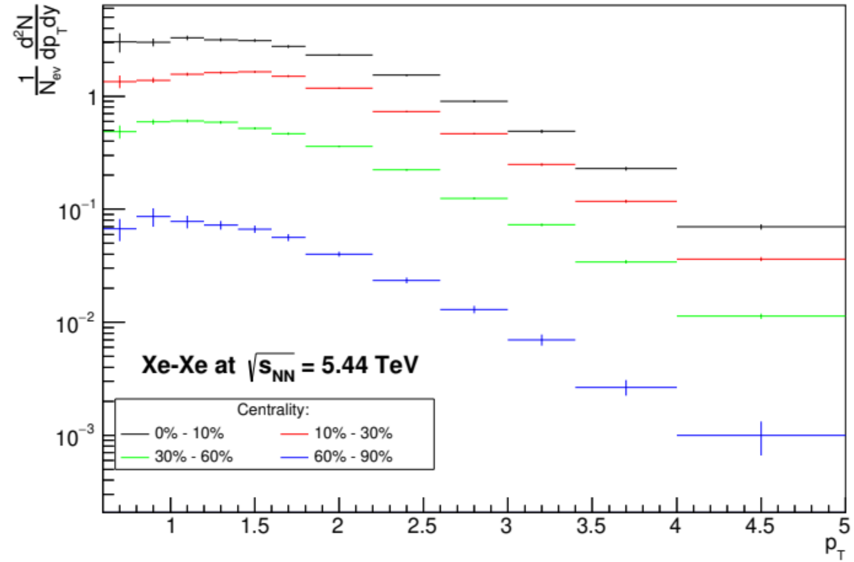


Corrected Yields

- Corrected p_T spectra for acceptance and efficiency factor normalized to the number of events
- Statistical uncertainties
- Progressively decreasing character with decreasing centrality of the collision
- Typical collective behavior at high multiplicity
- Successfully described by models based on relativistic hydrodynamics
- Blast – wave model describing the production of particles from the QGP thermal source with temperature T

Ξ



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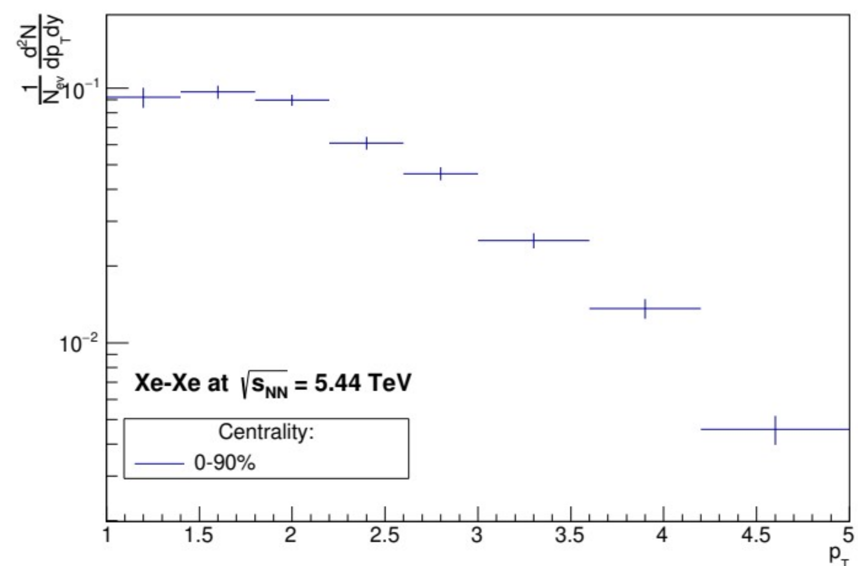
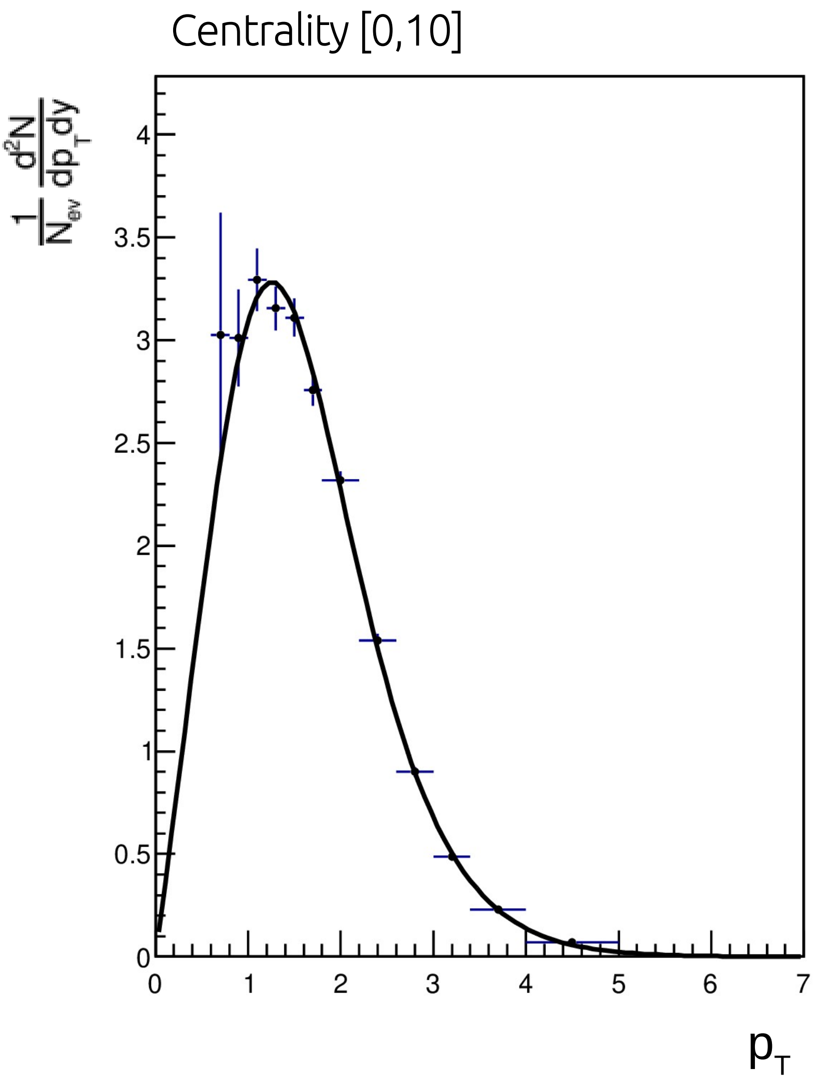
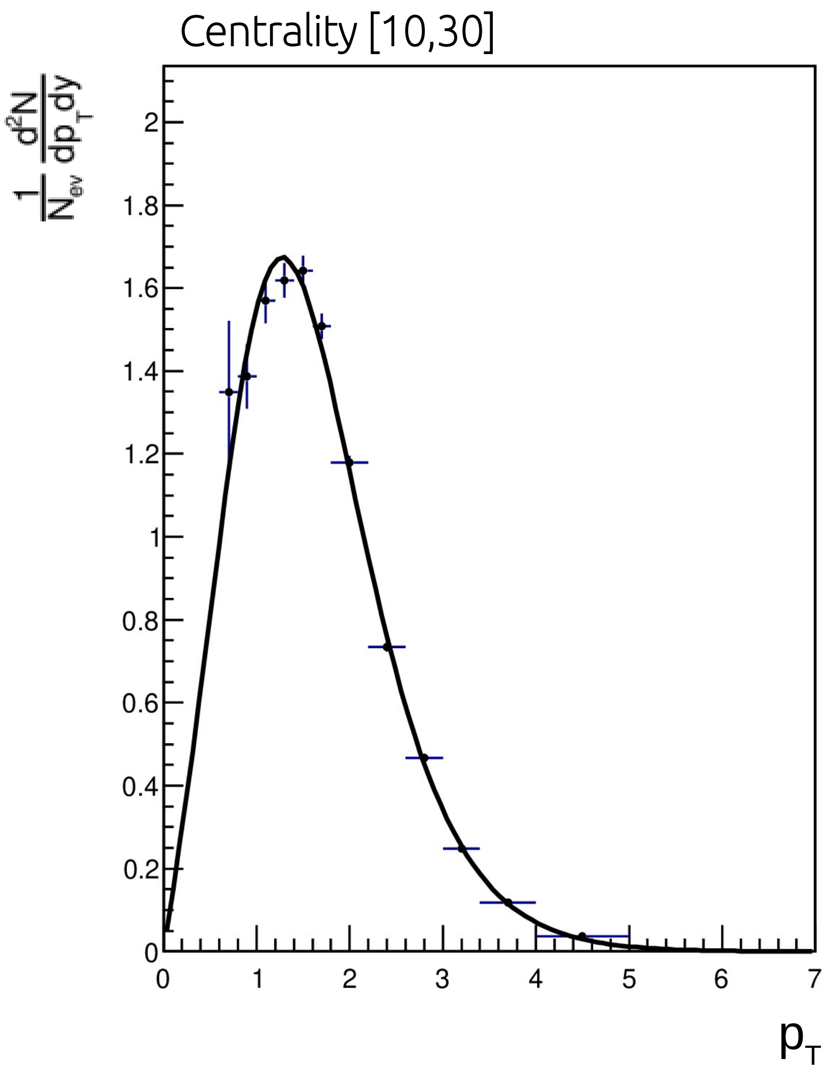


Blast – Wave Fits Ξ





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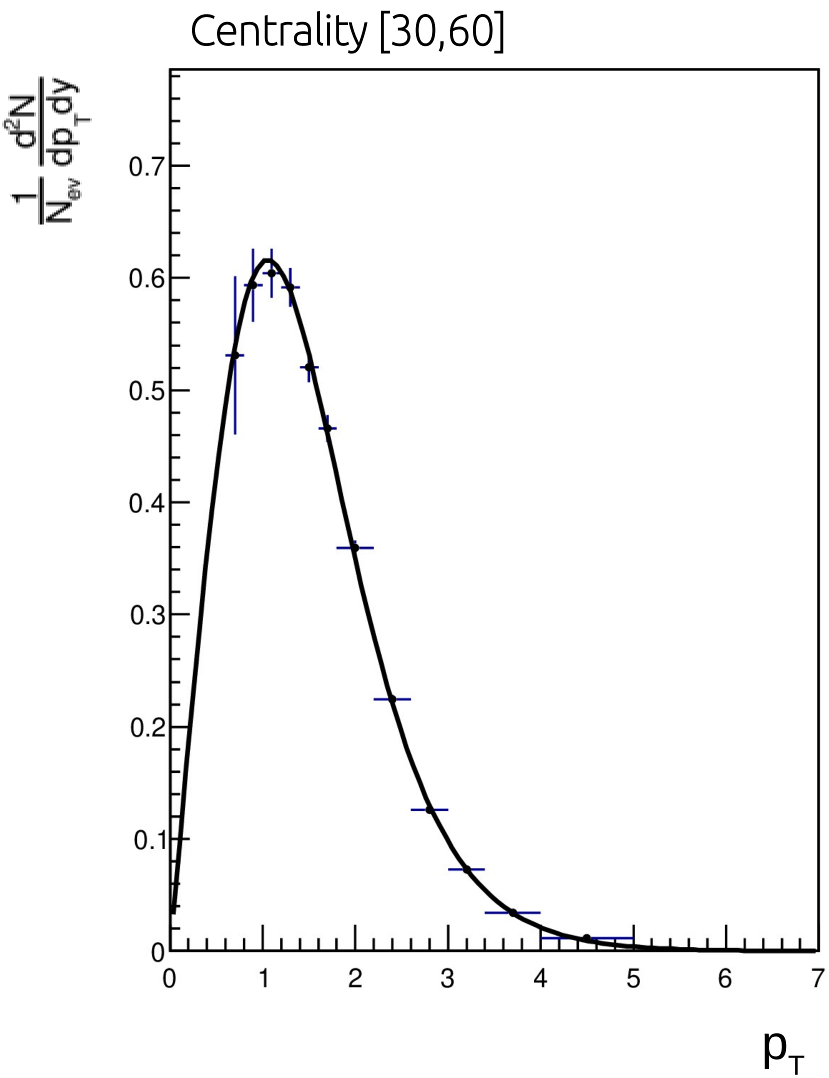
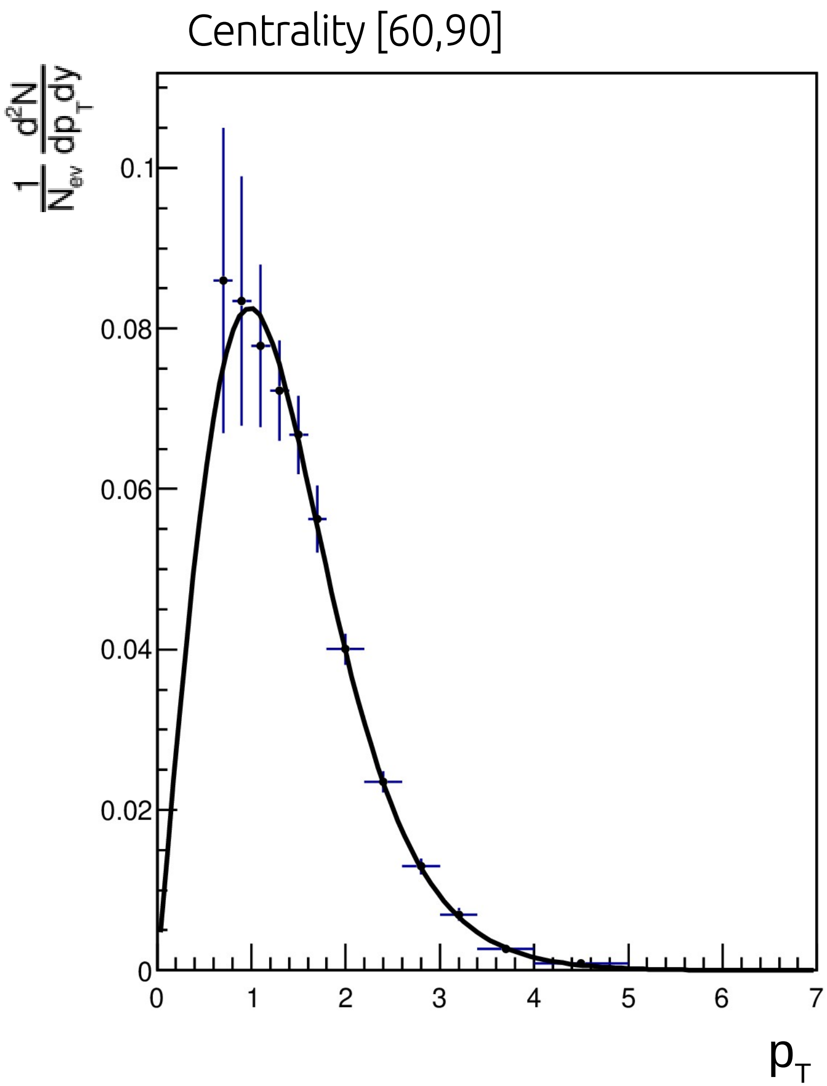
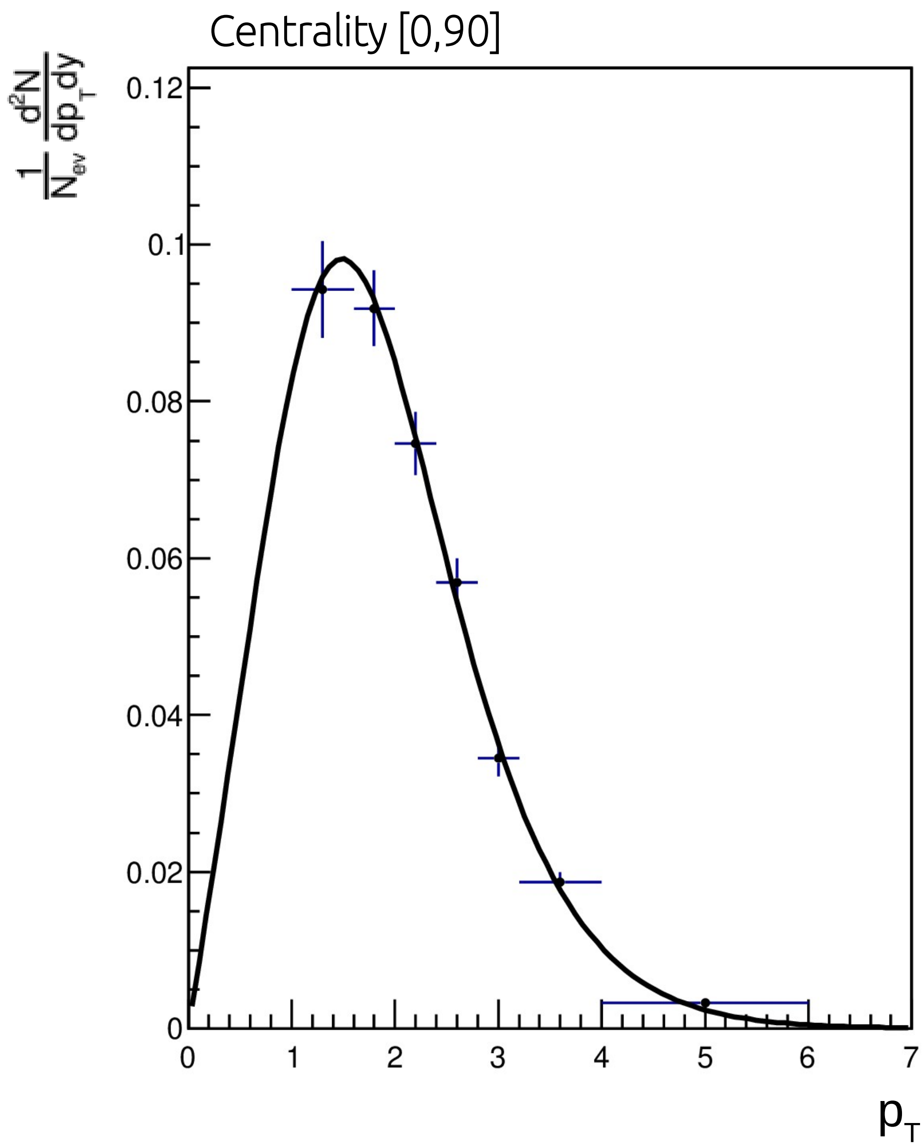




Blast – Wave Fit Ω



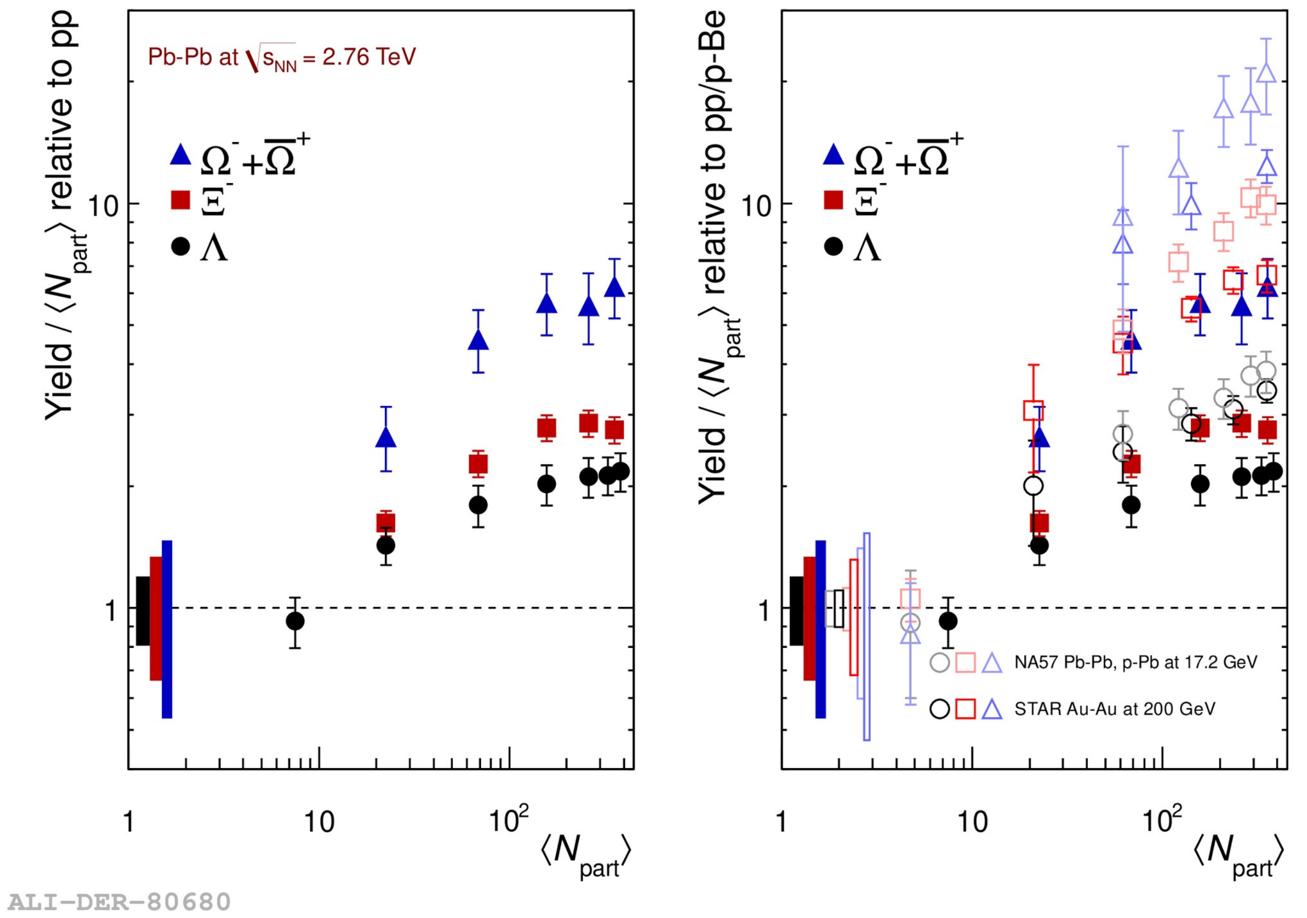
Conclusion

- The measurement , reconstruction and identification of multi–strange baryon production in Xe – Xe collisions at 5.44 TeV
- Transverse momentum spectra obtained at mid-rapidity for Ξ and Ω particles have been measured in four centrality intervals for Ξ particle and in one interval for Ω
- The spectra were compared and fit with function based on relativistic hydrodynamic models and were found to be in a good agreement
- The corrected spectra will be further processed in order to get integrated yield and average p_T for strangeness enhancement observation

THANK YOU FOR YOUR ATTENTION

Strangeness enhancement

$$E(h)=\frac{dN/dy(h)^{AA} < N_{part} >^{pp} N_{evt}^{pp}}{N_{evt}^{AA} < N_{part} >^{AA} dN/dy(h)^{pp}}$$



Chyby určenia účinnosti rekonštrukcie (cez binomické rozdelenie)

- $N_{recon+asoc}$ úspechov (všetky zrekonštruované kaskády tým istým algoritmom ako dáta s podmienkou, že kandidát korešponduje skutočnému rozpadu kaskády v MC zázname) z $N_{generated}$ pokusov (všetky generované kaskády bez ohľadu na to akým rozpadovým kanálom sa rozpadli – vetviaci pomer je v účinnosti automaticky zahrnutý)
- Pravdepodobnosť úspechu je funkciou účinnosti

$$P=\frac{N_{generated}!}{N_{recon+asoc}!(N_{generated}-N_{recon+asoc})!}\epsilon^{N_{recon+asoc}}(1-\epsilon)^{N_{generated}-N_{recon+asoc}}$$

- Potom pre odhad

$$\epsilon=\frac{N_{recon+asoc}}{N_{generated}}$$

- A neistotu $$\delta_{\epsilon}=\sqrt{\frac{\epsilon(1-\epsilon)}{N_{generated}}}$$

- Calculating Efficiency Uncertainties, Louise Heelan, August 14 2009, (Carleton ATLAS Group Meeting)

Roger Barlow Test

- To disentangle systematic from statistical uncertainties ➞ systematic is estimated after taking into account the statistical fluctuations
- Identification of cut value for which raw yield varies more than 2%
- Barlow σ $\sqrt{|\sigma_m^2 - \sigma_v^2|} / y_m$
- Relative systematic uncertainty $|y_m - y_v| / y_m$
- Test: if Barlow σ < Relative systematic uncertainty ➞ keep it
  if Barlow σ > Relative systematic uncertainty ➞ rejection

Blast - Wave Model

- Model describing the production of particles from the QGP - radiation from a thermal source with temperature T, boost-invariant longitudinal expansion (p_T spectra to first order does not depend on rapidity), transverse flow
- r is the radial distance in the transverse plane from the center of the fireball, R is the fireballs radius, I_0 is the modified Bessel function and T_{kin} is the temperature of the kinetic freeze out

$$\frac{1}{p_T}\frac{dN}{dp_T} \propto \int_0^R r dr m_T I_0\left(\frac{p_T \sinh\rho}{T_{kin}}\right) K_1\left(\frac{m_T \cosh\rho}{T_{kin}}\right)$$

- ρ is the velocity profile given by $\rho = \tanh^{-1}\beta_T = \tanh^{-1}\left(\left(\frac{r}{R}\right)^n \beta_s\right)$
- where β_T is the transverse expansion velocity, n is the velocity profile's exponent and β_s is the transverse expansion velocity at the surface