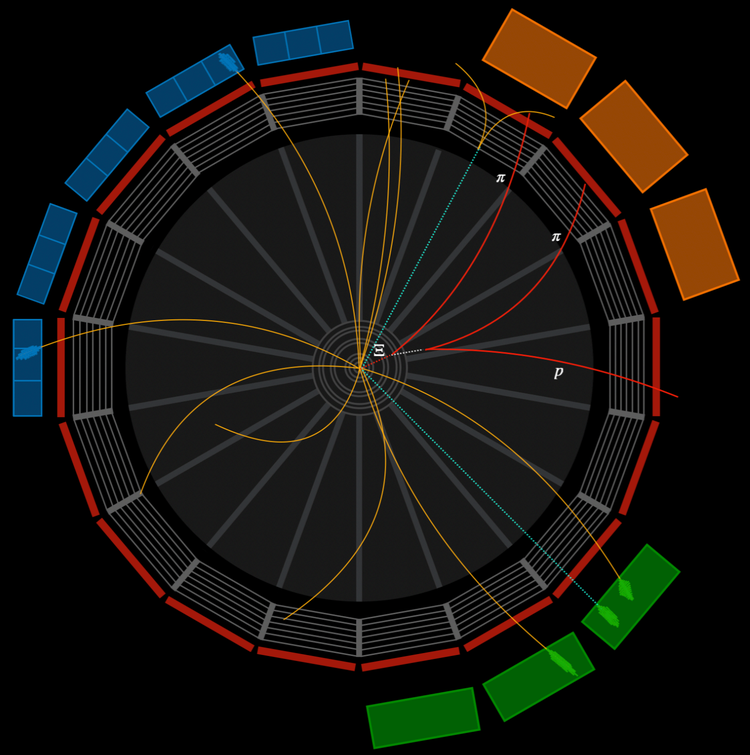
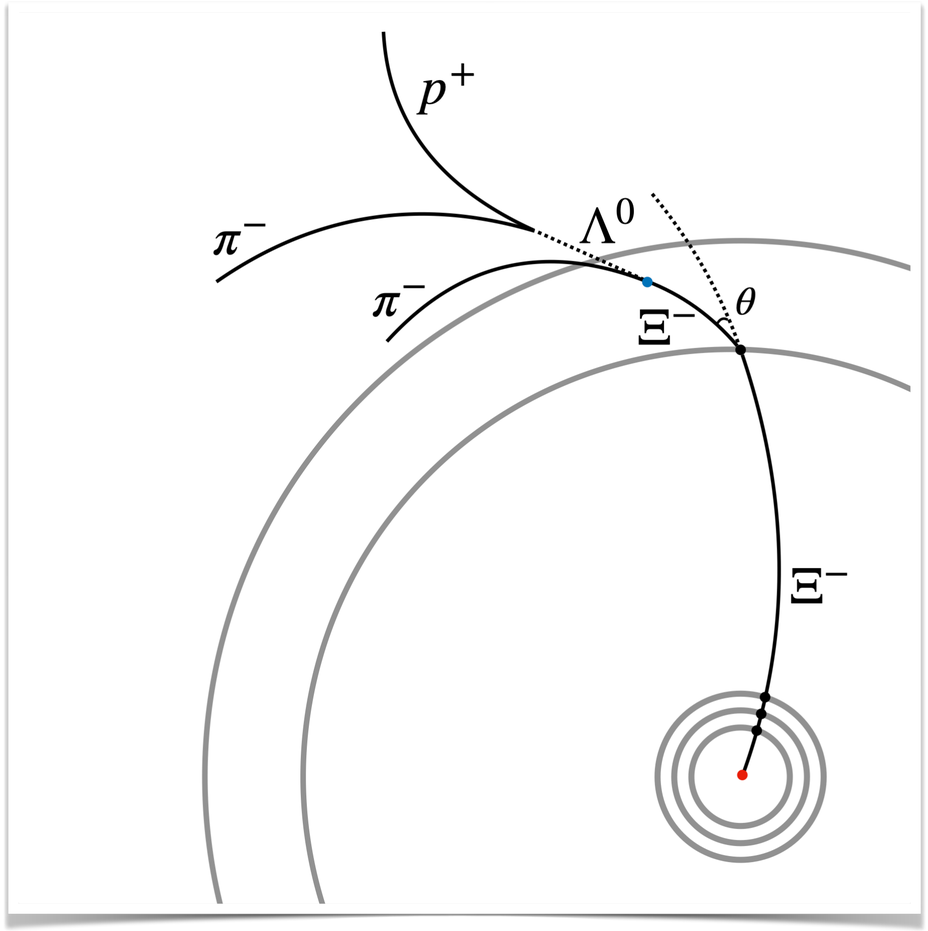
Study of the ITS cluster size of tracked cascades



ALICE-EPIC Meeting
30 April 2025

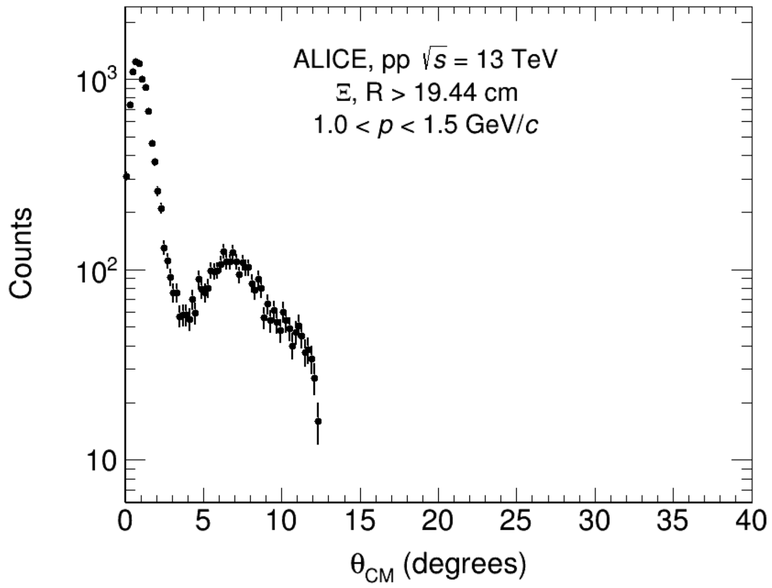
Alberto Calivà, Francesca Ercolessi

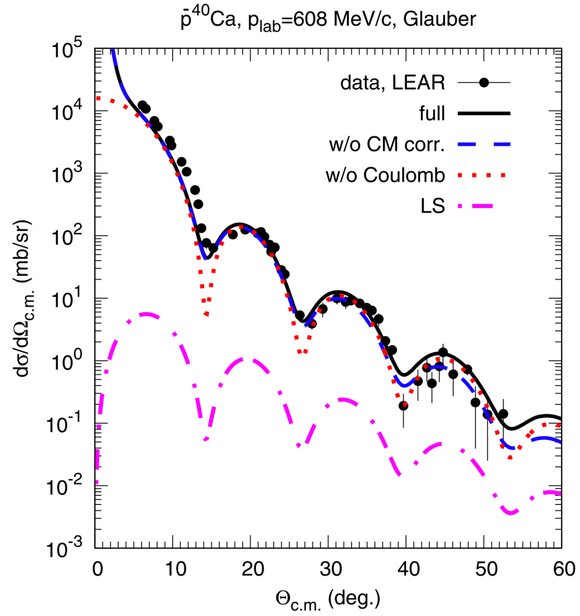
Introduction and Physics Motivation



Measurement of $\Xi^{\pm}$ – nucleus (Si) elastic scattering

- Matching of ITS "mini-track" produced by $\Xi^{\pm}$ before scattering (and decay) with fully-reconstructed cascade
- Promising measurement

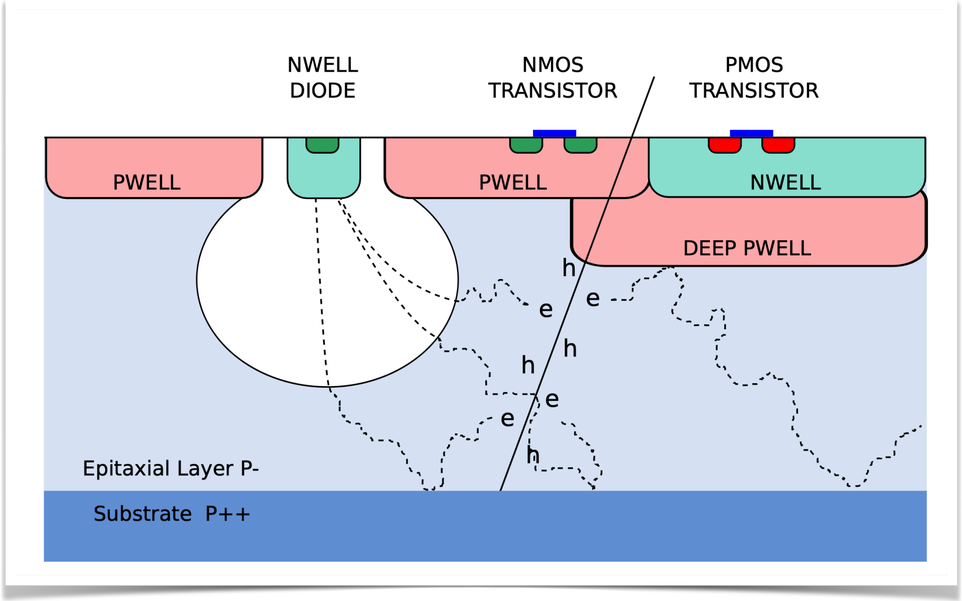




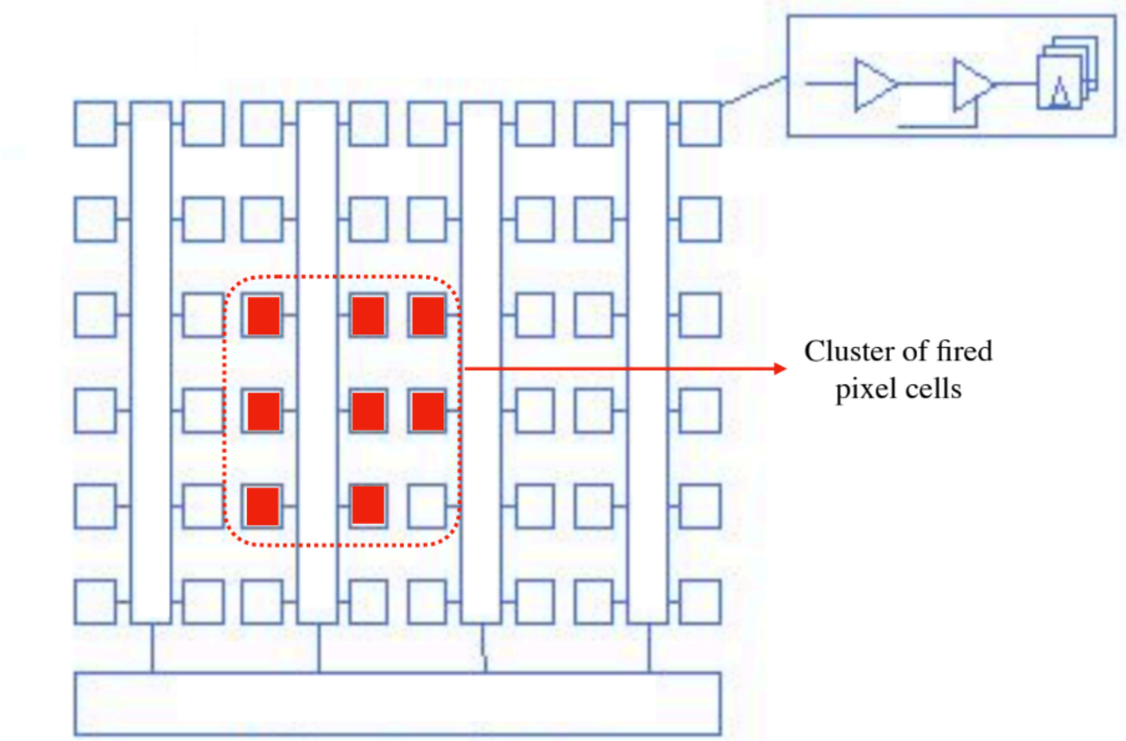
ITS cluster size could be used for track-by-track identification of $\Xi^{\pm}$ candidates

ITS Cluster Size

J. Phys. G: Nucl. Part. Phys. 41 (2014) 087002

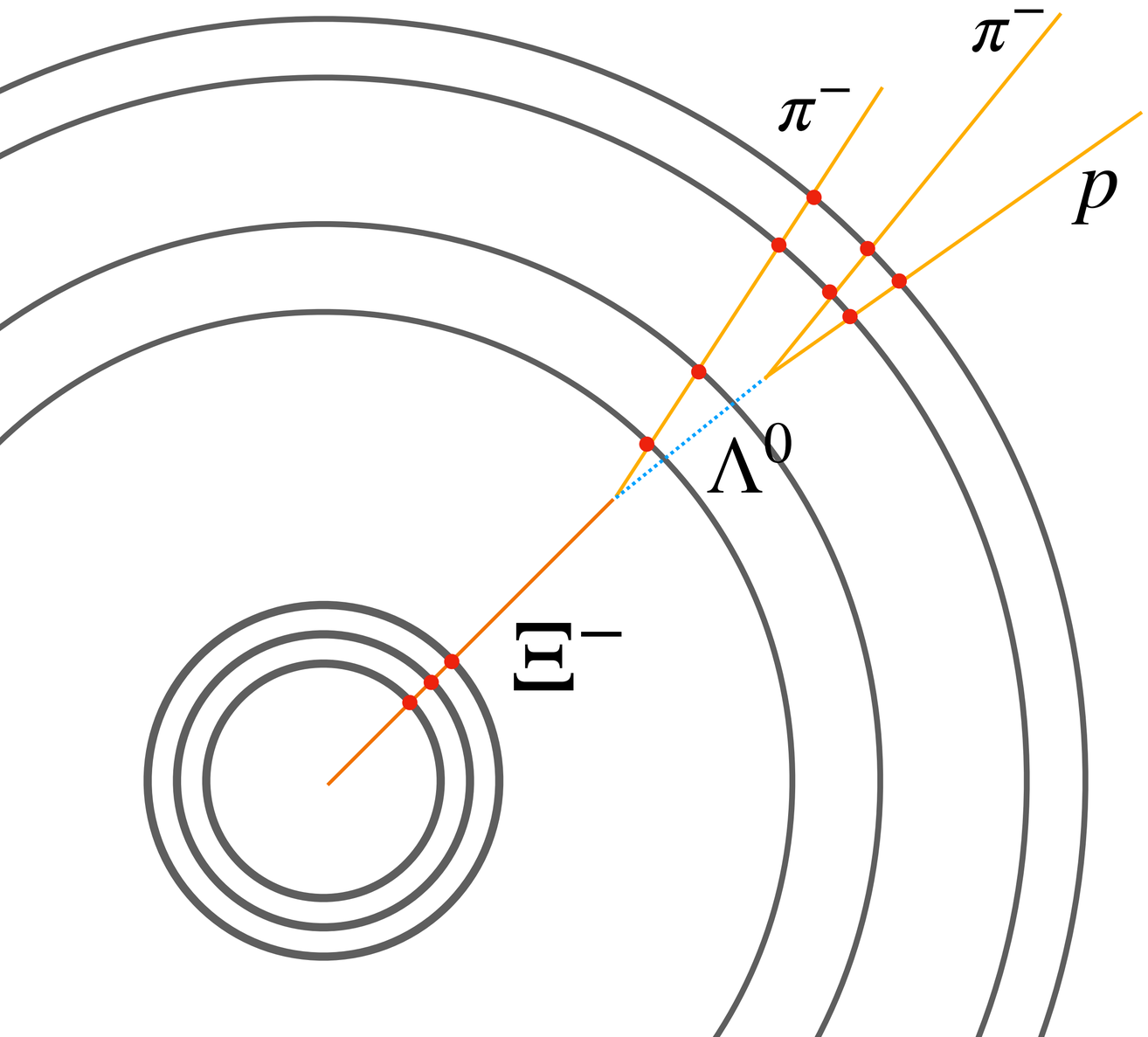


Schematic cross section of a MAPS pixel



- Charged particles crossing the silicon sensor create electron-hole pairs (~60 e^-/μm for MIPs)
- Electrons in the depletion region drift toward the NWELL diode, generating a signal
- Some carriers diffuse to neighboring diodes, forming a **cluster**
- Cluster size is proportional to ionization (similar to dE/dx behavior)

The Strangeness Tracker



Cascade reconstructed from its weak decay daughters

Strangeness tracker associates hits in inner ITS layers compatible with the cascade trajectory

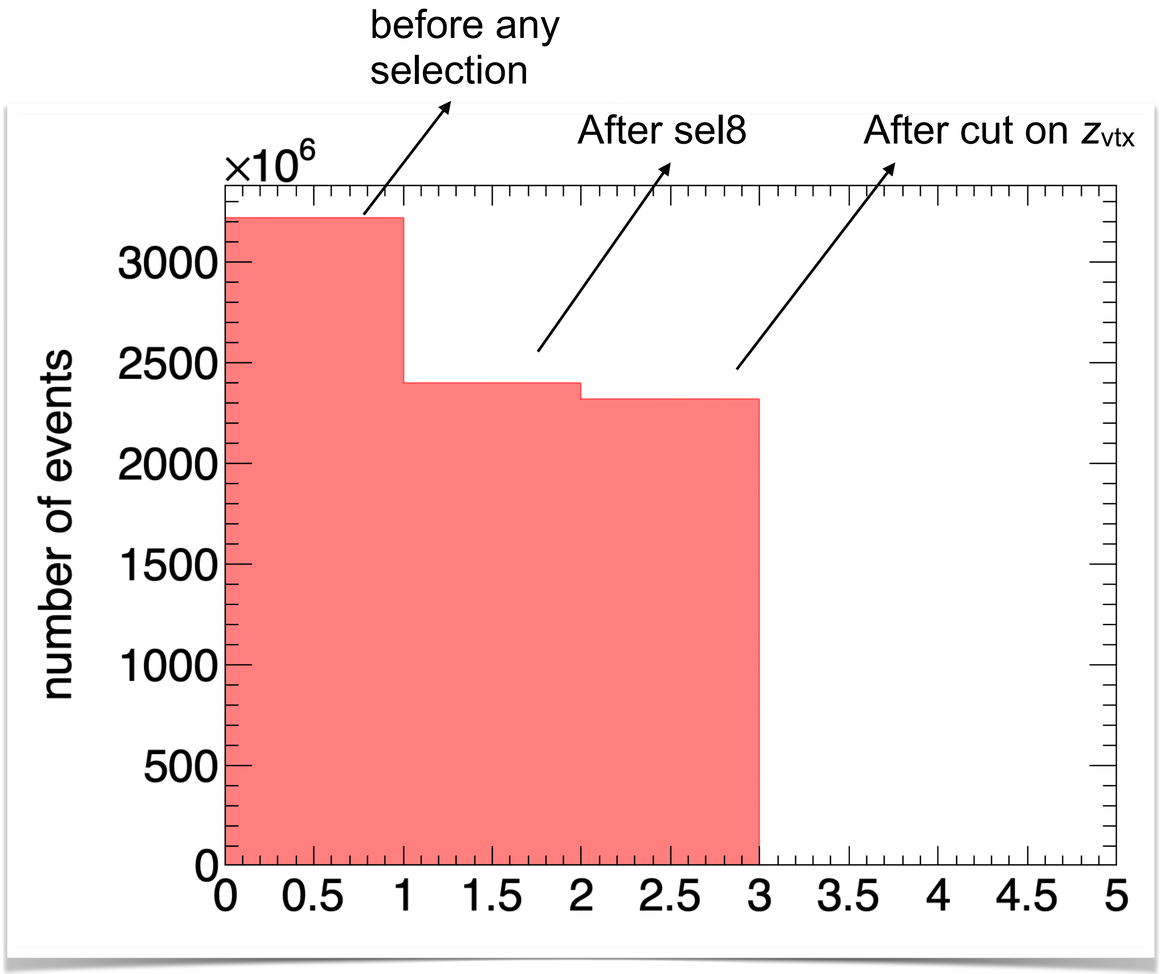
Data Set and Event Selection

Dataset: LHC22o_pass7_minBias_small

Event selection

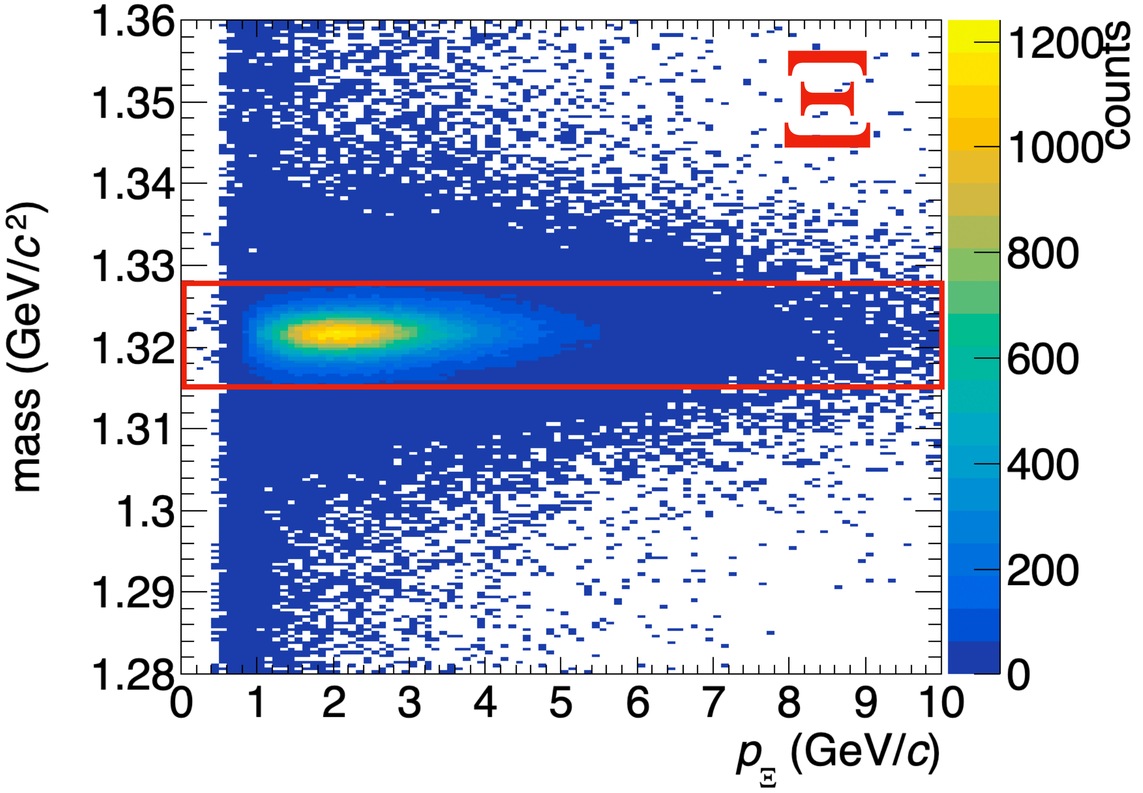
- Sel8
- $|z_{vtx}| < 10$ cm

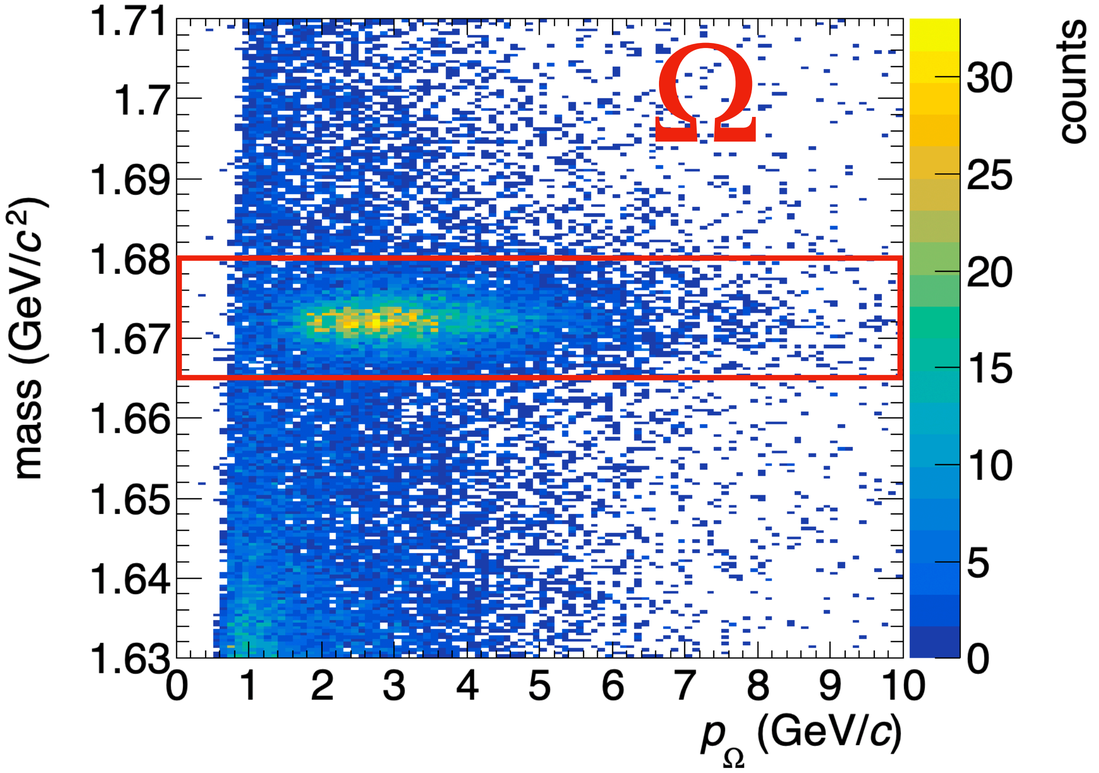
Number of selected events = 2.32×10^9



Analysis task: https://github.com/AliceO2Group/O2Physics/blob/master/PWGLF/Tasks/QC/trackedCascadeProperties.cxx

Candidate Selection

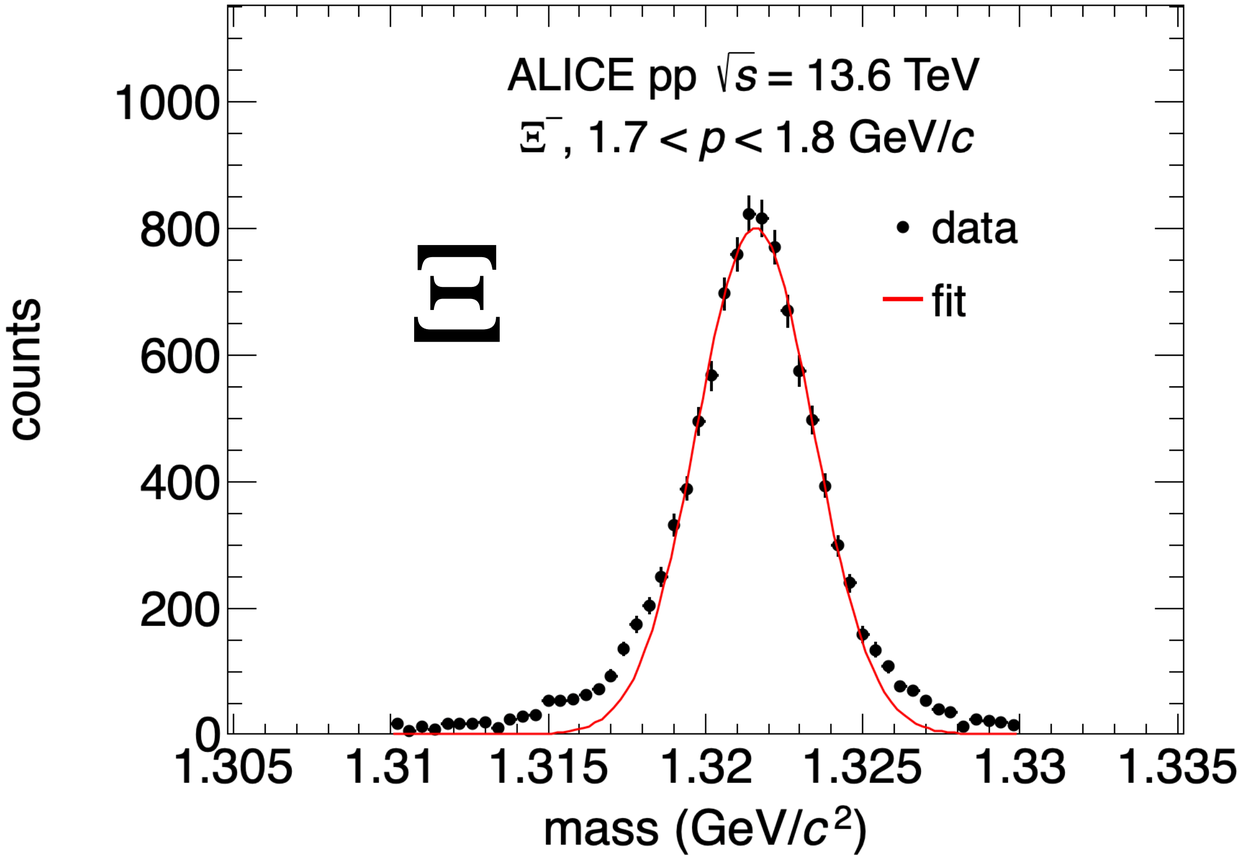


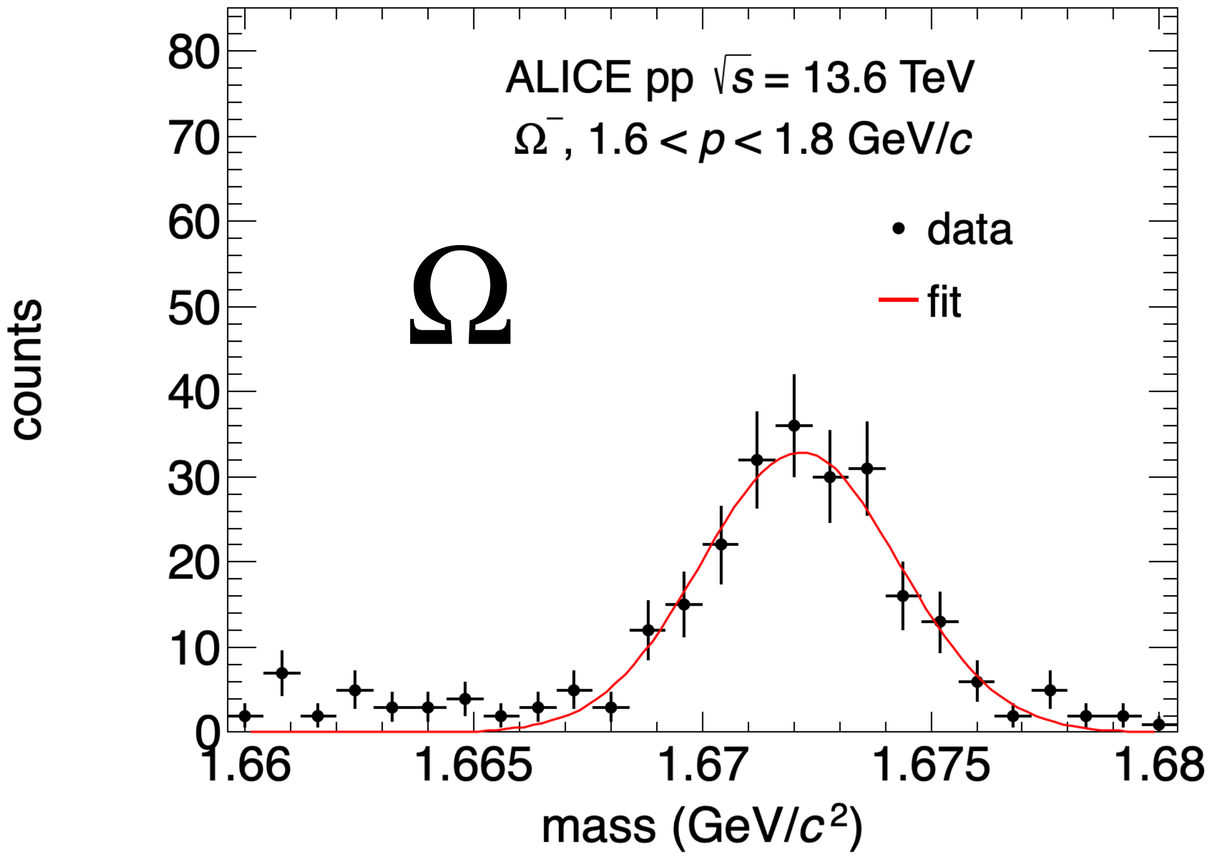


Invariant mass selections:

- Ξ candidates: $1.315 < m_\Xi < 1.328$ GeV/c
- Ω candidates: $1.665 < m_\Omega < 1.680$ GeV/c + $m_\Xi \notin [1.315,1.328]$ GeV/c

Invariant Mass Distributions

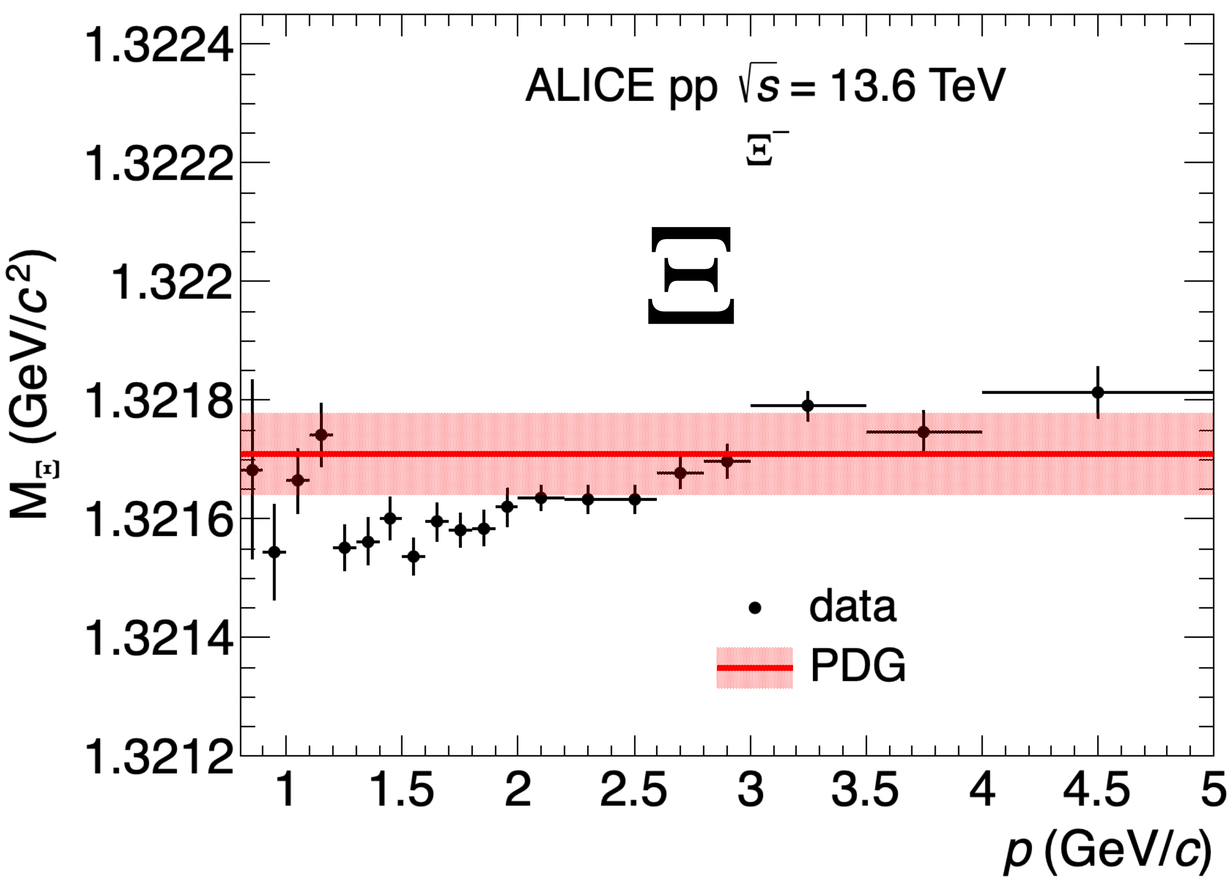


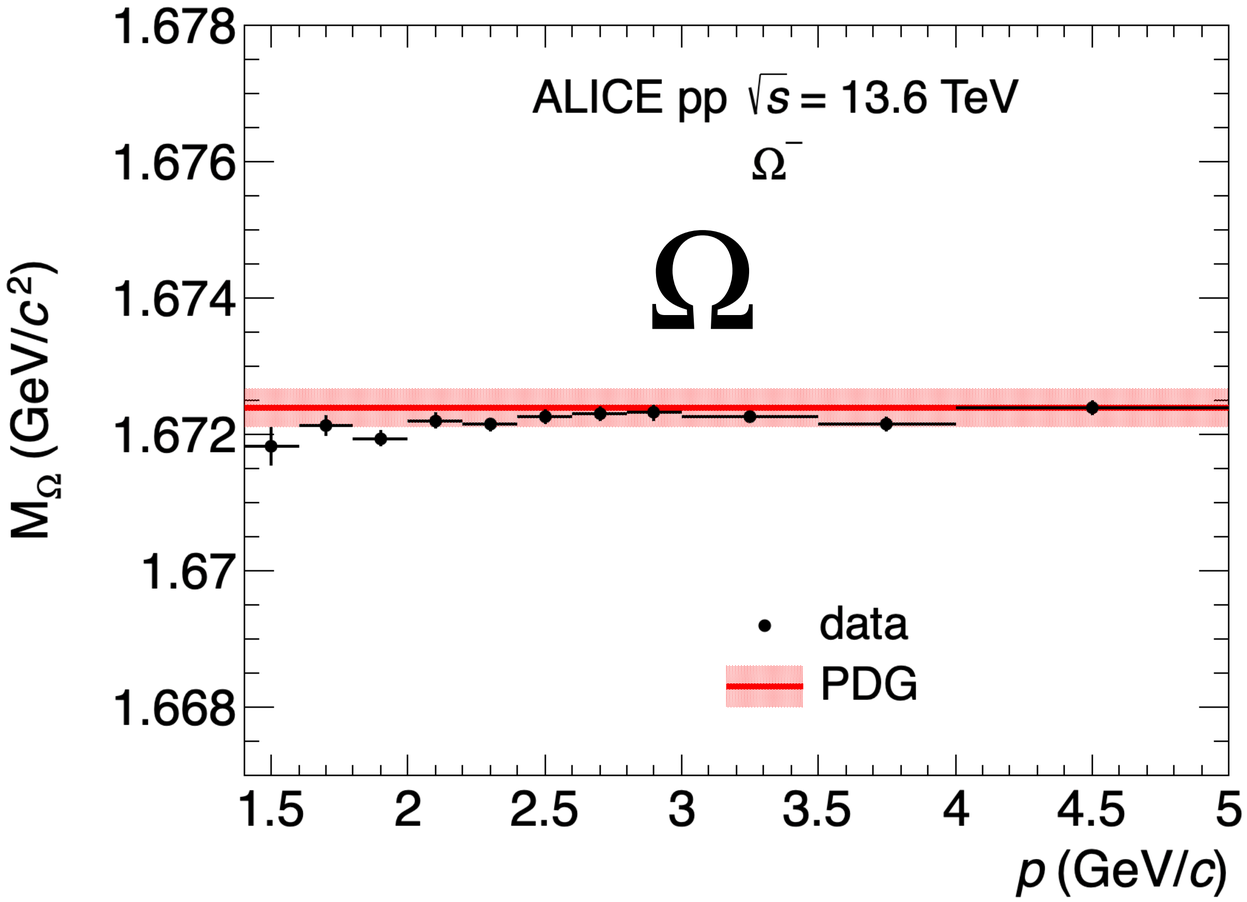


Central core of the distributions fitted with a Gaussian function

Extraction of pole mass and resolution

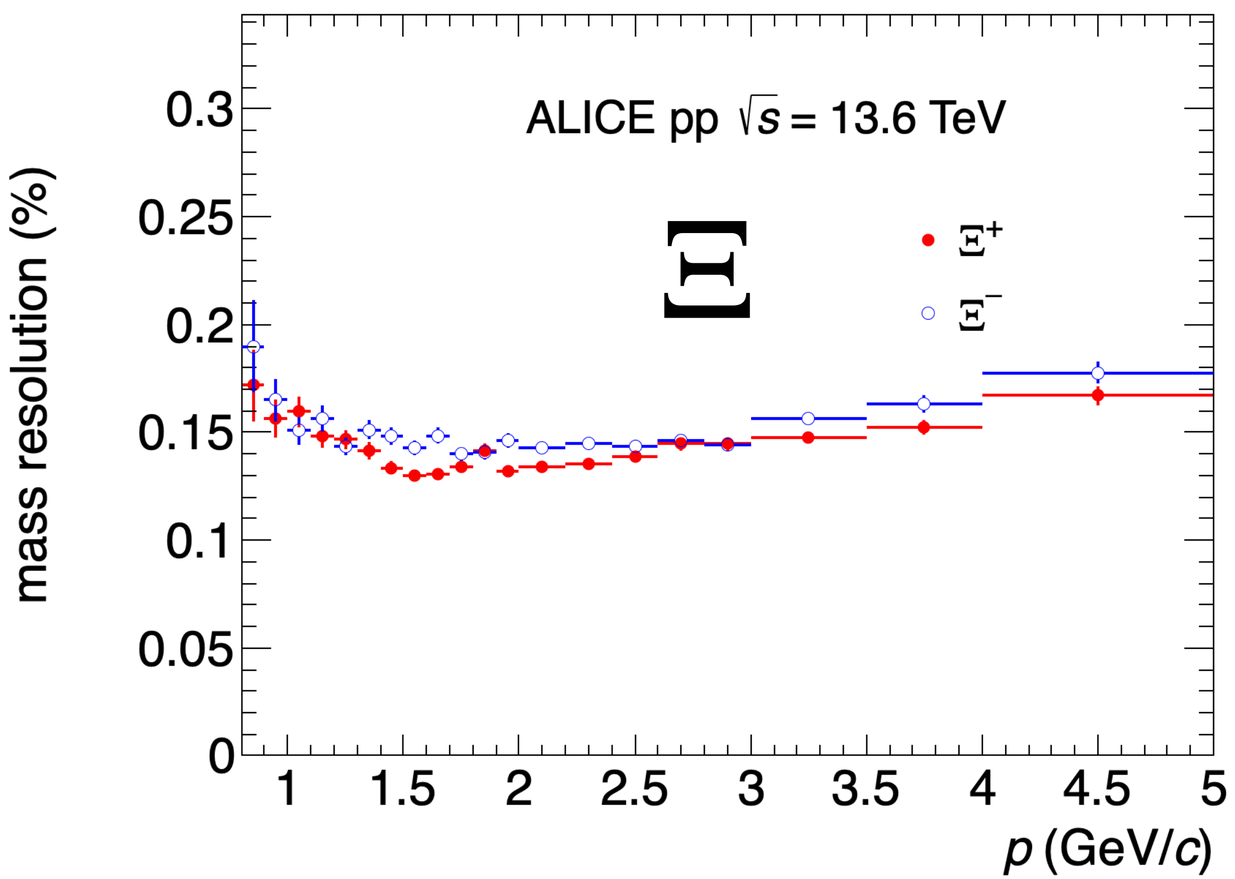
Invariant Mass vs. Momentum

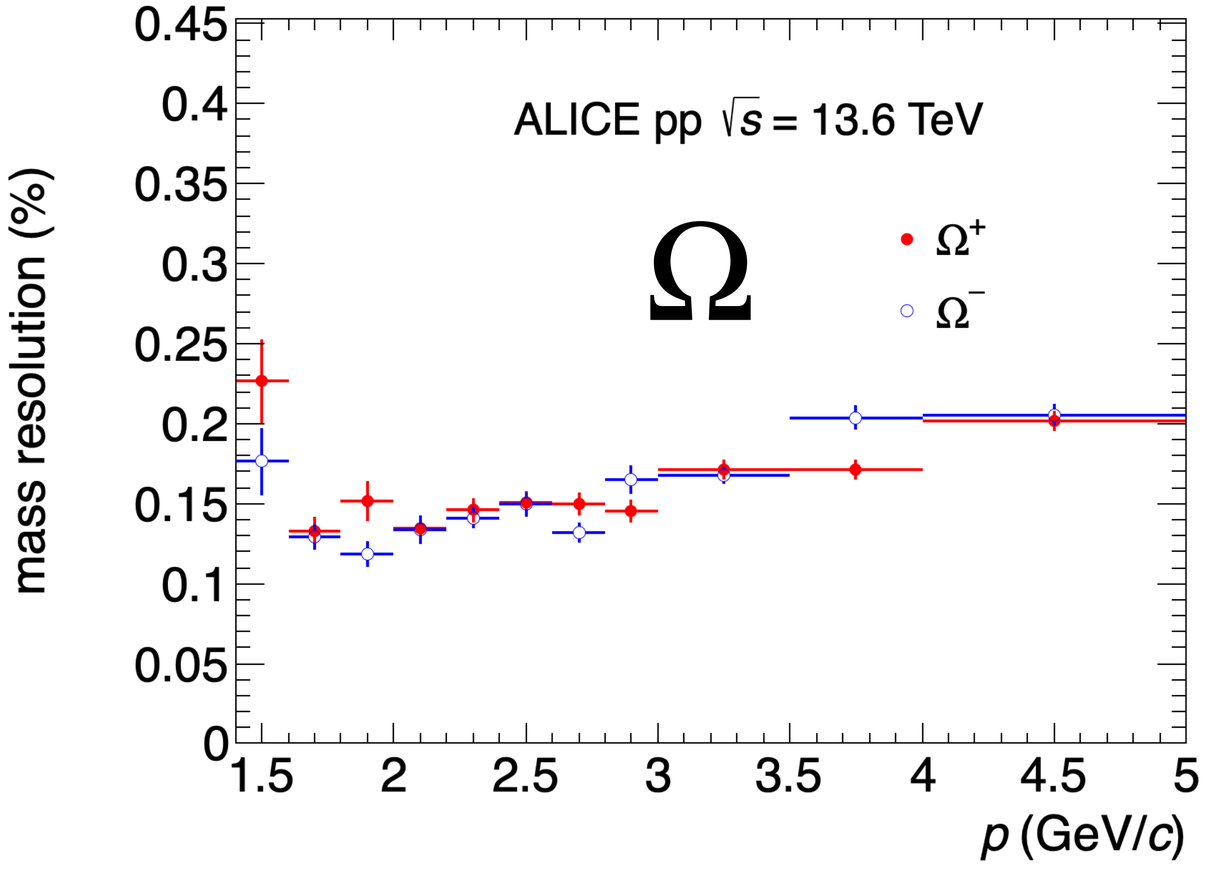




Pole mass very close to the PDG value for both Ξ and Ω

Invariant Mass Resolution

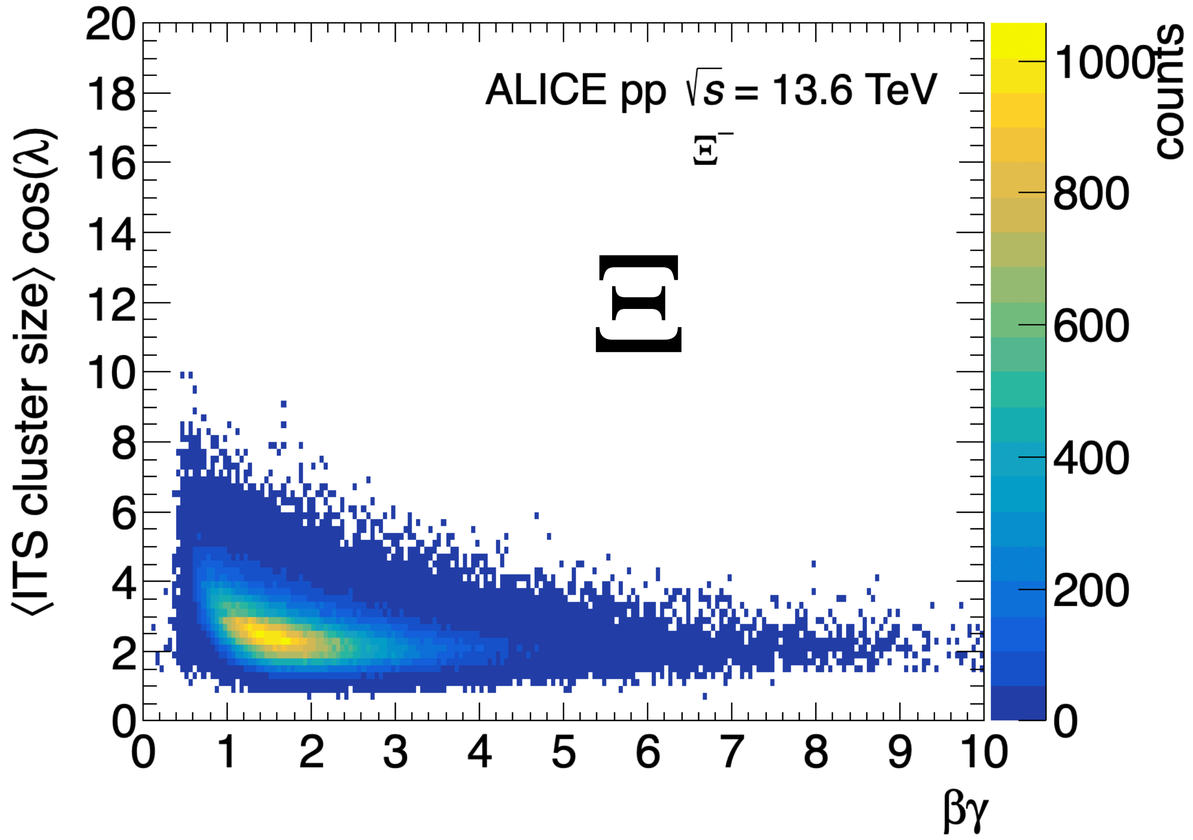


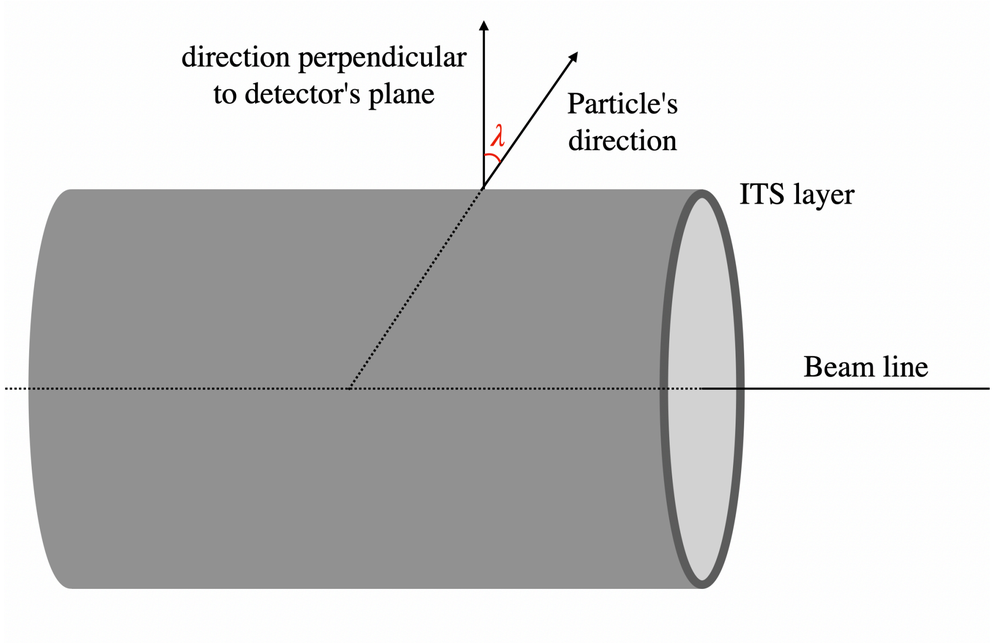


Invariant mass resolution (σ of gaussian core) $\approx$ 0.2% for both Ξ and Ω

Values in GeV/c^2 in backup

Correction for Geometrical Effects

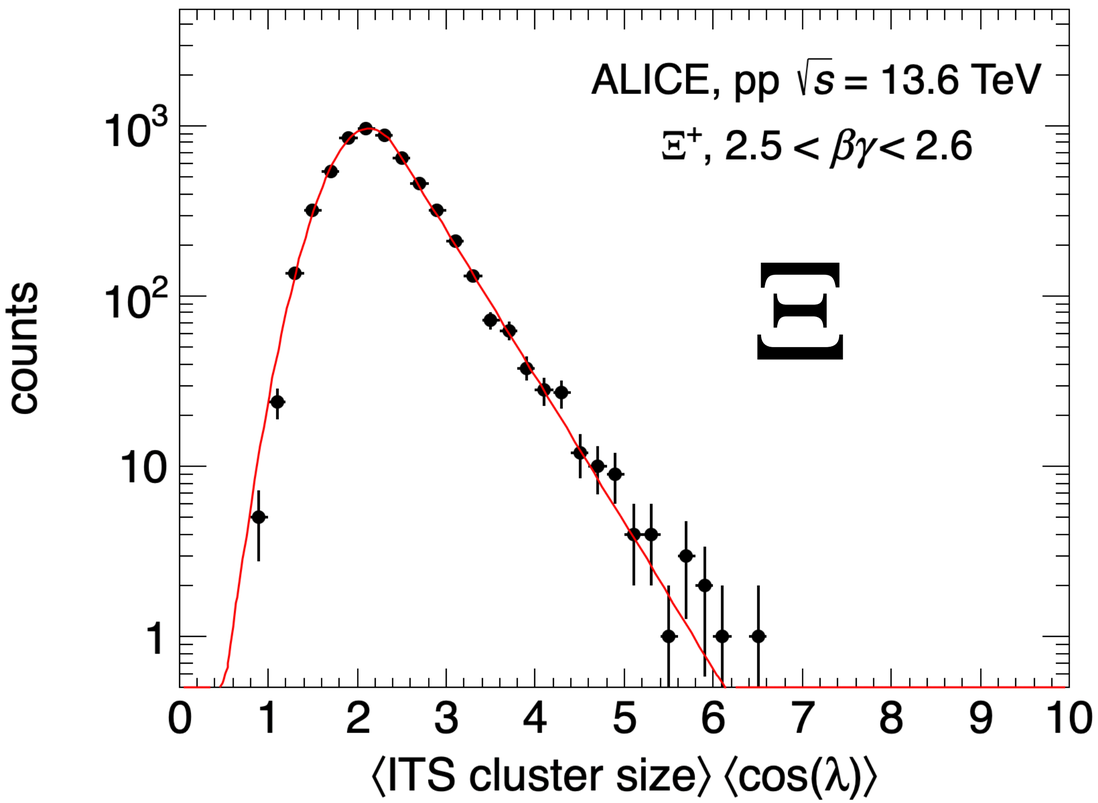


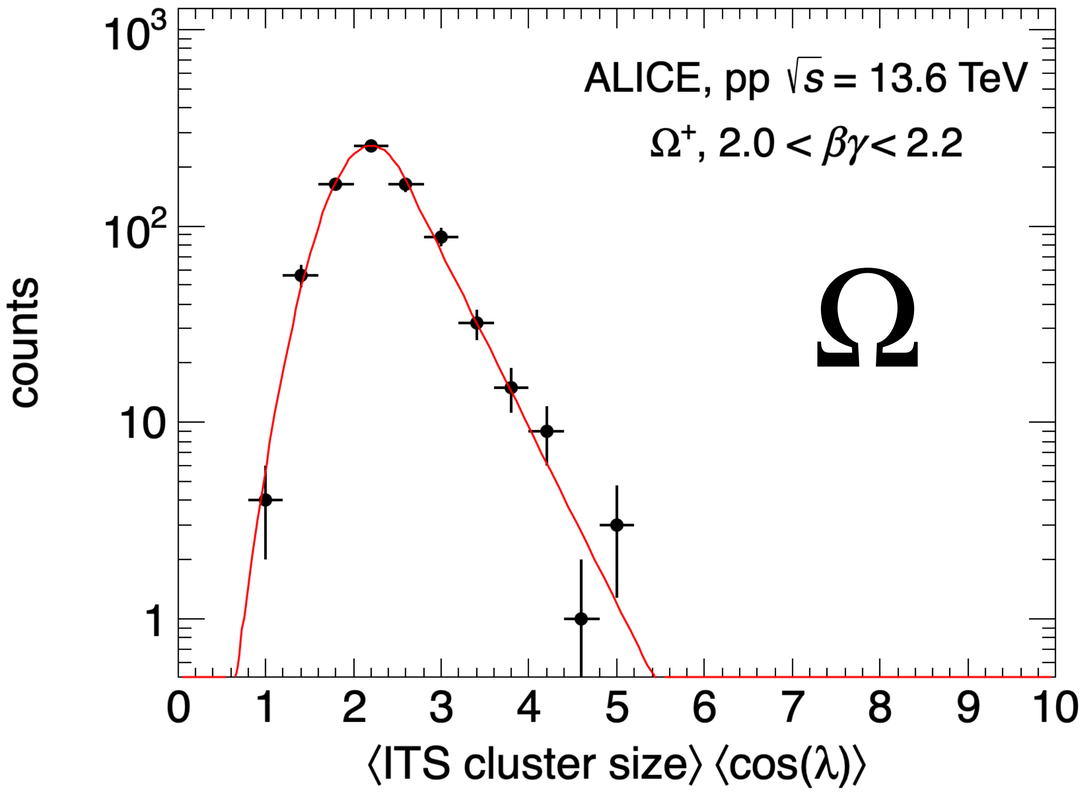


- $\beta\gamma = p/M_{\mathrm{PDG}}$
- λ = track inclination wrt vertical

$\rightarrow \cos(\lambda) = \dfrac{p_{\mathrm{T}}}{p}$ used to correct for trivial geometrical effects

Cluster Size Distribution



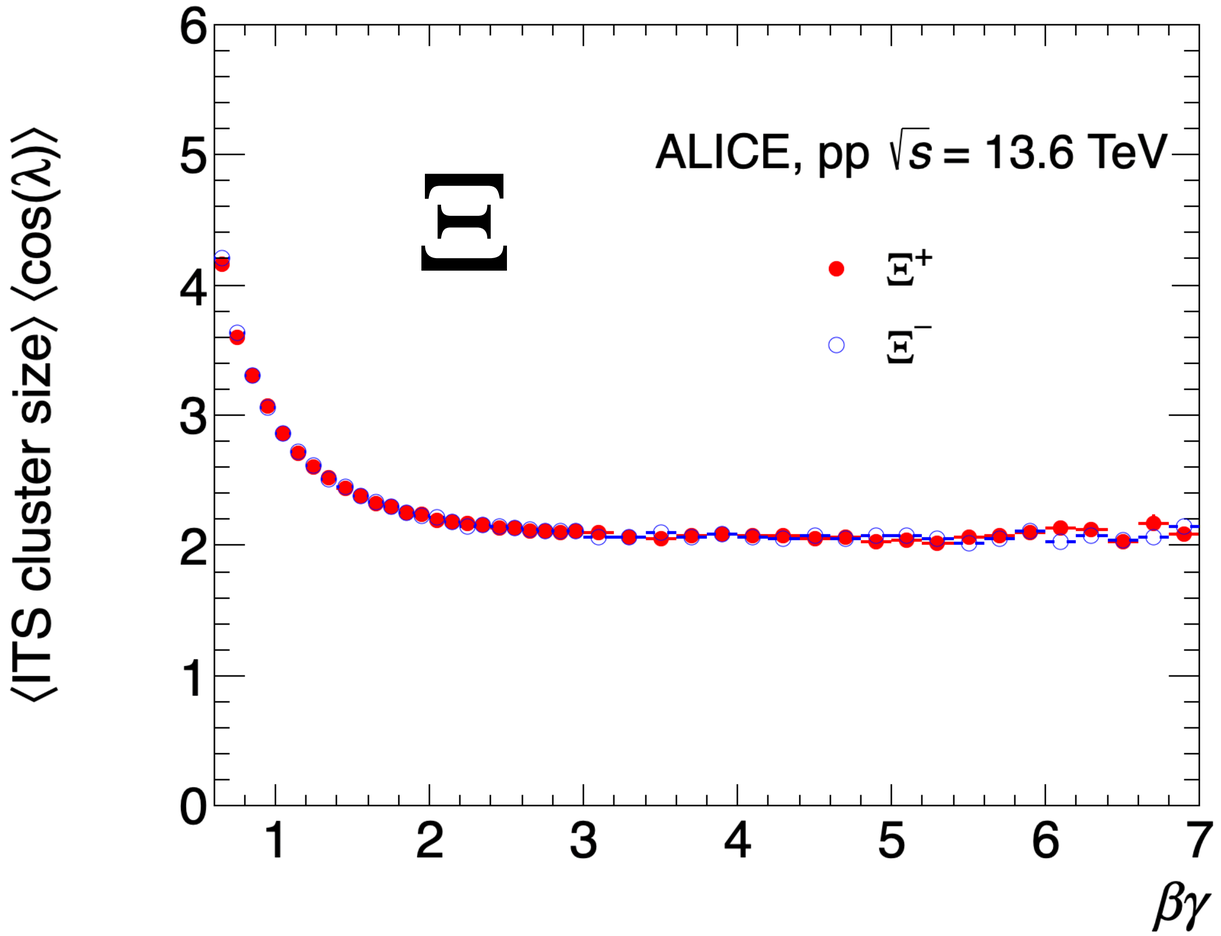


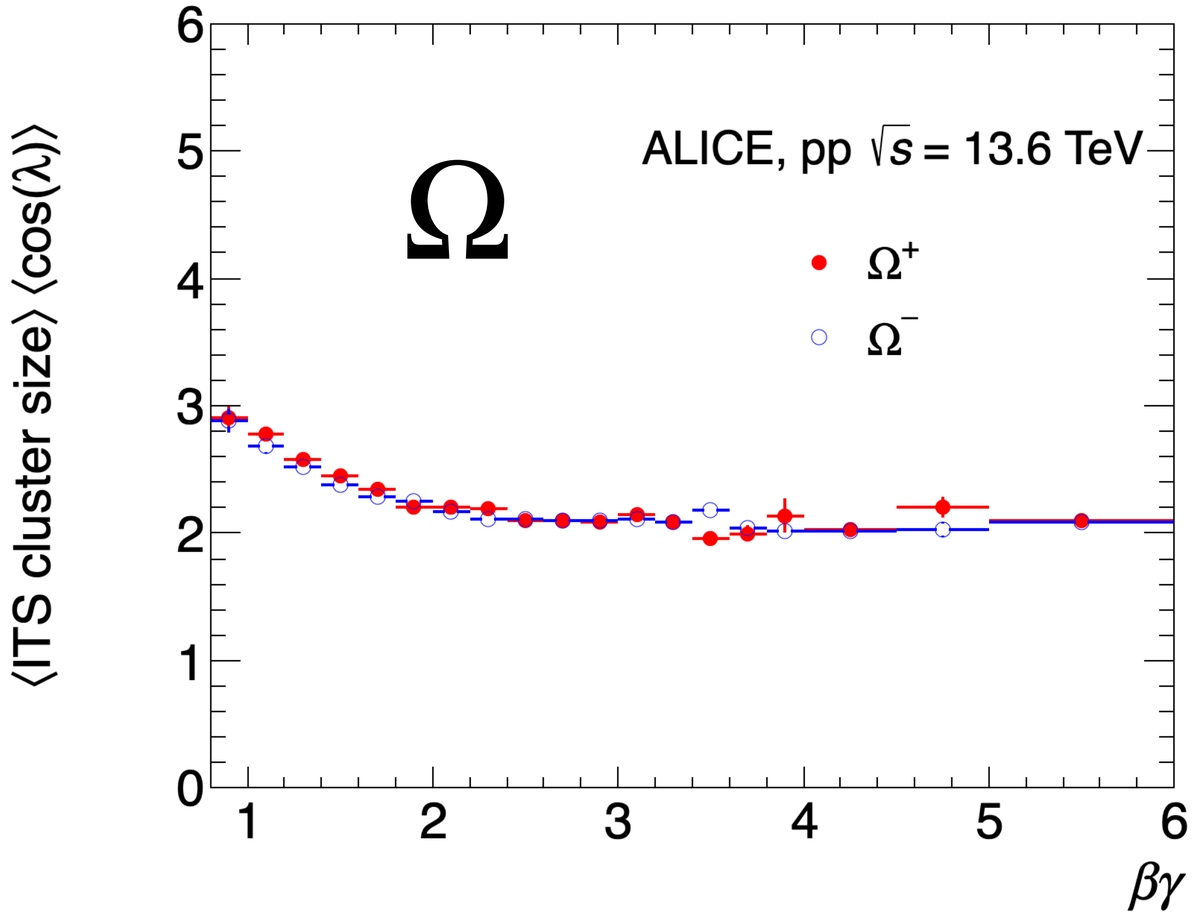
Distribution is asymmetric

→ fitted with Gaussian + exp tail (formally identical to TOF signal function)

$$f(x) = A \begin{cases} \exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) & x < \mu + \tau\sigma \\ \exp\left(-\left(\frac{x-\mu}{\sigma} + \frac{\tau}{2}\right)\tau\right) & x \geq \mu + \tau\sigma \end{cases}$$

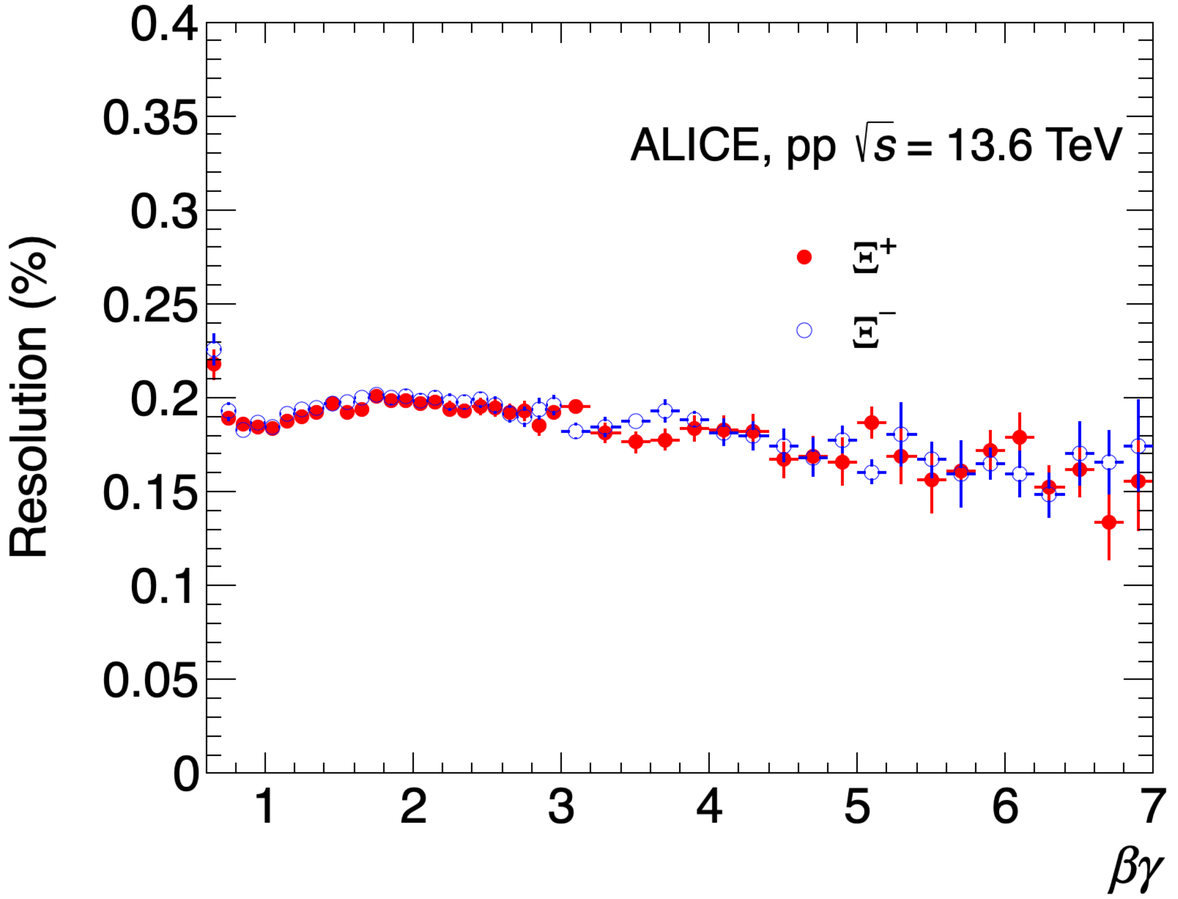
Charge Independence

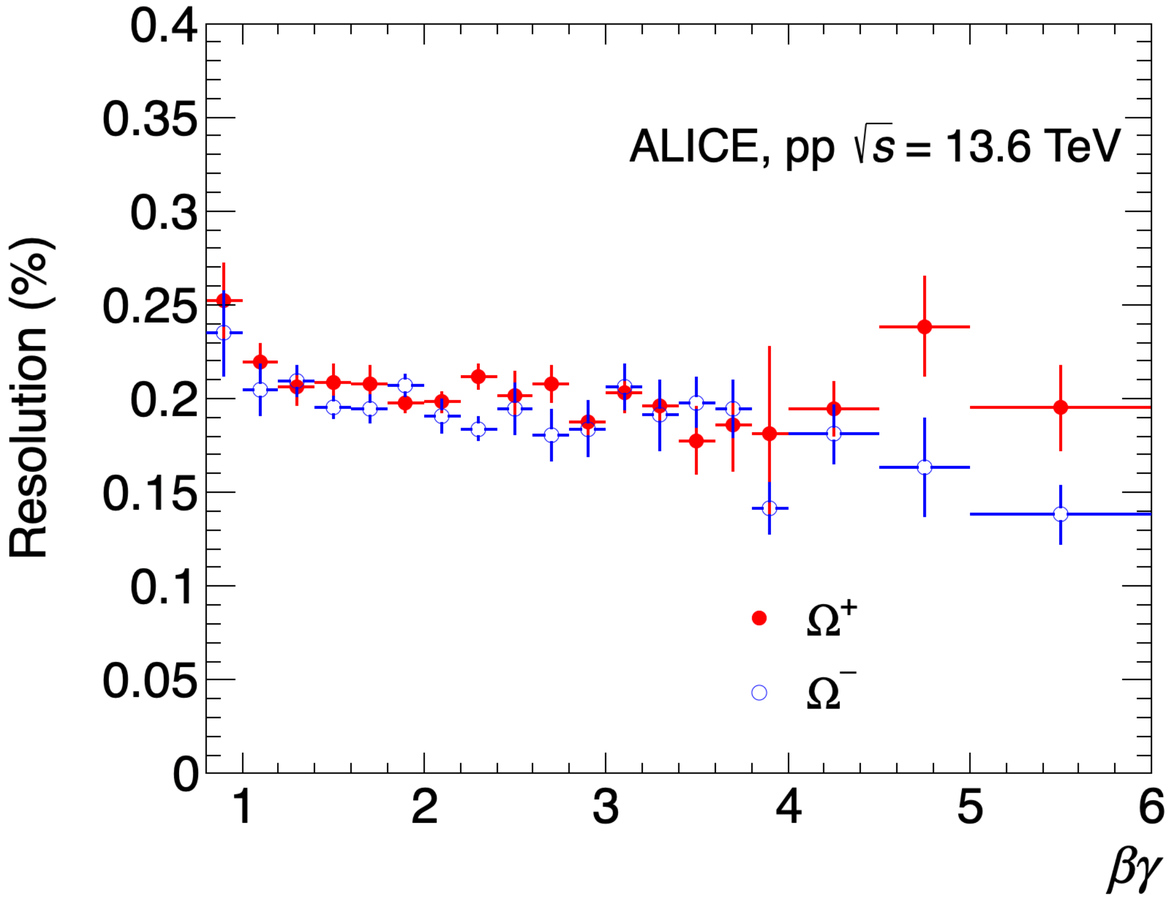




- <ITS cluster size · cos(λ)> behaves similarly to dE/dx (as expected)
- Cluster size is charge independent for both Ξ and Ω

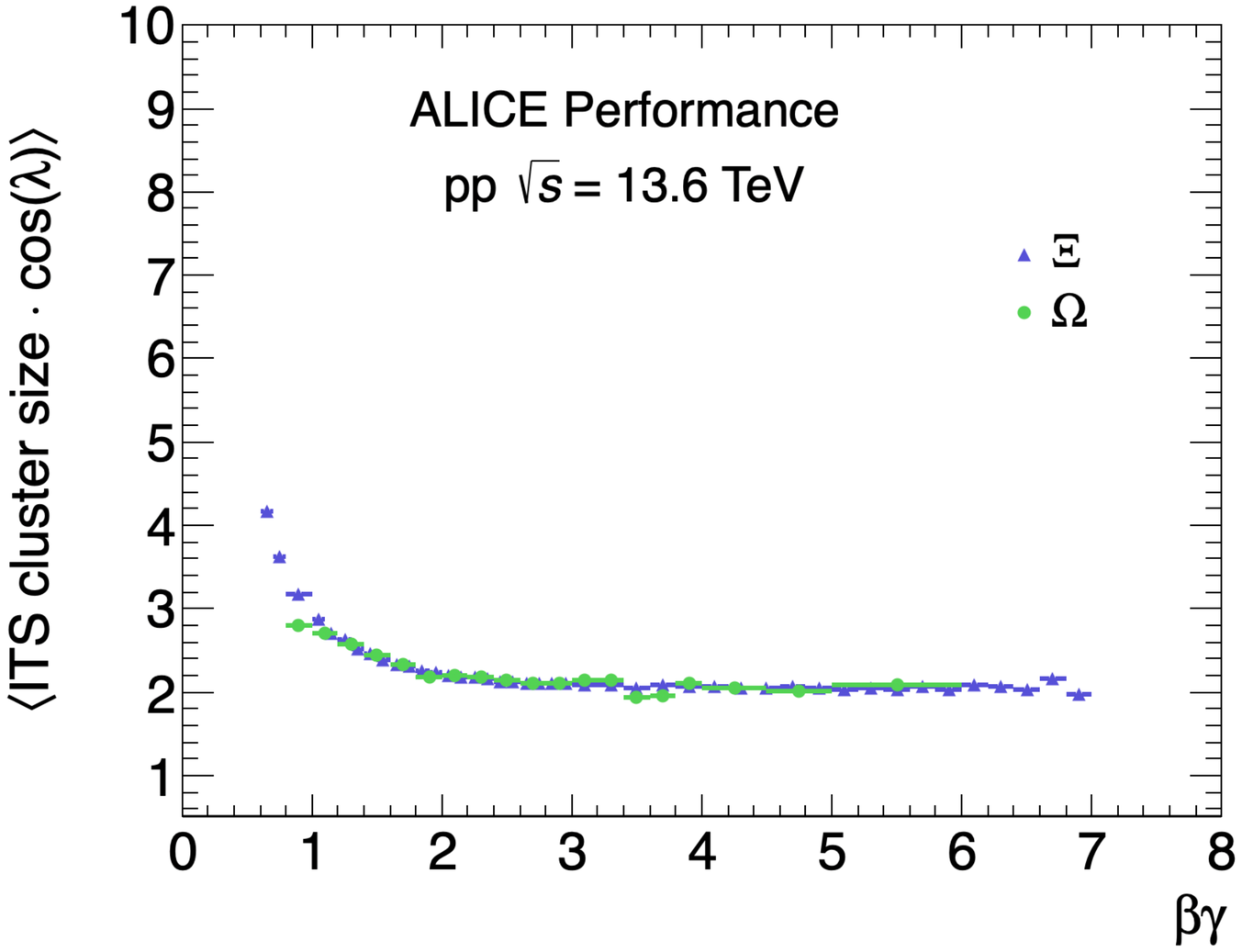
Resolution of the Cluster Size Distribution



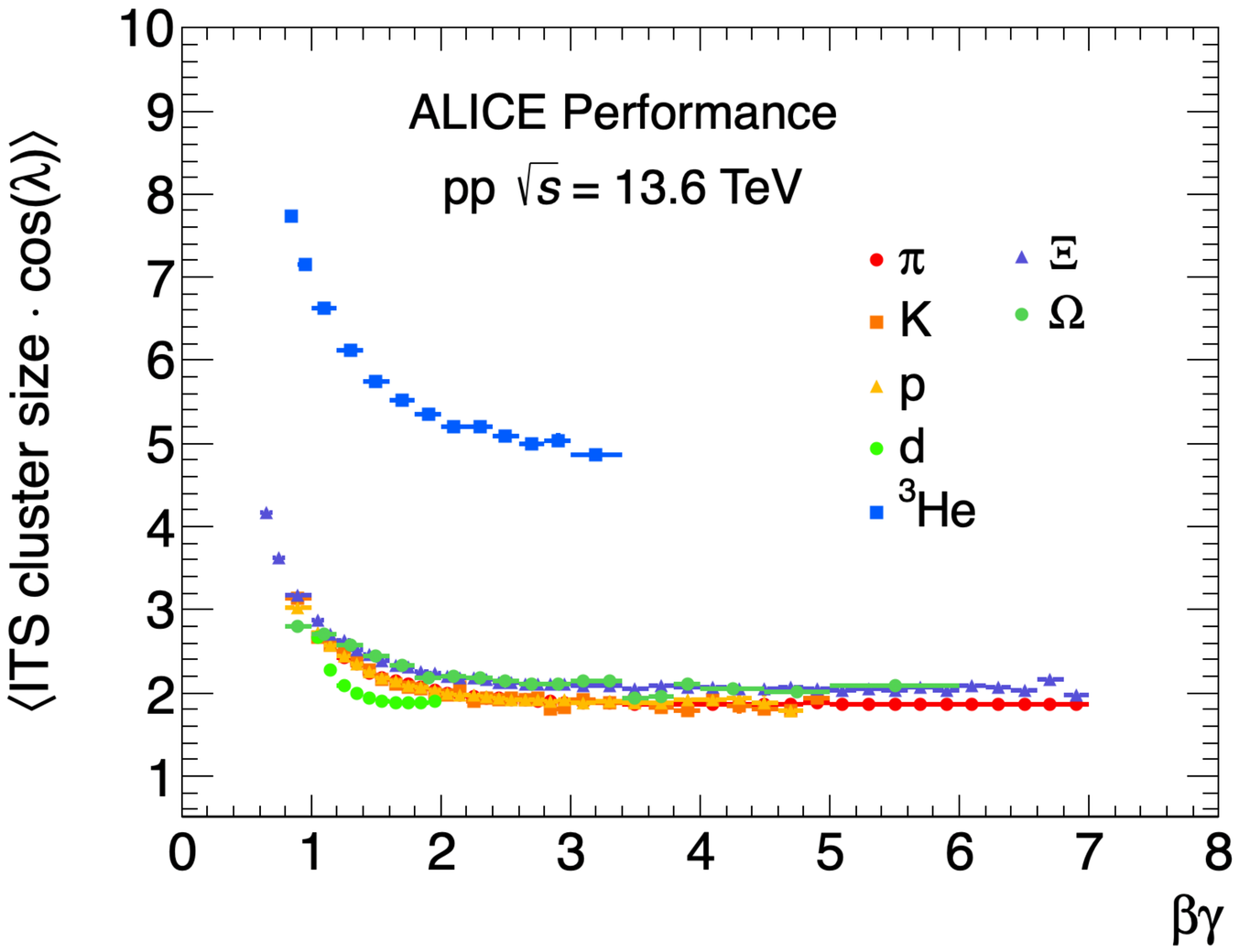


Resolution is ~20% for both Ξ and Ω

Results


ALICE Performance
pp $\sqrt{s}$ = 13.6 TeV
Ξ
Ω
⟨ITS cluster size · cos(λ)⟩
βγ
0
1
2
3
4
5
6
7
8
9
10

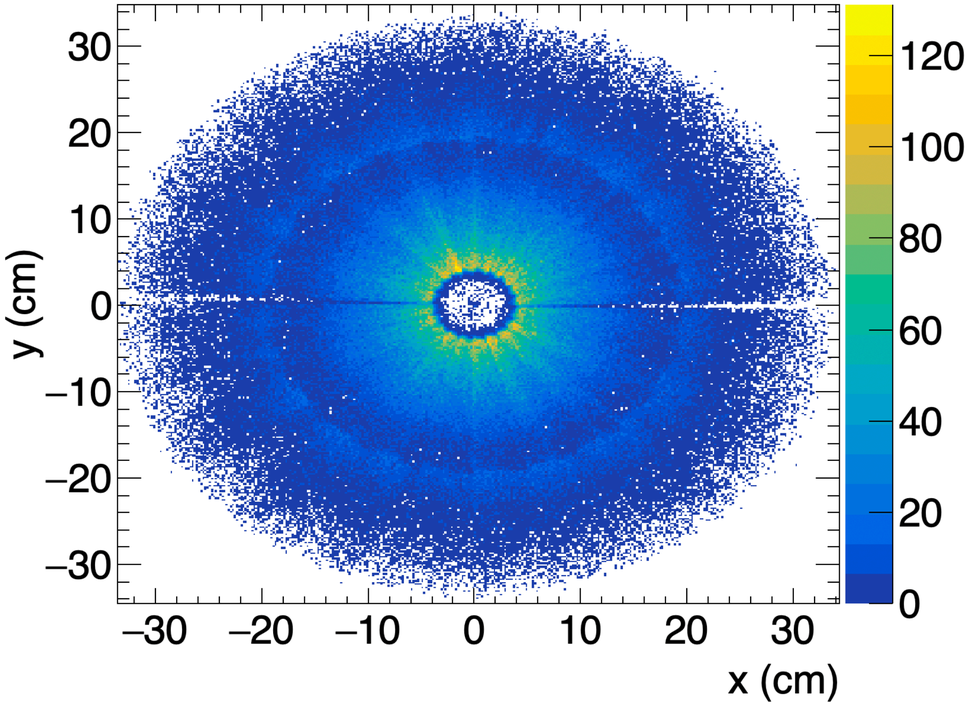
Results

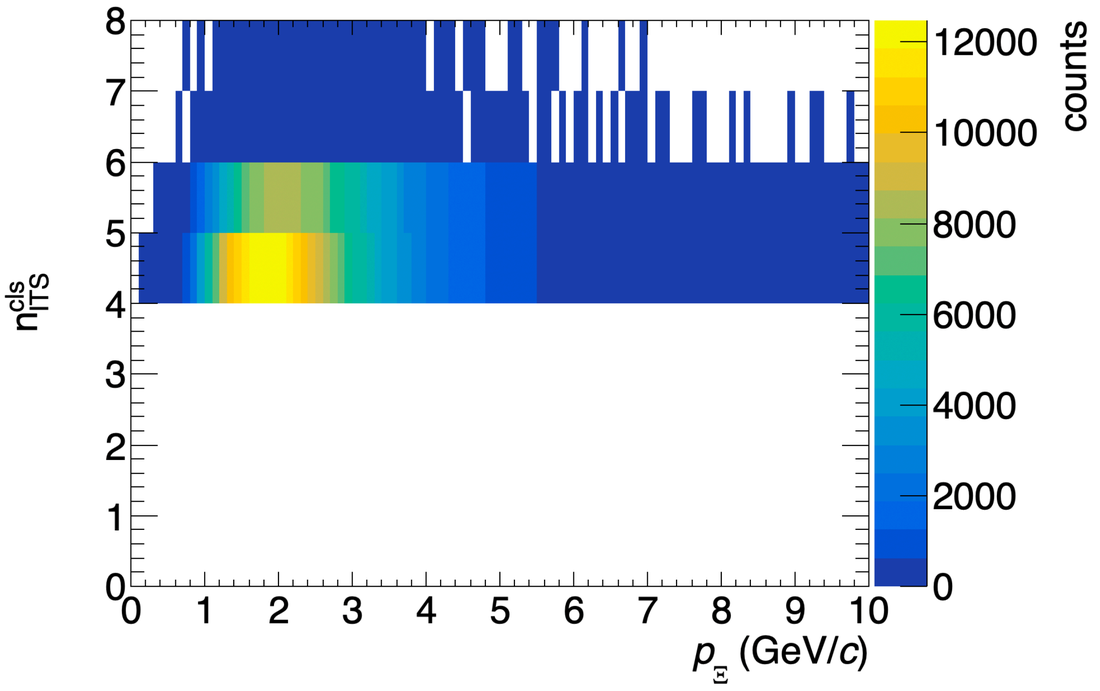


- New ITS provides particle identification via <ITS cluster size · cos(λ)>
  → behaves similarly as the Bethe Bloch

- This allows, **for the first time**, to identify cascades on a track-by-track basis

Decay Radius

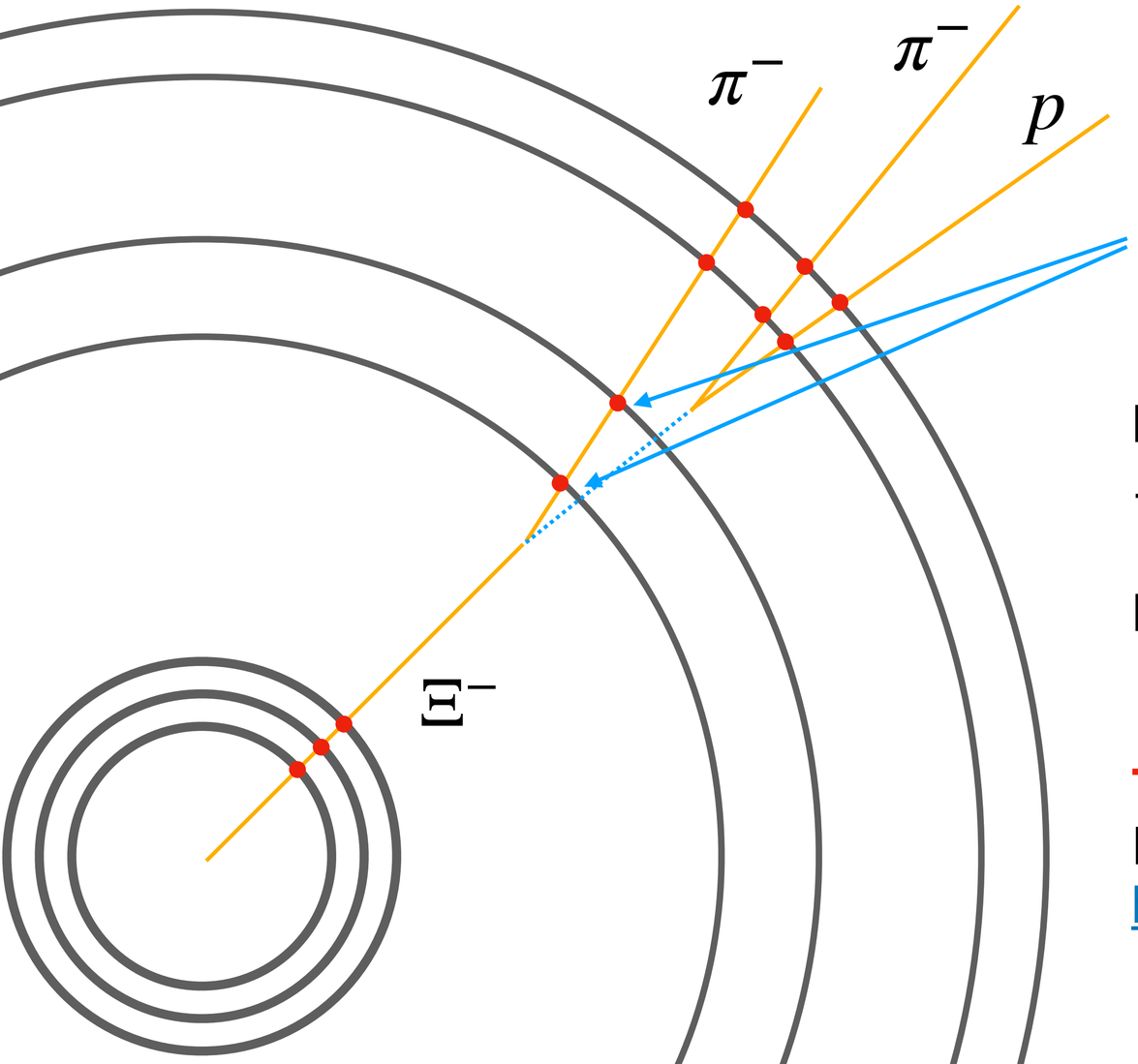




- Cascade decay radius as low as ~ 3 cm
- However, $n_{\mathrm{ITS}}^{\mathrm{cls}} \geq 4$ for tracked cascades

Layer	Barrel Segment	Radius (cm)
0	Inner Barrel	2.2
1	Inner Barrel	2.8
2	Inner Barrel	3.6
3	Middle Layer	20.0
4	Middle Layer	22.0
5	Outer Layer	37.0
6	Outer Layer	39.0

Bias in the Cluster Size Calculation



ITS hits of bachelor track closer to decay point might be wrongly associated to the tracked cascade

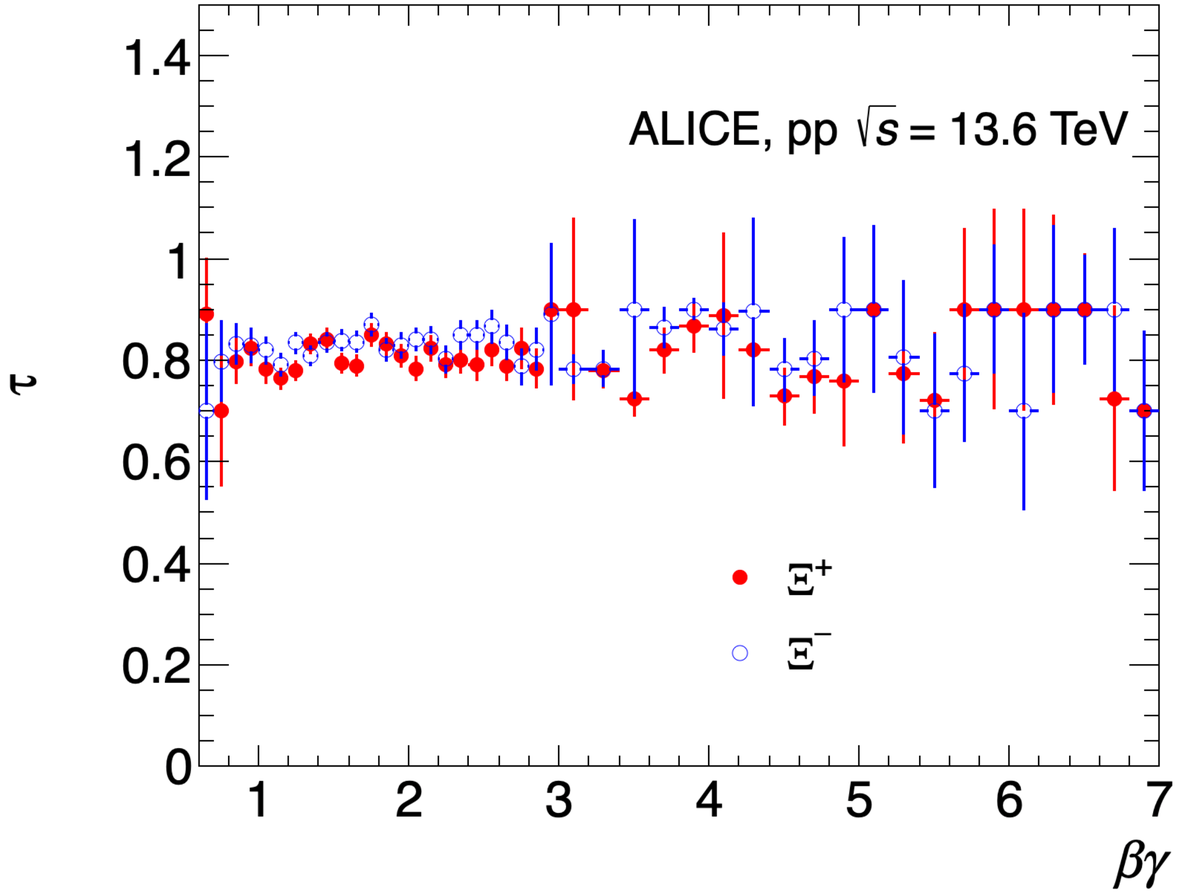
Removed after refit but still associated to the ITStrack
→ bias in the cluster size calculation!

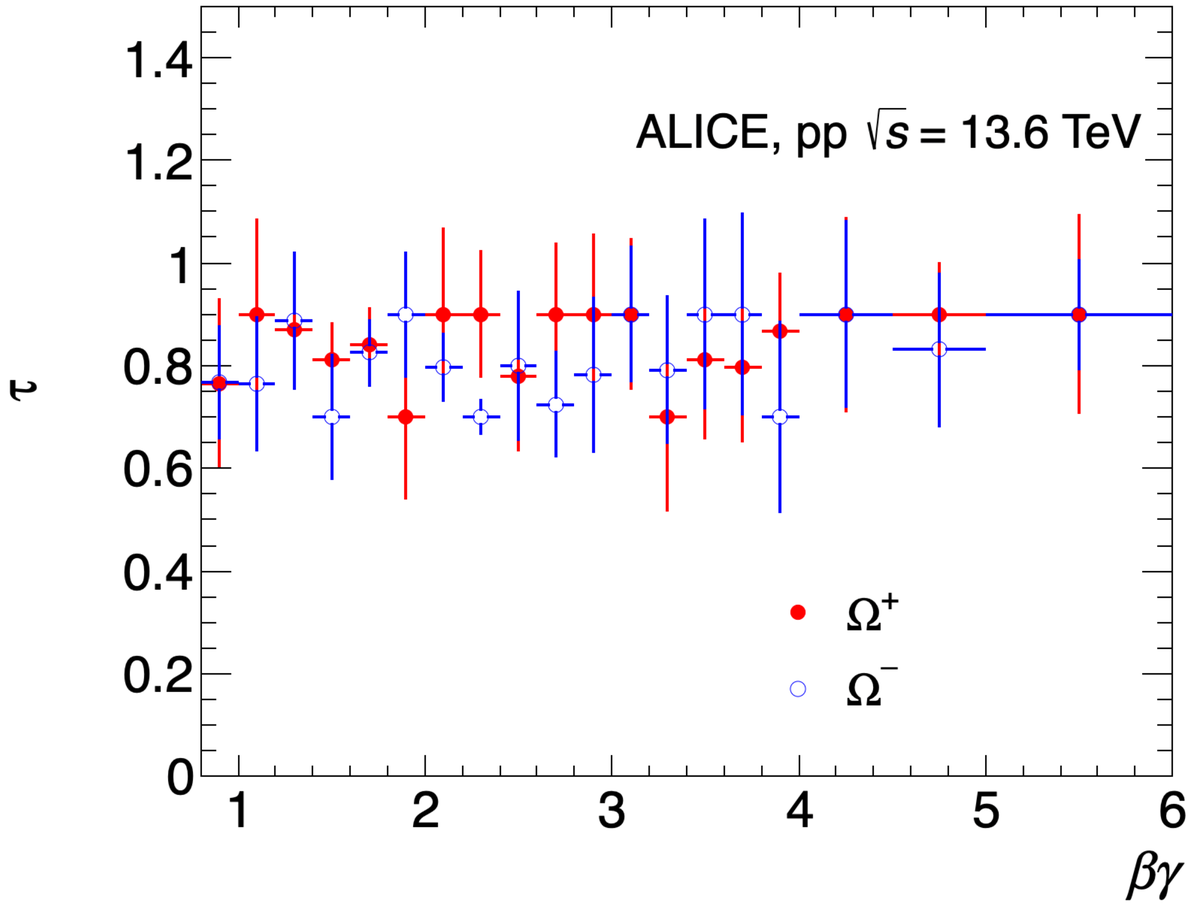
Fixed for future apass, but present up to apass1 of 2024

Temporary fix: calculate cluster size using only hits in ITS layers with radius < decay radius
https://github.com/AliceO2Group/O2Physics/pull/11018

Backup slides

Tau parameter



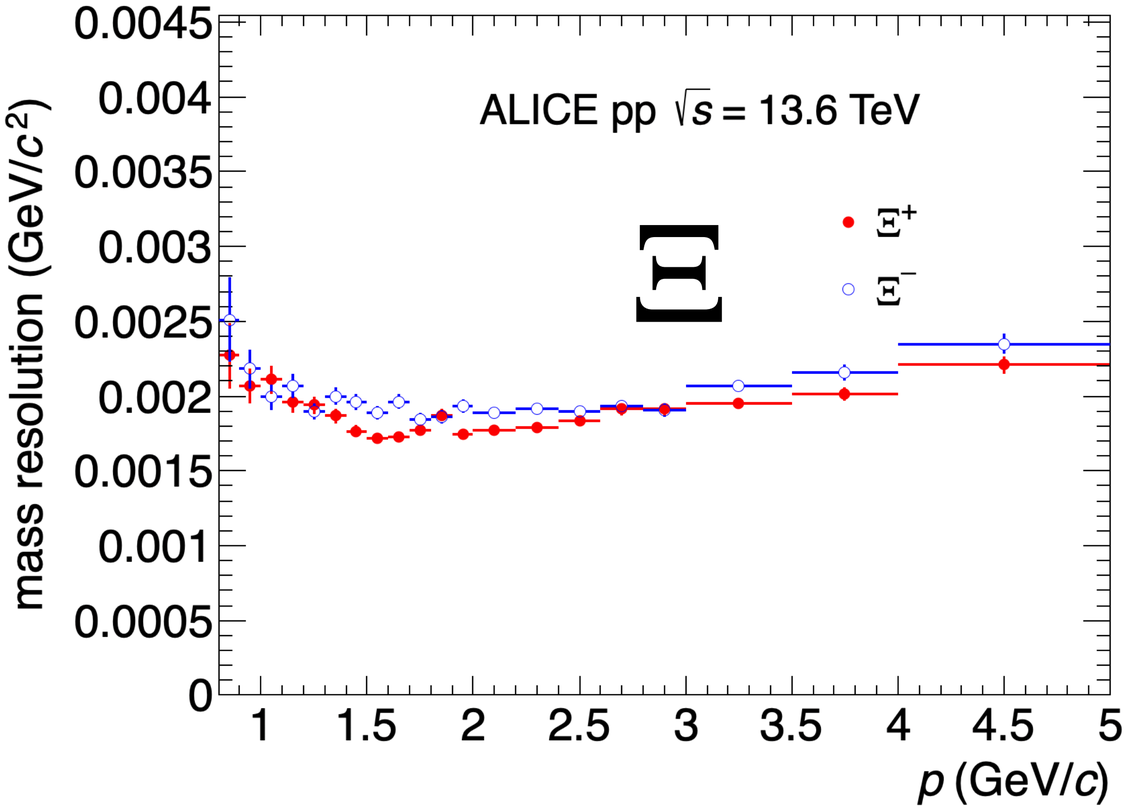


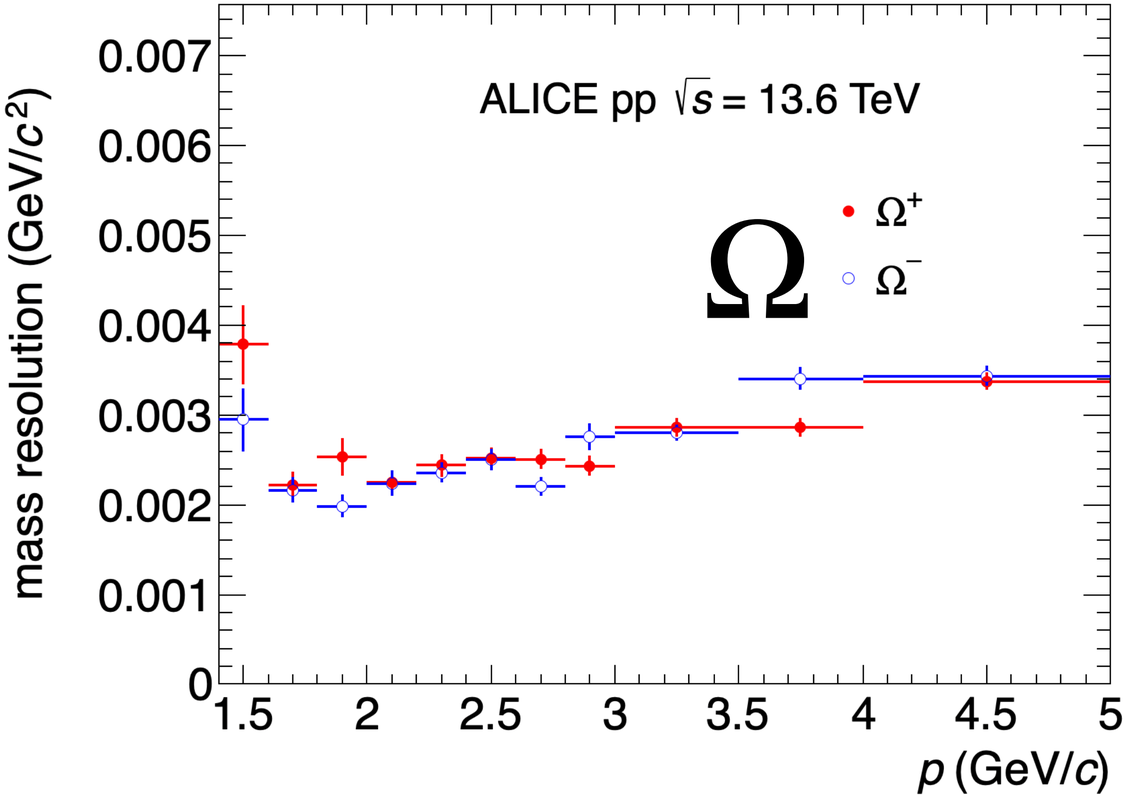
The parameter τ is constrained in the range

$$0.7 < \tau < 0.9$$

$$f(x) = A \begin{cases} \exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) & x < \mu + \tau\sigma \\ \exp\left(-\left(\frac{x-\mu}{\sigma} + \frac{\tau}{2}\right)\tau\right) & x \geq \mu + \tau\sigma \end{cases}$$

Invariant mass resolution

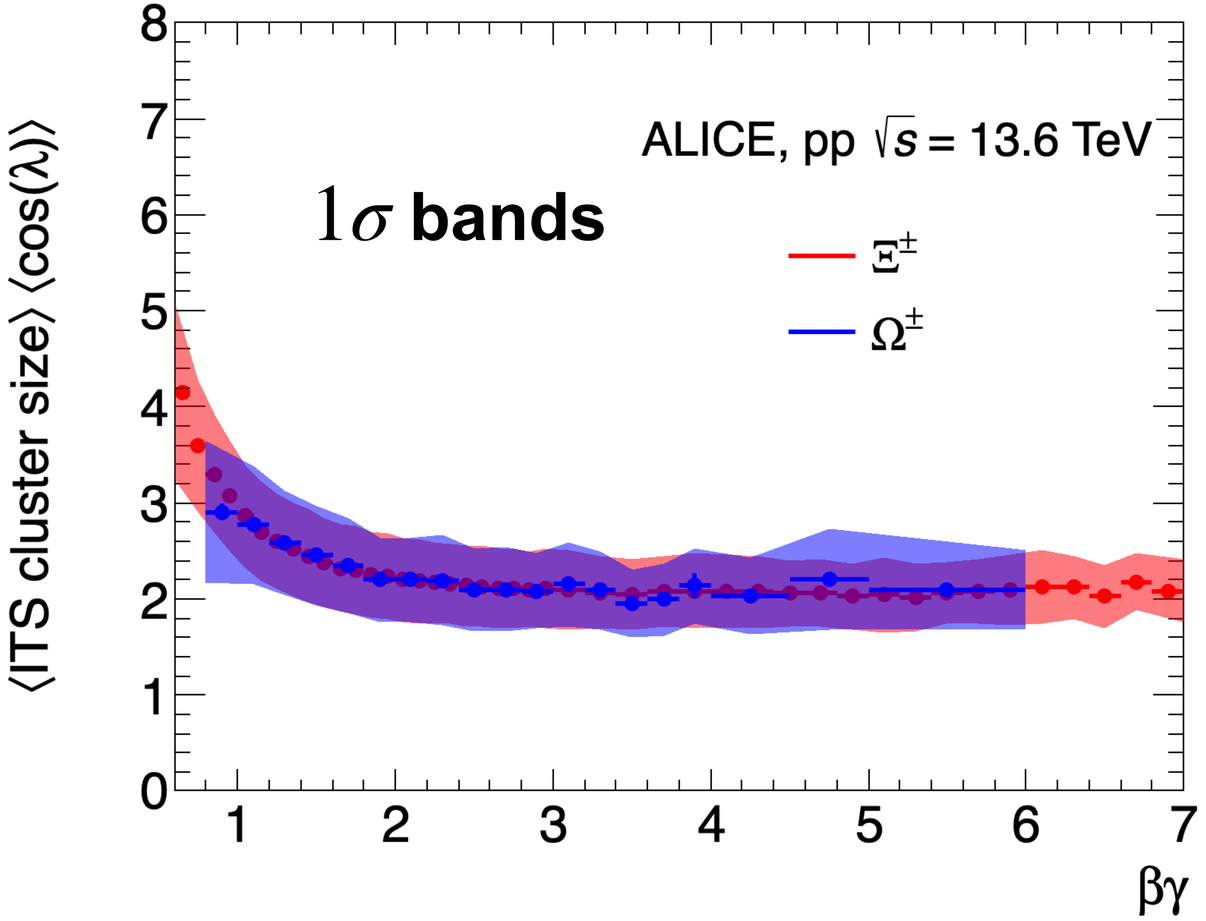


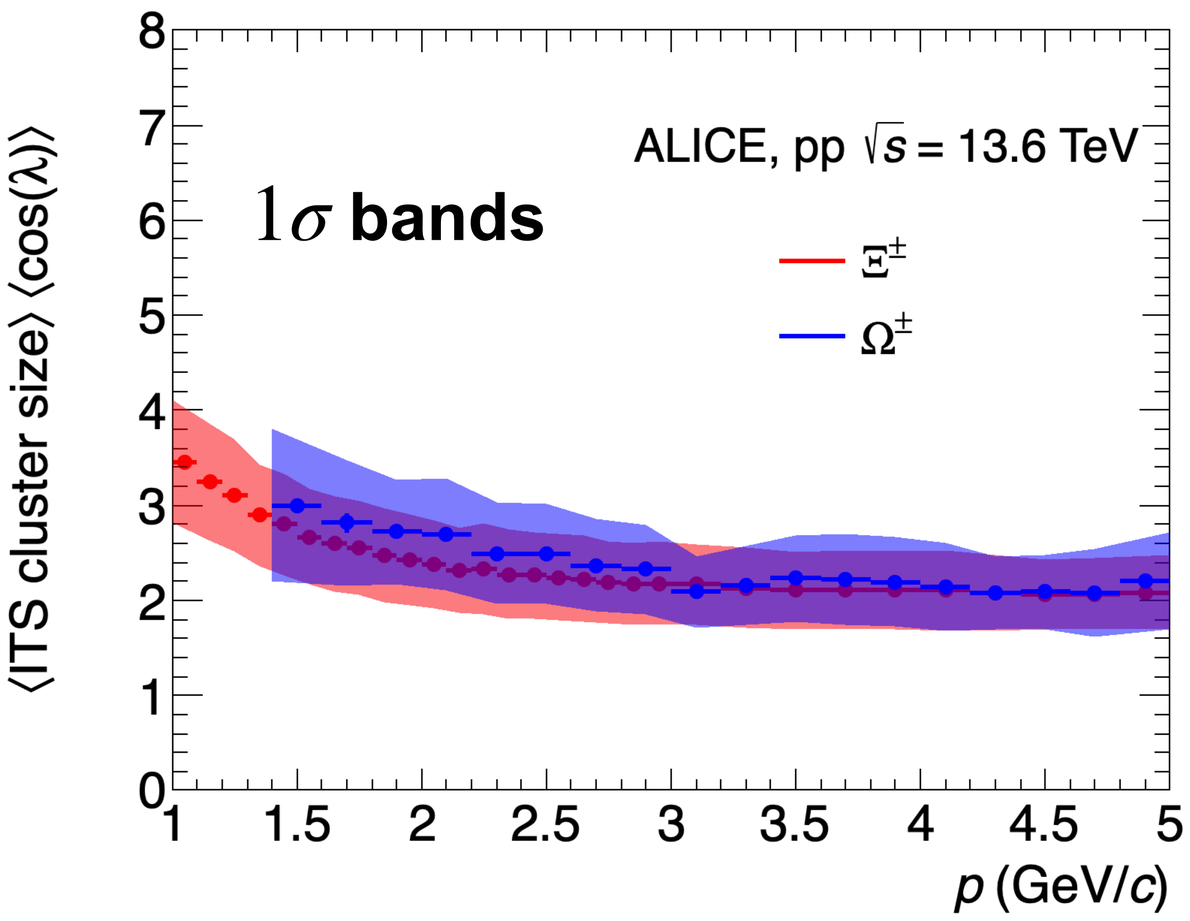


Average Cls Size Calculation

```
for (const auto& trackedCascade : trackedCascades) {

      const auto track = trackedCascade.track_as<FullTracks>();
      const auto trackITS = trackedCascade.itsTrack_as<FullTracks>();

      const auto& casc = trackedCascade.cascade();
      const auto& btrack = casc.bachelor_as<FullTracks>();
      double dx = trackedCascade.decayX();
      double dy = trackedCascade.decayY();
      double r = std::sqrt(dx * dx + dy * dy);
      int nClsCascade = findBin(edgesItsLayers, r);

      // Calculate (Average) Cluster Size
      double averageClusterSize(0);
      int nCls(0);
      for (int i = 0; i < nClsCascade; i++) {
        int clusterSize = trackITS.itsClsSizeInLayer(i);
        averageClusterSize += static_cast<double>(clusterSize);
        if (clusterSize > 0)
          nCls++;
      }
      averageClusterSize = averageClusterSize / static_cast<double>(nCls);
```

Results


ALICE, pp $\sqrt{s}$ = 13.6 TeV
1σ bands
$\Xi^{\pm}$
$\Omega^{\pm}$
⟨ITS cluster size⟩ ⟨cos(λ)⟩
βγ


ALICE, pp $\sqrt{s}$ = 13.6 TeV
1σ bands
$\Xi^{\pm}$
$\Omega^{\pm}$
⟨ITS cluster size⟩ ⟨cos(λ)⟩
p (GeV/c)