# Effect of event classification on the Tsallis thermometer

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25. Zimanyi Winter School

03.12.2025

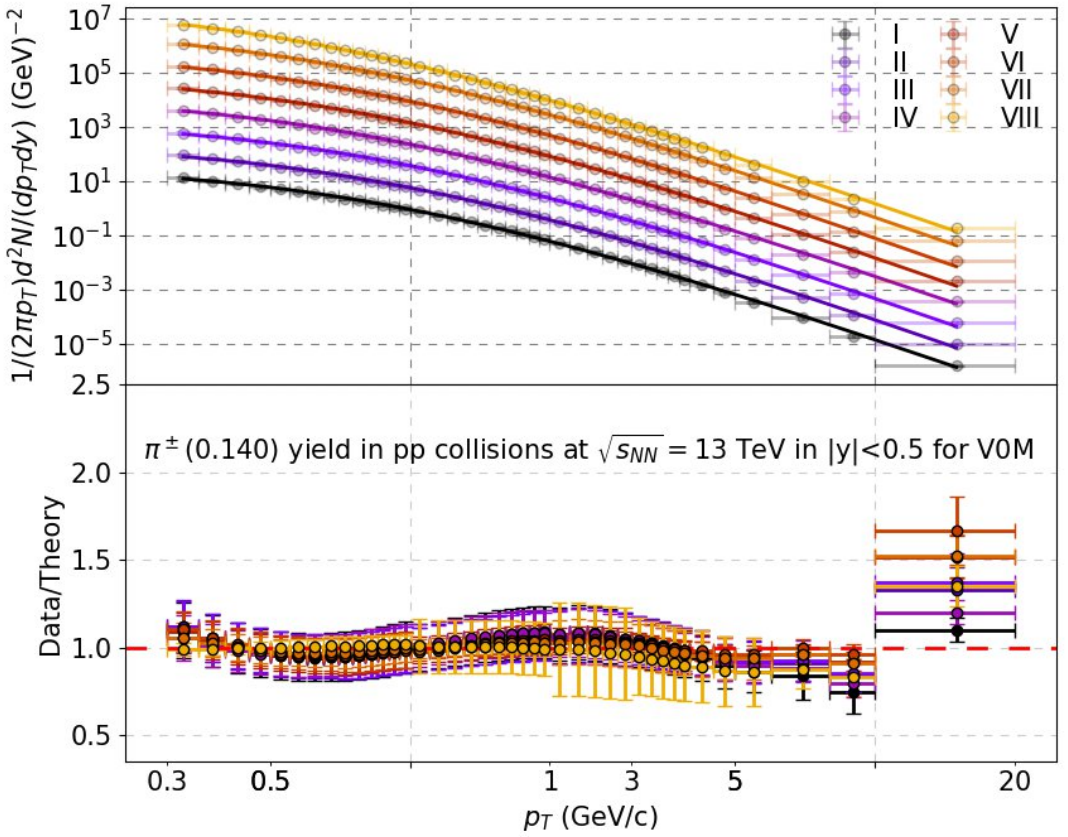
This work has been supported by the Hungarian 2025-1.1.5-NEMZ_KI-2025-00002 grant.

# A non-extensive statistical framework

Identified particle spectrum:

- **Low-$p_T$ part**:
  - soft particle production
  - exponential-like (Boltzmann-Gibbs) distribution
  - stemming from a thermal equilibrium

- **High-$p_T$ part**:
  - jet-like origin
  - power-law tail distribution
  - described by the perturbative QCD




Tsallis-Pareto distribution smoothly connects the two parts:

$$\left.\frac{\mathrm{d}^2N}{2\pi p_T \mathrm{d}p_T \mathrm{d}y}\right|_{y\approx 0} = A m_T \left[1 + \frac{q-1}{T}(m_T - m)\right]^{-\frac{q}{q-1}}$$

# Light flavours in Tsallis thermometer

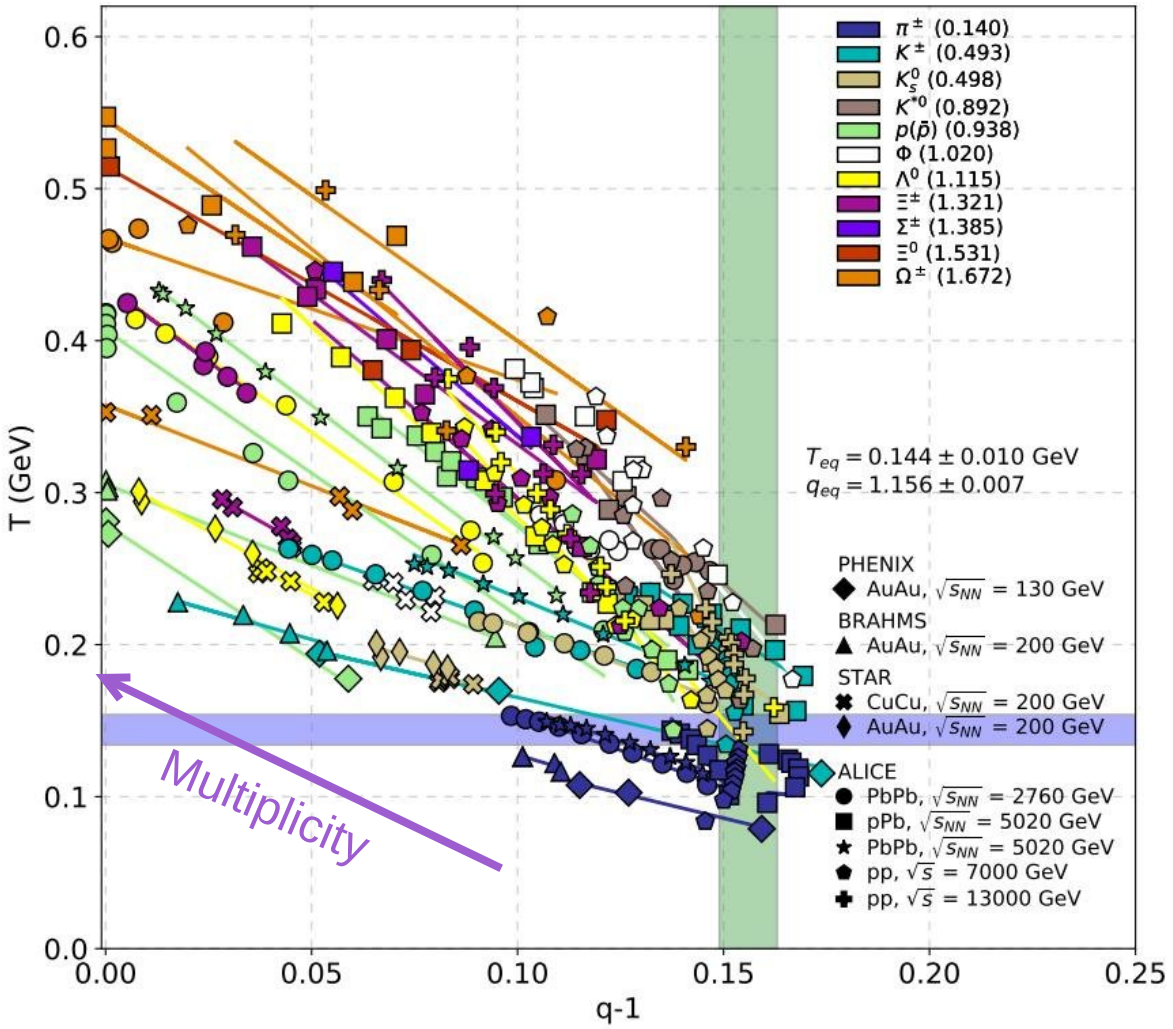
Tsallis temperature $T$: $T = \frac{E}{\langle n \rangle}$

Non-extensivity parameter $q$: $q = 1 - \frac{1}{\langle n \rangle} + \frac{\Delta n^2}{\langle n \rangle^2}$

Observations:

- Strong dependence on event multiplicity
- Mass hierarchy
- Dependence on collision system and energy
- All points aiming towards $T_{eq}$≈0.14 GeV and $q_{eq}$≈1.15 - diluted system limit

*J.Phys.G* **47** (2020) 10, 105002



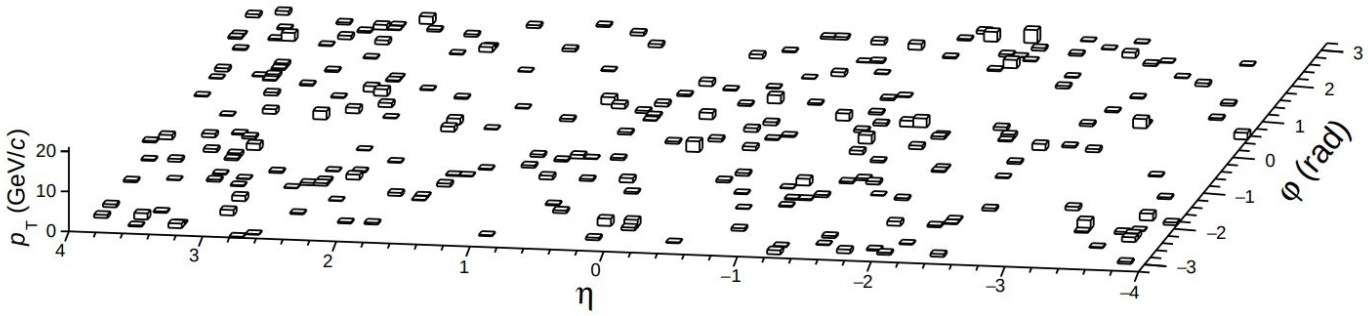
# Flattenicity

Classifies events based on uniformity of $p_T$ distribution

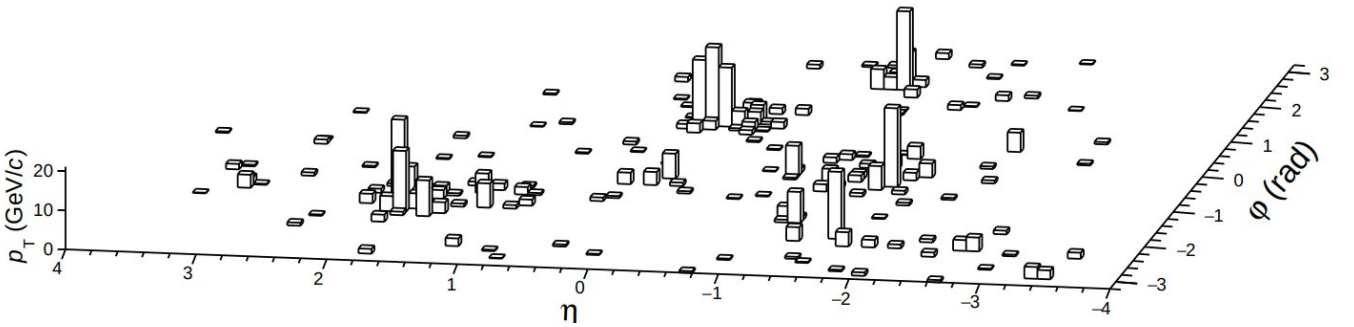
$$\rho = \frac{\sqrt{\sum_i \left(p_{\mathrm{T}}^{\mathrm{cell},i} - \langle p_{\mathrm{T}}^{\mathrm{cell}} \rangle\right)^2 / \mathrm{N}_{\mathrm{cell}}}}{\langle p_{\mathrm{T}}^{\mathrm{cell}} \rangle}$$

The whole η-φ plane is divided into cells

Lower flattenicity values **(ρ→0)** correspond to more uniform (hedgehog) distributions




High flattenicity **(ρ→1)** describes non-uniform (jetty) events



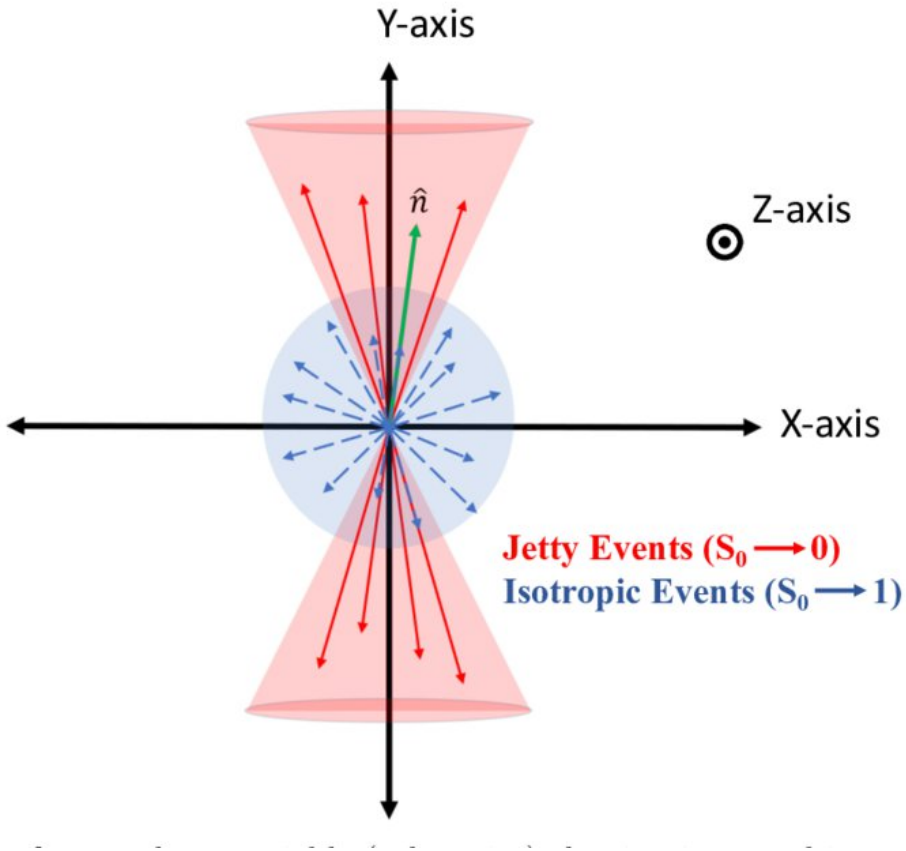
# Transverse spherocity

Classifies events based on geometrical distribution of $p_T$

$$S_0^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}_T} \left( \frac{\sum_{i=1}^{N_{trk}} |\hat{p}_{T,i} \times \hat{n}_T|}{N_{trk}} \right)^2$$

Lower spherocity values **($S_0 \to 0$)** are observed in hard, jetty events

High spherocity **($S_0 \to 1$)** corresponds to soft isotropic events



# Analysed data

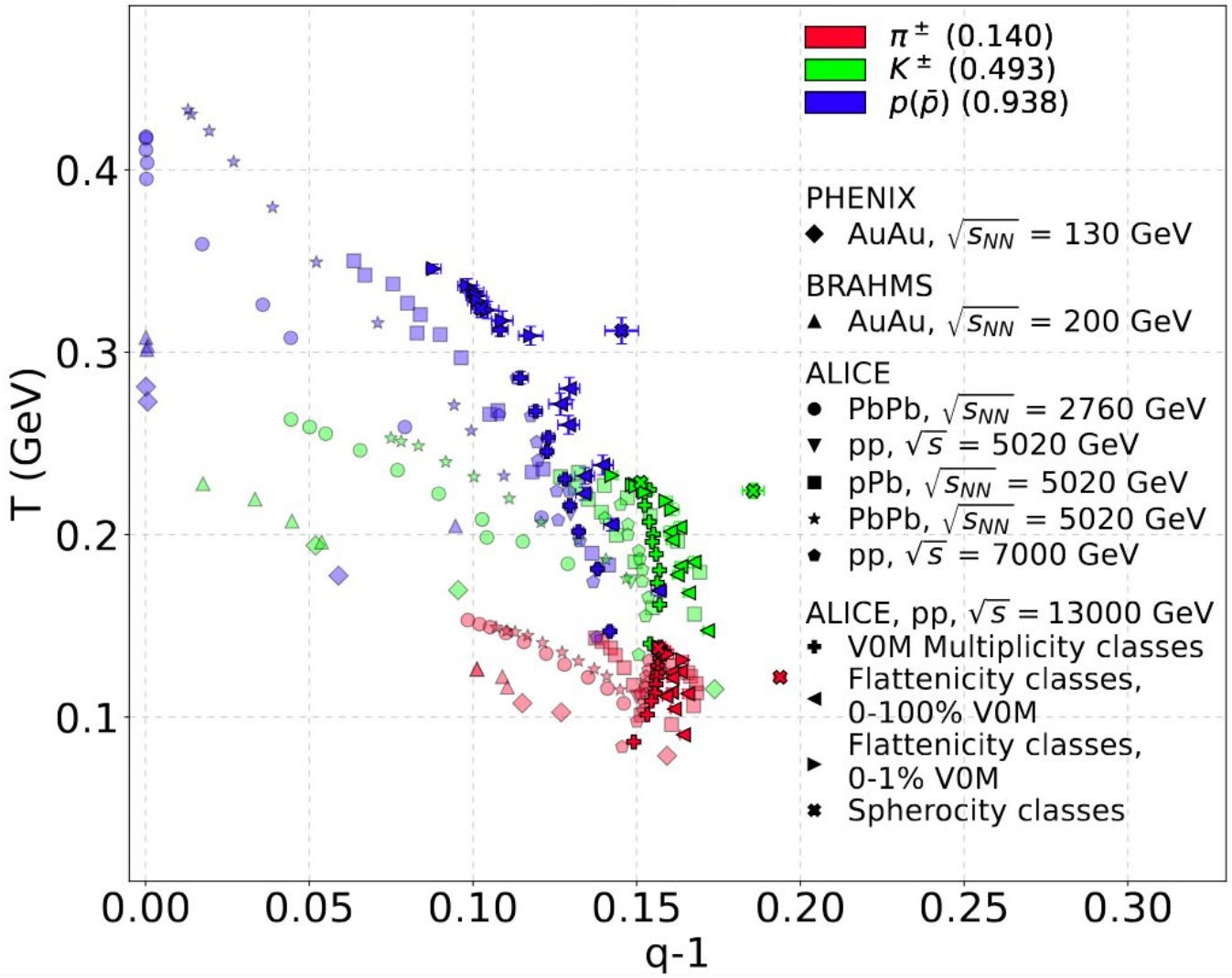
Measurements of pion, kaon, and proton spectra in pp collisions at √s=13 TeV by ALICE experiment

Event classification:

- **V0M multiplicity** (10 classes)
- **Flattenicity**
  - V0M integrated data (8 classes)
  - data from highest V0M percentile (8 classes)
- **Spherocity** at highest V0M percentile (2 classes)

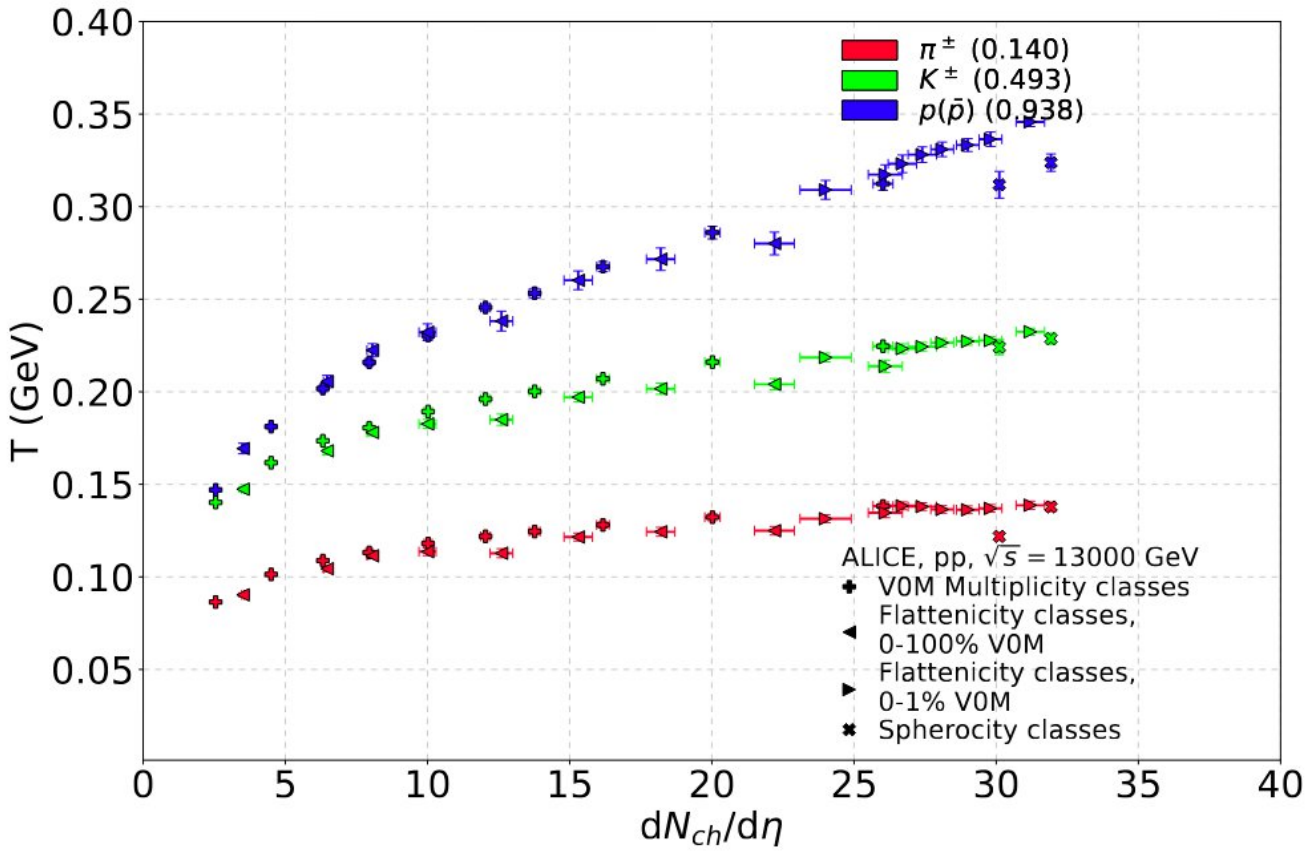
# Tsallis thermometer

- Multiplicity-dependent trends are preserved
- Points shifted towards higher *T* and *q* values w.r.t. √s=7 TeV data
- Points from flattenicity-dependent study behave in similar way to multiplicity-dependent points
- For spherocity-related points a strong *q* dependence is observed



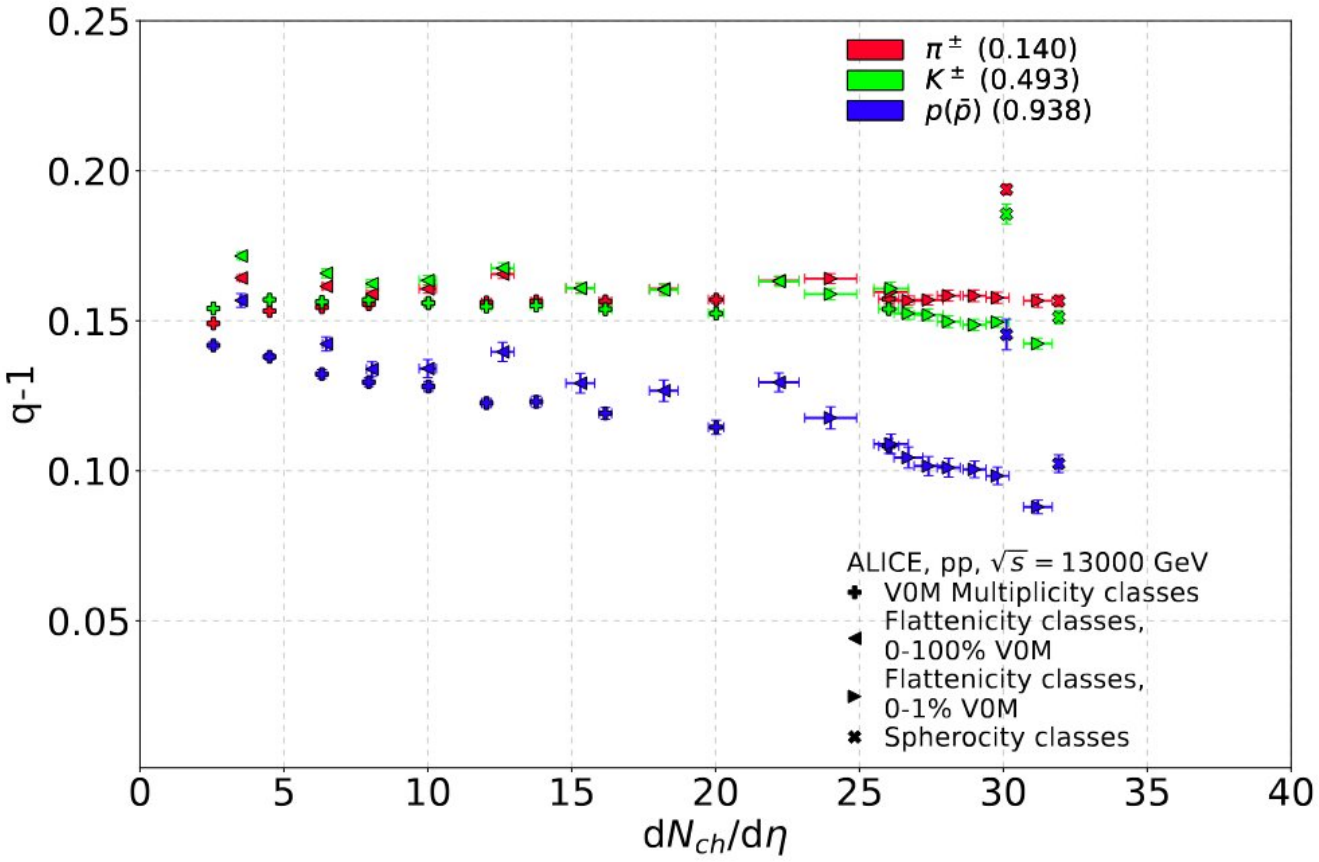
# Tsallis temperature as a function of multiplicity

- For each dataset, *T* rises monotonously with multiplicity
- Multiplicity-dependent data is well complemented by flattenicity-dependent data
- Flattenicity-dependent points from highest V0M percentile continue the trend towards higher multiplicities
- Spherocity selects jetty events that are not part of this trend - sensitivity to event geometry



# Non-extensivity as a function of multiplicity

- No strong multiplicity dependence of *q* parameter on multiplicity for pions and kaons
- A slight decrease is observed for heavier protons
- Spherocity related points show different behaviour for all 3 particle species: *q* values differ significantly based on geometry of events
- Indication that *q* is shifting solely due to the differing event shapes, and not because of multiplicity



# Conclusion

- We studied the non-extensive statistical framework using different event classifiers

- We find that multiplicity and flattenicity classes preserve the scaling trends:
  - $T$ is rising monotonically with multiplicity
  - $q$ shows only a weak dependence

- Spherocity-dependent classifications reveal a different behavior, with considerably higher $q$ values in jetty events:
  - Tsallis framework is sensitive to the event geometry and the underlying production mechanisms
  - The $q$ parameter can be linked to the role of early hard processes

- Tsallis-thermometer is a powerful tool for disentangling the interplay between multiplicity, event shape, and hadron species in high-energy collisions

# Thank you for your attention!