

Collective effects in pp collisions with the balance function of identified particles



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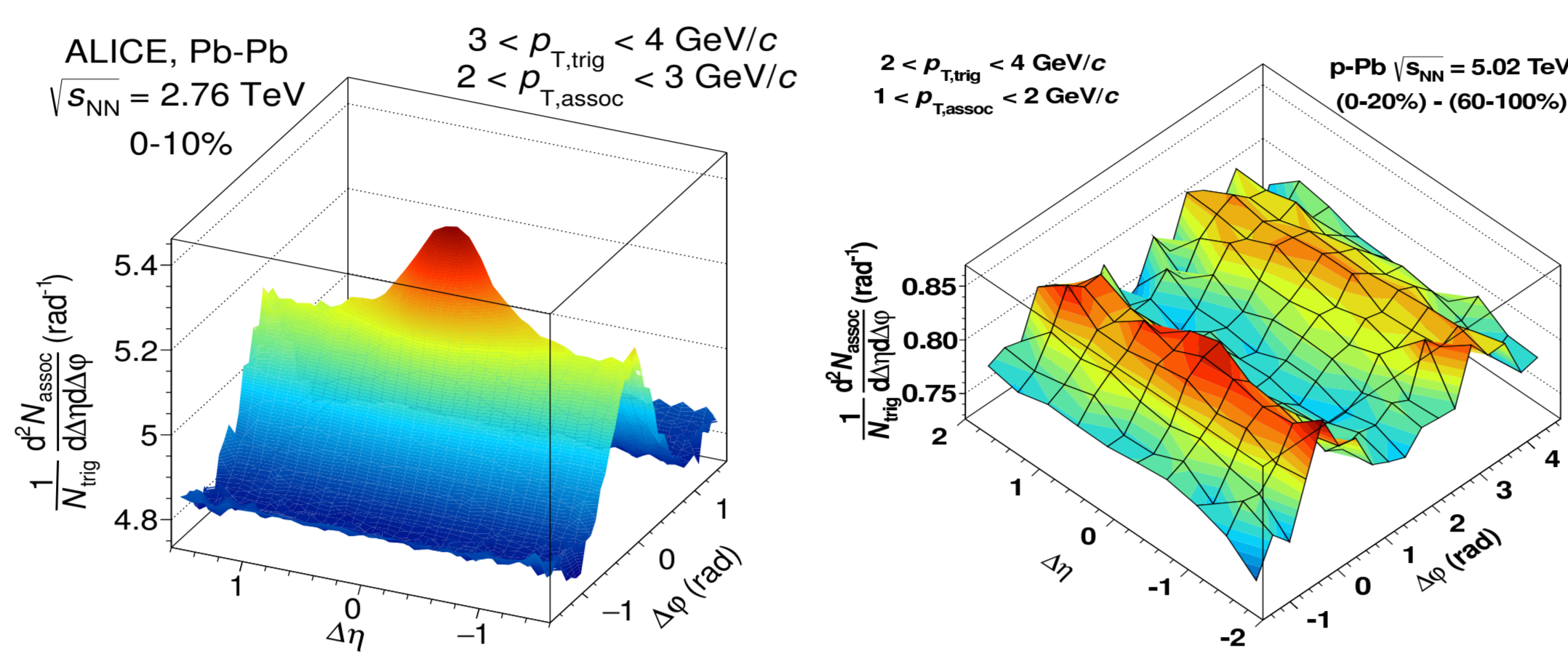
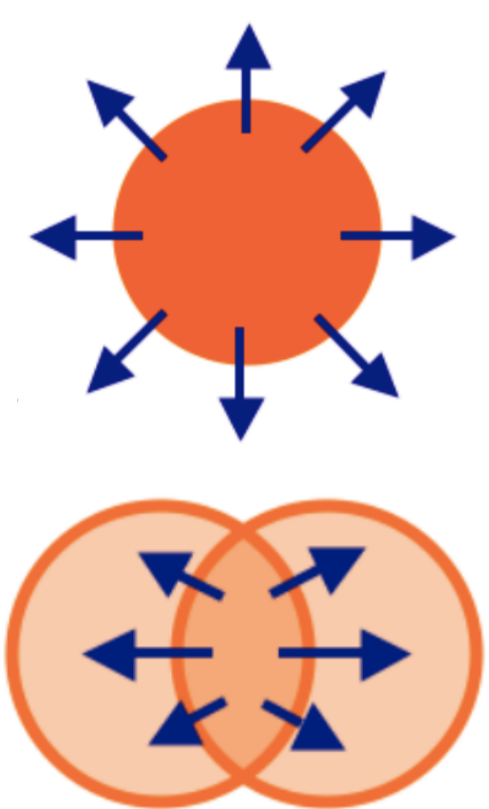


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Collectivity in small systems: two-particle angular correlations

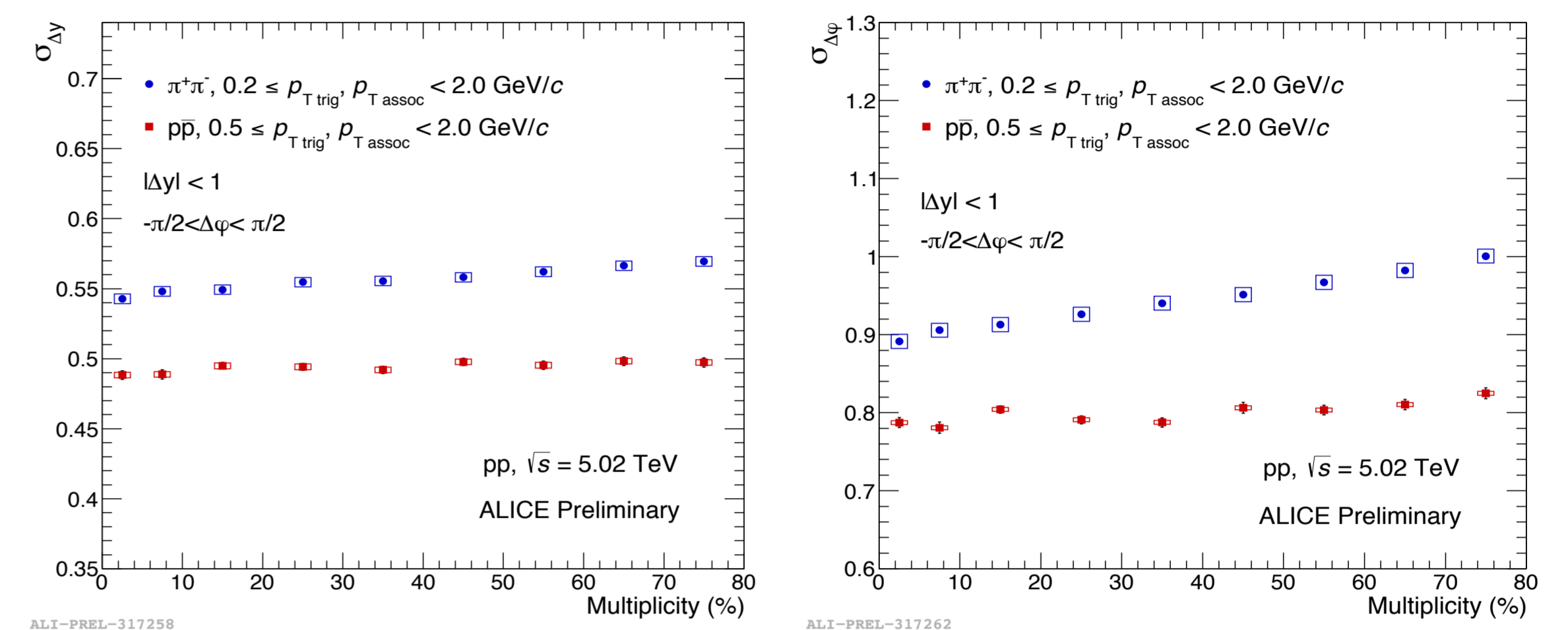
- Collectivity: **feature of the hydrodynamic expansion of quark-gluon plasma (QGP)** created in the heavy-ion collisions
- Recent experimental measurements at RHIC and the LHC indicate the **presence of collectivity signs also in small collision systems** [1,2,3]
- Two-particle angular correlations: observation of the “**near-side ridge**” in the per-trigger yield measurements in **p-Pb and high-multiplicity pp collisions** [1,2]



- The **origin** of these effects in small systems is **not fully understood**

Results: balance function width

- Expectation:** if radial flow drives the narrowing in pp collisions, **heavier particles** (i.e. protons) **should** be affected more than lighter particles (i.e. pions) by higher radial flow, therefore **show more significant narrowing**
- Results:** pions - **narrowing** with increasing multiplicity, **protons - flat dependence** on multiplicity



- Interpretation:** radial flow-like effects might not be the main driving force behind the narrowing of the balance function width in pp system
- What do the models predict?

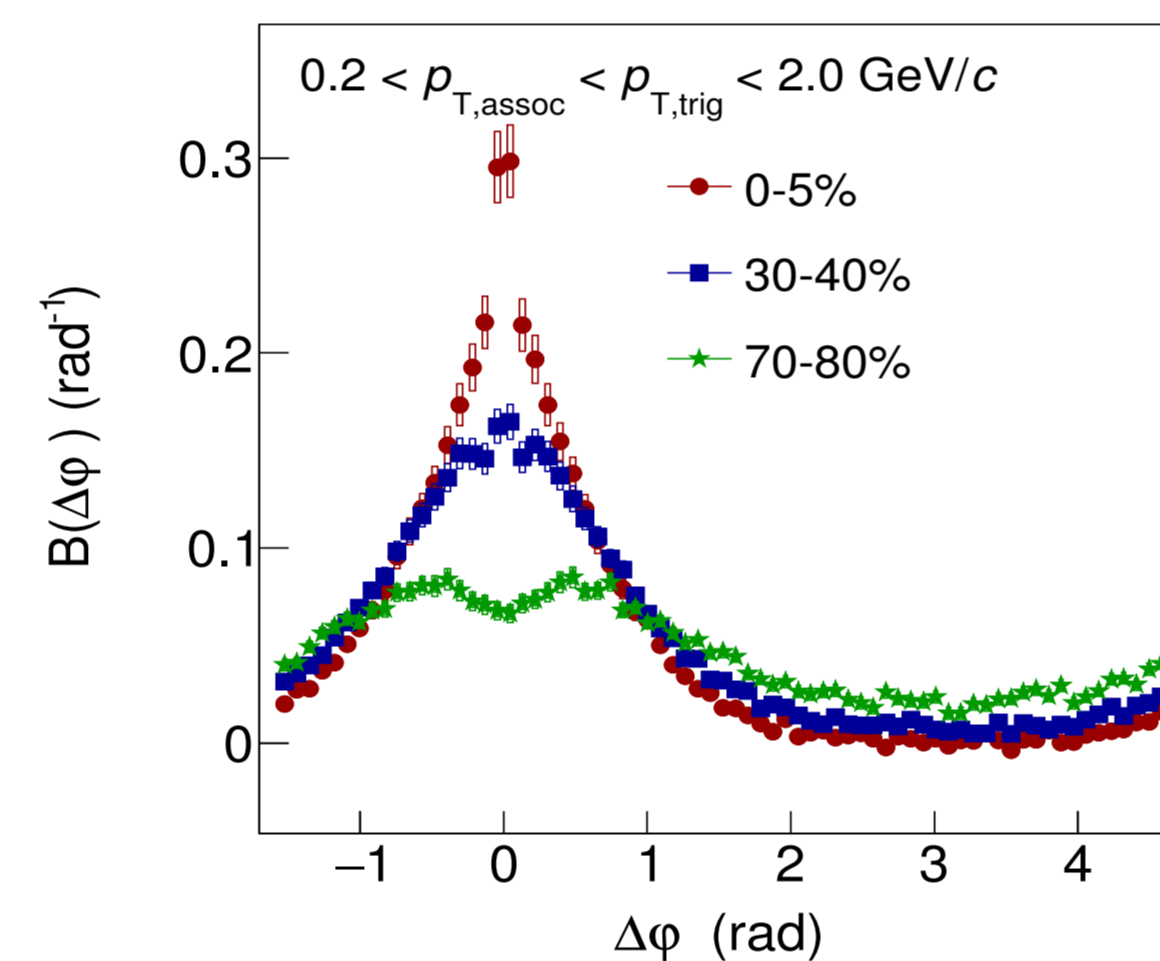
Balance function measurement

- Balance function:** combination of the **charge-dependent per-trigger yields**
- Per-trigger yield:** distribution of the relative pseudorapidity ($\Delta\eta$) and azimuthal angle ($\Delta\phi$) of particle pairs - a “trigger” particle from a certain transverse momentum $p_{T, trig}$ interval and an “associated” particle from a $p_{T, assoc}$ interval corrected for particle pair acceptance

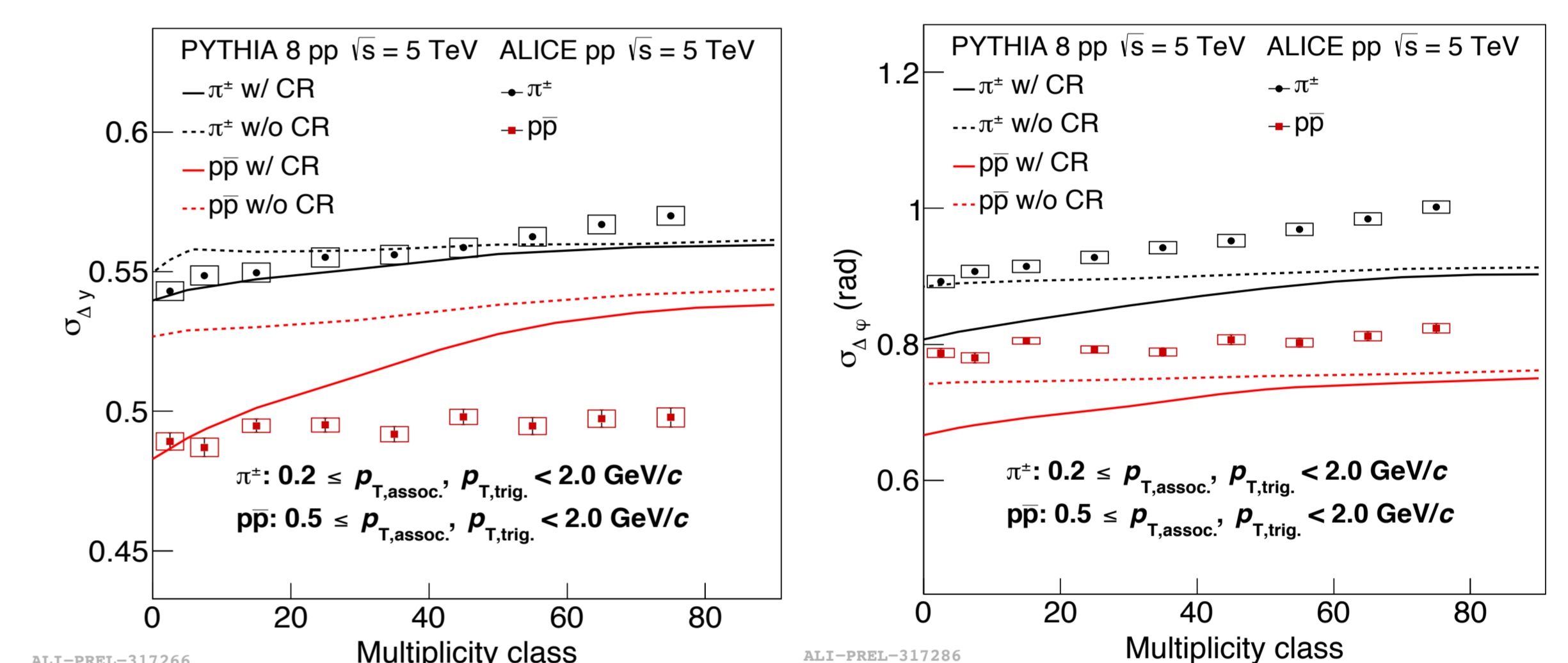
$$B(\Delta\phi, \Delta\eta) = \frac{1}{2} [C_{(+,-)} + C_{(-,+)} - C_{(+,+)} - C_{(-,-)}]$$

$$C_{(+,-)}(\Delta\phi, \Delta\eta) = \frac{1}{N_{trig,+}} \frac{d^2 N_{assoc,-}}{d\Delta\eta d\Delta\phi} = \frac{S_{(+,-)}}{f_{(+,-)}}$$

- Like-sign part is subtracted to keep only **charge-dependent effects** (anisotropic flow cancels out)
- Width (RMS)** $\sigma_{\Delta\eta}$, $\sigma_{\Delta\phi}$ and the **yield (integral)** of the balance function projections reflect the **strength between the balancing charges and their number**



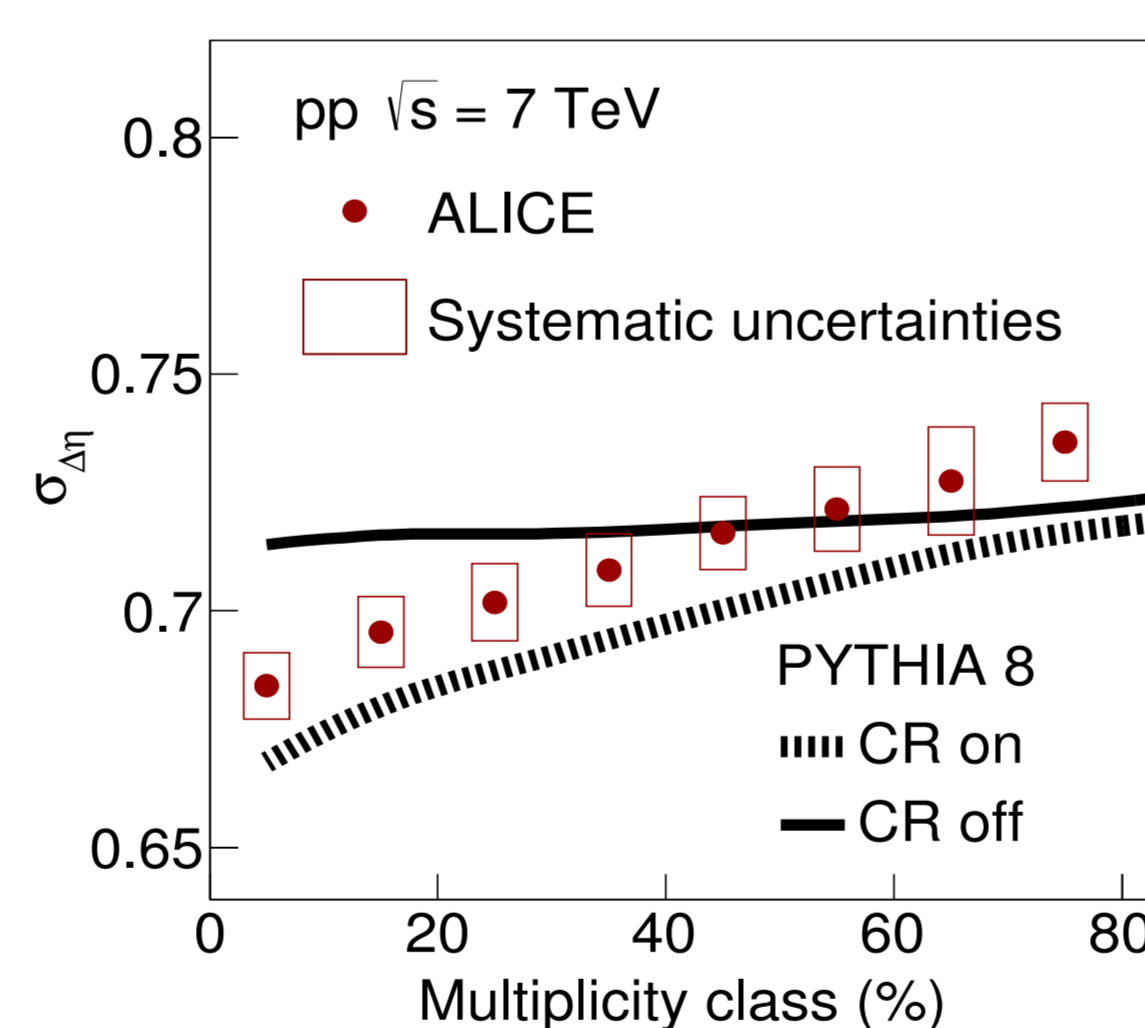
Model comparison



- PYTHIA8 w/o CR:** no significant multiplicity dependence of the balance function width for pions and protons
- PYTHIA8 w/CR:** significant multiplicity dependence more pronounced for protons
- Data not reproduced** by PYTHIA8 predictions
- Color reconnection is disfavored** as the origin of narrowing?

Why study the balance function for identified particles?

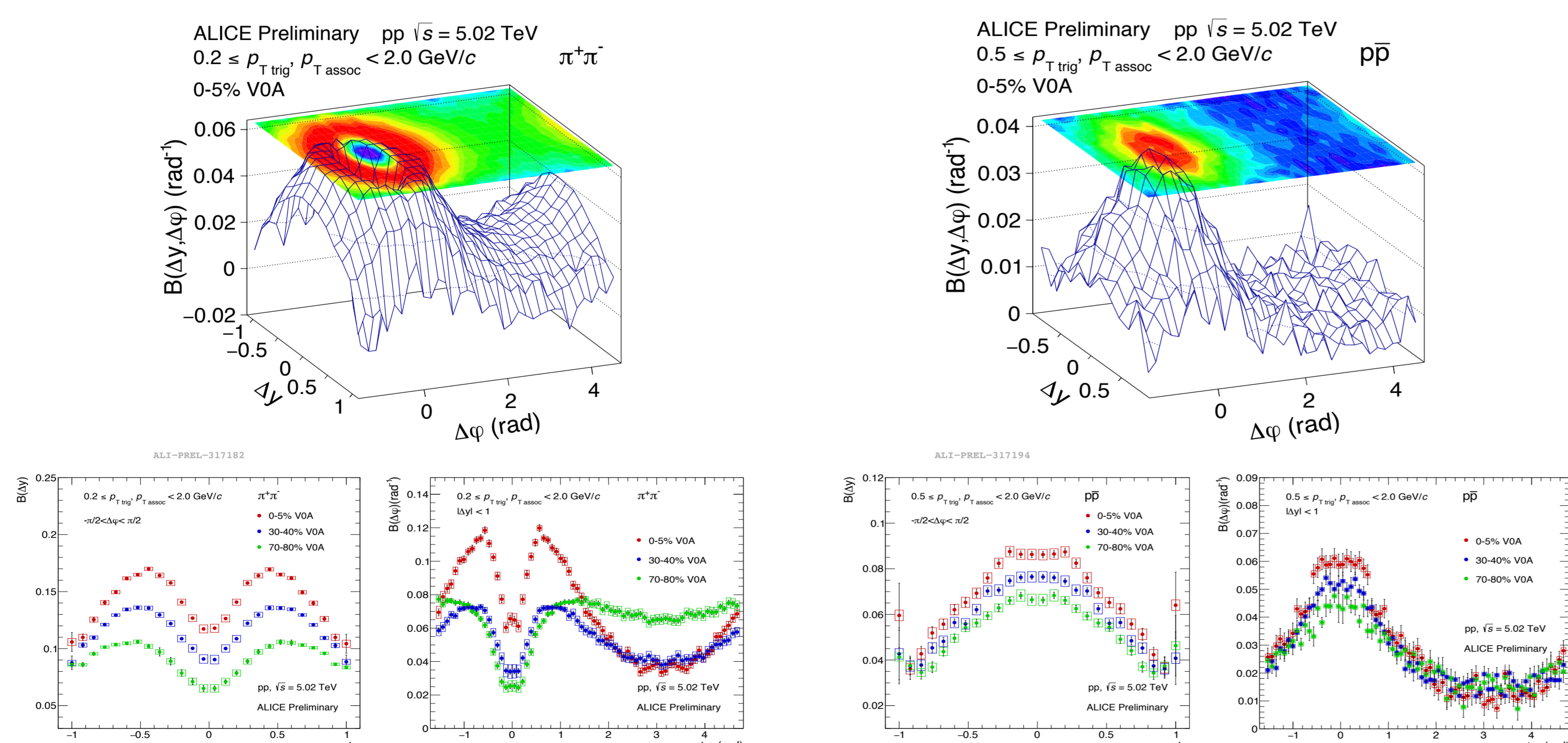
- Previous measurements** for charged particles in pp show **narrowing of the balance function width with increasing multiplicity** in low p_T range (0.2-2 GeV/c) similarly to that observed in Pb-Pb collisions
- Origin in Pb-Pb: **higher radial flow and later-stage production of the charges** in the central collisions [4]
- Origin in pp: **collectivity** or other effects that resemble it, i.e. **color reconnection?** (time component is not relevant because of the small system size)
- Measurements of identified particles** in pp **further investigate the narrowing** due to mass's influence on the momentum



Summary

- Narrowing** of the balance function width with increasing multiplicity is observed **for pions but not for protons**
- The data is not in agreement with the expectation** of radial flow-like effects being the main driving force behind narrowing in pp collisions
- Models that incorporate collectivity** such as PYTHIA8 with color reconnection expect more pronounced decrease for heavier particles which is **not supported by data**

Results: two-dimensional balance function and projections



- Near-side dip in pion balance function** presumably originating from Hanbury Brown and Twiss (HBT) effect and resonance contribution
- Significant **multiplicity dependence**

Outlook

- Kaon balance function:** removal of ϕ resonance contribution in the data
- Extensions** that will help with understanding of hadron formation processes and provide an important input to the particle production models for pp collisions:
 - balance function **yield studies**
 - balance function at **high p_T**
 - balance function for **cross correlations** (πK , $K p$, πp etc)
- Same studies and comparison** of the results **across different systems** (pp, p-Pb, Pb-Pb) at the same energy

References

- [1] V. Khachatryan et al. [CMS Collaboration], Phys.Rev.Lett. 116 (2016) no.17, 172302 arXiv: 1510.03068 [nucl-ex]
- [2] B.Abelev et al. [ALICE Collaboration], Phys.Lett. B719 (2013) 29-41, arXiv:1212.2001 [nucl-ex]
- [3] S.Acharya et al. [ALICE Collaboration], Phys.Rev.Lett. 123 (2019) no.14, 142301, arXiv: 1903.01790 [nucl-ex]
- [4] J. Adam et al. [ALICE Collaboration], Eur.Phys.J. C76 (2016) no.2, 86 arXiv:1509.07255 [nucl-ex] CERN-PH-EP-2015-263