Measurements of Pion Balance Functions in Pb-Pb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE
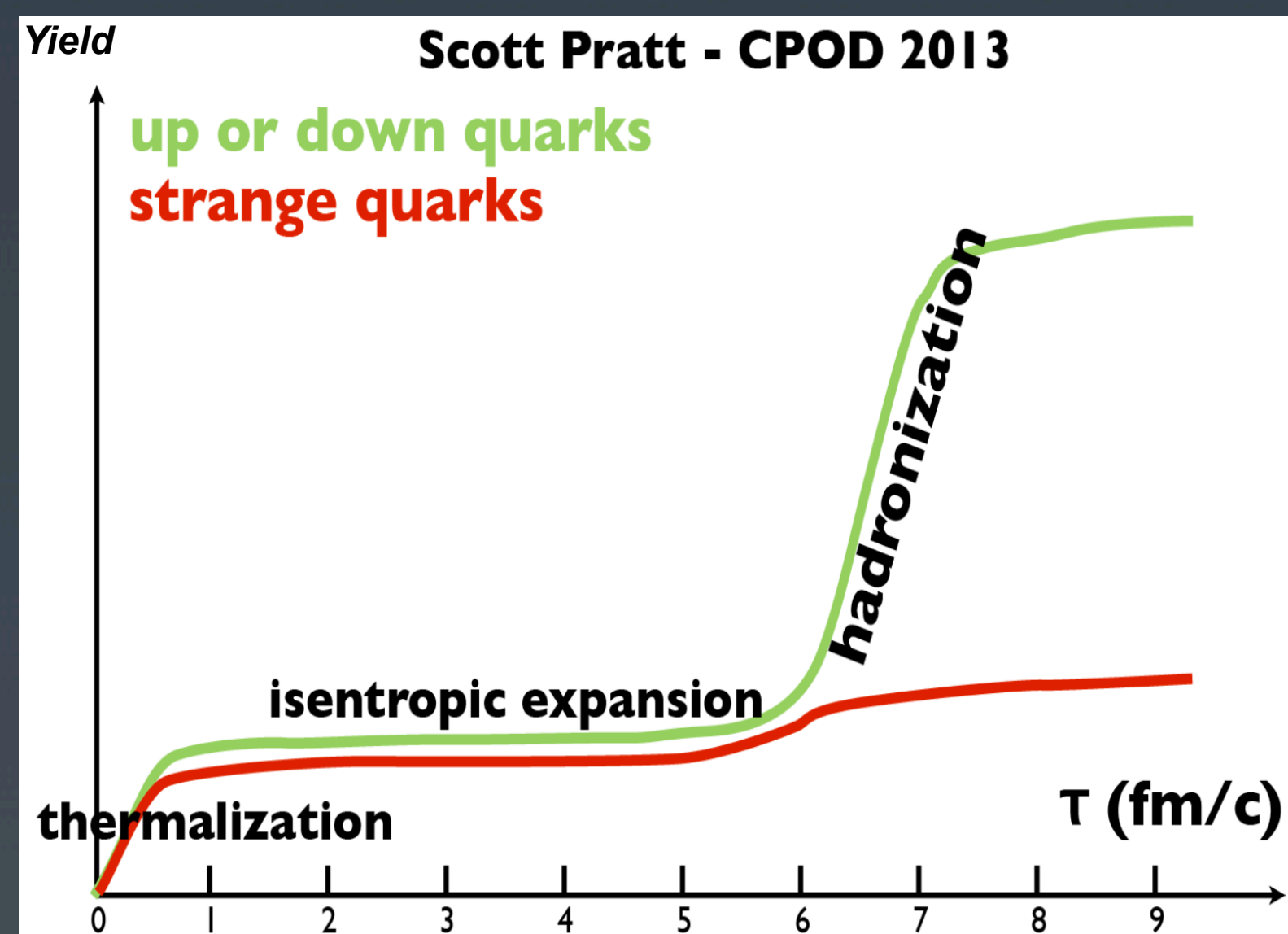
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I. Motivation:

The two-wave quark production scenario is investigated experimentally by measuring Balance Functions of identified particle pairs [1].

Scott Pratt - CPOD 2013
up or down quarks
strange quarks
hadronization
isentropic expansion
thermalization
Yield
τ (fm/c)

Charged-pion Balance Functions measured in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV by ALICE.

II. Balance Function Observable:

Balance Functions characterize correlations between charge/anti-charge pairs.

$$B(\Delta y) = \frac{1}{2}\left\{ \frac{\langle N_{+-}(\Delta y)\rangle - \langle N_{++}(\Delta y)\rangle}{\langle N_+\rangle} + \frac{\langle N_{-+}(\Delta y)\rangle - \langle N_{--}(\Delta y)\rangle}{\langle N_-\rangle} \right\}$$

N_i — single particle number; $N_{ij}(\Delta y)$ — pair number.

Balance Functions rewritten in terms of R_2:

$$B(\Delta y) \approx \frac{dN_{ch}}{dy} R_2^{CD} = \frac{dN_{ch}}{dy}\frac{1}{2}\left[R_2^{+-}(\Delta y) - R_2^{++}(\Delta y) + R_2^{-+}(\Delta y) - R_2^{--}(\Delta y) \right]$$

dN_{ch}/dy — multiplicity factor.

$$R_2(y_1, y_2) = \frac{\rho_2(y_1, y_2) - \rho_1(y_1)\rho_1(y_2)}{\rho_1(y_1)\rho_1(y_2)}$$ Normalized Cumulant

$\rho_1(y)$, $\rho_2(y)$ — single, pair number densities.
Similar for $B(\Delta\varphi)$

III. Factors Influencing Balance Function:

- Two-stage quark production
  - String/Color tube Fragmentation
  - QGP Hadronization
  - 2-, 3-decays of Resonances
- Presence of Jets (quenched or not)
- Coulomb Effects, Net-Q>0
- HBT contributions to the LS correlators
- Collective Expansion — Radial Flow
- (Charge Dependent) Anisotropic Flow
- Viscous Effects
- Thermal Diffusion Effects
- Momentum Conservation

IV. Pion Balance Function Measurement Results:
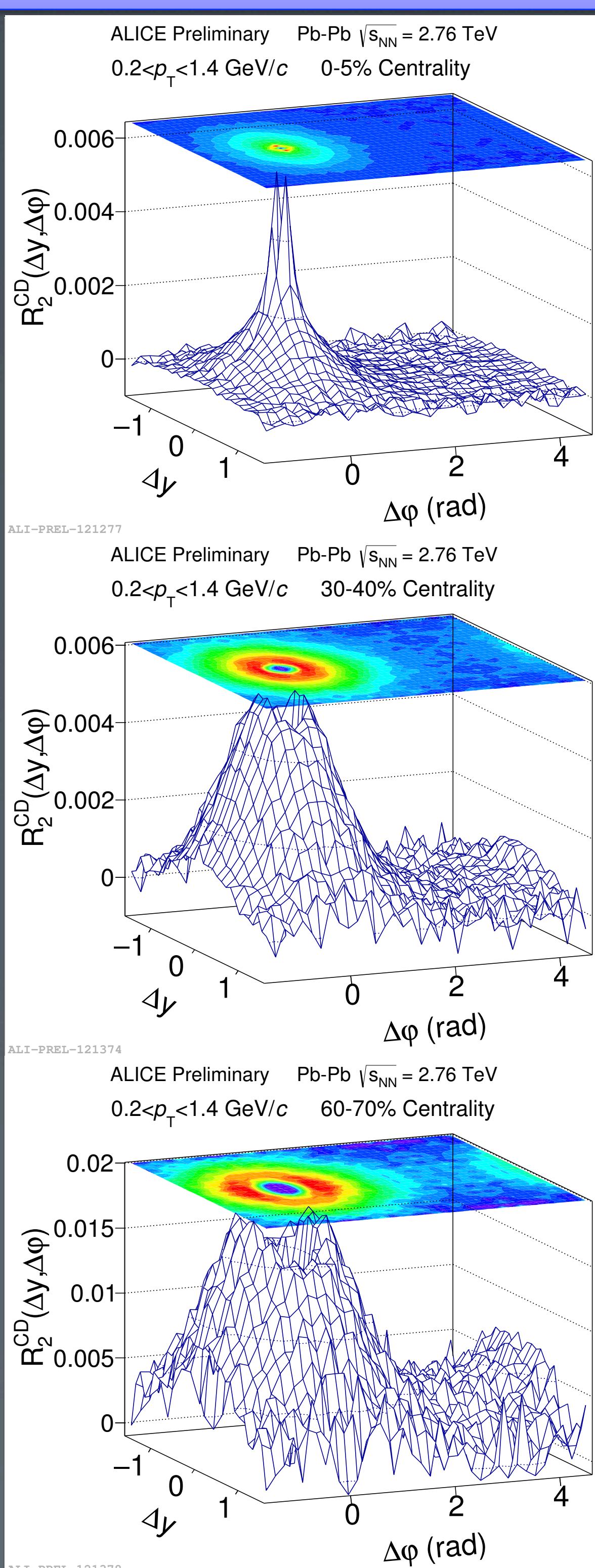
- 2D $R_2^{CD}(\Delta y, \Delta\varphi)$ for selected centralities.
- Prominent near side peak observed at all centralities.
- Near side peak determined by charge conservation, particle production, system evolution, and HBT effect.
- $R_2^{CD}(\Delta y, \Delta\varphi)$ without showing HBT downward peak .
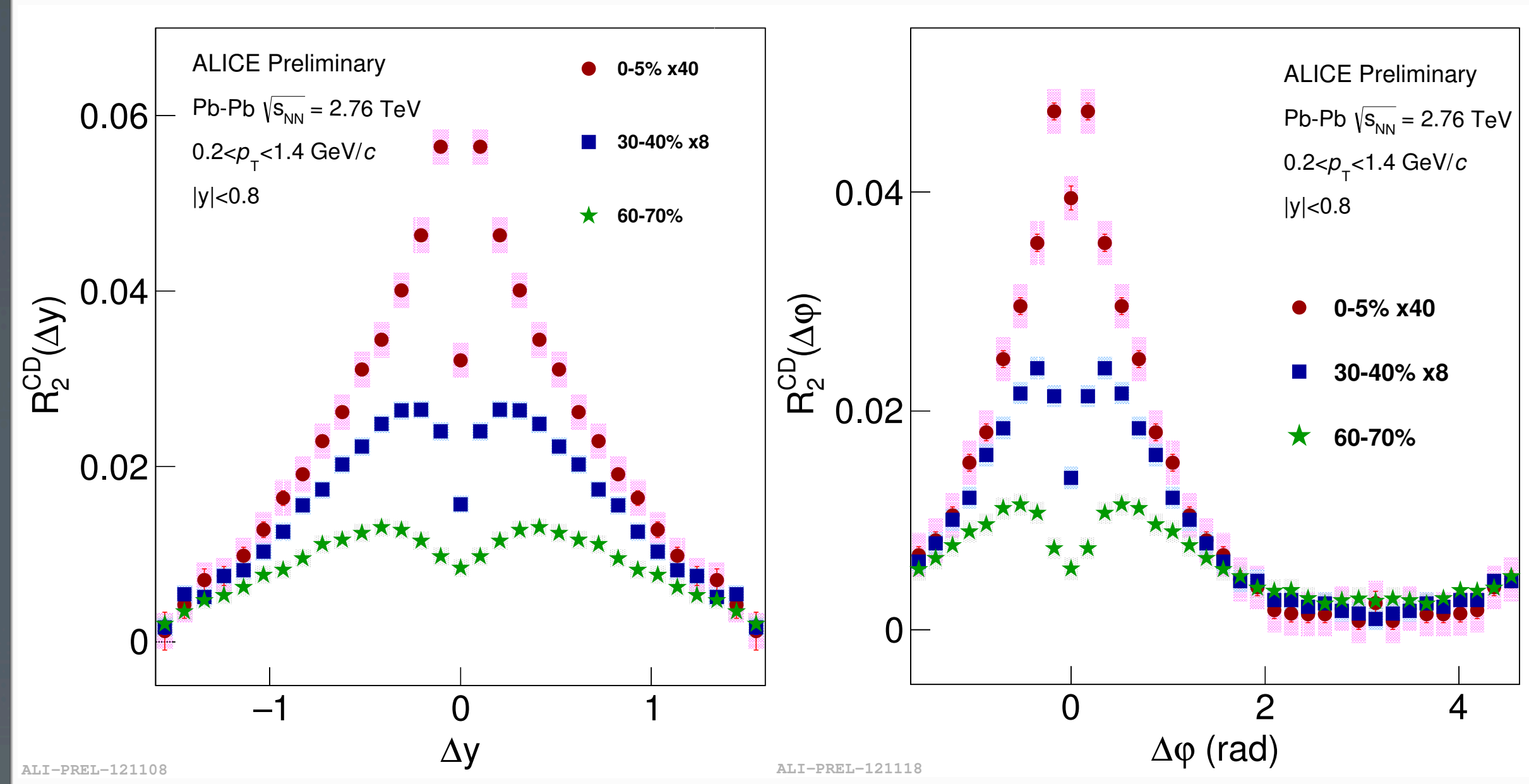
- Projections of 2D $R_2^{CD}(\Delta y, \Delta\varphi)$ along Δy and $\Delta\varphi$ used to quantitatively assess the widths of pion Balance Functions.
- $R_2^{CD}(\Delta y)$ projected for near side ($|\Delta\varphi|<\pi/2$).
- $R_2^{CD}(\Delta\varphi)$ projected for full Δy range ($|\Delta y|<1.6$).
- RMS and weighted average reported as pion Balance Function widths.
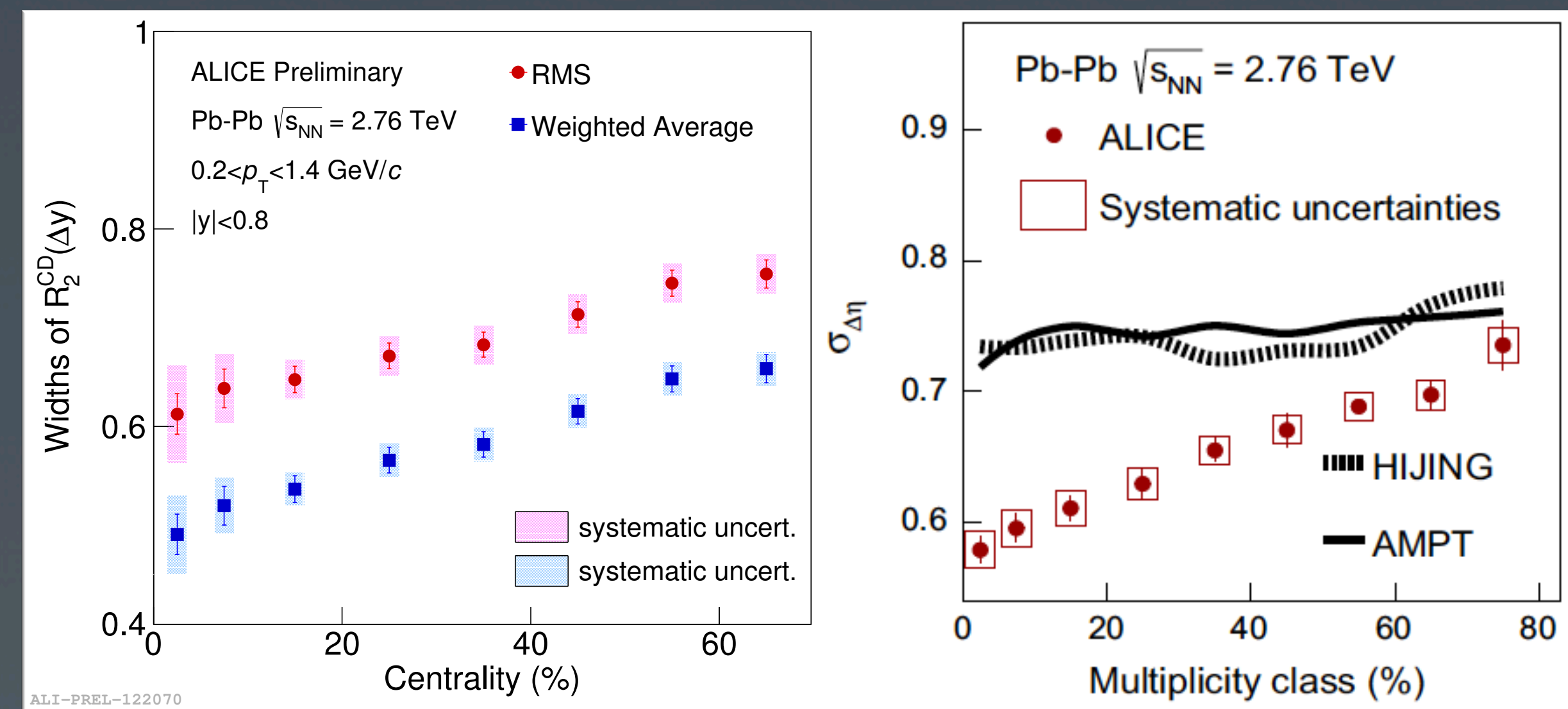
- Left: Pion Balance Function widths in Δy.
- Right: ALICE published [3] unidentified particle $B(\Delta\eta)$ widths.
- Pion $B(\Delta y)$ widths and unidentified particle $B(\Delta\eta)$ widths — similar narrowing trend with increasing centrality.
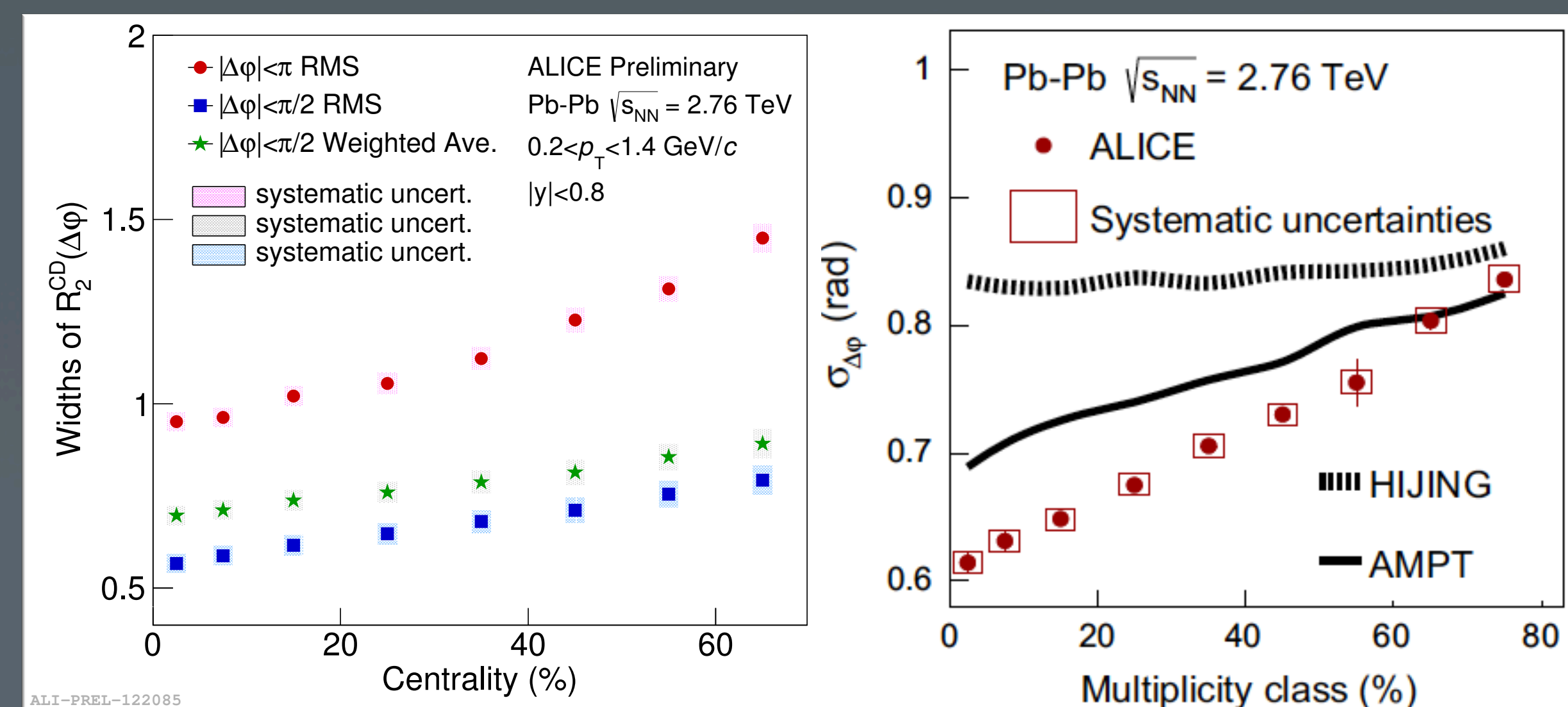
- Left: Pion Balance Function widths in $\Delta\varphi$.
- Right: ALICE published [3] unidentified particle $B(\Delta\varphi)$ widths.
- Pion and unidentified particle $B(\Delta\varphi)$ widths — qualitatively similar narrowing trend with increasing centrality.

V. Summary & Outlook:

- Widths of pion Balance Functions along Δy and $\Delta\varphi$ observed to reduce with increasing centrality in Pb-Pb collisions.
- Observations in agreement with results from STAR[2] for pion and ALICE[3] for unidentified particle Balance Functions.
- Observed narrowing Balance Functions with increasing centrality consistent with expectations for two-wave quark production and strong radial flow.
- Detailed modeling required to assess roles of radial flow, system evolution, thermal viscous diffusion, momentum correlations, and other effects.

VI. Reference:

[1] Pratt, Phys. Rev. C 85 (2012) 014904

[2] STAR Collaboration, Phys. Rev. C 82, 024905 (2010)

[3] ALICE Collaboration, Eur. Phys. J. C 76 (2016) 86

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