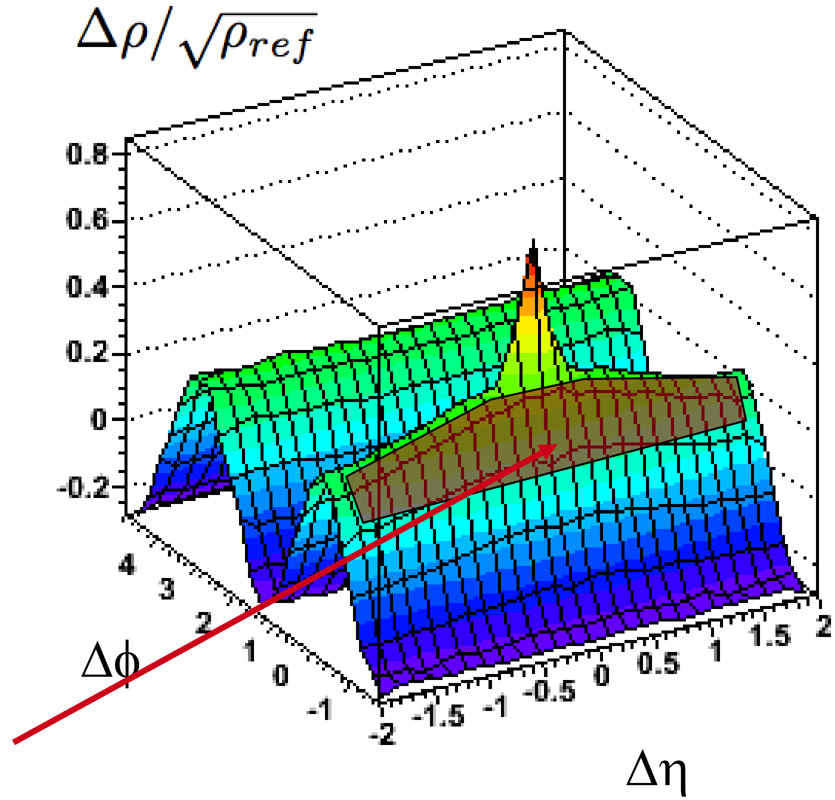
Untriggered di-hadron correlations in Pb+Pb $\sqrt{s_{NN}}$ = 2.76 TeV

Anthony Timmins for the ALICE collaboration

Motivation…

- Untriggered correlations provide **map of bulk correlation structures**
  - Examine all hadron pairs as a function of (Δϕ, Δη)
- **Main contributors at RHIC energies:**
  - **Elliptic flow**
    - Shows up as cos (2Δϕ) structure….
  - **“Soft ridge”**
    - Shows up as elongated nearside 2D Gaussian..
- **Spike (0,0)**: HBT + γ->e+e- conversions…

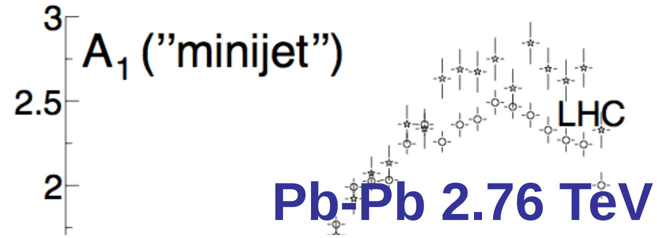
Au+Au 200 GeV



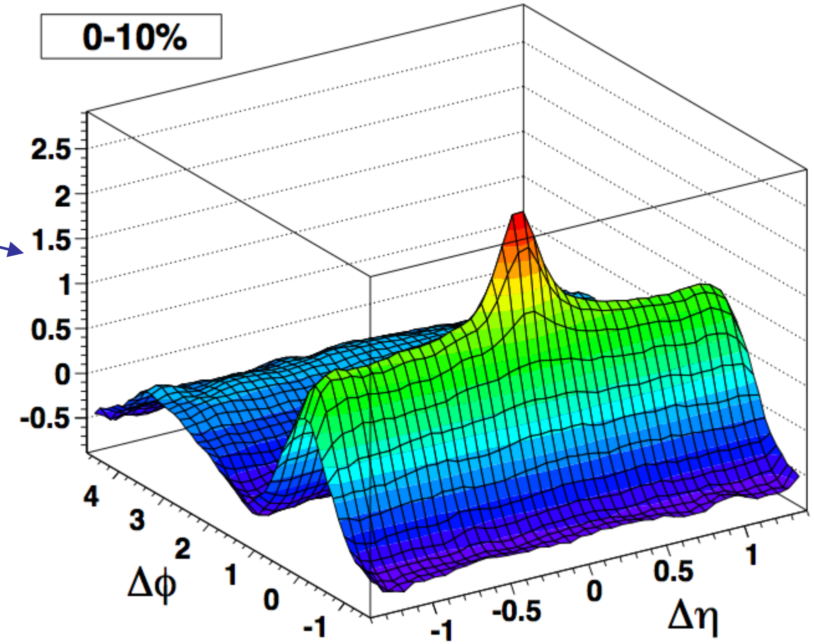
J. Phys. G35:104090, 2008 *(STAR)*

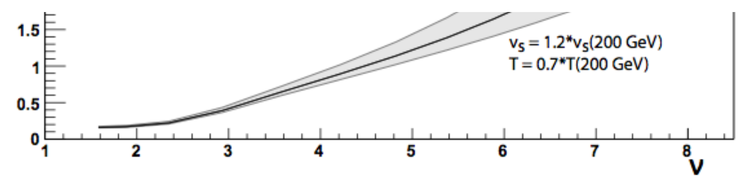
Motivation…

- **Initial energy density fluctuations**
  - Mishra et.al, Phys. Rev. C 77 (064902) 2008
  - Takahashi et.al, Phys. Rev. Lett. 103, 242301 (2009)
  - Alver and Roland, Phys. Rev. C 81 (2010) 054905
  - **Werner et al, arXiv:1104.3269v1**
  - **Sorensen et al, arXiv:1101.1925v1** \Delta \rho
- **CGC flux tubes and/or radial flow**
  - Voloshin, Phys. Lett. B 632 (2006) 490
  - Dumitru, Gelis, McLerran, Venugopalan Nucl.Phys.A810:91-108,2008
  - **Gavin, McLerran and Moschelli: Phys. Rev. C79 (2009) 051902**
  - Moschelli and Gavin: Nucl.Phys.A836:43-58,2010
- **Modified mini-jets (pQCD related explanation)**
  - T. Trainor, Phys. Rev. C 80 (2009) 044901



Pb-Pb 2.76 TeV





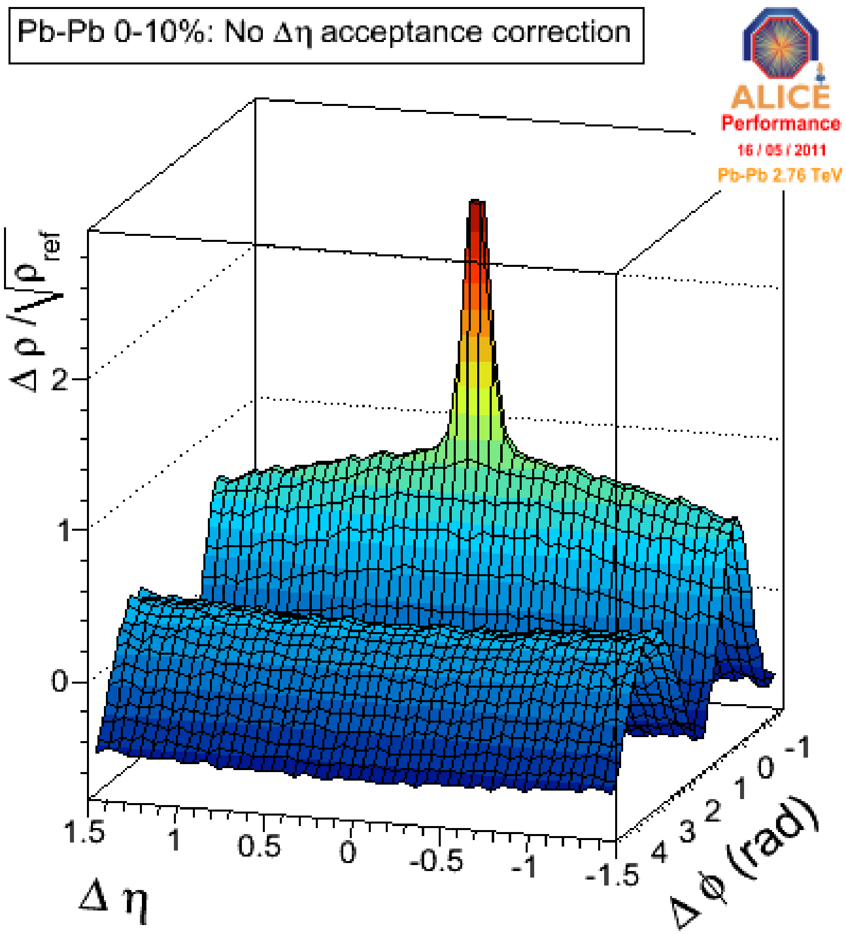
$\nu = 2\langle N_{bin}\rangle / \langle N_{part}\rangle$

Correlation function extracted…

$$\frac{\Delta\rho}{\sqrt{\rho_{ref}}} = \frac{\rho_{sib} - \rho_{ref}}{\sqrt{\rho_{ref}}} = \frac{dN^2}{d\eta d\phi}\left(\frac{\rho_{sib}}{\rho_{ref}} - 1\right)$$

- Designed to be **independent of multiplicity if Pb+Pb is superposition of p+p**
- **Correlation function measure # of correlated pairs per particle**
  - ρ_{sib} signal +background (real events)
  - ρ_{ref} background (mixed events)
    - $\sqrt{\rho_{ref}} = d^2N/\,d\eta d\phi$ = yield of charged hadrons
- **Charged hadrons with p_T > 0.15 GeV/c** used to form correlation function
  - Prefactor: Use published **yield (p_T > 0 GeV/c)**
  - Convert to **yield (p_T > 0.15 GeV)** with estimated fraction

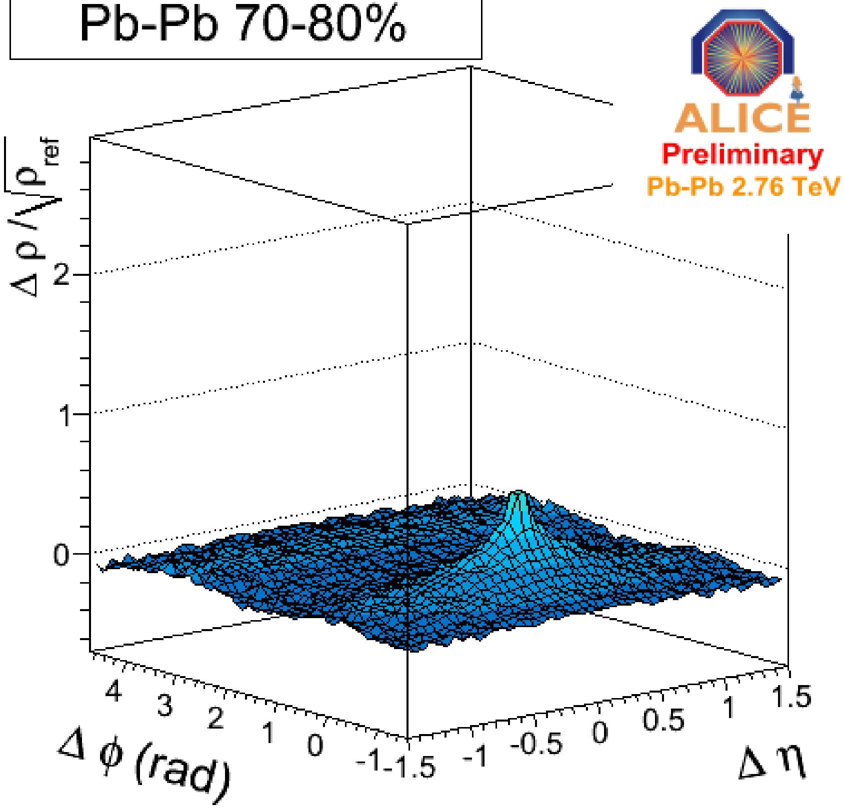
Sources of systematic uncertainty…



- **Normalisation: $d^2N/ d\eta d\phi$**
  - Published uncertainties
  - Yield conversion uncertainty
- **Mixed event Δη acceptance**
  - Slightly more narrow than sibling
    - Causes small "wings"
    - Change with analysis details
    - Can be parameterised
- **Δη acceptance correction**
  - Refers to wing removal via parameterisation….

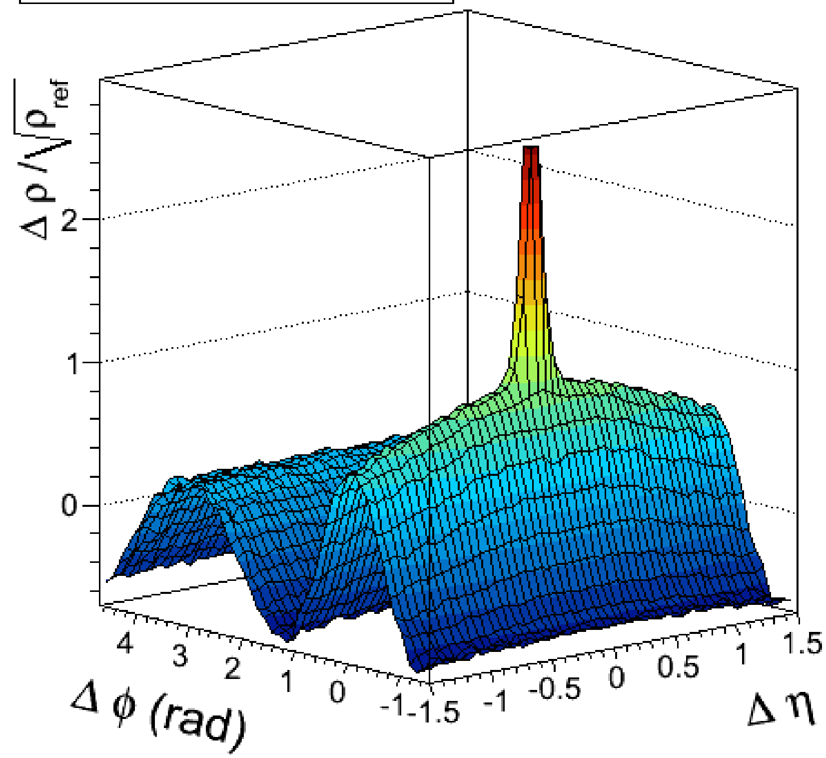
Untriggered correlations…

Pb-Pb 70-80%



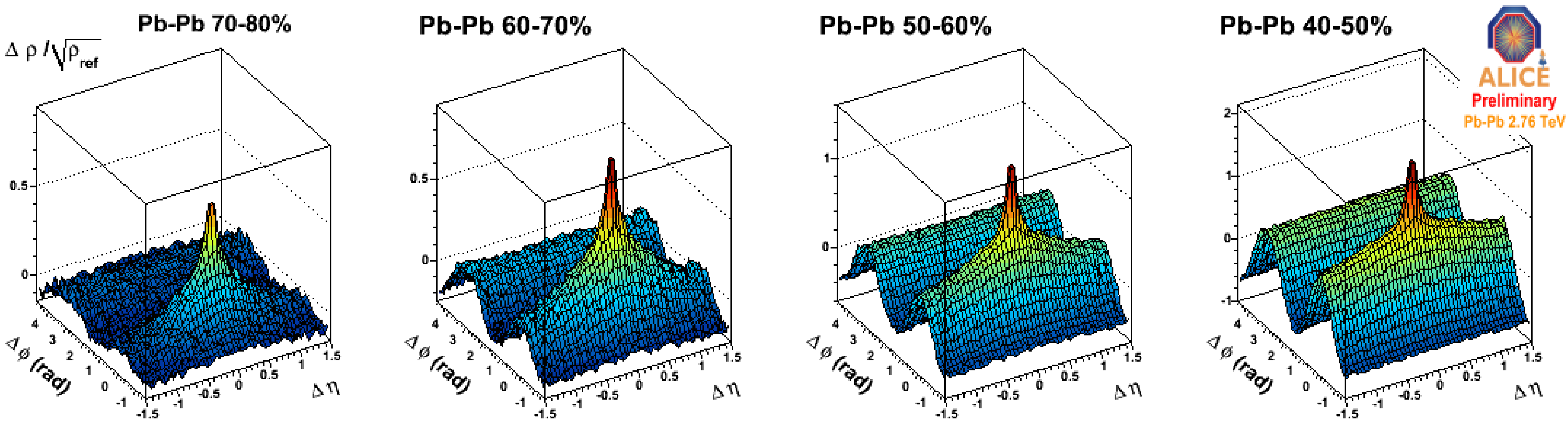
Pb-Pb 0-10%

Same scale



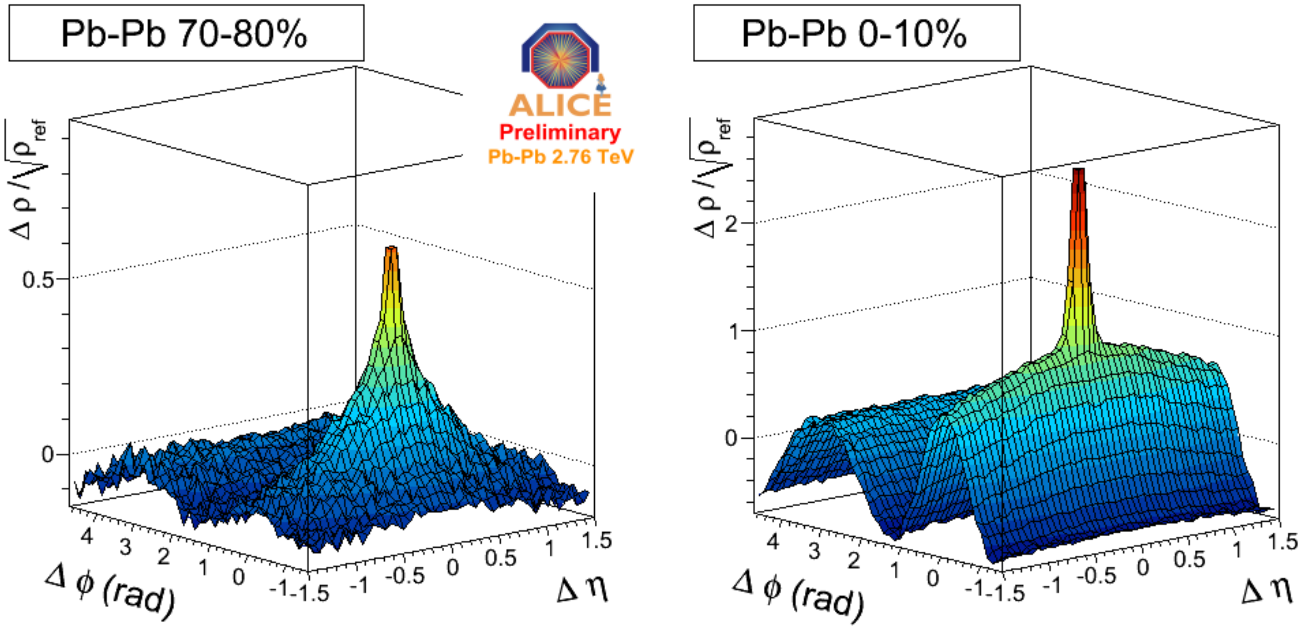
- **Pronounced difference** in **central Pb+Pb** collisions

Untriggered correlations…



- **Evolution:** cos (2Δϕ) structure (v_2) becomes dominant in mid-central collisions..

Fit decomposition…



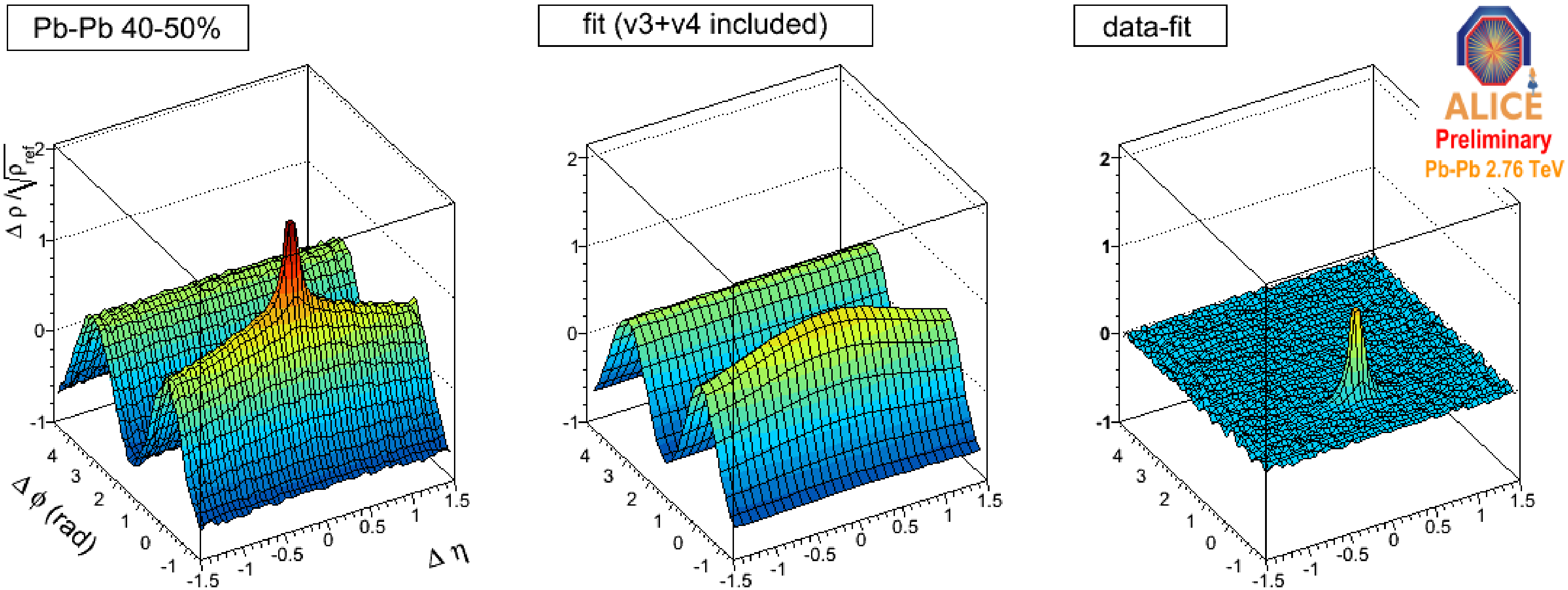
Previous RHIC method

$$\Delta\rho/\sqrt{\rho_{ref}} = A + gaus(\Delta\eta, \Delta\phi) + Bcos(\Delta\phi) + Ccos(2\Delta\phi)$$

Alternative method: Include v_3 and v_4

Direct evidence for higher harmonics observed for A-A 0-1%:

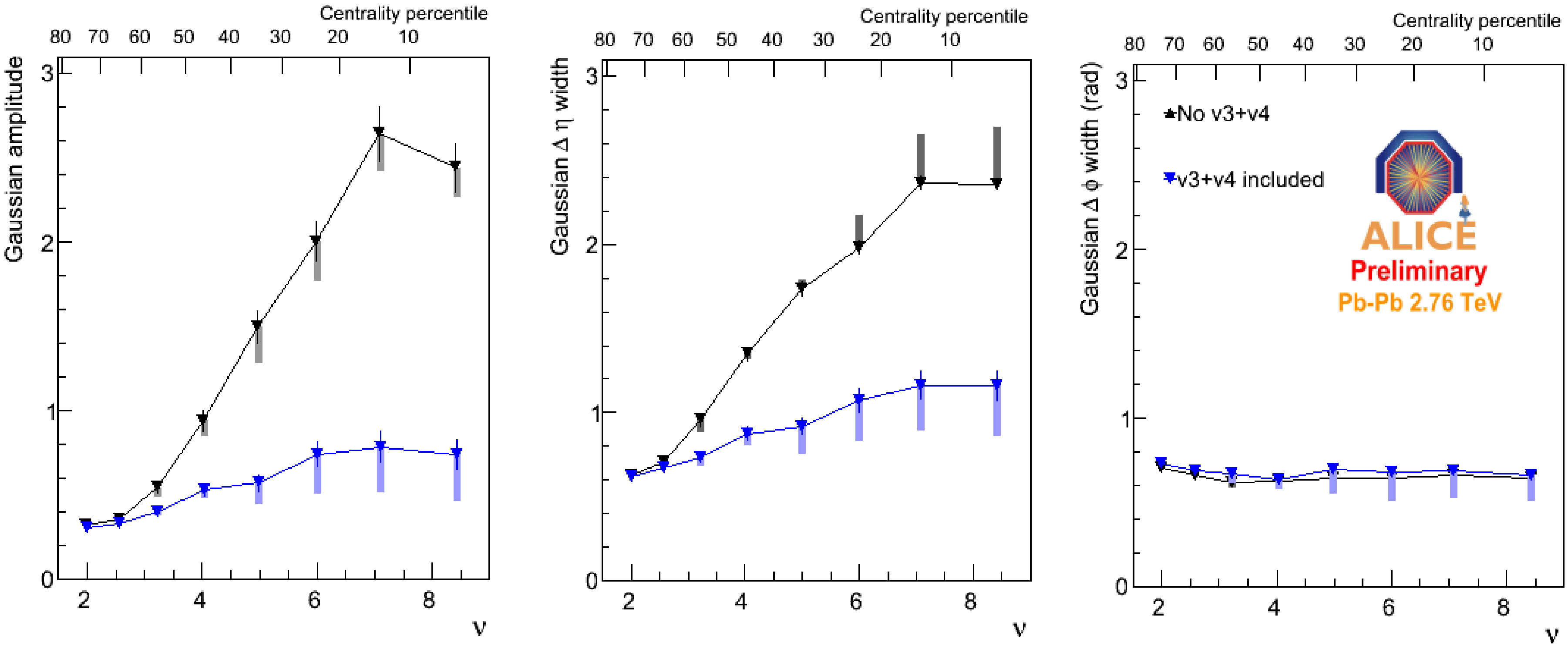
Fit decomposition…



- **Fits reproduce the data well outside 0,0 peak**
  - Peak bins given zero weight…

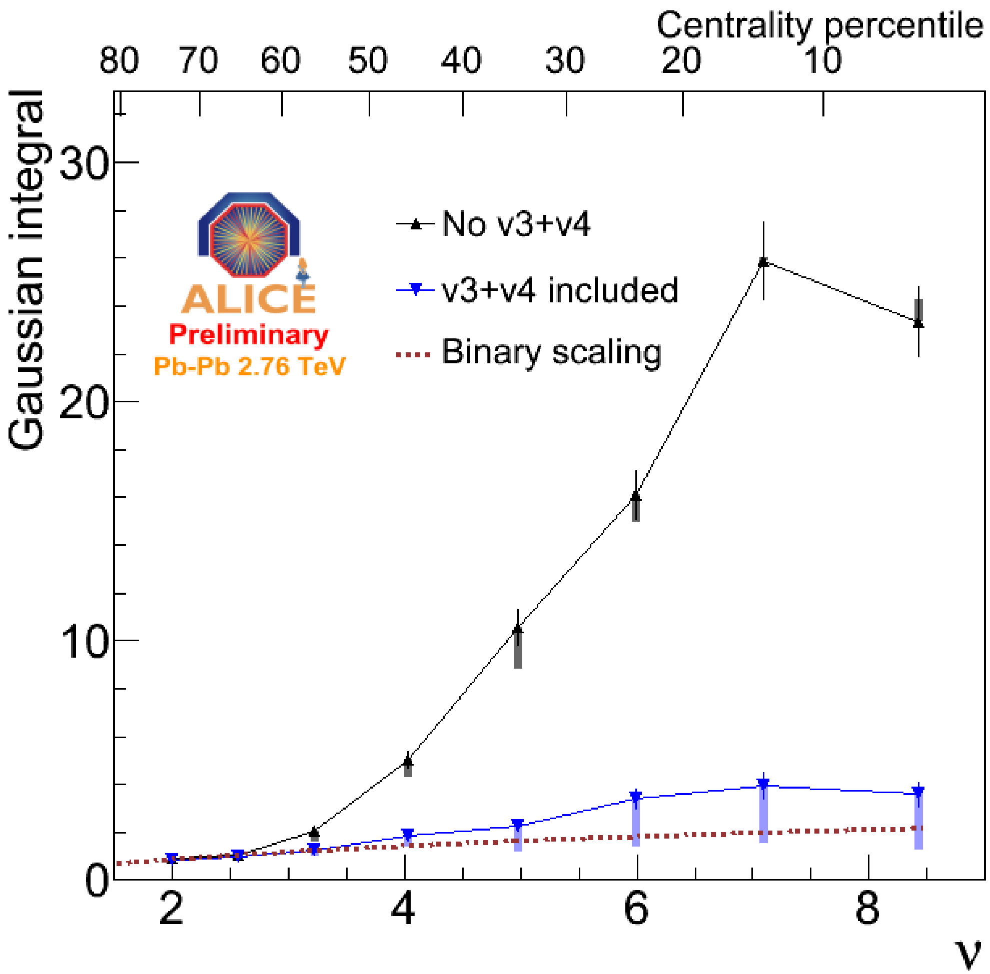
- **χ^2/DOF 1→ 1.5 (evaluated outside 0,0 peak)**
  - Fits with higher harmonics slightly better

Soft ridge terms vs centrality…



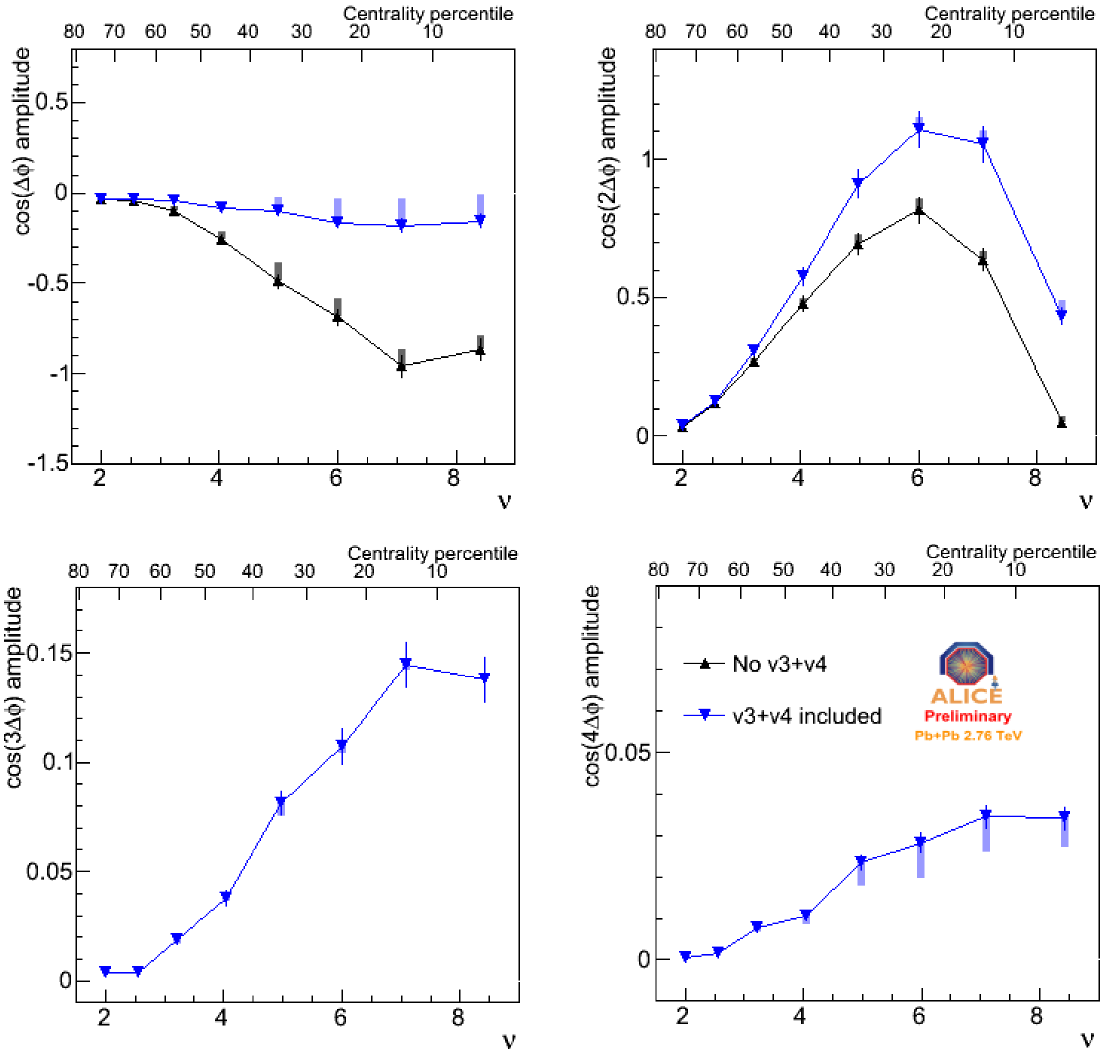
- **Boxes** show uncertainties from **Δη acceptance correction,** errors bars all other uncertainties
- Including **higher harmonics has significant effect** on 2D Gaussian parameters…

Soft ridge terms vs centrality…



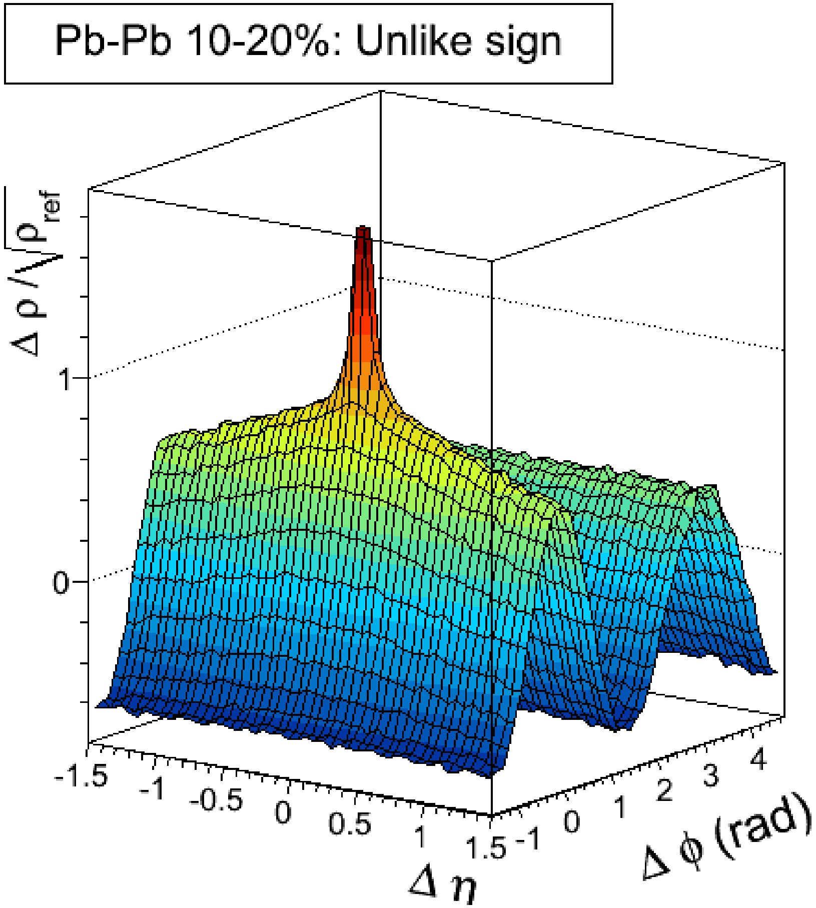
- **Gaussian integral** related to # of correlated pairs in 2D Gaussian…
- **Dashed line**
  - Assumes # Gaussian pairs scales with $\langle N_{bin} \rangle$ from peripheral collisions
- **Blue Gaussian** scales more closely with $\langle N_{bin} \rangle$
  - **Is the soft ridge hard**?

Background terms vs centrality…



- Increases in **cos(2Δϕ)**, **cos(3Δϕ), cos(4Δϕ)** reduce soft ridge for **blue** case
- **cos (Δϕ)** amplitude gets smaller…
- **Blue amplitudes** can be **converted to v_N** (not shown):
  - Consistent with http://arxiv.org/abs/1107.0285 (ALICE) results…

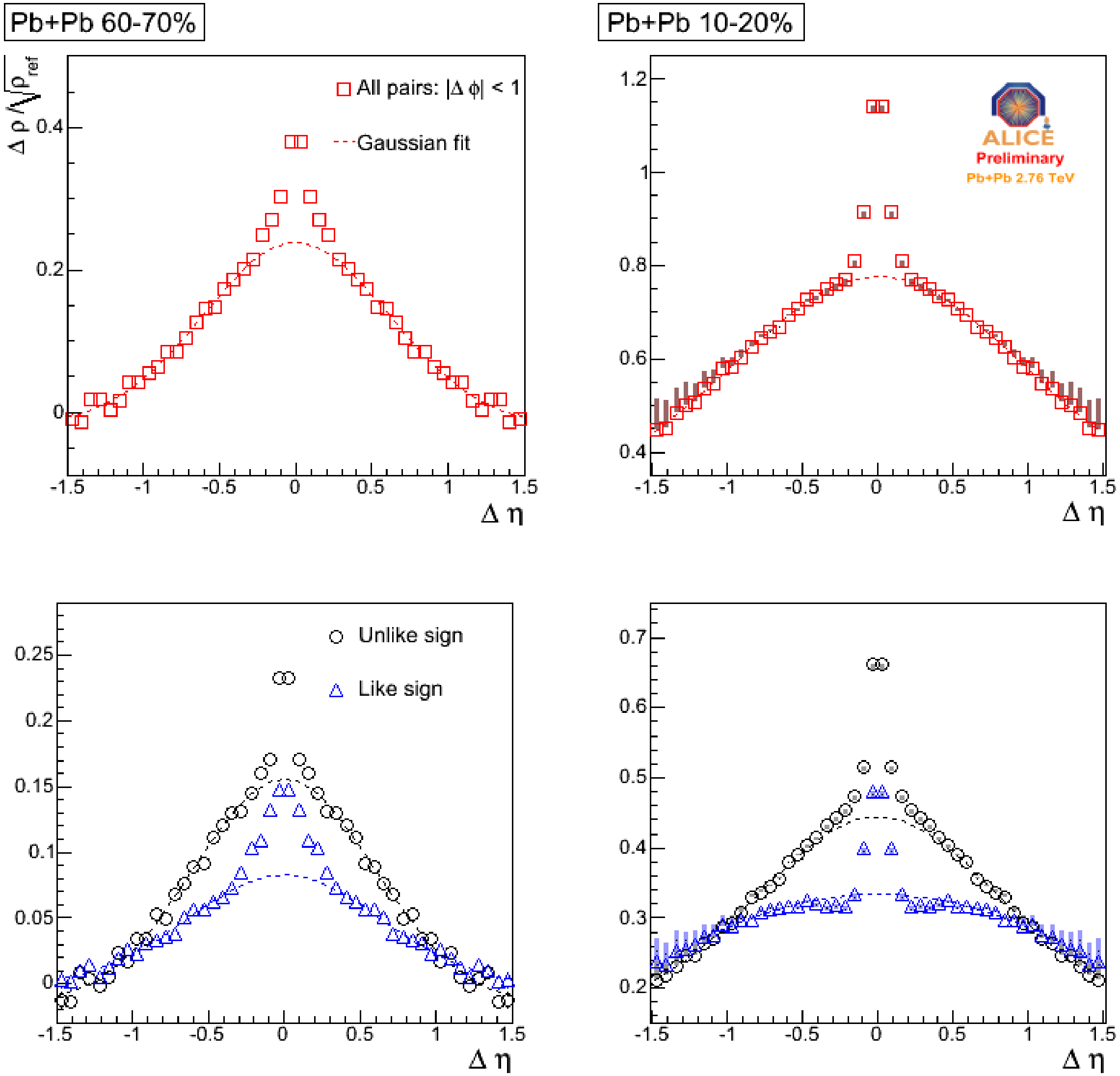
Charge dependence…



- **Why look at charge sign dependence?**
- **Global correlations:**
  - Many particles
  - e.g. Radial flow, v_2 etc
  - Should be **independent of charge sign**
- **Local correlations:**
  - Few particles
  - e.g. string, jet fragmentation
  - **Charge sign dependence if charge conservation** effects are relevant

- **Nearside 2D Gaussian** has strong charge sign dependence

Charge dependence…

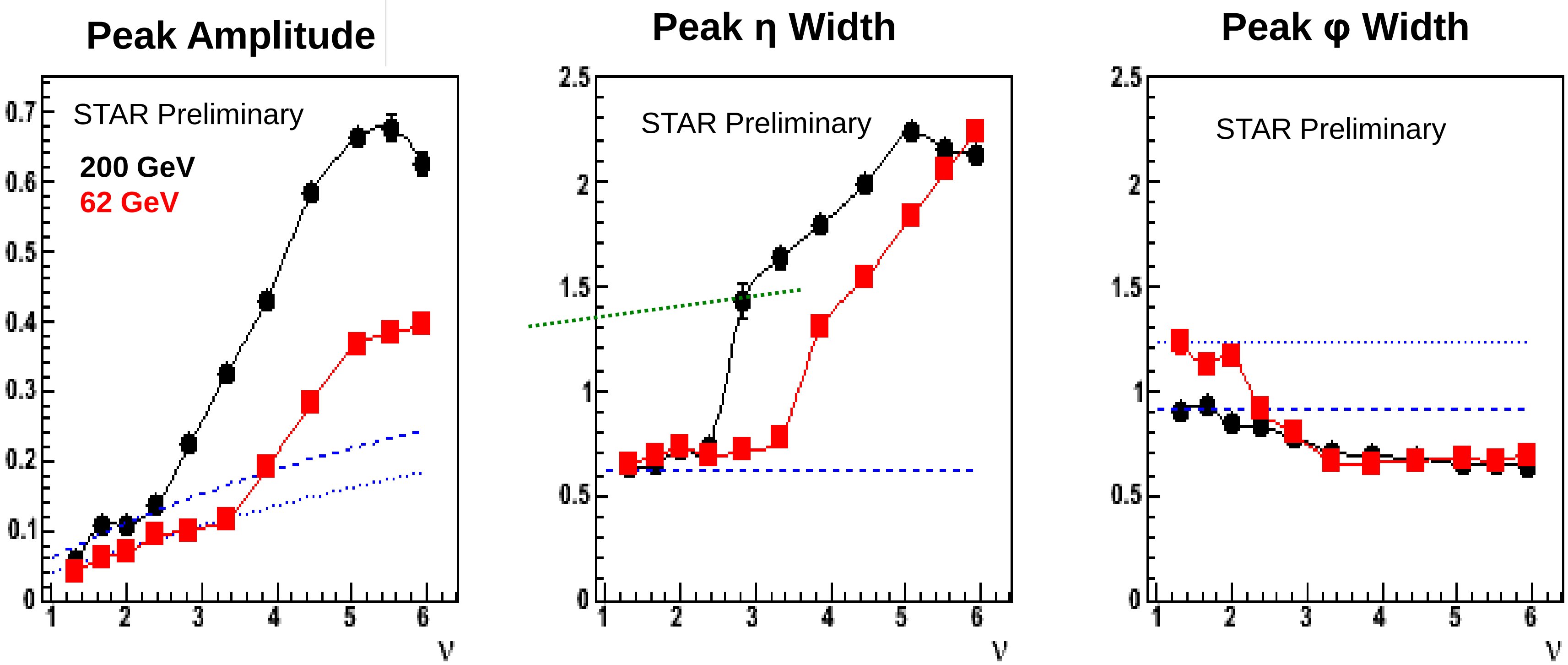


- $\Delta\eta$ projection over near side..
- **Unlike sign nearside strongest contributor** in ALICE's acceptance..
- **Like sign nearside structure wider** in peripheral and central collisions….

Summary…

- **Extracted untriggered di-hadron correlations in Pb+Pb 2.76 TeV**
  - Pronounced change in correlation structure from peripheral -> central
  - Gaussian structure observed on nearside in Pb+Pb 0-10%
- **Quantified nearside Gaussian with 2 methods**
  - With and without v3, v4 in background
  - Adding higher harmonics reduces, but does not remove soft ridge
  - Gaussian with higher harmonic background scales more closely with $\langle N_{bin} \rangle$
- **Charge sign dependence seen for nearside Gaussian:**
  - Unlike sign correlations narrower and stronger in central collisions

Backup: RHIC results…



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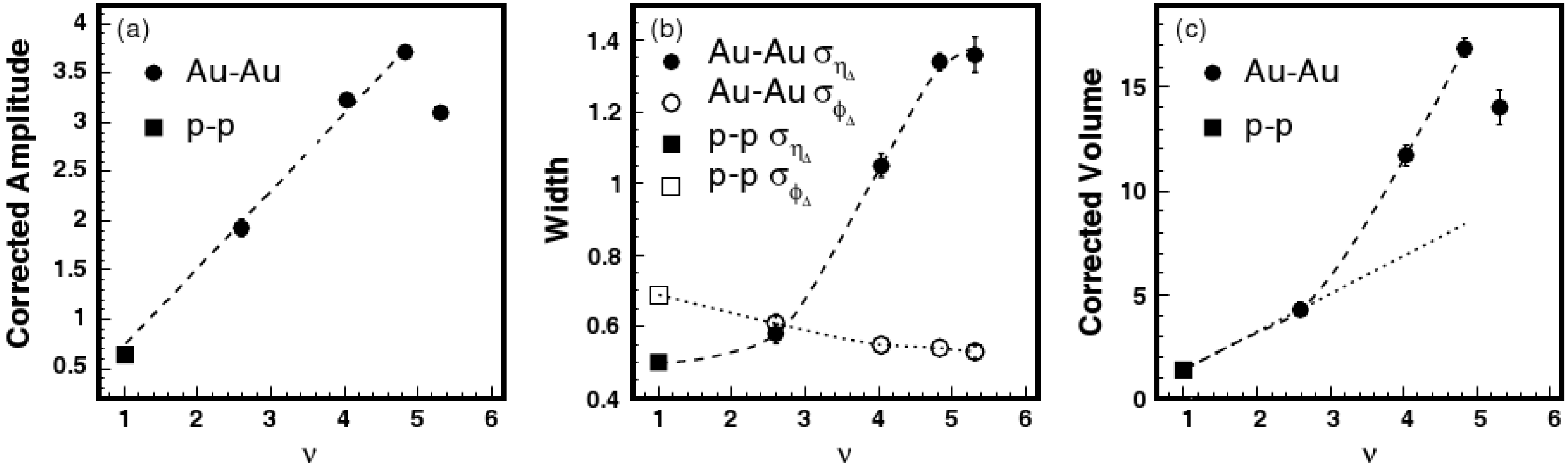

FIG. 4. Panel (a): Efficiency corrected amplitudes from model fits (given in Table I) for the same-side correlation peak plotted vs centrality, where the latter is represented by the mean participant path length ν [35]. Au-Au collision results are shown by the solid dots and the p-p result by the solid square. The dashed curve is a linear fit excluding the most central datum. Error bars in each panel, if visible, indicate only the fitting errors from Table I. Panel (b): Fitted widths for the same-side peak in Au-Au collisions are shown by the solid dots (σ_{η_Δ}) and open circles (σ_{ϕ_Δ} in radians). Corresponding widths for p-p collision data are indicated by the solid and open squares at $\nu = 1$. Curves guide the eye. Panel (c): Volumes (see text) for the same-side correlation peak for Au-Au (solid dots) and p-p collisions (solid square). The dotted and dashed curves are explained in the text.

STAR, PHYSICAL REVIEW C 73, 064907 (2006)