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 $(\Delta\phi, \Delta\eta)$

- Main contributors at RHIC energies:
  - Elliptic flow
    - Shows up as $\cos (2\Delta\phi)$ structure….
  - “Soft ridge”
    - Shows up as elongated nearside 2D Gaussian..

- Spike (0,0): HBT + $\gamma \rightarrow e^+e^-$ conversions…

Motivation...

- **Initial energy density fluctuations**
  - Werner et al, arXiv:1104.3269v1
  - Sorensen et al, arXiv:1101.1925v1

- **CGC flux tubes and/or radial flow**

- **Modified mini-jets (pQCD related explanation)**

\[ \Delta \rho = 2 \frac{\langle N_{\text{bin}} \rangle}{\langle N_{\text{part}} \rangle} \]
Correlation function extracted...

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

- Designed to be independent of multiplicity if Pb+Pb is superposition of p+p

- Correlation function measure # of correlated pairs per particle
  - \( \rho_{\text{sib}} \) signal +background (real events)
  - \( \rho_{\text{ref}} \) background (mixed events)
    - \( \sqrt{\rho_{\text{ref}}} = \frac{d^2N}{d\eta d\phi} \) = yield of charged hadrons

- Charged hadrons with \( p_T > 0.15 \text{ GeV/c} \) used to form correlation function
  - Prefactor: Use published yield \((p_T > 0 \text{ GeV/c})\)
  - Convert to yield \((p_T > 0.15 \text{ GeV})\) with estimated fraction

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Sources of systematic uncertainty...

- **Normalisation:** \( \frac{d^2N}{d\eta d\phi} \)
  - Published uncertainties
  - Yield conversion uncertainty

- **Mixed event \( \Delta\eta \) acceptance**
  - Slightly more narrow than sibling
    - Causes small “wings”
    - Change with analysis details
    - Can be parameterised

- **\( \Delta\eta \) 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

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Untriggered correlations...

- **Evolution**: \( \cos(2\Delta\phi) \) structure \( (v_2) \) becomes dominant in mid-central collisions.
Fit decomposition…

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…

- $\chi^2/\text{DOF} \rightarrow 1.5$ (evaluated outside 0,0 peak)
  - Fits with higher harmonics slightly better
Boxes show uncertainties from $\Delta \eta$ 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 $\langle N_{\text{bin}} \rangle$ from peripheral collisions

- **Blue Gaussian** scales more closely with $\langle N_{\text{bin}} \rangle$
  - Is the soft ridge hard?
Background terms vs centrality…

- Increases in $\cos(2\Delta\phi)$, $\cos(3\Delta\phi)$, $\cos(4\Delta\phi)$ reduce soft ridge for **blue** case

- $\cos(\Delta\phi)$ 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 $\langle N_{\text{bin}} \rangle$

- **Charge sign dependence seen for nearside Gaussian:**
  - Unlike sign correlations narrower and stronger in central collisions
Backup: RHIC results…

Peak Amplitude

STAR Preliminary
200 GeV
62 GeV

Peak \( \eta \) Width

STAR Preliminary

Peak \( \phi \) Width

STAR Preliminary

Backup: RHIC results…

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 \( v \) [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 (\( \sigma_{\eta} \)) and open circles (\( \sigma_{\phi} \) in radians). Corresponding widths for \( p-p \) collision data are indicated by the solid and open squares at \( v = 1 \). 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.

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