Perspective of angular correlations study triggered by V^0 strange particles in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

Marek Bombara on behalf of the ALICE Collaboration

(Pavol Jozef Šafárik University, Košice, Slovakia)

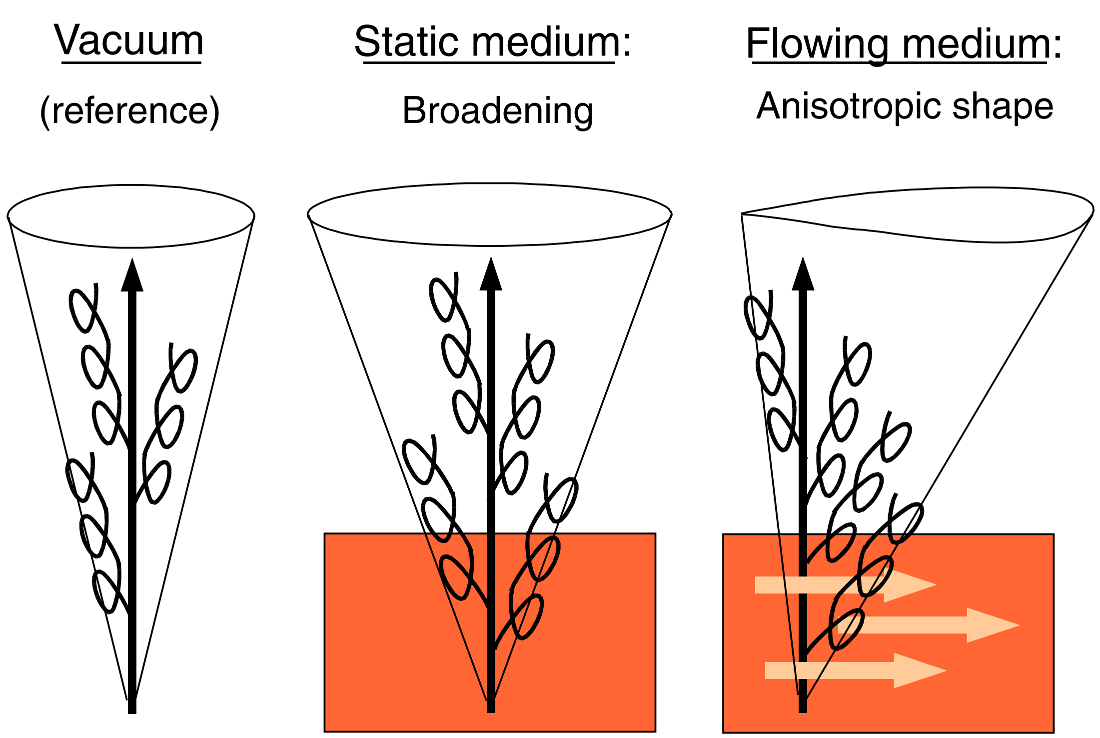
Strangeness in Quark Matter 2013
University of Birmingham, UK
22-27 July 2013

Contents

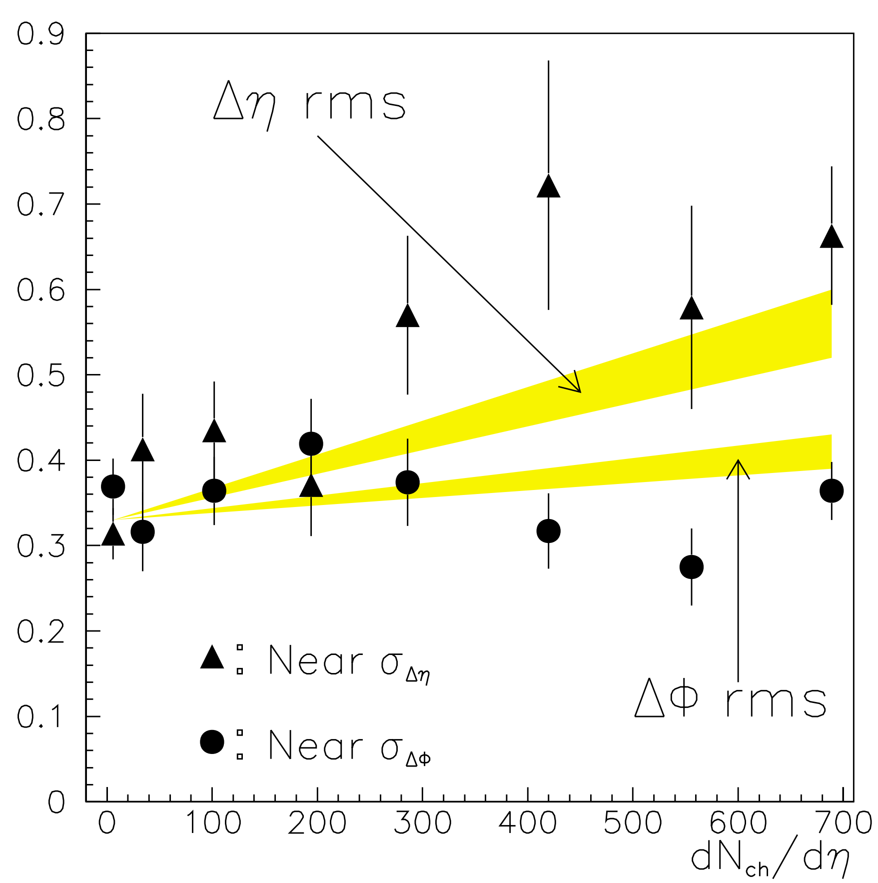
- Motivation:
  - Di-hadron correlations
  - V^0-h correlations
- Two-particle correlation technique
- Results:
  - Jet-like peak shape evolution
  - Centrality dependence of the $\sigma_{\Delta\varphi}$ and $\sigma_{\Delta\eta}$
  - Centrality dependence of excess kurtosis
- Outlook on studying V^0-h correlations
- Summary

Motivation

- Jet shapes and fragmentation functions show excess at low p_T (large radii) but high p_T (core) is unchanged [G. Veres for the CMS, Nucl. Phys. A 904-905 (2013) 146c-153c]
- Two-particle correlations are sensitive to jet quenching and modification of jet fragmentation
- The jet shape can be deformed by a longitudinally flowing medium [N. Armesto, C. Salgado, U. Wiedemann - PRL 93, 242301 (2004)] ⇒ different jet widths in $\Delta\varphi$ and $\Delta\eta$ in central heavy-ion collisions:

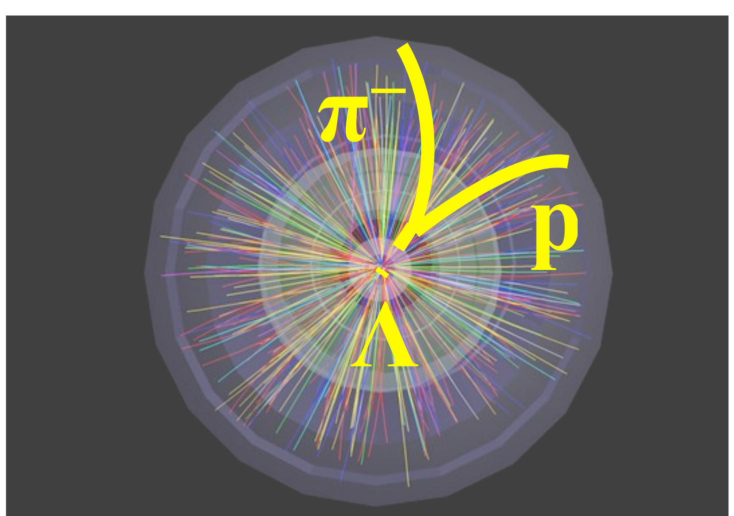


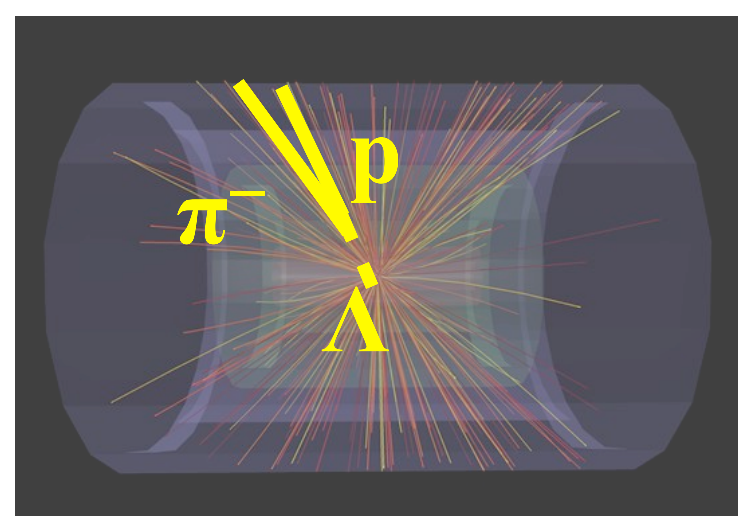
Data points: STAR preliminary [F. Wang for the STAR Collaboration, Quark Matter 2004]



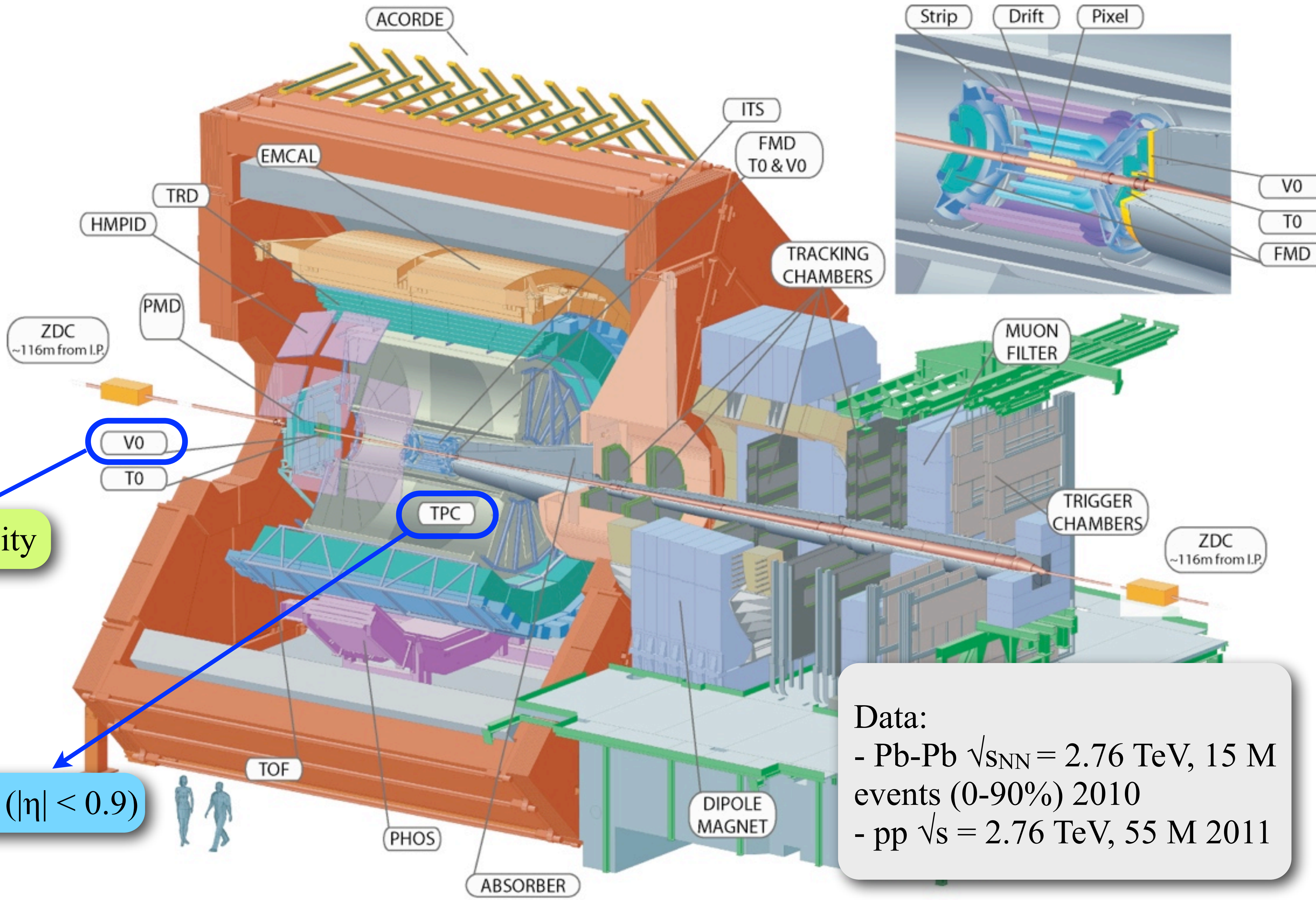
V^0-h angular correlations

- The quark and gluon jets can be distinguishable (on statistical basis) due to their multiplicity and width [J. Gallicchio and M. D. Schwartz, PRL 107, 172001 (2011)] and also baryon and meson content [OPAL, Eur.Phys.J.C8:241-254,1999]:
  - the baryon production in gluon jets is enhanced with respect to quark jets
- Dividing V^0-h correlations into two samples: meson-h (K^0-h) and (anti)baryon-h ((anti)Λ-h) we might be able to study (on statistical basis):
  - gluon jet enriched sample via (anti)Λ-h correlations
  - quark/gluon jet sample via K^0-h correlations
- The advantage using V^0-h correlations is good V^0 identification up to very high p_T via reconstruction of the daughter tracks:





A Large Ion Collider Experiment

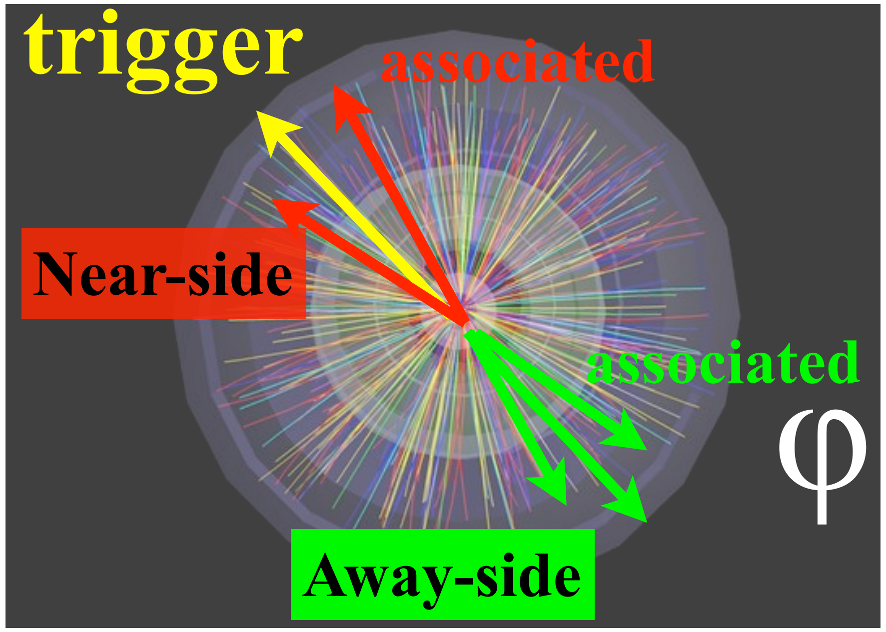


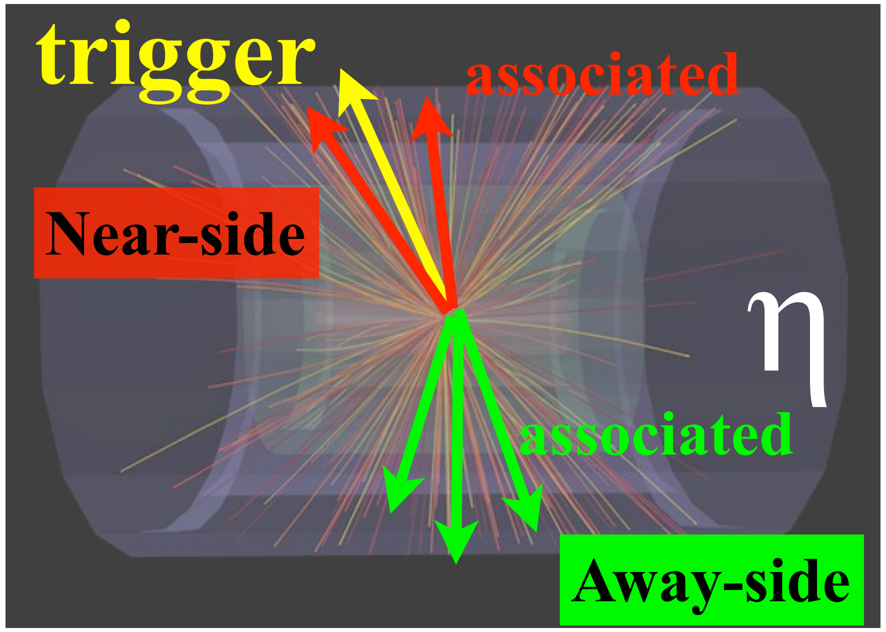
Centrality

Tracking (|η| < 0.9)

Data:
- Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, 15 M events (0-90%) 2010
- pp $\sqrt{s}$ = 2.76 TeV, 55 M 2011

Same $N_{pairs}(\Delta\varphi,\Delta\eta)$ (uncorrected) distribution



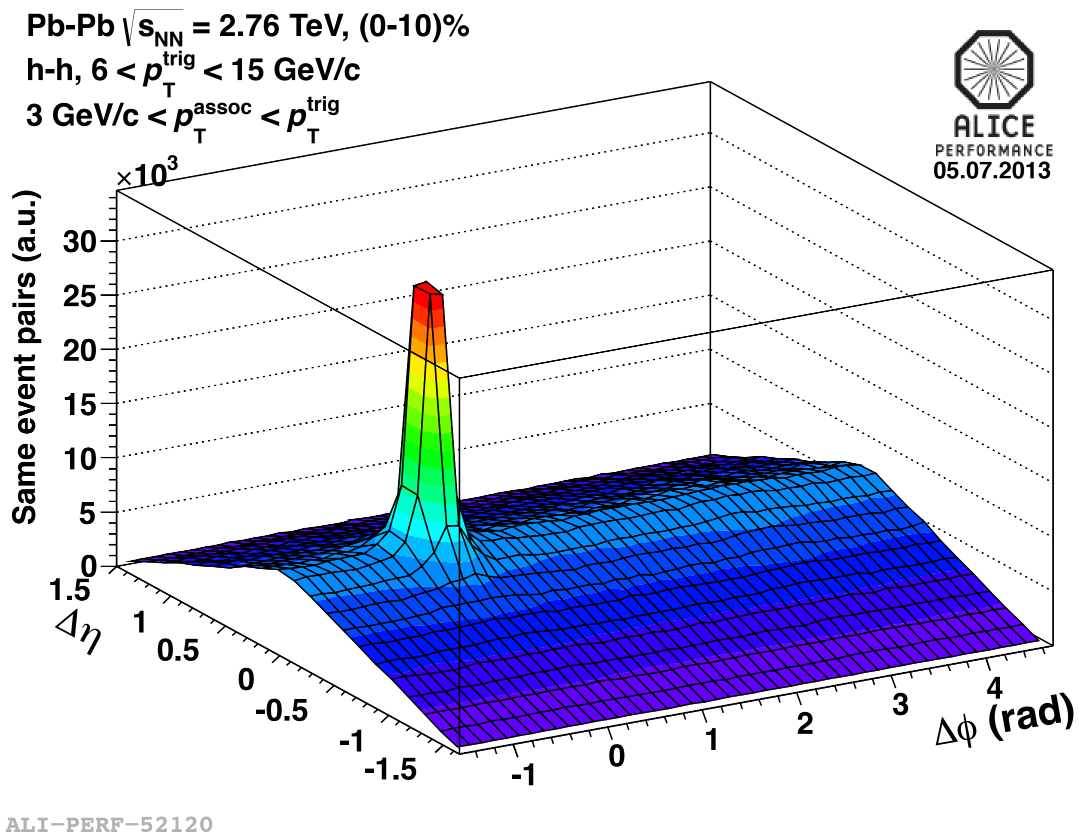


$$\Delta\varphi = \varphi_{associated} - \varphi_{trigger}$$

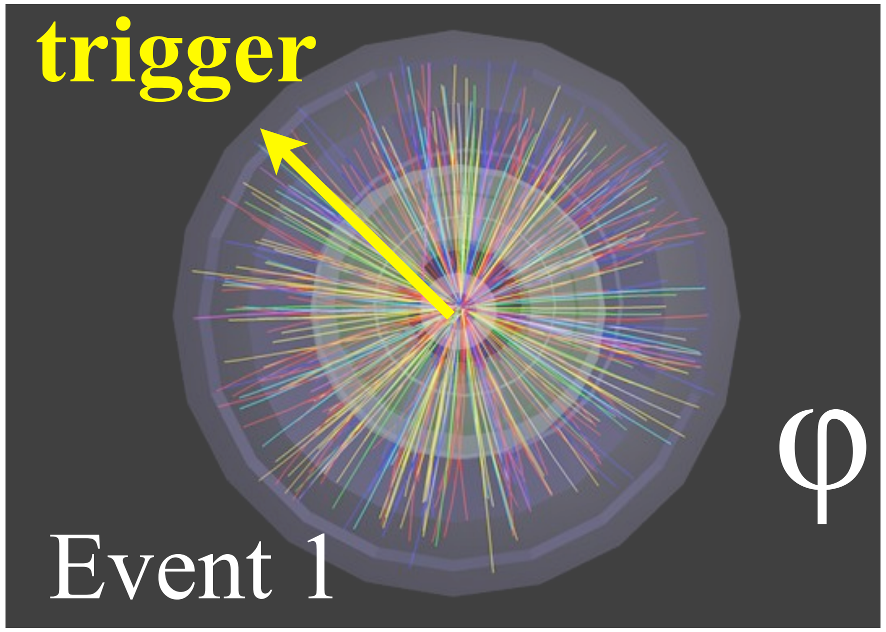
$$\Delta\eta = \eta_{associated} - \eta_{trigger}$$

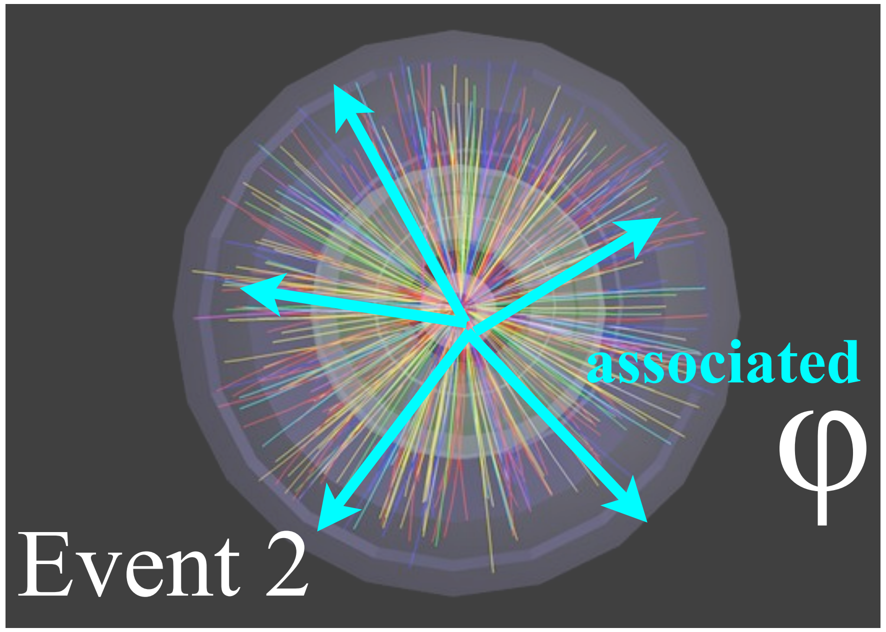
Trigger particles (h): $6 < p_{T,trig} < 15$ GeV/c
Associated particles (h): $3 < p_{T,assoc} < p_{T,trig}$

Same event pairs: the Near-side jet-like peak sits on a triangular shaped background.



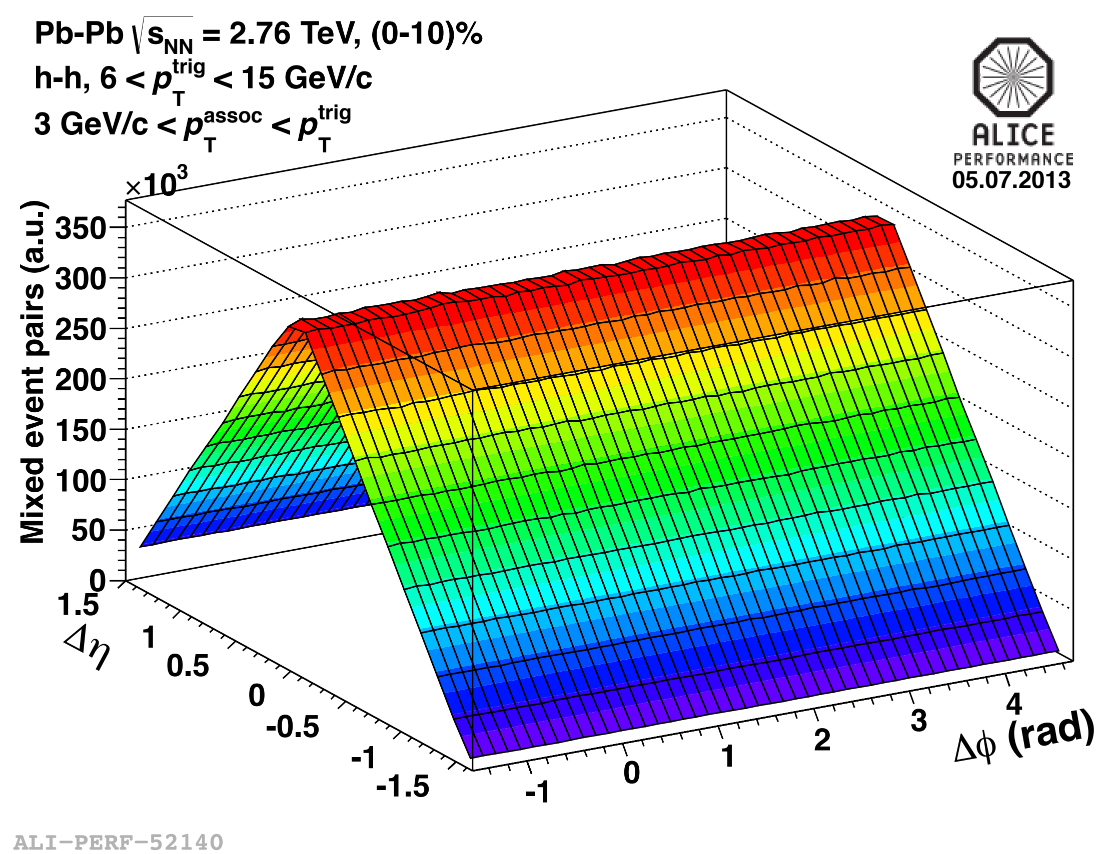
Mixed $N_{pairs}(\Delta\varphi,\Delta\eta)$ distributions





$$\Delta\varphi = \varphi_{associated} - \varphi_{trigger}$$

Background determination: the triangular shape can be reproduced by mixed pairs, where the trigger and the associated particle come from different events.

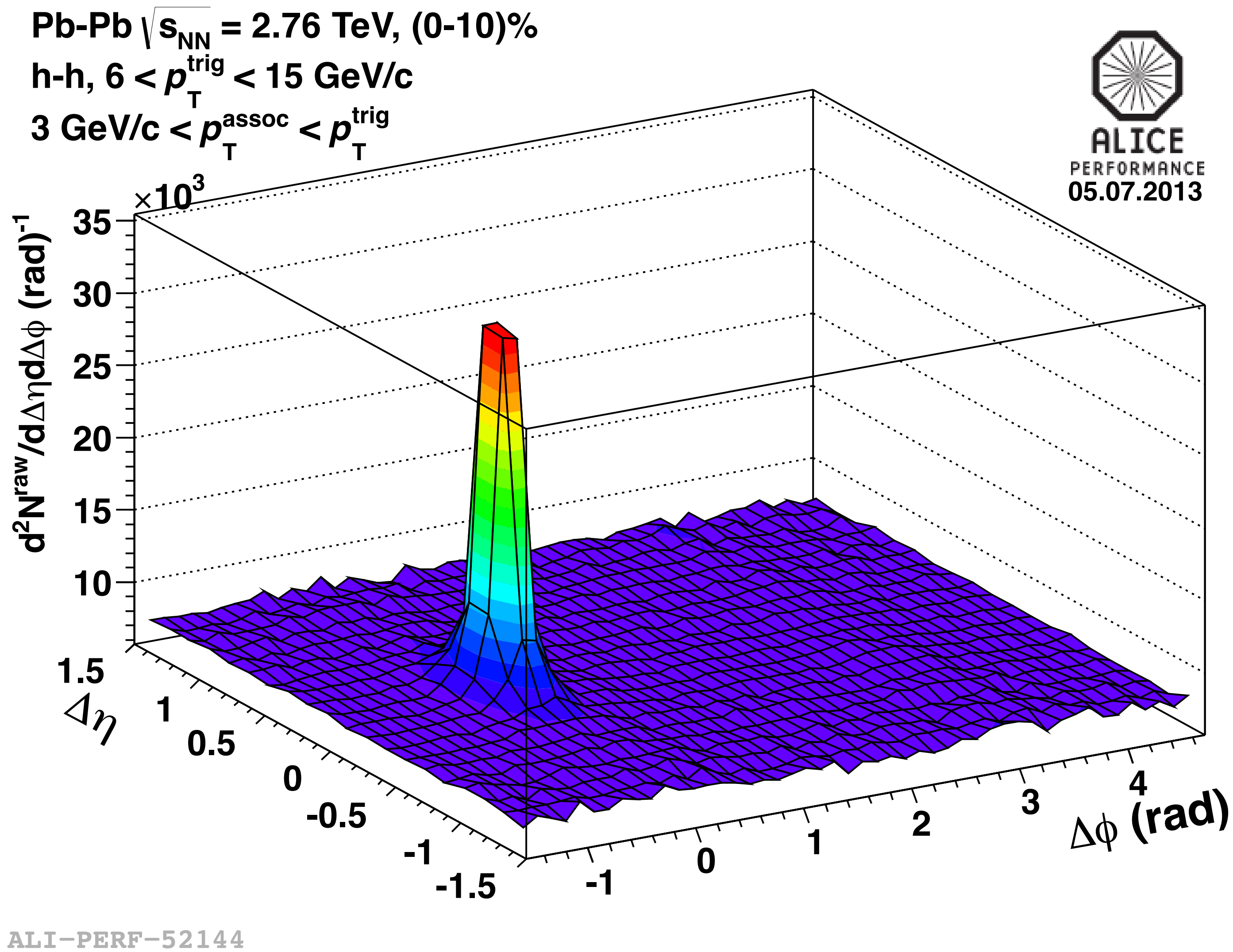


Acceptance corrected correlations

Background subtraction:

$$\frac{d^2N^{raw}}{d\Delta\phi d\Delta\eta}(\Delta\phi,\Delta\eta) = \frac{N^{same}_{pair}(\Delta\phi,\Delta\eta)}{N^{mixed}_{pair}(\Delta\phi,\Delta\eta)}\beta$$

The normalization factor β was chosen in such a way that the mixed $N_{pairs}(\Delta\varphi,\Delta\eta)$ distribution is 1 at $\Delta\varphi = \Delta\eta = 0$.



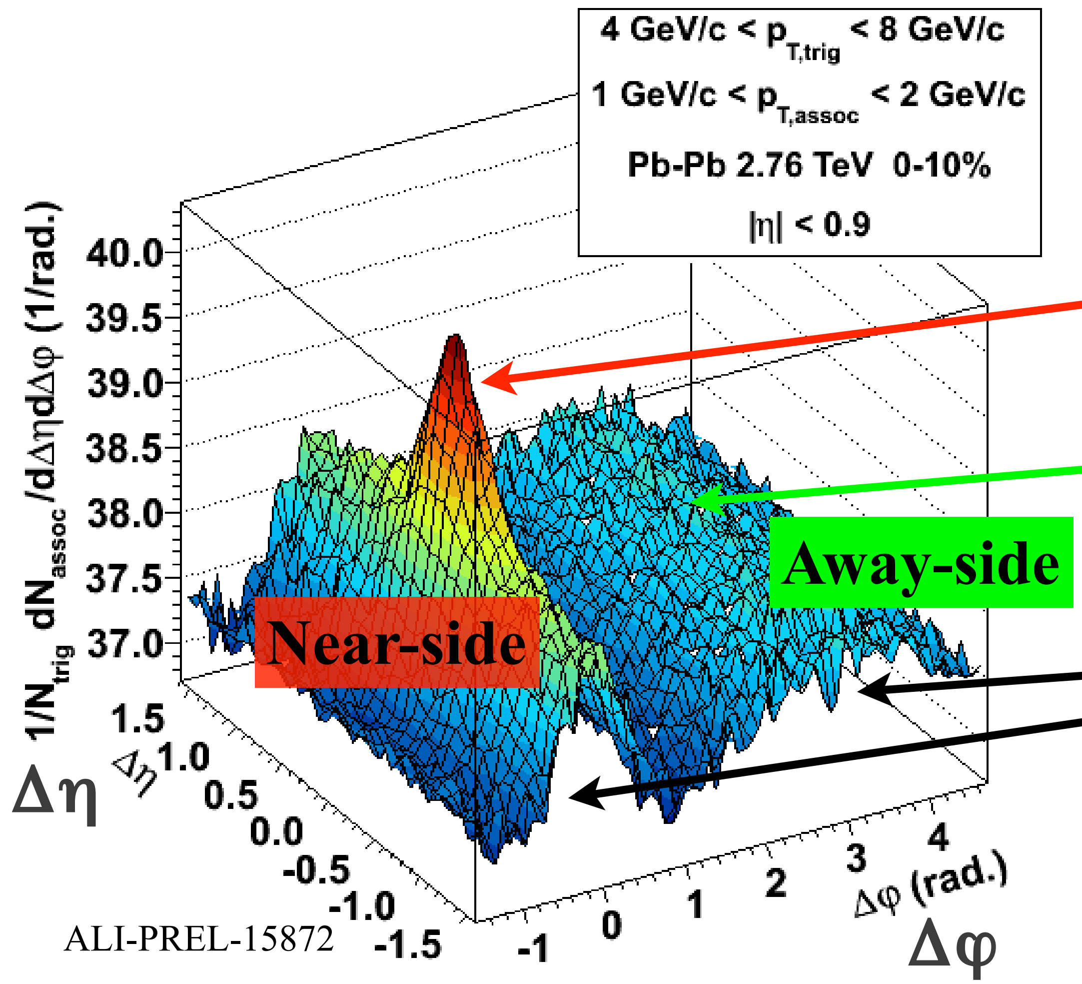
Additional corrections to be applied:
- single track efficiency and contamination correction (from secondary particles)
- track merging/splitting correction

Di-hadron angular correlations

The angular correlations can be quantified by the per trigger associated particle yield:

$$\frac{d^2 N}{d\Delta\phi d\Delta\eta}(\Delta\phi, \Delta\eta) = \frac{1}{N_{trig}} \frac{d^2 N_{assoc}}{d\Delta\phi d\Delta\eta}$$

for $p_{T,trig}$ and $p_{T,assoc}$ intervals.

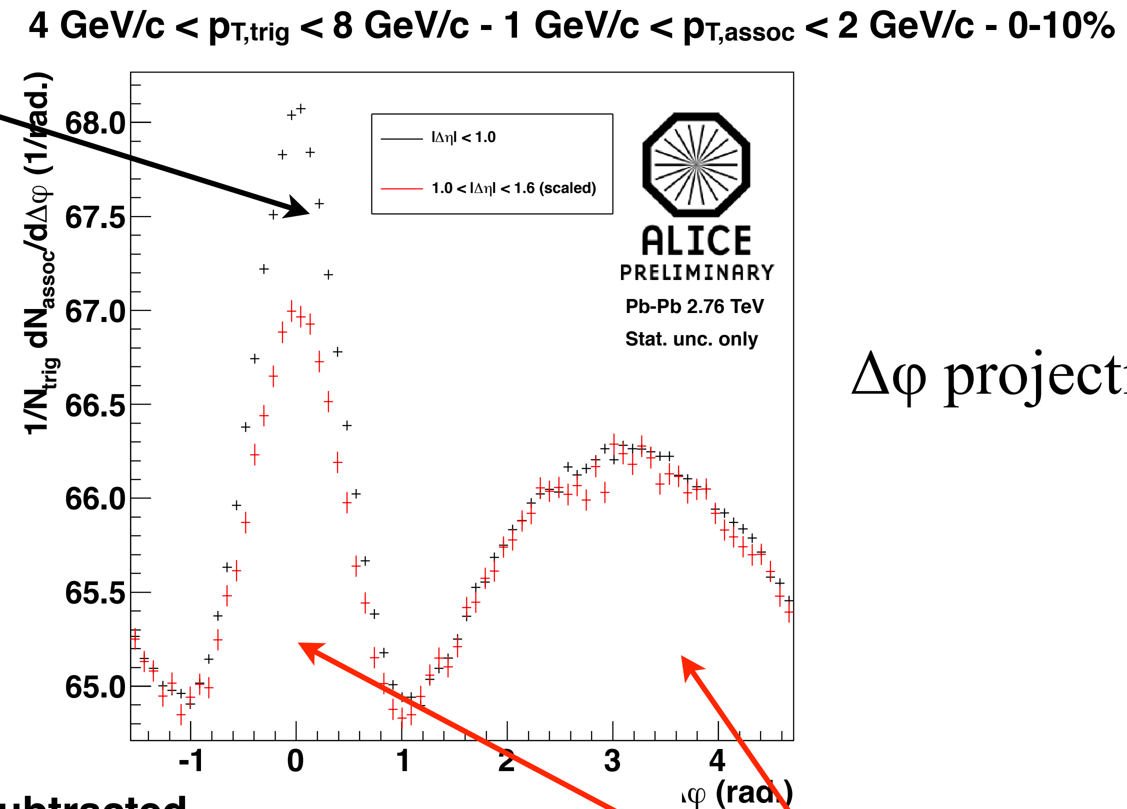


- The Near-side peak located at Δφ ≈ Δη ≈ 0
- The Away-side peak (recoiling jet) located at Δφ ≈ π and spread out in Δη
- Both peaks sit on a flow modulated background (more pronounced for low $p_{T,trig}$ and $p_{T,assoc}$ intervals)

Flow modulated background subtraction

- Assumptions: flow is independent of $\Delta\eta$ and the jet does not contribute to $|\Delta\eta|>1.0$
- Signal extracted by subtracting the side bands $1 < |\Delta\eta| < 1.6$ (η-gap method)
  - Not suitable for Away-side peak study

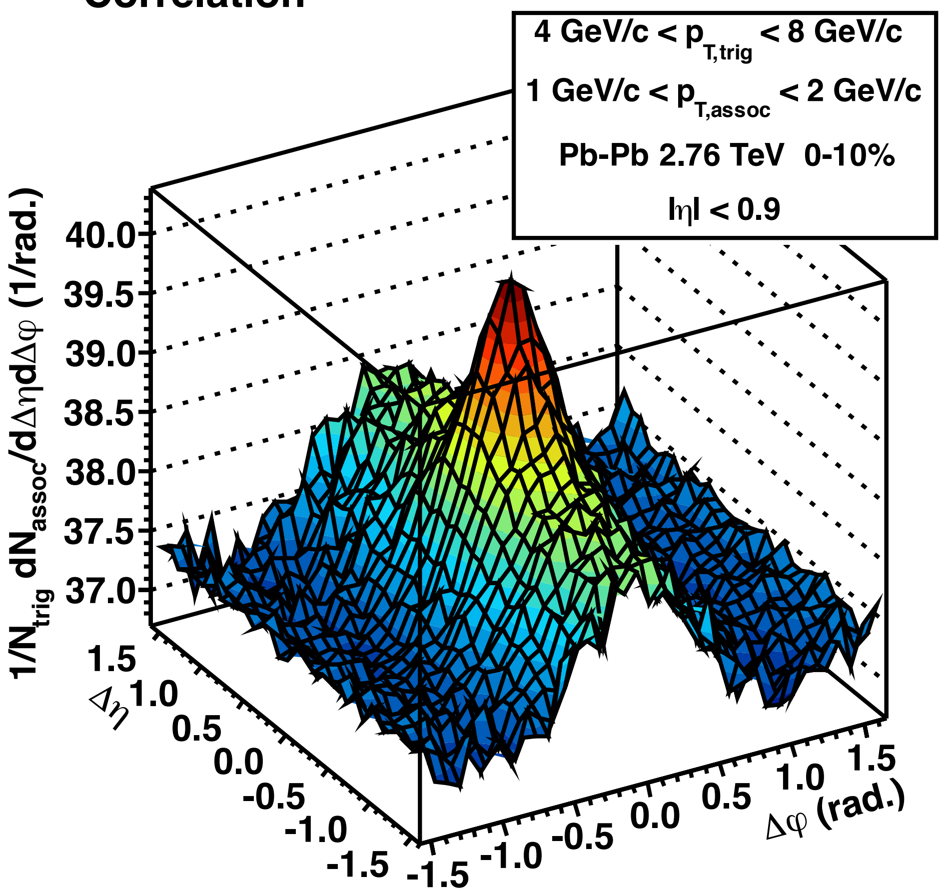
Signal



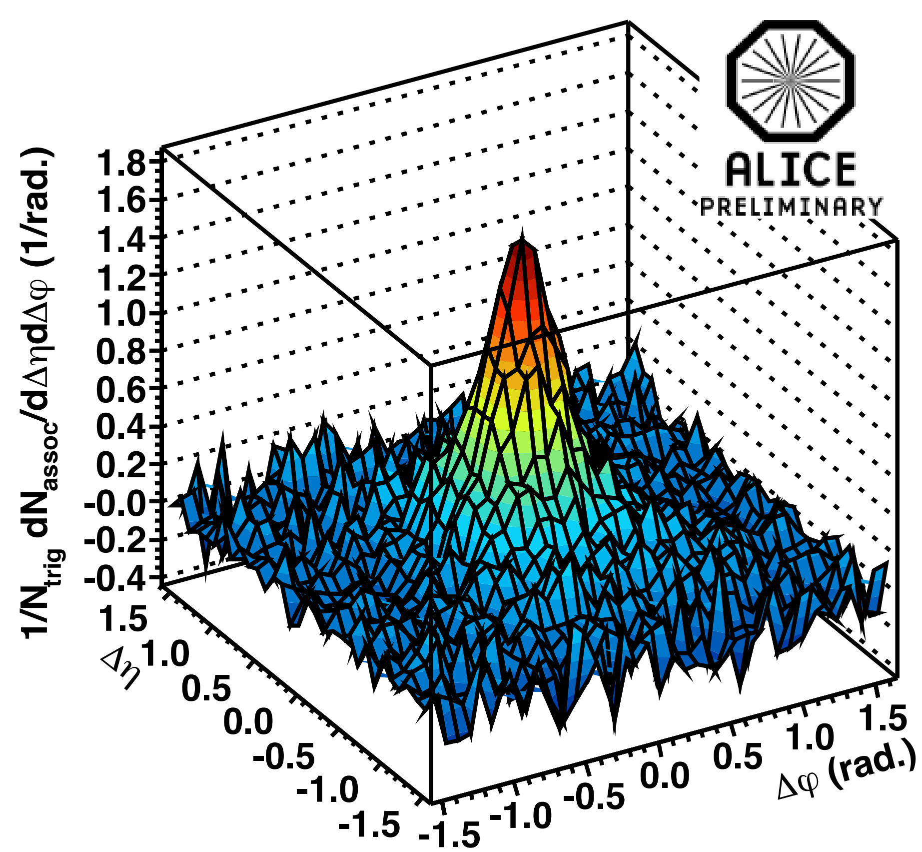
Δφ projection

Background from the side bands (red)

Correlation



η-gap subtracted



Jet-like peak shape evolution

0-10% | 60-70% | pp

similar

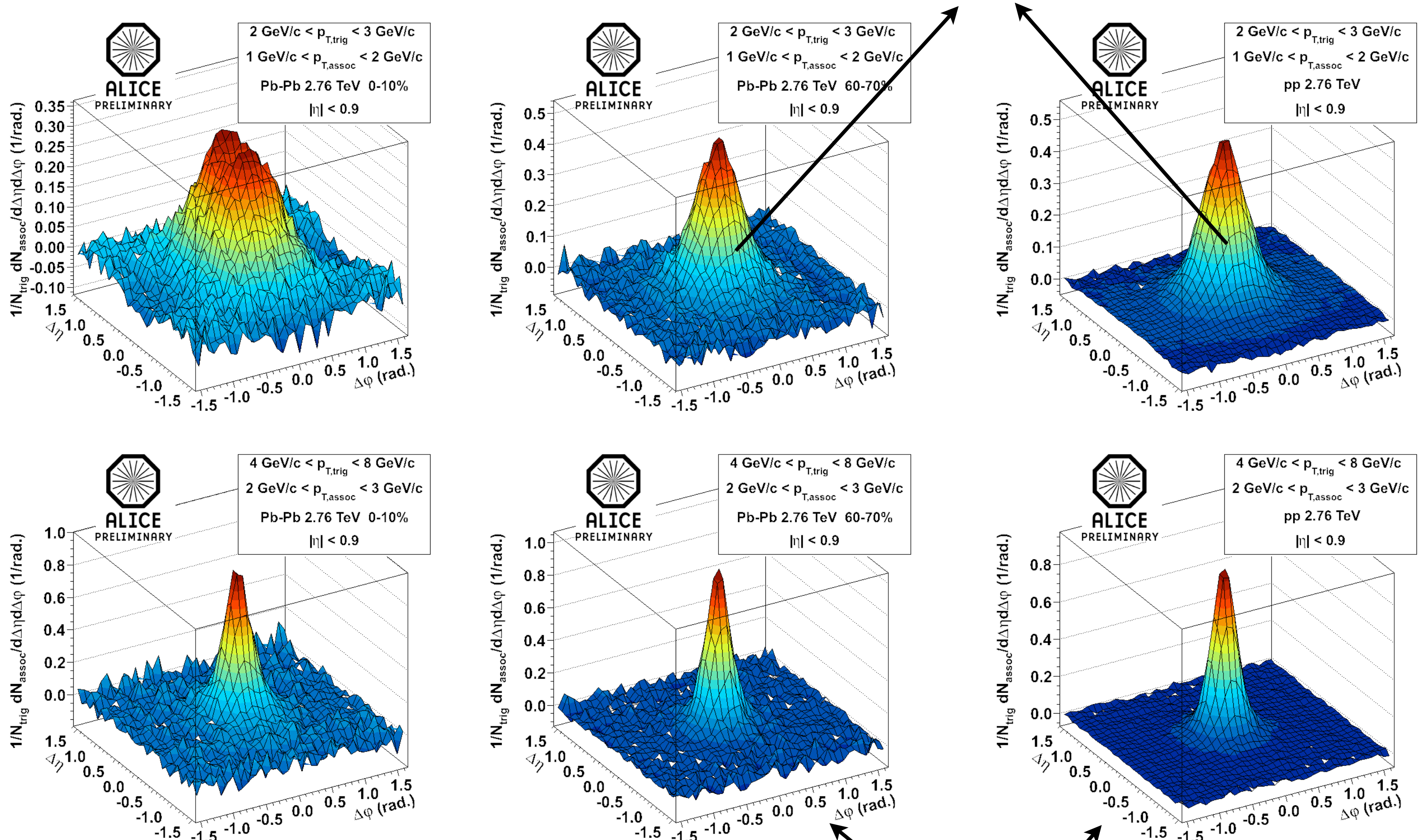
$2 < p_{T,trig} < 3$ GeV/c
$1 < p_{T,assoc} < 2$ GeV/c

lower p_T

broadening

$4 < p_{T,trig} < 8$ GeV/c
$2 < p_{T,assoc} < 3$ GeV/c

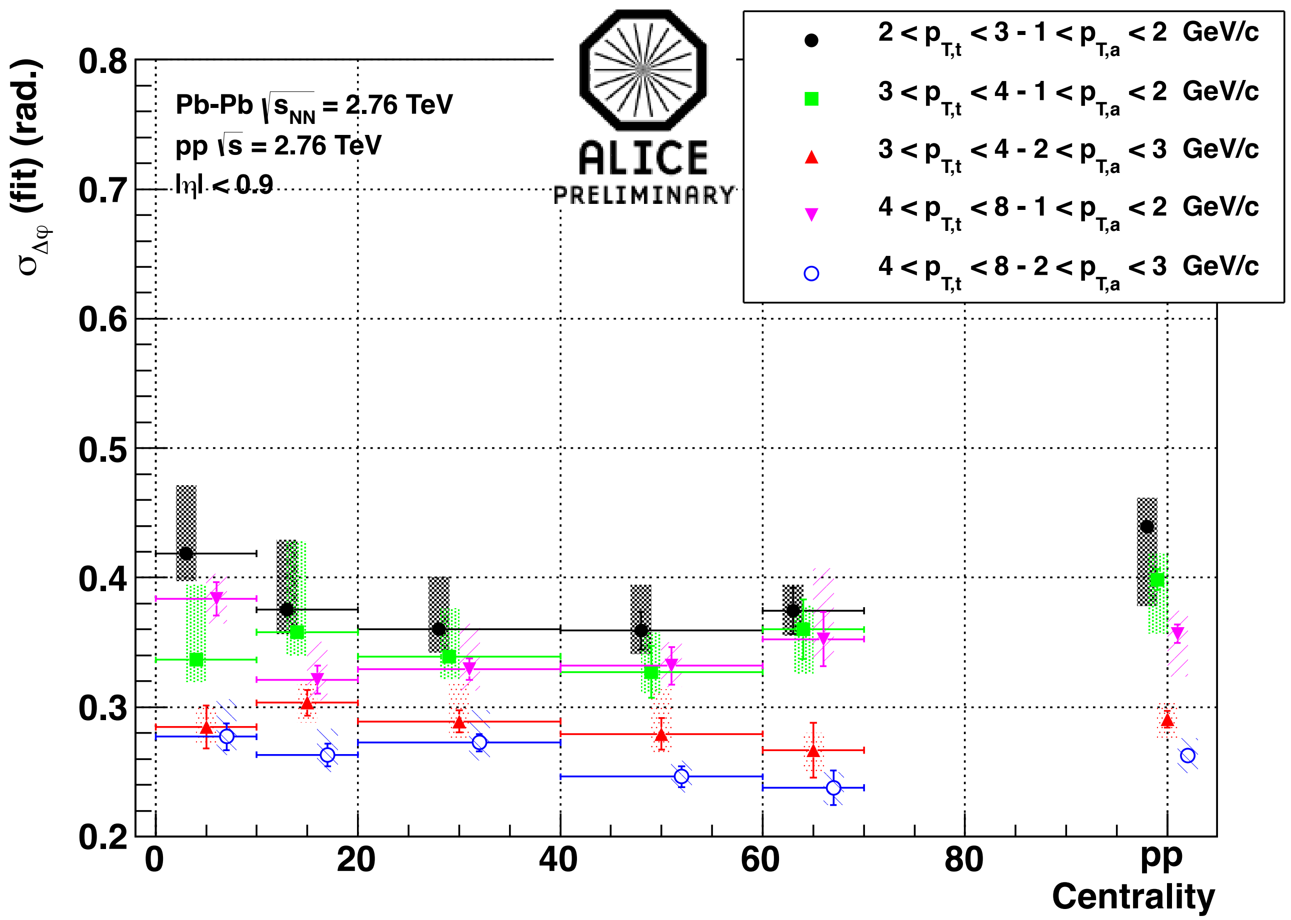
higher p_T

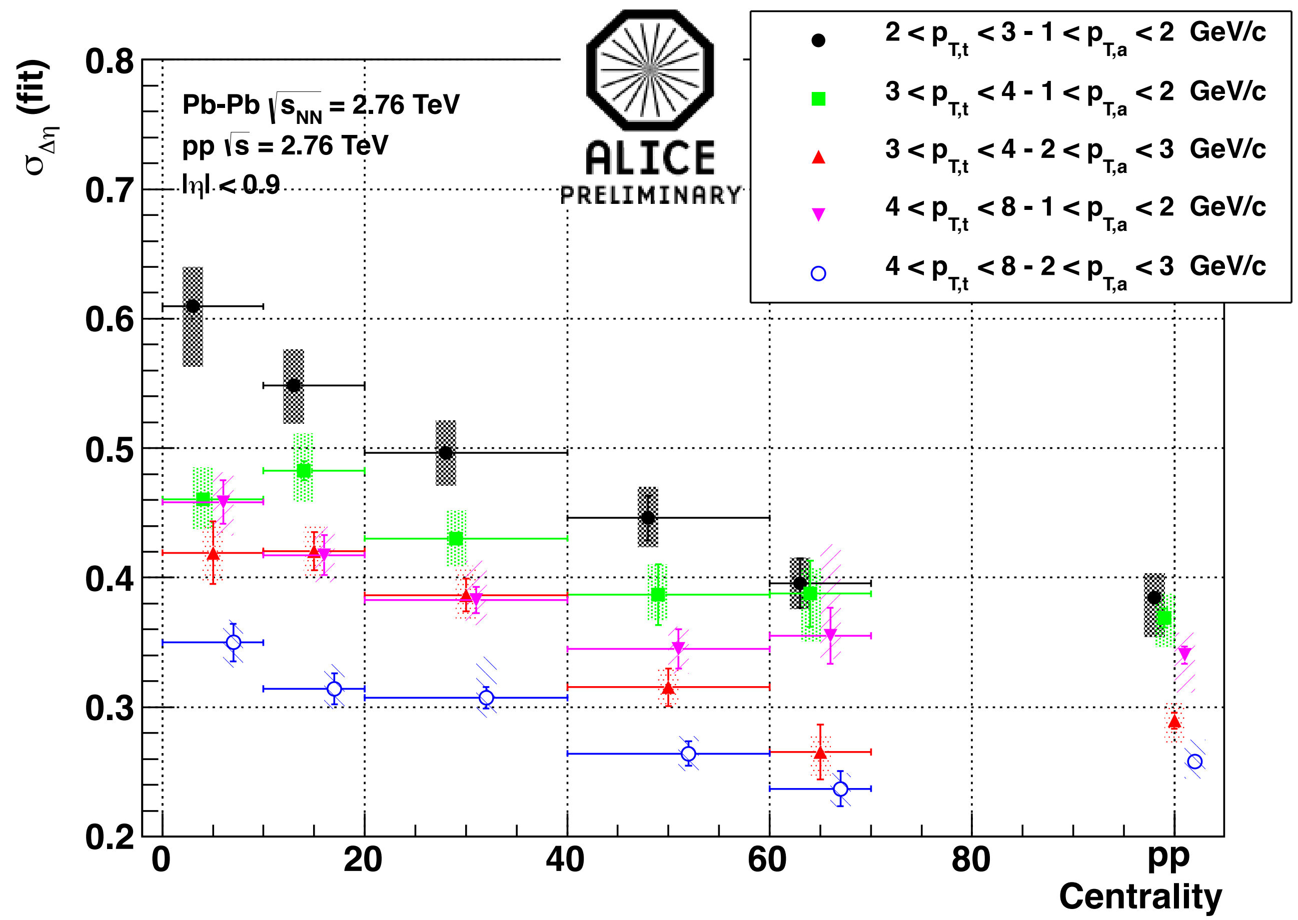


similar

broadening

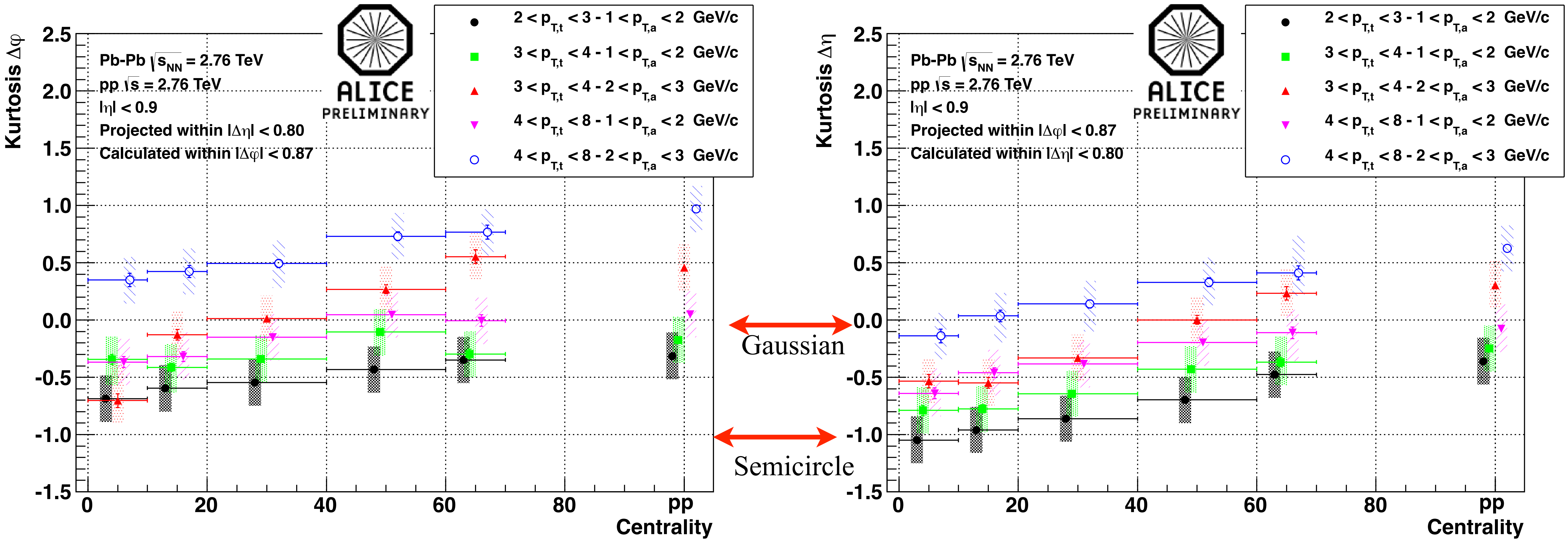
Centrality dependence of the $\sigma_{\Delta\varphi}$ and $\sigma_{\Delta\eta}$





- The Near-side peak was fitted with a sum of two 2D Gaussians centred at $\Delta\varphi = \Delta\eta = 0$, the fit parameters were used to calculate σ in $\Delta\varphi$ and in $\Delta\eta$
- The $\sigma_{\Delta\varphi}$: independent of centrality, decreasing with higher $p_{\mathrm{T,assoc}}$ and $p_{\mathrm{T,trig}}$
- The $\sigma_{\Delta\eta}$: broader moving to central events, decreasing with higher $p_{\mathrm{T,assoc}}$ and $p_{\mathrm{T,trig}}$

Centrality dependence of the excess kurtosis



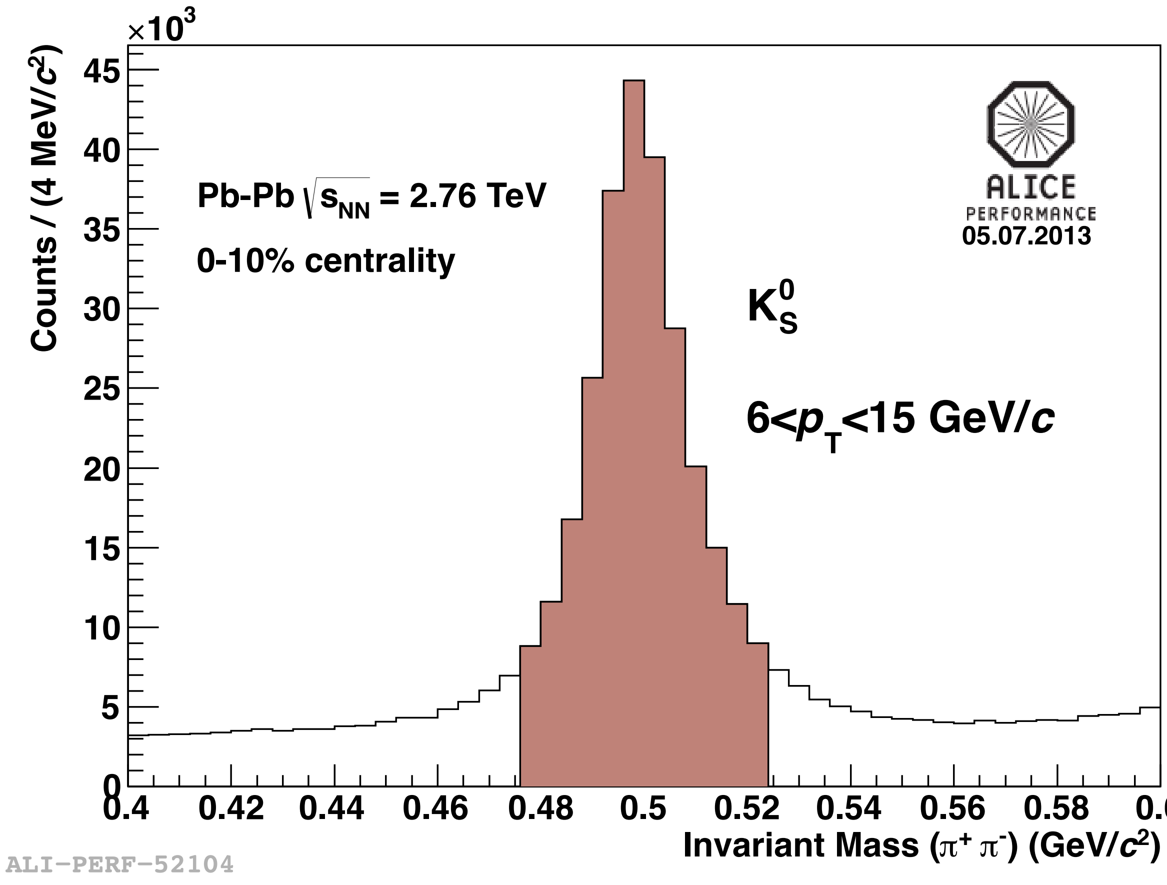
- Excess kurtosis ($K_{\Delta\varphi}$, $K_{\Delta\eta}$) = $\mu_4/\mu_2^2 - 3$ (μ_n - nth moment about the mean): measurement of peakedness of the distribution (Laplace: K=3, Gaussian: 0, semicircle: -1, uniform: -1.2)
- Both kurtosis (in Δφ and in Δη) decrease going to lower p_T (the peaks are “less sharp”) and decrease in more central events
- Almost flat top for lowest p_T interval in Δη

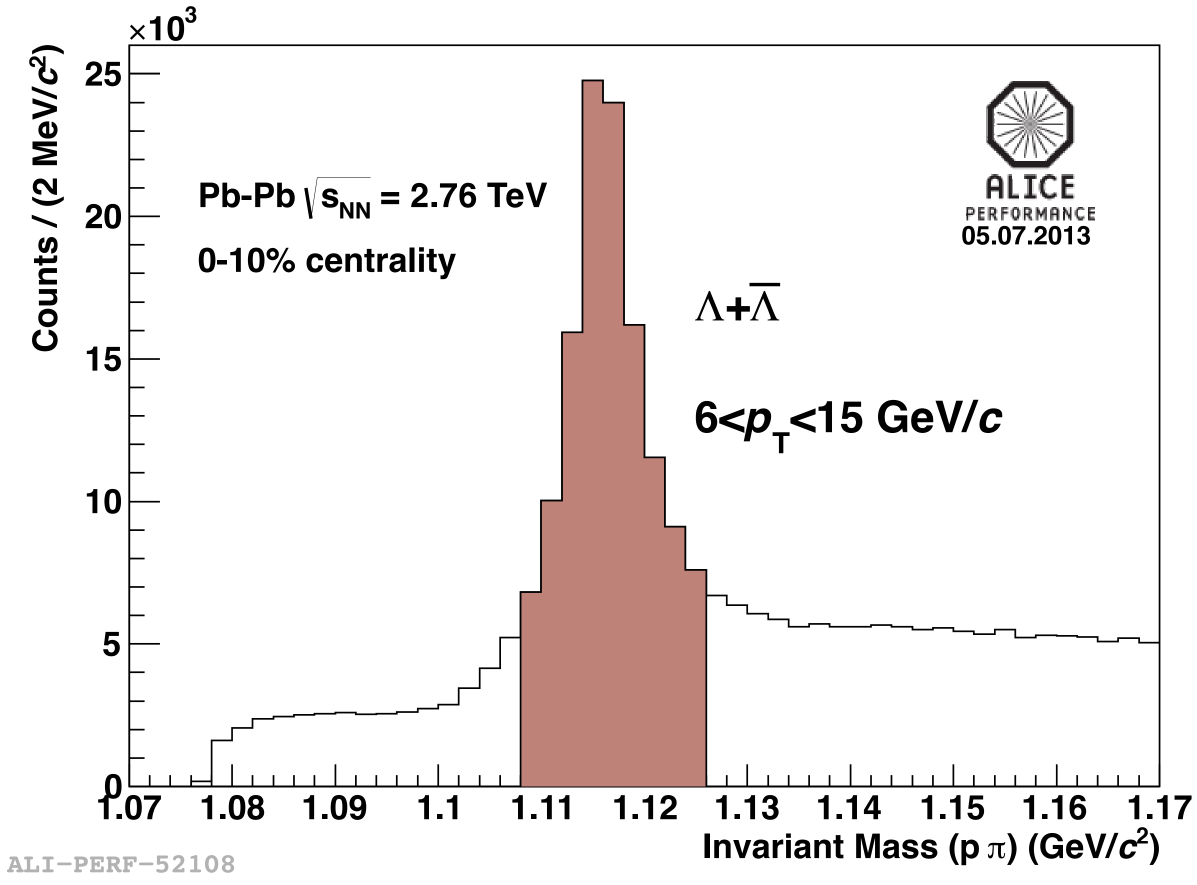
Outlook on studying V^0-h correlations

Data:
- Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV, 30 M events effectively triggered on centrality, taken in 2011

V^0 selection:
- V^0 candidates were selected using track topological cuts
- $|y|<0.75$

Invariant mass distributions for most central events (0-10%):



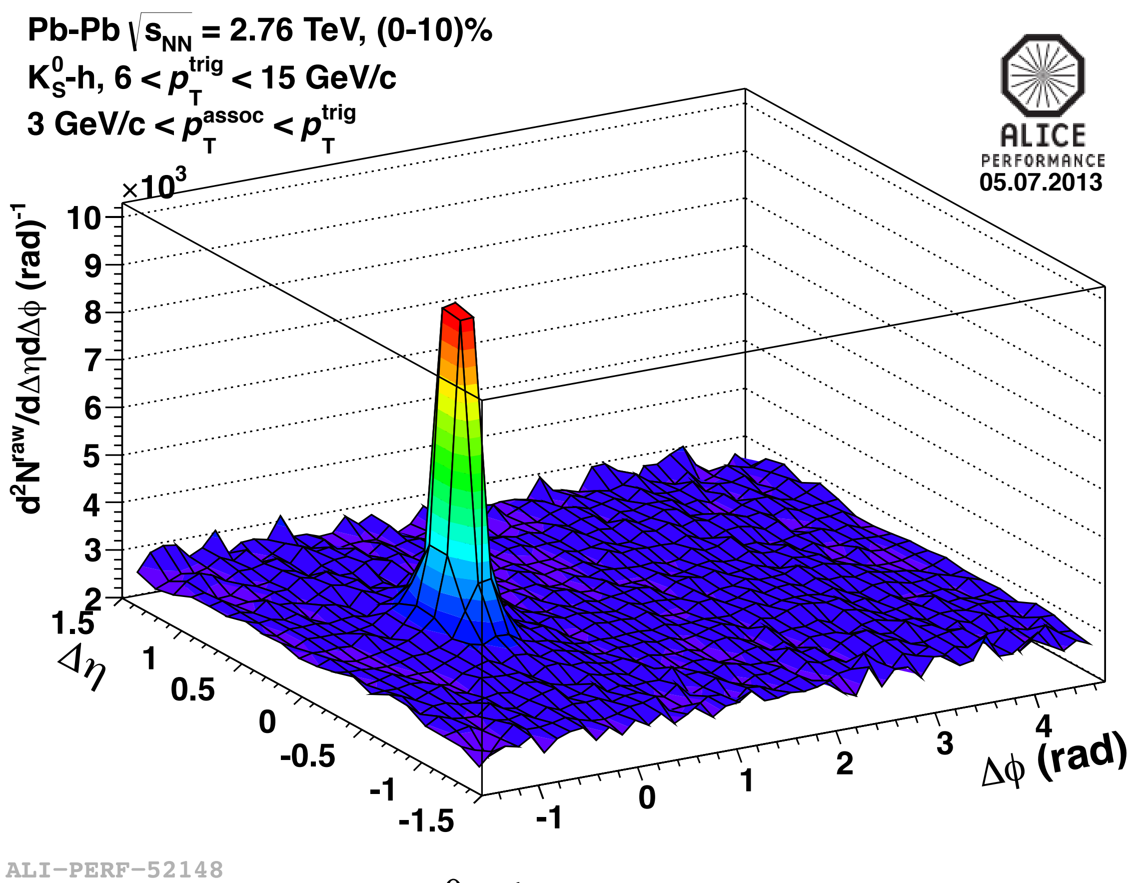


V^0 candidates in coloured area are used for the correlation analysis.

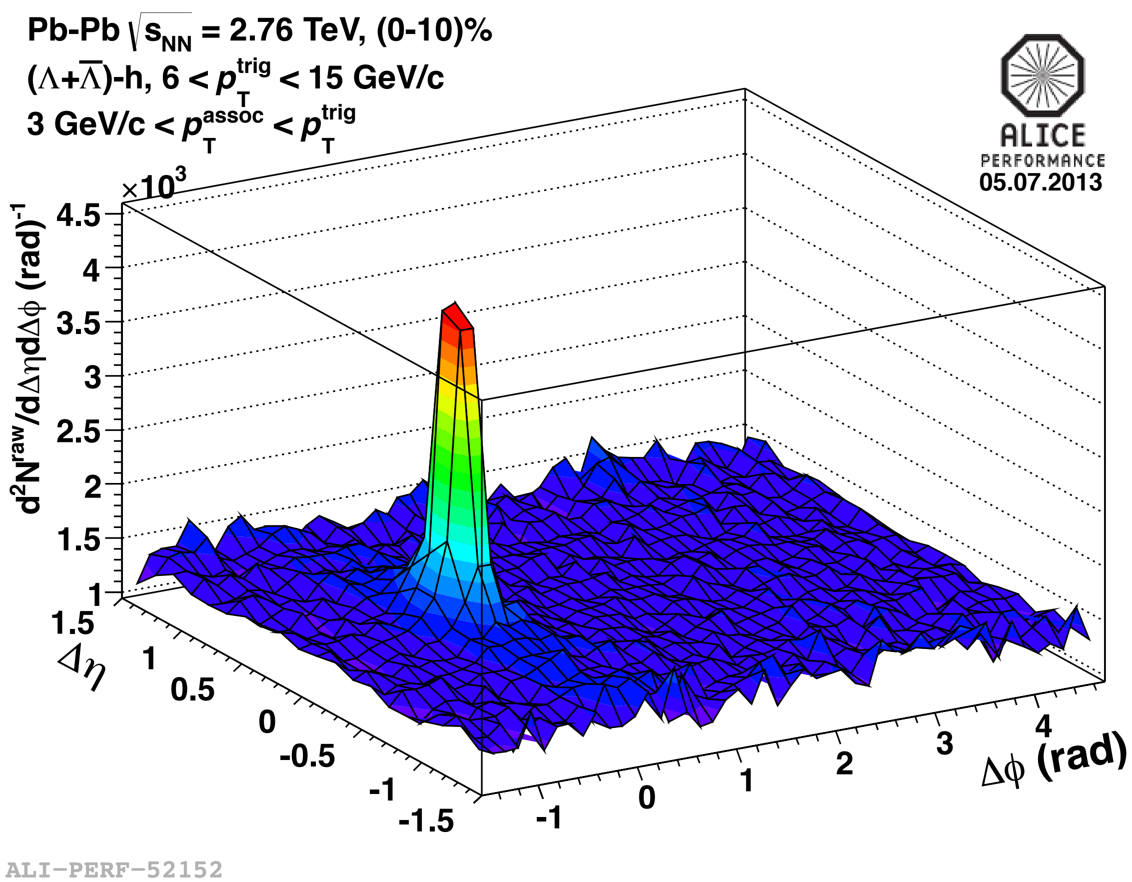
Outlook on studying V^0-h correlations

Acceptance corrected correlations (the plots are not efficiency corrected):

Trigger particles (V^0): $6 < p_{T,trig} < 15$ GeV/c
Associated particles (h): $3 < p_{T,assoc} < p_{T,trig}$



K^0_S-h



(Λ+antiΛ)-h

The jet-like peaks are clear and well above the background: the analysis is feasible.

Summary

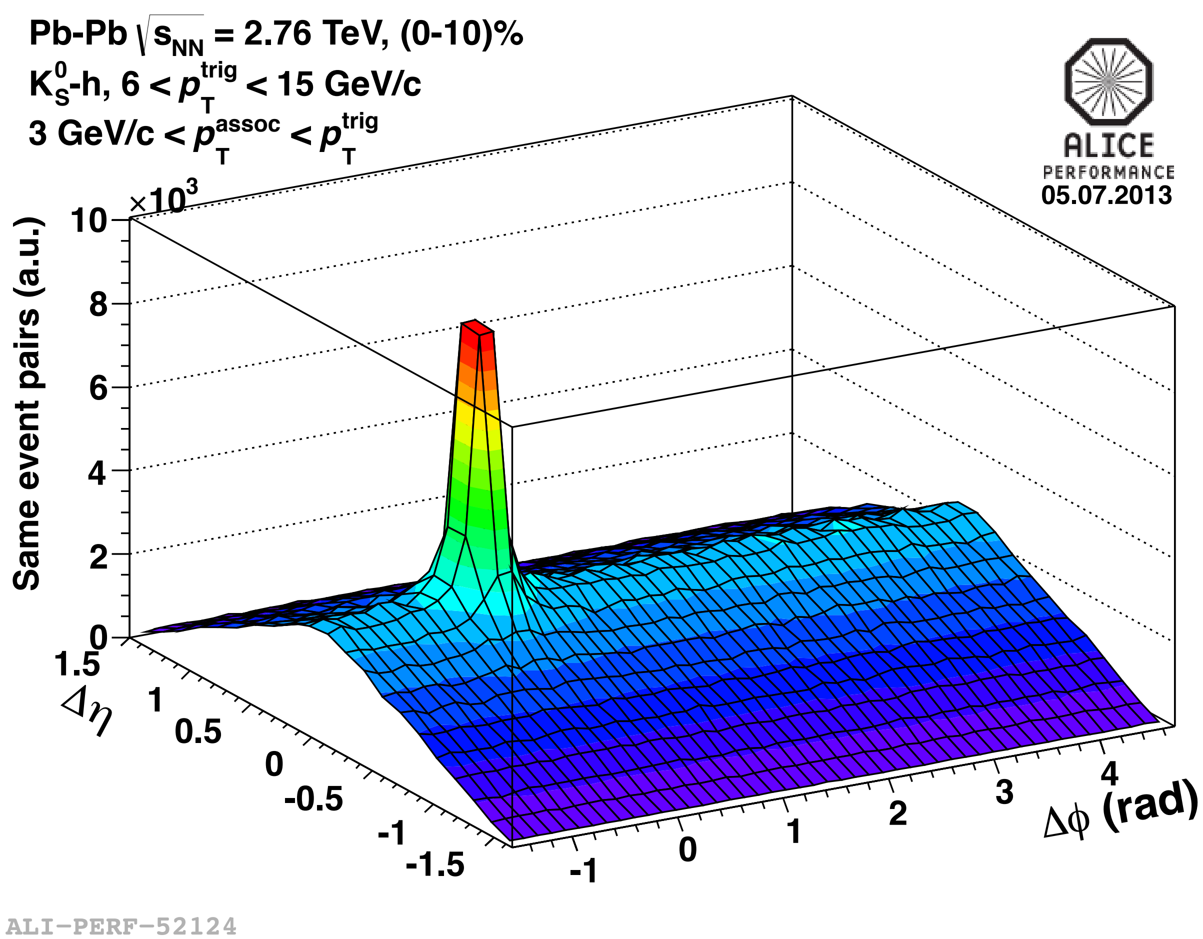
- Jet-like peaks in di-hadron correlations get broader going to lower p_T intervals of trigger and associated particles and to more central Pb-Pb collisions
- Jet-like peak width in $\Delta\varphi$: no centrality dependence
- Jet-like peak width in $\Delta\eta$: broadening in central Pb-Pb collisions (interplay with longitudinal flow?)
- Kurtosis study: peak narrowing for higher p_T (trigger and associated) correlations and flattening in central Pb-Pb collisions
- V^0-h correlations: with possible tagging of quark and gluon jets on statistical basis it is an interesting alternative of measuring colour charge type energy loss
- Outlook for V^0-h: clear jet-like peaks show feasibility of measurement in central Pb-Pb (0-10%), it will be interesting to study V^0-h also in pp and p-Pb collisions

Backup slides

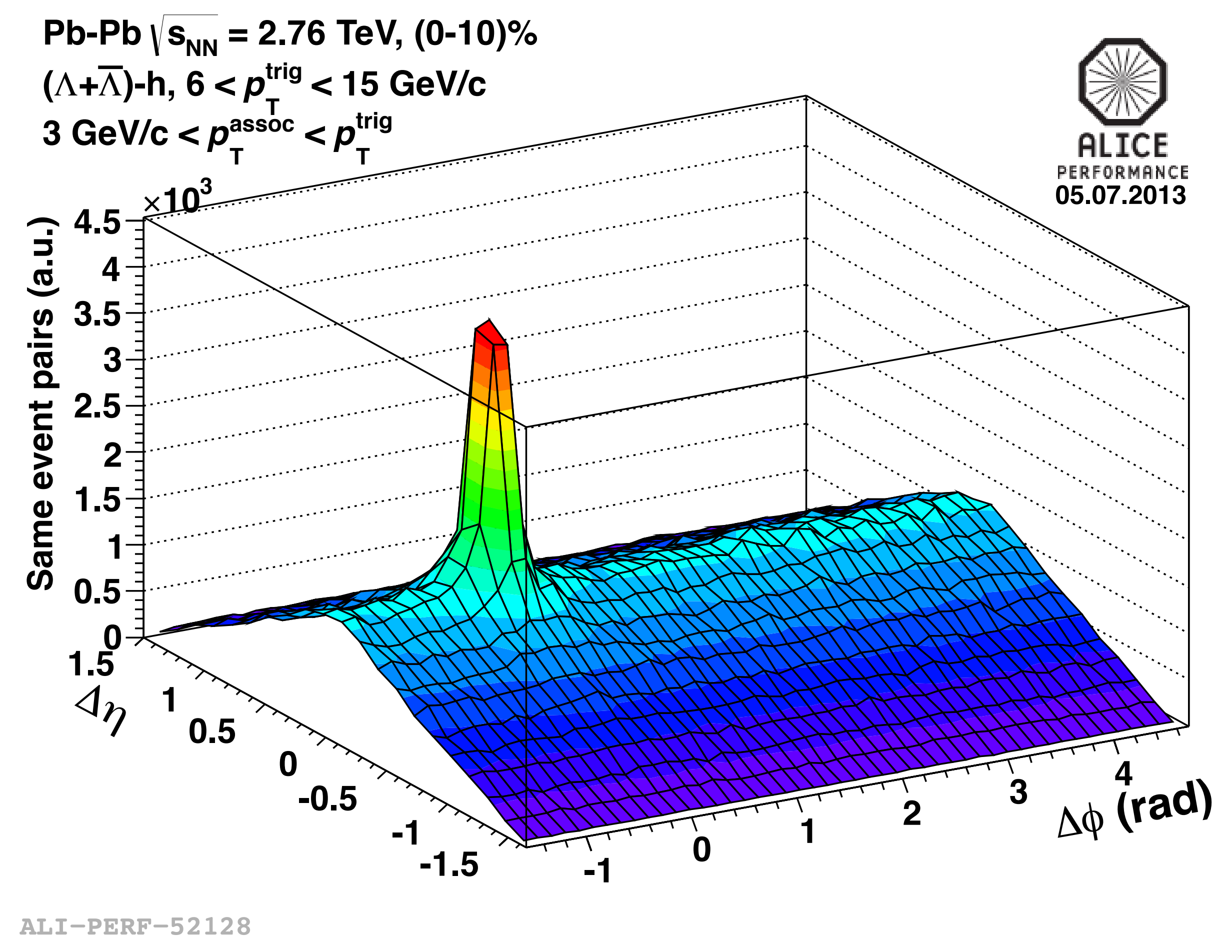
Same $N_{pairs}(\Delta\varphi,\Delta\eta)$ (uncorrected) distributions (0-10%)

Trigger particles (V^0s/h): $6 < p_{T,trig} < 15$ GeV/c
Associated particles (h): $3 < p_{T,assoc} < p_{T,trig}$

Same event pairs: the Near-side jet-like peak sits on a triangular shaped background.



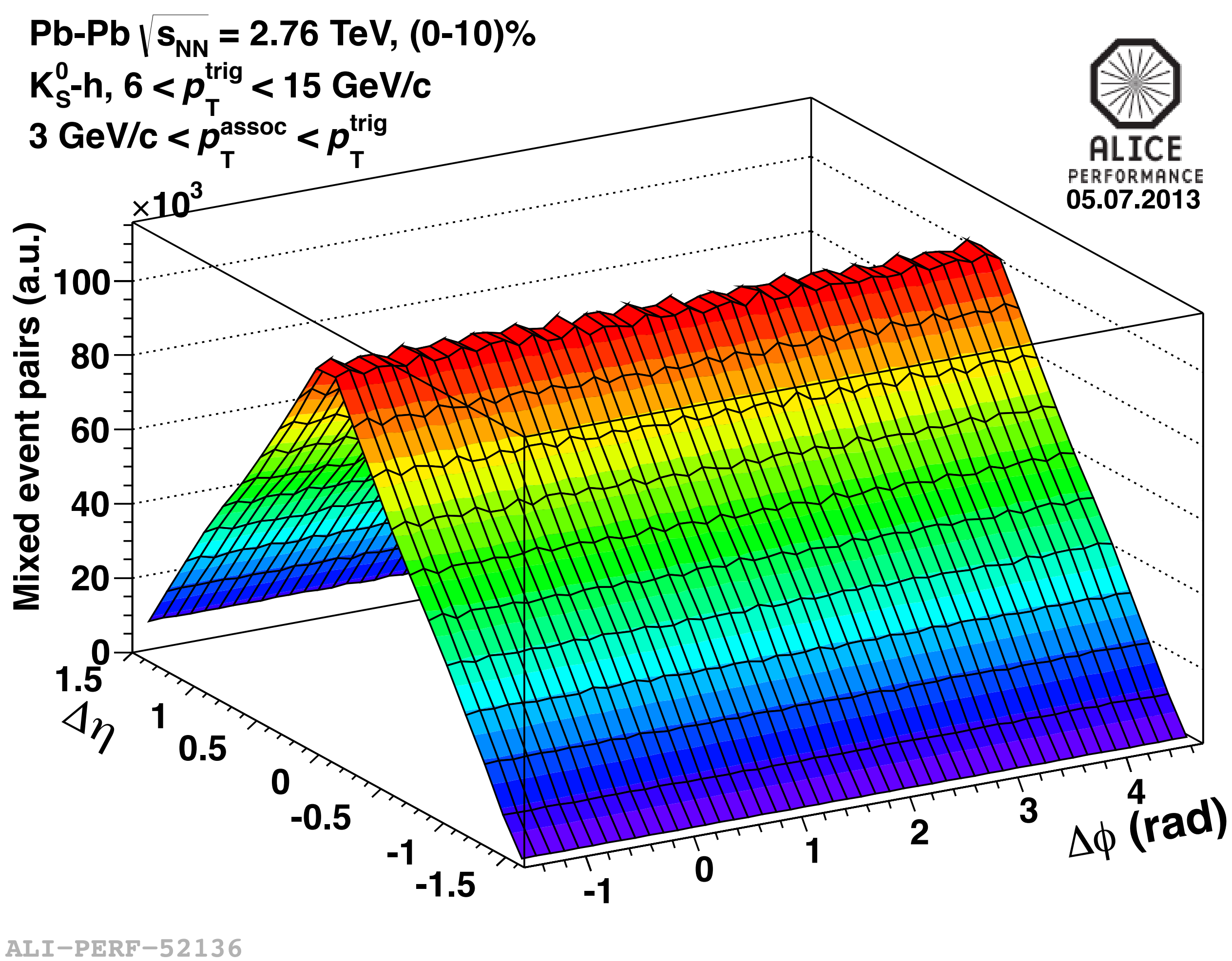
K^0_S-h



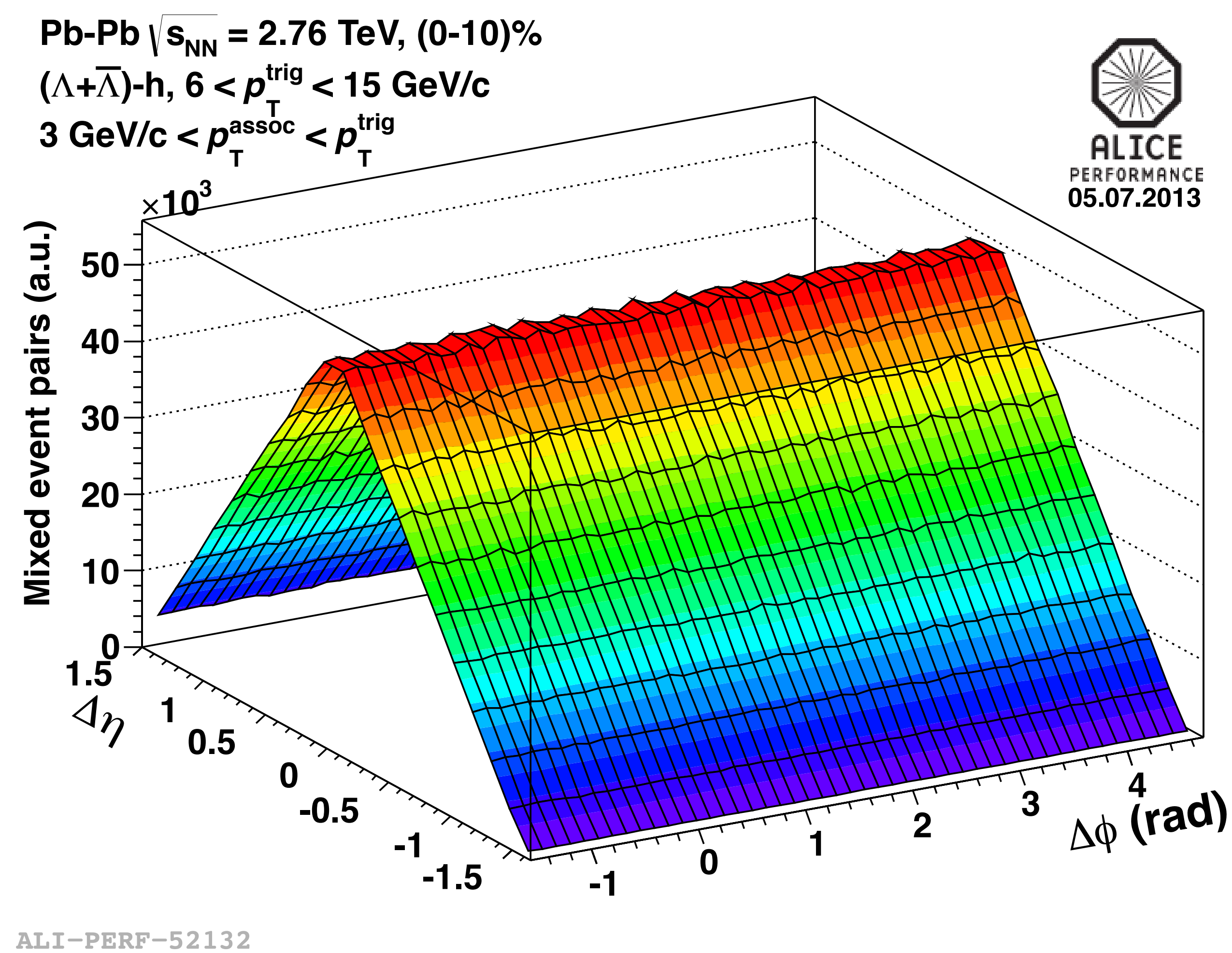
(Λ+antiΛ)-h

Mixed $N_{pairs}(\Delta\varphi,\Delta\eta)$ distributions (0-10%)

Background determination: the triangular shape can be reproduced by mixed pairs, where the trigger and the associated particle come from different events.



K^0_S-h



(Λ+antiΛ)-h