Study of jet fragmentation with two particle correlations in Pb-Pb collisions at 2.76 ATeV by ALICE

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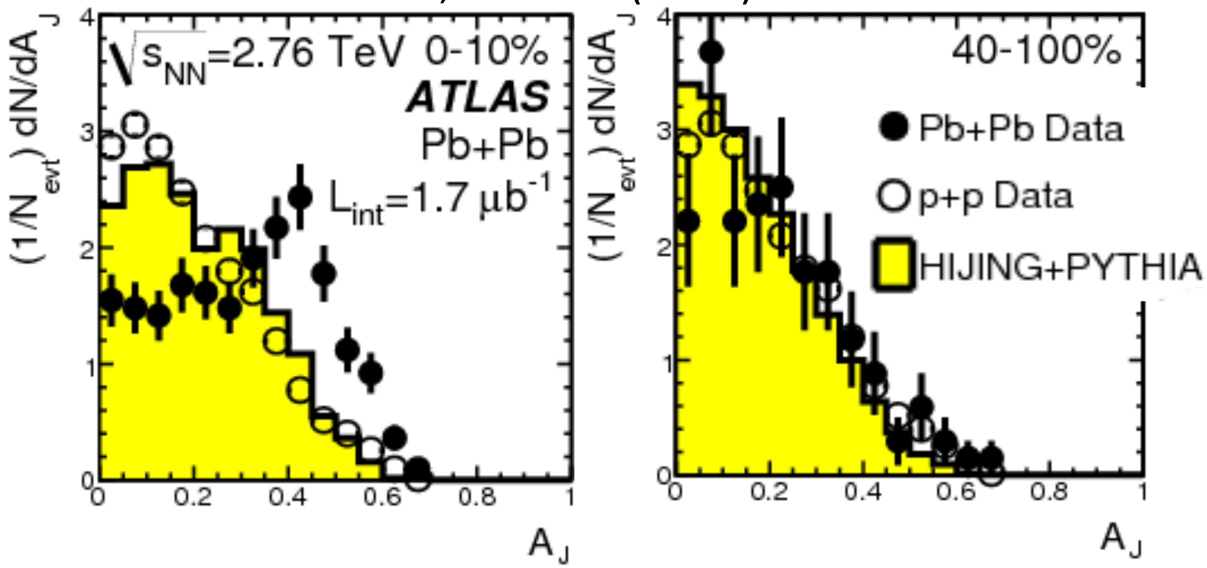
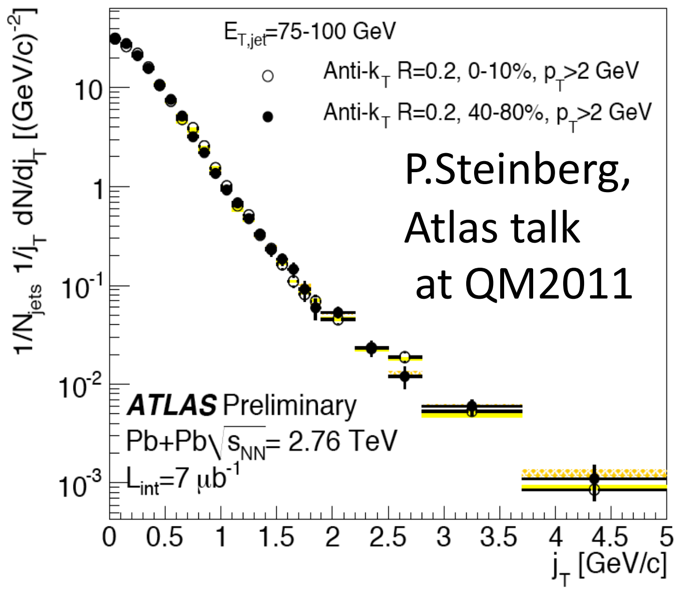
for the ALICE collaboration

Study of the E_{loss} mechanism (jets)

- Strong jet quenching is observed in HI collisions at RHIC and LHC.
- Analyses based on full jet reconstruction show
  - strong di-jet energy asymmetry [ATLAS PRL 105(2010) 252303, CMS, PRC 84, 024906 (2011)]
  - jet fragmentation (of the quenched parton) seems to look as unmodified [P.Steinberg ATLAS talk at QM2011, CMS arXiv:1205.5872]
  - quenched energy reappears at low p_T, also outside the jet cone [CMS, PRC 84, 024906 (2011)]

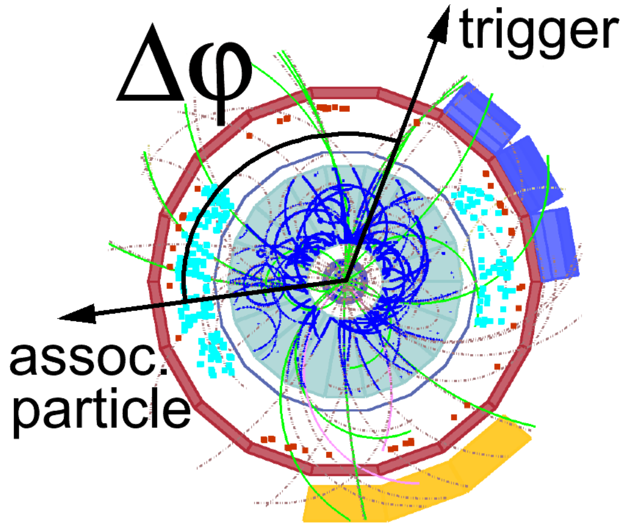
ATLAS, PRL 105 (2010) 252303





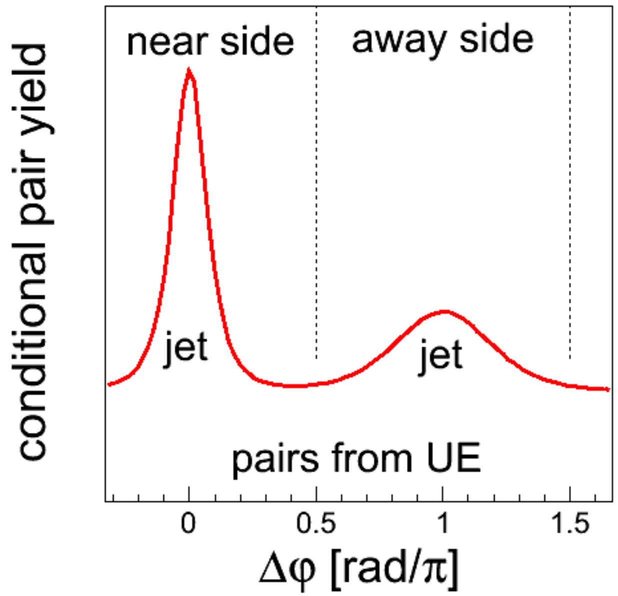
Di-hadron correlations

- Indirect method (only 2 hadrons from jet)
- Jet properties studied statistically



Basic quantities

$$\Delta\varphi = \varphi_{\mathrm{assoc}} - \varphi_{\mathrm{trig}}$$
$$\Delta\eta = \eta_{\mathrm{assoc}} - \eta_{\mathrm{trig}}$$
$$R = \sqrt{\Delta\varphi^2 + \Delta\eta^2}$$
$$I_{AA} = \frac{1/N_{\mathrm{trig}}^{\mathrm{Pb\text{-}Pb}} \times Y^{\mathrm{Pb\text{-}Pb}}\Big|_{p_{T,\mathrm{trig}};\,p_{T,\mathrm{assoc}}}}{1/N_{\mathrm{trig}}^{\mathrm{pp}} \times Y^{\mathrm{pp}}\Big|_{p_{T,\mathrm{trig}};\,p_{T,\mathrm{assoc}}}}$$



Near side (intra jet) : Single jet properties

such as jet transverse fragmentation momentum

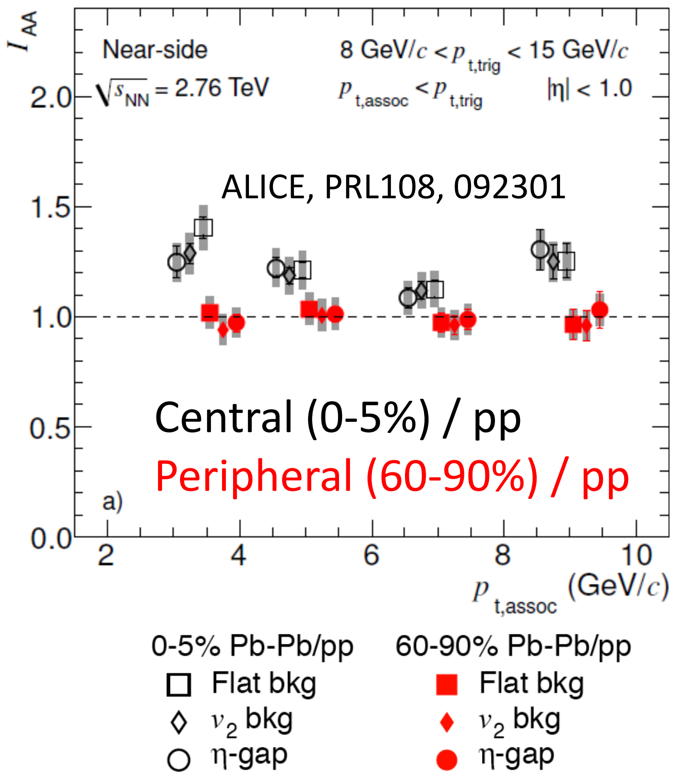
Away side (inter jet) : Di-jet properties

such as accoplanarity + mom. imbalance due to k_T

Study of E_{loss} mechanism (di-hadron correl.)

- I_{AA} measurements by ALICE for
  $8<p_{T,trig}<15$ GeV/c & 3 GeV/c < $p_{T,assoc}$
  - away side I_{AA} ~ 0.5
  - near side I_{AA} ~ 1.2 – 1.3
  - near side parton is sensitive to medium
    a) modification of jet fragmentation (softening)?
    b) modification of quark/gluon jet ratio (g filtering) ?
    c) bias of the parton p_T spectrum after energy loss due to trigger selection ?

Near side I_{AA} Pb-Pb 2.76 ATeV

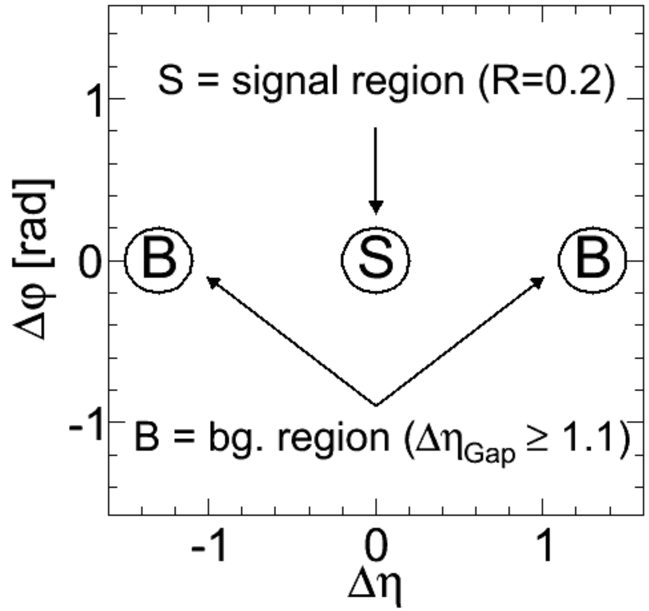


- How does near side I_{AA} continue at lower $p_{T,assoc}$?
- Can we see some modification in transverse jet shape at near side?
- Method: Two-particle correlations

Near side I_{AA} (in R<0.2) at low $p_{T,assoc}$

- Signal yield Y_S from a cone (radius R = 0.2)
- Background yield Y_B estimated using two R=0.2 cones placed at large $\Delta\eta_{Gap} > 1.1$

$$I_{AA} = \frac{(Y_S - 0.5 \times Y_B)/N_{trig}\big|_{Pb\text{-}Pb}}{(Y_S - 0.5 \times Y_B)/N_{trig}\big|_{pp}}$$



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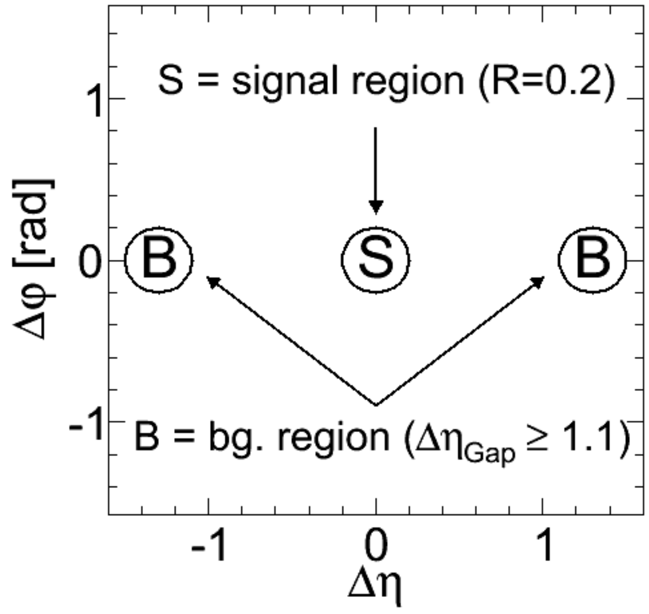
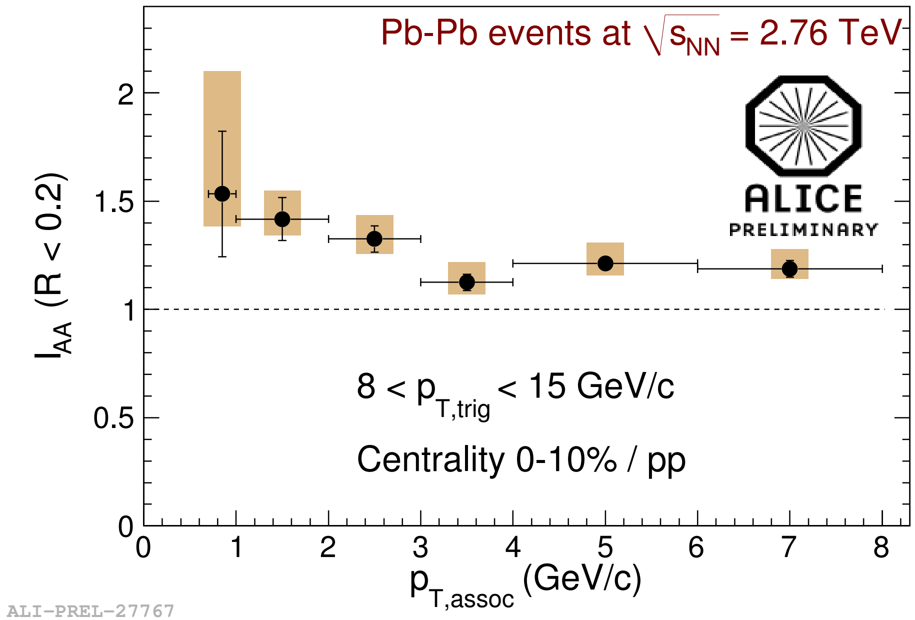
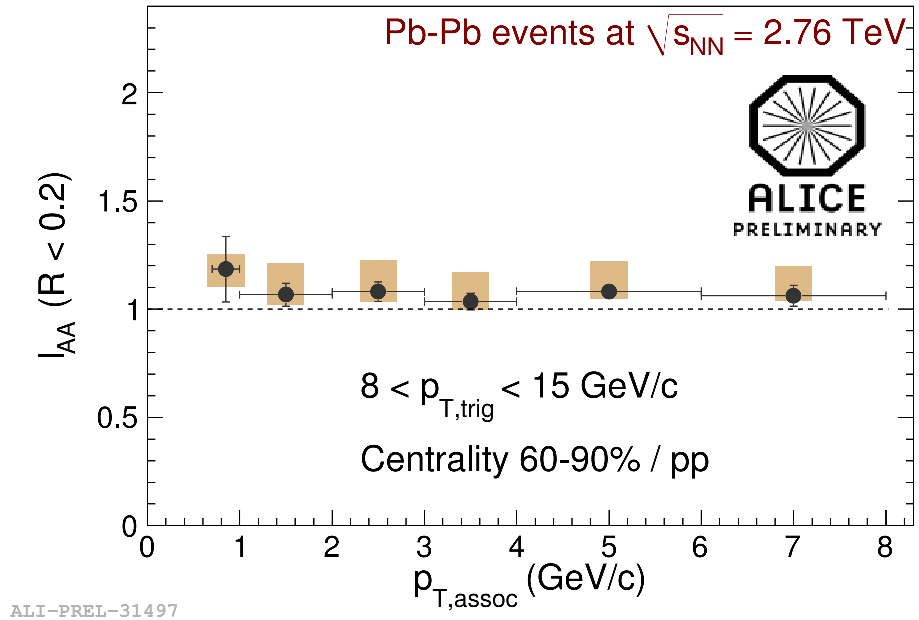


- Near side I_{AA} in 0-10% central collisions shows moderate enhancement by ~ 20-50%



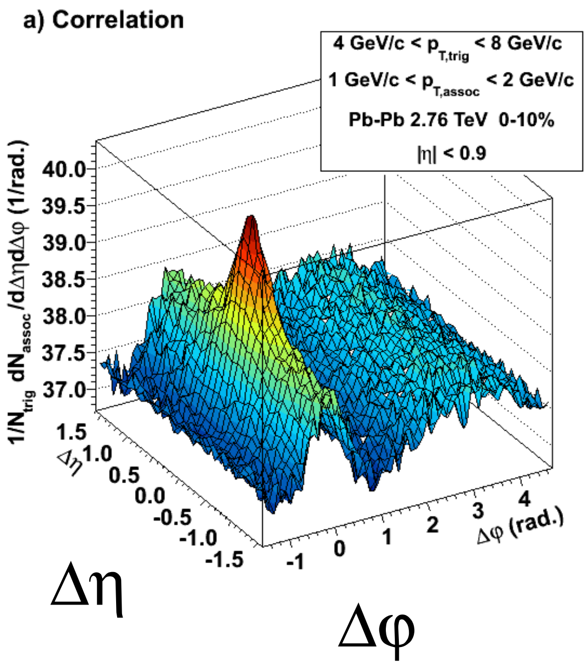


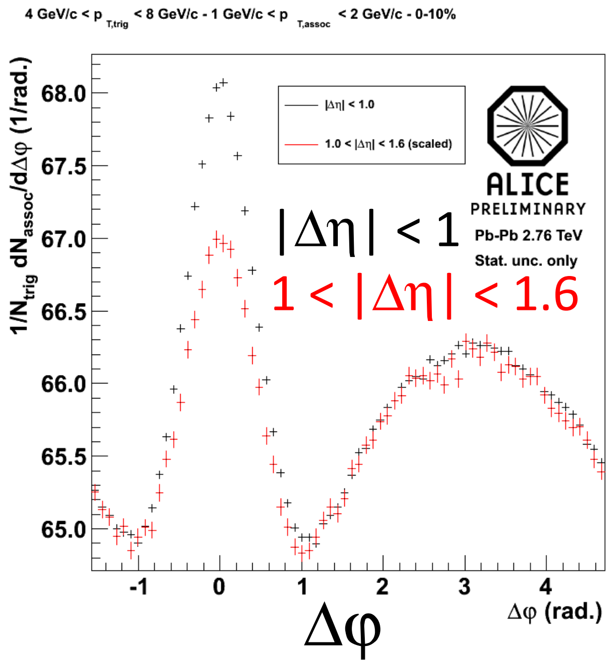
Analysis of near side peak shape

- Near-side jet peak is centered around $\Delta\eta = 0$
- Estimate $\Delta\eta$-independent effects (e.g. flow) by studying the long-range correlation region ($|\Delta\eta| > 1$)
- Subtract from short-range region ($|\Delta\eta| < 1$)

Pb-Pb 2.76 ATeV Cent 0-10%

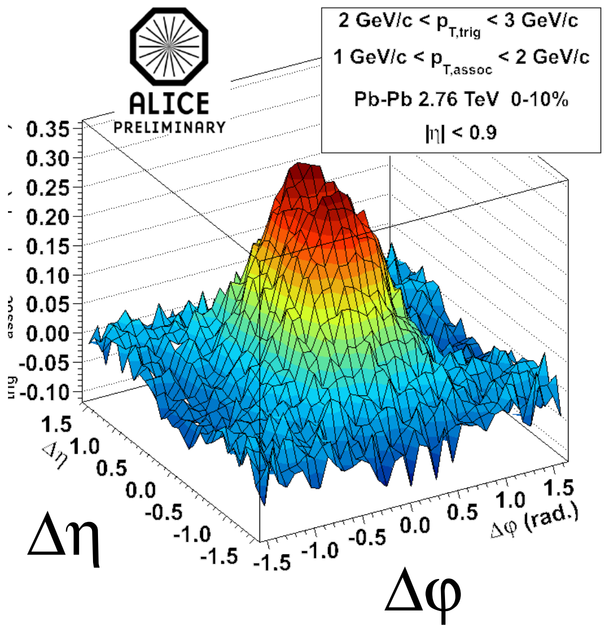
$4 < p_{T,trig} < 8$ GeV/c + $1 < p_{T,assoc} < 2$ GeV/c



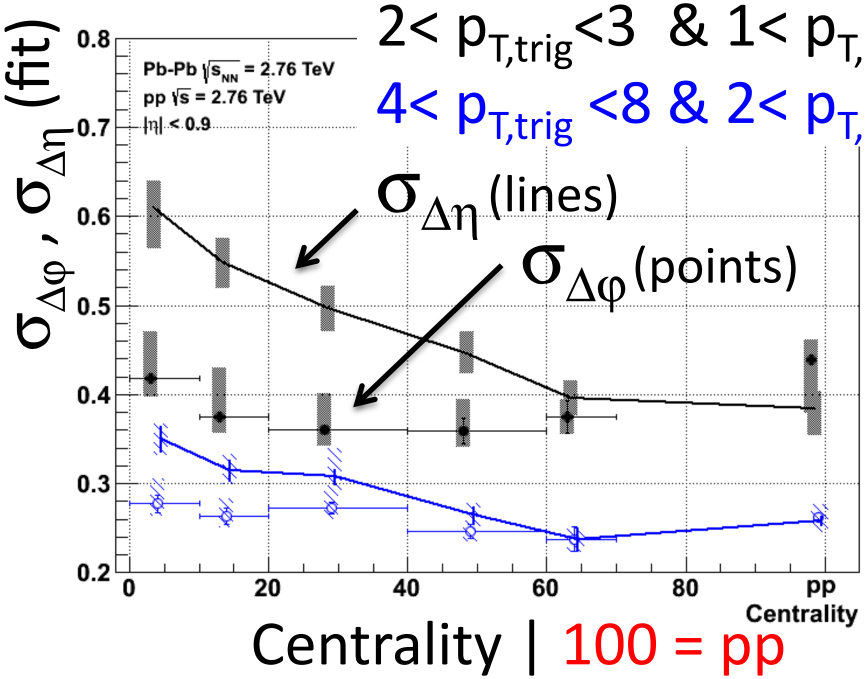


$2 < p_{T,trig} < 3$ GeV/c

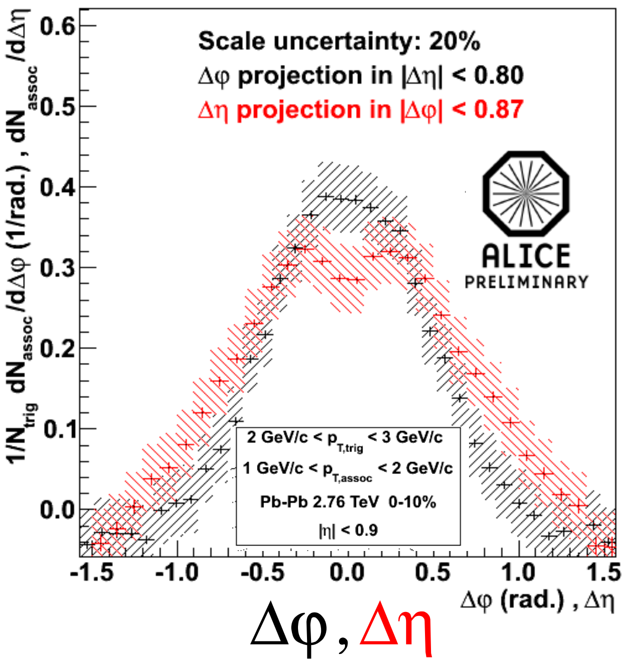
$1 < p_{T,assoc} < 2$ GeV/c



Evolution of near side peak shape



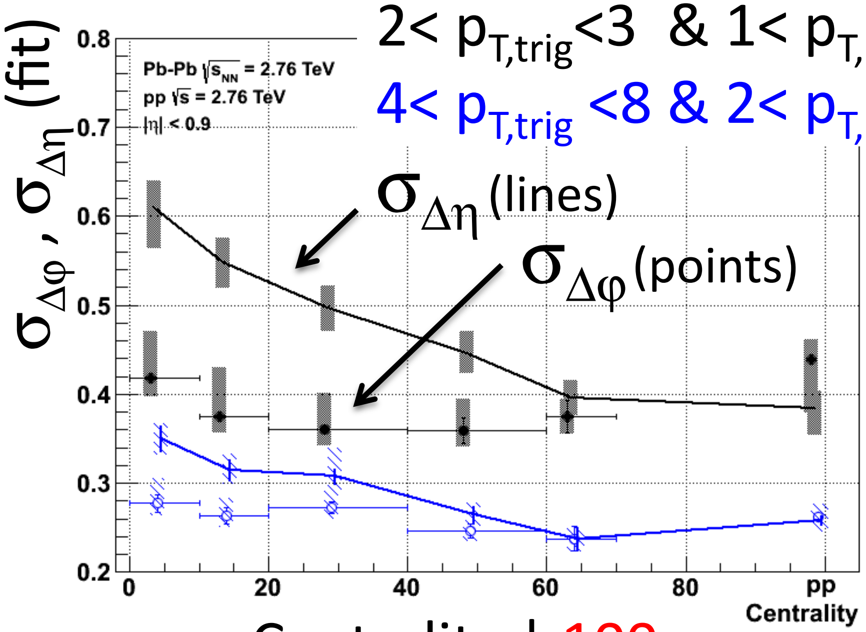
Pb-Pb 2.76 ATeV
Cent. 0-10%
2< $p_{T,trig}$ <3 GeV/c
1< $p_{T,assoc}$ <2 GeV/c



Evolution of near side peak shape

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

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



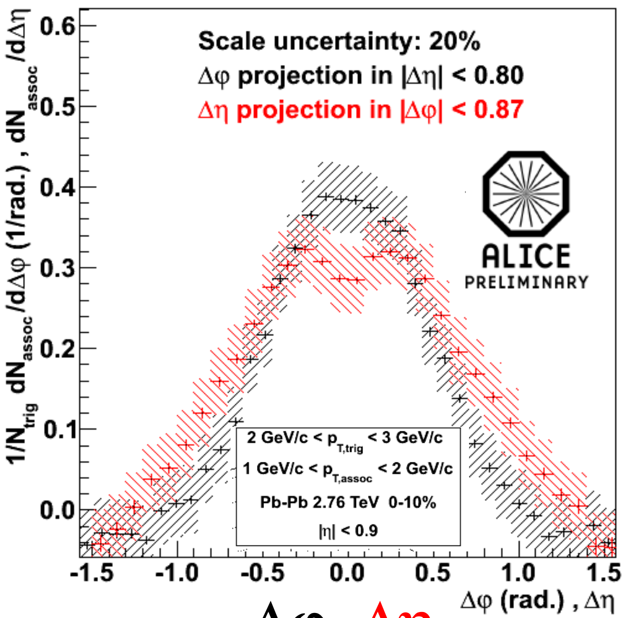
Centrality | 100 = pp

Pb-Pb 2.76 ATeV

Cent. 0-10%

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

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



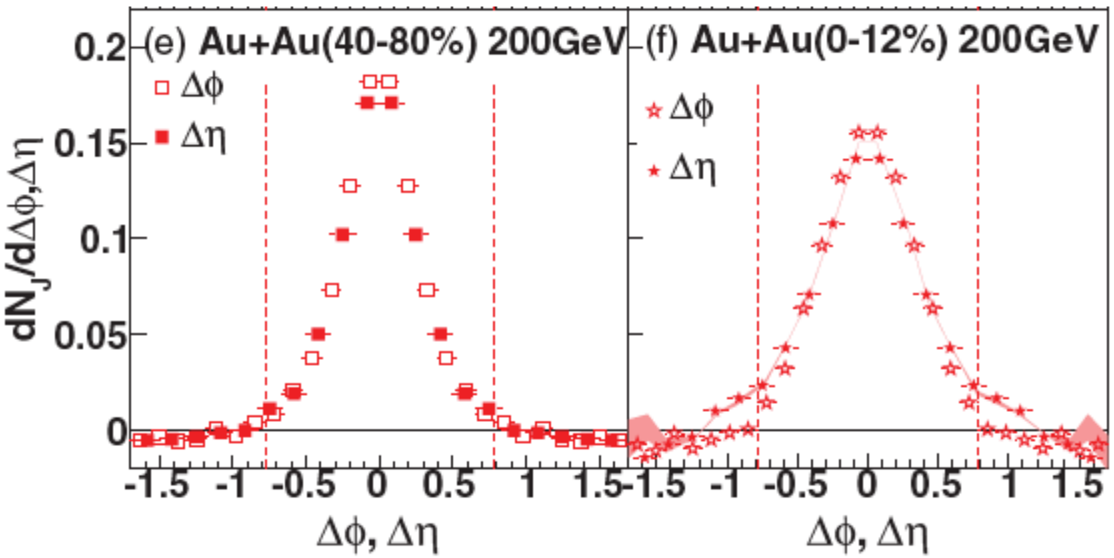
Δφ , Δη

STAR, PRC **85** (2012) 14903

3 < $p_{T,trig}$ < 6 GeV/c

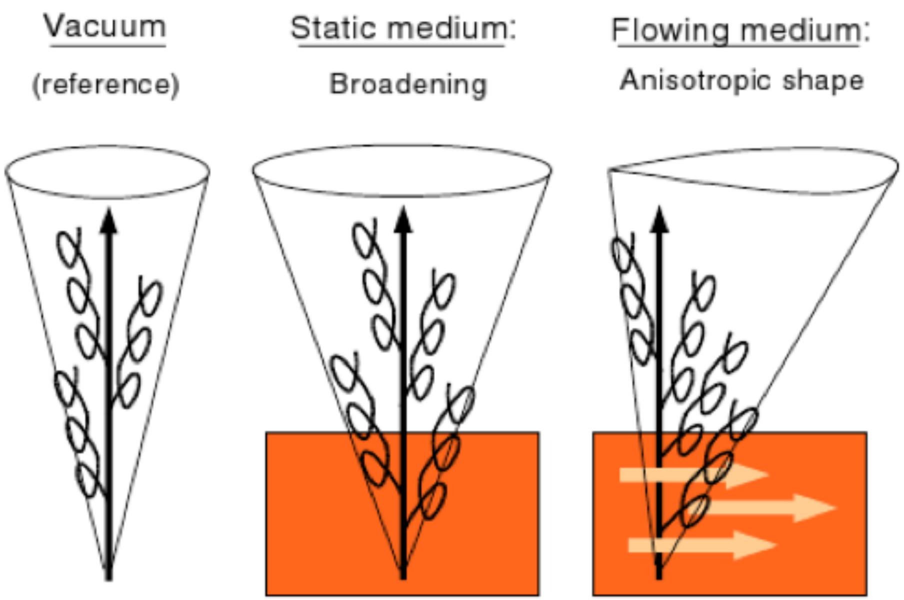
1.5 GeV/c < $p_{T,assoc}$ < $p_{T,trig}$

Paper reports a clear increase of Δη width with increasing $\langle N_{part} \rangle$ in Au+Au at 200 AGeV

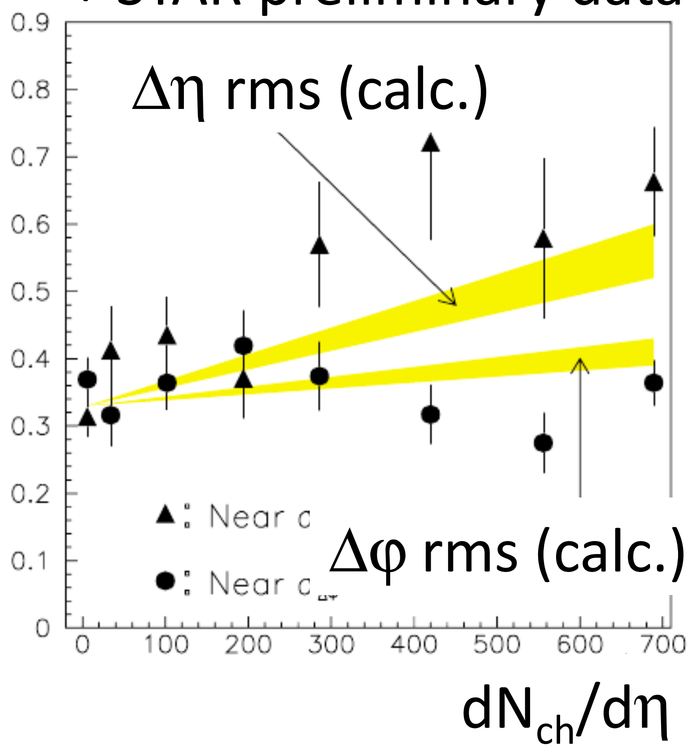


Possible scenario for peak deformation

- Armesto, Salgado, Wiedemann suggested that longitudinal flow can deform the conical jet shape (PRL 93,242301 (2004))
- Interplay between jet and flow



Calculation
+ STAR preliminary data

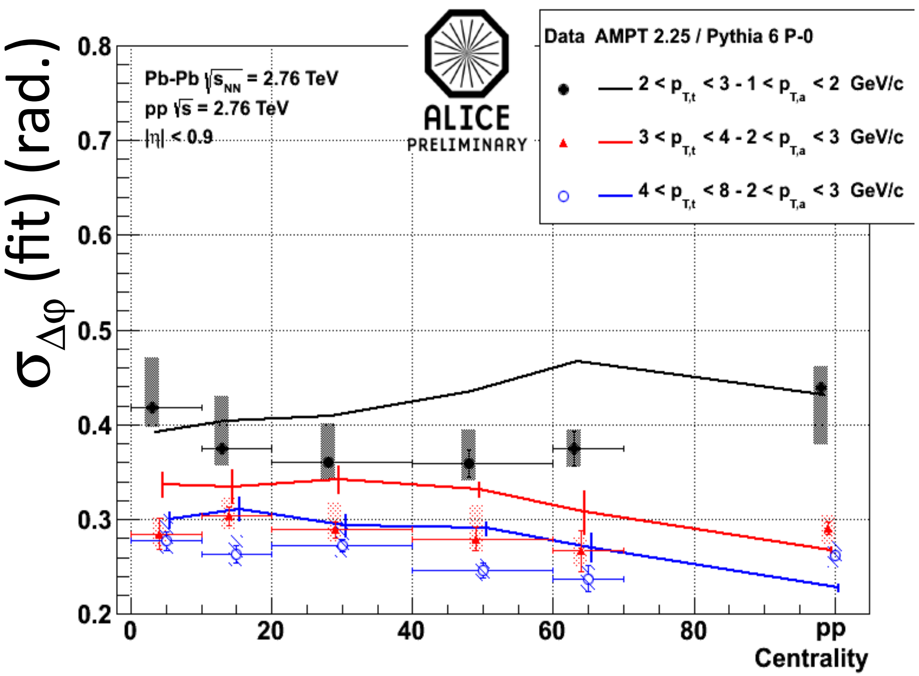


PRL 93,242301 (2004)

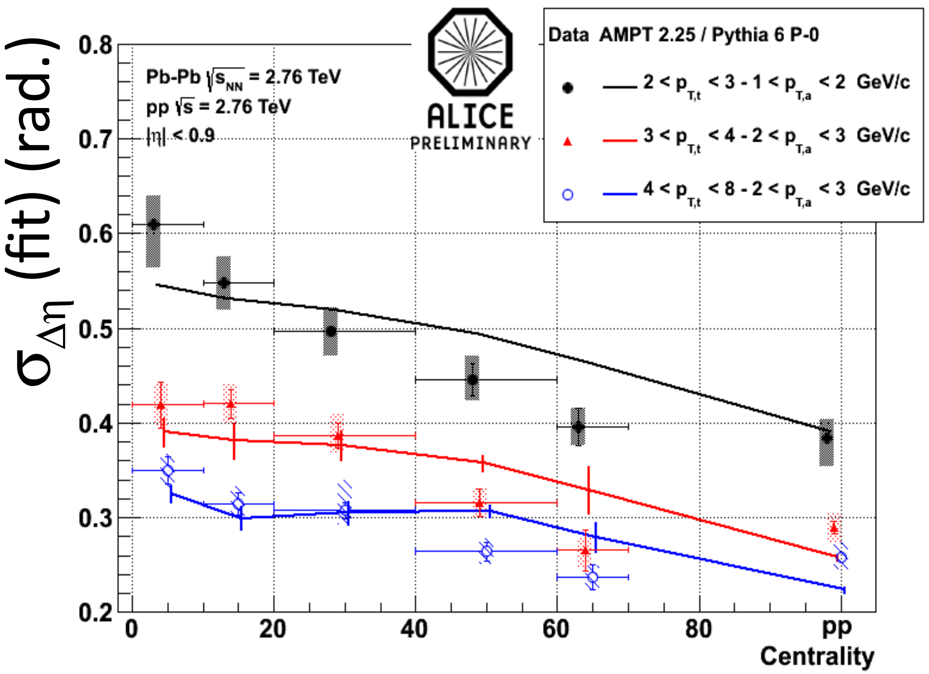
AMPT comparison

- AMPT (A MultiPhase Transport Code, Phys.Rev. C72 (2005) 064901) describes collective effects (e.g. v_2, v_3, v_4) in HI collisions at LHC
  - Here version with string melting (2.25) is shown
- It also does rather well for the rms of the near side peak
  - Interplay of jet and flow in AMPT via parton and hadron scattering

AMPT calculation is shown as lines



Centrality | 100 = pp



Centrality | 100 = pp

$I_{AA}(\Delta\eta)$ and jet shape modification

- Analyze $dN/d|\Delta\eta|$

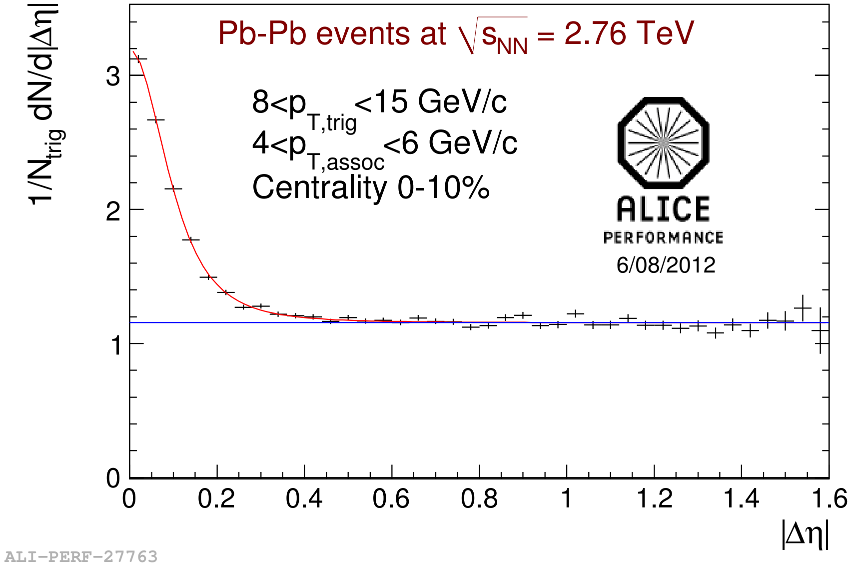
  (positive and corresp. negative bins combined)

- Background level estimated by a fit

  Kaplan plus constant (parameters A, b, n, k)

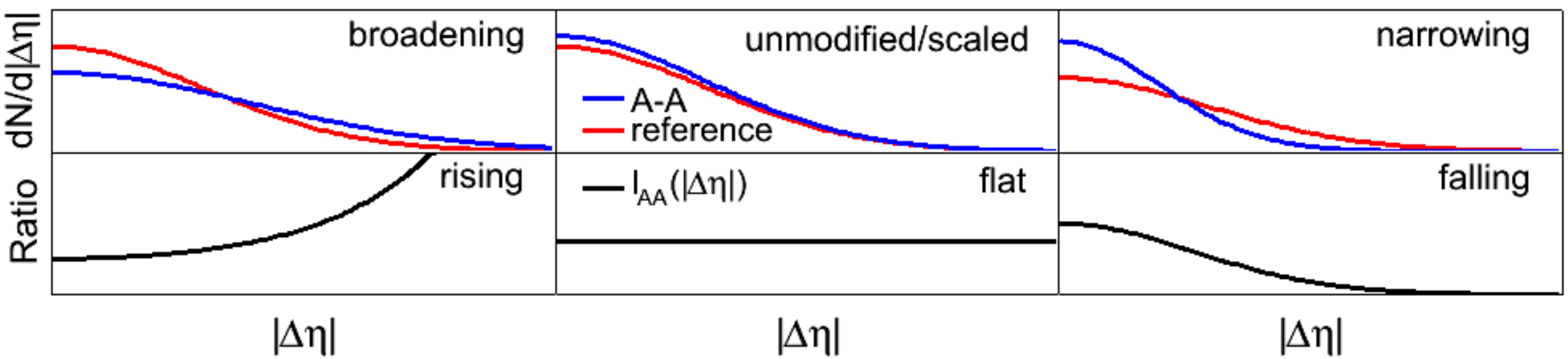
$$f(\Delta\eta) = A(\ 1 + b\Delta\eta^2)^{-n} + k$$

- Evaluate the ratio

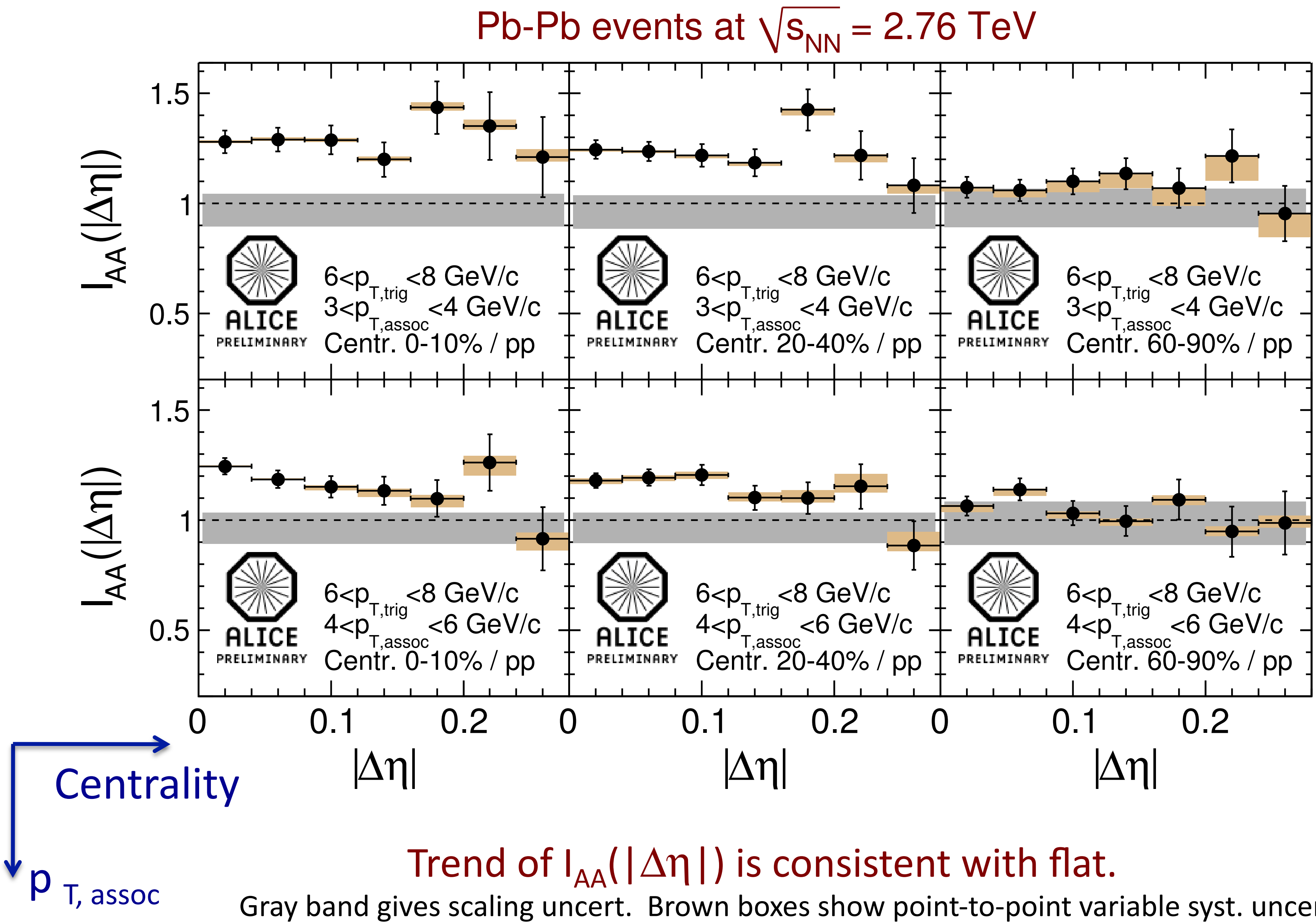


$$I_{AA}(|\Delta\eta|) = \frac{1/N_{\rm trig}^{\rm Pb\text{-}Pb} \times dN^{\rm Pb\text{-}Pb}/d|\Delta\eta|\Big|_{p_{\rm T,trig};\, p_{\rm T,assoc}}}{1/N_{\rm trig}^{\rm pp} \times dN^{\rm pp}/d|\Delta\eta|\Big|_{p_{\rm T,trig};\, p_{\rm T,assoc}}}$$

Cartoon showing possible scenarios of jet shape modification



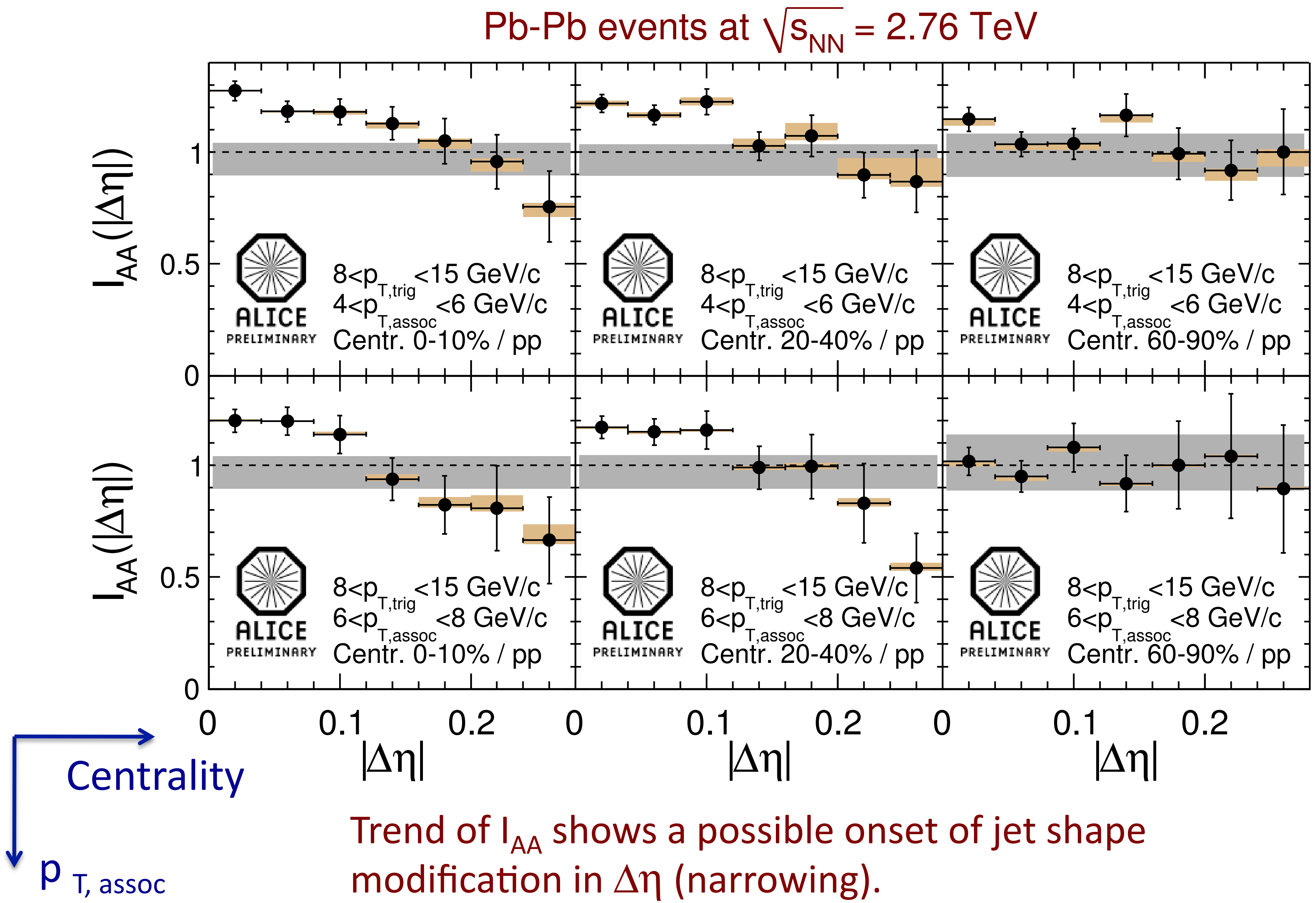
$I_{AA}(|\Delta\eta|)$ at intermediate p_T ($6<p_{T,trig}<8$ GeV/c)



Trend of $I_{AA}(|\Delta\eta|)$ is consistent with flat.

Gray band gives scaling uncert. Brown boxes show point-to-point variable syst. uncert.

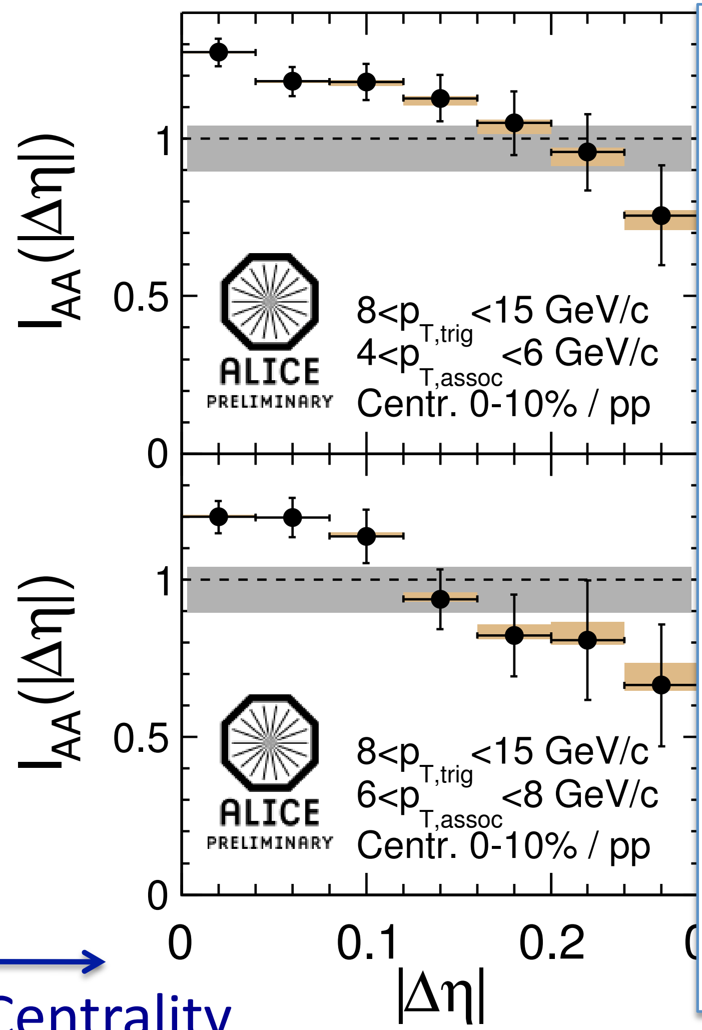
$I_{AA}(|\Delta\eta|)$ at high p_T ($8<p_{T,trig}<15$ GeV/c)



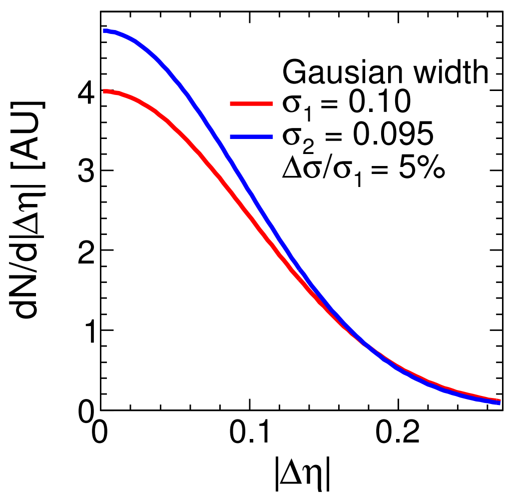
Trend of I_{AA} shows a possible onset of jet shape modification in $\Delta\eta$ (narrowing).

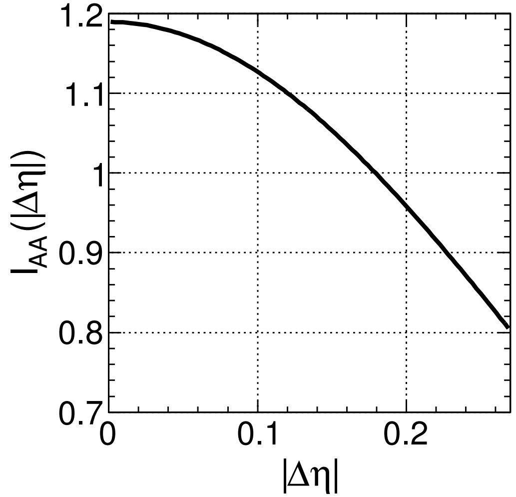
$I_{AA}(|\Delta\eta|)$ at high p_T ($8<p_{T,trig}<15$ GeV/c)

Pb-Pb events at $\sqrt{s_{NN}} = 2.76$ TeV



- Observed effect on $I_{AA}(\Delta\eta)$ does not need significant modification of near side peak rms
- Cartoon below shows two gaussians having some typical rms of near side peak at high p_T
  - rms differ only by 5%
  - I_{AA} ($|\Delta\eta|$) ratio on the right plot shows similar magnitude of decrease





Centrality

$p_{T,\ assoc}$

Trend of I_{AA} shows a possible onset of jet shape modification in $\Delta\eta$ (narrowing).

Summary

- Near side I_{AA} measured in 0-10% centrality bin of Pb-Pb collisions in cone with R=0.2 exhibits enhancement of 20-50% down to $p_{T,assoc}$ = 0.7 GeV/c

- Study of the near side peak shape evolution

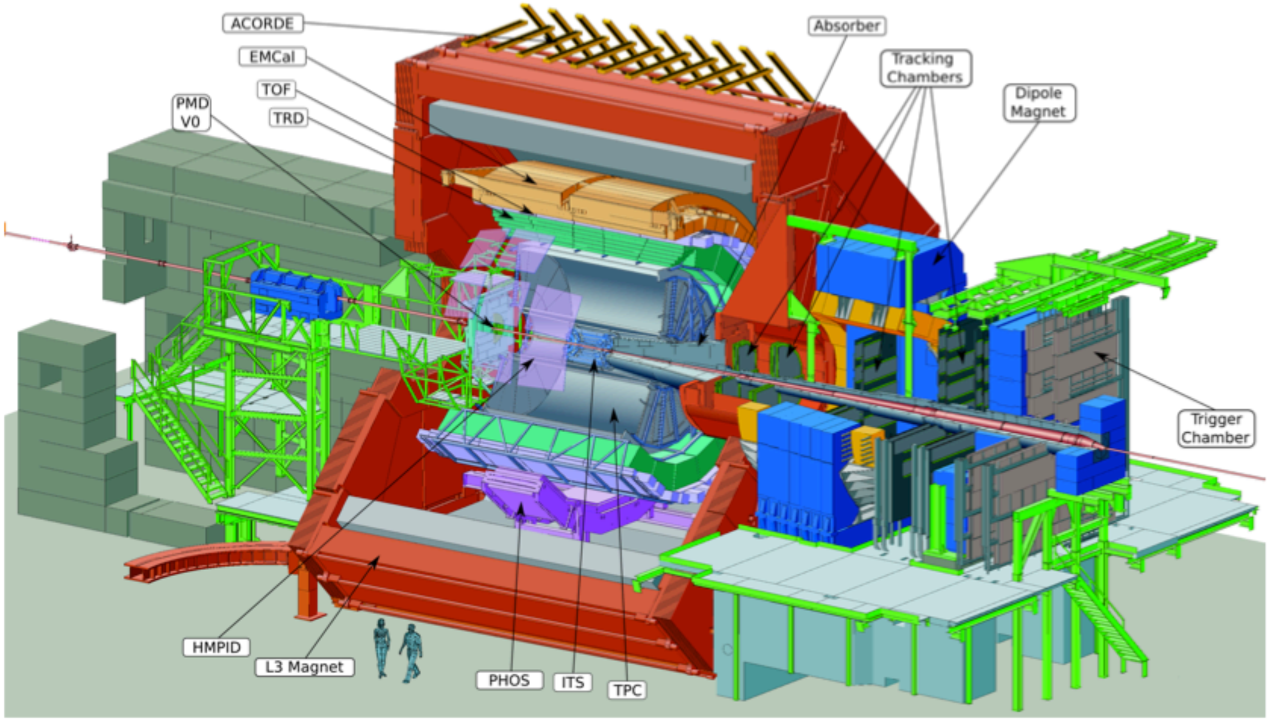
a) Asymmetric near side peak in central Pb-Pb collisions at low p_T

- $\Delta\eta$ rms shows a strong centrality dependence (broadening), contrary to $\Delta\varphi$
- rms well reproduced by AMPT
- interplay of the jet with flow?

b) At high p_T ($8 < p_{T,trig} < 15$ GeV/c + $p_{T,assoc} > 4$ GeV/c) we see a hint for onset of the near side peak modification (narrowing along $\Delta\eta$)

Backup slides

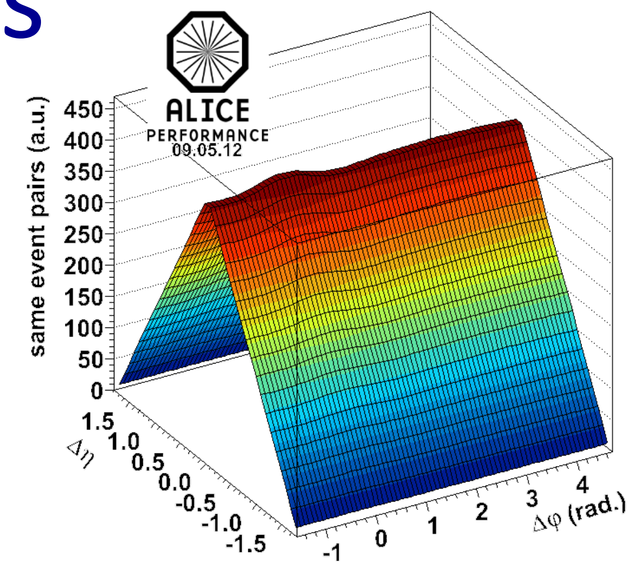
ALICE, experiment dedicated to HI at LHC

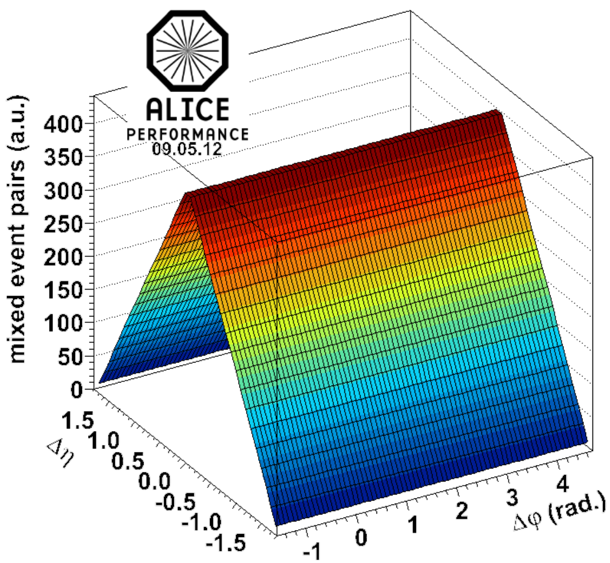


- Studies properties of hot and dense strongly interacting matter under extreme conditions
- B = 0.5 T, 0.15 $< p_T <$ 100 GeV/c
- Main tracking devices ITS + TPC
- PID detectors TOF, TRD, HMPID, EMCAL, PHOS
- Forward detectors V0, T0, ZDC, PMD, FMD, MCH

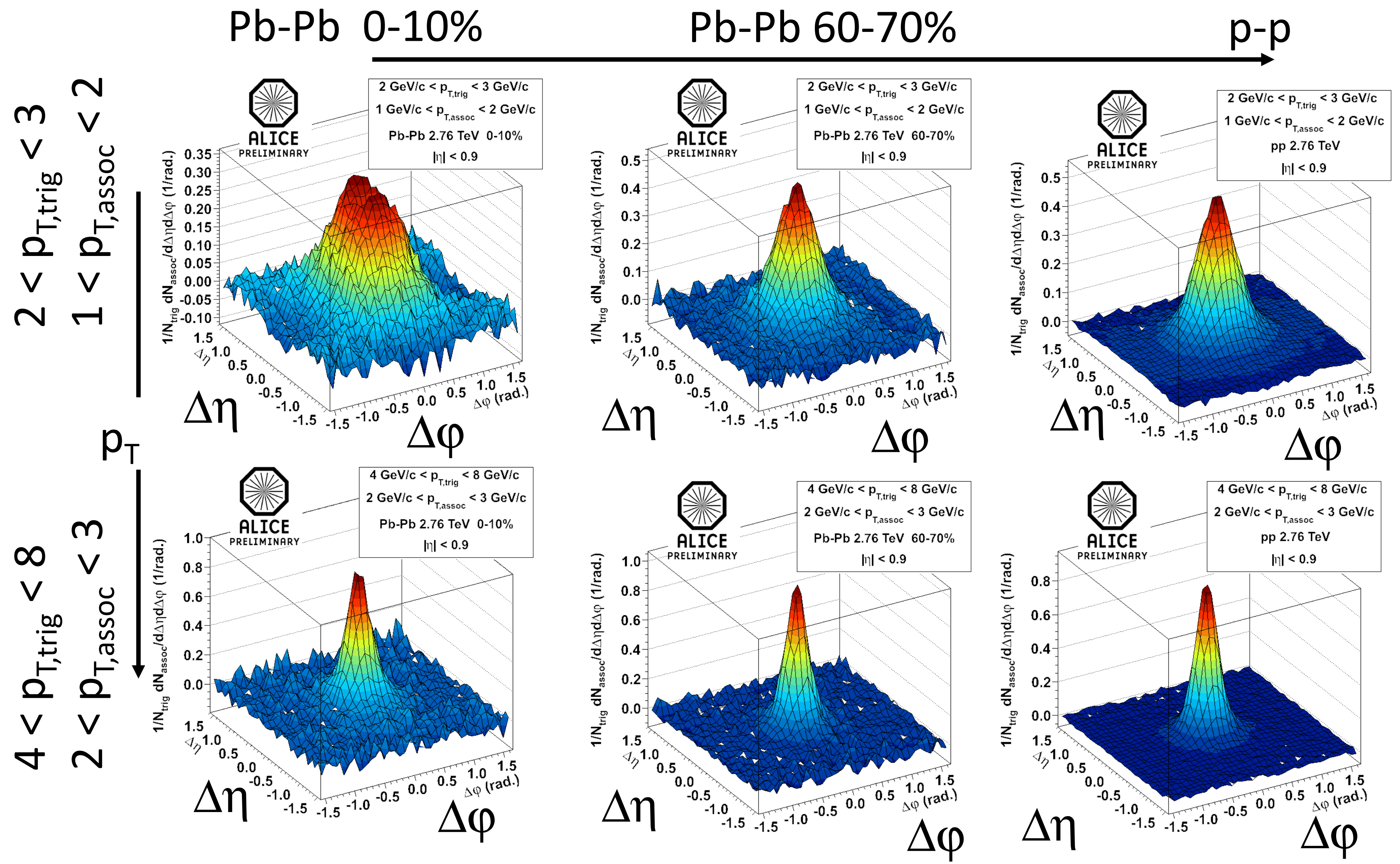
Analysis details

- Event sample
  - 15M Pb-Pb events at $\sqrt{s_{NN}}$ = 2.76 TeV
  - 55M p-p events at $\sqrt{s}$ = 2.76 TeV
- Track selection benefits from uniform φ acceptance of TPC
  - $|\eta| < 0.9$
  - Two-track efficiency cut on distance of closest approach of a track pair in the TPC volume
- Event mixing corrects for two-track acceptance [in bins of centrality and vertex position]
- Per-trigger yields corrected for tracking efficiency and contamination (no influence on shapes)





Near side peak shape evolution



Peak rms in $\Delta\varphi$ and $\Delta\eta$ extracted from a fit (sum of two 2D Gaussians)

Low p_{Ta} I_{AA} (R<0.2) compared with published I_{AA} data (central collisions)