Jet azimuthal distributions with high p_T neutral pion triggers in pp 7 TeV and PbPb 2.76 TeV

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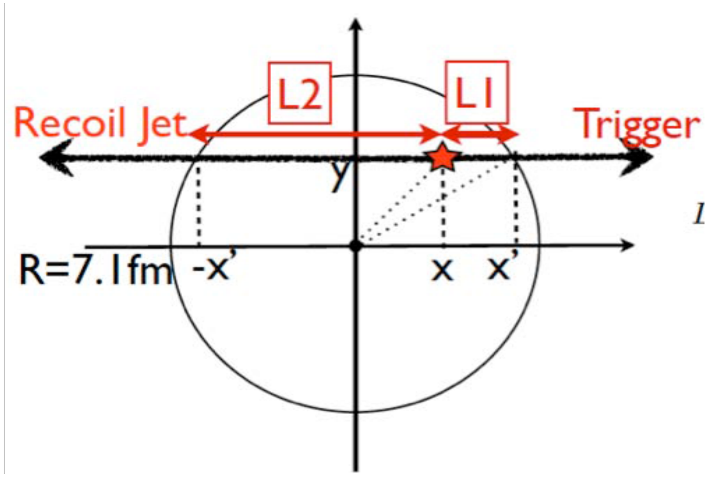
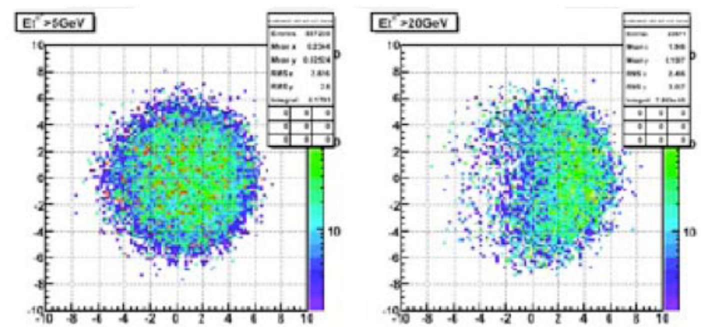
Outline

- Physics motivation of π^0 – jet correlation
- Data set and cut condition
- Analysis procedure
- Results
  - pp analysis
  - Pb-Pb analysis
- Summary

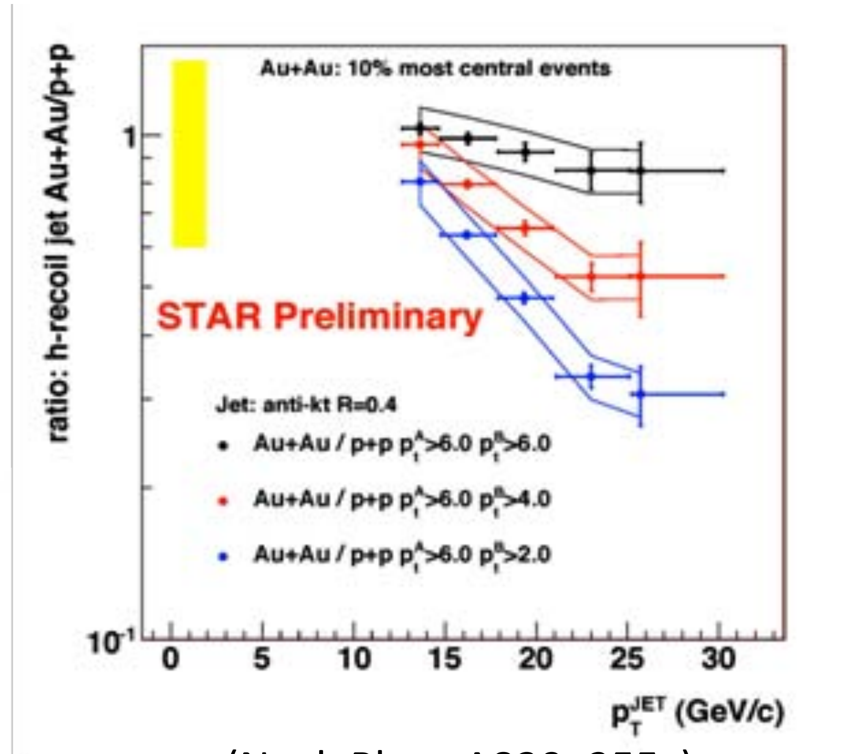
Physics motivation of π^0-jet correlation



Qhat=50 GeV2/fm



(CERN-LHCC-2010-011, ALICE-TDR-014-ADD-1)

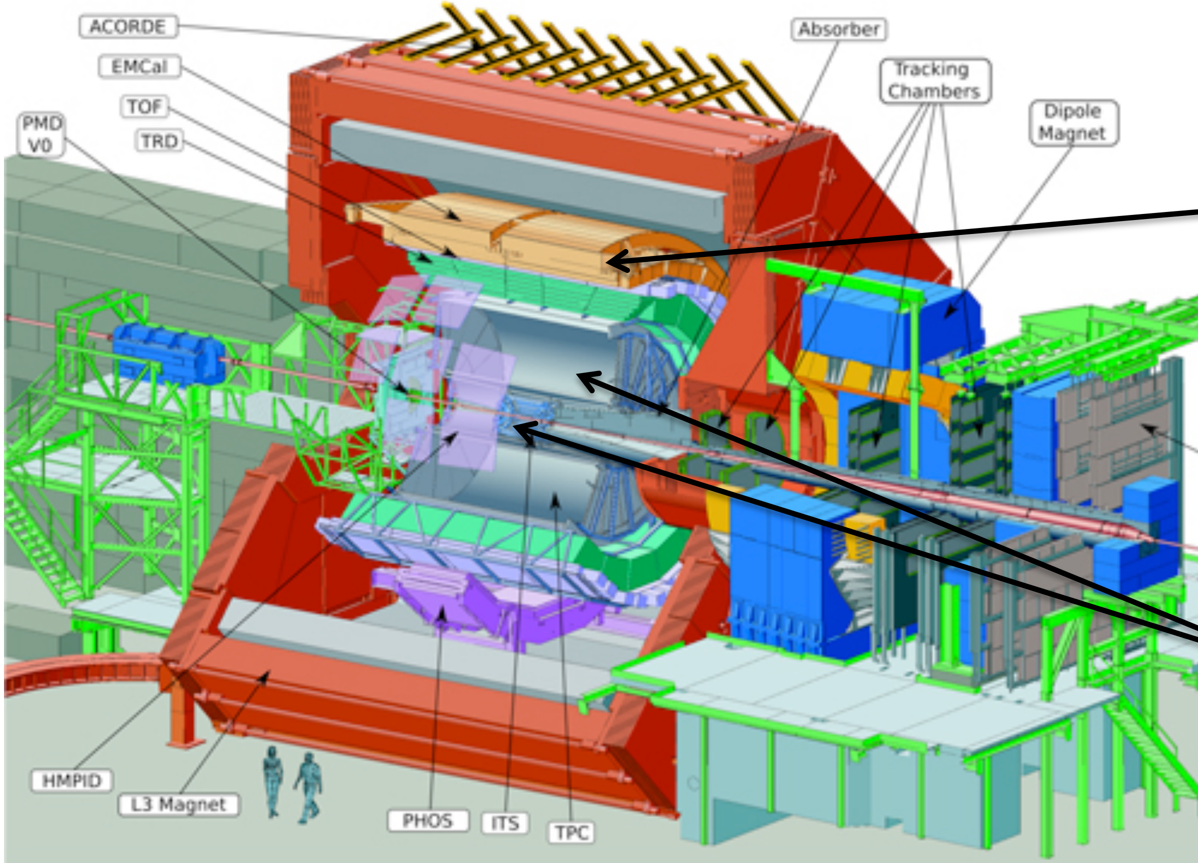


(Nucl. Phys. A839, 255c)

- Can control path length by tagging a recoil jet with triggered π^0 and changing p_T for π^0
- High p_T of π^0 -> longer path length of recoiling jets
- Direct measurement of path length dependence of "jet" quenching, not by hadron
- pp analysis is an important baseline for PbPb analysis

A Large Ion Collider Experiment (ALICE)

ALICE

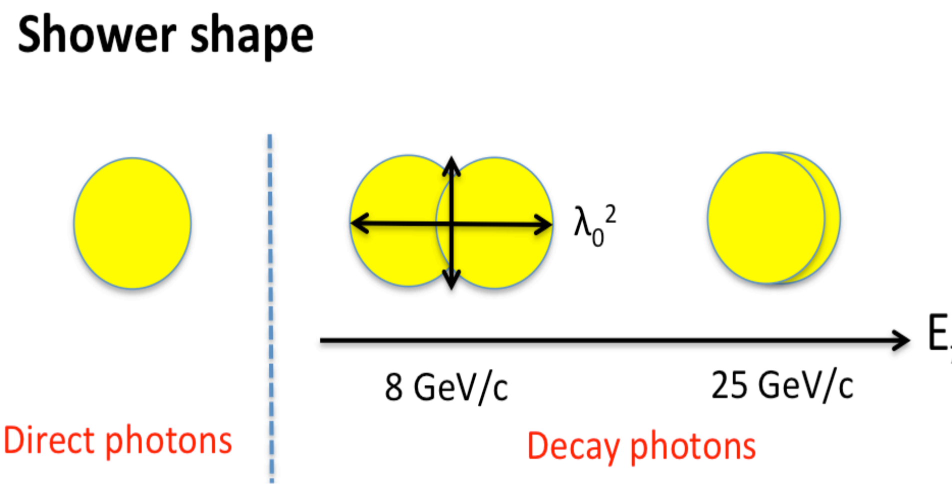


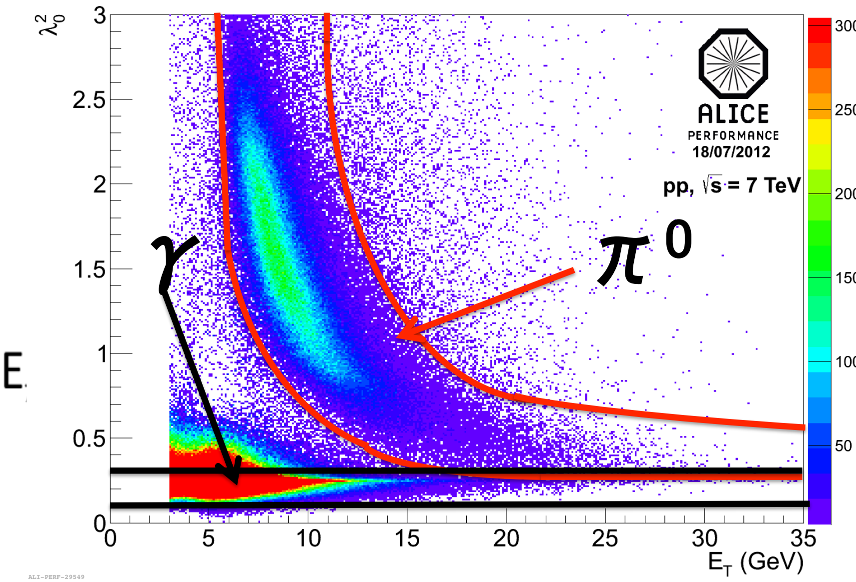
Photon identification
EMCal : Pb-scintillator calorimeter
$|\eta| < 0.7$, $\Delta\varphi = 110°$

Tracking
ITS : Silicon tracker
TPC : Time projection chamber
$|\eta| < 0.9$, $\Delta\varphi = 360°$

- Data set
  - pp collisions at √s = 7 TeV with EMCal triggered events
  - Pb-Pb collisions at √s_NN = 2.76 TeV with EMCal triggered events

π^0 identification method (cluster splitting method)





- The opening angle of the neutral mesons decay photon becomes smaller, when increasing the neutral meson energy due to Lorentz boost
- In the EMCAL, when the energy of π^0 is lager than 5 GeV
  - The two clusters of decay photon start to be close
  - The electromagnetic showers start to overlap

Charged jet reconstruction (FASTJET)

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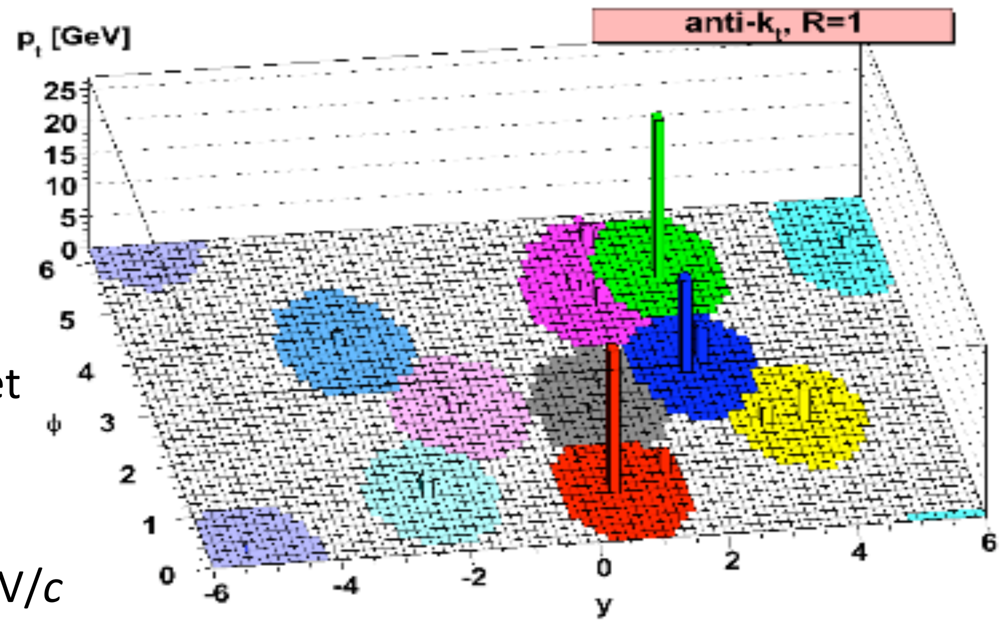
$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p}) \frac{\Delta R^2}{R^2} \begin{cases} p = 1 & k_T \text{ algorithm} \\ p = 0 & \text{Cambridge/Aachen algorithm} \\ p = -1 & \text{anti-}k_T \text{ algorithm} \end{cases}$$

Procedure of jet finding

1. Calculate particle distance : d_{ij}
2. Calculate Beam distance : $d_{iB} = k_{ti}^{2p}$
3. Find smallest distance (d_{ij} or d_{ib})
4. If d_{ij} is smallest combine particles
   If d_{ib} is smallest and the cluster momentum larger than threshold call the cluster Jet



M. Cacciari et al, JHEP 0804 (2008) 063

Parameters

- R size ($= \sqrt{\Delta\phi^2 + \Delta\eta^2}$) : 0.4
- p_T cut on a single particle : 0.15 GeV/*c*
- Jet energy threshold : 10 GeV/*c*
- Jet acceptance : $|\eta| < 0.5$, $0 < \phi < 2\pi$

Calculation of BKG density by E-by-E in Pb-Pb collisions

- ALICE jet analysis have used an event-averaged energy density per unit area ρ

$$p_{\mathrm{T},j}^{sub} = p_{\mathrm{T},j} - \langle\rho\rangle \times A_j \qquad \rho = \mathrm{median}\{\frac{p_{\mathrm{T},i}}{A_i}\}$$

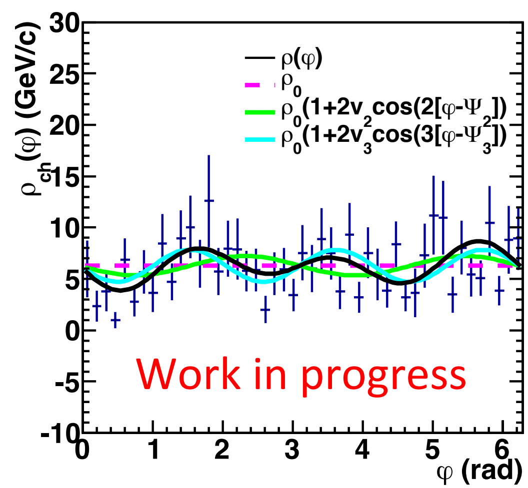
- Local energy density ρ(ϕ)
  - estimate background density with including the effect of the azimuthal anisotropy

$$\rho(\varphi) = \rho_0 \times \left(1 + 2\left\{v_2^{\mathrm{obs}}\cos(2[\varphi - \Psi_{2,EP}]) + v_3^{\mathrm{obs}}\cos(3[\varphi - \Psi_{3,EP}])\right\}\right)$$

Procedure of Local BKG density estimation

1. Calculate ρ_0 by using median method
2. Fill a histogram of the ϕ of soft track ($0.2<p_T<5.0$)
3. Exclude area of the leading jet of an event from the sample and all tracks within the same η region of leading jet are rejected from the sample ($|\eta_{track}-\eta_{leading\ jet}| < R$)
4. Calculate the event plane
5. Fit a histogram

Centrality:0~10%

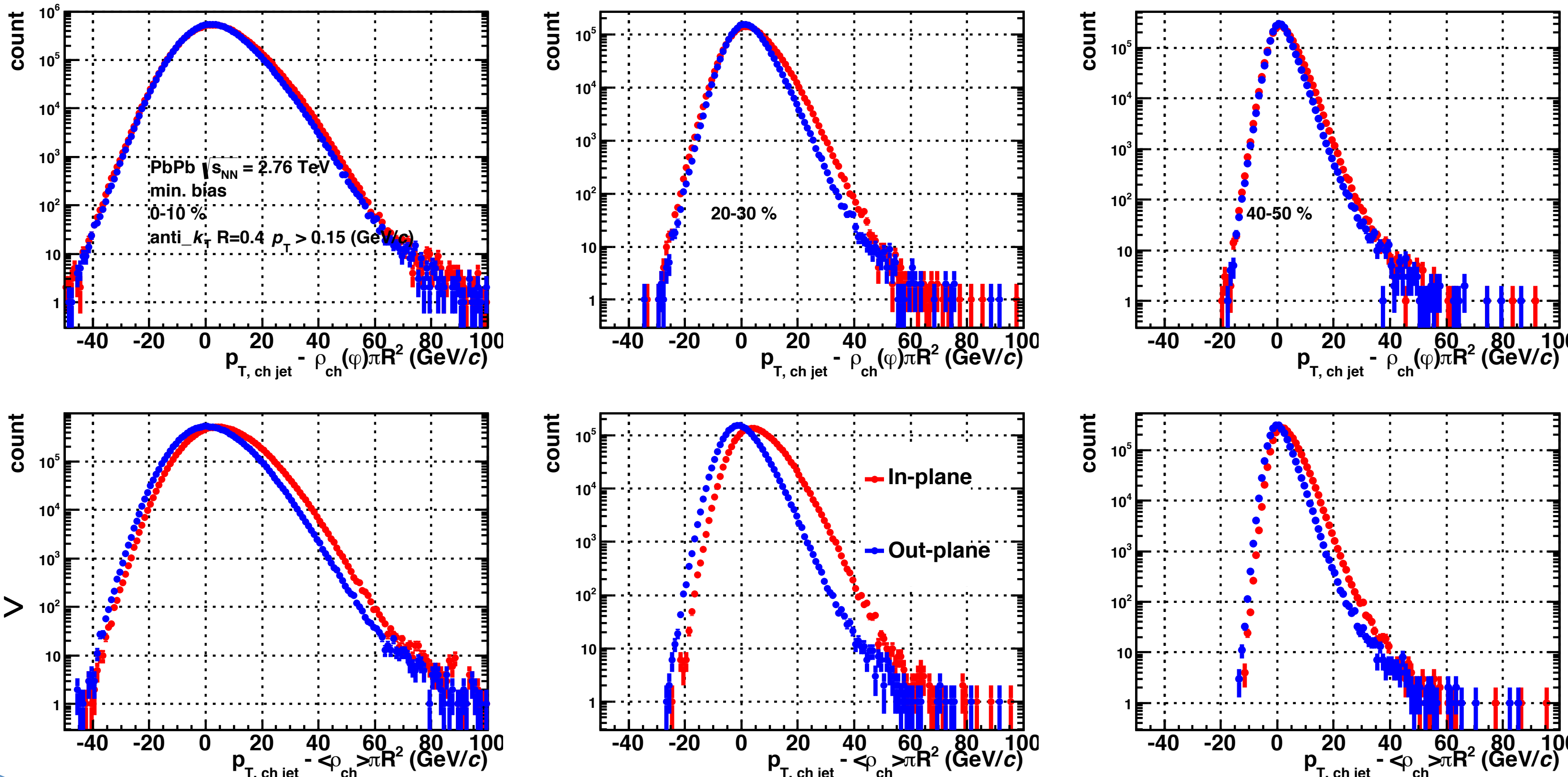


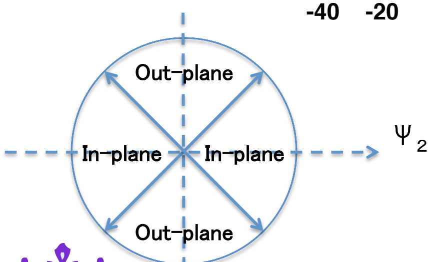
Jet p_T spectrum with two different event plane regions

Work in progress

Local ρ(ϕ)

Median <ρ>



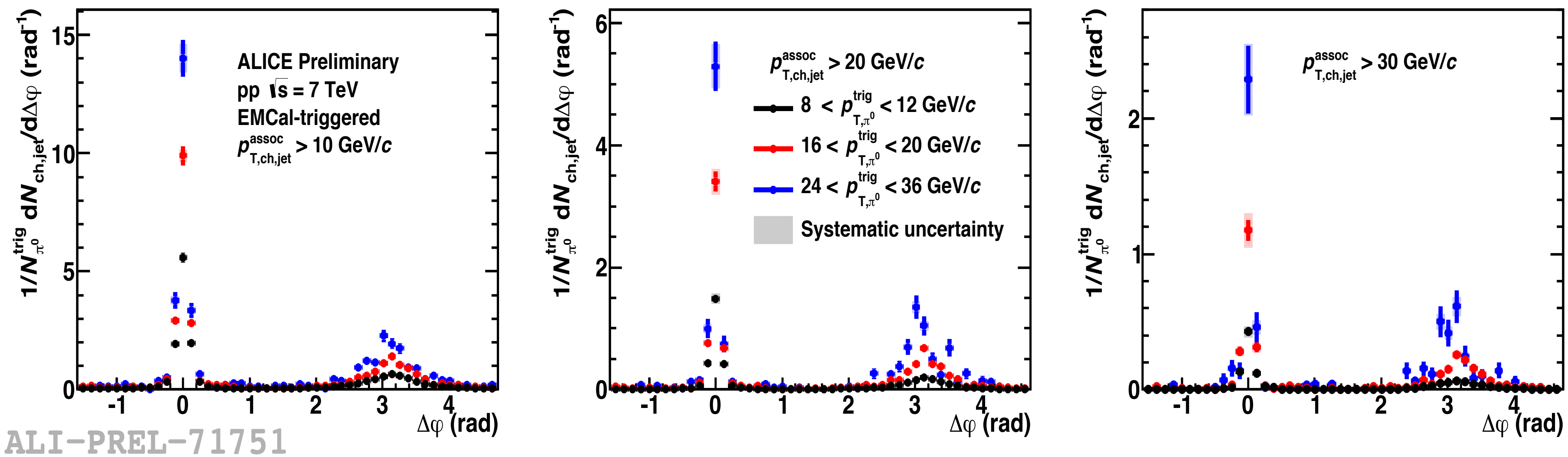


- Distributions of median method have the differences between in and out-of-plane due to flow effect

pp 7 TeV

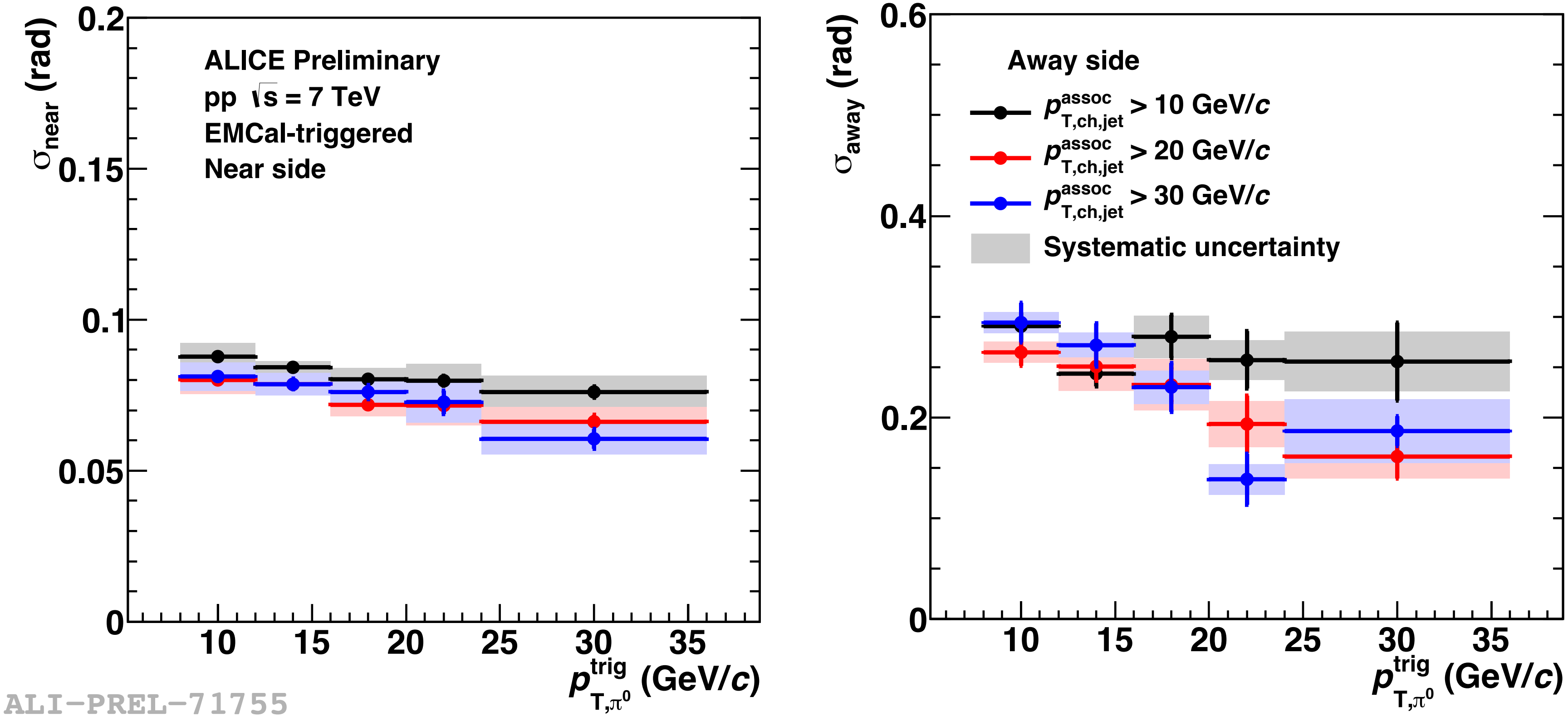
Trigger p_T dependence of azimuthal correlations

Increasing charged jet p_T threshold



- Two clear jet-like peaks are observed, indicating that high p_T π^0 production is correlated with jet production
- Jet yields of near and away side increase with increasing trigger π^0 p_T

Near and away-side widths as a function of π^0 p_T



- Near and away-side widths decrease slightly with increasing trigger π^0 p_T
- Almost no difference observed for different jet p_T thresholds studied

Pb-Pb 2.76 TeV

π^0-jet azimuthal correlation in Pb-Pb 2.76 TeV

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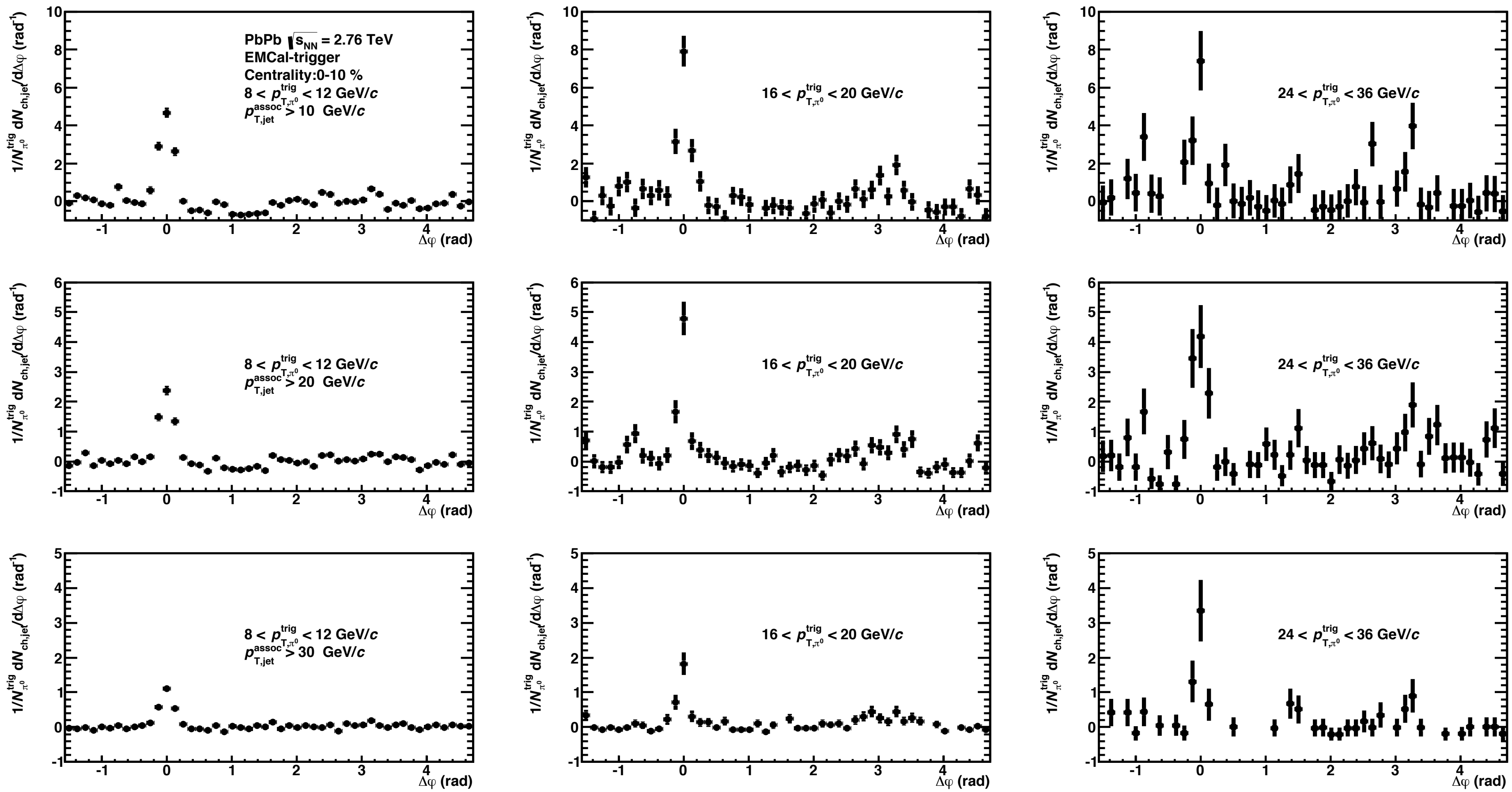
Increasing π^0 p_T region

Work in progress



Increasing jet p_T threshold

- Near and away side peaks increase with increasing trigger p_T
- Away side jets with lower trigger pi0 p_T regions were emitted towards large $\Delta\phi$ angle

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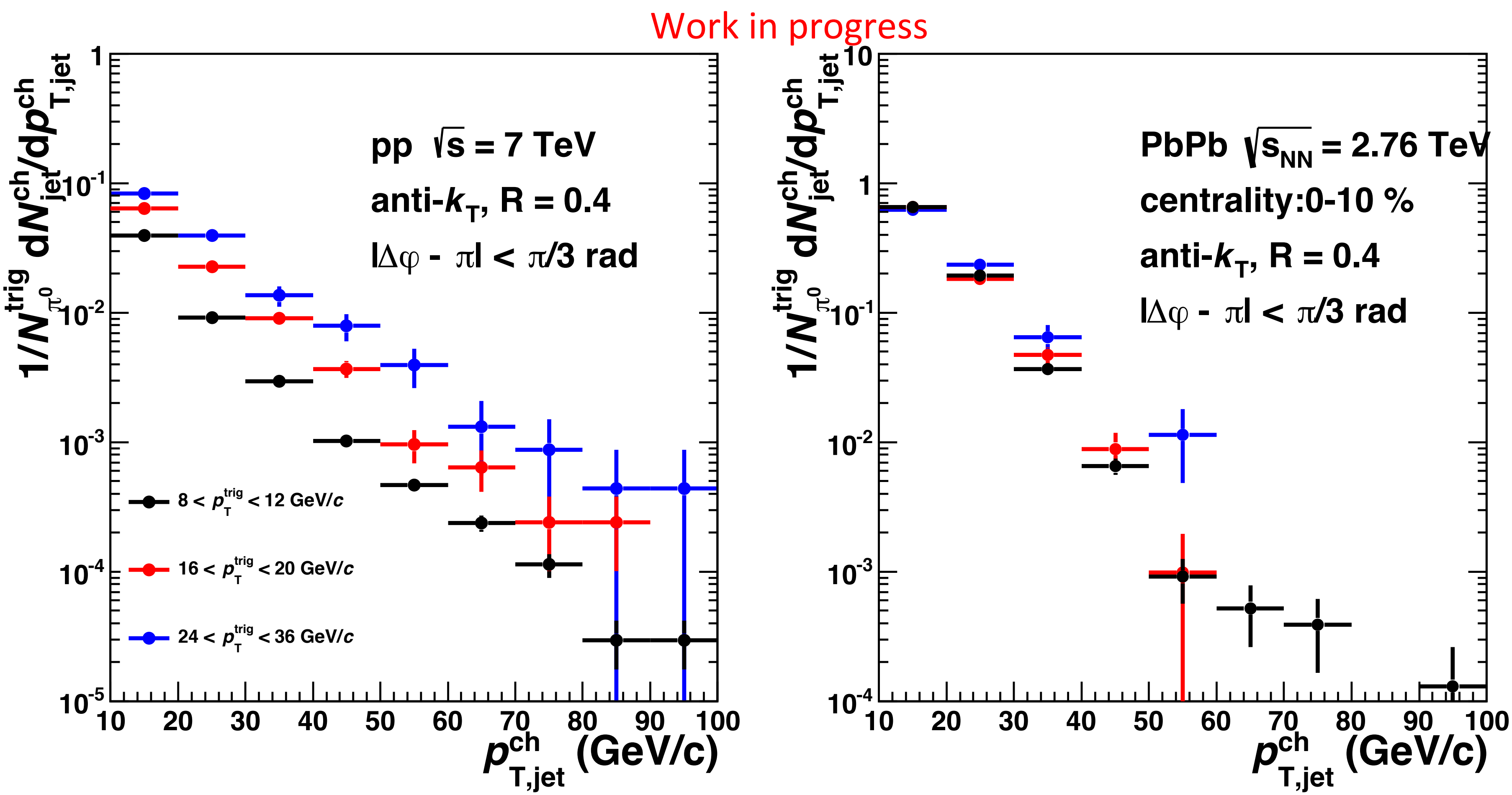
Recoil jet pt distribution



- Distributions of pp 7 TeV are strongly biased towards high p_T region with increasing trigger π^0 p_T

Summary

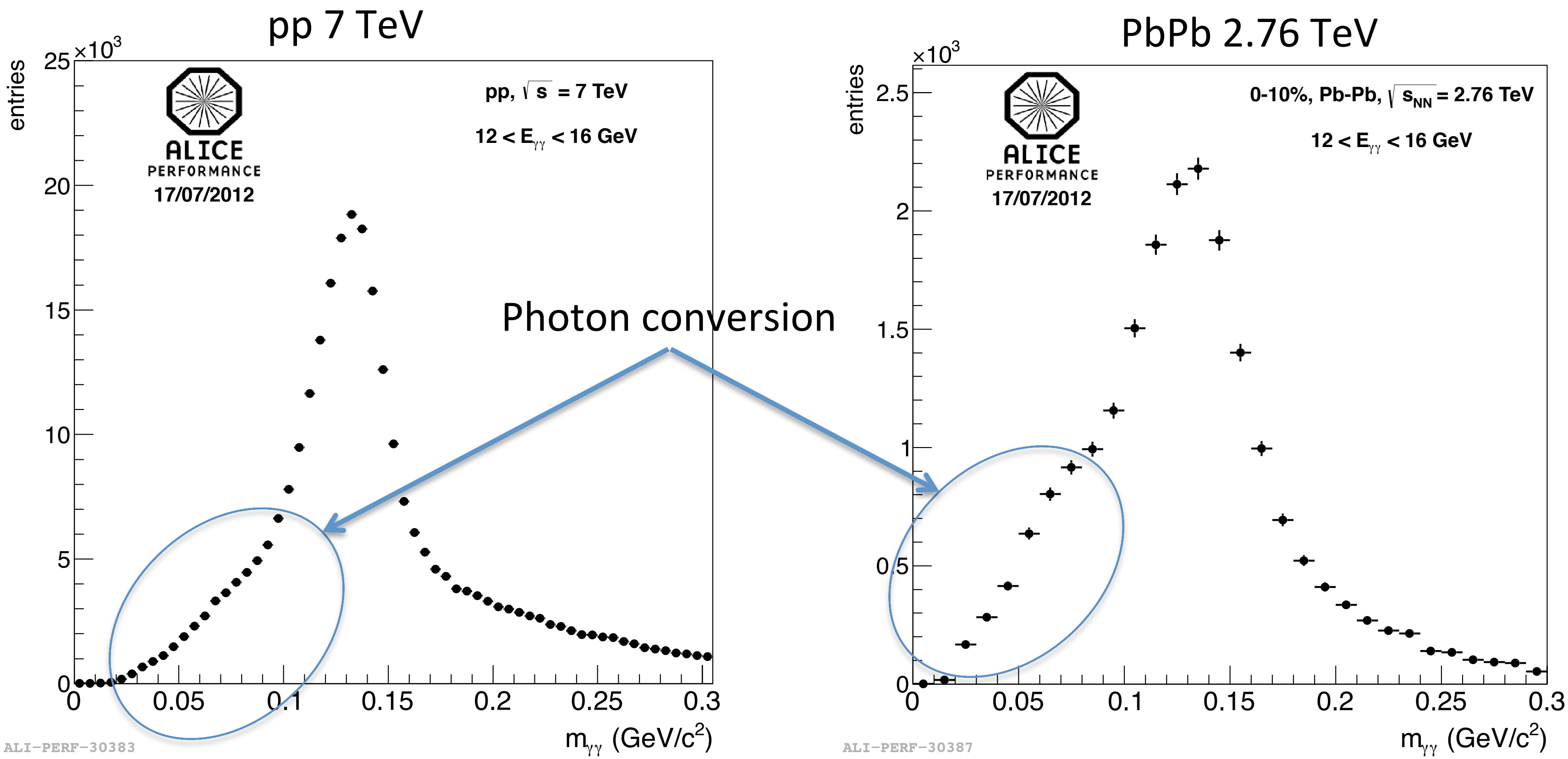
- π^0-jet correlations have been measured in pp collisions at $\sqrt{s}$ = 7 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with cluster splitting method

- pp collisions $\sqrt{s}$ = 7 TeV
  - Azimuthal yields per trigger π^0 increase with increasing trigger π^0 p_T
  - Both near and away side Gaussian widths are decreasing with increasing p_T of trigger π^0
  - π^0-jet correlation measurement in pp collisions provides a important baseline for Pb-Pb data

- Pb-Pb collisions $\sqrt{s_{NN}}$ = 2.76 TeV
  - Near and away side peaks increase with increasing trigger p_T
  - Recoil jet yields are suppressed with increasing trigger π^0 p_T compared with pp 7 TeV

Back up

Invariant mass reconstruction

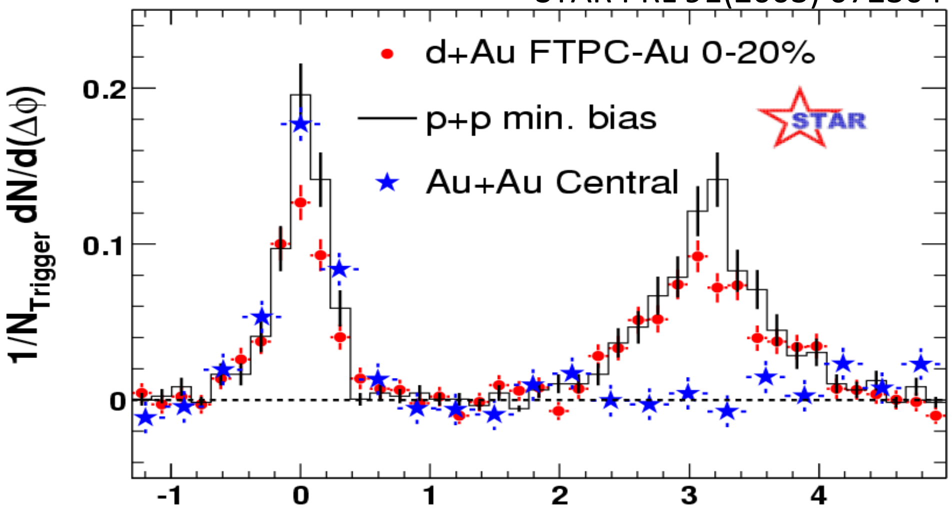


- 3σ invariant mass window from peak mean is selected as π^0
- We can identify π^0 up to 40 GeV/*c*

Jet physics of heavy ion collisions at the RIHC and LHC

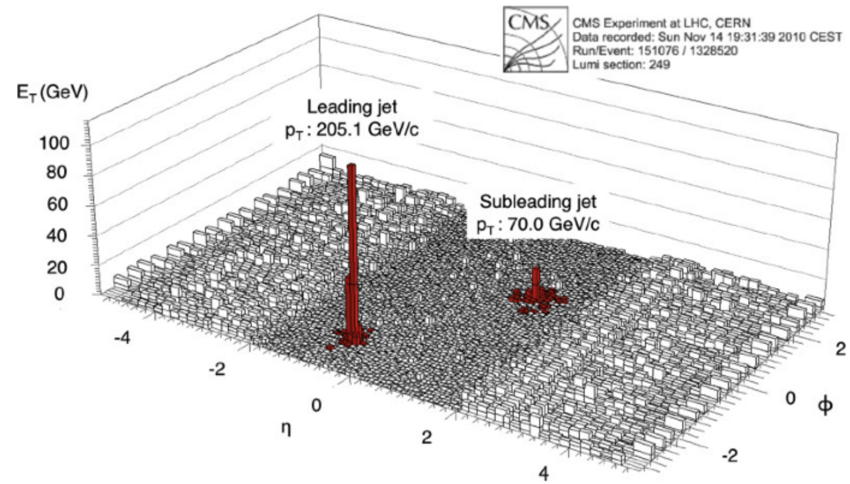
Two particle correlations (RHIC)

STAR PRL 91(2003) 072304



$4 < p_T^{trig} < 6$ GeV/c, 2 GeV/c $< p_T^{asso} < p_T^{trig}$

Di-jet energy imbalance (LHC)



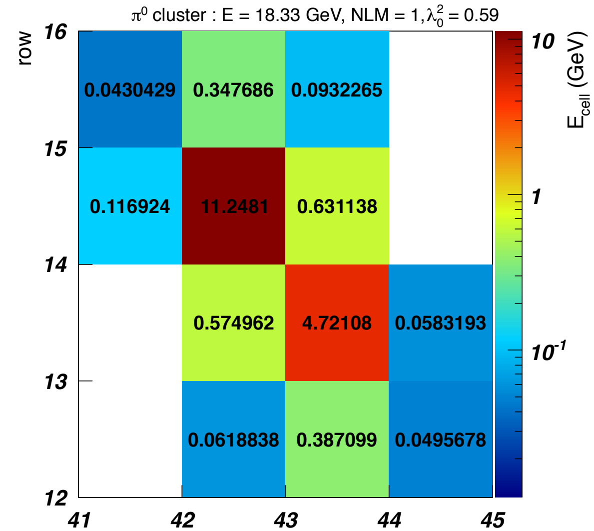
- Mainly particle correlation analyses due to lower jet cross section at the RHIC than at the LHC

- Difficult to extract information on initial parton energy and parton path length in QGP

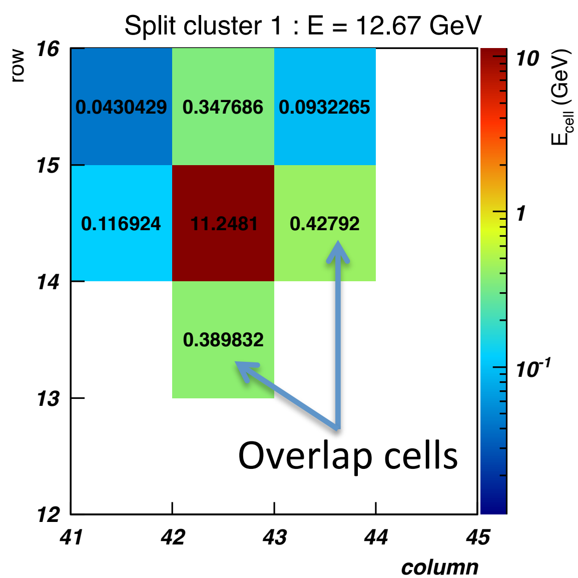
More detailed measurements are needed
- Initial parton energy : γ-jet analysis
- Parton path length : hadron-jet analysis

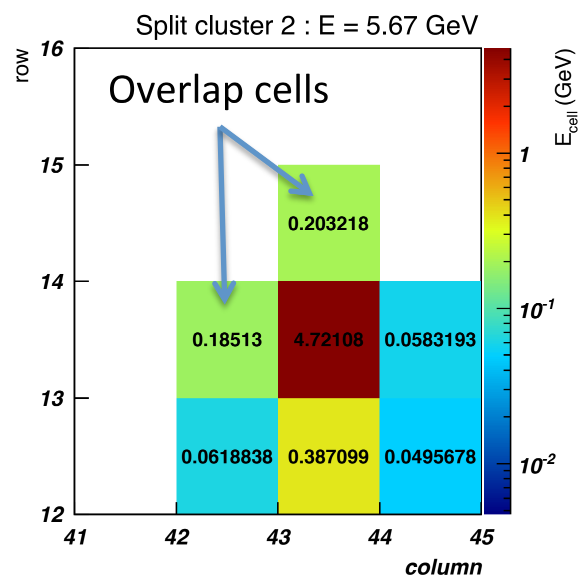
The procedure of cluster splitting method

1. Select neutral cluster with $\lambda_0^2 > 0.3$, track matching etc
2. Find local maxima in the cluster
3. Split the cluster in two new sub-clusters taking the two highest local maxima cells and aggregate all towers around them (form 3x3 cluster)
4. Get the two new sub-clusters, and calculate energy asymmetry and invariant mass



- Overlap cell energy is calculated by using weight of each local maxima cell energy





π^0 identification purity and efficiency (pp 7 TeV)

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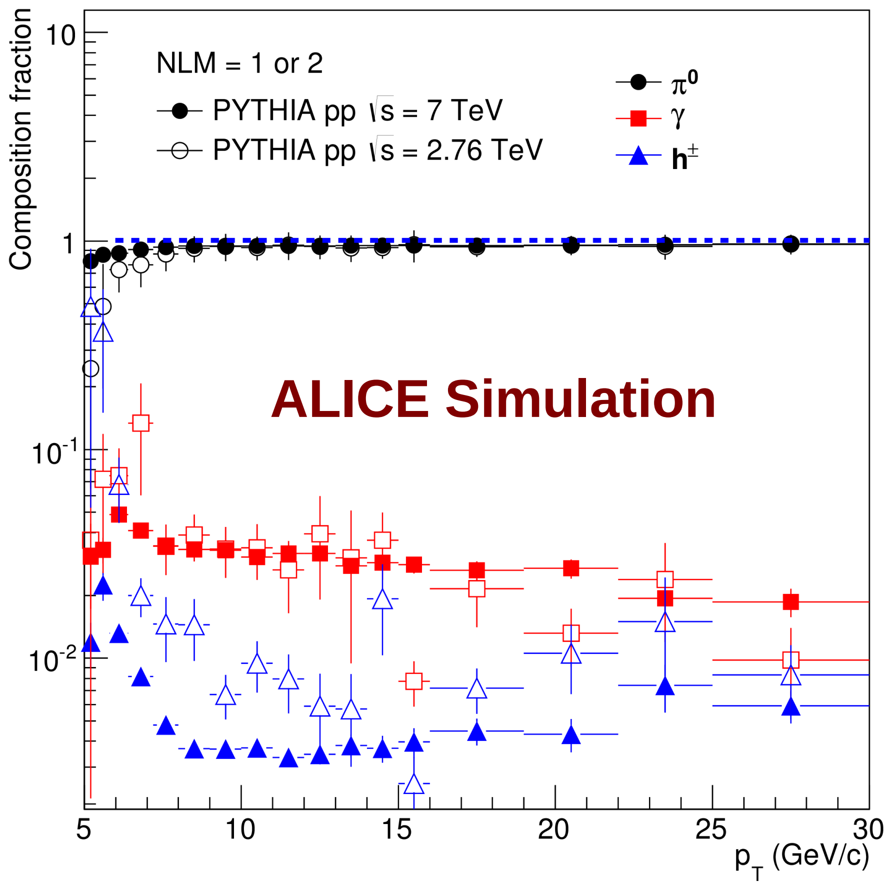
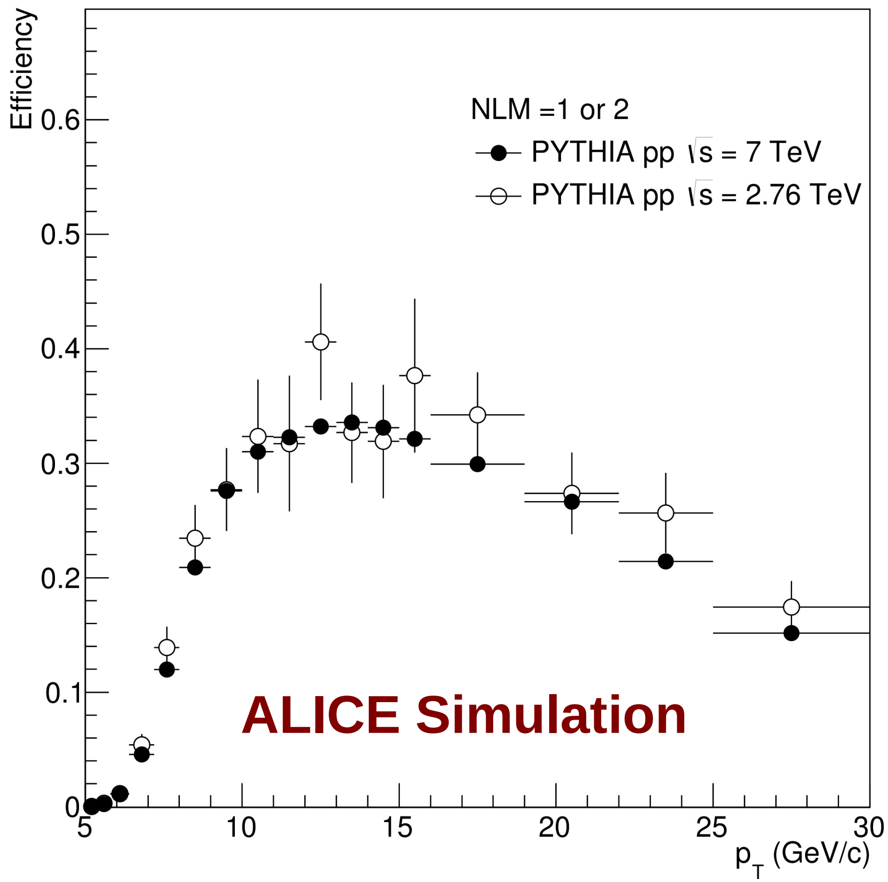
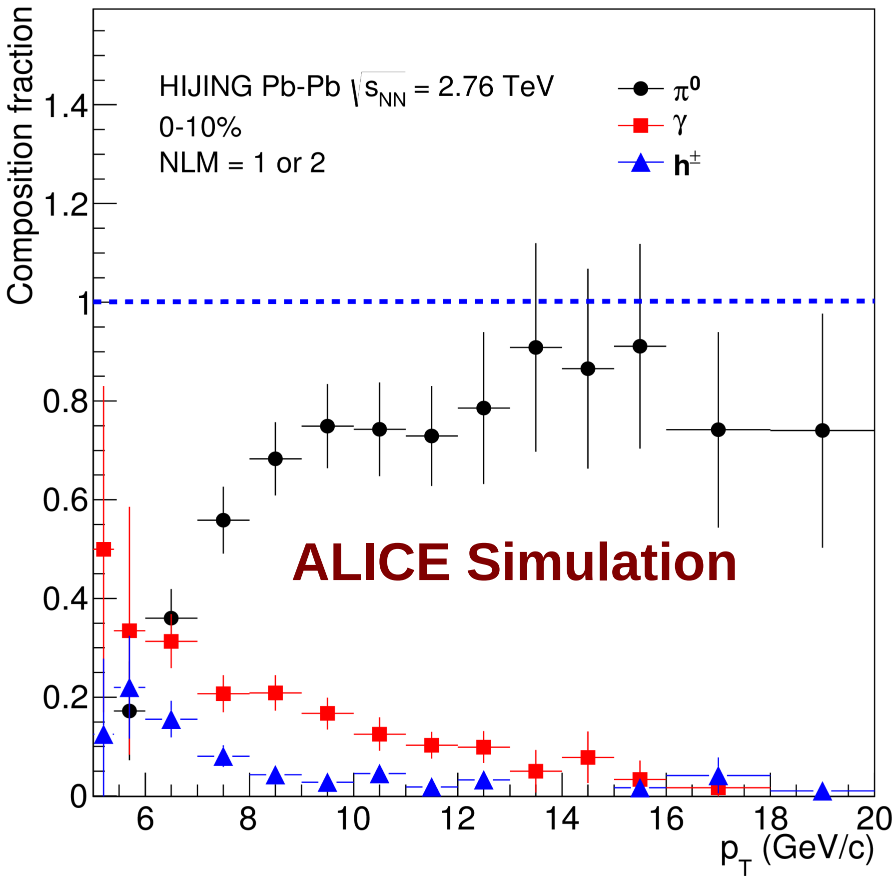
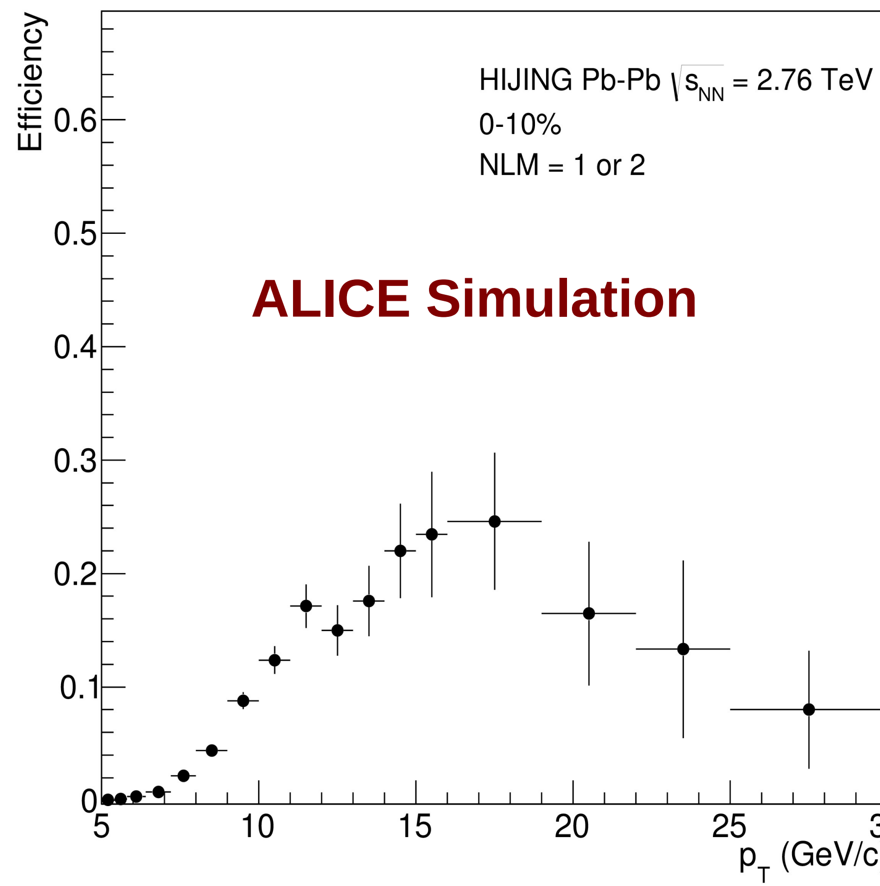


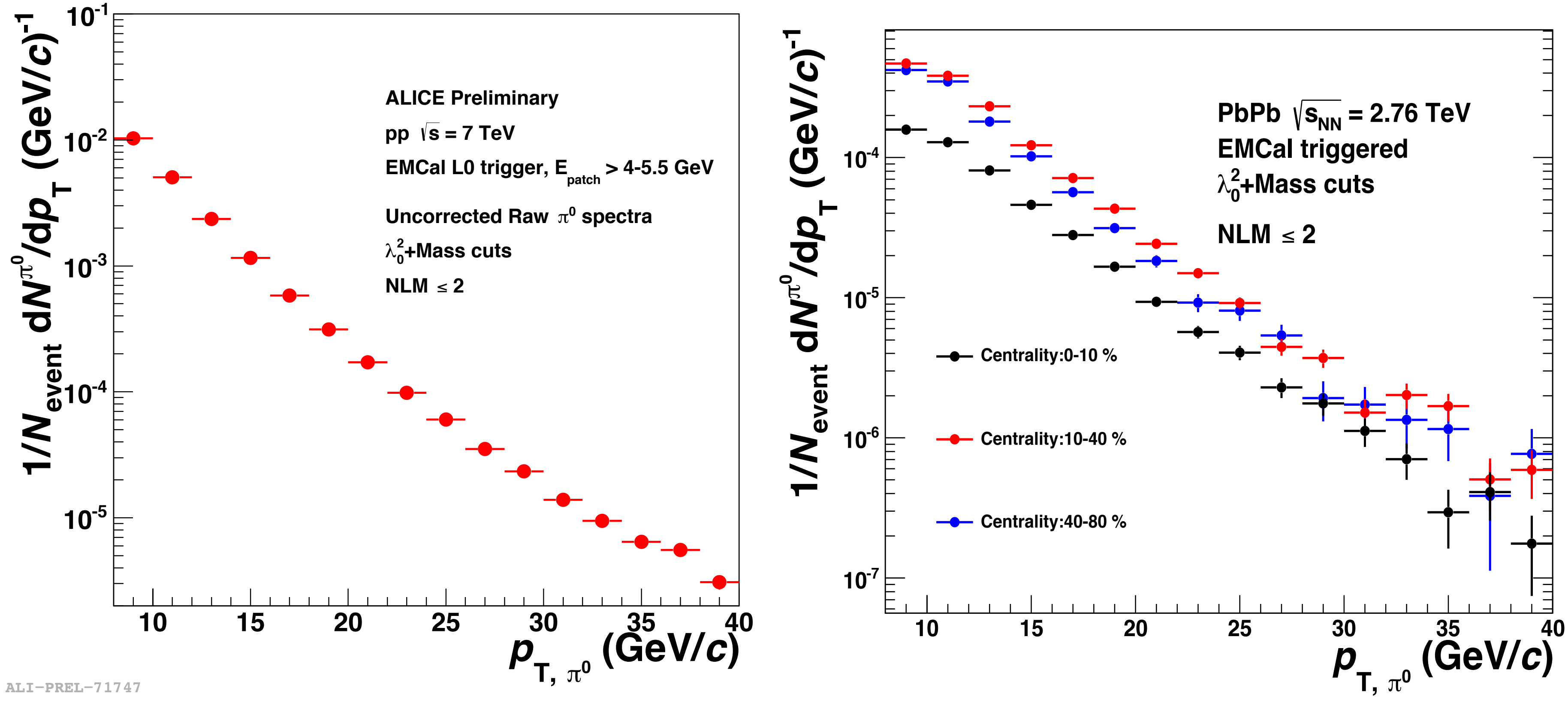


π^0 identification purity and efficiency (PbPb 2.76 TeV)





π^0 p_T spectrum



Event mixing and reconstruction efficiency correction

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- Detector acceptance correction (event mixing method)
  - 100 events pool
  - Z vertex = (-10, 10) cm, 2 cm wide bins
  -Track multiplicity, 9 bins on multiplicity (pp analysis)
  - Centrality, 10 bins (PbPb analysis)

$$C(\Delta\varphi) = \frac{\int N_{pair}^{mixed}(p_T^{\pi^0}, \Delta\varphi) d\Delta\varphi}{\int N_{pair}^{same}(p_T^{\pi^0}, \Delta\varphi) d\Delta\phi} \cdot \frac{N_{pair}^{same}(p_T^{\pi^0}, \Delta\varphi)}{N_{pair}^{mixed}(p_T^{\pi^0}, \Delta\varphi)}$$

$$\frac{1}{N_{trig}^{\pi^0}} \frac{dN^{jet}}{d\Delta\phi} = \frac{\int N_{pair}^{same}(p_T^{\pi^0}, \Delta\phi) d\Delta\phi}{N_{trig}^{\pi^0}(p_T^{\pi 0})} \cdot C(\Delta\phi)$$

- π^0 and jet reconstruction efficiency correction (bin-by-bin correction, only pp analysis)
  - π^0 reconstruction efficiency (non-uniform): Δp_T = 1.0 GeV/*c*
  - Jet finding efficiency (uniform) : 3 different jet p_T bins

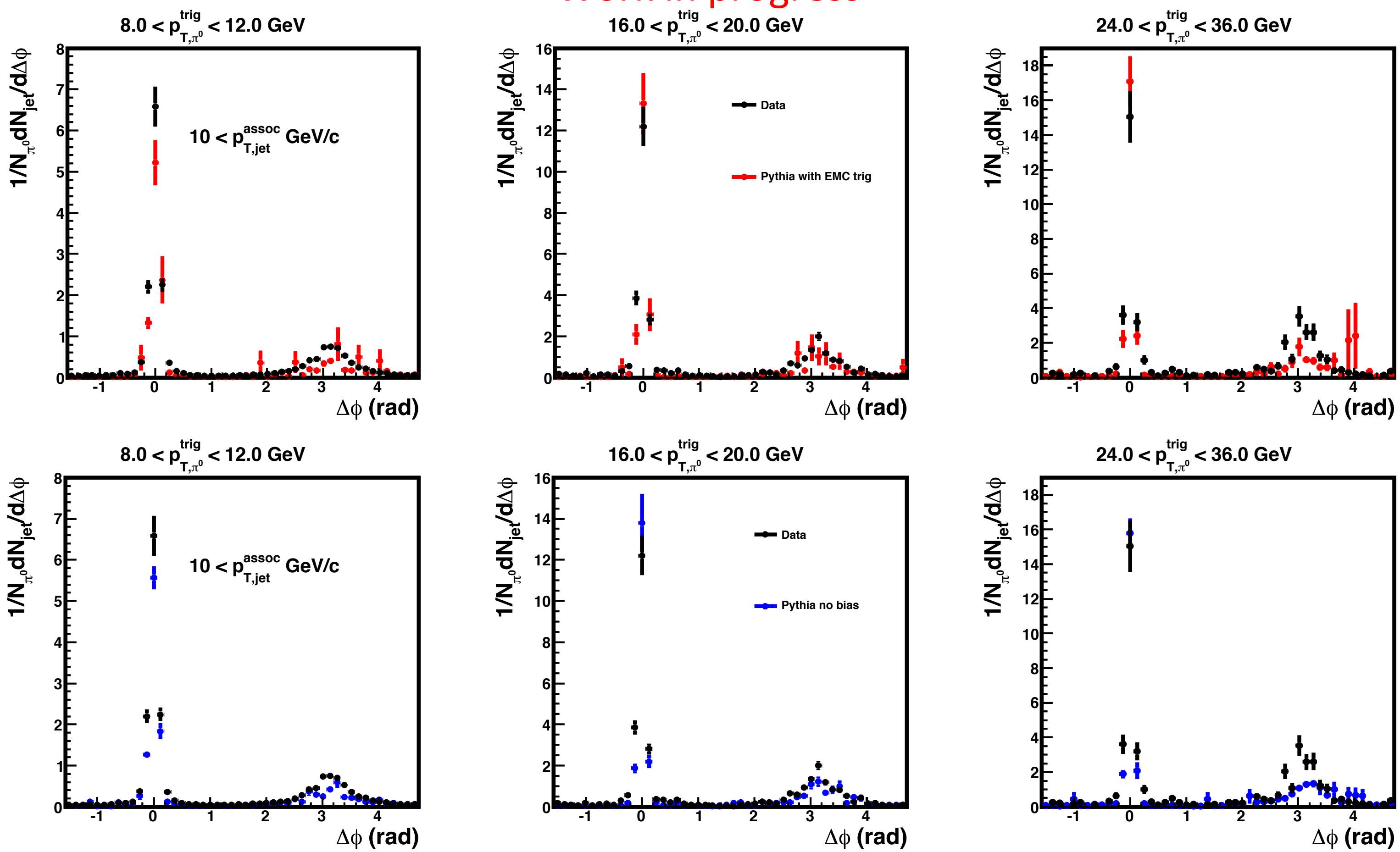
    -> 10-20, 20-30, 30 > GeV/*c*

$$\frac{1}{N_{trig}^{corrected}} \frac{dN_{pair}^{corrected}}{d\Delta\phi} = \frac{1}{\Sigma_{\Delta p_{T,(i)}} \frac{1}{\varepsilon_i^{\pi^0}} \cdot N_{trig(i)}^{\pi^0}(\Delta p_T^{trig})} \sum_{\Delta p_{T,(i)}} \frac{1}{\varepsilon_i^{\pi^0} \varepsilon^{jet}} \frac{dN_{pair(i)}^{Raw}}{d\Delta\phi}(\Delta p_T^{trig})$$

Azimuthal yield comparison to MC (corrected data vs particle level MC)

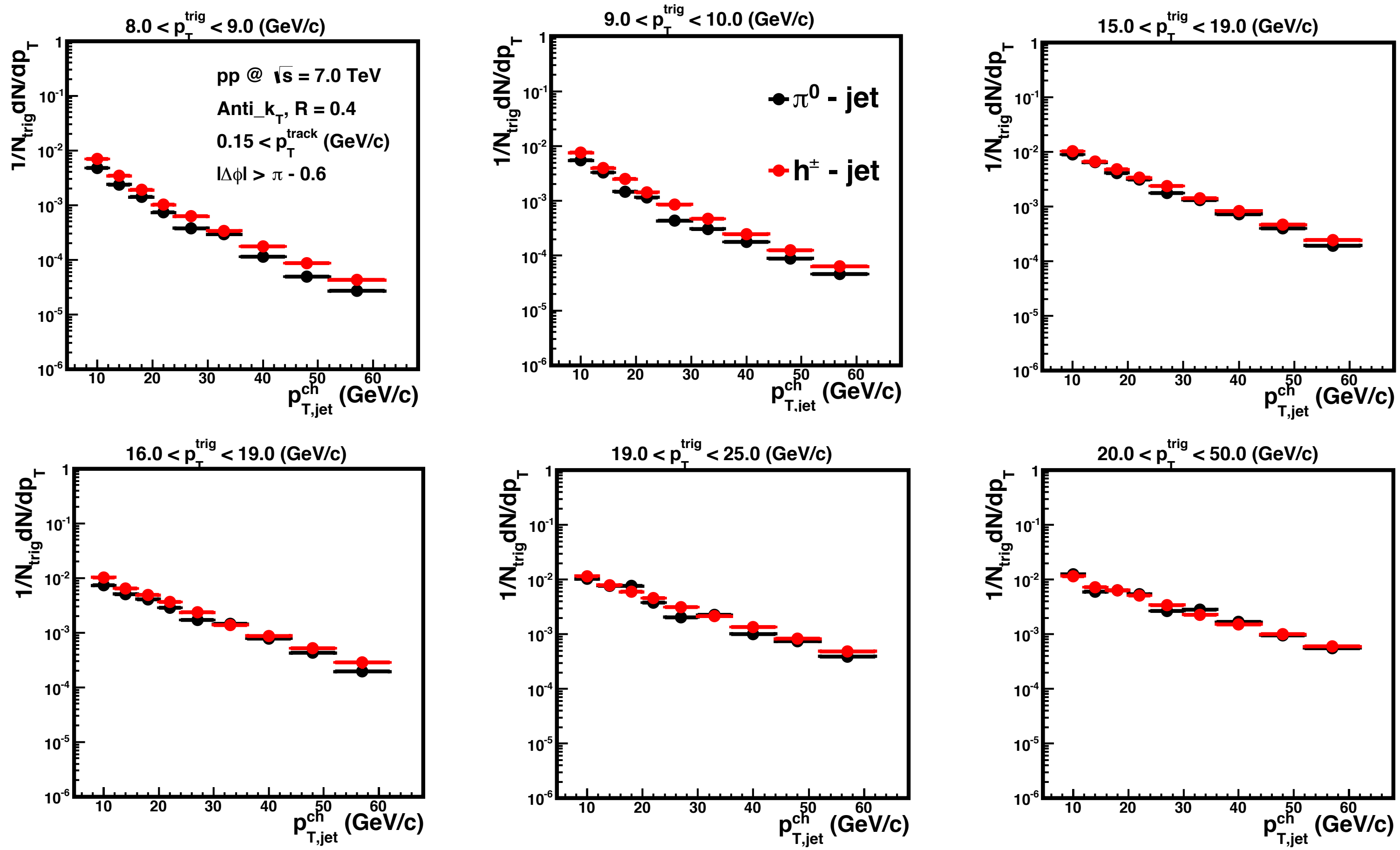
ALICE

Work in progress



- PYTHIA calculations consistent with pp 7 TeV data

Comparison of away side yields between h±-jet(Filip's analysis) and π⁰-jet



- These figure are applied a bin-by-bin correction.
- The correction factors are the ratios of particle level to detector level.