# Neutral pion and jet measurements in Pb-Pb collision $\sqrt{s_{NN}}$ = 2.76 TeV in ALICE

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# Outline

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  - Jet analysis in Pb-Pb collision at LHC.
  - Why $\pi^0$ - jet correlation ?
- Analysis procedure
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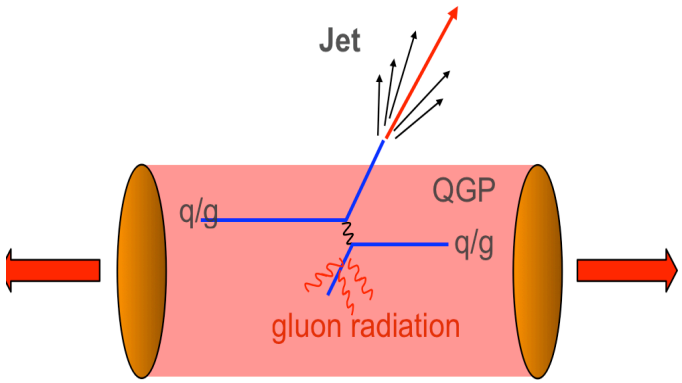
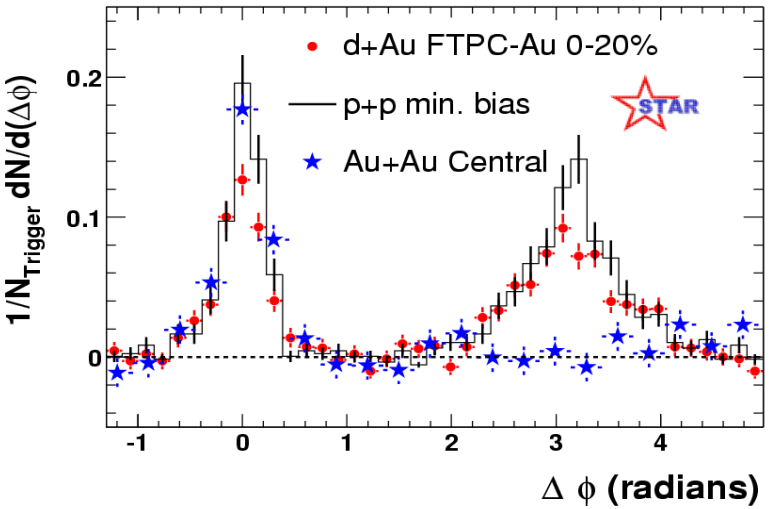
  - background for jet reconstruction in Pb-Pb
  - jet and $\pi^0$ reconstructions
- Results
  - $\pi^0$ and jet azimuthal angler correlations
- Summary

# Jet analysis in Pb-Pb collision at LHC

- Jet quenching
  - disappearance of away side jet . ($\Delta\phi = \pi$ )
  - energy loss of energetic parton from hard scatterings in QGP.
- hadron-hadron correlation
  - Bias towards a surface of matter due to strong quenching.

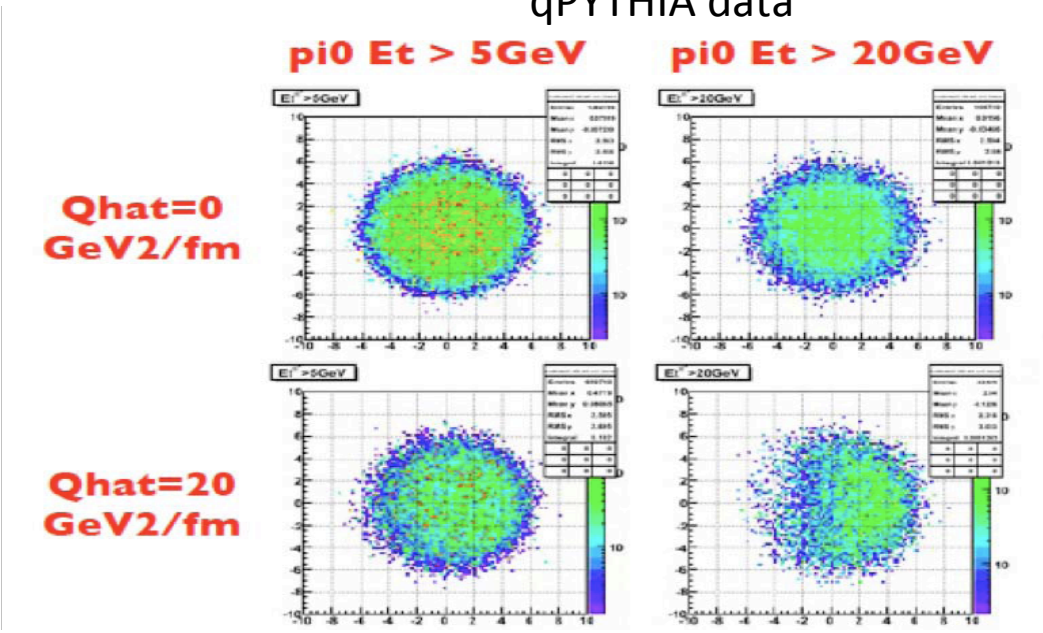


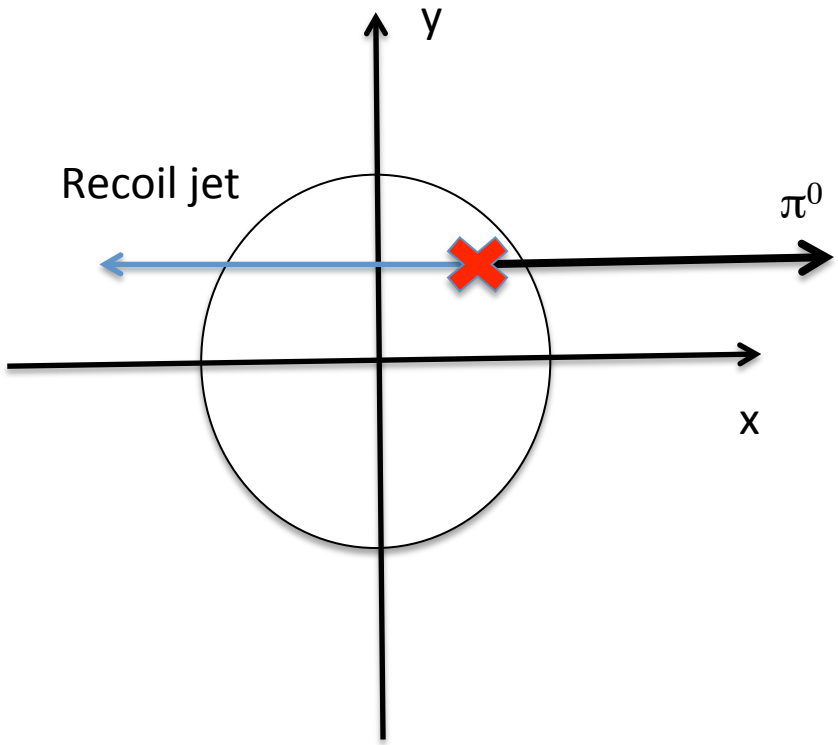

Two particle correlation
Phys. Rev. Lett. 91, 072304 (2003)

# $\pi^0$– jet correlation

qPYTHIA data




CERN-LHCC-2010-011



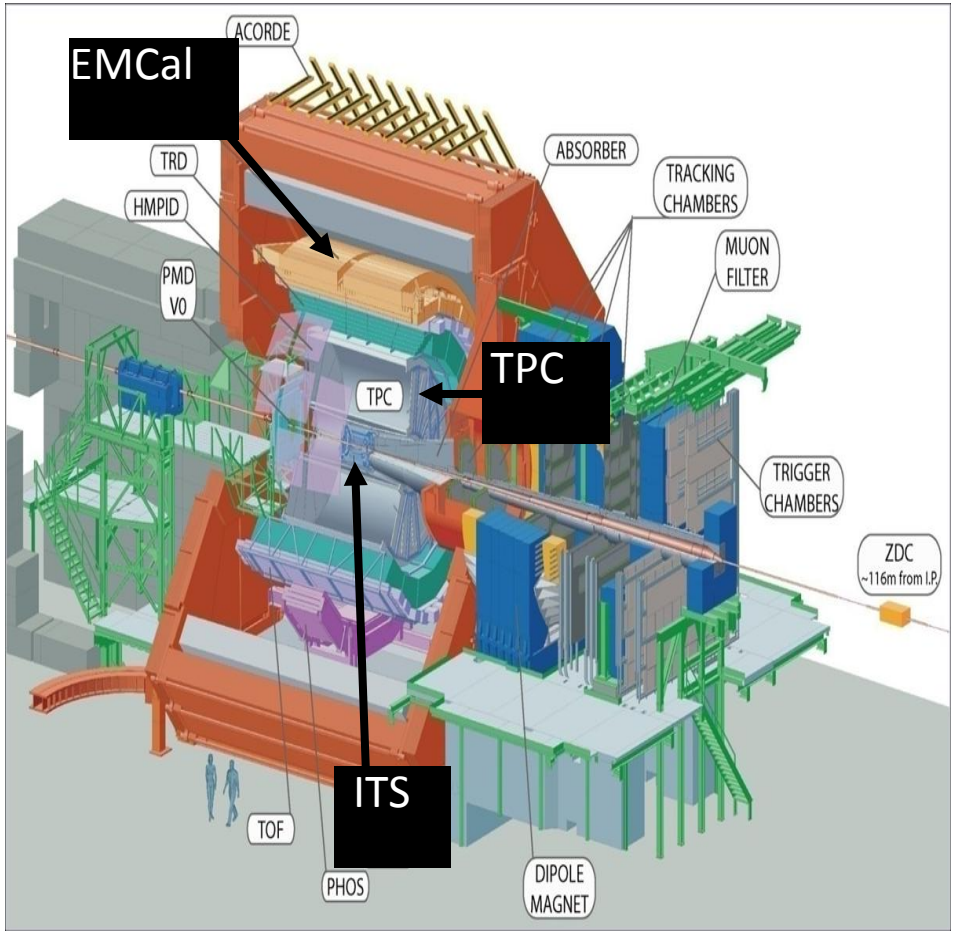

- Can control a path length of jet by tagging a recoil jet with triggered $\pi^0$, and changing $p_t$ for $\pi^0$.
- If $\pi^0$ $p_t$ is high, path length of recoil jet is long.
- If $\pi^0$ $p_t$ is low, path length of recoil jet is short.
- Study of jet quenching by controlling path length.

# In this talk

- $\pi^0$-jet correlation ($\pi^0$ trigger) in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV in ALICE.
- Study of background for jet in heavy ion collision.
- $\pi^0$ and jet(charged only) reconstruction in Pb-Pb.
- First look at $\pi^0$-jet (charged only) correlation in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV.

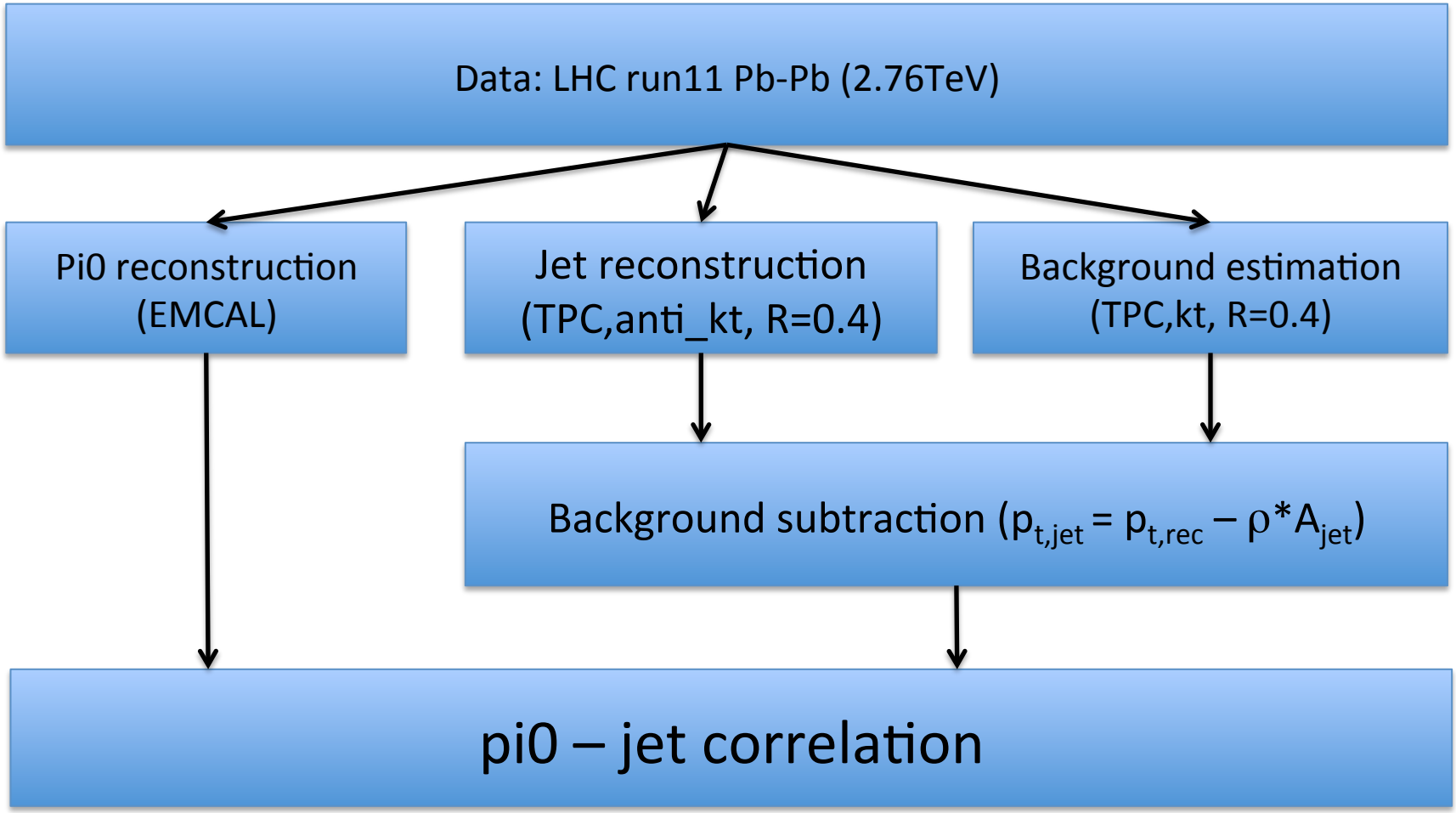
# ALICE experiment, data set and cuts

- TPC
  - reconstruct charged jet.
- EMCAL
  - $\pi^0$ reconstruction, L1 trigger for gamma and jets
- ITS
  - vertex selection
- V0
  - Centrality selection

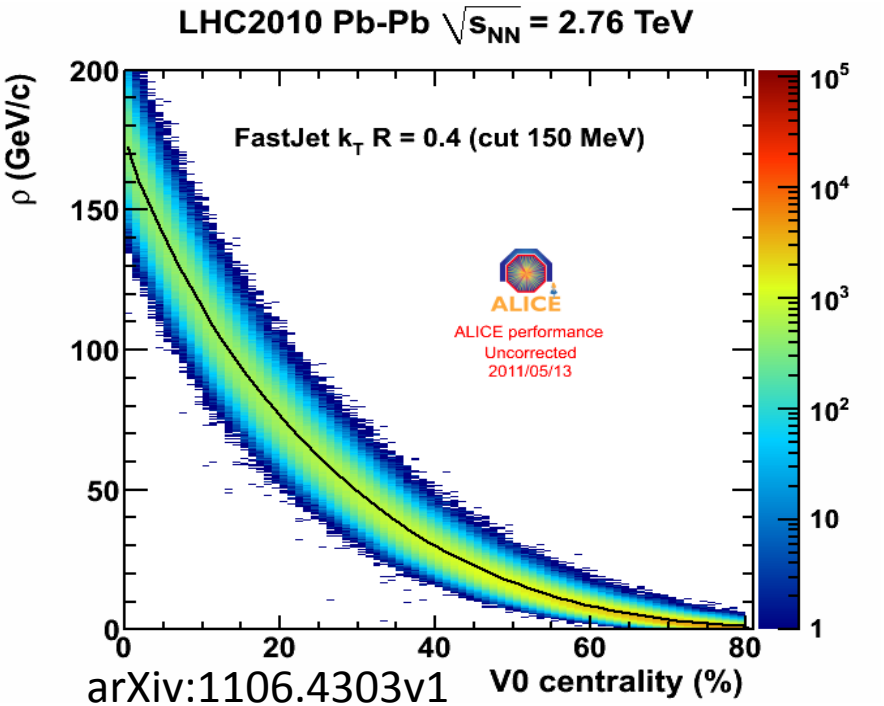


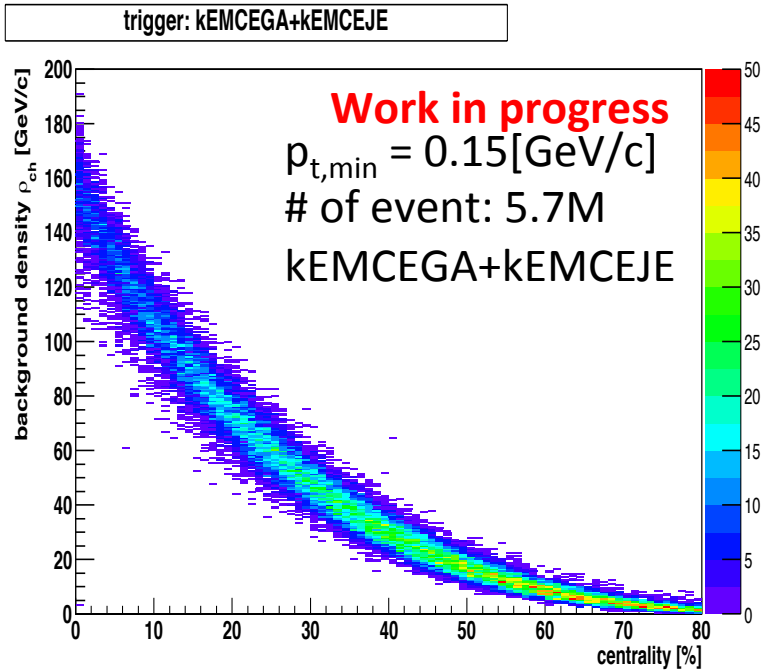

- Data
  LHC run11 Pb-Pb 2.76 TeV
- Event selection
  |vertex z| < 10 cm
- Track selection
  $|\eta| < 0.9$
  # of TPC cluster > 70
- Trigger
  kEMCEGA+kEMCEJE

# Analysis procedure



# Background for jet reconstruction (charged particle only)




arXiv:1106.4303v1
arXiv:1201.2423v1

$\rho = \text{median}(p_{t,jet}/\text{Area}_{jet})$

- ρ vs centrality: consistent with the previous result.
- See detail in arXiv:1106.4303v1.
- This analysis doesn't subtract background level.

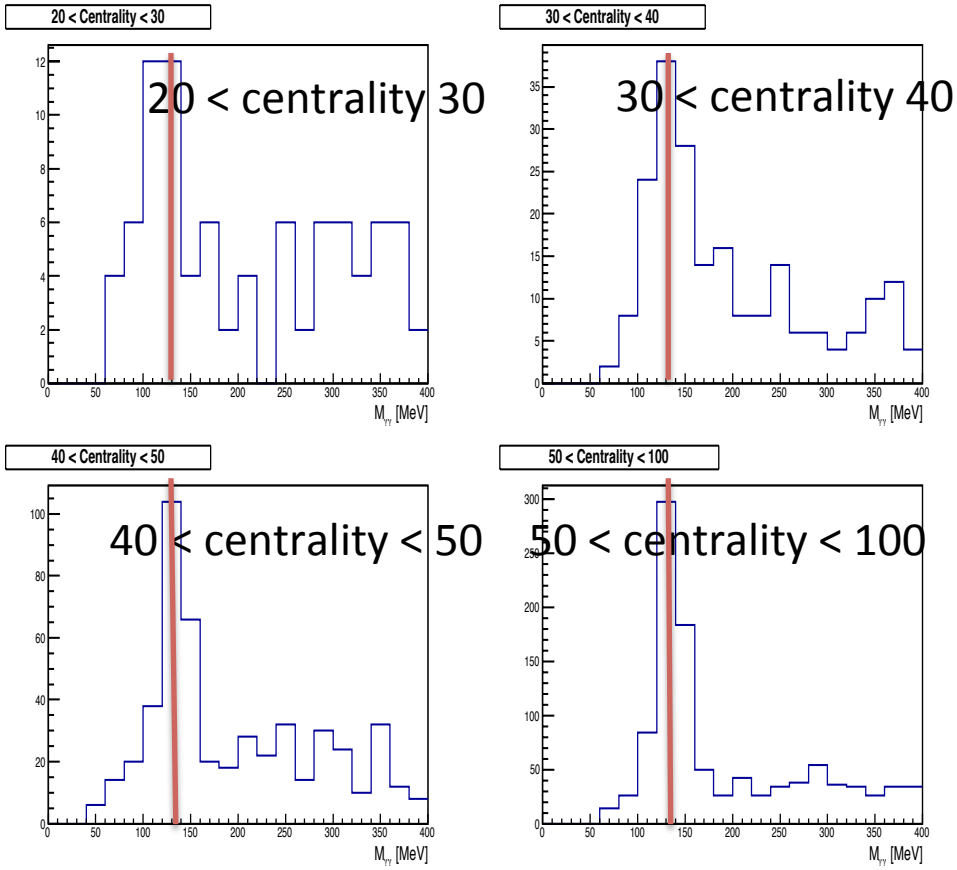
# $\pi^0$ reconstrunction (Pb-Pb run11) trigger: kEMCEGA +kEMCEJE(photon and jet trigger in EMC)

- Cut
  - track matching 3 sigma
  - # of cell in cluster > 2
  - cluster Energy asymmetry < 0.7
- # of Event : 5.7M

$M_{\gamma\gamma}$ = sqrt(2*E1*E2*(1-cos$\phi$))
E1,E2: EMCAL photon cluster

Red line: $\pi^0$ mass in MeV/$c^2$

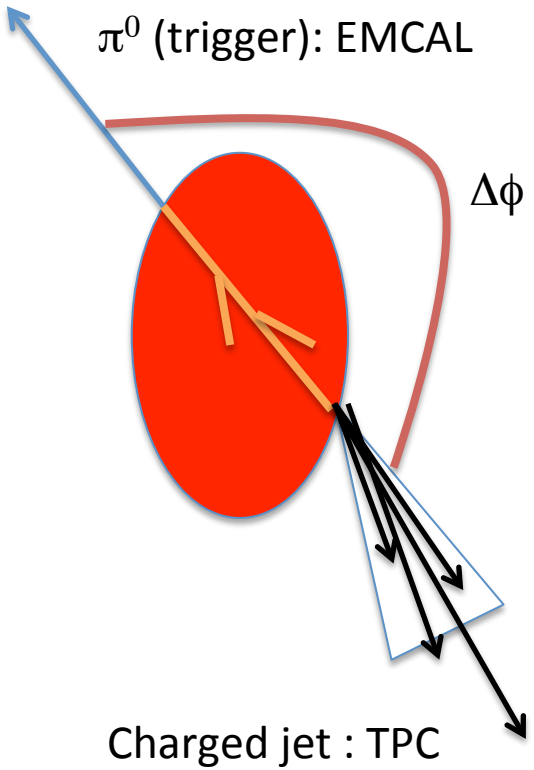
6.0 < pi0 $p_t$ [GeV/c] < 7.0




Reconstruct $\pi^0$ invariant mass at high $p_t$ region.

# $\pi^0$–jet correlation

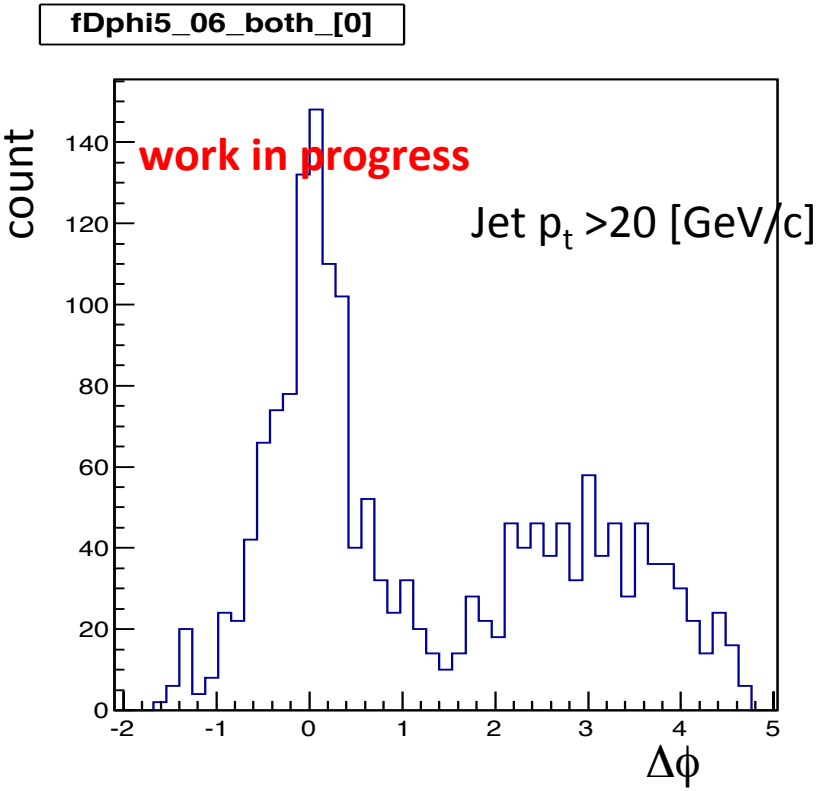
1. $\pi^0$ reconstructed by using no track matching EMCAL cluster.
2. Charged jet reconstruct by using TPC.
3. azimuthal correlation between high $p_t$ $\pi^0$ and jet.



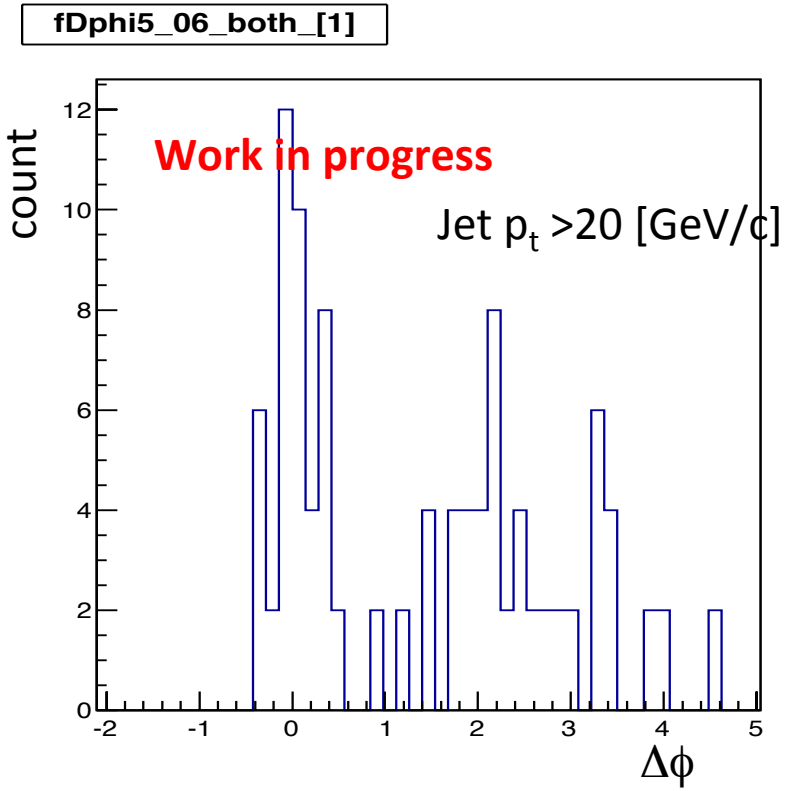

$$\Delta\phi = \phi_{pi0} - \phi_{charged\ jet}$$

# $\pi^0$ – jet correlation (50 < centrality <100[%], peripheral)

No jet BG subtraction, trigger: kEMCEGA+kEMCEJE



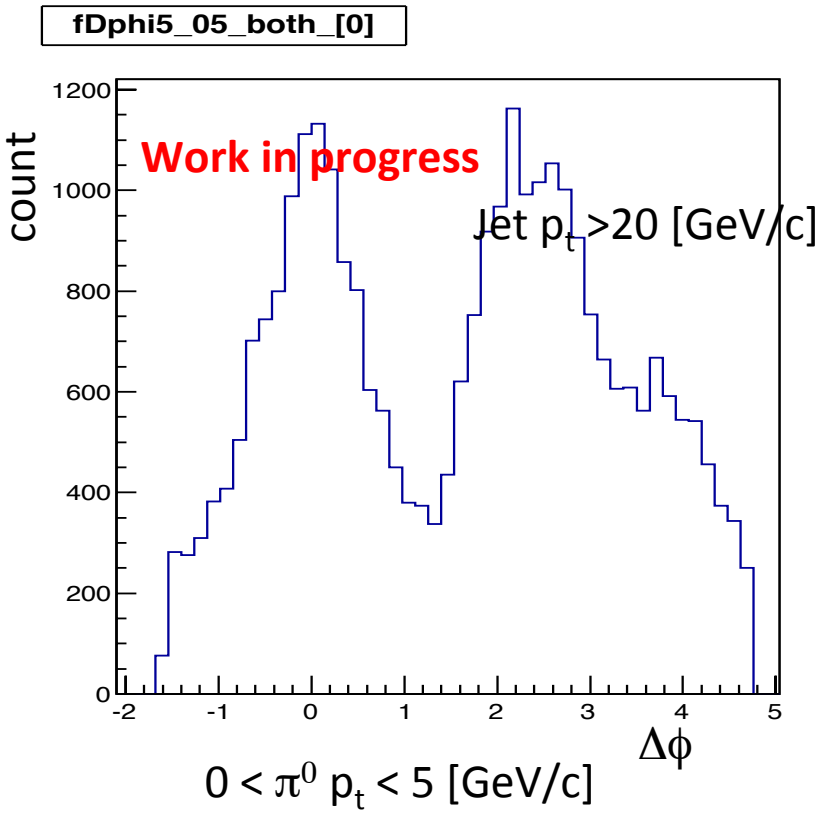

$0 < \pi^0\ p_t < 5$ [GeV/c]

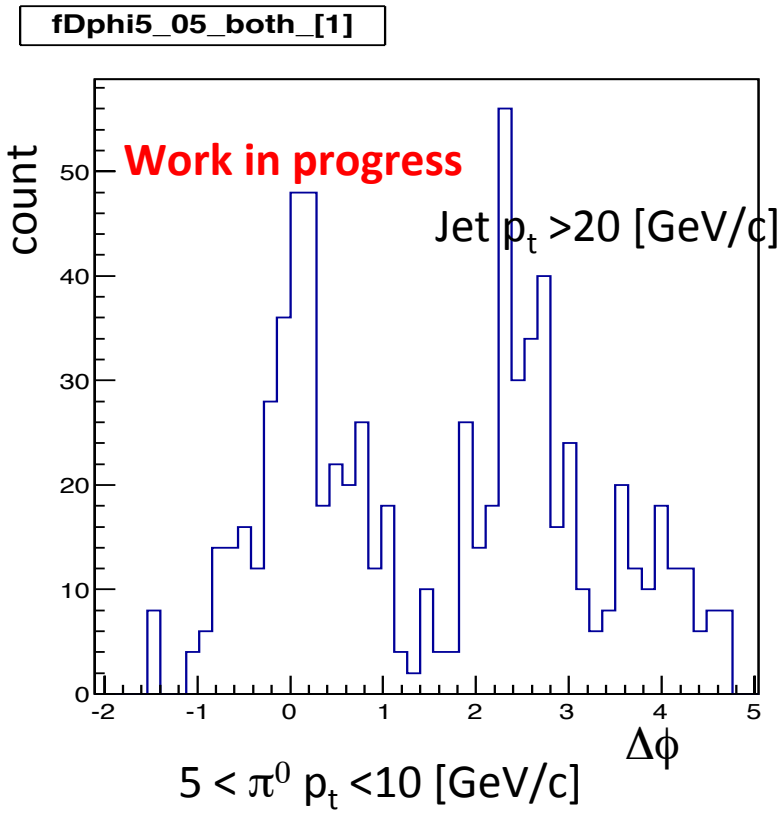



$5 < \pi^0\ p_t < 10$ [GeV/c]

# $\pi^0$- jet correlation (40 < centrality <50 [%])

No jet BG subtraction, trigger: kEMCEGA+kEMCEJE




- Clear back-to-back jets with high $p_t$ $\pi^0$ are seen without BG subtractions for peripheral.

# Summary

- $\pi^0$-jet correlation ($\pi^0$ trigger) in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV in ALICE.
- Clear back-to-back jets with high $p_t$ $\pi^0$ are seen without BG subtractions for peripheral.
- $\Delta\phi$ distribution increase background at central collision and low $\pi^0$ $p_t$ region.
- Next step
  - Study correlation between $\pi^0$ and BG subtracted jet.
  - Event plane dep. of $\pi^0$-jet correlations.

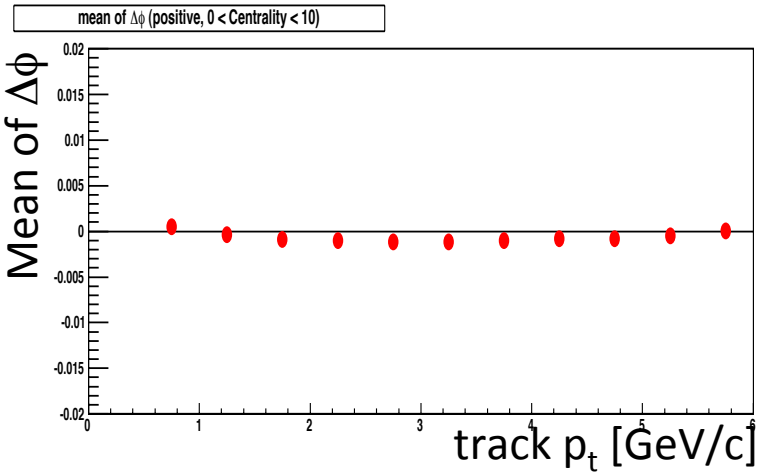
# Back up

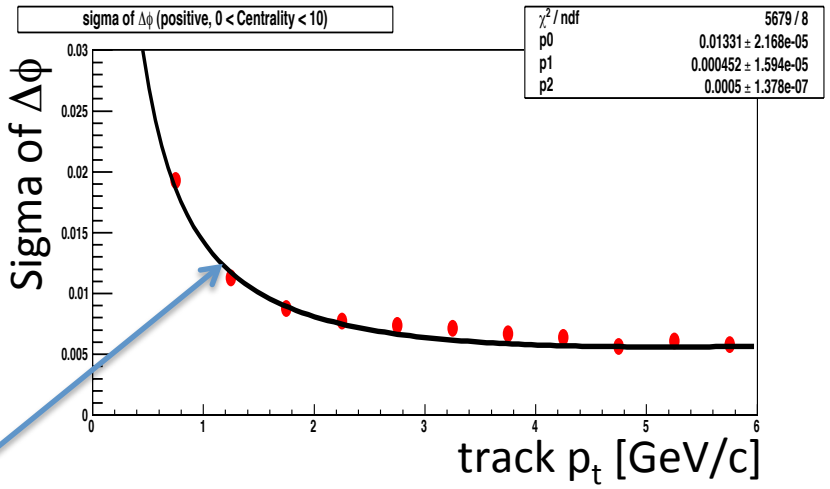
# Data set and cut

- Event selection
  - LHC10h(Pb-Pb 2.76TeV) pass2, ESD file
  - trigge : no selection
  -|vertex z| <10 cm
- Track selection
  - EtaRange : $|\eta| < 0.9$
  - MinNClusterTPC = 70
  - MaxChi2PerClusterTPC = 4.0
  -RequireTPCRefit(kTRUE)
  -MaxDCAToVertexXY = 1.0
  -MaxDCAToVertexZ = 3.0
- Centrality
  - 0~10[%], 10~20[%], 20~30[%], 30~40[%],
  40~50[%], 50~100[%]

# Charged particle rejection for EMC cluster (track matching procedure)

1. Make $\Delta\phi$ and $\Delta\eta$ distributions.
   $\Delta\phi$ = EMCAL cluster $\phi$ - TPC track $\phi$
   $\Delta\eta$ = EMCAL cluster $\eta$ – TPC track $\eta$
2. Fit $\Delta\phi$ and $\Delta\eta$ distributions by gaussian function.
3. Calculate mean of $\Delta\phi$ and $\Delta\eta$ from fit function.
4. Correct mean so as to be mean value to zero.
5. Repeat step 1 and step2.
6. Calculate sigma of $\Delta\phi$ and $\Delta\eta$ from fit function.
7. fit sigma as pt function.
8. If a cluster which is not within +- 3 sigma windows in $\Delta\phi$ and $\Delta\eta$ , then the cluster is used as a photon, otherwise used as a charged track.



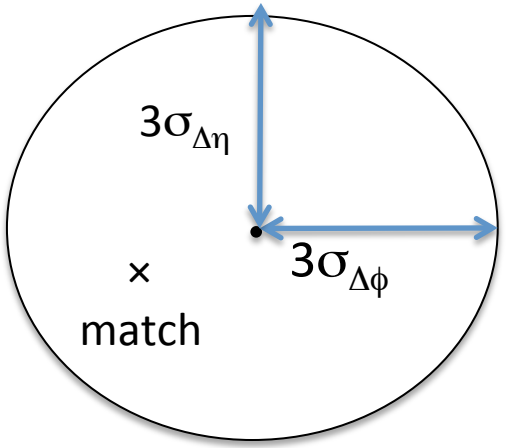




This fit function equal 1 sigma.

# Data set and cut

- Event selection
  - LHC11h(Pb+Pb, 2.76TeV) pass2, ESD file
  - |vertex z| < 10 cm
  - run number : back up
  - number of event : $576*10^4$ event
- Trigger Selection
  - using kEMCEGA and kEMCEJE
- Track selection
  - EtaRange : $|\eta| < 0.9$
  - MinNClustersTPC = 70
  - MaxChi2PerClusterTPC = 4.0
  - RequireTPCRefit(kTRUE)
  - MaxDCAToVertexXY = 1.0
  - MaxDCAToVertexZ = 3.0
  - $pt_{min}$ = 0.15 [GeV/c]
- Cluster selection
  - I use track matching in order to choosing photon cluster
  - track matching : 3sigma
- Centrality
  - 0~10[%], 10~20[%], 20~30[%], 30~40[%], 40~50[%], 50~100[%]

Track matching




× No match

× : track position • : EMC cluster position

If $\Delta\phi$ and $\Delta\eta$ are $3\sigma$ and less, the cluster match with track.

$\Delta\phi$ = EMC cluster $\phi$ − TPC track $\phi$
$\Delta\eta$ = EMC cluster $\eta$ − TPC track $\eta$

# Jet Background Calculation (method)

- Package : fastjet 2.4.2
- Algorithm : $k_t$ algorithm
- Cone radius : R = 0.4
- Strategy : Best
- RecombinationScheme : BIpt_scheme
- ghostEtamax(charged): 0.9
- ghostEtamax(charged+neutral, neutral) : 0.7
- ghostArea : 0.01
- activeAreaRepeats : 1
- $p_{t,min}$ = 0.15[Gev/c]
- Phi range : $0 < \phi < 2\pi$ (charged), $1.8 < \phi < 2.74$ (charged+neutral, neutral)
- Eta range : $|\eta|<0.5$ (charged), $|\eta|<0.3$ (charged+neutral, neutral)
- Using function to extract BG :

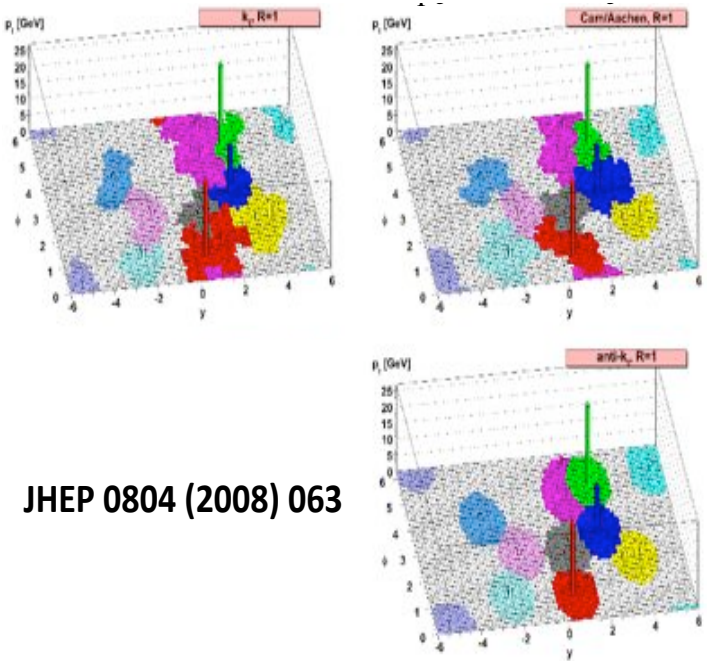
  get_median_rho_and_sigma() ($\rho$=median($p_{t,j}/A_j$))

# Jet reconstruction algorithm

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

## Procedure of Jet reconstruction

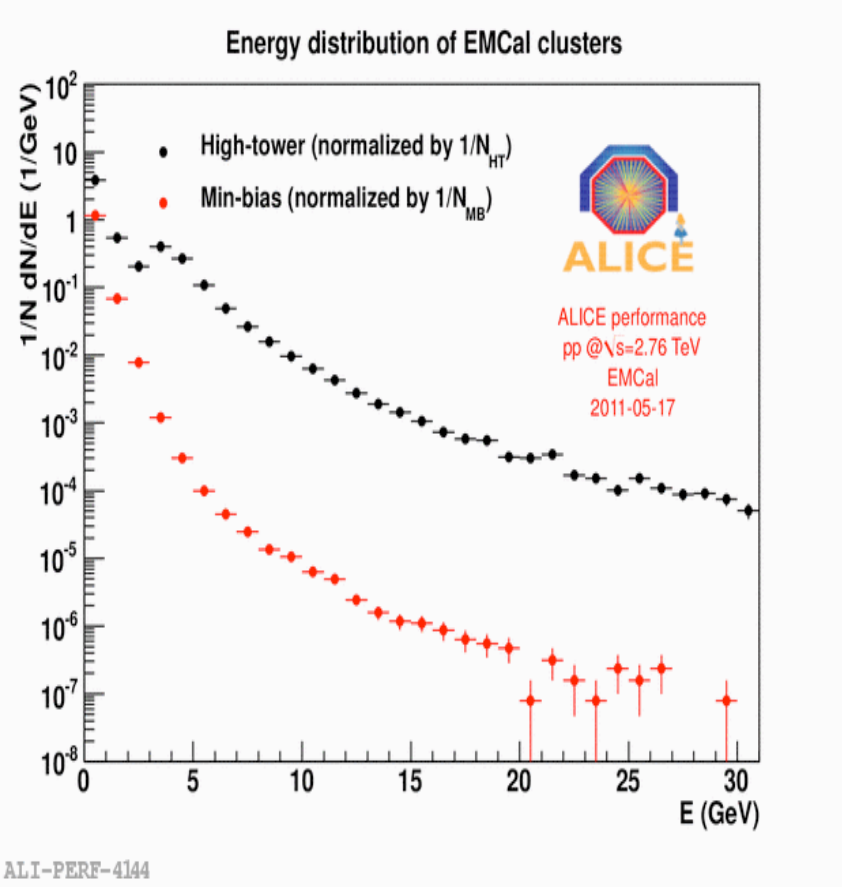
- calculate particle distance : $d_{ij}$
- calculate Beam distance : $d_{iB} = k_{ti}^{2p}$
- Find smallest distance($d_{ij}$ or $d_{ib}$ )
- If $d_{ij}$ is smallest combine particles
- If $d_{iB}$ is smallest and the cluster momentum larger than threshold call the cluster a jet.



JHEP 0804 (2008) 063

# EMCAL trigger

- kEMCEGA (EMCAL photon trigger)
  - 1cell energy > 3.0 [GeV]
- kEMCEJE (EMCAL jet trigger)
  - 1 cluster Energy > 10 [GeV]



# Jet spectrum after background subtraction