Jet properties from triggered particle correlations

Dr. Yaxian MAO

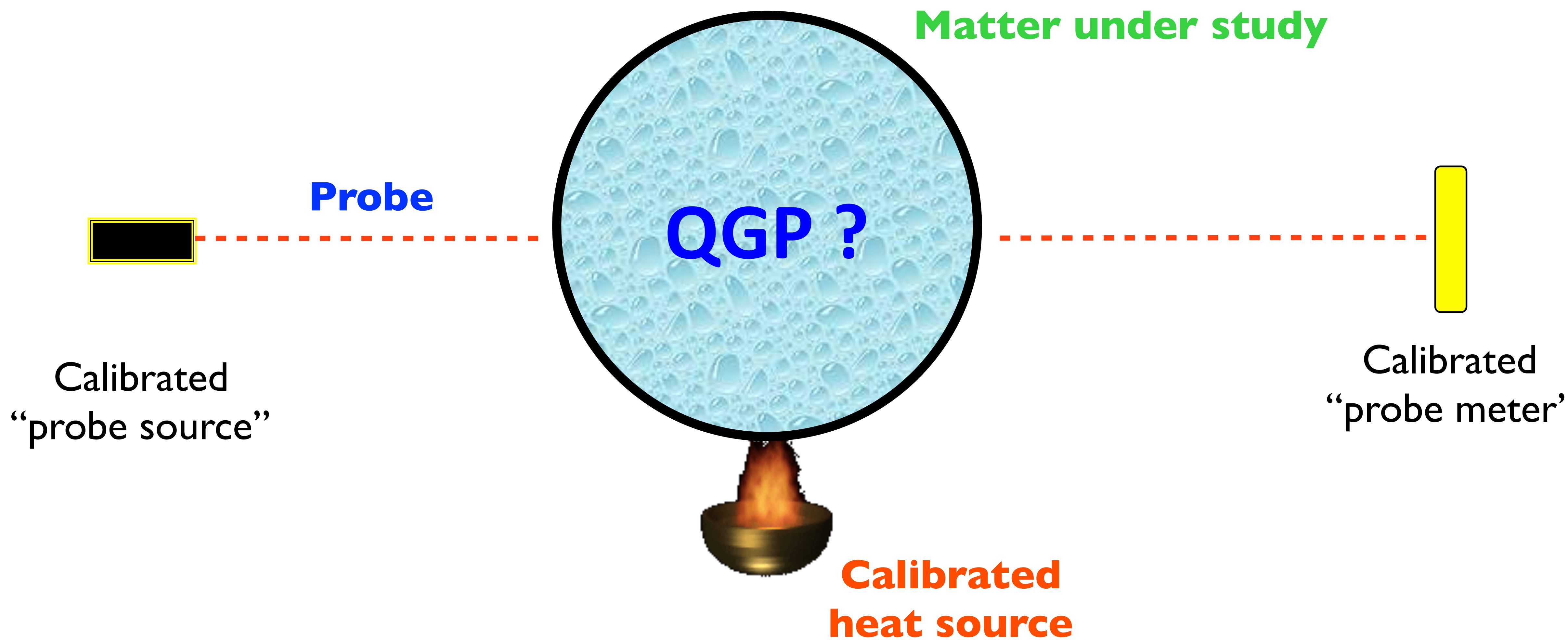
Central China Normal University

9th FCPPL Workshop

Strasbourg, March 30th - April 1st, 2016

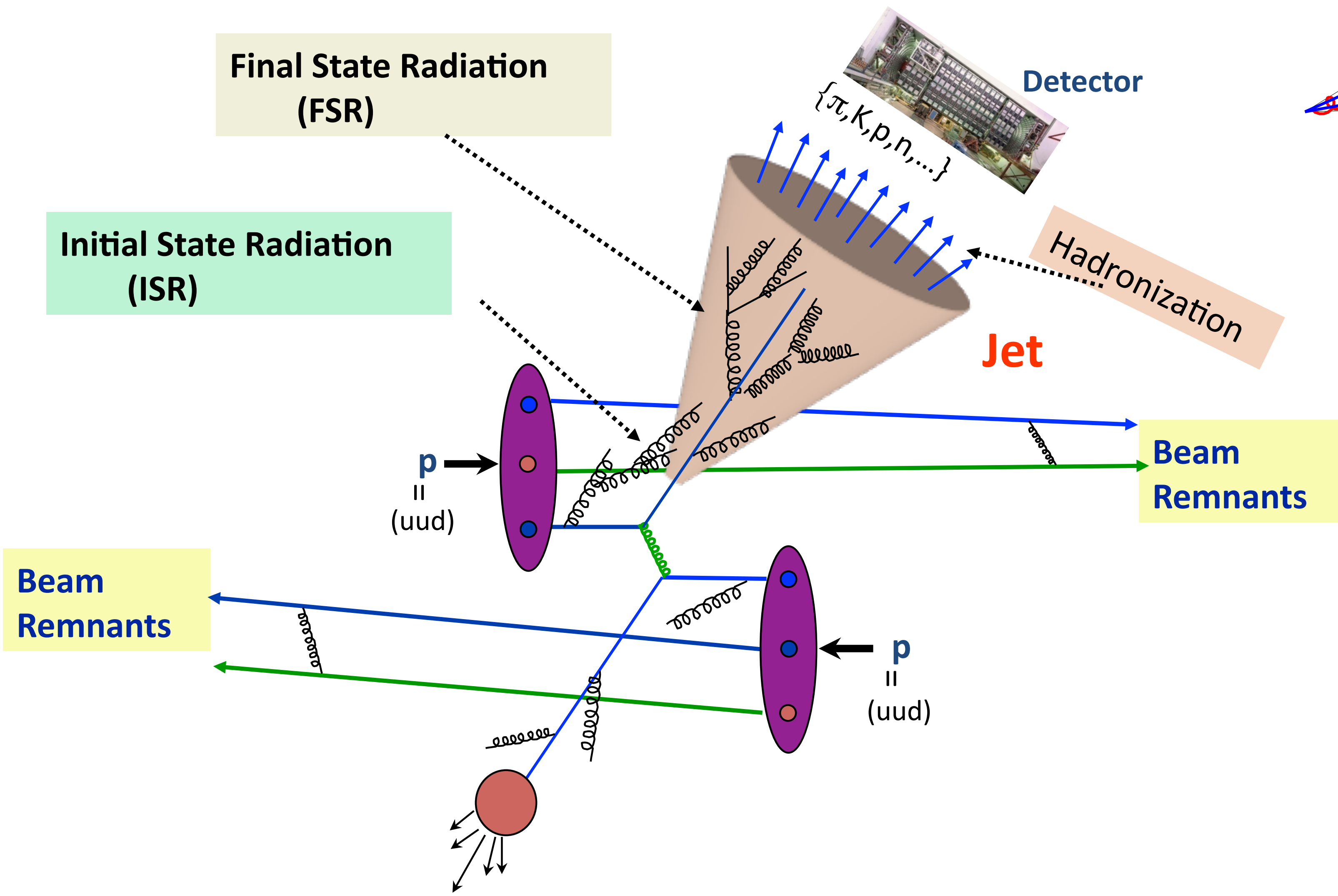
Probing QGP

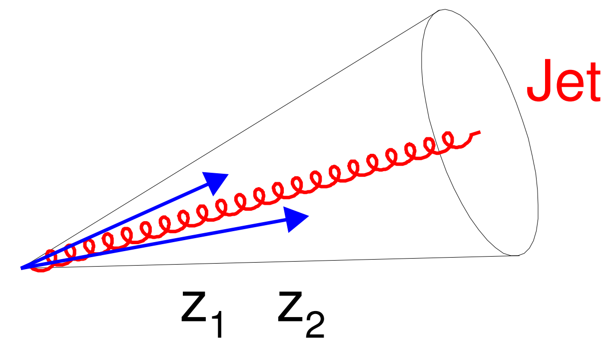
We study the QCD matter produced in HI collisions by searching for modifications of well controlled probes: f(temperature, centrality of the collisions)



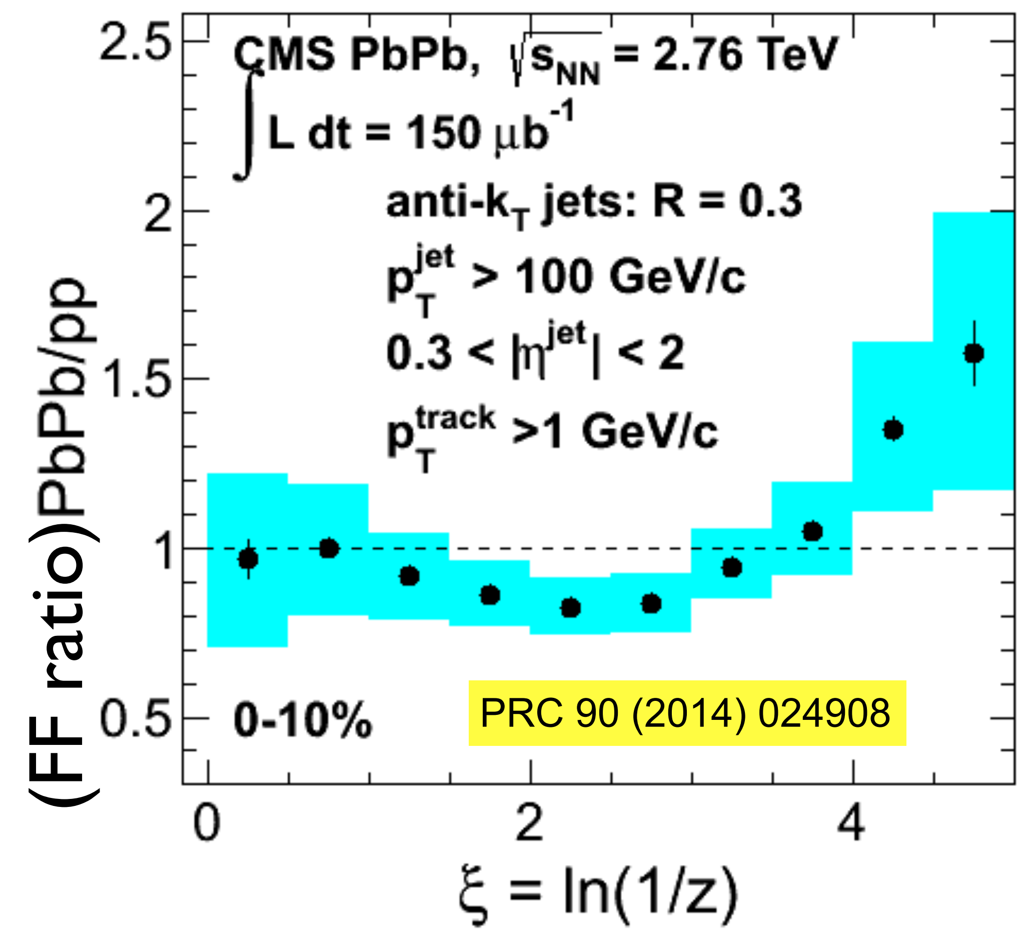
Hard scattering and jet production

Probe source(QCD) + probe (jet) → QGP properties



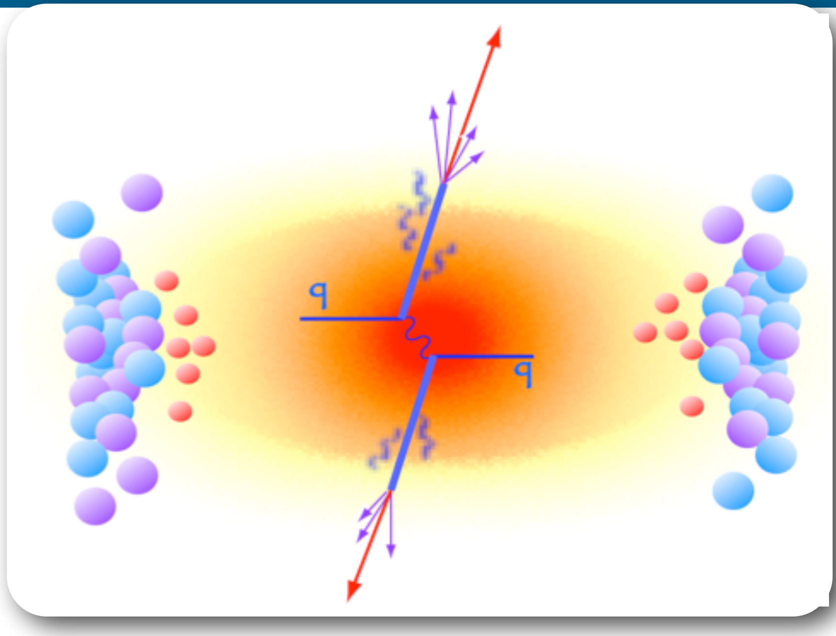


$$z = \frac{p_{\text{hadron}}}{p_{\text{jet}}}$$

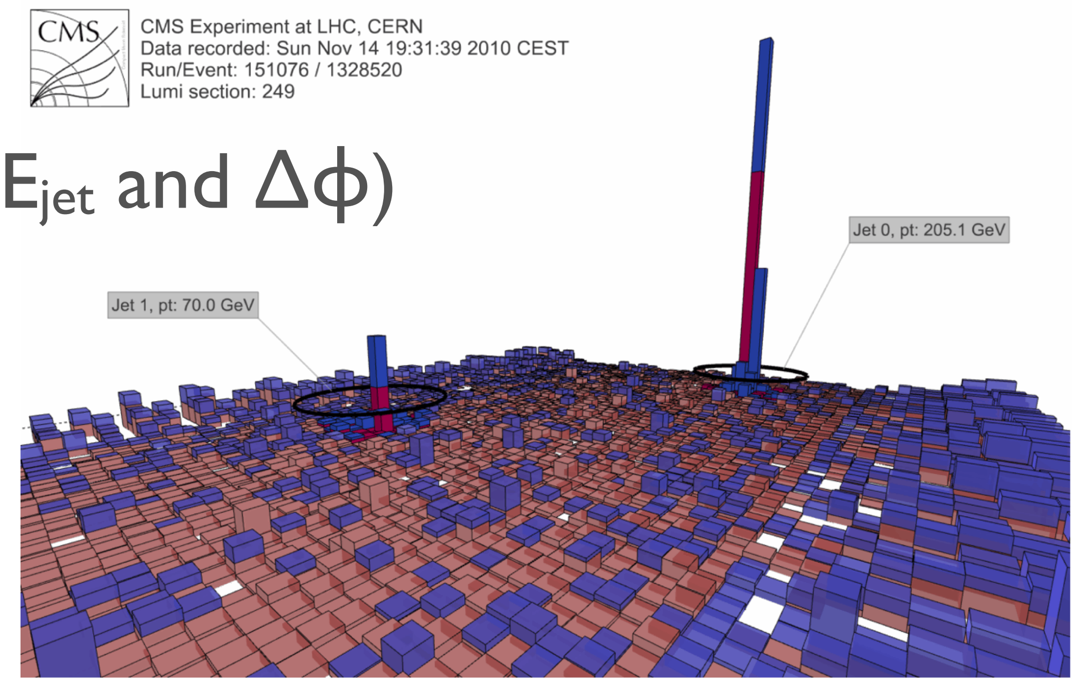


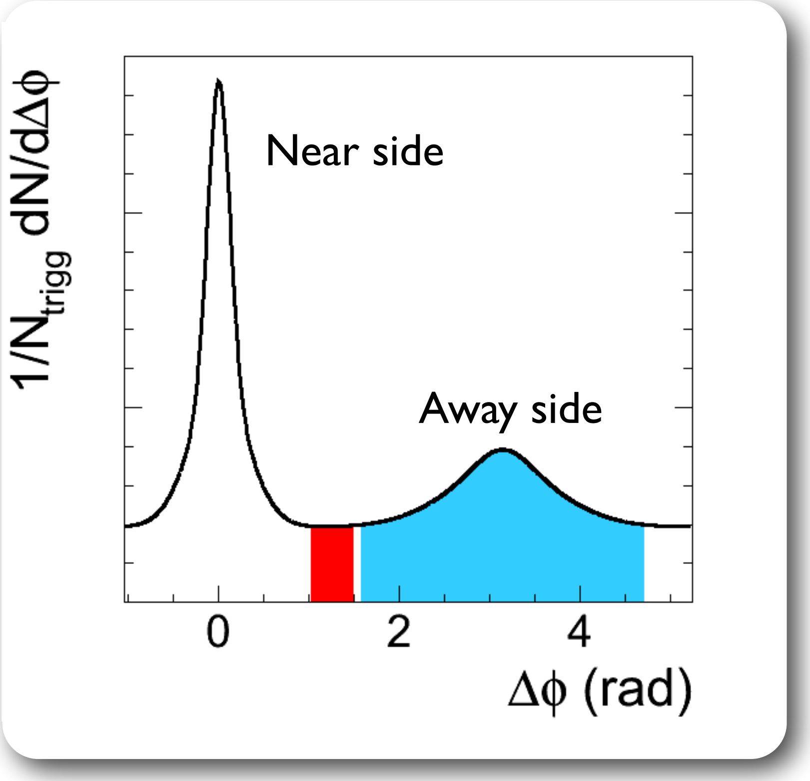
- Spray of hadrons from jets produced in high energy parton-parton scattering
- Fragmentation function (FF): hadron distribution as a function of z, (fraction of jet momentum carried by hadron)

Di-jet and di-hadron correlations

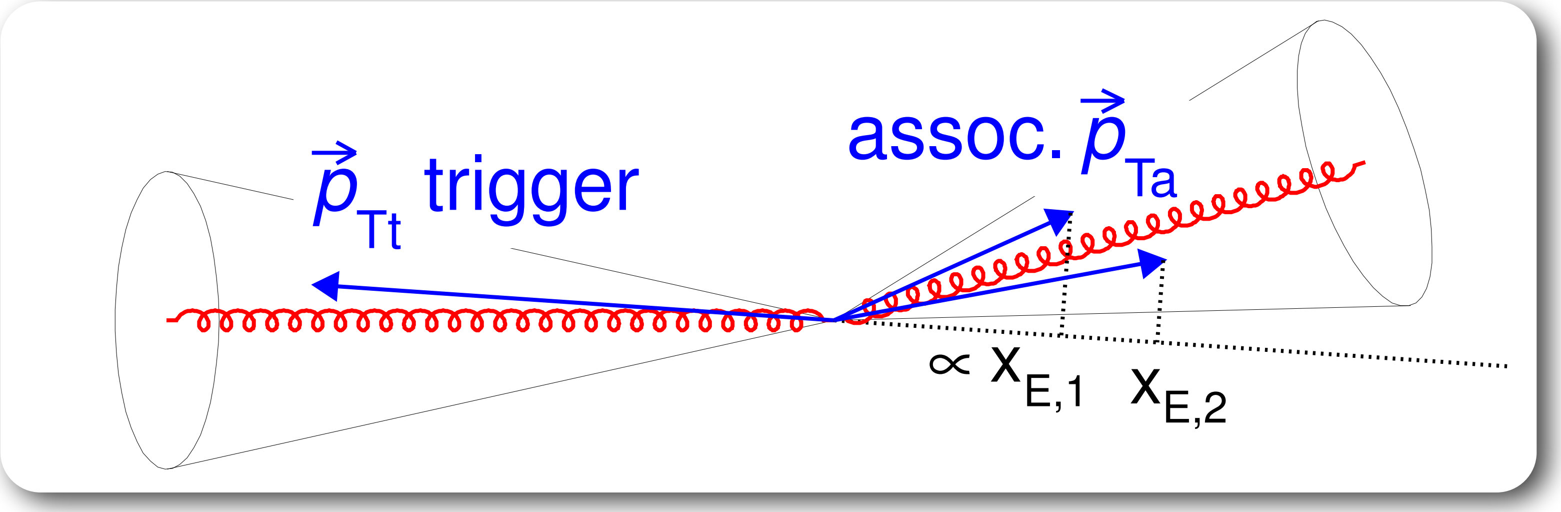


- hard scattered parton looses energy while traversing the medium
  - di-jet (im)balance (E_{jet} and $\Delta\phi$)



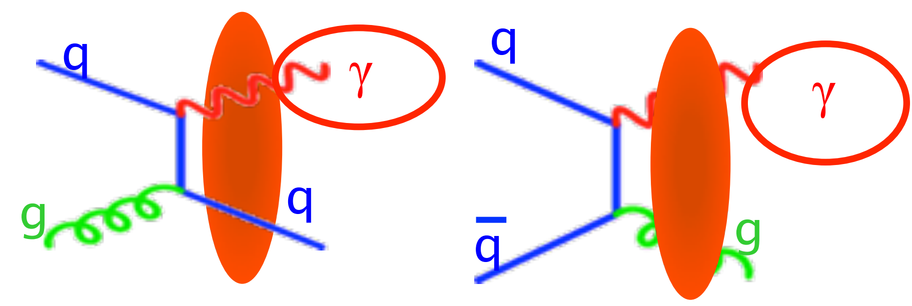


  - di-hadron correlation pattern
    - Inter-jet properties ($\Delta\phi$, away side x_E)

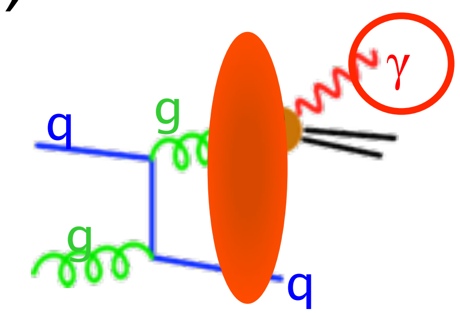


Trigger particles: Photon and π^0

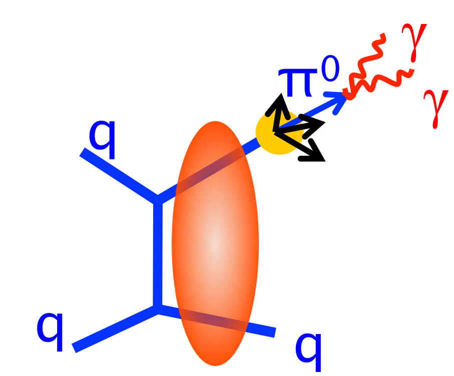
- Photons produced during every phase of the expanding system, carry undistorted information about the medium conditions at their production time.
  - LO pQCD direct photons ($E_\gamma = E_{jet}$, isolated)



  - NLO pQCD fragment photons ($E_\gamma < E_{jet}$, non-isolated)



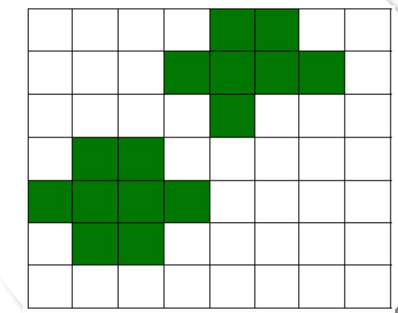
  - Medium induced thermal photons (temperature)
  - Medium induced bremsstrahlung and conversion (chemical composition)



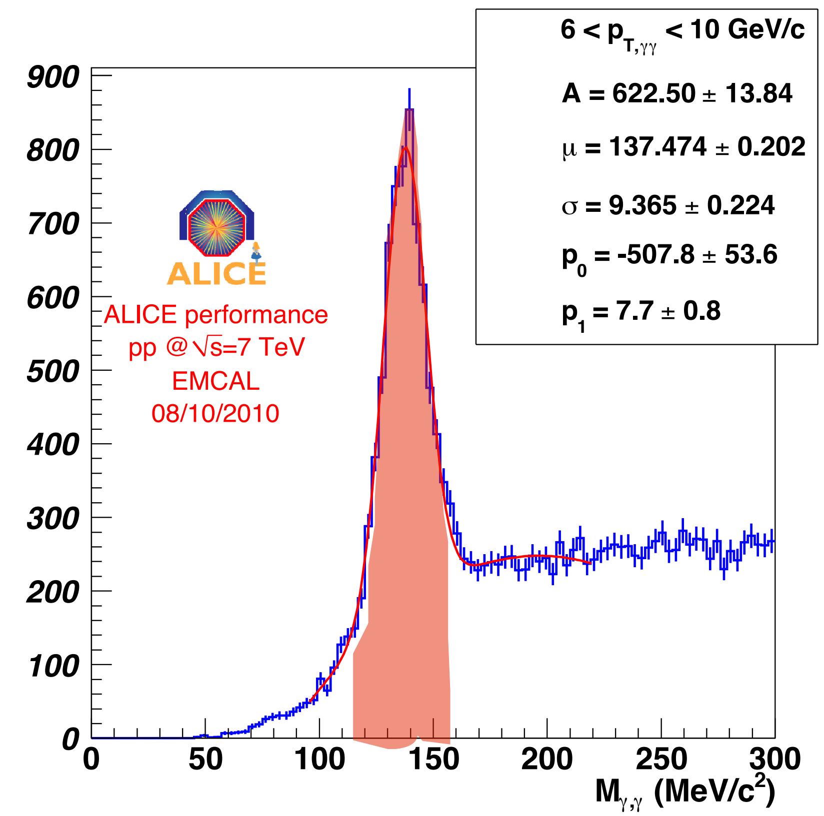
  - Decay photons from neutral mesons (jet quenching)

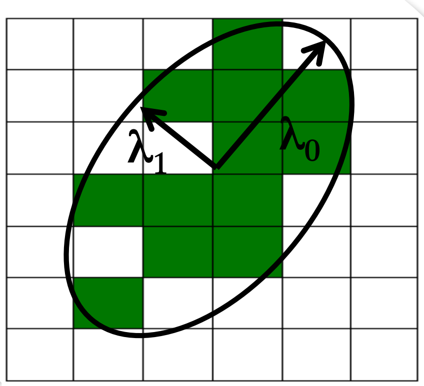
Photon and π^0 detection

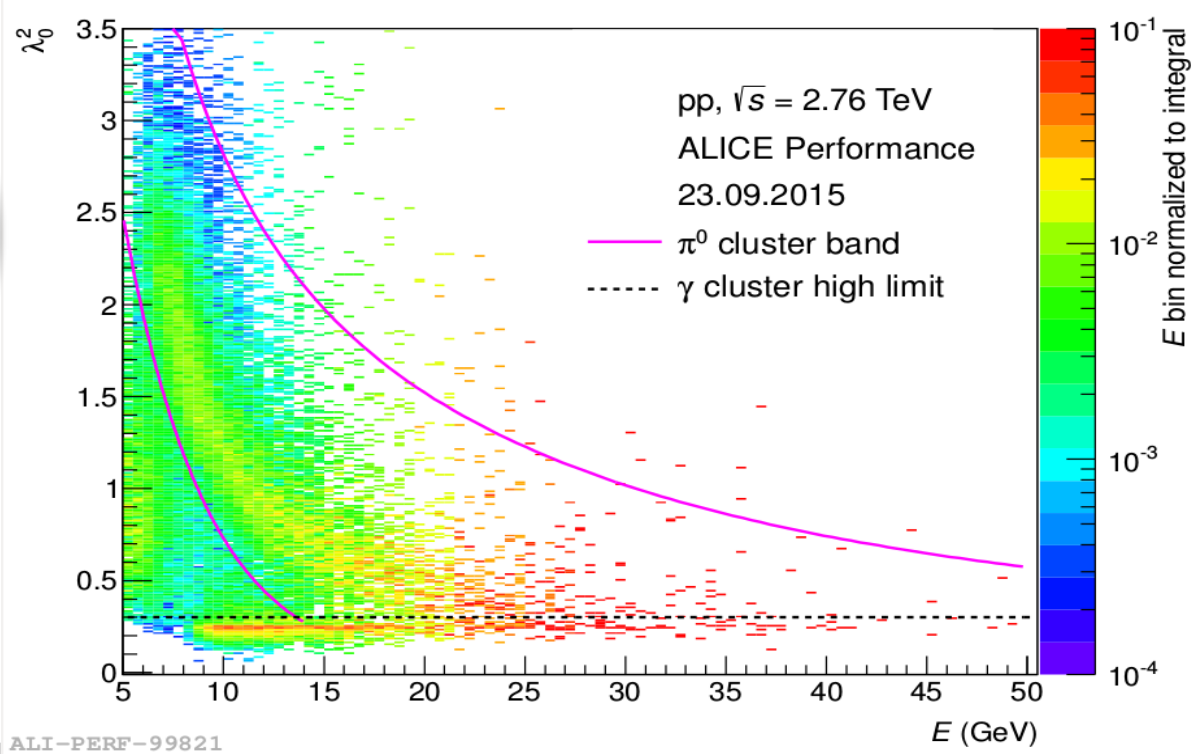
Photons are detected as clusters of cells in the calorimeters



- clusters originated mainly from π^0 (single decay or merged)
  - low energy cluster originates from a single photon
  - high energy cluster from π^0 merged

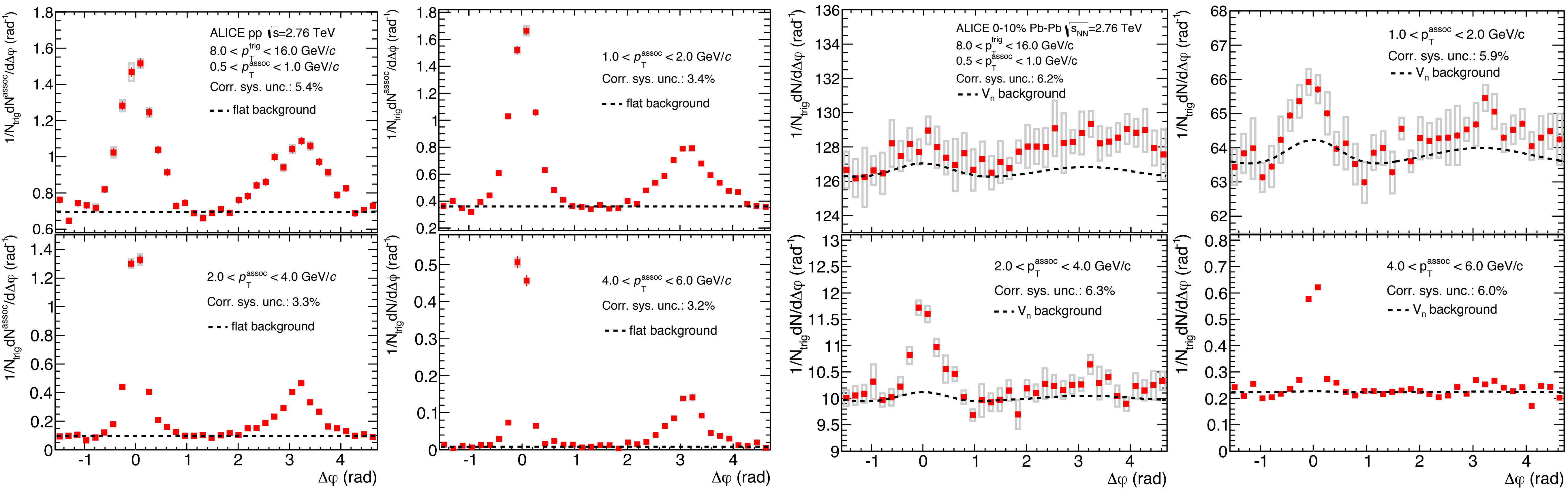






π^0-hadron azimuthal correlations

pp PbPb



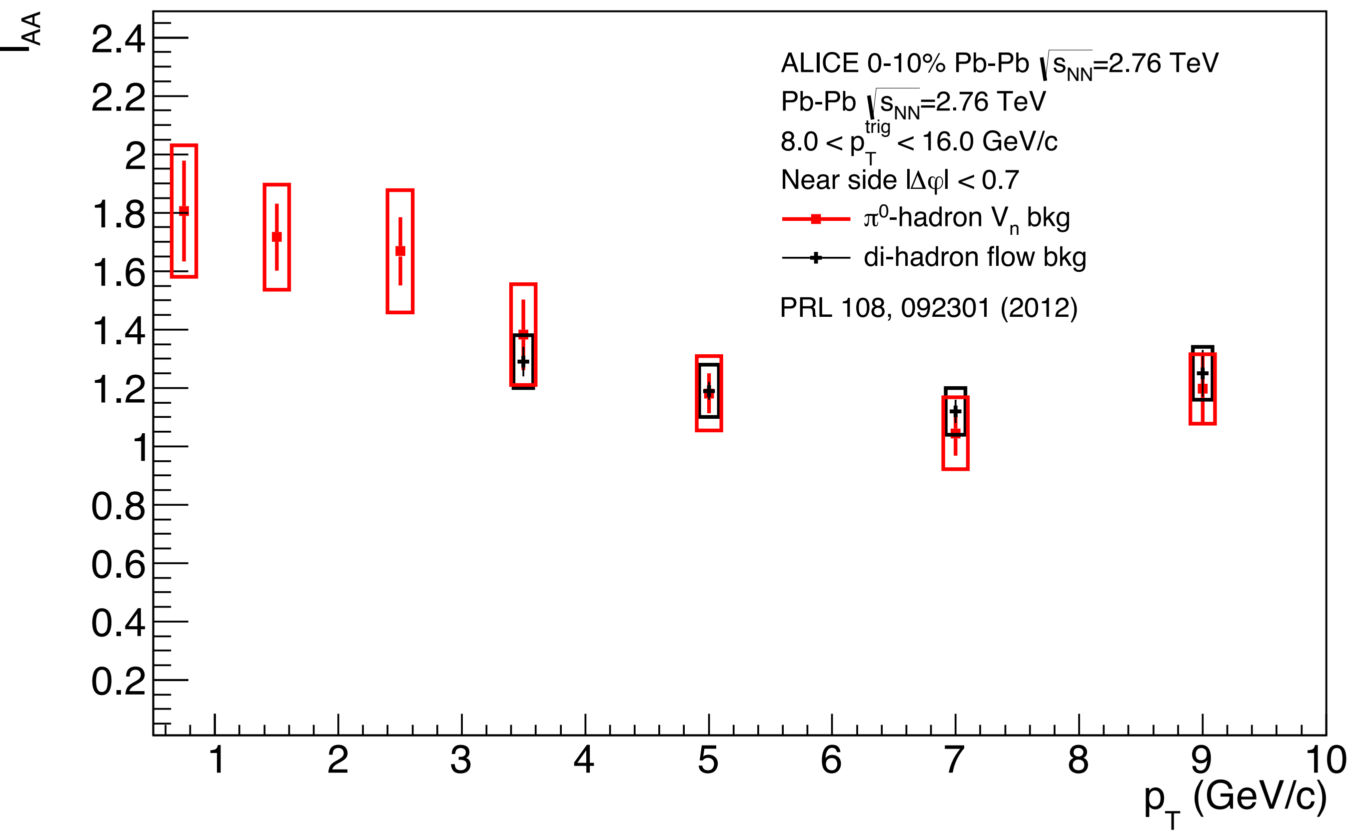
- Double peaks observed → di-jet structure
- Near side peak width broader in PbPb compared to pp → jet broadening
- Away side peak in central PbPb collision is strongly suppressed → jet quenching

Yield modification I_{AA}

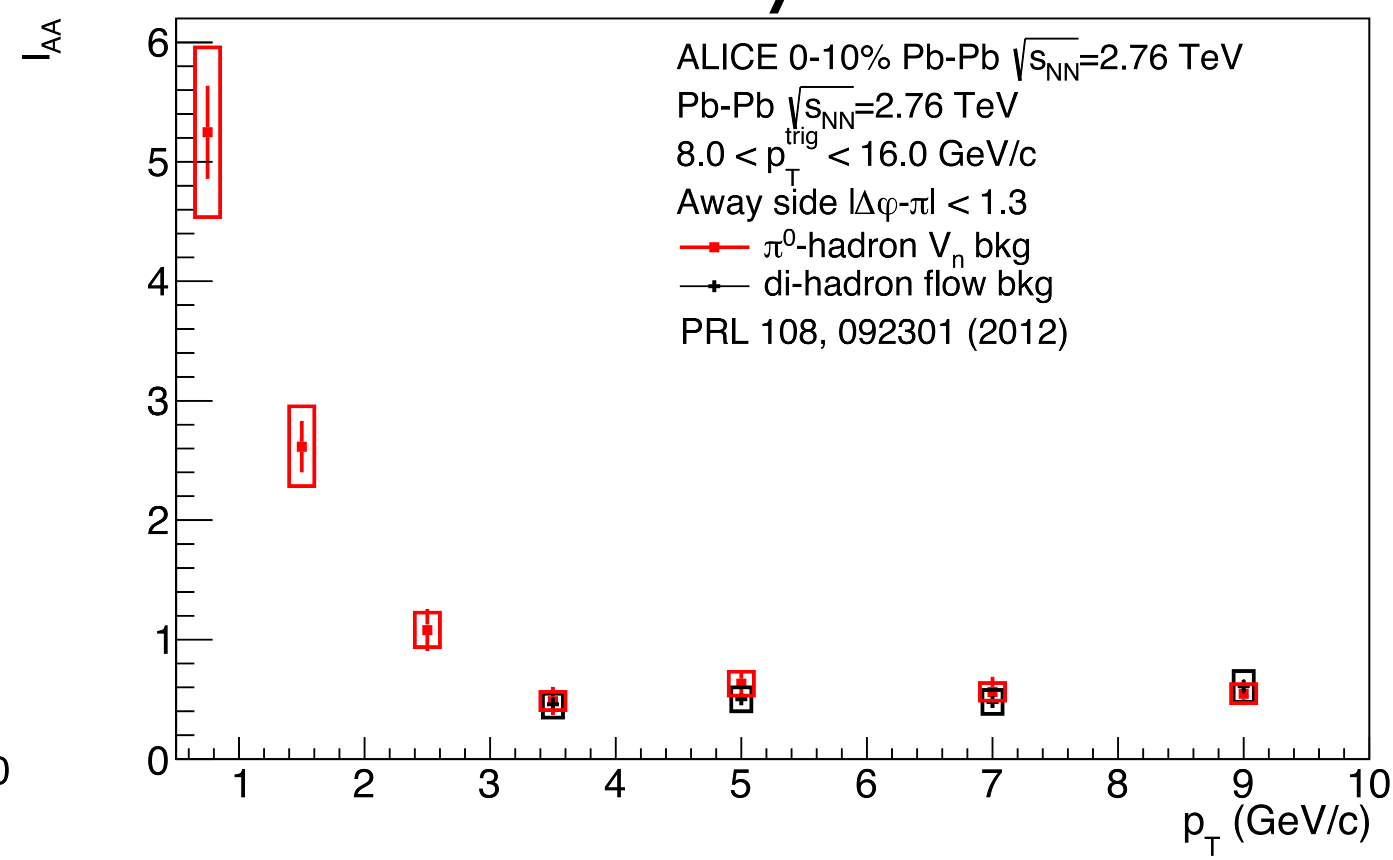
$$I_{AA}\left(p_T^{\pi^0}, p_T^{h^\pm}\right) = \frac{Y_{PbPb}\left(p_T^{\pi^0}, p_T^{h^\pm}\right)}{Y_{pp}\left(p_T^{\pi^0}, p_T^{h^\pm}\right)}$$

$$Y = \int \frac{1}{N_{trig}} \frac{dN_{assoc}}{d\Delta\varphi\varphi} d\Delta\varphi$$

near side



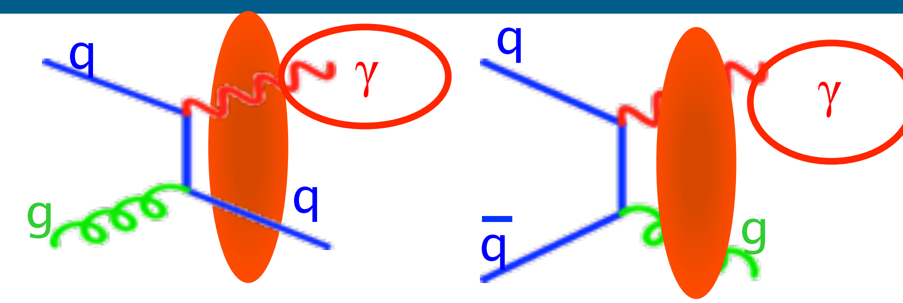
away side

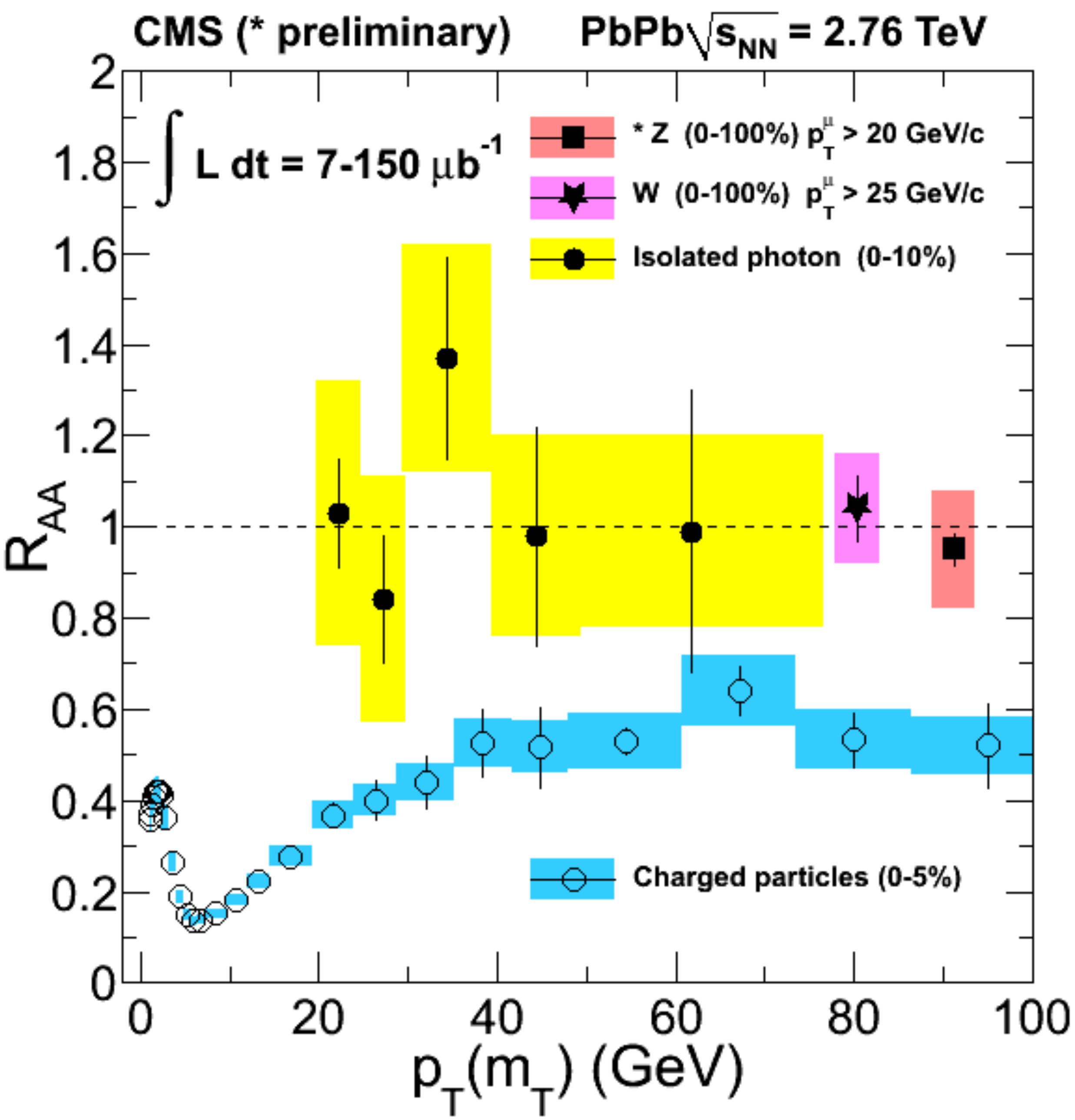


- π^0 triggered correlation identical to non identified di-hadron correlations
- No or little yield modification in the near side and yield suppression in the away side for high p_T particles
- Yield enhancement observed at very low p_T for both near and away side

Photon-hadron correlations

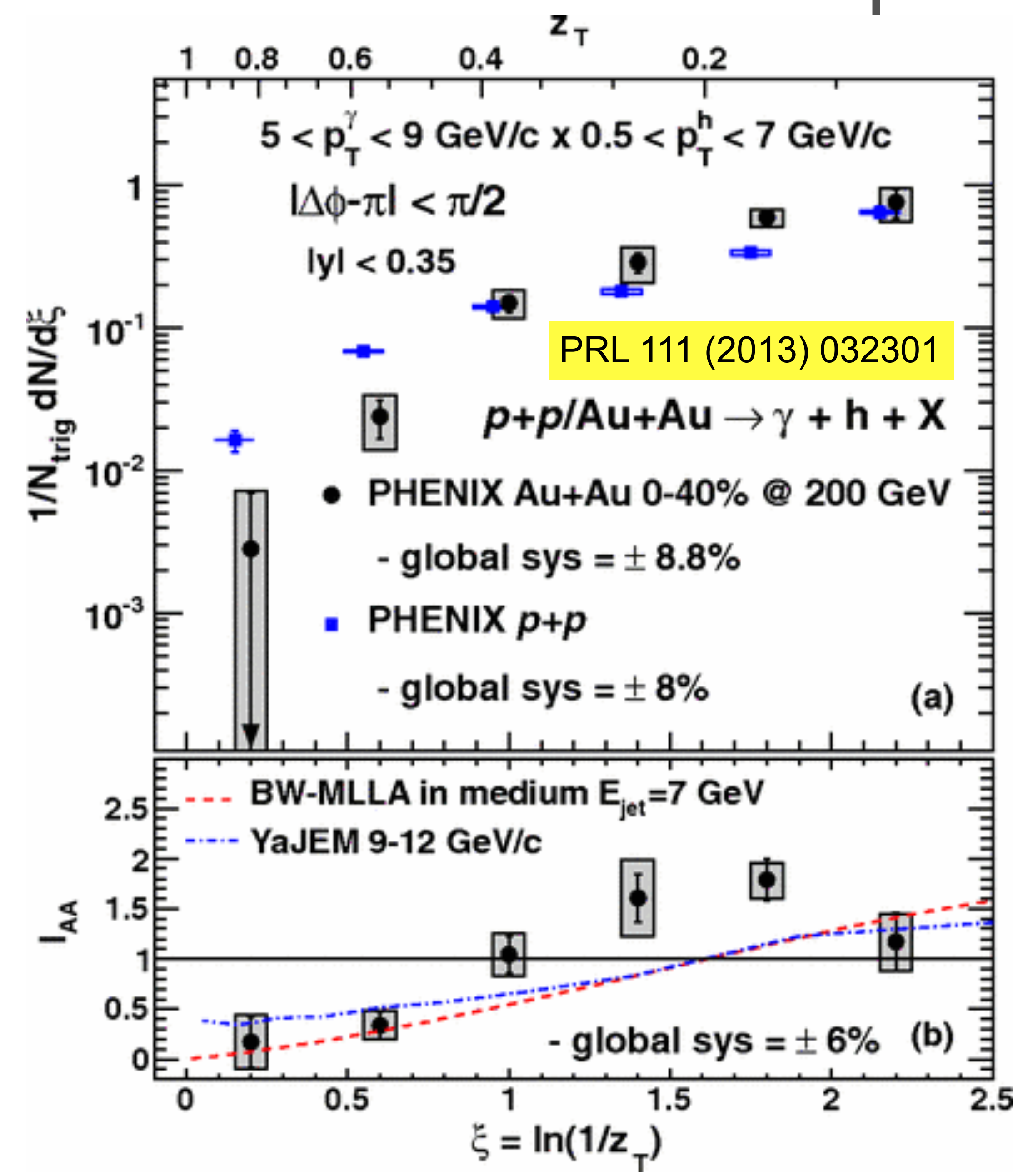
- Photons do not interact with the medium



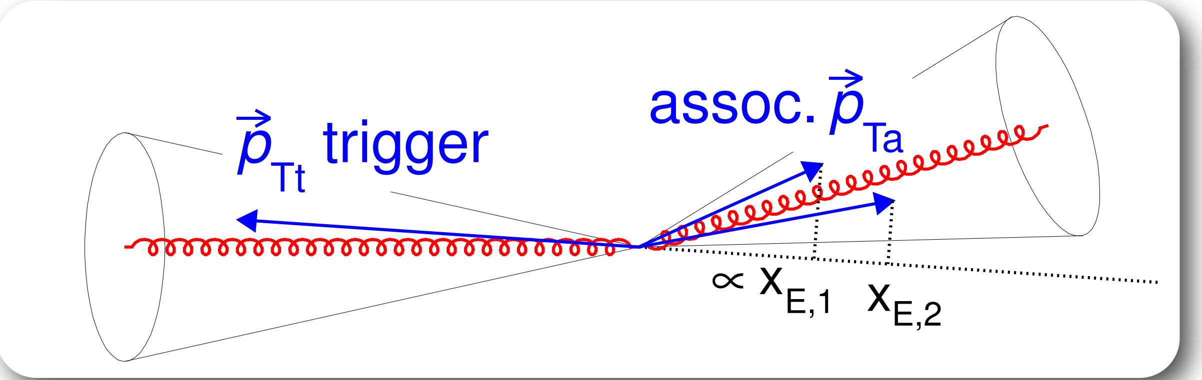


$$R_{AA} = \frac{\sigma_{pp}^{inel}}{\langle N_{coll} \rangle} \frac{d^2 N_{AA}/dp_T d\eta}{d^2 \sigma_{pp}/dp_T d\eta}$$

- Provide reference for hard process



x_E kinematics

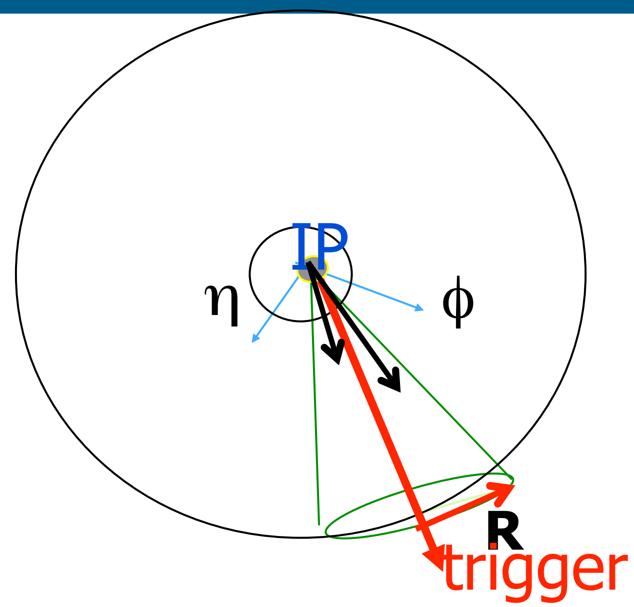


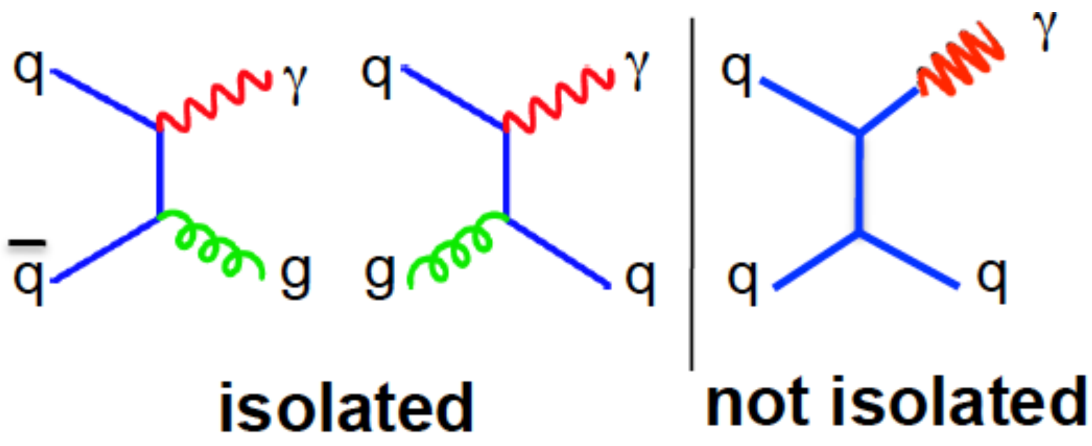
$$x_E = -\frac{\vec{p}_{Tt}\cdot\vec{p}_{Ta}}{\left|\vec{p}_{Tt}\right|^2} = -\frac{p_{Ta}}{p_{Tt}}\cos(\Delta\phi)$$

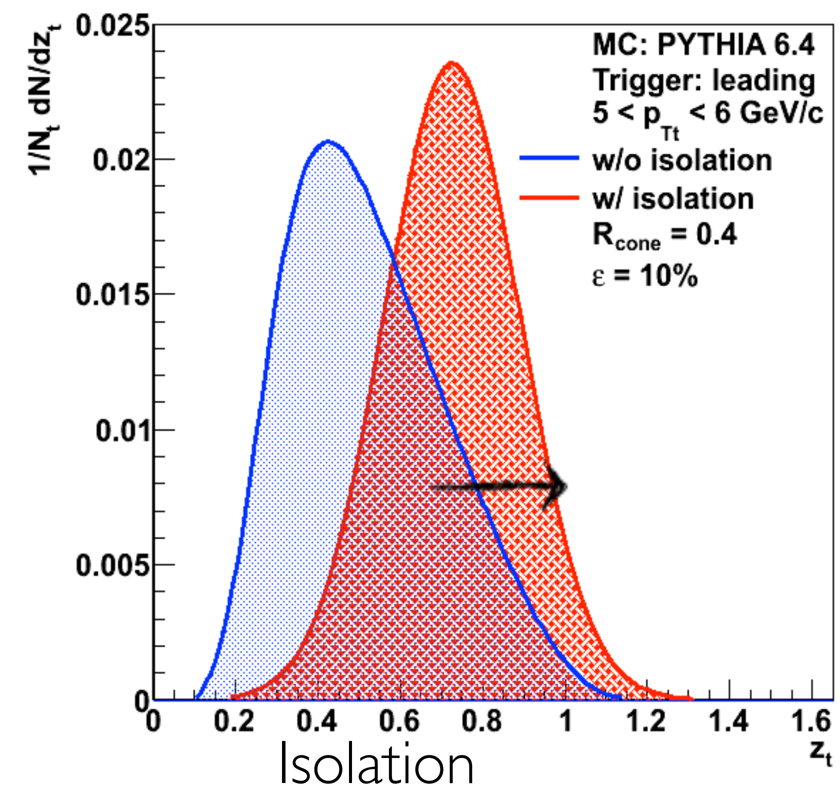
$$z_t = \frac{p_{Tt}}{p_{jet}^{near}} \qquad z_a = \frac{p_{Ta}}{p_{jet}^{away}}$$

- $\Delta\phi = \phi_{trigger} - \phi_{associate} \sim \pi$ $\Rightarrow$ $x_E \approx \frac{z_a \cdot p_{jet}^{away}}{z_t \cdot p_{jet}^{near}}$
- No k_T (di-jet balance) $\Rightarrow$ $x_E \approx \frac{z_a}{\langle z_t \rangle}$
  - Charged/neutral trigger: $\langle z_t \rangle < 1 \Rightarrow x_E \neq z_a$
  - Isolated trigger: $\langle z_t \rangle \rightarrow 1 \Rightarrow x_E \rightarrow z_a$
  - Direct Photon-jet : $\langle z_t \rangle = 1 \Rightarrow x_E \approx z_a$

Isolation





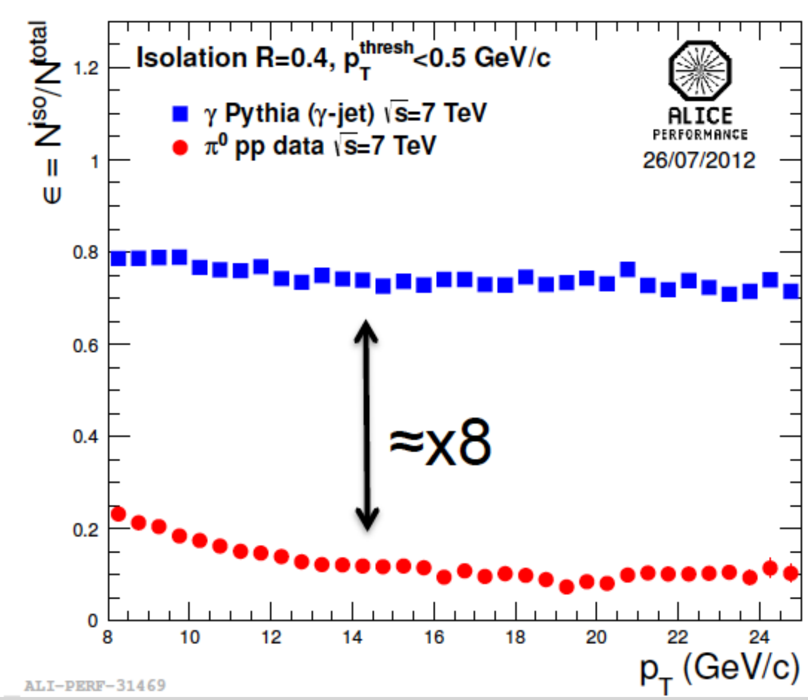


- Enrich the trigger sample with $\langle z_t \rangle \rightarrow 1$

$< z_t > \sim 0.5 \rightarrow < z_t^{isolated} > \sim 0.8$

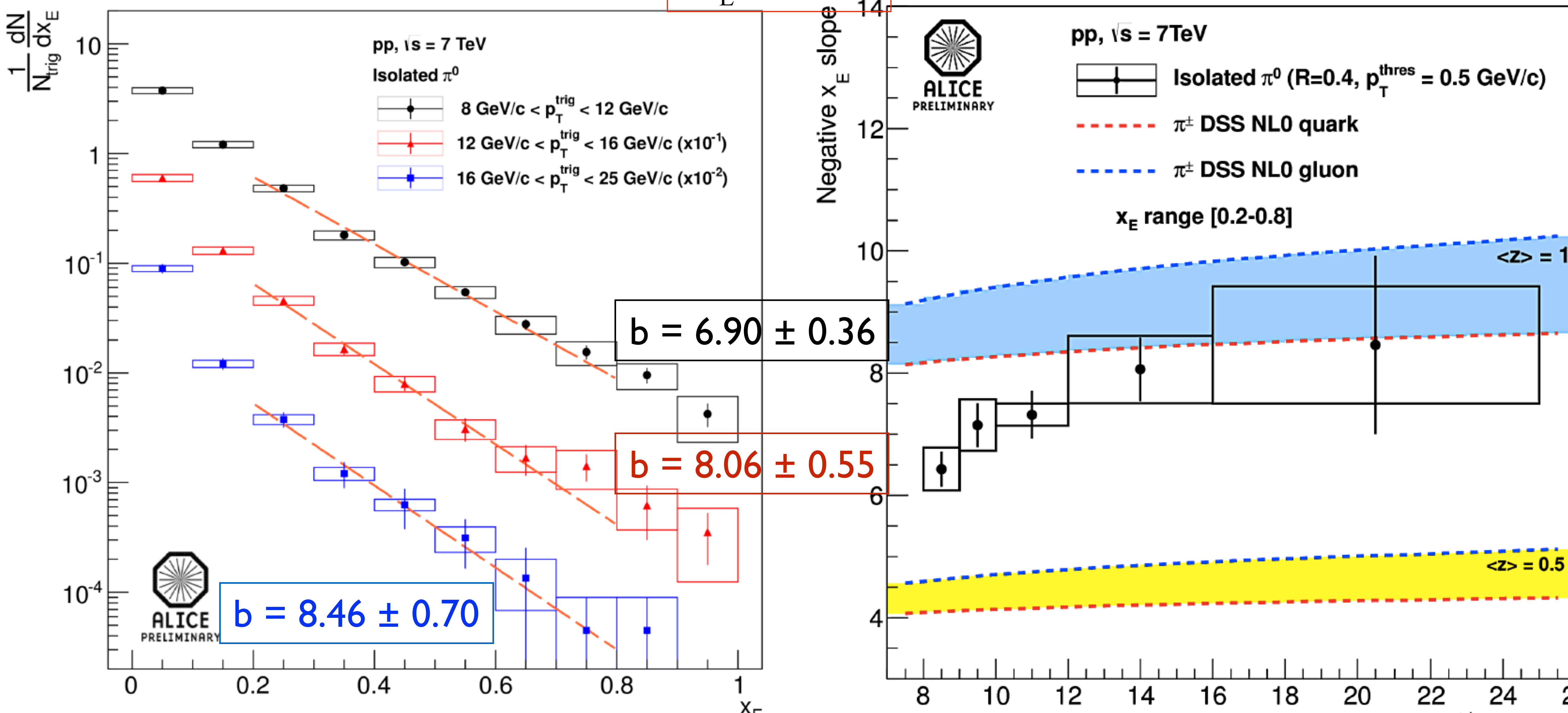
- estimate hadronic (charged only) activity around the trigger
  - R (= 0.4) of the cone
  - hadronic behaviour inside the cone
- trigger (p_{Tt}) is isolated if

$\sum_{cone} p_T^{h\pm} < 1$ and $p_T^{h\pm} < 0.5$



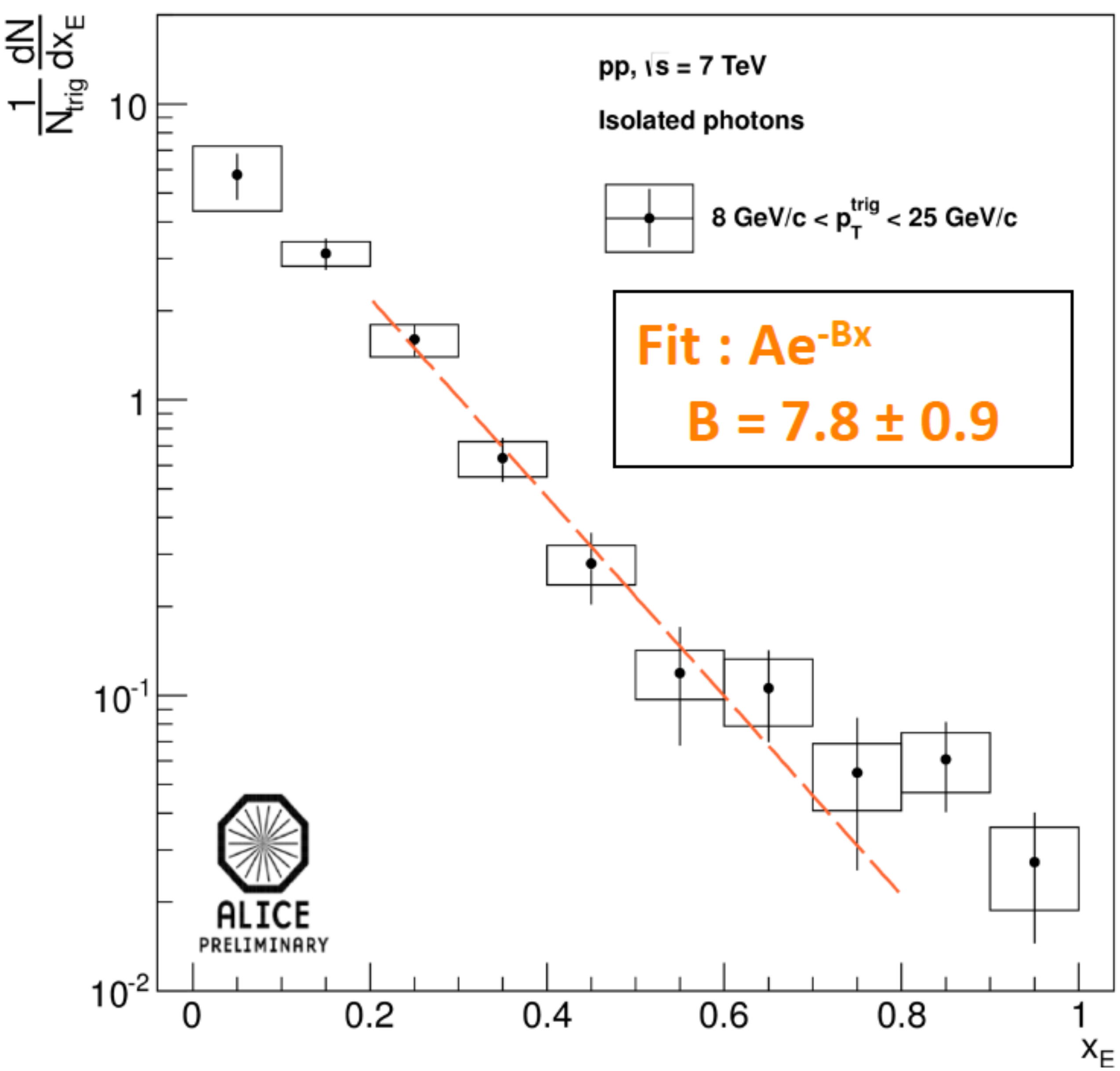
Isolated π^0-hadron x_E distributions

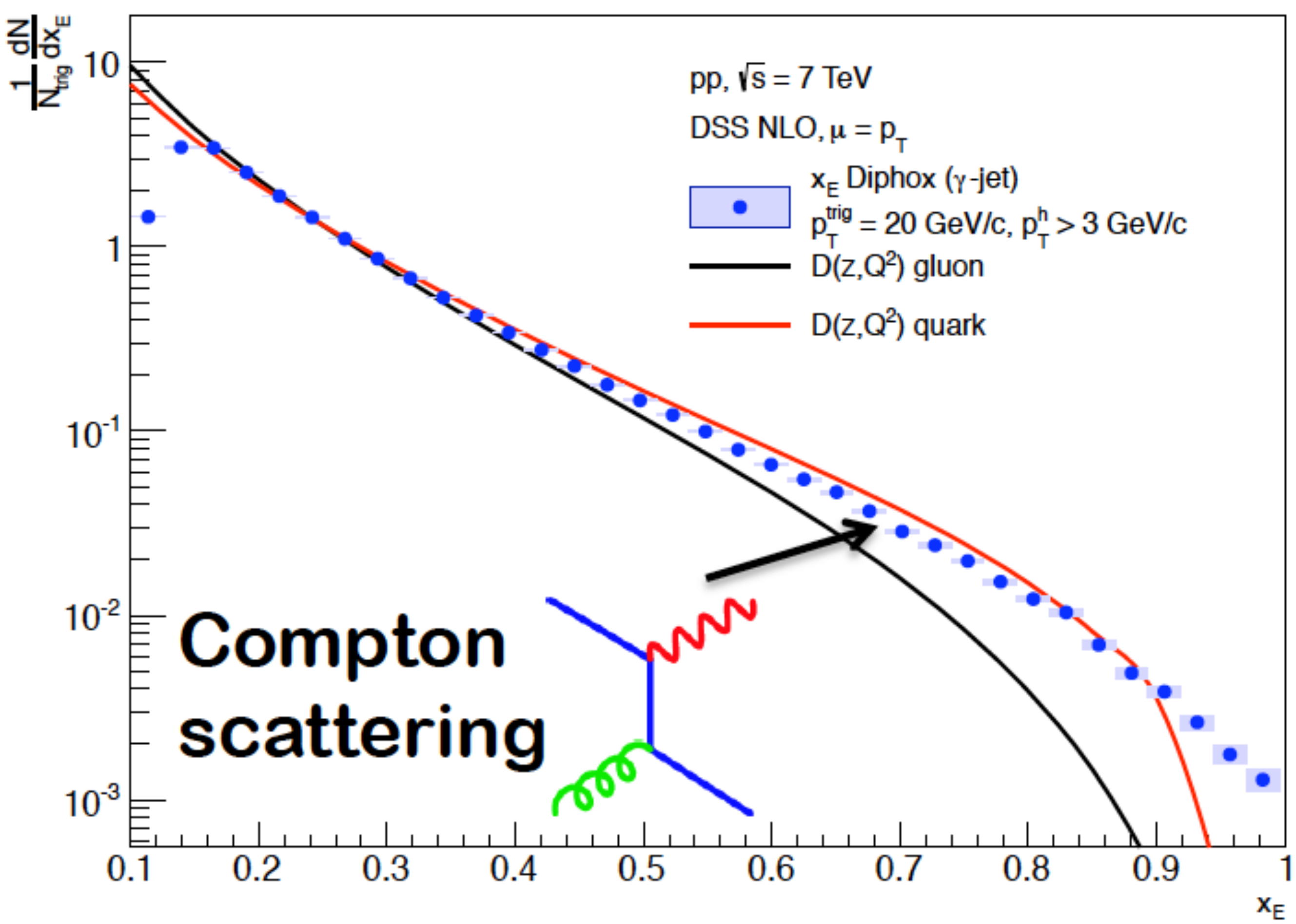
$$\frac{dN}{dx_E} = Ne^{-bx_E}$$



- x_E slope moves towards to <z> =1 direction → isolated π^0 samples a large fraction of jet energy
- Very limited statistics and large uncertainties from Run1 analysis

Isolated γ-hadron x_E distributions





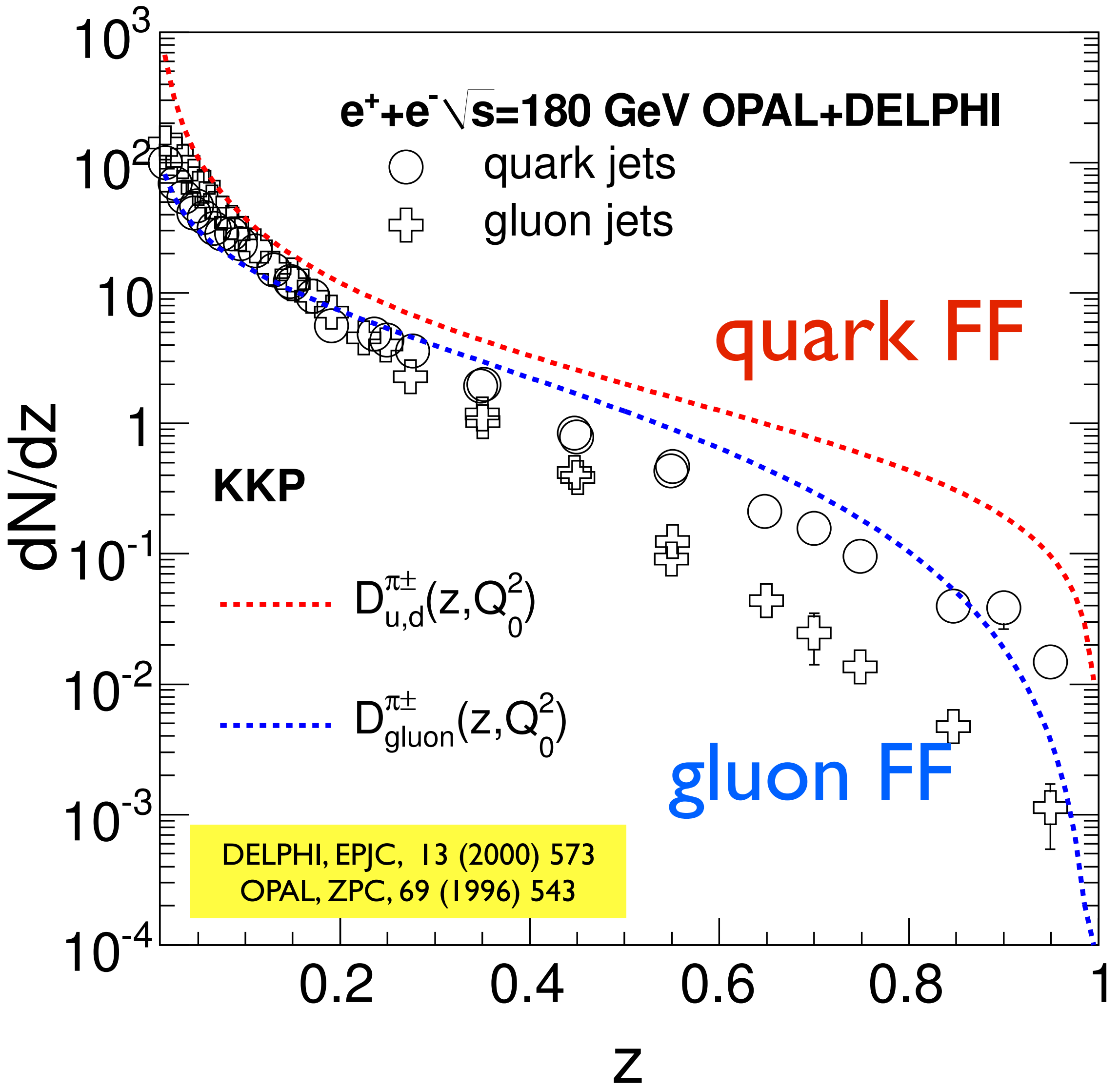
- Isolated γ-hadron x_E distributions seems in favour of quark jet FF
- Detailed tagging study limited by Run 1 statistics

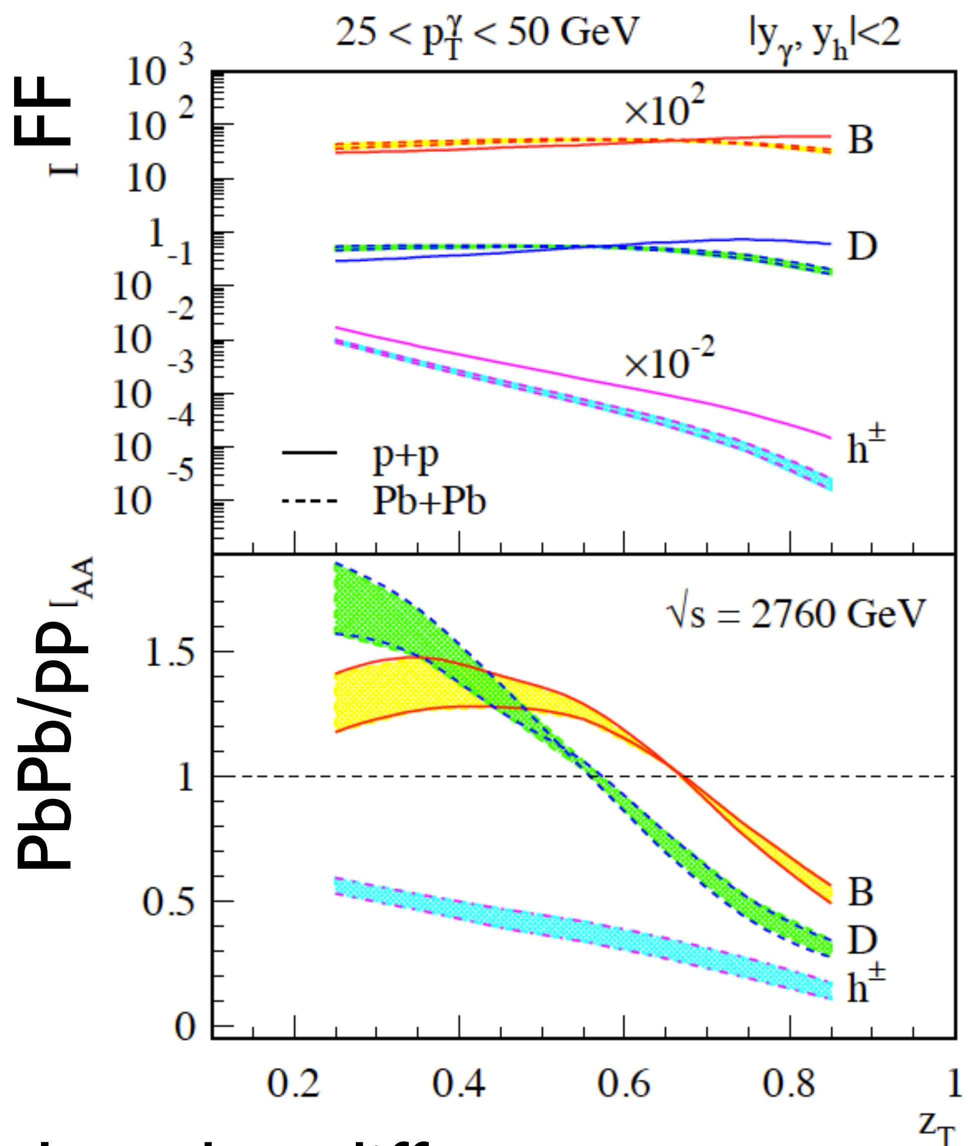
Summary and outlook

- Jet properties can be studied using triggered particle correlations
    - di-jet structure observed
    - Low p_T particle enhanced and away side high p_T suppressed, consistent picture for jet quenching
- Isolated trigger particle correlations can be used as a proxy to study jet fragmentation pattern
- Unable to draw precise conclusion with Run1 data due to limited statistics
    - ➡ but can be further checked and addressed by higher Lint and extended detection capabilities during Run II and Run III data with more differential measurements
        - ✤ flash in the next two slides towards other possibilities for precise measurements…

Color and mass dependent jet FF

Tagging jets by different triggered-particle correlations





PRD 84 (2011) 014034

- OPAL and DELPHI measured quark and gluon has different fragmentation pattern in e+e-
- Theory predicted jet fragmentation pattern modified differently for g, q and Q
  - ➡ can be further tested at LHC with coming data

Path length dependent medium effect

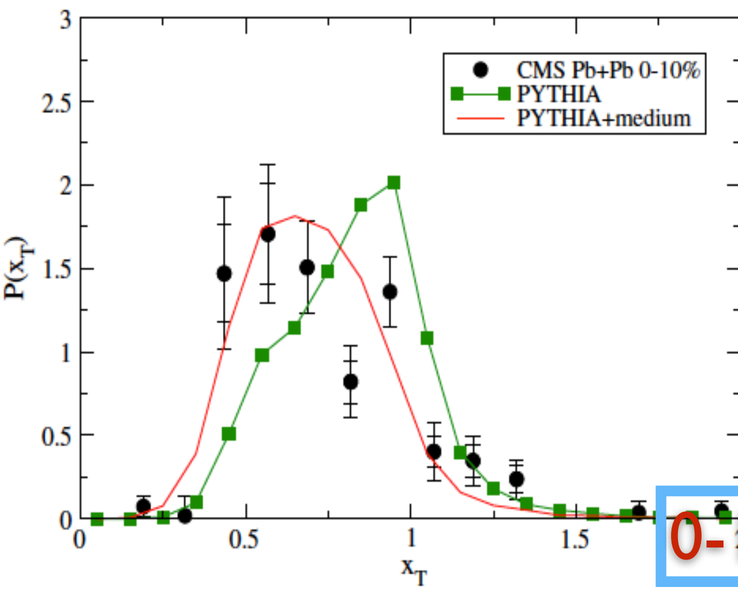
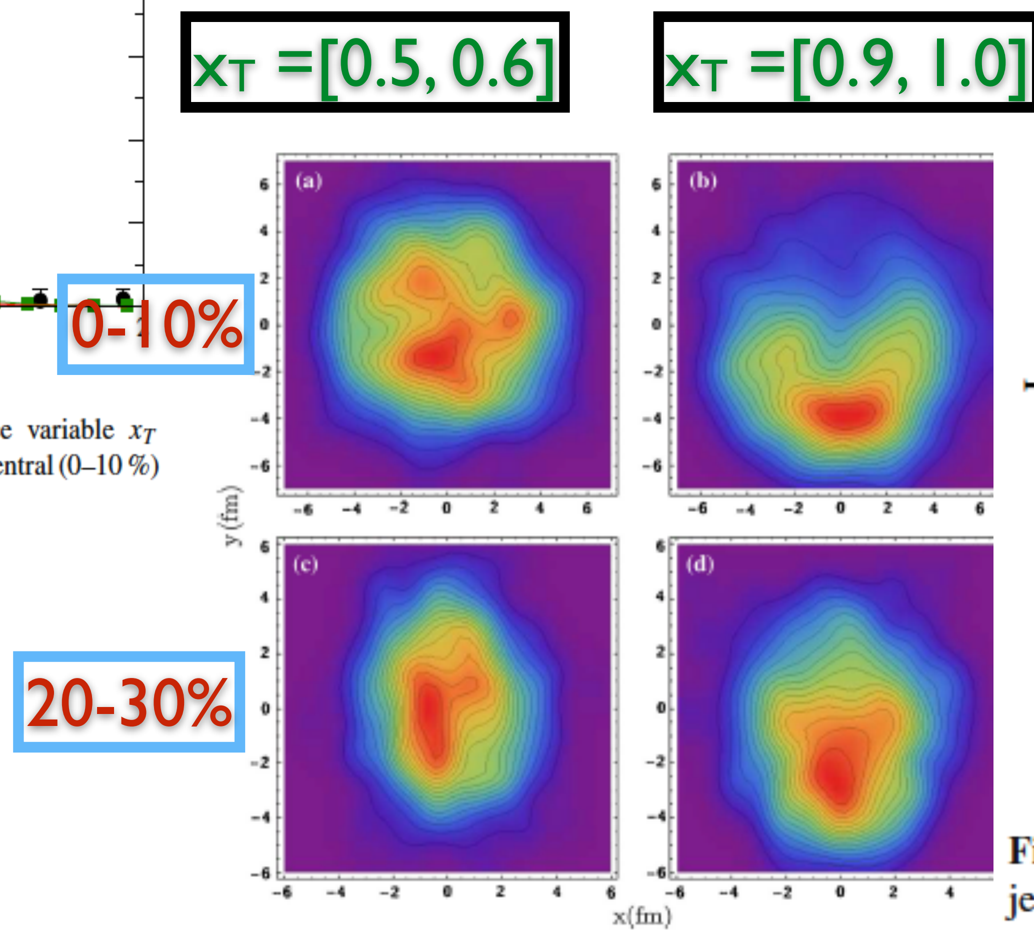


Fig. 3 The distribution of the momentum imbalance variable x_T between triggered photons and associated jets for most central (0–10 %) Pb+Pb collisions at the LHC. The jet size is $R = 0.3$

Probe medium density by asymmetric γ-jet events



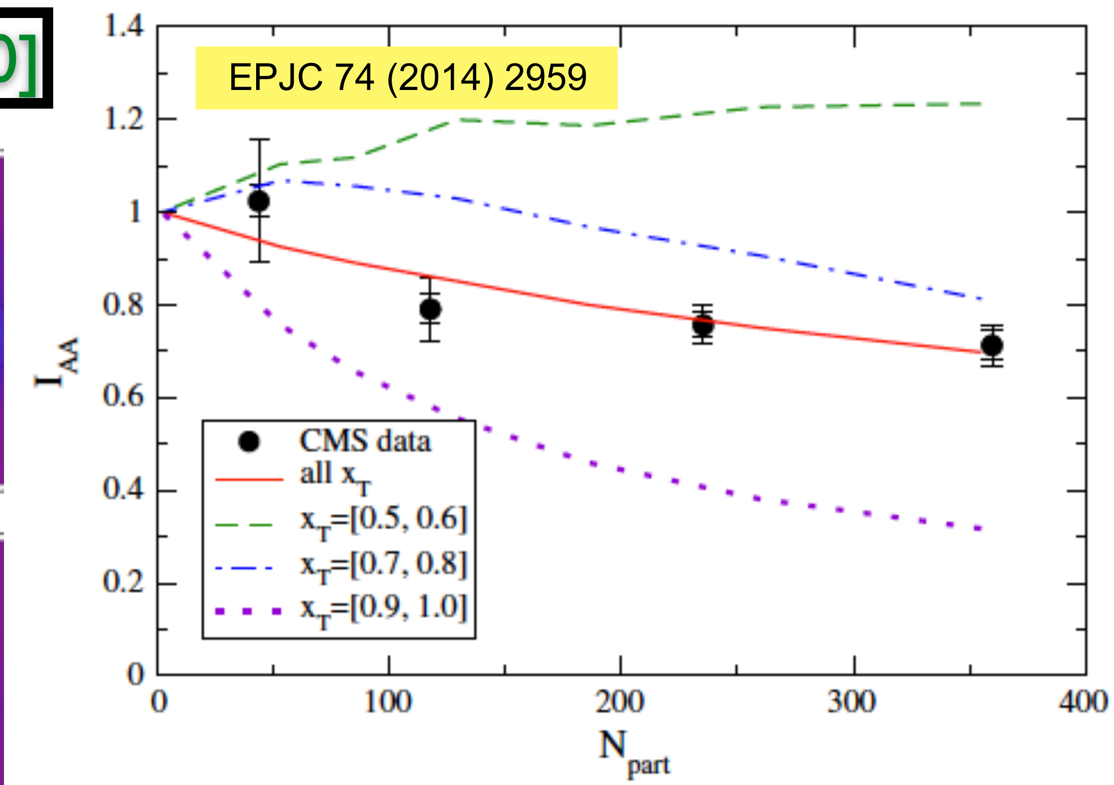


Fig. 8 The nuclear modification factor I_{AA} for the photon-triggered jets as a function of centrality for Pb+Pb collisions at the LHC. The results for different x_T values are compared. The jet size is $R = 0.3$

- By selecting jet pair events using different asymmetry (x_T) value, one can probe different medium lengths and density profile, and result different modification patterns

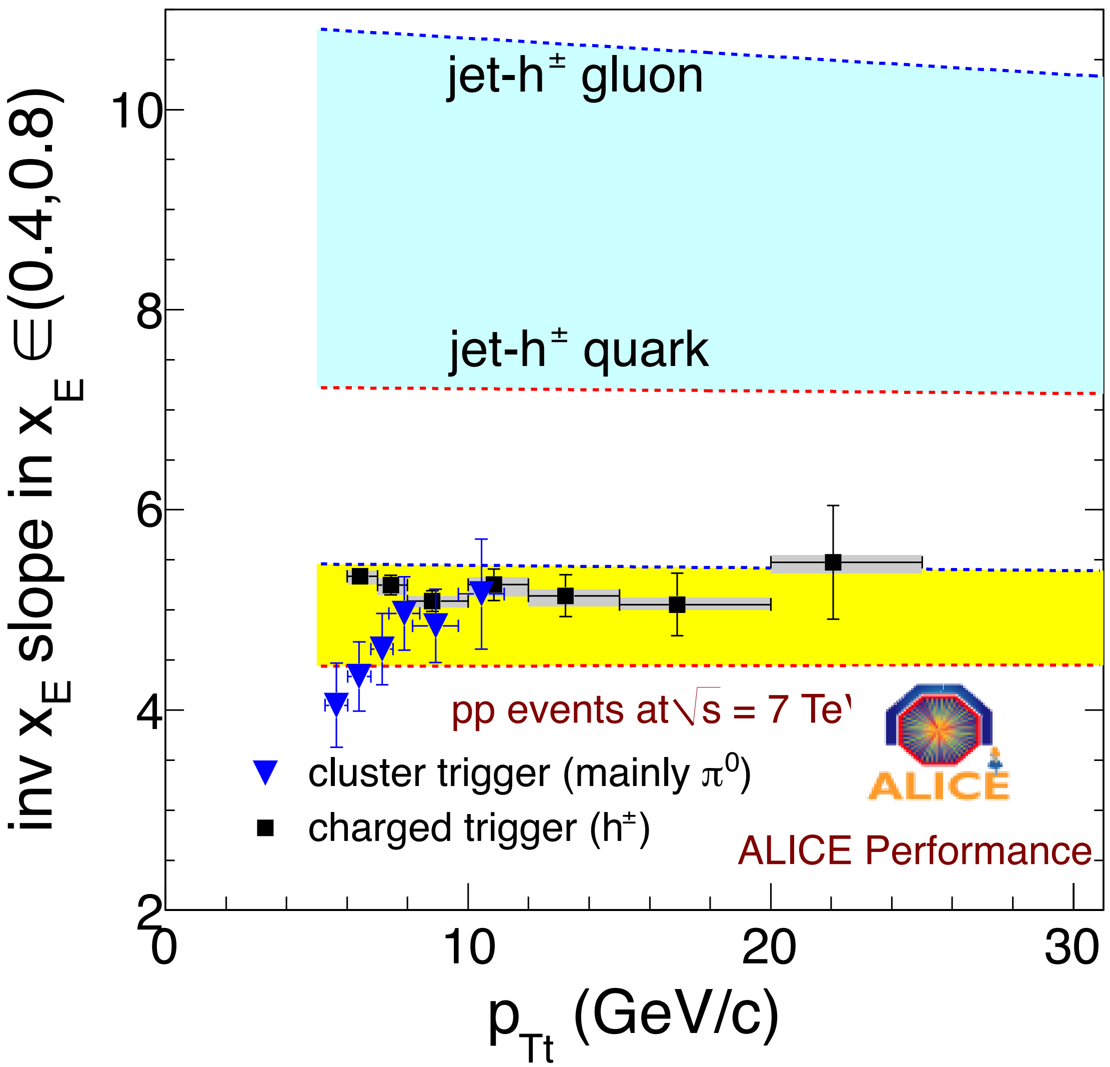
  ➡ can be studied at LHC with coming data

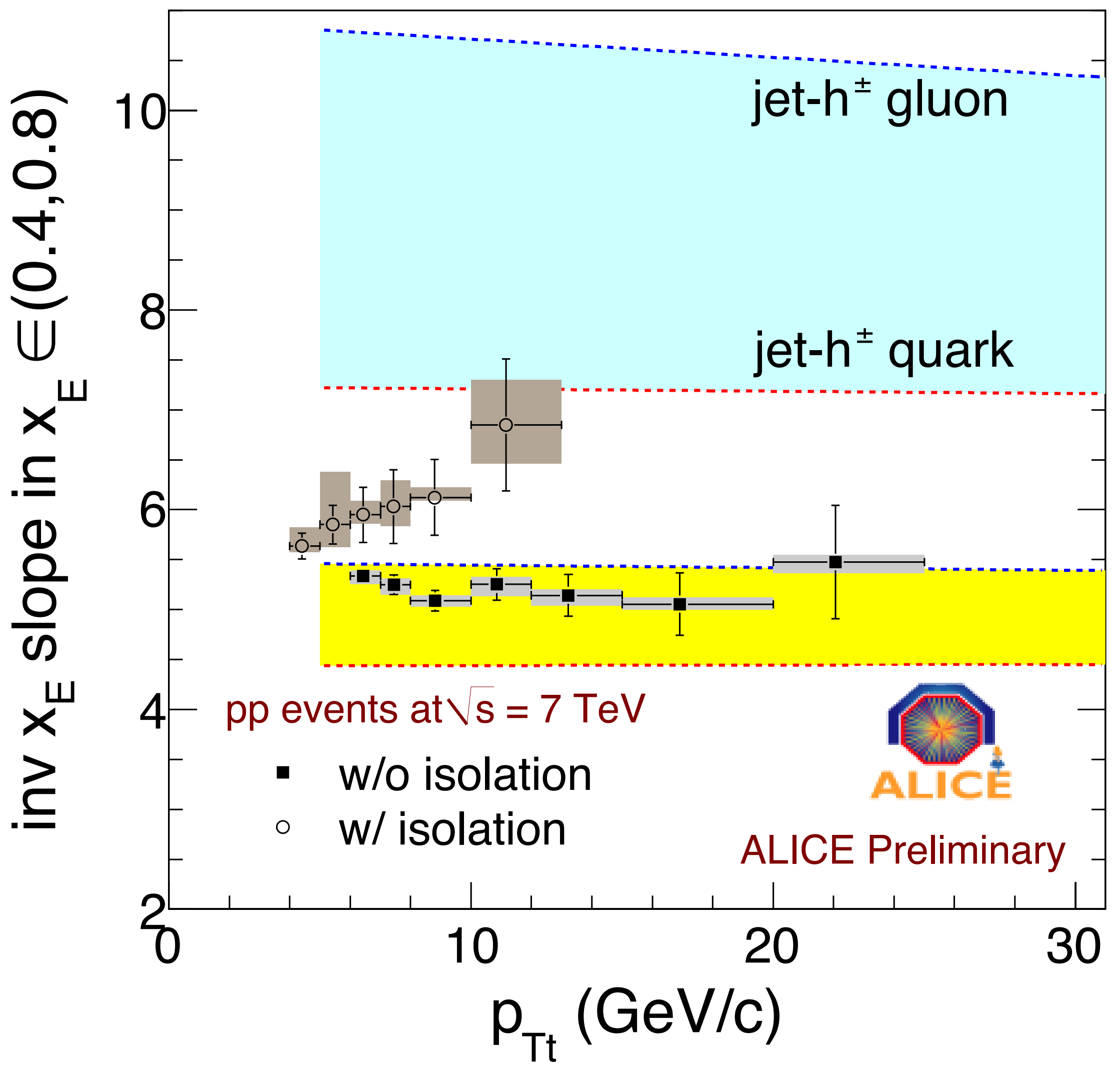
Thank you for your attention!

Please stay tuned...

backup

Inverse x_E slope





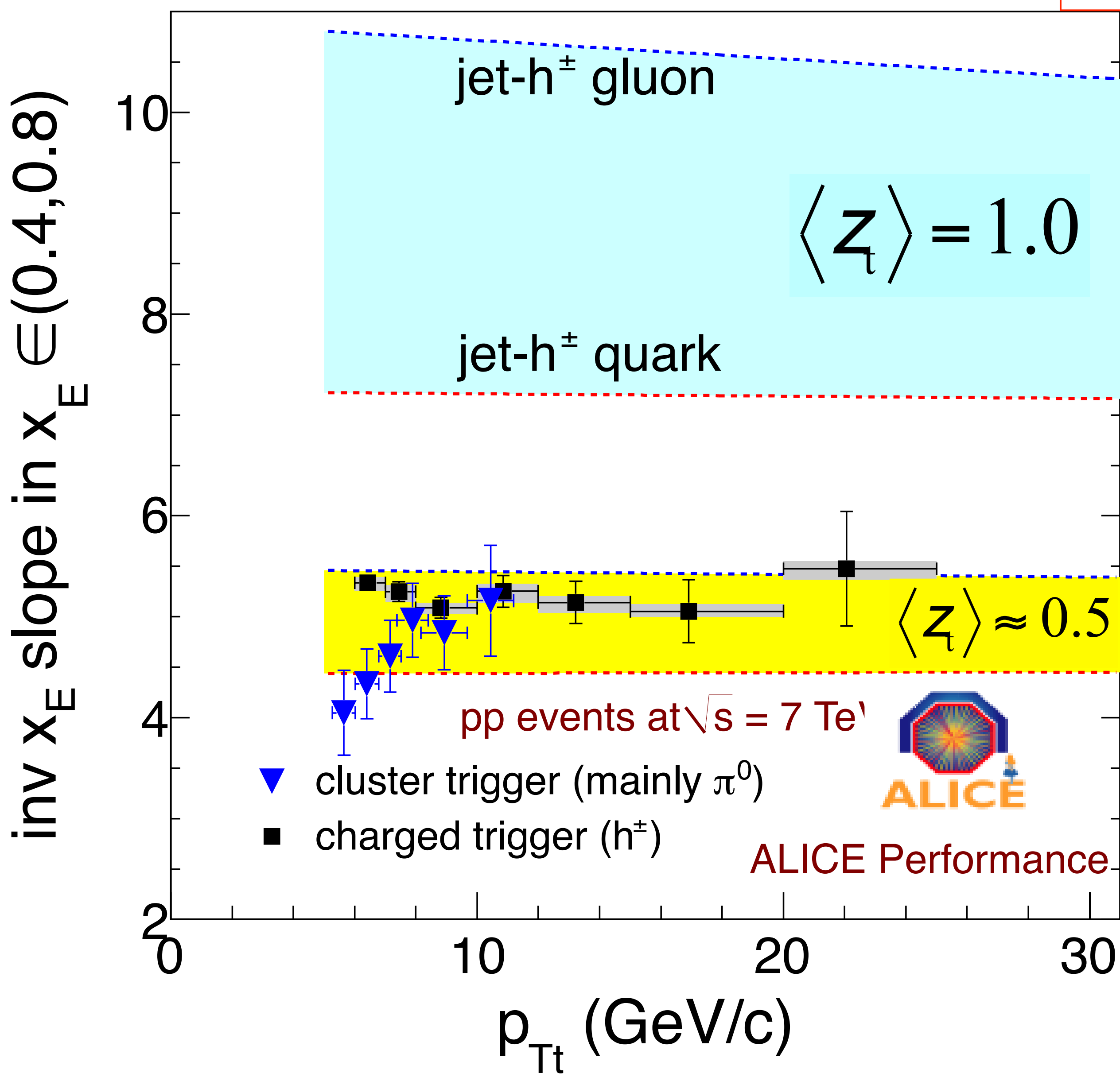
$\langle z_t \rangle = 1.0$

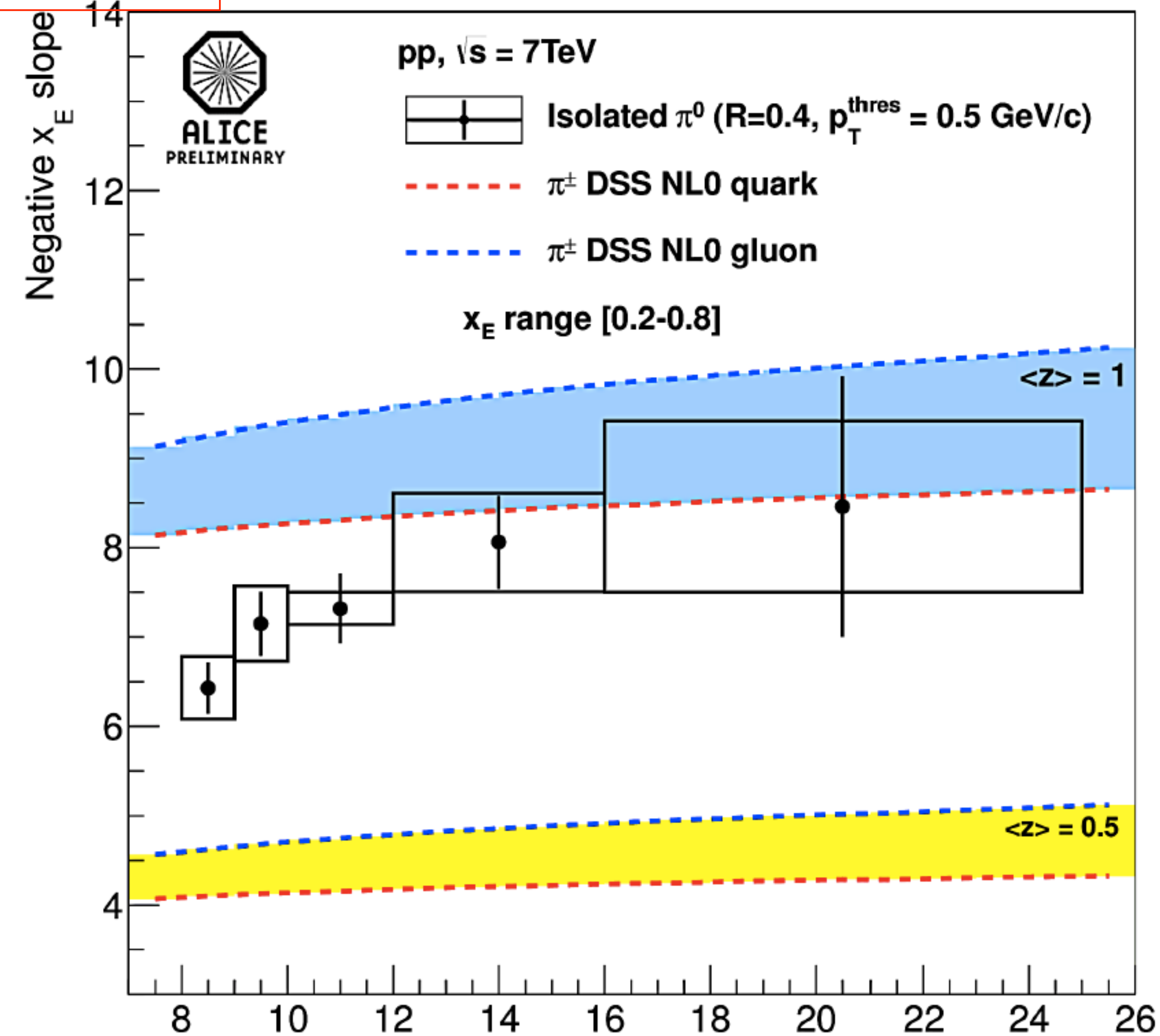
$\langle z_t \rangle \approx 0.5$

- cluster trigger (mainly π^0) and charged trigger has similar slope on x_E distribution

x_E slope parameter

$$\frac{dN}{dx_E} = Ne^{-bx_E}$$



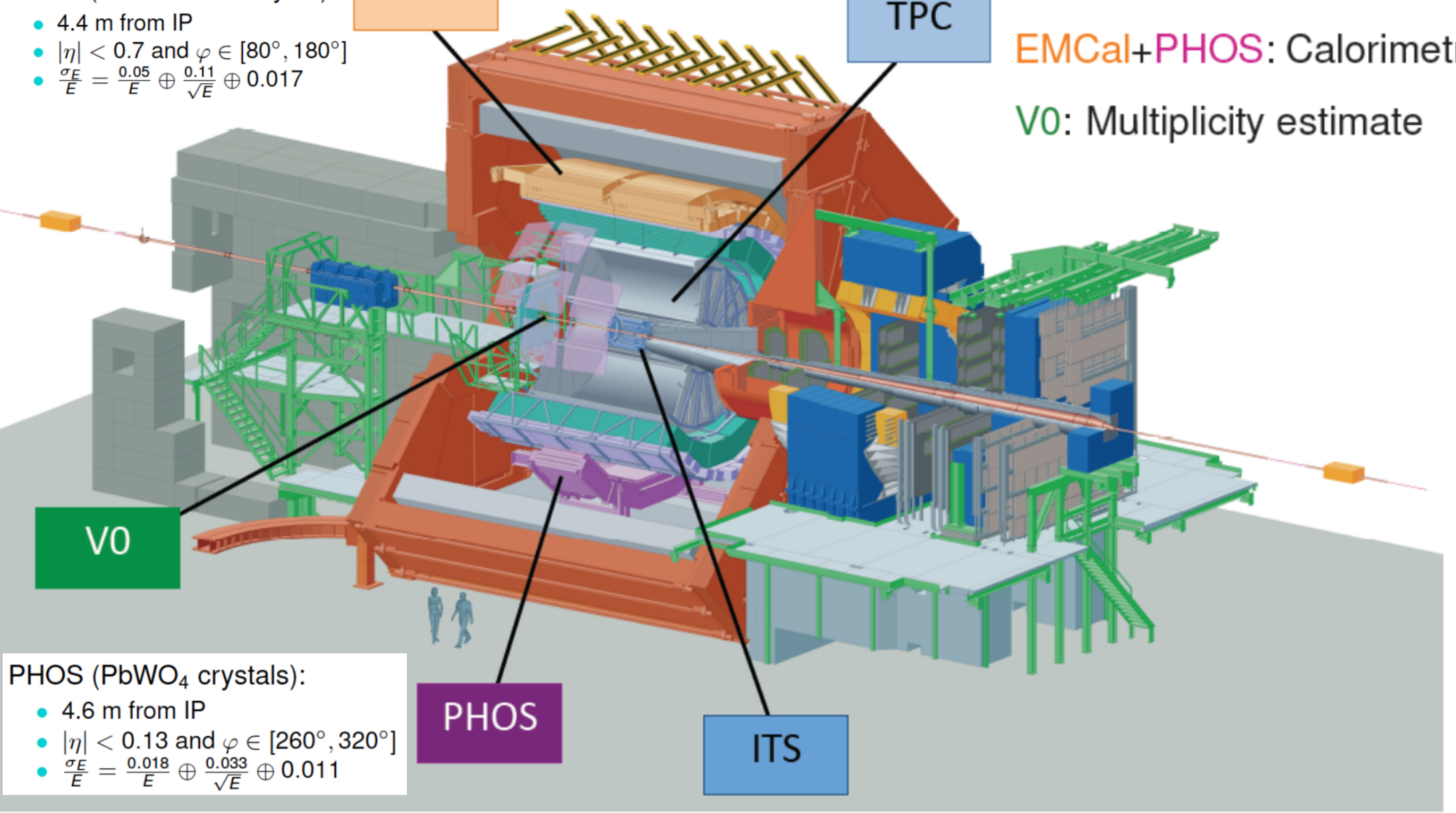


- Non-isolated trigger-correlations

ALICE Experiment

EMCal (Pb/scintillator layers):

- 4.4 m from IP
- $|\eta| < 0.7$ and $\varphi \in [80°, 180°]$
- $\frac{\sigma_E}{E} = \frac{0.05}{E} \oplus \frac{0.11}{\sqrt{E}} \oplus 0.017$



ITS+TPC: Tracking

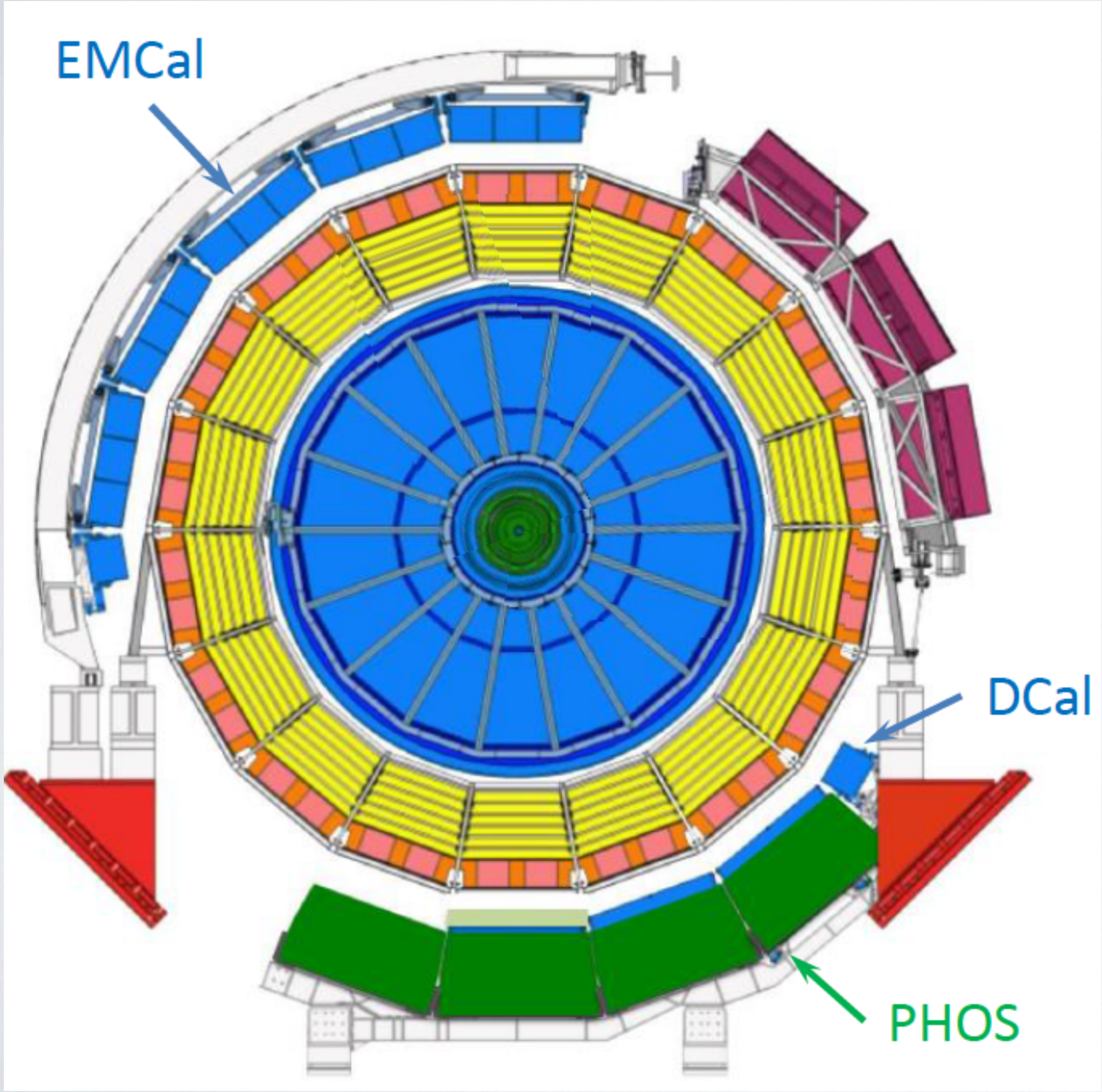
EMCal+PHOS: Calorimetry

V0: Multiplicity estimate

PHOS ($PbWO_4$ crystals):

- 4.6 m from IP
- $|\eta| < 0.13$ and $\varphi \in [260°, 320°]$
- $\frac{\sigma_E}{E} = \frac{0.018}{E} \oplus \frac{0.033}{\sqrt{E}} \oplus 0.011$

The relevant detectors



- Photons are detected in the EM calorimeters
  - PHOS ($|\eta| < 0.12, \Delta\Phi = 70°$)
  - EMCAL ($|\eta| < 0.7, \Delta\Phi = 107°$)
  - DCal ($0.22 < |\eta| < 0.7, \Delta\Phi = 67°$)
- Charged particles are detected by the central tacking system
  - ITS+TPC ($|\eta| < 0.9, \Delta\Phi = 2\pi$)

Strategy of measurements

- Reconstruct and identify trigger(request leading)

  ➜ p_{Tt}

- Reconstruct associate charged tracks

  ➜ p_{Ta}

- Azimuthal correlation between trigger and charged hadrons

  ➜ $\Delta\Phi = \Phi_{trigger} - \Phi_{associate}$

- Calculate k_T

  ➜ $k_T \propto$ width, $\Delta\Phi = \pi$

- Construct the fragmentation function

  ➜ $x_E = -p_{Ta} \cdot p_{Tt} / |p_{Tt}|^2, \Delta\Phi = \pi$

- Estimate and subtract background