Photon-Tagged correlation measurements in ALICE/LHC

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(for the ALICE collaboration)

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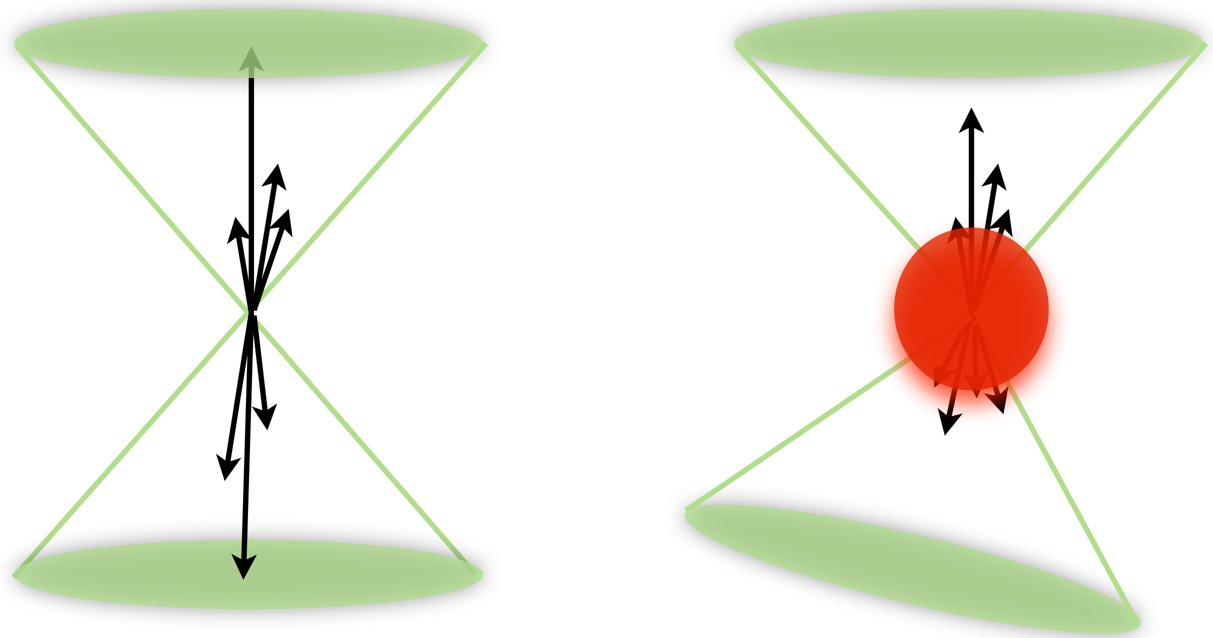
Objective

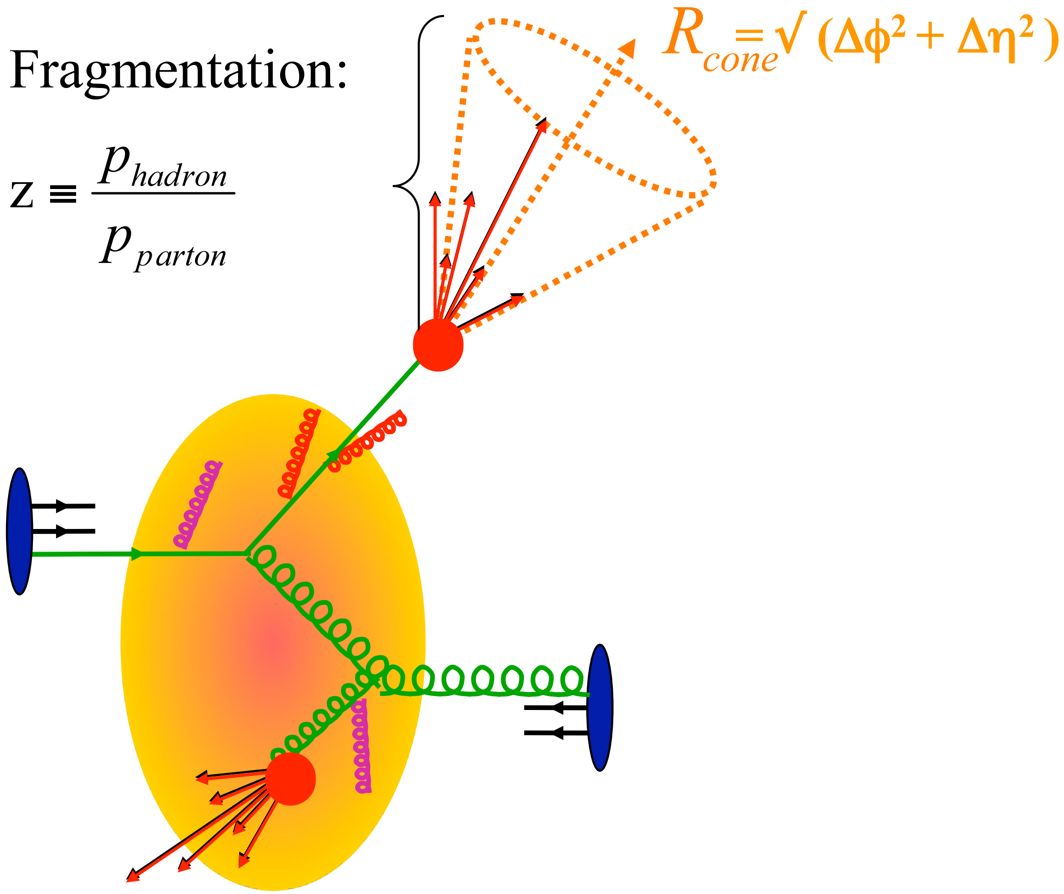


- Exploit jets at LHC energies:
  - High p_T partons produced in hard interactions in the initial phase of the collision...
    - ✓ in pp: understand and characterize the probe
  - ...Undergo multiple interaction inside the collision region prior to hadronization
    - ✓ in AA: probe the QCD medium created in the collision

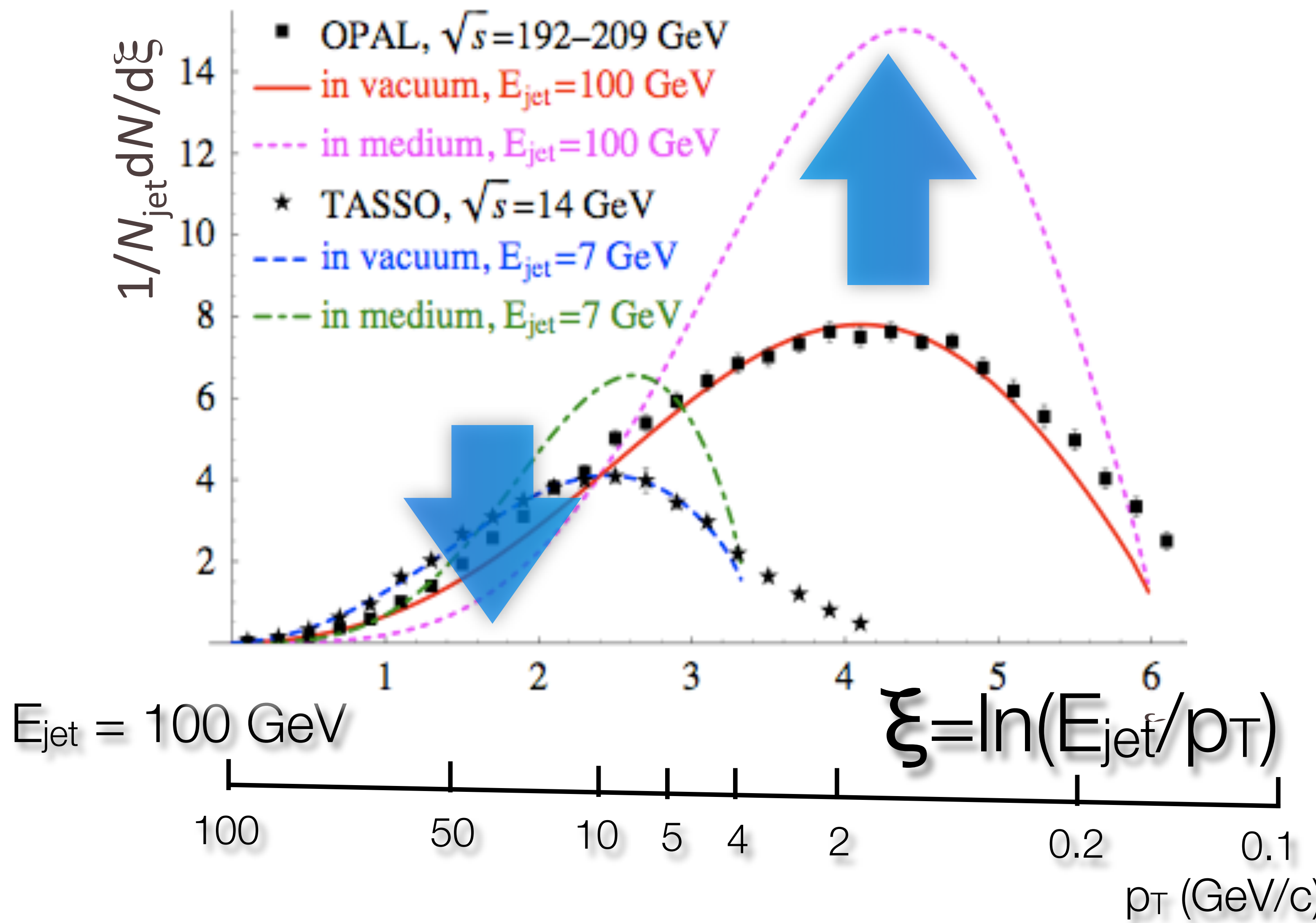
Jet fragmentation function

Fragmentation:

$$z \equiv \frac{p_{hadron}}{p_{parton}}$$

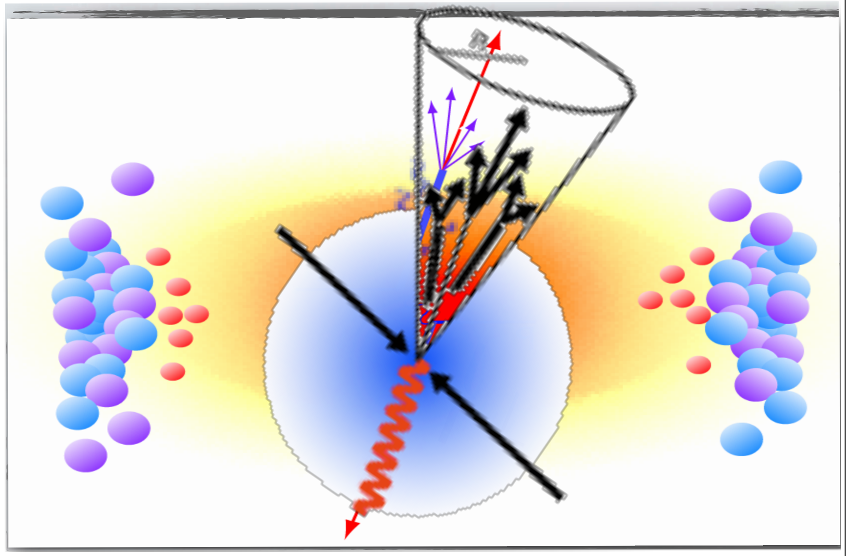


Borghini and Wiedemann, hep-ph/0506218

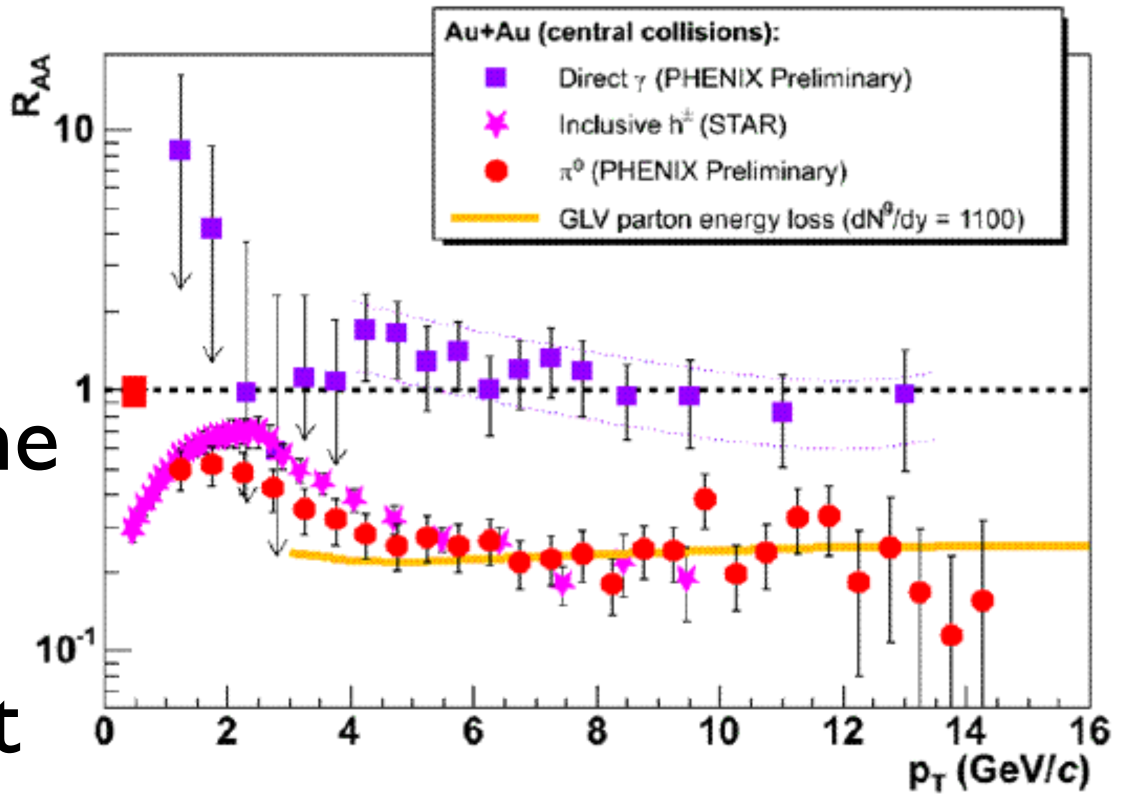


- Modification of the fragmentation function (FF) and the jet shape: hard scattered partons loose energy by radiating soft gluons which fragment as low p_T hadrons in the final state

γ+Jet: "Golden" channel



- Tag the jet with the direct photon, emitted back-to-back
  - Photon 4-momentum remains unchanged while traversing the medium and sets the reference of the hard process
  - Independent measurement of the jet energy, balance jet and photon energy
- Measure the jet fragmentation function

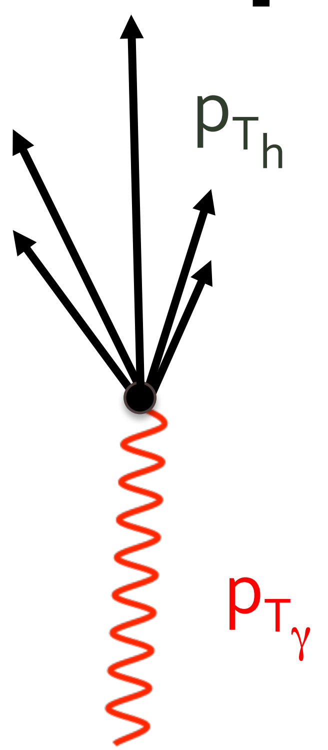


R_{AA} = medium / vacuum

Yaxian.Mao@FCPPL 2010, Lyon

Wednesday, April 7, 2010

Photon-tagged hadrons Correlation



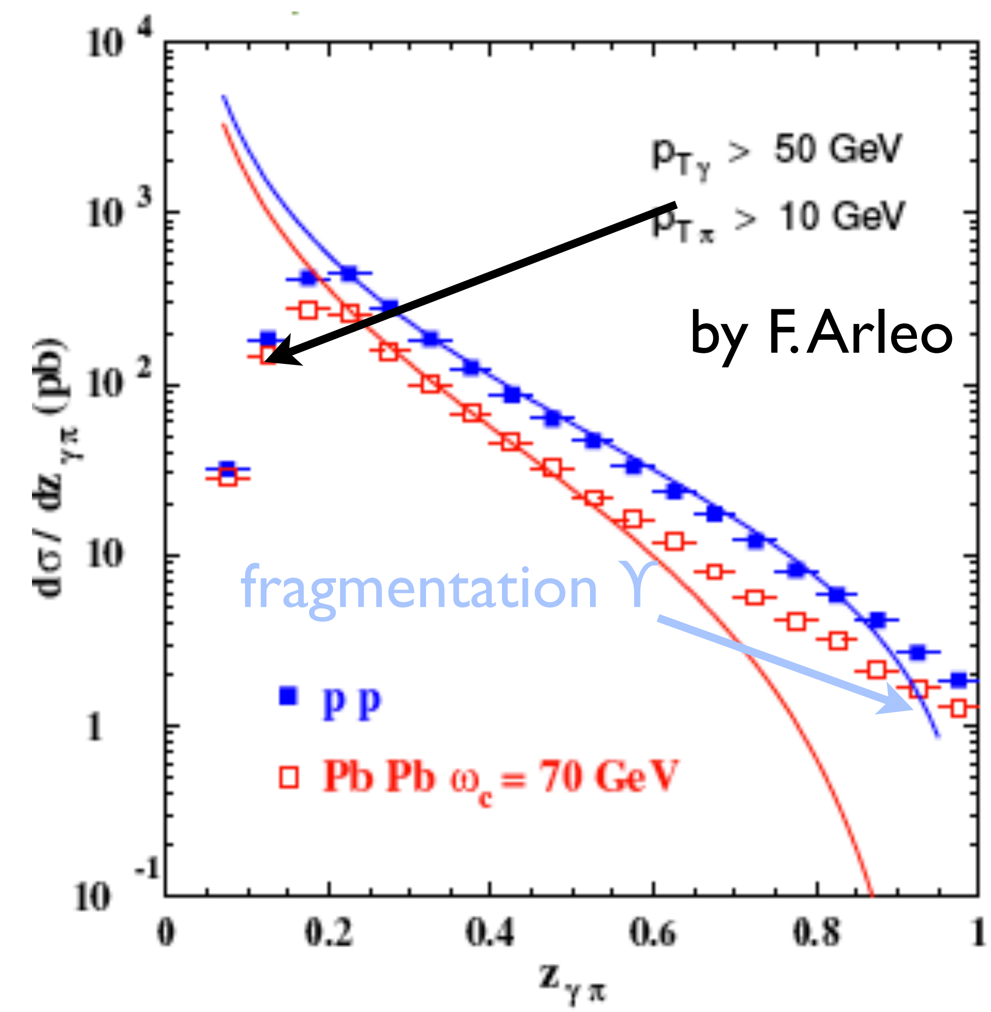
pp CF

PbPb CF

pp FF

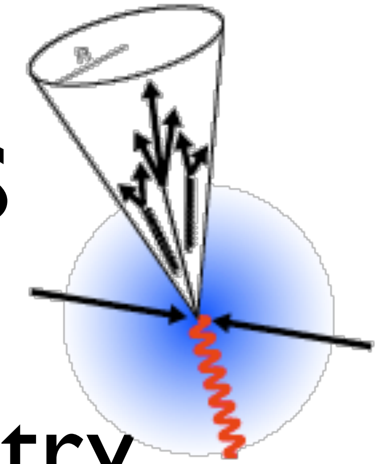
PbPb FF

$$z_{\gamma\pi} = X_E = -p_T^h \cdot p_T^\gamma / |p_T^\gamma|^2$$

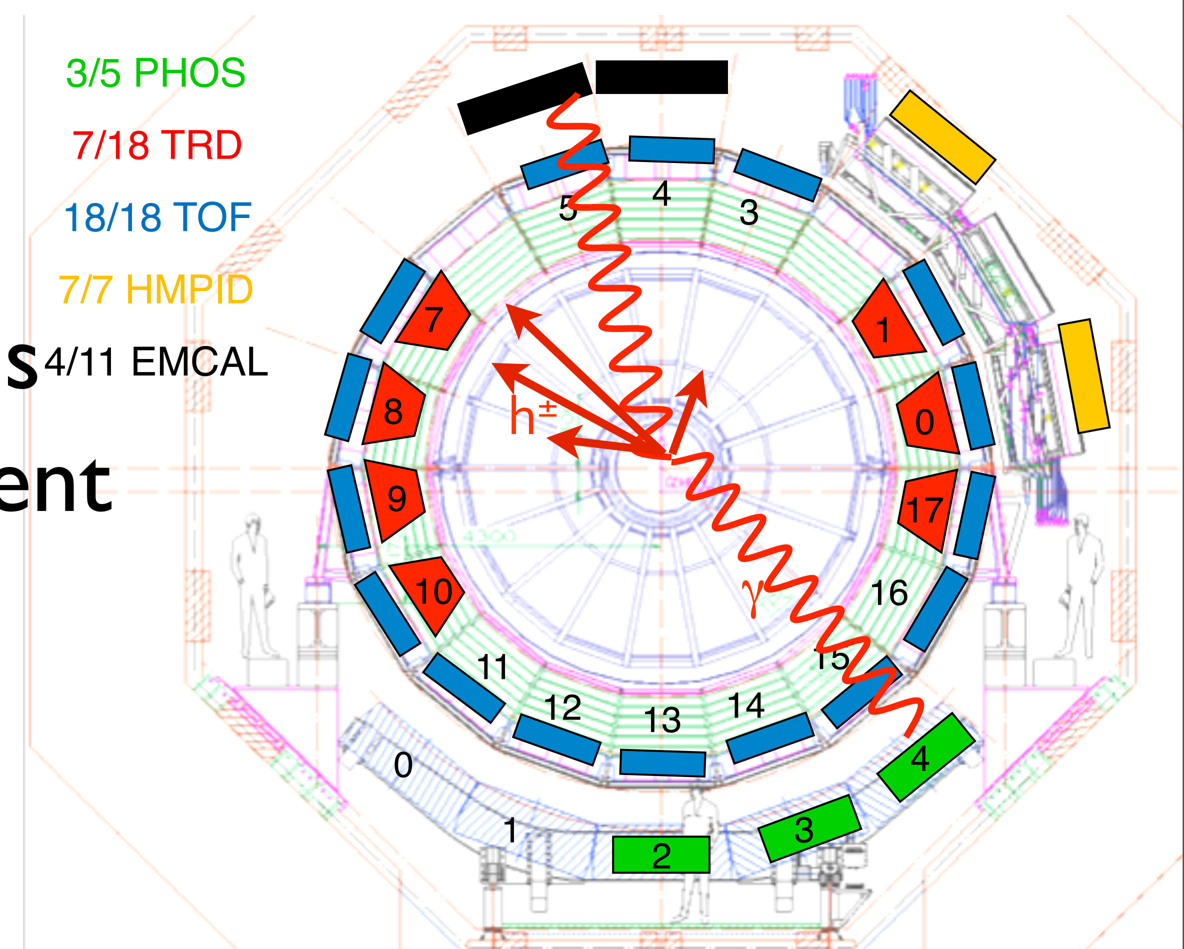


- Jet reconstruction in HI will be difficult especially at low energy (E < 50 GeV)
- Within appropriate kinematics condition, the fragmentation function (FF) can be measured by photon-tagged correlation function (CF) without the need to reconstruct the jet.

Strategy of measurements

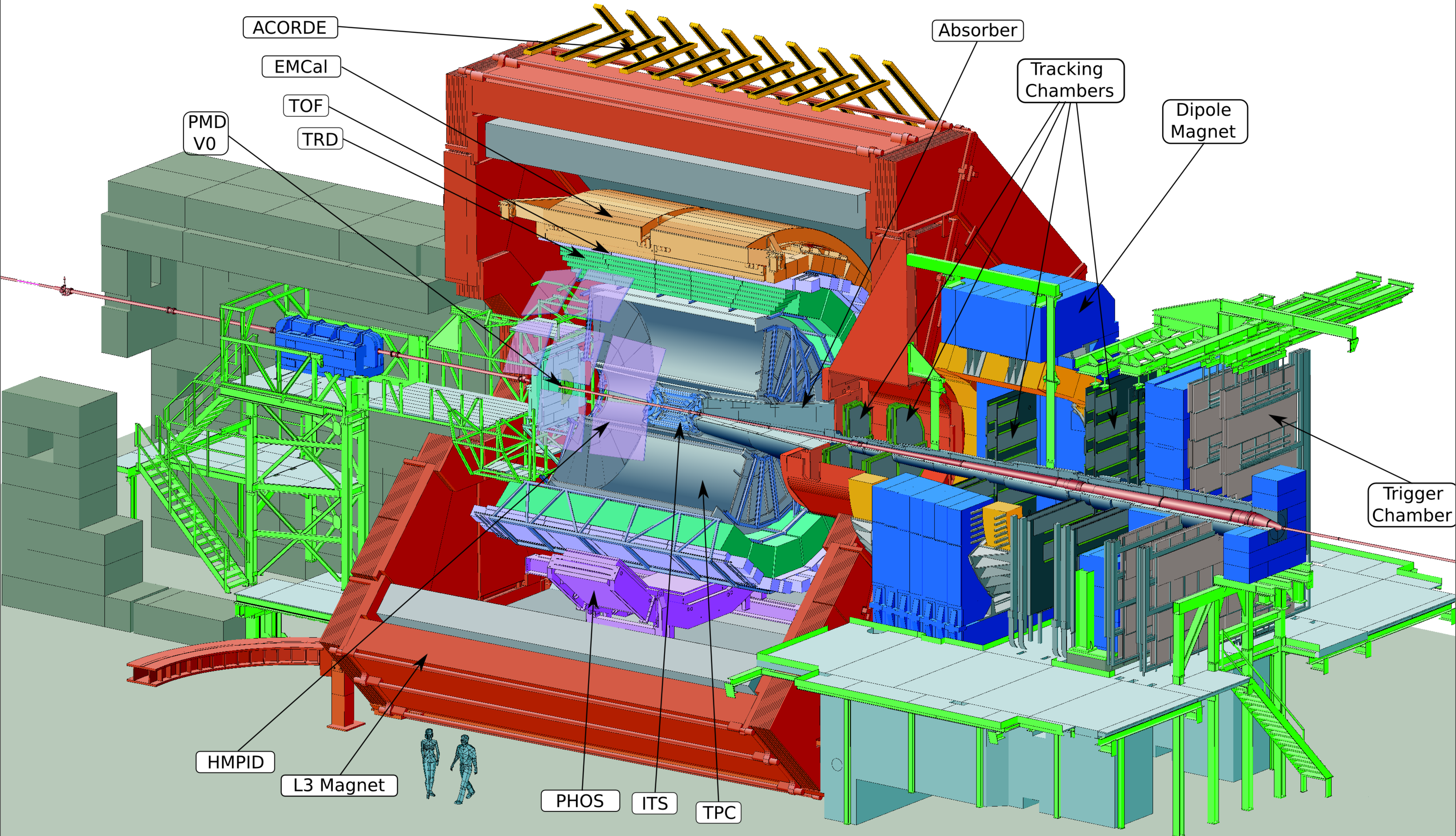


- Measure and identify direct photons (calorimetry + shower shape + isolation cut)
- Measure charged hadrons (tracking, p_T)
- Construct the fragmentation function by correlating opposite hadrons with the direct photons ($X_E = -p_T^h \cdot p_T^\gamma / |p_T^\gamma|^2$)
- Subtract background
  - decay and fragmentation photons
  - soft hadrons from underlying event

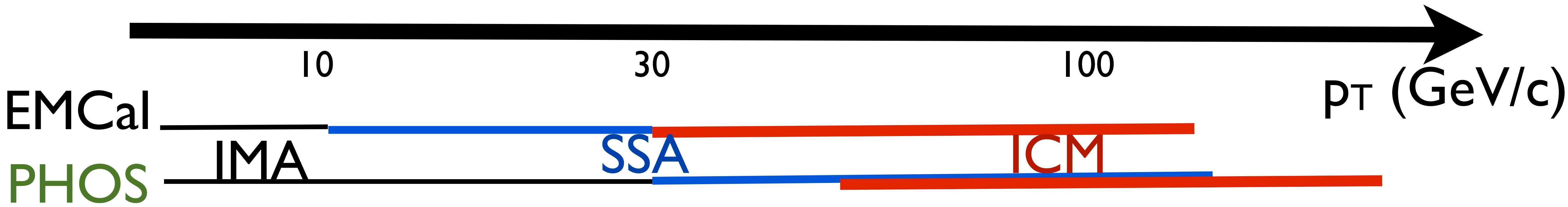


ALICE: A Large Ion Collider Experiment

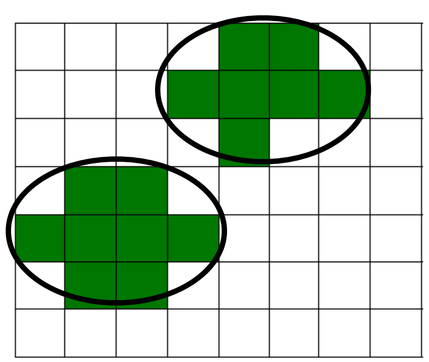
http://aliceinfo.cern.ch/Collaboration/

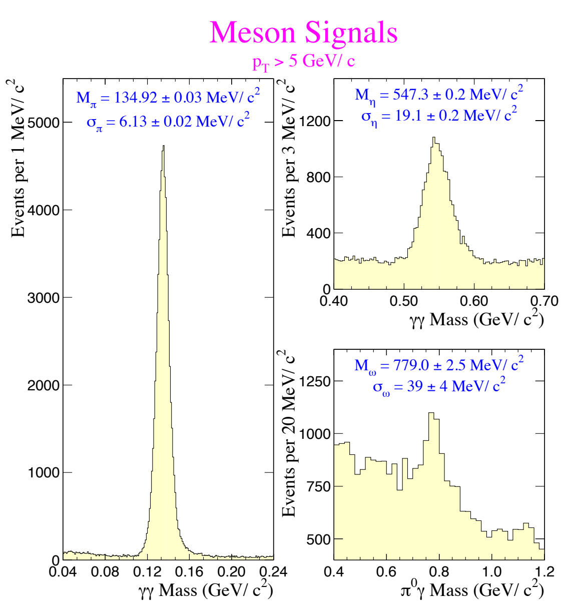


Particle identification in calorimeters

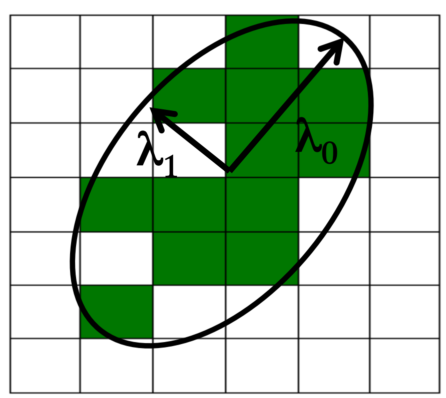


Invariant Mass Analysis (IMA) (γ, π^0, η, ω...)
=>well separated clusters





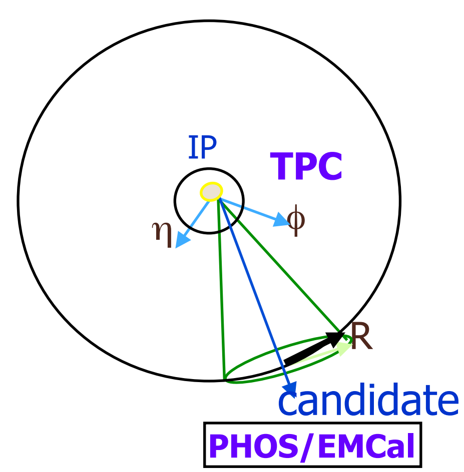
Shower Shape Analysis (SSA)
(γ/e, π^0, hadrons, ...)
=>merged clusters not spherical: $\lambda_0 / \lambda_1 = 1$?

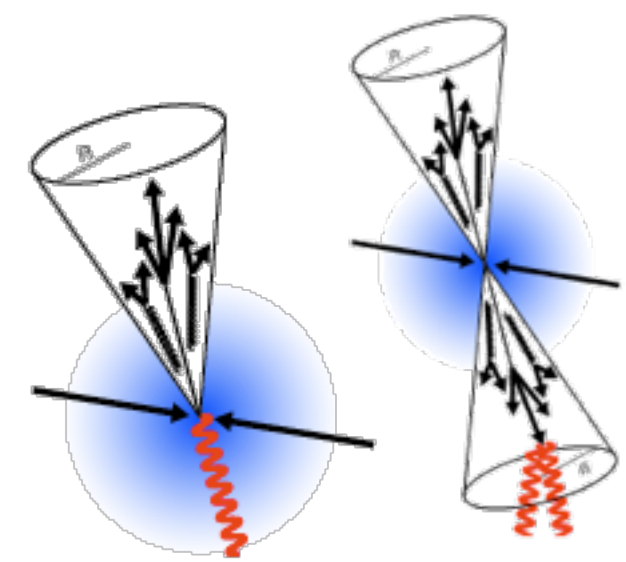


Isolation Cut Method (ICM)
(γ, e, π^0)
=>two clusters from π^0 are merged

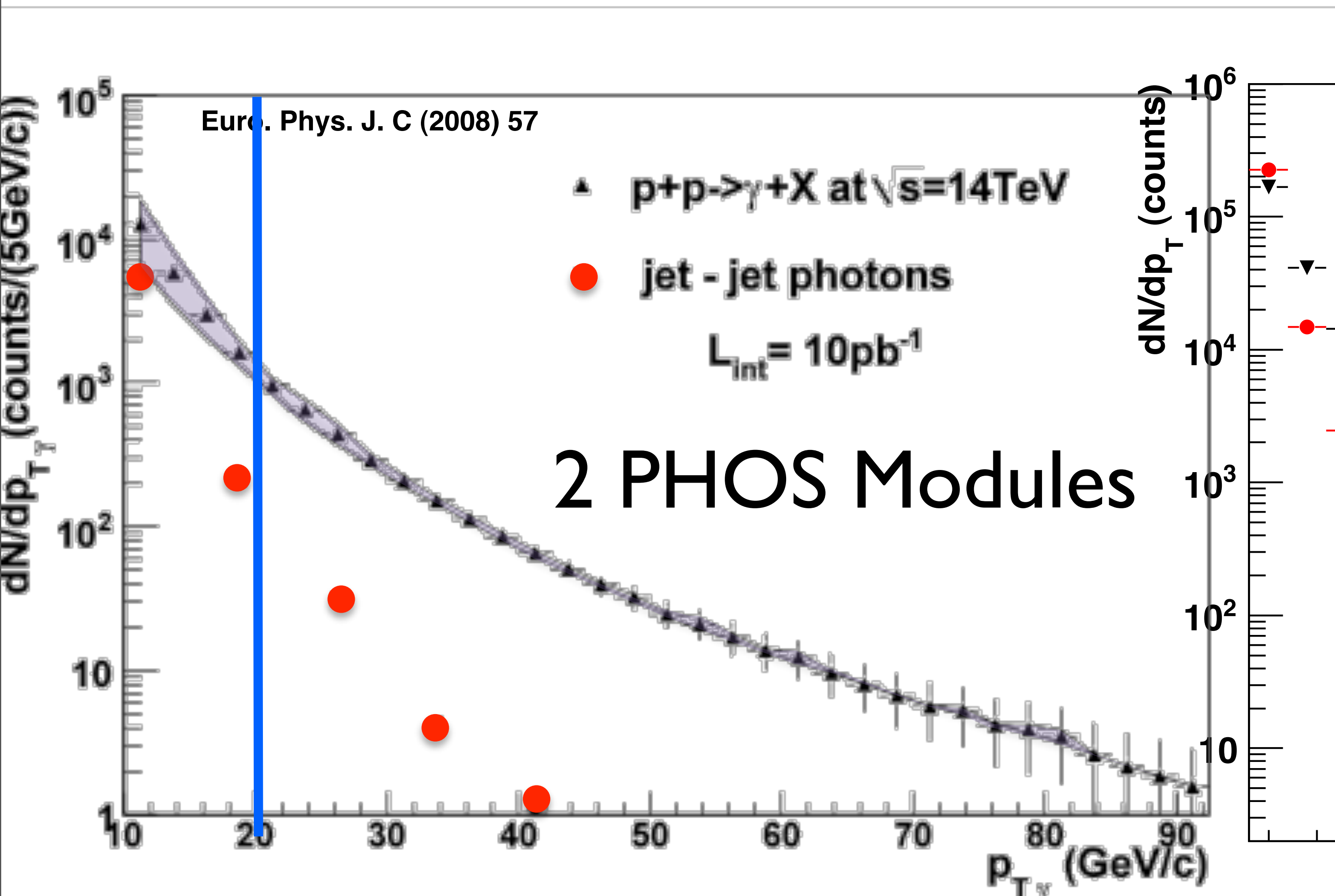
Isolated if:

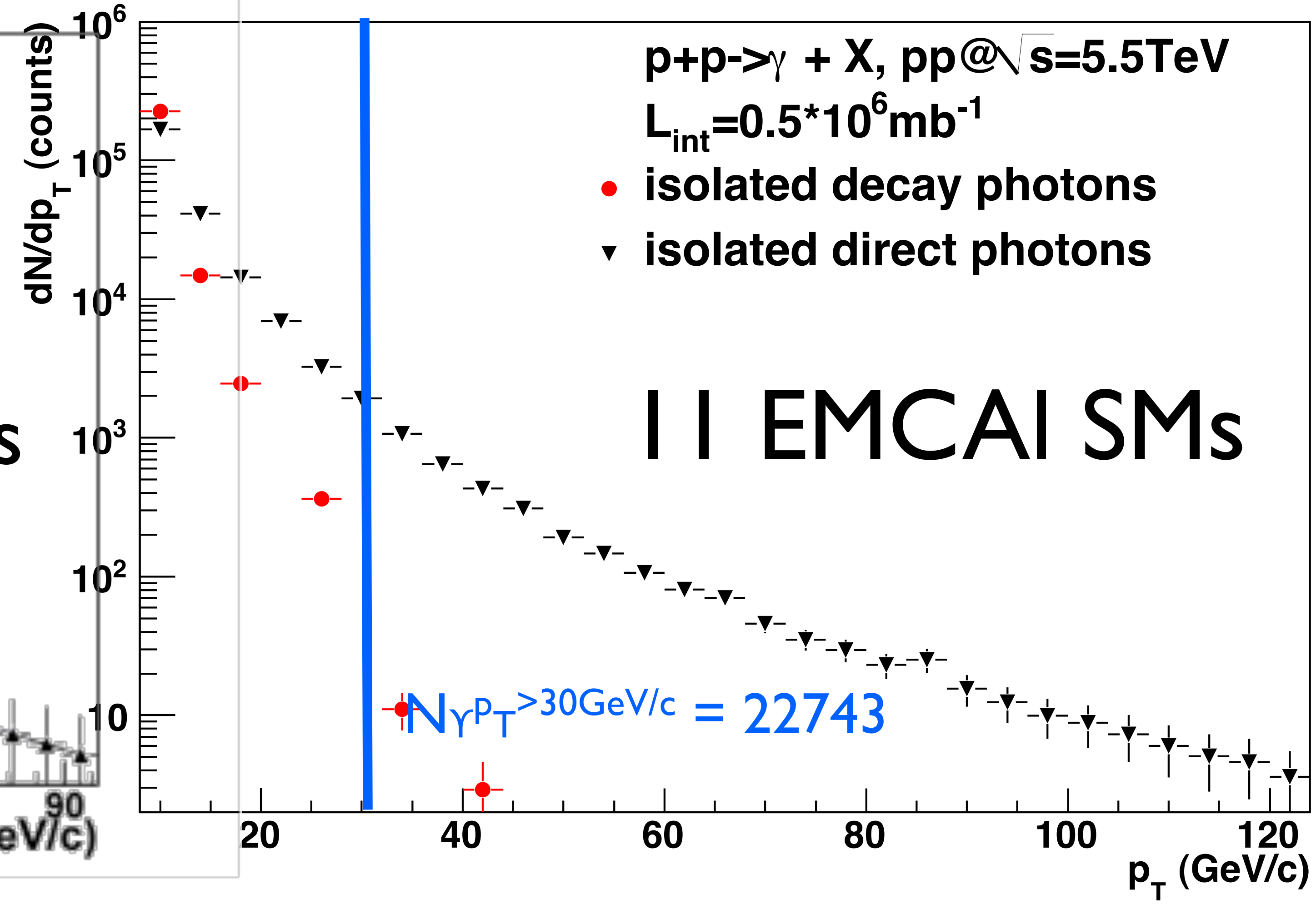
- no particle in cone with $p_T > p_T^{thres}$
- p_T sum in cone, $\Sigma p_T < \Sigma p_T^{thres}$





Direct Photon Spectrum

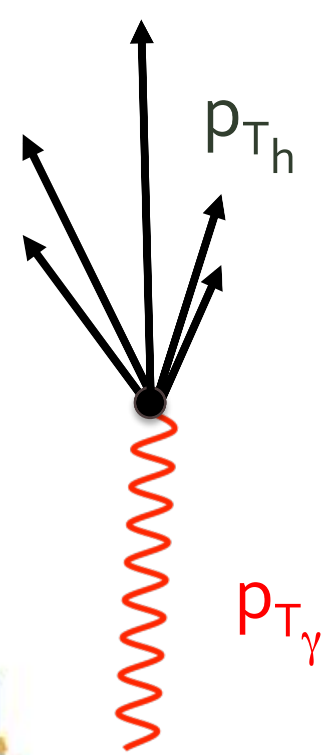


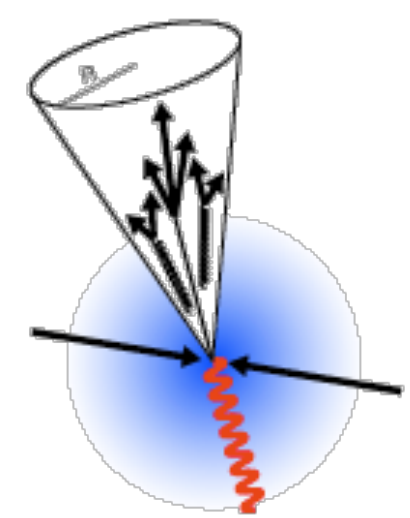


- Direct photon measurements by PHOS and EMCAL
- Contamination for misidentified decay photons are estimated as well.

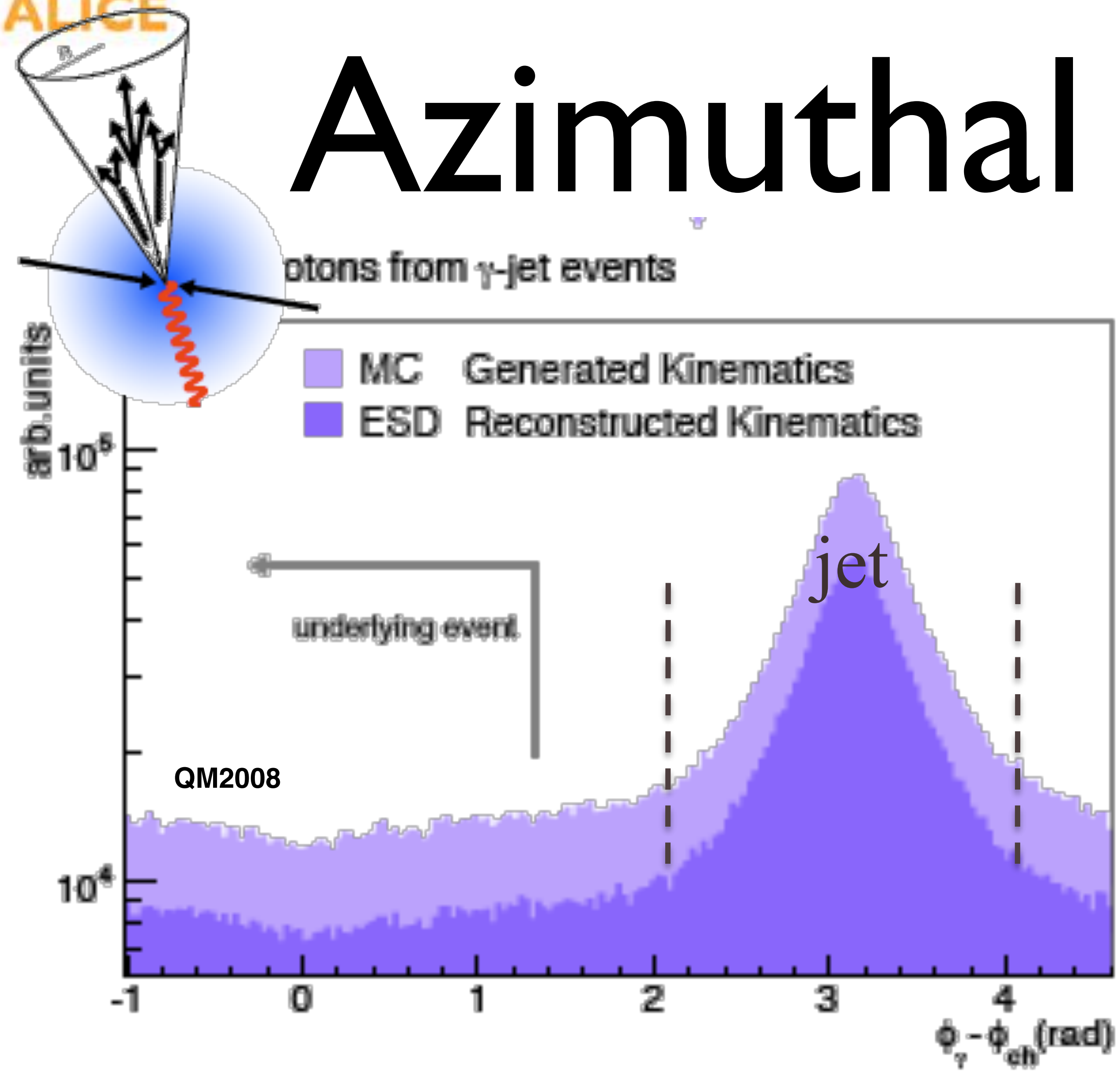
Photon Tagged Correlation

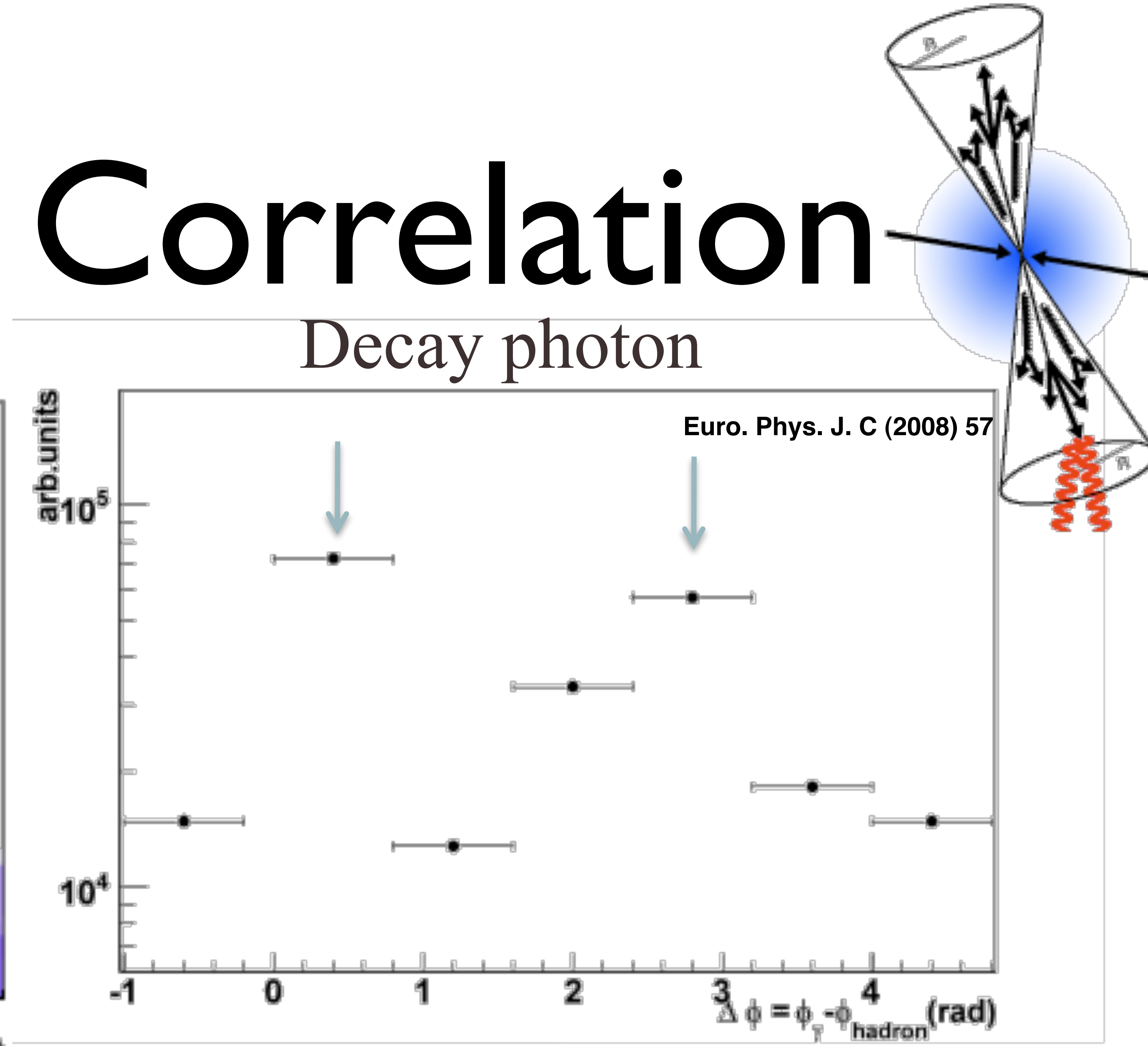
- ➡ azimuthal correlation: $\Delta\Phi = \Phi_\gamma - \Phi_h$
- ➡ correlation function (CF): $X_E = -p_T^h \cdot p_T^\gamma / |p_T^\gamma|^2$





Azimuthal Correlation

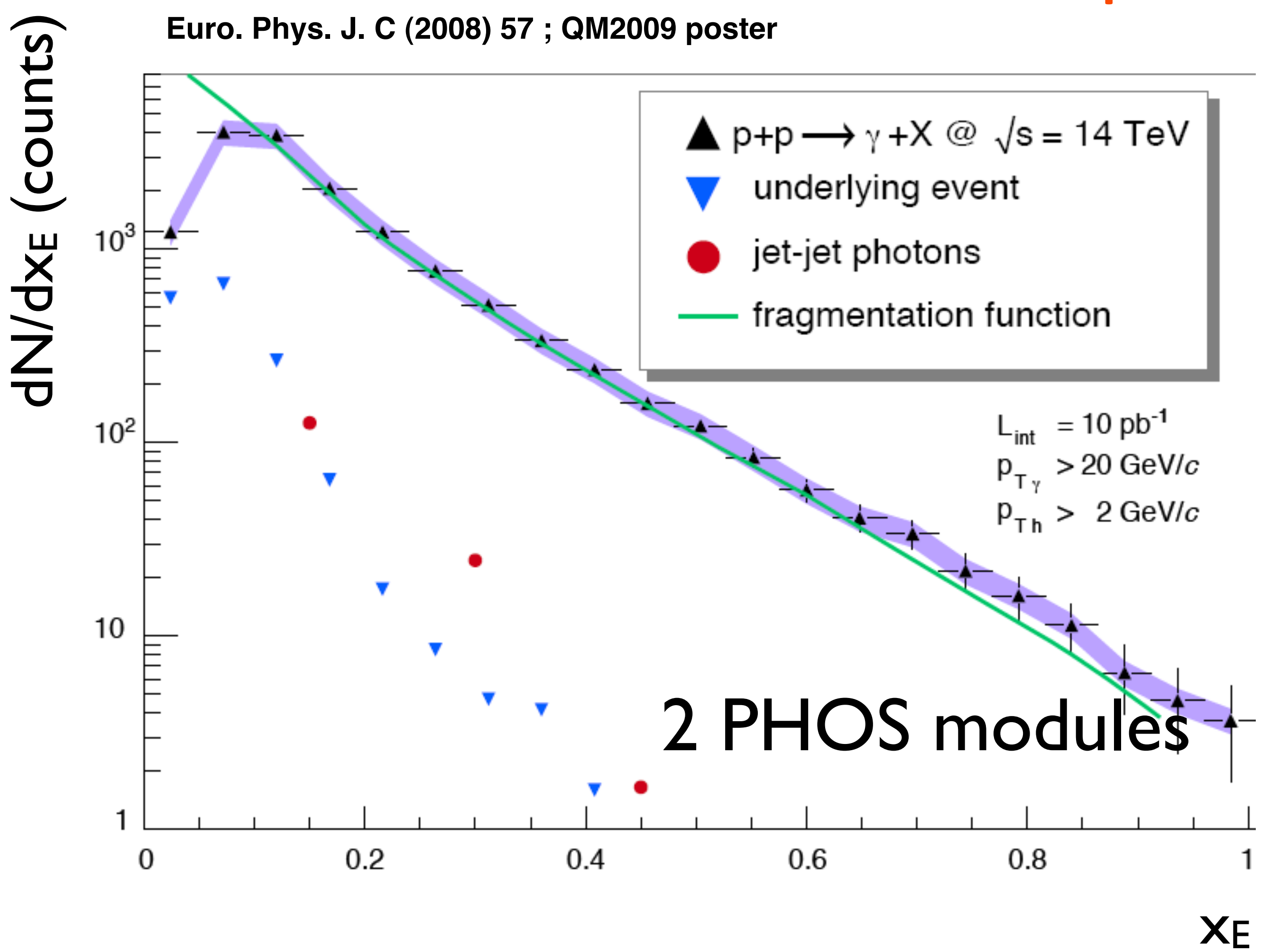


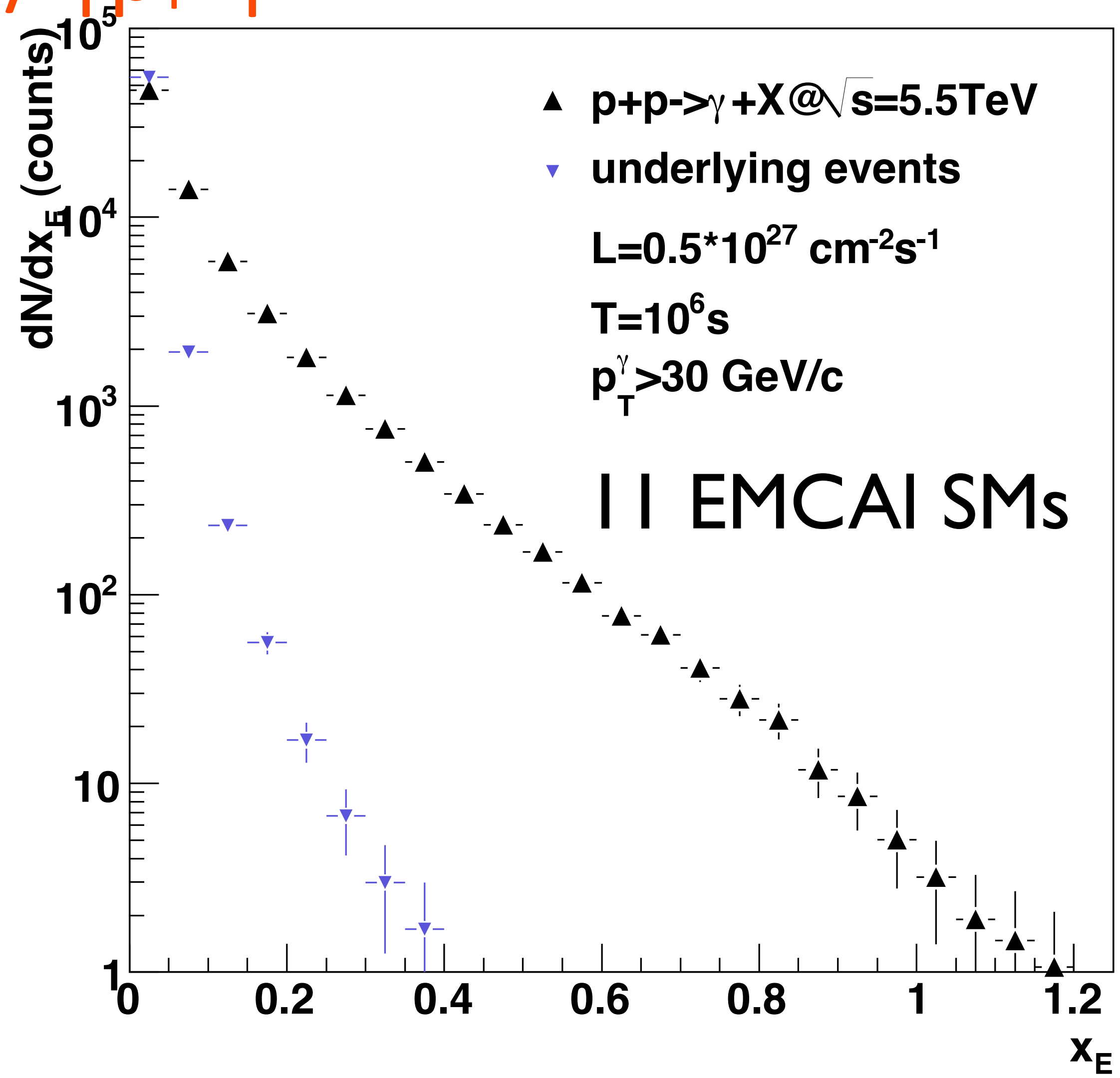


- Clear jet signal opposite to the photon in γ-jet events
- A near side and a far side peak found, the later being shifted and broader compared to γ-jet events.

Correlation Function (CF) in pp

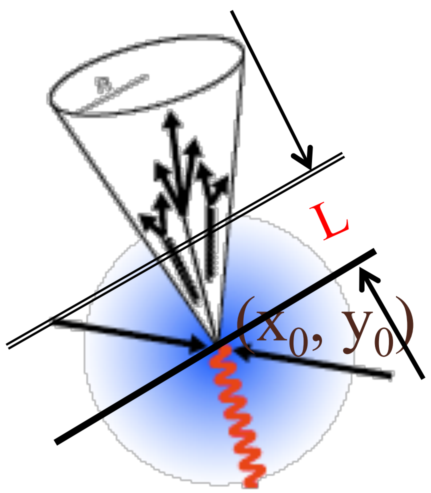
$X_E = -p_T^h \cdot p_T^\gamma / |p_T^\gamma|^2$





- Statistical errors correspond to one standard year of data taking with 2 PHOS modules or 11 EMCal SMs.
- Systematic errors from decay photon contamination and hadrons from underlying event.

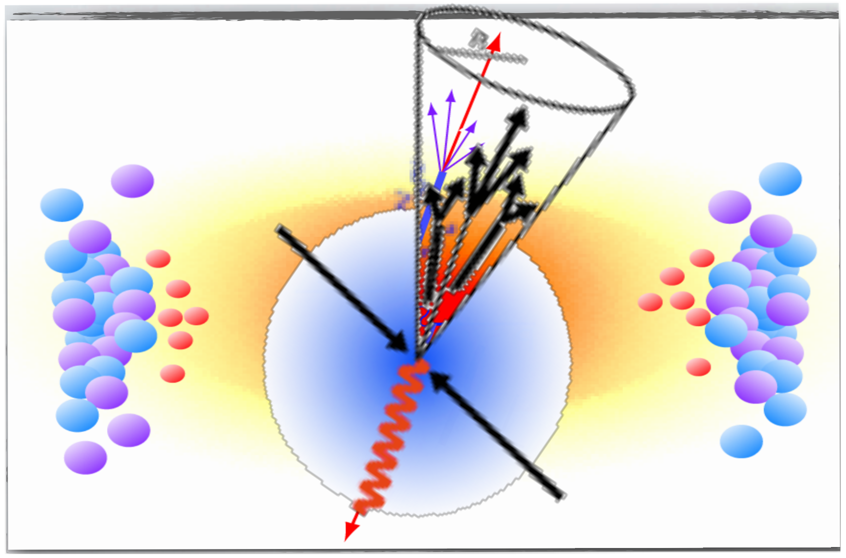
Going to AA...



- ➡ Azimuthal correlation broadening:
- ➡ Medium modification: $I_{AA} = CF_{AA}/CF_{pp}$

$$\xi = \ln (1/x_E)$$

- ➡ Tomography: path length L



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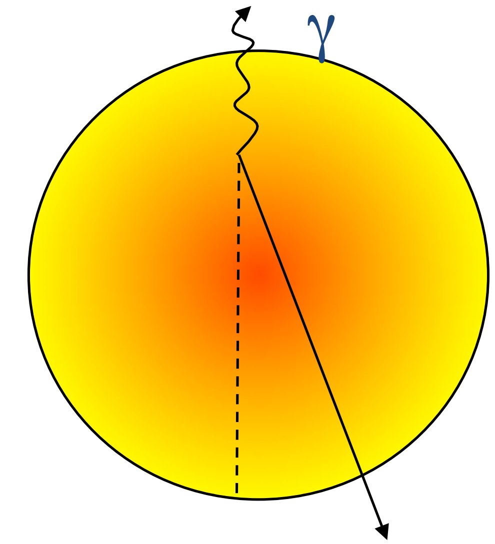
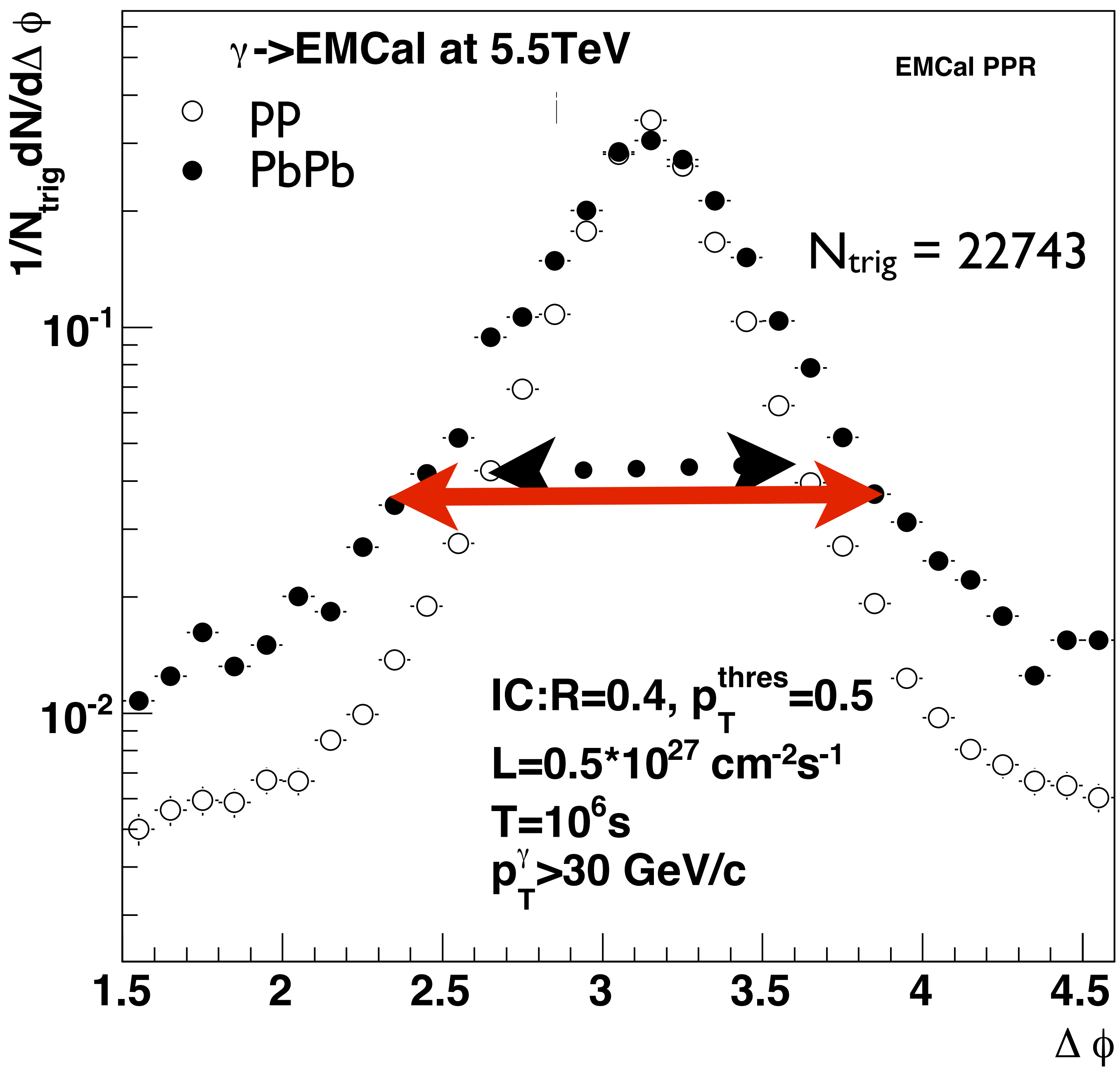
Azimuthal Correlation



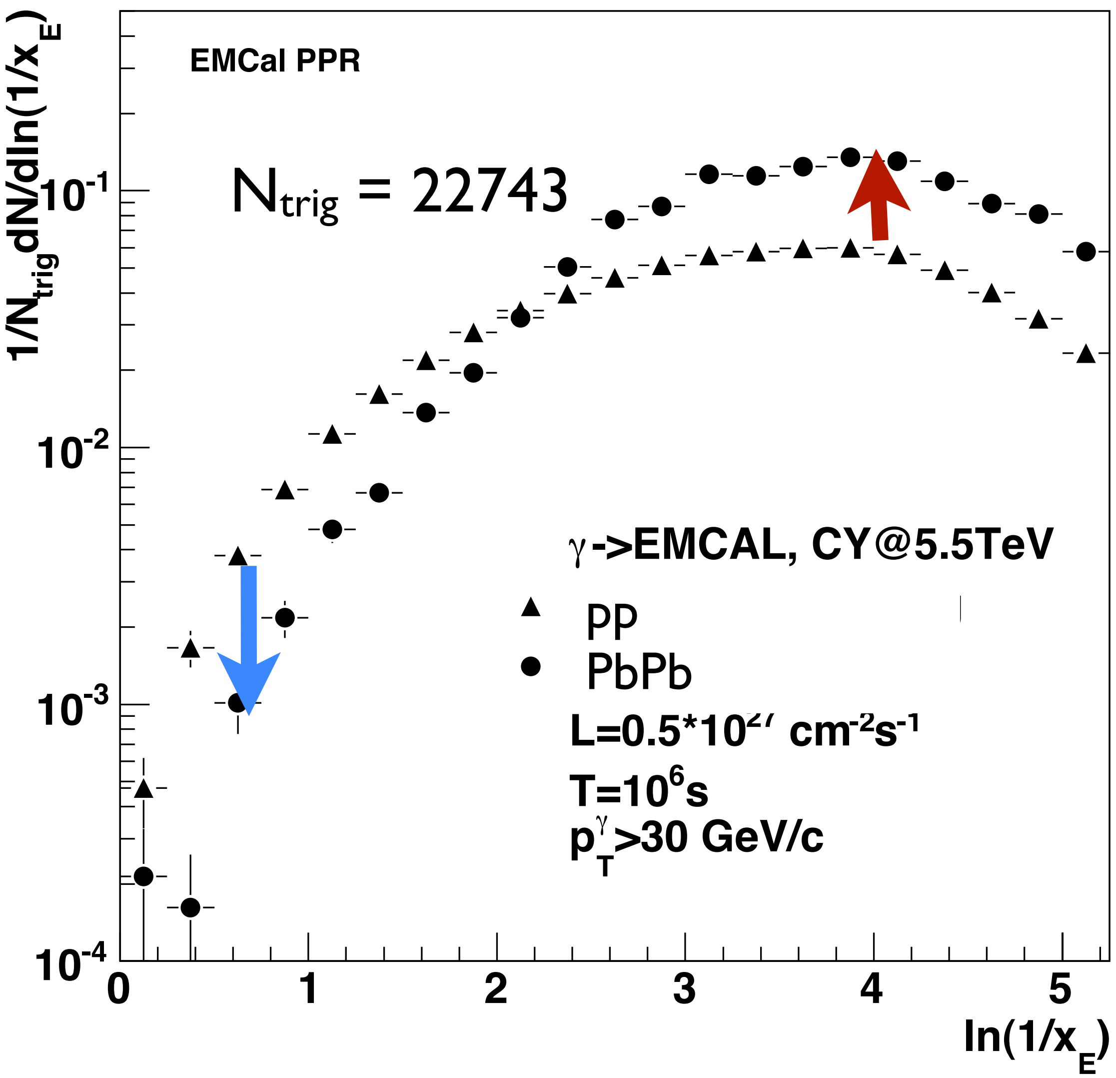


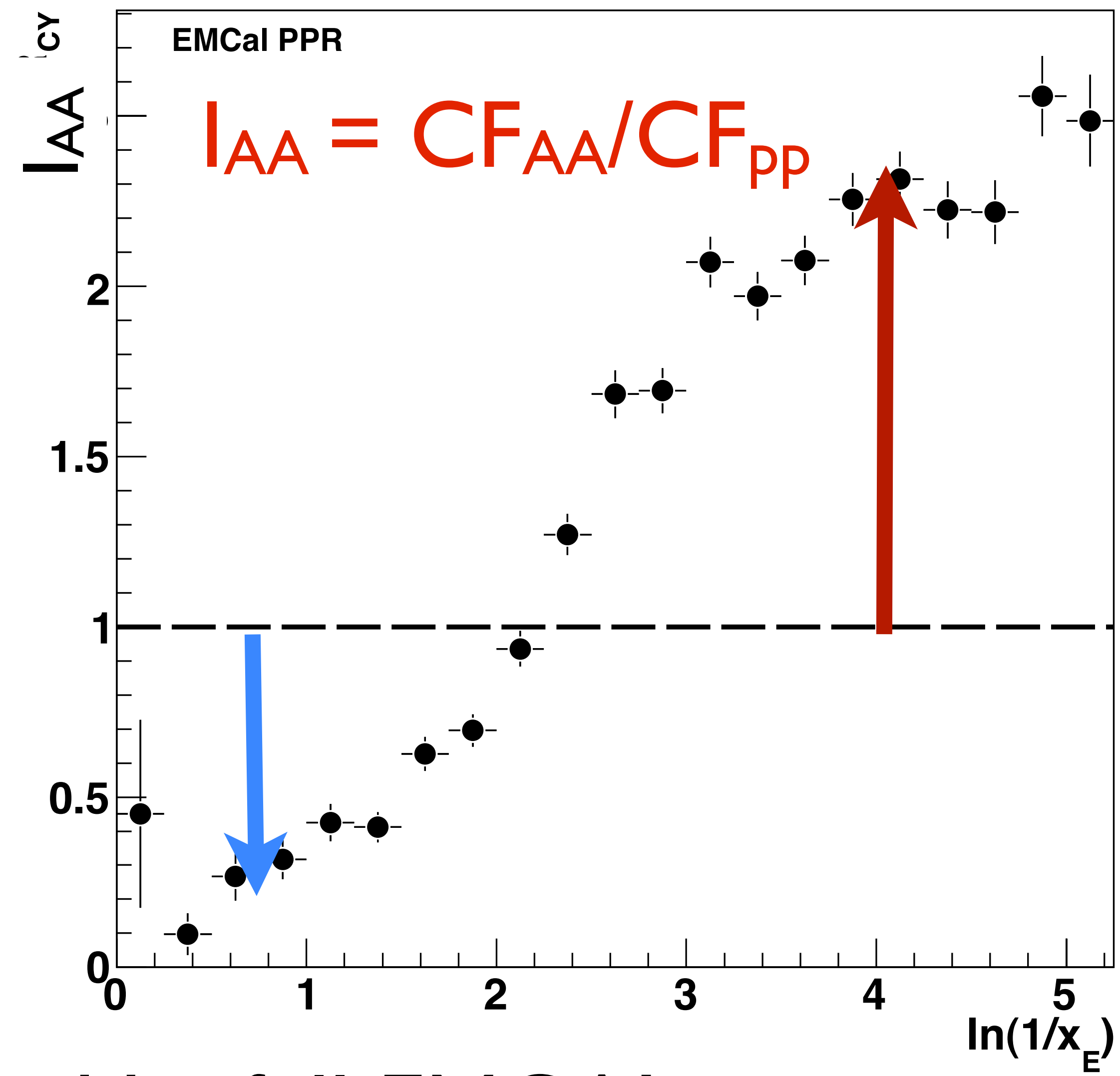
- Medium effect broadens the azimuthal correlation
- A measure of the transport properties of the medium

$$\left\langle \Delta q_T^2 \right\rangle = \int dy \hat{q}(y, E)$$

- The broadening effect is challenging to measure.

Medium Modification of CF





- Medium modification measured by full EMCAL super modules.
- A suppression at large x_E and an enhancement at small x_E could be observed
- Modifications related to the medium transport properties

Toward a true tomography measurement of QCD medium in AA

X. N. Wang, arXiv: 0902.4000v1

- Triggering γ-hadrons correlation measurement with hadrons of various x_E allows to select the production point of the hard scattering:
  - large x_E, contributions to CF come mostly from hard scattering at the surface;
  - small x_E, contributions to CF are mostly from hard scattering inside the volume.
- What can be measured with ALICE?

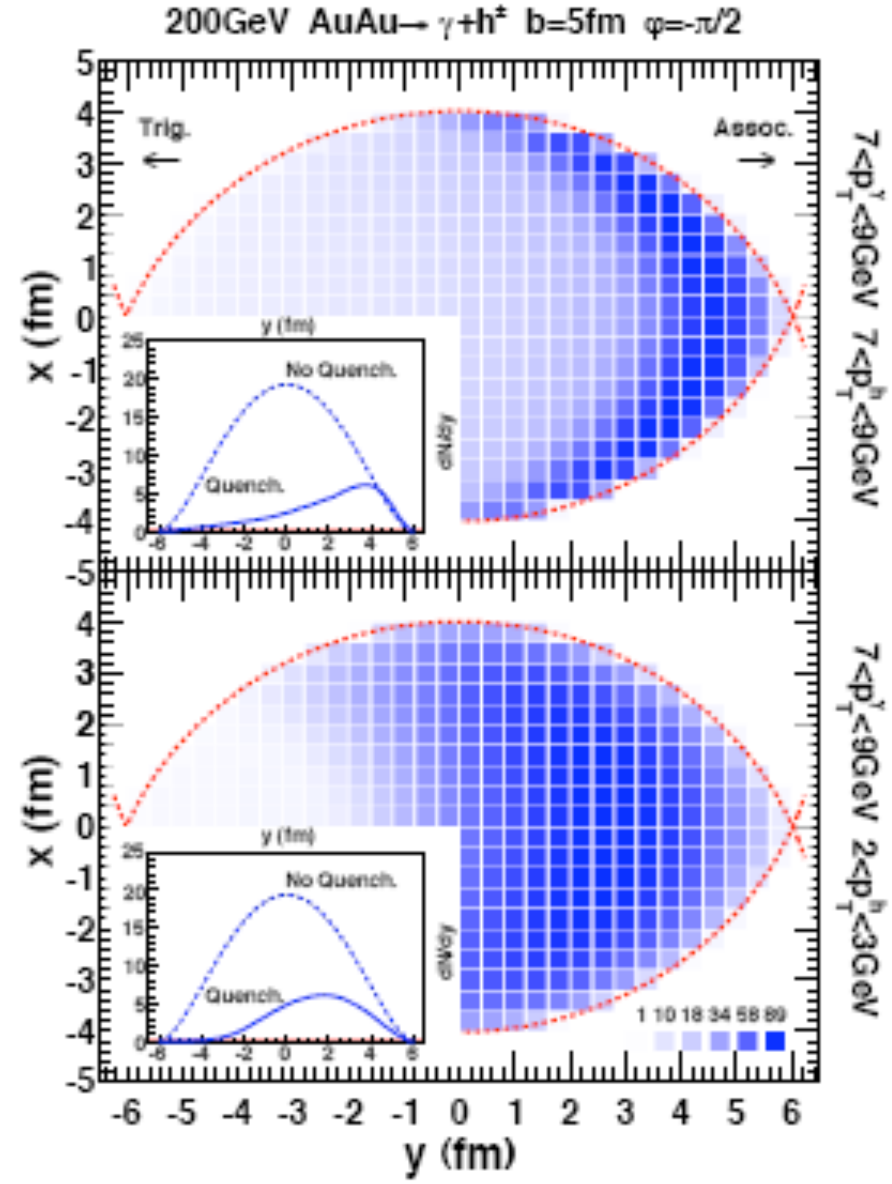
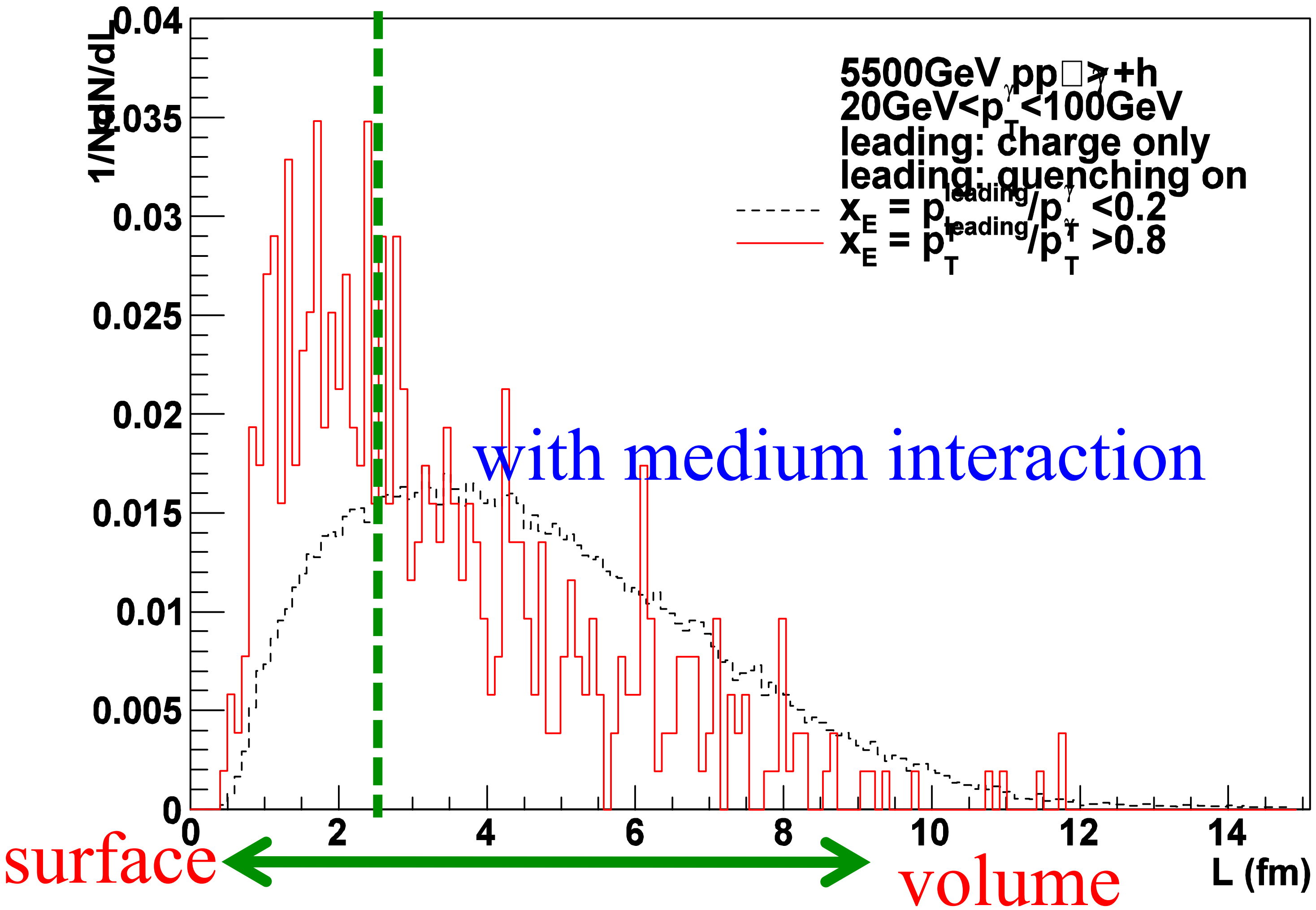
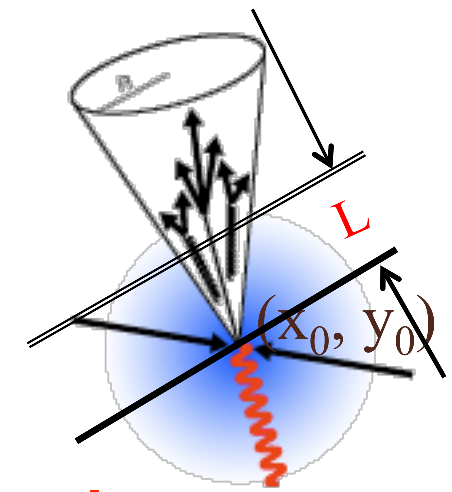


FIG. 3: (color online). Transverse spatial distributions of the initial γ-jet production vertexes that contribute to the final observed γ-hadron pairs along a given direction (arrows) with $z_T \approx 0.9$ (upper panel) and $z_T \approx 0.3$ (lower panel).

x_E cut vs medium length (L) dependence

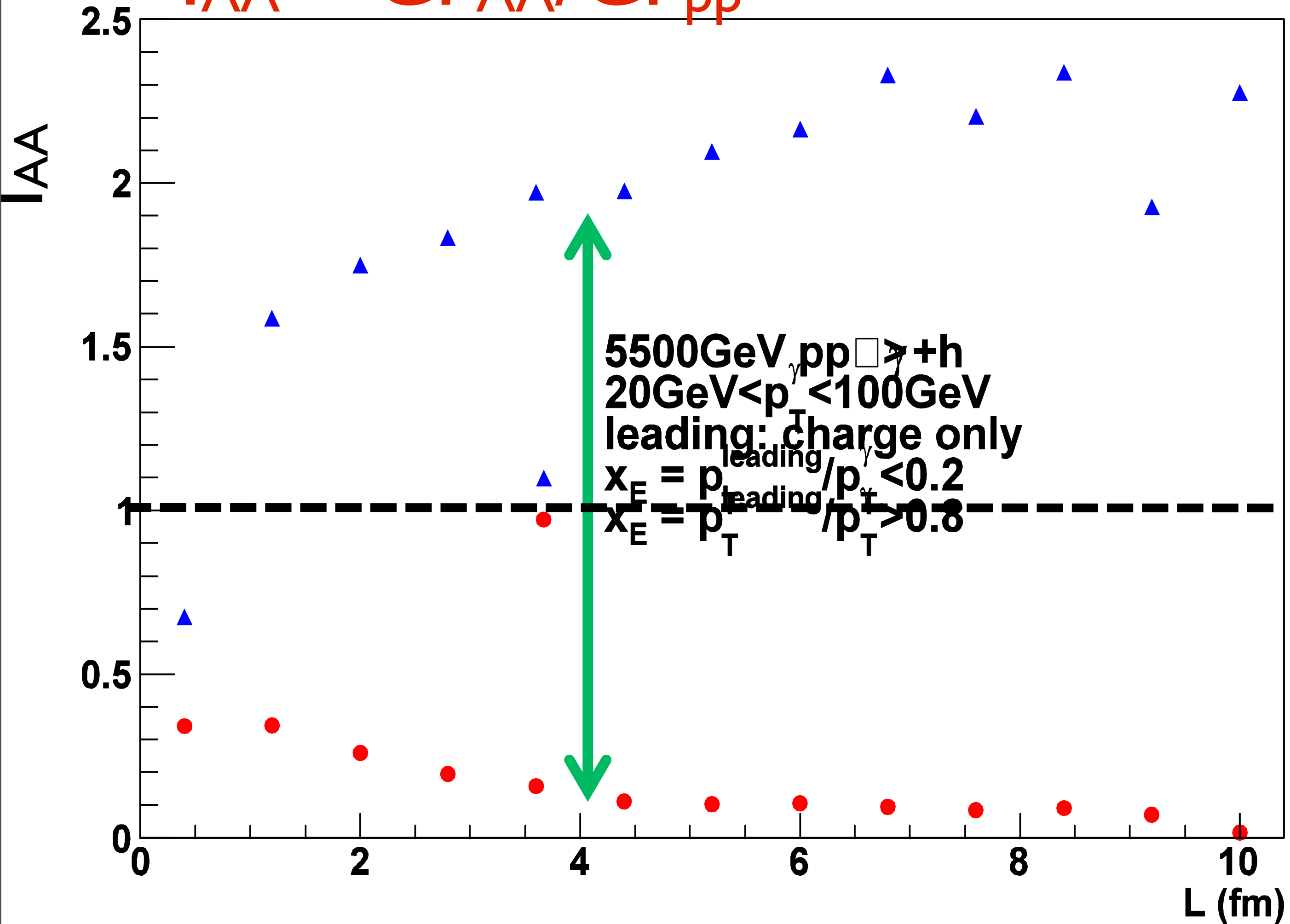




- High p_T particles come mostly from h.s. at the surface
- Low p_T particles come mostly from h.s. in the volume
- **However separation not very much pronounced!!**

Suppression vs Enhancement

$I_{AA} = CF_{AA}/CF_{pp}$



- High p_T particle suppression stronger for h.s parton traversing large L
- Low p_T particle enhancement stronger for traversing large L
- But L dependence is not very pronounced
- xE and L dependence study will be necessary since L is not measurable: L=f(xE)

Conclusions

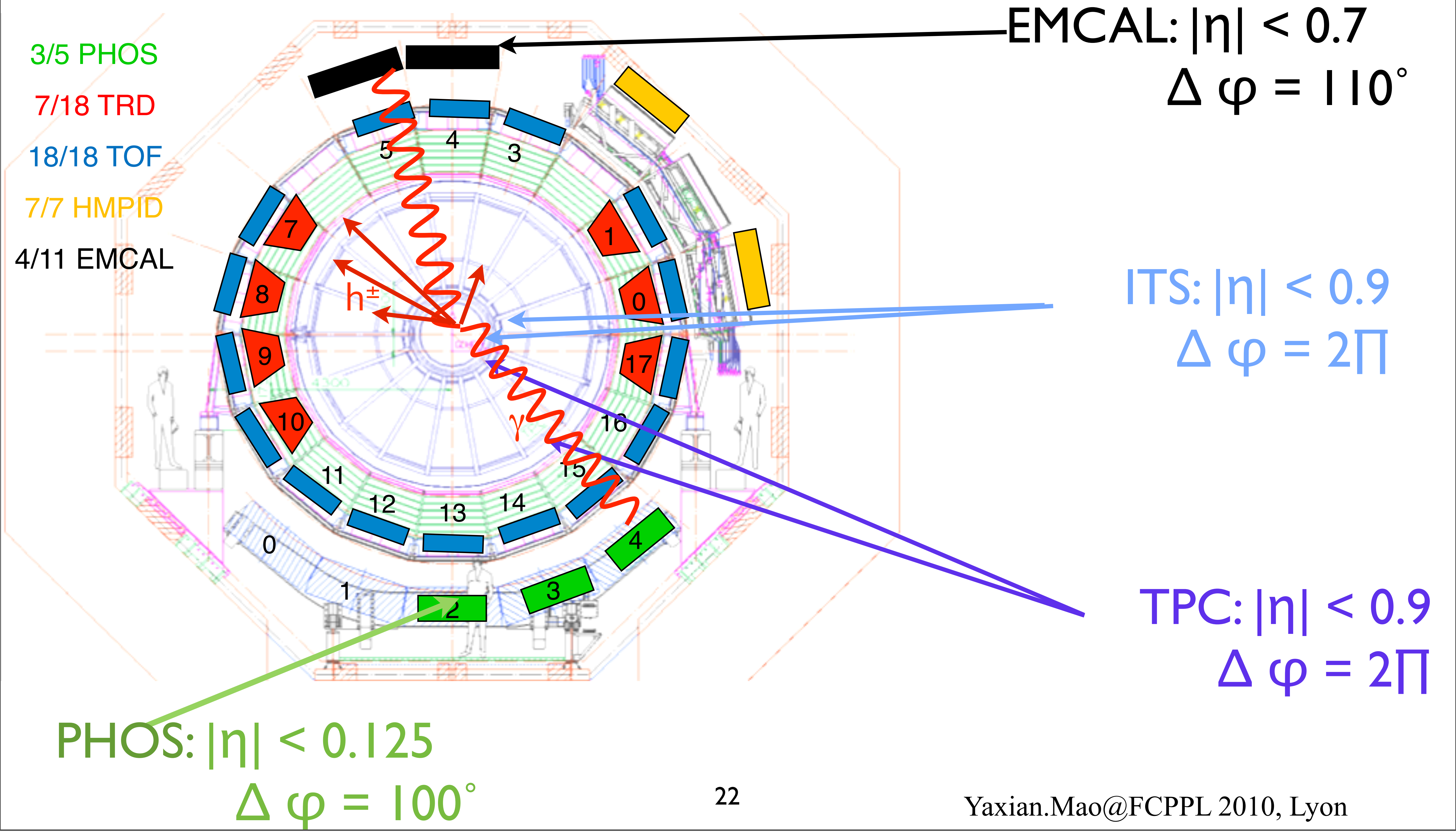
- Photon-hadrons correlation measurement is feasible in ALICE
- Medium effect could be measured by γ-hadrons correlation:
  - Modification of the photon tagged hadrons correlation function -> medium properties
  - Detailed tomography of HI collision is possible
  - k_T from pp to HI is an additional way to infer the medium property
- The measurements in HI are challenging but worth the effort

Thanks for your attention!

Back up

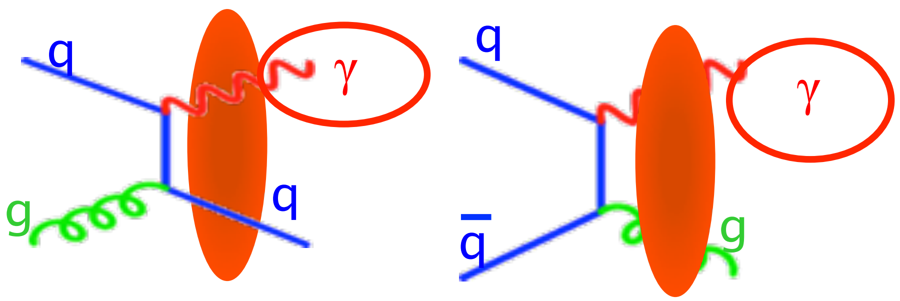
ALICE detectors

http://aliceinfo.cern.ch/Collaboration/

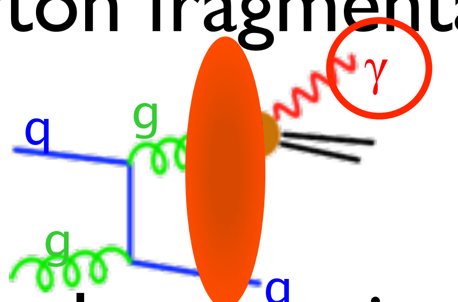


Prompt Photon: Hard Probes

- Prompt photons: $p_t^{\gamma} >> \Lambda_{QCD}, T_{medium}$
  - LO



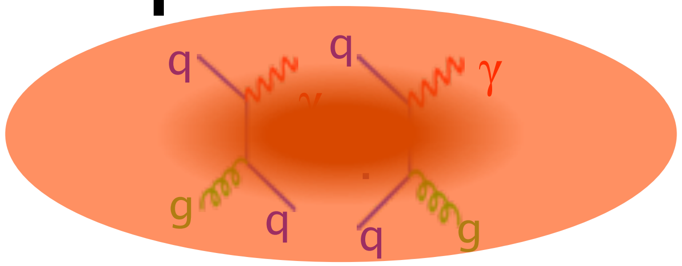
    - Measured as isolated photons
    - Reference study for medium effect
- Prompt photons: $p_t^{\gamma} >> \Lambda_{QCD}, T_{medium}$
  - NLO (parton fragmentation)



    - Measured as non-isolated photon
    - Quenched by the medium (aka parton)

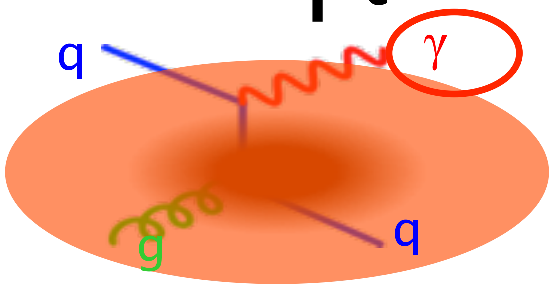
Photon Source: medium generated

- Thermal: $p_t^{\gamma} \sim T_{medium} \sim 1$ GeV



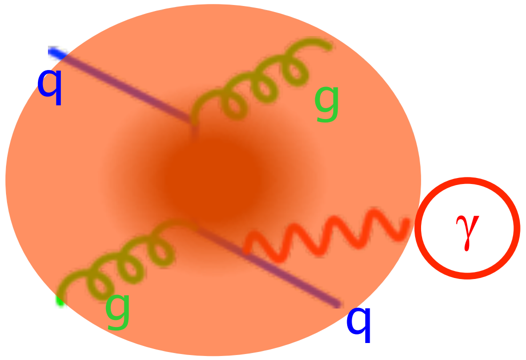
$R_{AA} > 1, v_2 > 0$

- Jet conversion: $p_t^{\gamma} \sim \ p_t^{q}$



$R_{AA} > 1, v_2 < 0$

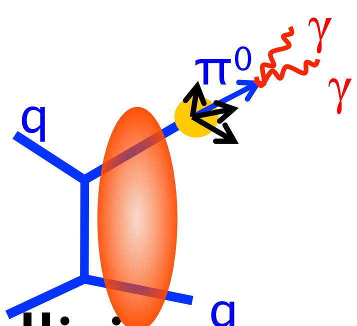
- Bremstrahlung (aka g radiation): $p_t^{\gamma} < p_t^{q}$



$R_{AA} > 1, v_2 < 0$

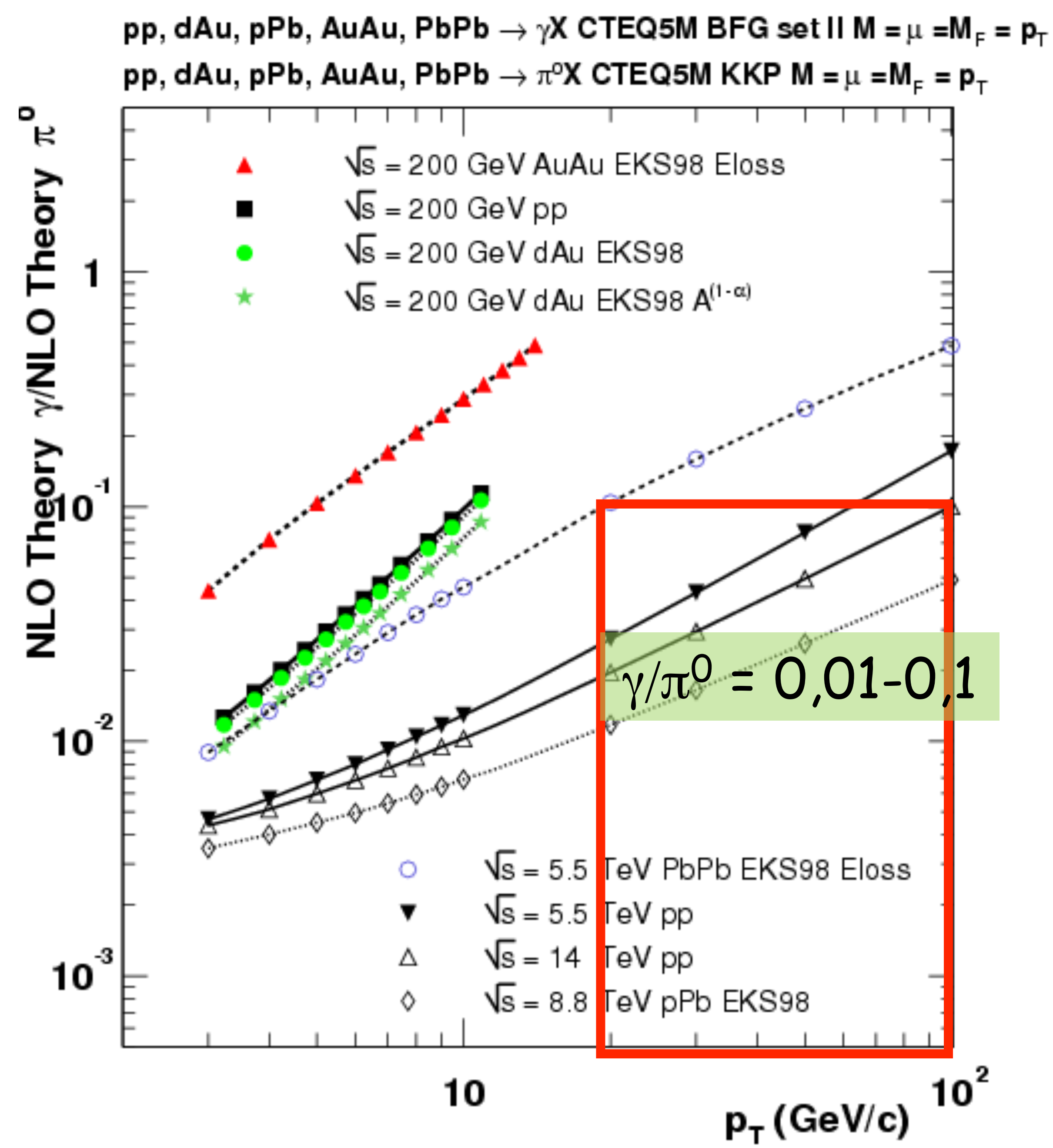
Photon Source: Decay

- Decay photons form the bulk:
  $p_t^{\gamma} = p_t^{\pi} / 2 < p_t^{q}$



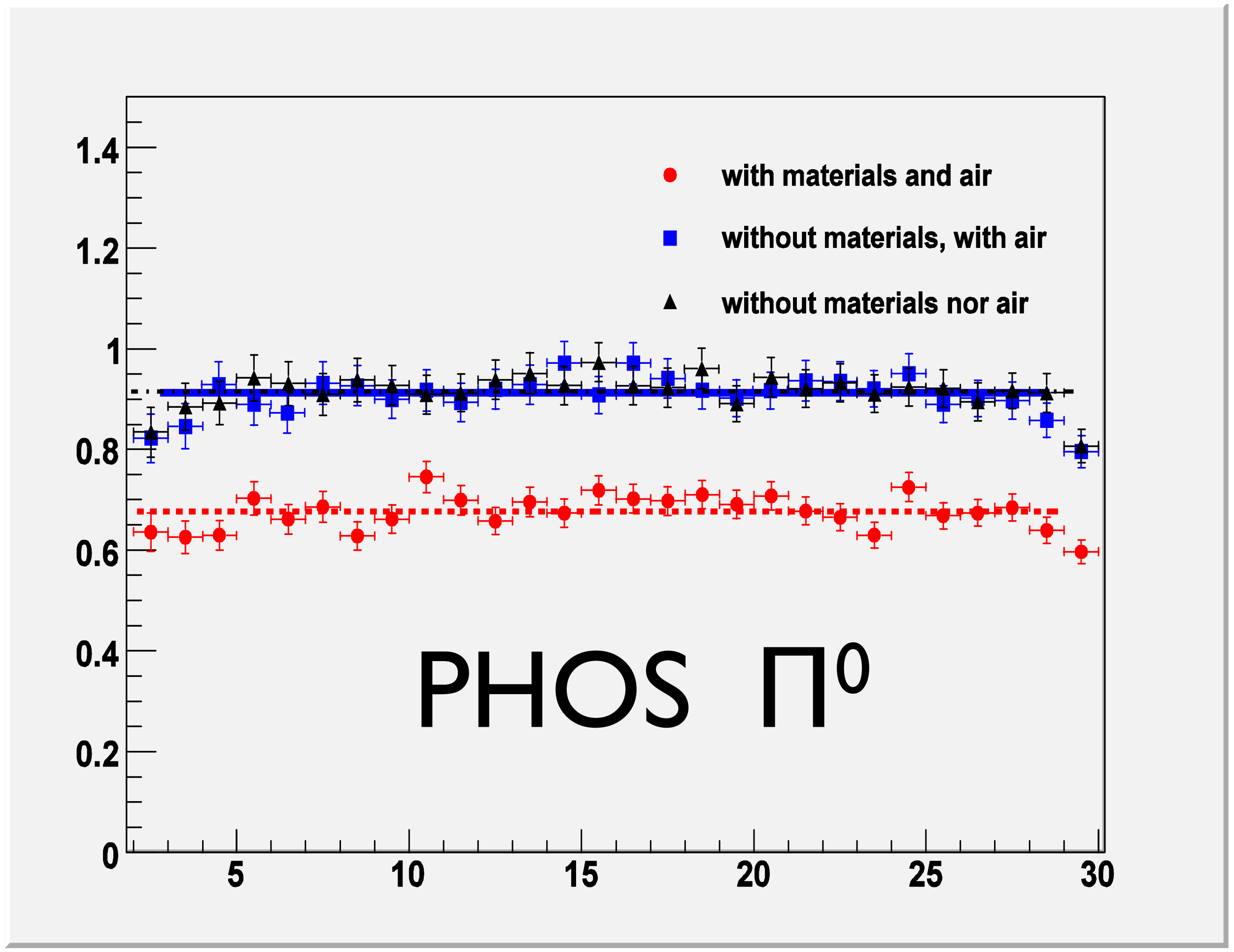
$R_{AA} < 1, v_2 > 0$

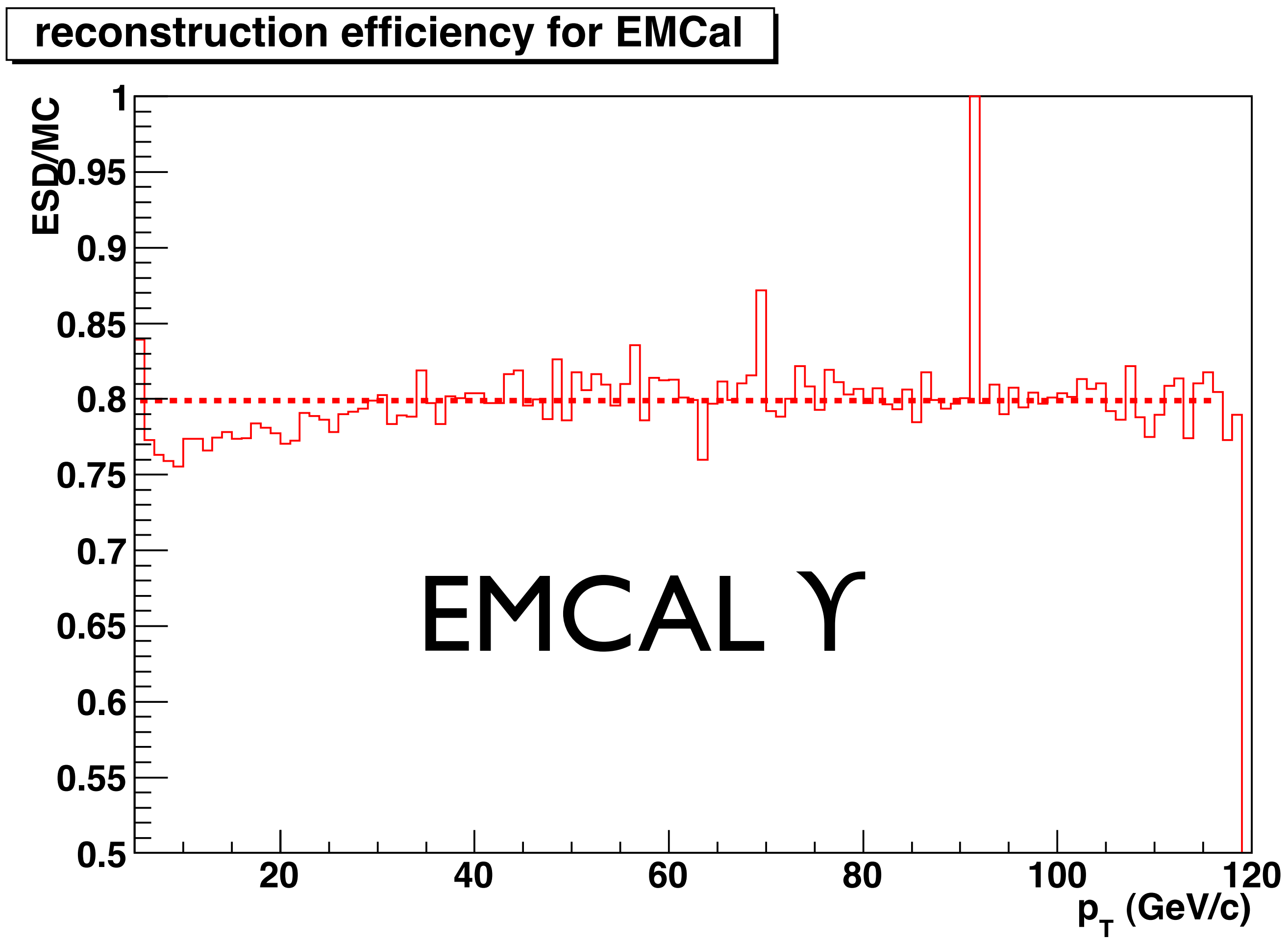
- p+p collisions:
  - mainly π^0
- A+A collisions:
  - Jet-Quenching
  - LHC:
    - $N_{\gamma} / N_{\pi} \approx 0.3$ for $p_T = 100$ GeV/c



Yellow Report **hep-ph/0311131**

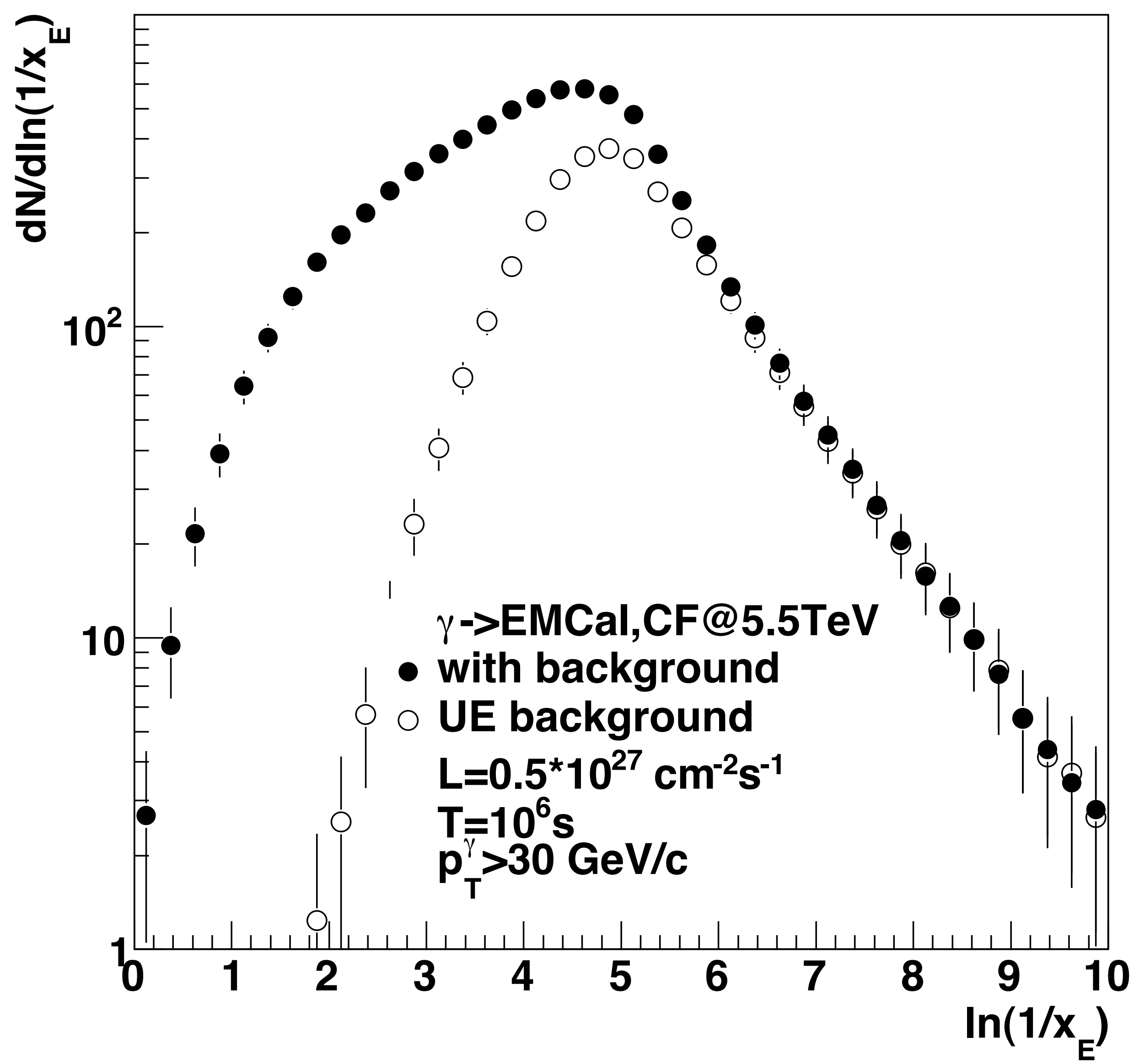
Identification Efficiency

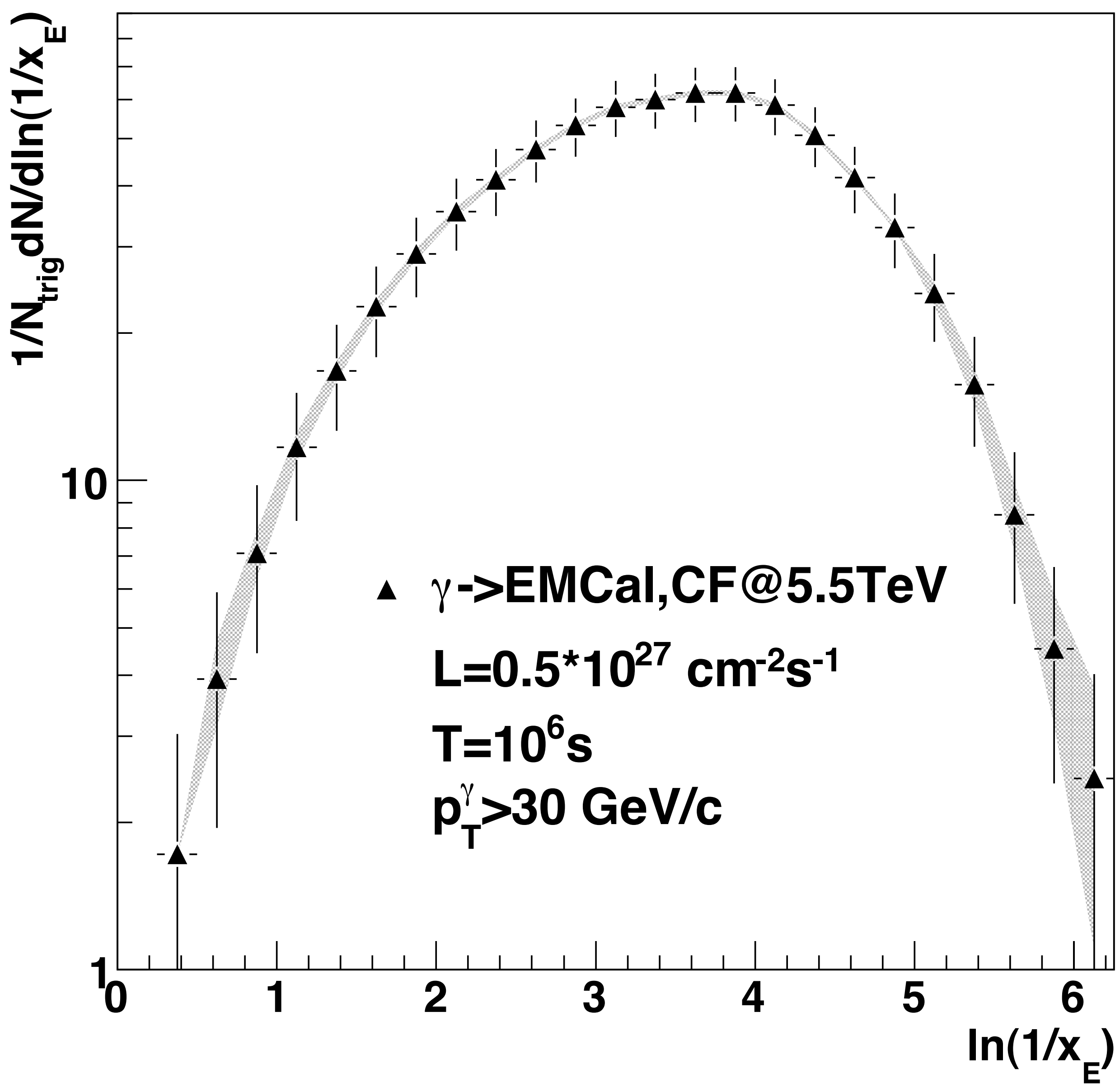




- Photon identification efficiency ~ 80% (PHOS and EMCAL)
- pi0 reconstruction by IMA ~ 68% (PHOS)

CF Measurement with EMCAL





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- Systematic errors from decay photon contamination and hadrons from underlying events.