Photon Physics with the ALICE Detector

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For the ALICE Collaboration

High p_T physics at LHC – Hanau 2012

Theoretical aspects

- Photons production in Pb-Pb collisions :
  - hard QCD process (prompt+NLO bremsstrahlung)
  - thermal : partons diffusion in medium
  - hadronic decay

- Direct (prompt+thermal) photons spectra :
  - test of perturbative QCD at high energy (gluon PDF)
  - study of QGP : p_T = 1-5 GeV/c -> QGP radiation
    p_T > 20 GeV/c -> prompt photon production

- Neutral mesons spectra (π^0,η) :
  - reference for direct photons estimate ($\gamma_{direct} = \gamma_{inclusive} - \gamma_{decay}$)
  - medium suppression R_{AA}

- Correlations of direct photon-hadrons/jets :
  - medium effects on parton fragmentation

Experimental aspects

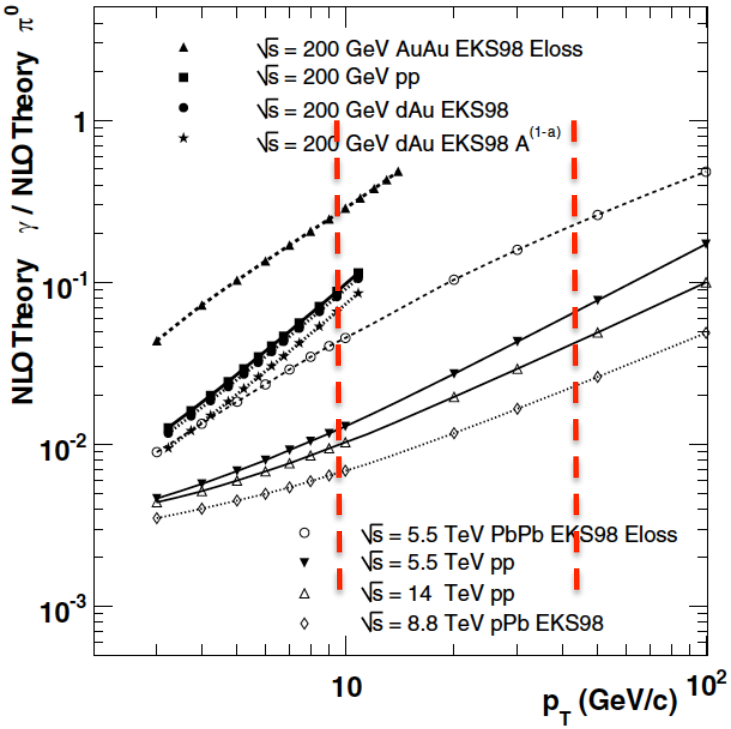
For all photon analysis :

→ photon reconstruction in high multiplicity environment

For prompt photons analysis :

- **Background from decay**

ALICE PPR, vol.II

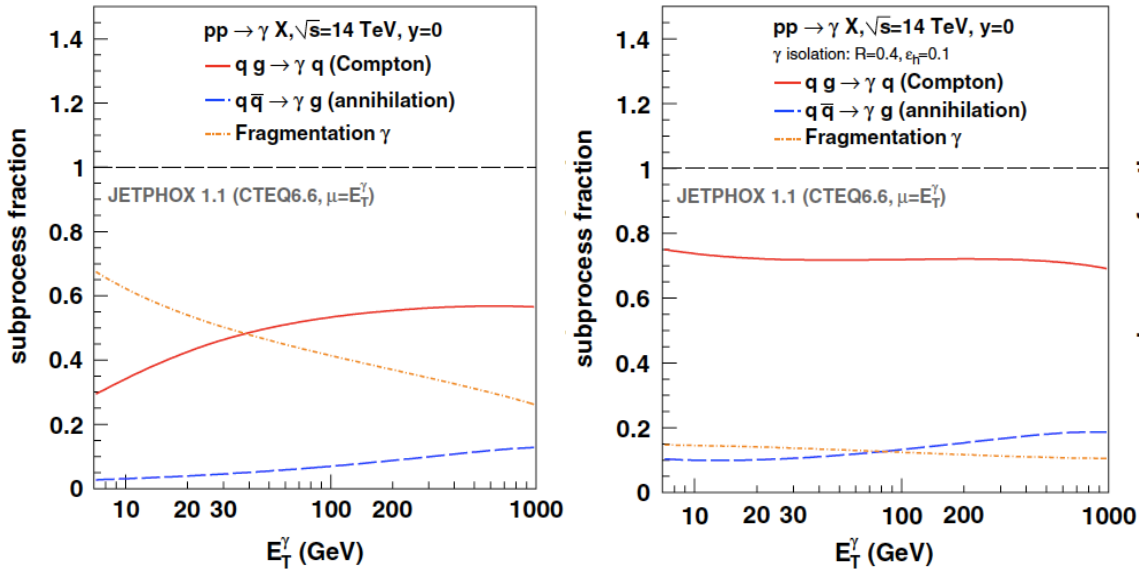


→ S/B ≈ 0.01 – 0.1 at LHC !

- **Isolation advantages**

- Apply isolation cone around photon candidate
- It reduces both fragmentation and decay component

R. Ichou et al. arXiv:1005.4529[hep-ph]

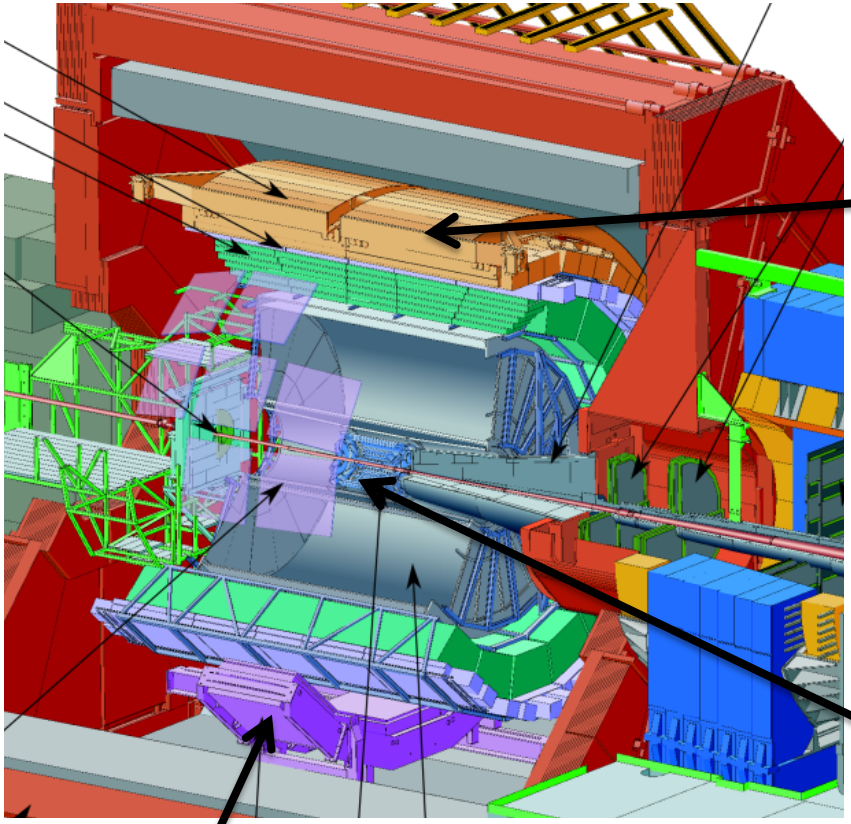


→ Challenge in Pb-Pb collisions !

In this talk

- Photons reconstruction with the ALICE detectors
- π^0 , η spectra in pp collisions at 0.9, 2.76 and 7 TeV
- π^0 suppression in Pb-Pb collisions
- On-going γ-hadrons analysis

Photons, neutral mesons reconstruction



EMCAL
Sandwich Pb-Scintillator

$|\eta| < 0.7$, $\Delta\Phi = 100°$ (107° in 2012)
pp-$E_{\pi^0} = 5$ GeV → $\sigma_{\pi^0} \approx 10$ MeV/c^2

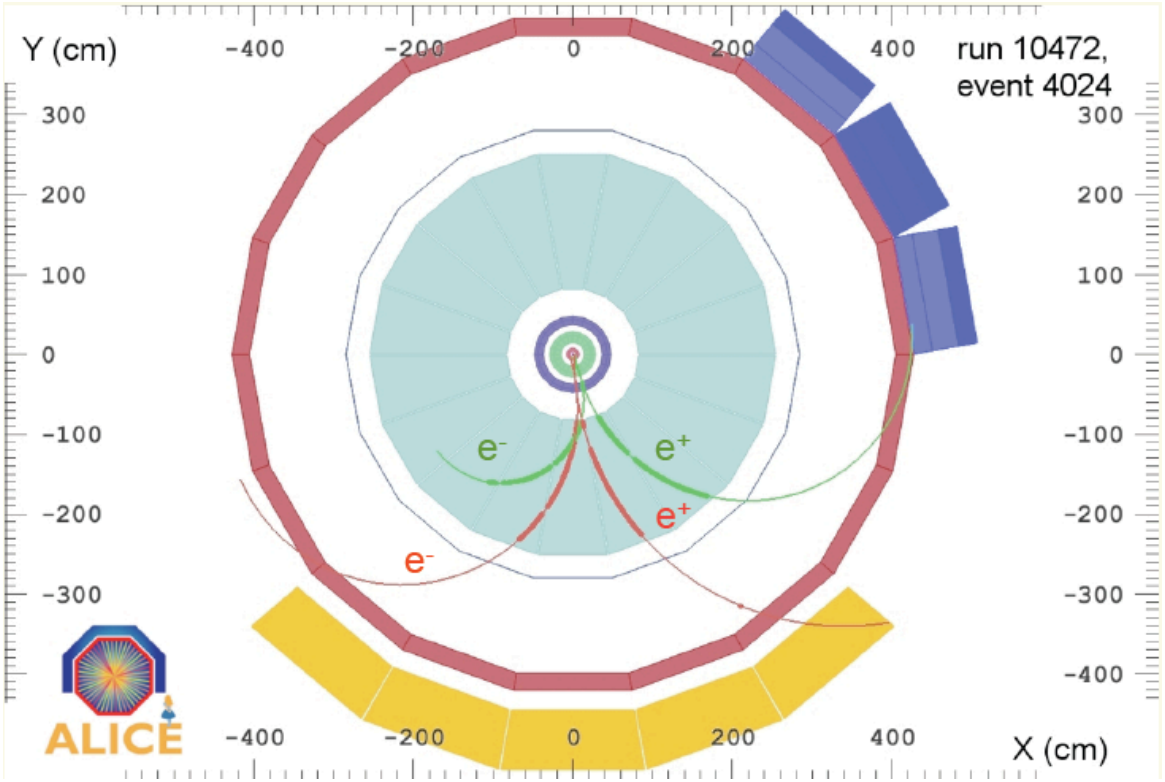
Photon conversion + tracking
γ's converted into $e^{\pm}$ pairs between beam pipe and middle of TPC can be detected
(conversion *probability* ≈ 8.5%)

$|\eta| < 0.9$, $\Delta\phi = 360º$
pp – $E_{\pi^0} = 5$ GeV → $\sigma_{\pi^0} \approx 4$ MeV/c^2

PHOS
$PbWO_4$ crystals

$|\eta| < 0.12$, $\Delta\Phi = 60°$
pp-$E_{\pi^0} = 5$ GeV → $\sigma_{\pi^0} \approx 7$ MeV/c^2

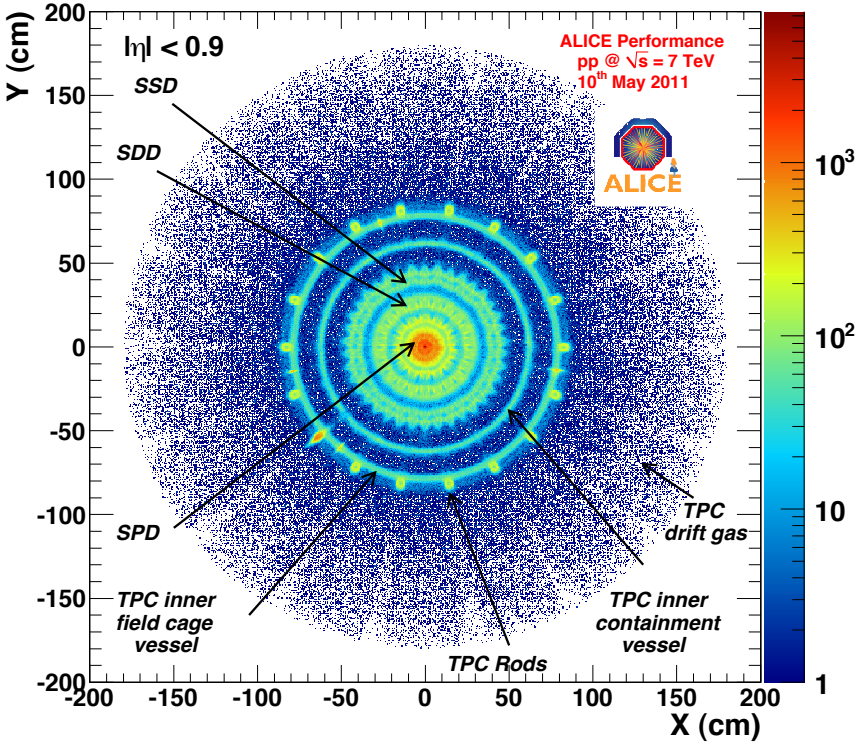
Conversion method



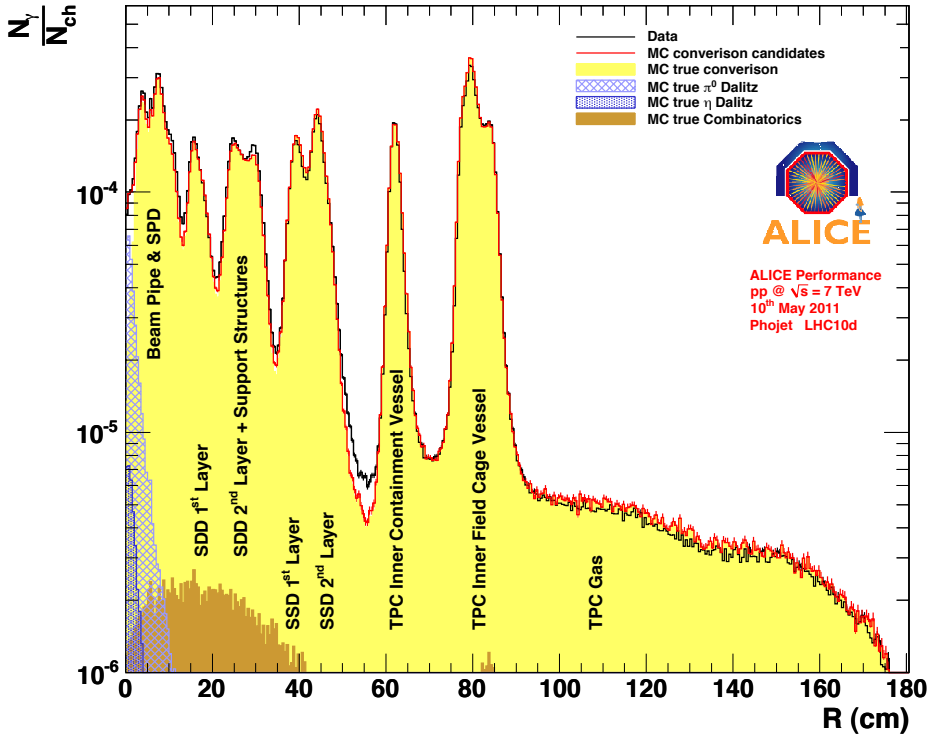
$\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^-e^+e^-$

- 2 opposite charged tracks reconstruction (conversion point)
- Cuts on energy loss (in TPC) and time of flight of tracks (separate e^{+-} from p,K,π,μ)
- Resolution of conversion point reconstruction : 1.5 cm in z, 3 cm in R and 2.5 mrad in Φ

Material budget



Distribution of photon conversion points



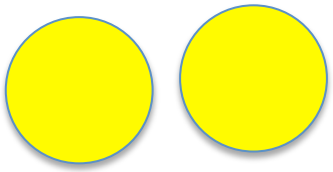
Distribution of photon conversion vs R (Data/simulation)

- ALICE material budget (11.4% X_0 up to middle of TPC) agrees within +3.4%/-6% with its implementation in GEANT

Calorimeters identification

- Decay photons PID is detector and p_T dependent :

Invariant mass



2 separated clusters

$$M_{ij} = \sqrt{2E_iE_j(1-\cos\theta)}$$

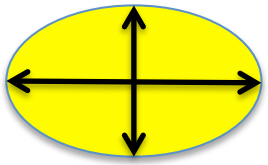
EMCal :

$1 < p_T(\pi^0) < 20$ GeV/c

PHOS :

$0.5 < p_T(\pi^0) < 40$ GeV/c

Shower shape



2 merged clusters

Long/short axis of the cluster

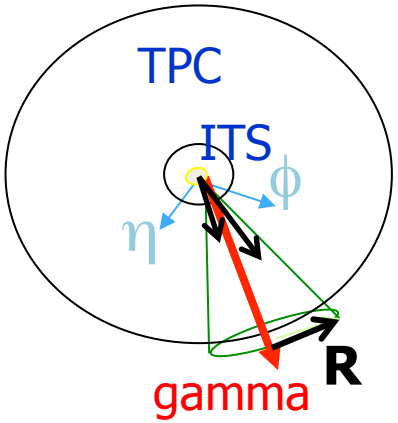
EMCal :

$6 < p_T(\pi^0) < 40$ GeV/c

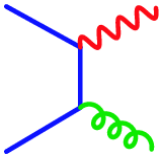
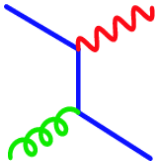
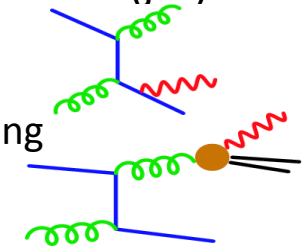
PHOS :

$30 < p_T(\pi^0) < 100$ GeV/c

Isolation

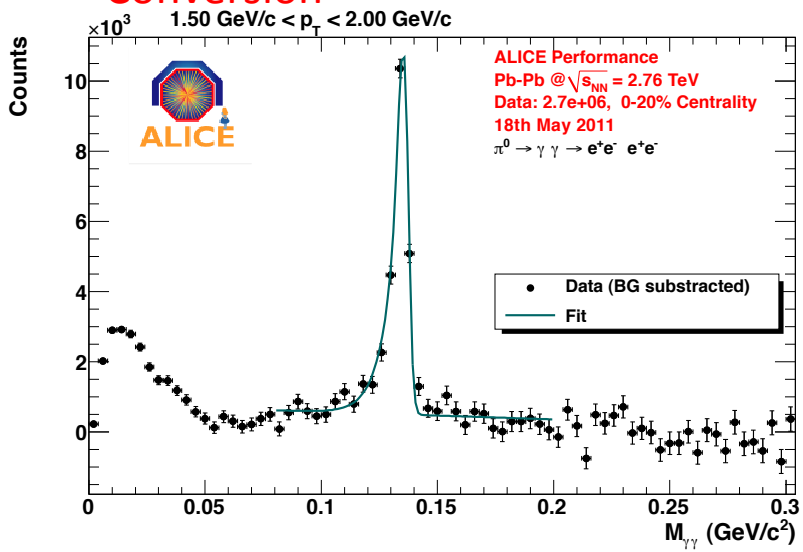


- Apply isolation cut on hadronic energy in a cone
- Isolation parameters : $R = \sqrt{\eta^2 + \phi^2}$, threshold
- Direct gamma should be isolated, neutral mesons should not (jet)

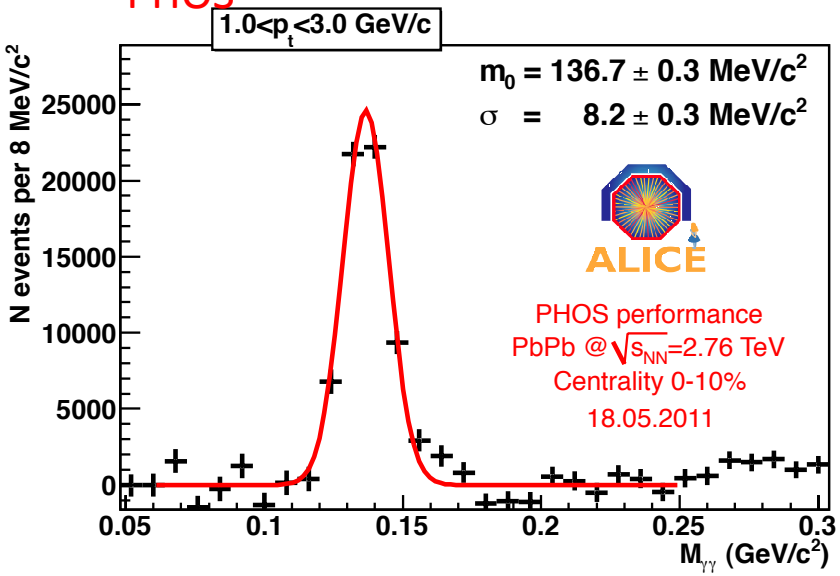
Annihilation  Compton  Bremsstrahlung 

π^0 reconstruction performances in Pb-Pb

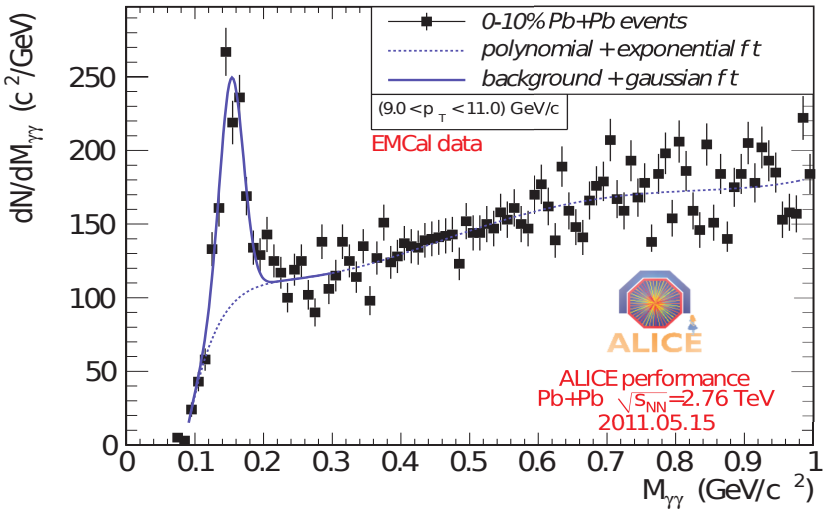
Conversion



PHOS



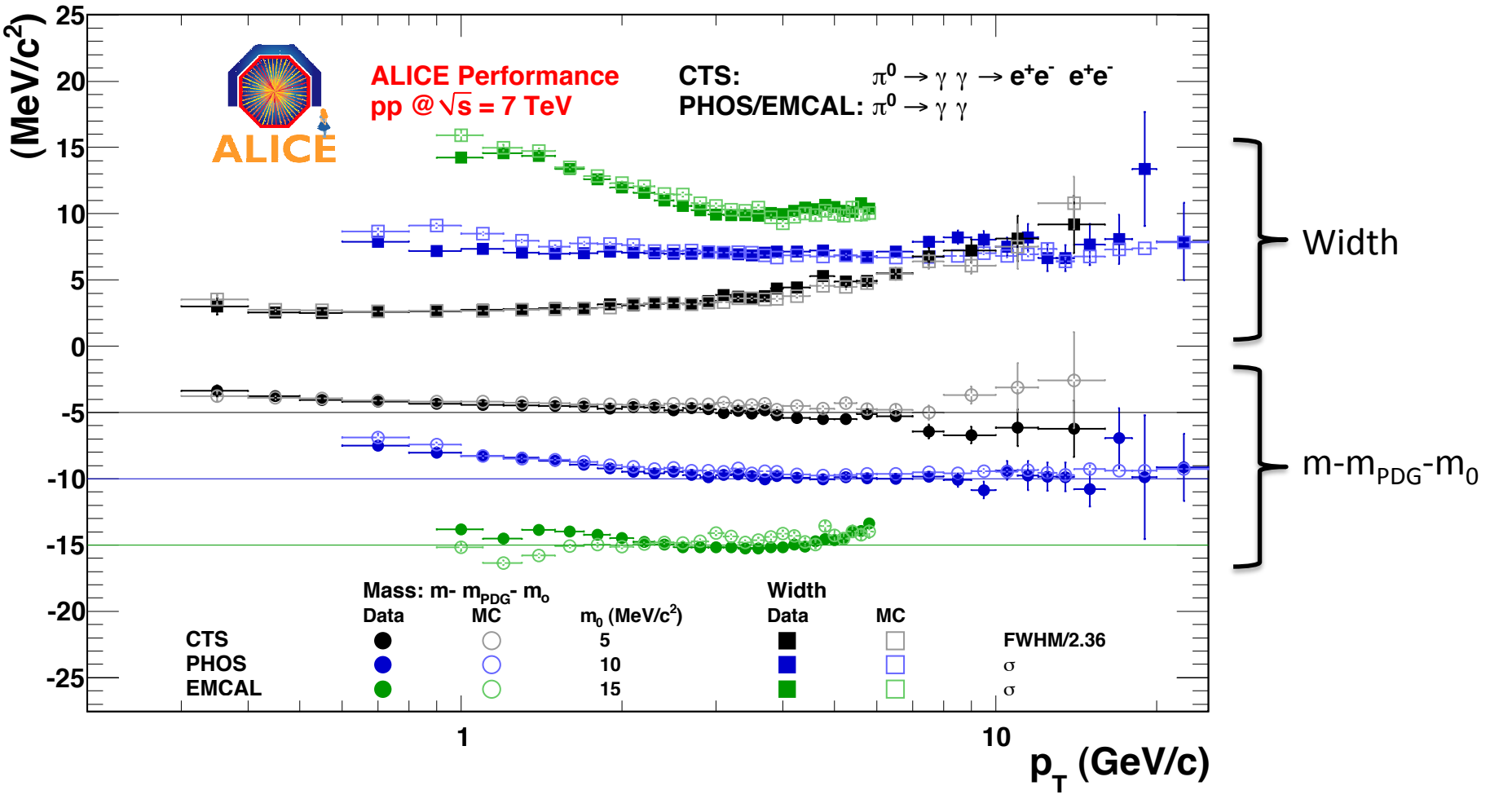
EMCAL



- Conversion gives very precise measurement $0.5 < p_T < 30$ GeV/c
- PHOS could measure π^0 with $0.5 < p_T < 40$ GeV/c (*)
- EMCAL could measure π^0 with $1 < p_T < 20$ GeV/c (*)

(*) for higher p_T shower shape selection is needed due to clusters merging

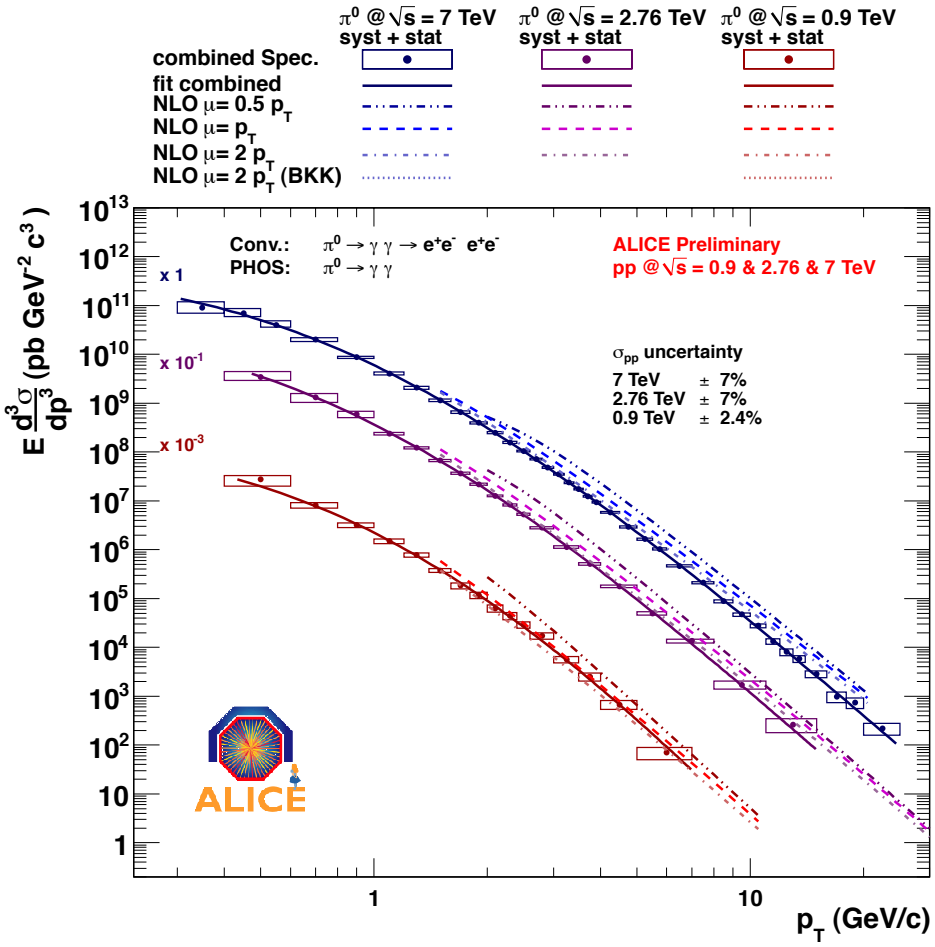
π^0 reconstruction performances in pp



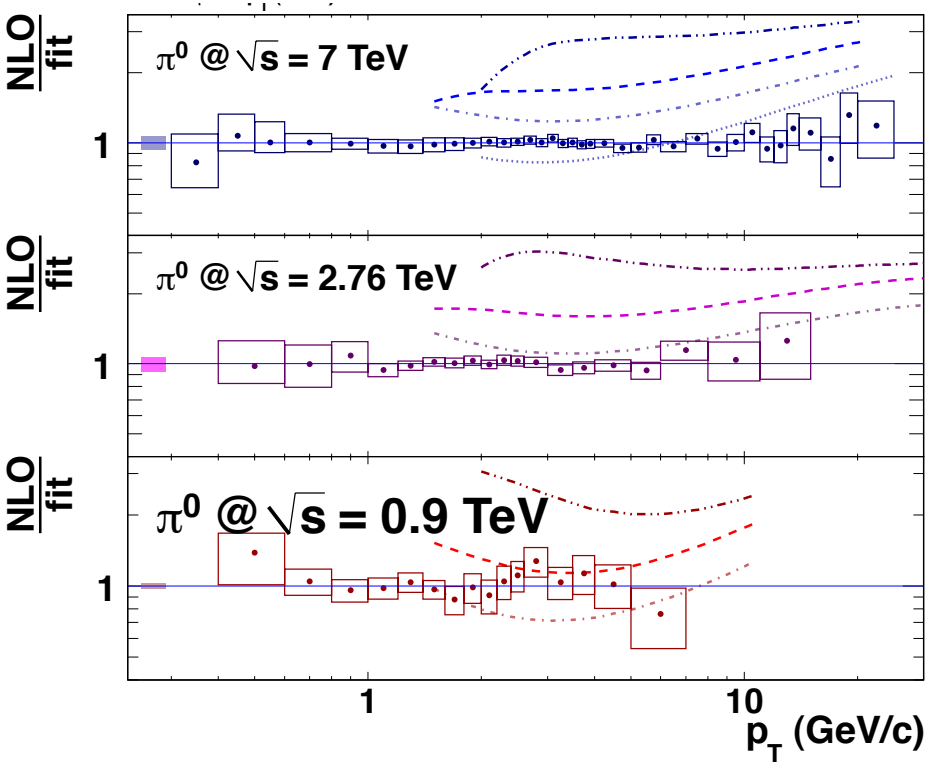
Good agreement between data and simulation

π^0 spectra in pp at 0.9, 2.76 and 7 TeV

Nucl. Phys. B 327 105
Phys. Rev. D 67 054005



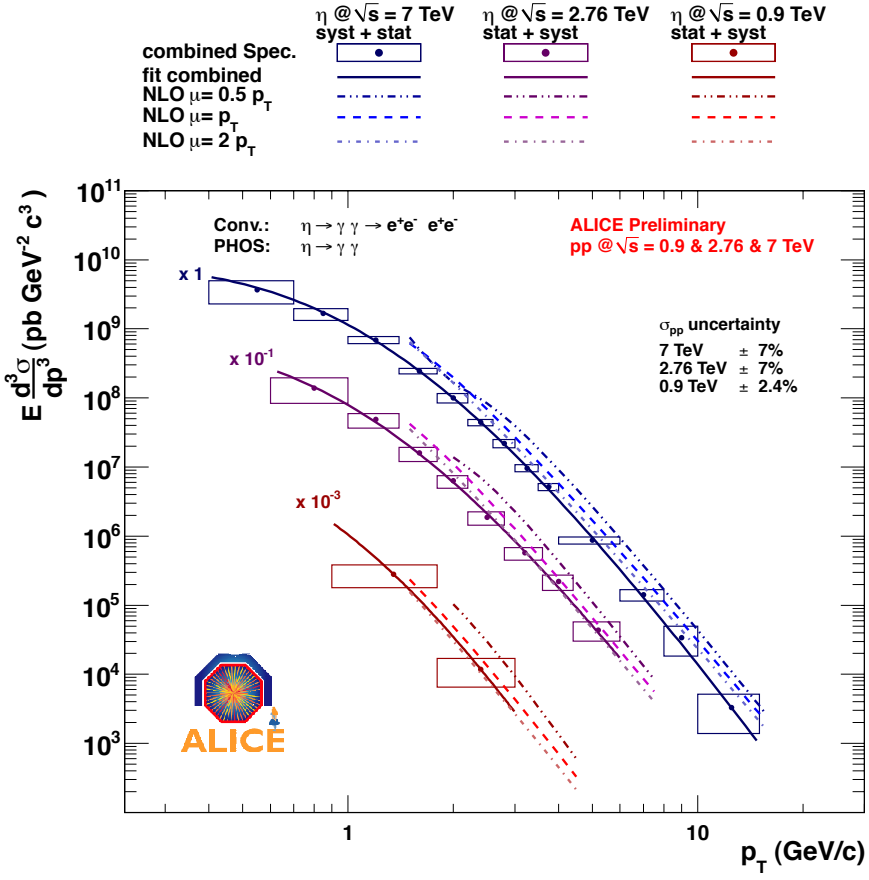
NLO pQCD
PDF : CTEQ6M5, FF : DSS, scales μ = 0.5p_T, p_T, 2p_T
AlsoFF : BKK (with INCNLO)



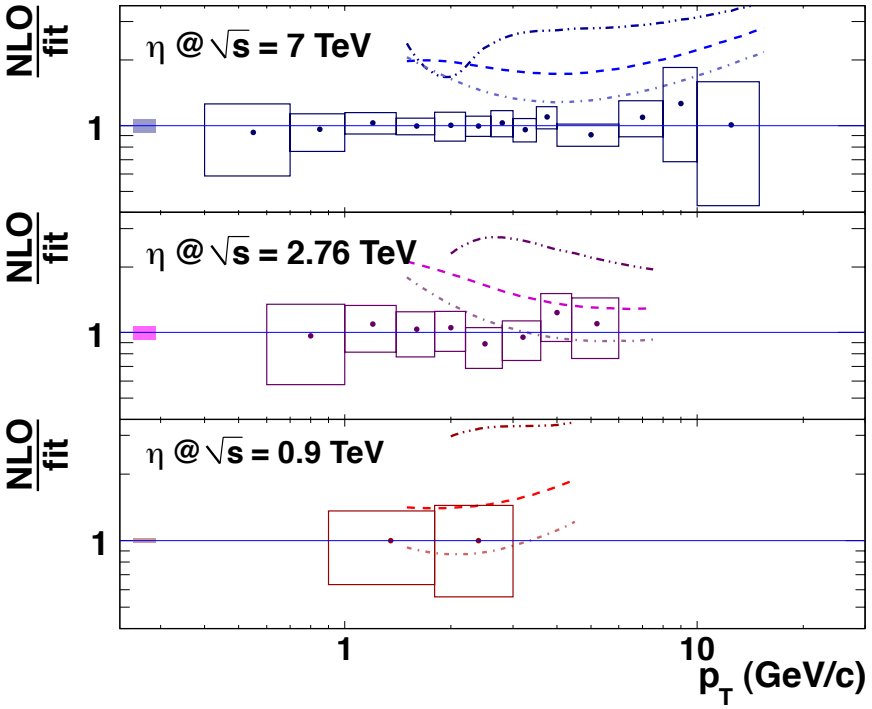
- Good agreement PHOS/Conversion
- Use Tsallis fit function as parametrization

- NLO pQCD (DSS) describes 0.9TeV data
- But 2.76TeV and 7TeV are overestimated

η spectra in pp at 0.9, 2.76 and 7 TeV

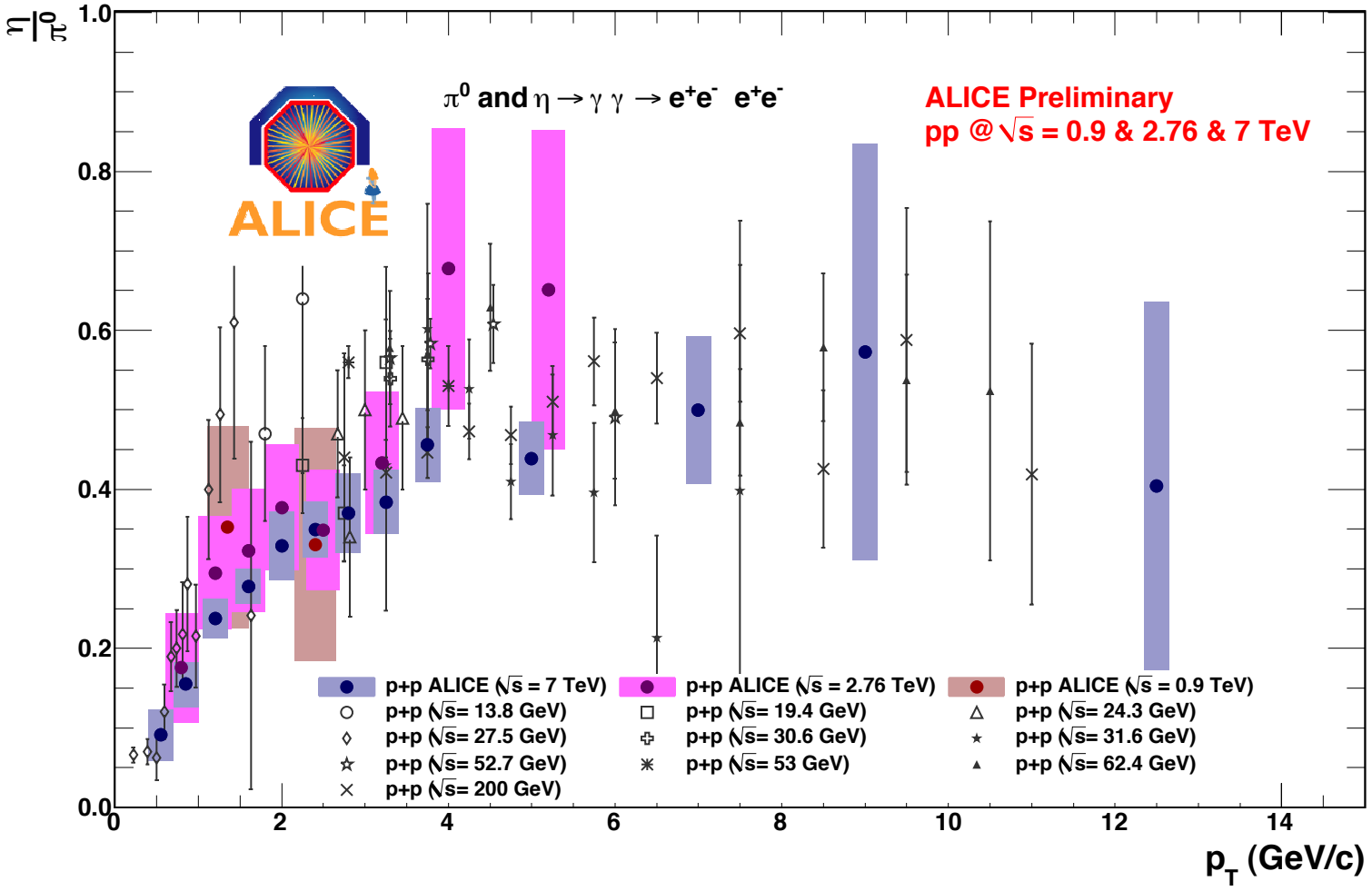


NLO pQCD
PDF : CTEQ6M5, FF : DSS, scales μ = $0.5p_T$, p_T, $2p_T$



- Same conclusions as for π^0
- Hypothesis : higher-twists corrections, gluon PDF uncertainties at LHC

η / π⁰ at 0.9, 2.76 and 7 TeV



- η / π^0 ratio measured in ALICE fits with lower √s experiment results

π^0 suppression in medium (1)

- Parton energy loss in the QGP :

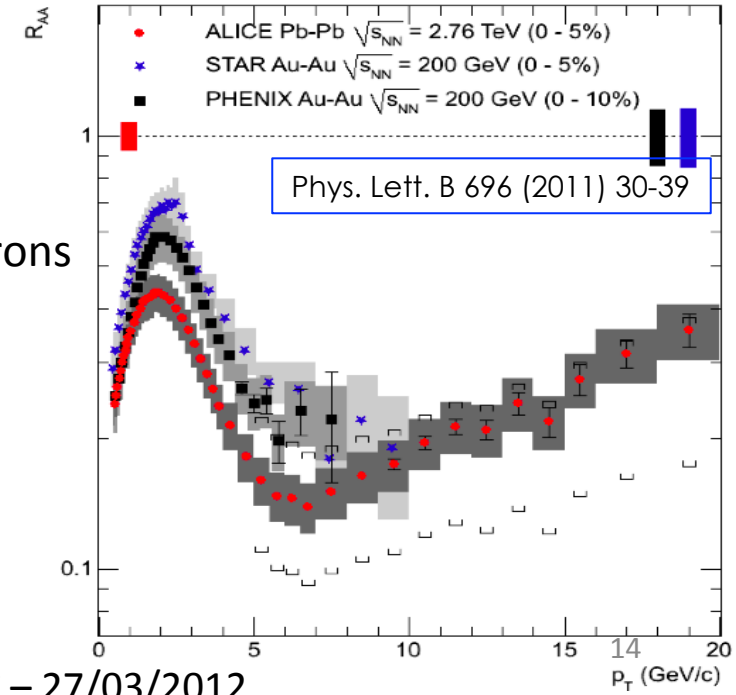
  → measurement of the nuclear modification factor

$$R_{AA}(p_T) = \frac{(1/N_{evt}^{AA})\, d^2N_{ch}^{AA}/d\eta dp_T}{\langle N_{coll}\rangle\,(1/N_{evt}^{pp})\, d^2N_{ch}^{pp}/d\eta dp_T}$$

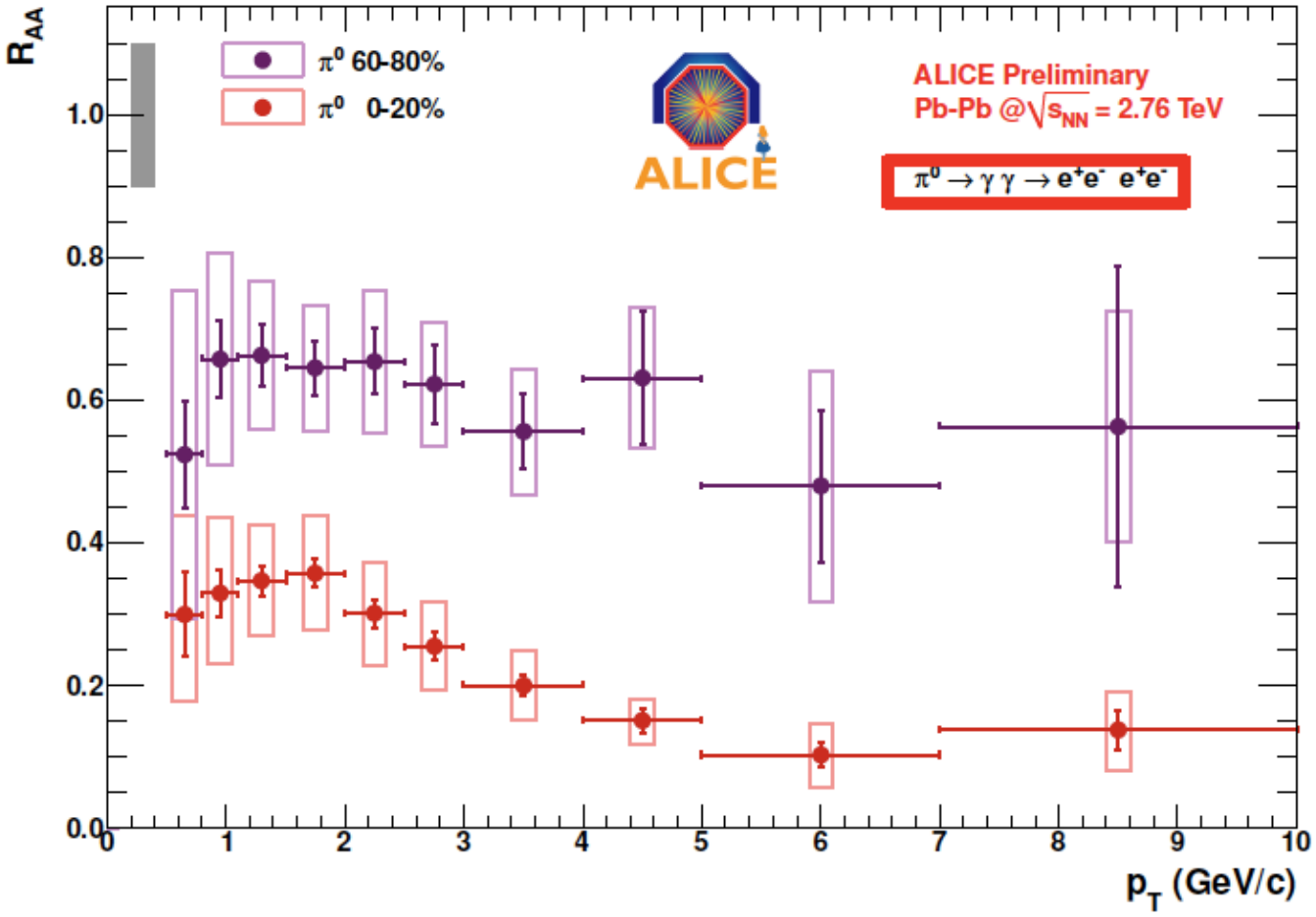
- Why using π^0 ?

→ compare with R_{AA} p_T dependence from charged hadrons

→ R_{AA} dependence on baryon/meson ?
- comparison with charged hadrons
- comparison with charged pions

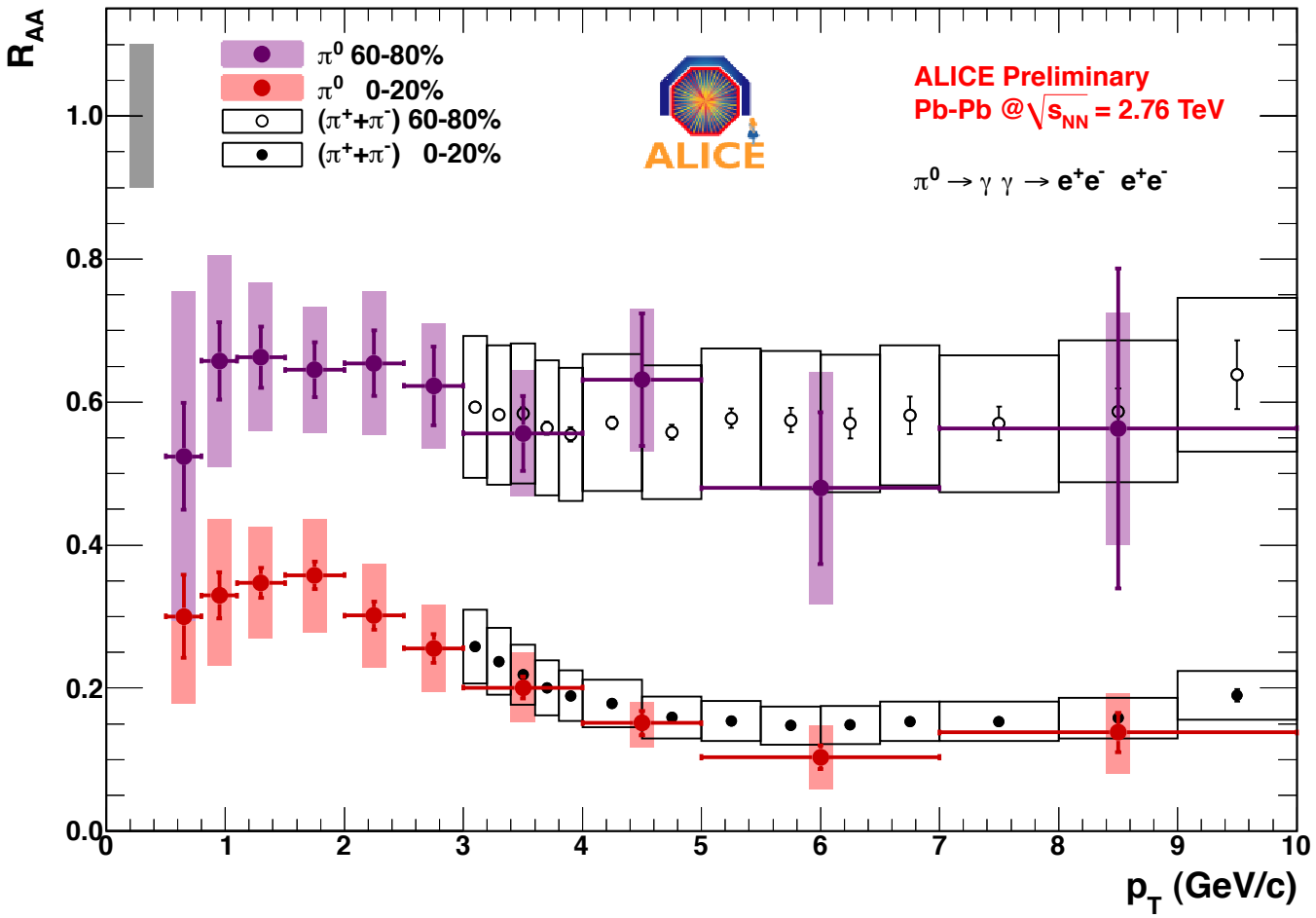


π^0 suppression in medium (2)



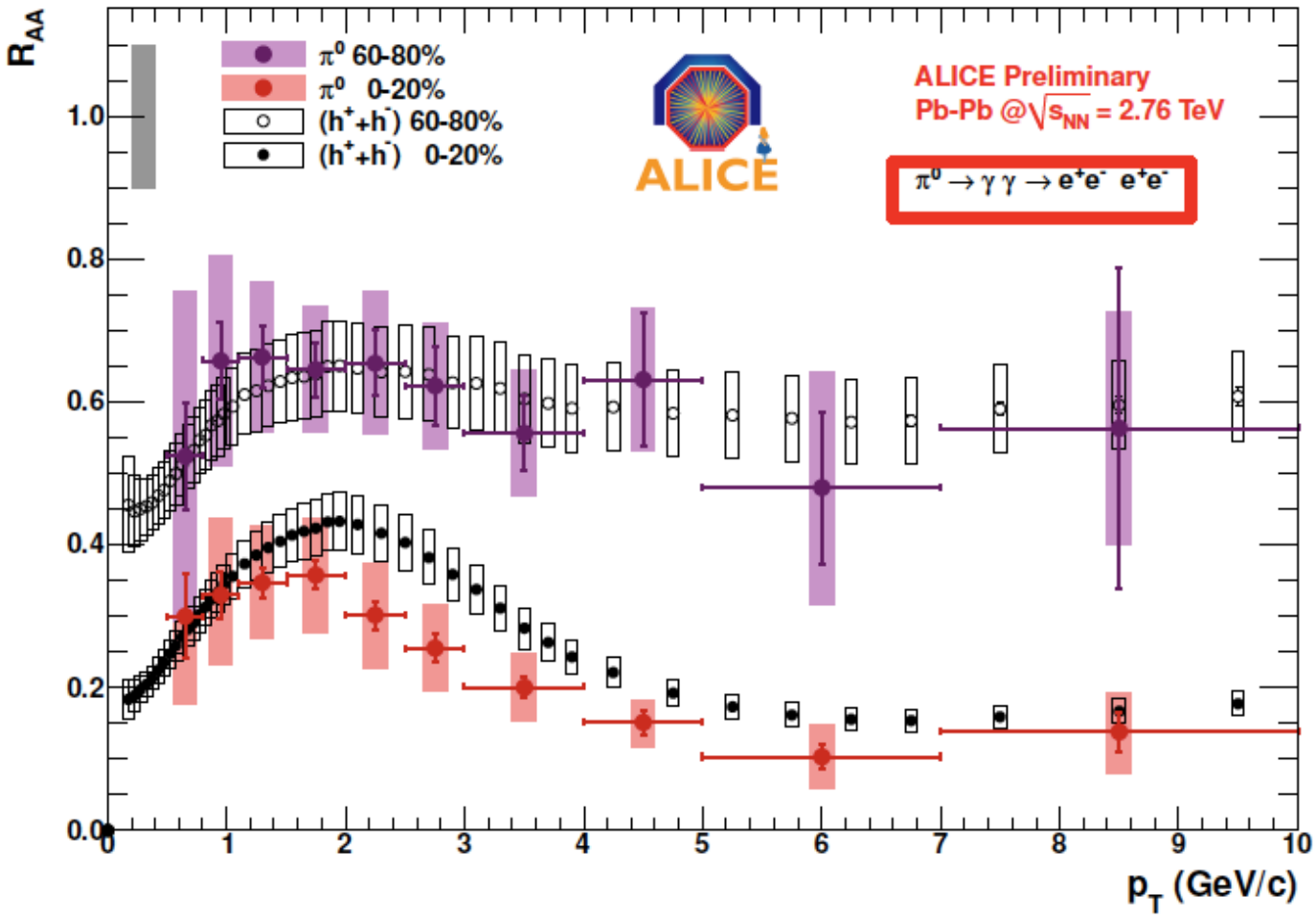
- Strong dependence with respect to centrality

π^0 R_{AA} compared to $\pi^{\pm}$



- Good agreement (within uncertainties) for all centralities

π^0 R_{AA} compared to charged hadrons



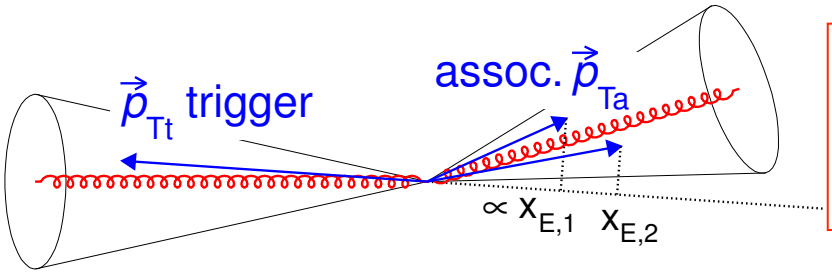
- Centrality 0-20% : discrepancy below 5 GeV/c
- Could be explained by meson/baryon anomaly

See talk from P. LUETTIG

Gamma-hadrons correlations

- Single particle spectra are only *indirectly* sensitive to the energy loss of the parton
  → parton fragmentation should give us new information

- Gamma-hadrons correlations approximate fragmentation w.o jet reconstruction



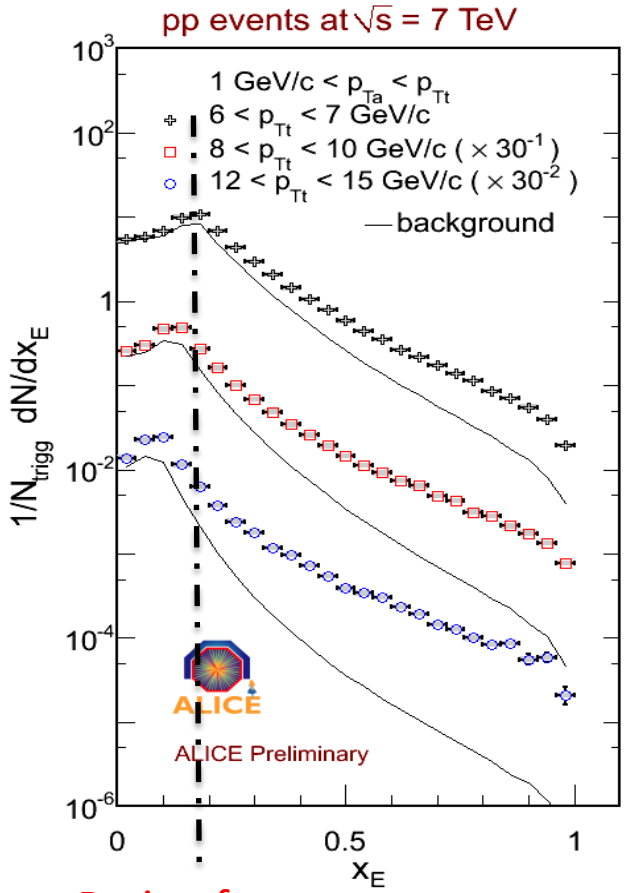
$$x_E = -\frac{\vec{p}_{Tt} \cdot \vec{p}_{Ta}}{\left|\vec{p}_{Tt}\right|^2} = -\frac{p_{Ta}}{p_{Tt}}\cos(\Delta\phi) = -\frac{z_a}{z_t}\cos(\Delta\phi)$$

$$z_i = \frac{p_{Ti}}{\hat{p}_T} \quad \text{with} \quad \hat{p}_T = p_T parton$$

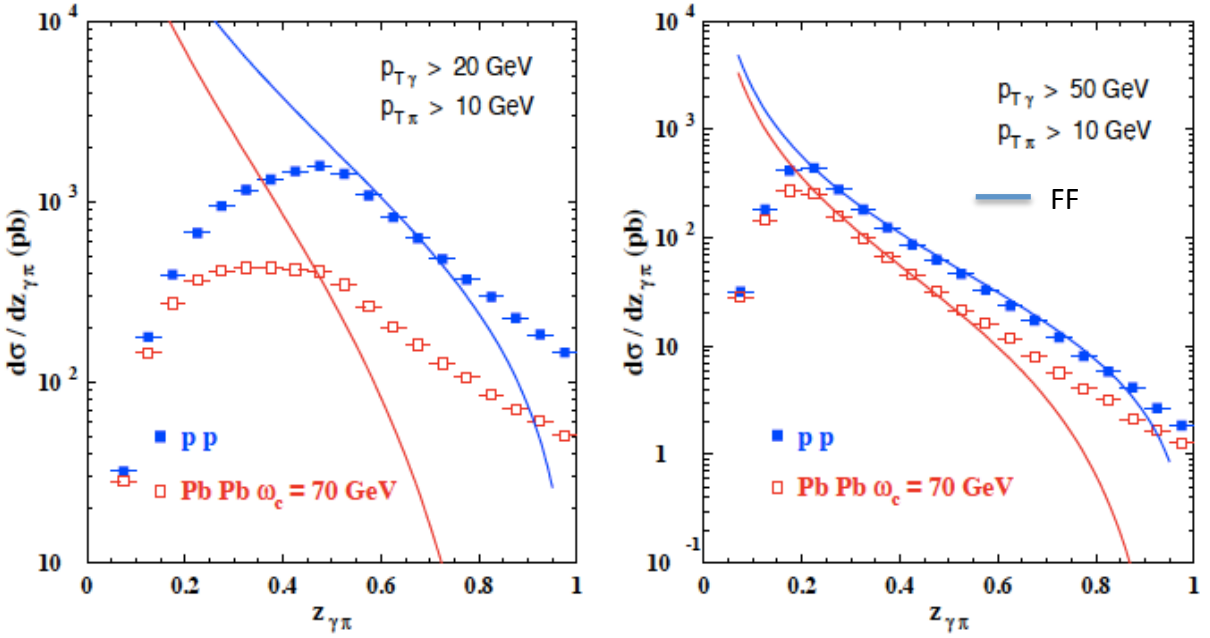
- Charged/neutral trigger: $\langle z_t \rangle < 1 \Rightarrow x_E \neq z_a$
- Isolated trigger: $\langle z_t \rangle \to 1 \Rightarrow x_E \to z_a$
- Direct photon trigger : $\langle z_t \rangle = 1 \Rightarrow x_E \approx z_a$

Kinematic cuts

x_E distribution for h^{+-}-h^{+-} correlations



x_E distribution for γ-h^{+-} correlations with DIPHOX simulation

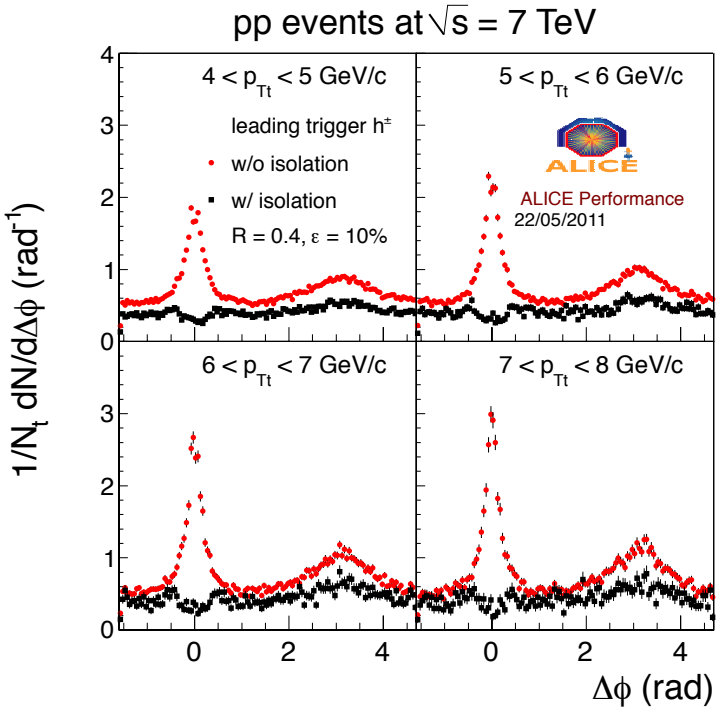


F. Arleo, arXiv:hep-ph/0701207

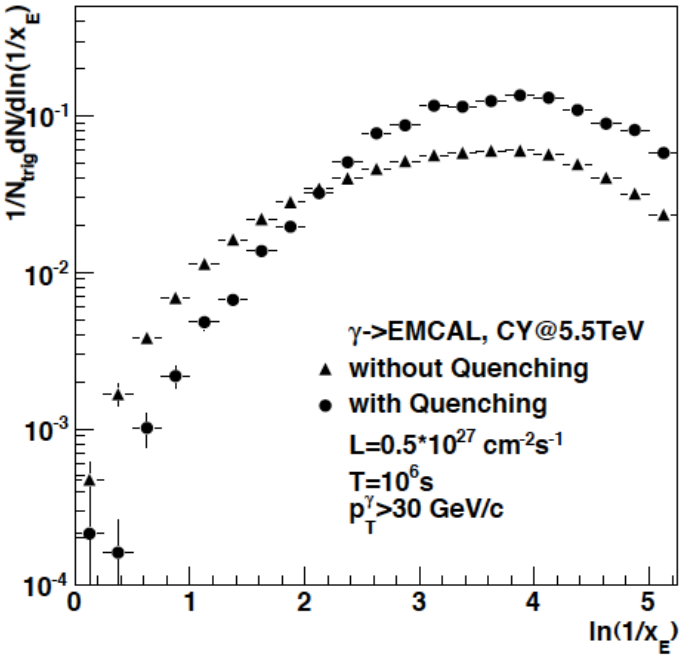
- Ratio of p_{Tasso} to $p_{Ttrigger}$ cuts gives *usable* range of xE distribution
- Kinematics cuts are important to *reproduce* parton fragmentation

Gamma-hadrons : outlook

- On-going analysis in ALICE
- Medium effects (x_E, azimuthal correlations) will depend on quenching behaviour



Isolated trigger-hadrons correlations at QM2011



EMCal PPR simulation

Conclusion

- Photon physics provides a wide range of analysis :
  - Test of QCD predictions (direct photons, neutral mesons)
  - High-p_T hadrons suppression
  - Study of parton fragmentation

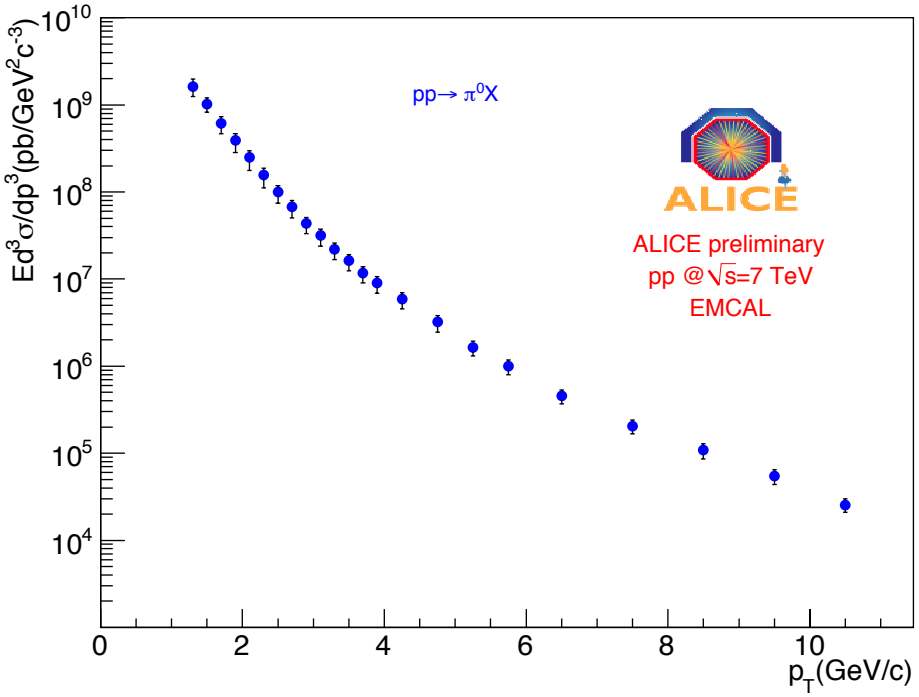
- Neutral meson reconstruction in pp provides additional constraints for PDFs and FFs used in NLO

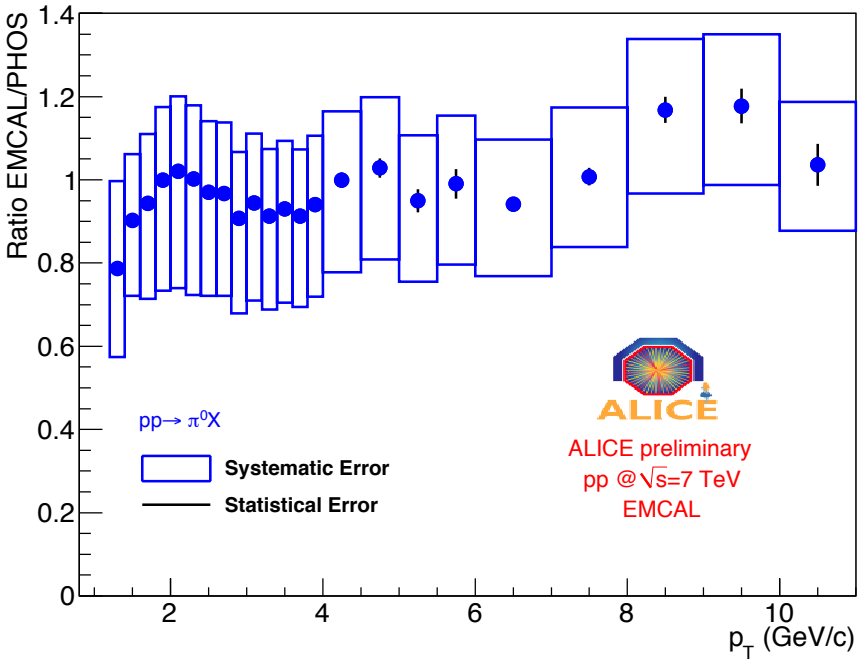
- Direct photon reconstruction in Pb-Pb collisions is a (fascinating) challenge !

Thanks for your attention !

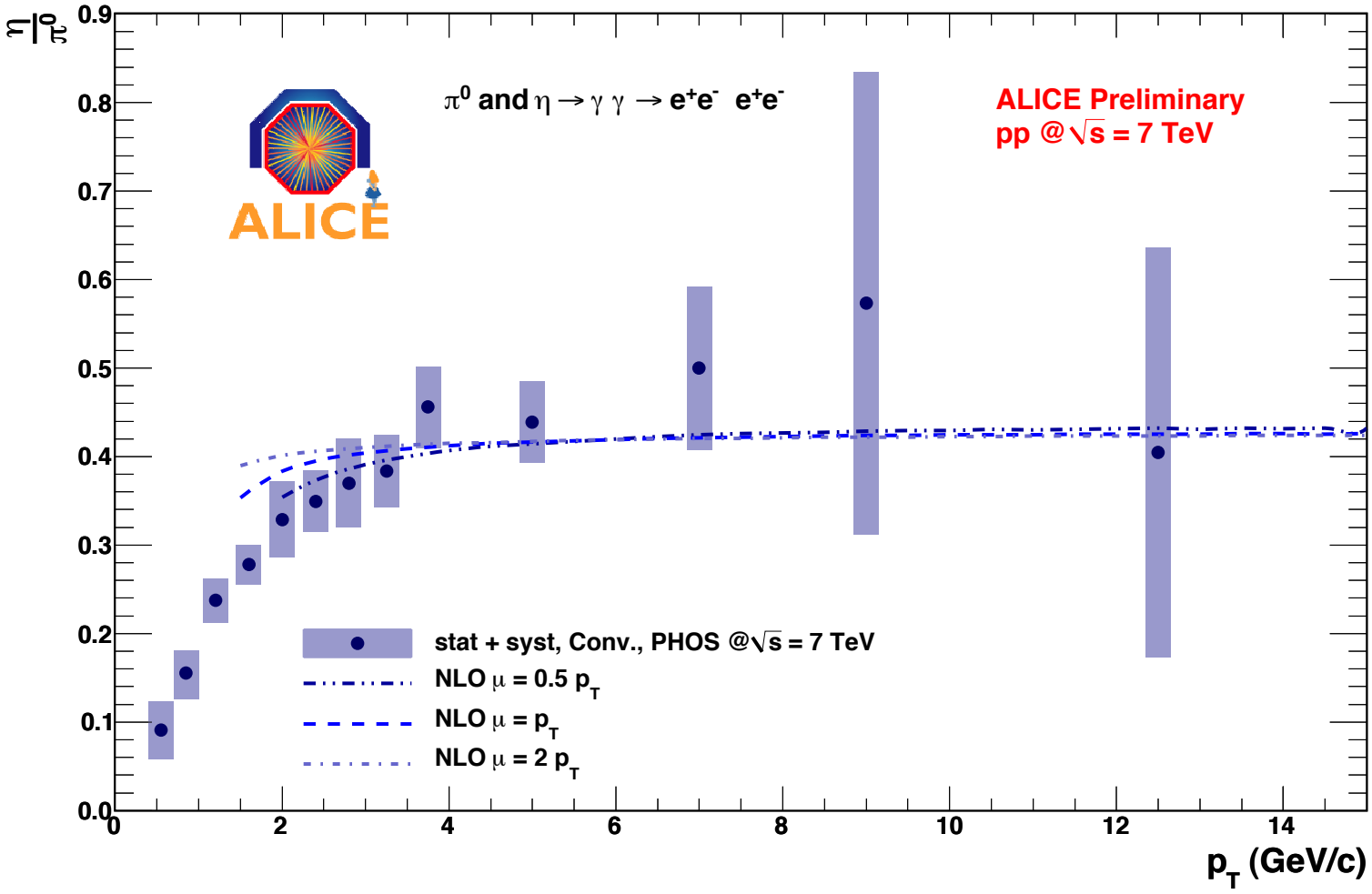
Back up

π^0 with EMCal for pp 7 TeV

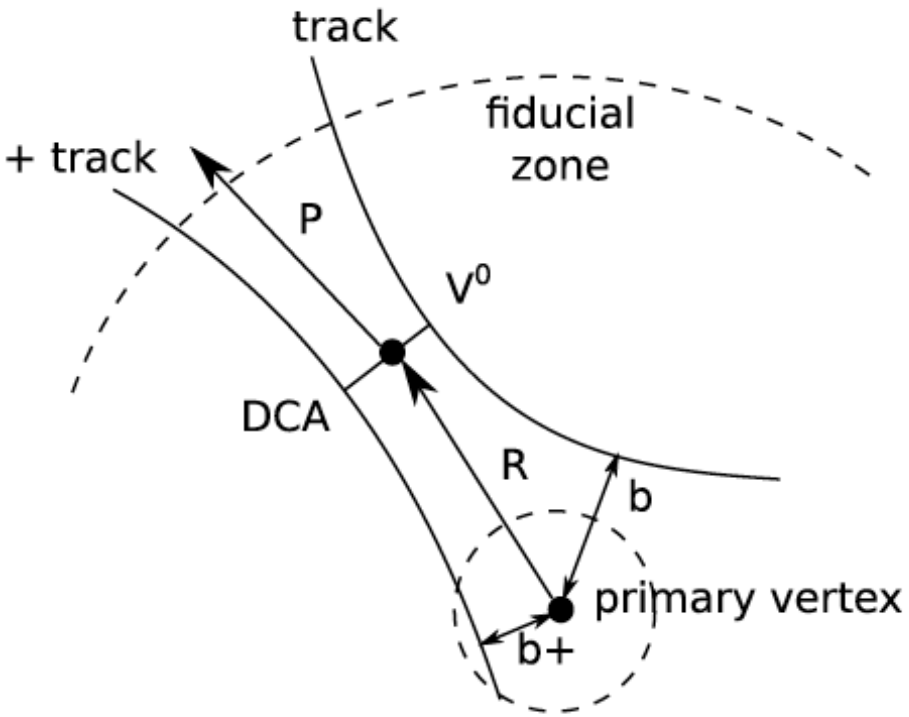




η to π^0 ratio for pp 7 TeV



γ Conversion reconstruction



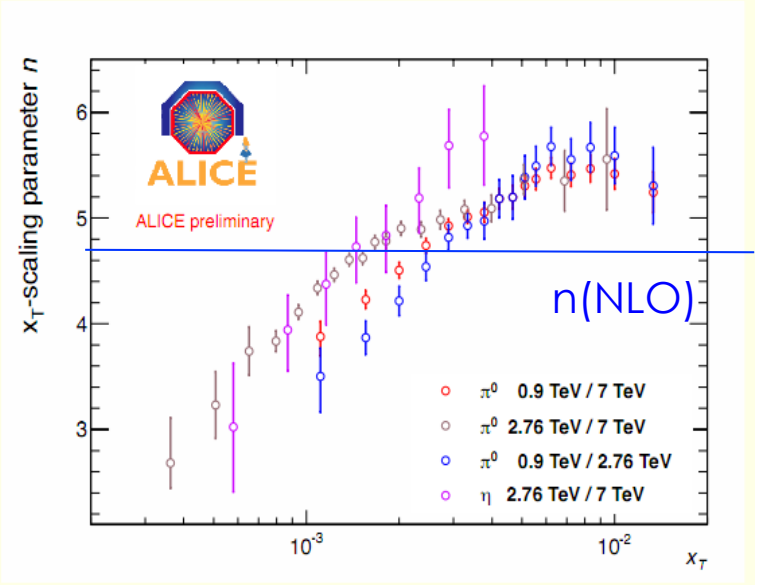
- Reconstruct tracks in ALICE inner trackers (TPC, ITS)
- Calculation of decay point (DCA)
- Electron identification using TPC dE/dx and Time Of Flight
- Reconstruction of V0 decay vertex using Kalman Filter

x_T scaling

- Invariant cross section for a given x_T is proportional to √s
- Deviations from pQCD for $n(x_T)$ observed before LHC – Higher Twist (HT)?

$$E\frac{d^3\sigma}{d^3p} = \left(\sqrt{s}\right)^n F(x_T), \qquad x_T = 2p_T/\sqrt{s}$$

$$n(x_T) = -\ln\left(\frac{\sigma(x_T,\sqrt{s_1})}{\sigma(x_T,\sqrt{s_2})}\right) \Big/ \ln\left(\frac{\sqrt{s_1}}{\sqrt{s_2}}\right)$$

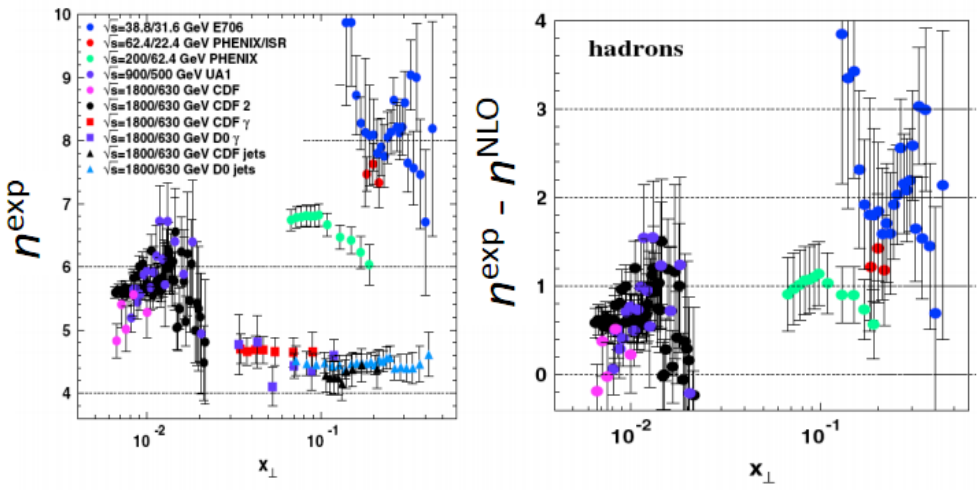


Conclusion : possible contribution from HT

For hadrons $n^{NLO} \approx 4.8$ and $n^{exp} \approx 5.2$

at $x_T = 0.01$ and √s = 0.9,2.76 and 7 TeV

$n(x_T)$ world data (so far)



Arleo et al., PRL 105, 062002 (2010)