CNRS IN2P3 Les deux infinis — UNIVERSITÉ DE NANTES — ECOLE DES MINES DE NANTES

ALICE
A JOURNEY OF DISCOVERY

Subatech

Direct photon measurement in pp @ 7 TeV with EMCal, the ALICE electromagnetic calorimeter

Alexis Mas for the ALICE collaboration

Outline

I - Physics motivation

II – Isolated photons: two measurements with ALICE

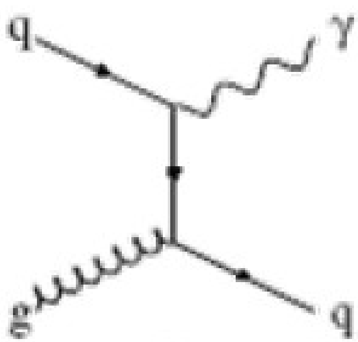
a) Imbalance parameter for parton Fragmentation Function (FF) study

b) Isolated photons to constrain Parton Distribution Functions (PDFs)

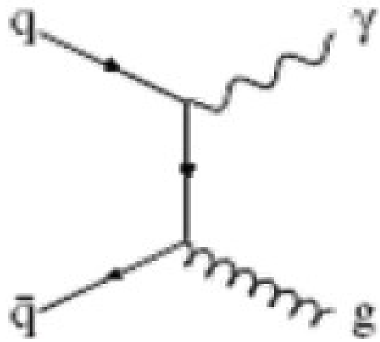
III – Conclusions and outlook

Direct photon production

Direct photons: produced in ultra-relativistic hadron collisions via « hard processes »



Compton scattering



annihilation

Cross section of direct photons can be estimated by QCD calculations:

$$\sigma_{\gamma,\mathrm{direct}} \approx \sum_{a,b} f_{a/A} \times f_{b/B} \times \sigma_{\mathrm{hard\ process}}$$

Parton Distribution Functions (PDFs):
≈ probability of a parton **a, b** to be present in a hadron **A, B** (e. g. proton)

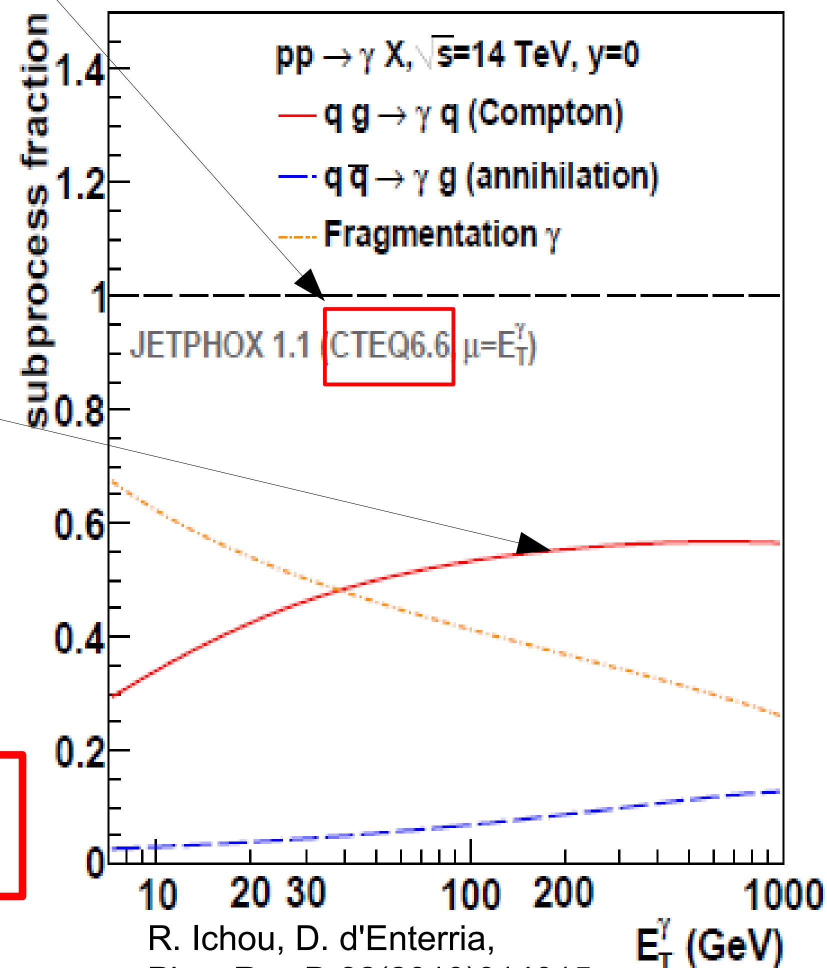
Hard process cross section, calculable with QCD

Direct photon production: PDF constraint

- PDFs constraints ➡ accurate pQCD calculation

- Gluon has one of the least constrained PDF

Compton process is the dominant channel of direct photon production at LHC energy



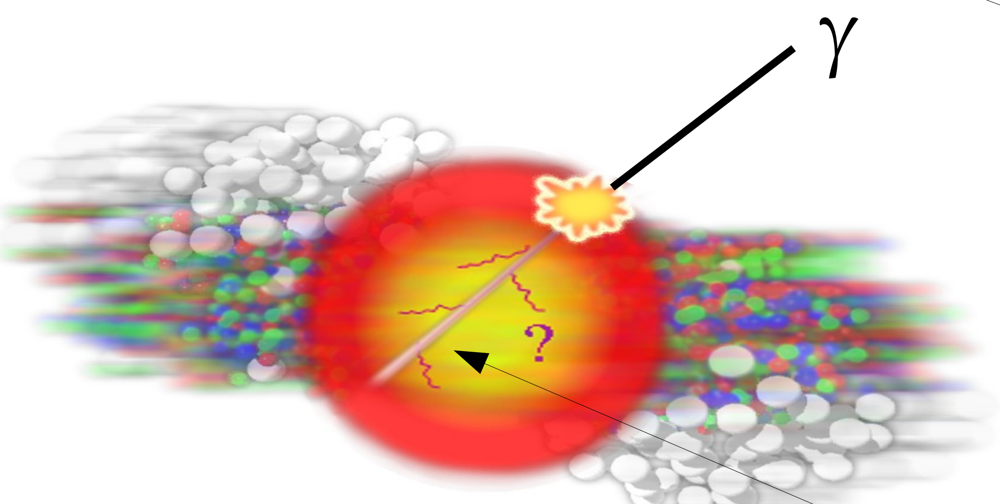
R. Ichou, D. d'Enterria, Phys.Rev D 82(2010)014015

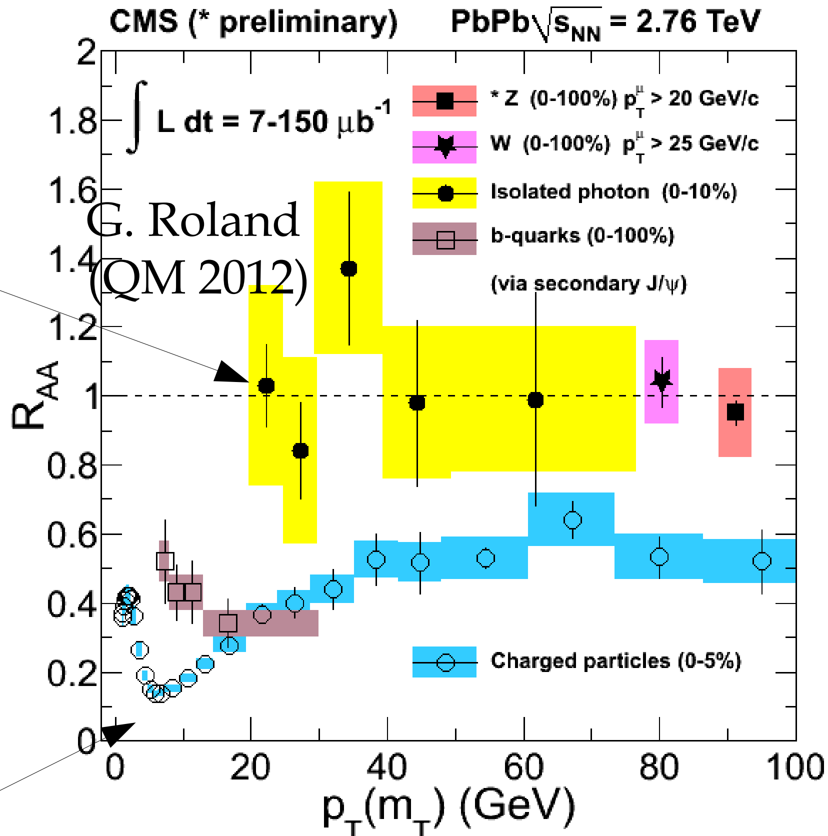
Direct photon measurement gives a strong constraint of gluon PDF

Direct photon production & jet quenching

$$R_{AA}(p_T) = \frac{d^2N_{AA}/dy\,dp_T/\langle N_{bin}\rangle}{d^2\sigma_{pp}/dy\,dp_T/\sigma_{pp}^{inel}}.$$

Photons do not interact strongly with the plasma: **access to the energy of initial hard process**





G. Roland (QM 2012)

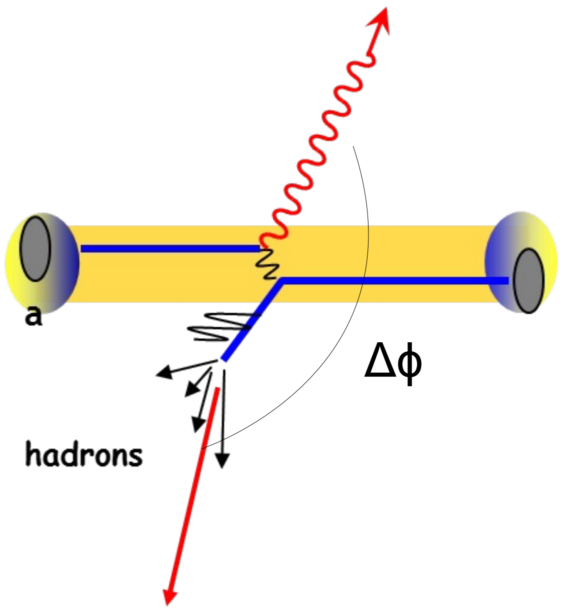
« Jet quenching »: partons loose their energy interacting with the medium **modifying their fragmentation**

Direct photon production: FF constraint

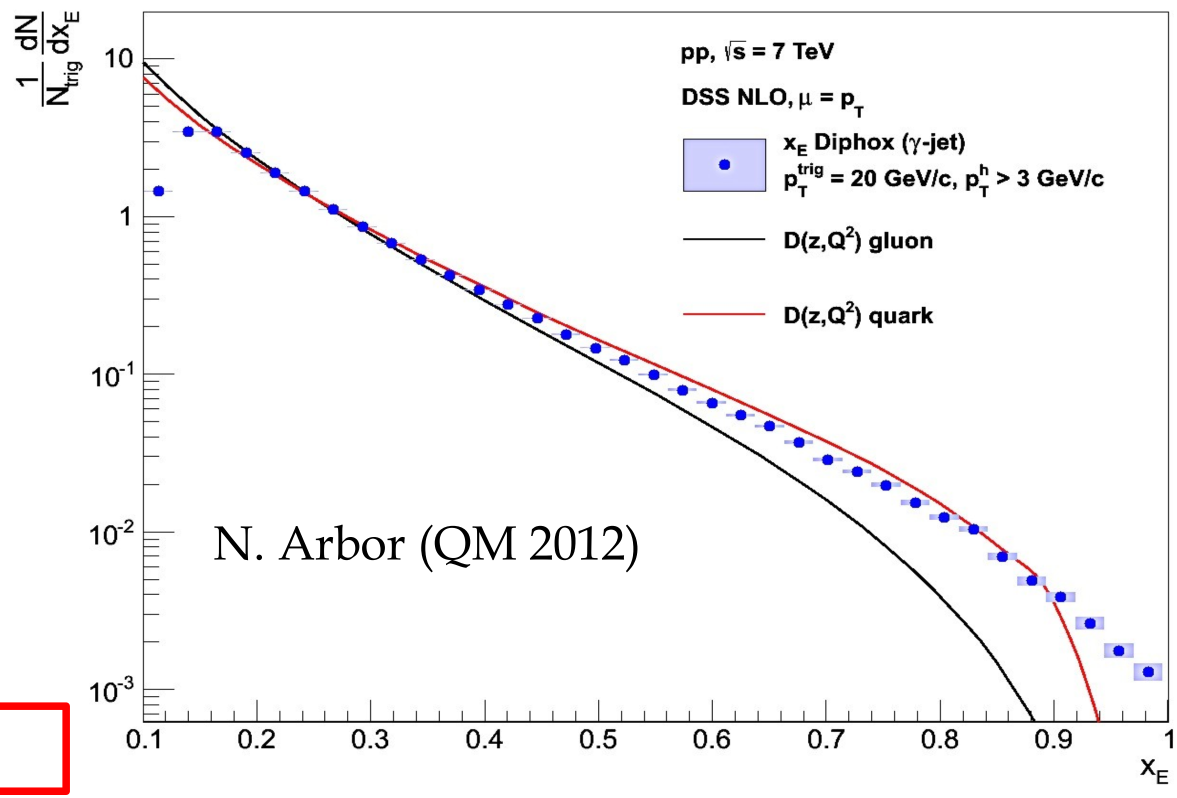
$$x_E = -\frac{p_T^h}{p_T^\gamma}\cos(\Delta\phi)$$

$$x_E \simeq z = \frac{p_T^h}{p^{parton}}$$

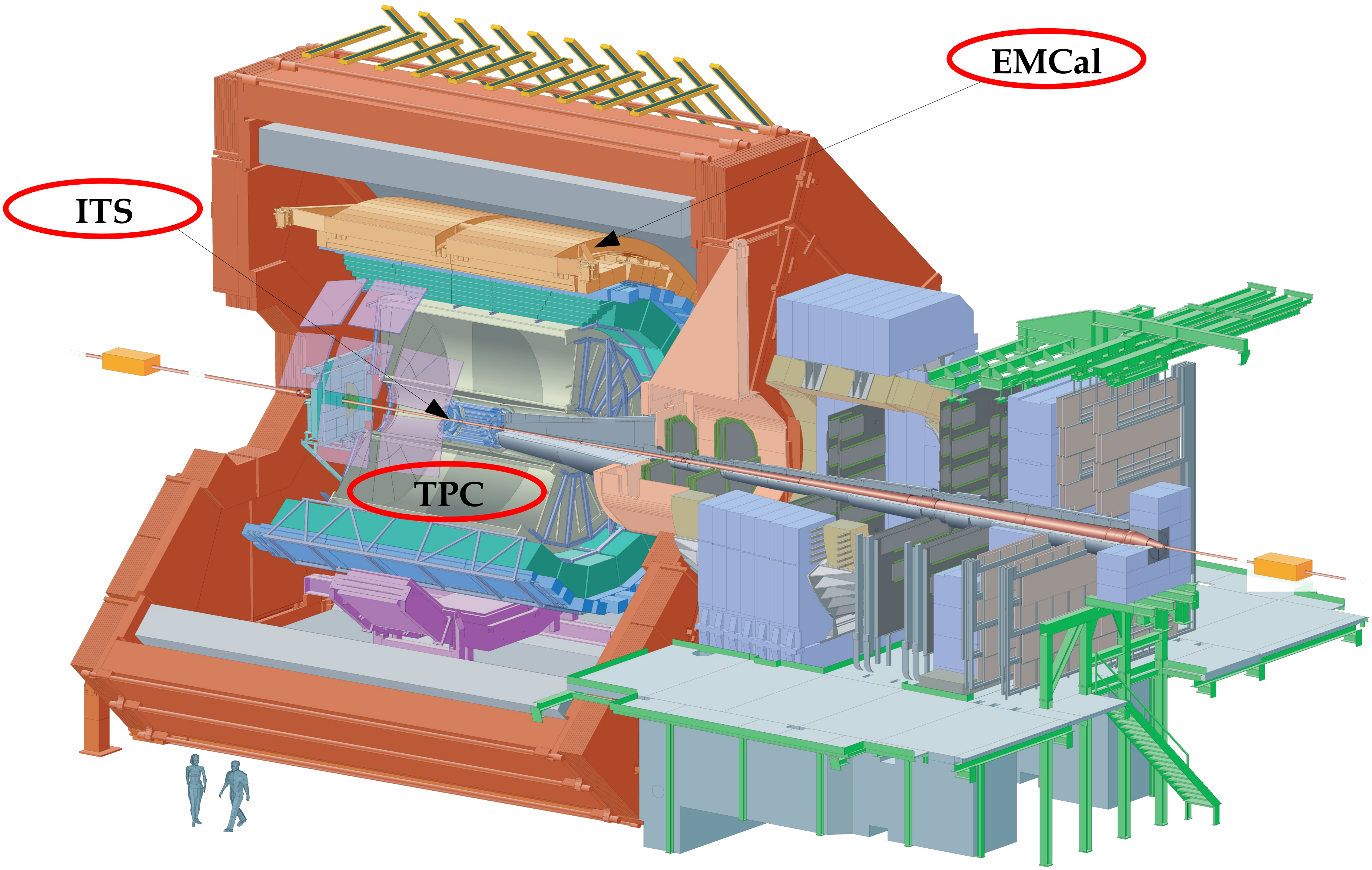
Trigger on photon



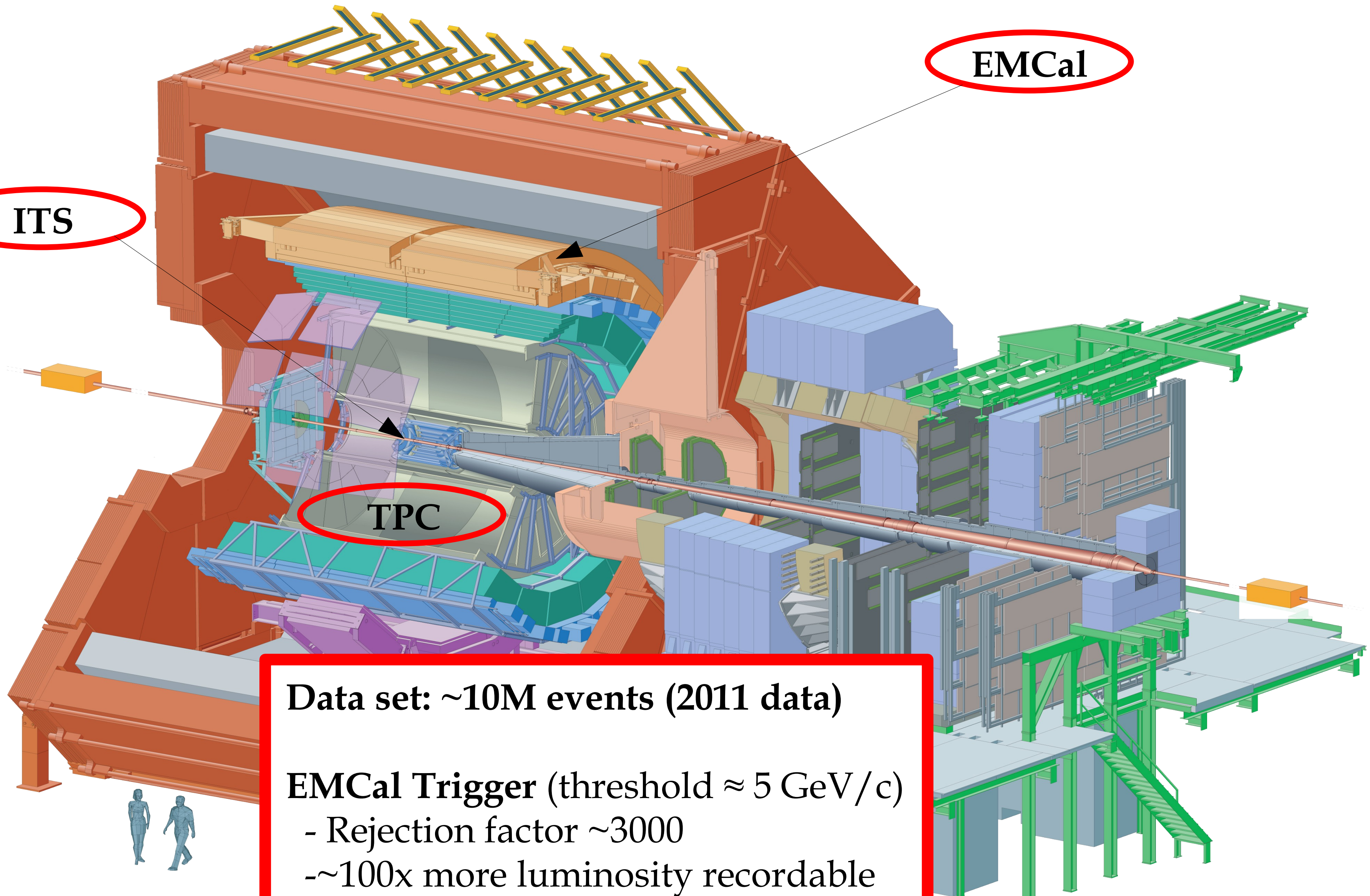
gamma-hadron correlations



ALICE Detector Setup



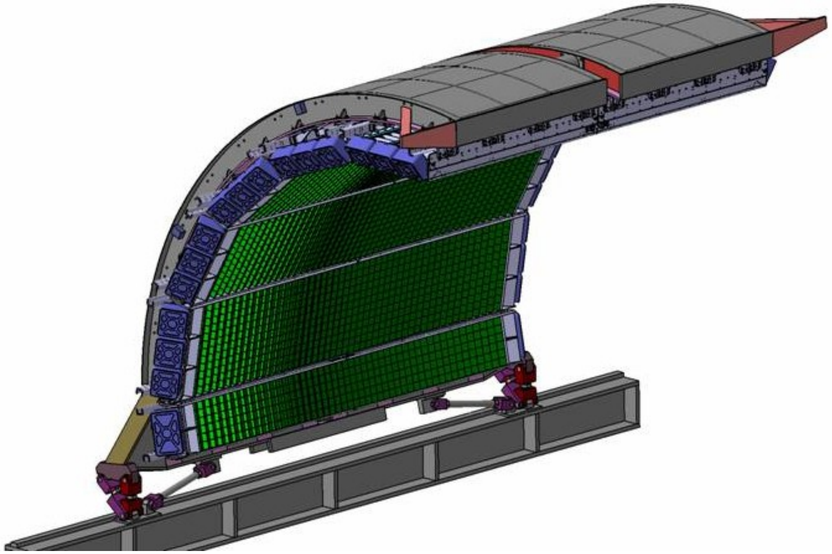
ALICE Detector Setup



Data set: ~10M events (2011 data)

EMCal Trigger (threshold ≈ 5 GeV/c)
- Rejection factor ~3000
- ~100x more luminosity recordable

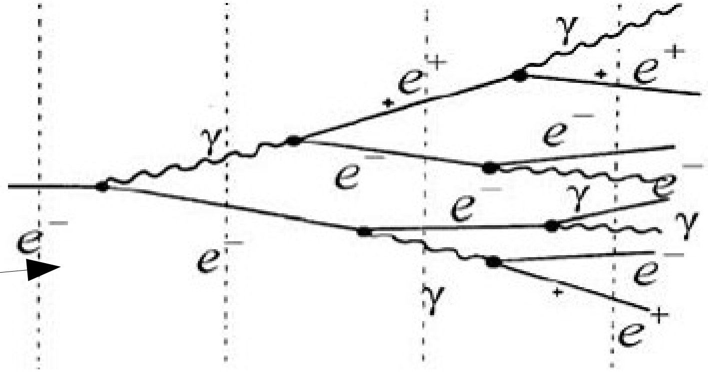
EMCal



- 10 super modules composed of 24x12 modules
- 11520 towers grouped by 4 (module)
- Granularity : $\Delta\eta \times \Delta\varphi$ = 0.014 x 0.014 rad
- 78 layers of scintillator separated by 77 lead layers (~ 19 X_0)
- Acceptance : $\Delta\varphi$ = 100°, $|\eta| < 0{,}7$
- Measurement of particles (electrons, photons) at high p_T

EMCal module

Electromagnetic shower



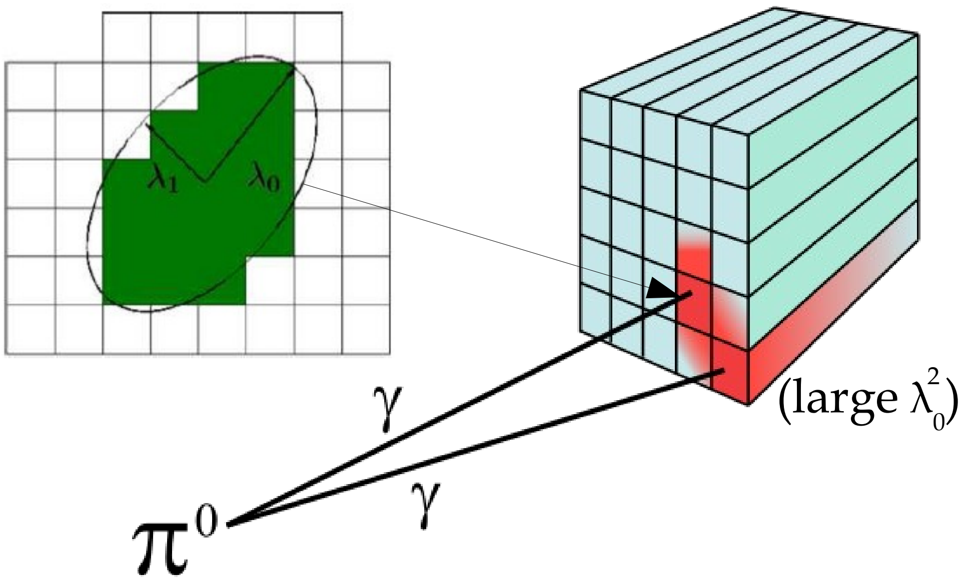
Photon identification

I – Charged particle veto

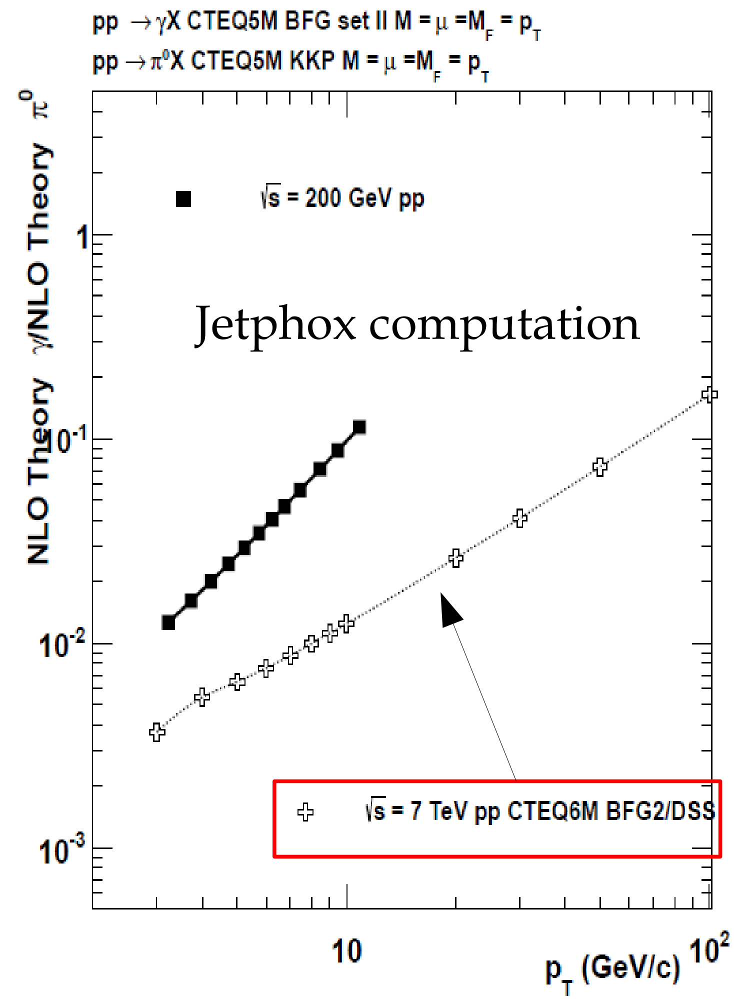
Selection of clusters that are not matching a track ($\Delta\eta > 0.02$ & $\Delta\varphi > 0.03$)

II – Shower shape discrimination ($\lambda_0^2 < 0.27$)

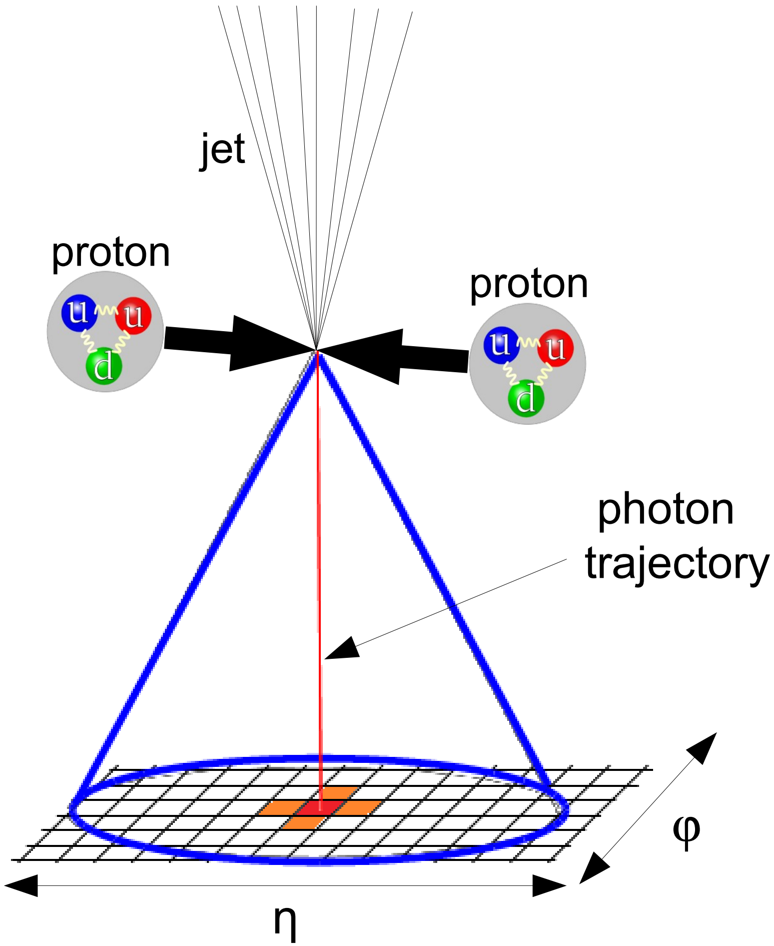
$$\lambda_0^2 = 0.5*(d_{xx} + d_{zz}) + \sqrt{(0.25*(d_{xx} - d_{zz})^2 + d_{xz}^2}$$



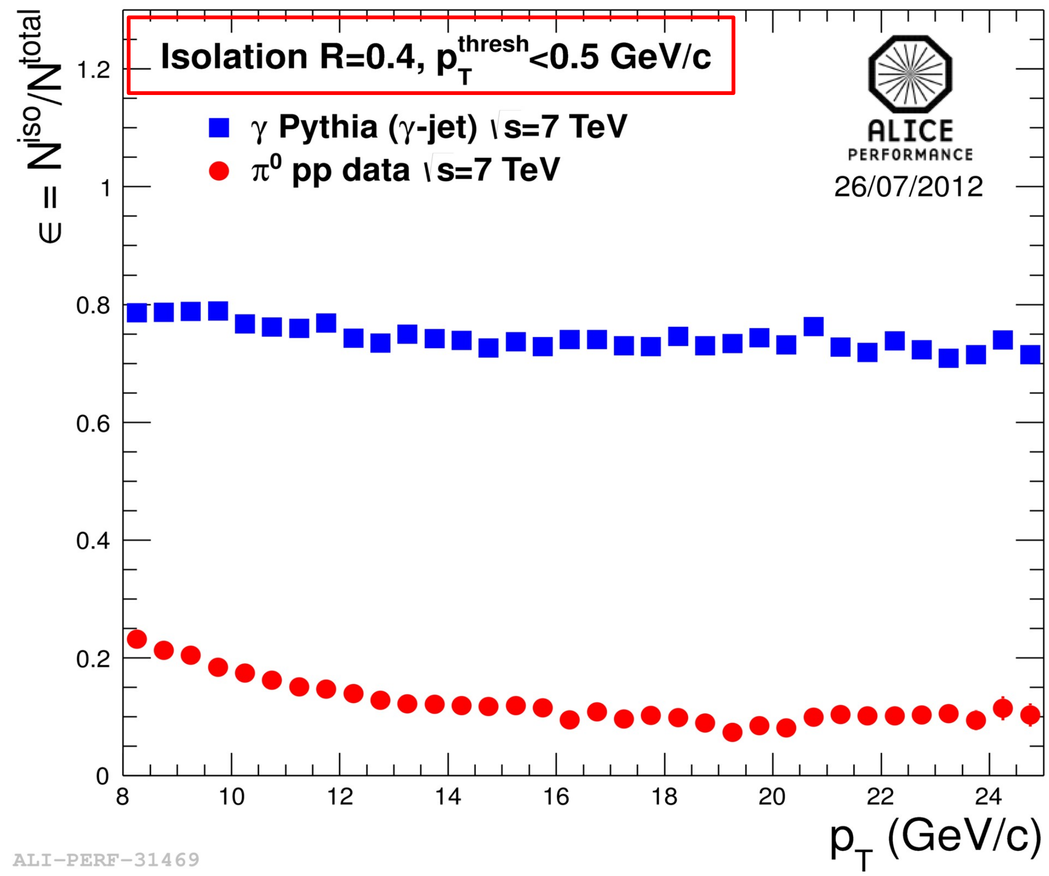
Background: mainly π^0



Photon isolation



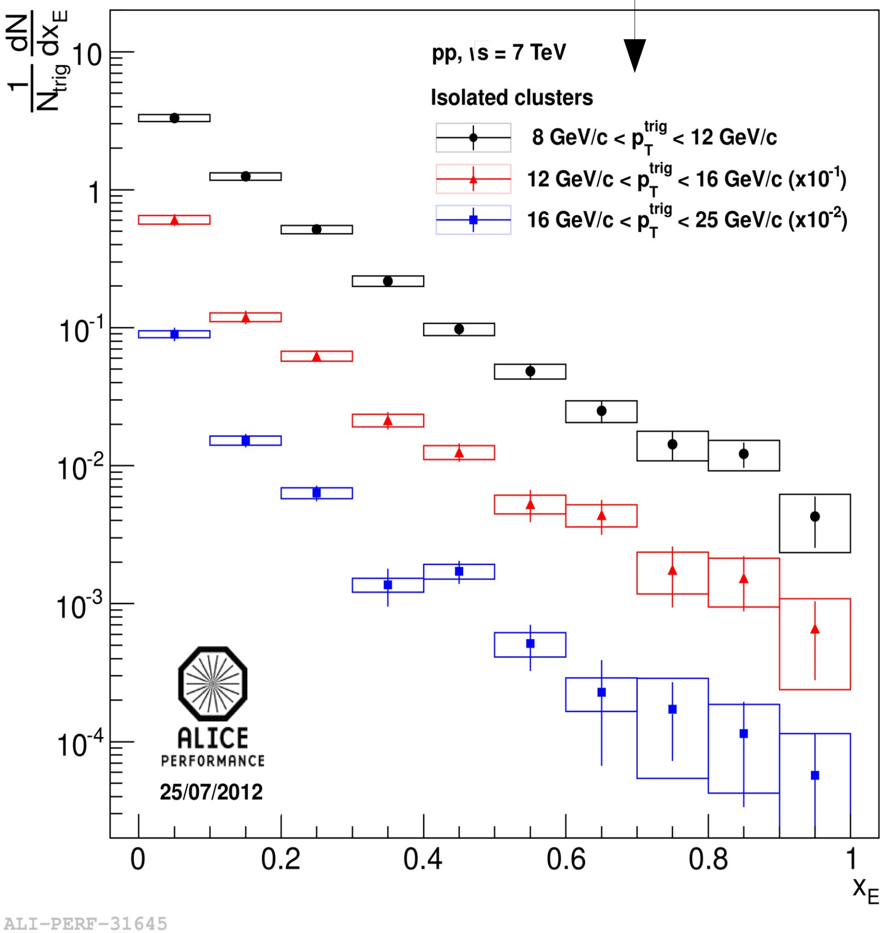
$$R = \sqrt{\Delta^2\varphi + \Delta^2\eta}$$

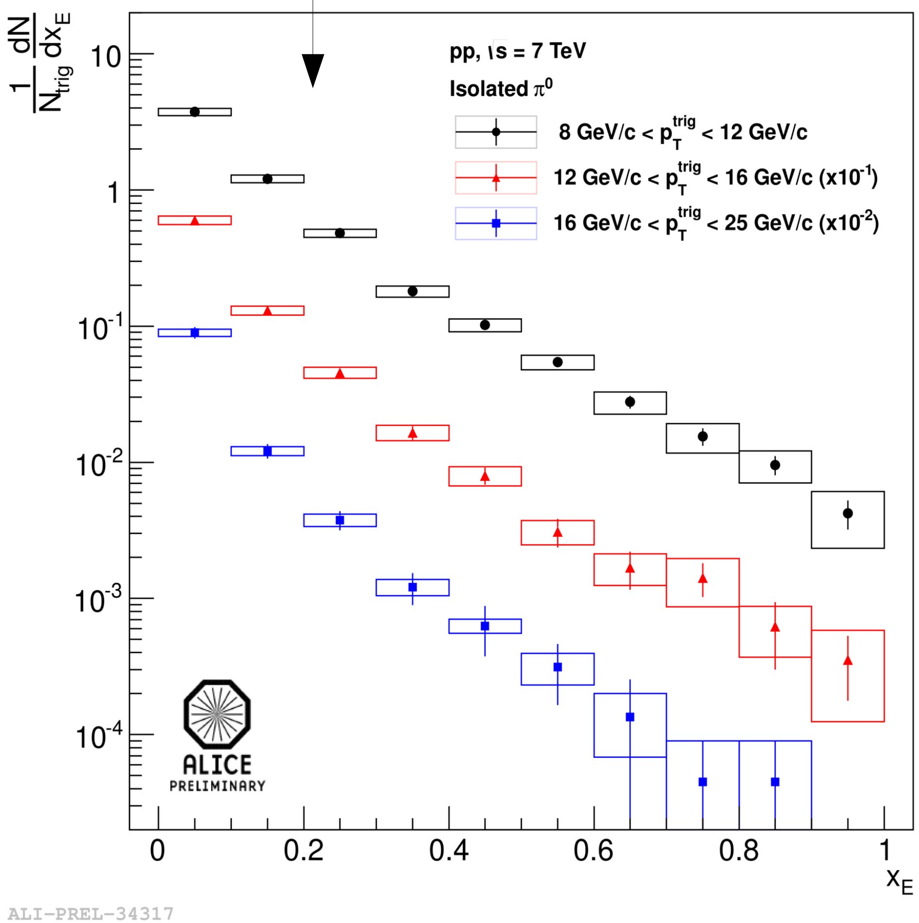


Imbalance parameter measurement

Photon candidate sample = Signal (direct photons) + Background (mainly π^0)

$$x_E^{\gamma\, iso} = \frac{1}{p}\, x_E^{cluster\, iso} - \frac{(1-p)}{p}\, x_E^{\pi^0\, iso}$$





Purity estimation

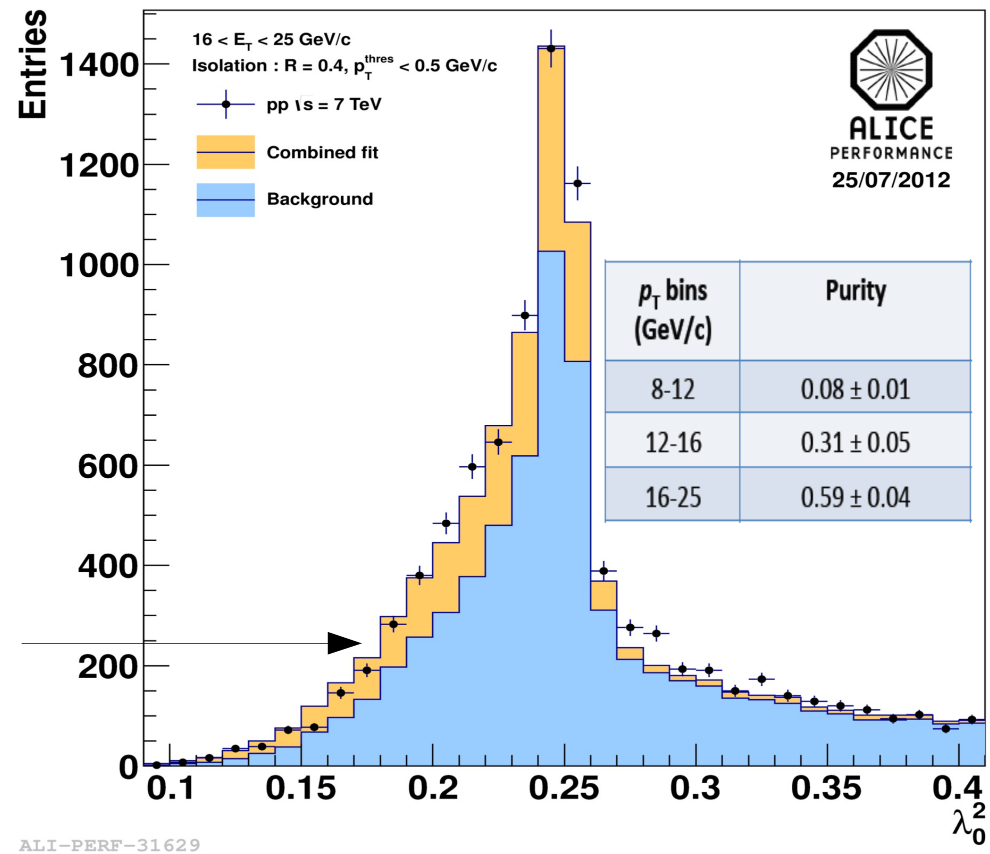
Data driven method using the difference of shower profile (λ_0^2) between direct photons and background:

<u>The 3 following λ_0^2 distributions are needed:</u>

- $(\lambda_0^2)^{sig}$: from gamma-jet simulation
- $(\lambda_0^2)^{bkg}$: from data, particles that fail isolation criterion
- $(\lambda_0^2)^{sig+bkg}$: from data, particles that satisfy isolation criterion

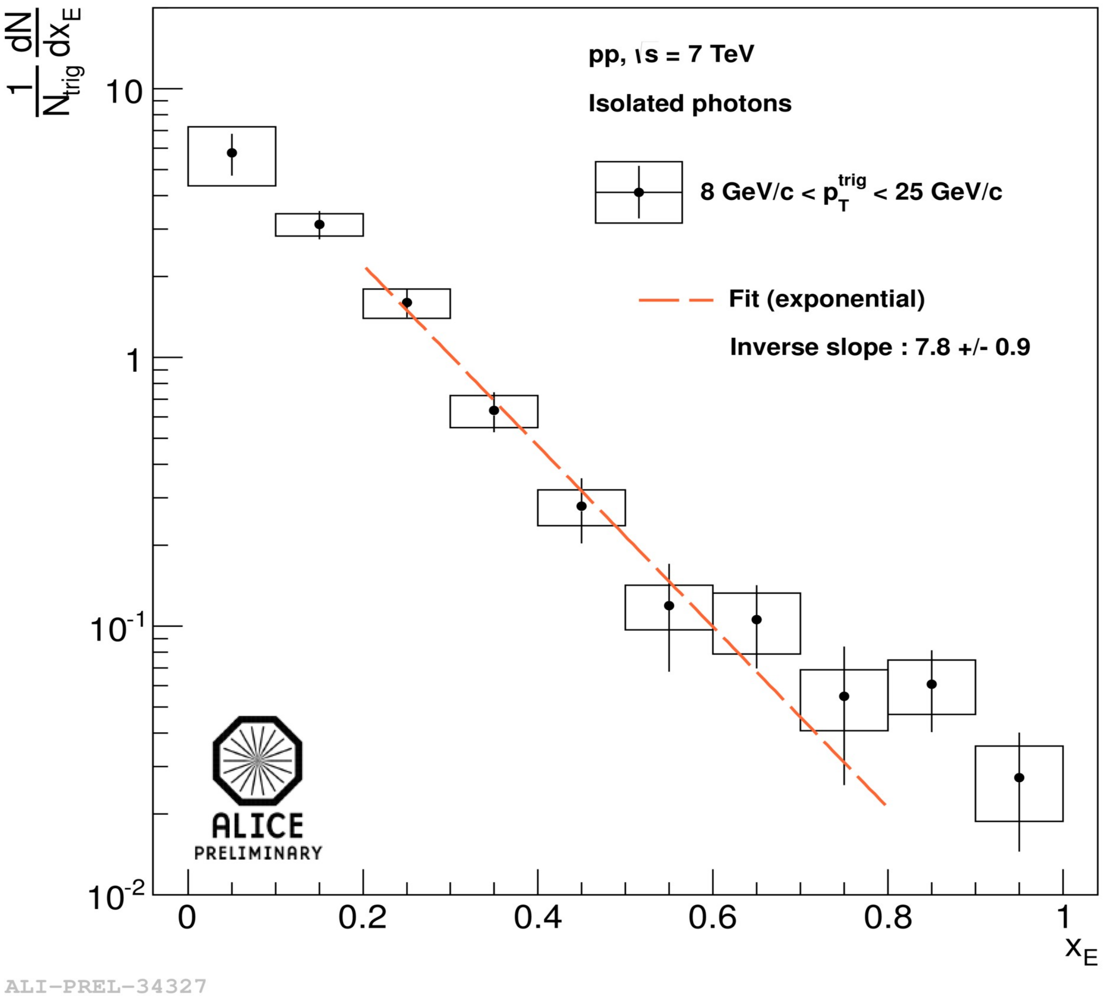
Purity is extracted from combined fit:

$$p = \frac{S}{(S+B)}$$



X_E of isolated photons

$$x_E^{\gamma\, iso} = \frac{1}{p}\, x_E^{cluster\, iso} - \frac{(1-p)}{p}\, x_E^{\pi^0\, iso}$$



First step for comparison of x_E in pp and in Pb-Pb:

Access to medium modified parton fragmentation function

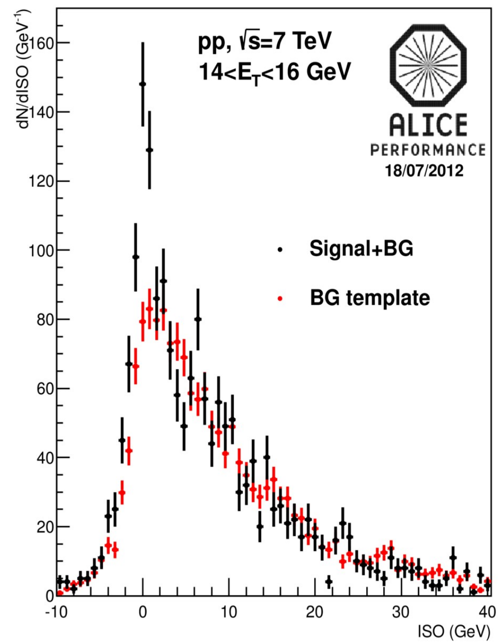
Isolated photons: spectrum measurement

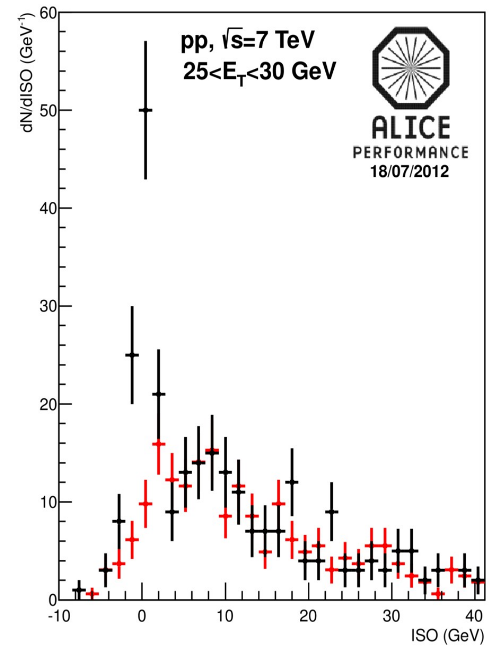
Isolation criterion

$\sum E_{T,\text{in cone}}$ < 2 GeV (R=0.4)

BG template = clusters with $0.5<(\lambda_0^2)<2$

Signal+BG = clusters with $0.1<(\lambda_0^2)<0.3$





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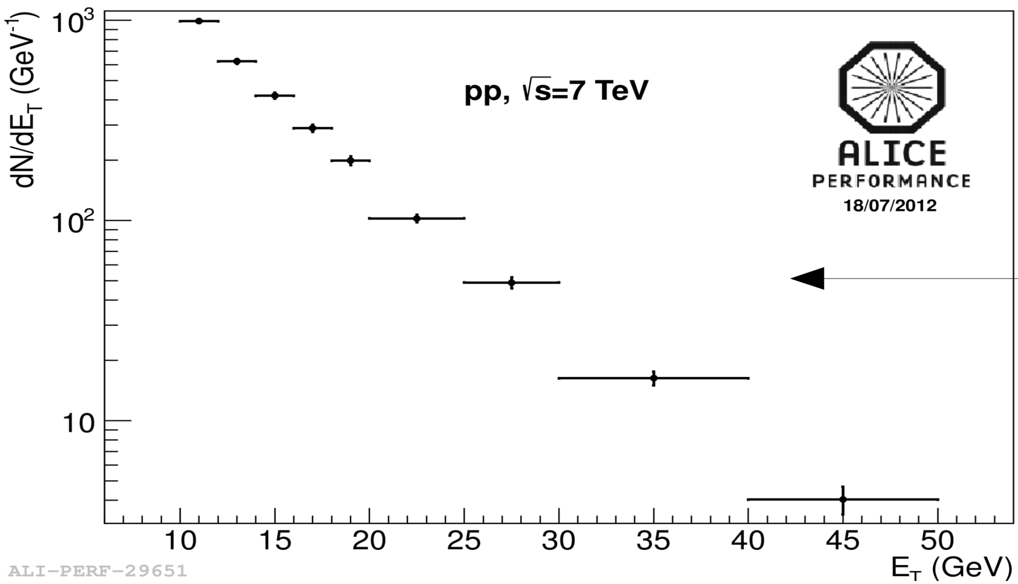
$\text{ISO} = E_T^{cone} - E_T^{UE}$



Signal+BG – BG template
=
Isolated photon raw yield

Toward a cross-section of direct photons

$$\sigma(pp \rightarrow \gamma_{dir} + X) = \frac{N_{\gamma}^{iso} \times p}{(\varepsilon \otimes \mathcal{A})^{reco\&iso} \times \varepsilon_{trigger} \times \mathcal{L}_{int}}$$

- $N_{\gamma}^{iso}, \; p$:
- $\mathcal{L}_{int}$:
- $(\varepsilon \otimes \mathcal{A})^{reco\&iso}, \varepsilon_{trigger}$:
- Systematics uncertainties estimation

Toward a cross-section of direct photons

$$\sigma(pp \rightarrow \gamma_{dir} + X) = \frac{N_{\gamma}^{iso} \times p}{(\varepsilon \otimes \mathcal{A})^{reco\&iso} \times \varepsilon_{trigger} \times \mathcal{L}_{int}}$$

- $N_{\gamma}^{iso}, \; p$: **shown today**
- $\mathcal{L}_{int}$:
- $(\varepsilon \otimes \mathcal{A})^{reco\&iso}, \varepsilon_{trigger}$:
- Systematics uncertainties estimation

Integrated luminosity

Integrated luminosity for EMCal triggered data has been determined:

$$\mathcal{L}_{int} = \frac{N_{evt}}{\varepsilon_{MB} \times \sigma_{MB} \times R}$$

Rejection factor computed from minimum bias data:

$$R = \frac{N_{MB\&EMC}}{P \times N_{MB}}$$

MB events with EMCal trigger input

Pileup correction factor

Total number of MB events

$$\mathcal{L}_{int} = 380\, nb^{-1} \pm\ 40\ (stat)$$

Toward a cross-section of direct photons

$$\sigma(pp \rightarrow \gamma_{dir} + X) = \frac{N_{\gamma}^{iso} \times p}{(\varepsilon \otimes \mathcal{A})^{reco\&iso} \times \varepsilon_{trigger} \times \mathcal{L}_{int}}$$

- N_{γ}^{iso}, p: shown today ✓
- $\mathcal{L}_{int} = 380\, nb^{-1} \pm 40\ (stat)$ ✓
- $(\varepsilon \otimes \mathcal{A})^{reco\&iso}$, $\varepsilon_{trigger}$:
- Systematics uncertainties estimation

Toward a cross-section of direct photons

$$\sigma(pp \rightarrow \gamma_{dir} + X) = \frac{N_{\gamma}^{iso} \times p}{(\varepsilon \otimes \mathcal{A})^{reco\&iso} \times \varepsilon_{trigger} \times \mathcal{L}_{int}}$$

- $N_{\gamma}^{iso},\ p$: shown today ✓
- $\mathcal{L}_{int} = 380\, nb^{-1} \pm 40\ (stat)$ ✓
- $(\varepsilon \otimes \mathcal{A})^{reco\&iso}, \varepsilon_{trigger}$:
- Systematics uncertainties estimation

} **Analyzes ongoing**

Conclusions & outlook

Conclusions

- Shape of fragmentation function in pp at 7 TeV via x_E measurement for $p_T \in [8; 25]$ GeV/c : baseline for Pb-Pb

- Isolated photon raw spectrum for $p_T \in [10; 50]$ GeV/c

Outlook

- Study modification of fragmentation function in medium (x_E measurement in Pb-Pb)

- Constraint gluon PDF with isolated photon cross section in pp @ 7 TeV

	p_T range (GeV/c)	η range	reference
CMS	20 – 300	-1.45 - 1.45	PRL106(2011)082001
ATLAS	45 - 400	-1.37 - 1.37	Phys.Lett. B706(2011)150
ALICE (with e+ e-)	0.5 - 11	-0.9 - 0.9	ALICE
ALICE (in EMCal)	10 - 50	-0.3 - 0.3	ALICE

BACK UP

Purity computation: 2nd method

Data driven method: based on the difference of the isolation probability between photons and background:

The 3 following isolation efficiencies are needed:

- ε^{sig} : from gamma-jet simulation

- ε^{bkg}: = $\frac{B^{iso}}{B^{tot}}$ from data, particles selected with: $0.35 < \lambda_0^2 < 1.5$

- $\varepsilon^{sig+bkg}$ = $\frac{(B+S)^{iso}}{(B+S)^{tot}}$ from data, particles selected with: $0.1 < \lambda_0^2 < 0.27$

We can extract purity: $$p = \frac{\epsilon^{sig}(\epsilon^{sig+bkg} - \epsilon^{bkg})}{\epsilon^{sig+bkg}(\epsilon^{sig} - \epsilon^{bkg})}$$

Purity computation: 2nd method

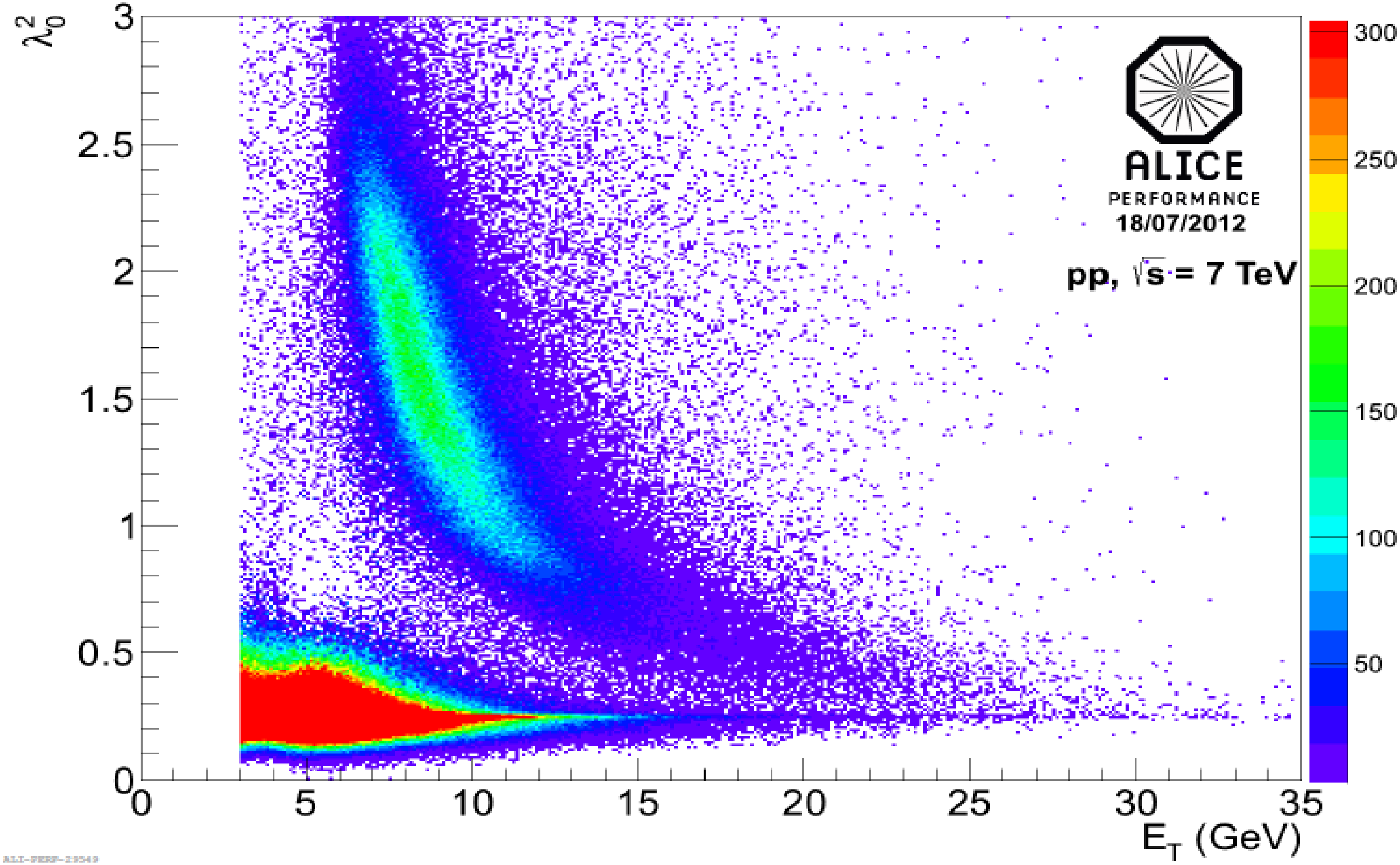
assumption: $(S + B) \times \epsilon^{sig+bkg} = B \times \epsilon^{bkg} + S \times \epsilon^{sig}$

$$\frac{S}{S+B} = \frac{\epsilon^{sig+bkg} - \epsilon^{bkg}}{\epsilon^{sig} - \epsilon^{bkg}}$$

$$p = \frac{S^{iso}}{S^{iso} + B^{iso}} = \frac{S \times \epsilon^{sig}}{S \times \epsilon^{sig} + B \times \epsilon^{bkg}} = \frac{\frac{S}{S+B} \times \epsilon^{sig}}{\frac{S}{S+B} \times \epsilon^{sig} + \frac{B}{S+B} \times \epsilon^{bkg}}$$

$$p = \frac{\epsilon^{sig}(\epsilon^{sig+bkg} - \epsilon^{bkg})}{\epsilon^{sig+bkg}(\epsilon^{sig} - \epsilon^{bkg})}$$

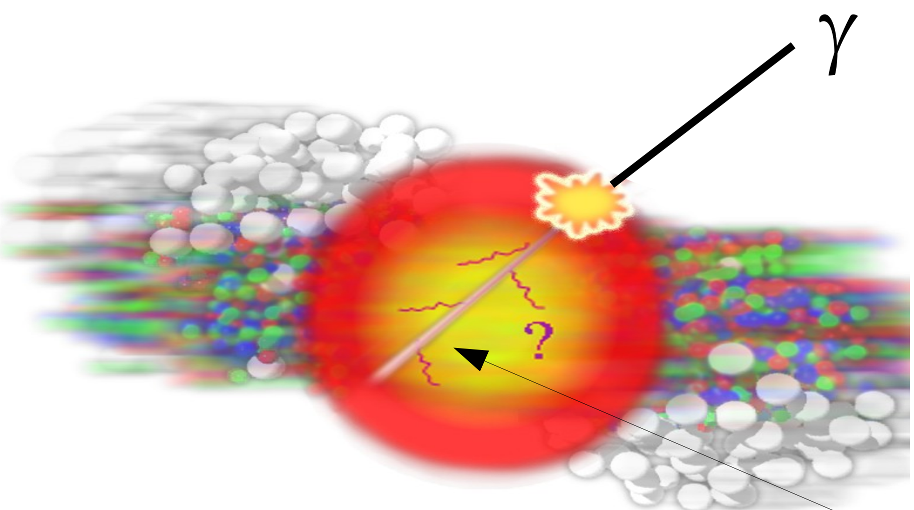
Shower shape of clusters after TM:



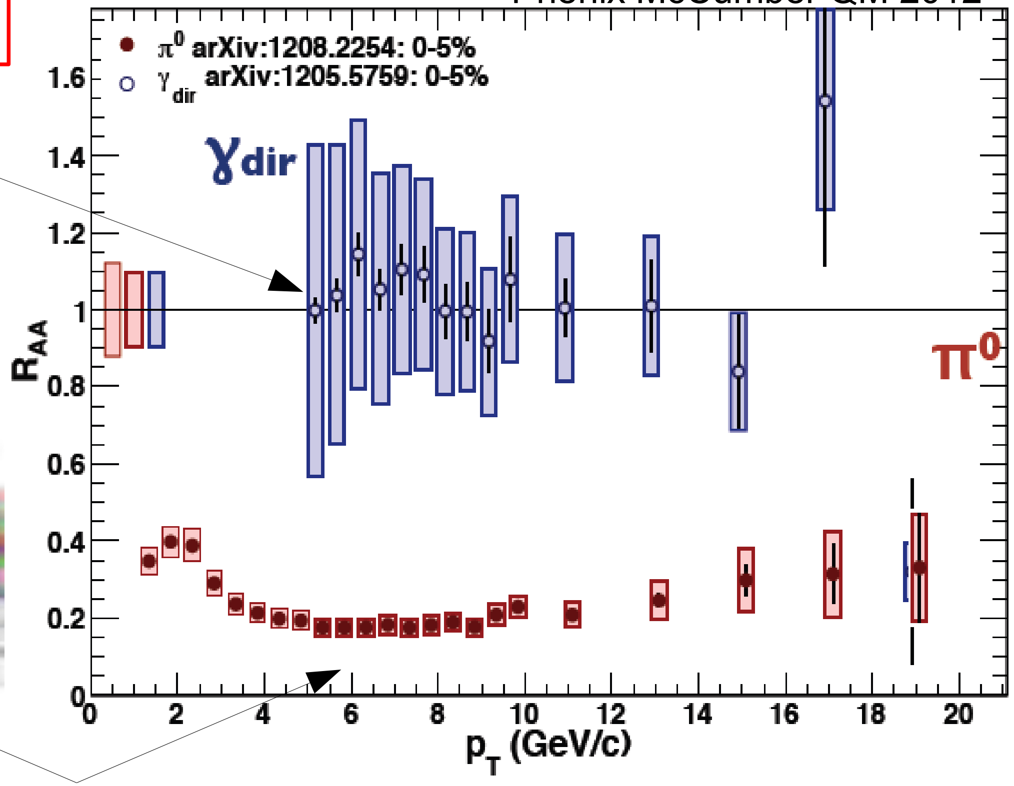
Direct photon production & jet quenching

$$R_{AA}(p_T) = \frac{d^2N_{AA}/dy\,dp_T/\langle N_{bin}\rangle}{d^2\sigma_{pp}/dy\,dp_T/\sigma_{pp}^{inel}}.$$

Photons do not interact strongly with the plasma: **access to the energy of initial hard process**

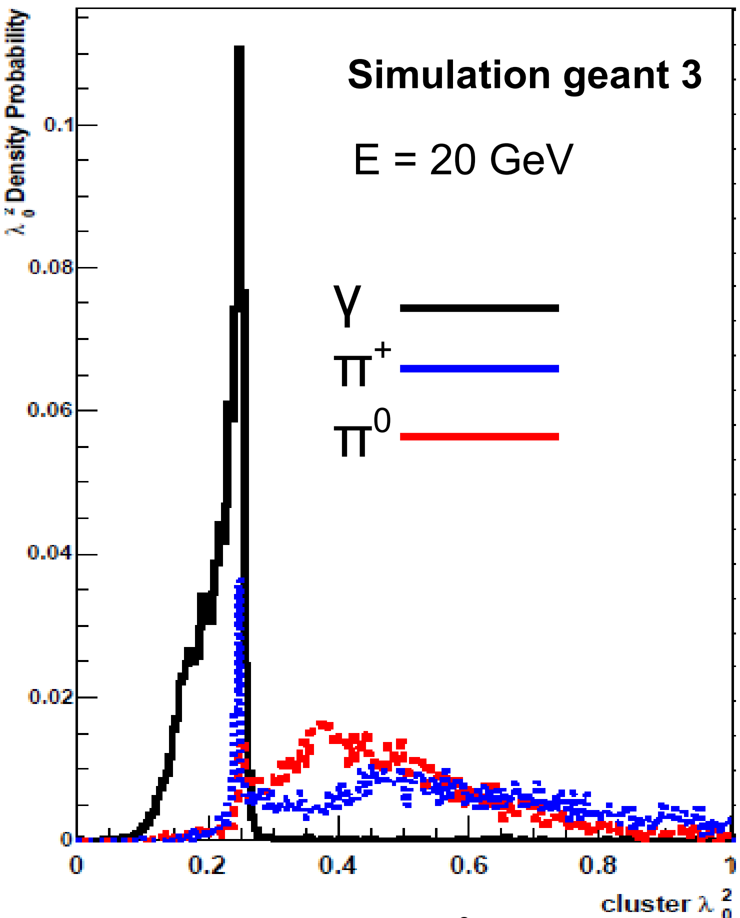


Phenix McCumber QM 2012



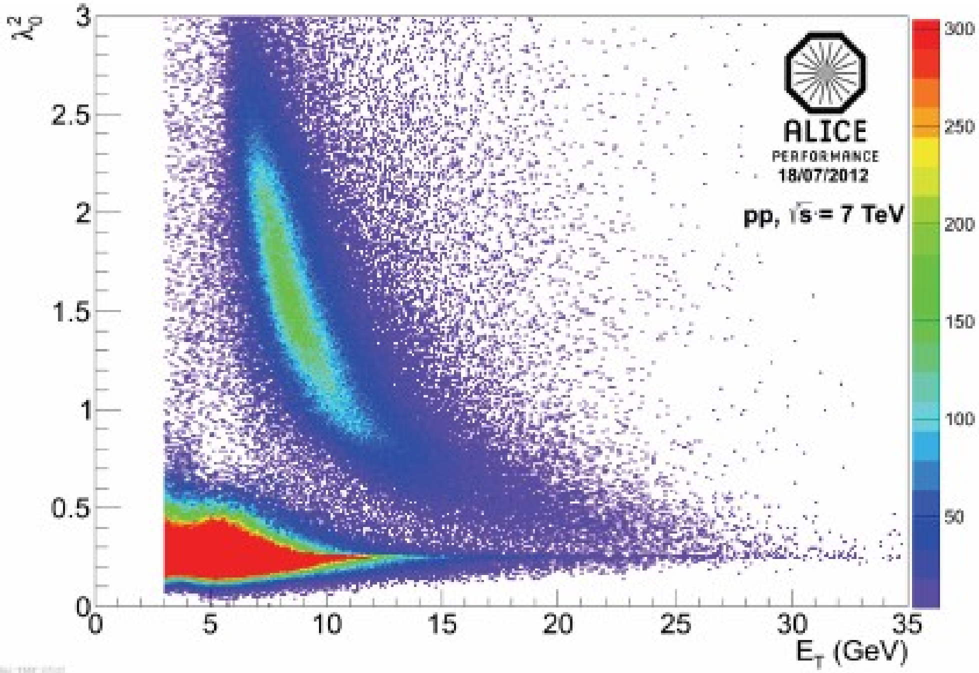
« Jet quenching »: partons loose their energy interacting with the medium **modifying their fragmentation**

Photon identification

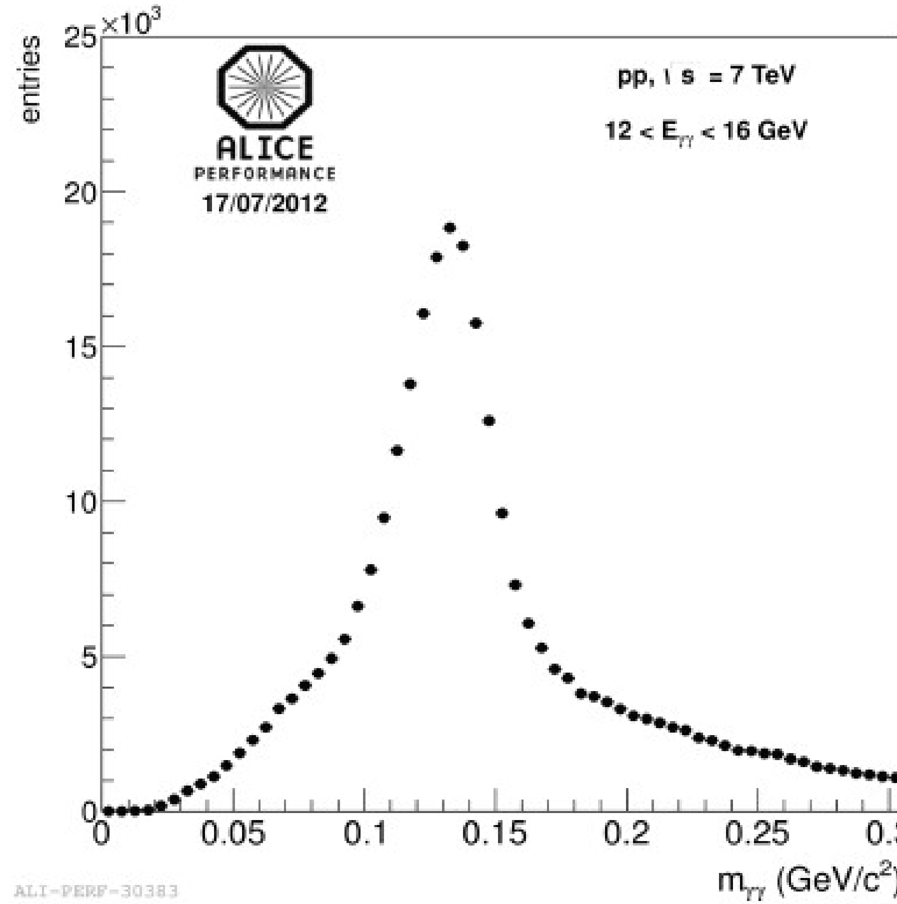


Density of probability of λ_0^2

π^0 identification



Shower shape from neutral clusters



Invariant mass of splitted clusters

QA cuts/selection

Clusterizer V1 with:

- Minimum energy of the seed: 100 MeV
- Minimum energy of a cell: 50 MeV

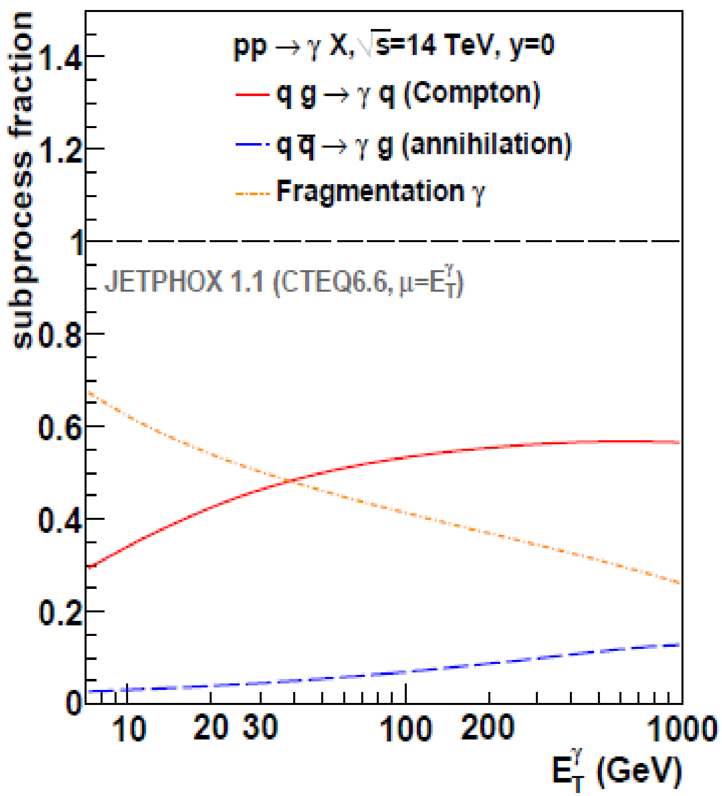
Cluster selection:

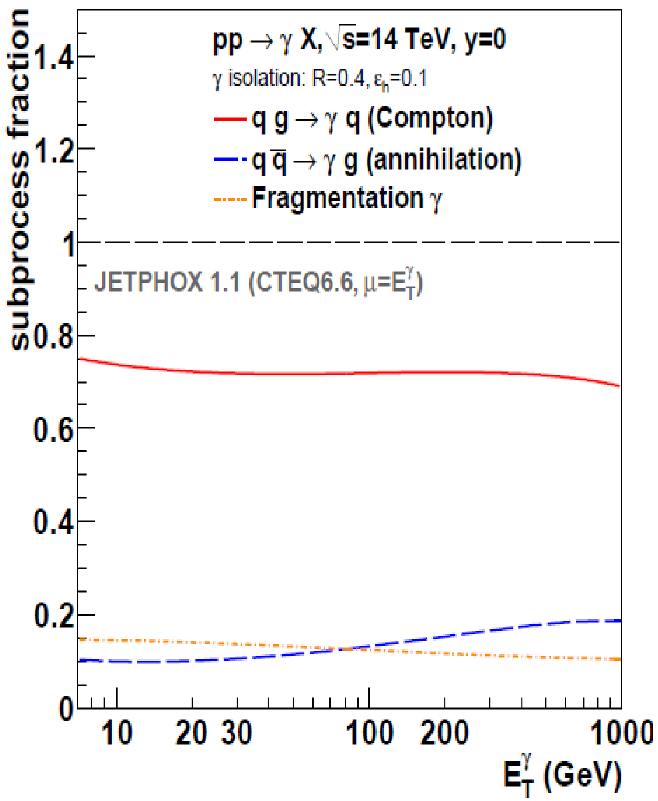
- Eclus > 0.3 GeV
- Ncells/cluster: at least 2 cells
- Distance to bad channel: at least 2 cells
- Exotic clusters removed

Photon selection:

We only consider **clusters > 8 GeV as photon candidates** to be far from trigger threshold (5.5 GeV except first runs which have 4 GeV threshold)

Fragmentation photon and isolation





R. Ichou, D. d'Enterria, Phys.Rev D 82(2010)014015

L0 counter pile-up

In one bunch crossing (BC) we can have several p-p (Pb-Pb) collisions but the L0 counter will only count one event. To correct for this effect we use P which corresponds to the average number of MB event per L0 count, with Poisson law assumption we obtain:

Average number of MB event per BC

$$P = \frac{\mu^{MB}}{1 - e^{-\mu^{MB}}} \simeq 1 + \frac{\mu^{MB}}{2}$$

$$\mu^{MB} = -ln(1 - \frac{R_{L0_b^{MB}}}{nBC_{|orbit}\nu_{LHC}})$$

Bunch crossing not masked per orbit

MB $L0_b$ rate

LHC frequency