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

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Outline

I - Physics motivation for direct photon measurement

II – Direct photon measurement with EMCal

III – Normalization

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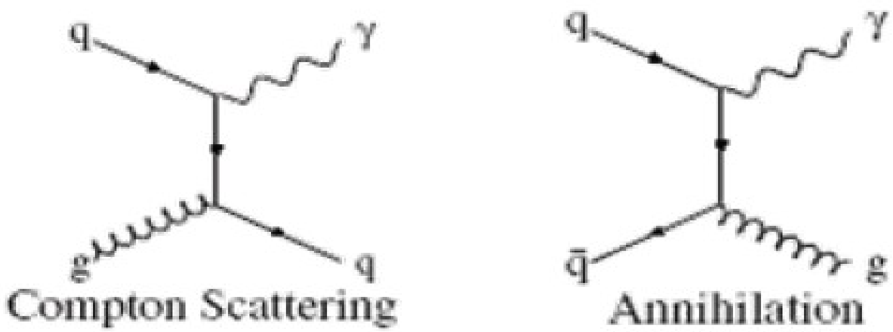
Direct photon production

Direct photons are produced in ultra-relativistic hadron collisions. They are produced via « hard processes » (strong interactions between initial partons):



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

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

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

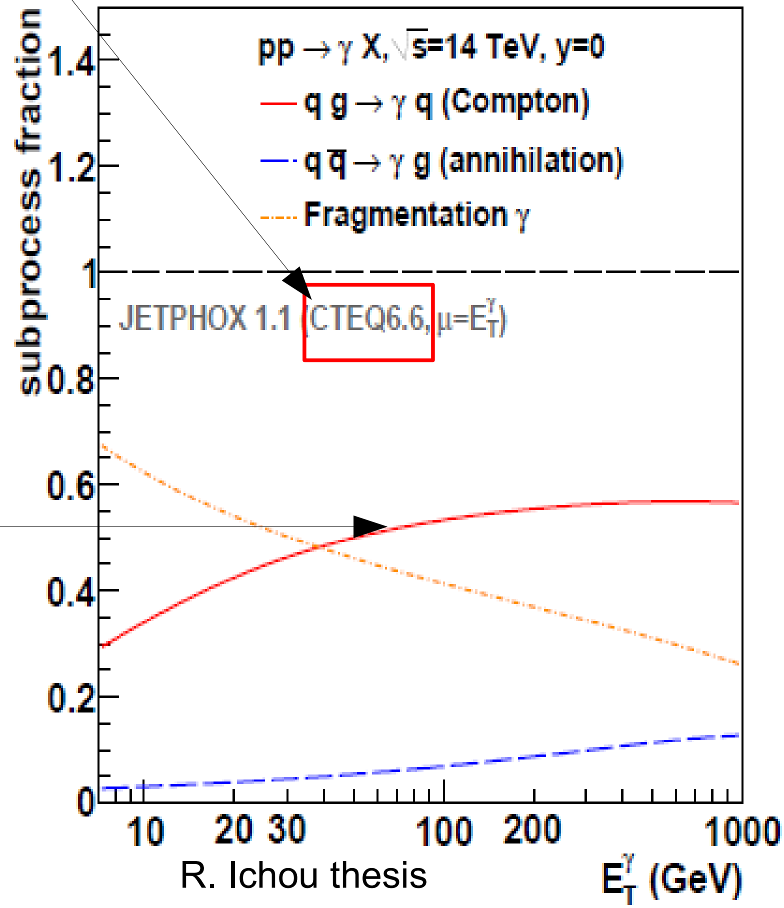
Hard process cross section, calculable with QCD

Physics motivation

- PDFs are essential to any pQCD computation, any improvement in their determination will decrease theoretical uncertainties

- Direct photon is a good observable to constrain PDFs, particularly the gluon one which is presently one of the least constrained PDF

Compton process which directly involves a gluon is the dominant channel of direct photon production at LHC energy

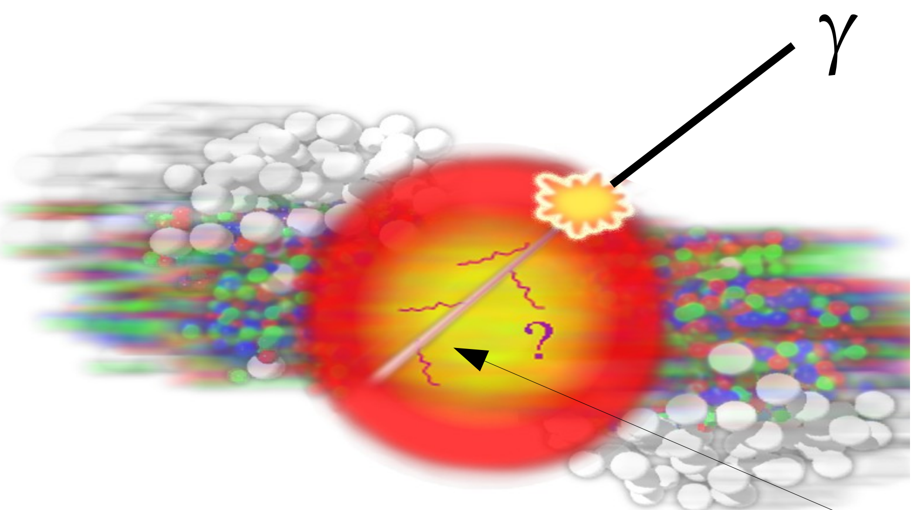


R. Ichou thesis

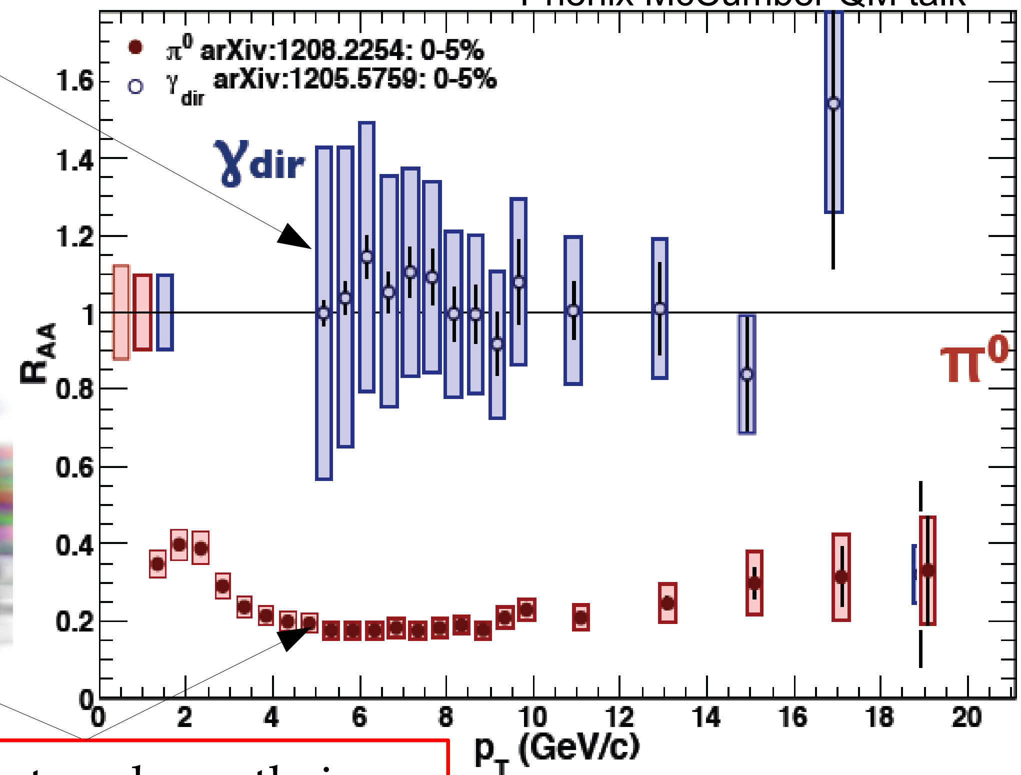
Physics motivation

Direct photon is of high interest also to study energy loss mechanisms of hadrons in quark gluon plasma (expected in HI collision)

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



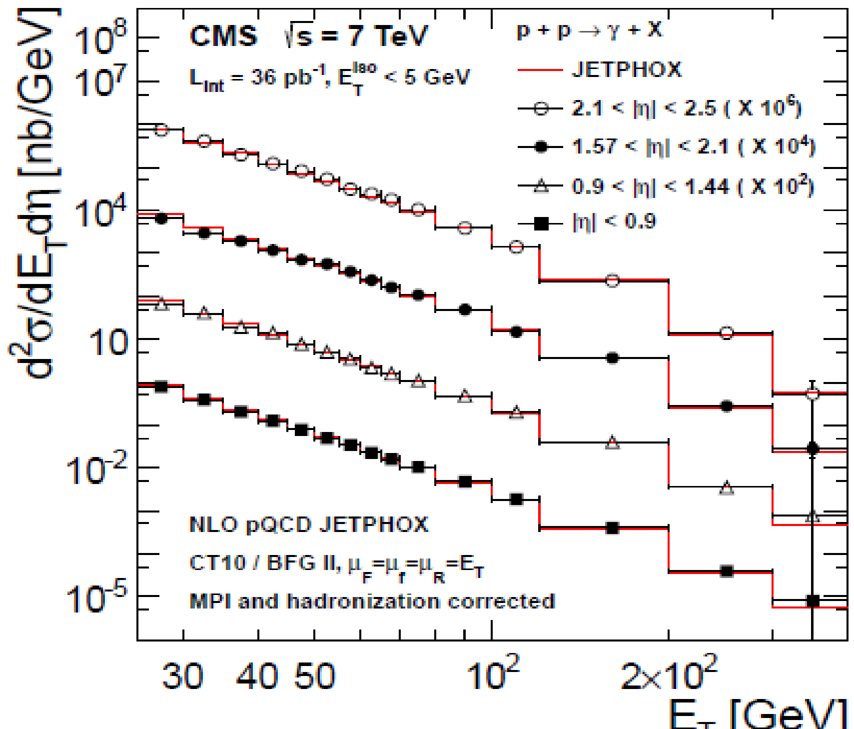
Phenix McCumber QM talk



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

Isolated/direct photon measurement @ LHC

	p_T range (GeV/c)	η range	reference
CMS	20 – 300	-1.45 - 1.45	PRL106,082001 2011
ATLAS	45 - 400	-1.37 - 1.37	Phys.Lett. B706(2011)150
ALICE (with e+ e-)	0.5 - 11	-0.9 - 0.9	Martin Wilde QM12 talk
ALICE	10 - 50	-0.3 - 0.3	M. Consentino's poster (QM12)



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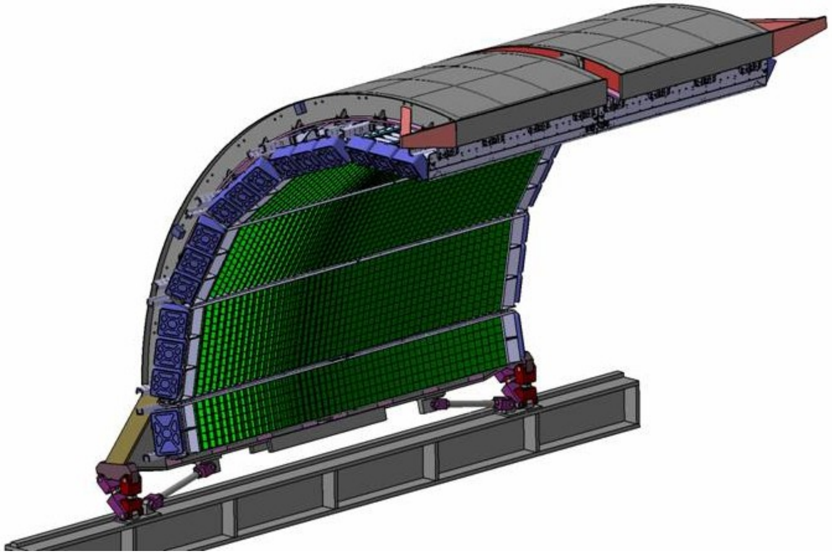
II – Direct photon measurement with EMCal

III – Normalization studies

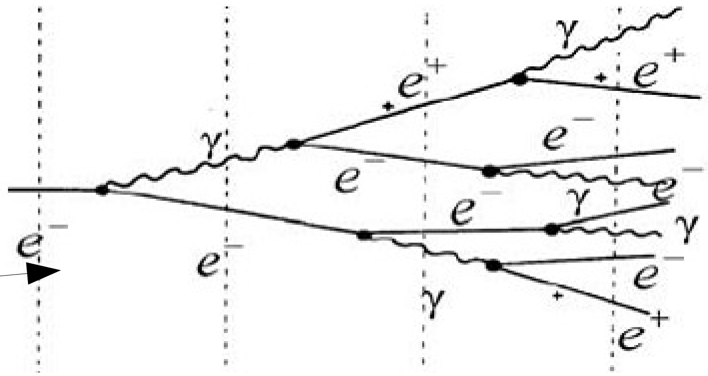
EMCal



- 10 super modules (+ 2 mini) composed of 24x12 modules
- 12288 towers grouped by 4 (module)
- Granularity : $\Delta\eta \times \Delta\phi = 0.014 \times 0.014$ rad
- 78 layers of scintillator separated by 77 lead layers (~ 19 X_0)
- Acceptance : $\Delta\phi = 110°$, $|\eta| < 0{,}7$
- Possibility to measure particles (electrons, photons) at very high p_T (up to 100 GeV/c)

EMCal module

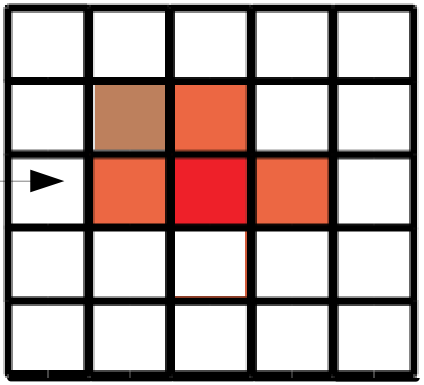
Electromagnetic shower



Analysis strategy

Toward direct photon cross section measurement

Hit neighbouring cells are grouped into **clusters**



Example of EMCal cluster

To obtain a direct photon cross section from a cluster spectrum we will proceed in three stages :

Step n°1: **Photon identification**: Select between all clusters photon candidates

Step n°2: **Direct photon search**: Produced far from other particles (underlying event excepted), direct photons can be identified with **isolation criteria**.

Step n°3: Correct and normalize to **obtain a cross section**

Quality assurance

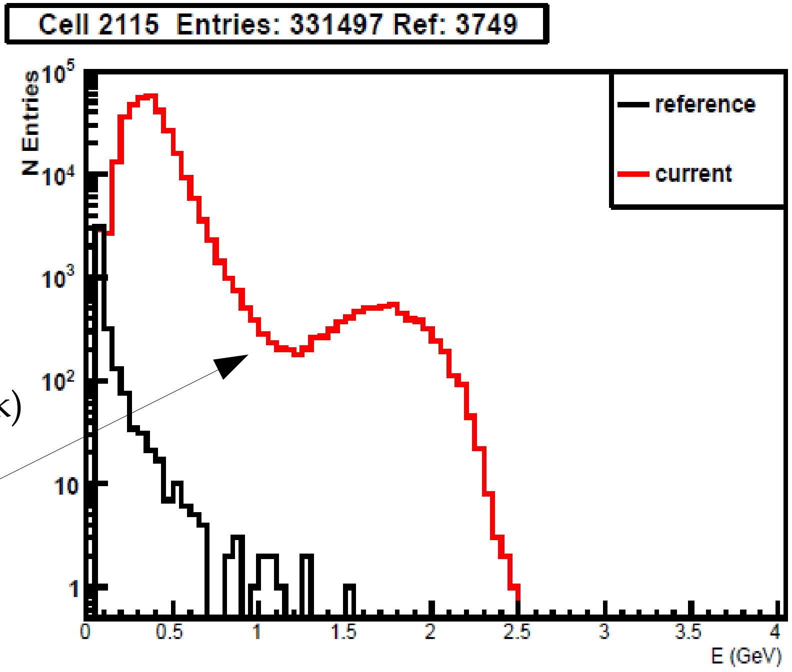
Physics analyses require to ensure data quality. We took responsability of EMCal QA since 2011, this covers two main aspects:

Calorimeter performance:
- Check EMCal channel behaviour
- Create « bad channel map »

Run quality:
- Verify stability of basic quantities (energy multiplicity of clusters, timing…)
- Assess on quality

To complete these tasks we developed some automatized procedures (based on Olga Driga's work)

Example of bad cell found by our bad channel analysis program



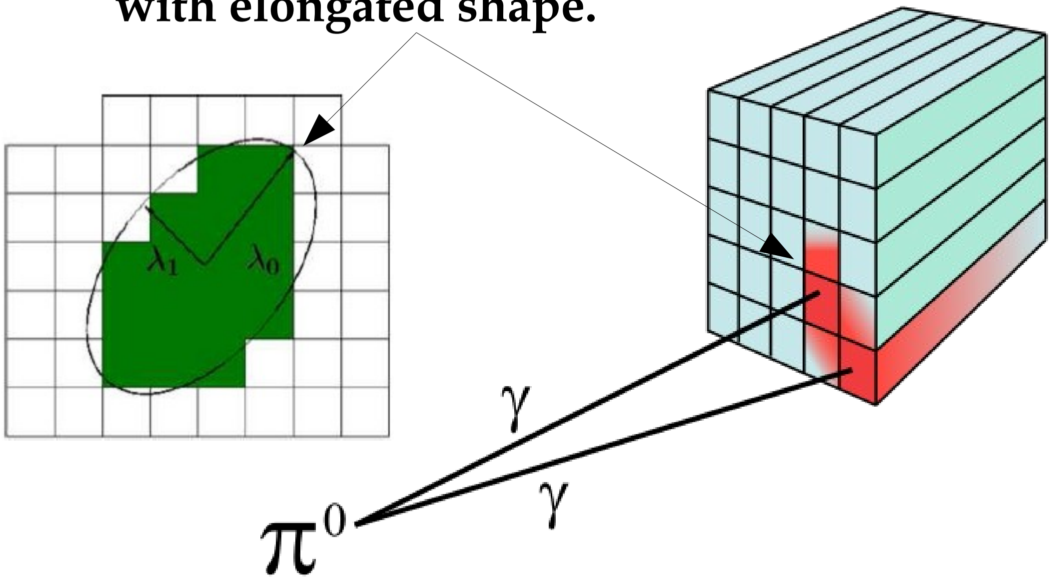
Photon identification

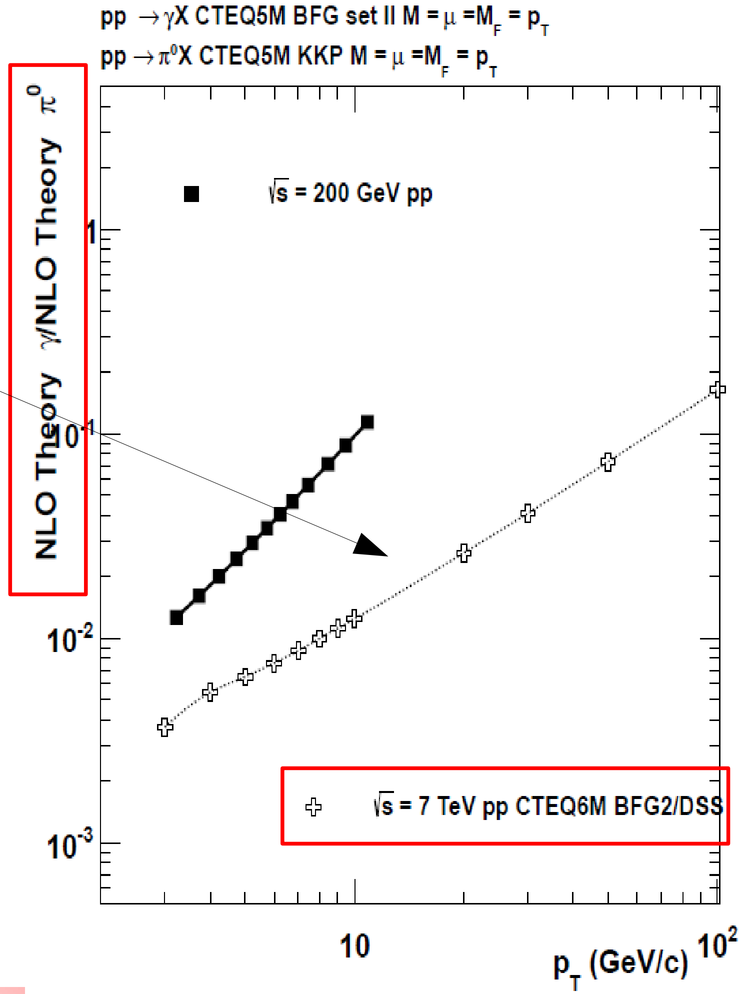
I – Charged particle veto (« charged cluster » removal)

If an EMCal cluster matches a TPC track, it is discarded

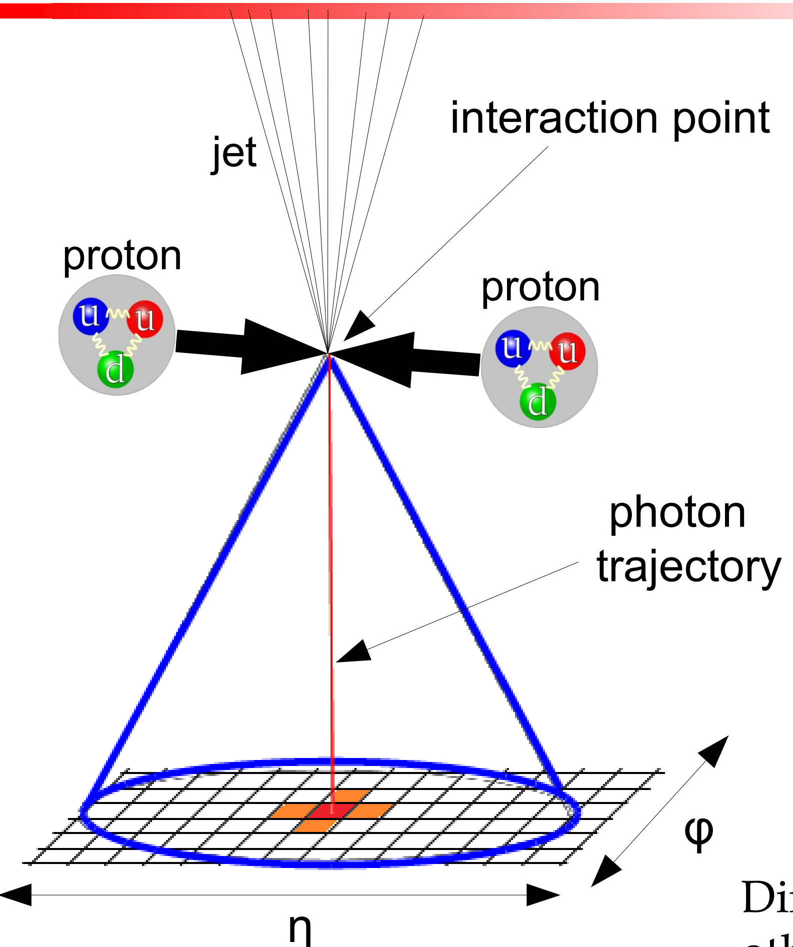
II – Shower shape discrimination ($\lambda_0^2 < 0.27$)

Above ~7 GeV , « **neutral clusters** » are mainly due to **decay photons** that merge into a single **cluster with elongated shape.**



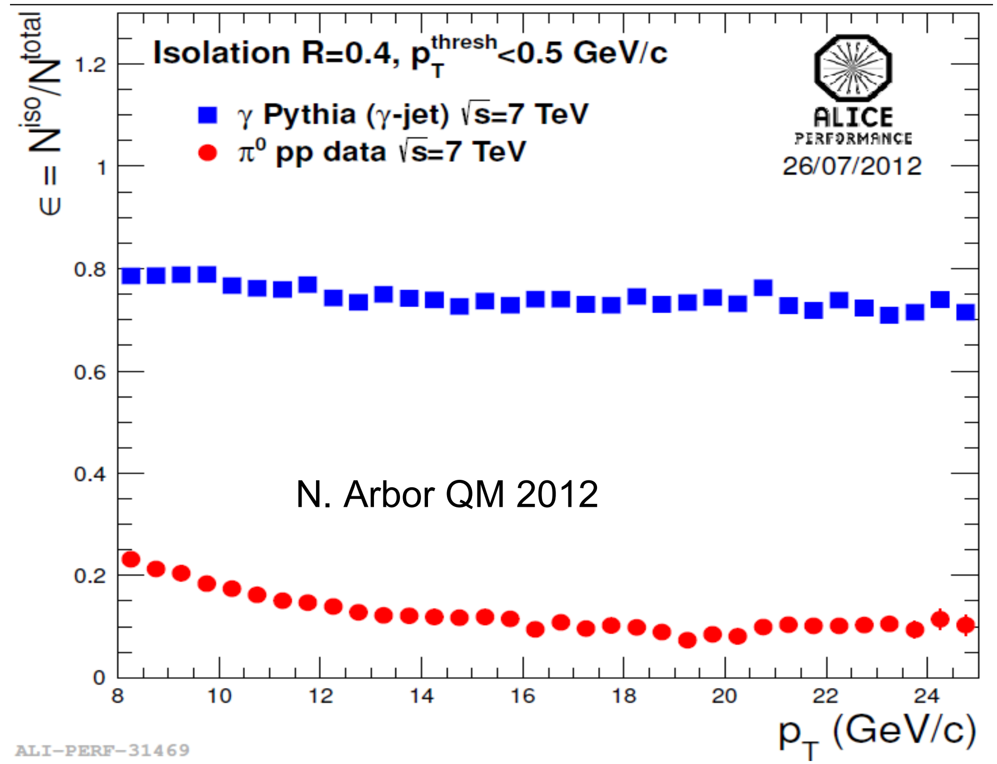


Direct photon search



Cone radius (R=0.3, 0.4...)

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



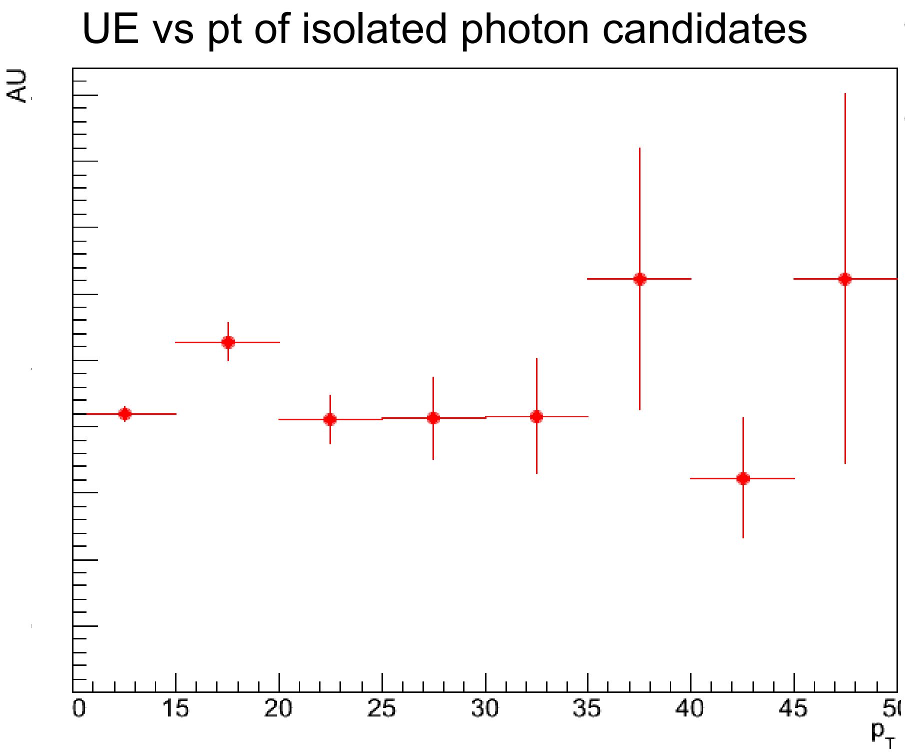
Direct photons are much more isolated than other contribution, several isolation criteria exist:

1) No particle in cone with $p_T > p_T^{thresh}$ (0.5, 1 GeV/c ...)

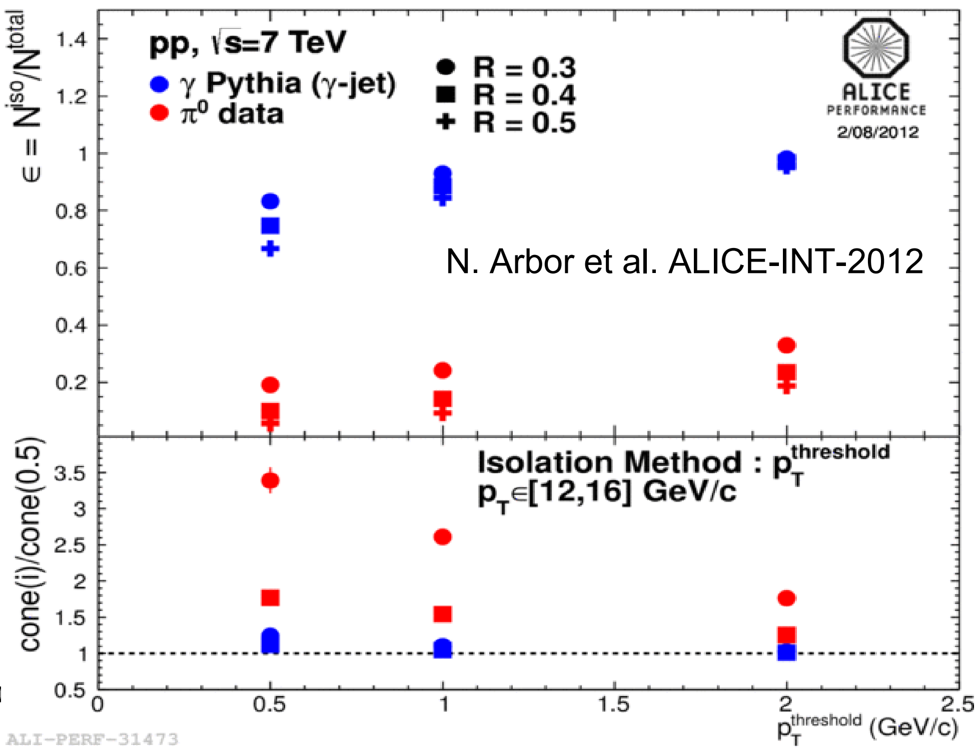
2) $\sum p_{T,\text{in cone}} < \varepsilon\, p_{T,\gamma}$ (with ε = 0.1, 0.2 ...)

Direct photon search

Which isolation criteria should we choose ?



No clear dependence of UE vs photon transverse momentum



Low contamination and good efficiency for R=0.4 and threshold =0.5 GeV/c

Our isolation criterion: no particle with p_T > 0.5 GeV/c inside cone of R=0.4

Direct photon analysis

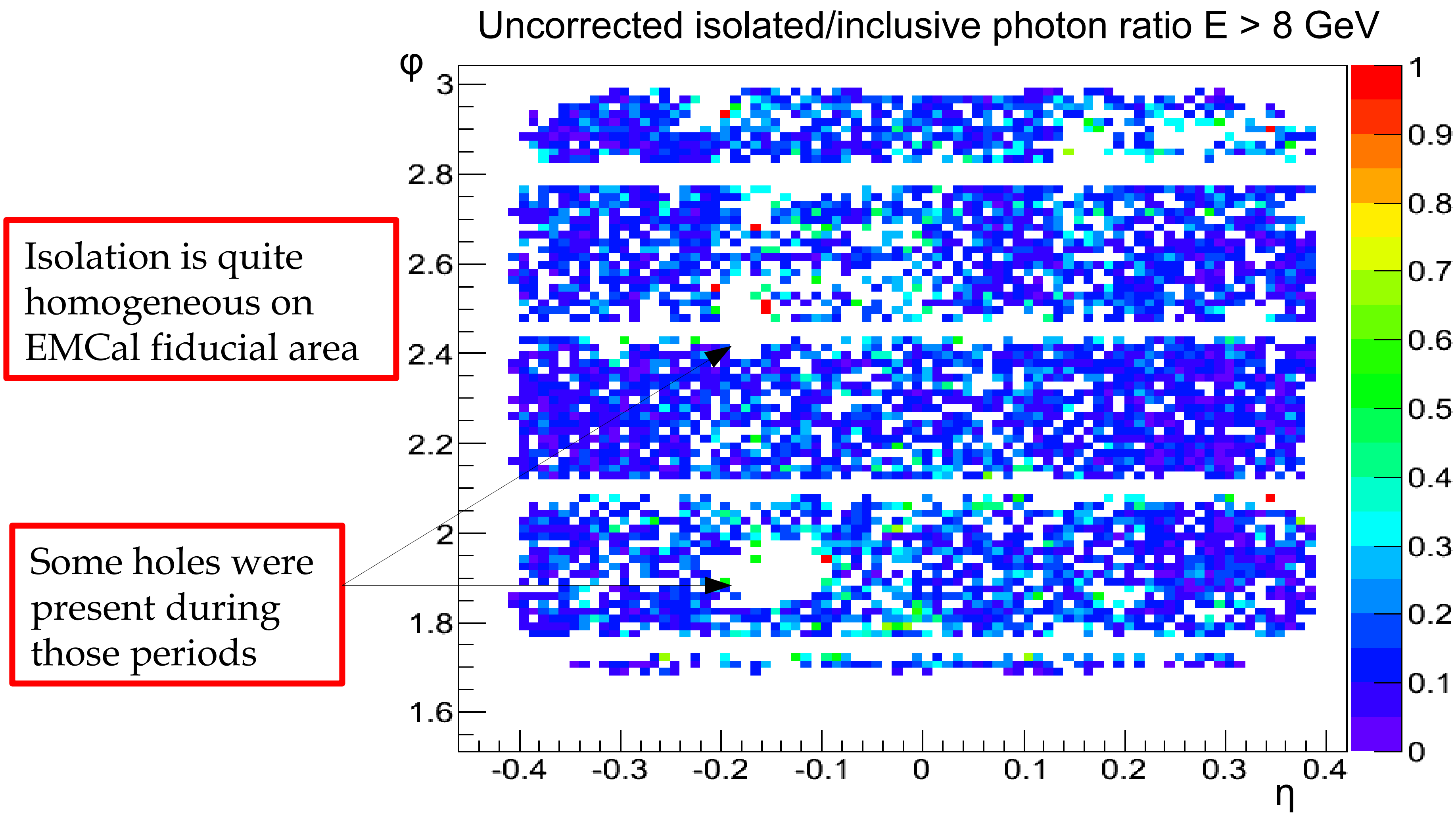
Data set used:

- 50 runs of pp collisions @ 7 TeV (2011 data)

- 5 millions of EMCal triggered events (« EMC L0 »), with 4 GeV and 5.5 GeV threshold (on a 4x4 cells patch)

- Runs with full EMCal and full TPC have been used (no sector missing)

Isolation performance



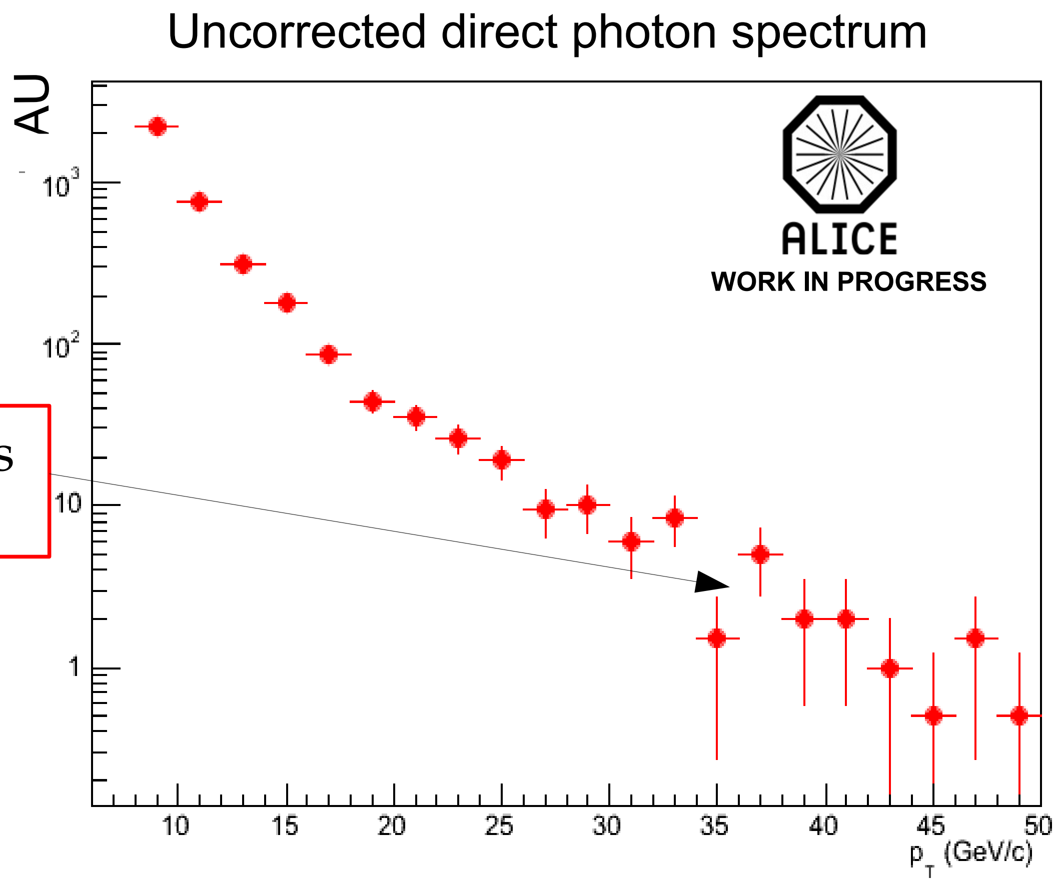
Fiducial cut used: 90 % of the cone should be in the EMCal active area.
It increases the available EMCal area by a factor of ~2 compared to a strict fiducial cut

Direct photon : raw spectrum

≈ 5M pp collisions @ 7 TeV analyzed (2011 data)

Trigger: EMCal (« EMC L0 »)

The analyzed statistics allows to go up to 40-50 GeV/c



We have to correct and normalize this spectrum to obtain a cross section

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Normalization

Cross-section of X particle production reads:

$$\sigma(pp \to X + ...) = \frac{N^X}{B \times (\varepsilon \otimes \mathcal{A})^{reco} \times \varepsilon_{trigger} \times \mathcal{L}_{int}}$$

We need to estimate the integrated luminosity analyzed $\mathcal{L}_{int}$. We have developed a method to estimate it for EMCal triggered data:

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

Analyzed events

We use rejection factor computed from MB data:

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

Number of MB events with EMCal trigger input

Pileup correction factor

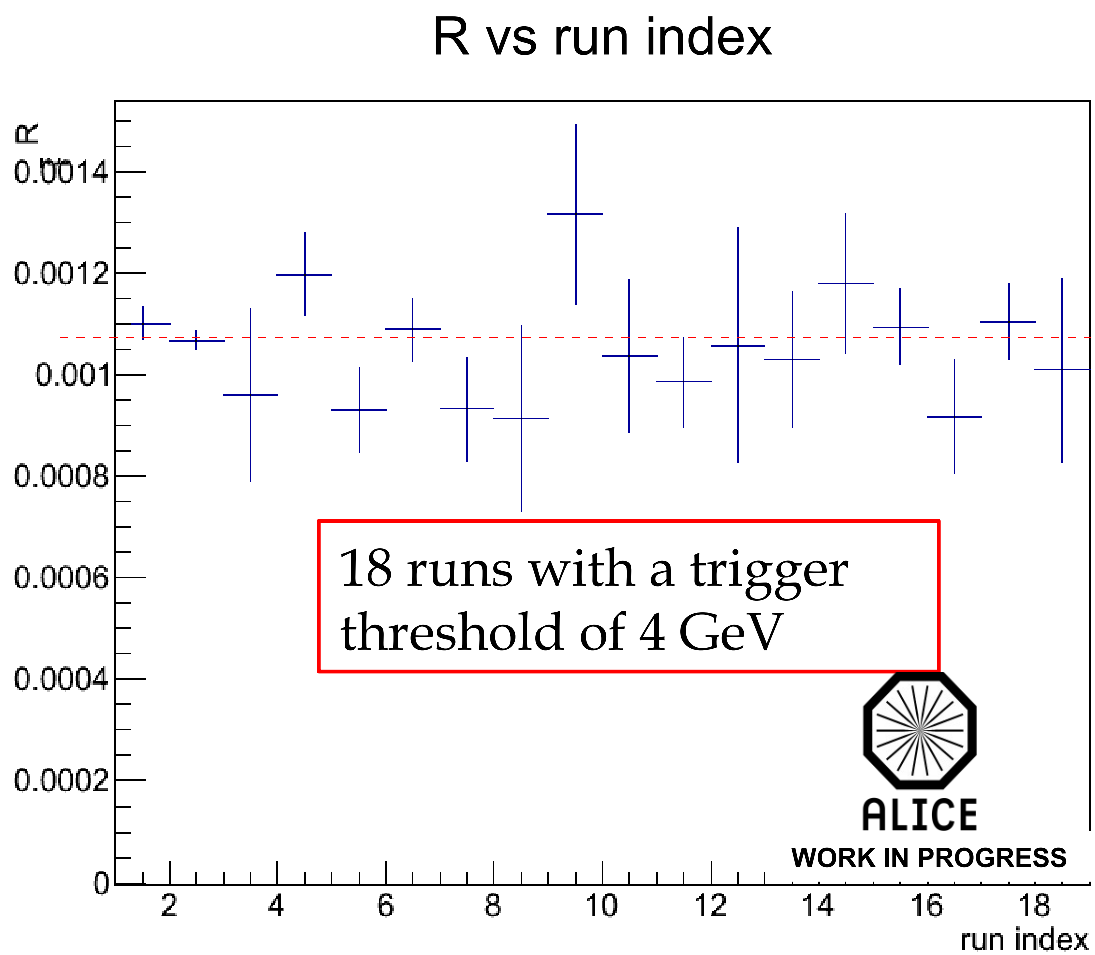
Total number of MB events

Normalization

We want to compute R factor and to check its stability

- Only few trigger entries in each run

- Good stability (within error bars)



Average value :
(weighted by number of events)

$$R = 0.00107 \pm 0.00002\ (stat)$$

Normalization

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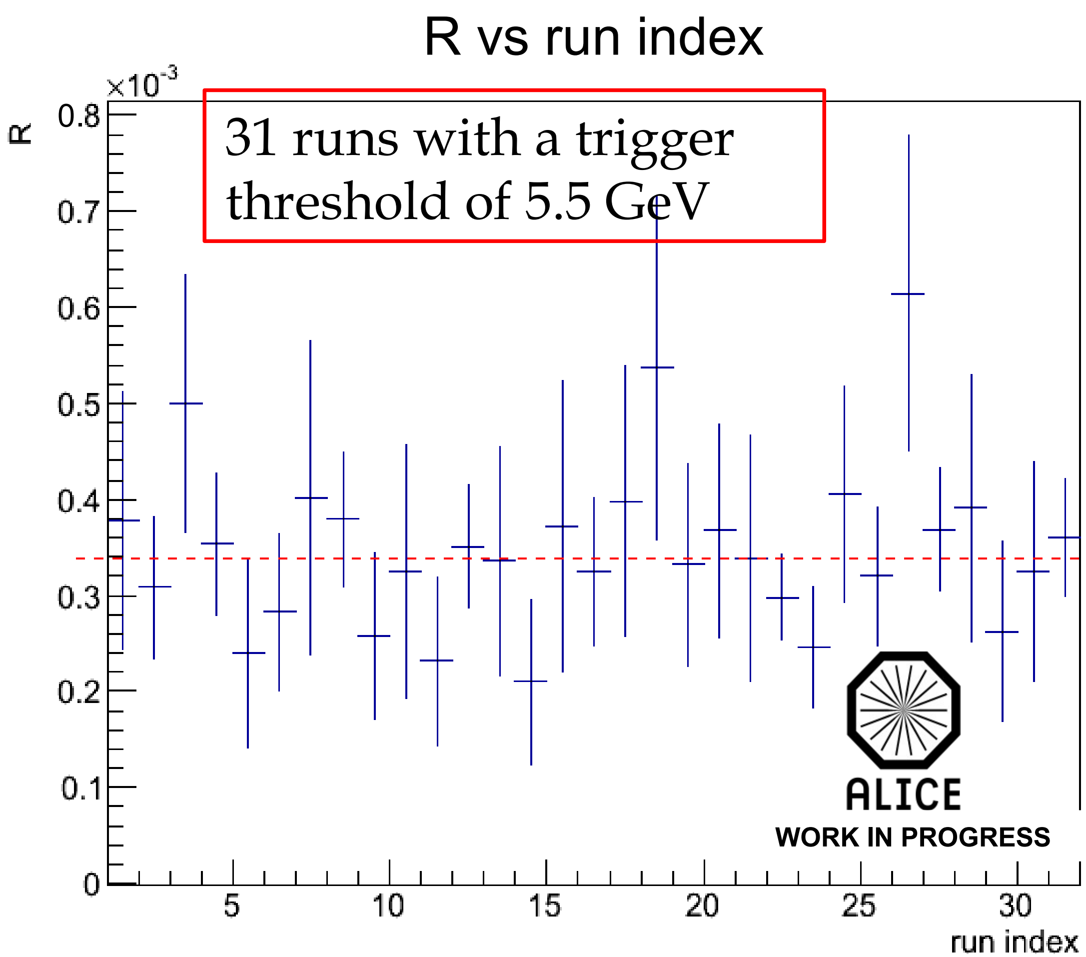


Average value :
(weighted by number of events)

$$R = 0.00034 \pm 0.00002\ (stat)$$

Conclusion & outlooks

Conclusions

- We have obtained a direct photon raw spectrum

- We have developed a normalization method for EMCal triggered data

Outlooks

- Compute efficiency/contamination of our isolated photon spectrum

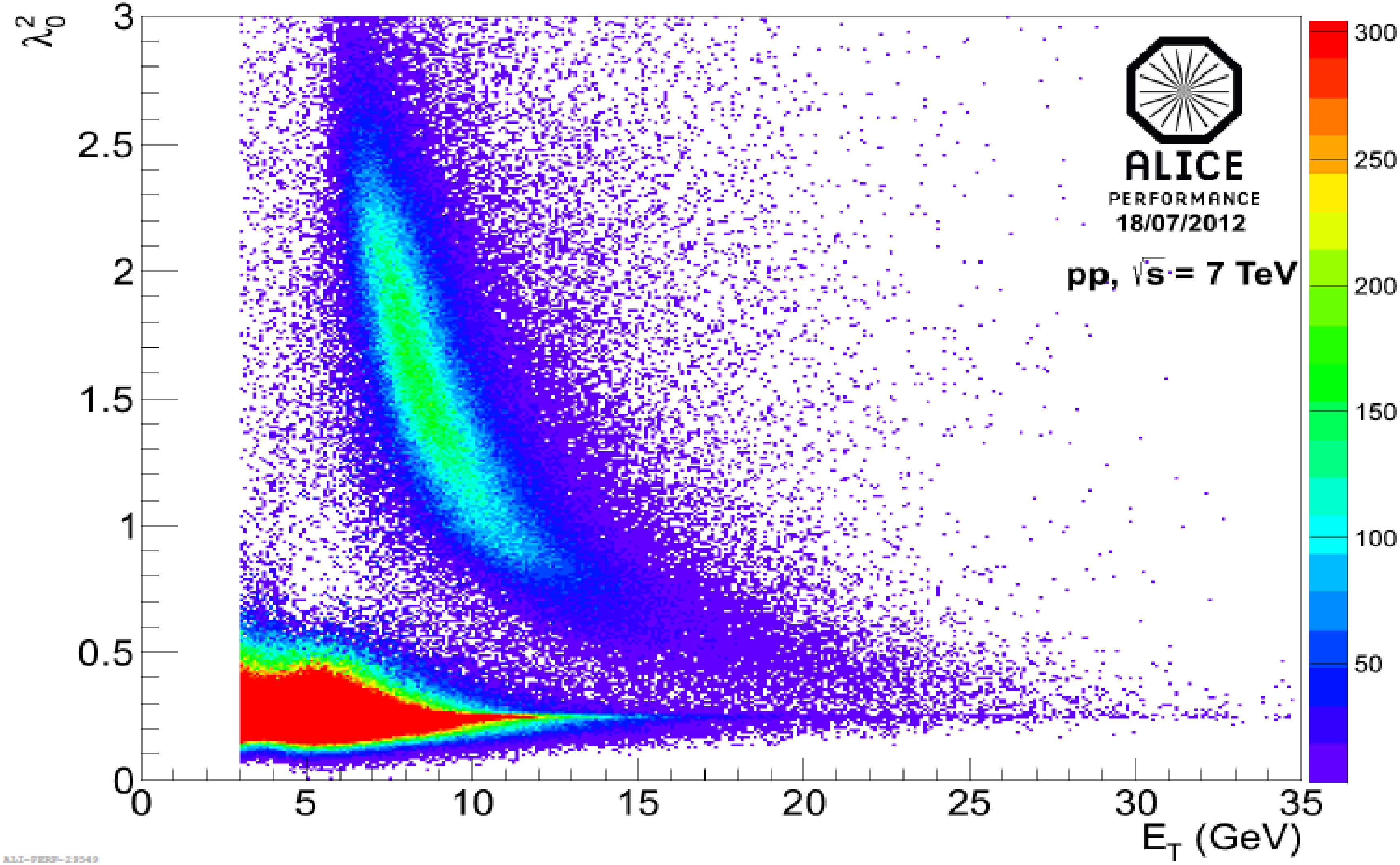
- Evaluate systematic errors

- Comparison with CMS/ATLAS and Jetphox (work in progress)

BACK UP

Photon identification

Shower shape of clusters after TM:

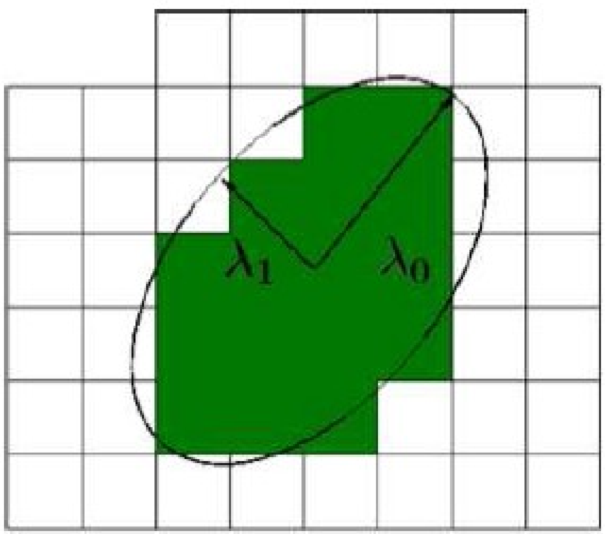


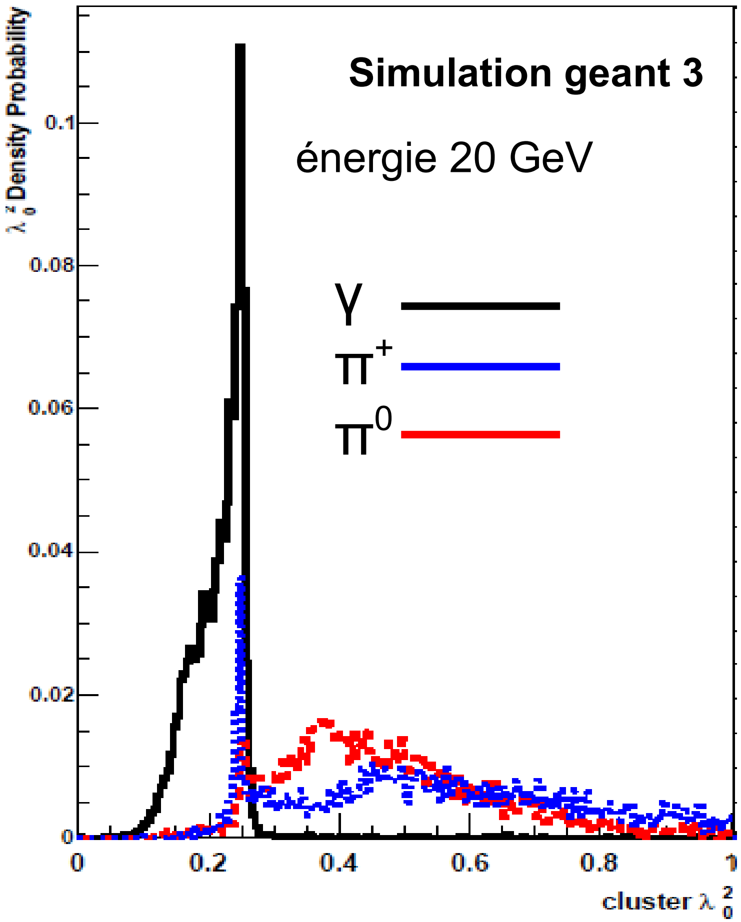
Identification des photons

<u>Test n°2 : Forme de la gerbe électromagnétique</u> ($0{,}1 < \lambda_0^2 < 0{,}27$)

- Quand un photon atteint EMCal, il produit une gerbe électromagnétique ayant des caractéristiques bien connues

- Expérimentalement l'étude de la « forme » du cluster, plus précisément la variable λ_0^2 nous permet d'identifier un photon :





Densité de probabilité du λ_0^2 pour un cluster engendré par différentes particules

QA cuts/selection

Clusterizer V1 with:

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

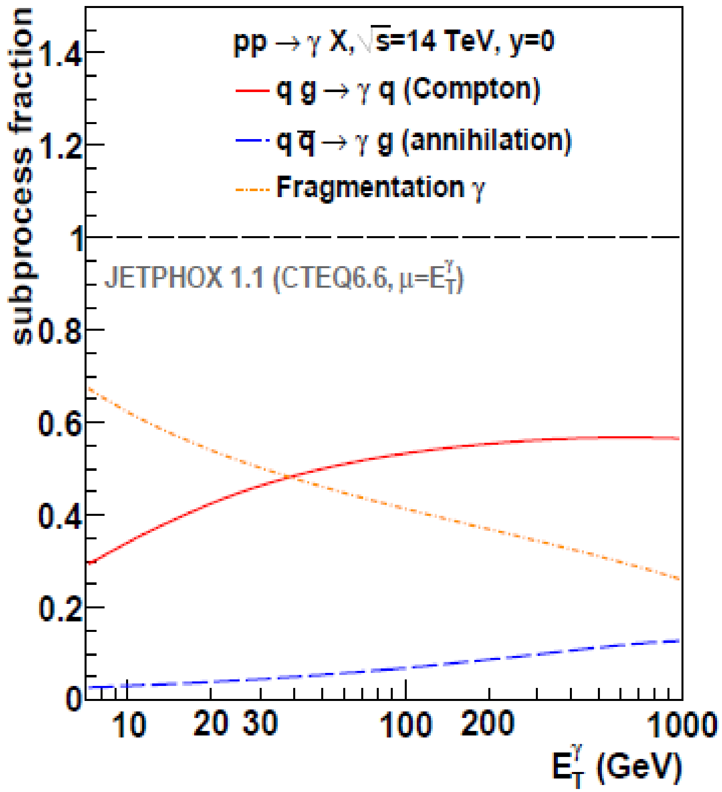
Cluster selection:

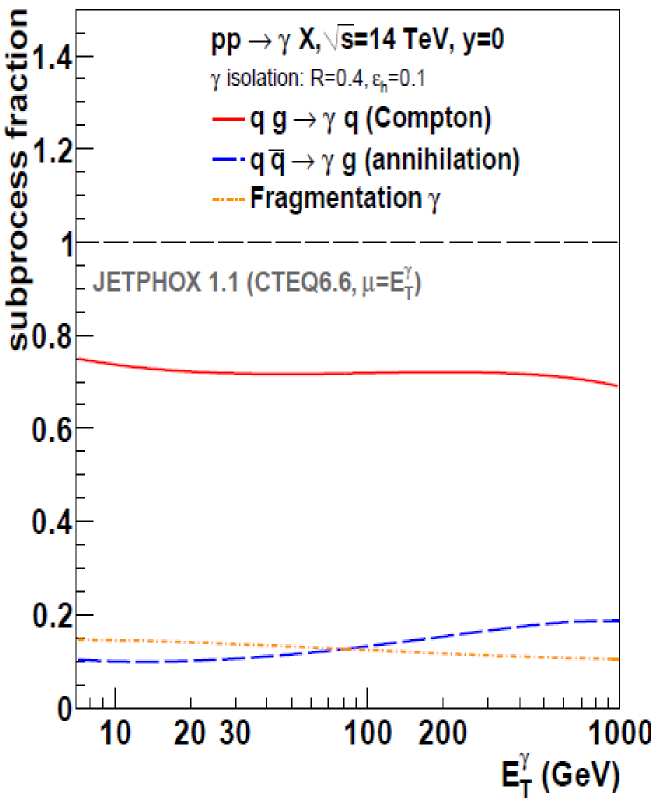
- Eclus > 0.3 GeV
- Ncells/cluster: at least 2 cells
- Distance to bad channel: at least 2 cells
- Exotic clusters removed

Photon selection:

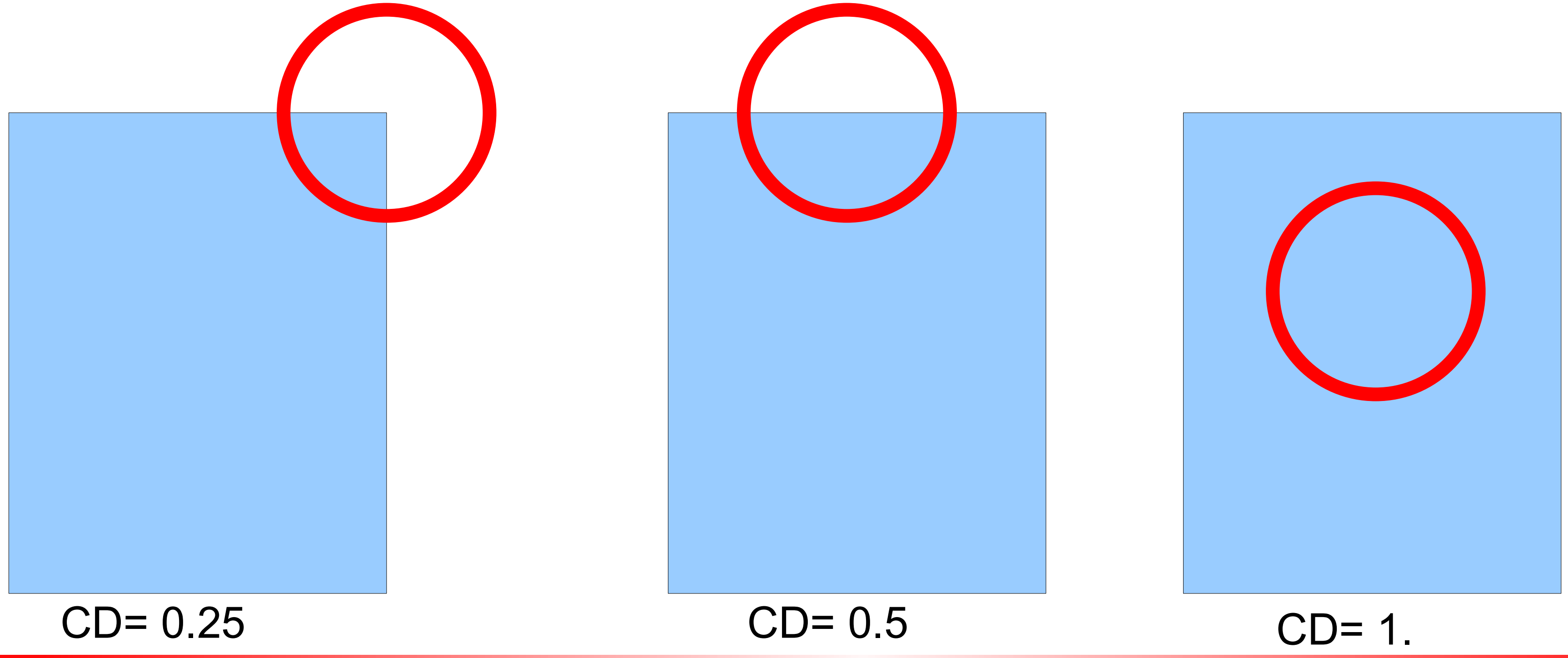
We only consider **clusters > 8 GeV as photon candidates** to be far from trigger threshold (5.5 GeV except first runs which have 4 GeV threshold)

Photons de fragmentation et isolation





Cell density variable (CD)



Cell density: fiducial cut

Cone size →	0.3	0.4	0.5
CD > 0.5	97%	96%	92%
CD > 0.8	69%	56%	44%
CD > 0.94	50%	37%	24%

Estimation of EMCal available area vs CD cut and cone size

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

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

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

Bunch crossing not masked per orbit

MB $L0_b$ rate

LHC frequency