Isolated photon with EMCAL in ALICE experiment

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SUBATECH - Nantes

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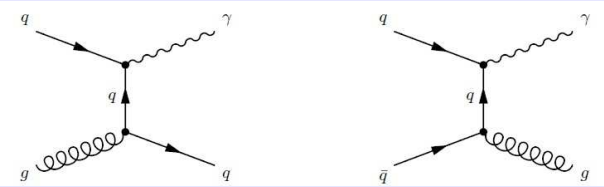
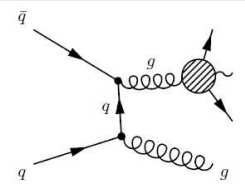
1. Physics motivation
2. Photon measurement in ALICE-EMCAL
3. Isolated photon in p-p collisions @7 TeV
4. Isolated photon in p-Pb collisions @ 5.02TeV

Prompt photon production in p-p, p-Pb and Pb-Pb

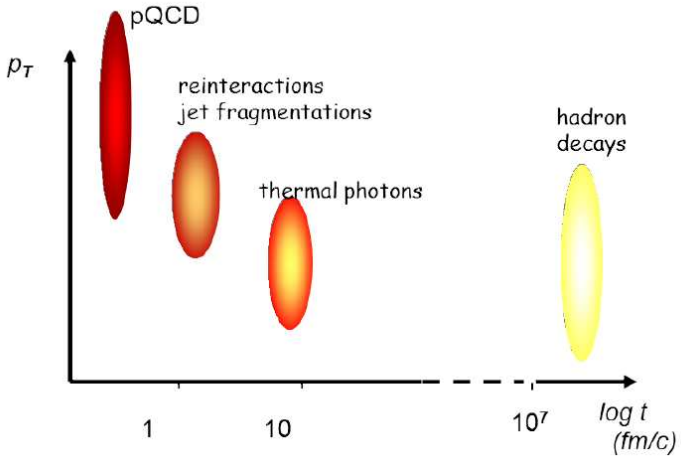


Direct photon via Compton and Annihilation



Fragmentation photon

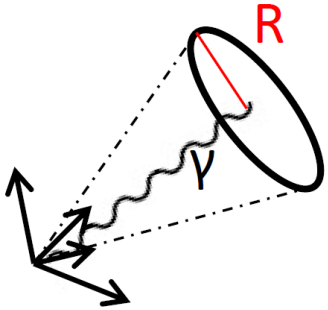
- Test pQCD
- Constrain models
  - p-p collisions: PDFs
  - Pb-Pb, p-Pb collisions: nPDFs
- Correlations in p-p, p-Pb and Pb-Pb collisions to study jet medium interaction



Other photon production in p-p, p-Pb and Pb-Pb

Thermal photons in heavy ion collisions
Hadronic decays ($\pi^0, \eta, ...$)

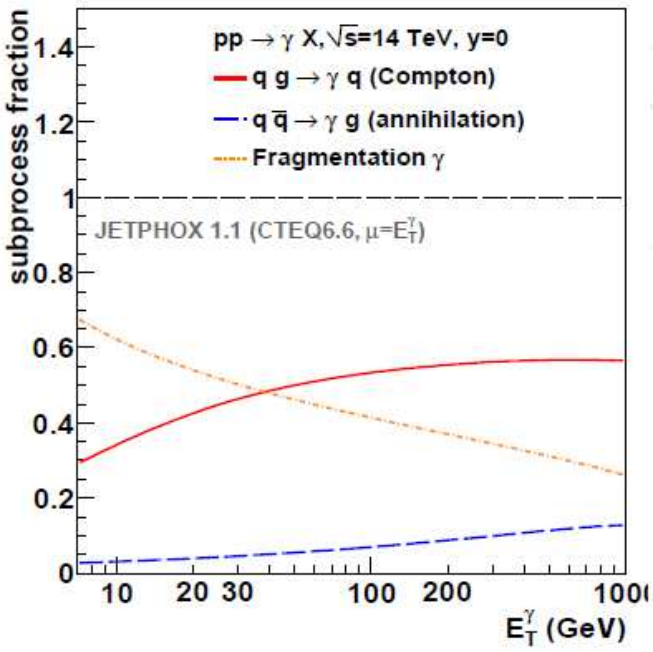
Isolated photon



- $R = \sqrt{(\Phi - \Phi_{photon})^2 + (\eta - \eta_{photon})^2}$
- $\sum^{cone} p_T \leq p_T^{threshold}$

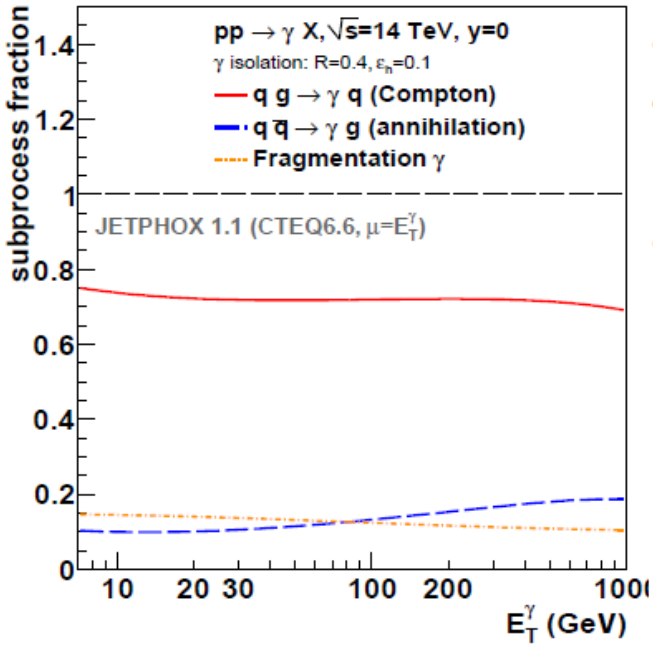
Decrease drastically fragmentation contribution and decay photons
⇒ **Access to direct photons**

without isolation

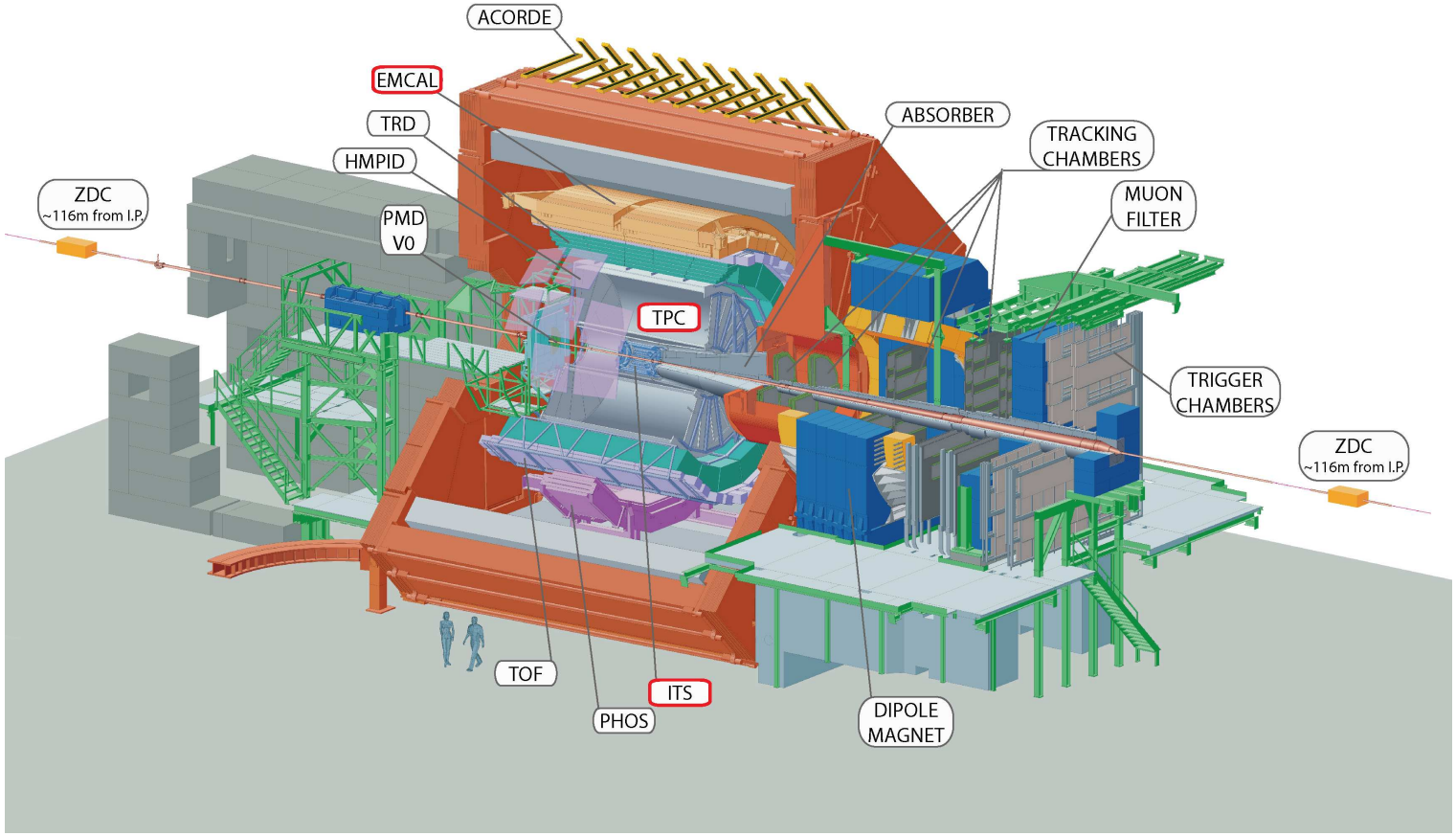


R.Ichou and al.Phys.Rev.D82

with isolation



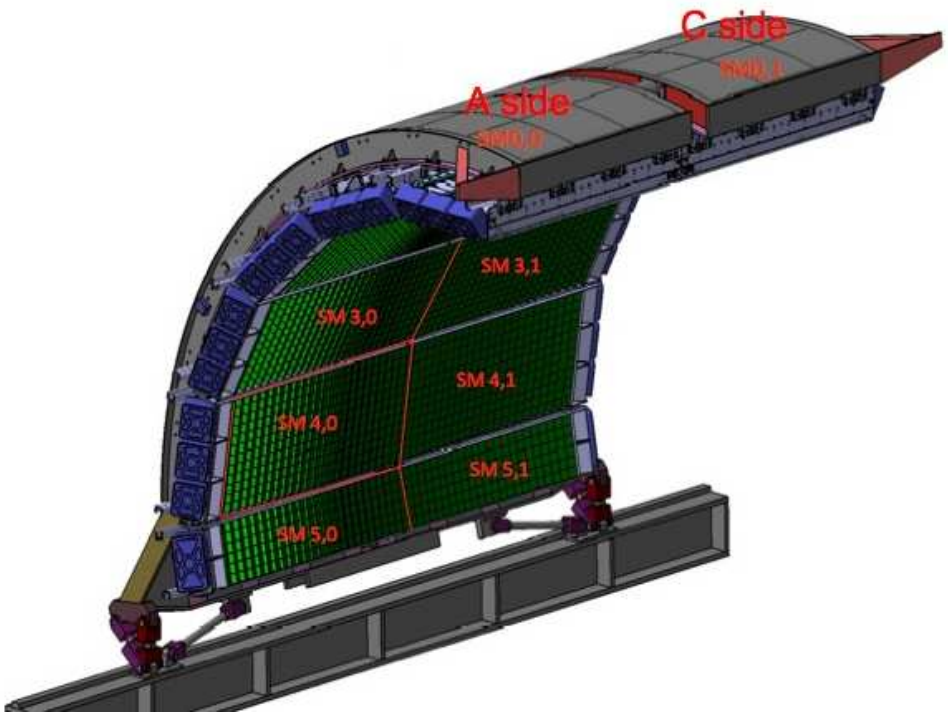
ALICE experiment

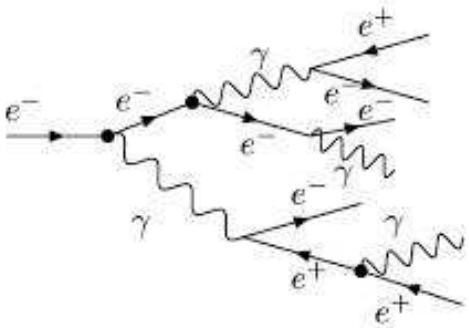


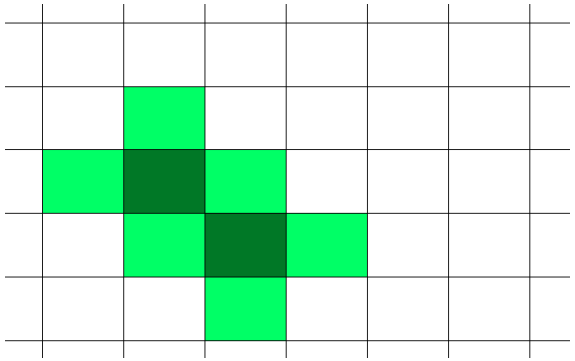
Main involved dectectors in isolated photon studies:

- Charged particle track studies: **ITS** and **TPC** ($|\eta| < 0.9$ and $\phi = 2\pi$)
- Electromagnetic particle cluster studies: **EMCAL** $|\eta| < 0.7$ and $1.4 < \phi < 3.3$

EMCAL







Clusterisation

- Pb/scintillator calorimeter
- 10 supermodules used in analysis (2011-2013)
- 11 520 cells
- $\Delta\phi \times \Delta\eta = 0.014 \times 0.014$

Isolated photon in p-p collisions @7 TeV: Data selection

- 2011 data set for pp collisions @ 7 TeV
- L_0 EMCAL trigger with $p_T^{threshold} = 5.5 GeV$
- EMCAL acceptance $|\eta| < 0.7$ and $1.4 < \phi < 3.3$
- $v_z < 10$ cm
- $N^{evts} \sim 8M$
- $L^{int} = 473 \pm 22^{stat} \pm 17^{syst} nb^{-1}$

Cluster selection

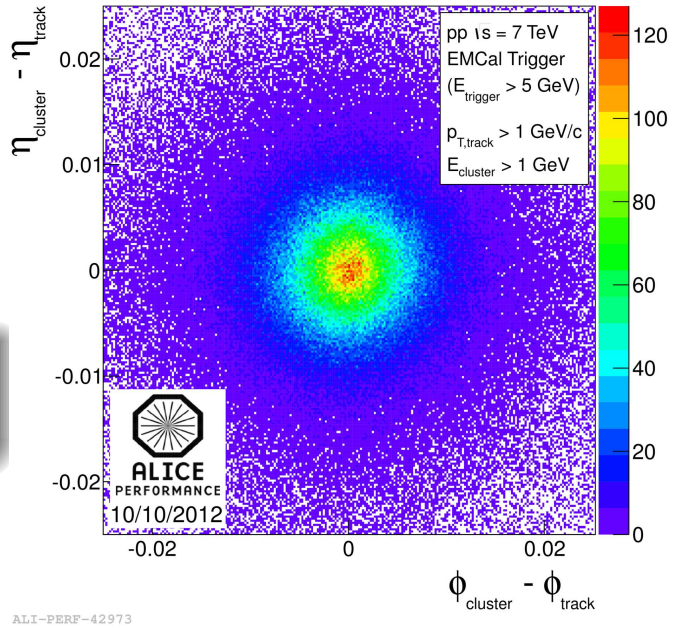
- At least two cells in cluster
- Minimum distance to bad channel: 2 cells
- At least 300 MeV
- Rejection of multiple particle contribution (max 2 local maxima)
- Exotic clusters rejection
- Timing cut: $|t| < 30$ ns

Photon candidate

Charged particle veto

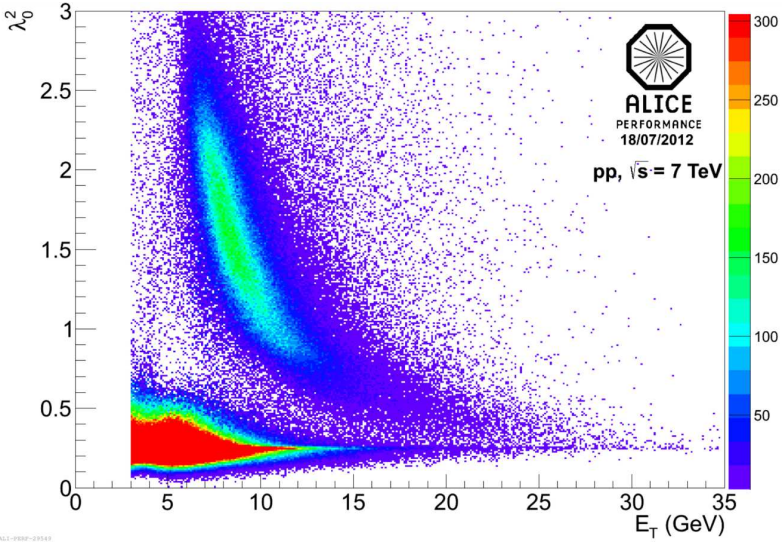
- Neutral cluster selection

$$|\Phi_{track} - \Phi_{cluster}| > 0.03$$
$$|\eta_{track} - \eta_{cluster}| > 0.02$$

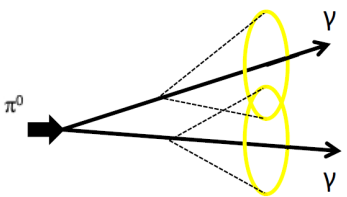


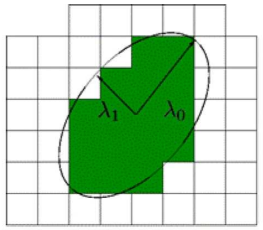
Shower shape

- Photon identification and π^0 rejection



$p_T^{\pi^0}$ 10-60 GeV: merged π^O decay photon clusters into a high p_T cluster

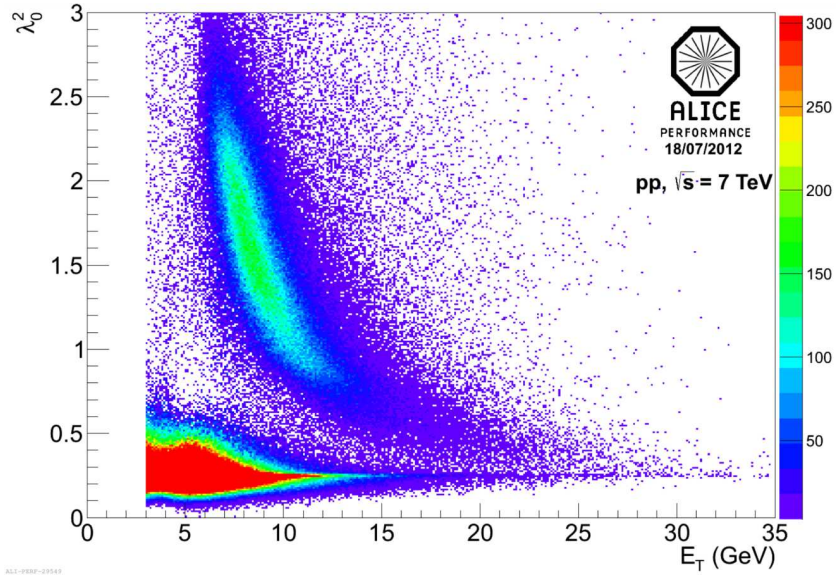




$$\lambda_0^2 = 0.5 \times (d_{\eta\eta} + d_{\Phi\Phi}) + \sqrt{0.25 \times (d_{\eta\eta} + d_{\Phi\Phi})^2 + d_{\eta\phi}^2}$$

Isolation and shower shape criteria

E_T	Signal range
10-16 GeV	$0.1 < \lambda_0^2 < 0.45$
16-18 GeV	$0.1 < \lambda_0^2 < 0.35$
18-60 GeV	$0.1 < \lambda_0^2 < 0.3$



Isolation criteria

$R = 0.4$

$p_T^{threshold} = \sum p_T^{tracks+neutralclusters} = 2GeV$

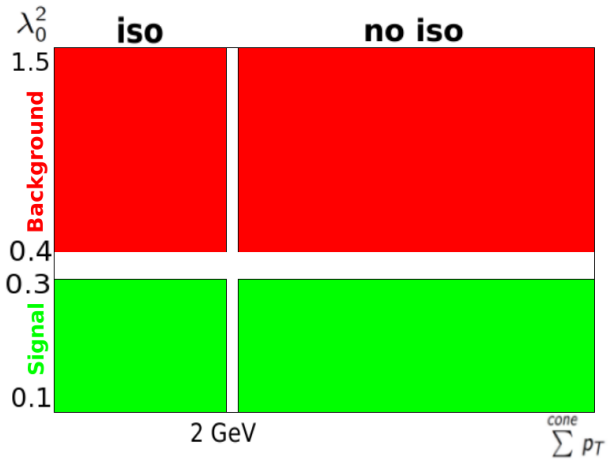
Leading to fiducial cut in EMCAL acceptance: $|\eta| < 0.27$

Signal extraction: purity

- Isolation probability in signal and background ranges
- Spectra corrected from purity
- Semi data driven method to estimate purity corrected by a Monte-Carlo correction

$$p = 1 - \left(\frac{N^{\neq iso}(E_T)}{N^{iso}}\right)^S \left(\frac{N^{iso}(E_T)}{N^{\neq iso}}\right)^B \times \alpha(E_T)$$

E_T	Signal range	Background range
10-12	$0.1 < \lambda_0^2 < 0.45$	$0.55 < \lambda_0^2 < 1.55$
12-16	$0.1 < \lambda_0^2 < 0.4$	$0.5 < \lambda_0^2 < 1.5$
16-18	$0.1 < \lambda_0^2 < 0.35$	$0.45 < \lambda_0^2 < 1.45$
18-60	$0.1 < \lambda_0^2 < 0.3$	$0.4 < \lambda_0^2 < 1.4$



Monte-Carlo correction

$\alpha(E_T)$: calibration factor obtained with a mixing of Gamma-Jet and Jet-Jet Monte Carlo simulations

Reconstruction efficency

Efficiency has been computed using gamma-jet Monte Carlo simulations with Pythia

$$\epsilon(E_T) = \frac{dN^{id}_{\gamma_{iso}}}{dE_T^{reco}} \Big/ \frac{dN^{gen}_{\gamma_{iso}}}{dE_T^{gen}}$$

Isolated photon in p-p collisions @7 TeV

$$\frac{d^2\sigma}{dE_T d\eta} = \frac{d^2 N^{iso}}{N^{evt} dE_T d\eta} \frac{1}{A_{cc}\mathscr{L}^{int}} \frac{p}{\epsilon}$$

- A new energy range have been reached (10 to 15 GeV)
- Accuracy is competitive up to 25 GeV
- results compatible with theory
- results coherent with CMS *(CMS PRL 106 (2011) 082001)* and ATLAS *(Phys.Lett. B706(2011)150)*

Jetphox computation with CTEQ6.6 PDF and BFG II

Isolated photon in p-Pb collisions @ 5.02TeV: Data selection

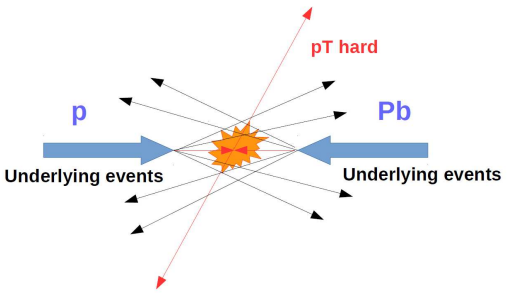
- 2013 data set for pPb and Pbp collisions @ 5.02 TeV
- L_1 EMCAL trigger with $p_T^{EG1threshold} = 11GeV$ and $p_T^{EG2threshold} = 7GeV$
- EMCAL acceptance $|\eta| < 0.7$ and $1.4 < \phi < 3.3$
- Clusters selection similar to pp analysis

Associated luminosity

- L_1 EMCAL trigger with 2 thresholds:
  - 7GeV ($N^{evts} \sim 400k$)
    - $RF^{7GeV} \simeq 1600$
    - $L_{int}^{7GeV} \simeq 0.3nb^{-1}$
  - 11 GeV ($N^{evts} \sim 1.2M$)
    - $RF^{11GeV} \simeq 6300$
    - $L_{int}^{11GeV} \simeq 3.6nb^{-1}$

- Combine EG2 for the first bins and EG1 for last bins to reach a similar p_T range as in p-p @ 7TeV

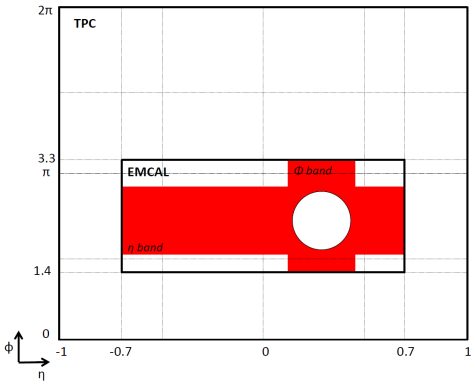
Isolation criteria determination: Underlying events study

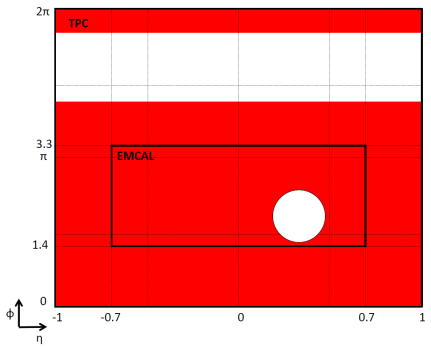


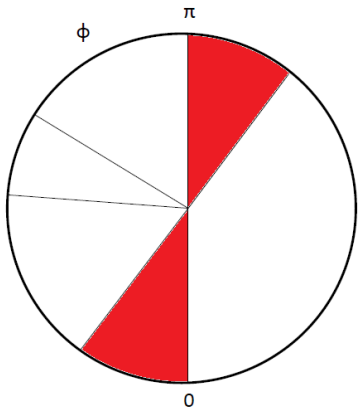
Energy contribution in isolation cone:

- Photon candidate energy
- Hadronic activity
- Underlying events

- Different methods using EMCAL or TPC acceptance have been used to evaluate UE







- Choice to use eta band in order not to be sensitive to flow like events *[ALICE, Phys.Lett. B719 (2013) 29-41]*
- Isolation will be performed on charged particles for 2 main reasons:
  - maximize EMCAL acceptance to reach more statistics
  - limit the bias in the isolation cone energy and so in the purity estimation

Underlying events study and isolation criteria choice

- In the p-Pb (Pb-p) analysis the underlying events contribution will be substracted event by event

Isolation criteria

$R = 0.4$

$p_T^{threshold} = \sum^{cone} p_T^{tracks} - \sum p_T^{UE} \frac{A^{cone}}{A^{EtaBand}} = 2GeV$

$|\eta| < 0.6$

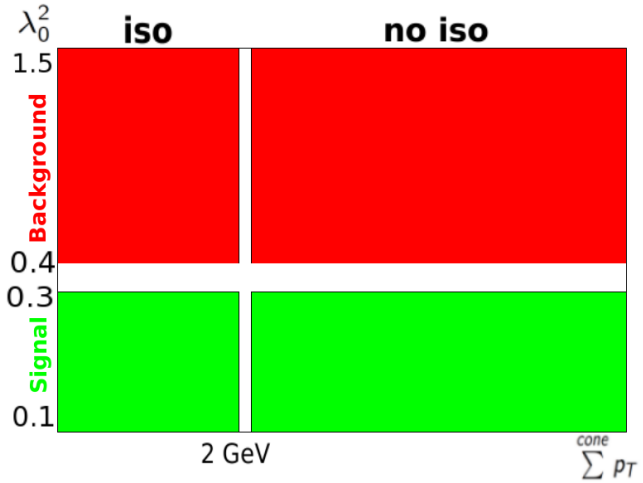
- Check on isolation efficiency in Monte-Carlo will be needed

Isolated photon spectra

Normalized per the number of events and the trigger rejection factor

Signal extraction: uncorrected purity

$$p^{uncorr} = 1 - \left(\frac{N^{\neq iso}(E_T)}{N^{iso}}\right)^S \left(\frac{N^{iso}(E_T)}{N^{\neq iso}}\right)^B$$



To the final cross section

Determination of isolated photon cross section in pPb collisions @5.02TeV

$$\frac{d^2\sigma}{dE_T d\eta} = \frac{d^2 N^{iso}}{dE_T d\eta N^{evt} L_{int} Acc} \frac{p}{\epsilon}$$

- **Purity correction**

  Study of invariant mass correction in data and MC
  Only available at low energy in data for not totally merged π^0 (η)

- **Reconstruction efficiency** (ϵ))
- **Integrated luminosity** (L_{int})

Conclusion

Isolated photon in p-p @7 TeV with EMCAL in ALICE

- Isolated photon cross-section measured in ALICE-EMCAL for transverse energies [10-60]GeV
- Extention of ATLAS *(Phys.Lett., B 706:150–167, 2011)* and CMS *(Phys. Rev. D 84, 052011)* measurements to lower transverse energy
- Agreement with pQCD Jetphox calculation
- Paper in preparation

Isolated photon in p-Pb @5.02 TeV with EMCAL in ALICE

- Conclusion
  - Study of underlying events and isolation criteria : isolation on charged particles
  - Similar energy range than in p-p @ 7 TeV
- Outlook
  - MC productions pending
    - purity correction
    - efficiency
  - Cross section determination
- Larger time scale: R_{pA}

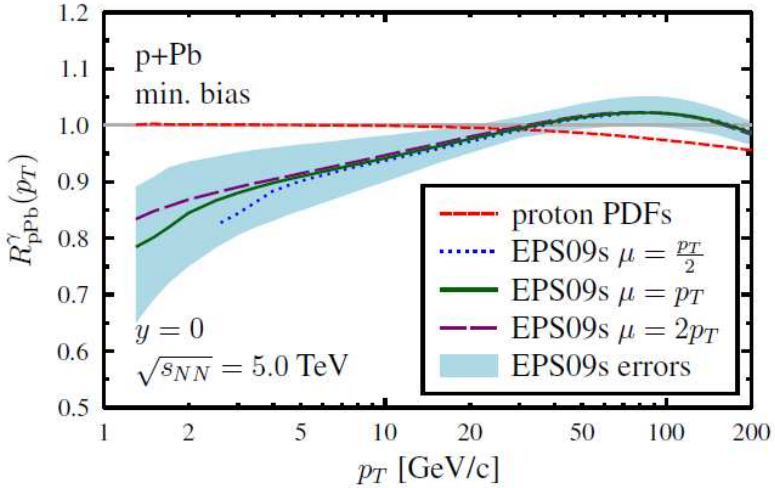
Thanks!

Back up

Parton distribution function

Partonic distribution function describe the probability of a parton to be into an hadron.
$\Rightarrow$ the nuclear PDF are known with large uncertainties especially for small x.

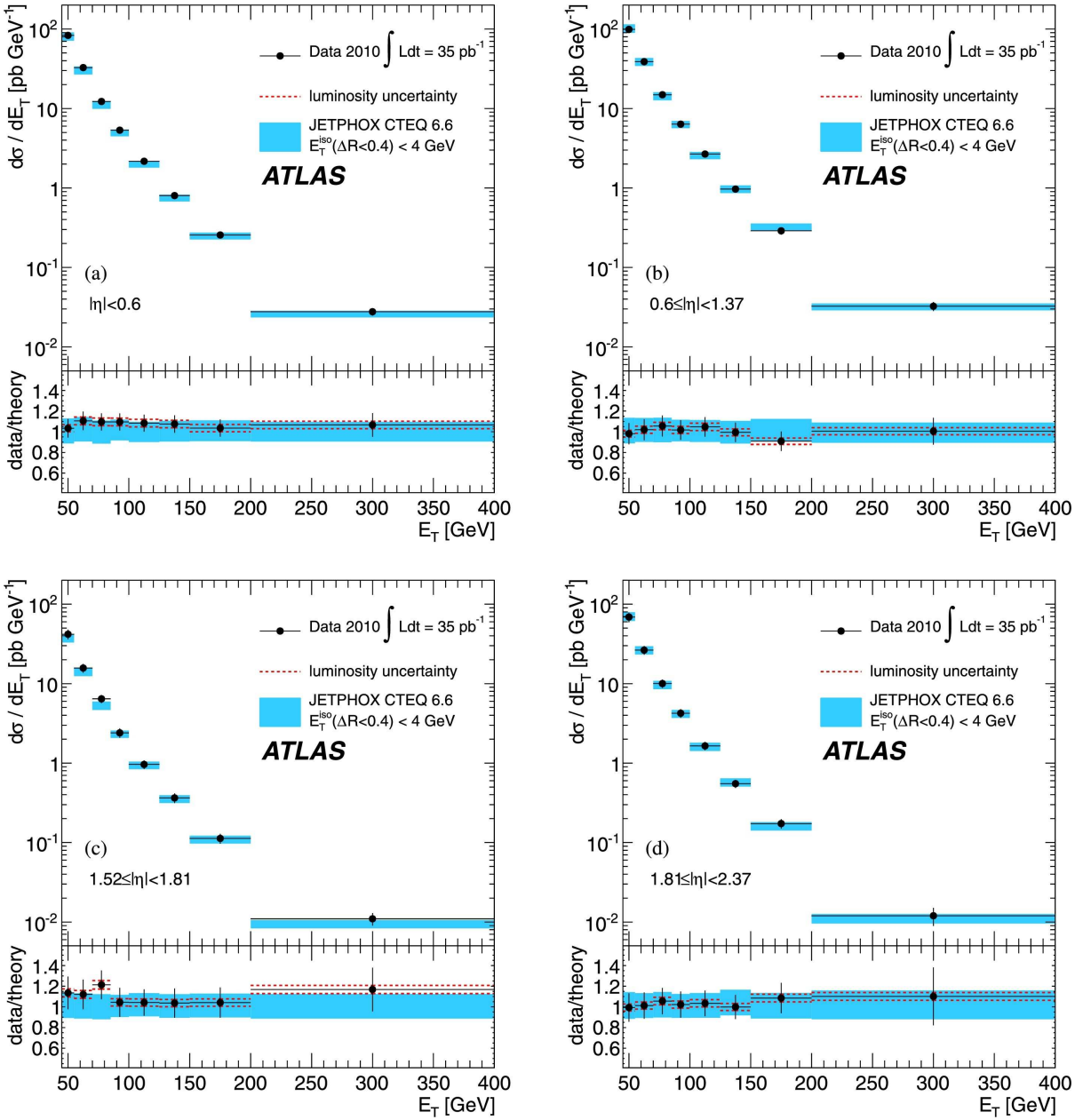
Direct photon production cross section:
$d\sigma^{ij\to k+X}(p_\gamma) = \sum_{i,j,X'} f_i^p(x_1, Q^2) f_j^{pPb}(x_2, Q^2) \otimes d\sigma^{ij\to k+X'} + \bigcirc(1/Q^2)$
f_i^p the parton distribution function
$f_j^{Pb} \equiv R_j^{Pb} f_j$ the nuclear parton distribution function

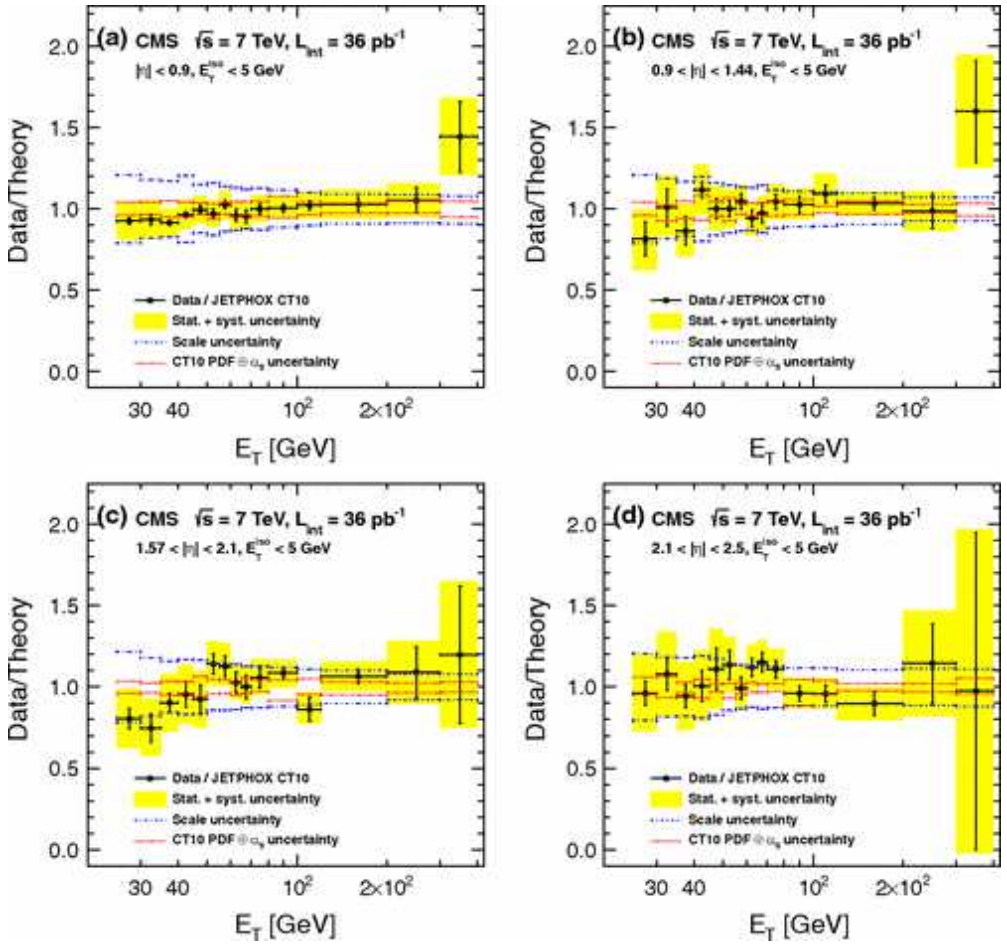


R^{γ}_{Pb} is the nuclear modification ratio which can be measured experimentally.
$\Rightarrow$The direct photon cross section measurement enables to constrain it.

ATLAS

ATLAS collaboration, Phys.Lett., B 706:150–167, 2011.



CMS

CMS collaboration, Phys. Rev. D 84, 052011