Isolated photons in pp collisions at $\sqrt{s}$ = 7 TeV with the ALICE EMCal

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Motivation

Photons are of great interest in relativistic heavy-ion collisions due to the fact that they do not interact strongly, thus, the ratio of their yield in Pb-Pb to pp collisions is sensitive to initial state effects. Furthermore, direct photons can be used to tag the away-side parton in photon-jet or photon-hadron correlations studies. The application of isolation criteria to the selected prompt photon candidates is an important experimental tool to suppress the contamination from decay photons, as well as fragmentation and Bremstrahlung photons. The dominant production of process in LO is the so called "QCD Compton Effect", as depicted in the diagram below. In such a process, no – or negligible – energetic activity is present in the vicinity of prompt photons, hence the isolation will discriminate against other direct photon production processes that may contain any hadronic production.

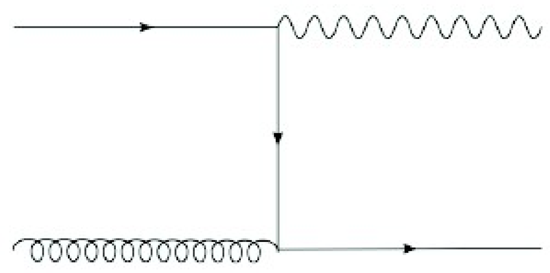

Figure 1: LO "QCD Compton" diagram

Experimental setup

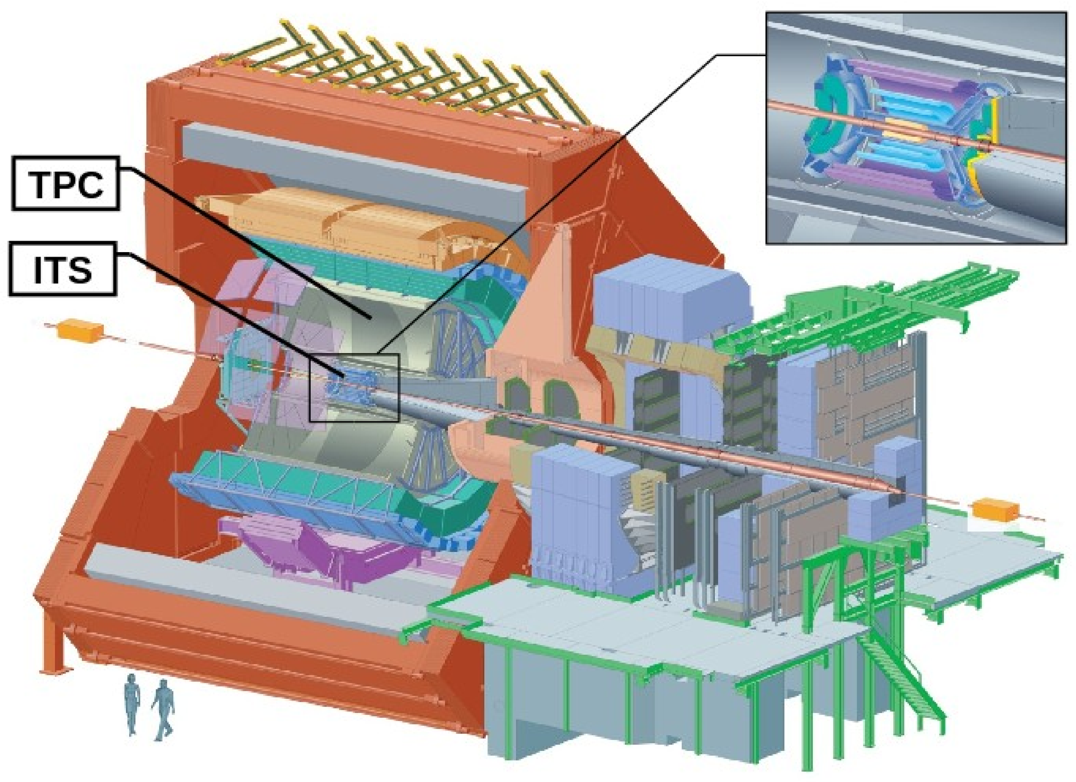

Figure 2: Schematic view of the ALICE detector setup

ALICE [1] is a general purpose heavy-ion experiment. It consists of several subsystems, of which the more relevant for this work are the Electromagnetic Calorimeter (EMCal) and the tracking devices in the barrel (central rapidity), the Inner Tracker System (ITS) and the Time Projection Chamber (TPC).

The tracking systems (ITS+TPC) [1] have full azimuthal coverage and their combined pseudo-rapidity coverage is $|\eta|<0.9$, as depicted in figure 2. The tracking systems reconstruct the charged particle which are used for both, the isolation and charged particle veto.

The EMCal [2] reconstructs all the electromagnetic interacting particles – prompt and direct photons, decay photons (from neutral mesons, e.g. π^0) and electrons/positrons – with high efficiency and good energy resolution. The detector is divided in super-modules which are composed of cells of $(\delta\eta,\delta\varphi=0.014,0.014)$ in size.

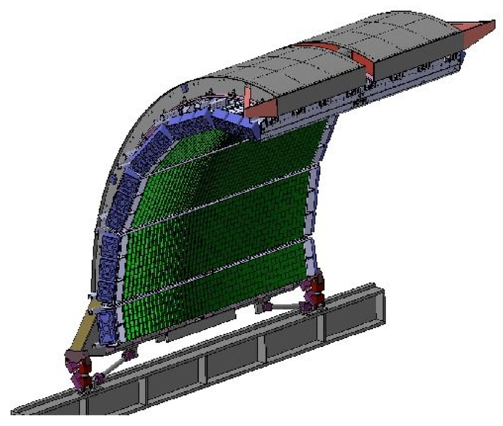

Figure 3: Schematic view of the EMCAL

In 2011 the EMCal had 10 super-modules installed, as depicted in Figure 3, with an acceptance of $\Delta\varphi<100^0$ and $|\eta|<0.7$, and besides of being a read-out detector it was used as a L0 and L1 trigger detector, which increased significantly the kinematical reach of ALICE capabilities. L0 triggered events (~5 GeV threshold), with a total integrated luminosity of about 500 nb^{-1}, are used in this analysis.

Analysis I: PID

The photon ID is based primarily on the charged particle veto (CPV) and in the shape of the electromagnetic showers in the EMCal (see the "Shower Shapes" box).

The showers normally spread over several cells that are grouped in clusters at reconstruction level. There are several clusterization algorithms within ALICE, and we use the standard (v1), which best preserves the original shower shapes.

CPV is applied by extrapolating charged tracks to the reconstructed clusters. If no extrapolations are found within $\delta\eta,\delta\varphi>0.020,0.030$ around the cluster, then it is considered to be "neutral".

Once the neutral clusters are selected, then the shower shape cut $0.1<\lambda_0^2<0.3$ is applied. In figure 4, single particle simulations show the trend of λ_0^2 distribution as a function of the cluster transverse energy for photons and π^0s. From the simulations it is possible to extract that the contamination start to be significant at ~20 GeV, and increases with E_T. This behavior can be observed in real data as well, and although statistics are limited, we conclude from both plots that the shower shape alone does not help beyond 30 GeV, and isolation becomes more important. The photon candidates are those who pass the CPV and λ_0^2 cuts.

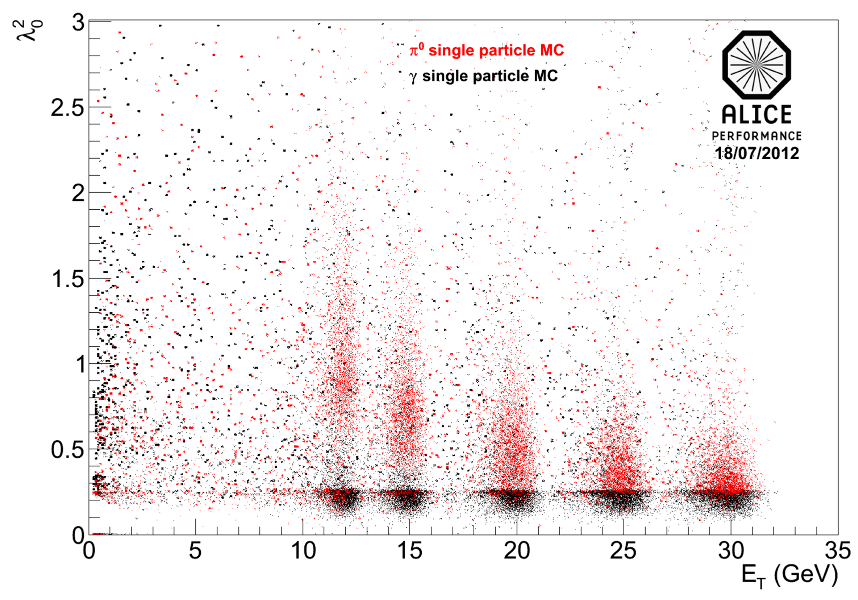

Figure 4: Single particle MC shower shapes

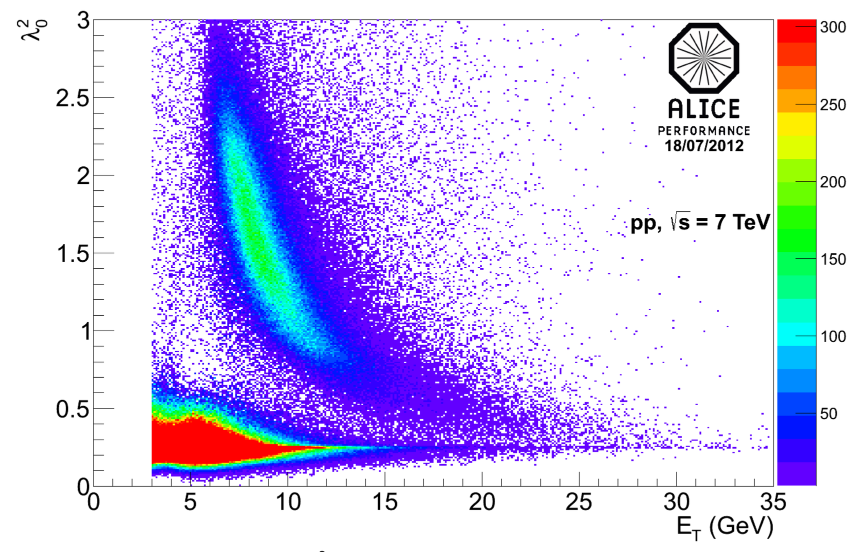

Figure 5: λ_0^2 from real data clusters after CPV cut

Shower Shapes

Shower shapes are obtained from the elliptical parametrization of clusters. The parameters give the energy spread along both ellipse axes, and are named as λ_0^2 for the long axis and λ_1^2 for the short. λ_0^2, depicted in figure 6, gives the best discrimination against the background, and it is expressed as

$$\lambda_0^2=\frac{d\varphi\varphi+d\eta\eta}{2}+\sqrt{\left(\frac{d\varphi\varphi-d\eta\eta}{2}\right)^2+(d\varphi\eta)^2}$$

$$dXY=\frac{\sum_i \omega_i X_i Y_i}{\sum_i \omega_i}-\frac{\sum_i \omega_i X_i \sum_i \omega_i Y_i}{\left(\sum_i \omega_i\right)^2} \qquad \omega_i=4.5-\log\left(\frac{E_i}{E_{clus}}\right)$$

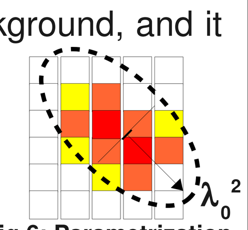

Fig 6: Parametrization scheme of clusters.

Data driven λ_0^2

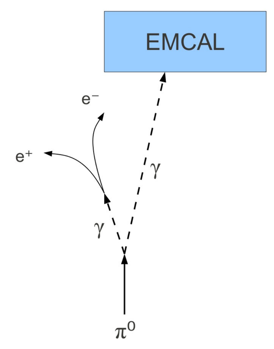

Fig. 7: Semi-converted π^0 detection

We test our shower shapes simulations with a data driven investigation of how they should look like from data, by selecting semi-converted π^0s, according to the schematics in figure 7. In such cases, one of the decay photons converts into pairs in the inner material, and the second one hits the EMCal, leaving a clear photon signature in the detector.

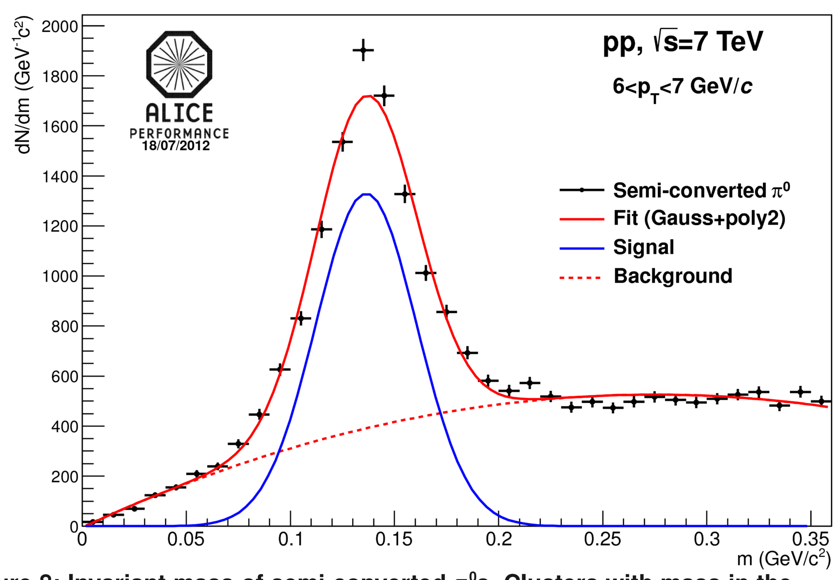

Figure 8: Invariant mass of semi-converted π^0s. Clusters with mass in the $0.11<m<0.17$ GeV/c² are selected as photons.

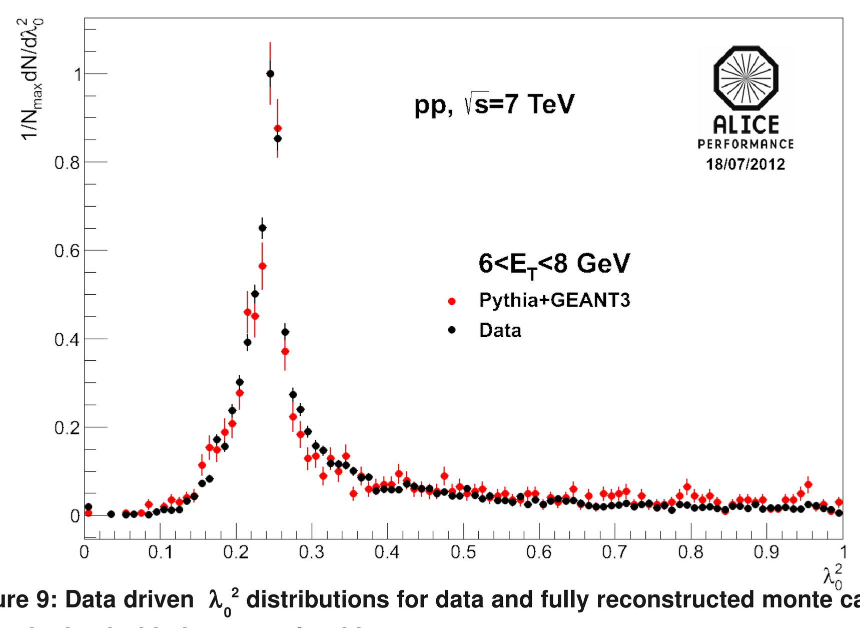

Figure 9: Data driven λ_0^2 distributions for data and fully reconstructed monte carlo, both obtained with the same algorithm.

Analysis II: Isolation

The isolation methodology of this analysis consists of defining a cone of R=0.4 (in η,φ space) around the photon candidate, and adding the $E_T(p_T)$ of all cells (tracks) inside the cone, and subtract the E_T of the candidate. To estimate the underlying event (UE) energy density, we use the $E_T(p_T)$ in the rectangular area of the remaining EMCal η range, at the same $\Delta\varphi$ of the cone. Figure 10 depicts all the elements described above in a sketch of the EMCal. Then the energy in the rectangle is re-normalized to the area of the cone.

After getting the normalized UE energy, it is then subtracted from the energy in the isolation area. This net energy inside the cone we defined as our isolation quantity, or simply ISO.

Figure 11 shows the distribution of the ISO quantity of photon candidates for two E_T bins. To estimate the background, we select clusters with λ_0^2 in the π^0 band, as seen in fig. 5, or $\lambda_0^2>0.4$ for higher E_T.

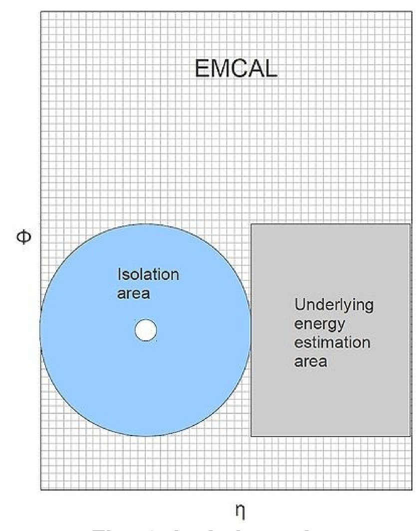

Fig 10: Isolation scheme

The ISO distribution for the background is also plotted in figure 11 (red). The background selection is scaled by the tails to the right for ISO>15 GeV. From the plots it is visible that the background estimation describes very well the underlying background of the photon candidates, as is also possible to see a strong enhancement on ISO ~0 GeV, where the signal is expected to be.

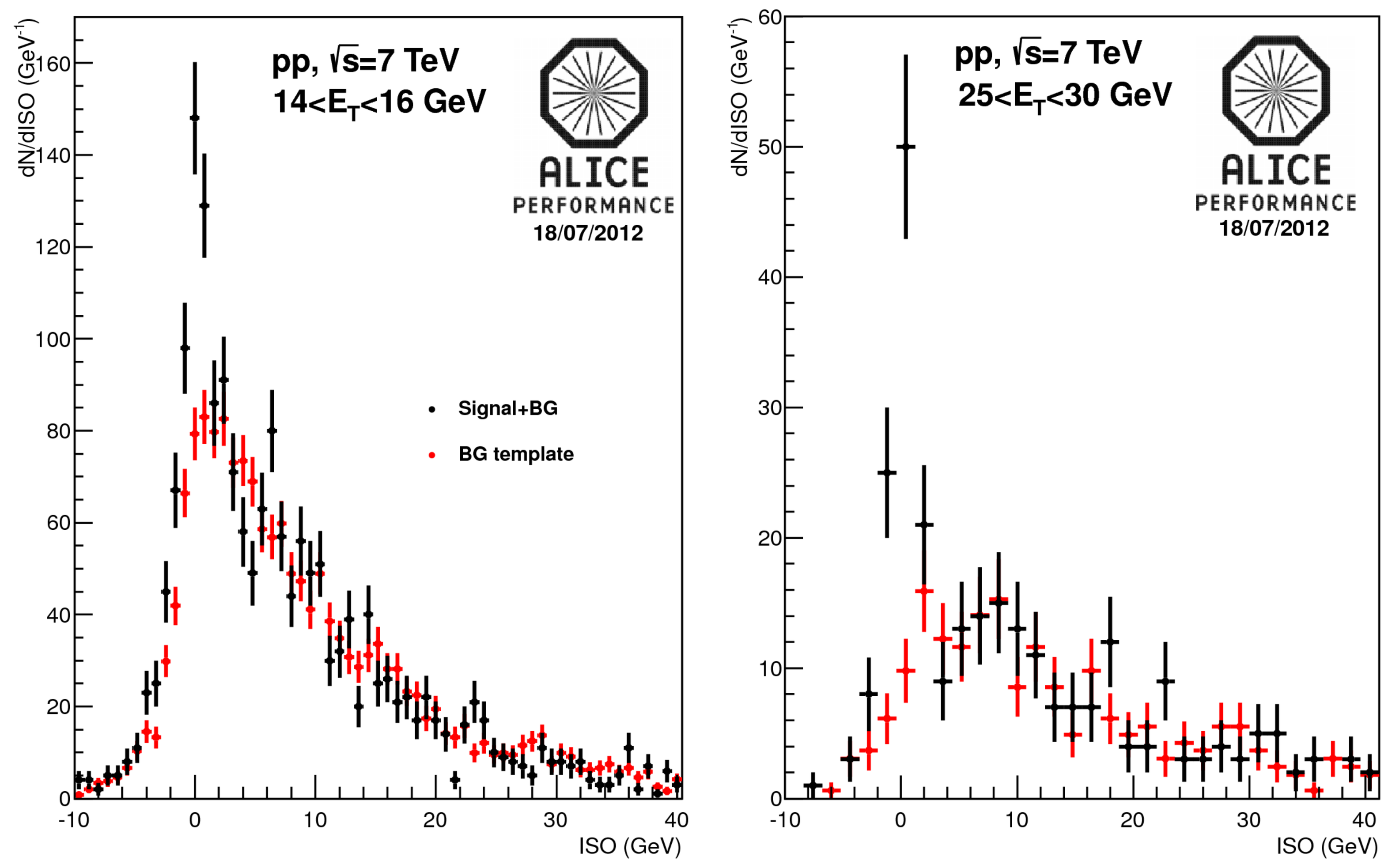

Figure 11: Signal and background isolation distributions for two E_T bins

Figure 12 shows the the increase of the of the purity of the isolation as a function of the photons energies, obtaining for this energy range a purity level as high as ~70%

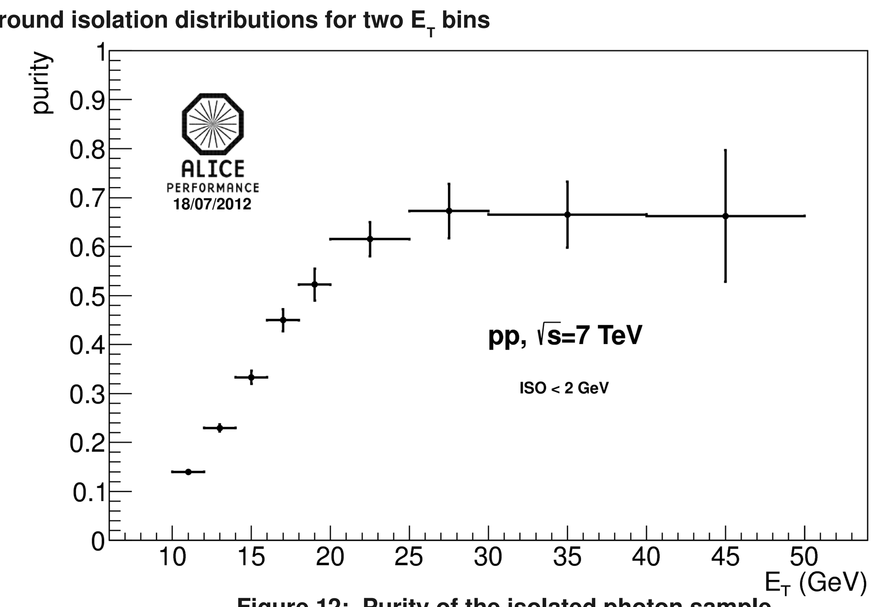

Figure 12: Purity of the isolated photon sample

Raw Yield

The raw yield of the isolated photons after background subtraction is presented in figure 13. The kinematical range for the isolated photon measurement using the ALICE EMCal covers the lower end of the energy spectrum not covered by similar measurements of other LHC experiments [4,5].

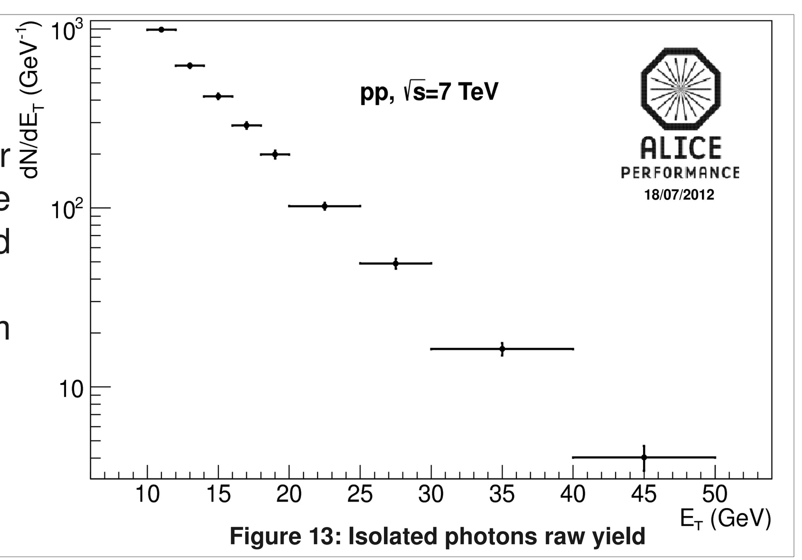

Figure 13: Isolated photons raw yield

Conclusions

We showed that the ALICE EMCal, is capable of reconstructing, identifying and selecting isolated photons in the $10<E_T<50$ GeV range in pp collisions at c.m.s. energy of 7 TeV.

This method can be used to measure the isolated photon spectra in pp and Pb-Pb collisions at 2.76 TeV, and especially the upcoming p-Pb collisions.

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References

[1] – The ALICE experiment at the CERN LHC, 2008 JINST 3 S08002
[2] – EMCal TDR, CERN-LHCC-2006-014
[3] – CMS Collaboration,Physical Review Letters, 106(8):082001
[4] – ATLAS Collaboration,Phys. Rev. D 83, 052005 (2011)