The Compact Muon Solenoid Experiment
Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

05 January 2011 (v3, 07 January 2011)

Photon reconstruction with CMS

Anna Falkiewicz for the CMS Collaboration

Abstract

The performance of photon reconstruction and identification has been studied at $\sqrt{s} = 7$ TeV. Reconstruction and identification variables are compared between data and Monte Carlo for signal and background. Level 1 Trigger and High Level Trigger efficiencies have been measured. The implications for heavy-ion running will be presented as well.

Presented at *HP2010: 4th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions*

Photon reconstruction with CMS

Anna Falkiewicz*

L'Institut de Physique Nucléaire de Lyon

Abstract

The performance of photon reconstruction and identification has been studied at $\sqrt{s} = 7$ TeV. Reconstruction and identification variables are compared between data and Monte Carlo for signal and background. Level 1 Trigger and High Level Trigger efficiencies have been measured. The implications for heavy-ion running will be presented as well.

Keywords:

1. Introduction

Lead-Lead collisions at a centre-of-mass energy of 2.76 TeV per nucleon pair at LHC will allow detailed measurement of in-medium modifications of fragmentation functions of parton initiated jets, using the γ -jet channel. The use of photons as probes of the hard interactions has many advantages over purely hadronic states. Photons do not hadronize and thus their state is not changed by the final state QCD dynamics. Detector performances in terms of position and energy measurement are much better for photons than for jets.

Isolated photon spectrum can be already measured in proton-proton collisions at LHC. Prompt photons are produced either directly in the hard scattering or collinear fragmentation of a parton producing large transverse momentum. Prompt photons are the signal of the measurement, with respect to the background from electromagnetic showers resulting from decays of neutral hadrons in jets such as π^0 and η mesons.

2. Photon detection in CMS experiment

The CMS detector is a general-purpose detector built to explore the physics at the TeV scale[1]. The main instrument for photon detection is the homogenous crystal electromagnetic calorimeter (ECAL) covering pseudo-rapidity $|\eta| < 3.0$. The ECAL is divided in barrel (EB) and endcap (EE) sections, with the barrel covering $|\eta| < 1.479$. In the endcap region there is a lead-silicon-strip preshower detector (ES) consisting of two orthogonal silicon strip detectors that have a strip pitch of 1.9 mm. One plane of the detector is at a depth of $2 X_0$ and the other is at $3 X_0$. The ECAL is surrounded by brass/scintillator sampling hadron calorimeter (HCAL) with coverage up to $|\eta| < 5.0$. The HCAL is sub-divided into towers with a segmentation of $\Delta\eta \times \Delta\phi = 0.087 \times 0.087$, corresponding to 5×5 ECAL crystals in the barrel region. The CMS tracking system is composed of multiple silicon pixel and microstrip layers and covers the regions $|\eta| < 2.5$. Both tracker and calorimeters are immersed in a 3.8 Tesla solenoidal field. Data used for the analysis[2] corresponds to 74 nb^{-1} collected at $\sqrt{s} = 7$ TeV of LHC collision energy.

*on behalf of CMS Collaboration

Email address: falkiewi@cern.ch (Anna Falkiewicz)

Figure 1: The supercluster candidates reconstructed in CMS ECAL with η distribution (a) and p_T distribution of EB region (b). The Monte Carlo distributions are normalized to the same area of data.

3. Photon reconstruction

In CMS photons are primarily reconstructed through the energy deposits in ECAL. 5x5 crystals contain 95% of the energy of the unconverted photon. However, the presence of material in front of the calorimeter can cause conversion of photons and bremsstrahlung from electrons and positrons. Because of the strong magnetic field the energy flow associated to primary electrons or converted primary photons then spreads in ϕ with increasing distances from the collision vertex within the tracker volume. The superclusters combine clusters in the ECAL to recover the energy lost due to bremsstrahlung and conversions.

Reconstructed superclusters in data are compared to those in a Monte Carlo sample of QCD and photon plus jet events with outgoing parton transverse momentum in the centre of mass frame of $\hat{p}_T > 15$ GeV simulated with PYTHIA 6, tune D6T. The comparison of supercluster η and raw E_T distributions is shown in figure 1. The supercluster has no energy corrections and the transverse energy is calculated using the nominal interaction point. Good agreement is found between data and Monte Carlo. To avoid the gap between EB and EE, an EB(EE) supercluster is required to be in the region of $|\eta| < 1.4442$ ($1.566 < |\eta| < 2.5$).

Photon objects are constructed from the superclusters by assigning the candidate momentum to the location of the primary vertex. The energy corrections on superclusters, typically at the 1% level, depend on the supercluster E_T and η .

4. Photon identification

The most important background to isolated photons comes from jets fragmenting mainly into light neutral mesons π^0 and η decaying to a pair of photons. Angular separation between the photons becomes of the order of the ECAL granularity for $p_T^{\pi^0} > 20$ GeV. Separation of the isolated photon component from this background becomes very challenging at high energies. The photon identification is analysis dependent. For commissioning of the photon identification the selection criteria and the cut values are adjusted on the basis of Monte Carlo simulation, in absence of a data-driven control sample, aiming to maximize the background rejection while keeping the efficiency flat as a function of η and E_T . This is a robust selection intended to be used for commissioning and early analysis. We use

Figure 2: The combined (ECAL+HCAL+Tracker) isolation variable (a) and $\sigma_{\eta\eta}$ (b) with different contributions illustrated.

for photon identification only the variables that have similar behaviour for electrons and photons, so that photon ID efficiencies can be measured on an electron control sample in data when sufficient statistics are available.

For commissioning of the photon identification the following variables are used:

- The supercluster is required not to match pixel hits consistent with a track from the interaction region.
- ECAL isolation, which is the sum of ECAL E_T around the photon candidate in an annular region of inner radius $R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.06$ and outer radius 0.4. In order to remove the contribution due to the photon candidate a five-crystal wide strip along ϕ is excluded.
- HCAL isolation, which is the sum of HCAL E_T around the photon candidate in an annular region of inner radius $R = 0.15$ and outer radius 0.4.
- Tracker isolation, the scalar sum of p_T of tracks consistent with the primary vertex in a hollow cone around the photon candidate in an annular region of inner radius $R = 0.04$ and outer radius 0.4.
- Showers initiated by charged hadrons are rejected by using E^{HCAL}/E^γ , where E^{HCAL} is the sum of energy in the HCAL towers behind the photon candidate and within $R < 0.15$.

While isolation criteria remove the bulk of the neutral meson background, a substantial contribution remains, mainly due to fluctuations in the fragmentation of jets leading to neutral mesons carrying most of the parton energy. Powerful instrument to separate signal and background is based on analysis of topology of the energy deposits. $\sigma_{\eta\eta}$ variable, which is η - η element of η - ϕ covariance matrix, is sensitive to the differences between isolated prompt photons and hadron decay photons; the former have a well-defined peak, while the latter have a tail extending to large values of $\sigma_{\eta\eta}$. It measures the width of the photon SC in the η direction. It is calculated with logarithmic weights, and relative to the energy of the 5x5 crystals around the seed crystal (E_{5x5}). It is given by:

$$\sigma_{\eta\eta}^2 = \frac{\sum_i^{5x5} w_i (\eta_i - \eta_{seed})^2}{\sum_i^{5x5} w_i}, w_i = \max(0, 4.7 + \ln \frac{E_i}{E_{5x5}}), \quad (1)$$

where E_i and η_i are the energy and η index of the i^{th} crystal within 5x5 electromagnetic cluster and η_{seed} is the η index of the seed crystal.

Figure 3: The ET distributions of isolated photon candidates in EB (a) and EE (b).

Variable	Pixel seed	E_T	Tracker Iso	ECAL Iso	HCAL Iso	E^{HCAL}/E^γ	$\sigma_{i\eta i\eta}$
Barrel	require none	30 GeV	2.0 GeV	4.2 GeV	2.2 GeV	0.05	0.01
Endcap							0.03

Table 1: Photon ID thresholds for the barrel and the endcap regions.

The values of the cuts adopted for the photon ID are shown in table 1.

Two distributions, the combined ECAL+HCAL+Tracker isolation and $\sigma_{i\eta i\eta}$, are shown in figure 2. In each figure, we show the estimated contributions (based on Monte Carlo truth information) from real photons coming from both the hard interaction (partonic) and from ISR/FSR, as well as that coming from the residual jet background (MC other). With this selection, the Monte Carlo predicts a purity of about 50% signal photons with $E_T > 30$ GeV. The efficiency of the selection on isolated photons in Monte Carlo is about 90% in the EB and 80% in EE.

The E_T spectrum of isolated photon candidates, with above photon identification selections applied, are shown in figure 3. Each of the contributions is estimated from Monte Carlo simulation and normalized to the relative cross-section obtained from PYTHIA.

5. Summary

The basic reconstruction quantities for photons are compared to the Monte Carlo simulation with quite good agreement. Using a selection which is intended to enrich the sample in signal photons (partonic and from ISR/FSR) and suppress the background from QCD, we have illustrated that the photon reconstruction and identification performance is similar to that expected from simulation.

References

- [1] CMS Collaboration, The CMS experiment at the CERN LHC, JINST 3 (2008) S08004. doi:10.1088/1748-0221/3/08/S08004
- [2] CMS collaboration, Photon reconstruction and identification at p s = 7TeV, CMS Physics Analysis Summary EGM-10-005 (2010).