Electron and Photon performance using data collected by CMS at $\sqrt{s} = 13$ TeV and 25ns

EGamma POG

Abstract

This note describes preliminary performances of the electron and photon reconstruction with the CMS experiment using data collected at $\sqrt{s} = 13$ TeV and with a LHC bunch spacing of 25ns. Electron and photon key discriminating variables and their data to simulation agreement are shown. The identification and reconstruction efficiencies are also computed and compared to the ones from the simulation. Performances and data to simulation agreement are expected to improve with future calibrations and reprocessing.
Outline

- Dielectron mass plot
- Electron ID and Isolation Variables (using $Z \rightarrow ee$)
- Electron Reconstruction and Identification Efficiency
- Photon ID and Isolation Variables (using $Z \rightarrow \mu\mu\gamma$)
- Photon Identification and Electron Veto Efficiency
Electrons data / MC agreement, event selection

- **Data**: recorded with single electron trigger, 2.1 fb⁻¹
- **Simulation**: only Drell Yan simulated using madgraph generator
- **Data/MC agreement** shown for probe electrons selected using a tag and probe methods with the following criteria

**Tag electron selection**
- \( p_T(e) > 30 \text{ GeV} \)
- \( |\eta(e)| < 2.1 \)
- Tight identification criteria
- Trigger matched

**Probe electron selection**
- \( p_T(e) > 10 \text{ GeV} \)
- \( |\eta(e)| < 2.5 \)
- Loose identification criteria
- Relative isolation (PU corrected) < 0.1

**Event selection**
- \( 80 < m(ee) < 100 \text{ GeV} \)
Leading Electron $p_T$

Electron transverse momentum spectrum for the leading electron. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
Electron transverse momentum spectrum for the trailing electron. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
Leading Electron $\eta$ & $\phi$

Electron pseudorapidity (left) and phi (right) distributions for the leading electron.
Electron pseudorapidity (left) and phi (right) distributions for the trailing electron.
ECAL-crystal-based shower covariance in the $\eta$ direction. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
The sum of transverse energies of neutral electromagnetic candidates in a $\Delta R = 0.3$ cone around the electron, divided by the electron transverse momentum. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right), isolation cut removed.
The sum of transverse energies of charged hadron candidates in a $\Delta R = 0.3$ cone around the electron, divided by the electron transverse momentum. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right), isolation cut removed.
The sum of transverse energies of neutral hadron candidates in a $\Delta R = 0.3$ cone around the electron, divided by the electron transverse momentum. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right), isolation cut removed.
The ratio of energy measured in the hadronic calorimeter (HCAL), in a $\Delta R = 0.15$ cone behind the electron seed, over the energy measured in the ECAL. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
The difference in $\eta$ between the energy-weighted supercluster position in the electromagnetic calorimeter (ECAL) and the track direction at the innermost tracker position. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).

Disagreement in the EE due to Tracker/ECAL misalignment not corrected yet.
The difference in $\phi$ between the energy-weighted supercluster position in the electromagnetic calorimeter (ECAL) and the track direction at the innermost tracker position. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
The fraction of momentum lost to bremsstrahlung measured in the tracker, defined as $f_{Brem}$. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
Absolute difference between the inverse electron energy measured in the electromagnetic calorimeter (ECAL) and the inverse momentum measured in the tracker. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
The number of missing inner layer hits in the electron track. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).
The output of the electron identification MVA, which uses track and supercluster variables as input. Shown for electrons in the ECAL barrel (left) and ECAL endcap (right).

The data/MC discrepancy on the left tail is due to background contamination.
Electron efficiency measurement

- **Data**: recorded with single electron trigger, 2.5 fb⁻¹
- Efficiency measured in data with the tag and probe method using Z\(\rightarrow\)ee
  - number of probe electrons obtained from a fit to the dielectron invariant mass
  - signal modeled by (Z/\(\gamma^*\)→ee) simulation
  - background modeled with ad hoc analytical function

- Three different types of efficiency are measured:
  - electron reconstruction criteria
  - electron cut-based identification criteria
  - electron mva-based identification criteria (for triggering and non-triggering electrons)

- Sources of systematic uncertainties considered
  - Modeling: signal and background modeling
  - Simulation: kinematics, pile-up
  - Event selection: tag electron selection
Electron reconstruction efficiency in data (top) and data to MC efficiency ratios (bottom).

The efficiency is measured with the tag and probe method and shown in five pseudorapidity ranges as a function of the electron transverse momentum.

Blue points correspond to the Barrel-Endcap transition region.
Electron cut-based ID

Electron identification efficiency in data (top) and data to MC efficiency ratios (bottom) measured for the tight cut-based work points.

The efficiency is measured with the tag and probe method and shown in five pseudorapidity ranges as a function of the electron transverse momentum.

Blue points correspond to the Barrel-endcap transition region, hence have a much lower efficiency.
Electron triggering MVA ID

Electron identification efficiency in data (top) and data to MC efficiency ratios (bottom) measured for the identification criteria based on a MVA discriminant with an average efficiency of 80%.

The efficiency is measured with the tag and probe method and shown in three pseudorapidity ranges as a function of the electron transverse momentum.
Photon data/MC agreement, event selection

- **Data**: recorded with double muon trigger, 2.2 fb\(^{-1}\)
- **Simulation**: only Drell Yan simulated using MC@NLO generator
- Photon sample from \(Z \rightarrow \mu\mu\gamma\) decay selected with

**Muon selection**
- \(p_T(\mu) > 20\), 10 GeV
- Tight identification criteria

**Photon selection**
- \(p_T(\gamma) > 10\) GeV
- \(H/E < 0.05\)
- \(\sigma_{\text{in}\eta} < 0.011\) (0.031) for EB (EE)
- Charged isolation (corrected from PU) < 3.0 GeV

**Event selection**
- \(\Delta R(\mu,\gamma)_{\text{min}} < 0.8\)
- \(m(\mu\mu\gamma) + m(\mu\mu) < 180\) GeV
- \(70 < m(\mu\mu\gamma) < 110\) GeV
Photon SuperCluster $\eta$ and $\phi$

Pseudorapidity (left) and $\phi$ (right) distributions of the SuperCluster of selected photons.
SuperCluster energy (left) and transverse momentum (right) distributions of the SuperCluster of selected photons.
ECAL-crystal-based shower width in the $\eta$ direction for barrel (left) and endcap (right) photons.
Covariance $\text{_{\phi \eta}}$

ECAL-crystal-based covariance for barrel (left) and endcap (right) photons.
Ratio of energy in the HCAL to the energy of the ECAL SuperCluster for barrel (left) and endcap (right) photons.
Width of the Photon SuperCluster in $\eta$ and $\phi$

$\eta$ (left) and $\phi$ width of the SuperCluster of the selected photons.
Relative Charged Hadron Isolation

Sum of transverse energy of the charged hadrons around the selected photons. This is shown in the barrel (left) and endcap (right).
Relative Electromagnetic Isolation

Sum of transverse energy of the photons around the selected photons. This is shown in the barrel (left) and endcap (right).
Relative Neutral Hadron Isolation

Sum of transverse energy of the neutral hadrons around the selected photons. This is shown in the barrel (left) and endcap (right).
The output of the photon identification MVA. Shown for photons in the barrel (left) and endcap (right)
Photon efficiency measurement

Data: recorded with single electron trigger, \(2.5 \text{ fb}^{-1}\)

Efficiency measured in data with the tag and probe method using \(Z \rightarrow \text{ee}\)

- probe candidates are electrons reconstructed as photons
- number of probe photons obtained from a fit to the dielectron invariant mass
- signal modeled by \((Z/\gamma^* \rightarrow \text{ee})\) simulation
- background modeled with ad hoc analytical function

Two different types of efficiency are measured:

- photon cut-based identification criteria
- photon mva-based identification criteria

Sources of systematic uncertainties considered

- Modeling: signal and background modeling
- Simulation: kinematics, pile-up
- Event selection: tag electron selection
Photon ID efficiency

Photon identification efficiency in data and data to MC efficiency ratios measured for the tight cut-based work point (left) and for the identification based on a MVA discriminant (right). The efficiency is measured with the tag and probe method and shown in three pseudorapidity ranges as a function of the photon transverse momentum.
Photon conversion safe electron Veto (CSEV) efficiency

- Pure sample of photons selected from $Z \rightarrow \mu\mu\gamma$ decay (see page 23)
- Efficiency measured counting numbers of photon passing and failing the CSEV criteria

CSEV identification efficiency in data (top) and corresponding data to MC efficiency ratios (bottom).

Statistical uncertainties only