Electron and Photon reconstruction and identification with the CMS detector in pp collisions at $\sqrt{s}=7$ TeV

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Outline

- Physics with electrons and photons at CMS
- Electron/Photon triggers
  - Electron candidates in Minimum Bias events
  - Prompt electrons from W/Z decays
    - electron reconstruction commissioning
    - electron selections commissioning
    - electron variables commissioning
  - Electron fake rate measurement
- Photon reconstruction
  - Selection of photon enriched sample
  - Converted photons
Physics with e and γ at LHC

On the critical paths of LHC major discoveries $H \rightarrow ZZ^* \rightarrow 4e$, $H \rightarrow γγ$, $Z' \rightarrow ee$,...

Vital objects to establish calibration and SM candles $Z \rightarrow ee$, $W \rightarrow ev$,...

Performance for physics depends on: efficiency, energy resolution, particle identification, isolation.
CMS Detector

The Electromagnetic CALorimeter
made of homogeneous PbWO₄ crystals

**Barrel**
61200 crystals with APD readout

**Endcap**
14648 crystals with VPT readout

**Preshower**

More details in the P.Grás’s talk in this session

The Tracker
all silicon, coverage |η|<2.5

**Pixels**
~1 m² of Si sensors, 65 M channels

**Strips**
~198 m² of Si sensors, ~9.6 M channels

More details in the S.Lowette’s talk in this session

ECAL and Tracker inside the superconducting solenoid (B=3.8T)
Important material budget before ECAL → dedicated algorithms
Level I and High Level Trigger

Events filtered online in two steps: Level I (hardware) and High Level Trigger (software).

Trigger efficiencies have been measured on Minimum Bias data.

The Level I trigger efficiency for a nominal 5 GeV threshold.

Electrons in the ECAL barrel (black dots), electrons in the ECAL endcaps (red empty squares).

The HLT efficiency for nominal 15 GeV threshold.
Electron reconstruction

**Energy clustering** to recover bremsstrahlung
- **Superclusters** are built by collecting clusters of crystals within in $\phi$ window

**Electron seeding** two complementary algorithms
- Start from ECAL superclusters and search for compatible hits in the tracker inner layers (ECAL driven)
- Start from tracks (Tracker driven)

**Electrons tracking**
- Bremsstrahlung energy loss modeled with a mixture of Gaussians (Gaussian Sum Filter)

**Electrons preselection**
- Track Supercluster position matching cuts
- Multivariate analysis
First electron commissioning
assessment with Minimum Bias events

The contribution of **ECAL driven**
electron is above 4 GeV/c
The contribution of **tracker driven**
electron extends coverage at low pT

At this stage the inclusive sample of **electron candidates** is composed from
4.6% real electrons (mainly Ds/Bs decays, few J/Ψ)
33.9% gamma conversion
61.5% fakes from hadrons
Electron commissioning at high pT
with more statistics use electrons from W/Z

W and Z selections are used to commission reconstruction and measure efficiencies

**W Selection:**
- high MET
- 1 high energy ECAL supercluster
- little hadronic activity

**Z Selection:**
- Tag: identified/isolated electron
- Probe: 1 ECAL supercluster
- Invariant mass

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Figures are for selected electrons
Electron reconstruction

**ECAL driven seeding**

- Start by high ET ECAL supercluster and extrapolate toward innermost tracker layers
- Pair of hits are selected within a window around the expected position (r-phi and r-z planes)

**Electron reconstruction efficiencies**

<table>
<thead>
<tr>
<th>Detector</th>
<th>Method</th>
<th>Data</th>
<th>MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrel</td>
<td>Z Tag &amp; Probe</td>
<td>0.993 ± 0.014</td>
<td>0.985</td>
</tr>
<tr>
<td>Endcap</td>
<td>Z Tag &amp; Probe</td>
<td>0.968 ± 0.034</td>
<td>0.961</td>
</tr>
</tbody>
</table>

Electron reconstruction efficiency ratio between data and MC. The shaded region is the combined efficiency data/MC ratio.
Electron selections

Electron selection is based on Identification, Isolation, Conversion rejection variables

Selection for first physics uses **simple cuts** on the discriminating observables
The selection is tuned to different tightness e.g. here 80% and 95% efficiencies

95% working point

80% working point

A more elaborate selection is obtained using an **electron classification** to separate electrons as function of the radiated bremsstrahlung and E/p variables (Cuts in Categories)
Electron variables

Examples of discriminating variables:

- supercluster shower spread in $\eta$ ($\sigma_{i\eta_{i\eta}}$)
- electron isolation
  - combined ECAL/Tracker/HCAL isolations
  - removal of the electron footprint in each detectors

Figures are normalized to integrated luminosity
Selection efficiencies

<table>
<thead>
<tr>
<th>Simple Cuts Selection</th>
<th>Z Tag&amp;Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measured efficiency</strong></td>
<td><strong>Error (stat. + syst)</strong></td>
</tr>
<tr>
<td>WP95 Barrel</td>
<td>92.5%</td>
</tr>
<tr>
<td>WP95 Endcap</td>
<td>86.4%</td>
</tr>
<tr>
<td>WP80 Barrel</td>
<td>77.5%</td>
</tr>
<tr>
<td>WP80 Endcap</td>
<td>75.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cuts in Categories Selection</th>
<th>Z Tag&amp;Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measured efficiency</strong></td>
<td><strong>Error (stat. + syst)</strong></td>
</tr>
<tr>
<td>CiC Loose Barrel</td>
<td>96.4%</td>
</tr>
<tr>
<td>CiC Loose Endcap</td>
<td>94.1%</td>
</tr>
<tr>
<td>CiC Tight Barrel</td>
<td>89.3%</td>
</tr>
<tr>
<td>CiC Tight Endcap</td>
<td>85.5%</td>
</tr>
</tbody>
</table>

Electron selection efficiency ratio between data and MC
The shaded region is the combined efficiency data/MC ratio
Fake rate measurement

Background selection:

- Single jet trigger with Raw ET > 15 GeV
- Small MET
- Reconstructed electrons outside triggering jet

Electron fake rate per reconstructed electron as a function of ET in data and simulation.
Photon reconstruction

Photon objects are reconstructed from the superclusters

Supercluster selection

- HLT Photon15
- ET > 20 GeV
- SC in |η| ≤ 2.5 but excluding barrel/endcap transition region
- H/E < 0.05

E_{3x3}/E_{SC} is used to separate converted from unconverted photons

More details on photon in the R. Shyang’s talk in the QCD session
Photon selection

Simple selection allows to define a sample with more than 50% purity from prompt photons with an efficiencies around 90% for the Barrel and 80% for the Endcap.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Barrel photon</th>
<th>Endcap photon</th>
</tr>
</thead>
<tbody>
<tr>
<td>photon $E_T$</td>
<td>$&gt; 30$ GeV</td>
<td></td>
</tr>
<tr>
<td>tracker isolation</td>
<td>$&lt; 2.0$ GeV</td>
<td></td>
</tr>
<tr>
<td>ECAL isolation</td>
<td>$&lt; 4.2$ GeV</td>
<td></td>
</tr>
<tr>
<td>HCAL isolation</td>
<td>$&lt; 2.2$ GeV</td>
<td></td>
</tr>
<tr>
<td>(hadronic/EM) energy</td>
<td>$&lt;0.05$</td>
<td></td>
</tr>
<tr>
<td>shower shape $\sigma_{\text{sh}}$</td>
<td>$&lt;0.01$</td>
<td>$&lt;0.03$</td>
</tr>
</tbody>
</table>

Require not to match a pixel hit

Photon purity increases with $E_T$
Converted photons

Selection

- \(|\Delta \cot \theta|\) between the tracks at vertex < 0.3
- \(|\Delta \varphi|\) between the tracks at vertex < 0.2
- \(P(\text{vertex})\) returned by fitter > 0.0005.

**HLT Photon, \(\text{ET} > 20 \text{ GeV},\) selection cuts applied**

Conversion \(p/E\) with \(p\) from the tracks and \(E\) from the supercluster

Variable may be used to extract photon purity in physics analysis
Conclusions

• With 200 nb\(^{-1}\) of analyzed data at \(s\sqrt{s} = 7\) TeV electrons from W and Z have been measured

• CMS has commissioned the **key observables** for the measurement, identification and isolation of primary ("prompt") electrons and photons

• Trigger, reconstruction and electron selection **efficiencies** have been measured and found to be very close to Monte Carlo simulation

• **Electron fake** rate has been measured and found in good agreement with expectation

• **Photon variables** have been compared between data and simulation for background and photon enriched samples and found in very good agreement with Monte Carlo expectation
BACKUP
Efficiency of Electron Step of HLT

CMS Preliminary, 7 TeV

$\int L \, dt = 23 \, nb^{-1}$

$|\eta| < 1.442$

$1.56 < |\eta| < 2.00$