# Electron and Photon reconstruction and identification with the CMS detector in pp collisions at sqrt(s)=7 TeV


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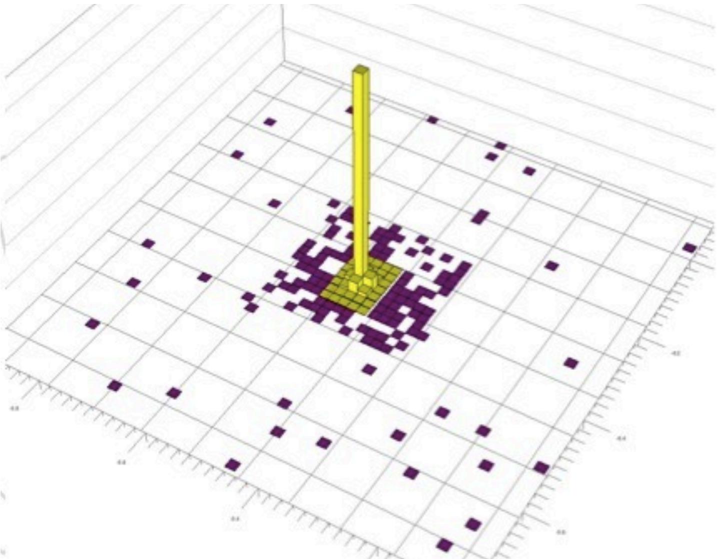
**LLR/Ecole Polytechnique**

on behalf of CMS collaboration

# Outline

- Physics with electrons and photons at CMS

- Electron/Photon triggers

Electron

- 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

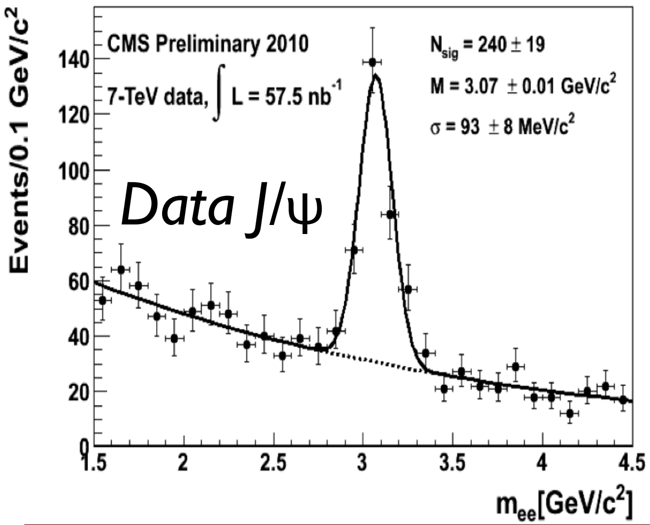
- Photon reconstruction
- Selection of photon enriched sample
- Converted photons

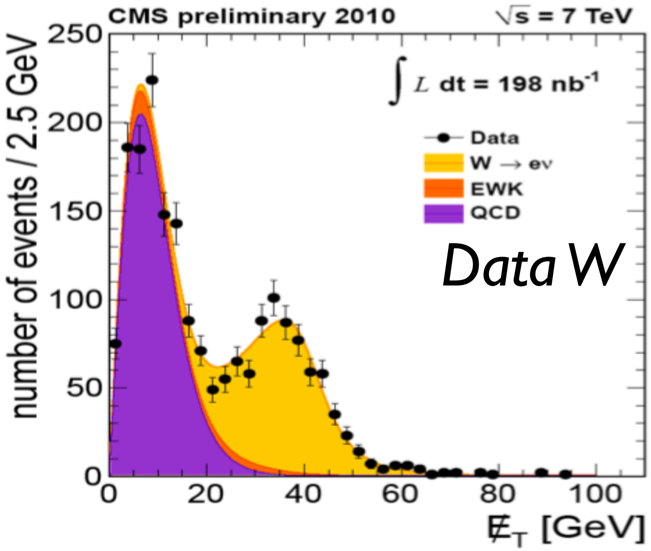
# Physics with e and γ at LHC

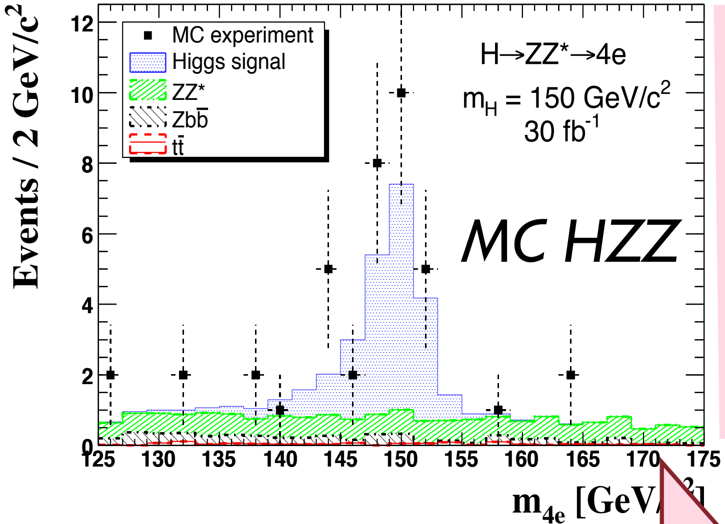
On the critical paths of LHC major discoveries $H \to ZZ^* \to 4e$, $H \to \gamma\gamma$, $Z' \to ee$,...

Vital objects to establish calibration and SM candles $Z \to ee$, $W \to e\nu$,...

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



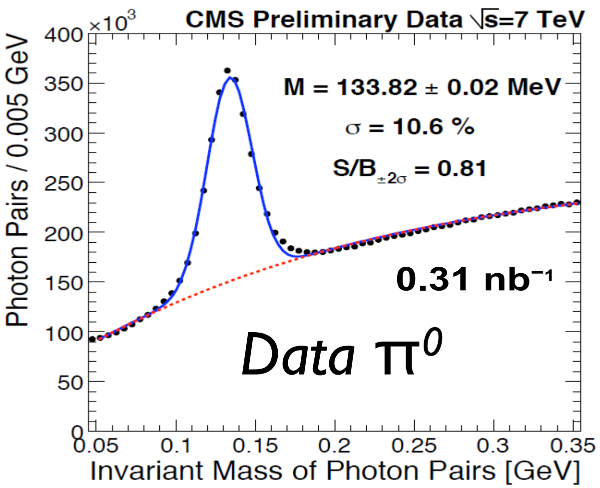



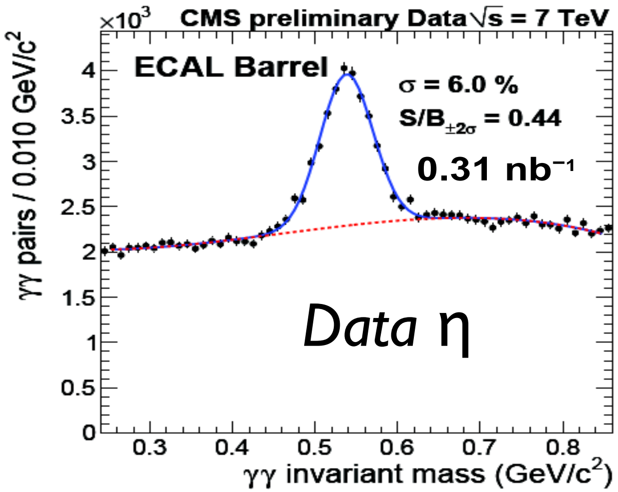



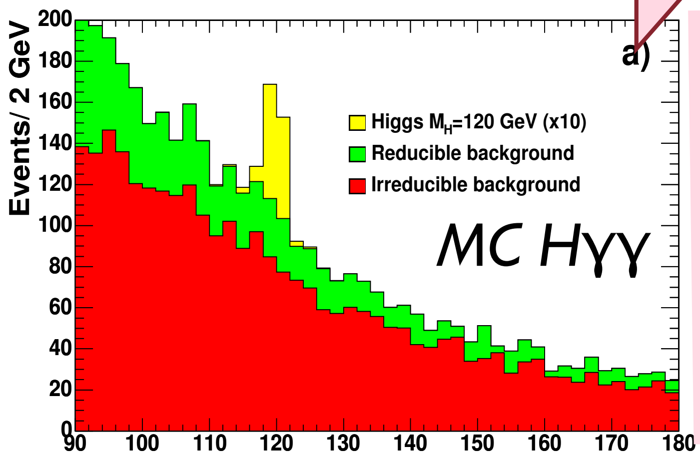

Electron

Present

Future



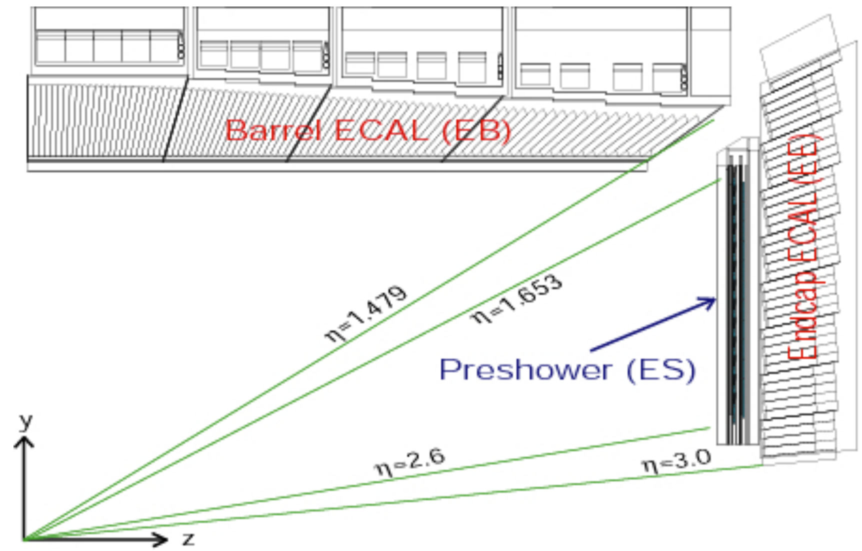

Photon

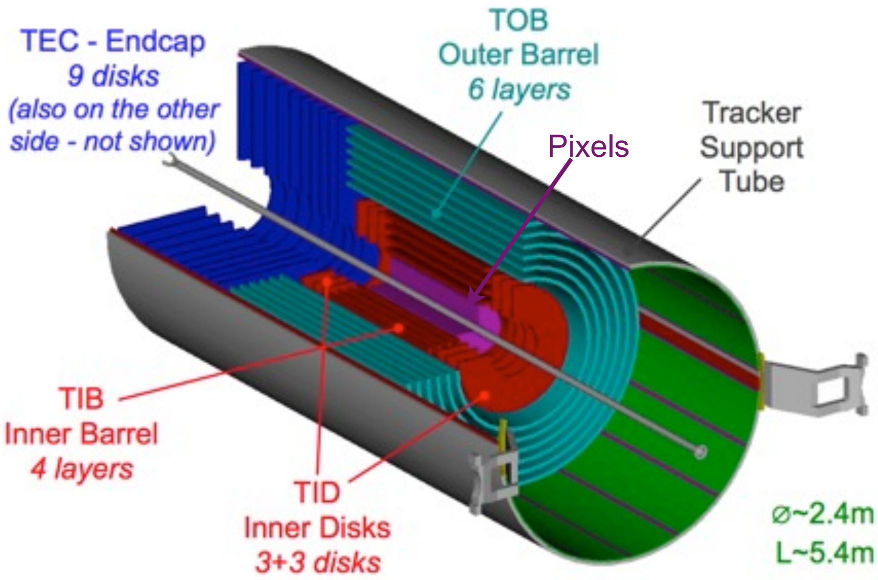
# CMS Detector

## The Electromagnetic CALorimeter
made of homogeneous $PbWO_4$ crystals

**Barrel**
61200 crystals with APD readout
**Endcap**
14648 crystals with VPT readout
**Preshower**

*More details in the P.Gras's talk in this session*




## The Tracker
all silicon, coverage $|\eta|<2.5$

**Pixels**
~1 $m^2$ of Si sensors, 65 M channels
**Strips**
~198 $m^2$ of Si sensors, ~9.6 M channels

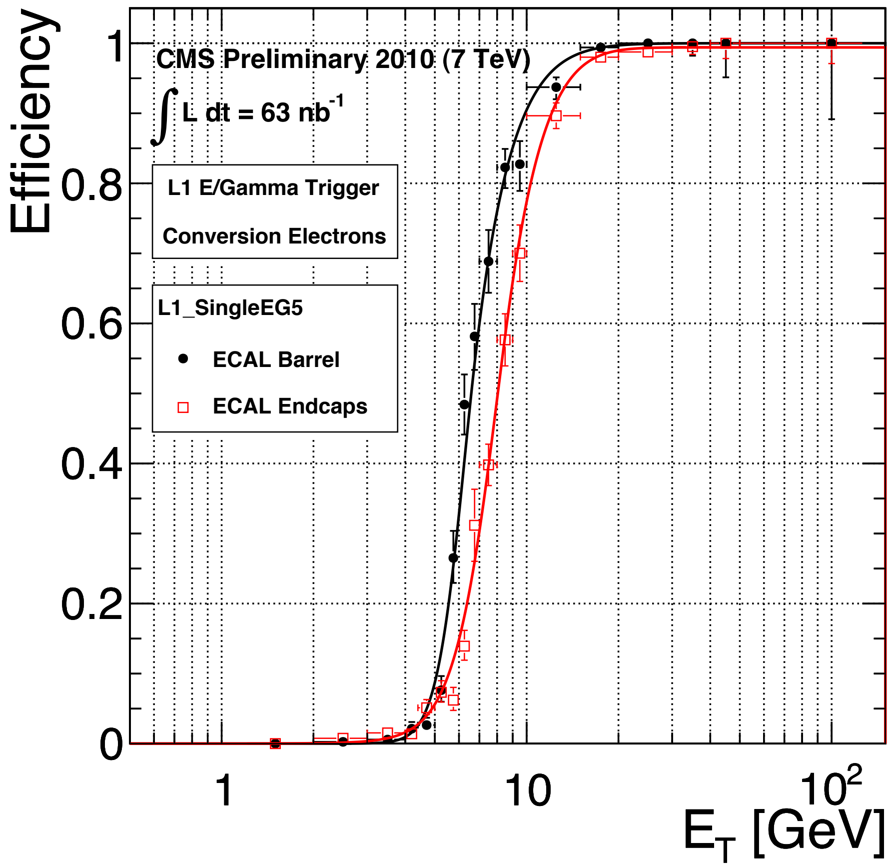
*More details in the S.Lowette's talk in this session*

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

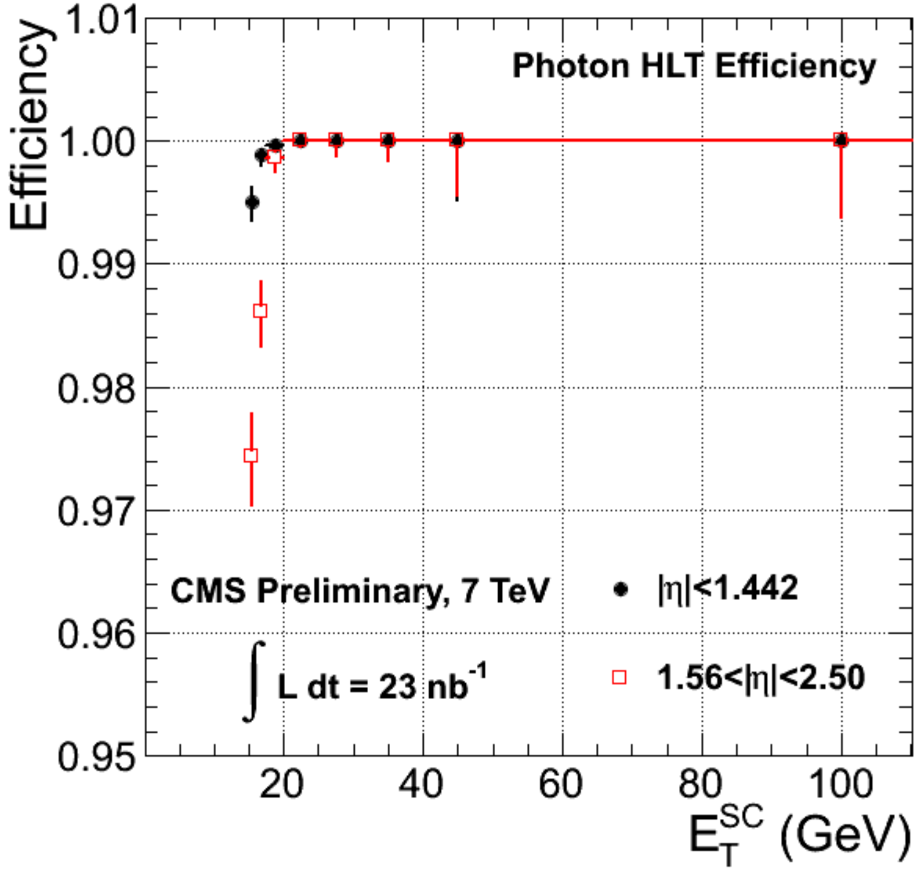
# Level1 and High Level Trigger

Events filtered online in two steps: Level1 (hardware) High Level Trigger (software)

Trigger efficiencies has been measured on Minimum Bias data




The Level1 trigger efficiency for a nominal 5 GeV threshold




The HLT efficiency for nominal 15 GeV threshold

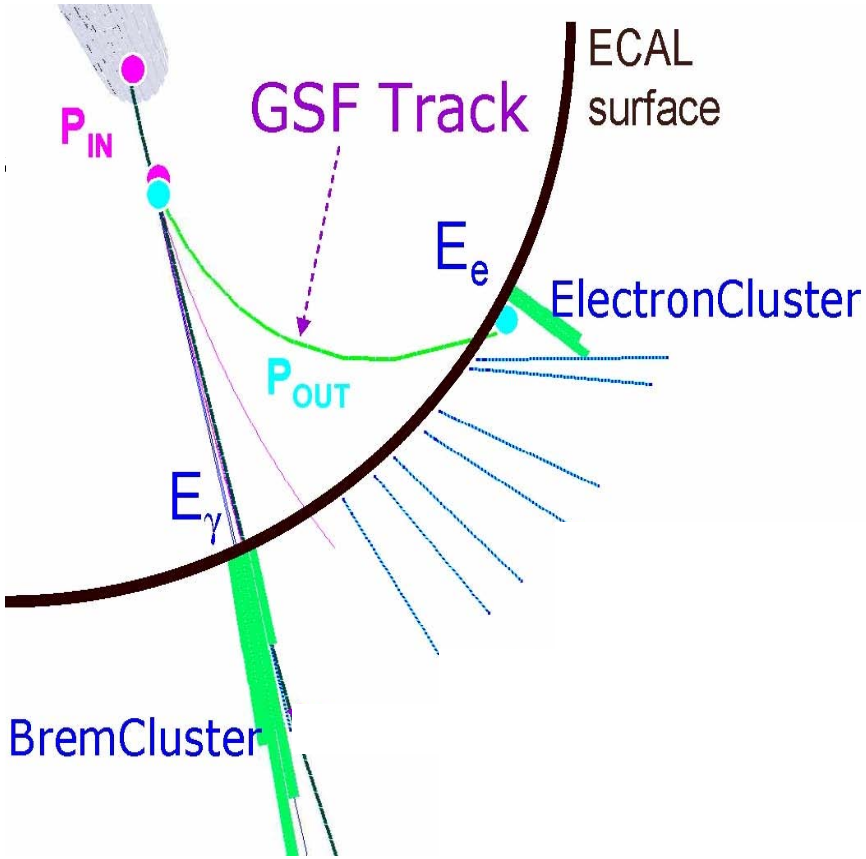
Minimum Bias Data

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

# Electron reconstruction

Energy clustering to recover bremsstrahlung

• **Superclusters** are built by collecting clusters of crystals within in φ 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)

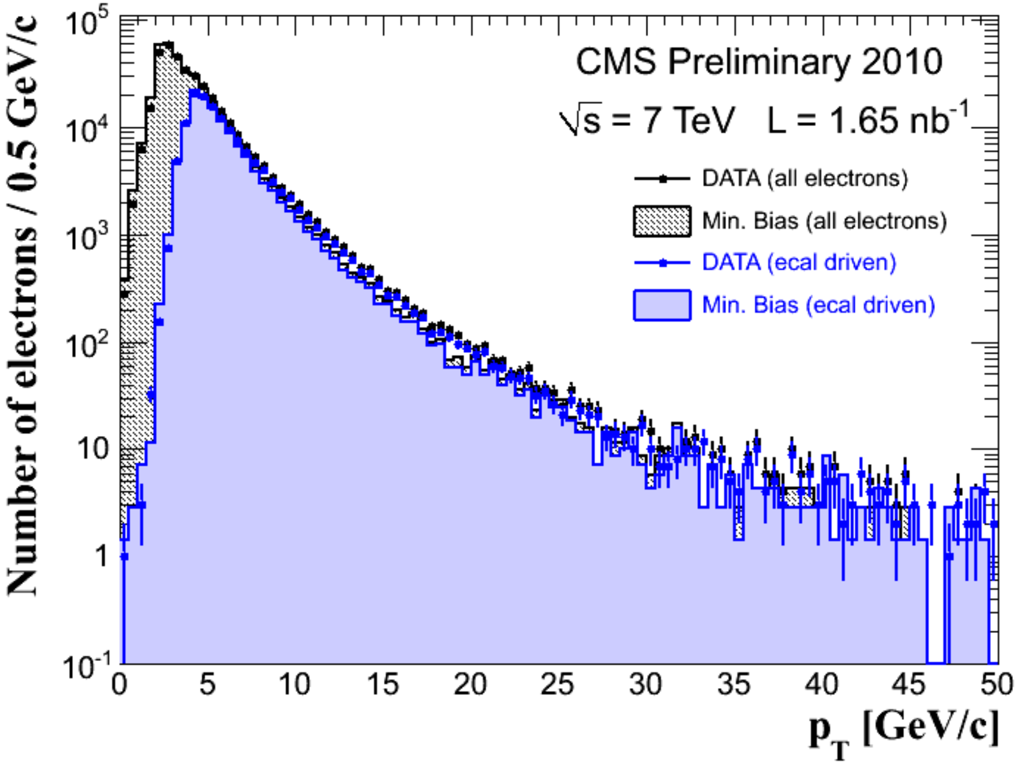
Electrons preselection

• Track Supercluster position matching cuts

• Multivariate analysis

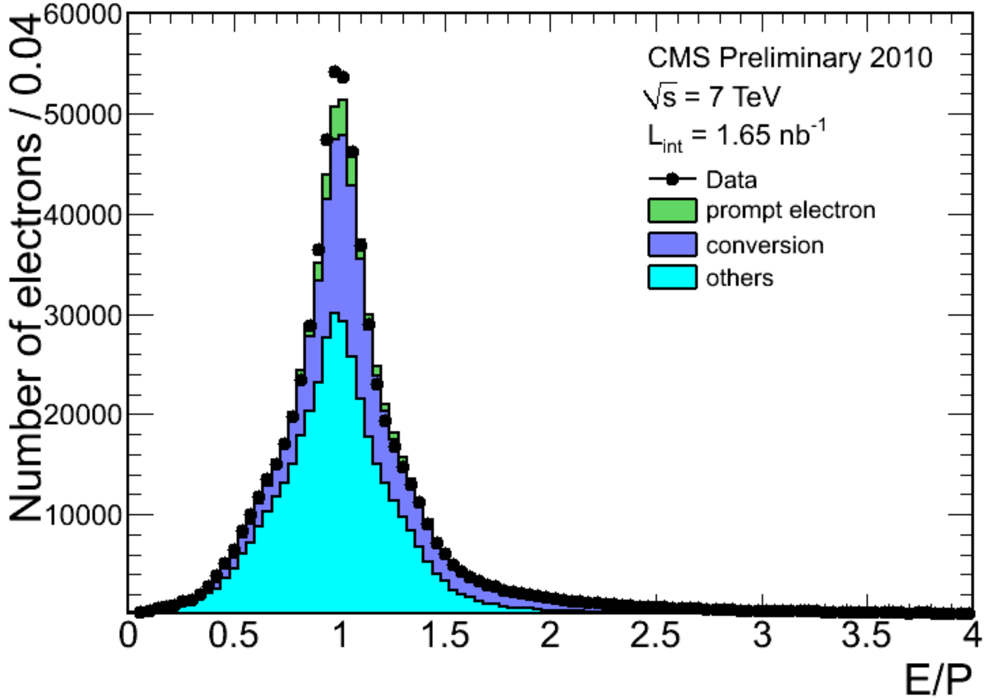
# First electron commissioning

## 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




Figures are normalized to number of entries

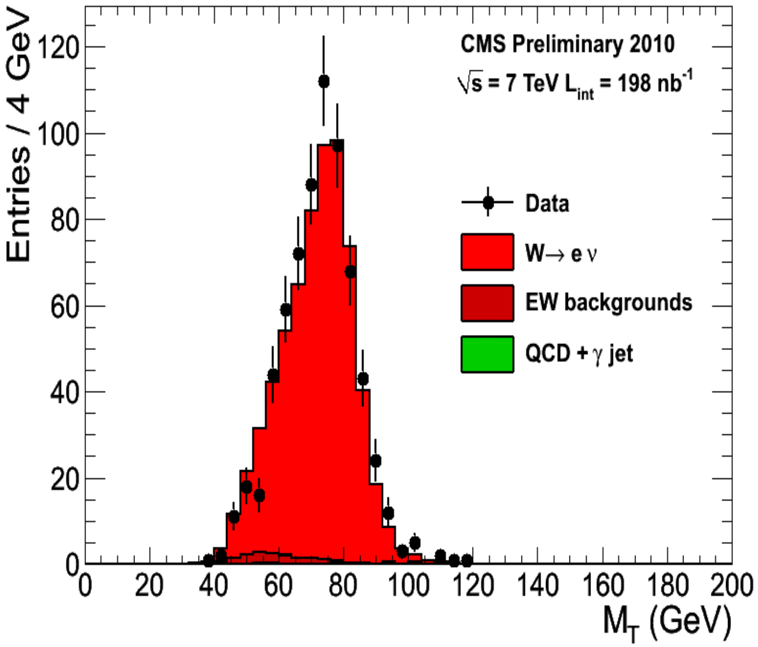
# Electron commissioning at high pT

with more statistics use electrons from W/Z

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

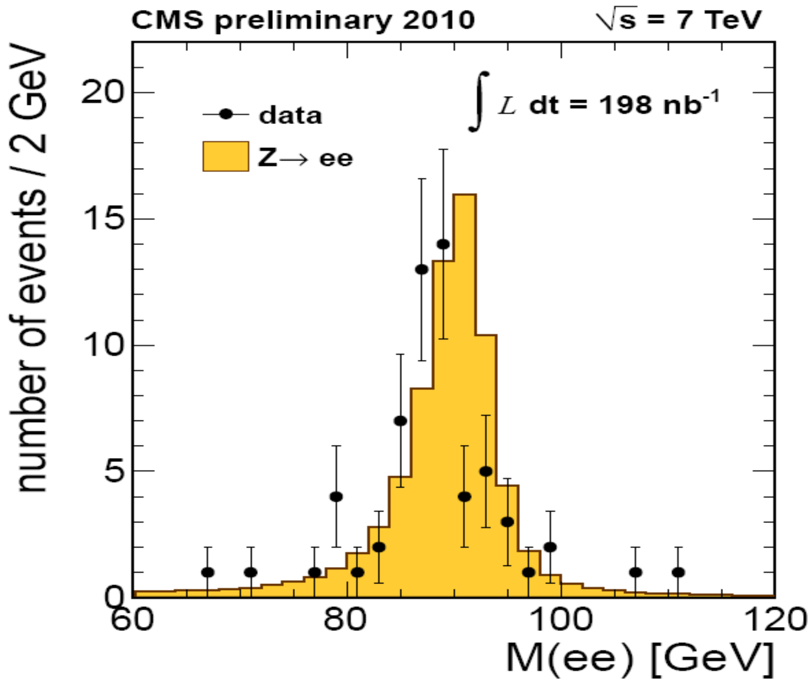
W Selection:

- high MET
- 1 high energy ECAL supercluster
- little hadronic activity




Z Selection:

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

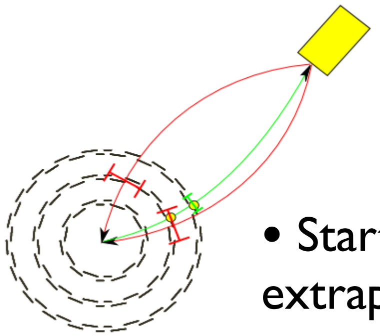



Z peak out of the box shift within 1%

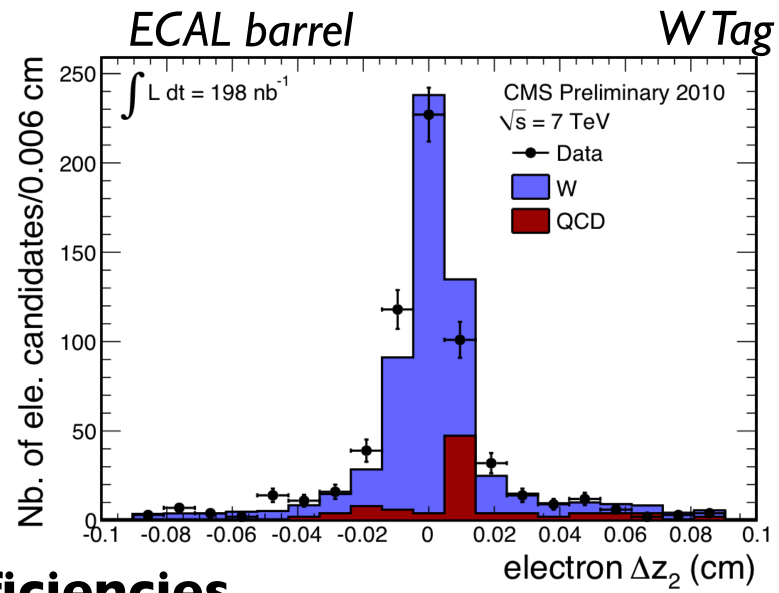
Figures are for selected electrons

# Electron reconstruction

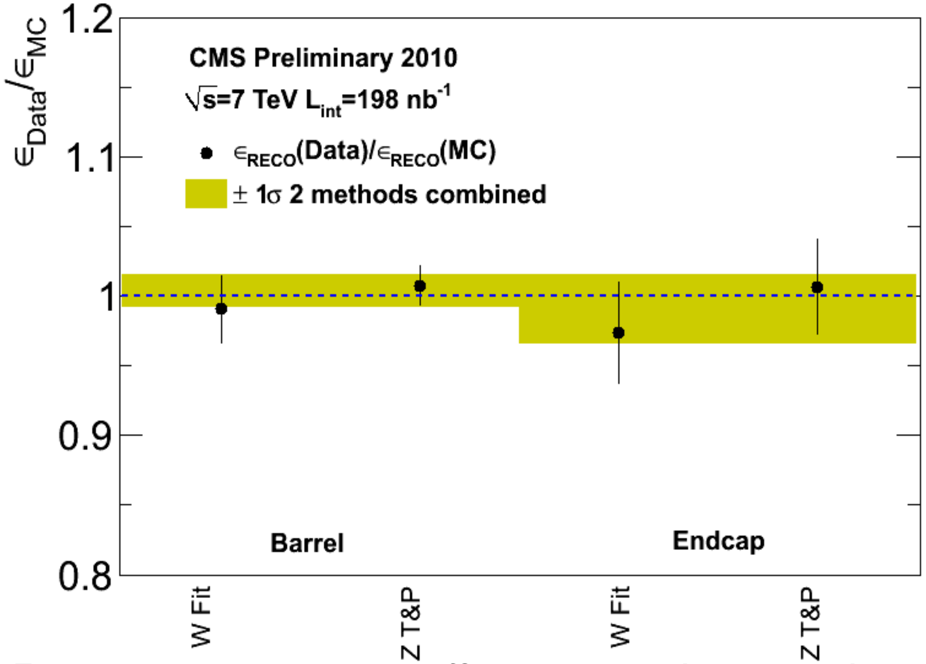
## ECAL driven seeding



- 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




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

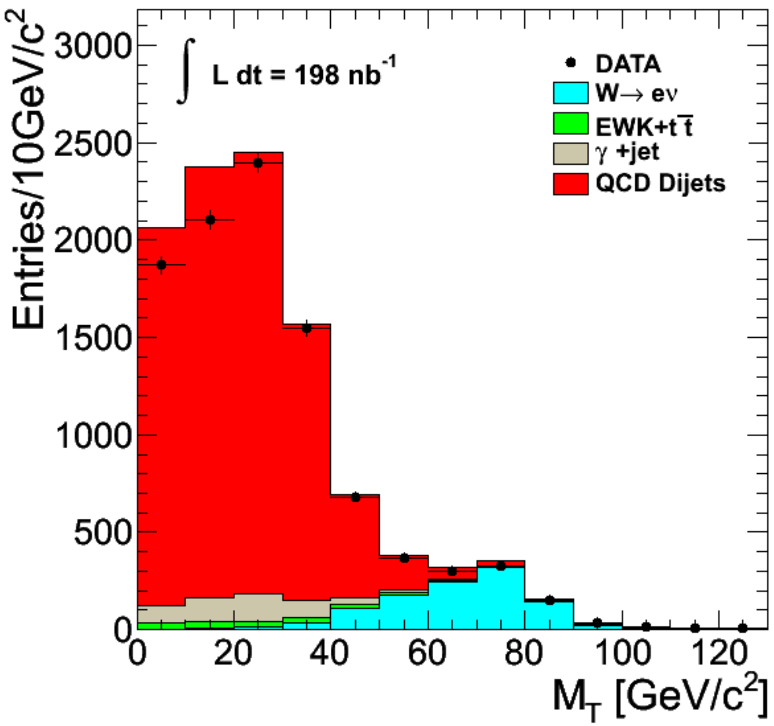
| Detector | Method | Data | MC |
|---|---|---|---|
| Barrel | *Z Tag&Probe* | 0.993 ± 0.014 | 0.985 |
| Endcap | *Z Tag&Probe* | 0.968 ± 0.034 | 0.961 |

# Electron selections

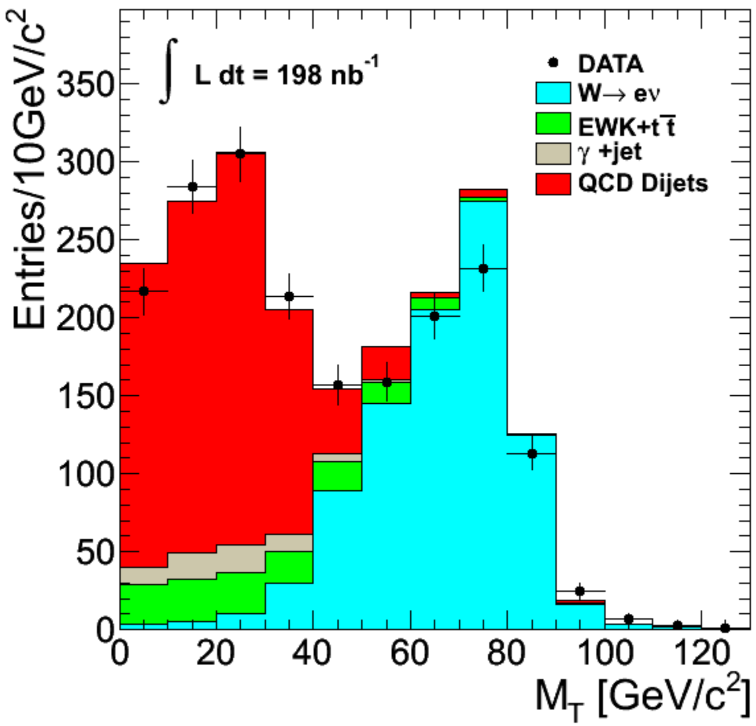
Electron selection is based on Identification, Isolation, Conversion rejection variables

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*




Figures are normalized to integrated luminosity

Simple Cuts

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)

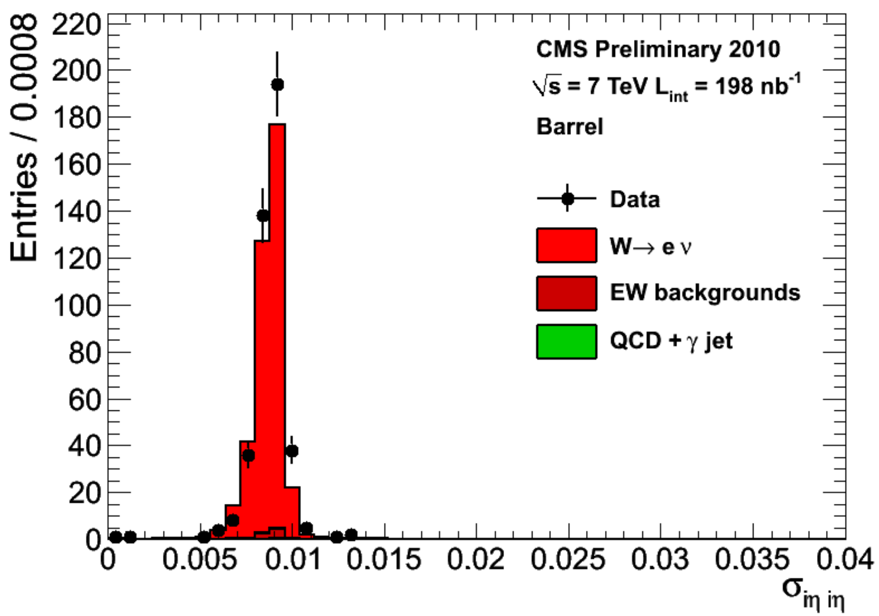
Cuts in Categories

# Electron variables

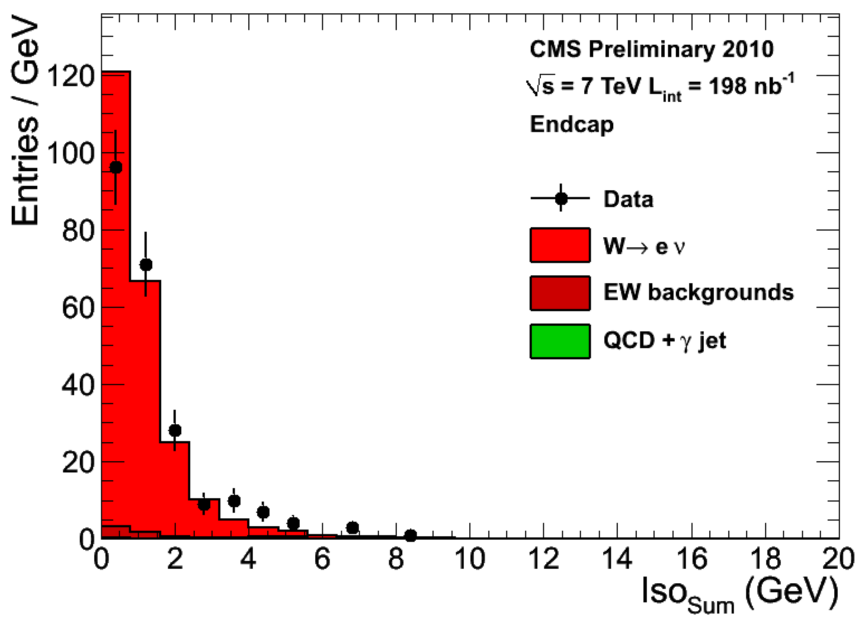
Examples of discriminating variables:

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

*ECAL barrel*




*ECAL endcap*




Figures are normalized to integrated luminosity

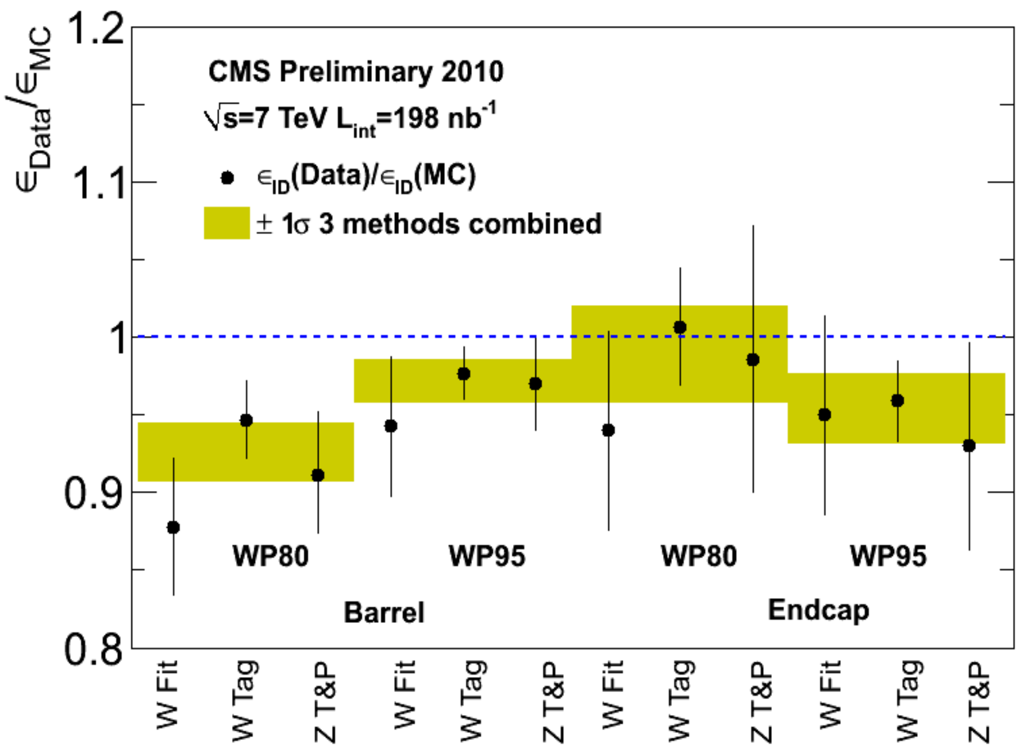
# Selection efficiencies

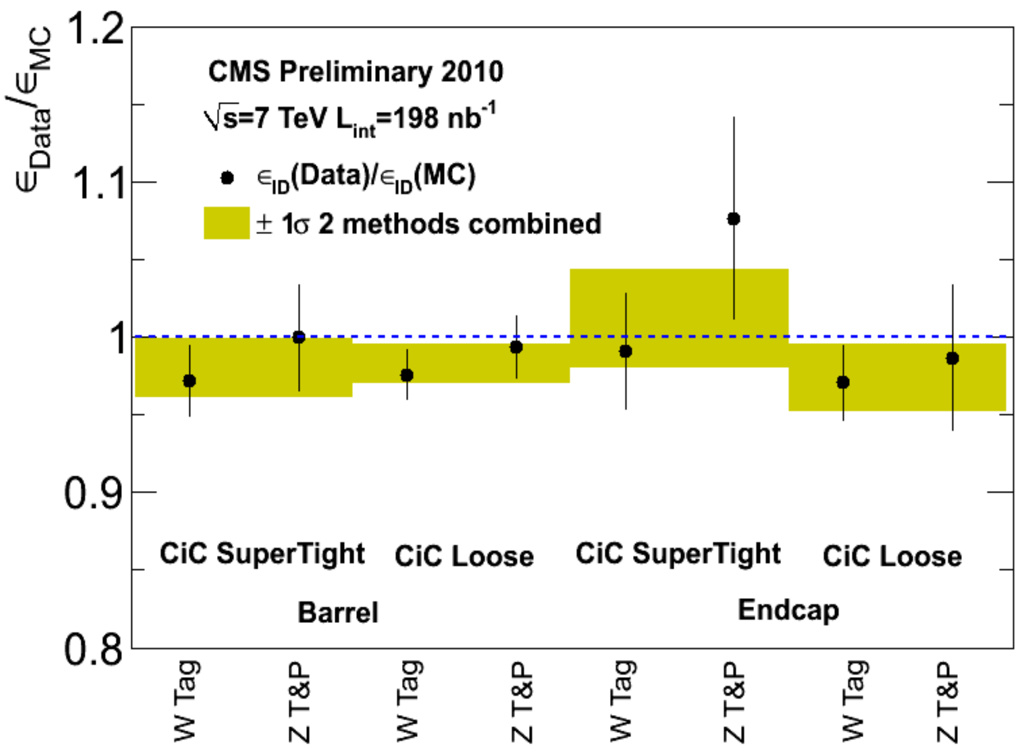
*Simple Cuts Selection* — *Z Tag&Probe*

| | Measured efficiency | Error (stat. + syst) | MC efficiency |
|---|---|---|---|
| WP95 Barrel | 92.5% | 3.2% | 95.4% |
| WP95 Endcap | 86.4% | 6.7% | 92.9% |
| WP80 Barrel | 77.5% | 4.7% | 85.1% |
| WP80 Endcap | 75.1% | 8.6% | 76.2% |

*Cuts in Categories Selection* — *Z Tag&Probe*

| | Measured efficiency | Error (stat. + syst) | MC efficiency |
|---|---|---|---|
| CiC Loose Barrel | 96.4% | 2.1% | 97.0% |
| CiC Loose Endcap | 94.1% | 4.7% | 95.3% |
| CiC Tight Barrel | 89.3% | 3.4% | 89.3% |
| CiC Tight Endcap | 85.5% | 6.5% | 79.4% |



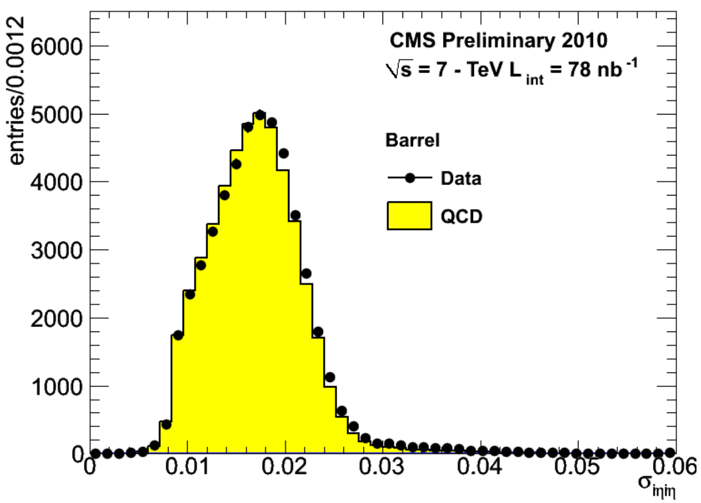

Electron selection efficiency ratio between data and MC
The shaded region is the combined efficiency data/MC ratio

# Fake rate measurement

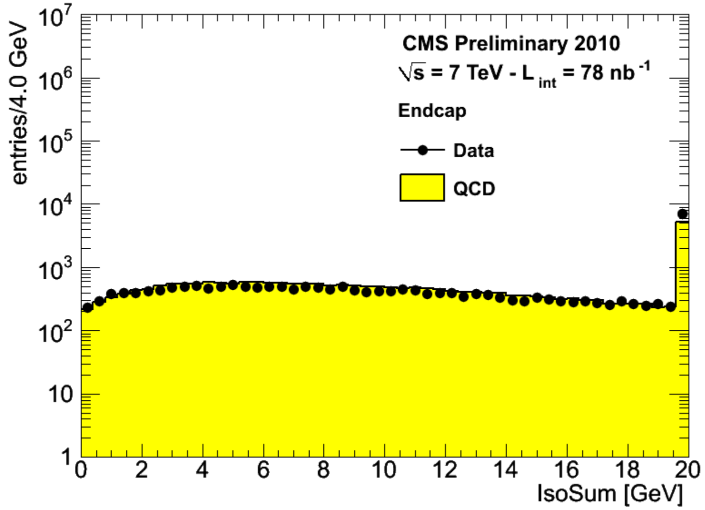
Background selection:

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

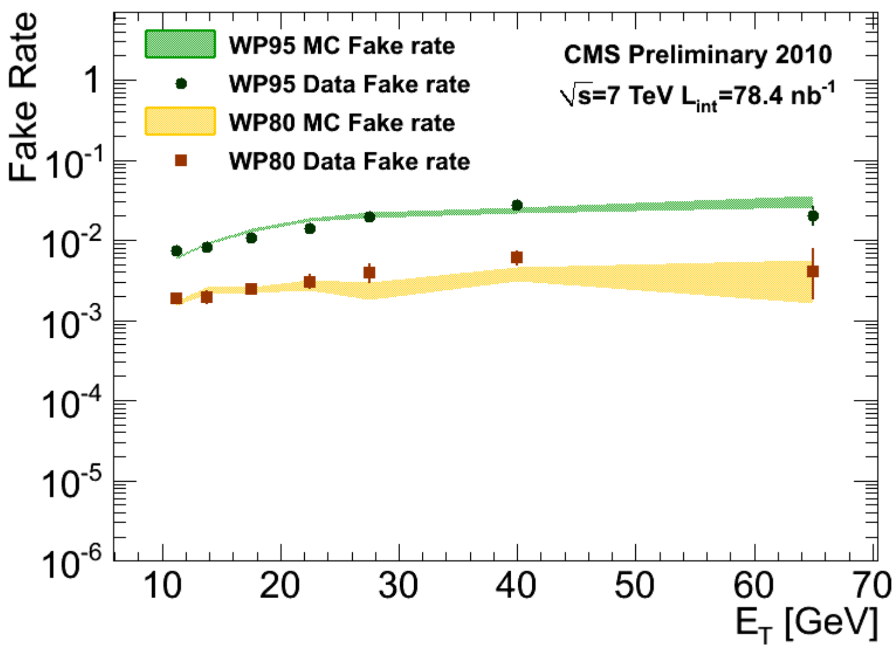
*ECAL barrel*



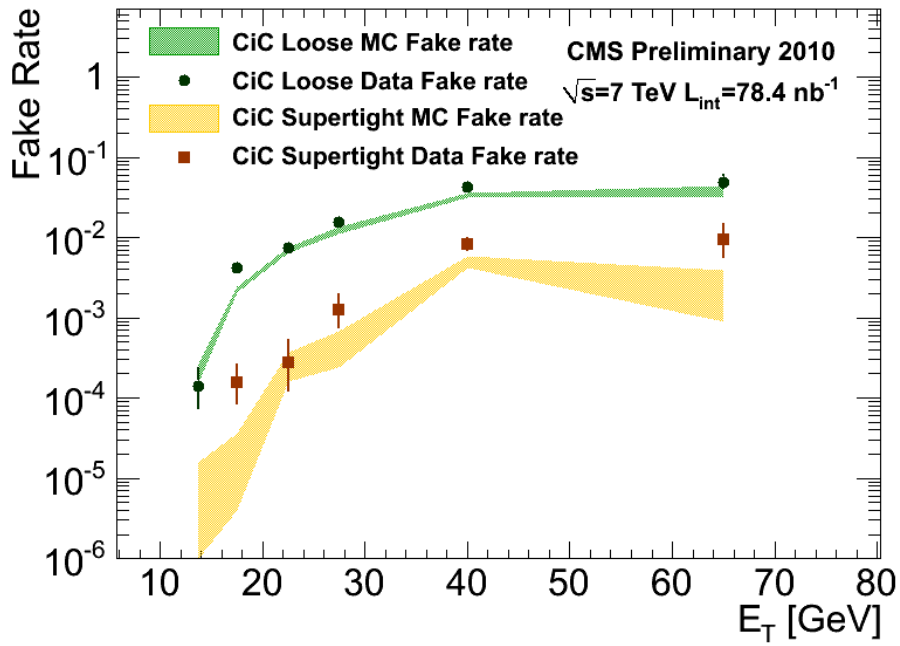

*ECAL endcap*




*Simple Cuts Selection*

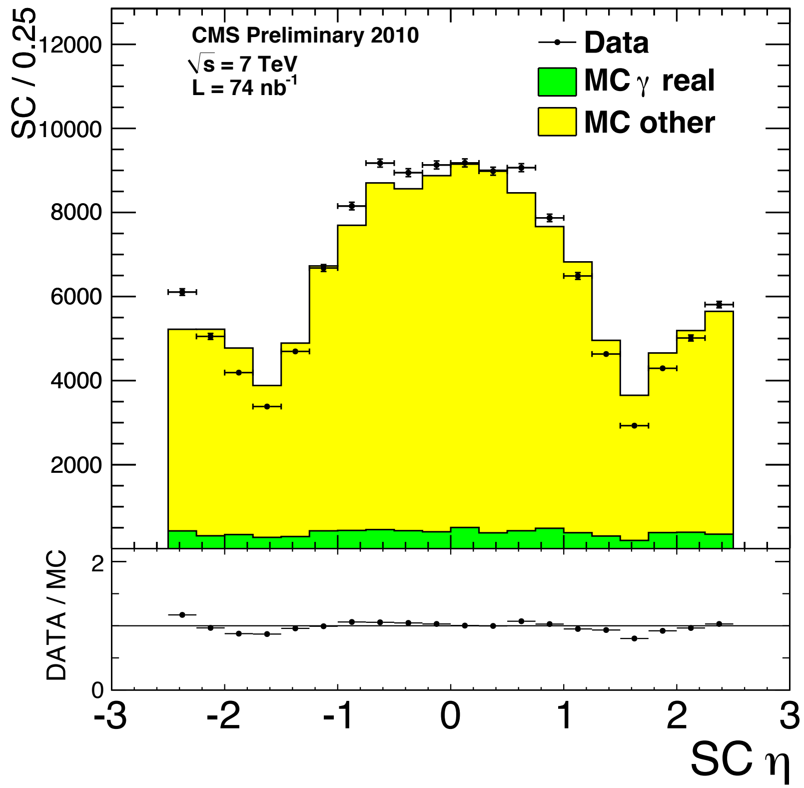



*Cuts in Categories Selection*




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

# Photon reconstruction

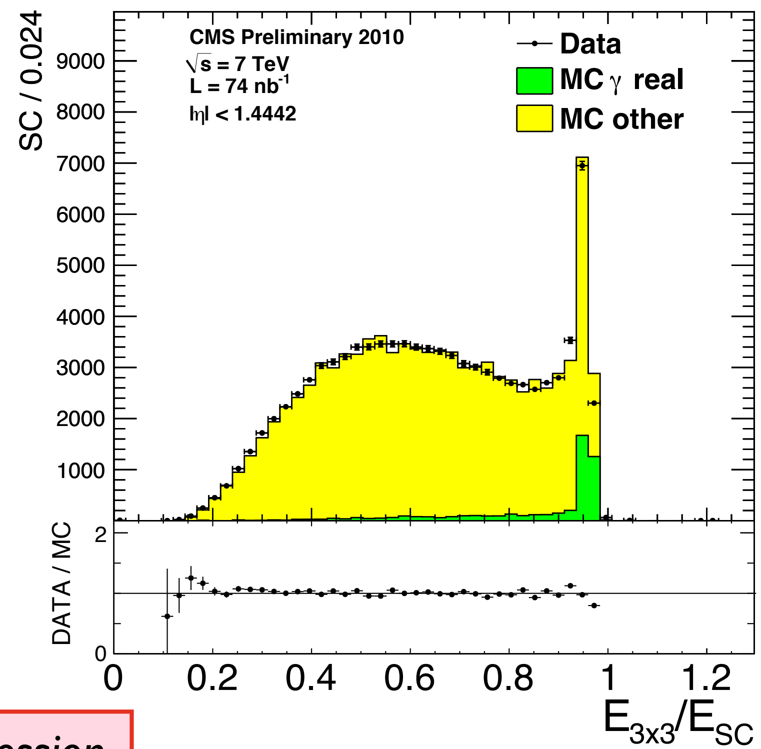



Photon objects are reconstructed from the superclusters

Supercluster selection

- HLT Photon15
- ET > 20 GeV
- SC in $|\eta| \leq 2.5$ but excluding barrel/endcap transition region
- H/E < 0.05

$E_{3\times3}/E_{SC}$ is used to separate converted from unconverted photons



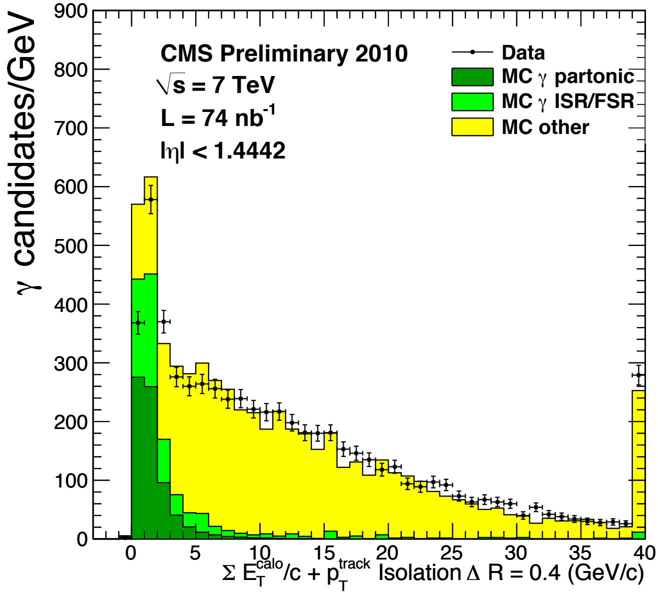

*More details on photon in the R.Shyang's talk in the QCD session*

# Photon selection

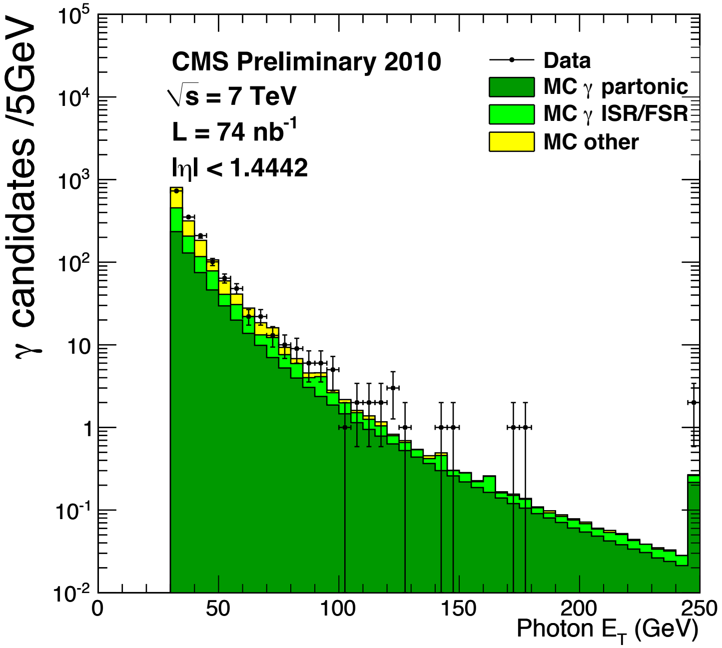
Simple selection allows to define a sample with more than 50% purity from prompt photons with an efficiencies around 90% for the Barrel and 80% for the Endcap

| Variable | Barrel photon | Endcap photon |
|---|---|---|
| photon $E_T$ | > 30 GeV | |
| tracker isolation | < 2.0 GeV | |
| ECAL isolation | < 4.2 GeV | |
| HCAL isolation | < 2.2 GeV | |
| (hadronic/EM) energy | <0.05 | |
| shower shape $\sigma_{i\eta i\eta}$ | <0.01 | <0.03 |
| | Require not to match a pixel hit | |

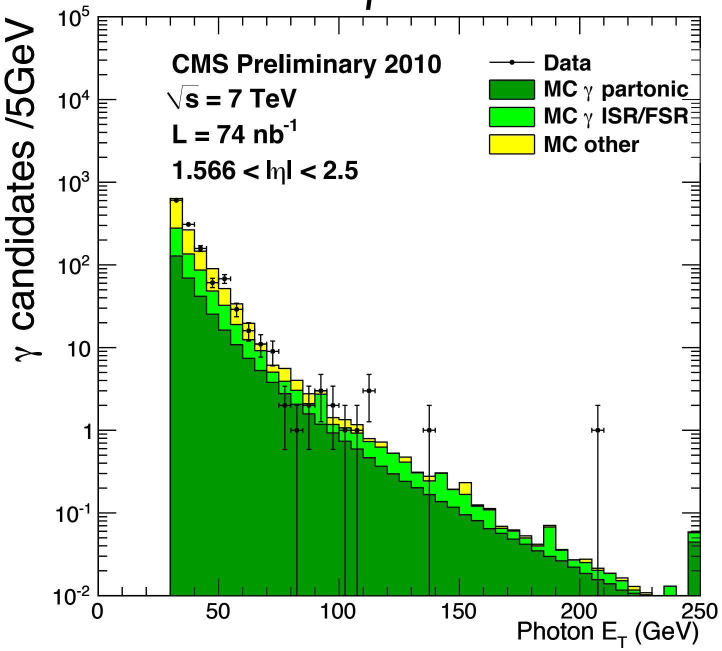
*ECAL barrel*




*ECAL barrel*

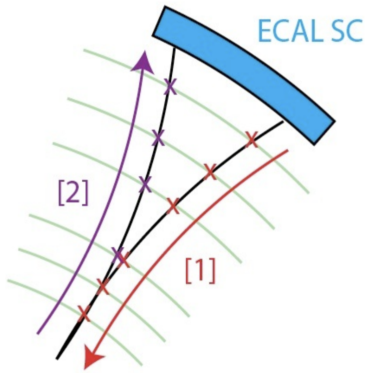



*ECAL endcap*



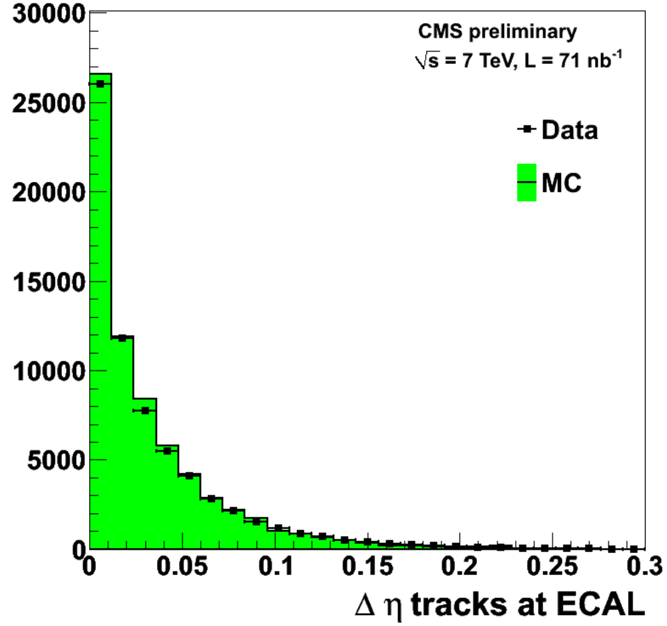

Photon purity increases with ET

# Converted photons

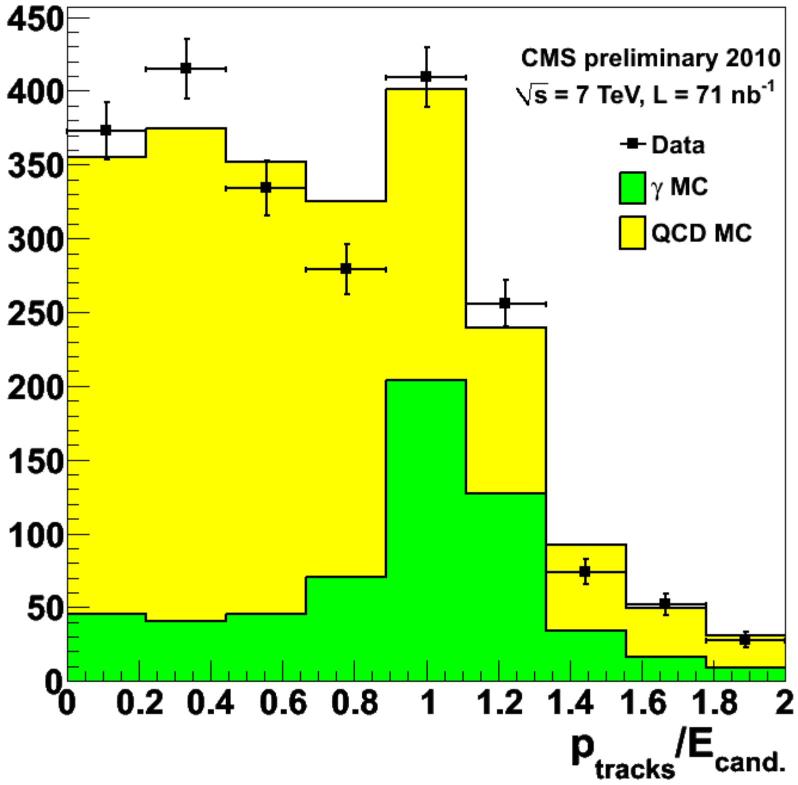



Selection

- |Δ cot θ| between the tracks at vertex < 0.3
- |Δφ| between the tracks at vertex < 0.2
- P(vertex) returned by fitter > 0.0005.




*HLT Photon, ET > 20 GeV, selection cuts applied*



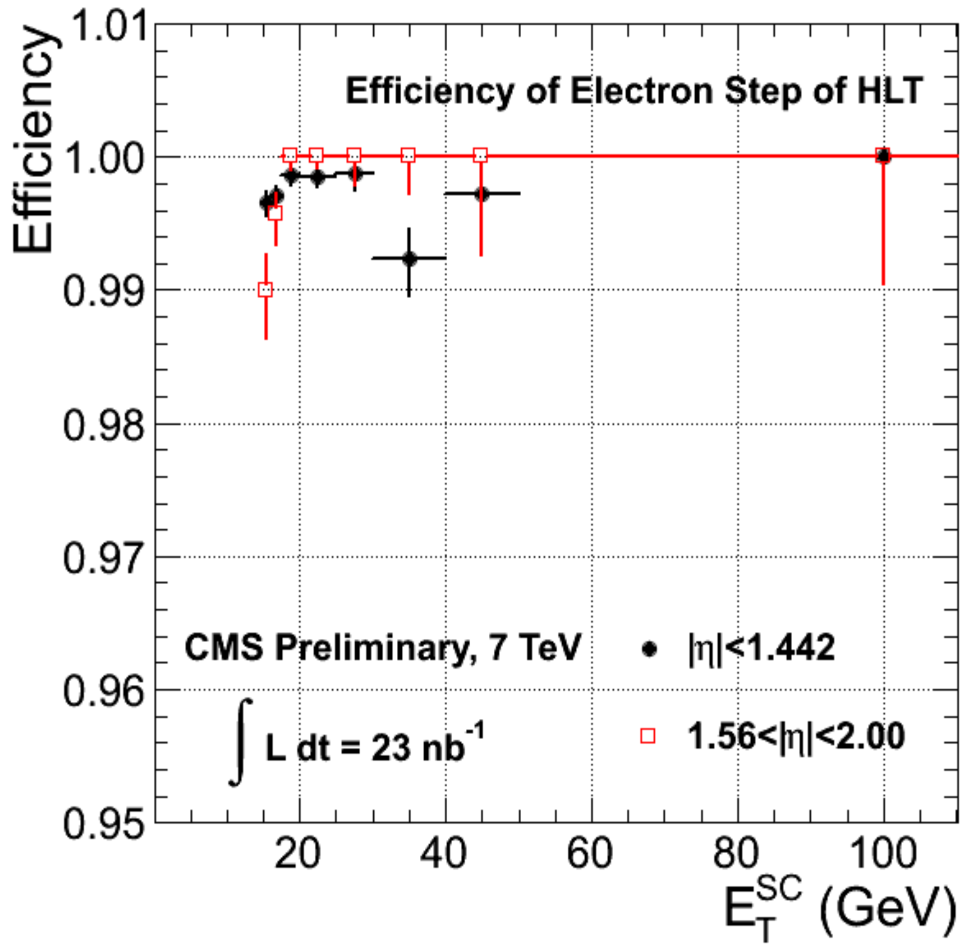

Conversion p/E with p from the tracks and E from the supercluster

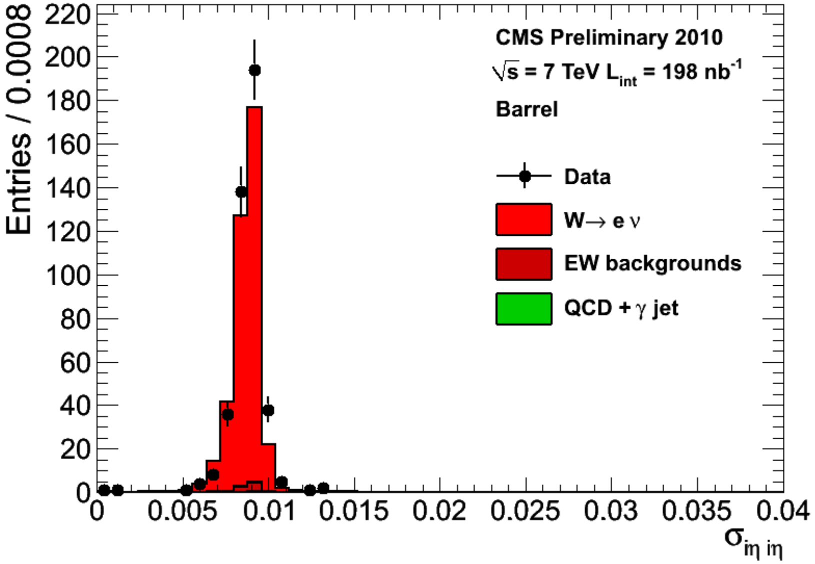
Variable may be used to extract photon purity in physics analysis

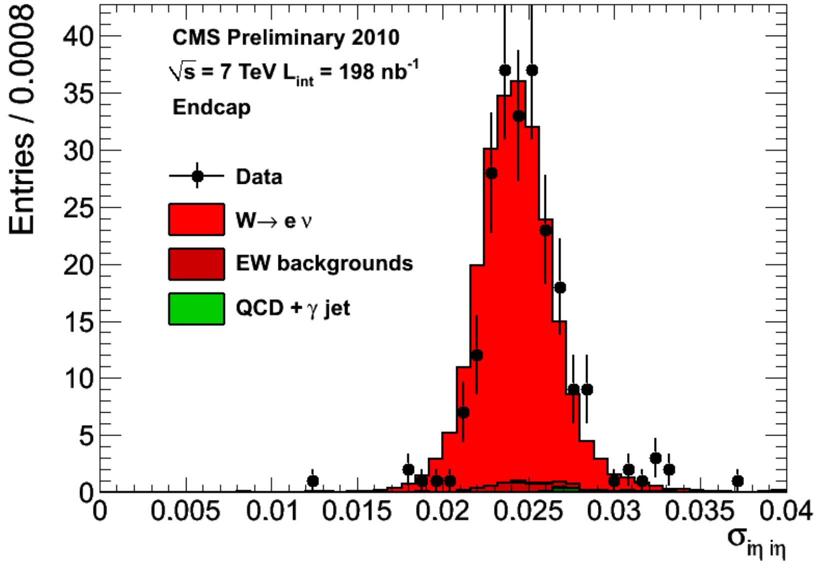
# Conclusions

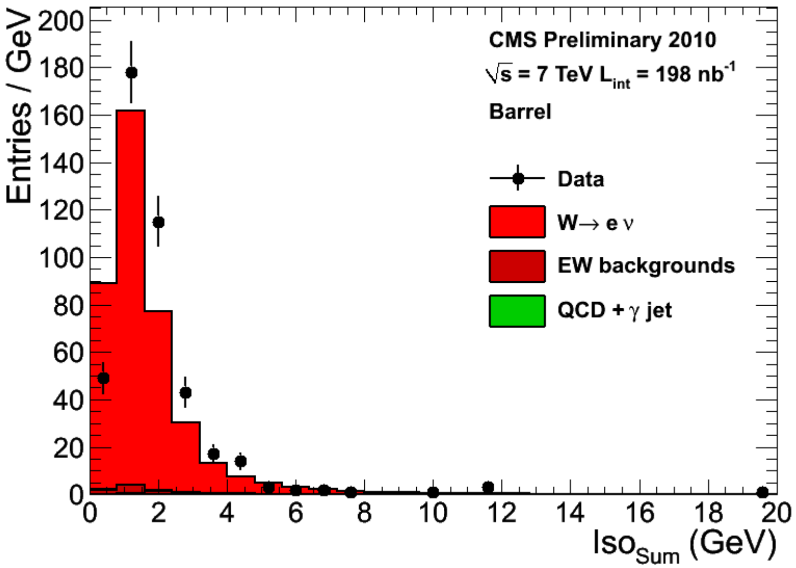
- With **200 nb$^{-1}$** of analyzed data at sqrs(s) = 7 TeV electrons from W and Z have been measured
- CMS has commissioned the **key observables** for the measurement, identification and isolation of primary ("prompt") electrons and photons
- Trigger, reconstruction and electron selection **efficiencies** 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

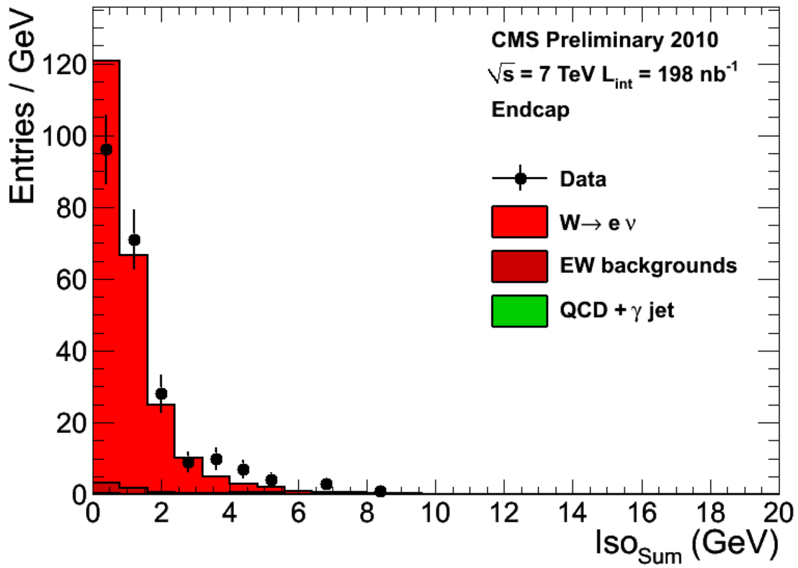
# BACKUP

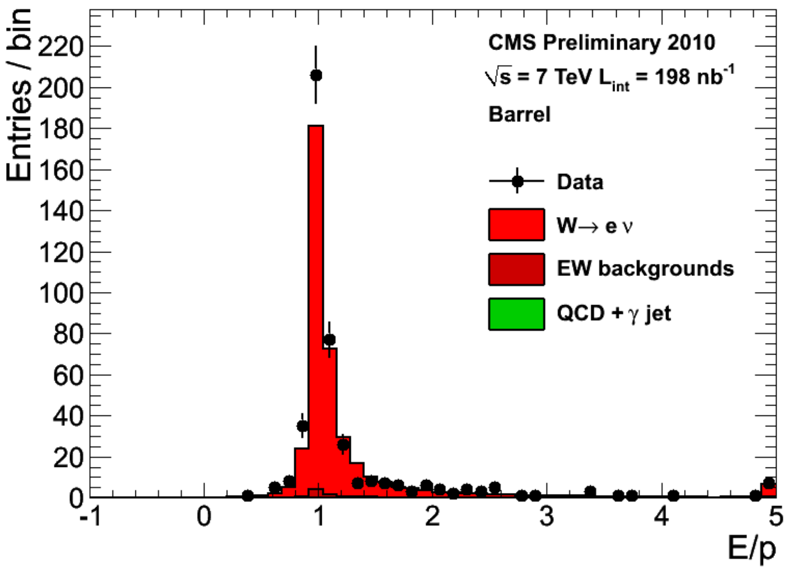

Efficiency of Electron Step of HLT
Efficiency
1.01
1.00
0.99
0.98
0.97
0.96
0.95
CMS Preliminary, 7 TeV
∫ L dt = 23 nb^-1
|η|<1.442
1.56<|η|<2.00
20
40
60
80
100
E_T^SC (GeV)

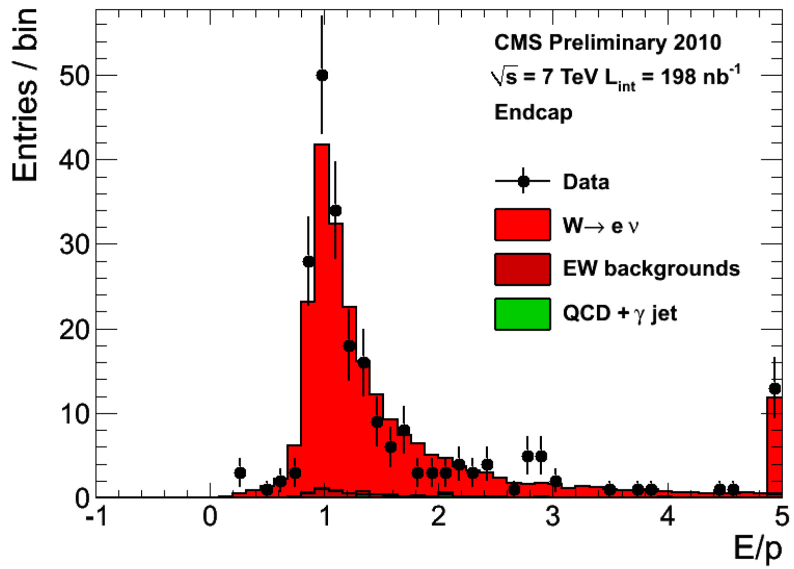

CMS Preliminary 2010
$\sqrt{s}$ = 7 TeV $L_{int}$ = 198 $nb^{-1}$
Barrel
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / 0.0008
$\sigma_{i\eta\, i\eta}$

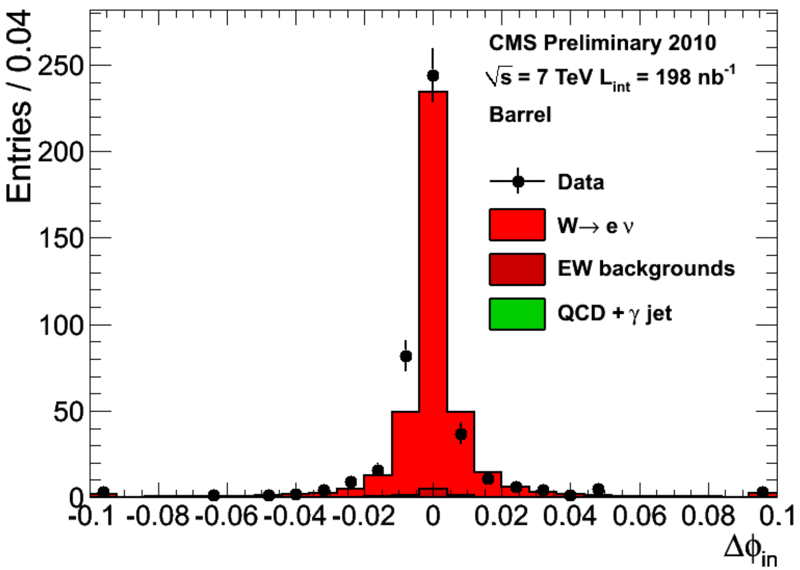

CMS Preliminary 2010
$\sqrt{s}$ = 7 TeV $L_{int}$ = 198 $nb^{-1}$
Endcap
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / 0.0008
$\sigma_{i\eta\, i\eta}$

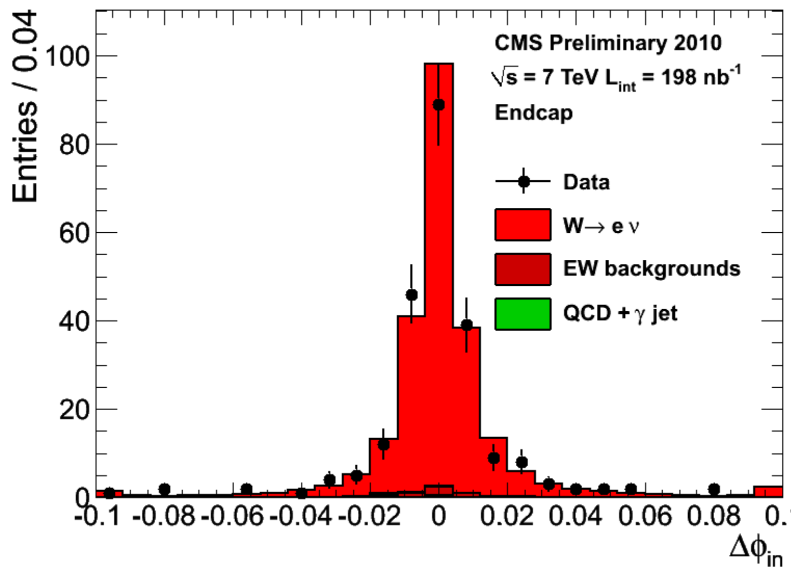

CMS Preliminary 2010
$\sqrt{s}$ = 7 TeV $L_{int}$ = 198 $nb^{-1}$
Barrel
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / GeV
$Iso_{Sum}$ (GeV)

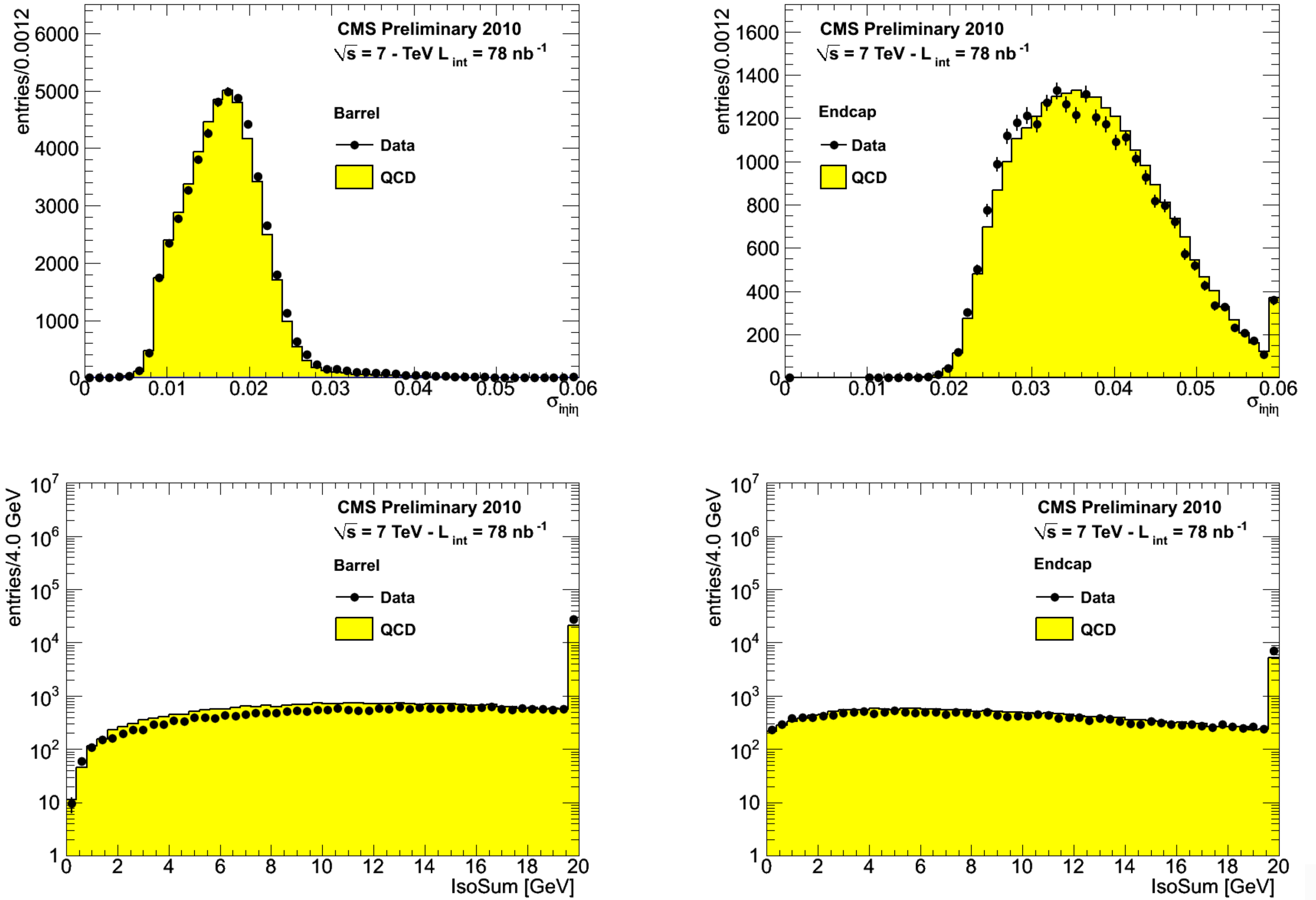

CMS Preliminary 2010
$\sqrt{s}$ = 7 TeV $L_{int}$ = 198 $nb^{-1}$
Endcap
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / GeV
$Iso_{Sum}$ (GeV)


CMS Preliminary 2010
√s = 7 TeV L_int = 198 nb^-1
Barrel
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / bin
E/p

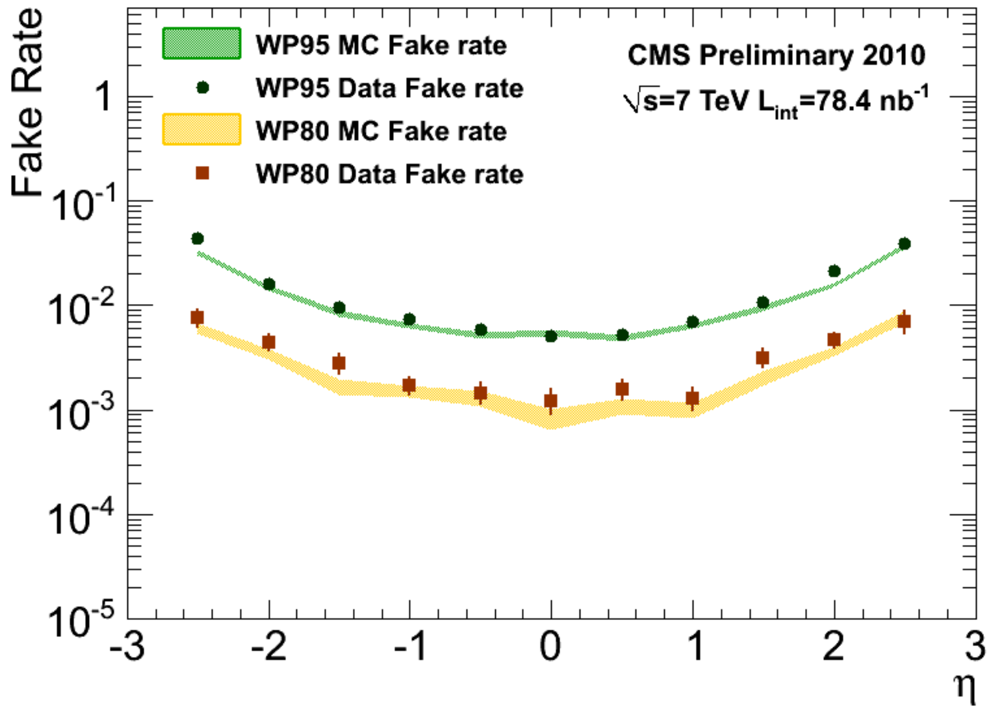

CMS Preliminary 2010
√s = 7 TeV L_int = 198 nb^-1
Endcap
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / bin
E/p

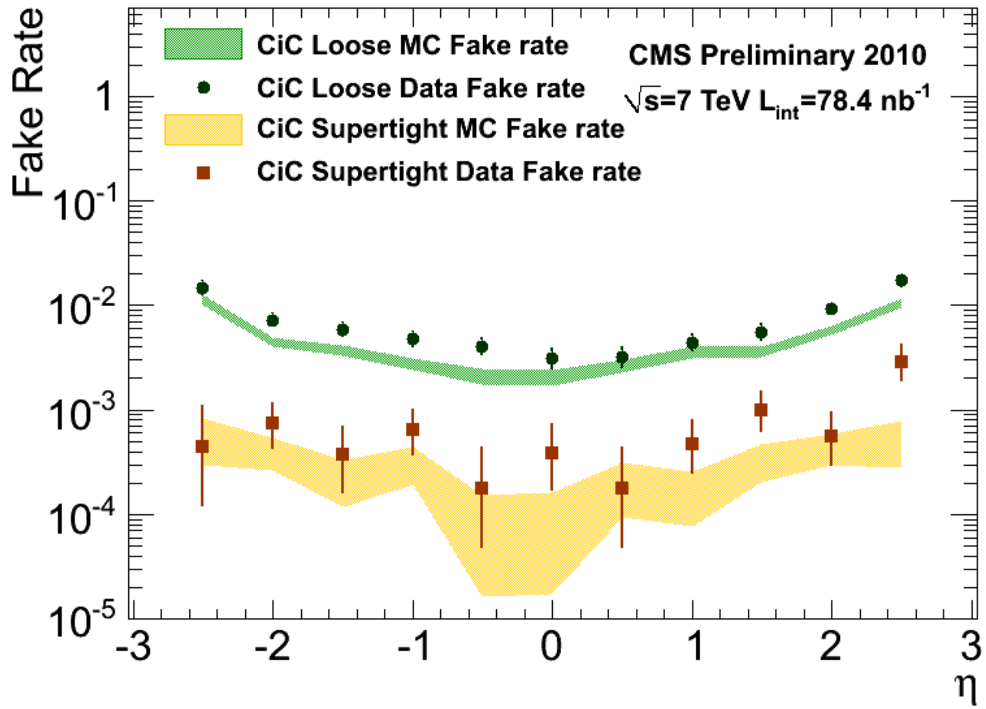

CMS Preliminary 2010
√s = 7 TeV L_int = 198 nb^-1
Barrel
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / 0.04
Δφ_in

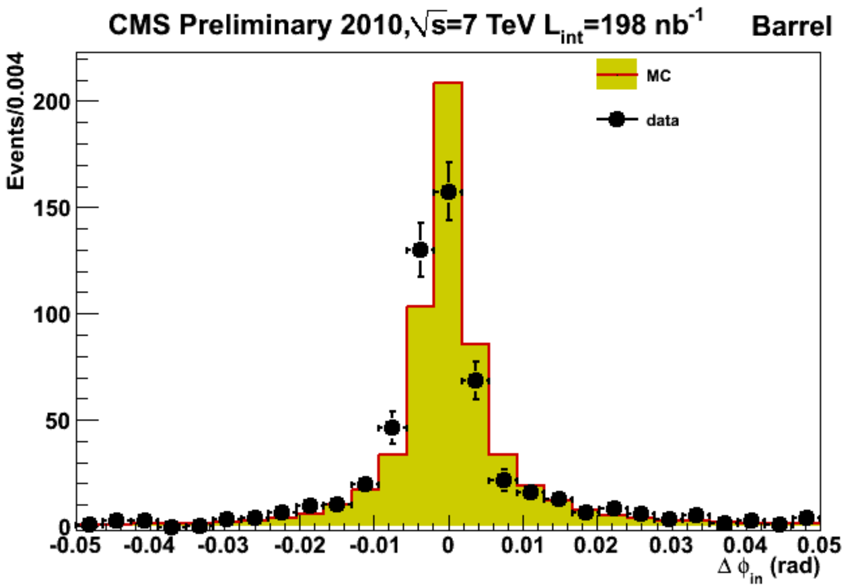

CMS Preliminary 2010
√s = 7 TeV L_int = 198 nb^-1
Endcap
Data
W→ e ν
EW backgrounds
QCD + γ jet
Entries / 0.04
Δφ_in

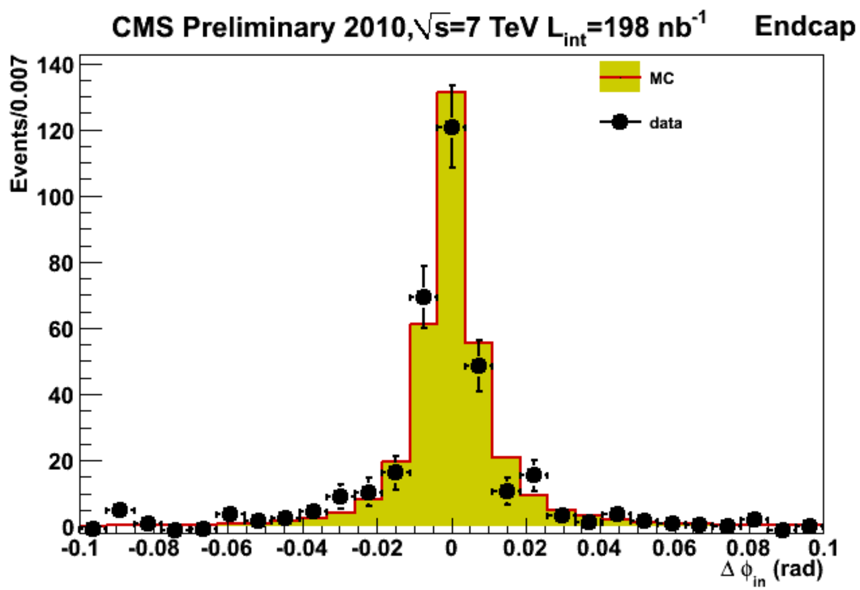


CMS Preliminary 2010
√s = 7 - TeV L int = 78 nb -1
Barrel
Data
QCD
entries/0.0012
σ iηiη
CMS Preliminary 2010
√s = 7 TeV - L int = 78 nb -1
Endcap
Data
QCD
entries/0.0012
σ iηiη
CMS Preliminary 2010
√s = 7 TeV - L int = 78 nb -1
Barrel
Data
QCD
entries/4.0 GeV
IsoSum [GeV]
CMS Preliminary 2010
√s = 7 TeV - L int = 78 nb -1
Endcap
Data
QCD
entries/4.0 GeV
IsoSum [GeV]


Fake Rate
WP95 MC Fake rate
WP95 Data Fake rate
WP80 MC Fake rate
WP80 Data Fake rate
CMS Preliminary 2010
√s=7 TeV L_int=78.4 nb^-1
η


Fake Rate
CiC Loose MC Fake rate
CiC Loose Data Fake rate
CiC Supertight MC Fake rate
CiC Supertight Data Fake rate
CMS Preliminary 2010
√s=7 TeV L_int=78.4 nb^-1
η


CMS Preliminary 2010,√s=7 TeV L$_{int}$=198 nb$^{-1}$ Barrel
MC
data
Events/0.004
0
50
100
150
200
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Δ $\phi_{in}$ (rad)


CMS Preliminary 2010,√s=7 TeV L$_{int}$=198 nb$^{-1}$ Endcap
MC
data
Events/0.007
0
20
40
60
80
100
120
140
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
Δ $\phi_{in}$ (rad)