CMS Electromagnetic Calorimeter performance during the 2011 LHC run

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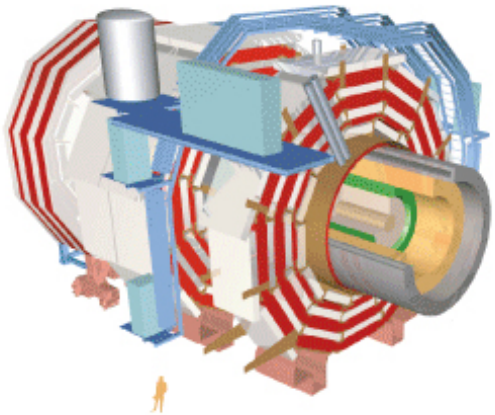
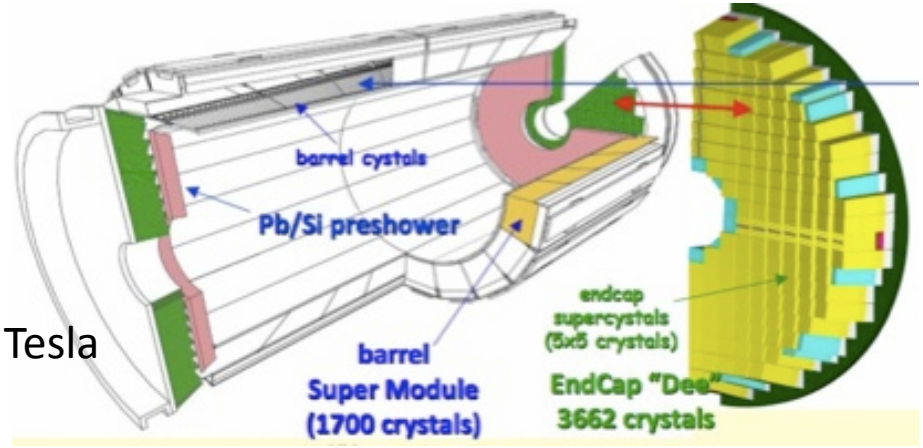
ECAL



B=3.8 Tesla



$PbWO_4$ Crystals $\rho = 8.3.g/cm^3$
61200 Xtals (25.8 X_0) in Barrel (EB) $|\eta|<1.479$)
14648 Xtals (24.7 X_0) in Endcaps (EE) $1.479<|\eta|<3.0$
Rad-Length X_0 = 0.89 cm
Moliere radius r= 2.2 cm
Light Yield Temperature dependence -2.2%/deg.
Low light yield 4.5 pe/MeV on APD-pair or VPT
but rapid light emission: 90 % in 25ns at 420 nm
Transparency radiation dependant

Preshower $1.653<|\eta|<2.6$
$Pb(2X_0)+Si+Pb(1X_0)+Si$
4288 Silicon Sensors of 32 strips

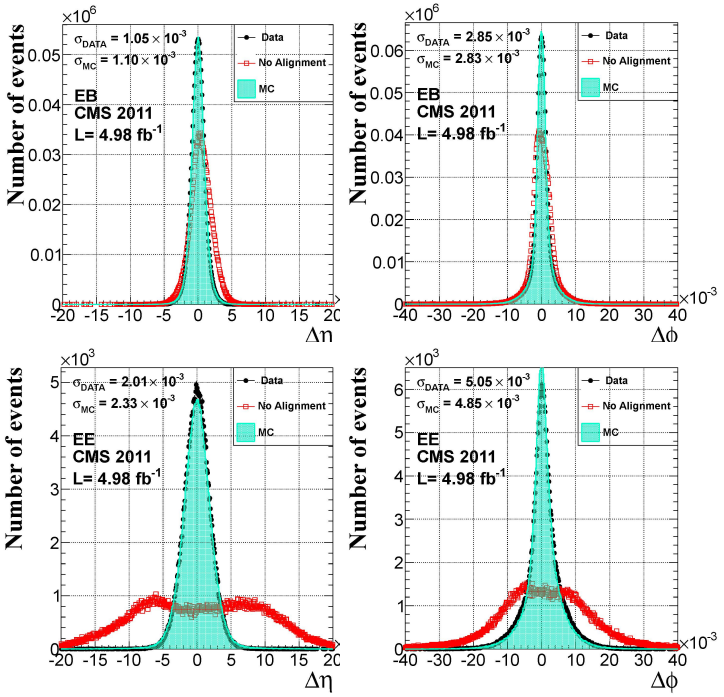
Photodetectors:
AvalanchePhotoDiode (APD) in EB
Two APD per Xtal
Gain ~ 50 but $\Delta G/G$ -2.4%/deg
VaccumPhotoTriode (VPT)
Gain ~ 8 to 10

Permanent transparency monitoring at Xtal level using light injection system

Cooling and Temperature Regulation

ECAL behaviour

Alignment and position resolution

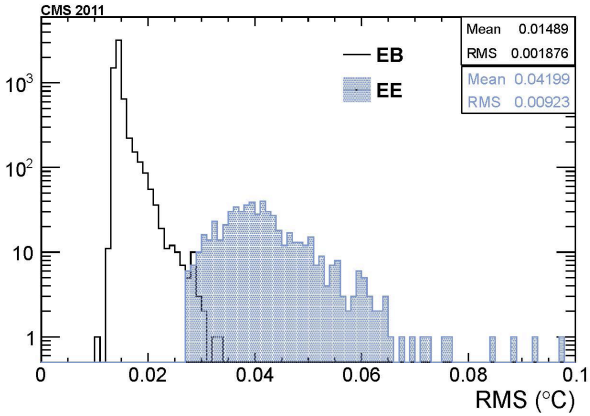


-Relative alignment of the ECAL crystals and the CMS tracker measured using electrons from Z→ee and (chiefly) W→ev events.

Conclusion:

- Relative ECAL-tracker alignment precision of 2.8 (5)x10^{-3} rad in φ in EB (EE) and 1(2)x10^{-3} units in η in EB (EE) has been achieved. This meets the ECAL alignment goals for electron ID and di-photon resonance reco, which are 4x10^{-3} units in Δη and 20x10^{-3} rad in φ

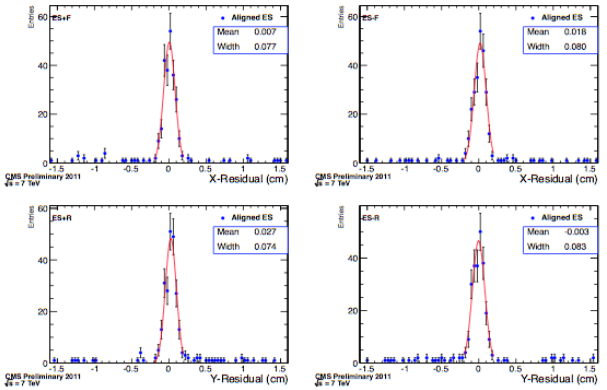
Temperature Stability



Temperature stability of the ECAL Barrel and Endcap detectors during the period April 2011 - October 2011.

- RMS calculated during LHC beam-on periods only
-Estimated precision of DCU thermistors is 0.004 °C

-Temperature stability during 2011 well within allowed limits (<0.05 °C for EB, <0.1 °C for EE) [2].



Preshower Spatial Precision

The expected precision for minimum ionizing particles is about 1.9mm/√12 = 550μm. The residuals above are convolutions of the ES precision and the error on the track extrapolation from the CMS Tracker (about 500μm)

ECAL

$$E_{e,\gamma} = \underbrace{\text{“}F_{e,\gamma}(\eta)\text{”}}_{\text{Cluster correction}} \sum_i \underbrace{G(GeV/ADC) \times S_i(T,t) \times c_i}_{\text{Single channel calibration}} \times A_i$$

A_i: Measured amplitude in each channel

- c_i - crystal inter-calibration constants, Determined from combination of in-situ (π^0,η,phi-symmetry, eventually W→ev) and lab/test-beam measurements
- S_i - transparency correction, Determined from light monitoring measurements taken during the calibration sequence (LHC abort gap, global running at P5)
- G - ADC/GeV conversion - Absolute energy scale, determined using physics signals (chiefly Z→ee). Tuned separately for EB and EE.
- $F_{e,g}$ - cluster correction - Object dependent correction factor. Factorises geometry and material effects. Tuned on MC.

in unit of GeV/MIP

in unit of MIPs

$$E^{e/\gamma \text{ in Endcap}} = E^{EE} + \gamma\,(E^{ES1} + \alpha E^{ES2})$$

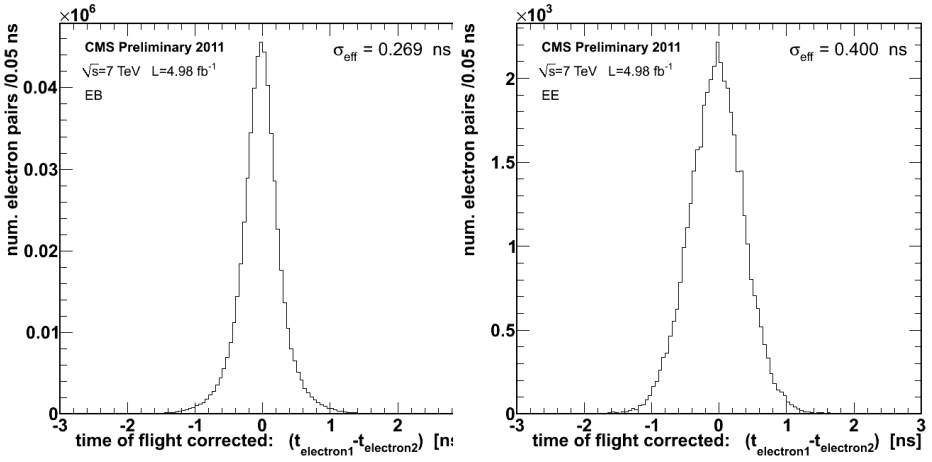
Crystal intercalibration and Tranparency correction are discussed By Maria Margherita Obertino in a Poster at this conference

In 2011
Active Channels
Barrel (EB) > 99.1%
EndCap (EE) >98.7%

Preshower (ES)> 95.1 %

ECAL Time resolution and Trigger efficiency

Time resolution



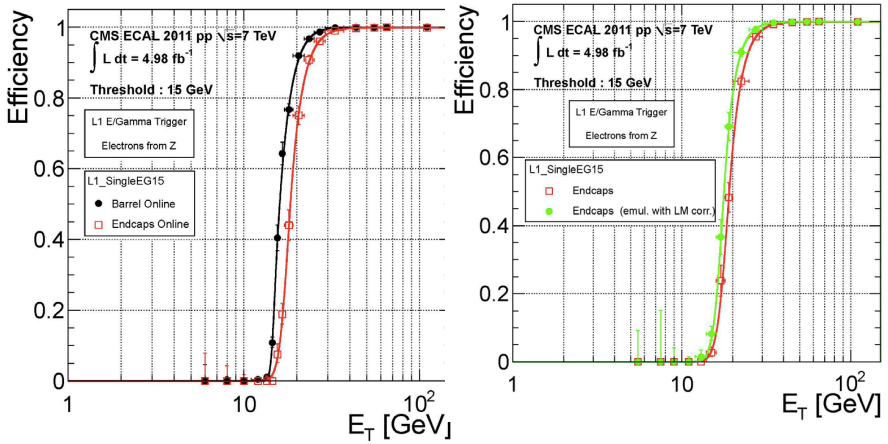
	$\sigma_{eff}(t_{seed})$ [ps] abs time	$\sigma_{eff}(t_1-t_2)/\sqrt{2}$ [ps] single precison
EB	376	190
EE	356	282

Time difference between two ECAL cluster associated to tracks coming from a common vertex and with a reconstructed invariant mass consistent with the Z mass.

Conclusion: The time resolution for a single ECAL cluster in the ET range of electrons from Z decays is found to be 0.19 ns in the barrel and 0.28 ns in the endcap.

Trigger efficiency

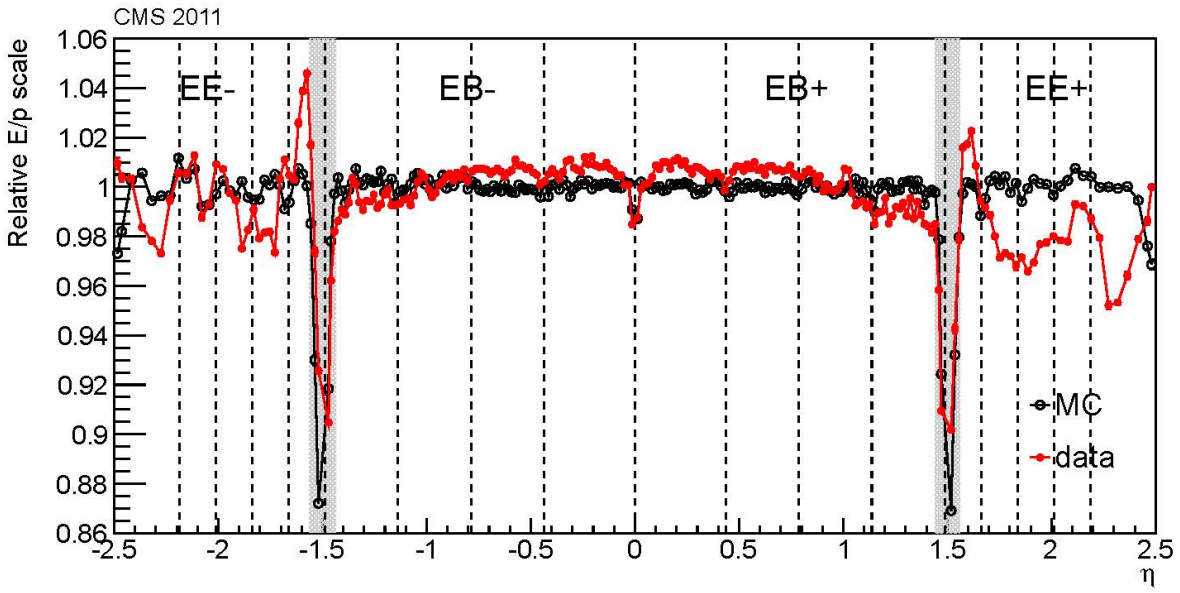
Trigger efficiency from emulator with laser corrections



Trigger efficiency as a function of ET for an trigger path with a threshold of 15 GeV for the barrel and the endcap.
The plot on the left shows the trigger efficiency as measured on 2011 data.
The plot on the right is based on data emulating the effect of the transparency corrections on the trigger level as used for the 2012 data taking.
The trigger efficiency is measured using pre-scaled, lower threshold control triggers.

Ecal Energy Scale and Resolution

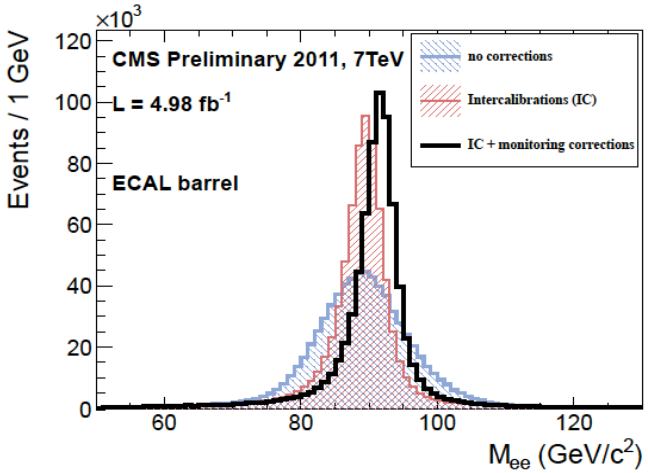
Local energy scale calibration using W→eν decays



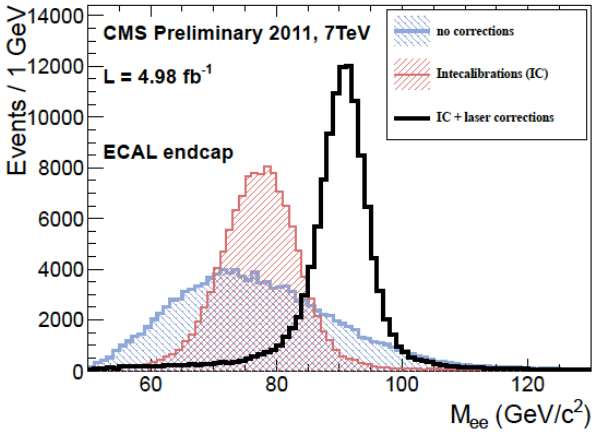
Relative energy scale as measured from the energy-momentum balance in W→eν decays as a function of pseudo rapidity η. The measured scale shows a much larger variation as a function of η than the MC. The scale is DATA is adjusted to the one observed in MC

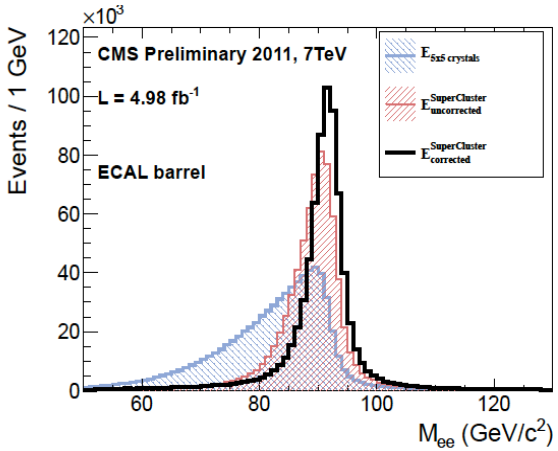
Relative E/p scale as a function of the electron pseudorapidity in data and MC. E/p is the ratio between the electron energy E, measured in ECAL, and the electron momentum p, measured in the tracker. The electrons are selected from W→eν decays. Each point is obtained by fitting the E/p distribution of electrons at a given eta to a reference E/p distribution obtained from the MC simulation. As the E/p shape varies along eta, nine reference distributions are used: these regions are symmetric around η = 0 and correspond to the four modules of the ECAL barrel, and to five additional regions in the endcaps made by 10 crystal wide rings on both sides of ECAL. Both MC and data E/p distributions are fitted to MC templates in order to study relative differences between data and MC. The momentum p is calibrated along eta using Z→ee events.

Ecal Performance illustration plots

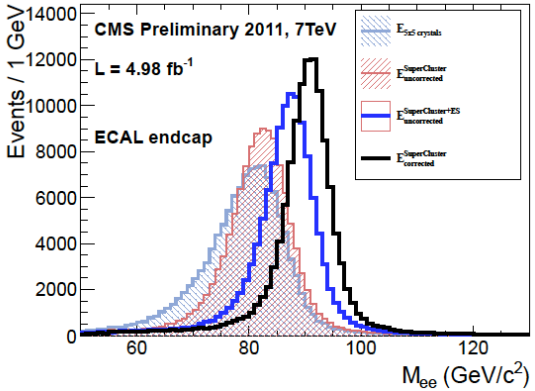


The top plot show the impact on the Z→ee energy scale and resolution that are obtained from applying energy scale corrections to account for the intrinsic spread in crystal and photo-detector response, and time-dependent corrections to compensate for crystal transparency loss.





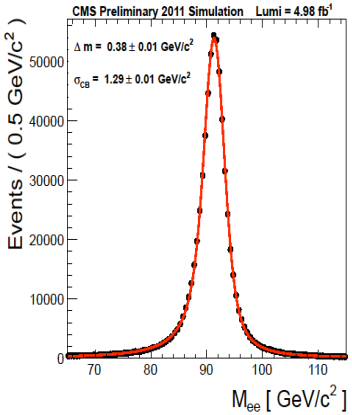
These two plots show the impact on the Z→ee energy scale and resolution from the incorporation of more sophisticated clustering and cluster correction algorithms.

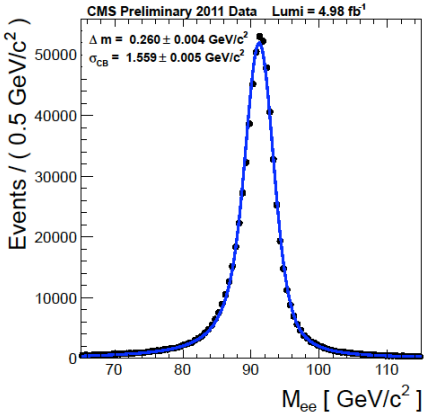


Good energy resolution is achieved with preliminary energy calibration for 2011. Instrumental resolution (obtained from Z -> ee invariant mass with ECAL energies and electron track directions): 1.0 GeV in ECAL Barrel

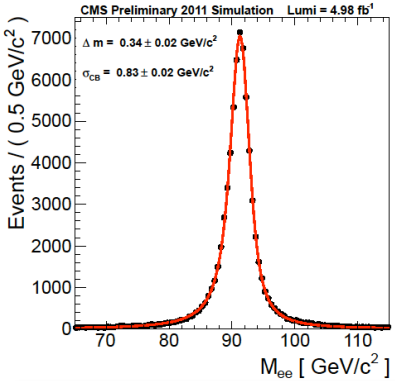
Z→ee peaks

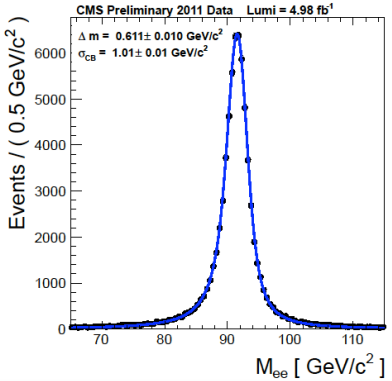
Z→ee, EB inclusive



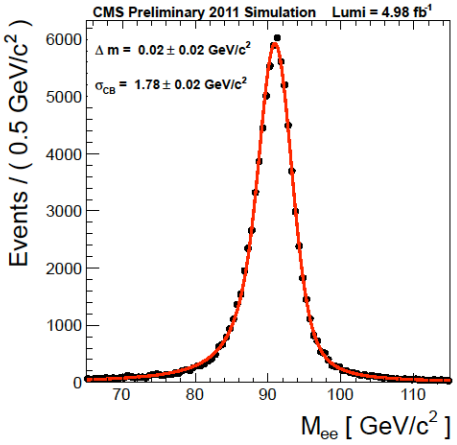


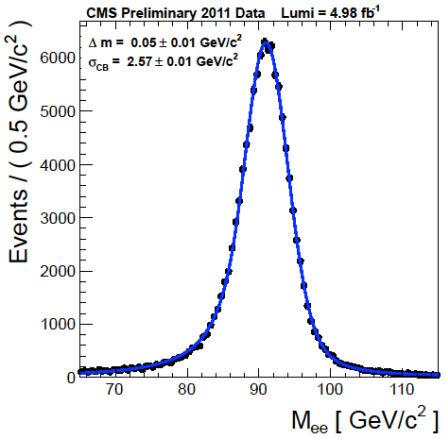
Z→ee, EB highR9





Z→ee, EE inclusive





Invariant mass distribution of Z→ee events for events with

a) both electrons in EB and having R9>0.94,

b) both electrons in EB and

c) both electrons in EE.

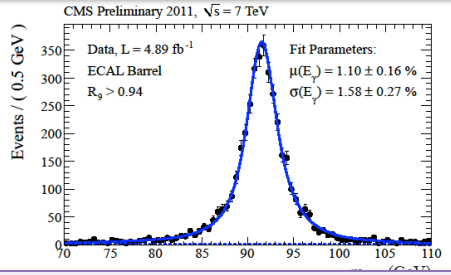
Data (right plot) and Monte Carlo (left plot) distributions are shown. Parameters listed are Δm_{CB} - the difference (in GeV) between the Crystal Ball mean and the true Z mass, σ_{CB} - the width of the gaussian term of the Crystal Ball function.

The parameter R9 is a measure of the extent of electron bremsstrahlung.

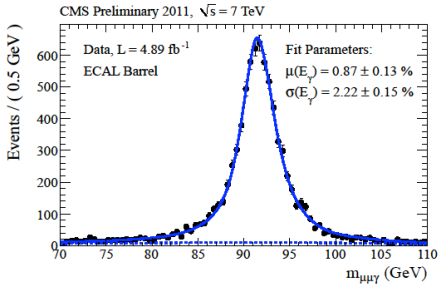
Width of the gaussian term of the CB function in the barrel is 1.01 GeV and 1.56 GeV for high and low R9 and 2.57 GeV for the endcap.

Photon energy scale and resolution Z→μμγ

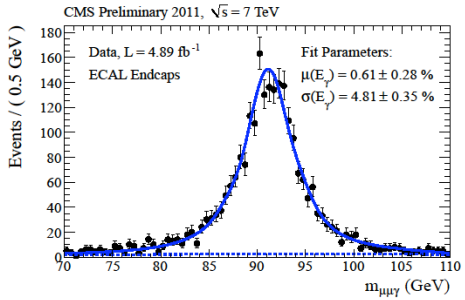
Z→μμγ, ECAL Barrel, high R9



Z→μμγ, ECAL Barrel, inclusive



Z→μμγ, EE inclusive



Invariant mass distribution of Z→μμγ final states from 2011 DATA. The photon energy scale and resolution are extracted from de-convoluting the Z line shape in this final state. Plots for DATA and MC for EB for R9>0.94, EB inclusive and EE inclusive.

The mean E_T (E) of the photons is approximately 32 GeV (42 GeV in EB for high R9, 44 GeV in EB for low R9, 114 GeV in EE).

The photon energy scale agrees to within 0.7% between DATA and MC.
The energy resolution for photons is 2.2% in the barrel (1.6% for high R9) and 4.8% in the endcaps.
The energy scale and resolution are in agreement with the values measured for electrons from Z→ee decays.