PSROC 2011

NTNU, Taipei
Jan 26, 2011

Preshower Performance and Photon Physics at CMS

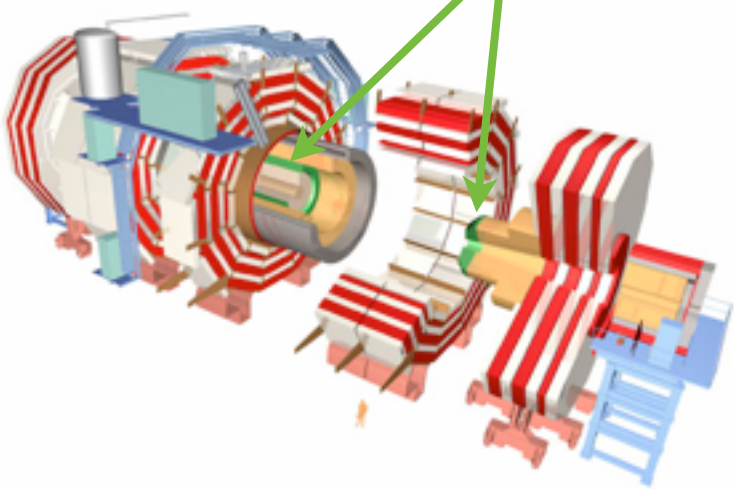
Chia Ming, Kuo
National Central University, Taiwan

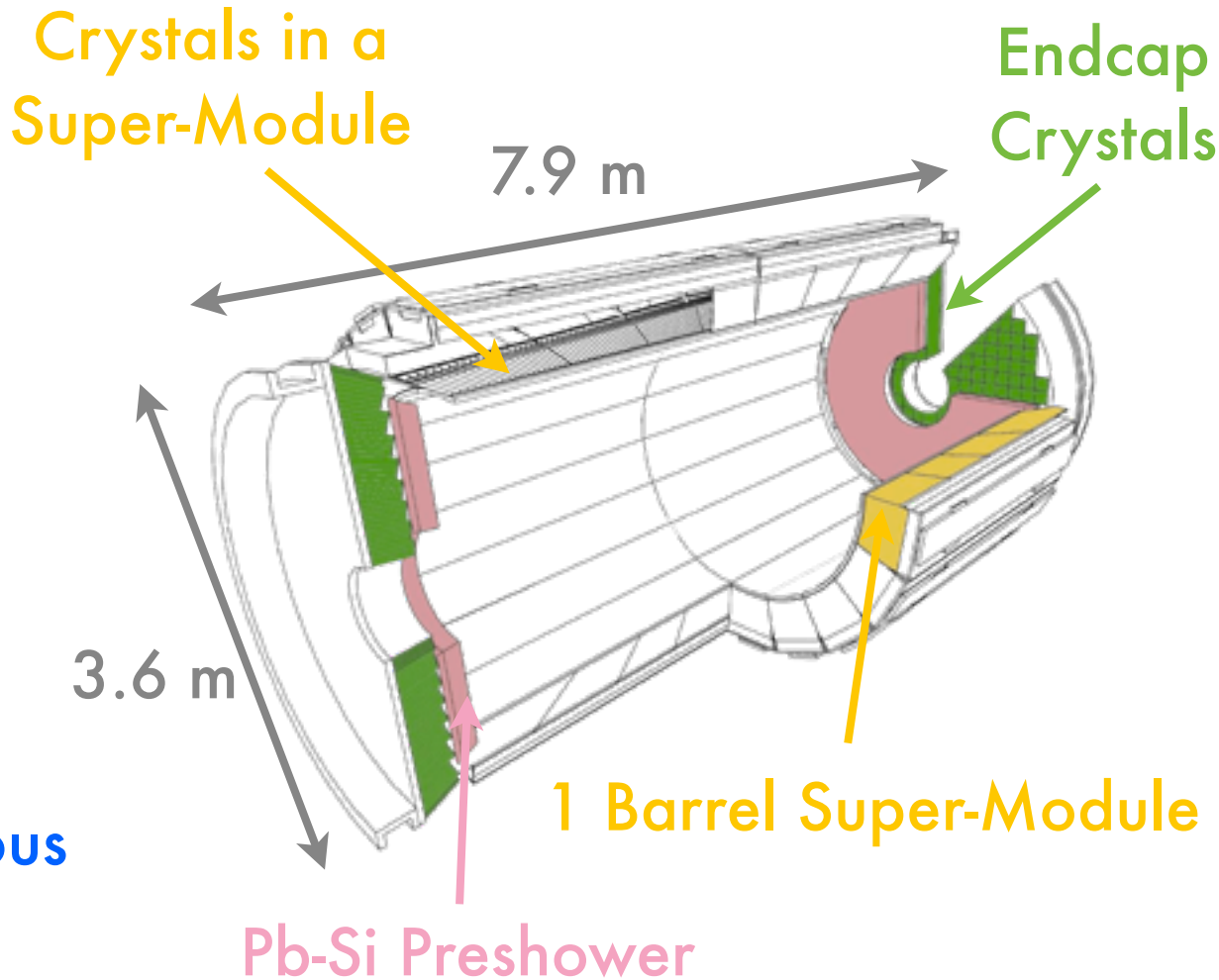
on behalf of Taiwan-CMS

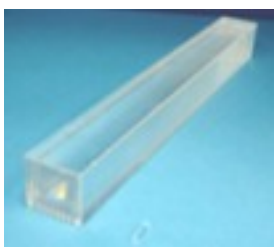
Contents of presentation

- CMS Electromagnetic Calorimeter
- Performance of CMS ECAL Preshower
- Inclusive Photon Spectra at 7 TeV
- Prospects of Photon-related Physics with Taiwan-CMS

Electromagnetic Calorimeter (ECAL)



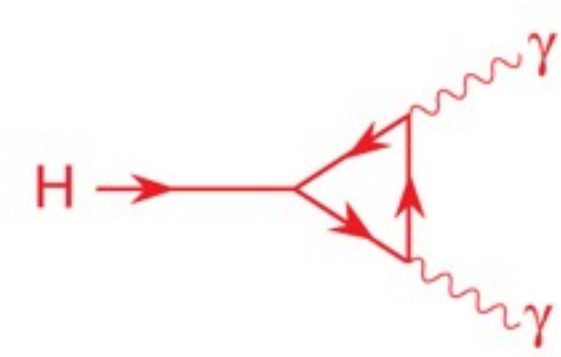




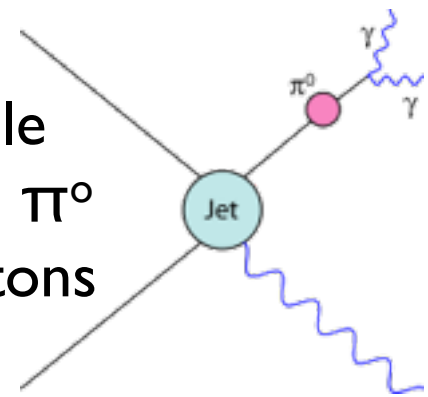
75848 Homogenous
$PbWO_4$ Crystal +
Pb-Si Preshower

Physics Objective

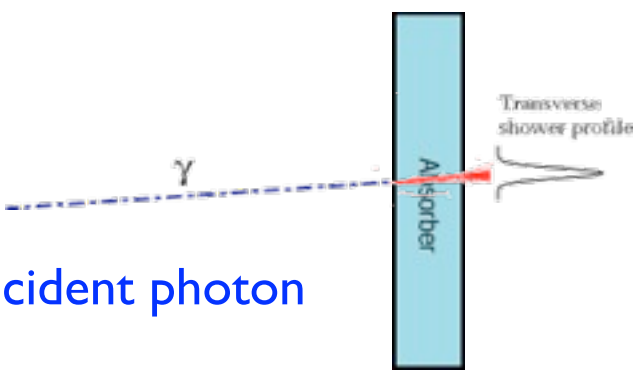
One of the main physics goals of CMS is search for SM Higgs
If m_H < 140 GeV, best chance is through γγ decay



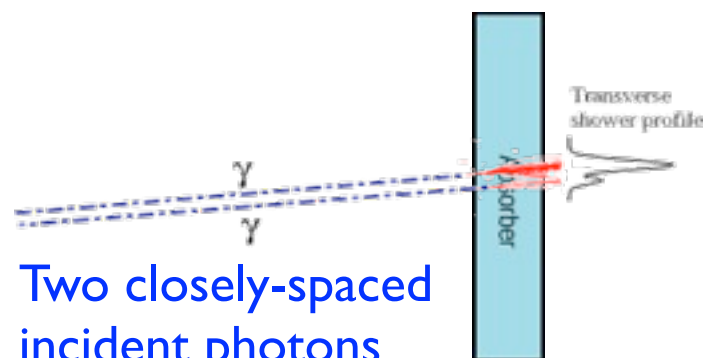
But large reducible background from π° faking single photons



Idea of Preshower:



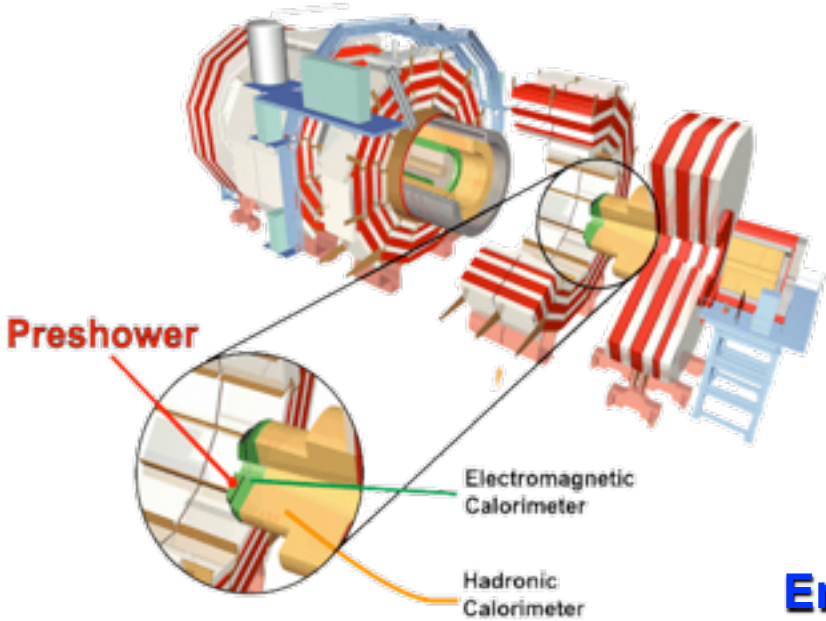
Single incident photon

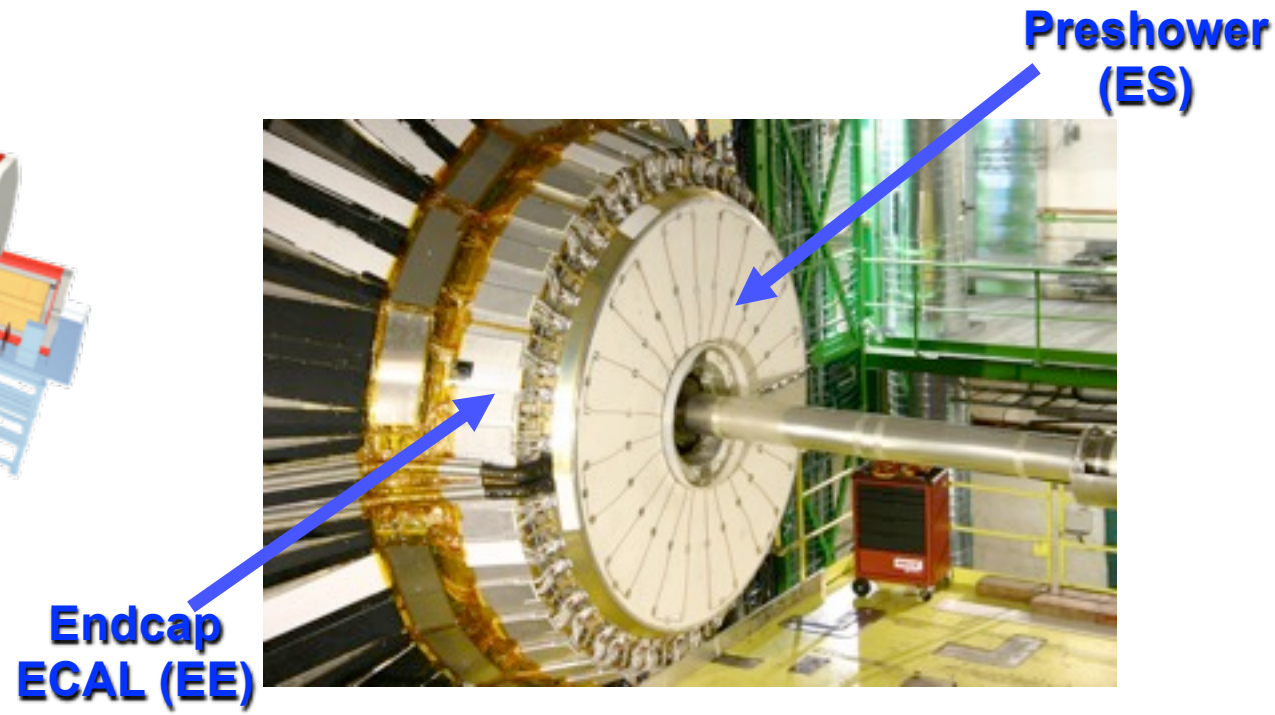


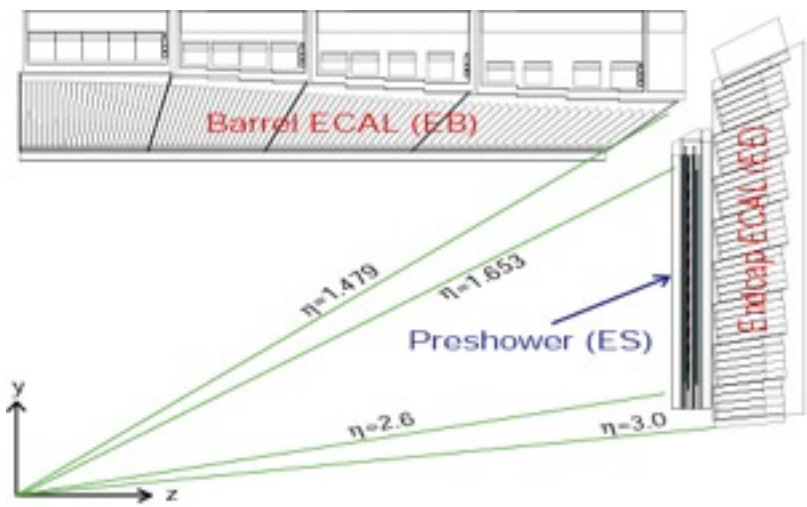
Two closely-spaced incident photons

- By adding a Preshower in front of endcap crystals, the reducible backgrounds to H→γγ search can be further reduced by about 50%

Physical Location



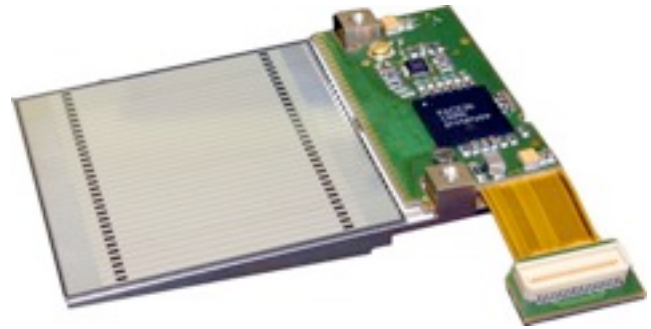




- 2.5m diameter discs, less than 20cm thick, containing 2 layers of:
  - lead absorber ($2X_0$ + $1X_0$)
  - silicon strip sensors + front-end electronics
  - mechanical supports, cooling etc.

Preshower assembly

- The heart of CMS ECAL Preshower : 4288 silicon μ-modules
  - Silicon sensor : 6.3 x 6.3 cm^2, 310 μm thick, 32 strips
  - Custom front-end electronics

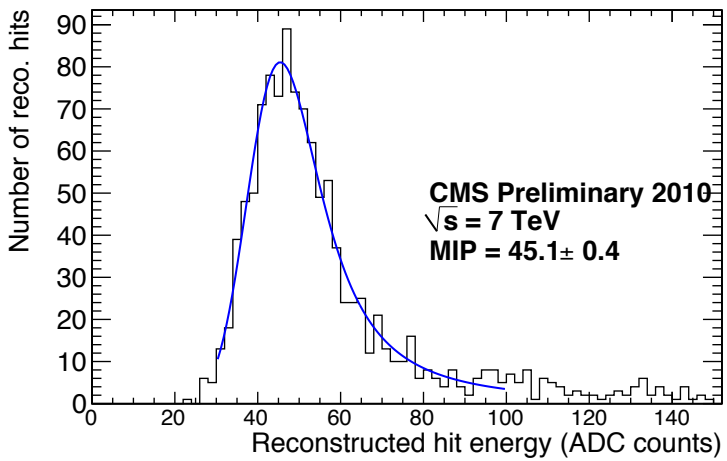


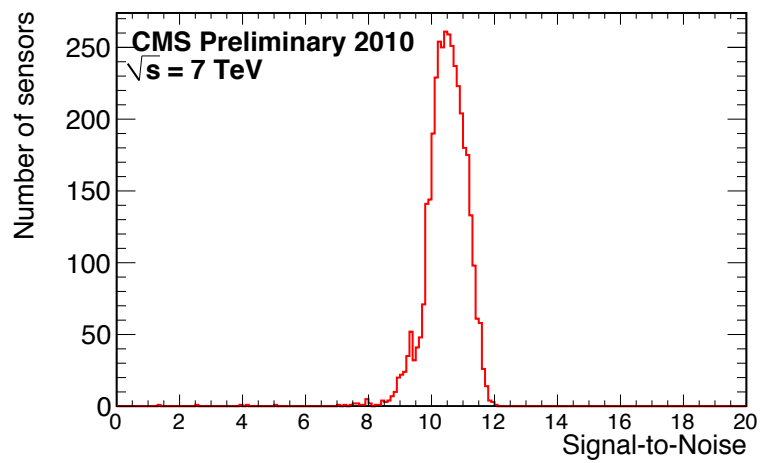
$17m^2$ of silicon sensors arranged in an X-Y grid

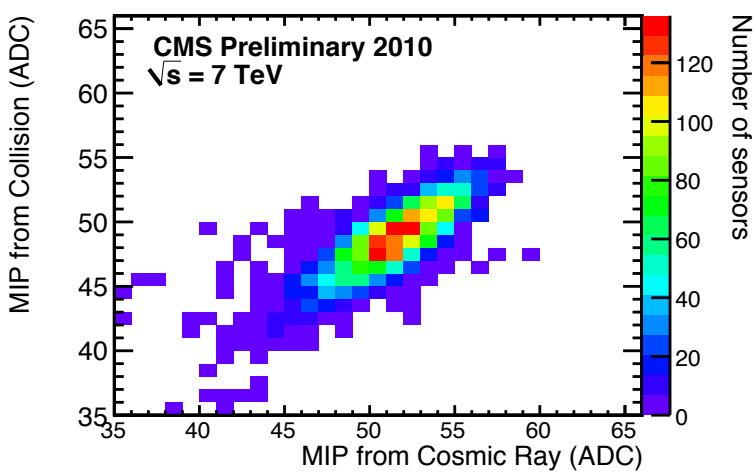
The largest EM sampling calorimeter based on silicon ever built !

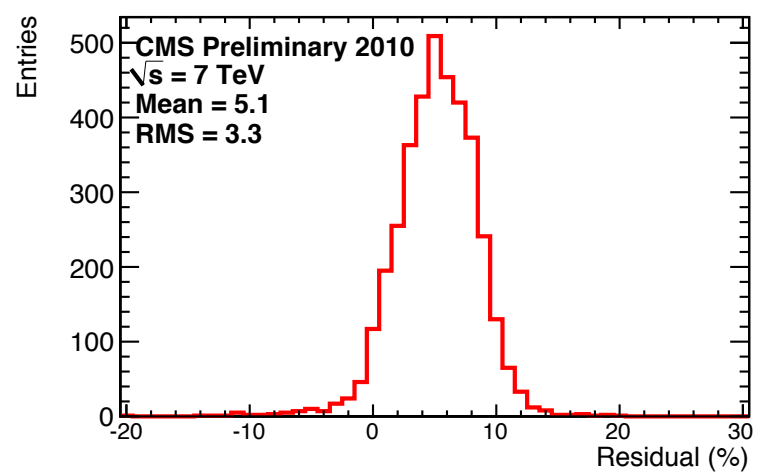
First in-situ MIP calibration

- The accuracy of MIP pre-calibration using cosmic rays : 2.5% (requirement : 5%)
- Use charged tracks with p > 1GeV to point to Preshower and find the associated hits
- Signals are corrected by the incidence angle
- Precision of first in-situ calibration is around 3.3% w.r.t. the pre-calibration



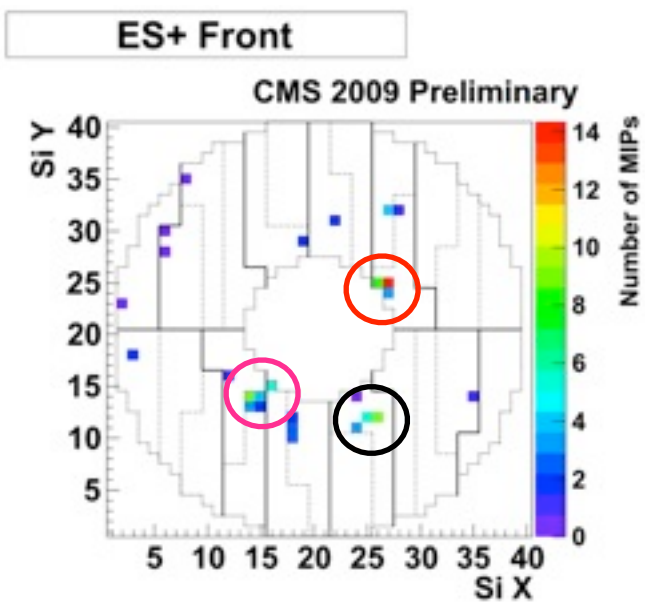


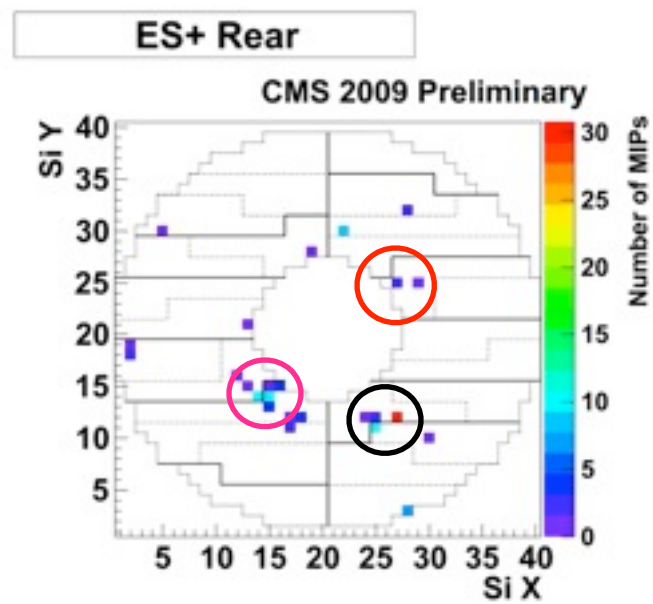


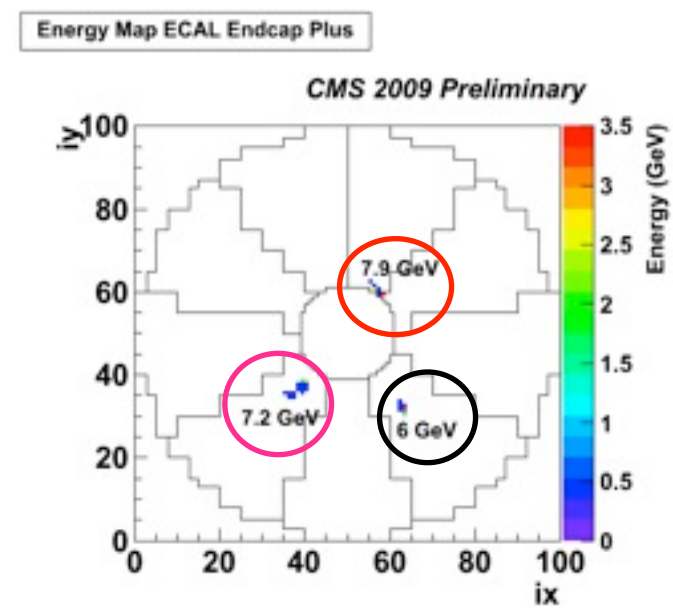


Nov 23rd, '09 : first 900GeV collisions

- Cluster matching between two Preshower planes and ECAL crystals
  - start from the significant amount of energy deposit in CMS EE crystals
  - extrapolate back to the origin and find the intersection on Preshower planes
  - open a search window and find the energy deposit within it



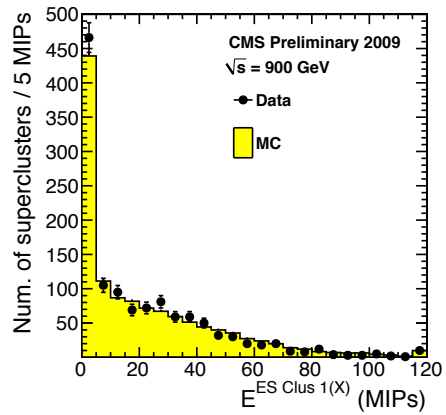


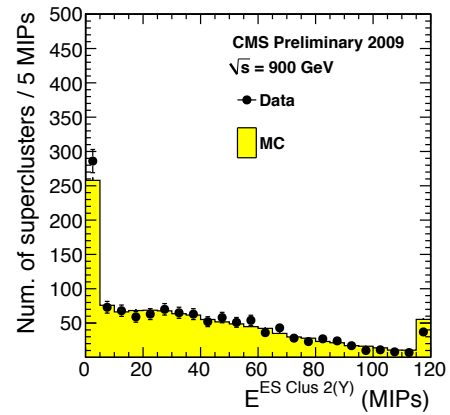


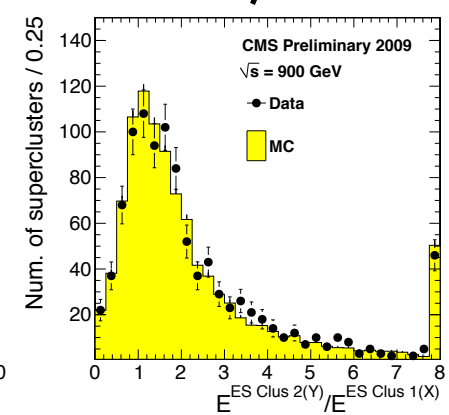
Energy deposit on Preshower planes

Plane 1 | Plane 2 | Plane 2 / Plane 1

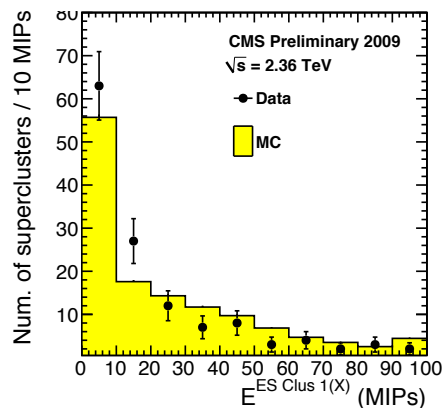
900 GeV

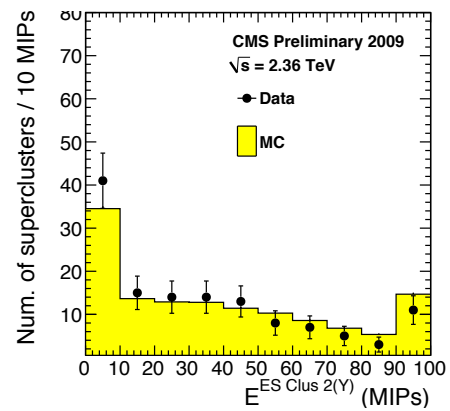


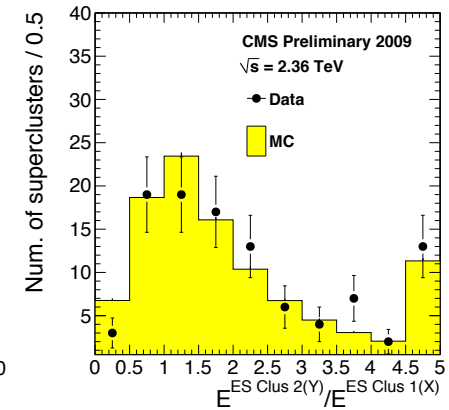




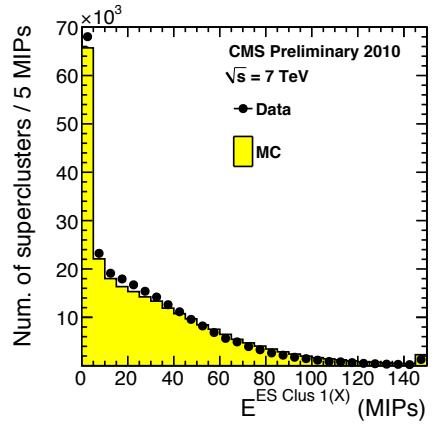
2.36 TeV

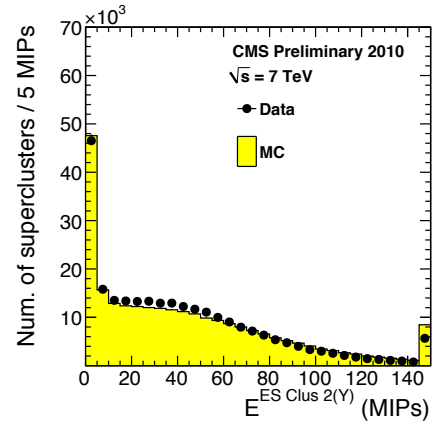


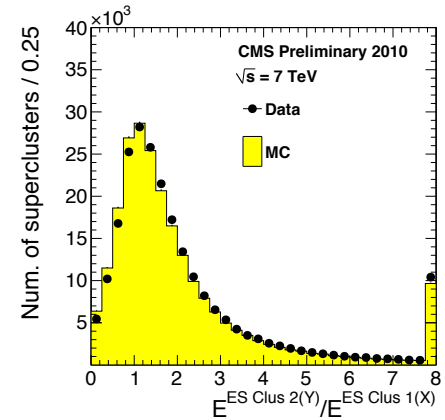




7 TeV

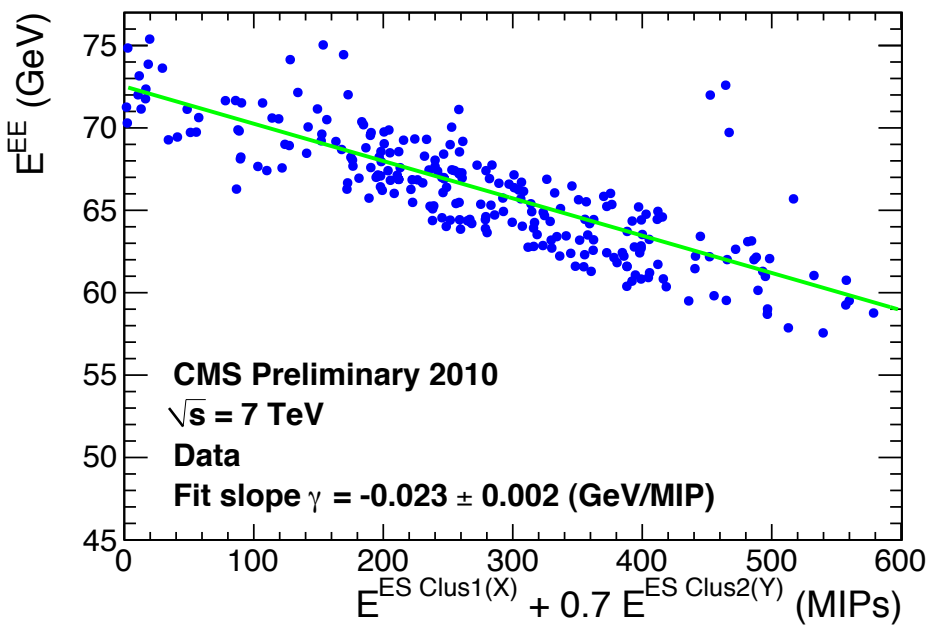


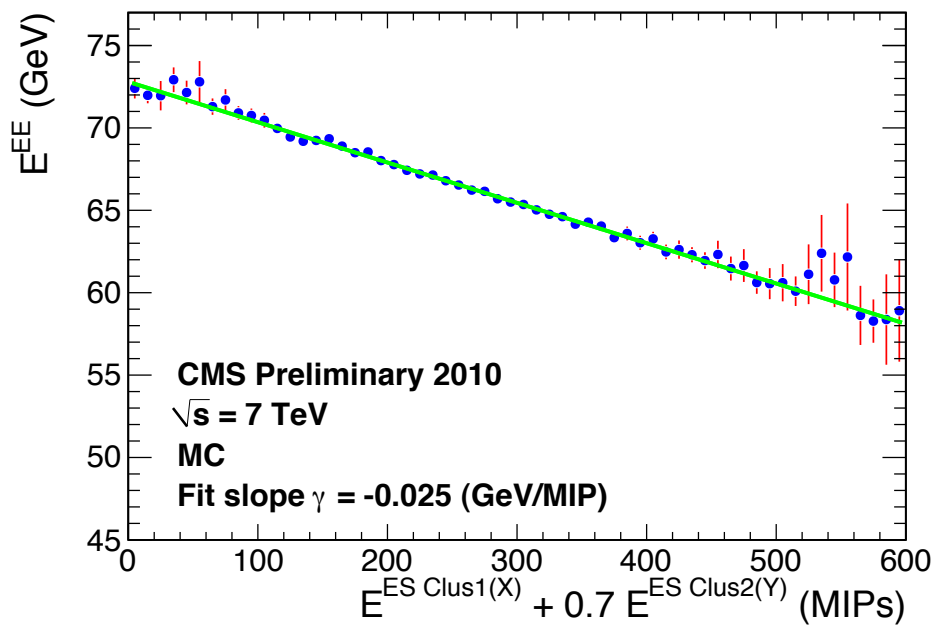




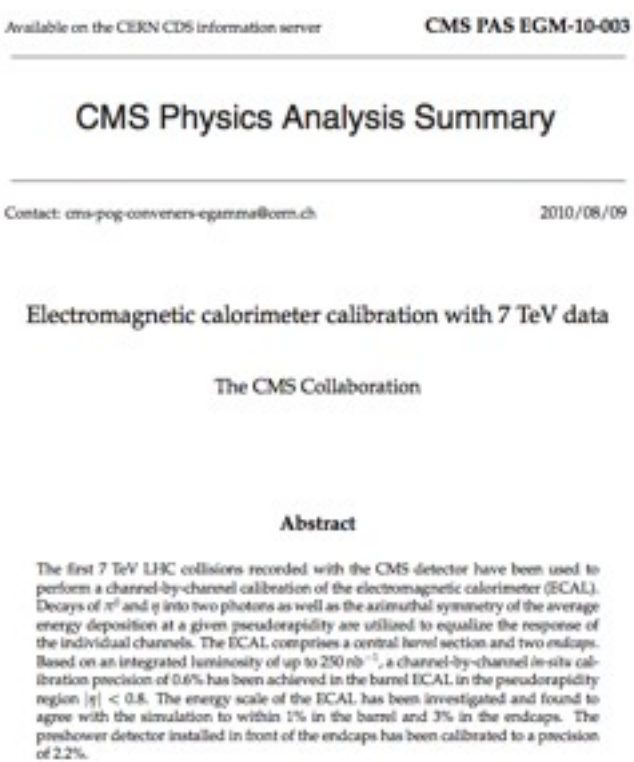
EE-ES inter-calibration

- Energy measured by endcap crystals vs. the energy deposit in ES for electrons without any identification requirement with energies measured by the combination of the silicon tracker and ECAL between 70 and 75 GeV





Preshower results in CMS PAS



Available on the CERN CDS information server

CMS PAS EGM-10-003

CMS Physics Analysis Summary

Contact: cms-pog-conveners-egamma@cern.ch

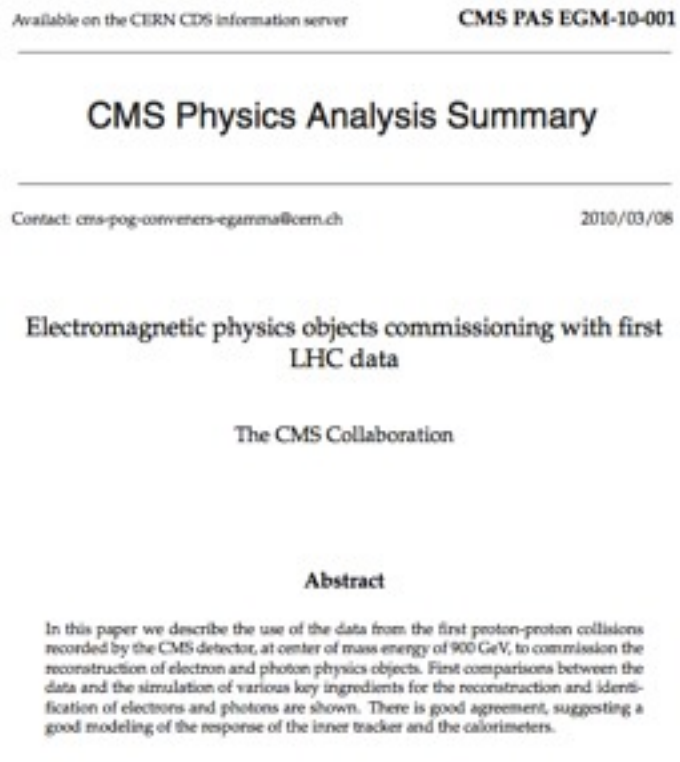
2010/08/09

Electromagnetic calorimeter calibration with 7 TeV data

The CMS Collaboration

Abstract

The first 7 TeV LHC collisions recorded with the CMS detector have been used to perform a channel-by-channel calibration of the electromagnetic calorimeter (ECAL). Decays of π^0 and η into two photons as well as the azimuthal symmetry of the average energy deposition at a given pseudorapidity are utilized to equalize the response of the individual channels. The ECAL comprises a central *barrel* section and two *endcaps*. Based on an integrated luminosity of up to 250 nb^{-1}, a channel-by-channel *in-situ* calibration precision of 0.6% has been achieved in the barrel ECAL in the pseudorapidity region $|\eta| < 0.8$. The energy scale of the ECAL has been investigated and found to agree with the simulation to within 1% in the barrel and 3% in the endcaps. The preshower detector installed in front of the endcaps has been calibrated to a precision of 2.2%.



Available on the CERN CDS information server

CMS PAS EGM-10-001

CMS Physics Analysis Summary

Contact: cms-pog-conveners-egamma@cern.ch

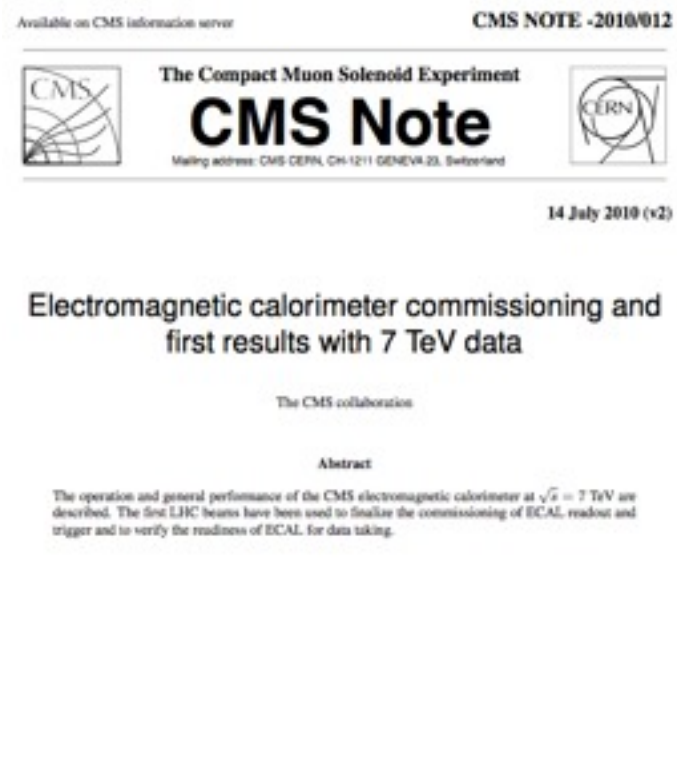
2010/03/08

Electromagnetic physics objects commissioning with first LHC data

The CMS Collaboration

Abstract

In this paper we describe the use of the data from the first proton-proton collisions recorded by the CMS detector, at center of mass energy of 900 GeV, to commission the reconstruction of electron and photon physics objects. First comparisons between the data and the simulation of various key ingredients for the reconstruction and identification of electrons and photons are shown. There is good agreement, suggesting a good modeling of the response of the inner tracker and the calorimeters.



Available on CMS information server

CMS NOTE -2010/012

The Compact Muon Solenoid Experiment

CMS Note

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

14 July 2010 (v2)

Electromagnetic calorimeter commissioning and first results with 7 TeV data

The CMS collaboration

Abstract

The operation and general performance of the CMS electromagnetic calorimeter at $\sqrt{s} = 7$ TeV are described. The first LHC beams have been used to finalize the commissioning of ECAL readout and trigger and to verify the readiness of ECAL for data taking.

2 PASes and 1 Note
(available in CERN Document Server)

Summary on Preshower

- CMS ECAL Preshower is fully operational at the CERN LHC
  - Installation and commissioning done in April 2009, according to schedule
  - 99.8% of channels are functioning perfectly

- Preshower successfully recorded collision events at LHC
  - First in-situ MIP calibration and Preshower-crystal inter-calibration have been carried-out, achieving required accuracy
  - Nice agreement between data and MC for energy deposit on Preshower planes and position correlation of Preshower-crystal

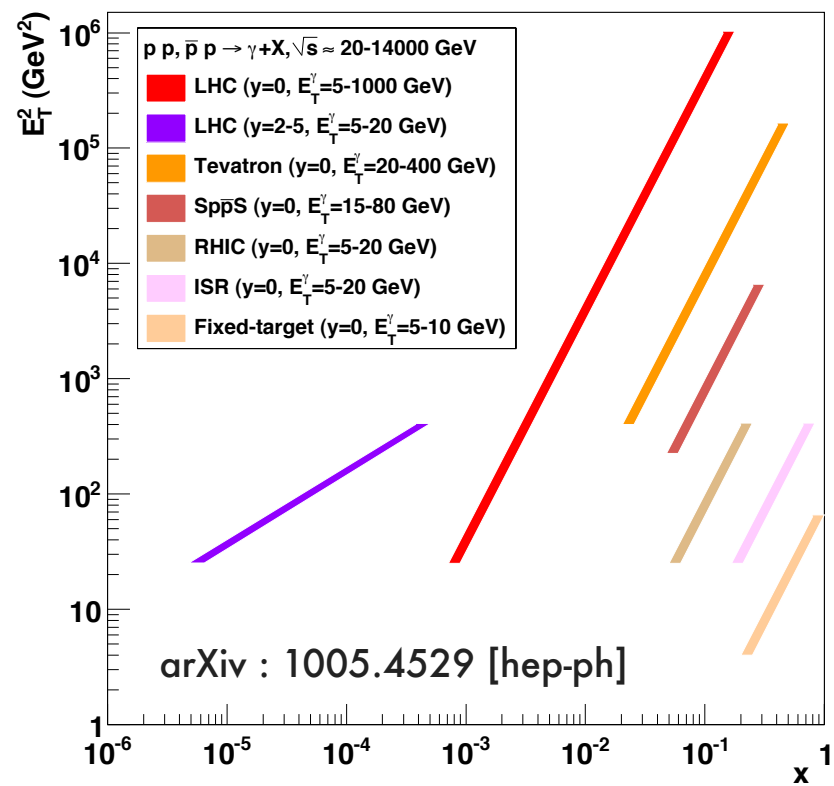
Inclusive Photon Spectra at 7 TeV

arXiv : 1012.0799v1 [hep-ex]

Accepted by PRL

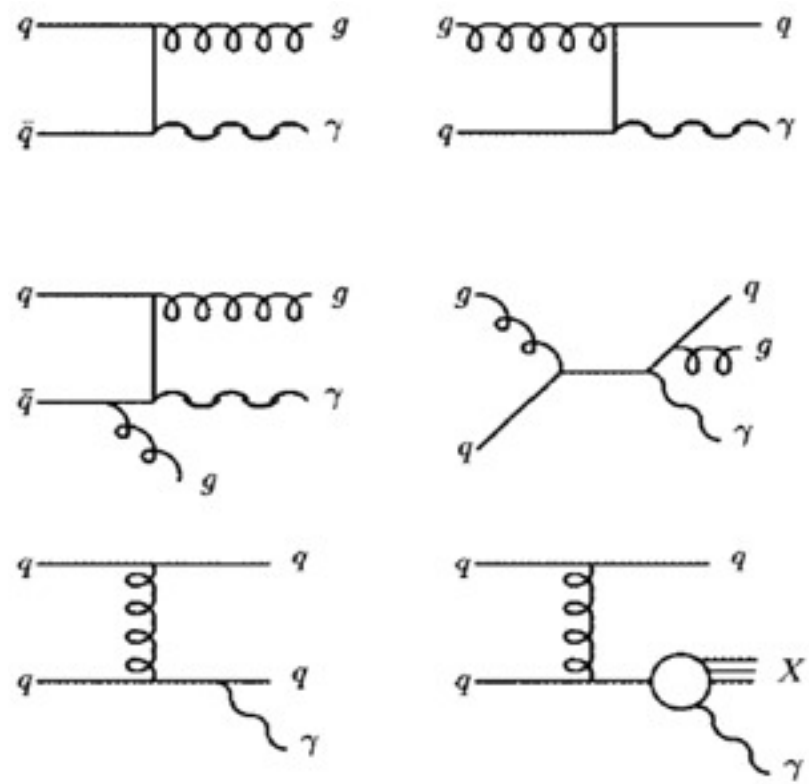
Motivations

- Test perturbative quantum chromodynamics (pQCD)
- Constrain the parton distribution functions (PDFs) of the proton
- higher center-of-mass energy allows to explore the new kinematic regions
- Background to searches for new phenomena involving photons in the final state
- Provide an ideal playground for the commissioning of the identification techniques used to study final states with isolated photons

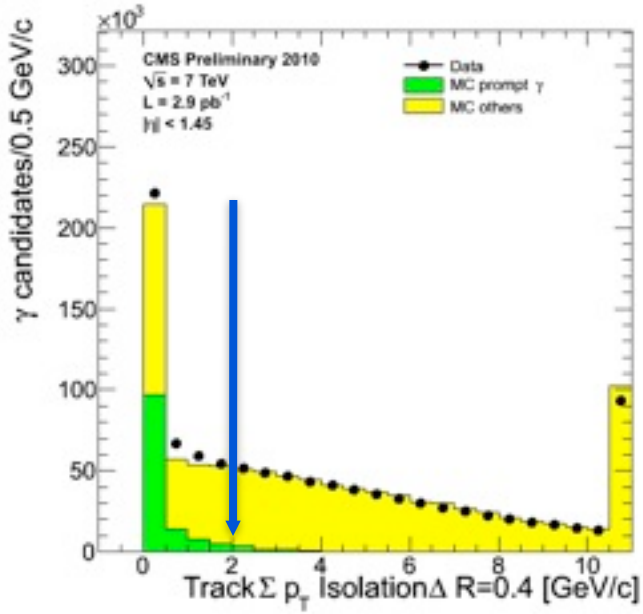


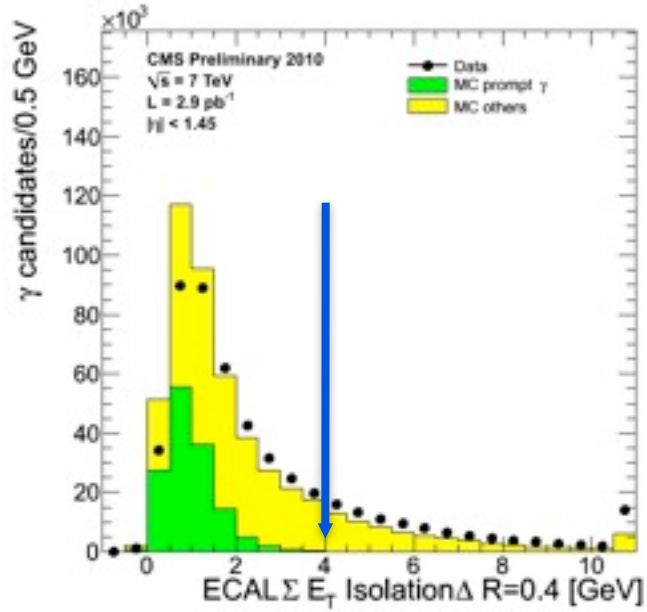
Prompt Photons

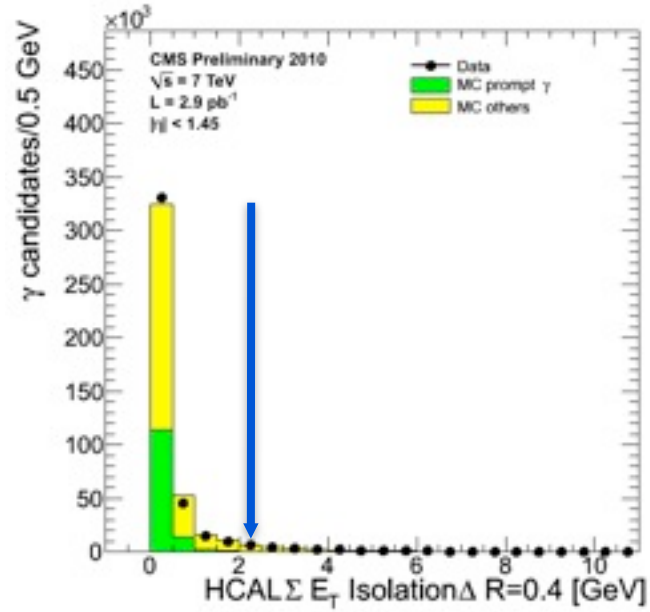
- Direct photons :
  - quark-gluon Compton scattering
  - quark-quark annihilation
- Fragmentation photons :
  - the collinear fragmentation of a final state parton into a photon
- Background photons :
  - mostly from the decays of energetic π^0 and η mesons



Isolated Photons







Isolation variables

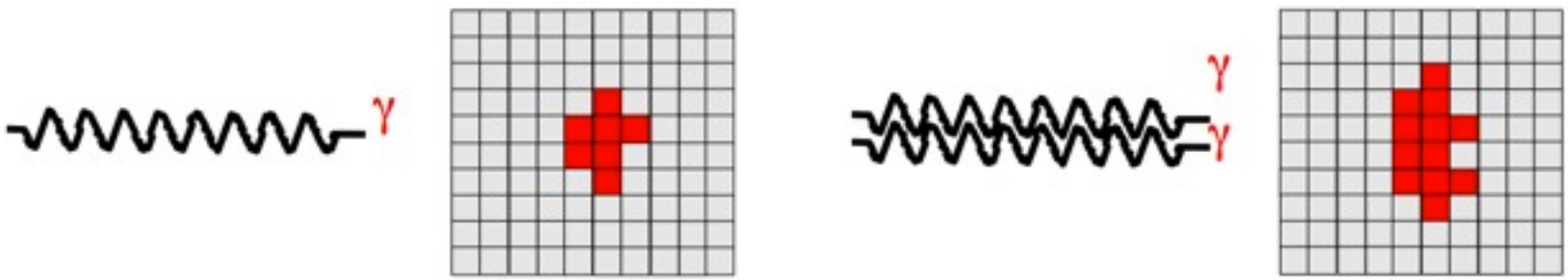
$Iso_{TRK} = \Sigma_{R<0.4}$ track p_T

$Iso_{ECAL} = \Sigma_{R<0.4} E_{T\,ECAL}$

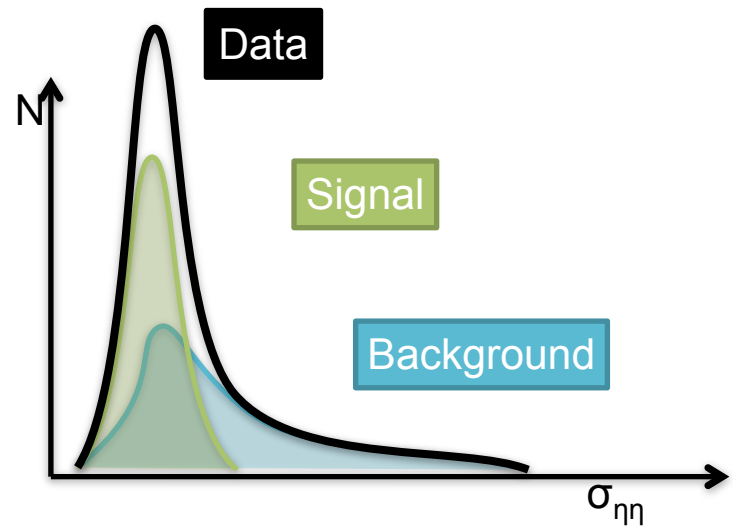
$Iso_{HCAL} = \Sigma_{R<0.4} E_{T\,HCAL}$

$H/E = \Sigma_{R<0.15} E_{HCAL}/E_{ECAL}$

Signal Yield Extraction

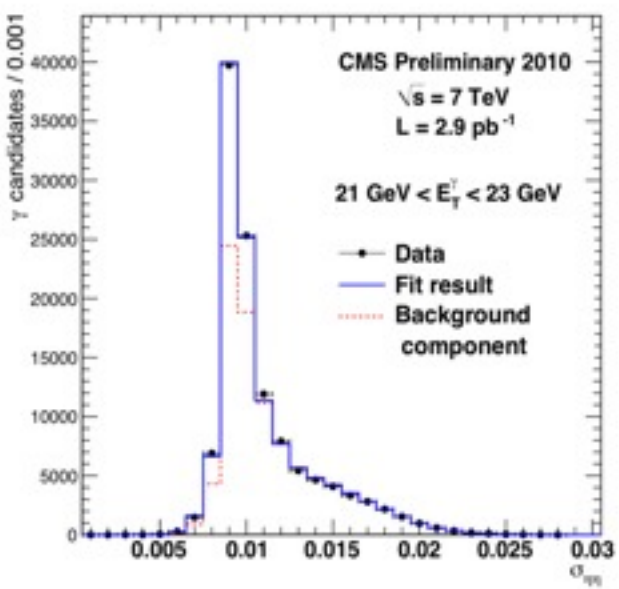


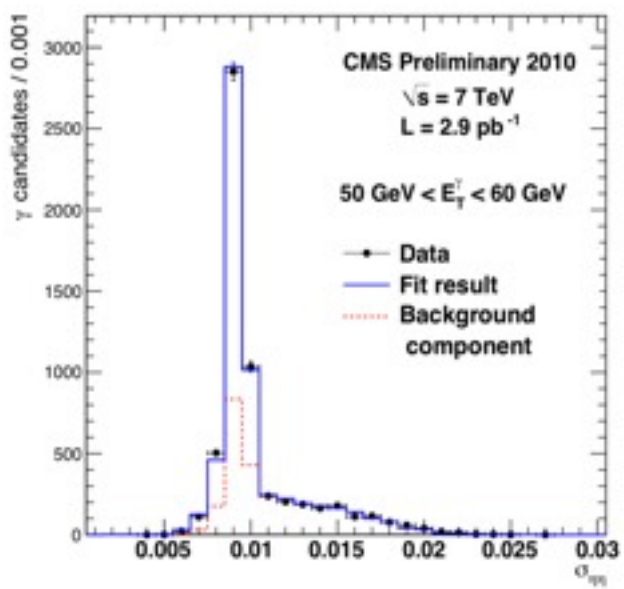
- A substantial background contribution remains when neutral mesons carry most of parton energy
- Using the difference in the shower shape between the signal and background photons
- Signal template : from MC
- Background template : from data

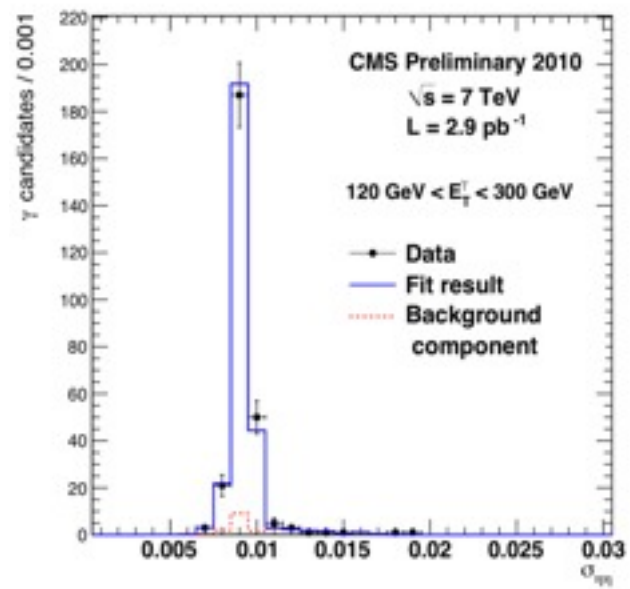


Signal Yield Extraction

- Data shower shape distribution is fitted with signal and background shower shape using the binned extended maximum likelihood fit

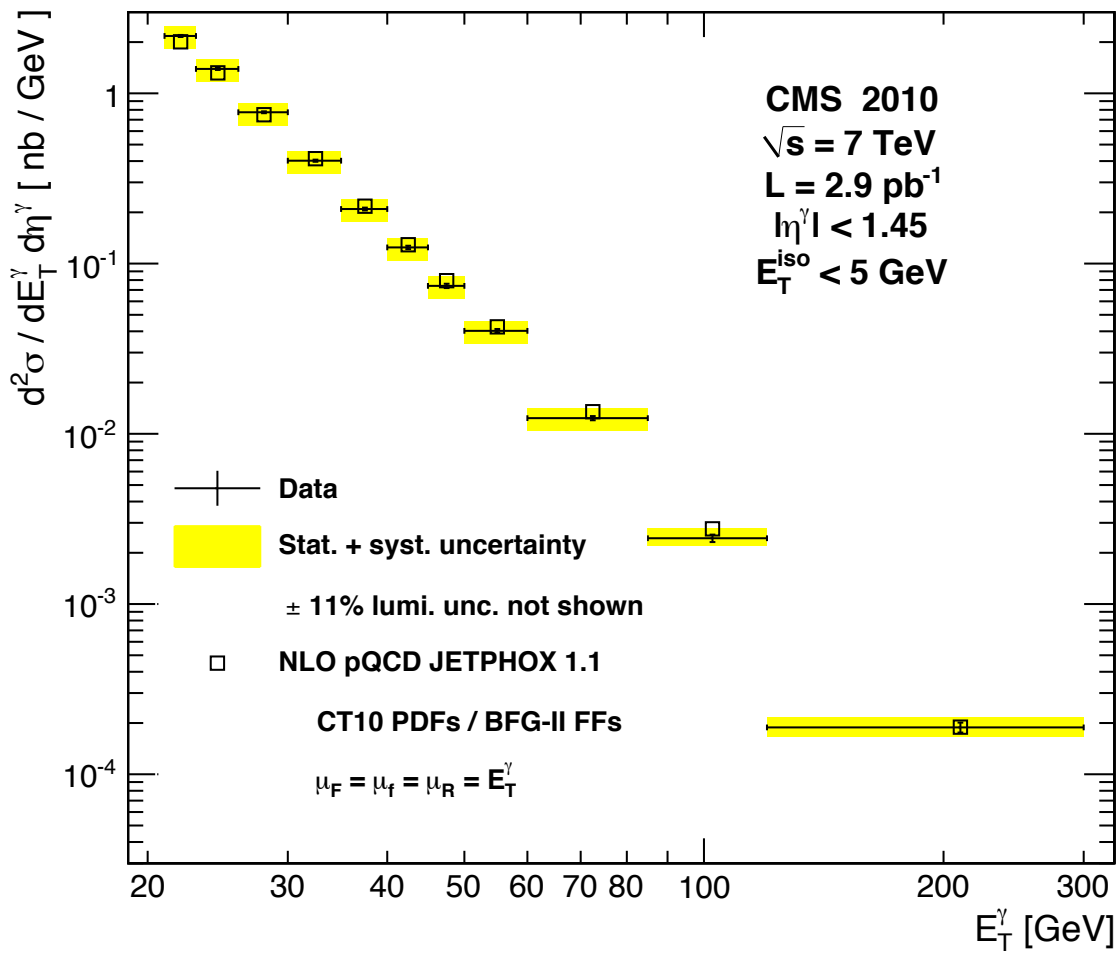




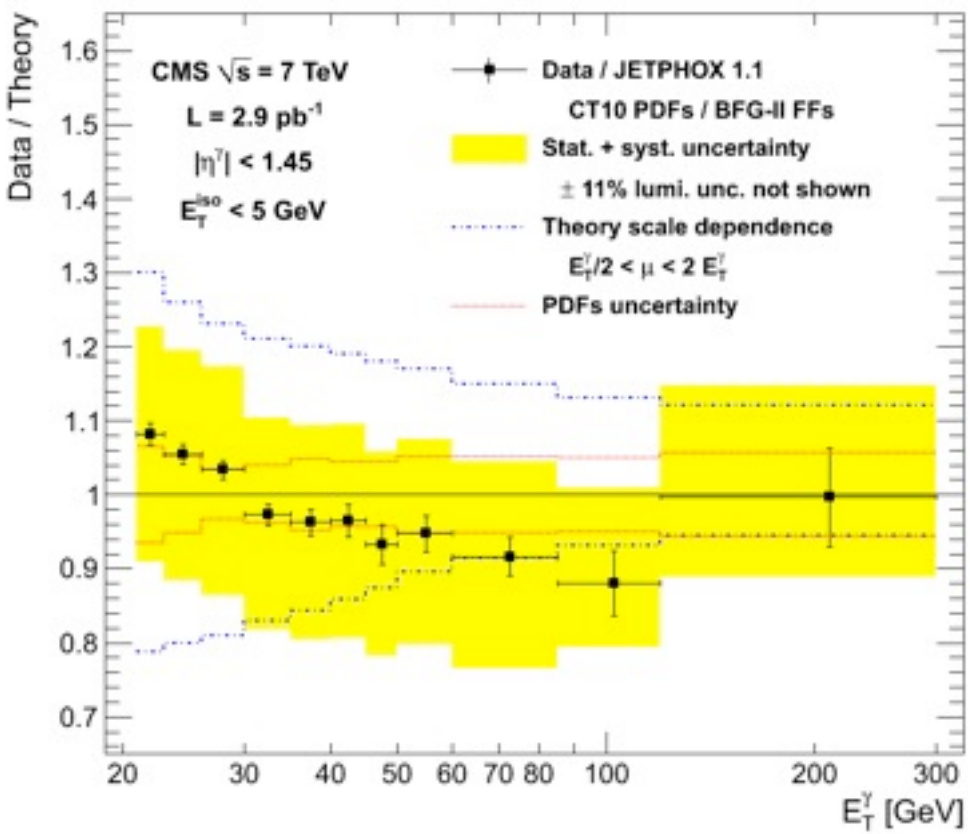


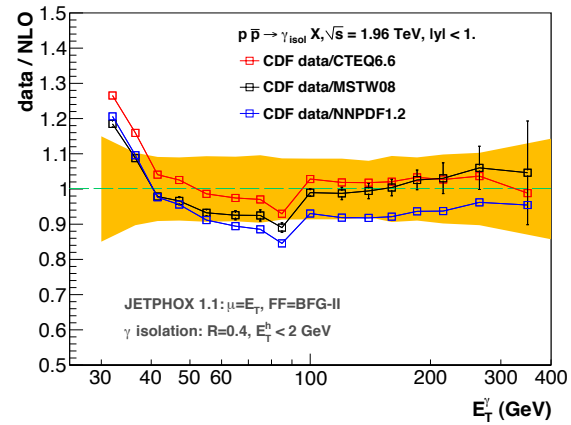
Inclusive Photon Spectra @ CMS

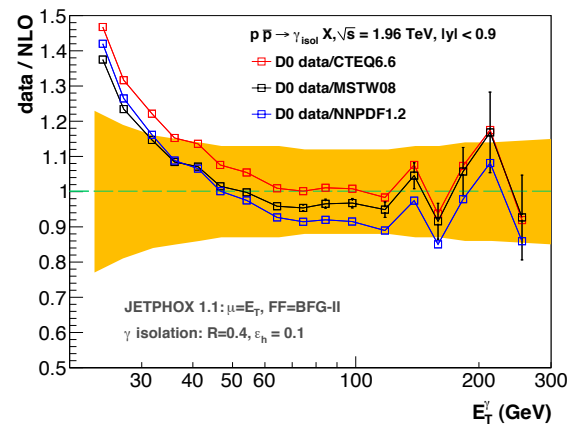
- Good agreement with the NLO predictions from JETPHOX is observed



Data/Theory







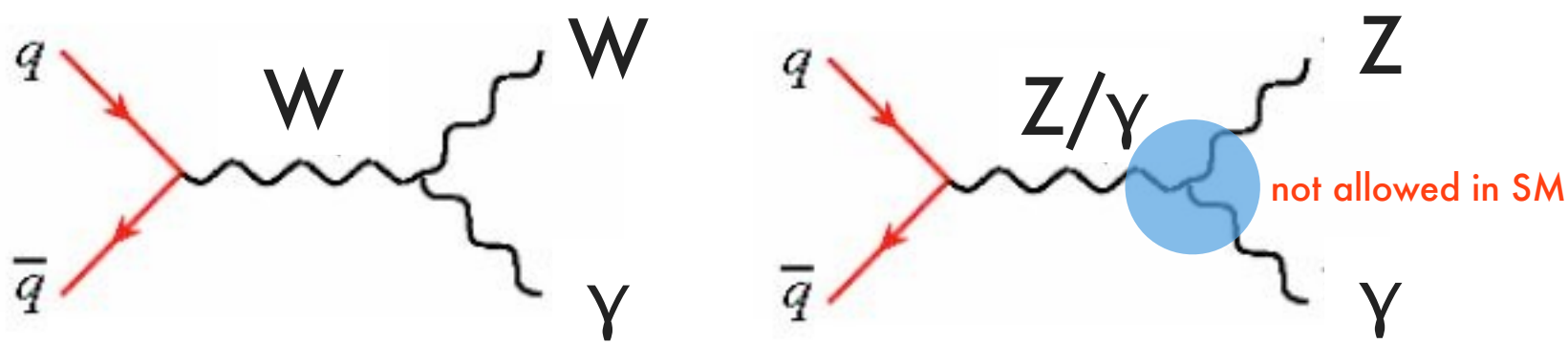
- At 7 TeV CMS probes a low x_T value between 0.006 and 0.086
- Data at low pT is better described by the theoretical predictions than in previous measurements at lower $\sqrt{s}$ and higher x_T ($= 2E_T/\sqrt{s}$)

Di-boson Wγ and Zγ

Motivation

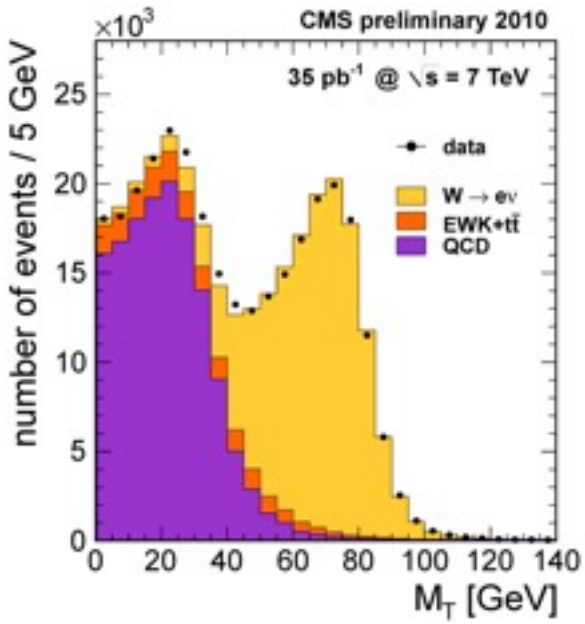
- Probing the coupling between gauge bosons tests the core of the SM
- Deviations from SM would indicate the presence of new physics
- An important, often irreducible, background in the search for new physics

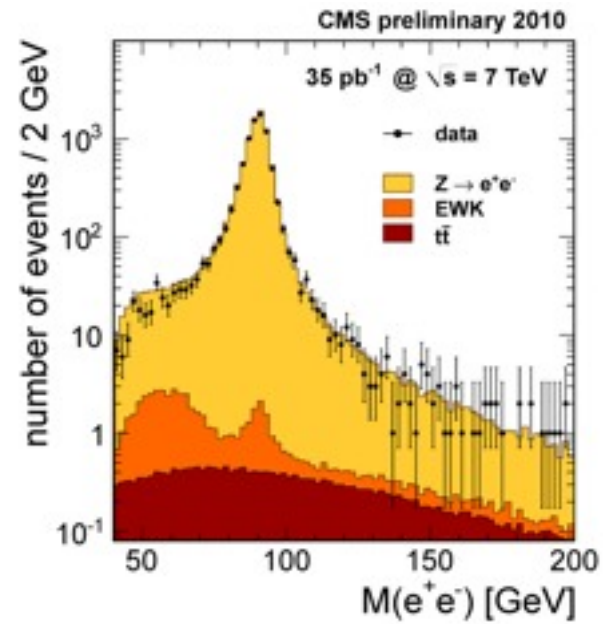
Triple Gauge Coupling

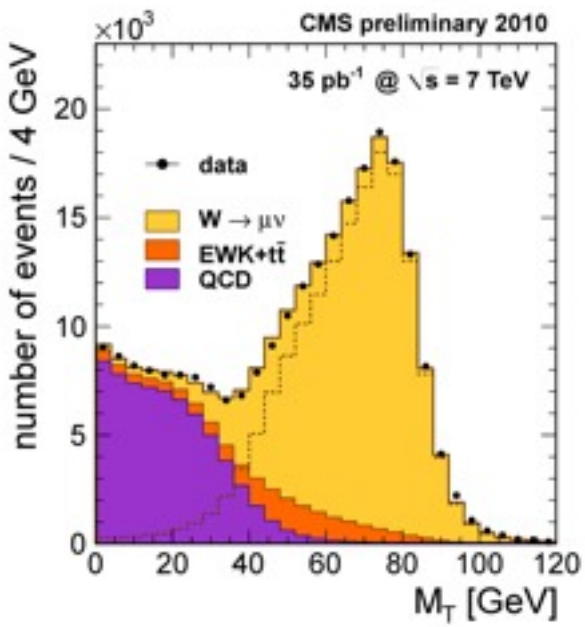


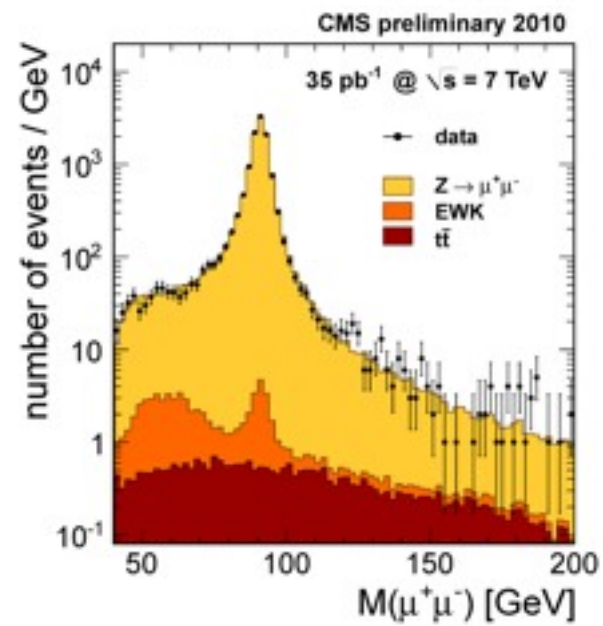
- We are looking into Wγ and Zγ production at CMS
- Aims : Measure Wγ and Zγ cross section (and TGC if possible) at 7 TeV

W and Z candidates

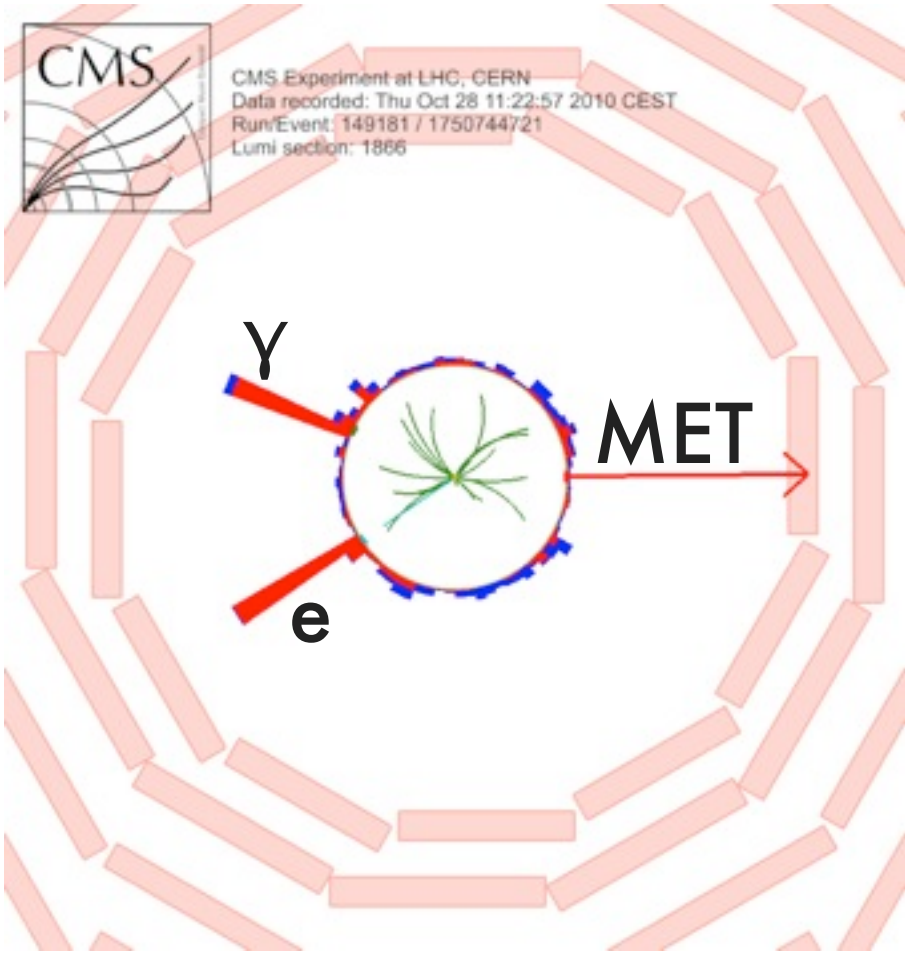


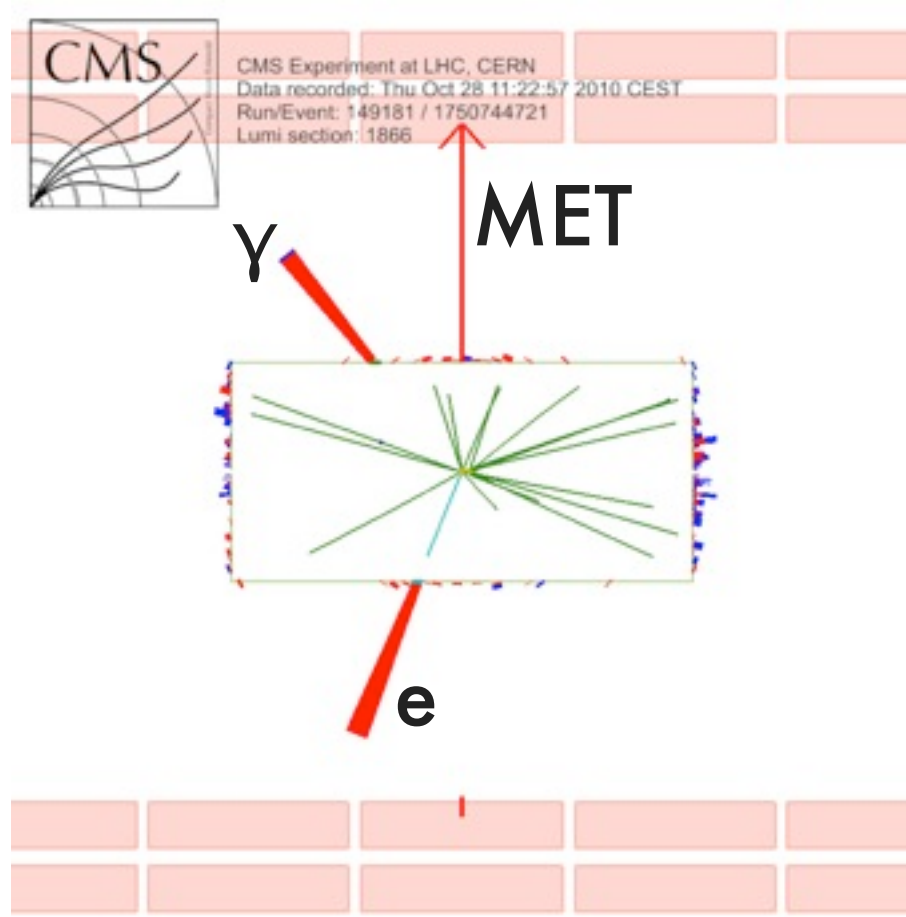




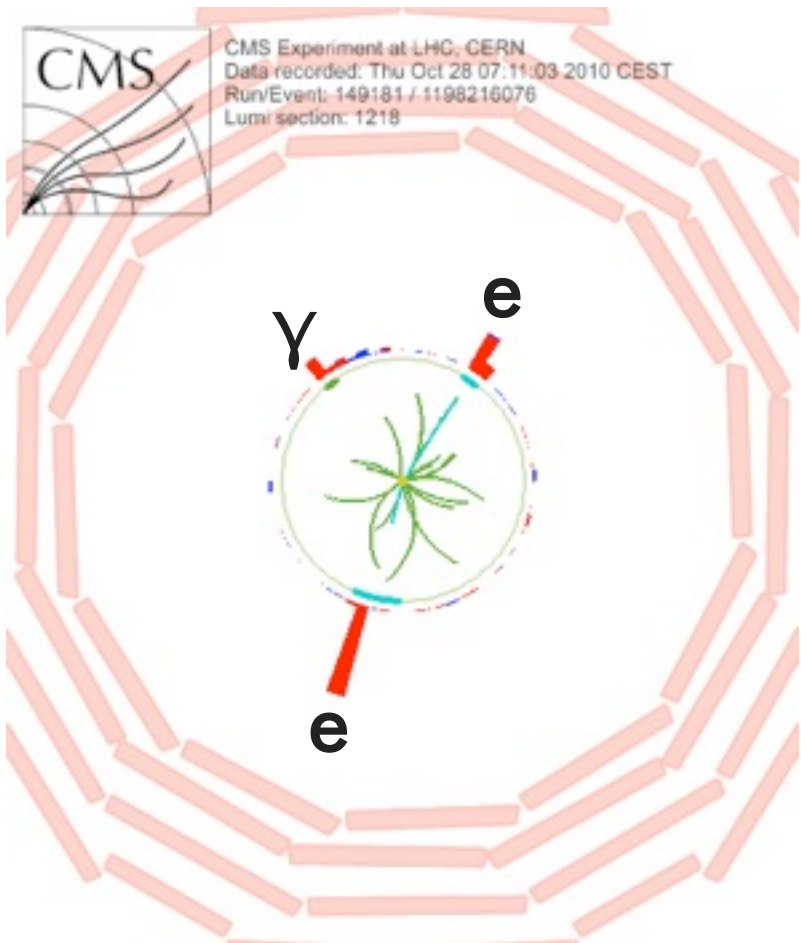


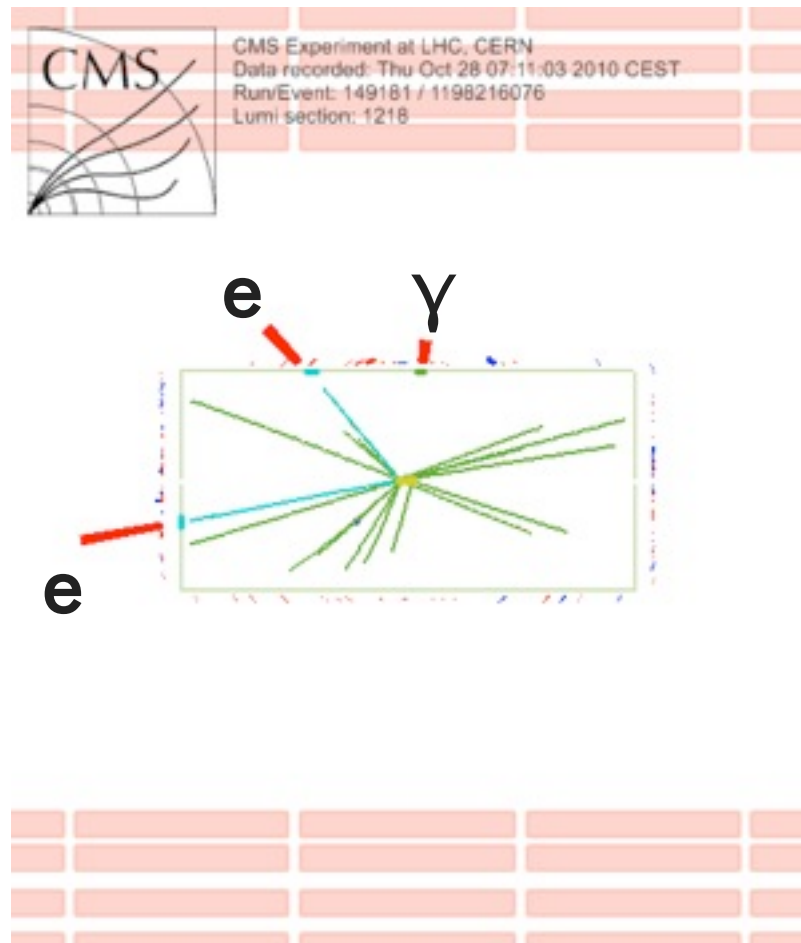
A Wγ candidate





A Zγ candidate



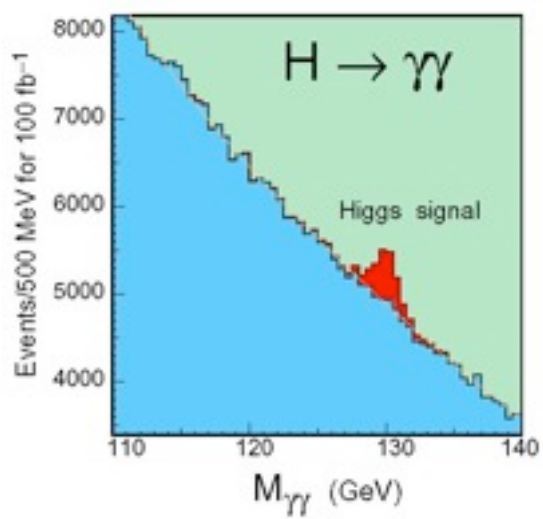


M_{ee} = 90.12 GeV

Single γ measurement

Wγ and Zγ measurement

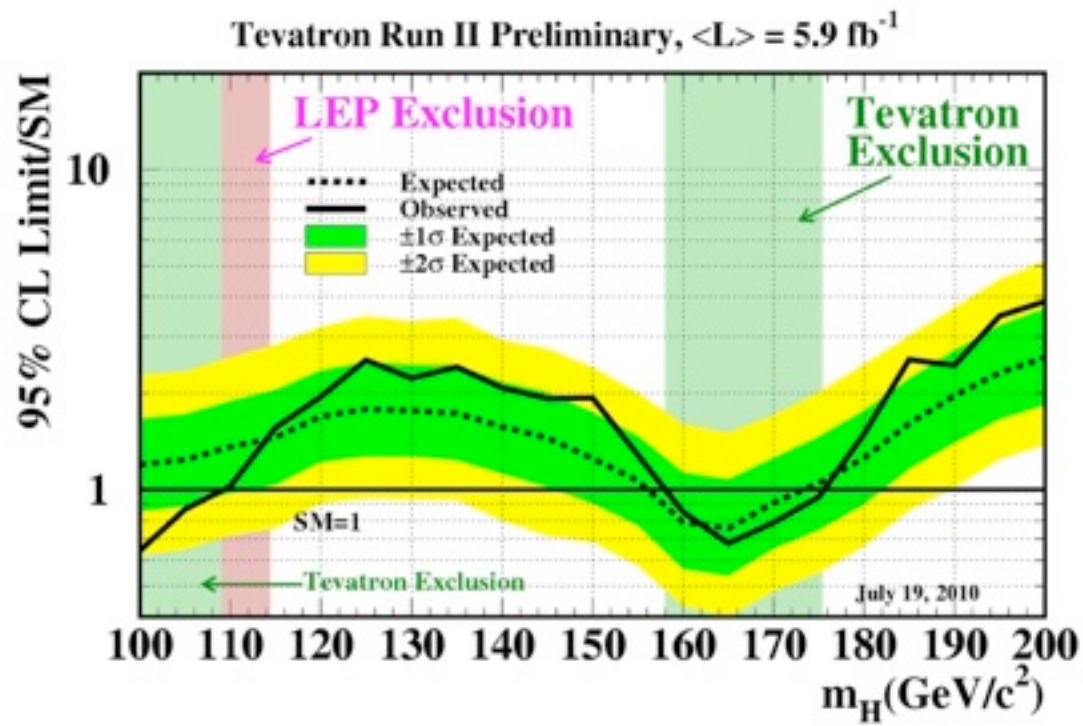
Next step is .....



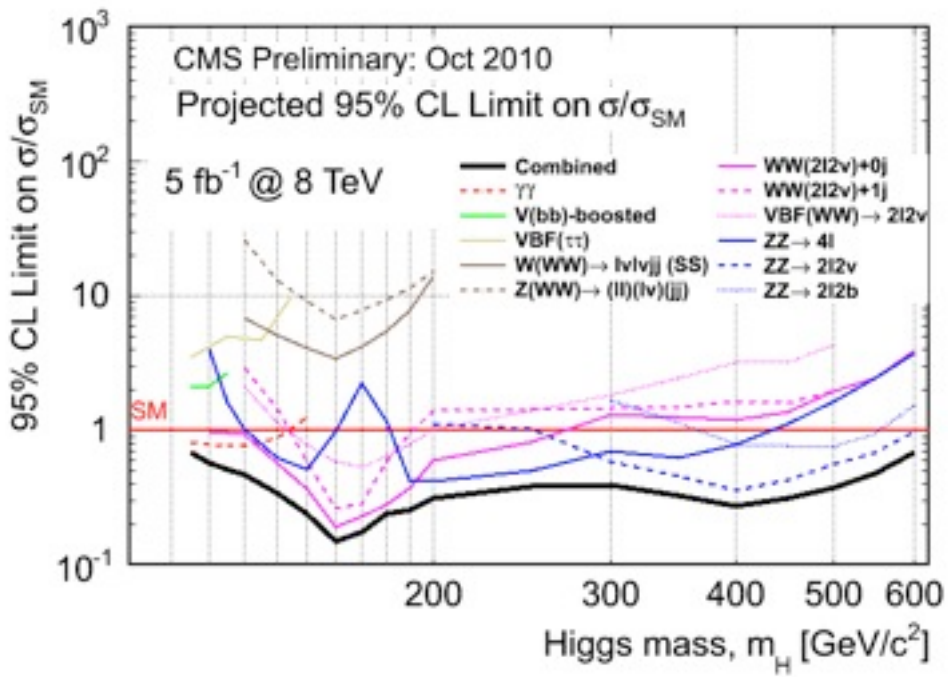
SM Higgs Search Status

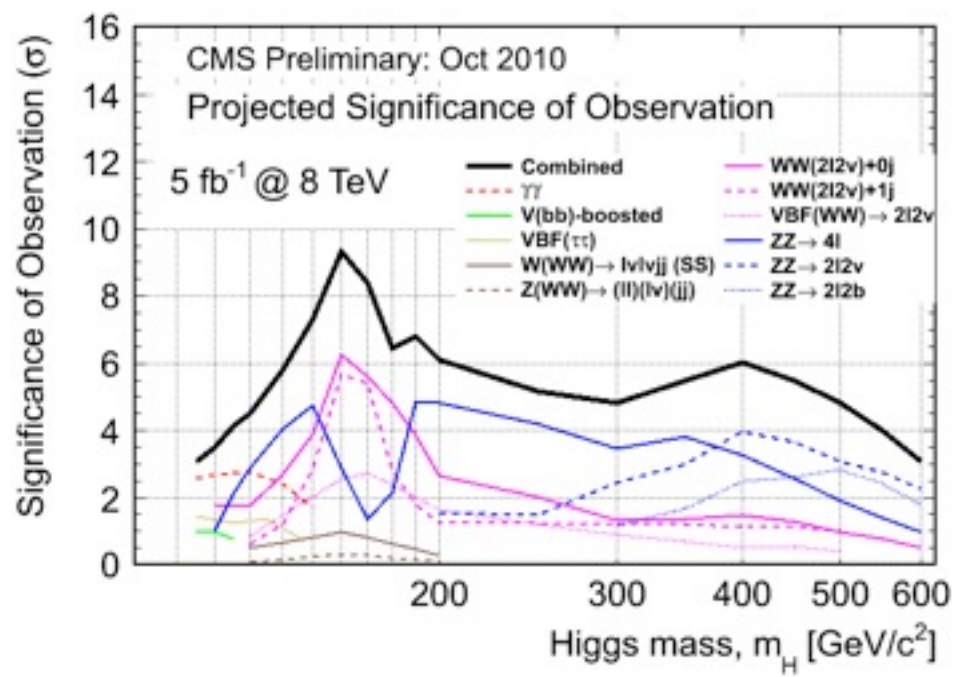
Hunting the Higgs particle is among the most fundamental challenges of modern science

- LEP direct searches : $m_H > 114$ GeV @ 95% C.L.
- Tevatron : 95% CL exclusion $158 < m_H < 175$ GeV



Higgs Search @ 8 TeV @ CMS





- At $\sqrt{s}$ = 8 TeV with L = 5/fb
  - CMS is expected to reach an exclusion sensitivity from 114 to 600 GeV
  - the observation sensitivity in the same mass range is expected to be 3σ or higher, depending on the Higgs mass

Summary on Physics Results

- The first measurement of the isolated prompt photon production cross section in pp collisions at $\sqrt{s}$ = 7 TeV using CMS detector is presented
  - the results explore lower x_T value compare to previous measurements
  - a good agreement between data and theory is observed

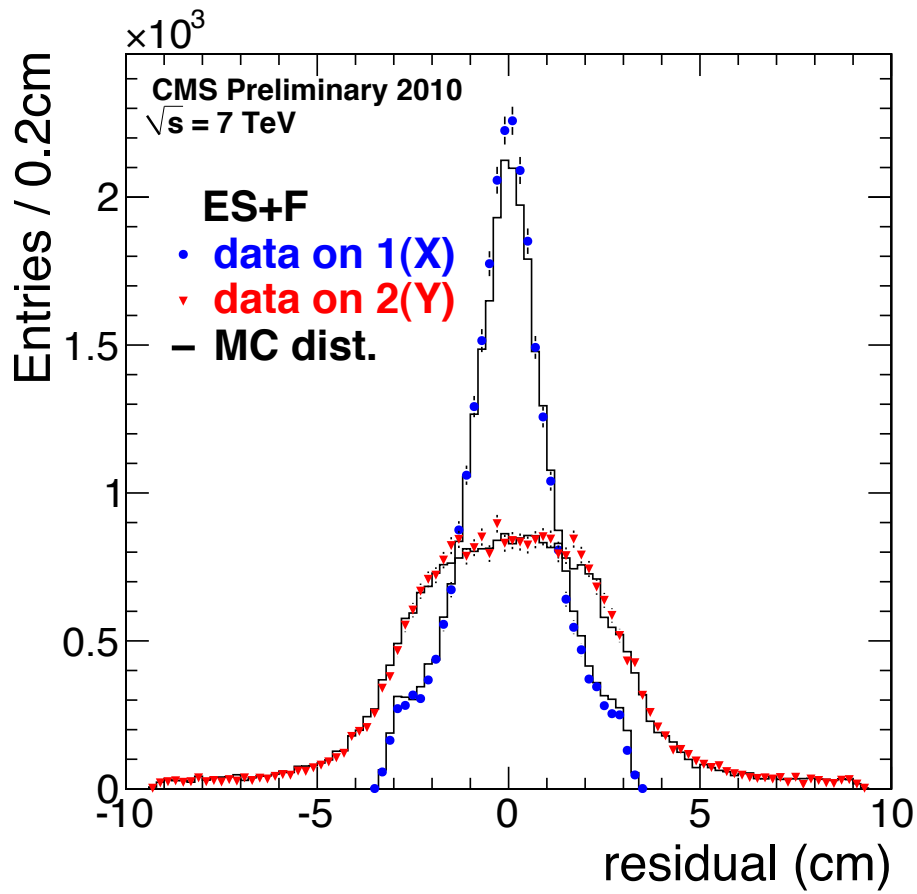
- Di-boson $W\gamma$ and $Z\gamma$ analysis is in progress
  - candidates were found in CMS detector

- We start looking into $H\rightarrow\gamma\gamma$
  - Commission pi0 rejection using Preshower detector
  - Looking forward to the restart of data taking at LHC in 2011

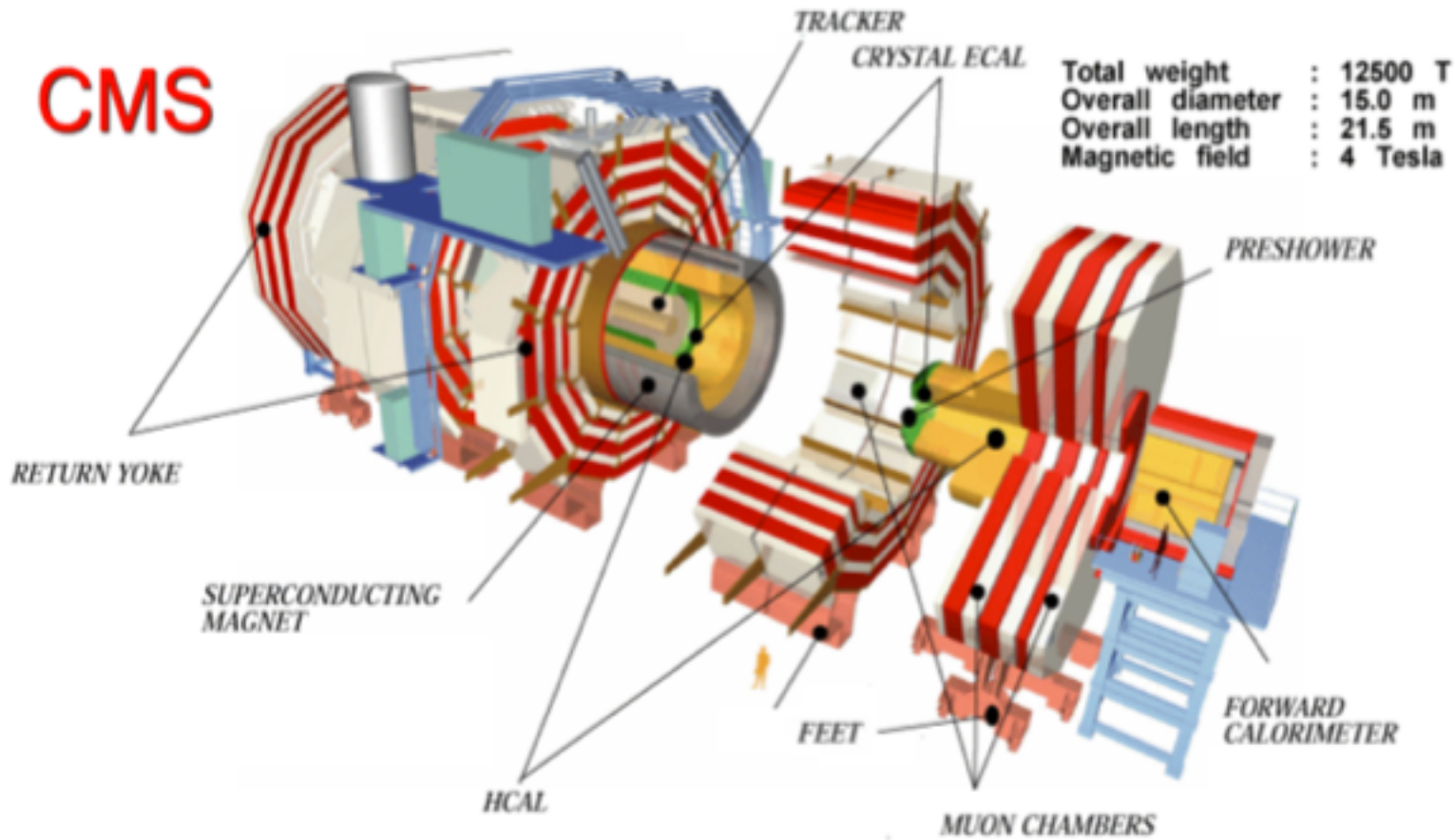
backup

Position Correlation of EE-ES clusters

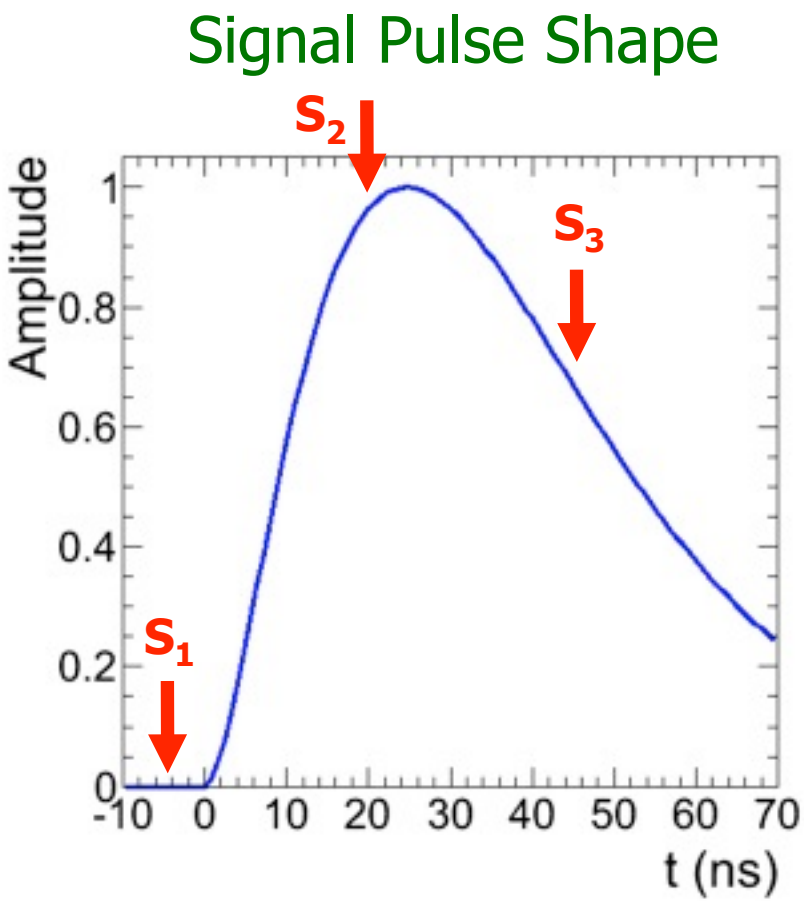
- Each ES plane measure X or Y with good resolution
- Residual distribution between most energetic Preshower (ES) cluster and seeded EE basic cluster shows alignment between EE and ES better than 0.2 cm
- Residual widths dominated by low-energy particles in clusters - will decrease to less than 1mm when samples of high energy electrons/photons available



The CMS Detector



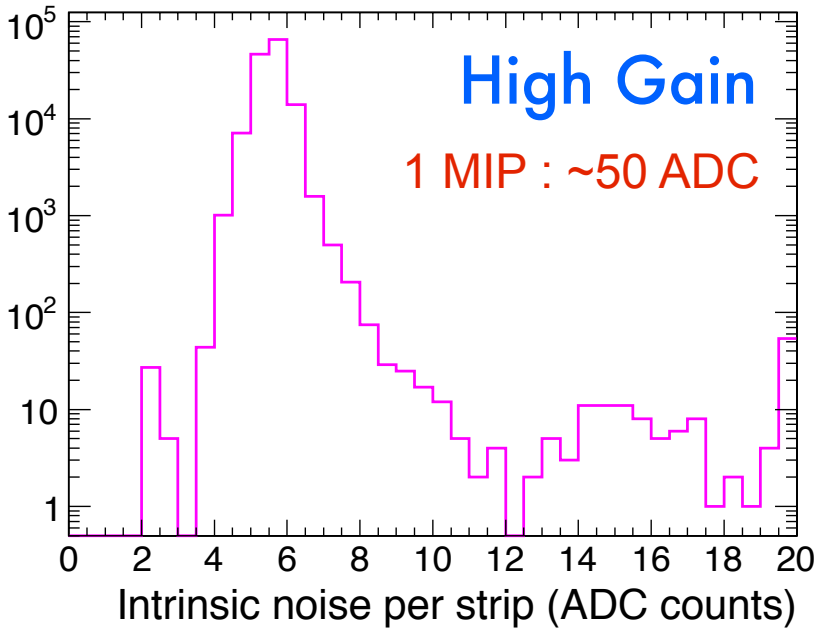
Readout electronics scheme

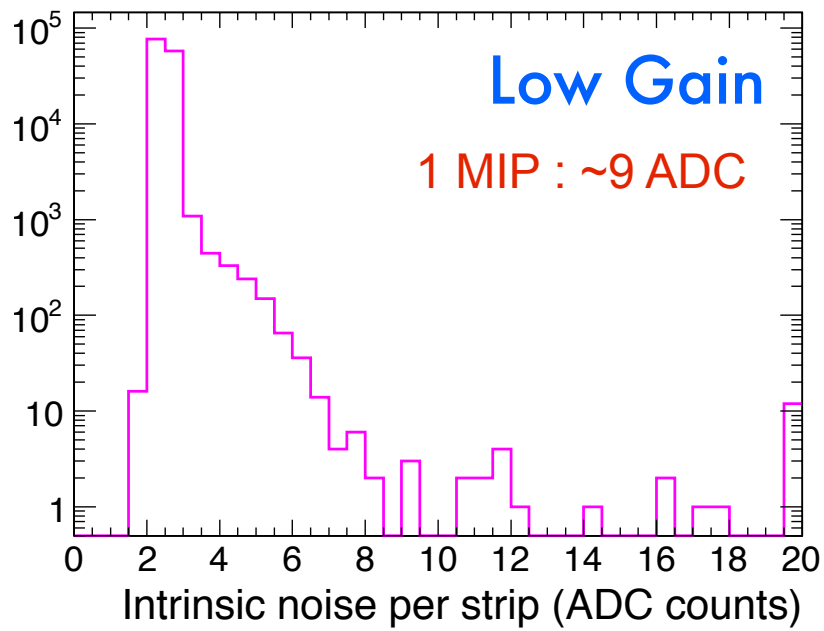


- Number of channels : **137216**
- amplified & shaped; sampled every 25 ns (S_1 for pedestal subtraction and S_2, S_3 for signal reconstruction)
- digitized by 12-bit ADCs
- Two switchable gains
  - **High gain** (0→70 MIPs) for absolute calibration and low energy LHC running. S/N is about **10** for a MIP.
  - **Low gain** (0→450 MIPs) for "high" energy running. S/N is about **3** for a MIP.

MIP : the energy deposited by a high energy charged particle traversing the 310μm silicon sensor.

First commissioning : Noise level





- > 99.88 % of channels functioning perfectly

(64 strips are not biased and 100 strips have intrinsic noise > 15 ADC counts in high gain so are masked from the readout)

- agrees with test beam performance

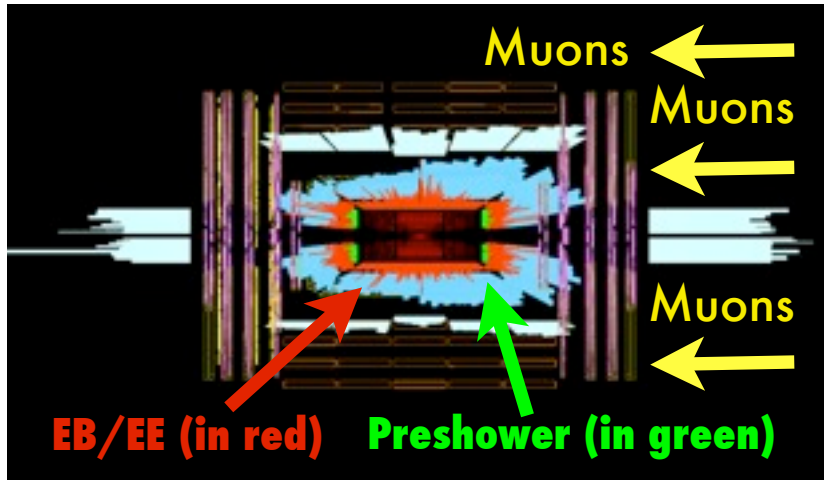
Response to Beam Splashes '09

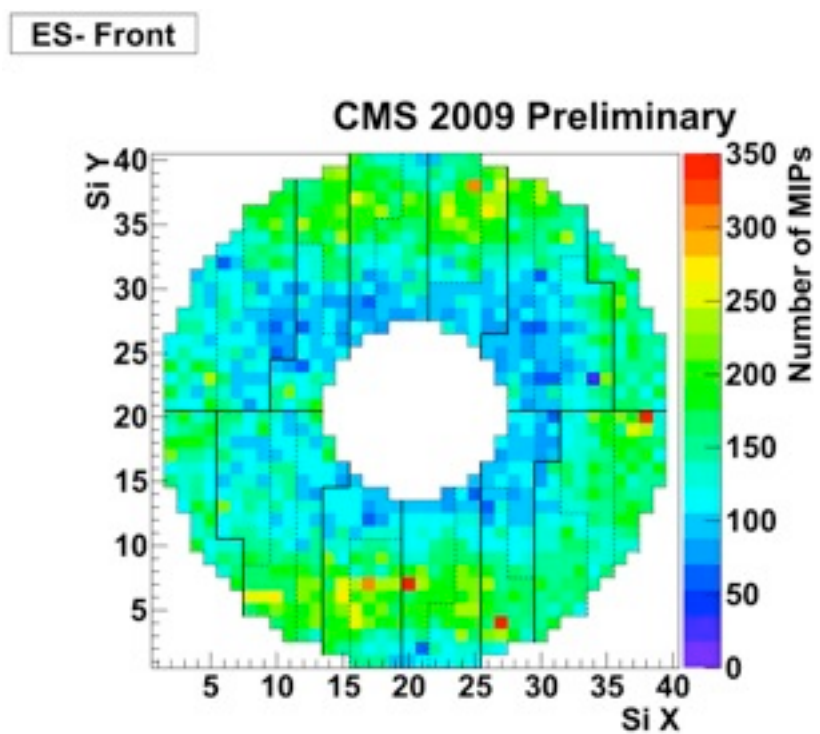
- Beam splash : beam was deliberately dumped on collimators 150m away from CMS, producing spray of 2ndary particles

- average particle flux is about 5 muons per cm^2 for a "splash" event. Preshower signals
  - consistent with results from other detectors
  - isolated hot spots attributed to muon bremsstrahlung

- improve Preshower timing adjustment

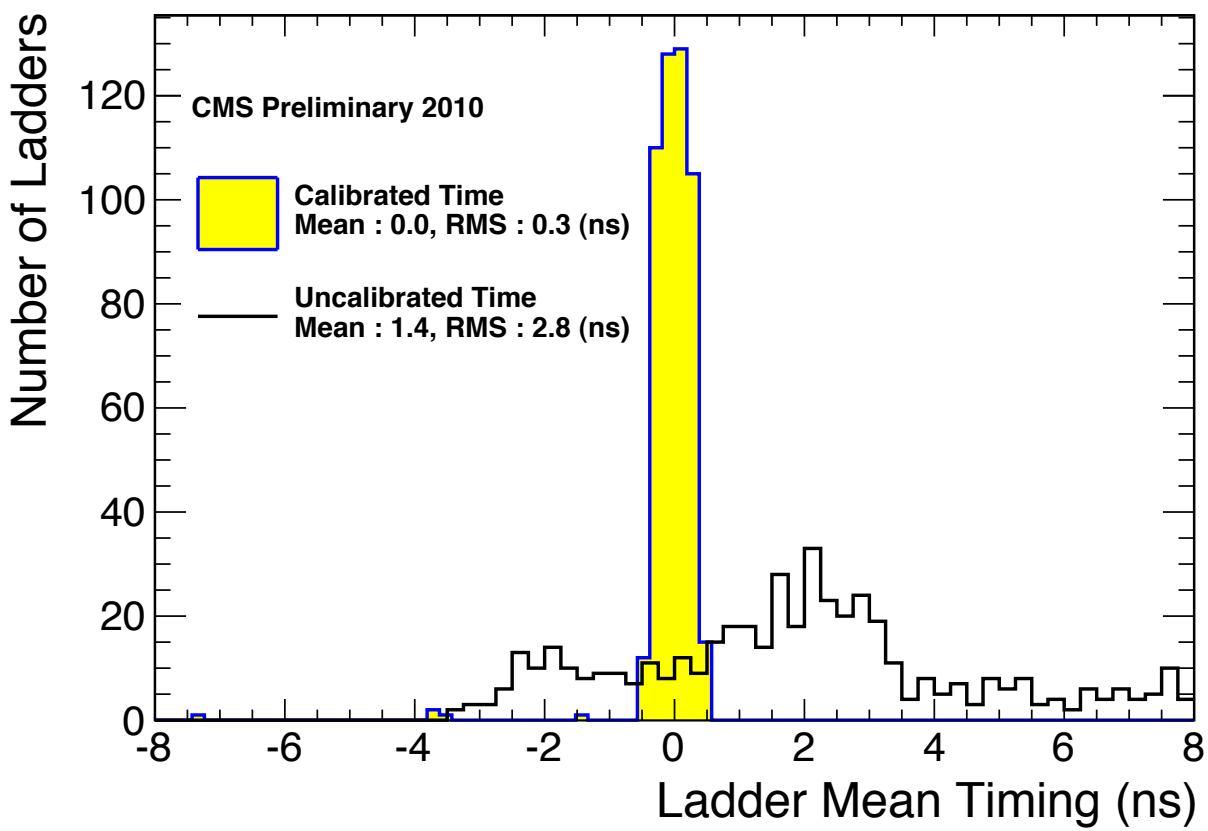
- improve EE crystals inter-calibration





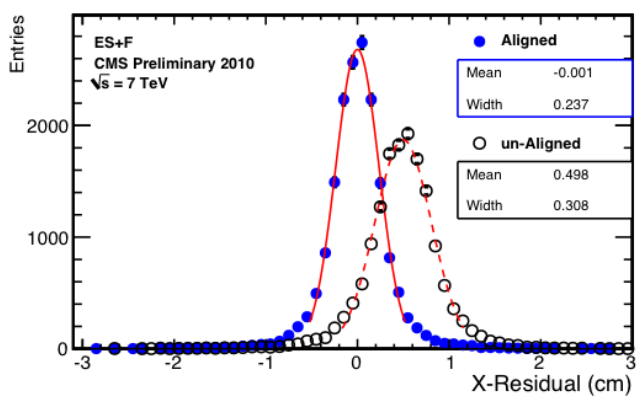
Timing Alignment

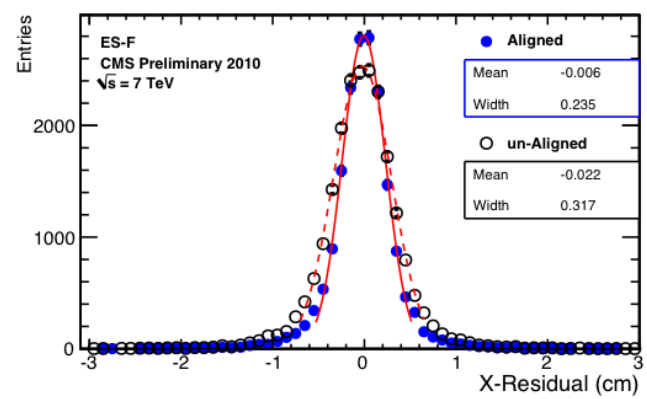
- Started with CMS cosmic ray data taking
- Beam splash data provided time synchronization of Preshower silicon sensors and used for LHC startup
- Improved with collision data

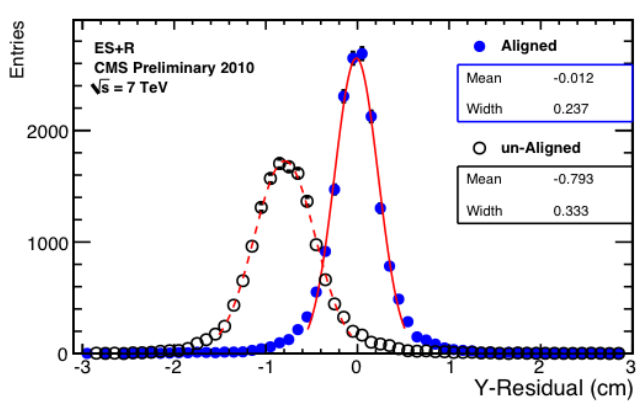


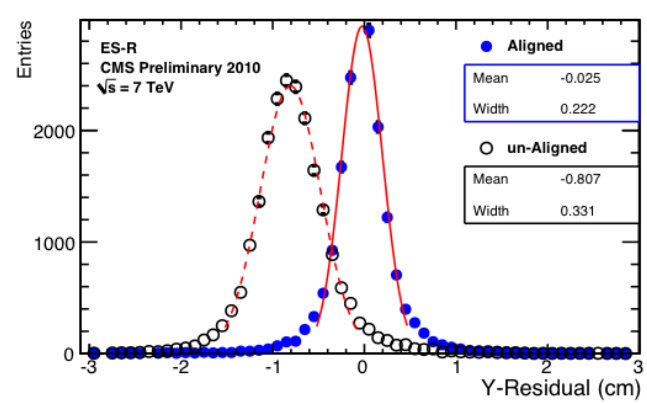
Alignment w.r.t Tracker

- Minimizing residuals between track trajectory and Preshower hits while floating Preshower in 3-D space
- After alignment, residual is narrower with mean at zero



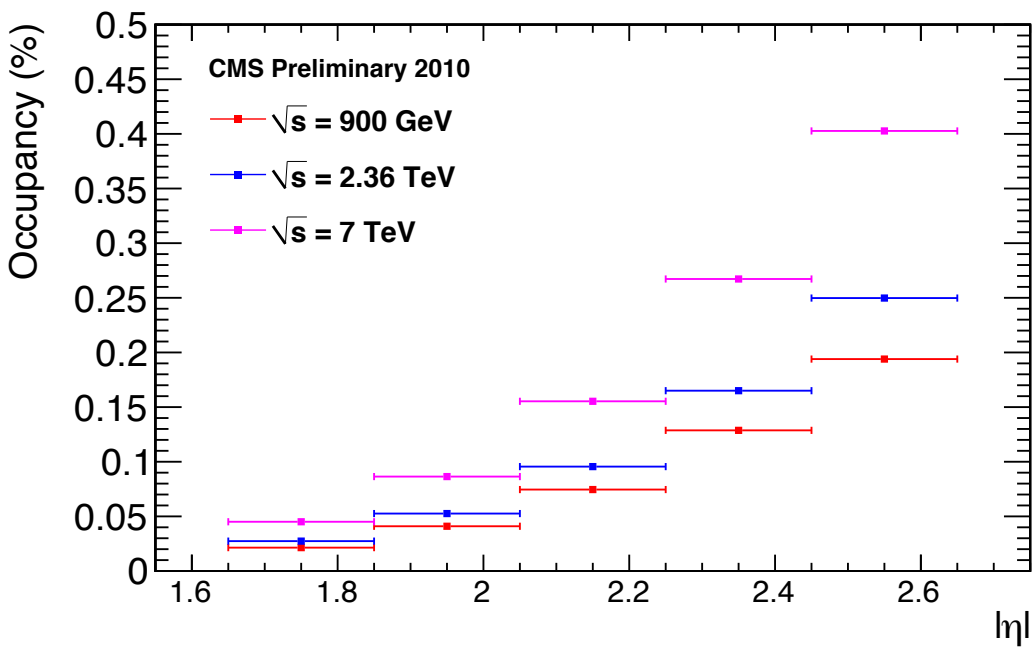


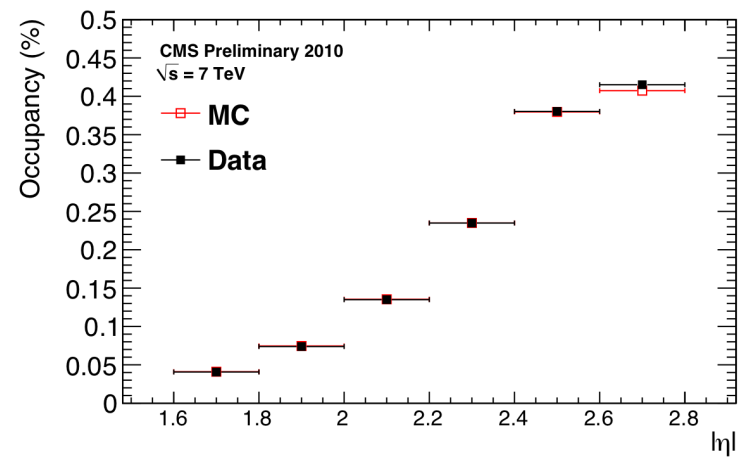


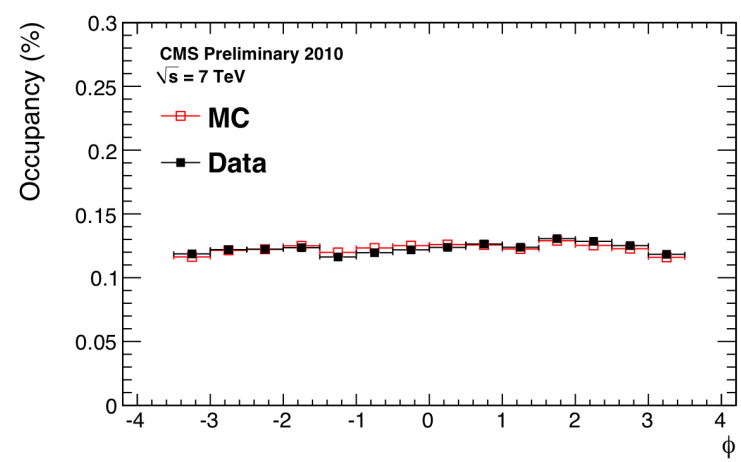


Occupancy for MinBias events

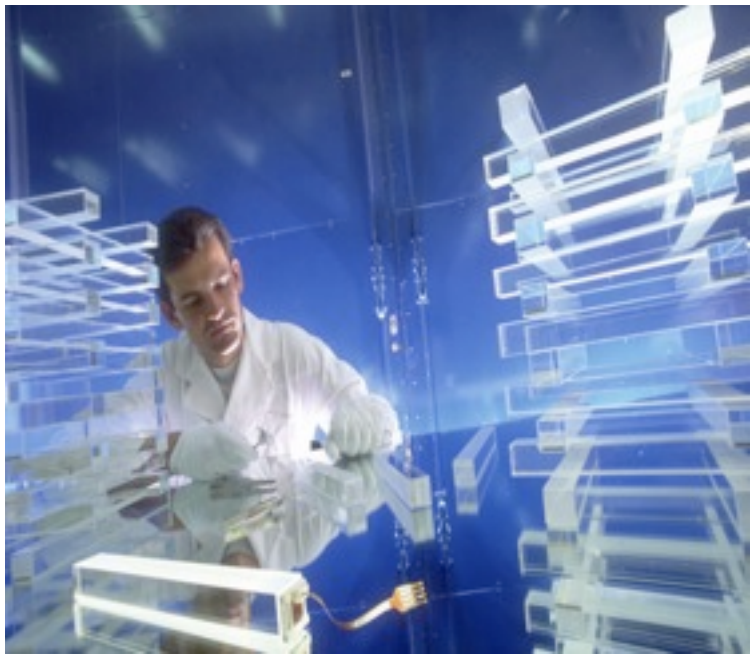
- The occupancy is defined as the percentage of strips with a signal at least $4\times\sigma^{noise}$
- The occupancy increases as a function of η and √s

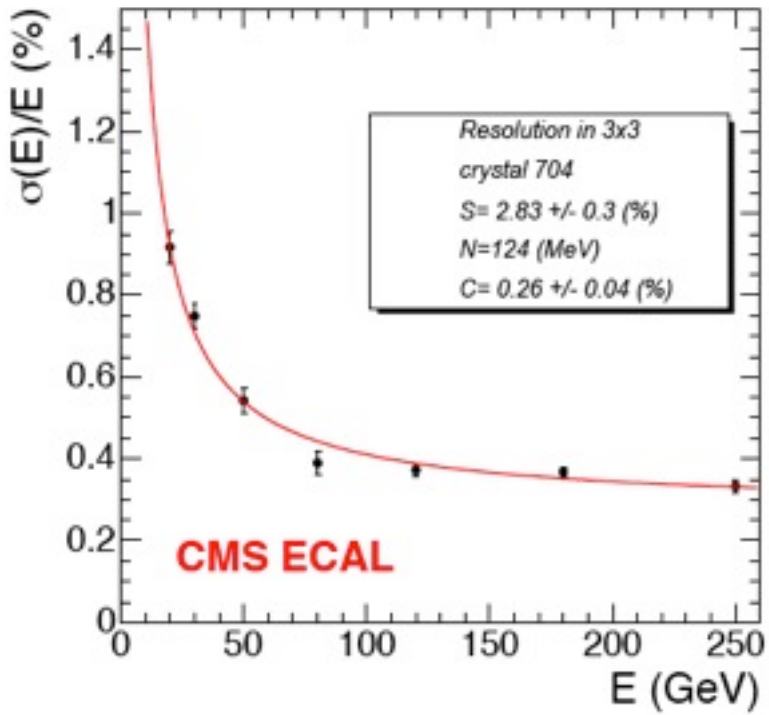






Electromagnetic Calorimeter





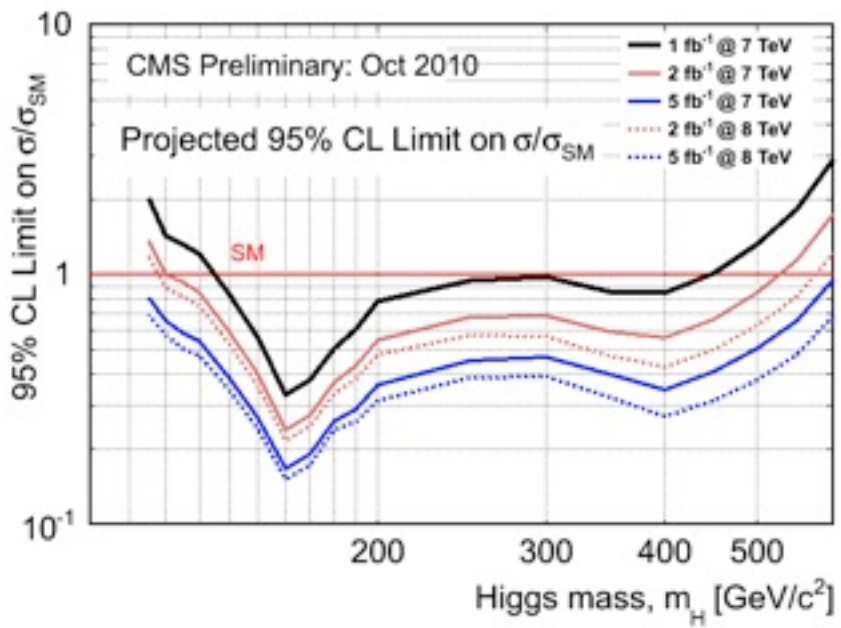
Shower Shape Definition

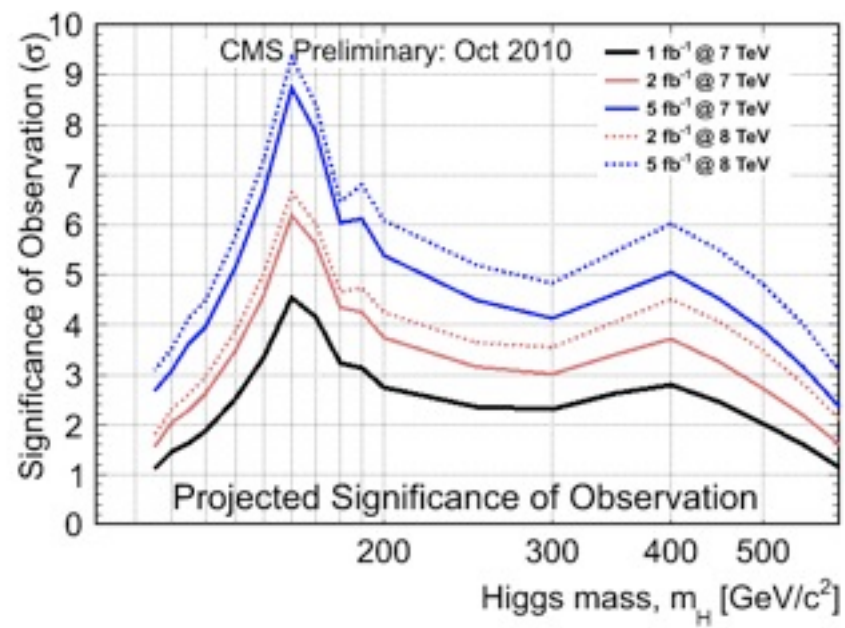
Shower shape definition

$$\sigma_{i\eta i\eta}{}^2 = \frac{\sum(\eta_i - \bar{\eta})^2 w_i}{\overline{w_i}}, \bar{\eta} = \frac{\sum \eta_i w_i}{\sum w_i}$$

$$w_i = \max(0, 4.7 + \log(E_i / E_{5X5}))$$

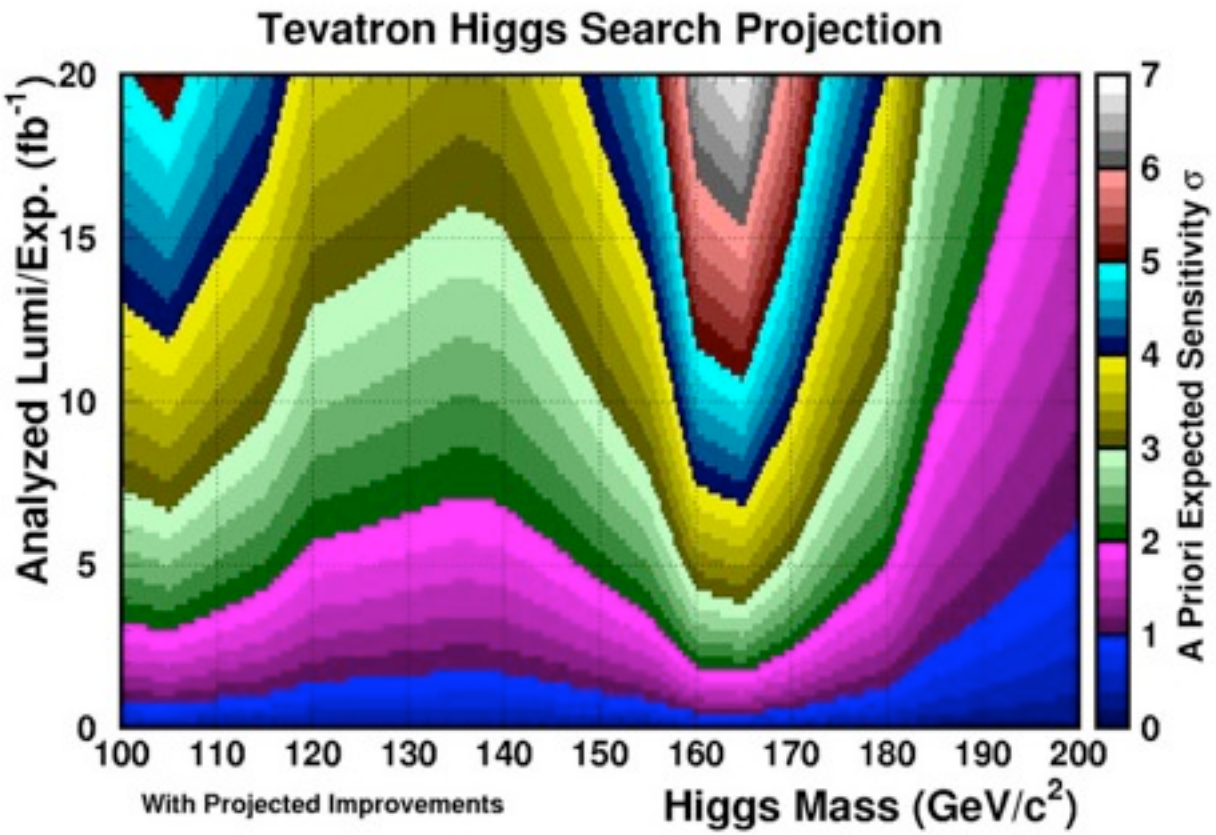
Higgs Search @ CMS





SM Higgs Search Status

- Tevatron expects 2.4σ sensitivity across all mass range and 3σ at 115 GeV by end of 2011



Higgs @ LHC

- Dominant production mechanism : $gg \rightarrow H$
- For $M_H > 140$ GeV
  - dominant decay mode : WW, ZZ
- For $M_H < 140$ GeV
  - dominant decay mode : bb, ττ, γγ
- We are looking into $H \rightarrow \gamma\gamma$
- If we can run at 8 TeV in 2011, >20% increase in production cross section