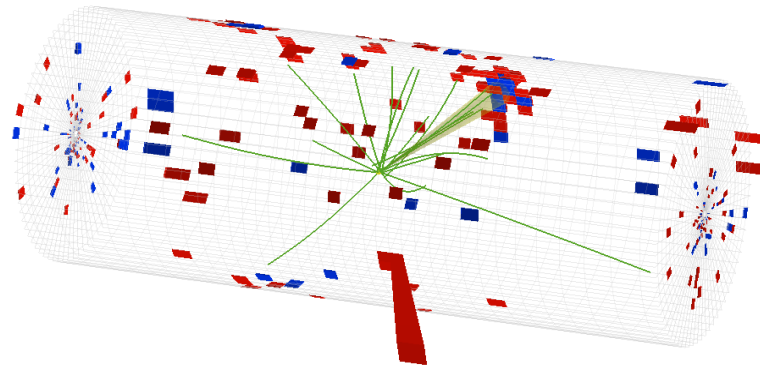


*Photon reconstruction and identification with the CMS
detector at $\sqrt{s}=7\text{TeV}$*

Satyaki Bhattacharya, Sandhya Jain*

University of Delhi

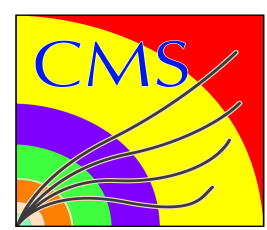
on behalf of CMS collabartion



**XIX DAE-BRNS High
Energy Physics Symposium**

Jaipur, India

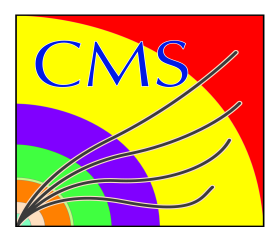
December 13-18, 2010



Outline



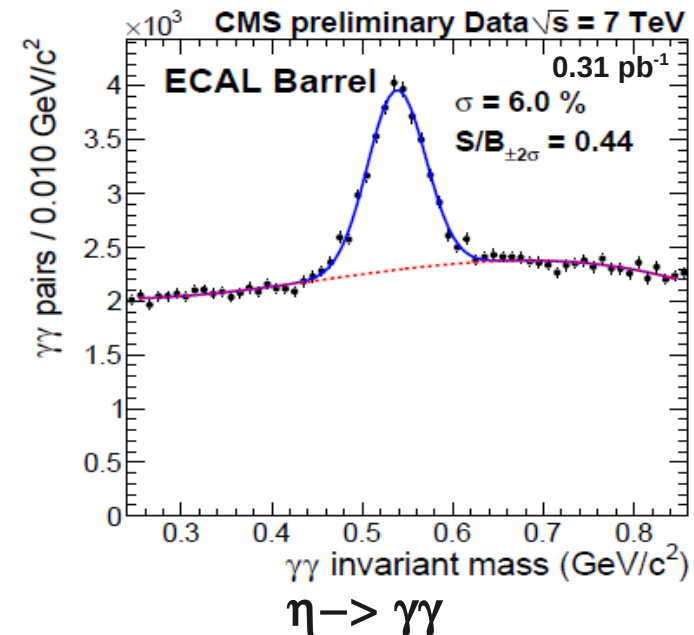
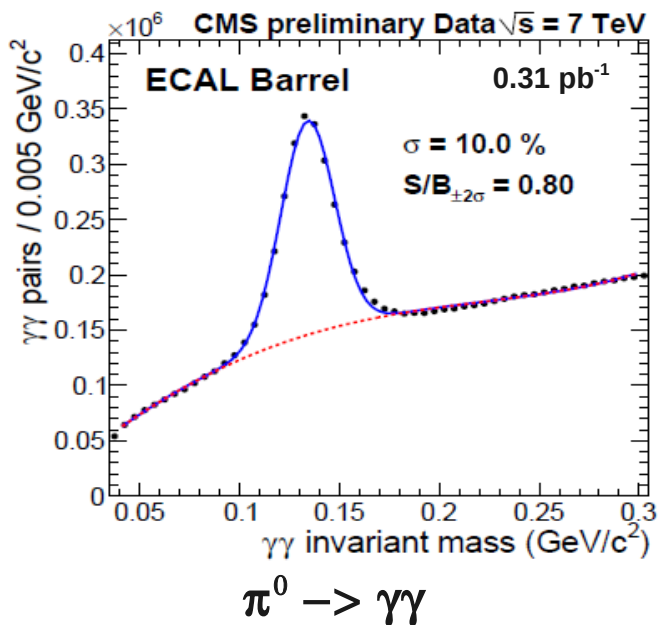
- Physics with Photons
- CMS detector
- Photon reconstruction
- Photon identification in data
- Converted photons
- Contamination from beam Halo bremsstrahlung



Photons

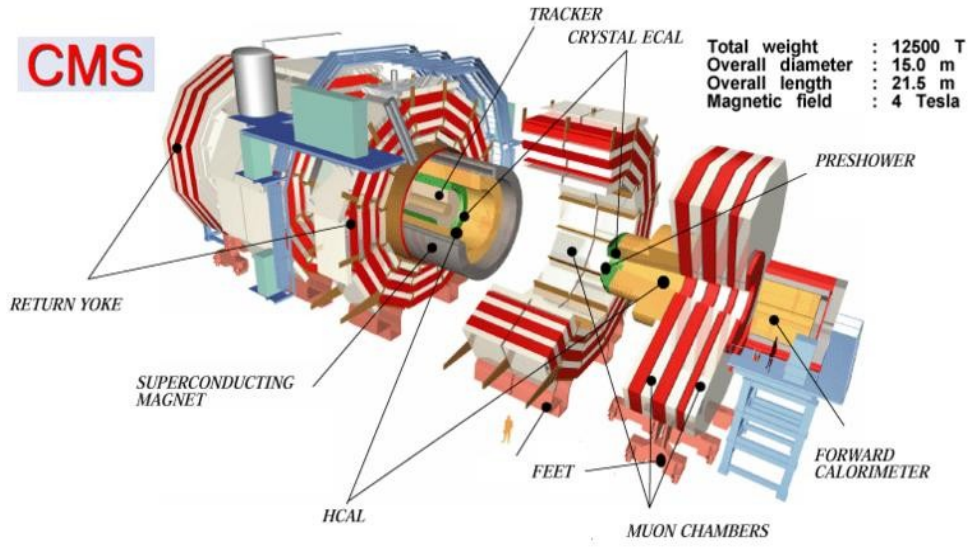


- vital for ecal calibration
- A key object to major discoveries
 - ◆ SM physics - $qq \rightarrow H \rightarrow \gamma\gamma$
 - ◆ Extra dimensions - $qq \rightarrow G\gamma$, $qq \rightarrow G \rightarrow \gamma\gamma$.
 - ◆ SUSY – MET + $\gamma\gamma$.

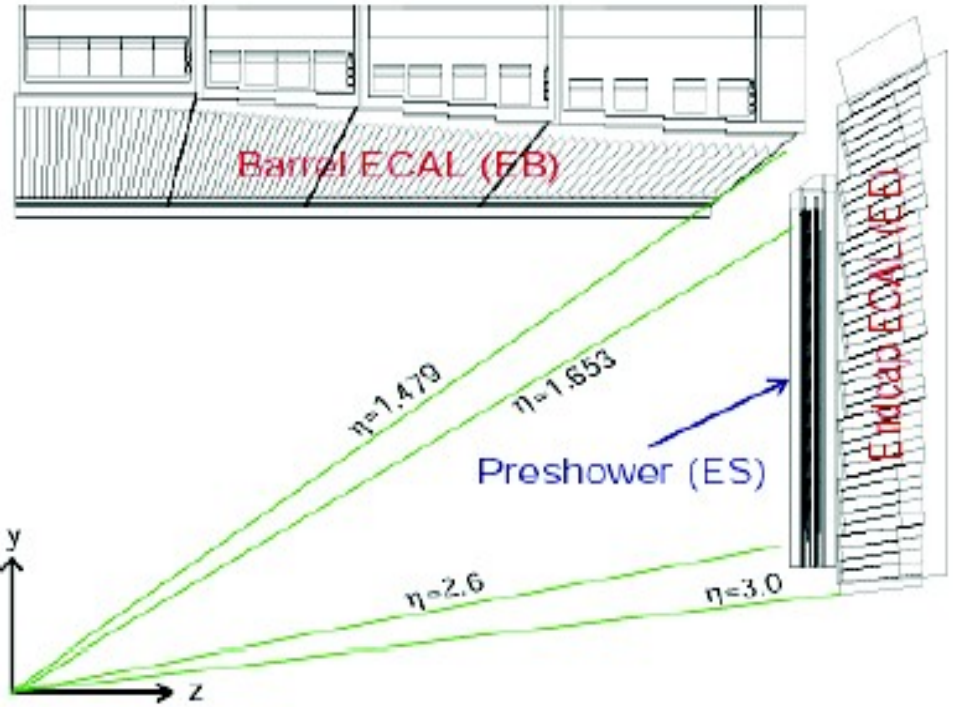




CMS detector



CMS - a general purpose detector
Electromagnetic CALorimeter- a subdetector to detect electrons and photons



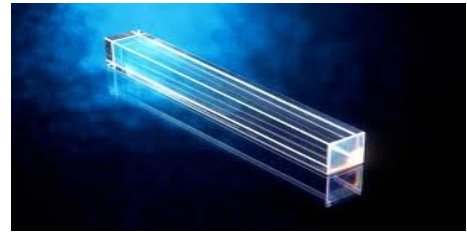
Basic Unit: PbWO_4 Crystal

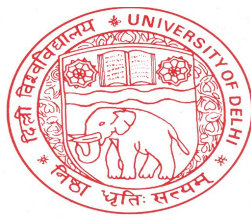
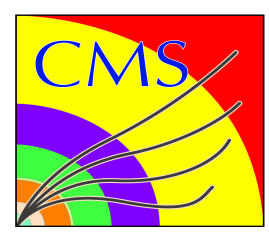
Barrel:

36 Supermodules(SM) with 1700 crystals each

Endcap:

4 Dees with 3662 crystals each





ECAL commisioning

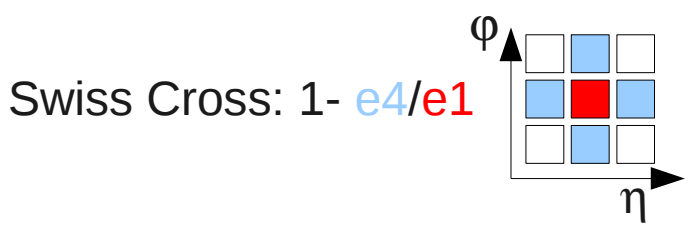
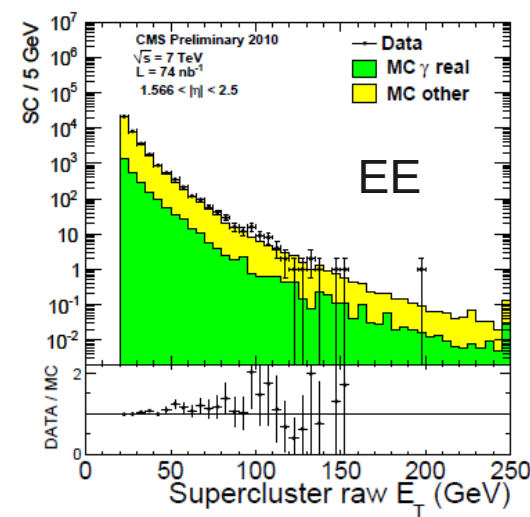
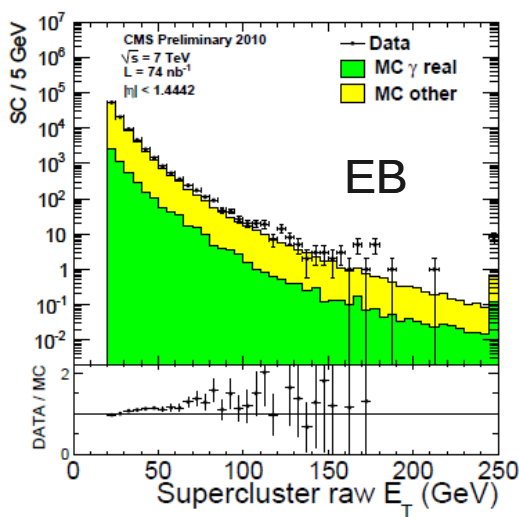


Supercluster(SC) reconstruction

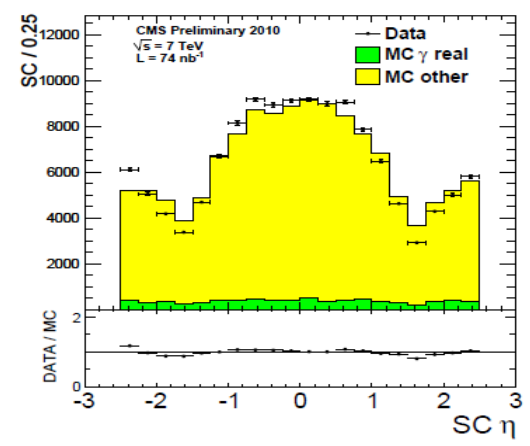


- Local energy deposits called as basic clusters in ECAL are summed up to recover energy loss due to conversions or bremsstrahlung to form Superclusters.
- Comparison between data and MC is made imposing the selection:

- HLT_Photon15_L1R
- SC raw energy > 20 GeV
- SC's in fiducial range of the detector excluding the gaps and transition between EB and EE.
- Swiss Cross < 0.95 and seed timing < 4ns
- H/E < 0.05



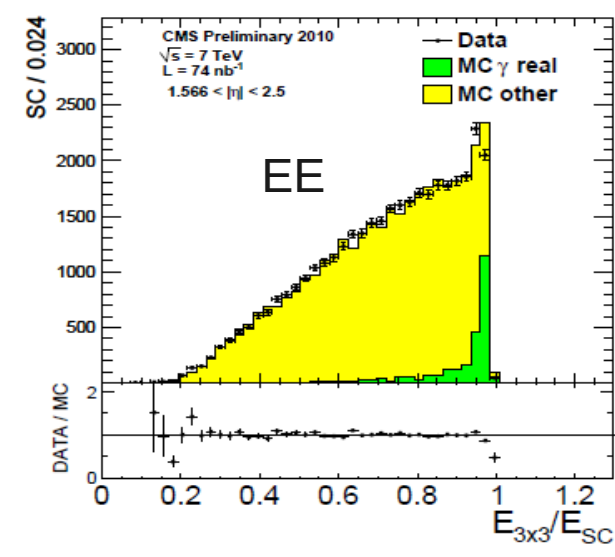
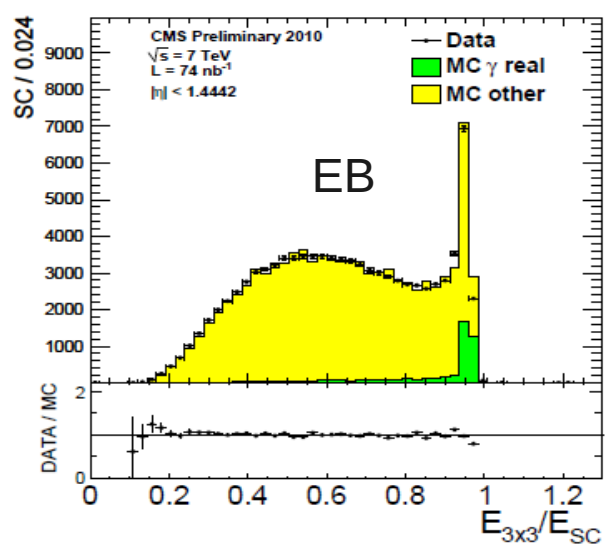
- Normalized with total integrated luminosity for data
- Good agreement





Photon Candidate

- ➔ Various energy corrections are applied to SC. For simulated signal photons, these corrections are of the order of 1% of the uncorrected energy.
- ➔ Photon candidate is reconstructed from these corrected SC assigning them the location of primary vertex and so the momentum direction.
- ➔ Photon candidate can be a converted or unconverted. It can be determined based on the observable, $r9 = e9/e_{SC}$. If $r9 > 0.94$ (0.95) in EB (EE), the e25 is used around the seed crystal.



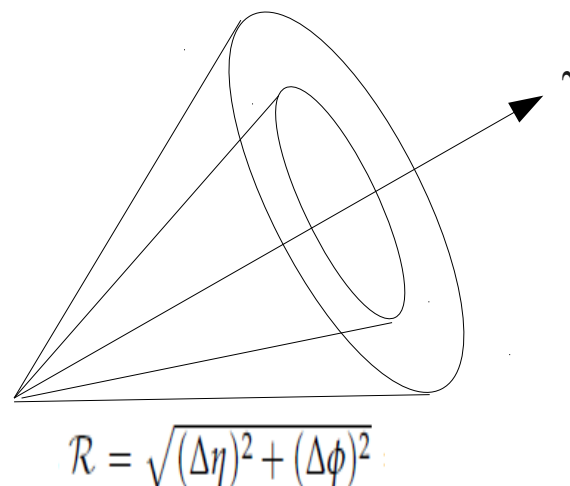


Photon identification



- To increase the purity of photon sample from fakes, additional selection is applied:
 - ◆ SC is required to match with **no pixel hit** consistent with a track
 - ◆ **Et > 30 GeV**
 - ◆ **Tracker Isolation < 2 GeV** : Scalar sum of pt of tracks in hollow cone around the photon direction in an annular region $0.04 < R < 0.4$
 - ◆ **Ecal Isolation < 4.2 GeV** : Sum of ECAL Et around the direction of photon candidate in an annular cone of $0.06 < R < 0.4$
 - ◆ **Hcal Isolation < 2.2 GeV** : Sum of Hcal Et around the photon in an annular cone $0.15 < R < 0.4$
 - ◆ $\sigma_{i\eta i\eta} < 0.01(0.03)$ in EB (EE) where,

$$\sigma_{i\eta i\eta}^2 = \frac{\sum_i^{5 \times 5} w_i (i\eta_i - i\eta_{seed})^2}{\sum_i^{5 \times 5} w_i}, \quad w_i = \max(0, 4.7 + \ln \frac{E_i}{E_{5 \times 5}})$$

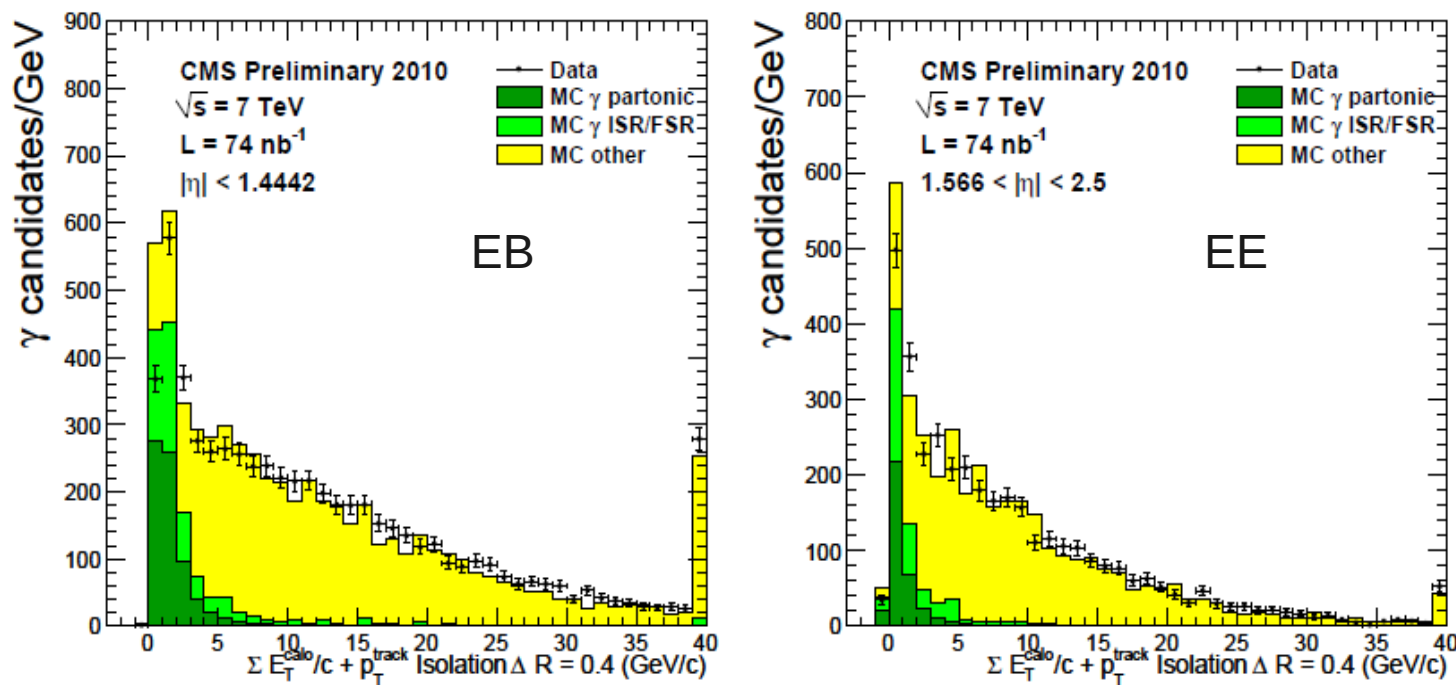




N-1 plots with ID variables



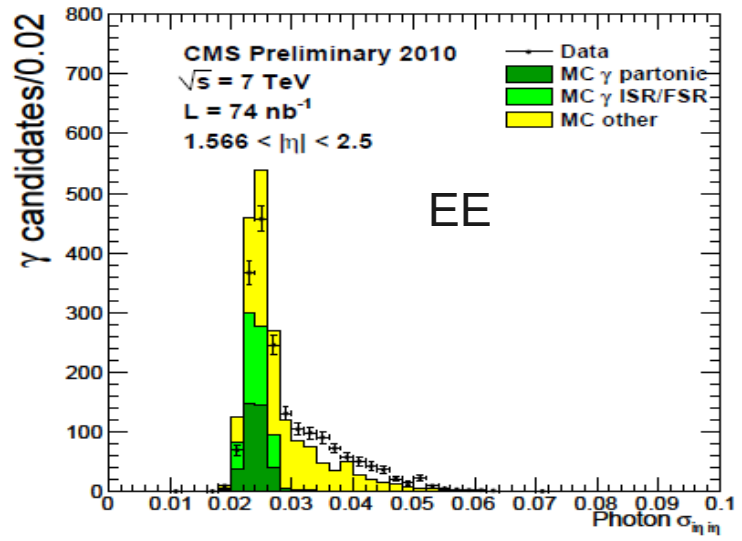
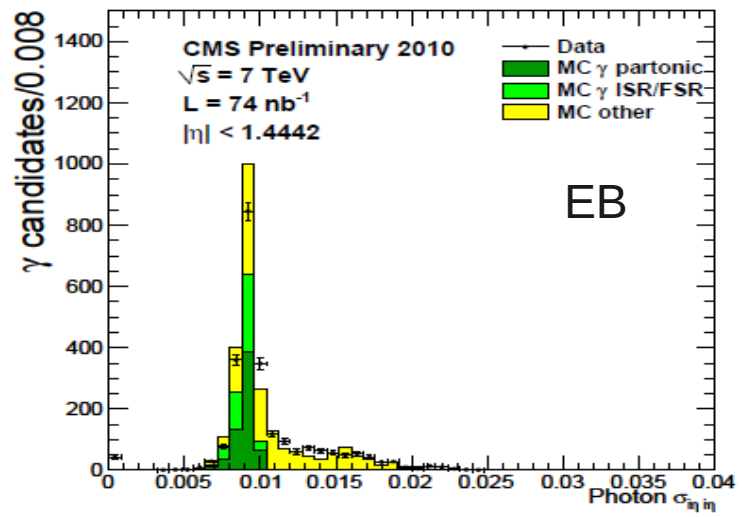
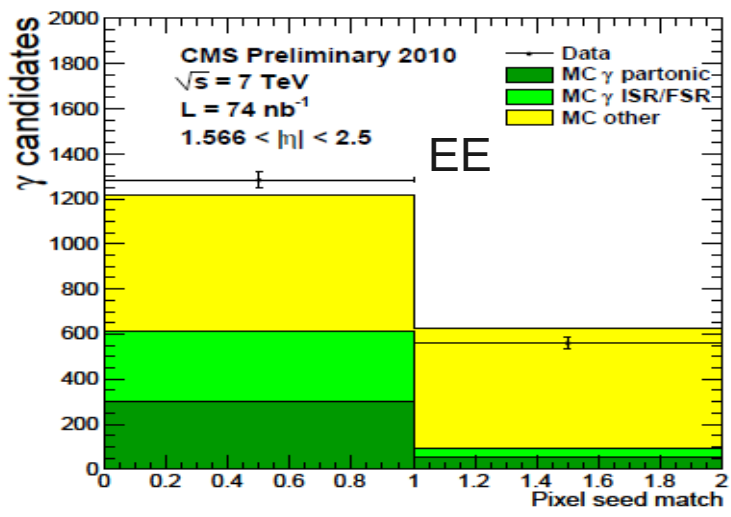
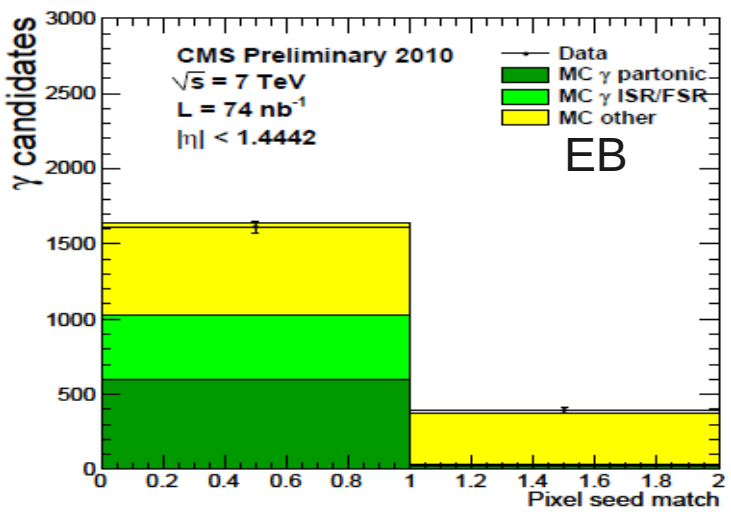
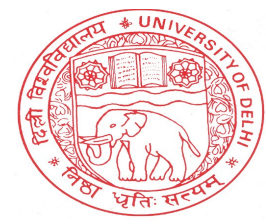
- N-1 plots show distributions after applying all the cuts in selection except the one being plotted.
- Normalized separately for each plot to the number of entries in data.

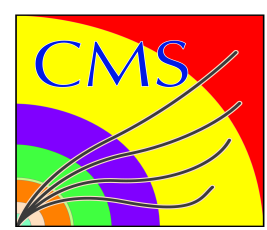


Sum of ECAL, HCAL and Tracker Isolation variables



N-1 plots continued...

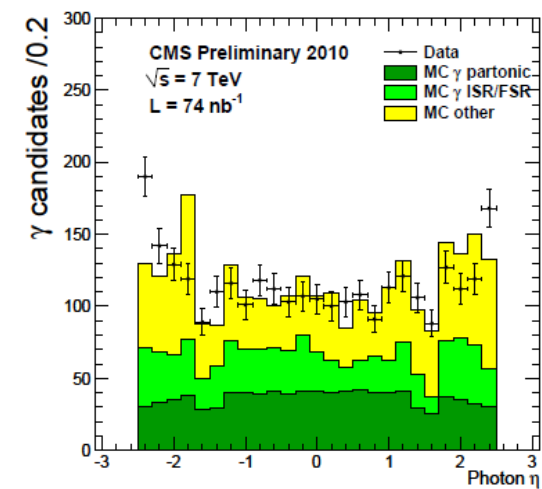
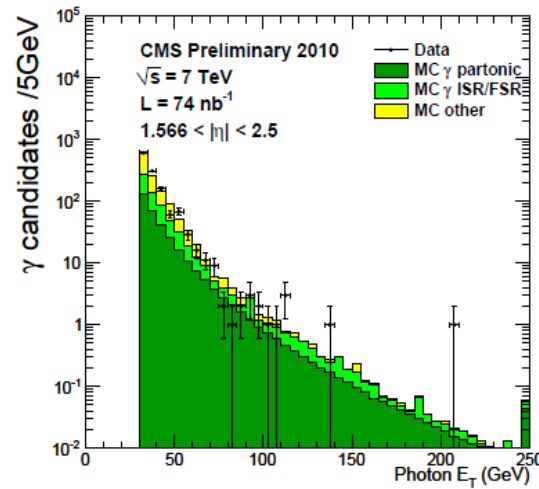
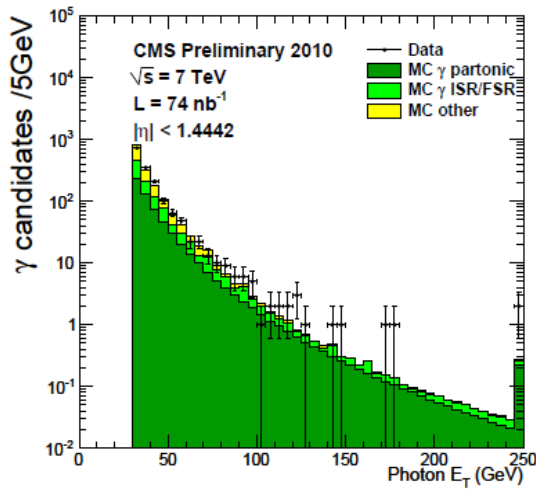


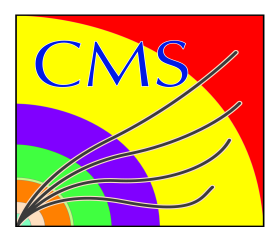


Photon observables



- ✓ 50% of purity for signal photons with $E_T > 30$ GeV
- ✓ Good Agreement

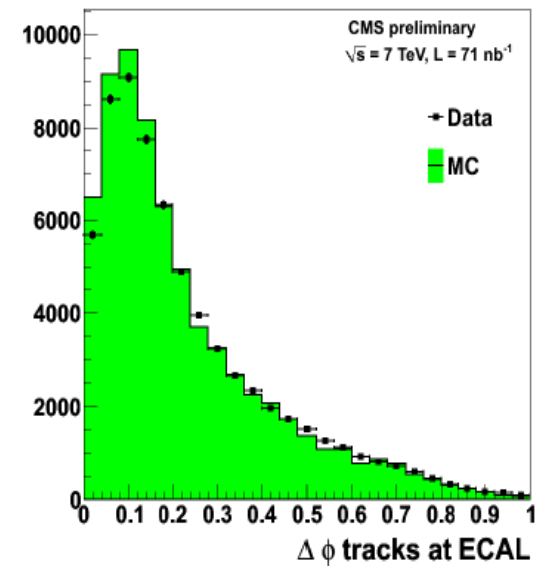
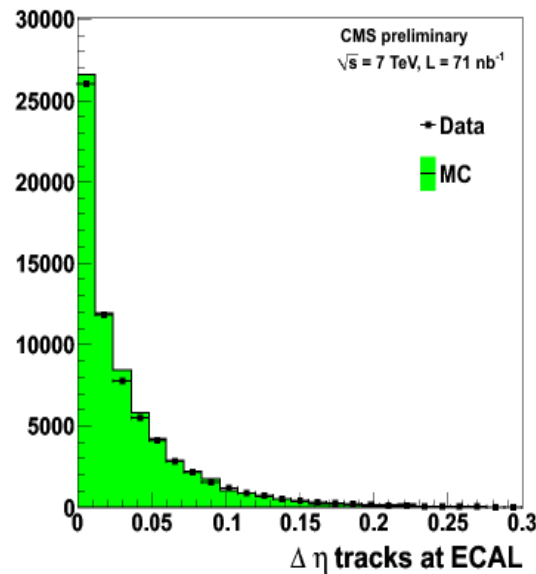
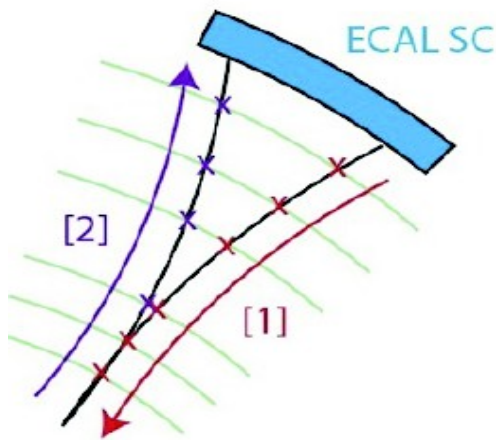




Photon conversions



- Large probability of photon conversion due to tracker material in front of ECAL.
- Starting from supercluster, look back inwards to find a track towards the interaction point.
- From the innermost hit, look for track going to the supercluster.

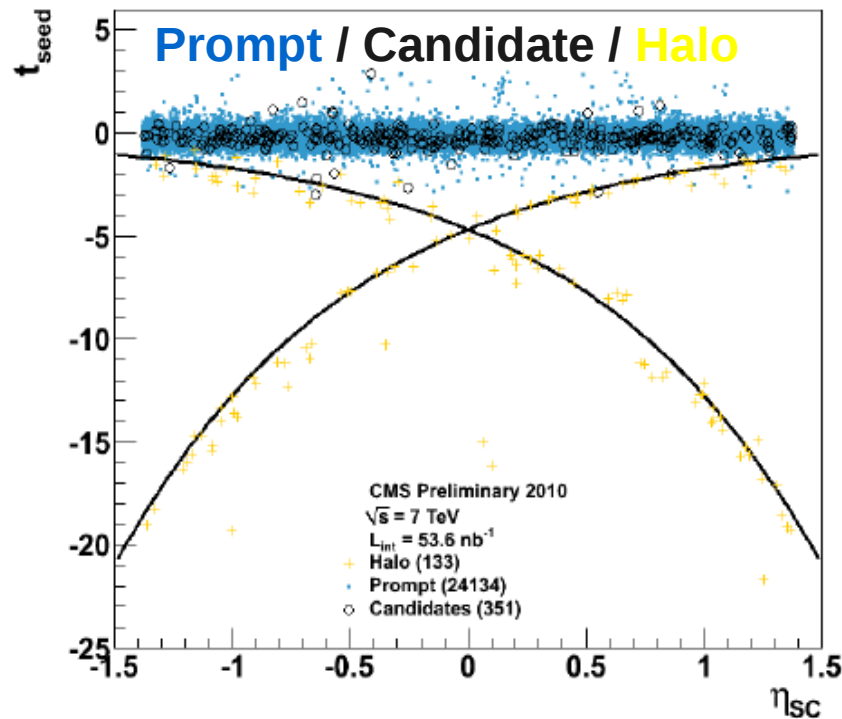




Non collision background



- For signatures of photons and missing energy, significant background comes when photons brem from high energy muons from cosmics or beam halo.
- Cosmic rays are flat in time but halo is correlated with bunch crossing.





Beam Halo Contamination



→ Base Sample from data: (mixed with prompt photons and halo)

- ◆ $E_t > 15 \text{ GeV}$
- ◆ Ecal, Hcal and tracker Isolation
- ◆ $e2/e25 < 0.95$

→ Halo candidates for base template:

- ◆ No reconstructed tracks
- ◆ Missing $E_t > 25 \text{ GeV}$
- ◆ Tagged by either HE or EMU tagger

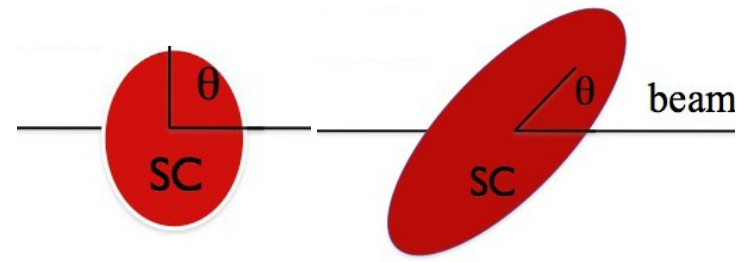
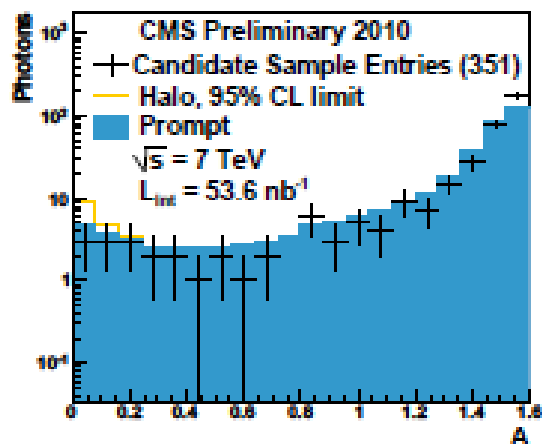
→ Prompt photon sample for base template:

- ◆ Missing $E_t < 15 \text{ GeV}$
- ◆ No HE or EMU tagged, seed time $< 3 \text{ ns}$
- ◆ More than three reconstructed tracks

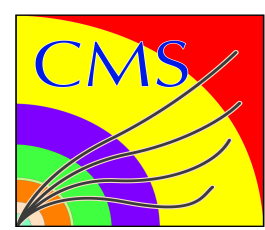
→ Candidate Sample:

- ◆ At least 3 reconstructed tracks
- ◆ Missing $E_t > 25 \text{ GeV}$, photon $E_t > 30 \text{ GeV}$
- ◆ No HE or EMU tagged, seed time $< 3 \text{ ns}$

Candidate Sample



Beam halo contamination is estimated to be below 5.9 events at 95% CL with 53.6 nb^{-1} of data.



Summary



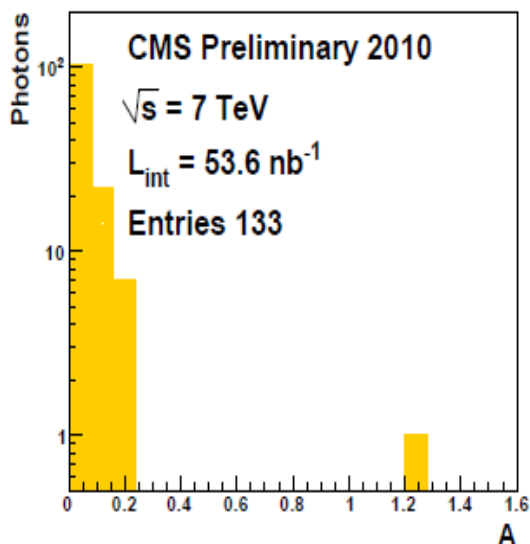
- With the first data at 7TeV, basic reconstruction quantities show a good comparison with MC simulation.
- With the photon identification and conversions, we see what we expect from MC simulation.
- Also the number of fakes due to non collision background is under control.



Back up slides

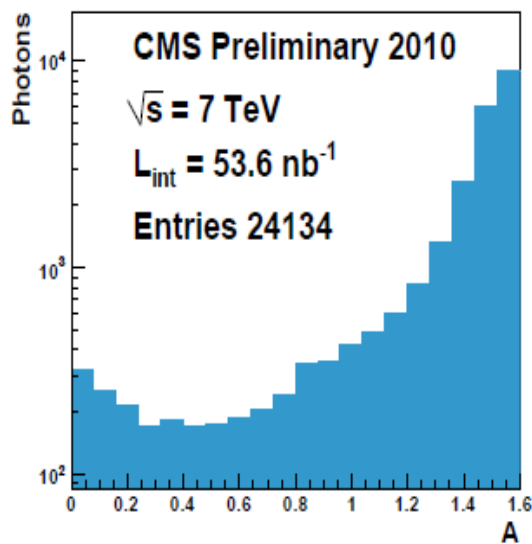


Halo Sample



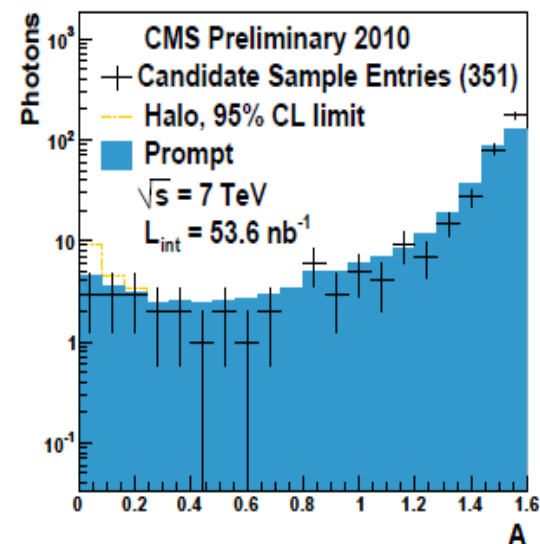
(a) Halo template for shower's angle, A .

Prompt Sample



(b) Prompt template for shower's angle, A .

Candidate Sample



(c) Black crosses are the shower's angle A of the candidate sample. The prompt template (blue) is shown stacked with the 95% CL upper limit contribution from halo (gold)