Isolated Photons at CMS

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on behalf of CMS collaboration

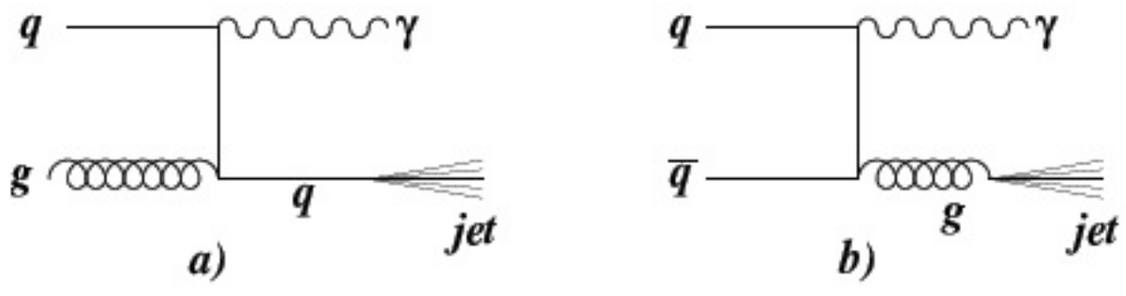
35th International Conference on High Energy Physics
Paris, France

Outline

- Introduction
- ECAL and photon
- Photon ID and isolated photons
- Photon conversion
- Non-collision backgrounds
- Summary

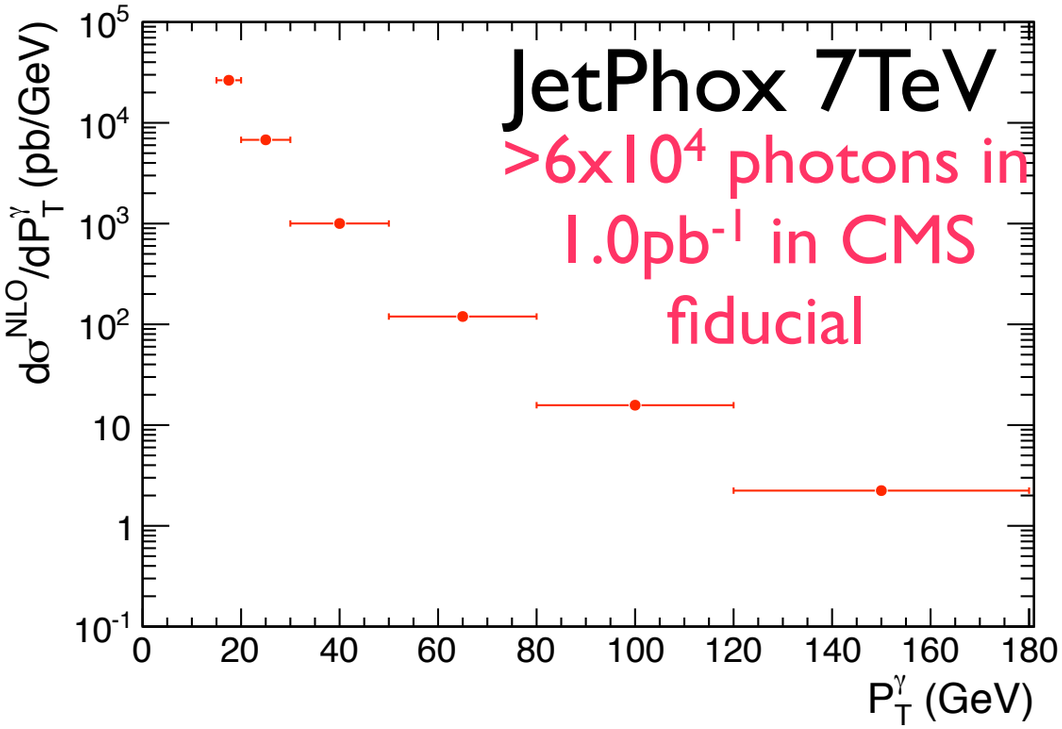
Introduction

- Study of single isolated photon production gives a good test and information on pQCD as well as PDFs.

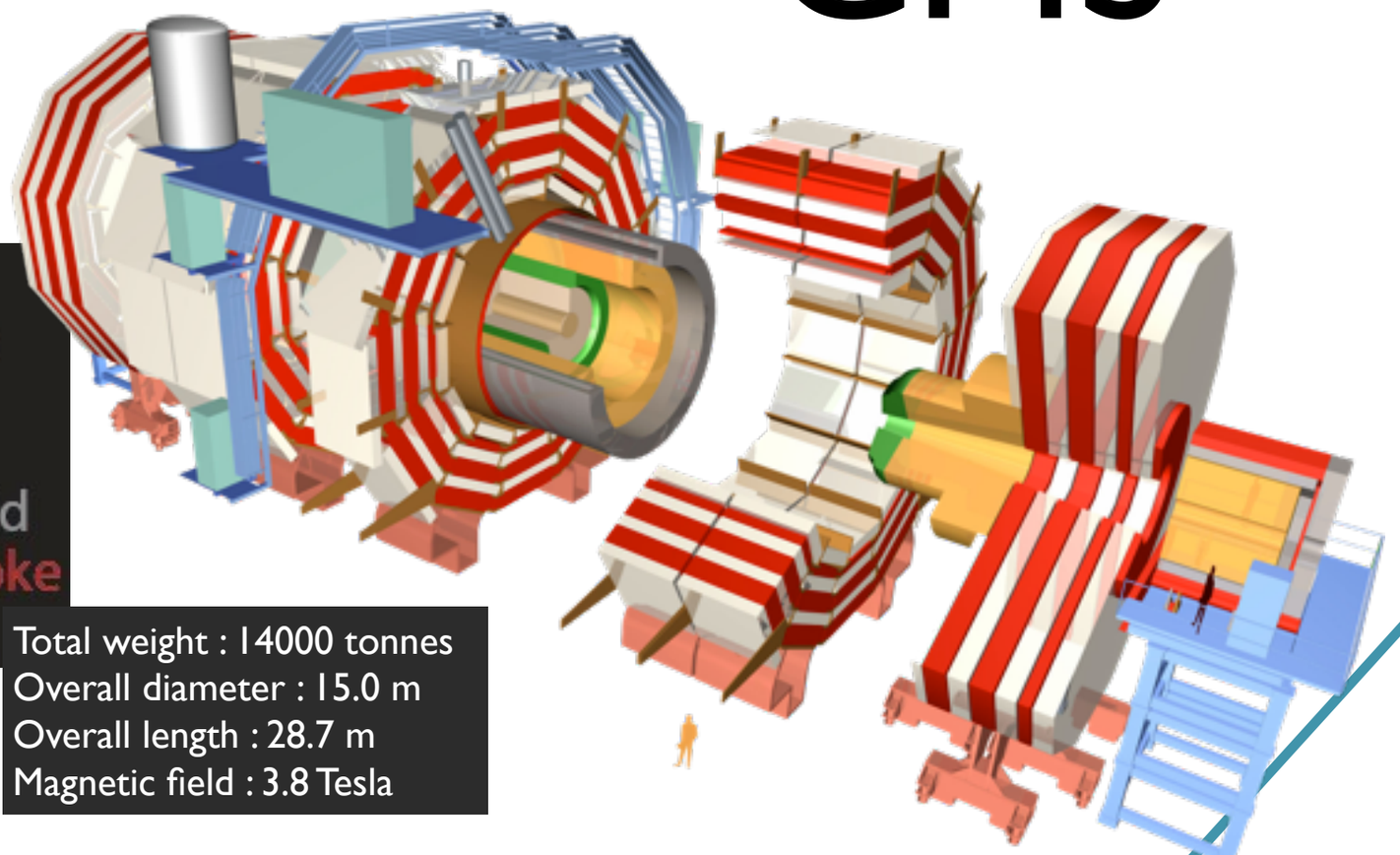


- Provide basic understanding of photons in CMS

- Foundation of photon+X analyses, such as photon +jet or Higgs to 2 photons.

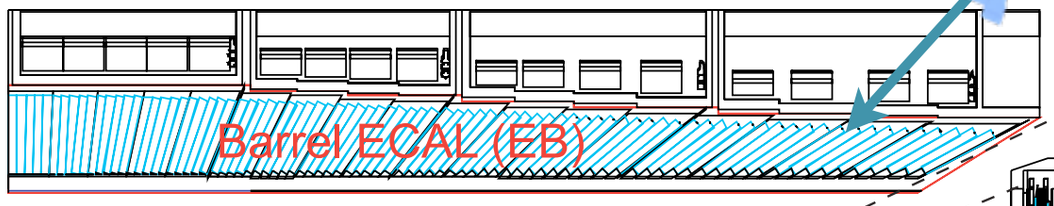


CMS

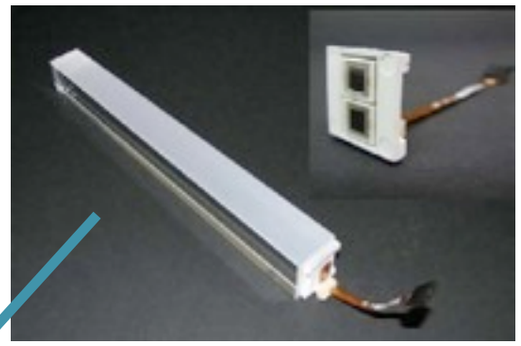


Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons

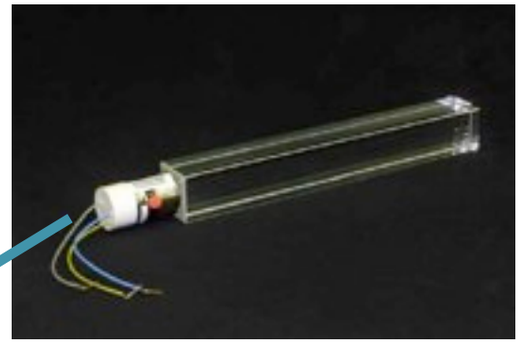
Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 Tesla



EB : $PbWO_4$ with APDs
22mm x 22mm x 25.8X_0
(Molière radius 22mm)



EE : $PbWO_4$ with VPTs
29mm x 29mm x 24.7X_0

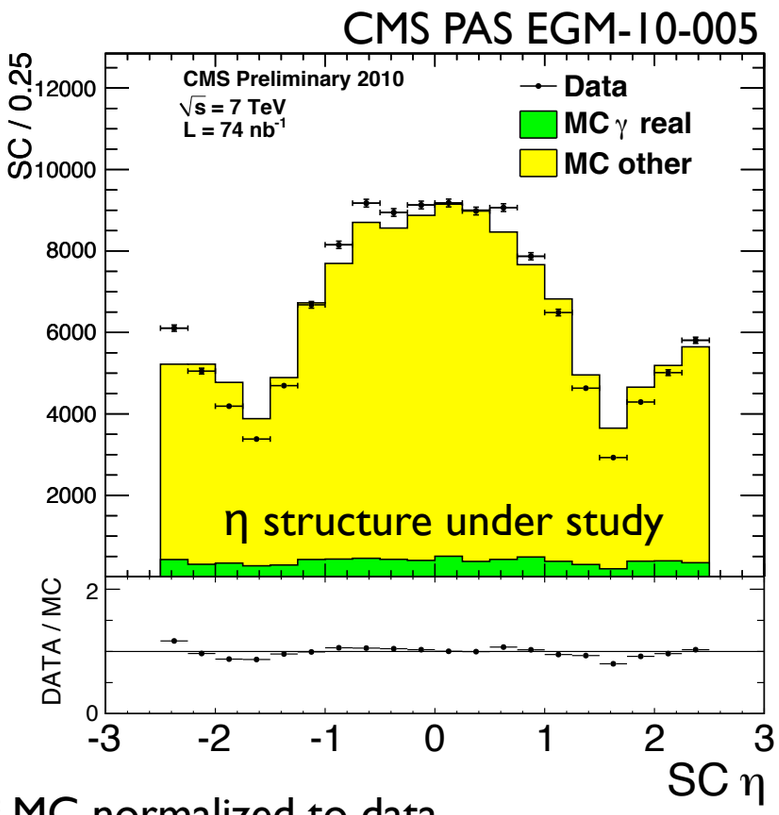


ES : silicon strip sensors
strip width 1.9mm

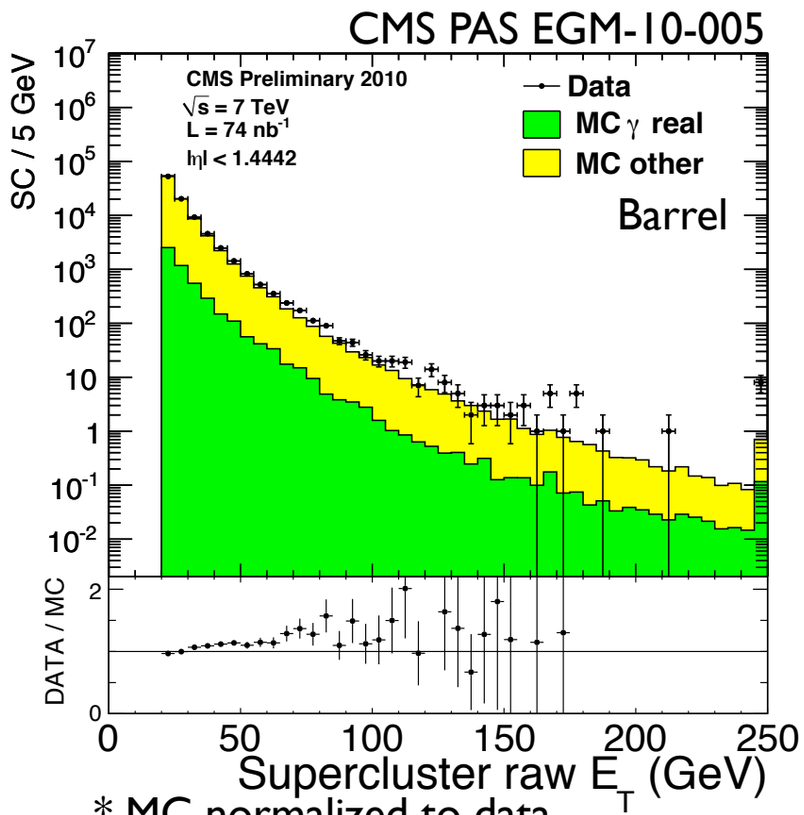
ECAL and photon

Commissioning of ECAL

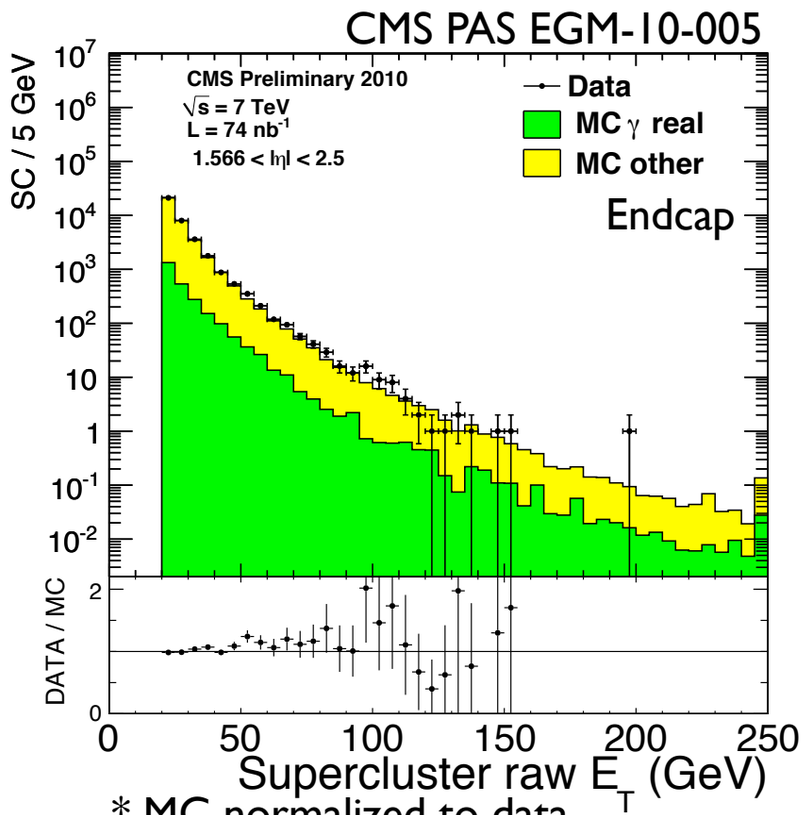
- A SuperCluster is a group of clusters in ECAL that recovers energy loss due to bremsstrahlung or conversions
- Good agreement between data and MC in modeling event characteristics and ECAL performance.



* MC normalized to data



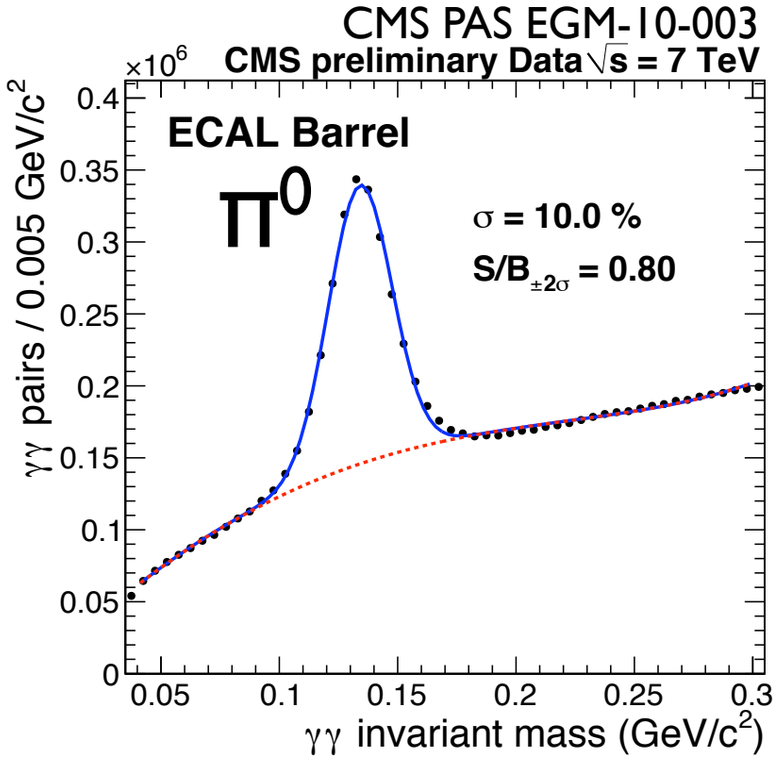
* MC normalized to data

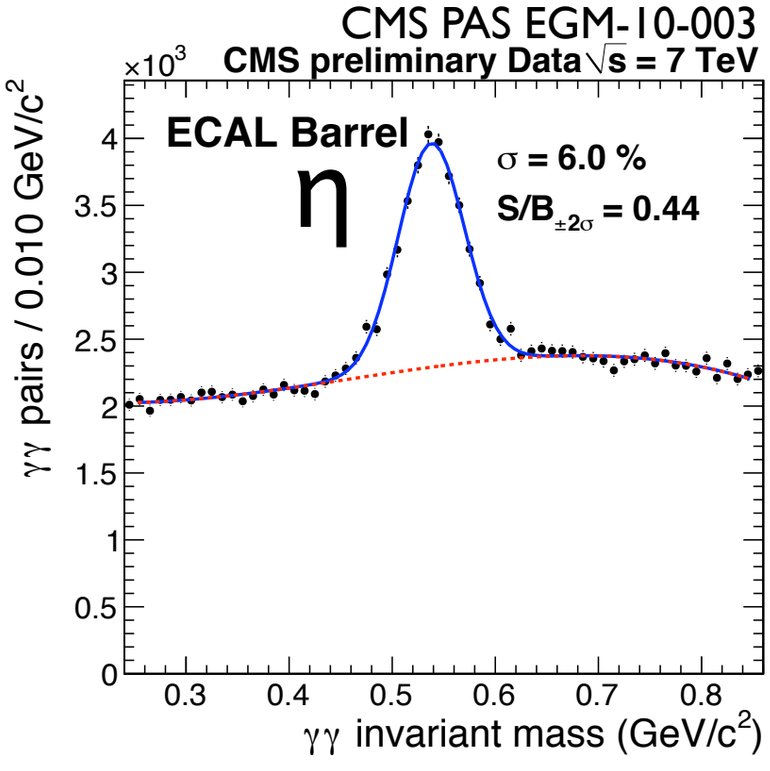


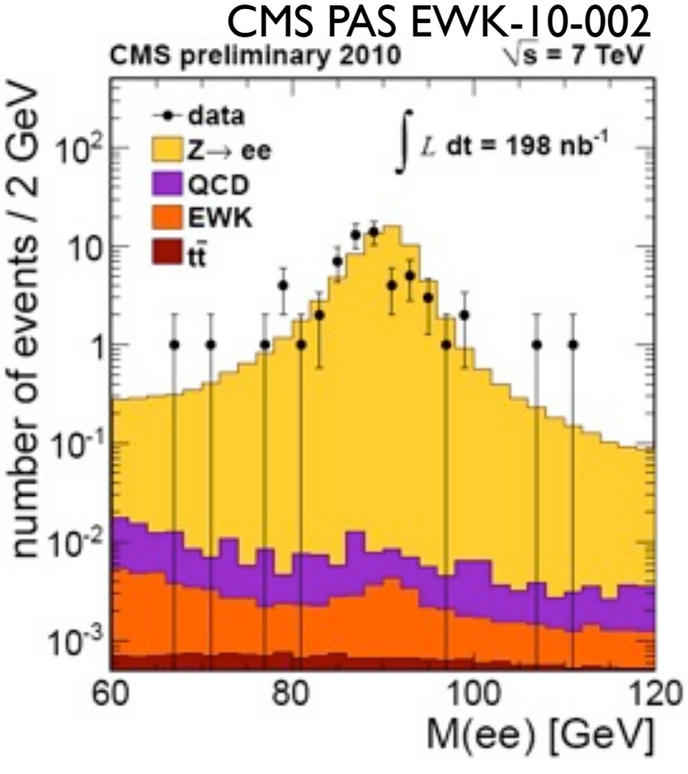
* MC normalized to data

Resonances seen in ECAL

- Resonances are seen in different energy scale of photons
- Reconstructing π^0, η and Z improves the understanding and calibration of ECAL detector



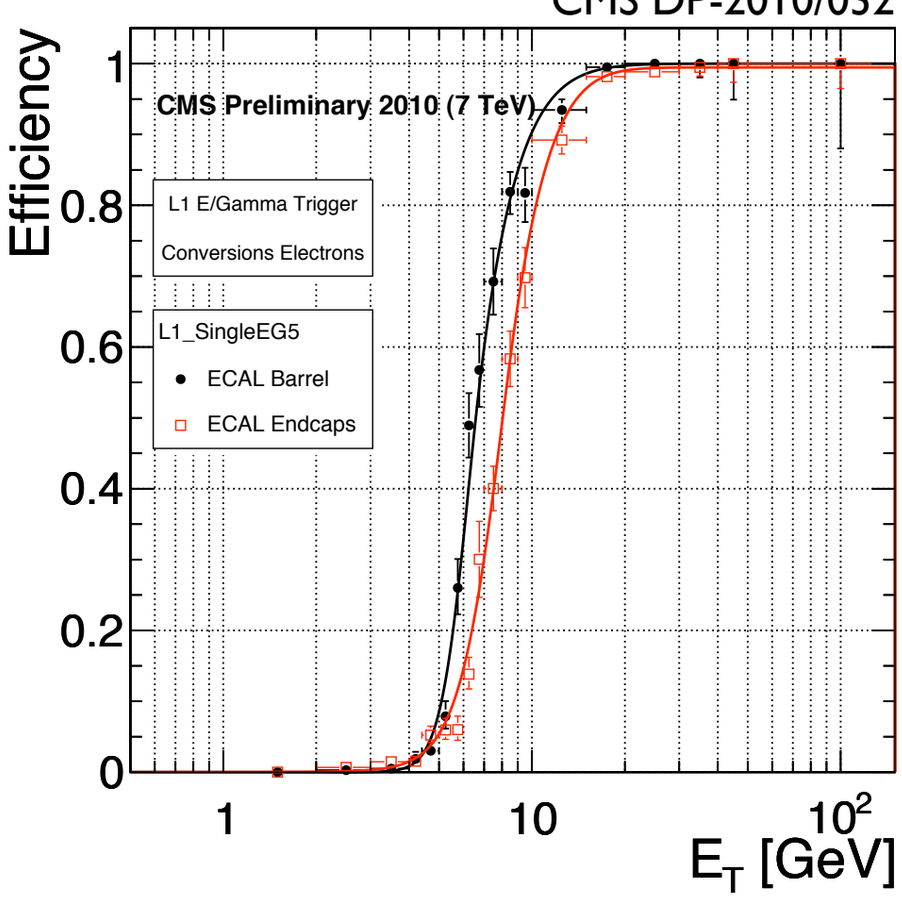




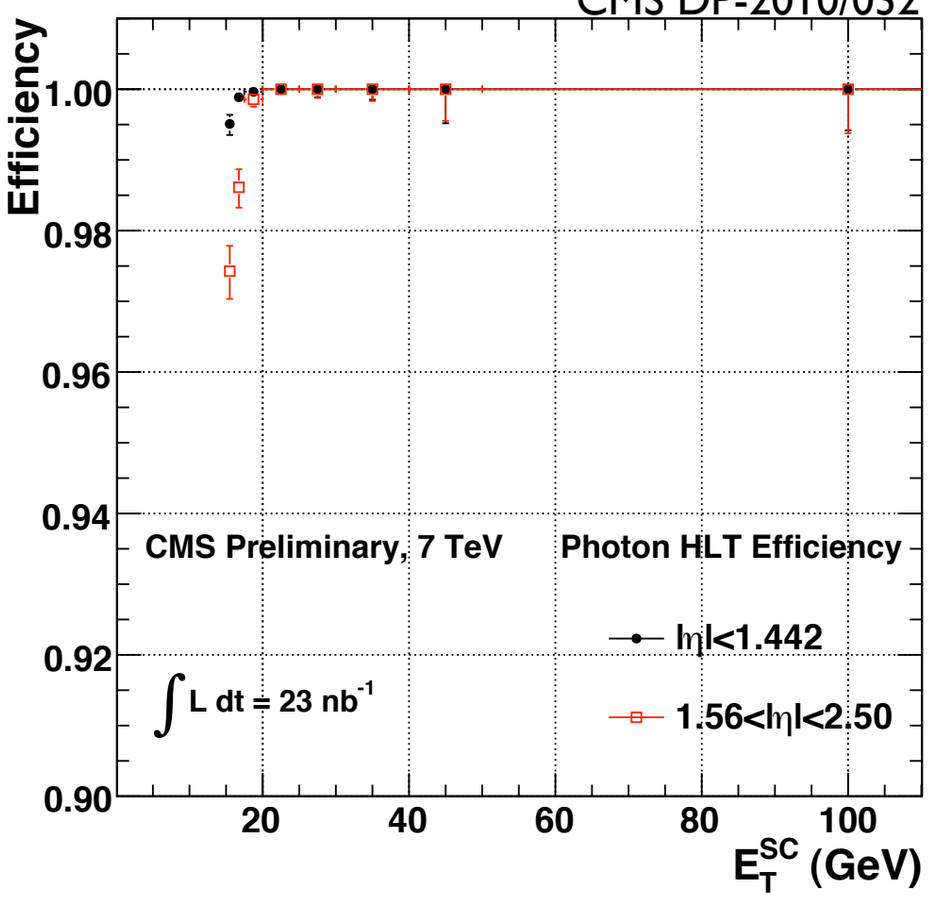
Photon Trigger

- L1 (hardware trigger) on ECAL trigger object with E_T>5GeV
- High Level Trigger (software trigger, after L1) with SuperCluster above 15GeV. Quick turn-on and fully efficient after 20GeV.

CMS DP-2010/032



CMS DP-2010/032

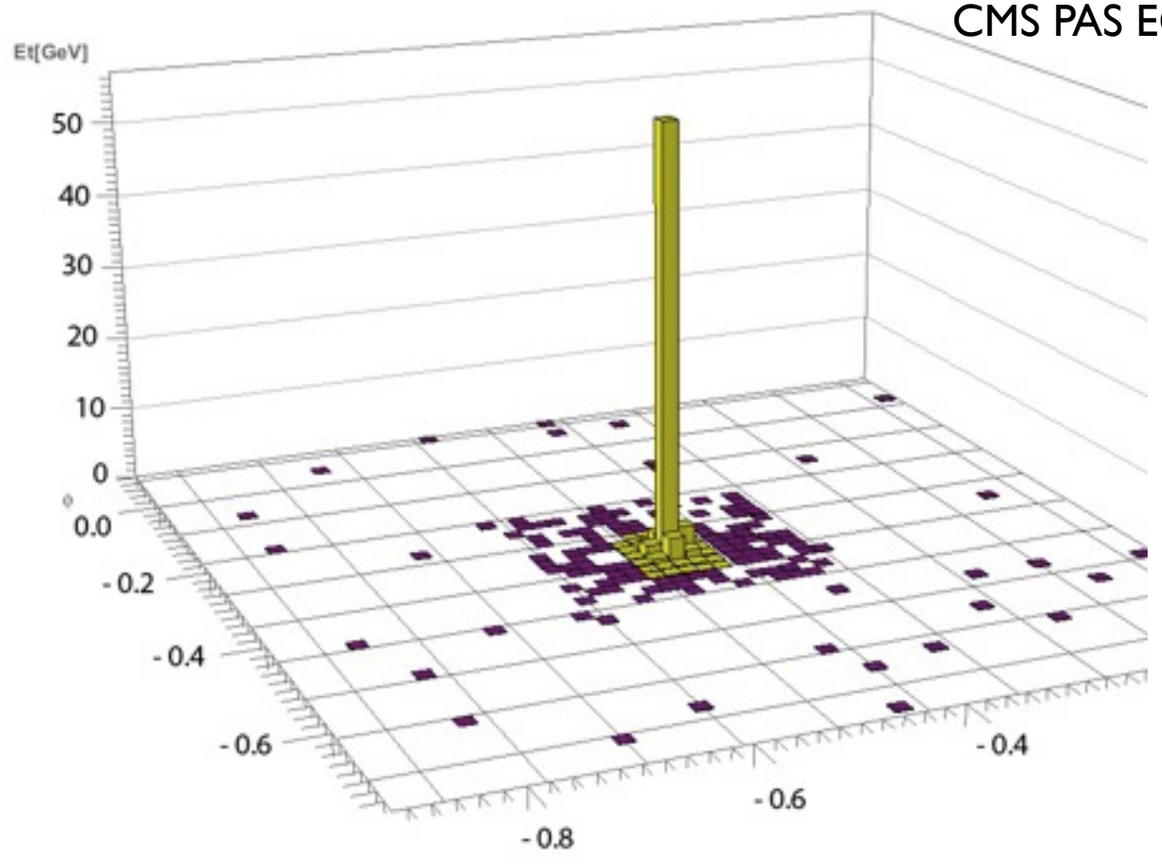


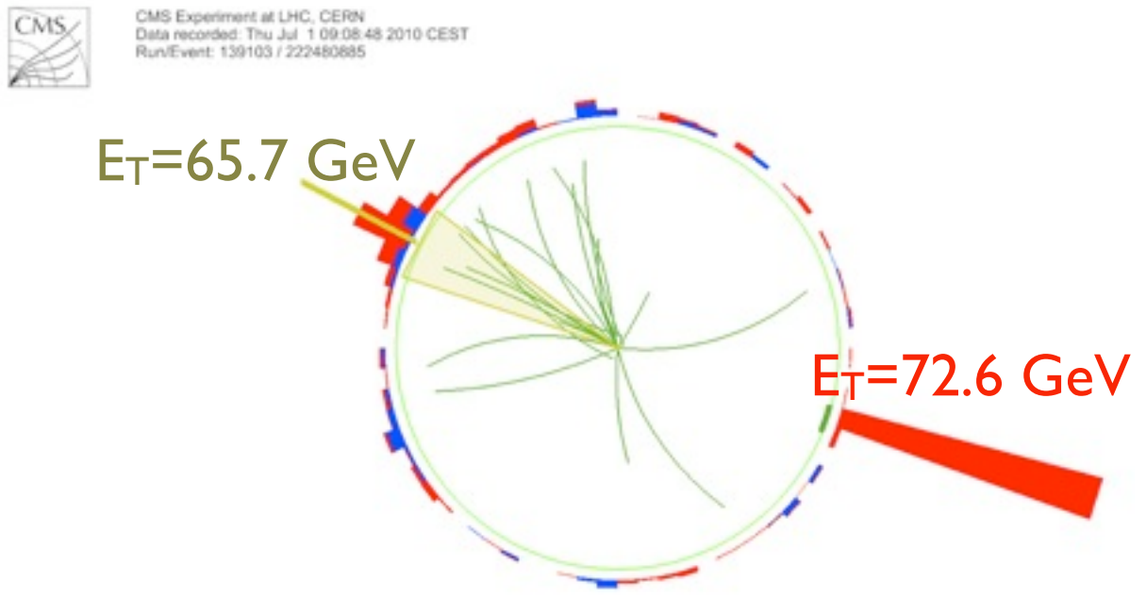
Photon ID and isolated photons

Event Display

- This event shows a photon+jet event with good balance on E_T and ϕ.
- Photon is isolated with energy spread (shower shape) match expectation of a photon.

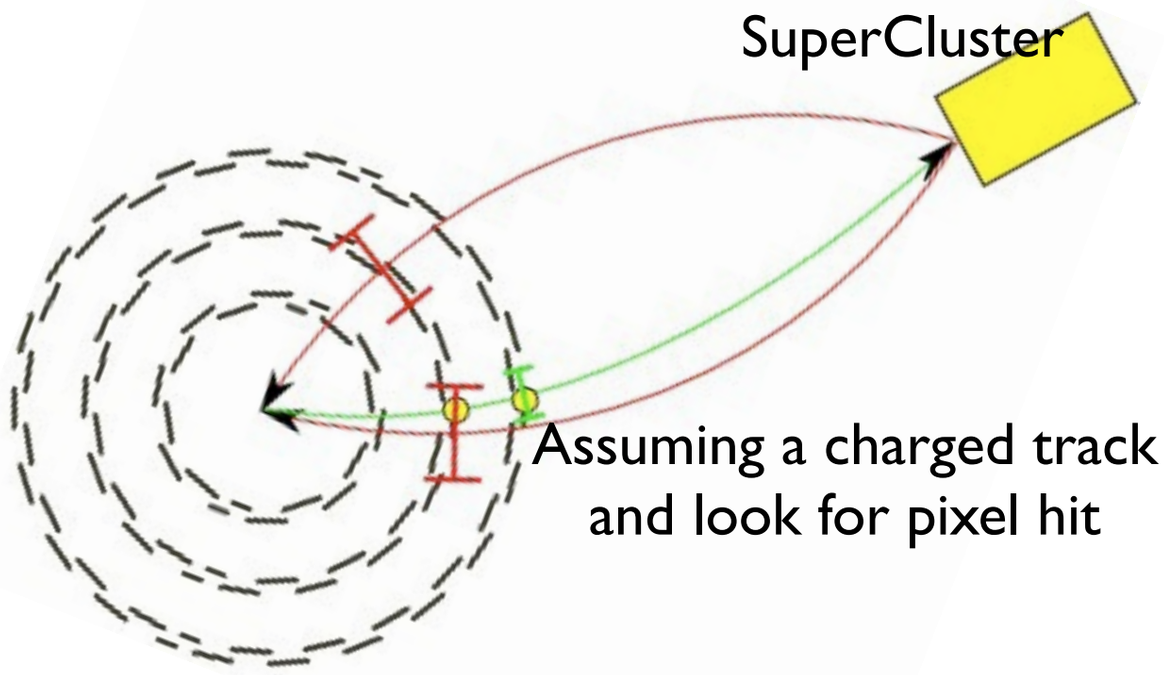
CMS PAS EGM-10-005

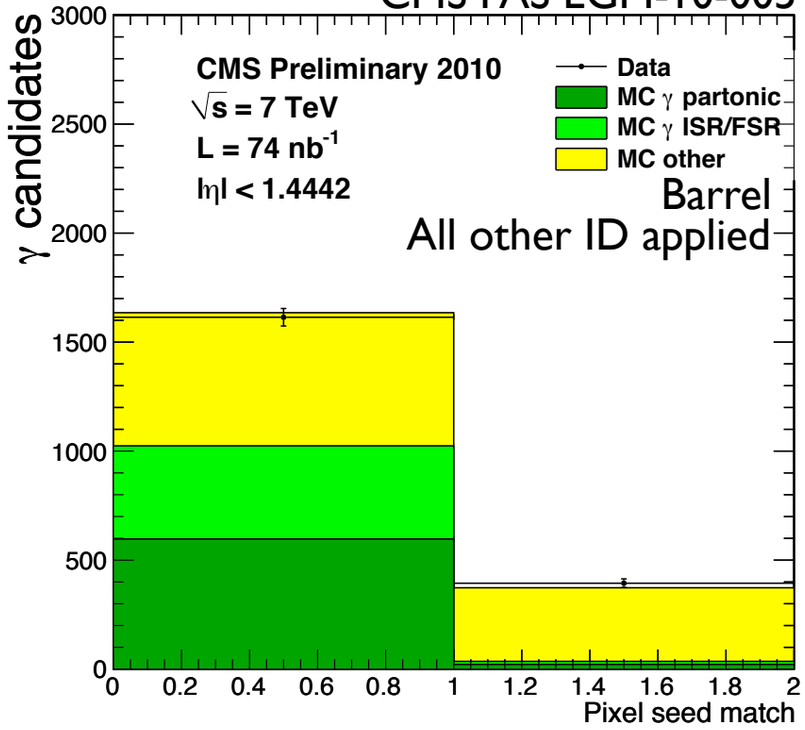


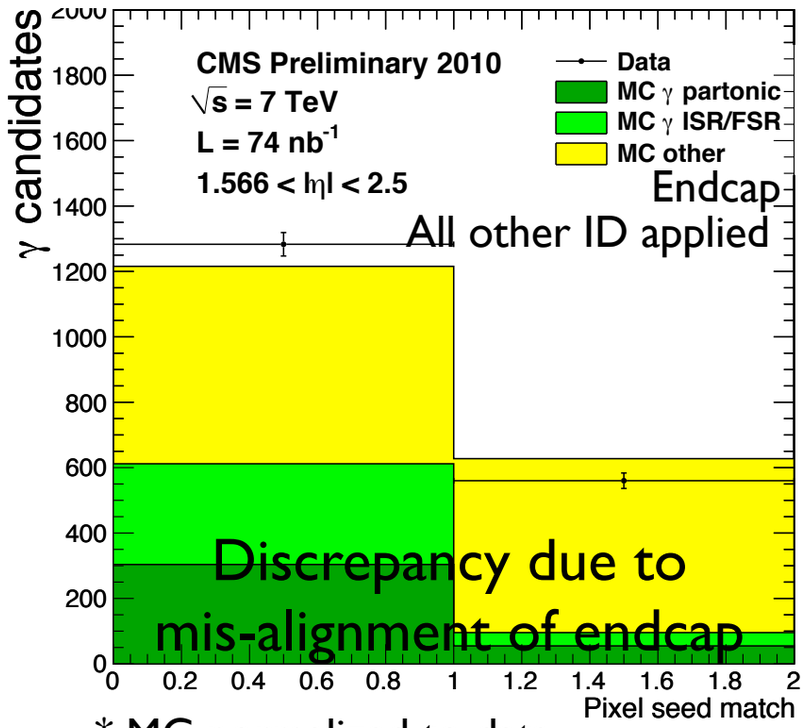


Photon ID Variables

- MC sample compositions based on PYTHIA cross sections.
- Use 74 nb^{-1} data for the following results, MC distributions are normalized to data observed.
- Require not to match pixel hit consistent with a track from interaction point.



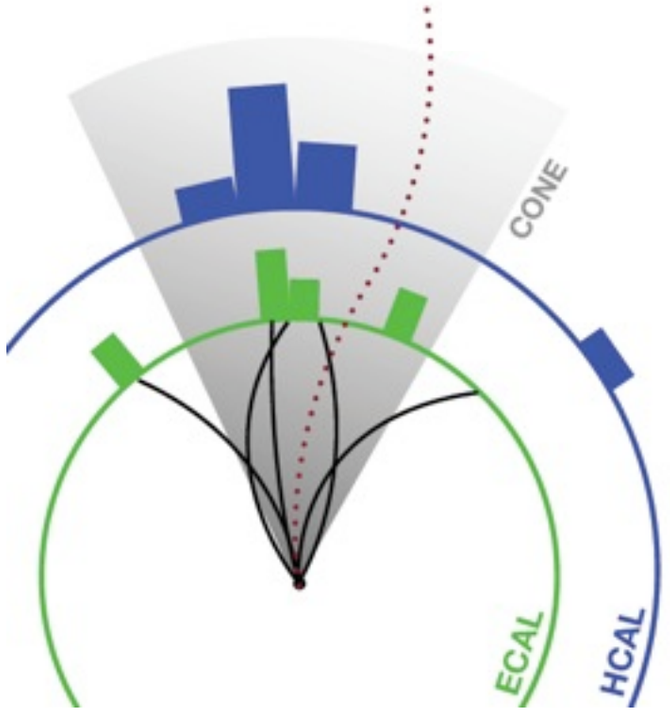


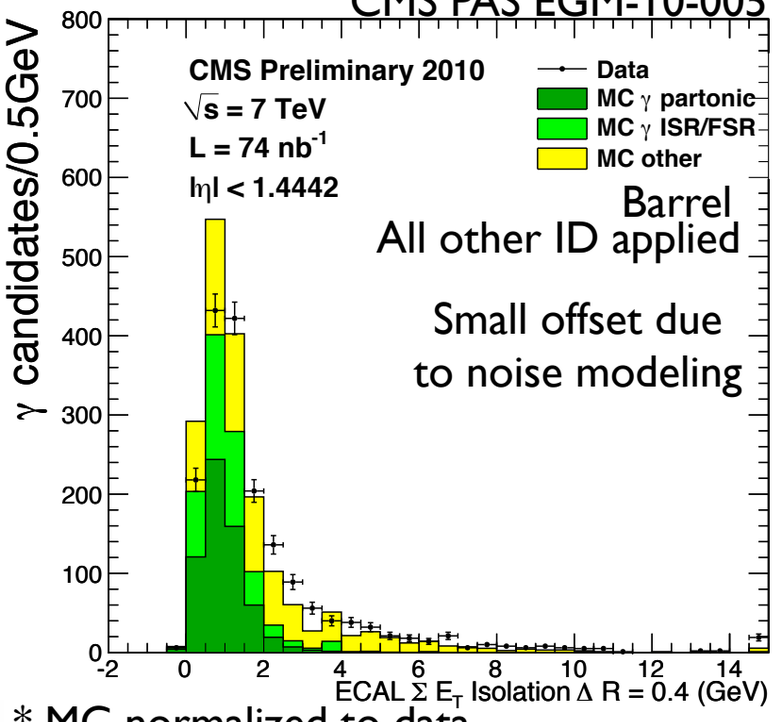


* MC normalized to data

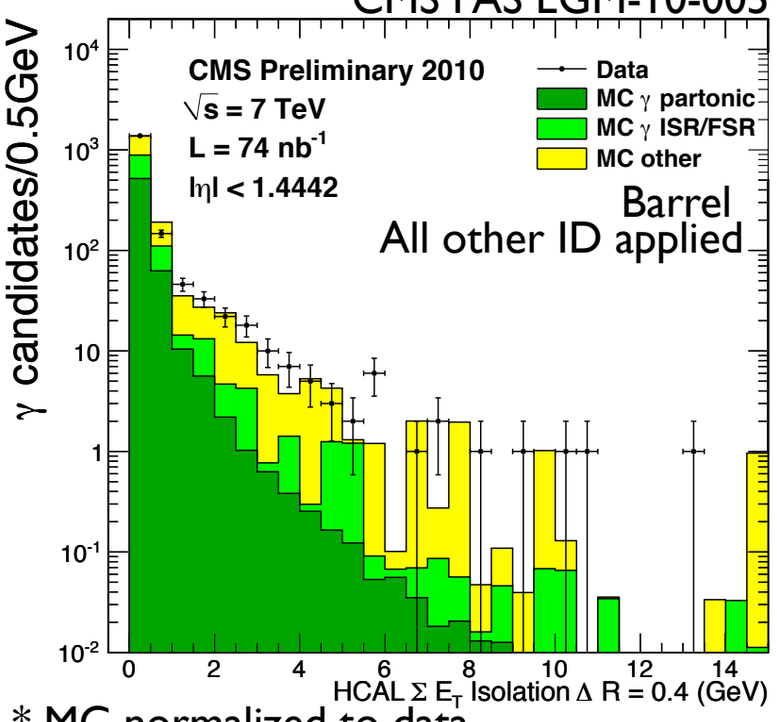
Isolation Variables

- Cone isolation variables (radius of ΔR=0.4) in ECAL / HCAL / tracker identifie isolated objects.

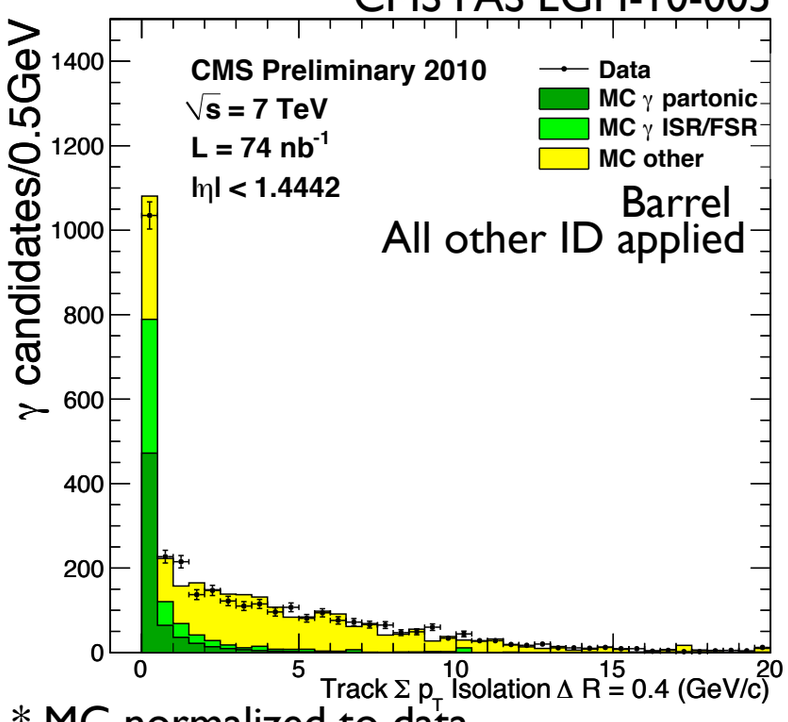




* MC normalized to data

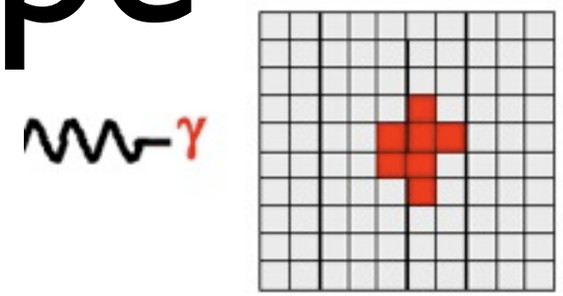


* MC normalized to data

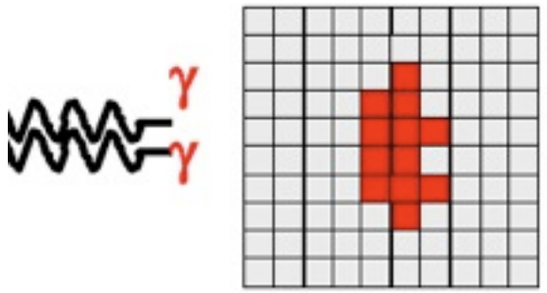


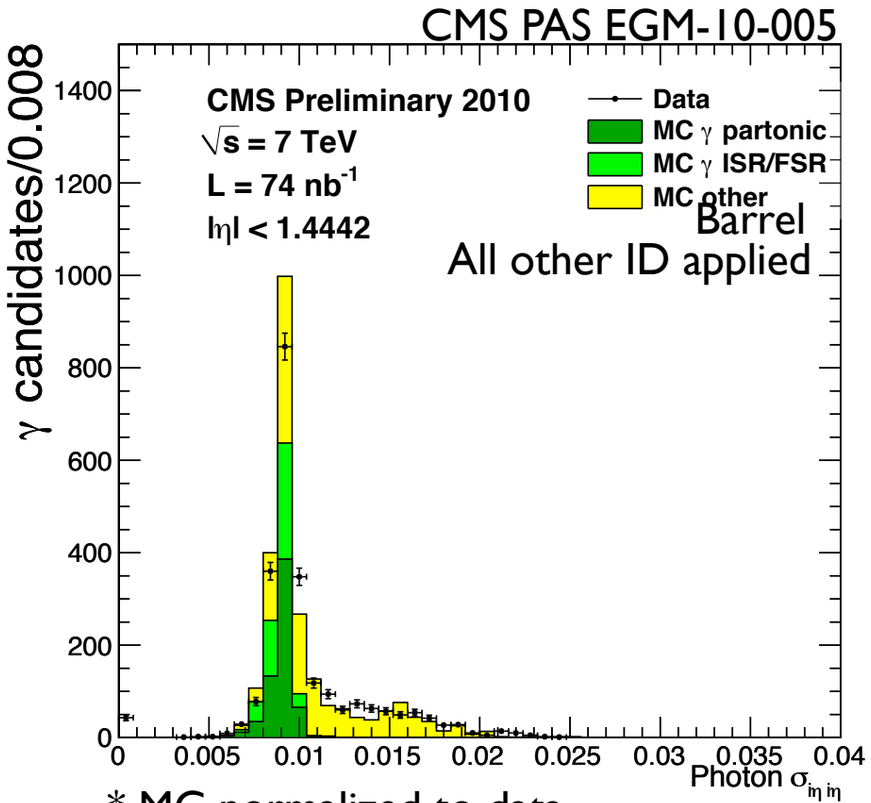
* MC normalized to data

Shower Shape

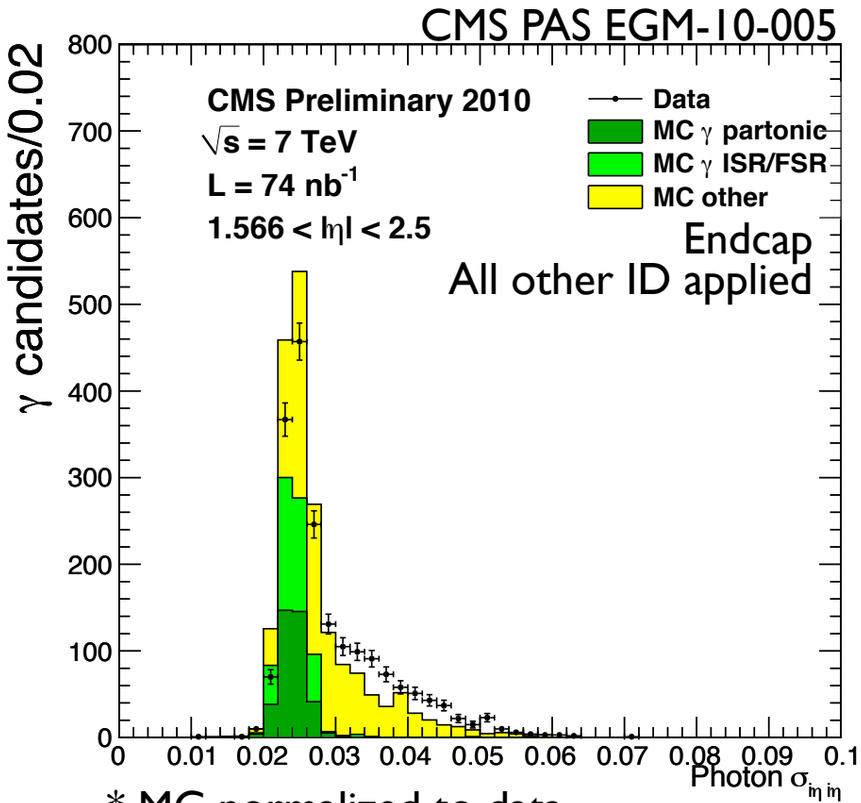


- Powerful shape variable $\sigma_{i\eta i\eta}$ (shower width in η) to distinguish photons from fakes.
- Can be used to extract photon yields or purity of the sample





* MC normalized to data



* MC normalized to data

Photon ID

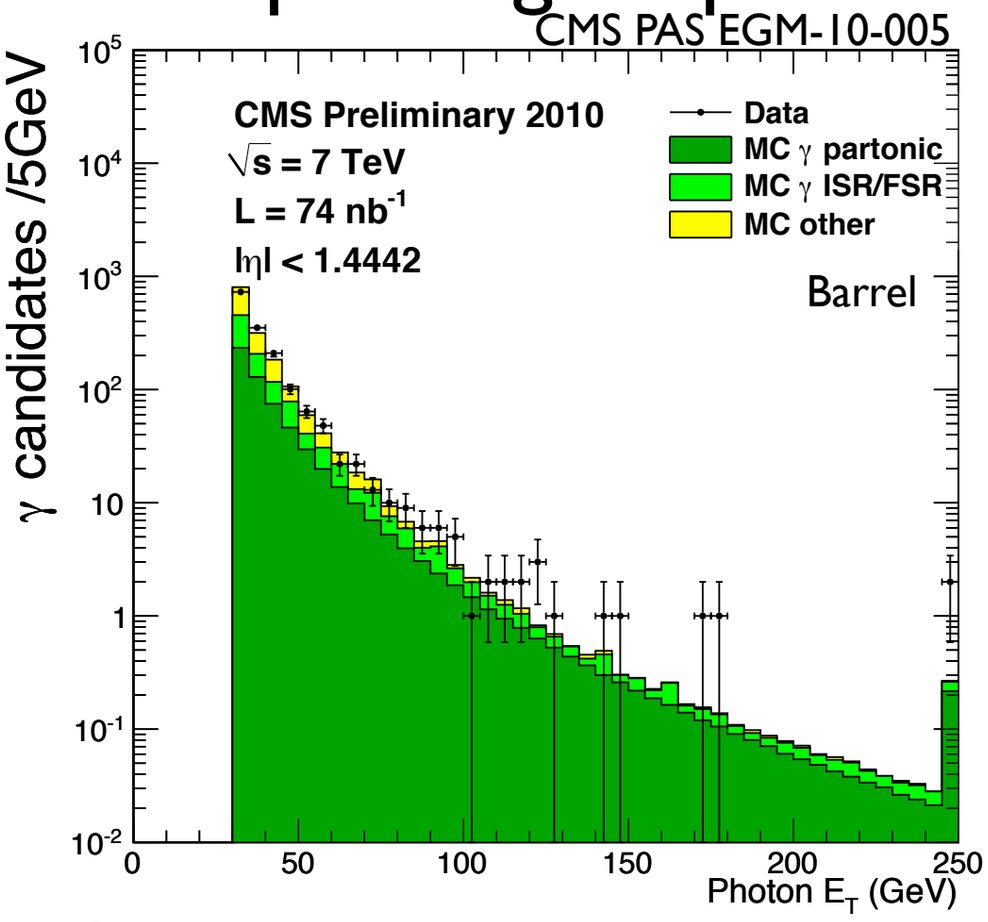
- Apply selection cut to enhance prompt photons over fakes (π^0 or jets)
- Based on MC, the efficiency is around 90% for Barrel and 80% for Endcap.
- Signal photons from hard-process, not decays.

CMS PAS EGM-10-005

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	
(hadonic/EM) energy	< 0.05	
shower shape ($\sigma_{i\eta i\eta}$)	< 0.01	< 0.03
	Require not to match a pixel hit	

Isolated Photons

- With photon ID applied, clear component from prompt isolated photons can be seen.
- Purity is estimated between 40 to 100% depending on photon E_T



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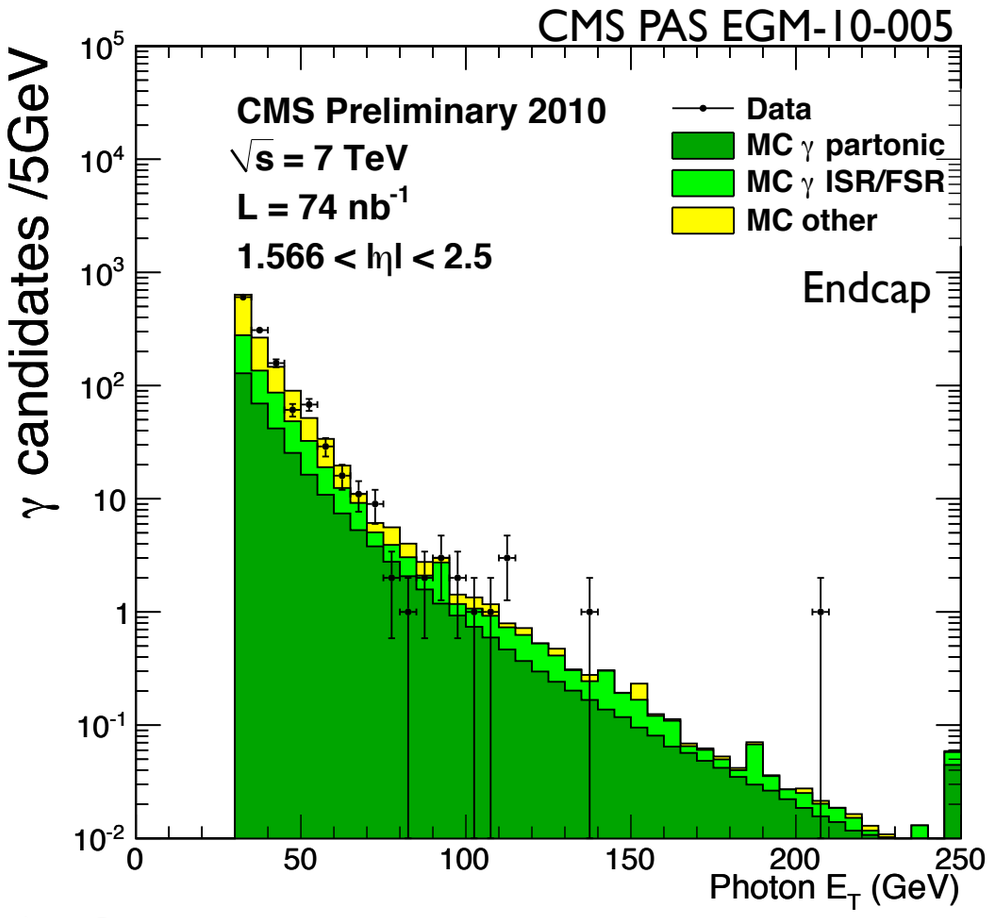
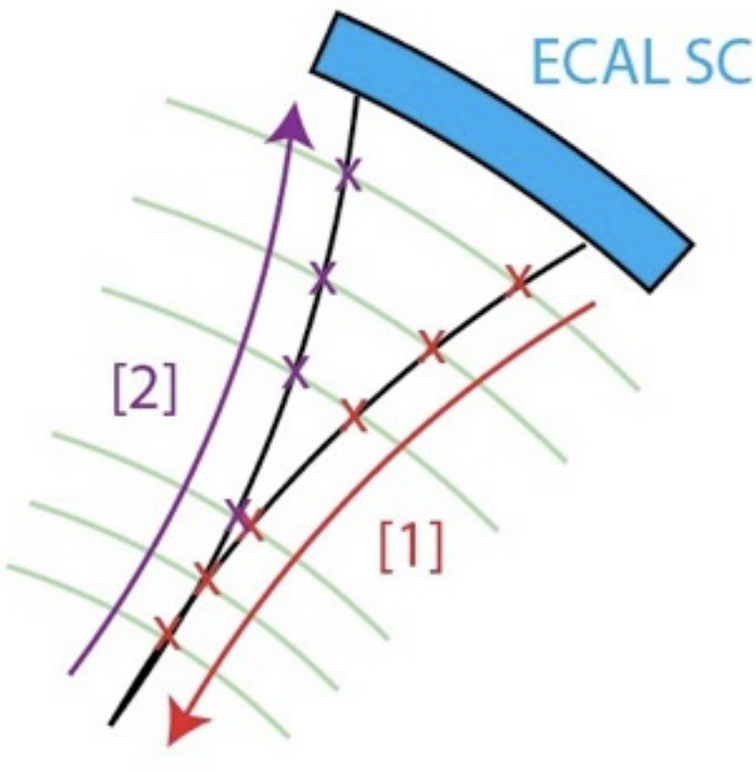


* MC normalized to data

Photon conversions

Finding Conversions

- Significant amount of photon conversion is expected in CMS due to tracker material
- Look for pair of electrons based on two legs associated with the same SuperCluster.
  - start from a SuperCluster
  - look for a track toward IP
  - from innermost hit find 2nd track back to SuperCluster



Conversion variables

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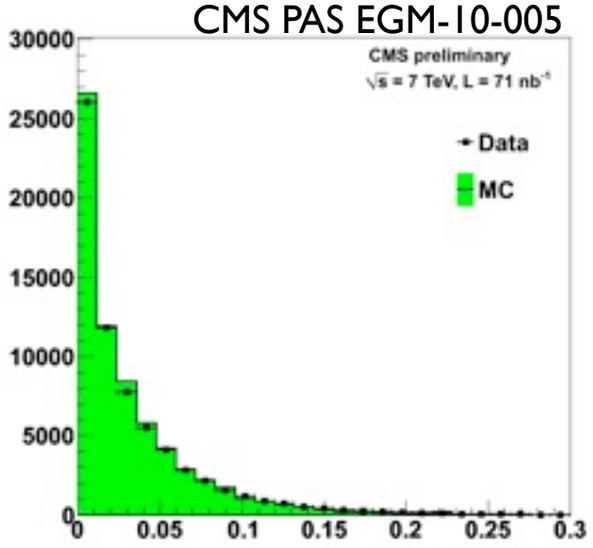
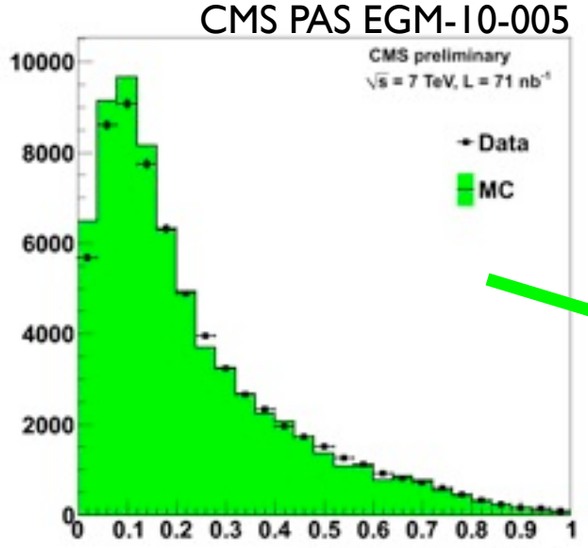
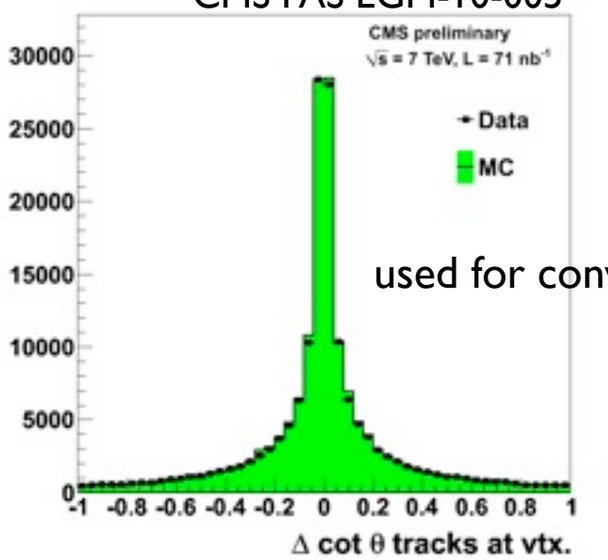


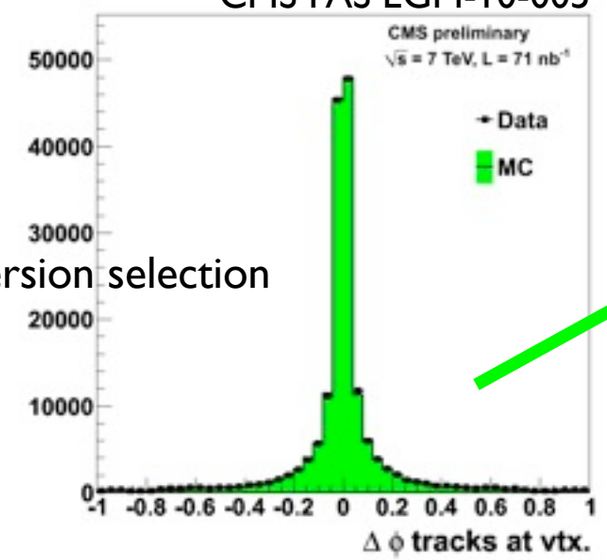
CMS PAS EGM-10-005



CMS PAS EGM-10-005



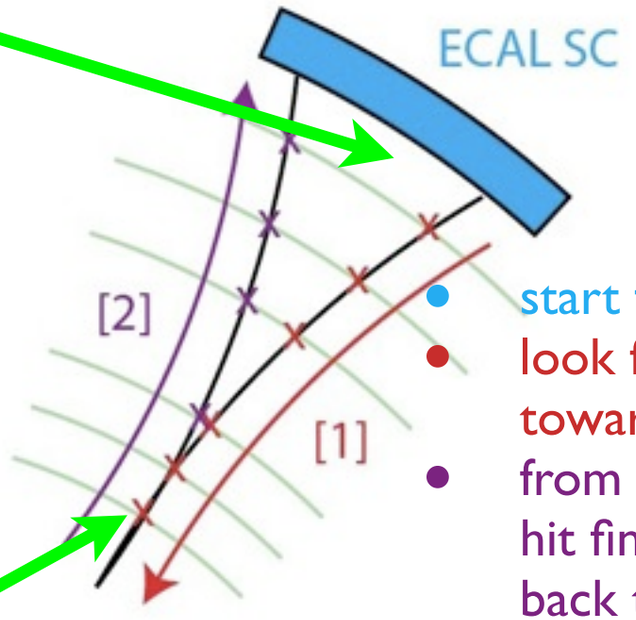
CMS PAS EGM-10-005



used for conversion selection

* MC normalized to data

At ECAL level



- start from SC
- look for a track toward IP
- from innermost hit find 2nd track back to SC

At vertex level

Converted Photons

- Agreement between data and MC on distributions of conversion legs.
- Additional cut on top of photon ID is used for conversion selection
  - $|\Delta\phi| < 0.2$
  - $|\Delta\cot\theta| < 0.3$
  - fit probability > 5×10^{-4}
- Contribution from prompt photons can be seen.

Applying all selections

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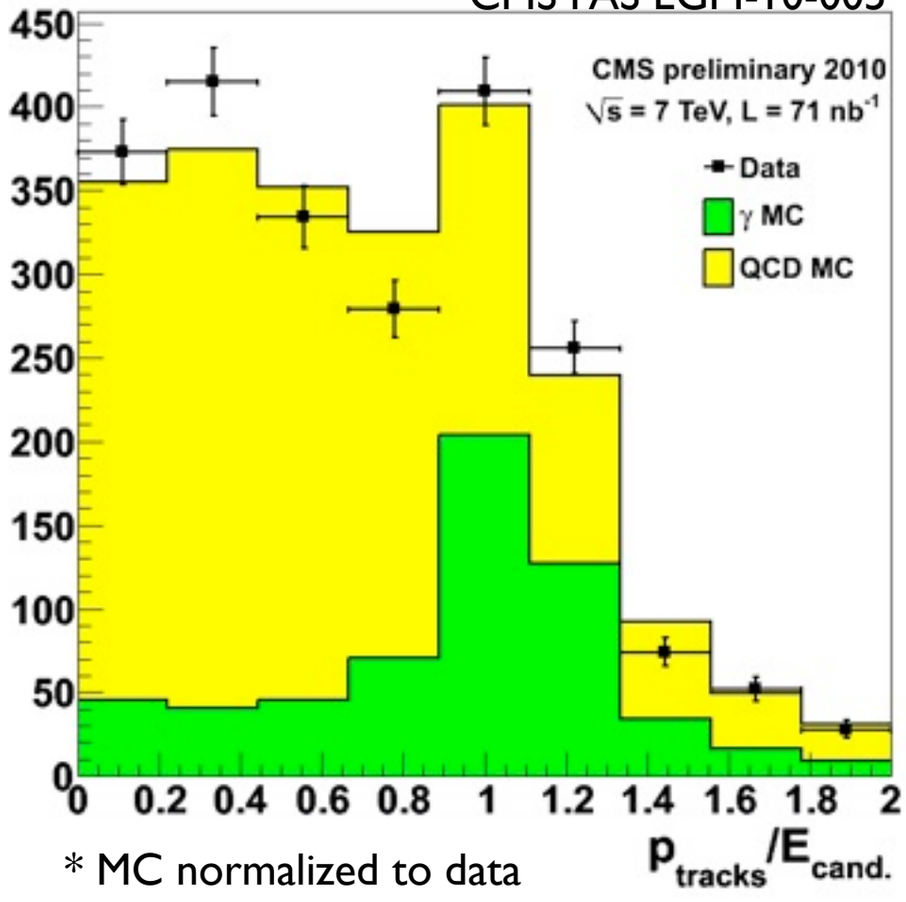


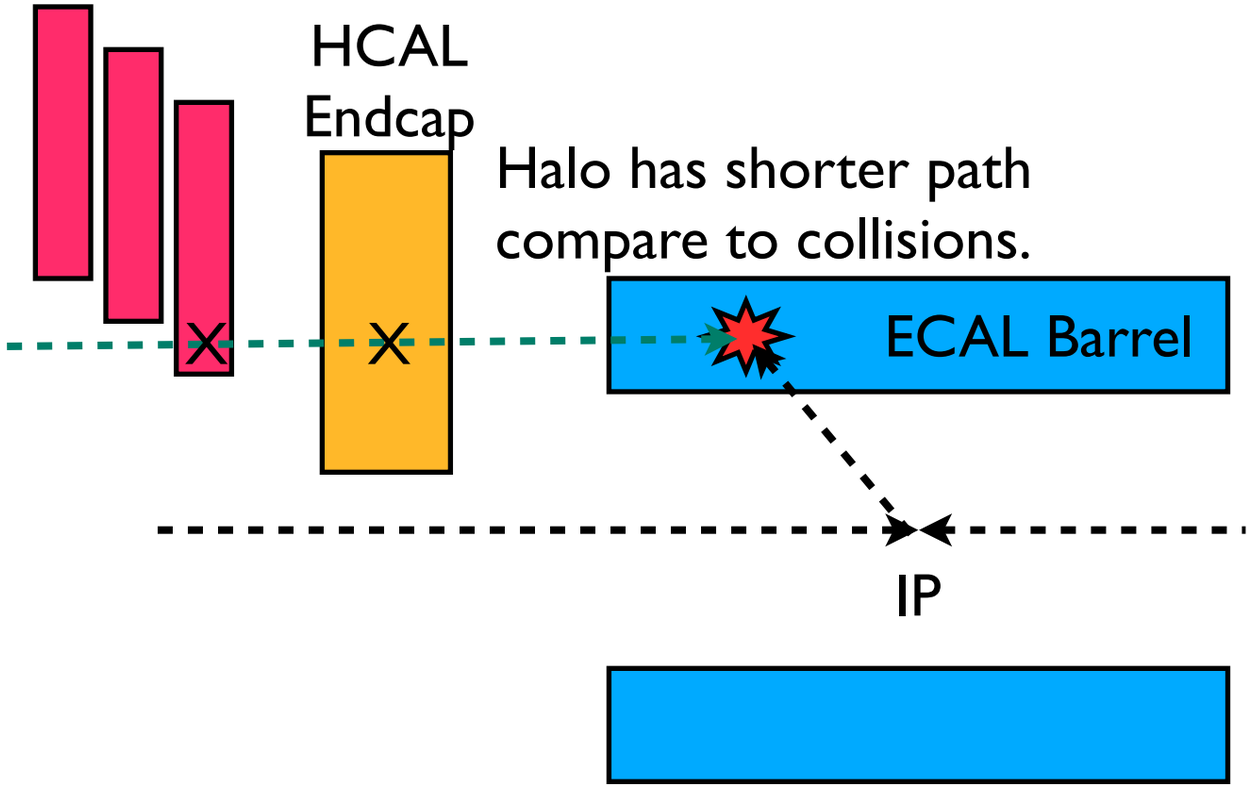
* MC normalized to data

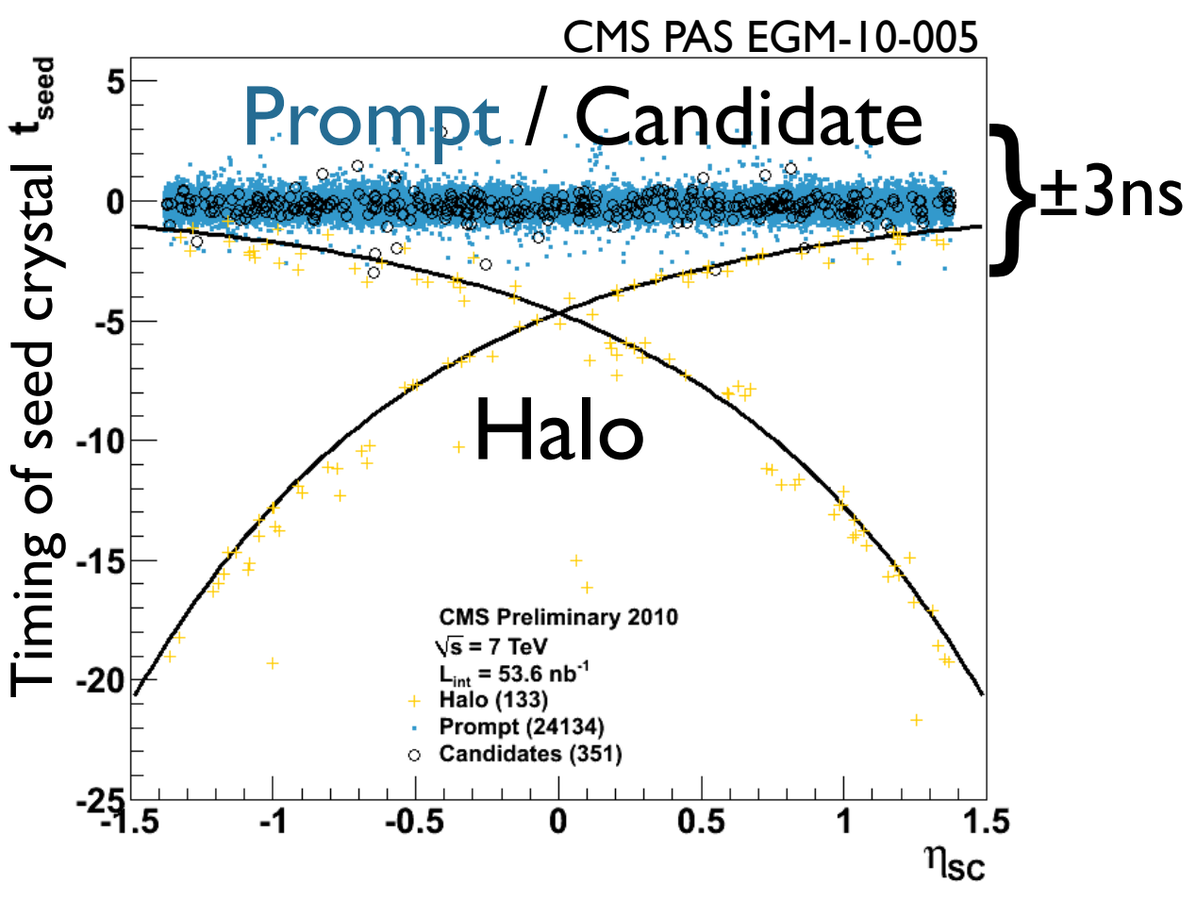
Non-collision backgrounds

Beam Halo

- Halo contribution is estimated from data by
  - Halo events : tagged by muon chamber
  - Prompt events : seed crystal timing $|t_{seed}| < 3ns$ with missing $E_T < 15GeV$
  - Candidate events : $|t_{seed}| < 3ns$ with missing $E_T > 25GeV$

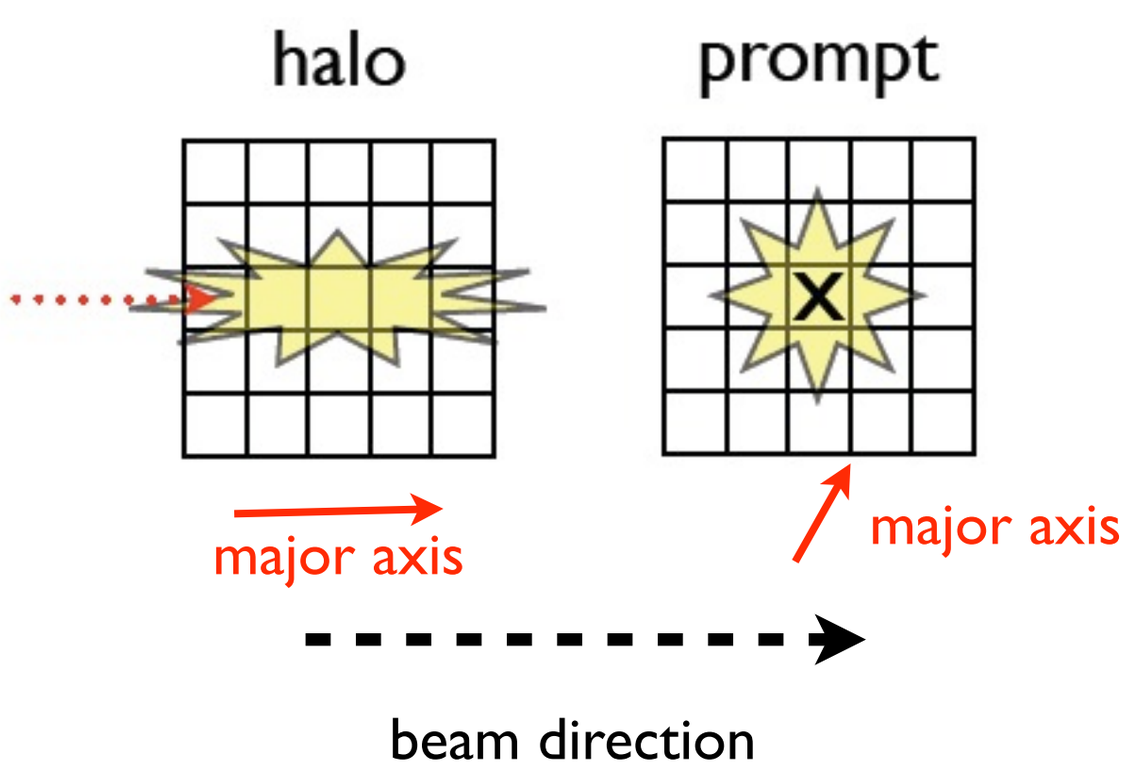
Muon chamber



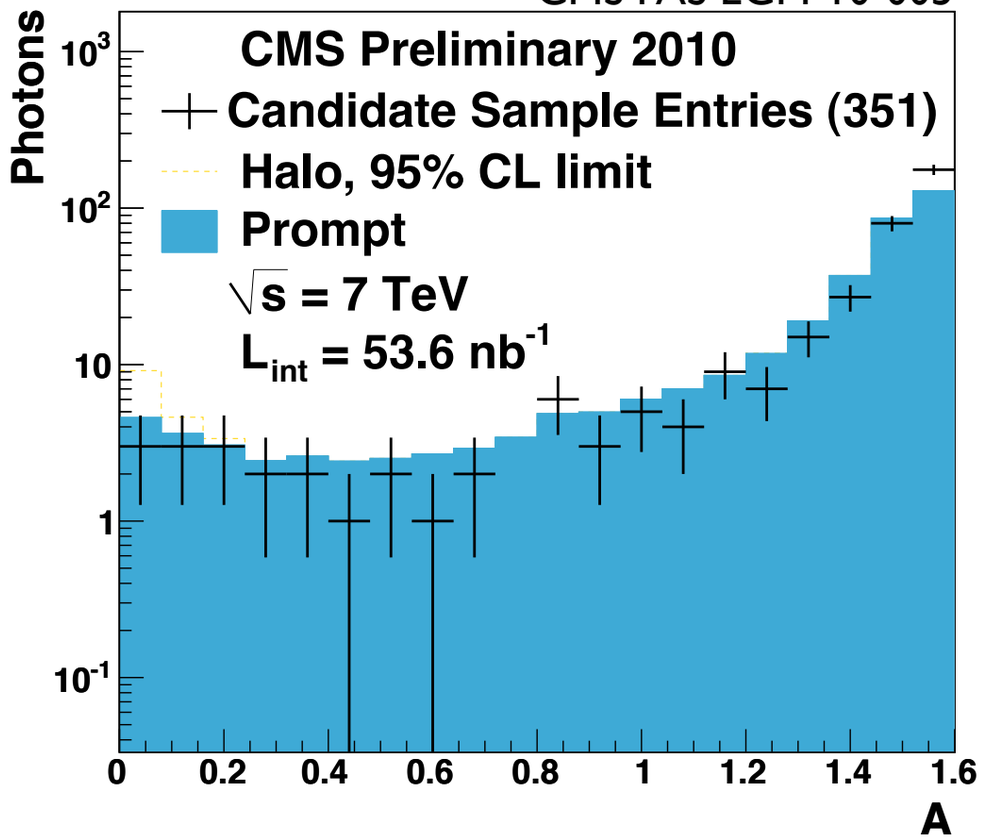


Beam Halo Contribution

- Within candidate events, no evidence in low value of angle(**A**) between beam line and major axis of photon shower
- The estimate of contribution is less than 5.9 event in 53.6 nb^{-1}.



Candidate Sample CMS PAS EGM-10-005

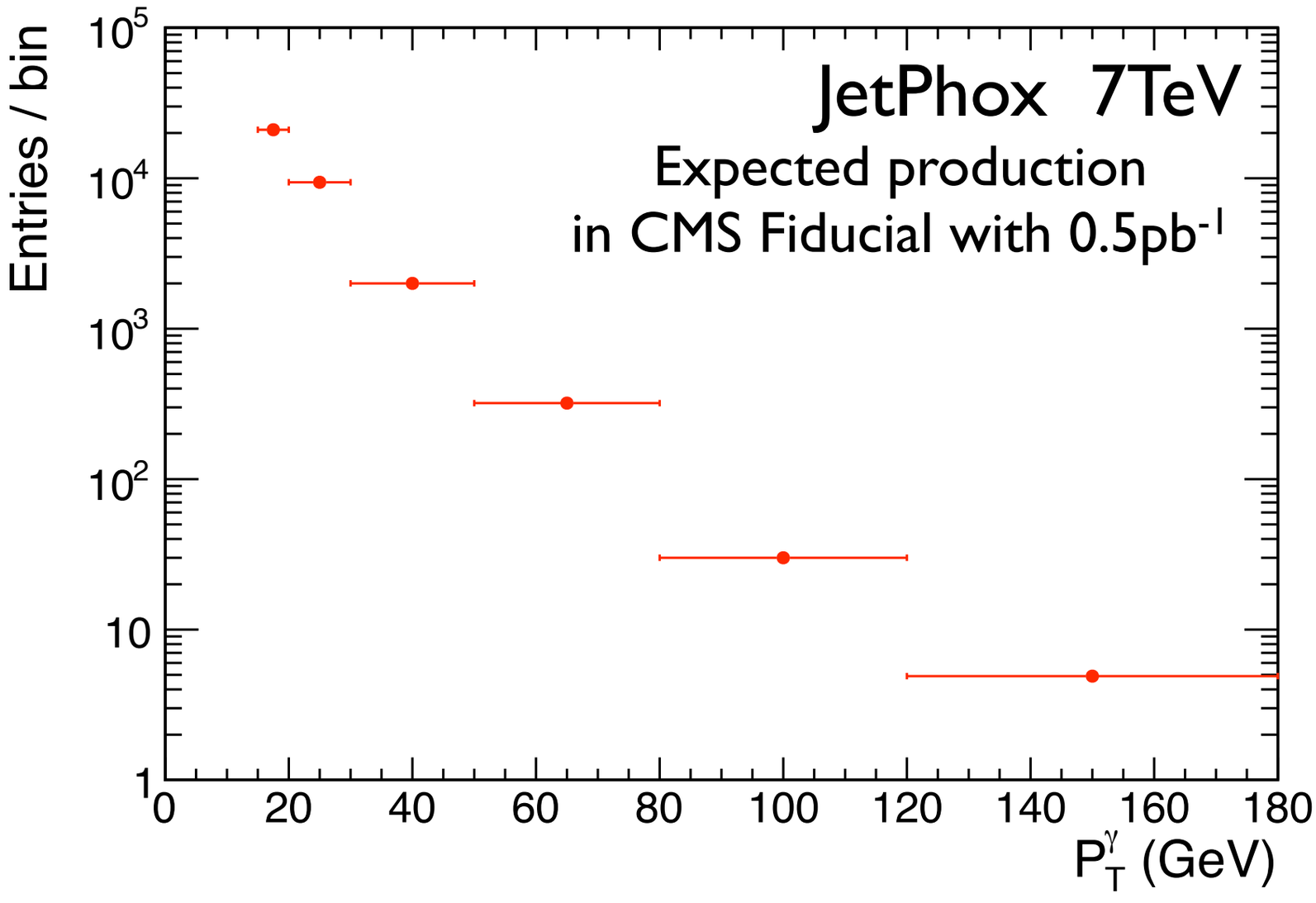


Summary

- We have studied the photon objects at CMS with collision data
- Applying photon ID, clear contribution from prompt isolated photons can be seen
- Analysis of photon production is on-going as the baseline of multiple photon+X analyses.

backup slides

JetPhox

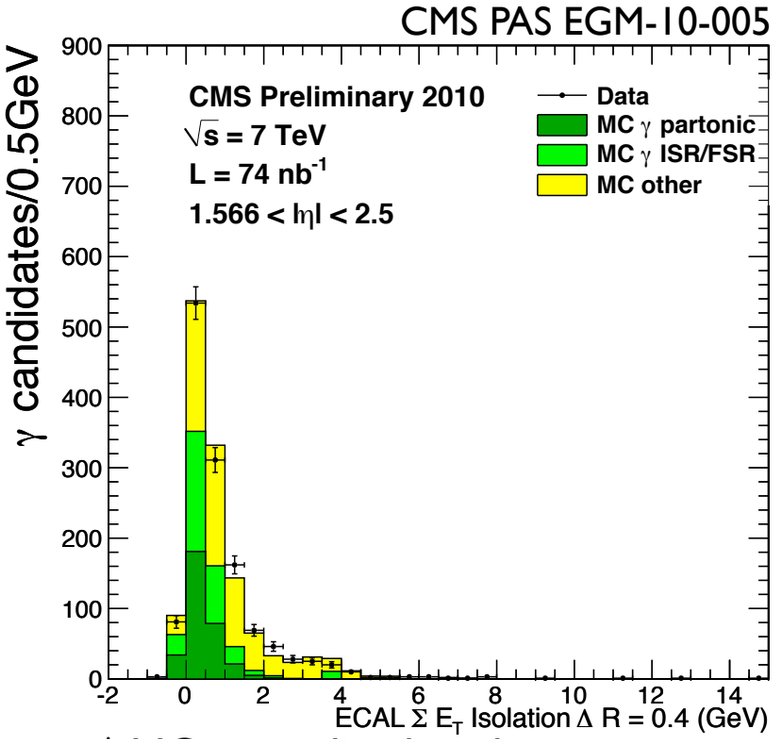

JetPhox 7TeV
Expected production
in CMS Fiducial with 0.5pb-1
Entries / bin
10^5
10^4
10^3
10^2
10
1
0
20
40
60
80
100
120
140
160
180
P_T^γ (GeV)

Photon ID variables

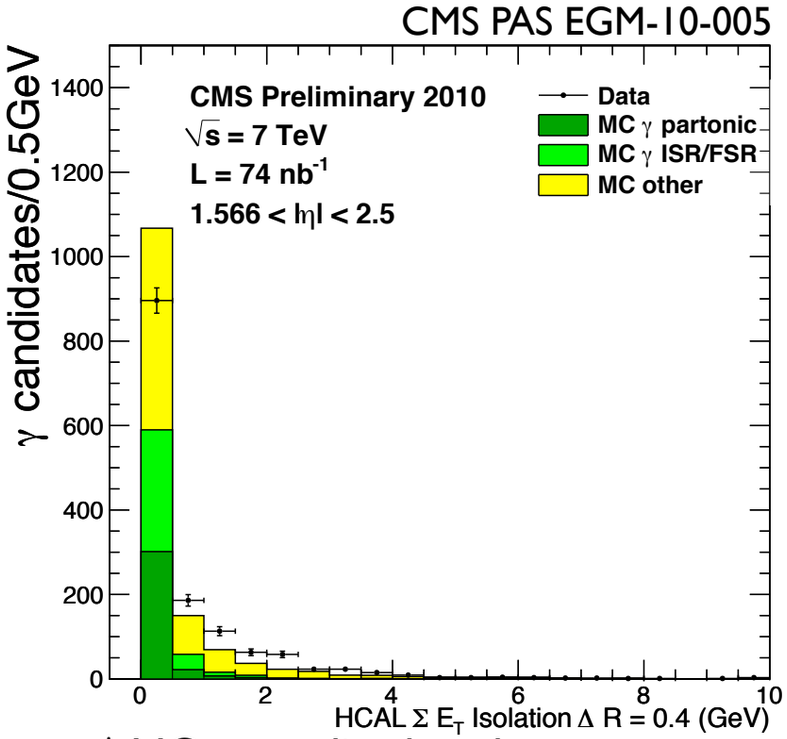
- ECAL isolation : Jurassic cone with inner cone 0.06, outer cone 0.4 and eta slice of 3 crystals.
- HCAL isolation : Inner cone 0.15 and outer cone 0.4.
- tracker isolation : Inner cone 0.04 and outer cone 0.4.
- shower shape : η distribution of shower

$$\sigma^2_{i\eta i\eta} = \frac{\sum_i^{5\times5} w_i (i\eta_i - i\eta_{seed})^2}{\sum_i^{5\times5} w_i},\ w_i = \max(0,\ 4.7 + \ln\frac{E_i}{E_{5\times5}}).$$

Isolation of EE



* MC normalized to data



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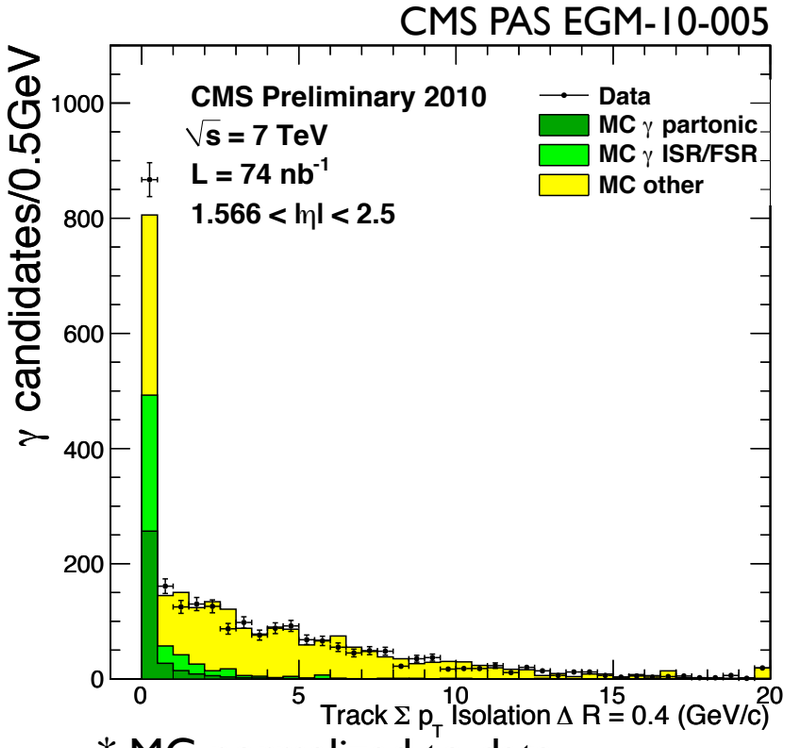
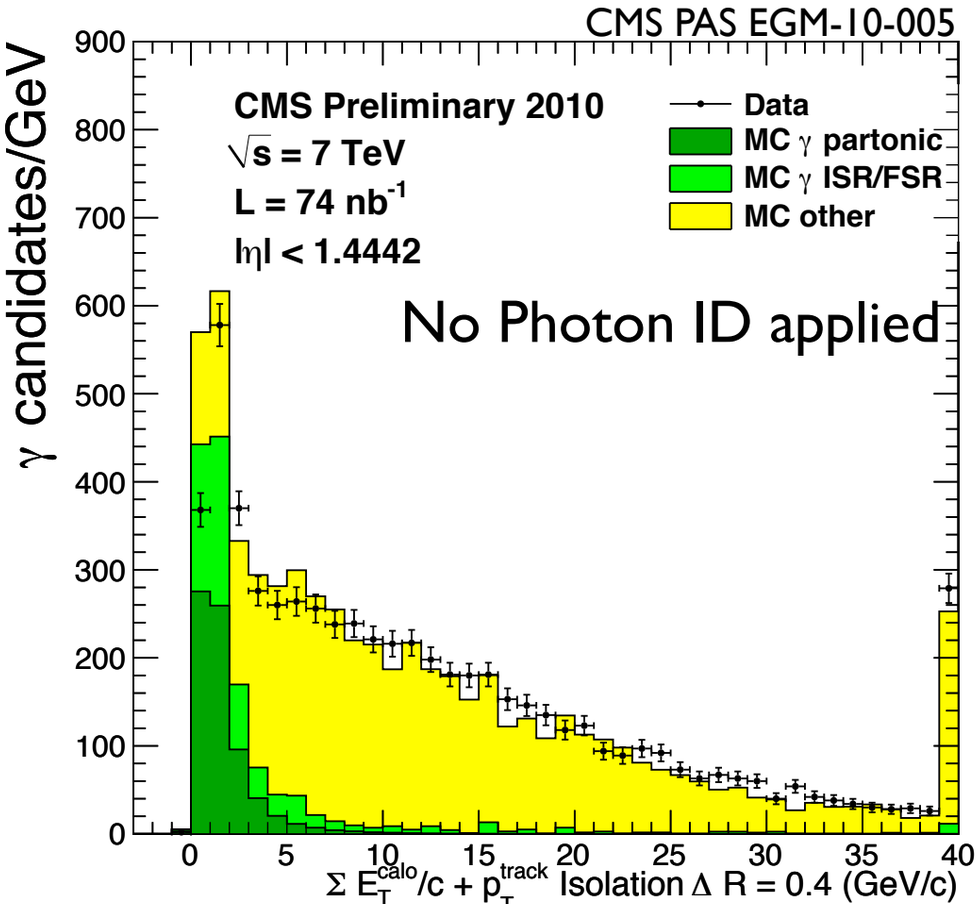


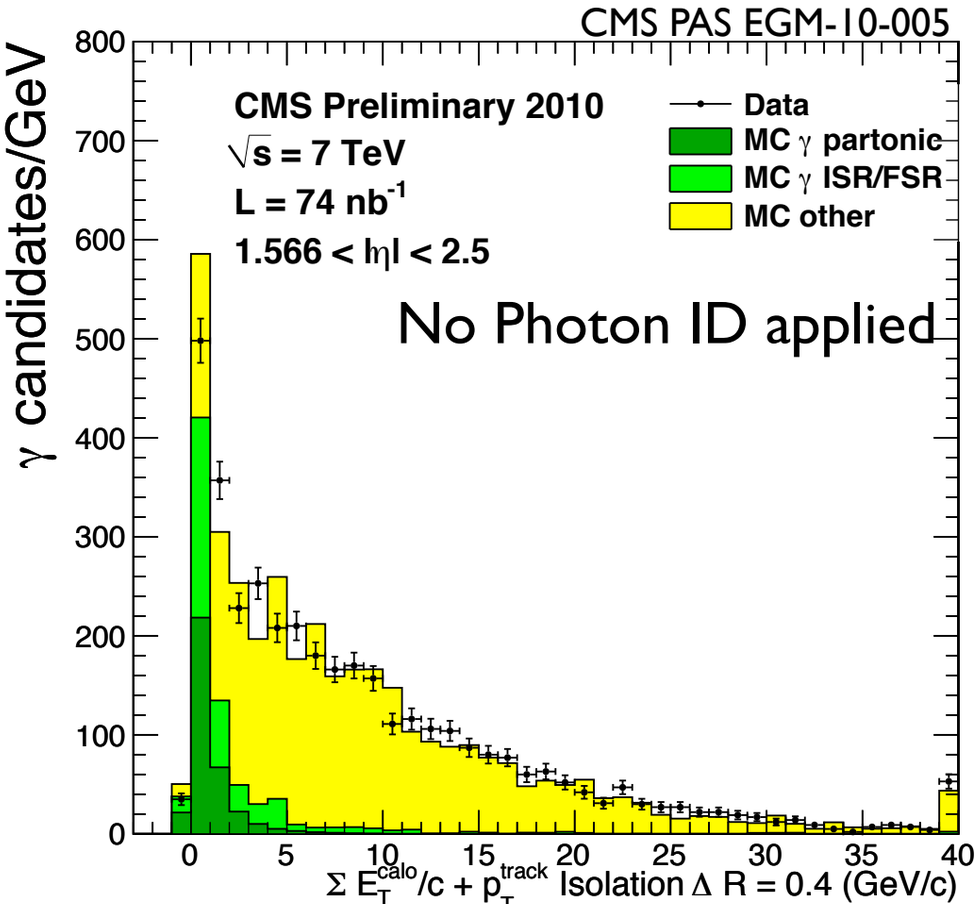
* MC normalized to data

Sum of isolation

- Sum of isolation for candidate photons.
- Prompt photons contribute in low value bins.



* MC normalized to data



* MC normalized to data