Searches for SUSY in Di-photon Events

Bernadette Heyburn

University of Colorado

For the CMS Collaboration

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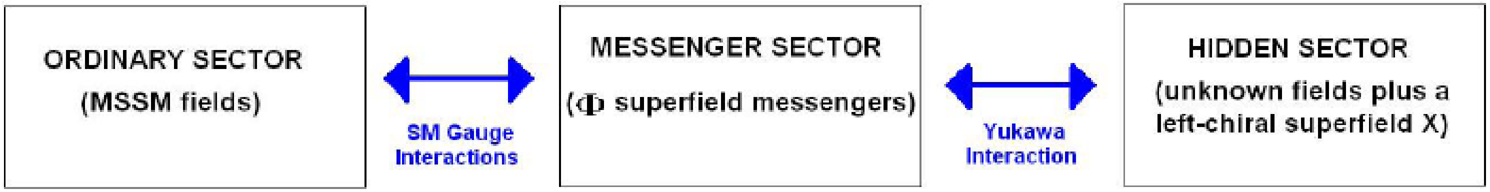
Outline

1. Physics Motivation
2. CMS/LHC
3. Methodology
4. MC Studies
5. Data Results

Search for new physics with di-photon + missing transverse energy (MET)

Gauge Mediated Supersymmetry Breaking (GMSB)



Lightest Supersymmetric Particle

LSP = gravitino

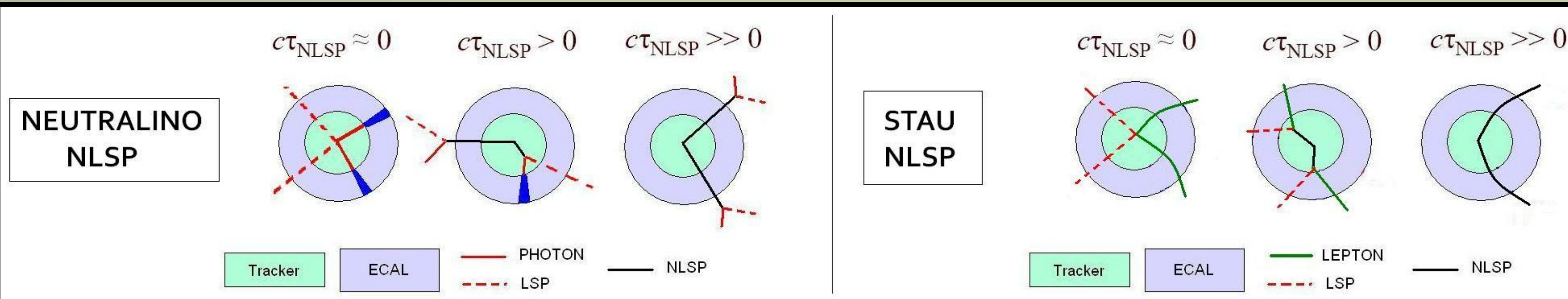
Next to Lightest Superymmetric Particle

NLSP = $\tilde{\tau}$ or $\tilde{\chi}^0$

If R-parity is conserved…

super partners are produced in pairs and decay by cascading down to the NLSP, which then decays to the NLSP's partner + LSP, which is stable.

$R = (-1)^{2j+3B+L}$



See: Meade, Seiberg, and Shih *arXiv:0801.3278* and Buican, Meade, Seiberg, and Shih *arXiv:0812.3668*

At the LHC…

Choose to study prompt di-photon signature because

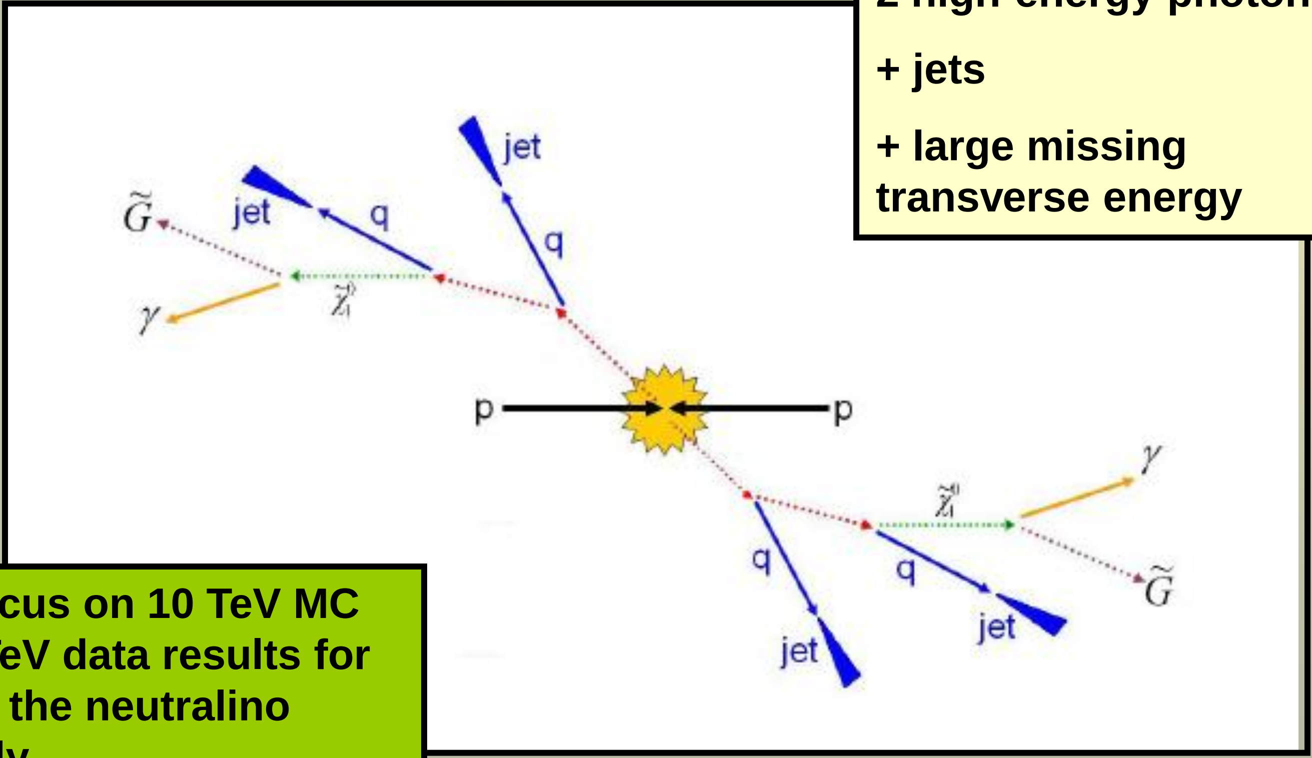
1) **It is different from other SUSY signatures**
2) **It is a distinctive signature**

SEARCH FOR:

2 high-energy photons

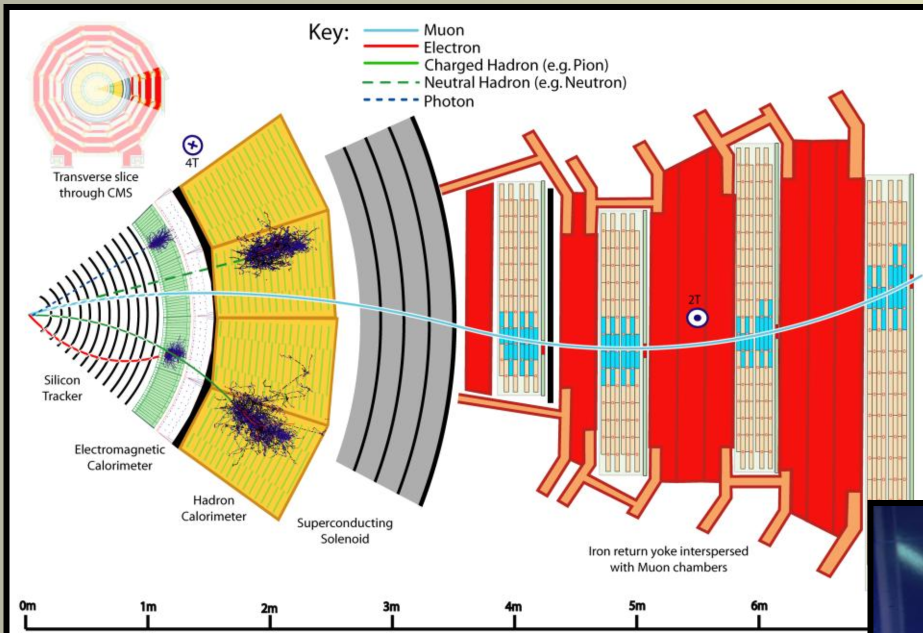
+ jets

+ large missing transverse energy



This talk will focus on 10 TeV MC studies and 7 TeV data results for the case where the neutralino decays promptly.

CMS: ideal for di-photon signatures originating from LHC events



The Compact Muon Solenoid (CMS) is one of two all-purpose detectors at the LHC

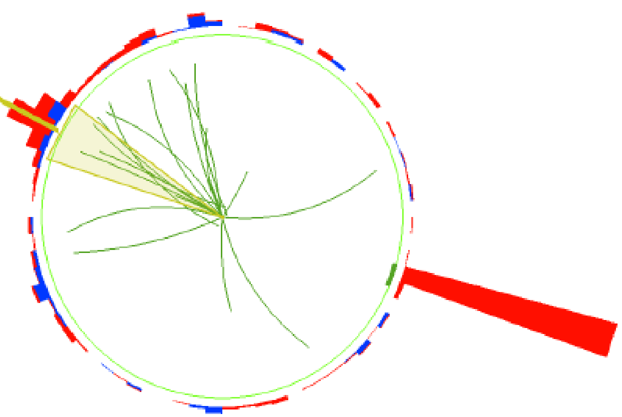
The electromagnetic calorimeter (ECAL) is a homogenous, hermetic detector with over 74,000 channels, making it well-suited to study signatures with photons and MET

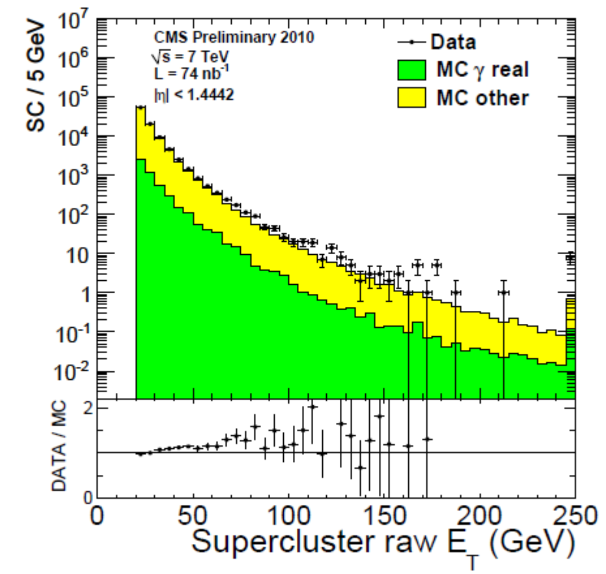
Methodology – Object Selection

- Photon selection
  - High energy (>30 GeV for MC, >10 GeV for data)
  - Isolated
    - Sum of track pTs, ECAL energy, HCAL energy in a specified cone around the photon must be small
  - Minimal hadronic energy associated with them.
  - Shower shape cut to discriminate against cosmics and beam halo
  - Timing cut (not too far away from interaction time)
  - No pixel track stub associated to these objects, which indicates a charged track
- Electron selection
  - Identical to photon selection, but requires pixel track stub.

EGM-10-005

Example photon event display



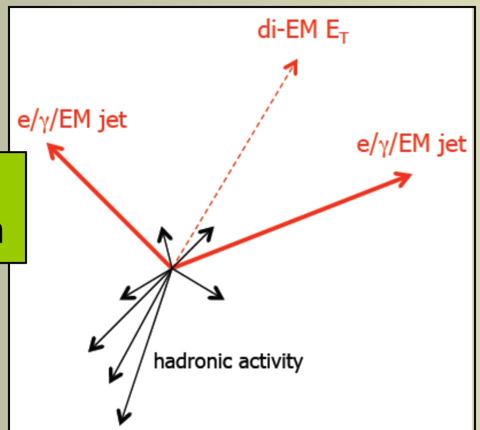


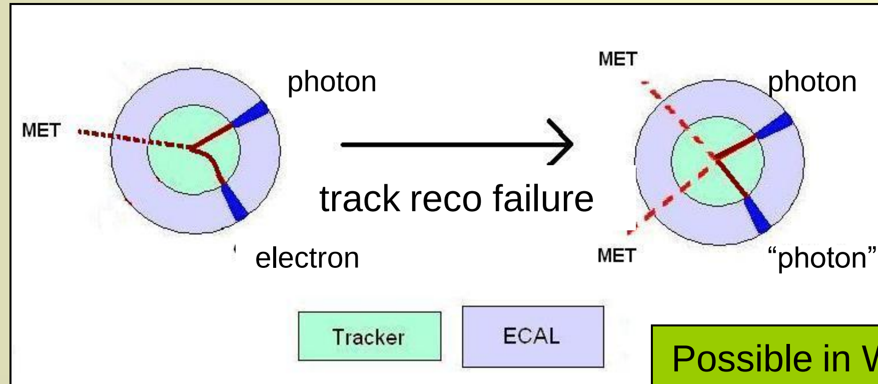
Methodology

- Di-photon + MET is one of the early search channels
  - Main challenge is to separate signal from the many **backgrounds**
  - The di-photon + MET analysis has been developed – jets will also be added

1). QCD Multi-jet
2). Direct di-photon

MET from mis-measured jets

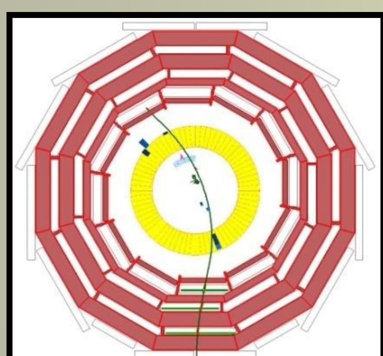




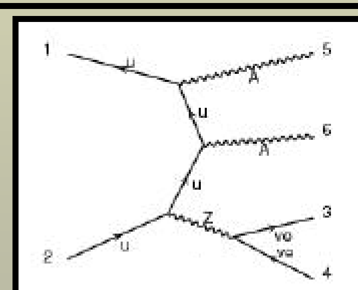
Possible in Wγ and Wj events

QCD (no true MET)

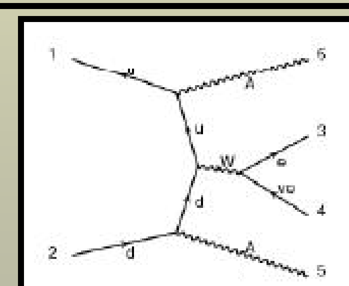
Electroweak (true MET)



Non-beam backgrounds



qq→Zγγ

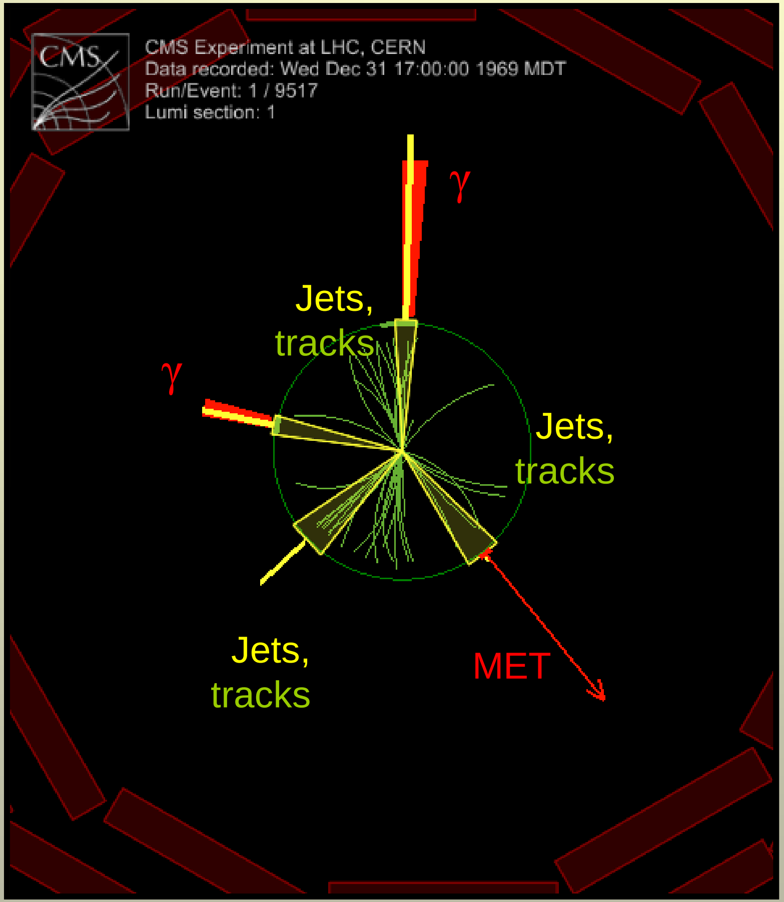


qq→Wγγ

Real Physics Backgrounds (neglible)

In-depth methodology description illustrated with Monte Carlo Studies

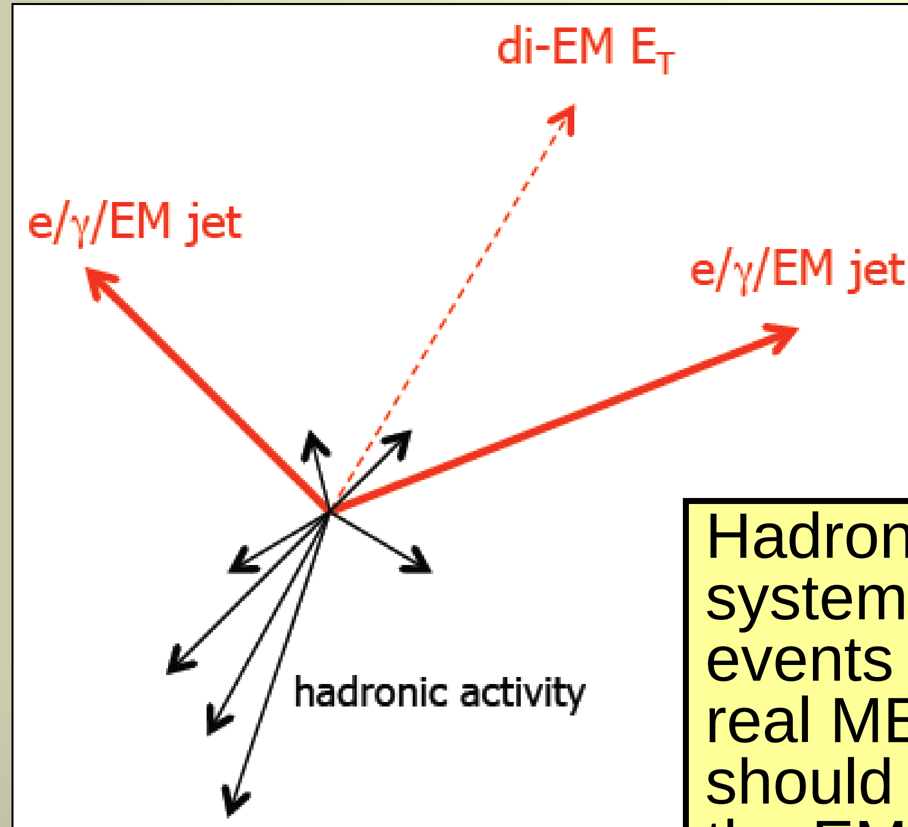
- 10 TeV Monte Carlo samples
  - All applicable backgrounds
  - Signal point: Snowmass Points and Slopes Line 7 with Λ = 100 TeV
    - See hep-ph/0202233v1
    - Neutralino mass = 138.8 GeV
  - **Normalized to an integrated luminosity of 100 pb^{-1}**
- Selected various samples needed for analysis:
  - $\gamma\gamma$ sample, or candidate sample, comprising events with at east two photons;
  - eγ sample - with at least one electron and at least one photon;
  - ee sample - with at least two electrons;



QCD Background Strategy

No True MET

The MET resolution is determined by the hadronic activity in the event because the ECAL resolution, due to the crystals, is better than the HCAL resolution.



Hadronic recoil system, in events with no real MET, should balance the EM system

HCAL: $|\eta|<5.0$, $\delta E/E \sim 70\% / \sqrt{E} + 8\%$

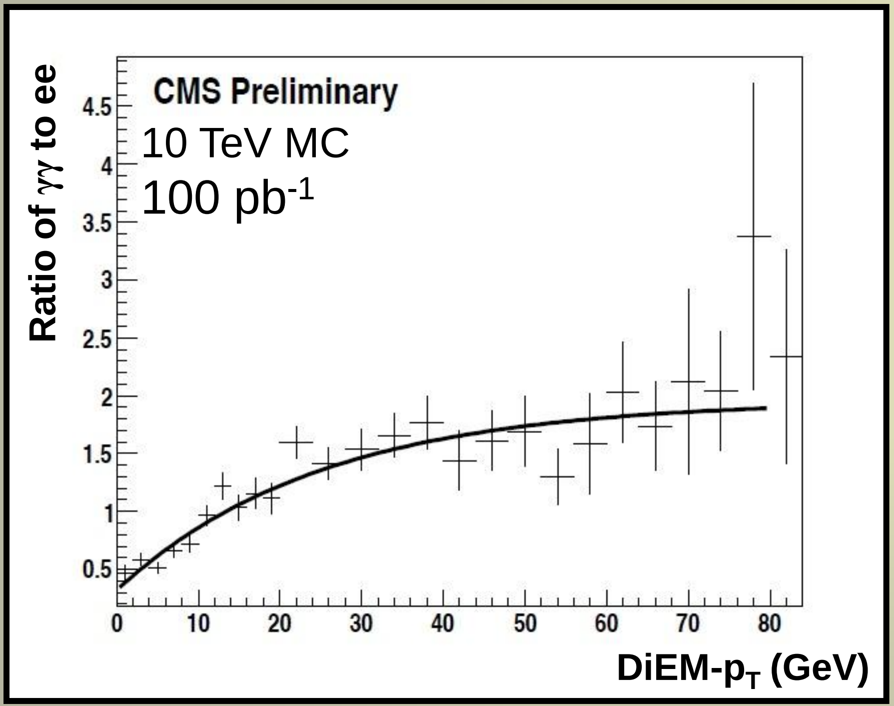
ECAL: $|\eta|<3.0$, $\delta E/E \sim 2.8\% / \sqrt{E} + 0.3\% + 12\% / E$

Must find a control sample that reproduces the hadronic activity in the candidate sample and has no true MET

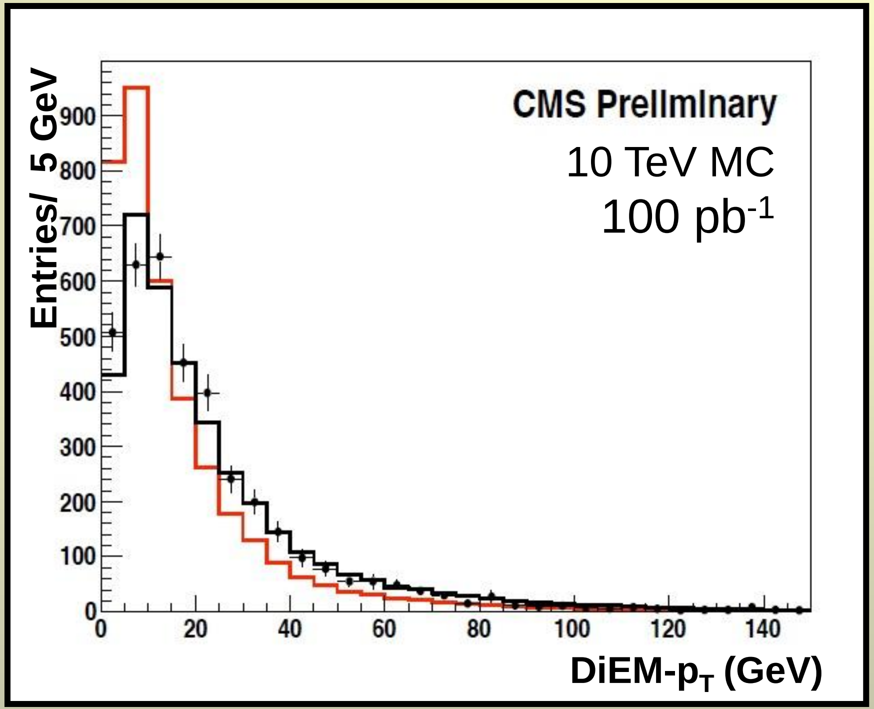
QCD Background Strategy 2

- Select Control Sample for QCD background determination
  - Z→ee (used in MC plots shown here)
  - “fake-fake” (used in data plots shown here)
    - A “fake” is identical to a photon but with the track isolation requirement flipped - so we have essentially EM, non-track-isolated jets.
- Create ratio plot: $\Sigma \vec{p}_T$ of the two leading photons in candidate sample to $\Sigma \vec{p}_T$ of the two leading EM objects in control sample (either electrons or fakes)
  - Use to reweight control sample MET distribution.
- Assume no new physics with low values of MET.
  - Scale control sample MET distribution so that the total number of control sample events at low MET is equal to the number in the candidate sample

QCD MC Studies



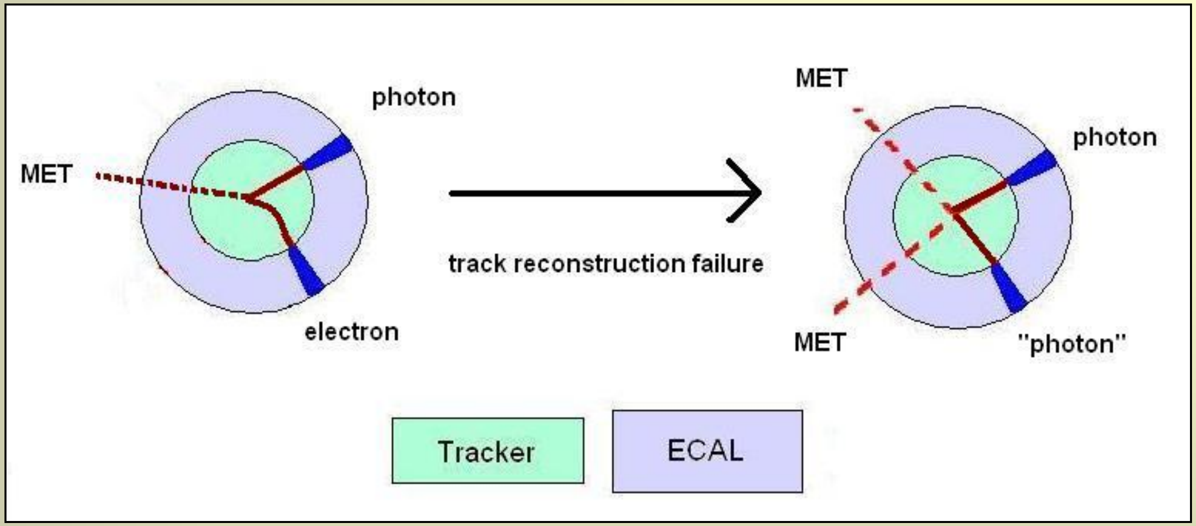
Ratio of di-EM pT of candidate (γγ) to QCD control sample (Z→ee) (with fit)



di-EM pT of γγ (candidate) sample (points), and (Z→ee) before (red) and after (black) re-weighting

EW Background Strategy

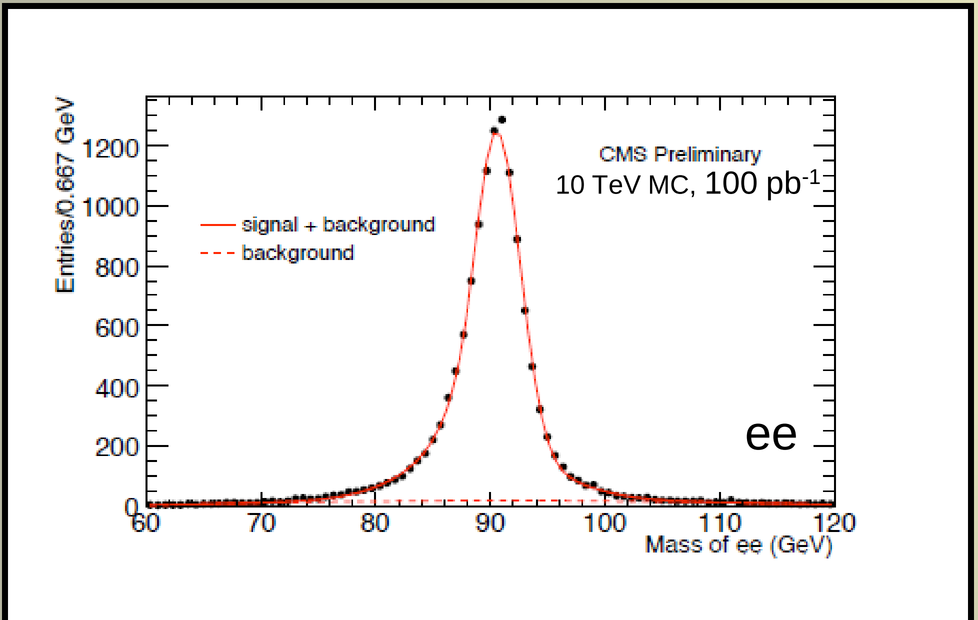
- **EW backgrounds are primarily from *W*γ and *Wj* events where the *W* decays into an electron and neutrino.**
  - If the electron track is not reconstructed, the electron will pass the photon identification and therefore also our event selection.

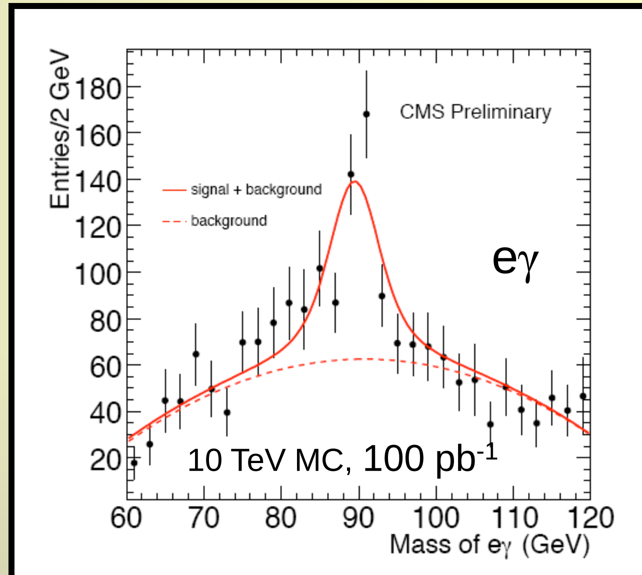


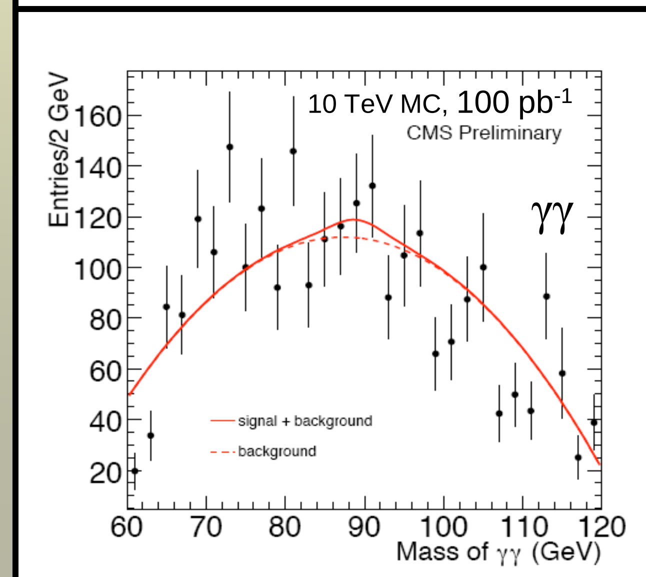
- Determine the electron-photon mis-identification rate, $\mathbf{f_{e\gamma}}$, from Z → ee events.
  - Select two final states, “ee” and “eγ” (where the γ is really an electron with a failed track reconstruction).
  - Determine number of Z events in each sample (N) by using fit to invariant mass
- Scale eγ EW background according to the mis-identification rate.

If the fake rate were large, would consider ttbar/Drell-Yan events as well. This is not the case.

EW MC Studies







Electron-Photon Efficiency = (97.5 ± 1.5)%

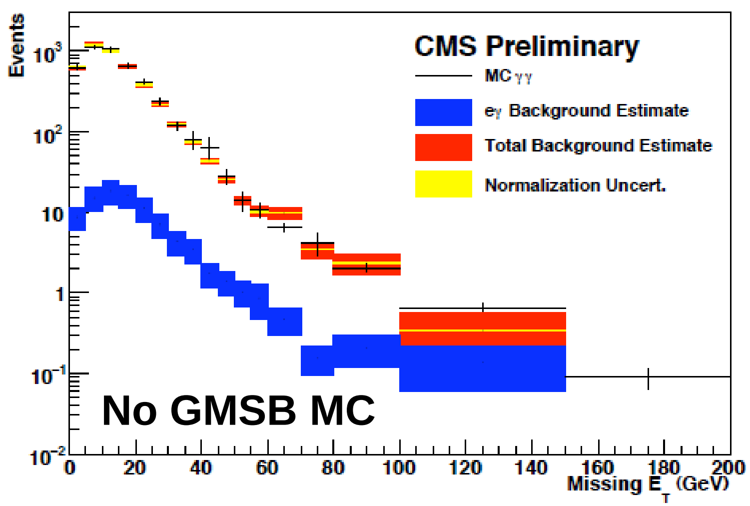
Predicted number of γγ events = 7.8 ± 9.6
Actual number of γγ events = 39 ± 47

→No correlation between reconstruction efficiencies of the two Z electrons

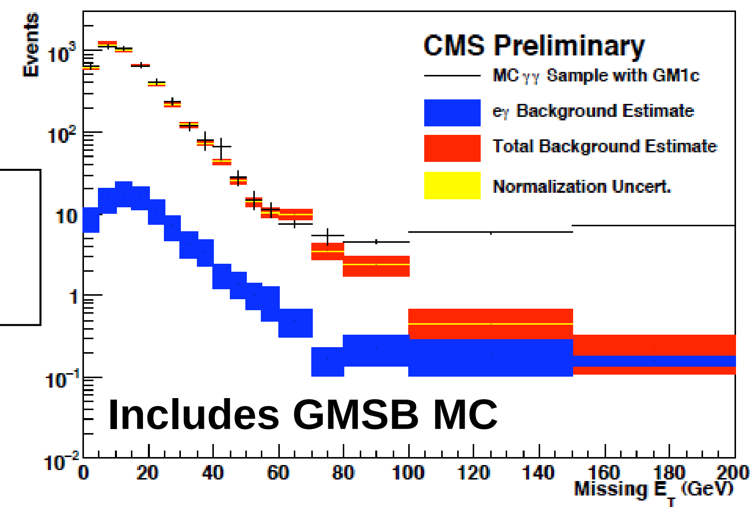
CMS PAS SUS-09-004, 10 TeV

MC Studies: MET Distribution

10 TeV MC, 100 pb^{-1}



Last bin contains overflows



Very good agreement between data-driven estimates and the predicted background.

Method also works for "fake-fake" events used at QCD control sample instead of Z→ee

MC sample	all events	> 80 GeV
$\gamma\gamma$	1055 ± 4	1.3 ± 0.16
γ+jet	3189 ± 100	1.3 ± 0.16
multijets	173 ± 37	
$t\bar{t}$	0.12 ± 0.05	
W, $W\gamma$	8.3 ± 3.0	0.04 ± 0.04
Z, $Z\gamma$	23 ± 1.3	0.06 ± 0.02
$W\gamma\gamma$	0.245 ± 0.002	0.051 ± 0.001
$Z\gamma\gamma$	0.093 ± 0.001	0.031 ± 0.001
Total SM	4449 ± 108	**2.78 ± 0.24**
GM1c	20.7	14.8

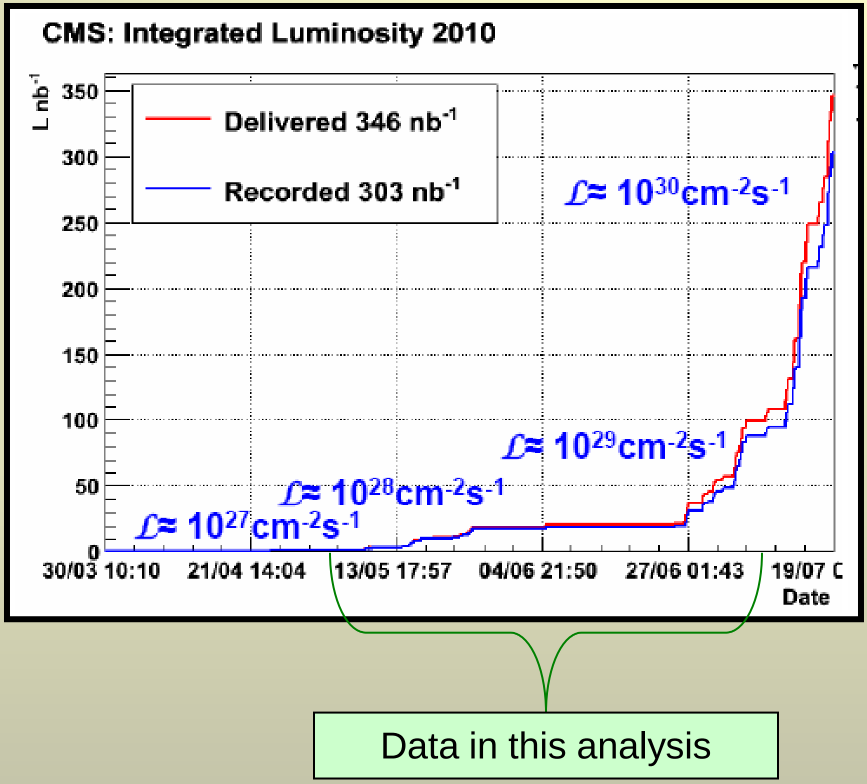
CMS PAS SUS-09-004, 10 TeV

7 TeV Data Results

Data taken March 30, 2010 – July 8, 2010

Operational status of all detectors > 98%

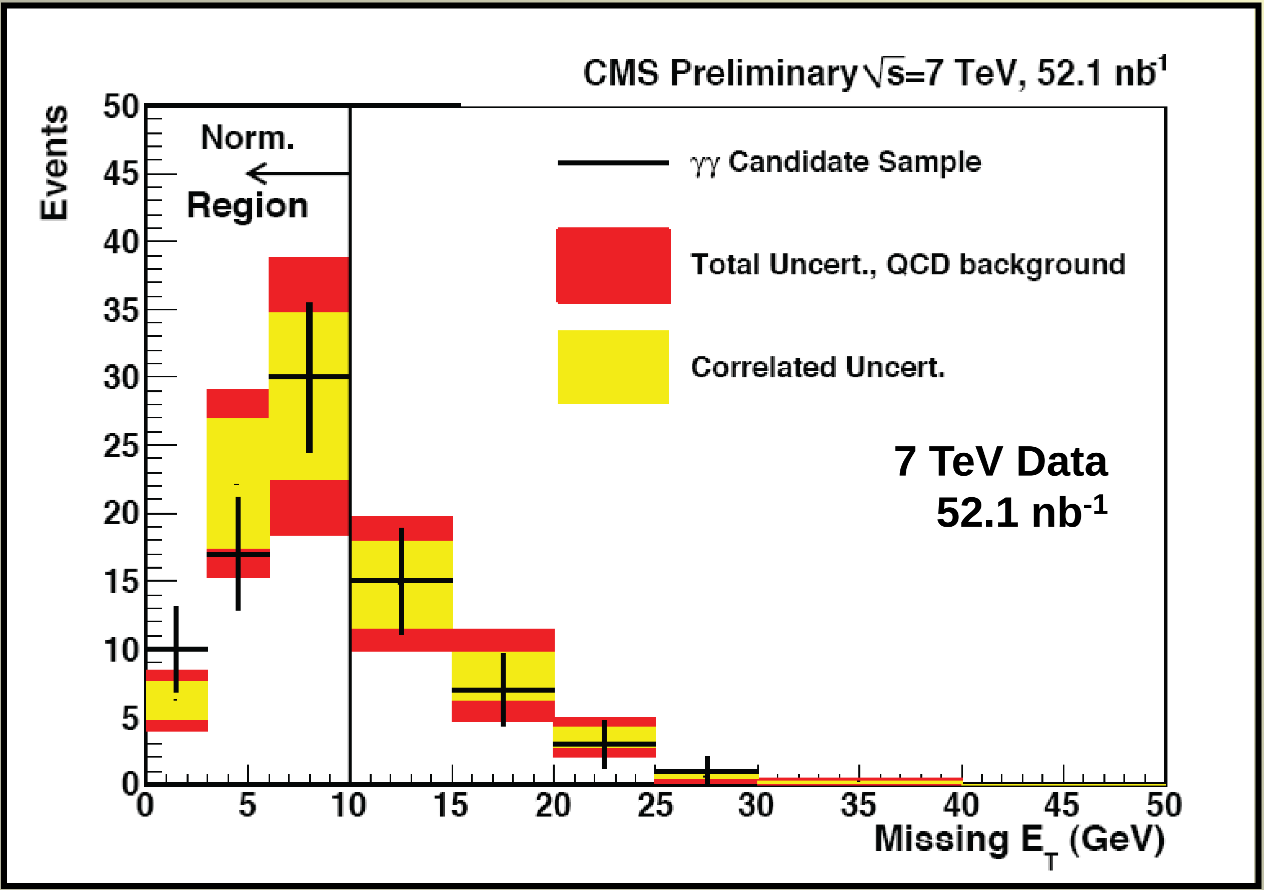
Use 52.1 nb^{-1} in this analysis



Differences with respect to MC analysis:

1). Use "fake-fake" in data analysis as opposed to Z→ee events in MC analysis.
2). pT cut decreased from data (pT > 10 GeV), different set of triggers
3). Shower-shape cut not used
4). EW analysis not completed for data analysis due to a lack of statistics.

Data Results



1. **Weight the ff events so that the di-photon pT distribution in the ff sample after reweighting matches the one in the signal sample.**

2. **Normalize the resulting MET distribution to the observed number of events with MET < 10 GeV in the signal sample.**

For MET >20 GeV:

Predicted = 4.2 ± 1.5
Observed = 4 events

Background prediction consistent with number of observed events.

CMS PAS SUS-10-001, 7 TeV

Summary

- For this analysis, we have demonstrated the ability to measure all backgrounds in data, increasing our confidence in these methods.
- Future studies will implement a jet requirement.

For more information, see:

SUS-10-001 (data)

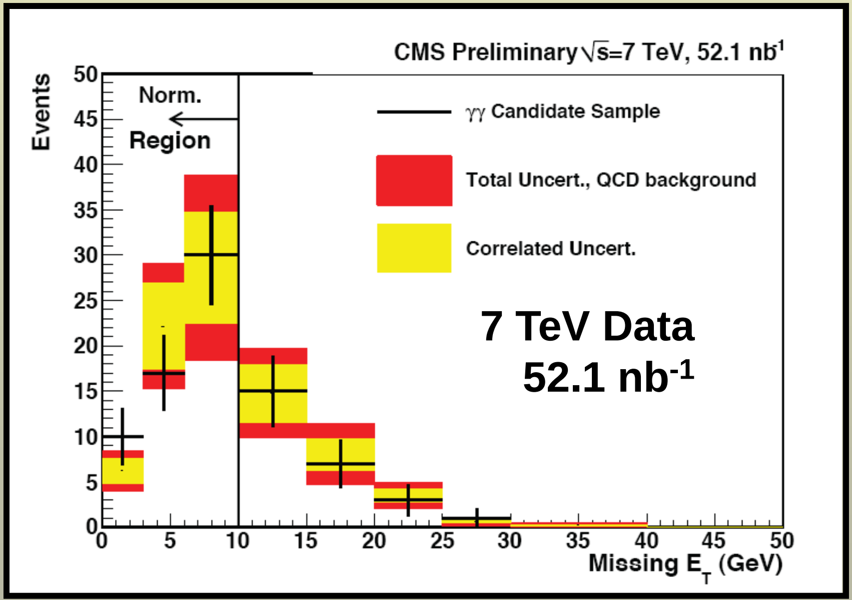
http://cdsweb.cern.ch/record/1194508/files/SUS-09-004-pas.pdf

SUS-09-004 (MC)

http://cdsweb.cern.ch/record/1279147/files/SUS-10-001-pas.pdf

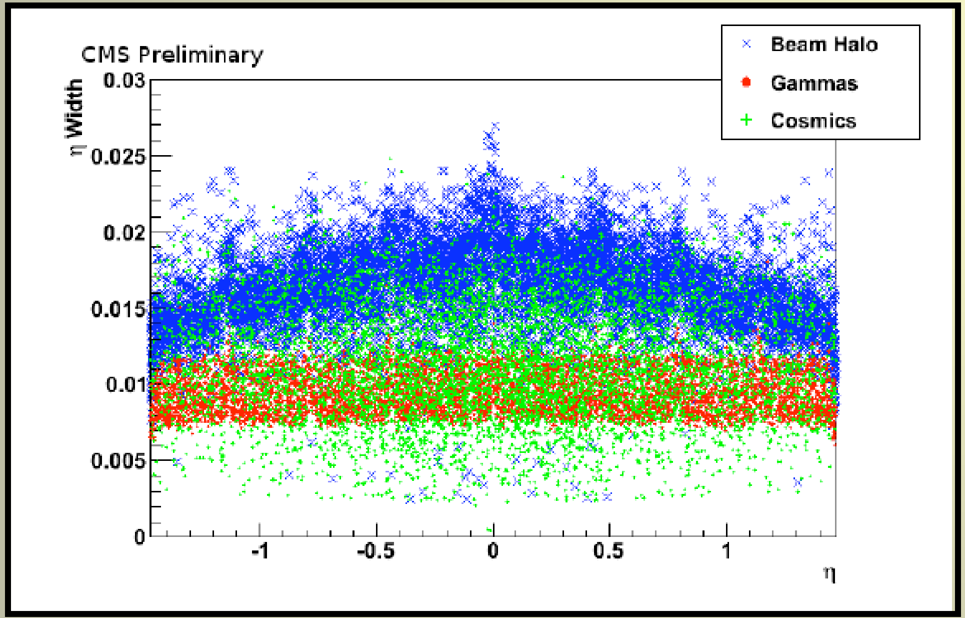
EGM-10-005 (photon reconstruction with data)

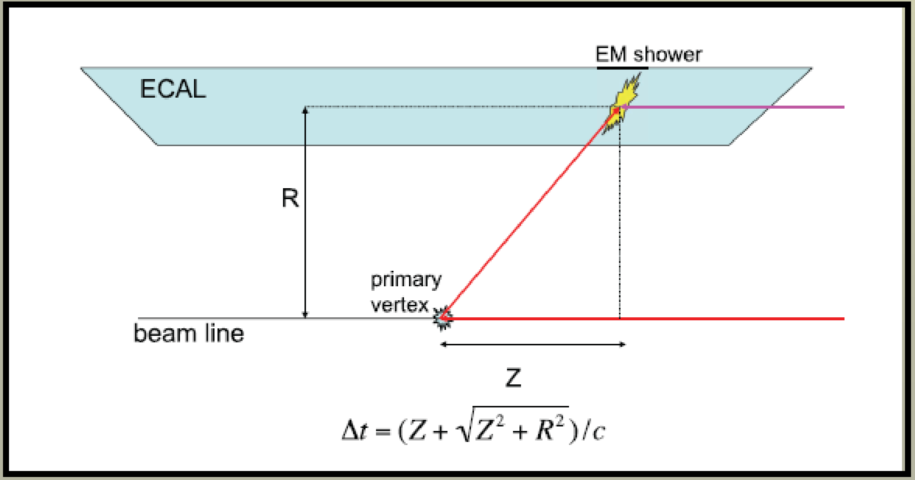
http://cdsweb.cern.ch/record/1279147/files/EGM-10-005-pas.pdf

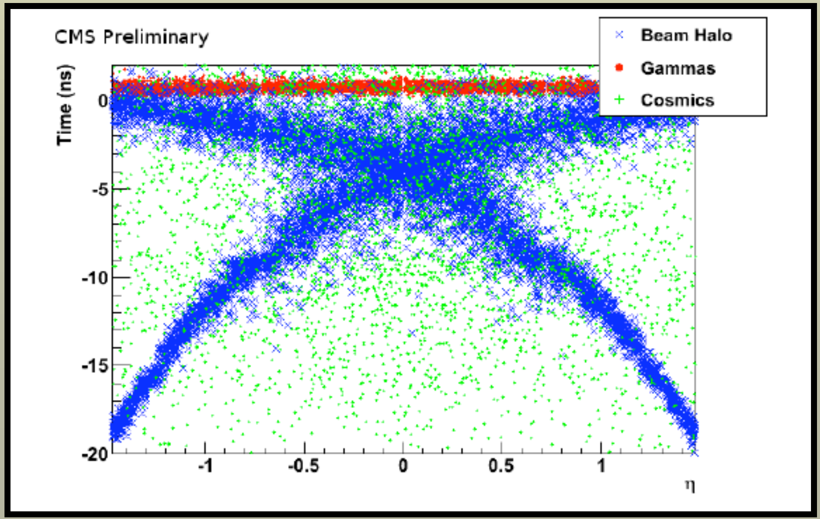


BACKUP SLIDES

Non-beam backgrounds







Photon Cuts Used

MC

- ECAL E_T > 30 GeV
- ECAL E_T in the ECAL isolation cone < 0.004 * E_T + 4.2 GeV
- HCAL E_T in HCAL isolation cone <7 GeV
- H/E < 0.1
- E_T of the tracks in the track isolation cone < 9 GeV
- Cluster width in η, Sqrt(Covηη) < 0.013

Data

- ECAL E_T > 10 GeV
- ECAL E_T in the ECAL isolation cone < 0.004 * E_T + 4.2 GeV
- HCAL E_T in HCAL isolation cone < 0.001 * E_T + 2.2 GeV
- H/E < 0.05
- E_T of the tracks in the track isolation cone < 0.001 * E_T + 2.0 GeV
- The seed shower crystal is not allowed to be within η=0.1(≈6 crystals) of the edge of the barrel at η =1.479
- The time of the seed crystal must be within ±3ns of the interaction time.

Isolation Cones