Search for Higgs Bosons Decaying to Long-Lived Exotica in the Displaced Lepton Channel: Electron ID

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Introduction

- In this talk:
    - ➡ Explain our analysis approach
    - ➡ Explain why we cannot use standard offline electrons
    - ➡ Present our electron ID
    - ➡ Explain how we measure our relevant systematics

- We welcome any comments/feedback regarding our electron ID

- Much more detail available in Analysis Note

What we are looking for

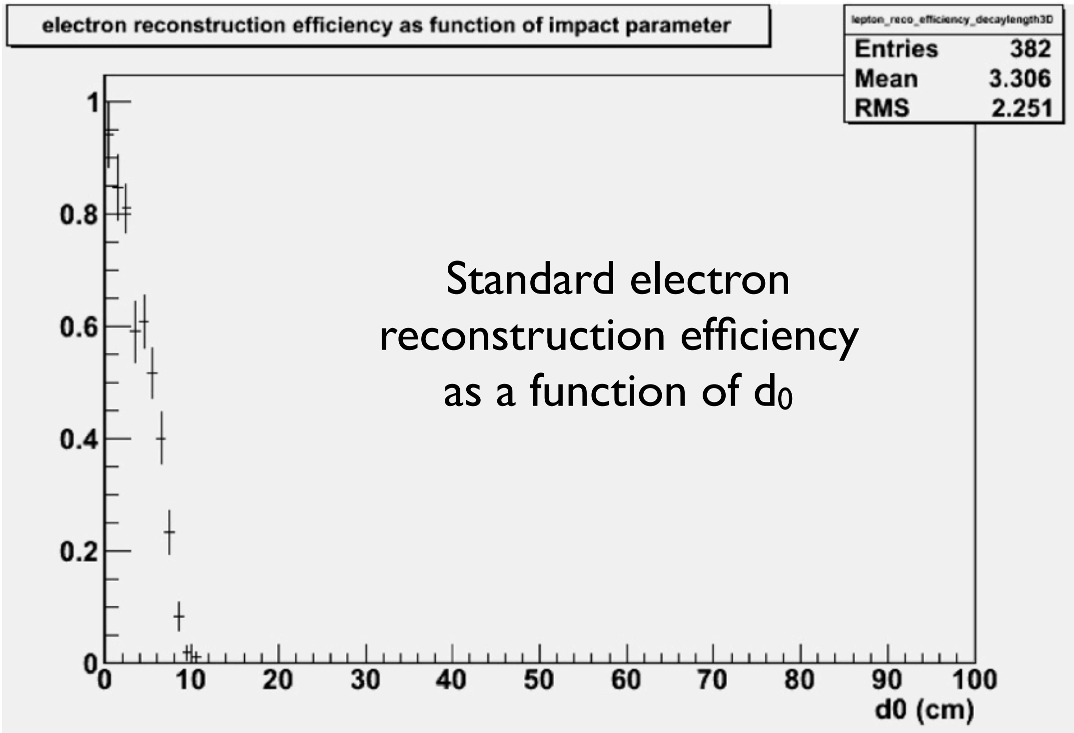
- Many models predict long-lived exotica that could decay inside CMS:
  - ➡ weakly R-parity violating SUSY
  - ➡ "split SUSY": long-lived gluinos (squarks very heavy)
  - ➡ GMSB SUSY: Neutralino→Gravitino + γ/Z with weak coupling
  - ➡ "Hidden Valley" models
- We search for the simple Hidden Valley signature: Higgs → XX → e+e-
  - ➡ X is a long-lived, neutral, spin 0 particle decaying inside the tracker volume
  - ➡ Can constrain other models where a long-lived particle decays to dielectrons with our result

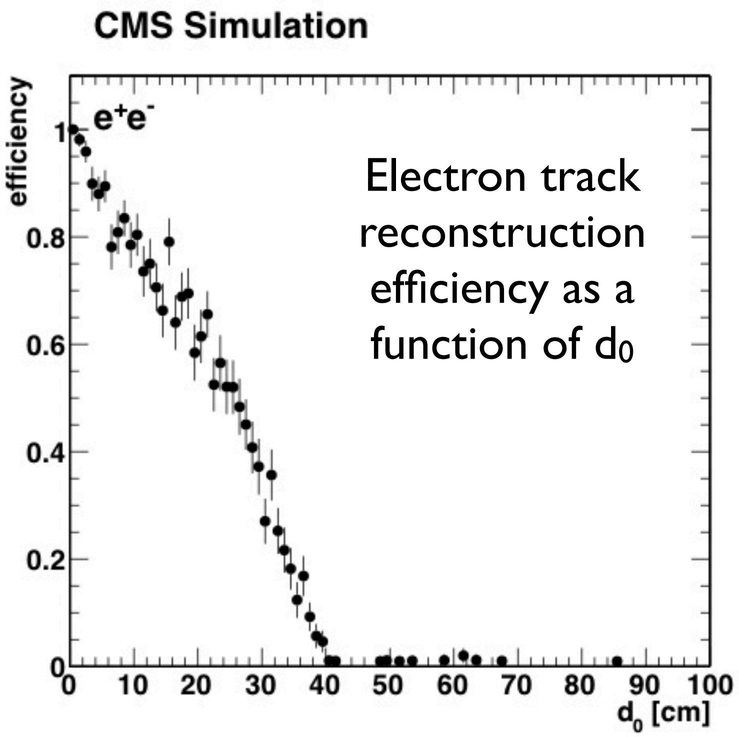
History

- Our analysis was approved for 2011 Summer Conferences (PAS EXO-11-004)
  - ➡ along with our results on long-lived particles decaying to dimuons
  - ➡ Link to CADI
- Now have a very similar analysis, except:
  - ➡ Now use all available 2011 data
  - ➡ Trigger pt thresholds increased
  - ➡ Refined limit calculation
  - ➡ Link to CADI

Why we cannot use offline electrons

- When standard offline electrons are formed by combining tracks with ECAL clusters, large impact parameter tracks from final tracking iterations are rejected
  - ➡ We would only then have electrons with impact parameters < a few cm
  - ➡ Require RECO to be able to run re-reconstruction of electrons to include tracks from final track iterations
  - ➡ Would need RECO skim of data and full set of large SM backgrounds in RECO
- We also have an issue with stand-alone muons, which are currently biased to the primary vertex





Analysis approach

- Find isolated, high p_t tracks
- Define these tracks to be electron candidates if they match to EM trigger objects
    - ➡ Don't use any offline lepton ID
    - ➡ Similar strategy for muon side of analysis
- Select only electron-pairs that form a displaced vertex
- Search for a resonance in the dielectron mass spectrum

Analysis approach

- Analysis is based on tracks that happen to be geometrically matched to trigger objects
- The behaviour and properties of our candidates are that of tracks
    - ➡ not of leptons

Triggers and datasets

- Triggers used:
  - ➡ HLT_DoublePhoton33
  - ➡ HLT_DoublePhoton33_HEVT
  - ➡ HLT_DoublePhoton38_HEVT
- Can't use electron triggers, as these require presence of a prompt track
- Photon primary dataset, integrated luminosity of 3817 pb^{-1}

Candidate Reconstruction

- Track selection:
  - ➡ high purity track selection
  - ➡ at least 6 valid hits
  - ➡ $|\eta|<2$
  - ➡ d_{xy} / σ >3
  - ➡ p_t > 41 GeV/c

This applies to all tracks in this analysis

Displaced tracking becomes inefficient beyond this point

Reject promptly produced particles

3 GeV/c higher than trigger threshold

Candidate Reconstruction

- Track selection:
  - ➡ high purity track selection
  - ➡ at least 6 valid hits
  - ➡ $|\eta|<2$
  - ➡ $d_{xy} / \sigma > 3$
  - ➡ $p_t > 41$ GeV/c

- Displaced Electron ID:
  - ➡ Define an "electron candidate" if a selected track can be matched to EM trigger object within $\Delta R < 0.1$
  - ➡ Tracker isolation: $\Sigma p_t < 4$ GeV/c within $0.03 < \Delta R < 0.3$ of electron candidate (using all tracks with $p_t > 1$ GeV/c)
  - ➡ Require offline supercluster within $\Delta R < 0.2$ of electron candidate. Electron p_t is determined from the supercluster energy instead of track p_t

Loose criteria here as background rejection comes mostly from vertexing

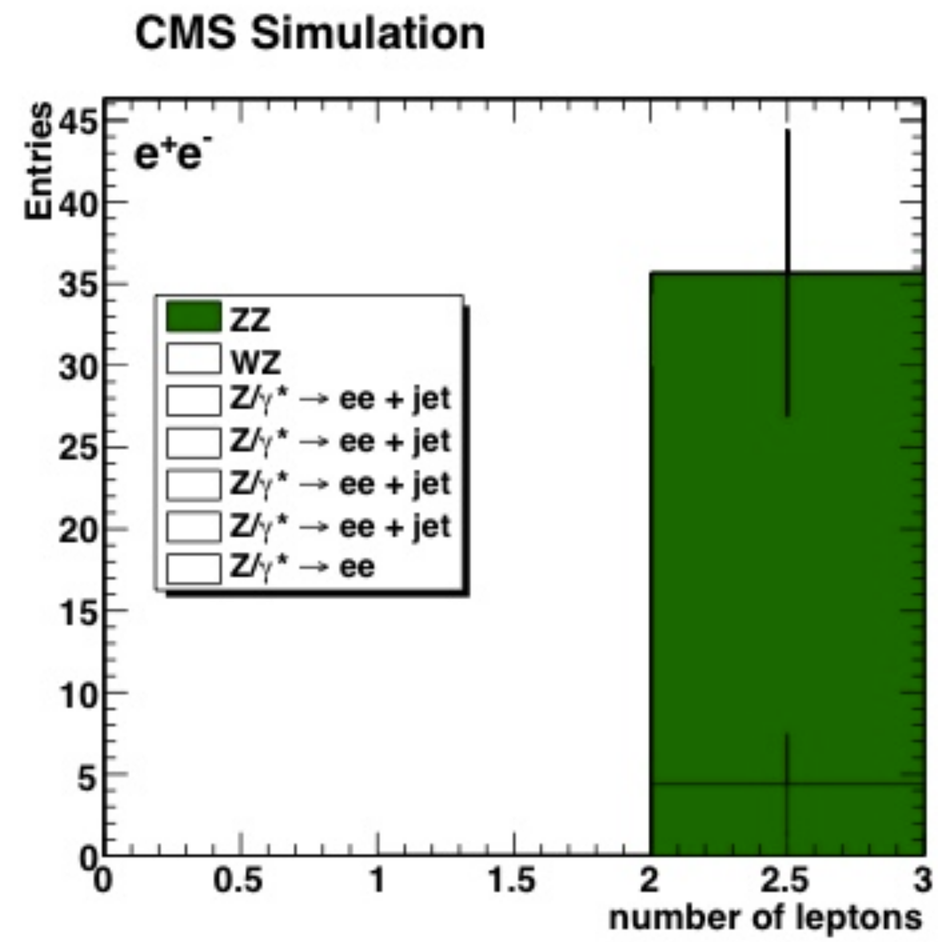
Monte Carlo simulation shows that this matching is virtually 100% efficient for genuine electrons

Candidate Reconstruction

- Negligible probability that the supercluster was produced by an electron other than the track matched to it

- Plot shows number of genuine electrons assigned to our dielectron candidates in our simulated background samples (passing all selection cuts) - there are almost always two

  - ➡ Same can be said about our simulated signal samples
  - ➡ Isolation requirement also makes it unlikely that the ECAL cluster and track were not produced by the same particle

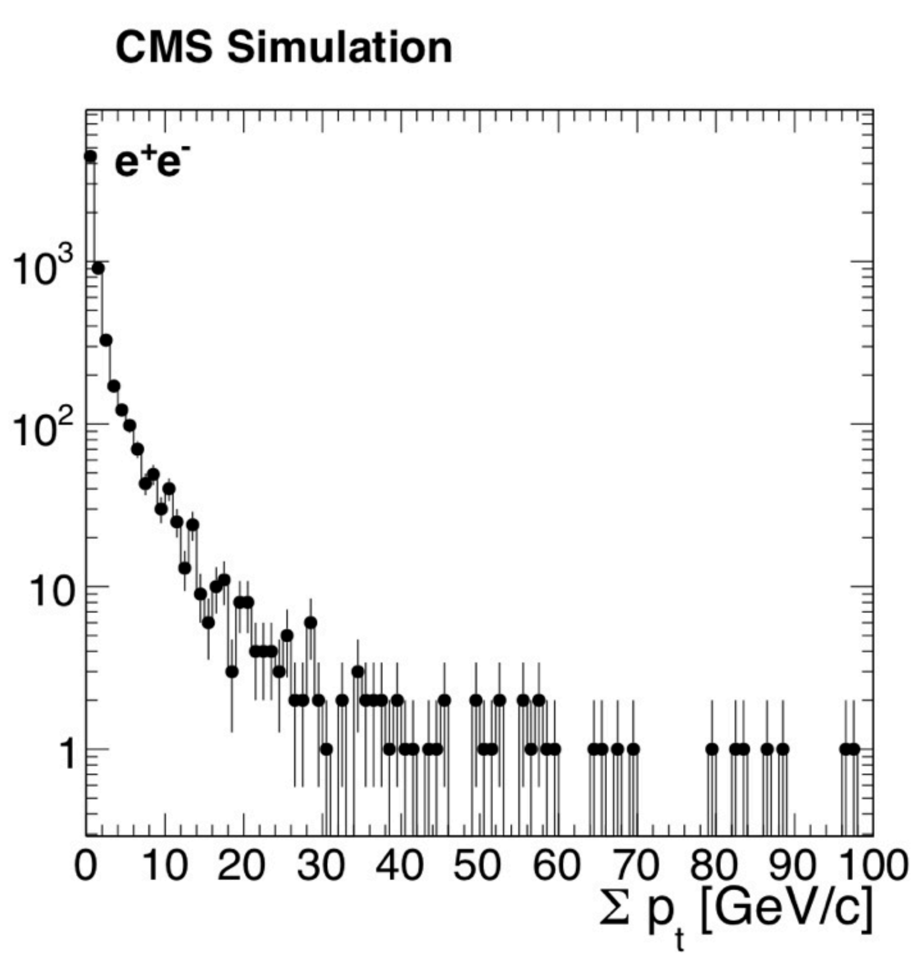


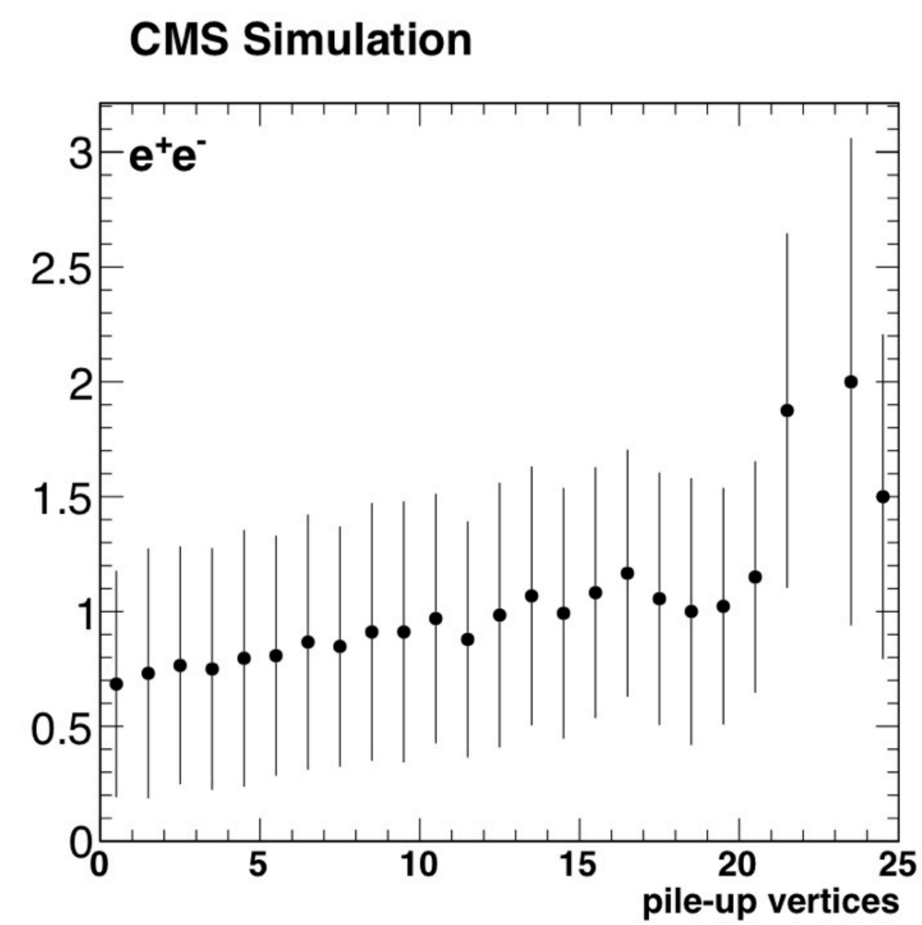
Normalisation of histogram is arbitrary

Plot currently only showing result for ZZ - fixing this

Tracker Isolation Cut

- Σp_t of tracks with p_t>1 GeV/c in isolation cone
- Mean Σp_t in isolation cone vs. number of pile-up vertices
  - ➡ For H→XX, X→ee; M_H=1000 GeV/c^2, M_X=350 GeV/c^2
  - ➡ Shows small dependance on PU





Error bars incorrect - fixing this

Candidate Reconstruction

- Track selection:
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- Displaced Electron ID:
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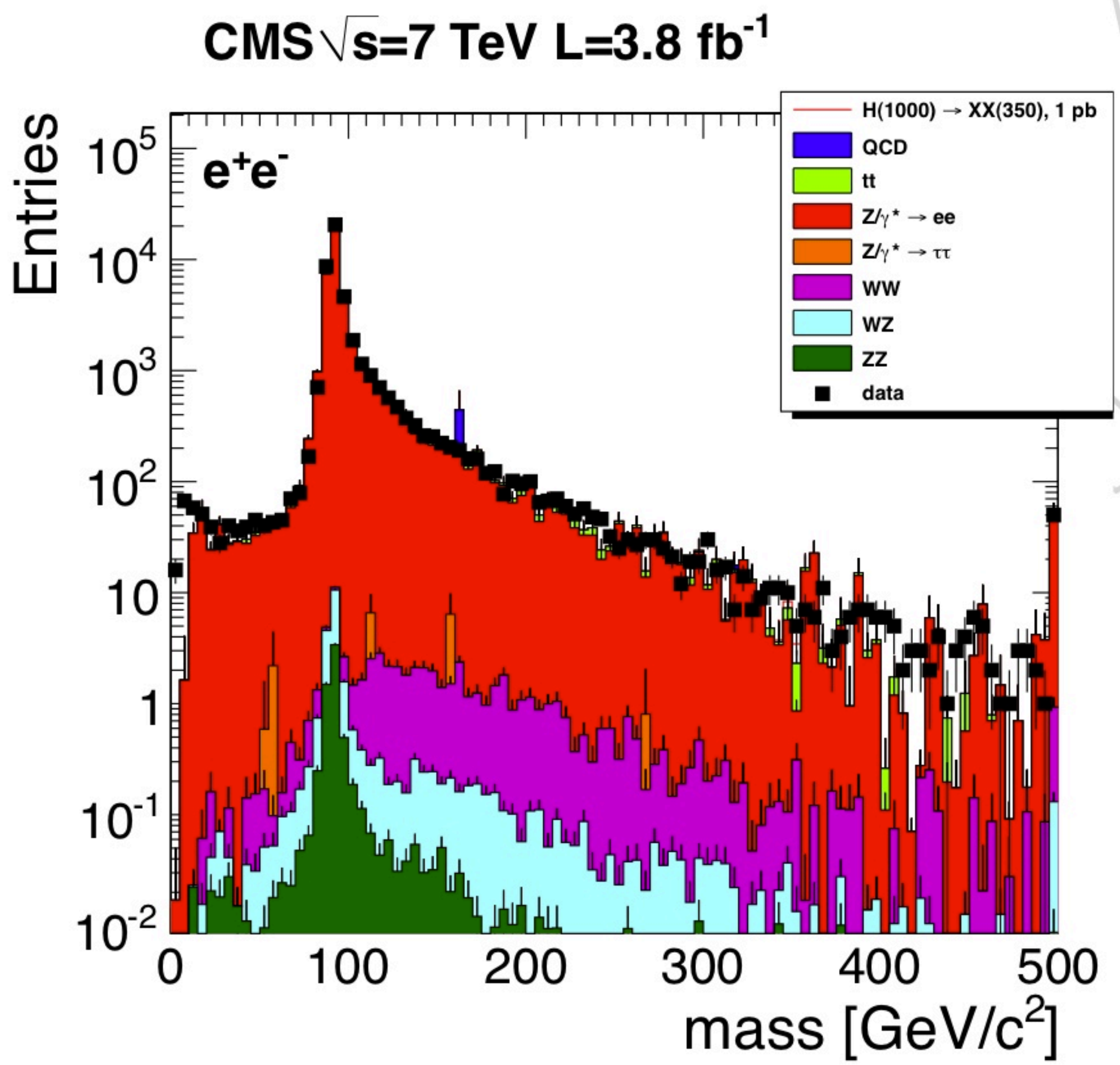
- Dielectron candidate selection
  - ➡ Require opposite charge
  - ➡ Vertex fit $\chi^2/NDF < 5$
  - ➡ Tracks have no more than one hit in front of the vertex
  - ➡ Transverse displacement of vertex > 8σ from IP
  - ➡ Candidate momentum collinear with vertex flight direction ($\Delta\phi<0.8$)
  - ➡ Plots of main selection variables and efficiency of candidate selection in Backup/AN

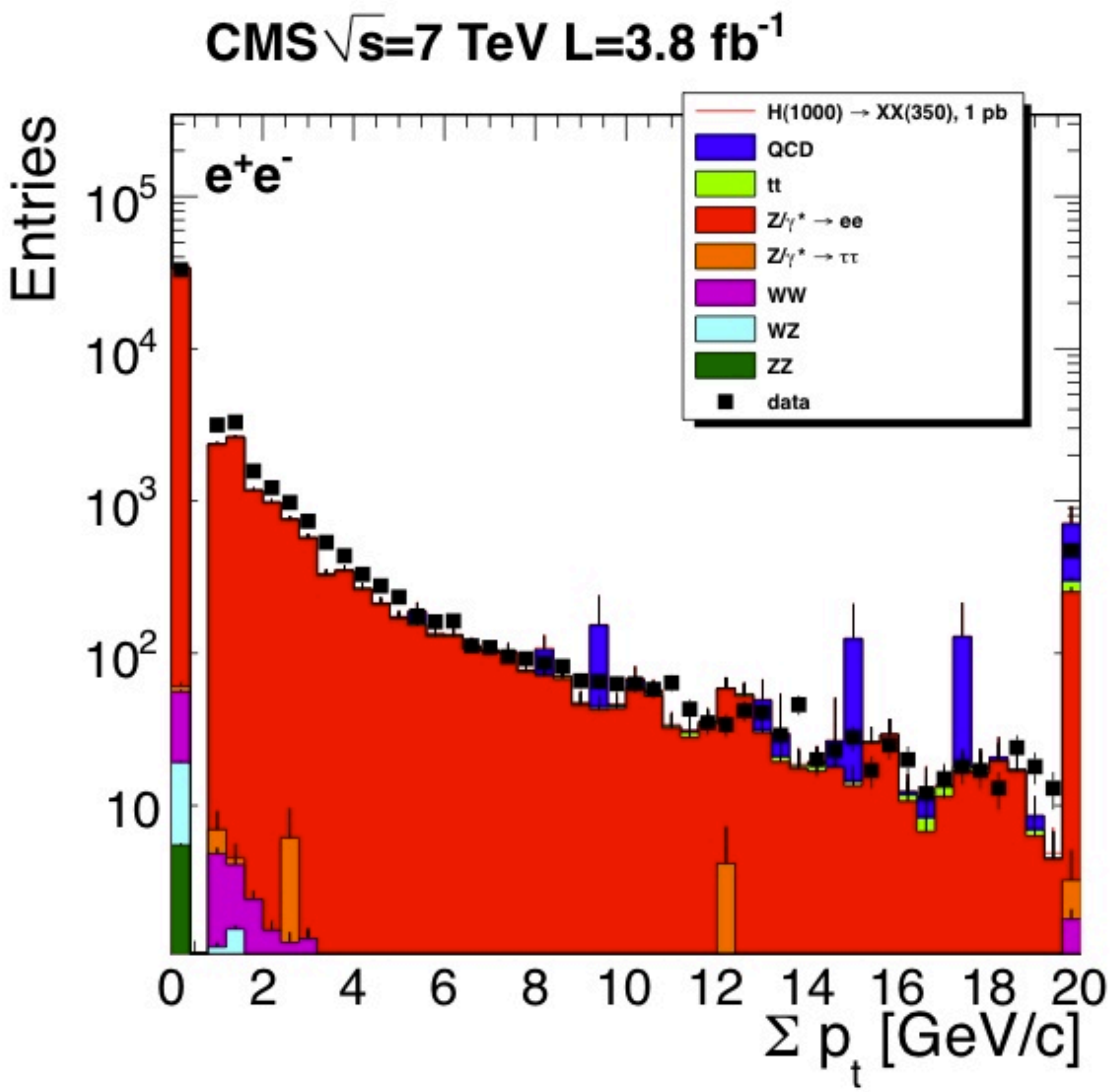
Cross-Checks Using Prompt Candidates

- By inverting transverse decay length significance cut on dielectron candidates, can get control sample.
- We see good agreement between data and MC in the dielectron mass spectrum.
    - ➡ using our electron ID



Cross-Checks Using Prompt Candidates

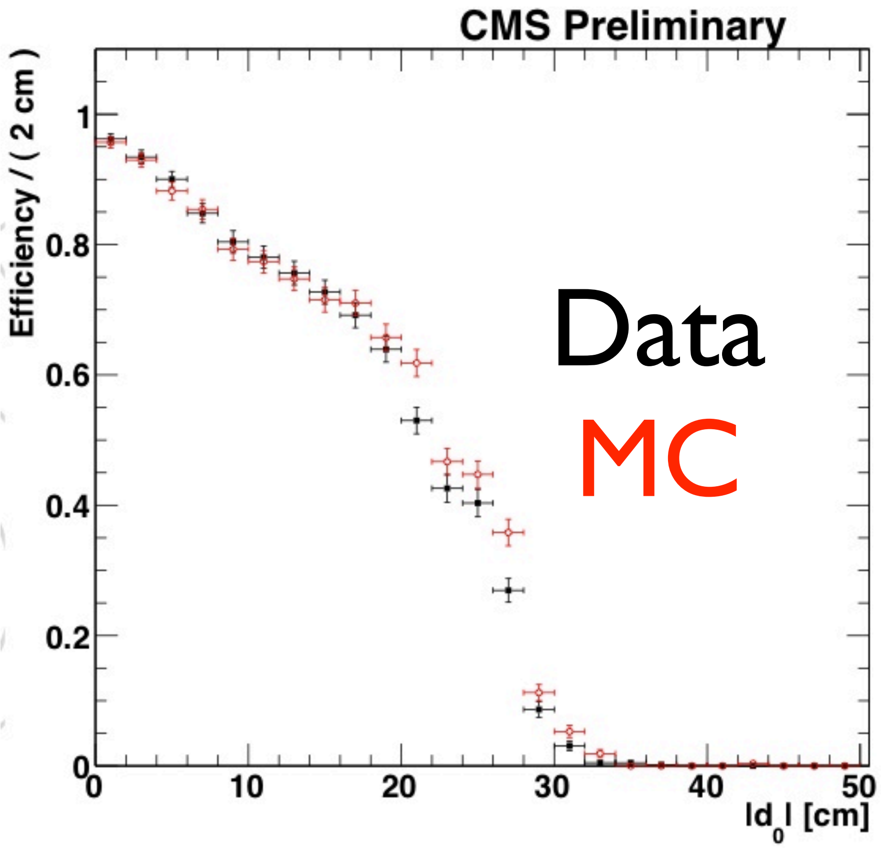
- Σp_t of tracks in isolation cone for electron candidates
    - ➡ Pass all cuts except isolation and lifetime cuts
- Again, agreement between data and MC



Plot in previous public result showed better agreement - see backup.
Problem with PU re-weighting in new analysis

Tracking Efficiency

- Provided the track of an electron has been reconstructed in the tracker (and fired the trigger) our ID is almost 100% efficient for genuine electrons
  - ➡ To reiterate, this involves geometrically matching a track to a trigger object ($\Delta R<0.1$) & matching an offline supercluster to this track ($\Delta R<0.2$)
- We have measured the tracking efficiency and associated systematic
  - ➡ By using cosmic muons
  - ➡ Details in backup
  - ➡ See good agreement between data and MC
  - ➡ Verified by using a track embedding method and from K_S^0 production



Tracking efficiency for displaced leptons understood to better than 10% relative

So corresponding relative systematic on efficiency to reconstruct dielectron candidate is 20%

Tracking Efficiency

- None of our methods to measure the tracking efficiency explicitly measures this for electrons

- However, efficiency for electrons is predicted to be only slighter lower than that for muons

  ➡ Due to Bremsstrahlung

- Material budget in tracker simulated to accuracy better than 10%

  ➡ Assume difference in tracking efficiency is modelled with similar precision

  ➡ Can be neglected in comparison to much larger systematic uncertainty on generic tracking efficiency

Track Embedding

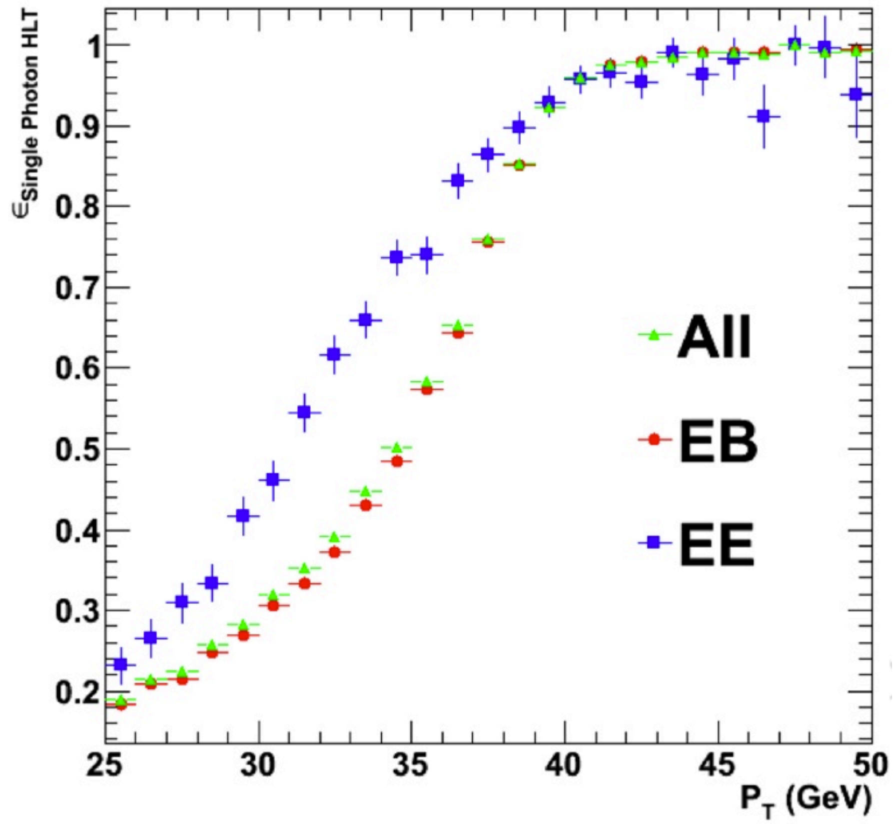
- Estimate displaced tracking efficiency by embedding single displaced, high p_t, muons into real data (HT dataset) and simulated collisions (QCD_Pt-120to170)

- Only select tracks if successfully reconstructed
  - ➡ Track passes same criteria as in physics analysis

- Can measure efficiency that muon tracks are reconstructed in tracker as function of impact parameter and number of reconstructed primary vertices
  - ➡ Difference between MC and data < 2%
  - ➡ No strong dependence on amount of PU

Trigger Efficiency Uncertainty

- Use standard tag & probe tool to determine efficiency of trigger relative to offline selection as function of offline E_t
- Use sideband trigger with diphotons, E_t threshold 18 GeV and 26 GeV
- Select dielectrons using offline selection
  - ➡ excluding lifetime cut
  - ➡ invariant mass constraint of $60<M_{ee}<120$ GeV
- Match good offline electron to trigger object (tag)
  - ➡ $\Delta R < 0.1$, $E_t > 38$ GeV
- Use other leg (probe) to determine trigger efficiency
  - ➡ Asses whether probe passes same trigger matching criterion
- Vary offline E_t threshold



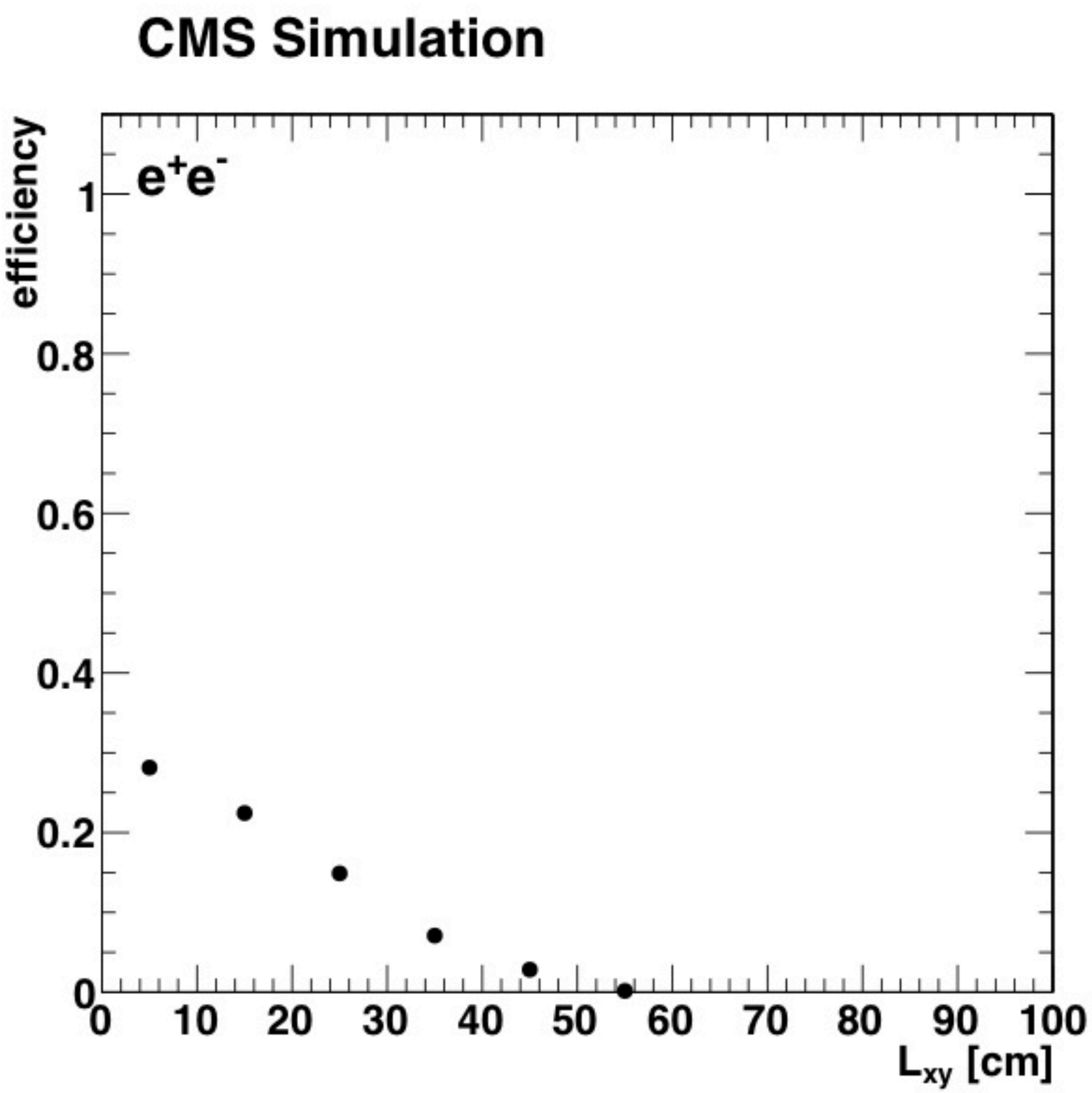
Systematic Uncertainty: 2.6%

Conclusions

- We cannot use standard electrons to search for displaced electrons
  - ➡ Instead match high purity tracks to trigger objects from double photon trigger
  - ➡ Require offline supercluster to match with this track to determine electron p_t
  - ➡ Tracker isolation applied on electron
- Have shown how we calculate systematics relevant to our electron ID
  - ➡ Understood tracking efficiency and systematic
  - ➡ Understood trigger efficiency and systematic

BACKUP

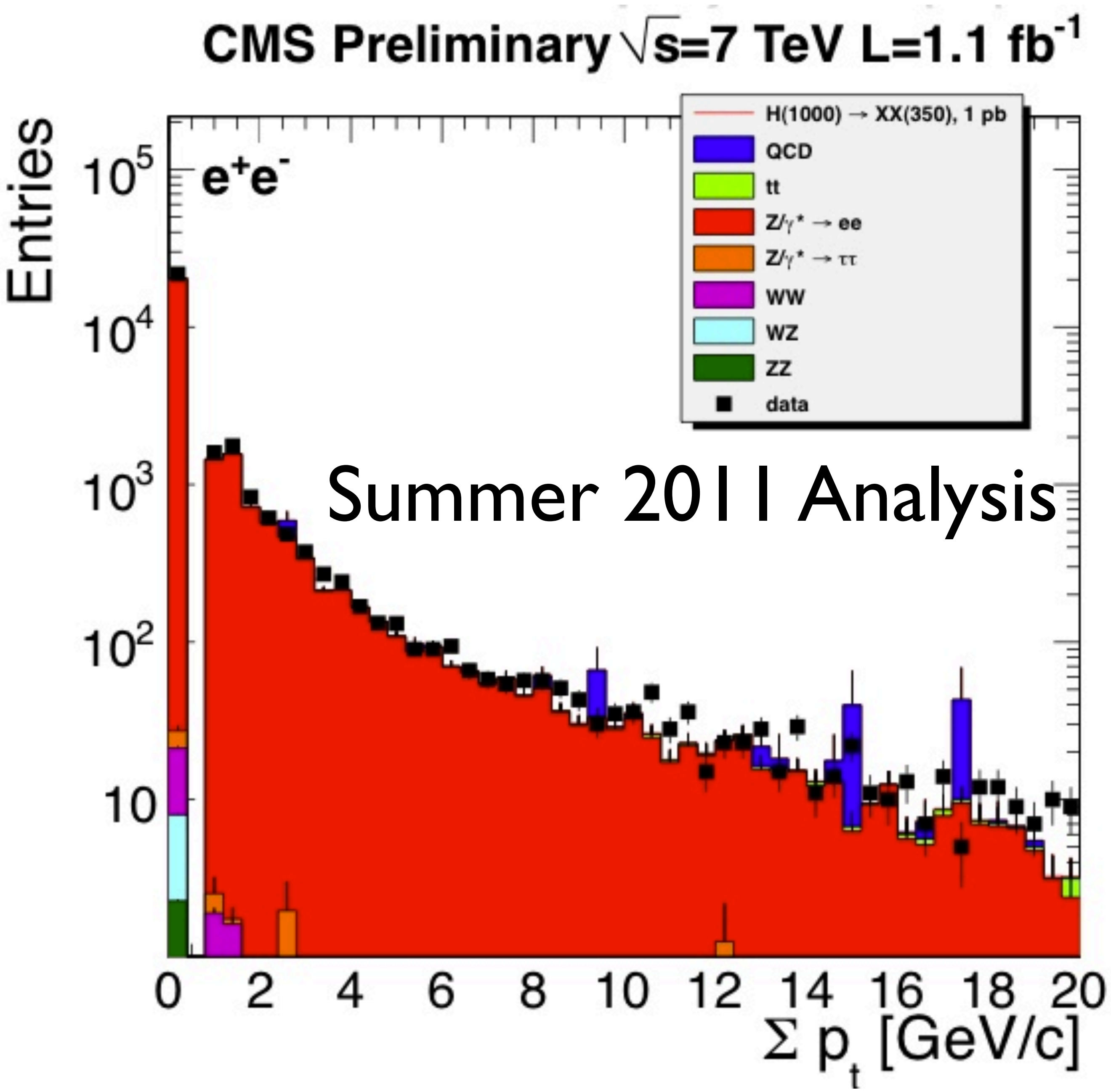
Efficiency of candidate selection



Efficiency decreases with impact parameter. Zero above ~50cm

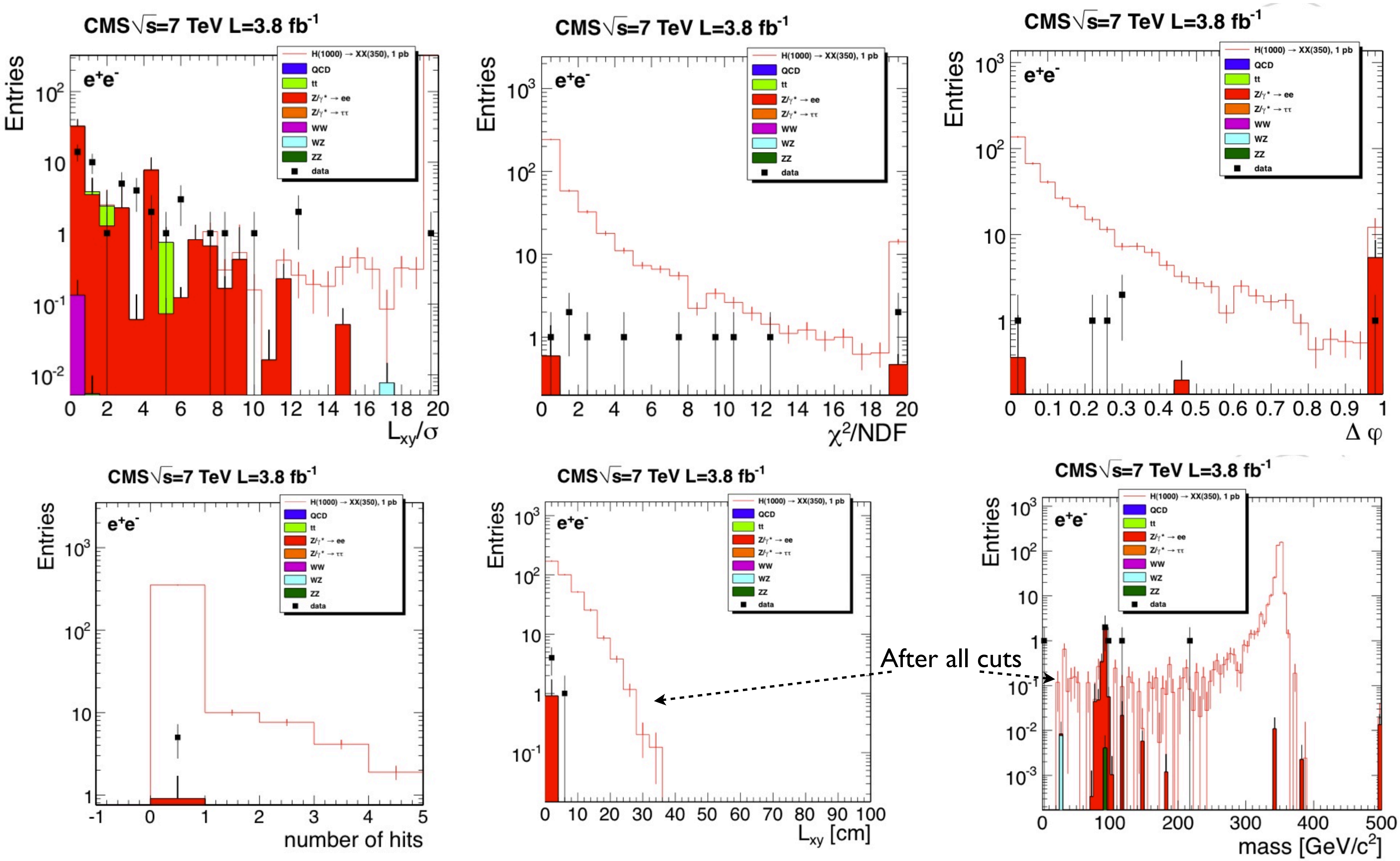
For $H \rightarrow XX$, $X \rightarrow ee$; $M_H = 1000$ GeV/c^2, $M_X = 350$ GeV/c^2

From Summer 2011



Σp_t of tracks in isolation cone for electron candidates

Selection Variables



Tracking Efficiency from Cosmic Muons

- Use cosmic muons
  - ➡ Take good cosmic tuns. Trigger: L1_SingleMuOpen
  - ➡ Tracker HV on
  - ➡ Compare with dedicated MC of simulated cosmic rays
- Cosmic muons reconstructed as two stand alone muons. Combine to give single reconstructed track
  - ➡ Exactly one cosmic muon per event
  - ➡ p_t>35 GeV/c, $|\eta|<2$
  - ➡ Estimated uncertainties on impact parameters < 1cm
- Has a track been reconstructed in tracker? Reconstruct tracks as usual and apply cuts. Match in $\Delta R<1$ cone to cosmic muon tracks.
  - ➡ p_t>25 GeV/c, $|\eta|<2$
  - ➡ High purity, >= 6 valid hits

Trigger Efficiency

Data/MC Comparison