Study of the pp→Z(→ee)+X Differential Cross Section as a Function of Z Rapidity with the CMS Detector

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For the CMS Collaboration

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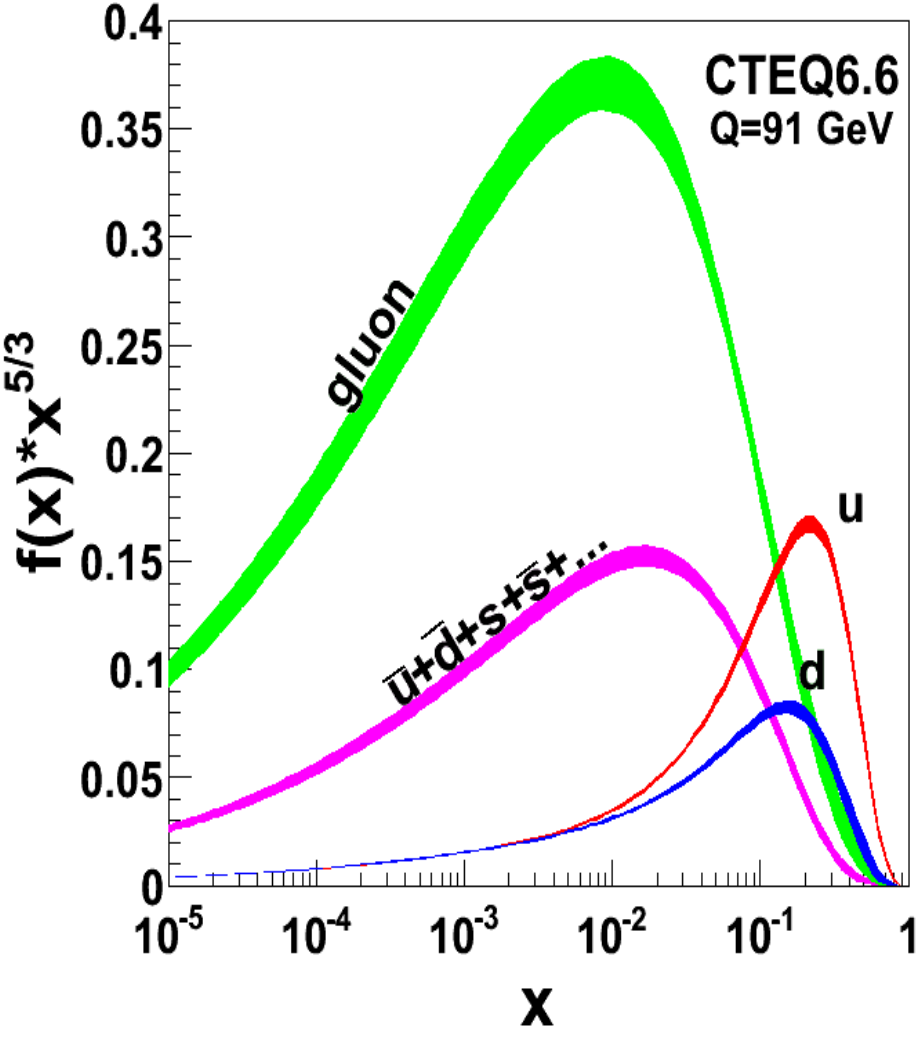
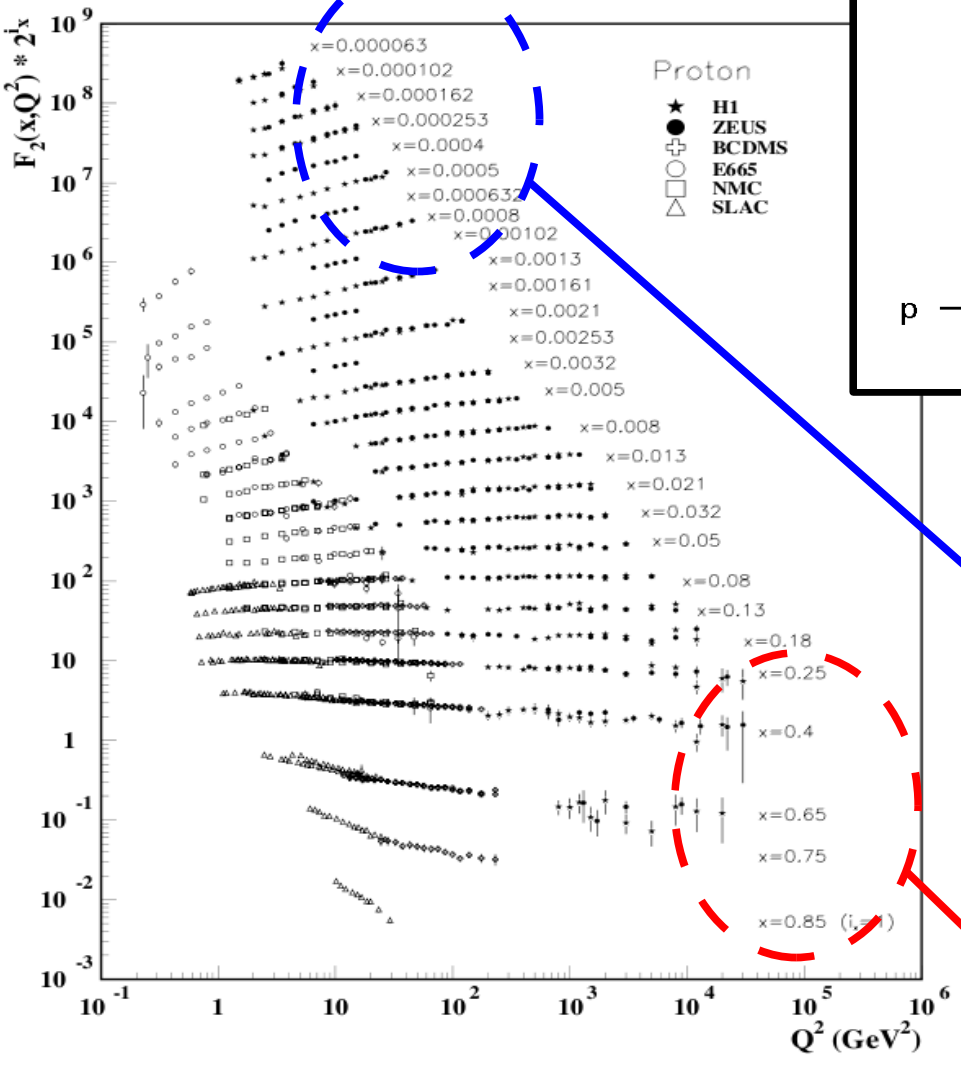
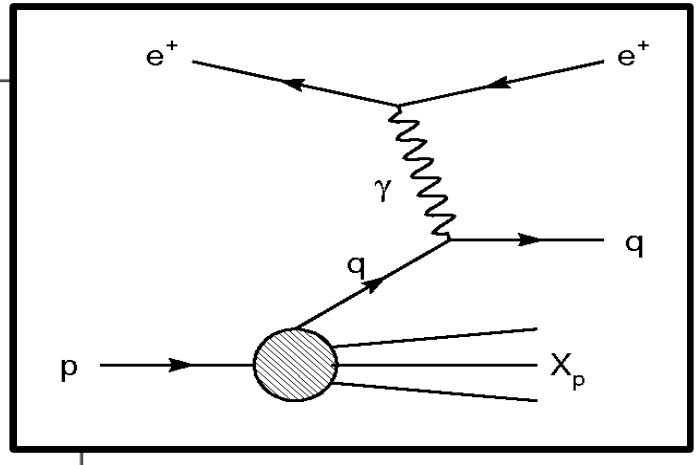
Introduction

- Collisions at the LHC are complex
  - Quarks (valence/sea), Gluons
  - Colliding partons carry only a fraction of the proton momentum
- Our understanding of the Parton Distribution Functions can be expanded at the LHC

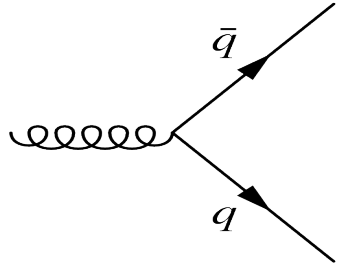


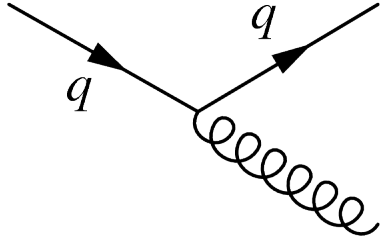
Known Behavior from DIS





Gluon splitting processes increase the density of quarks with small *x* observed at high Q^2



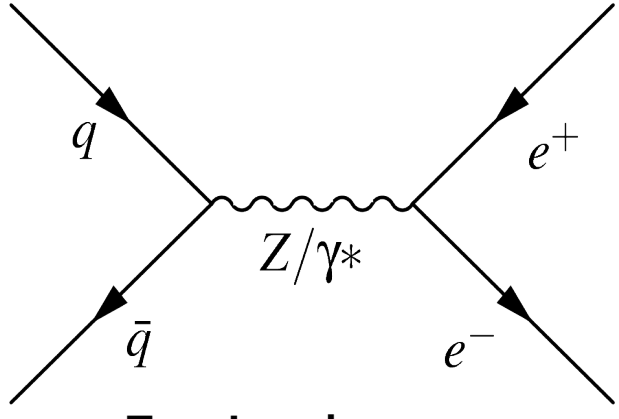


Gluon radiation processes decrease the density of quarks with large *x* observed at high Q^2

Using the Z to Probe PDFs

- Probing PDFs at LHC
  - Theoretical challenges
  - Jet challenges
  - Photon challenges
- Probing PDFs using Z bosons
  - Lepton reconstruction has high precision
  - Z event reconstruction has low background levels
  - Theory advantages of weak-scale physics

For the annihilation diagram there is a direct link between Z rapidity and the parton momentum fraction



Tree Level

$$x = \frac{m_Z}{\sqrt{s}} e^Y$$

CMS Detector

SUPERCONDUCTING COIL

|η| < 3.0

ECAL
Scintillating PbWO4 crystals

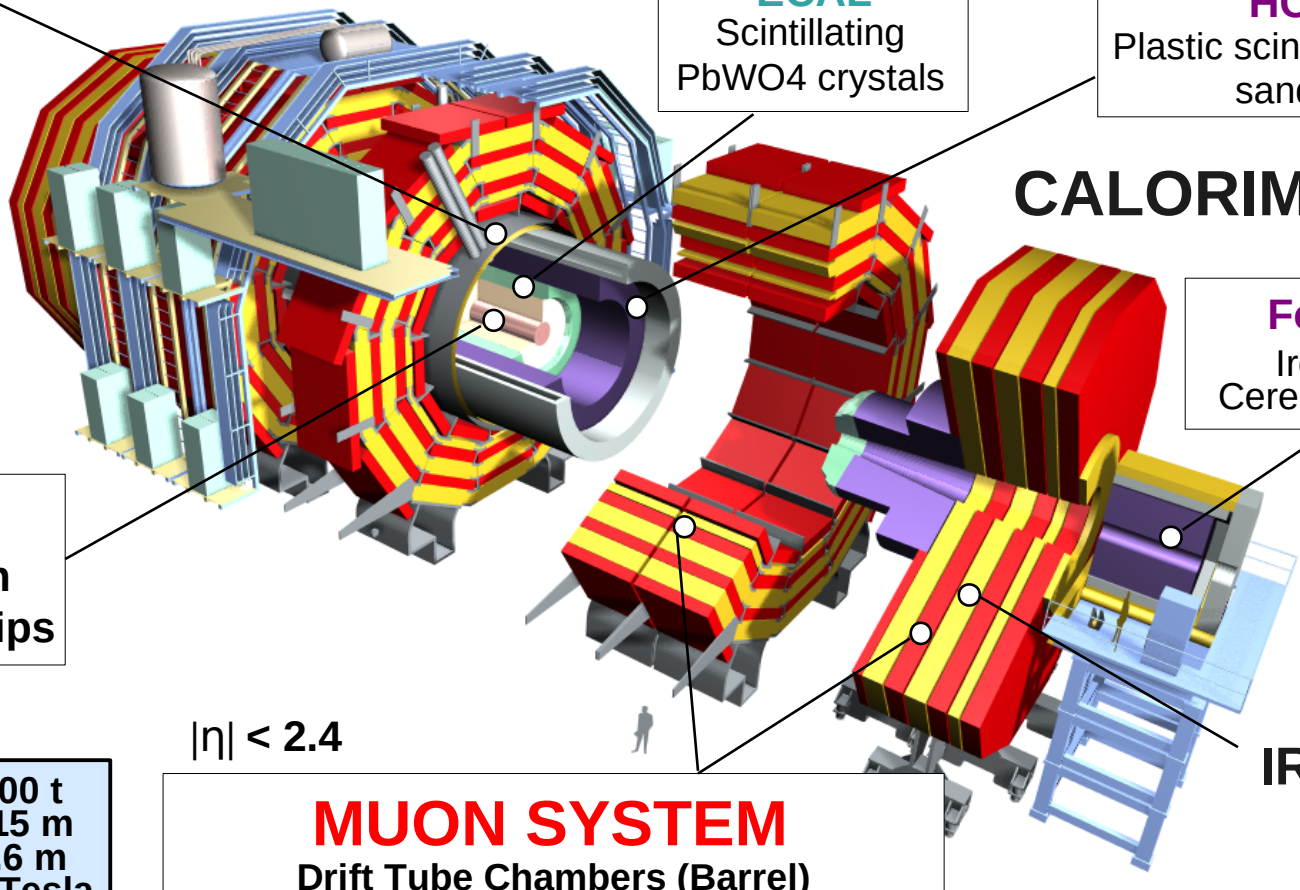
|η| < 3.0

HCAL
Plastic scintillator/brass sandwich

CALORIMETERS

Forward (HF)
Iron/quartz fiber Cerenkov Calorimeter

3.0 < |η| < 5.0



|η| < 2.4

TRACKER

Pixels

Silicon Microstrips

|η| < 2.4

MUON SYSTEM
Drift Tube Chambers (Barrel)
Cathode Strip Chambers (Endcap)
Resistive Plate Chambers (Barrel, Endcap)

IRON YOKE

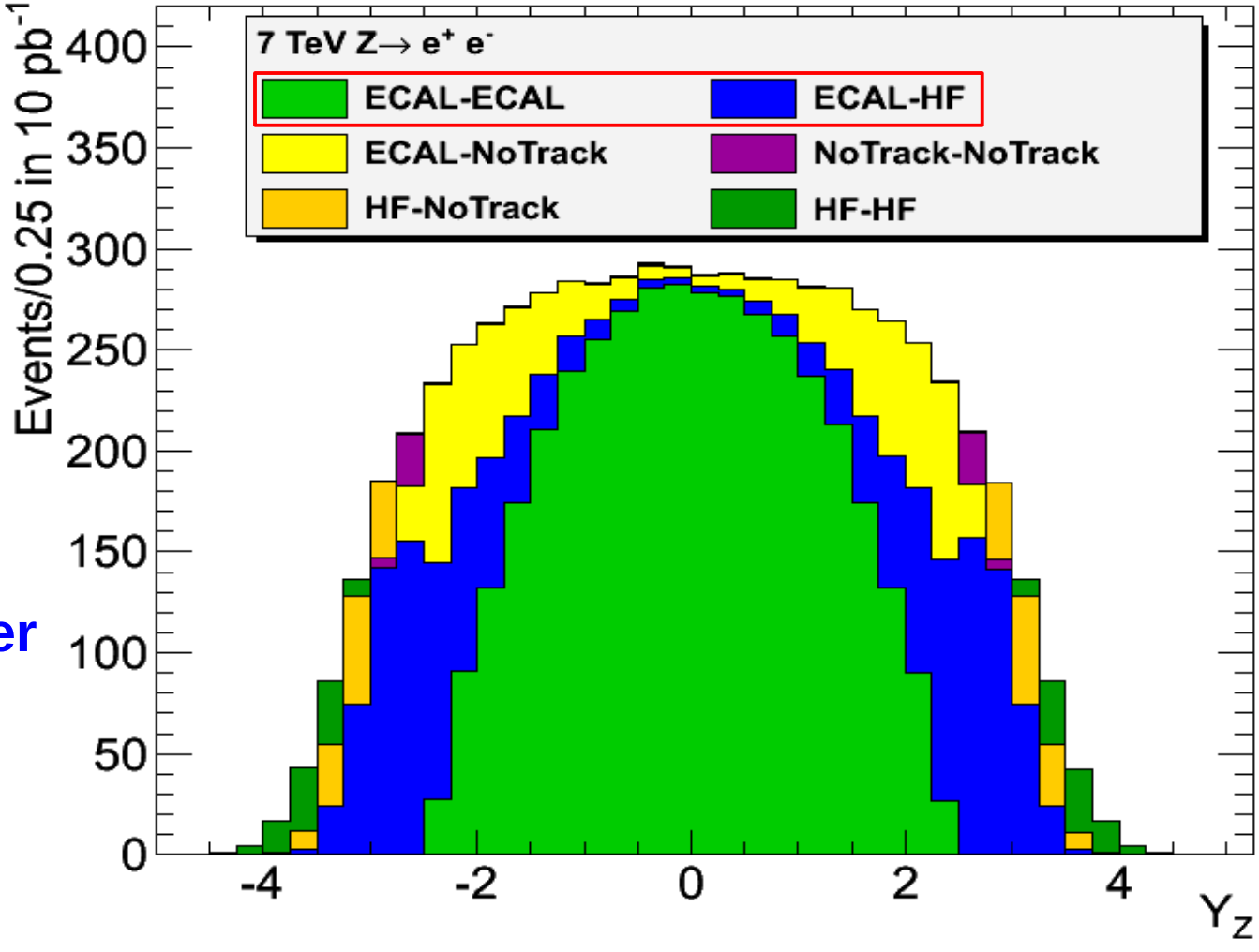
Total weight: 14,000 t
Overall diameter: 15 m
Overall length: 21.6 m
Magnetic Field: 3.8 Tesla

Detector Acceptance

CMS acceptance balanced around η=0

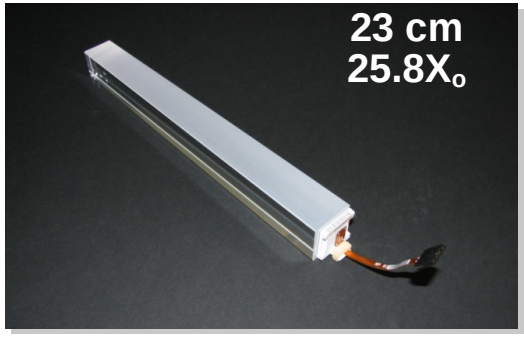
Access to $|Y_z| > 2$ requires use of the forward calorimeter

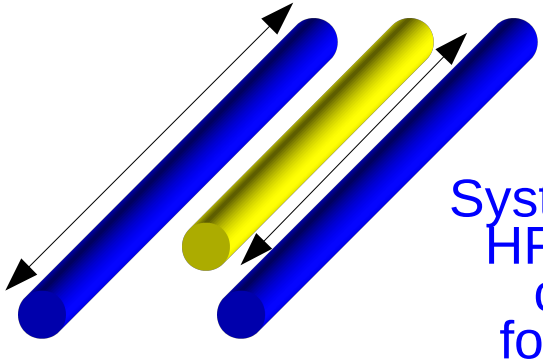
Region not accessible to Z→μμ at CMS



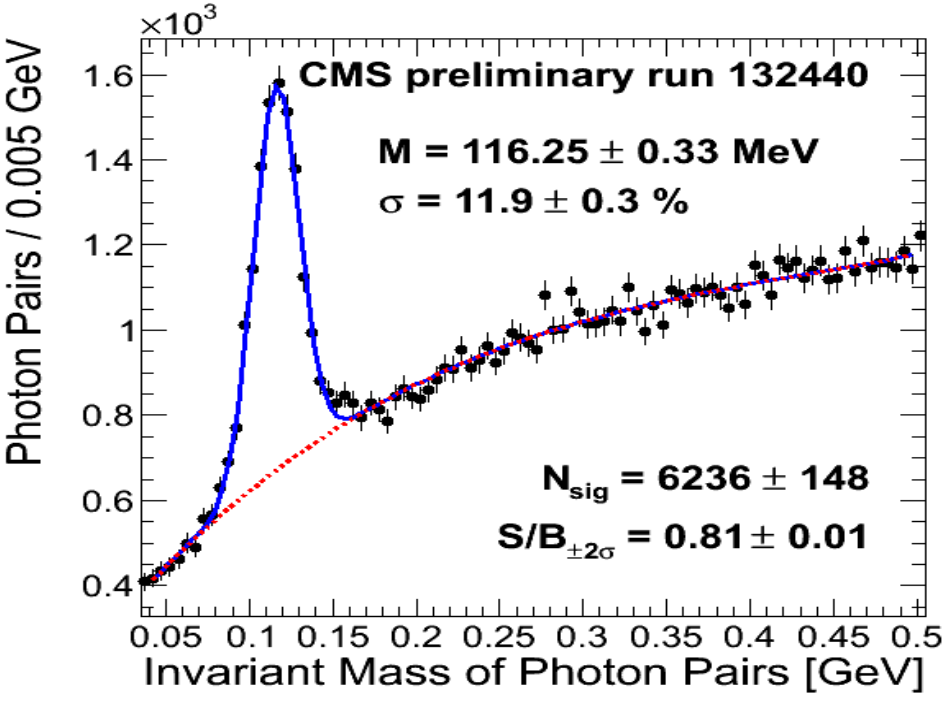
Electrons in the Detector

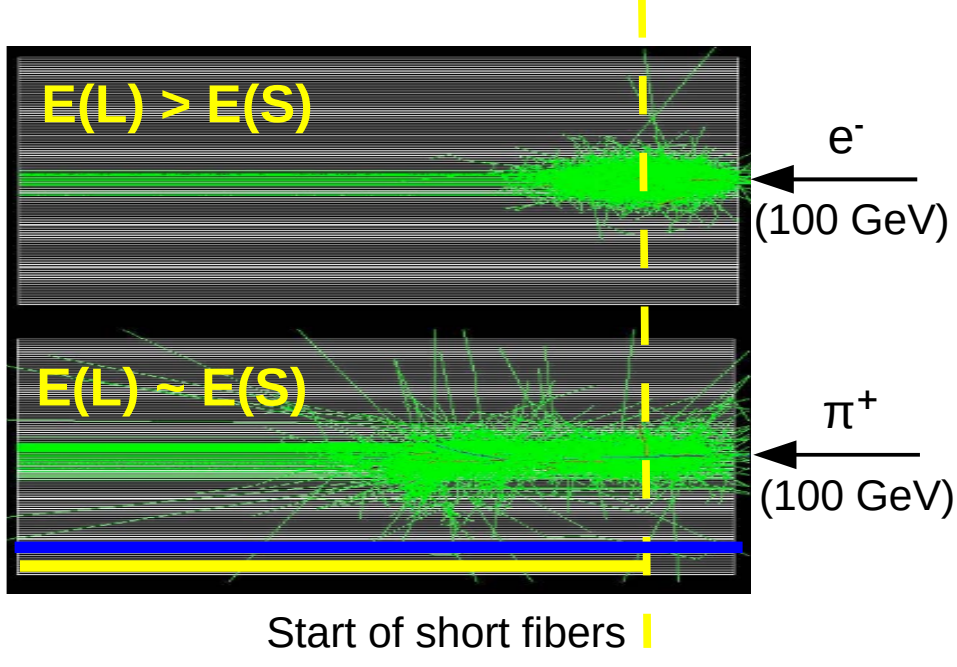
$PbWO_4$ crystal
(ECAL Barrel)





System of long/short HF fibers partially compensates for E/H response

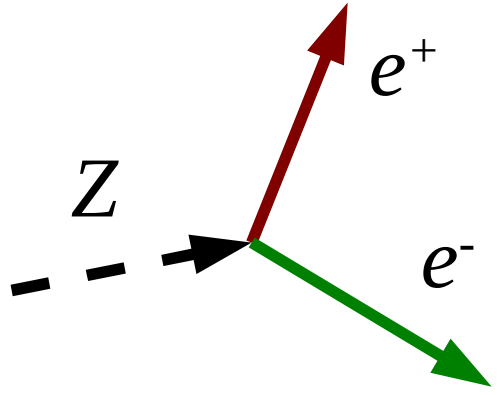




Rapidity Measurement

$$\frac{1}{\sigma}\frac{d\sigma(Z \to e^+e^-)}{dY_i} = \frac{(\epsilon \times A)}{N - B} \cdot \frac{N_i - B_i}{\Delta_i(\epsilon \times A)_i}$$

Shape measurement:
Many systematics cancel



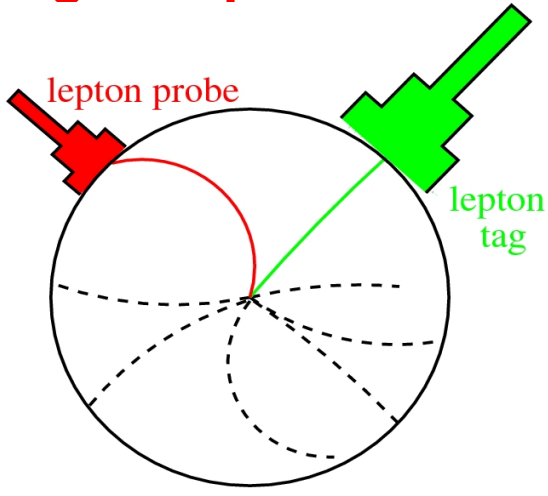
Determine single electron efficiencies from data, convolve with simulated Z electron distributions

$$(\epsilon \times A)_i = \int P_i(\eta_1, \eta_2, p_{T1}, p_{T2})\,\epsilon(\eta_1, p_{T1})\,\epsilon(\eta_2, p_{T2})$$

Note: Studies performed with 10 TeV simulated events (100 pb^{-1})

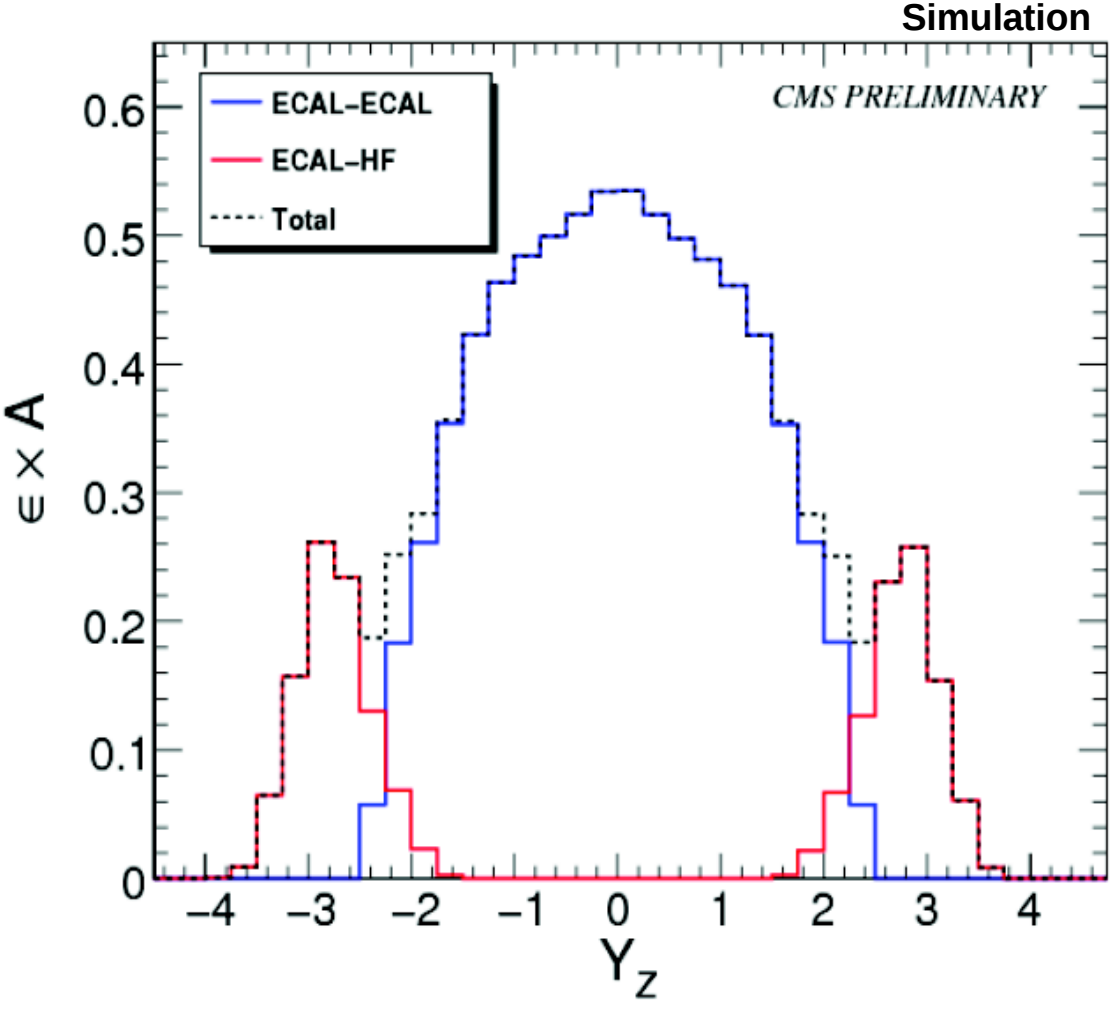
Efficiency x Acceptance

Electron efficiencies computed from data using the **tag and probe** technique



Simulation corrected to match kinematic distributions from data

Data-driven (ϵ x A) is determined for each rapidity bin



PDF Systematics and Sensitivity

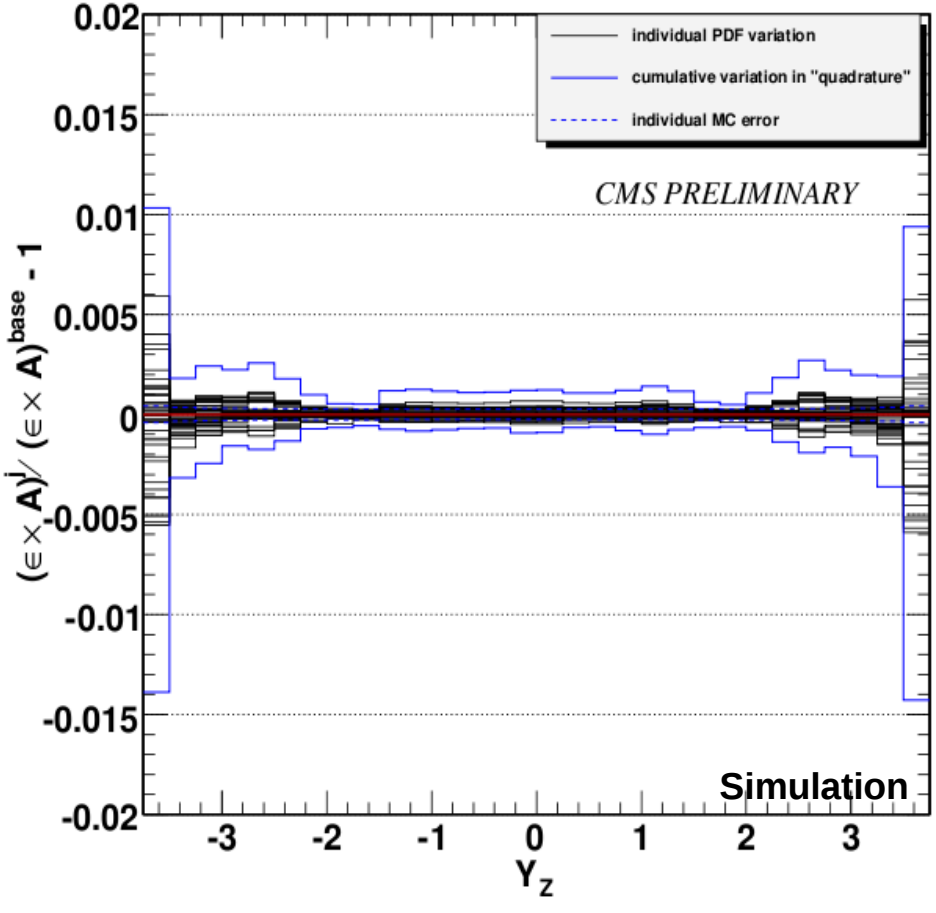
$$\frac{1}{\sigma}\frac{d\sigma(Z \rightarrow e^{+}e^{-})}{dY_i} = \left[\frac{N_i - B_i}{N - B}\right] \cdot \left[\frac{(\epsilon \times A)}{\Delta_i(\epsilon \times A)_i}\right]$$

Ratio will vary as a function of the Y bin
if PDFs differ from base expectation
This describes the PDF measurement sensitivity

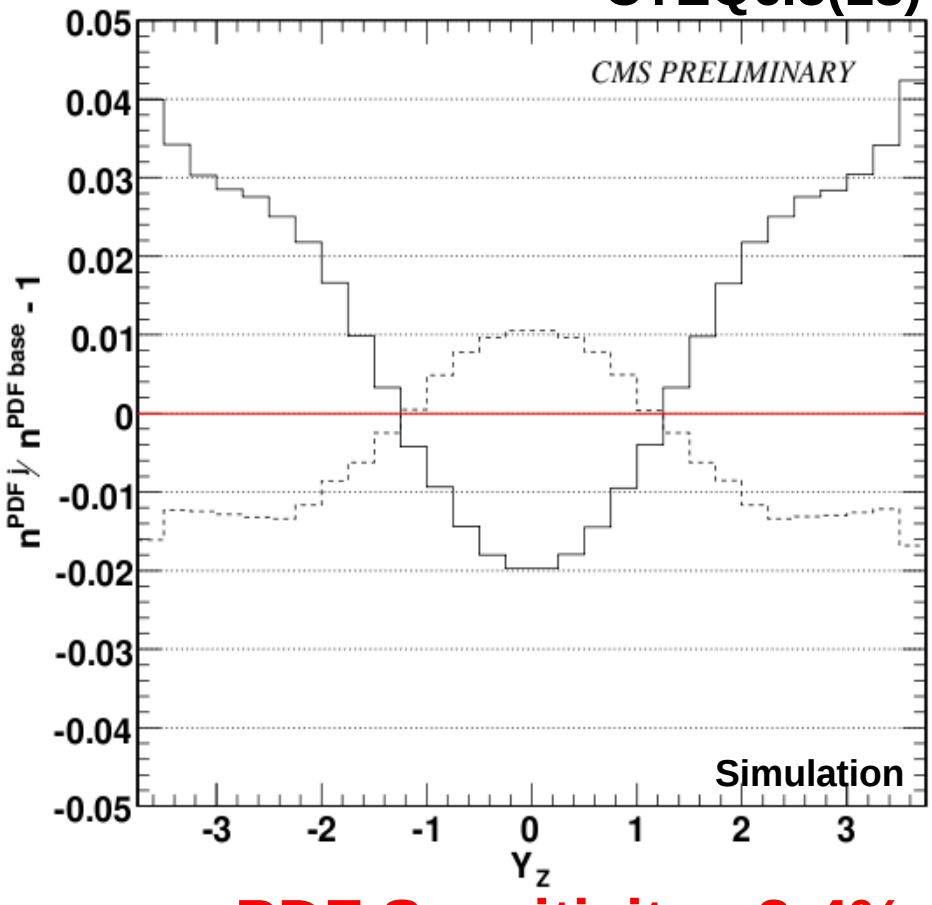
The ratio of (Є x A) for a given Y bin
should not change for different PDFs
Assign a systematic uncertainty to this

Systematics and Sensitivity

Systematic Uncertainty < 0.2%

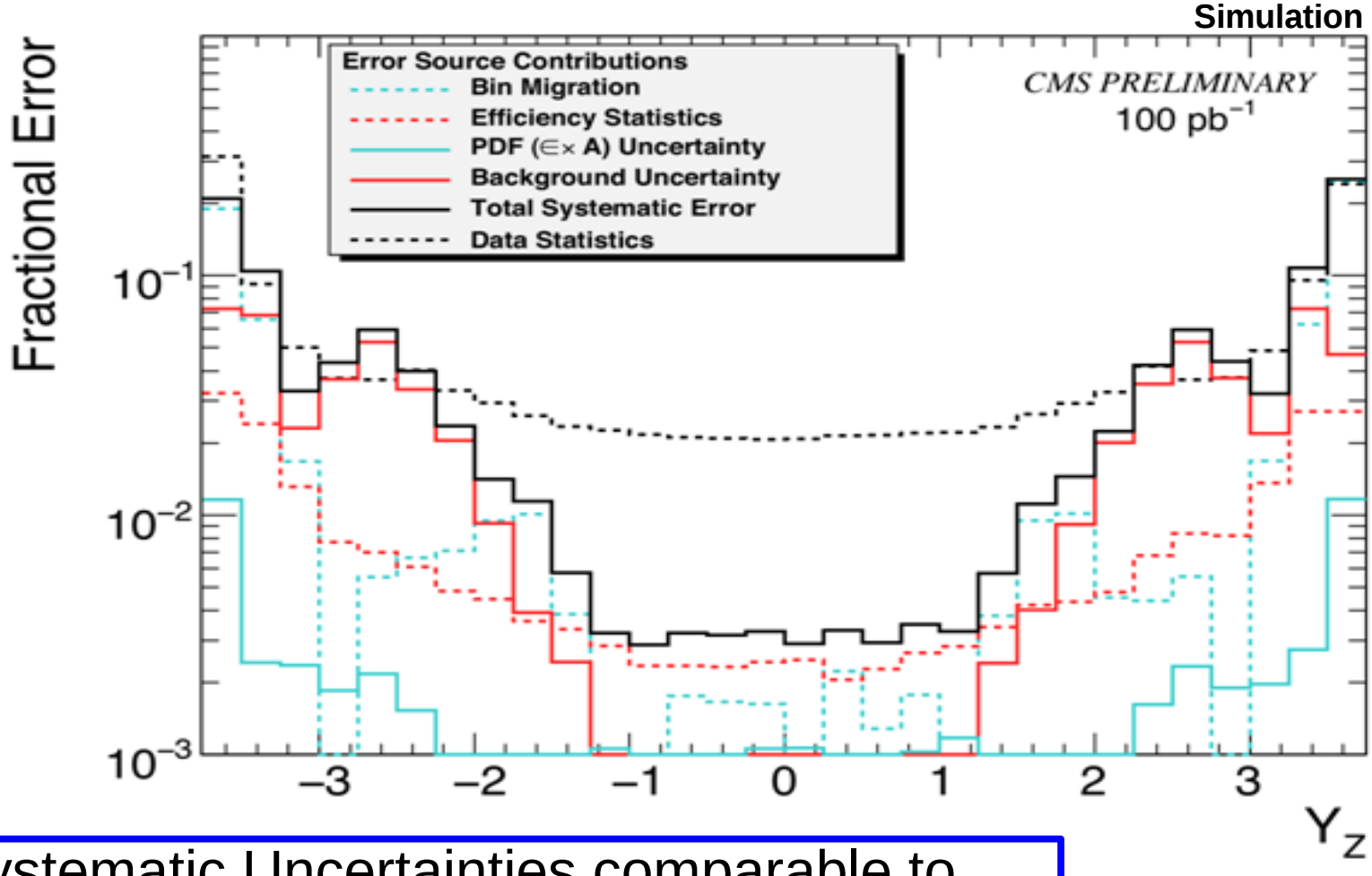


CTEQ6.5(13)



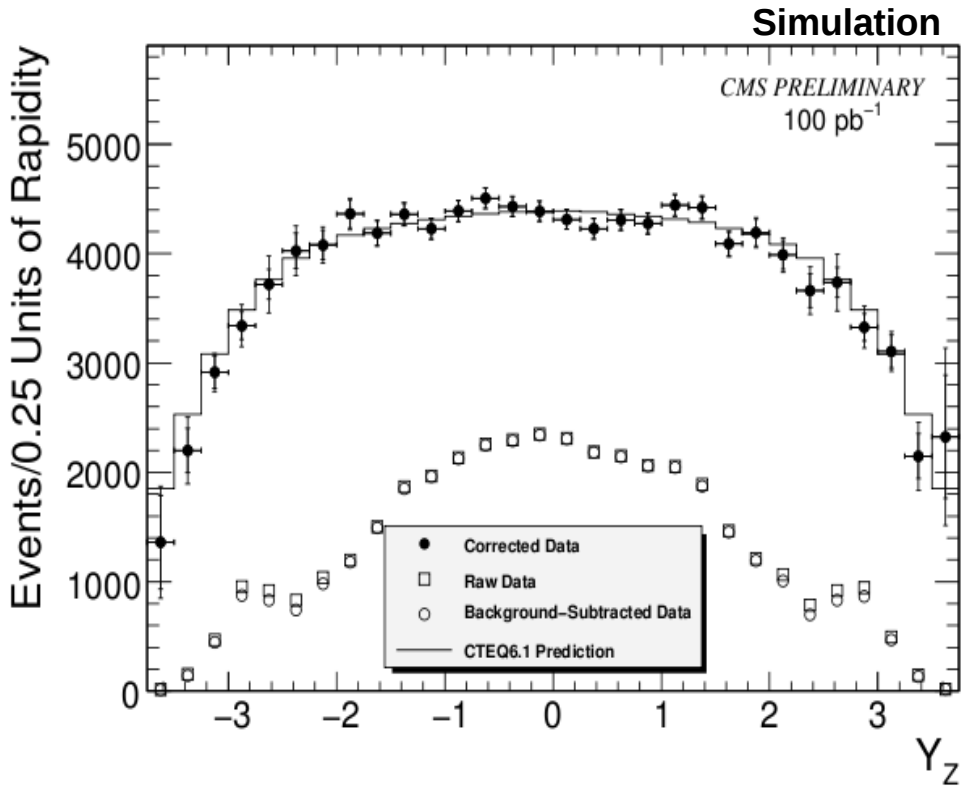
PDF Sensitivity ~2-4% at large |Y|

Sources of Systematic Uncertainty

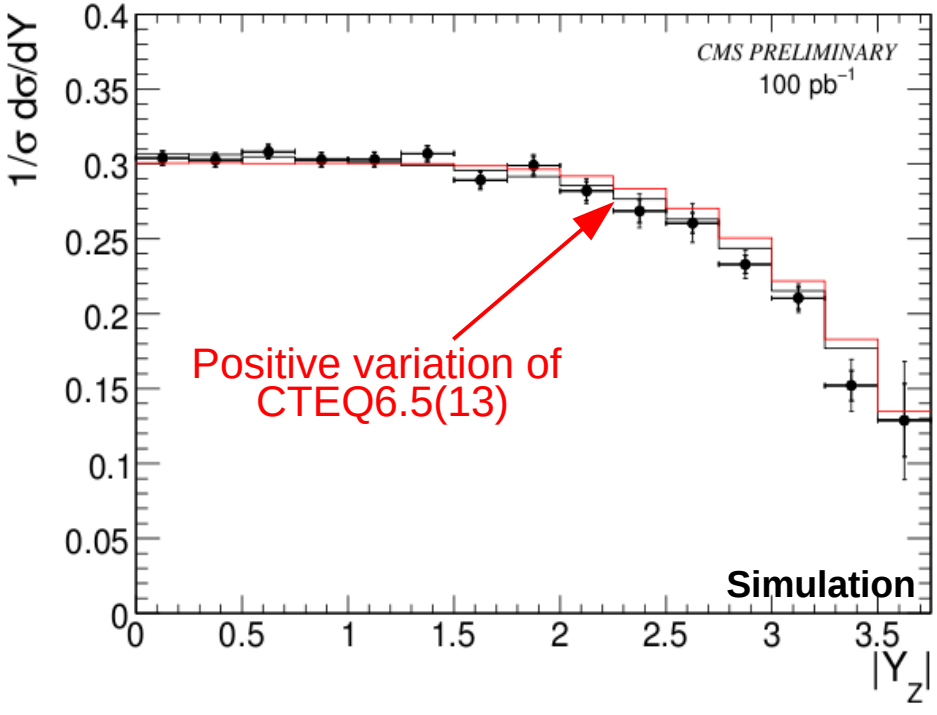


Systematic Uncertainties comparable to Measurement Statistics at high Y_z for 100 pb^{-1}

Sensitivity for 10 TeV (100 pb^{-1})



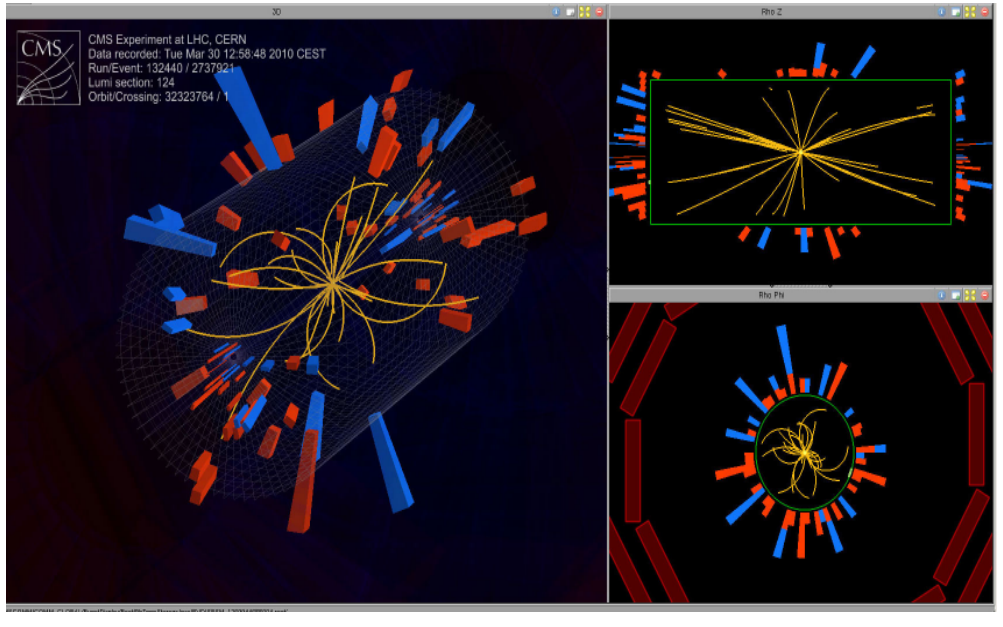
Assuming no forward/backward structure in pp collisions, we can fold over the Y_Z distribution to reduce uncertainties



Insufficient statistics for a 10 pb^{-1} measurement, although signal is visible

Conclusion

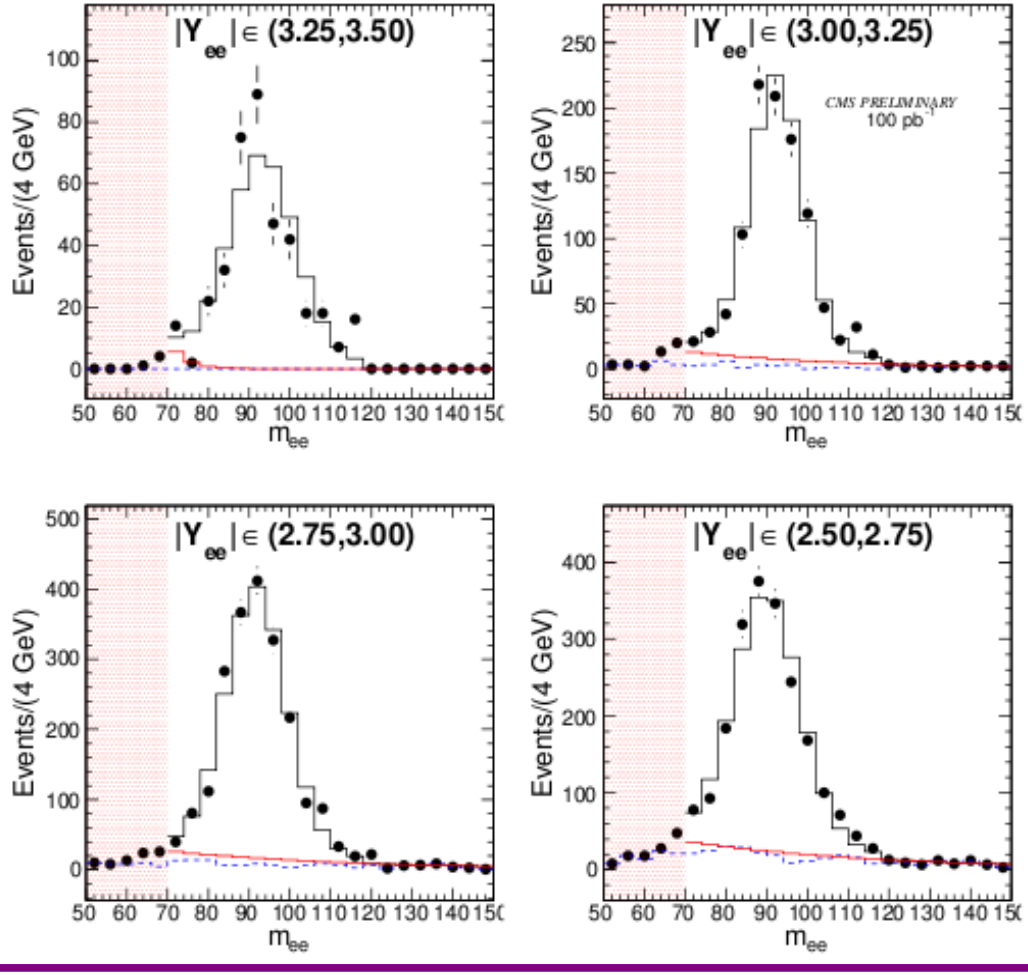
- CMS is prepared to make a data-driven analysis of the Z rapidity shape
  - Initial results possible at 10 pb^{-1}, and able to begin constraining PDFs at 100 pb^{-1}
- As luminosity (and Z production) increases, continue constraining PDF
  - Differential cross section as a function of Y,p_T
- Bring on more data!



Sample event from first 7 TeV collisions

Backup: Z Backgrounds

ECAL-HF



ECAL-ECAL