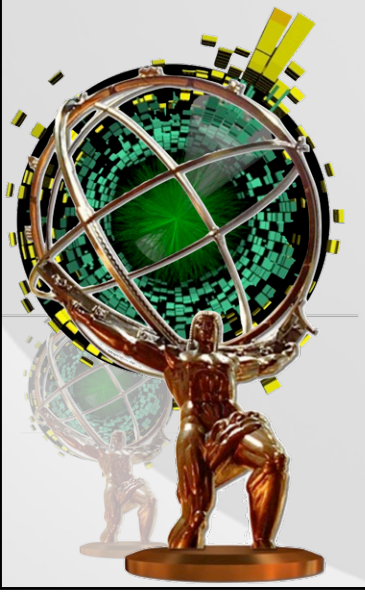
בס"ד

Measurements of the Z boson via the two-lepton channels in heavy ion collisions in ATLAS

Zvi Citron

for the ATLAS Collaboration

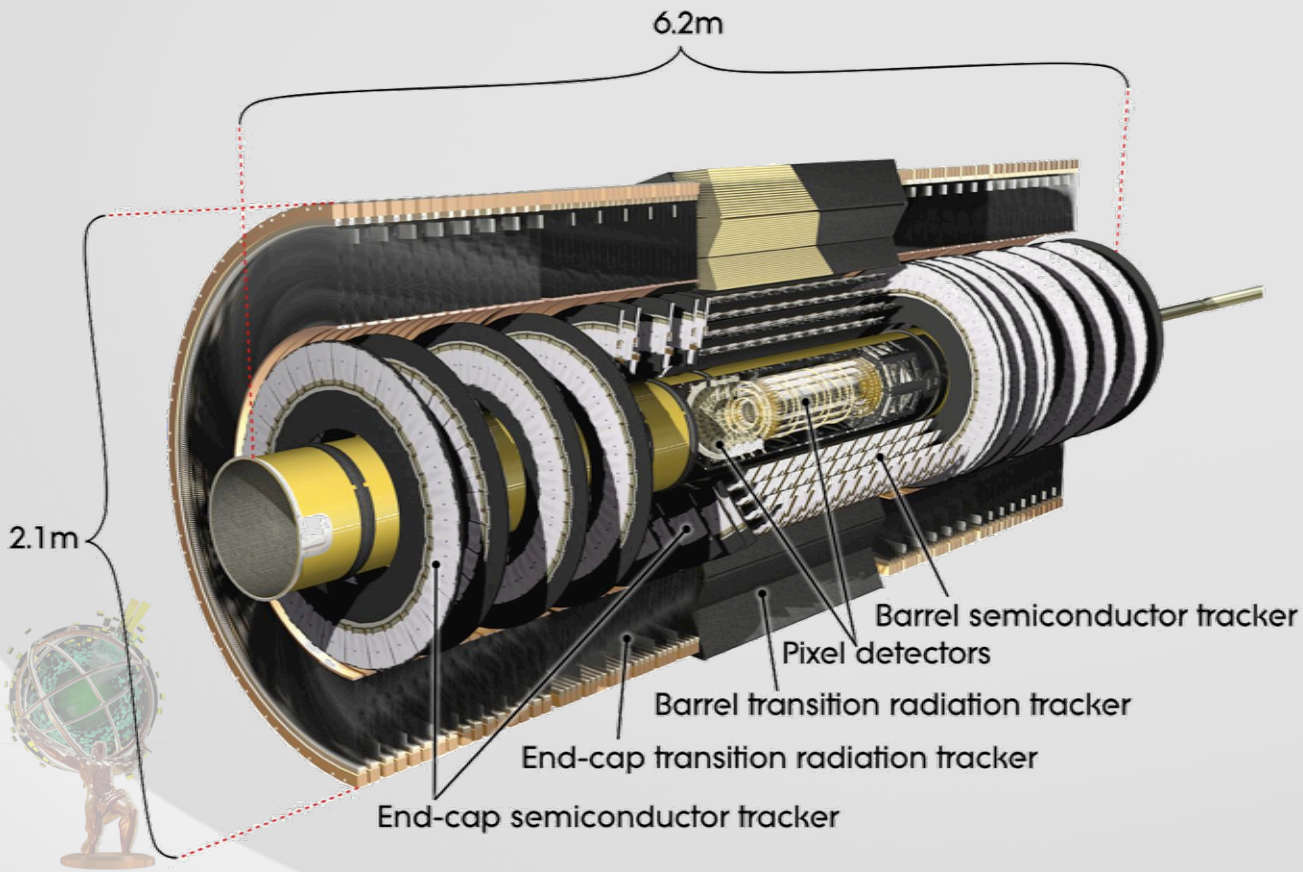


Why Measure Z Bosons?

- Large mass ensures production is confined to initial hard scattering
- Color neutral final states – do not interact with the QCD medium
- No energy loss expected, should scale with $\langle N_{coll} \rangle$
- First step to Z correlations
- Clean signal in two channels, $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$
- 0.15 nb^{-1} of Pb+Pb @ $\sqrt{S_{NN}}$=2.76 TeV

The ATLAS Detector

- ATLAS has excellent electron and muon reconstruction using charged tracking + calorimetry/muon spectrometry



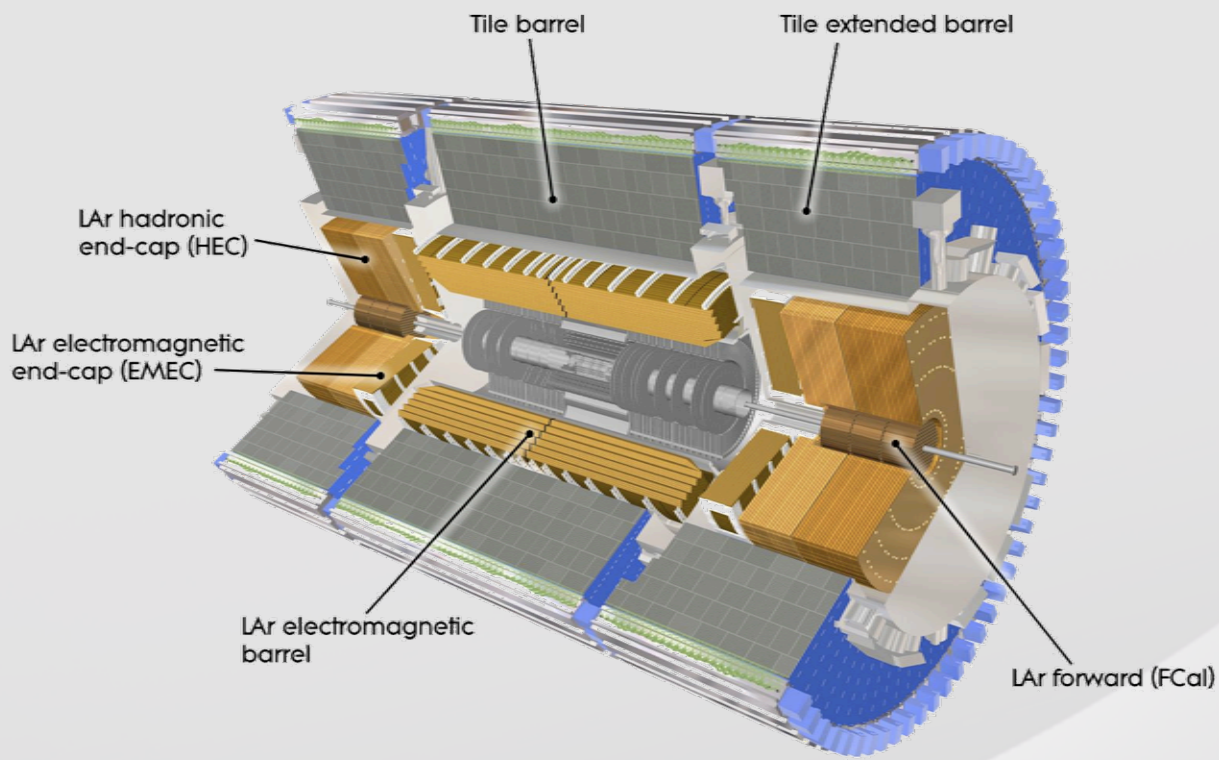
- ***Tracking***
- *Precise tracking and vertexing*
- *coverage: $|\eta|<2.5$*
- *B (solenoid) =2T*
- *Pixels (Si): σ = 10 μm [$r\varphi$]*
- *80M channels ; 3 layers and 3 disks ;*
- *SCT (106 Si strips): σ = 17 μm [$r\varphi$]*
- *Transition Radiation Tracker*

The ATLAS Detector

- ATLAS has excellent electron and muon reconstruction using charged tracking + calorimetry/muon spectrometry

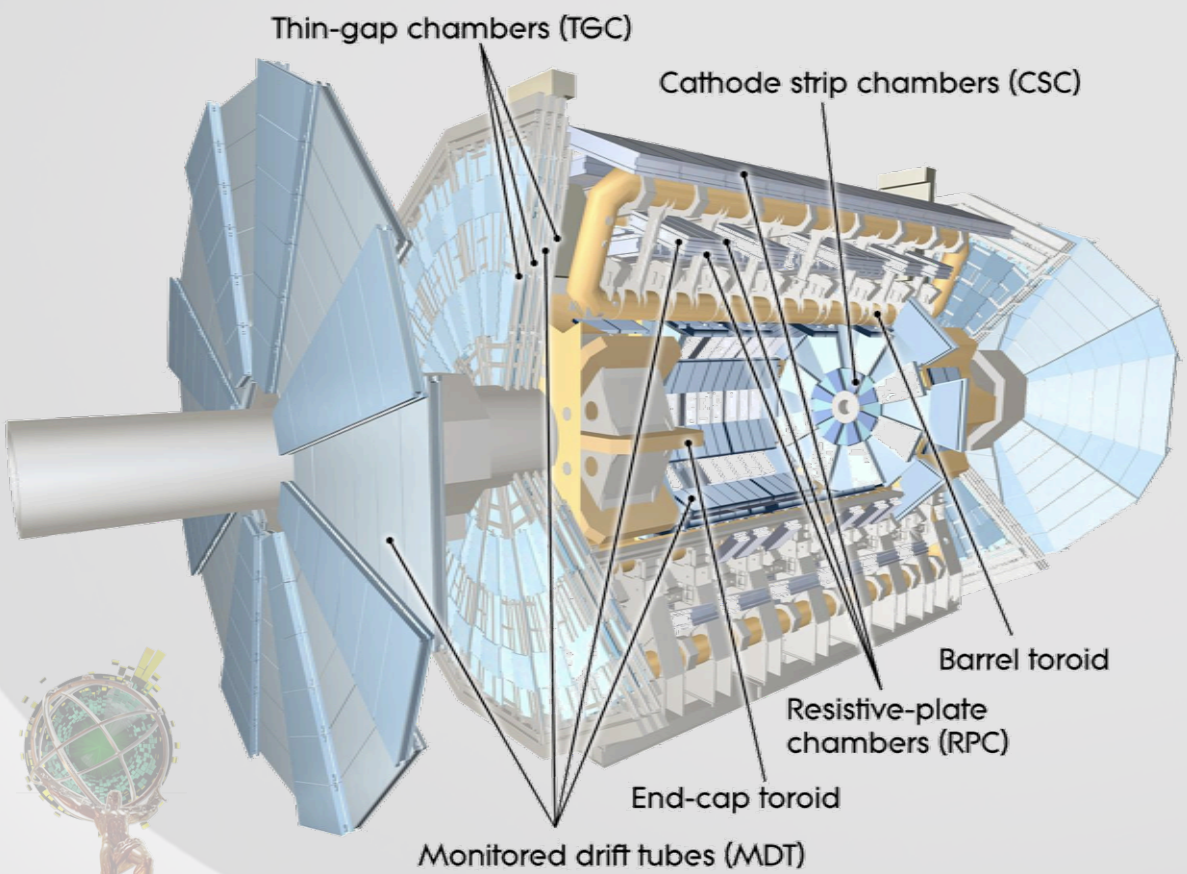
•**Lar-Pb EM calorimeter (|η| <3.2)**
•e/γ trigger, identification; measurement
•Granularity: 0.025x0.025 in Φxη
•3 long. layers + presampler(0 <|η| <1.8) \ 180x103 channels

•***Hadronic Calorimeter***
•|η|<1.7: Fe/scint. Tiles (Tilecal)
•3.2 <|η|<1.5: Cu-Lar (HEC)
•3.1<|η|<4.9: FCAL Cu/W-Lar



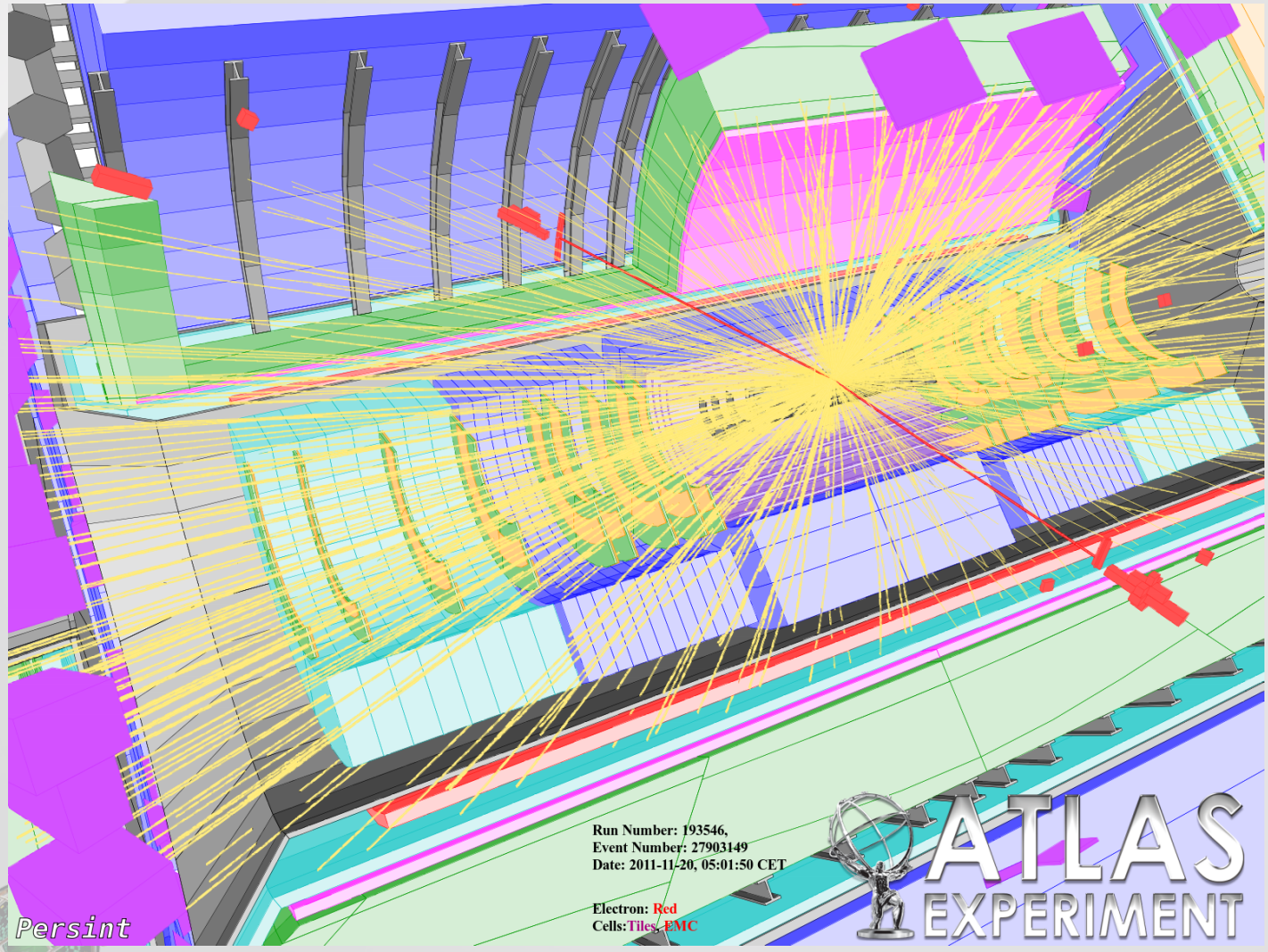
The ATLAS Detector

- ATLAS has excellent electron and muon reconstruction using charged tracking + calorimetry/muon spectrometry



- **Muon spectrometer (MS)**
- Air-core toroid magnetic field
- Covers up to $|\eta|=2.7$
- Triggers
- Filtering provided by the calorimeters
- Tracking in B field for momentum
- Measurement matching with Inner Detector (ID) to improve resolution and vertex capabilities

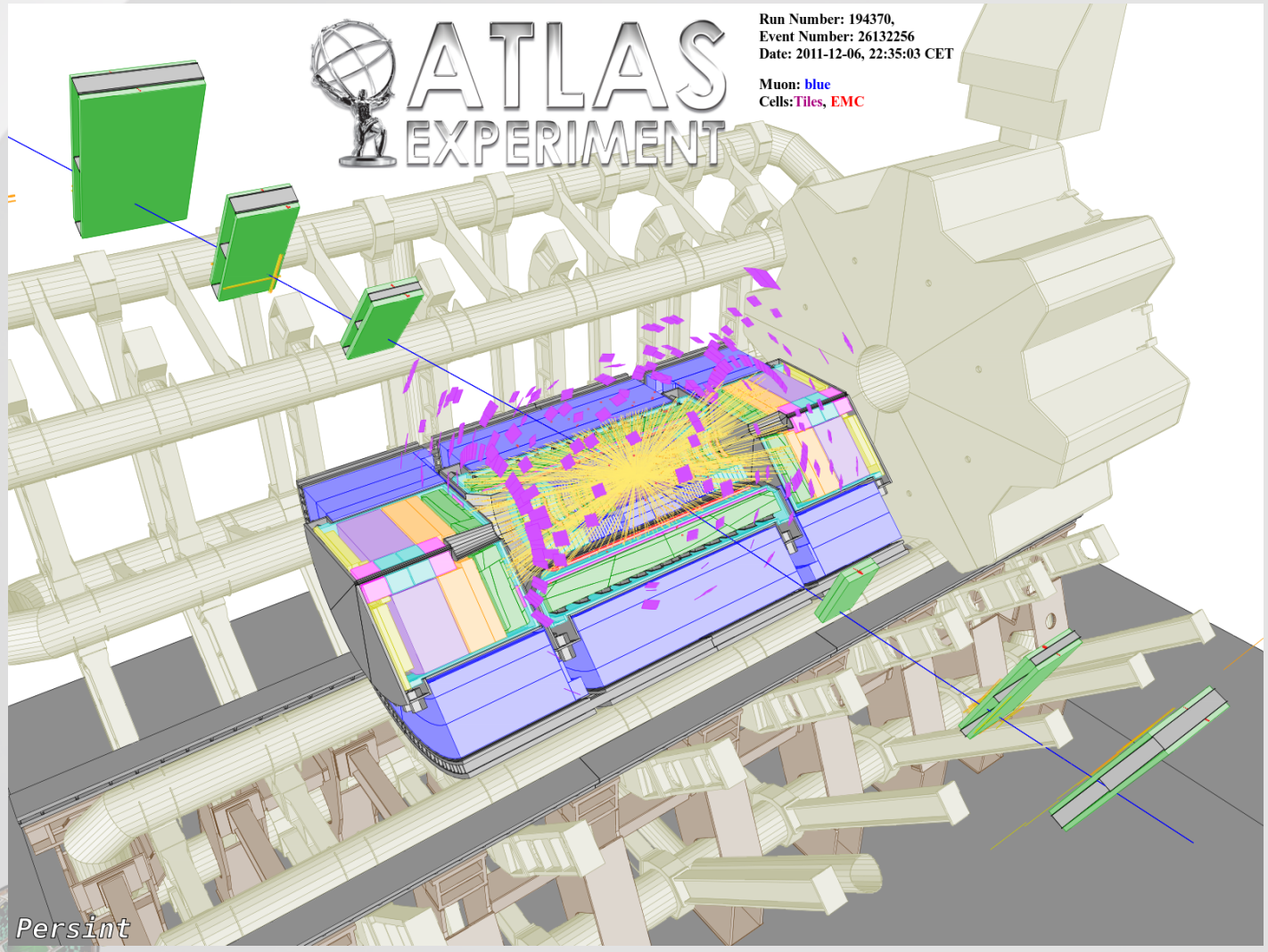
Z→ee Event Display



- FCal ΣE_T = 1.58 TeV (10-20% Centrality)
- m_{ee} = 92.2 GeV
- p_T^Z = 4.8 GeV
- y^Z = -0.2

Inner Tracking + Calorimeter

Z→μμ Event Display



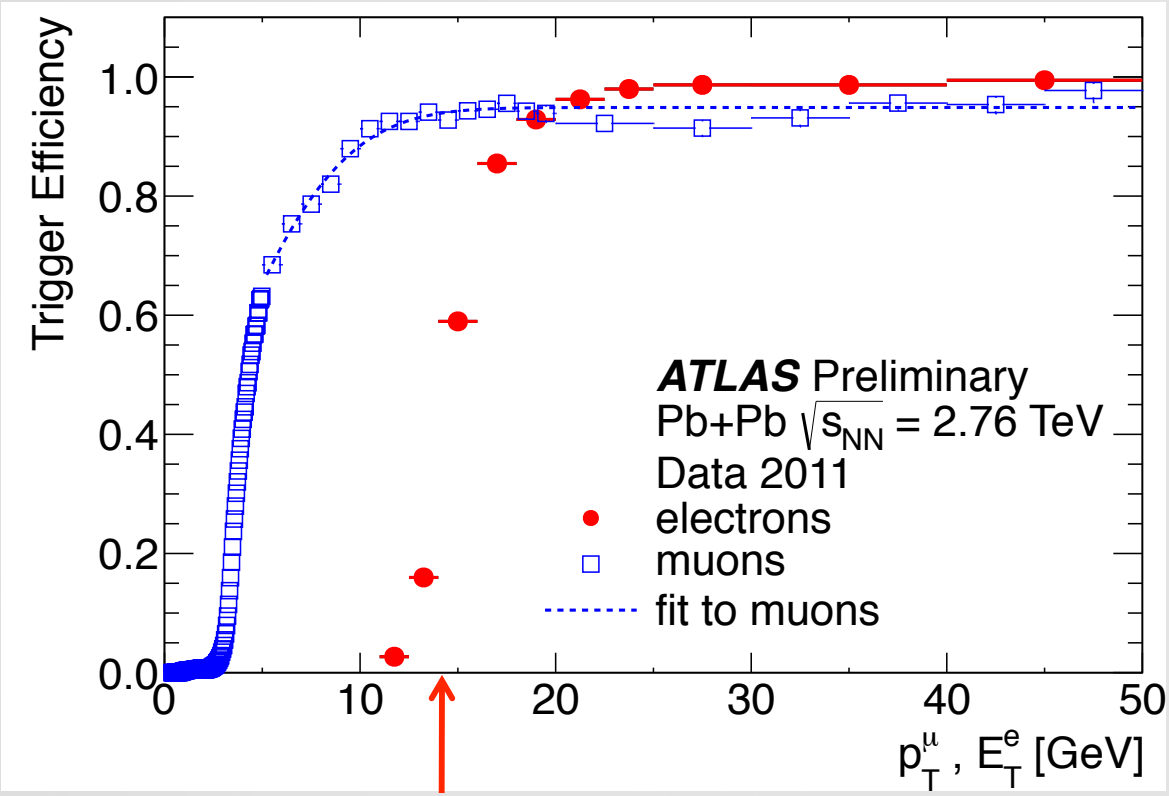
- FCal ΣE_T = 2.16 TeV (10-20% Centrality)
- $m_{\mu\mu}$ = 102 GeV
- p_T^Z = 4.96 GeV
- y^Z = -0.13

Inner Tracking + Muon Spectrometer

Selecting the Leptons

- Electrons
  - E_T >20 GeV
  - $|\eta|<2.5$
  - Shower shape and energy cuts in calorimetry
  - Subtract underlying event energy from each electron
- Muons
  - p_T > 10 GeV
  - $|\eta|<2.7$
  - Track quality cuts

Triggering on Electrons



Nominal Trigger Threshold

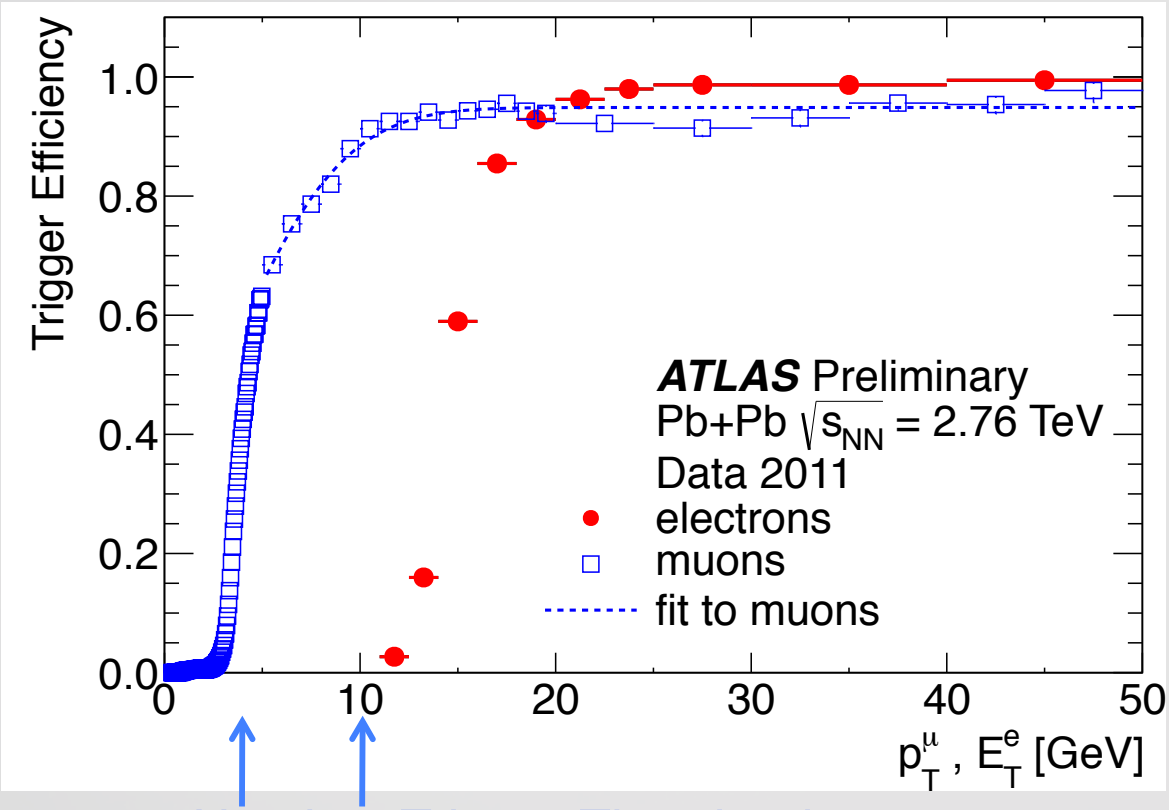
Electron Trigger :

- Calorimeter cluster based trigger

- For E_T>20 GeV, electron efficiency = (98.1 ± 0.1)%

- **pair efficiency = (99.9 ± 0.1)%**

Triggering on Muons

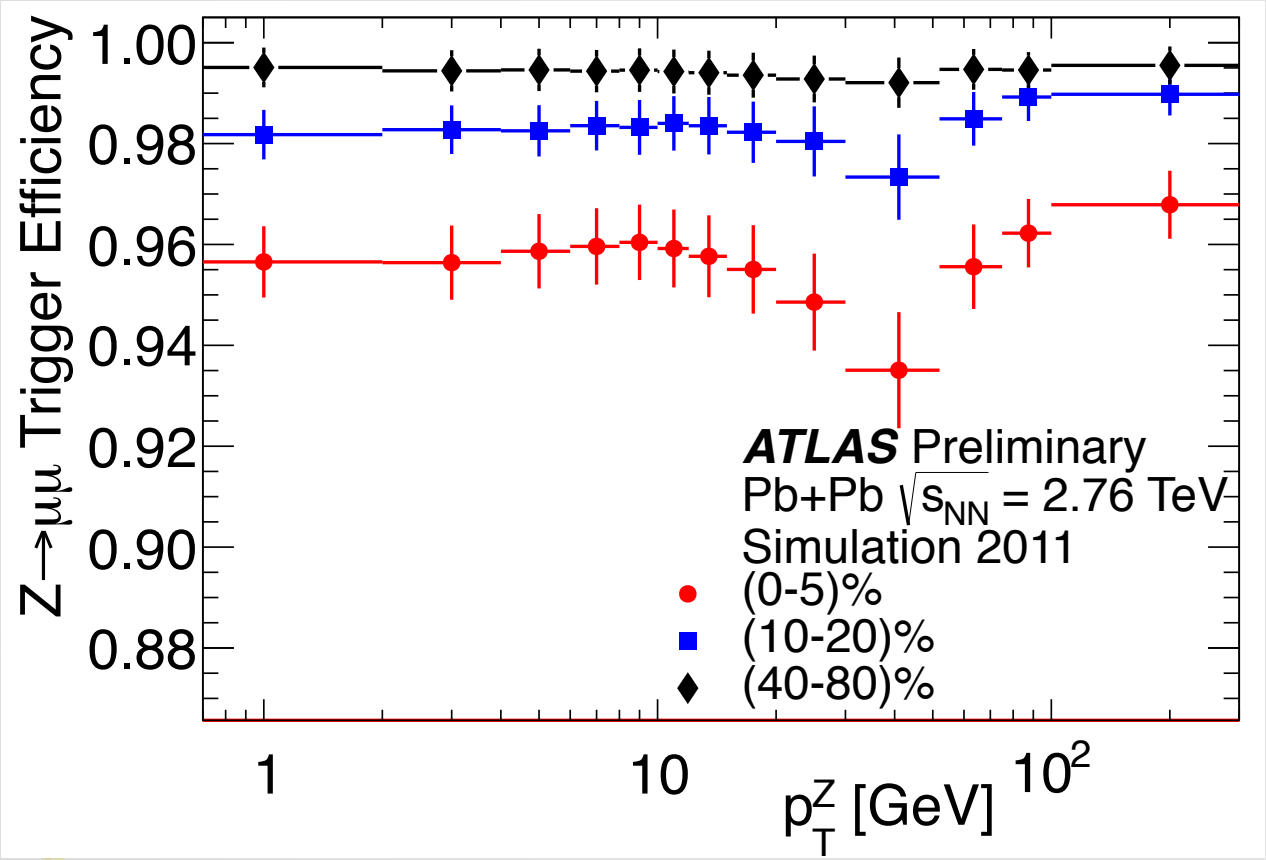


Nominal Trigger Thresholds

Muon Trigger:

- Muon spectrometer based trigger
- Two trigger thresholds used
  - 4 GeV (less efficient)
  - 10 GeV (more efficient)
- For p_T>10 GeV
  - (98.2 ± 0.5)% peripheral
  - (90.9 ± 0.5)% central

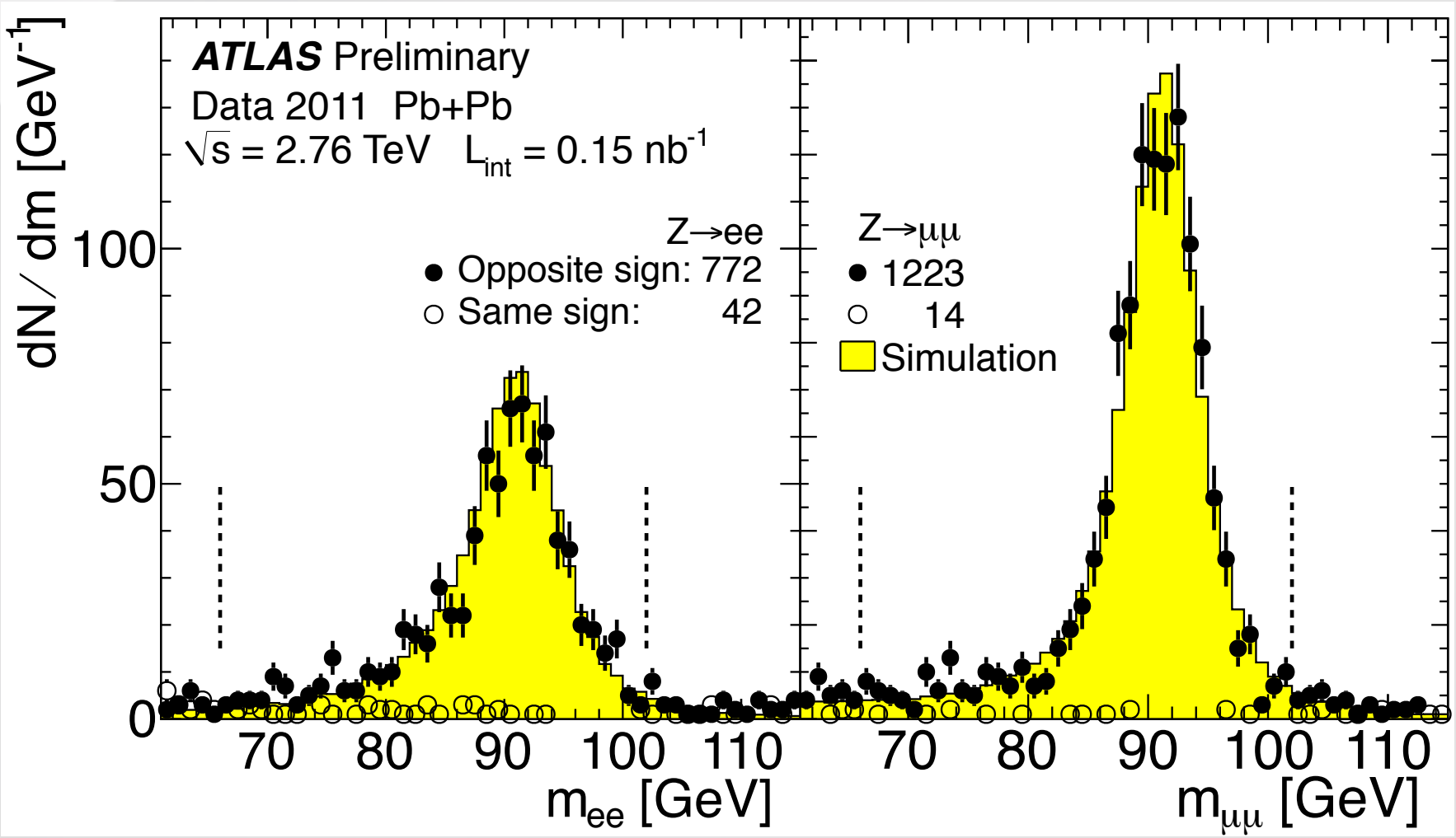
Triggering on Muons



Muon Trigger:

- Muon spectrometer based trigger
- Two trigger thresholds used
  - 4 GeV (less efficient)
  - 10 GeV (more efficient)
- For p_T>10 GeV
  - (98.2 ± 0.5)% peripheral
  - (90.9 ± 0.5)% central
- Pair efficiency:
  - (99.0 ± 0.6)% peripheral
  - (95.0 ± 0.9)% central

Mass Distributions



Pair the selected leptons

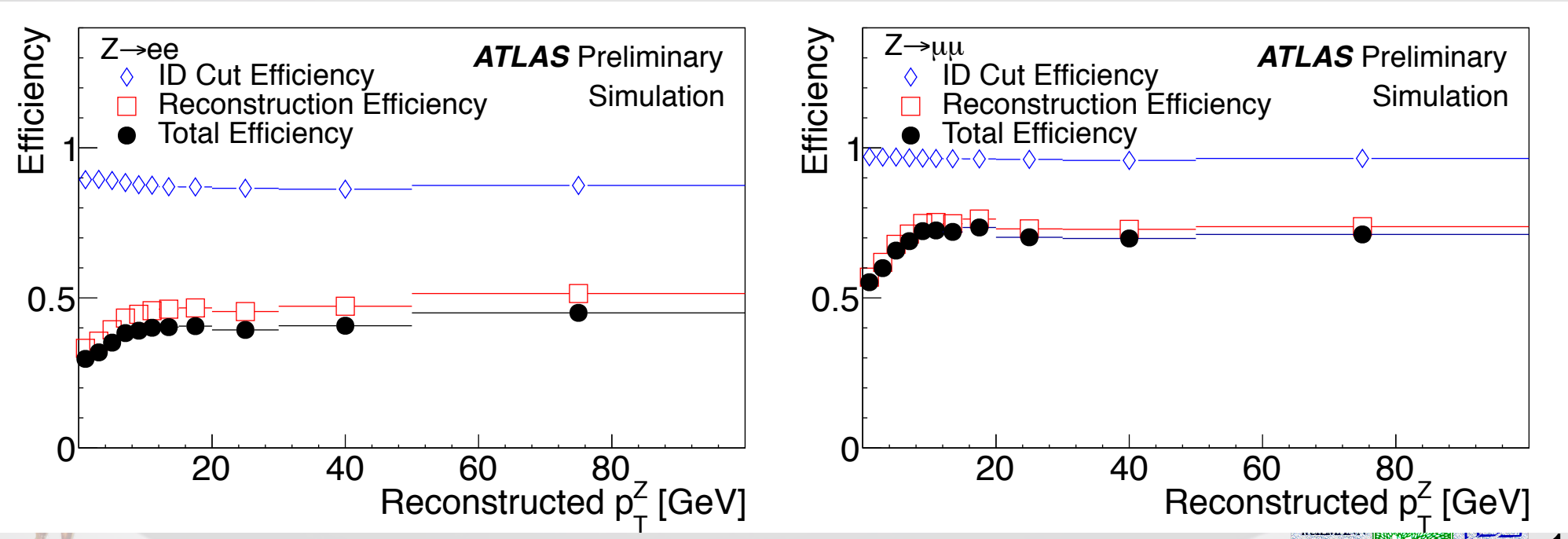
Select Z boson in mass window 66-102 GeV

Signal Purity ~ 95% in Z➔ee and ~99% in Z➔μμ

Simulation is PYTHIA in HIJING events, reconstructed

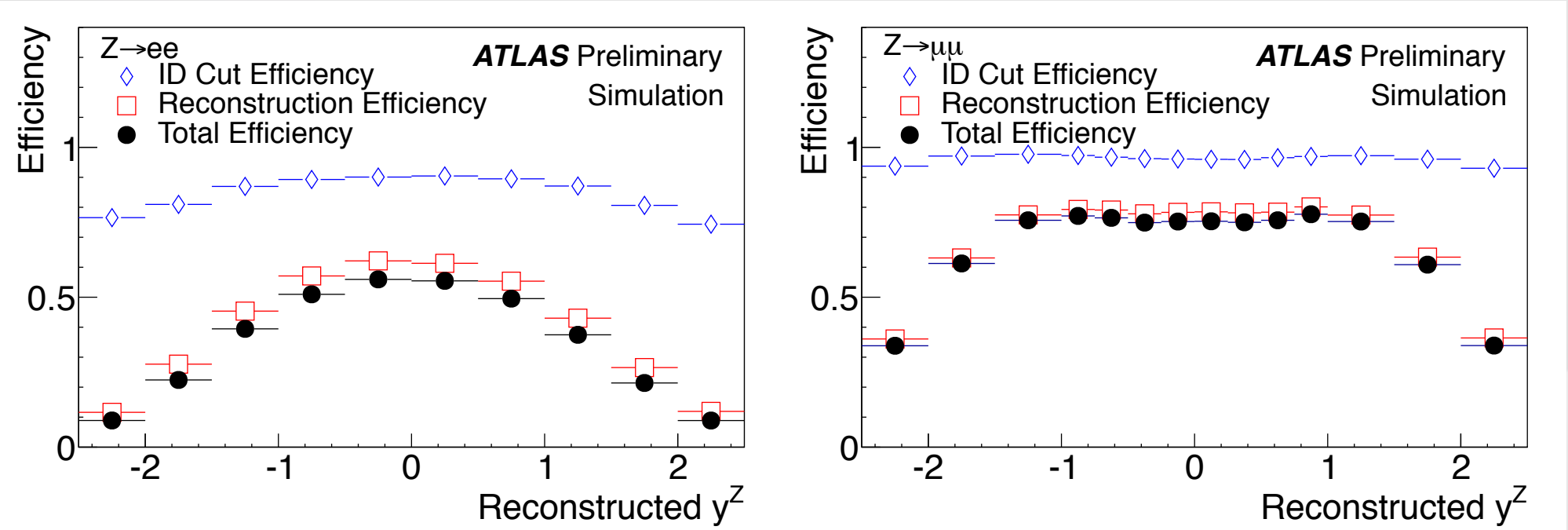
Corrections to Yield

- Use PYTHIA Z→ℓℓ embedded into HIJING to calculate corrections:
  - Look in centrality, momentum, and rapidity
  - Bin-by-bin unfolding
  - Reconstruction efficiency (including minimum p_T^{lepton}, and mass)
  - Lepton identification cuts efficiency
  - Correct up to mass window 66-116 GeV



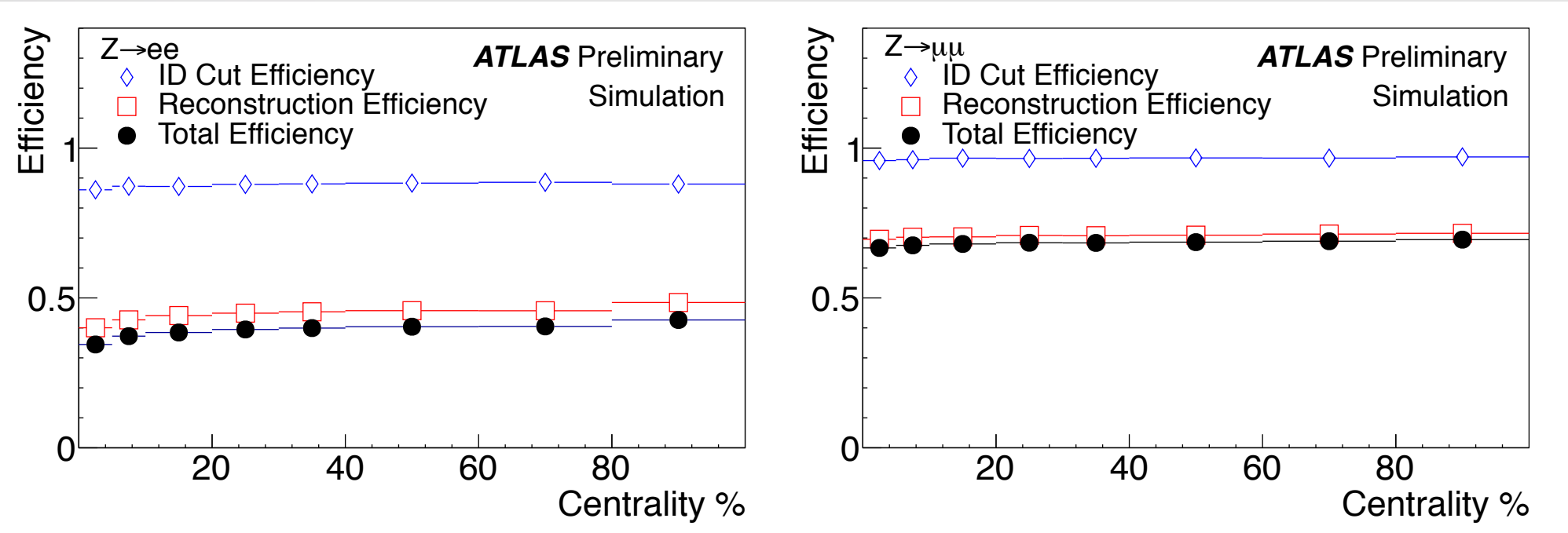
Corrections to Yield

- Use PYTHIA $Z \rightarrow \ell\ell$ embedded into HIJING to calculate corrections:
  - Look in centrality, momentum, and rapidity
  - Bin-by-bin unfolding
  - Reconstruction efficiency (including minimum p_T^{lepton}, and mass)
  - Lepton identification cuts efficiency
  - Correct up to mass window 66-116 GeV

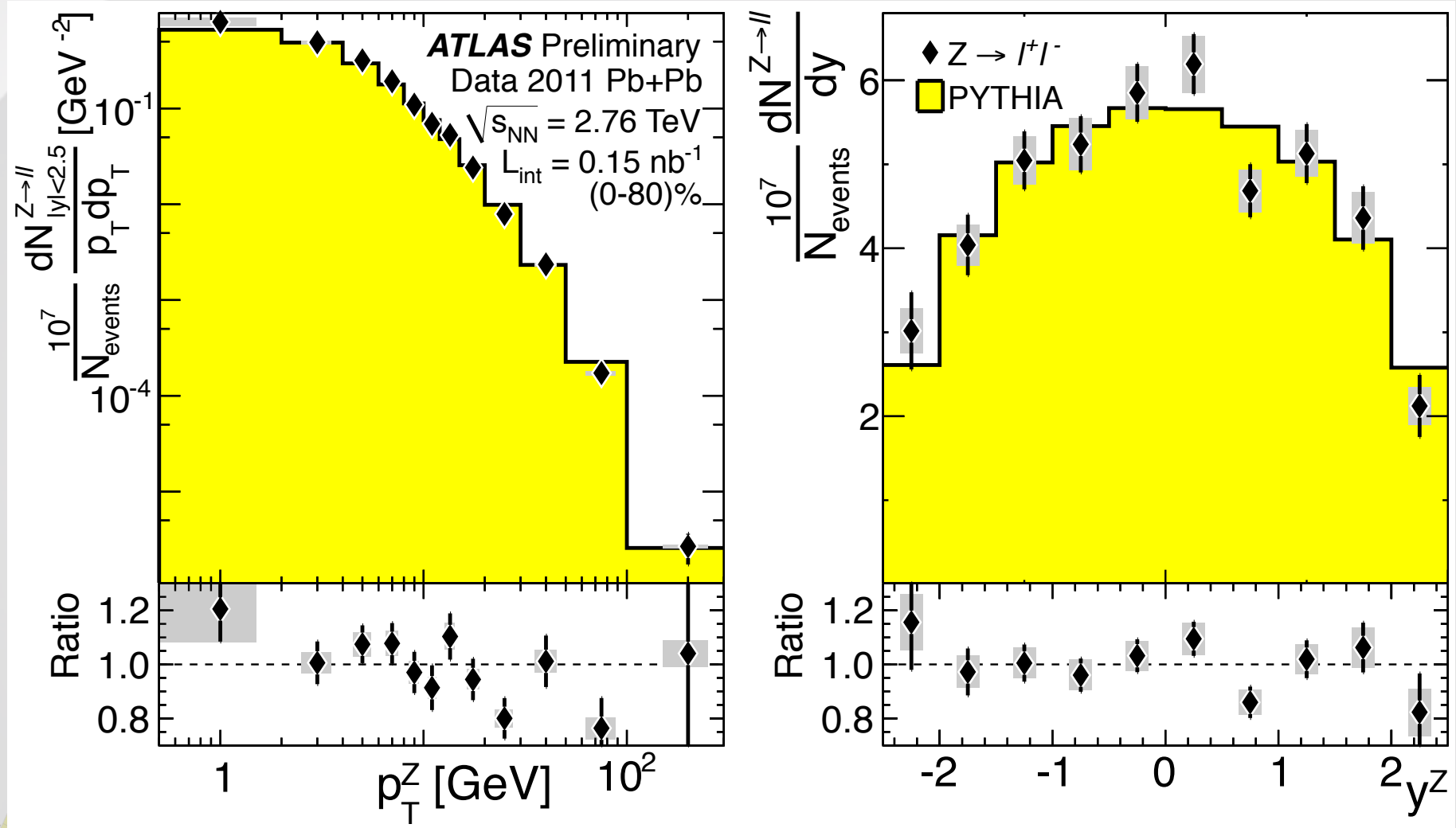


Corrections to Yield

- Use PYTHIA Z→ℓℓ embedded into HIJING to calculate corrections:
  - Look in centrality, momentum, and rapidity
  - Bin-by-bin unfolding
  - Reconstruction efficiency (including minimum p_T^{lepton}, and mass)
  - Lepton identification cuts efficiency
  - Correct up to mass window 66-116 GeV



Corrected Spectra

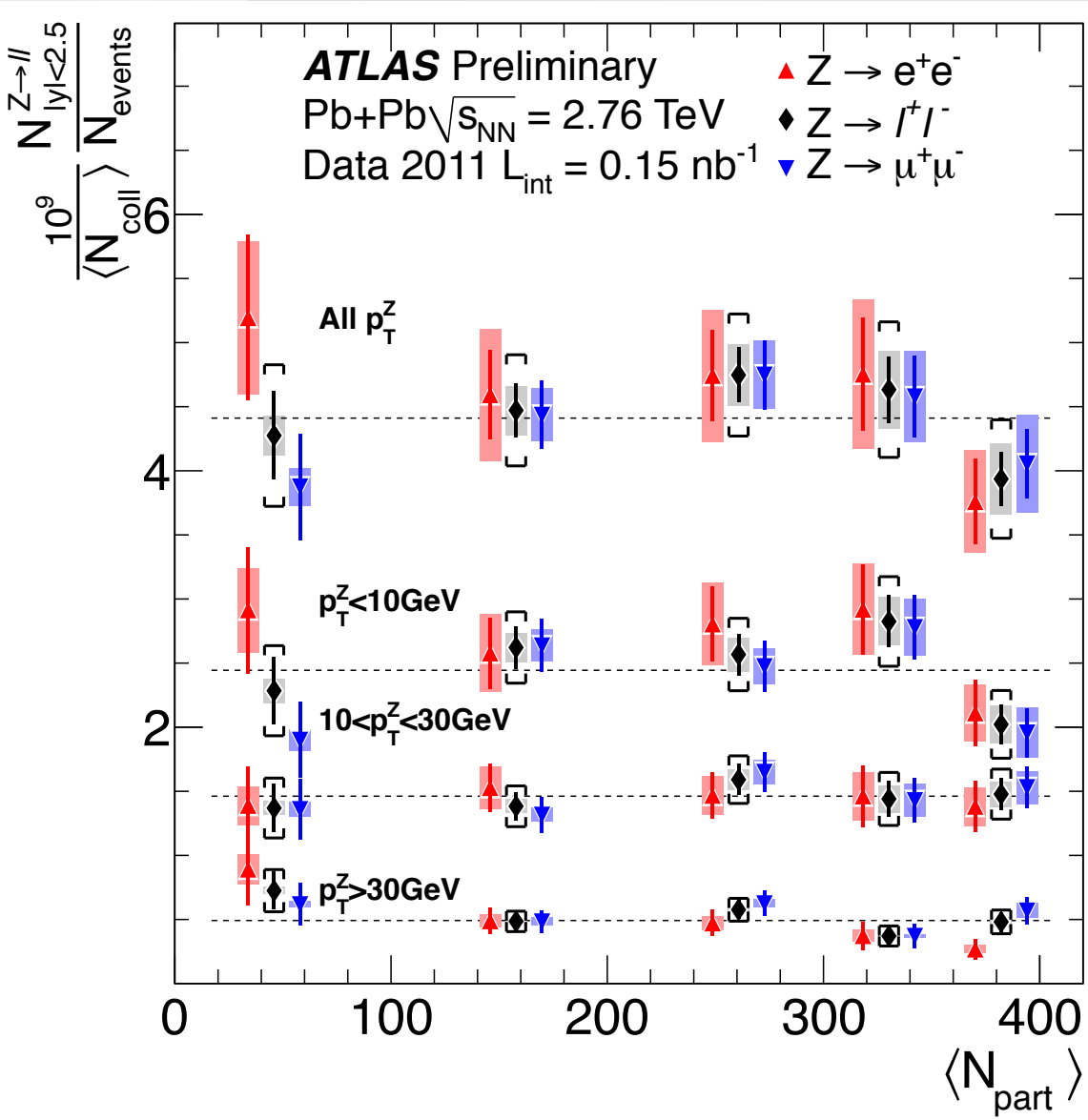


Each decay channel corrected and background subtracted

Channels combined according to uncertainties (uncorrelated across channels)

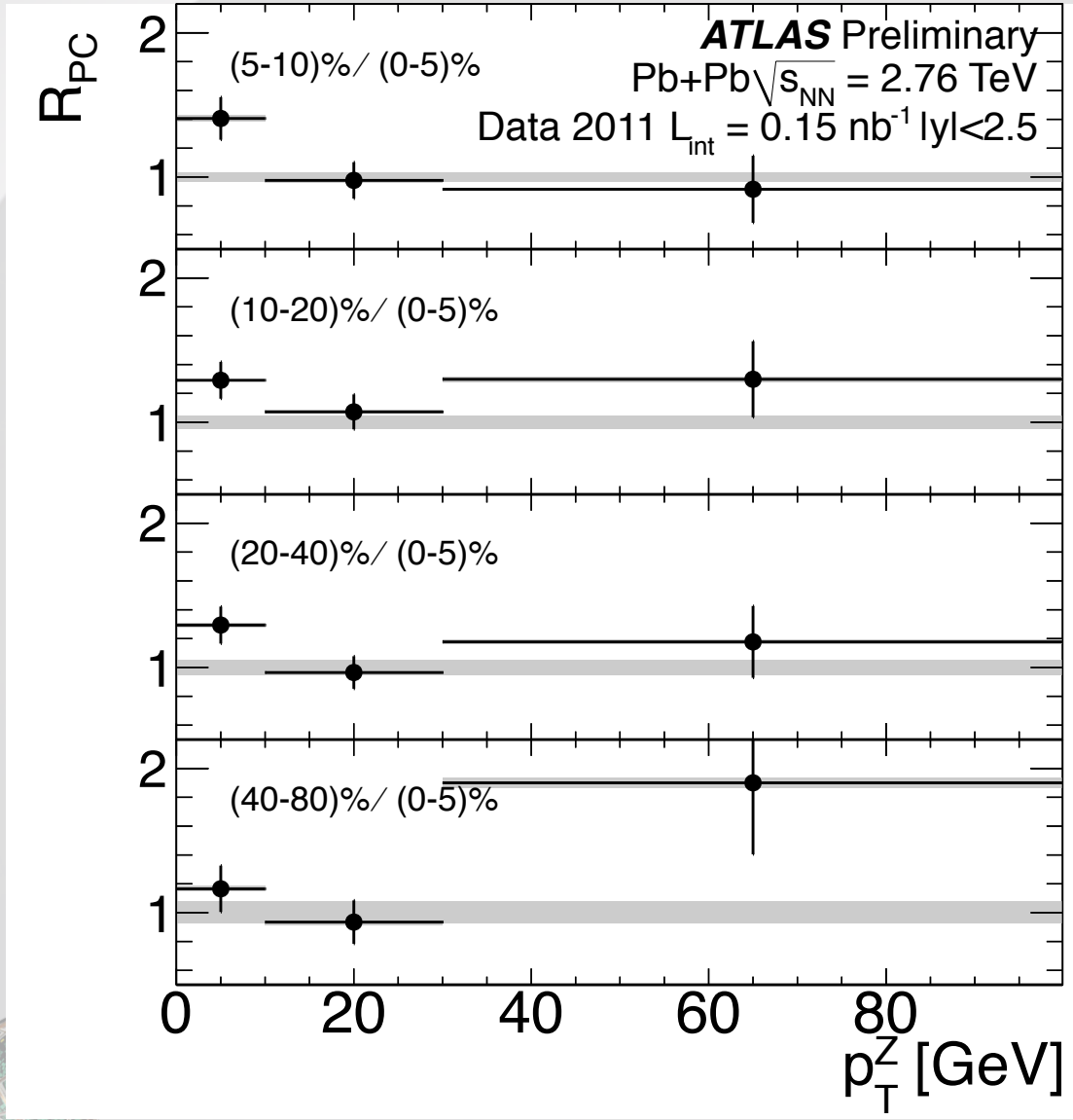
PYTHIA normalized by area for shape comparison – agrees well

Binary Collision Scaling



- Fully corrected Z boson Yield scaled by $\langle N_{coll} \rangle$
- Statistical uncertainty bars, systematics in boxes, and brackets combined (including $\langle N_{coll} \rangle$
- Dashed lines are flat line fits to combined channel yields
- Consistent with binary collision scaling appears to hold true!

Nuclear Modification Factor

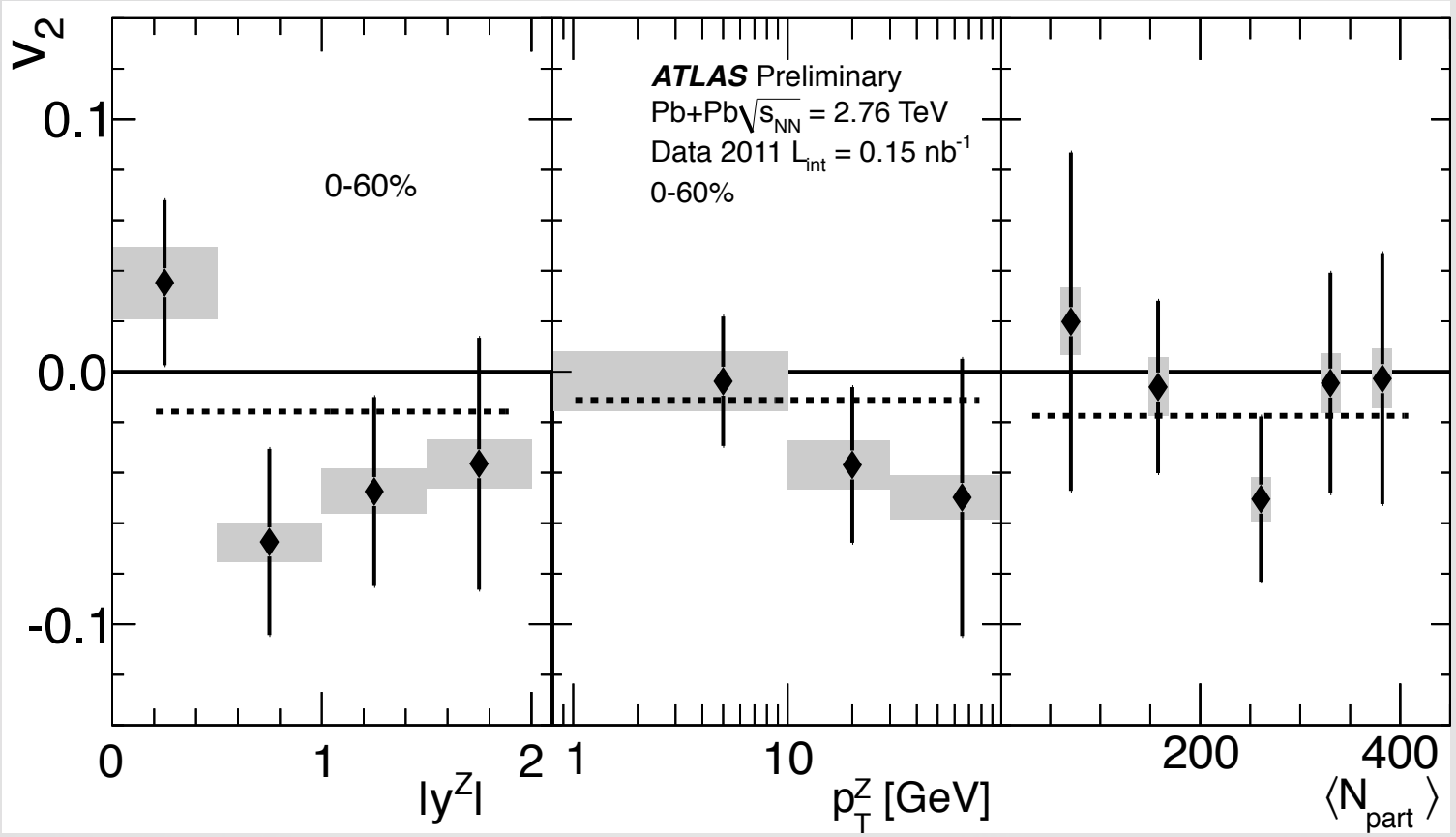


Form nuclear modification factor by taking ratio of points on previous slide

R_{PC} = Yield in central collisions/ Yield in peripheral collisions

$$R_{PC} = \frac{\langle N_{coll}\rangle(C)}{\langle N_{coll}\rangle(P)} \frac{(1/N_{evt,P})d^2N_P/dydp_T}{(1/N_{evt,C})d^2N_C/dydp_T}$$

Flow of Z bosons?



Measure the elliptic flow, v_2, of the Z bosons

Z boson production in unmodified hard scattering should not flow

$v_2 = -0.011 \pm 0.018(\text{stat.}) \pm 0.014(\text{sys.})$ in 0-60% centrality

Summary

- $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ measured in $L = 0.15\ nb^{-1}$ of Pb+Pb @ $\sqrt{S_{NN}}$=2.76 TeV
- 1995 Z candidates reconstructed, signal purity about 97%
- Spectral shape and rapidity distribution match well with PYTHIA prediction for p+p
- Comparing production in different centrality bins consistent with binary collision scaling
- Elliptic flow measured, consistent with zero