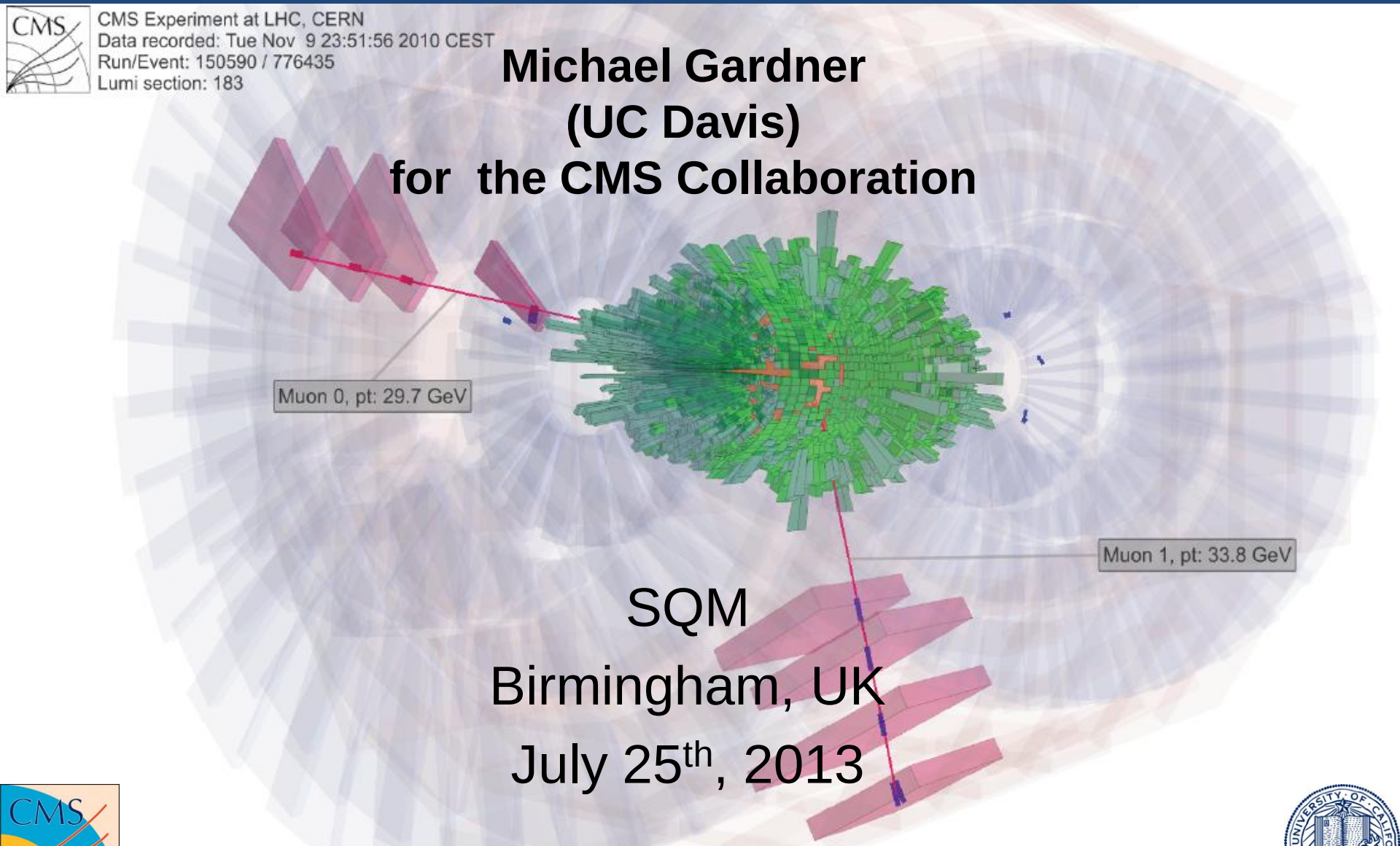
Electroweak boson production in Heavy Ion collisions with CMS



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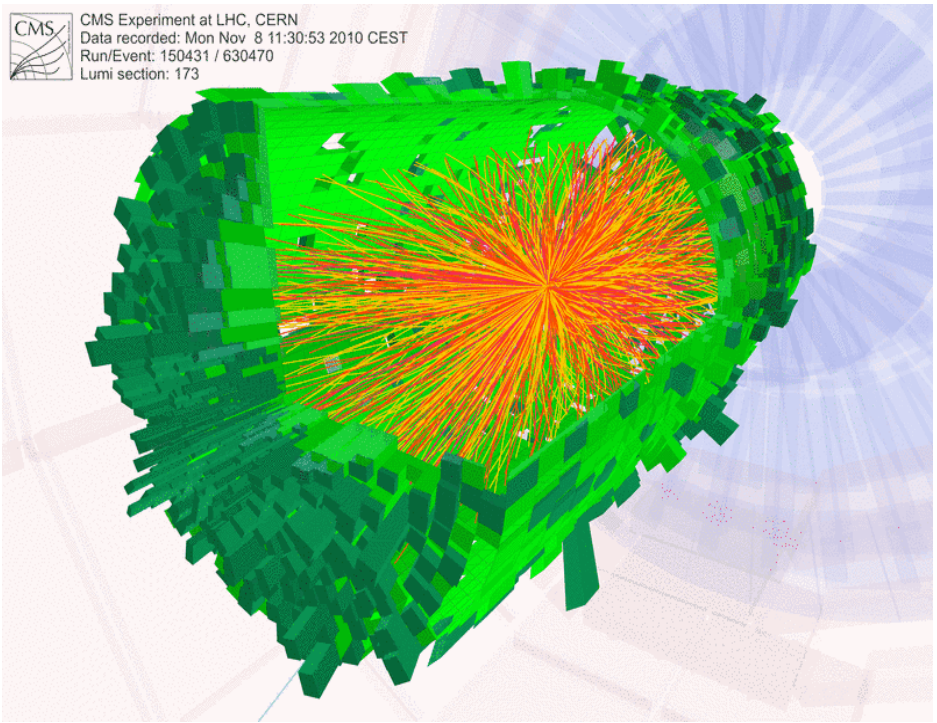
July 25th, 2013

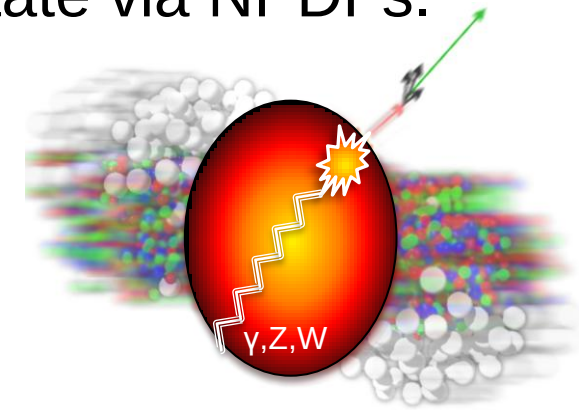
Outline

- **Motivation: Z, W Measurement in Heavy Ions**
- **CMS: Z → l^+l^-**
- **Z:** (new!)
  - **PbPb:** (L_{int} = 150 μb^{-1})
    - **Z→$\mu^+\mu^-$**
    - **Z→e^+e^-**
  - **pp:** (L_{int} = 5.35 pb^{-1})
    - **Z → $\mu^+\mu^-$**
    - **Z → e^+e^-**
  - **R_{AA}**
- **W:** (2012)
- **Conclusion**

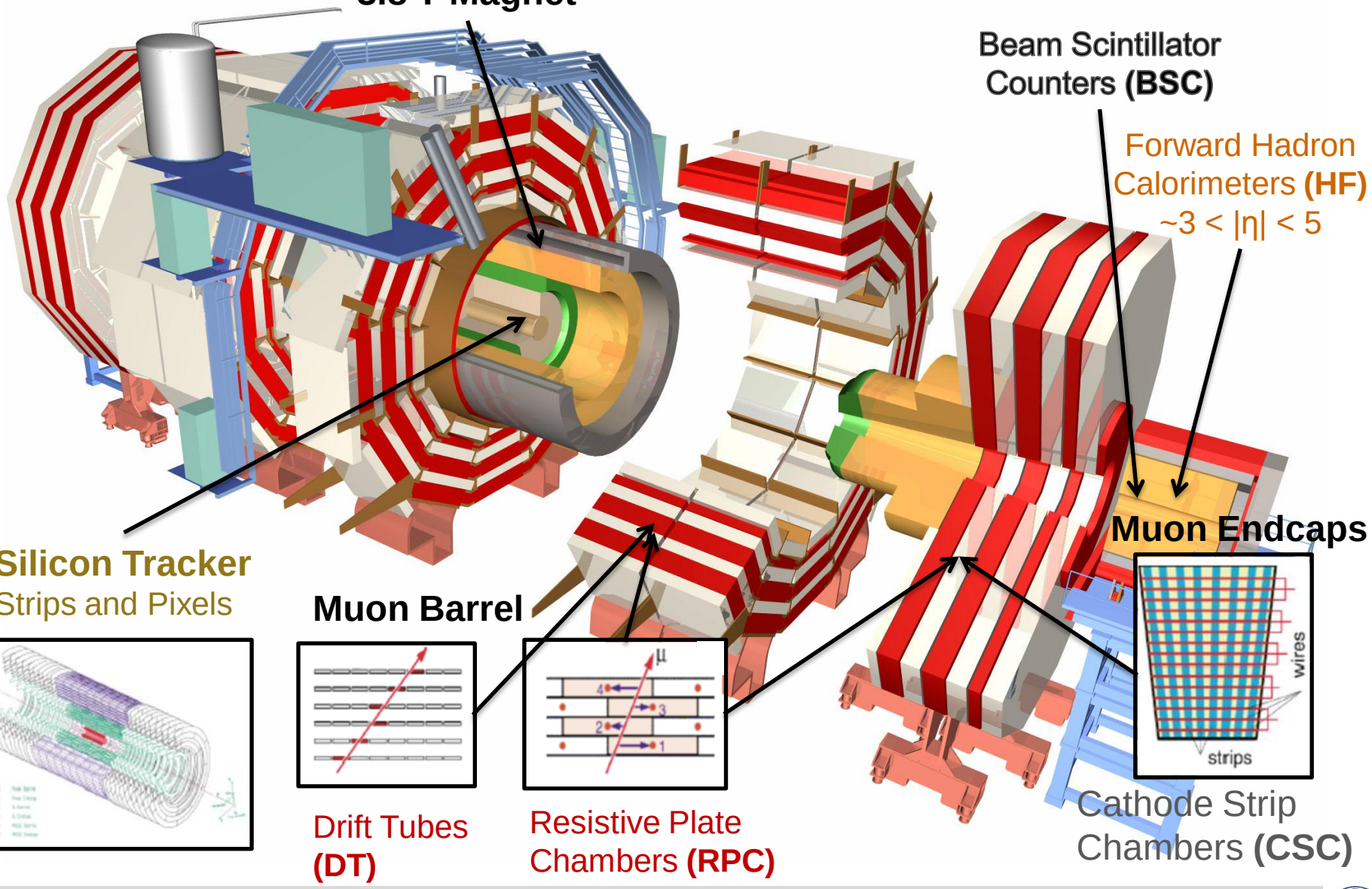


Z, W Measurement in Heavy Ions - Motivation

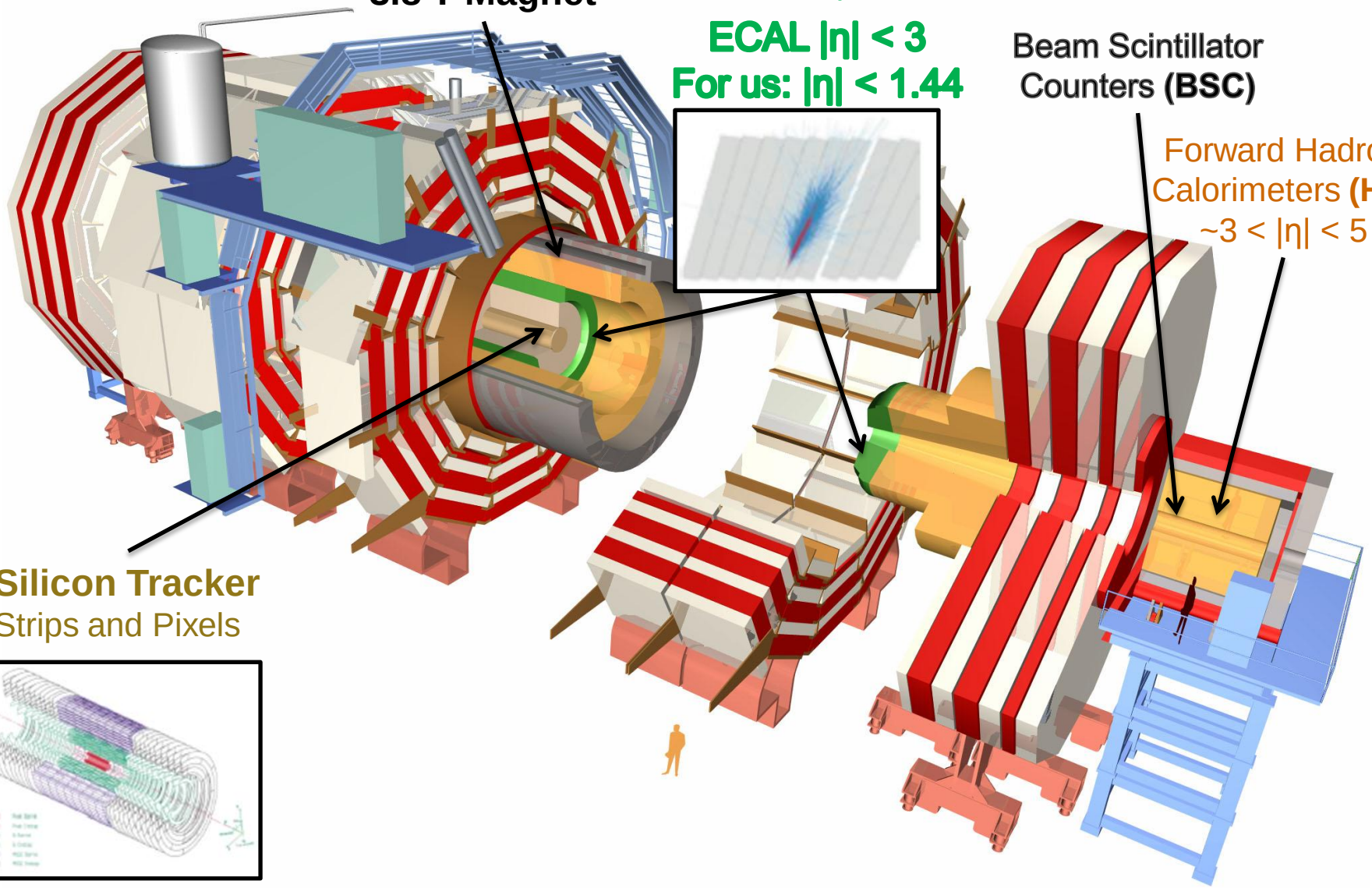
- LHC Energy allows for first observation and measurement of **Z** and **W** bosons in Heavy Ion collisions.
- **Z**, **W** via leptonic decay: No modifications from Hot QCD medium.
- Excellent reference measurement:
  - 1st order: check binary scaling hypothesis.
  - Serve as reference to modified processes, e.g. jets.
  - 2nd order: modifications constrain initial state via NPDFs.



$Z \rightarrow \mu^+\mu^-$ in CMS

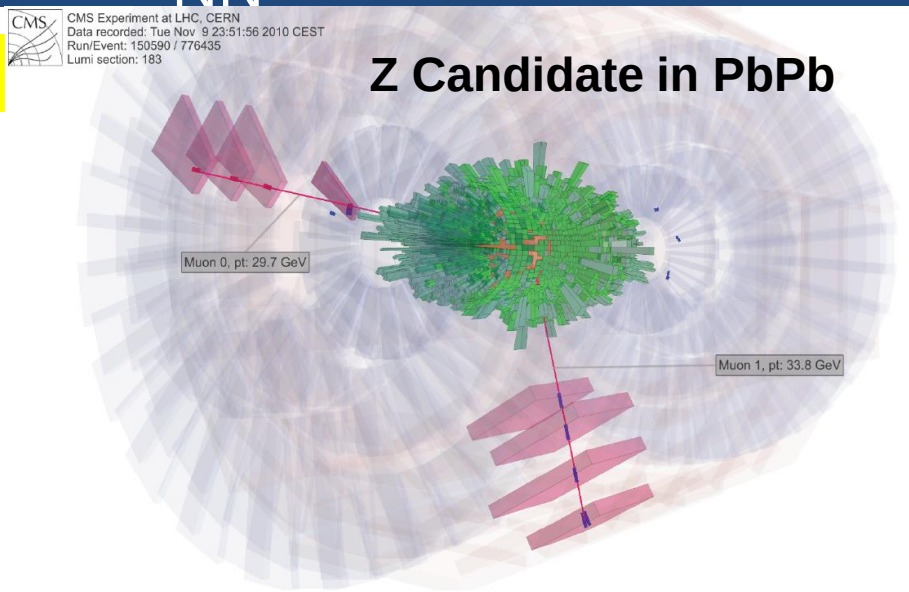


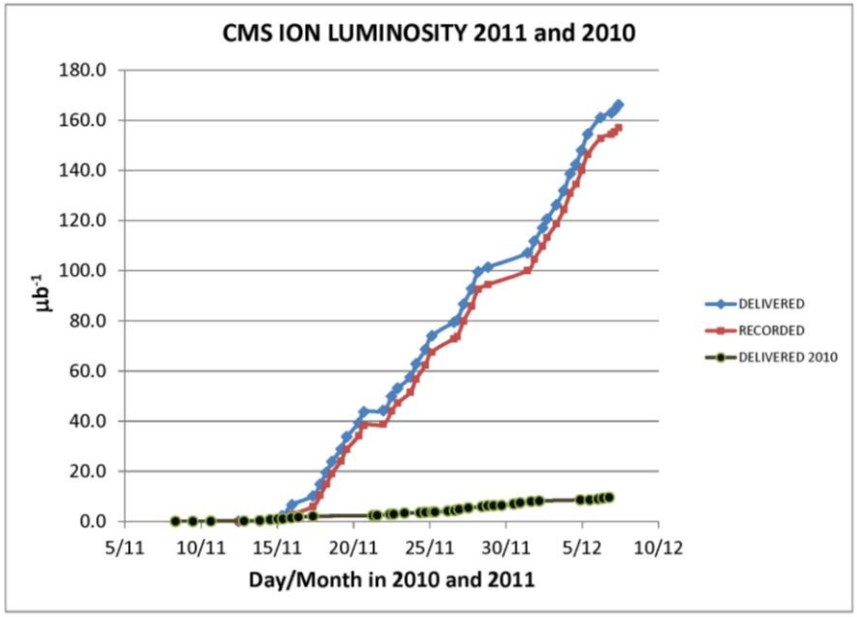
$Z \rightarrow e^+e^-$ in CMS

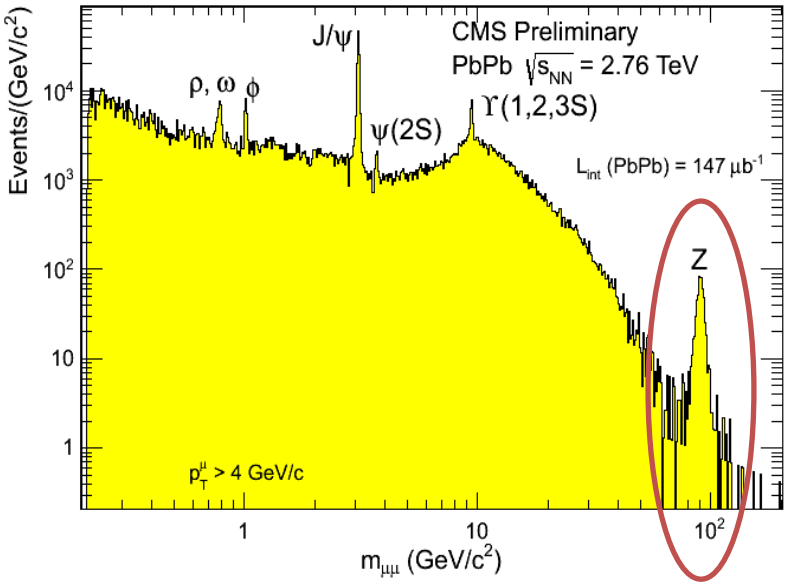


Z Production in PbPb $\sqrt{s_{NN}}$ = 2.76 TeV

- Dec. 2010: **PRL 106 (2011) 212301**
  - L_{int}: 7 μb^{-1}.
  - 1st HI **Z** measurement (27 Zs)
- Dec. 2011:
  - L_{int}:150 μb^{-1}.
  - 20x Increase!

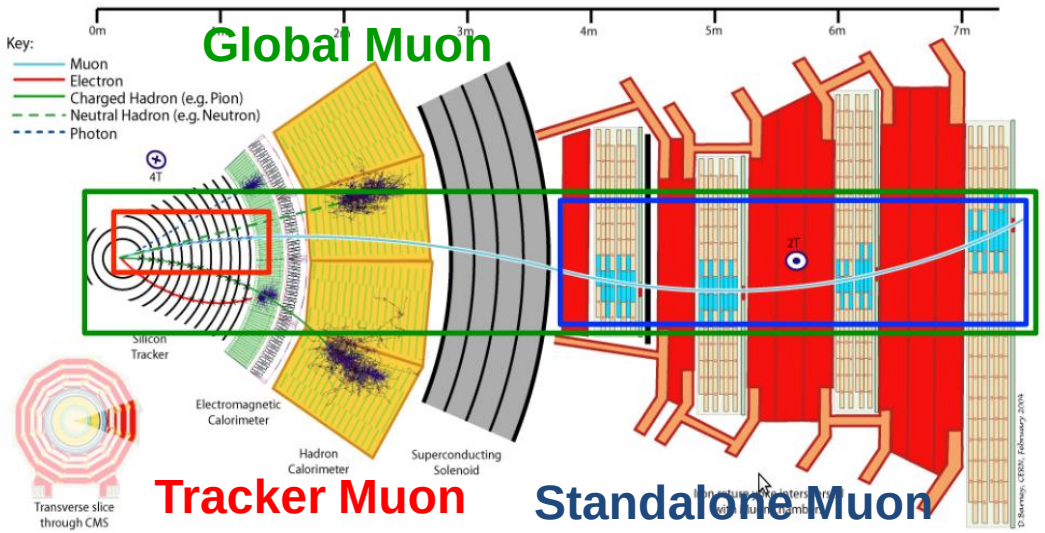




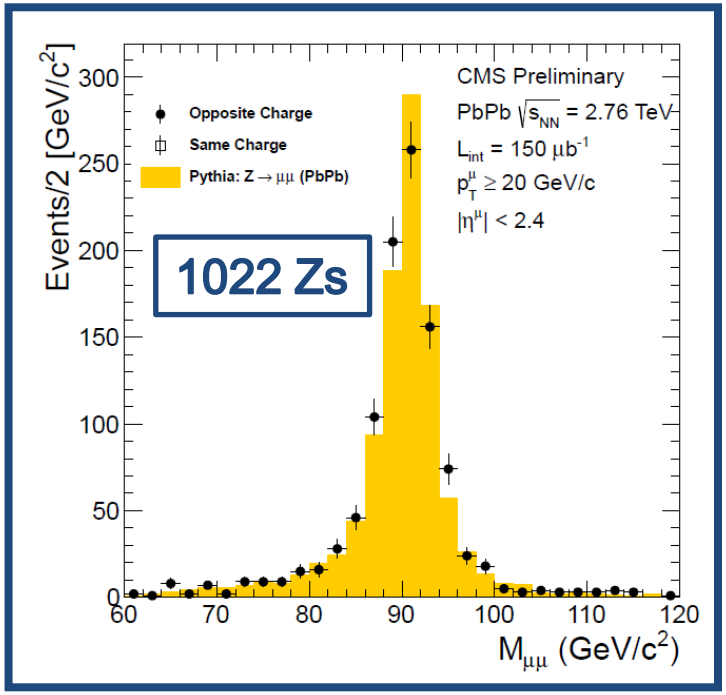


$Z \rightarrow \mu^+\mu^-$ in PbPb Collisions @ 2.76 TeV

- **Muon Reconstruction:** take tracks reconstructed in tracker and match to tracks reconstructed in muon system.

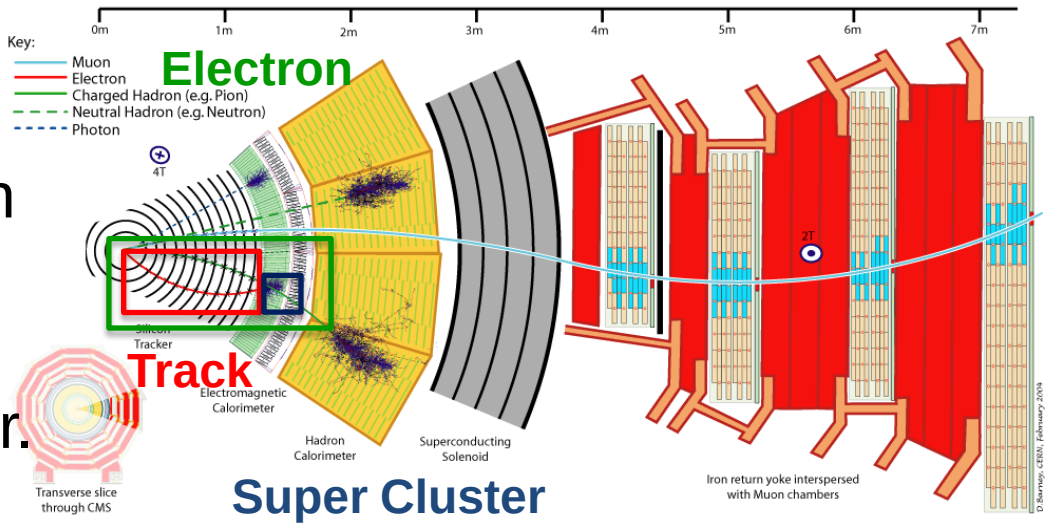


- **High-p_T muon resolution:** 1-2% for muons up to 100 GeV/c.
- **Triggers:** Unprescaled single high-p_T and dimuon trigger.
- **Background:**
  - No same-charge pairs.
  - Other Background: < 1%.

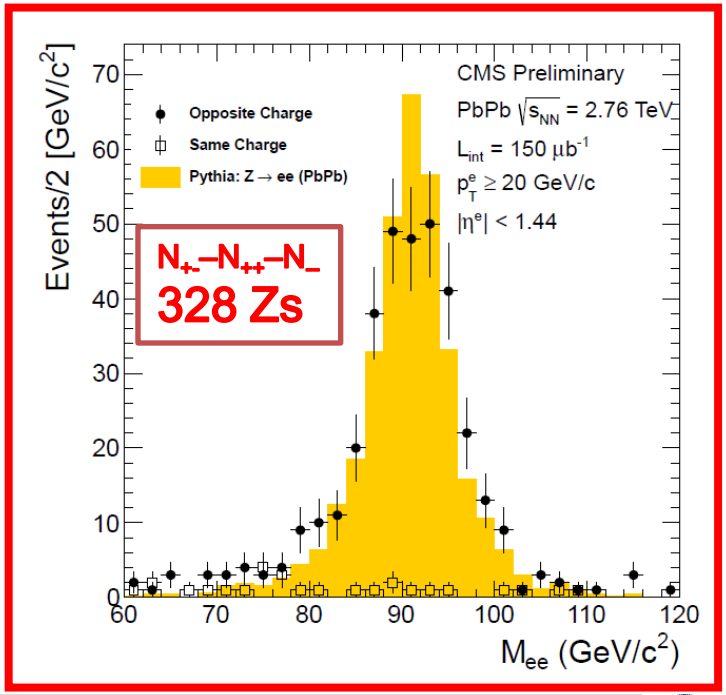


$Z \rightarrow e^+e^-$ in PbPb Collisions @ 2.76 TeV

- **Electron Reconstruction:** take tracks reconstructed in tracker and match to super clusters reconstructed in electromagnetic calorimeter.

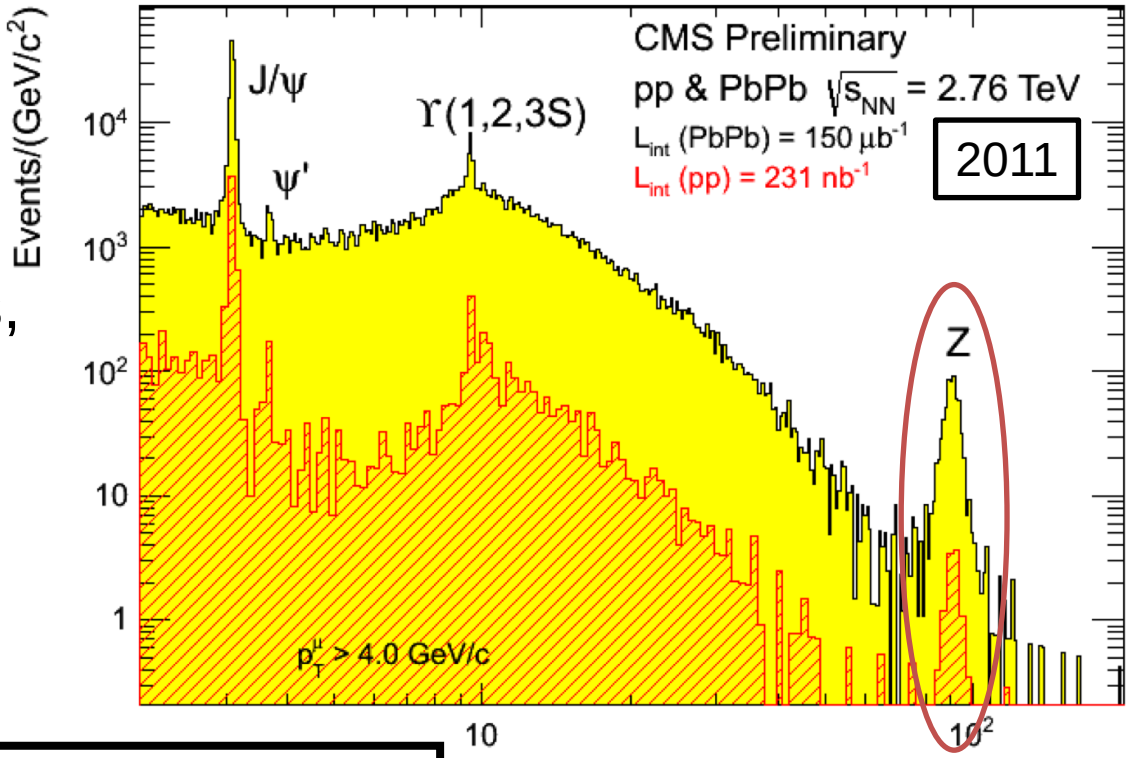


- **Electron ID Cuts:** Shower shape and ratio of Energy deposit in the ECAL and HCAL used to reject background.
- **Trigger:** Unprescaled high-p_T trigger for dielectrons.
- **Background:**
  - Same-charge pairs: ~7.5%
  - Other Background: < 2%.



Z Production in pp $\sqrt{s}$ = 2.76 TeV

- **Mar. 2011:**
  - **L_{int}**: 231 nb^{-1}.
  - ~30 Zs
- From lack of pp statistics, previous results were shown with POWHEG NLO calculation as reference.

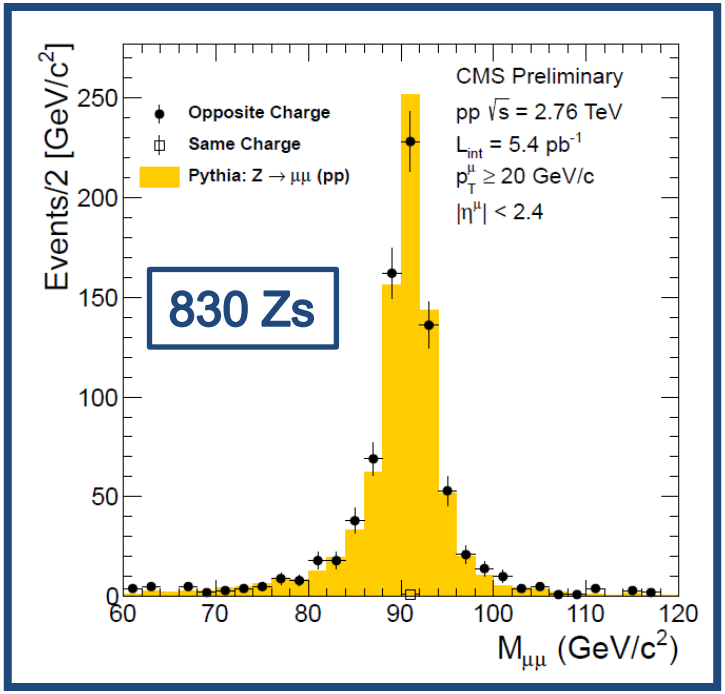


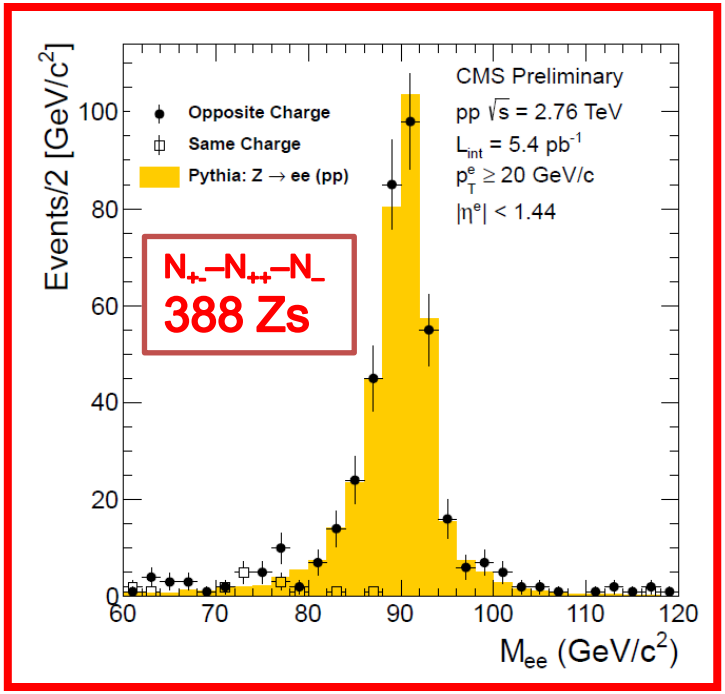
- **Feb. 2013:**
  - **L_{int}**: 5.4 pb^{-1}.
  - > 20x Increase!

$$R_{AA} = \frac{dN_{AA}}{d\sigma_{pp} \times T_{AA}}$$

- ***pp* run at 2.76 TeV at LHC driven in part by desire for R_{AA} measurements of hard probes.**

$Z \rightarrow l^+l^-$ in pp Collisions @ 2.76 TeV





- **$Z \rightarrow \mu^+\mu^-$** and **$Z \rightarrow e^+e^-$:**
  - Followed same analysis method as in *PbPb*.
  - Around the same number of **Z**s in *PbPb* and *pp*.
  - Direct measurement of Nuclear Modification Factor (R_{AA})

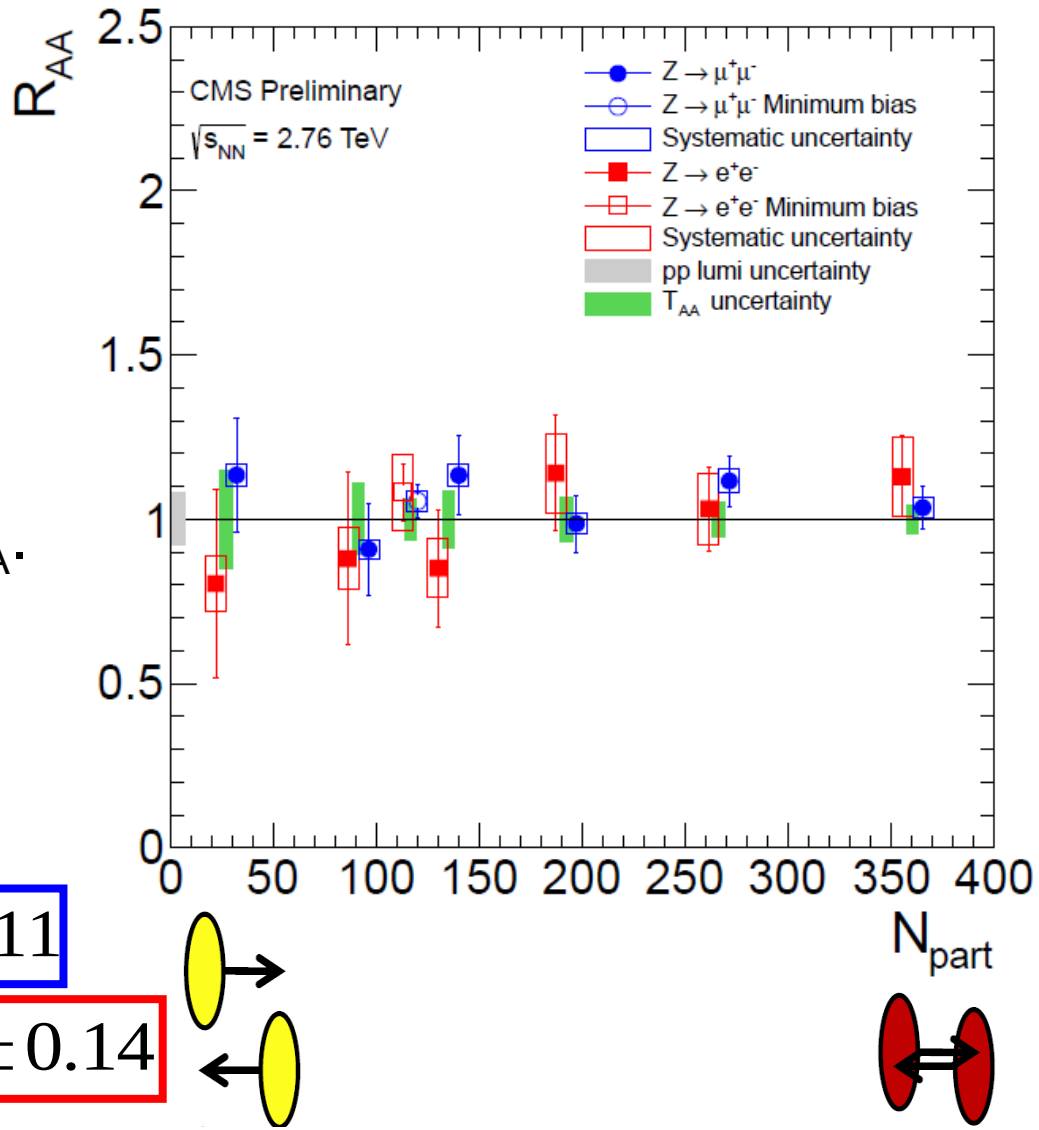
R_{AA} vs N_{part}

- R_{AA} vs N_{part} shows:
  - Agreement between **$Z \rightarrow \mu^+\mu^-$** and **$Z \rightarrow e^+e^-$**.
  - **Z** boson production in both channels in PbPb collisions scales with T_{AA}.

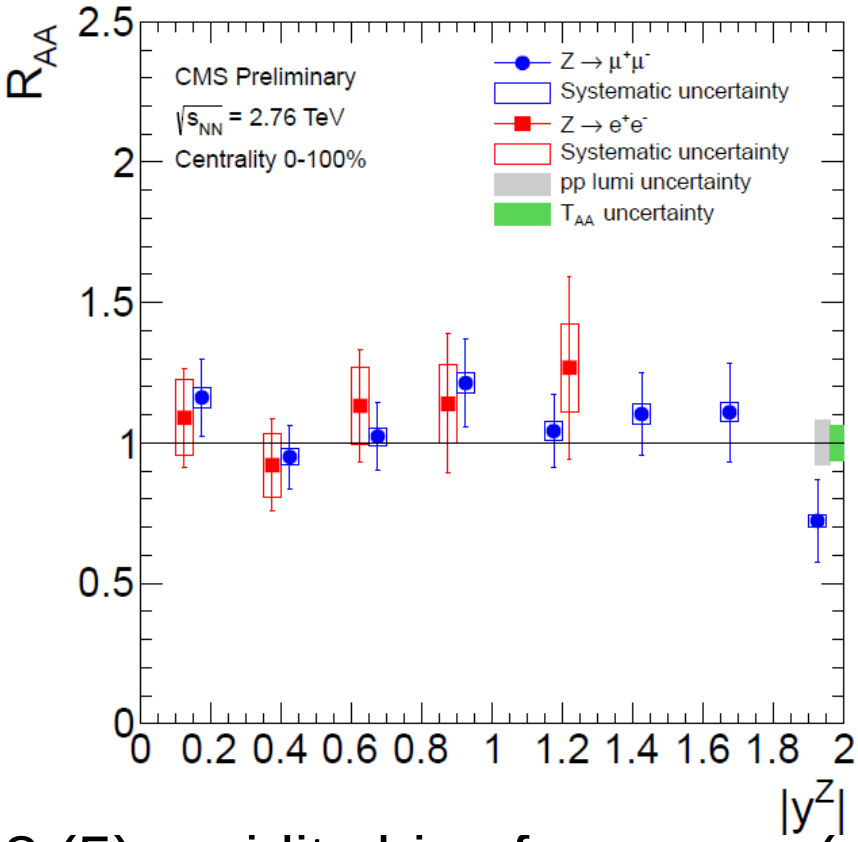
$$R_{AA} = \frac{dN_{AA}}{d\sigma_{pp} \times T_{AA}}$$

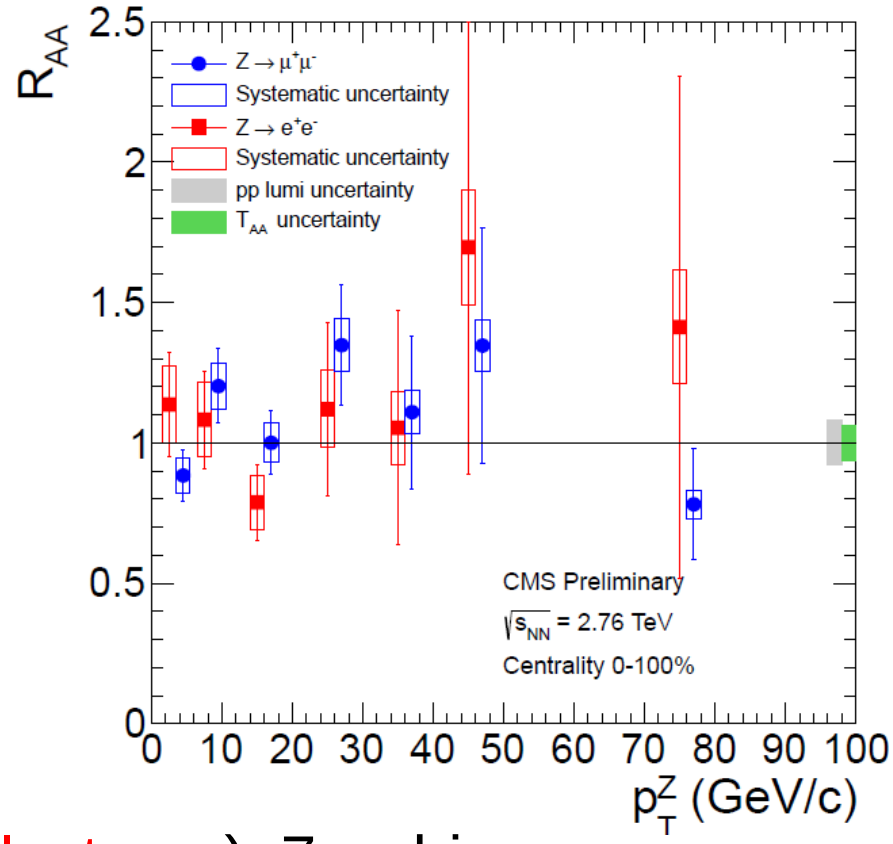
$$R_{AA}(\text{muon}) = 1.06 \pm 0.05 \pm 0.11$$

$$R_{AA}(\text{electron}) = 1.08 \pm 0.09 \pm 0.14$$



R_{AA} vs |y| and p_T

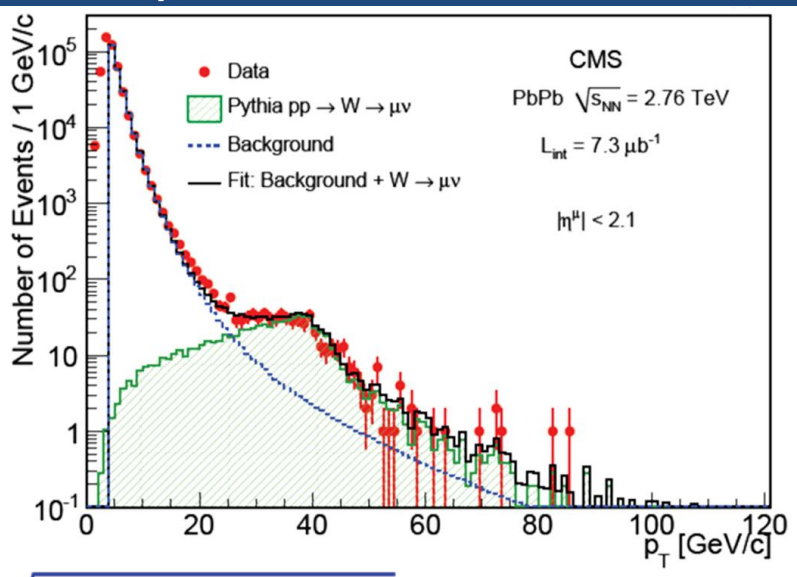




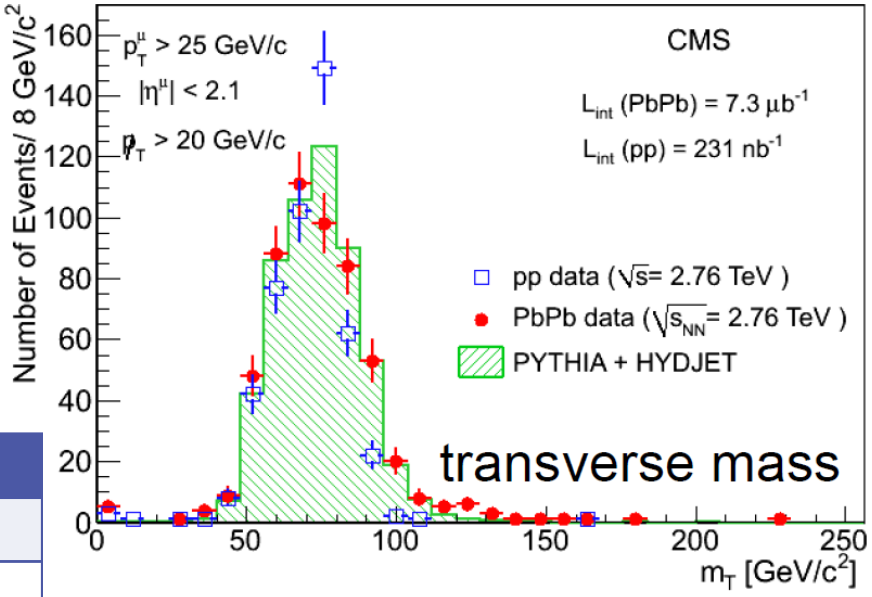
- 8 (5) rapidity bins for muons (electrons), 7 p_T bins.
- R_{AA} vs |y| and p_T shows:
  - Agreement between **$Z \to \mu^+\mu^-$** and **$Z \to e^+e^-$.** Agreement with R_{AA} of 1.
  - Nuclear effects: need more statistics to probe this scale.

W analysis: muons + missing-p_T in Heavy Ions

- **W (2012):** L_{int}(PbPb) = 7.3 μb^{-1}, L_{int}(pp) = 231 nb^{-1}
- **Signature:** high-p_T muon recoiling against (undetected) neutrino in transverse plane.
- **Good quality muons:**
  - |η| < 2.1.
  - p_T > 25 GeV/c.
  - Veto on Z candidates.
- **Missing p_T** ($\not{p}_T$):
  - reconstructed using p_T>3 tracks
  - select events: $\not{p}_T$ >20 GeV
- 2010 PbPb ≈ pp data



$$m_T = \sqrt{2 p_T^{\mu} \not{p}_T (1 - \cos\phi)} \qquad \phi = \phi(\mu) - \phi(\not{p}_T)$$



	PbPb	pp
W$^+$	275	301
W$^-$	264	165

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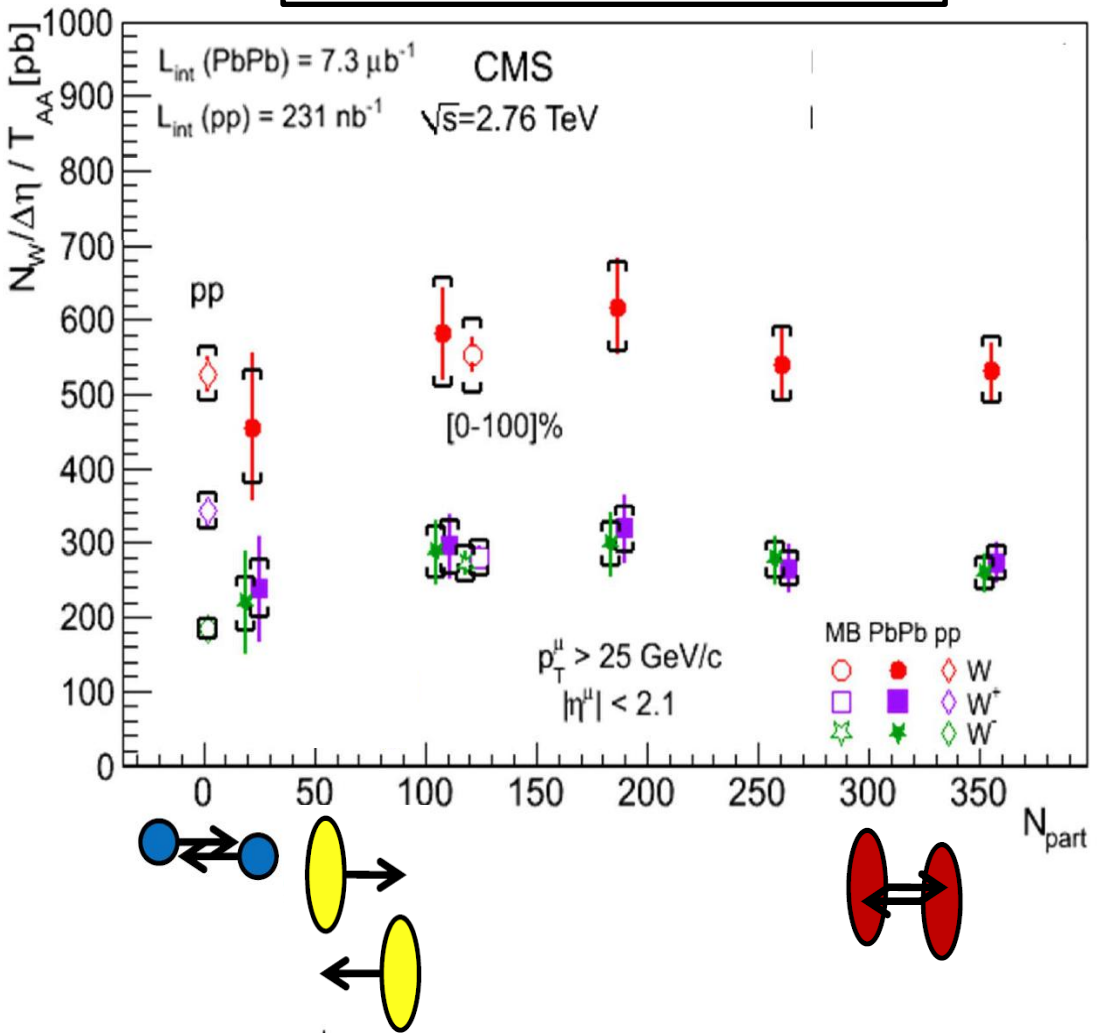
W (2012): Results (R_{AA})

$R_{AA}(W) = 1.04 \pm 0.07 \pm 0.12$
$R_{AA}(W^+) = 0.83 \pm 0.07 \pm 0.09$
$R_{AA}(W^-) = 1.46 \pm 0.14 \pm 0.16$

- Consistent With Pure Isospin Effects:
  - pp:
    - (u:d quark content = 4:2 = 2)
    - $\sigma_{W+} > \sigma_{W-}$ (open green & purple points on the left)
  - PbPb:
    - (u:d = 580:668 = 0.9)
    - $\sigma_{W+} \sim \sigma_{W-}$ (full green & purple points, and mid open points)
  - R_{AA} for **W^+** and **W^-** reflect different up and down quark content in Pb and p.



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Conclusions

- **$Z \rightarrow l^+l^-$ @ 2.76 TeV:**
  - $Z \rightarrow \mu^+\mu^-$ and $Z \rightarrow e^+e^-$ channels show consistent results.
  - No modification (within statistical and systematic uncertainties) of **Z** production is observed in PbPb collisions with respect to pp yields scaled by T_{AA}:

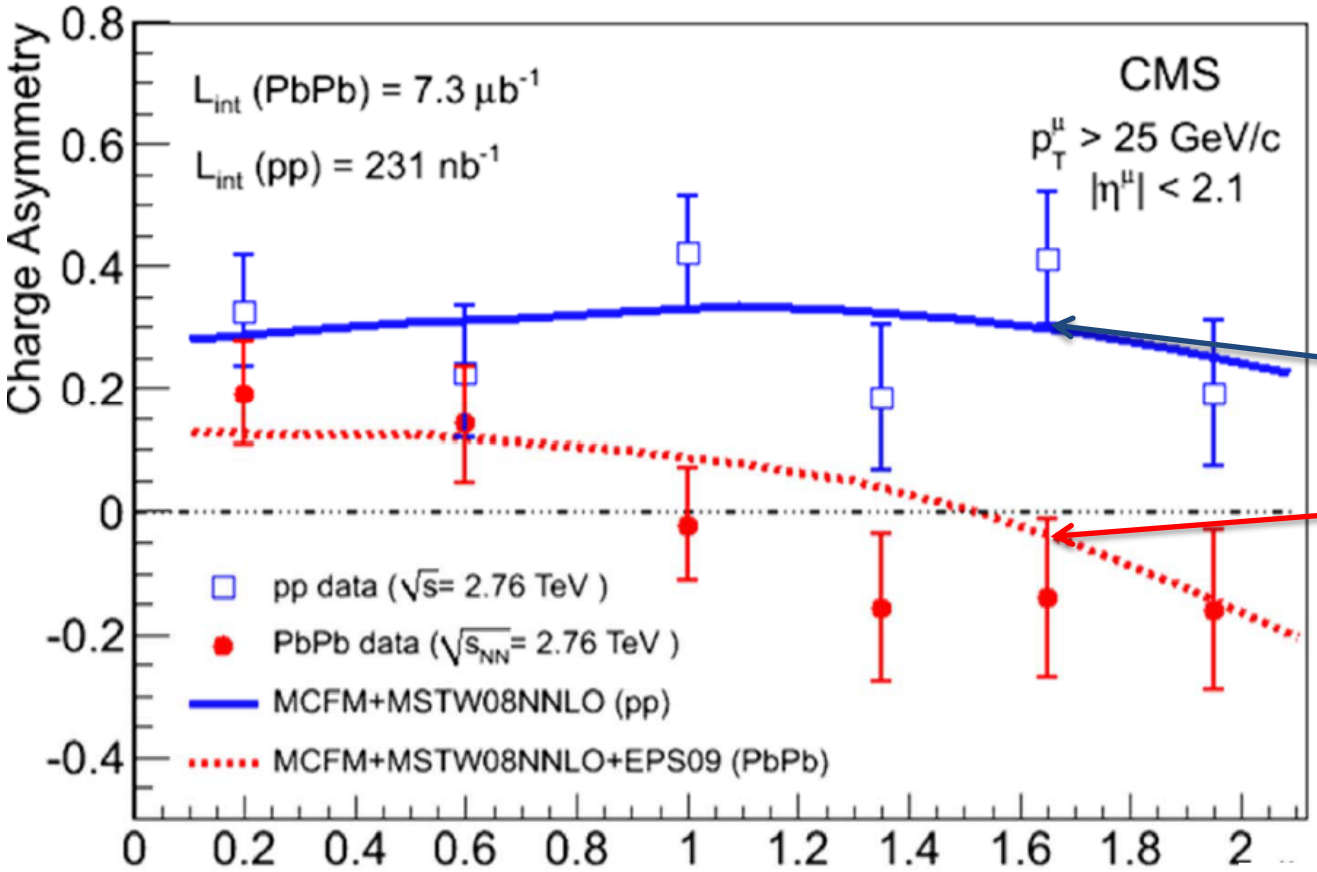
$$R_{AA}(\text{muon}) = 1.06 \pm 0.05 \pm 0.11$$

$$R_{AA}(\text{electron}) = 1.08 \pm 0.09 \pm 0.14$$

  - Confirms scaling based on Glauber model.
- **$W \rightarrow \mu\nu$ @ 2.76 TeV:**
  - **$W^{\pm}$** yields in PbPb collisions exhibit isospin effect as expected.
  - **W** yields scaled by T_{AA} are consistent with pp yields.
- **Z and W probes**: 'standard candles' for initial state of PbPb collisions.

Backup Slides

W (2012): Results (Muon Charge Asymmetry)



Muon Charge Asymmetry:

$$\frac{N(W^+) - N(W^-)}{N(W^+) + N(W^-)}$$

pp: W+ production higher than W-

PbPb: W^- production dominates for large $|\eta^\mu|$

- Experimental values compatible with theoretical predictions:
  - MCFM calculation (@NNLO) + nucleon PDF (MSTW08) (pp data)
  - + [nuclear PDF (EPS09)] (PbPb data)

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Future

- Low stats Z+jet, or Z+track measurement in *PbPb* may be pursued.
- Before LS1 very important run completed:
  - *pPb* at $\sqrt{s_{NN}}$ = 5 TeV:
    - Test geometric scaling.
    - Calibrate dijet measurements.