Z boson production in pp, pPb and PbPb collisions with CMS

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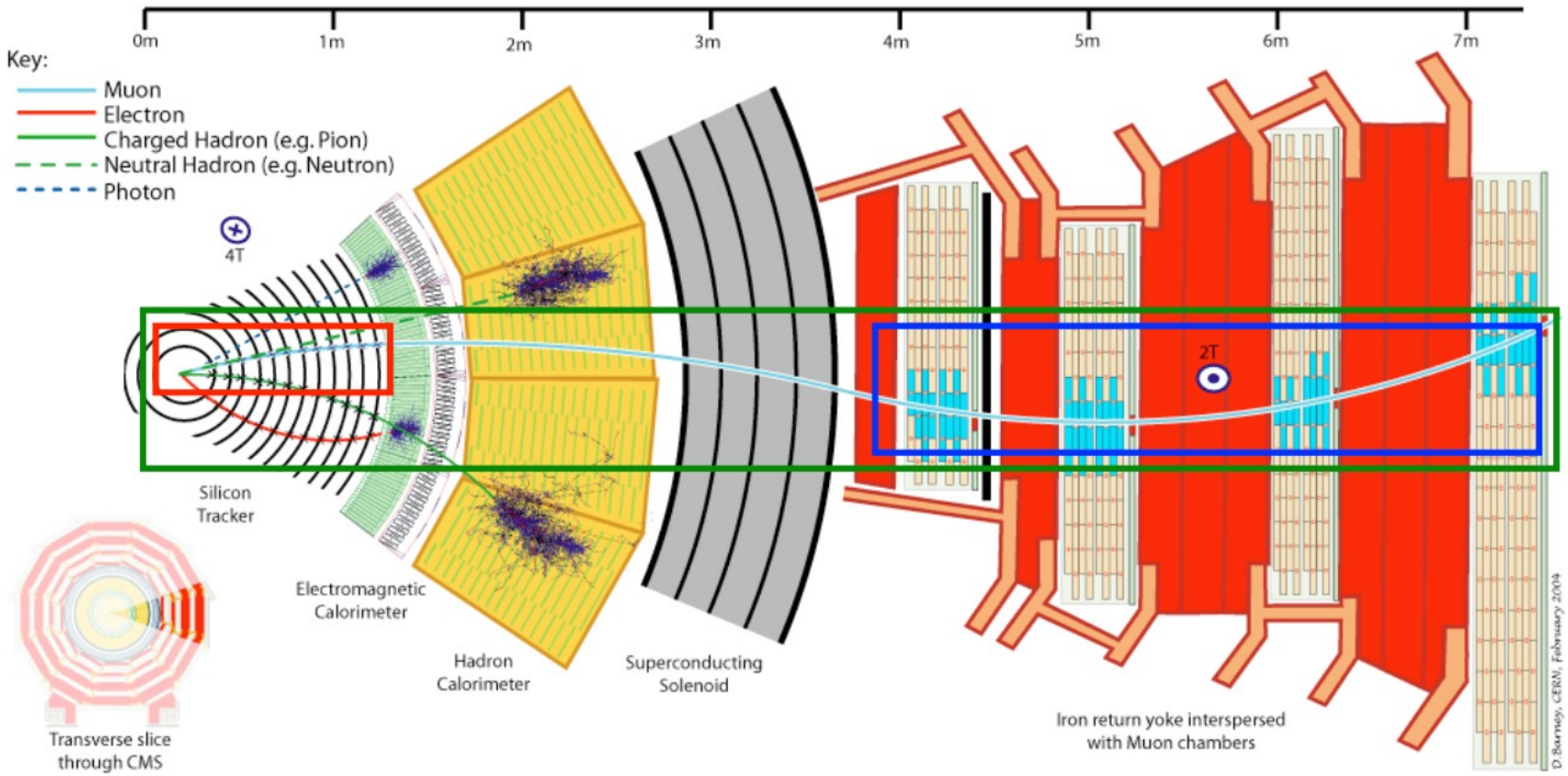
Introduction

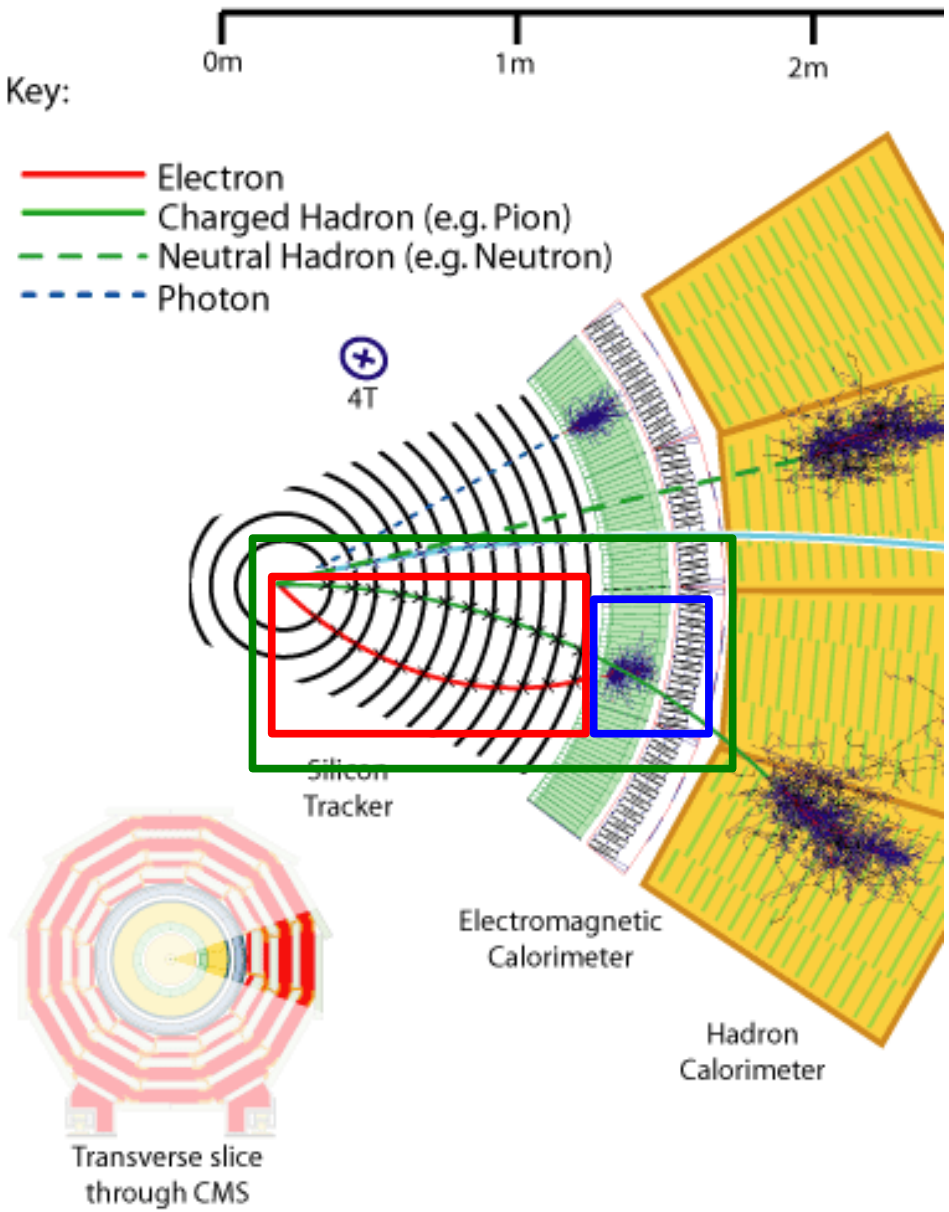
- LHC energies allow first measurements of Z and W bosons in heavy ion collisions
- Electroweak bosons are essentially not modified by the QCD medium
  - Check the binary scaling hypothesis
  - Serve as a reference to modified processes (jets...)
  - Constrain nuclear parton distribution functions (nPDFs)
- CMS results on Z boson production
  - 2010 PbPb data, muon channel: PRL 106 (2011) 212301
  - 2011 PbPb data and 2013 pp data, including muon and electron channel: CMS-PAS-HIN-13-004
  - 2013 pPb data, muon channel: CMS-PAS-HIN-14-003
- W boson production was presented by Emilien Chapon

Muon reconstruction



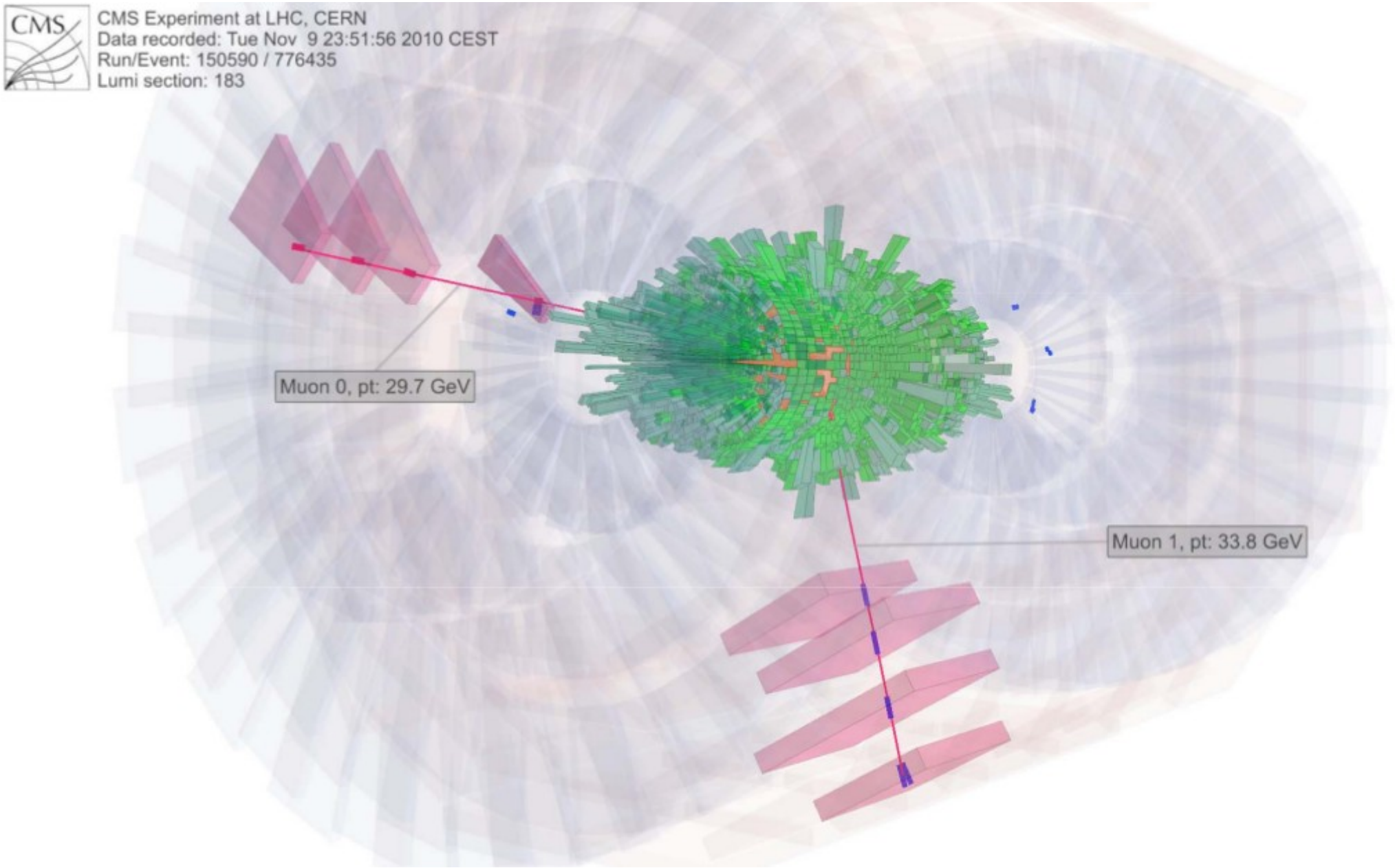
- Global muons reconstructed with information from inner tracker and muon stations
- 1-2% resolution up to muon p_T ~ 100 GeV/c

Electron reconstruction

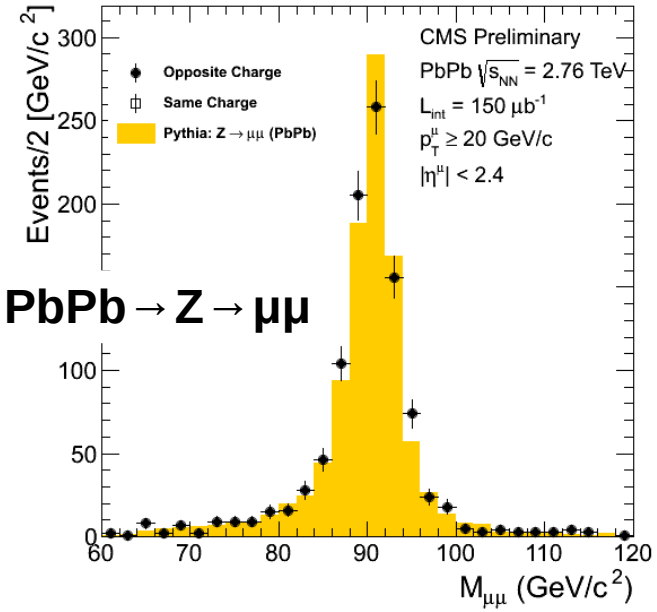


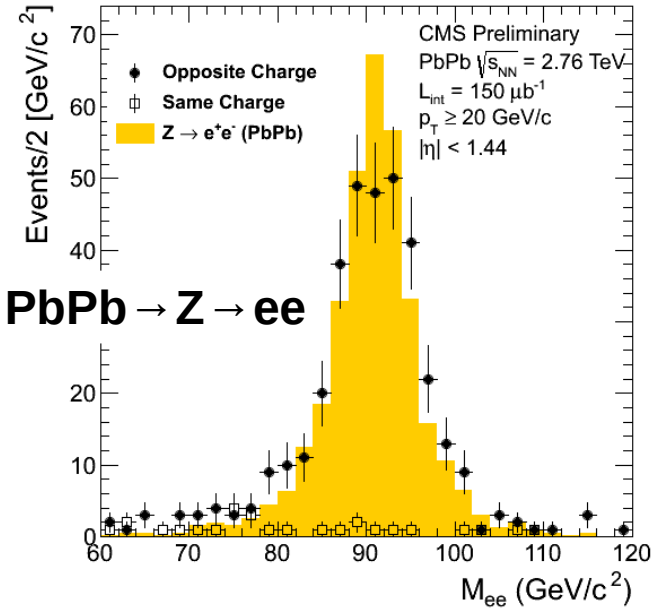
- Electron candidate is a supercluster matched to an inner track
- Dedicated outside-in tracking to take into account radiation
- Resolution is 1-2% for high p_T (~45 GeV/c) electrons

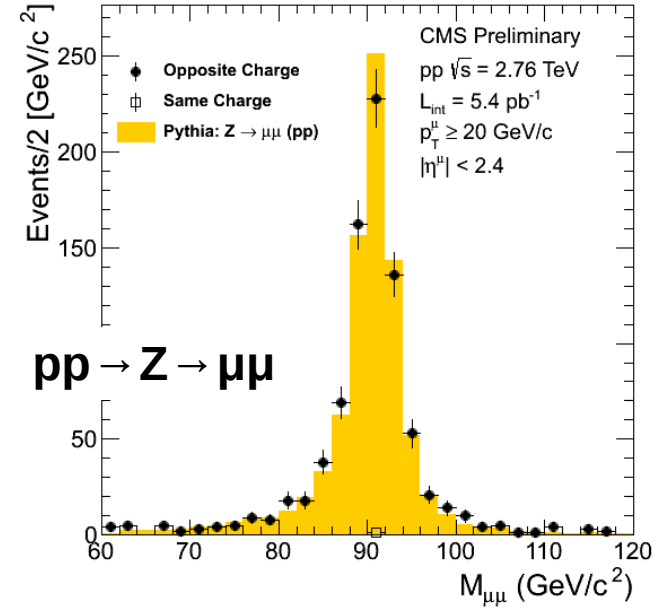
Z bosons in PbPb and pp @ 2.76 TeV

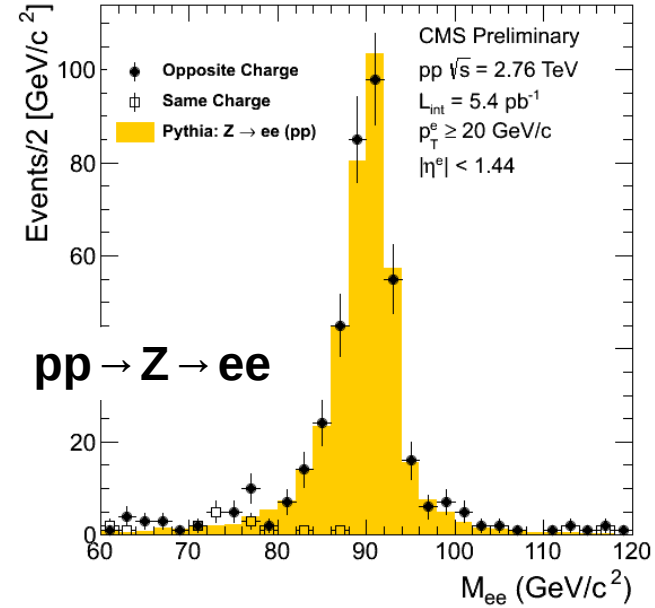


Z bosons in PbPb and pp @ 2.76 TeV





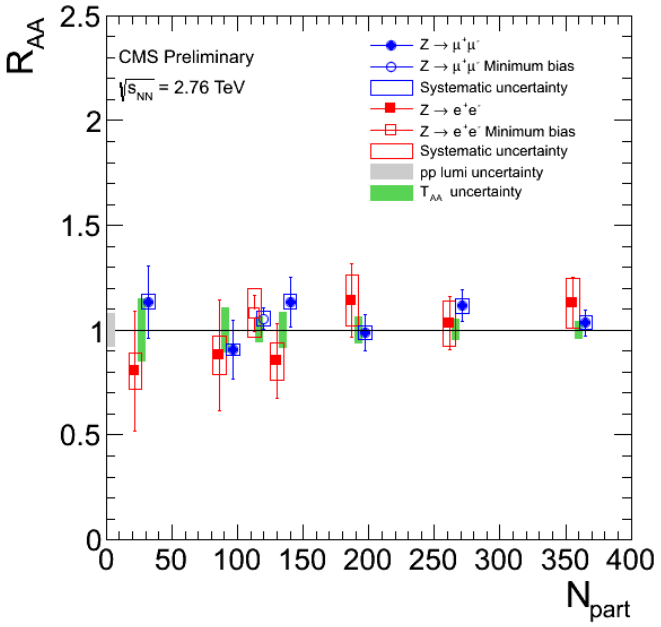


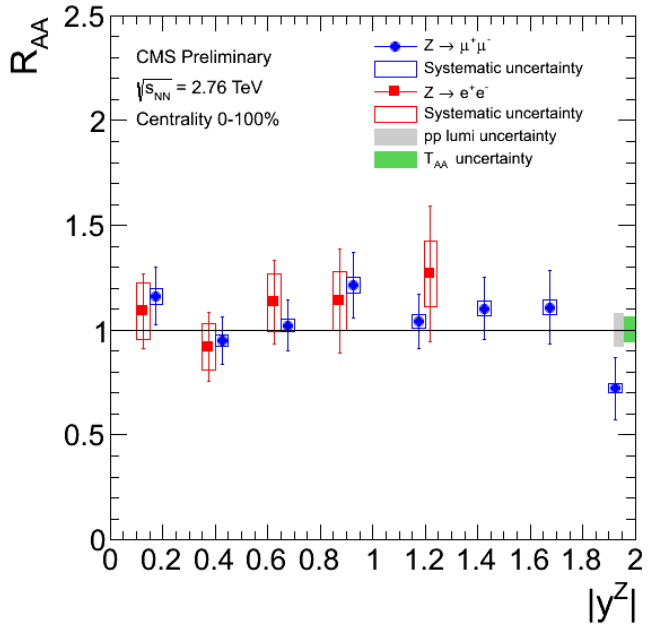


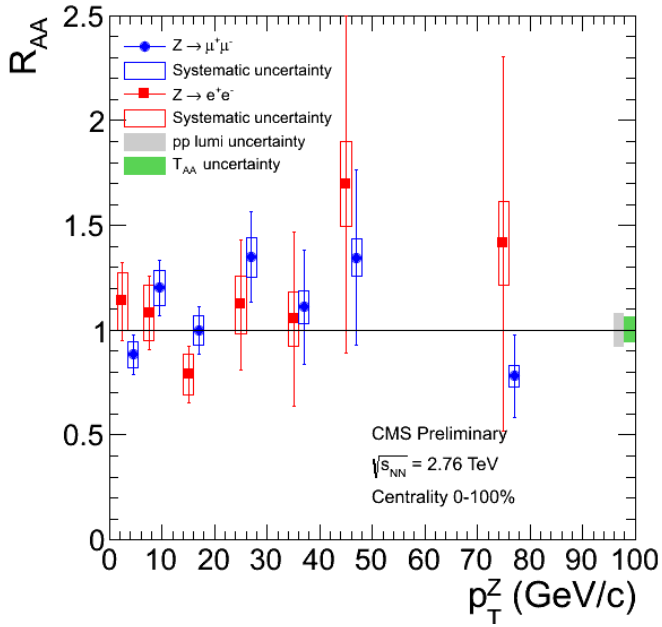
- 2011 PbPb data
- 2013 pp data
- Both muon and electron channels included
- Lepton selection:
  - $p_T > 20$ GeV/c
  - $|\eta^{\mu\,(e)}| < 2.4$ (1.44)
- Dilepton mass in [60, 120] GeV/c^2

CMS-PAS-HIN-13-004

Z bosons in PbPb and pp @ 2.76 TeV



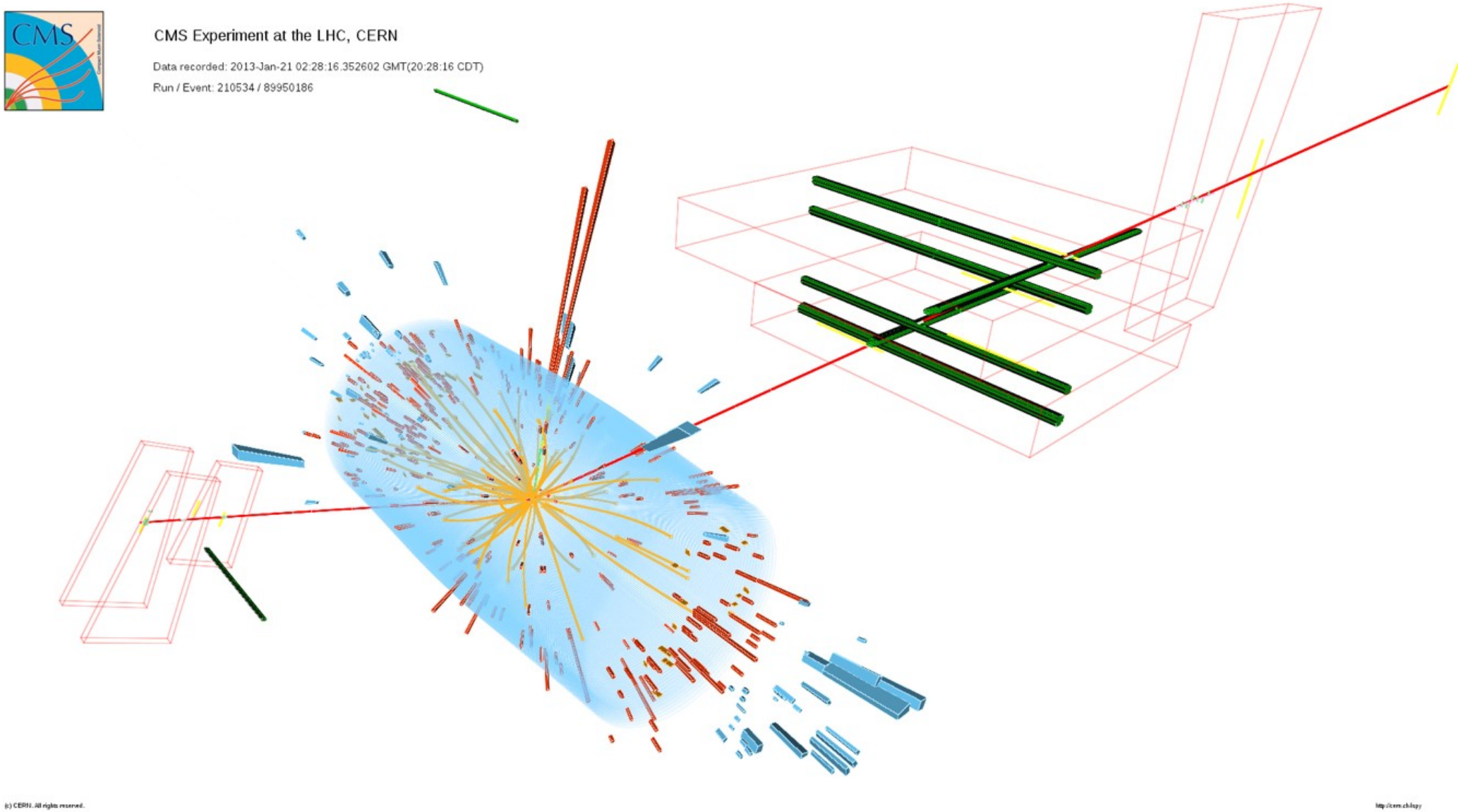




- Muon and electron results agree
- R_{AA} consistent with 1
- Scaling with number of binary collisions confirmed
- Possible nuclear effects on the p_T or rapidity spectrum are within the uncertainties of the measurement

CMS-PAS-HIN-13-004

Z bosons in pPb @ 5.02 TeV



Nuclear parton distribution functions

- Nuclear PDF parametrizations

$$f^{\text{proton,A}} = R_f(x, Q^2) f^{\text{free proton}}(x, Q^2)$$

$$Q^2 \approx m^2_{W/Z} \qquad x \approx 10^{-3} - 10^{-1}$$

- Z and W bosons are sensitive to (valence) quark and (sea) antiquark content of the nucleus
- Dominant processes (LO)

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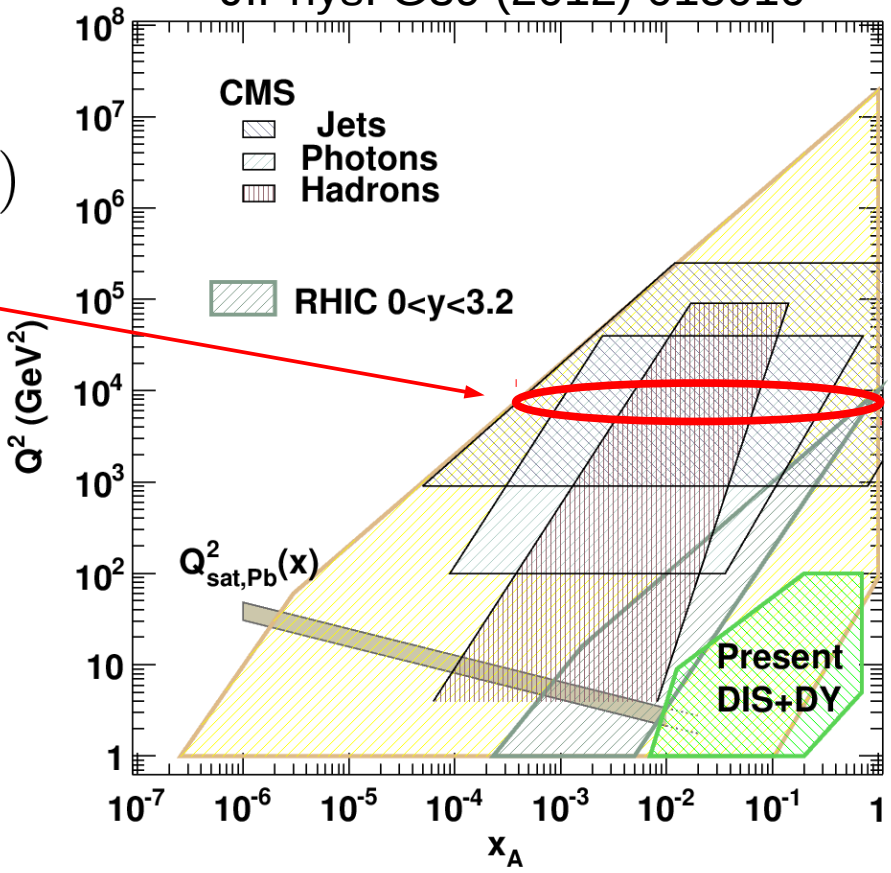
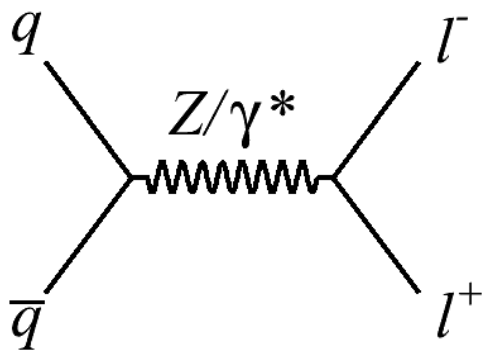
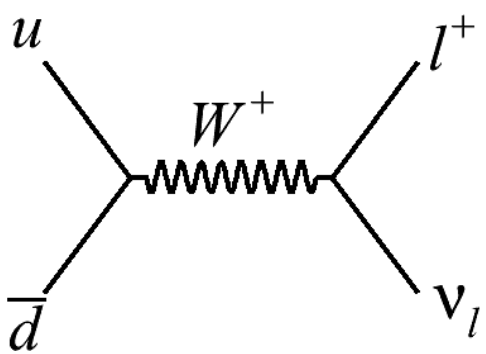
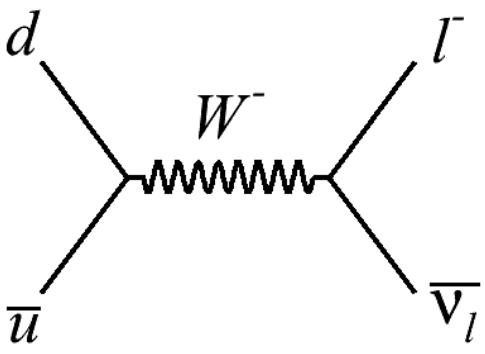


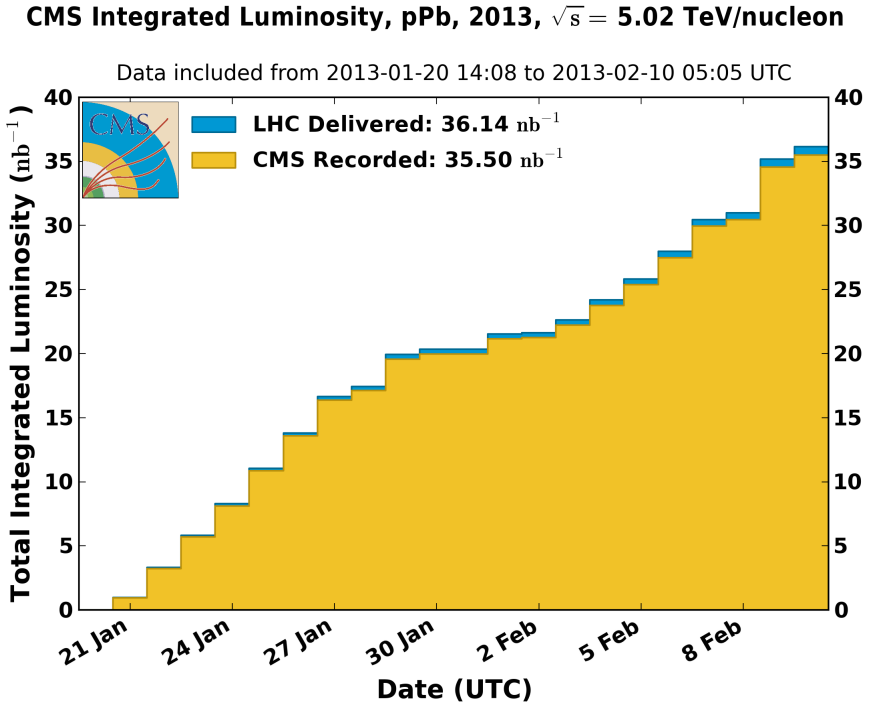






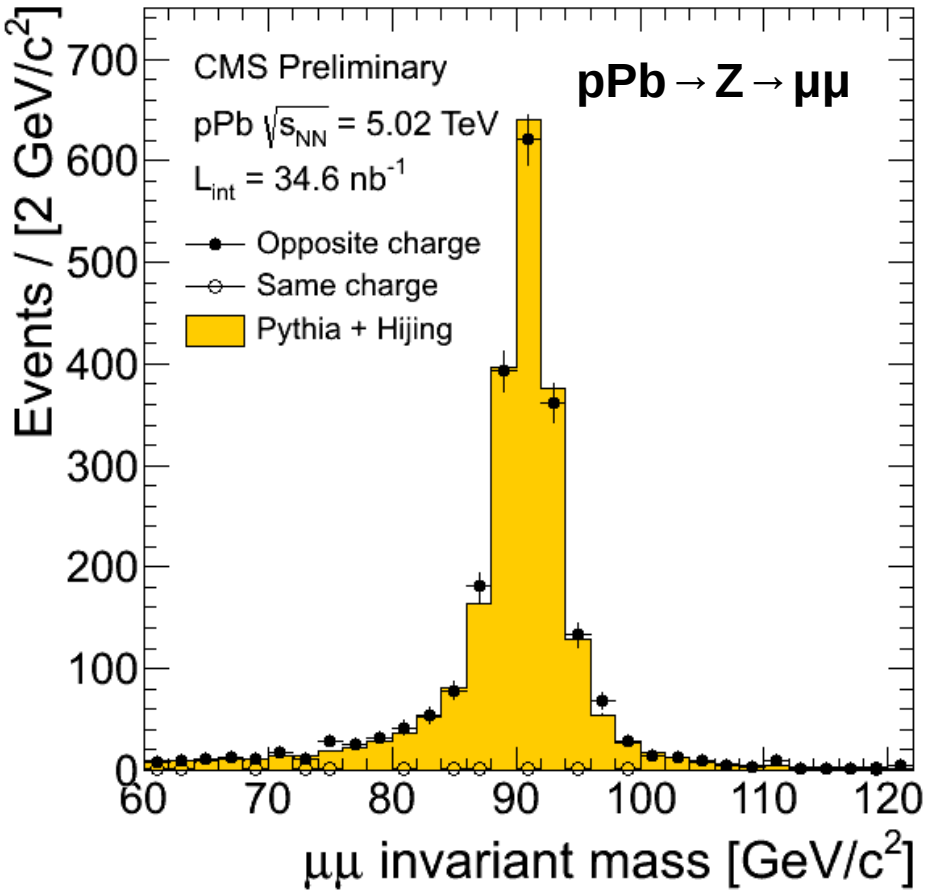
pPb collisions @ LHC

- Data taking in 2013
- Integrated luminosity
  - 34.6 ± 1.2 nb^{-1} (certified)
  - Calibrated by Van der Meer scans
- 5.02 TeV center-of-mass energy per nucleon pair
  - 4 TeV proton + 1.58 ATeV Pb
  - Rapidity boost of Δy = (-)0.465



- Data taking with both beam direction settings
- Results presented with proton fragmentation (forward) region probed at positive values of rapidity

Z bosons in pPb @ 5.02 TeV



- Dimuon invariant mass in [60, 120] GeV/c^2
- Muon selection
  - $p_T^{\mu} > 20$ GeV/c
  - $|\eta^{\mu}_{lab}| < 2.4$ (muon detector coverage)
- Asymmetric acceptance in rapidity in the center-of-mass frame due to the boost
- 2183 Z candidates

CMS-PAS-HIN-14-003

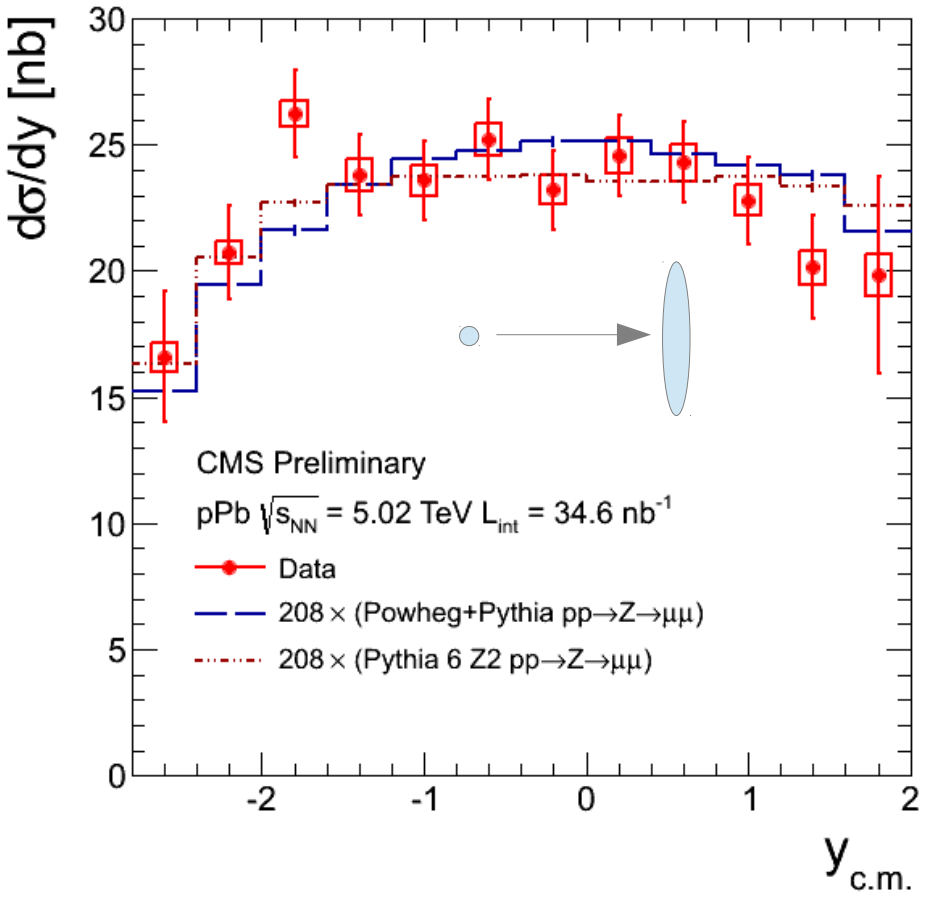
Z bosons in pPb @ 5.02 TeV

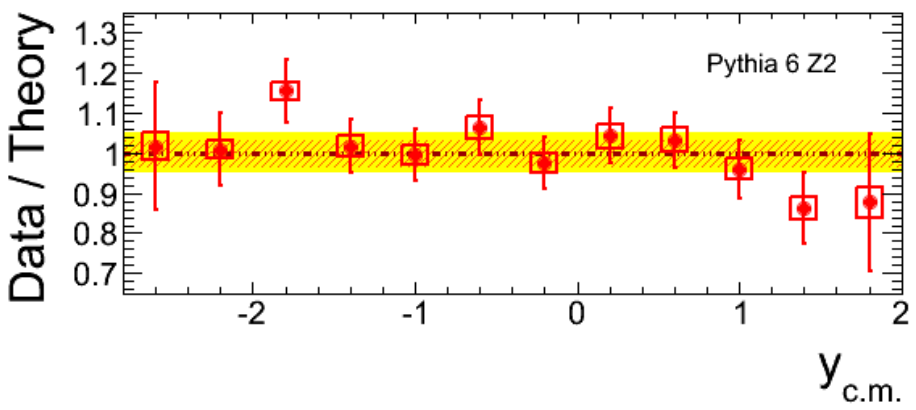
- Inclusive Z production cross section in pPb collisions
- Compared to NLO POWHEG calculation scaled by A=208

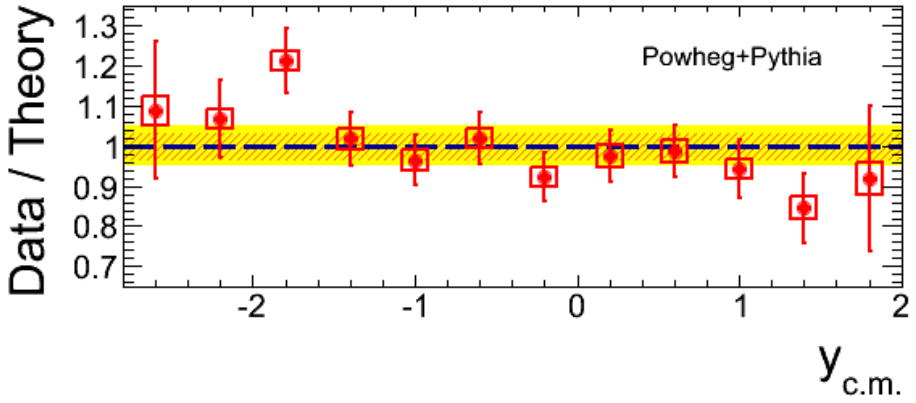
$\sigma(pPb \to Z \to \mu\mu)$	Measured $\sigma \pm$ stat. $\pm$ syst. $\pm$ lumi.	$\sigma^{\text{NLO POWHEG}} \times A$
Full phase space	134.4 ± 2.9 ± 7.1 ± 4.7 nb	134 ± 7 nb
$-2.5 < y_{\text{c.m.}} < 1.5$	94.1 ± 2.1 ± 2.4 ± 3.3 nb	94.0 ± 4.7 nb

- Restricted rapidity range to reduce uncertainties on the acceptance correction
- Results consistent with $\sigma^{pp} \times A$

Z bosons in pPb @ 5.02 TeV







- dσ/dy shifted to center-of-mass frame
- Uncertainties dominated by statistical uncertainties
- Consistent with scaled pp predictions

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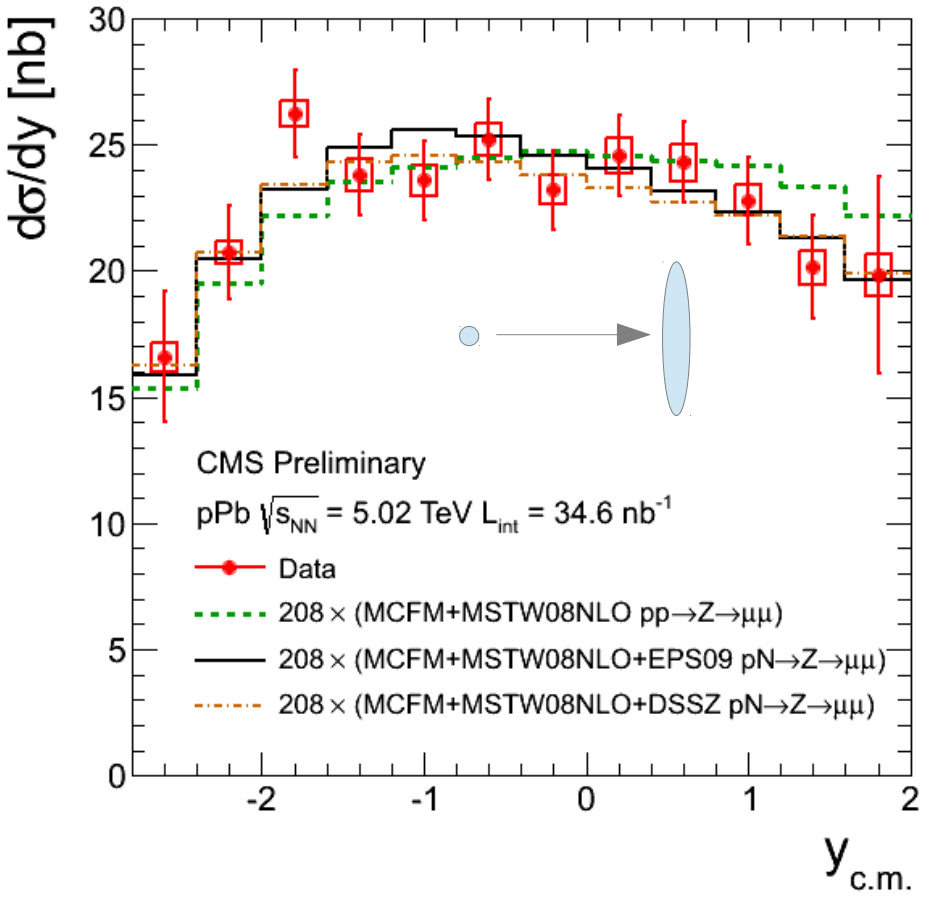
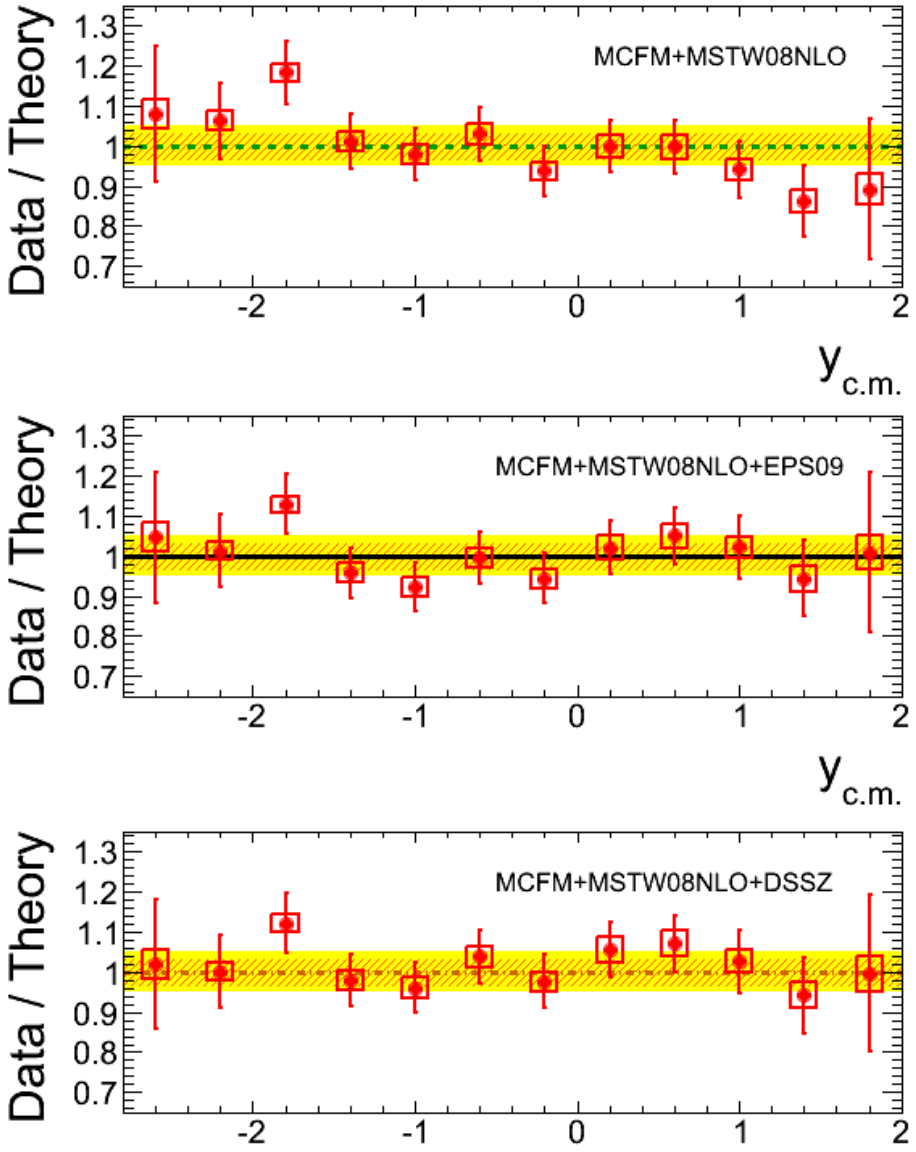
Z bosons in pPb @ 5.02 TeV





- Nuclear effects expected in the forward and backward regions

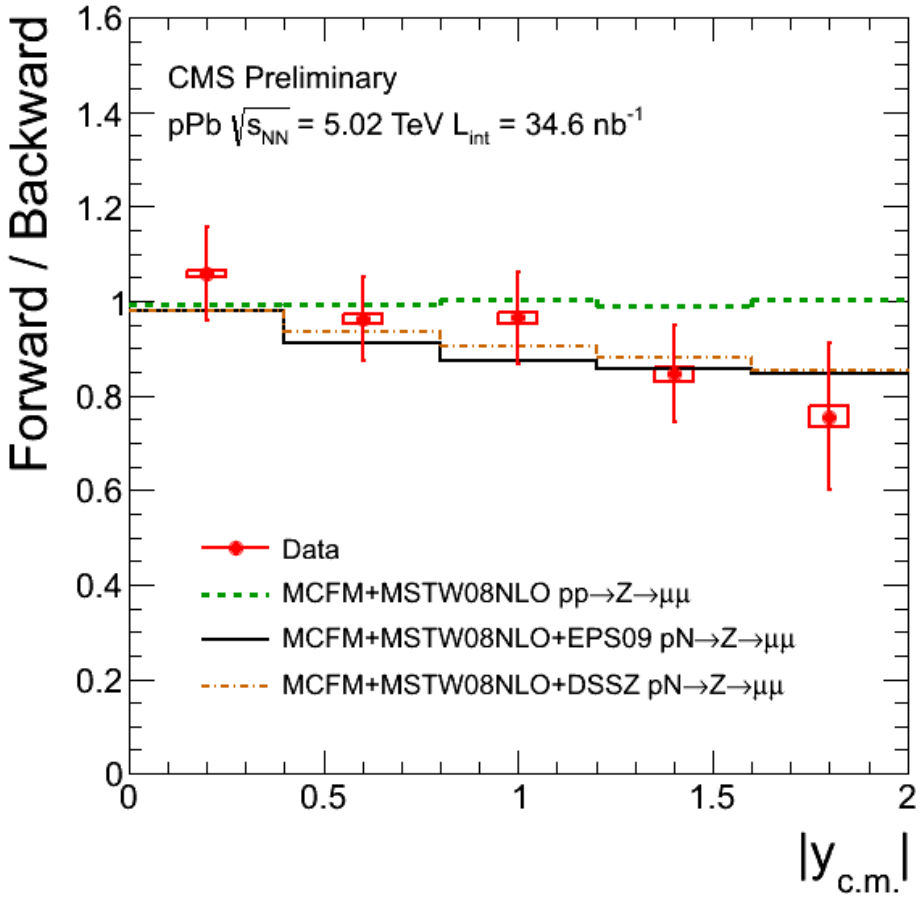
CMS-PAS-HIN-14-003

Z bosons in pPb @ 5.02 TeV

- Forward-backward ratio expected to be more sensitive to nuclear effects

$$R_{FB} = \frac{d\sigma(+y_{\mathrm{c.m.}})/dy}{d\sigma(-y_{\mathrm{c.m.}})/dy}$$

- Without nuclear effects should be 1
- Hint of nuclear effects visible
- Large uncertainties both on data and nuclear PDF central predictions



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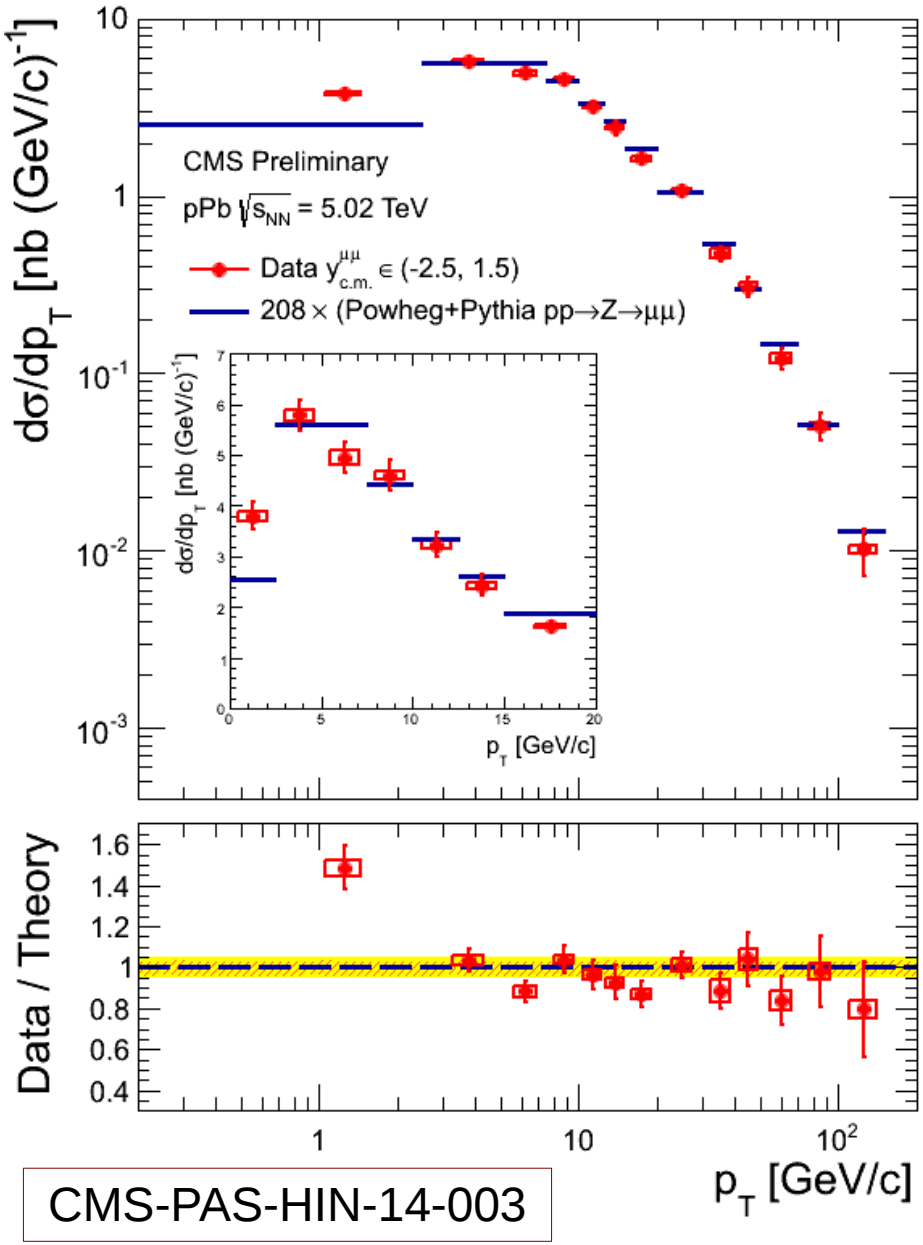
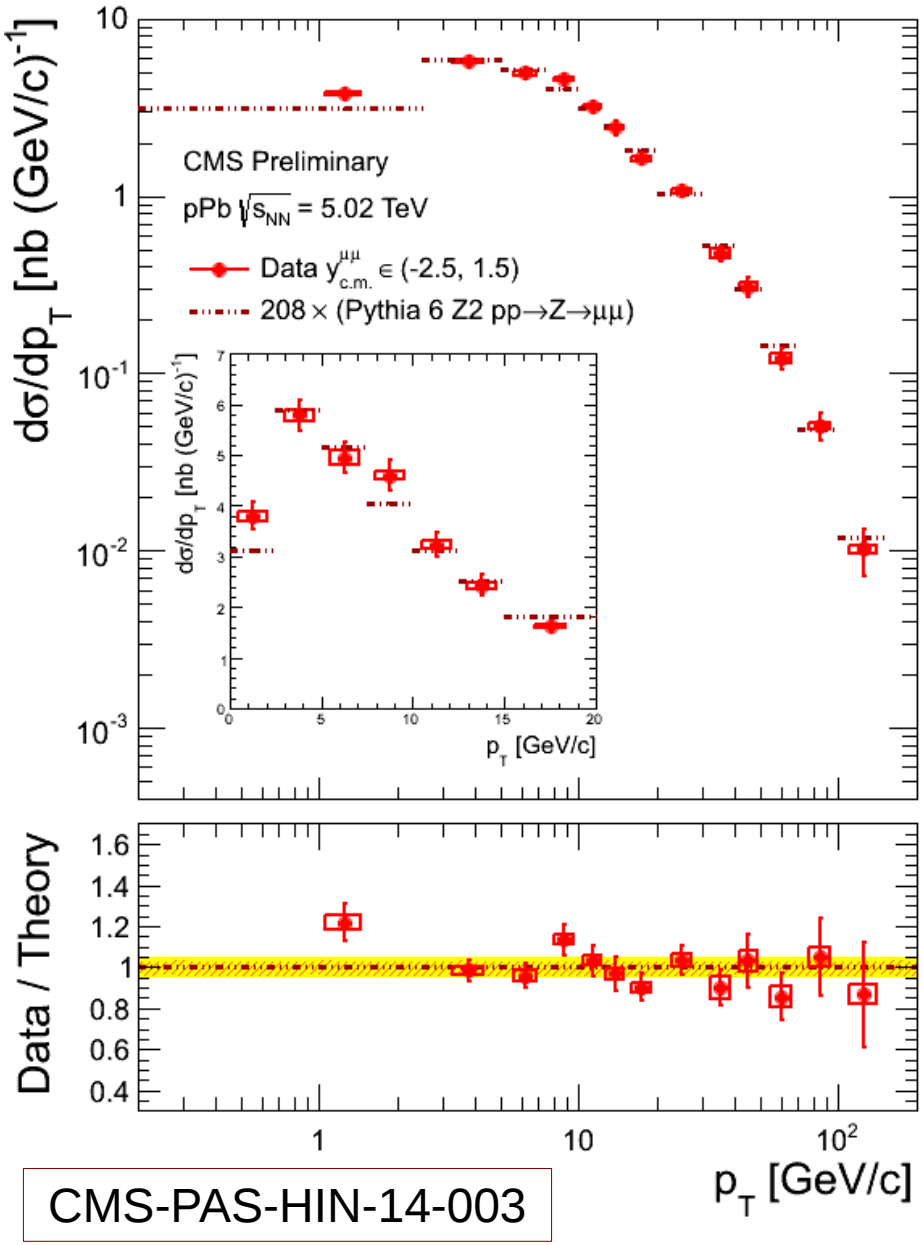
Z bosons in pPb @ 5.02 TeV



CMS-PAS-HIN-14-003

- p_T differential cross section
  - Wide range from 0 – 150 GeV/c
- Expected nuclear effects are small → comparing only to pp
- Compared to POWHEG+PYTHIA
  - Deviations seen consistent with 7 & 8 TeV pp results

Z bosons in pPb @ 5.02 TeV



CMS-PAS-HIN-14-003

- p_T differential cross section
  - Wide range from 0 – 150 GeV/c
- Expected nuclear effects are small → comparing only to pp
- Compared to POWHEG+PYTHIA
  - Deviations seen consistent with 7 & 8 TeV pp results
- Compared to PYTHIA
  - Better agreement in the low p_T region

Summary

- At first order, Z boson production scales with the number of binary collisions in both pPb and PbPb collisions
- R_{AA} in the muon and the electron channel does not show large deviations from unity
- Cross section measured in pPb collisions set constraints on the global fits of nuclear parton distribution functions in a previously unexplored region of phase space
- Hints of nuclear effects seen but more luminosity is needed to distinguish between nPDFs

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN