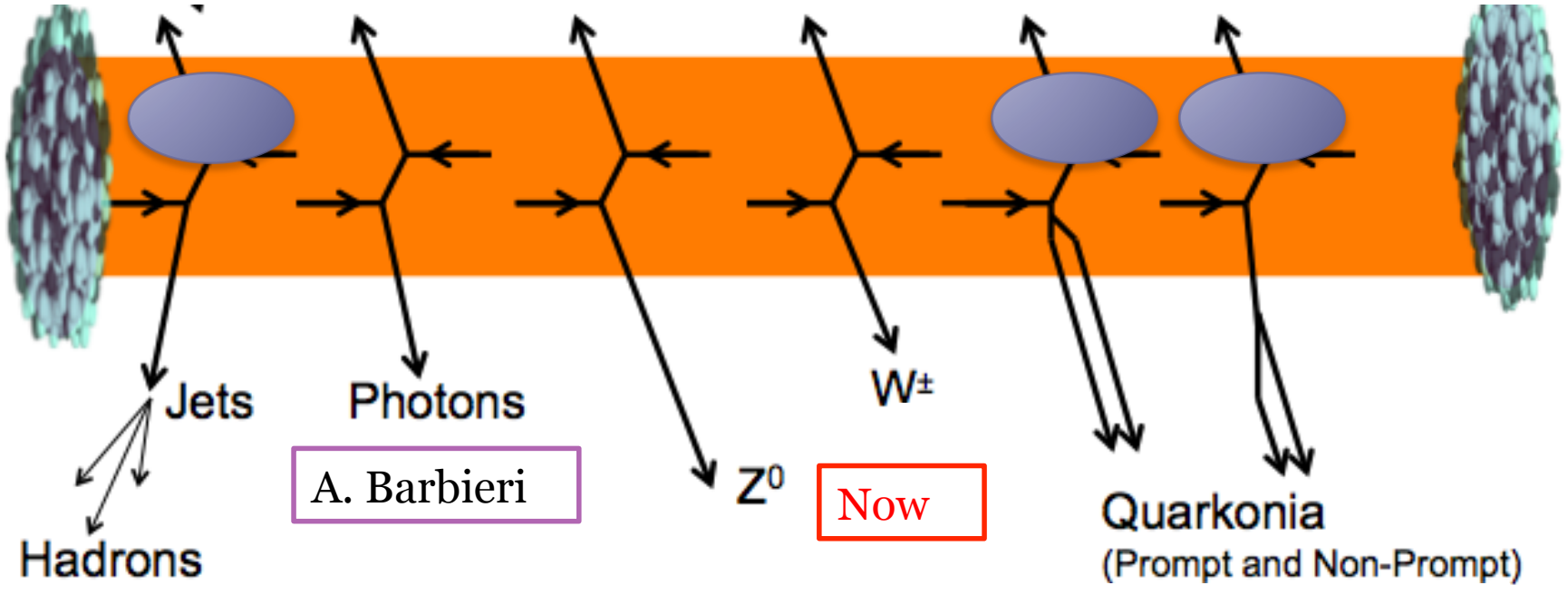
Production of W and Z bosons in heavy-ion collisions with CMS

Hard Probes 2013, Cape Town

Alice Florent
On behalf of the CMS collaboration

Hard processes in QCD medium



A. Barbieri

Now

Y. Lai
Y. Mao
K. Jung

L. Benhabib
D. Moon

- Weak bosons are formed before QGP due to their large mass t ≅ 1/M ≅ 0.003 fm/c
- Weak boson life time **≈ 0.1 fm/c**

Unmodified probes

Electro + weak bosons (through their leptonic decays) are **medium-blind**

- References for modified processes
- Ultimately can help to constrain initial state

Which ones can we detect in heavy-ion collisions with CMS?

Unmodified probes

All of them

Collision	Z_μ	Z_e	W_μ	W_e	Isolated γ
pp 2.76 2011			PLB 715 (2012) 66 *		PLB 710 (2012) 256 PLB 718 (2013) 773
pp 2.76 2013	PAS-13-004*	PAS-13-004*			PAS-13-006
PbPb 2.76 2010	PRL 106 (2011) 212301		PLB 715 (2012) 66 *		PLB 710 (2012) 256
PbPb 2.76 2011	PAS-13-004*	PAS-13-004*			PLB 718 (2013) 773
pPb 5.02 2013	On going				PAS-13-006

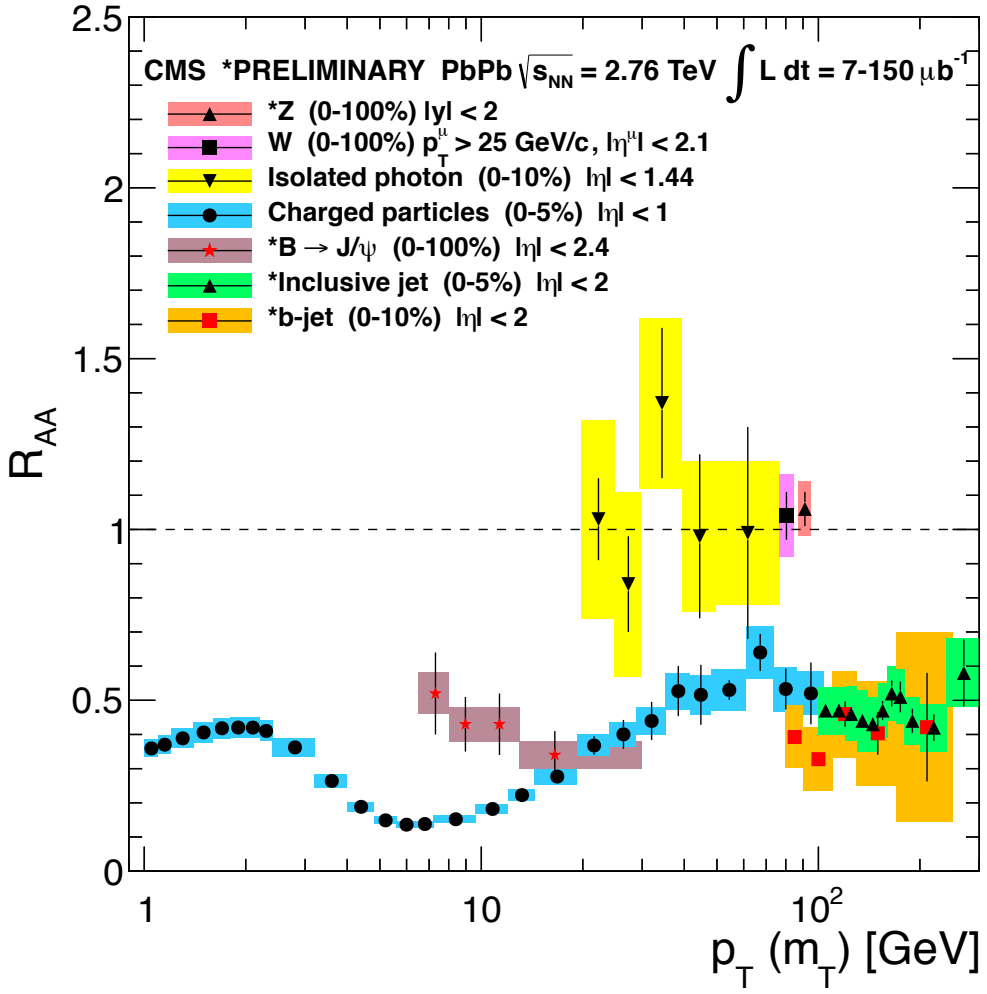
* results presented in this talk

How to measure if a probe is affected by the medium?

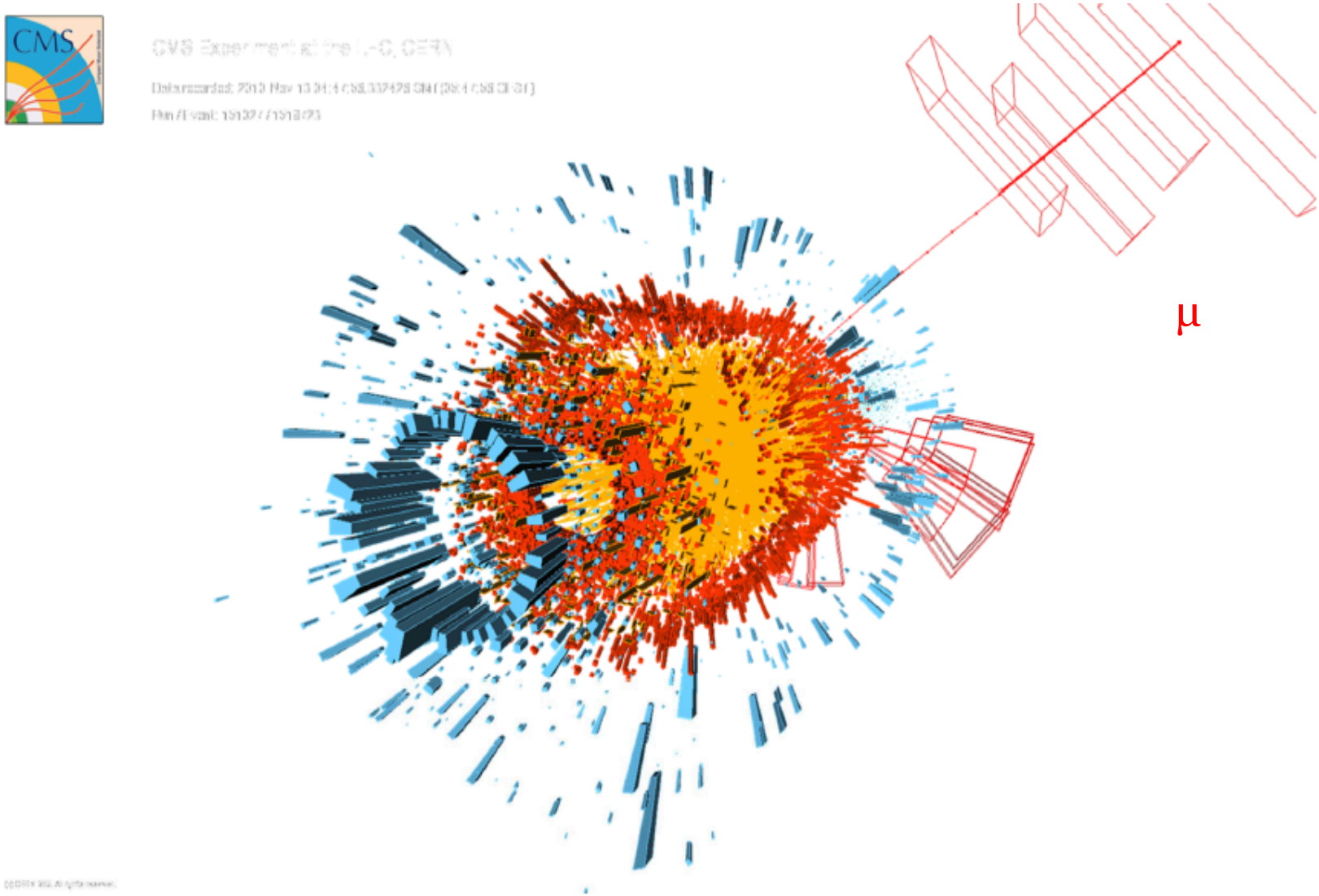
R_{AA} = ratio between the production yield in PbPb and the production yield in pp, normalized by the number elementary collisions

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

T_{AA}= overlap nuclear function
Estimated with Glauber model



1. W ➔ $\mu^{\pm}$ + ν



μ and ν

$\mathbf{p^{\mu}_{T}}$

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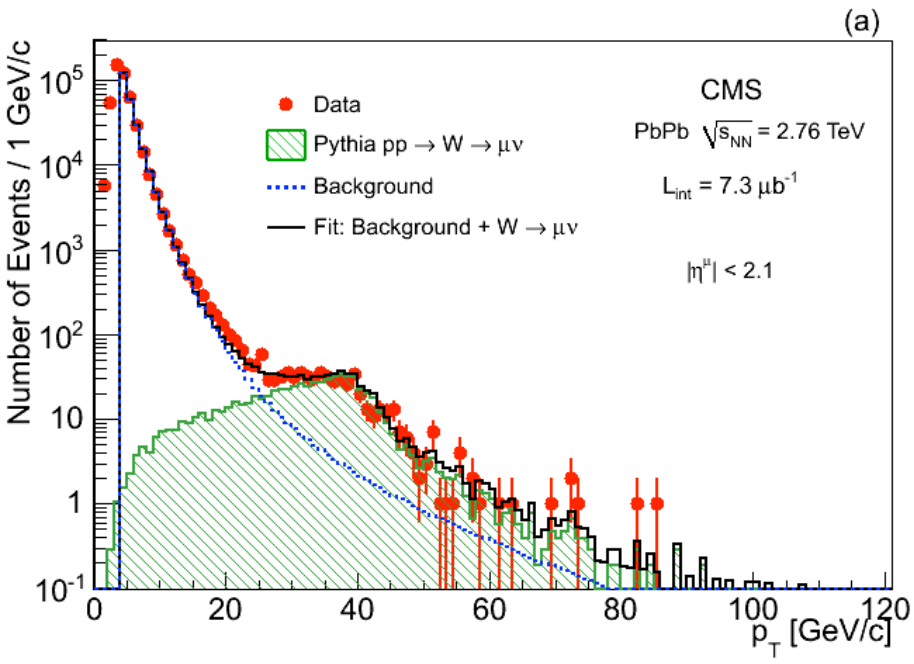
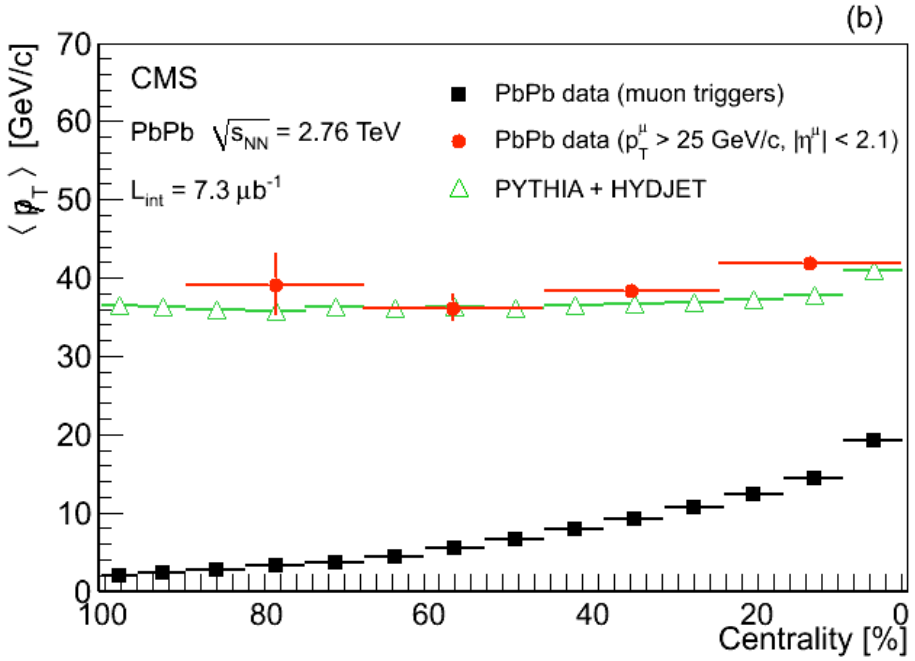
$$\not{p} = -\sum \vec{p}_T$$





Signal already visible in muon p_T spectrum

ν reconstruction: unbalanced energy in the transverse plane

Missing p_T from tracks

Transverse mass

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

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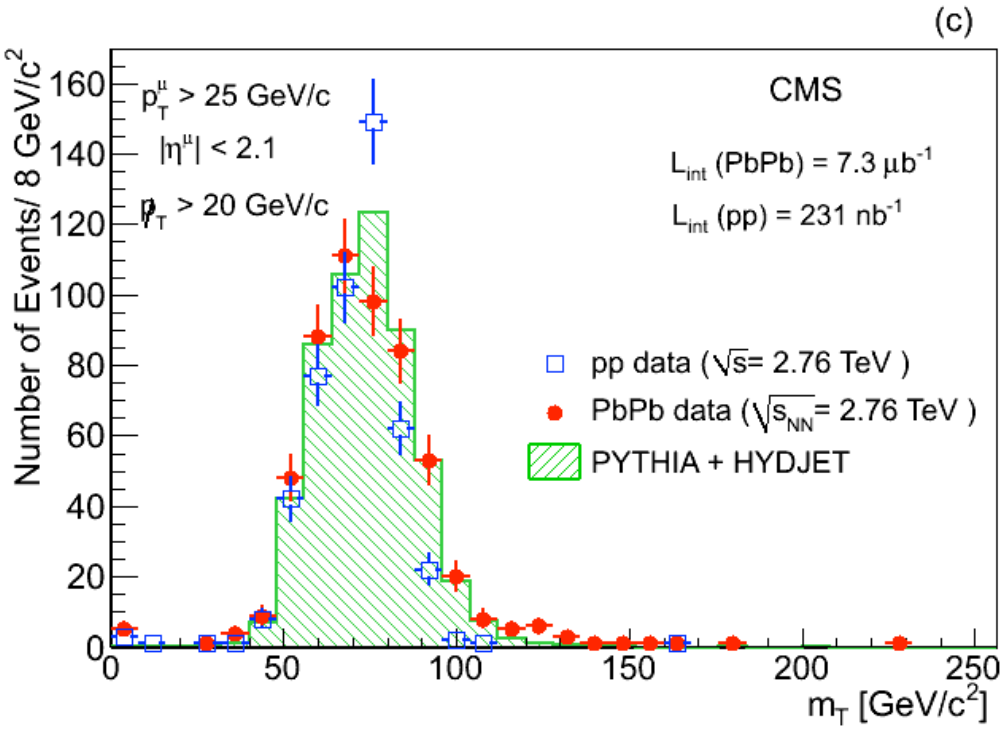


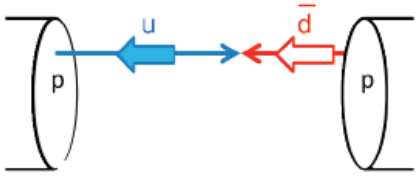
Yields extraction:
$m_T > 40$ GeV/c²

Almost no background
- 1% taken as systematic for QCD
- 2% EWK subtracted

	PbPb	pp
W+	275	301
W-	264	165

- Slightly worse resolution in PbPb
- PbPb data compatible with simulations

- **Why different yield for W^+ and W^- ?**



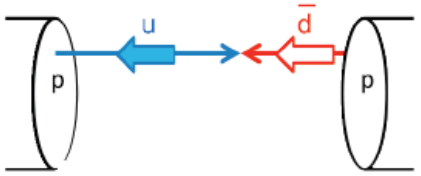
$u\bar{d} \rightarrow W^+$

$d\bar{u} \rightarrow W^-$

pp collisions = more W^+ than W^-

PbPb collisions = more W^- than W^+

- **Why different yield for W^+ and W^- ?**

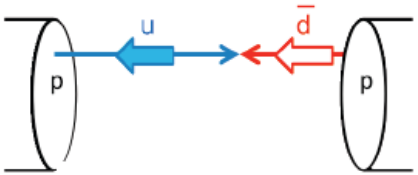


$u\bar{d} \rightarrow W^+$

$d\bar{u} \rightarrow W^-$

pp collisions = more W^+ than W^-
PbPb collisions = more W^- than W^+

- **Then why don't we have less W^+ than W^-?**

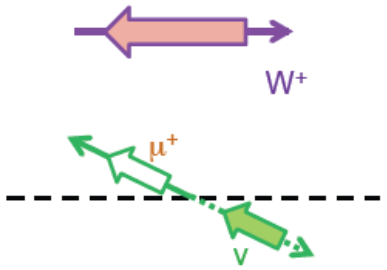


1. $W^{\pm}$ are boosted in the direction of valence quark

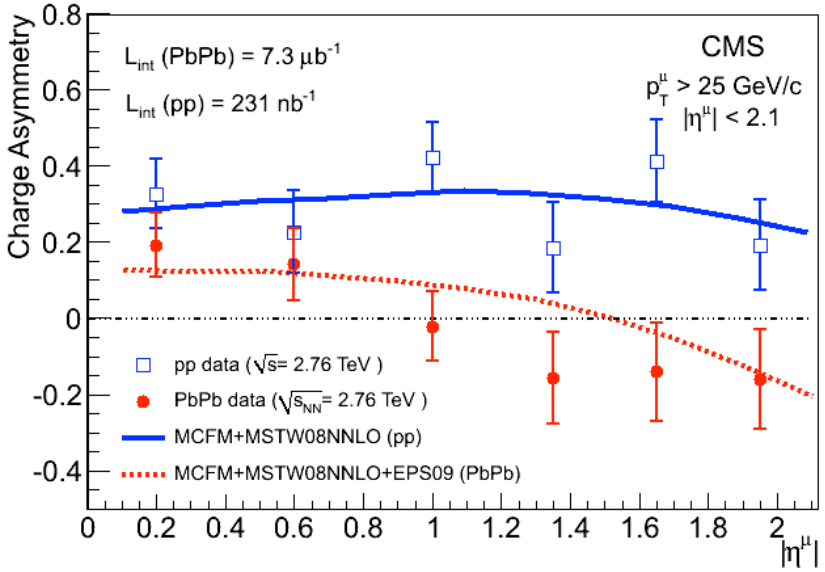
Spin conservation:

1. μ^+ boosted back to the W^+
2. μ^- boosted along with the W^-

➔ Muons charge asymmetry



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



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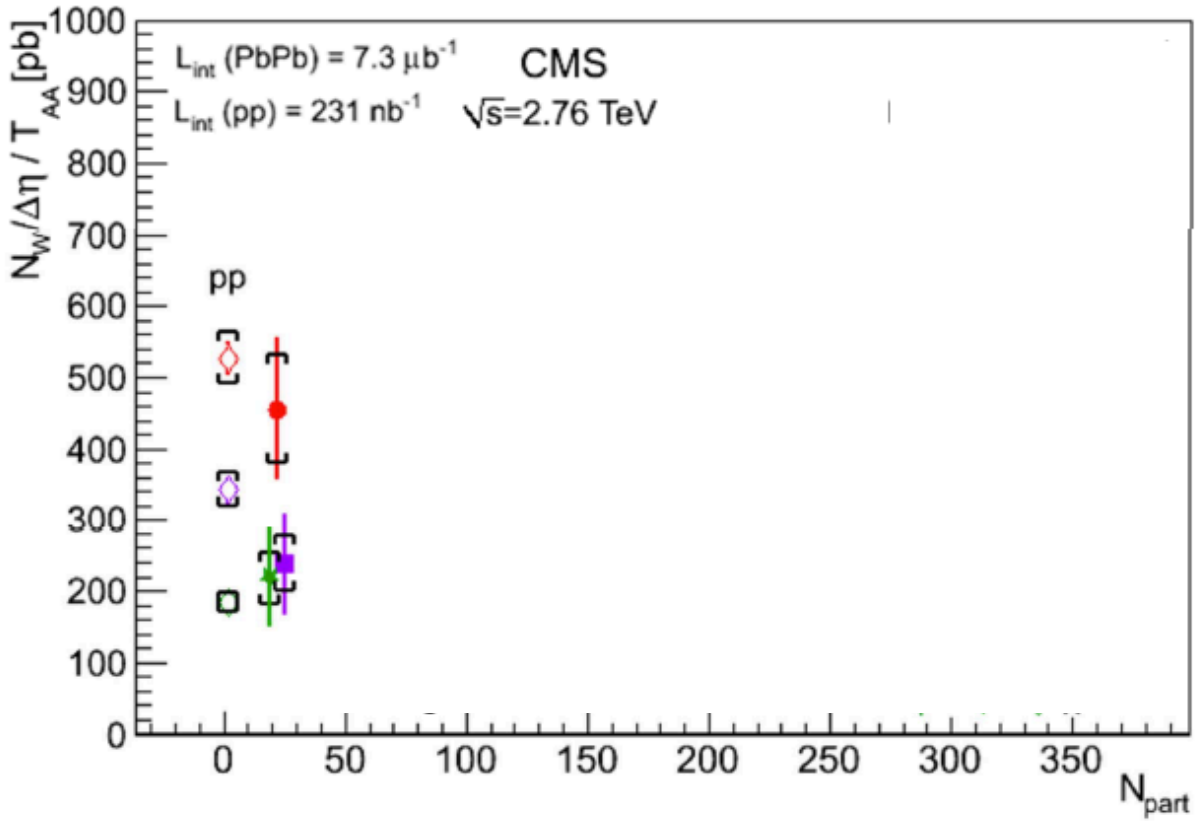
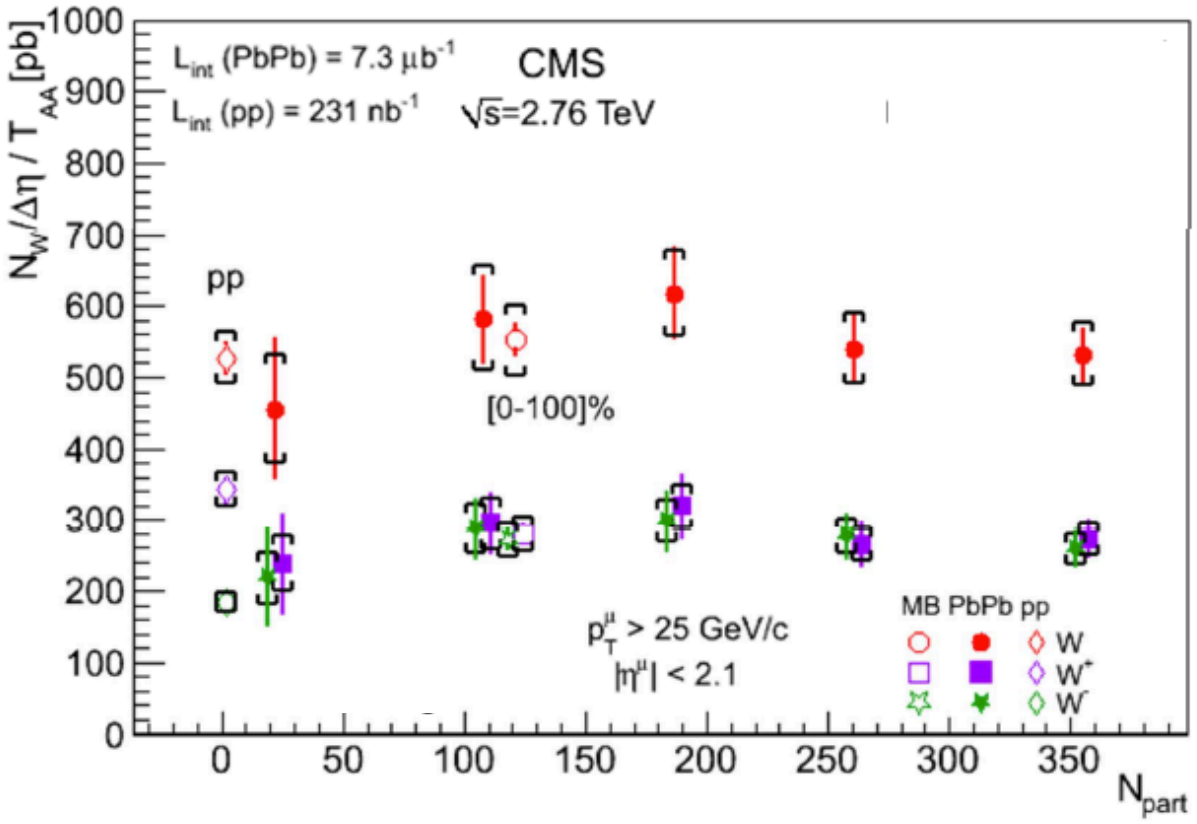
Centrality independence and R_{AA}

$d\sigma_{pp}$



Centrality independence and R_{AA}

$$dN_{AA} / T_{AA} = d\sigma_{pp}$$



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Centrality independence and R_{AA}

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

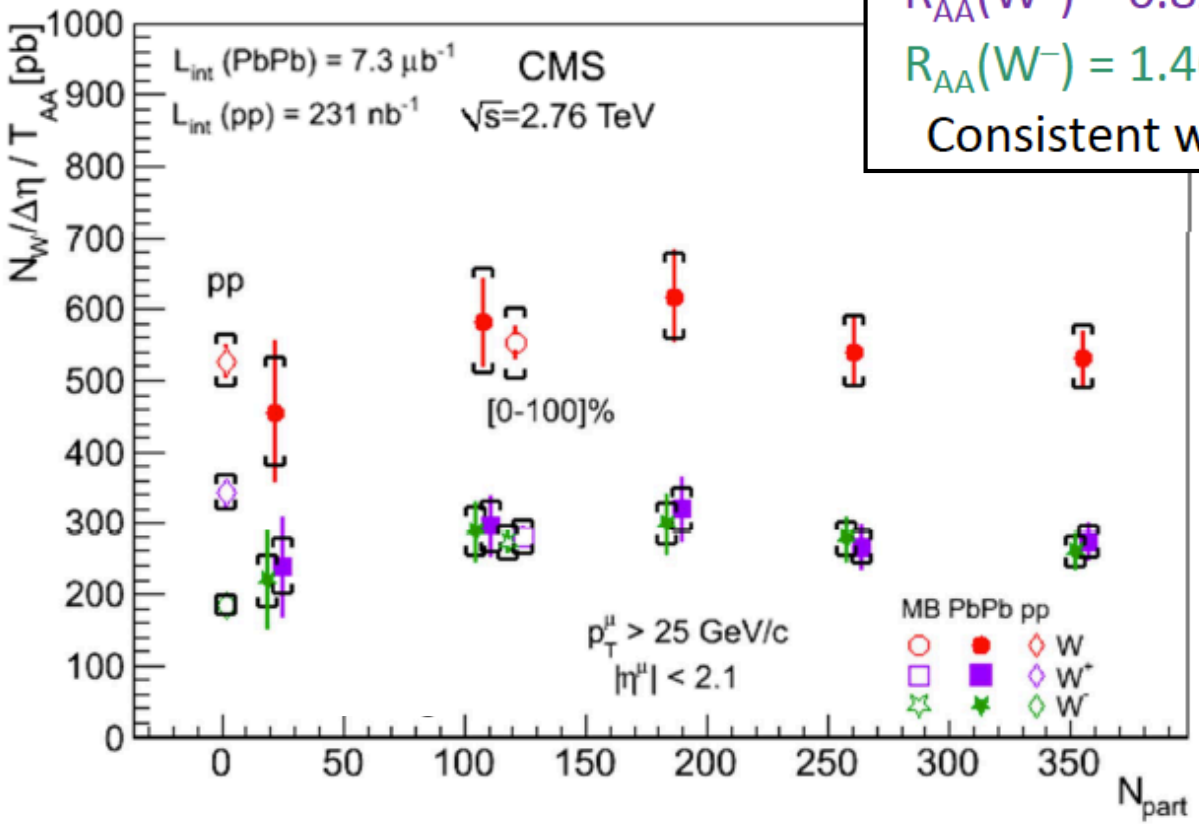
2010 PbPb ≈ pp data

$R_{AA}(W) = 1.04 \pm 0.07 \pm 0.12$

$R_{AA}(W^+) = 0.82 \pm 0.07 \pm 0.09$

$R_{AA}(W^-) = 1.46 \pm 0.14 \pm 0.16$

Consistent with pure isospin



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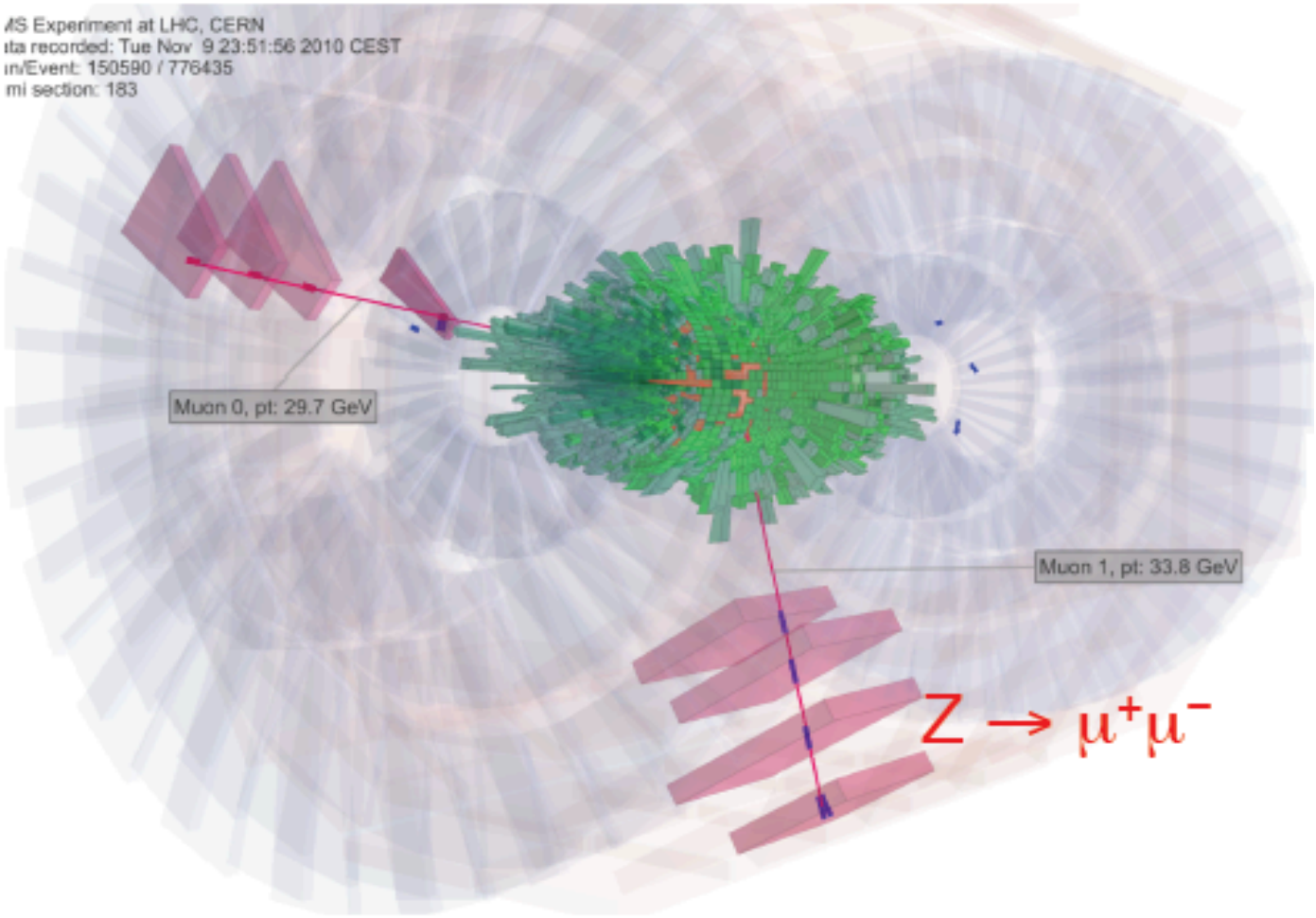
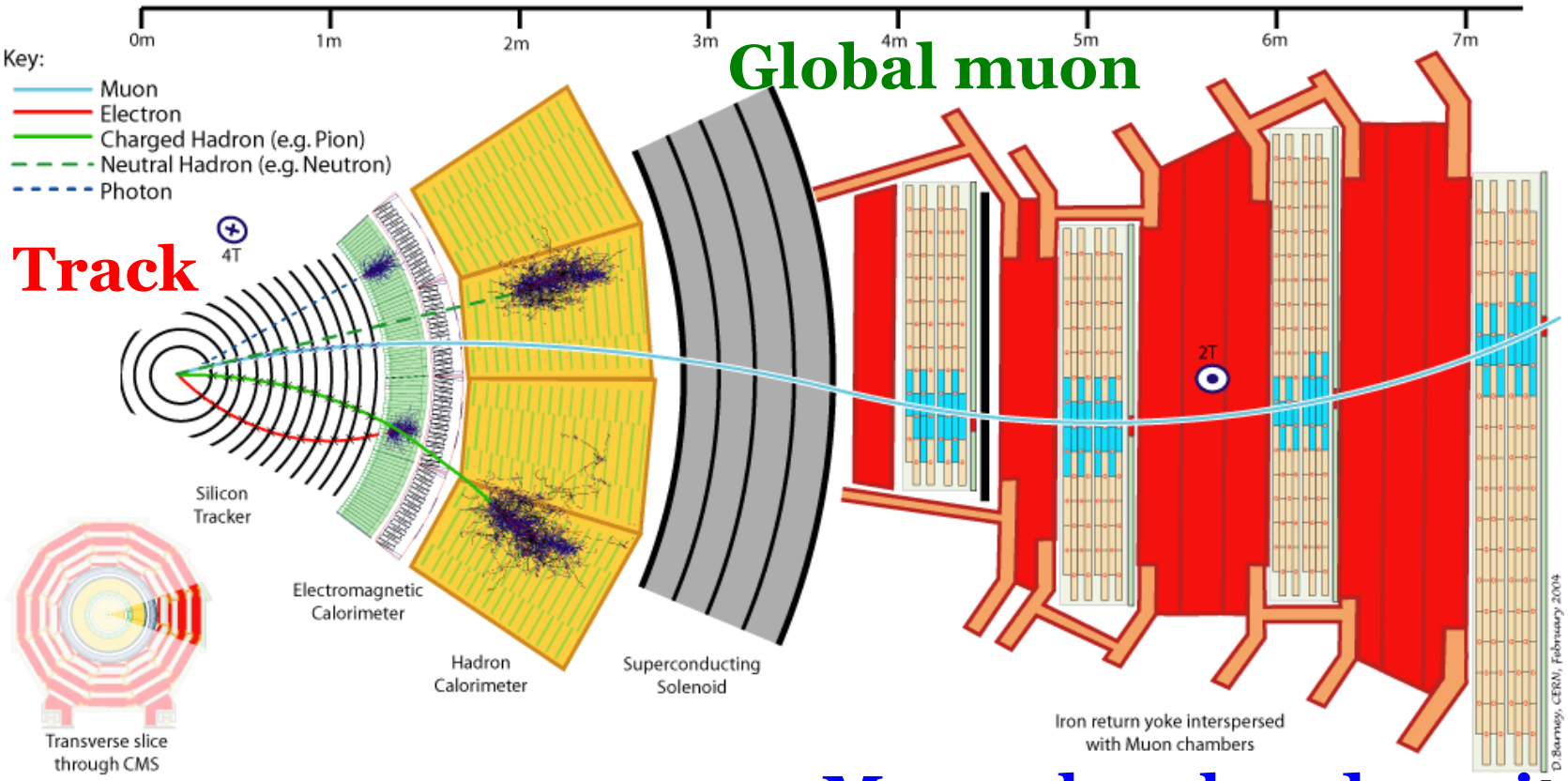
Partial Conclusion

- $W^{\pm}$ → $\mu^{\pm} + \nu$
  - Yields of W+ and W− show isospin effect, as expected
  - Muon charge asymmetry compatible with pure isospin within statistical uncertainties
  - R_{AA} (W) = 1.04 ± 0.07 ± 0.12

2. Z ➔$\mu^+ + \mu^-$ and Z ➔$e^+ + e^-$



Muon reconstruction



- Muon pattern: hits in the tracker + muon seed in the muon stations
- High-p_T resolution: 1-2% for muons up to 100 GeV/c
- New muon reconstruction for PbPb collision: before 85% efficient in muon reconstruction, now **98%**

Dimuon invariant mass

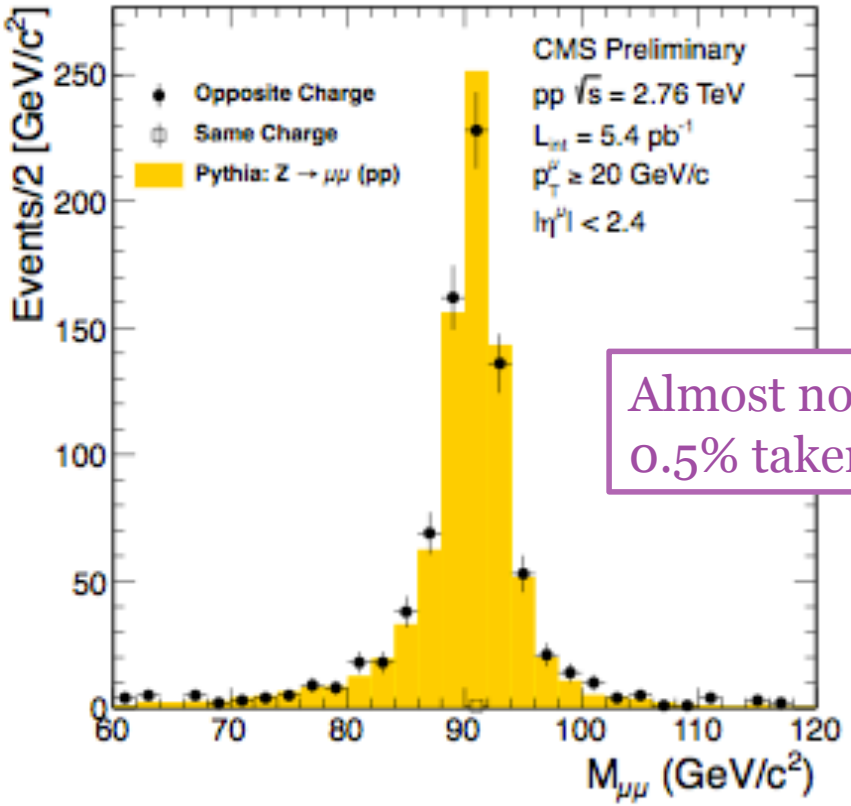
PbPb collisions @ $\sqrt{s}$ = 2.76 TeV

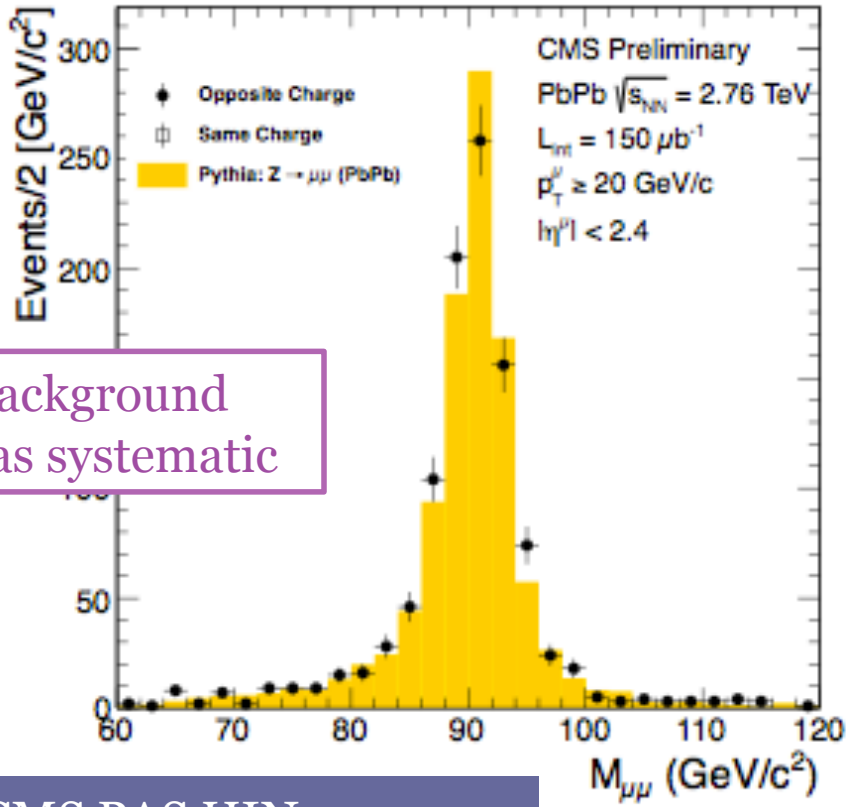
L_{int} = 150 μb^{-1}

New pp 2013 run @ $\sqrt{s}$ = 2.76 TeV

L_{int} = 5.4 pb^{-1}

Similar numbers of Z

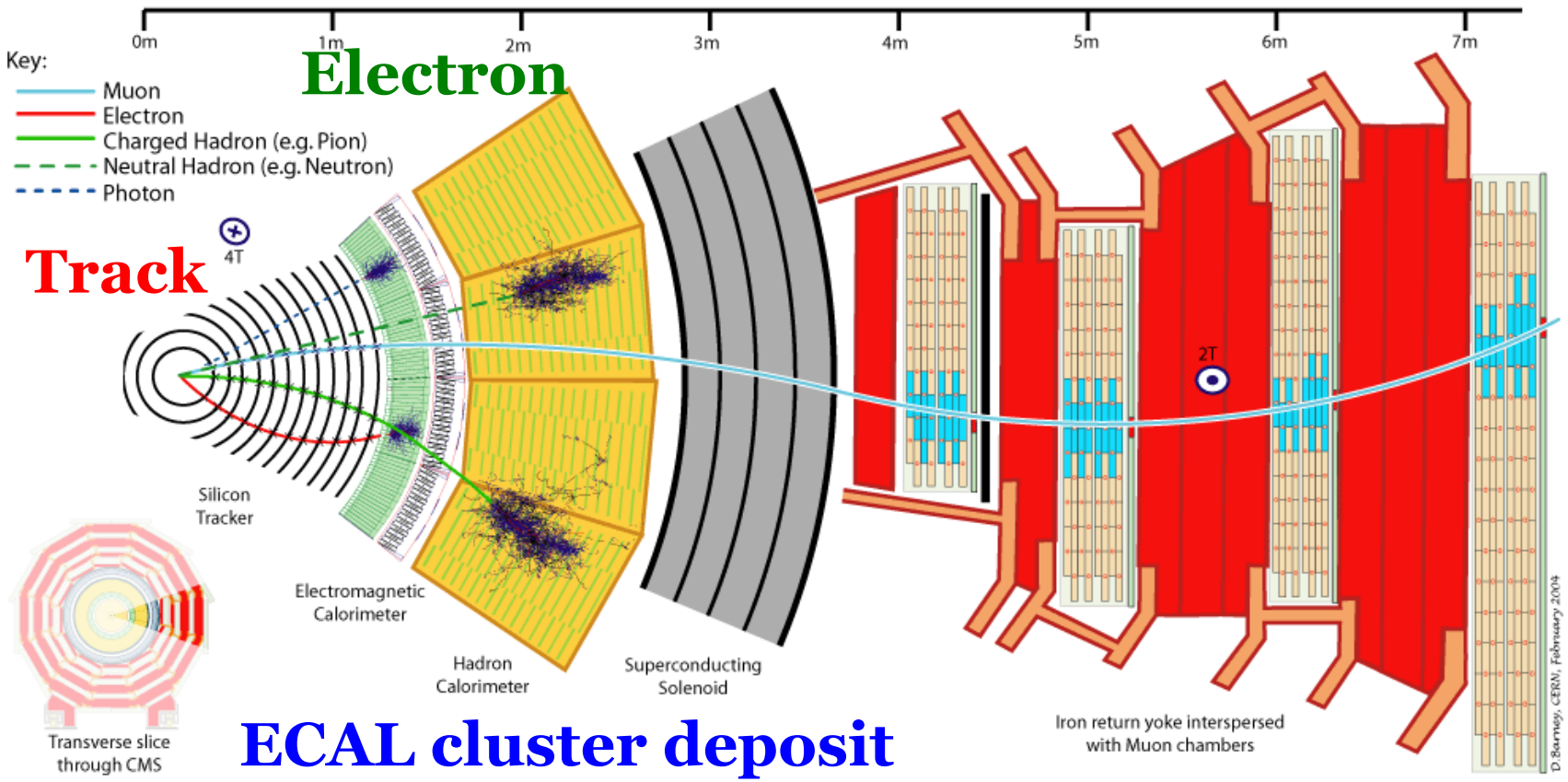




Almost no background
0.5% taken as systematic

CMS PAS HIN-13-004

Electron Reconstruction



- Electron pattern: tracks associated with a cluster in the calorimeter (ECAL)
- Hadron rejection cut: shower shape + and ratio of energy deposits in ECAL and HCAL

DiElectron invariant mass

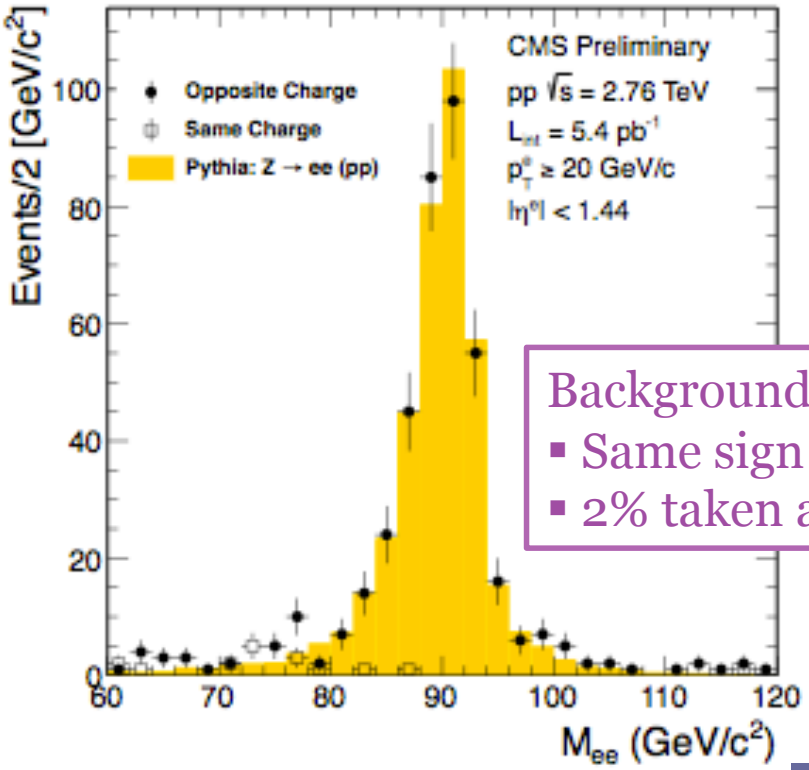
PbPb collisions @ $\sqrt{s}$ = 2.76 TeV

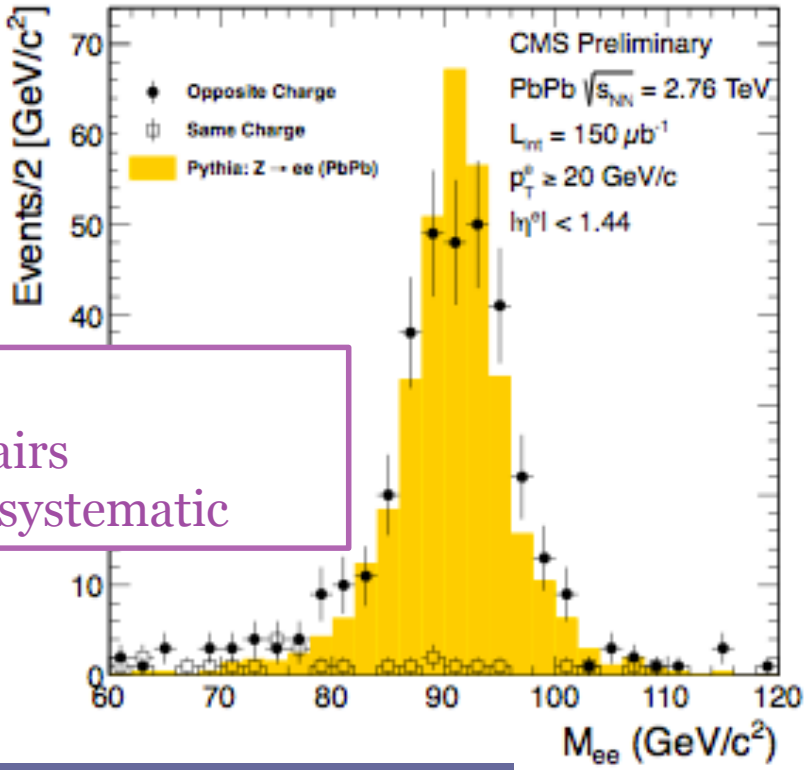
L_{int} = 150 μb^{-1}

New pp 2013 run @ $\sqrt{s}$ = 2.76 TeV

L_{int} = 5.4 pb^{-1}

Similar numbers of Z





Background:
- Same sign pairs
- 2% taken as systematic

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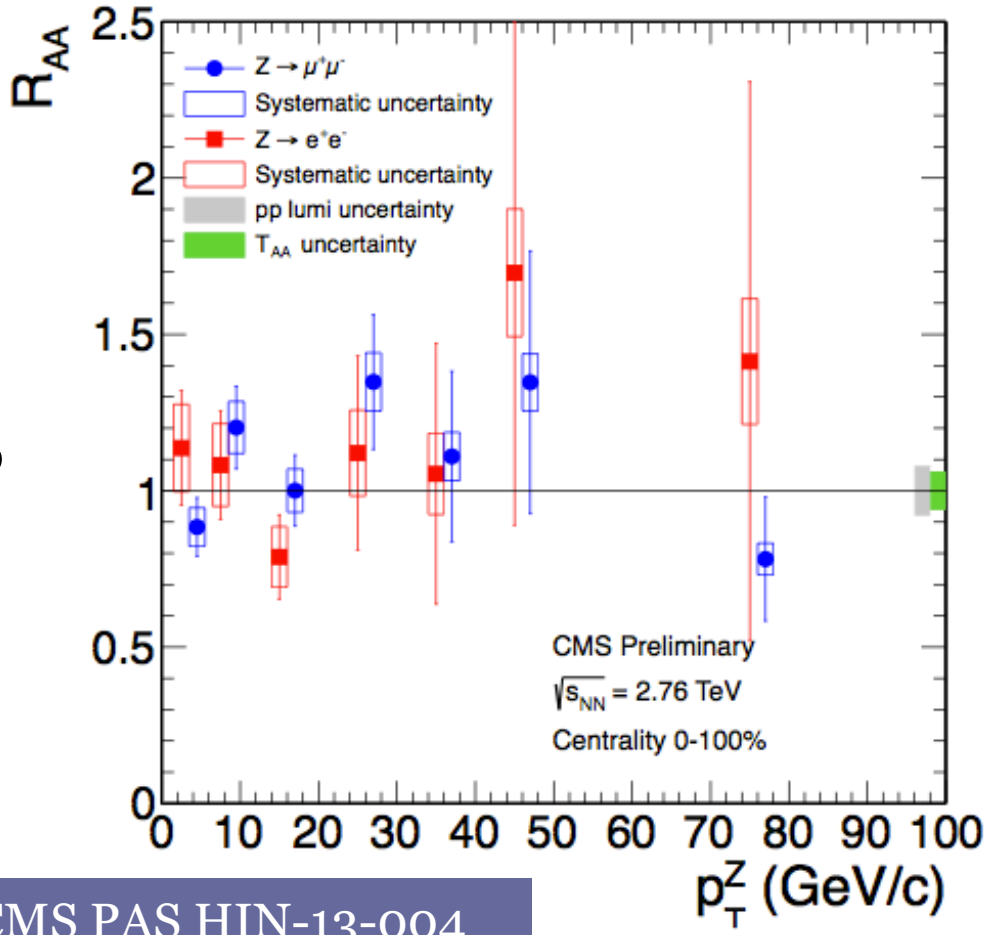
R_{AA} vs Z boson p_T

pp 2.76 TeV
L_{int} = 5.4 pb^{-1}

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

PbPb 2.76 TeV
L_{int} =150 μb^{-1}

- Compatible with R_{AA} = 1
- Not enough statistic at high p_T to detect nuclear effect



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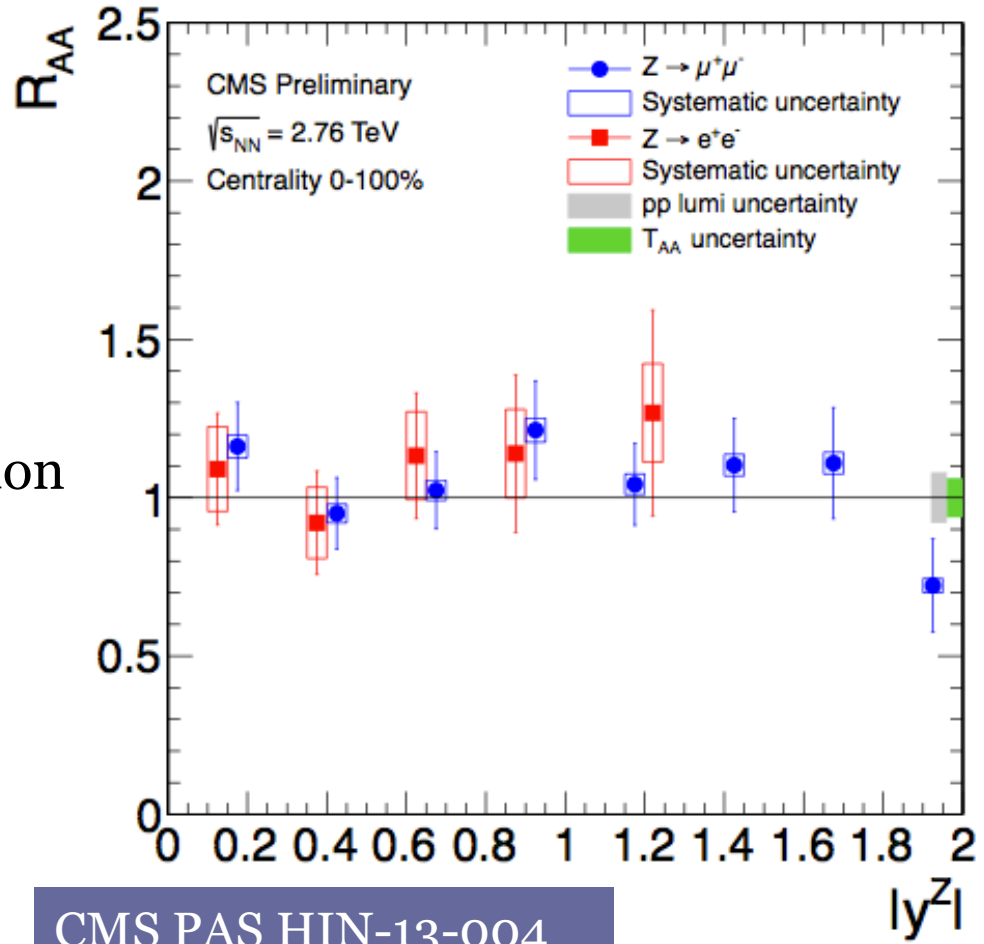
R_{AA} vs Z boson |y|

pp 2.76 TeV
L_{int} = 5.4 pb^{-1}

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

PbPb 2.76 TeV
L_{int} =150 μb^{-1}

- Compatible with R_{AA} = 1
- Good agreement electron/muon



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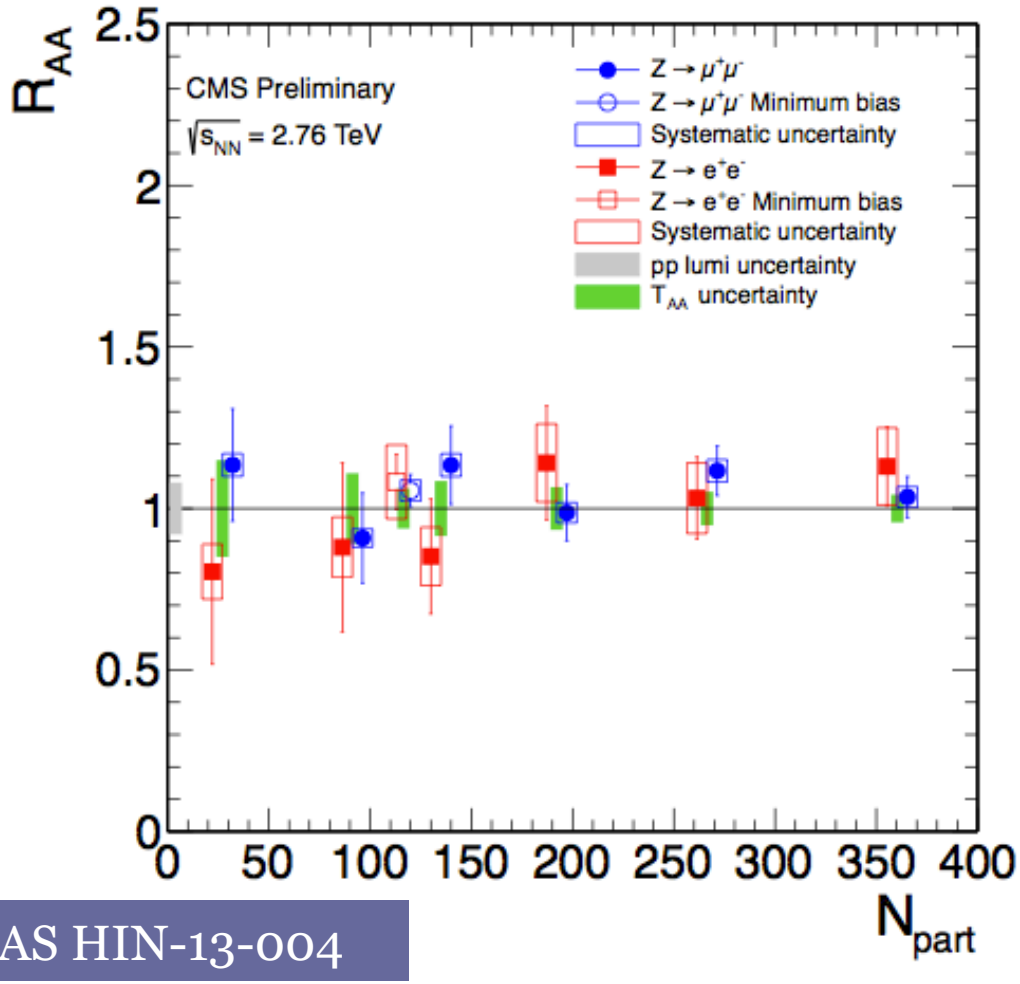
R_{AA} vs N_{part}

R_{AA} (muon) = 1.06 ± 0.05 ± 0.11

R_{AA} (electron) = 1.08 ± 0.09 ± 0.14



CMS PAS HIN-13-004

Conclusion

- $W^{\pm}$ → $\mu^{\pm} + \nu$
  - Yields of W+ and W− shows isospin effect as expected
  - Muon charge asymmetry compatible with pure isospin but limited statistics

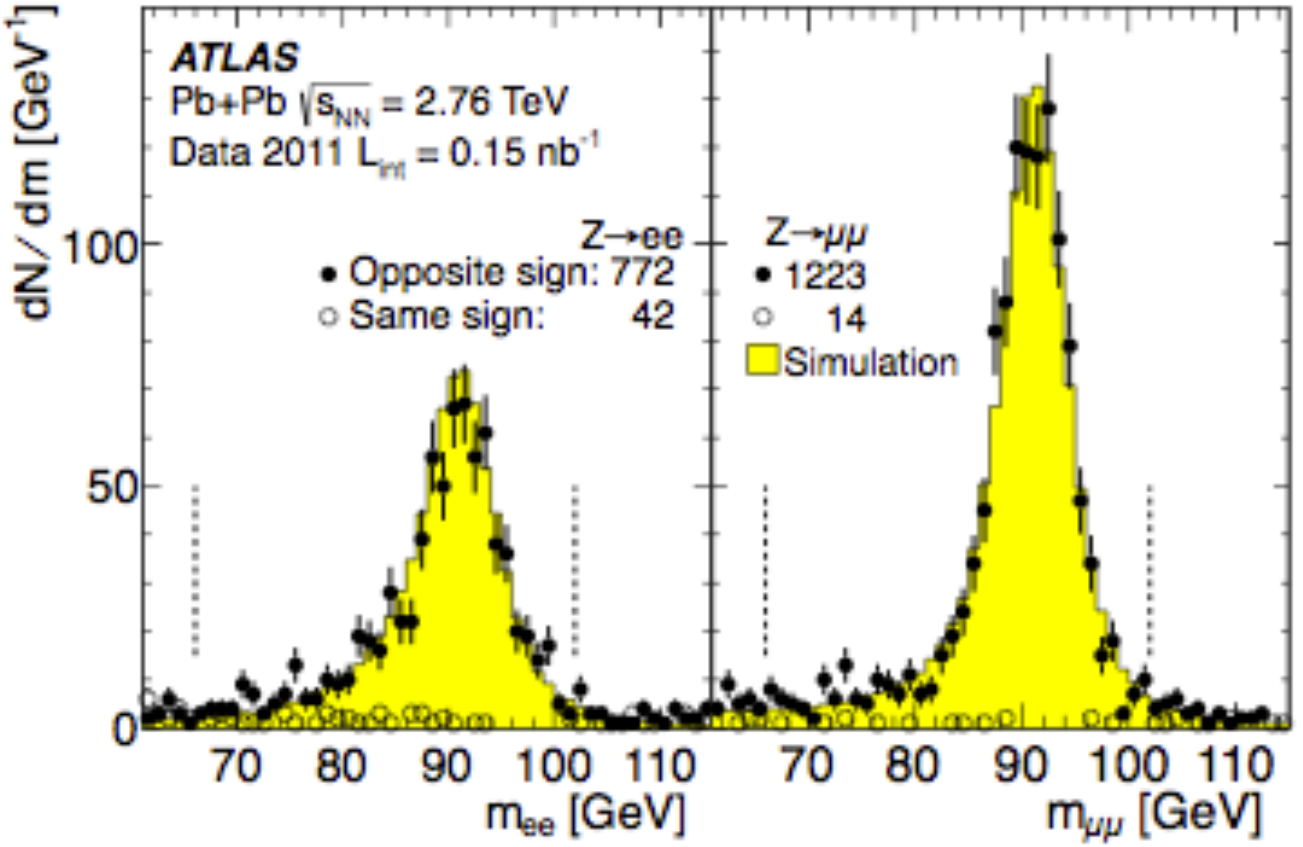
- Z → $l^{+} + l^{-}$
  - Electron and muon channels show consistent results
  - Possibility of small nuclear effect (shadowing…) still limited by statistics

- $W^{\pm}$ → $\mu^{\pm} + \nu$ and Z → $l^{+} + l^{-}$
  - R_{AA} (W_{μ}) = 1.04 ± 0.07 ± 0.12
  - R_{AA} (Z_{μ}) = 1.06 ± 0.05 ± 0.11
  - R_{AA} (Z_{e}) = 1.08 ±0.09 ± 0.14
  - R_{AA} independent of centrality
  - R_{AA} consistent with pure isospin
  - Confirms scaling based on Glauber

Back up

Invariant Mass with the ATLAS detector

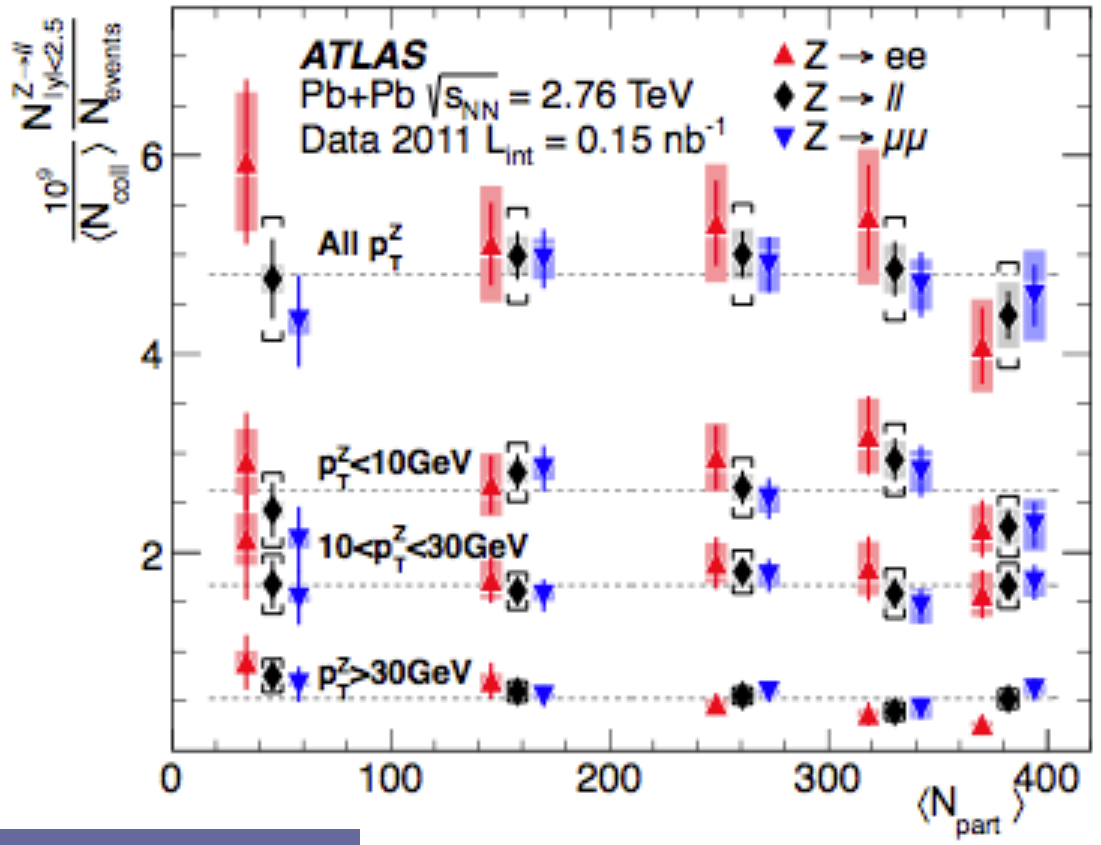
ATLAS: Muon: 1209 Z : 1223 opposite – 14 same charge
Compatible with CMS within errors



PRL 110 022301 (2013)

Z yields versus centrality with ATLAS

Z yields in PbPb data divided by $<N_{coll}>$ in function of centrality
1995 Z (muon and electron combined)



PRL 110 022301 (2013)