

Vector Boson and Charmonium Production in pPb and PbPb Collisions with ATLAS at the LHC



Zvi Citron

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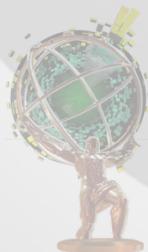
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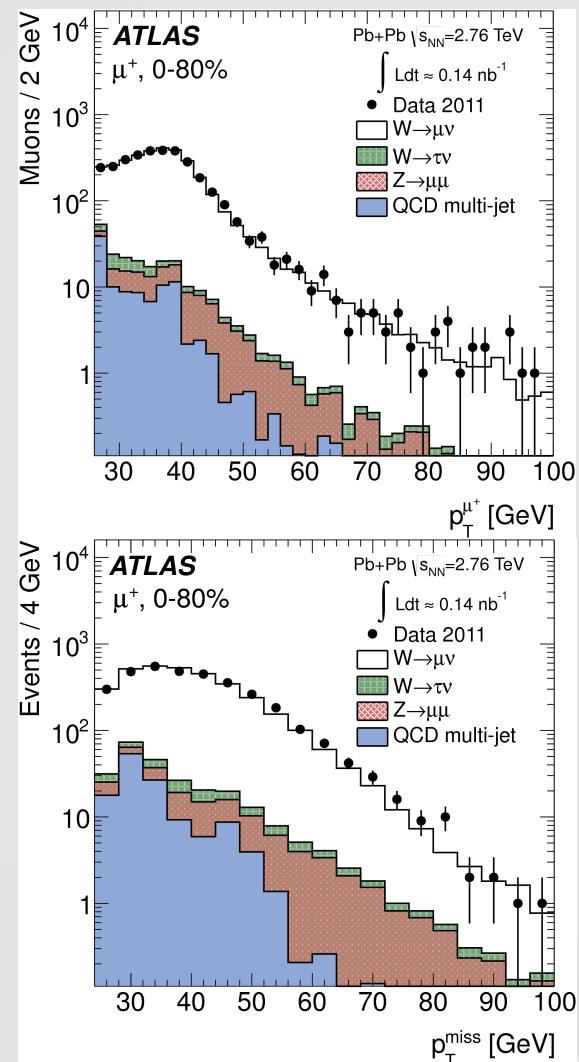
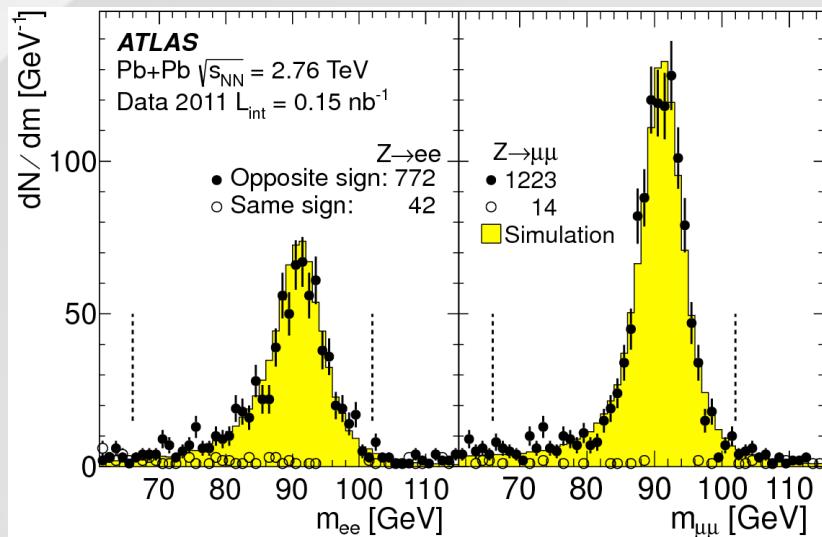


EW Bosons in Pb+Pb @ 2.76 TeV



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EW Boson Signal Extraction



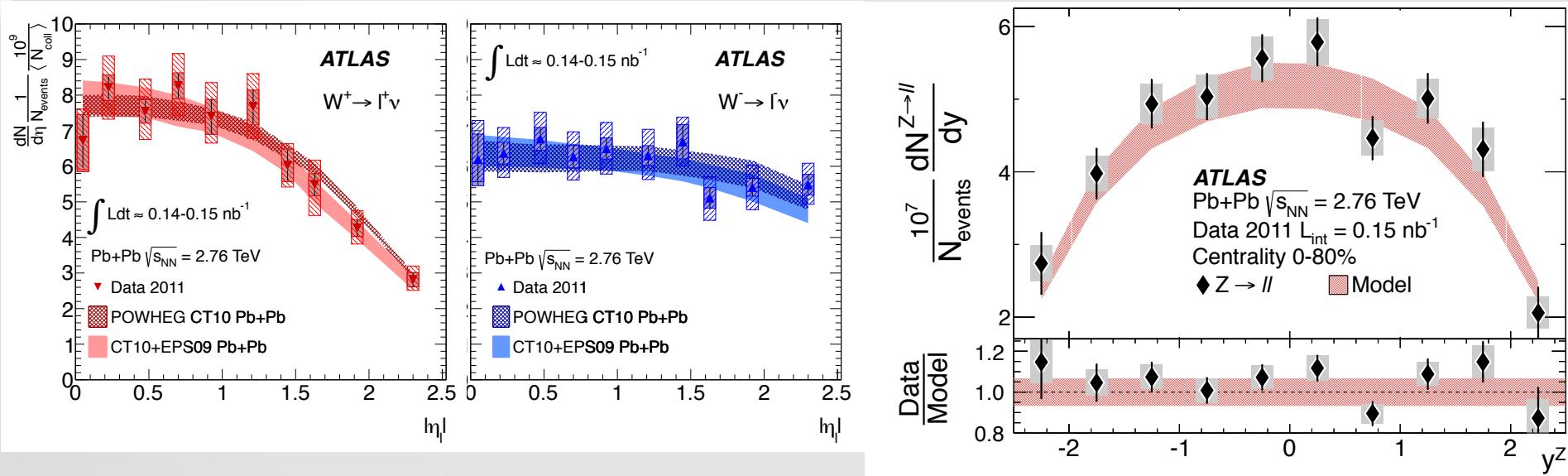
- Z bosons extracted from di-lepton peak
- W bosons extracted from templates using lepton p_T and missing p_T

PRL 110, 182302 (2013), EPJC (2015) 75:23



EW Bosons Consistent with Expectations

pQCD calculations that work for pp collisions are scaled up to account for the number of binary collisions in PbPb ...



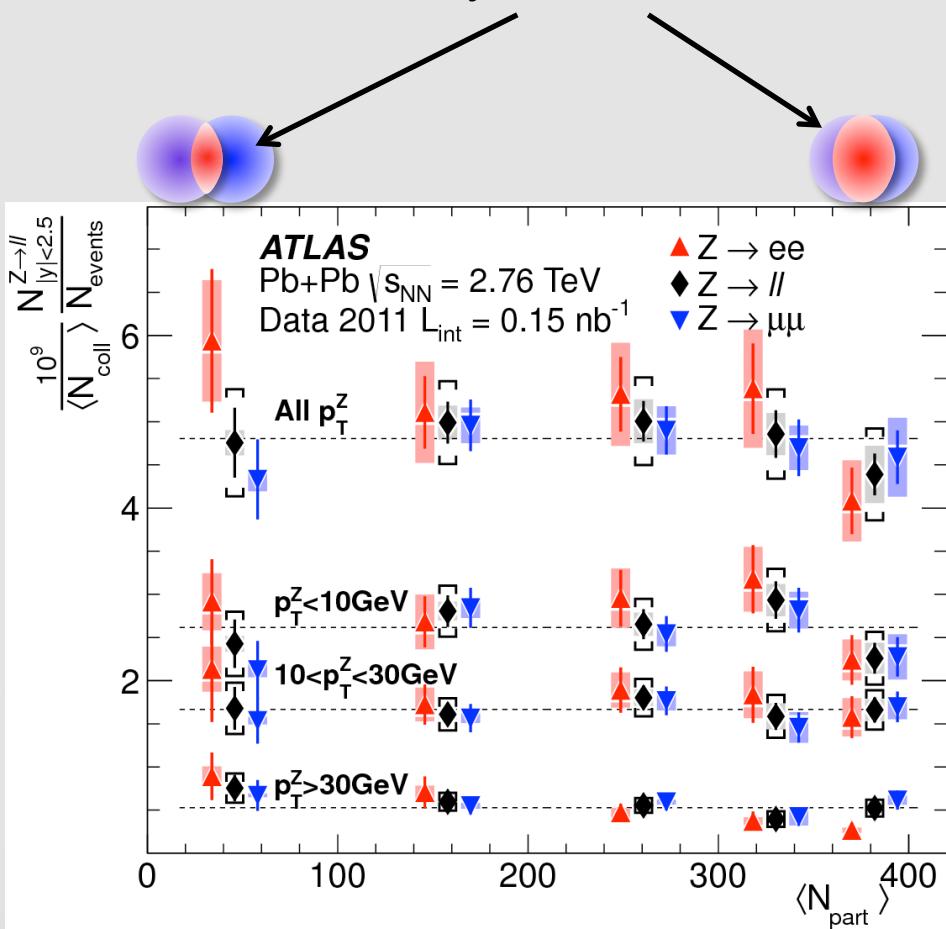
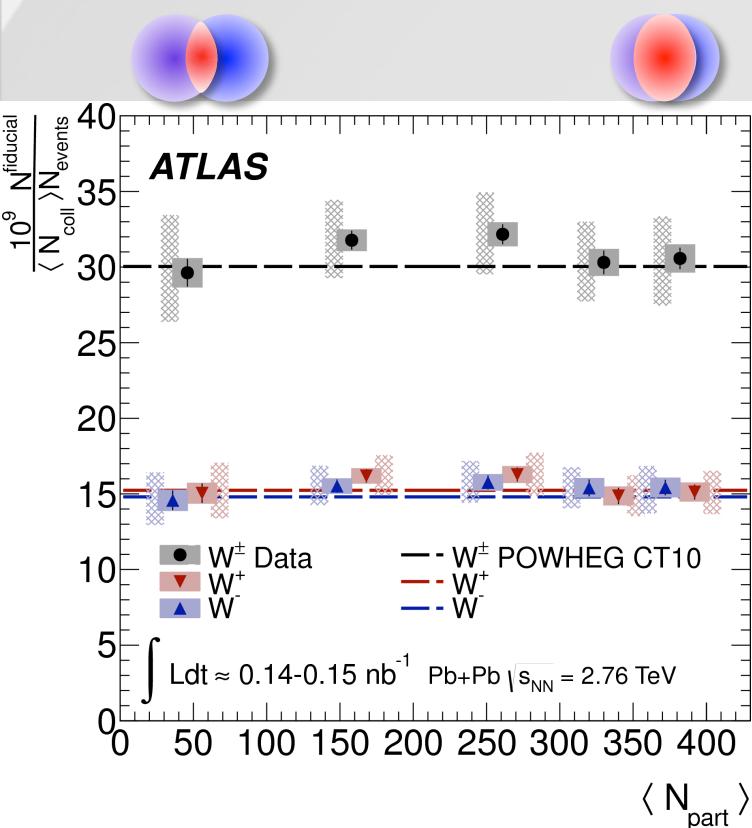
PRL 110, 182302 (2013), EPJC (2015) 75:23

**pQCD calculations describe the data
(even without nuclear modification of the PDF)**



EW Bosons Consistent with Expectations

Boson yield scales with number of binary collisions calculated by Glauber model



EW Bosons in p+Pb @ 5.02 TeV



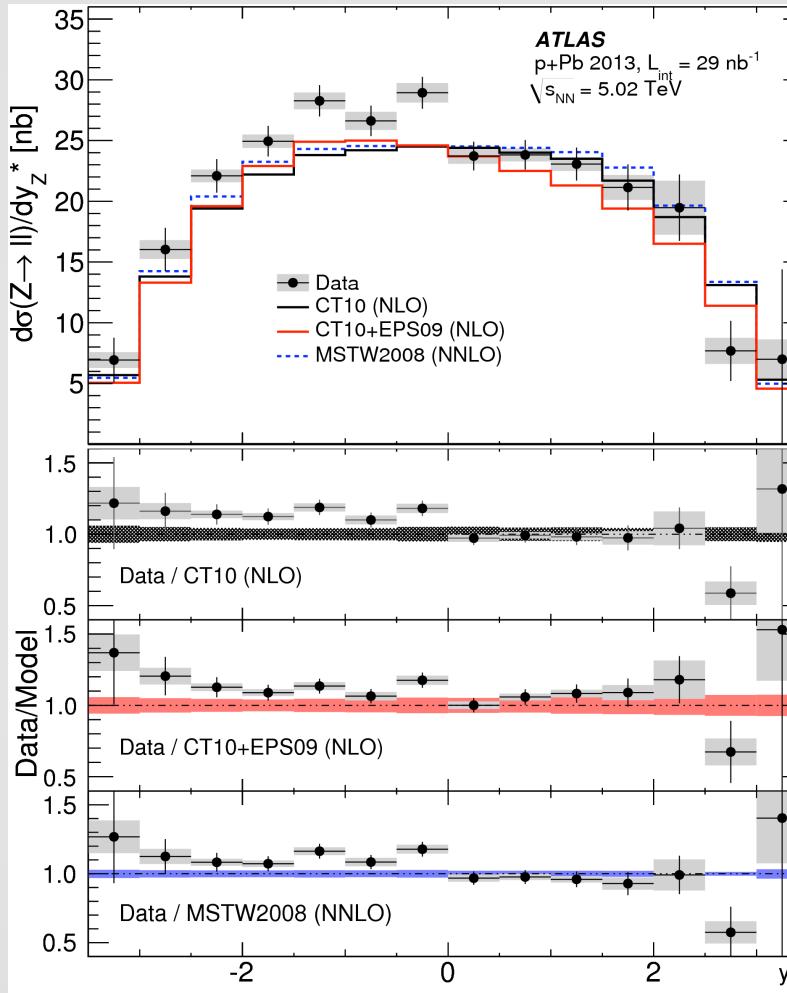
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Studying n PDF with EW Bosons

Rapidity differential Z boson cross section



PRC 92 (2015) 044915



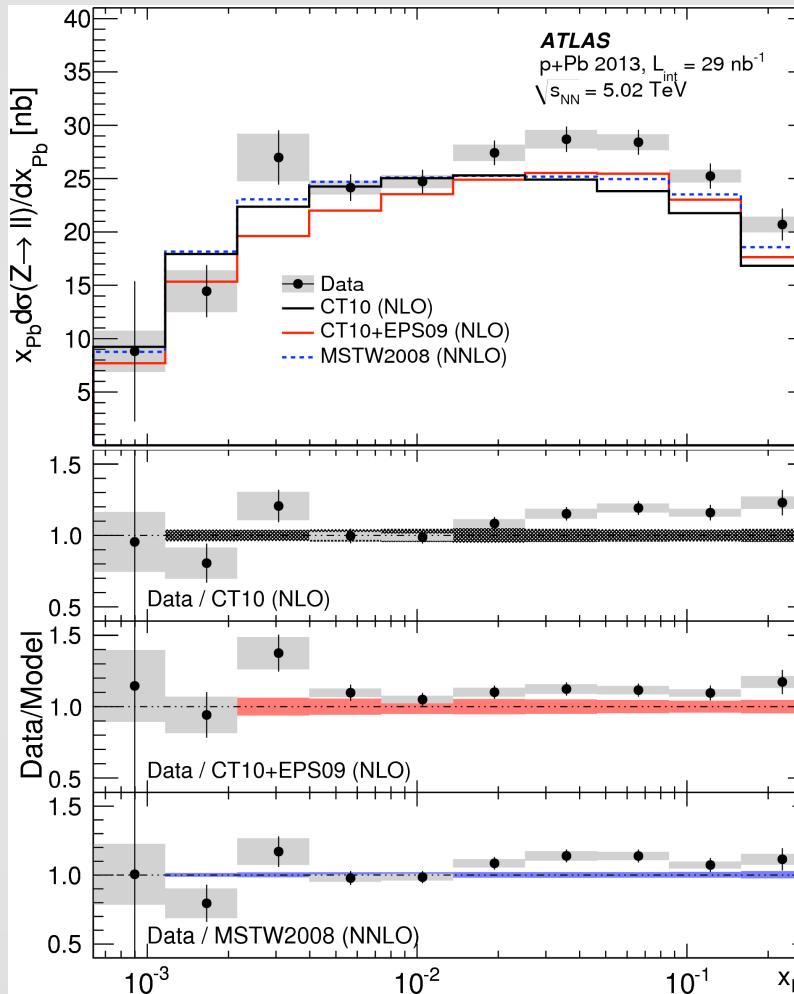
- Asymmetric in y
- Shape matched only with inclusion of nuclear PDF modification
- (Models underestimate total cross-section)

Studying n PDF with EW Bosons

x differential Z boson cross section



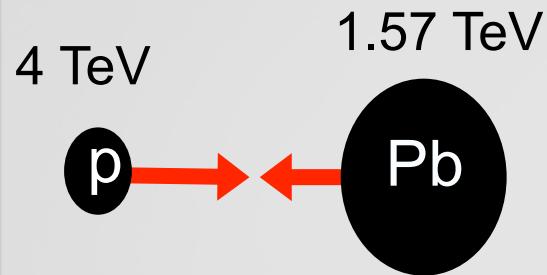
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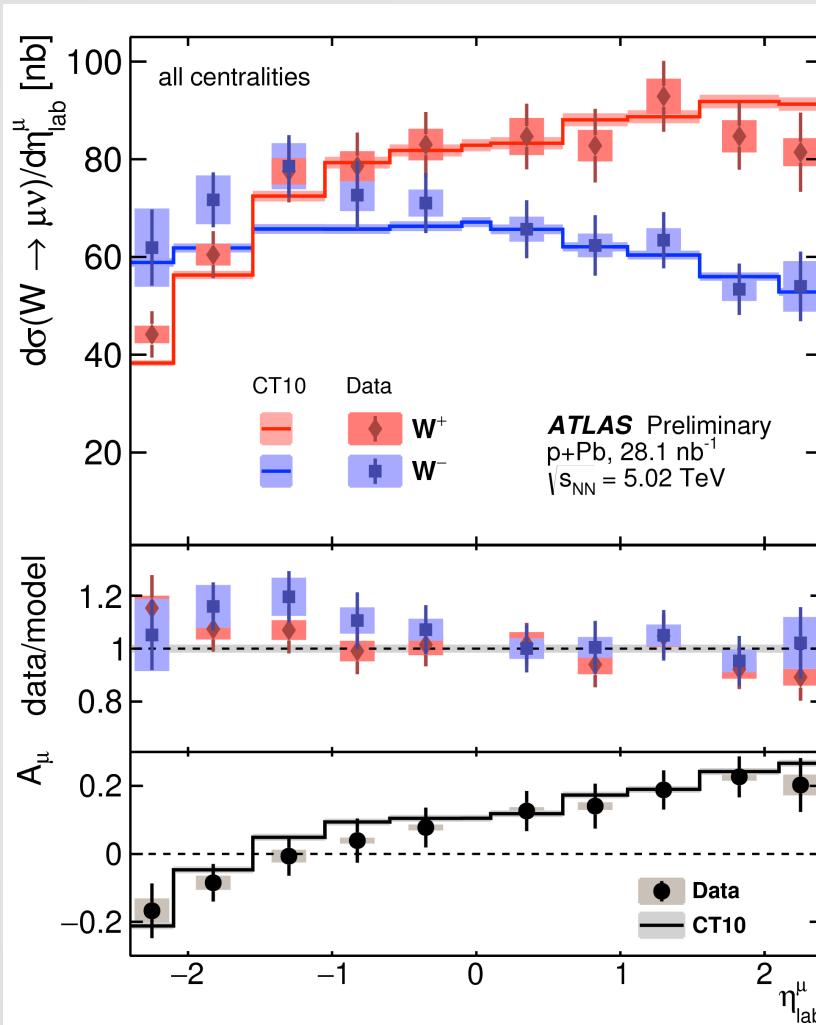
- Asymmetric in y
- Shape matched only with inclusion of nuclear PDF modification
- (Models underestimate total cross-section)
- x to $< 10^{-3}$

Studying n PDF with EW Bosons

Lepton η differential W boson cross section



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Similar trend as observed in Z bosons
Charge asymmetry gives added information on (n)PDF

Charmonium in p+Pb



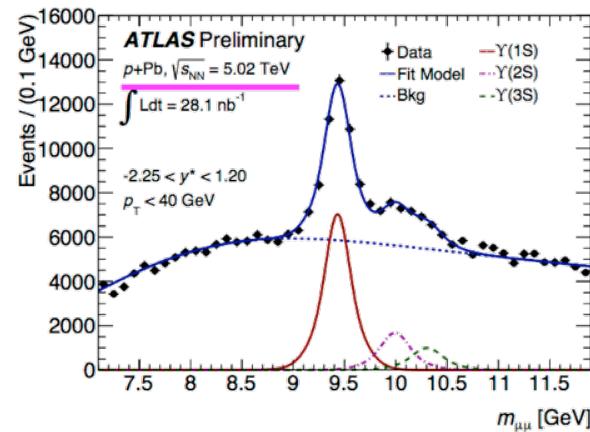
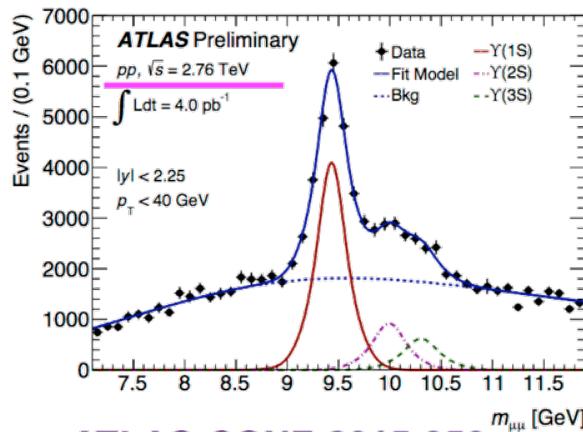
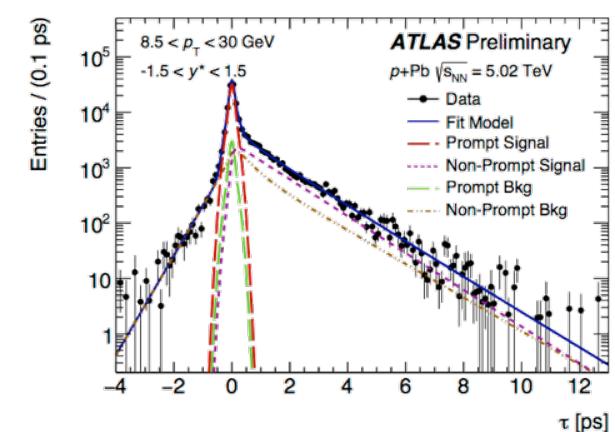
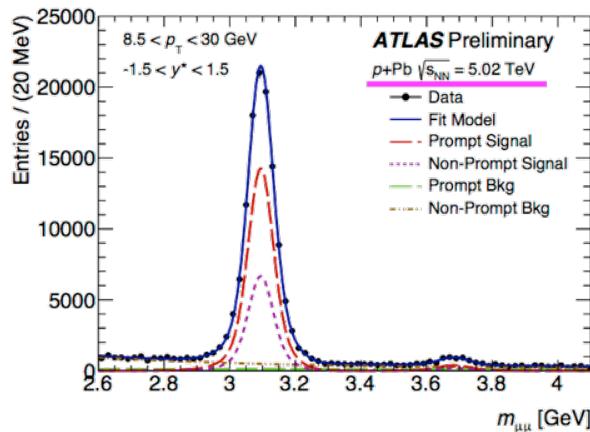
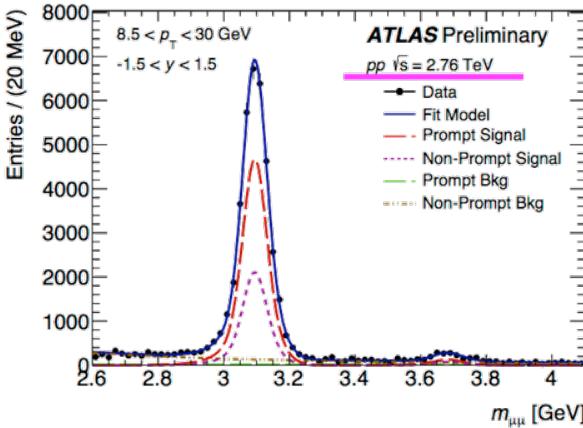
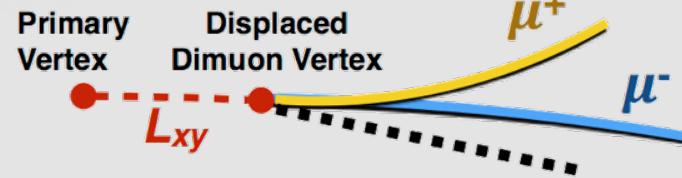
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Quarkonium Signal Extraction

Correct every event for acceptance and efficiencies.

→ Dominant source of uncertainty

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ATLAS-CONF-2015-050

Prompt $\psi(nS)$:

- Direct production
- Feed-down contribution

$$\tau = \frac{L_{xy} m_{\mu\mu}}{p_T^{\mu\mu}}$$

Non-prompt $\psi(nS)$:

- Decays from B hadrons

$\Upsilon(2S)$ and $\Upsilon(3S)$ are combined as $\Upsilon(2S+3S)$.

Nuclear Modification Factor

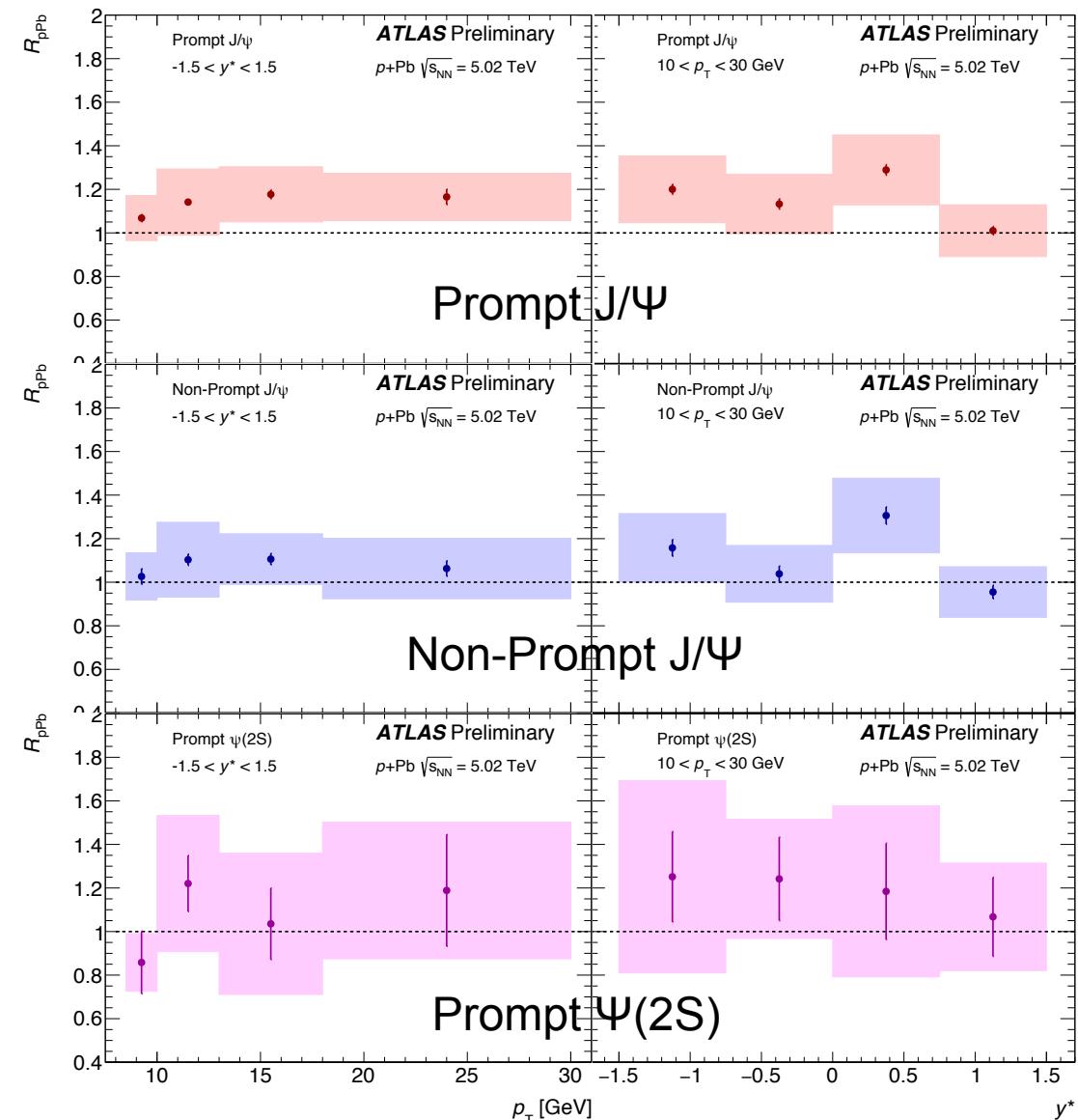
$$R_{p\text{Pb}} = \frac{1}{A^{\text{Pb}}} \frac{d^2\sigma_{\psi}^{p+\text{Pb}}/dy^*dp_T}{d^2\sigma_{\psi}^{pp}/dydp_T},$$

pp reference is constructed using interpolations

No significant suppression or enhancement for the kinematics range of $|y^*| < 1.5$ and $10 < p_T < 30 \text{ GeV}$



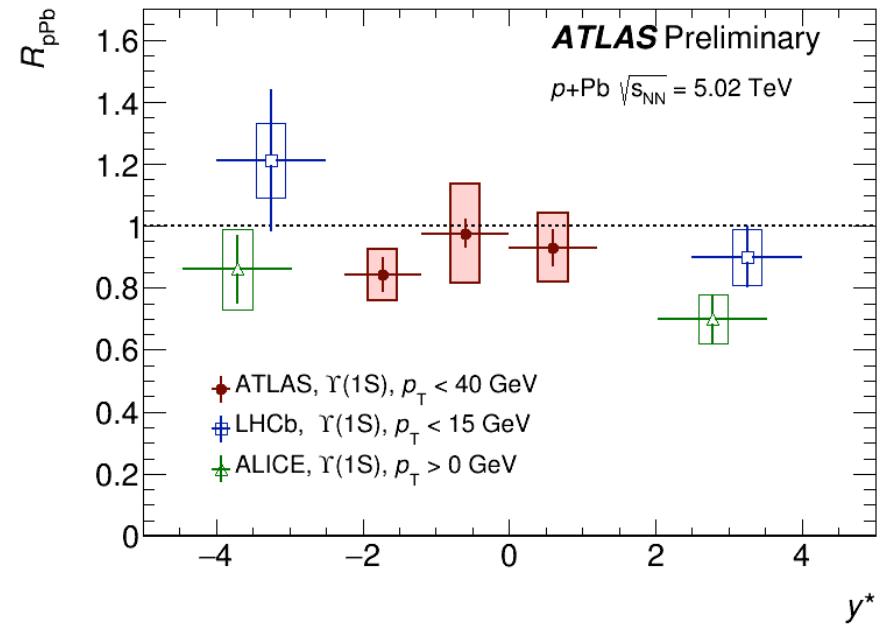
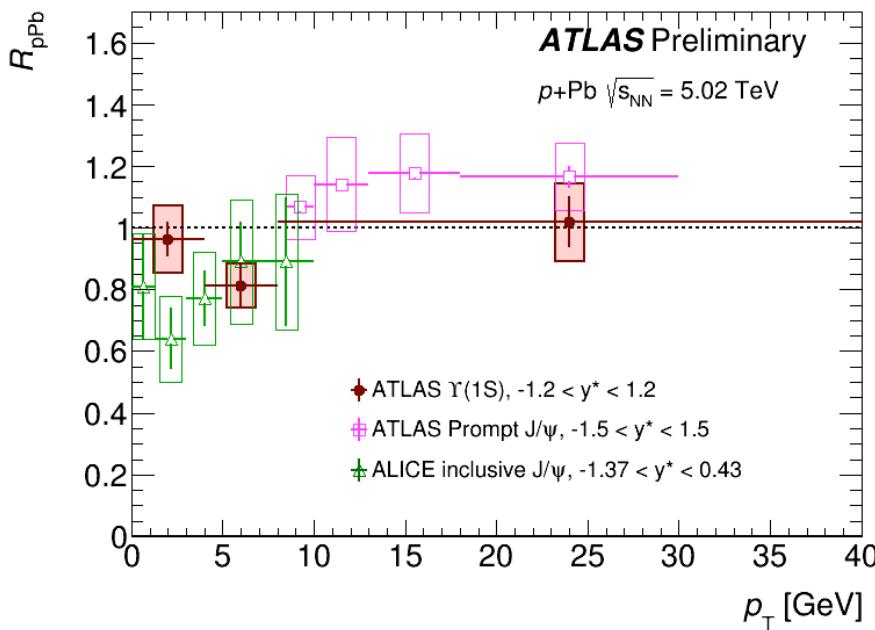
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Nuclear Modification Factor

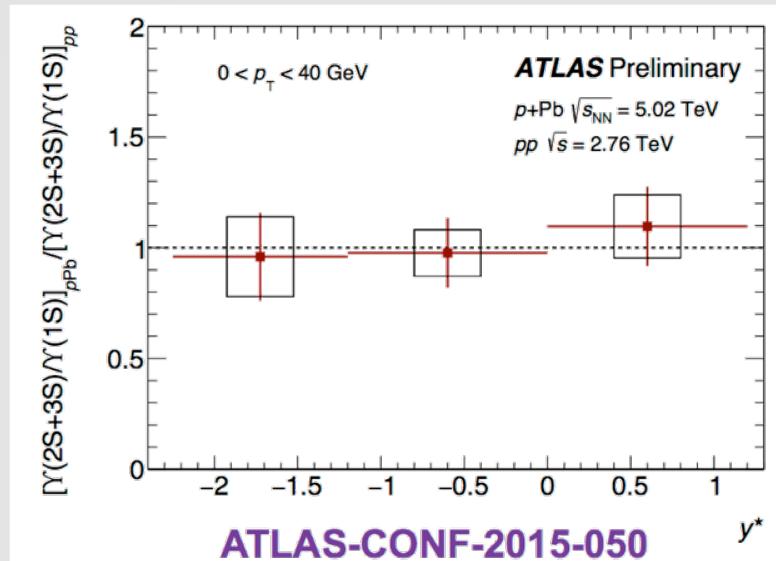
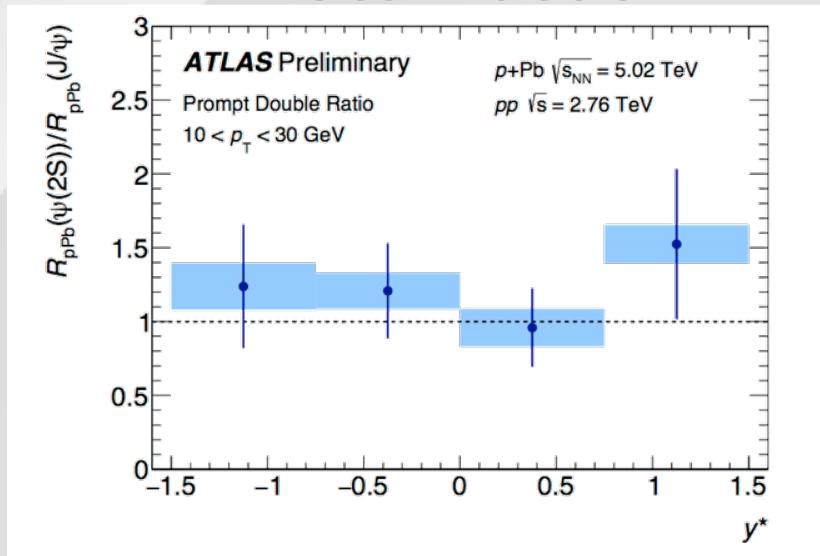
$$R_{p\text{Pb}} = \frac{1}{A^{\text{Pb}}} \frac{d^2\sigma_{\psi}^{p+\text{Pb}}/dy^*dp_T}{d^2\sigma_{\psi}^{pp}/dydp_T},$$

pp reference is
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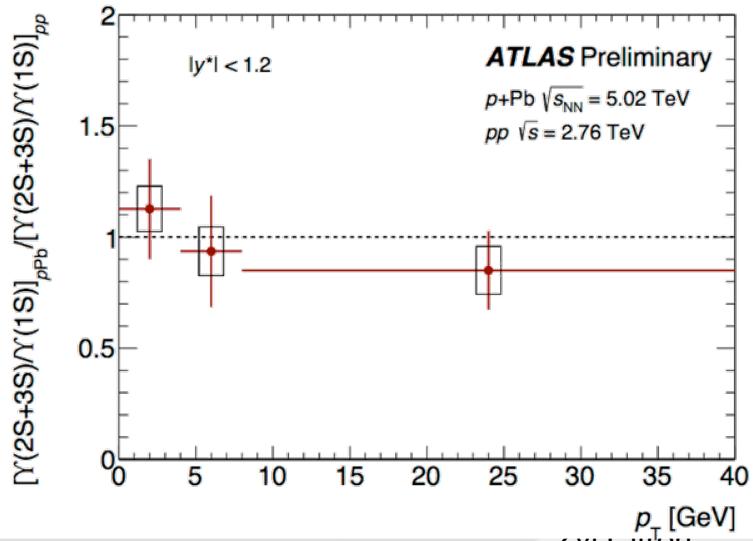
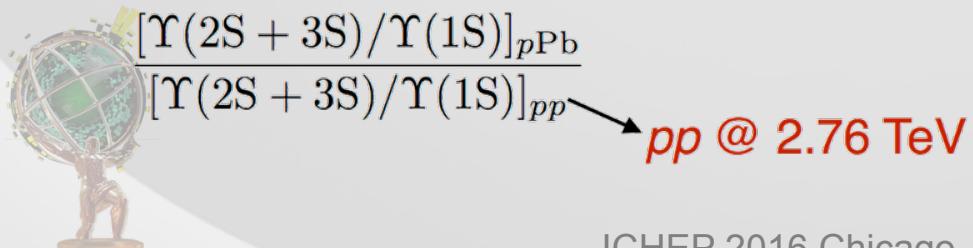
'Double Ratio' – (Excited/Ground) in $p+Pb/pp$

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- (Left) Prompt charmonium double ratio
- (Right) Bottomonium double ratio

No obvious p_T and rapidity dependence



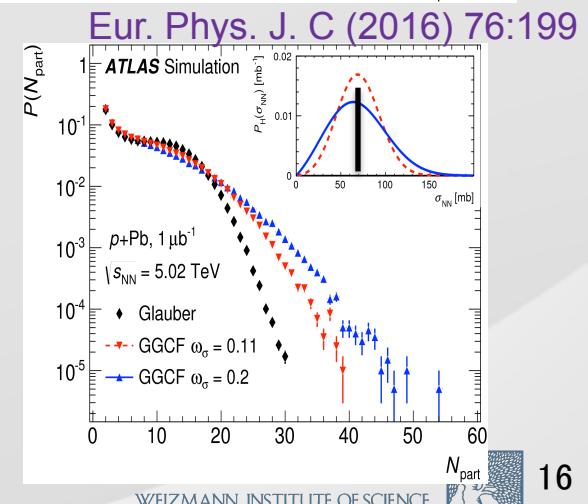
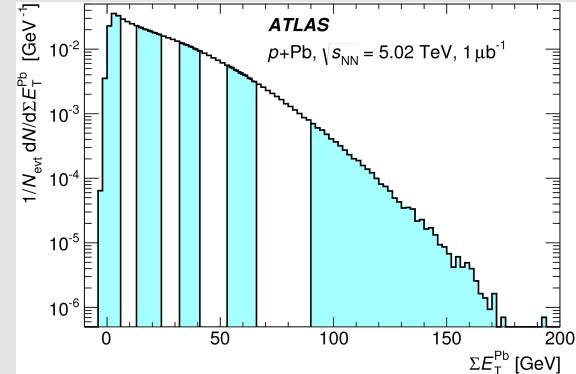
Centrality in p+Pb



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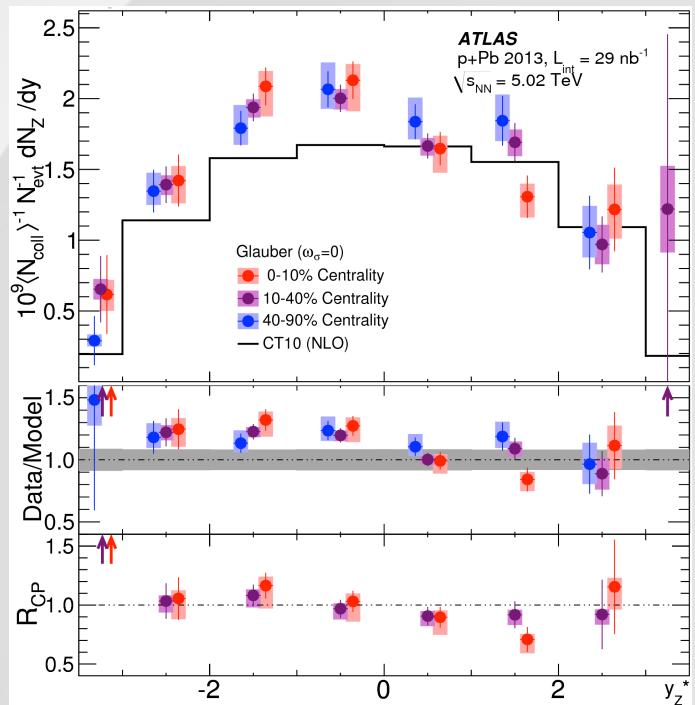
Unraveling centrality & nPDF effects

- Centrality is *difficult* in p+Pb collisions
 - Less overall activity and asymmetric system
 - Small **physics** effects that get averaged over in Pb+Pb may become significant
- ‘Centrality bias’ - hard processes are correlated with larger underlying event
- Glauber model may not be the full story: ‘Gribov’ color fluctuations may be at play which allow the nucleon-nucleon cross-section to fluctuate



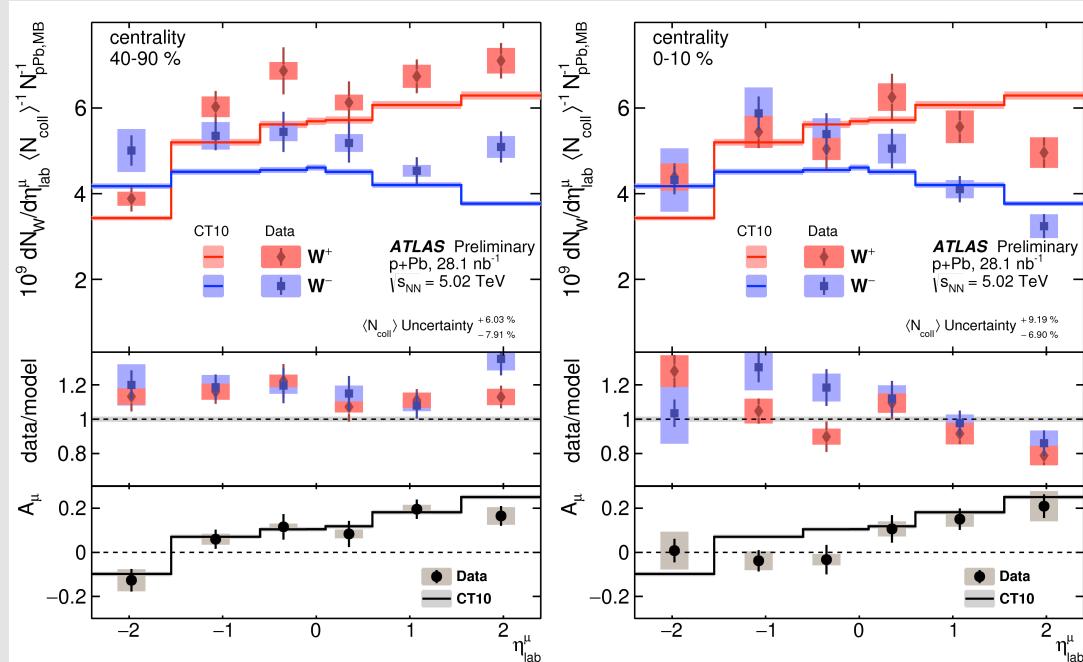
Unraveling centrality & nPDF effects

Z boson y distributions



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W boson η distributions

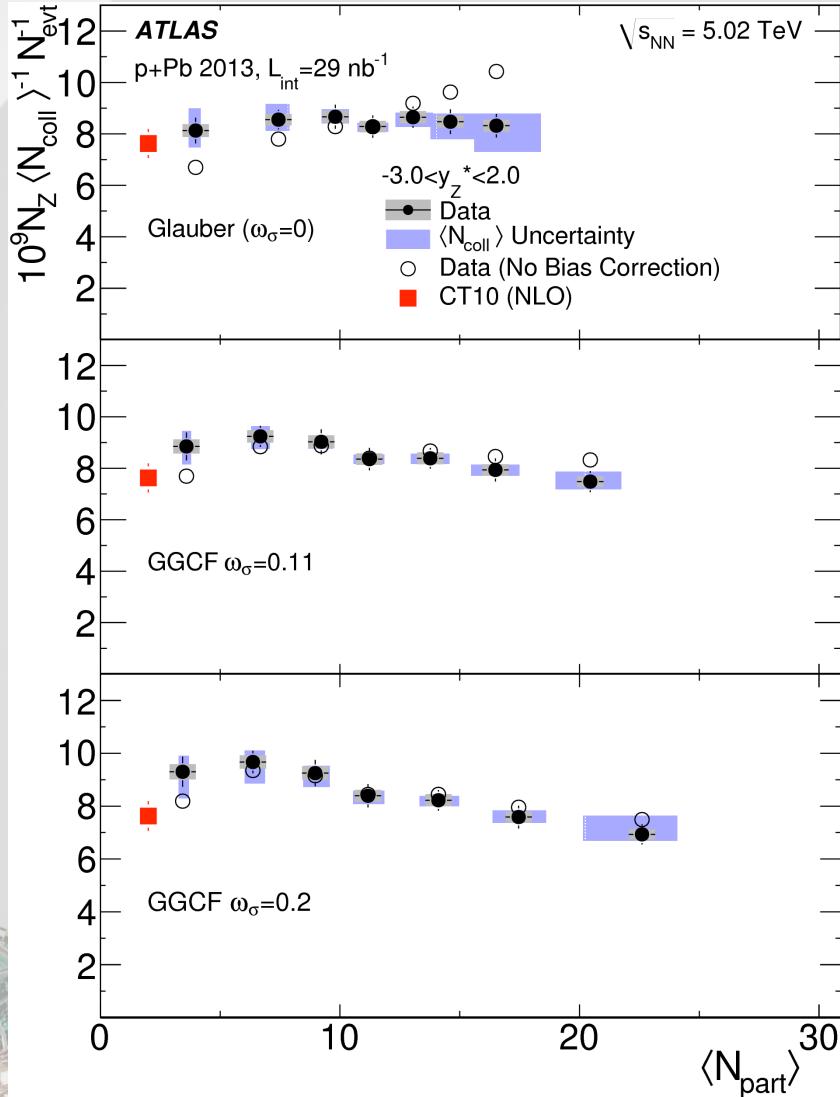


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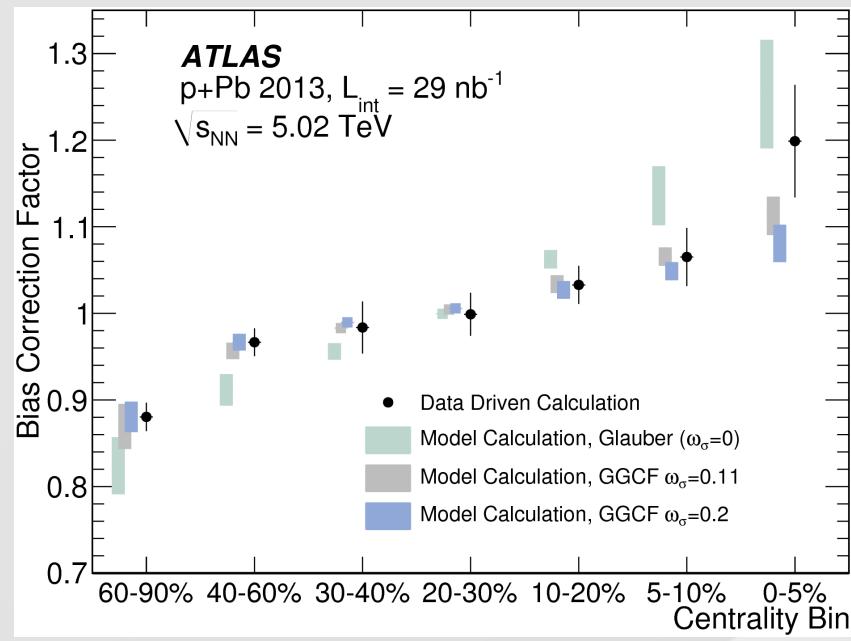
Modification of nPDF seen in both Z and W bosons looks centrality dependent



Unraveling centrality & n PDF effects



- ‘Raw’ Z boson yield grows with centrality
- Centrality bias **or** Gribov color fluctuations can ‘restore’ binary scaling

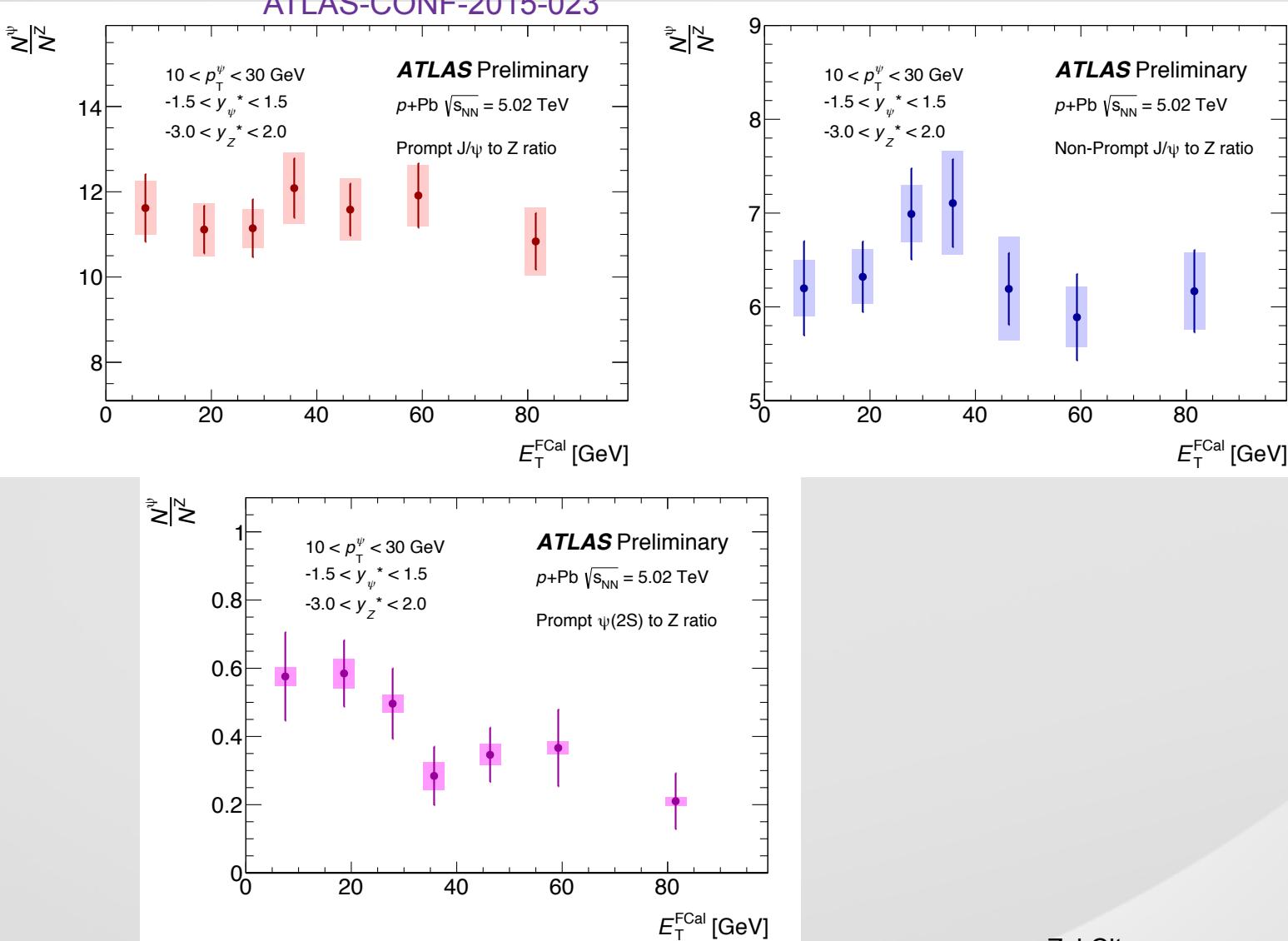


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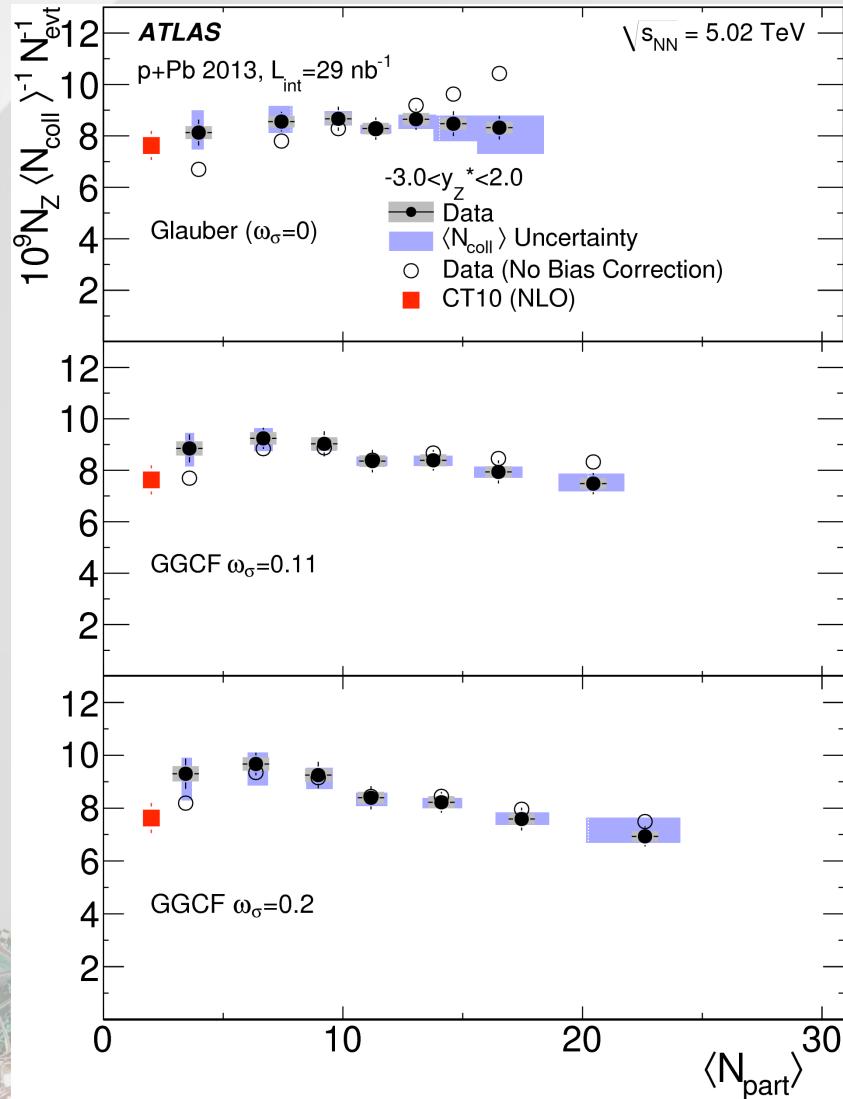
Charmonium and Z Boson Yields

Sidestep centrality definitions, and use Z boson as reference for charmonium centrality dependence

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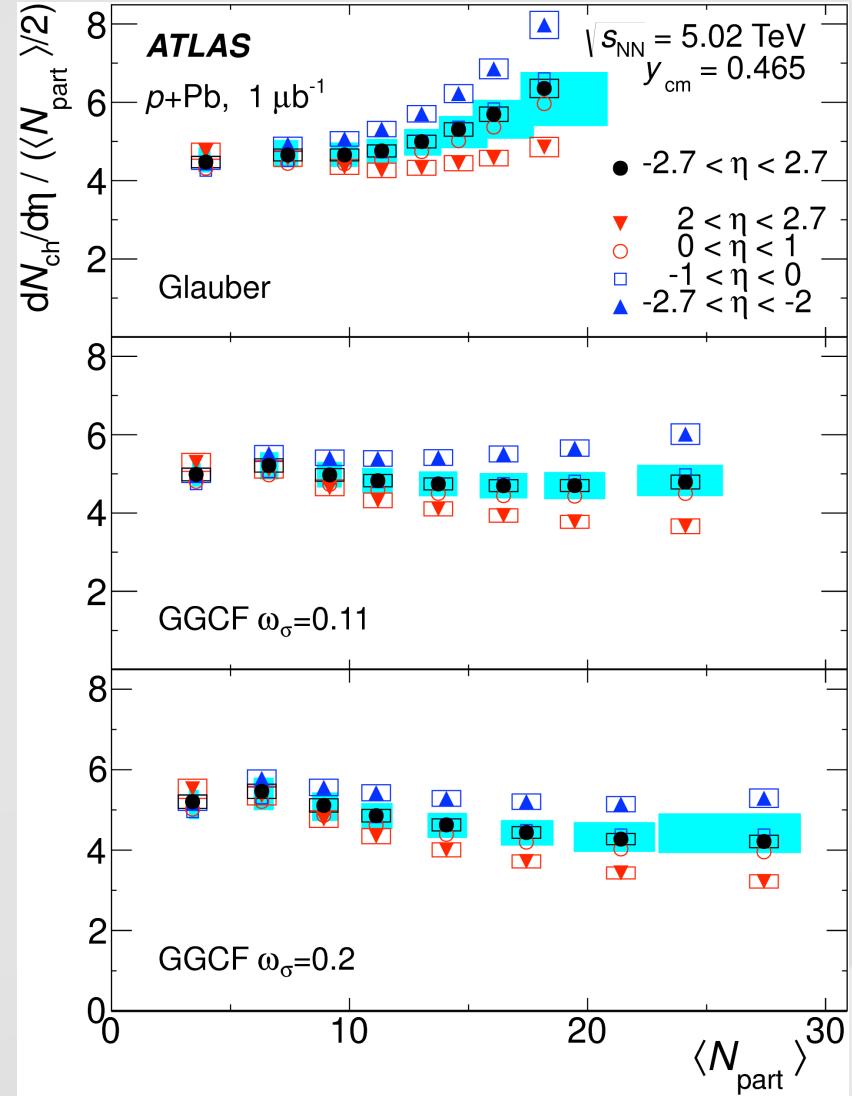
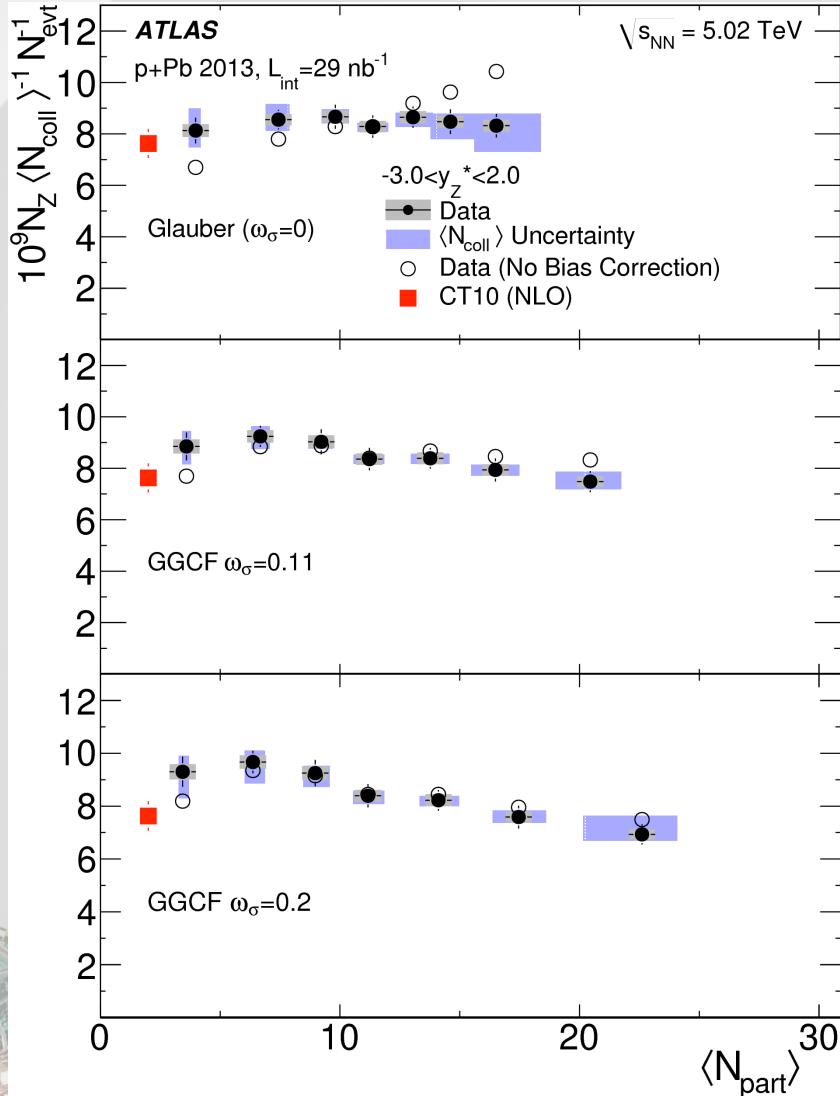
Unraveling centrality & nPDF effects



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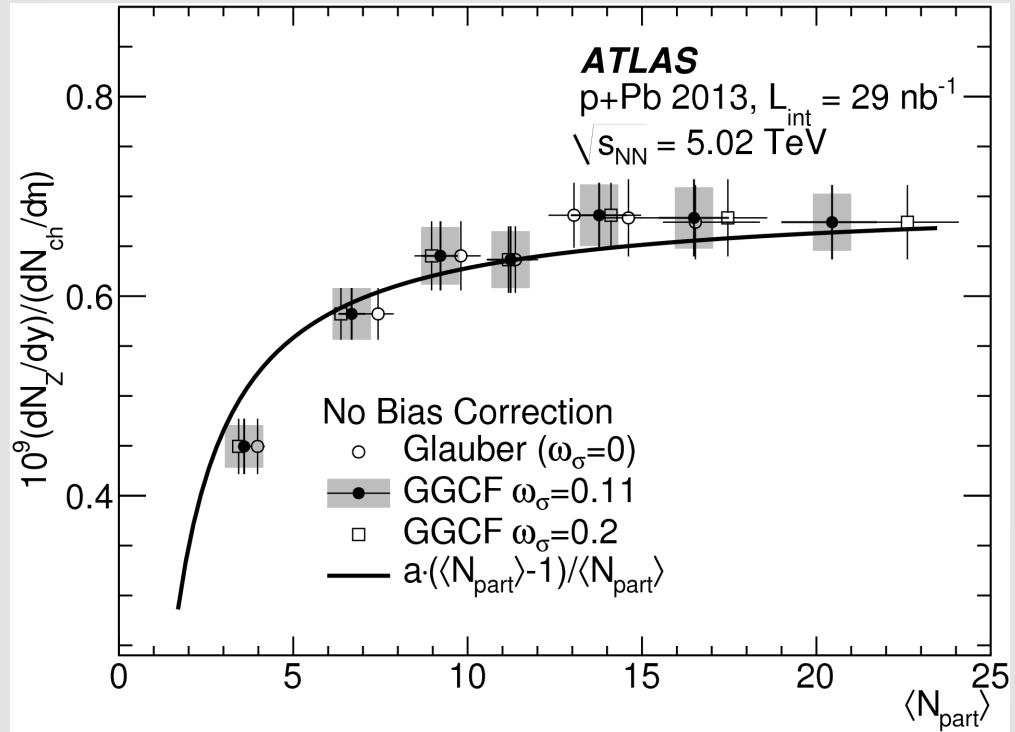


Unraveling centrality & n PDF effects



Unraveling centrality & nPDF effects

- Striking similarity between Z boson and charged particle yield
- Suggests centrality bias (inapplicable to charged particle yield) may not be the culprit
- Final conclusion remains elusive ...

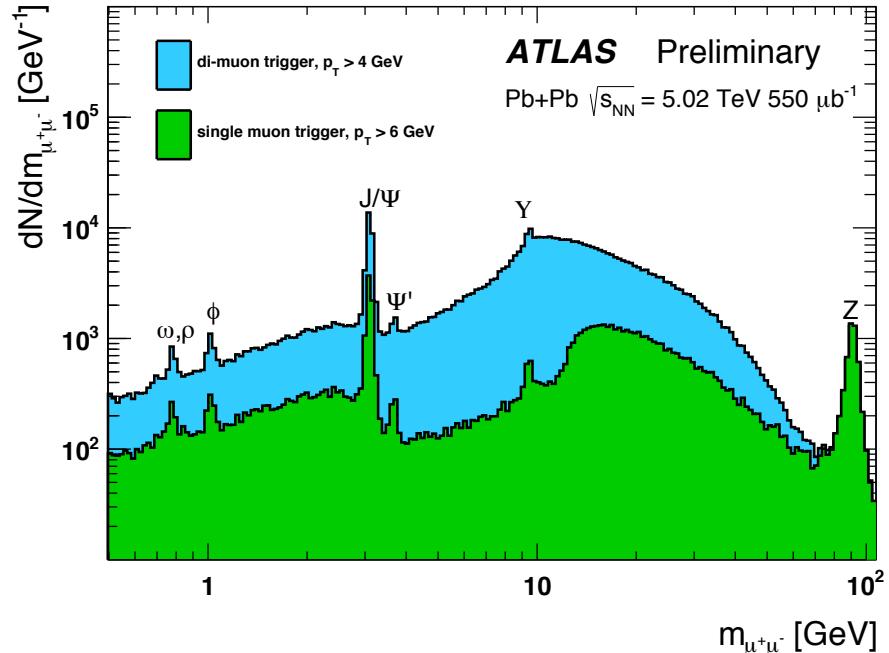
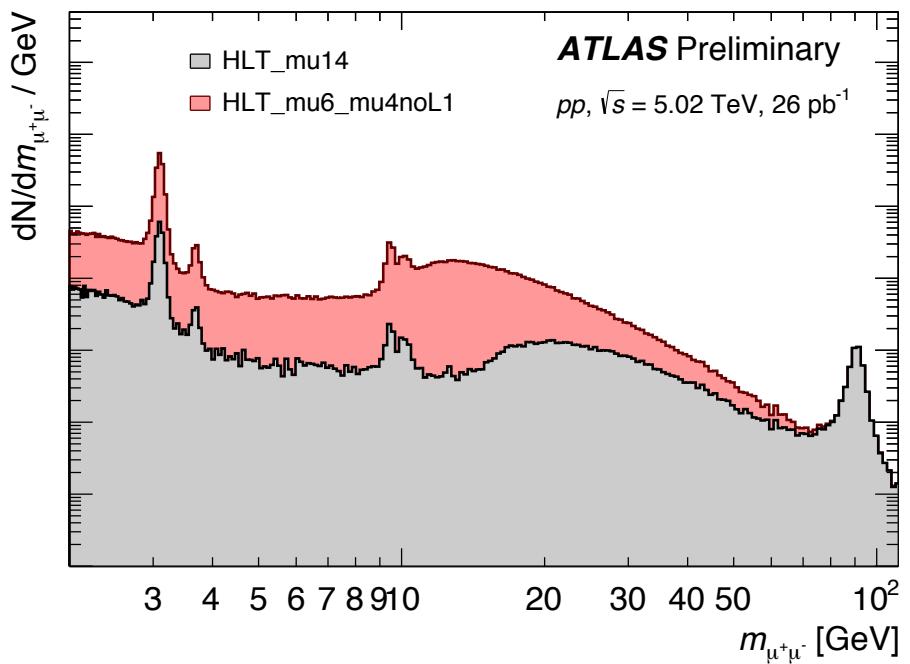


Summary

- EW Bosons in Pb+Pb demonstrate binary collisions scaling
 - Baseline for color sensitive QGP measurements
 - Relatively little sensitivity to nuclear effects
- EW bosons & charmonium probe nuclear effects in p+Pb collisions, inform our understanding of:
 - nPDF
 - Cold nuclear matter
 - Collision geometry



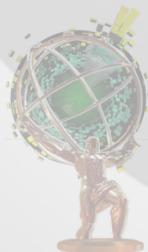
Looking Forward ...



- New pp data will provide reference for p+Pb at same energy
- New Pb+Pb measurements with higher precision coming soon!

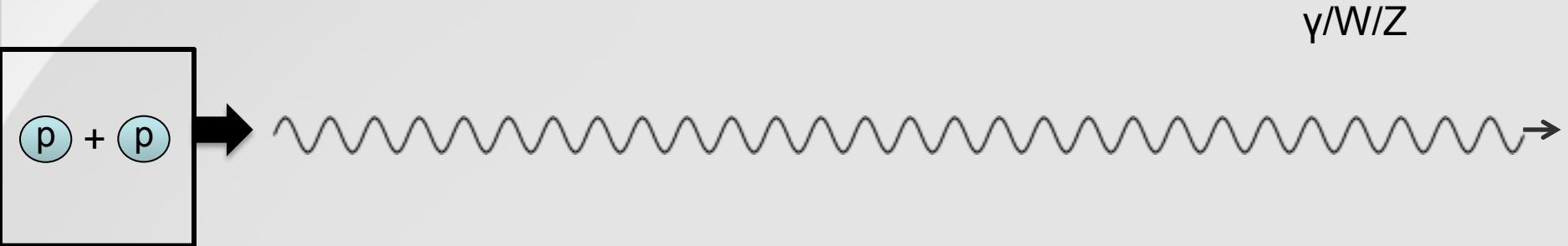


Backup Information



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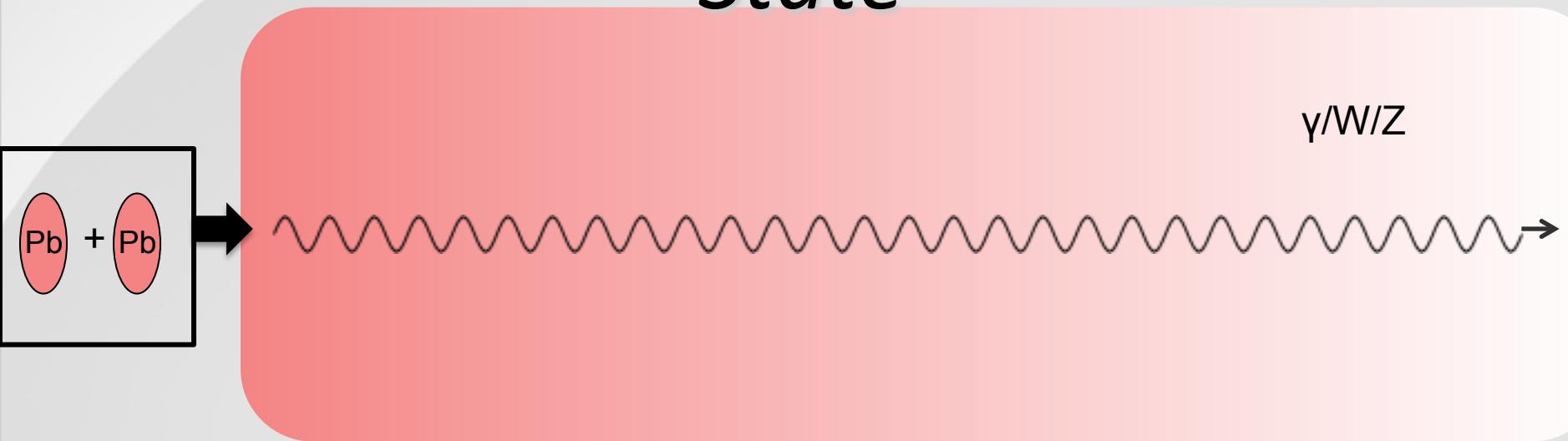
EW Bosons as a Probe of the Initial State



We can measure the EW boson production in $p+p$ collisions ...



EW Bosons as a Probe of the Initial State



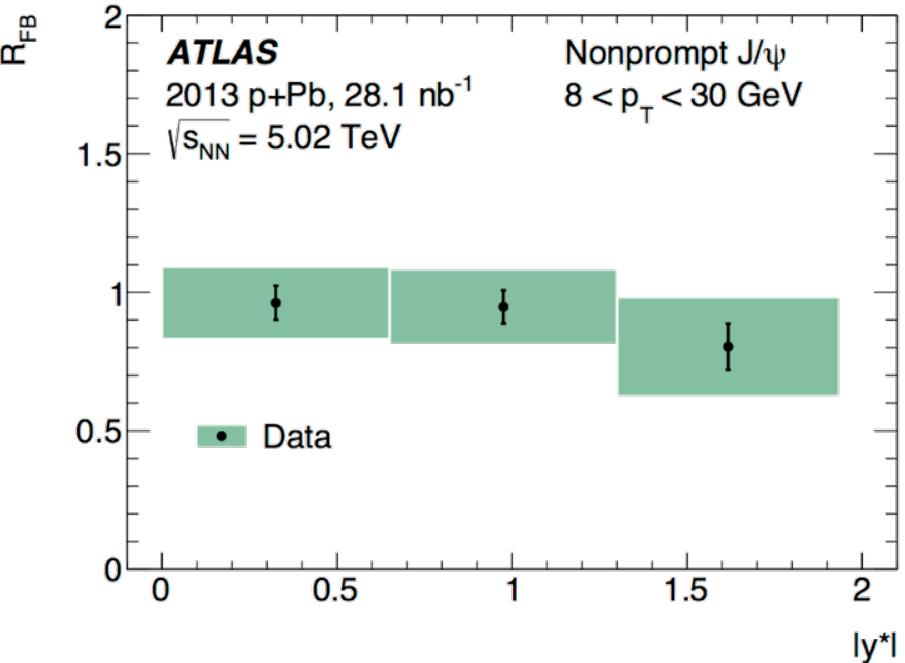
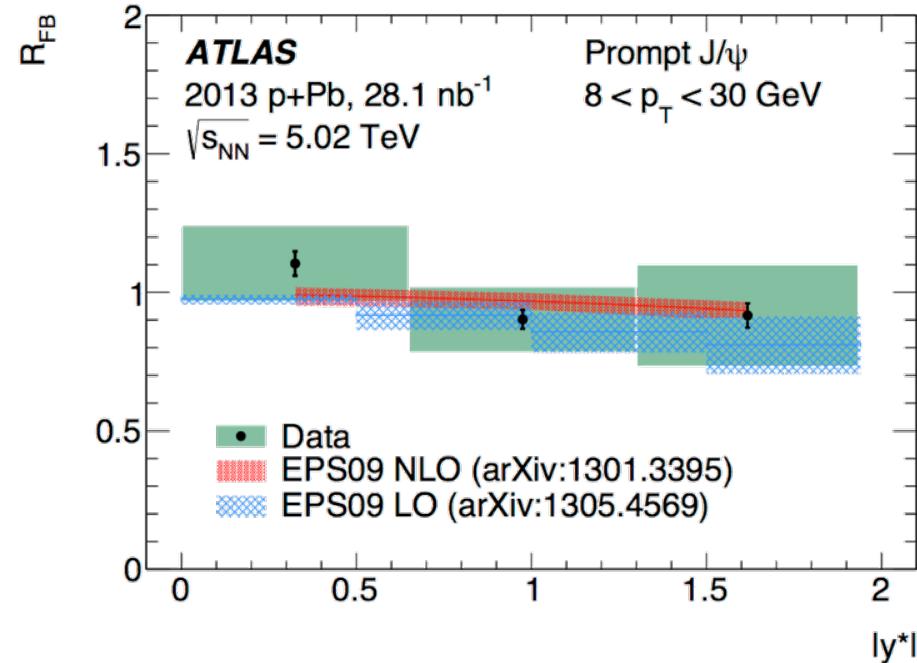
We can measure the EW boson production in p+p collisions ...

Add the medium and measure the same thing –
EW bosons won't interact with the colored QCD
medium any changes observed must be due to
initial state effects



Forward to Backward Ratio

PRC 92 (2015) 034904



- (*Left*) Prompt J/ ψ R_{FB}
- (*Right*) Non-prompt J/ ψ R_{FB}

$$R_{\text{FB}}(p_{\text{T}}, y^*) \equiv \frac{d^2\sigma(p_{\text{T}}, y^* > 0)/dp_{\text{T}}dy^*}{d^2\sigma(p_{\text{T}}, y^* < 0)/dp_{\text{T}}dy^*}.$$

Prompt J/ ψ R_{FB} is compatible with both EPS09 models.

y^* : CM rapidity being positive in forward (proton beam direction)

