Particle rapidity distribution in proton-nucleus collisions using the proton-contributor reference frame

arXiv:1408.3108 [hep-ph]

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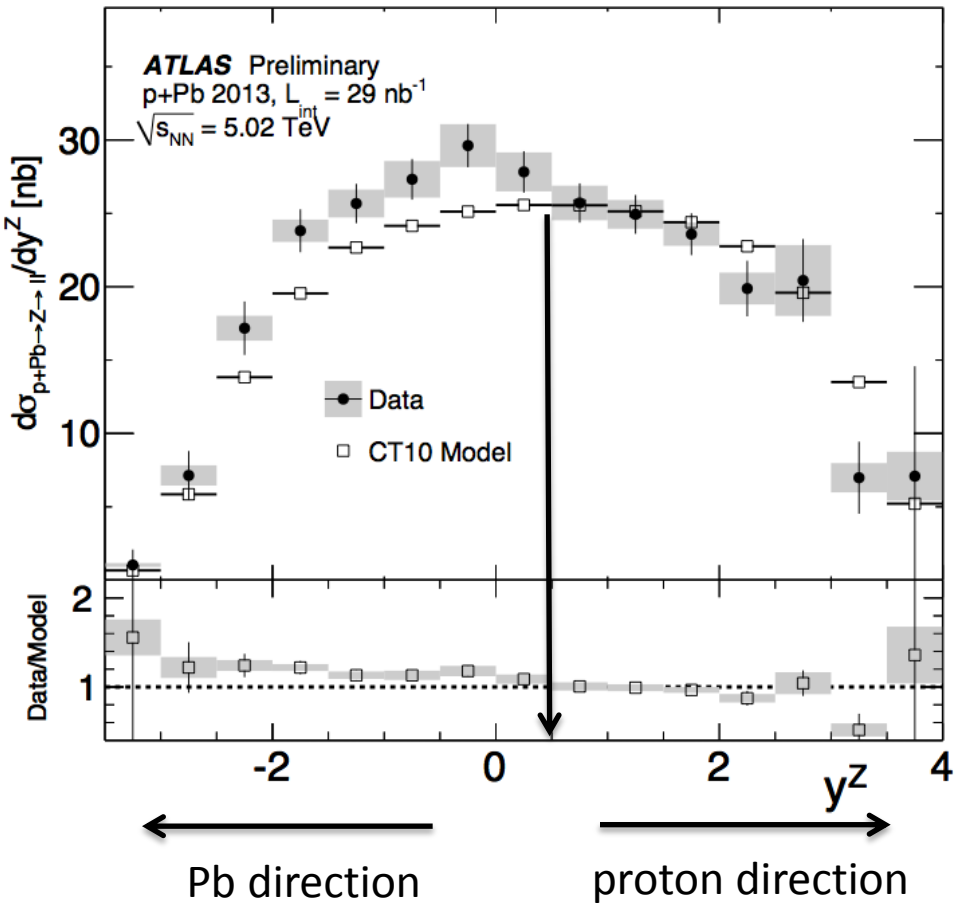
Oral presentation in the 10th International Workshop on High p_T Physics in the RHIC/LHC era

Outlook

- Results on Z boson production in p-Pb at the LHC.
- Rapidity shift hypothesis.
- Z Forward-backward ratio in p-Pb.
- J/ψ nuclear modification factor in p-Pb collisions.
- Distribution of the charge particle pseudo-rapidity distribution with centrality in p-Pb.

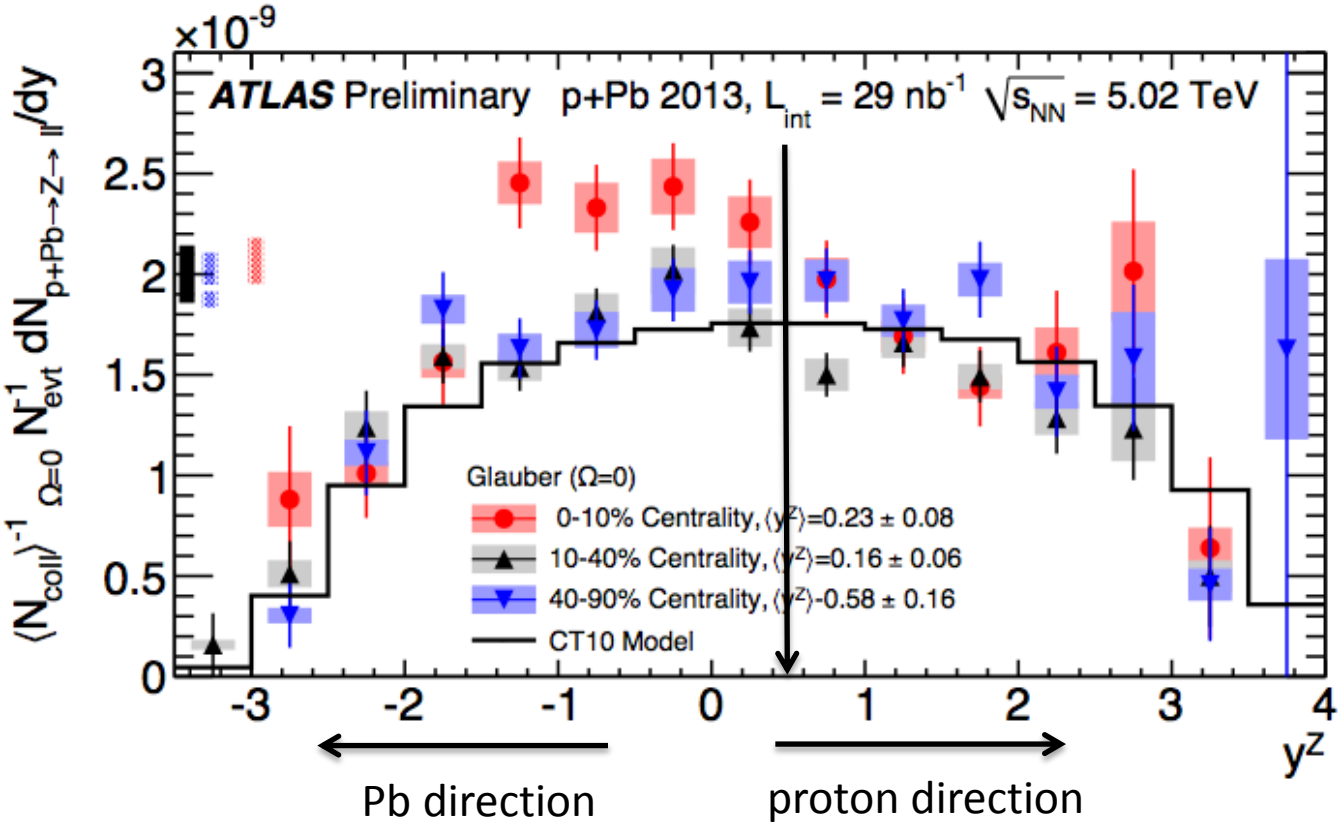
Z in p-Pb collisions at 5.02 TeV (ATLAS)

- ✓ y_{NN}=0.465 at the LHC due to the asymmetric beam energies per nucleon.
- ✓ Z rapidity distribution shifted to negative rapidity.



B. Cole, ATLAS plenary, QM2014
ATLAS-CONF-2014-020, http://cds.cern.ch/record/1603472

Z in p-Pb collisions at 5.02 TeV (ATLAS)



- ✓ Z rapidity shift toward negative rapidity, seems to increase with centrality.
- ✓ Uncertainties still large.

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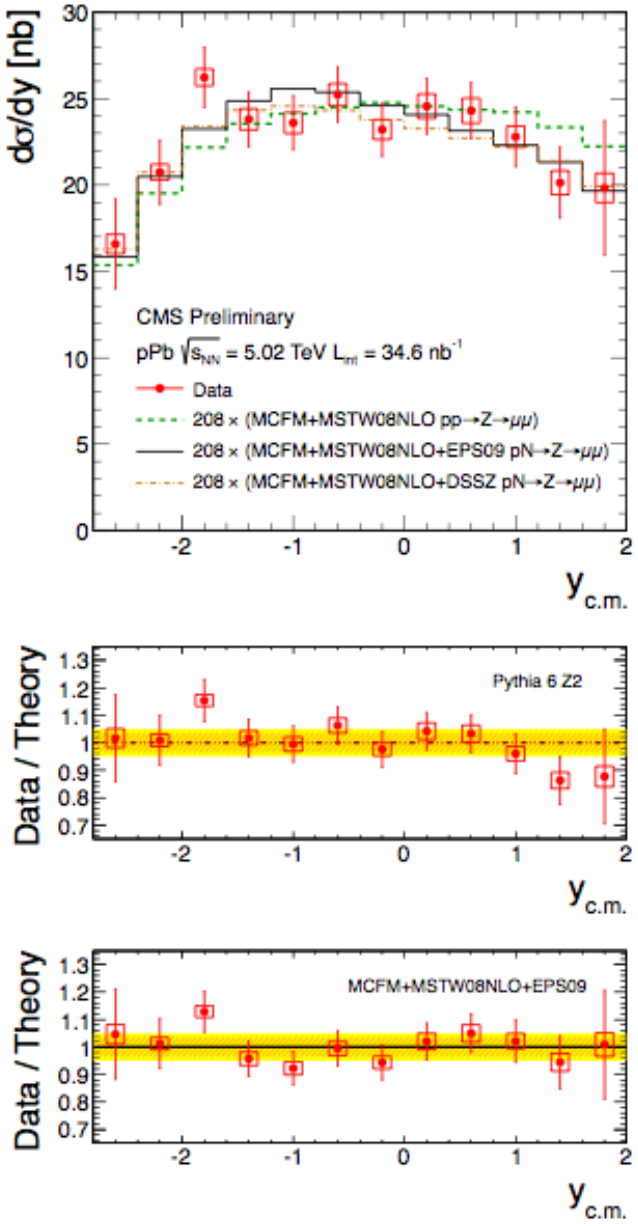
Few considerations

- ✓ Q-AntiQ interactions
- ✓ 2 body ➔ 1 body :
  - ✓ $x_{Bj}^{\pm}$ = M_Z/sqrt(s) x exp (±y); $Q^2 \sim 100^2$ GeV^2
  - ✓ y=0, $x_{Bj} \sim 0.02$ (J/ψ at RHIC);
  - ✓ y=±2, $x_{Bj} \sim 0.15$ & 0.0025;
- ✓ Shadowing is the natural explanation to this results. Still important at $Q^2 \sim 100^2$ GeV^2
- ✓ Dependence of shadowing with the impact parameter is necessary to interpret these data.
- ✓ Better data (more statistics) is needed.

Z in p-Pb at 5.20 TeV (CMS)

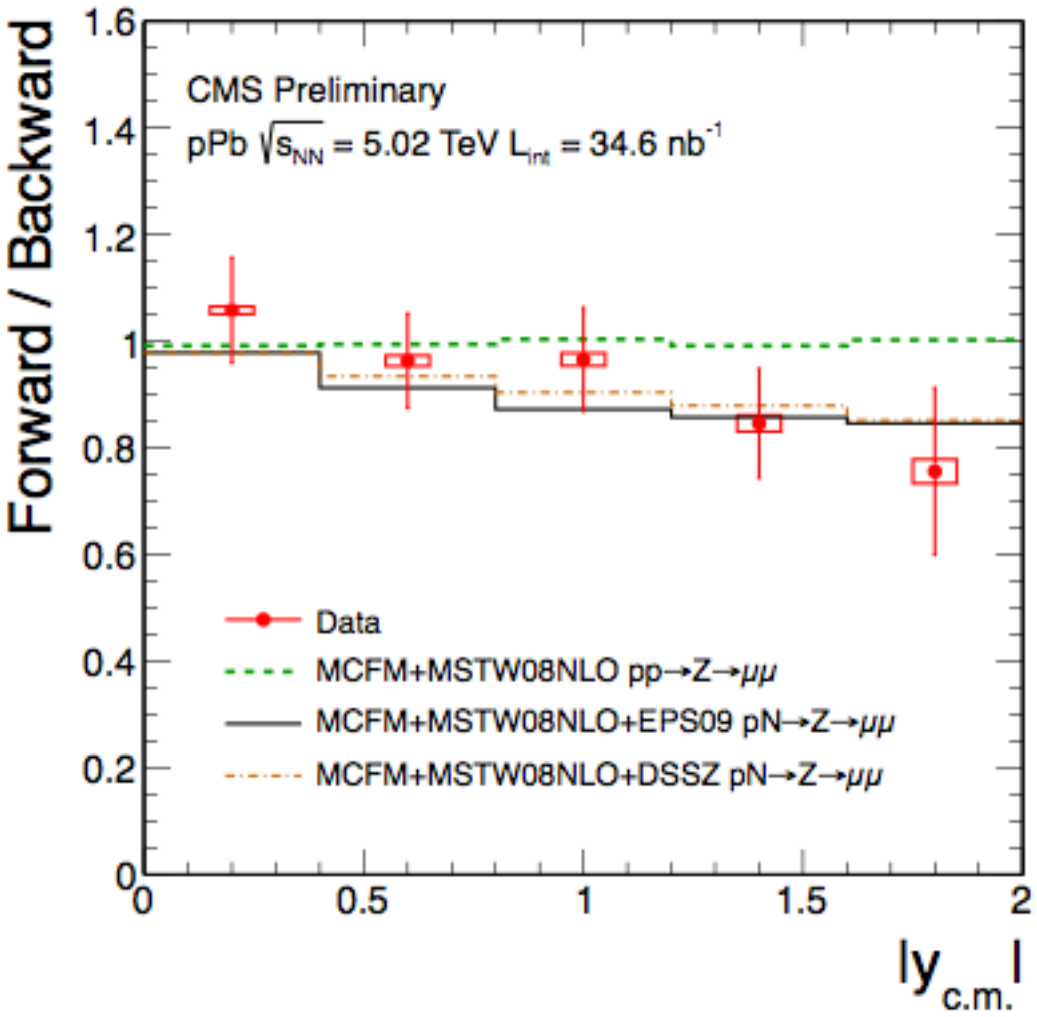
- EPS09 does a good job for explaining CMS data (integrated in centrality).
- Significance data (w and w/o EPS09) small.
- Better significance looking at backward-to-forward ratio.



R. Granier de Cassagnac, CMS plenary, QM2014
HIN-14-003 http://cms-physics.web.cern.ch/cms-physics/public/HIN-14-003-pas.pdf

Z in p-Pb at 5.02 TeV (CMS)

- Significance remains small.
- EPS09 seems to be needed to explain CMS data.
- Comparison/merging ATLAS-CMS is needed.



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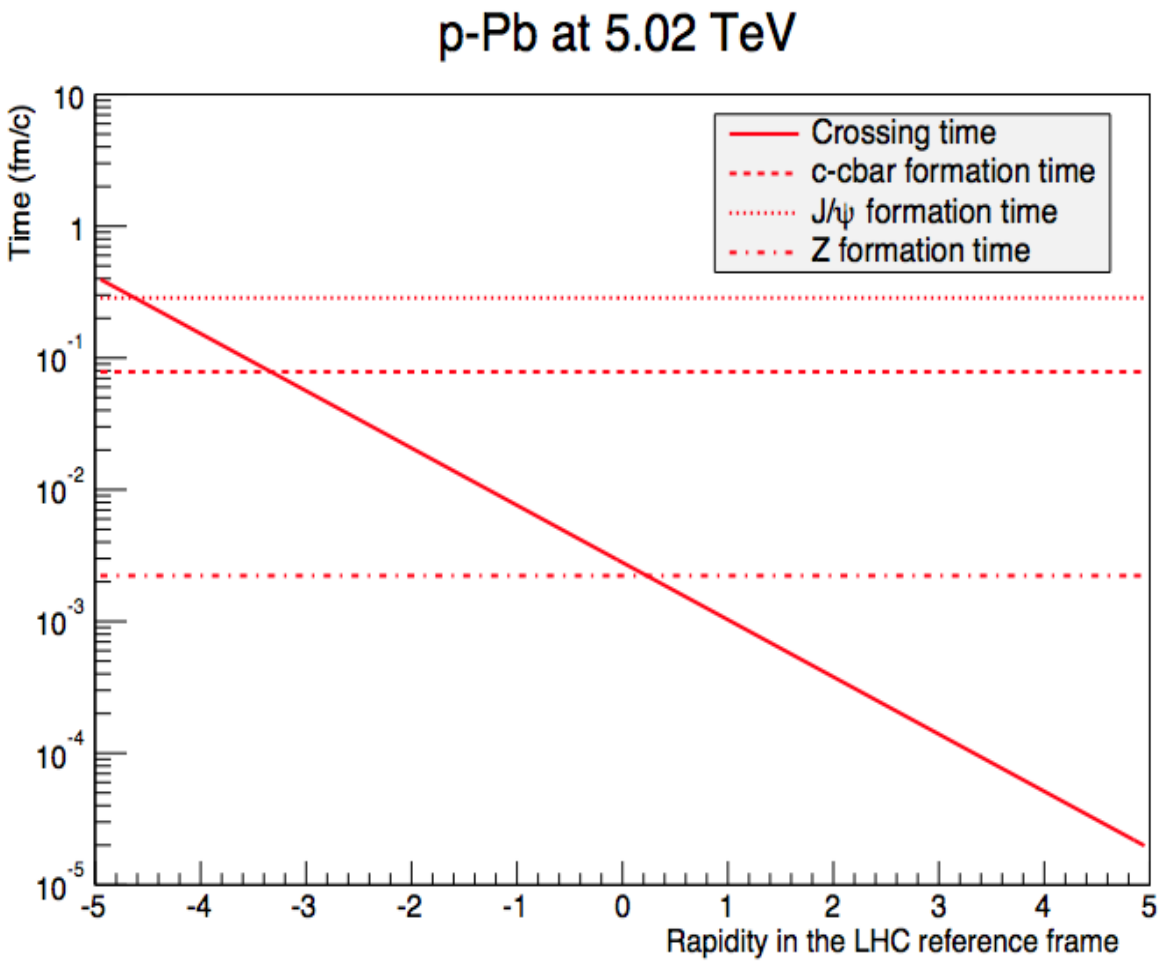
Time scale in p-Pb collisions at the LHC

- ✓ Dashed lines:
  - $\tau_f \sim Q^{-1}$
- ✓ Solid line:
  - $\tau_C \sim R_A/\gamma_R$
  - $\gamma_R = \cosh(y-y_A)$
- ✓ Crossing time smaller than formation times at LHC energies.
- ✓ Coherent interaction with low x_{Bj} partons in the nucleus.



Gines Martinez-Garcia
arXiv:1408.3108v1 [hep-ph], http://arxiv.org/abs/1408.3108v1

Proton-contributor frame

Considering the centre of mass of the proton – participant nucleons of the nucleus: *proton-contributor* centre of mass:

$$m_{\mathrm{C}} = N_{\mathrm{coll}}(b) \times m_{\mathrm{N}} \qquad P_{\mathrm{pC}} = P_{\mathrm{p}} - P_{\mathrm{C}}.$$

$$P_{\mathrm{C}} = N_{\mathrm{coll}}(b) \times P_{\mathrm{Pb}} \qquad E_{\mathrm{pC}} = \sqrt{P_p^2 + m_p^2} + \sqrt{P_{\mathrm{C}}^2 + m_{\mathrm{C}}^2}$$

$$\boxed{y_{\mathrm{pC}} = \tanh^{-1}\left(p_{\mathrm{pC}}/E_{\mathrm{pC}}\right)}$$

For 1 contributor y_{pC} =0.465, for 6 contributors (MB p-Pb) y_{pC} is -0.430 (1 unit of rapidity shift) and for 17 contributors, y_{pC}=-0.952.

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arXiv:1408.3108v1 [hep-ph], http://arxiv.org/abs/1408.3108v1

Rapidity Shift Simple Model

RSSM assume that particles in p–A collisions are produced with a rapidity differential cross section which is symmetric in the proton-contributor reference frame with a similar shape as in pp collisions.

$$\frac{\mathrm{d}N^{\mathrm{probe}}_{\mathrm{pA(Ap)}}}{\mathrm{d}y}\left(y\right) = \mathcal{N}\frac{\mathrm{d}N^{\mathrm{probe}}_{\mathrm{pp}}}{\mathrm{d}y}\left(y - (+)\Delta y_{\mathrm{pN-pC}}\right)$$

Relatively easy to make predictions for backward to forward ratio, R_{pA} or centrality dependence ratios.

Gines Martinez-Garcia
arXiv:1408.3108v1 [hep-ph], http://arxiv.org/abs/1408.3108v1

Indeed, an old idea

After arXiv:1408.3108 [hep-ph]was completed, I was aware (J. Schukraft) that similar approaches based on rapidity shifts were already proposed in the past.

Simple kinematics gives the result that the rapidity of the center-of-mass (CM) frame in a p+A collision, where the proton interacts with a "tube" of ν nucleons in the nucleus, is

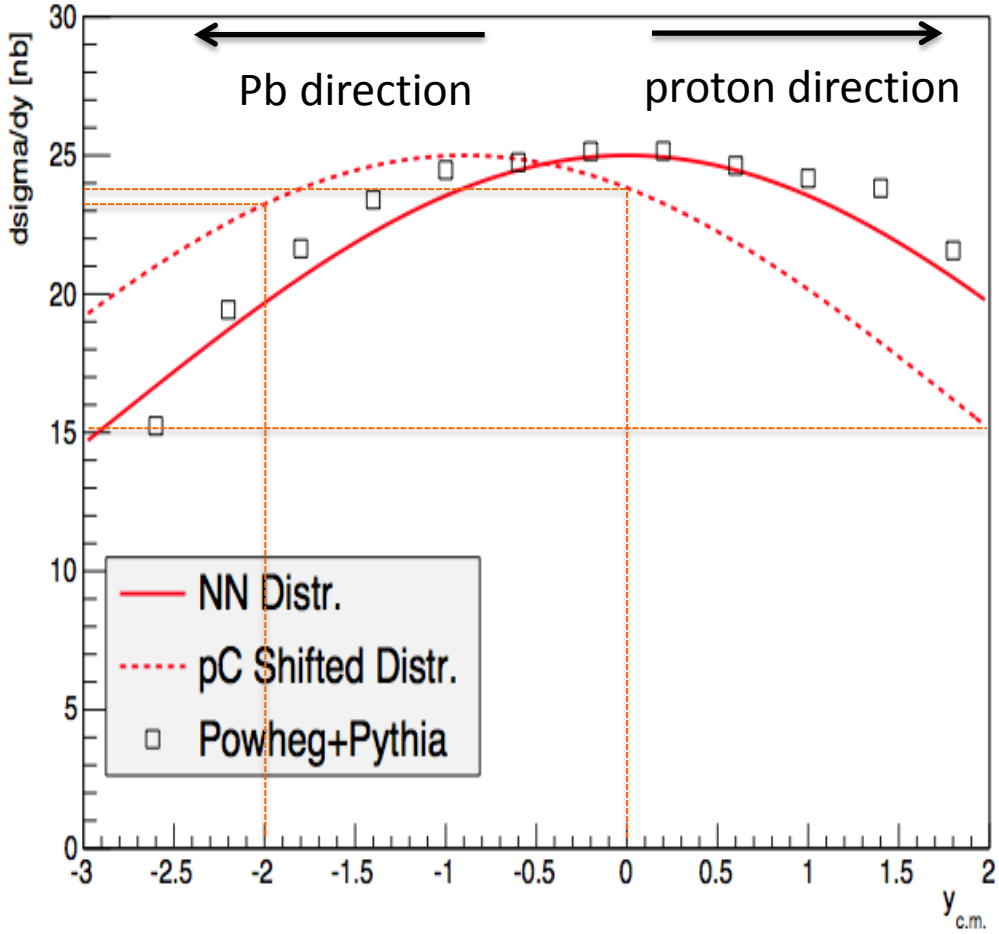
$$\Delta y_{p+A} = \frac{1}{2} \ln(\nu)$$

Peter Steinberg
arXiv:nucl-ex/0703002, http://arxiv.org/abs/nucl-ex/0703002
and references in.

In the following, I apply this approach to the production of Z bosons, J/ψ and charged particles in p-Pb collisions at the LHC.

RSSM Z back2forw ratio (I)

- ✓ Expected Z boson production in NN collision estimated with MC.
- ✓ Distribution shifted to the proton-contributor frame (dashed line).
- ✓ Backward to forward ration is then easily computed.



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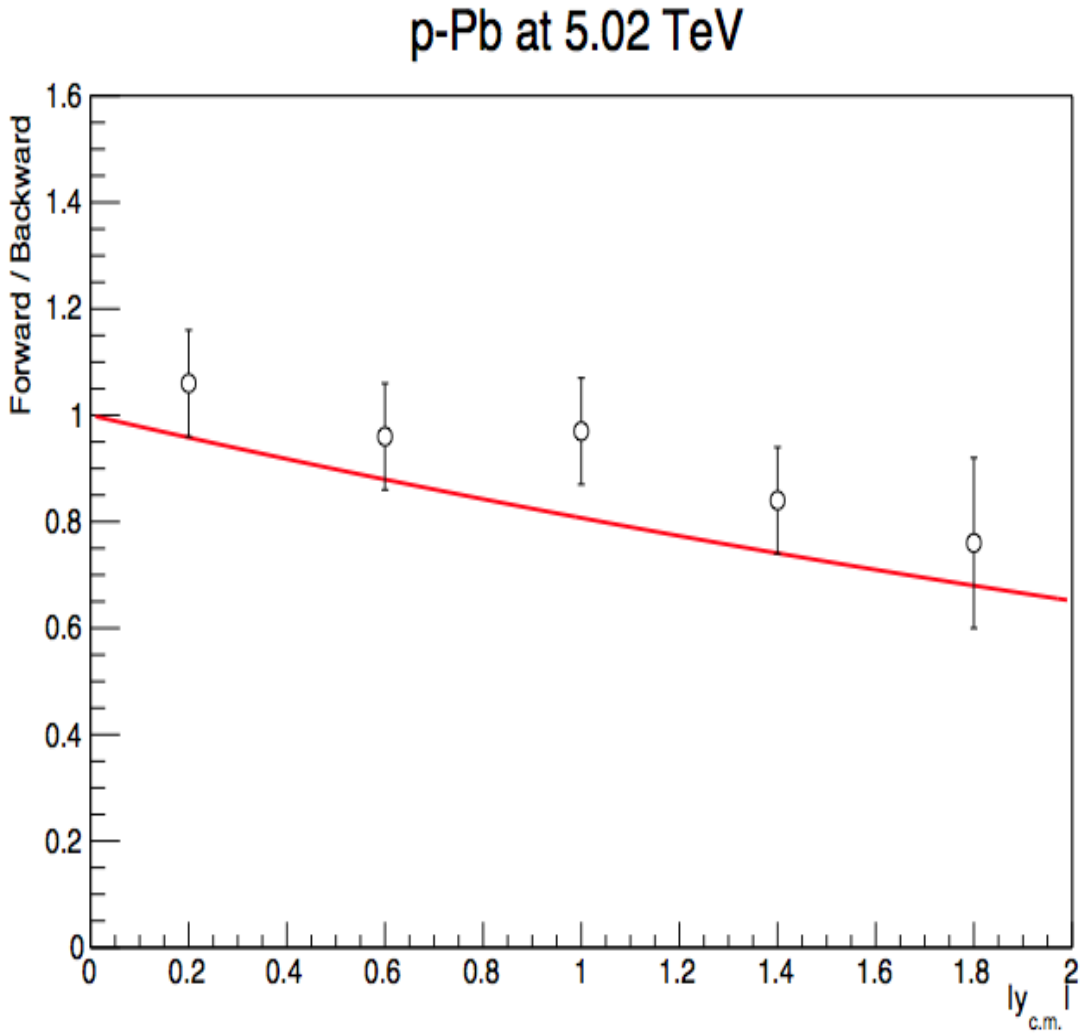
RSSM Z back2forw ratio (II)

- ✓ Good agreement.
- ✓ Still large error bars.
- ✓ Why does it work so well?
- ✓ Intriguing.



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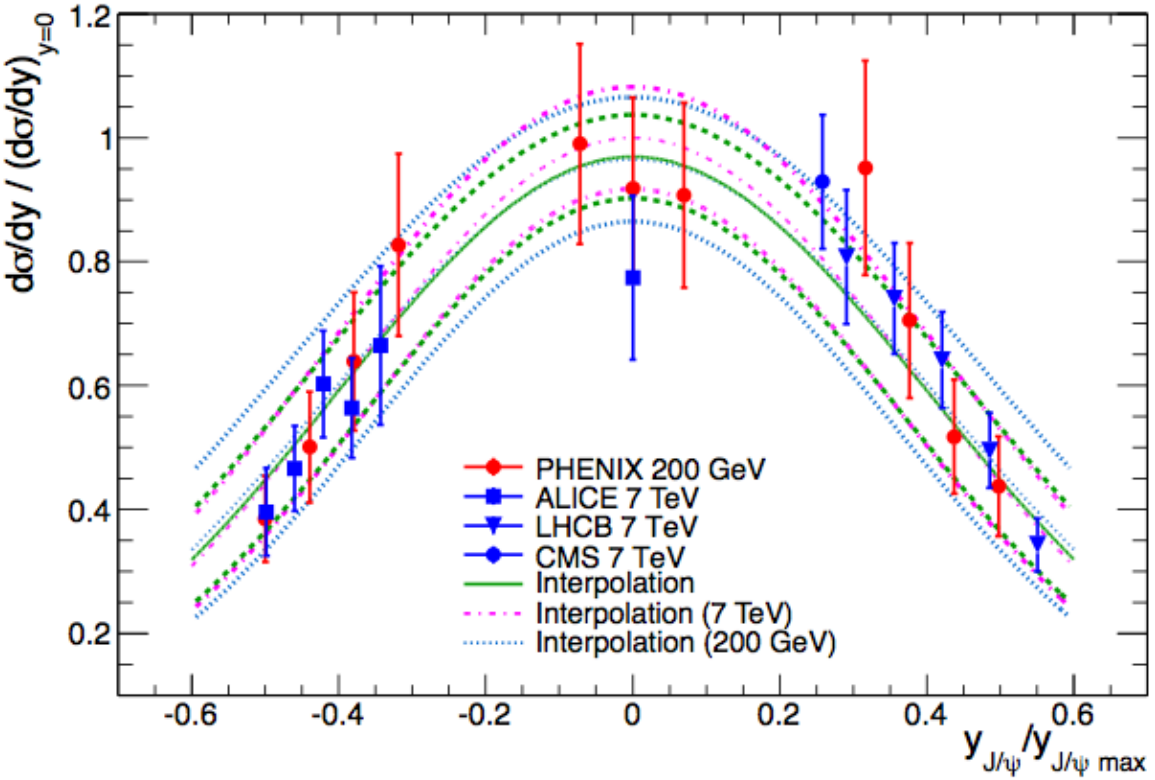
J/ψ y distribution in pp collisions

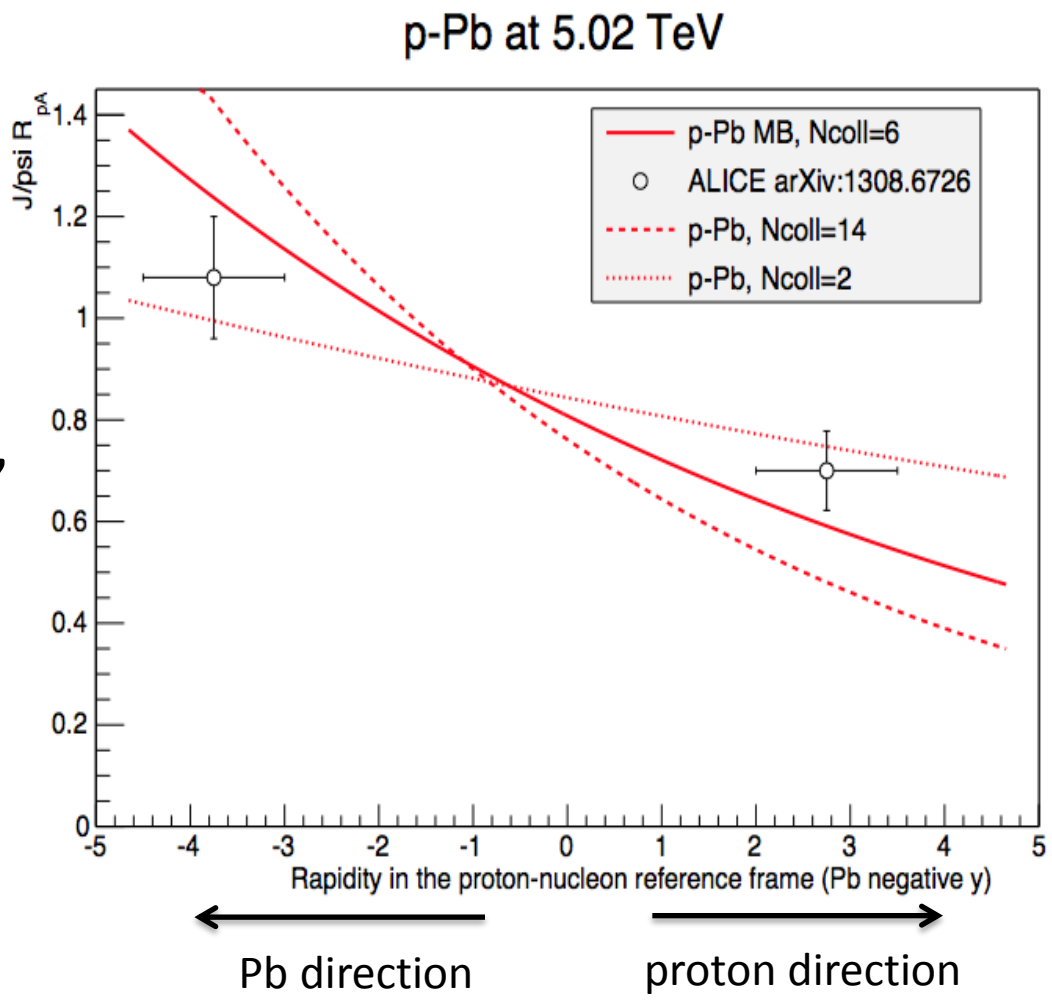
$$\frac{\mathrm{d}\sigma}{\mathrm{d}y} \Big/ \frac{\mathrm{d}\sigma}{\mathrm{d}y}\Big|_{y=0} = e^{-(y/y_{\max})^2/2\sigma_y^2}$$



F. Bossu et al.
arXiv:1103.2394 [nucl-ex] http://arxiv.org/abs/1103.2394

RSSM J/ψ R_{pPb}

- ✓ In pPb collisions, the rapidity distribution is shifted to the proton contributor frame.
- ✓ Ad-hoc 0.85 normalization factor, rapidity independent, is added.
- ✓ RpPb is obtained with via the ratio of two Gaussians functions.



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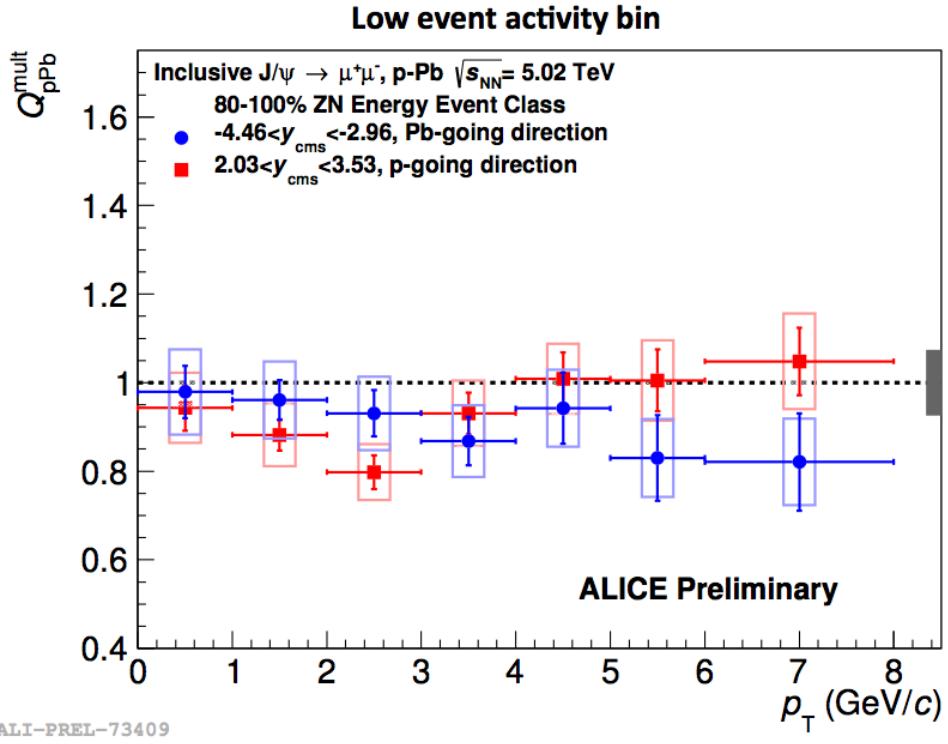
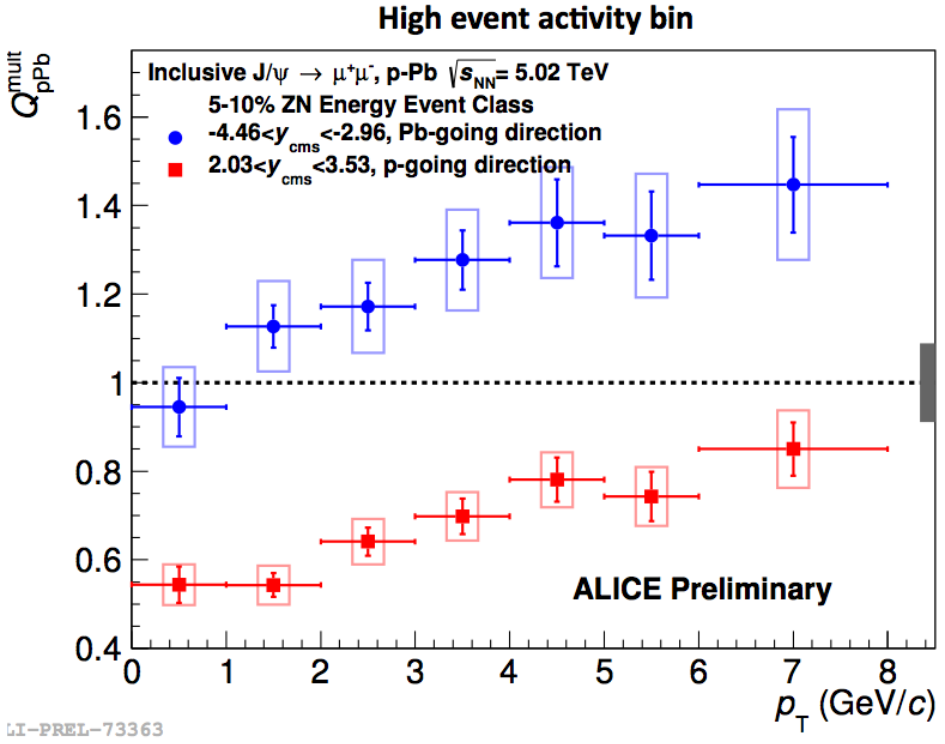
J/ψ R_{pPb} Centrality dependence



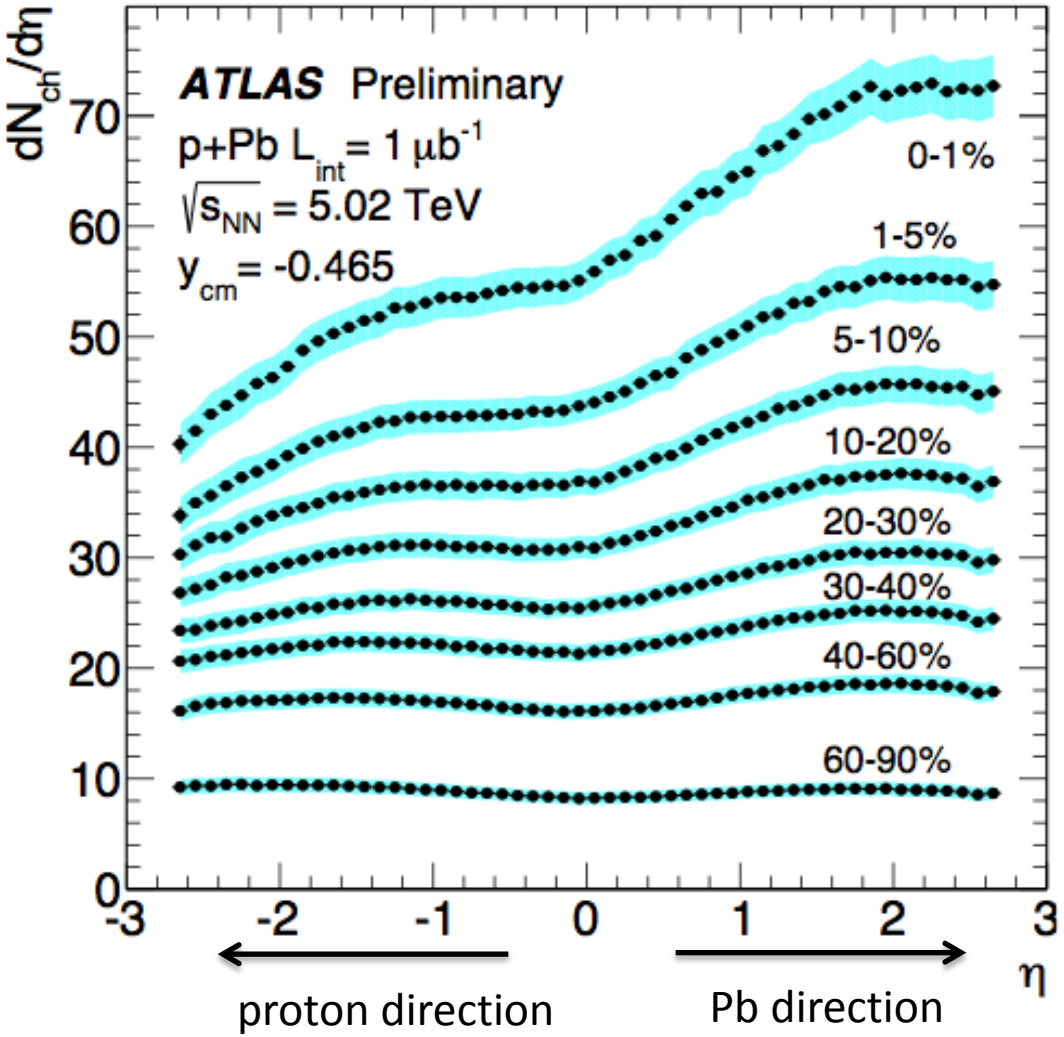


Backward (forward) R_{pPb} increases (decreases) with centrality.

Qualitatively expected due to the increase of the rapidity shift (larger number of contributors) in most central collisions.

$dN_{ch}/d\eta$ in p-Pb collisions

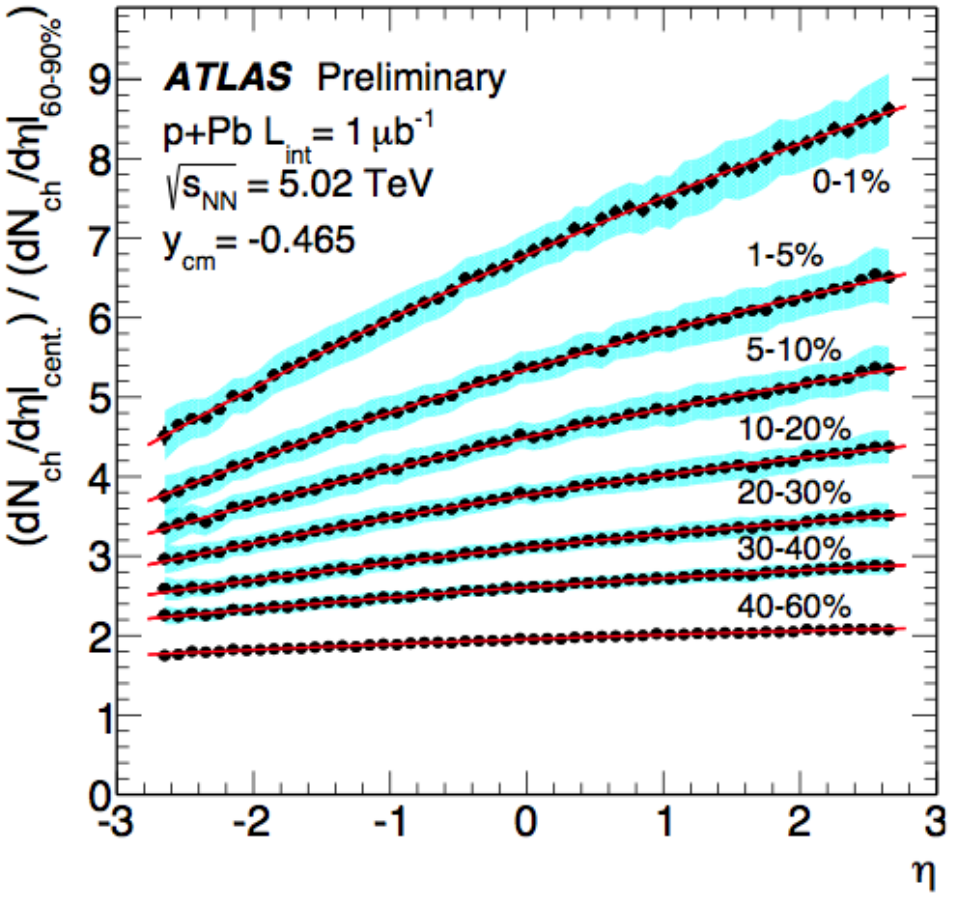
- ✓ Pb going in positive η.
- ✓ Asymmetry increases with the centrality.



R. R. Debbe-Velasco et al. (ATLAS Collaboration),
Quark Matter 2014, ATLAS-CONF-2013-096, https://indico.cern.ch/event/219436/session/9/contribution/225

$dN_{ch}/d\eta$ ratio wrt 60-90%

- ✓ Triangular shapes.
- ✓ Several (old) models explain this observation.
- ✓ What about the Rapididity Shift Simple model?



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RSSM estimation $dN_{ch}/d\eta$

- ✓ dN_{ch}/dy with a Gaussian shape centred in the pC frame.
- ✓ $\langle m \rangle = 450$ MeV/c^2 and $\langle p_T \rangle = 700$ MeV/c.

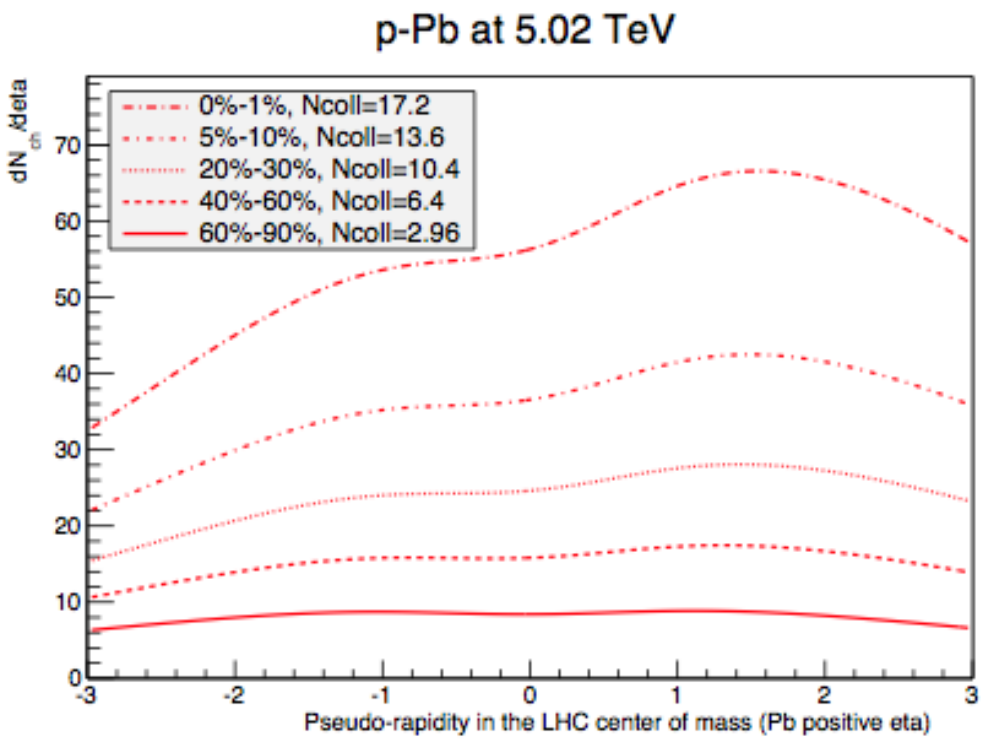
$$\frac{dN_{ch}}{d\eta} = \frac{dN_{ch}}{dy} \times \frac{dy}{d\eta}$$

$$\theta = 2 \cdot \arctan\left(e^{-\eta}\right)$$

$$m_T = \sqrt{p_T^2 + m^2}$$

$$p_z = \frac{p_T}{\tan\theta}$$

$$y = \sinh^{-1}\left(\frac{p_z}{m_T}\right)$$



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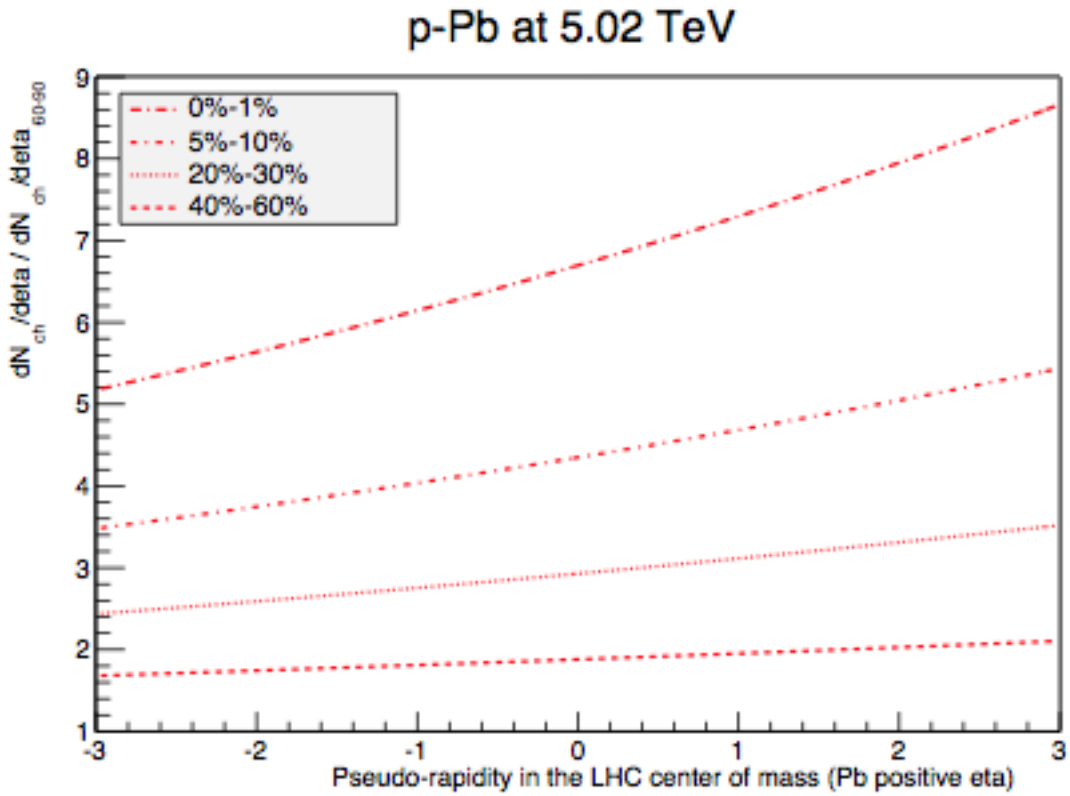
RSSM estimation $dN_{ch}/d\eta$

The double peak structure present in the distributions disappears in the ratios. The ratios are observed to grow nearly linearly with pseudo-rapidity, and the slope increases from peripheral to central collisions.



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Conclusions

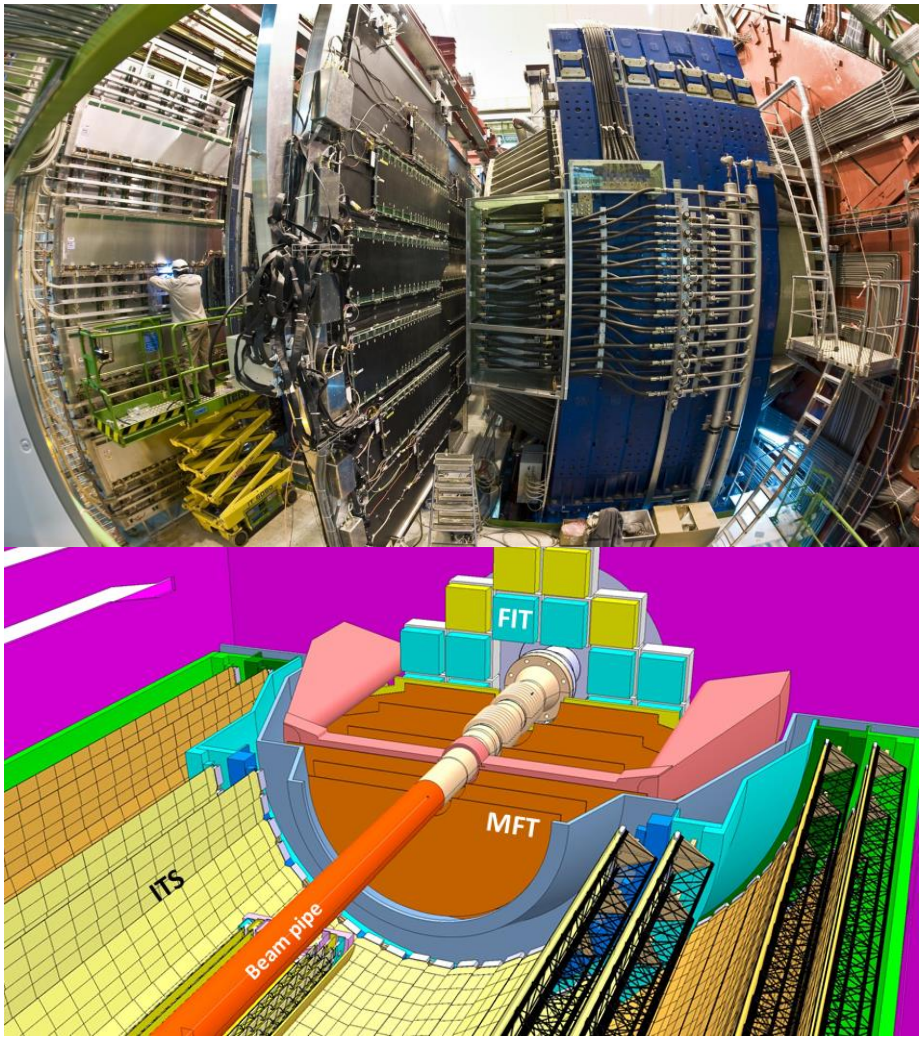
- ✓ Model based on a rapidity shift from NN to pC reference frame.
- ✓ Not clear physics justification.
- ✓ It describes different observations at LHC energies: $dN_{ch}/d\eta$ (see also P. Steinberg arXiv:nucl-ex/0703002), J/ψ RpA, Z back2forw ratio.
- ✓ Other observables? W? Upsilon? etc …
- ✓ I hope this presentation will trigger new ideas.
- ✓ Why not defining new observables in pA?

$$R_{\mathrm{pA}}^{pC}(y) = \frac{Y_{\mathrm{pA}}(y)}{\langle N_{\mathrm{coll}} \rangle Y_{\mathrm{pp}}(y - \Delta y_{\mathrm{pN-pC}})}$$

- ✓ Comments and suggestions on draft arXiv:1408.3108v1 are welcome.

ALICE MFT Upgrade

- ✓ Pixel Internal Tracker for the ALICE Muon Spectrometer.
- ✓ Golden measurement : beauty down p_T=0 via displaced J/ψ.
- ✓ Ready for LHC run#3.
- ✓ TDR end of the year.
- ✓ It is still time to join us!



Acknowledgements

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Thanks for your attention!