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

arXiv:1408.3108 [hep-ph]

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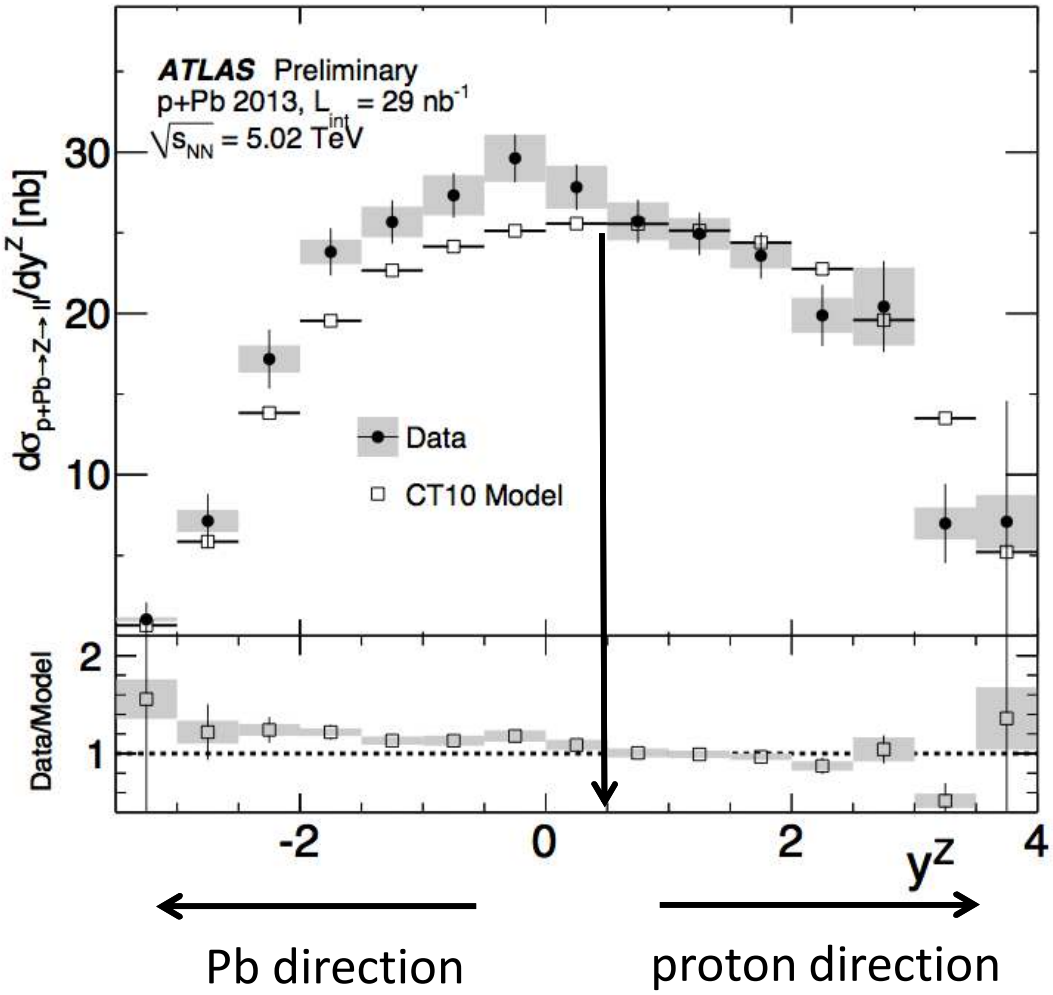
Outlook

- 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.

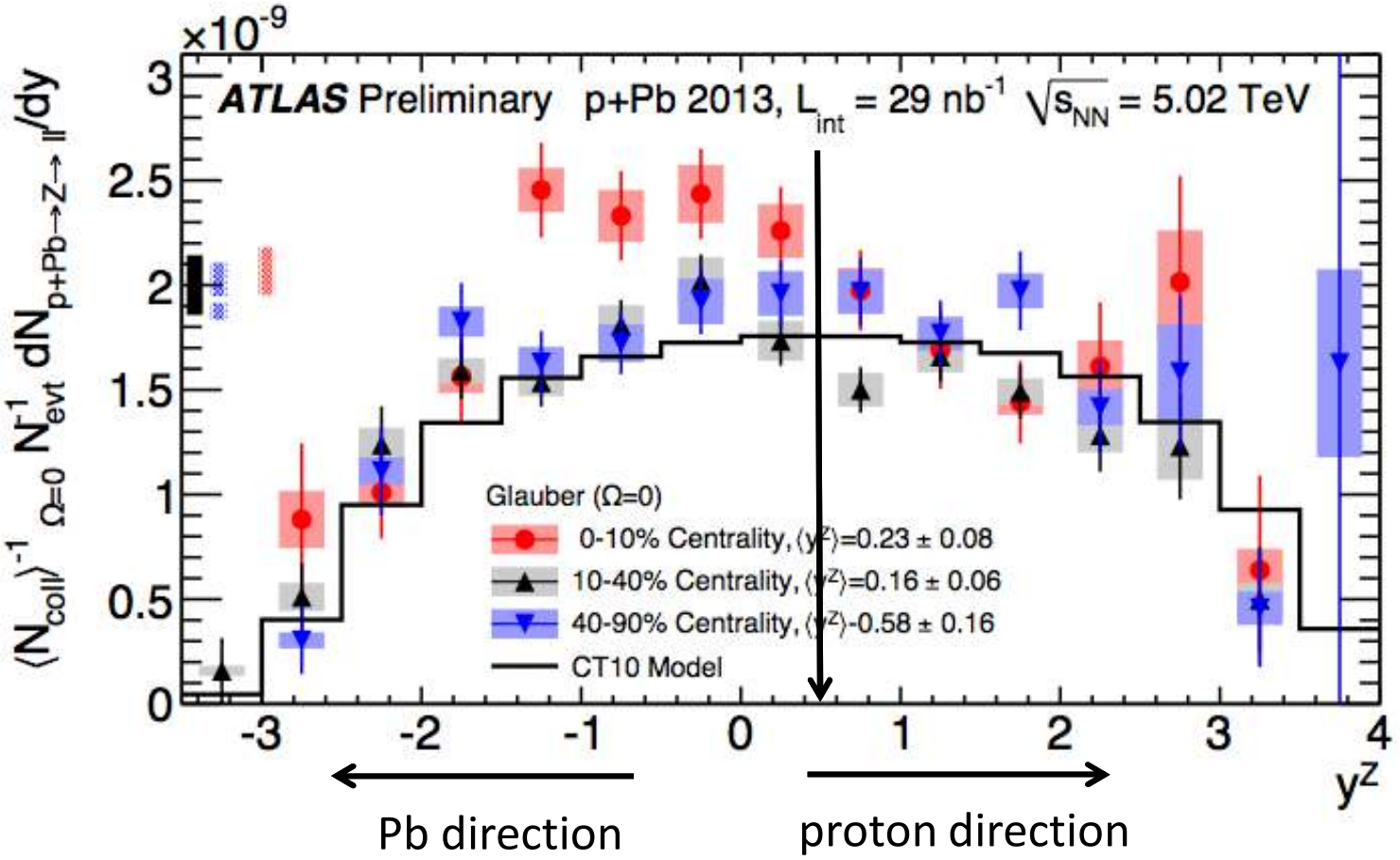
Z in p-Pb collisions at 5.02 TeV (ATLAS)

- ✓ 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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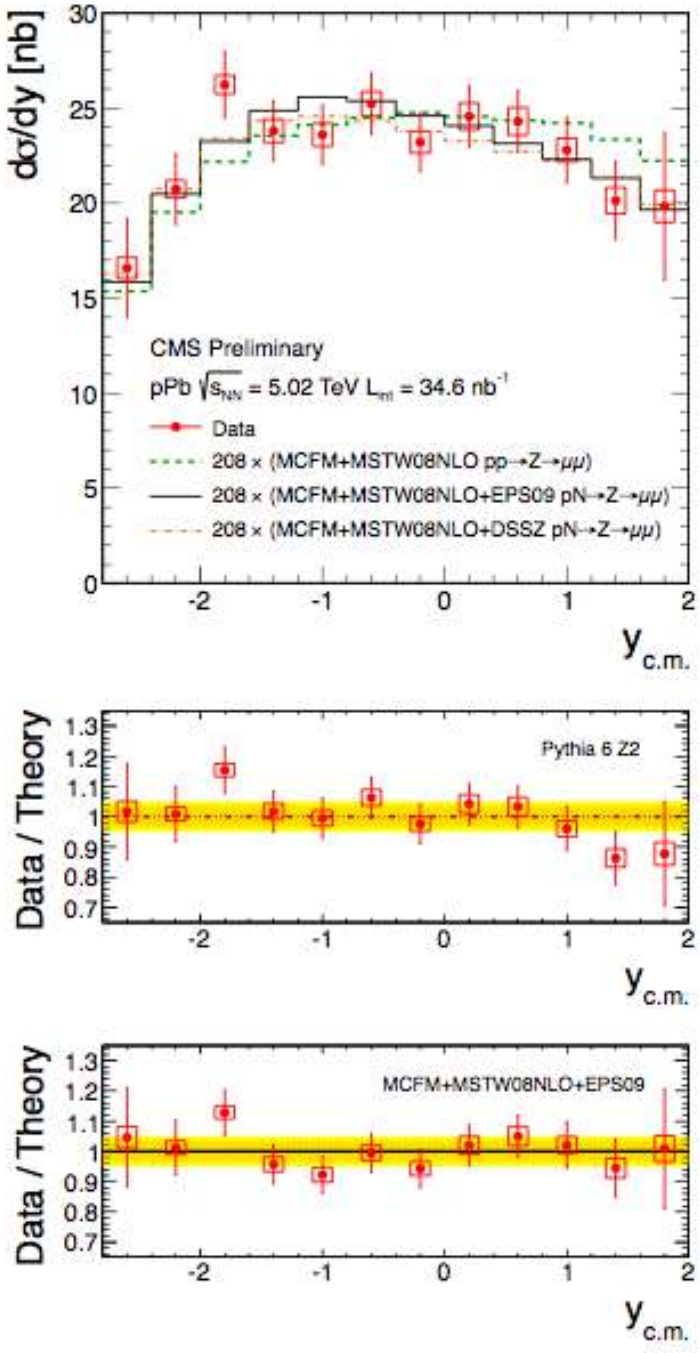
Few considerations

- ✓ Q-AntiQ interactions
- ✓ 2 body 1 body :
  - ✓ $x_{Bj}^{\pm} = M_Z/\mathrm{sqrt}(s) \times \exp(\pm y)$; $Q^2 \sim 100^2$ GeV^2
  - ✓ y=0, $x_{Bj} \sim 0.02$ (J/ψ at RHIC);
  - ✓ y=±2, $x_{Bj} \sim 0.15$ & 0.0025;
- ✓ Shadowing seems to be 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)

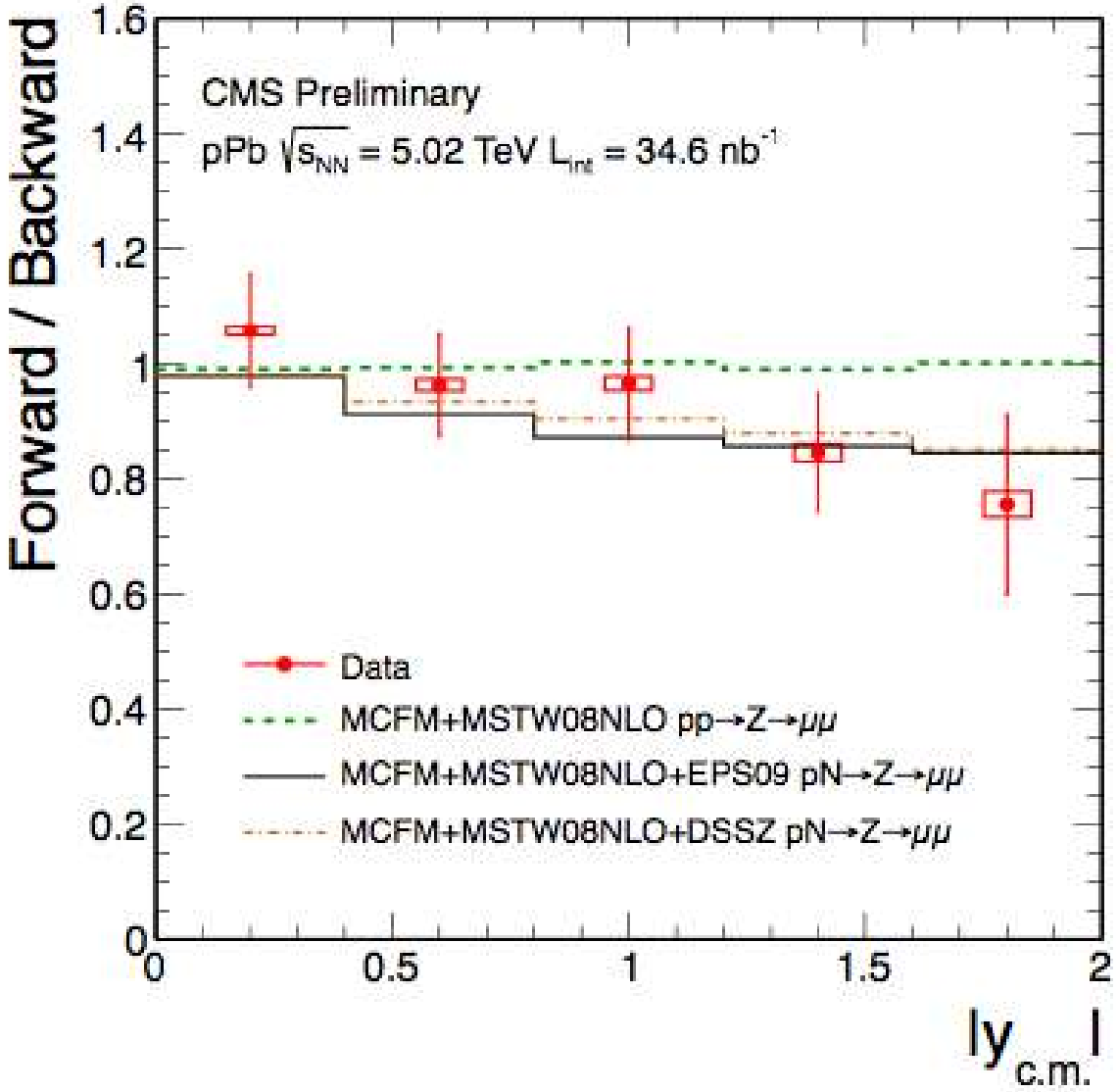
- EPS09 does a good job for explaining CMS data (integrated in centrality).
- Significance data (w and w/o EPS09) small.
- Better significance looking at backward-to-forward ratio.



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.
- Dependence with centrality missing in the CMS analysis.
- Comparison/merging ATLAS-CMS is needed.



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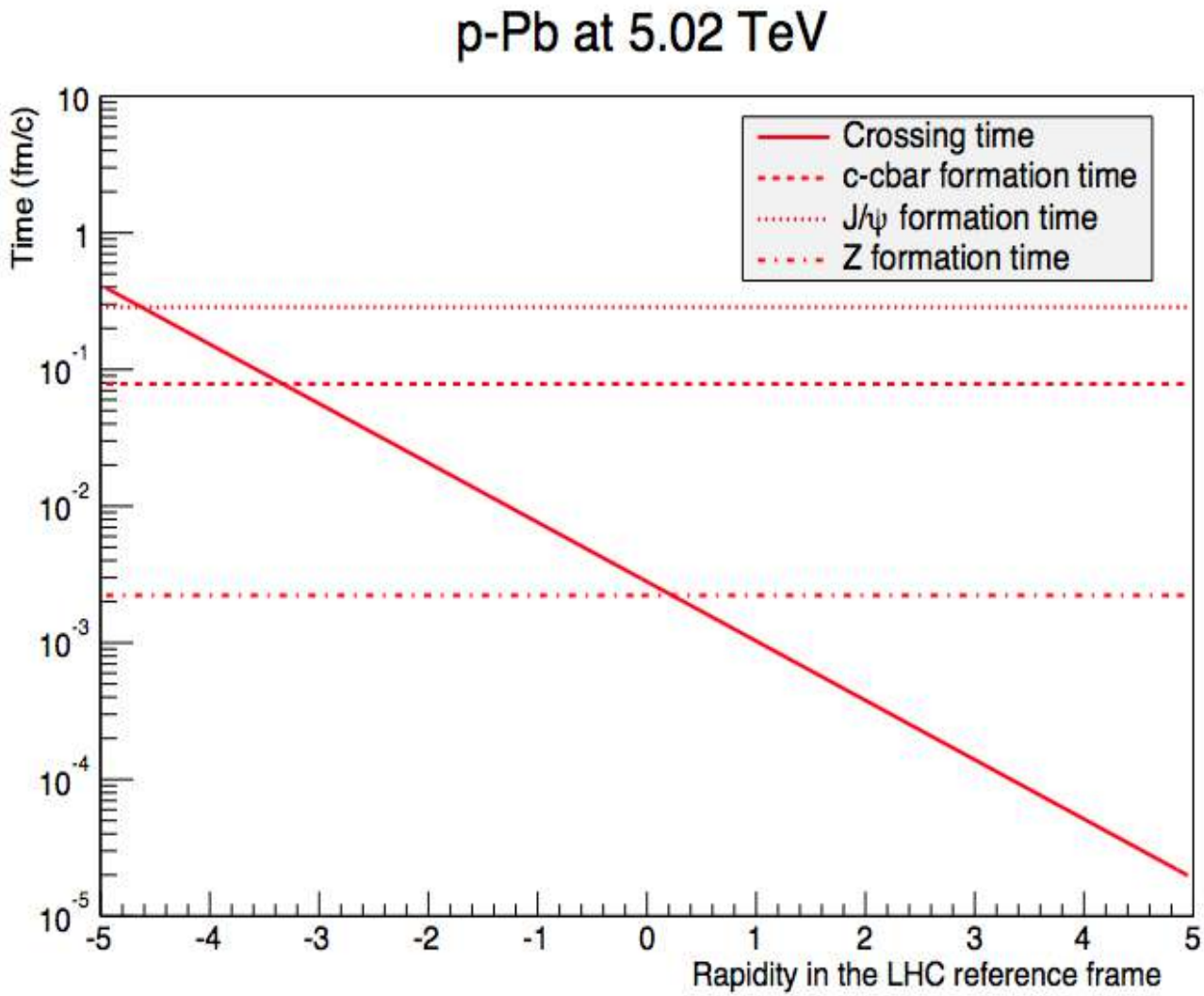
HIN-14-003 http://cms-physics.web.cern.ch/cms-physics/public/HIN-14-003-pas.pdf

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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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.

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

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

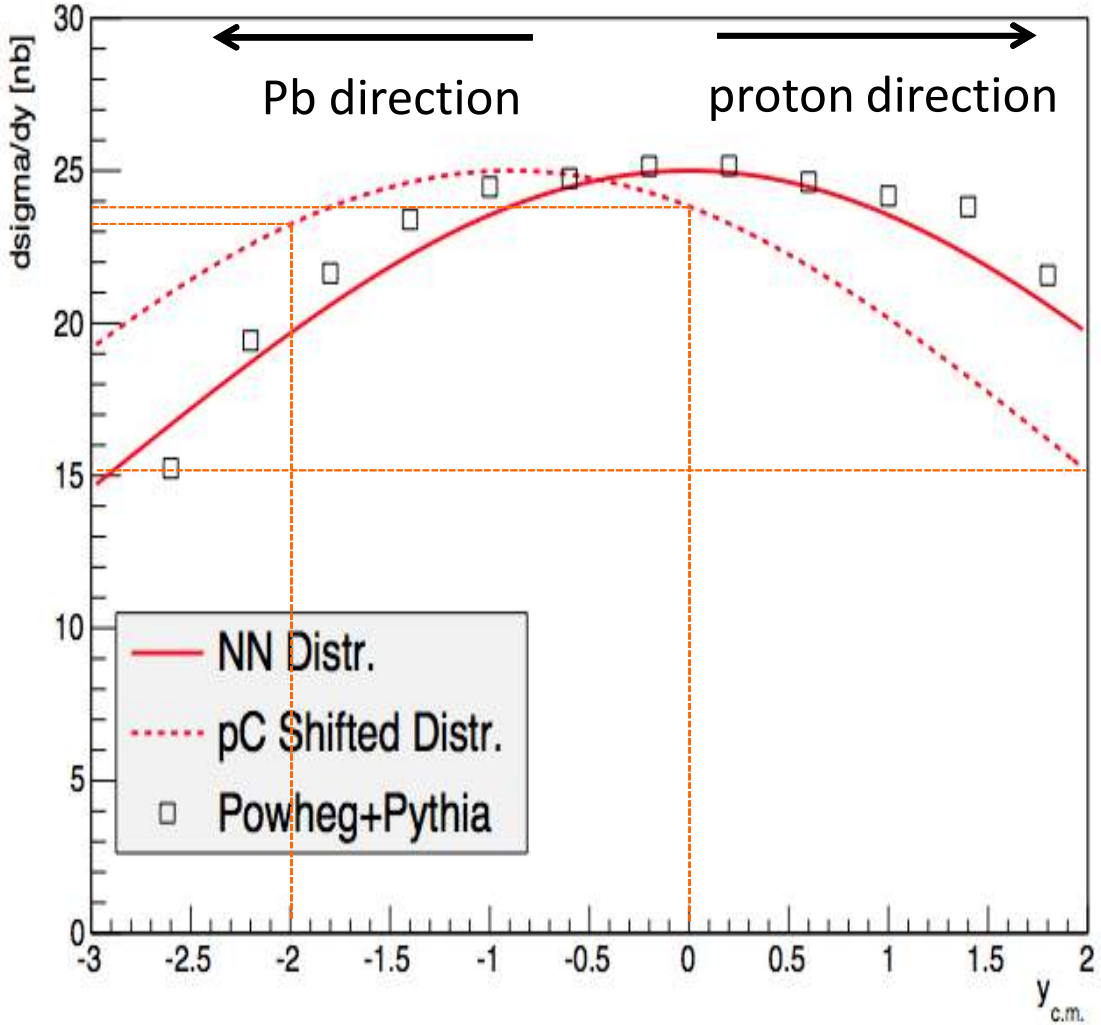
$$\Delta y_{p+A} = \frac{1}{2} \ln(\nu)$$

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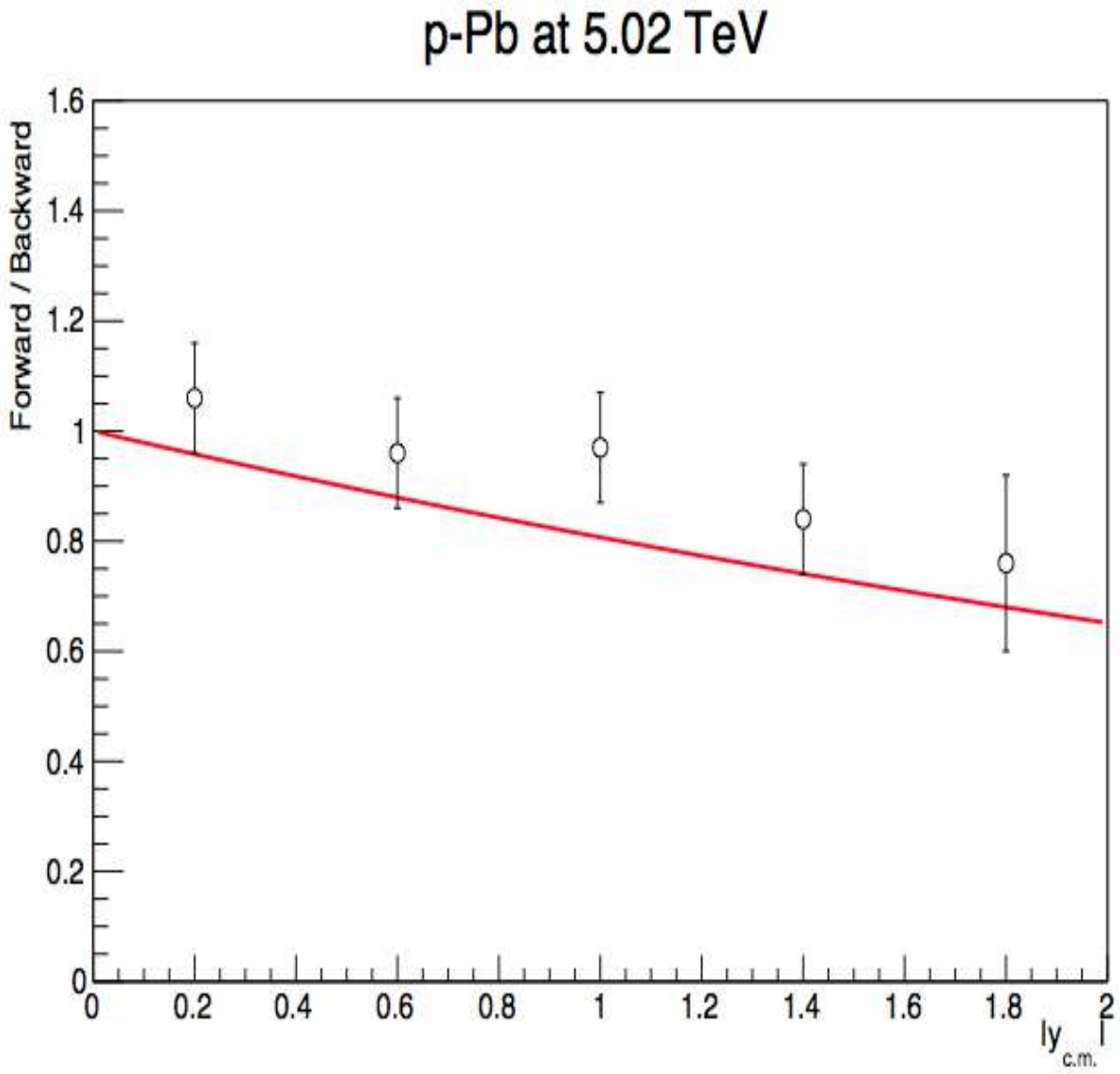
arXiv:1408.3108v1 [hep-ph], http://arxiv.org/abs/1408.3108v1

RSSM Z back2forw ratio (II)

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



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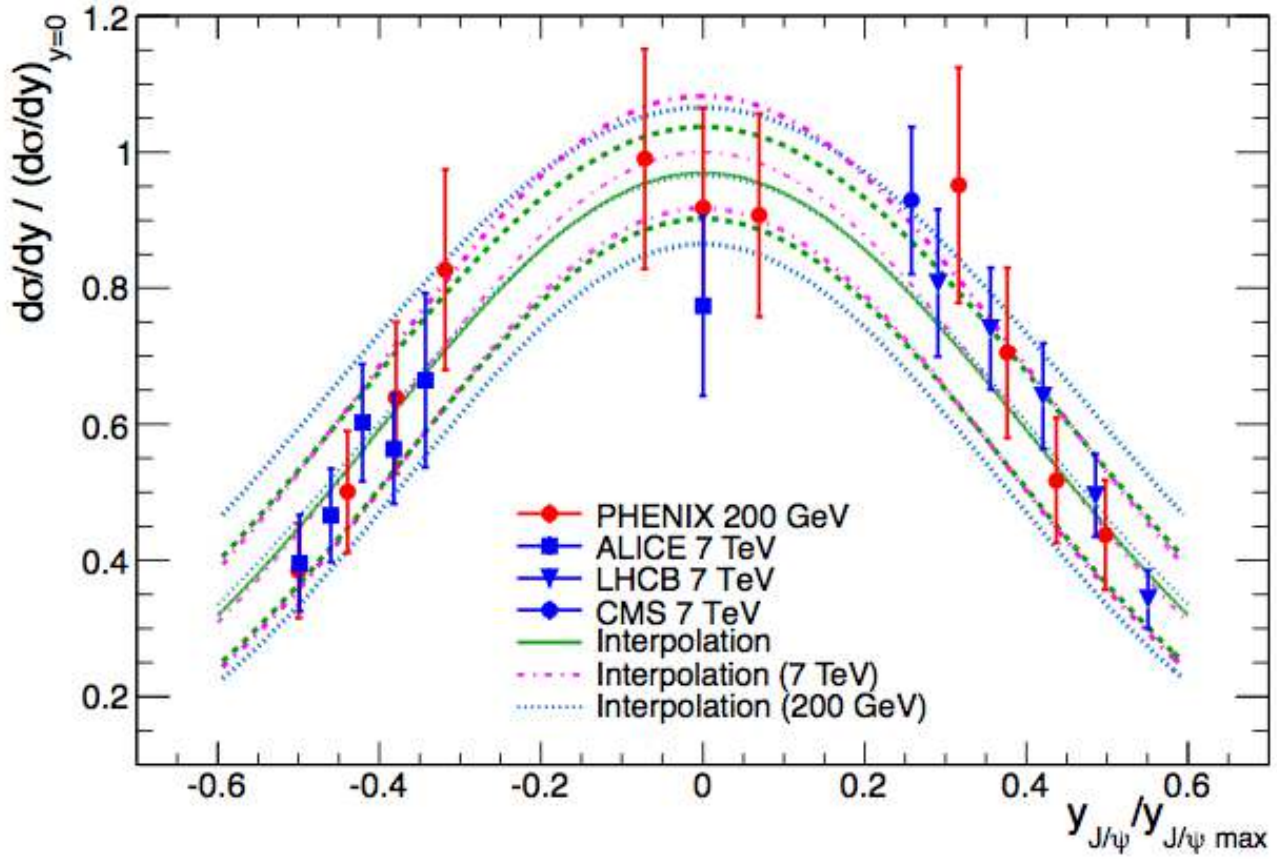
J/ψ y distribution in pp collisions

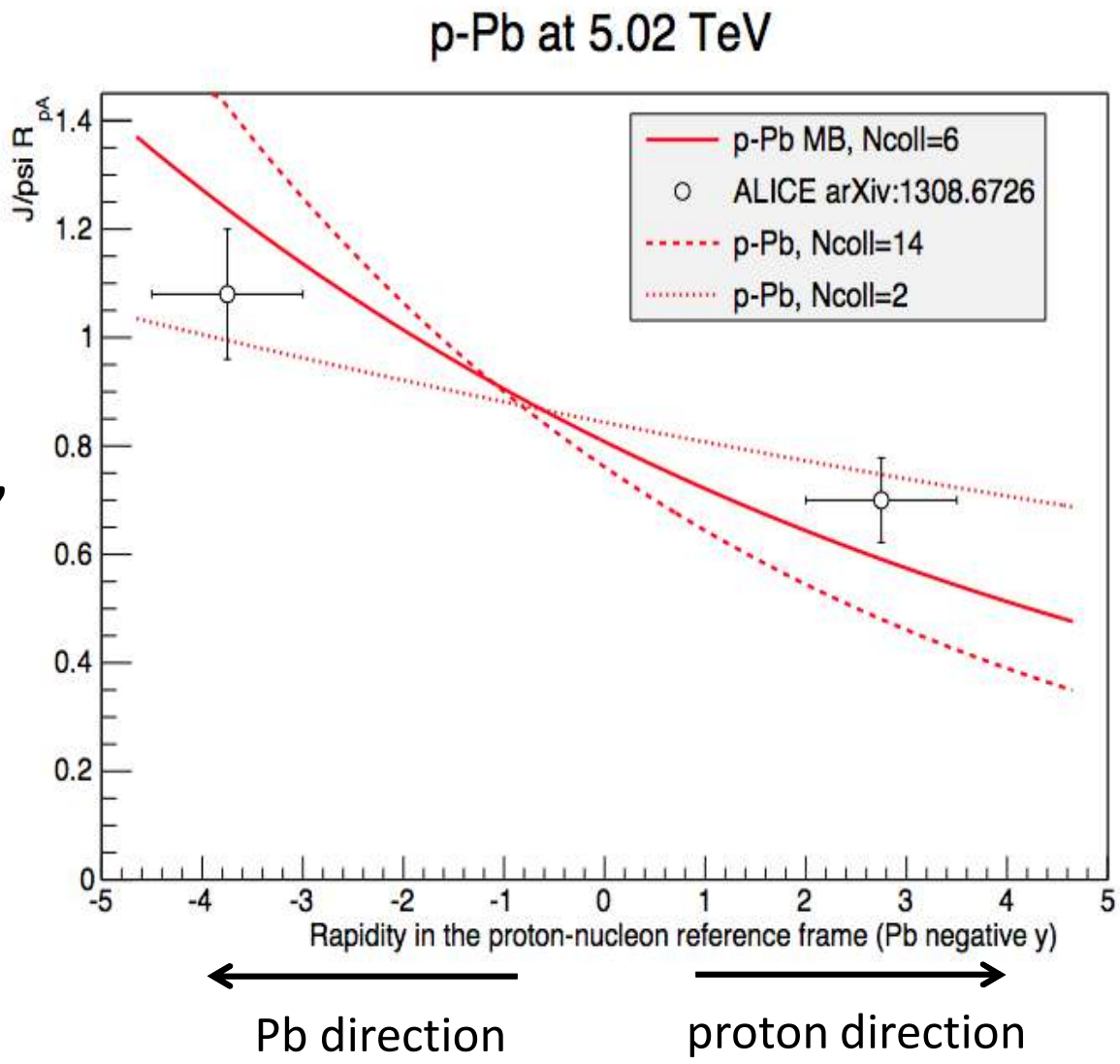
$$\frac{\mathrm{d}\sigma}{\mathrm{d}y} \Big/ \frac{\mathrm{d}\sigma}{\mathrm{d}y}\Big|_{y=0} = e^{-(y/y_{\max})^2/2\sigma_y^2}$$



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

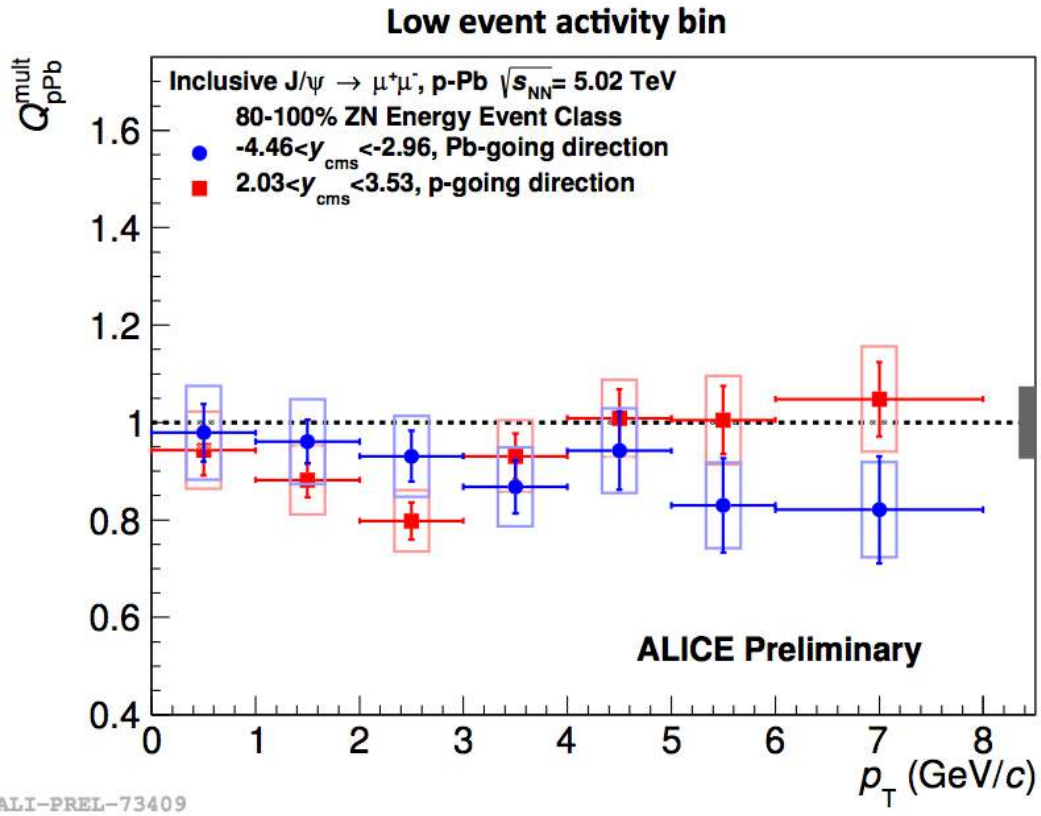
RSSM J/ψ R_{pPb}

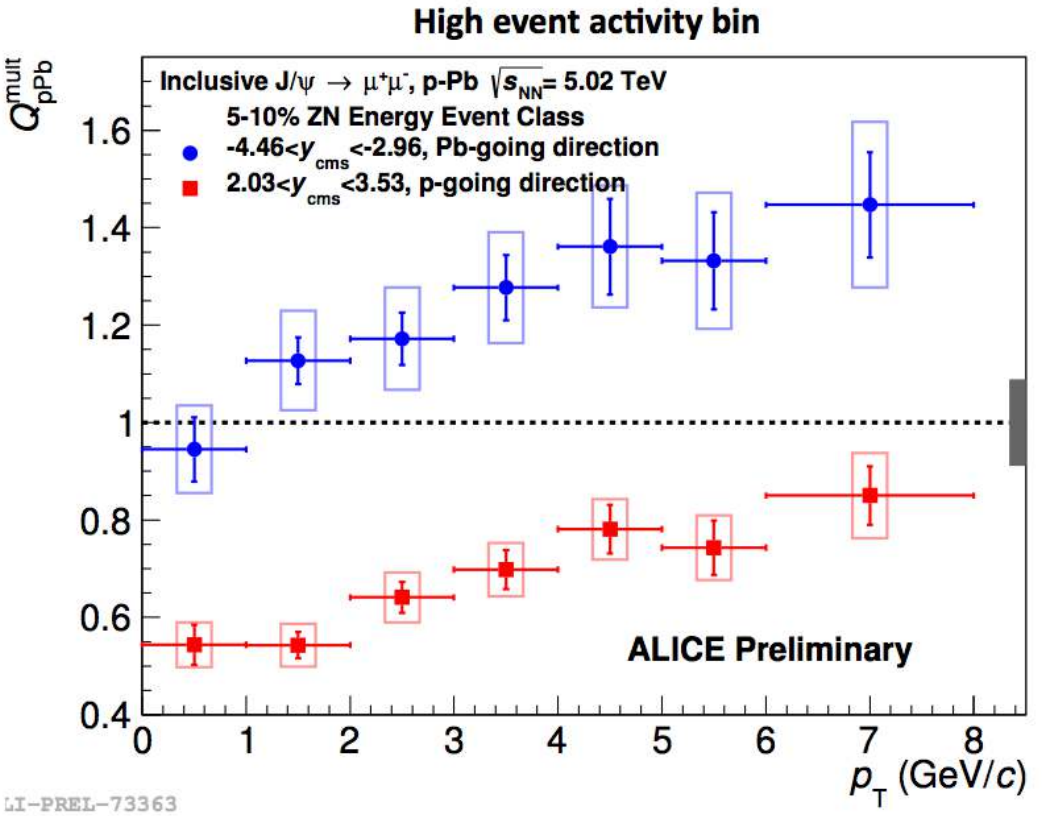
- ✓ In pPb collisions, the rapidity distribution is shifted to the proton contributor frame.
- ✓ Ad-hoc 0.85 normalization factor, rapidity independent, is added.
- ✓ RpPb is obtained with via the ratio of two Gaussians functions.



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

J/ψ R_{pPb} Centrality dependence





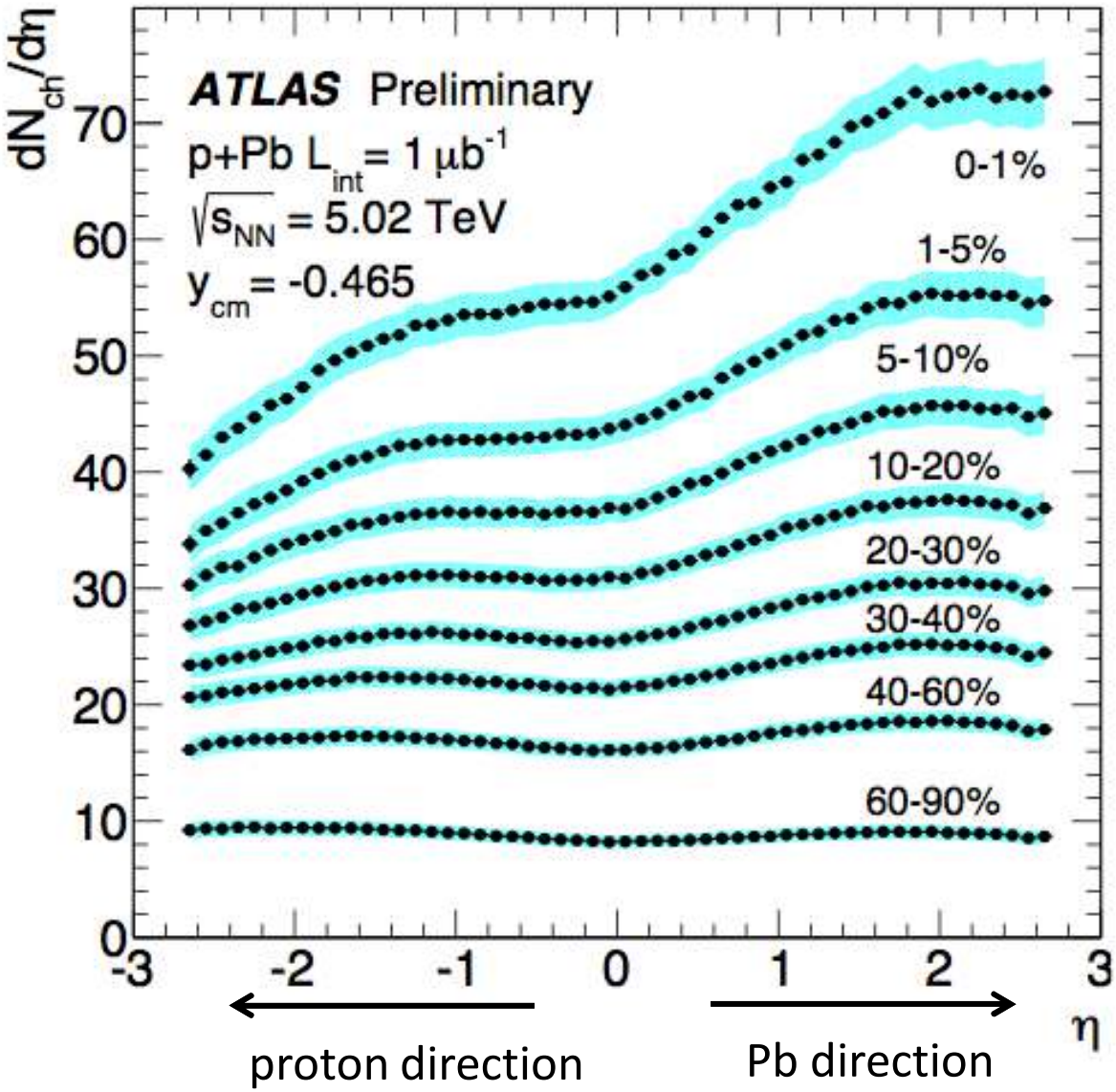
Backward (forward) R_{pPb} increases (decreases) with centrality.

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

Javier Martin Blanco (ALICE Collaboration)
Quark Matter 2014, https://indico.cern.ch/event/219436/session/17/contribution/135

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

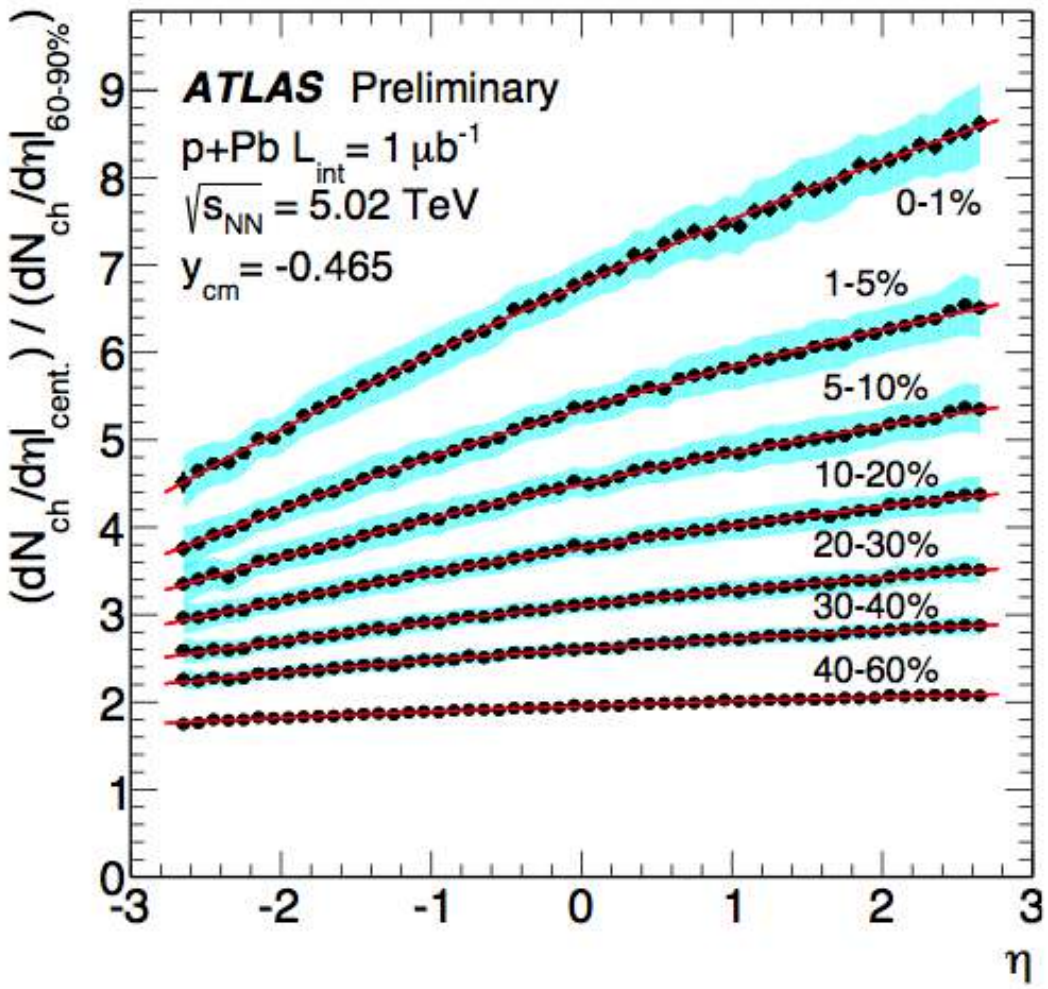
- ✓ Pb going in positive η.
- ✓ Asymmetry increases with the centrality.



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?



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

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.

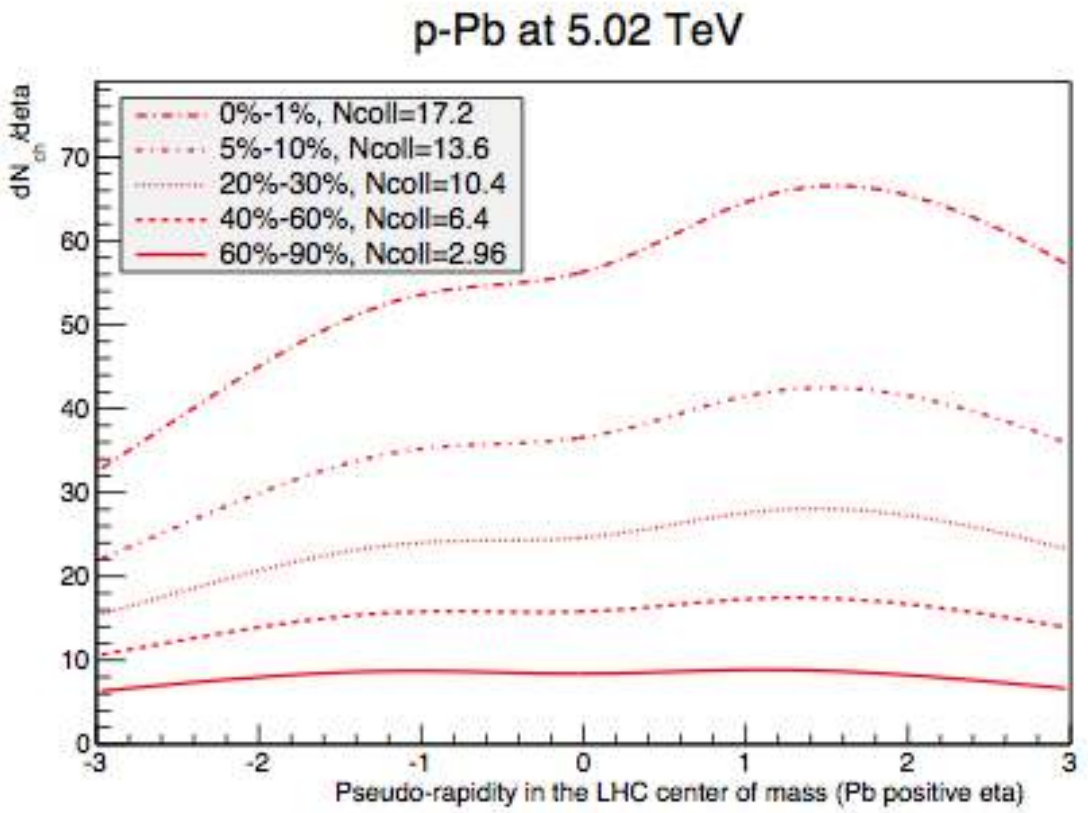
$$\frac{dN_{ch}}{d\eta} = \frac{dN_{ch}}{dy} \times \frac{dy}{d\eta}$$

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

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

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

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



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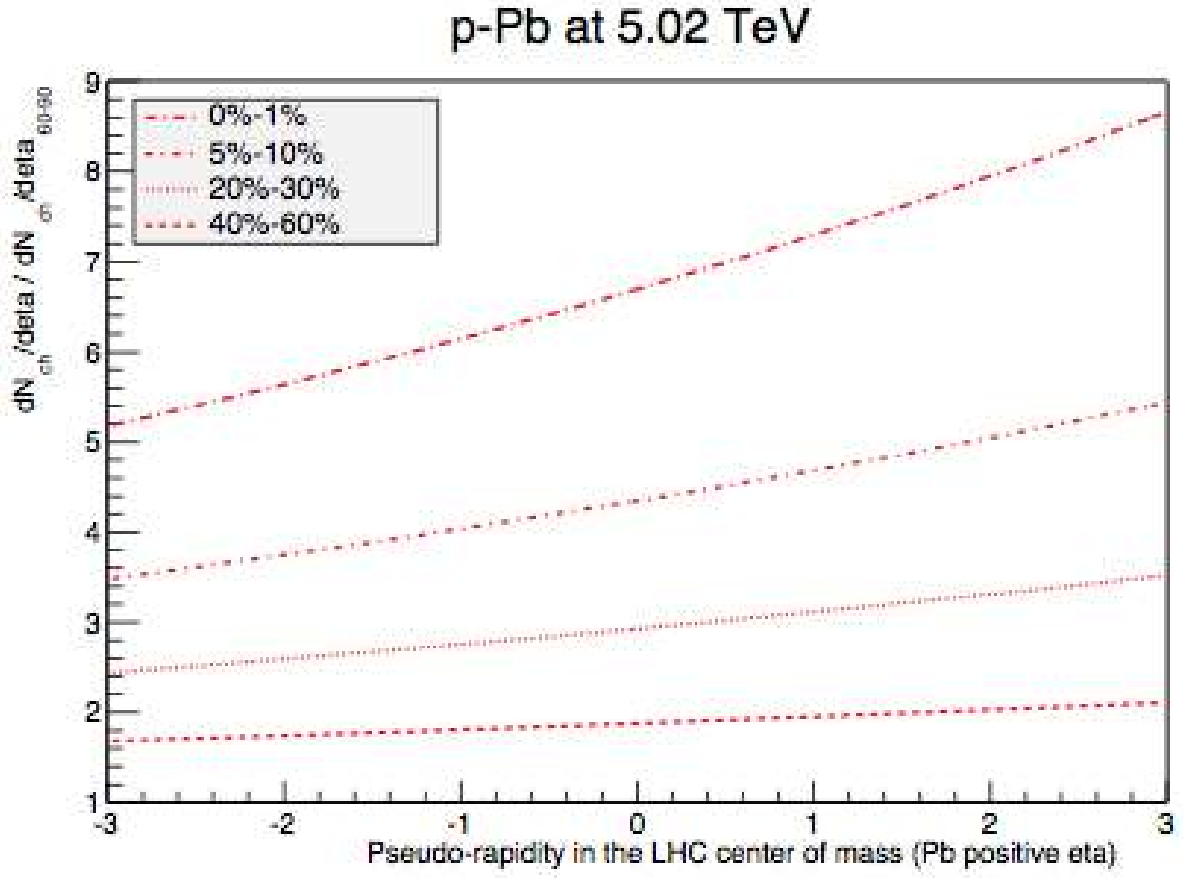
arXiv:1408.3108v1 [hep-ph], http://arxiv.org/abs/1408.3108v1

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? Dijets? 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.

Acknowledgements

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Thanks for your attention!