בס"ד

Understanding p+A Geometry: Multiplicity and Bosons

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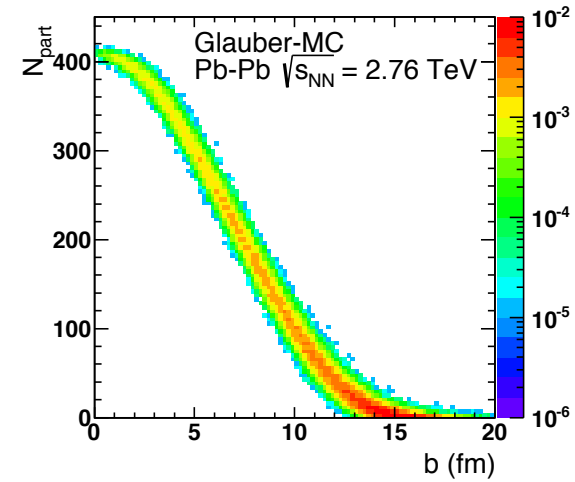
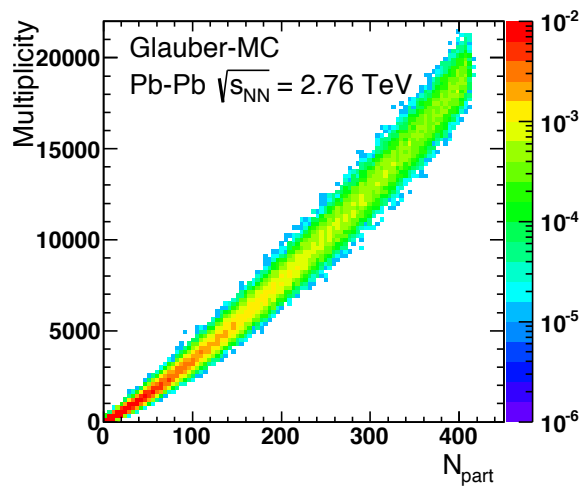
What's the matter with pA today?

In Pb+Pb collisions:

- N_{part} is tightly correlated with b



- Multiplicity (somewhere) is tightly correlated with N_{part}



arxiv.org/abs/1412.6828

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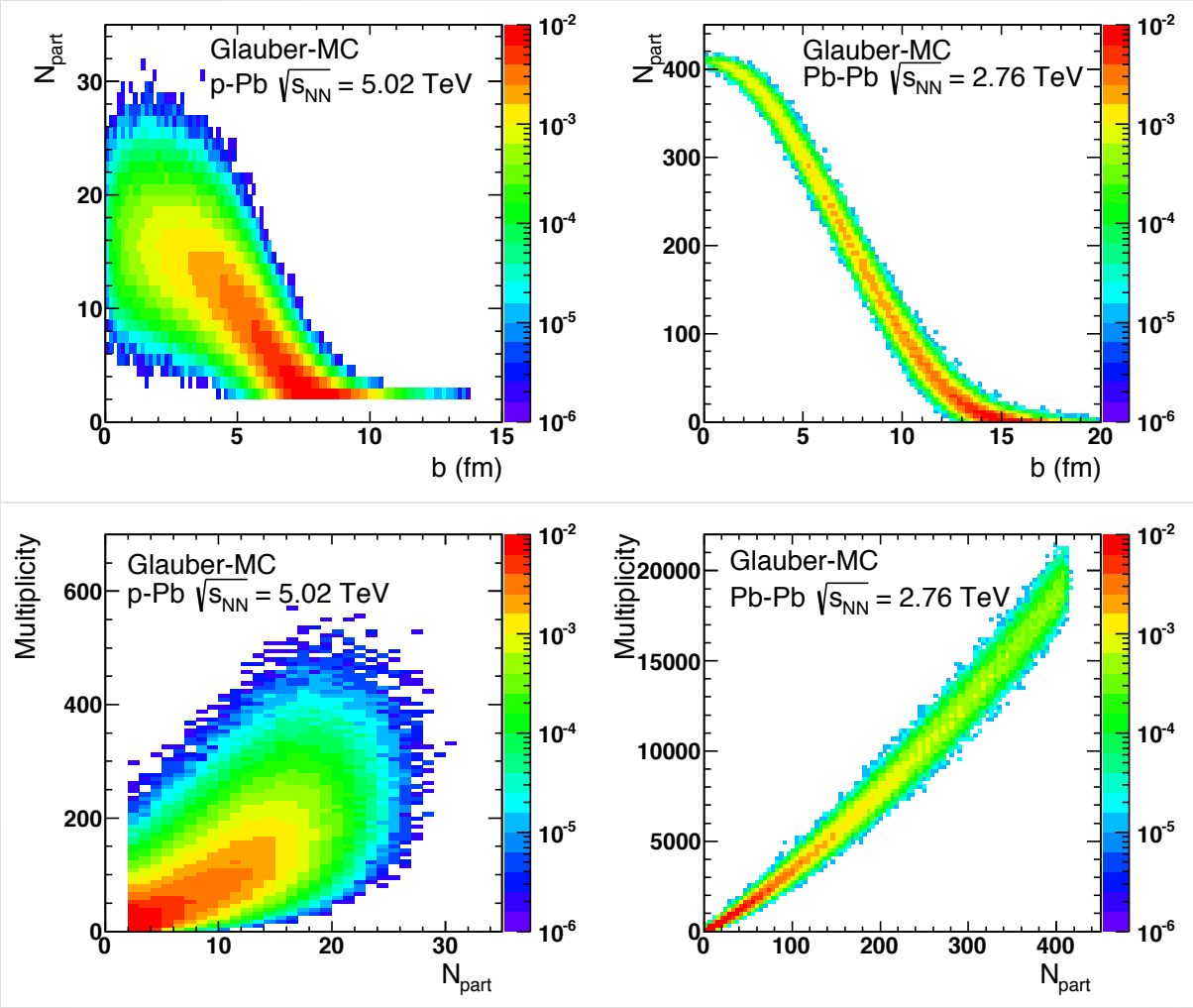


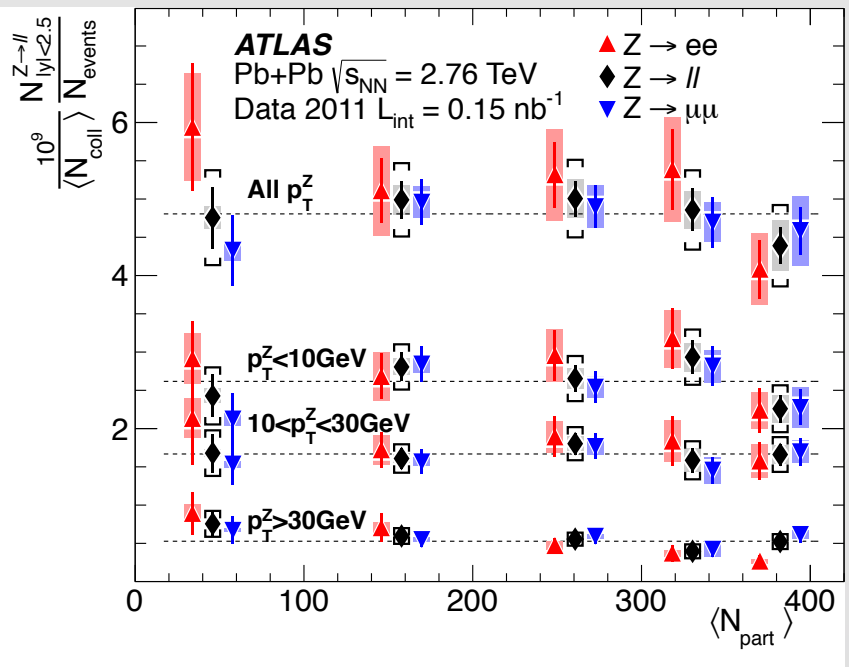
Not so in p+Pb!

arxiv.org/abs/1412.6828

What's the matter with pA today?

Do they in p+Pb?

EW bosons scale like <N_{coll}> in Pb+Pb

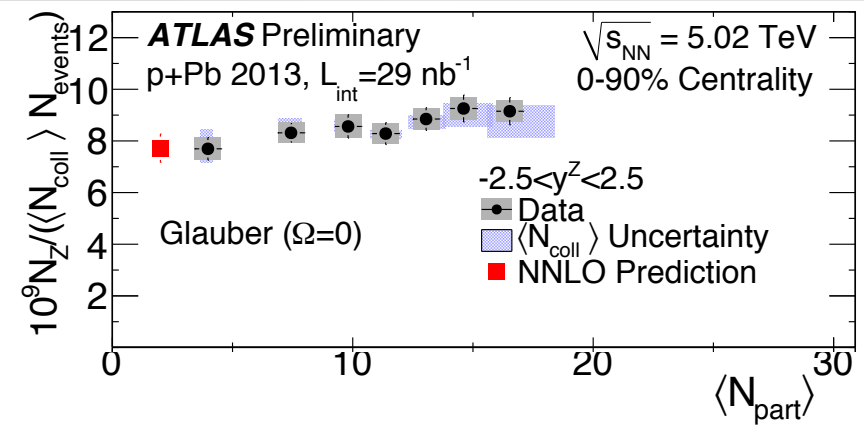


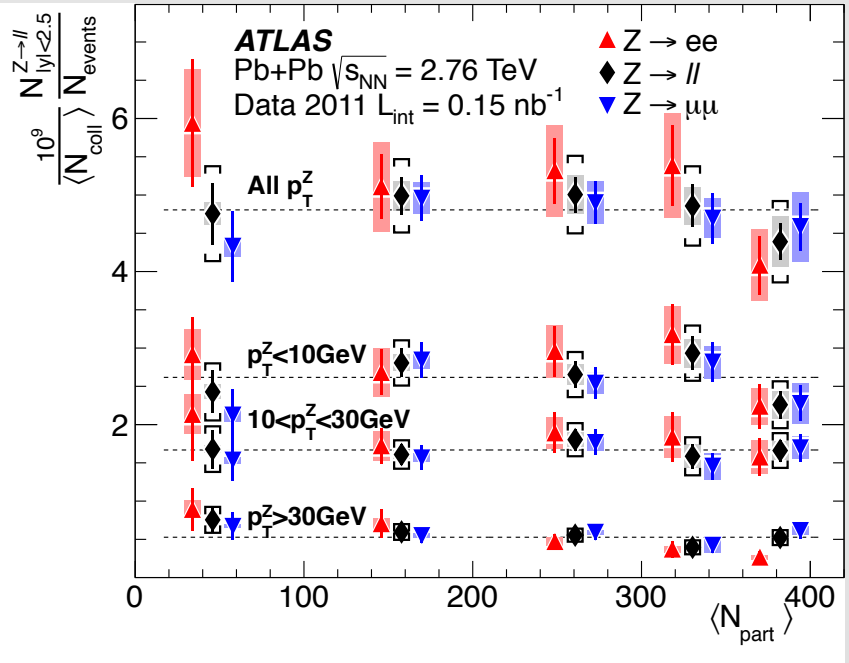
They do resemble charged particles …

ATLAS-CONF-2014-020

What's the matter with pA today?

Do they in p+Pb?





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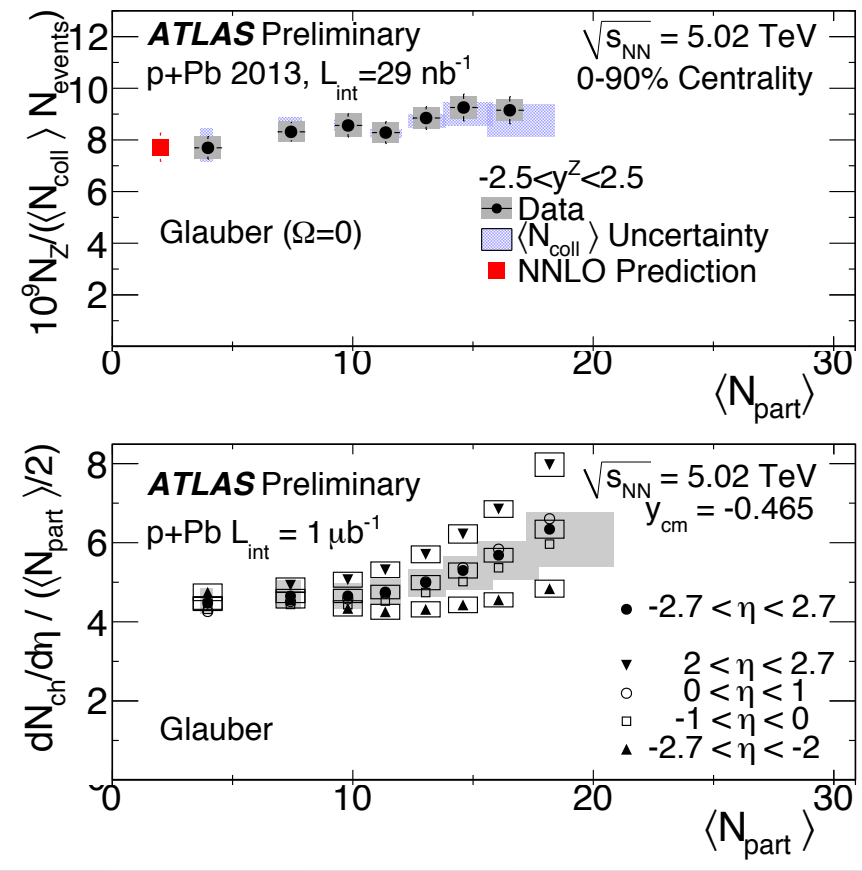
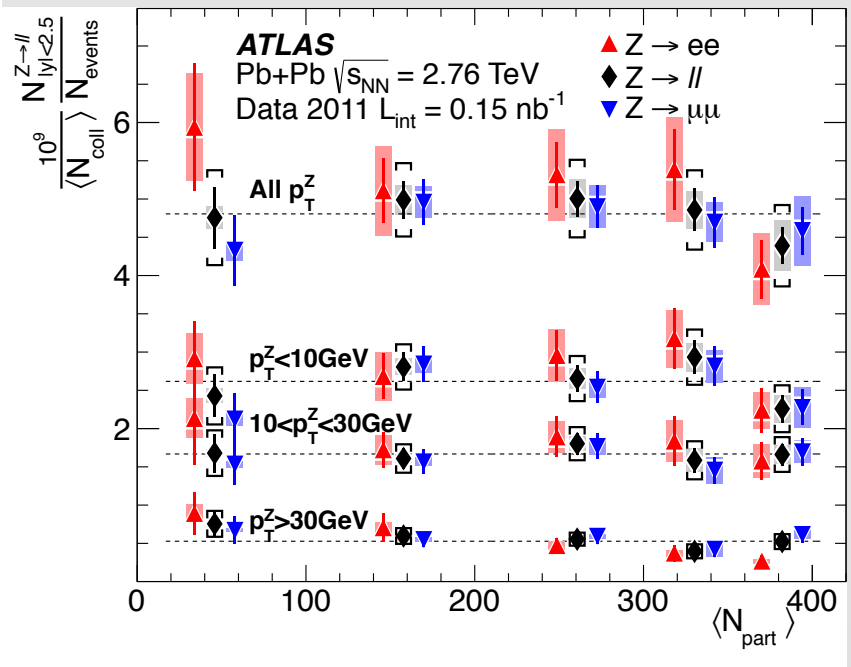
What's the matter with pA today?

Do they in p+Pb?



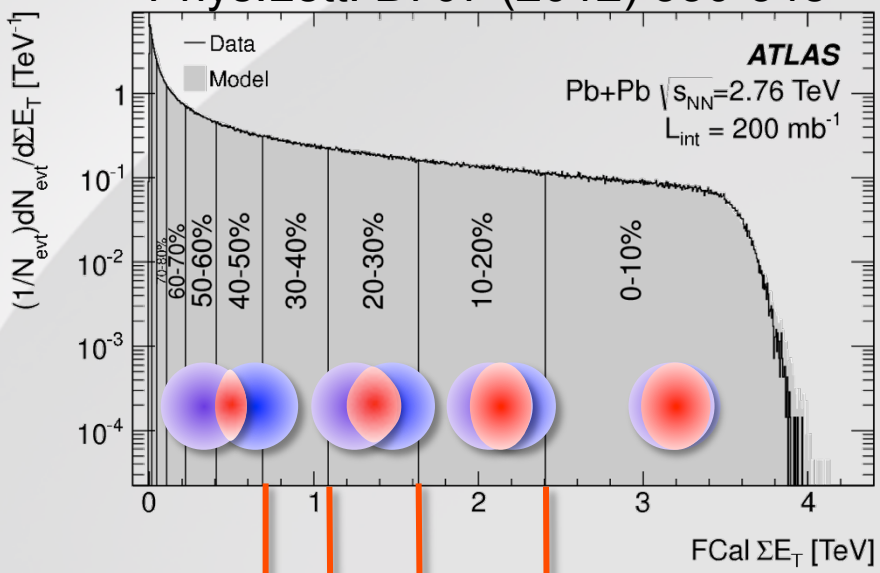


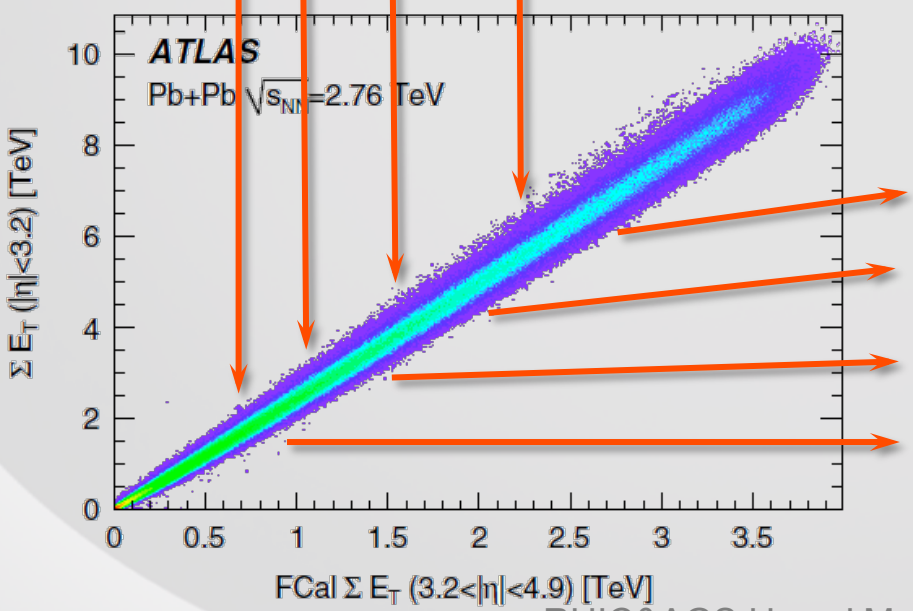
They do resemble charged particles …

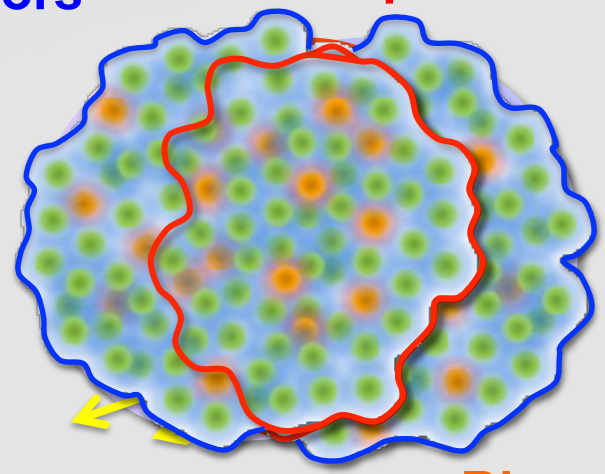
ATLAS-CONF-2014-020

Centrality in Pb+Pb

Phys.Lett. B707 (2012) 330-348

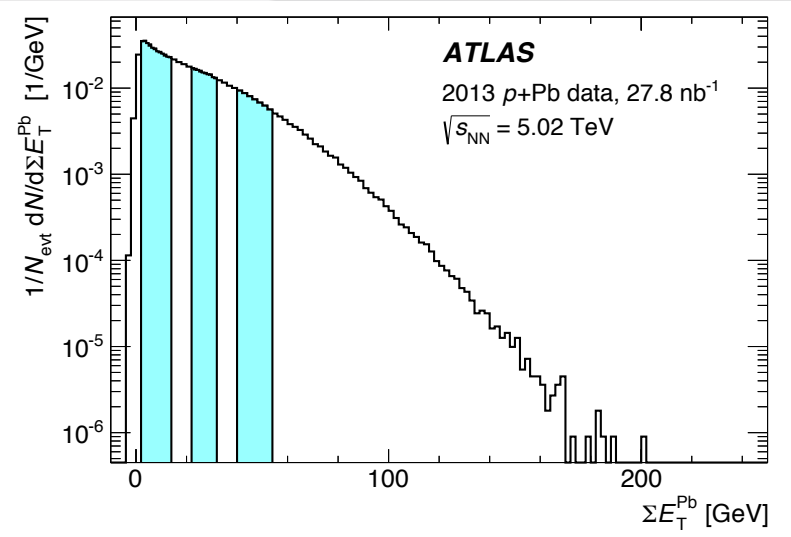


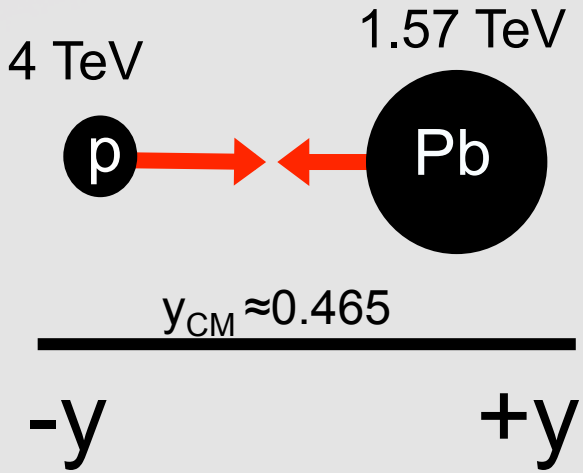




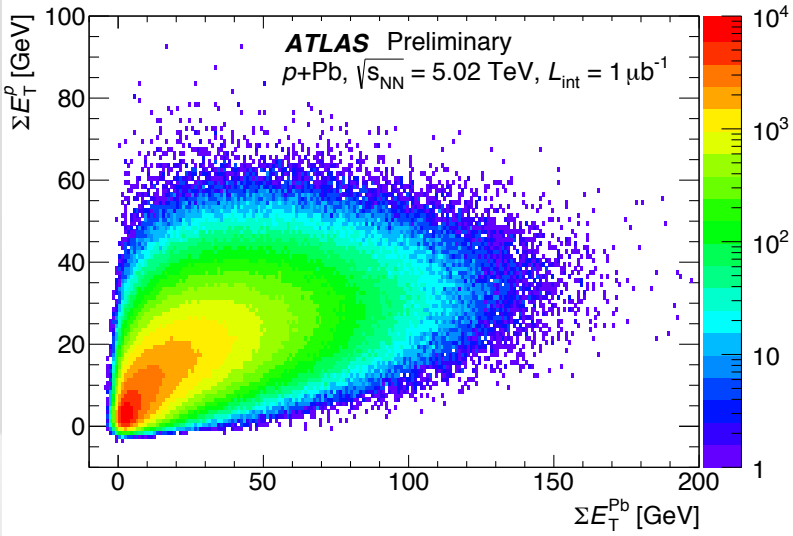
	$\langle N_{part} \rangle$	$\langle N_{coll} \rangle$
0-5%	382 ± 1%	1683 ± 8%
5-10%	330 ± 1%	1318 ± 8%
10-20%	261 ± 2%	923 ± 7%
20-40%	158 ± 3%	441 ± 7%
40-80%	46 ± 6%	78 ± 9%

Same Approach for Centrality in p+Pb?



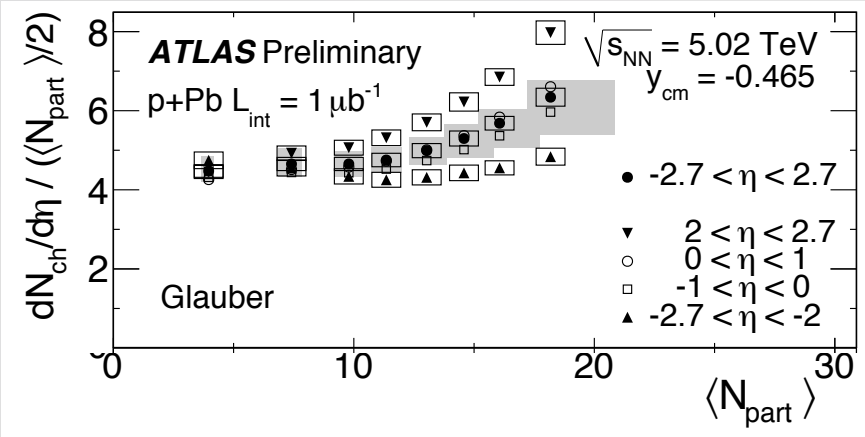


ATLAS uses the Pb-going side (backward) region, similar to RHIC experiments



	$\langle N_{coll}\rangle = \langle N_{part}\rangle - 1$
0-5%	**15.5 (+11 -5)%**
5-10%	**13.5 (+8 -6)%**
10-20%	**12 ± 6%**
30-40%	**8.8 ± 6%**
60-90%	**3 ±7%**

Centrality Dependence of Multiplicity in ATLAS

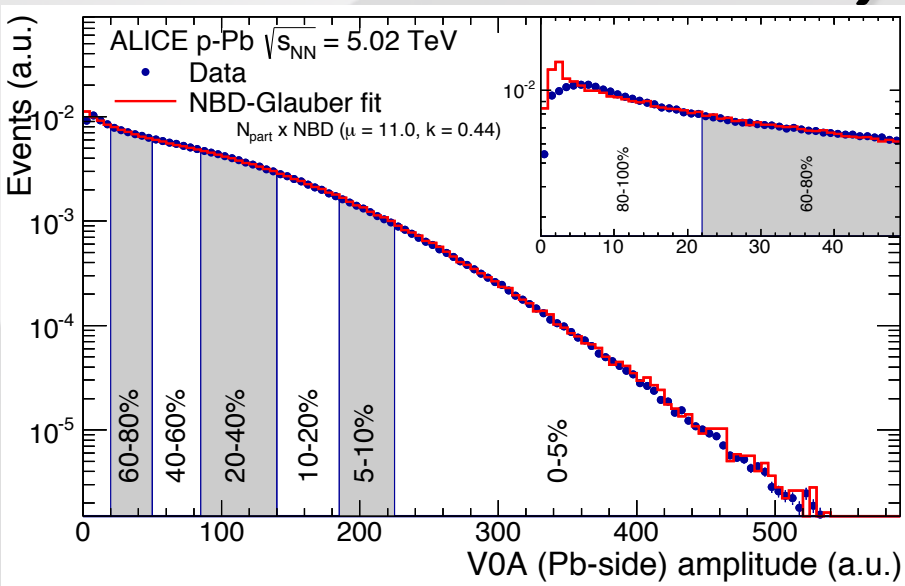


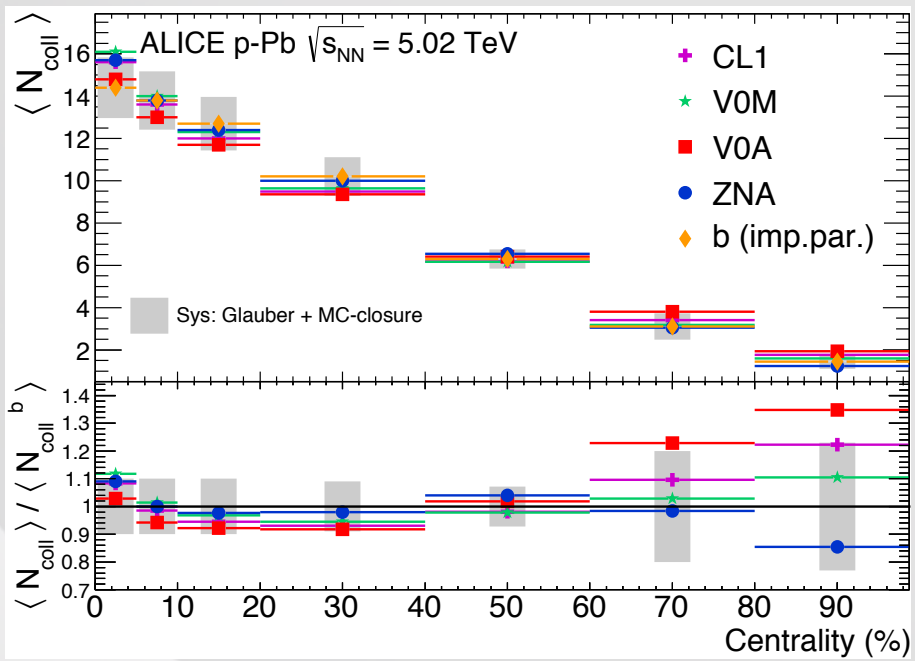
- Naively, we may have expected centrality scaling with <N_{part}>
- That's not the case!

- Essentially we are measuring the correlation between two multiplicities (ok, one is a transverse energy) and observing that they do not scale the same way

- **There is a basic question of what should be in the 'denominator'?**
  What is the baseline and what is the measurement?

All the Pretty Multiplicities



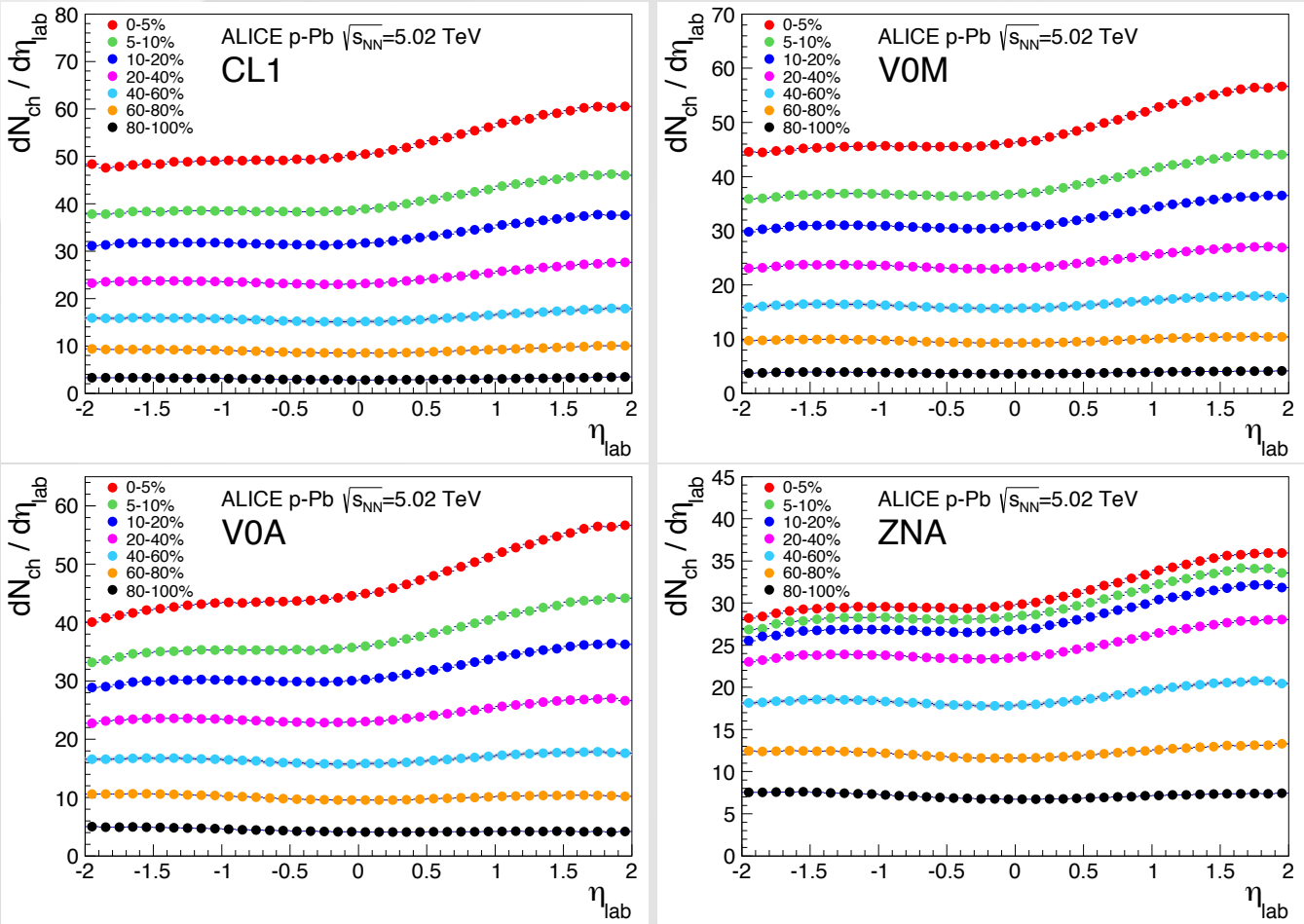


ALICE has taken the approach of measuring many multiplicities:

- CL1: clusters in $|\eta|<1.4$
- V0A: amplitude in Pb-going side $2.8<\eta<5.1$
- V0C: amplitude in p-going side $-3.7<\eta<-1.7$
- V0M: V0A+V0C
- ZNA: neutron signal on Pb-going side ZDC

And then defining from each a different centrality estimator

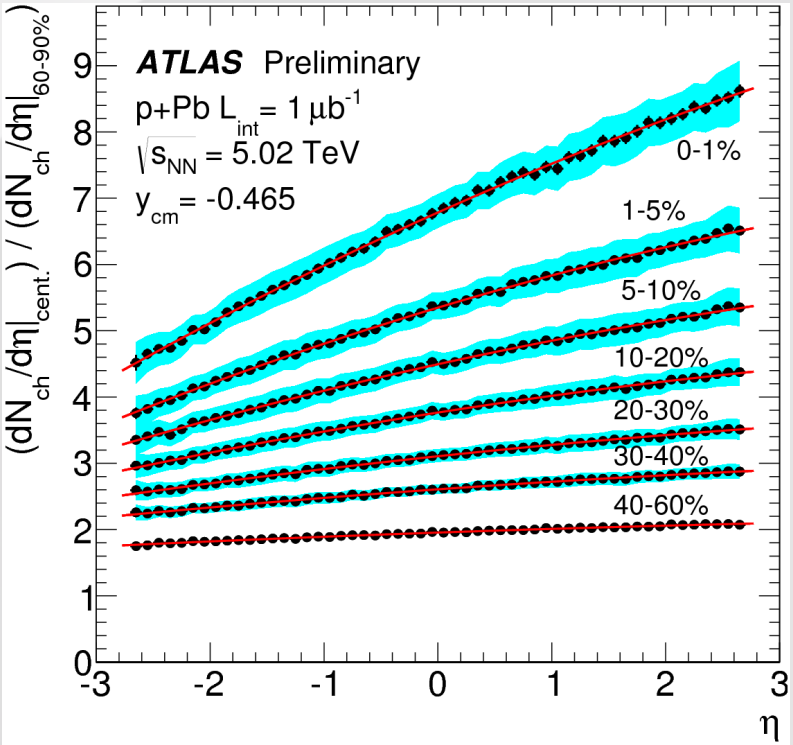
All the Pretty Multiplicities

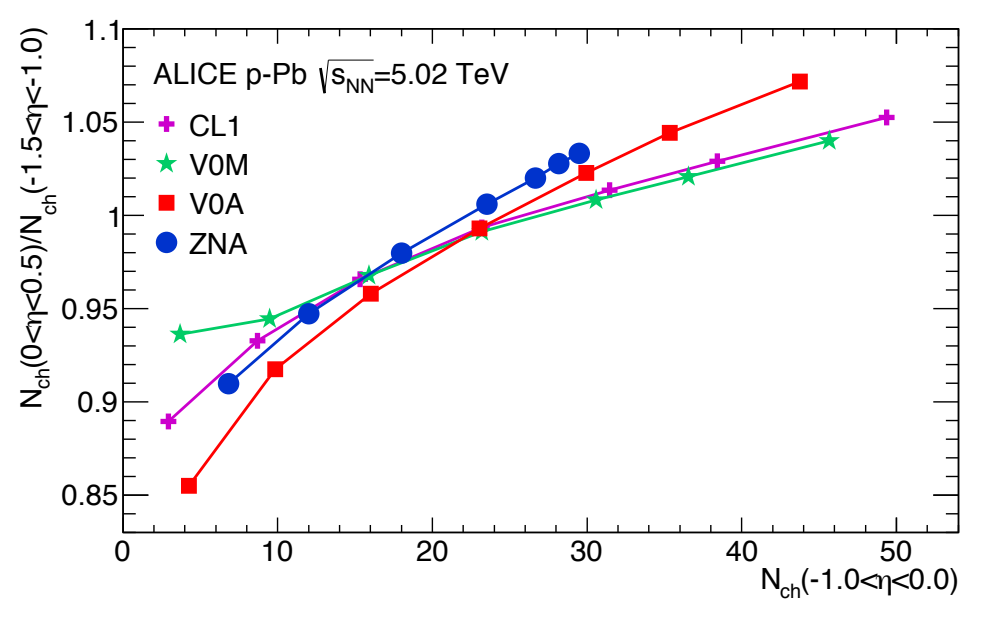


Then see the 'normal' event multiplicity correlated with different centrality estimators

(Note that there's a lot of variation here)

All the Pretty Multiplicities

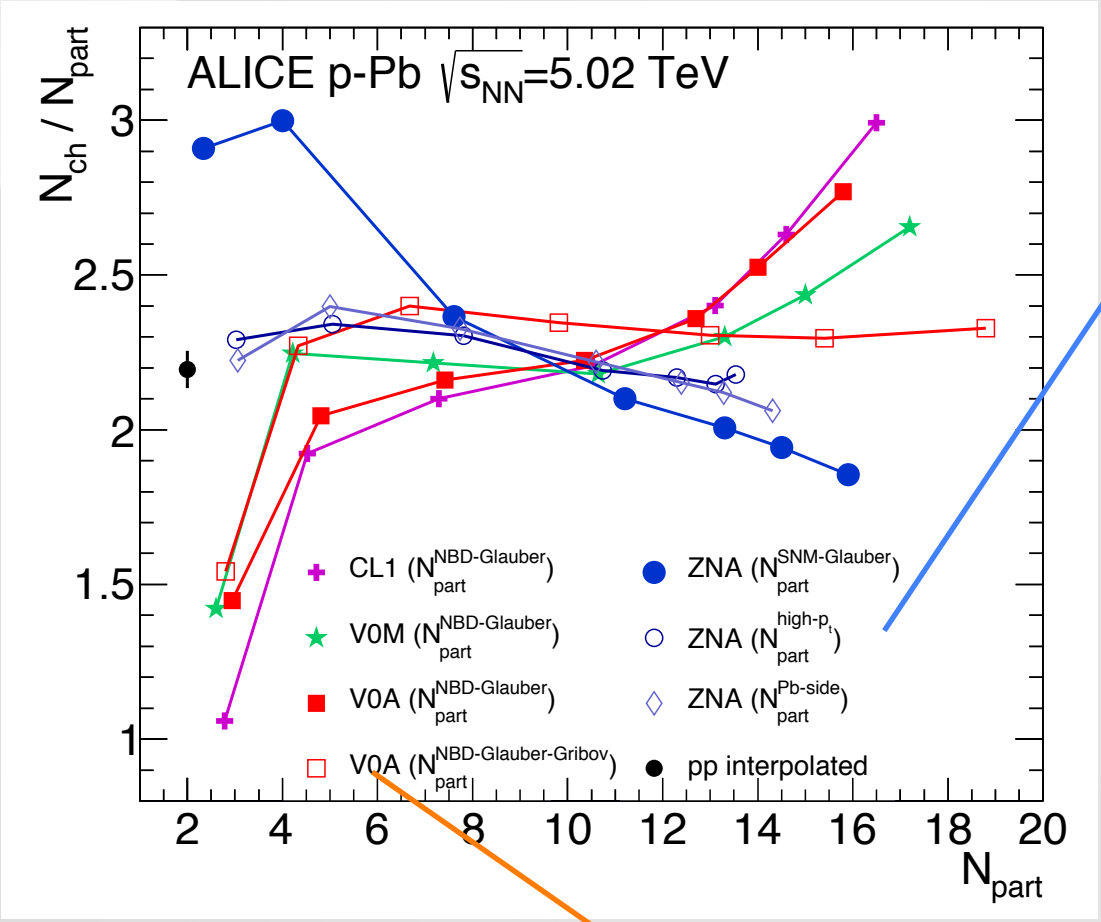




The centrality dependence of the *shape* may teach us about the physics
Different centrality definitions alter the picture

All the Pretty Multiplicities

Integrated multiplicity plotted against N_{part}



Hybrid method assumes:

- Spectator neutron detection is unbiased

Combine with

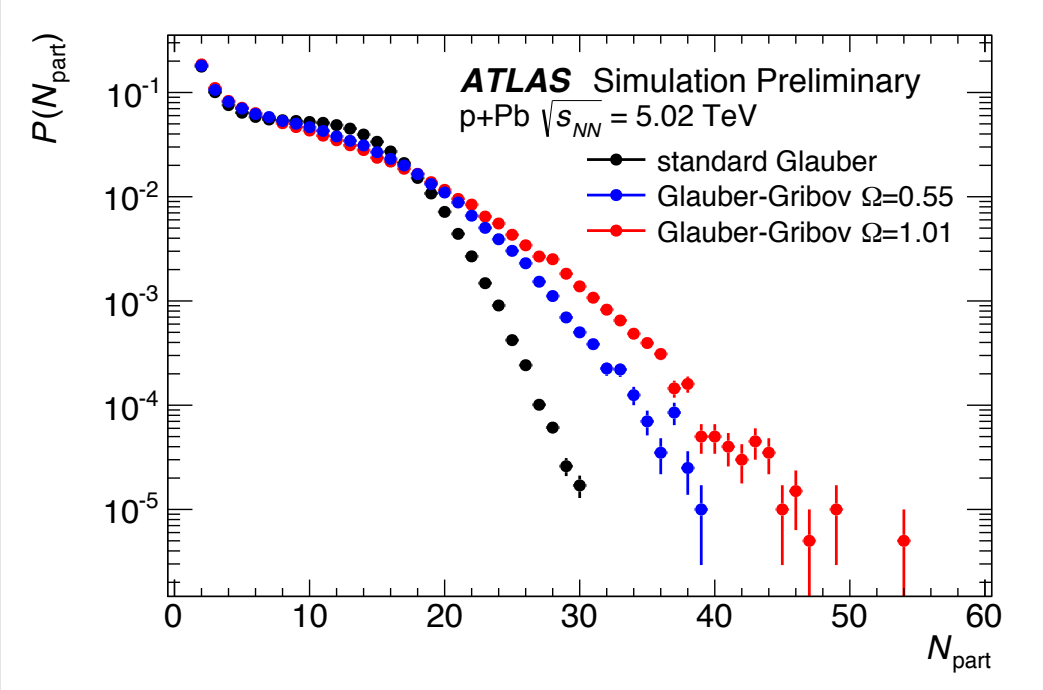
- mid-rapidity multiplicity scales with N_{part}
- mid-rapidity high p_T multiplicity scales with N_{coll}

This one doesn't look too bad either …

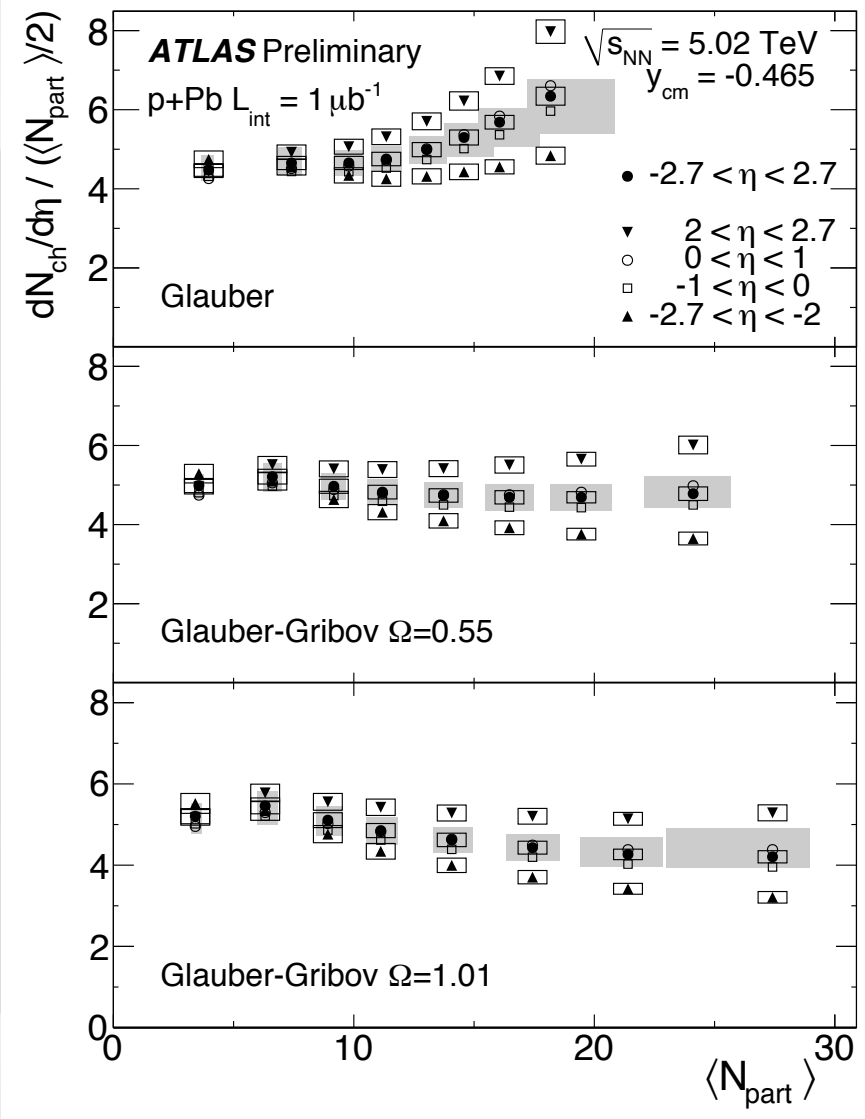
Glauber-Gribov Color Fluctuations

Let the NN cross section have fluctuating strength event by event

Introduce Glauber-Gribov MC model and relate back to centrality

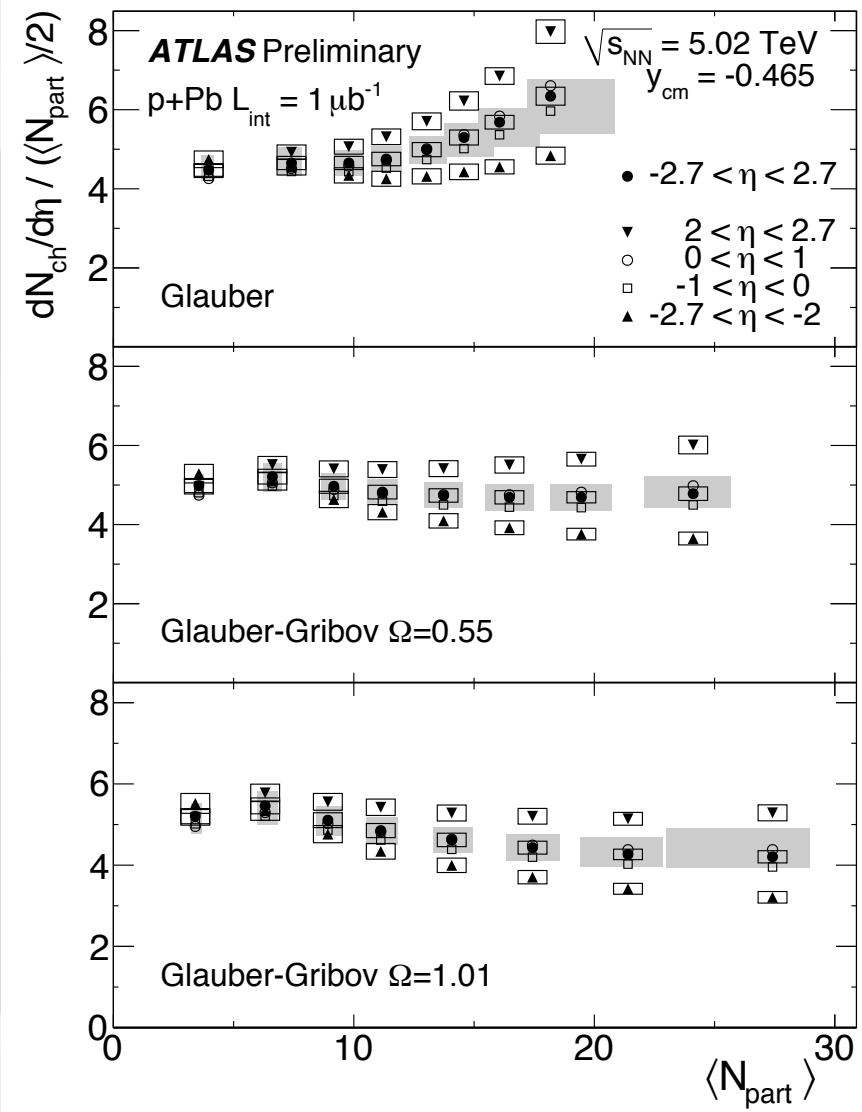


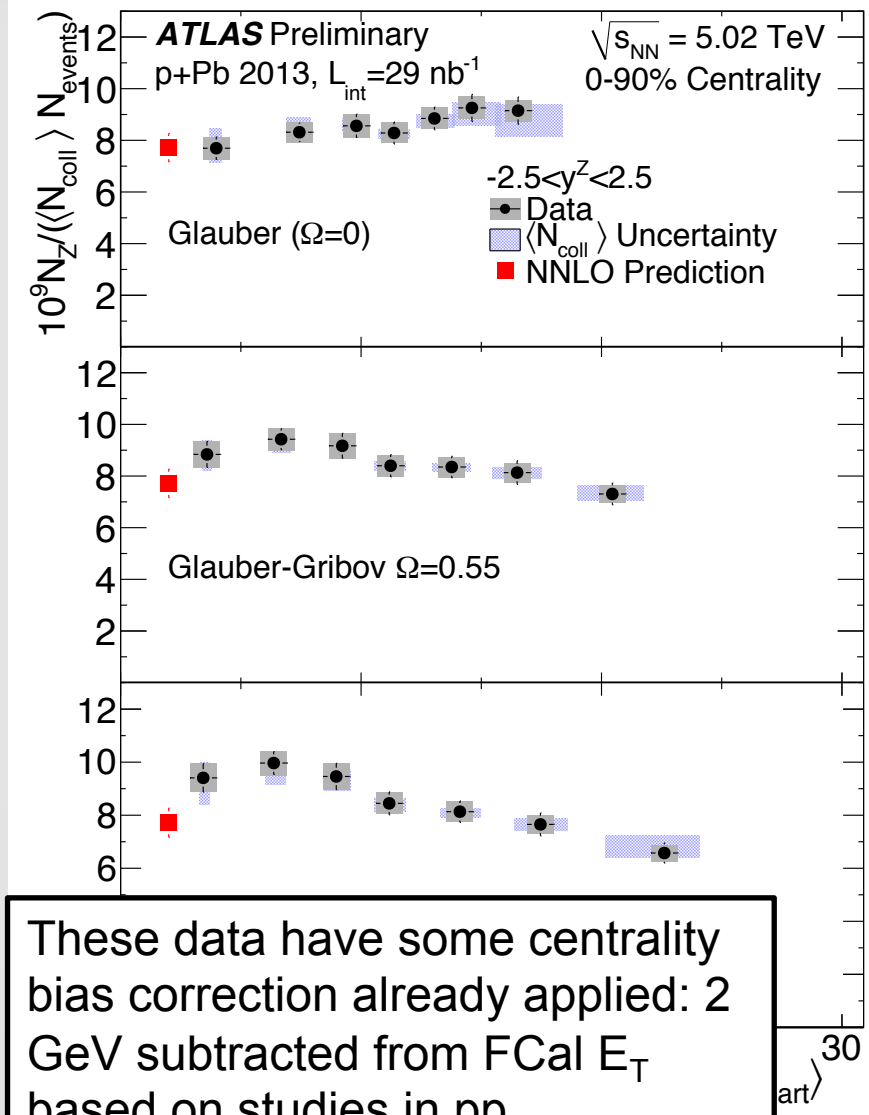
Glauber-Gribov Color Fluctuations



Without invoking centrality bias corrections, multiplicity scales with centrality!

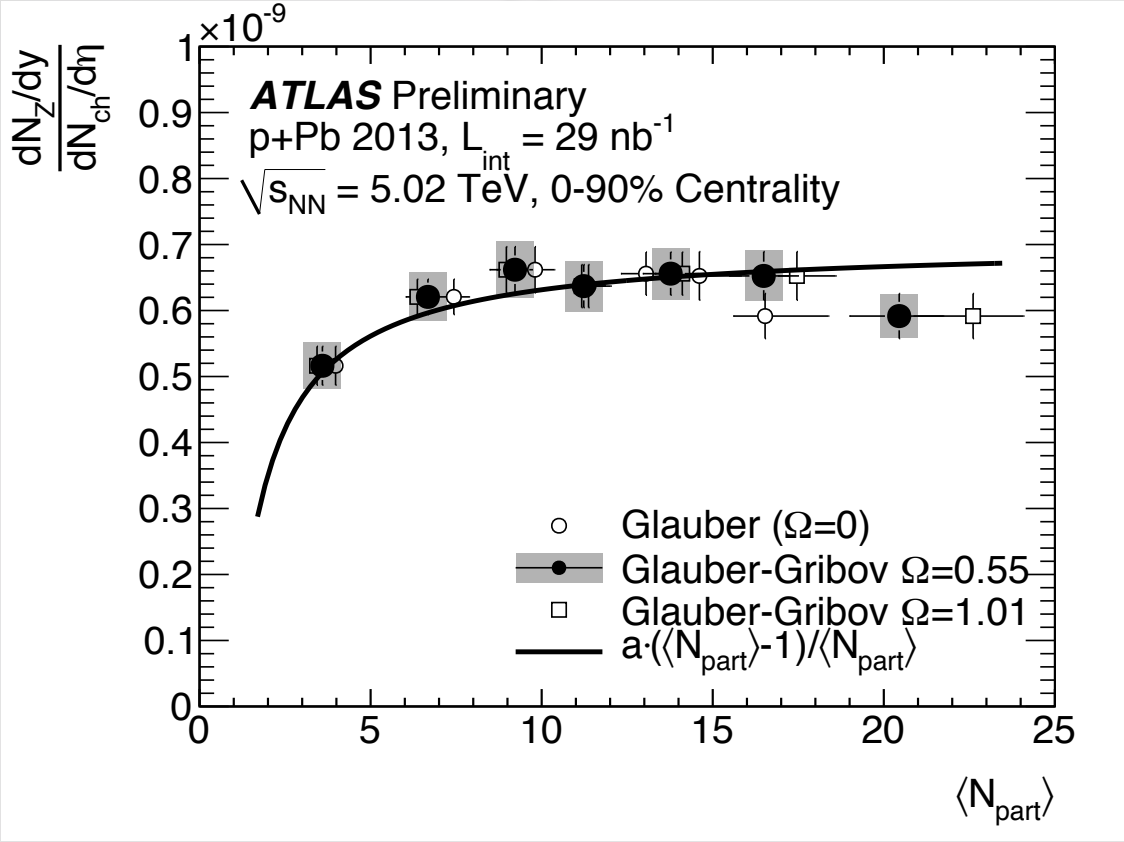
And Now For Something (maybe not) Completely Different





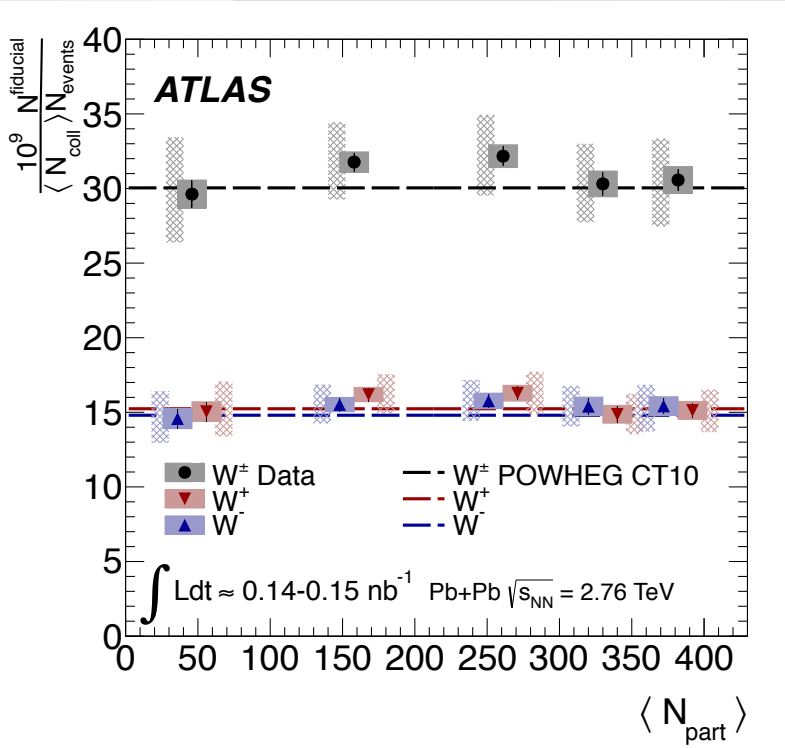
These data have some centrality bias correction already applied: 2 GeV subtracted from FCal E_T based on studies in pp

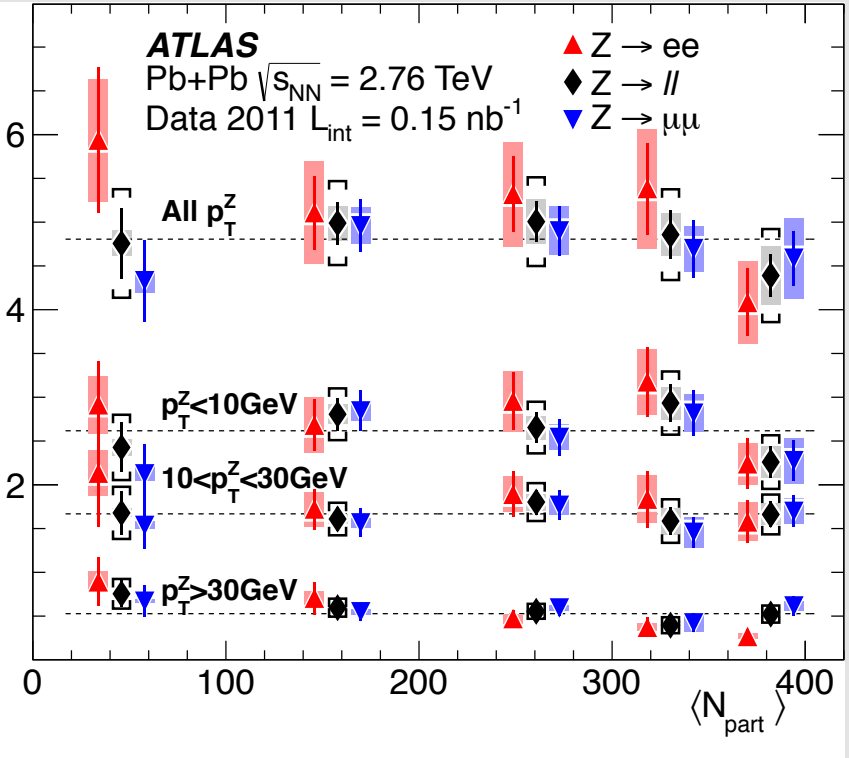
And Now For Something (maybe not) Completely Different



Reasonable agreement in centrality distribution (across scale of 10^9!)

Are EW Bosons Good For Centrality?

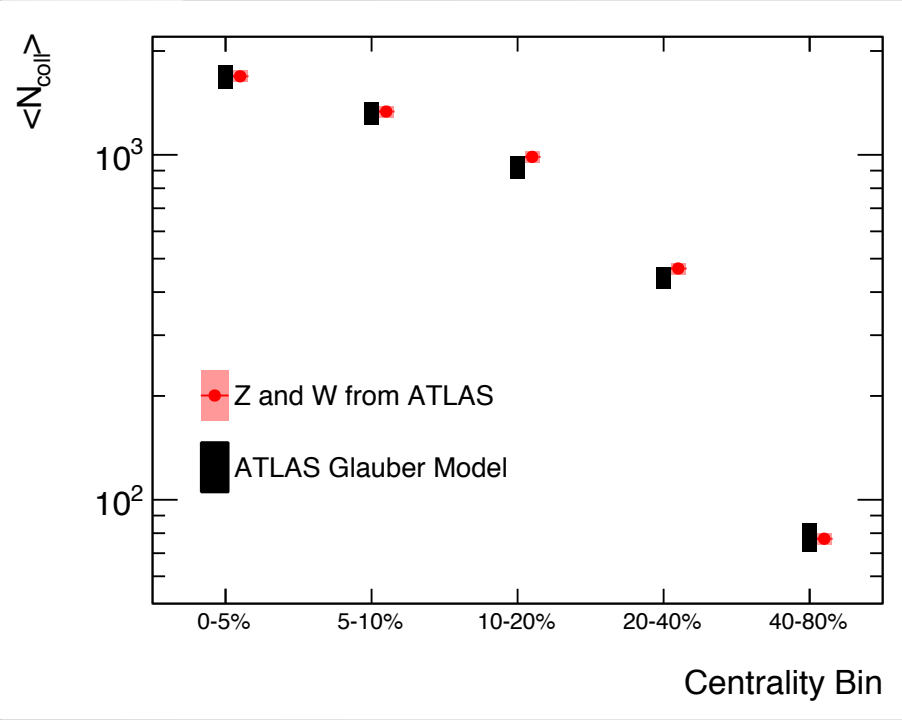


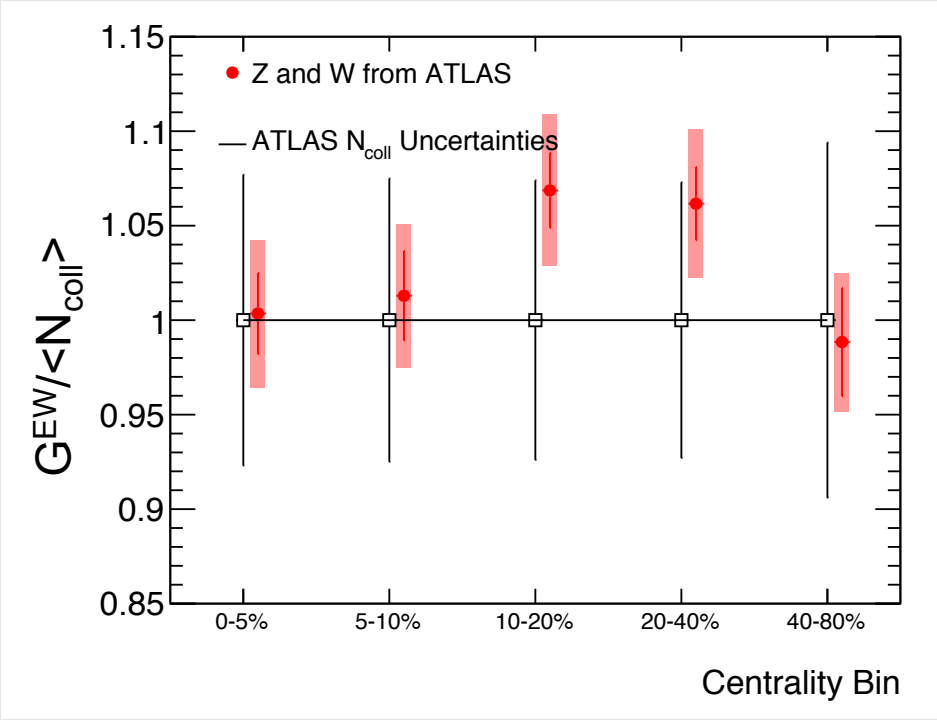


- In AA we exploit the fact that EW bosons scale like NN production × geometry to contrast with color sensitive observables

Phys. Rev. Lett. 110, 182302 (2013), arxiv.org/abs/1408.4674

EW Bosons To Define Centrality Variable ~ $\langle N_{coll} \rangle$

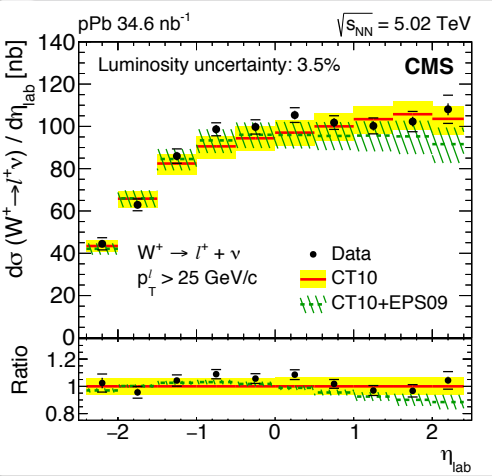


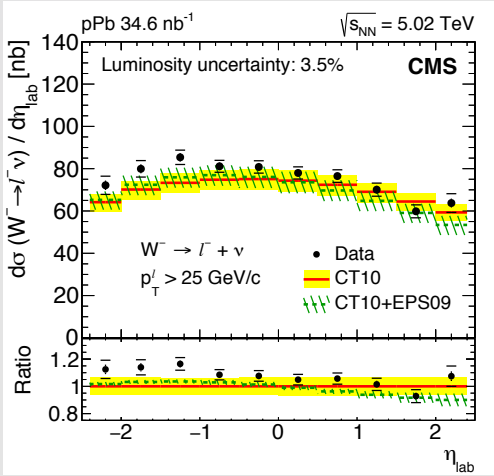


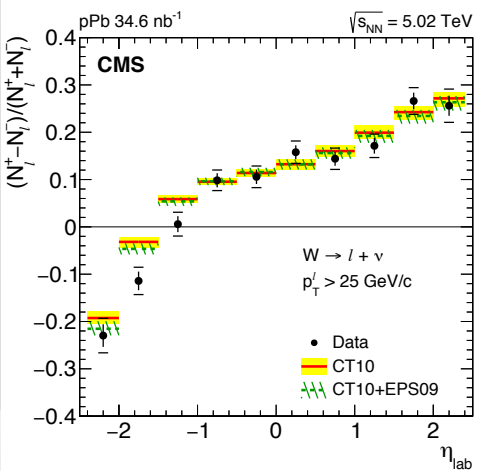
- Agreement with scaling measured
- Reverse our assumptions – assume scaling calculate geometric factor necessary for 'perfect' scaling
- **Derive geometric factors from EW bosons**
- Competitive uncertainties

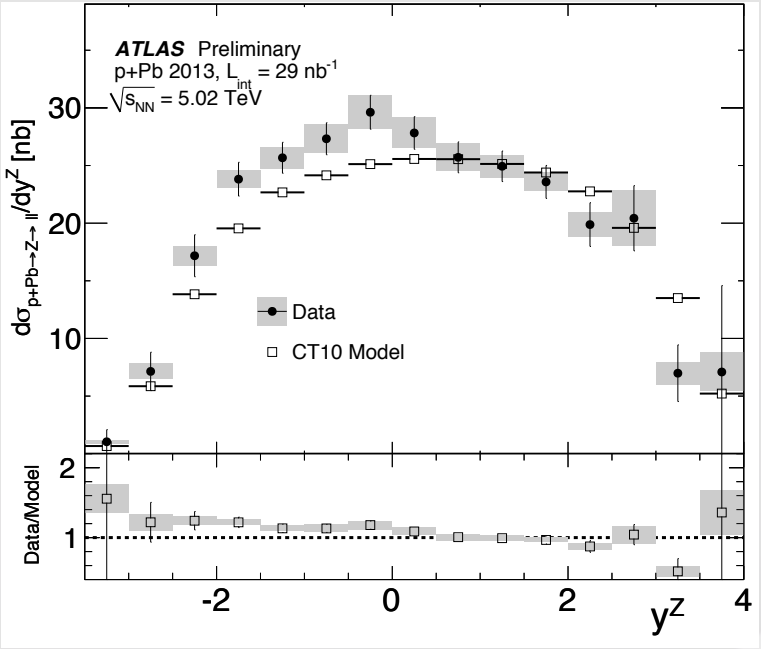
Some Caution

- We need to be sure we understand initial state nuclear corrections to the PDF
- EW bosons-centrality correlations may also be subject to bias





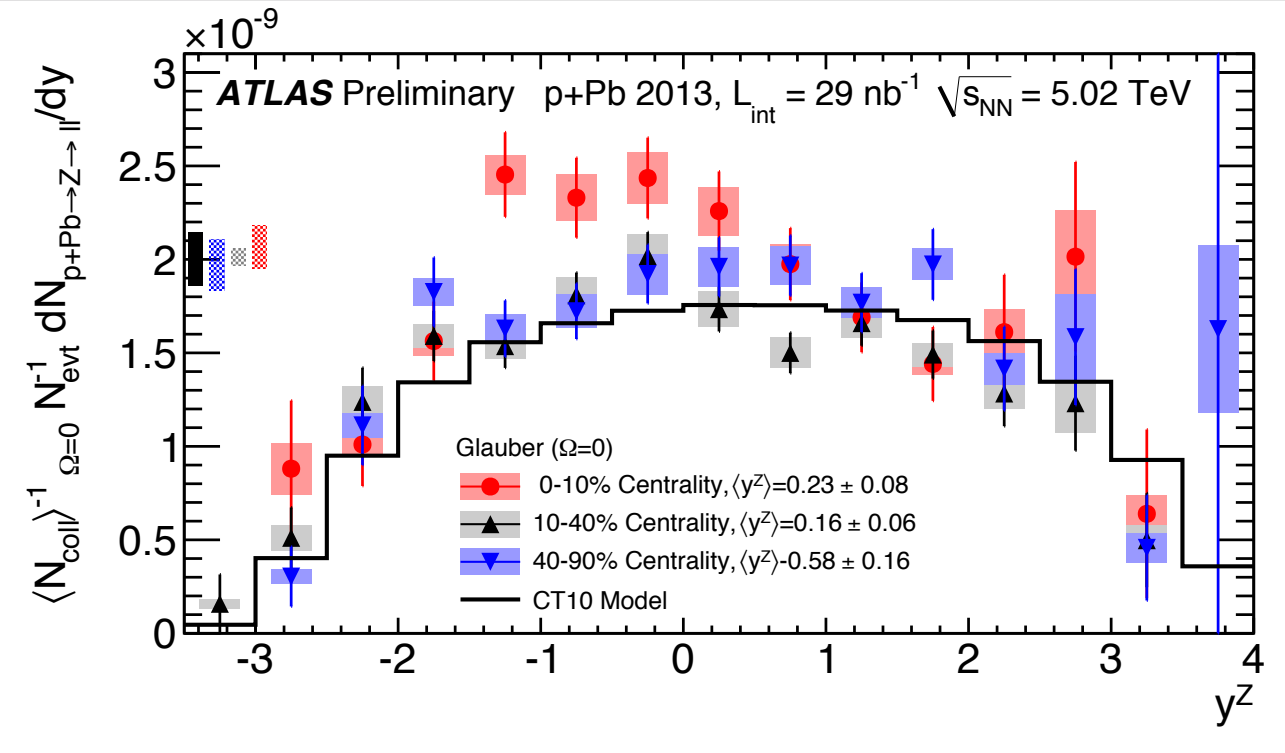




More Reason for Caution

- We need to be sure we understand initial state nuclear corrections to the PDF

  nPDF corrections may be centrality dependent



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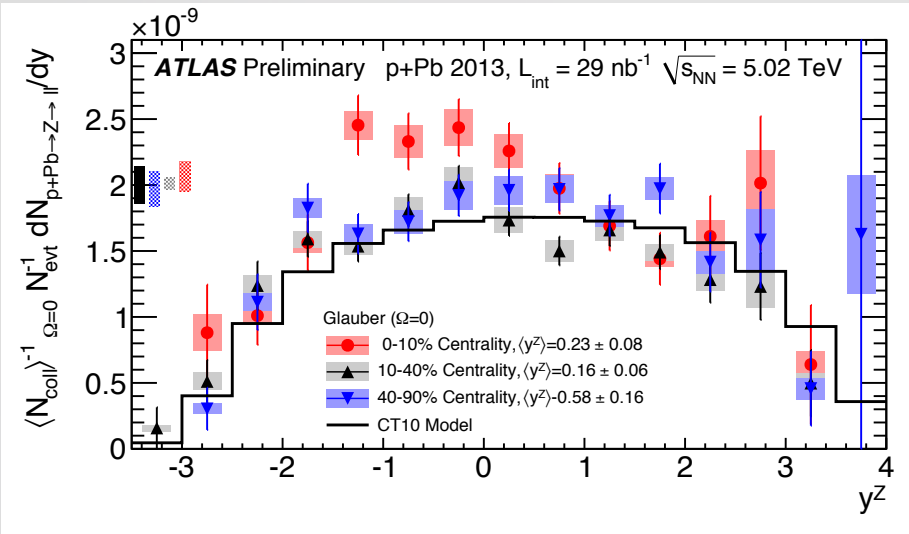
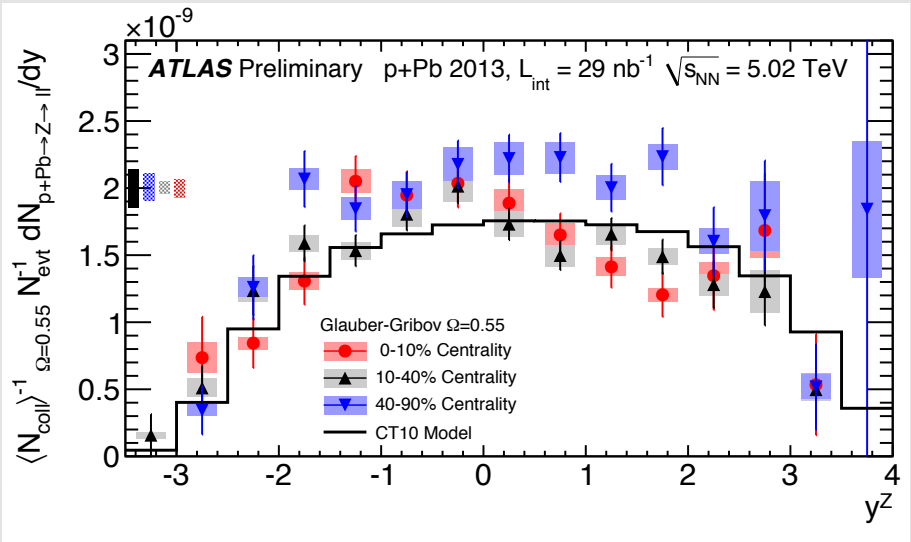
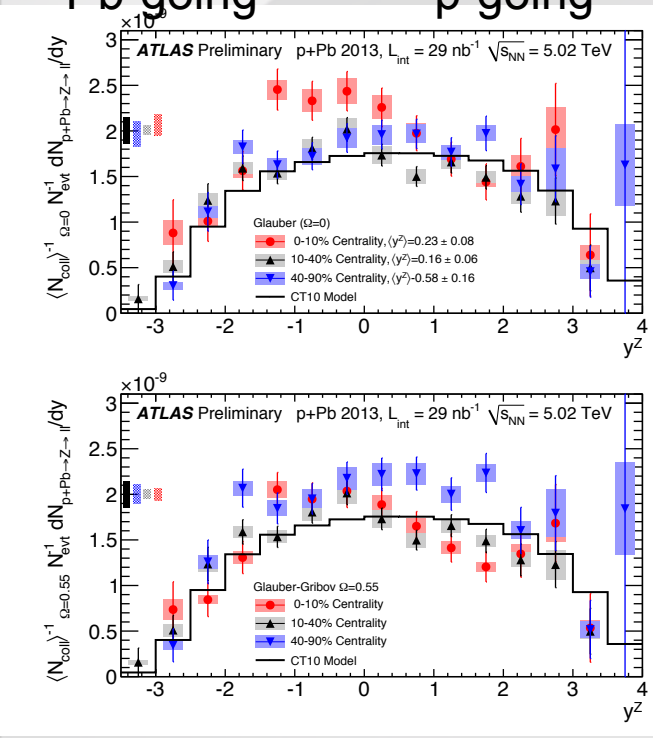




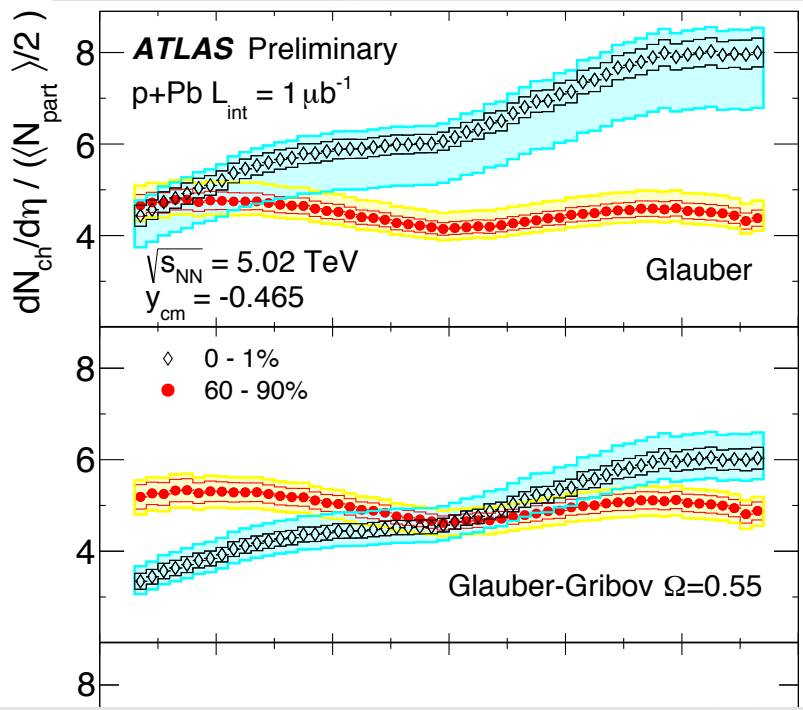
And understanding those corrections may be centrality model dependent!

By the way …

Pb-going p-going



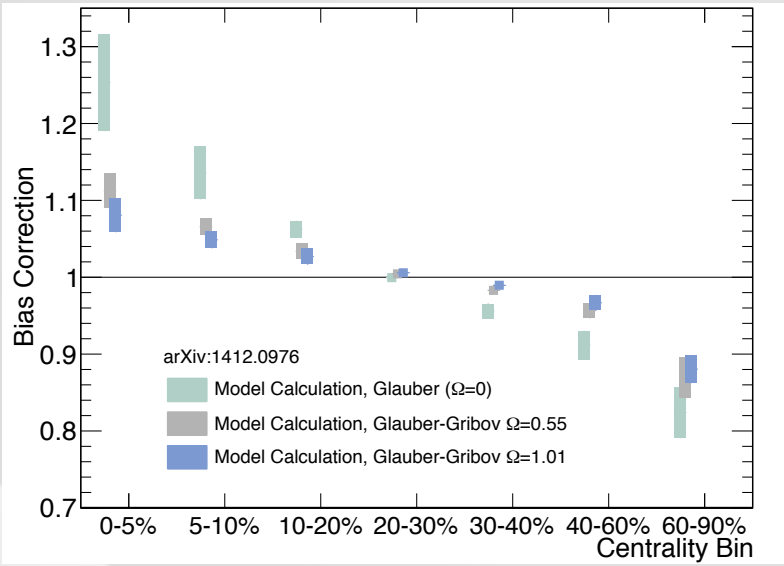
p-going Pb-going

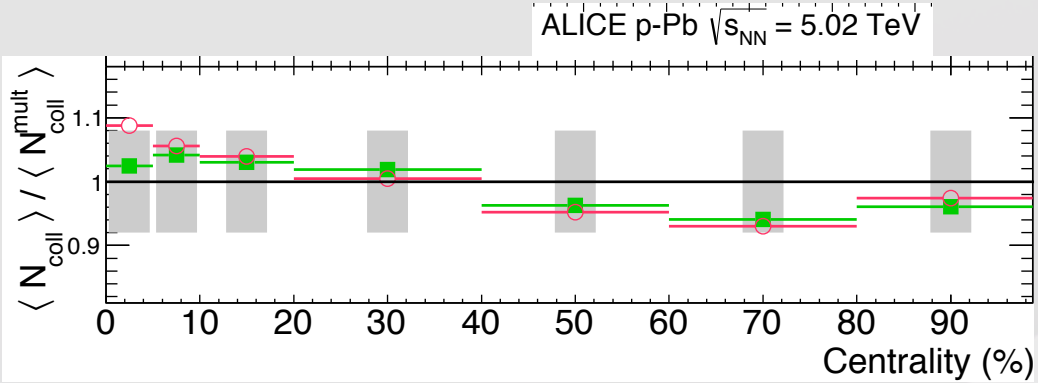


Centrality dependent rapidity dependence is something we need to understand for multiplicity too

How about Biases?

- Biases don't disappear for EW bosons
- Several models out there that aim to explain the correlation between different centrality observables and hard processes
  - Dennis and Peter have a model based on idea that hard scattering yield is proportional to multiplicity for each NN collision
  - PHENIX studies with HIJING
  - 'Simple' p conservation, see e.g. jet measurements
- EW bosons may be the best way to *test* these …



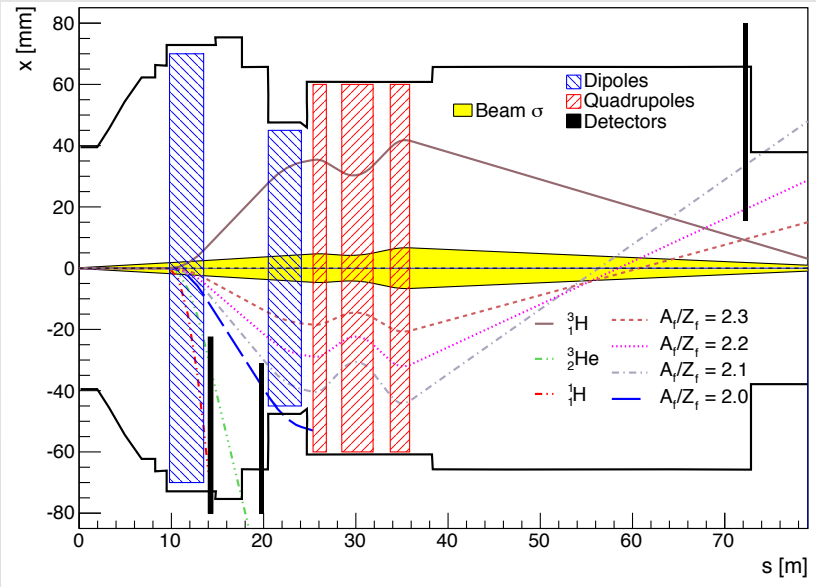


A modest proposal

- EW bosons may be the common denominator for tricky centrality studies
- Maybe eventually used to calibrate centrality
- Calibration includes biases
  - Elides the problem of what we call a measurement and what we call a bias
- Can be compared across experiments
- **All pA experimentalists: Measure centrality dependence ofEW bosons!**

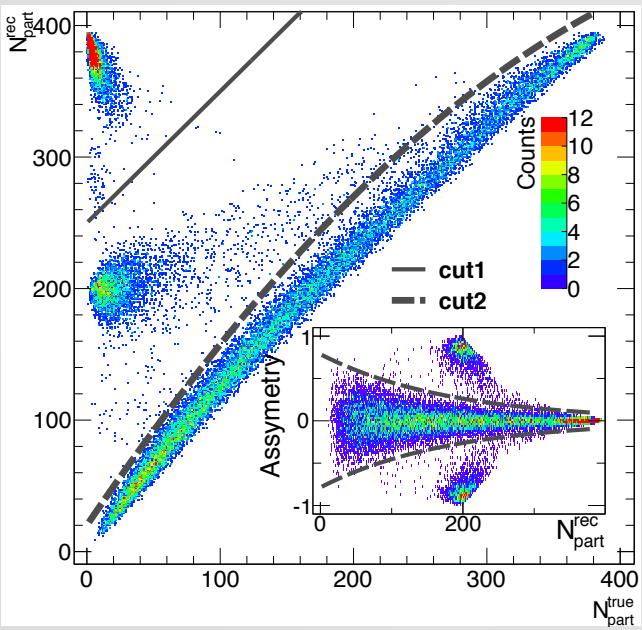
A less modest proposal

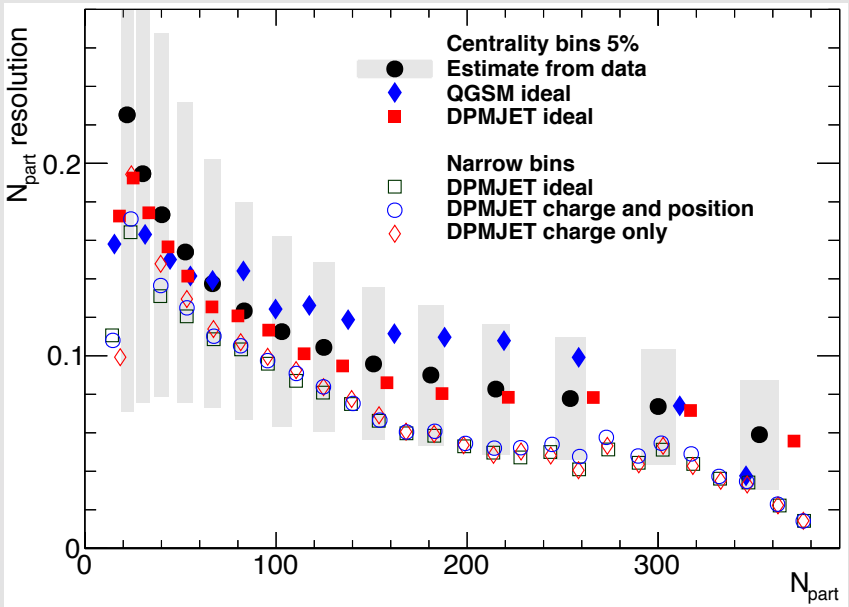
- Build a centrality detector!
- ALICE method uses neutrons in ZDC but the 'dynamic range' is limited looking only at spectator neutrons
- Build downstream detectors that can measure all spectators
  - Use accelerator magnets as mass spectrometer, and detect fragments with identified $A/Z \sim N_{spec}$
- Calculations for Au+Au @ RHIC in NIM. A 768, 170 (2014)



A less modest proposal

- Full simulation for pA needed with details of pA accelerator structure for LHC or RHIC
- Could answer many questions …





Summary

- Many non-trivial observations in pA centrality measurements α multiplicity correlations
- Ambiguity about 'anomalous/novel' phenomena vs centrality definitions
- Still at a stage where more measurements may give more information
- Measuring EW bosons may help break the impasse …