Centrality determination in pPb collisions with CMS

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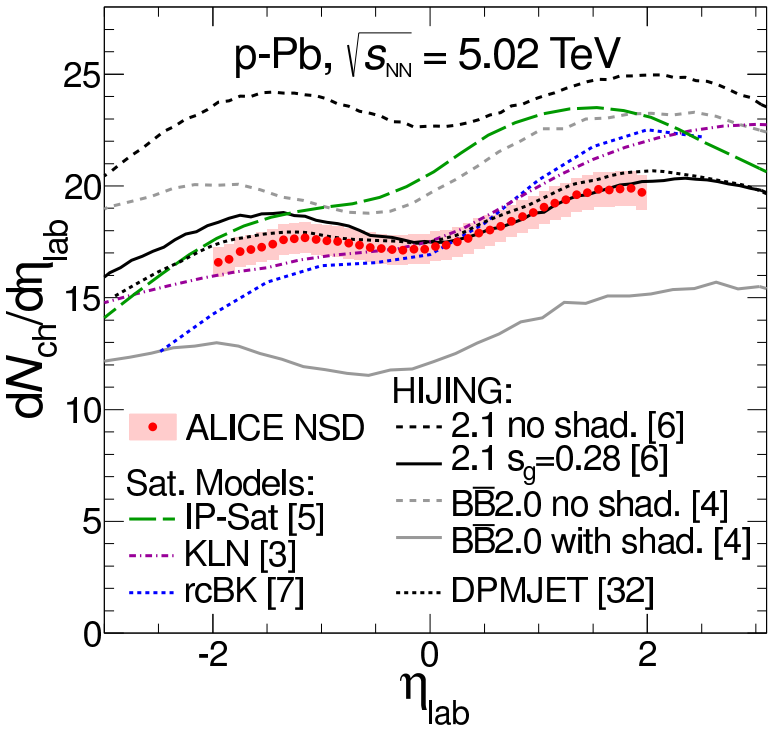
for the CMS Collaboration

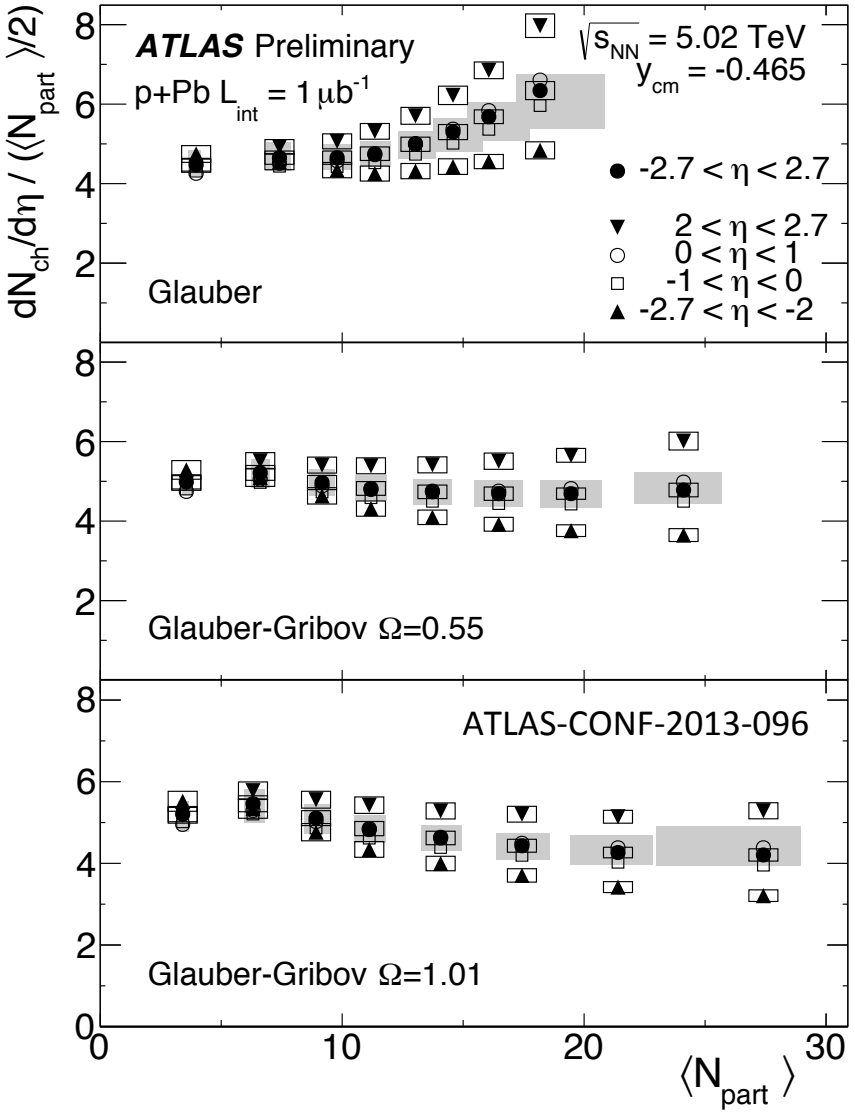
Workshop on the determination of centrality in pA collisions at the LHC
February 14th, 2014

pPb "Centrality" dependent measurements

Charged particles $dN_{ch}/d\eta$ →

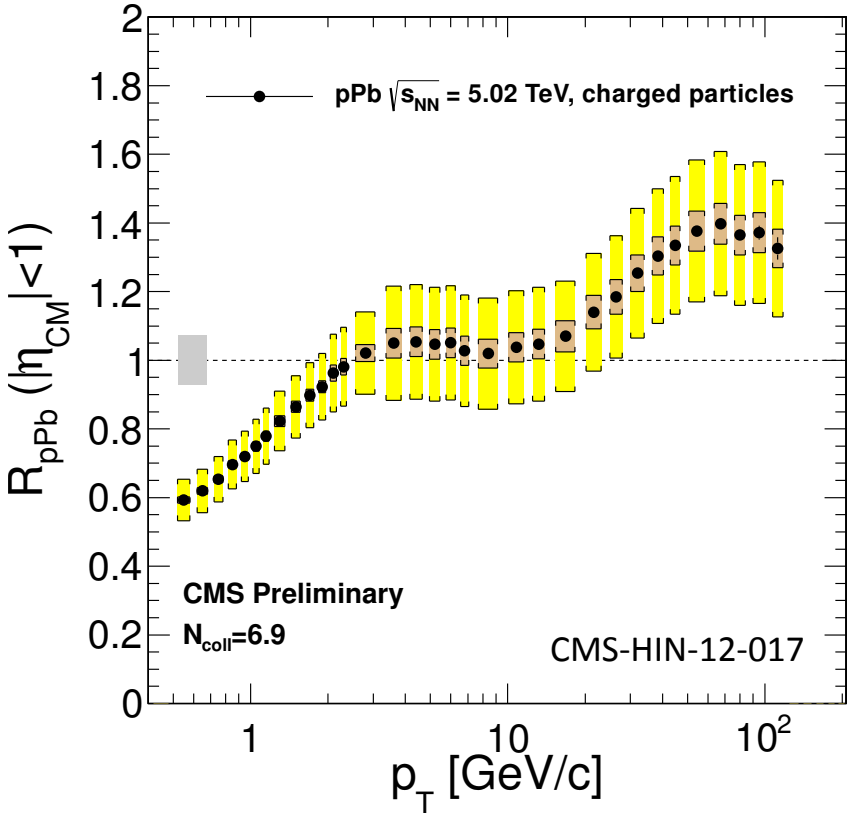


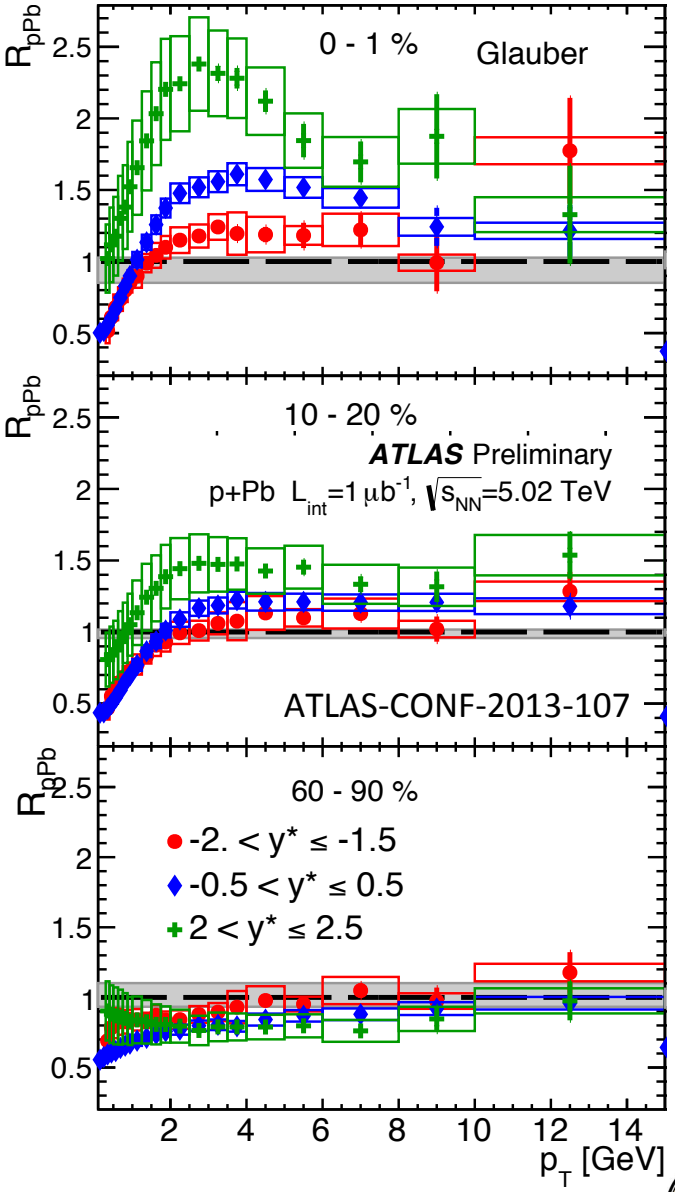
Phys. Rev. Lett. 110, 032301 (2013)



pPb "Centrality" dependent measurements

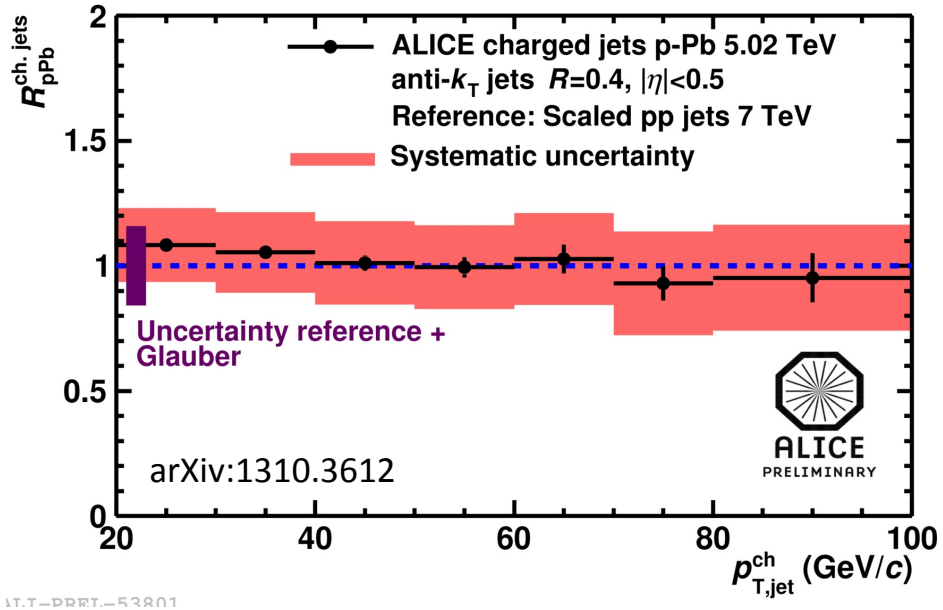
Charged particles R_{pPb}

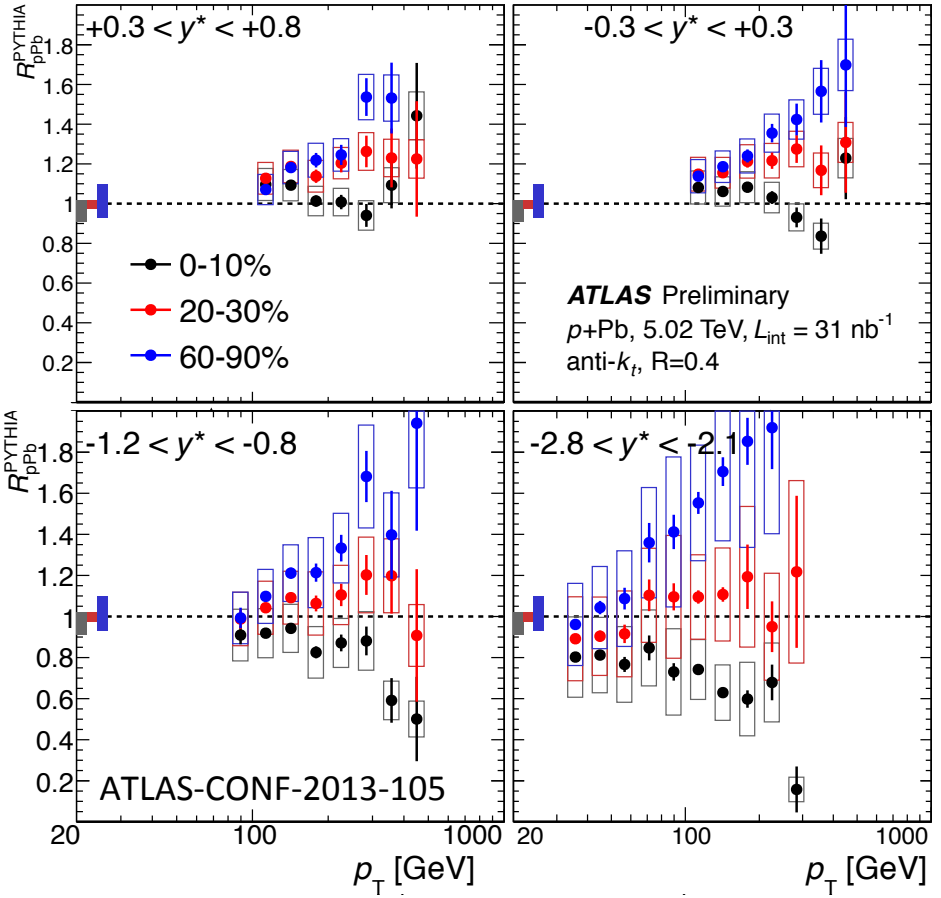




pPb "Centrality" dependent measurements

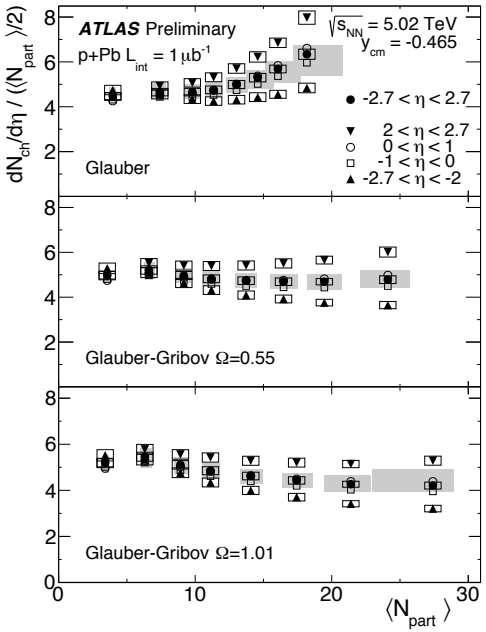
Jets R_{pPb}



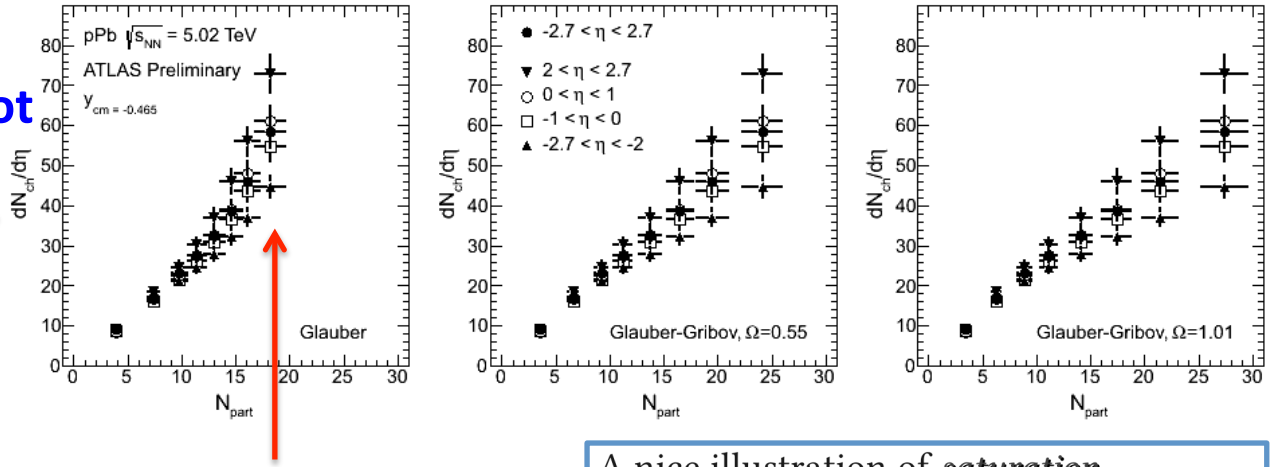


Think about biases before interpreting the results

An example :

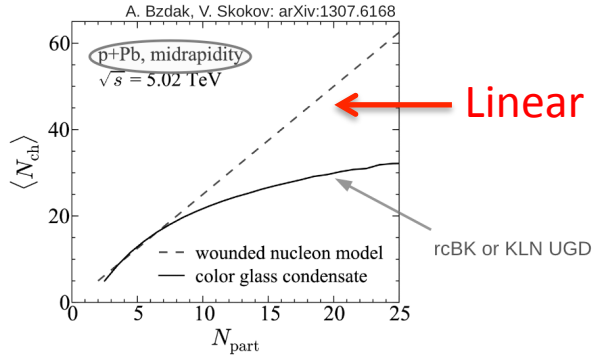


Re-plot



- Going up more than linear
- Is it true? or because of centrality biases? Need to be careful

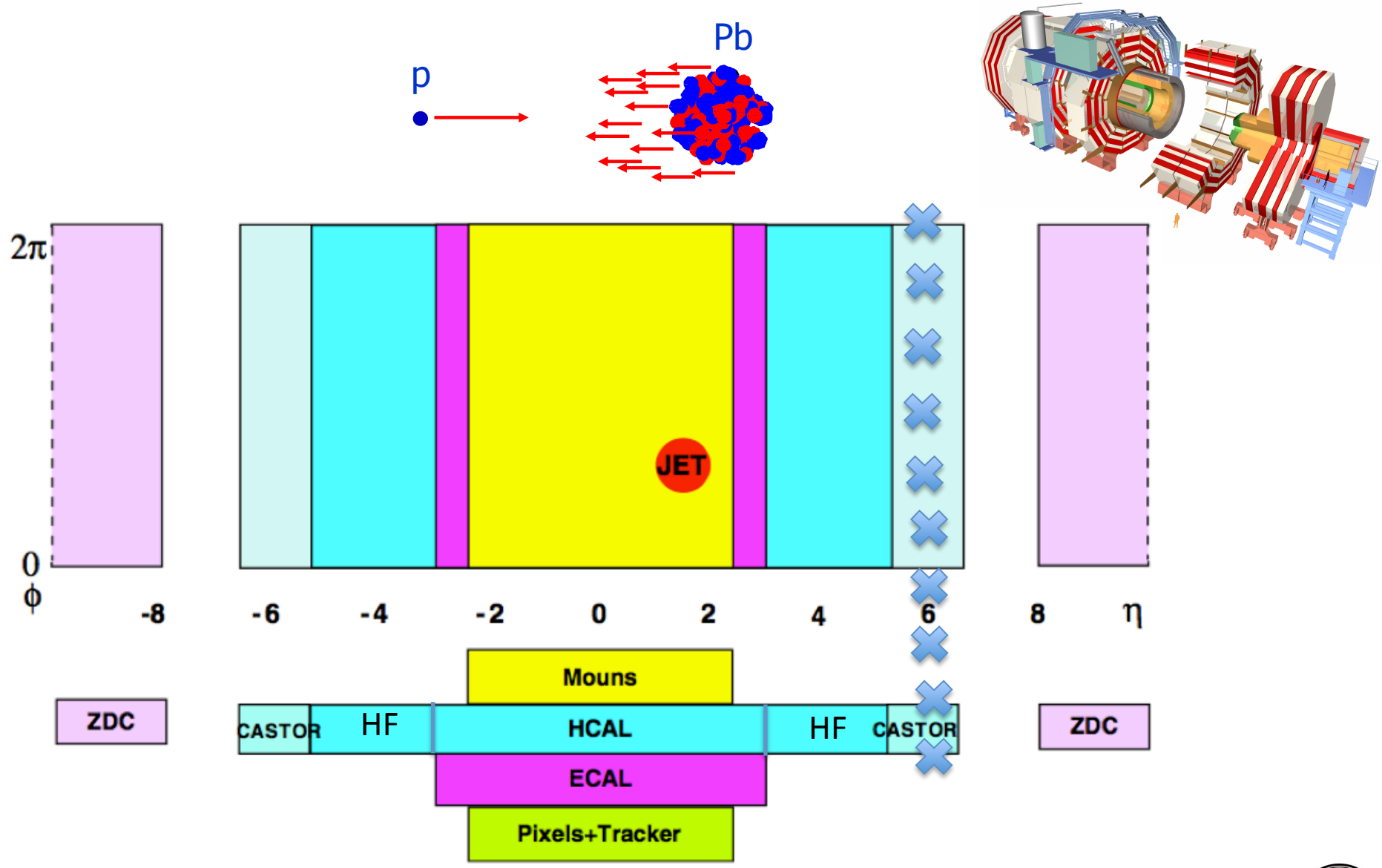
A nice illustration of ***saturation***



Outline of the talk:

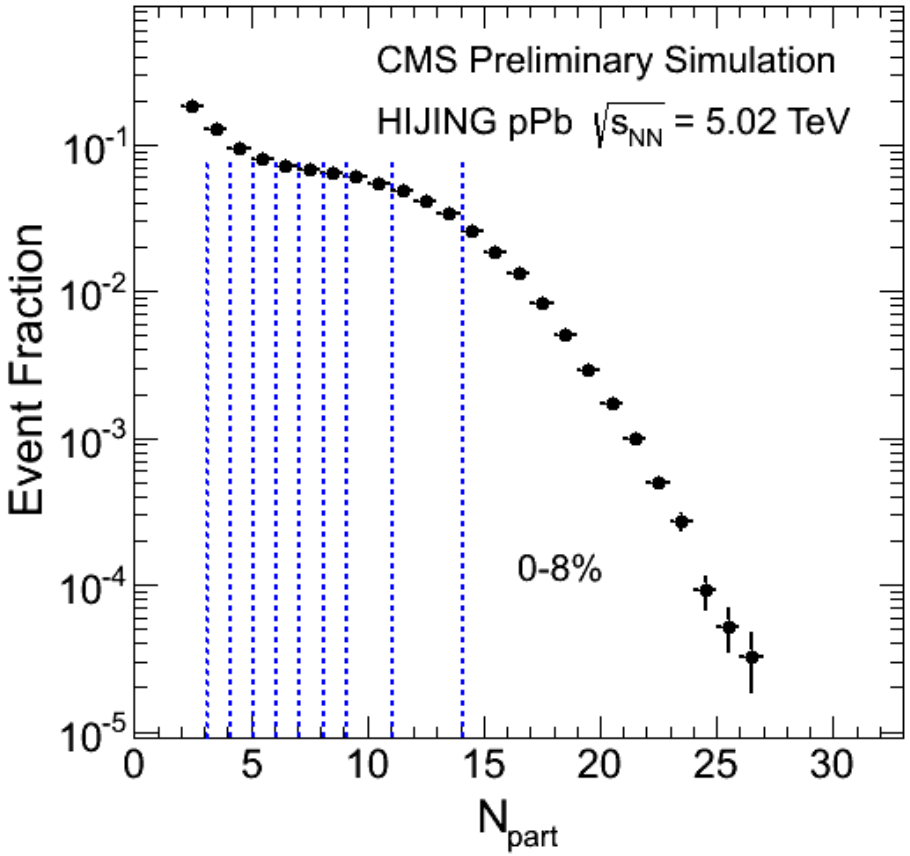
- Centrality bias study for $dN_{ch}/d\eta$ analysis
- Bias study for higher p_T , up to 10 GeV/c
- Estimating $\langle N_{coll} \rangle$, Glauber + NBD

CMS detector acceptance

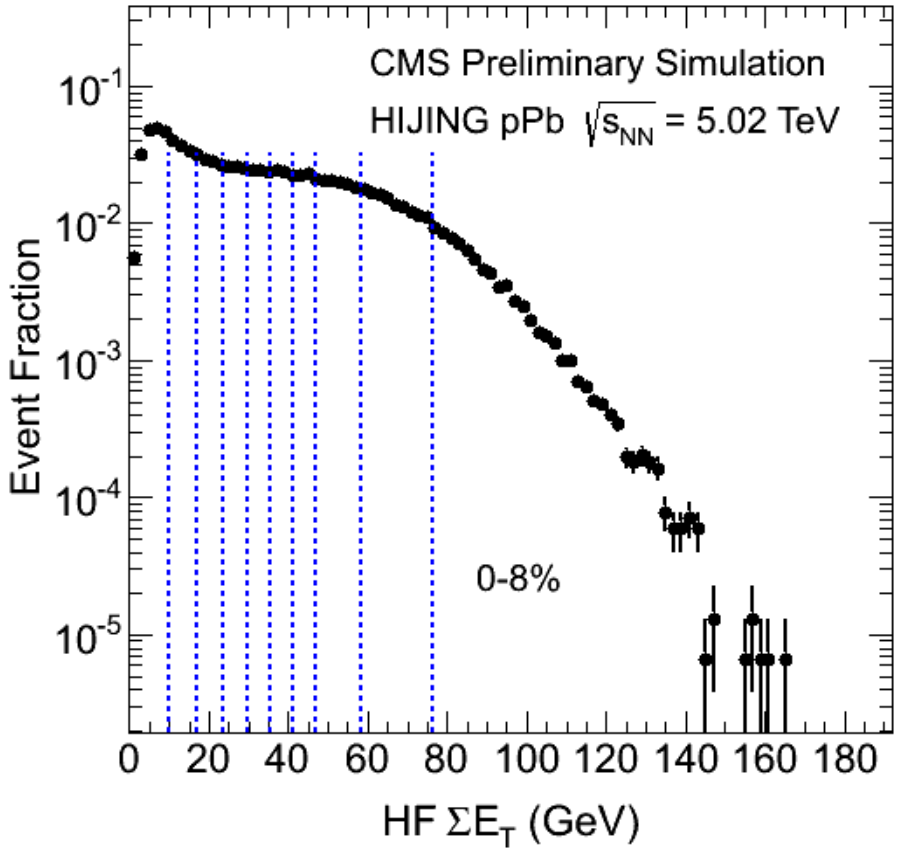


Variables for centrality selection

Using N_{part} distribution in simulations



Using detector variables in simulations and real data



Method for choosing centrality variable

1. How to find the best centrality variable from simulations?

Define centrality with N_{part} distribution, get $dN_{ch}/d\eta$

Define centrality with detector variables, get the $dN_{ch}/d\eta$

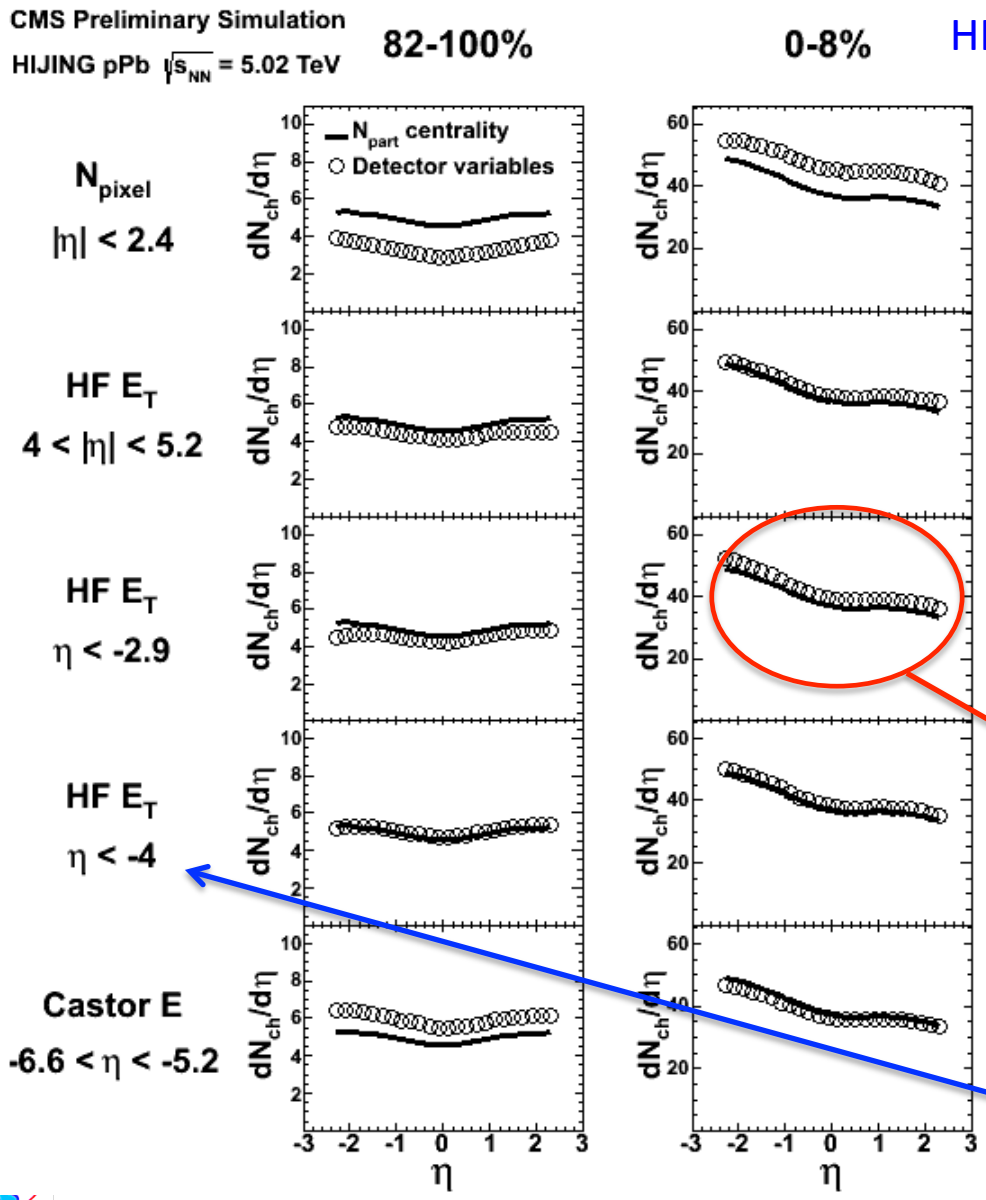
Compare the $dN_{ch}/d\eta$ above. Find the best variable for the definition of centrality

2. How to check if the simulation describe the centrality biases?

Look at the ratio of $dN_{ch}/d\eta$ from different variables to $dN_{ch}/d\eta$ from the best centrality variable in simulation

Look at the same ratio in real data. Compare the ratio in simulation and real data

Results: HIJING most peripheral and most central

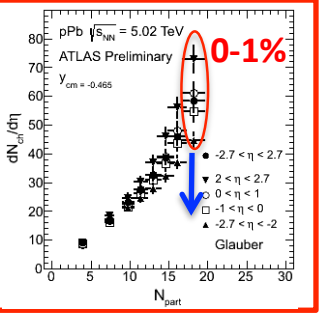


HIJING simulation

Overestimate in central.
Underestimate in peripheral.

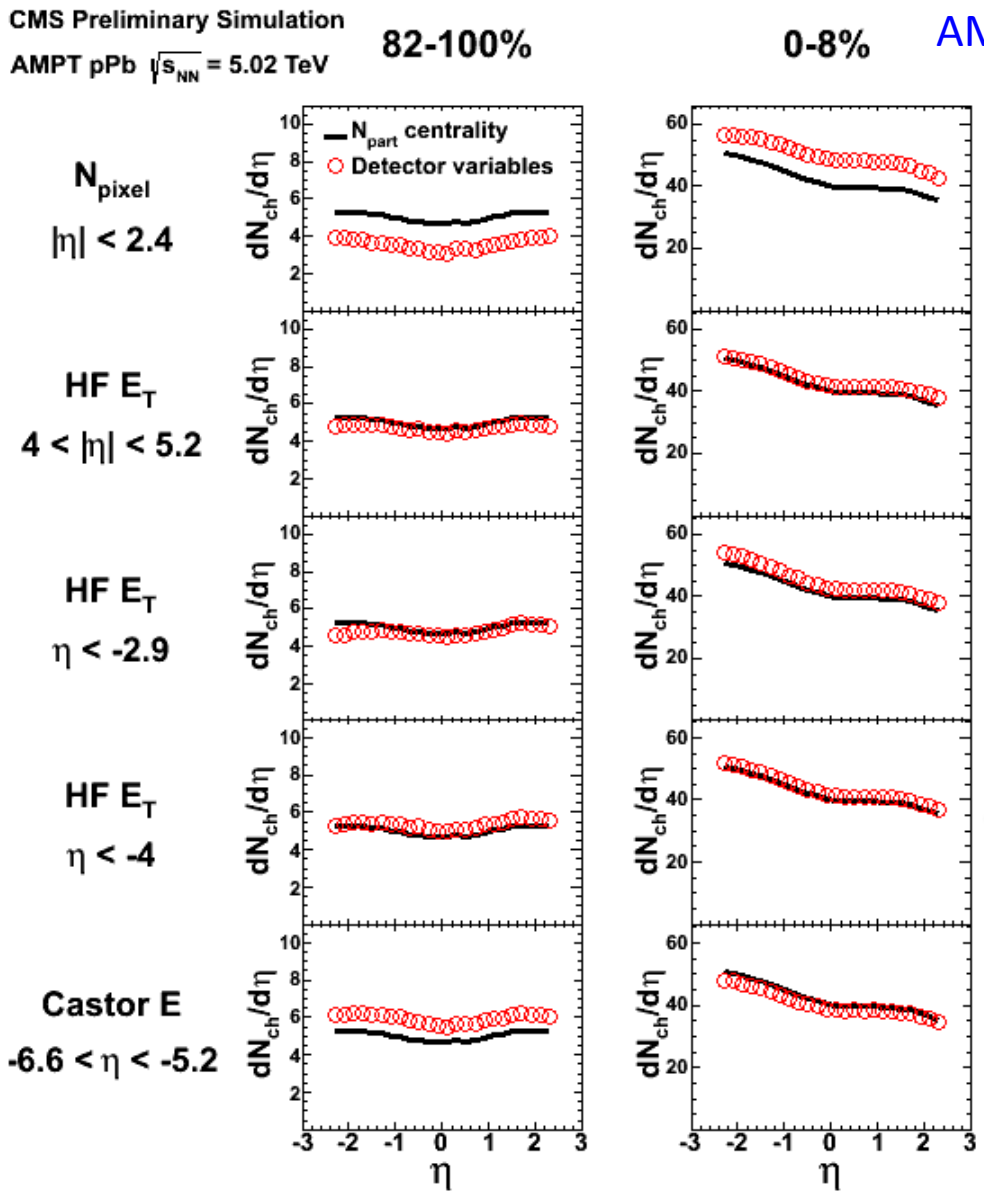
$\eta < -2.9$ is Pb-going side.
Overestimate in central.
Underestimate in peripheral.
The biases will be much larger in small central bins, like 0-1%

HF E_T $\eta < -2.9$ is very close to ATLAS centrality variable.
~9% biases for 0-8%.
Biases in 0-1% is larger.



The best centrality variable

Results: AMPT most peripheral and most central

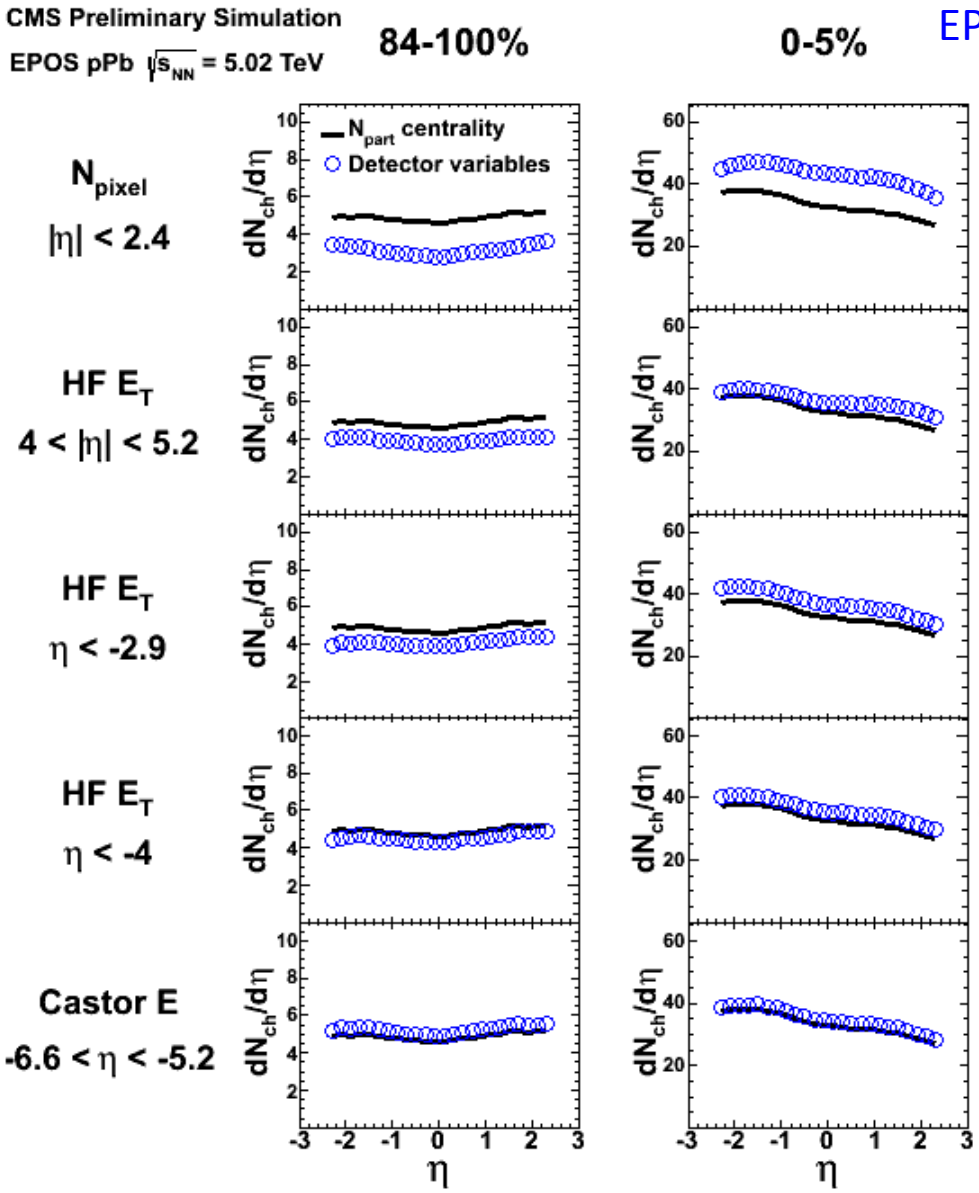


AMPT simulation

The same conclusions as in HIJING

← The best centrality variable

Results: EPOS most peripheral and most central



EPOS simulation

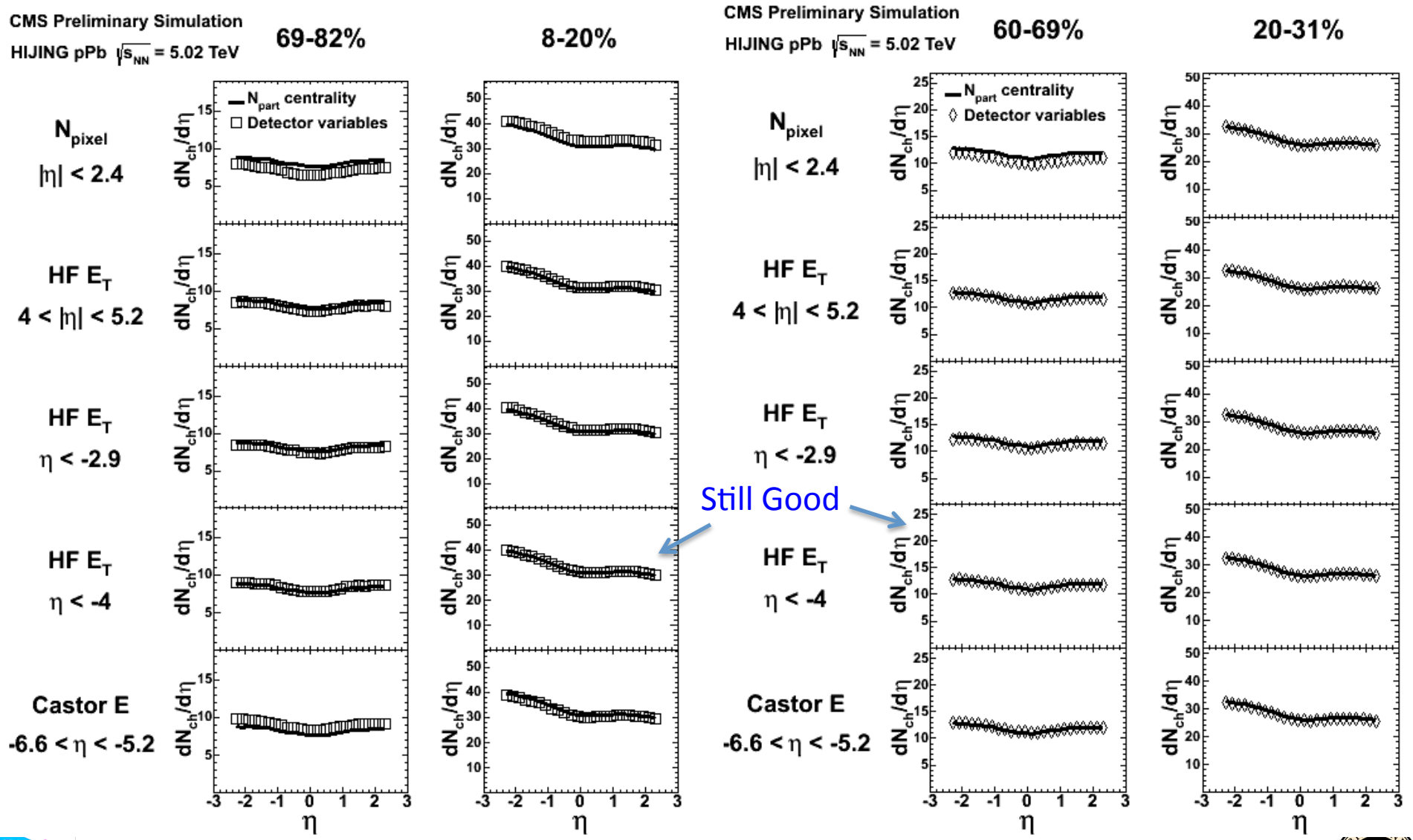
The same conclusions as in HIJING and AMPT

← Good centrality variable overall

← Castor is also good

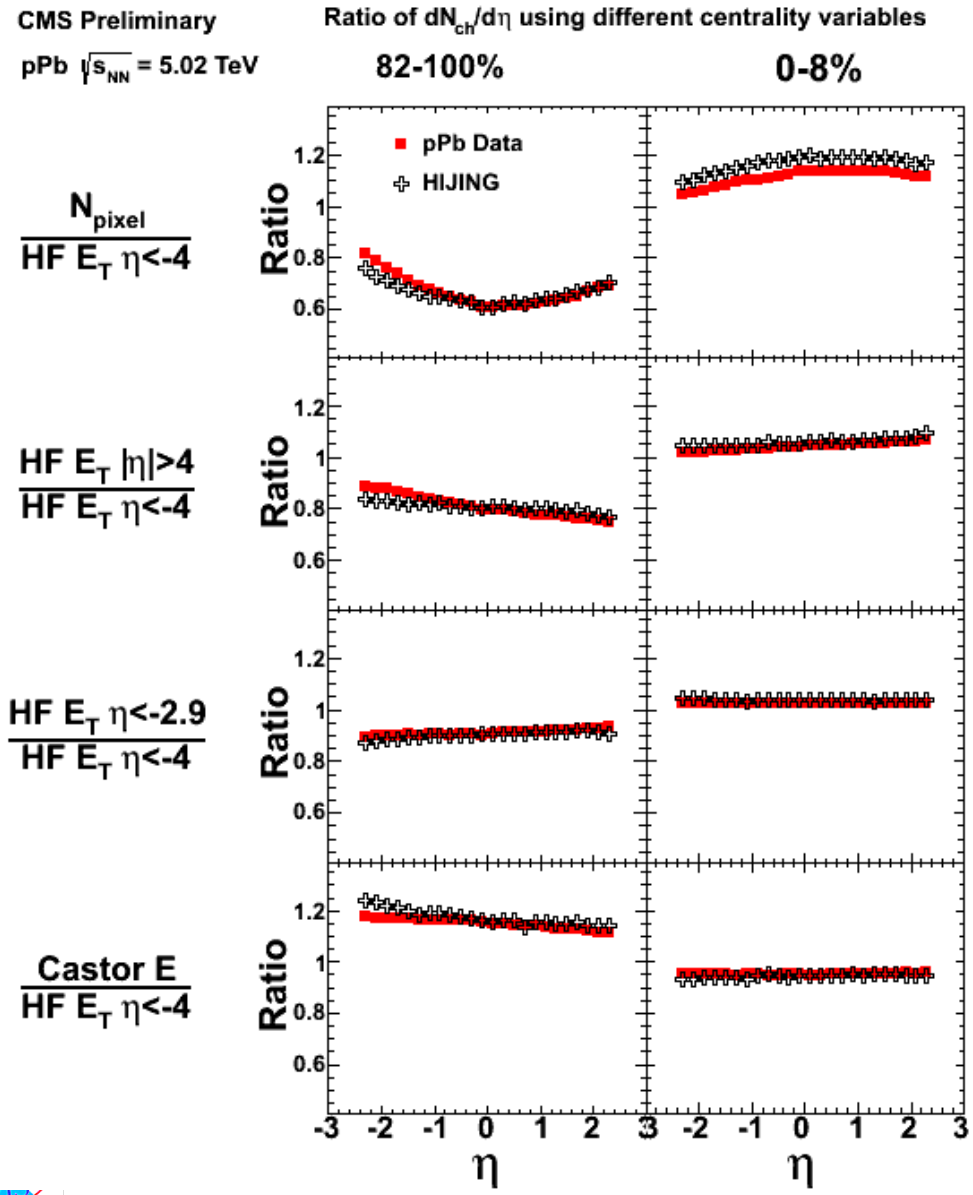
HIJING other centrality bins

HIJING simulation



Ratio of $dN_{ch}/d\eta$ from different centrality variables to $dN_{ch}/d\eta$ from the best centrality variable in MC and data

Ratio of $dN_{ch}/d\eta$, HIJING compare with data



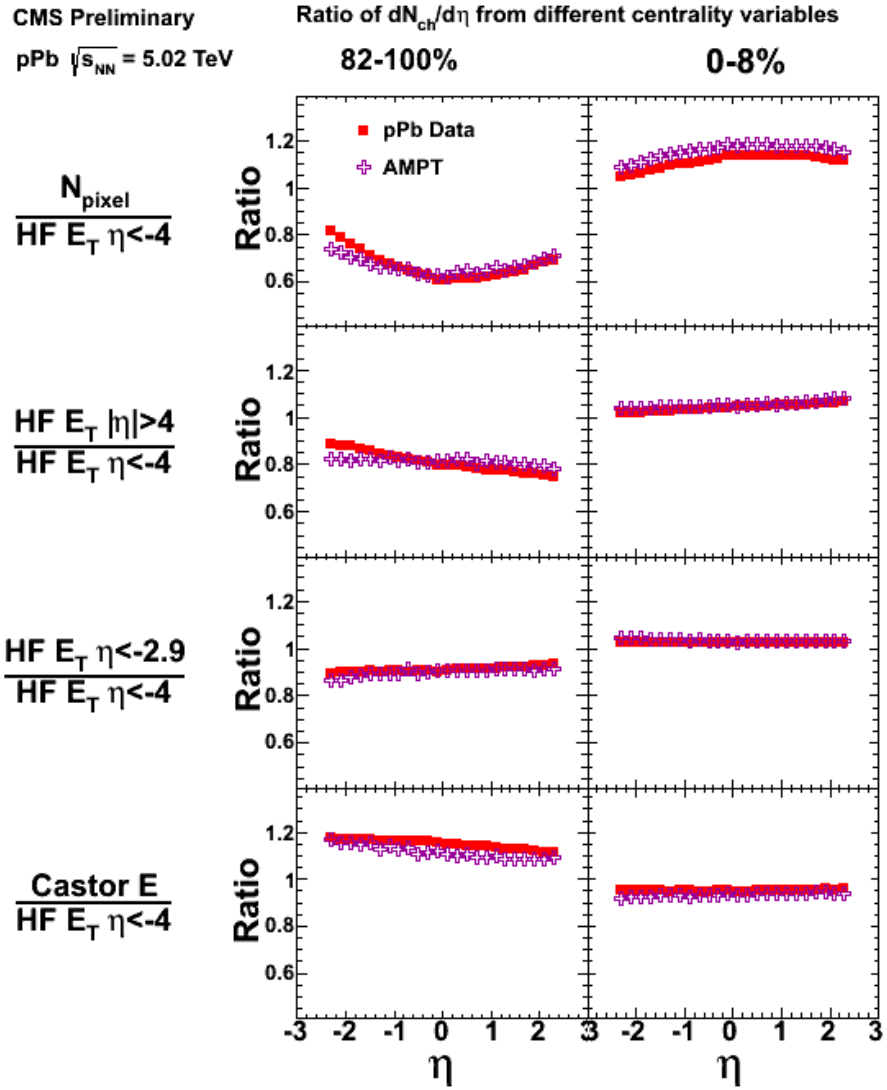
HIJING simulation and Real data

Ratio of $dN_{ch}/d\eta$ with centrality from different centrality variables to $dN_{ch}/d\eta$ with centrality from the best centrality variable in MC and data

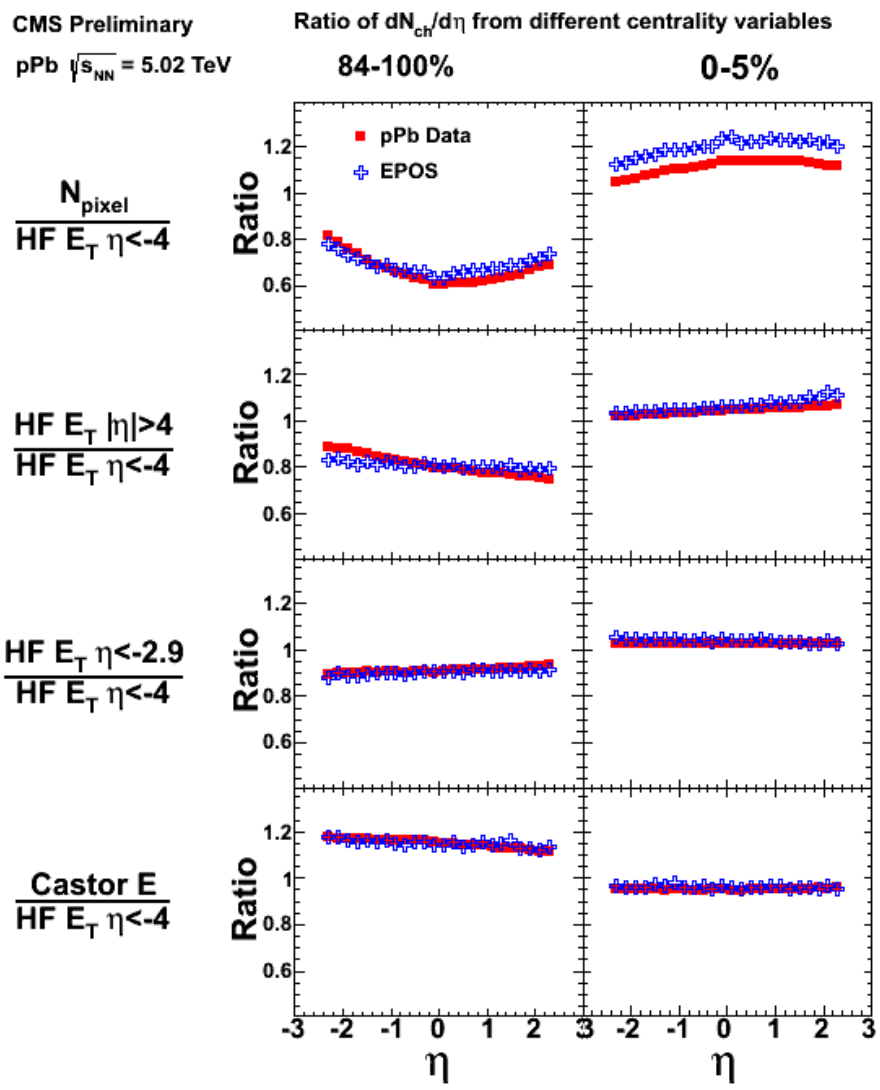
The biases in MC match the biases in real data

Ratio of $dN_{ch}/d\eta$, AMPT and EPOS compare with data

AMPT simulation and Real data



EPOS simulation and Real data



The biases in MCs match the biases in real data

Bias study for higher p_T in simulation

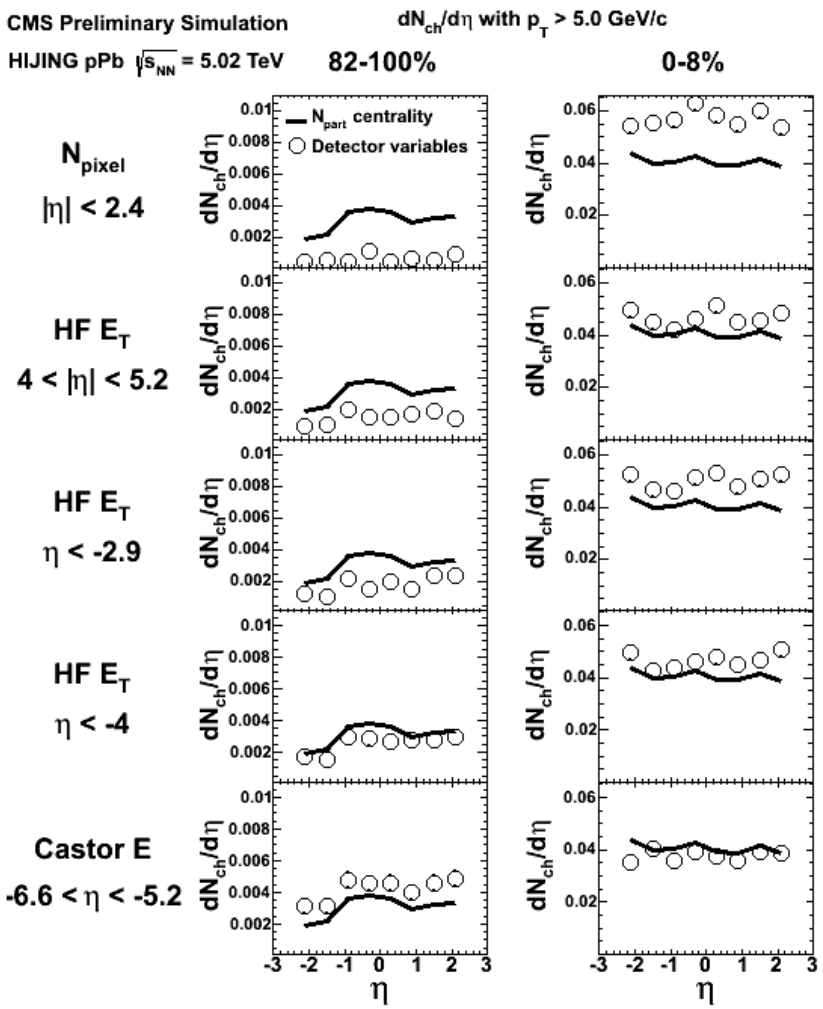
Centrality variable for higher p_T probes

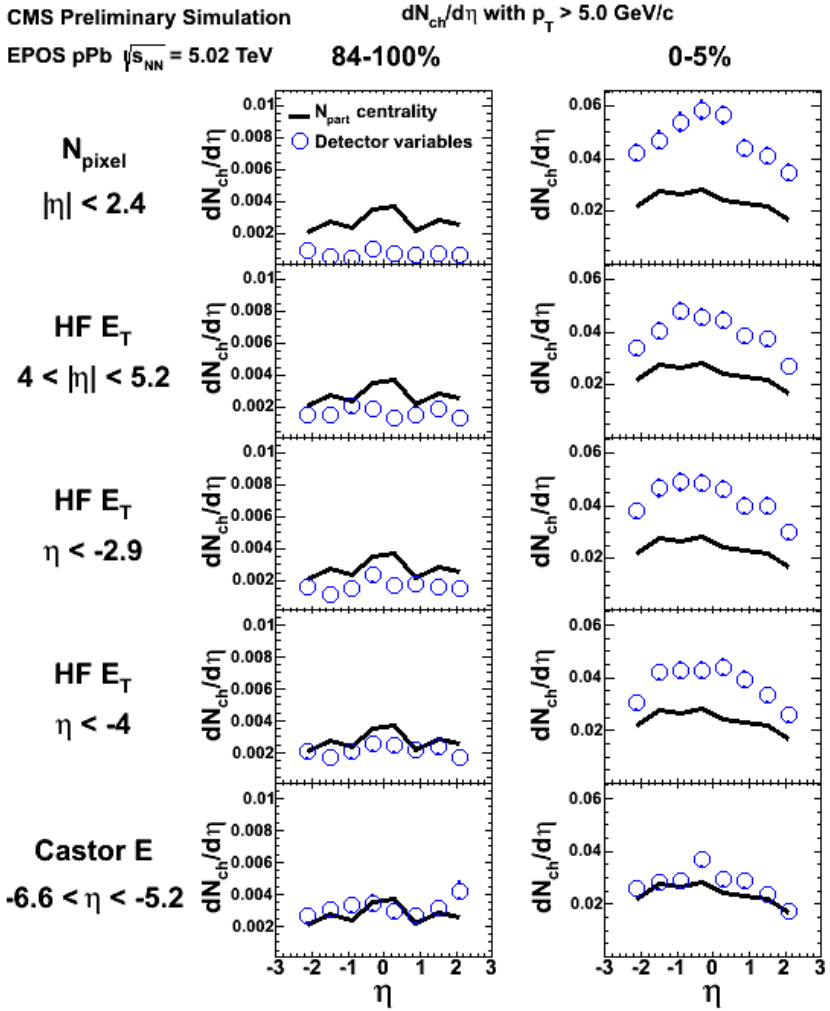
Is the best centrality variable the same for soft and hard probes?

HIJING simulation

$dN_{ch}/d\eta$ with $p_T > 5$ GeV/c

EPOS simulation





HF η<-4 seems still good from HIJING but Castor -6.6<η<-5.2 is better for EPOS

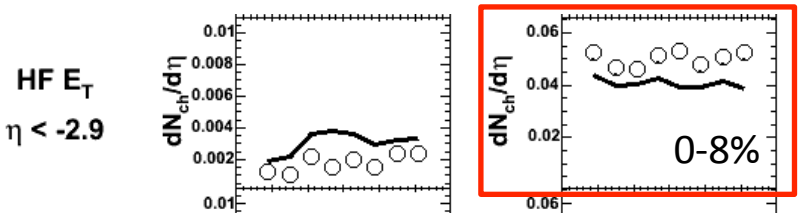
Centrality variable for higher p_T probes

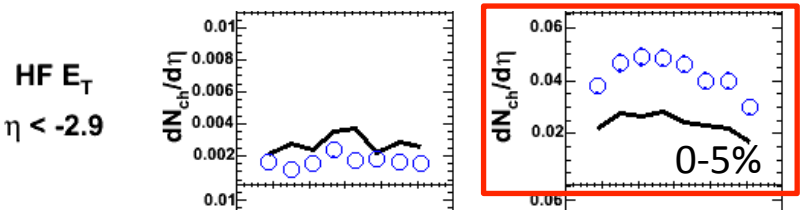
Is the best centrality variable the same for soft and hard probes?

HIJING simulation

$dN_{ch}/d\eta$ with $p_T > 5$ GeV/c

EPOS simulation





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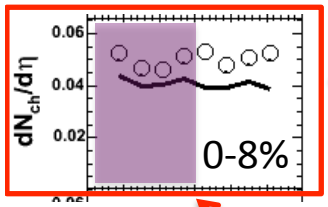
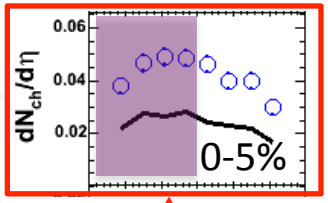
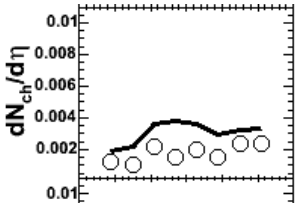


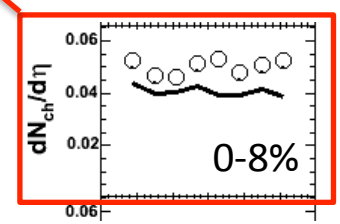


- The centrality is using HF E_T η<-2.9
- The bias don't change much in the positive or negative η side

HF E_T

η < -2.9





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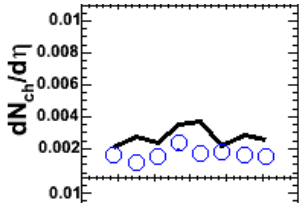

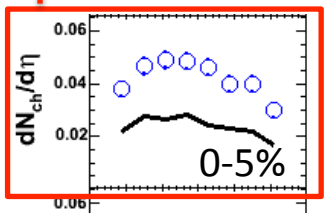

Centrality variable for higher p_T probes

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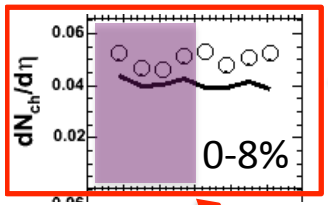
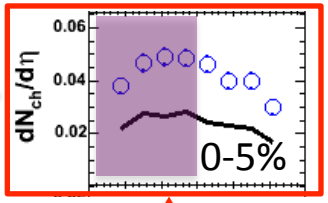
$dN_{ch}/d\eta$ with $p_T > 5$ GeV/c

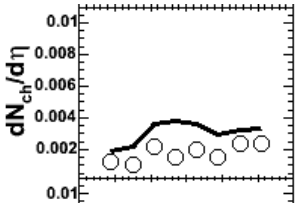
EPOS simulation

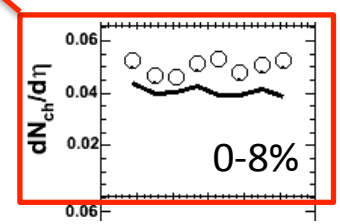




- The centrality is using HF E_T η<-2.9
- The bias don't change much in the positive or negative η side

HF E_T
η < -2.9





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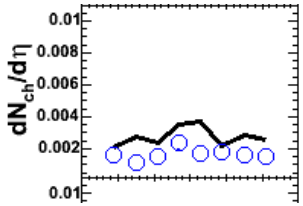
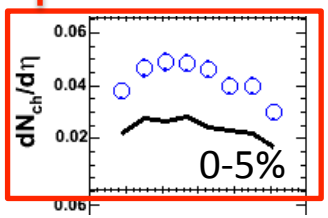
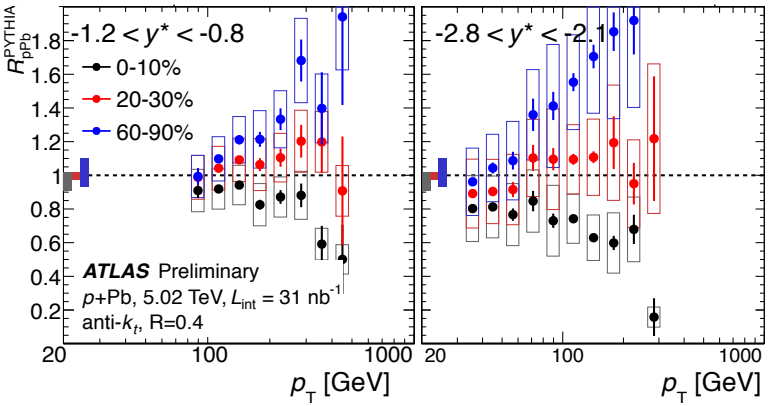


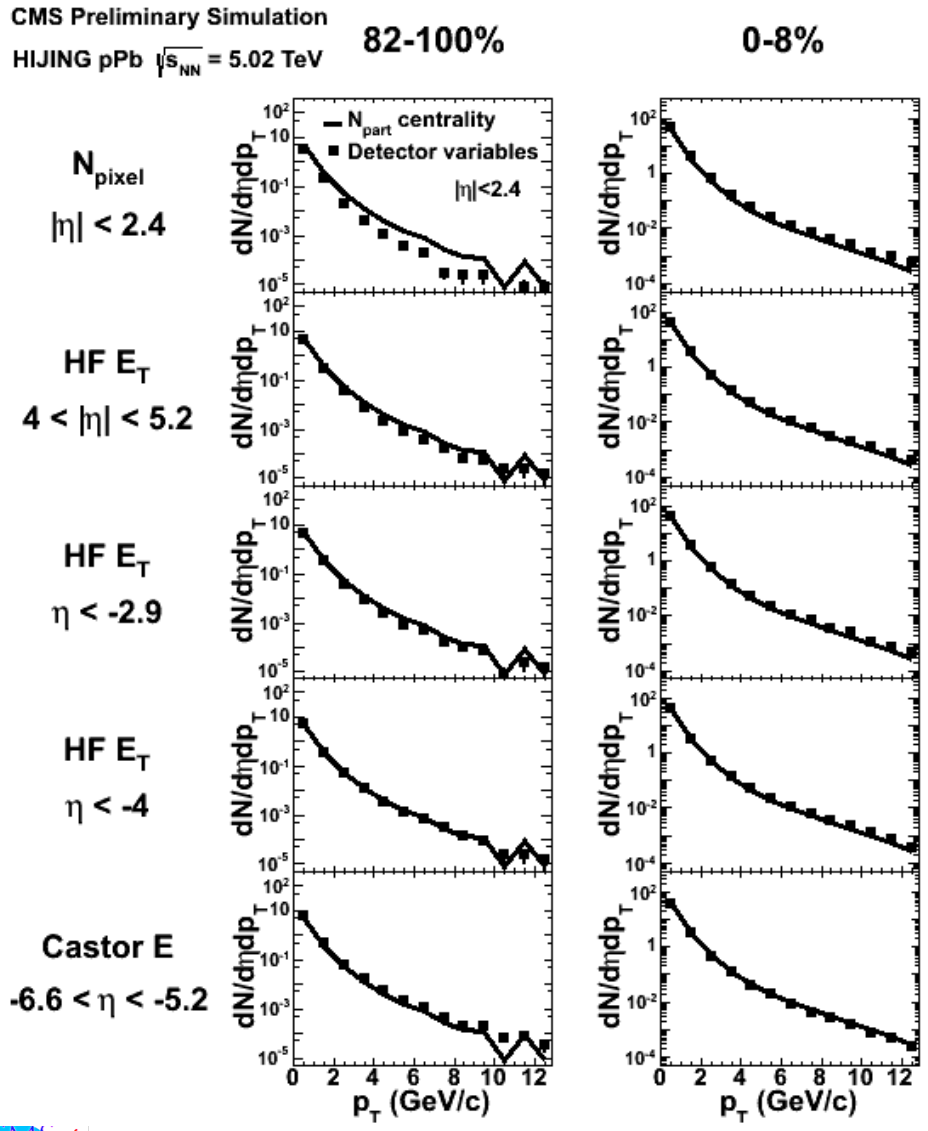


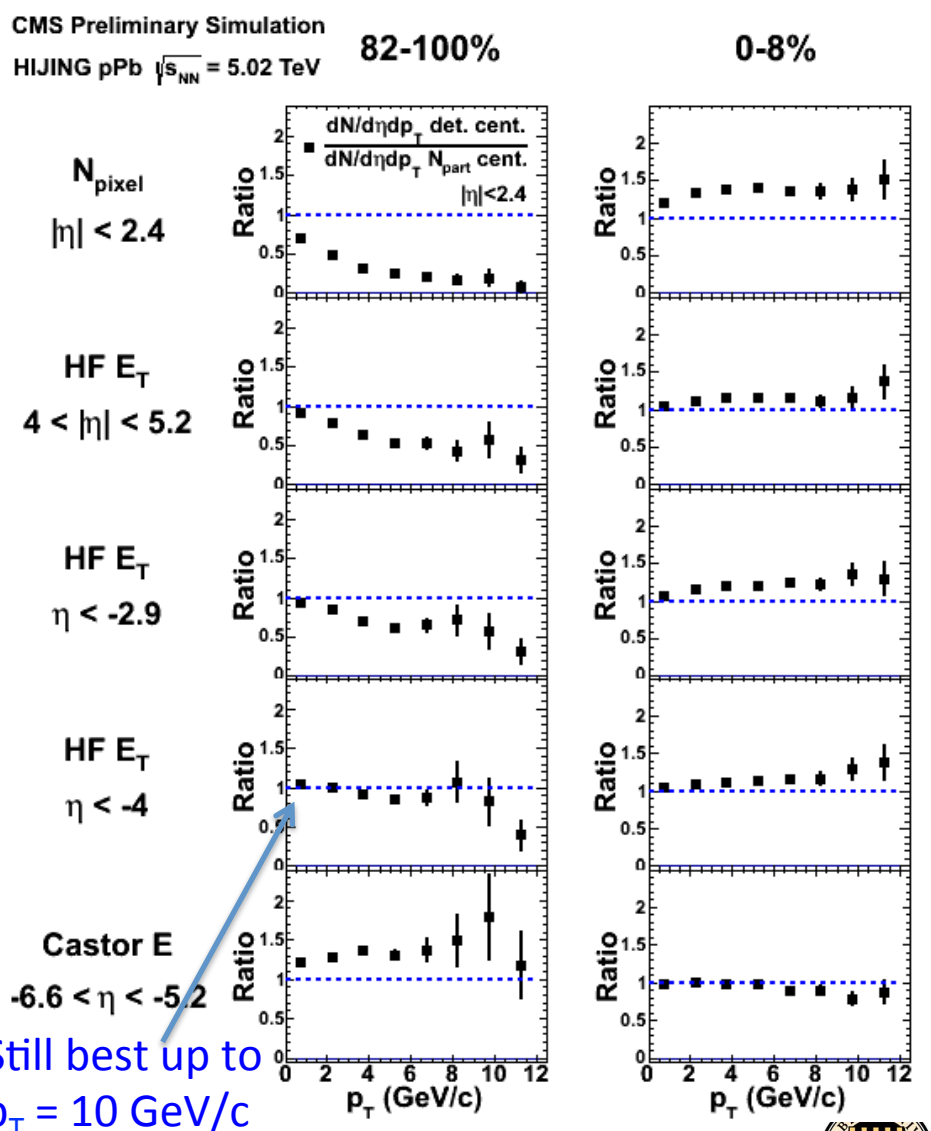


- The ATLAS centrality is using Pb-going side Fcal 3.2<η<4.9
- The Jets R_{pPb} mostly done in negative p-going side
- However, the large gap between centrality and measurements may not able to remove the biases?

p_T dependent biases in HIJING

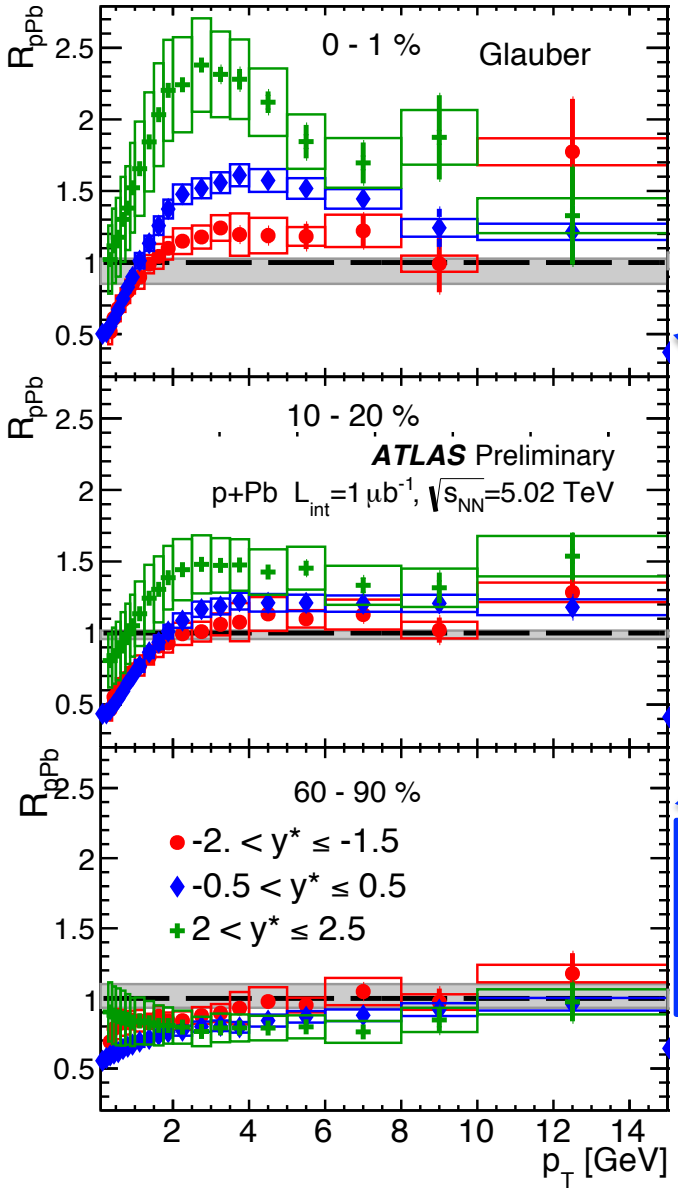
HIJING simulation



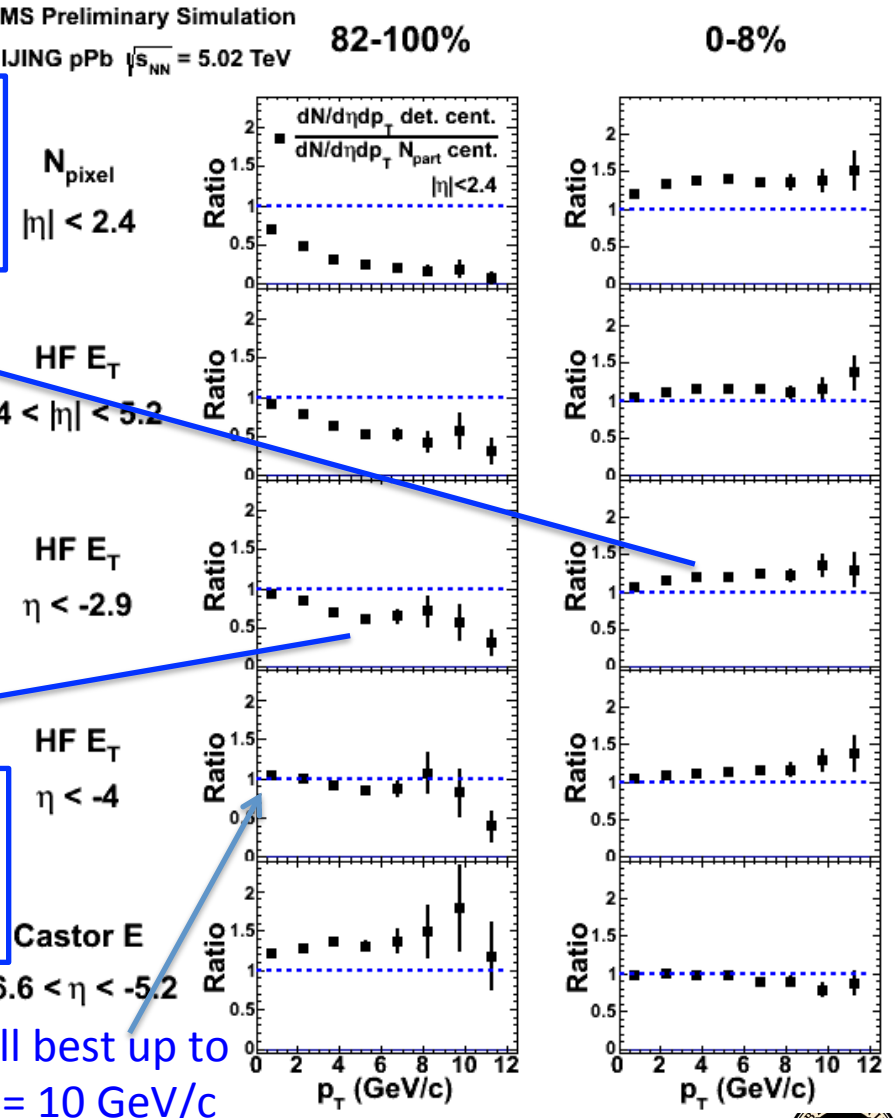


Still best up to p_T = 10 GeV/c

p_T dependent biases in HIJING



HIJING simulation



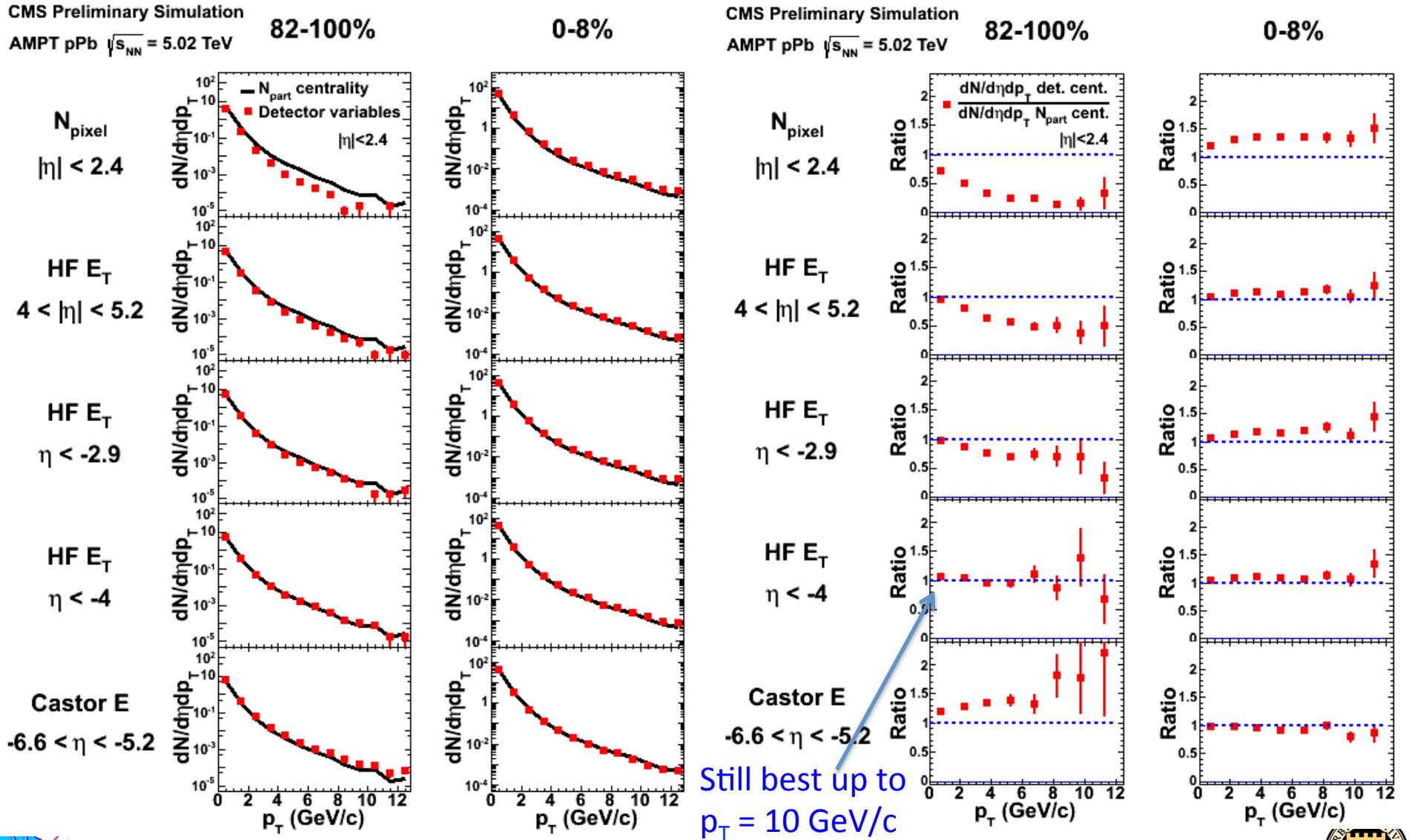
Overestimate from biases in central

Underestimate from biases in peripheral

Still best up to p_T = 10 GeV/c

p_T dependent biases in AMPT

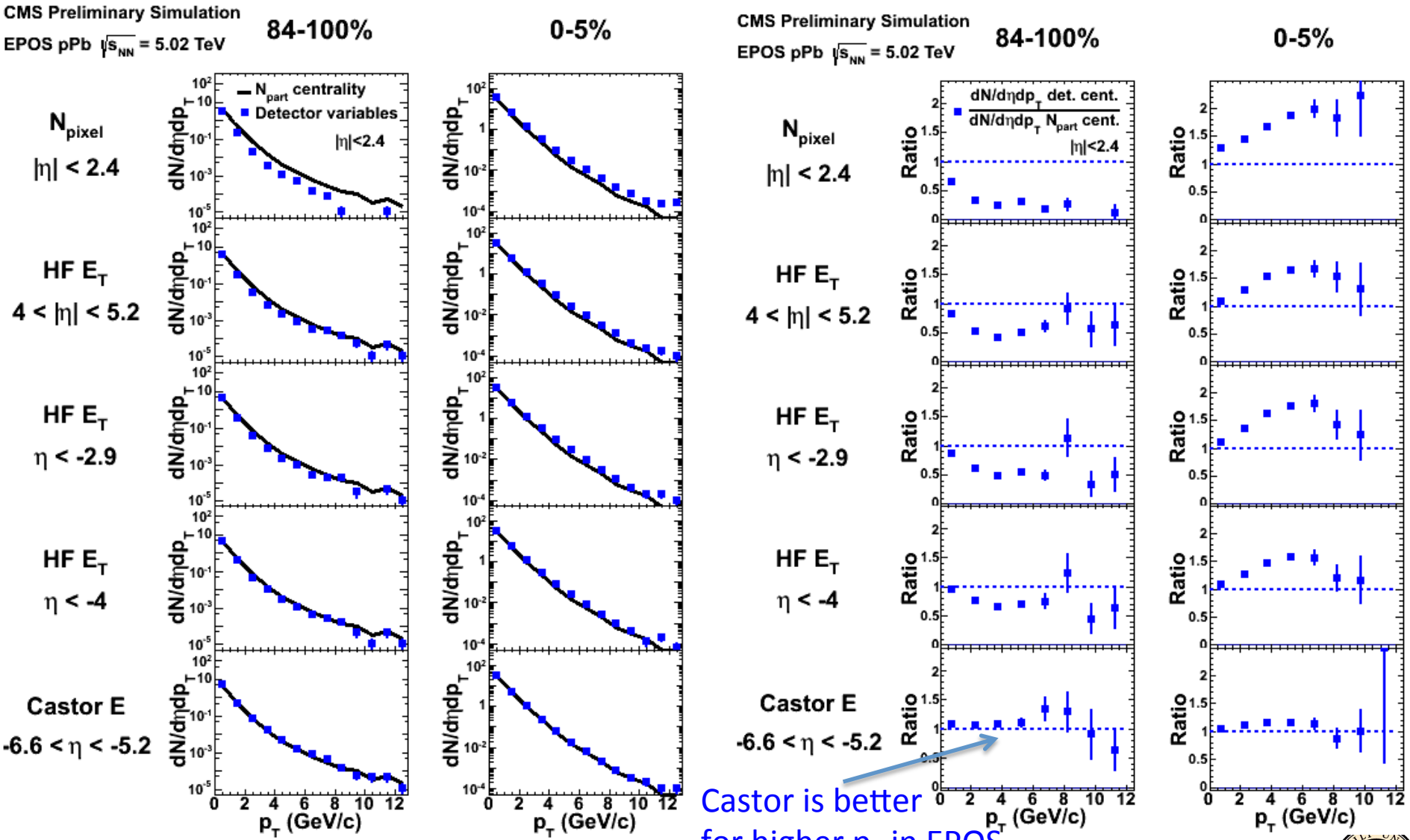
AMPT simulation



Still best up to p_T = 10 GeV/c

p_T dependent biases in EPOS

EPOS simulation



Castor is better for higher p_T in EPOS

Estimating $\langle N_{coll} \rangle$ with Glauber + NBD fit

<N_{coll}> estimation: Glauber + NBD

Negative binomial distribution (NBD) can describe the pp multiplicity distribution

Glauber + NBD

Sampling NBD "N_{coll}" times and sum them together can describe the multiplicity distribution in pPb

Fit the multiplicity or ΣHF E_T from pPb by Glauber + NBD, slice it to define centrality and estimate the <N_{coll}>

NBD: $p_{\mu,k}(n) = \frac{\Gamma(n+k)}{\Gamma(n+1)\Gamma(k)} \frac{(\mu/k)^n}{(\mu/k+1)^{n+k}}$

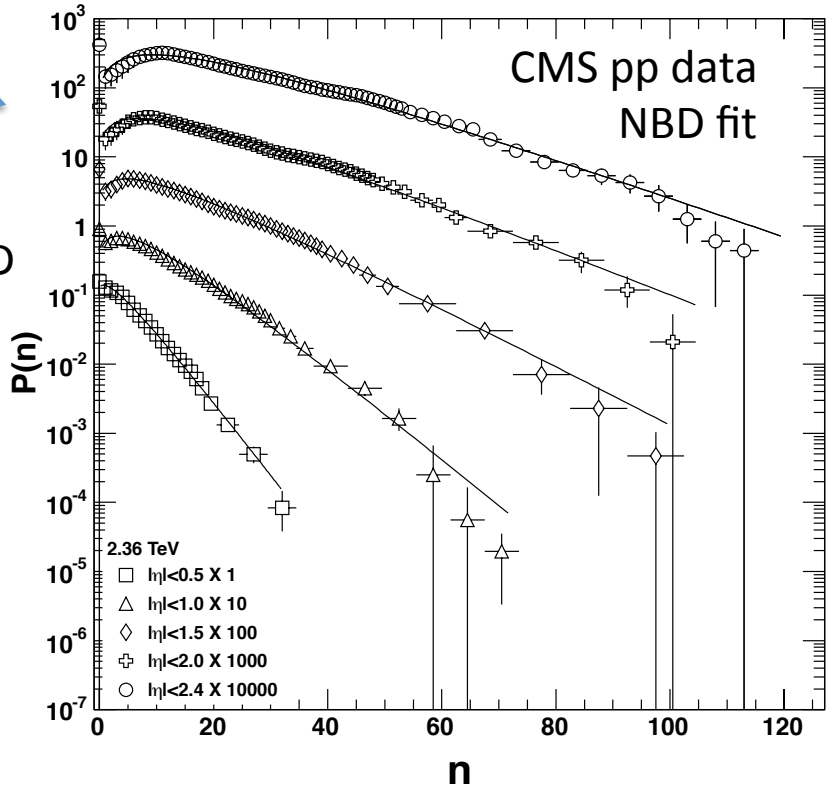
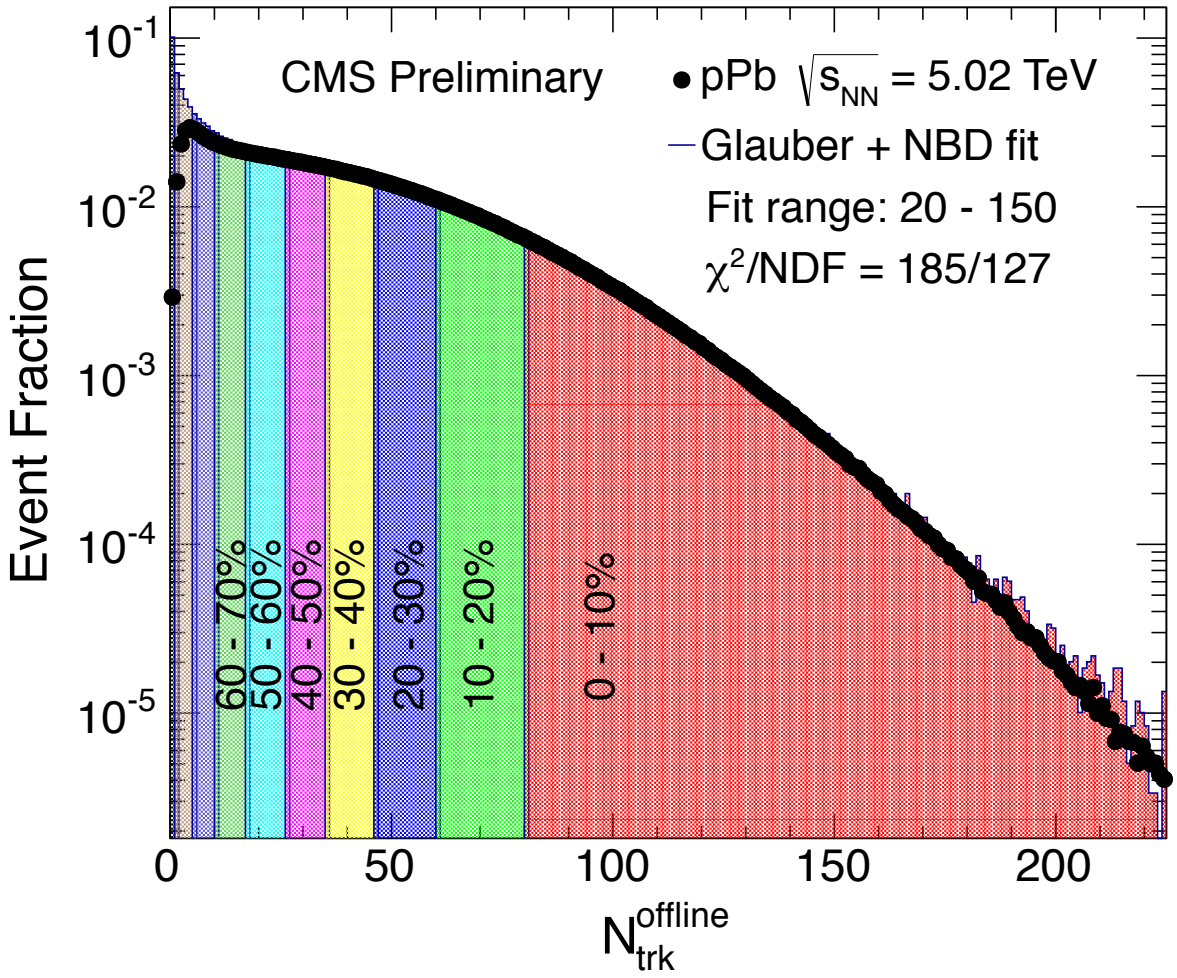


FIG. 4: Primary charged hadron multiplicity distributions for $|\eta|$ <0.5 to 2.4 for $\sqrt{s} = 2.36$ TeV. The solid lines drawn along the data-points correspond to respective fits of NBD. The error-bars include both the statistical and the systematic uncertainties

arXiv:1202.4221

Fold N_{coll} distribution with NBD

Fitting the distribution

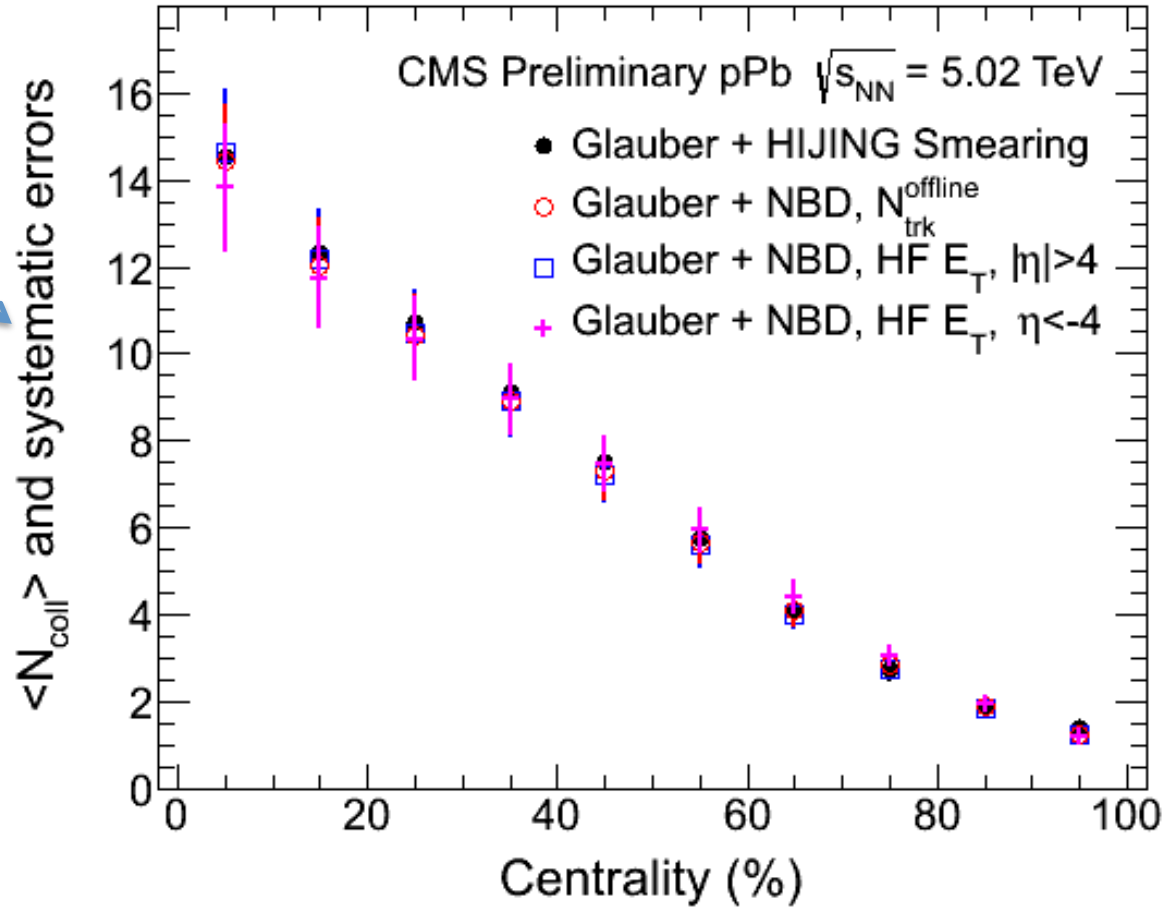


$N_{trk}^{offline}$: charged particle with p_T>0.4 GeV/c and |η|<2.4

- Fit the real data multiplicity distribution with the Glauber + NBD
- Similar study is done for ΣHF E_T

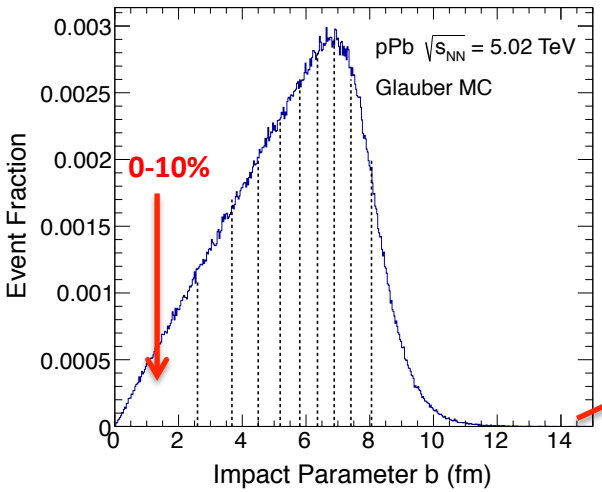
$\langle N_{coll} \rangle$ from different methods agree well

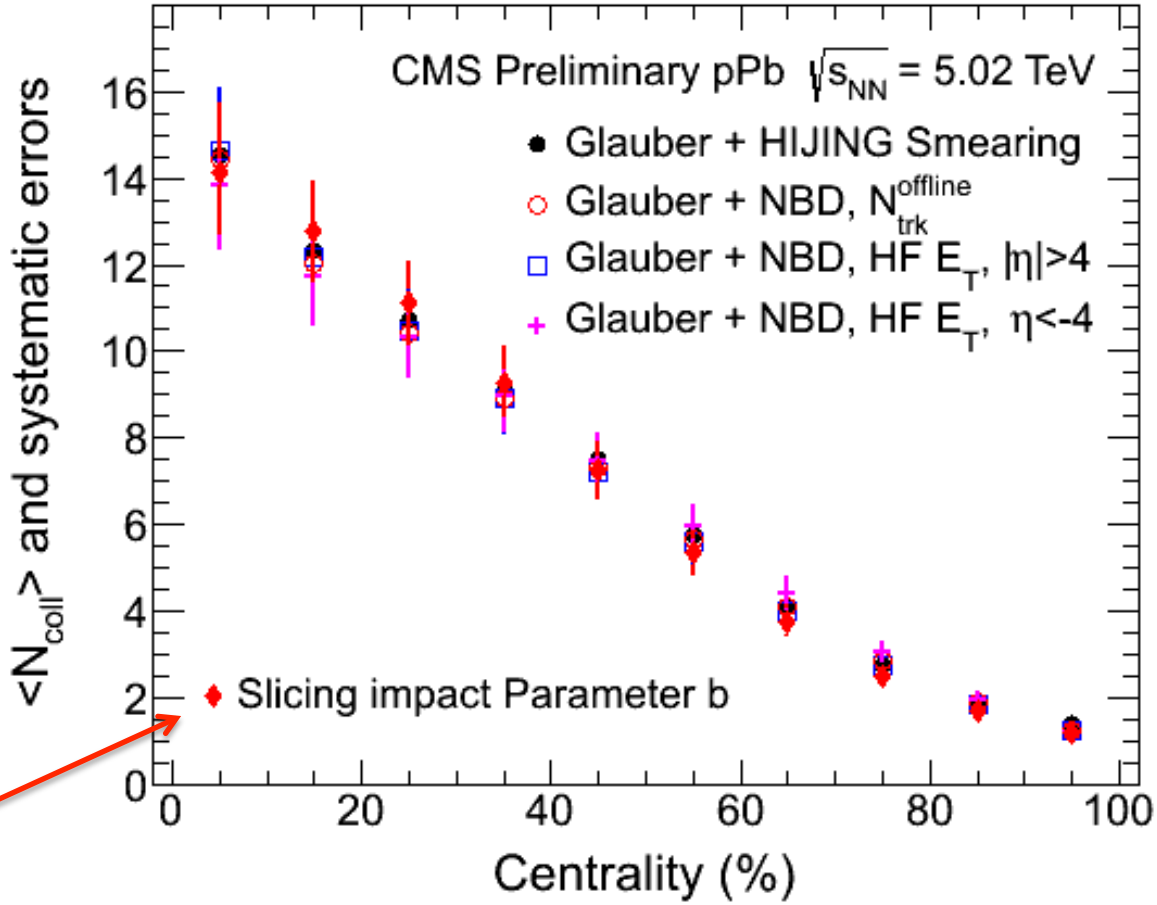
Uncertainties of Glauber parameters



- Glauber + Smearing is another method for cross check
- Different methods show small difference
- $\langle N_{coll} \rangle$ estimated from different detector η ranges agree well

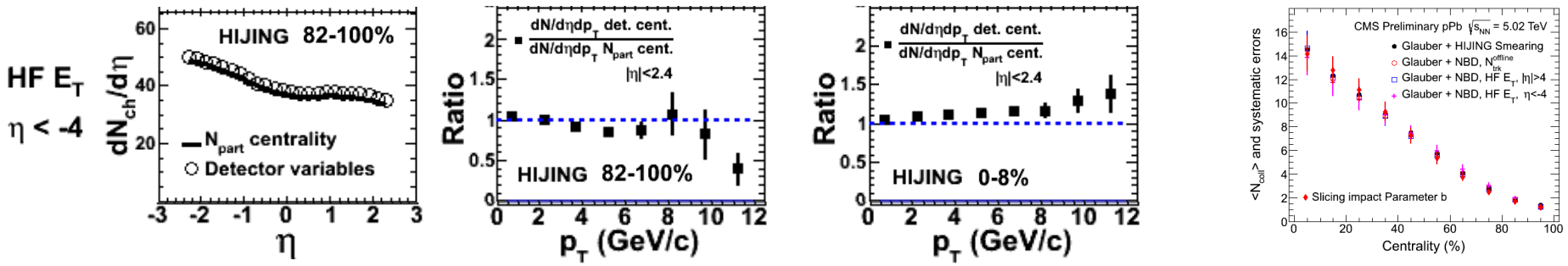
<N_{coll}> from different methods agree well





<N_{coll}> estimated from different methods and variables agree well

Summary



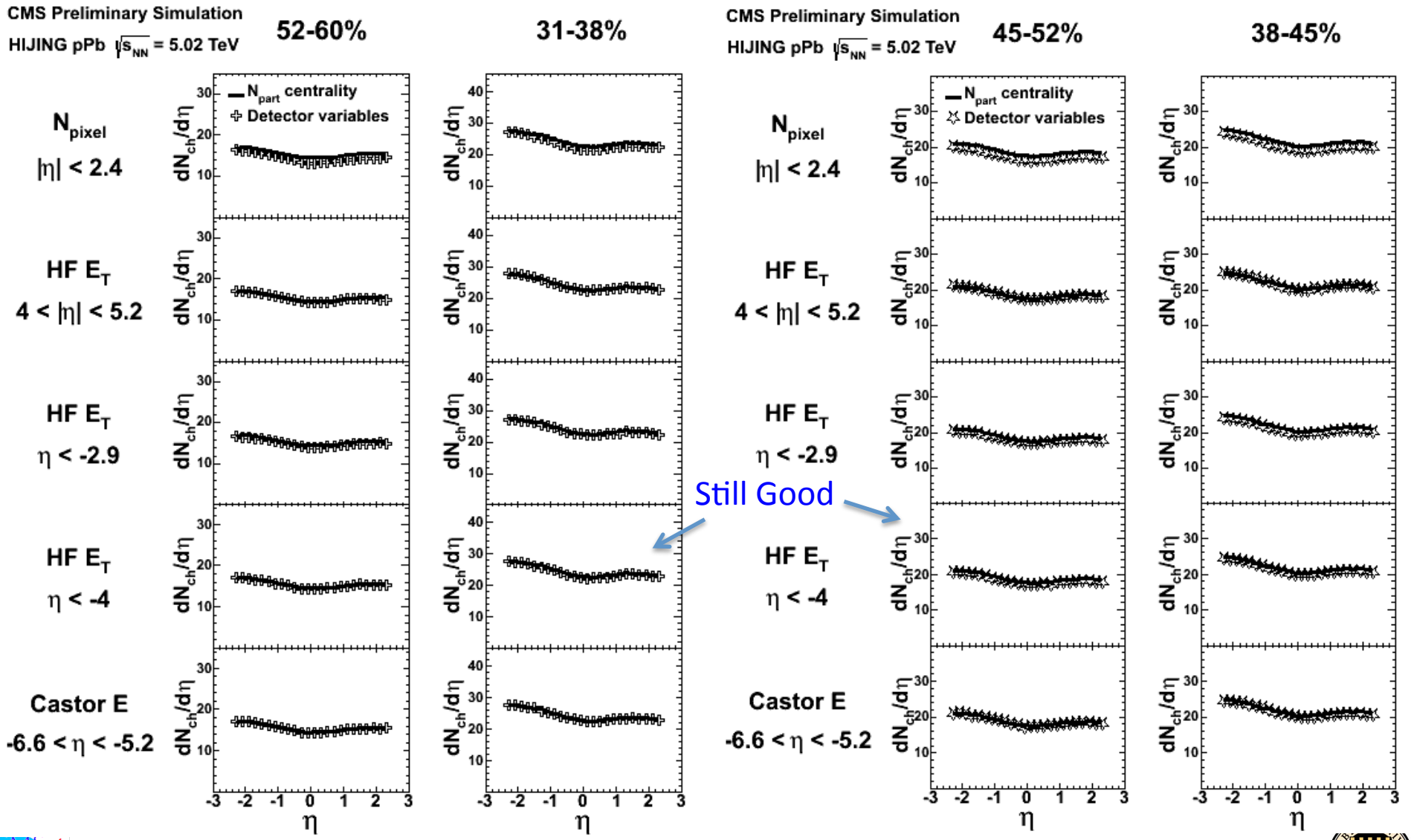
- The centrality measurement for $dN_{ch}/d\eta$ analysis are studied in HIJING, EPOS and AMPT. Pb going side forward HF E_T $\eta < -4$ is the best centrality variable
- The centrality variable HF E_T $\eta < -4$ is still good for p_T up to 10 GeV/c in HIJING and AMPT, but Castor Energy with $-6.6 < \eta < -5.2$ is better in EPOS
- $<N_{coll}>$ estimated from different methods and different variables agree well

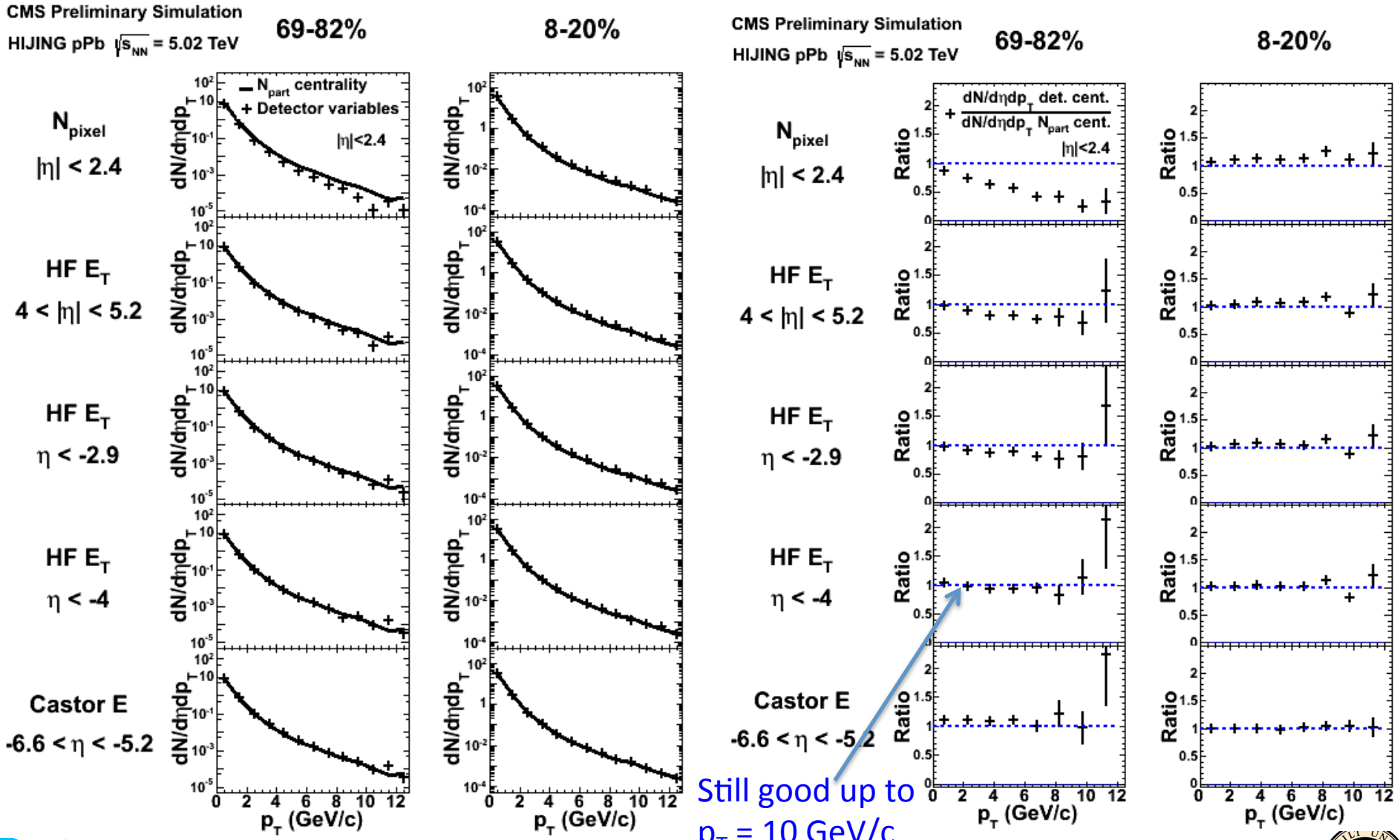
Yetkin Yilmaz, afternoon:
Centrality dependent measurements from CMS

Backup

HIJING other centrality bins

HIJING simulation



p_T dependent biases in HIJING for other centrality bins

HIJING simulation