PHOBOS: centrality in dAu @ 0.2 TeV (at RHIC)

- Efficiency determination in dAu was harder than for AuAu and it had both lower overall efficiencies and larger variations with centrality
- Choice of centrality “variable” in data had a significant effect on some results (i.e. must worry about more than just getting a high/low $\langle N_{part} \rangle$ value)
- As a result PHOBOS explored many different options and fully propagated these different options through many analyses
- The multiplicity analysis provided PHOBOS a good foundation to get a handle on these things
- Overall: Centrality in pA is likely somewhat nontrivial & it is very good we are talking about it

PHOBOS: Significant efficiency variations as function of centrality in d+Au

First result 4 centrality bins:
Phys. Rev. Lett. 91, 072302 (2003)

TABLE I. Estimated values for $\langle N_{part} \rangle$ and $\langle N_{coll} \rangle$ and the respective systematic uncertainties for the four centrality bins used in this analysis. Also shown is the average event selection efficiency for each of the bins. The centrality bins are based on the signal of multiplicity counters covering $3.0 < |\eta| < 5.4$

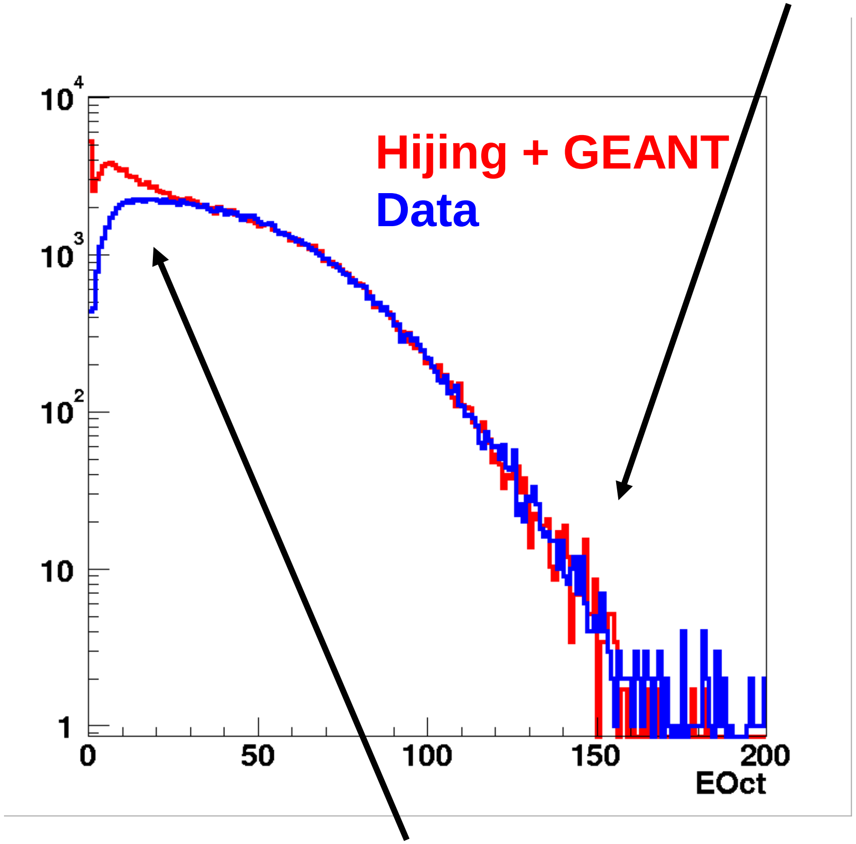
Centrality selection	$\langle N_{part} \rangle$	$\langle N_{coll} \rangle$	Efficiency
0%–20%	15.5 ± 1.0	14.6 ± 0.9	82%
20%–40%	10.9 ± 0.9	9.7 ± 0.8	73%
40%–70%	6.7 ± 0.9	5.4 ± 0.8	49%
70%–100%	3.3 ± 0.7	2.2 ± 0.6	14%

→ Will be better in CMS (also improved in PHOBOS with better vertexing algos in peripheral region), but still need to nail this down for good physics measurements.

d+Au Event Selection

- Event Selection
  - Clean-up by requiring a valid silicon vertex
- Efficiency
  - Used a shape matching algorithm between Data and Simulations (HIJING or AMPT)
  - Efficiency includes Trigger and Vertex finding efficiency

Shapes agree reasonably in High multiplicity region



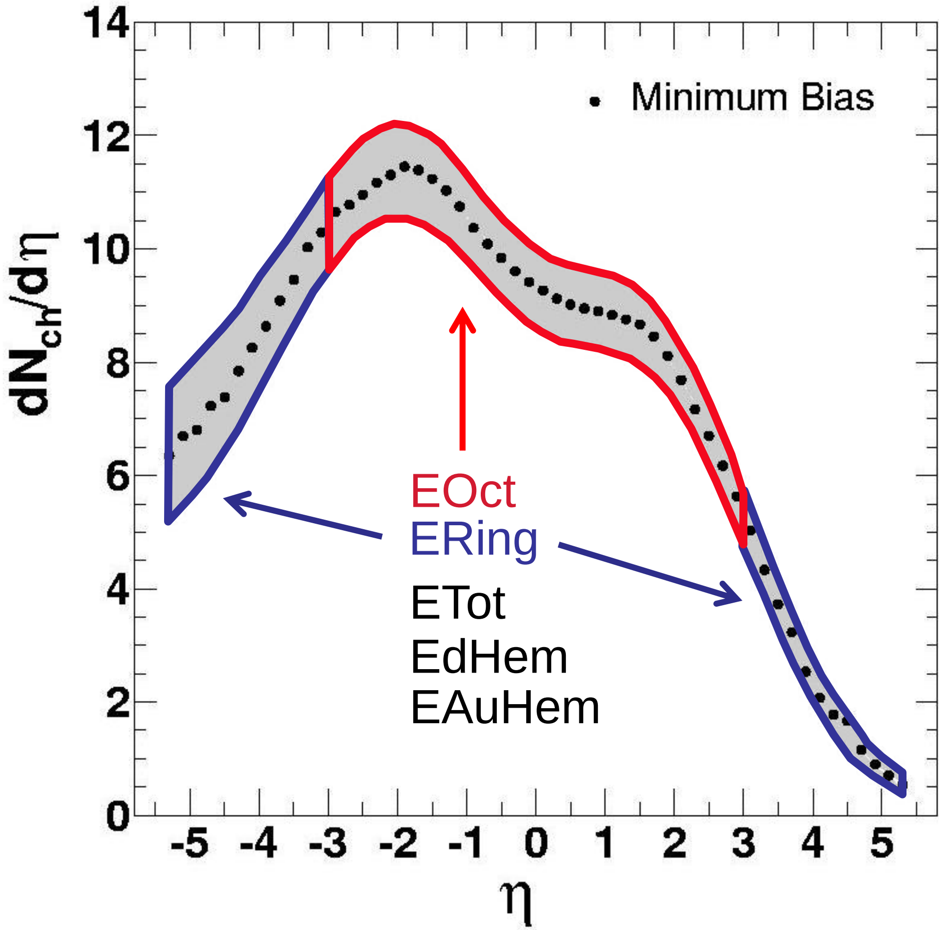
Data inefficient for more peripheral events

EOct is the summed charge deposited in the Octagon detector

From R. Hollis 2004 DNP meeting

d+Au Data Centrality Regions

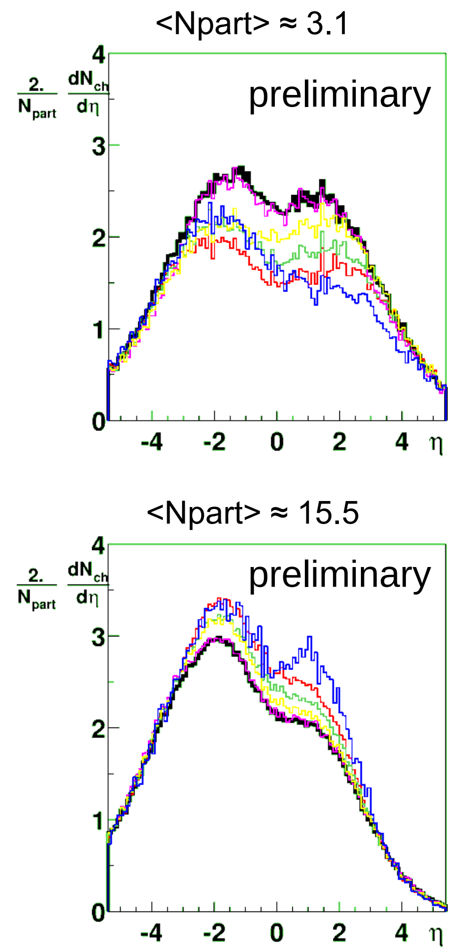
- Unique PHOBOS η coverage
  - Many regions to pick from
  - Not just the 'paddles'
- All regions were used
  - same basic algorithm
  - Sum the charge deposited in these regions (from Silicon)



Which Region of η is best? Why do we need so many?

- Auto-Correlations!
  - Could this introduce a Centrality Bias?
- Method (here)
  - Cut on N_{part} directly (Black)
    - Form <dN/dη>
    - Calculate the $<N_{part}>$
  - Cut on all the other variables such that all have the same $<N_{part}>$
    - Form <dN/dη>
- Each method derives a different <dN/dη> for the same $<N_{part}>$
- ERing yields the closest shape

HIJING+Detector



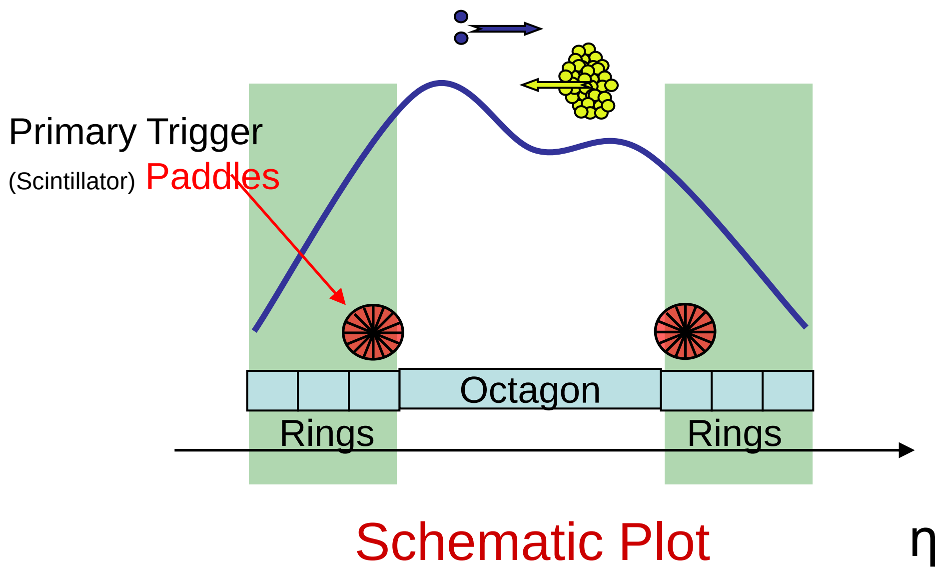
Npart
EOct
ETot
ERing
AuHem
dHem

See also Appendix of Nucl. Phys. A 757, 28 (2005) and PRC 72, 031901(R) (2005)

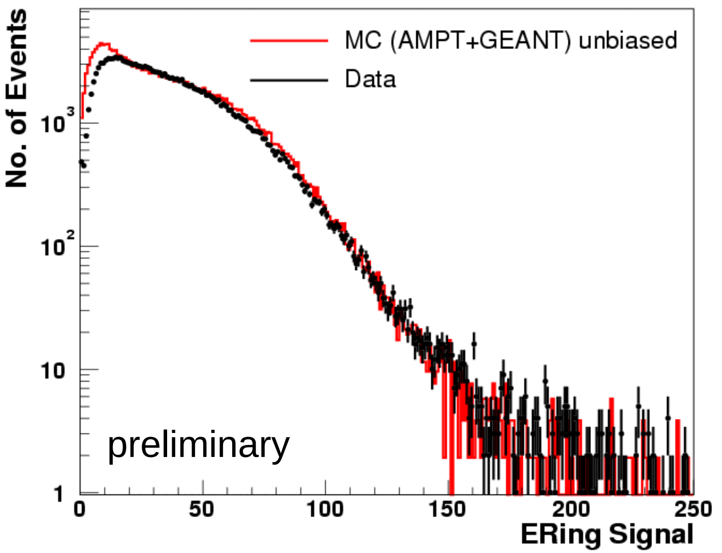
From R. Hollis 2003 DNP meeting

d+Au Centrality

- Centrality binning
  - Used ERing
  - Least auto-correlation bias (from MC and Data studies)
- Centrality
  - Correct for efficiency
  - Divide data into 20% bins



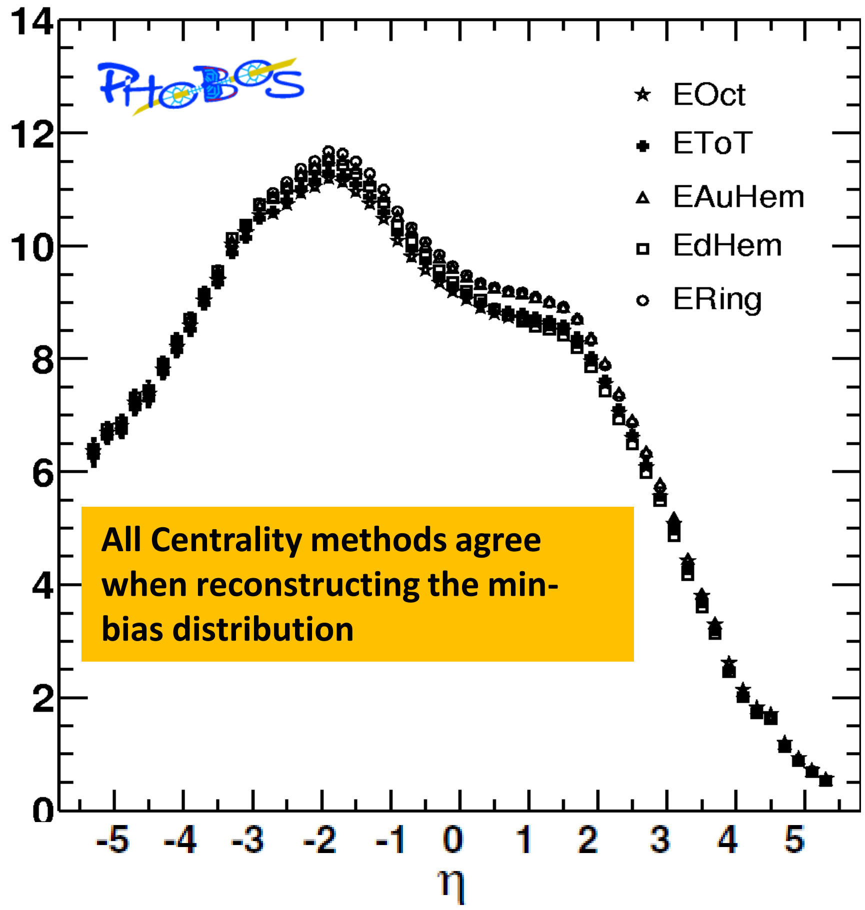
Schematic Plot
not to scale



From R. Hollis 2004 DNP meeting

Cross-check performed with dAu Data: Reconstructed MinBias distribution agrees for different centrality measures

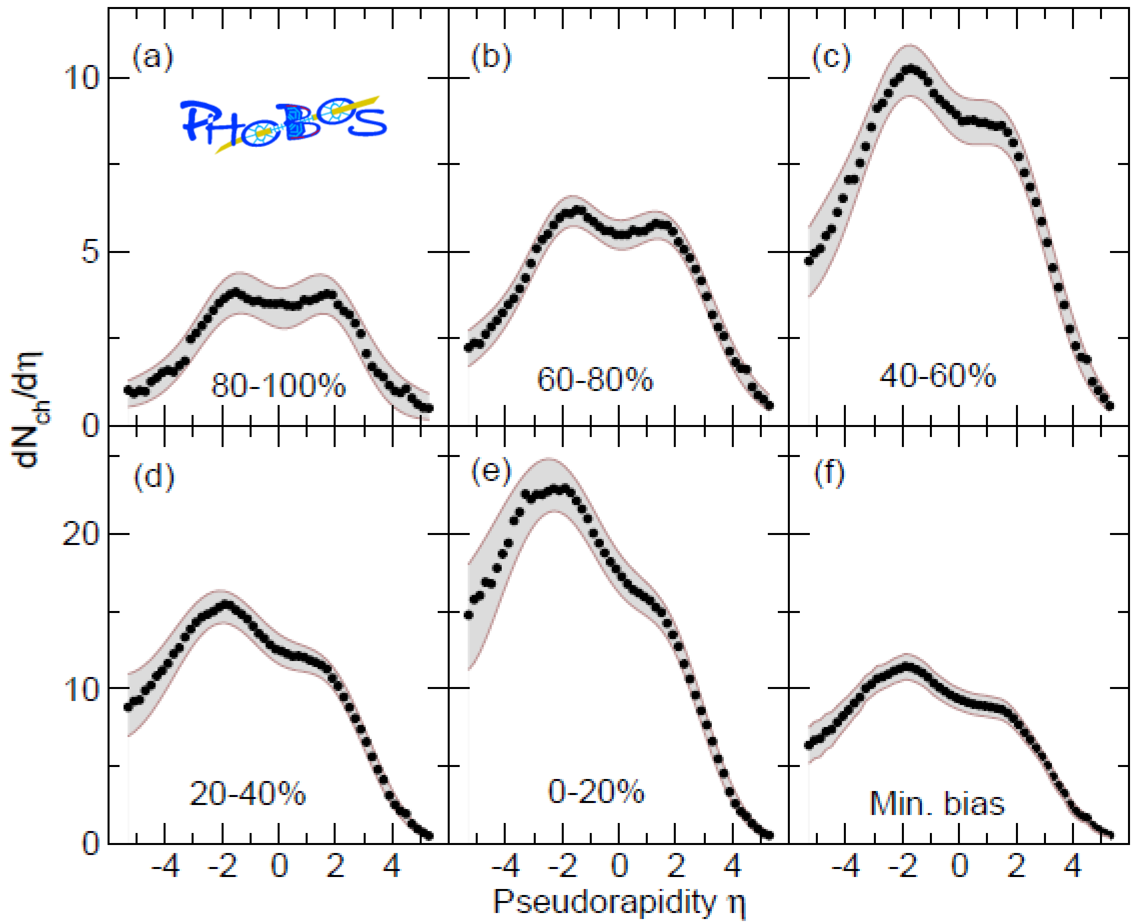
PRL 93, 082301 (2004)



→ Importance of closely coupling Centrality work with Multiplicity analyses

“Final word” from PHOBOS: dAu Multplicity Distributions in 5 Centrality Bins

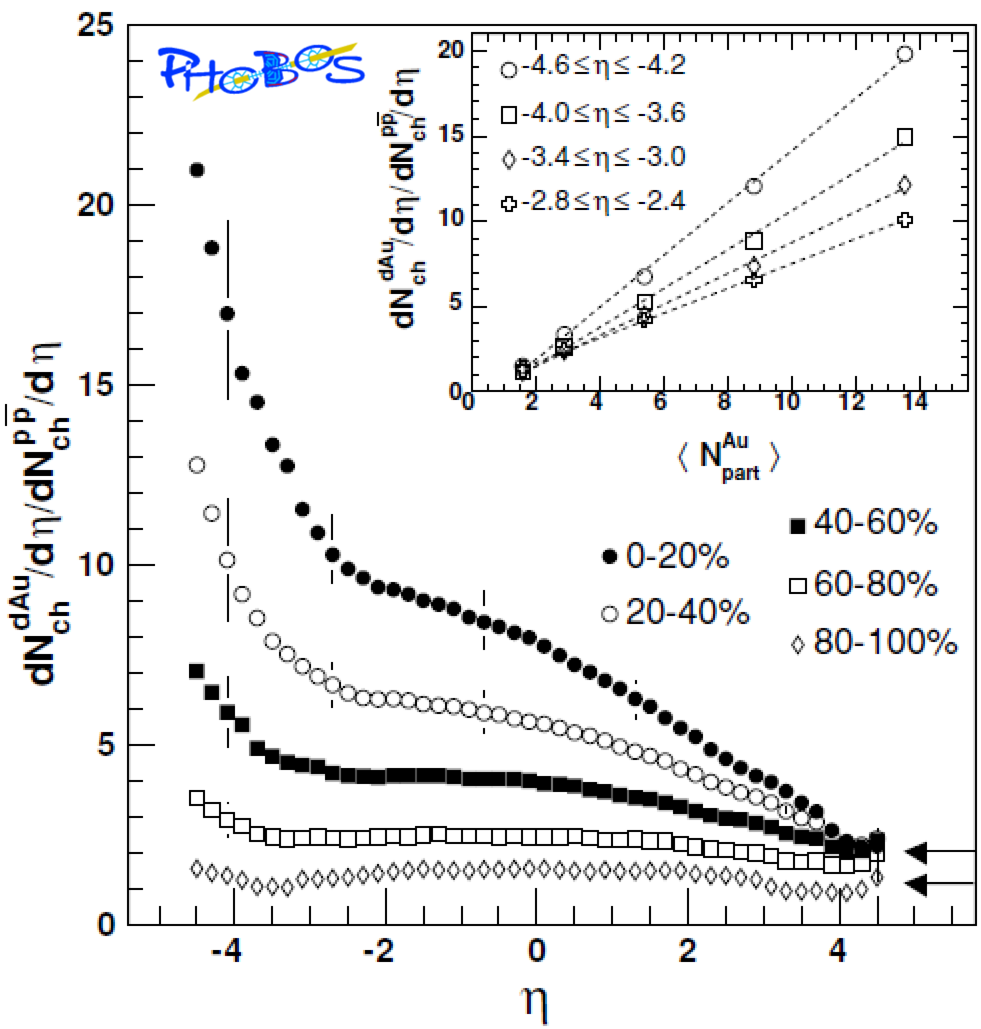
Phys. Rev. C 83, 024913 (2011)



Two other views of same data (1/2)

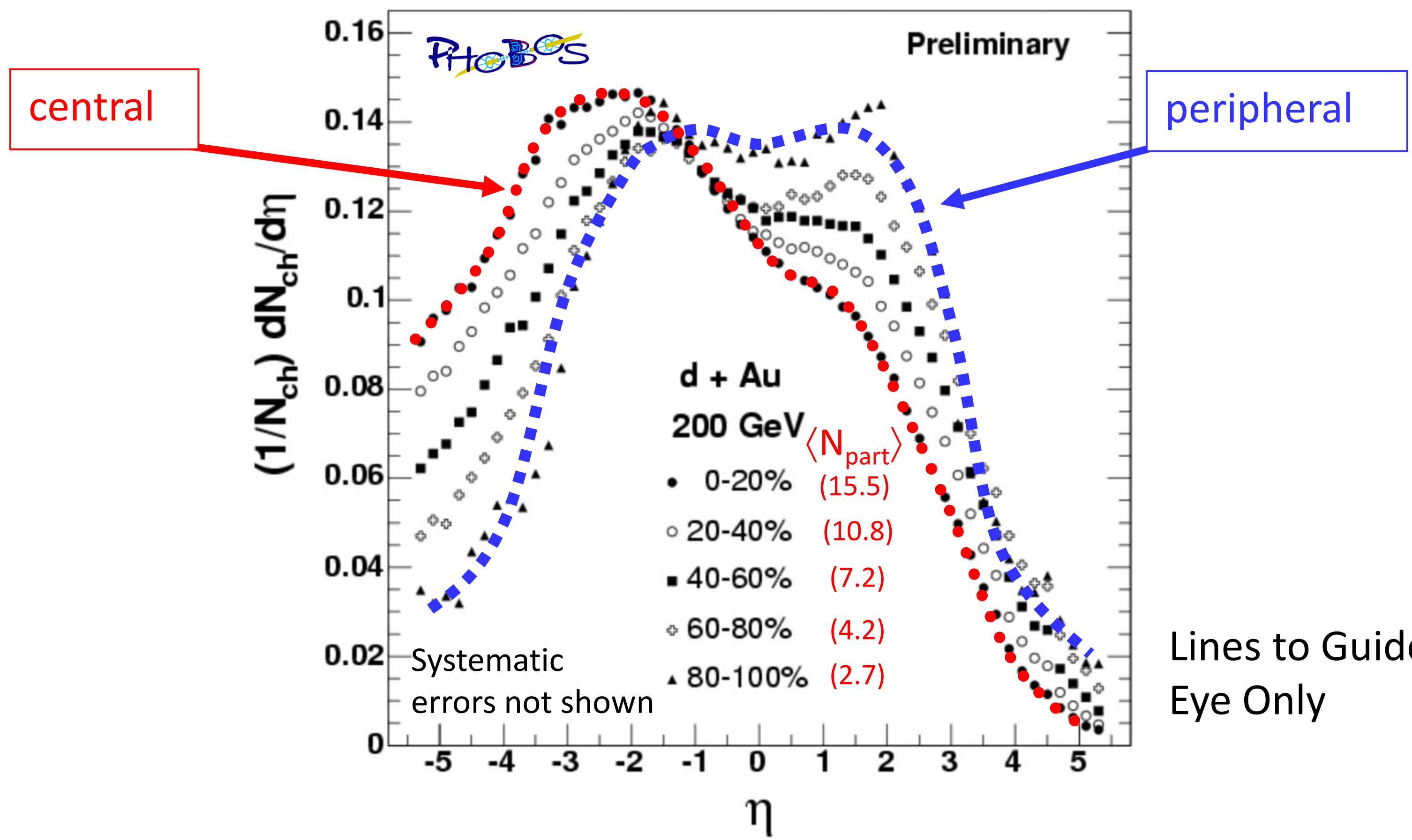
Ratio of dAu to inelastic pp at same energy

PHYSICAL REVIEW C **72**, 031901(R) (2005)



Two other views of same data (2/2)

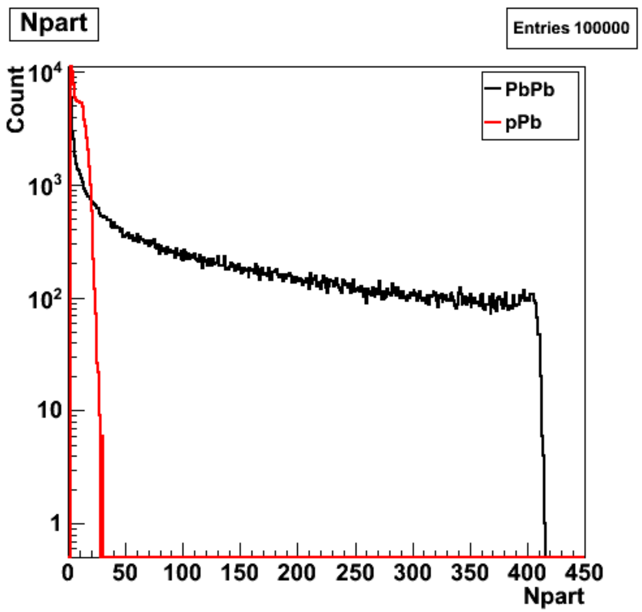
dAu results ormalized to N_{ch} so can compare shape change

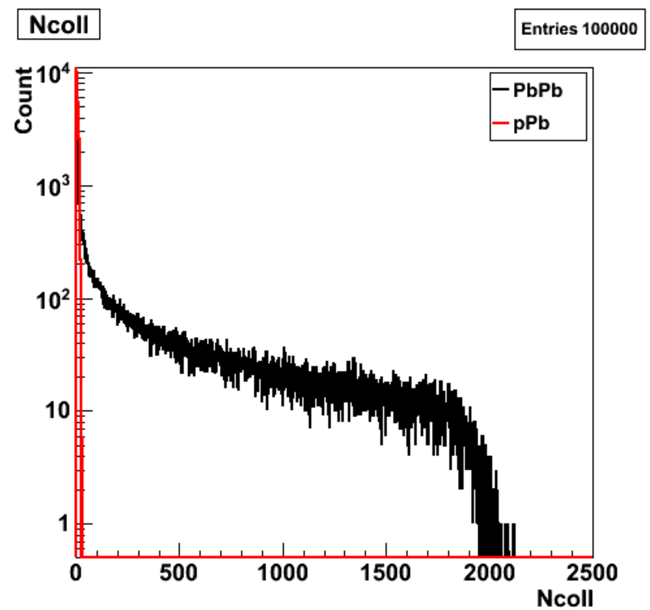


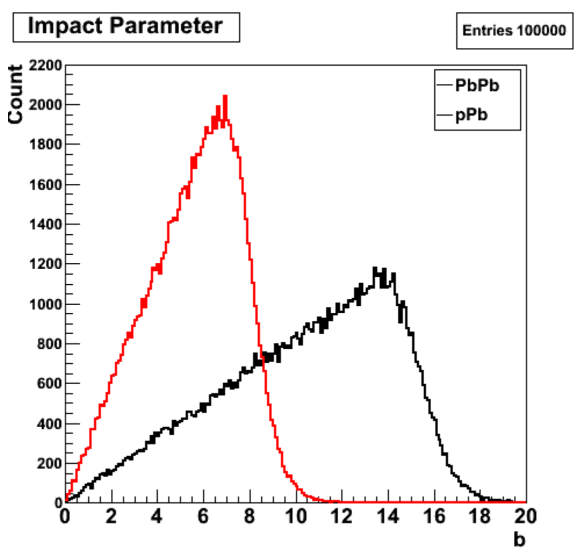
Lines to Guide Eye Only

From 2004 Talk by D. Hofman at Moriond http://moriond.in2p3.fr/QCD/2004/Indext.html

Final Comment – Glauber Parameters







Would be very helpful if we could come to an agreement on the Glauber "baseline" parameters and associated systematic uncertainties (sooner the better).

ADDITIONAL

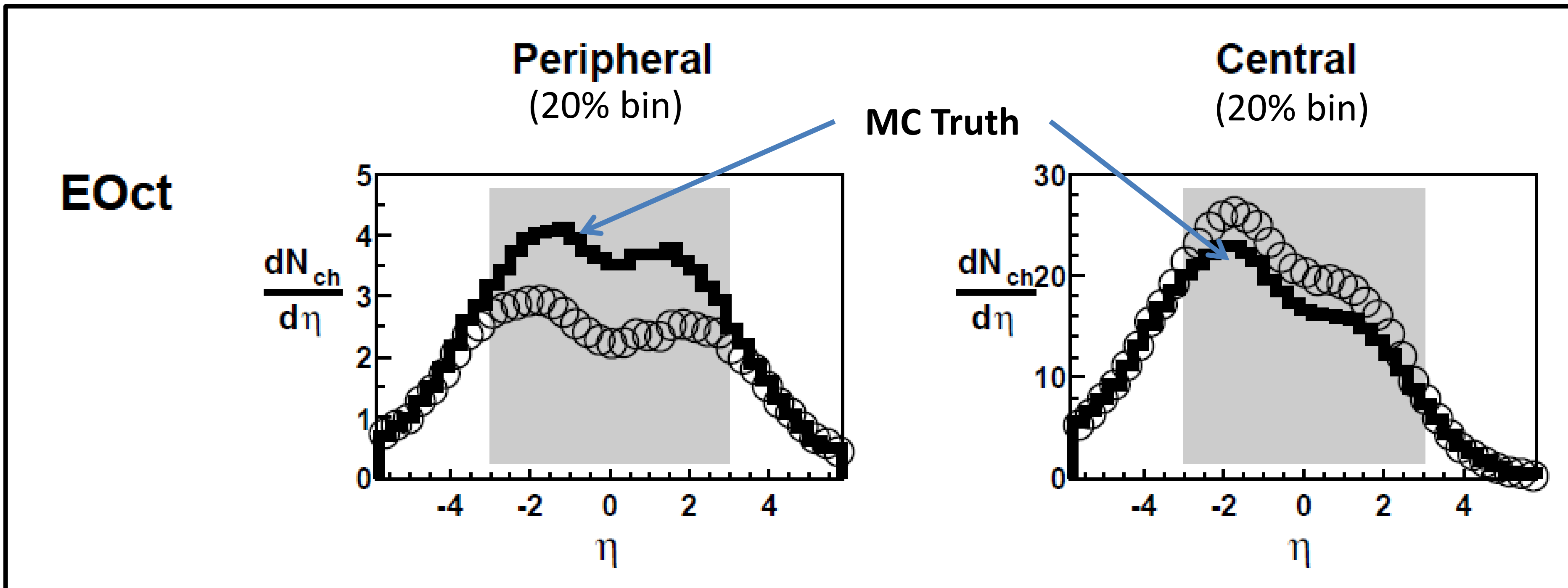
Centrality "Biases" in 0.2 TeV d+Au

Example shown using HIJING MC + full GEANT PHOBOS detector simulation.

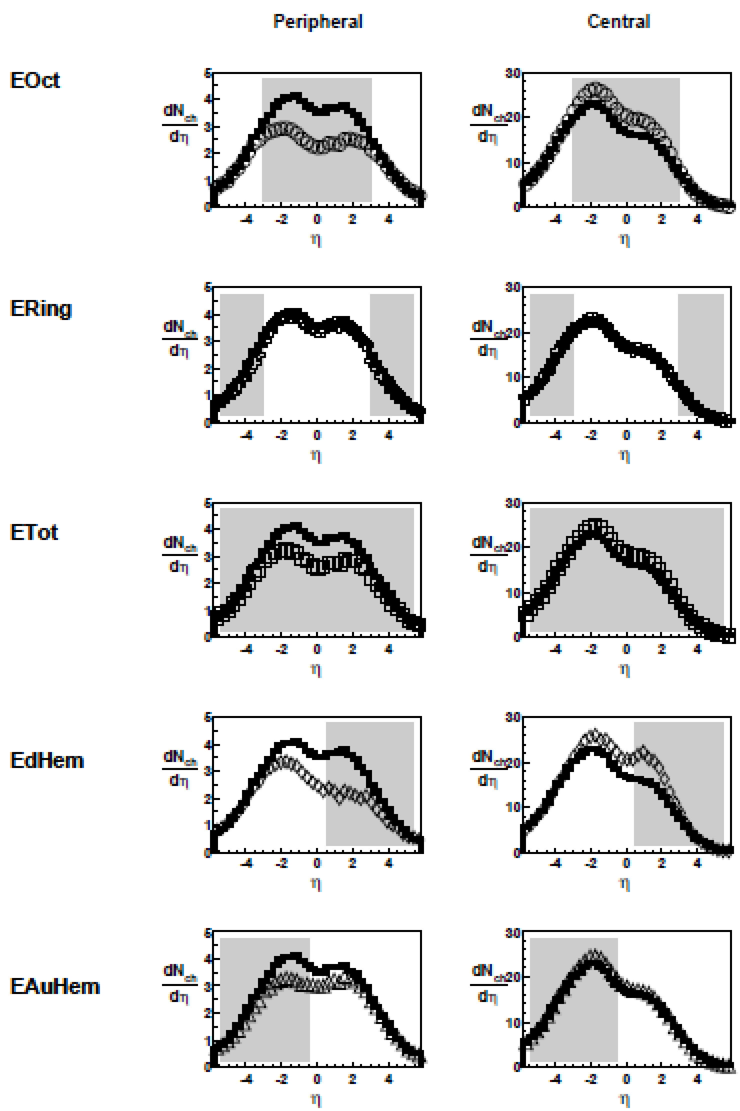
Grey Band = pseudorapidity region covered by EOct centrality variable
(i.e. EOct is centrality from Energy in Octagon Silicon Detector for |Eta|<3)

Solid Marker = MC Truth

Open Circles = Reconstructed result from MC analysis using that centrality definition



Centrality Biases in 0.2 TeV d+Au

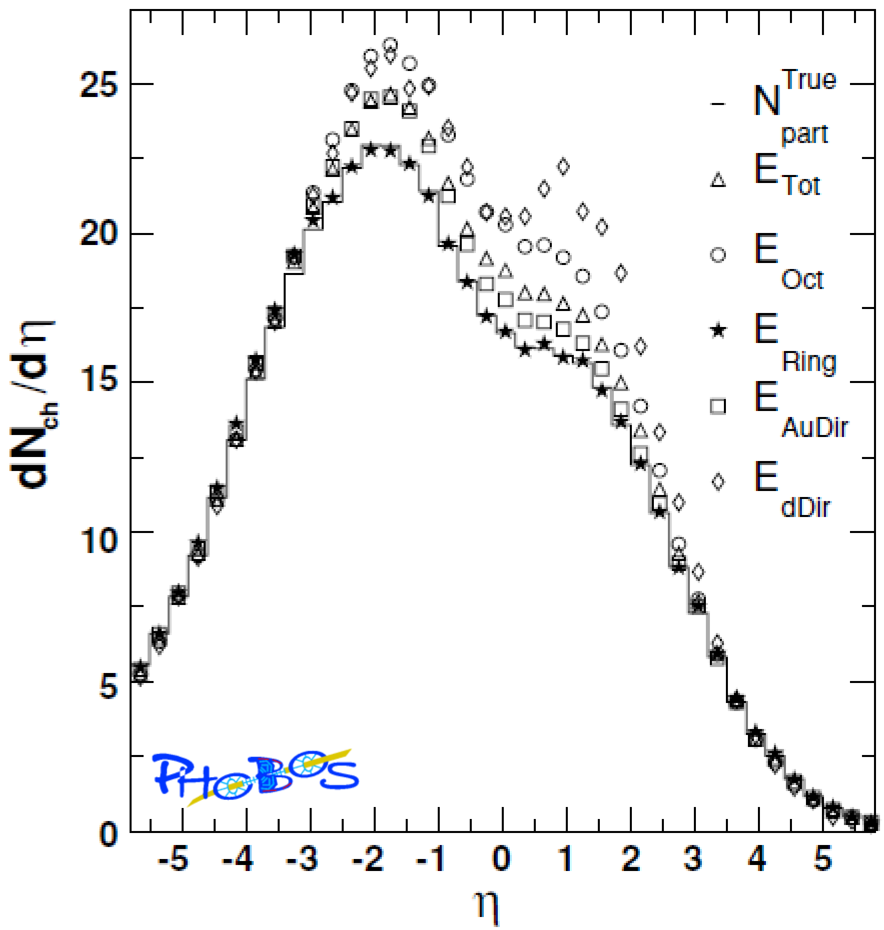


From Richard Hollis PhD Thesis

Fig. also in Appendix of Nucl. Phys. A 757, 28 (2005)

Figure 71. Centrality variables and correlation biases in $\sqrt{s_{NN}} = 200$ GeV $d + Au$ HIJING simulated collisions. Solid lines represent the MC Truth distribution and markers represent the reconstructed distributions from the corresponding centrality variables.

Another published “biases” example



PHYSICAL REVIEW C 72, 031901(R) (2005)

FIG. 1. HIJING simulations of the $dN_{ch}/d\eta$ distributions of charged particles in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV obtained for a selected $N_{part}^{True} = 15$ (solid line) compared with four other distinct centrality measures (symbols) done for centrality bins that yield to the same $\langle N_{part}^{True} \rangle$.

Data Check of dAu Centrality Biases

PHOBOS Collaboration / Nuclear Physics A 757 (2005) 28–101 95

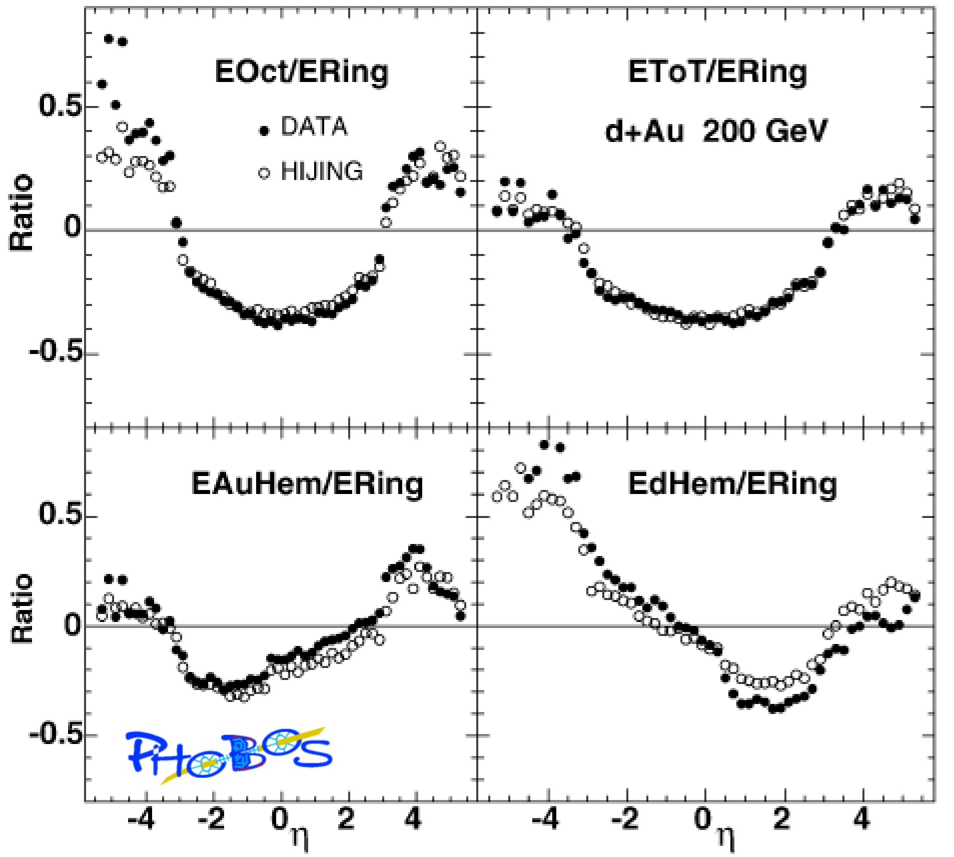
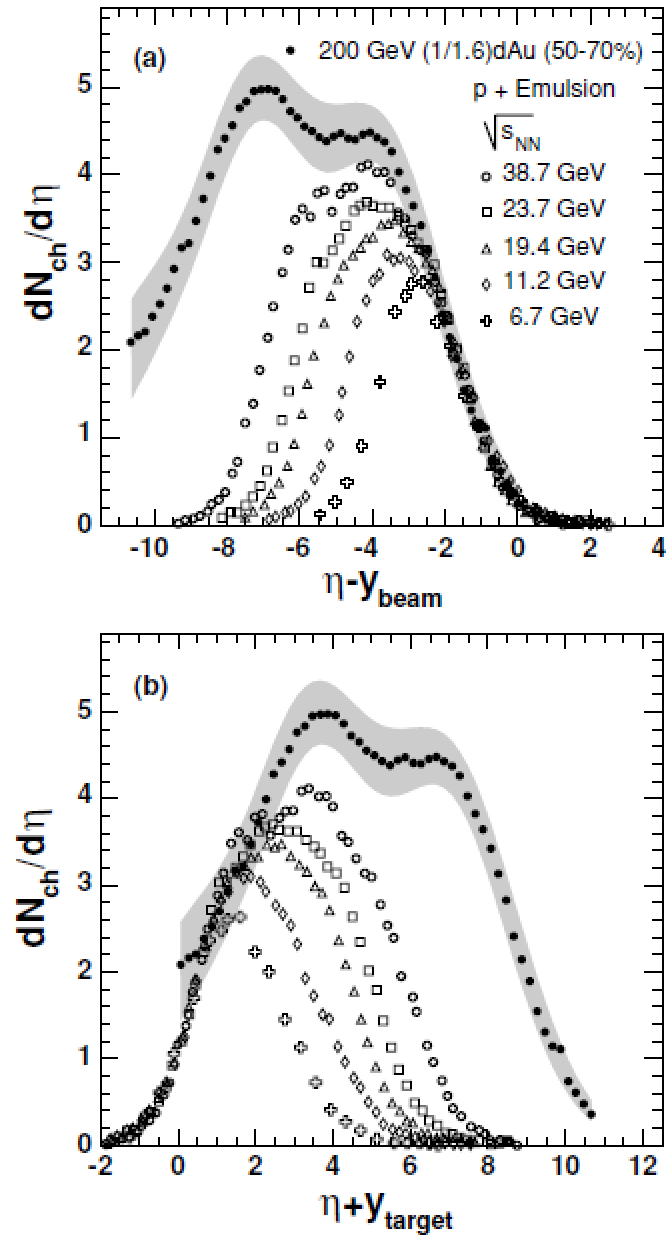


Fig. 43. Ratios of reconstructed $dN_{ch}/d\eta$ distributions in $d+$Au collisions at $\sqrt{s_{NN}} = 200$ GeV for both data and MC simulations using different centrality measures, each of which is selecting on the same percentile of central collisions. The good agreement in these ratios gives confidence that the MC simulations are providing a good basis on which to study the effects of biases created in the data that result from using different regions of pseudorapidity for the centrality determination.

Note: ERing is in “Limiting Fragmentation Scaling” Region

PHYSICAL REVIEW C **72**, 031901(R) (2005)

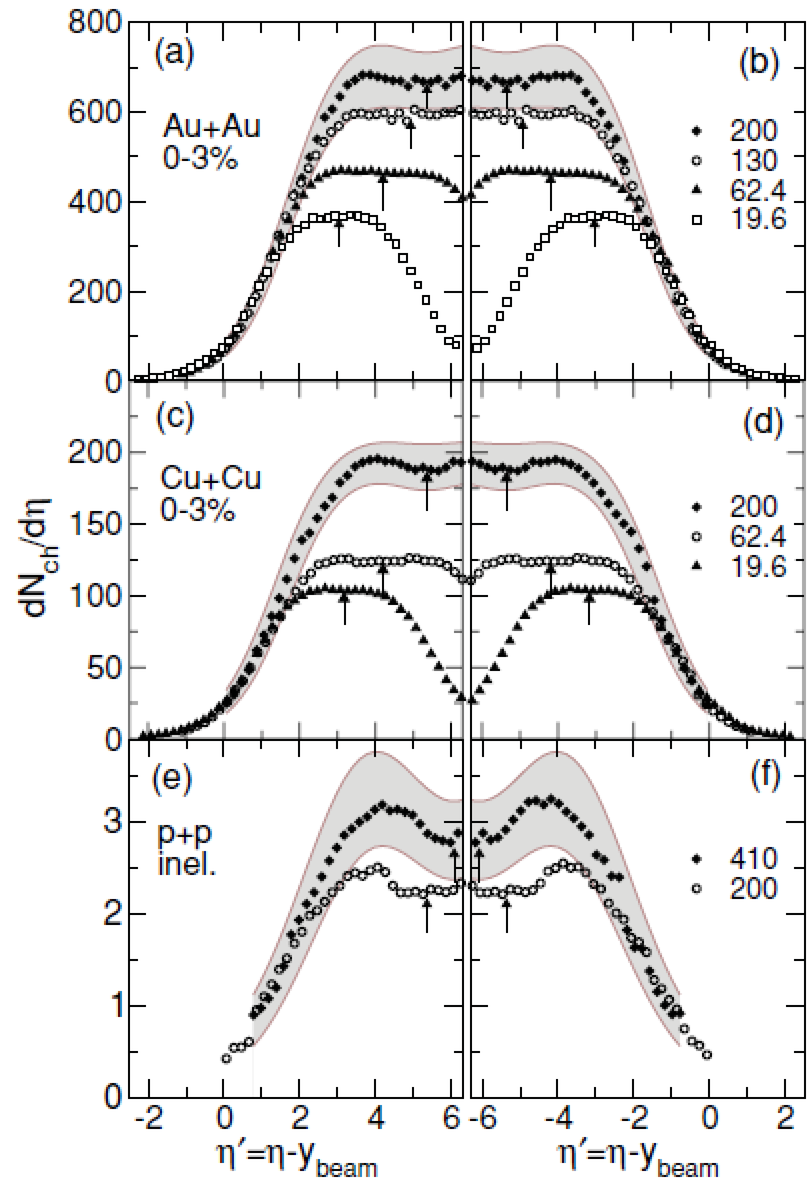
FIG. 6. (a) Comparison of $dN_{ch}/d\eta$ distributions for d+Au collisions scaled (see text) to p+Em collisions (sum of shower and gray tracks) at five energies [4,27,28]. η measured in the c.m. system has been shifted to $\eta - y_{beam}$ to study fragmentation regions in the deuteron/proton rest frame. (b) Same as (a), but shifted to $\eta + y_{target}$ to study fragmentation regions in the gold/Emulsion rest frame.



Limiting Fragmentation Scaling AuAu, CuCu, pp

PHYSICAL REVIEW C **83**, 024913 (2011)

FIG. 30. (Color online) Illustration of the extended longitudinal scaling (also known as limiting fragmentation scaling) for Au + Au [panels (a) and (b)], Cu + Cu [panels (c) and (d)], and $p + p$ collisions [panels (e) and(f)]. The systematic errors (90% confidence limit) are shown as shaded areas for the highest energy only for each system. The arrows indicate the location of midrapidity ($\eta = 0$).



Cent. Dependence of Limit. Frag. Scaling in Heavy Ions (AuAu)

Phys. Rev. Lett. 91, 052303 (2003)

FIG. 2. Au + Au data for $\sqrt{s_{NN}} = 19.6$, 130, and 200 GeV, plotted as $dN_{ch}/d\eta'$ per participant pair, where $\eta' \equiv \eta - y_{beam}$ for (a) 0%–6% central and (b) 35%–40% central. Systematic errors (90% C.L.) are shown for selected, typical, points.