Multiplicity Results from PHOBOS Experiment

Centrality Dependence of Charged Particle Pseudorapidity Distributions in d + Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

Rachid NOUICER

University of Illinois at Chicago
and
Brookhaven National Laboratory

for the PHOBOS Collaboration

PHOBOS Collaboration



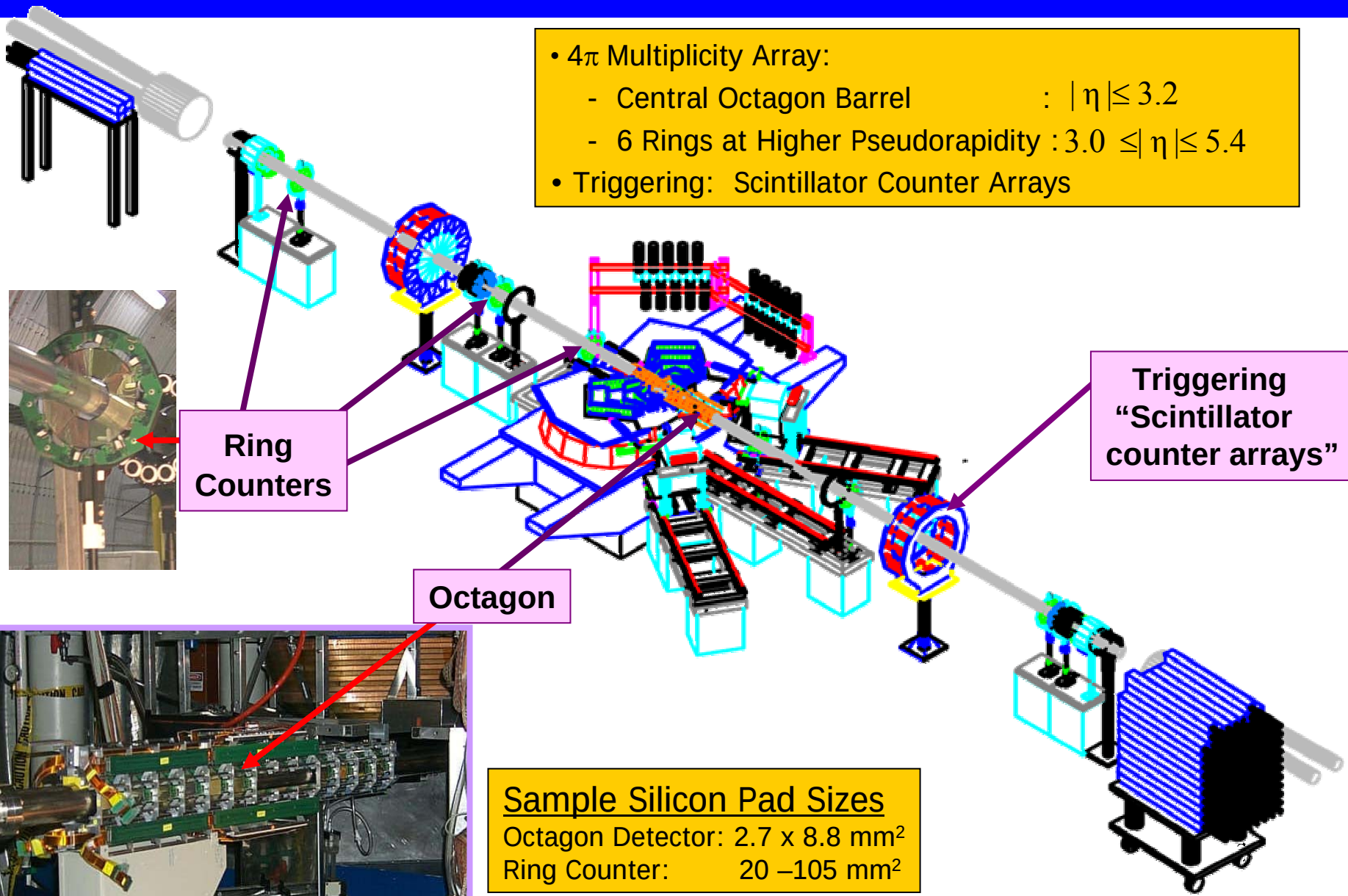
Birger Back, Mark Baker, Maarten Ballintijn, Donald Barton, Russell Betts, Abigail Bickley, Richard Bindel, Wit Busza (Spokesperson), Alan Carroll, Zhengwei Chai, Patrick Decowski, Edmundo García, Tomasz Gburek, Nigel George, Kristjan Gulbrandsen, Stephen Gushue, Clive Halliwell, Joshua Hamblen, Adam Harrington, Conor Henderson, David Hofman, Richard Hollis, Roman Hołyński, Burt Holzman, Aneta Iordanova, Erik Johnson, Jay Kane, Nazim Khan, Piotr Kulinich, Chia Ming Kuo, Willis Lin, Steven Manly, Alice Mignerey, Gerrit van Nieuwenhuizen, Rachid Nouicer, Andrzej Olszewski, Robert Pak, Inkyu Park, Heinz Pernegger, Corey Reed, Michael Ricci, Christof Roland, Gunther Roland, Joe Sagerer, Iouri Sedykh, Wojtek Skulski, Chadd Smith, Peter Steinberg, George Stephans, Andrei Sukhanov, Marguerite Belt Tonjes, Adam Trzupek, Carla Vale, Siarhei Vaurynovich, Robin Verdier, Gábor Veres, Edward Wenger, Frank Wolfs, Barbara Wosiek, Krzysztof Woźniak, Alan Wuosmaa, Bolek Wysłouch, Jinlong Zhang

68 Collaborators; 8 Institutions; 3 Countries

ARGONNE NATIONAL LABORATORY
INSTITUTE OF NUCLEAR PHYSICS, KRAKOW
NATIONAL CENTRAL UNIVERSITY, TAIWAN
UNIVERSITY OF MARYLAND
BROOKHAVEN NATIONAL LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
UNIVERSITY OF ILLINOIS AT CHICAGO
UNIVERSITY OF ROCHESTER

PHOBOS Multiplicity Detector

- 4π Multiplicity Array:
  - Central Octagon Barrel : $|\eta| \leq 3.2$
  - 6 Rings at Higher Pseudorapidity : $3.0 \leq |\eta| \leq 5.4$
- Triggering: Scintillator Counter Arrays

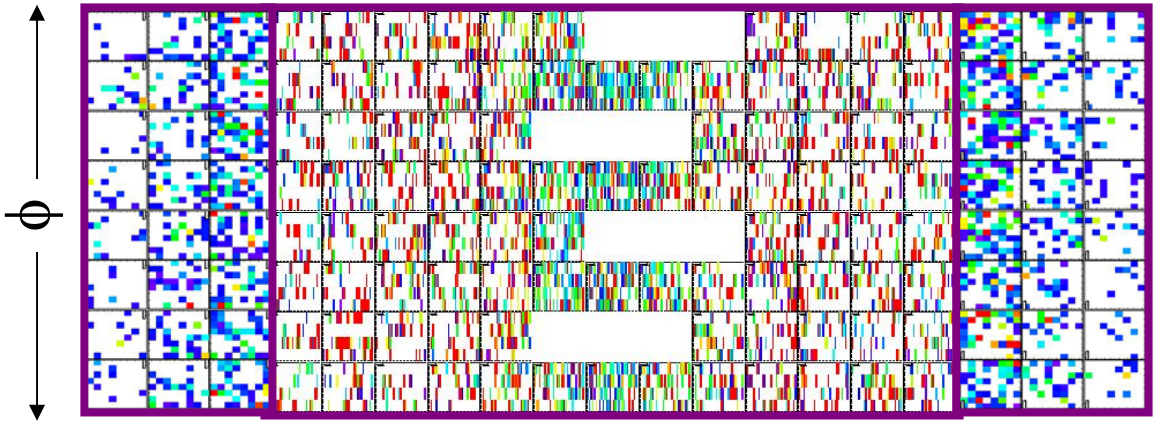


Sample Silicon Pad Sizes

Octagon Detector: 2.7 x 8.8 mm^2
Ring Counter: 20 –105 mm^2

PHOBOS Charged Particle Multiplicity Analysis

Event display of a 200 GeV Au+Au collision



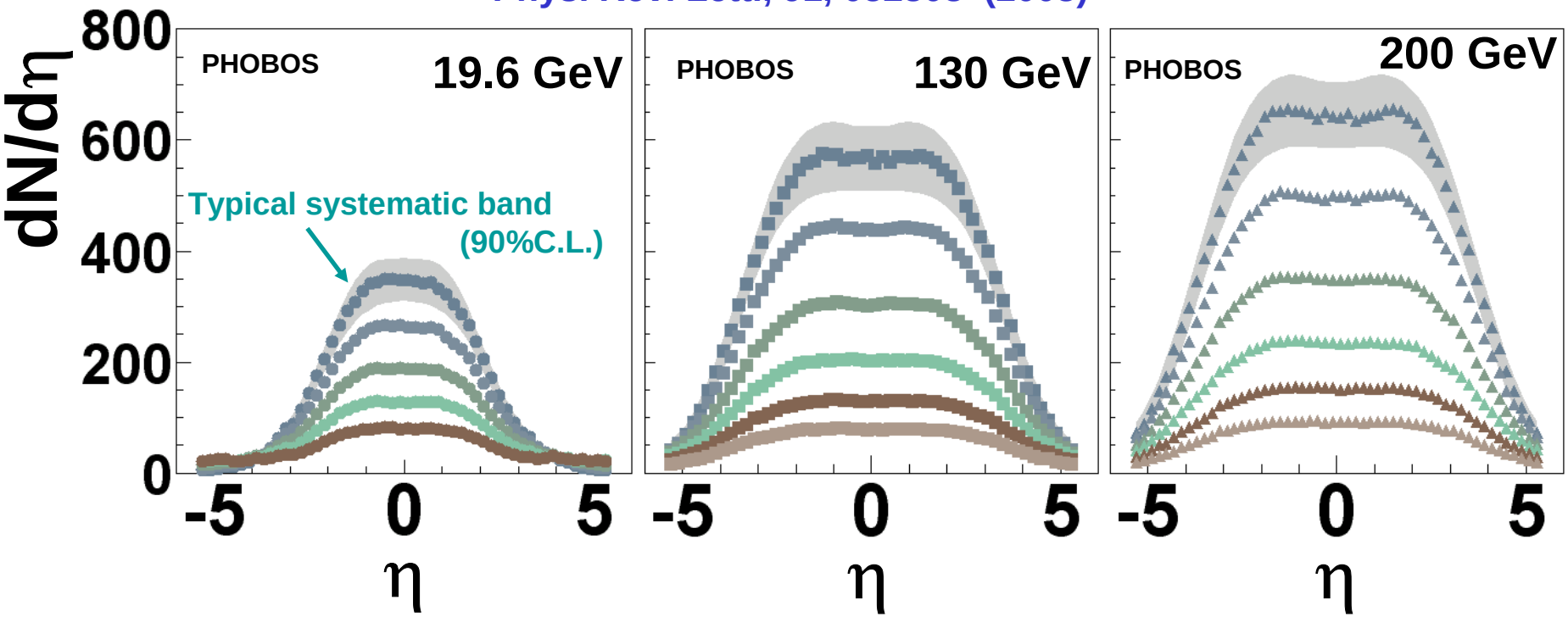
- Two analysis methods :

  1- Hit-Counting analysis based on ratio of hit pads to empty pads using Poisson statistics

  2- Analog analysis based on particle energy deposited in each pad

Extensive Systematic Au + Au Data

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



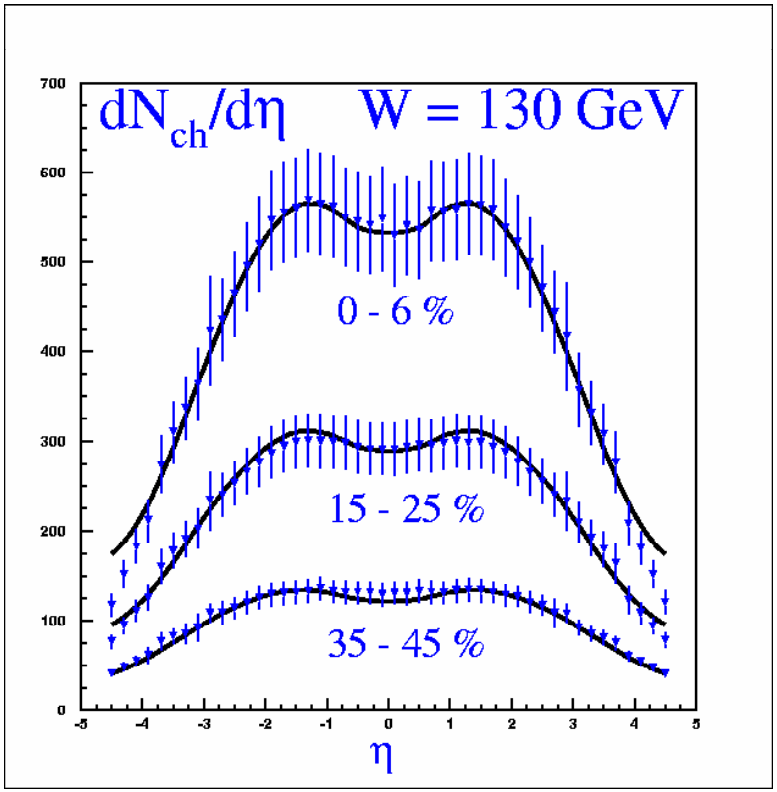
PHOBOS Multiplicity Papers :

- Phys. Rev. Lett. 85, 3100 (2000)
- Phys. Rev. Lett. 87, 102303 (2001)
- Phys. Rev. C 65 , 31901R (2002)
- Phys. Rev. Lett. 88 , 22302 (2002)
- Phys. Rev. C 65 , 061901R (2002)
- Phys. Rev. Lett. 91, 052303 (2003)
- nucl-ex/0301017, subm. to PRL
- nucl-ex/0311009, subm. to PRL

Parton Saturation Describes Au + Au

Kharzeev & Levin, Phys. Lett. B523 (2001) 79

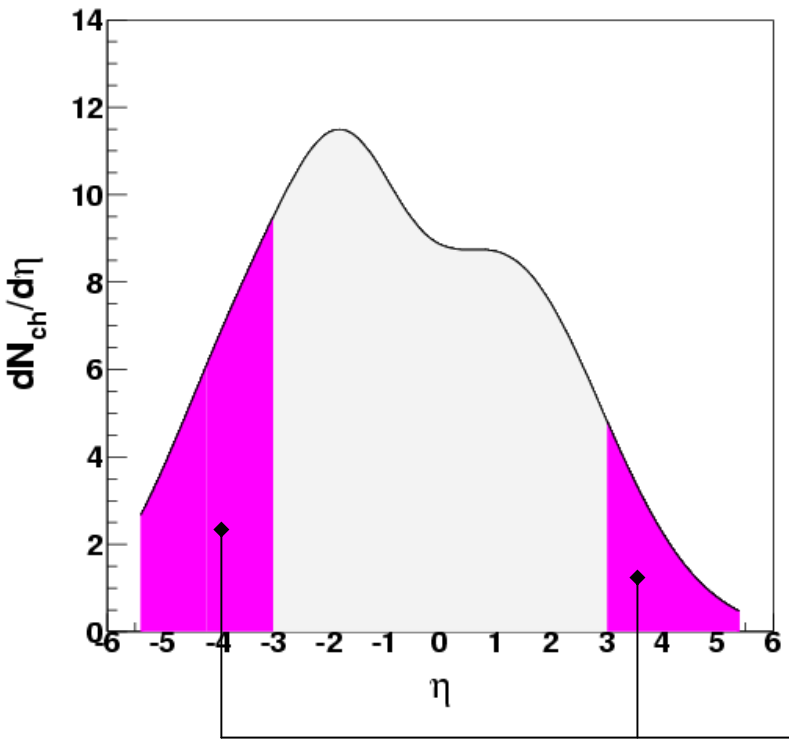
Au + Au at 130 GeV



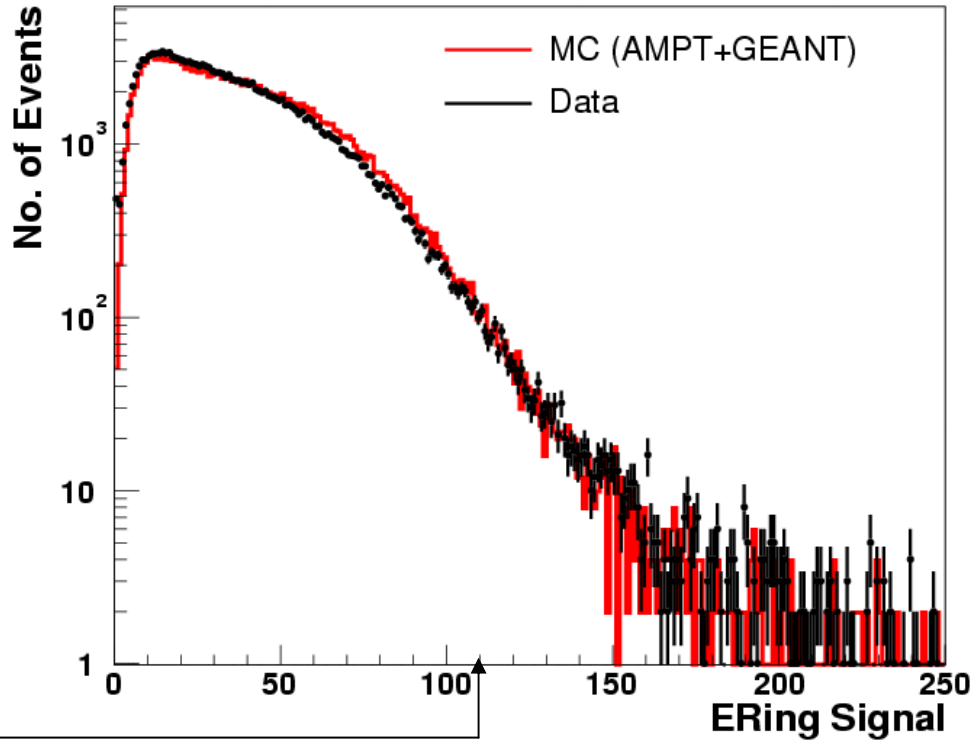
- We need a simpler system such as d + Au in order to understand a complex system Au + Au
- The results of d+Au are crucial for testing the saturation approach

Centrality Determination

ERing method
3 < |η| < 5.4



Comparison of the signal distributions from Data and MC (AMPT + Geant)

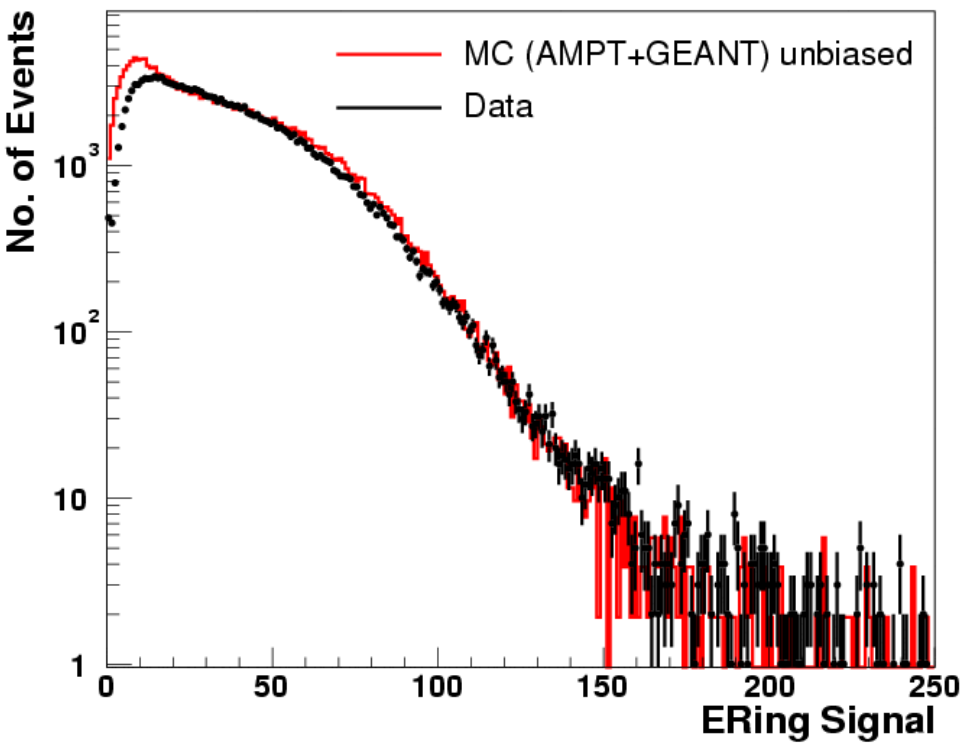


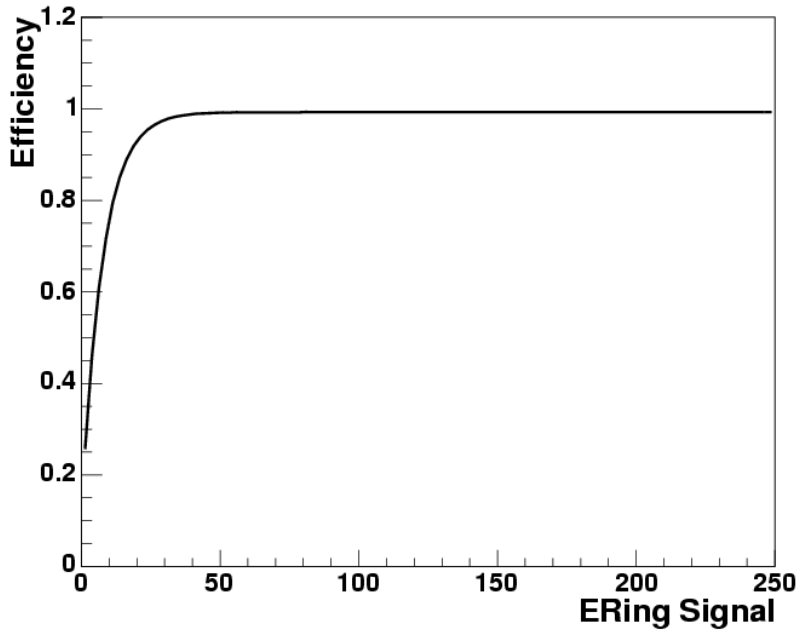
- Compare data to fully simulated & reconstructed AMPT + Geant including trigger and event selection effects

See posters by R.Hollis Corr2 and A.Iordanova Corr3

Centrality Determination

- Using simulation to estimate the trigger/event selection inefficiency for very peripheral events

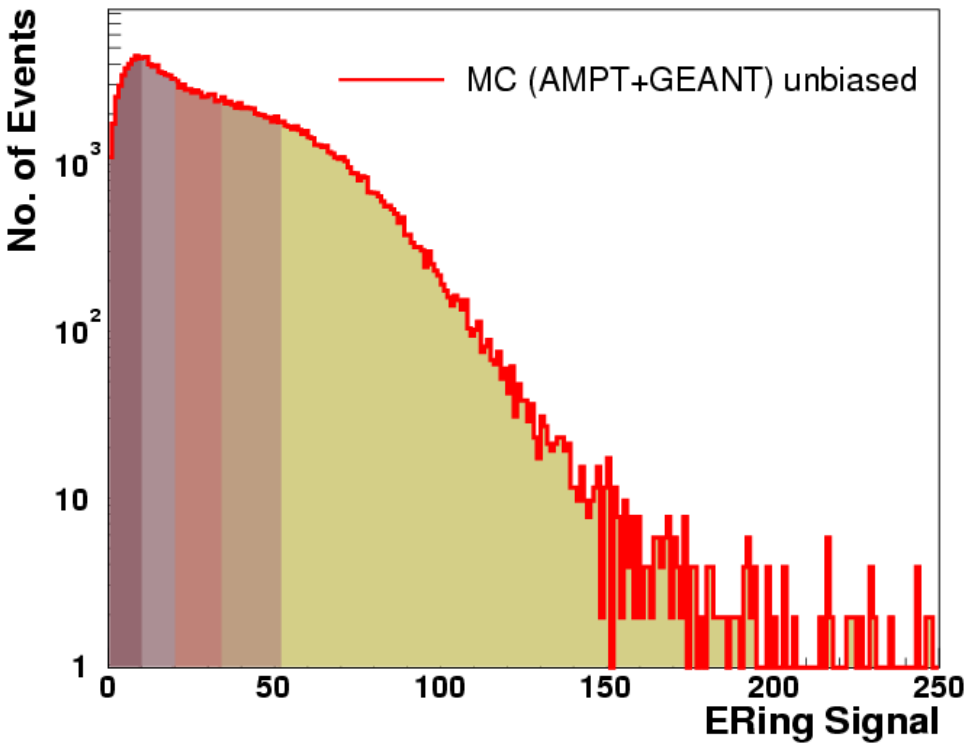




Overall trigger and vertex-finding efficiency is ~ 83 %

Centrality Determination

- Unbiased ERing signal distribution presents the full geometrical cross section
- Slice this distribution into percentile bins
- For each slice we extract dN/dη

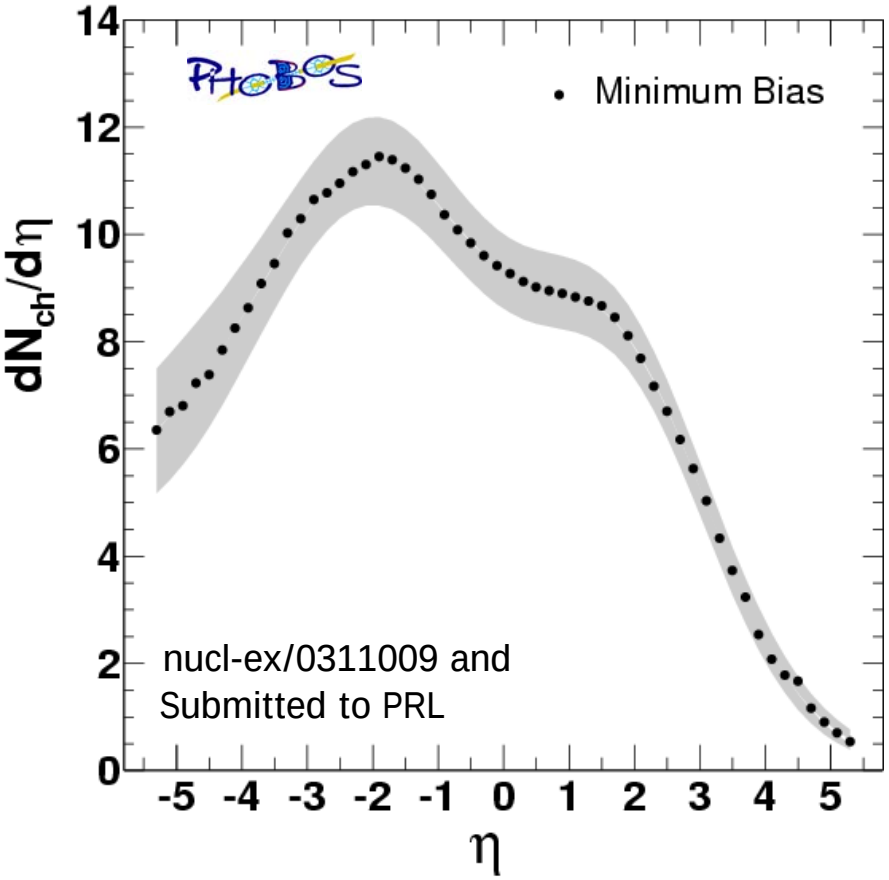


- Number of Participants: Npart

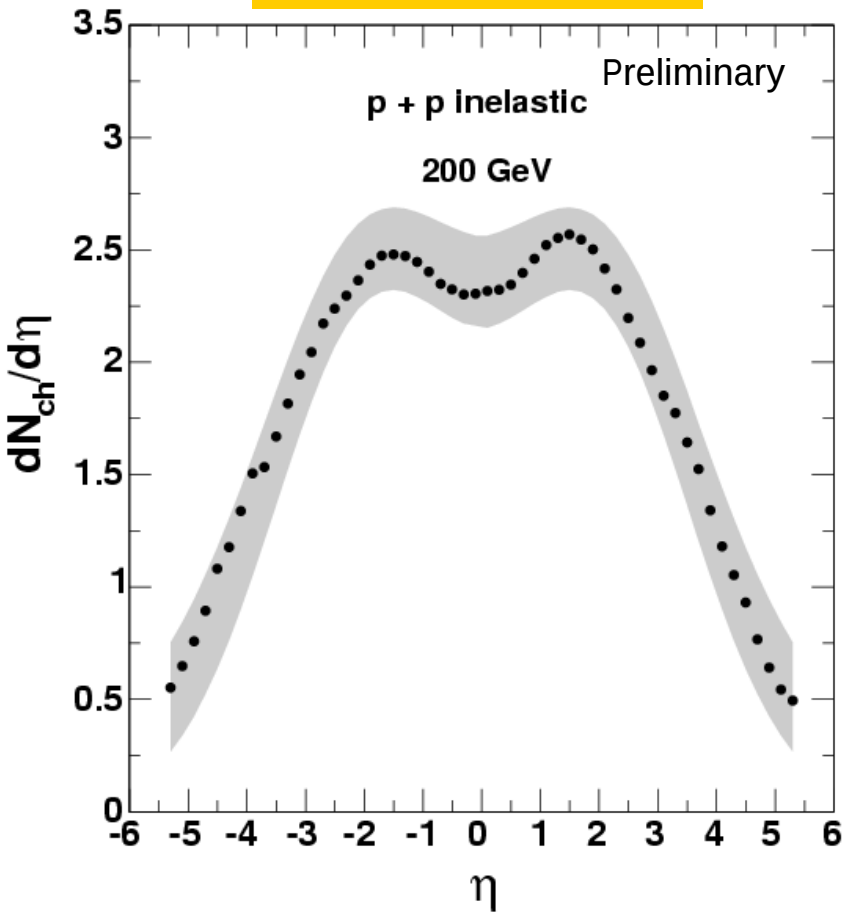
Centrality (%)	N_{part}	N_{part}(Au)	N_{part}(d)
0-20	15.5	13.5	2.0
20-40	10.8	8.9	1.9
40-60	7.2	5.4	1.7
60-80	4.2	2.9	1.4
80-100	2.7	1.6	1.1

Pseudorapidity Distribution of Charged Particles in d + Au and p + p Collisions at 200 GeV

• d + Au at 200 GeV Min-Bias



• p + p at 200 GeV



For more details about pp
see poster by J.Sagerer Spectra36

Pseudorapidity Distribution of Charged Particles in d + Au and p + p Collisions at 200 GeV

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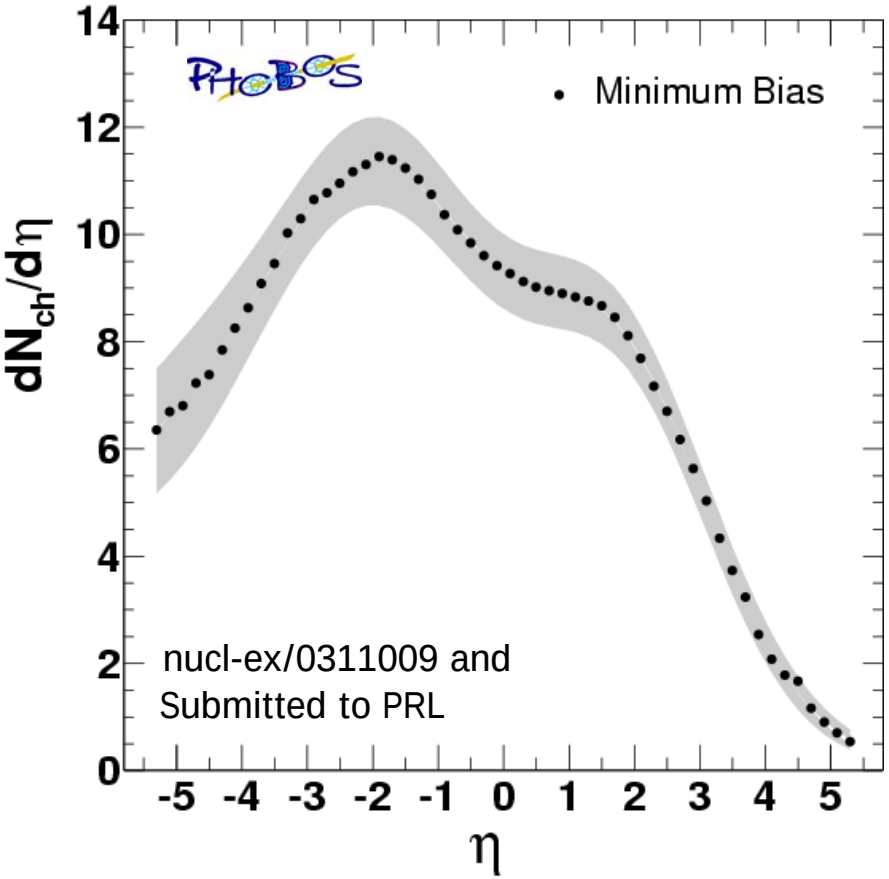
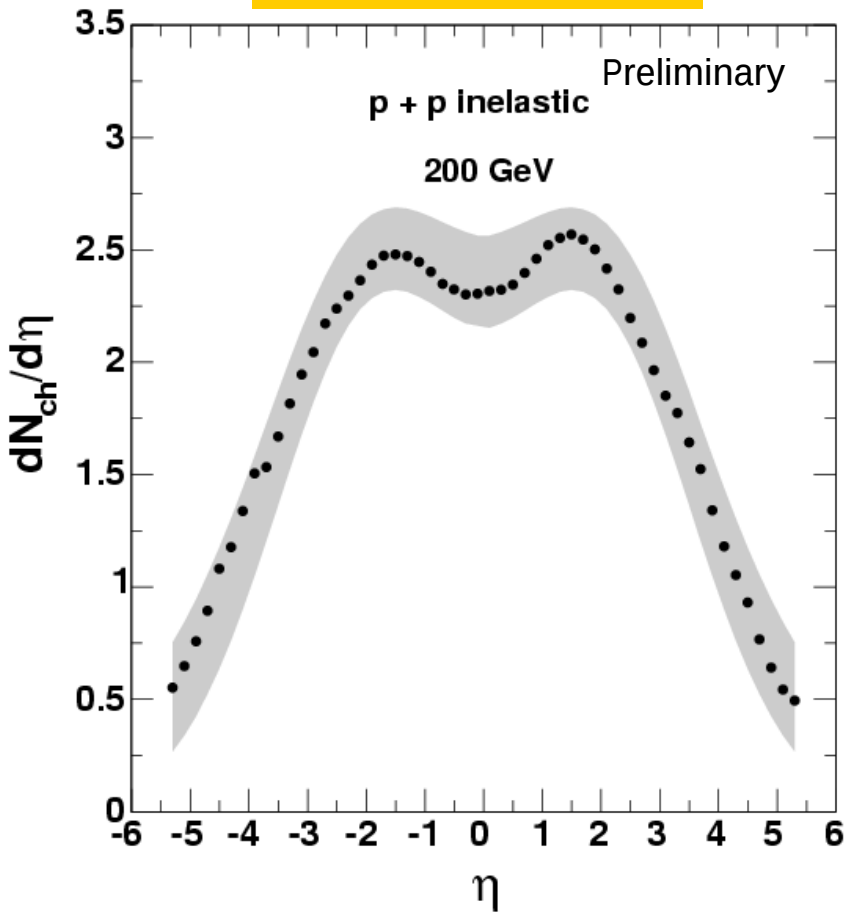


• p + p at 200 GeV



• The total integrated charged particle multiplicity normalized to the number of participant in d + Au and p + p is approximately the same.

Pseudorapidity Distribution of Charged Particles in d + Au and p + p Collisions at 200 GeV

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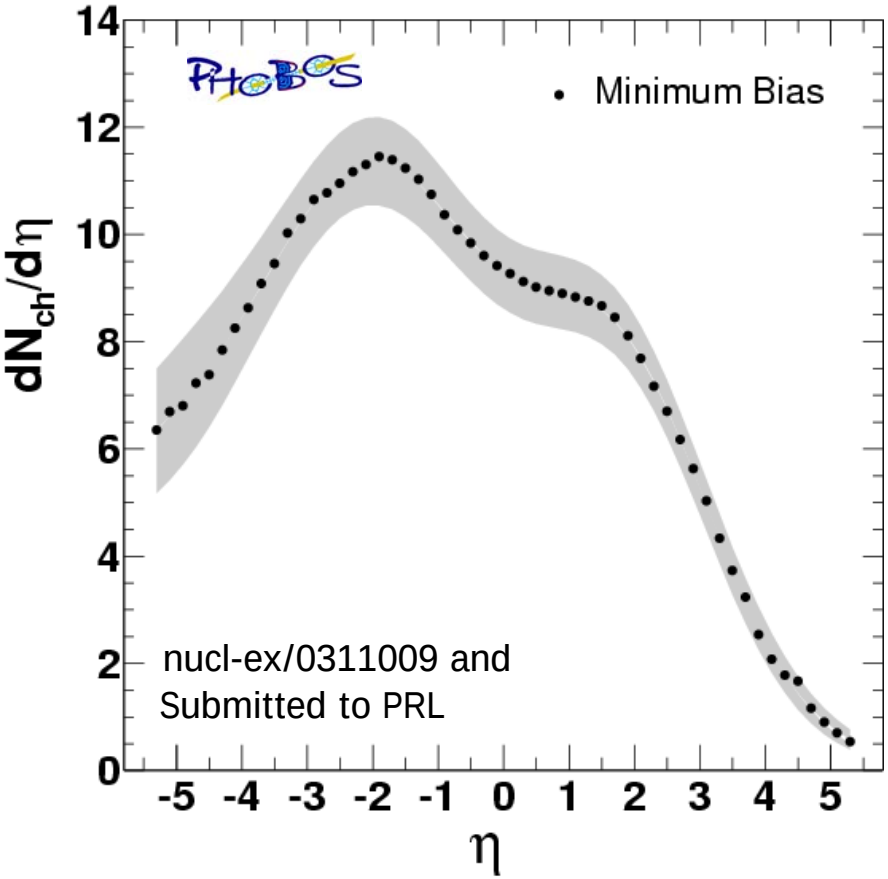
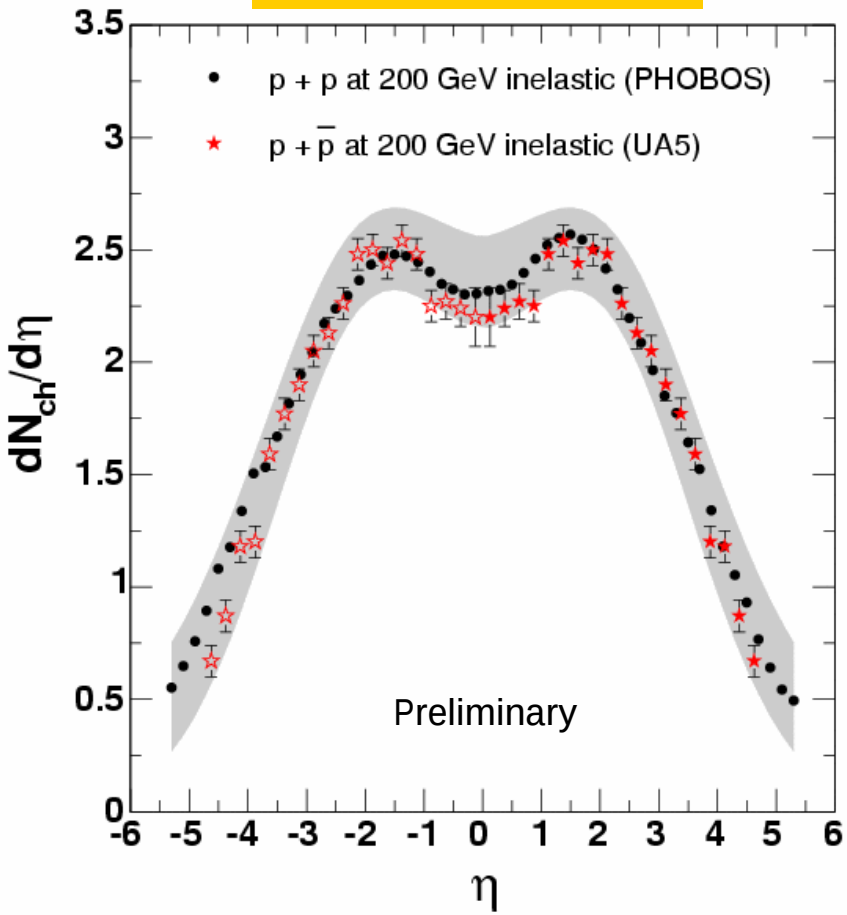
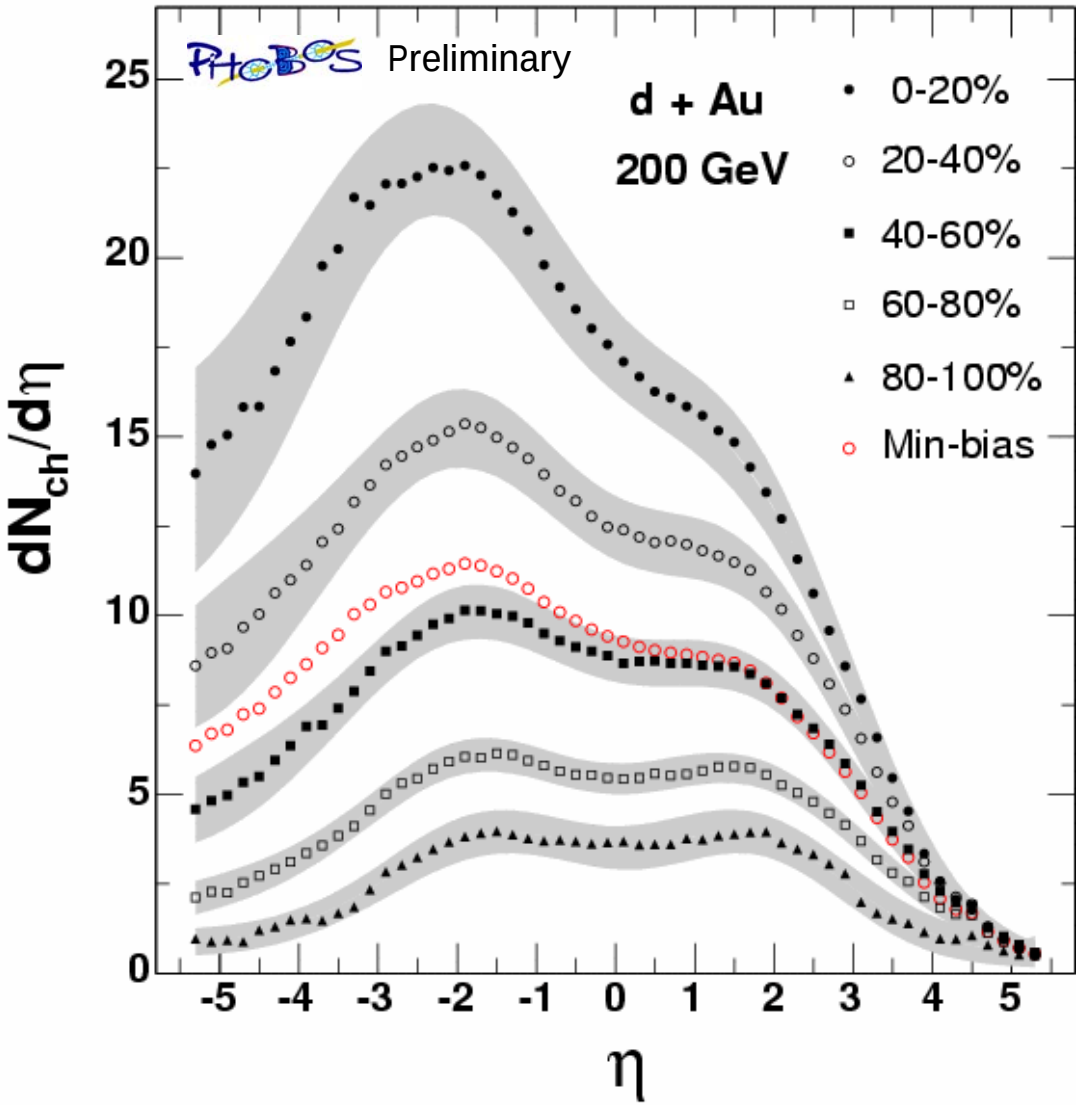


• p + p at 200 GeV



• The total integrated charged particle multiplicity normalized to the number of participant in d + Au and p + p is approximately the same.

Centrality (Impact Parameter) Dependence of dN/dη for d + Au Collisions at 200 GeV

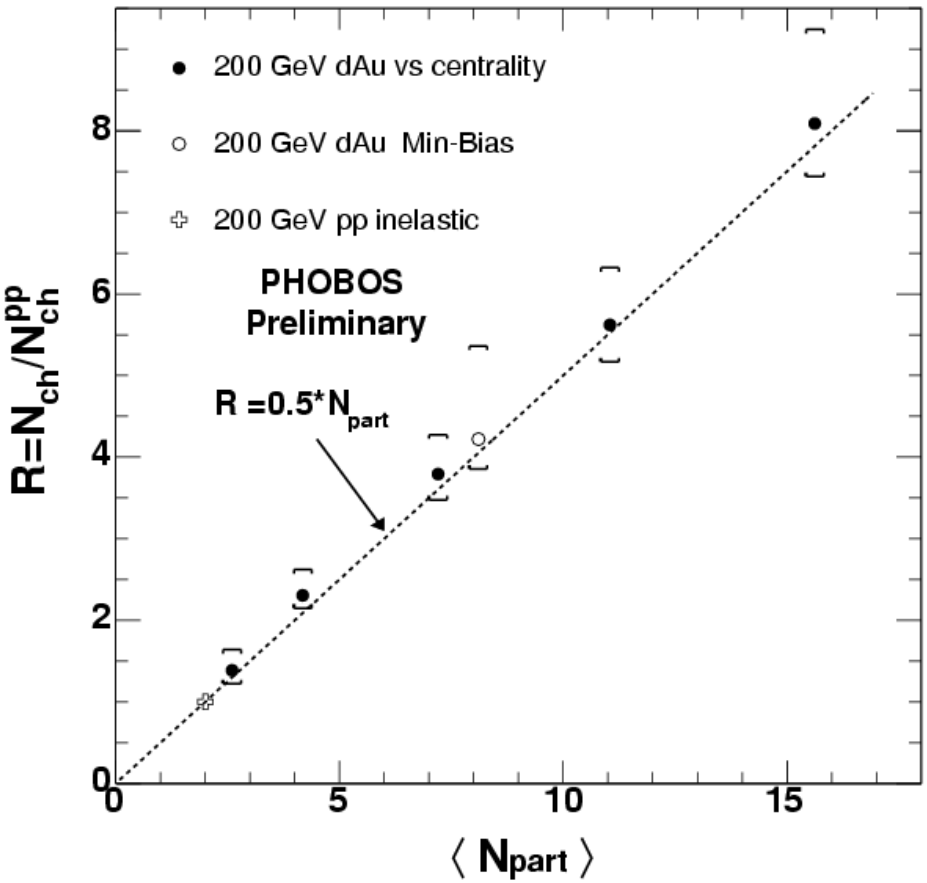


- High particle production toward gold direction and increasing as function of centrality

- PHOBOS has extensive dN/dη data on AuAu and now dAu, pp

Centrality Dependence of Total N_{ch}

- Evolution of N_{ch}/N_{pp} ratio vs N_{part}



Centrality Dependence of Total N_{ch}

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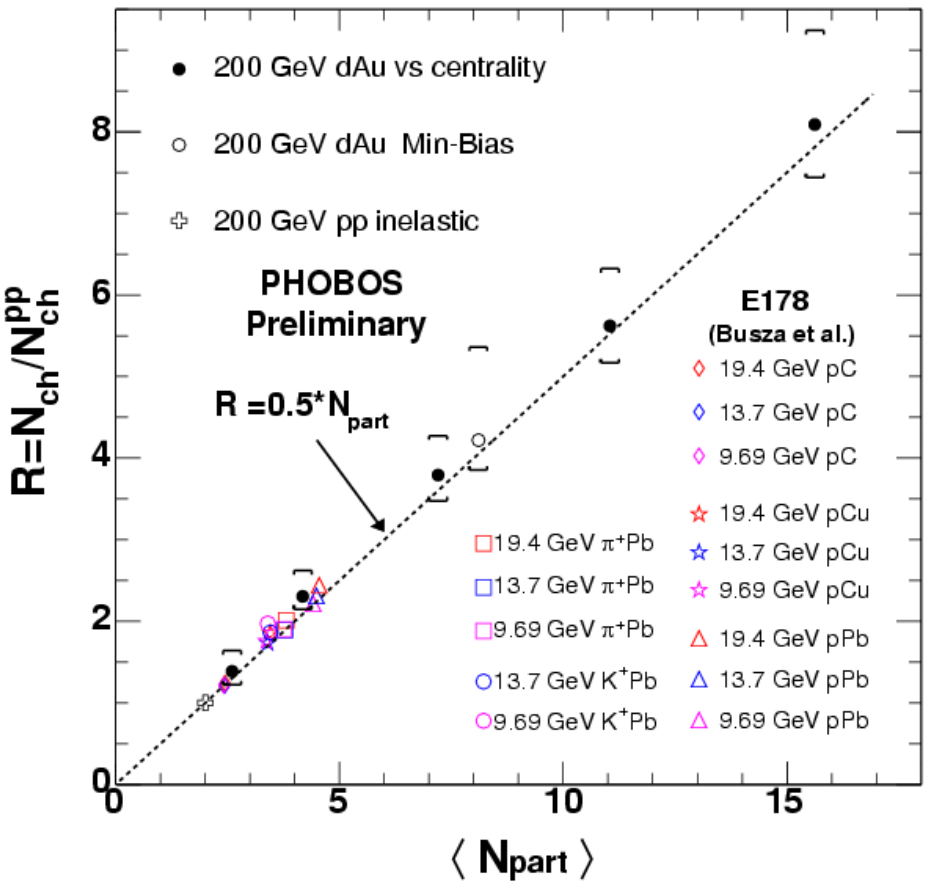
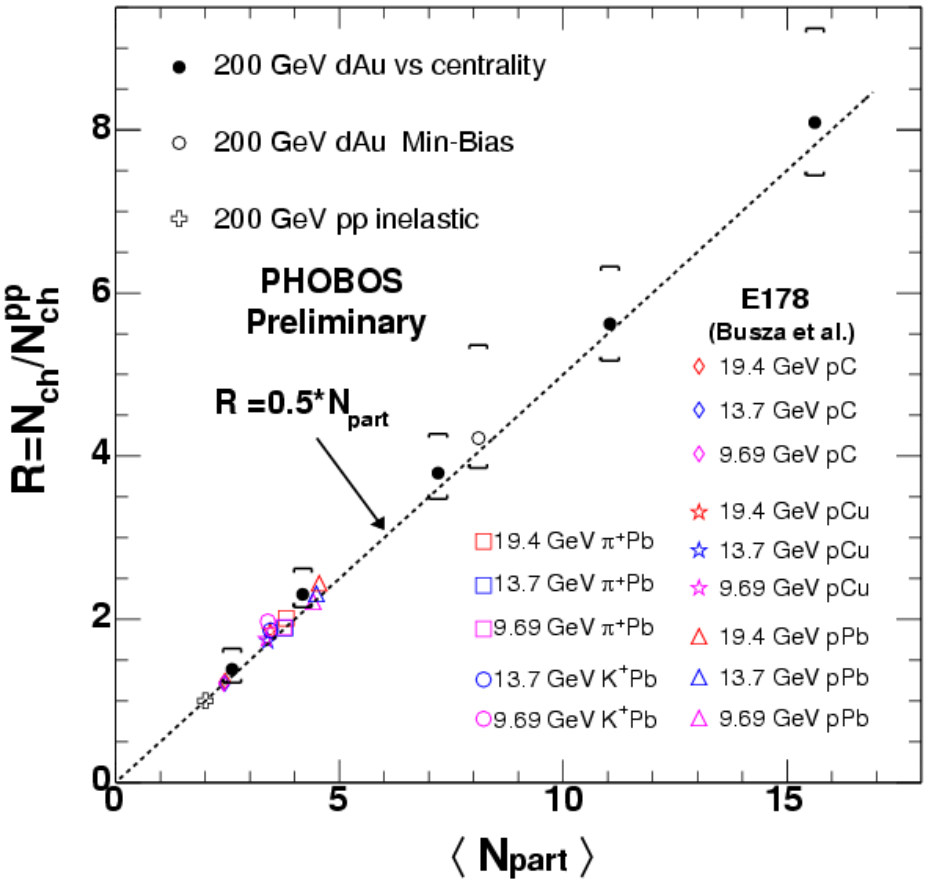


dAu data shows features similar to lower energy pA

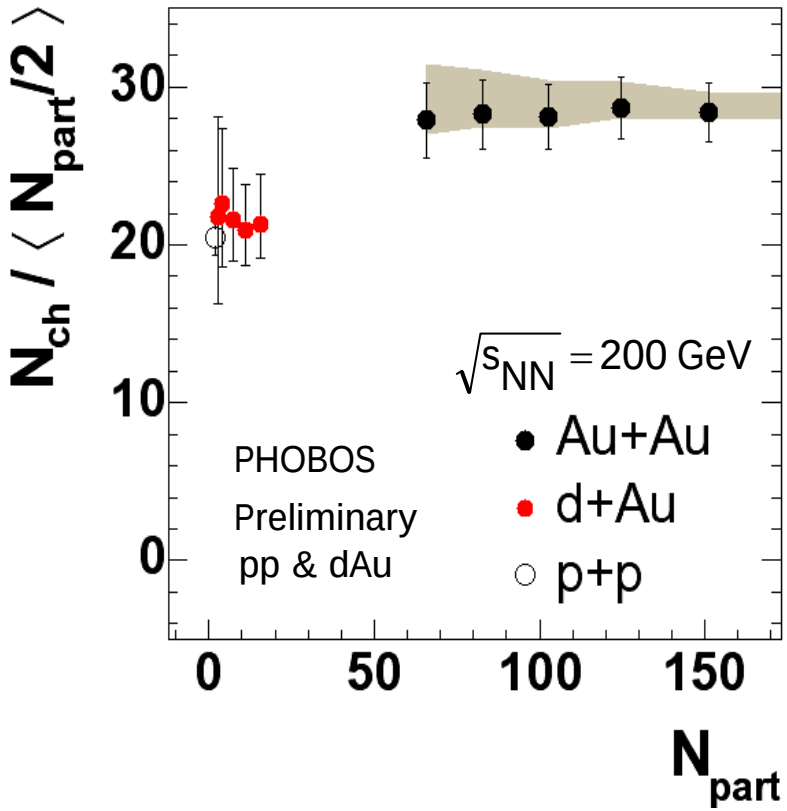
- Nch(dAu)=[(1/2)N_{part}] N_{ch}(pp)

Centrality Dependence of Total N_{ch}

- Evolution of N_{ch}/N_{pp} ratio vs N_{part}



- Evolution of $N_{ch}/(N_{part}/2)$ vs N_{part}



dAu data shows features similar to lower energy pA

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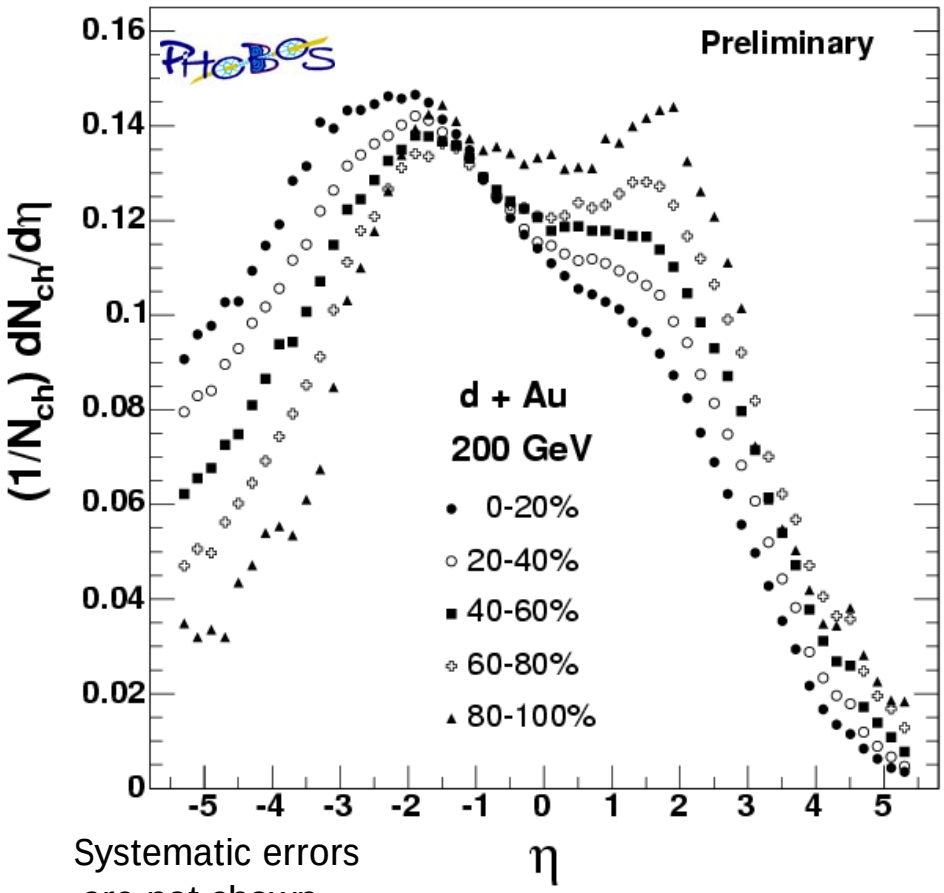
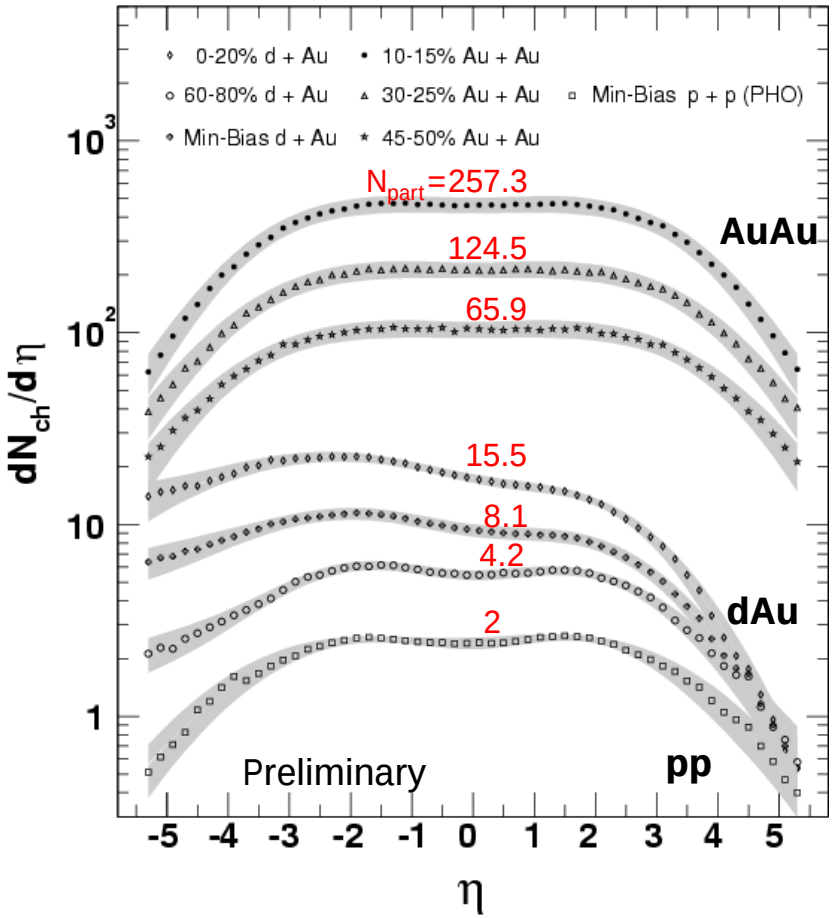
Shape Dependence on N_{part} of Pseudorapidity Distribution



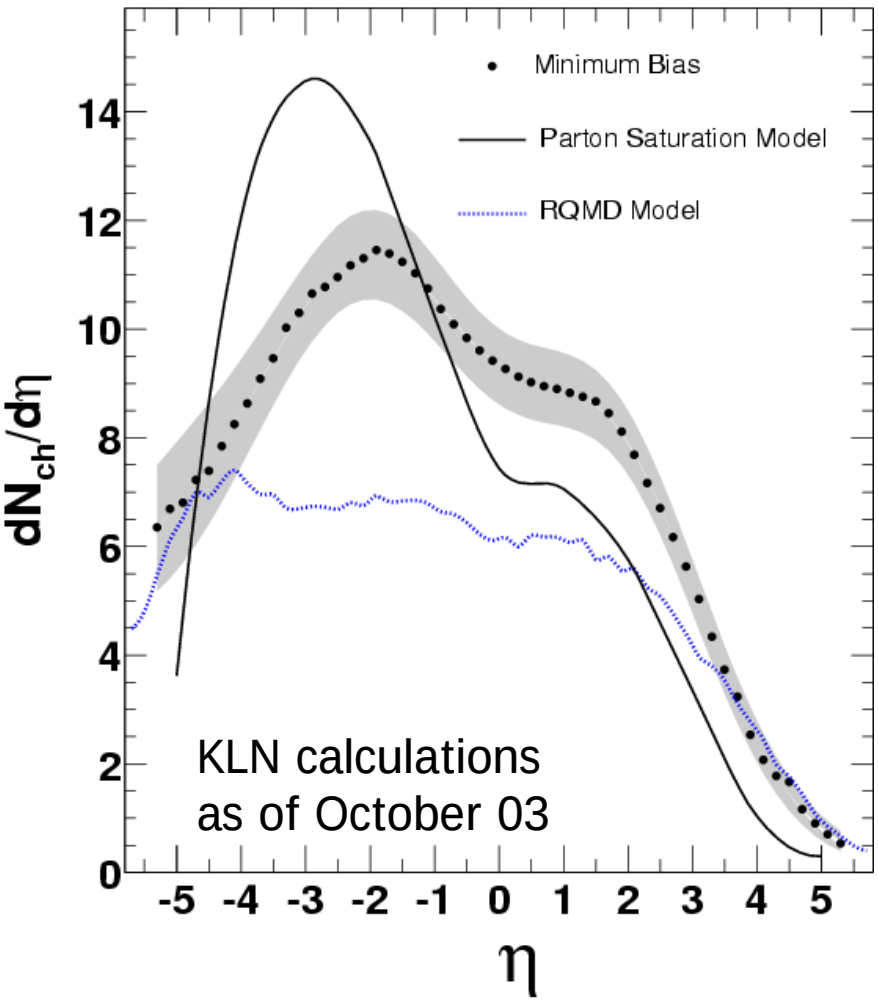
Systematic errors are not shown



- In dAu with increasing Npart, particle production shifts toward negative rapidities

Comparison dAu Minimium-bias to Parton Saturation (KLN), RQMD, HIJING and AMPT Models

nucl-ex/0311009 and Submitted to PRL



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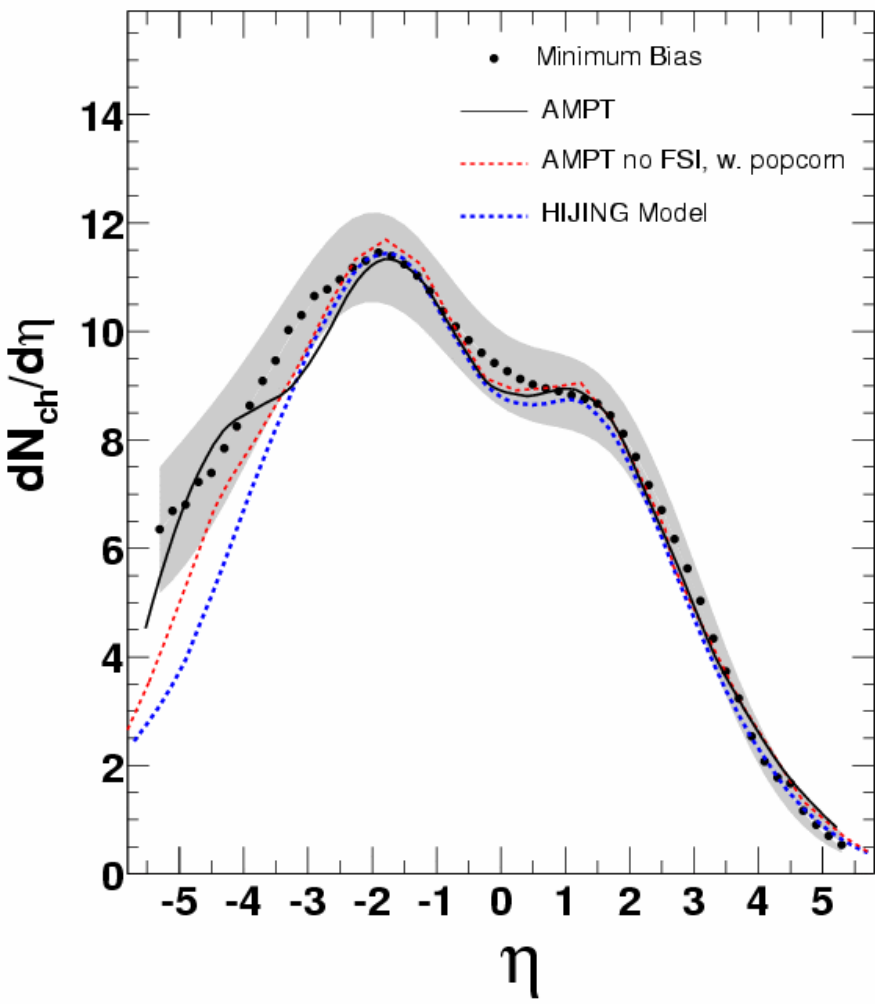

Parton saturation model predictions for d + Au:
D. Kharzeev et al., arXiv:hep-ph/0212316

Comparison dAu Minimium-bias to Parton Saturation (KLN), RQMD, HIJING and AMPT Models

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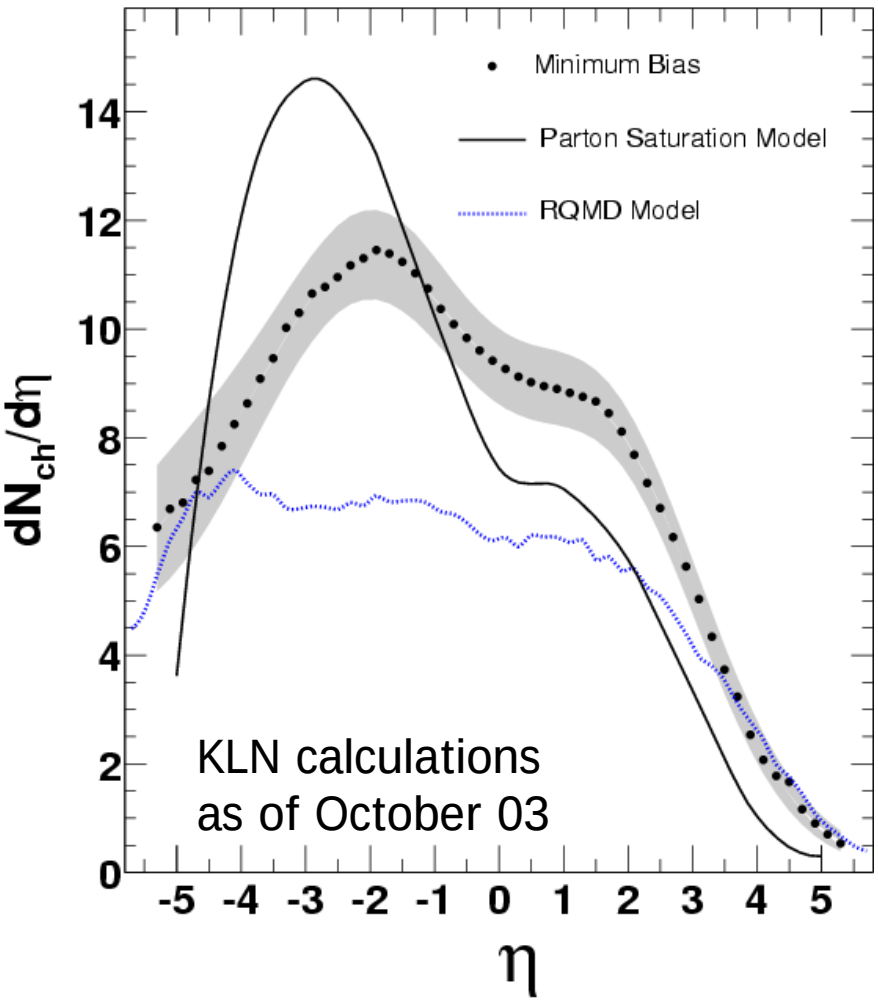

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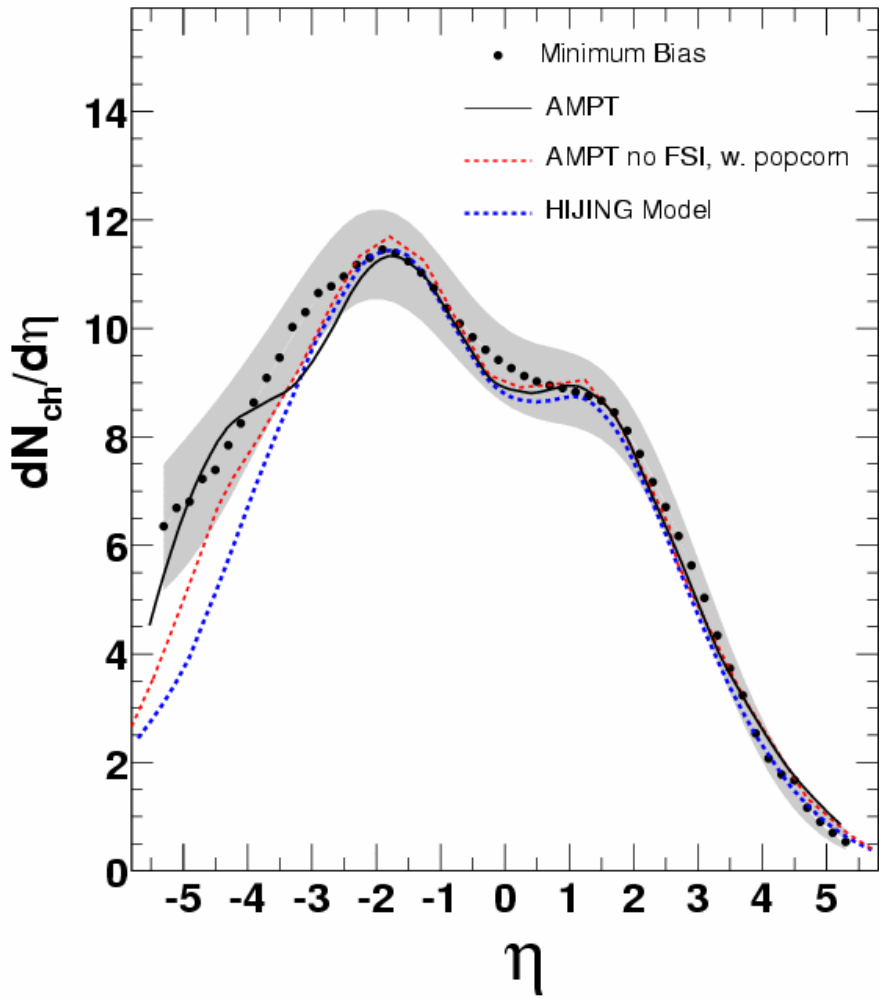
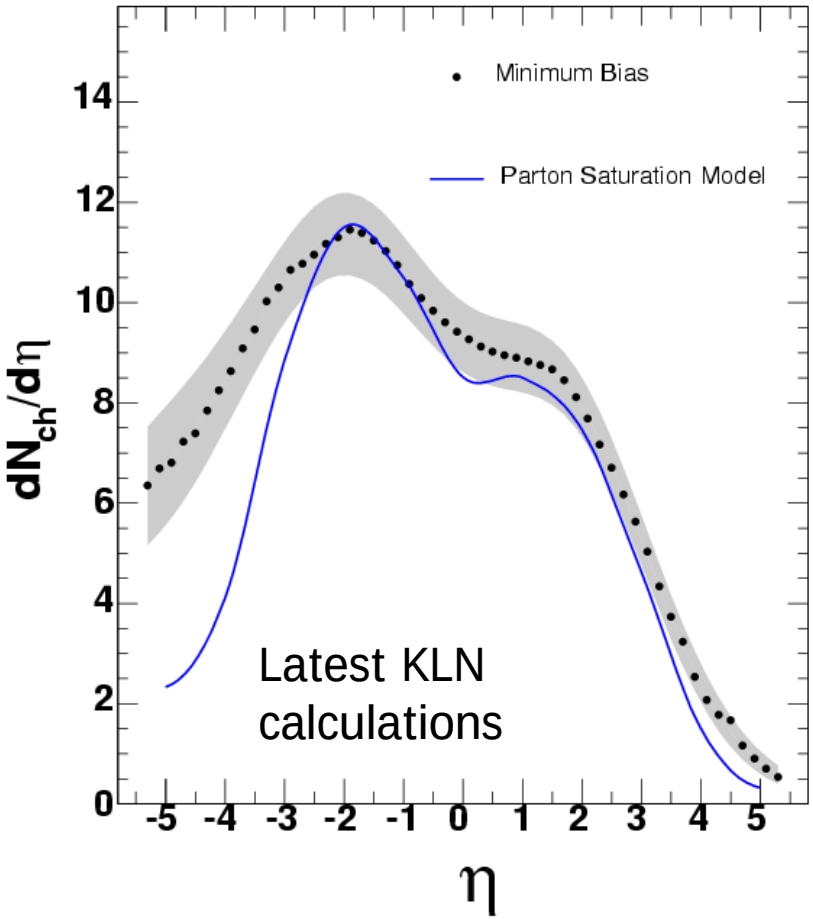


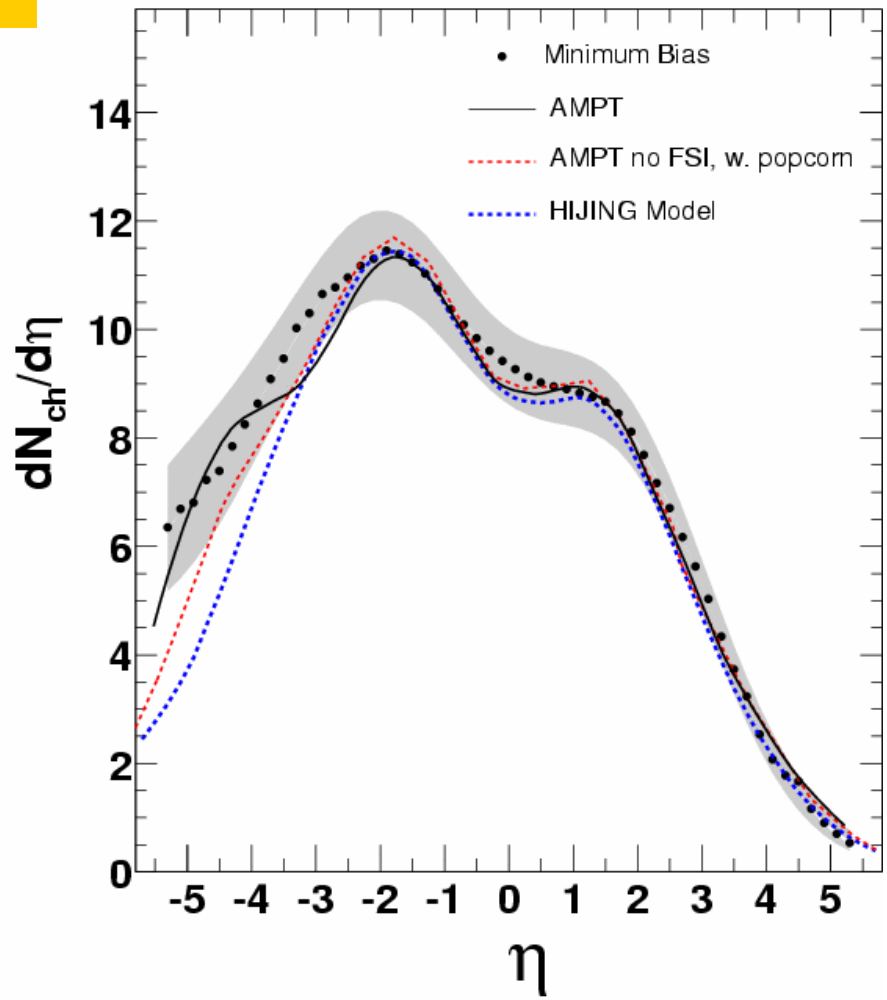
- The centrality dependence in d+Au is crucial for testing the saturation approach

Comparison dAu Minimium-bias to Parton Saturation (KLN), RQMD, HIJING and AMPT Models

Data and Parton Saturation model

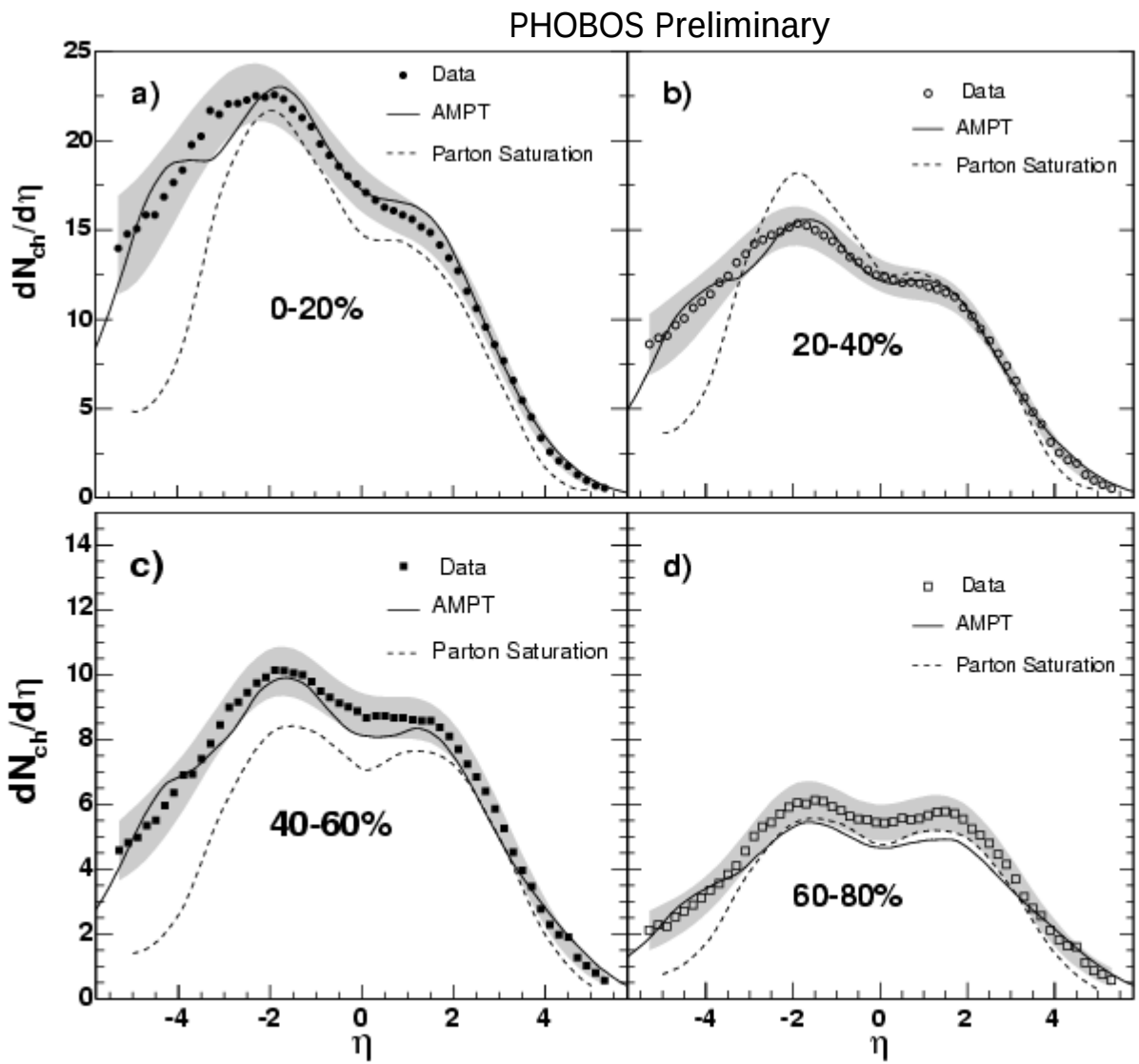


nucl-ex/0311009 and Submitted to PRL



- The centrality dependence in d+Au is crucial for testing the saturation approach

Centrality Dependence Compared to Models
Parton Saturation (KLN) and AMPT Models



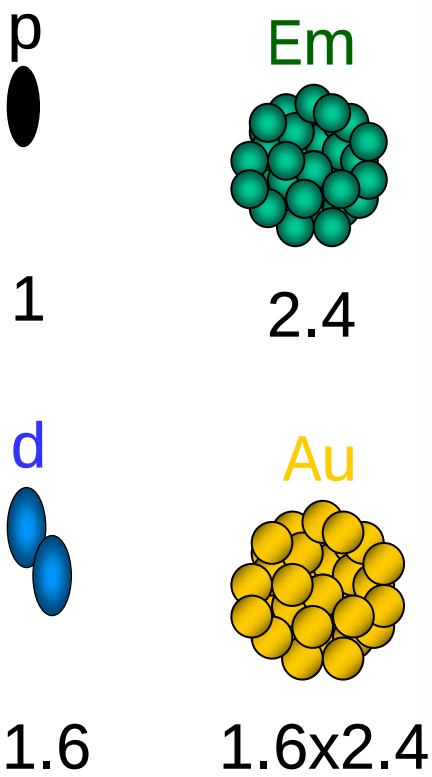
AMPT predictions for d + Au :
Zi-Wei Lin et al., arXiv:nucl-th/0301025

- Centrality dependence is inconsistent with Saturation model (KLN)
- AMPT cannot be ruled out

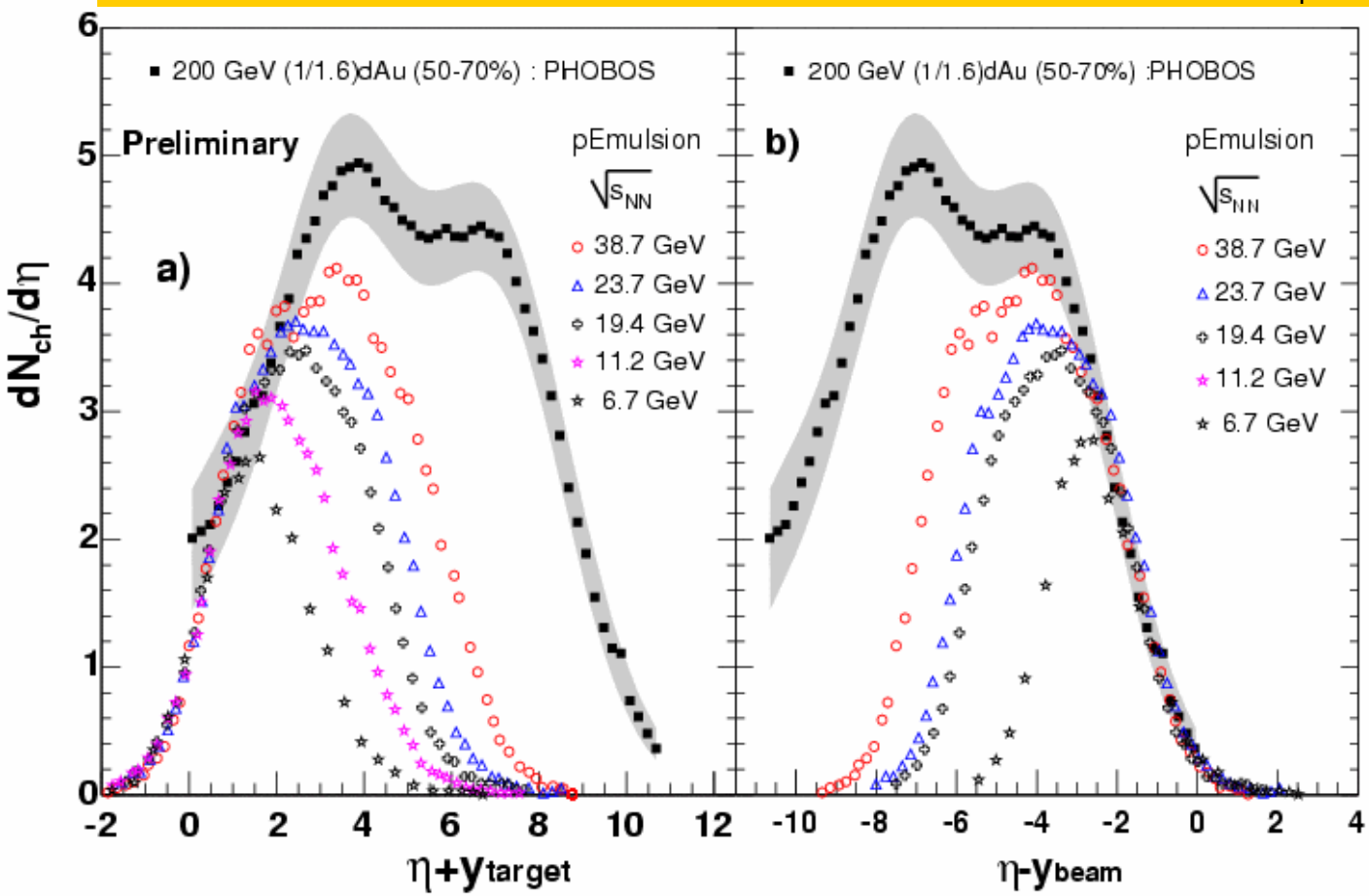
Limiting Fragmentation in dAu and pEmulsion Data

- Compilation of world pEmulsion N_s + N_g data

N_{part} Selection:



- dAu & pEmulsion per incident nucleon and approx. same N_{part}



- Energy independent fragmentation regions continue to cover wider and wider extent in η as energy increases

Rachid Nouicer

Limiting Fragmentation in dAu and pPb Data

• dAu & pPb per incident nucleon and approx. same N_{part}

N_{part} Selection:

p

1

Pb

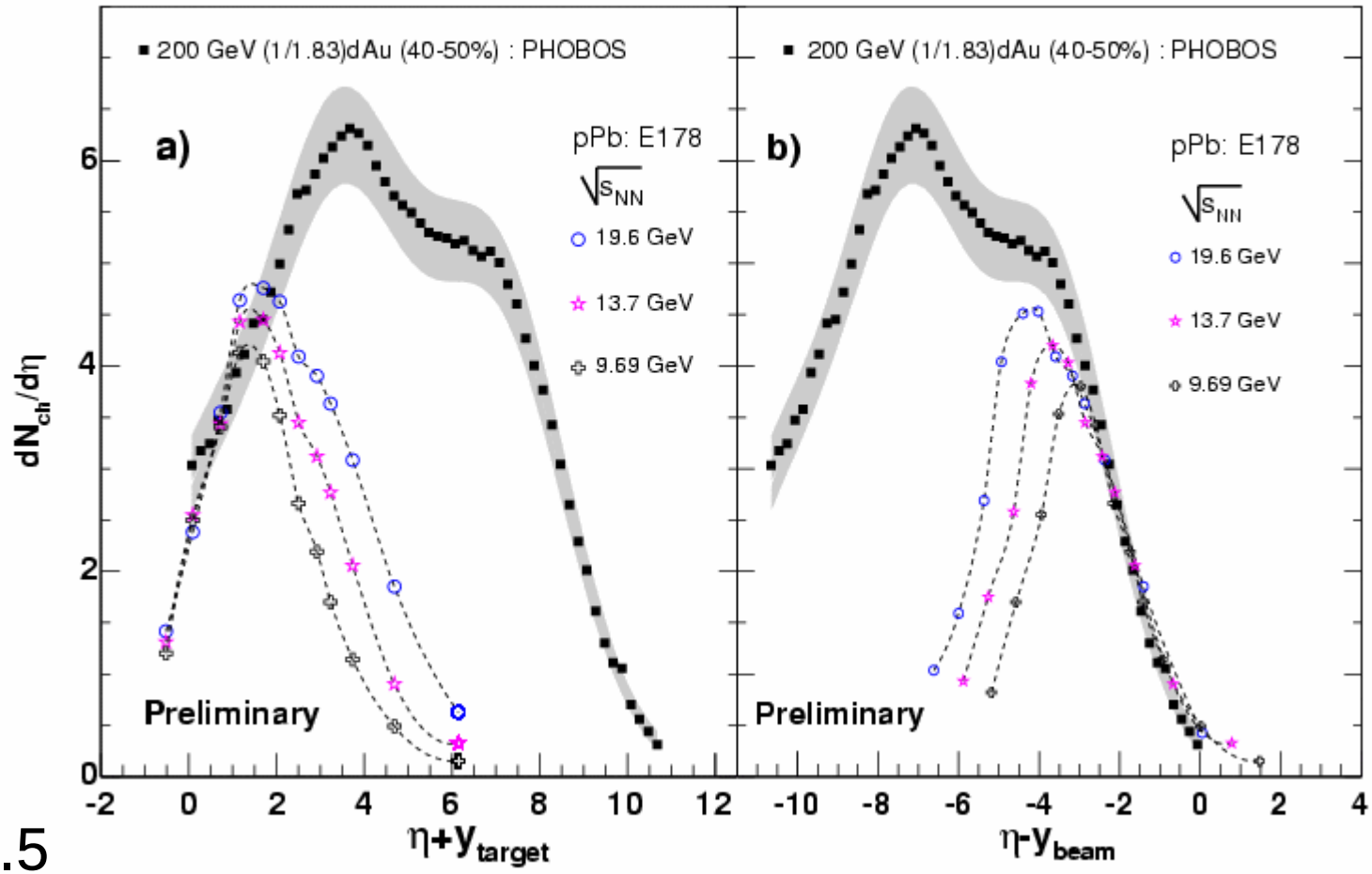
3.5

d

1.83

Au

1.83x3.5

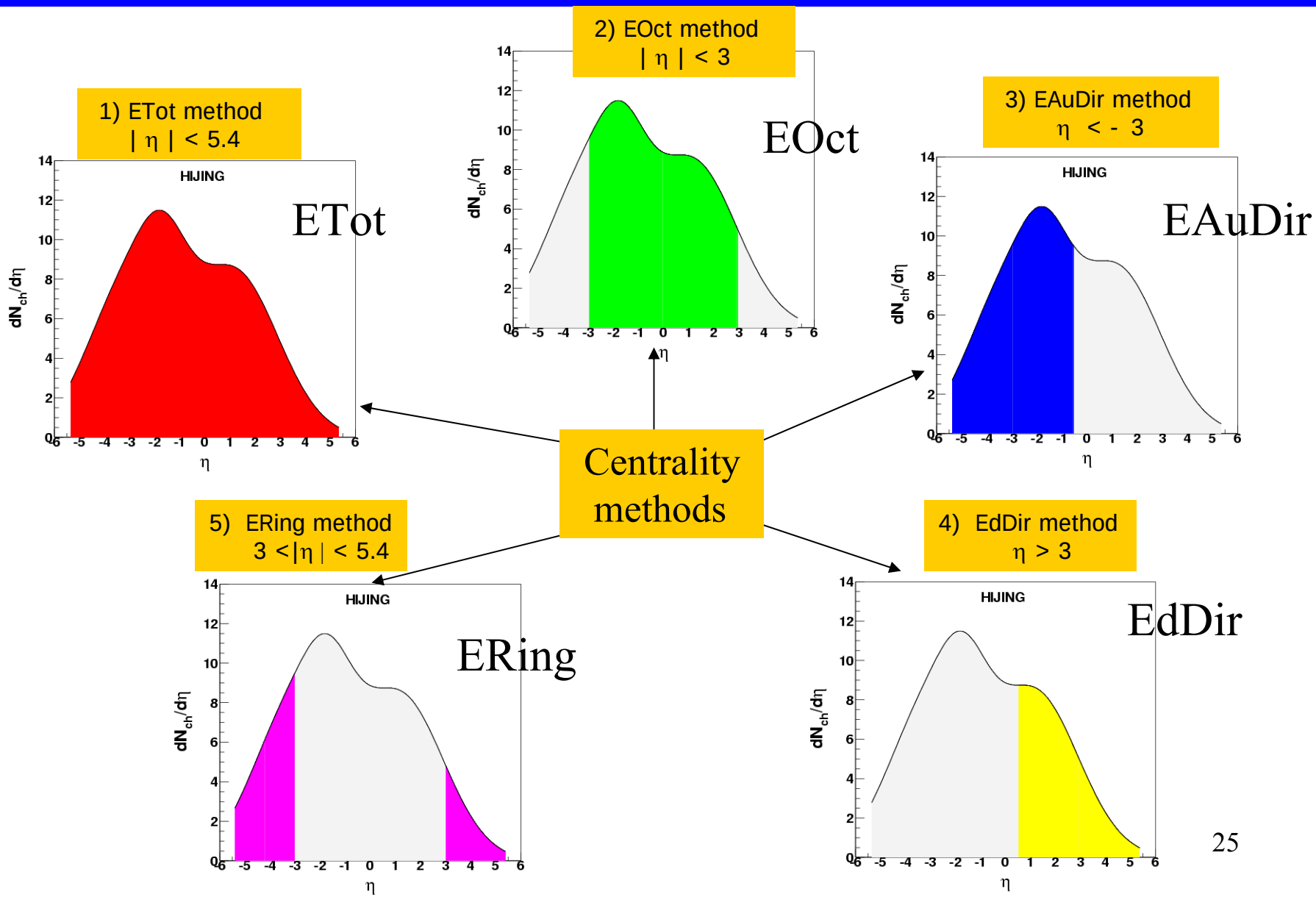


• No accident: holds for bigger system such as pPb

Summary

- PHOBOS has extensive dN/dη data on Au+Au and now p+p, d+Au
- The total integrated charged particle multiplicity normalized to the number of participant in d + Au and p + p is approximately the same
- Centrality dependence inconsistent with Saturation model (KLN)
- AMPT cannot be ruled out
- dAu data shows similar features as lower energy p+A
  - N_{part} scaling of d+Au and p+A relative to p+p
  - with increasing Npart, particle production shifts toward negative rapidities
  - energy independent fragmentation regions continue to cover wider and wider extent in η as energy increases

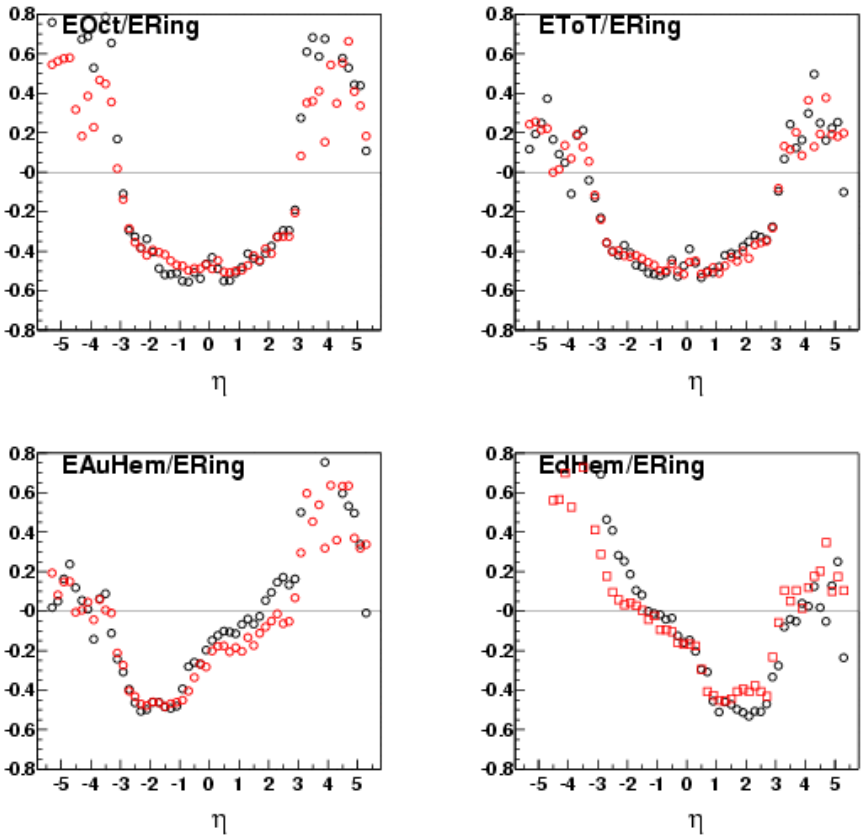
Five Distinct Silicon Centrality Methods for Cross Checks



Does HIJING Reproduce the Relative Bias like Data?

Most peripheral: 90-100%

Bin = 0

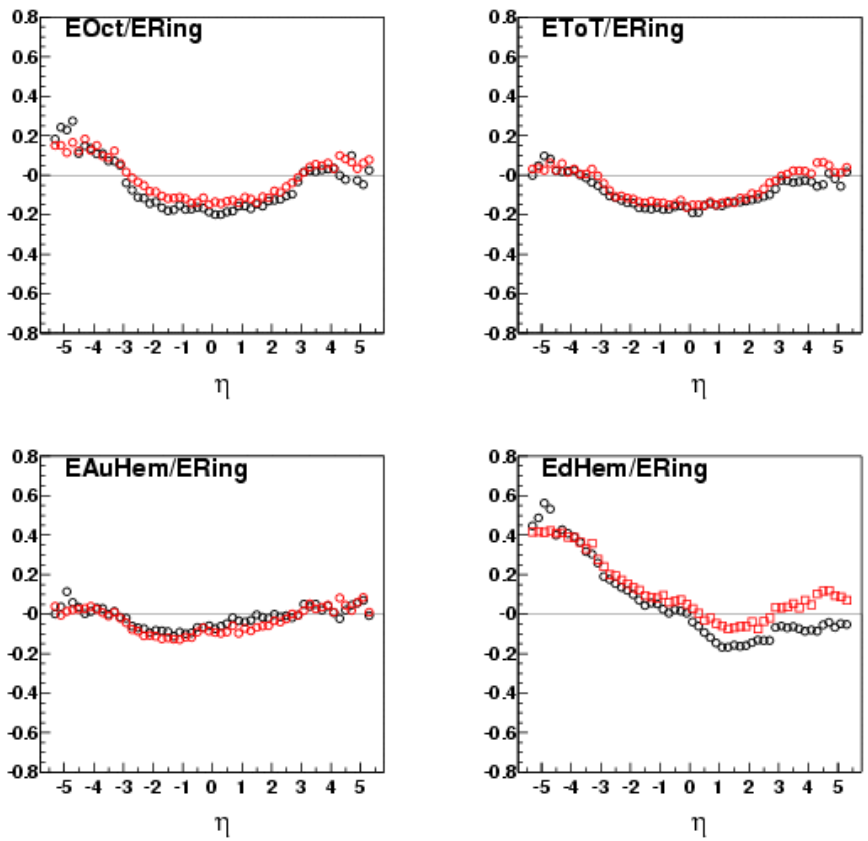


Data

HIJING

Peripheral: 60-70%

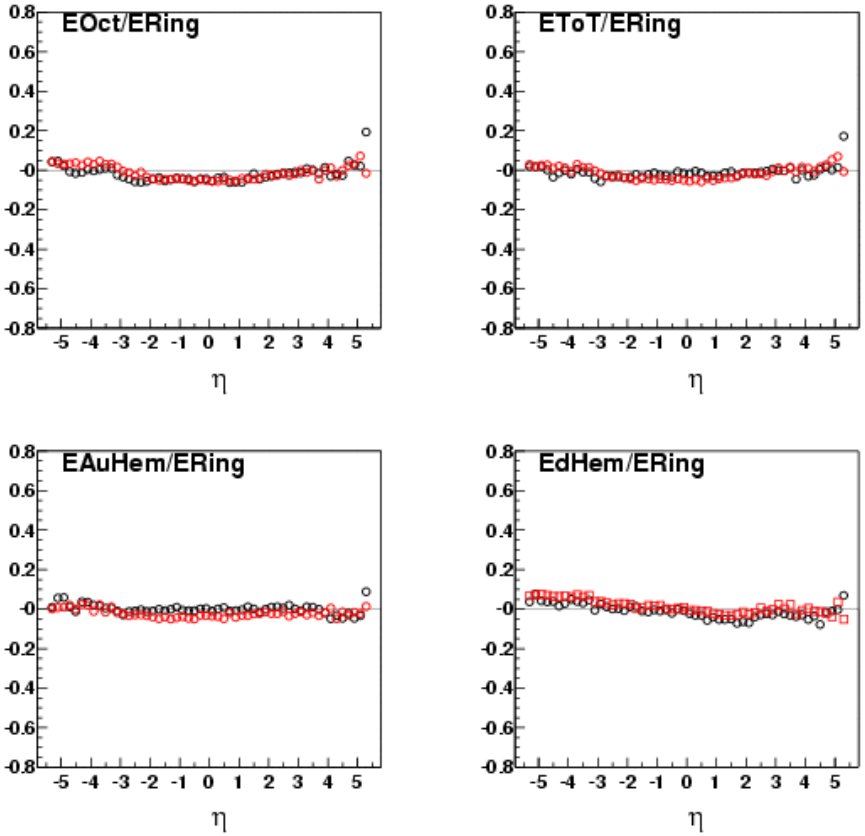
Bin = 3



Does HIJING Reproduce the Relative Bias like Data?

Mid-Central: 30-40%

Bin = 6

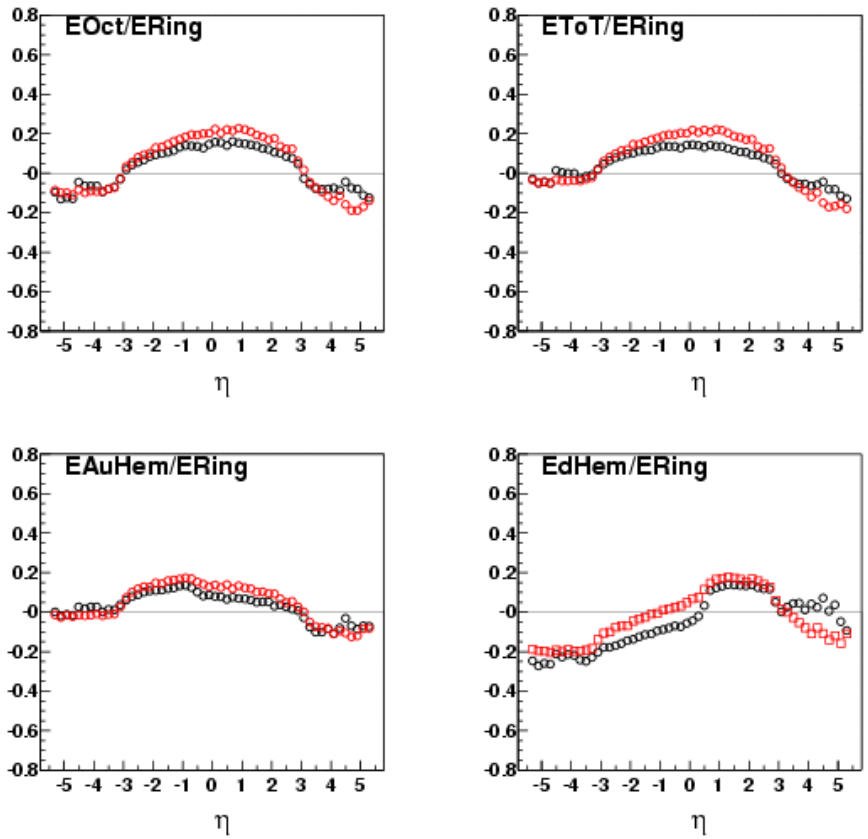


Data

HIJING

Central: 0-10%

Bin = 9



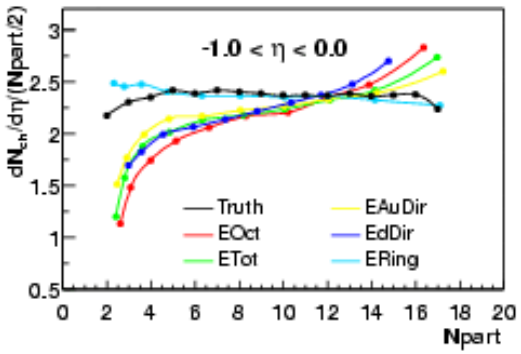
Answer:

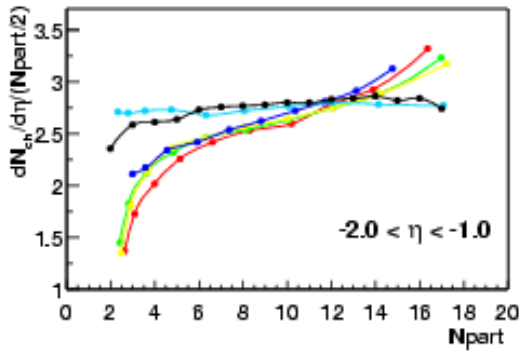
Yes, HIJING Reproduces the Relative Bias as Data

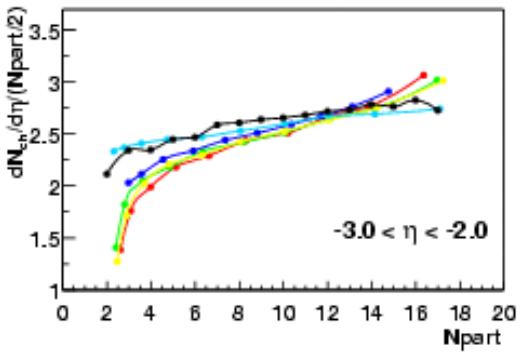
Selecting the Best Trigger Cut

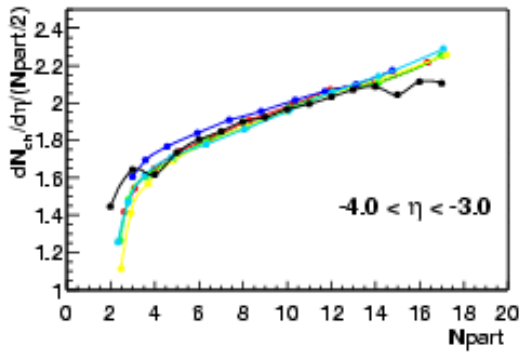
Negative Pseudorapidity region ⟶ ERing seems to be the best trigger cut

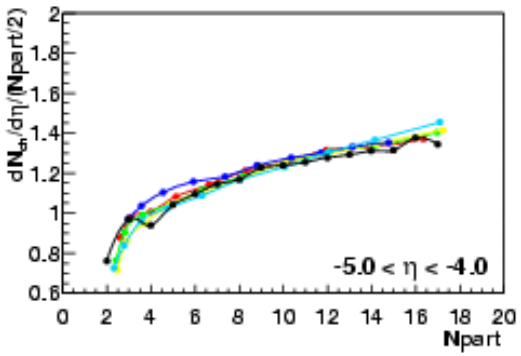
HIJING

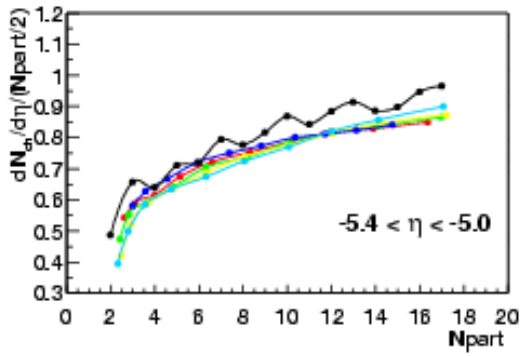












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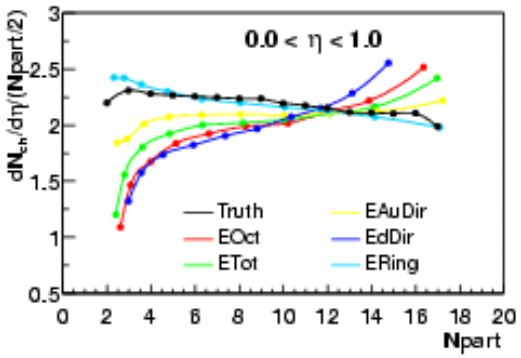
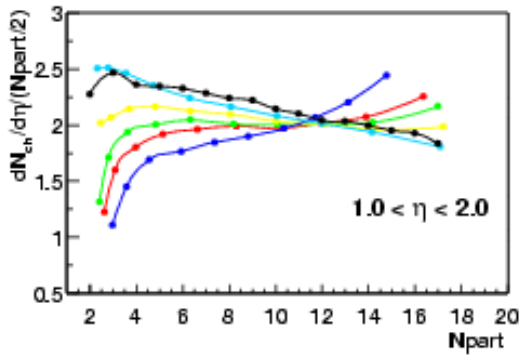
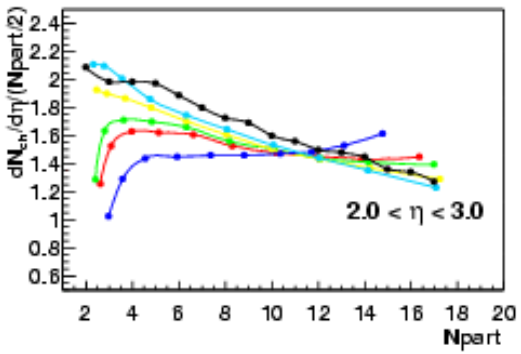
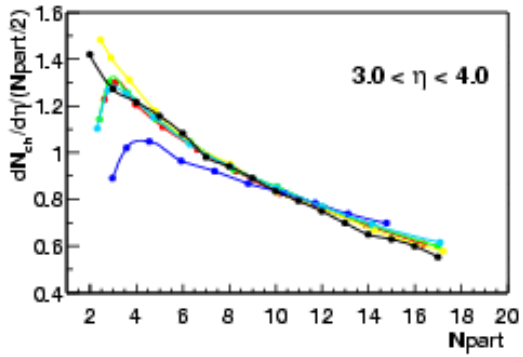
Negative Pseudorapidity region ⟶ ERing seems to be the best trigger cut

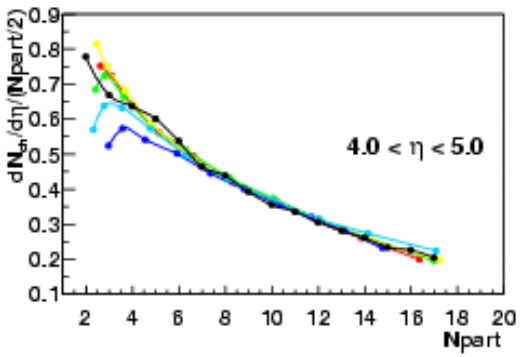
HIJING

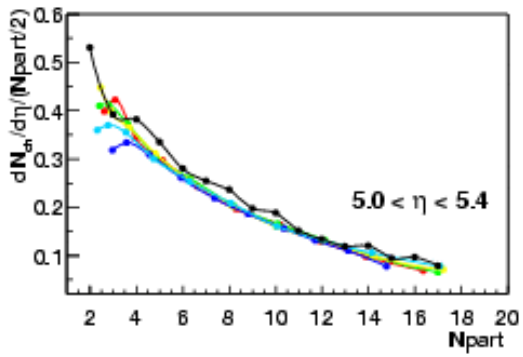






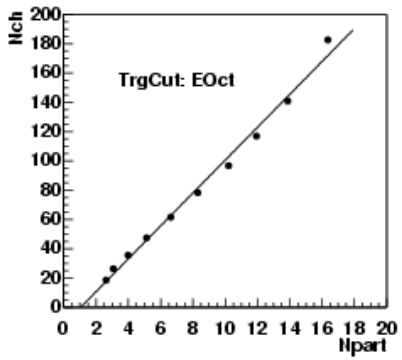


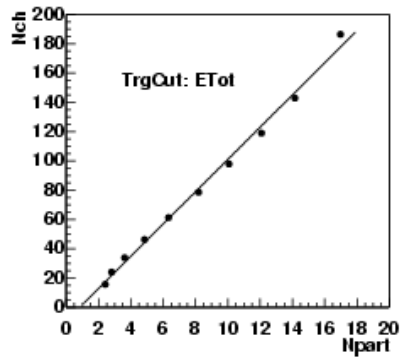


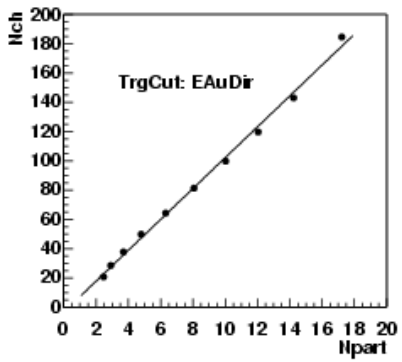


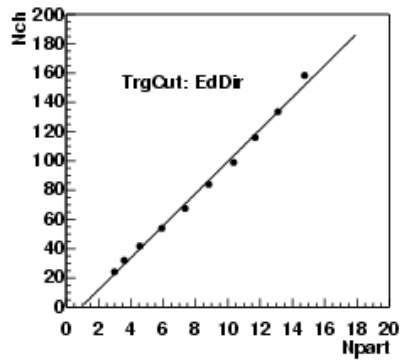
N_{ch} vs N_{part} for Different Trigger cuts

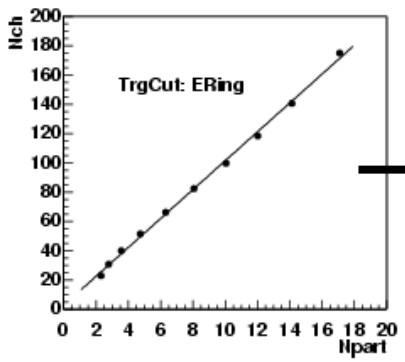
Data







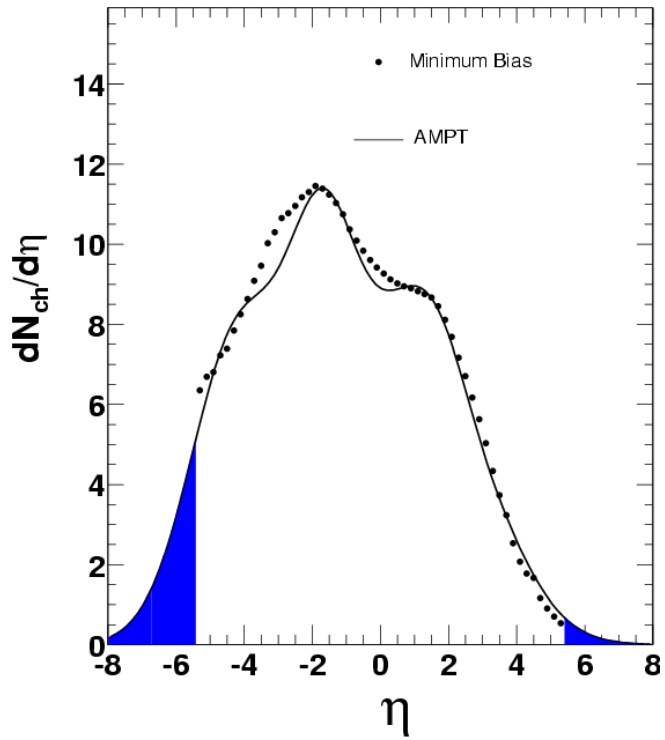




The best linear fit to the data resulting in the relation N_{ch} vs N_{part} is given by ERing trigger cut

Estimates of the Total Charged Particle Production

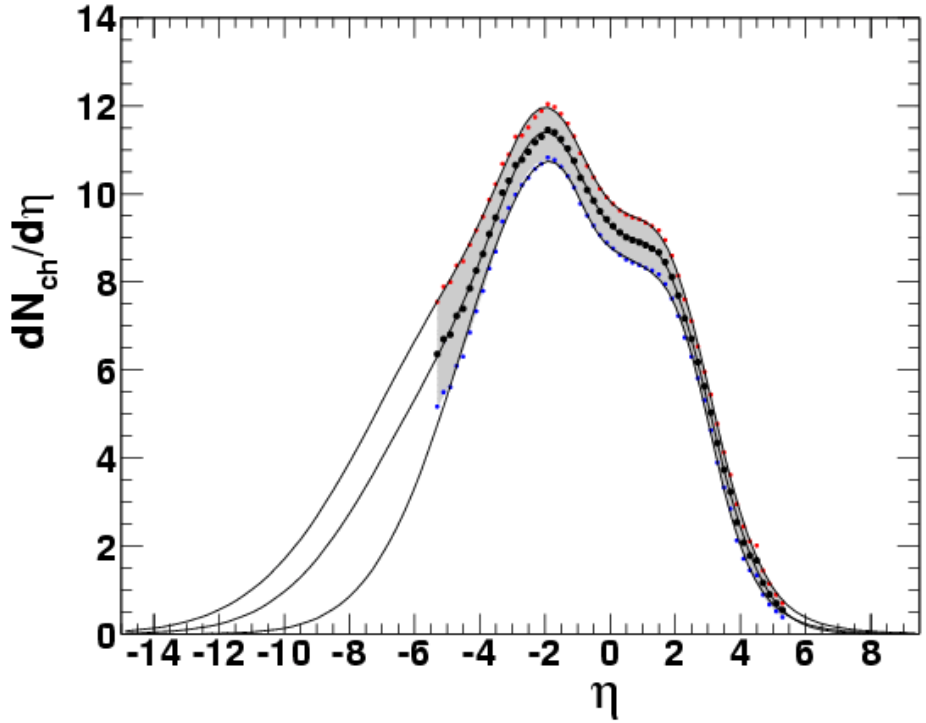
Using AMPT Model



- Missing charged particle multiplicity is

$$N^{ch}_{miss} = 5$$

Using Triple Gaussian fit

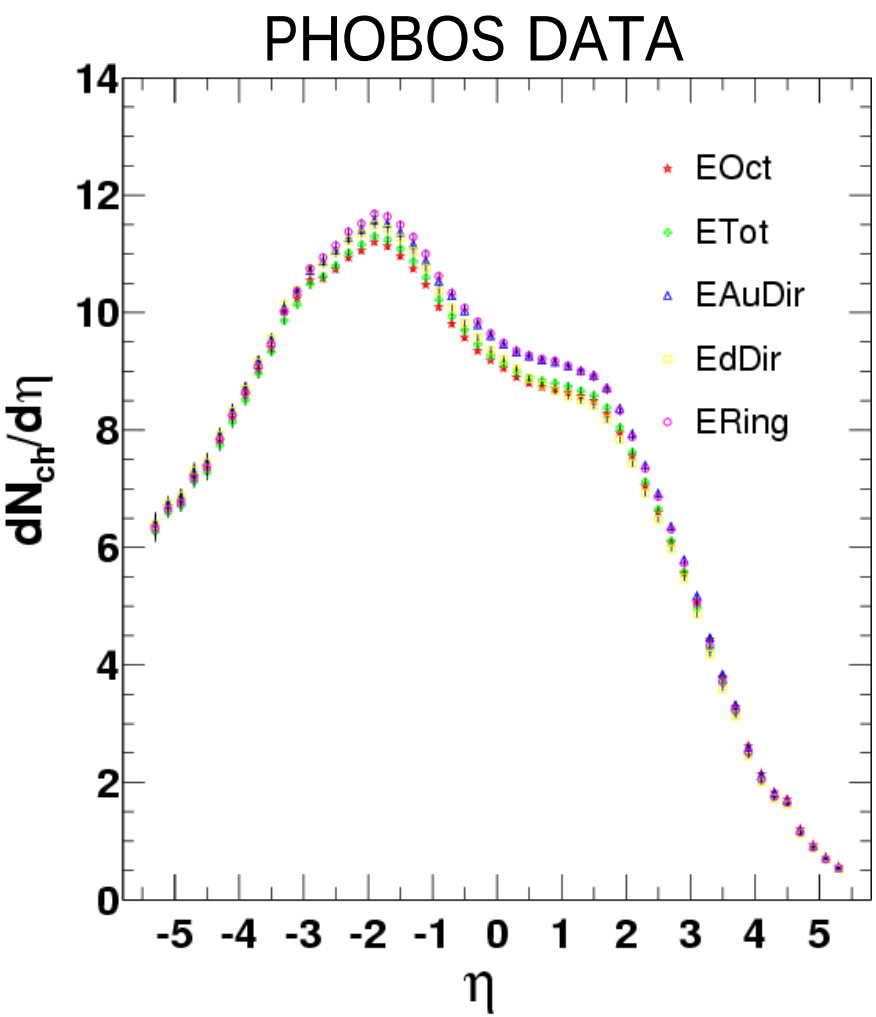


- Upper limit including systematic errors :

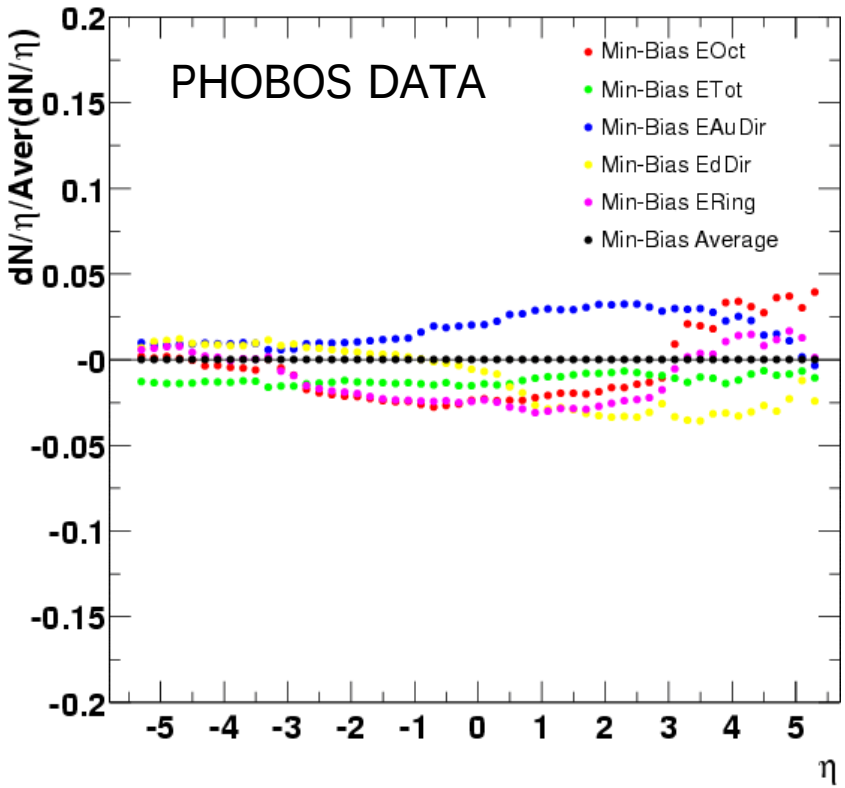
$$N^{ch}_{tot} = 110$$

- Estimated total charged particle multiplicity is $N^{ch}_{tot} = 87^{+23}_{-07}$

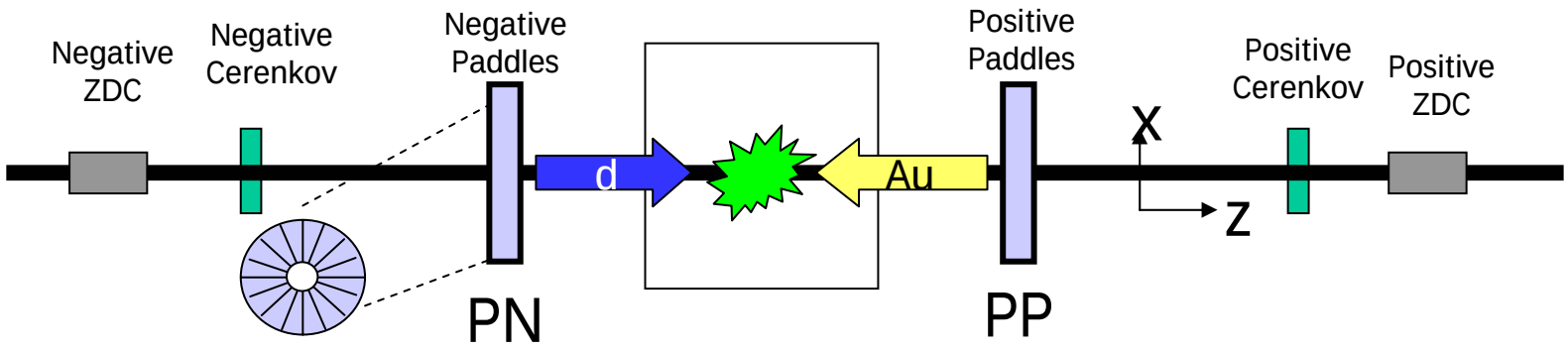
Minimum-Bias dN/dη Obtained from the Five Distinct Silicon Centrality Methods

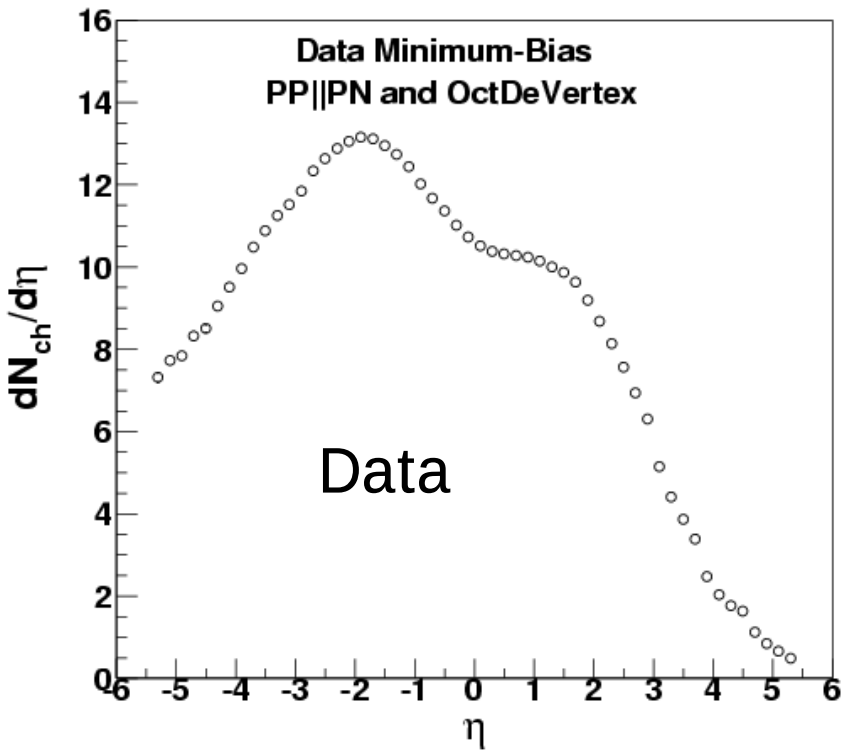


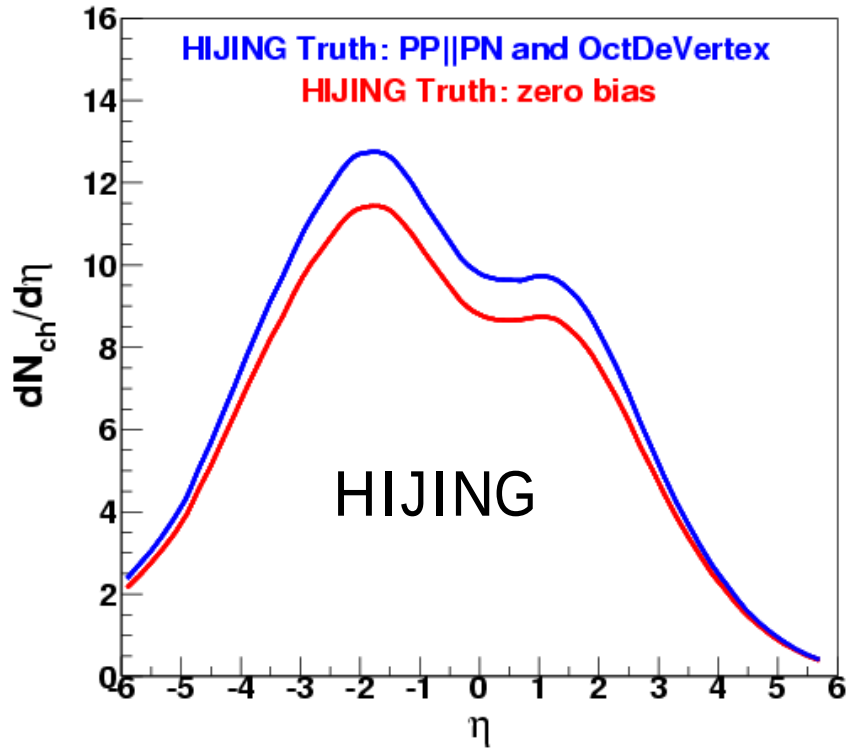
The distributions agree to within 5%



Second Analysis: Requiring at Least One hit in One of the Paddle Counters (Scintillator Counters arrays)

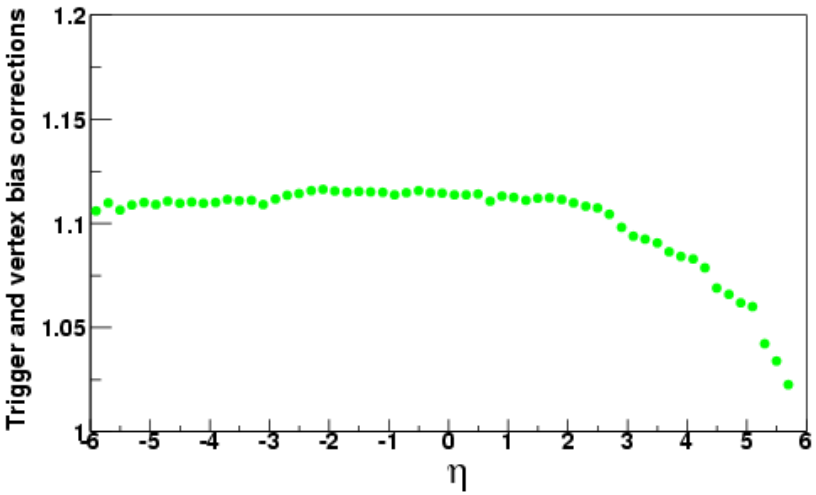




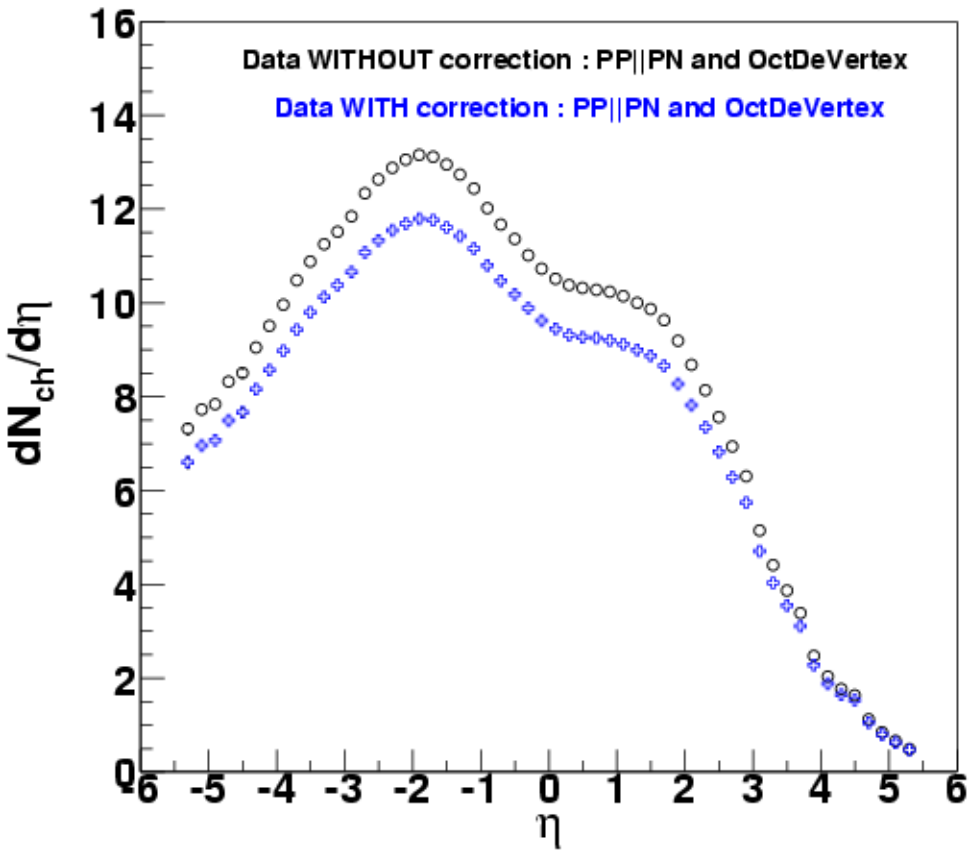


Correction Factor Distribution and Minimum-bias Distributions

Trigger and Vertex Bias corrections obtained from HIJING

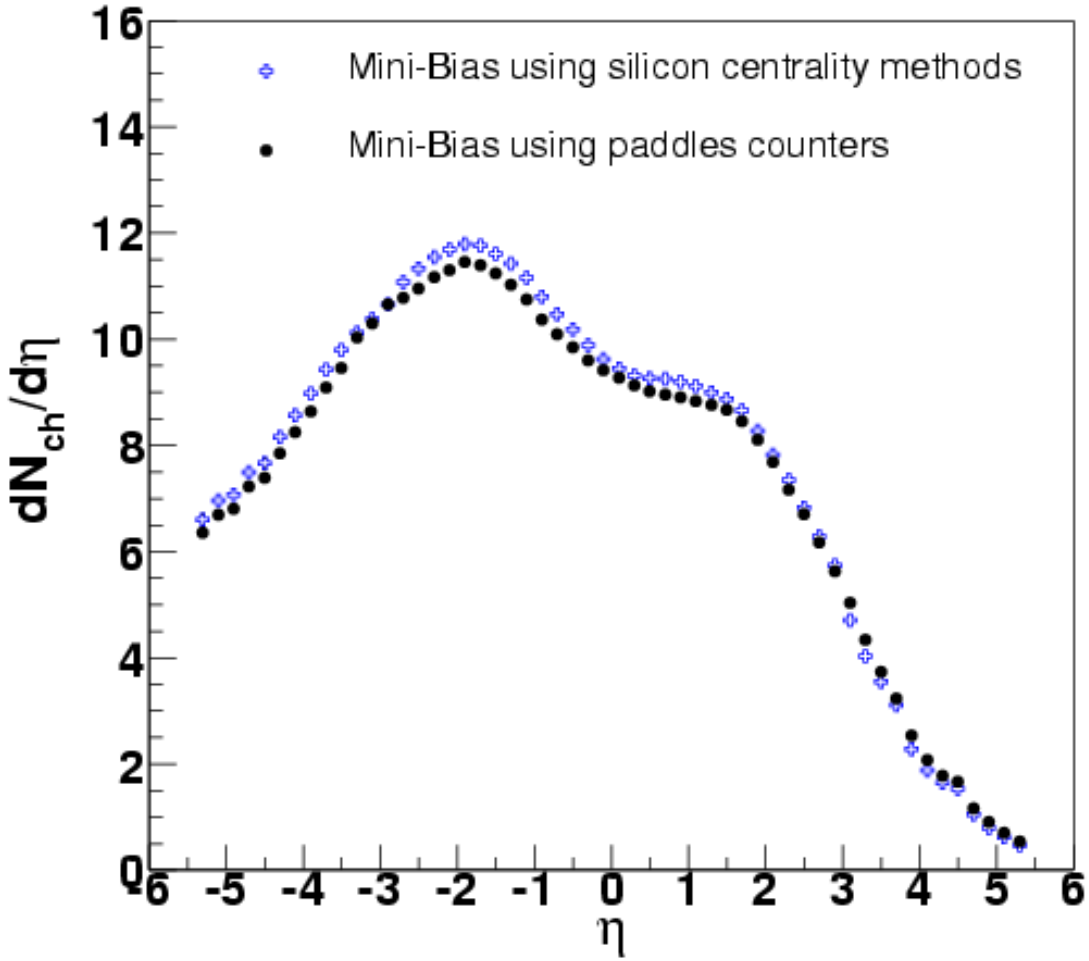


Minimum-bias distributions with and without correction

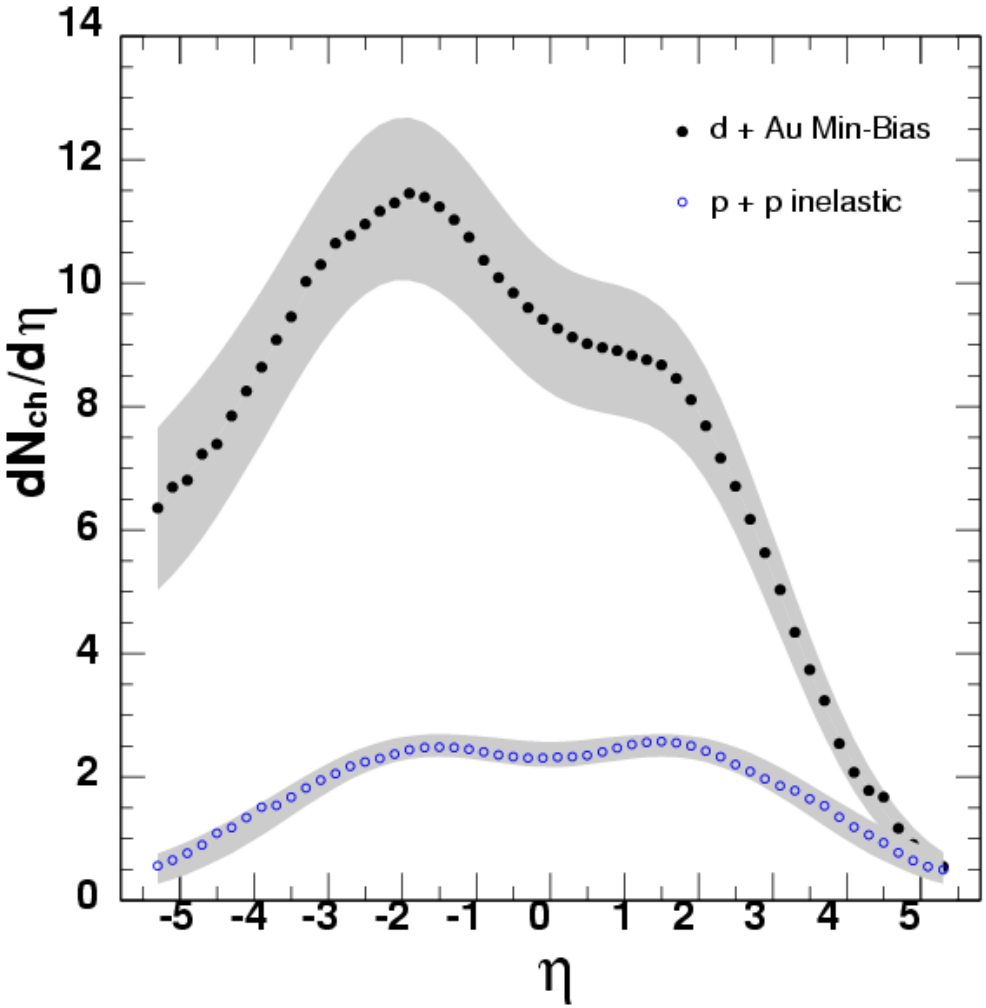


Comparison between the two analysis methods

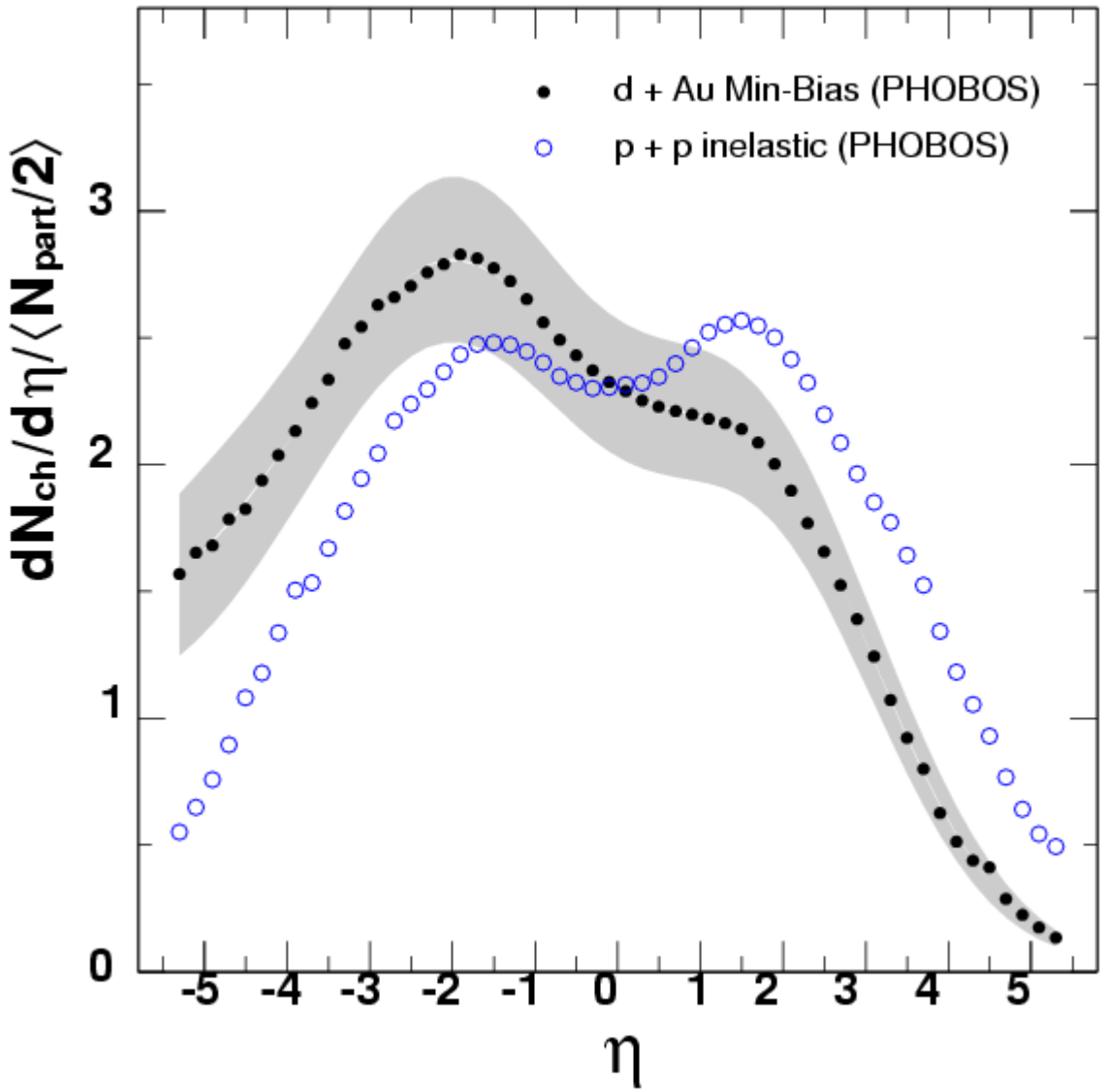
Comparison between minimum-bias distributions obtained by silicon centrality methods and paddle counters



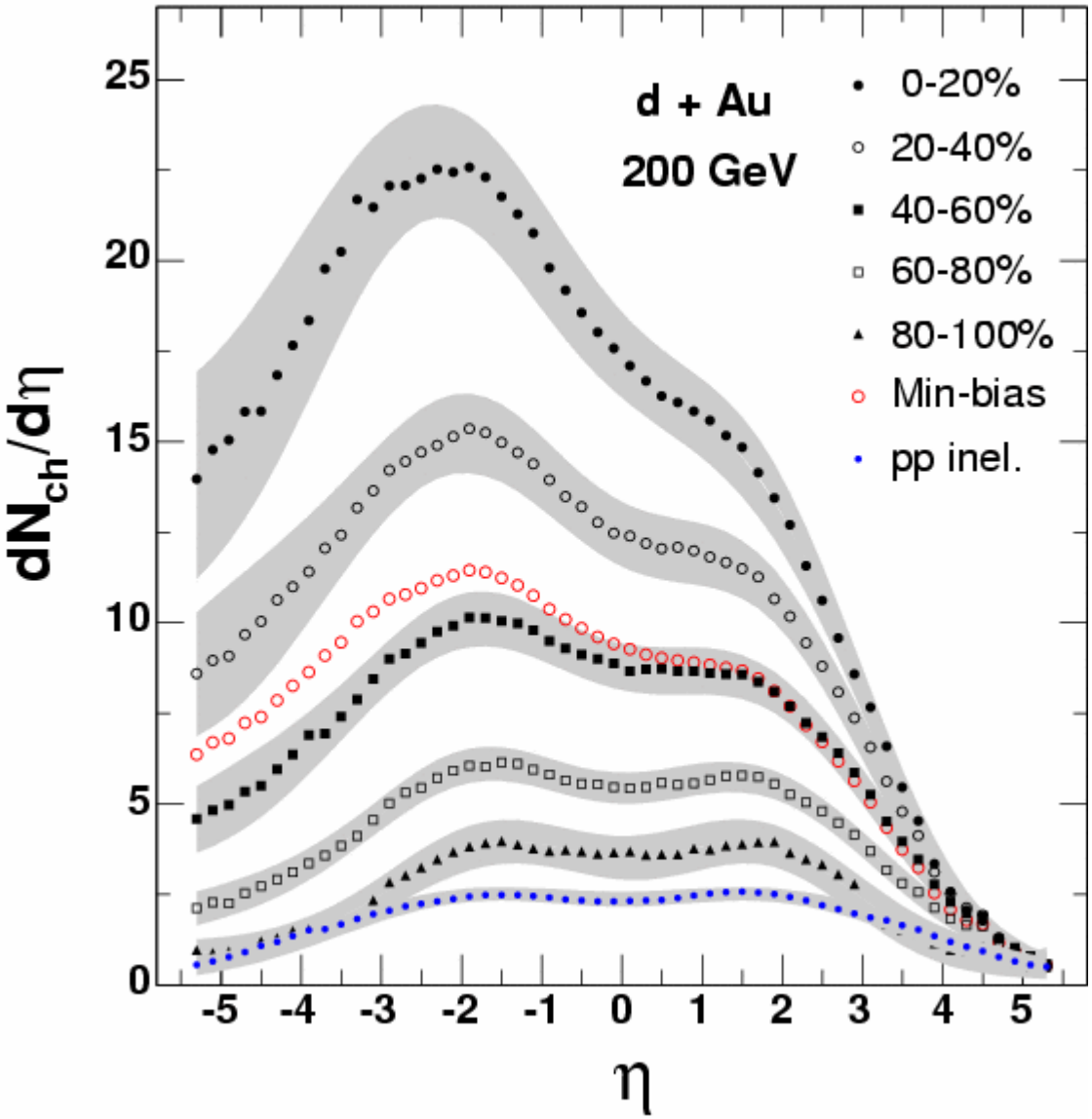
Spare


d + Au Min-Bias
p + p inelastic
dN_ch/dη
η
14
12
10
8
6
4
2
0
-5
-4
-3
-2
-1
0
1
2
3
4
5

Spare


d + Au Min-Bias (PHOBOS)
p + p inelastic (PHOBOS)
$dN_{ch}/d\eta/\langle N_{part}/2\rangle$
0
1
2
3
-5
-4
-3
-2
-1
0
1
2
3
4
5
η

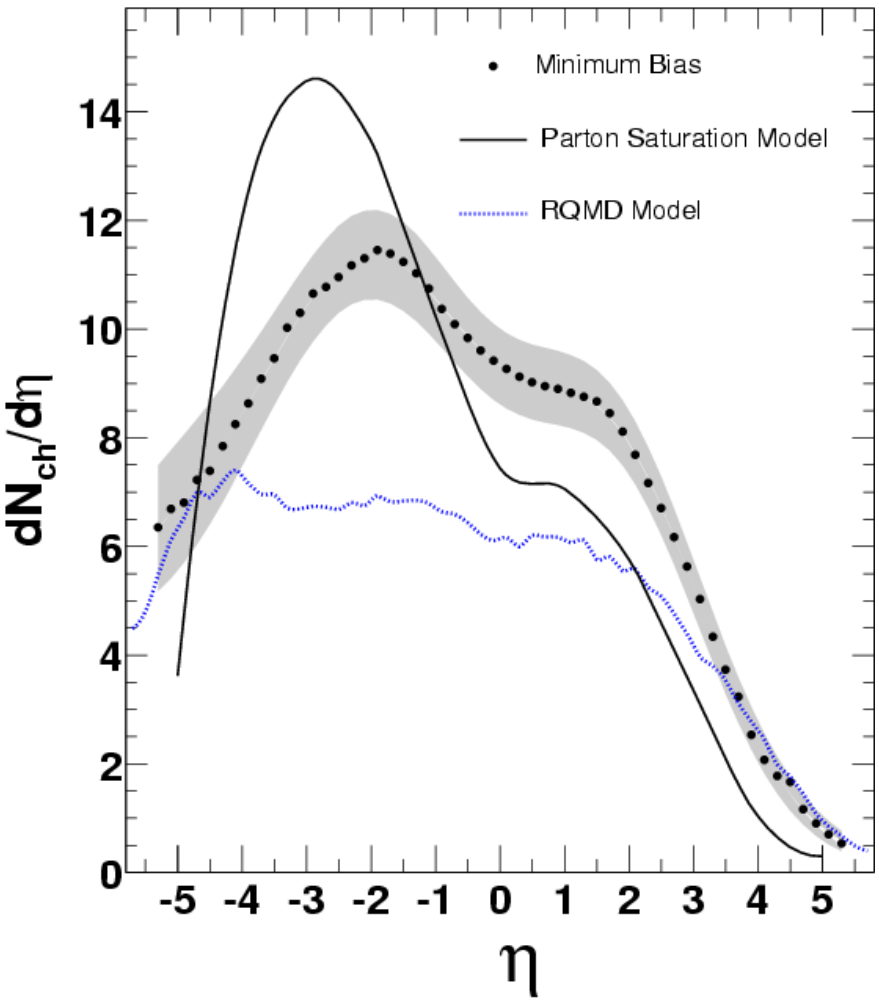
Spare


d + Au
200 GeV
0-20%
20-40%
40-60%
60-80%
80-100%
Min-bias
pp inel.
$dN_{ch}/d\eta$
η
25
20
15
10
5
0
-5
-4
-3
-2
-1
0
1
2
3
4
5

Comparison to Parton Saturation and RQMD Models

- Parton saturation (KLN) and RQMD models are inconsistent with the data
- KLN model overestimates the height of the gold side peak, underestimates its width, and predicts the peak at $\eta \sim -3$ rather than $\eta = -1.9$ as in data.

nucl-ex/0311009 and Submitted to PRL

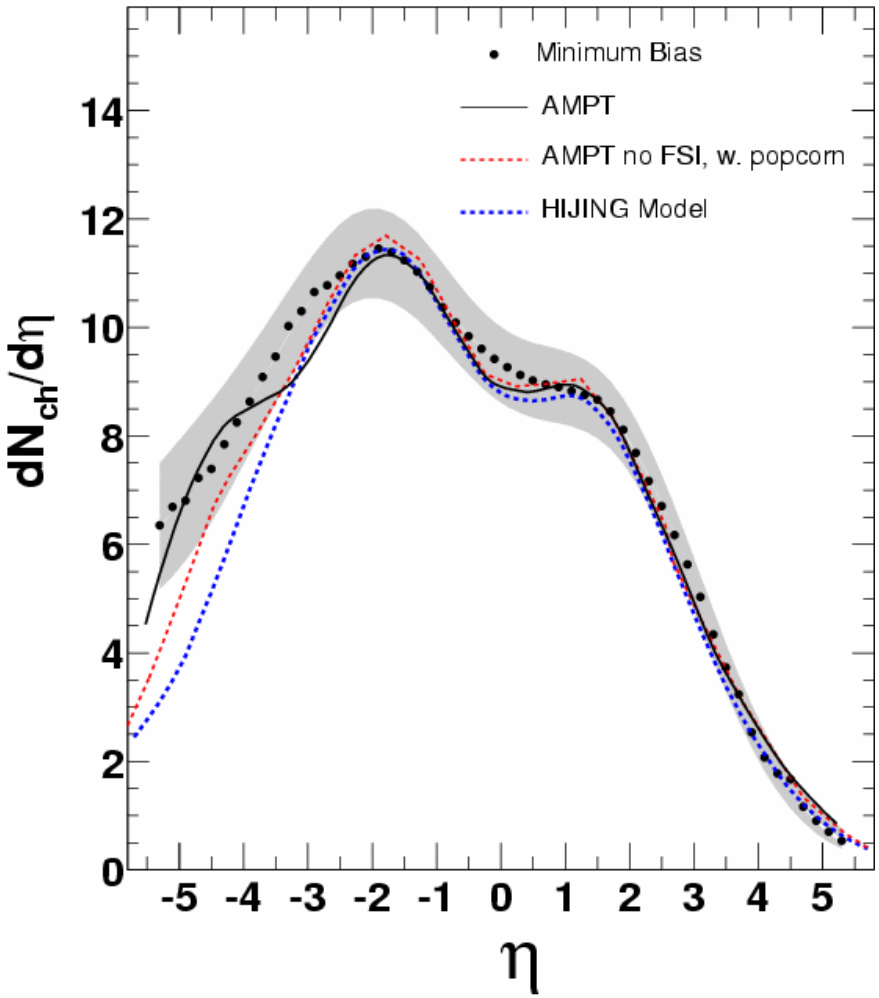


Parton saturation model predictions for d + Au:
D. Kharzeev et al., arXiv:hep-ph/0212316

Comparison to AMPT and HIJING Models

nucl-ex/0311009 and submitted to PRL

- The HIJING calculation
  - reproduces the deuteron side and the peak of the gold-side
  - fails to reproduce the tail in the gold direction ($\eta < -2.5$).
- AMPT predictions
  - With & without final-state interactions fall close to the data.
  - FSI appear to broaden the gold-side peak, leading to moderate increase of the particle multiplicity in the region $\eta < -3.5$.



AMPT predictions for d + Au :
Zi-Wei Lin et al., arXiv:nucl-ph/0301025

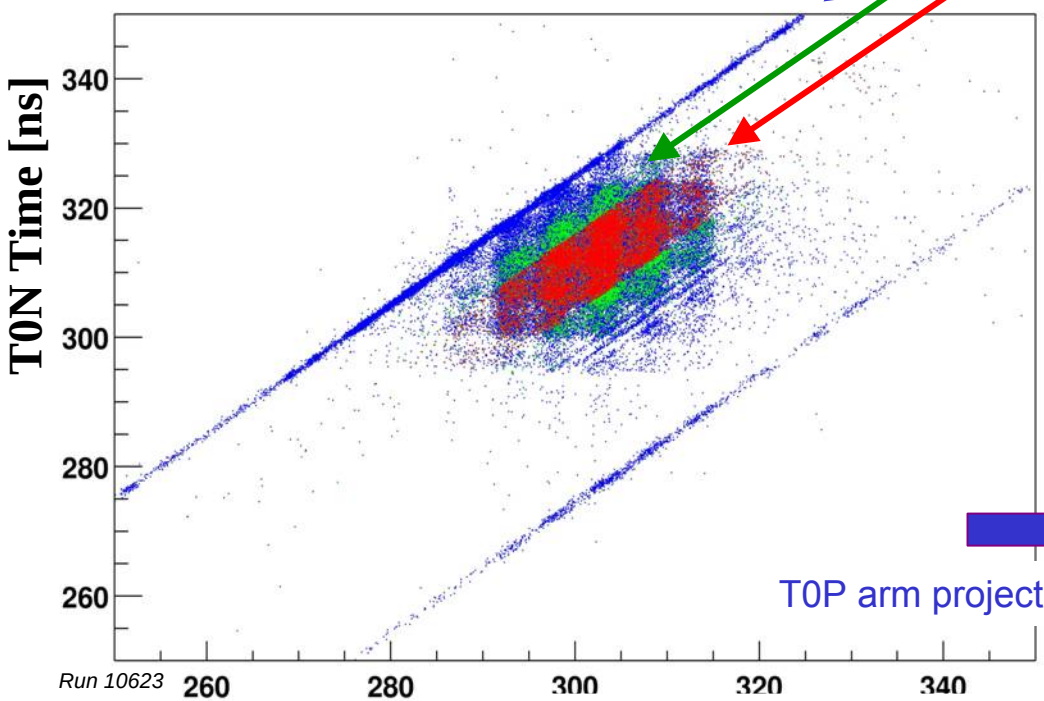
Vertex Restriction → 'Clean' Events

"De-bunched Beam" cleaned away with Vertex cut (Paddle Timing resolution not sufficient)

(T0P&T0N)||T0Single

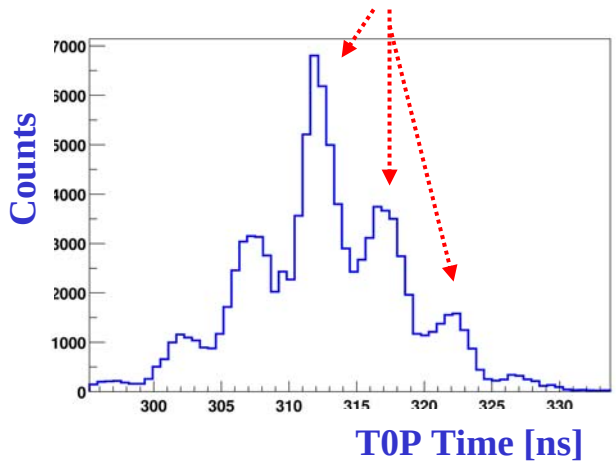
T0P&T0Nn

T0P&T0N&Vertex



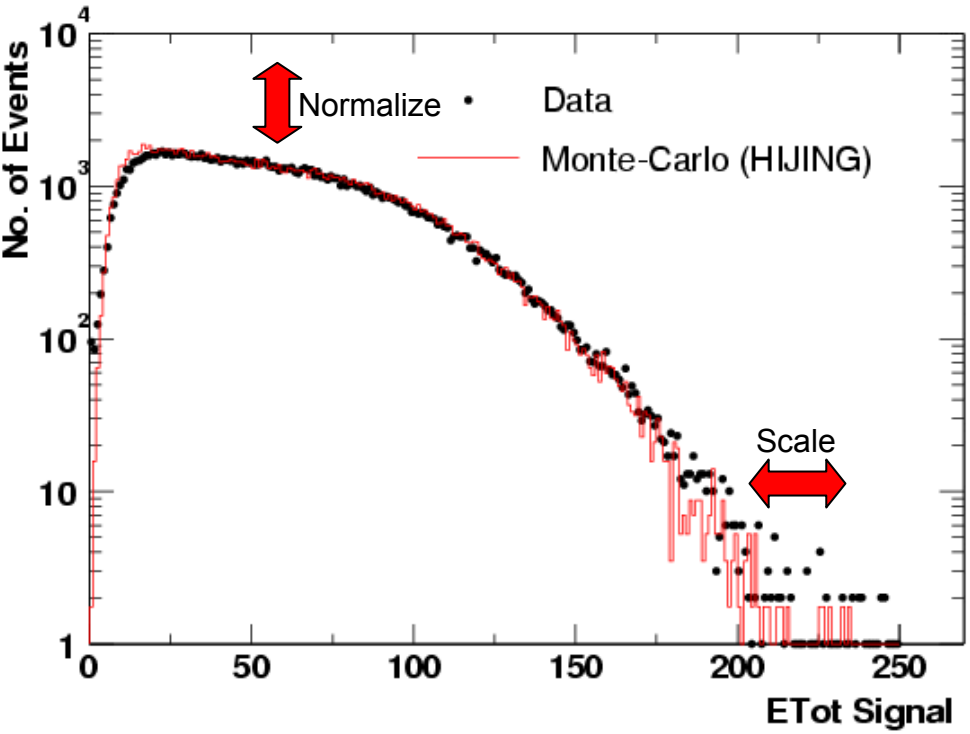
T0P arm projection

Collisions from different buckets



Centrality Determination

Comparison of the signal distributions from Data and MC (HIJING)



DATA
measured cross section

MC distribution with trigger and vertex bias

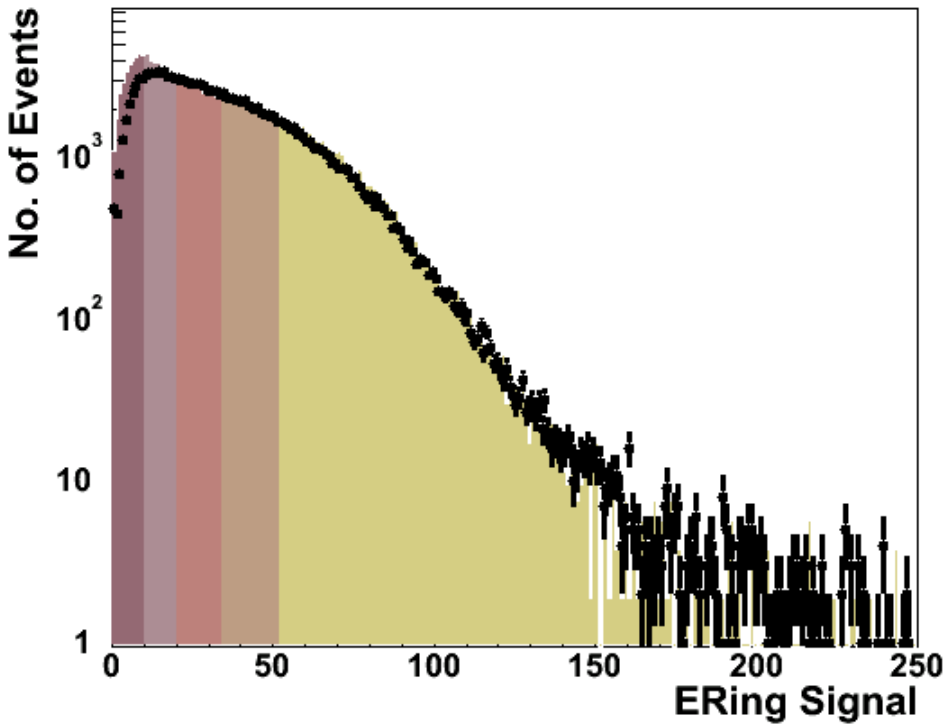
- Data and MC (biased) distributions match well
- **Data** cut = MC cut **X** scale factor

Scaling factor =1.046

Details of centrality determination were presented in DNP talks: A. Iordanova and R. Hollis at UIC

Centrality Determination

- Using simulation to estimate the trigger /event selection inefficiency for very Peripheral events



Centrality (%)	N_{part}	N_{part}(Au)	N_{part}(d)
0-20	15.62	13.63	1.99
20-40	11.04	9.10	1.94
40-60	7.20	5.44	1.77
60-80	4.18	2.78	1.40
80-100	2.61	1.50	1.11

Overall trigger and vertex-finding efficiency is ~ 83 %