Limiting Fragmentation Observations at PHOBOS

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For the PHOBOS Collaboration

PHOBOS Collaboration (April 2004)



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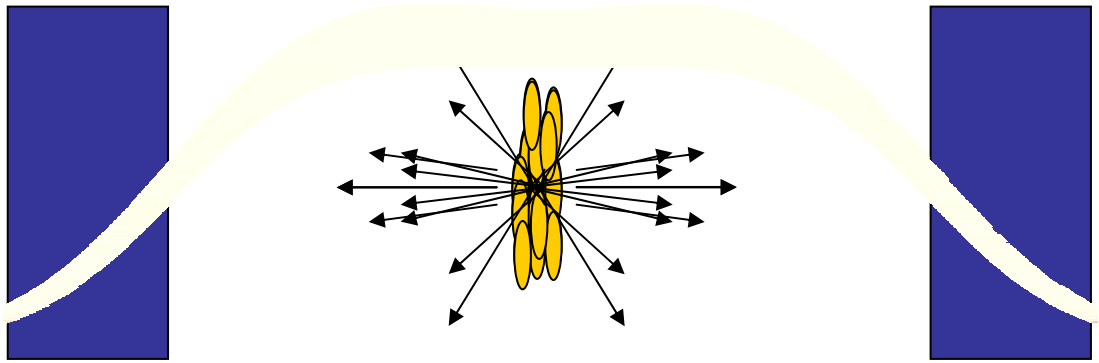
Outline

- PHOBOS
  - Detector
  - Multiplicity Measurement Technique
- Multiplicity measurements
  - *Au+Au*
  - *p+p*
  - *d+Au*
- Flow measurements

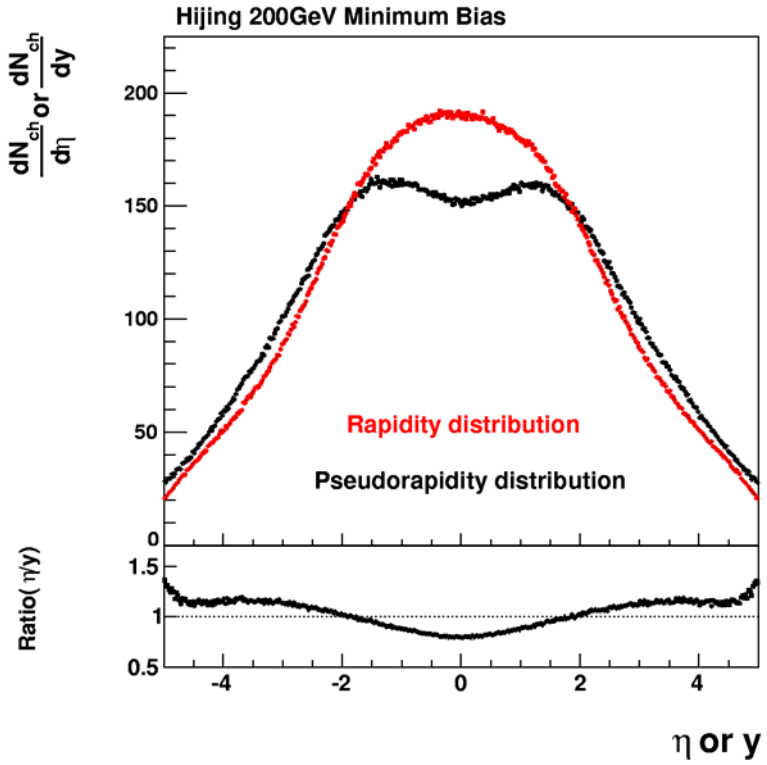
Limiting Fragmentation

- Term for particles produced at high η.
  - Particles produced close to the beam rapidity of one of the colliding nuclei
  - Same “Limiting” distribution of charged-particles in this region independent of energy

Center-of-mass System



Rapidity and Pseudorapidity

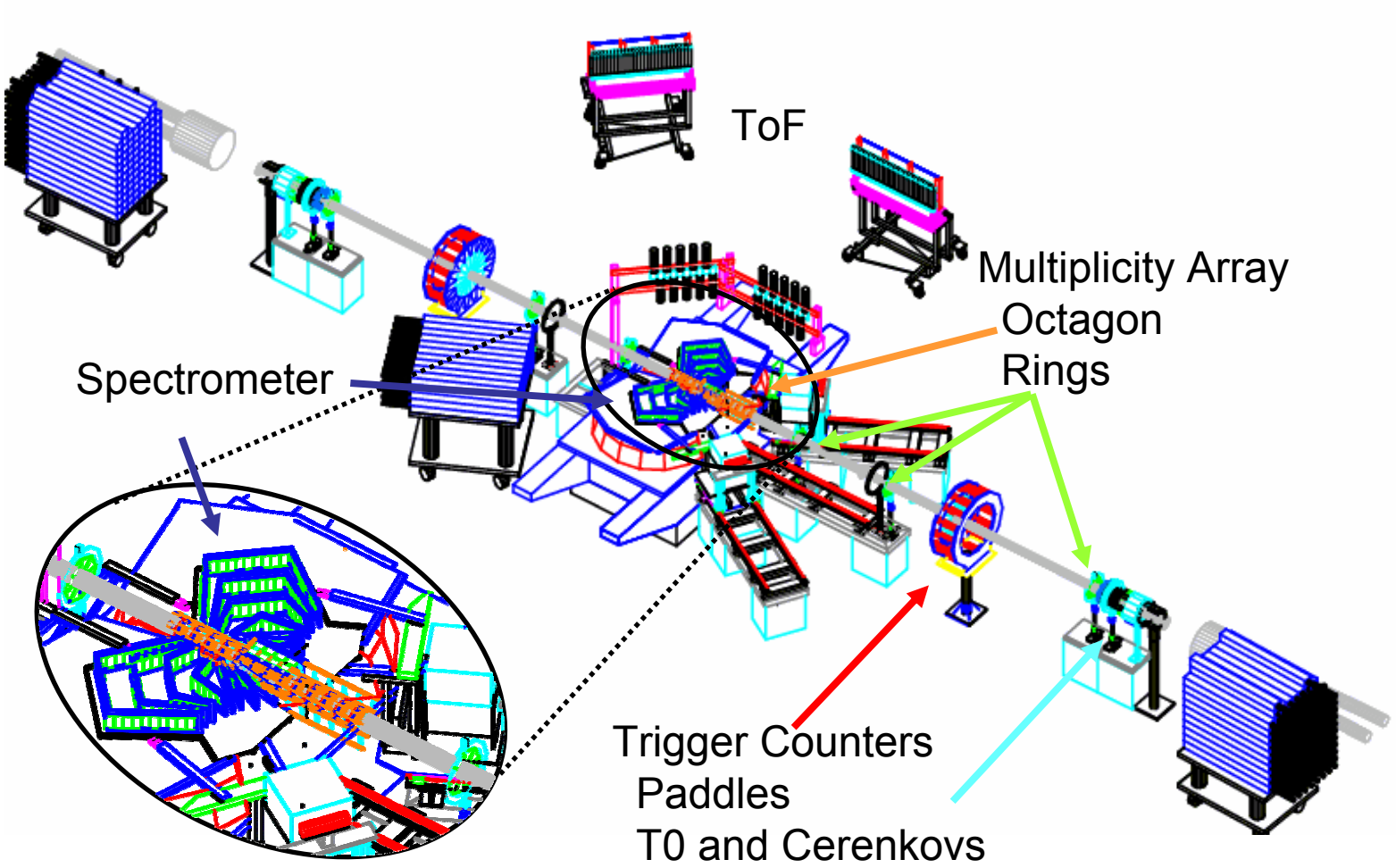


- |y|<2
  - significant deviation between y and η
- |y|>2
  - Shape is similar
  - η distribution is wider
  - Approximation y ≈ η
- y shifts under a longitudinal boost
  - dN/dy is not distorted
- ***Shift*** to target rest frame by y_{beam}
  - For both η and y

Limiting Fragmentation

- Expected → a ***narrow*** Fragmentation Region
- Observed → “Extensive Longitudinal Scaling”

PHOBOS Detector

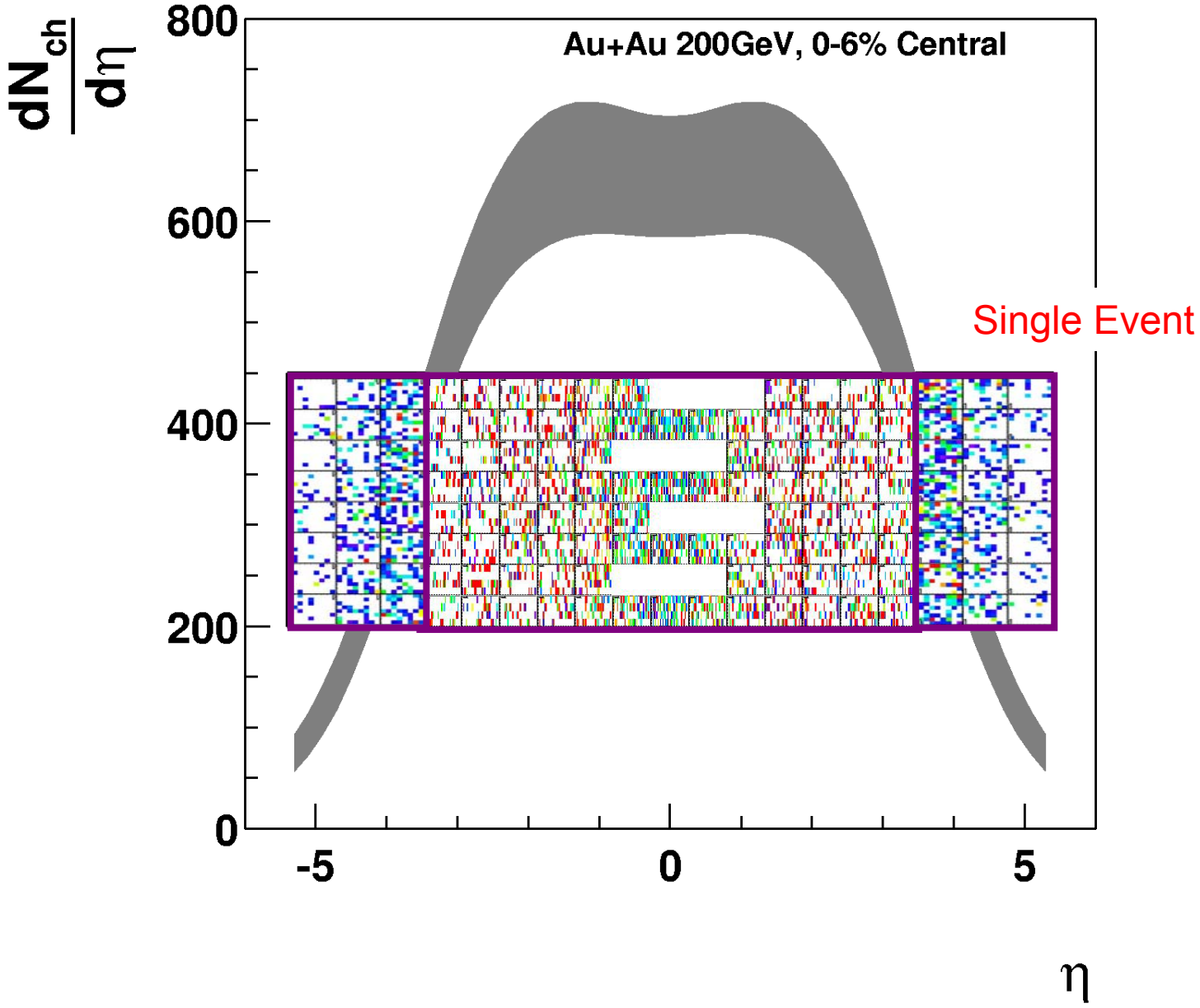


Multiplicity Detectors

- Octagon:
  - Mid-rapidity ($|\eta| < 3.2$)

- Rings:
  - Forward detectors ($3.0 < |\eta| < 5.4$)

Multiplicity Array



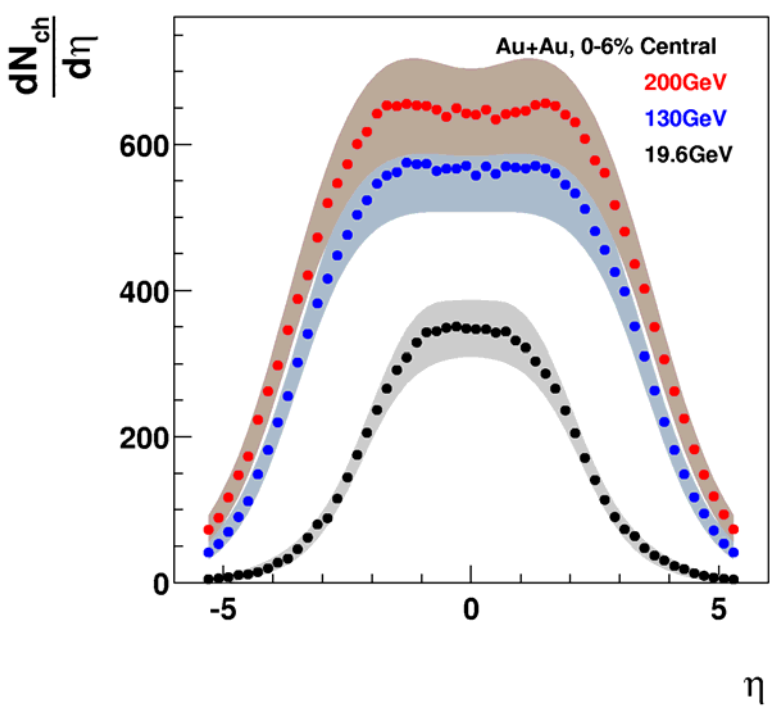
Multiplicity Reconstruction

- Hit Counting
  - Basic
    - Count digital hit pads
  - Hit density correction
    - Count digital unoccupied pad
    - Assume Poisson statistics
    - Determine mean occupancy → Apply correction
  - Occupancy corrections derived from data
- Analogue
  - Correction Applied
    - Energy deposition spectra
    - A fit to this determines the relative multi-hit contribution

Au+Au $dN_{ch}/d\eta$ vs η

- Multiplicity
  - Almost all Phase space covered
  - 3 energies
    - $\sqrt{s}$ = 19.6 to 200 GeV
  - Large range of collision geometries

Total Number of Charged Particles

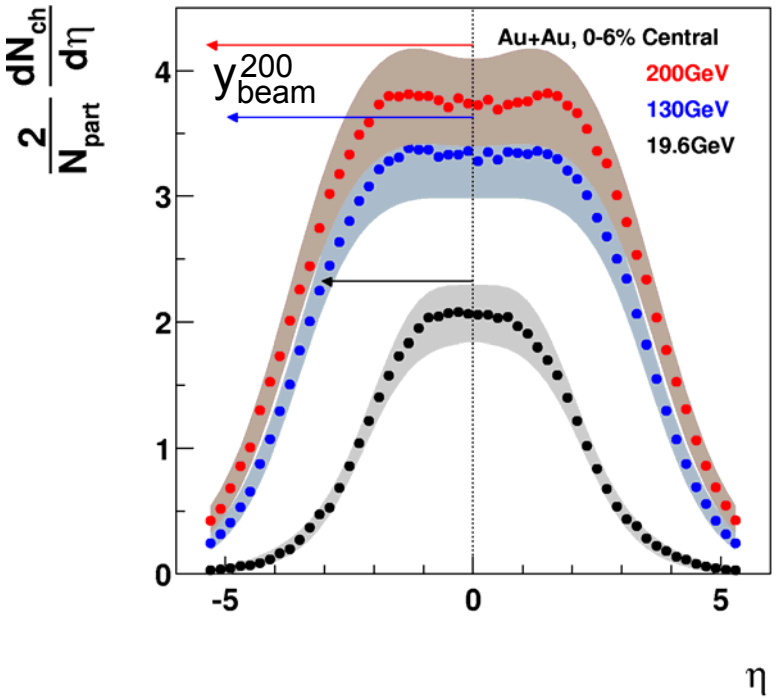


Data from PRL **91** 052303 (2003)

Au+Au $dN_{ch}/d\eta$ vs η

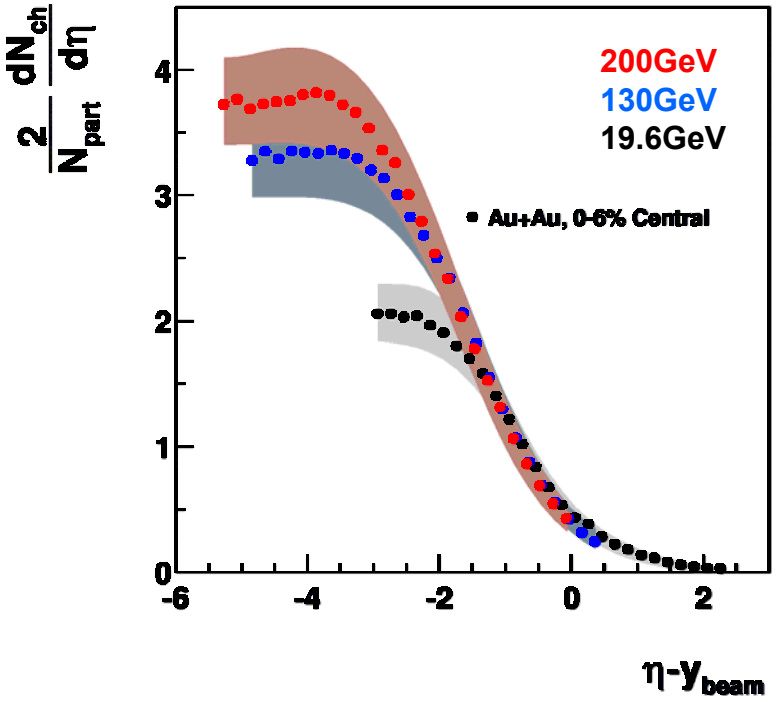
- Scaling by $N_{part}/2$
  - Distributions are relatively the same
  - $<N_{part}>$ is almost the same for each energy
- y_{beam} grows with energy
- Shift each η by y_{beam}

Total Number of Charged Particles divided by half N_{part}



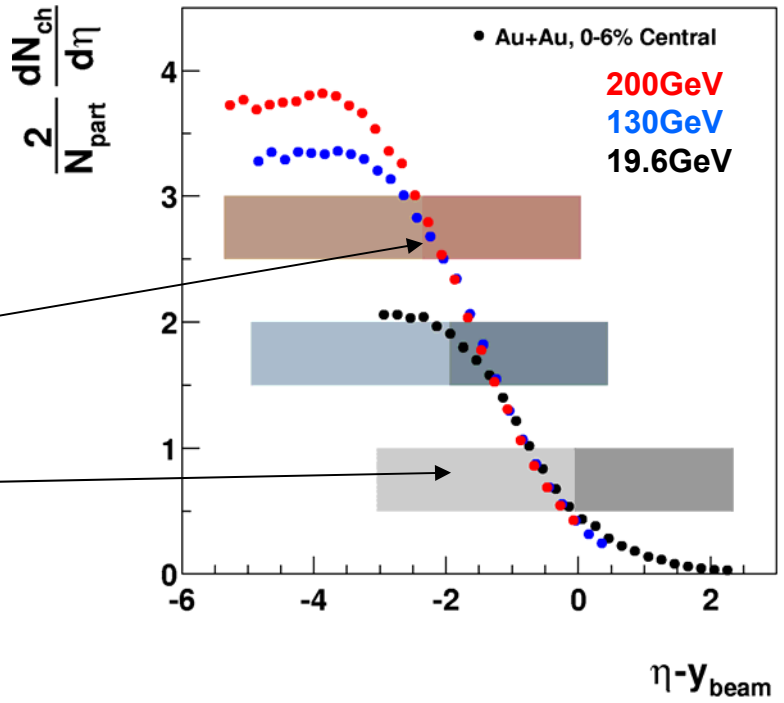
Au+Au $dN_{ch}/d\eta$ vs $\eta - y_{beam}$

- Region of 'overlap'
  - For each energy
  - Close to rapidity of one projectile
- Expected
  - Narrow fragmentation region
- Observed
  - Extensive longitudinal scaling
- Fragmentation Region
  - Grows with energy

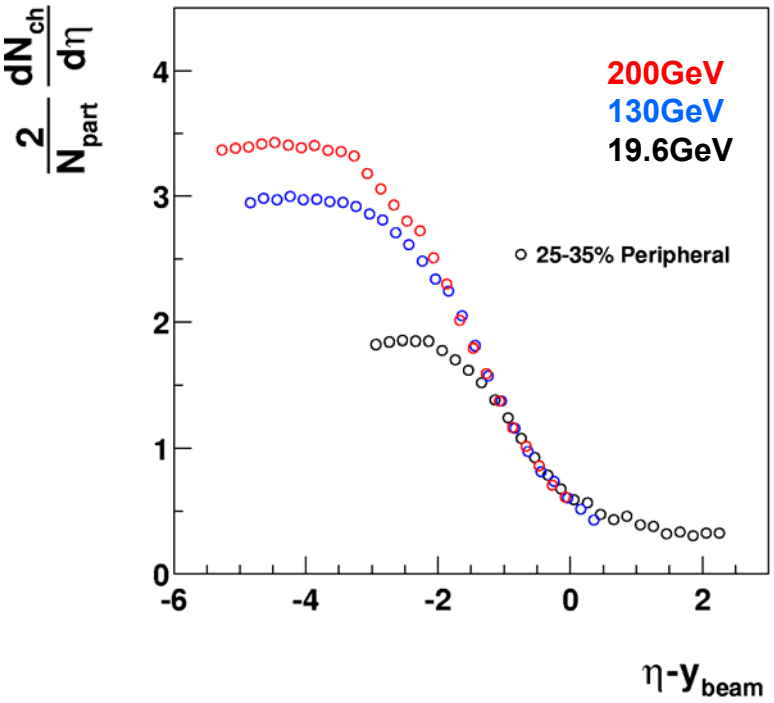


Au+Au $dN_{ch}/d\eta$ vs $\eta - y_{beam}$

- Region of overlap
  - Also covered by an overlap in detector-space
  - $-1 < \eta - y_{beam} < 0$
    - Covered by Rings for 200GeV
    - Covered by Octagon for 19.6GeV
- This is not a 'detector' effect!!

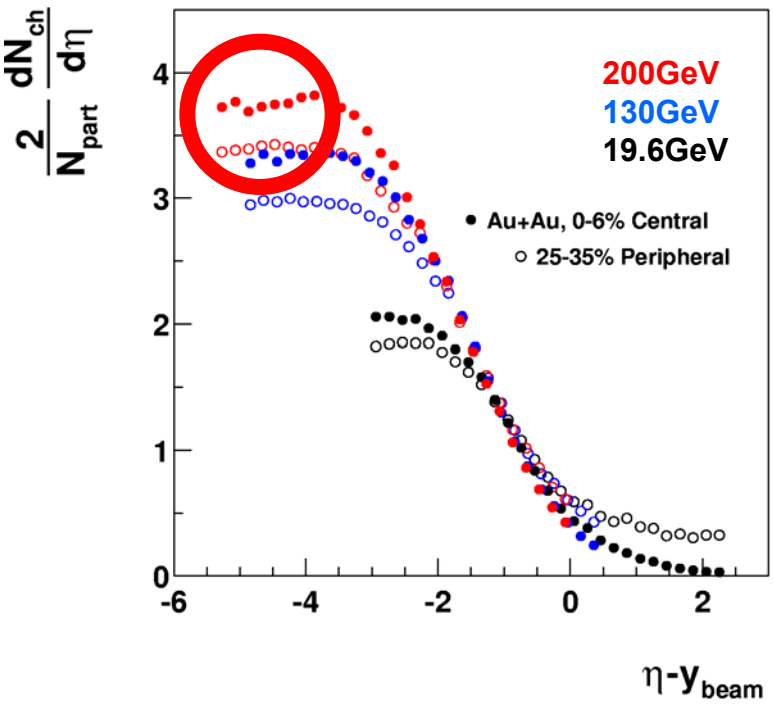


Centrality Dependence



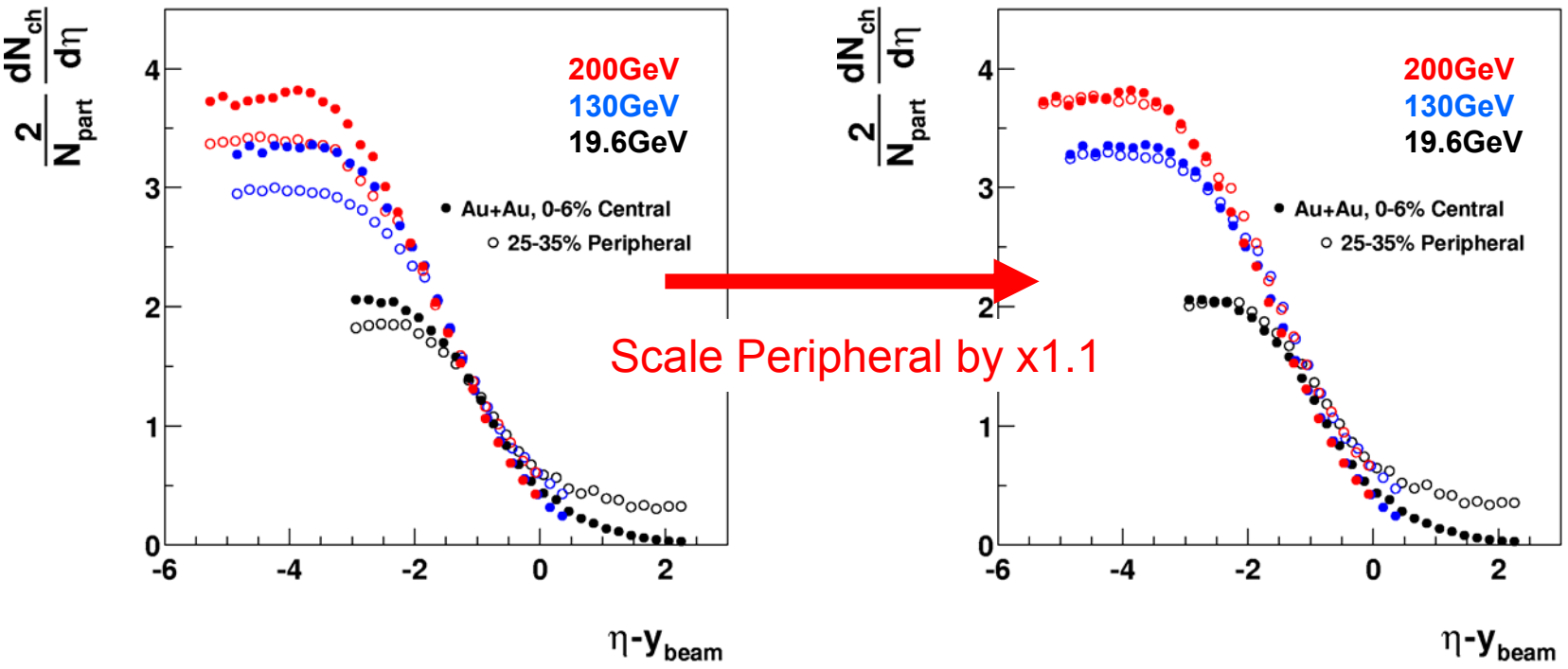
- Centrality
  - Data divided into distinct multiplicity bins
- Central 0-6%
  - N_{part} ~ 340
- Peripheral 25-35%
  - N_{part} ~ 140
- Not too peripheral
  - Restricted by the 19.6GeV data

Centrality + Energy Dependence



- Observations
  - Reduction at $\eta \sim 0$
  - Increase at $\eta - y_{beam} > 0$
  - Important observation for the total yield
- Measure the yield at $\eta \approx 0$ for 200GeV
  - Central/Peripheral≈1.1

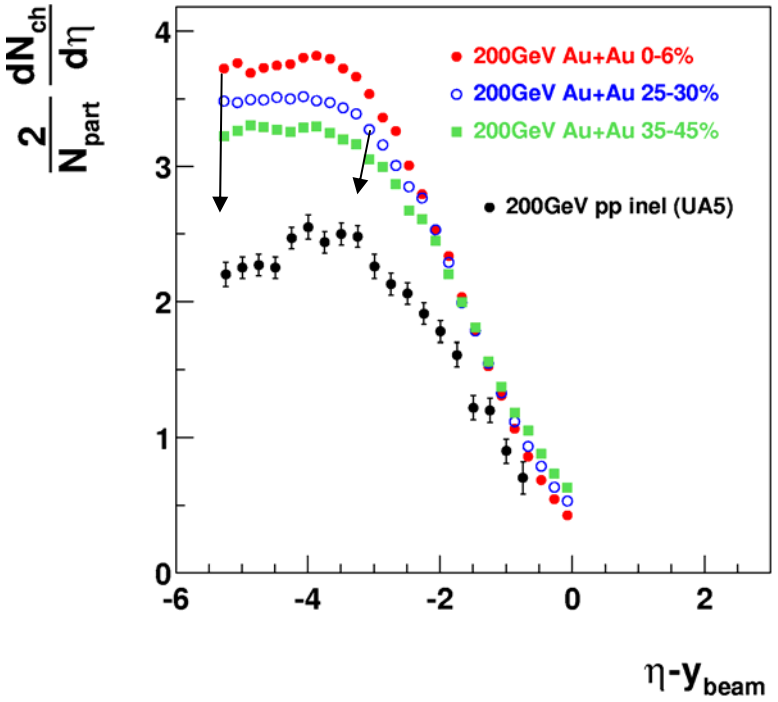
Departure Point from Limiting Curve



Same ‘relative’ departure point

Centrality dependence at 200GeV

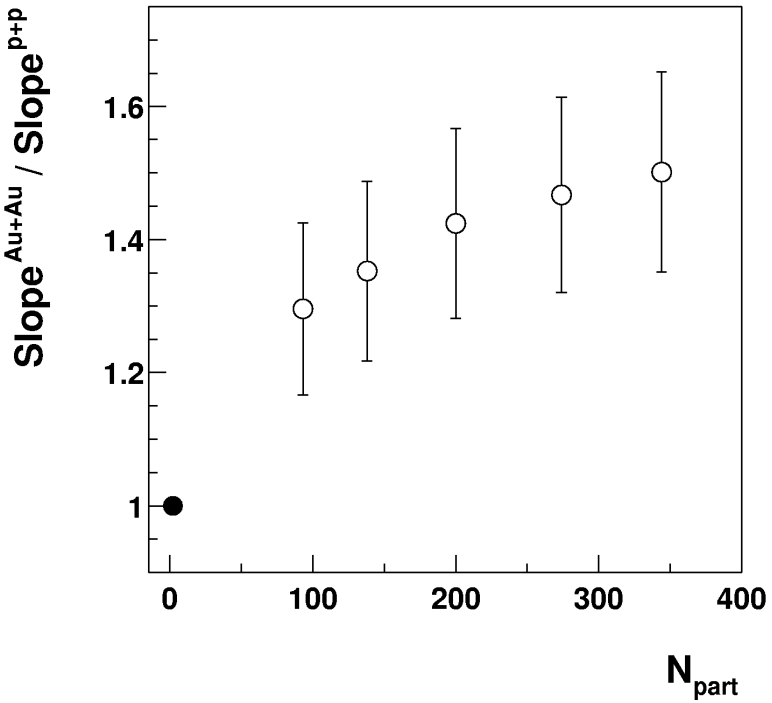
- Evolution from Central to peripheral
  - Slope decreases
- Can measure slope
  - From η-y_{beam}~-2 and 0
    - For each centrality
- Parameterize *p+p*
  - extract the slope



UA5 data from Z.Phys.C **43** (1989) 1

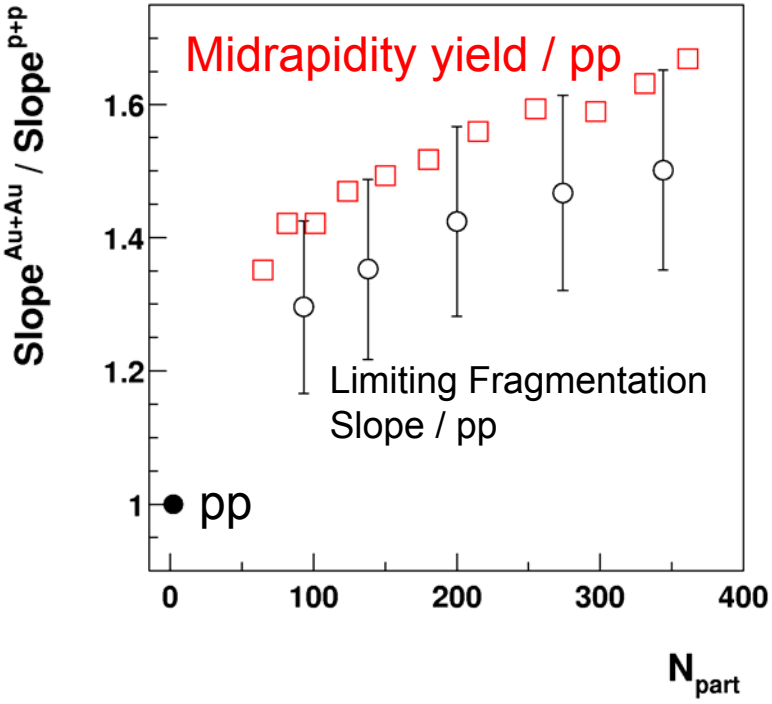
Centrality dependence of the slope

- As expected
  - Slope trend declines
  - Systematically higher than *p*+*p*
- A more peripheral measurement is needed



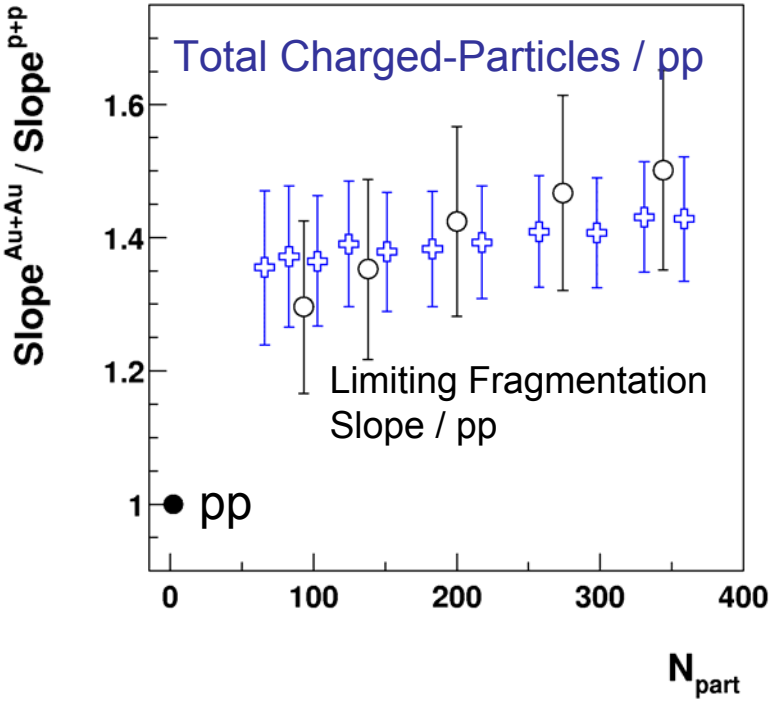
Slope and Midrapidity yield

- As expected
  - Slope trend declines
  - Systematically higher than *p+p*
- Same trend seen at midrapidity



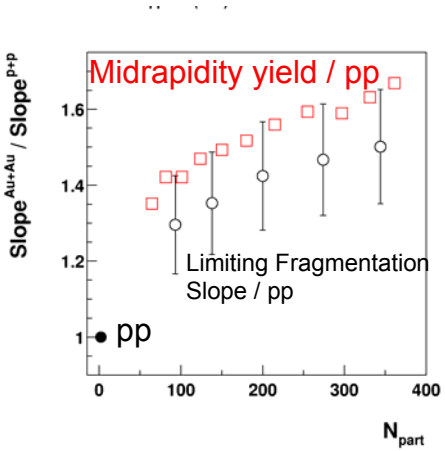
Slope and Total charged-particles

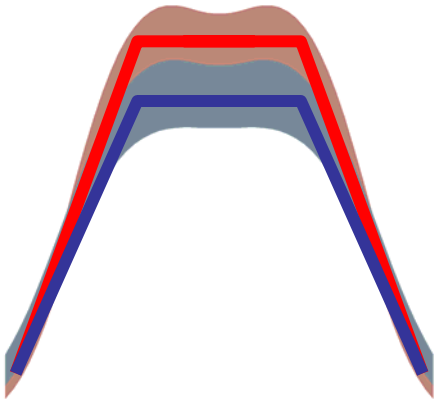
- As expected
  - Slope trend declines
  - Systematically higher than *p+p*
- Same trend seen at midrapidity
- Total yields ‘flat’
  - For increasing centrality
    - Midrapidity rise
    - Decrease for $\eta - y_{beam} > 0$
  - Effects cancel each other



Slope and Midrapidity yield

- Same trend seen at midrapidity
  - Not Surprising
    - dN/dη ~ trapezoid
  - Midrapidity α slope

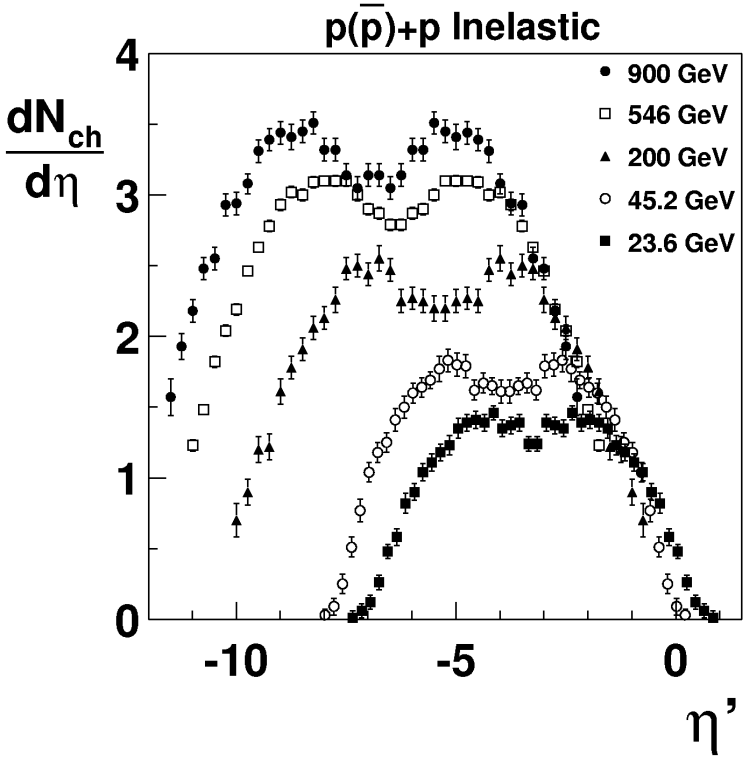




Smaller systems

- This measurement is not peculiar to *Au+Au*
  - First observed in *p+p*
  - Also in *d+Au*
- All exhibit the similar features

p+p



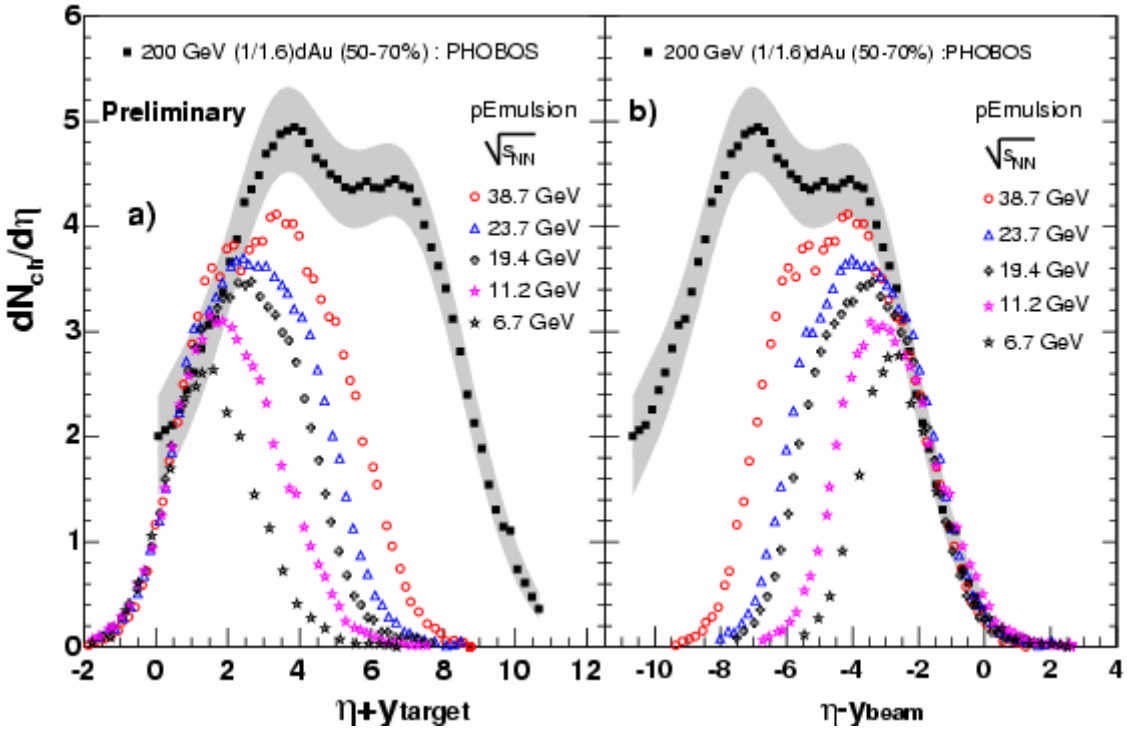
- Collection of many data over a factor of ~50 in $\sqrt{s}$
  - Reasonable Limiting Fragmentation agreement!

- $\eta' = \eta - y_{beam}$

UA5 (200-900) → Z.Phys.C **43** (1989) 1
ISR (23.6,45.2) → Nucl.Phys **B129** 365 (1977)

d+Au

50-70% Centrality, PHOBOS data

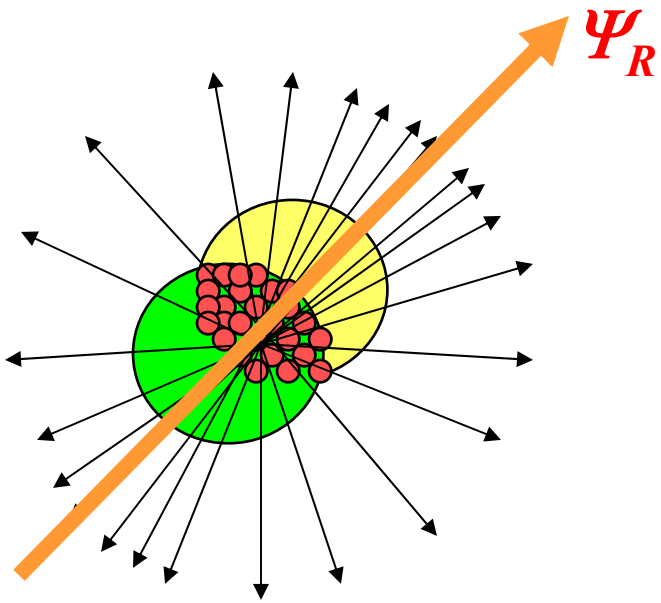


d+Au data from nucl-ex/0409021
p+Em referenced therein

d+Au

- Limiting fragmentation in both
  - Projectile rest frame
  - Target rest frame
- Centrality dependence
  - Systematic comparison with lower energy data
  - No need to change species
    - All measured in same collision system
  - Limiting fragmentation in each centrality bin

Elliptic Flow

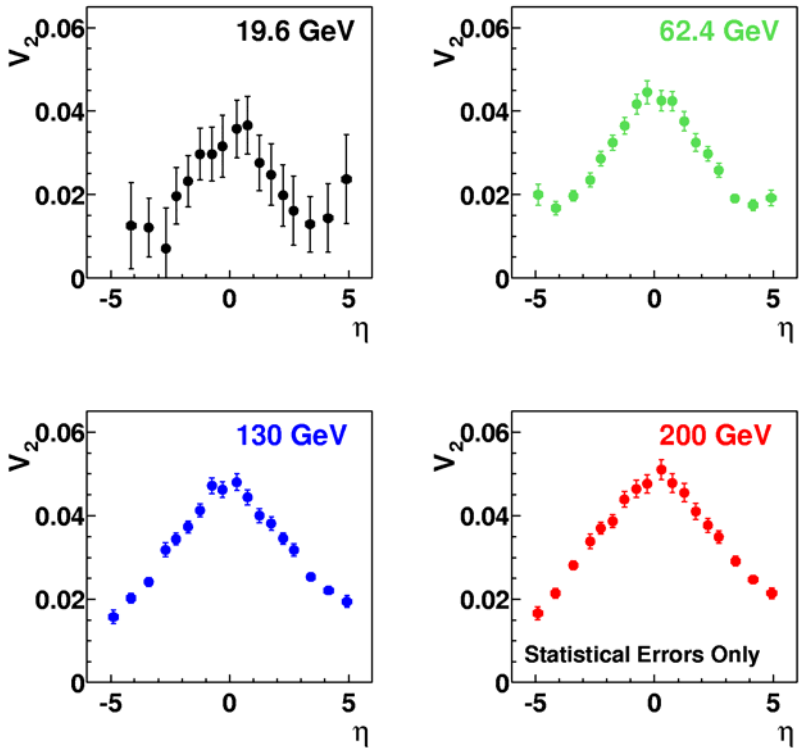


- The effect of the geometrical asymmetry
  - Non-central collisions
- Procedure
  - Measure the angle for the highest yield (Ψ_R)
    - Relative to the detector
    - "Reaction Plane"
  - Measure all particles relative to this angle
    - $2V_2 cos\ (2(\phi - \Psi_R)$

$$dN/d(\phi - \Psi_R) = N_0 (1 + 2V_1 cos\ (\phi - \Psi_R) + 2V_2 cos\ (2(\phi - \Psi_R) + \ldots)$$

Flow Results

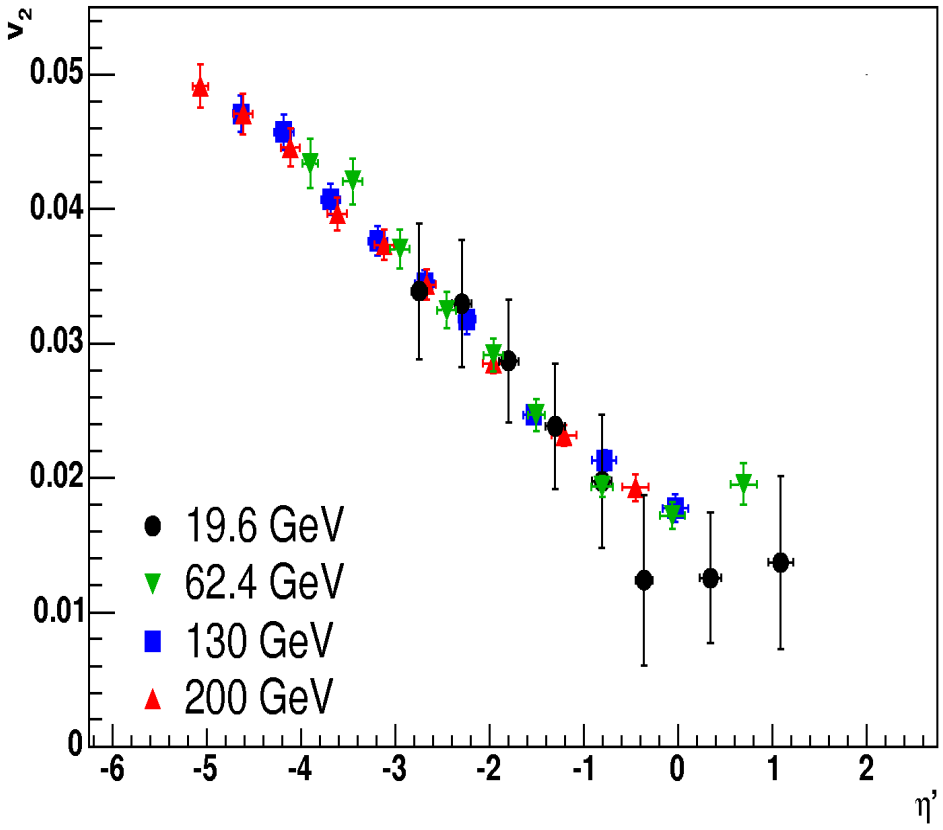
- Elliptic flow results
  - Statistical errors only
- Shift by y_{beam} again



Data from nucl-ex/0406021

Flow Results

- Elliptic flow results
  - Statistical errors only
- Shift by y_{beam} again
  - Fold and average signals

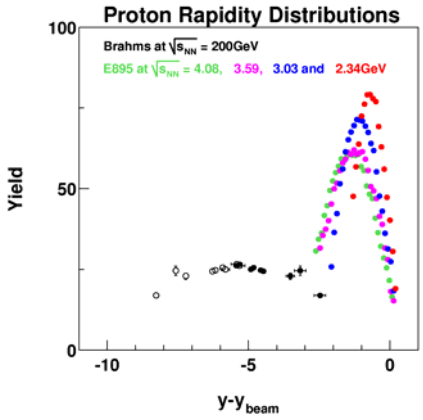


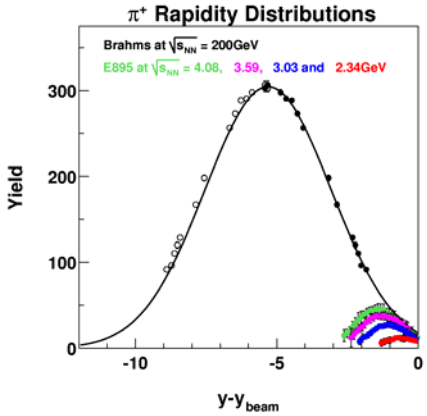
Data from nucl-ex/0406021

Outlook

- Several questions remain
  - Centrality dependence for whole range
  - Collision species dependence
    - Will *Cu+Cu* fit into *Au+Au* data?
  - Is this observation specific to η?
    - Original hypothesis was for rapidity distributions
  - Does each particle species exhibit the same features?
    - PHOBOS cannot identify particles away from midrapidity

Particle Species





- Lots of data available
  - Pions, Protons
  - Large rapidity and energy coverage

Brahms (200) → PRL 91 072305 (2003) (protons)
arXiv:nucl-ex/0403050 (mesons)
E895 (others) → PR **C66** 054905 (2003)

Summary

- PHOBOS has measured multiplicity and flow at high-η.
  - Large systematic dataset
  - $-5.4<\eta<5.4$
  - 2 to 360 participants
  - $\sqrt{s}$ = 19.6 to 200 GeV
- In the target rest frame
  - Multiplicity exhibits a common yield curve close to the beam rapidity of one nucleus
    - Extensive longitudinal scaling observed in
      - *Au+Au*, *d+Au* and *p+p*
  - Flow exhibits similar type behavior