Results from the PHOBOS experiment at RHIC

Gunther Roland (MIT)
for the
PHOBOS Collaboration

PHOBOS Collaboration

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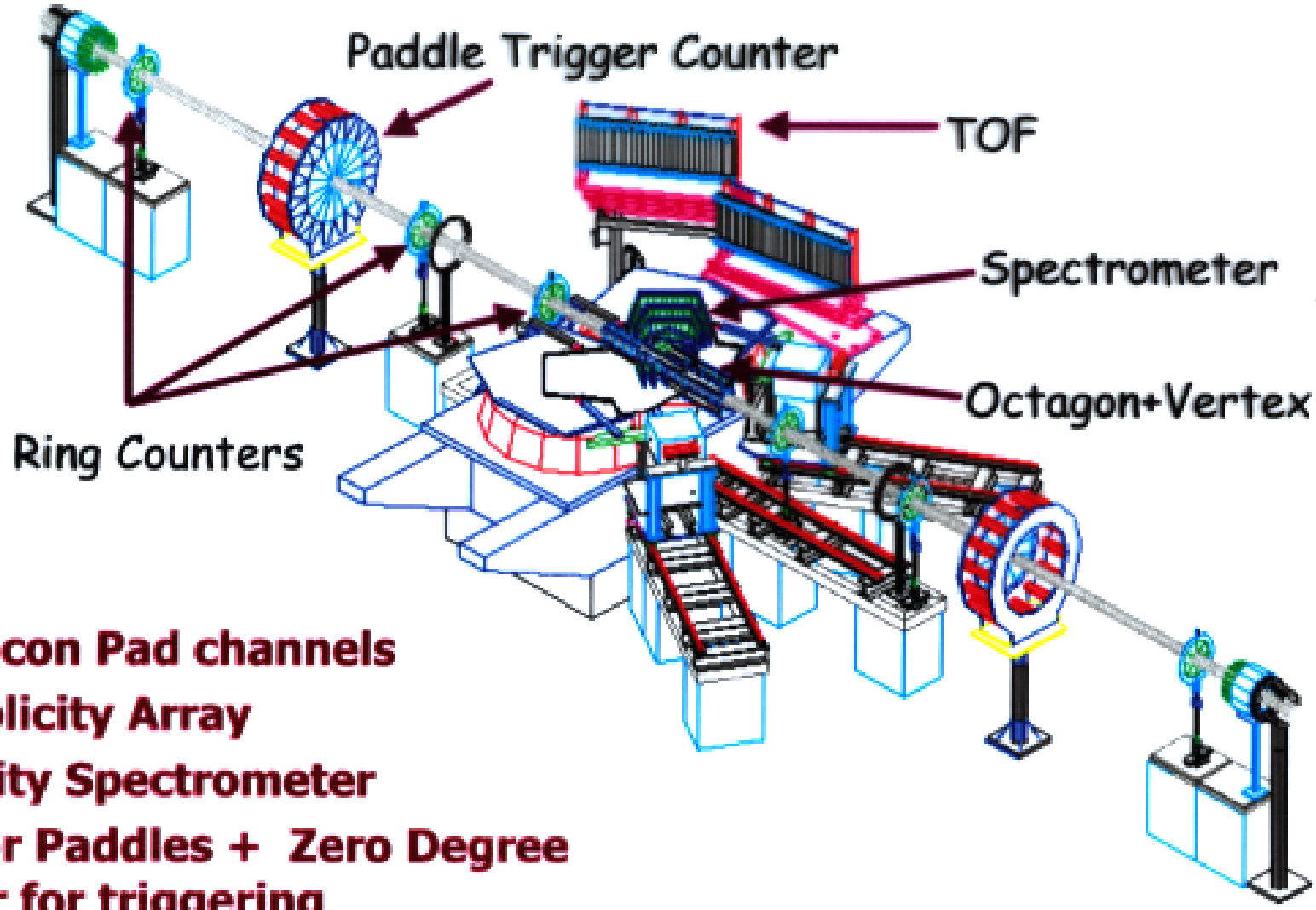
PHOBOS Detector



- 96000 Silicon Pad channels
- 4-π Multiplicity Array
- Mid-rapidity Spectrometer
- Scintillator Paddles + Zero Degree Calorimeter for triggering
- TOF wall for high-momentum PID

see talk by R. Pak Tue 3:20 PM

Year 1: The Big Picture

Q:

- **Entropy Production** → **Charged Particle Density**
- **Thermal Equilibration** → **Event Anisotropy - Flow**
- **Hadro-Chemistry** → **Particle Ratios**

Context:

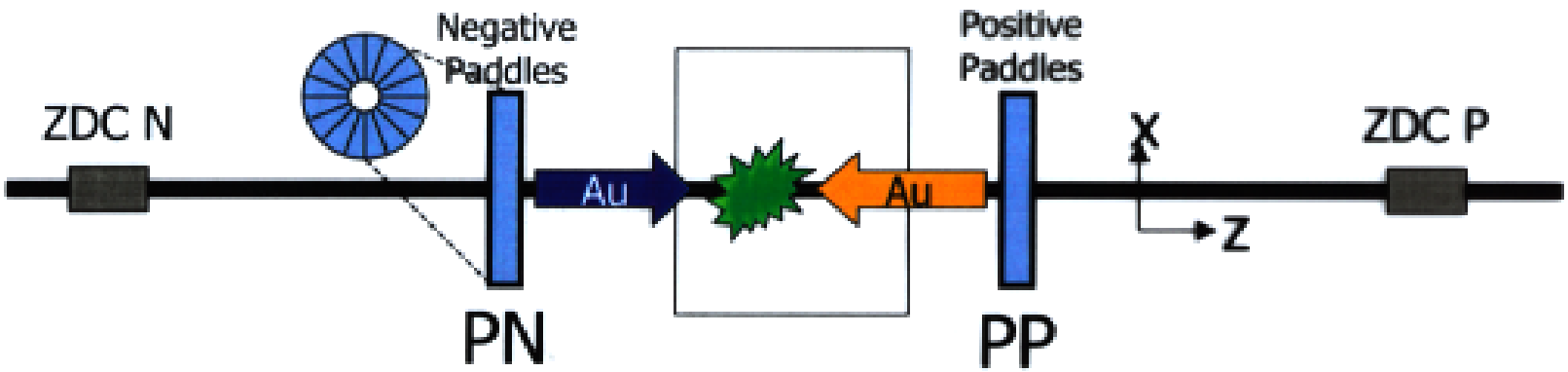
- **Energy Dependence (vs. AGS/SPS Data)**
- **System Size (p+p, N_{part} Dependence)**

Event selection and Centrality Determination

See talk by Judith Katzy Wed, 4:40 PM

- **Minimum bias trigger on Au+Au interactions**
- **Determine number of participating nucleons**

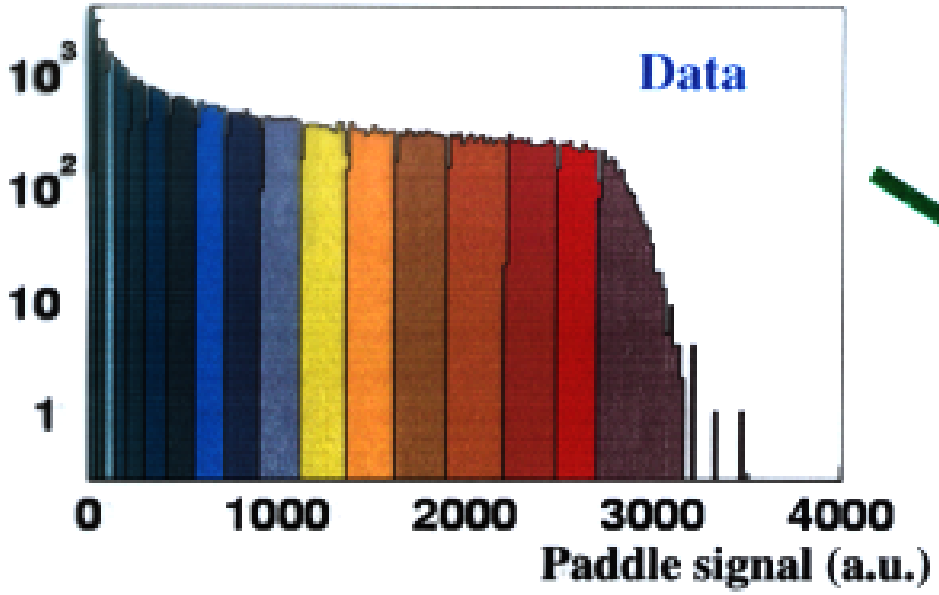
Selecting Collisions



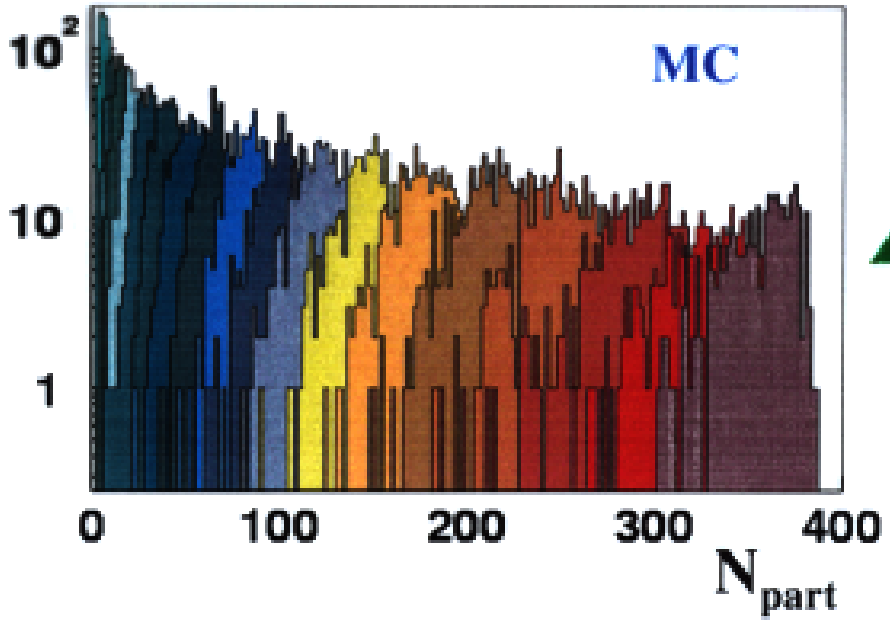
- **Coincidence between Paddle counters**
- **Paddle + ZDC timing reject background**

- **Sensitive to 97% of inelastic cross-section for Au+Au at sqrt(s_{NN}) = 130 GeV**

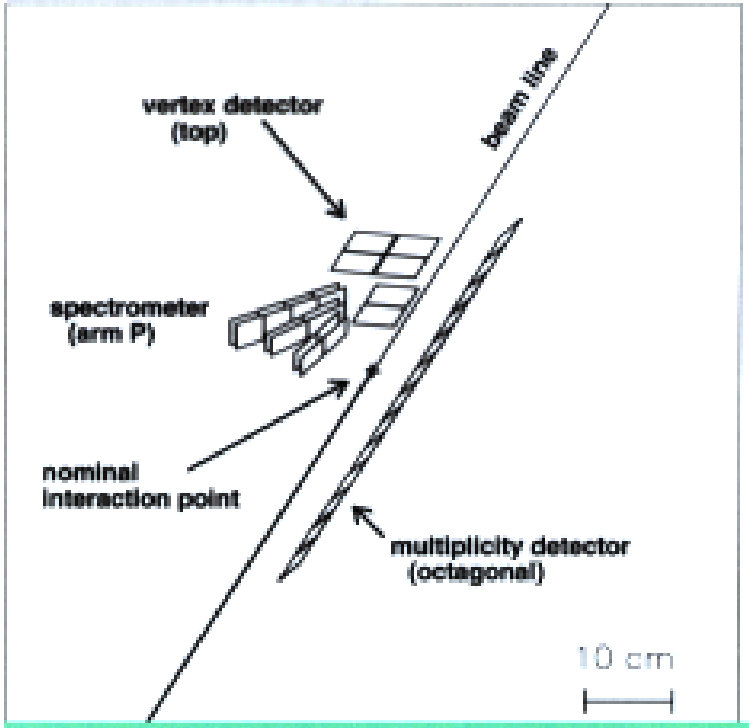
Determination of N_{part}



- HIJING +GEANT
  - Glauber Calculation
  - Model of Paddle trigger



$dN_{ch}/d\eta$ @ η=0 vs Energy



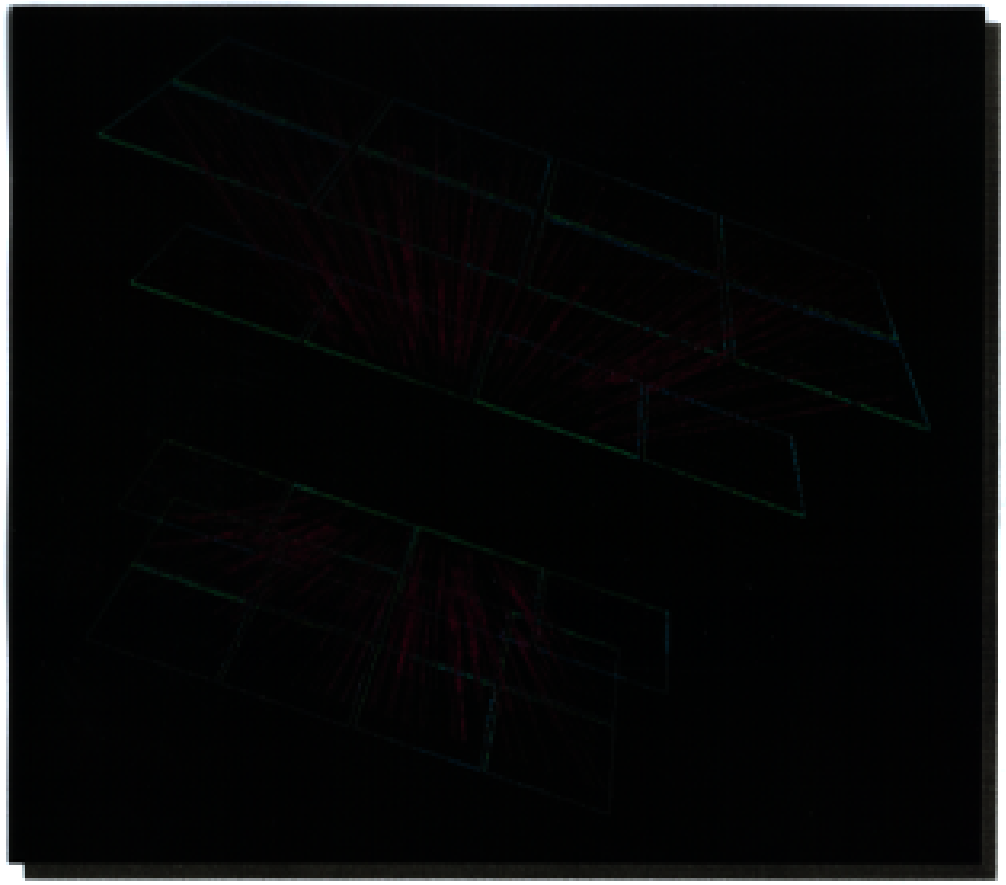
- Two values of sqrt(s_{NN}):
  - 56 GeV
  - 130 GeV
- Select 6% most central events
- Count Tracklets near η = 0

For method , see poster by P. Decowski

Q:

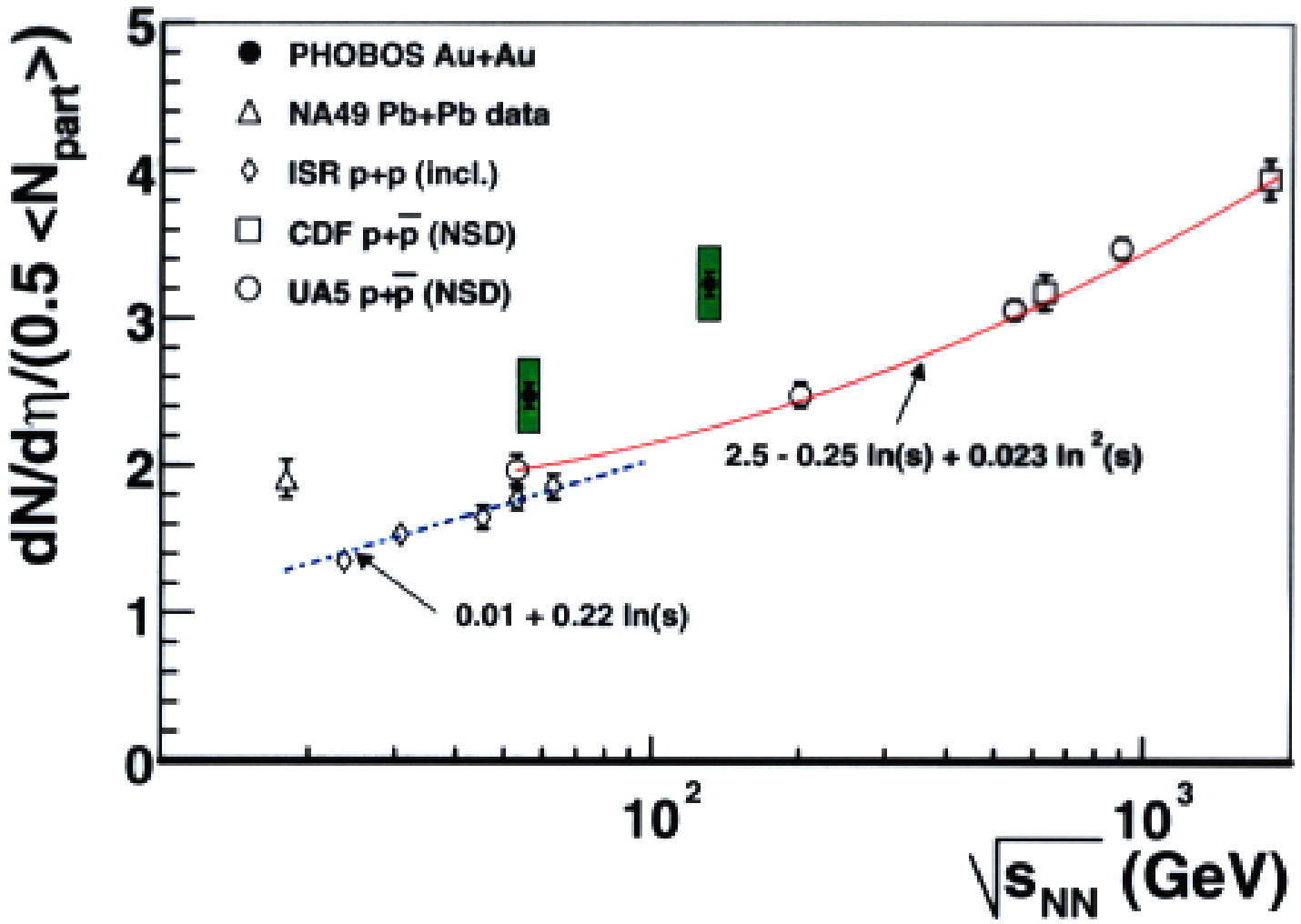
- **What is the density of particles near η=0?**
- **How does it compare to p+p and A+A @ SPS**

Tracklets and $dN_{ch}/d\eta$



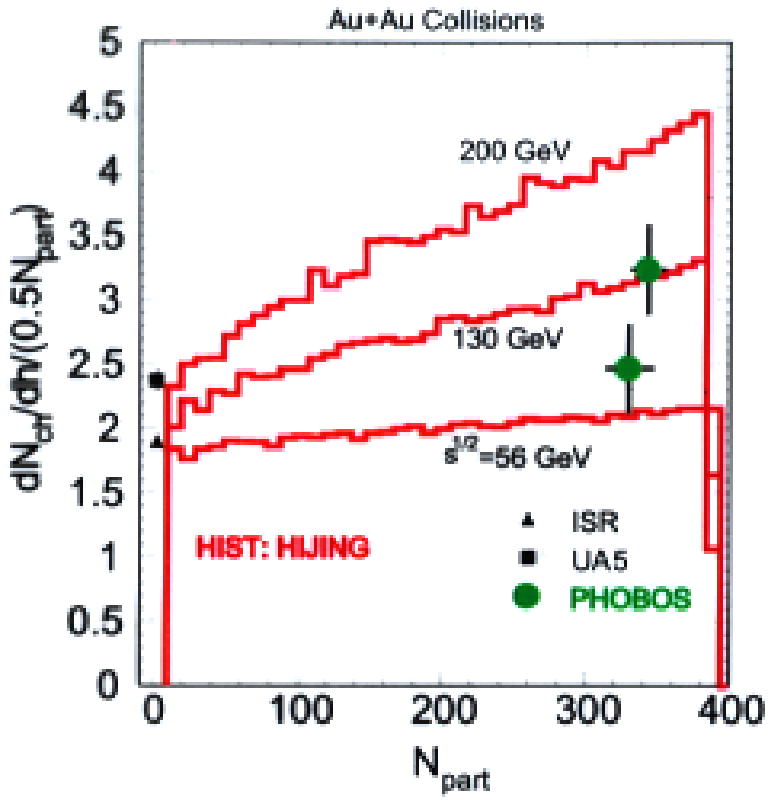
- Hundreds of tracklets per central event
- Corrections
  - Background subtraction
  - Uncertainty due to model differences
  - Feed-down from strange decays
  - Stopping particles
- Total uncertainty on $dN_{ch}/d\eta$ is ±8%

$dN_{ch}/d\eta$ @ η=0 vs Energy

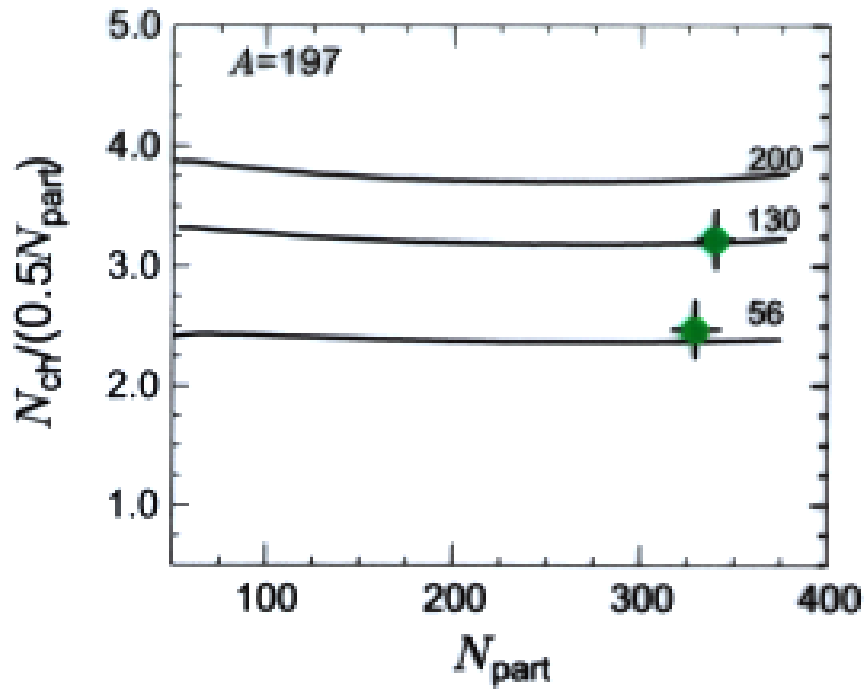


PRL 89 (2000) 3100

Model comparisons



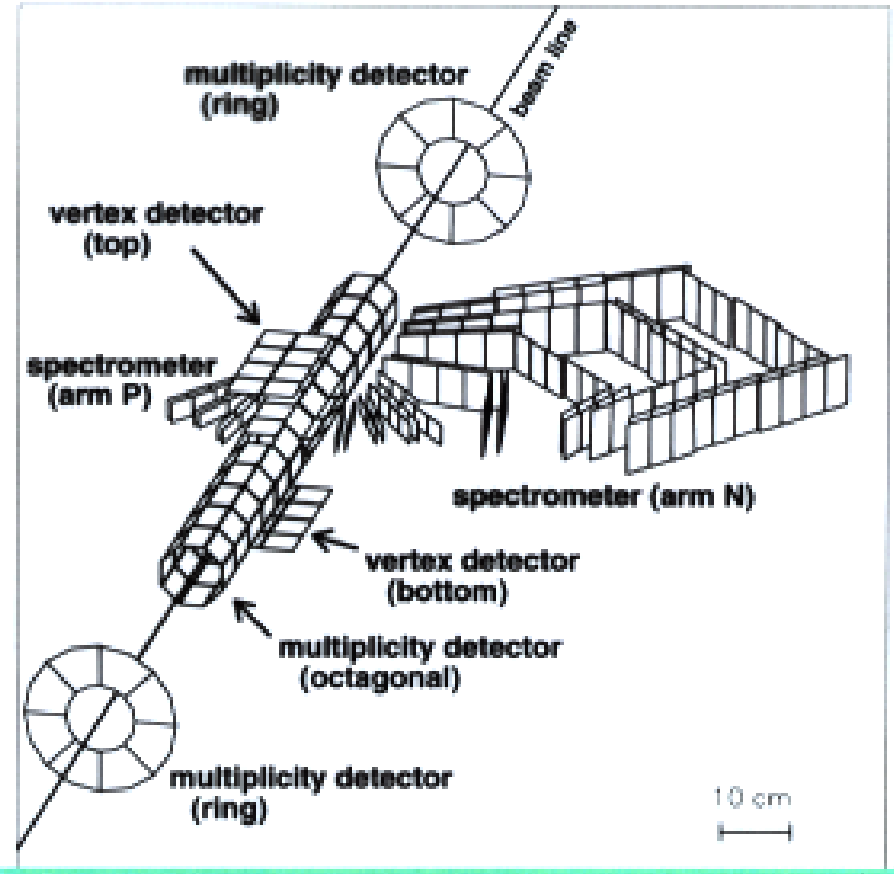
HIJING



EKRT (saturation model)

- 40% increase from p+p to central Au+Au
- Data constrain model parameter space
- Further insight from centrality dependence

$dN_{ch}/d\eta$ @ η=0 vs Centrality



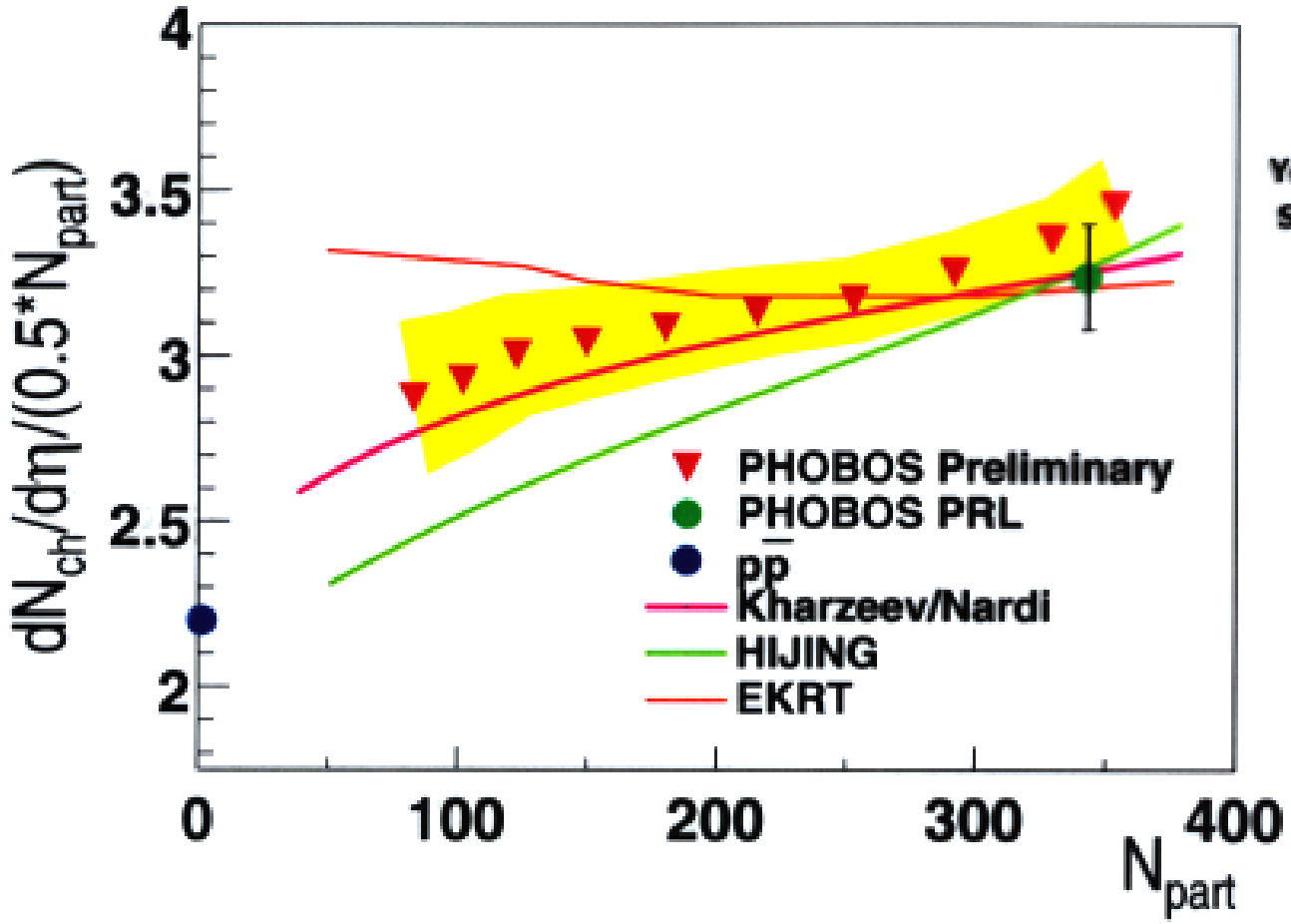
See talk by Judith Katzy, Wed 4:40 PM

Q:
How does $dN_{ch}/d\eta@\eta=0$ evolve from 2.3 (p+p) to 3.25 (Au+Au) per participant pair?

- **Count tracklets**
- **12 centrality bins for upper 55% of cross-section**

Preliminary

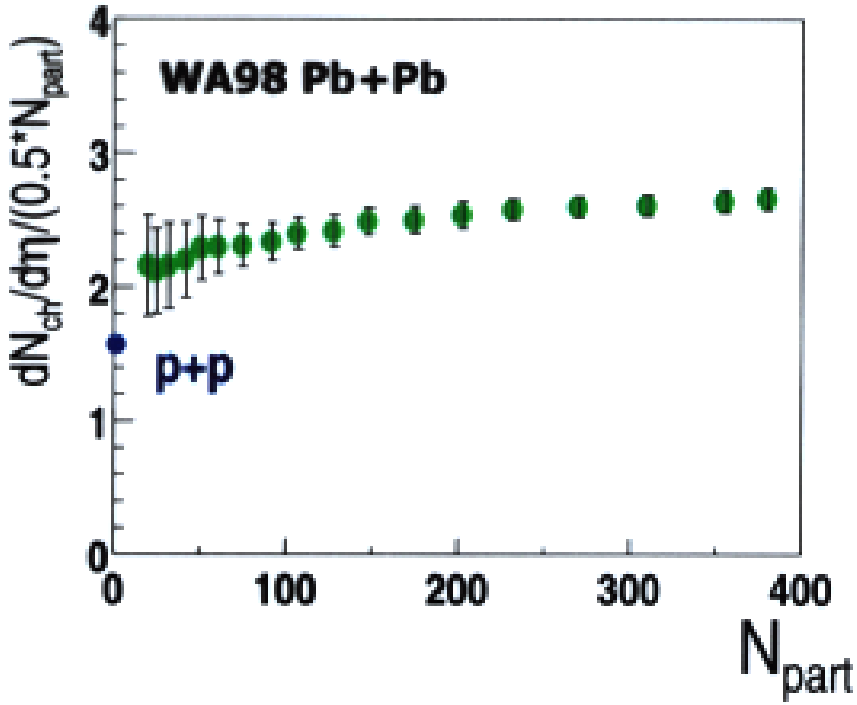
$dN_{ch}/d\eta$ @ η=0 vs N_{part}

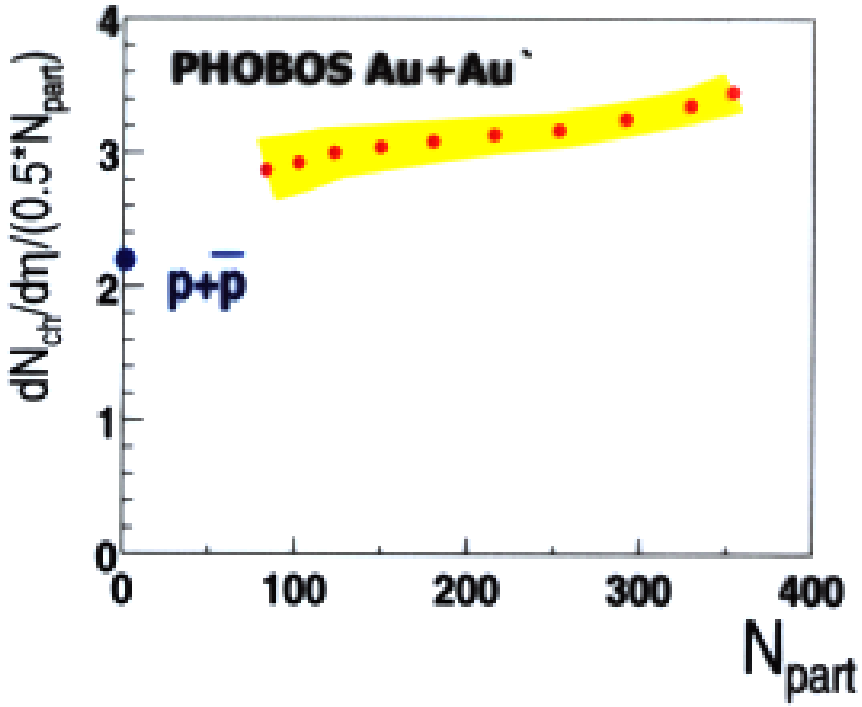


Yellow band:
Systematic uncertainty

- Good agreement with previous PHOBOS point
- Good agreement with recent PHENIX data
- Neither HIJING nor EKRT describe data well

Comparison to SPS

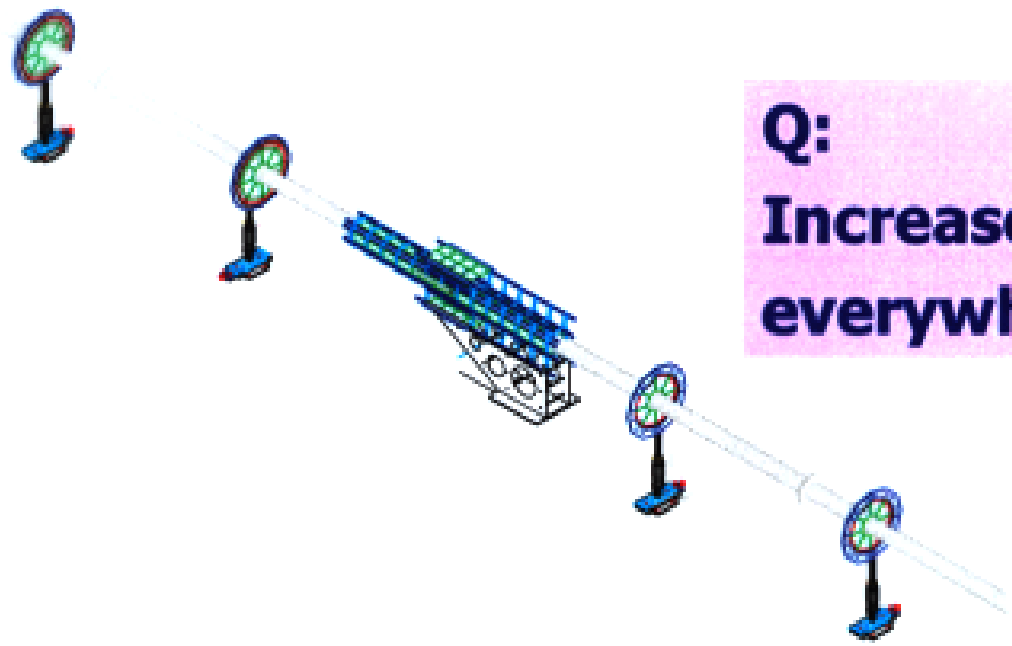




- General features (rapid rise/flat top) similar
- Note that WA98 $dN_{ch}/d\eta$ measured in lab frame

$dN_{ch}/d\eta$ in 4-π

See talk by Alan Wuosmaa Mon 5:35 PM



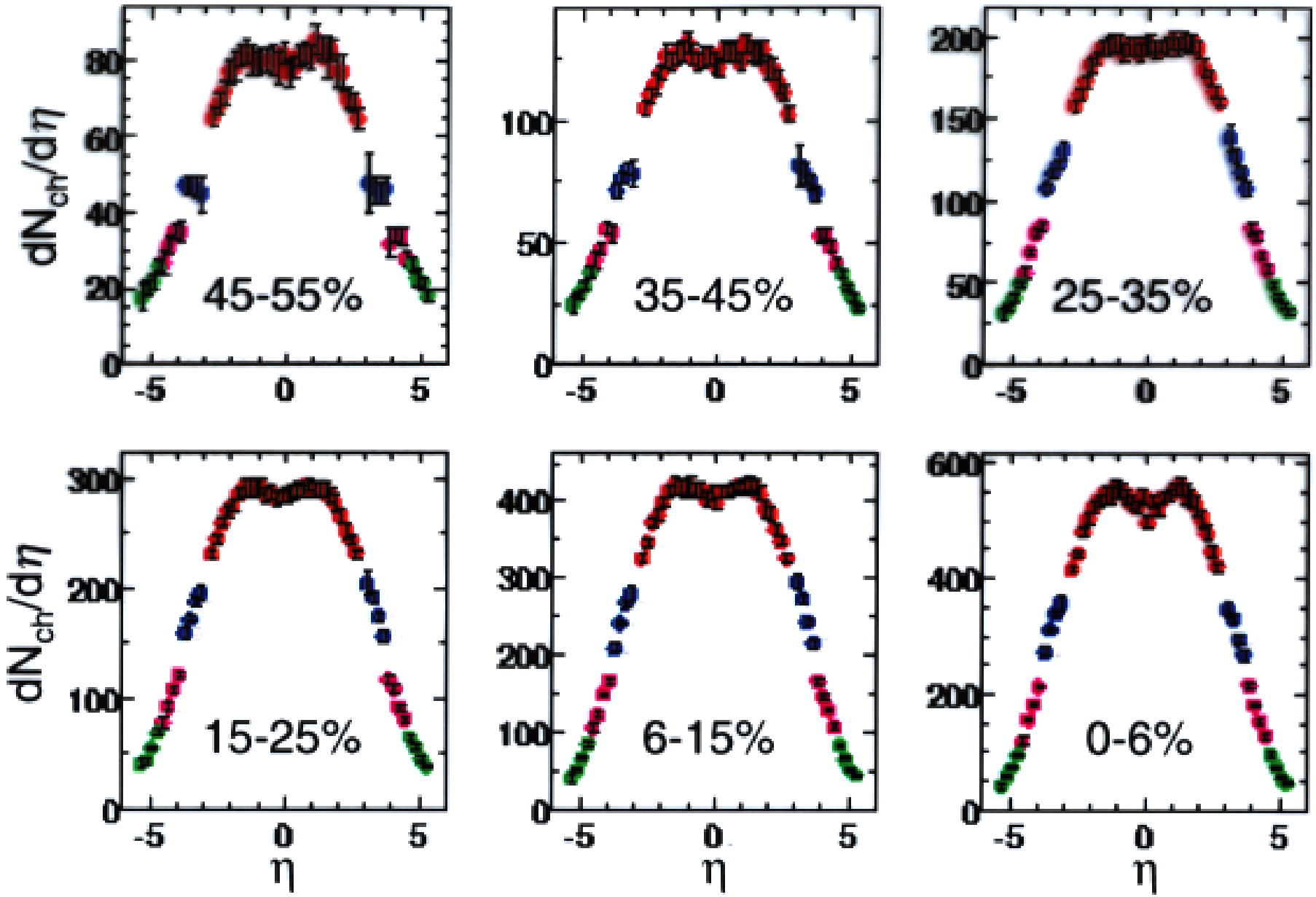
Q:
Increased particle production everywhere or only near η=0?

- Determine $dN_{ch}/d\eta$ for $-5.4 < \eta < 5.4$
  - Shape
  - Total multiplicity
  - Evolution vs N_{part}
- Hit counting

Gunther Roland/MIT

$dN_{ch}/d\eta$ vs Centrality

PHOBOS Preliminary



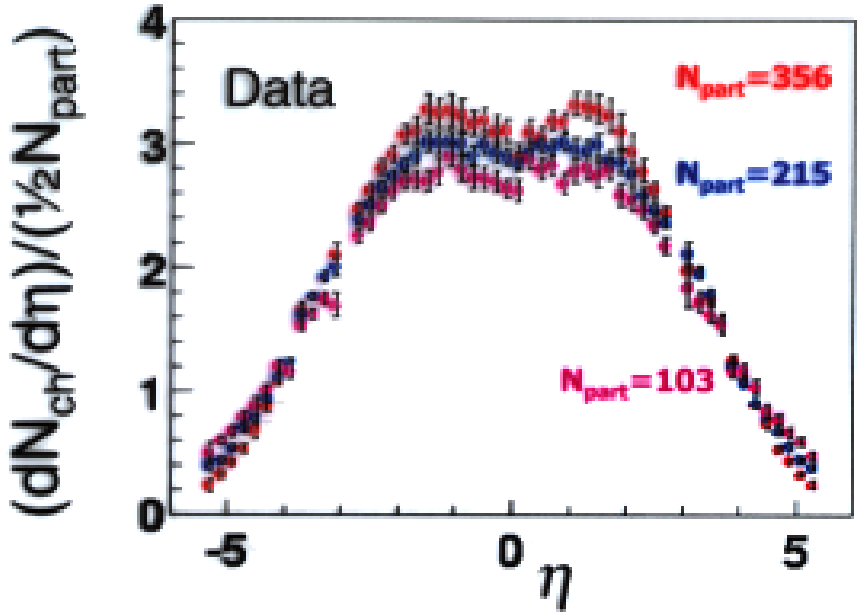
Statistical errors only - 10-20% systematical uncertainty

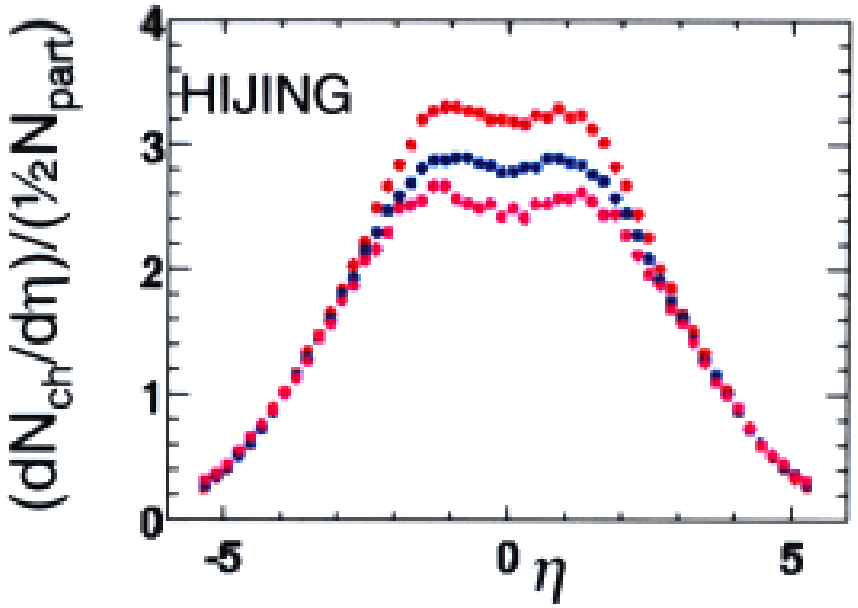
Quark Matter '01

Evolution of $dN_{ch}/d\eta$ vs N_{part}

Preliminary

Statistical errors only

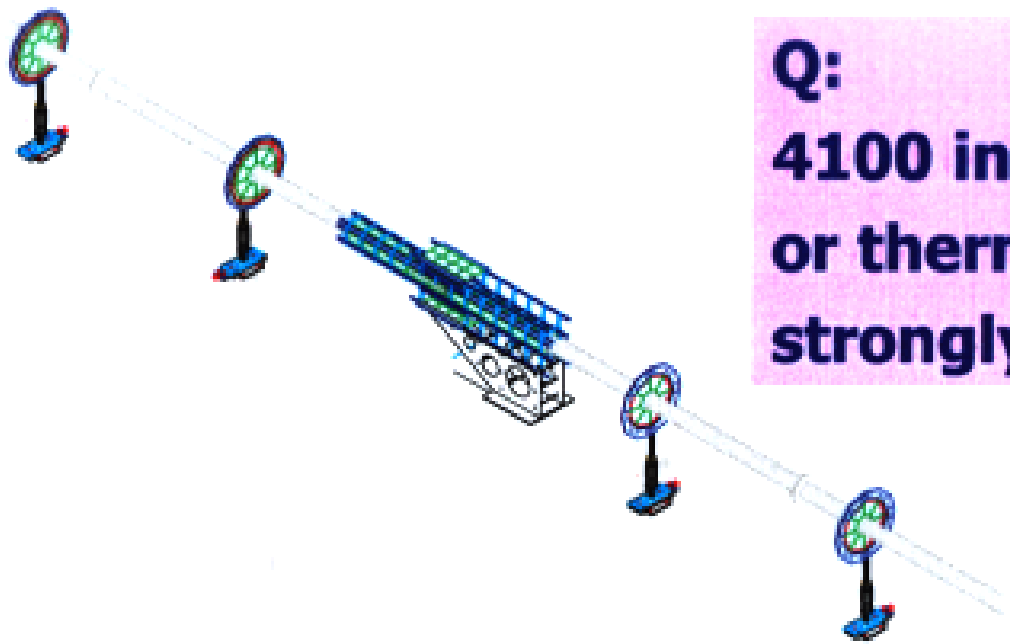




- **$\langle N_{ch} \rangle$ = 4100 +/- 410 for 3% most central**
- **Additional particle production near η=0**
- **Wider + more particles relative to HIJING**

Event Anisotropy

See talk by Inkyu Park Wed 5:55 PM

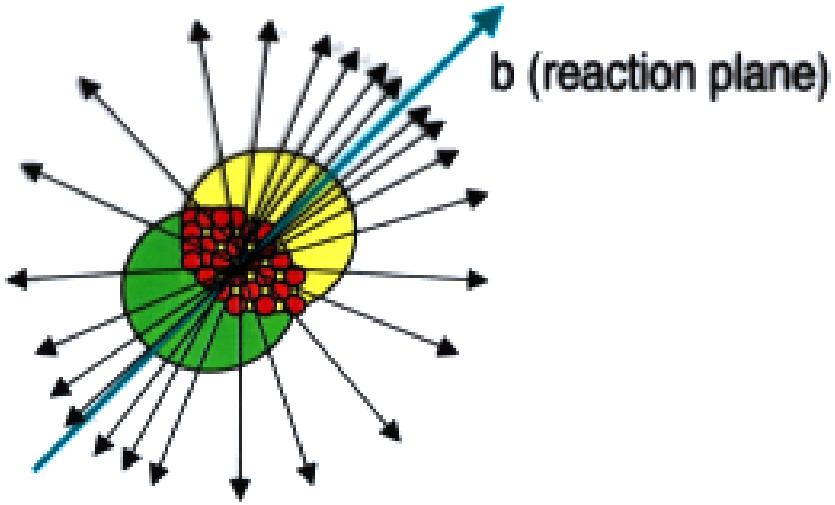


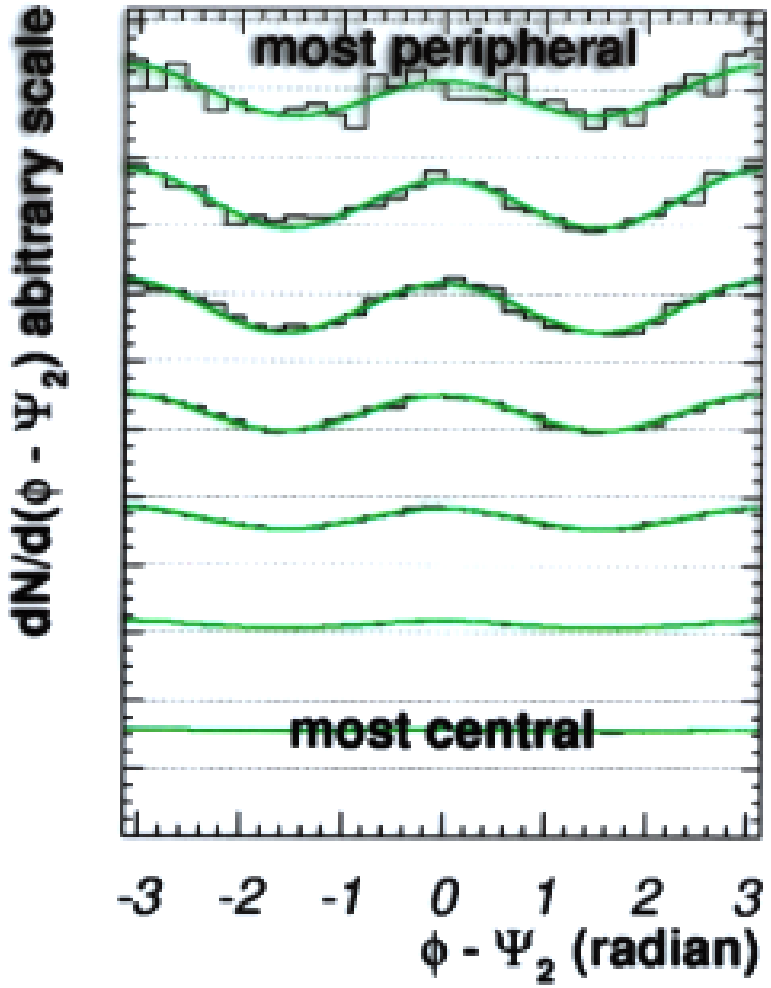
Q:
4100 independent particles or thermally equilibrated strongly interacting matter?

- **Elliptic flow of charged particles**
  - V_2 for $-5.0 < \eta < 5.3$
  - Evolution of V_2 vs N_{part}

Elliptic Flow

Q:
Does the initial space anisotropy translate into final state momentum space anisotropy?

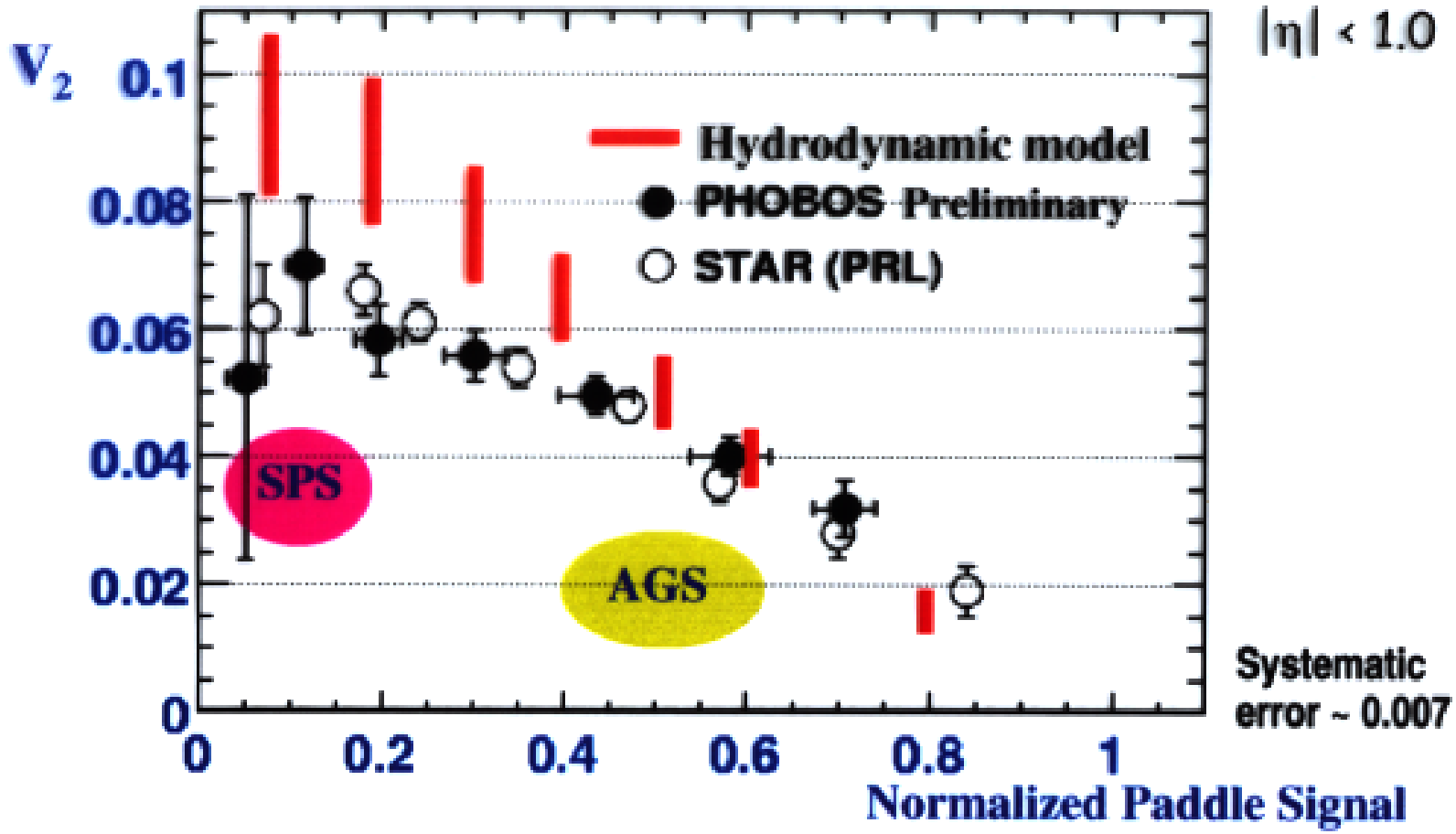




$$dN/d(\phi - \Psi_R) = N_0 (1 + 2V_1 \cos(\phi - \Psi_R) + 2V_2 \cos(2(\phi - \Psi_R) + \ldots)$$

Centrality Dependence

Preliminary



Large V_2 Signal compared to lower energy

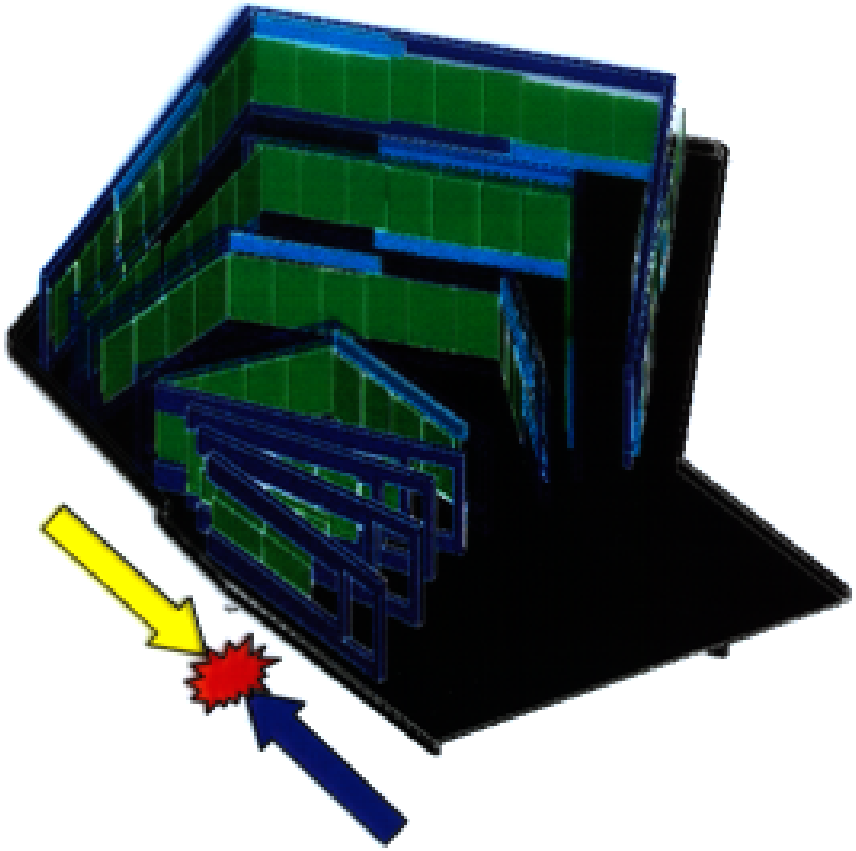
PHOBOS
Preliminary

V_2 vs η

Systematic error ~ 0.007

- Averaged over centrality
- V_2 drops for $|\eta| > 1.5$

Hadro-Chemistry

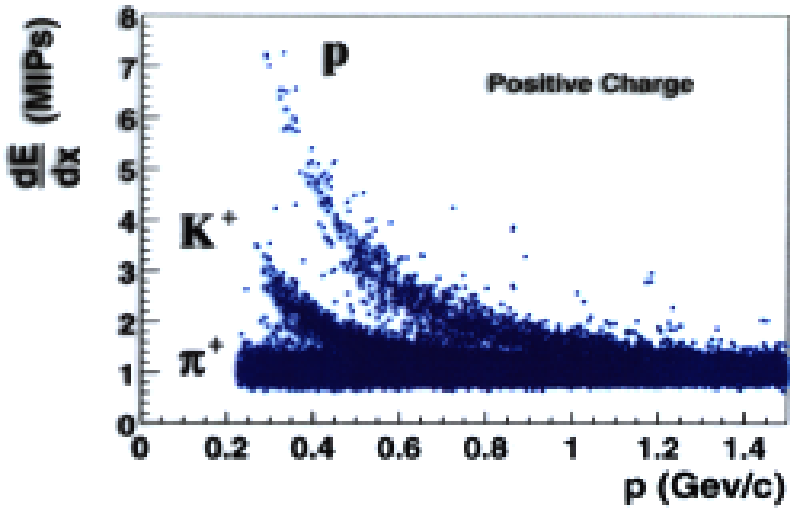


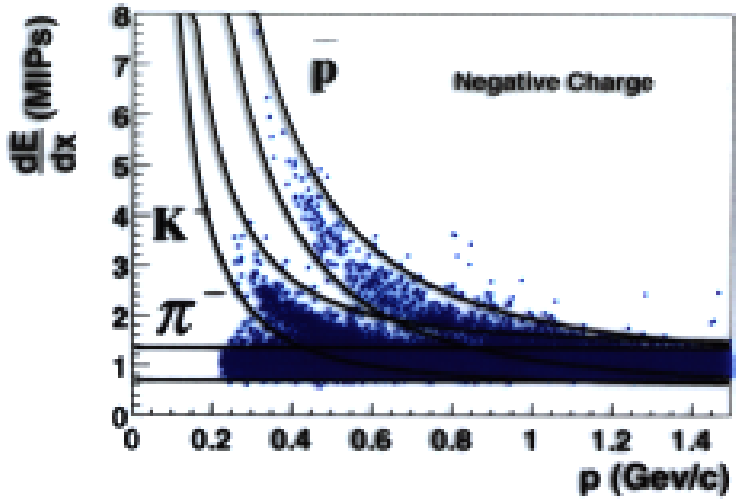
See talk by Nigel George Fri 4:25 PM

Q:
- **Baryo-Chemical Potential**
- **Baryon Stopping**

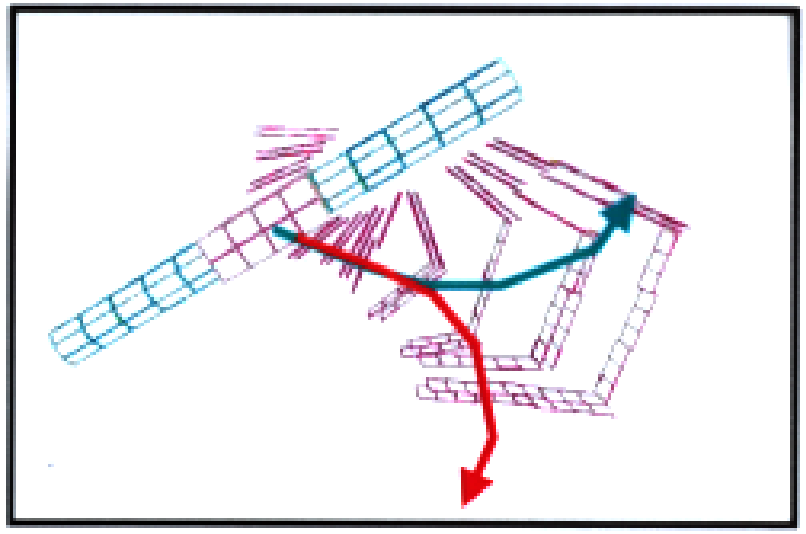
- **Determine ratio of π^-/π^+, K^-/K^+, $\bar{p}/p$**
- **Compare to AGS/SPS results**

Tracking and Particle ID

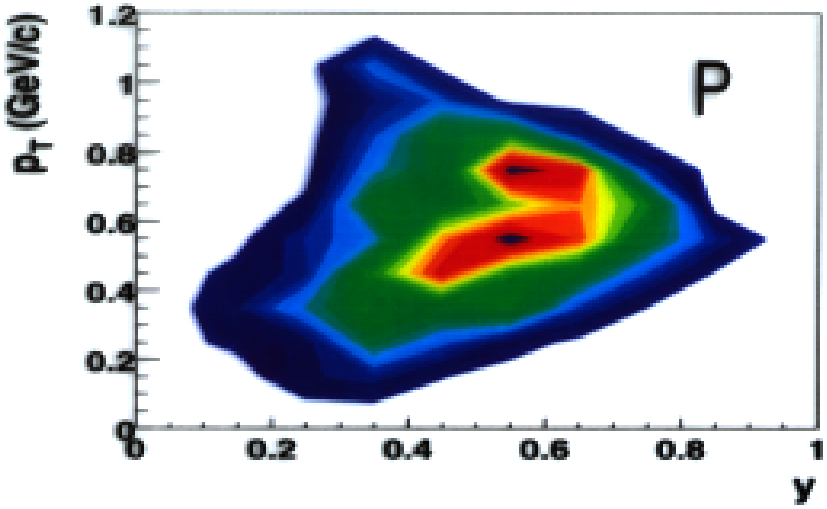




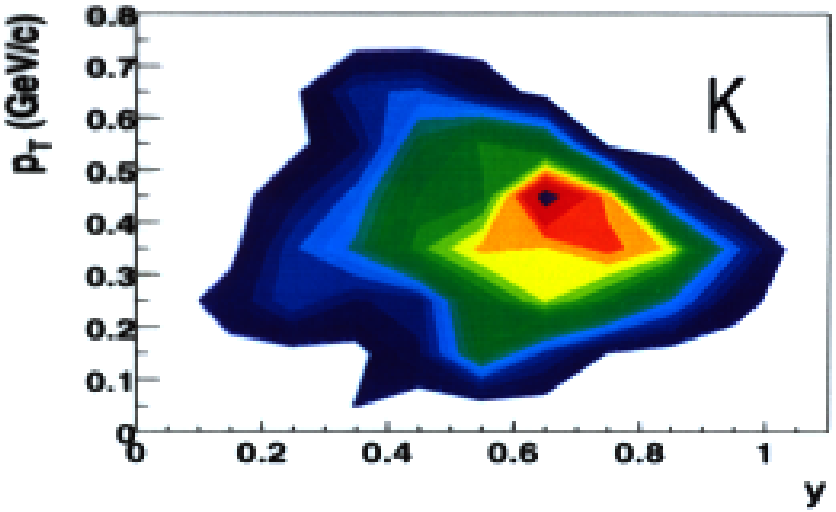
- **Particle ID**
  - **dE/dx in silicon**
- **Two B-field polarities**
  - **Many systematic effects cancel in the ratio**

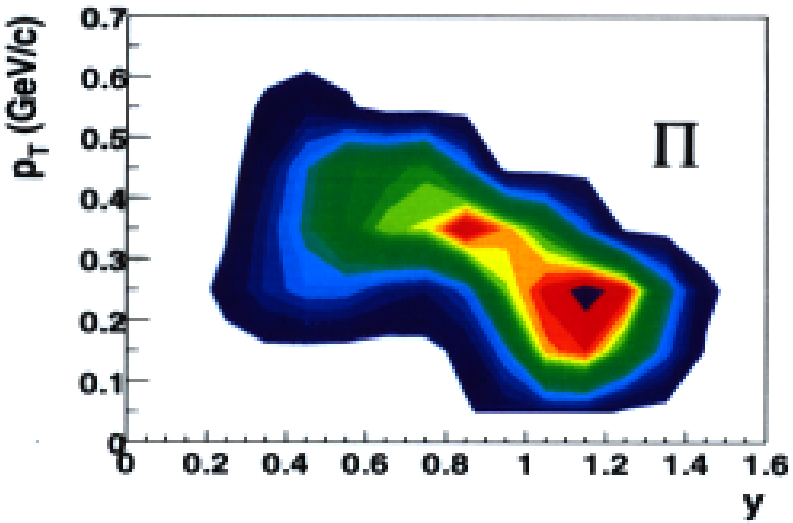


Kinematic Coverage



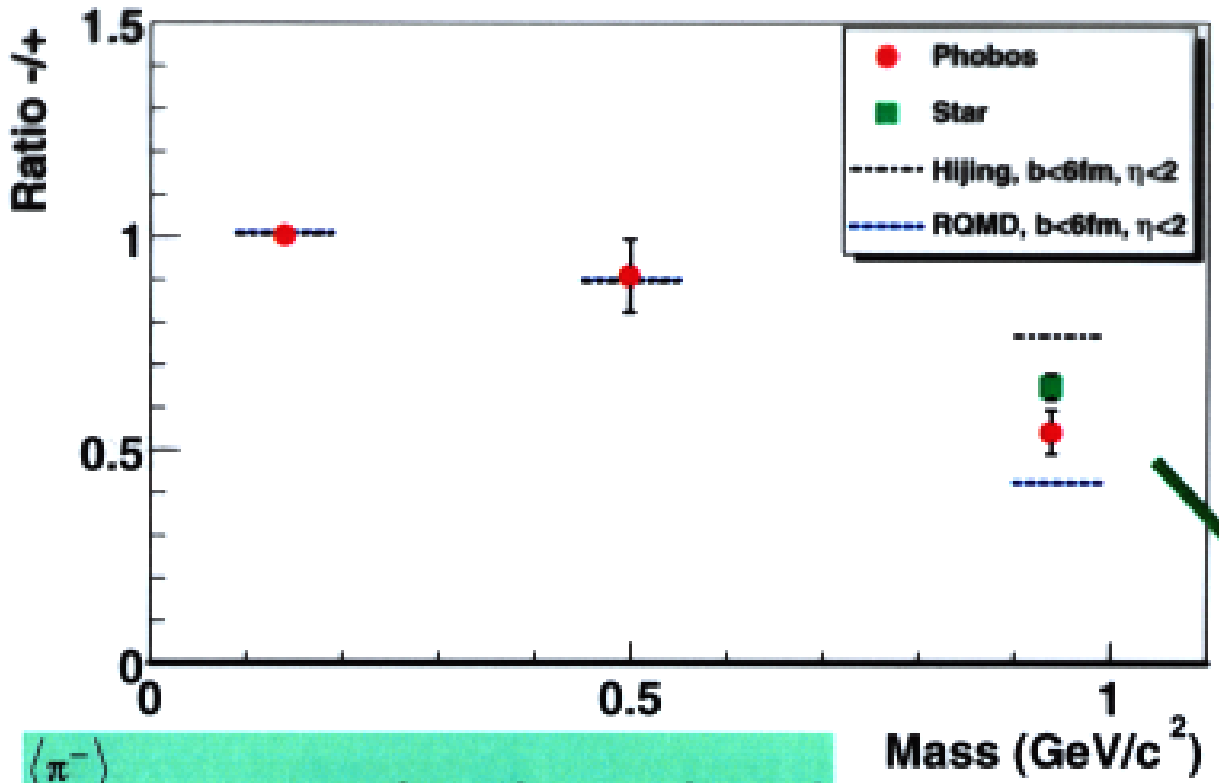
- Acceptance near y=0.5
- Identical for positive particles in BPLUS/negative particles in BMINUS





Particle Ratios

Preliminary



Centrality =12 %
<Npart> ~ 310

$$\frac{\langle \pi^- \rangle}{\langle \pi^+ \rangle} = 1.01 \pm 0.01(\text{stat.}) \pm 0.05(\text{syst.})$$

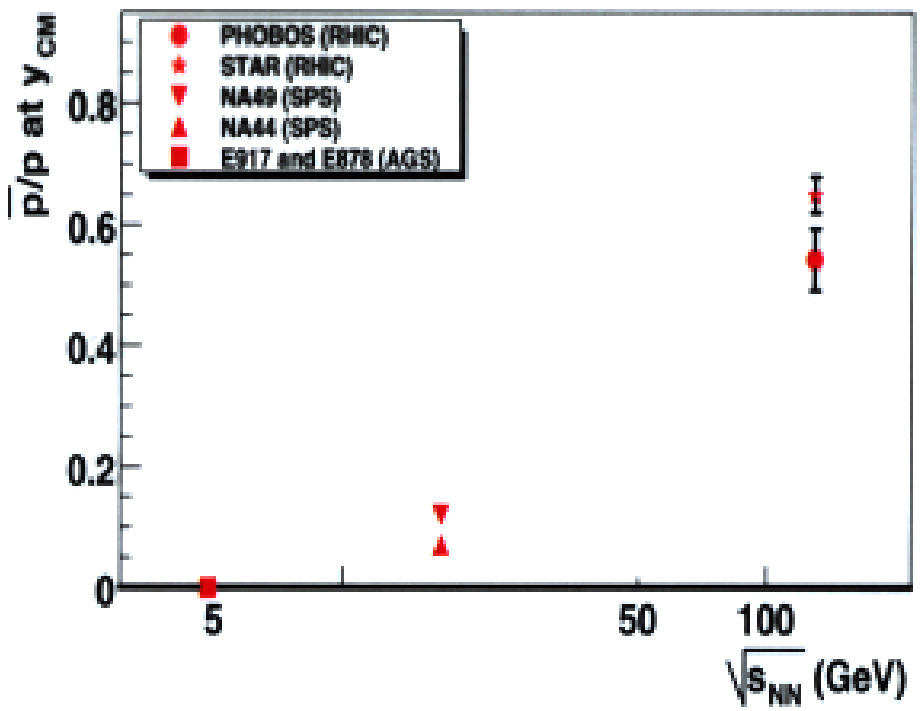
$$\frac{\langle K^- \rangle}{\langle K^+ \rangle} = 0.91 \pm 0.09(\text{stat.}) \pm 0.1(\text{syst.})$$

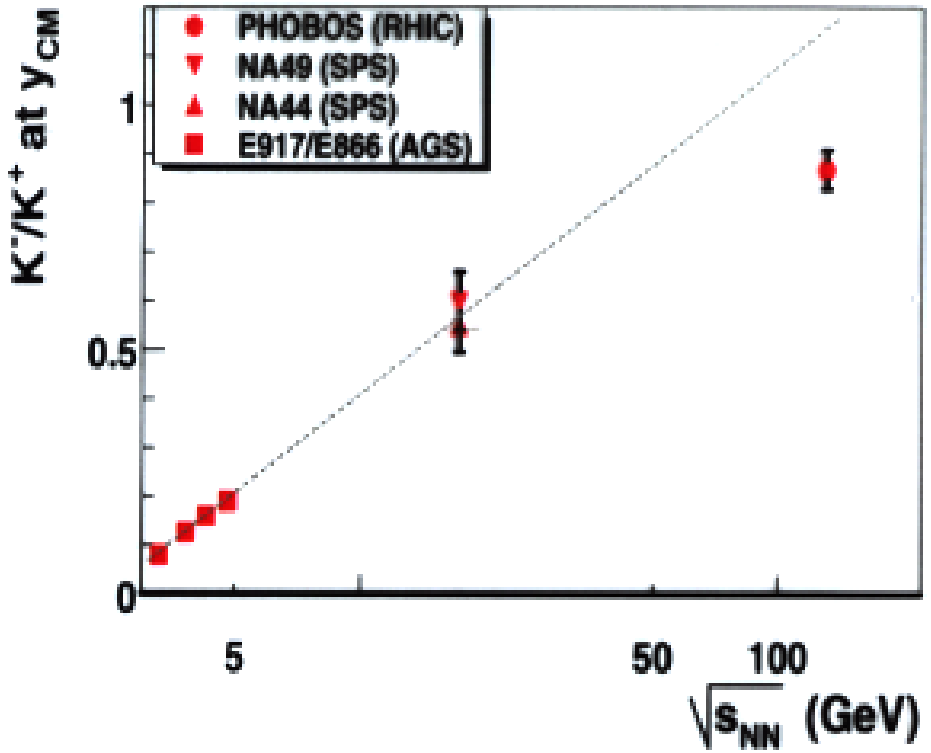
$$\frac{\langle \bar{p} \rangle}{\langle p \rangle} = 0.54 \pm 0.05(\text{stat.}) \pm 0.1(\text{syst.})$$

Central region not baryon-free

Preliminary

Energy Dependence





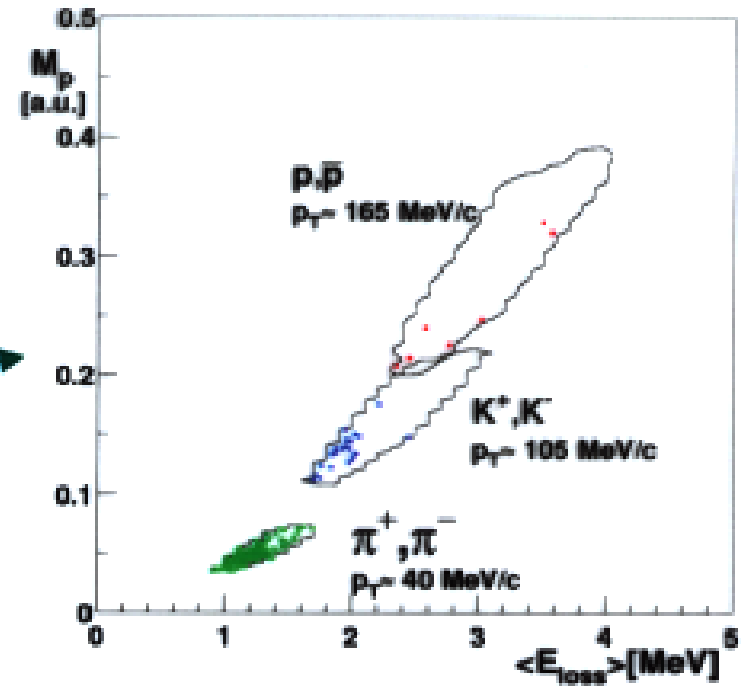
- **Ratios @ y_{cm} closer to unity than at lower energy**
- **Estimate μ_B = 50 MeV vs 200 MeV at SPS**

Summary

- **$dN_{ch}/d\eta$ @η=0 per participant**
  - 70% higher than SPS for central Au+Au
  - 40% higher than p+p at RHIC energy
  - N_{part} evolution between HIJING and EKRT
- **$dN_{ch}/d\eta$ in 4-π**
  - $\langle N_{ch} \rangle$ = 4100 +/- 410 ($|\eta| < 5.4$) for 3% central
  - Additional particle production near η=0 for central events
  - Wider than HIJING
  - Cross-over in $dN_{ch}/d\eta$ per N_{part} near η = 4
- **Elliptic flow**
  - V_2 up to 0.06 – close to hydrodynamic limit
  - larger than SPS
  - V_2 drops for $|\eta| > 1.5$
- **Particle ratios**
  - $\bar{p}/p$ ratio 0.55 +/- 0.1
  - between HIJING and RQMD
  - $\mu_B \sim$ 50 MeV vs 200 MeV at SPS

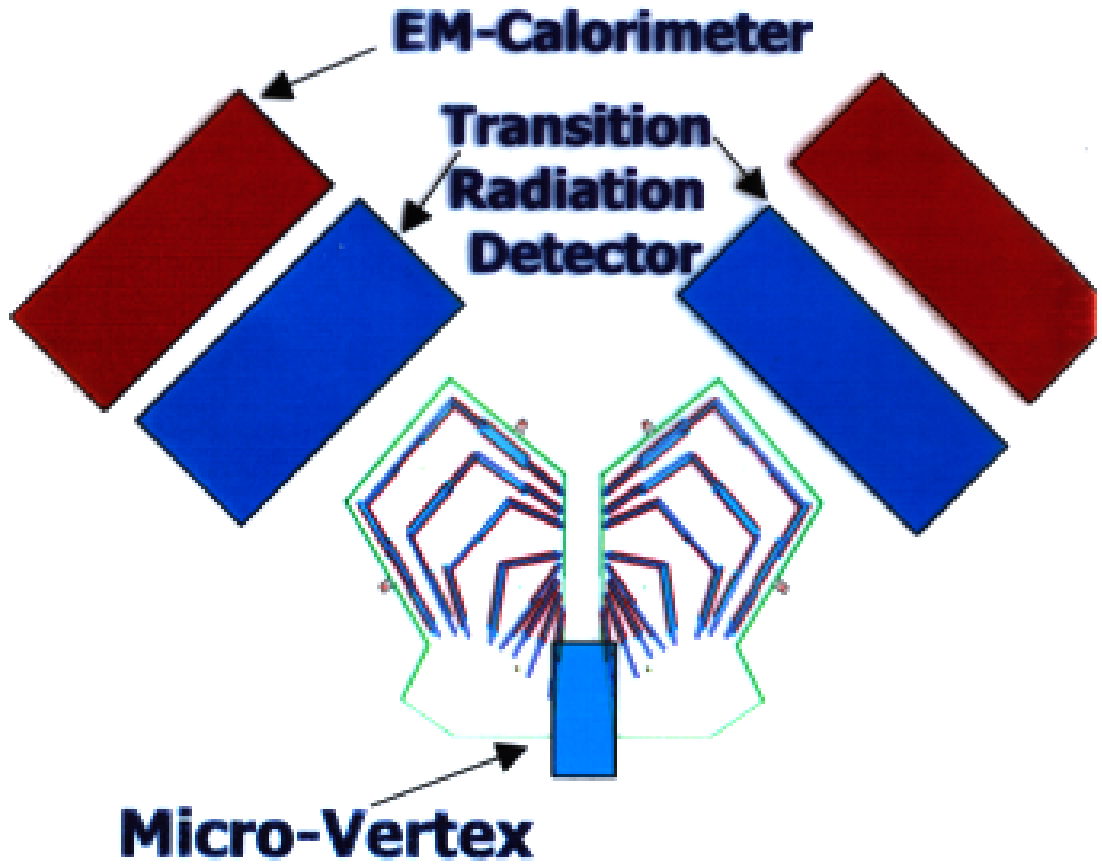
Outlook I: 2001

- 100x statistics
- Both arms completed
- Physics:
  - low-p_T physics
  - Spectra
  - HBT
  - Resonances (ϕ at low p_T)
  - Event-by-Event physics
- Energy systematics
- Species systematics



Outlook II: 2003 + beyond

Q: Charm Production at RHIC?

A: Measure single electrons from displaced vertices

- **Existing Spectrometer**
  - **High rate (> 0.5 kHz)**
  - **High Resolution**
- **Add**
  - **Micro-Vertex Detector**
  - **ALICE prototype TRD Electron-ID**
  - **EM-Calorimeter**