Simulation Studies of Contributions to Event-by-Event Average p_T Fluctuations

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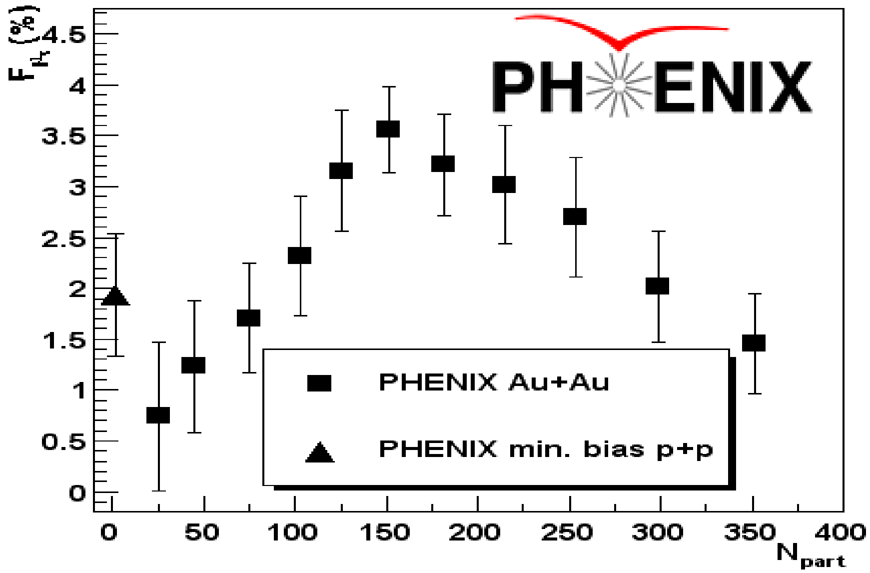
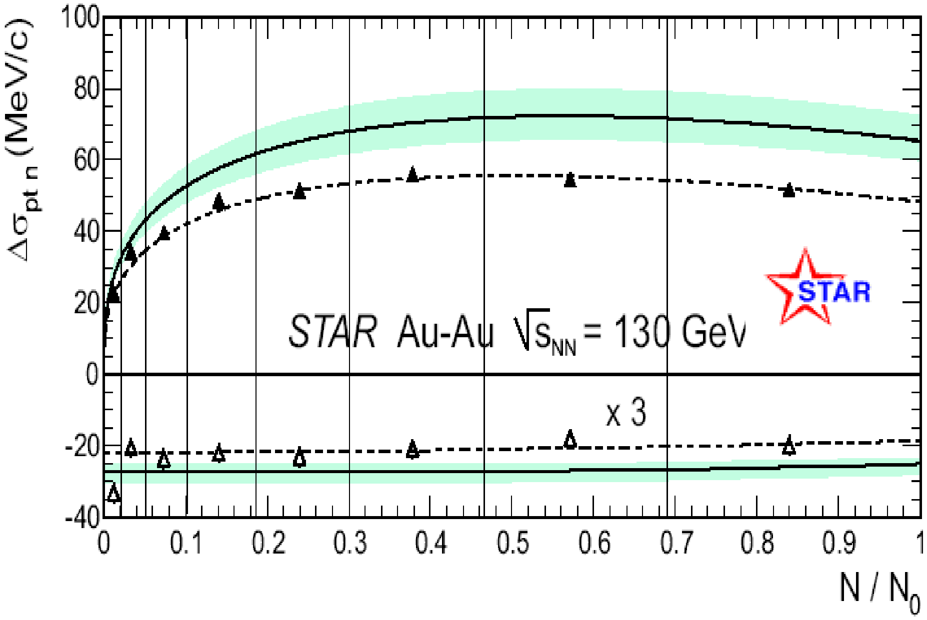
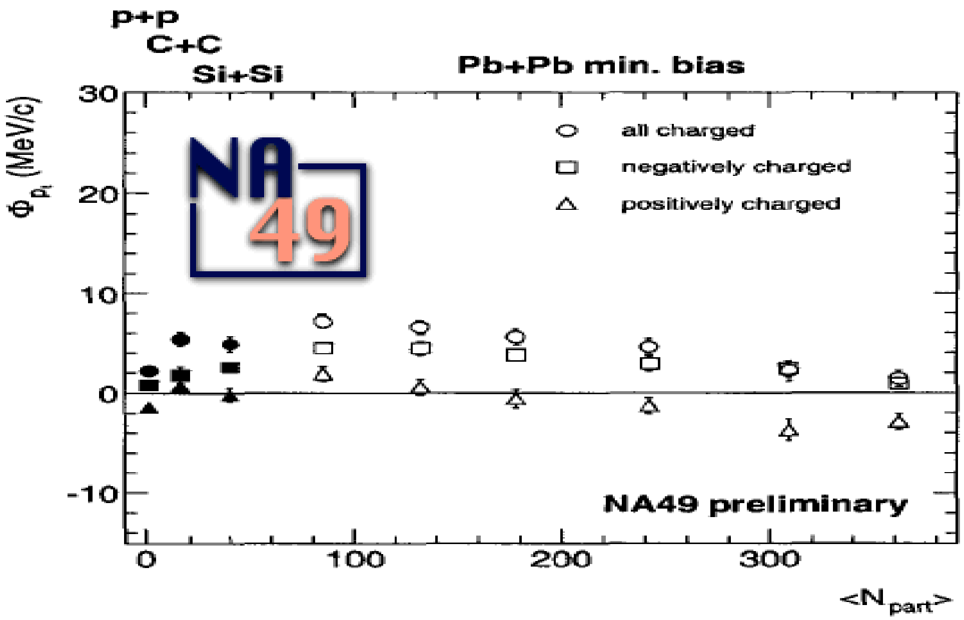
Outline:

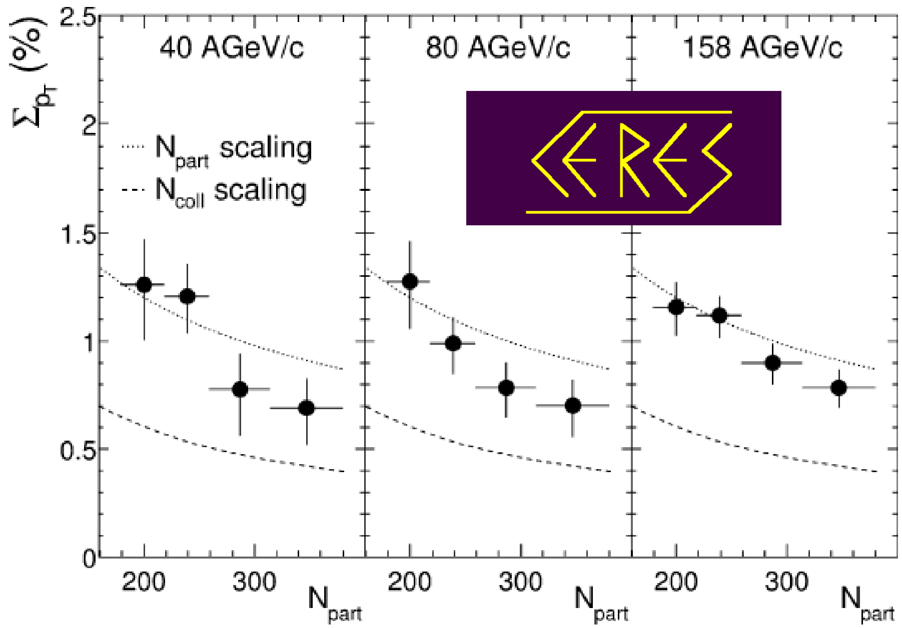
- Data and Observables
- Description of the simulation
- Elliptic Flow Contributions
- Jet Contributions at RHIC?
- Jet Contributions at CERN?
- Conclusions

Behold The <p_T> Fluctuation Signal!









The Pentagon of Fluctuation Variables

Goal of the observables:

State a comparison to the expectation of statistically independent particle emission.

$\mathbf{F_{pT}}$

The F_{pT} variable, which is a direct comparison to mixed events, will be quoted in this poster.

$\sigma^2_{\mathbf{pT,dyn}}$

$\Delta\sigma_{\mathbf{pT,n}}$

$$F_{p_T} \approx \frac{\Phi_{p_T}}{\sigma_{p_T,incl.}}$$

$$\sigma^2_{p_T,dyn} \cong \frac{2\Phi_{p_T}\sqrt{\overline{\Delta p_T^2}}}{\langle N \rangle} \qquad \Delta\sigma_{p_T,n} \cong \sqrt{\left(\Phi_{p_T} + \sigma_{p_T,incl}\right)^2 - \sigma^2_{p_T,incl}}$$

$$\sigma_{p_T,incl.} = \sqrt{\langle p_T^2 \rangle - \langle p_T \rangle^2} \qquad \overline{\Delta p_T^2} \equiv \overline{p_T^2} - \overline{p_T}^2$$

$$\Sigma_{p_T} \equiv \mathrm{sgn}\left(\sigma^2_{p_T,dyn}\right)\frac{\sqrt{|\sigma^2_{p_T,dyn}|}}{\overline{p}_T}$$

$\Phi_{\mathbf{pT}}$

$\Sigma_{\mathbf{pT}}$

Designing a Baseline Simulation for Fluctuation Studies, “Mean Max”

This is a data-driven simulation designed to simulate statistically independent particle production via the following method:

- Generate the number of particles in an event, N, by sampling a Gaussian distribution fit to the data.

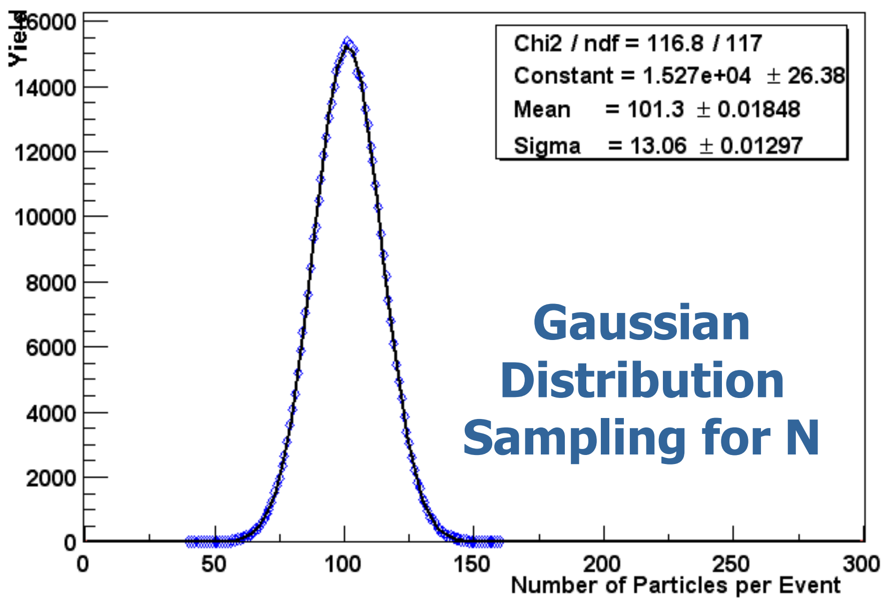
- Assign a p_T to each particle by sampling an m_T exponential distribution fit (or double exponential, or Gamma distribution) to the data inclusive p_T distribution.

- Calculate the event-by-event $<p_T>$, M_{pT}, over a specified p_T range.

- Generate mixed events for calculation of fluctuation quantities from the simulated data events.

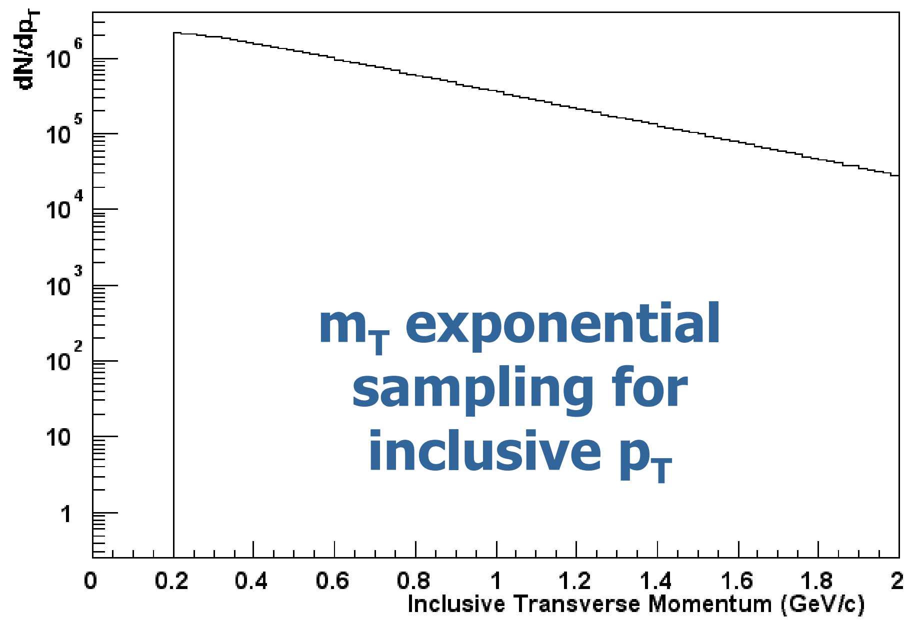
The only input parameters are: $<N>$, $\sigma_{<N>}$, inclusive p_T function parameters, p_T range for the $<p_T>$ calculation.

Sample Results from the Baseline Simulation



Sample: Using a match to PHENIX 0-5% centrality data

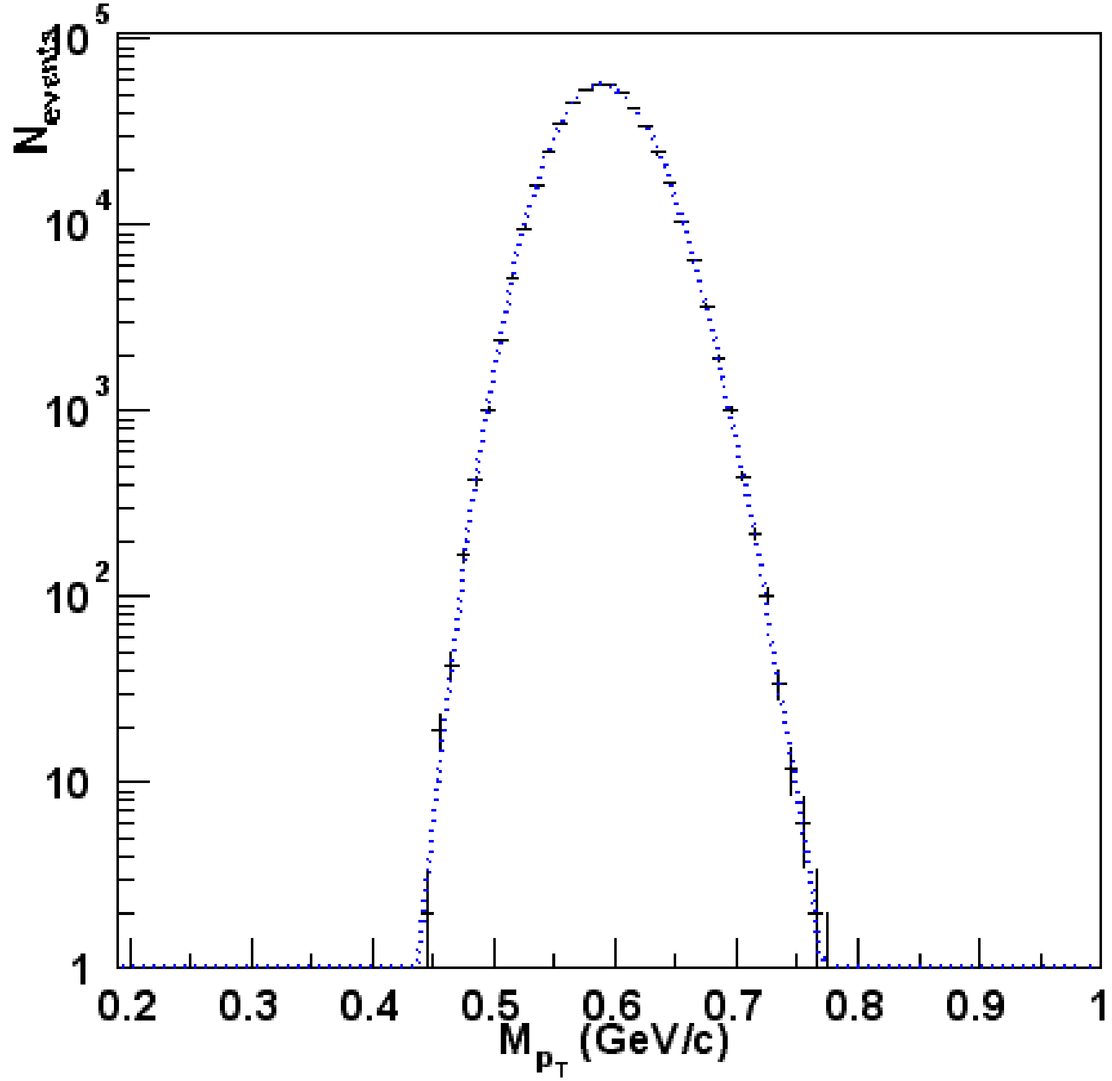
Inclusive $<p_T>$, σ_{pT}, $<N>$, $\sigma_{<N>}$ matched to the data for each centrality class.



Sample results from the Baseline Simulation

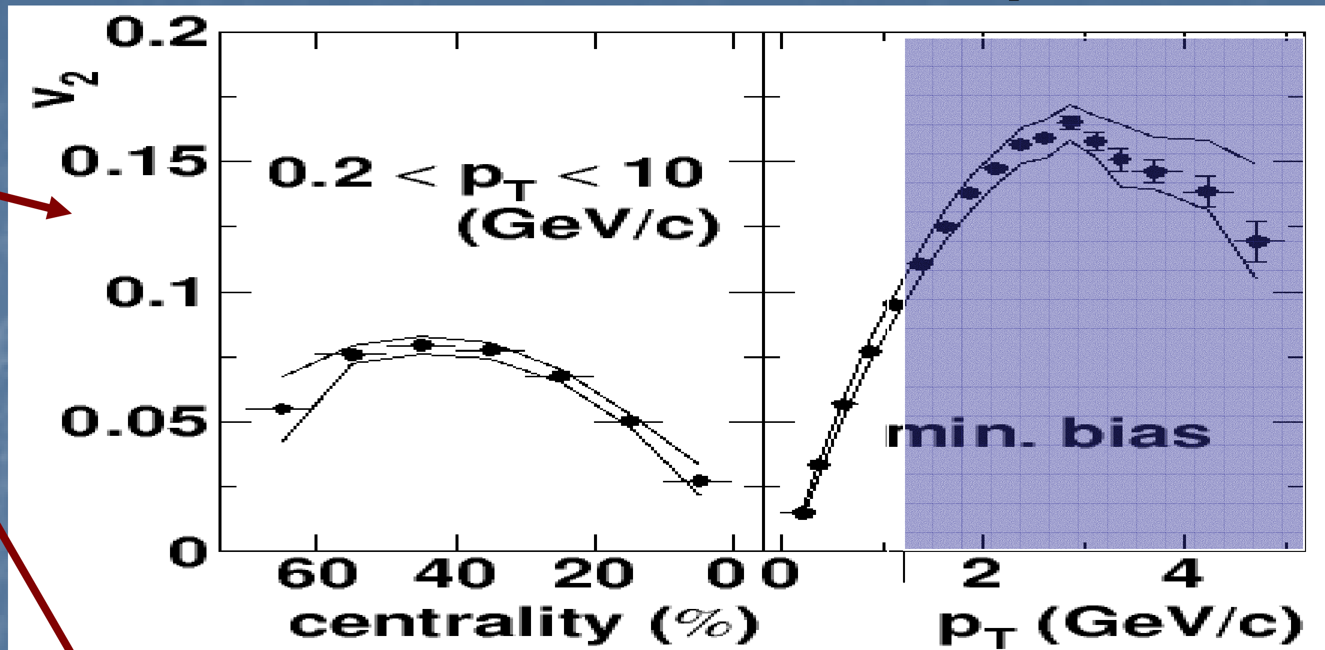
Black points: Simulation Output using the input on the previous page.

Blue curve: Gamma distribution calculation for statistically independent particle emission with input parameters taken from the inclusive spectra. *See M. Tannenbaum, Phys. Lett. B498 (2001) 29.*

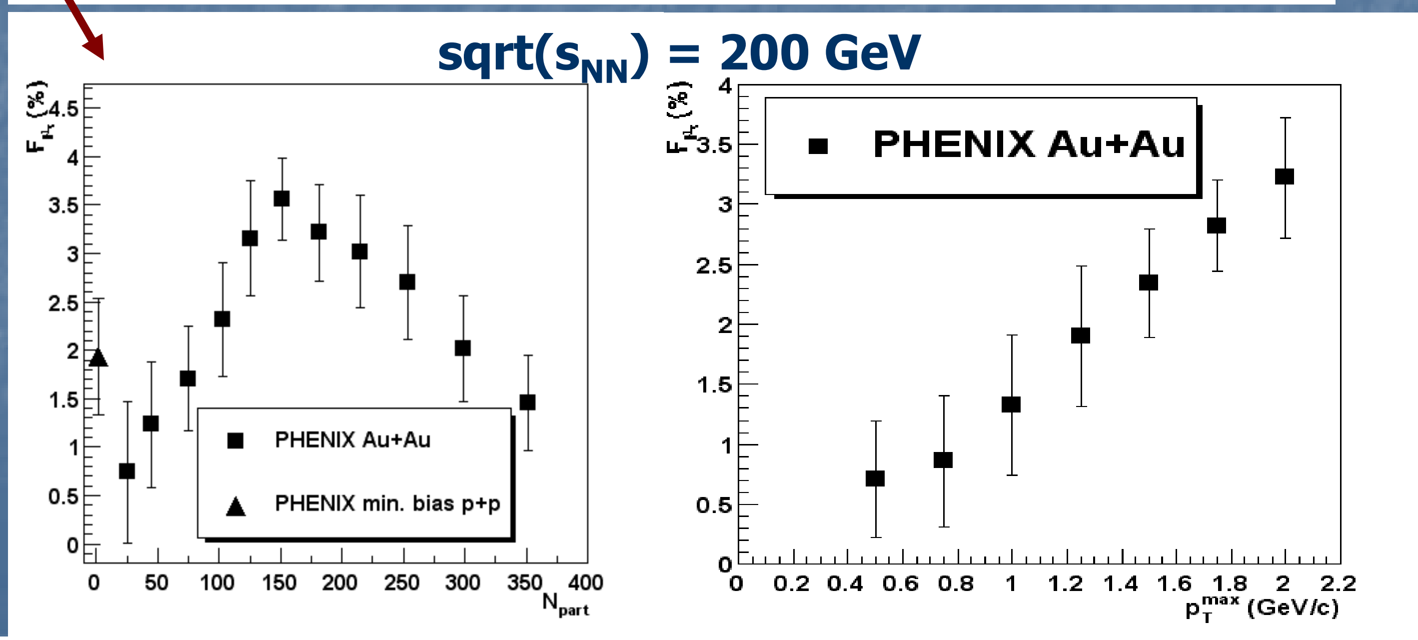


Fluctuation Trends and Elliptic Flow

Elliptic Flow



Average p_T Fluctuations



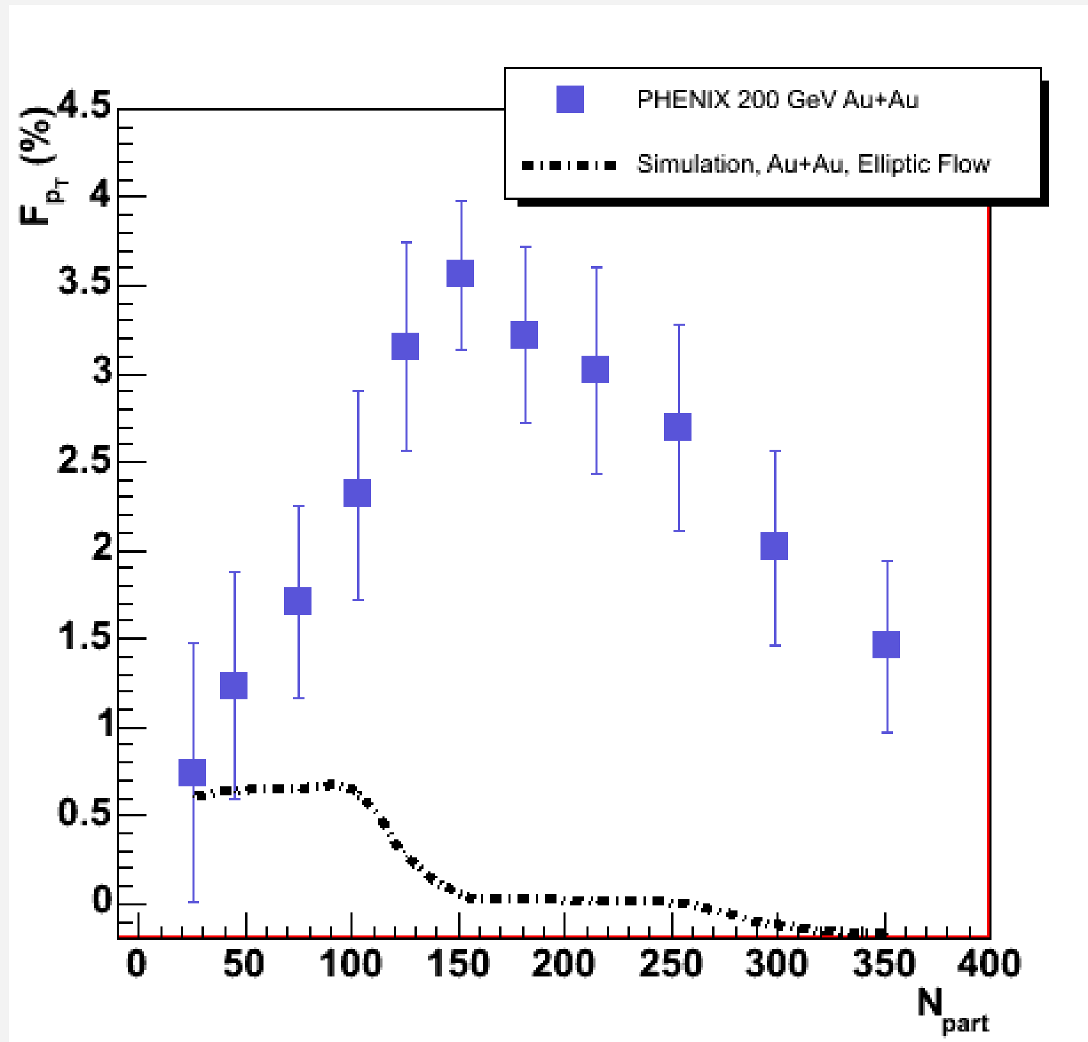
PHENIX

Similar properties vs. centrality observed in STAR.

Elliptic Flow Contribution Simulation

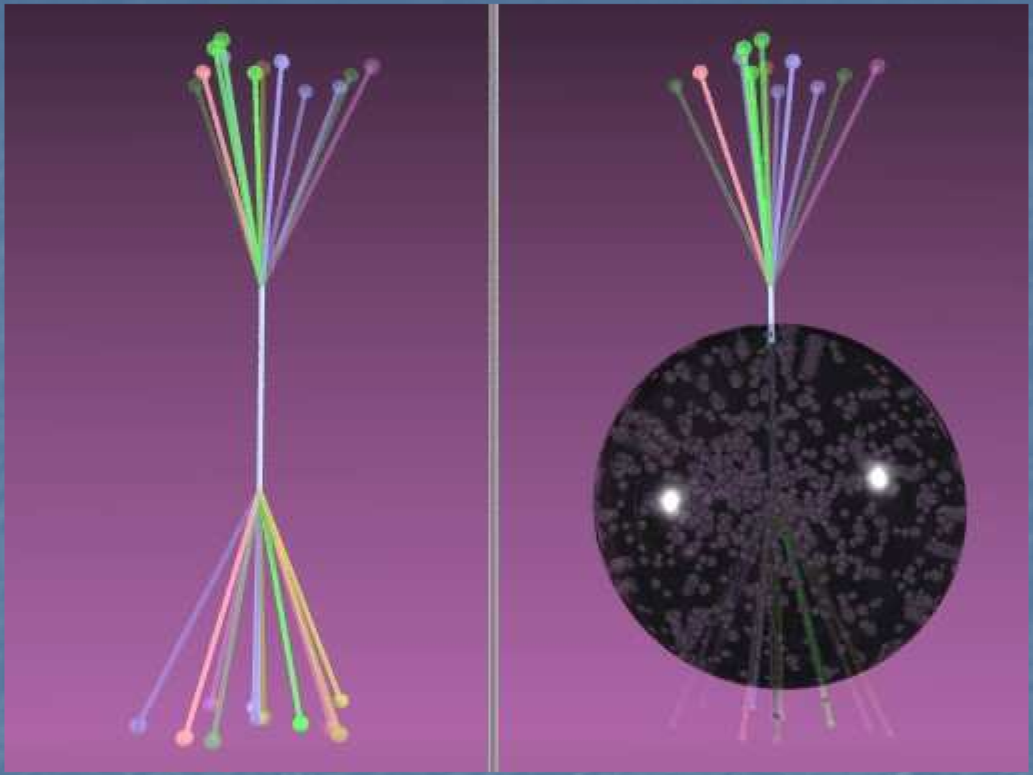
Algorithm: Particles are assigned an azimuthal coordinate based upon the PHENIX measurement of v_2 (wrt the reaction plane) as a function of centrality and p_T. Only particles within the PHENIX acceptance are included in the calculation of M_{pT}.

With the exception of peripheral collisions, the elliptic flow contribution is a small fraction of the observed fluctuation.



Fluctuations: A Jet Contribution?

Jets are simulated using a hybrid algorithm which embeds Pythia hard scattering events into Mean Max baseline events.



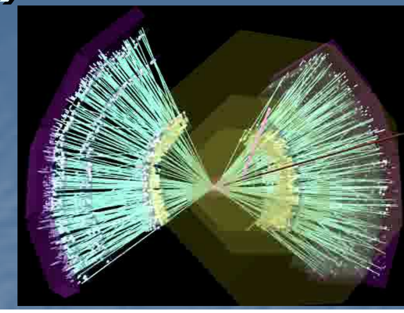
A single varying parameter is defined: A hard scattering probability factor, S_{prob}, is randomly tested for each thrown particle. If the test is true, a single PYTHIA event is embedded into the baseline event after applying experimental acceptance criteria.

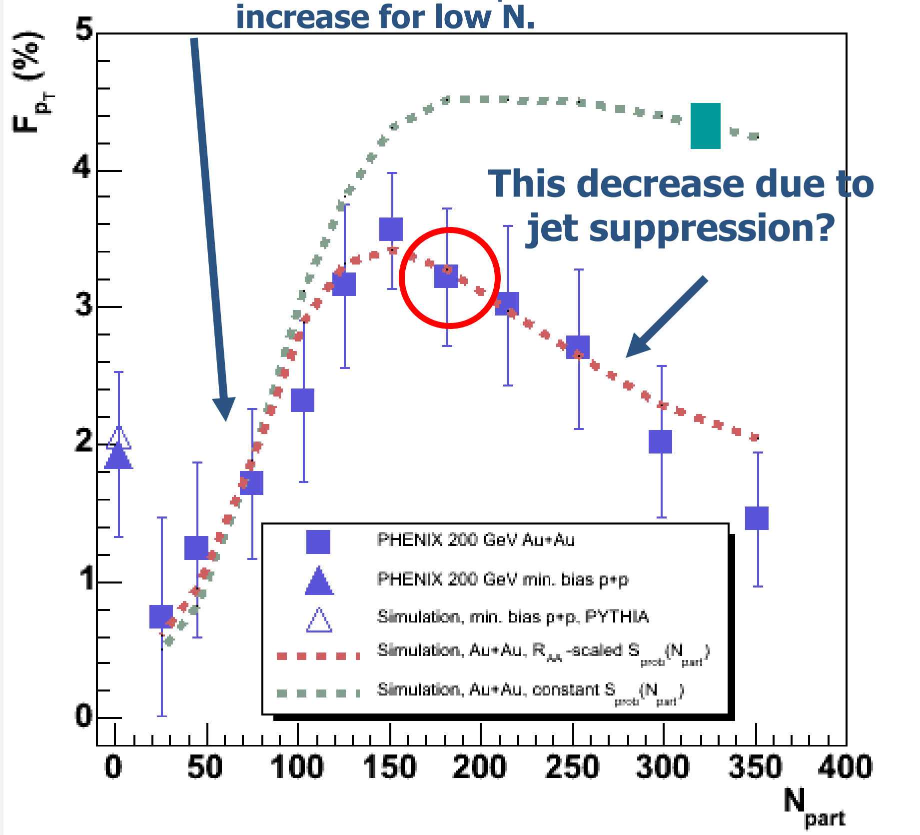
To mock up jet suppression, S_{prob} is scaled by the experimentally measured value of the nuclear modification factor, R_{AA}, as a function of centrality.

NOTE: The N distribution is preserved in this simulation. The inclusive $\langle p_T \rangle$ and $\sigma(p_T)$ are affected by less than 1%.

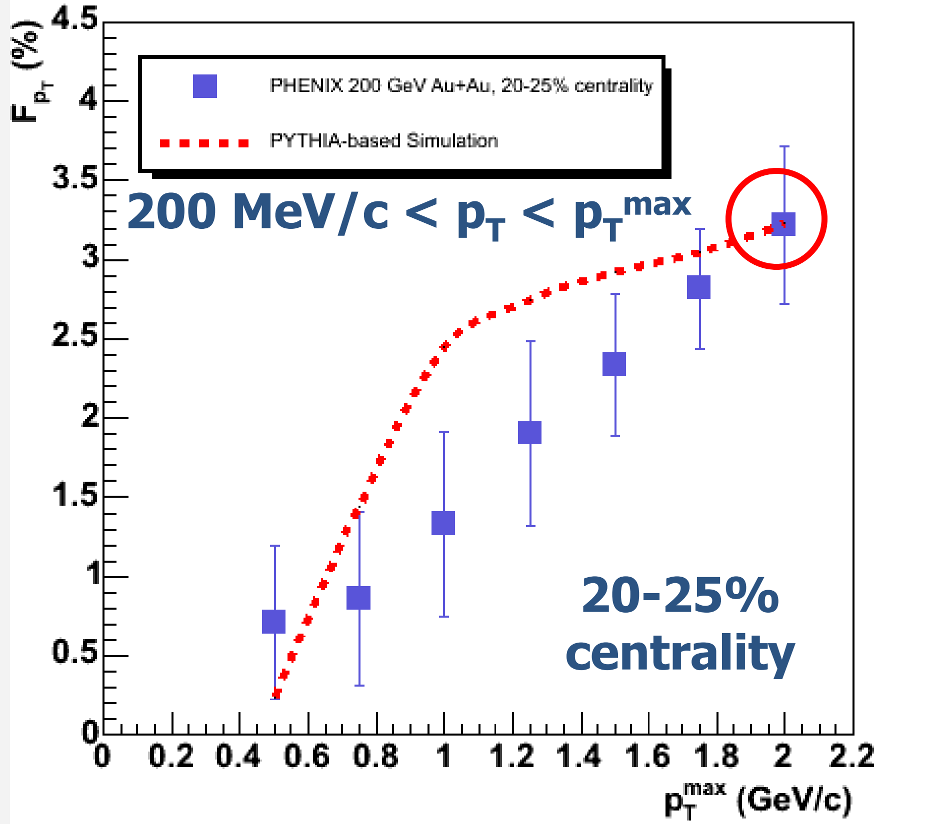
Jet Simulation Results: PHENIX at $\sqrt{s_{NN}}$ = 200 GeV

The S_{prob} parameter is initially adjusted so that F_{pT} from the simulation matches F_{pT} from the data for 20-25% centrality (circled). It is then FIXED and finally scaled by R_{AA} for all other centralities.

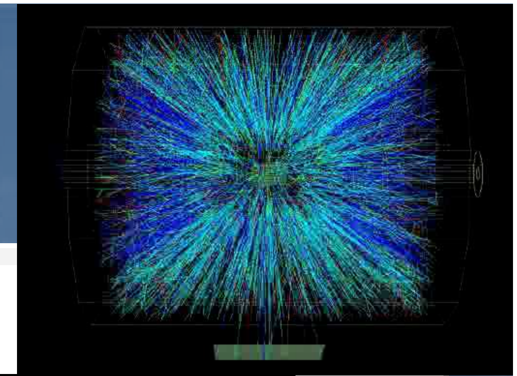




PHENIX Data: nucl-ex/0310005



Jet Simulation Results: STAR at sqrt(s_{NN}) = 130 GeV

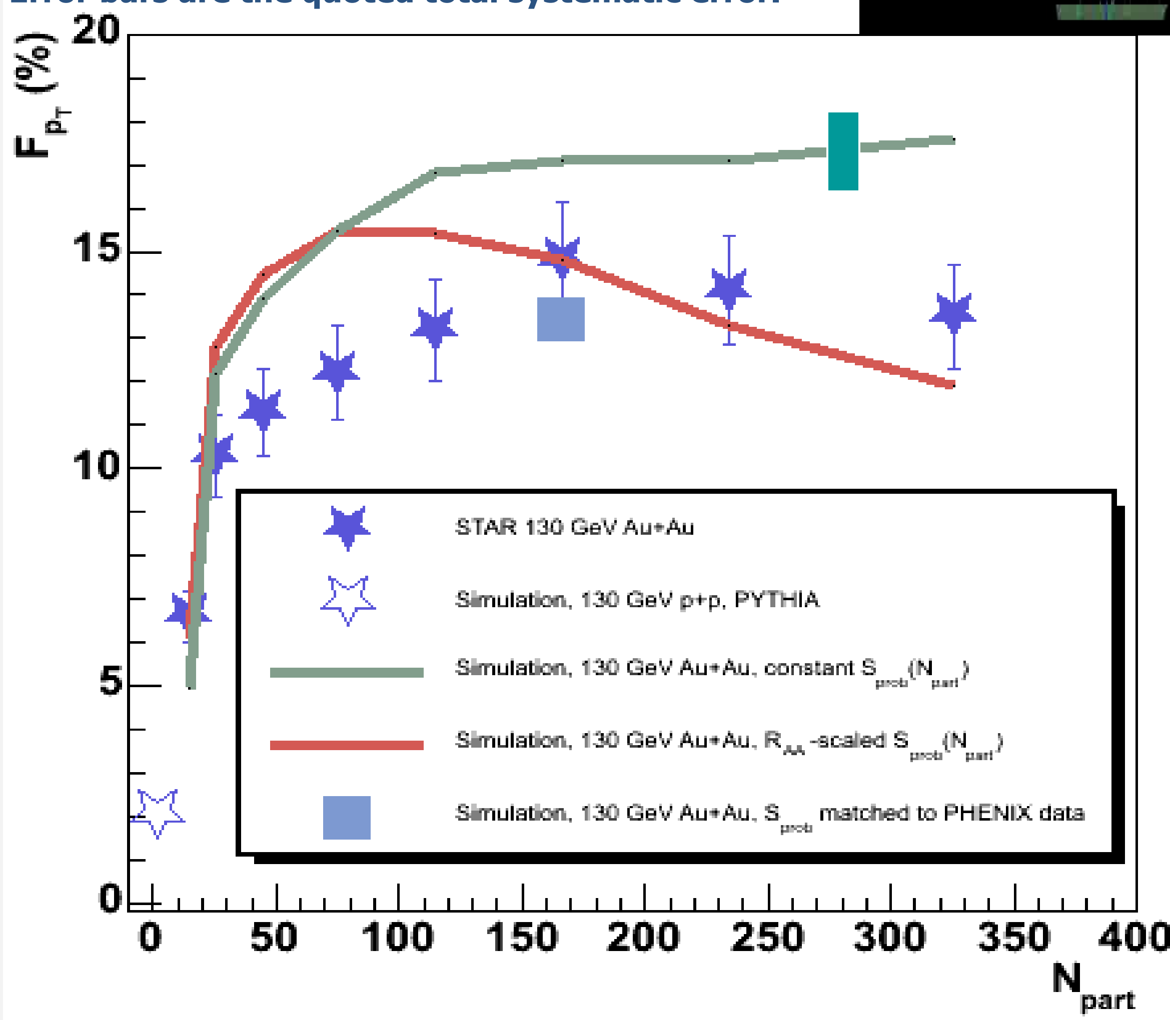


The square is the result using the initial value of S_{prob} that matches the PHENIX data with the PYTHIA events filtered through the increased STAR acceptance. The lines are the result with S_{prob} adjusted to reproduce the STAR 20-30% centrality data.

PREDICTION: The STAR values of F_{pT} should increase by ~15% for centralities 0-40% at sqrt(s_{NN})=200 GeV.

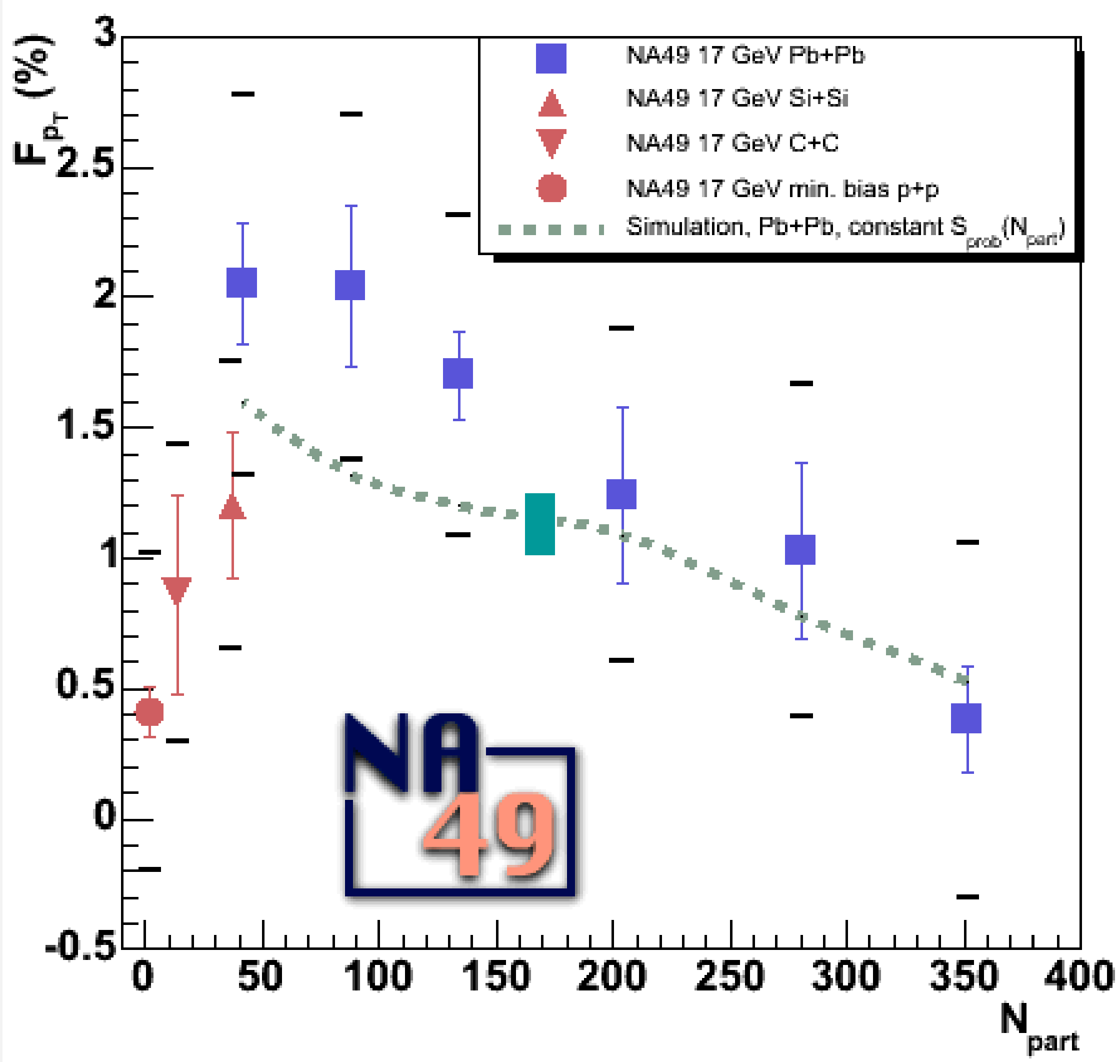
STAR data: nucl-ex/0308033

Error bars are the quoted total systematic error.



Jet Simulation Results at SPS Energies: NA49 at sqrt(s_{NN}) = 17 GeV

Preliminary NA49 data presented at this conference.



Jet Simulation Results: CERES at sqrt(s_{NN}) = 17 GeV

Energy dependence study:

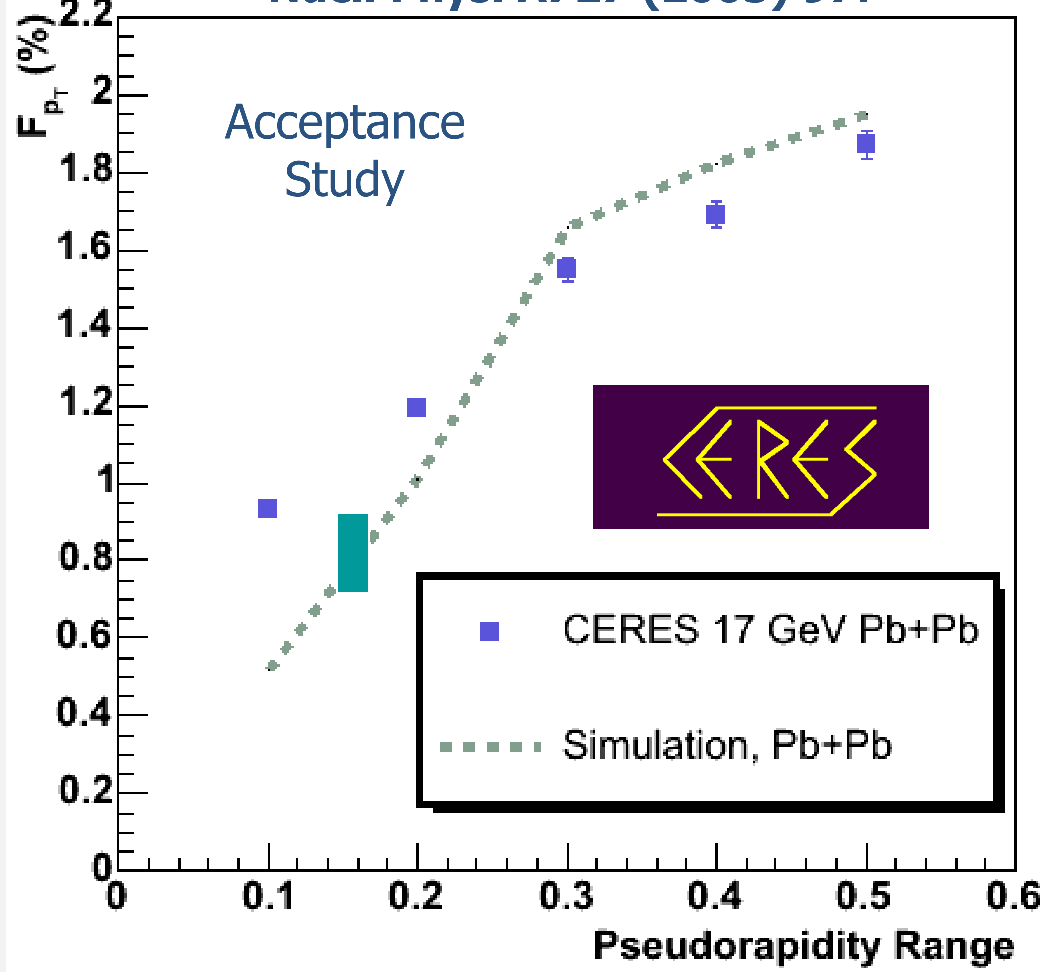
CERES data:
F_{pT}(80 A GeV/c)/F_{pT}(158 A GeV/c) = 0.72

Simulation:
F_{pT}(80 A GeV/c)/F_{pT}(158 A GeV/c) = 0.68

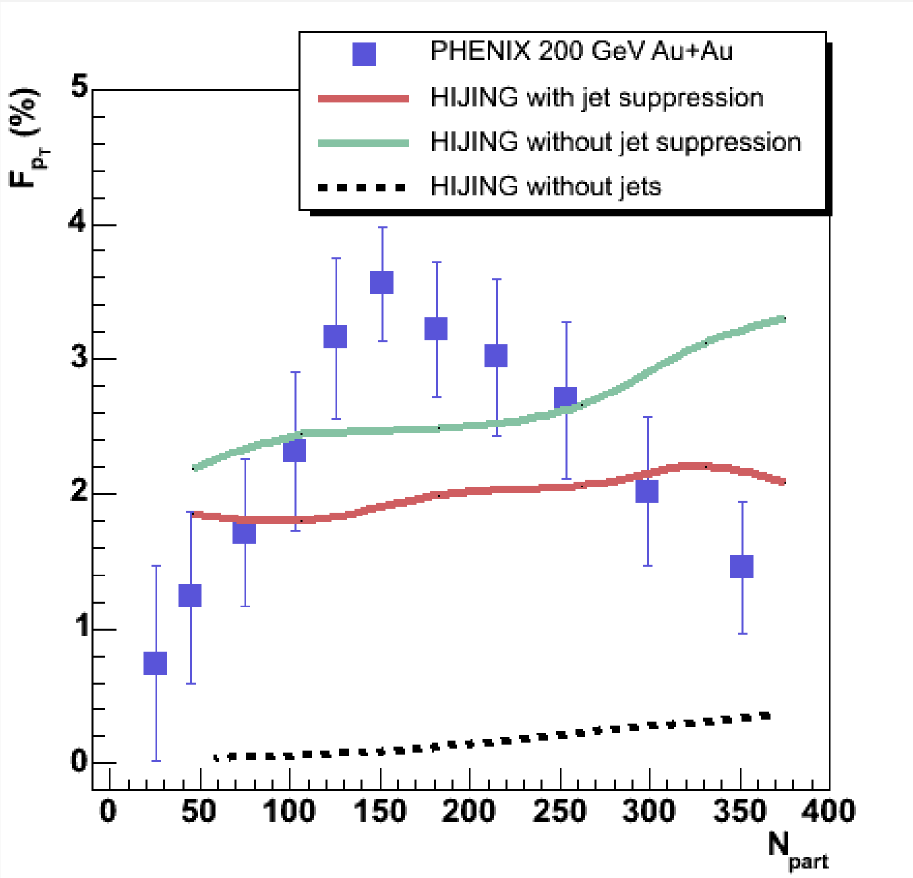
Averaged over 0-30% centrality.

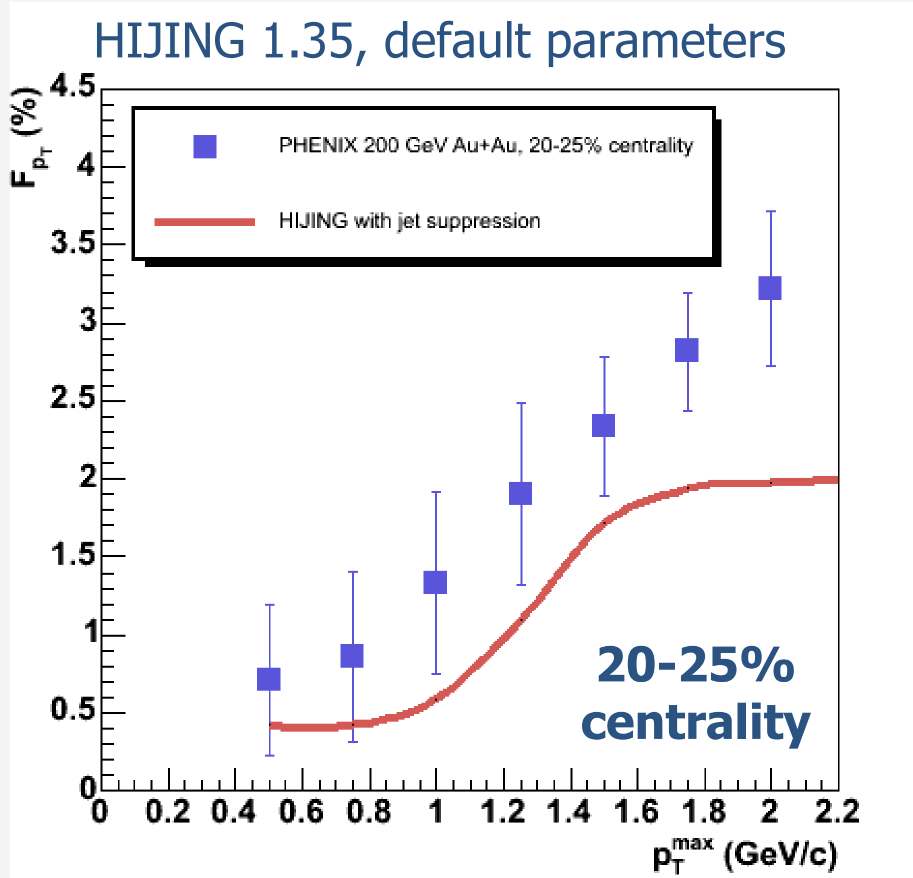
In a jet contribution scenario, F_{pT} may decrease with decreasing η range since a fraction of the jet cone is no longer accepted.

CERES Data: D. Adamova, et al., Nucl. Phys. A727 (2003) 97.



Fluctuations According to HIJING





HIJING cannot reproduce the centrality dependence of the fluctuations.

One problem is that <N> changes depending on the HIJING settings – not matched to the observed dataset. Matching would increase F_{pT} without jet suppression.

For example: for 0-5% centrality in PHENIX: <N> = 93.0 with jet suppression (close to the measured data value), 76.6 without suppression, and 51.2 without jets entirely.

Estimate of the Magnitude of Event-by-Event Temperature Fluctuations

$$\frac{\sigma_T}{<T>} = \sqrt{\frac{2F_{p_T}}{p(<N>-1)}}$$

R. Korus and S. Mrowczynski,

Phys. Rev. C64 (2001) 054908.

Measurement	**sqrt(s_{NN})**	**σ_T/<T>, Most central**	**σ_T/<T>, At the peak**
PHENIX	200	1.8%	3.7%
STAR	130	1.7%	3.8%
CERES	17	1.3%	2.2%
NA49	17	0.6%	2.6%

Conclusions

- A simulation for studying the sources of event-by-event average p_T fluctuations has been described.
- A hybrid simulation using PYTHIA events to simulate hard process products can well reproduce the trends in fluctuation data at RHIC energies – but only if an R_{AA}-scaling is invoked.
- Within a jet contribution scenario, the PHENIX and STAR results agree within errors. The difference in signal strength can be attributed primarily to the difference in the azimuthal acceptance of the jet cone.
- The hybrid PYTHIA simulation can also describe the energy, centrality, and pseudorapidity-range dependence of the SPS data with a constant scaling.
- Estimates of the remaining signal available for temperature fluctuations are small at about 2% for both RHIC and SPS energies.