Event-by-Event <P_T> Fluctuations in PHENIX

Quark Matter 2002

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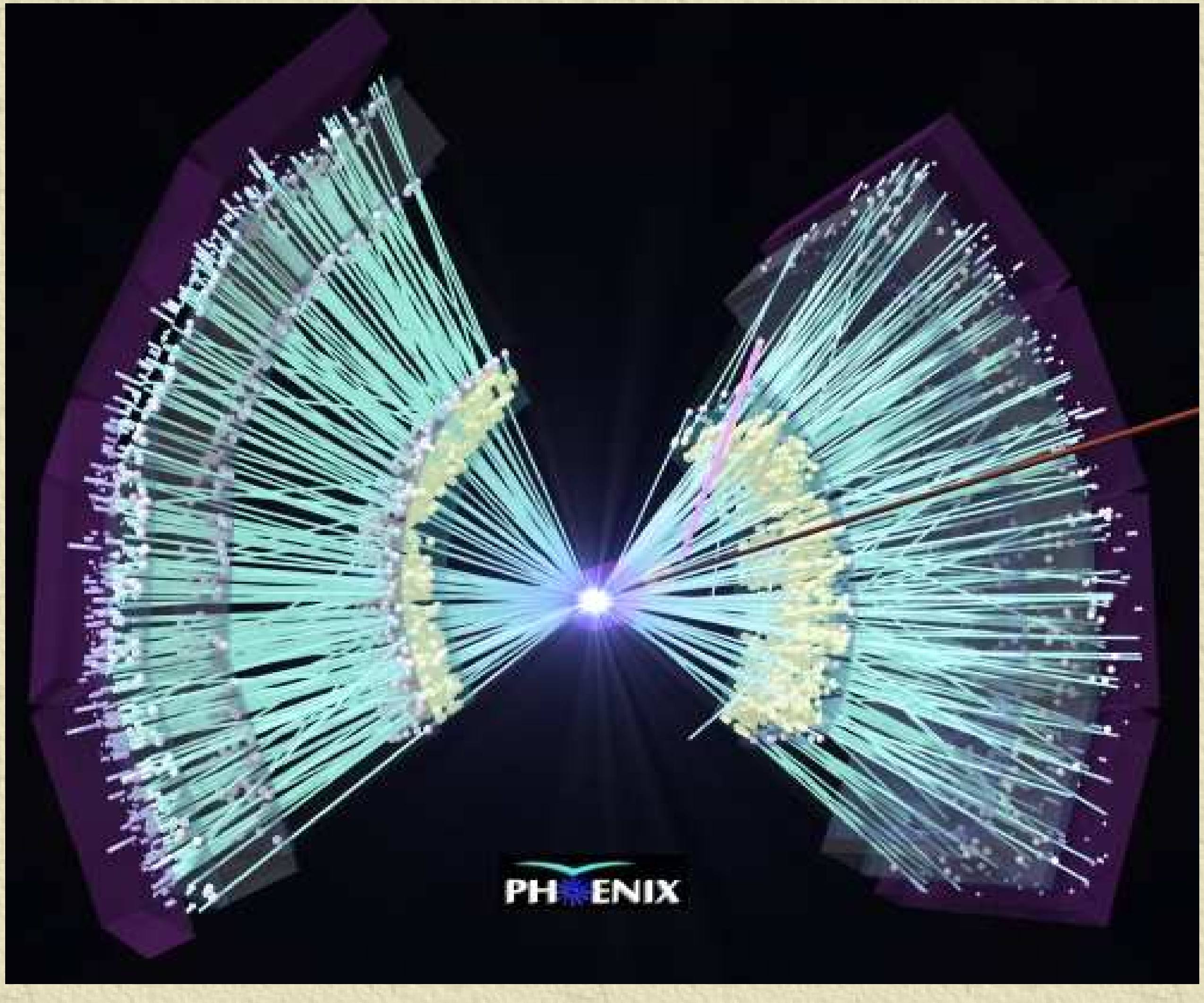


Searching for Critical Behavior

Analogy: Critical Opalescence (as observed in a CO_2 liquid-gas transition)

- ***S. Mrowczynski (see Phys. Lett. B314 (1993) 118.)*** **Instability of the plasma could be present, initiated as random color fluctuations. For some events, the fluctuations of particle transverse quantities would be magnified.**

- ***M. Stephanov, et. al. (see hep-ph/9903292)*** **suggest that near a tri-critical point in the QCD phase diagram, the event-by-event fluctuations in p_T could increase significantly.**

Analysis Details

Data:

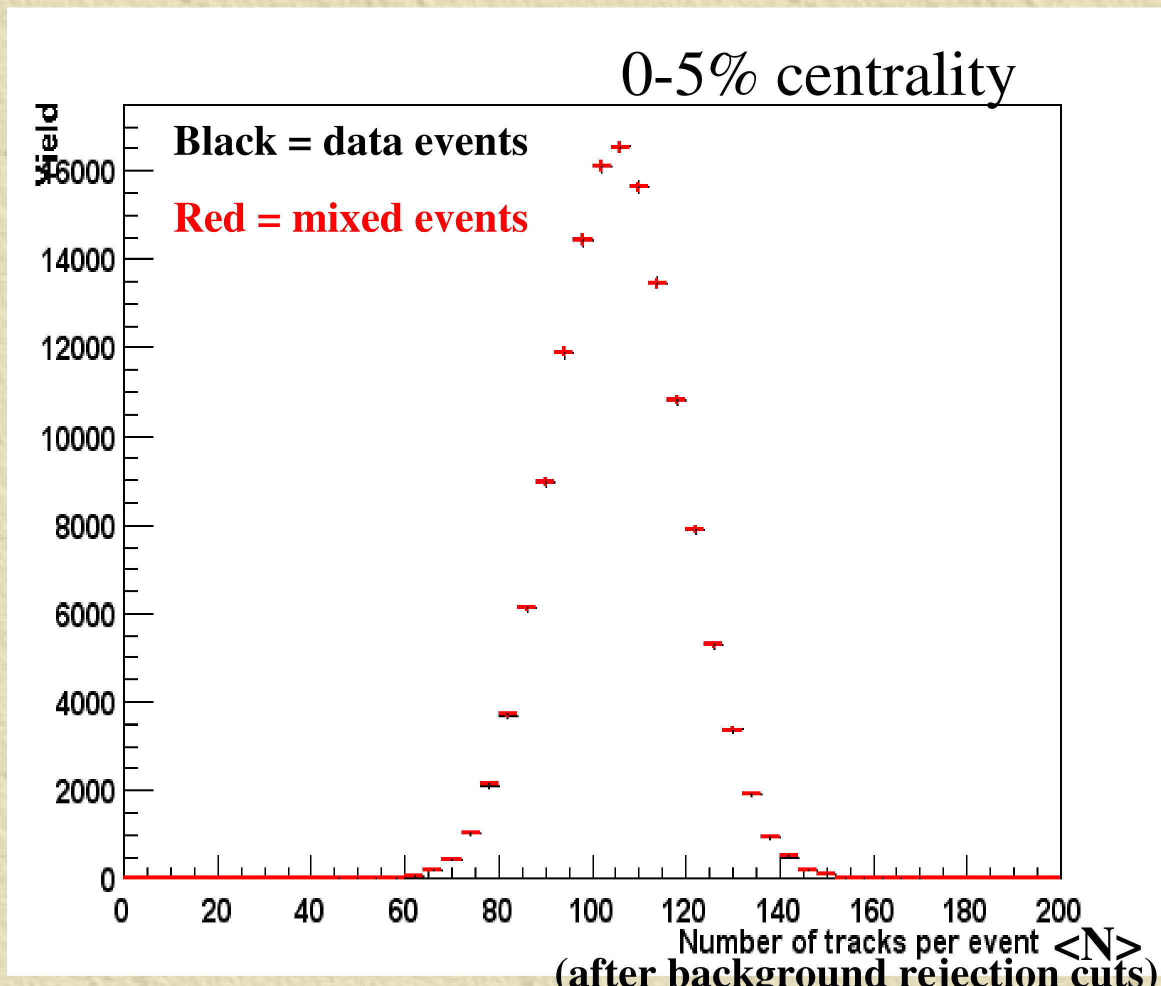
- The average p_T are determined on an event-by-event basis.
- Improvements over the $\sqrt{s_{NN}}$ = 130 GeV analysis include:
    - *3x increase in azimuthal aperture. 2x event statistics.*
    - *Enhanced background rejection from the additional detectors.*

Mixed Events:

- Mixed events serve as the random baseline distributions.
- Mixed event distributions are built from reconstructed tracks in real data events from the same centrality/multiplicity and event vertex class.
- *No two tracks from the same real event are allowed in the same mixed event.*

Important Note:
Matching mixed events to data events

Since the width of the $\langle p_T \rangle$ distribution depends on <N>, it is important that there is an exact match of the mixed event <N> distribution to the data <N> distribution. The mixed events are constructed by sampling the data <N> distribution.



Definition of Fluctuation Quantities

Define the magnitude of a fluctuation, ω:

$$\omega = \frac{\sqrt{< X^2 > - < X >^2}}{< X >} \times 100\% = \frac{\sigma}{\mu} \times 100\%$$

Define the fractional fluctuation difference from random, F_{pT}:

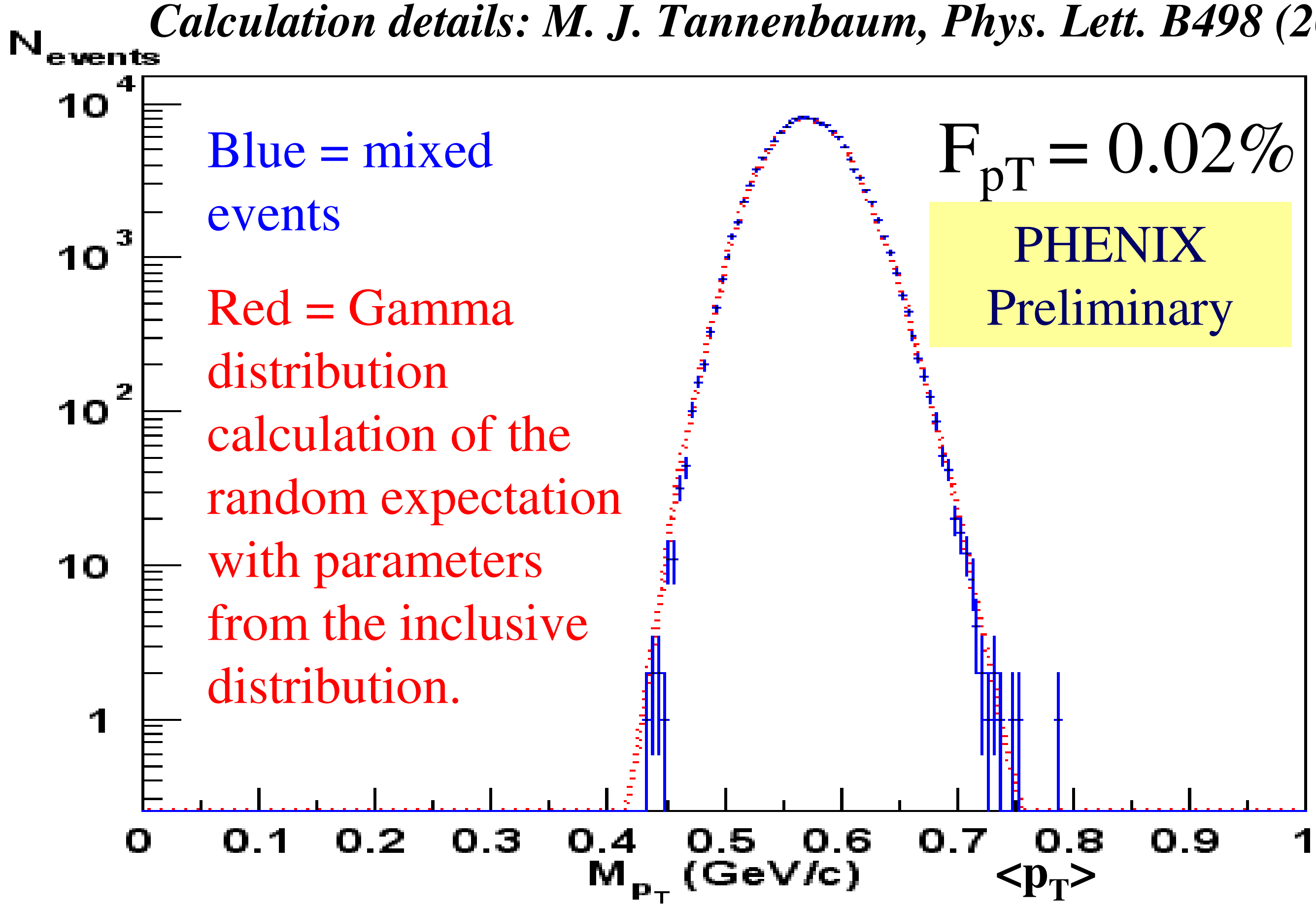
$$F_{p_T} = \omega_{data} - \omega_{random} \Big/ \omega_{random}$$

Also commonly used is the variable, ϕ:

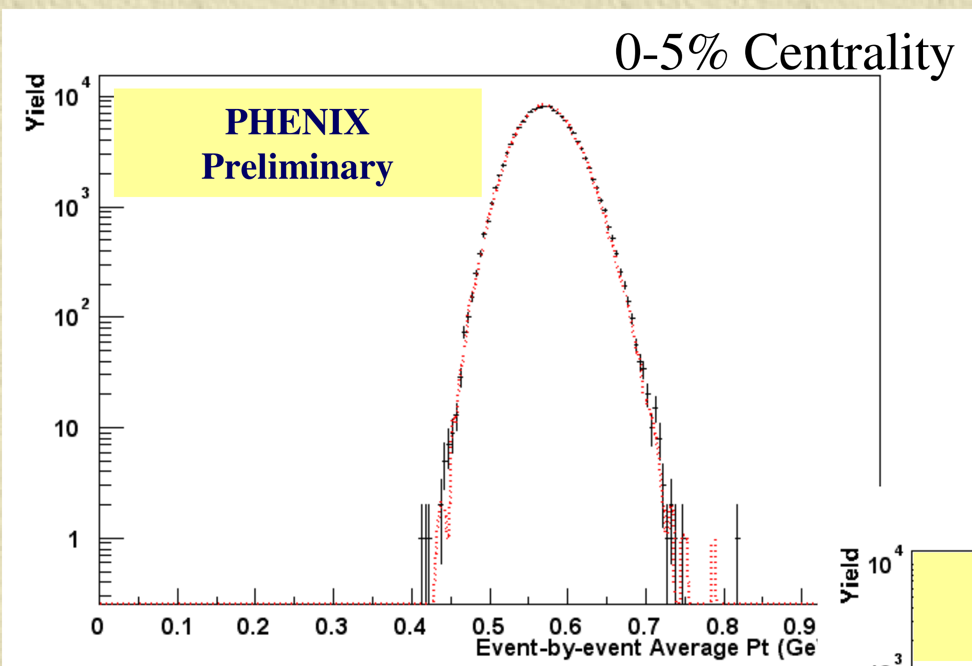
$$\phi = \sqrt{n}\left(\sigma_{data} - \sigma_{random}\right) = F_{p_T}\,\sigma_{random}\sqrt{< N >}$$

Mixed events as the random baseline distribution

Calculation details: M. J. Tannenbaum, Phys. Lett. B498 (2001) 29.

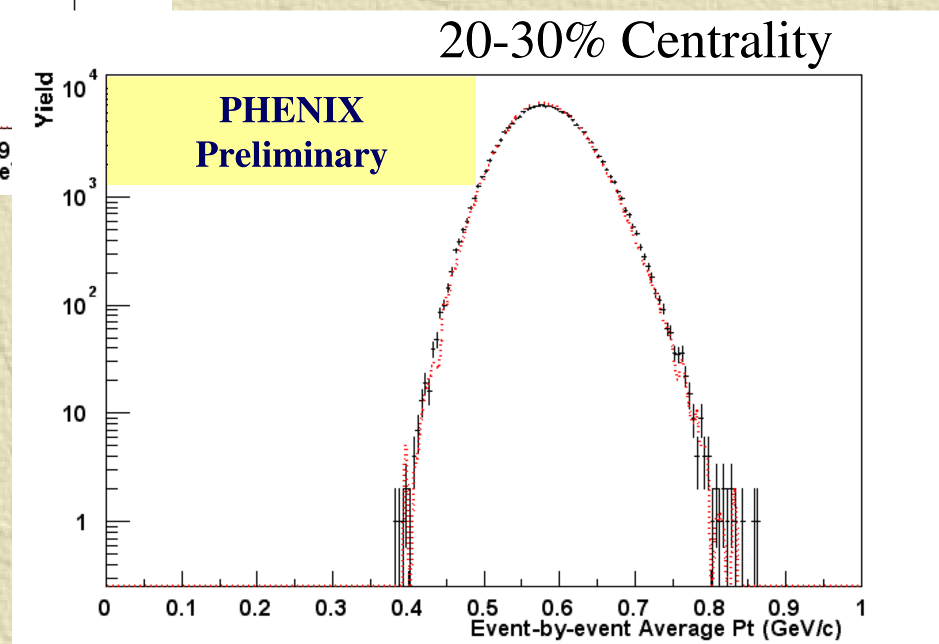


$\langle P_T \rangle$ distributions



$\sqrt{s_{NN}}$ = **200 GeV**

A small positive fluctuation is apparent.

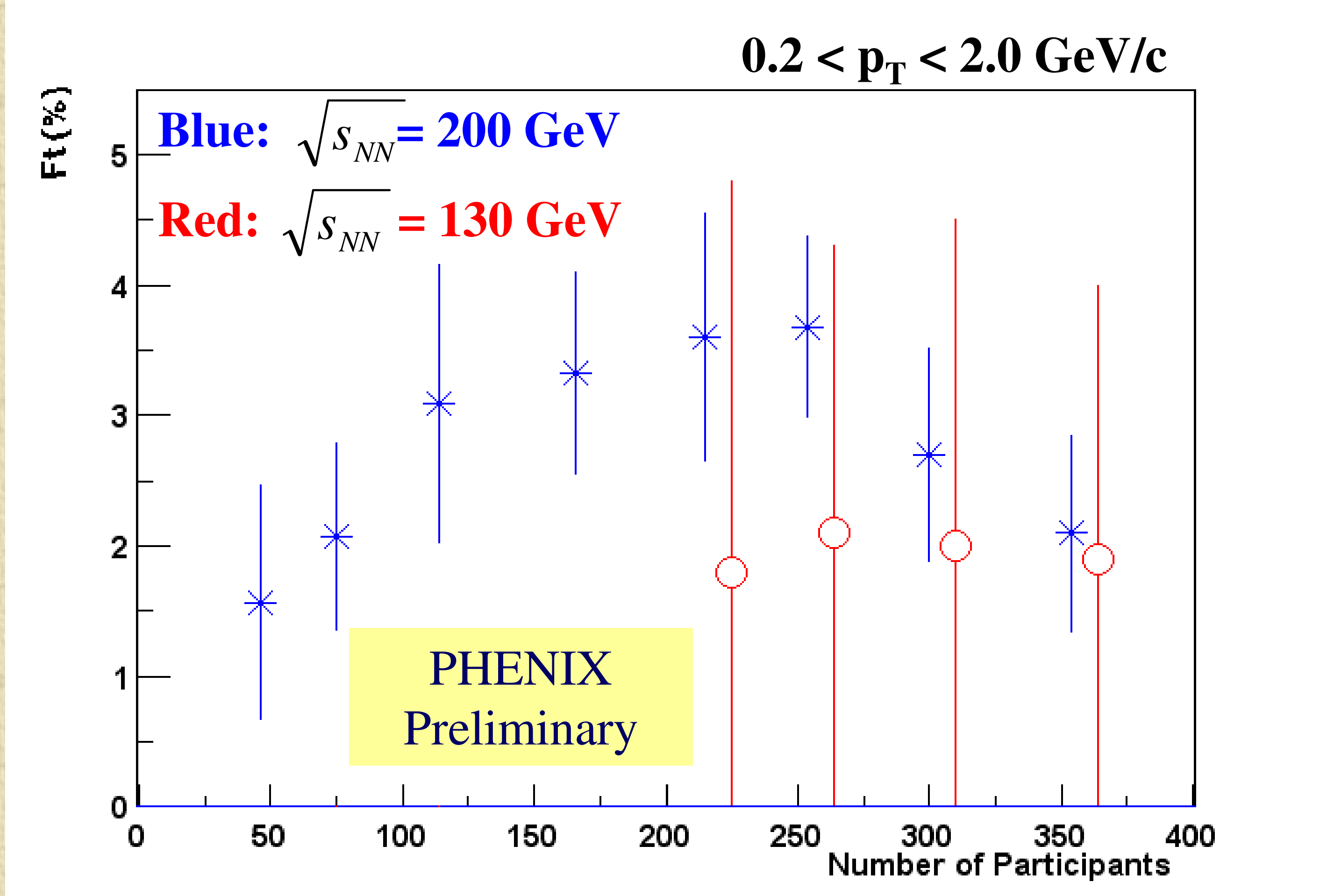


Black = data events

Red = mixed events

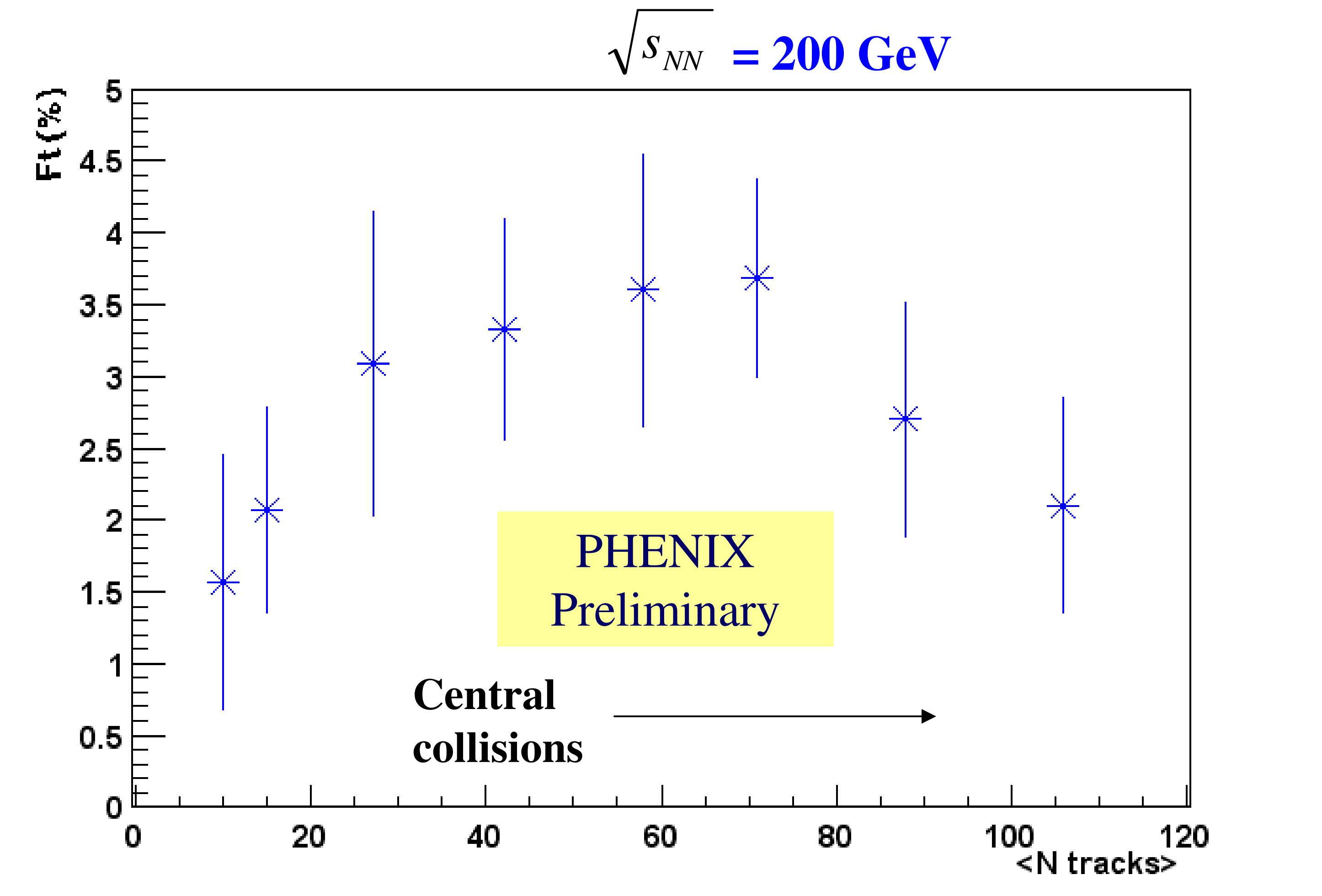
F_{pT} as a function of centrality

The fluctuation magnitude follows a decreasing trend for peripheral collisions.



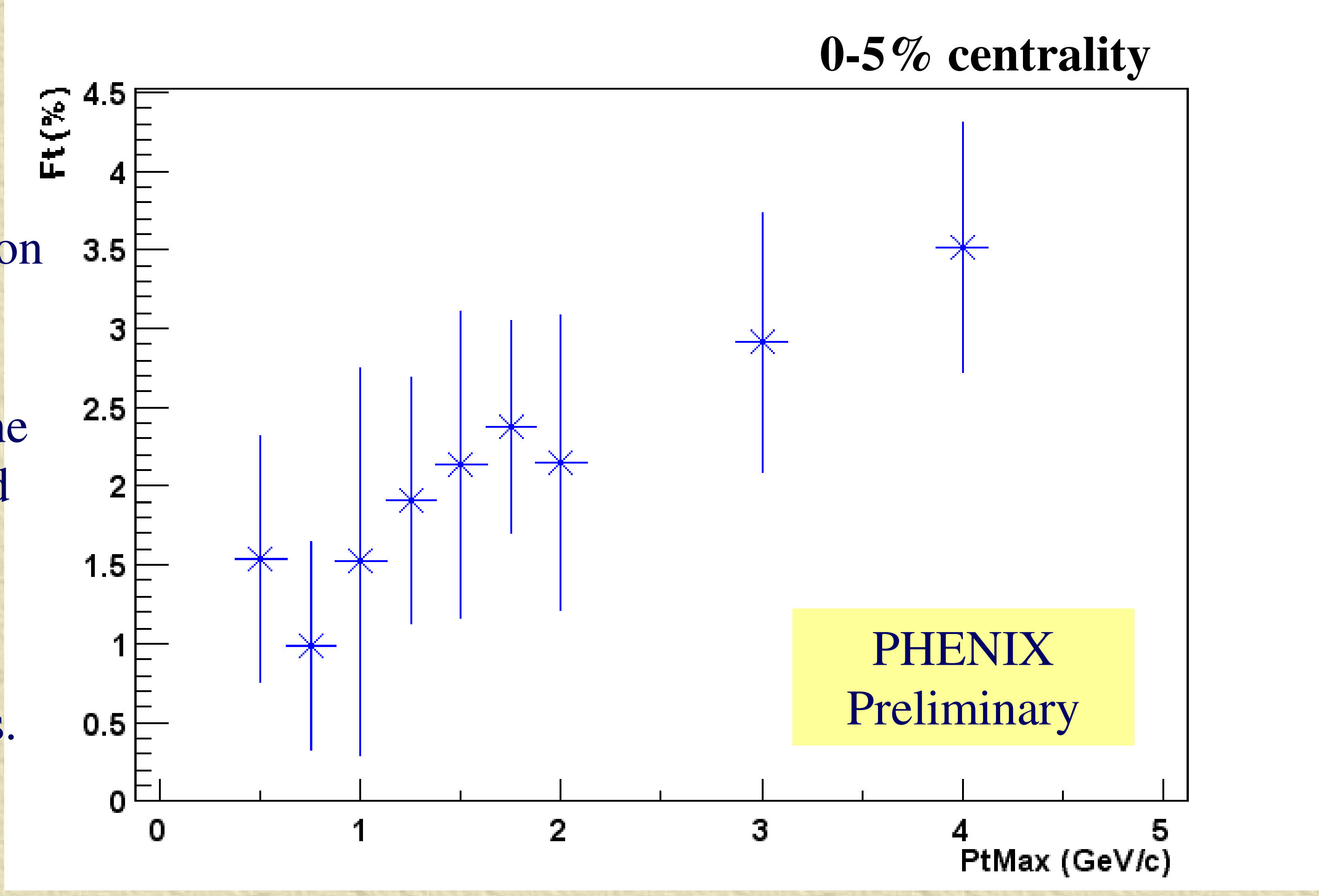
F_{pT} vs. <N_{tracks}>

Using the same centrality binning as in the previous figure.



F_T vs. P_T range ($0.2<p_T<p_{T, max}$)

The fluctuation magnitude tends to increase as the p_T range used to calculate $<p_T>$ is extended to higher values.



Sensitivity: Modeling a Fluctuation

Goal: Produce a fluctuation that does not change the mean or variance of the final inclusive distribution.

- The final inclusive distribution <u>(fixed by observation)</u> can be expressed as a Gamma distribution:

$$\frac{dN}{dp_T} = \Gamma(p_T, p, b)$$

where T = 1/b is the *inverse slope parameter* of the distribution.

- Consider an event sample with two classes of events.

Define $q = N_{\text{events, class 1}} / N_{\text{events, total}}$

- The distribution for the two component fluctuating sample can be taken as:

$$f(p_T) = q \times \Gamma(p_T, b1, p1) + (q-1) \times \Gamma(p_T, b2, p2)$$

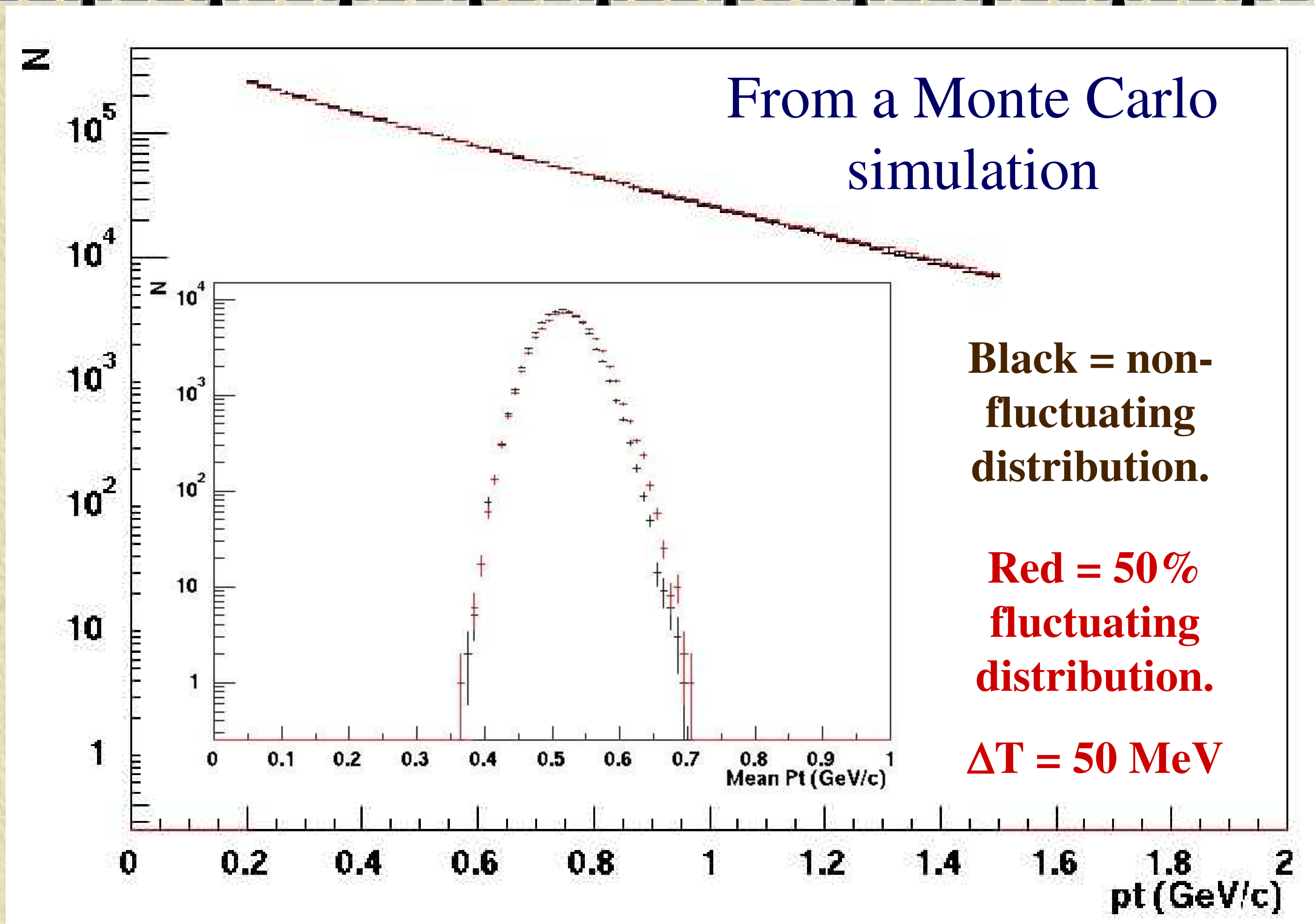
Fluctuation Models

Goal: Produce a fluctuation that does not change the mean or variance of the final inclusive distribution.

- We consider two models of this type:
  - Fluctuation Model A: *The inclusive distributions of the two event classes have the same mean, but different variance.*
  - Fluctuation Model B: *The inclusive distributions of the two event classes have the same variance, but different means.*
- After applying the constraints for each model, two event classes are defined with differing inverse slope parameters.

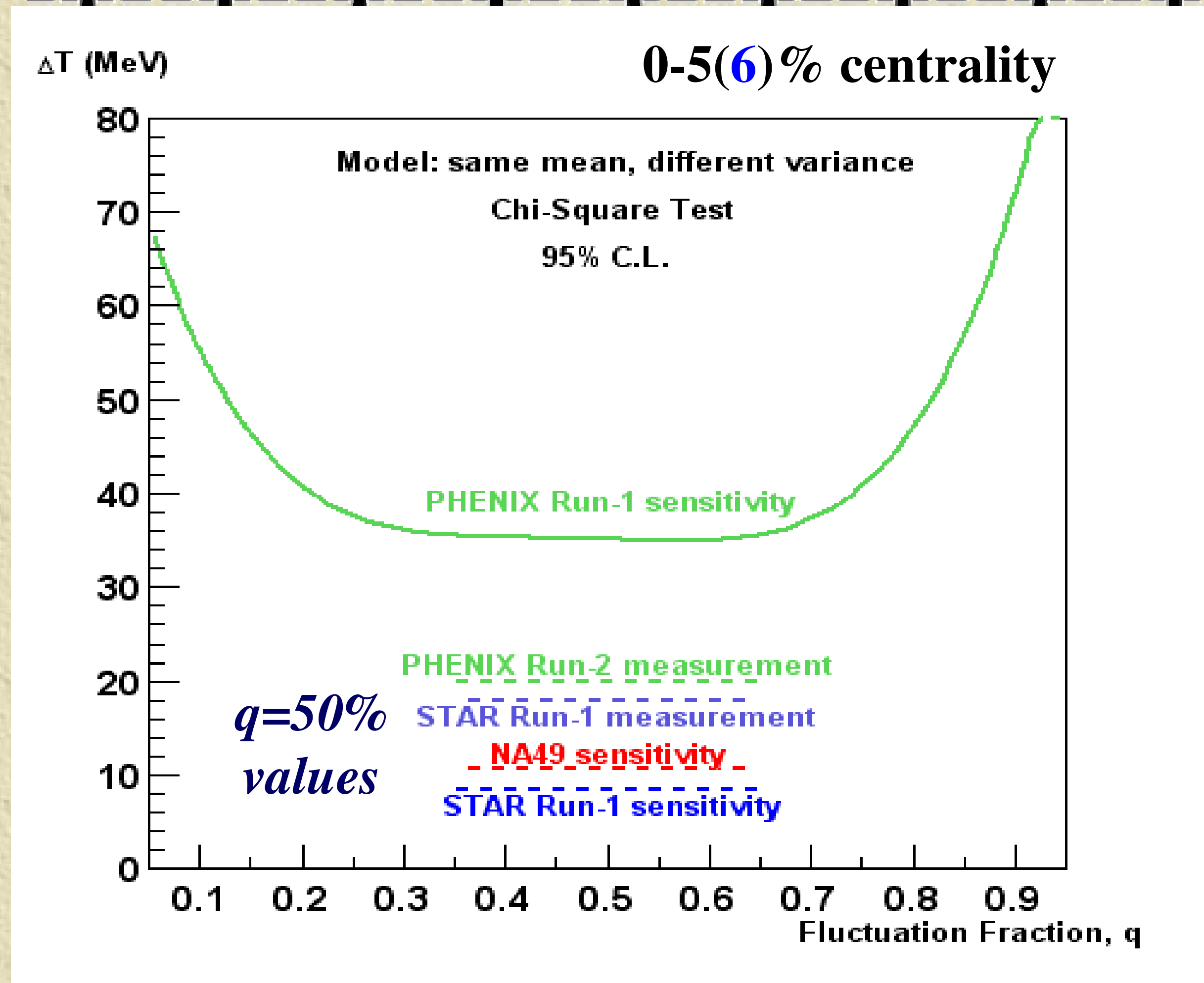
Define $\Delta T = T_{class\ 1} - T_{class\ 2} > 0$

"Different Mean, Same Variance" Model Demonstration



Estimated Experimental Sensitivities: Model A

Run-1: $\sqrt{s_{NN}} = 130$ GeV
Run-2: $\sqrt{s_{NN}} = 200$ GeV

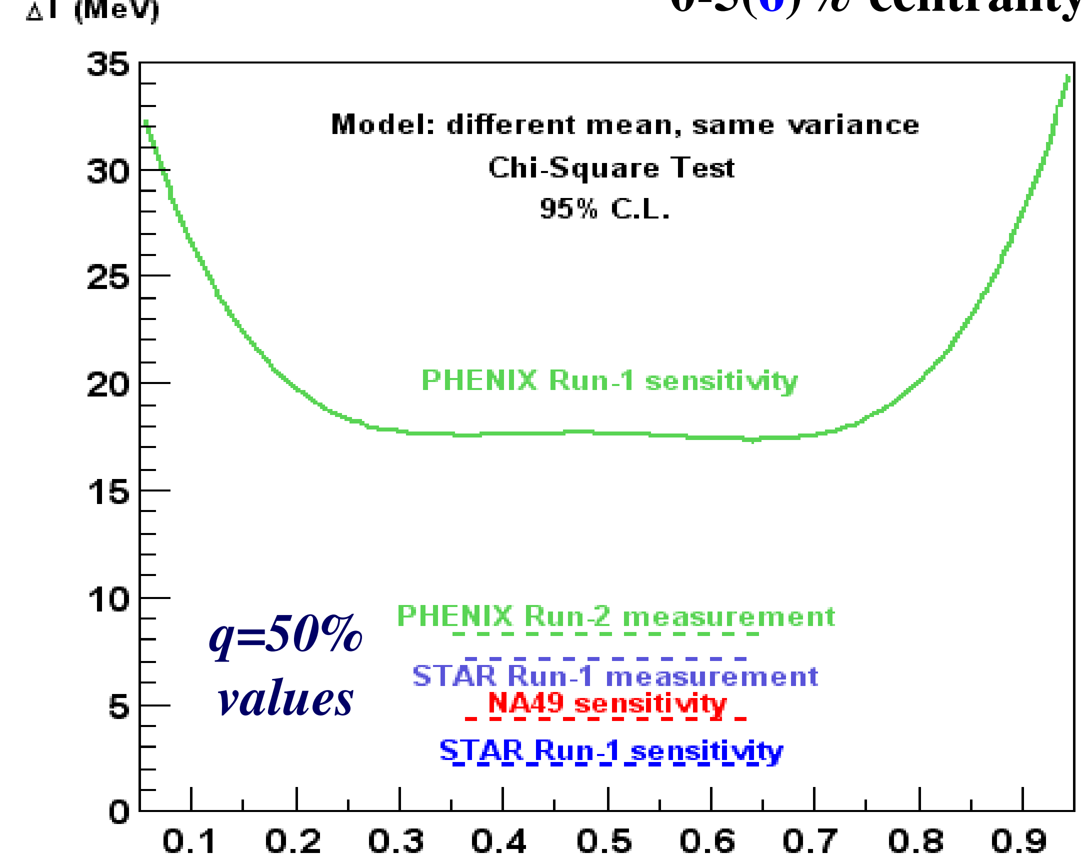


Estimated by comparing the experimental data to Monte Carlo simulation results that reproduce the <N> and inclusive p_T distributions.

Estimated Experimental Sensitivities: Model B

Run-1: $\sqrt{s_{NN}} = 130$ GeV
Run-2: $\sqrt{s_{NN}} = 200$ GeV

0-5(6)% centrality



Estimated by comparing the experimental data to Monte Carlo simulation results that reproduce the <N> and inclusive p_T distributions.

Summary and Conclusions

- With the increased PHENIX azimuthal aperture and improved background rejection, a positive non-random fluctuation in event-by-event average p_T is now observed. The fluctuations tend to decrease for peripheral collisions.
- The magnitude of the fluctuation tends to increase slightly with increasing p_T range. Possible causes for this trend await further investigation.
- The contribution of elliptic flow into the PHENIX azimuthal acceptance is estimated (via Monte Carlo simulation using PHENIX preliminary p_T-dependent v_2 measurements wrt to the reaction plane) to be on the order of –0.3% for mid-central collisions, thus not accounting for the observed signal.
- The magnitude of the fluctuations within a pair of dual-event-class models processed through the PHENIX acceptance are estimated to be on the order of ΔT = 10-20 MeV.