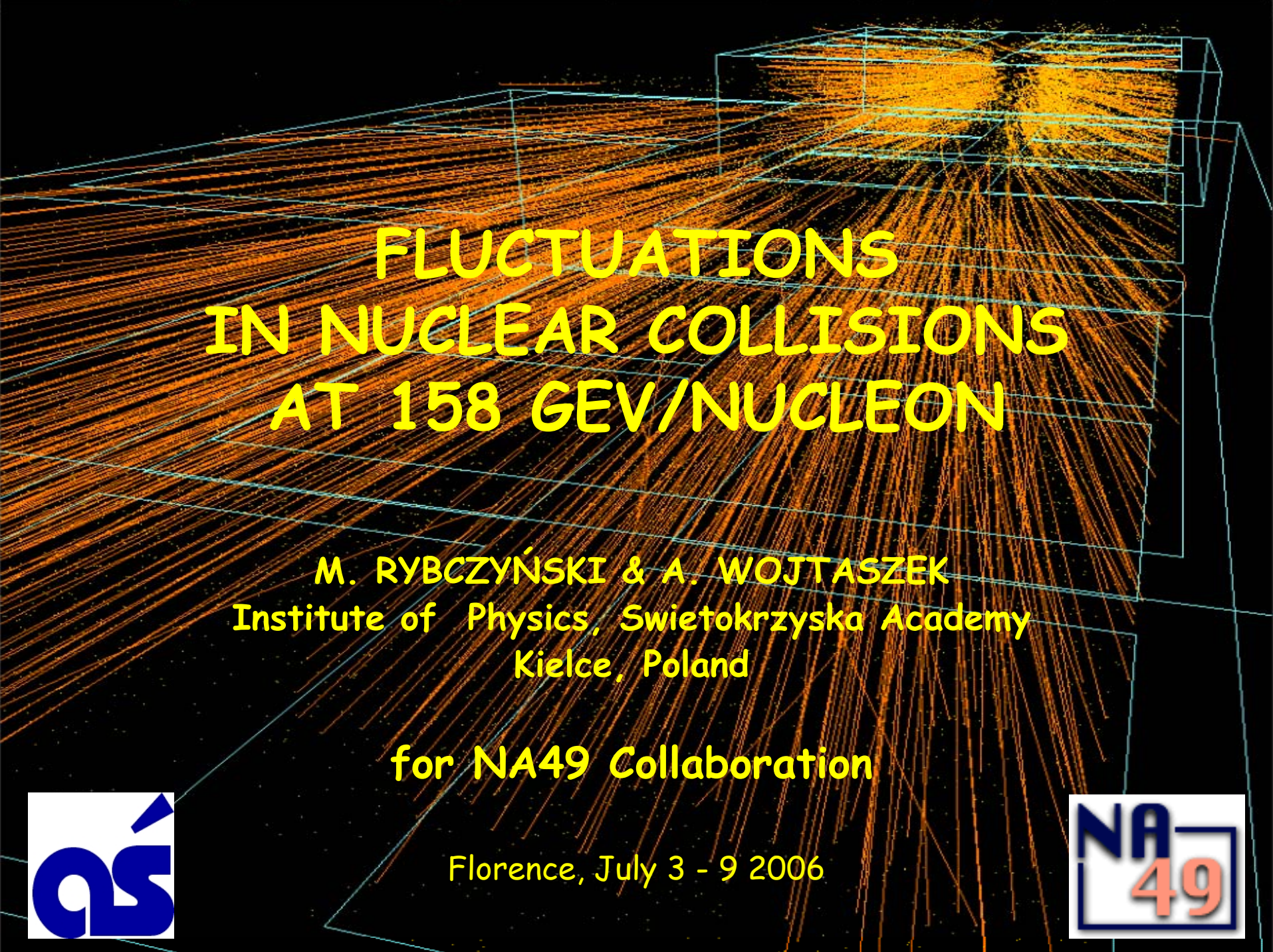

FLUCTUATIONS IN NUCLEAR COLLISIONS AT 158 GEV/NUCLEON

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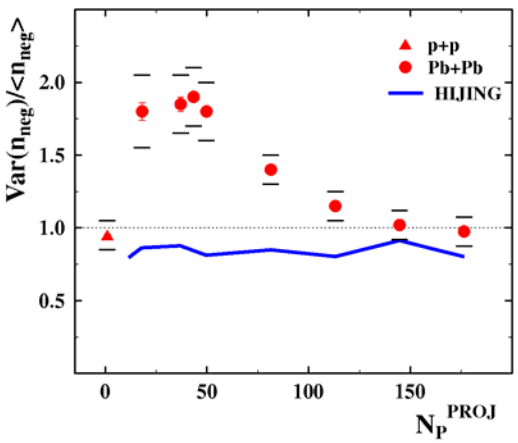
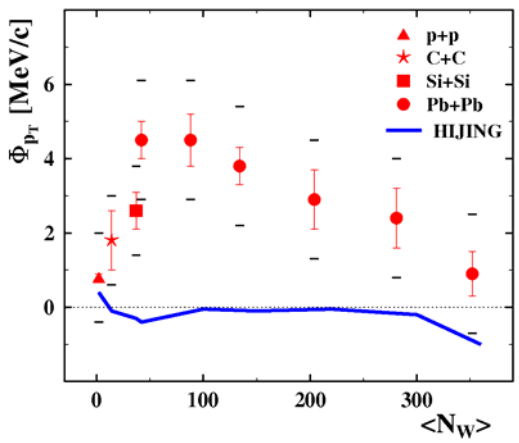
Kielce, Poland

for NA49 Collaboration

Florence, July 3 - 9 2006

OUTLINE

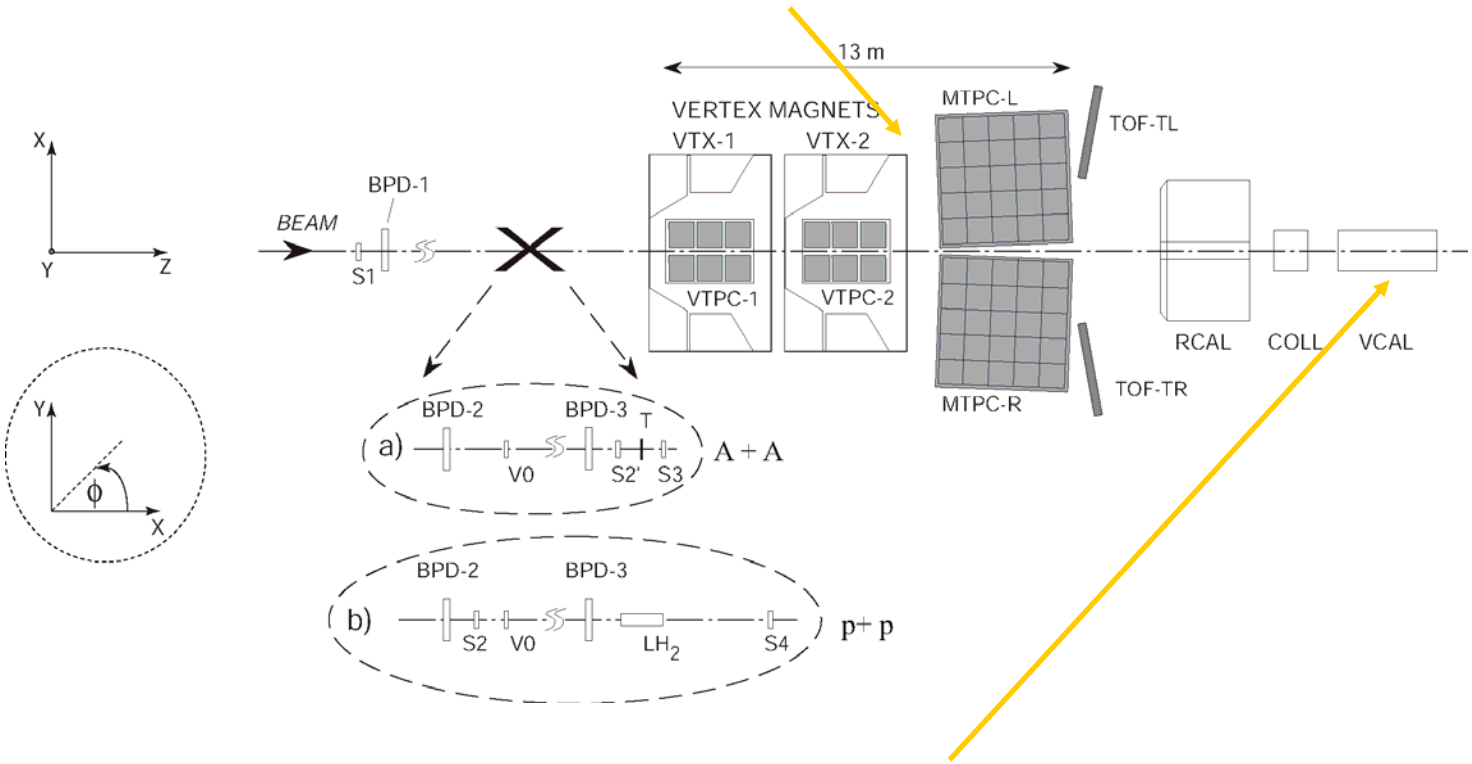




- Introduction
- Results on multiplicity fluctuations
- Connection between multiplicity fluctuations and Φ_{p_T} measure
- Summary

NA49 EXPERIMENT

Charged particle multiplicity is measured by the large TPC's



Veto Calorimeter measures energy carried by PROJECTILE SPECTATORS

THE ACCEPTANCE

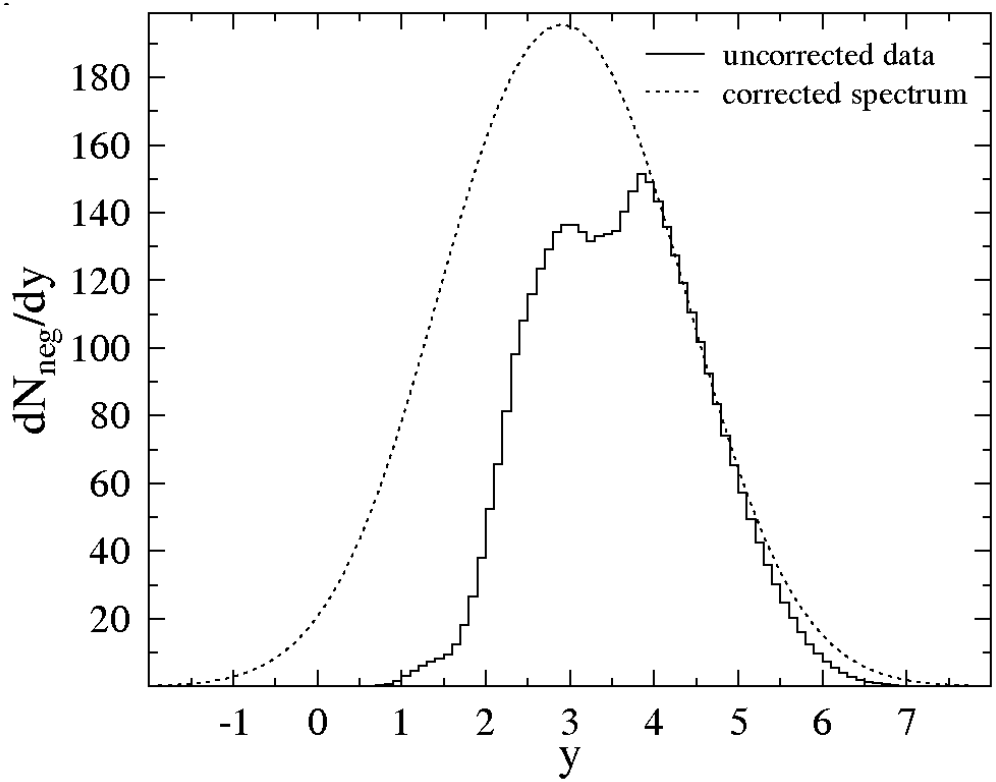
The acceptance used for analysis

$$4 < y < 5.5$$

(center of mass rapidity at y=2.9)

$$0.005 < p_T < 1.5\ GeV/c$$

$$\phi(p_T, y)$$



Given in:

Phys. Rev. *C* **70** (2004) 034902

OBSERVABLES

$$\langle N \rangle = \sum N \cdot P(N)$$

$$Var(N) = \langle N^2 \rangle - \langle N \rangle^2$$

$$\frac{Var(N)}{\langle N \rangle}$$ - scaled variance

For Poisson distribution:

$$P(N) = \frac{\langle N \rangle^N}{N!} \cdot e^{-\langle N \rangle} \quad \Rightarrow \quad \frac{Var(N)}{\langle N \rangle} = 1$$

MULTIPLICITY FLUCTUATIONS IN SUPERPOSITION MODEL

ASSUMPTION: $$N = \sum_{i=1}^{N_P} m_i$$

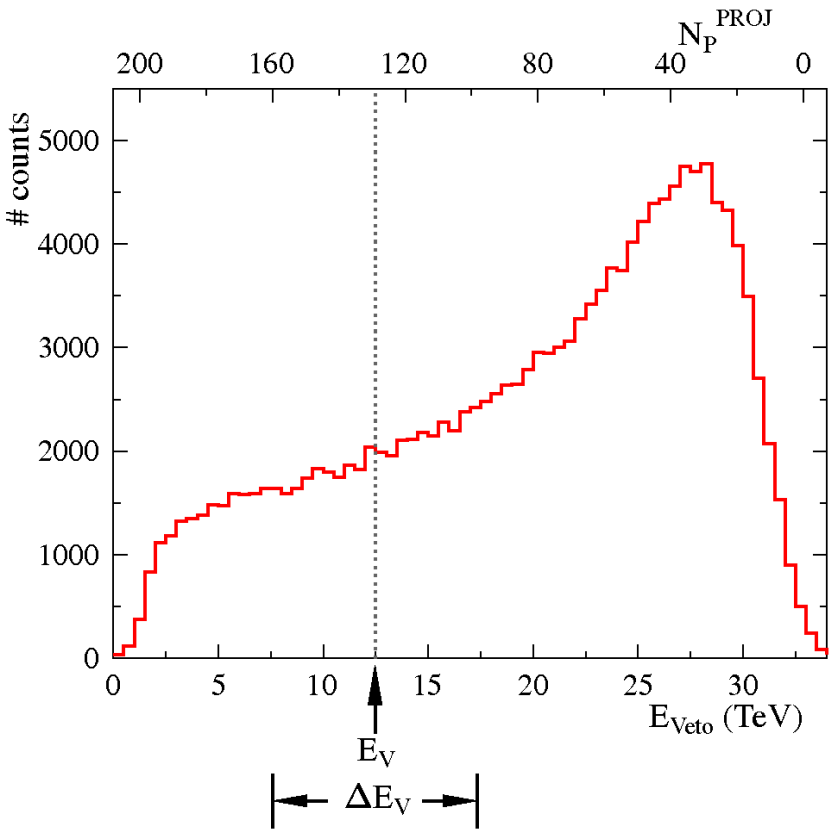
$$\langle N \rangle = \langle N_P \rangle \cdot \langle m \rangle$$

$$Var(N) = \langle N_P \rangle \cdot Var(m) + \langle m \rangle^2 \cdot Var(N_P)$$

$$\frac{Var(N)}{\langle N \rangle} = \frac{Var(m)}{\langle m \rangle} + \langle m \rangle \frac{Var(N_P)}{\langle N_P \rangle}$$

CENTRALITY SELECTION

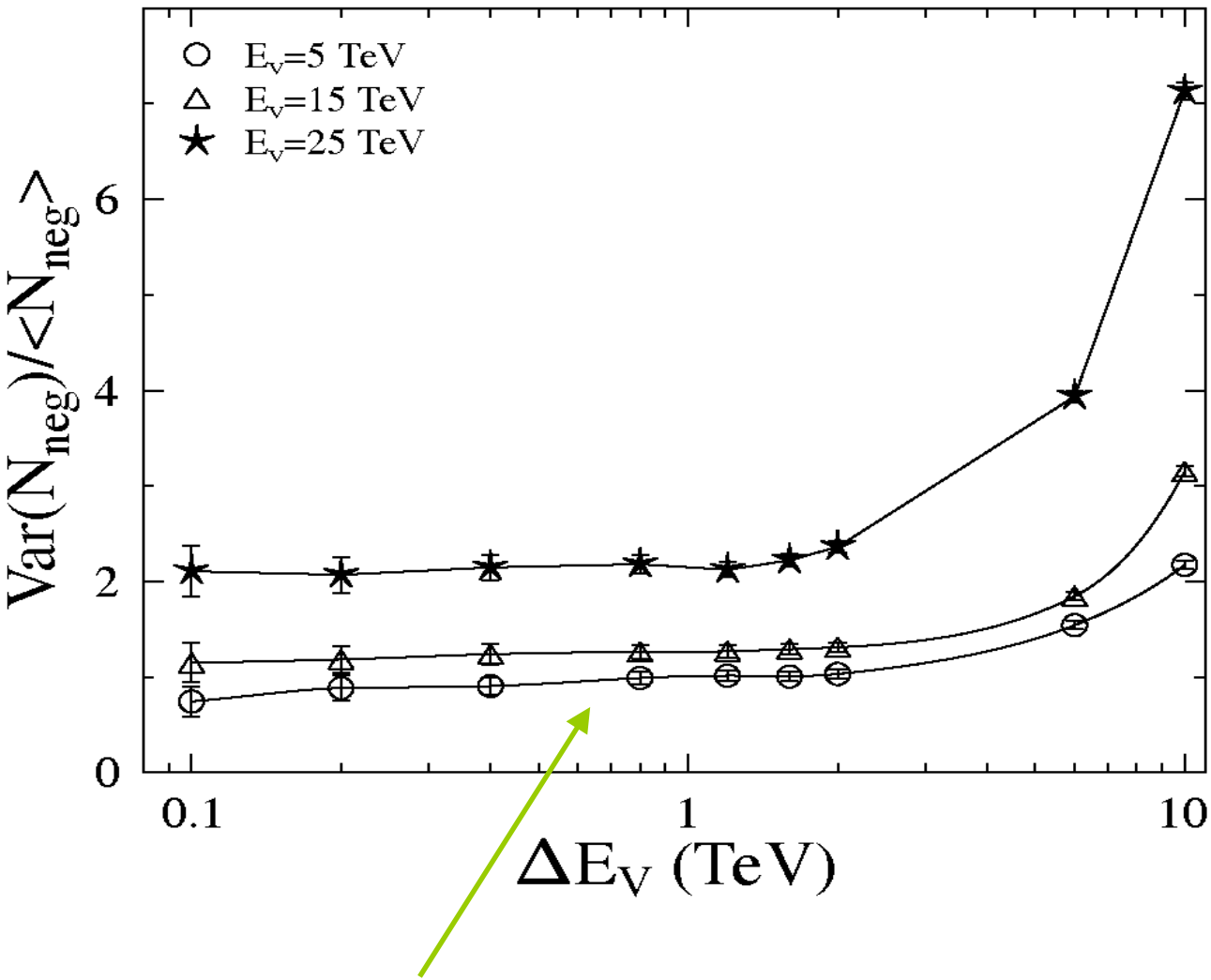
Distribution of energy E_{Veto} of the projectile spectators registered by the NA49 Veto Calorimeter



Events are selected within narrow ΔE_V intervals in E_{Veto} centered at various positions E_V

The number of projectile participants can be estimated as:

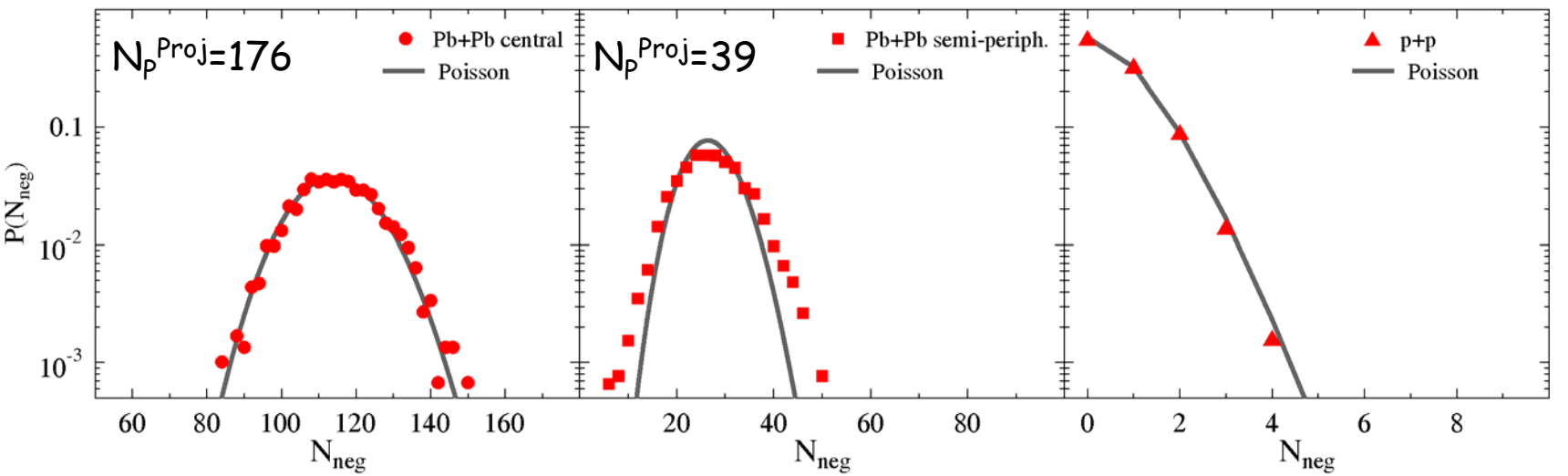
$$N_P^{PROJ} = A - \frac{E_{Veto}}{E_{LAB}}$$



Saturation for $\Delta E_\nu < 1\,TeV$

EXAMPLES OF MULTIPLICITY DISTRIBUTIONS

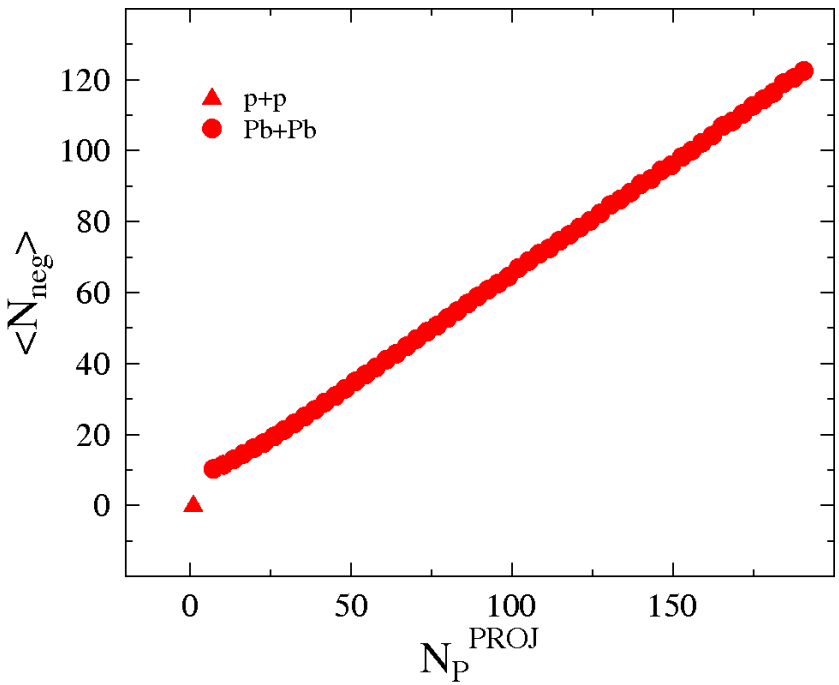
$$\Delta E_V = 500\ GeV$$

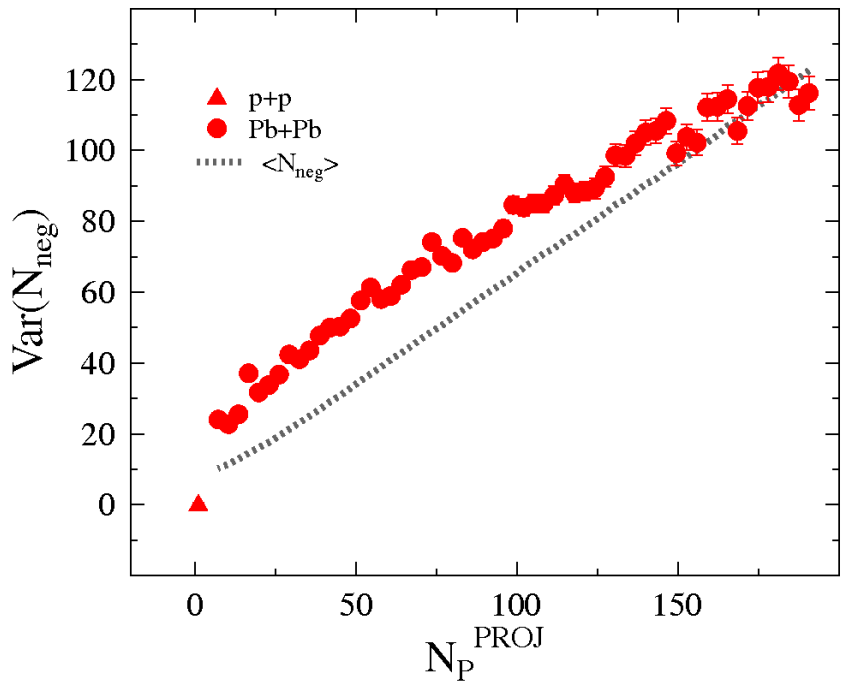


Large fluctuations for semi-peripheral Pb+Pb collisions

MEASURED MEAN VALUE AND VARIANCE OF MULTIPLICITY DISTRIBUTION VS N_P^{PROJ}

$$N_P^{PROJ} = A - \frac{E_{Veto}}{E_{LAB}} \qquad \Delta E_V = 500\ GeV$$





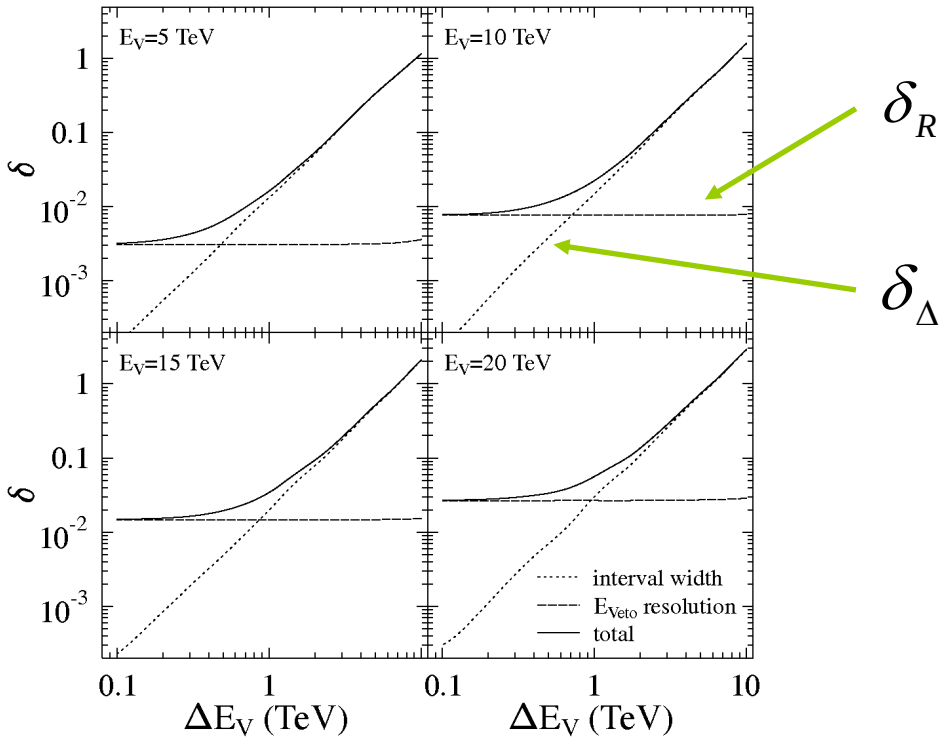
The scaled variance is corrected for:

δ_Δ - the finite width of E_{Veto} bin

δ_R - the finite Veto calorimeter resolution

Total correction is calculated as:

$$\delta = \delta_\Delta + \delta_R$$



δ_R

δ_Δ

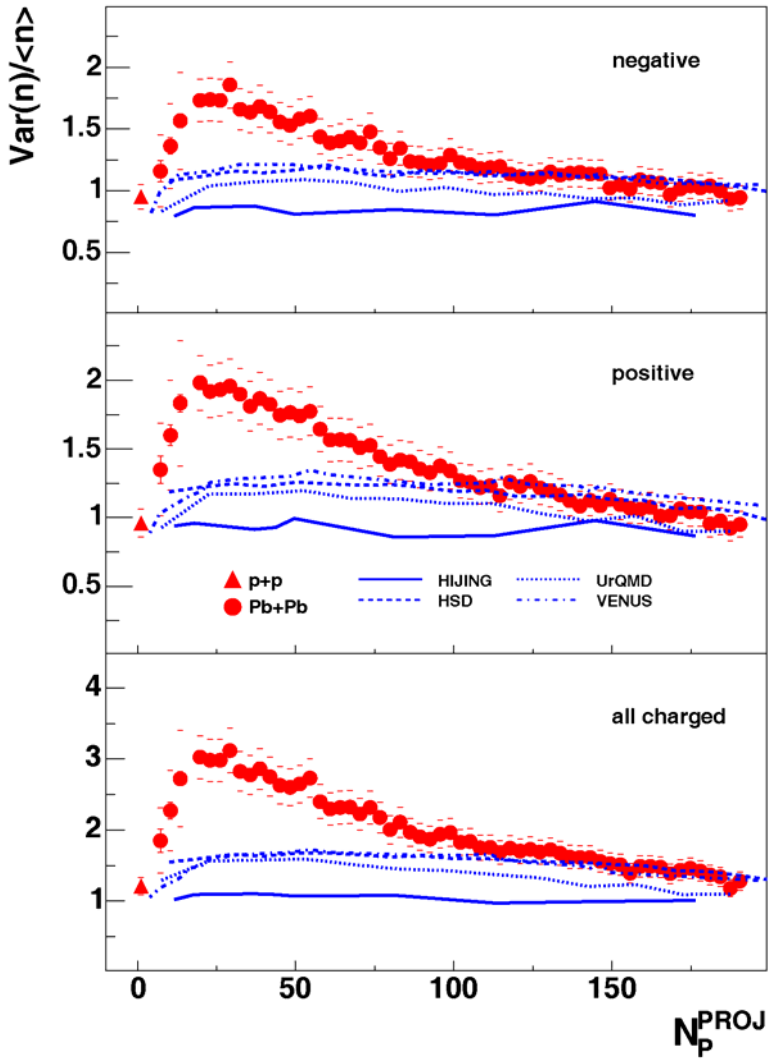
Corrections are small!

Corrected scaled variance:

$$\frac{Var(n)}{\langle n \rangle} = \frac{Var(N)}{\langle N \rangle} - \delta$$

Systematic error is lower than 10% for $N_P^{PROJ} > 20$

MULTIPLICITY FLUCTUATIONS IN Pb+Pb COLLISIONS AT 158A GeV



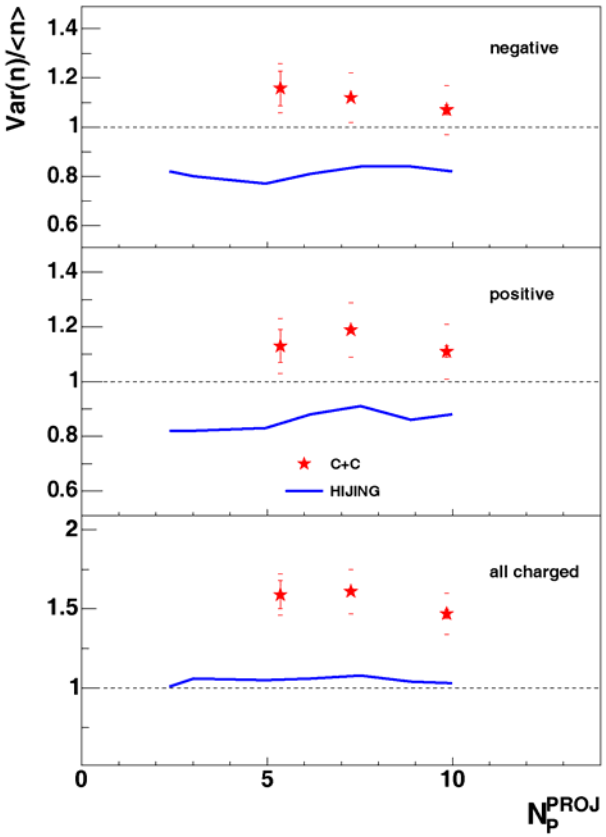
LARGE

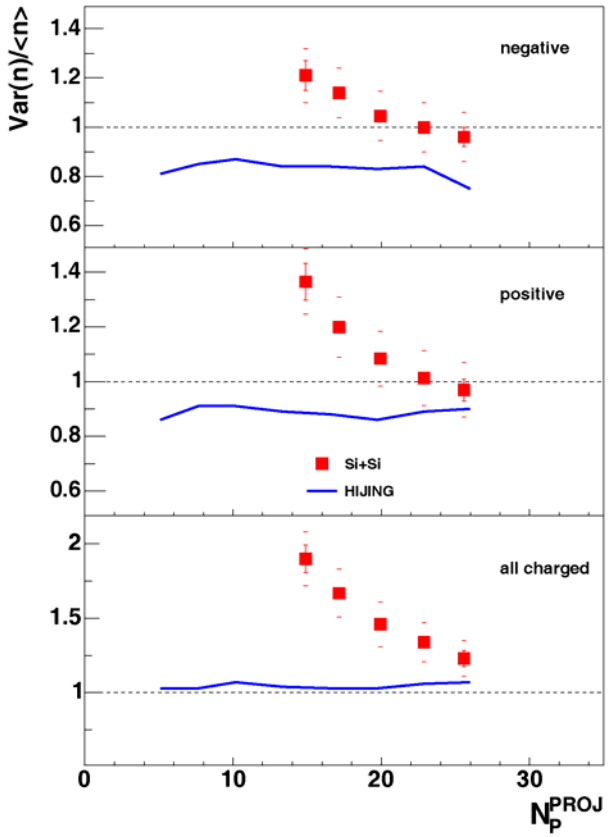
fluctuations for semi-peripheral Pb+Pb collisions

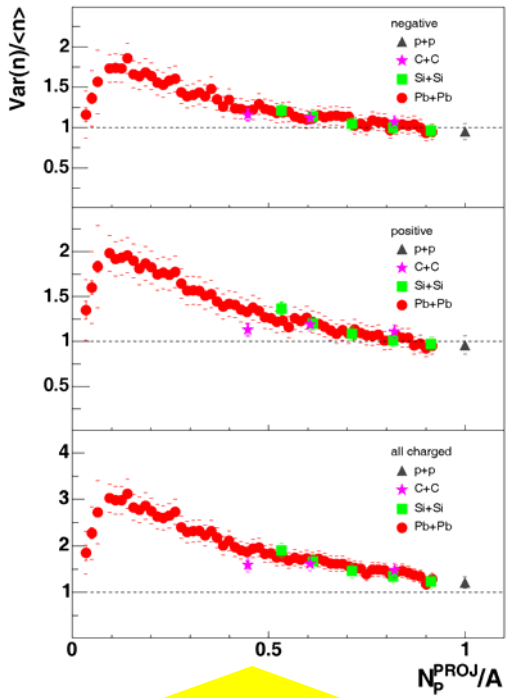
String-hadronic models

do not reproduce the data

MULTIPLICITY FLUCTUATIONS IN C+C AND Si+Si COLLISIONS AT 158A GeV

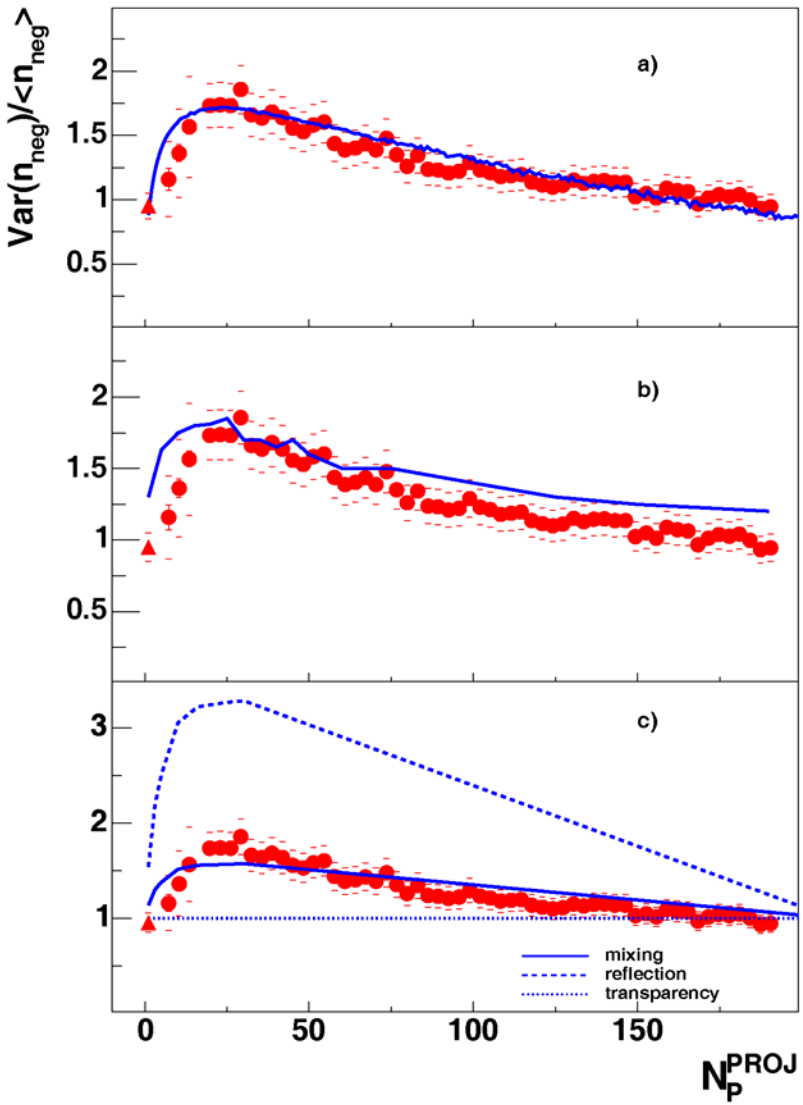






SCALING!

ATTEMPTS TO EXPLAIN OBSERVED FLUCTUATIONS



TWO-PARTICLE CORRELATIONS

J. Phys.:Conf. Series 5 (2005) 238

PERCOLATION

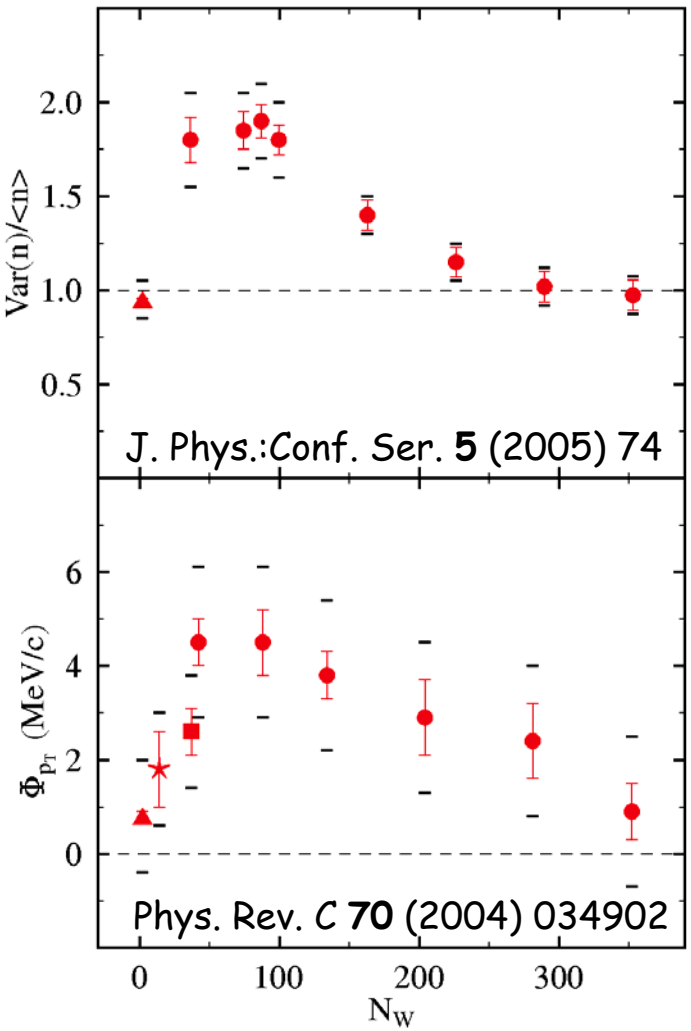
Phys. Rev. C 72 (2005) 044903

MIXING, REFLECTION AND TRANSPARENCY

hep-ph/0511058

CONNECTION BETWEEN MULTIPLICITY FLUCTUATIONS AND Φ_{p_T} MEASURE

158A GeV, all negatives, acceptance: 4 < y < 5.5 and 0.005 < p_T < 1.5 GeV/c



$$P(p_T) \sim p_T \exp\left(-\frac{\sqrt{m^2 + p_T^2}}{T_N}\right)$$

$$T_N = T + \delta T\left(1 - \frac{N}{\langle N \rangle}\right)$$

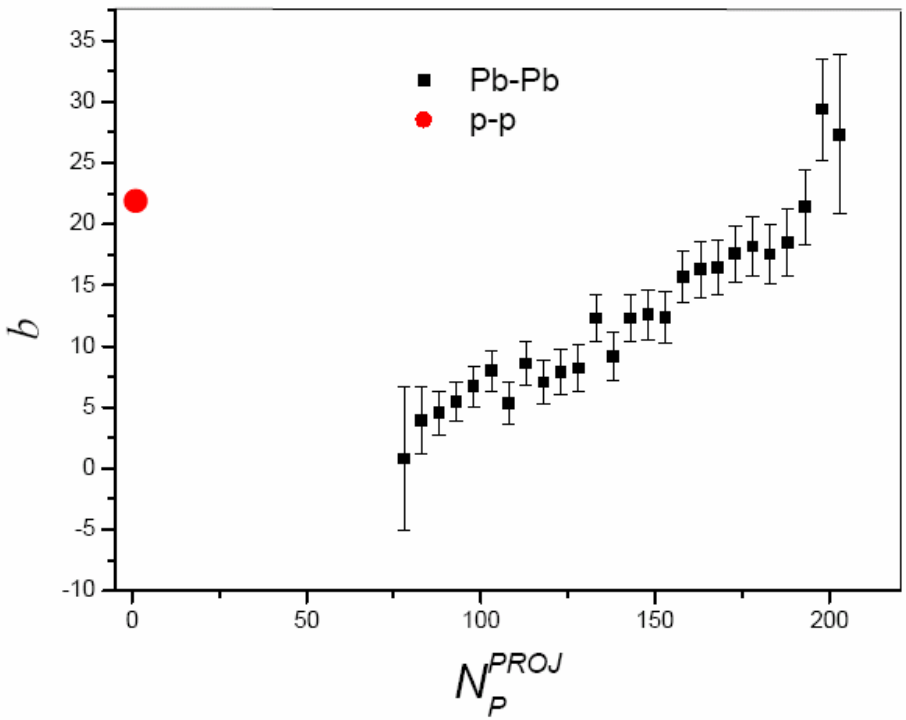
$$\Phi_{p_T} = \sqrt{2}\frac{(\delta T)^2}{T}\frac{Var(N)}{\langle N \rangle}$$

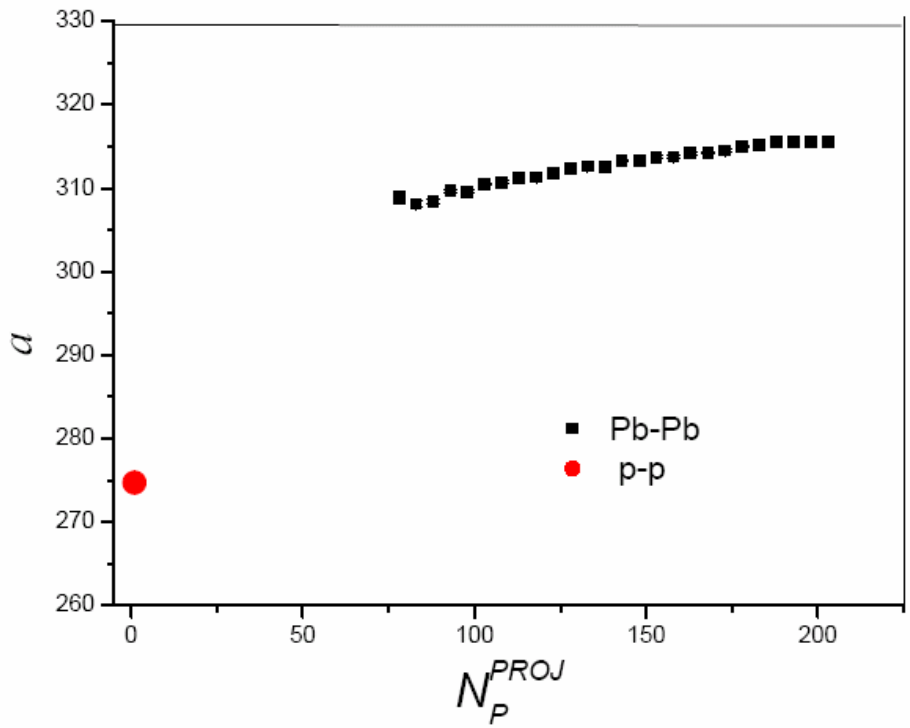
Details in:

Phys. Rev. C 70 (2004) 054906

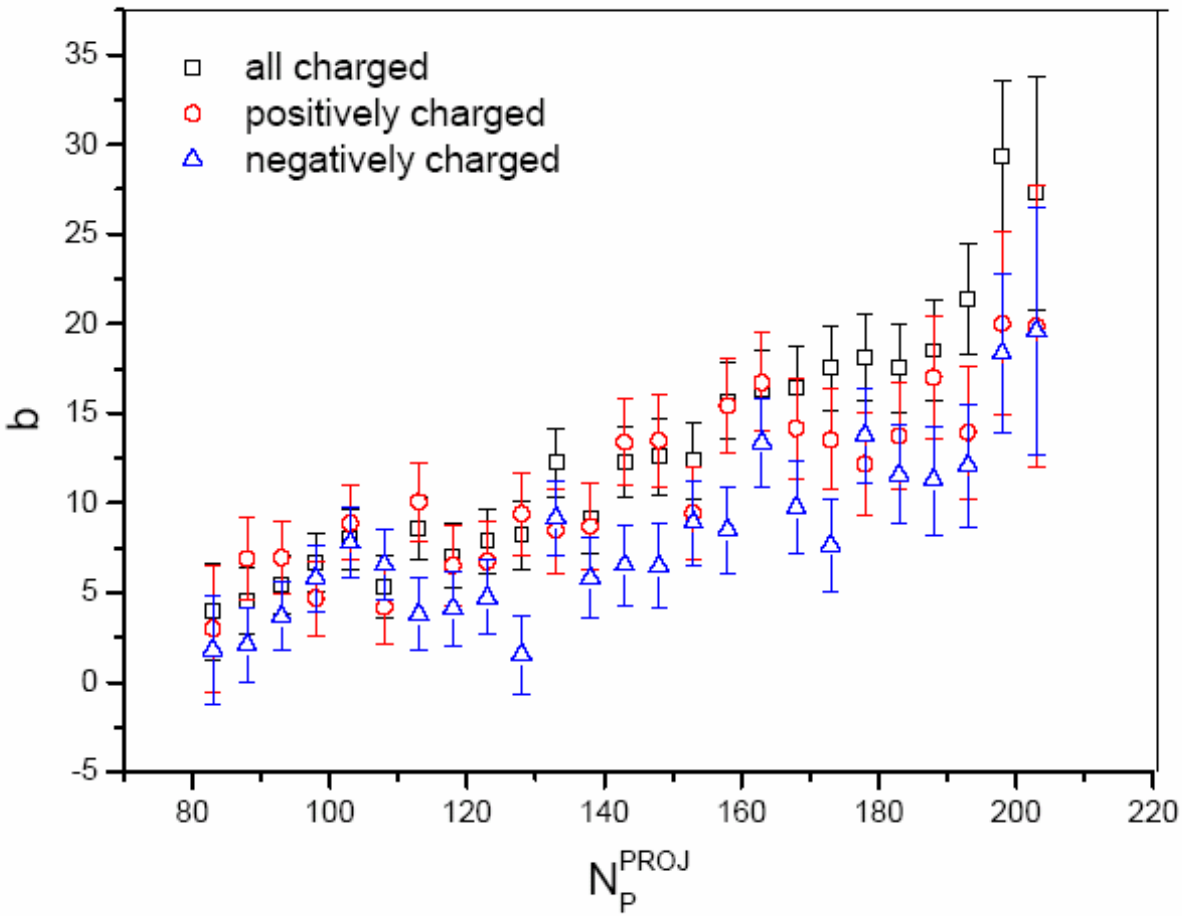
$\langle p_T \rangle$ – N CORRELATIONS

$$\langle p_T \rangle = a + b\left(1 - \frac{N}{\langle N \rangle}\right)$$





RESULTS FOR h^+, h^- AND $h^\pm$



$$\langle p_T \rangle = a + b\left(1 - \frac{N}{\langle N \rangle}\right)$$

$\langle p_T \rangle$ – N CORRELATION IN SUPERPOSITION MODEL

(St. Mrówczyński Phys.Rev. C**74** (2006) 044907)

1) single source

$$\langle p_T \rangle = a + b\left(1 - \frac{N}{\langle N \rangle_1}\right)$$

2) k – sources

$$\langle p_T \rangle \approx a + b\left(1 - \frac{N}{\langle N \rangle_k}\right)$$

$$\langle N \rangle_k = k \langle N \rangle_1$$

3) Varying number of sources

$$\langle p_T \rangle \approx a + b'\left(1 - \frac{N}{\langle N \rangle_k}\right)$$

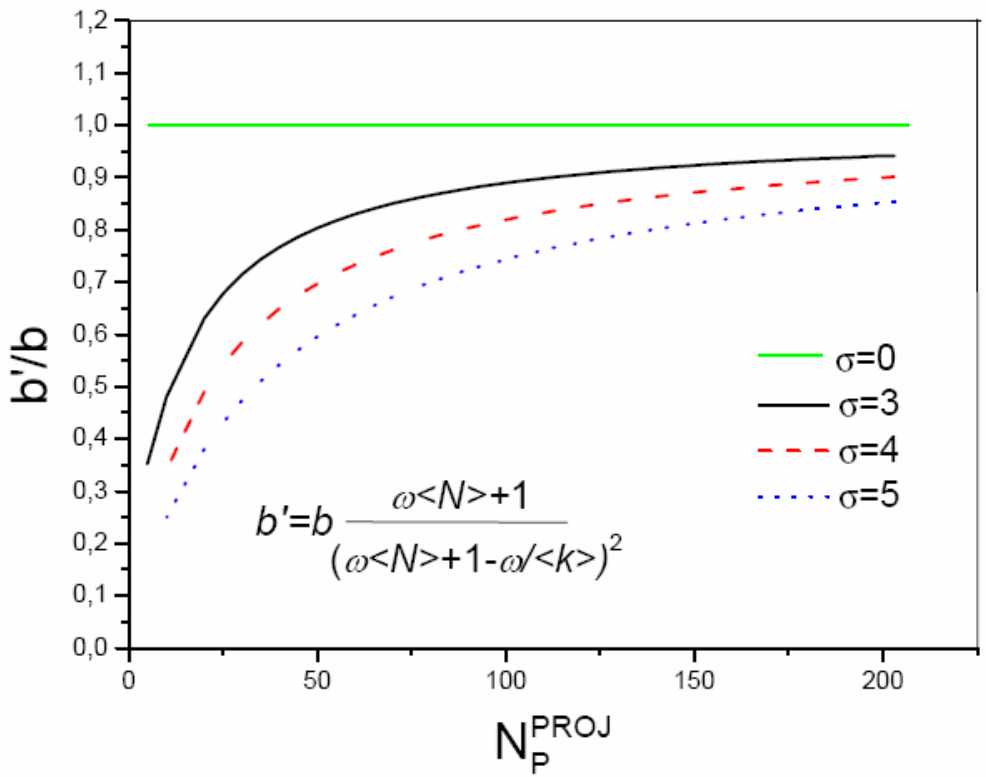
$\langle p_T \rangle$ – N CORRELATION IN SUPERPOSITION MODEL

$$b' = b\frac{\sigma^2\langle N\rangle\langle k\rangle^3 + \langle k\rangle^4}{\left(\sigma^2\langle N\rangle\langle k\rangle + \langle k\rangle^2 - \sigma^2\right)^2}$$

$$\sigma^2 \to 0, \quad \text{then} \quad b' \to b$$

$$\sigma^2 \to \infty, \quad \text{then} \quad b' \to 0$$

$$\omega = \frac{\sigma^2}{\langle k\rangle}$$



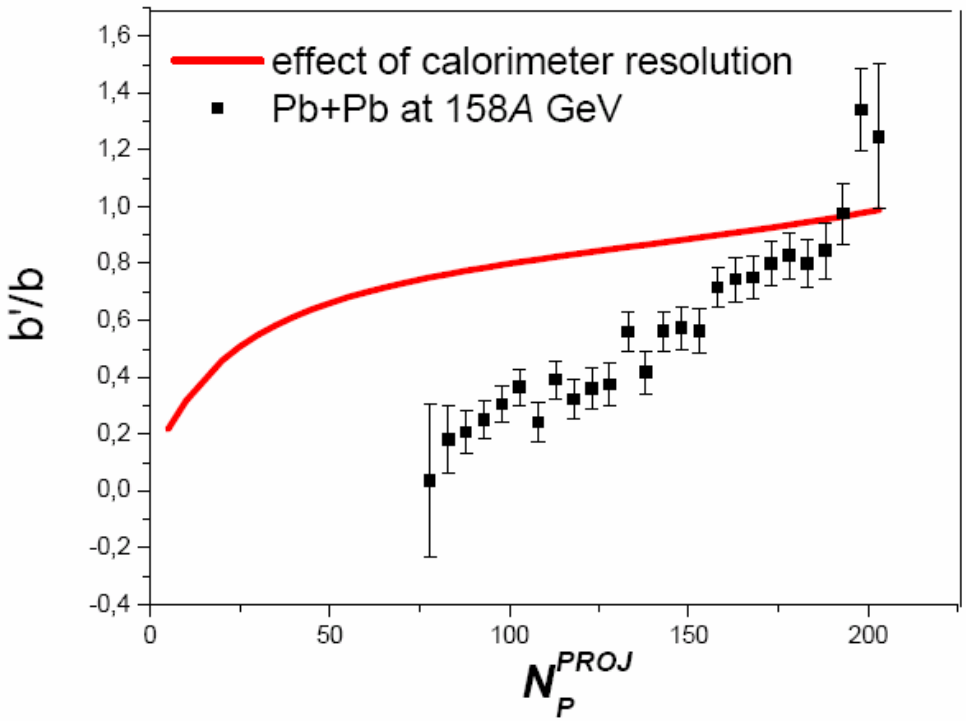
EFFECT OF VETO CALORIMETER RESOLUTION

Parameterization of the energy resolution of the veto calorimeter:

$$\frac{\sigma(E_{Veto})}{E_{Veto}} = \frac{9.3}{\sqrt{E_{Veto}}} - \frac{44.4}{E_{Veto}} - 0.032$$

Given in:

M. Rybczyński, PhD Dissertation, Kielce 2005



and

$$N_P^{PROJ} = A - \frac{E_{Veto}}{E_{LAB}}$$

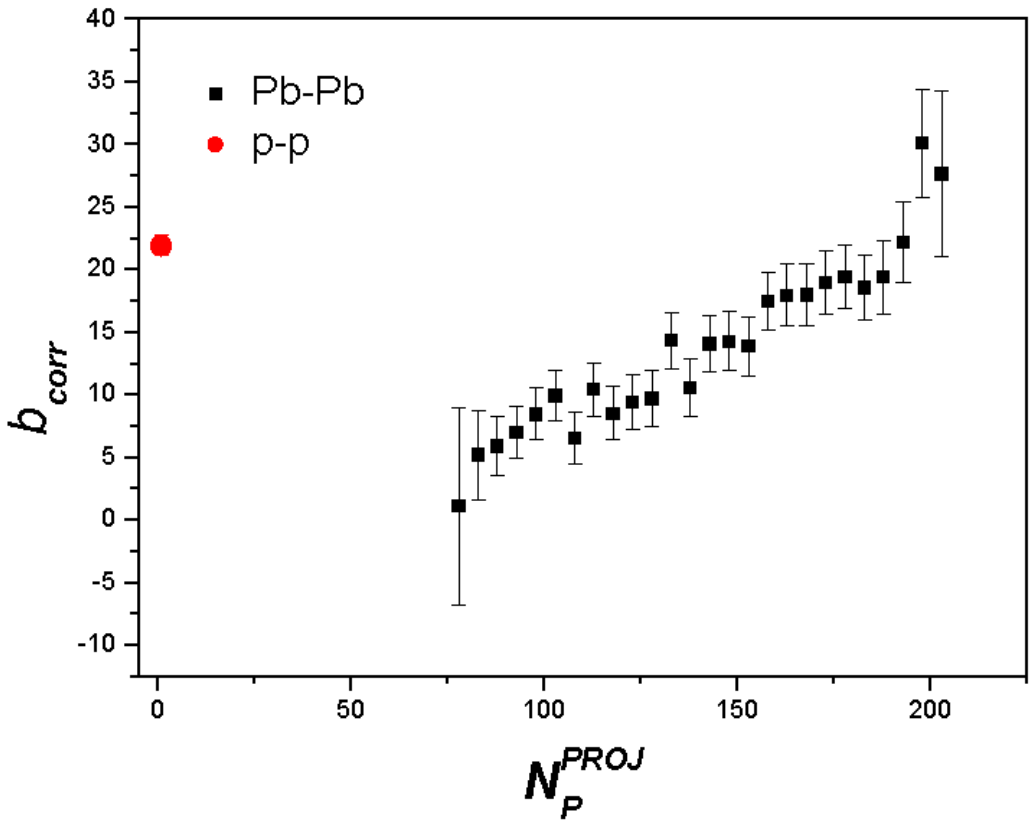
then:

$$\sigma\left(\left\langle N_P^{PROJ}\right\rangle\right) = 0.77\sqrt{A - \left\langle N_P^{PROJ}\right\rangle} - 0.28 - \left(A - \left\langle N_P^{PROJ}\right\rangle\right)$$

$\langle p_T \rangle$ – N CORRELATIONS

AFTER CORRECTION FOR VETO CALORIMETER RESOLUTION

$$\langle p_T \rangle = a + b_{corr}\left(1 - \frac{N}{\langle N \rangle}\right)$$



SUMMARY

- Multiplicity fluctuations and $\langle p_T \rangle$ - N correlations in nuclear collisions at 158 GeV/nucleon were studied;

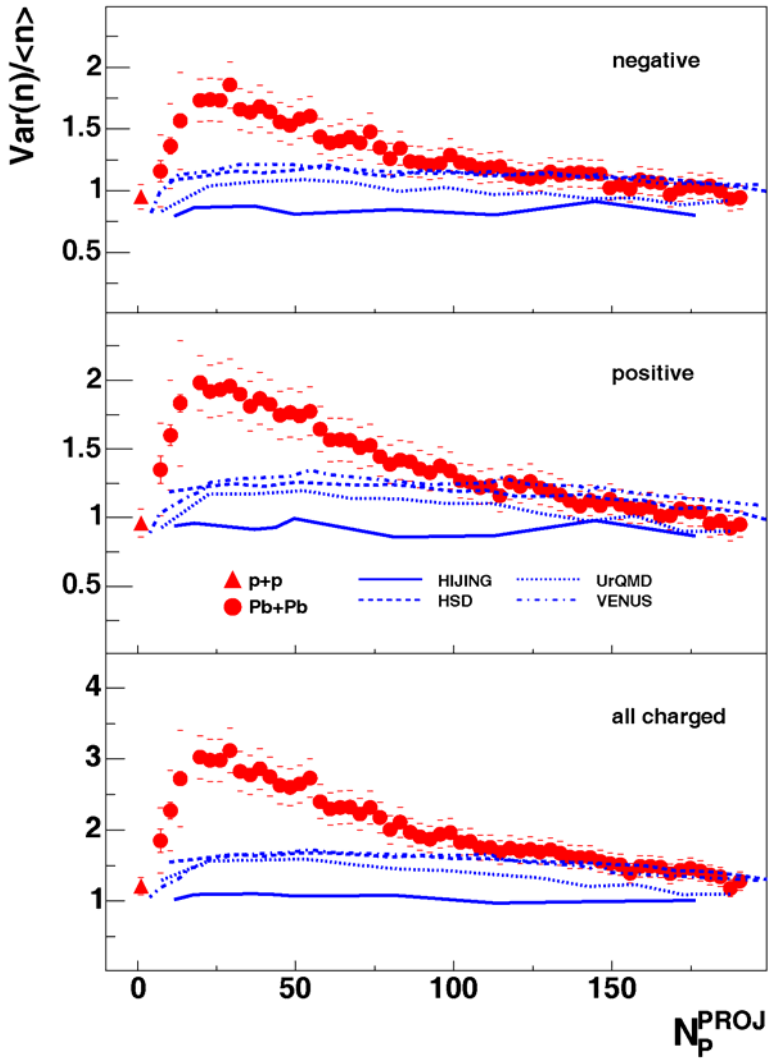
- The results in the projectile hemisphere at fixed number of projectile participants show:
  - an increase of the scaled variance of N - fluctuations with decreasing centrality
  - a decrease of the $\langle p_T \rangle$ - N correlations with decreasing centrality

OUTLOOK:

- Quantitative predictions of p_T - fluctuations from the measured N – fluctuations and $\langle p_T \rangle$ - N correlation.

BACKUP SLIDES…

MULTIPLICITY FLUCTUATIONS IN Pb+Pb COLLISIONS

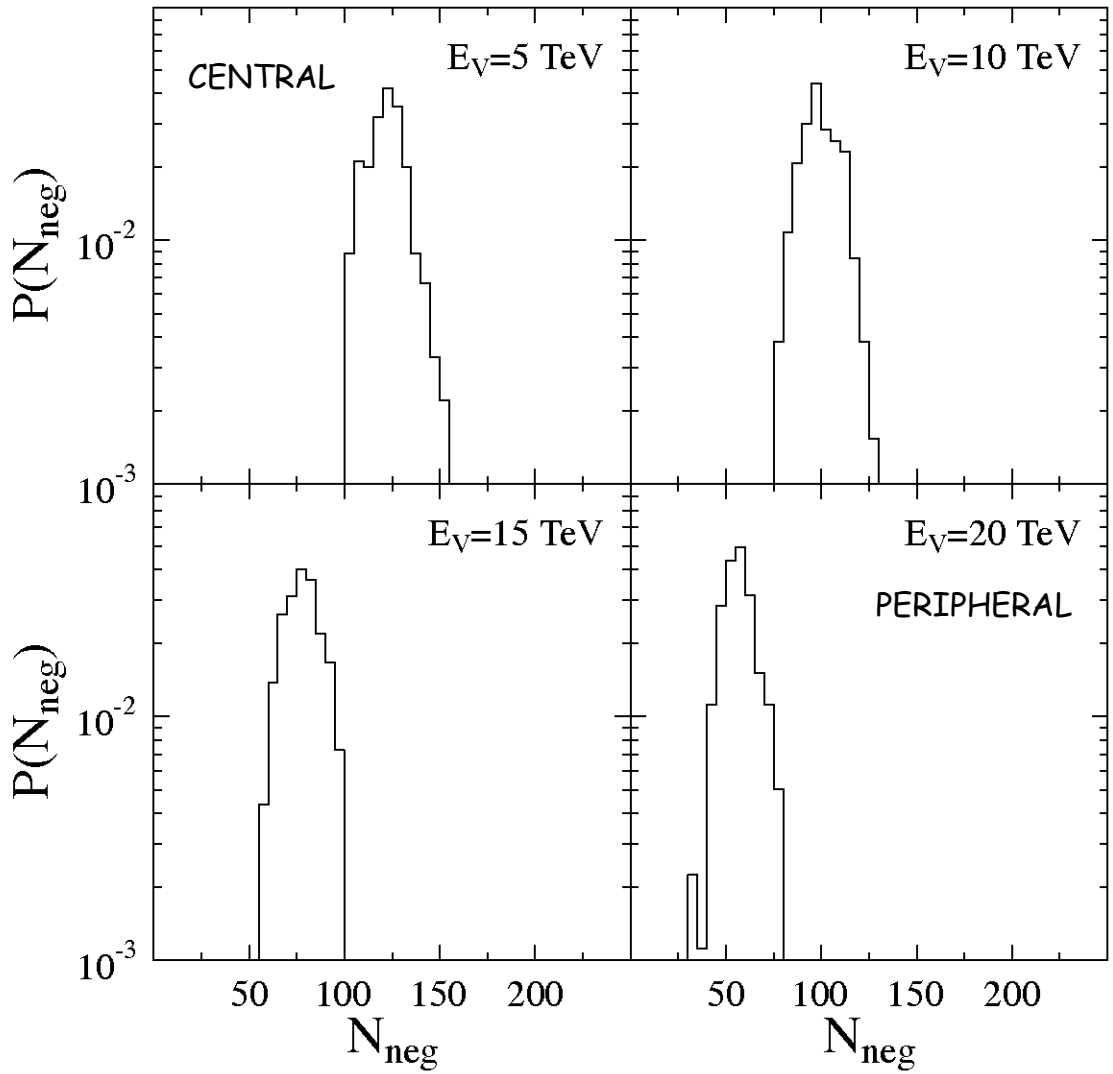


LARGE

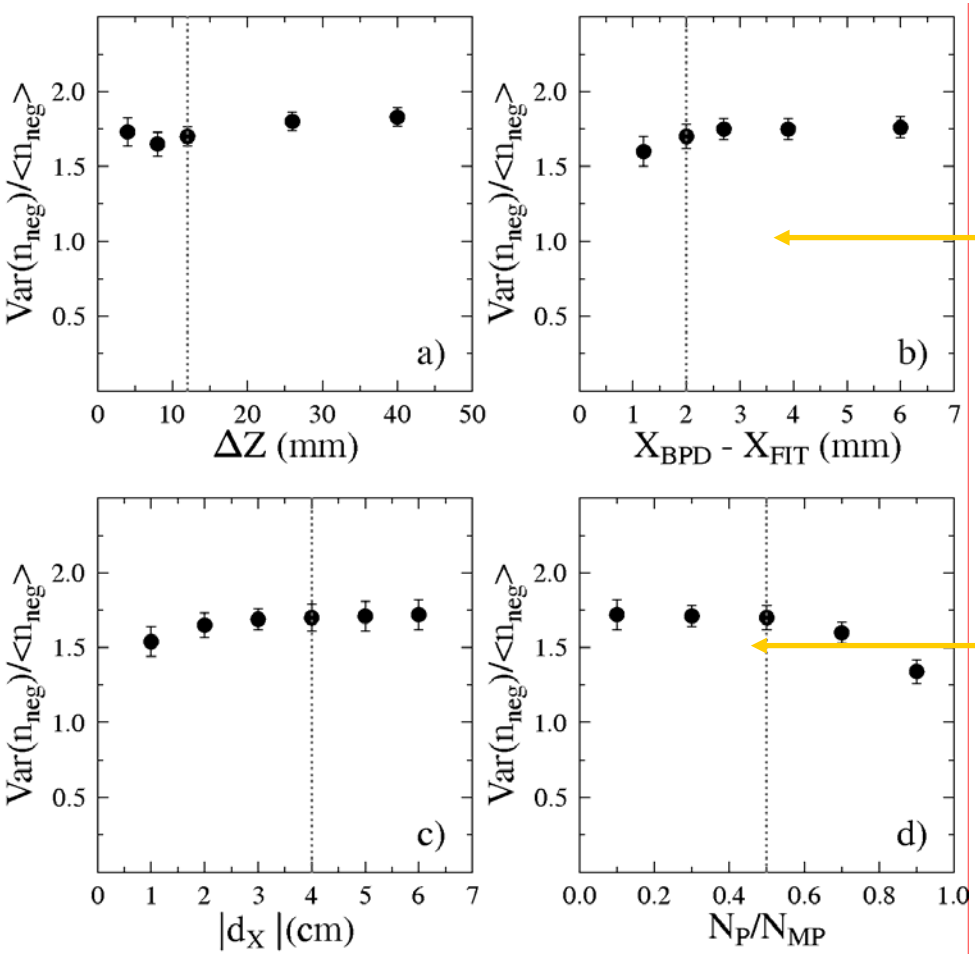
fluctuations for semi-peripheral Pb+Pb collisions

UNCORRECTED MULTIPLICITY DISTRIBUTIONS OF NEGATIVELY CHARGED PARTICLES

Pb+Pb at 158 GeV/nucleon; $\Delta E_V = 500\ GeV$



STABILITY OF THE RESULTS WITH RESPECT TO THE ANALYSIS CUTS

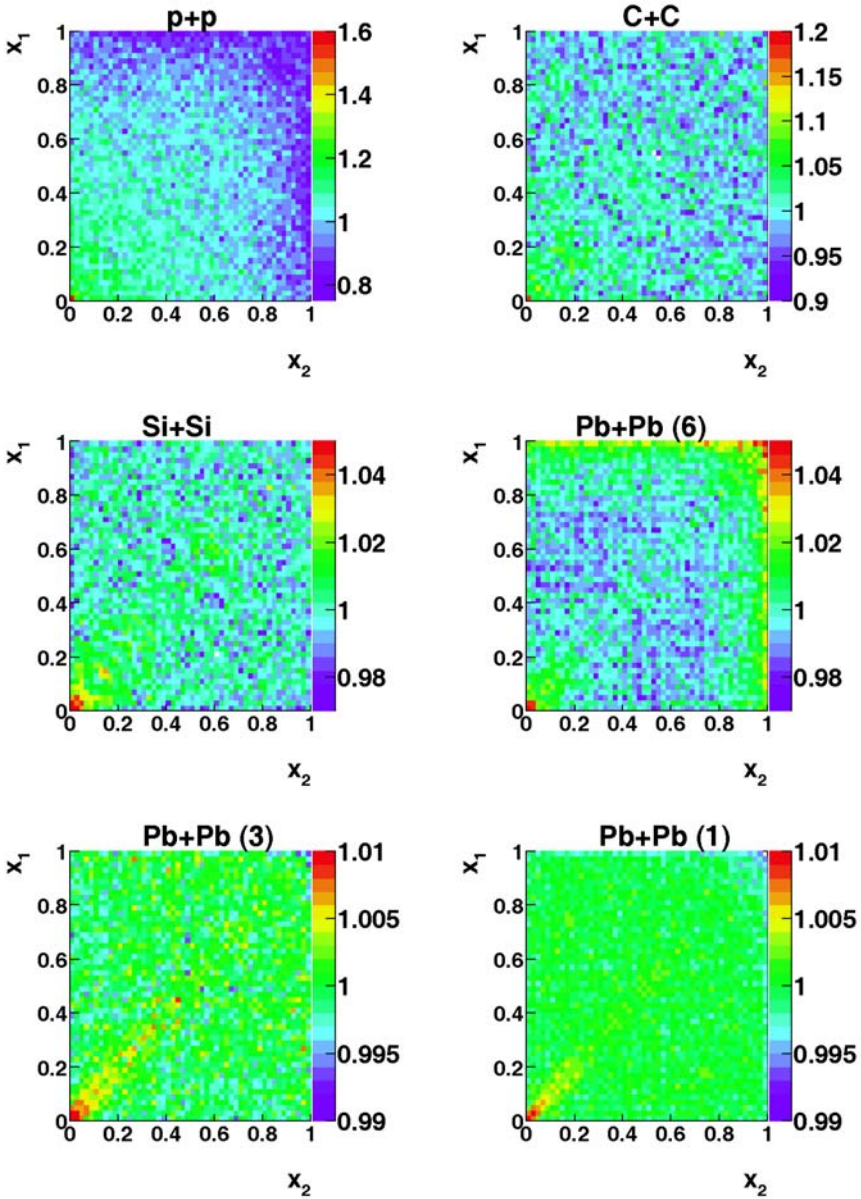


All checks done for $N_P^{PROJ} = 39$

Event selection cuts

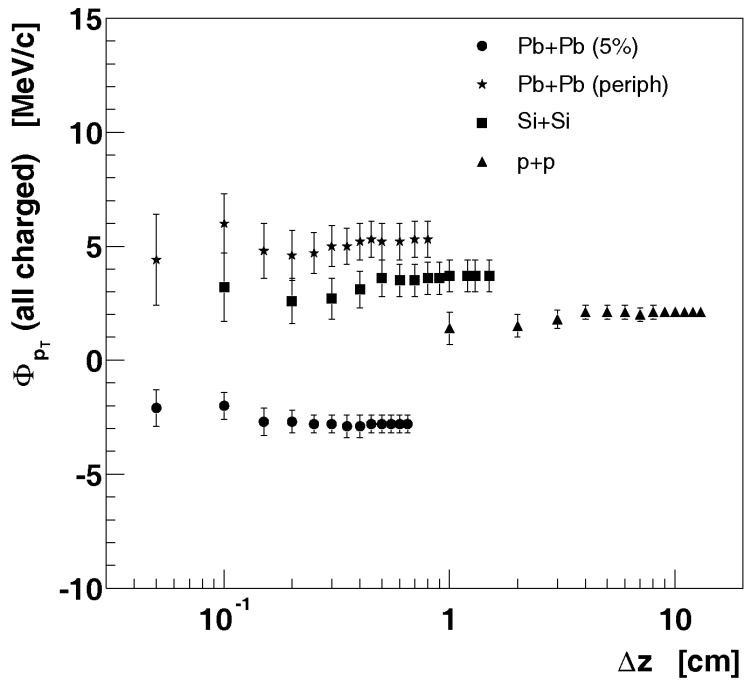
Track selection cuts

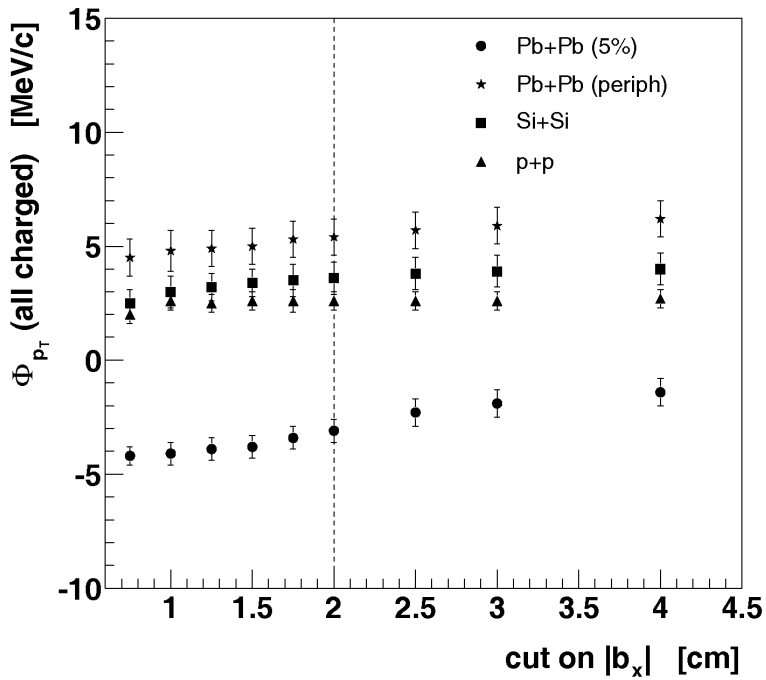
Scaled variance changes by less than 15 %



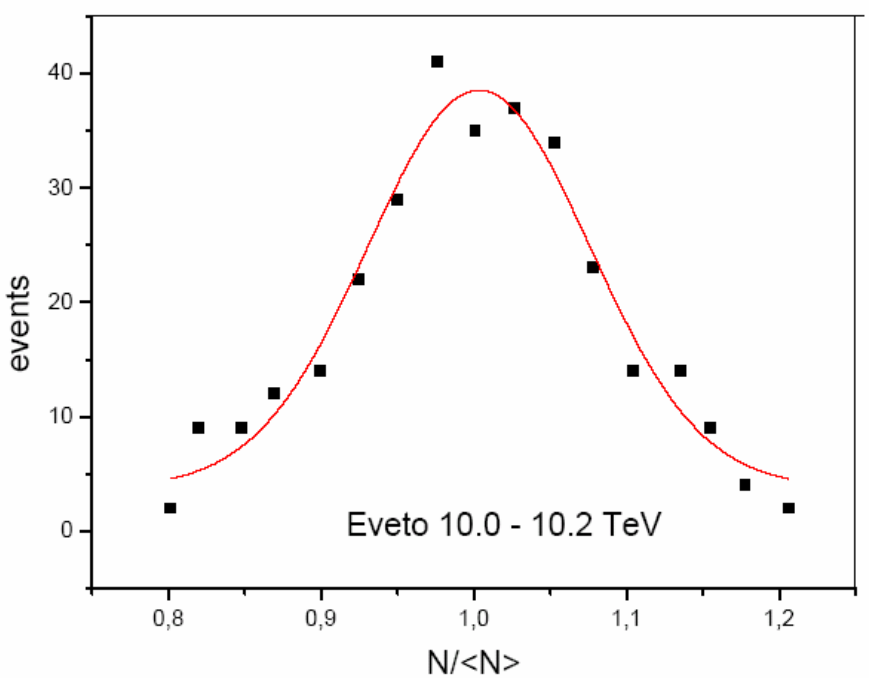
$$x(p_T) = \int_0^{p_T} \rho(p_{T'}) dp_{T'}$$

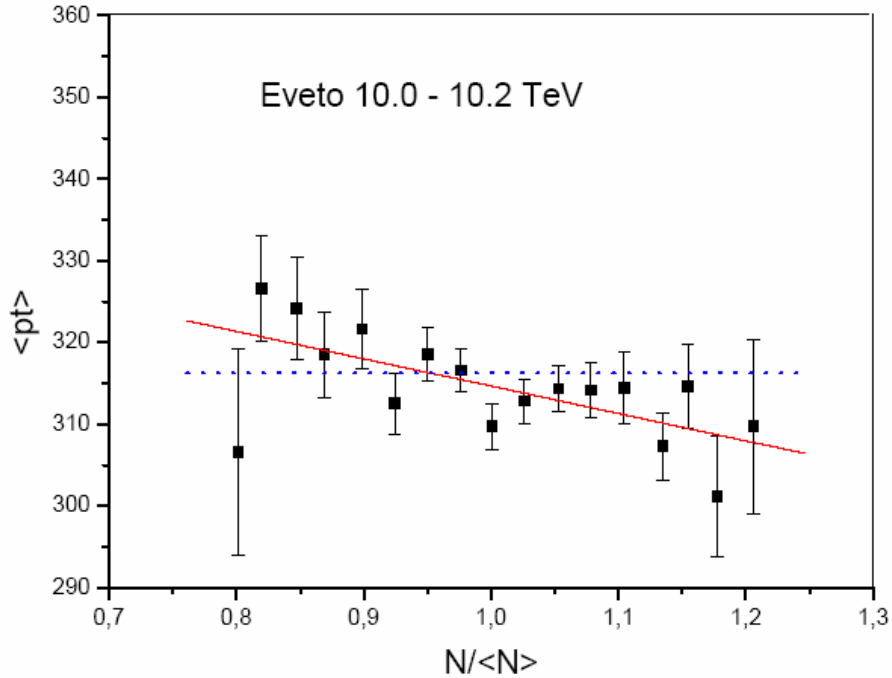
STABILITY OF THE RESULTS WITH RESPECT TO THE ANALYSIS CUTS





EXAMPLE OF p_T – N CORRELATIONS





CALCULATIONS WITHIN MIXING MODEL

Fluctuations of the target participant are calculated at:

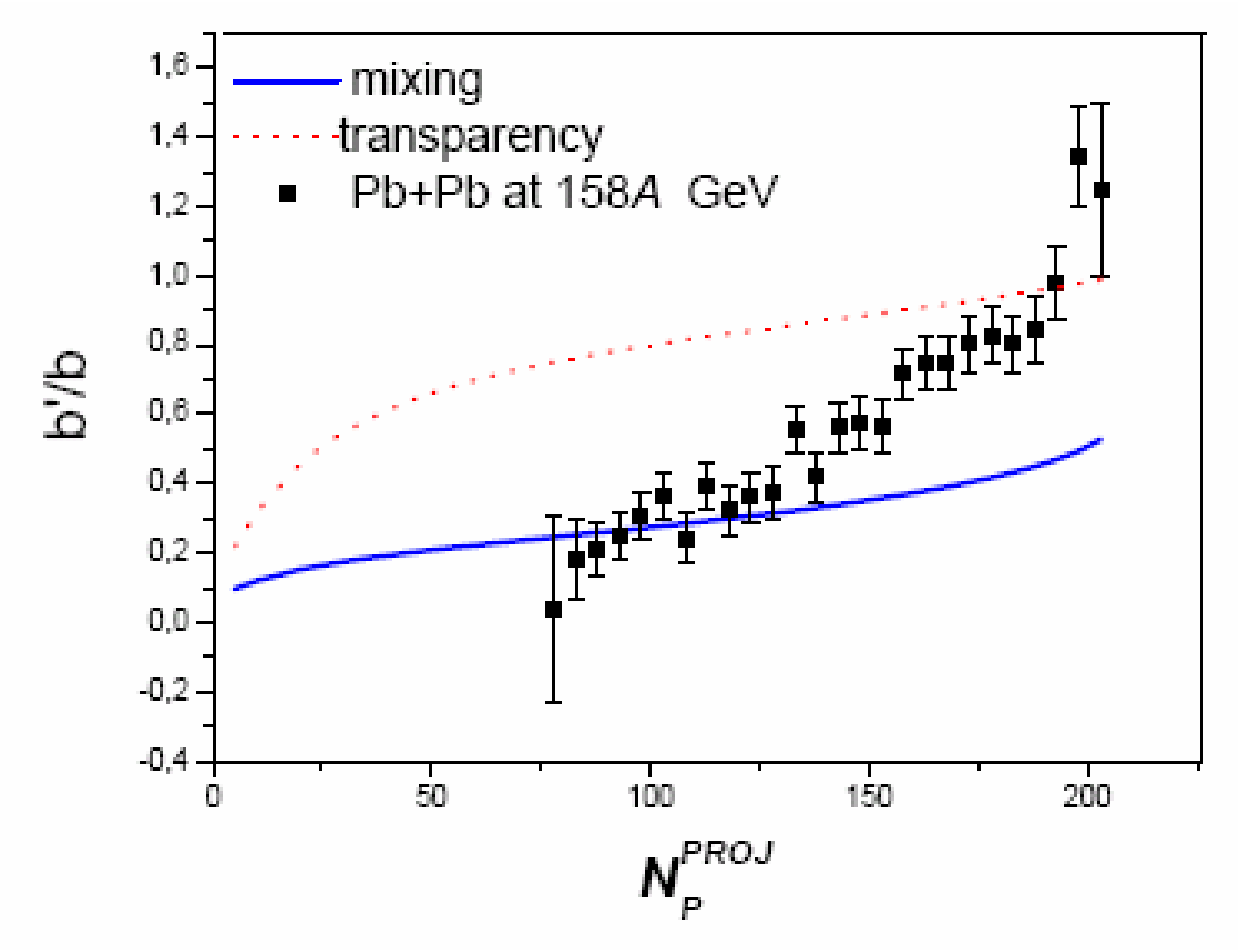
$$\sigma^2_{TARG} = 3.28 N_P^{PROJ} - 0.0158 \left(N_P^{PROJ} \right)^2$$

Taken from: V.P.Konchakovski Phys.Rev. **C** 73 (2006) 034902

The variance of the number of particle sources in mixing model is:

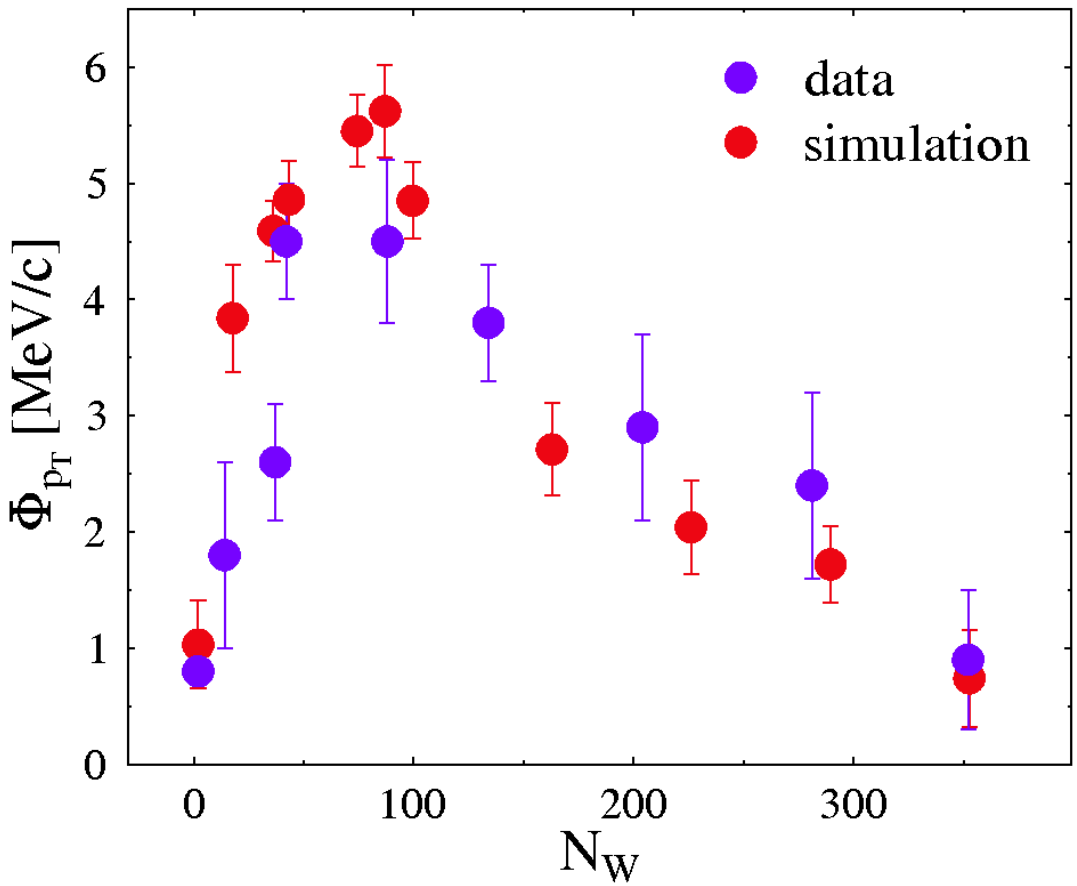
$$\sigma^2 \left(N_P^{PROJ} \right) = 1.32 N_P^{PROJ} - 0.004 \left(N_P^{PROJ} \right)^2$$

MIXING IN SUPERPOSITION MODEL



Effect of E_{veto} resolution was taken into account in model calculations

Φ_{p_T} as a function of number of wounded nucleons.



Simulation:

- Var(N)/<N> from the data
- $\langle p_T \rangle$ vs N/<N> as in p+p