Energy dependence of fluctuations in central Pb+Pb collisions from NA49 at the CERN SPS

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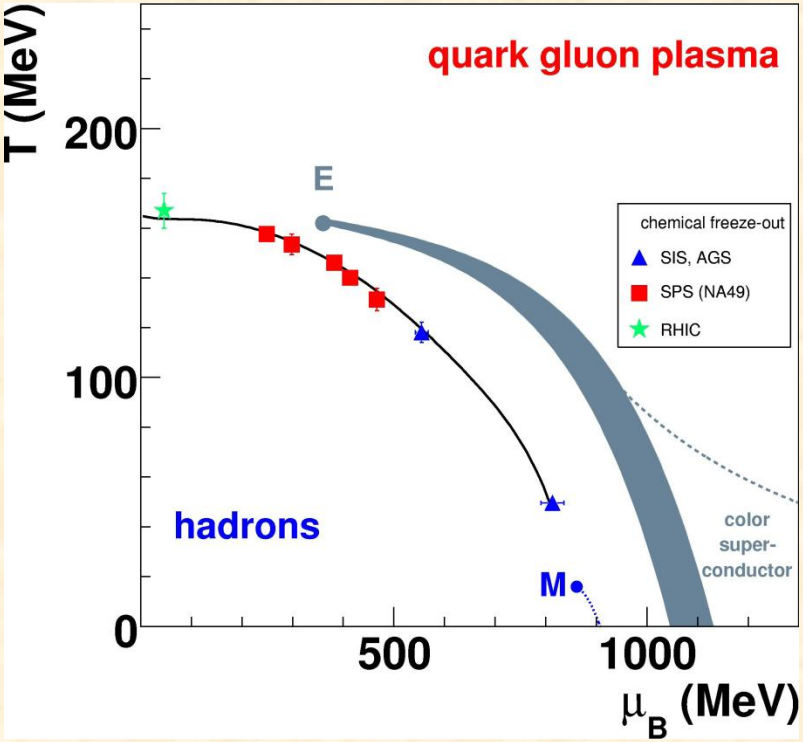
Jaipur, February 4 - 10 2007

OUTLINE

1. Motivation
2. Experiment, data & analysis
3. Review of previous results
4. Multiplicity fluctuations
5. Transverse momentum fluctuations
6. Summary & Outlook

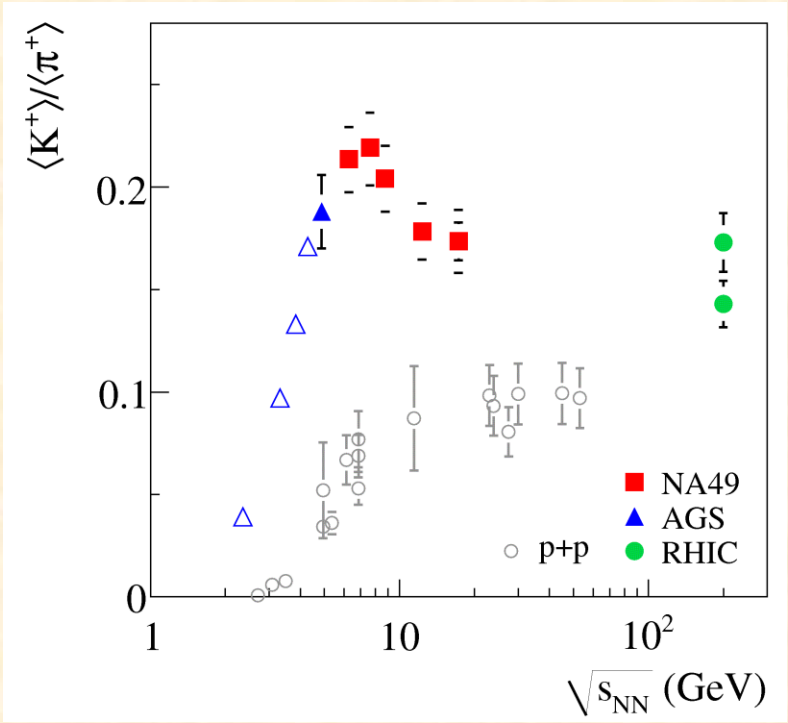
MOTIVATION



Non-monotonic dependence of p_T and N fluctuations on control parameters (energy, centrality, ion size) can help to locate the second-order critical end-point, if it coincides with the freezeout point.

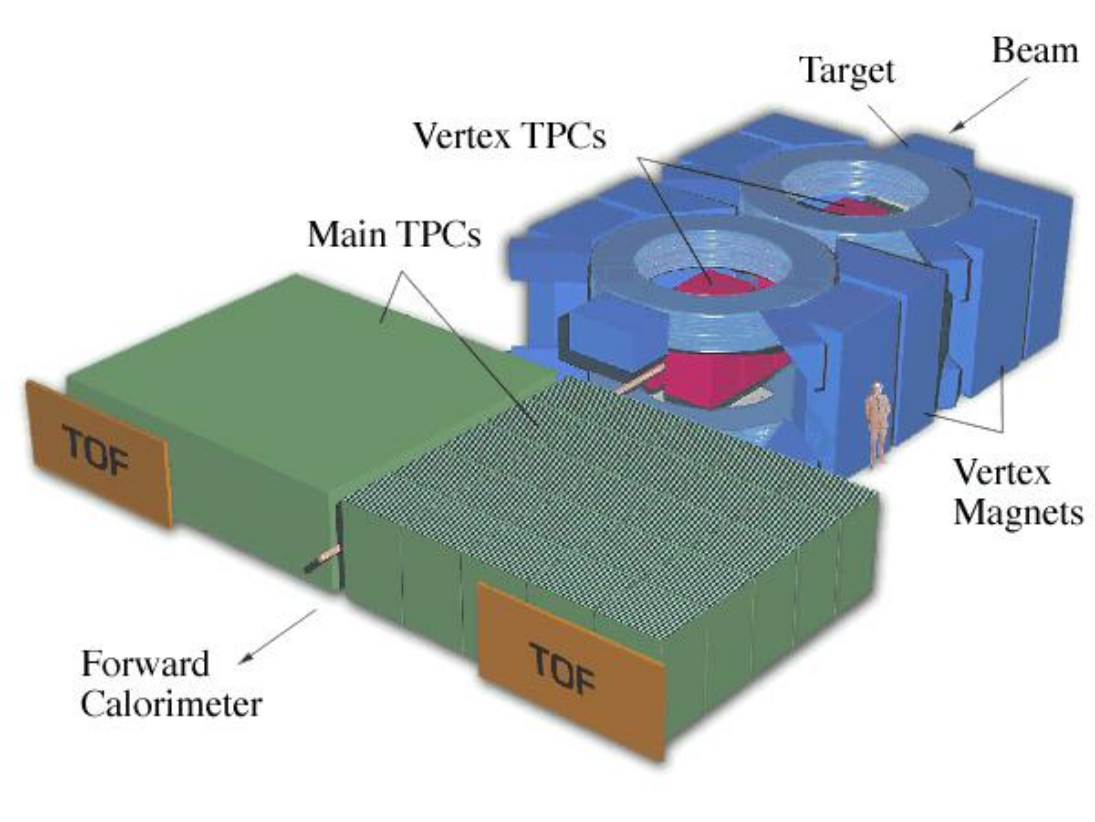
M. Stephanov, K. Rajagopal, E. V. Shuryak, Phys. Rev. D60, 114028, 1999

Rapid change of the energy dependence of several hadron production properties indicates an onset of deconfinement located at the low SPS energies.



EXPERIMENT, DATA & ANALYSIS

NA49 DETECTOR @ CERN SPS



Operating since 1994;
p+p, C+C, Si+Si and Pb+Pb interactions
at center of mass energy 6.3 – 17.3 GeV for
N+N pair

NIM A430 (1999) 210

EXPERIMENT, DATA & ANALYSIS

DATA:
✓central Pb+Pb at 20A, 30A, 40A, 80A and 158A GeV
=> $\sqrt{s_{NN}}$ = 6.27, 7.62, 8.73, 12.3 and 17.3 GeV

CENTRALITY SELECTION:
✓selection of the most central events using energy of the projectile spectators (Centr.=sig_sel/sig_inel*100%)

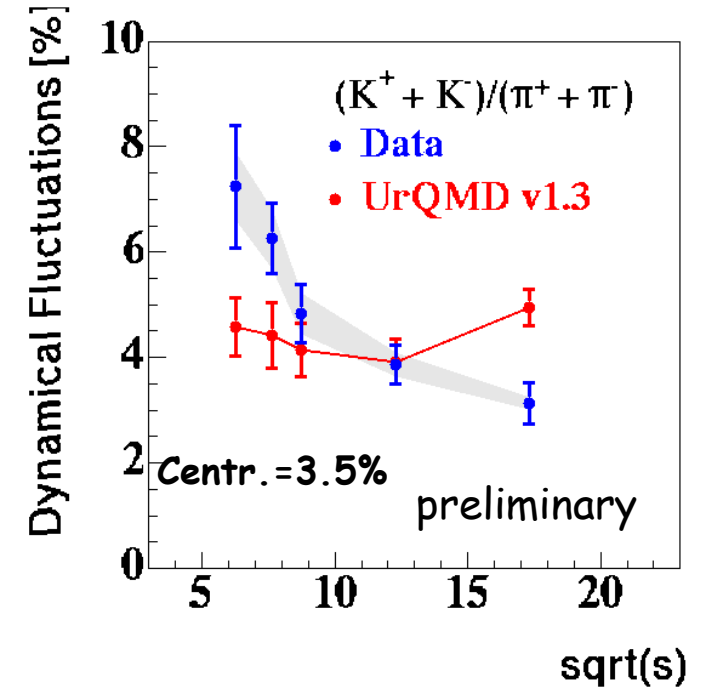
ACCEPTANCE:
✓particles emmited to the forward hemisphere

PARTICLE IDENTIFICATION:
✓energy loss in TPC's & electric charge via magnetic field

UNCERTAINTIES:
✓statistical error
✓systematic error determined from stability for different event and track selection criteria & Monte-Carlo simulation

PREVIOUS NA49 RESULTS

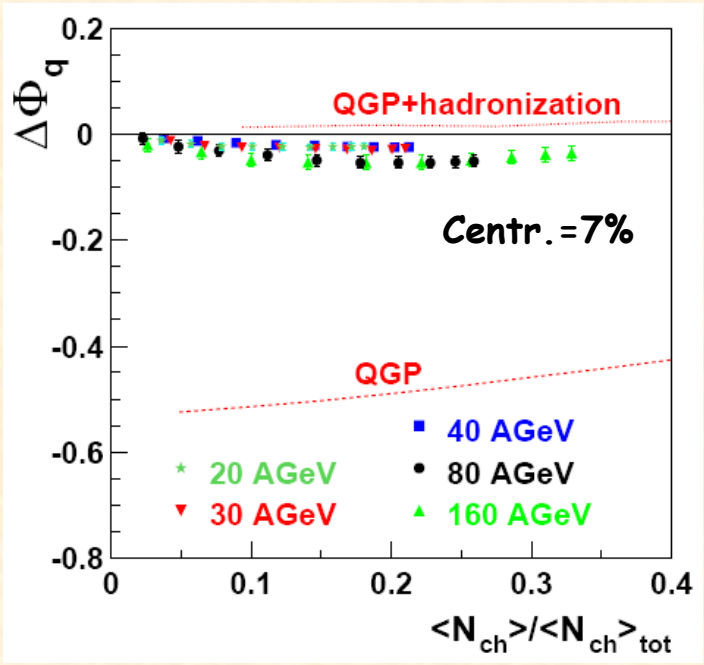
Kaon/Pion Ratio



- ✓K/π fluctuations increase towards lower beam energy
- ✓Significant enhancement over hadronic cascade model

*NA49: PoS, **CFRN** (2006) 12*

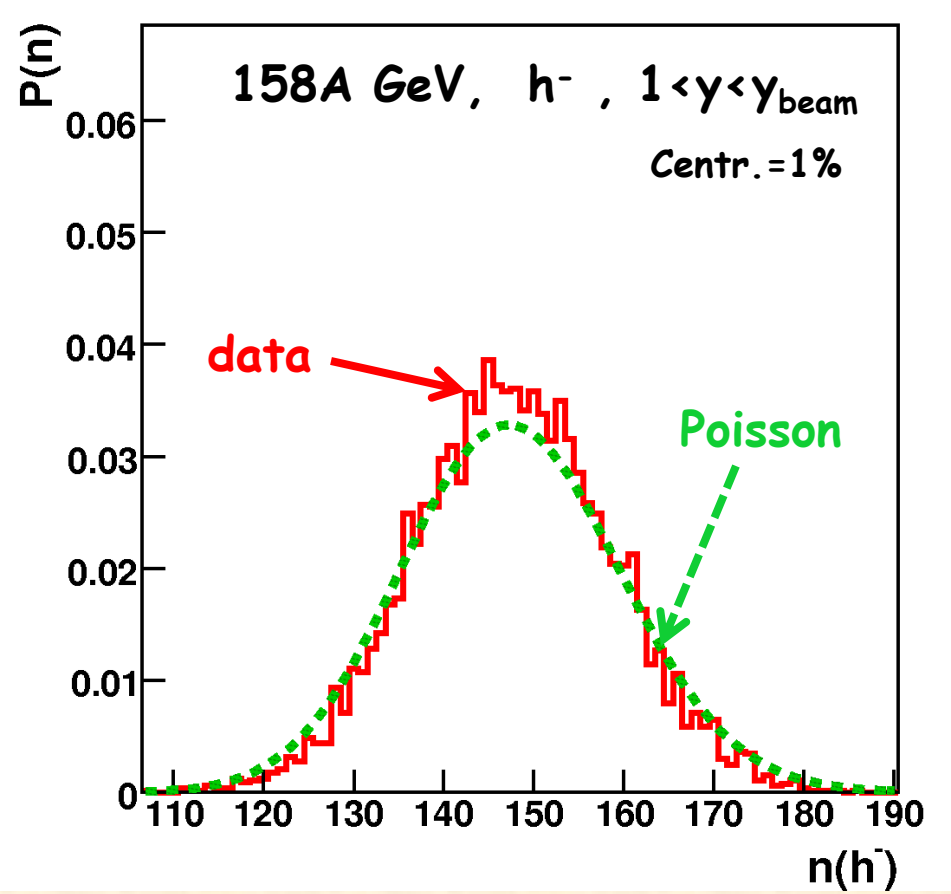
Net Charge



- ✓$\Delta\Phi_q$ independent of energy & acceptance
- ✓Values close to zero, much higher as expected in QGP
- ✓Hadronization may increase $\Delta\Phi_q$ from QGP value to the measured one

*NA49: PRC **70** (2004) 064903*

MULTIPLICITY FLUCTUATIONS



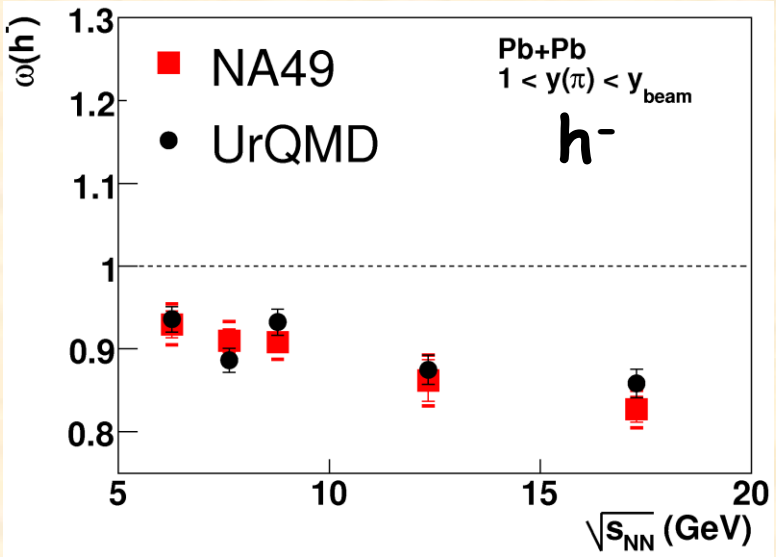
Scaled variance:

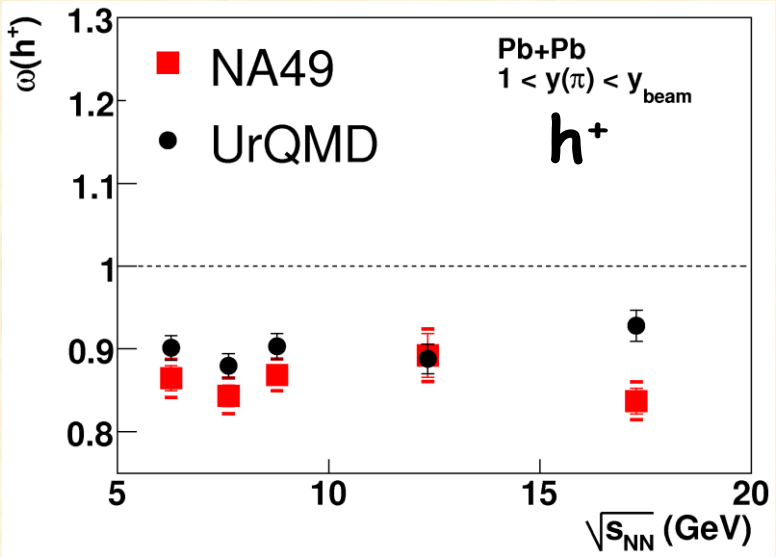
$$\omega(n) = \frac{Var(n)}{\langle n \rangle} = \frac{\langle n^2 \rangle - \langle n \rangle^2}{\langle n \rangle}$$

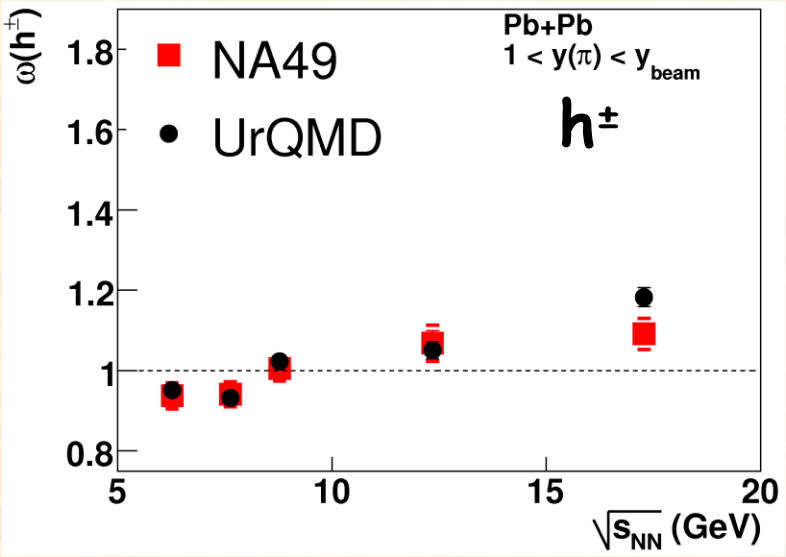
(=1 for Poisson distribution)

MULTIPLICITY FLUCTUATIONS

SCALED VARIANCE FOR CHARGED HADRONS, Centr.=1%





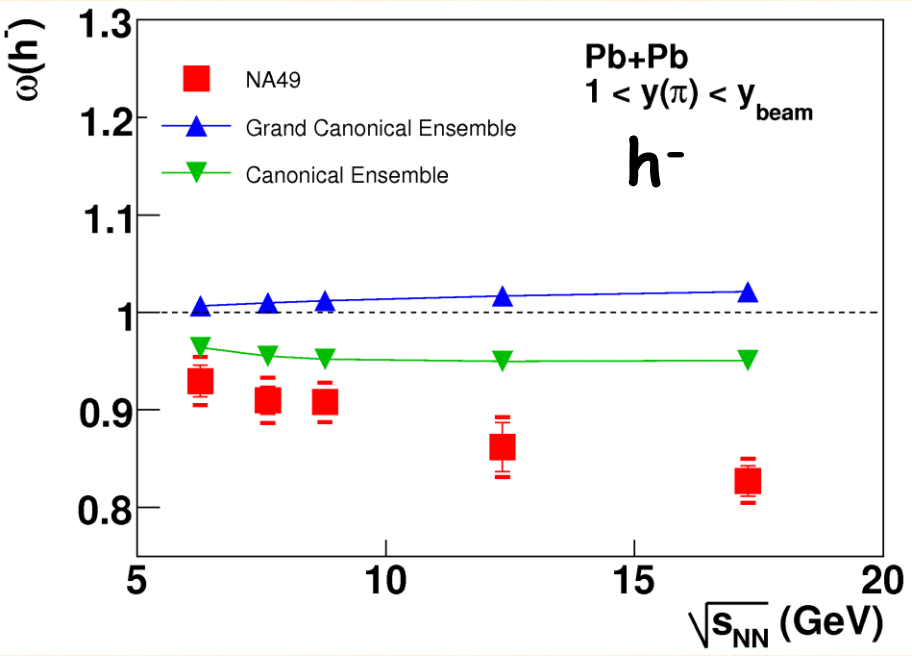


- ✓ω is similar for positively and negatively charged hadrons
- ✓ω is larger for all charged hadrons (resonance decays, charge conservation)

NA49: arXiv:0712.3216v1

MULTIPLICITY FLUCTUATIONS

COMPARISON TO STATISTICAL MODEL

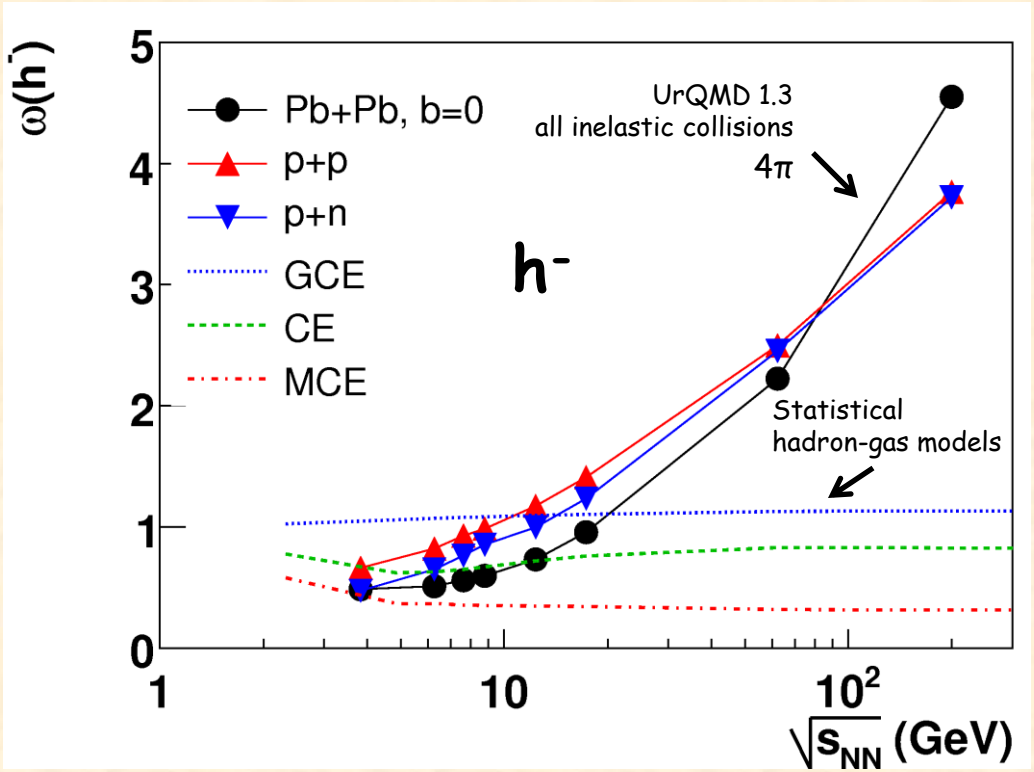


- ✓Acceptance scaling assuming no correlations in momentum space: $\omega_{acc} = p \cdot (\omega_{4\pi} - 1) + 1$
- ✓GCE and CE overpredict fluctuations at forward rapidity
- ✓No predictions for MCE

*PRC **76** (2007) 024902*

MULTIPLICITY FLUCTUATIONS

STATISTICAL MODEL & URQMD PREDICTIONS FROM SPS TO RHIC



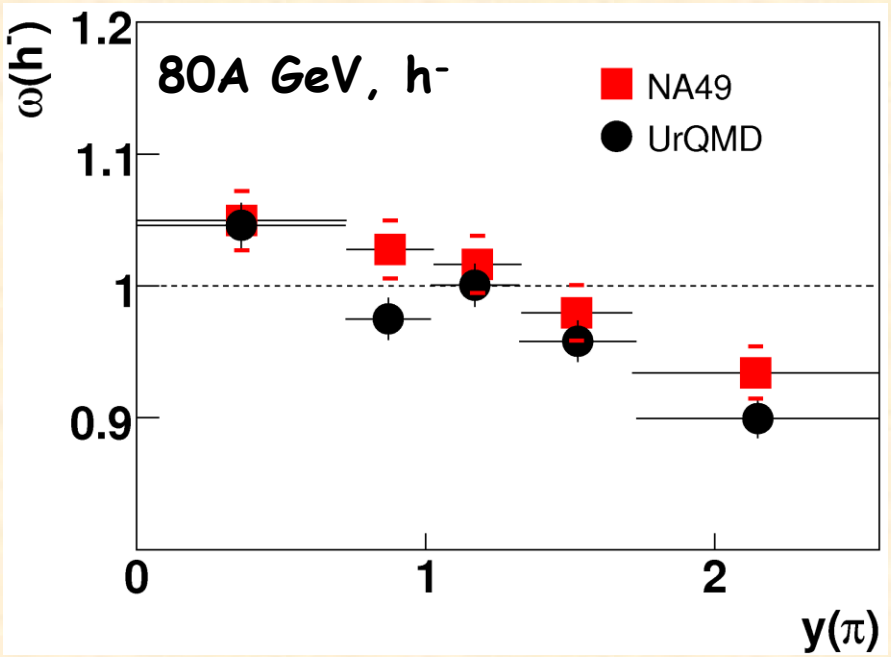
Large differences at RHIC energies

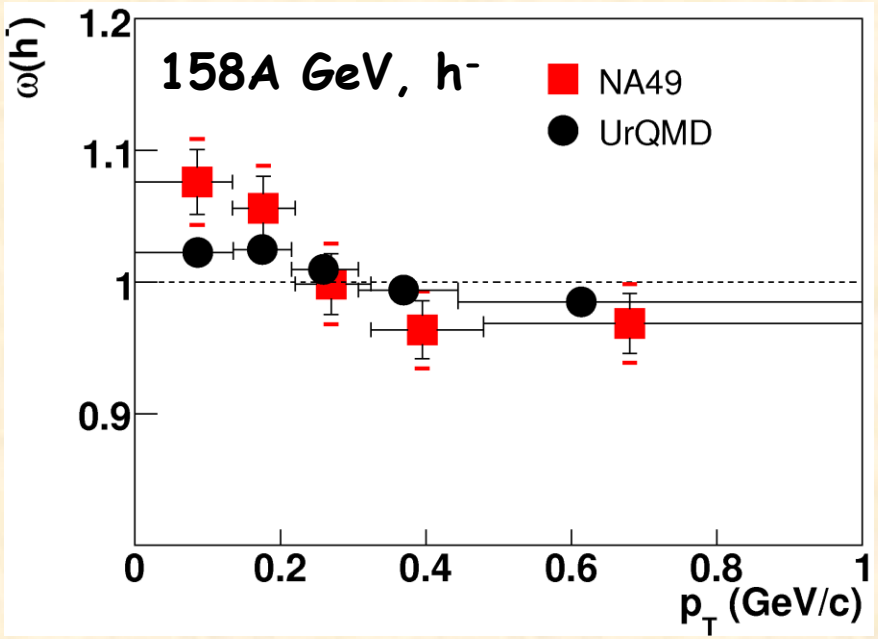
*PRC **76** (2007) 024902*
*PRC **76** (2007) 044904*

MULTIPLICITY FLUCTUATIONS

EXAMPLE OF RAPIDITY & TRANSVERSE MOMENTUM DEPENDENCE

Same mean multiplicity in each y & p_T bin



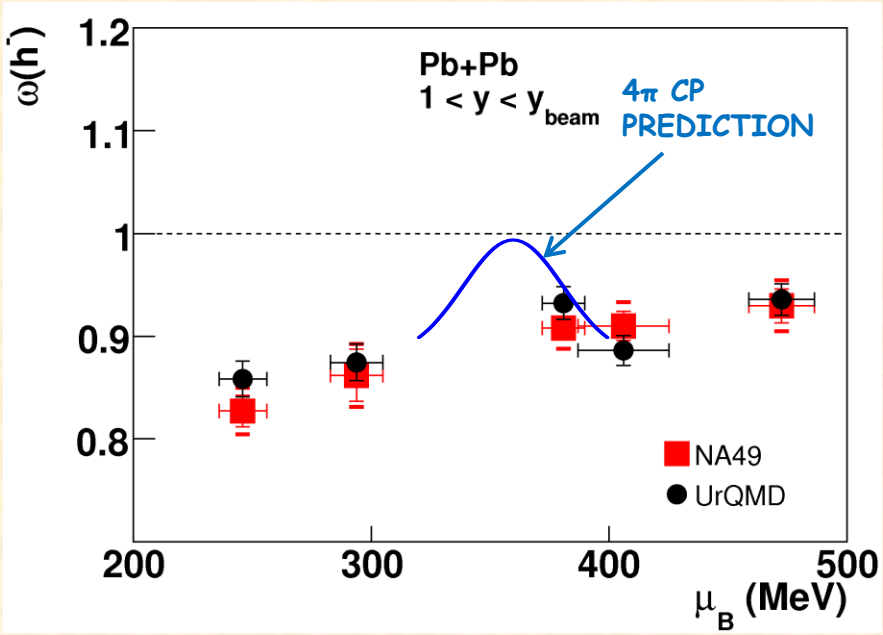


✓Larger fluctuations for particles with smaller y & p_T

✓UrQMD reproduces the data

MULTIPLICITY FLUCTUATIONS

PREDICTION FOR CRITICAL POINT



POSITION:
$T_E \approx 162$ MeV
$\mu_E \approx 360$ MeV

SIZE:
$\Delta T_E \approx 10$ MeV
$\Delta \mu_E \approx 50$ MeV

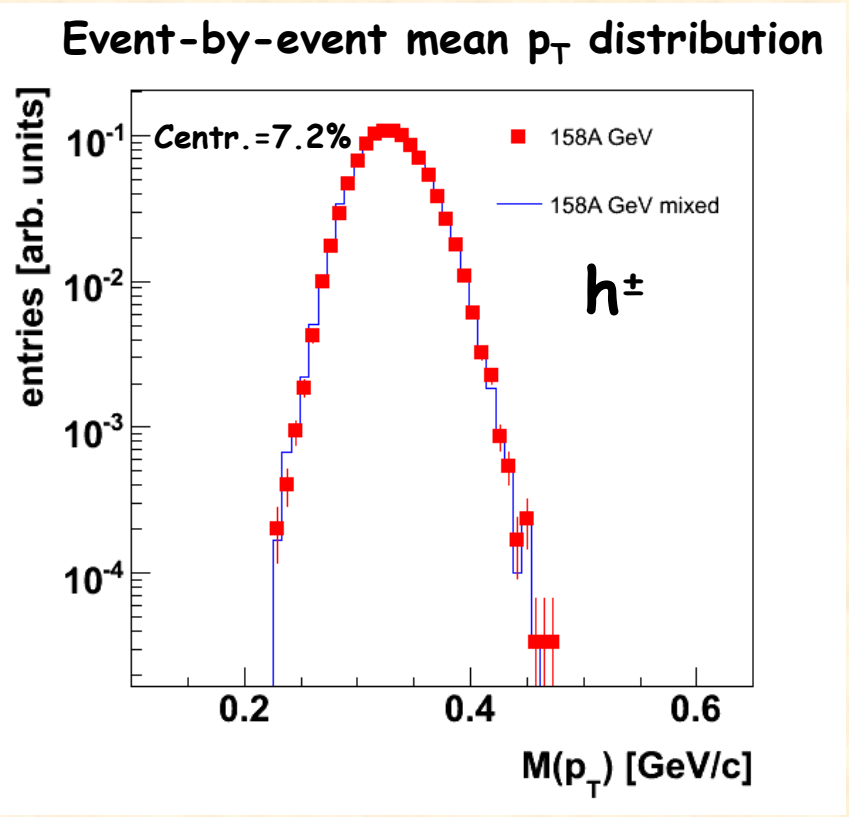
SIGNAL:
$\Delta \omega_E \geq 0.1$

Scaled variance as a function of μ_B derived from the hadron-gas model

PRC **73** (2006) 044905

JHEP **04** (2004) 050
PRD **67** (2003) 014028
PRD **60** (1999) 114028

TRANSVERSE MOMENTUM FLUCTUATIONS



Φ_{pT} measure:

single-particle variable: $z = p_T - \overline{p_T}$

$\overline{p_T}$ - average over single-particle inclusive distribution

event variable: $Z = \sum_{i=1}^{N} \left(p_{T_i} - \overline{p_T}\right)$

where summation runs over particles in a given event

Finally: $\Phi_{p_T} = \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\overline{z^2}}$

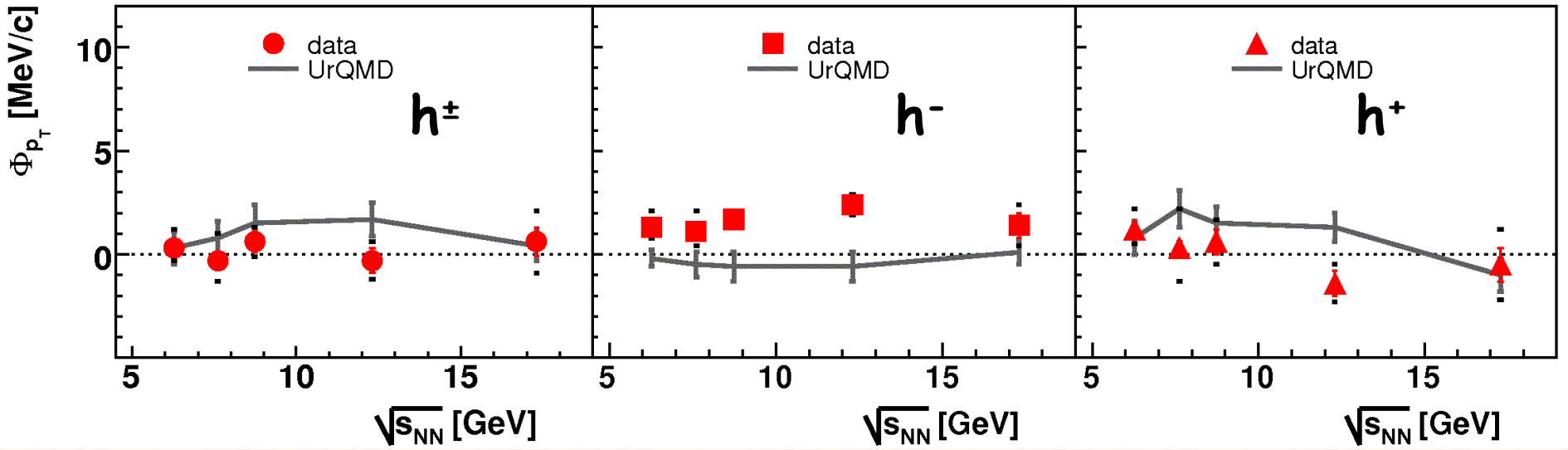
$\langle \cdots \rangle$ - averaging over events

✓If *A+A* is a superposition of independent N+N
=> Φ_{pT} (*A+A*) = Φ_{pT} (N+N)

✓For a system of independently emitted particles (no interparticle correlations) => Φ_{pT} = 0

TRANSVERSE MOMENTUM FLUCTUATIONS

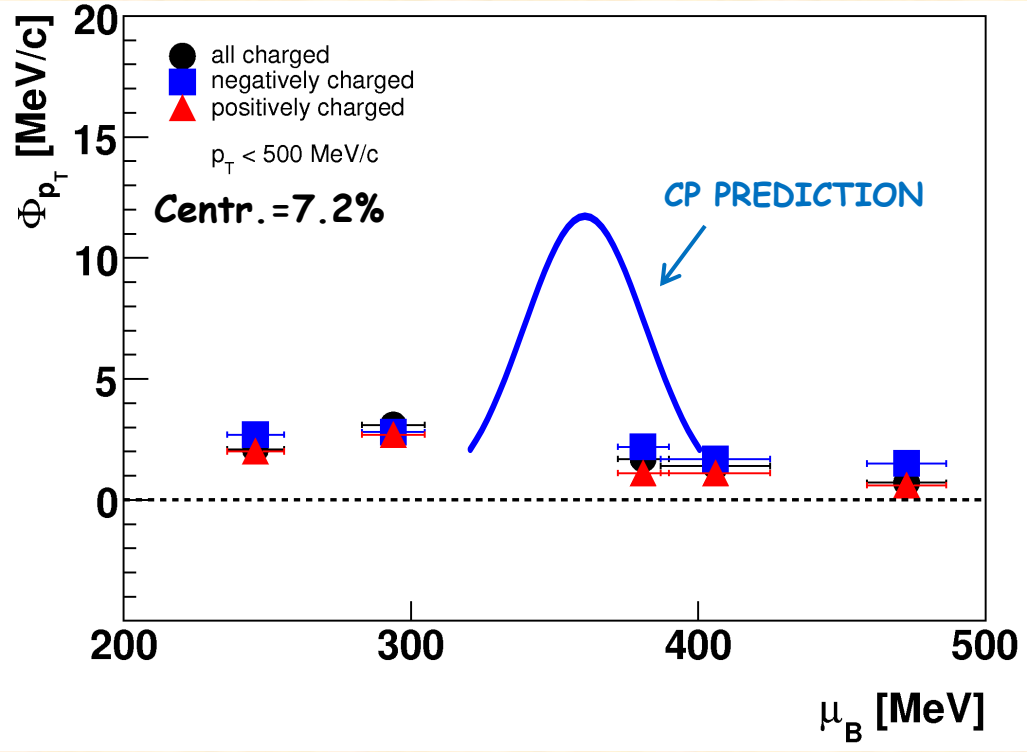
RESULTS AND COMPARISON TO THE URQMD MODEL, Centr.=7.2%



- ✓No significant energy dependence
- ✓Results for different charges are similar
- ✓UrQMD approximately reproduces the data

TRANSVERSE MOMENTUM FLUCTUATIONS

ANALYSIS FOR p_T < 500 MeV/c



Fluctuations due to the critical point should be dominated by fluctuations of pions with $p_T \leq 500$ MeV/c

STEPHANOV, RAJAGOPAL, SHURYAK
PRD **60** (1999) 114028

Remark:
Predicted fluctuations at the critical point should result in
$\Phi_{pT} \approx 20$ MeV/c,
The effect of limited acceptance of NA49 reduces them to
$\Phi_{pT} \approx 10$ MeV/c

✓No significant energy dependence of Φ_{pT} measure also when low transverse momenta are selected.

SUMMARY

Kaon/Pion Ratio

- ✓K/π fluctuations increase towards lower beam energy
- ✓Significantly enhanced over hadronic cascade model

Net Charge

- ✓$\Delta\Phi_q$ independent of energy & acceptance
- ✓Values close to zero, much higher as expected in QGP
- ✓Hadronization may increase $\Delta\Phi_q$ from QGP value to the measured one

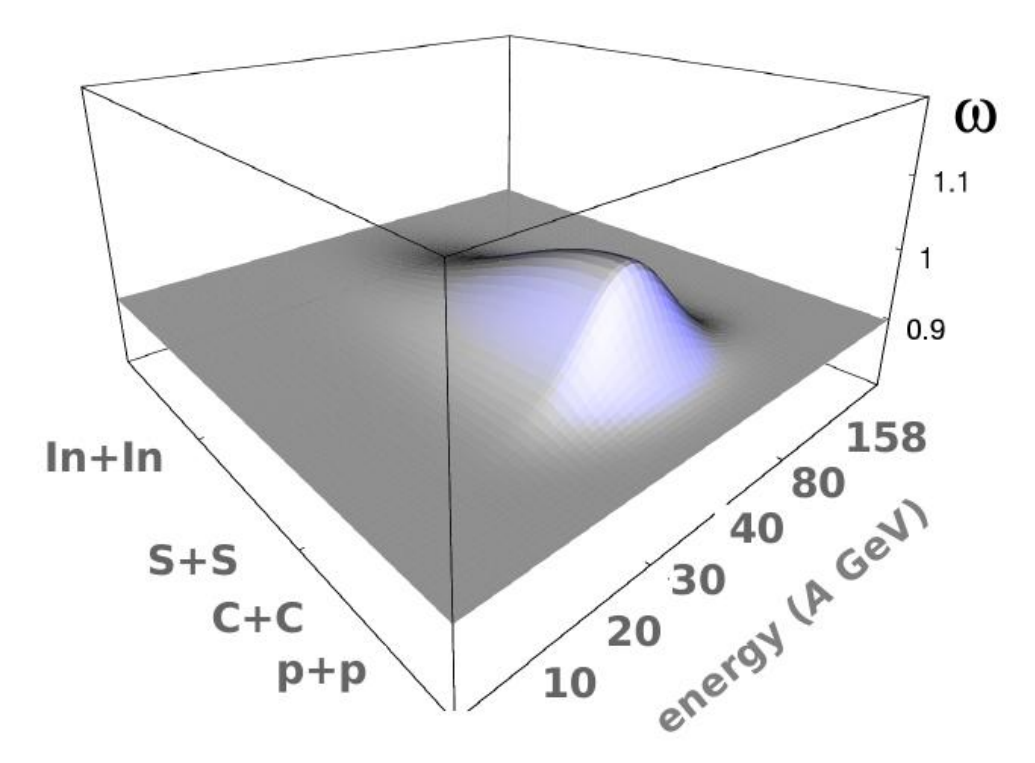
Multiplicity

- ✓No anomalies related to the critical point observed
- ✓Statistical model predictions for the grand-canonical and canonical ensemble in disagreement with data
- ✓UrQMD model reproduces data

Transverse momentum

- ✓No significant energy dependence of p_T fluctuations at SPS energies
- ✓The energy dependence of p_T fluctuations shows no evidence of the critical point
- ✓UrQMD approximately reproduces the data

OUTLOOK



CRITICAL POINT SEARCH STRATEGY – critical point can lead to an increase of N and p_T fluctuations provided the freezeout takes place in its vicinity ($\Delta T \approx 10$MeV, $\Delta\mu_B \approx 50$ MeV);

Results from the future NA61 experiment at SPS may show a "hill" of fluctuations over smoothly varying background in the two-dimensional "system-size" – "collision-energy" plot.

Back-up slides

SUMMARY

Multiplicity fluctuations in central Pb+Pb collisions for h^+, h^- and h^{+-} at 20, 30, 40, 80 and 158A GeV beam energy were analysed

1) No anomalies related to the critical point or the onset of deconfinement observed
2) Statistical model predictions for the grand-canonical and canonical ensemble in disagreement with data
3) UrQMD model reproduces data

Also transverse momentum fluctuations in central Pb+Pb collisions for h^+, h^- and h^{+-} at 20, 30, 40, 80 and 158A GeV beam energy were studied

1) No significant energy dependence of p_T fluctuations at SPS energies
2) The energy dependence of transverse momentum fluctuations does not show any anomalies suggestive of an approach to the phase boundary
3) The energy dependence of p_T fluctuations shows no evidence of the critical endpoint

But:

Kaon/pion fluctuations increase towards lower beam energy
Significant enhancement over hadronic cascade model!