Energy Dependence of Multiplicity Fluctuations in Heavy Ion Collisions

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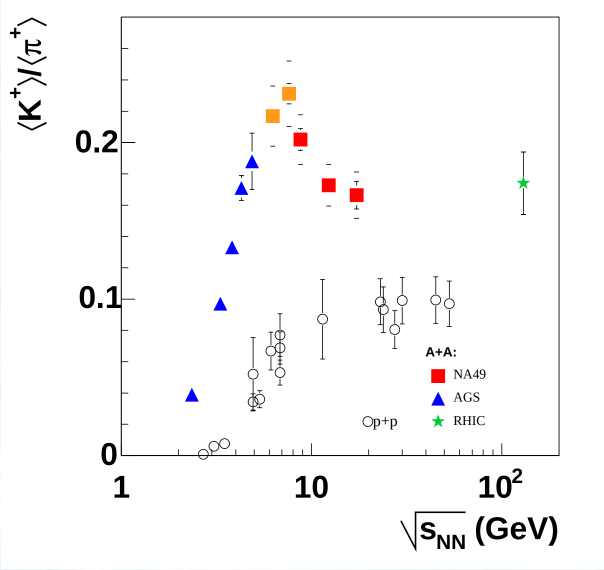
for the NA49 collaboration

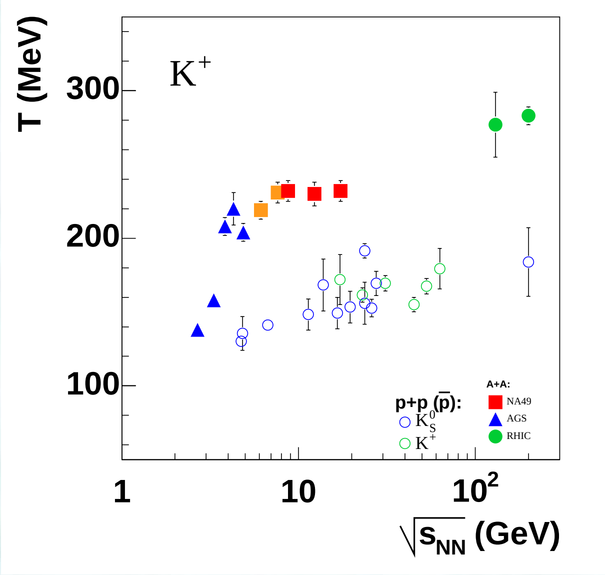
Outline

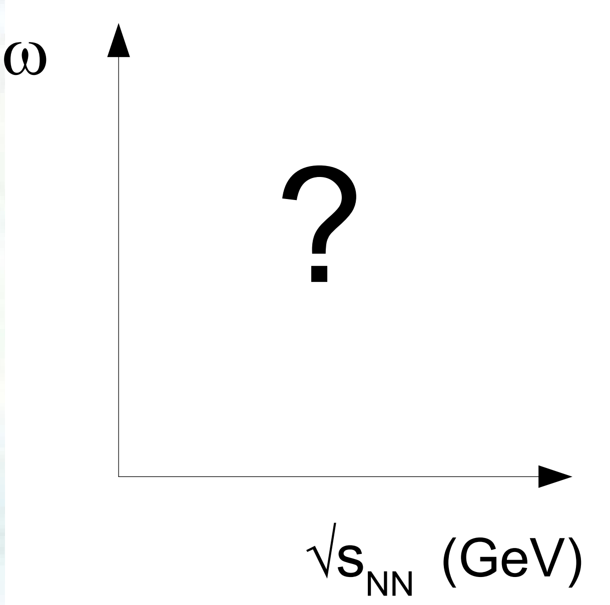
- Introduction
- Analysis of energy dependence
- Energy dependence of multiplicity fluctuations
  - Acceptance scaling
  - Model comparison
- Summary

Motivation

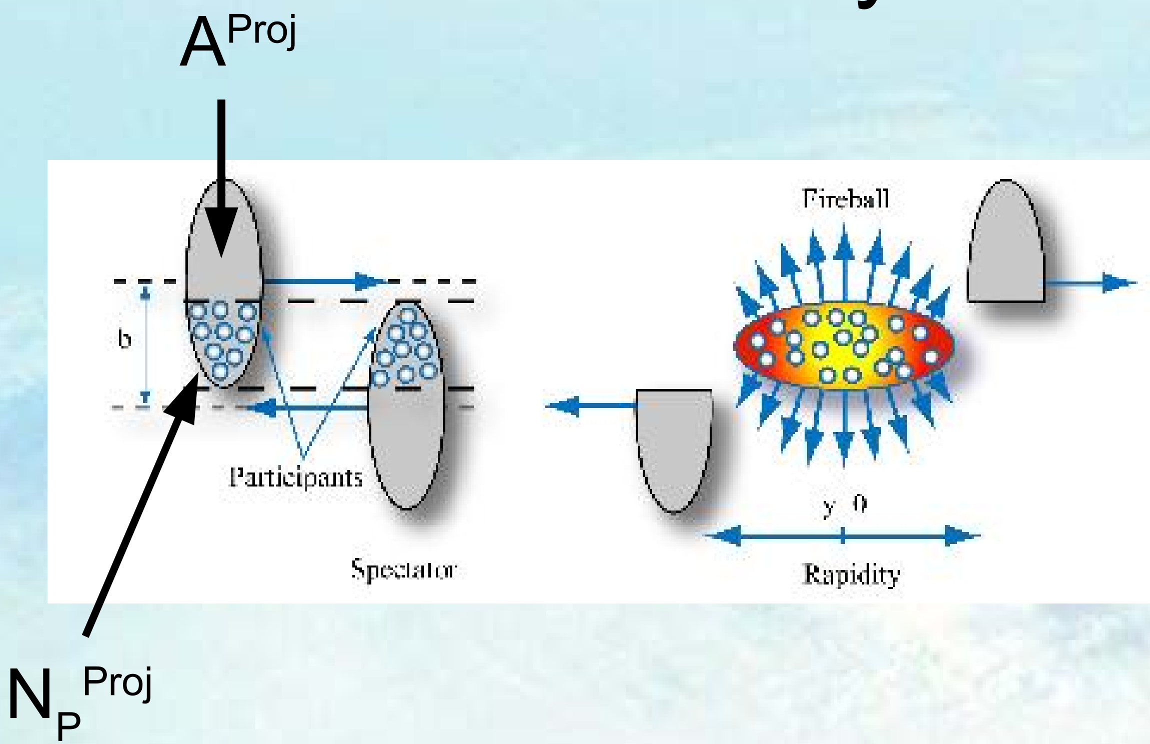
- Anomalies in energy dependence seen at low SPS energies -> hint for onset of deconfinement ?
- Models predict large fluctuations near onset of deconfinement or critical point







Centrality Selection



VCAL

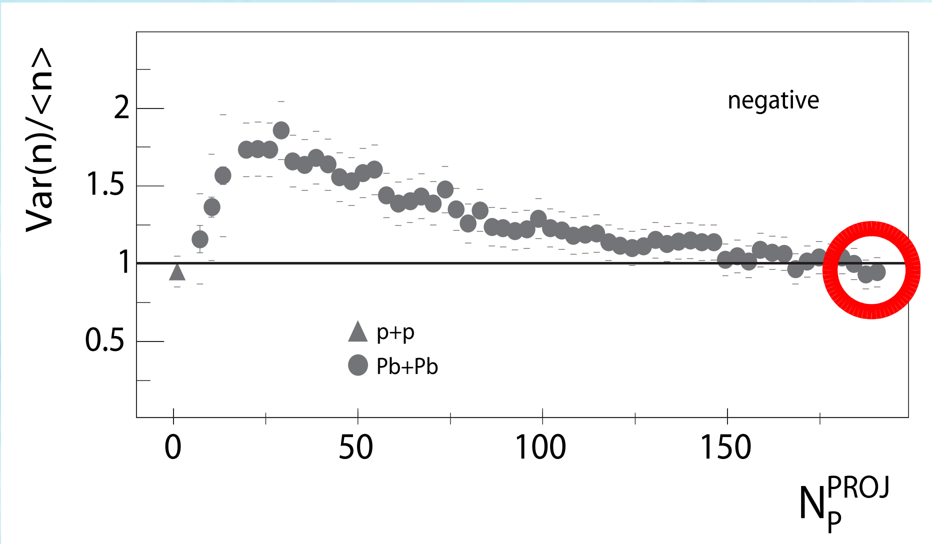
Veto calorimeter

$E_{Veto} \approx (A^{Proj} - N_P^{Proj}) * E_{kin}$

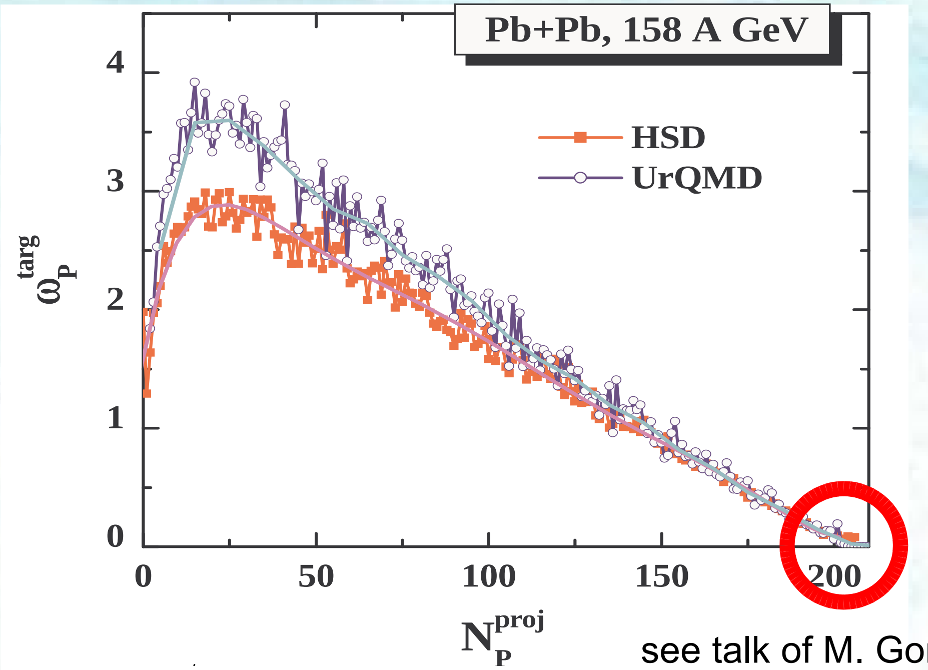
- Veto calorimeter -> projectile spectators, number of projectile participants N_P^{Proj}
- Target spectators not measured in NA49 !

System Size Dependence of n- Fluctuations

158A GeV



see talk of M. Rybczynski

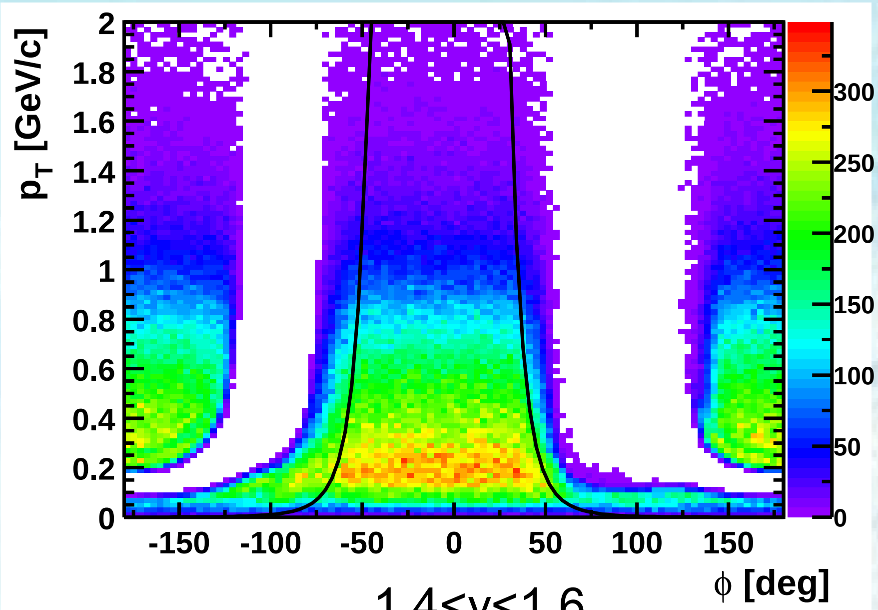


see talk of M. Gorenstein, V. Konchakovskyi et al. Phys. Rev. C 73 (2006) 034902

- N_P^{Proj} experimentally fixed, N_P^{Targ} fluctuate
- Peripheral collisions: Large N_P^{Targ} fluctuations may cause large ω in forward hemisphere (e.g. mixing)
- Central collisions: N_P^{Targ} fluctuations negligible

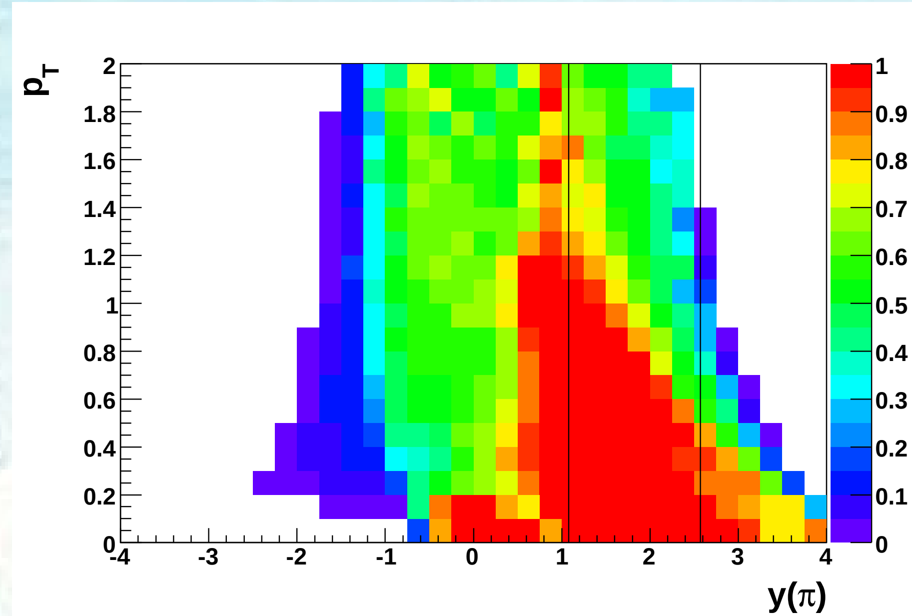
Track Selection

158*A* GeV



1.4<y<1.6

h^-



y in cms system

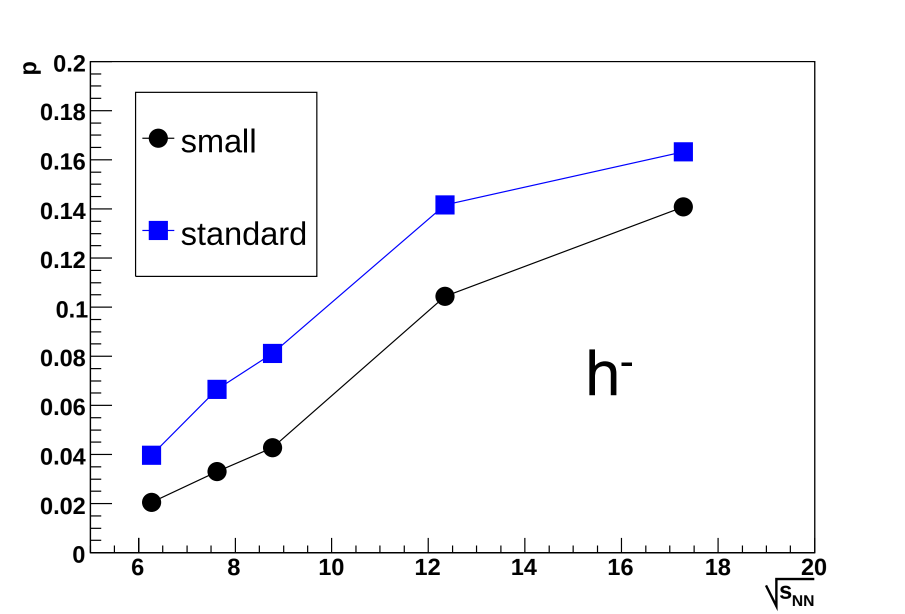
- Only hadrons in a limited forward acceptance (projectile hemisphere) were selected (158A GeV: equal to M. Rybczynski)
  - Safe acceptance (no problems with efficiency etc.)
    - (p_T, ϕ) cut:

      C. Alt et al., Phys.Rev.C70:064903, 2004
    - y-cut:

      20*A* – 80*A* GeV: $1<y<y_{beam}$

      158A GeV: 1.08<y<2.57

Experimental Acceptance



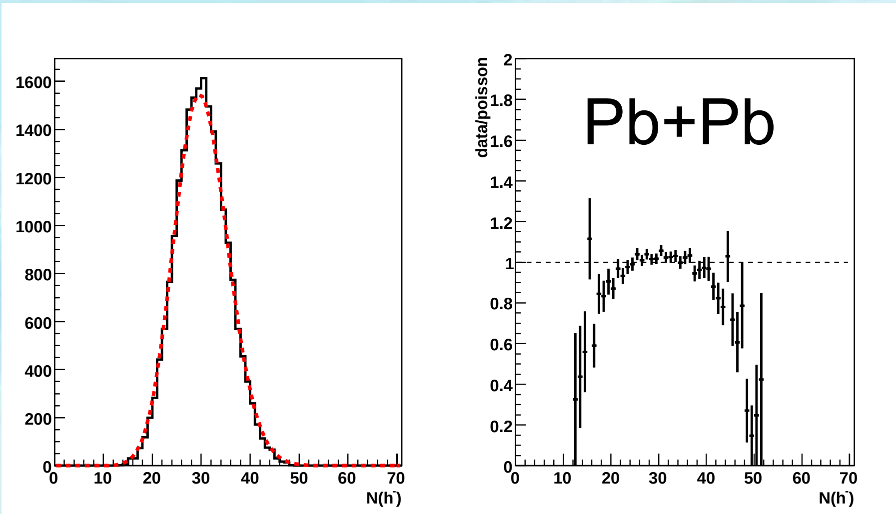
- Strong energy dependence of experimental acceptance
  - Difficult to compare different energies
- Small acceptance ($1<y<(y_{beam}-1)/2+1$) used to study acceptance effects

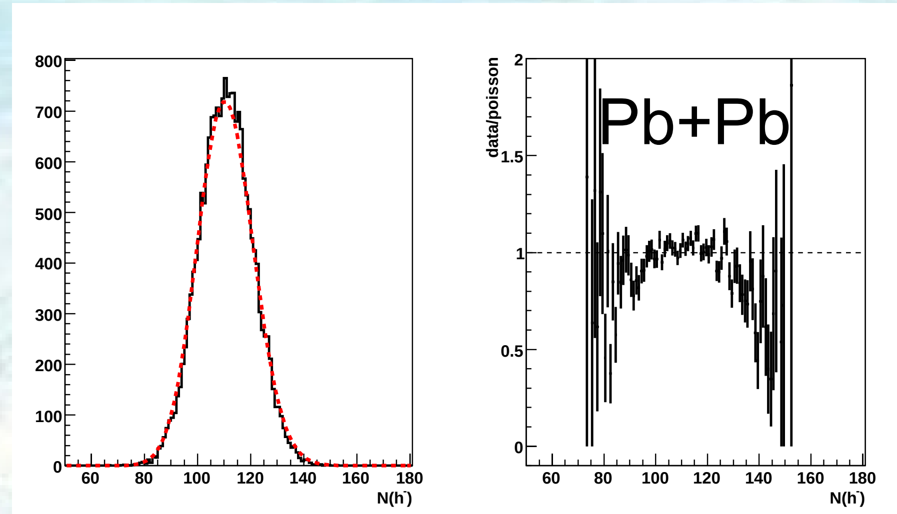
Multiplicity Distributions

40A GeV

h^- at N^P_{Proj}=195

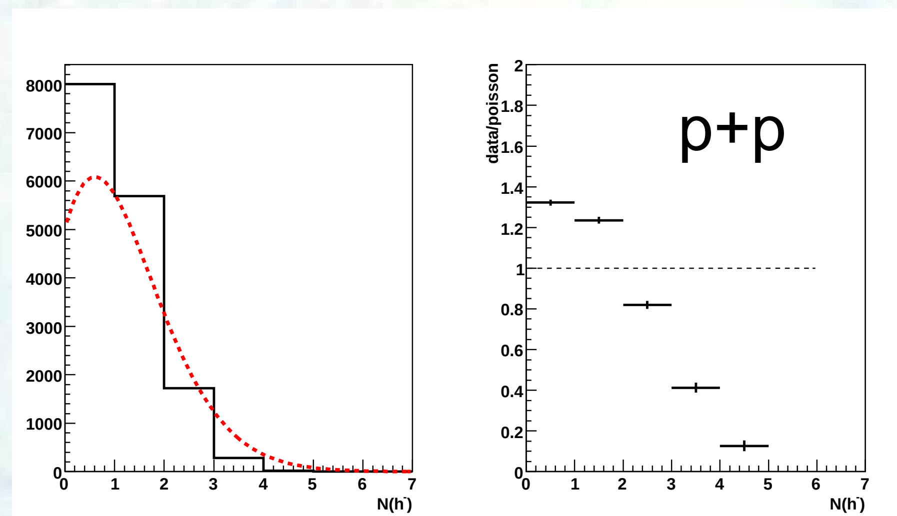
158A GeV





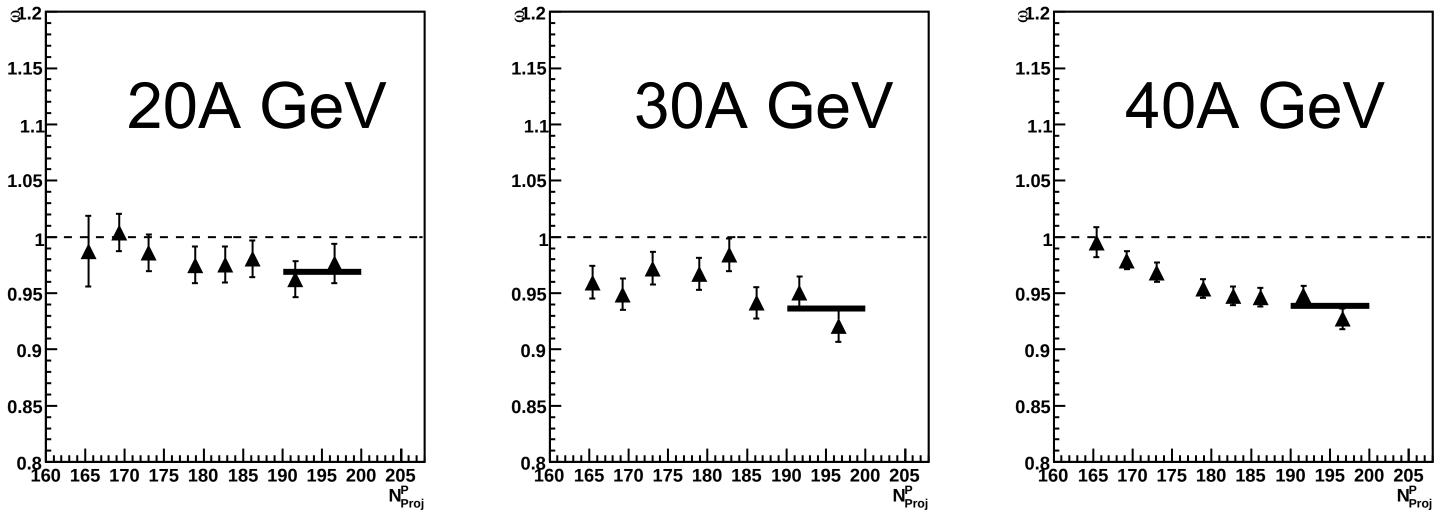
black: data
red: Poisson distribution

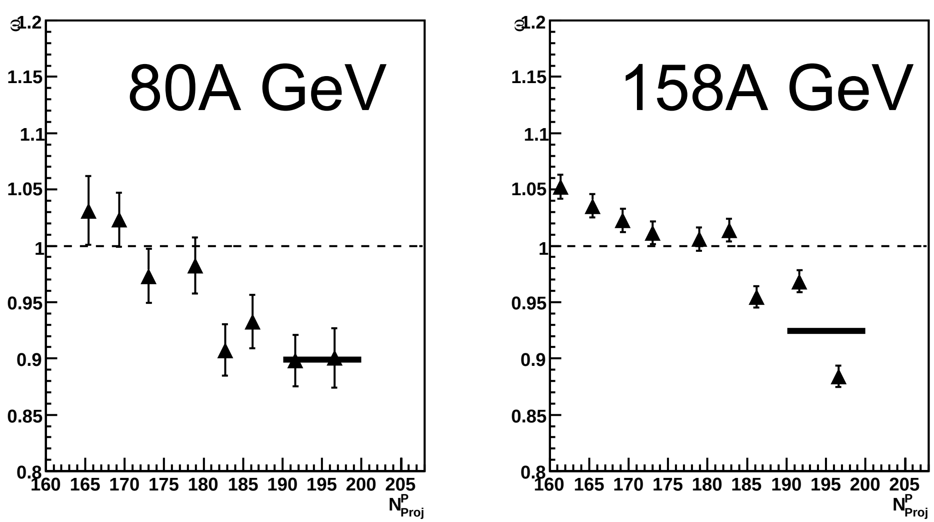
all data are preliminary !



- Multiplicity distributions for central collisions are significantly narrower than Poisson distribution !

Centrality Dependence at all Energies





h^-

- Not corrected for resolution of veto calorimeter
- $190 < N^{P}_{Proj} < 200$ selected

Corrections and Biases

- Correction applied for finite size of centrality bins

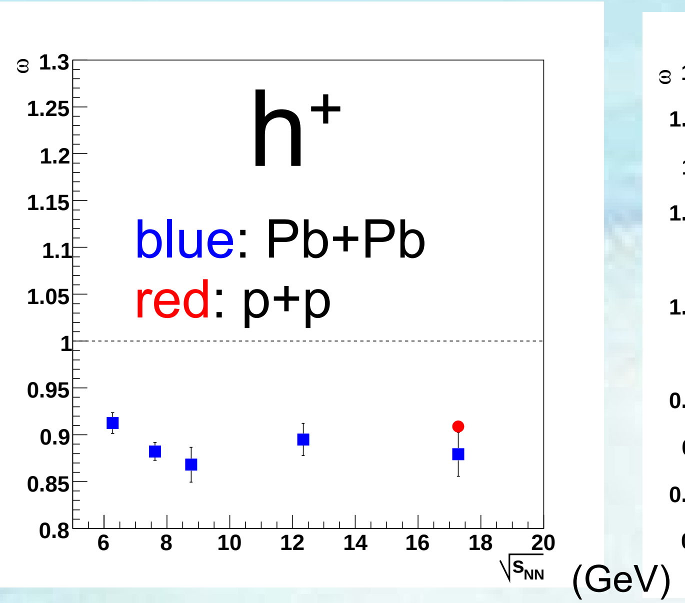
$$\delta_{bw} = \langle n \rangle \frac{Var(N_P^{Proj})}{\langle N_P^{Proj} \rangle^2}$$

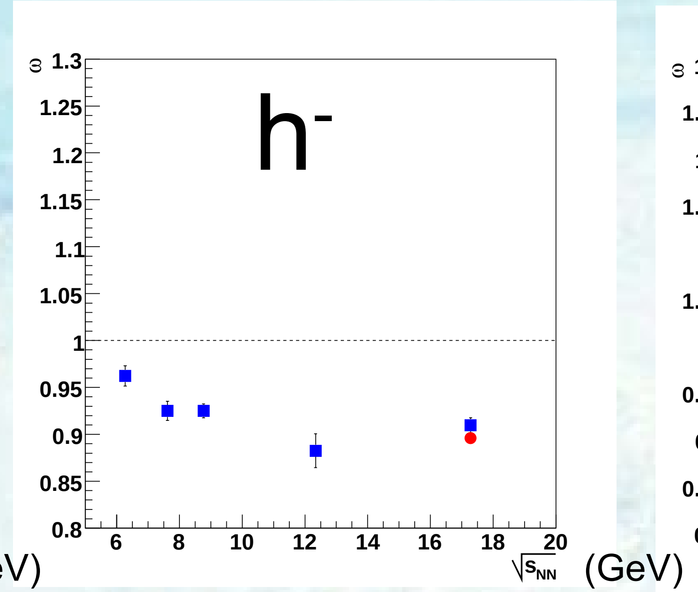
in the order of 2%

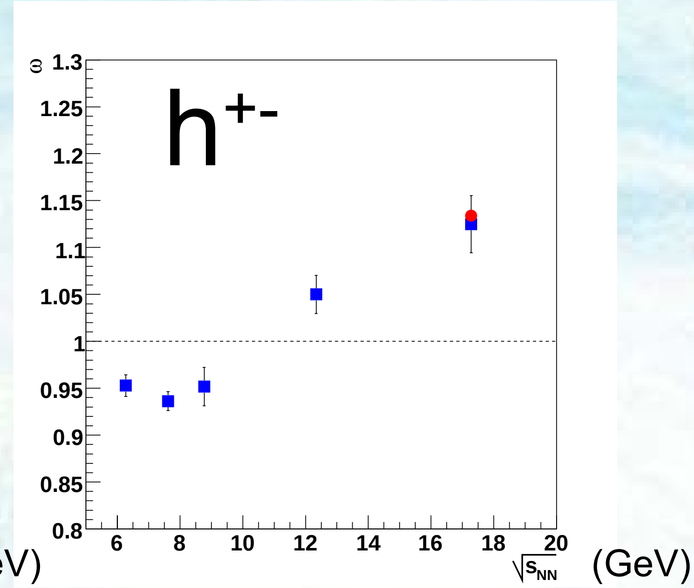
- Known uncorrected biases:
  - N^P_{Proj} fluctuations due to finite Veto calorimeter resolution (estimated to be <2%)
  - A possible N^P_{Targ} fluctuations contribution to projectile hemisphere

-> They both increase fluctuations

Energy Dependence of n- Fluctuations







Note: different acceptance for different energies !

only statistical errors shown

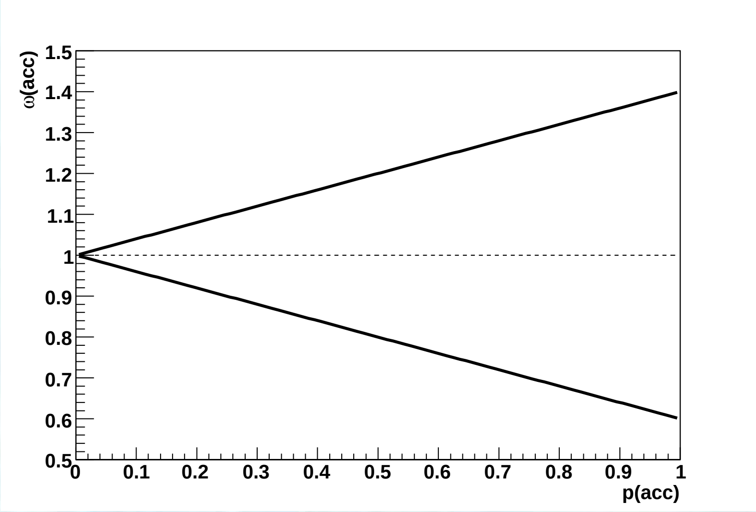
- Scaled variance for h^+, h^- smaller than 1
- ω for $h^{+-} < 1$ for low energies, $\omega^{+-} > 1$ for higher energies
- ω(p+p) ≈ ω(central Pb+Pb) at 158A GeV

Effect of Limited Acceptance

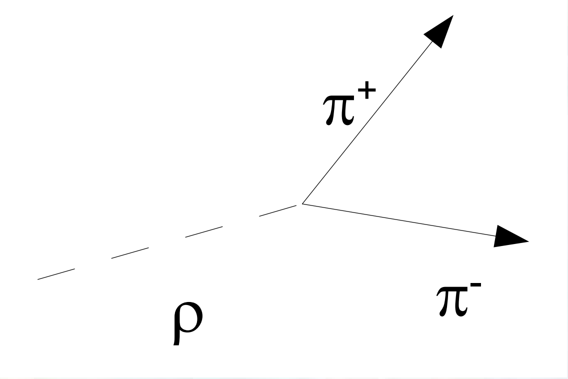
- Assuming no correlations in momentum space

$$\omega(acc) = (\omega(4\pi) - 1) \cdot p(acc) + 1 \qquad (*)$$

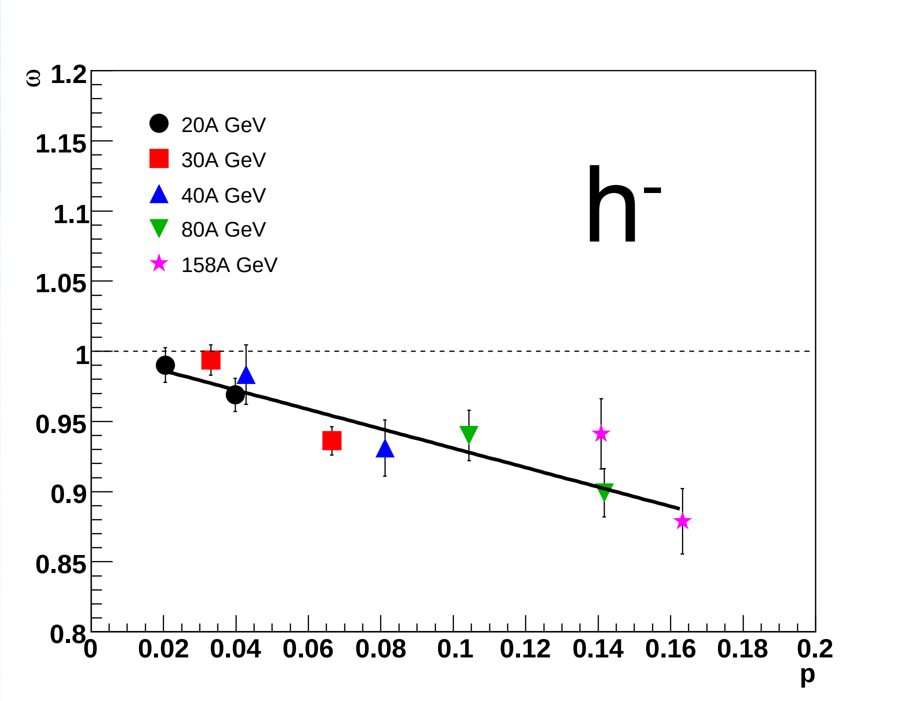
- $\omega(4\pi) > 1 \Leftrightarrow \omega(acc) > 1$, $\omega(4\pi) < 1 \Leftrightarrow \omega(acc) < 1$



- Formula (*) not valid if more than one daughter particle of a decay is detected
  - very few particles decay into 2 h^-
  - many particles decay into h^+ and h^-



Acceptance Scaling for h^-

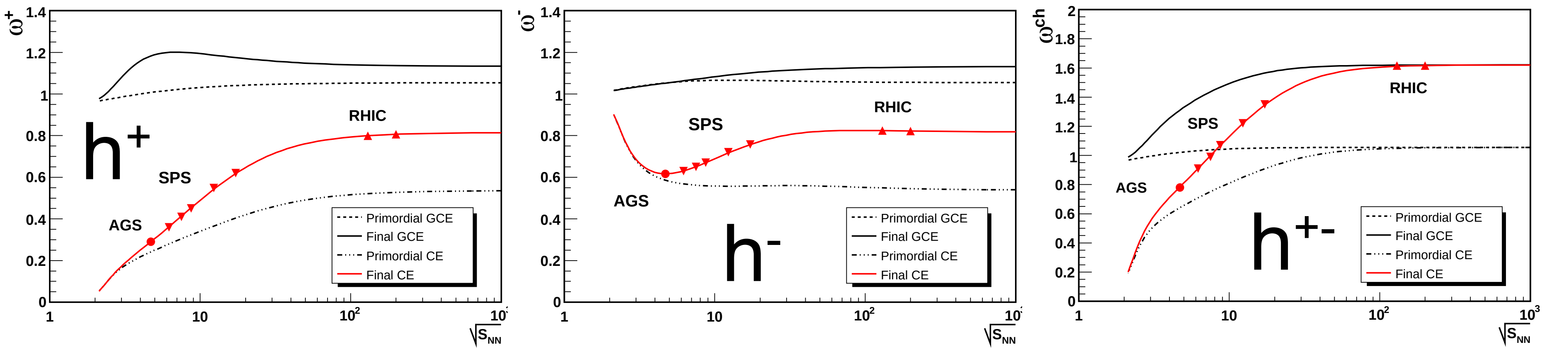


$<\omega(4\pi)> \approx 0.3$

small and standard acceptance

- Data comparable with acceptance scaling and no (or weak) energy dependence of multiplicity fluctuations in 4π

Statistical Model

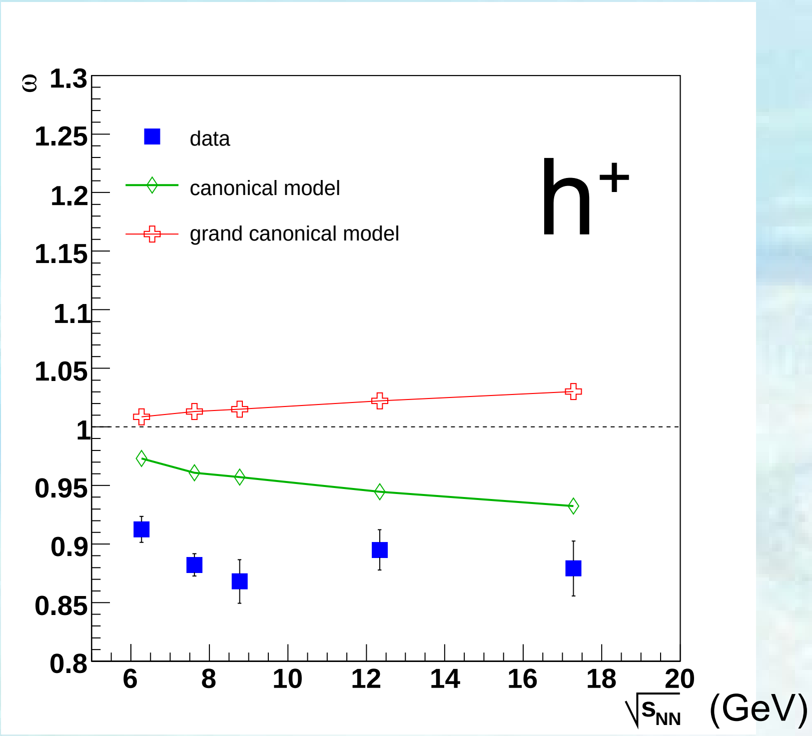


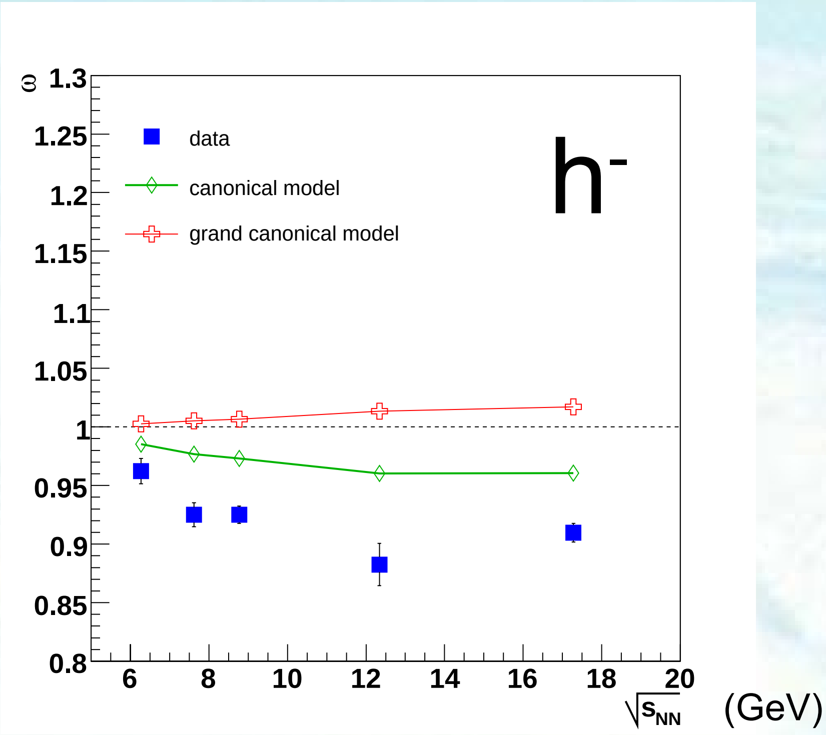
4π acceptance !

see talk of M. Gorenstein,V. Begin
M. Hauer et. al. nucl-th/0606036

- Grand canonical ensemble (no charge conservation):
  - ω>1 for all energies
- Canonical ensemble (B,Q,S conserved):
  - ω<1 for h^+ and h^-, ω crosses 1 for h^{+-}
- Final state: resonance decays

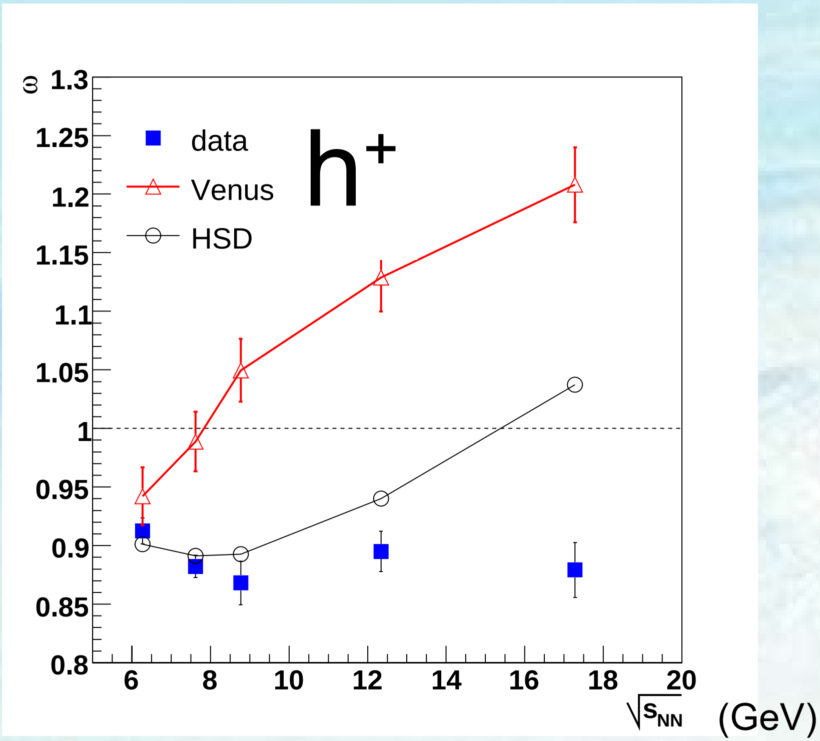
Statistical Model and Data

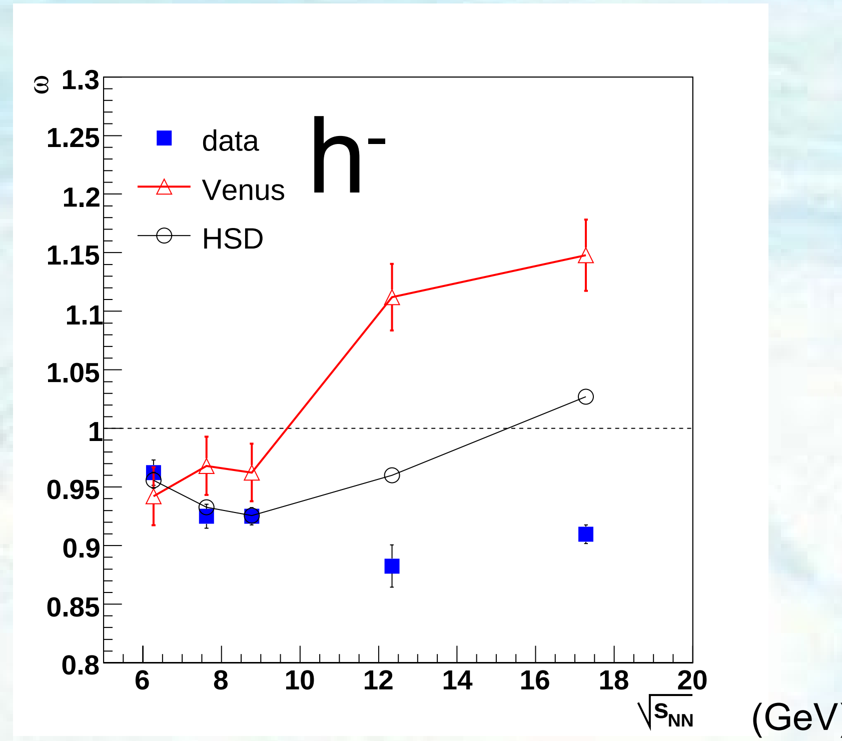




- 4π values scaled down to exp. acceptance assuming no correlations in momentum space (eg. due to resonance decays)
- Grand canonical model overpredicts fluctuations
- Canonical model works better, but its fluctuations are also too high (energy conservation needed ?)

String Hadronic Models: Venus, HSD

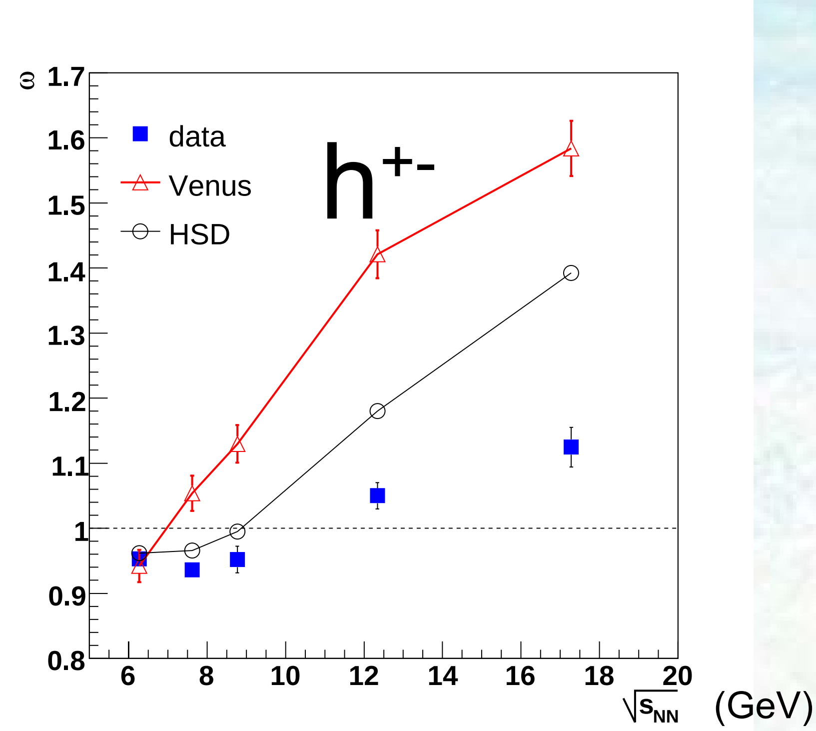




HSD: V. Konchakovski, priv. com.

- HSD: works good for 20A – 40A GeV, but overpredicts data at 80A and 158A GeV
- Venus overpredicts data for energies > 20A GeV

String Hadronic Models: Venus, HSD (2)



- All string hadronic models overpredict fluctuations of h^{+-} for energies > 20A GeV

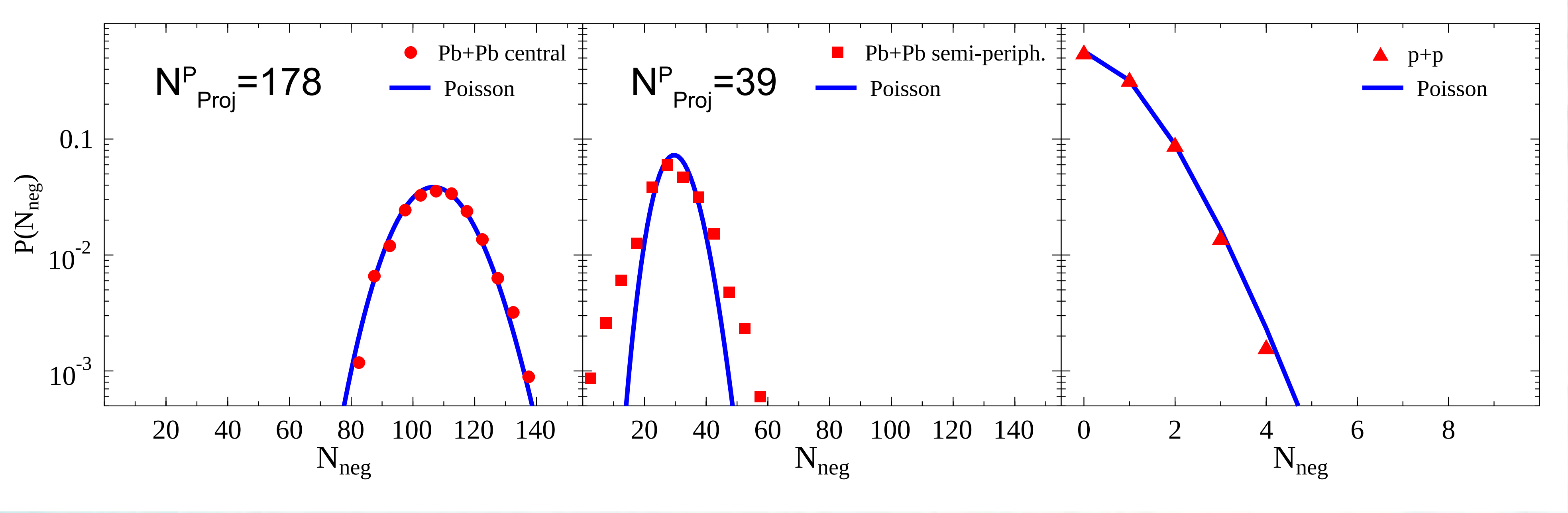
Summary

- Multiplicity fluctuations in central Pb+Pb collisions for h^+, h^- and h^{+-} at 20, 30, 40, 80 and 158A GeV were analysed
- ω^- scales with p(acc) for h^- at all energies
  -> weak energy dependence of ω in 4π [$\omega(4\pi) \approx 0.3$]
- ω^+ and ω^- smaller than 1 for all energies
  -> Grand canonical ensemble does not work !
- Canonical statistical model shows similar trend as the data but ω(data) < ω(CE)
- String hadronic models (Venus, HSD) work for lower energies (20-40A GeV) but fail for higher (80-158A GeV)

Backup

Multiplicity Distributions

158A GeV



negative hadrons, N_P^{Proj} fixed

Used measure of fluctuations: scaled variance

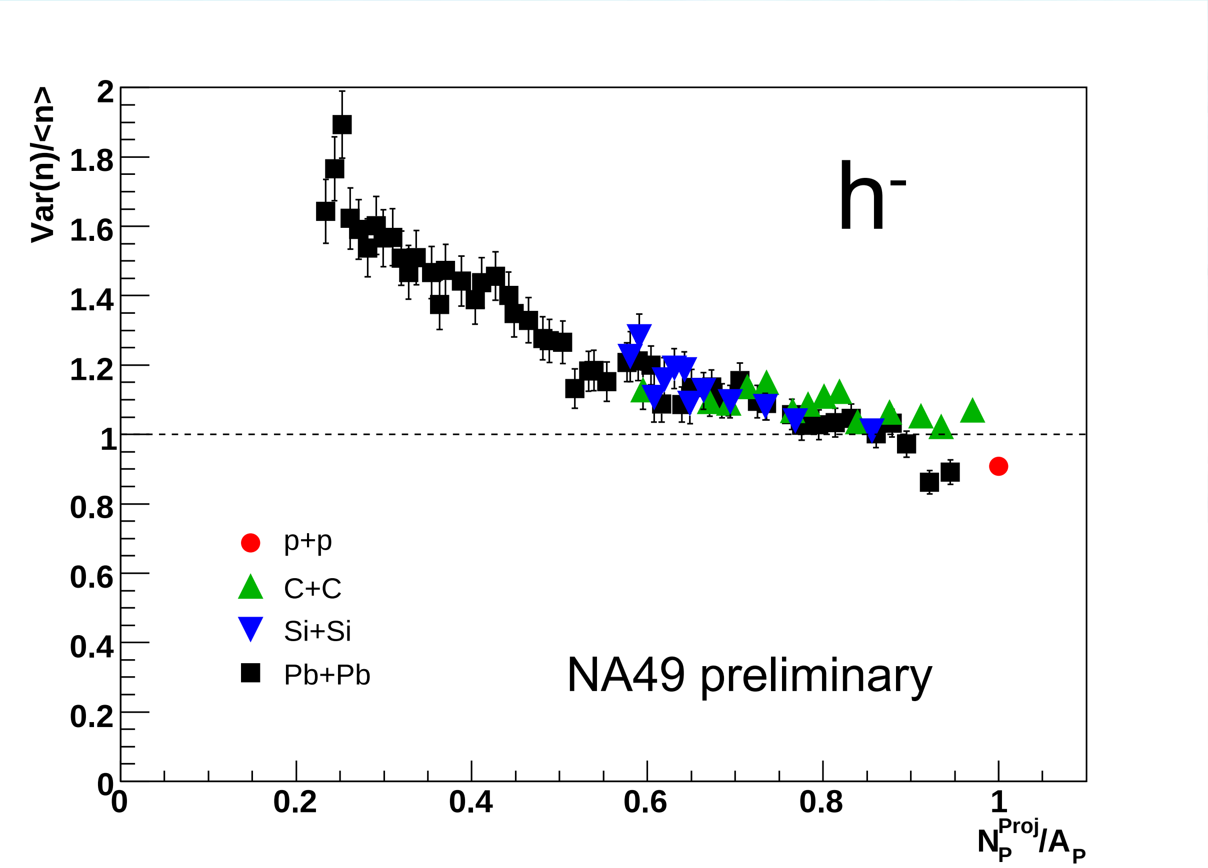
$$\omega(n) = \frac{Var(n)}{\langle n \rangle} = \frac{\langle n^2 \rangle - \langle n \rangle^2}{\langle n \rangle}$$

[=1 for Poissonian distribution]

Centrality and System Size Dependence

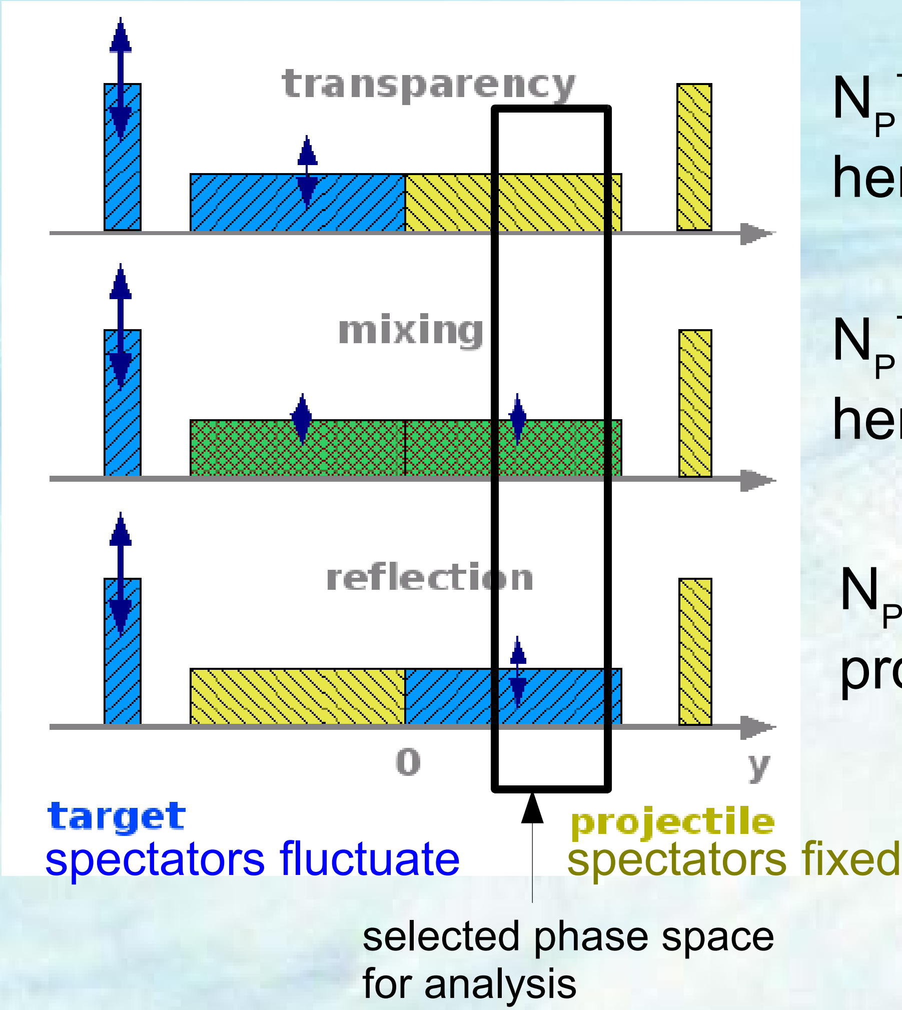
158A GeV

Projectile hemisphere



- Var(n)/<n> increases with decreasing centrality
- Approximate scaling in N_P^{Proj}/A^{Proj}

Different Extreme Reaction Scenarios



N_P^{Targ} fluctuations contribute in target hemisphere (most string hadronic models)

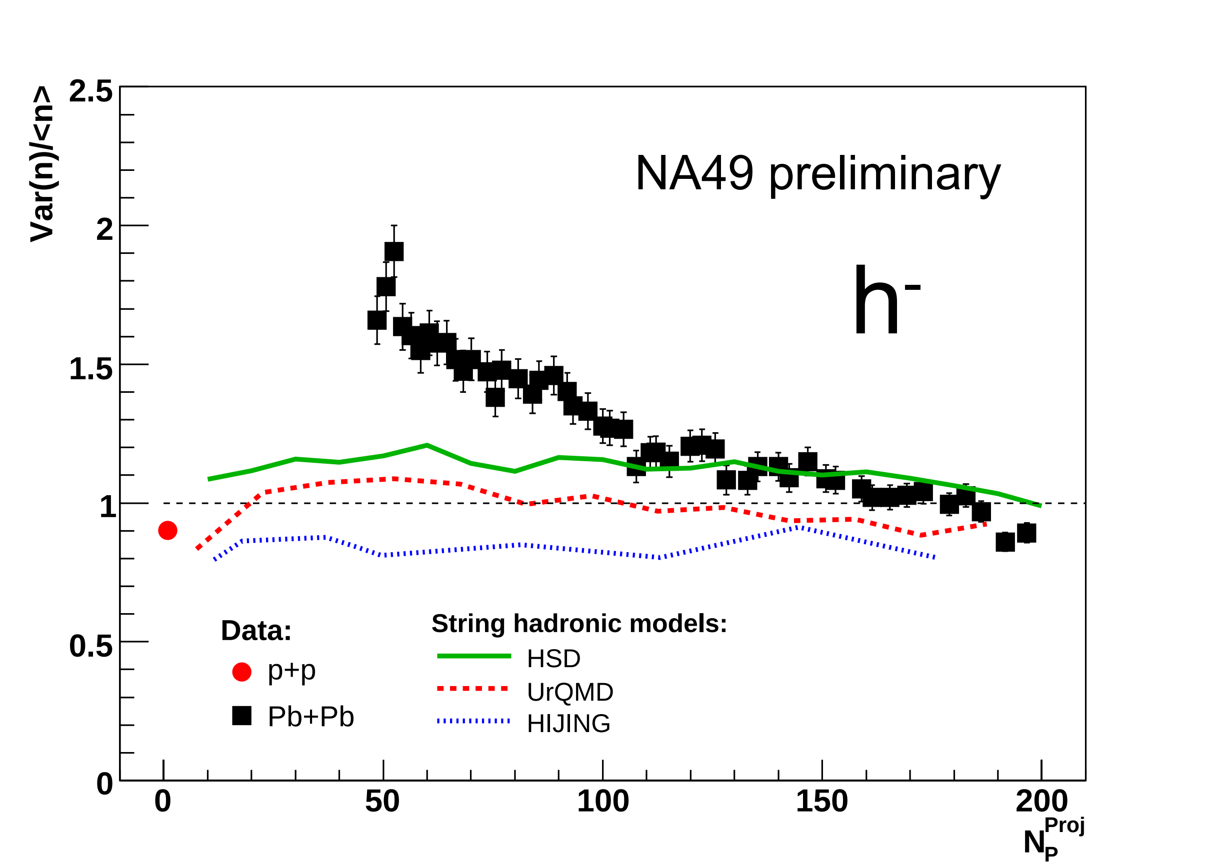
N_P^{Targ} fluctuations contribute in both hemispheres (most statistical models)

N_P^{Targ} fluctuations contribute in projectile hemisphere

M. Gazdzicki,
M. Gorenstein
arXiv:hep-ph/0511058

- Multiplicity fluctuations sensitive to reaction scenario

String Hadronic Models

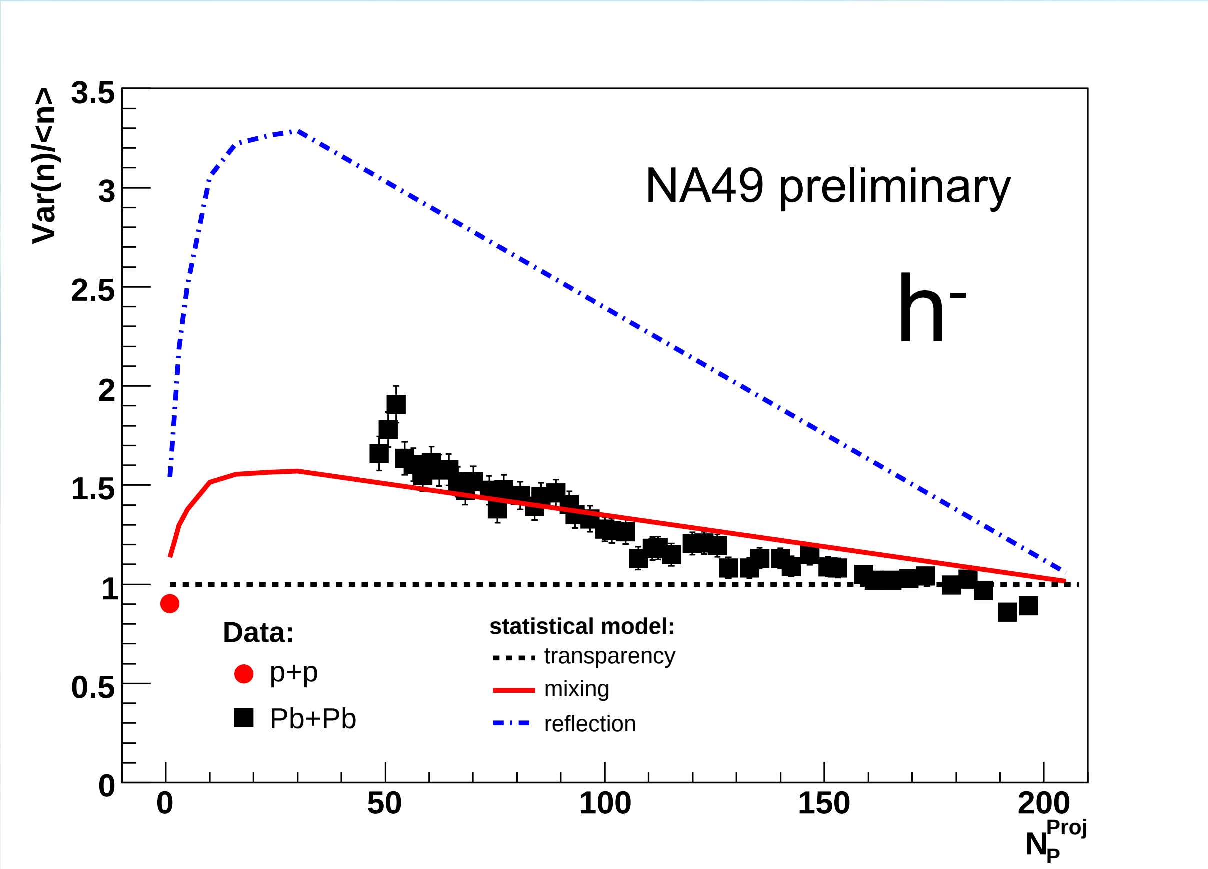


Projectile hemisphere

HSD, UrQMD:
V. Konchakovskyi et al.
Phys. Rev. C 73 (2006) 034902
HIJING:
M. Gyulassy, X. N. Wang
Comput. Phys. Commun. 83 (1994) 307
Simulation performed by:
M. Rybczynski

- String hadronic models shown (UrQMD, HSD, HIJING) belong to transparency class
- They do not reproduce data on multiplicity fluctuations

Reflection, Mixing and Transparency



Projectile hemisphere

Model calculation:
M. Gazdzicki,
M. Gorenstein
arXiv:hep-ph/0511058

- Significant amount of mixing of particles produced by projectile and target sources