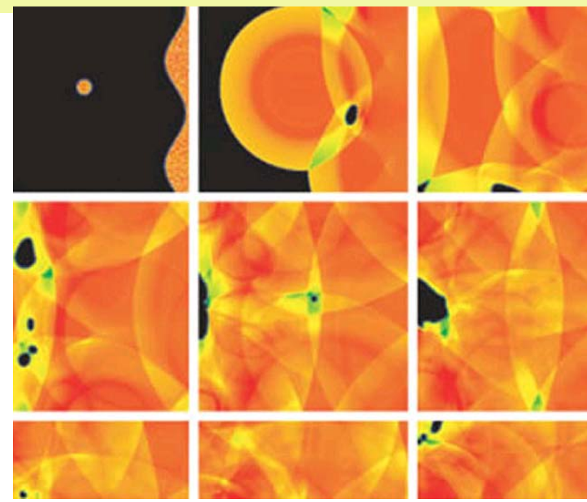
# Proton observables in NA49

H. Ströbele, Univ. Frankfurt

27th Winter Workshop on nuclear Dynamics

- Proton-lambda correlations.
- Centrality dependence of proton spectra.
- Kaon to proton number fluctuations.



# Introduction

- **proton-lambda correlations**
  - in central Pb+Pb collisions at 158 GeV/u.

    => size of the interaction volume
- **proton spectra**
  - in centrality selected Pb+Pb collisions at 40 and 158 GeV/u. Comparison to HSD/ UrQMD, and p+p at 158 GeV/c.

    => stopping
- **K/p fluctuations**:
  - In central Pb+Pb collisions at 20, 30, 40, 80, 158 GeV/u.

    => proton-strangeness correlation

# Proton-lambda correlations

Close pairs of protons and lambdas experience strong (attractive) interaction. Assumptions on scattering length and effective interaction range allow to derive radii from the p-Λ correlation function.

No Coulomb and no quant. mech. (identical particle) effects.

Data sample:
2.8 million Pb+Pb events (23%most central) at 158 GeV/u.

17520 (effective) p-Λ pairs.

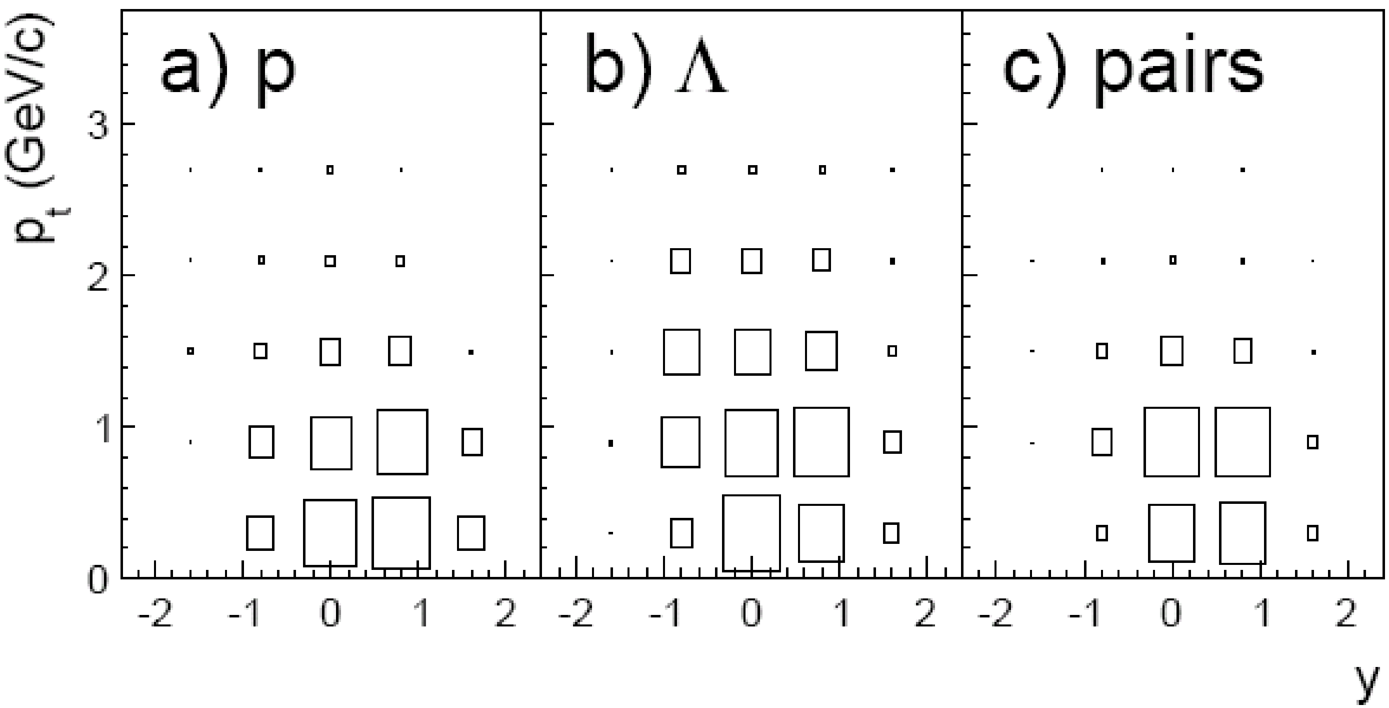
Corrections for purity, two-track and momentum resolution.

Preliminary analysis in C. Blume Nucl. Phys. A 750(2003)55c.
Publication of final results in a few months.

# Proton-lambda correlations

Phase pace population of protons, lambdas and p-Λ pairs

($y_{beam} \approx 3$)



# Proton-lambda correlations

$q_{inv} = \{0, 2|p_p - p_\Lambda|\}$

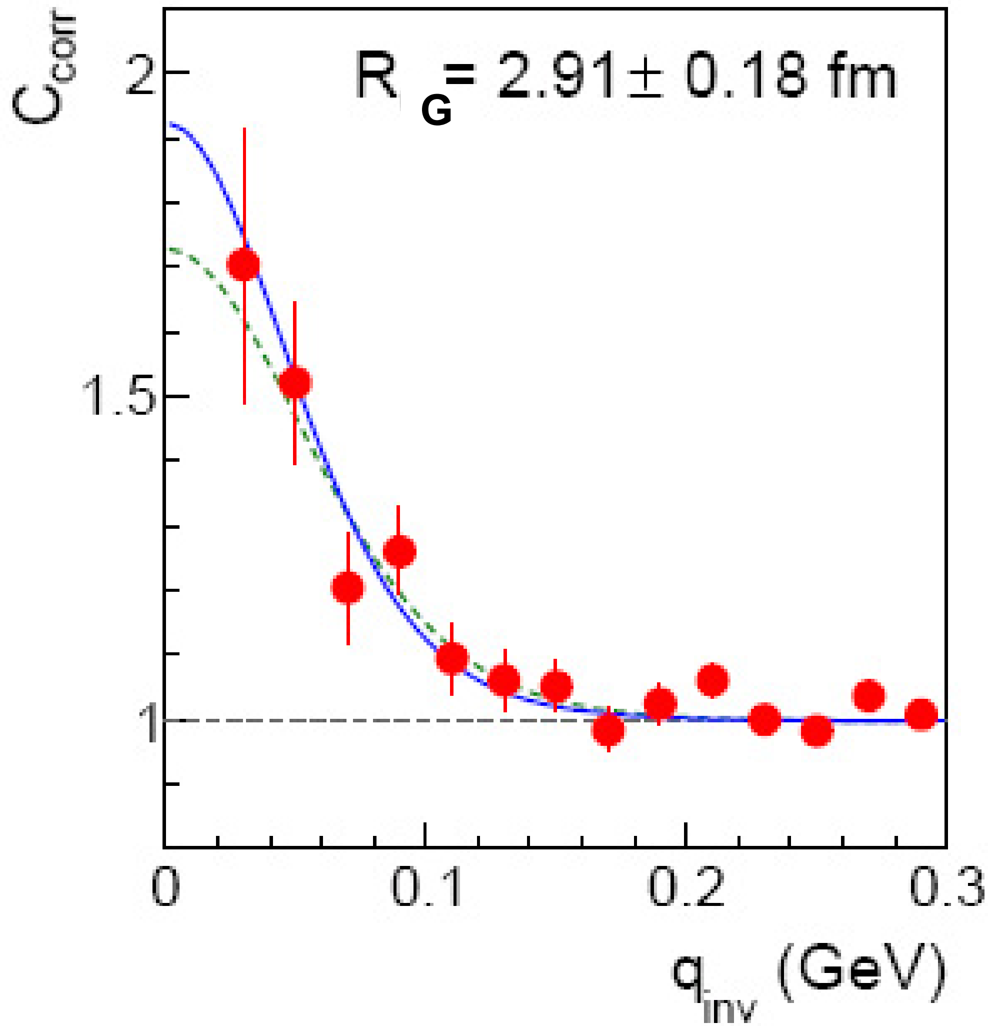
$C(q_{inv}) = N\,S(q_{inv})\,/B(q_{inv})$

$C_{corr} = (C-1)/\langle K\rangle + 1$

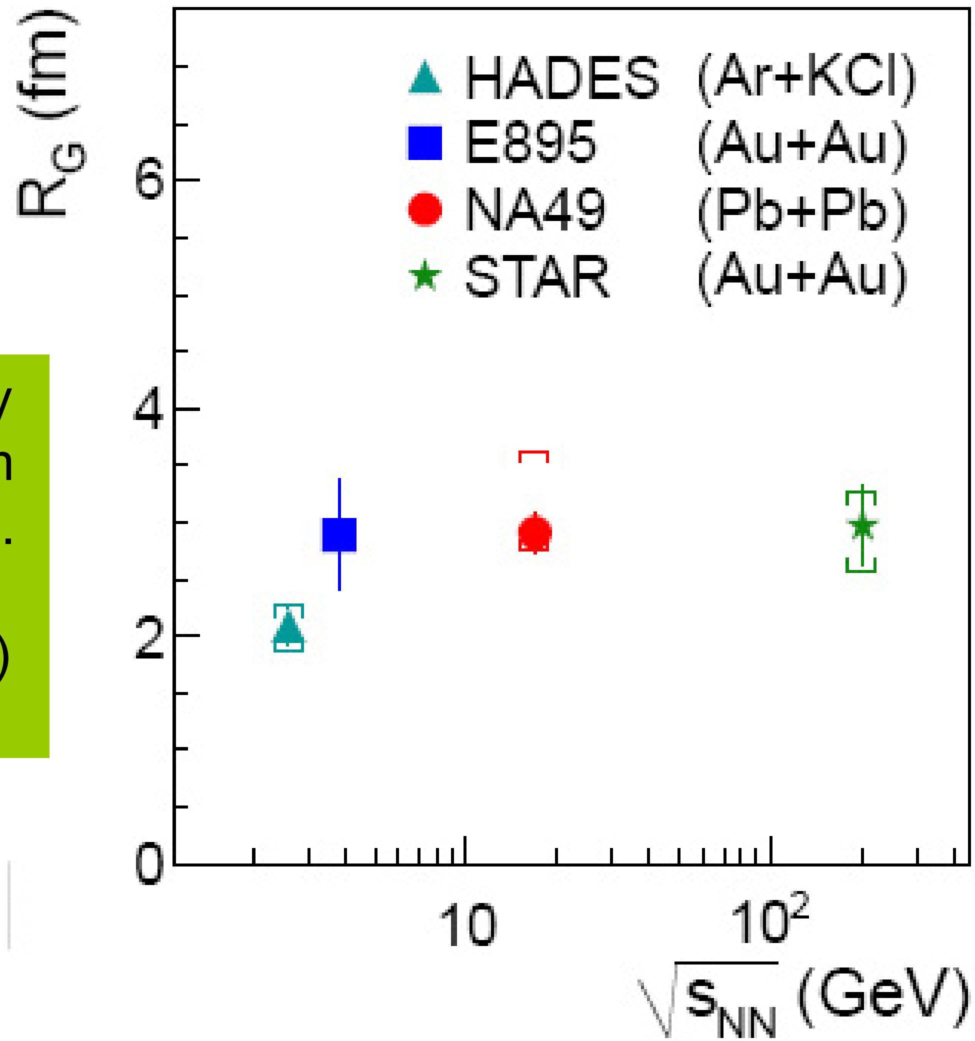
(<K> corrects for purity and feed-down)

Theoretical correlation function as in B.I. Abelev et al., STAR, PRC74, 54902 (Lednicky's scheme).

Dashed (full) line for fit with (without) λ parameter.



# Proton-lambda correlations




Region of homogeneity has the same size from AGS to RHIC energies. Smaller system and negligible (longitudinal) flow at SIS energies.

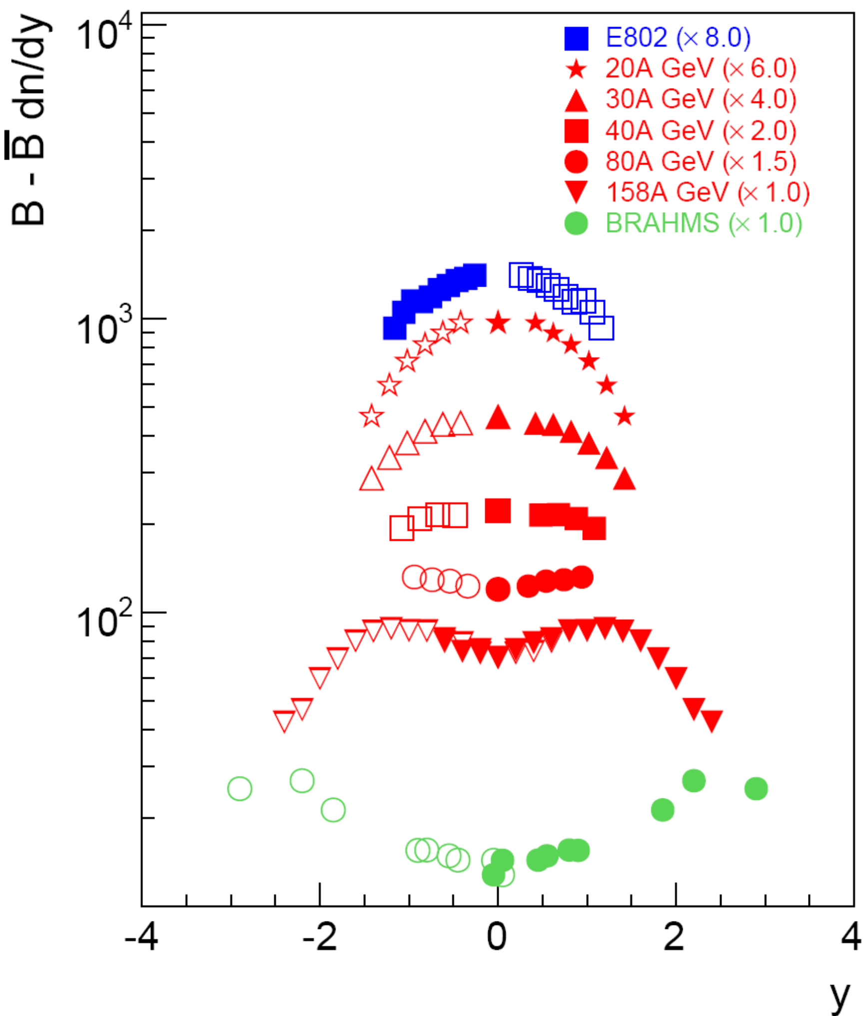
# proton spectra in the SPS energy range

The SPS represents the transition region from the baryon rich (AGS) to the meson dominated (RHIC) regime …… in central collisions!

What about the transition from large systems (central Pb+Pb) to small systems (p+p or peripheral Pb+Pb) at fixed energy.

How does stopping change with centrality ?

New NA49 data in PRC83/014901

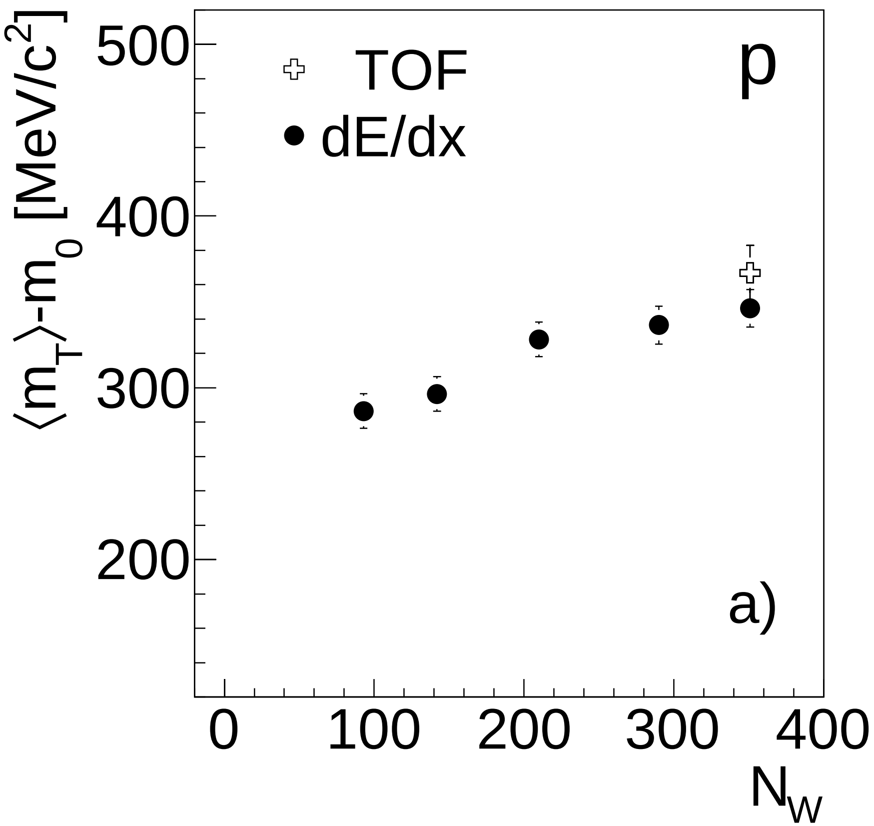


# proton spectra in the SPS energy range

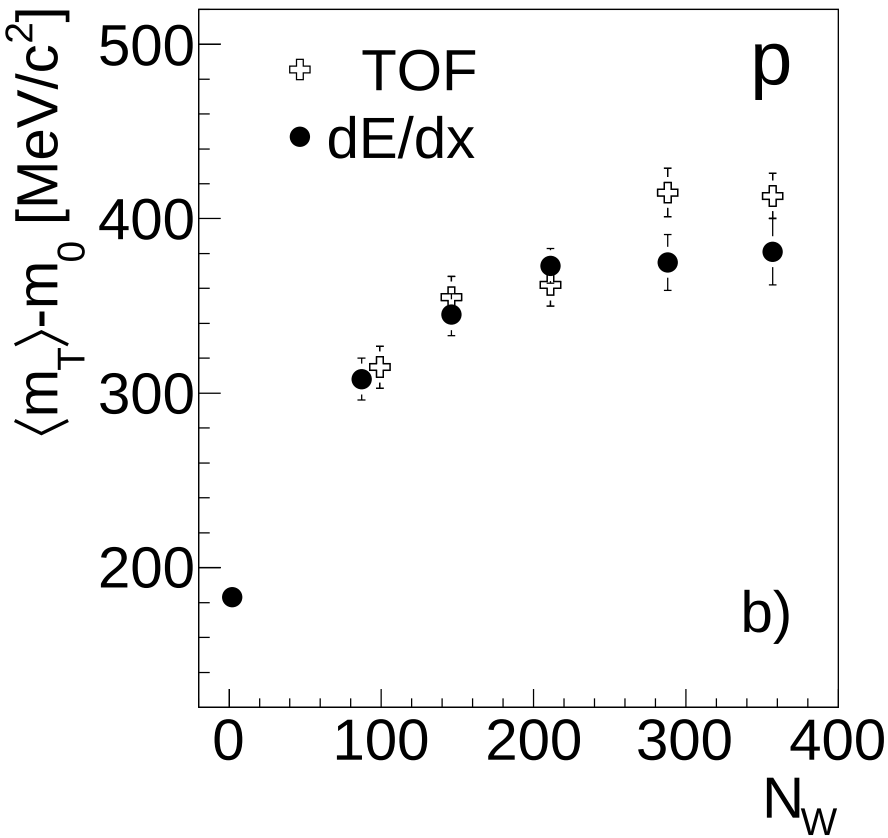
**<$m_T$> as function of the number of wounded nucleons (y=0)**

(note $N_w$ values)

**40 GeV/u**



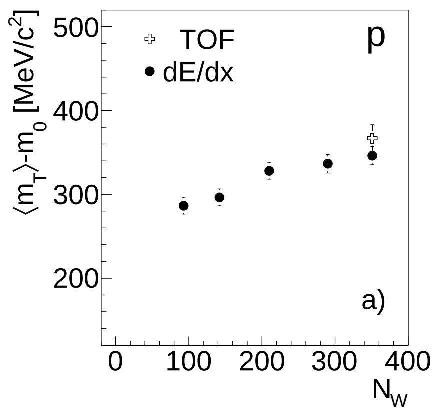

**158 GeV/u**



# proton spectra in the SPS energy range

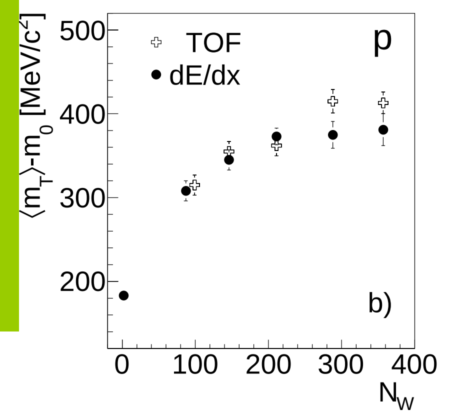
**$<m_T>$ as function of the number of wounded nucleons**

**40 GeV/u** **158 GeV/u**



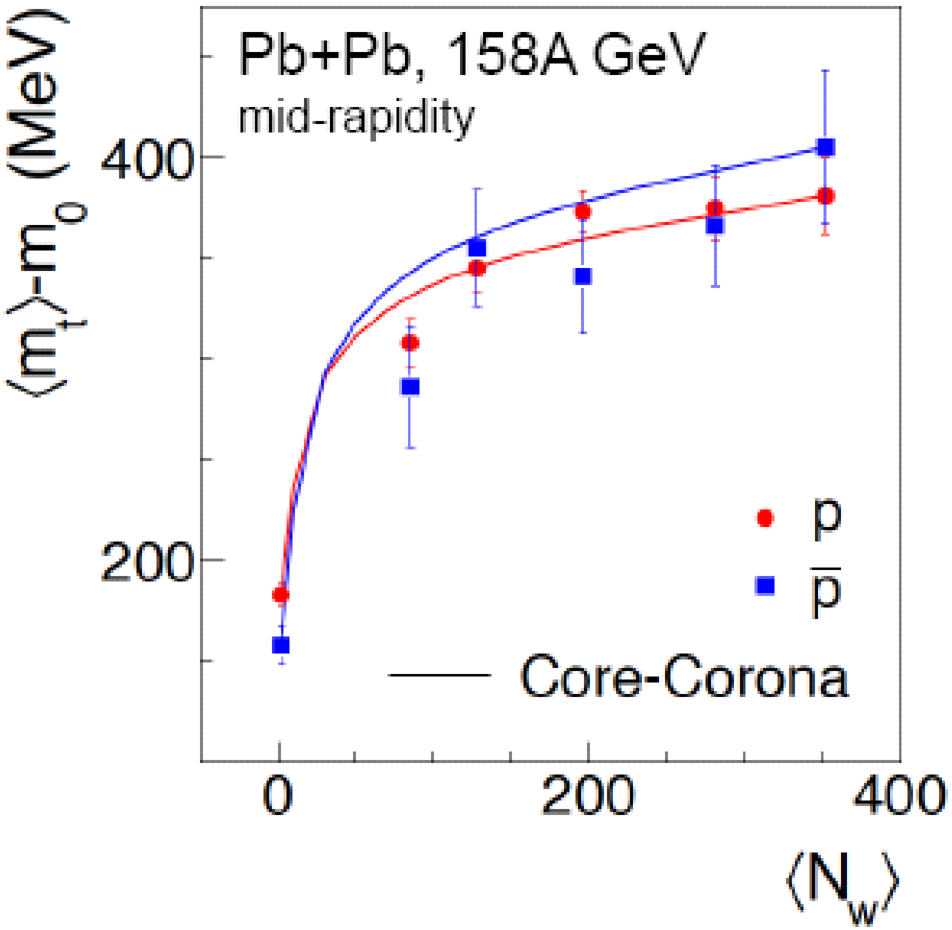

**Fast rise from 180 MeV for p+p to 300 MeV for Pb+Pb at $N_w$ = 100.**
**Then smooth increase to 350 MeV at 40 GeV/u and 380 MeV for 158GeV/u.**

**Strongest change from p+p to peripheral Pb+Pb!**



# proton spectra in the SPS energy range

<$m_T$> is well described by the core-corona model.
See C. Blume
J. Phys.Conf. Ser. 230 (2010)012003 and PRC80(1009)034906

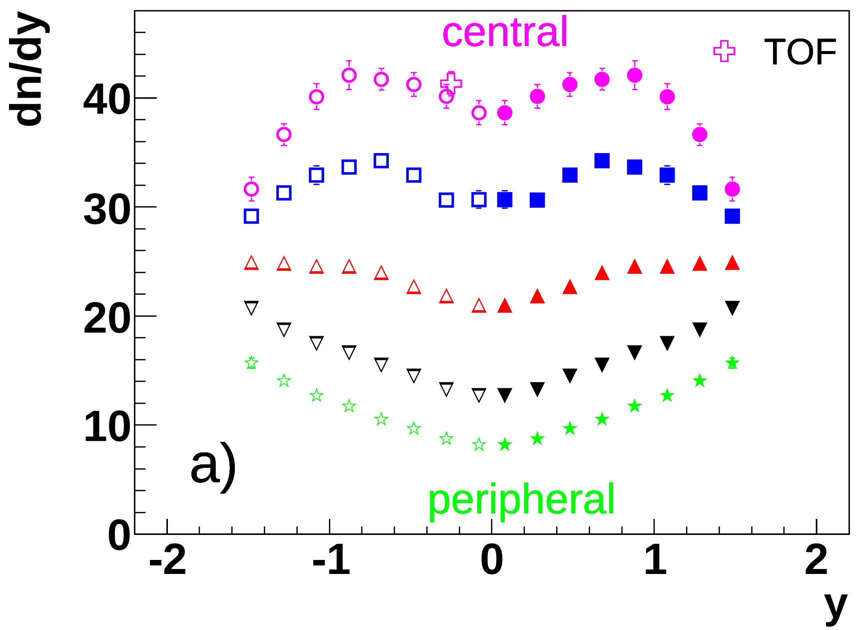


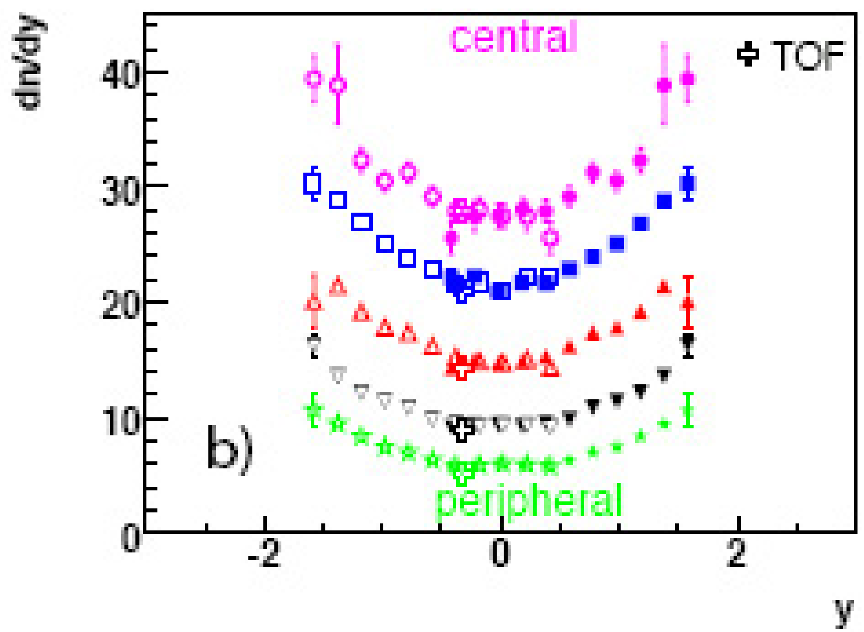
# proton spectra in the SPS energy range

Rapidity distributions of (net) protons for different centralities
(beam rapidity coincides with end of scale).

40 GeV/u

158 GeV/u



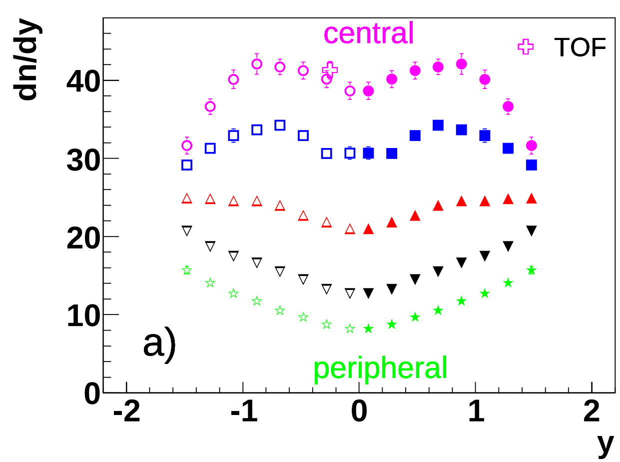



# proton spectra in the SPS energy range

Rapidity distributions for different centralities

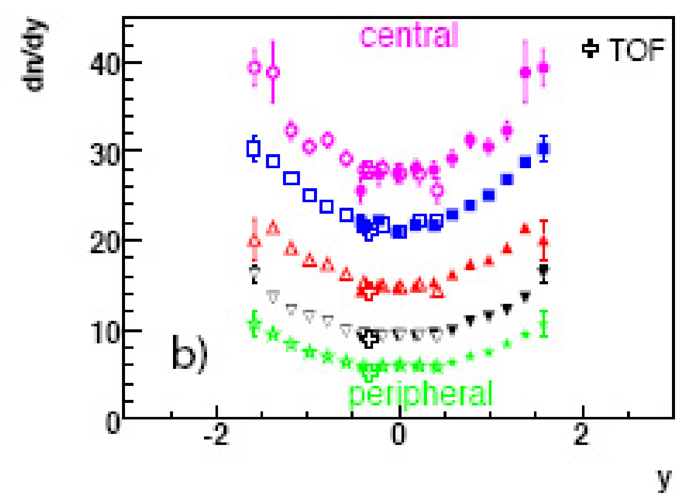
40 GeV/u

Significant change of shape.
The peaks start to overlap.




158 GeV/u

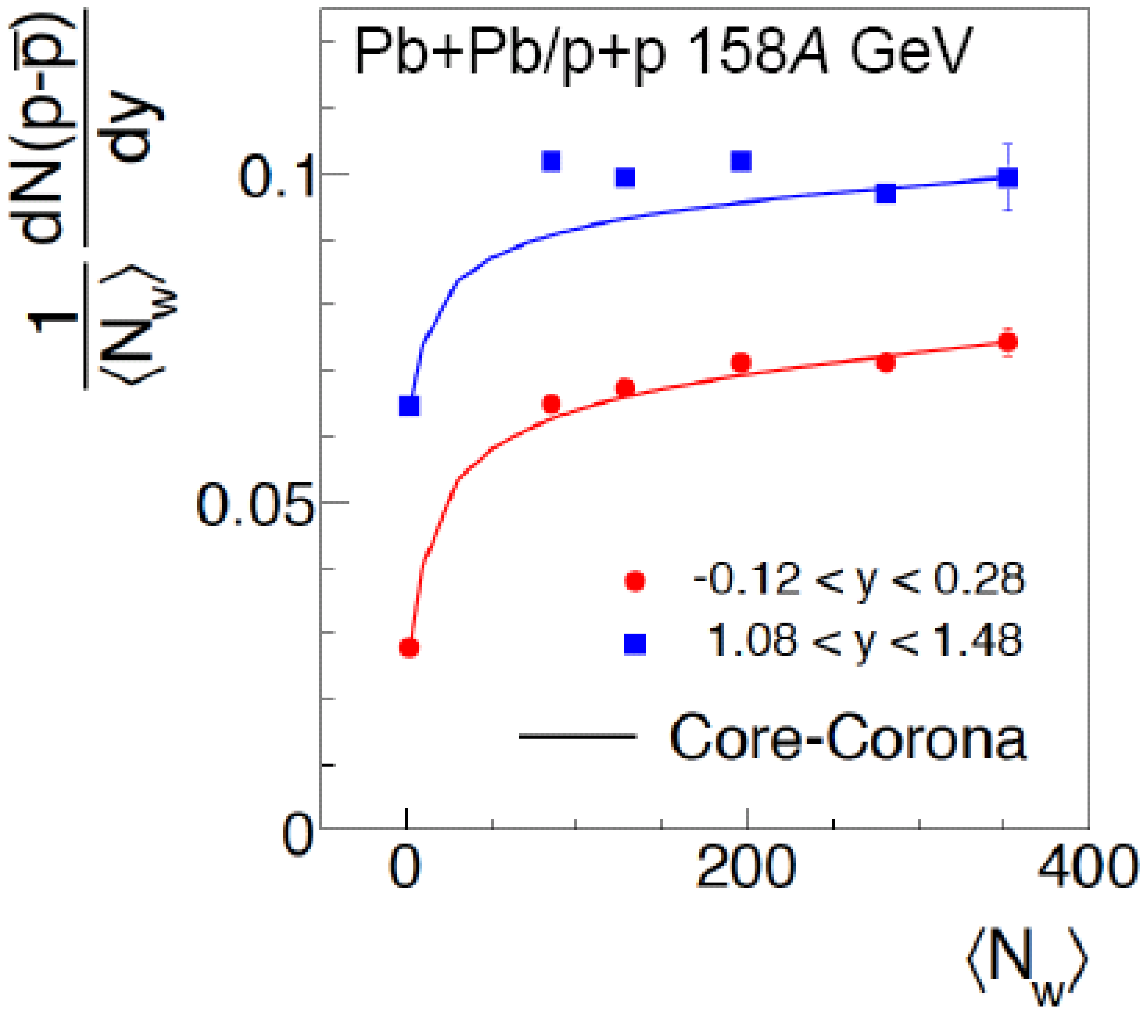
Gradual change.



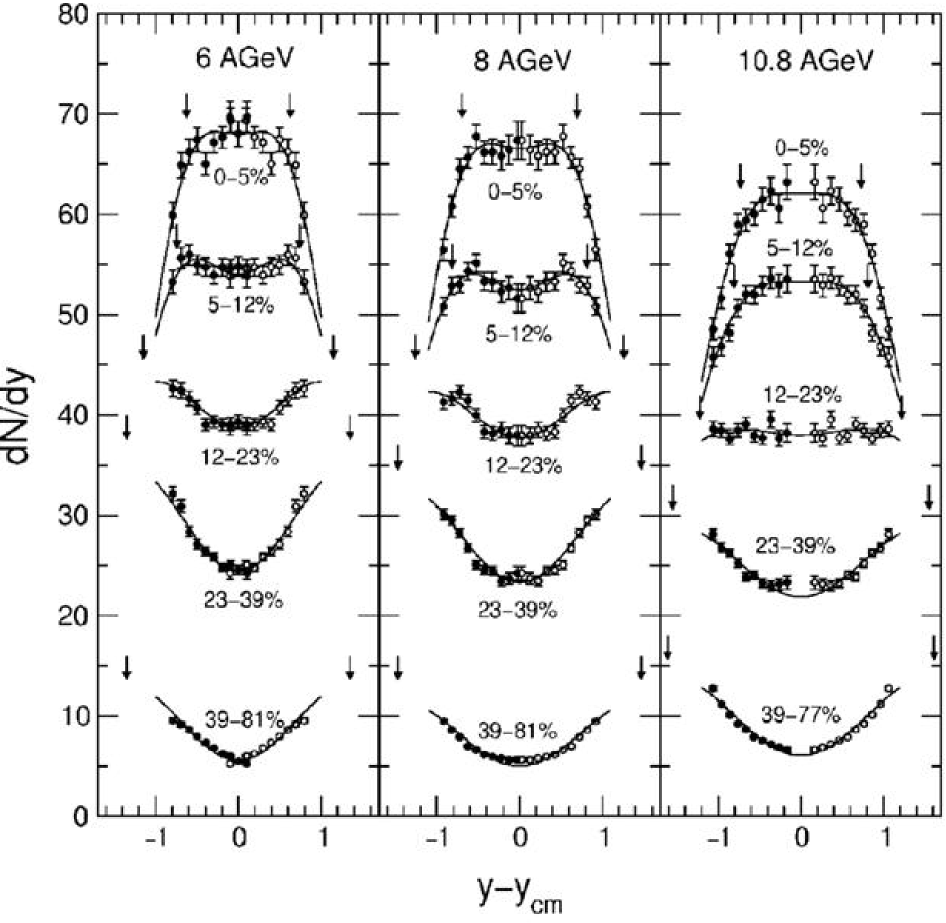
# proton spectra in the SPS energy range

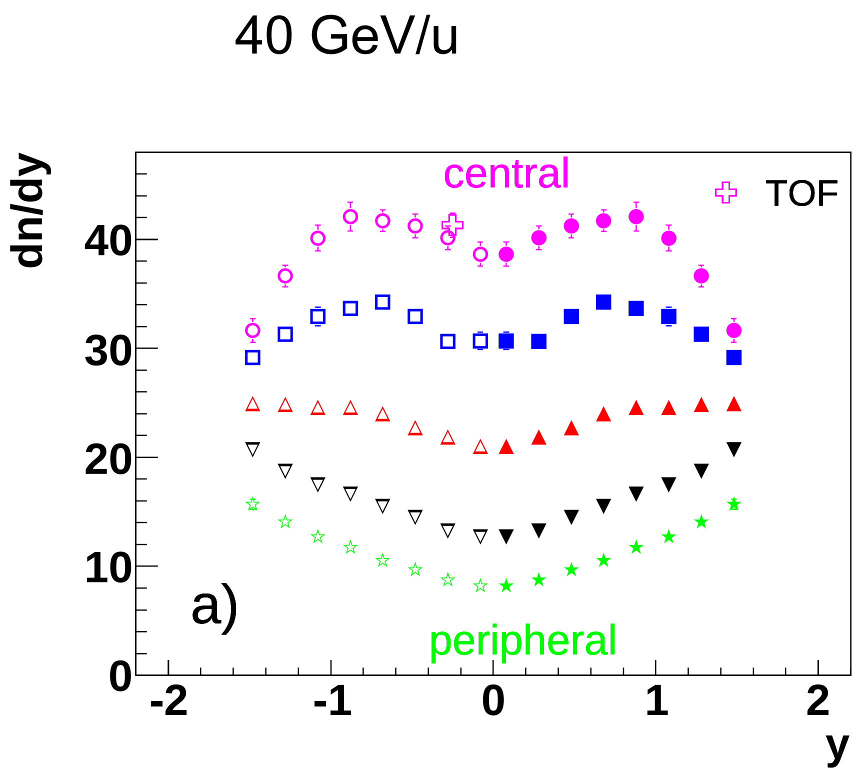
net protons

Core-corona model does not work for the protons!



# Centrality dependence at AGS




**(Back et al., PRL86(2001)1970)**

**No midrapidity plateau at 40 GeV/nucleon.**

# Centrality dependence at AGS

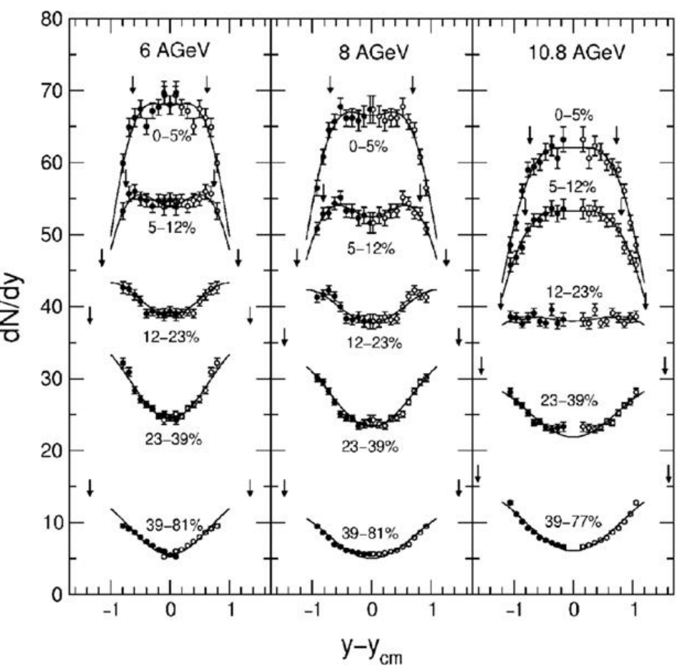
Centralities:

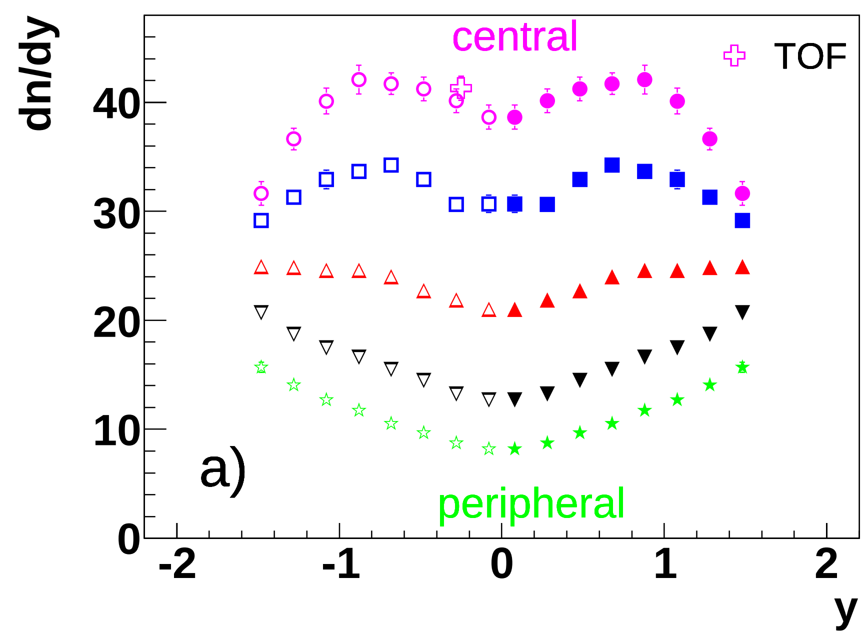
AGS | 0-5%, 5-12%, 12-23%, 23-39%, 39-80%.

$N_w$ | 339, 278, 202, 116, 30. (my estimates)

SPS | 0-5%, 5-12.5%, 12.5-23.5%, 23.5-33.5%, 33.5-43.5%.

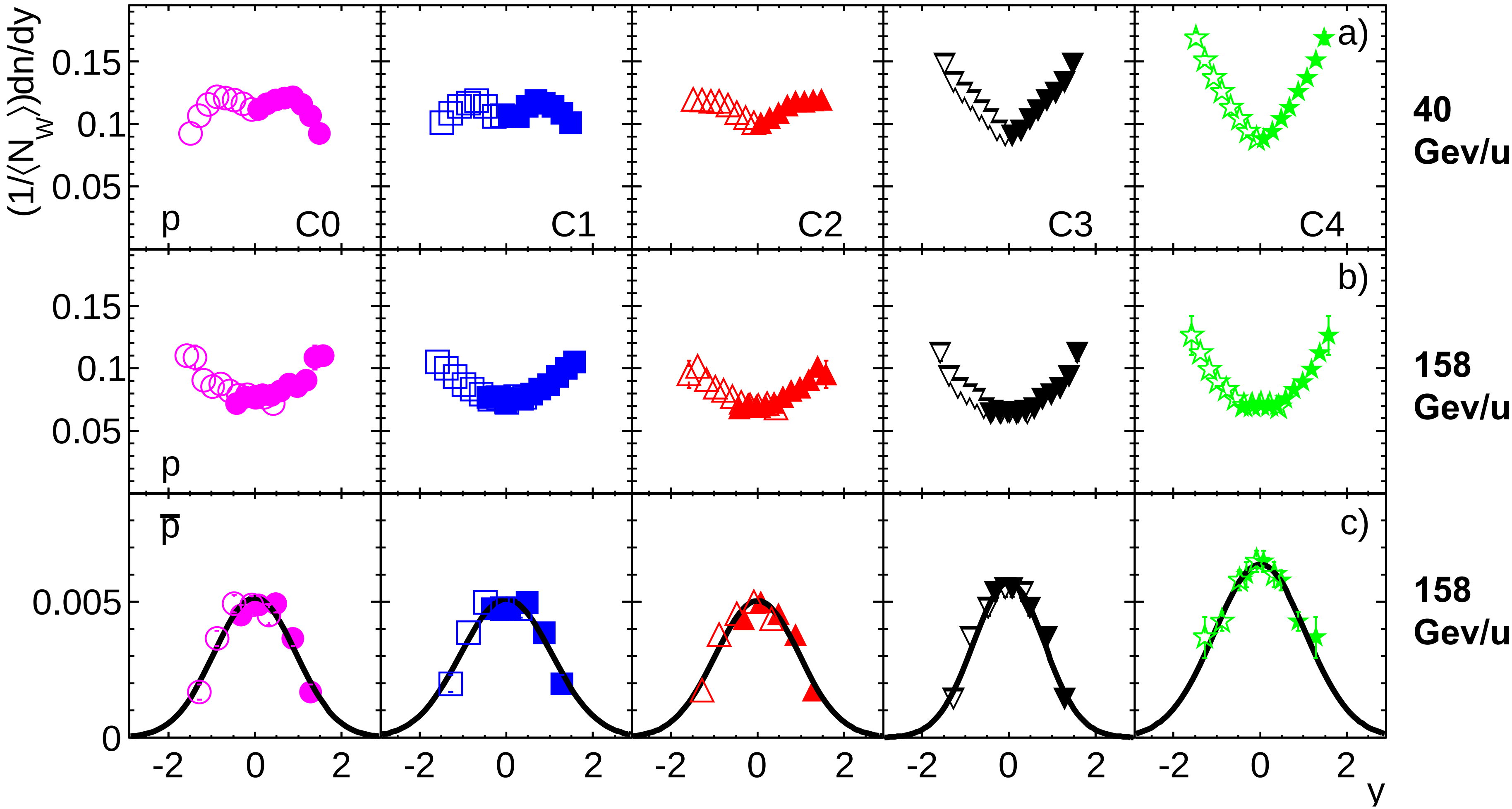
$N_w$ | 356, 292, 212, 144, 90.



# proton spectra in the SPS energy range

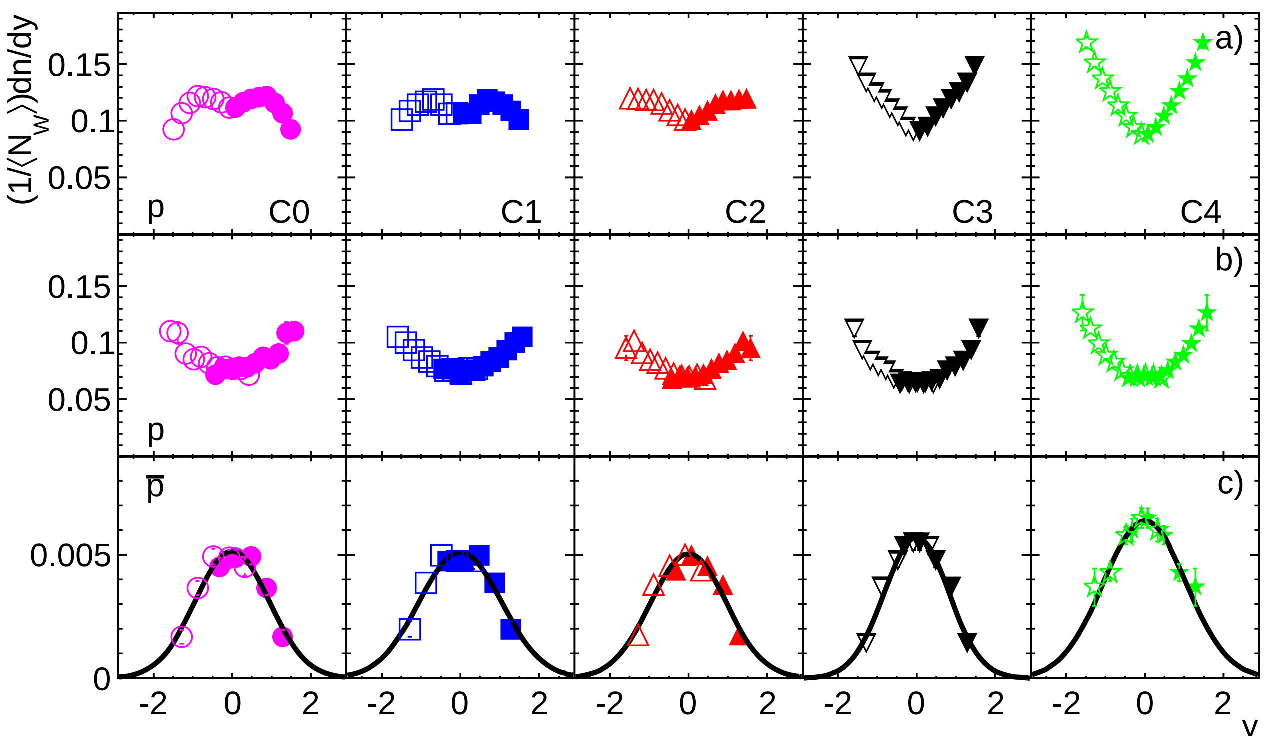
**dn/dy normalized to the number of wounded nucleons**



# proton spectra in the SPS energy range

**Integrals should all be the same (appr. 0.5)!**
**They increase with impact parameter.**
**Cross check with transport models.**

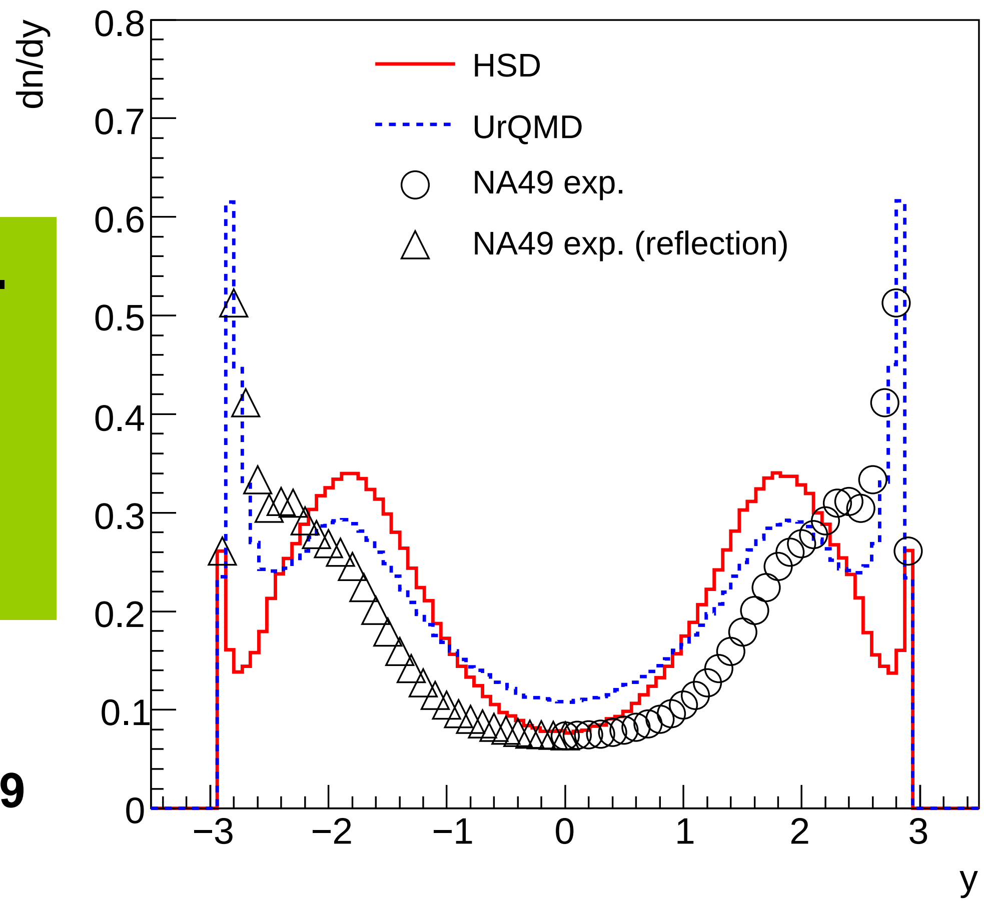
| **AGS** | | |
|---|---|---|
| 6 | 8 | 10.8 |
| 0,48 | 0,50 | 0,46 |
| 0,50 | 0,52 | 0,46 |
| 0,56 | 0,60 | 0,61 |
| 0,65 | 0,68 | 0,75 |
| 0,81 | 0,78 | 1,40 |



# proton spectra in the SPS energy range

p+p => net protons at 158 GeV/c

**Both models do fairly well.**
**But the range**
**|y| ≈ 2 to 3 is critical!**
**Δy = 1 means 50% energy loss!**



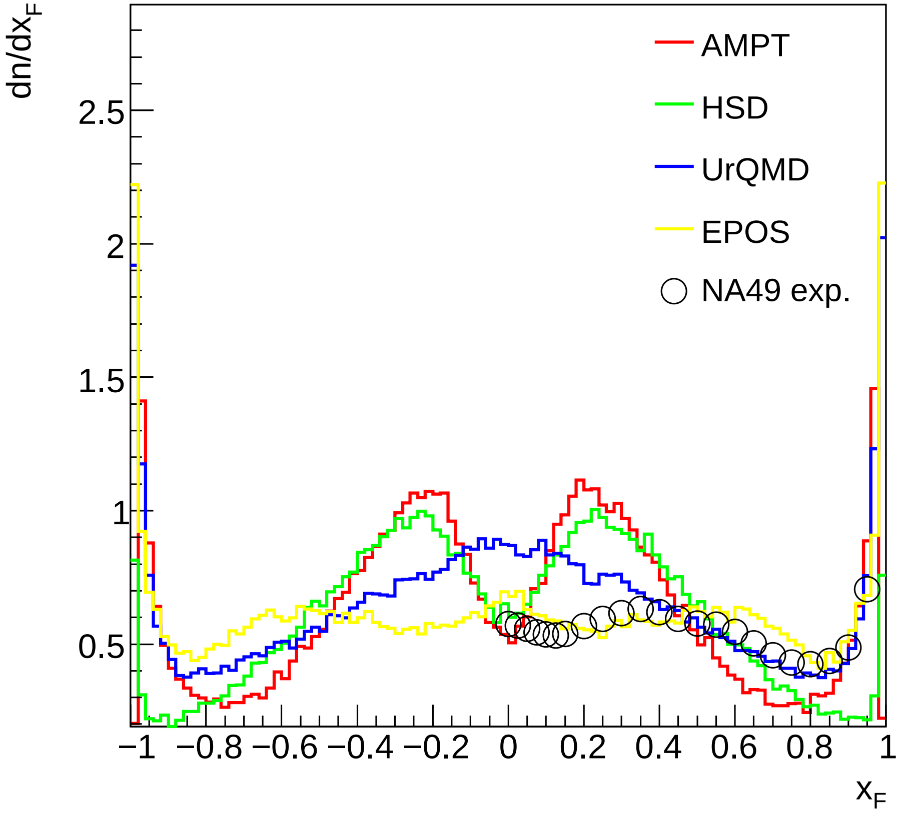

**Data: T. Antici et al., EPJC65(2010)9**

# proton spectra in the SPS energy range

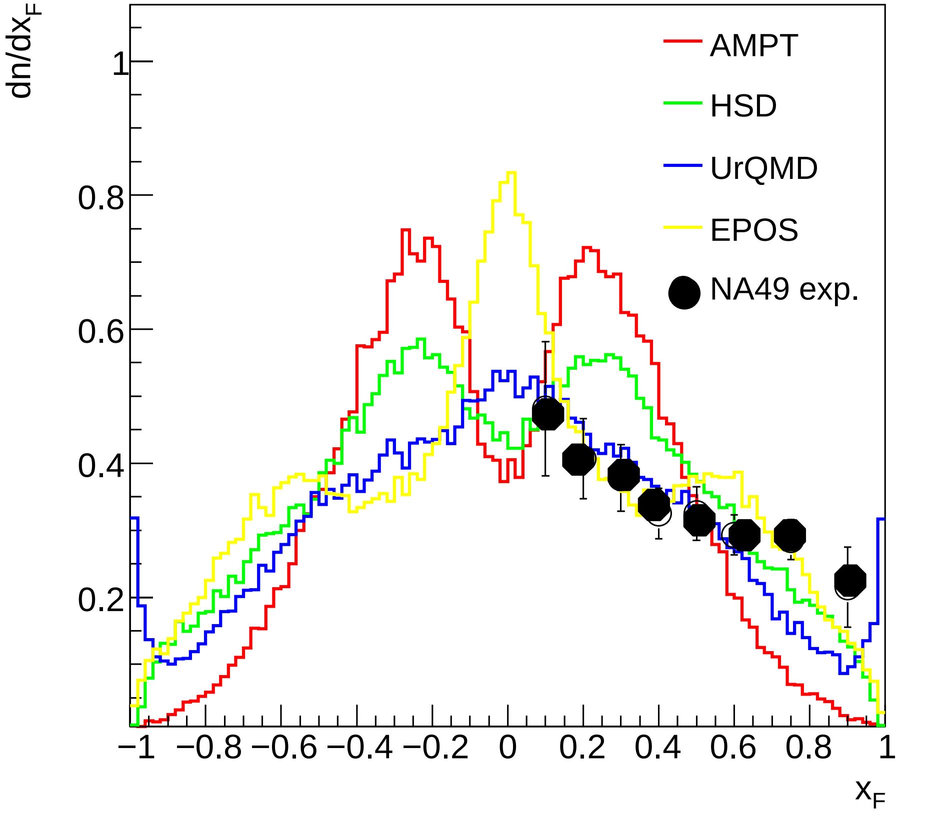
**p+p => protons and neutrons at 158 GeV/c**

**dn/dx$_F$**

**protons**

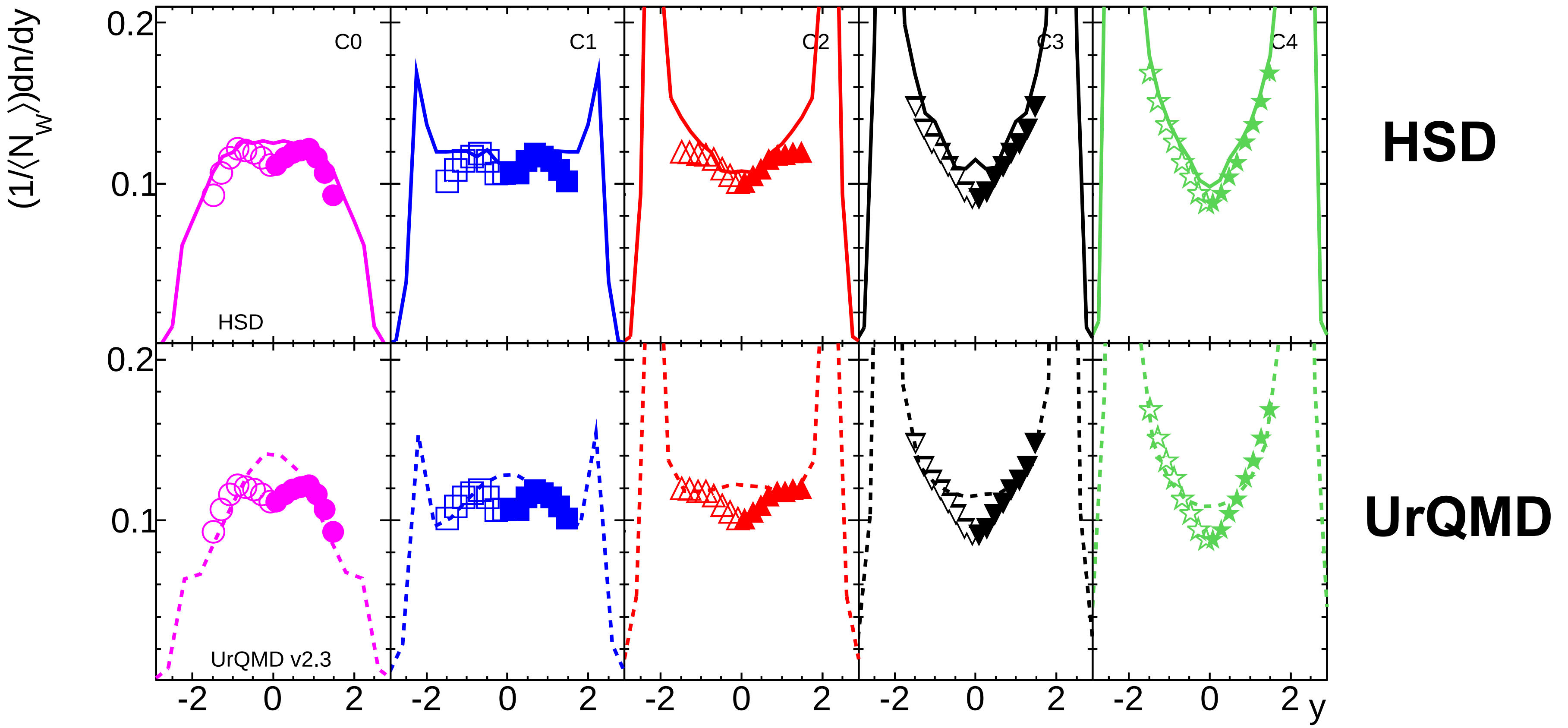



**Neutrons must be included**

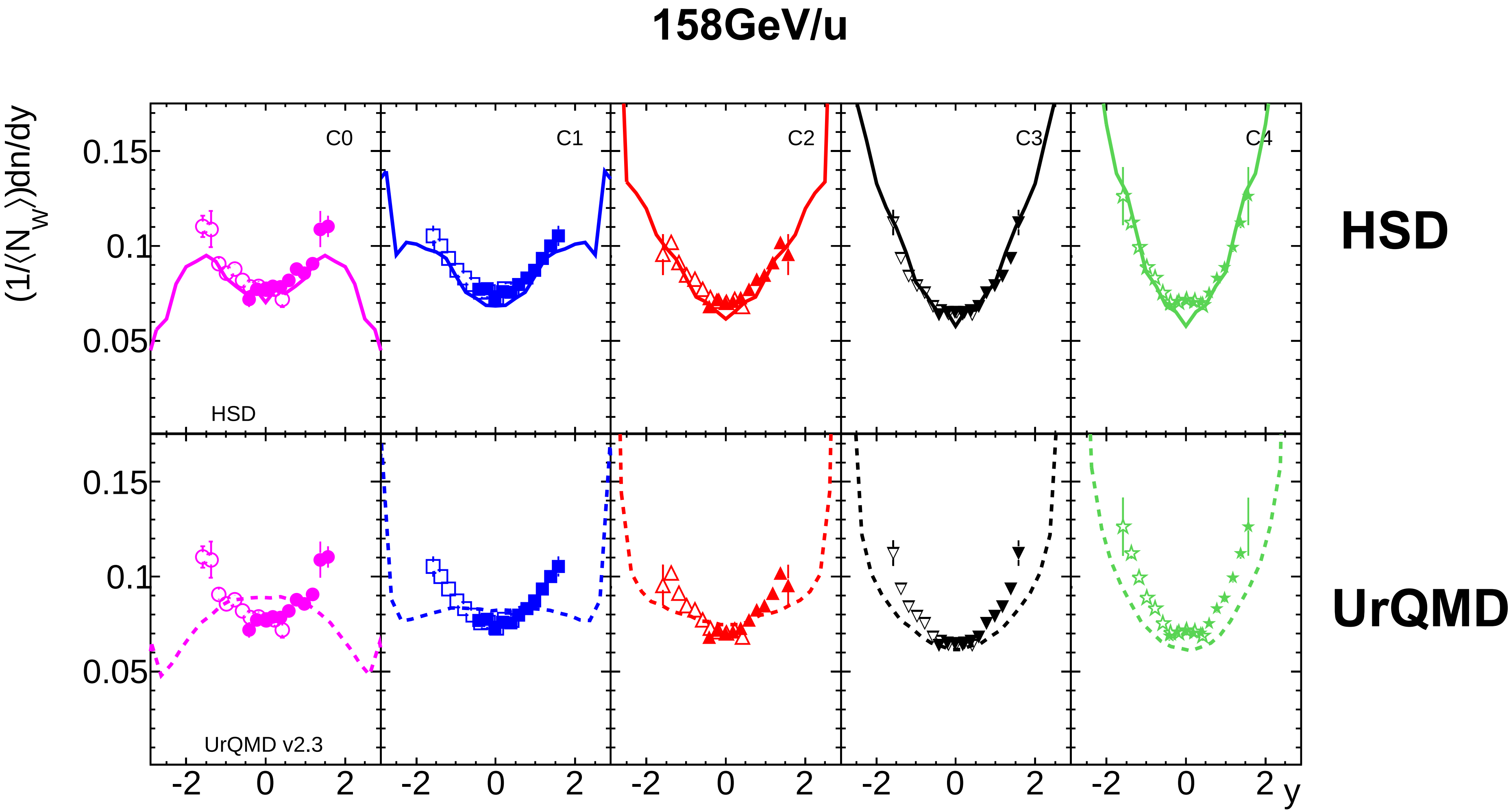


# proton spectra in the SPS energy range

**40 GeV/u**



# proton spectra in the SPS energy range

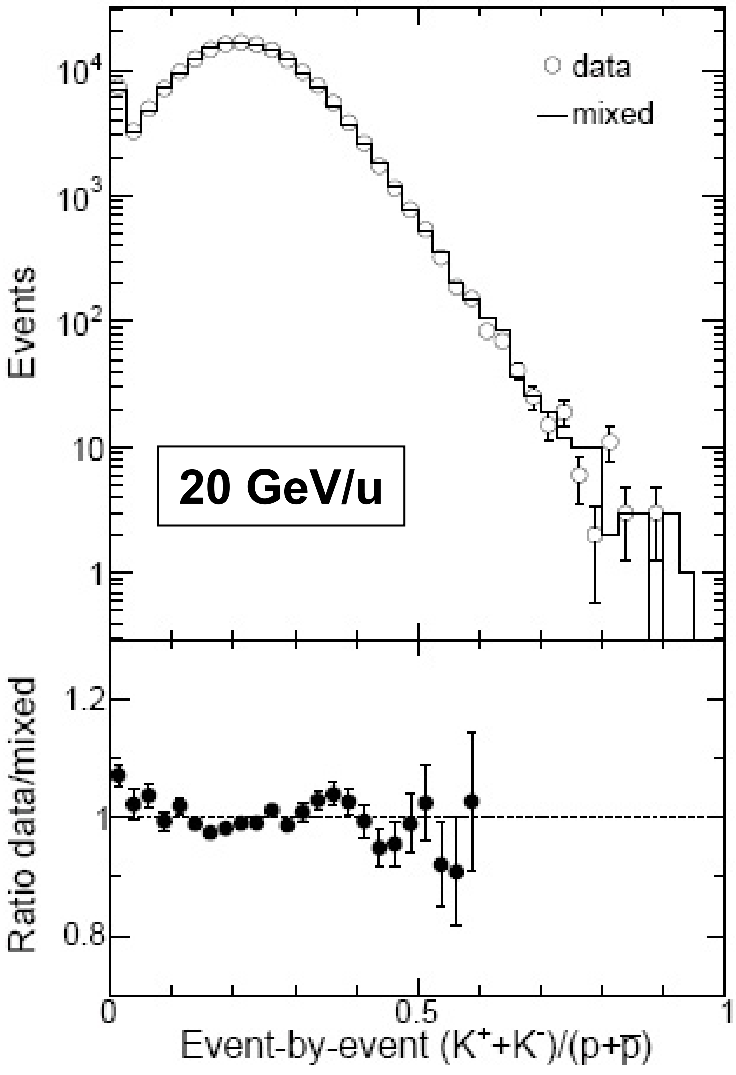


# proton spectra in the SPS energy range

•Rapidity shift and stopping analyses in peripheral collisions are problematic.
•Participating and wounded nucleons are not the same.
•Some of the nucleons within 1.5 units from beam rapidity. originate from the spectator region (pion nucleon interactions?).
•Core-corona model does not work for proton dn/dy.

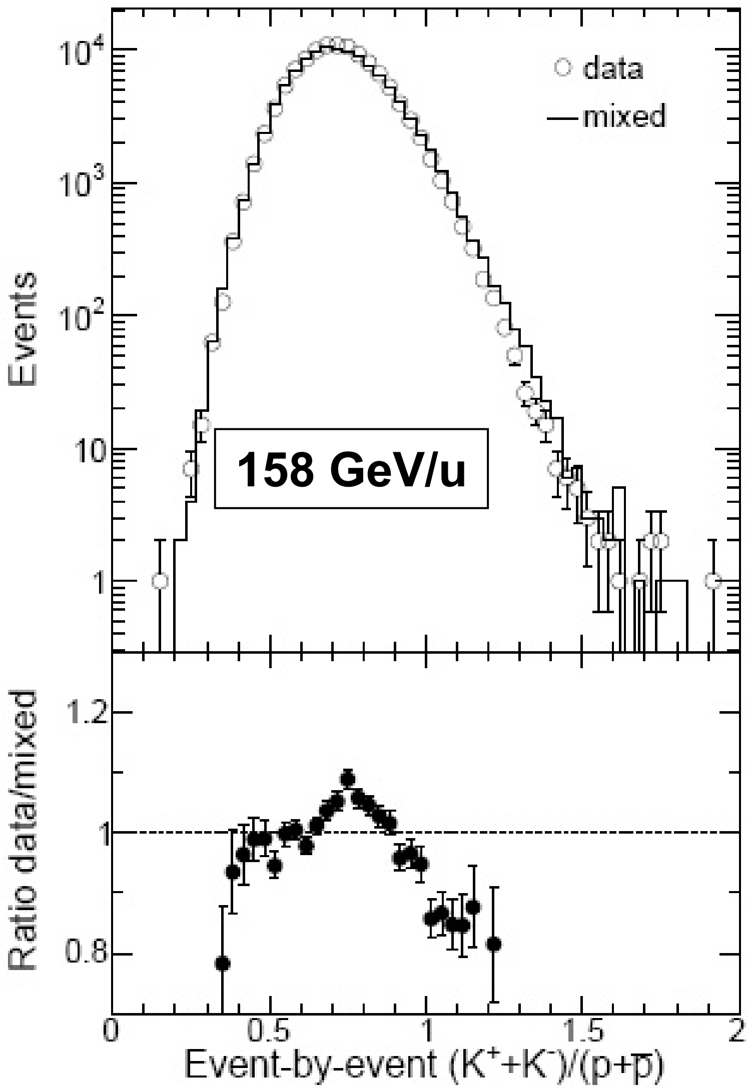
•**Stopping analyses are questionable in peripheral collisions.**

# K/p fluctuations




event-by event ratio of kaon number to proton number in central (3.5%) Pb+Pb collisions.

3 more such plots!



# K/p fluctuations

Motivation

K/p ratio fluctuations probe correlations betweenn baryon number (B) and strangeness (S).

-hadron gas: production of S unrelated to B is allowed (Kaons)

-deconfined medium: S produced in conjunction with (1/3)B

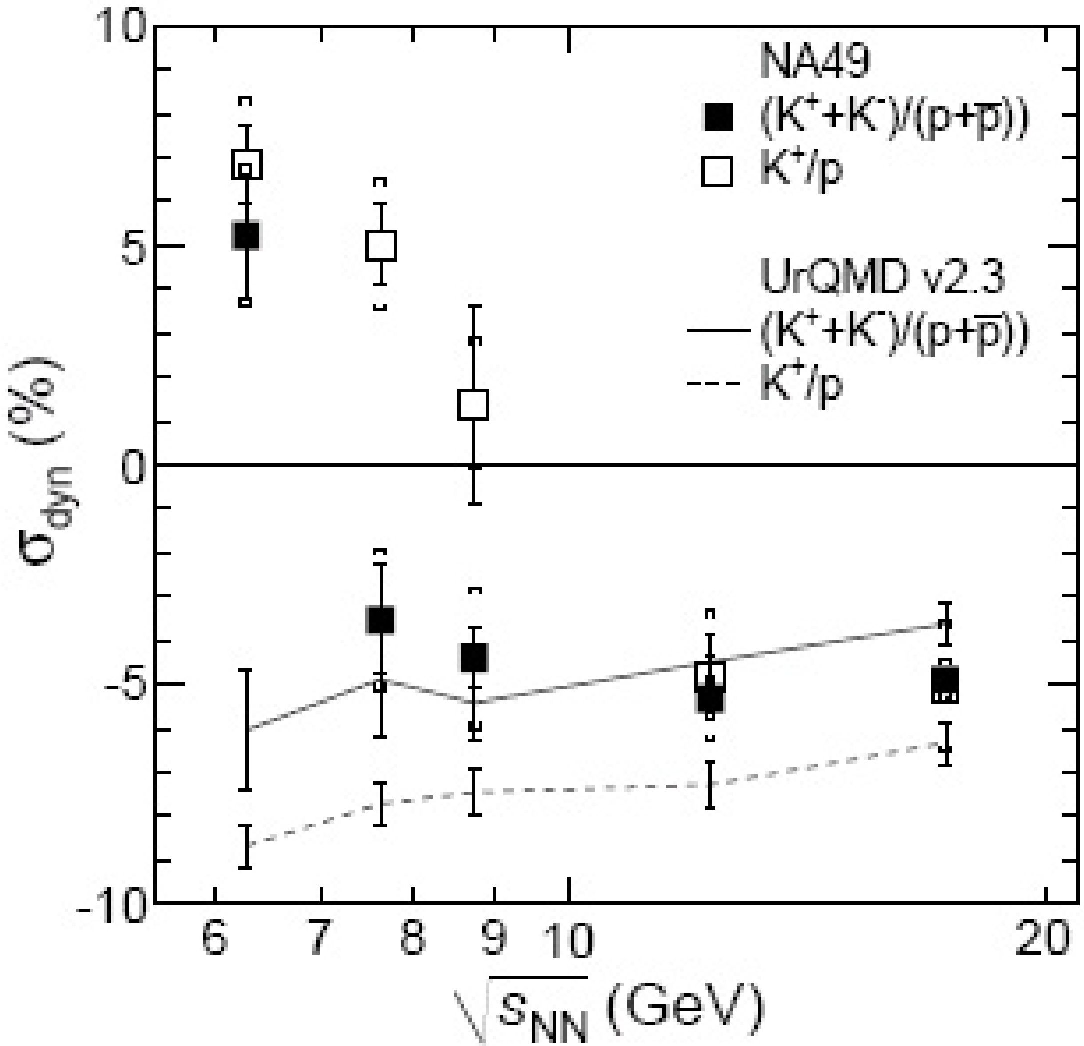
-Correlation coefficient $C_{BS}$ can be estimated, but the precise relation to $\sigma_{dyn}$ is unclear

$\sigma_{dyn} = \text{sign}(\sigma^2_{data} - \sigma^2_{mix}) \sqrt{|\sigma^2_{data} - \sigma^2_{mix}|}$ ; $\sigma^2_{dyn} \approx \nu_{dyn}$

**NA49 data: arXiv:nucl-ex1101.3250 T. Anticic et al., NA49 data, Submitted to PRC.**

**Theory: Koch and Randrup, PRL95(2005)182301**

# K/p versus sqrt(s)

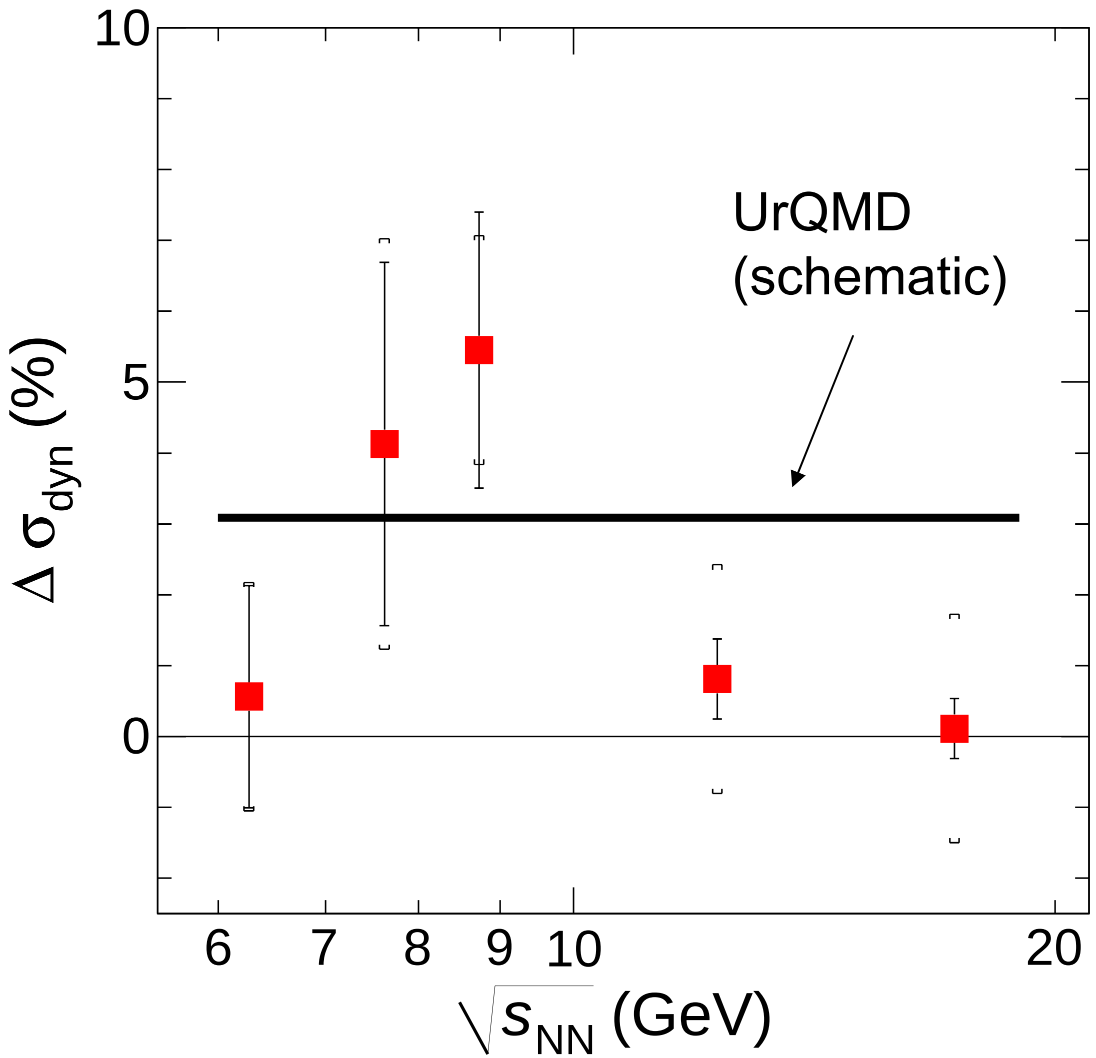


# Difference between $(K^+ + K^-)/(p + \bar{p})$ and $K^+/p$

Assumption: $\bar{p}$ negligible.
Then we "see" here
$K^-p$ correlations.

(too) few $K^-$ at low energies and resonance suppression above onset of deconfinement at high energies?

**UrQMD????**



# Summary

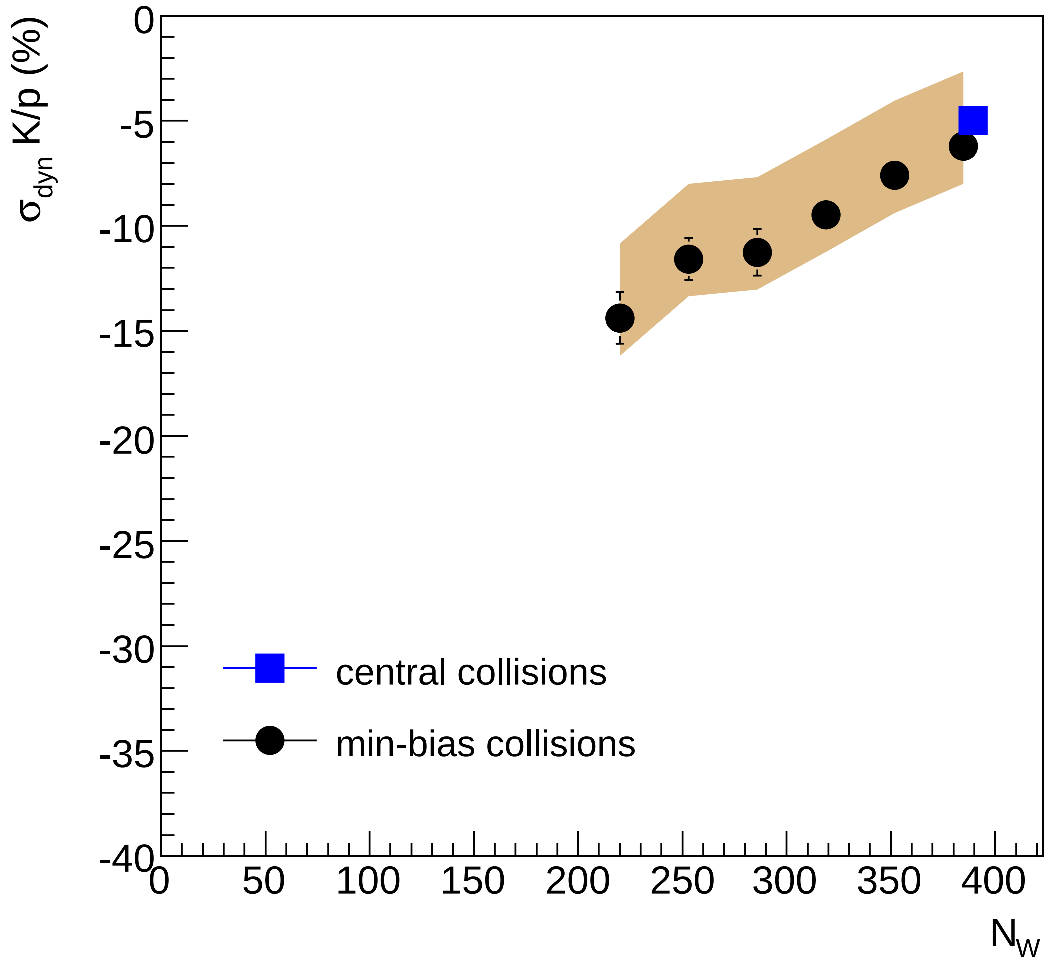
- Region of homogeneity for p-Λ interactions has the same size from AGS (SIS?) to RHIC energies.

- Rapidity shift and stopping analyses in peripheral collisions are problematic.
- Participating and wounded nucleons are not the same.
- Core-corona model does not work for proton dn/dy.

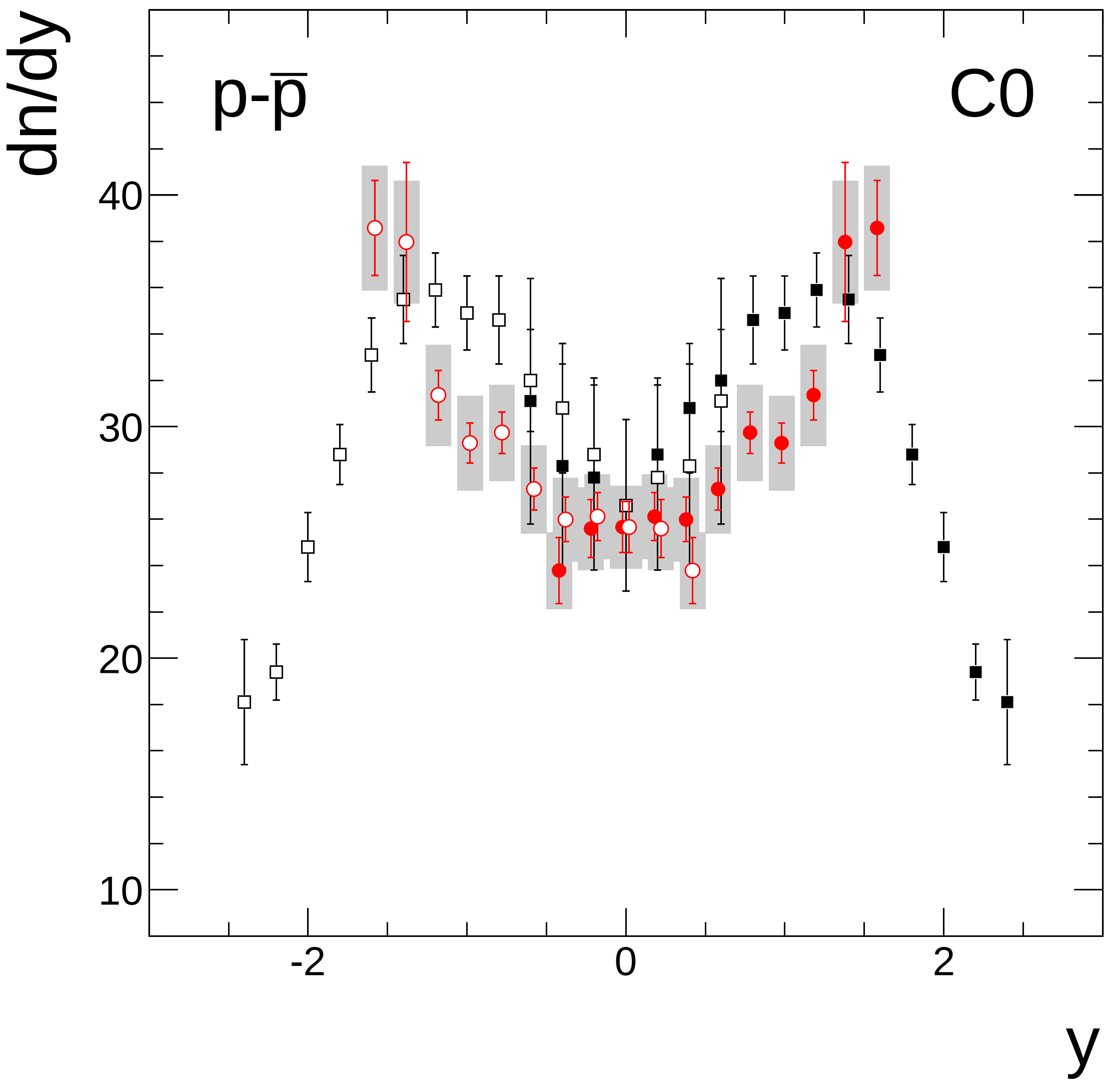
- K/p correlations have been measured. $\sigma_{dyn}$ changes sign and increases with decreasing $\sqrt{s}$. Signal in $K^-$/p correlation?

# Back-up

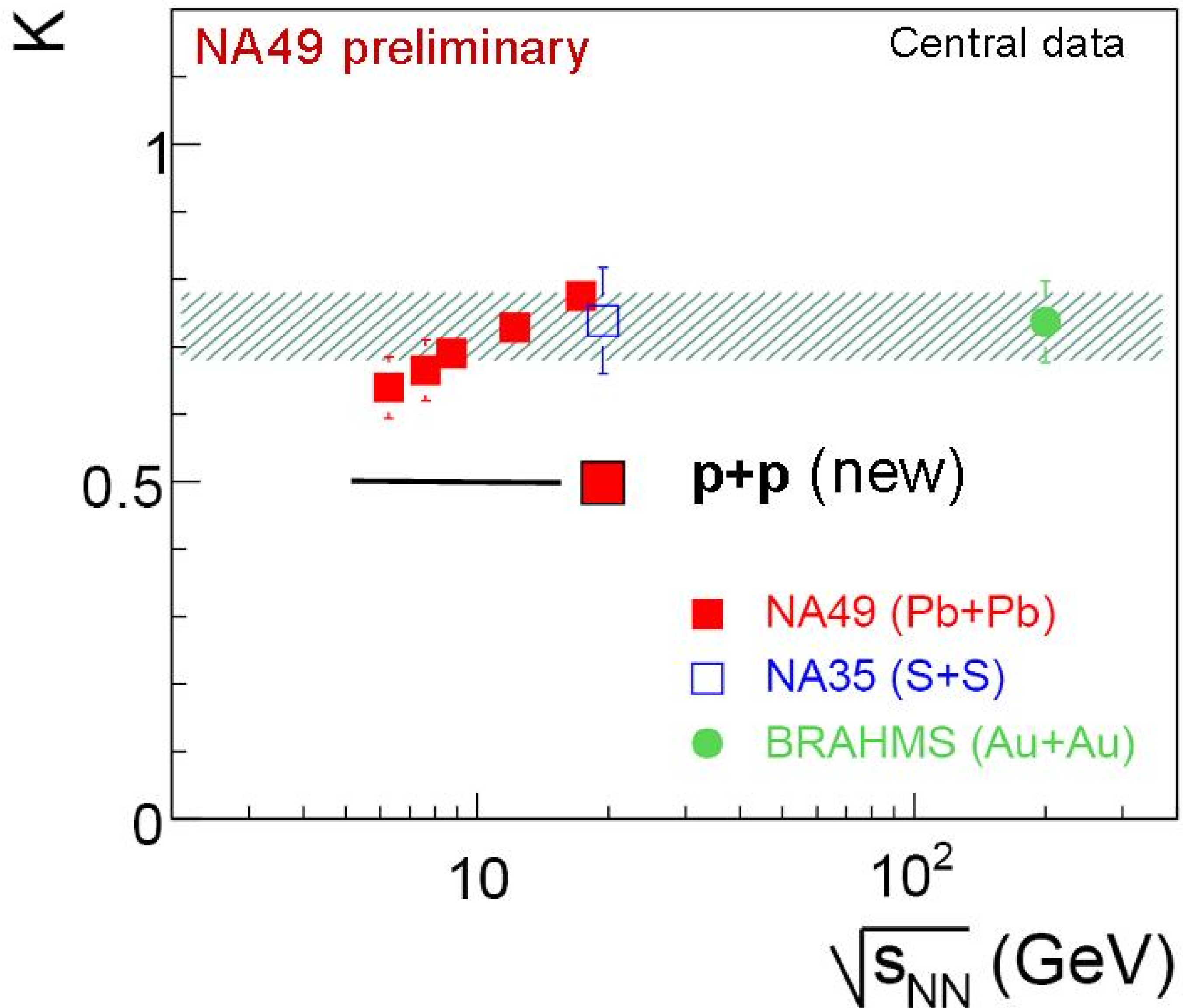
# K/p versus centrality



# Comparison to earlier data

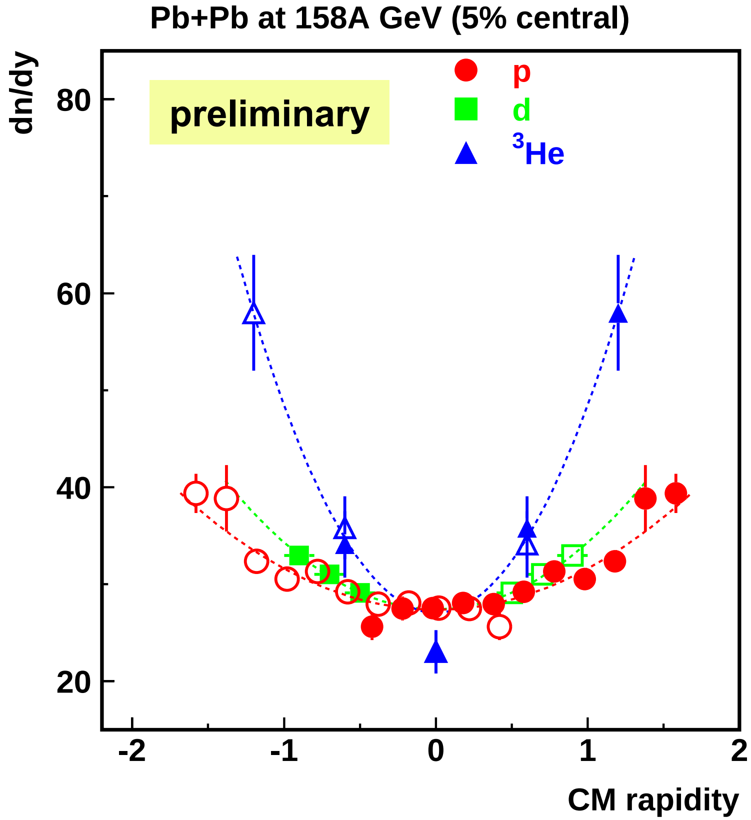


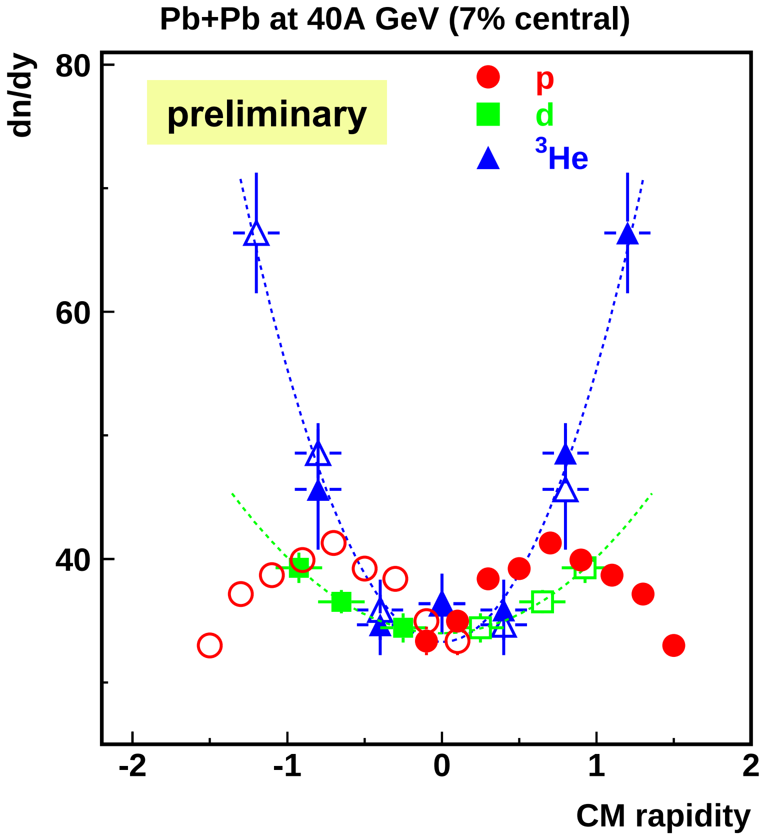
# inelasticity



# The (new NA49) data

**dn/dy of net protons, d, and 3He in central Pb+Pb**
**at 158 and 40 GeV/nucleon**




**Mapping of configuration space on rapidity?**