Transverse dynamics at the SPS

Radial flow and <p_t> fluctuations

Marco van Leeuwen

Introduction

Focus on NA49 data

- m_T spectra in central Pb+Pb at 40, 80, 158 AGeV
  +central C+C, Si+Si
- Deuteron coalescence at three energies
  +centrality dependence
- System size dependence of φ_{pt} at 158 AGeV

Other data at 158 AGeV (and 40AGeV) from

- Hyperons at midrapidity WA97/NA57
- Kaons, pions, protons at midrapity NA44
- Dimuons NA50
- Dielectrons (+hadrons) CERES (NA45)
- (anti-) protons, deuterons at p_T=0 NA52

Transverse mass spectra at 40 *A*GeV

Transverse flow fit

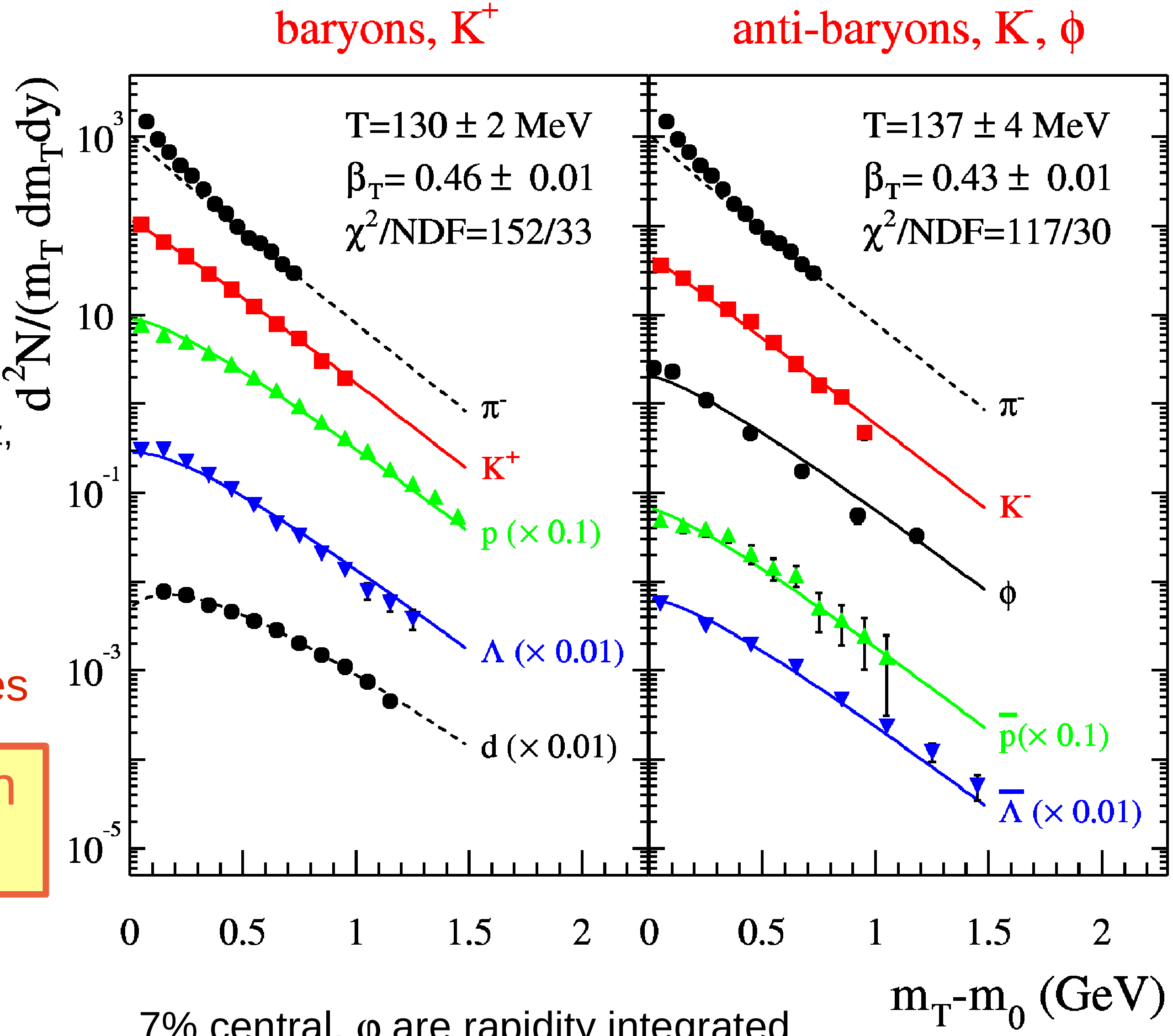
$$\frac{dN}{m_T\, dy\, dm_T} \propto m_T K_1\left(\frac{m_T \cosh\rho}{T}\right) I_0\left(\frac{p_T \sinh\rho}{T}\right) \qquad \rho = \mathrm{atanh}\,\beta_T$$

Schnedermann, Sollfrank, Heinz, Phys. Rev. C 48 (1993), 2462

Using simplest approach:
Single freeze-out velocity,
no feeddown from resonances

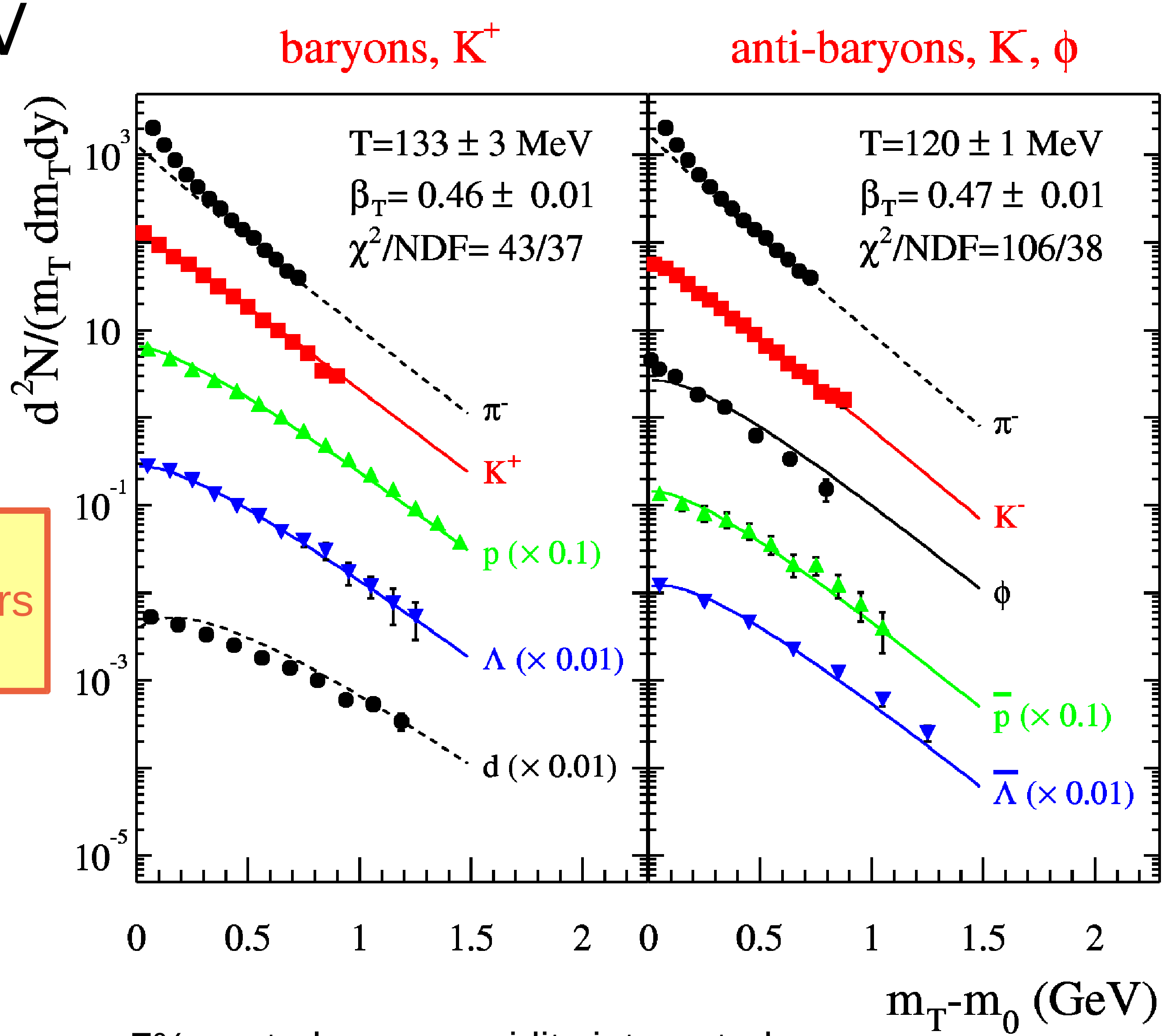
Reasonable description of spectra

not included in fit:
π due to resonance contribution,
d due to coalescence formation



7% central, φ are rapidity integrated

Transverse mass spectra 80 *A*GeV



Reasonable description of data, with flow parameters similar to 40 AGeV

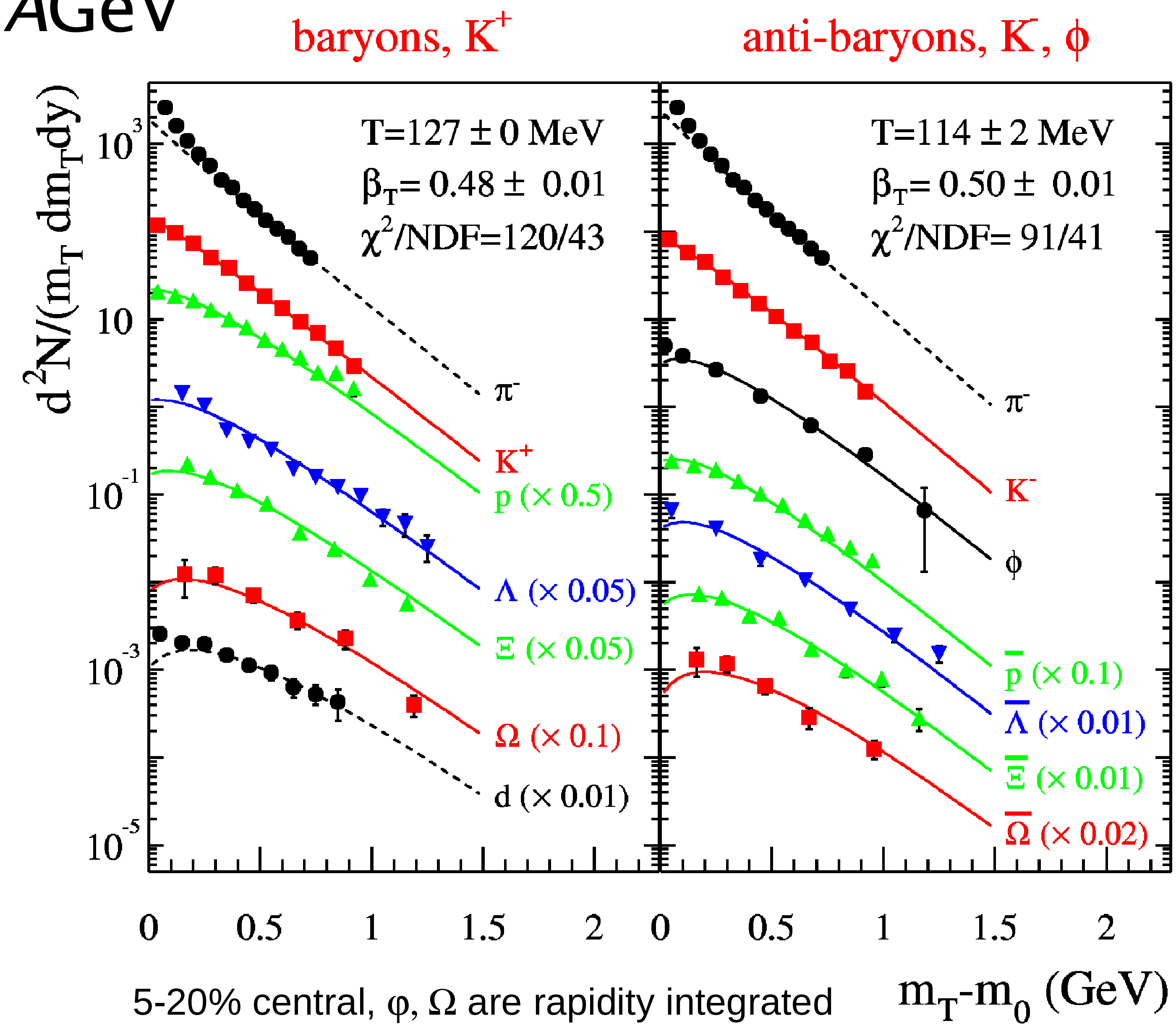
7% central, φ are rapidity integrated

Transverse mass spectra at 158 *A*GeV

More spectra available than at 40, 80 AGeV

Again similar flow parameters

No clear indication of early freeze-out of Ξ and Ω



5-20% central, φ, Ω are rapidity integrated

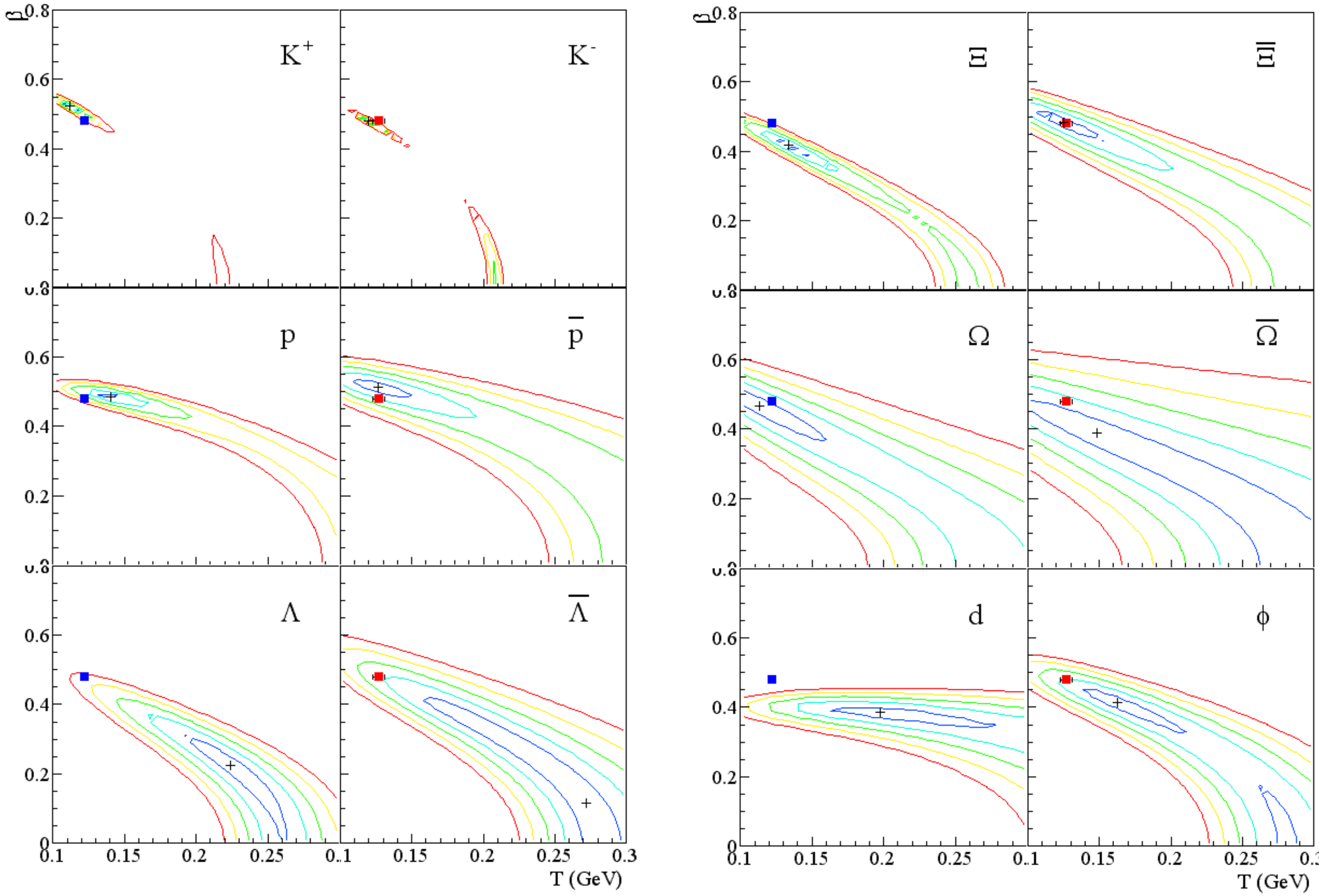
A more detailed look at the fits

158 *A*GeV data

χ^2 contours for fits to each particle species seperately

Only statistical errors

Particles Anti-particles Particles Anti-particles



1,2,3,4,5 σ contours

K, p, Ξ have minima close together

Λ seem to deviate

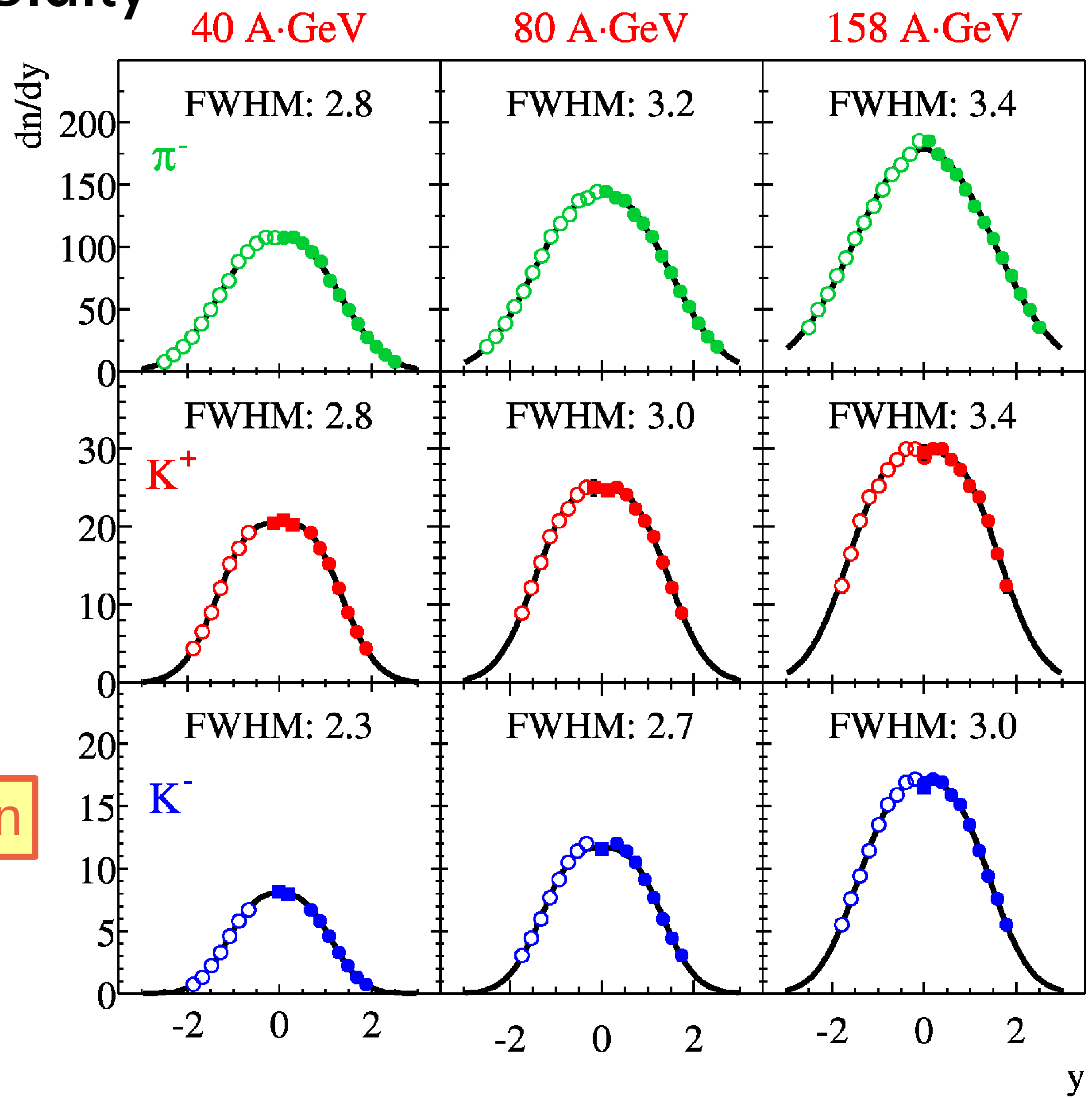
Ω have limited statistical power

Away from midrapidity

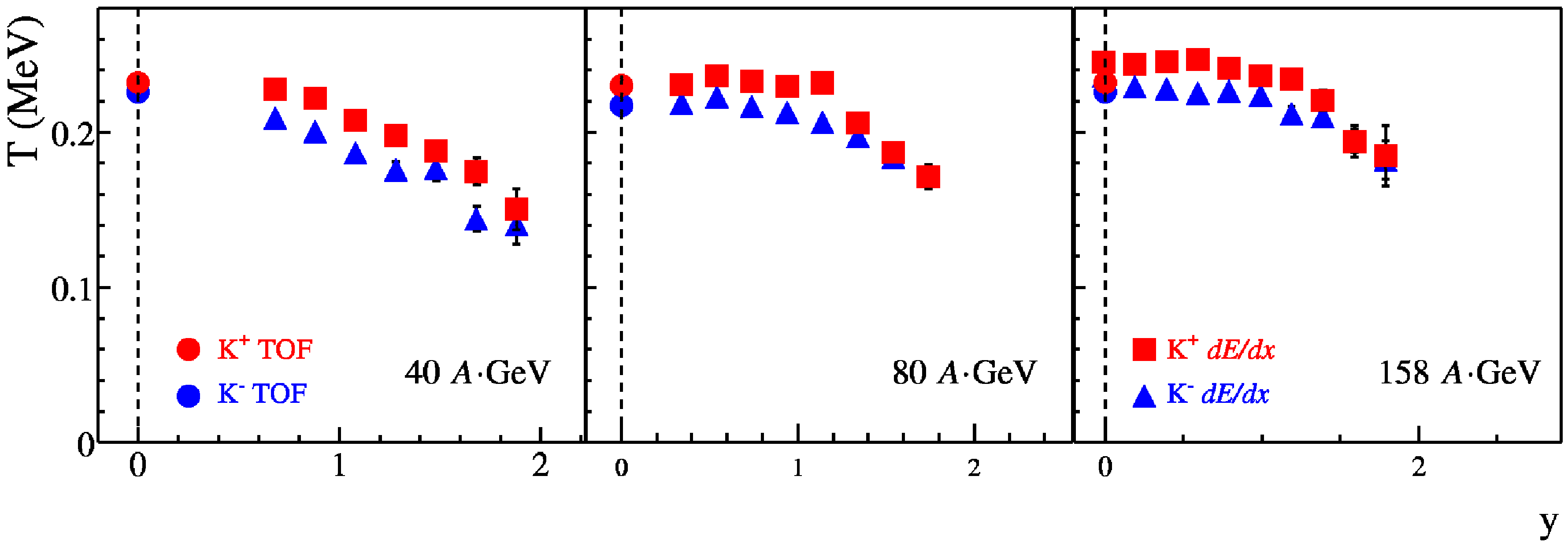
Width increases with beam energy

K^+ distribution wider than K^- at all energies

No boost invariant region



Inverse slope parameters versus rapidity



$$\frac{dN}{m_T\, dm_T} \propto \exp - \frac{m_T}{T}$$

Inverse slope parameter almost constant in a sizeable interval around mid-rapidity.

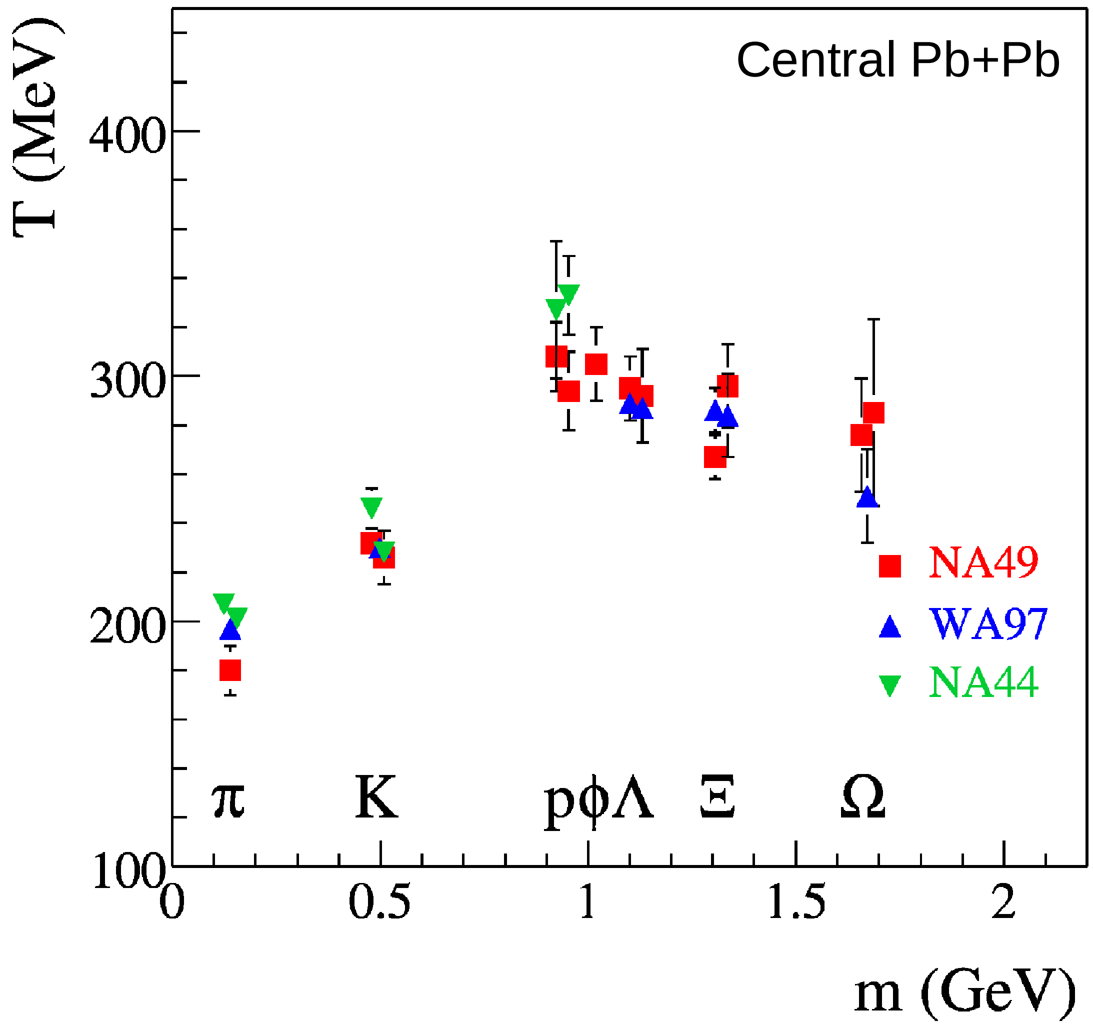
Shapes are approximately 'boost-invariant'

Overview of slope parameters at 158 *A*GeV

Good agreement between different experiments

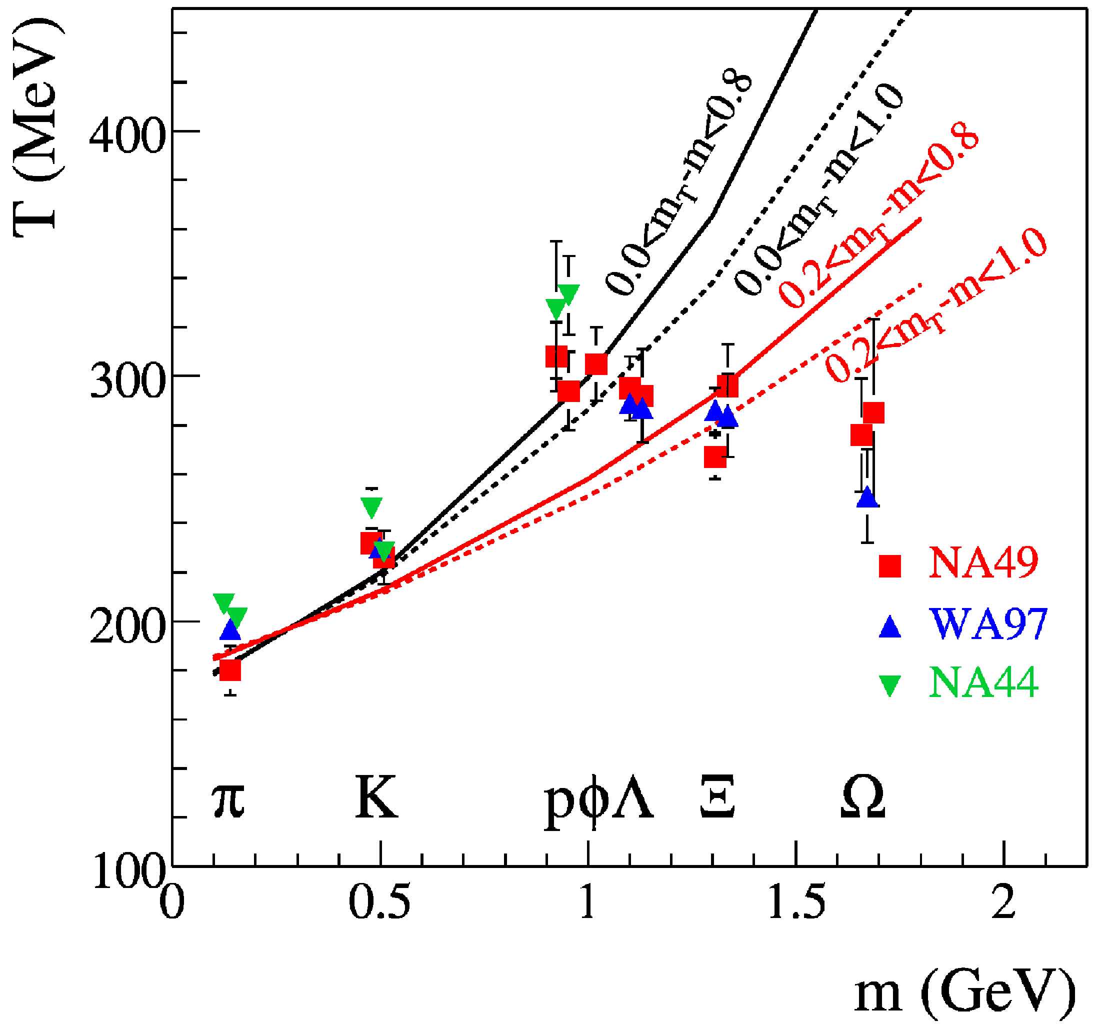
Note: centrality, fitted range is different for different particles and experiments

WA97: Eur Phys J. C 14 (2000) 633
NA44: Phys Rev C 66 (2002) 044907



Overview of slope parameters at 158 *A*GeV

Lines generated using 100 MeV m_T-bins

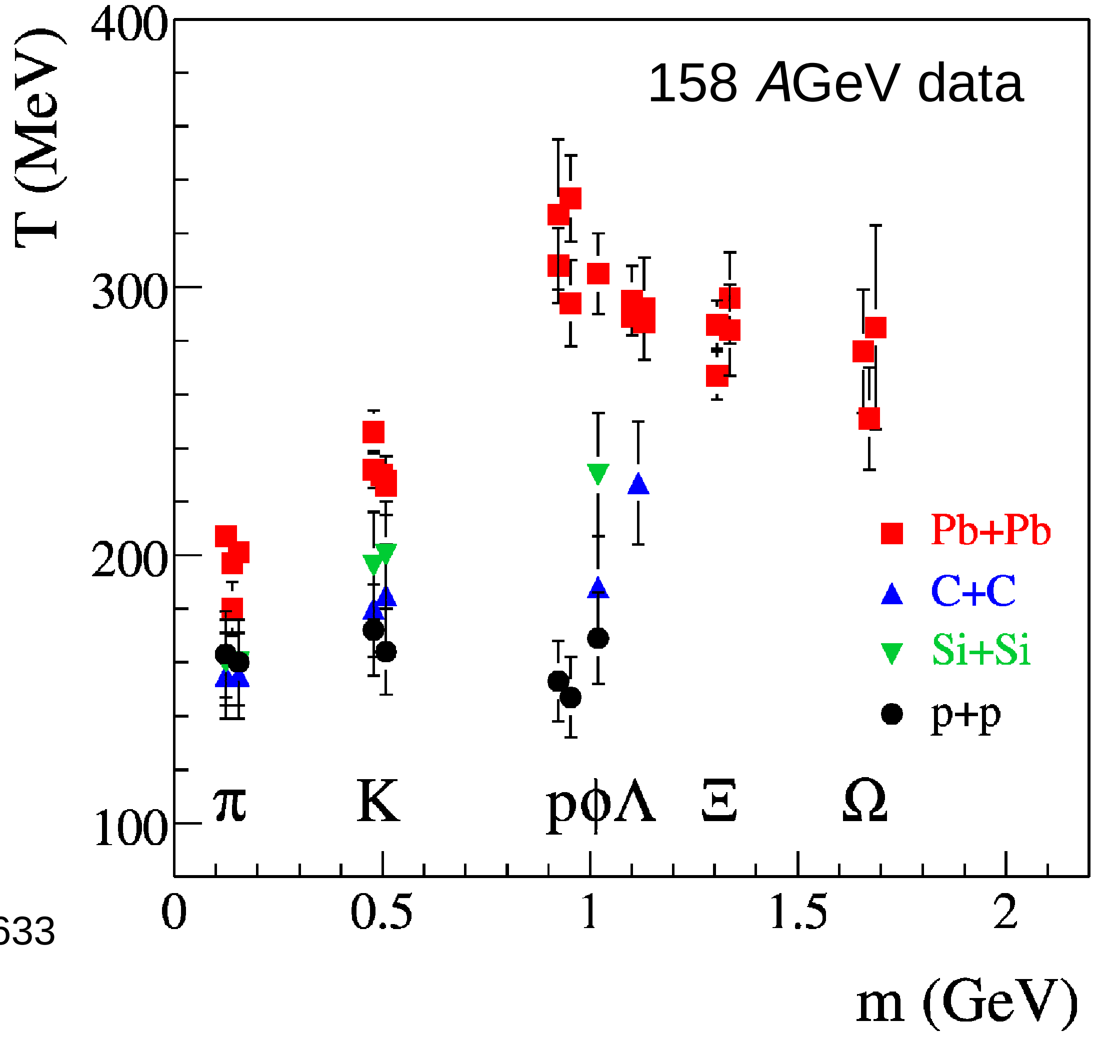


Dependence of inverse slope on fitted range is considerable in blast wave model

WA97: Eur Phys J. C 14 (2000) 633
NA44: Phys Rev C 66 (2002) 044907

System size dependence of flow

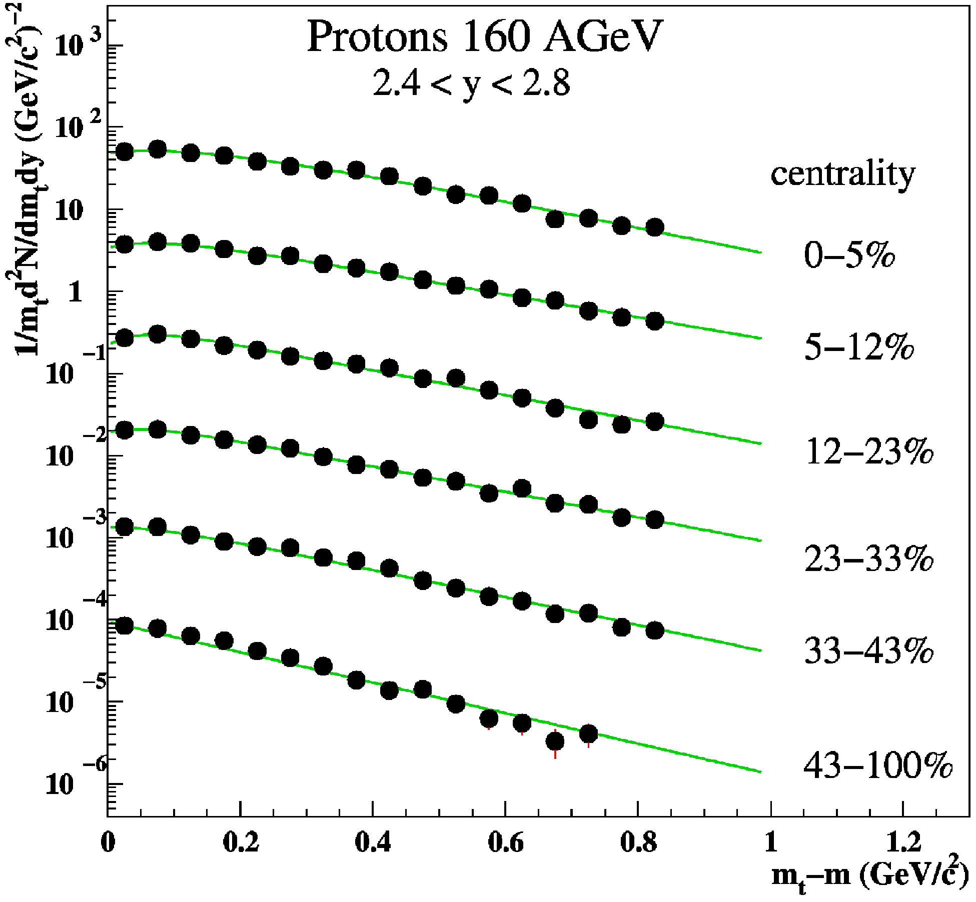
Strength of flow less for
C+C and Si+Si,
no flow in p+p

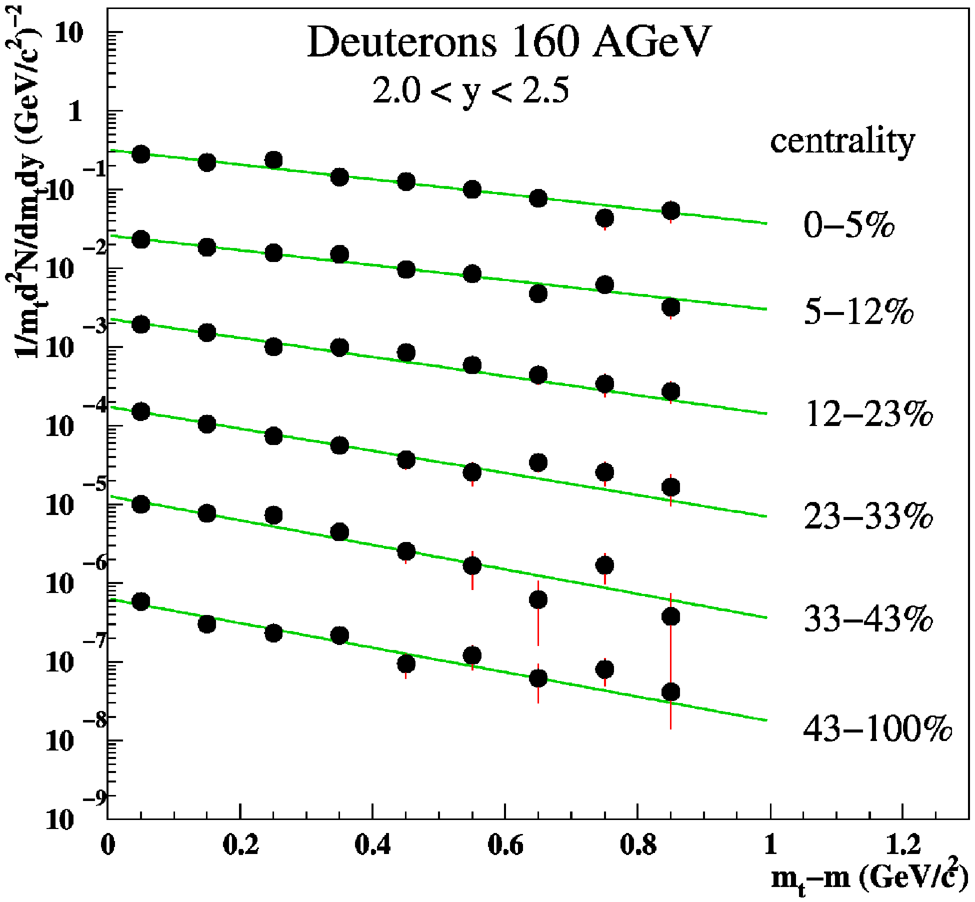


WA97: dependence of slope parameters of K0 and hyperons on centrality very weak for Pb+Pb

Eur. Phys. J. C14, 633

Centrality dependence of proton, deuteron spectra

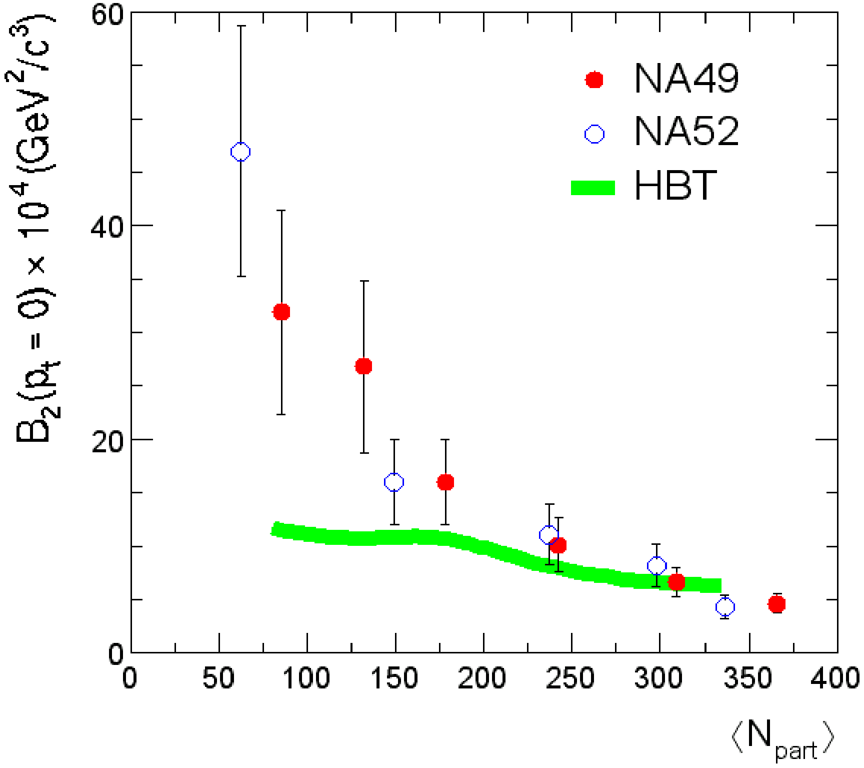




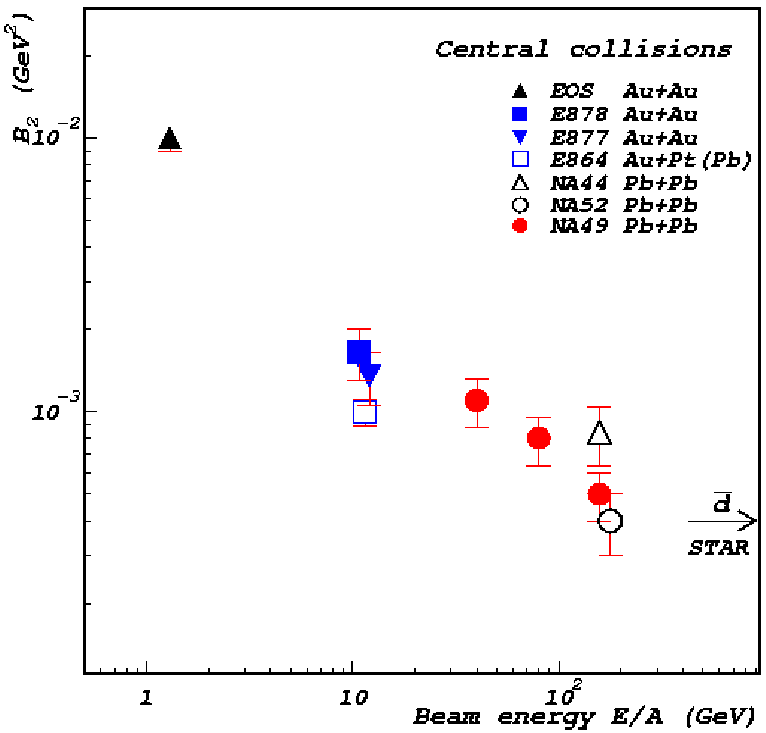
Inverse slope alsmost constant, decreases for most peripheral bins

Deuteron coalescence

System size dependence



Energy dependence

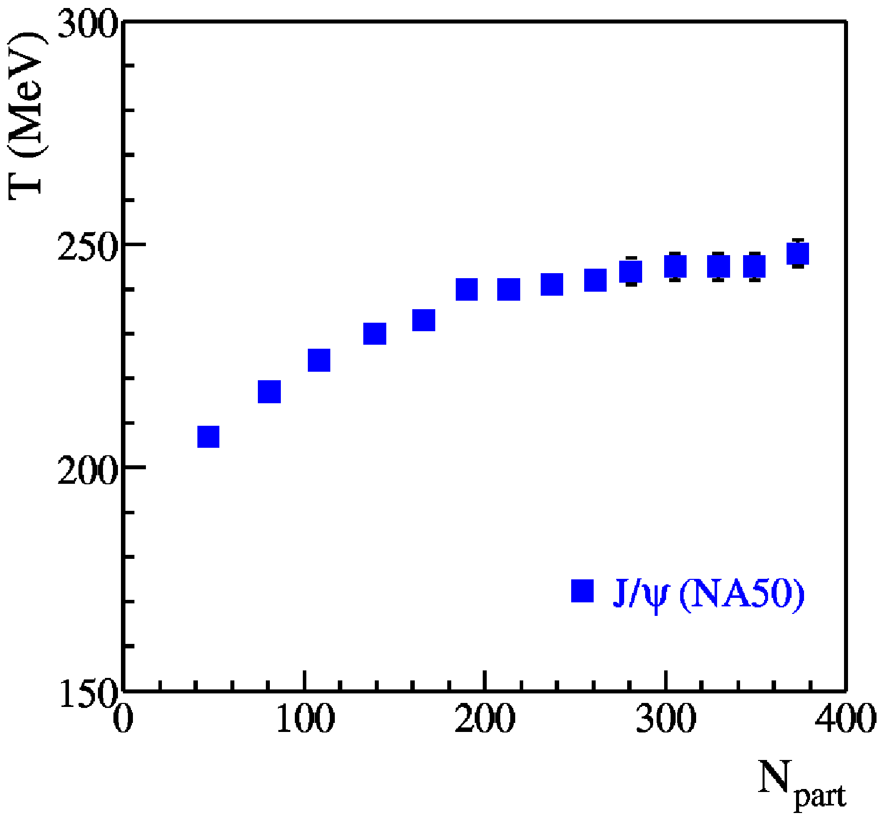


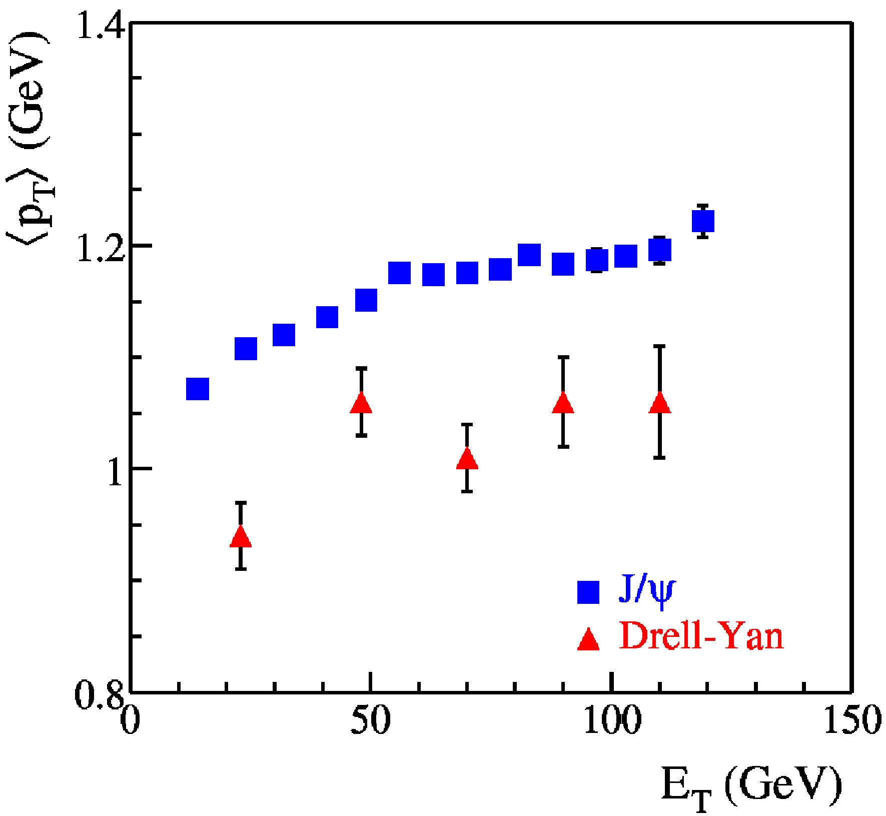
$$R_G^3 = \frac{3}{4} \left(\sqrt{\pi}\, c\, h\right)^3 \frac{m_d}{m_p^2} \frac{1}{B_2}$$

$$E_d \frac{d^3 N_d}{dP_d^3} = B_2 \left(E_p \frac{d^3 N_p}{dP_p^3} \right)^2, P_d = 2P_p$$

W. Llope et al. Phys Rev C 52, 2004

J/ψ slopes





$$\frac{dN}{m_T\, dm_T} \propto m_T K_1\left(\frac{m_T}{T}\right)$$

J/ψ suppression at low p_T or flow?

...or even initial state broadening?

NA50 data: Phys. Lett. B499 (2001) 85

Conclusion on m_T spectra

- Radial flow weakly dependent on beam energy, centrality
- Radial flow in C+C, Si+Si smaller
- B_2 strongly dependent on beam energy and centrality
- Even J/ψ subject to transverse dynamics

flow, absorption, or otherwise

P_t fluctuations

Eventwise mean P_t distributions compared to mixed events

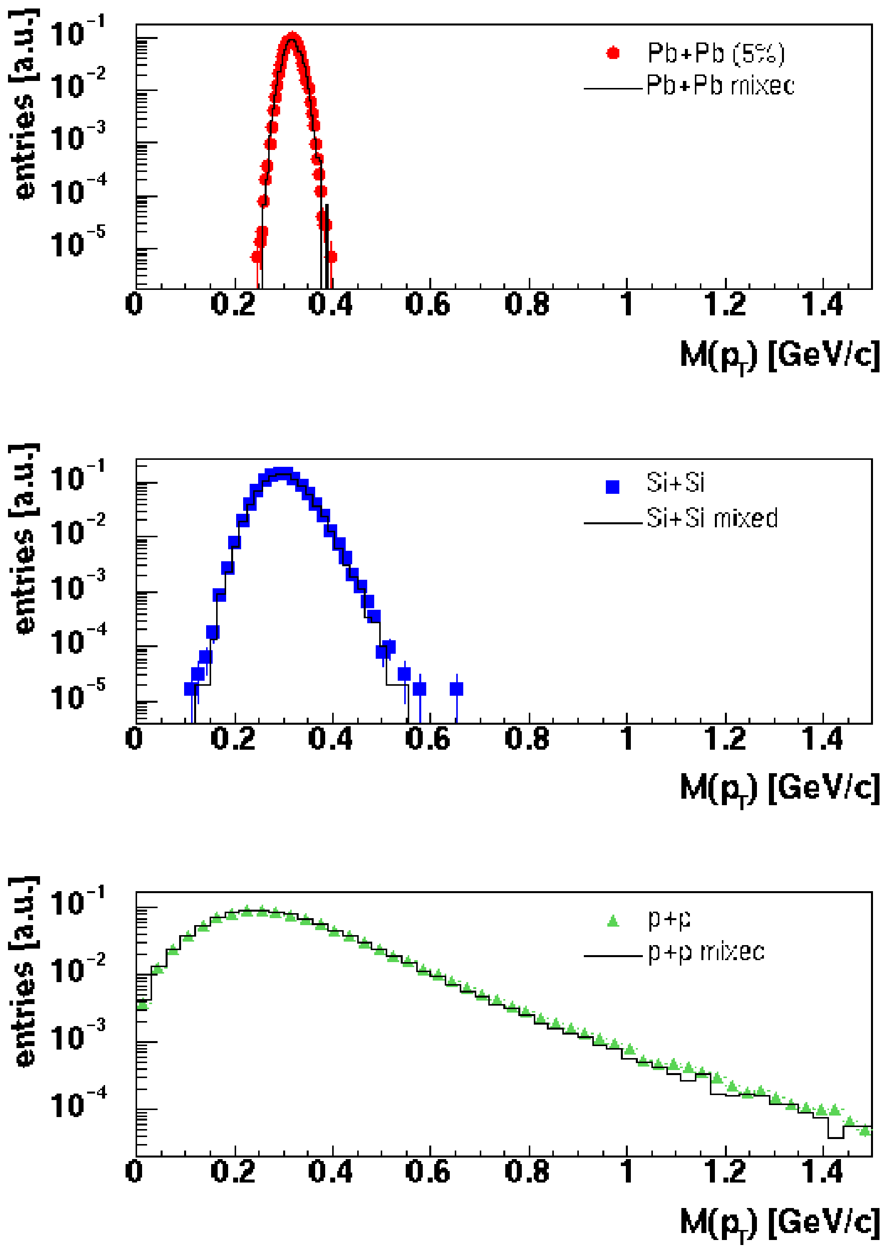
Dynamical fluctuation small (if any)

Width depends on multiplicity (+ tail in p+p)

Define intensive measure:

$$\phi_{p_t} = \sqrt{\frac{\langle \sigma^2_{p_t} \rangle}{\langle N \rangle}} - \sigma^{inclusive}_{p_t}$$

Gazdzicki, Mrowczynski, Z. Phys C54, 127

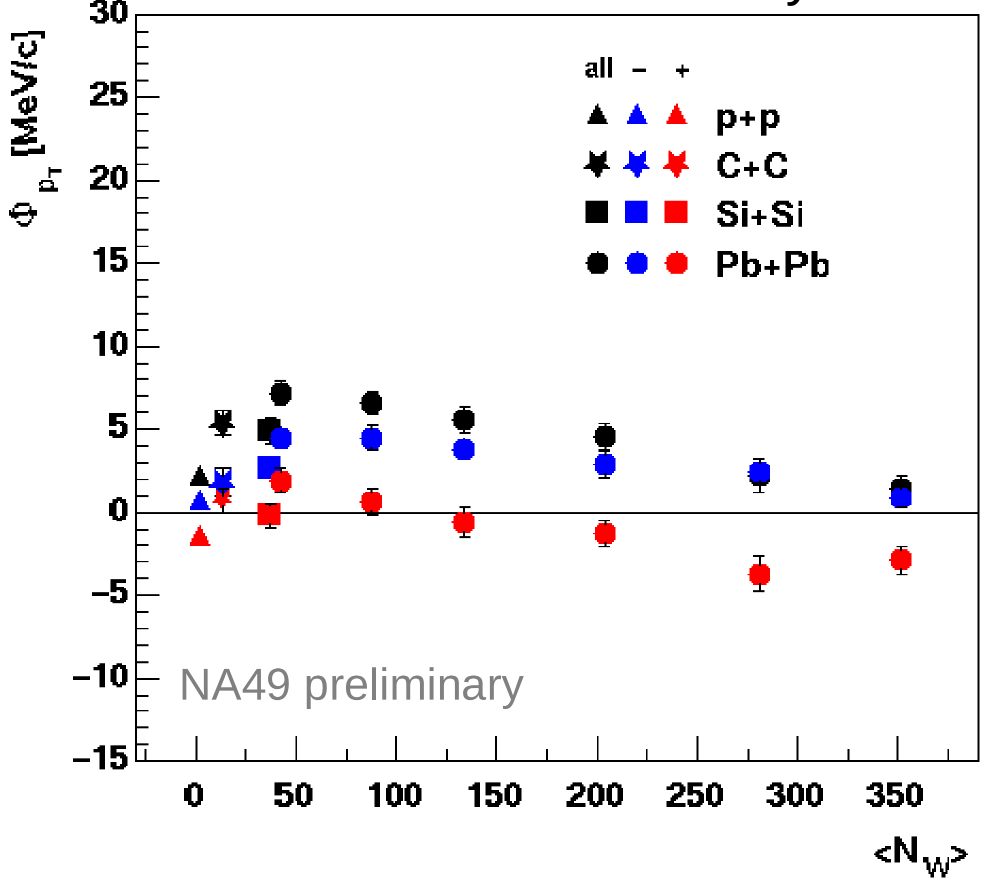


ϕ_{p_t} dependence on N_w

- Almost no system size dependence
- Small values (same order of magnitude as two-track resolution, BE effects)
- Values for all charges higher than positives and negatives seperately

Mean p_T fluctuations can be explained as superposition of p+p events

4.0 < y < 5.5



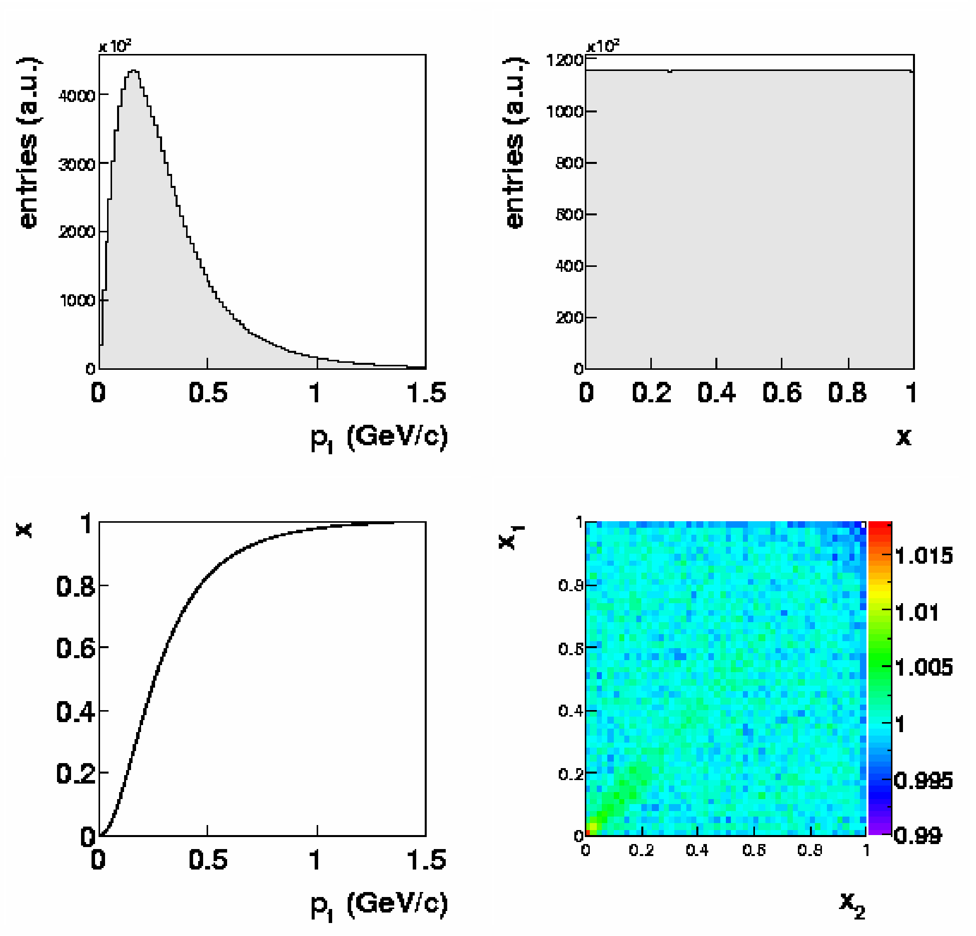
Be aware: ϕ_{p_t} depends on acceptance

Alternative approach

Examine full p_t-p_t correlation function

Use flattening transformation to obtain flat reference

As opposed to mixed events (e.g. Trainor, hep-ph/0001148)

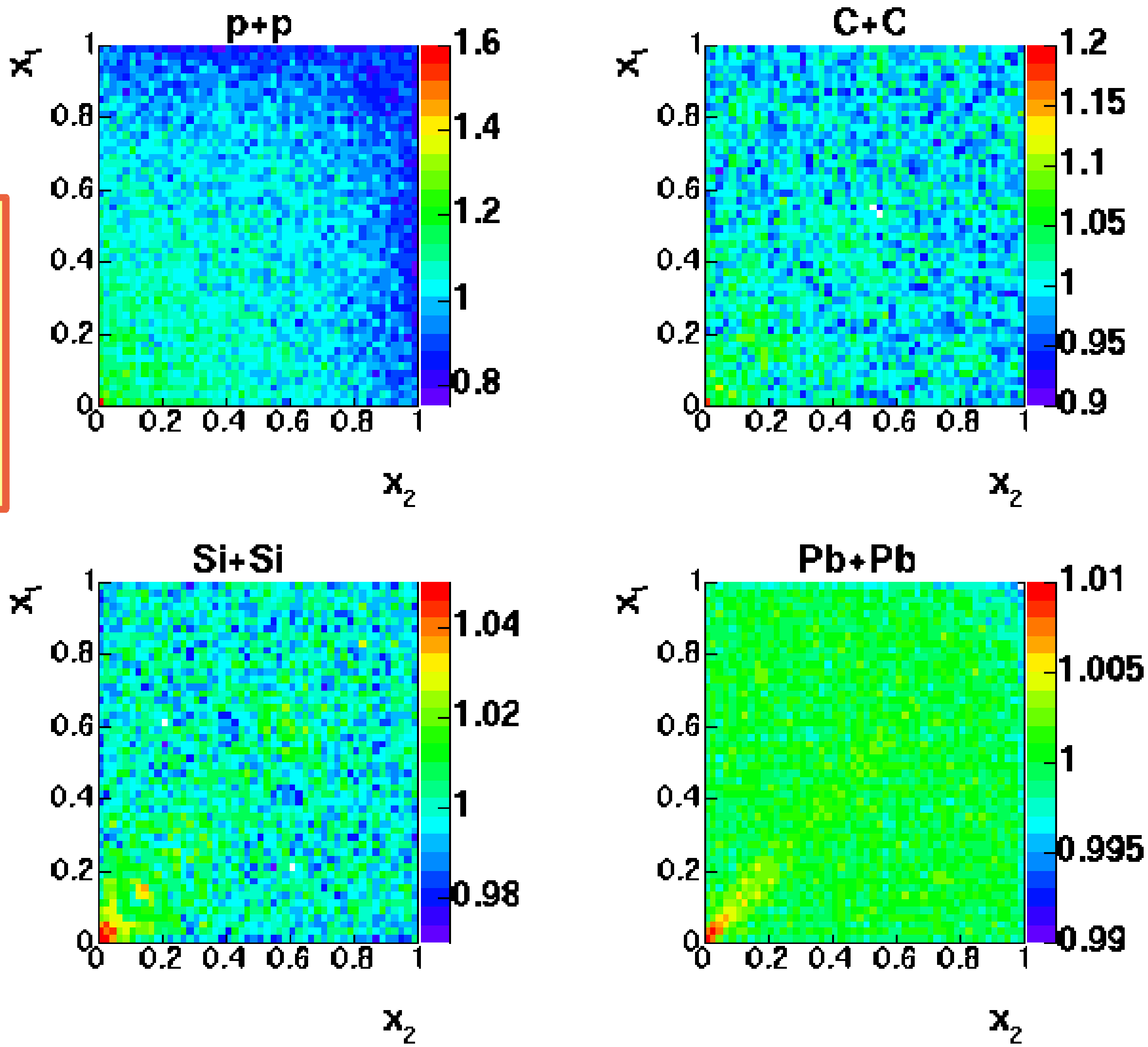


No longer intensive

System size dependence

Prominent feature in p+p

Nuclear collisions mainly show BE effect



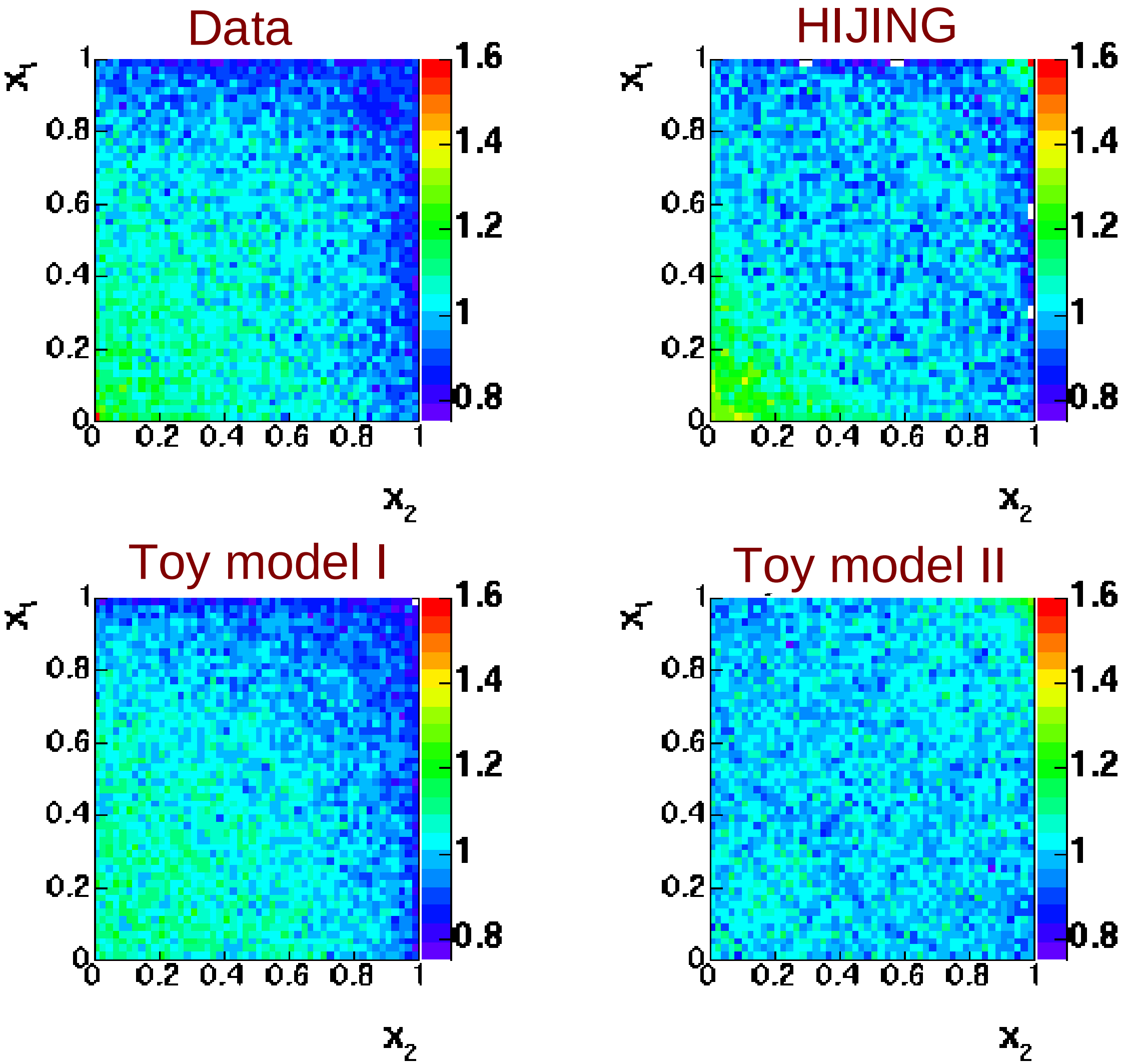
Comparison of p+p to models

All calculations take into account NA49 acceptance

Toy Model I: use multiplicity depedence of <p$_t$> observed in data.

Toy Model II: Inverse slope fluctuations of 10.5%

Main feature of p+p events: <pt>-multiplicity correlations

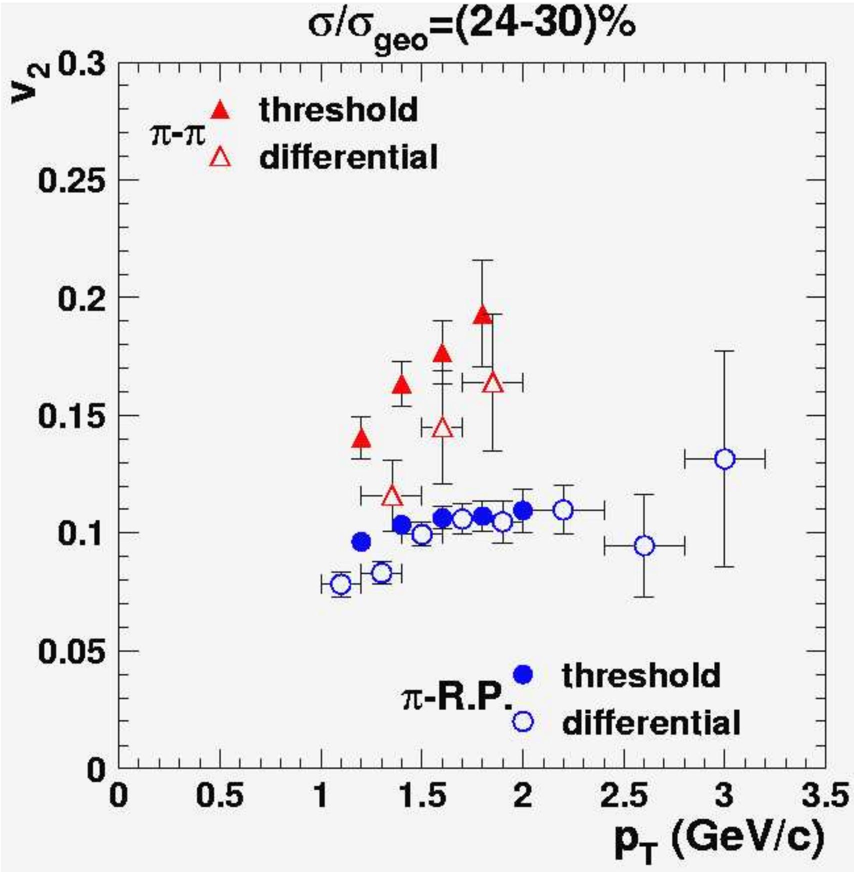


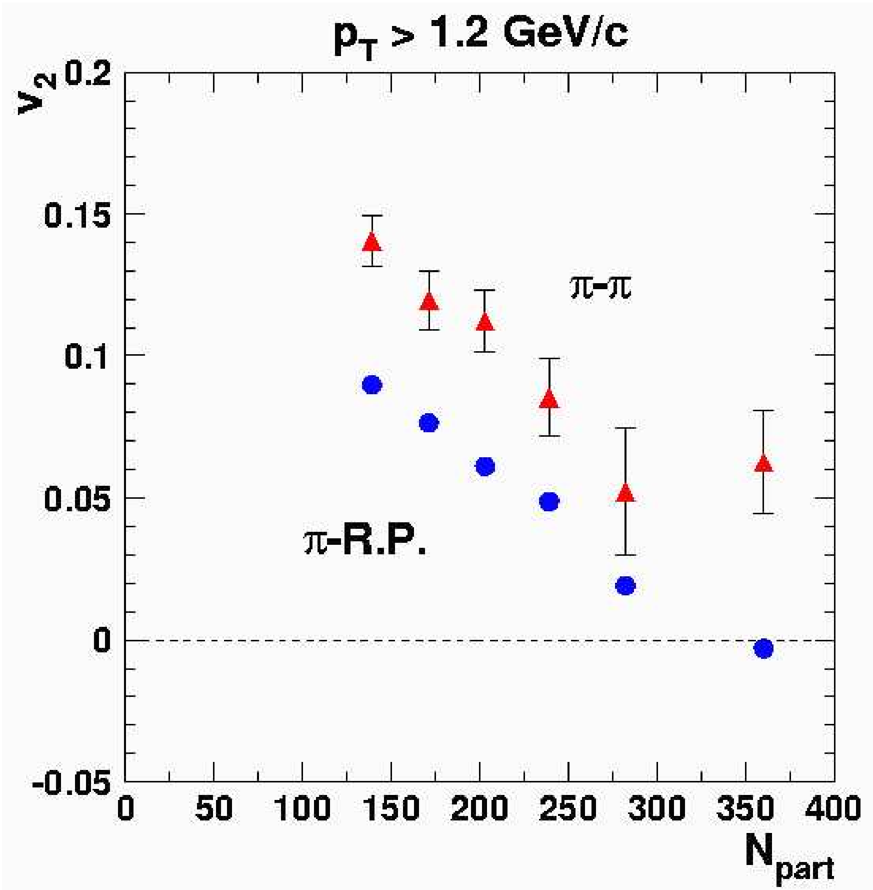
Conclusion on fluctuations

- ϕ_{p_T} only weakly dependent on centrality
- Fluctuation driven by $\langle p_t \rangle$-multiplicity correlations in p+p

ϕ_{p_T} not very sensitive to this effect?

CERES identified $\pi^{\pm}$ at 158 *A*GeV





CERES, QM2002 proceedings