Transverse momentum spectra of mesons in p+p collisions at CERN SPS energies from the UrQMD transport model

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in collaboration with

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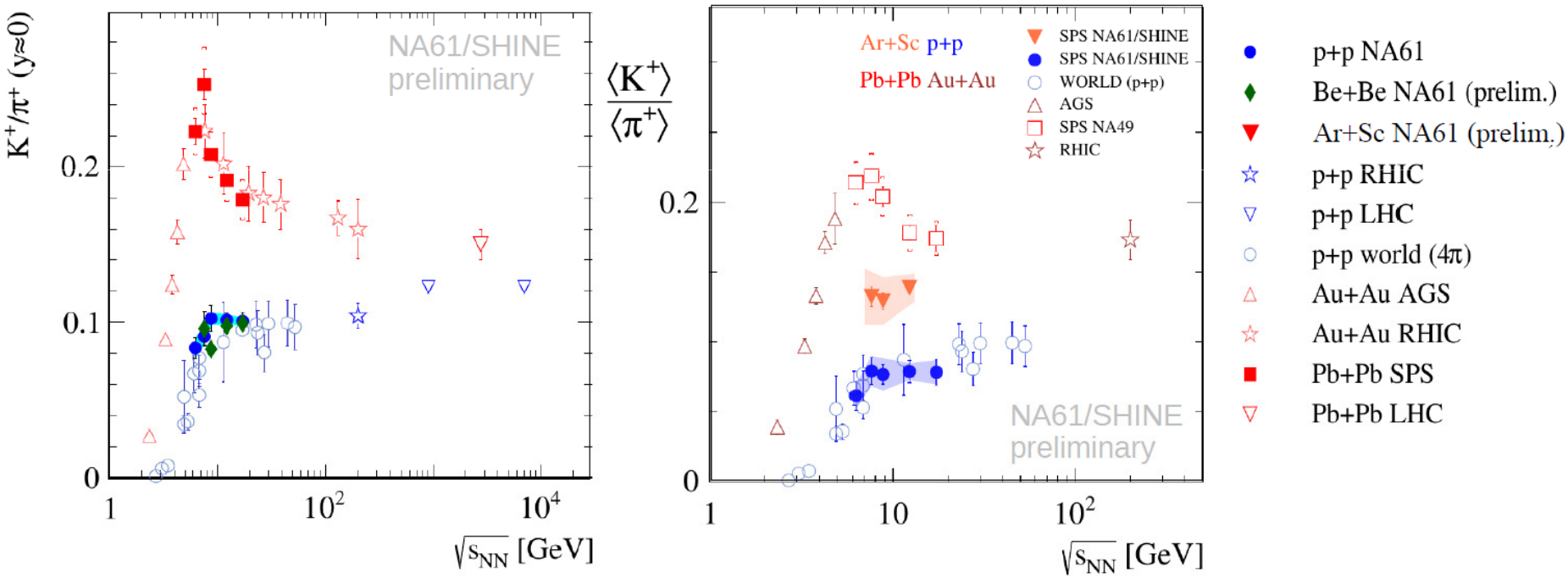
Outline

- Motivation
- Brief description of the UrQMD transport model
- UrQMD results for all identified mesons (positively and negatively charged pions and kaons) produced in inelastic p+p interactions at CERN SPS energies in comparison to the NA61/SHINE experimental data:
  - Rapidity spectra and mean multiplicities
  - Transverse momentum spectra and inverse slope parameter
- Summary

Motivation (I)

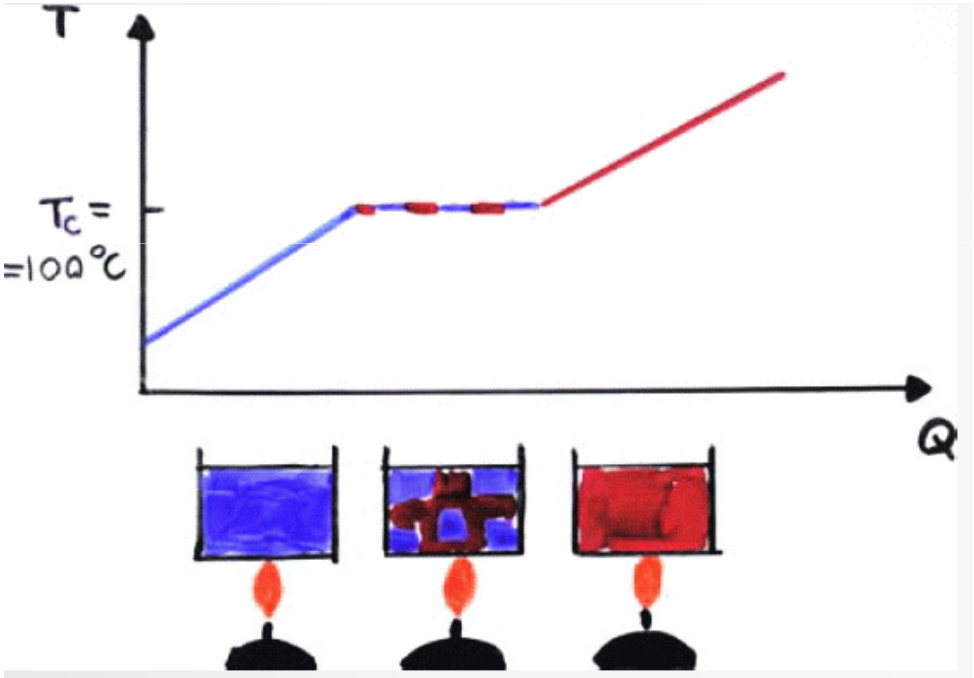
❑ **Rapid changes in K+/π+ is observed both for p+p and Pb+Pb collisions. This was predicted within the SMES as a signature of the onset of deconfinement**

M. Gazdzicki, M. I. Gorenstein, Acta Phys. Polon. B30 (1999) 2705

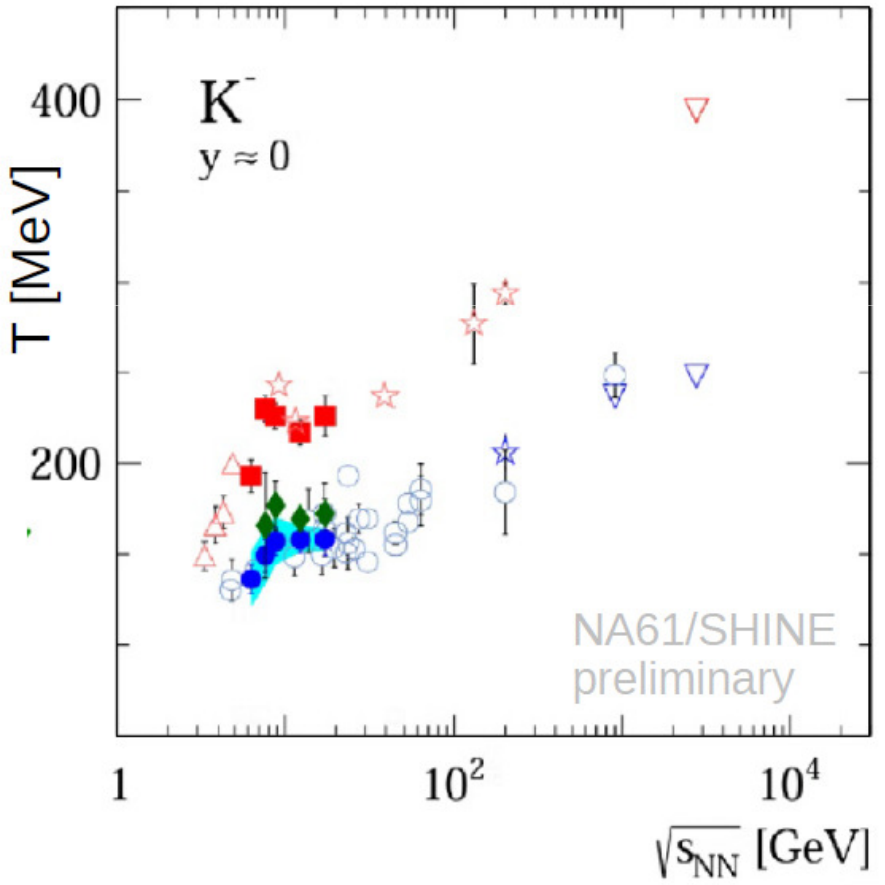


Motivation (II)

- **Step-like structure in T of K- at midrapidity is observed both for p+p and Pb+Pb collisions.**



Plot from M.Gazdzicki



UrQMD transport model (I)

- This non-equilibrium approach constitutes an effective solution of the relativistic Boltzmann equation:

$$p^\mu \cdot \partial_\mu f_i(x^\nu, p^\nu) = \mathcal{C}_i$$

- The underlying degrees of freedom are hadrons and strings that are excited in high energetic binary collisions

- In UrQMD 55 baryon and 32 meson species, ground states and all resonances with masses up to 2.25 GeV

- Full particle-antiparticle, isospin, and flavour-SU(3) symmetries are applied

S.A.Bass *et al.,* Prog. Part. Nucl. Phys. 41 (1998) 225; M.Bleicher *et al.,* J. Phys. G: Nucl. Part. Phys. 25 (1999) 1859

UrQMD transport model (II)

- The hadrons are propagated on straight lines until the collision criterium is fulfilled:

$$d_{\text{trans}} \leq d_0 = \sqrt{\frac{\sigma_{\text{tot}}}{\pi}}, \quad \sigma_{\text{tot}} = \sigma(\sqrt{s}, \text{type})$$

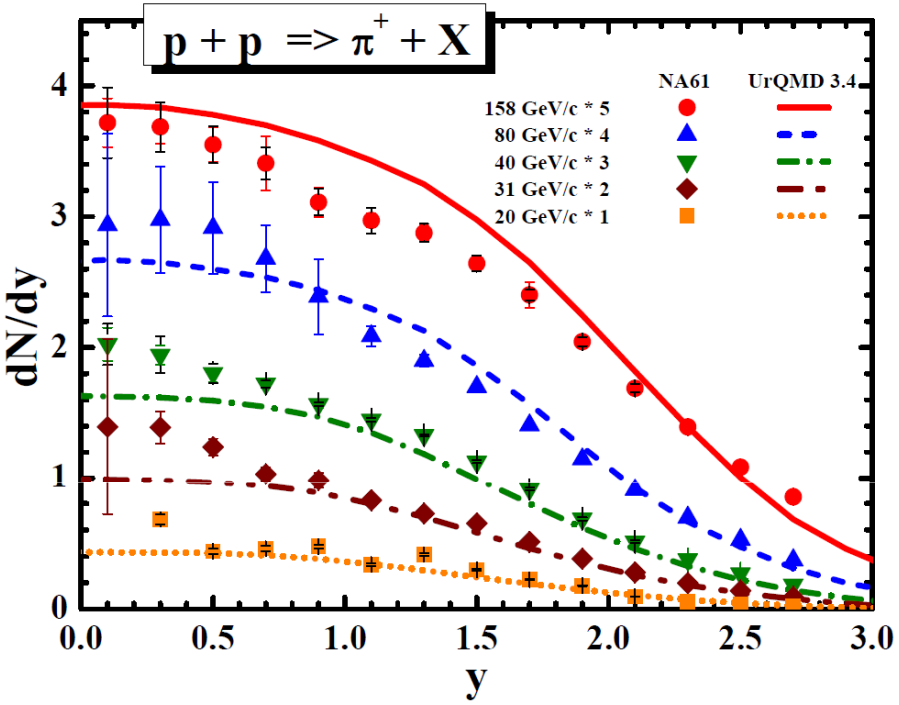
- The elementary cross sections are calculated by the detailed balance or the additive quark model or fitted and parametrized to the available experimental data

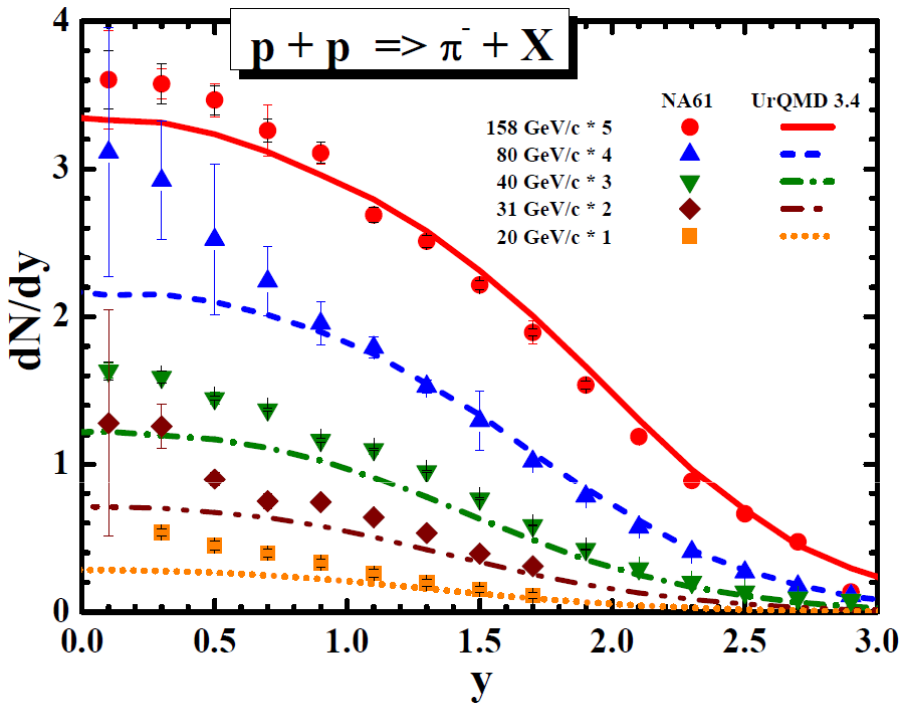
- For resonance excitations and decays the Breit-Wigner formalism is employed

- The initial high energy phase of the reaction is modeled via the excitation and fragmentation of strings treated according to the Lund model; for hard collisions with Q > 1.5 GeV PYTHIA is used

S.A.Bass *et al.,* Prog. Part. Nucl. Phys. 41 (1998) 225; M.Bleicher *et al.,* J. Phys. G: Nucl. Part. Phys. 25 (1999) 1859

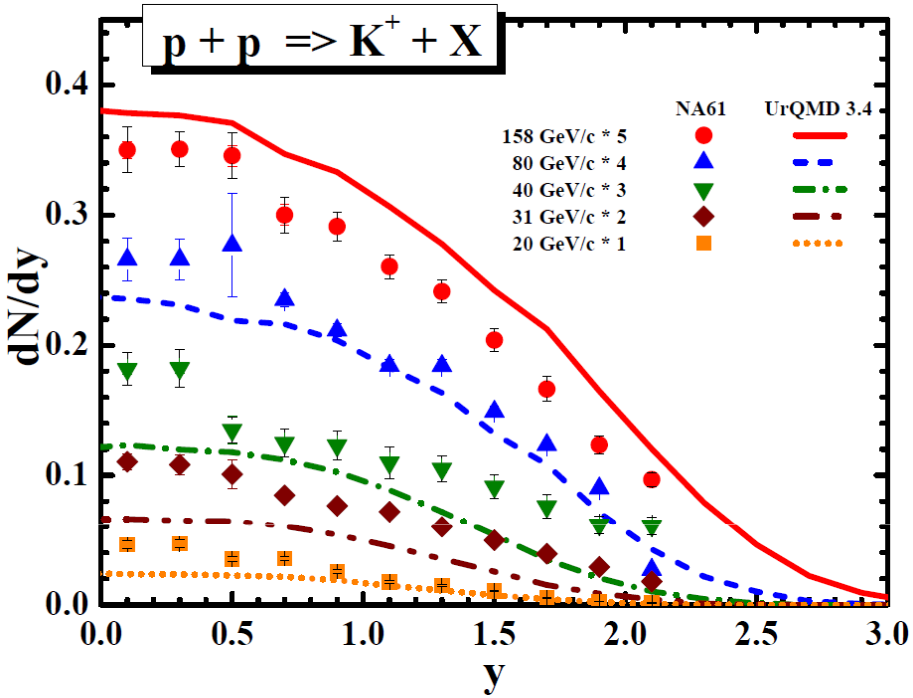
Rapidity spectra: positive and negative pions

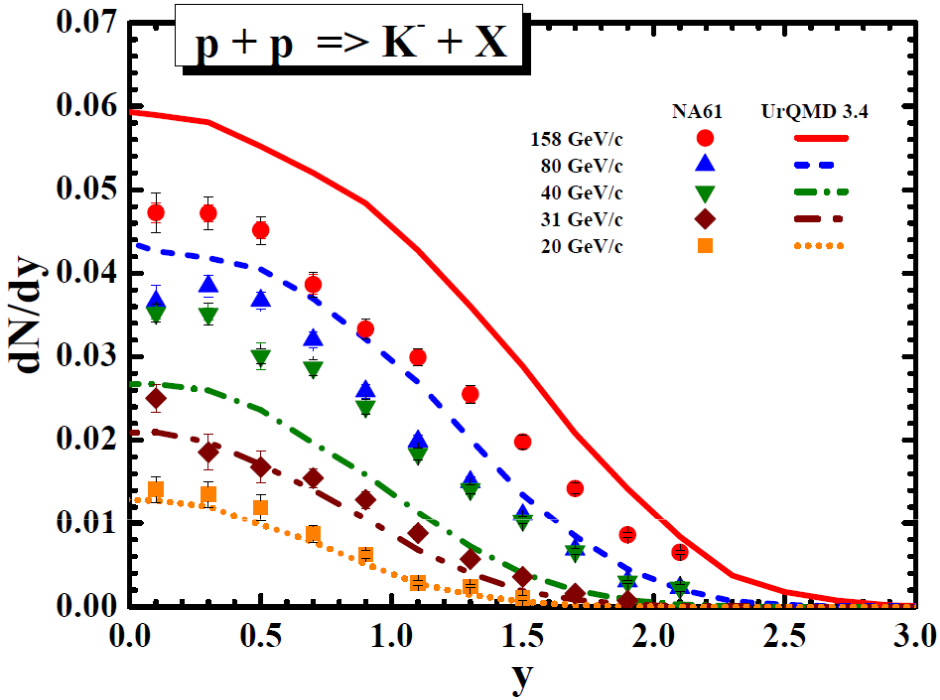




- The UrQMD model describes reasonably well dN/dy spectra of pions at high SPS energies
- It underestimates the dN/dy spectra at lower energies for both particles
- In 20-31 GeV/c discrepancies may reach a factor of two (up to 30%) for negative (positive) pion dN/dy values at y ≈ 0

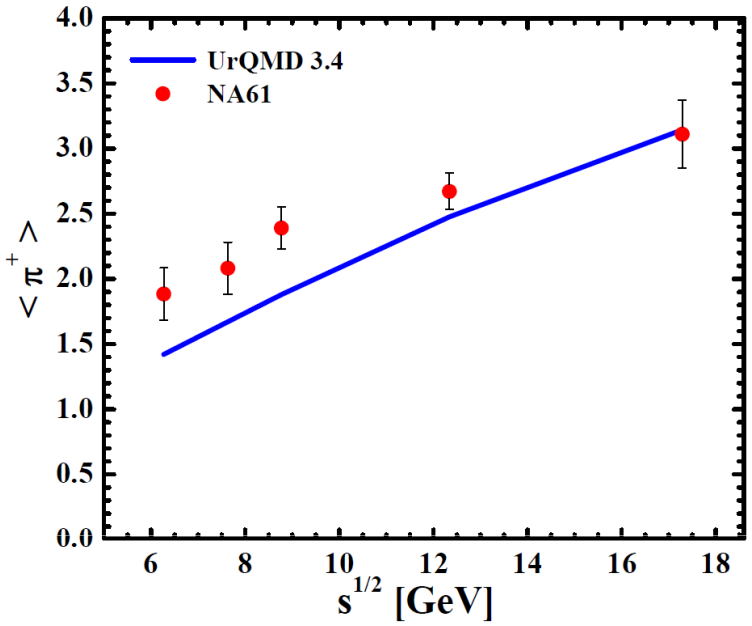
Rapidity spectra: positive and negative kaons

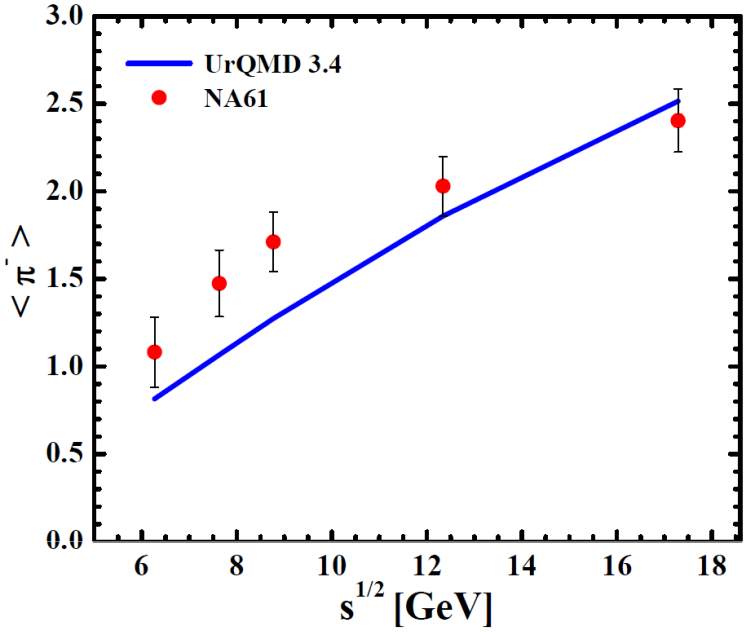


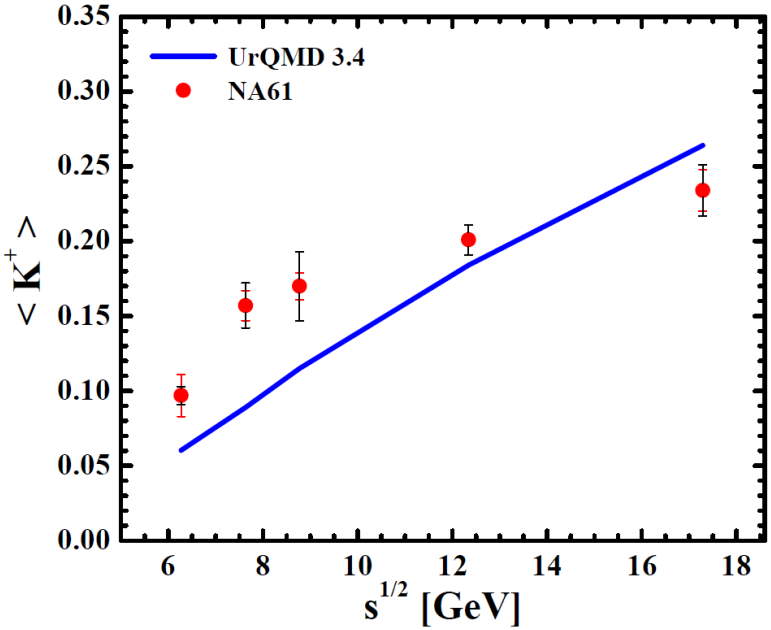


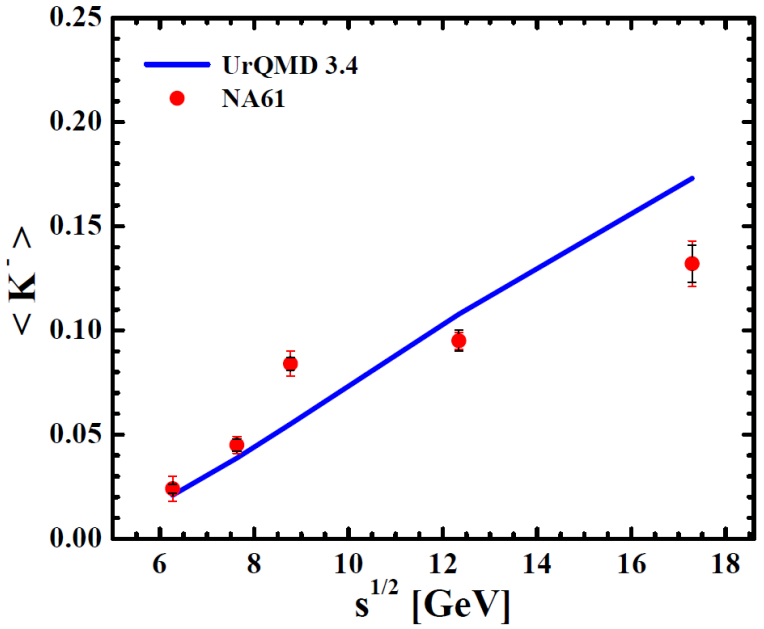
- **For positive kaons:**
  provides a rough description for the two top beam momenta; systematically underestimates at lower energies with discrepancies reaching a factor of two for dN/dy at y ≈ 0
- **For negative kaons:**
  it slightly underestimates at 20 and 31 GeV/c; underestimates it by about 30% at 40 GeV/c; overestimates it by up to 30% at higher energies

Mean multiplicities: pions and kaons



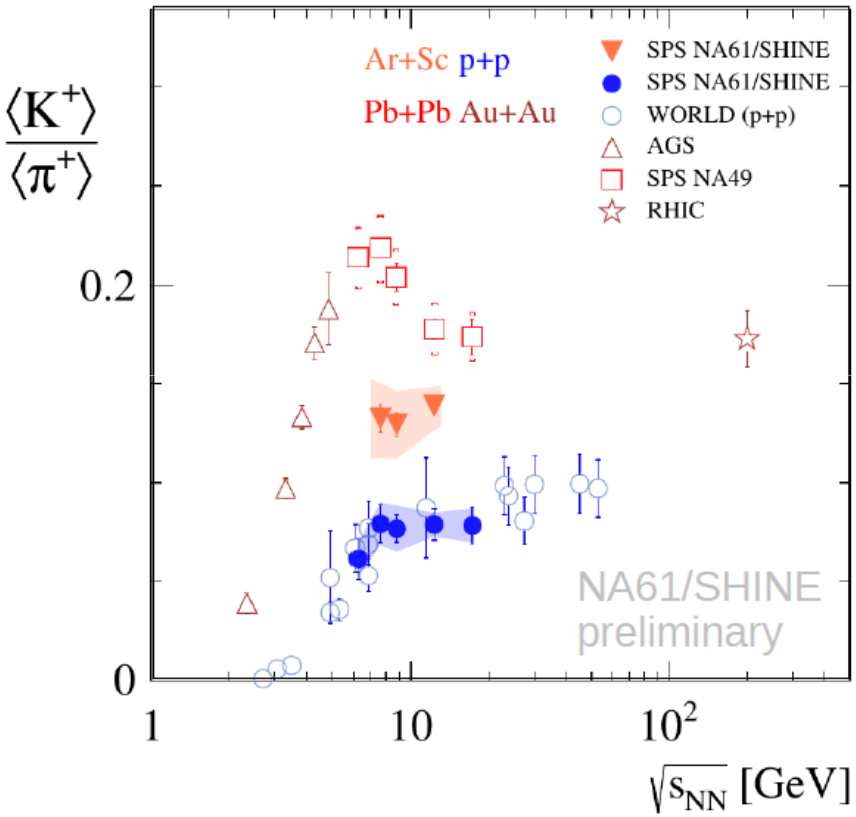


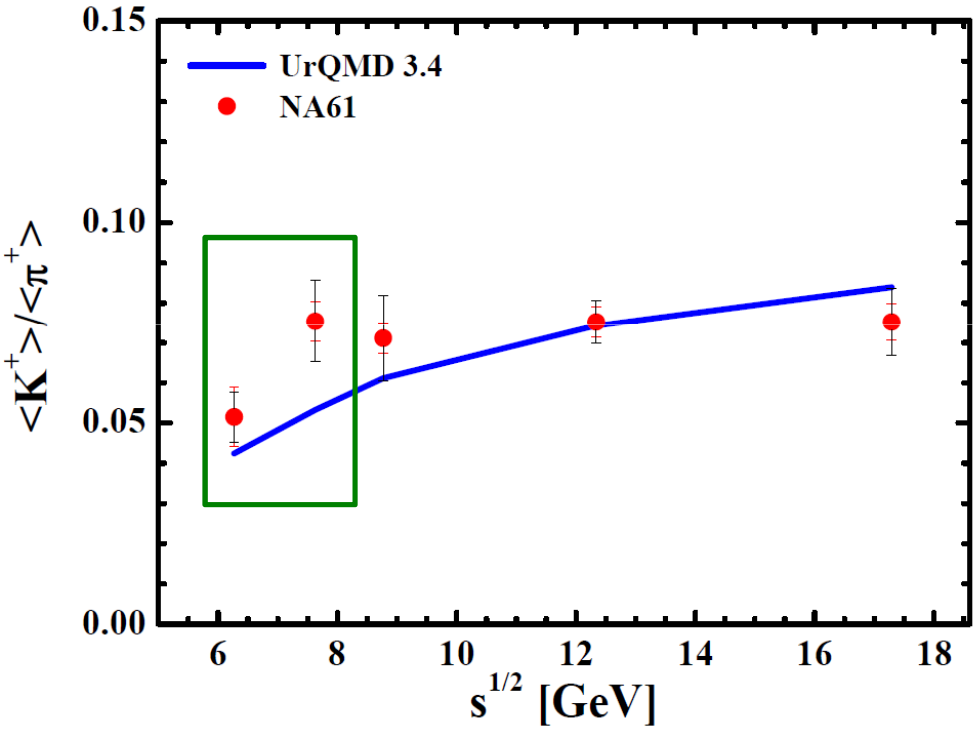




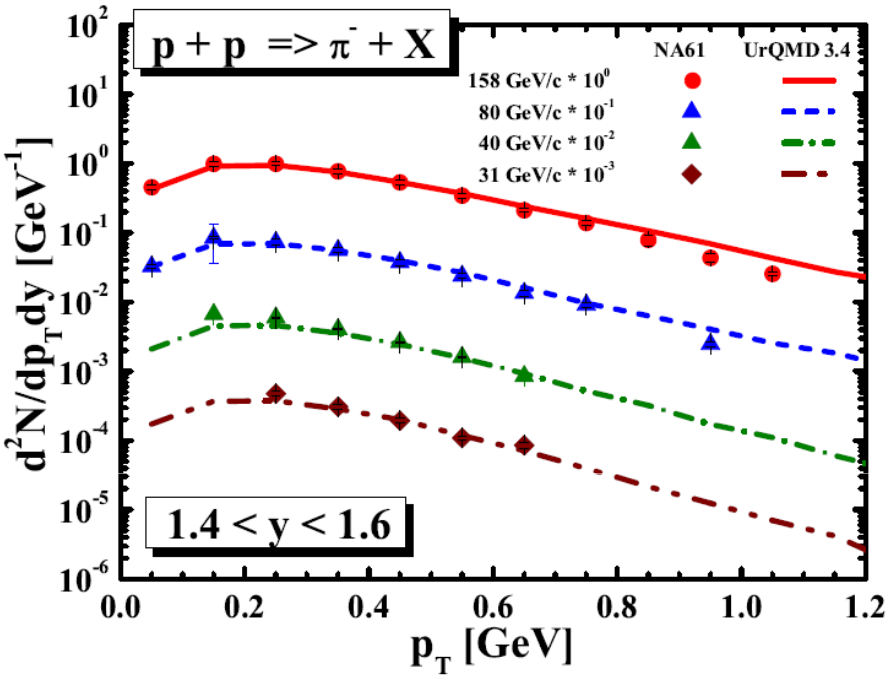
K/π ratio

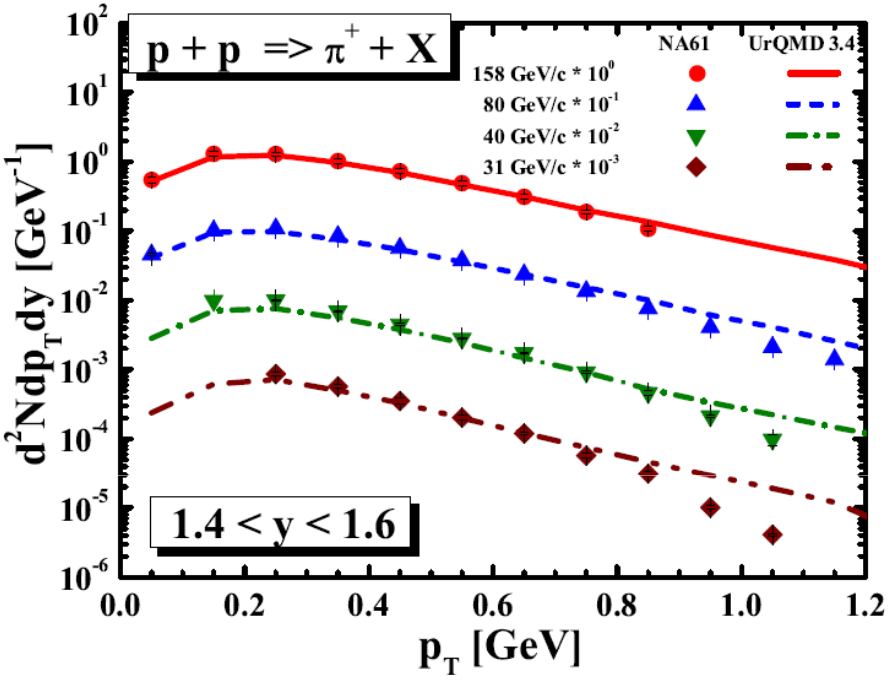
- The UrQMD model does not describe a rapid changes in K+/π+





Transverse momentum spectra: positive and negative pions

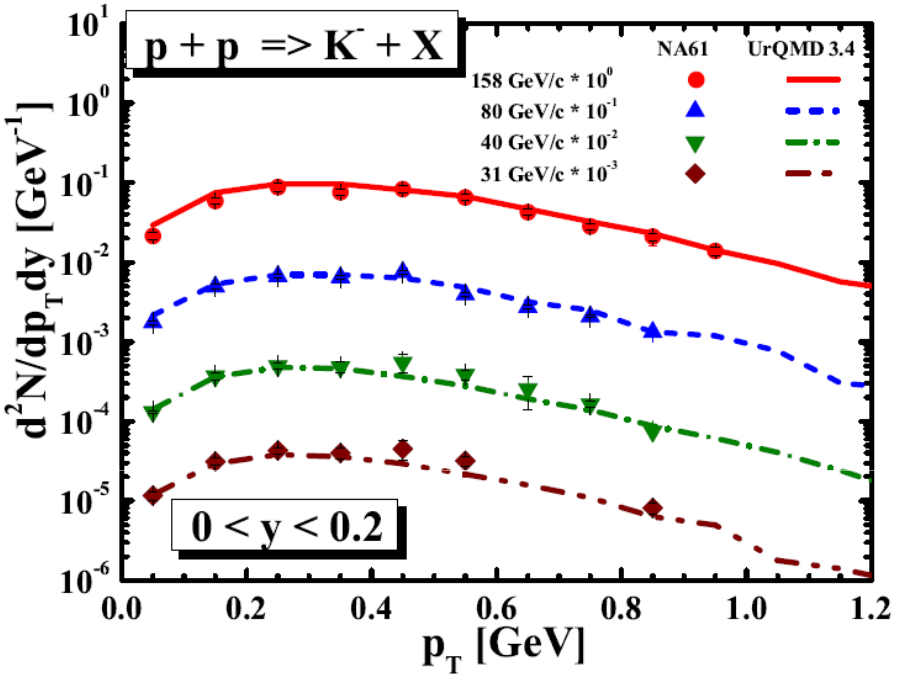


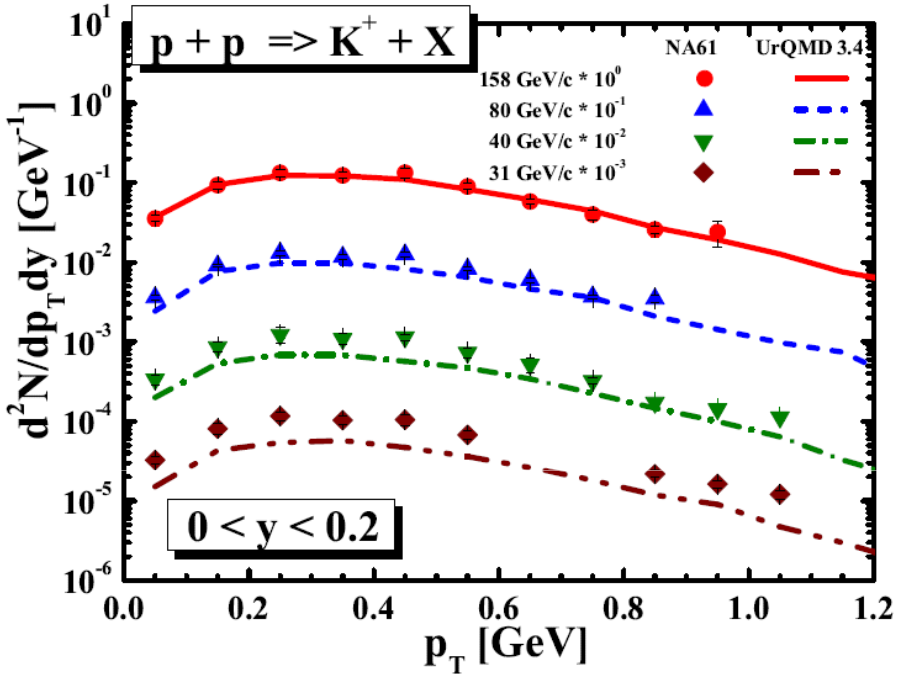


For all energies at forward rapidity:

- **The UrQMD model gives a good description of the transverse momentum disctribution of pions for p_T < 0.8 GeV/c**
- **It overestimates the pion yield for p_T > 0.8 GeV/c**

Transverse momentum spectra: positive and negative kaons



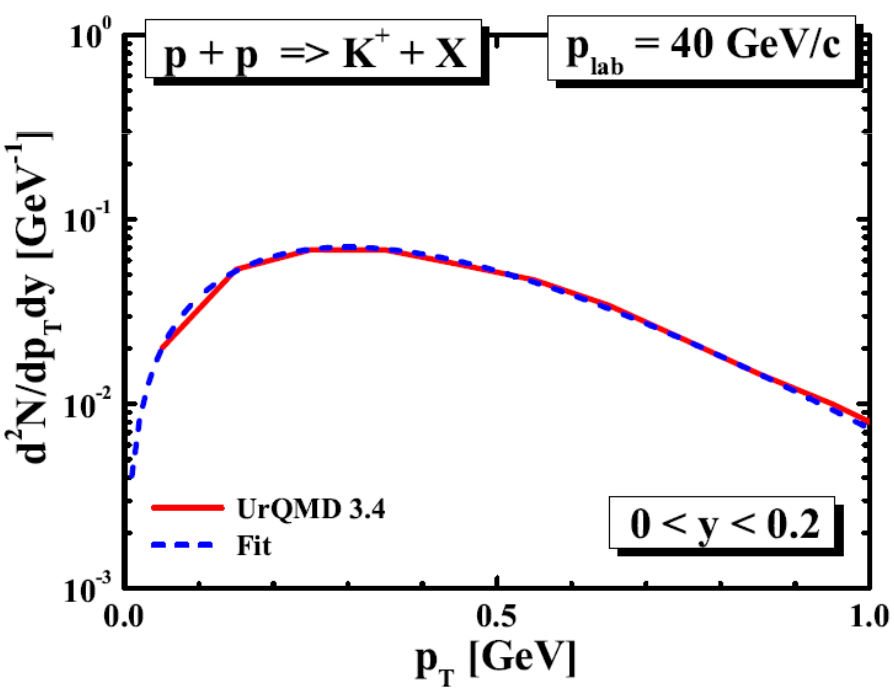


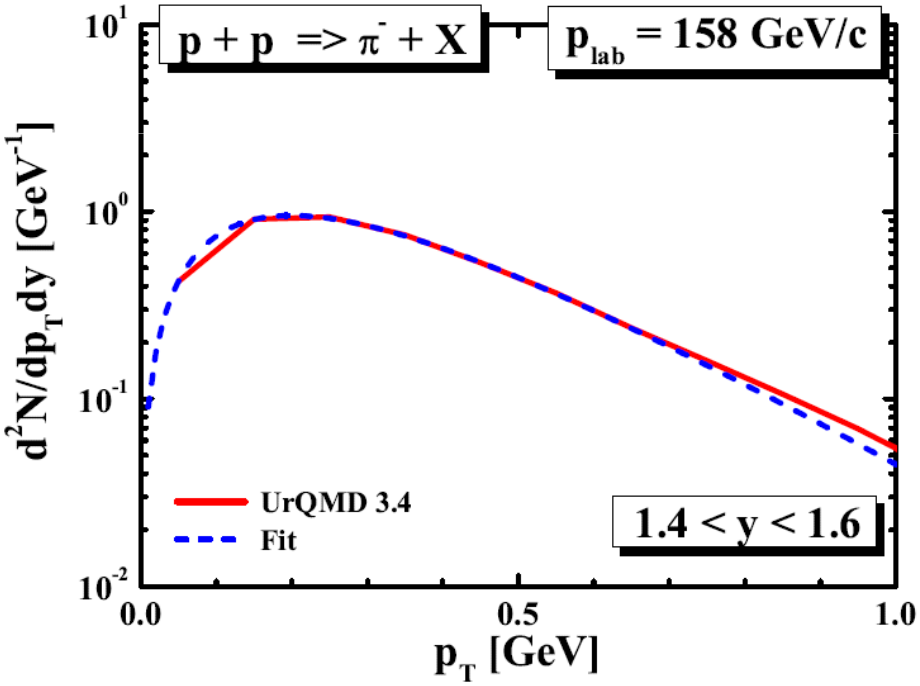
- **For negative kaons:**
  the model well describes the transverse momentum spectrum for the two top beam momenta; predicts smaller yield for 31 and 40 GeV/*c*
- **For positive kaons:**
  a fair agreement between data and model at 80 and 158 GeV/*c*
  underestimates the yield at lower beam momenta

The parametrization of transverse momentum spectrum

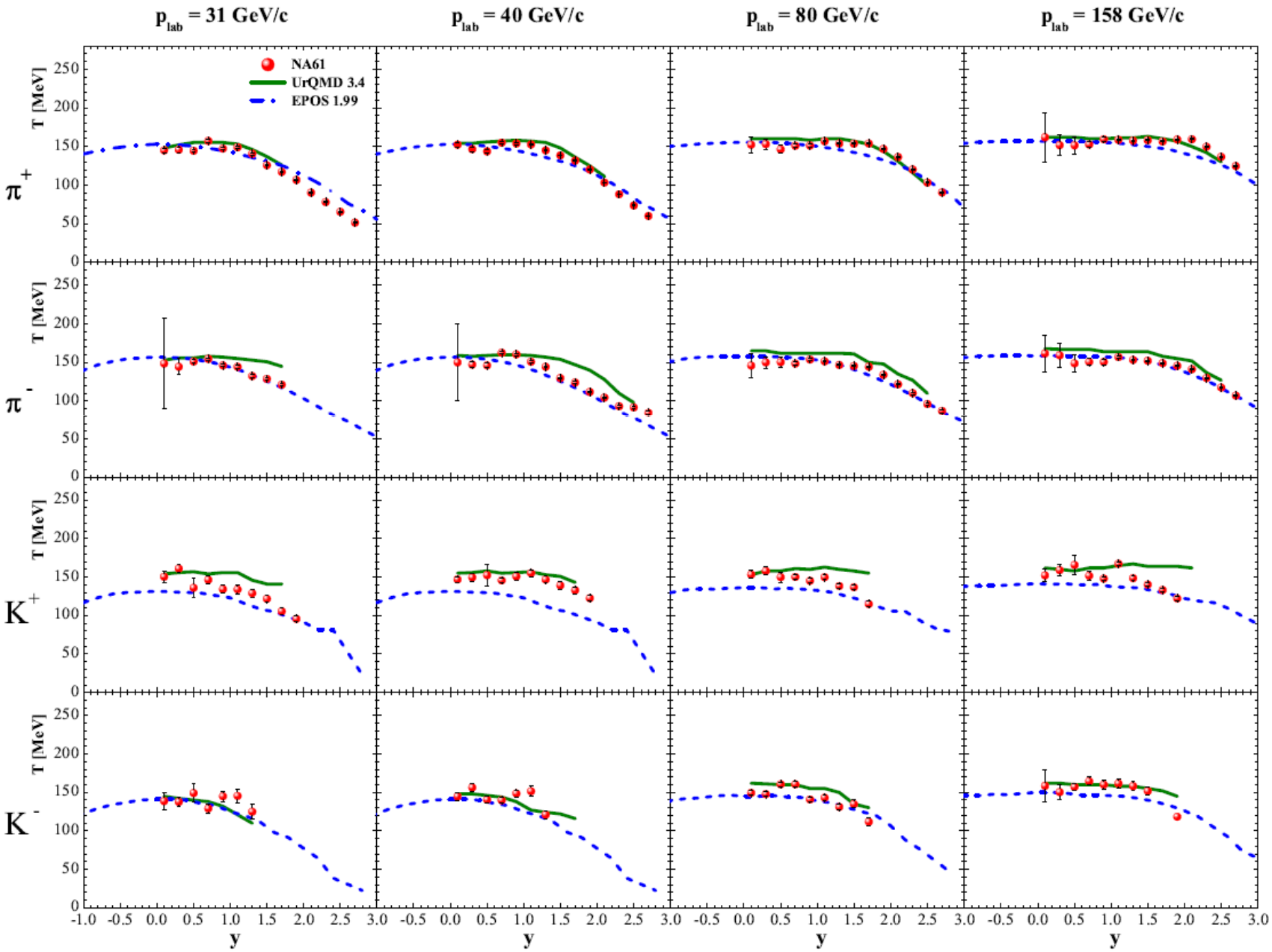
We attempt to parametrize the transverse momentum spectrum by the exponential function:

$$\frac{d^2N}{dp_T dy} = \frac{Sp_T}{T^2 + mT} \exp\left[-(m_T - m)/T\right]$$

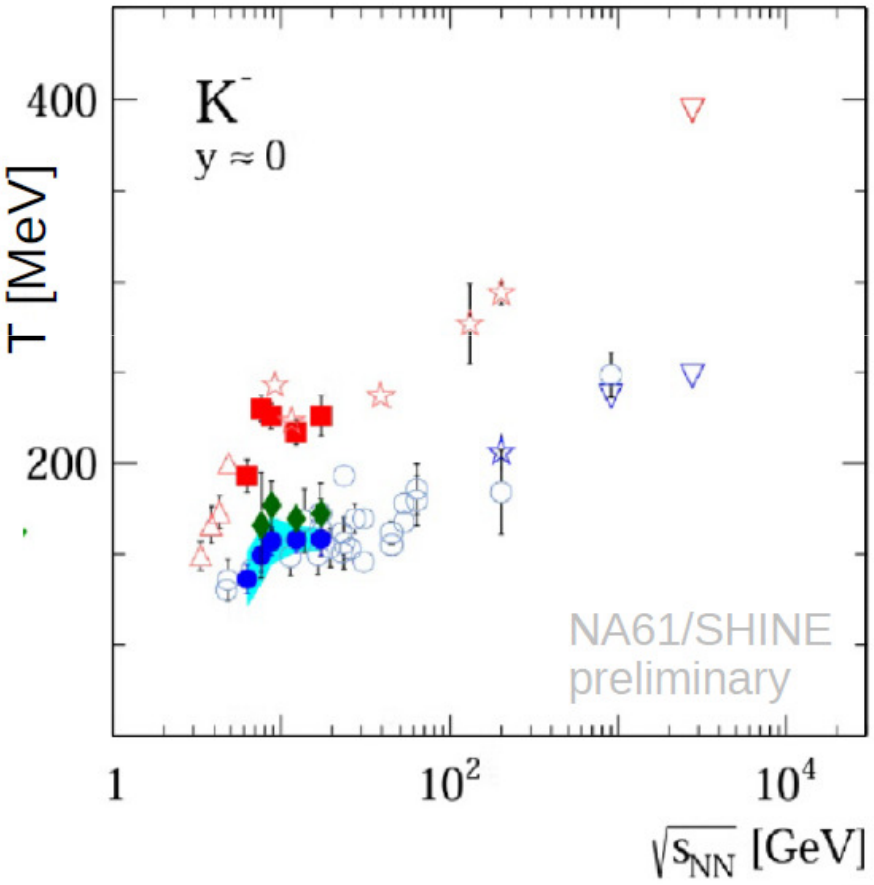




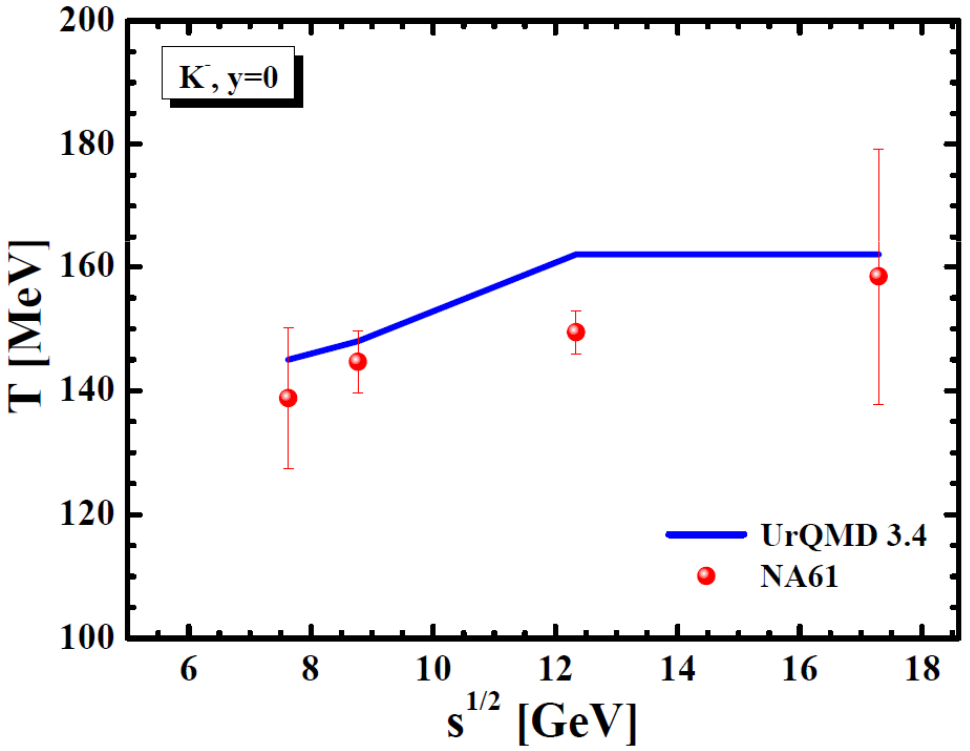
The inverse slope parameter (I)



The inverse slope parameter (II)



Data is taken from Fig.33 in Eur.Phys.J. C77 (2017) no.10, 671



Summary

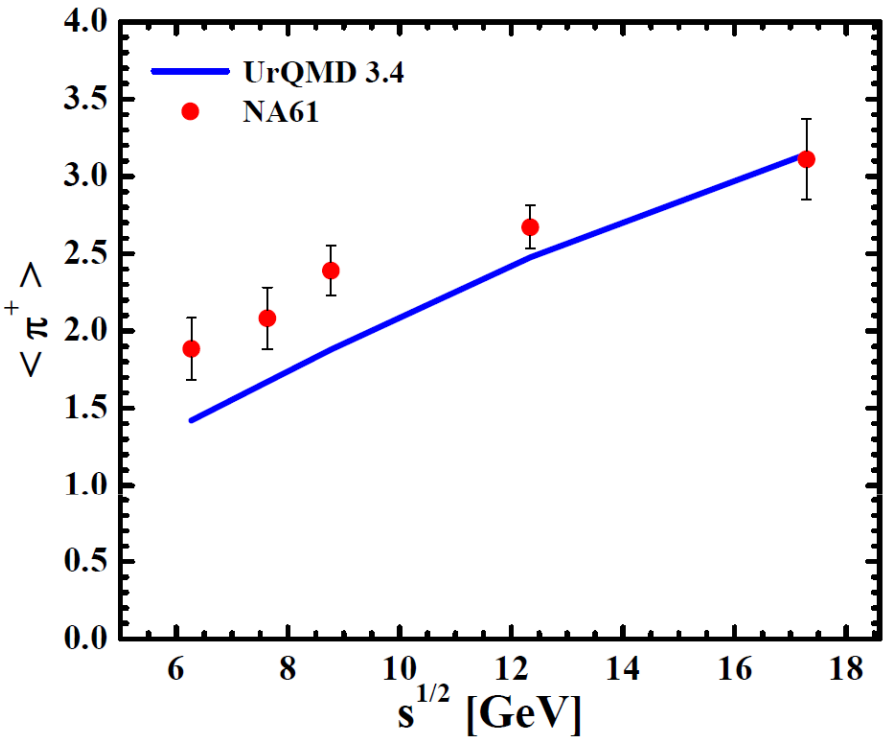
- We analyzed new NA61/SHINE data on meson production in inelastic p+p collisions at CERN SPS energies using the UrQMD transport model
- The meson mean multiplicities, rapidity spectra, transverse momentum spectra at central and forward rapidity and the extracted inverse slope parameters were shown
- A complicated pattern of discrepancies between the experimental data and the UrQMD transport model is apparent
- The UrQMD model does not describe a rapid changes in K+/π+
- New NA61/SHINE data on meson production in p+p reactions shows the similarities in the energy dependence of kaon inverse slope and kaon-over-pion ratios in p+p and heavy-ion collisions

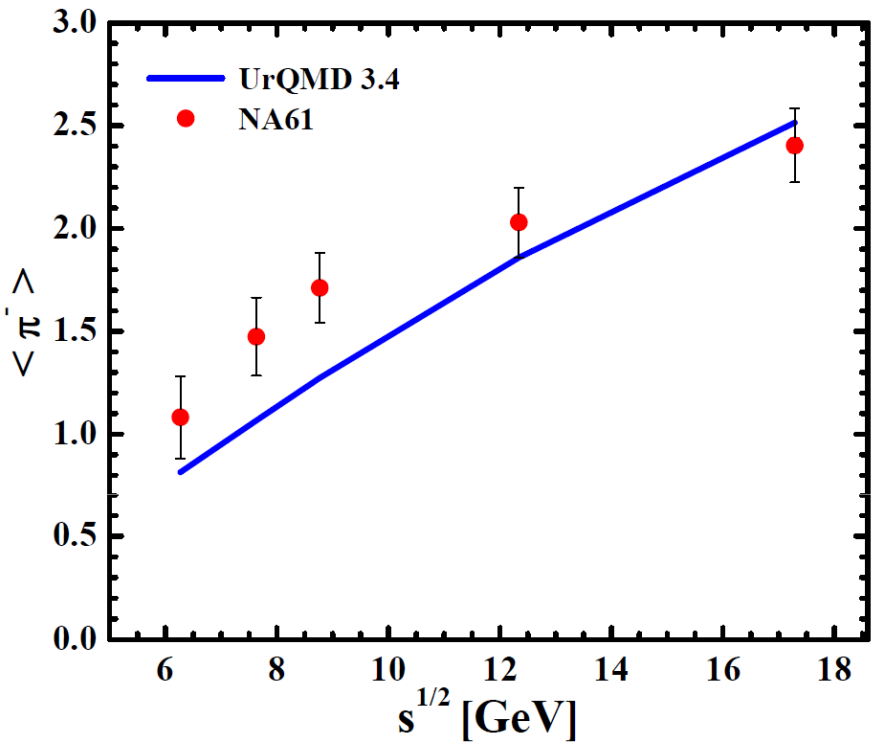
Thank you!

Acknowledgments:
This work was supported by the National Science Centre, Poland under grant no. 2014/14/E/ST2/00018

Back up

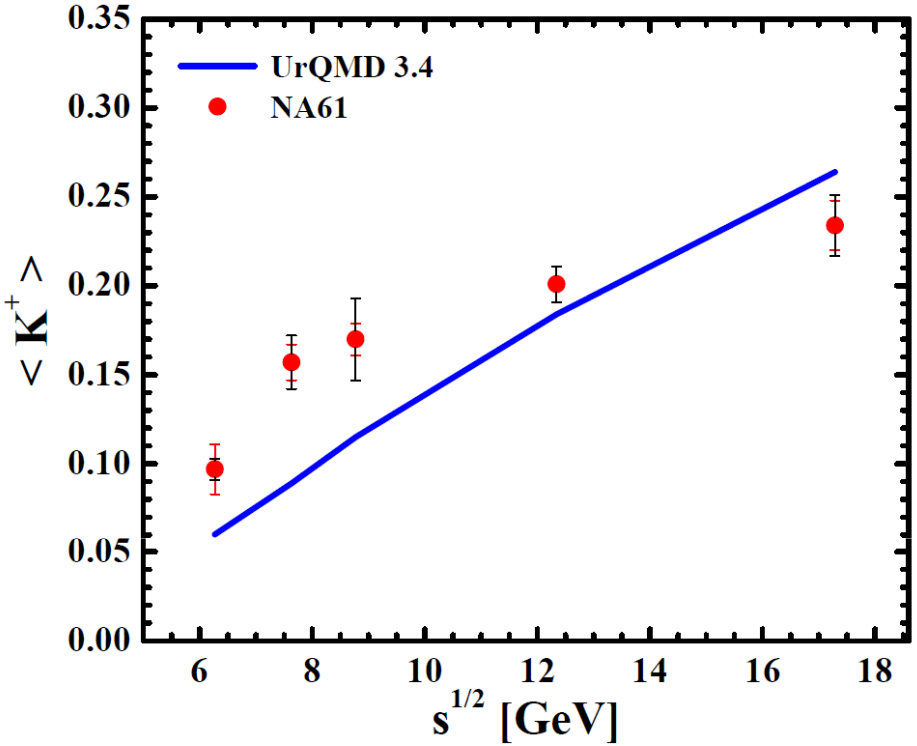
Mean multiplicities: positive and negative pions

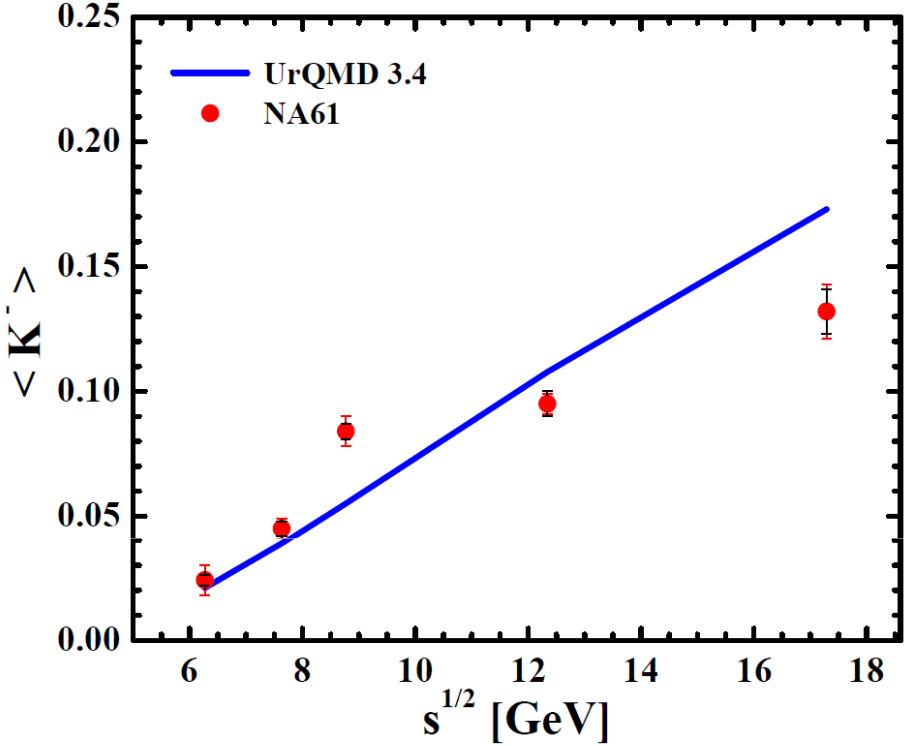




- The UrQMD model describes reasonably well the mean multiplicities of pions at high SPS energies
- It underestimates the mean multiplicities at lower energies for both particles
- In 20-31 GeV/*c* discrepancies may reach 30% for the mean pions multiplicities

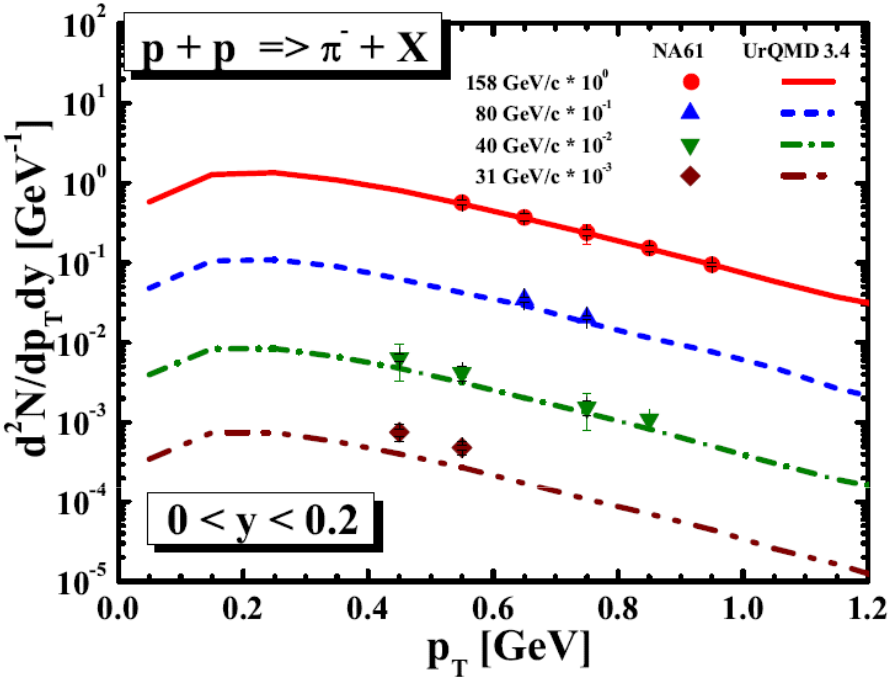
Mean multiplicities: positive and negative kaons

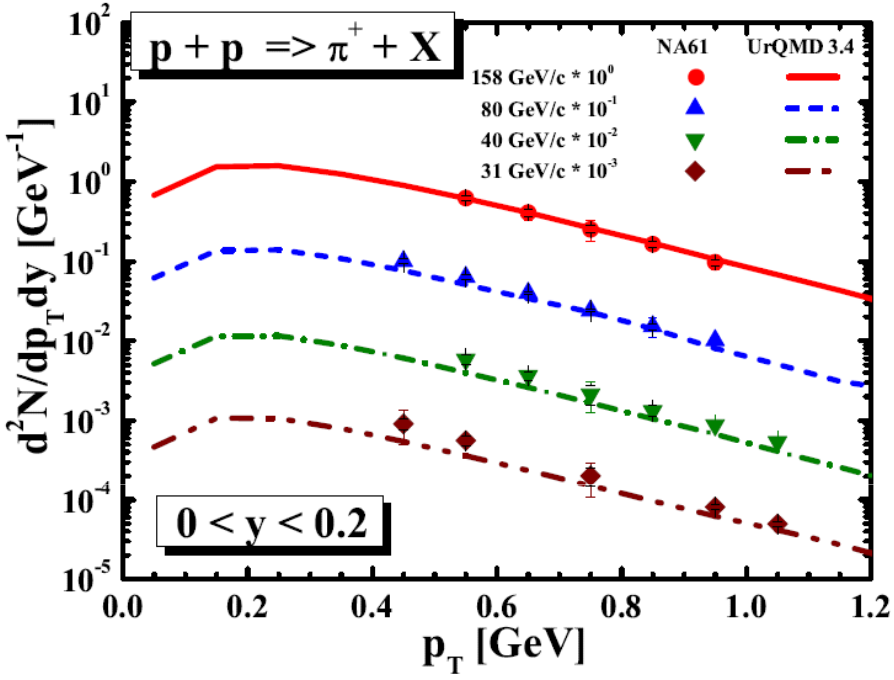




- **For negative kaons:**
  it slightly underestimates at 20 and 31 GeV/*c*; underestimates it by about 30% at 40 GeV/*c*; overestimates it by up to 30% at higher energies
- **For positive kaons:**
  provides a rough description for the two top beam momenta; systematically underestimates at lower energies with discrepancies reaching 40%

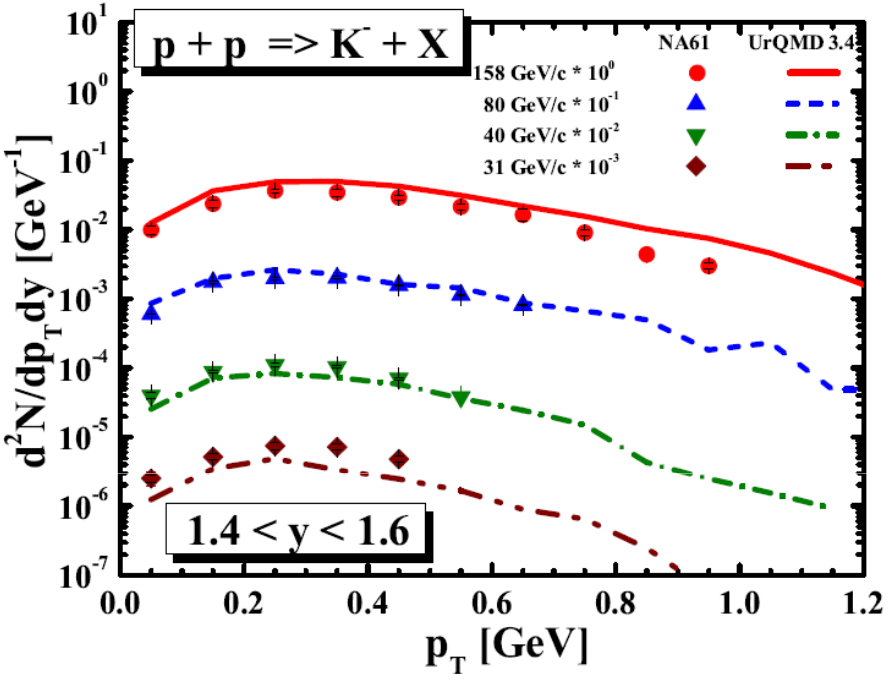
Transverse momentum spectra: positive and negative pions (I)

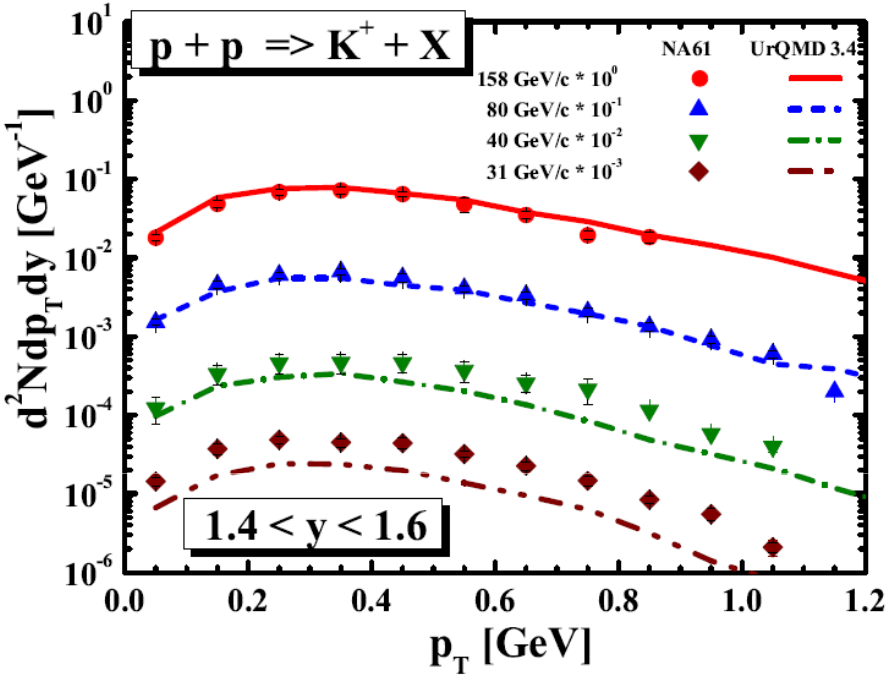




- The model describes well the transverse momentum spectra of both pions at 158 GeV/*c* at central rapidity
- It underestimates their yields at the lower energies for the whole transverse momentum range

Transverse momentum spectra: positive and negative kaons (II)





- **For negative kaons:**
  the model **overpredicts** the **K(-)** data at top energy momenta; **a good agreement** at 80 GeV/*c*; **predicts** smaller **yield** for 31 and 40 GeV/*c*
- **For positive kaons:**
  a fair agreement between data and model at 80 and 158 GeV/*c*
  underestimates the **yield** at lower beam momenta