Prediction of the particle production in pp collisions with the MPD detector at the NICA collider

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On behalf of the MPD Collaboration

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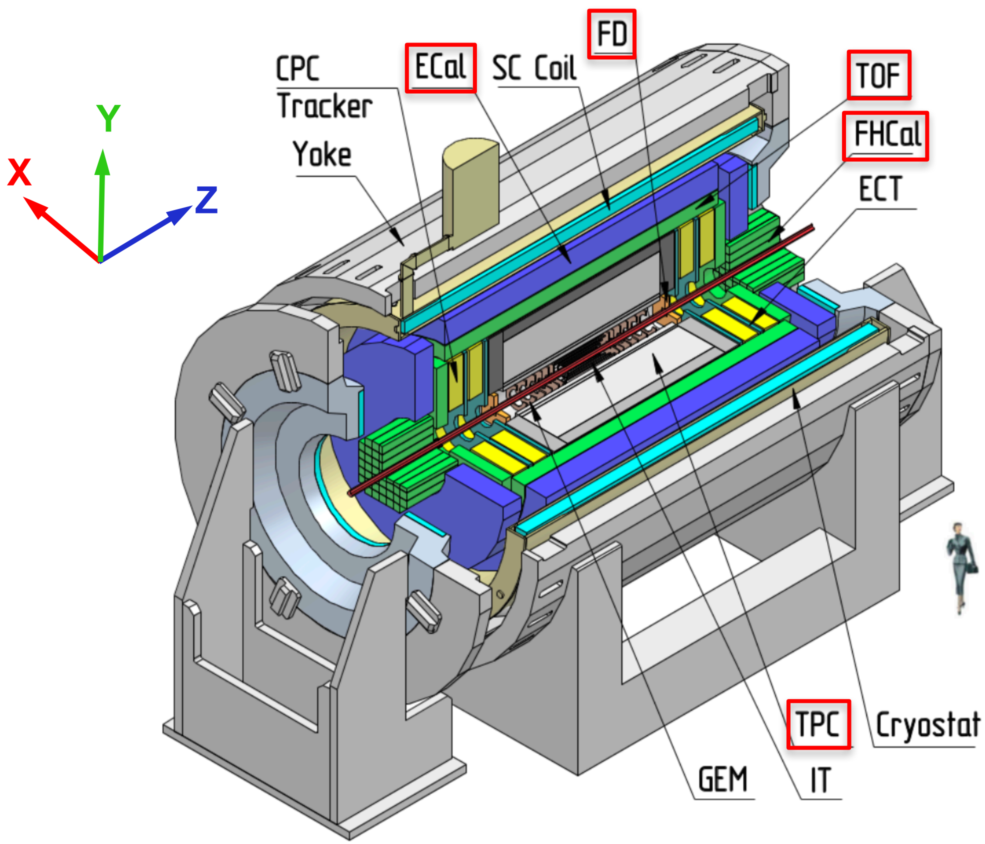
- Multipurpose detector (MPD)
- pp collisions in MPD
- Scheme of simulation
- Rapidity and transverse momentum distributions
- Mean multiplicity of charge particles vs $\sqrt{s}$
- Horn effect
- Λ^0 hyperon simulation (comparison with data)
- Λ^0 hyperon reconstruction in MPD

MPD: designed to accomplish a wide range of tasks of the NICA physics program.

Provide collisions in a wide range of atomic mass: A = 1 – 197.

High-precision tracking and particle identification in the full space-phase under a high multiplicity environment is expected.



Maximum centre-of-mass energy	Average luminosity
$\sqrt{s_{NN}}$ = 11 GeV (Au^{79+})	L = 10^{27} $cm^{-2}s^{-1}$
$\sqrt{s_{NN}}$ = 27 GeV (p)	L = 10^{32} $cm^{-2}s^{-1}$

Stage I: barrel part (- 2020):
TPC, TOF, ECAL, ZDC, FFD

TPC:

- $\eta < |1.8|$
- Momentum resolution better than 3% for: $|\eta| < 1.2$ and $0.1 < p_T < 1.6$ GeV/c

TOF:

- $\eta < |1.4|$
- High granularity

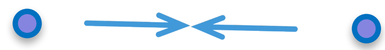
Exploring the **phase transition** and searching for the **critical end-point** → Priorities of the NICA project!

A wide range of collision energy and system size is required to study the nature of the transition region → **… this changes** → T : temperature, μ_B: chemical potential of matter at freeze-out stage

The study of diagnostic observables in proton – proton collisions, as well as other light systems constitute a necessary **baseline for reference** and better understanding of nucleus – nucleus interactions, e.g. fluctuations and correlations of *in medium* properties as function of the system size.

Simulation scheme

pp collisions @ $\sqrt{s} = 6 - 25$ GeV



Event generation
(models)

↓

MC transport
(*G3 - MpdRoot*)

↓

Reconstruction
(CF - KF)

Event generators based on the following models:

PHSD: (Parton Hadron String Dynamics) in HSD mode.
High energy inelastic hadron-hadron collisions in HSD are described by FRITIOF string model (including PYTHIA) while low energy hadron-hadron collisions are modelled based on experimental cross sections. This model takes into account the formation and multiple rescattering of leading pre-hadrons and hadrons. It emphasize on the hadronic phase based on DQPM . The *p+p* reactions are described by the Lund String model.

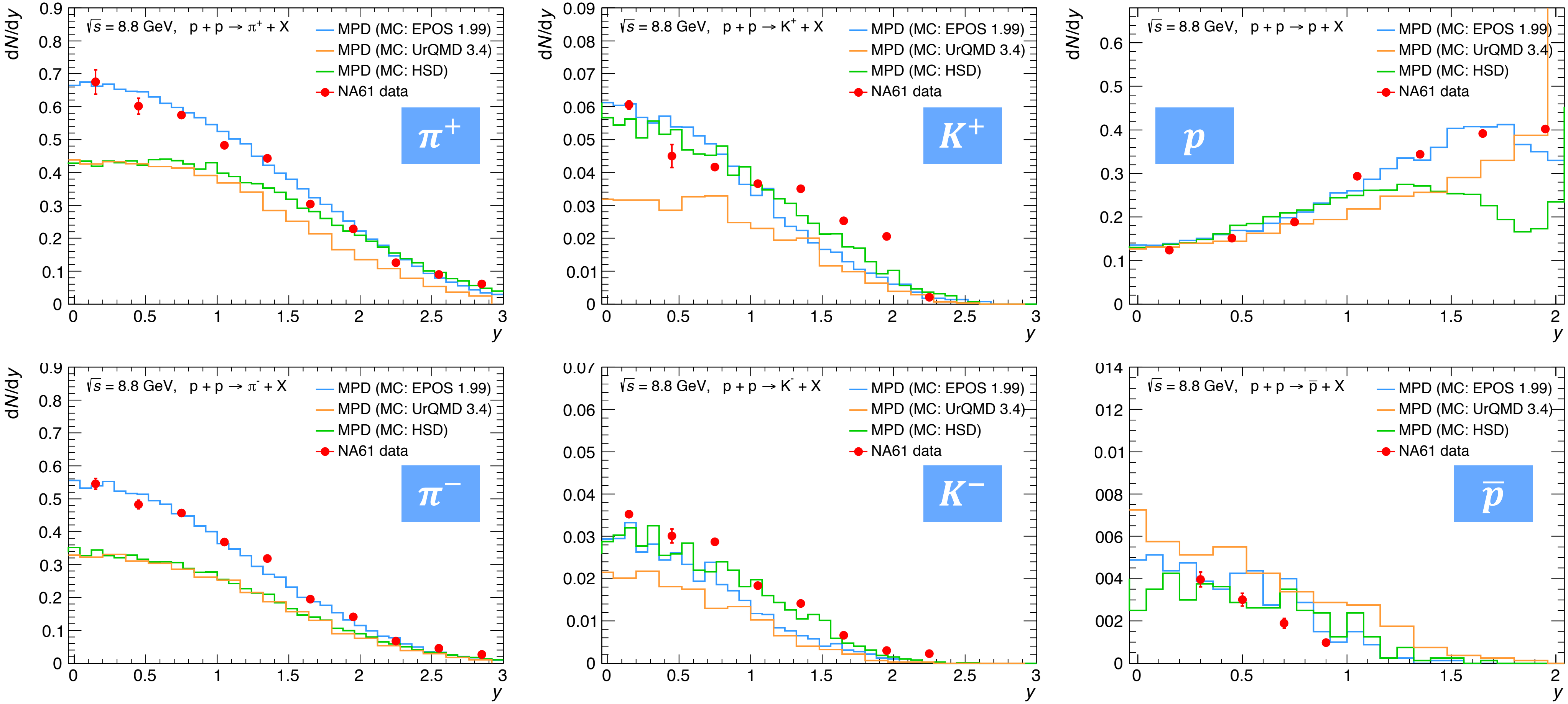
UrQMD: (Ultra Relativistic Quantum Molecular Dynamics)
Microscopic many-body approach to simulate nn, nN and NN interactions until 200 GeV. Degrees of freedom based on hadrons and strings.
Uses the basic treatment of baryonic equation of motion based on quantum mechanical approach. Ensures a phenomenological description of hadronic interactions between hadrons and their resonances.

EPOS 1.99: (Energy conserving quantum mechanical multiple scattering approach, based on Partons (parton ladders), Off-shell remnants, and Splitting of parton Ladders)
Combines parton model and Gribov-Regge theory.
Three sources of particle production: Hard and soft part of high energy hadron-hadron interaction and the two off-shell remnants. Gives an excellent description of baryon and antibaryon production.

pp @ $\sqrt{s}$ = 8.8 GeV

${dN}/{dy}$ $vs.$ y distributions of $\pi^+, K^+, p, \pi^-, K^-, \bar{p}$

MC simulations in MPD compared with exp. data from NA61/SHINE



- EPOS 1.99 agrees $\pi^{\pm}$ with data.
- UrQMD and HSD underestimate $\pi^{\pm}$ data

- EPOS 1.99 and HSD closer to K^+ data.
- HSD closer to K^- data.
- EPOS 1.99 underestimates K^- data
- UrQMD underestimates $K^{\pm}$ data.

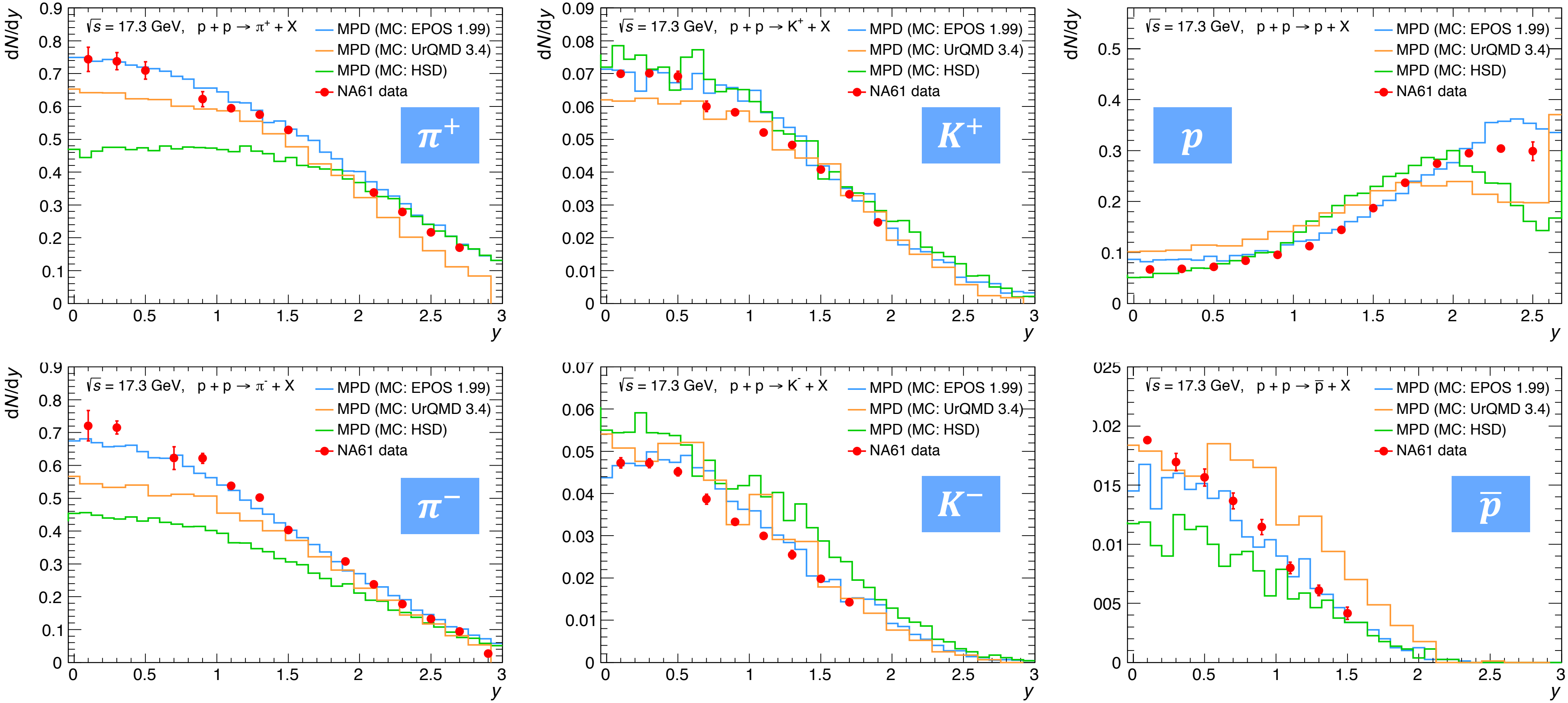
- EPOS 1.99 agrees with p data.
- UrQMD and HSD underestimate p data at y ≳ 0.8

Rapidity

pp @ $\sqrt{s}$ = 17.3 GeV

${}^{dN}/_{dy}$ *vs.* $\boldsymbol{y}$ distributions of $\pi^+, K^+, p, \pi^-, K^-, \bar{p}$

MC simulations in MPD compared with exp. data from NA61/SHINE



- EPOS 1.99 agrees with data.
- UrQMD and HSD underestimate data

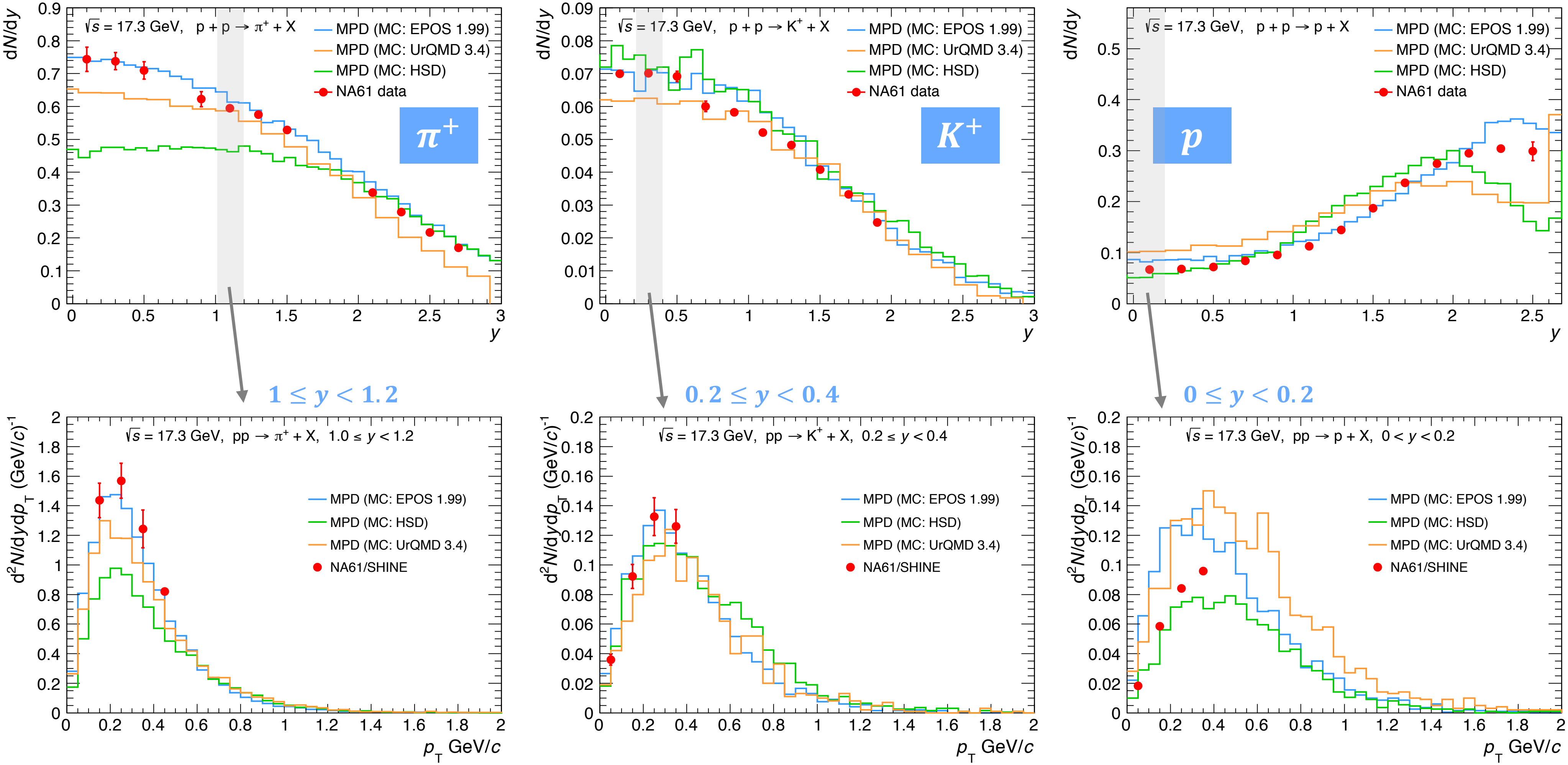
- EPOS 1.99 and HSD closer to K⁺ data.
- UrQMD underestimates K⁺ data at y < 0.6
- EPOS 1.99 and UrQMD closer to K⁻ data.
- HSD overestimates K⁻ data.

- EPOS 1.99 agrees with p data in a wide y range.
- UrQMD and HSD overestimate p data in wide y range and underestimate it at y ≳ 0.8
- $\bar{p}$ well described by EPOS 1.99, beyond mid-rapidity

Rapidity and transverse momentum

pp @ $\sqrt{s}$ = 17.3 GeV
y and p_T distributions of π^+, K^+, p

MC simulations in MPD compared with exp. data from NA61/SHINE



- EPOS 1.99 agrees with data.
- UrQMD and HSD underestimates yield of pions at low $p_T < 0.6$ GeV/c

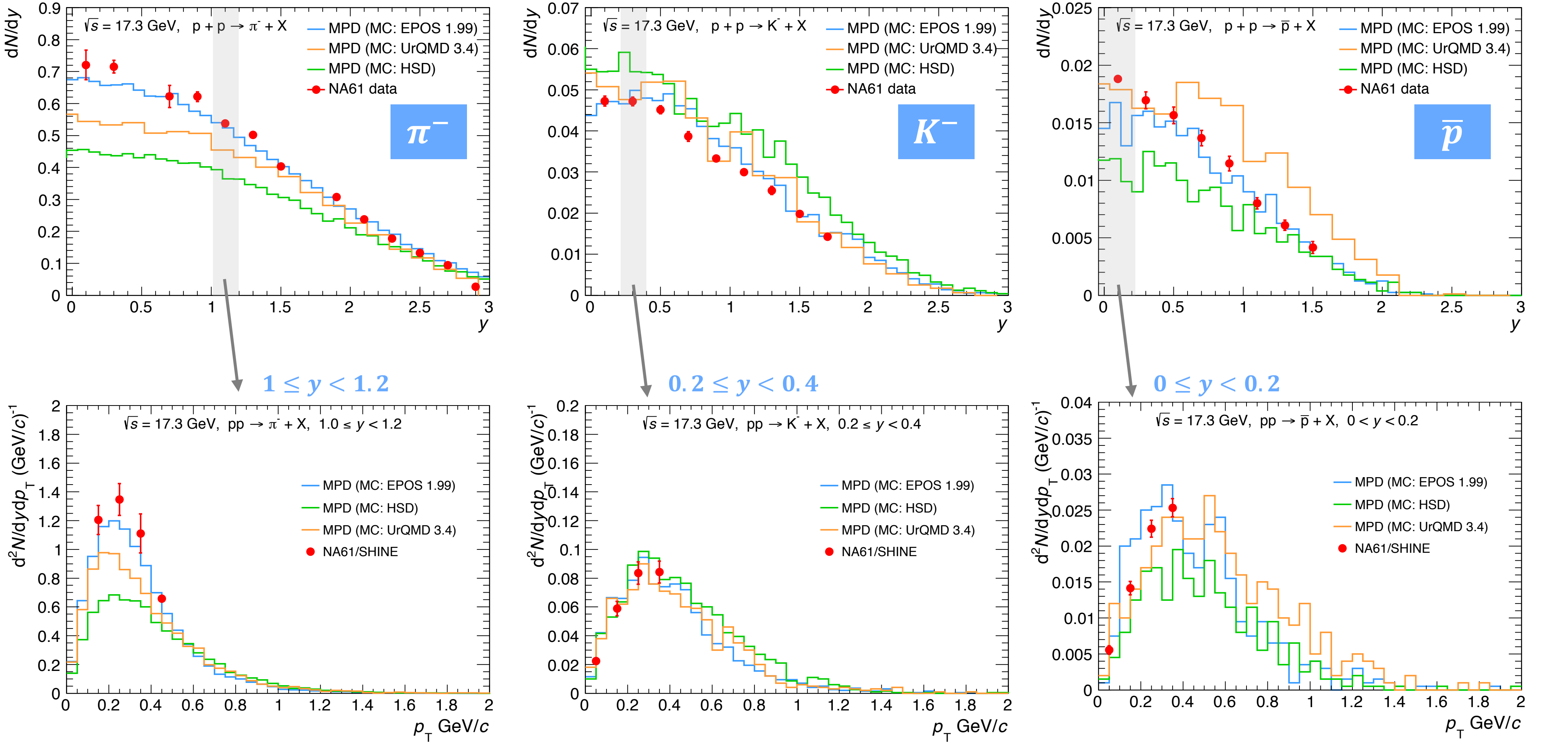
- UrQMD underestimates yield at $p_T < 0.4$
- HSD overestimates at $0.6 < p_T < 1.0$.
- EPOS 1.99 reproduces data at least at low p_T.

- HSD agrees with data at very low p_T
- EPOS 1.99 agrees with UrQMD at $p_T < 0.4$ and with HSD at $p_T > 0.7$, but overestimates data

pp @ $\sqrt{s}$ = 17.3 GeV

$\boldsymbol{y}$ and $\boldsymbol{p_T}$ distributions of $\pi^-, K^-, \bar{p}$

MC simulations in MPD compared with exp. data from NA61/SHINE



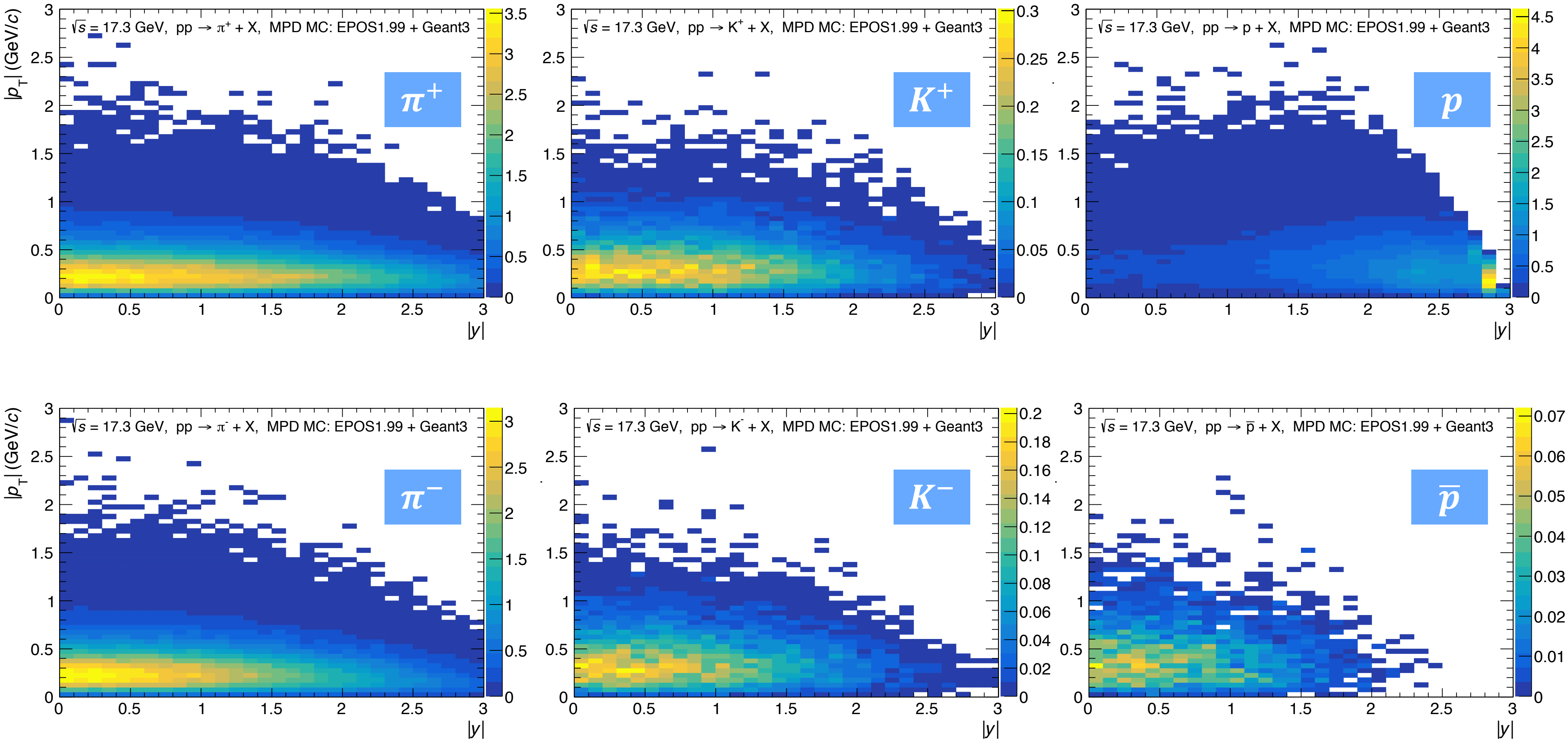
- EPOS 1.99 agrees with data.
- UrQMD underestimates at low p_T
- HSD underestimates at low p_T.

- Models agrees with data (low p_T) and differs each other at $p_T > 0.4$

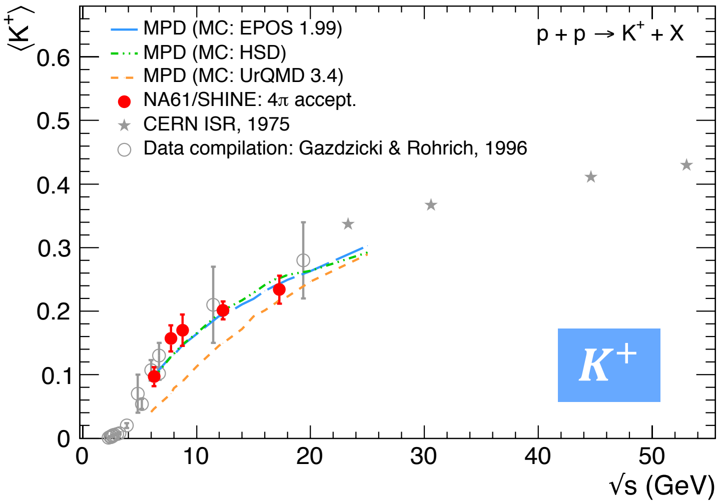
- EPOS overestimates data ($p_T < 0.4$)
- HSD and UrQMD underestimate data ($p_T < 0.4$)
- UrQMD predicts higher yield than other models ($p_T > 0.6$)

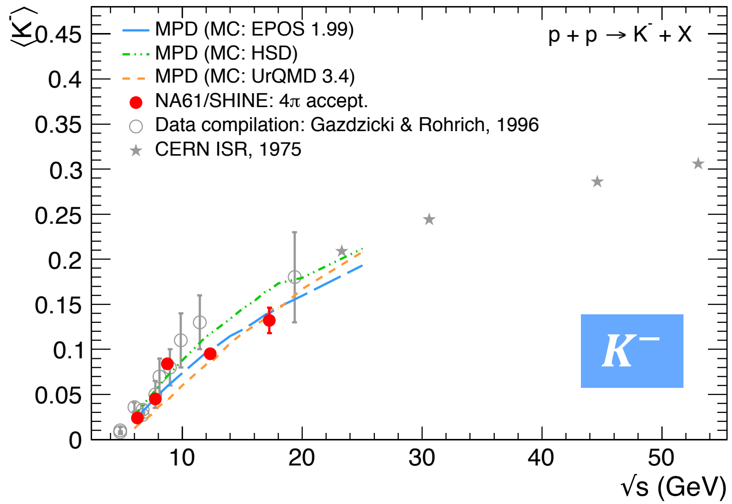
pp @ $\sqrt{s}$ = 17.3 GeV

Transverse momentum – rapidity MC distributions of $\pi^+, K^+, p, \pi^-, K^-, \bar{p}$

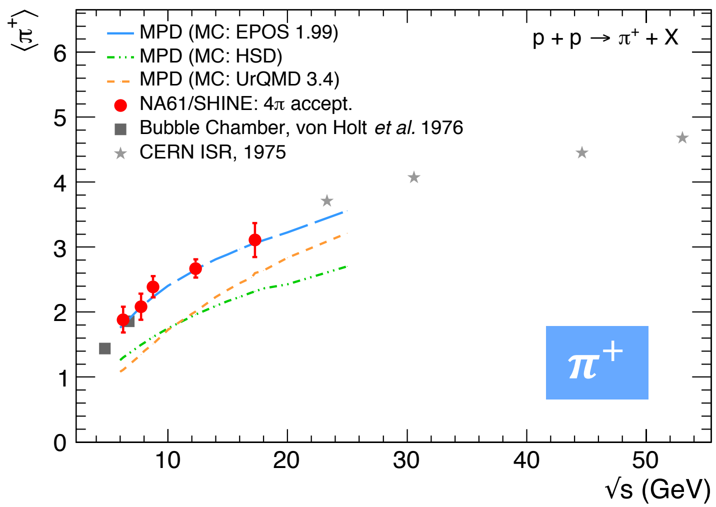


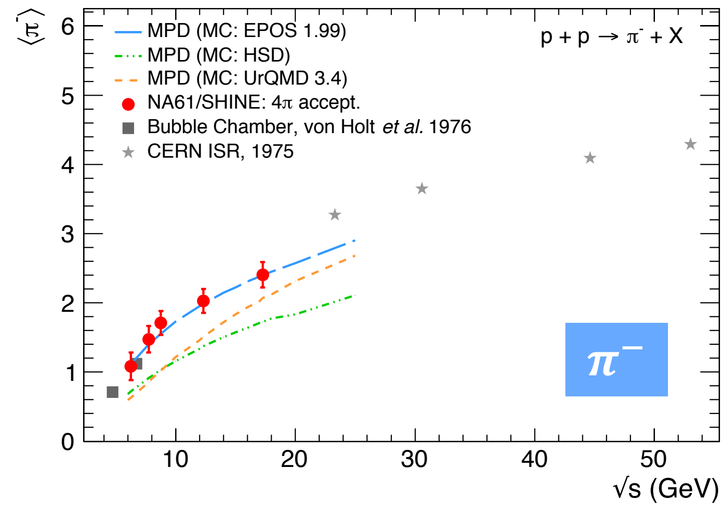
Mean multiplicity *vs.* collision energy



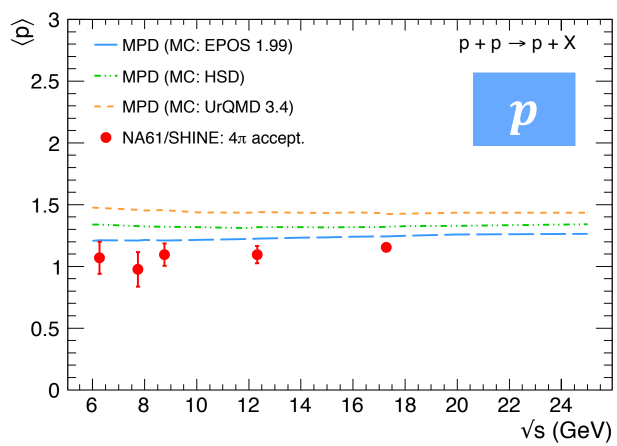


- EPOS 1.99 shows more consistency with NA61/SHINE data, than HSD and UrQMD for $K^{\pm}$ and $\pi^{\pm}$



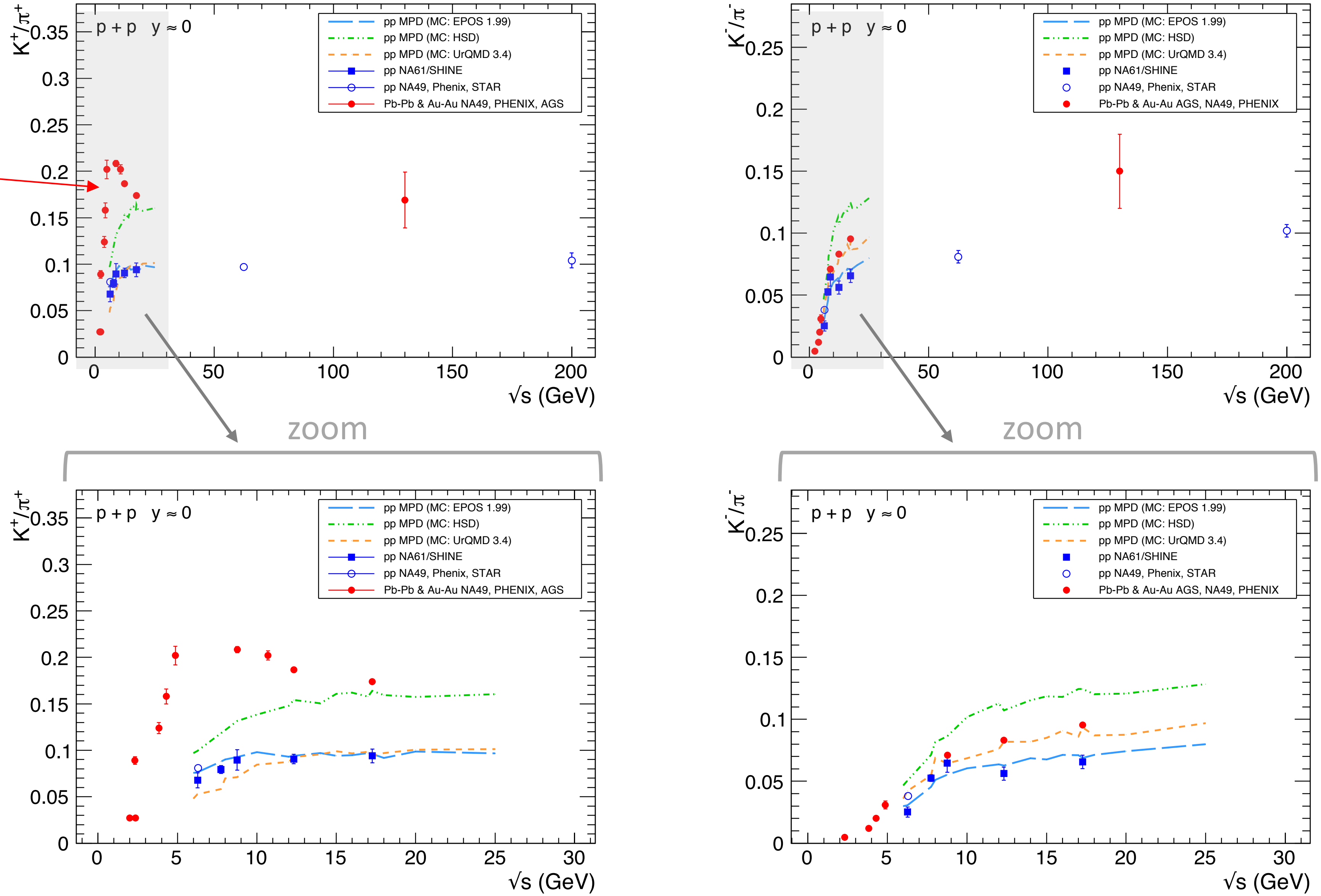


- HSD reproduces the K^+ data while UrQMD reproduces the K^- data.



Proton yield nearly constant at NICA energies

The ratio from heavy ion collisions is represented by red points for reference



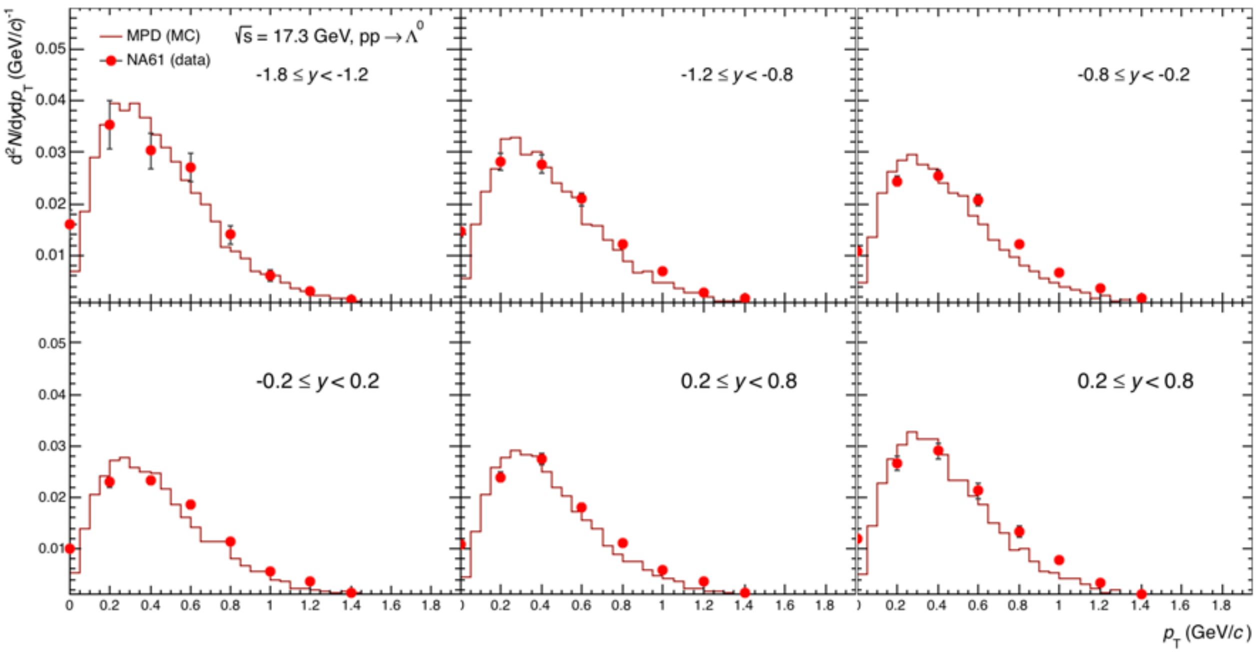
Rapid change of K^+/π^+ ratio at NICA energies for NN collisions → posible signature of deconfinement

There is a slight plateau-like structure for p+p.

Only EPOS 1.99 generator provides good agreement with p+p experimental data.

MC simulation (MPDRoot: EPOS-1.99 generator + Geant3), compared with NA61 experimental data.

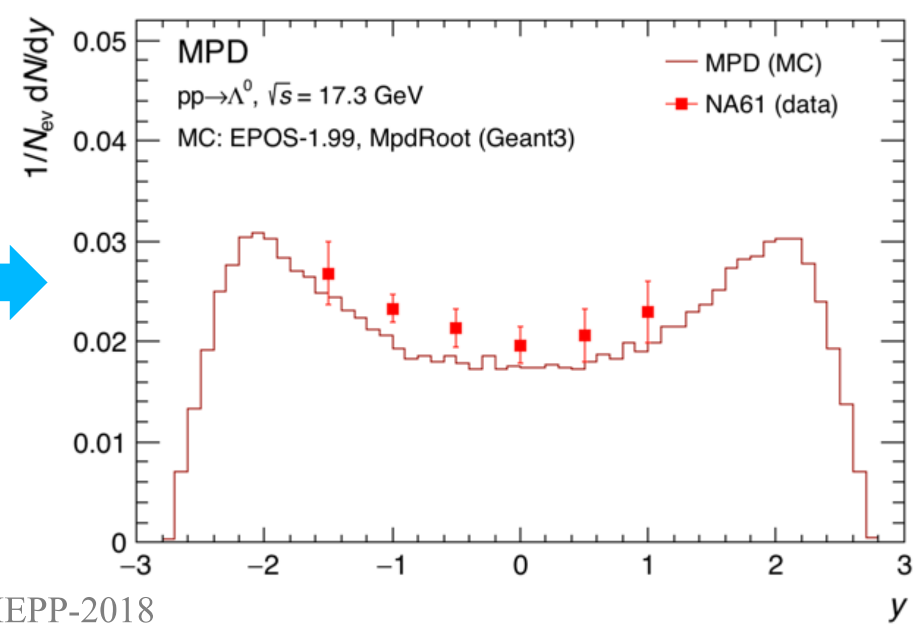
pp @ $\sqrt{s}$ = 17.3 GeV



Λ^0 hyperon predicted by Monte Carlo in MPD p+p collisions

Double-differential yield $\frac{d^2N}{dydp_T}$ of $\boldsymbol{\Lambda^0}$ **hyperon** at different rapidity intervals.

Pseudorapidity density distribution $\frac{dN}{dy}$ of $\boldsymbol{\Lambda^0}$ **hyperon**

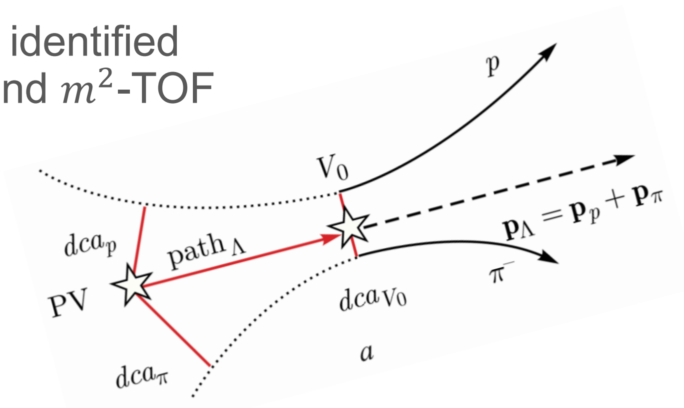


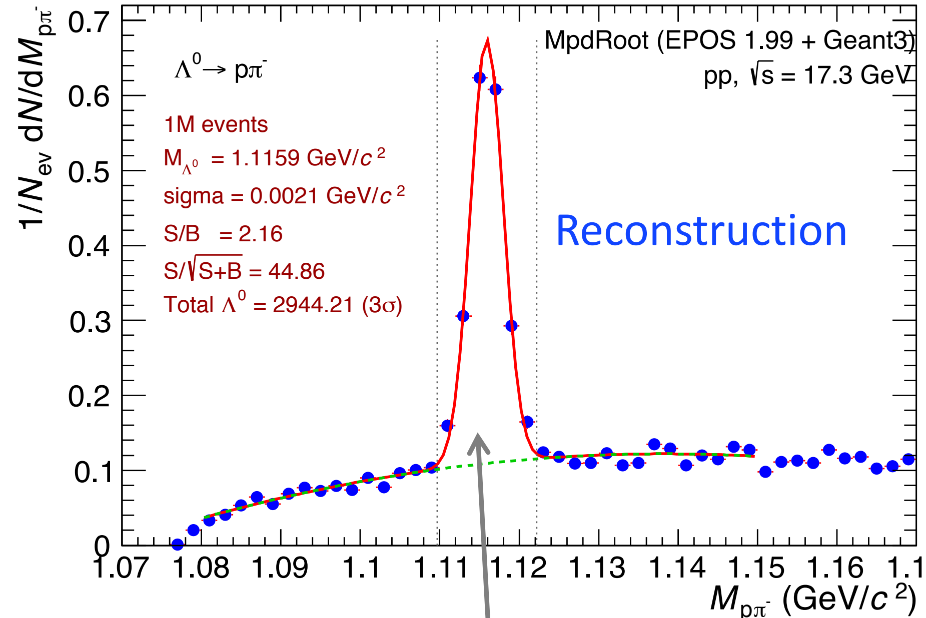
MC simulation of $pp \rightarrow \Lambda^0$ with EPOS-1.99 generator, very close to the data from NA61/SHINE (in the NICA energy range)

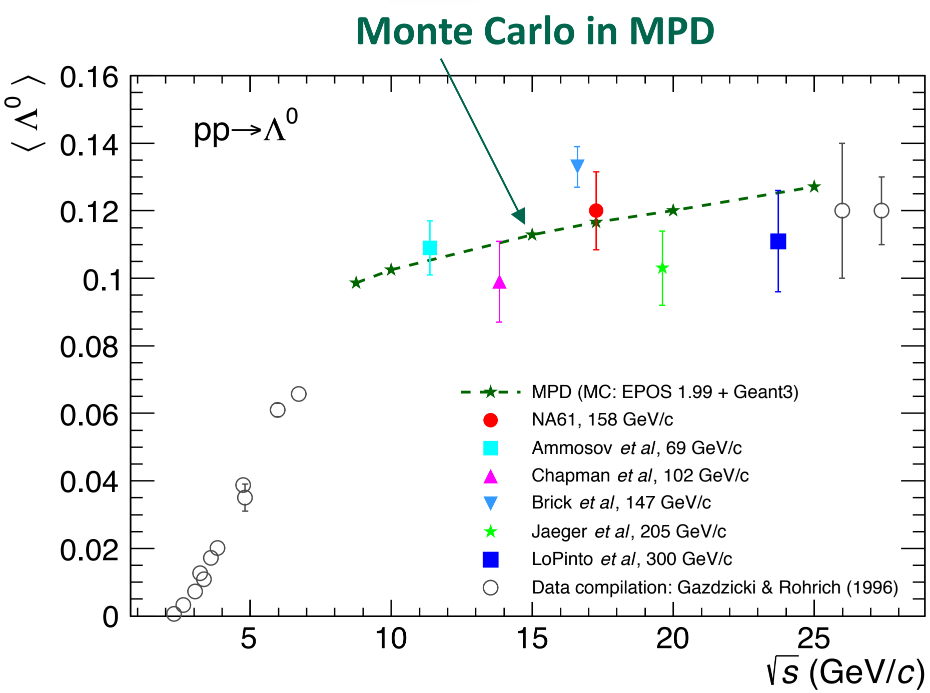
Λ^0 hyperon

Reconstruction of Λ^0 hyperon in MPD using particle identification

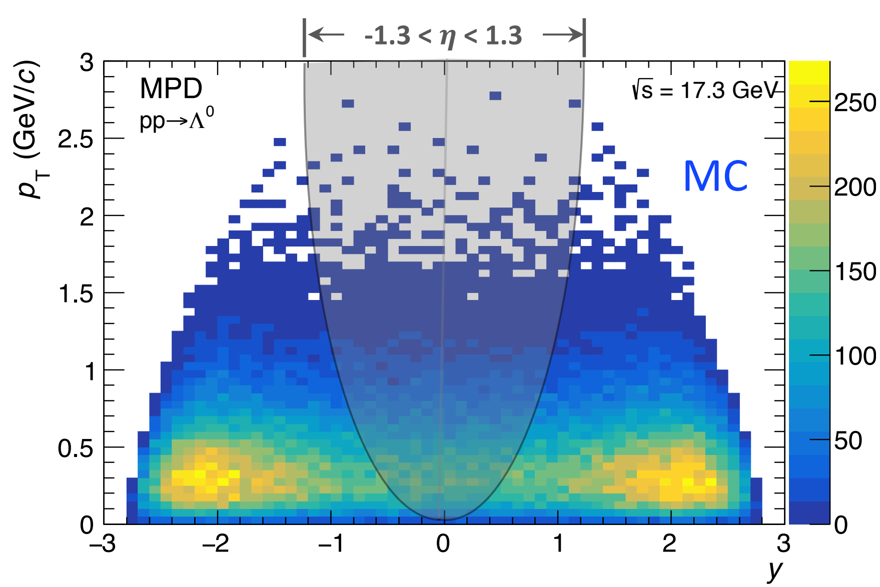
Track candidates identified via dE/dx-TPC and m^2-TOF methods.







Limited geometrical acceptance so far!



Summary

- A Monte Carlo simulation of charged particle and Λ^0 hyperon production from pp collisions in MPD was performed at $\sqrt{s}$ = 6 – 25 GeV and compared with experimental results of previous experiments in the energy range of NICA.

- Comparison between particle generators based on different models (EPOS 1.99, HSD and UrQMD) revealed differences between them, mainly at low p_T at central rapidities. In case of proton production there are also differences at high rapidity values (y > 2) where none of the models reproduces the data. The three models predict big differences concerning to the $\pi^{\pm}$ production, while the $K^{\pm}$ production shows closer agreement between them.

- The particle production simulations in MPD using - EPOS 1.99 - generator, shows better consistency with experimental results from p+p collisions performed in other experiments in the same energy interval of NICA.

- A systematic study of p+p collisions at the NICA energy range should provide a reference baseline, diagnostic observables from p+p collisions as well as to test and constraint model parameters describing hadron production mechanisms at lower energies.

- Monte Carlo simulation of Λ^0 hyperon production from p+p collisions in MPD using EPOS 1.99 generator, describes quite well experimental data reported in the literature.

- The reconstruction of the Λ^0 hyperon in the MPD geometrical acceptance given by the TPC and TOF detectors and using the PID method implemented in MPDRoot, gives rise to a well defined signal over a weak combinatorial background.