Prediction of particle production in pp collisions at MPD/NICA

Katherin Shtejer Díaz
On behalf of the MPD Collaboration

IV International Conference on Particle Physics and Astrophysics (ICPPA-2018)
October 22 – 26, 2018
Moscow, Russia
MPD: designed to accomplish a wide range of tasks of the NICA physics program.

Collisions in a wide range of atomic mass: \( A = 1 \rightarrow 197 \).

<table>
<thead>
<tr>
<th>Maximum centre-of-mass energy</th>
<th>Average luminosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sqrt{S_{NN}} = 11 \text{ GeV (Au}^{79+}) )</td>
<td>( L = 10^{27} \text{ cm}^{-2}\text{s}^{-1} )</td>
</tr>
<tr>
<td>( \sqrt{S_{NN}} = 27 \text{ GeV (p)} )</td>
<td>( L = 10^{32} \text{ cm}^{-2}\text{s}^{-1} )</td>
</tr>
</tbody>
</table>

The proton-proton collisions are in the MPD/NICA research program!

- Baseline for nucleus - nucleus interaction analysis.
- A good tool for detector performance studies.
- Study of fluctuations and correlations of in-medium properties as function of the system size.
- RAA – nuclear modification factor
- Horn effect, etc
Simulation framework

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

Event generators based on the following models:

**UrQMD 3.4**
(Ultra Relativistic Quantum Molecular Dynamics)


**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.

Rapidity spectra

\[ \frac{dN}{dy} \text{ vs. } y \] distributions of \( \pi^+, K^+, p, \pi^-, K^-, \bar{p} \)

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

- EPOS 1.99 agrees better with \( \pi^\pm \) data.
- UrQMD underestimate \( \pi^\pm \) data mainly at central rapidity.
- EPOS 1.99 agrees better with \( \pi^\pm \) data.
- EPOS 1.99 closer to \( K^+ \) data at mid-rapidity and overestimates for \( 0.5 < |y| < 1.5 \). The opposite happens to UrQMD.
- UrQMD 3.4 overpredicts the \( K^- \) data for \( 0.2 < |y| < 1.4 \).
- EPOS 1.99 systematically agrees with \( p \) data except at forward beam rapidity, while systematically describes with \( \bar{p} \) data except for mid-rapidity.
- UrQMD overestimates \( p \) data in a wide rapidity range and underpredicts it at forward rapidity.
- At mid-rapidity both models predict values larger than the \( p \) data and lower than \( \bar{p} \) data.
Rapidity and transverse momentum

\[ p \mp \sqrt{s} = 17.3 \, \text{GeV} \quad (\pi^+, K^+, p) \]

\( p_T \) distributions were determined in rapidity intervals

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

- EPOS 1.99 agrees with data.
- UrQMD underestimates yield of pions at \( p_T < 0.6 \) GeV/c
- EPOS 1.99 reproduces data available at low \( p_T \).
- UrQMD underestimates yield at \( p_T < 0.4 \)
- EPOS 1.99 agrees with UrQMD at \( p_T < 0.4 \) but both models overestimate data.
Rapidity and transverse momentum

$pp @ \sqrt{s} = 17.3 \text{ GeV} \quad (\pi^-, K^-, \bar{p})$

$p_T$ distributions were determined in rapidity intervals

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

- $\pi^-$
- $K^-$
- $\bar{p}$

$1 \leq y < 1.2$

$0.2 \leq y < 0.4$

$0 \leq y < 0.2$

○ EPOS 1.99 agrees with data.
○ UrQMD underestimates at $p_T < 0.6$ GeV/c

○ Models agrees with data.
○ EPOS overestimates data ($p_T < 0.4$)
○ UrQMD underestimate data ($p_T < 0.4$)
Mean multiplicity vs collision energy

- **K^+**
- **K^-**
- **π^+**
- **π^-**
- **p**
- **p^-**

Data compilation:
- Gazdzicki & Rohrich, 1996
- CERN ISR, 1975
- MPD (MC: EPOS 1.99)
- MPD (MC: UrQMD 3.4)
- NA61/SHINE: 4σ accept.

CERN ISR, 1975

K. Shtejer, ICPPA-2018

October 22 - 26, 2018
Rapid change of $K^+ / \pi^+$ ratio of NN collisions at NICA energies $\rightarrow$ possible signature of deconfinement.

There is a slight plateau-like structure for $p+p$ (in exp. Data from NA61 and EPOS 1.99 prediction).

EPOS 1.99 generator provides better agreement with $p+p$ experimental data.

UrQMD 3.4 underestimates $K^+ / \pi^+$ ratio at $\sqrt{s} < 12$ GeV and overestimates $K^- / \pi^-$ ratio in all the $\sqrt{s}$ range.
**Tracking efficiency**

\[ \varepsilon_{\text{prim}} = \frac{p_T \text{ good primaries}}{p_T \text{ all primaries}} \]

\[ \varepsilon_{\text{sec}} = \frac{p_T \text{ good secondaries}}{p_T \text{ all secondaries}} \]

**\( p_T \) resolution**

\[ \delta p_T = \sigma \left( \frac{p_{T,mc} - p_{T,rec}}{p_{T,mc}} \right) \]

*Software written by Alexander Zinchenko*
Particle identification

\[ E_{\text{eff}} = \text{correctly identified reconstructed} \]

\[ \text{Contam} = \frac{\text{incorrectly identified identified}}{\text{correctly identified identified}} \]

*PID implemented in MPDRoot by A. Mudrokh and A. Zinchenko
MC simulation (MPDRoot: EPOS-1.99 generator + Geant3), compared with NA61 experimental data.

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

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

**Monte Carlo in MPD**

$\Lambda^0$ hyperon predicted by Monte Carlo in MPD p+p collisions

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

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

$\Lambda^0$, $\sqrt{s} = 17.3$ GeV

PP data compilation: Gazdzicki & Rohrich (1996)

Data compilation: Gazdzicki & Rohrich (1996)

- MPD (MC): EPOS 1.99 + Geant3
- NA61, 158 GeV/c
- Ammosov et al, 69 GeV/c
- Chapman et al, 102 GeV/c
- Brick et al, 147 GeV/c
- Jaeger et al, 205 GeV/c
- LoPinto et al, 300 GeV/c
- Data compilation: Gazdzicki & Rohrich (1996)
Reconstruction of $\Lambda^0$ hyperon in MPD using particle identification

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

Limited geometrical acceptance so far!
The best combination of S/B and significance are obtained at $0.5 < p_T < 1.5$
The production of $p, \bar{p}, \pi^{\pm}$ and $K^{\pm}$ from pp @ 6 – 25 GeV was predicted through the spectra and multiplicities simulated by Monte Carlo in MPD/NICA. Comparison between predictions of two models, EPOS-1.99 and UrQMD-3.4, as well as with recent experimental results from NA61/SHINE were performed.

- EPOS 1.99 provides a reasonable description of the experimental data while UrQMD exhibits more discrepancies.

- Monte Carlo simulation of $\Lambda^0$ hyperon production from p+p collisions in MPD using EPOS 1.99 generator at $\sqrt{s} = 6 – 25$ GeV, describes quite well experimental data reported in the literature.

- The reconstruction of the $\Lambda^0$ 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.

- Performance study of MPD for pp collisions revealed a good track finding efficiency and momentum resolution, as well as a good particle identification efficiency with the combined method.

- 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 a tool for testing and constraining model parameters describing hadron production mechanisms at lower energies.