# **MPD PWG2 status report**

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#### □ Introduction : PWG2 tasks

**Update of feasibility study results :** 

- Models
- Light hadrons
- Hypernuclei
- AntiL and antiprotons
- Hyperon polarization
- □ Summary

#### PWG2 co-conveners:

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## **PWG2 physics cases**

#### • Light flavor hadron spectra, yields, and ratios

- Energy, system size and centrality dependence of the production of charged hadrons (pions, kaons, (anti)protons).
- Extraction of transverse momentum spectra, rapidity distributions, mean multiplicities, and particle ratios.
- Nuclear modification factor, antiparticle/particle ratio, radial flow, phase diagram mapping.

#### Strangeness (hyperons and hypernuclei)

- Analysis of strange hyperons (Lambda, Ksi, Omega) and their antiparticles: spectra, yields, antiparticle/particle ratio, nuclear modification factor, azimuthal anisotropy (together with PWG3).
- (Anti)Lambda polarization.
- Reconstruction of single and double hypernuclei: spectra, rapidity density, and lifetime.

#### Resonances

- Production of \rho, \phi, Kstar, Lambda(1520) etc.

#### Light nuclei

- Production of nucleon clusters (d, t, He3, He4) in various reactions (from p+p to Au+Au): spectra, yields, coalescence coefficients.

### **MPD** setup and overall performance



#### MPD at Stage'1:

- **TPC** tracking:  $|\eta| < 1.6$  (Npoints>15)
- **TOF & ECAL** coverage:  $|\eta| < 1.3$
- PID: TOF+dE/dx combined |η|<1.3, pT<3 GeV/c, limited PID 1.3<|η|<1.6 (dE/dx)</li>





# **Event generators used in PWG2 studies**

- UrQMD easy in the use, for simple tests only
- PSHD used in the study of hadroproduction (including multistrangeness) and hyperon polarization
- PHQMD strangeness, light nuclei and hypernuclei

#### PHSD/PHQMD model advantages:

- ✓ PHSD/PHQMD event generator simulates heavy-ion collisions from the initial touch until freezeout
- ✓ Partonic and hadronic degrees of freedom, tunable parameters for the EoS
- ✓ Implements chiral symmetry restoration (CSR) effects
- ✓ Reproduces experimental data for the bulk observables

### Input for the MPD feasibility study : PHQMD model

#### **PHQMD model**

J. Aichelin, E. Bratkovskaya, A. Le Fèvre, V. Kireyeu, V. Kolesnikov, Y. Leifels, V. Voronyuk, and G. Coci, Phys. Rev. C 101, 044905



<u>The goal:</u> to develop a unified n-body microscopic transport approach for the description of heavy-ion dynamics and dynamical cluster formation from low to ultra-relativistic energies <u>Realization:</u> combined model <u>PHQMD</u> = (PHSD & QMD) & SACA



PHQMD event generator is used as an input for the recent big DST production for PWG2 (40Mevents)

#### PHQMD model : predictions vs data at NICA energies (light nuclei)

V.Kireyeu, V. Voronyuk

- Realized and compared the coalescence and Minimum Spanning Tree (MST) in the deuteron production calculations for the PHQMD and UrQMD models (w/ and w/o nuclear potential interactions)
- Multiplicities, rapidity spectra, transverse momentum spectra, as well coalescence parameters and spacetime distributions for nucleons and deuterons in central A+A at 9 GeV are calculated

<u>arXiv.org</u> > <u>nucl-th</u> > arXiv:2201.13374v1, accepted in PRC



### PHQMD model : predictions vs data at NICA energies (hypernuclei)

- PHQMD reproduces results for hypernuclei from STAR
- Is used as an input for the simulation of hypernuclei at MPD

<u>arXiv.org</u> > <u>nucl-th</u> > arXiv:2106.14839, accepted in Phys. Rev. C





### **PHQMD** model predictions : space-time distributions for clusters



<u>arXiv.org</u> > <u>nucl-th</u> > arXiv:2201.13374

a systematic shift by approximately 5 fm/c between the freezeout time for free and bound nucleons

majority of nucleons and deuterons

freeze-out within 15 fm from the

deuterons remain at smaller radial

distances than free nucleons

center of the reaction





✓ 40Mevent Bi+Bi at 9 GeV from the PHQMD model – the largest data set produced ever!
 Many thanks to the Soft. Group and A.Moshkin for the job!

#### Several analyses with the recently produced 40M data sample are ongoing:

- Hypertriton yield and lifitime
- Performance study for LH4 and LHe4
- antihyperon production and antihepron-to-hyperon ratio at high-pT

### **MPD PID performance**

✓ 40MEvents Bi+Bi, PHQMD with nuclei

- ✓ Centralized DST production, MPD analysis chain
- Combined (dE/dx + TOF) particle ID, positively charged hadrons and nuclei well separated





#### **Results: spectra of hadrons and light nuclei**

- MPD provides large phase-space coverage for identified pions and kaons (> 70% of the full phase-space at 9 GeV)
- Hadron spectra can be measured from p<sub>T</sub>=0.2 to 2.5 GeV/c
- Extrapolation to full p<sub>T</sub>-range and to the full phase space can be performed exploiting the spectra shapes (see BW fits for p<sub>T</sub>-spectra and Gaussian for rapidity distributions)



### Light hadrons : Centrality dependence of particle production

#### A.Aparin + team

- Differential hadron production in Bi+Bi collisions (PHSD model)
- Centrality classes were calculated based on the number of charged particles registered in TPC (PWG3-Flow group method).
- PID: combined dE/dx@TOF + full set of corrections







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# **Results on hypernuclei**

### **Reconstruction of hypertritons in MPD**

V.Vasendina, A.Zinchenko

- **Precise information on YN interactions: strange sector of nuclear EOS, astrophysics**
- 40M Bi+Bi collisions at 9.2 GeV, |y|<1, no centrality selection





Rapidity density can be obtained in Min.Bias Bi+Bi collisions



 $^{3}_{A}H \rightarrow ^{3}He + \pi^{-}$ 

path

dca<sup>,</sup>

<sup>3</sup>He

distance

### H3L invariant spectra and lifetime

- Hyperon lifetime puzzle in HIC affects Y-N interactions in the medium and requires additional measurements
- Results in a broad region of cτ also requires large data sets

40Mevents, Bi+Bi at 9.2 GeV, b < 12 fm  $\tau = [0.1 - 1.5]$  ps p1 = 265 +/- 4 ps (2%, 1%)



40 MEvents allows extend the range by 50% and decrease uncertainty by factor of 3 (relative to 15 MEvents)

### H3L lifetime: 2-prong vs 3-prong mode



Results for two decay modes are consistent

#### More of hypernuclei in MPD

V.Vasendina, A.Zinchenko

• 40Mevents Bi+Bi at 9.2 GeV, b < 12 fm (PHQMD)



Signals for heavier hypernuclei are seen

### **News on antibaryons**

- With (anti)hyperon production we can address bulk properties, phase transition as well as critical phenomena
- Antibaryon-to-baryon ratio at intermediate momenta (pT >~ 1.5 GeV/c) can be sensitive to CEP (a falling trend in contrast to a constant behavior in the scenario without CEP) – Askawa, et al., Phys. Rev. Lett. 101, 122302 (2008)

## (anti)Hyperon reconstruction in MPD

- Generator: 40M Bi+Bi @ 9 GeV (PHQMD)
- Detectors: MPD Satge'1 configuration,  $|\eta| < 0.5$
- Track reconstruction and PID (dE/dx+TOF)
- Secondary vertex finding technique with a set of topological cuts





 $\Lambda \rightarrow p + \pi$ 

dca\_

PV

path



- Good MPD performance in antihyperon reconstruction
- 40MEvents sufficient to extend pT-coverage up to 4 GeV/c^2

## (anti)Hyperon spectra and ratio



- Corrected spectra of (anti)hyperons
- Those at midrapidity up to pT = 4.0 GeV/c. Good results of closure tests



## (anti)proton spectra and ratio : selection criteria

#### A. Mudrokh

- Problem with antiproton PID above pT = 1.5 GeV/c (low production yields and purity)
- Special considerations for selection criteria for the high-pT range (max. number of tight cuts)



#### (anti)proton spectra and ratio : antiproton PID at high-pT

1.5 < pt < 2.0 GeV/c



### (anti)proton spectra and ratio

#### https://git.jinr.ru/pwg2/mdrkh

- Preliminary midrapidity spectra of (anti)protons and the spectra ratio are obtained in Bi+Bi at 9 GeV
- Large pT-coverage achieved by a special PID procedure that is applied (lowering efficiency at high pT)
- Additional efforts are needed to unveil the remaining discrepancy first pT points



## Hyperon polarization at NICA/MPD (ongoing analysis)

Bi-Bi @ 9GeV, 10M MB events, b [0,12]fm (PHSD, request 23)
Global hyperon polarization (Thermodynamical approach)
Higher polarization for anti-Lambda w.r.t. Lambda
Transfer of polarization vector to MCTracks
Transfer of polarization during hyperon decays (feed-down)
Centrality determined through TPC multiplicity
Event plane resolution estimated via FHCal





$$\overline{P}_{\Lambda/\bar{\Lambda}} = \frac{8}{\pi\alpha} \frac{1}{R_{\rm EP}^1} \left\langle \sin(\Psi_{\rm EP}^1 - \phi_p^*) \right\rangle$$

•Global polarization extraction •«Event plane» method •Fit of  $N_{\Lambda}(\Delta \phi_p^*)$ •Dependent on statistics •Detailed study ongoing

Details in the talk of E.Nazarova

# Summary

MPD physics simulation within PWG2 is ongoing

<u>Steady progressing</u>: Hadron spectra, (Hyper)nuclei, antibaryons

The goal – finish analyses and prepare materials for the "MPD Performance Paper 2"

# Thank you for your attention!