

Rivet/HepMC for HICs



Elena Bratkovskaya
(GSI Darmstadt & Uni. Frankfurt)

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What is the concept of Rivet for HICs ?

Rivet home page:

“The Rivet toolkit ([Robust Independent Validation of Experiment and Theory](#)) is a system for **validation of Monte Carlo event generators**. It provides a large (and ever growing) set of experimental analyses useful for MC generator development, validation, and tuning, as well as a convenient infrastructure for adding your own analyses. “

What should be a **goal of Rivet for HICs (!?)**:

(Personal view!)

- ☐ a tool which **helps** to perform the **comparison of theoretical results with exp. data** – makes such analysis simple and robust
- ☐ collect / keep the exp. data including **analysis** to calculate observables (e.g. application of exp. cuts, acceptances etc.)

What should be a concept of Rivet for HICs ?

Questions to clarify:

❑ Rivet input format **HepMC** is **NOT suited for the HIC** event generators (using OSCAR or ROOT format for output).

❑ HepMC requires a lot of ,extra' information which is **NOT needed for comparison of theory to the HIC exp. data!** It requires a lot of disk space!

E.g.: the scattering vertexes, the information on particles' parentage, the lifetime, the number of hard scatterings, the number of projectile/target participants, the number of NN collisions, the number of spectator neutrons/protons, ...

❑ **Conceptual problems:** this ,extra' information **CAN NOT be measured** in experiments **directly**, it is model dependent and **should not** be used as ,input' for the comparison of theory to the data

Optimal concept of Rivet for HICs:

RIVET has to treat the theoretical input in the same way as experimental data →

Input: **only particle ID's in 4-momenta on event-by-event basis!**

→ All other **unmeasured quantities** (production or decay vertexes, N_{part} , N_{hard} etc.) have to be **RECONSTRUCTED** (if needed! For WHAT?!) from theory output in the same way as it is done with exp. data!

→ **real improvement of comparison of theory and experiments!**

Converter from HepMC to OSCAR/ROOT

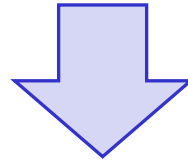
How to overcome present problems of Rivet/HepMC format?

❑ **Convertor has been developed :**

the PHSD (PHQMD) output "phsd.dat" (event-by-event output in OSCAR format) to the **HepMC2 format**

- **written by Viktor Kireyeu** (cf. presentation by Viktor, thanks to Christian Bierlich for the help)

➔ Application of convertor made it possible to use Rivet for the PHSD output for pp and A+A data (see examples)



❑ **Presently: standard converter** from transport model output (OSCAR/ROOT) to Rivet input for HICs has to be available

Way: reset all ,extra' information by zeros! ➔ Not the optimal way to fill the disk space and computer resources!

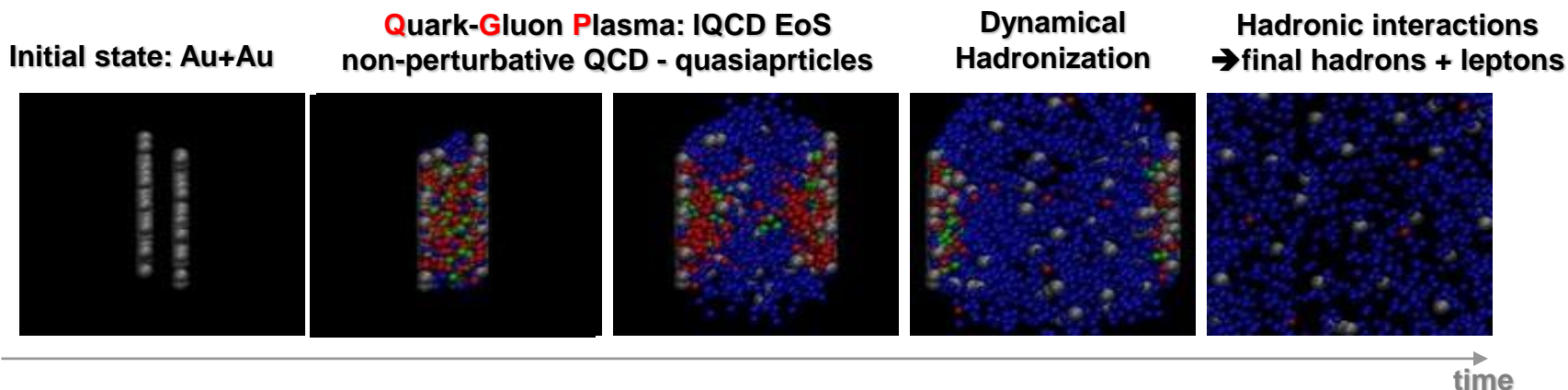
❑ **Future: Rivet input has to be updated** – to treat theory as exp. data!

Parton-Hadron-String Dynamics (PHSD) is a **non-equilibrium microscopic transport approach** for the description of strongly-interacting hadronic and partonic matter created in heavy-ion collisions

Dynamics: based on the solution of generalized off-shell transport equations derived from **Kadanoff-Baym many-body theory**

Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) is a unified **n-body** microscopic transport approach for the description of heavy-ion collisions and **dynamical cluster formation** from low to ultra-relativistic energies

Realization: PHQMD = (PHSD & **QMD**) & (**MST/SACA** for cluster recognition)



→ **PHSD, PHQMD** provide a good description of ‘bulk’ hadronic as well as electromagnetic observables from SIS to LHC energies



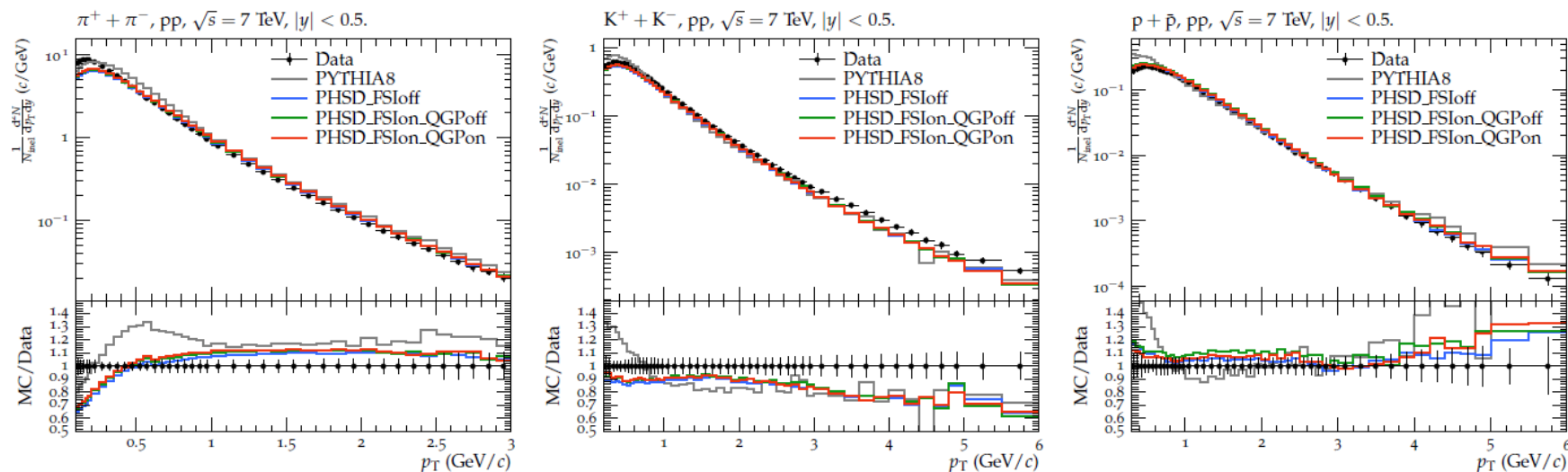
PHSD: W. Cassing, E. Bratkovskaya, PRC 78 (2008) 034919; NPA831 (2009) 215; W. Cassing, EPJ ST 168 (2009) 3

<http://theory.gsi.de/~ebratkov/phsd-project/PHSD/index1.html>

PHQMD: J. Aichelin et al., PRC 101, 044905 <http://phqmd.qitlab.io/>

ALICE_2015_I1357424

V. Kireyeu et al., Eur.Phys.J.A 56 (2020) 223
PHSD analysis by Ilia Grishmanovskii



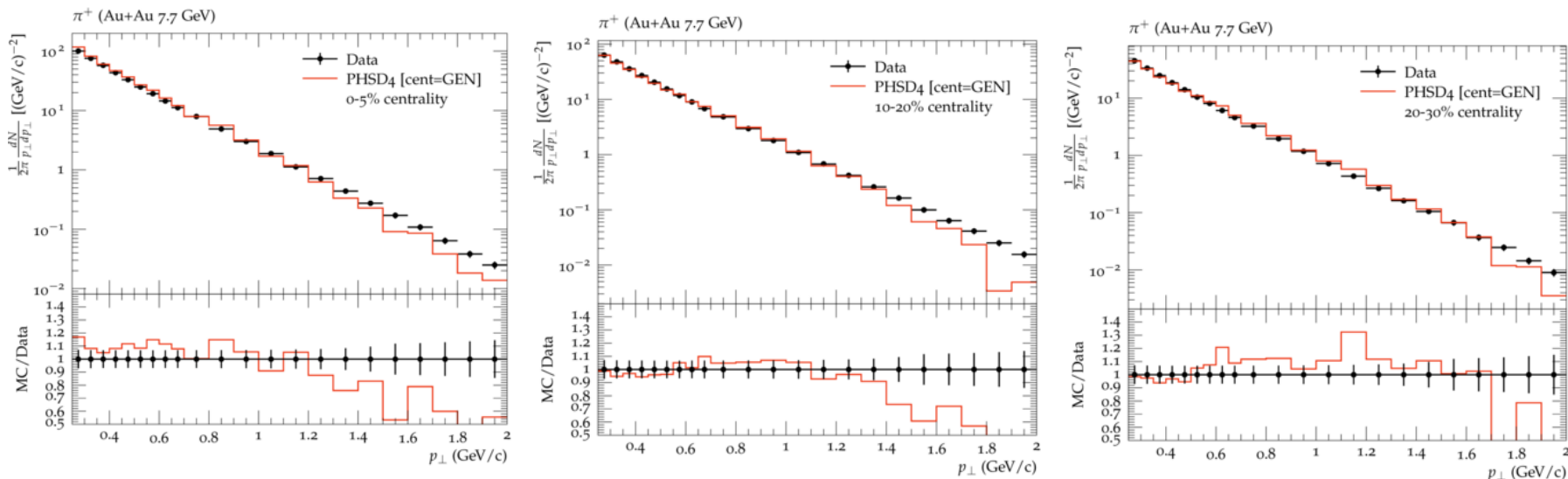
- Example of the application of the Rivet to **PHSD** output (after Converter) and comparison to ALICE experimental data on p+p



Rivet for HICs: PHSD vs. STAR

STAR_2017_I1510593

PHSD analysis from Viktor Kireyeu,
March 2021



- Example of the application of the Rivet to **PHSD output (after Converter)** and comparison to STAR experimental data on Au+Au at $s^{1/2}=7.7$ GeV

Rivet for HICs : open conceptual questions

Questions to clarify:

❑ **Special attention:**

- definition of centrality,
- reconstruction of the reaction plane for v_n observables
- reconstruction of resonances
- excitation functions of some observables

❑ How to deal with observables calculated via a “**perturbative treatment**” (**weighted method**) in transport models

→ **Dileptons and photons** (shining method)?

Such input can not be provided on e-by-e basis!

❑ What about theoretical models which can NOT present output on e-by-e basis, e.g. they deal with limited phase space or doing analytical calculations of some observables?

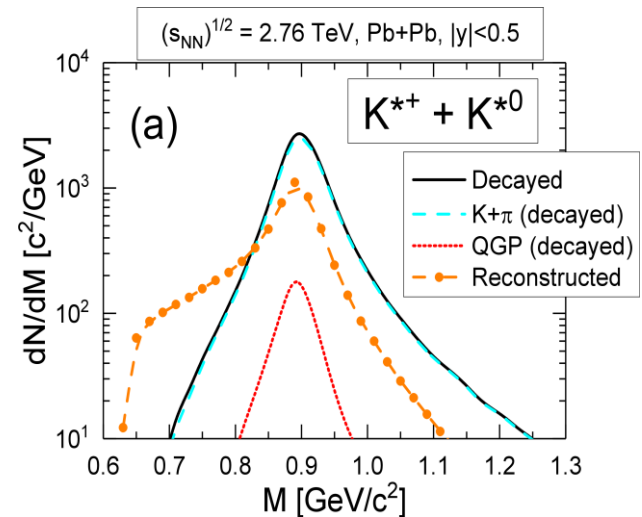
E.g.: Langevin models for charm, calculations with hydro (without particilization); the way to simulate centrality or to cover different rapidity ranges (e.g. 2D+1 hydro)

Further open questions (Christine's list)

- **Q: How do you handle decays?**
- In transport approaches **all resonances are decaying dynamically** during time evolution

Warnings:

- the resonances decay and re-created during the hadronic stage
- Their decay products can rescatter (being absorbed) in the medium
→ such resonances would be experimentally lost (but can be reconstructed in theory)
- The shape of dN/dM (and pt spectra) of resonances differs at the decay point and finally reconstructed!



A. Illner, D. Cabrera, C. Markert, E.B., PRC95 (2017) 014903;
A. Illner, J. Blair, D. Cabrera, C. Markert, E.B., PRC 99 (2019) 024914

(cf. also UrQMD studies)

- **the resonances must be reconstructed in the same way as in experiment**
 - from final stable particles by background subtraction as in experiment!
- **an 'extra' information on decay vertexes is not needed**

Further open questions (Christine list)

- **Q: Do you have any information on particles' parentage?**
- **PHSD has an information on production channel of the final particles** (cf. manual)
 - (1) This would require a huge(!) disc storage!
 - (2) Why do you need that (unmeasured quantity!)?
How does it help to compare to measured exp. data?
- **Q: Would it be possible to add at least information from the freezeout surface onward to the HepMC?**
- **Strictly speaking – conceptually impossible** due to causality !
In microscopic transport simulations the “freeze-out surface” has a very complicated profile, e.g. could be separate droplets etc.
It could be reconstruct (under some assumptions!) **ONLY** after the end of calculations with special output on history of collisions – going back in time and looking on the last scattering place!
- (1) This would require a huge(!) disc storage!
 - (2) Why do you need that (unmeasured quantity!)?
How does it help to compare to measured exp. data?

Rivet for HICs : final remarks/open questions

(cf. J. Aichelin talk)

Questions to clarify:

❑ **How to validate that the analysis is correctly implemented in Rivet ?!**

The way: take **exp. events** → Rivet → reproduce measured observables!

Who and how will perform such control of Rivet?

❑ Rivet is an open source code (it can be changed by users).

How to **control the quality** of the presented comparison? Should user modifications be absorbed by Rivet?!

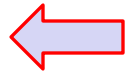
❑ How to deal with the **copyright problem**?

(Results analysed with Rivet → authorization?)

❑ How fast the **preliminary exp. data** will be available in Rivet?

How theory can make **predictions**?

Presently: „Reference data connection to **HepData**, avoid hard-coding”



Expectation:

Rivet – could be a great tool to help in theoretical analysis for HICs!