High-Energy Jet Interaction Monte Carlo for the Future Generations: HIJING++

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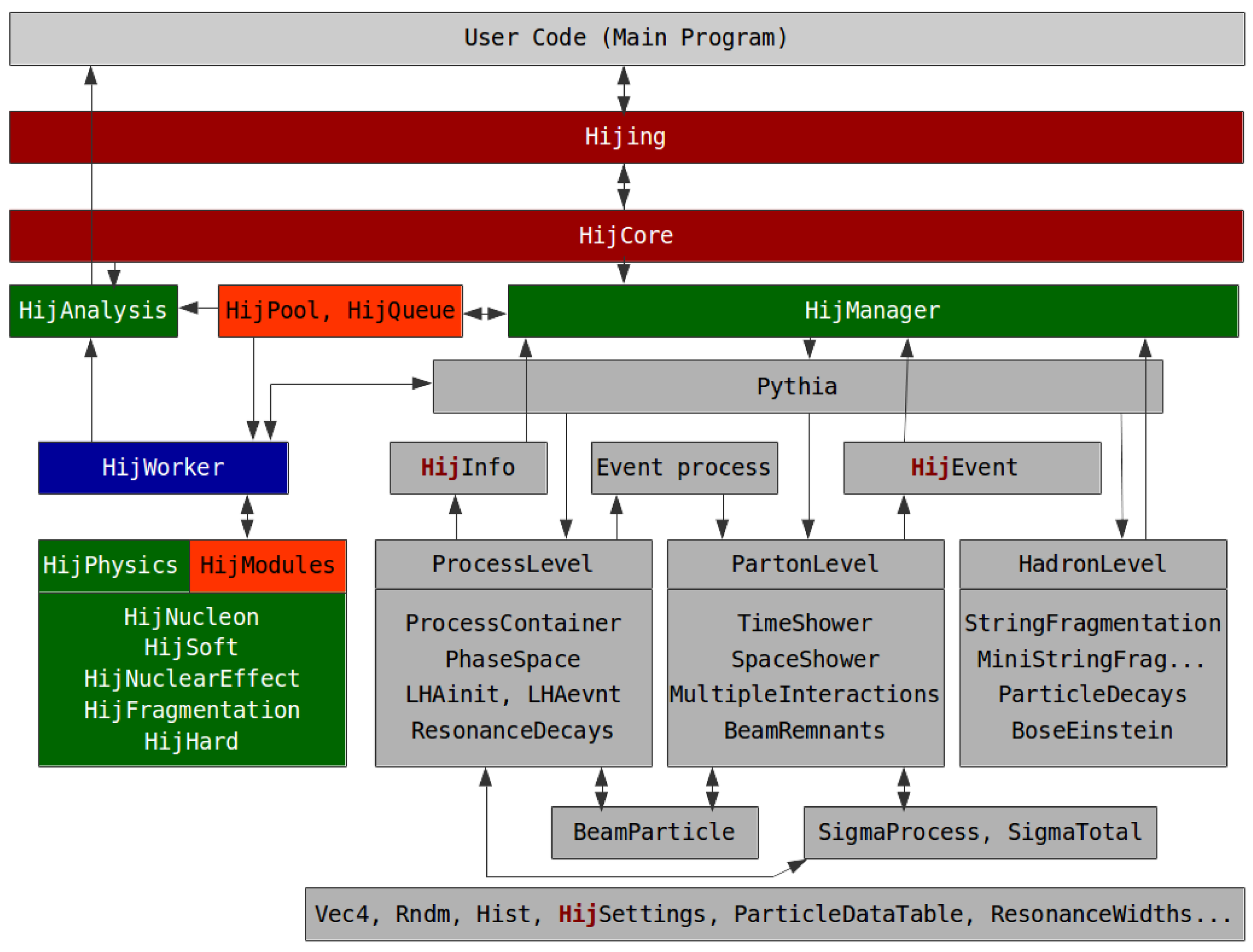
Introduction

The original HIJING [1] (Heavy Ion Jet INteraction Generator) Monte Carlo model was developed by M. Gyulassy and X.-N. Wang with special emphasis on the role of minijets in proton-proton (pp), proton-nucleus (pA) and nucleus-nucleus (AA) reactions at collider energies in a wide range from 5 GeV to 2 TeV. Since the release of the first HIJING version a number of underlying libraries has undergone a major upgrade connected with structural changes, and they got rewritten to C++, becoming a standard now in the high-energy community. Hence, we decided to upgrade HIJING accordingly, to be a genuine, C++ based, modular event generator, with the most recent versions of PYTHIA8 [2] and LHAPDF6 [3], and be compatible with the experimental frameworks. We present the current status of HIJING++ for LHC energies. Here, we summarize the structure and the speed gain due to parallelization of the new program code, also presenting some comparison between experimental data.

The HIJING++ program



During the designing we took great care of modularity, portability, maintainability and speed. The colored boxes represent the newly included HIJING modules and modifications neglecting cross-links.

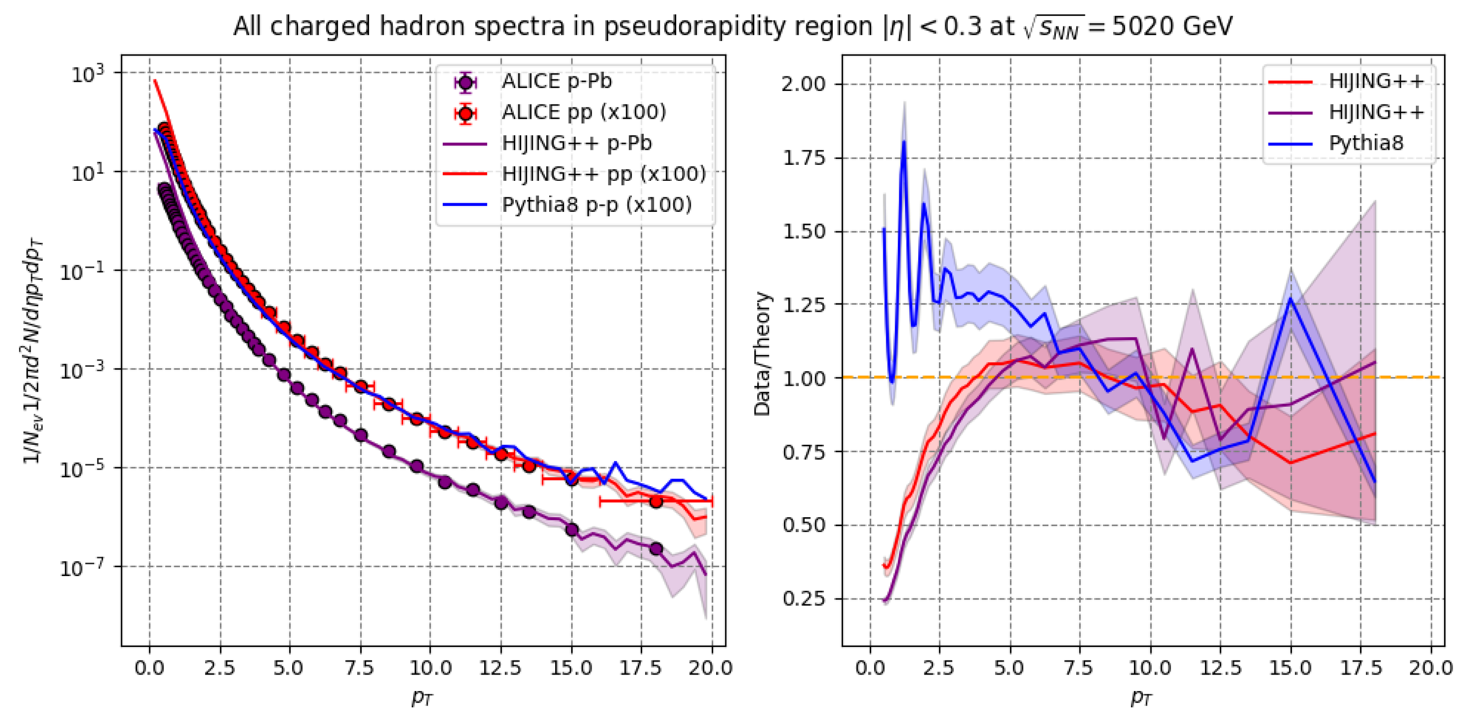
The `Hijing` class contains all the physics were coded in the FORTRAN subroutines, based on the latest version of HIJING version 2.552 [4]. The high-energy nuclear physics related part (hard collisions, soft collisions, fragmentation, Cronin effect, jet quenching) are moved to the `HijPhysics` class, where they can be called modularly, with the possibility to alter them to user supplied modules.

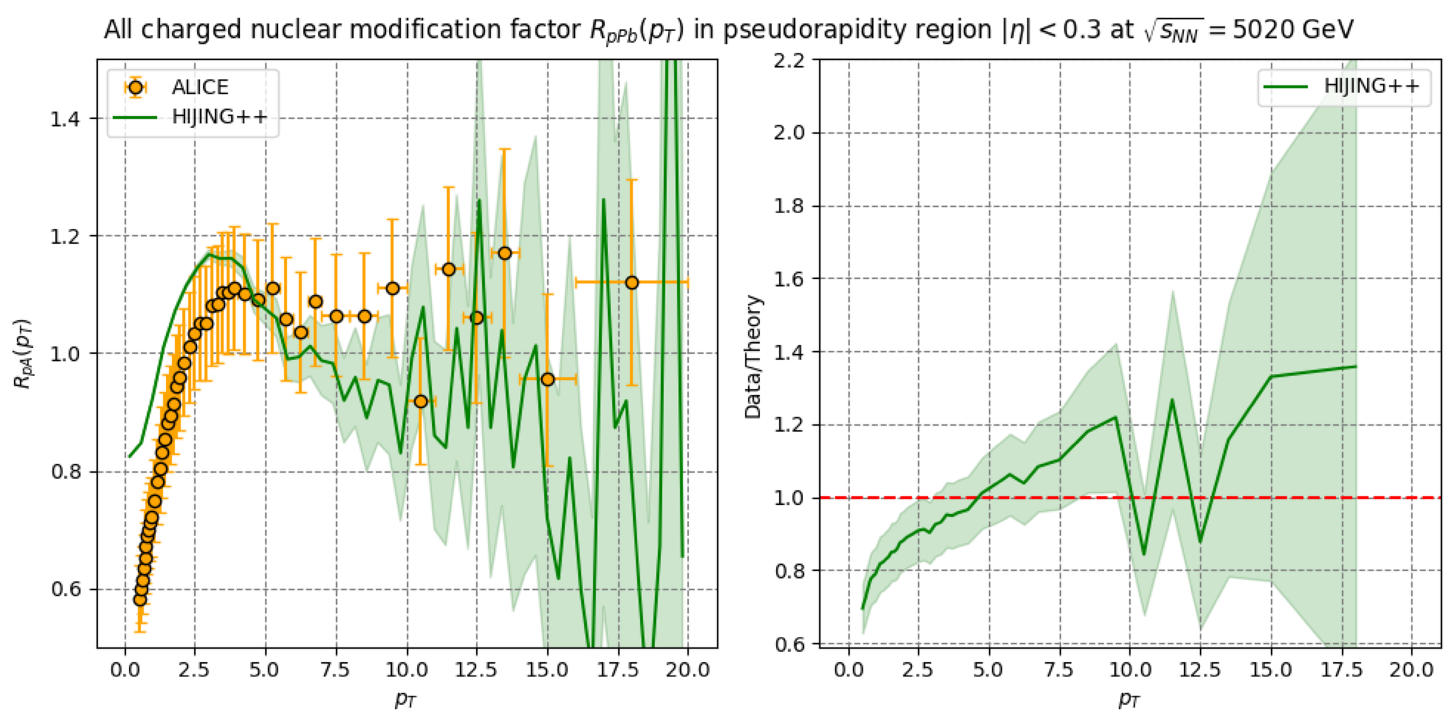
Due to the object oriented being of the C++, the original structure was optimized for modularity and compiler's improved parallel supports. The `HijQueue` and `HijManager` classes are responsible for distributing the separate Hijing events in a parallel environment.

A useful new feature is the `HijAnalysis` class, being an easy-to-use interface to user defined data collections and Rivet [5] tools within the run. The code has several entry points for user provided and built-in histogram collection modules, which are configurable in the user (main) code with one line commands.

Physics benchmark

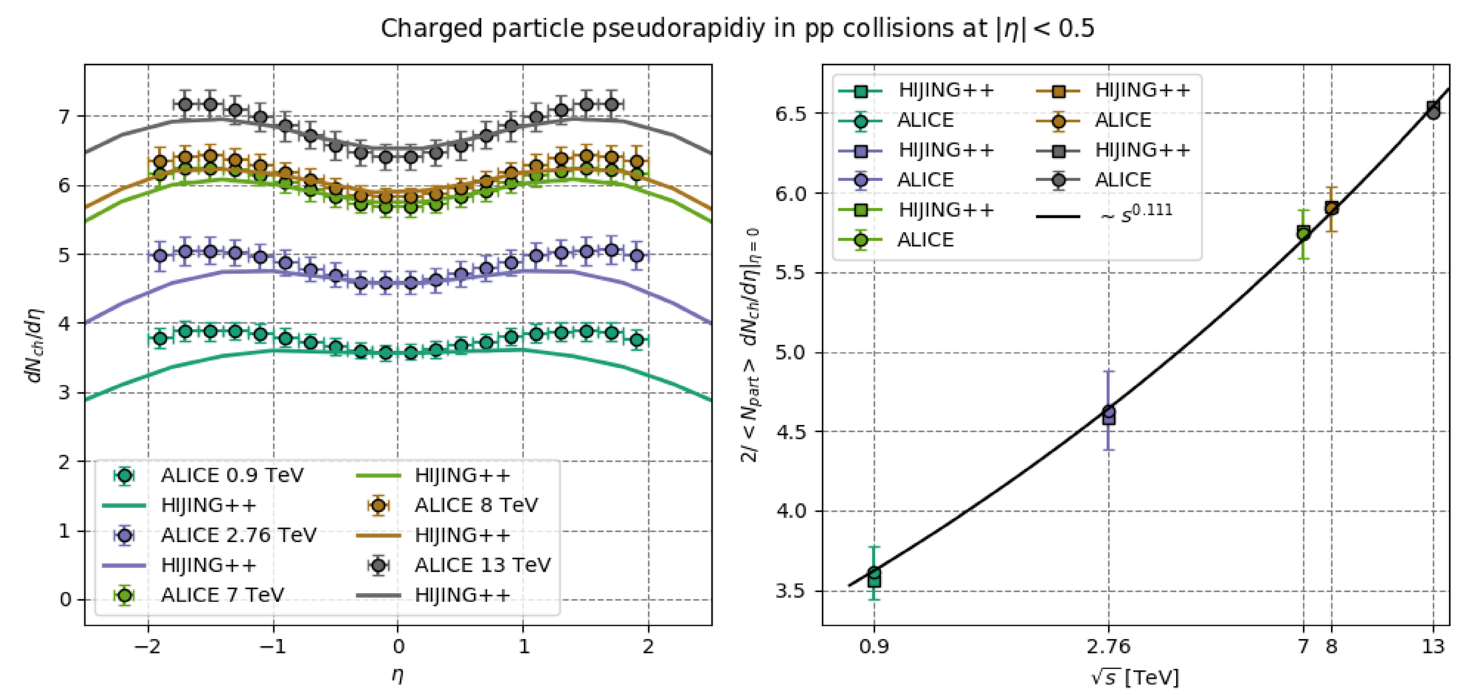
We present the charged hadron yields at LHCs 5020 GeV energy per nucleon at midrapidity $|\eta|<0.3$ region for proton-proton (pp) and proton-lead (p-Pb) collisions along with the PYTHIA8 calculations and ALICE experimental results. The spectra are generated with impact parameter dependent shadowing, and Cronin multiple scattering with average transverse momentum square exchange of 4 GeV/c. The hard separation scale was set to 3 GeV/c.

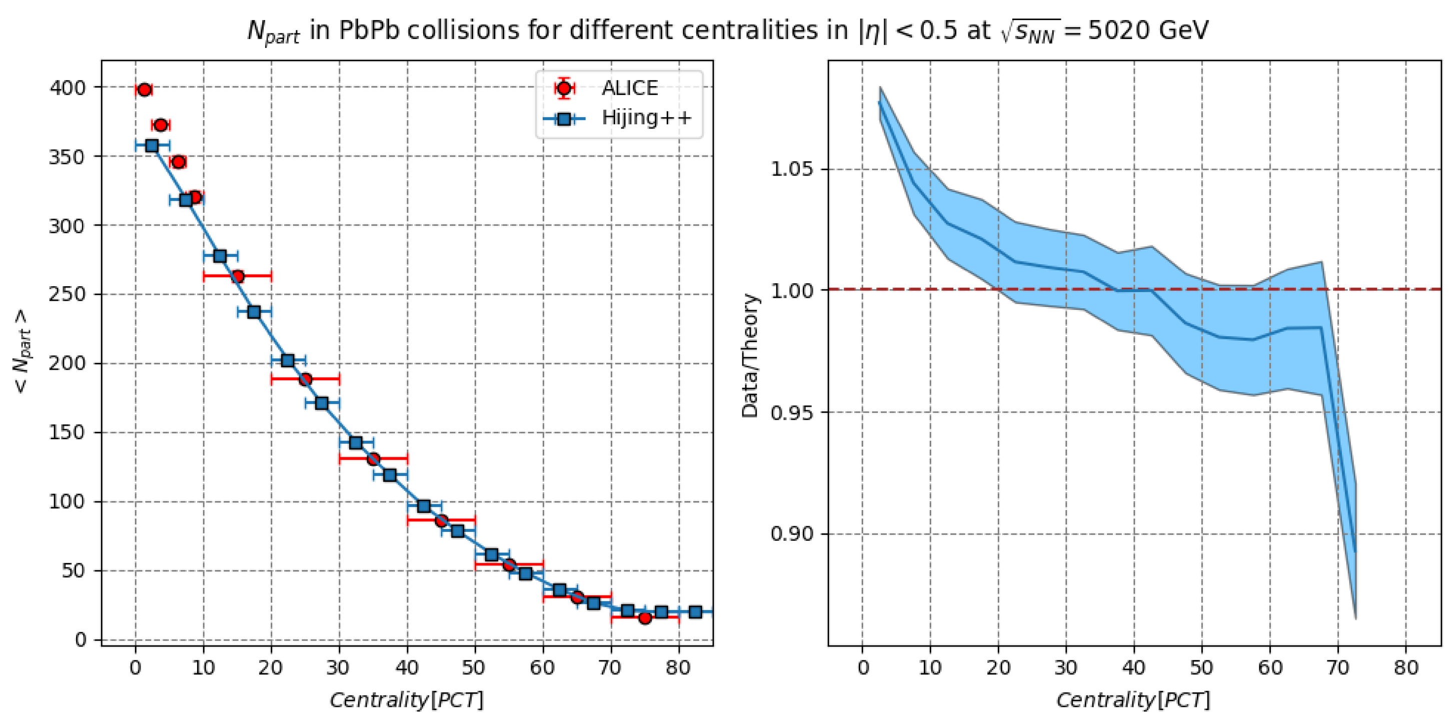




The nuclear modification factor calculation with HIJING++ contrasted to the experimental result. The code already contains an improved version of the final transverse momentum exchange (Cronin effect), introducing an energy dependent width for the distribution of the average transverse momentum exchange square.

The charged particle pseudorapidity distribution and multiplicity density at the central $|\eta|<0.5$ region in proton-proton collisions is compared to ALICE data at different centre-of-mass energies. The agreement with the measured data at midrapidity is very good, although the current untuned version of HIJING++ slightly underestimates the yield at larger $|\eta|$ values.



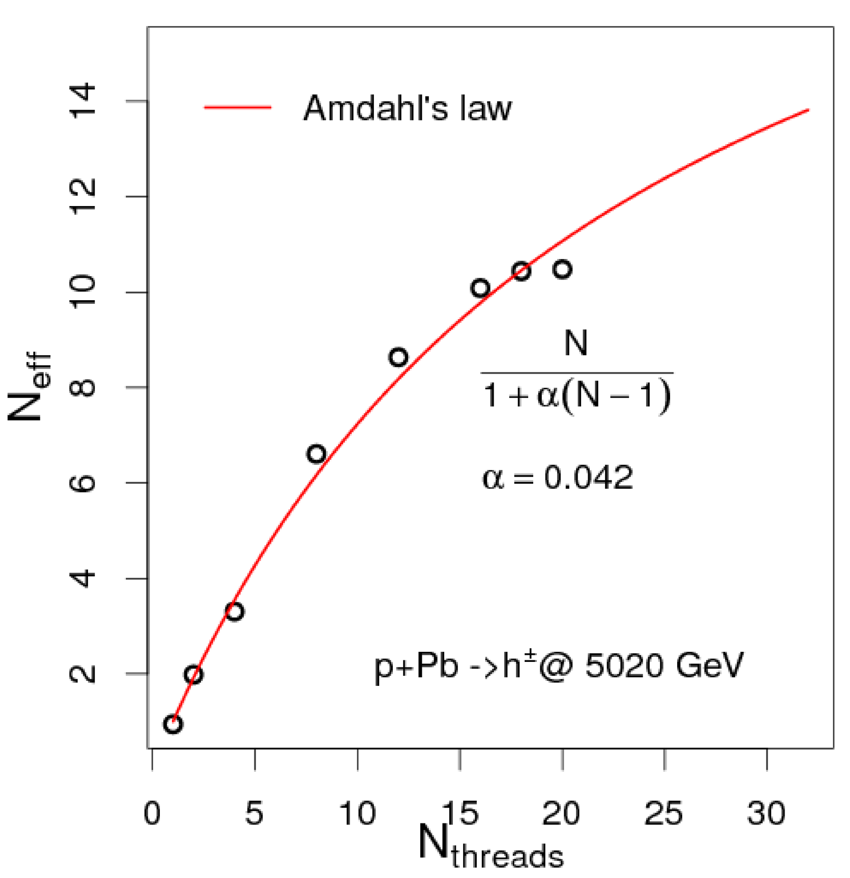


For nucleus-nucleus systems we are testing and developing various shadowing and jet quenching models. The main structure of the centrality dependent scaling of the number of participant nucleons (N_{part}) is already captured well by HIJING++. We compare the numerical results with ALICE data measured in Pb-Pb collisions at midrapidity region at 5020 GeV per nucleon collision energy.

Ongoing developments

HIJING++ is currently under validation, before release. In parallel to the testing of the code, a sophisticated theoretical development of the model is ongoing. Here we list some of these updates and features, which will be present in the final, public code:

- The original HIJING shadowing function, and also its modified, Q^2 dependent version are producing too much shadowing, so we are considereing to implement other shadowing models.
- A contemporary jet energy loss module is under development. This module is enable users to include various jet-quenching models in the future, such as we include Gyulassy-Lévai-Vitev (GLV) [6] **(see poster JET-25 for more details)**.
- Tuning of parameters relevant for physics and runtime (such as soft-hard separation scale, Cronin effect strength, thread management for multi-core CPUs and others) for LHC energies is ongoing.
- In the figure we present the speedup in computational time in parallel usage, compared to single thread performance. The tests were performed on a 20 thread Intel Xeon E312 processor machine at Wigner GPU Laboratory.



The fit on the non-parallel portion of the code (mostly queue management) being 4.2%, giving the current maximal speedup to be around 24. Optimalization for various multi-core and parallel architectures such as GPUs is also on the wish list.

Summary

Present milestone aims to communicate the status of this software development, moreover, give perspectives for the forthcoming applicabilities and features of the soon-to-be-released open source HIJING++ for the next generation of heavy-ion collision measurement, simulations, and facilities at future colliders.

For more info and updates about the project, preliminary datasets, requests and contact details check our webpage on https://gitlab.kfki.hu/hijing/QuarkMatter2018:

Acknowledgement

This work was supported by the Hungarian-Chinese cooperation Wigner HAS-OBOR-CCNU bilateral grant, Hungarian National Research Fund (OTKA) grant K120660 and THOR COST action 15213. We acknowledge the support of the Wigner GPU laboratory.

G. Bíró was supported by the ÚNKP-17-3 New National Excellence Program of the Ministry of Human Capacities.

Emberi Erőforrások Minisztériuma

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