HIJING++

HIC Monte Carlo for the Future Generations

arXiv:1701.08496

G.G. Barnaföldi[1,†], G. Bíró[1,2], M. Gyulassy[1,3,4,5] Sz.M. Harangozó[1,2], G-Y. Ma[3], P. Lévai[2], G. Papp[1], X-N. Wang[3,4], B-W. Zhang[3]

[1] Wigner Research Centre for Physics of the H.A.S., P.O. Box 49, H-1525 Budapest, Hungary, [2] Institute for Physics, Eötvös Loránd University, 1/A Pázmány P. Sétány, H-1117, Budapest, Hungary [3] Institute of Particle Physics, Central China Normal University, Wuhan 430079, China [4] Nuclear Science Division, MS 70R0319, Lawrence Berkeley National Laboratory, Berkeley, California 94720 USA [5] Pupin Lab MS-5202, Department of Physics, Columbia University, New York, NY 10027, USA

†e-mail: `barnafoldi.gergely@wigner.mta.hu`

Abstract

First calculated results with the new HIJING++ are presented for identified hadron production in high-energy heavy ion collisions. The recently developed HIJING++ version is based on the latest version of PYTHIA8 and contains all the nuclear effects has been included in the HIJING2.552, which will be improved by a new version of the shadowing parametrization and jet quenching module. Here, we summarize the major changes of the new program code beside the comparison between experimental data for some specific high-energy pp and pA collisions.

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. The original program itself is written in FORTRAN, and is based on the FORTRAN version of PYTHIA (version 5) [5], ARIADNE [6], and the CERNLIB package PDFLIB [7]. This program is today still the most-widely used particle event generator applied for high-energy heavy-ion collisions both in the theoretical model tests and experimental simulations. Its main features are:

- Soft beam jets are modeled by diquark-quark strings with gluon kinks along the lines of the Lund FRITIOF [8] and dual parton model (DPM). In addition, multiple low-p_T exchanges among the endpoint constituents are included to model initial state interactions.
- Multiple minijet production with initial and final state radiation is included along the lines of the PYTHIA model in an eikonal formalism.
- Exact, diffuse nuclear geometry is used to calculate the impact parameter dependence of the number of inelastic processes.
- An impact-parameter-dependent parton structure function is introduced to study the sensitivity of observables to nuclear shadowing, especially of the gluon structure functions.
- Gluon radiation from the strings is included according to the ARIADNE program code.
- Transverse momentum exchange of the created particles simulates the Cronin peak.
- A simple model for jet quenching is included to enable the study of the dependence of moderate and high-p_T observables on an energy loss of partons traversing the produced dense matter.

Main objectives

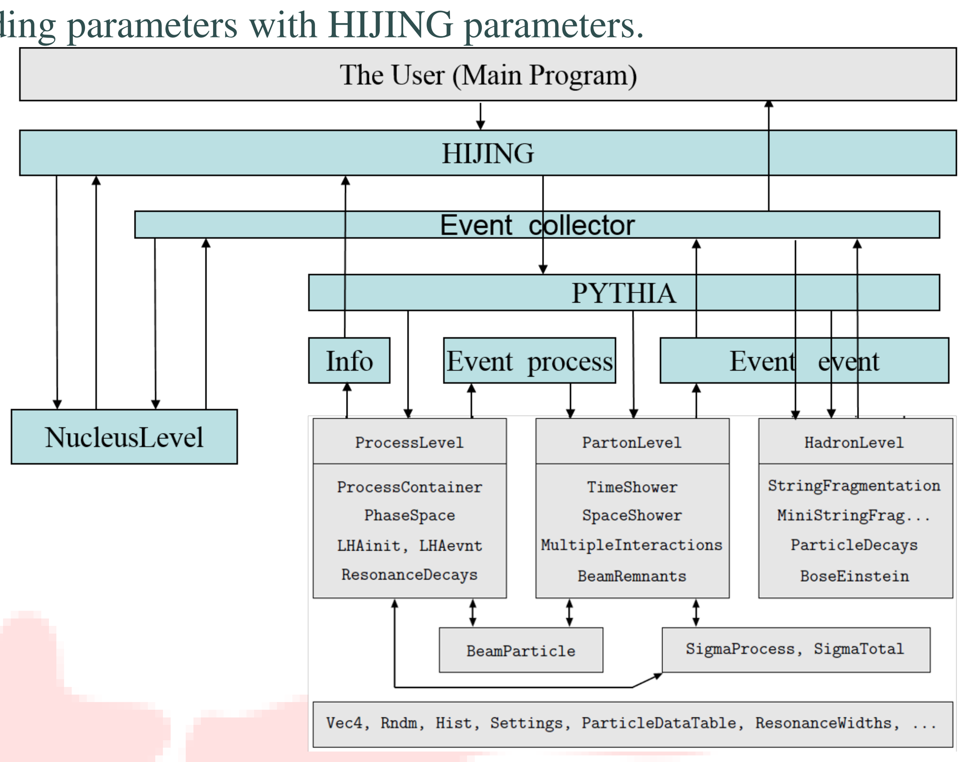
The HIJING event generator is based on PYTHIA, ARIADNE and PDF libraries, and mainly used for event generation in experimental environment for baseline estimation. Since the todays programming techniques shifted to C++ based programming, the new generation of PYTHIA and PDF libraries are written in this language, furthermore, the experimental platforms are also shifting to C++ (e.g. AliRoot [4]), it is demanding to upgrade the HIJING accordingly. Hence, the main objectives are:

- write a genuine C++ based event generator,
- include the most recent public packages (like PYTHIA8 [3], LHAPDF6 [9]),
- support modularity:
  - possibility of inclusion/change to new theories, alternative processes (like DIPSY [11]),
  - possibility of alternative finite state processes (jet quenching models [13], etc.),
- introduce compatibility with experimental platforms (AliRoot),
- clean and upgrade of the HIJING model (e.g. Q^2 dependent shadowing [14, 15]),
- prepare the code for parallelization.

Since C++ is an object oriented language, it is suitable for parallelization, as longer term objective.

The program

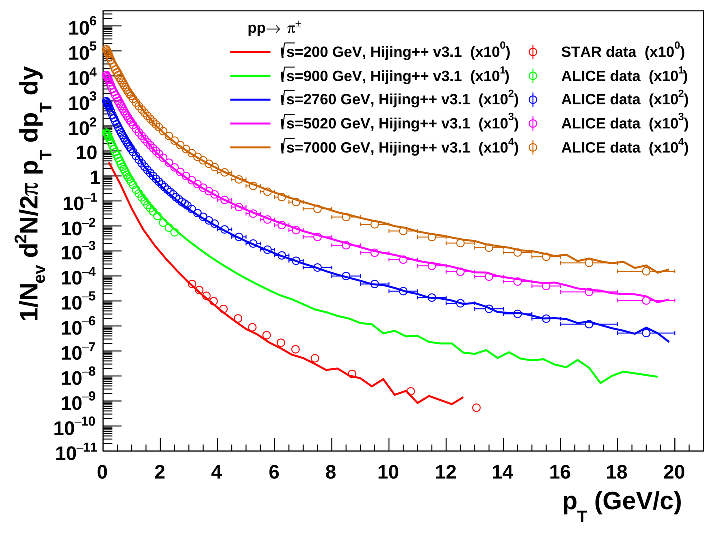
PYTHIA has already developed the appropriate classes to handle elementary collisions, hence the HIJING++ class is positioned in the PYTHIA8 namespace, using its functions to read configuration files (XML), extending parameters with HIJING parameters.

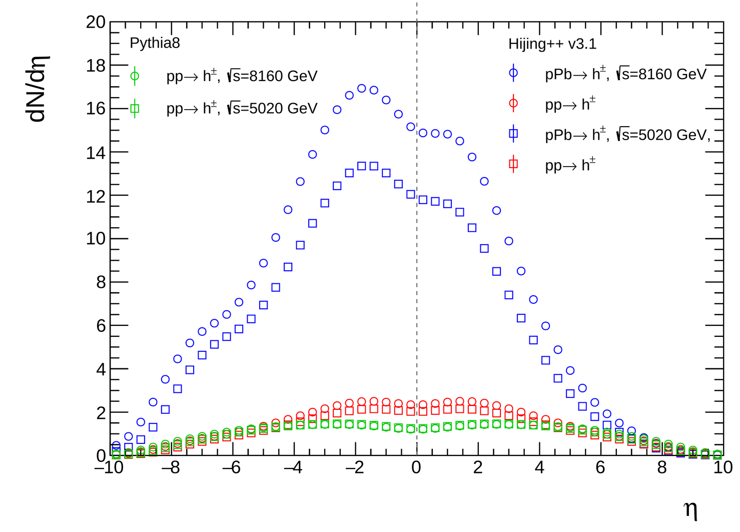


The main structure of the code is presented in the figure, where colored boxes represent the newly-included `Hijing` class and modifications neglecting cross-links. The `Hijing` class contains all the physics were coded in the FORTRAN subroutines, based on the latest version of HIJING version 2.552 [2]. Due to the object oriented being of the C++, the original structure was optimized for modularity and future compiler's with improved parallel supports. Technically in `Hijing` processes are ordered in a class hierarchy, common block were changed by class variables and processes are called through object functions. New sub-classes are: `HardCollisions`: for hard $2 \to 2$ processes; `SoftScatter`: for handling soft interactions; `Fragmentation`: based on Lund string model; `NucleonLevel`: for high-energy nuclear effects. The first version of C++ code, namely HIJING++ (v3.1) is ready now for test. The physical models of this recent version is based on PYTHIA8, and HIJING2.552, while the soft physics is still the original ARIADNEv4 based one. Hence, this version includes all the new physical processes included in the most recent versions of both codes.

Preliminary results with HIJING++

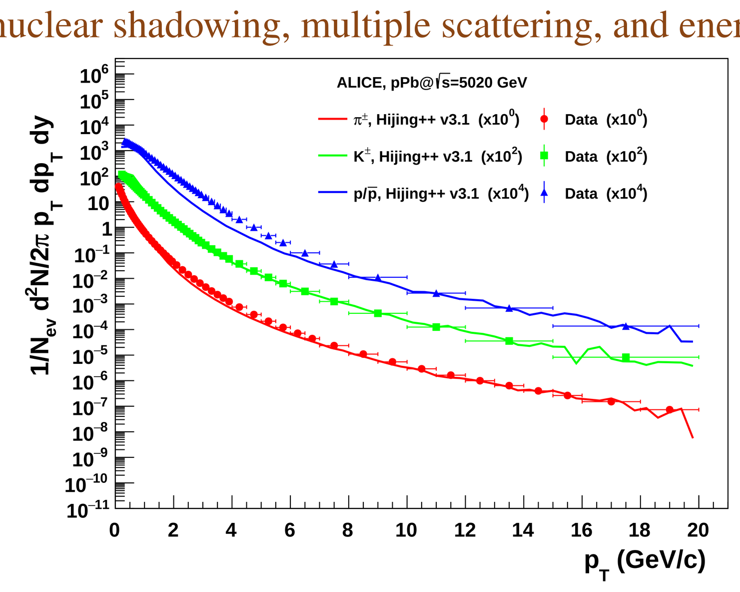
HIJING++ results in proton-proton collisions: We plotted the identified $\pi^{\pm}$ yields, calculated 10M events and compared to experimental data in pp collisions at 200 GeV [16], 900 GeV [17], 2.76 TeV [18], 5.02 TeV [19], and 7 TeV [20, 21] c.m. energies in the $|\eta| < 0.8$ range. We also show the $dN/d\eta$ for pp and pPb collicions at the $\sqrt{s_{NN}} = 5.02$ TeV and 8.16 TeV LHC energies.

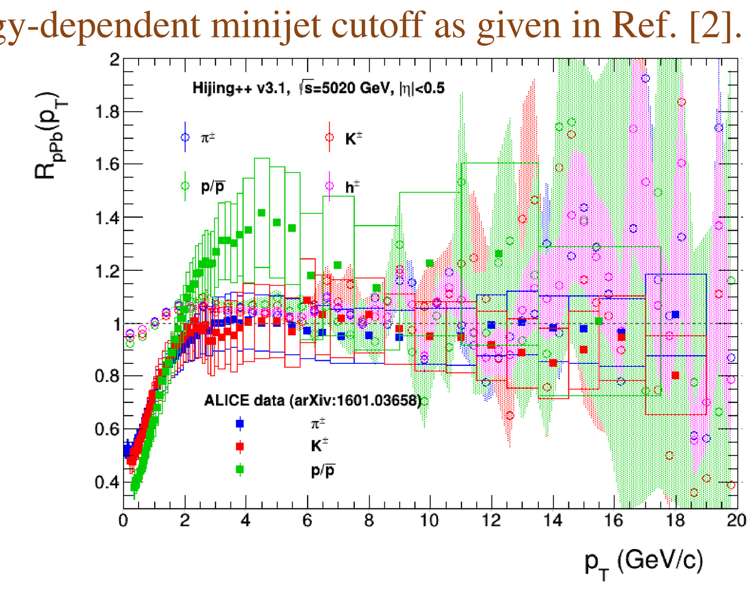




First comparison between measured spectra *dots* and the HIJING++ calculated *curves* shows nice overlap at high accuracy, especially at the highest c.m. energies. At lower $\sqrt{s}$ and small p_T, where soft processes play the role, the data over theory start to deviate, which suggest to apply the proper PYTHIA tune in the tests for further development phases.

HIJING++ results in proton-nucleus collisions: We tested the HIJING++ code in pPb collision at $\sqrt{s_{NN}} = 5.02$ TeV. For the case of the pPb collision we used 5M events and calculated the $\pi^{\pm}$, $K^{\pm}$, and $p/\bar{p}$ productions in $|\eta| < 0.5$ and nuclear modification factor, $R_{pPb}(p_T)$ too. Nuclear effect are based on the settings adopted from the original HIJING2.552, including impact-parameter dependent nuclear shadowing, multiple scattering, and energy-dependent minijet cutoff as given in Ref. [2].





We copared HIJING++ with ALICE [19] data. The calculated spectra show agreement with the identified hadron yield measurement, especially at the highest and lowest transverse momentum regimes. In the intermediate region, 2 GeV/$c < p_T <$ 7 GeV/c — where high-energy nuclear effects take place — the theoretical curves deviate from the experimental data. In the present status of the HIJING++ development we are now on, to identify and fine-tune the strength of these effects, especially according to the the latest, available, high-accuracy RHIC and LHC data. This is a challenging task, since in these phenomenological models we need to satisfy all previous and recently measured data in several manners. On the other hand we need to synchronize the included sub-nuclear theoretical features with the nuclear phenomenology to avoid double counting of effects.

Ongoing developments and future perspectives

Preliminary results calculated by the developed Monte Carlo heavy ion jet interaction generator, HIJING++, the well-know and widely-used FORTRAN-based HIJING, were rewritten in a modern and evolving programming language C++. We presented the comparison of charge-averaged identified hadron yields in pp collisions from 200 GeV to 7 TeV c.m. energies and at LHC energy, $\sqrt{s_{NN}} = 5.02$ TeV, in minimum bias pPb collisions in comparison to experimental data. Here, we list some of these forthcoming updates and features of the final, public code:

- The original HIJING shadowing function will be replaced by a scale-dependent nuclear shadowing. The Q^2-evolution is based on the original HIJING shadowing and the HOPPET [14] evolution.
- A contemporary jet energy loss module is under development. This module is enable users to include various jet-quenching models,such as we include Gyulassy – Lévai – Vitev (GLV) [13].
- The run-time of the HIJING++ is comparable to the previous, FORTRAN based version, the new code structure is capable to provide thread-level and/or MPI parallelization.
- Since the new version of the code is written in the modular C++, it is natural to include it to huge detector simulation frameworks, like ALICE's AliRoot [4].

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

Acknowledgements

This work was supported by the Hungarian-Chinese cooperation grant No TéT 12 CN-1-2012-0016 and No. MOST 2014DFG02050, Hungarian National Research Fund (OTKA) grants NK106119 and K120660. Author G.G. Barnaföldi also thanks the János Bolyai Research Scholarship of the Hungarian Academy of Sciences and the THOR COST action CA15213 . We acknowledge the support of the Wigner GPU laboratory.

References

[1] X.N. Wang, M. Gyulassy, Phys. Rev. **D44**, 3501 (1991).
[2] W.T. Deng, X.N. Wang, R. Xu, Phys. Rev. **C83**, 014915 (2011).
[3] T. Sjöstrand, Comput. Phys. Commun. **191**, 159 (2015).
[4] AliRoot: http://aliweb.cern.ch/Offline/AliRoot/Manual.html (2017)
[5] T. Sjostrand, Comput. Phys. Commun. **82**, 74 (1994).
[6] L. Lönnblad, Comput. Phys. Comm. **71**, 15 (1992).
[7] CERNLib: https://cernlib.web.cern.ch/cernlib/ (2017)
[8] B. Nilsson-Almqvist and E. Stenlund, Comput. Phys. Commun. **43**, 387 (1987).
[9] LHAPDF6: http://lhapdf.hepforge.org/ (2017)
[10] X.N. Wang, Phys. Rev.**C61**, 064910 (2001).
[11] C. Flensburg, Prog.Theor.Phys.Suppl. **193**, 172 (2012).
[12] J.F. Gunion and G. Bertsch, Phys. Rev.**D25**, 746 (1982)
[13] M. Gyulassy, P. Levai, I. Vitev, Phys .Rev. Lett. **85**, 5535 (2000).
[14] A. Vogt, S. Moch, J.A.M. Vermaseren, Nucl. Phys. **B691**, 129 (2004)
[15] G. Ma, G.G. Barnaföldi, Weitian Deng, Sz. Harangozó, G. Papp, X-N. Wang, B-W. Zhang, DGLAP-evolved Shadowing Parametrization for Simulating High-energy Nucleus-Nucleus Collisions in HIJING, (*in preparation*)
[16] STAR Collaboration. *Phys. Rev. Lett.* **2012**, *108*, 072302.
[17] ALICE Collaboration. *Eur. Phys. J C* **2010**, *71*, 1655.
[18] ALICE Collaboration. *Phys. Lett. B* **2014**, *736*, 196-207.
[19] ALICE Collaboration. *Phys. Rev. C* **2015**, *91*, 064905.
[20] ALICE Collaboration. *Eur. Phys. J. C* **2015**, *75(5)*, 226.
[21] ALICE Collaboration. *Phys. Lett. B* **2016**, *760*, 720.