HIJING++
HIC Monte Carlo for the Future Generations

Latest Results with HIJING++ for Strange Quark Matter from RHIC to LHC

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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.

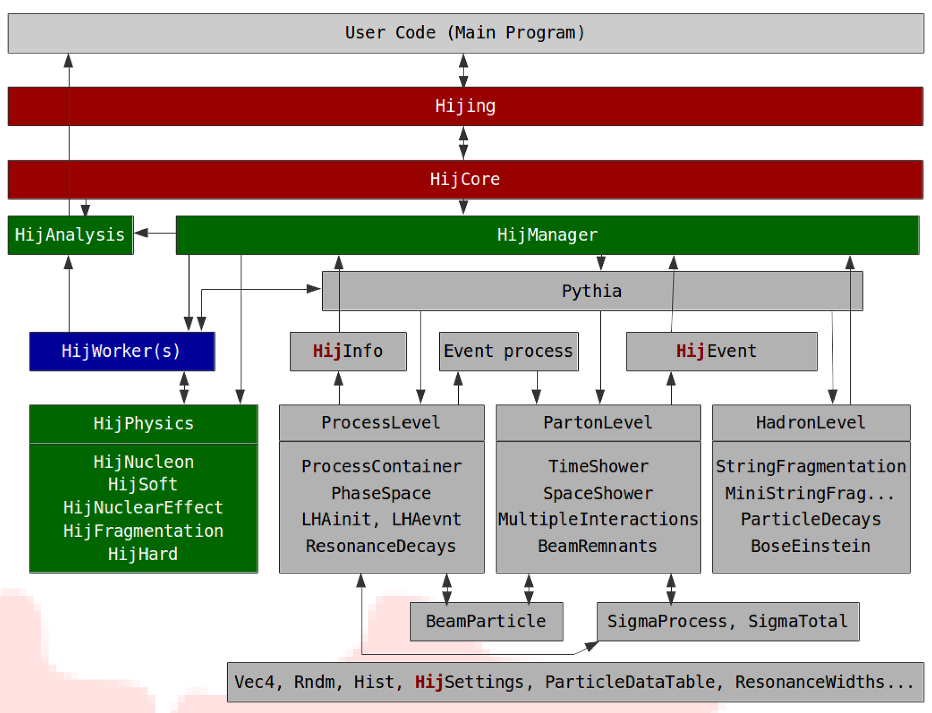
Main objectives

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

The HIJING++ program code

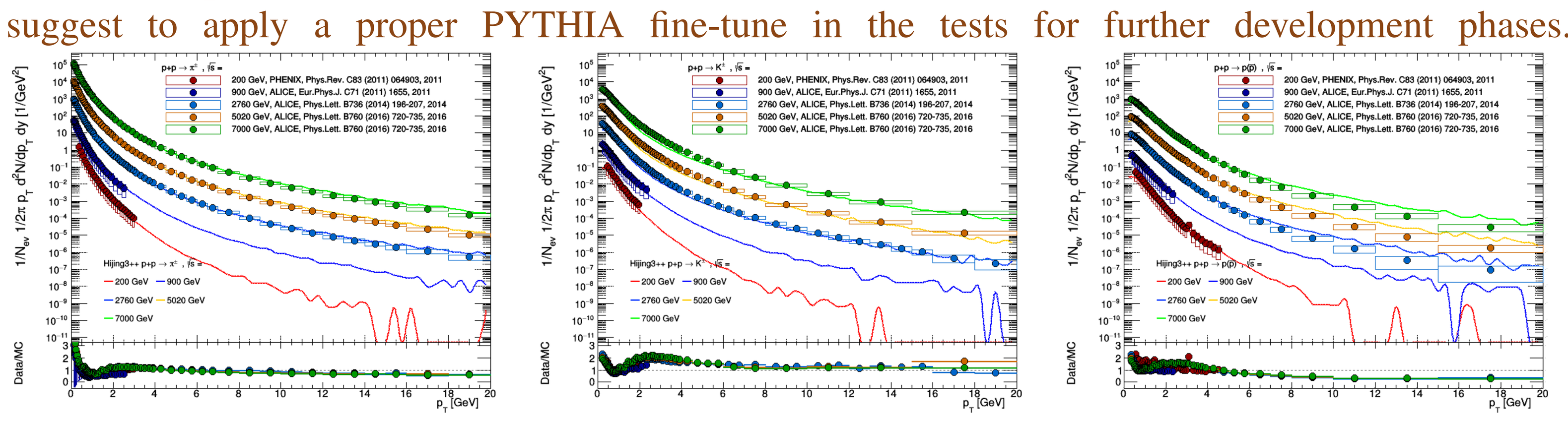
PYTHIA has already developed the appropriate classes to handle elementary collisions, hence the HIJING++ class is positioned in the PYTHIA8 namespace, using its functions to read configuration files (XML), extending parameters with HIJING parameters.



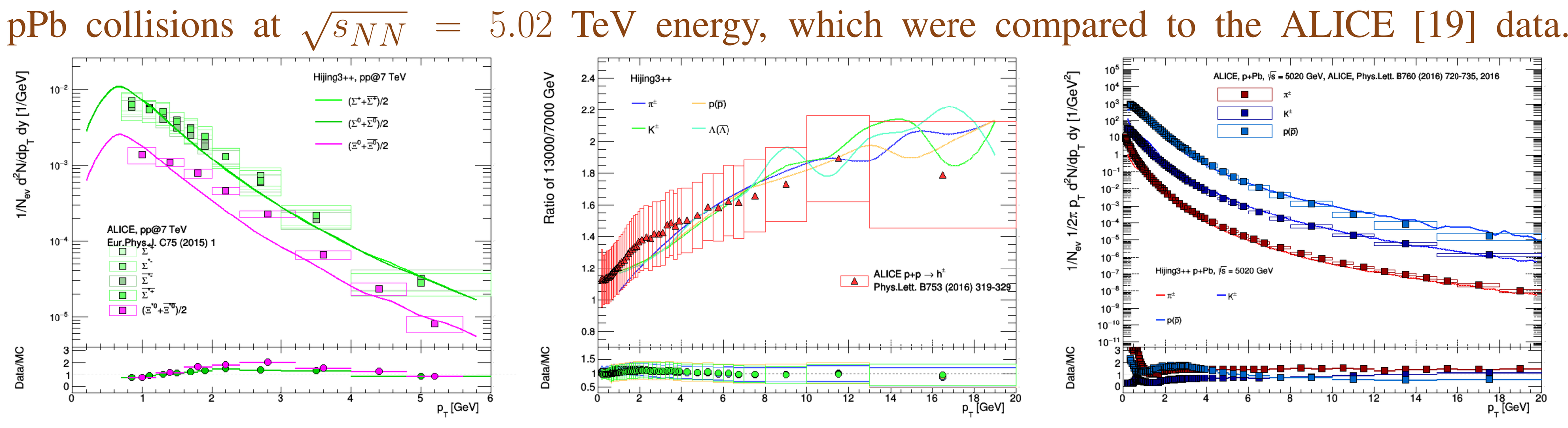
The main structure of the code is presented in the figure, where colored boxes represent the newly-included `Hijing` class and modifications neglecting cross-links. The `Hijing` class contains all the methods through which the user will define and control the parameters of a run, while under the hood everything happens under the `HijCore` class. All the physics that were coded in the FORTRAN subroutines, based on the latest version of HIJINGv2.552 [2] and also the new, improved processes are placed in `HijPhysics`, which contains all processes as objects like `HijHard` for $2 \to 2$ processes, `HijSoft` for handling soft interactions, `HijFragmentation` for fragmenting partons based on Lund string model and `HijNuclearEffect` for the high-energy nuclear effects. Due to the object oriented being of the C++, the original structure is optimized for modularity and future compiler's with improved parallel supports. This is mainly achieved with the `HijManager-HijWorkers-HijAnalysis` triangle, that will help the user to perform a run in an effective, highly parallelized but very convenient way.

Identified Hadron Production Results with HIJING++

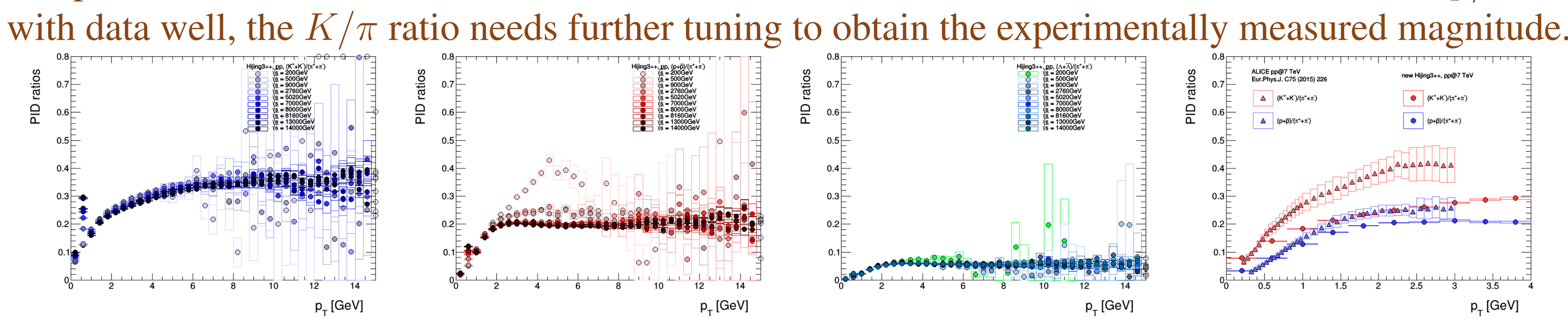
HIJING++ yields in pp and pA collisions: We plotted the identified charged hadron yields, the calculated 50M events were compared to experimental data in pp collisions at 200 GeV [16], 900 GeV [17], 2.76 TeV [18], 5.02 TeV [19], and 7 TeV [20, 21] c.m. energies in the $|\eta| < 0.8$ range. First comparison between measured spectra (*dots*) and the HIJING++ calculated *curves* shows nice overlap, especially at the highest c.m. energies. At lower $\sqrt{s}$ and small p_T, where soft processes play the role, the Data/MC curves start to deviate, which suggest to apply a proper PYTHIA fine-tune in the tests for further development phases.



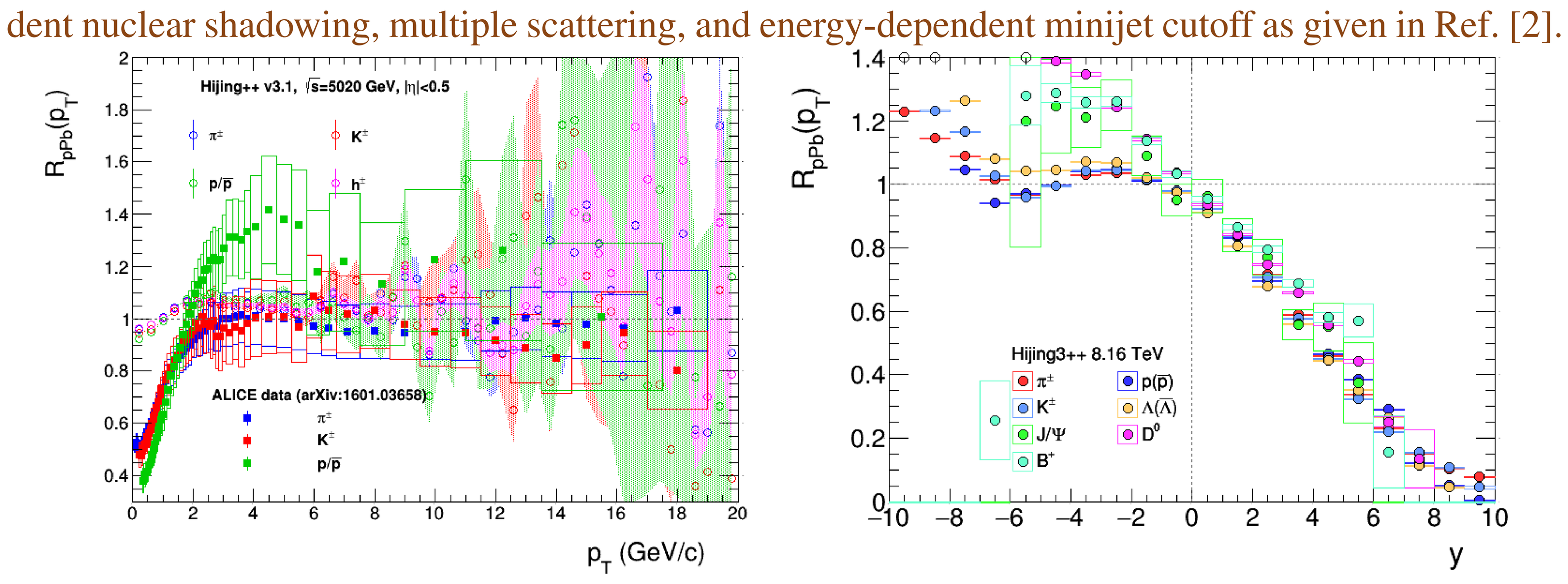
At $\sqrt{s_{NN}} = 7$ TeV we also presented the calculated Σ and Ξ yields (*dots*), where an order of magnitude suppression was seen as increasing the strangeness content. This was in agreement with the data (*boxes*). To test the proper $\sqrt{s}$ scaling, identified hadron spectra ratio (*dots*) of the 7 and 13 TeV data in pp collisions were plotted as well, nicely overlapping with $h^{\pm}$ data (*triangles*). We also show the HIJING++ calculated $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ yields for pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV energy, which were compared to the ALICE [19] data.



HIJING++ results on identified hadron ratios in pp collisions: The $\sqrt{s}$-dependence of the K/π, p/π, and Λ/π yield ratios present similar trends. Is is nicely seen, that the saturated magnitude of the ratios decrease at high-p_T limit, as increasing the mass of the hadrons. As further test of pp collisions, the charged identified hadron yields relative to the $\pi^{\pm}$ are plotted at $\sqrt{s_{NN}} = 7$ TeV in comparison to the ALICE [20, 21] data. However, the trends are similar and the HIJING++ p/π fits with data well, the K/π ratio needs further tuning to obtain the experimentally measured magnitude.



Nuclear modification in proton-nucleus collisions by HIJING++: We tested the HIJING++ code in pPb collision at $\sqrt{s_{NN}} = 5.02$ TeV. We used 5M events and calculated the $\pi^{\pm}, K^{\pm}$, and $p(\bar{p})$ productions in $|\eta| < 0.5$ and the nuclear modification factor, $R_{pPb}(p_T)$ too. Nuclear effect were 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 compared 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 slightly deviate from the experimental data at low p_T, especially for protons. The rapidity dependence of the $R_{pPb}(p_T)$ is presented for identified hadrons as well in the $|y| < 10$ regime at $\sqrt{s_{NN}} = 8$ TeV. It seems all similar for the forward, but it presents a strong mass dependence to the backward direction.

Ongoing developments and future perspectives: We continue the fine-tuning of the physics phenomena built into the HIJING++ code. In parallel the latest data at RHIC and LHC energies are continuously collected and compared to the HIJING++ results.

Acknowledgements

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