A novel Monte Carlo event generator for heavy-ion physics: HIJING++

GÁBOR BÍRÓ

03-07. December 2018

XVIII. ZIMÁNYI
WINTER WORKSHOP ON
HEAVY ION PHYSICS

Collaborators

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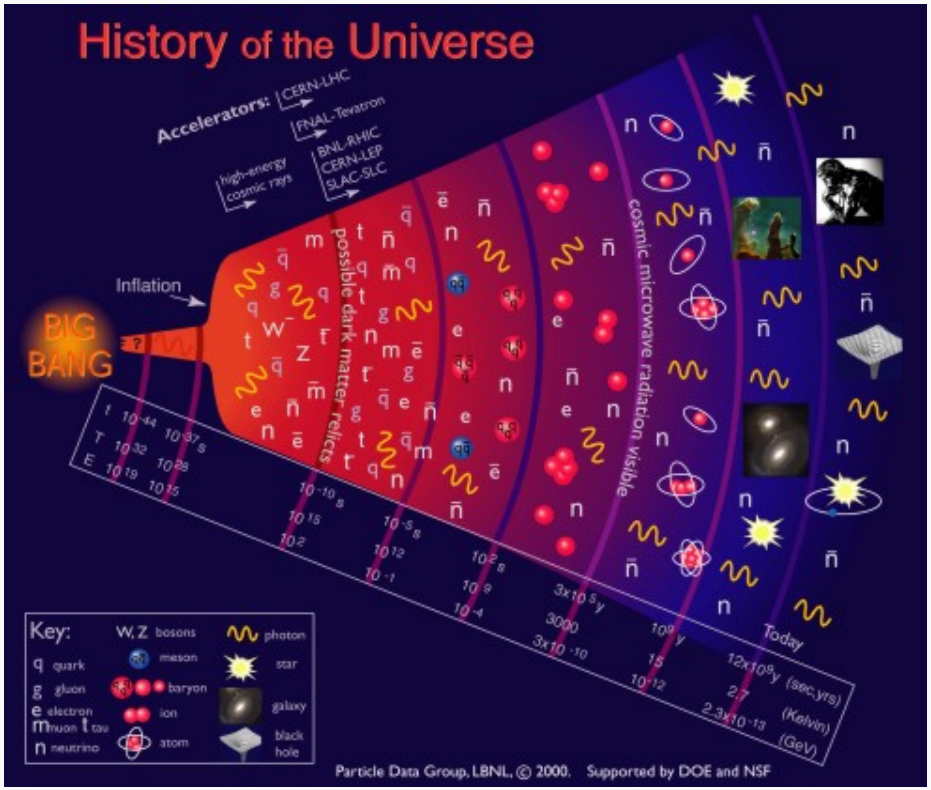
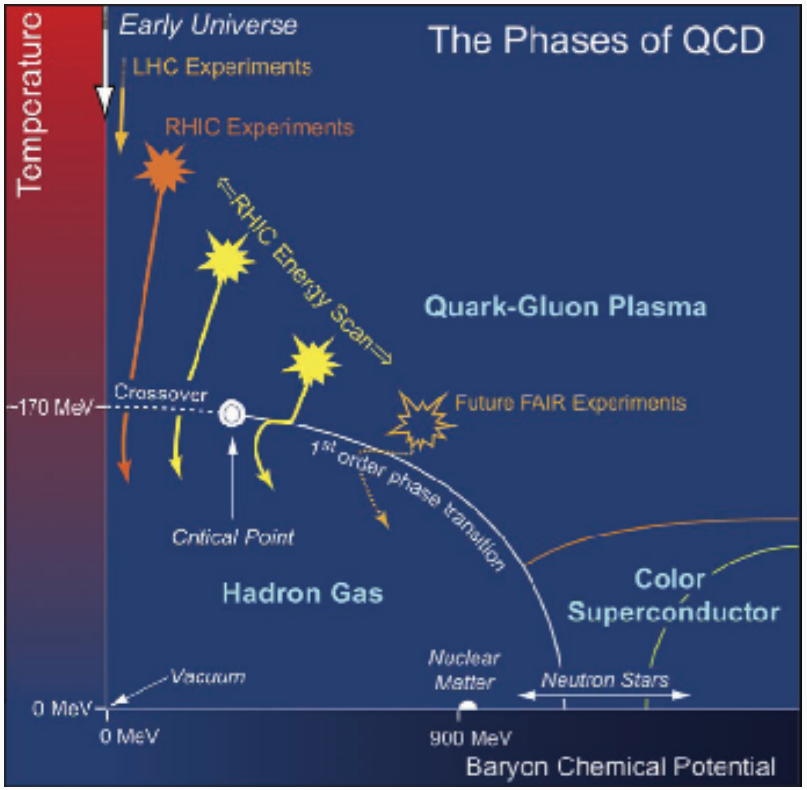
The research is supported by the

- Hungarian-Chinese cooperation grant No TéT 12 CN-1-2012-0016, No. MOST 2014DFG02050 and Wigner HAS-OBOR-CCNU grant
- OTKA grants K120660, K123815, THOR COST action CA15213
- Wigner Data Center, Wigner GPU Laboratory

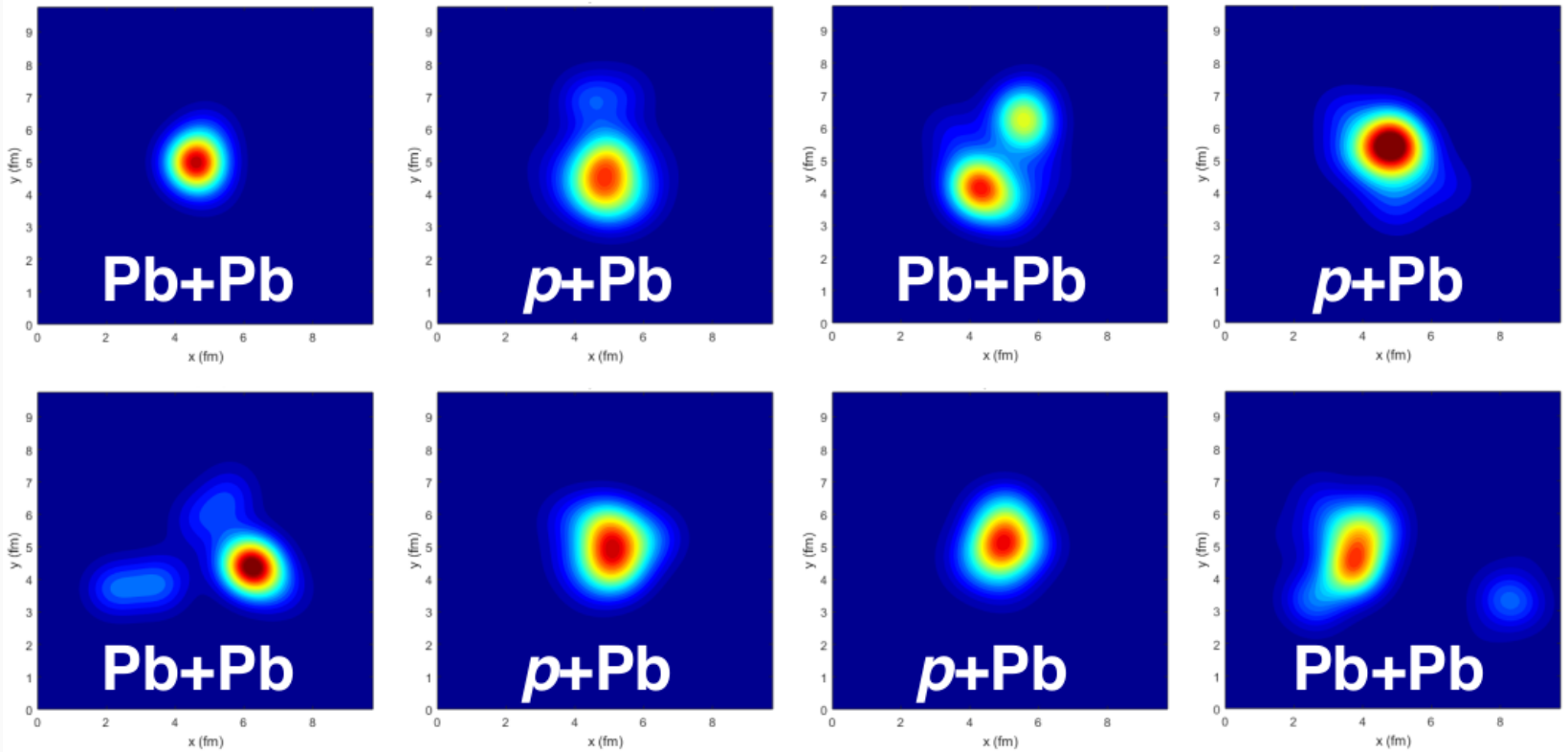
High-energy hadron collisions





QGP EVERYWHERE...?

where does the QGP “begin”?



0-10% *p*+A & 70-90% A+A

31

R. Weller and P. Romatschke, SuperSONIC

HIJING++...

HIJING++...

- (...**is** a Heavy Ion Jet INteraction Generator, C++ version.)

HIJING++...

- (...**is** a Heavy Ion Jet INteraction Generator, C++ version.)
- ...**is** a framework, **not** a black box.
- ...**is not** a direct port of the old FORTRAN code.
- ...**is** a direct port of the old FORTRAN code after all (regarding the physics).
- ...**is not** wrapper for Pythia8.
- ...**is not** published (yet).

HIJING++ SUMMARY

	FORTRAN HIJING	HIJING++
Precision	single	double
Pythia version	5.3*	8.2+**
PDF	GRV98lo	LHAPDF6.2+
Colour reconnection	✗	✓
Jet quenching	(✓)	(✓)
Multithreading	✗	✓
Analysis interface	✗	✓***
Module management**	✗	✓

*Was modified and hardwired into HIJING

**Default tune for HIJING++ is Monash, for that re-tuning of the parameters is needed

***Includes: simple ascii, ROOT and HepMC2 (Rivet)

****In Backup

HIJING++ PRE-RELEASE RESULTS

Before the release, a set of comparisons with experimental data (and fine-tuning) is needed:

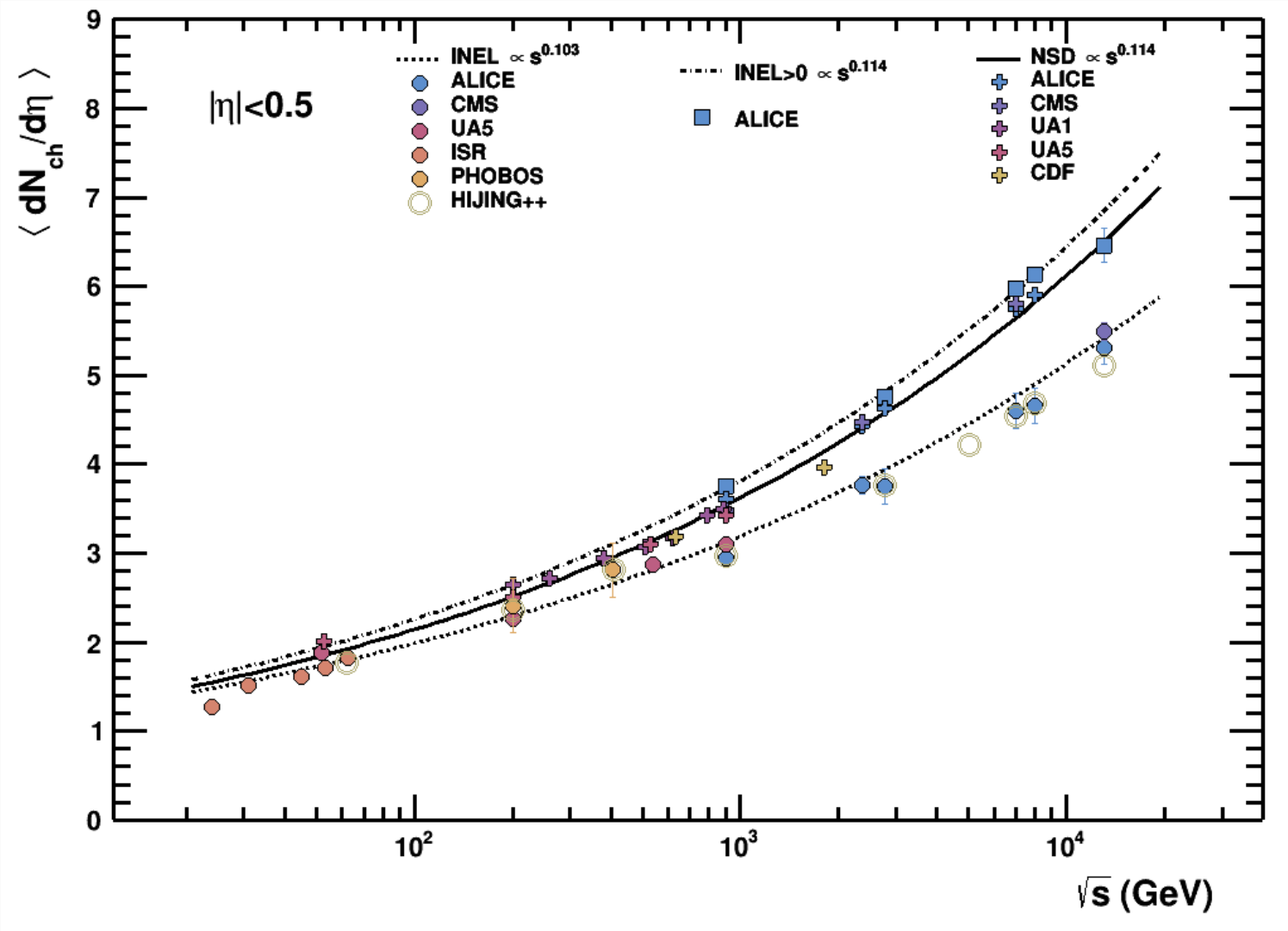
- Chosen (n)PDF set(s): nCTEQ15 (arXiv:1509.00792)
- Raw tuning: ✓
- Fine: ✍ (using Professor*)
- Main observables:
  - Pseudorapidity distributions and multiplicity
  - Charged and PID spectra
  - Nuclear modification factor
  - PID ratios
  - ...
- See arXiv:1701.08496, arXiv:1707.09973, arXiv:1805.02635 and arXiv:1811.02131 for earlier preliminary results

*Tool for systematic tuning of MC event generators, see arXiv:0907.2973

HIJING++ RESULTS: PSEUDORAPIDITY

Pseudorapidity of charged hadrons from RHIC to LHC energies in pp collisions:

HIJING++ describes the η distribution over a wide energy range without any further tuning



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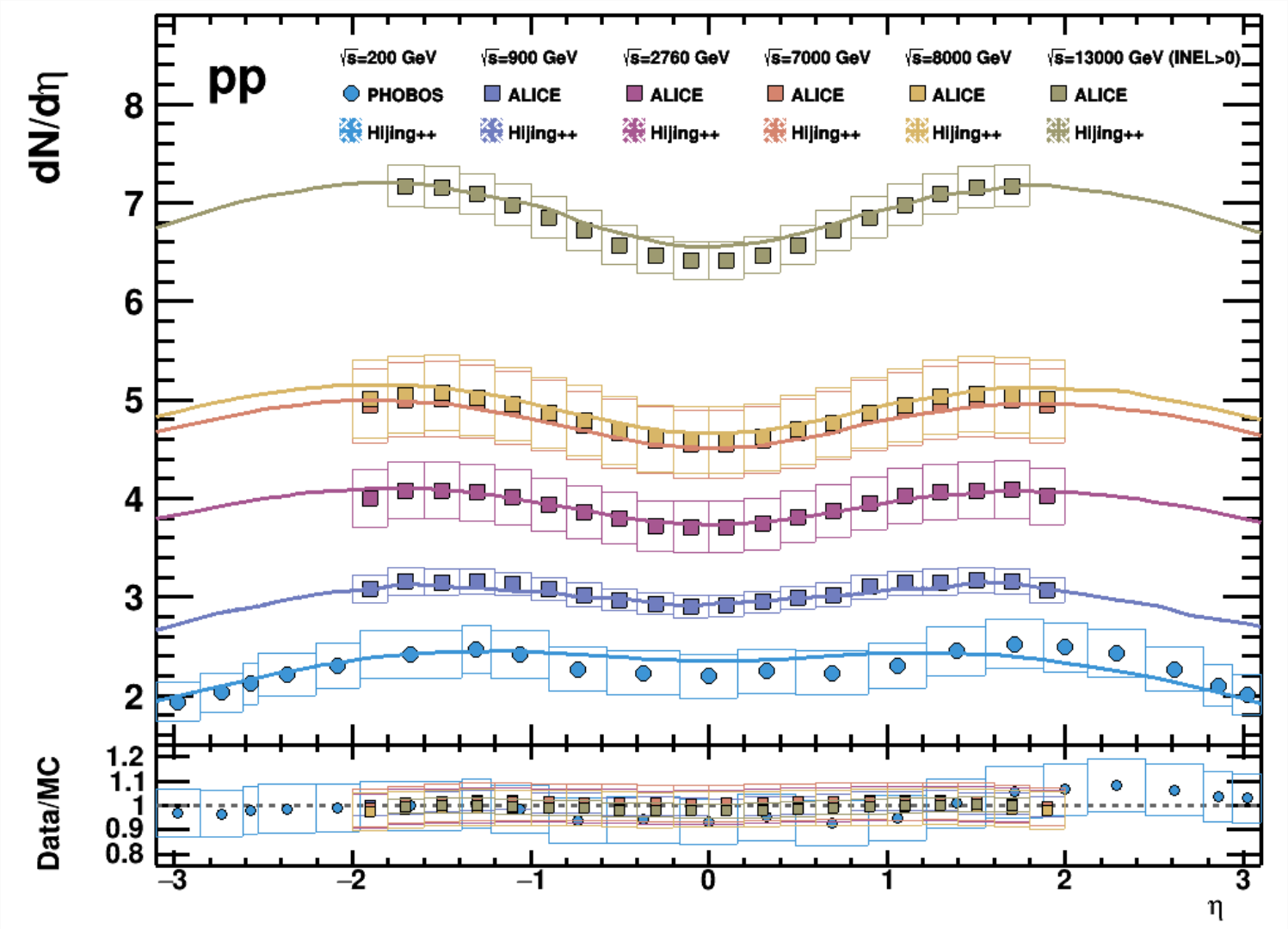
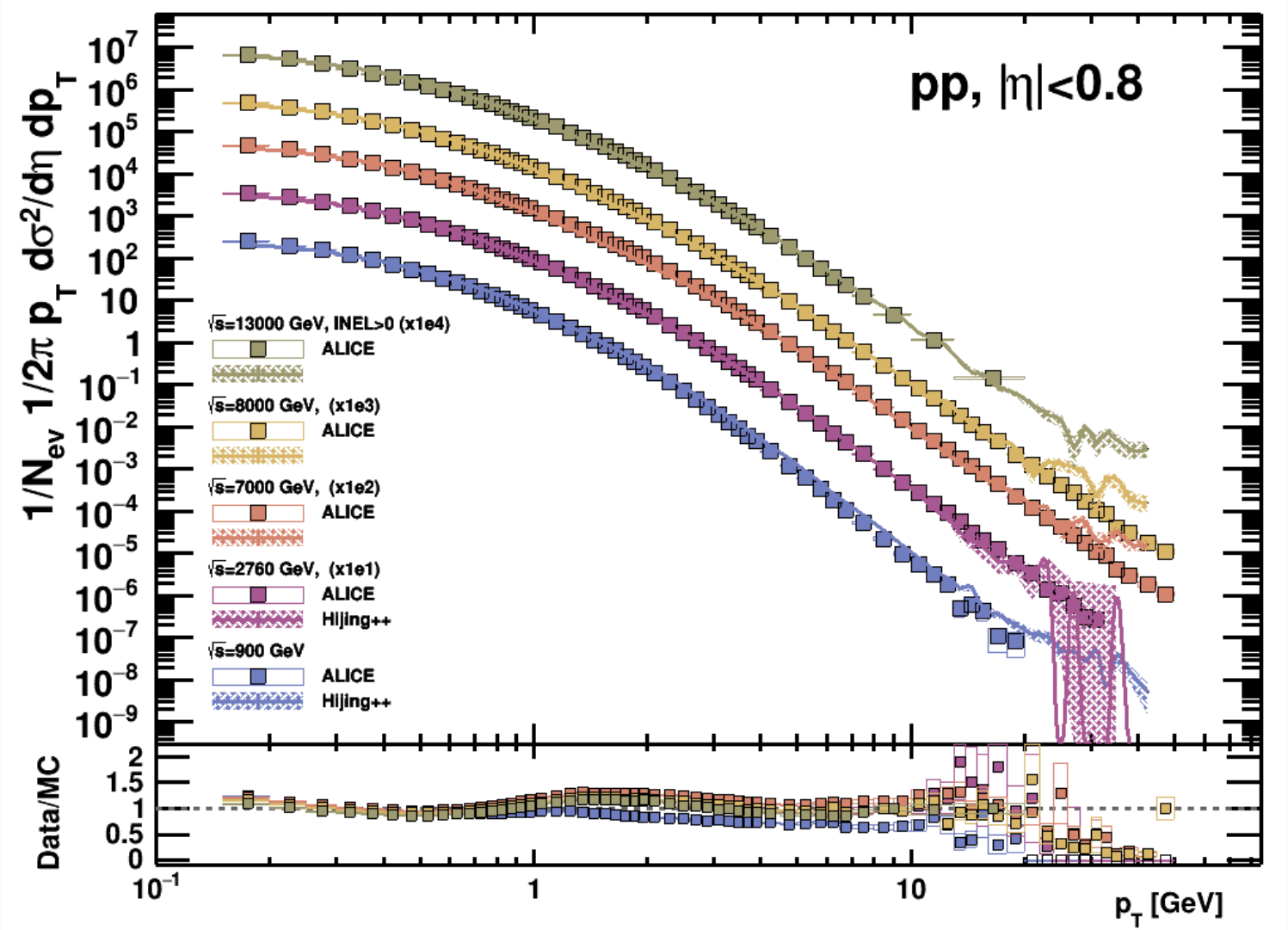


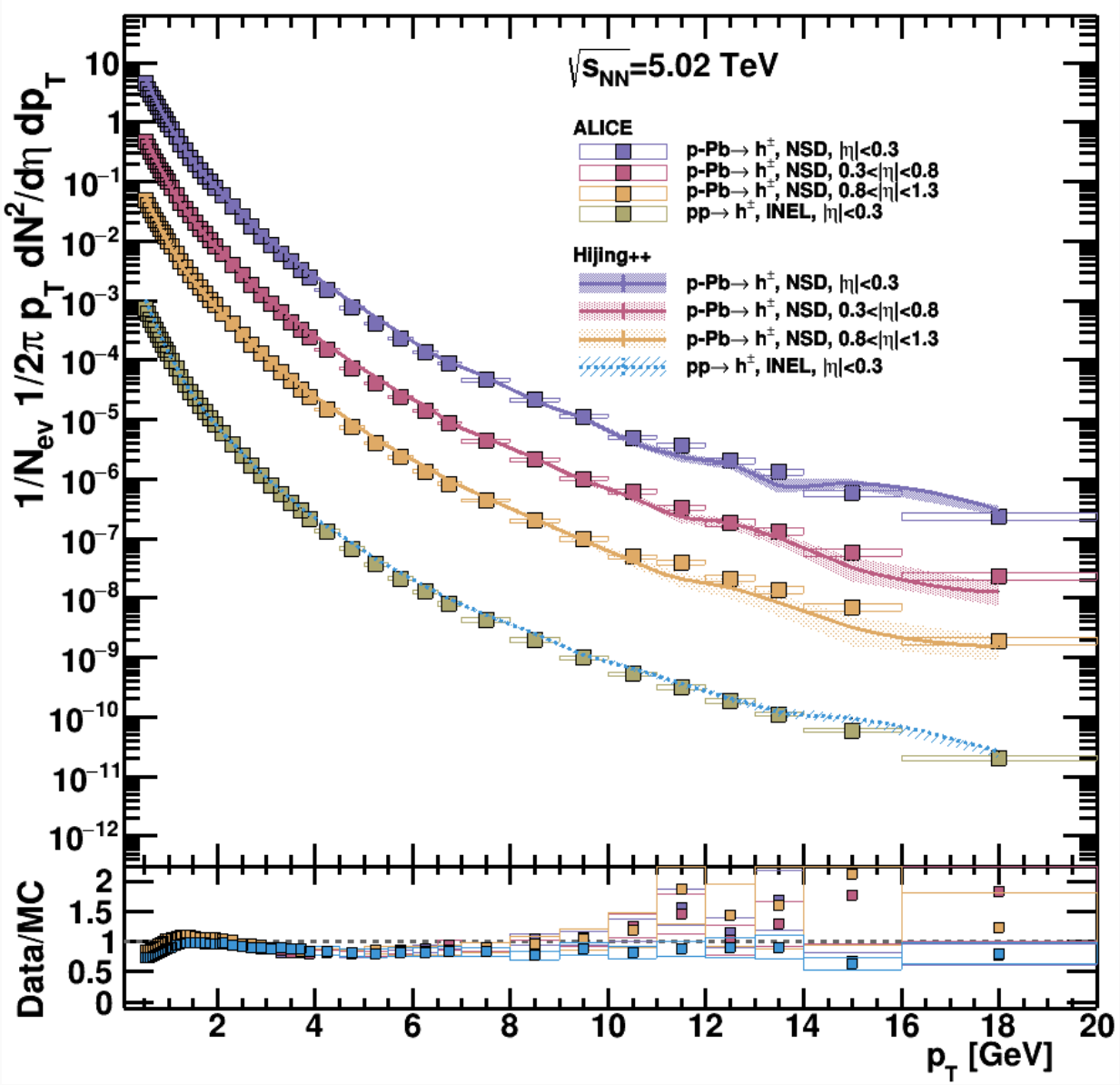
HIJING++ RESULTS: CHARGED HADRON p_T

Invariant yield of $h^{\pm}$ at mid-rapidity at various CM energies:

HIJING++ describes the p_T distribution over a wide energy range without any further tuning



HIJING++ RESULTS: p_T AND NUCLEAR MODIFICATION FACTOR AT PA



p_T spectrum of charged hadrons at pp and p-Pb: Good agreement

- The "experimental" pp reference is an interpolated curve (arXiv:1210.4520)

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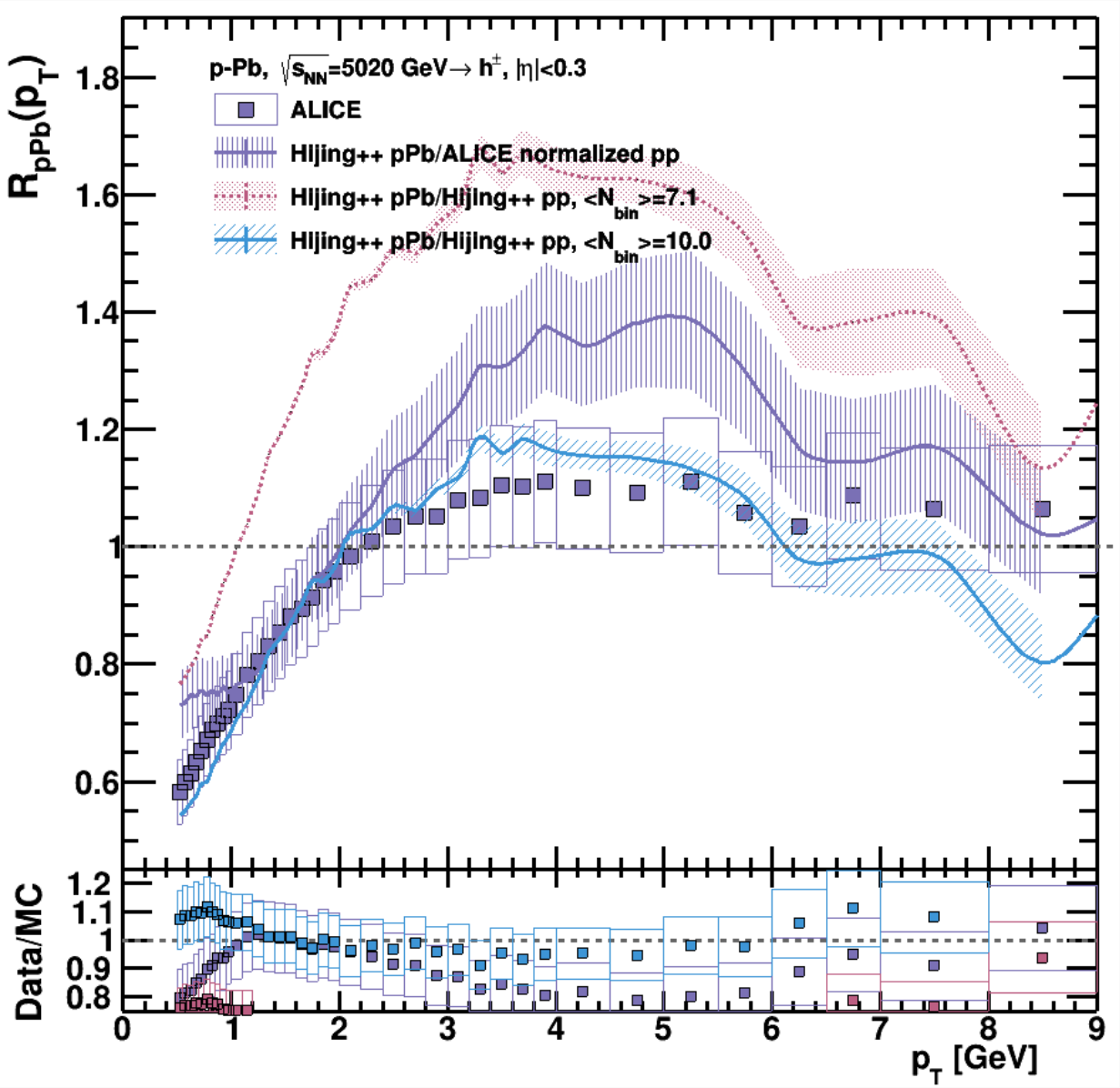


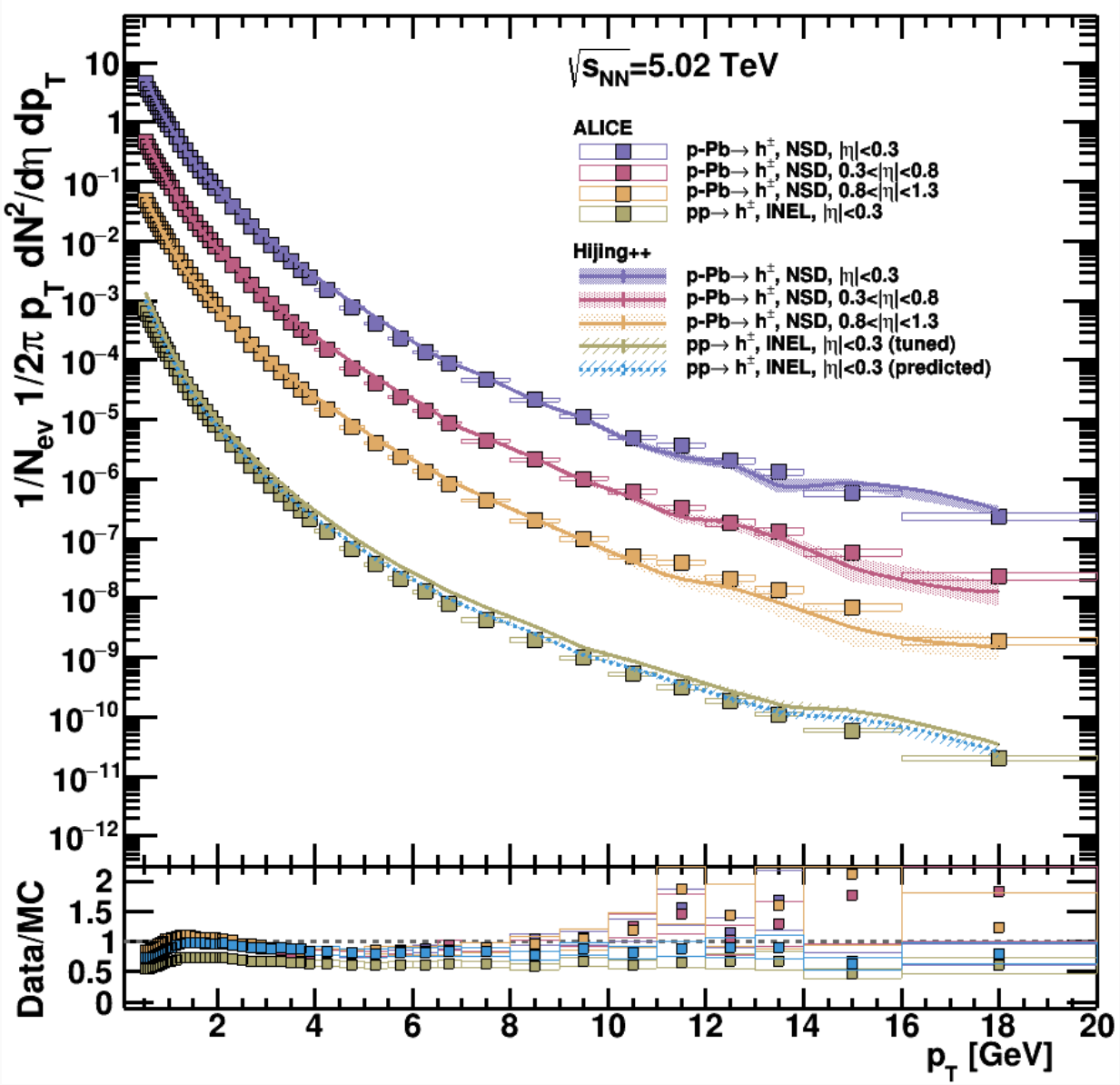
Nuclear modification factor of charged hadrons at p-Pb

$$R_{pPb} = \frac{d^2N_{pPb}/d\eta dp_T}{\langle N_{bin}\rangle d^2N_{pp}/d\eta dp_T},$$

$\langle N_{bin}\rangle = 7.1$
(Glauber: $\langle N_{bin}\rangle = 6.7 \pm 4.8$)

- The "experimental" pp reference is an interpolated curve (arXiv:1210.4520)
- The HIJING++ prediction differs from the ALICE interpolation

HIJING++ RESULTS: p_T AND NUCLEAR MODIFICATION FACTOR AT PA



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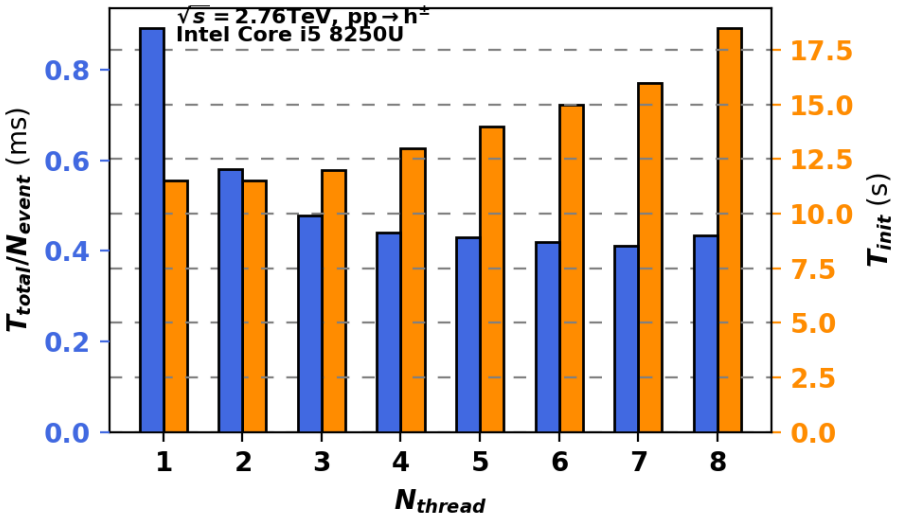
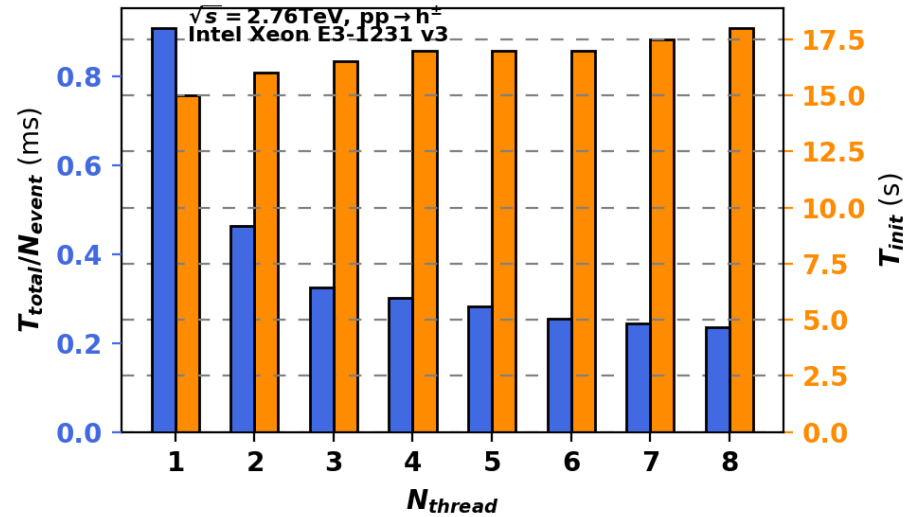
HIJING++ PERFORMANCE (ARXIV:1811.02131)

pp collisions at $\sqrt{s} = 2.76$ TeV:

Intel Core i5 8250U (4 core, 8 thread)



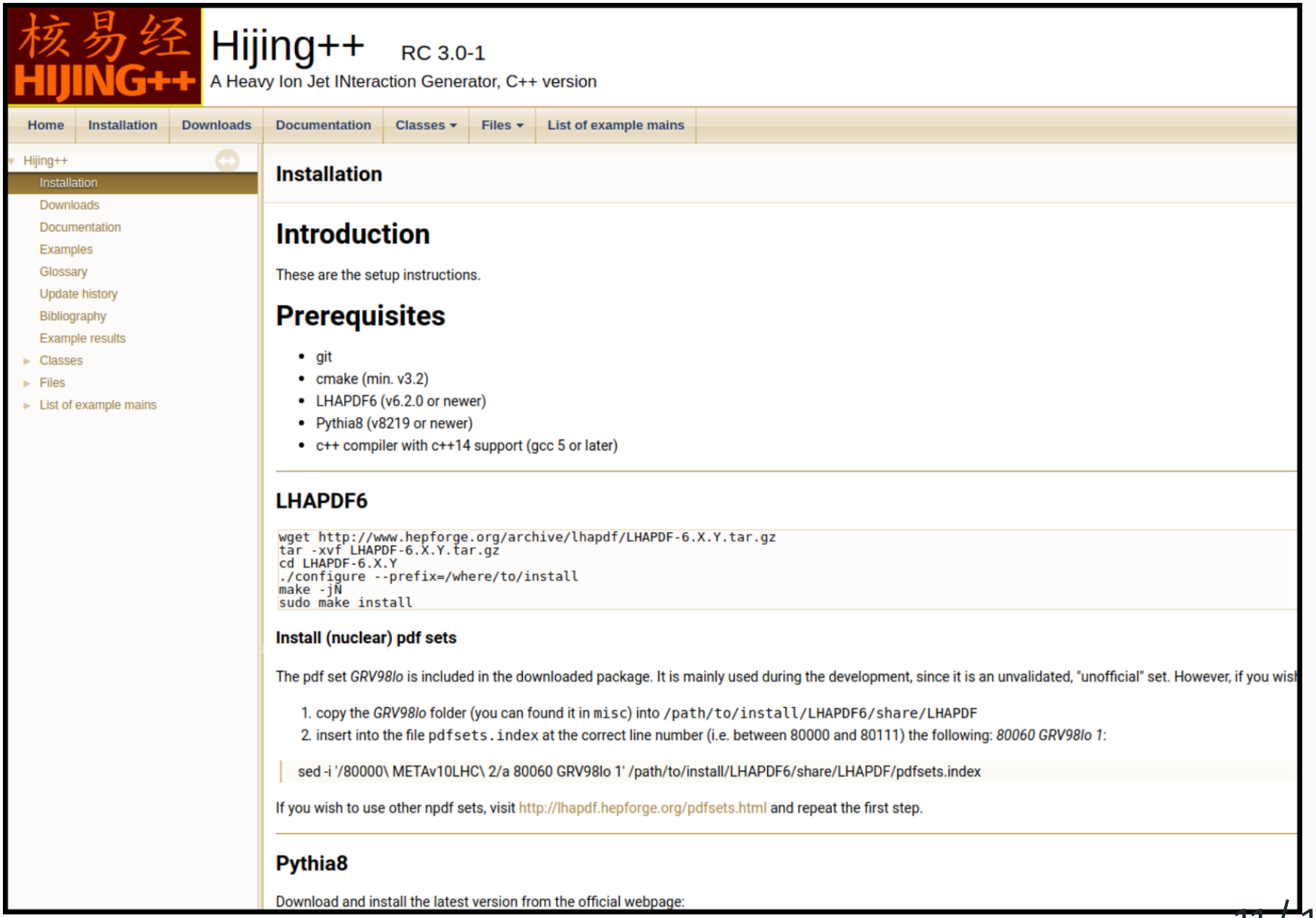
Intel Xeon E3 312 (4 core, 8 thread)



CPU	Speedup		
	pp	p-Pb	Pb-Pb
Intel Core i5-8250U	2.6x	2.7x	2.6x
Intel Xeon E3-1231 v3	6.4x	6.6x	4.5x

	Single thread speedup
Pythia8	+30%
HIJING 2.552	-50% (single precision)

HIJING++ DOCUMENTATION (BASED ON THE XML FILES)



核易经 HIJING++

Hijing++ RC 3.0-1

A Heavy Ion Jet INteraction Generator, C++ version

Home | Installation | Downloads | Documentation | Classes | Files | List of example mains

- Hijing++
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  - Downloads
  - Documentation
  - Examples
  - Glossary
  - Update history
  - Bibliography
  - Example results
- Classes
- Files
- List of example mains

Installation

Introduction

These are the setup instructions.

Prerequisites

- git
- cmake (min. v3.2)
- LHAPDF6 (v6.2.0 or newer)
- Pythia8 (v8219 or newer)
- c++ compiler with c++14 support (gcc 5 or later)

LHAPDF6

```
wget http://www.hepforge.org/archive/lhapdf/LHAPDF-6.X.Y.tar.gz
tar -xvf LHAPDF-6.X.Y.tar.gz
cd LHAPDF-6.X.Y
./configure --prefix=/where/to/install
make -jN
sudo make install
```

Install (nuclear) pdf sets

The pdf set *GRV98lo* is included in the downloaded package. It is mainly used during the development, since it is an unvalidated, "unofficial" set. However, if you wish

1. copy the *GRV98lo* folder (you can found it in `misc`) into `/path/to/install/LHAPDF6/share/LHAPDF`
2. insert into the file `pdfsets.index` at the correct line number (i.e. between 80000 and 80111) the following: *80060 GRV98lo 1*:

```
sed -i '/80000\ METAv10LHC\ 2/a 80060 GRV98lo 1' /path/to/install/LHAPDF6/share/LHAPDF/pdfsets.index
```

If you wish to use other npdf sets, visit http://lhapdf.hepforge.org/pdfsets.html and repeat the first step.

Pythia8

Download and install the latest version from the official webpage:

Summary

- Brand new framework in **C++**
- Good agreement with experimental data, fine-tuning is under progress
- CPU parallelization and analysis is included in the standard accessory
- Modules: room for any new model
- Only a little polishing is needed, release soon...

STAY TUNED!

Contacts:

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or

hijing@wigner.mta.hu


Zimányi School 2018
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Thank you for your attention!

HIJING++ Monte Carlo event generator

Solid C++ foundations

- User friendly usage (C++14 compiler, cmake, LHAPDF6, Pythia8)
- Many optional extension (ROOT, FastJet, Rivet, ...)
- Easily parallelizable

main.cc:

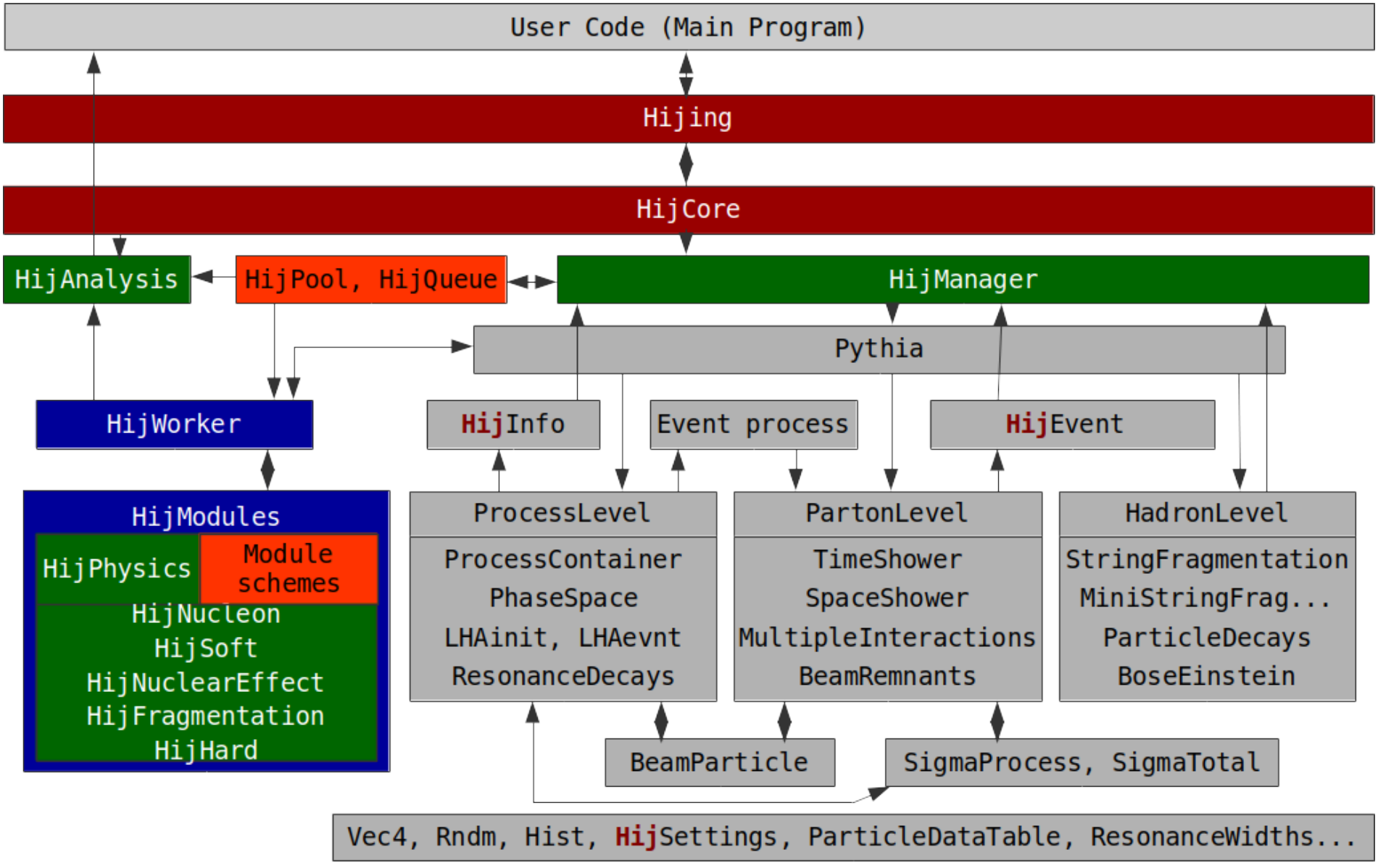
```
#include "Hijing.hpp"

using namespace Hijing3;

int main(int argc, char* argv[])
{
  Hijing hijing;
  hijing.readFile("testSettings.cmnd");

  hijing.init();
  hijing.newAnalysis("root", "EventEnd", "pt_cpion",
                     50, 0.0, 20.0);
  hijing.analysisProperties("pt_cpion", "final", "pT",
                            "yw-0.5to0.5",
                            "ID211", "ID-211");
  hijing.start();
}
```

testSettings.cmnd:

```
PDF:pSetProj = nCTEQ15_1_1
PDF:pSetTarg = nCTEQ15_208_82

Hijing:threads = 3
Beams:eCM    = 8160
Hijing:DoShadowing = off
Hijing:makeLog = off
Hijing:fileName = PbPb_5020_GLVtest

Main:numberOfEvents = 50000
Hijing:idA = P
Hijing:aproj = 1
Hijing:zproj = 1
Hijing:idB = A
Hijing:atarg = 208
Hijing:ztarg = 82
(...)
```

Highly customizable through run parameters stored in xml files

HIJING++ STRUCTURE



HIJING++ MODULARITY

In the xml:

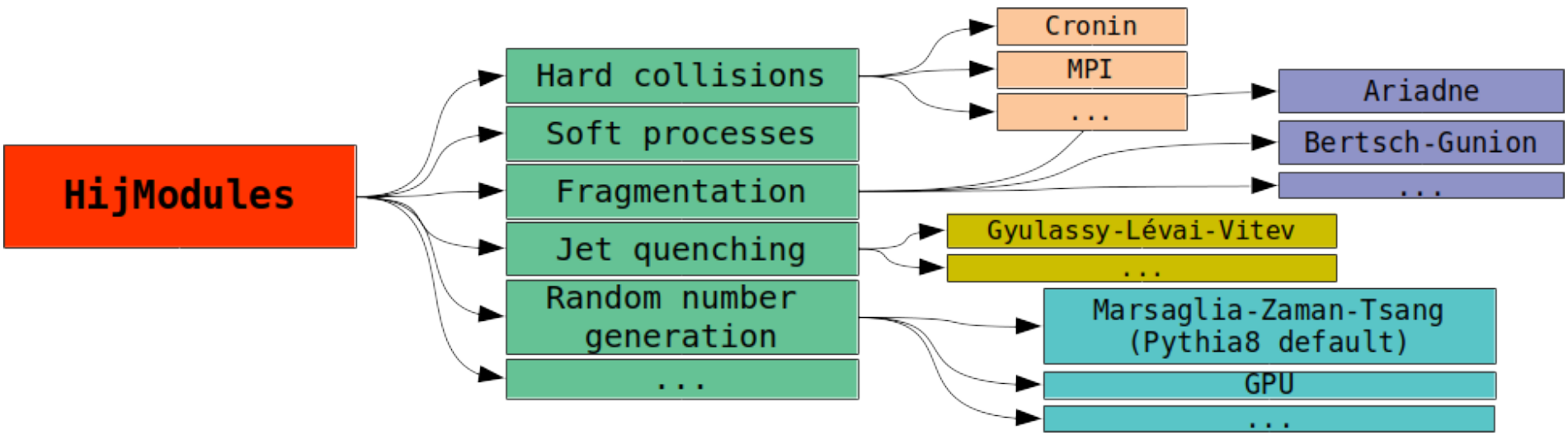
```
<word name="Hijing:Quenching" default="HijQuenching_GLV0">
Select the jet quenching definition: GLV model version 0.
</word>
```

Building the HijModules:

```
unique_ptr<IHijQuenching> ModuleFactory::makeQuenching(const string &name) {
    if (name == "HijQuenching_GLV0")
      return move(make_unique<HijQuenching_GLV0>());
    if (name == "HijQuenching_GLV1")
      return move(make_unique<HijQuenching_GLV1>());
}
```

At user level, in testSettings.cmnd:

```
Hijing:Quenching = HijQuenching_GLV0
```



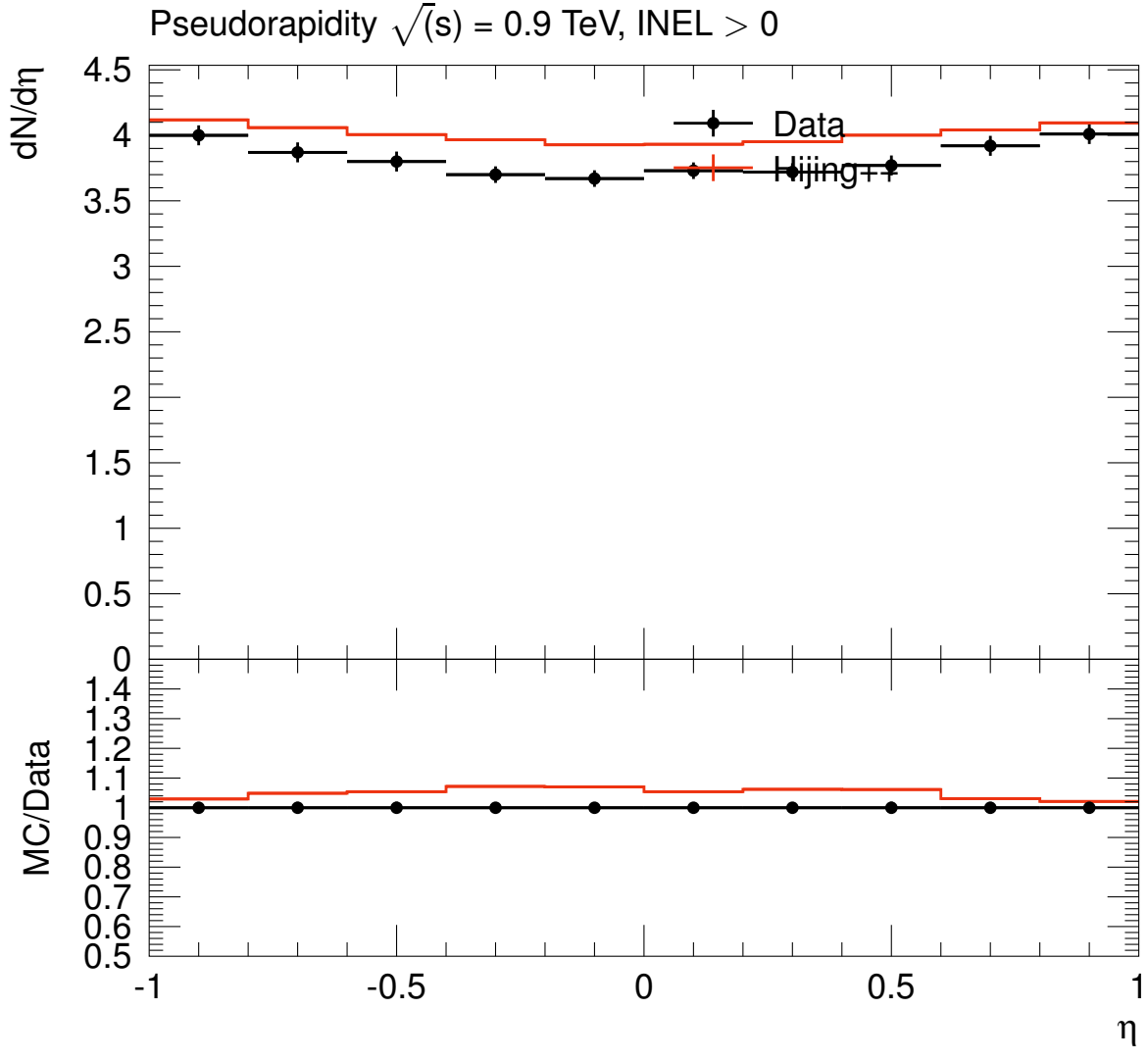
HIJING++ BUILT-IN ANALYSIS

```
hijing.newAnalysis("root", "EventEnd", "multiplicity_root", 100, 0.0, 100.0, "<dN_{ch}/d#eta>", "Prob");

hijing.newAnalysis("ascii","EventEnd", "eta_charged_ascii", 20, -5.0, 5.0);

hijing.newAnalysis("root", "raw","EventEnd","raw data");

auto myEventFilter = [&](const Event &event) {
    return true;
};

auto myHadronFilter = [&](const Particle &particle, const Event &event) {
    return particle.isFinal() && abs(particle.id()) == 211;
};

hijing.analysisBranches("raw data", "eta", "pT");

hijing.analysisFilter("raw data", myEventFilter, myParticleAccept);

hijing.analysisProperties("multiplicity_root", "charged", "final", "multiplicity", "nonorm",
                          "yw-0.5to0.5", "png");

hijing.analysisProperties("eta_charged_ascii","final","eta", "charged");
```

HIJING++ RESULTS: PSEUDORAPIDITY

Pseudorapidity of charged hadrons from RHIC to LHC energies in pp collisions

(Plots produced directly with Rivet analysis ALICE_2010_S8625980)



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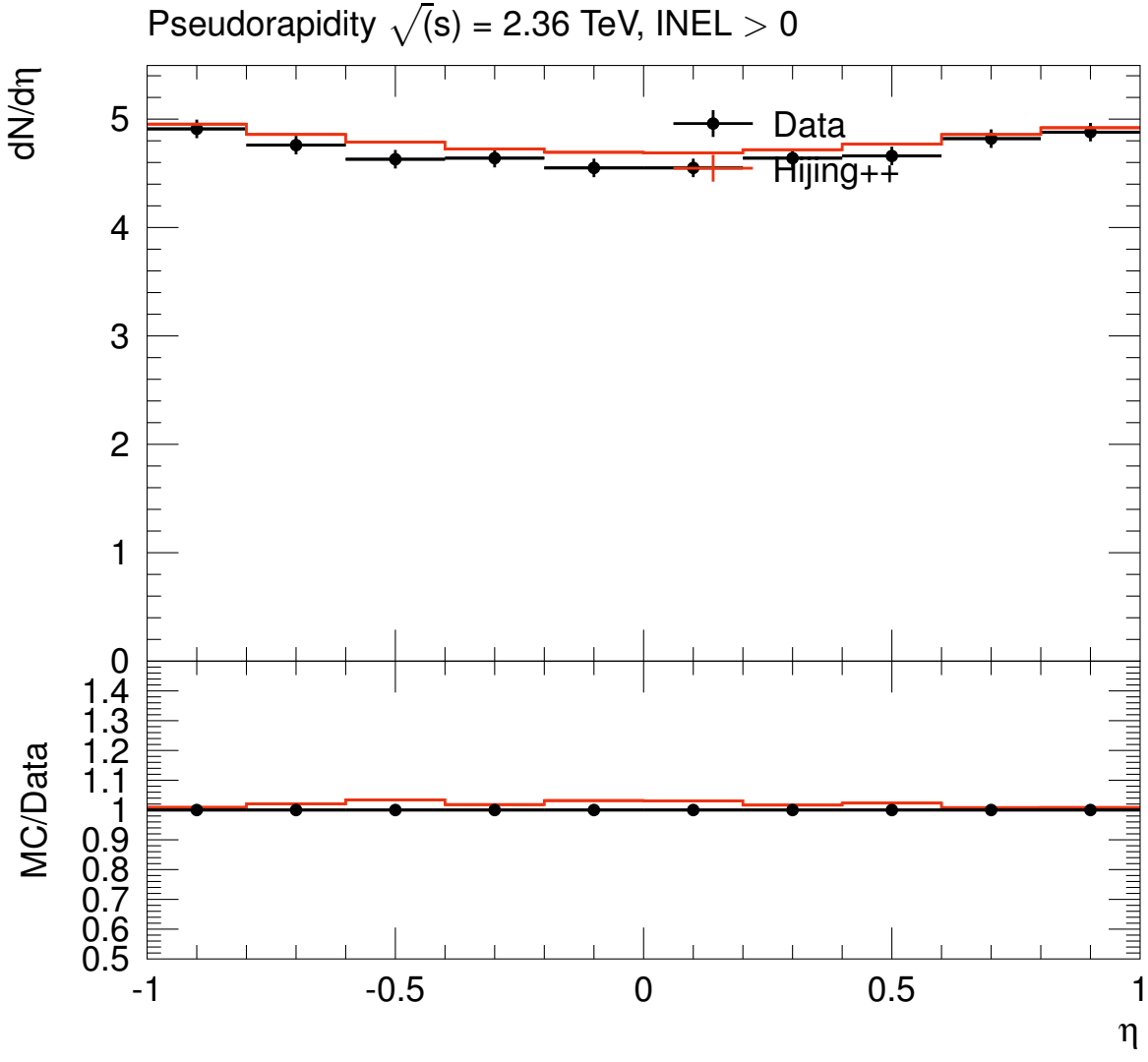

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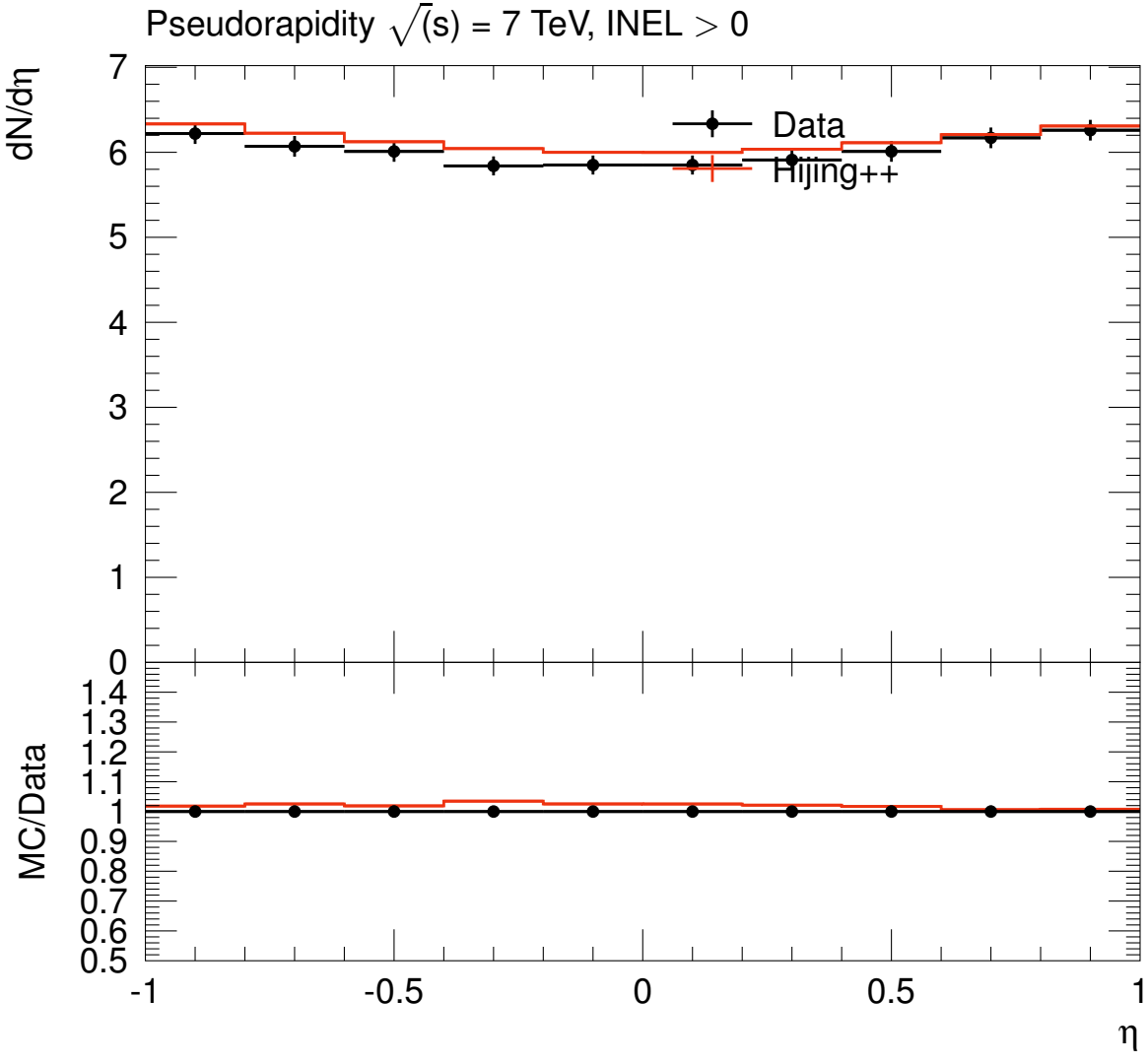
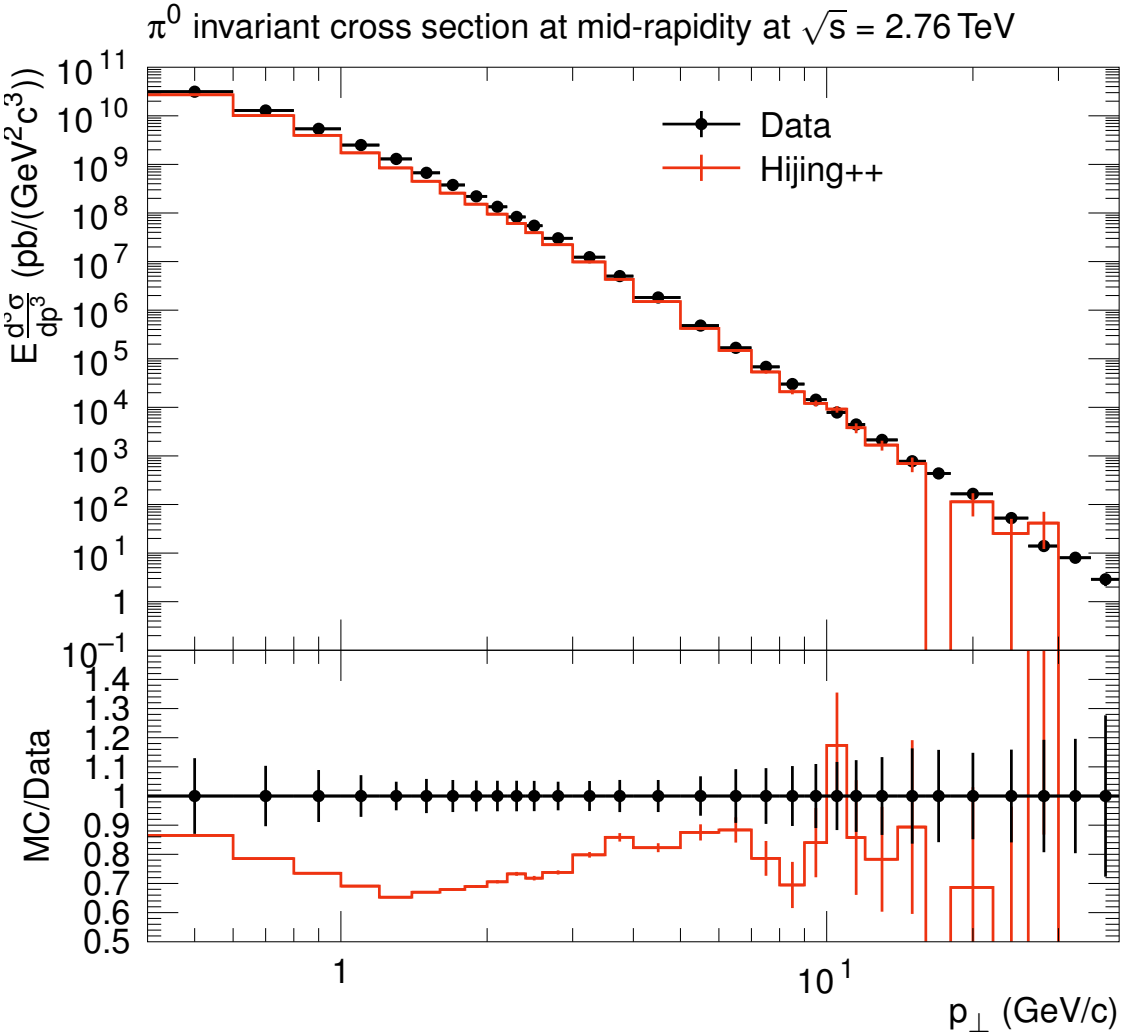


HIJING++ RESULTS: CHARGED/PID SPECTRA

Invariant yield/cross section of $\pi^{\pm}$, π^{0} and η particles at mid-rapidity

(Plots produced directly with Rivet analyses ALICE_2012_I1116147, ALICE_2015_I1357424, ALICE_2017_I1512110)



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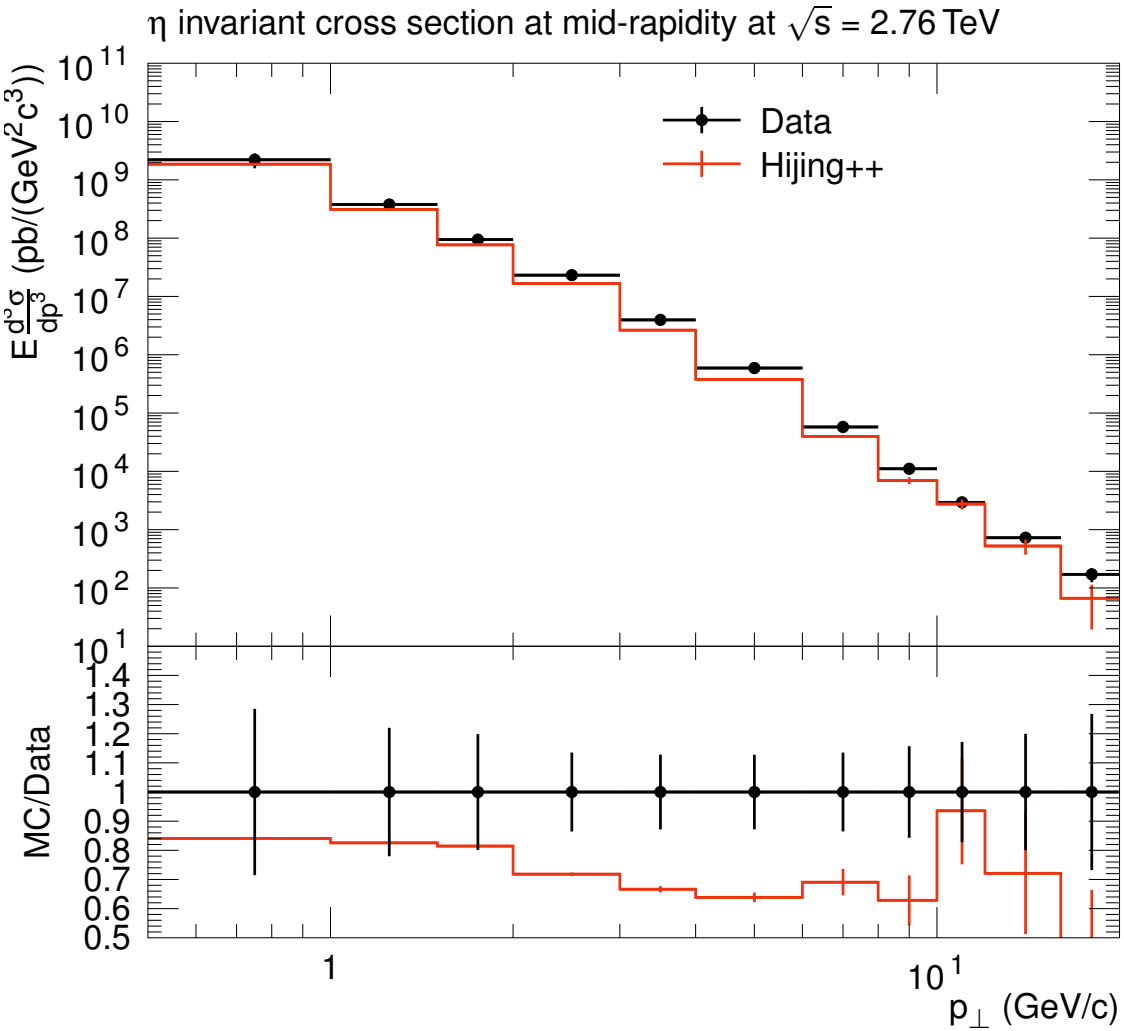

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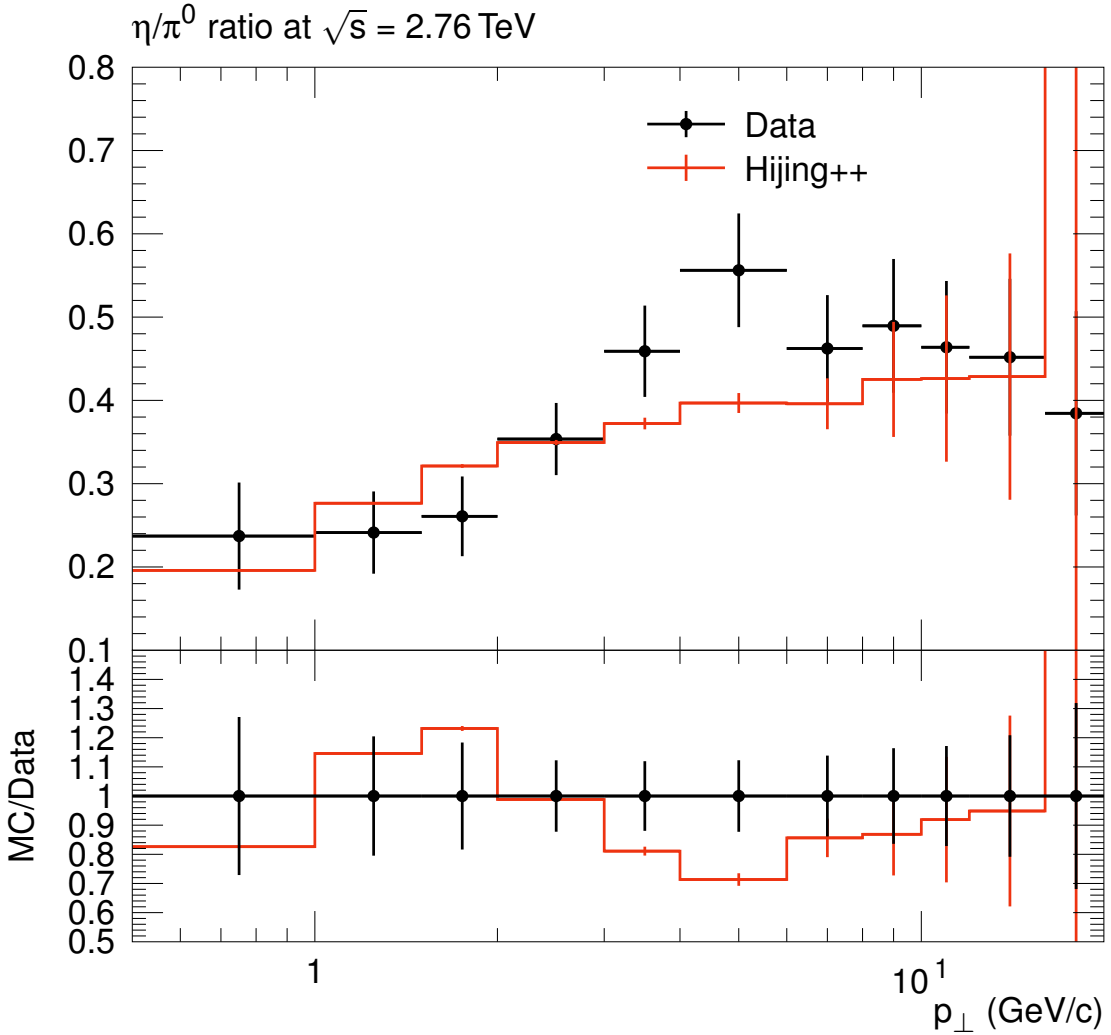

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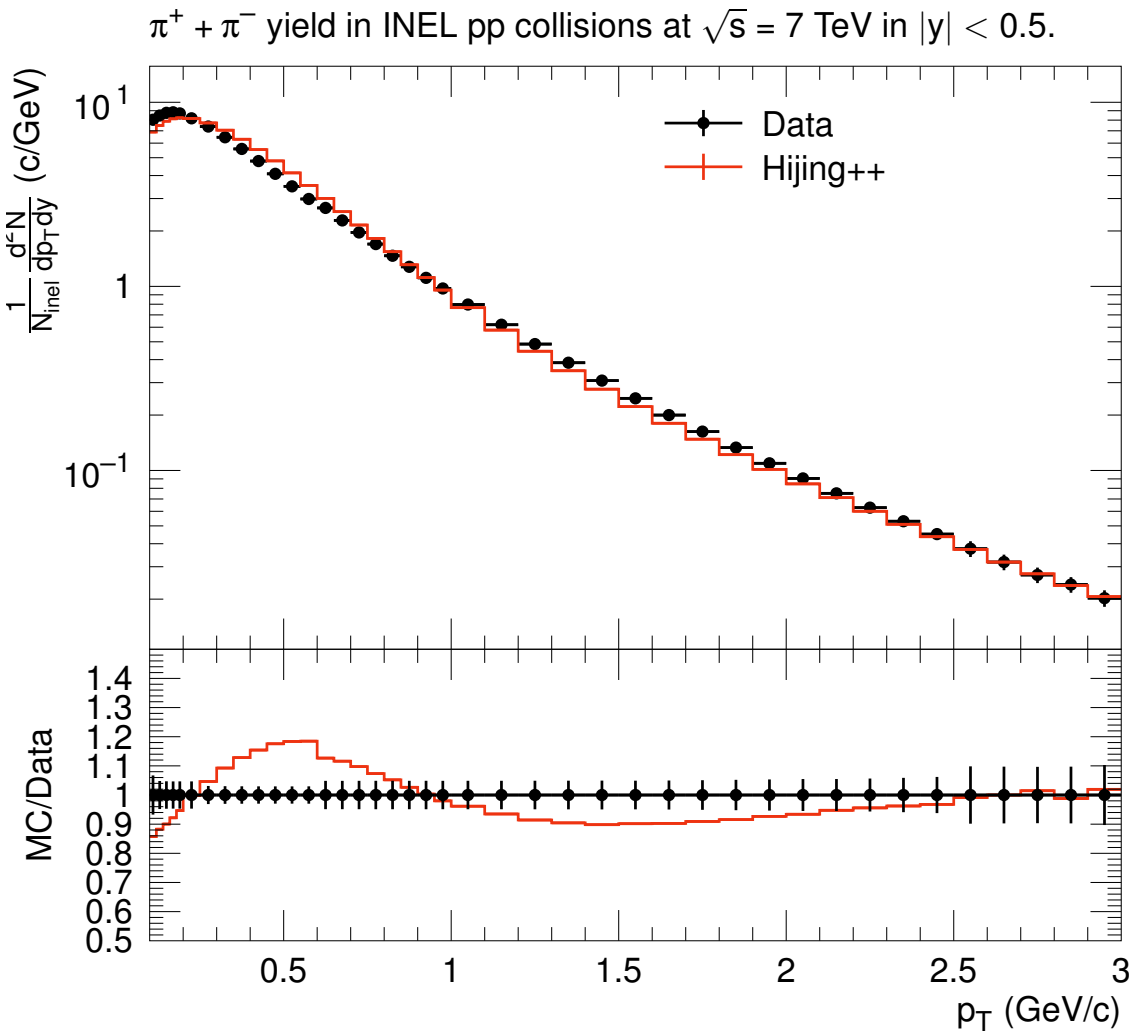

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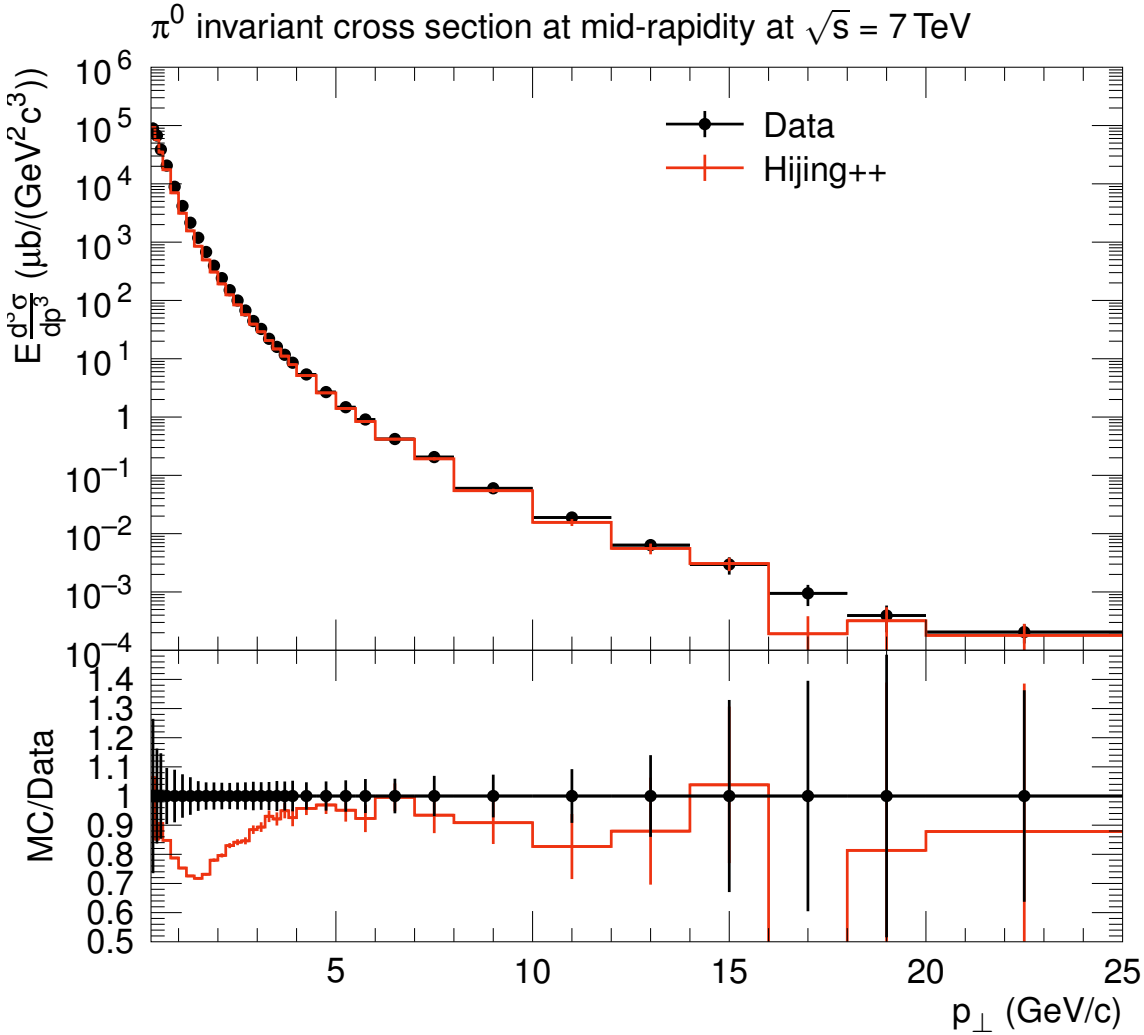

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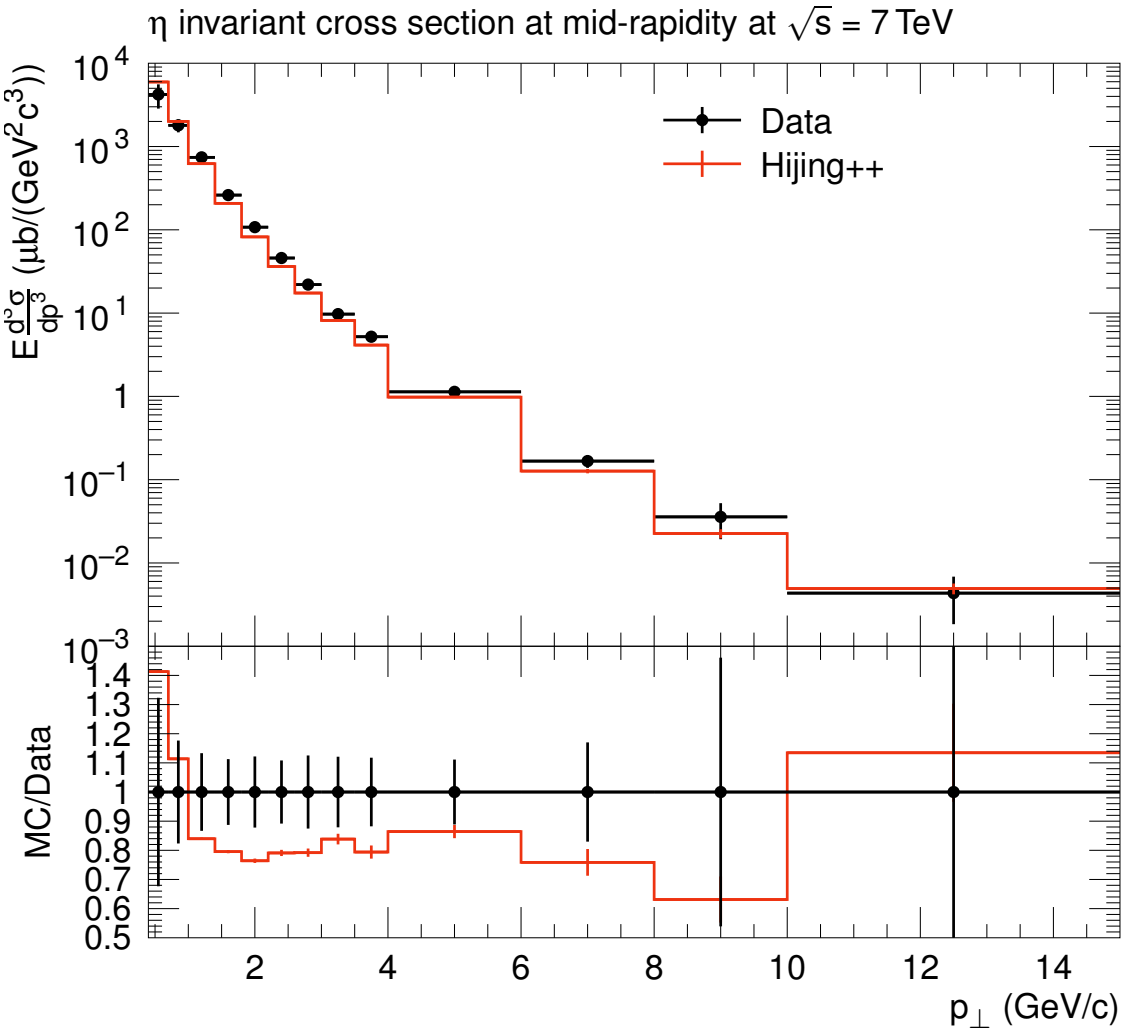

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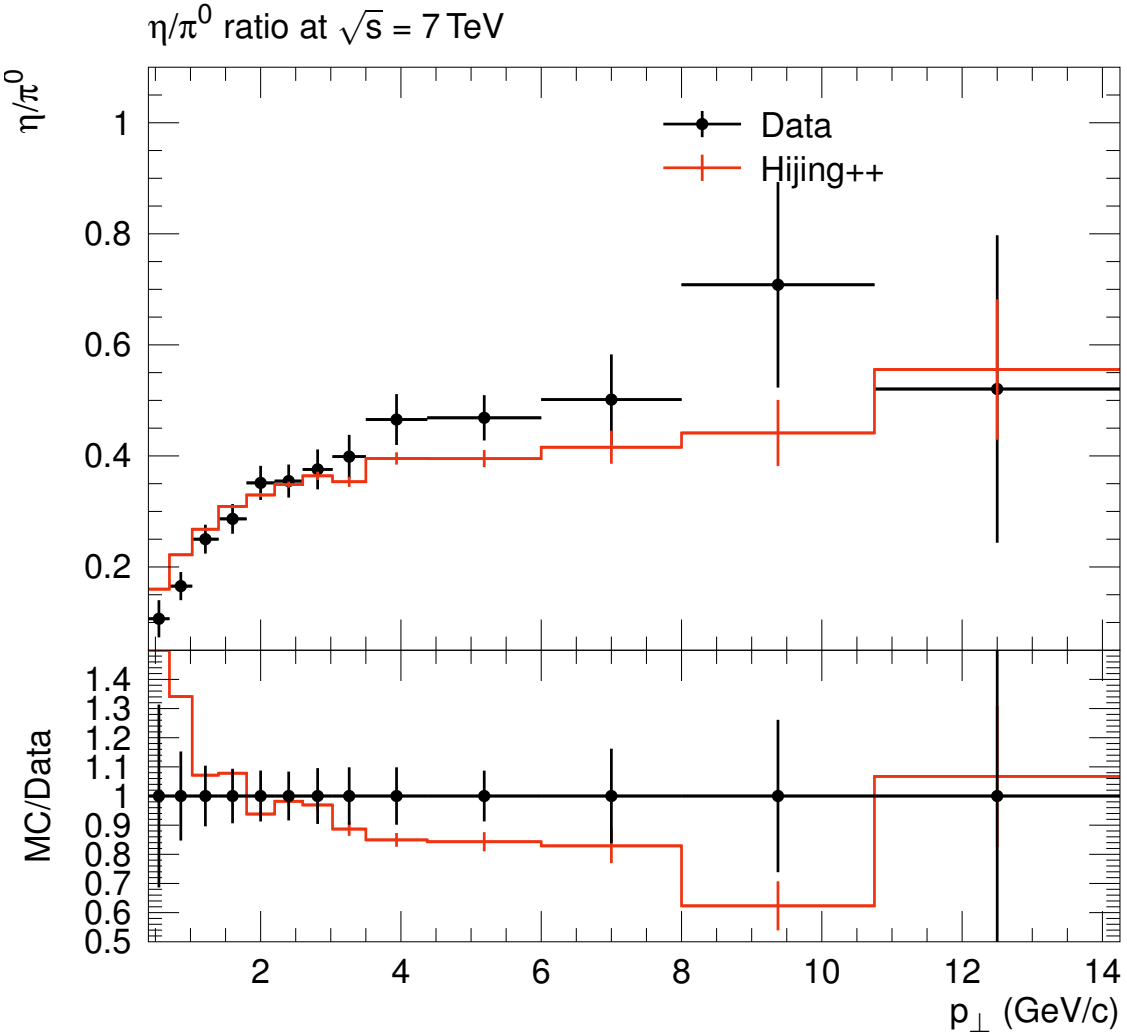

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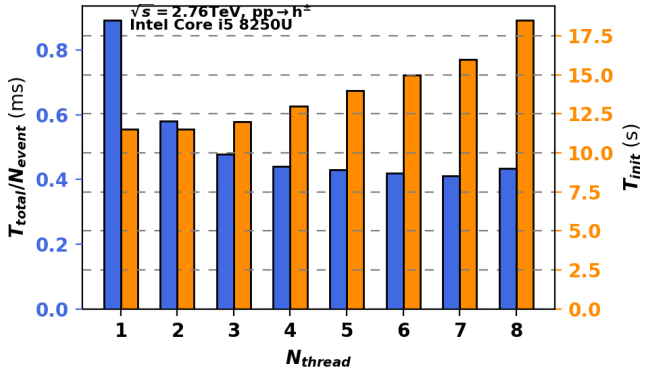
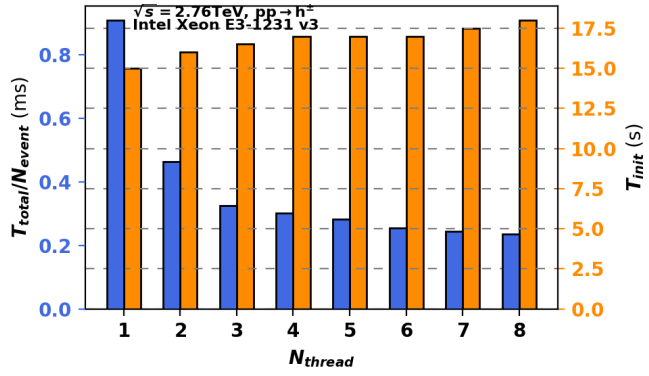
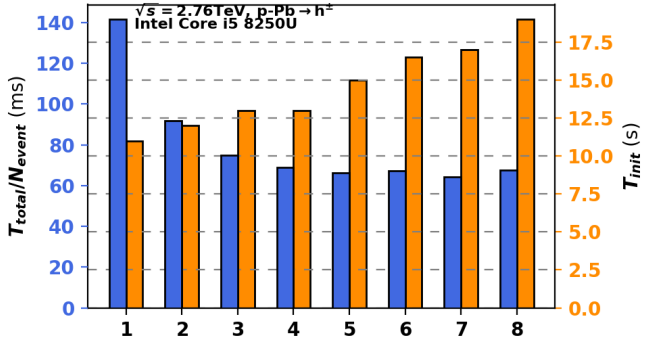
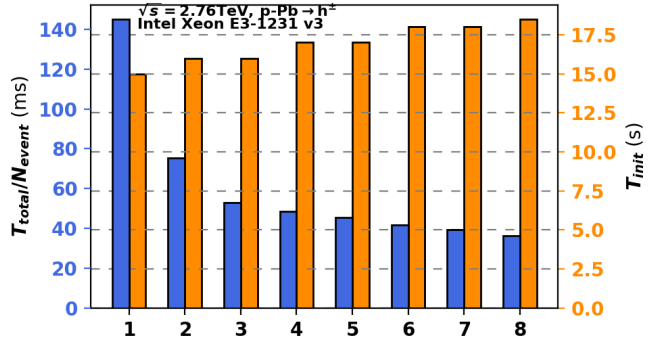
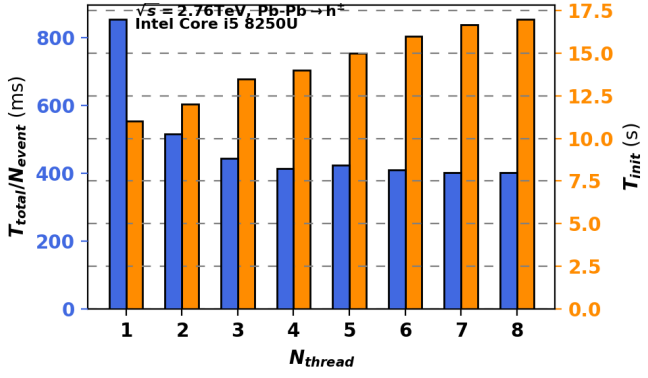
HIJING++ PERFORMANCE (ARXIV:1811.02131)

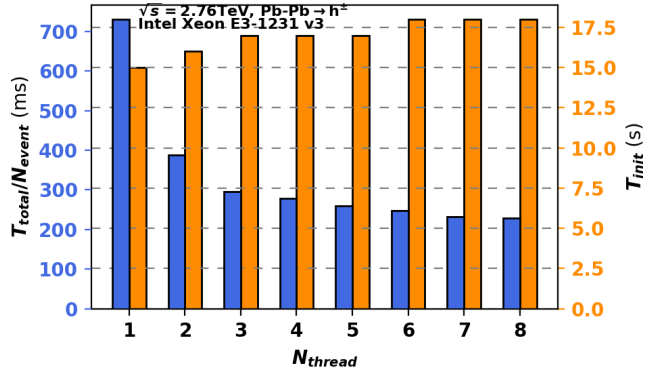








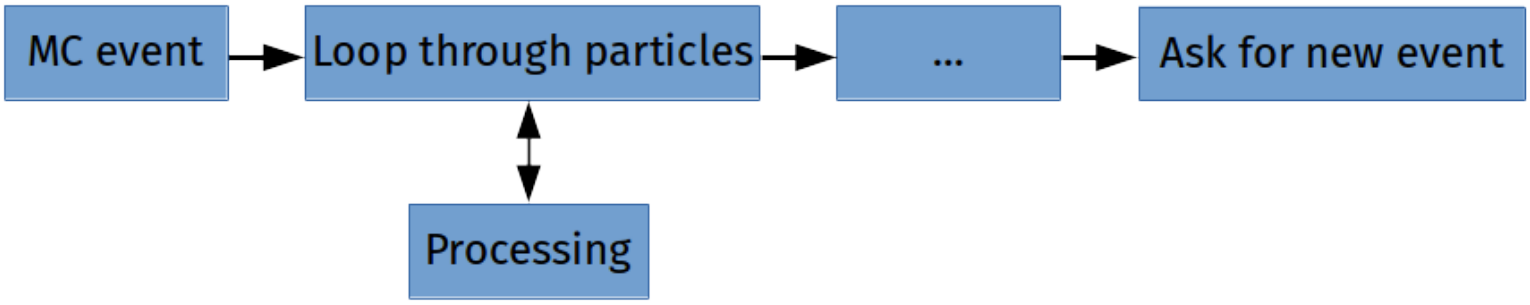




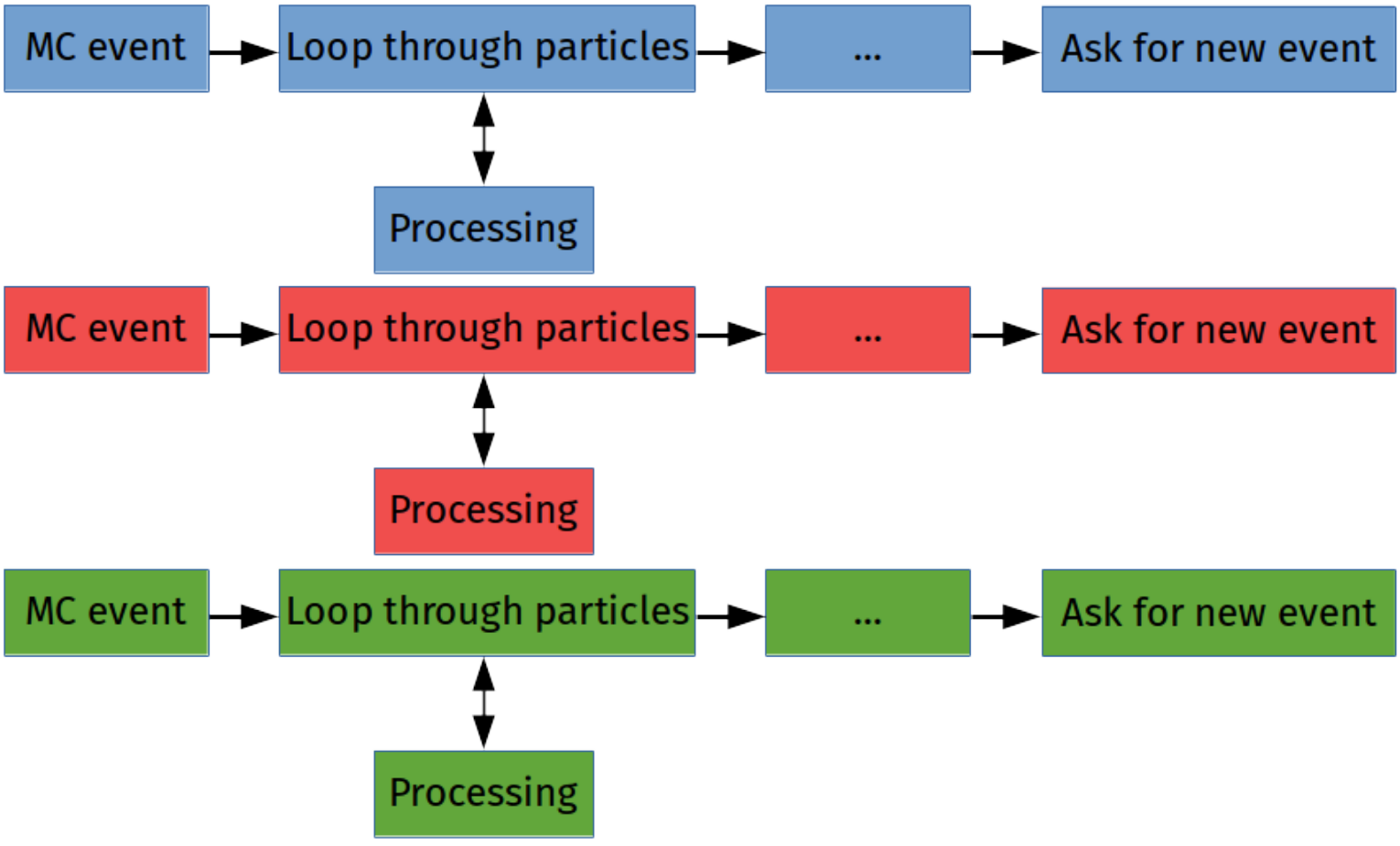
Intel Core i5 8250U (4 core, 8 thread)

Intel Xeon E3 312 (4 core, 8 thread)

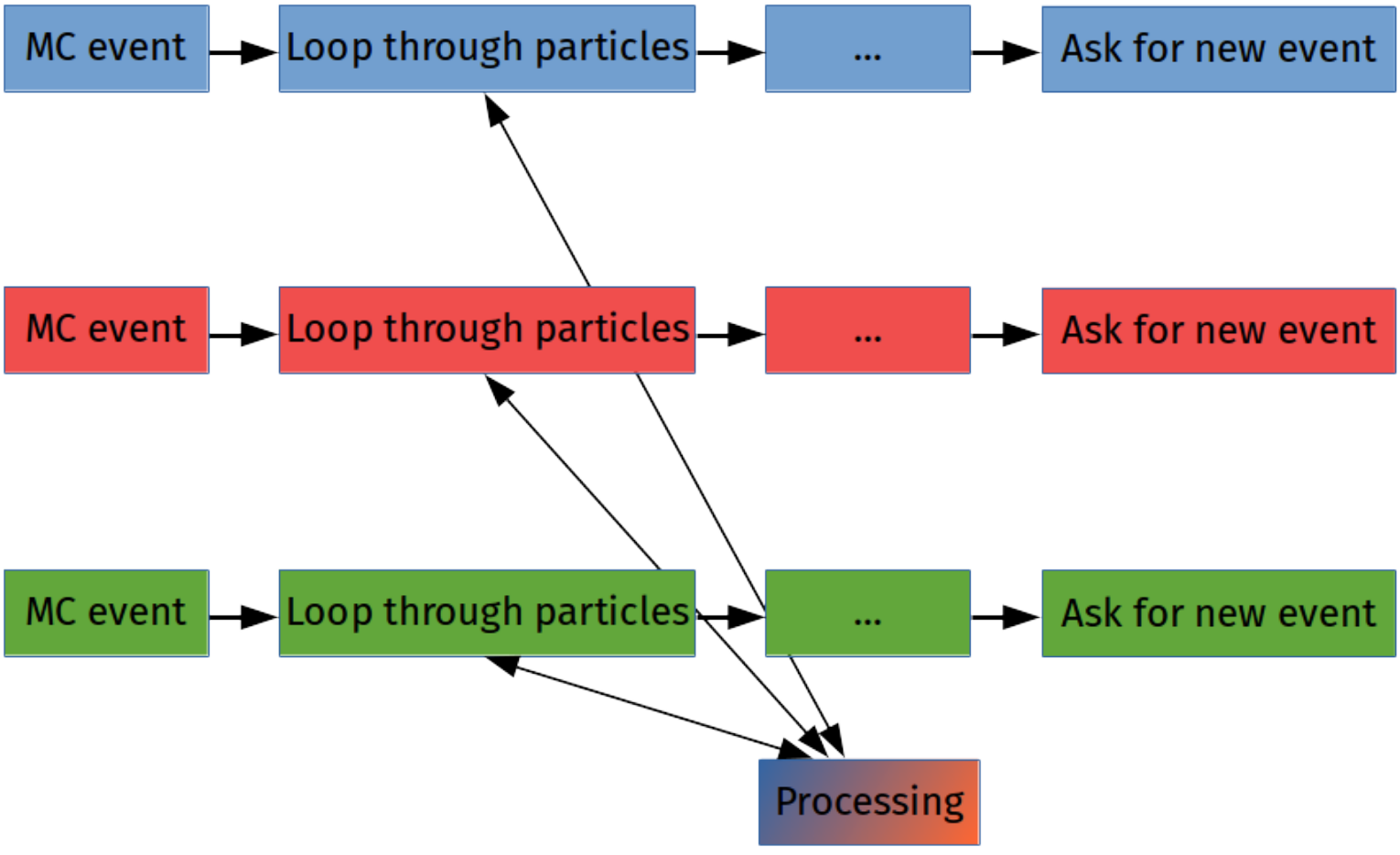
HIJING++ MULTITHREADING



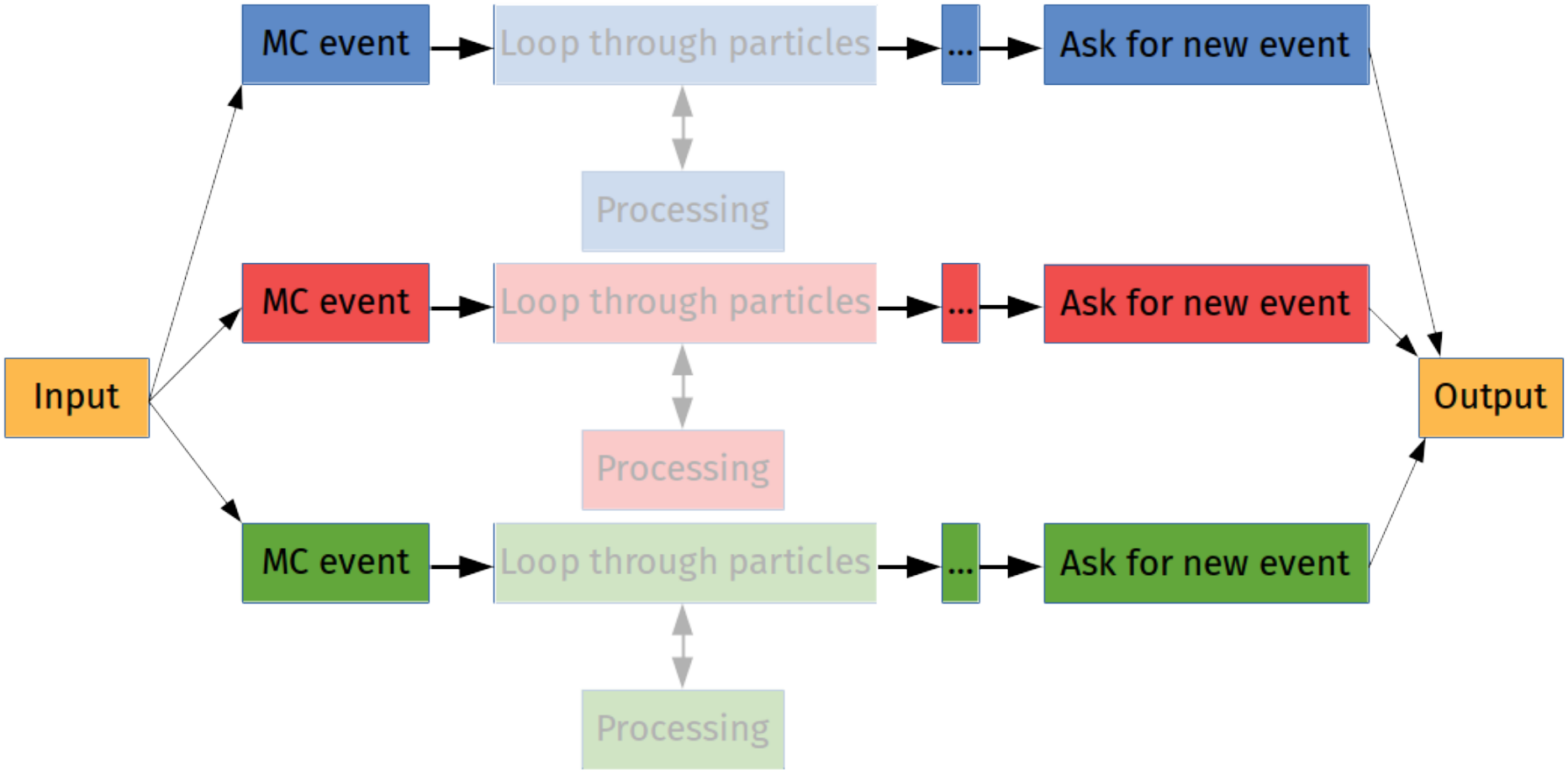
HIJING++ MULTITHREADING



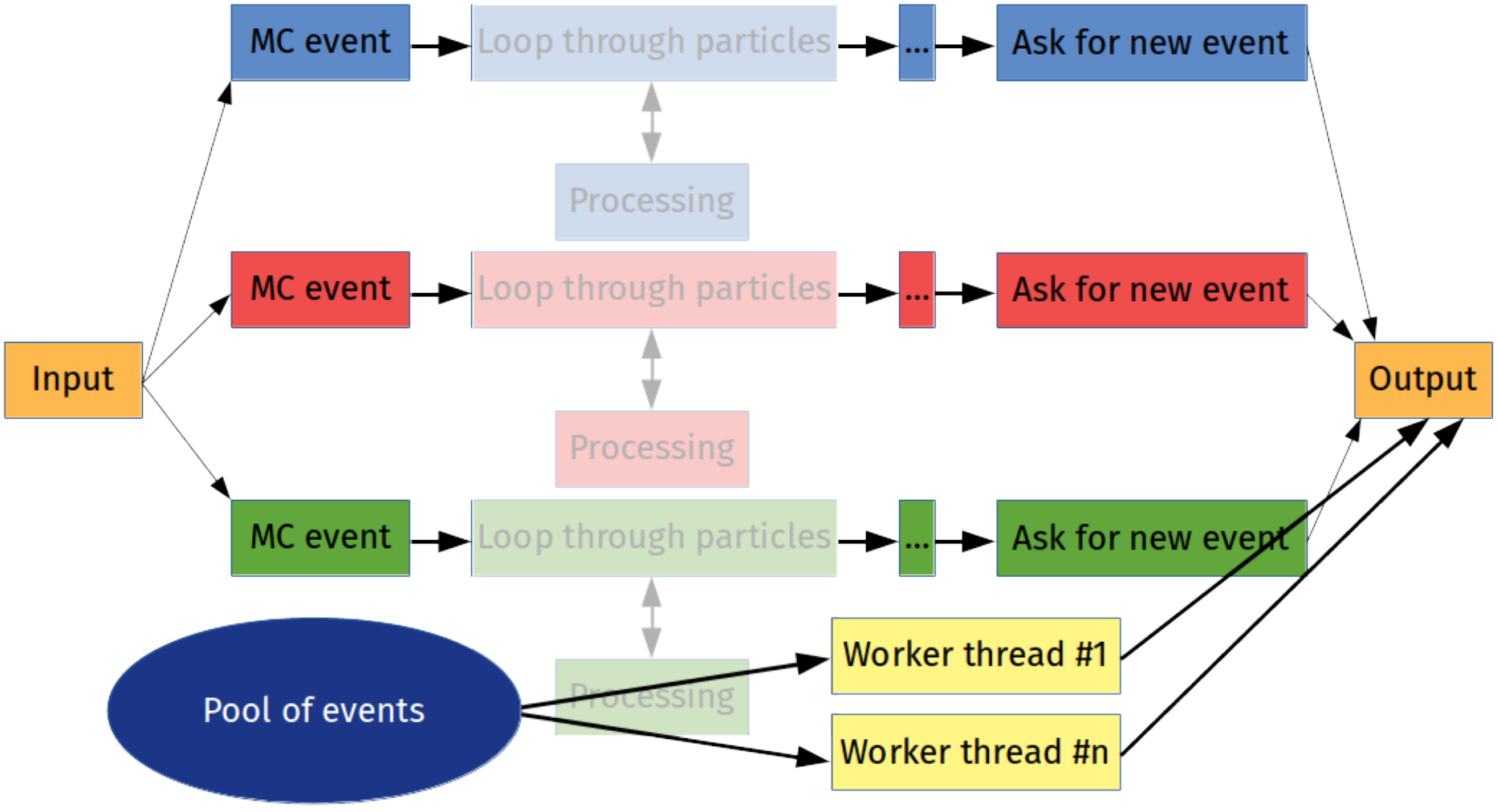
HIJING++ MULTITHREADING



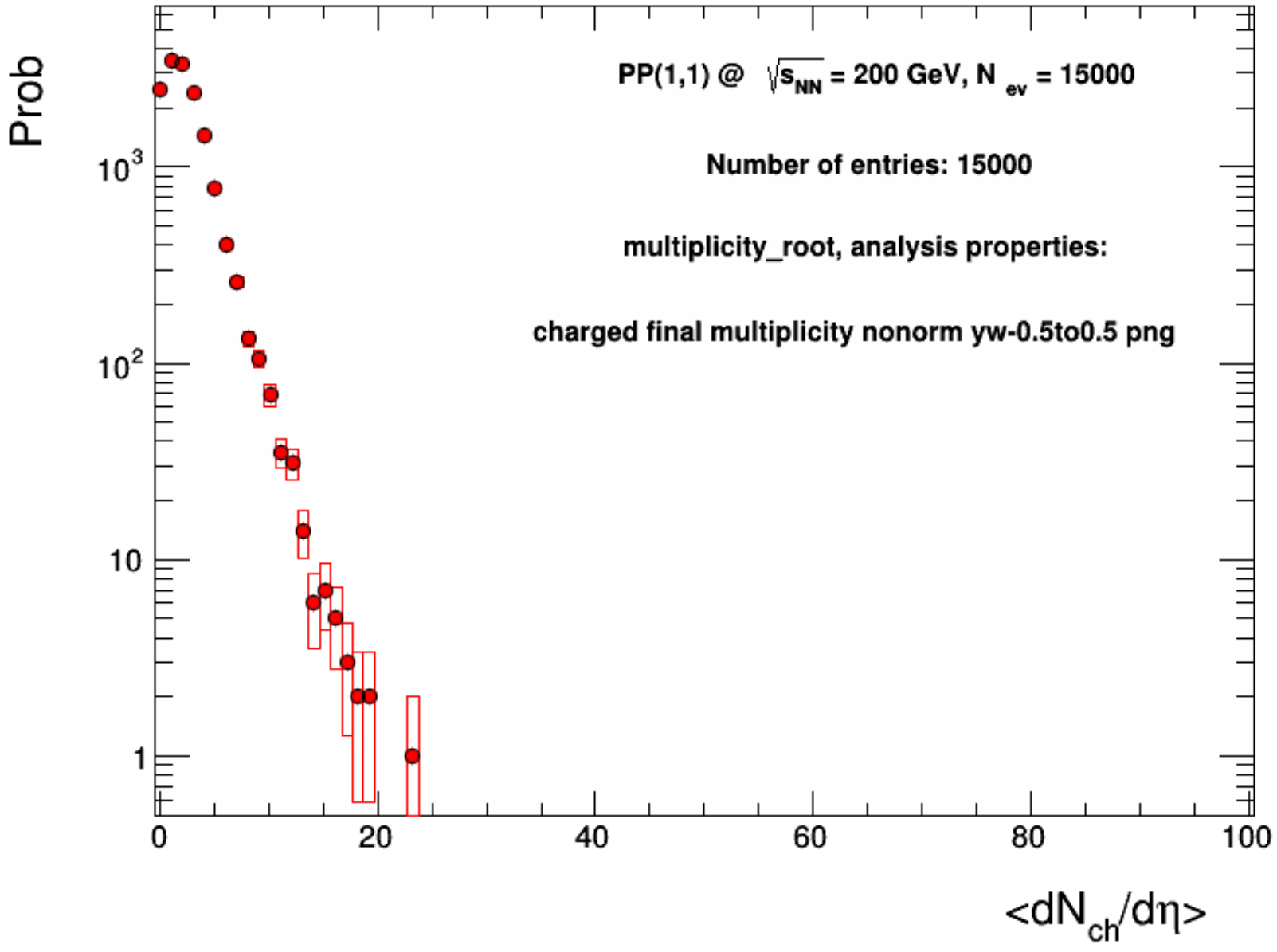
HIJING++ MULTITHREADING



HIJING++ MULTITHREADING



HIJING++ ANALYSIS EXAMPLE OUTPUTS



HIJING++ ANALYSIS EXAMPLE OUTPUTS

```
# Name: eta_charged_ascii
# System: PP(1,1) @ #sqrt{s_{NN}} = 200 GeV
# Event number: 15000
# Entries: 251506
# Analysis properties: final eta charged
# bincenter  binwidth  value stat.error
-4.9   0.1   0.20273   0.0036764
-4.7   0.1   0.23273   0.003939
-4.5   0.1   0.25573   0.004129
-4.3   0.1   0.26953   0.004239
-4.1   0.1   0.28187   0.0043349
-3.9   0.1   0.29753   0.0044537
-3.7   0.1   0.3106    0.0045505
-3.5   0.1   0.30907   0.0045392
-3.3   0.1   0.32467   0.0046524
-3.1   0.1   0.328   0.0046762
-2.9   0.1   0.3472    0.0048111
-2.7   0.1   0.35693   0.0048781
-2.5   0.1   0.36413   0.004927
-2.3   0.1   0.37133   0.0049755
-2.1   0.1   0.3744    0.004996
-1.9   0.1   0.3822    0.0050478
-1.7   0.1   0.3864    0.0050754
-1.5   0.1   0.38933   0.0050947
-1.3   0.1   0.3928    0.0051173
-1.1   0.1   0.39893   0.0051571
-0.9   0.1   0.38507   0.0050667
```

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