DESY 21-XXX
23 Aug 2021

Rivet, RivetHZTool and HERA

A validation effort for coding HERAmeasurements for Rivet

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Abstract

During the DESY summer student program 2021, young scientists from more than 13 different countries worked together, connecting from remote, to provide computer codes within the Rivet frame for HERA measurements. These measurements were originally available within the HZTool package, but no longer accessible for modern analysis packages as Rivet. The temporary RivetHZTool interface was used to validate the new Rivet plugins.

1 Introduction

Since HERA times, a dedicated effort was to code published measurements into computer codes which can be used for comparison with predictions from event generators. One of the first general package was HZTool [1,2], started in 1990, written in Fortran. With the preparation for LHC, new developments started to apply modern C++ and python techniques, and the Rivet [3] package is now a standard for comparison of experimental measurements with theoretical calculations, in form of Monte Carlo event generators, but also for fixed next-to-leading order (NLO) calculations.

Since Rivet was developed after many of the HERA measurements were completed, a dedicated effort was needed to make HERA measurements available and accessible in Rivet. One of the compilation was, that the original HERA publications contain comparison with measurements from predictions, which are no longer accessible, thus making the validation of the new codes difficult. A few years ago, an interface between HZTool and Rivet was developed, RivetHZTool, which allowed to make use of the Fortran code of HZTool to be called inside Rivet. While in principle RivetHZTool was functional, it had severe limitations, since all the histogramming was based on CERN HBOOK, and new developments were needed to port RivetHZTool, developed for Rivet 2.7.X to the newer versions Rivet 3.X. Instead of transporting RivetHZTool to newer Rivet, a dedicated effort was started to code HERA analysis directly in Rivet and to used RivetHZTool as a validation tool only.

During the DESY summer student program 2021, young scientists from more than 13 different countries joined together, connecting from remote, working in virtual meetings 2 times a day together, to provide the tools for future comparison of HERA measurements with moderns computer predictions.

2 Rivet and HZTool

The RivetHZTool [4,5] project was initiated several years ago, also as part of the DESY summer student program. The idea was to use as much as possible the FORTRAN code of HZTool and build an interface to RivetẆhile HZTool was build upon the CERN HBOOK histogramming package, in RivetHZTool the Rivet histogramming package was used, and all calls to HBOOK needed to be replaced or wrapped. This attempt was successful, only some of the features of HBOOK were difficult to port into the Rivet histogramming package, and also several features of Rivet could not be easily ported back to HZTool, an example is the usage of multiweights in Rivet3.

With the further development of Rivet, it was decided to concentrate the effort in coding HERA results entirely in Rivet. However, coding older analyses faces challenges: in most of the publications old and no longer existing Monte Carlo event generators were uses, and sometimes the detailed parameter settings for the theoretical calculations were not quoted. In other cases it turned out that the data points stored on HepData where either incomplete or sometimes missing, while they were available inside the HZTool codes. In a common effort, between the summer-student code developers and the representatives from the H1

and ZEUS collaborations and HepData missing information was provided, approved and uploaded to HepData to make it available for future analyses as well as also inside Rivet.

The working environment of RivetHZTool, although only in Rivet 2.7.X could be used to validate newly coded Rivet plugins, applying exactly the same Monte Carlo event generator predictions.

3 Rivet for HERA

In this section a brief description of the H1 and ZEUS HERA analyses now available in Rivet is given, together with validation figures obtained from the corresponding RivetHZTool code, where available. In all cases the RAPGAP [6,7] MC event generator was used.

3.1 H1_1995_I392386 (HZ95007): Measurement of multiplicity and momentum spectra in the current fragmentation region of the Breit frame at HERA (ZEUS)

Description: [8]

3.2 H1_1995_I394793 (HZ95072): A Study of the fragmentation of quarks in e-p collisions at HERA (H1)

3.3 ZEUS_1995_I395196 (HZ95084): Neutral strange particle production in deep inelastic scattering at HERA (ZEUS)

Description: [10]

3.4 H1_1996_I421105 (HZ96138): Inclusive D^0 and $D^{*\pm}$ production in neutral current deep inelastic ep scattering at HERA (H1)

Description: [11]

3.5 H1_1996_I422230 (HZ96160): Charged particle multiplicities in deep inelastic scattering at HERA (H1)

Description: [12]

3.6 H1_1996_I424463 (HZ96215): Measurement of charged particle transverse momentum spectra in deep inelastic scattering (H1)

Description: [13]

3.7 H1_1997_I445116 (HZ97108): Evolution of e p fragmentation and multiplicity distributions in the Breit frame (H1)

Description: [14]

3.8 ZEUS_1997_I449531 (HZ97183): Observation of scaling violations in scaled momentum distributions at HERA (ZEUS)

Description: [16]

3.9 ZEUS_1999_I470499, ZEUS_1999_I508906 (HZ98050): Forward jet production in deep inelastic scattering at HERA (ZEUS)

Description: [17,18]

3.10 H1_1999_I504022 (HZ99094): Forward π^0-Meson Production at HERA (H1)

Description: [20]

3.11 ZEUS_2000_I524911 (HZ00040): Measurement of azimuthal asymmetries in deep inelastic scattering (ZEUS)

Description: [21]

3.12 H1_2002_I561885 (HZ01100): Measurement of D^{*+-} Meson Production and F_2^c in deep inelastic scattering at HERA (H1)

Description: The inclusive production of $D^*\pm(2010)$ mesons in deep-inelastic scattering is studied with the H1 detector at HERA [22]

3.13 H1_2005_I676166 (HZH0502010): Measurement of beauty production at HERA using events with muons and jets (H1)

Description: [23]

3.14 H1_2006_I690939 (HZH0508055): Forward Jet Production in Deep Inelastic Scattering at HERA

Description: [24]
The production of forward jets has been measured in deep inelastic ep collisions at HERA, where the jets are defined using the kt-jet algorithm in the Breit frame. The results are presented in terms of single differential cross sections as a function of the Bjorken scaling variable x_{bj}, with the additional requirement $0.5 < p^2_{t,jet}/Q^2 < 5$, and as a triple differential cross sections as a function of x_{bj}, for three different regions of Q^2, which is the four momentum transfer squared, and of $p^2_{t,jet}$, the squared transverse momentum of the forward jet.
Event selection:
$0.1 < y < 0.7$, $5 < Q^2 < 85$ GeV^2, $0.0001 < x < 0.004$, $E_e > 10$ GeV, $156 < \theta_e < 175^o$
Forward Jet selection: (KTCLUS): $E_{jet} > 28.7$ GeV, $P_{T,jet} > 3.5$ GeV, $7 < \theta_{jet} < 20^o$, $0.5 < P^2_{T,jet}/Q^2 < 5$
Validation plots for the single differential cross section are shown in Fig. 1 and for the triple differential cross section in Fig. 2.
The other plots in terms of the triple differential cross section are reported below in Fig. 3. different kinematic regions, selected through some cut offs in the analysis code.

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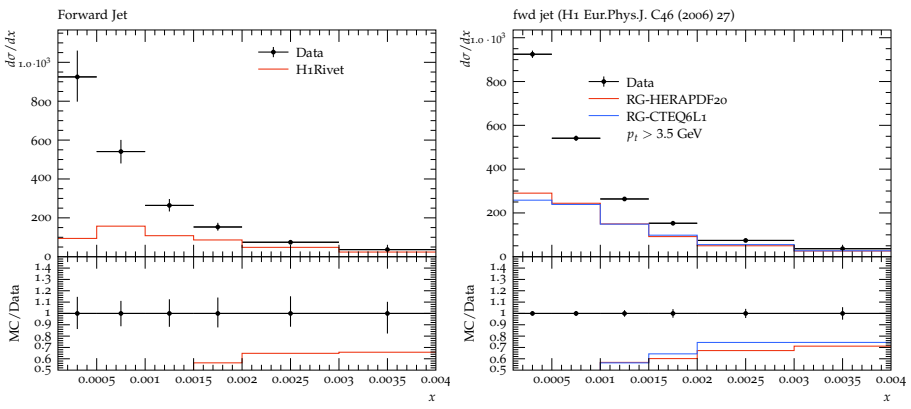

Figure 1: Comparison of results obtained from Rivet and the corresponding one from RivetHZTool.

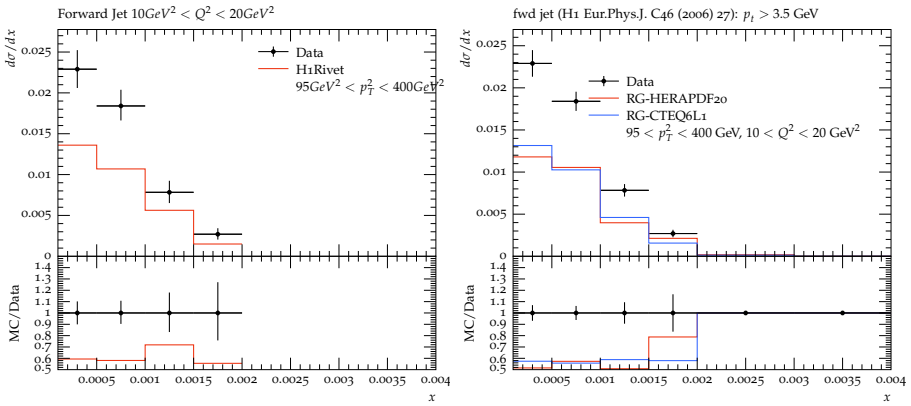

Figure 2: Comparison of results obtained from Rivet and the corresponding one from RivetHZTool.

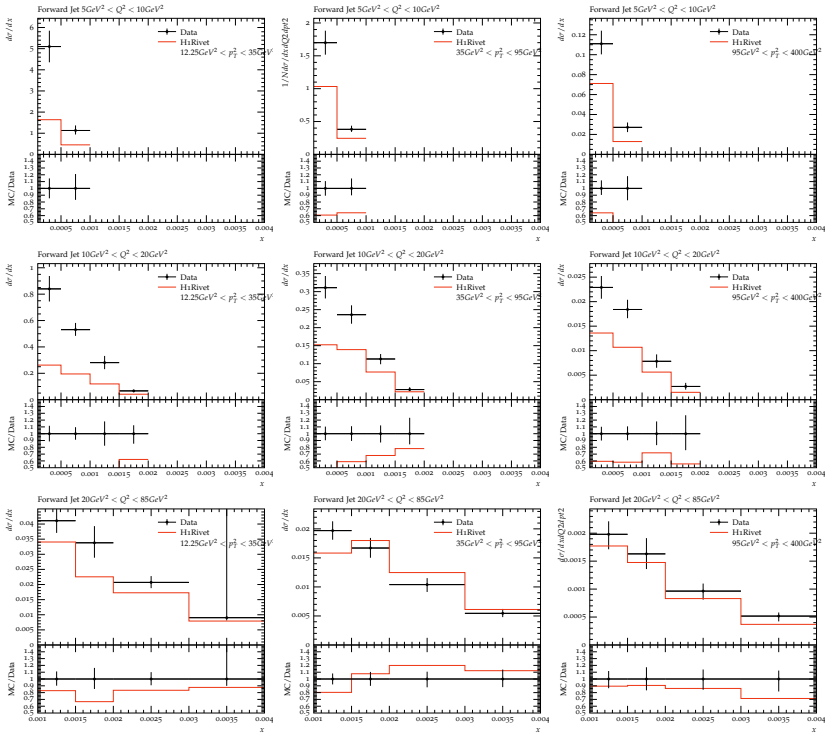

Figure 3: Triple differential cross sections obtained from Rivet in three different kinematic regions.

3.15 H1_2006_I699835 (HZH0512014): Measurement of Event Shape Variables in Deep-Inelastic Scattering at HERA (H1)

Description: [25]

3.16 H1_2007_I736052 (HZH0701023): Measurement of inclusive production of D^{*+-} mesons both with and without dijet production in DIS collisions at HERA (H1)

Description: [26]

3.17 ZEUS_2010_I875006: Inclusive dijet cross sections in neutral current deep inelastic scattering at HERA (ZEUS)

Description: [27]

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