Towards Validating LHC Era Monte Carlos with HERA Data

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Contents

1 Abstract

The motivation of my work at DESY was to test the Monte Carlos used at the LHC. For doing so we investigated the DIS process and compared it to the actual data from the "HERA" runs.

For generating the events we used the "Herwig++" generator and "Rivet" for the analyses.

The project was divided into two parts.

On the one side I wrote a small program which should be helpful identifying the initial lepton after the scattering since such a function is not yet directly implemented in Rivet. Therefore it was necessary to find a good criterion which separates this particle from the other ones occurring during the event.

On the other side we tried to adopt some analysis from "HZTool" the predecessor of "Rivet" and make them usable in "Rivet". For this task it was needed to create an interface which translates the Fortran based code from "HZTool" to the code of "Rivet" which is based on C++. This was done by my supervisors Simon Plaetzer and Hannes Jung.

Before I get into more detail about my project I want to shortly wrap up the basics of "Deep Inelastic Scattering".

2 Deep Inelastic Scattering

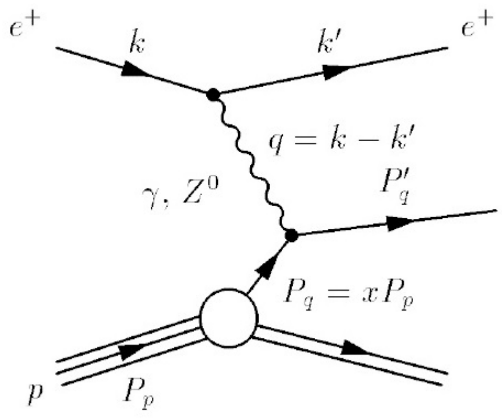


Figure 1: DIS Kinematics

In this process a boson radiated from the $e+/e-$ and scatters with a parton from the proton. This boson is most of the times a photon but a Z^0 or W^+/W^- radiation is also possible for high Q^2. To further investigate this process it seems useful to introduce the following variables [1]:

- Four momentum transfer: $Q^2 = -q^2 = -(k - k')^2$
- parton momentum fraction: $x = \frac{Q^2}{2p \cdot q}$
- fractional energy transfer: $y = \frac{p \cdot q}{p \cdot k}$
- mass square of hadronic system: $W^2 = (p + q)^2 \approx \frac{Q^2}{x}$

Furthermore we can a derive a so called structure constant F_2 for the proton [1]:

$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left[1 + (1 - y)^2\right]F_2(x, Q^2) \tag{1}$$

This structure constants was an early approximate description of the inner charge distribution of the proton and is used for inelastic scattering processes. Whereas the upper equation is just valid in the low Q^2 regime. For higher energies there need to be further terms taken into account due to possible gluon radiation. From analysing the structure constants for different energies, it was possible to proof the existence of quarks.

3 The HERA collider and the H1 detector

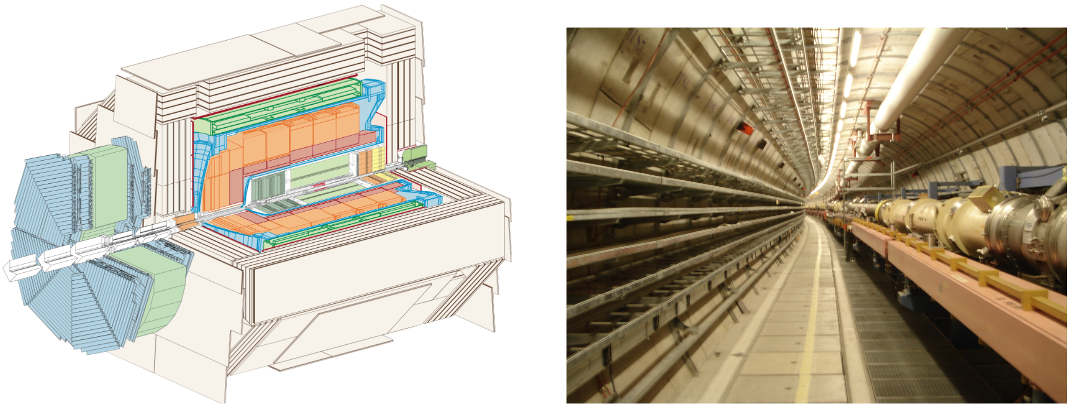


Figure 2: H1 Detector (left) and HERA collider (right) [pictures taken from www.desy.de]

Running during 1992 and 2007, the HERA collider was designed to collide protons and electrons (positrons) at nominal energies of 820 GeV and 17.5 GeV.

Such an asymmetry between the energies of both beams is rather unusual, and was achieved by accelerating them in separated storage rings. After transferring them to the main HERA tunnel, their interactions were measured at four interaction points, by the detectors ZEUS, H1, HERMES and HERA-B.

The H1 detector was designed for different purposes, e.g. search for physics beyond the standard model and studies of the proton structure. It is build in an asymmetric way to adapt to the different beam energies.

4 Highest pT as criterion for finding the initial electron

In this part the idea was to create a program which identifies the initial e^- or e^+ among all outgoing particles after the collision. As a good criterion it seems reasonable to order the particles by their transfers momentum, since it is most likely that the initial lepton is the one with maximum pT.

Like I already said, there is no implemented function in "Rivet" which is capable of directly identifying this particle, therefore it would be extremely useful if this criterion fits well for getting this information. For testing how efficient this method is, I needed to somehow trace back which of the outgoing particles is really the initial e^-/e^+.

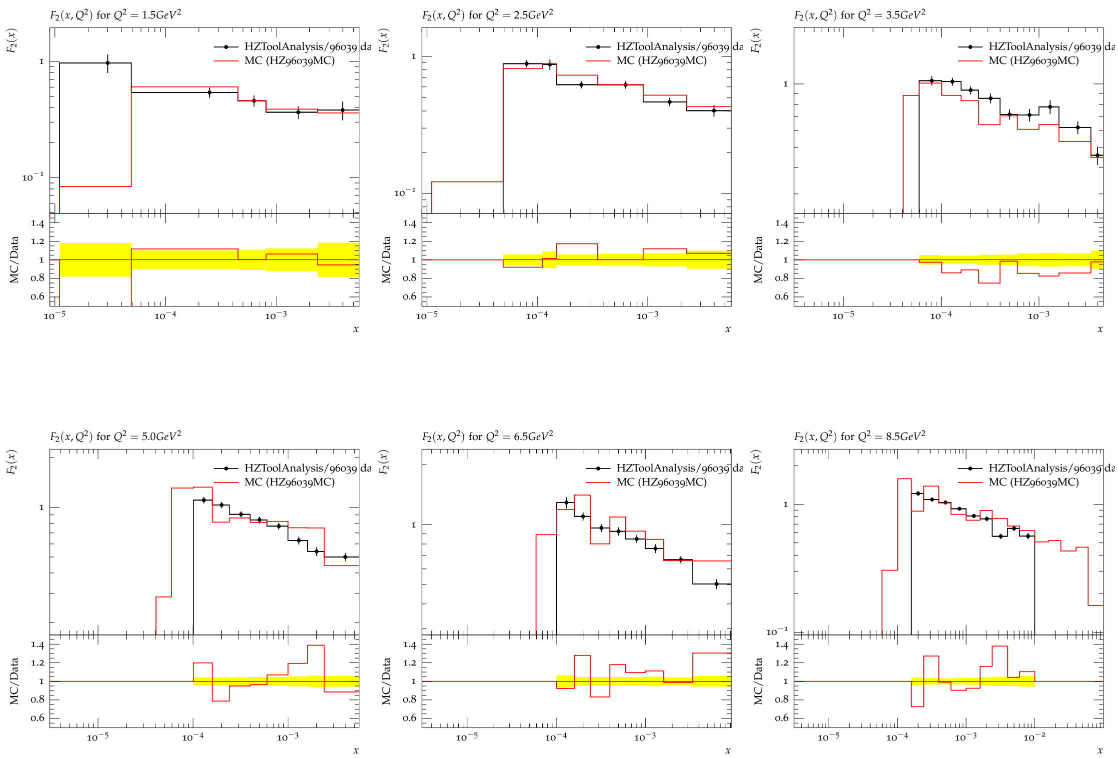
I used the functions "$production\_vertex()$" and "$particles\_in\_const\_end()$" for doing so.
That way it is possible to go from the outgoing particle back to the vertex it comes from and then to the particle that went into this vertex. By repeating this we can go back until we reach the initial particle.
By checking its physicality and if it is a e^-/e^+, we can validate if we found the incoming lepton of the DIS process.

Sadly the generated events from our DIS input file were not eligible for testing the program since the created plots showed that the simulated DIS processes contain just one electron. So in this case of course the found particles using the highest pT criterion and the trace back method were always the same.

For getting a confirmation of the functionality of the program it will be necessary to test it on events which contain more than just one e^-/e^+, what I sadly couldn't manage to do any more during my stay.

5 Adapting the analyses

Since most modern colliders like the LHC use the C++ based program "Rivet" for Monte Carlo analyses it is important to import useful analyses from HZTool, which is based on Fortran, to be able to still use them. My project was to do this for some selected analyses which are especially useful for "Deep Inelastic Scattering" processes. I based my work on an interface which was written by my supervisors Simon Plaetzer and Hannes Jung. For the HZ96039 analysis from "HZTool" this works quite fine. After implementing the analysis in Rivet I tested on some simulated DIS Monte Carlo data. Comparing the results with the actual data from the HERA runs, the Monte Carlo fits very good in most cases. Just for small x we get some differences. This is due to the fact that this region is lacking in statistics for our rather small number of events and the applied energy cuts.



For many of the other HZ analyses I tried, there occurred errors of different kind and there needs to be further work done on the interface to eliminate them. But as we saw for the HZ96039 analysis the interface is working in general.

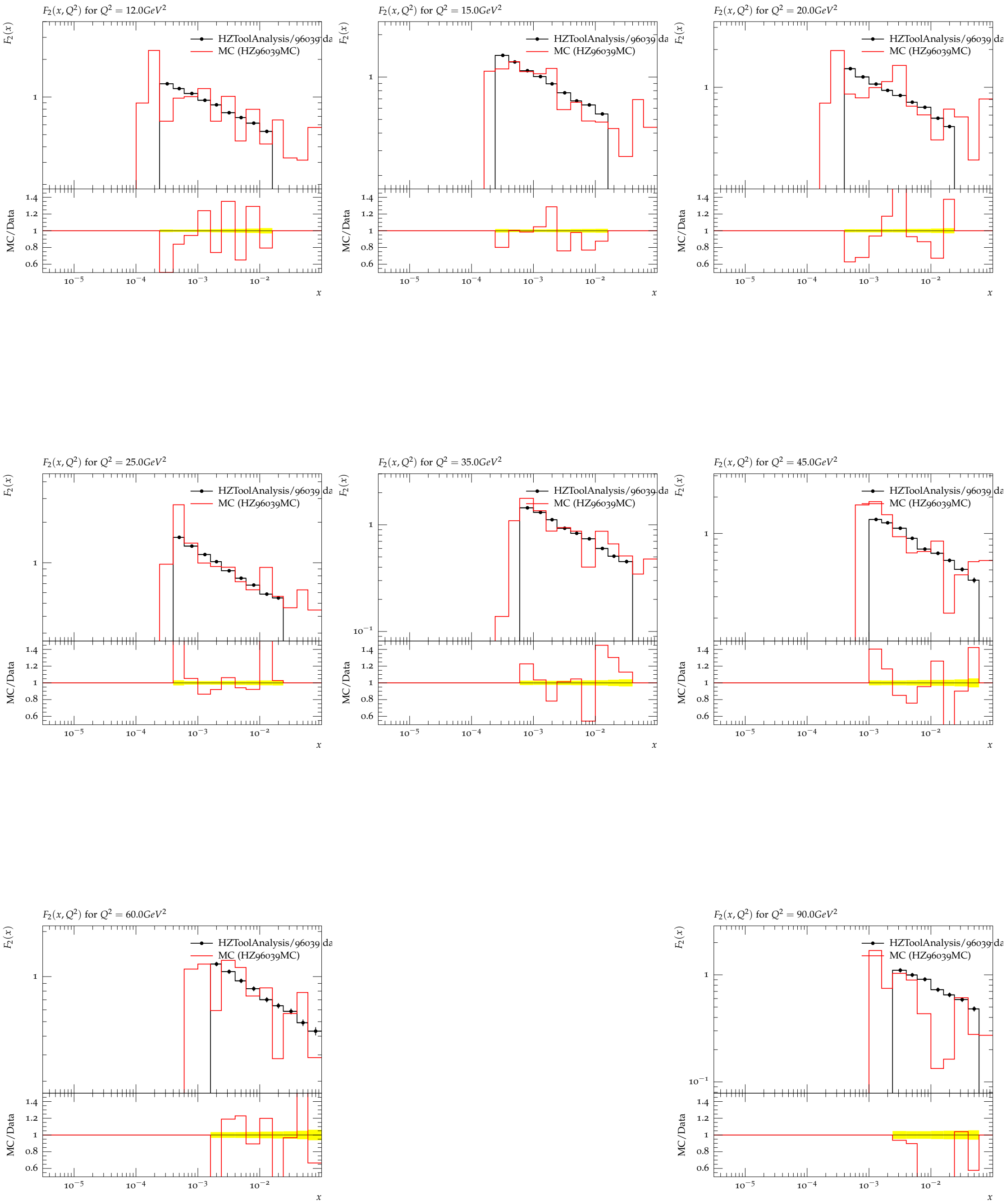


Figure 3: MC data analysed with HZ96039 compared with the real data from the HERA runs

6 Conclusion

I developed great joy in working with the DESY Theory group. The assigned project was especially appealing, since it was a conjunction of both, the experimental and the theoretical CMS group. It was interesting to see how tightly both of these groups are working together.

I am especially grateful for the help of my supervisors Simon Plaetzer and Hannes Jung, who provided valuable assistance during the whole project.

7 References

[1] DEEP INELASTIC SCATTERING AT HERA,Gregorio Bernardi,Paris,**2**