The H1 First Level Fast Track Trigger

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0.1 Abstract

In September 2000, the $e{-}p$ collider HERA and the H1 detector shut down for approximately a year to upgrade the luminosity by a factor of five. Currently, different detector parts are being upgraded or partially replaced in order to cope with the higher luminosity and the increased background rates which are associated with it. In order to exploit the full physics potential after the upgrade, it was decided to replace the old track trigger by a more efficient Fast Track Trigger (FTT). The latter should be used to trigger on exclusive states like the $D^{\star} \to \kappa\pi\pi$ channel. This will improve our understanding of QCD in the low x region of proton structure. Furthermore it will allow us to investigate the proton's gluon structure in detail. This report explains the L1-algorithm of the FTT as currently evolved, the implementation of the latter using ALTERA FPGA technology and tries to explain the general use of the FTT for triggering on physics events.

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Chapter 1

Introduction

1.1 The HERA Accelerator

The Hadron Electron Ring Accelerator (HERA)(see figure 1.1), based at DESY, was completed in 1992 in order to study deep inelastic lepton scattering. HERA is the first colliding beam DIS [1] experiment. Like previous fixed target experiments, HERA tries to provide a deeper understanding of the fundamental forces of nature, in particular the electro-magnetic interaction between quarks and leptons and the strong interaction between the quarks. With a centre of mass energy of 300 GeV, a new kinematic region became accessible. The unique kinematics at HERA makes it possible to study weak neutral and charged currents at high momentum transfer and to observe the hadronic recoil. Proton and lepton beams are accelerated and stored in separate beam pipes of circumference 6336 metres. Currently, positrons are accelerated to 27.5 GeV using conventional magnets. Protons, however, require super-conducting magnets in order to reach 920 GeV. As the cross section for $e-p$ interactions is small, very high fluxes are required. These are stored in electron and proton bunches with a typical current of 30 mA and 80 mA respectively. The time period between each bunch crossing is 96 ns.

Four experiments are located on the HERA ring. Two multipurpose detectors, H1 and ZEUS, are situated at the North and South interaction points respectively. A further two fixed target experiments called HERMES and HERA-B are located at the East and West interaction points respectively. However, the beams are only colliding at the North and South interaction points.

HERMES utilises the longitudinally polarised electron beam together with polarised targets in order to investigate the proton and neutron spin

[1] DIS stands for **d**eep **i**nelastic **s**cattering.

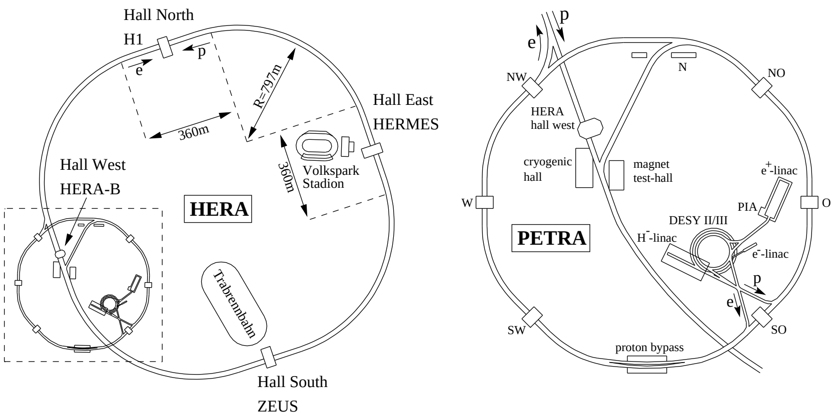

Figure 1.1: HERA and PETRA (pre-accelerator)

structure functions whereas the aim of HERA-B is to study CP violation. In order to do this, the latter produce b-quarks by inserting tungsten wires into the proton beam halo.

In this report the aim is to shortly review the operation of H1 so far, to motivate the HERA and H1 upgrades currently taking place and to give an overview of the trigger upgrade projects. The main part of this report will then be devoted to the Fast Track Trigger, which should eventually replace the current DC$r-\phi$ track trigger. The UK is mainly involved with the Level 1 design of the FTT.

1.2 The H1 Detector

The H1 detector was designed to look at all aspects of $e-p$ scattering. As all previous collider experiments collided either two identical particles or particle anti-particle pairs of equal energy, their detectors were symmetric about the interaction point. HERA, however, collides different particles of different energies. This constraint led to an asymmetric detector design. In order to look at all aspects of $e-p$ scattering, certain requirements have to be fulfilled:

- The detector should have a high resolution in energy and polar coordinates. This requires the calorimeters to have high granularity and to be calibrated as well as possible.
- The drift chambers should be able to reconstruct tracks accurately in order to identify all sorts of events.

- Often the kinematic variables x, y, Q^2 are reconstructed from the scattered electron, it is therefore very important to have a high efficiency and very good resolution in electron detection.

The detector layout and the coordinate system used at H1 are shown in figure 1.2. The beam pipe $\boxed{1}$ runs along the centre of the detector. The end where the electron (proton) enters the detector is referred to as the forward (backward) region. The tracking detectors are centred around the nominal interaction point. The silicon micro-vertex detectors in the central and backward regions give the best vertex constraints and are also used for reconstructing secondary vertices. More outward lie the central and forward tracking devices (CTD $\boxed{2}$ and FTD $\boxed{3}$ resectively). The Liquid Argon Calorimeter, which is divided into a electromagnetic $\boxed{4}$ and hadronic $\boxed{5}$ section, is used to reconstruct most of the hadrons and electrons at very high momentum transfer [1]. The trackers together with the Liquid Argon Calorimeter are surrounded by the solenoidal magnet $\boxed{6}$ that bends the tracks of charged particles. The SPACAL [2] $\boxed{12}$ and the PLUG Calorimeters $\boxed{13}$ are located in the backward and forward regions of the detector. Both are situated close to the beam pipe. The SPAghetti CALorimeter's main task is to efficienty identify electrons and measure energy accurately. One can also get hadronic energy in the backward region which is also measured by the SPACAL [3]. The PLUG Calorimeter minimises missing transverse momentum of hadrons by closing the gap in between the beam pipe ($\theta = 0.75°$ [3]) and the LAr calorimeter($\theta = 3.4°$) [4]. The Muon detection system consists of the instrumented iron return yoke $\boxed{10}$ $\boxed{9}$ of the solenoidal magnet in the central region. In the forward region it is complemented by the Forward Muon Detector (FMD) $\boxed{11}$. The instrumented iron yoke is also used to measure the hadronic energy leaked from the LAr calorimeter and SPACAL. Another detector is the proton remnant tagger(PRT). It is utilised in diffractive studies. It is located at 24 m in the $+z$ direction along the beam pipe. The Forward Proton Spectrometer (FPS) is constituted of Roman Pots positioned at certain intervals along the beam pipe. When being brought close to the proton beam, the pots are used to detect intact final state protons in DIS and photoproduction [5]. Situated at 107 m in the forward direction, the Forward Neutron Calorimeter (FNC) is used to detect high energy leading neutrons [6]. The H1 Luminosity system is constituted by three electron taggers (ET) and a photon detector (PD) [7]. This System

[2] The Backward electromagnetic calorimeter (BEMC) was replaced by the SPACAL in 1995. For a description of the BEMC see [2]

[3] The H1 coordinate system defines the $+z$ axis as the outgoing proton direction. The polar angle θ is measured with respect to this axis.