1 Introduction

The H1 detector described in this paper is one of the two detectors built around the interaction regions of the first ever constructed electron-proton storage ring – HERA at the DESY laboratory in Hamburg, Germany. In this accelerator 27.5 GeV electrons collide with 820 GeV protons at a centre of mass energy of 300 GeV. At HERA a new kinematic region becomes accessible for deep inelastic lepton scattering. Such experiments have played a crucial role in understanding the fundamental forces of nature and in providing first evidence for the pointlike constituents of the nucleons [1]. Compared to previous fixed target conditions, [2], experiments at HERA provide an increase by one order of magnitude in resolving power, with values of the momentum transfer squared Q^2 reaching 4×10^4 GeV^2, an increase of at least two orders of magnitude. In contrast to previous experiments the unique kinematics at HERA makes it possible to observe the hadronic recoil and to study the weak neutral and charged currents at high momentum transfer.

The extensive discussions of all aspects of HERA physics at the three workshops held before the experimental program started [3, 4, 5] led to a detector designed for good identification of leptons (especially electrons), high granularity and resolution for jets and good hermiticity to recognize missing transverse energy. These requirements follow from the fact that the final states will contain several leptons accompanied by quark and gluon jets. The inclusive measurements of neutral and charged current interactions also demand the best possible hadron calorimeter. In addition electron identification and charged particle reconstruction within jets require a high-resolution, large solid angle tracking system. The efficient use of all these tools must rely on a sophisticated trigger system to overcome the adverse background conditions met at an electron-proton machine.

The differential cross-section measurement at a collider such as HERA requires the reconstruction of kinematic variables as close as possible to the parton level. The most relevant kinematic quantities in the deep inelastic electron scattering process are Q^2, the fraction x (Bjorken scaling variable) of the proton momentum carried by the struck quark and the fractional energy loss y of the electron. These are given in terms of the energies of the incoming electron E_e, the scattered electron E'_e, the incoming proton E_p, the hadronic recoil jet E_h and the corresponding polar angles θ_e and θ_h (both measured relative to the proton direction $\theta = 0$, positive $z-$direction) as:

$$Q^2 = 4E_eE'_e\cos^2\frac{\theta_e}{2}\ ;\quad x = \frac{Q^2}{4E_eE_py} = \frac{E_eE'_e(1+\cos\theta_e)}{E_p(2E_e - E'_e(1-\cos\theta_e))}\ ;\quad y \equiv y_e = 1 - \frac{E'_e}{E_e}\sin^2\frac{\theta_e}{2}$$

$$Q^2 = \frac{E_h^2\sin^2\theta_h}{1-y_h} = \frac{(\sum_{h,i}\vec{p}_{th,i})^2}{1-y_h}\ ;\quad y \equiv y_h = \sum_{h,i}\frac{E_{h,i}-p_{zh,i}}{2E_e}$$

Q^2 and x can be reconstructed from measured electron or hadronic quantities or a combination of both. Figure 1 shows contour plots of fixed θ_e and E'_e in the x, Q^2 plane for $E_e = 30$ GeV and $E_p = 820$ GeV and illustrates the influence of finite angle and energy resolution using the actual design values of the H1 detector. The resolution in Q^2 is determined by the electron energy resolution except for large scattering angles, where the angular resolution becomes the dominant term. The latter term only influences the x resolution for large x and small Q^2. At low y the x resolution is quite poor. The areas in the x, Q^2 plane where a reliable structure function measurement is possible are also indicated in Figure 1. Here the effects of migration and the systematic errors are also included. Migration is the process where a fraction of events move from one bin in x, Q^2 into a neighbouring bin as a result of measurement errors. For the control of systematic errors the energy calibration, and its stability are of particular importance. Since event rates at high Q^2 are quite low, long term stability is clearly required.

Systematic shifts of the outgoing electron energy measurement can generate large shifts in the differential cross-section because there is an amplification factor roughly proportional to y^{-1}, e.g. for $y \approx 0.1, x < 0.5$ an energy shift of 1 % results in 10 % cross-section change. Since angles are measured both by the calorimeter and the tracker, alignment errors influencing angle measurements are less important.

On the hadron side the above formulae implicitly make use of the Jacquet–Blondel method [6]. It is possible to measure x and Q^2 by using only the outgoing hadrons, without using jet identification or assumptions concerning the proton structure. Furthermore, for HERA kinematics y and Q^2 are more suitably expressed in terms of laboratory variables using the energy-momentum balance between the leptonic and the hadronic system (as done above) and then deducing x. Because hadrons emitted in the forward direction contribute little to y_h or Q^2, the unavoidable dead areas along the beam pipe have only a minor impact. Reconstruction errors depend on the size of the beam hole, the uncertainties on the angles and the energies of the outgoing hadrons. Use of the hadron information alone or in combination with the electron information, e.g. by using θ_e and θ_h without direct energy information as in the so-called double angle method [7], extends the measurable regions to considerably lower values of y as shown in Figure 1.

The largest contribution to the event rates at HERA stems from low Q^2 photoproduction. For example the high cross-section for producing charmed quark-antiquark pairs makes HERA a prolific source of $D-$mesons with cleaner background conditions than obtained with hadron beams. This makes the study of rare and forbidden decays feasible. The momentum of a tagged $D^{*\pm}$ is correlated with that of the charmed quark produced in γ gluon fusion [7, 8] so that the gluon momentum can be reconstructed knowing y_h. Thus the gluon density within the proton may be measured. If forbidden decays such as $D^0 \rightarrow \mu^+\mu^-$ or e^+e^- are to be studied it is important to have good muon identification, and good electron identification at momenta near 1 GeV/c, because the D meson spectrum peaks at rather low energies in particular in the central rapidity region, where these low multiplicity events can be reconstructed.