Eur Phys J A (2005) **24,** s2, 159–160
DOI: 10.1140/epjad/s2005-04-040-0

EPJ A direct
electronic only

The Qweak tracking system

Measurement of the average Q^2 and the dilution by background events

Klaus H. Grimm, for the Qweak Collaboration

The College of William & Mary, Department of Physics, Williamsburg, VA 23187-8795, USA

Received: 1 November 2004 / Published Online: 8 February 2005

Abstract. The Q^p_{weak} experiment will measure the parity-violating elastic e-p scattering asymmetry to extract the weak charge of the proton. The experiment employs a toroidal magnet to focus electrons scattered at $8^\circ \pm 2^\circ$, corresponding to $Q^2 \sim 0.03$ (GeV/c)^2, on eight Čerenkov detectors located in the focal plane of the spectrometer. Since the asymmetry is proportional to Q^2, it is crucial to obtain an accurate measure of the acceptance-averaged value of Q^2. A tracking system will be used in a low-rate counting mode, allowing individual events to be observed. This will enable a determination of the average Q^2 by measuring the scattering angle and interaction vertex, for mapping the response across the surface of the Čerenkov detectors, and for the dilution of the Čerenkov detector signal by background.

PACS. 25.30.Bf Elastic electron scattering – 29.40.Gx Tracking and position-sensitive detectors

1 Introduction

In elastic electron-proton scattering the parity-violating asymmetry is proportional to Q^2. In the Q^p_{weak} experiment [1,2] a collimator system, optimized by GEANT simulations, defines the average value of the accepted Q^2 by setting kinematical cuts on the electron scattering angles. For Q^p_{weak} it is critical to determine the acceptance averaged value of Q^2 for the electrons from the e-p elastic scattering events of interest with $\simeq 1\%$ accuracy. This translates into a 0.6 mrad precision in the measure of the scattering angle. Since Q^p_{weak} is an integrating experiment, the Q^2 dependence of the *ep* cross-section will bias the average detected Q^2. This and any position-dependent detector bias must be taken into account since Q^2 may be correlated with position at the focal plane. Although in principle these matters can be simulated, it is essential to check the Monte Carlo using an ancillary calibration measurement: to measure the scattering angle, interaction vertex, shape of the focal plane distributions, and the position-dependent detector bias. This information will be extracted from ancillary measurements at low beam current in which the Čerenkov detectors will be read out in pulse mode and individual particles tracked through the toroidal spectrometer with a tracking system.

2 Tracking system design concept

The tracking system consists of a set of drift chambers at three locations along the track. It will be capable of mapping two opposing octants simultaneously where

[1] The Qweak Collaboration:
D. Armstrong[1], T. Averett[1], J. Birchall[2], T. Botto[3], J.D. Bowman[4], A. Bruell[5], R. Carlini[5], S. Chattopadhyay[5], C. Davis[6], J. Doornbos[6], K. Dow[3], J. Dunne[7], R. Ent[5], J. Erler[8], W. Falk[2], M. Farkhondeh[3], J.M. Finn[1], T. Forest[9], W. Franklin[3], D. Gaskell[5], K. Grimm[1], F.W. Hersman[10], M. Holtrop[10], K. Johnston[9], R. Jones[11], K. Joo[11], S. Kowalski[3], C. Keppel[12], M. Kohl[3], E. Korkmaz[13], L. Lee[6], Y. Liang[14], A. Lung[5], D. Mack[5], S. Majewski[5], J. Mammei[15], D. Meekins[5], G. Mitchell[4], H. Mkrtchyan[16], N. Morgan[15], A. Opper[14], S. Page[2], S. Pentillo[4], M. Pitt[15], M. Poelker[5], T. Porcelli[13], W.D. Ramsay[2], M. Ramsey-Musolf[17], N. Simicevic[9], G.R. Smith[5], T. Smith[18], R. Suleiman[15], S. Taylor[3], E. Tsentalovich[3], W.T.H. vanOers[2], S. Wells[9], W.S. Wilburn[4], S. Wood[5], H. Zhu[10], and C. Zorn[5].
[1]College of William & Mary
[2]University of Manitoba
[3]Massachusetts Institute of Technology
[4]Los Alamos National Laboratory
[5]Thomas Jefferson National Accelerator Facility
[6]TRIUMF
[7]Mississippi State University
[8]Universidad Nacional Autonoma de Mexico
[9]Louisiana Tech University
[10]University of New Hampshire
[11]University of Connecticut
[12]Hampton University
[13]University of Northern British Columbia
[14]Ohio University
[15]Virginia Polytechnic Institute
[16]Yerevan Physics Institute
[17]California Institute of Technology
[18]Dartmouth College

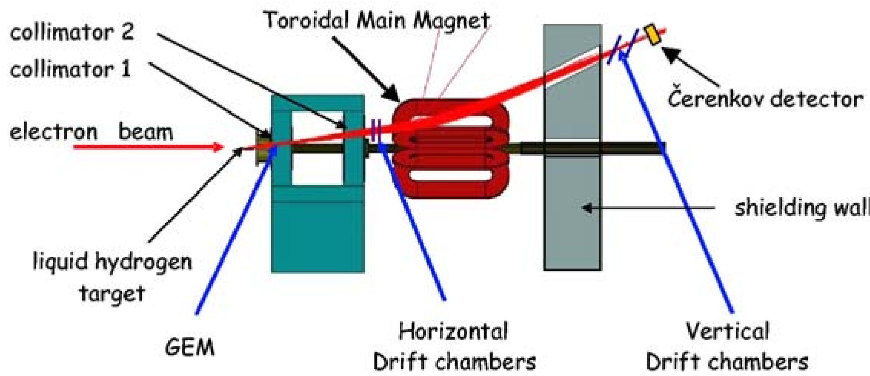

Fig. 1. Conceptual design of the Q^p_{weak} tracking system. The toroidal magnetic field spatially separates inelastic events from elastic events which will be focus on a fused silica (quartz) Čerenkov detector per octant located in the focal plane of the spectrometer. The tracking for single particle will be performed at low beam current using a set of drift chambers at three locations in two opposite octants at a time

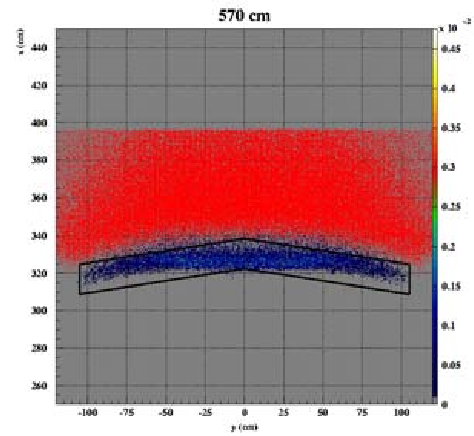

Fig. 2. GEANT simulation of the spatial separation of the elastic and inelastic events in the focal plane. The Λ-shaped Čerenkov detector made from joint quartz bars will cover/detect the elastic events with a $\simeq$0.02% inelastic rate contribution.

the tracking chambers will be mounted on a rotating wheel assembly. The Čerenkov detectors are operated in a low beam current counting mode (I$\sim$10 nA,) equivalent to an e-p elastic rate of $\sim$50 kHz/octant) for background/acceptance studies using the tracking system, and in a classic integrating mode (I$\sim$180 μA, equivalent to an e-p elastic rate of $\sim$800 MHz/octant) during high beam current production running where the tracking system will be retracted.

A Triple GEM (Gas Electron Multiplication) chamber is situated between the primary and secondary collimator. A GEM was chosen because of its high rate capability, fast time response and good position resolution, but it does not provide any track angle information. Each chamber has an active area of 16 cm$\times$16 cm, consists of 3200 channels supporting a rate of 10 MHz and an expected position resolution of $\simeq$200 μm.

A pair of horizontal drift chambers (HDC) separated by 50 cm is situated between the secondary collimator and the main magnet. Each chamber has an active area of 53 cm$\times$49 cm, and consists of 374 signal wires. The expected position resolution will be $\simeq$200 μm. The HDCs in combination with the GEM will measure the scattering angle, interaction vertex, and establish the trajectory upstream of the main magnet. The expected vertex resolution along the target will be $\simeq$1 mm ; the reconstruction of the scattering angle will be archived with an angular resolution of $\simeq$0.6 mrad. The HDCs will see both elastic and inelastic events and are in direct line of sight to the target. A low field toroidal sweeping magnet will be installed between the GEMs and the HDCs to prevent Møller events ($\sim$30-70 MeV, $\sim$10 MHz) from reaching the HDCs. The sweeping magnet will remain on during production run to maintain the same conditions between production running and Q^2 calibration runs.

A pair of vertical drift chambers (VDC) separated by 30 cm will be situated in front of the Čerenkov detectors, after the shielding wall. Each chamber has an active area of 200 cm$\times$ 50 cm, and consists of 800 signal wires. The expected position resolution will be $\sim$100 μm. The VDCs will map out the position-dependent Čerenkov detector response across the surface of each quartz bar. With a known field map of the main and sweep magnets and with the local track information of GEMs, HDCs, and VDCs it is possible to reconstruct the particle momentum. This allows the separation between elastic and inelastic track events needed for the mapping and background measurements. The global tracking in a toroidal magnetic fields is not a trivial issue since with a non-homogeneous field there is no simple analytic expression to describe the track. The Q^p_{weak} main magnet has a moderate focusing for electrons regarding the polar scattering angle but it has a strong defocusing in the azimuthal angle, so each track will have an unique trajectory parametrization. Therefore the final track fitting method will depend upon a iterative simulation and comparison method similar to existing algorithms used by BLAST and CLAS. In addition to the tracking technique for the background determination long calibration time-of-flight spectra out to 500 ns will be taken in order to verify that there are no long-lived backgrounds or delayed lights coming out of the quartz detectors that would require a correction to the central value of the measured asymmetry.

References

1. Qweak Collaboration, R. Carlini et al.: Jefferson Lab Proposal E-02-020, available at: `http://www.jlab.org/qweak/`
2. See G.R. Smith, in these proceedings, *Qweak: A Precision Measurement of the Proton's Weak Charge*