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The HARP TPC laser calibration system

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Abstract

A novel apparatus for the calibration of the HARP Time Projection Chamber has been designed, developed and built. The apparatus consists of a large number of point-like photo-electron sources located at precise positions inside the detector volume. The photo-electron sources are optical quartz fibers on which one end is coated with an aluminum layer of $\sim 80\,\mathring{A}$ thickness and are held in place on the high-voltage membrane. The fibers are used to guide UV laser light pulses that generate photoelectrons on the fiber tips acting as photo-electron emitters. The photo-electrons drift inside the detector and produce the calibration signals. The technique allows to assess $E \times B$ distortions and to measure drift velocity, ion feedback and time stability in real time.

Keywords: TPC calibration; Laser; Optical fibers; Photoelectron emission

1. The HARP time projection chamber (TPC)

The main structure of the HARP TPC is formed by two coaxial cylinders of different radius confining the detector active volume. The smaller cylinder houses the target where the interactions with a beam of protons occur. End-plates at both ends of the volume are supported by the outer cylinder. The upstream end-plate serves as support for the inner cylinder and for the readout electronics. The TPC parallel electric and magnetic fields are oriented parallel to the beam. The electric field is provided by a system of strips attached to the inner surfaces of the cylinders and maintained at degrading potential. The magnetic field is provided by a solenoid surrounding the TPC. The gas mixture used is argon–methane (91%–9%). The upstream end of the TPC is instrumented with a wire chamber parallel to the end-plate formed by a readout pad-plane, a plane of sense wires, a plane of cathode wires and a plane of gate wires. The total width of the wire chamber is only 21 mm and covers 97% of the TPC active volume. The pads of the pad-plane are physically printed on the same Printed Circuit Board (PCB) hosting the analog front-end electronics. Analog signals induced on the pads are digitized by a fast 10 bit Analog to Digital converter (ADC) and recorded by a Data Acquisition System [1].

2. Photo-electron point-like source for calibration purposes

Detector distortions can be evaluated by looking where drifting electrons from a known origin

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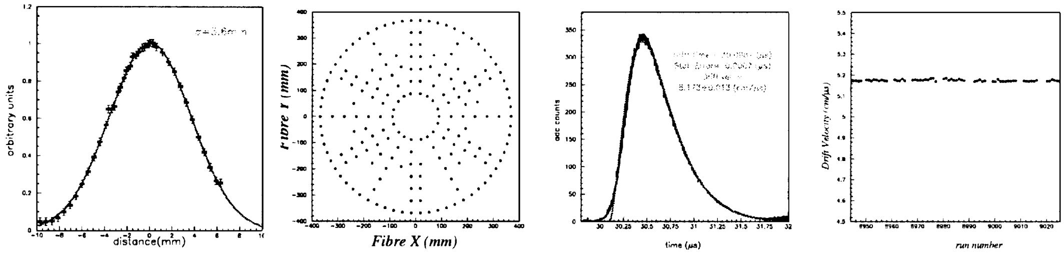

Fig. 1. Left: Pad Response Function as measured in a TPC prototype. The curve corresponds to a Gaussian fit resulting in a $\sigma = 3.6$ mm. Second left: Position of the fibers in the plane perpendicular to the beam. Third left: the photoelectrons signal generated on a single pad as reconstructed with the "phase-lock" technique. Fourth left: Drift velocity for a series of 65 consecutive runs taken in 2001. The drift velocity is determined from the drift time measured with the pads at a certain radius (so their signal can be related to the fibers at a constant radius) and the distance from the fibers that generated them to the anode wires. From Ref. [1].

are reconstructed. Elsewhere [2,3], this has been done using laser beams producing direct gas ionization inside the TPC volume [4]. However, such an optical system is typically delicate, expensive and complicate to build. In HARP, a novel calibration system, based on point-like photo-electron sources located at precise positions inside the detector volume, has been proposed, tested and constructed. The photo-electron sources are optical quartz fibers on which one end is coated with an aluminum layer of ~80 Å thickness and are held in place on the high-voltage membrane. The fibers are used to guide UV laser light pulses that generate photoelectrons on the fiber tips. The photoelectrons drift inside the detector and produce the calibration signals. The technique has been proved to work on a TPC protoype where all parameters relevant to the construction of the system have been measured [5].

3. The laser system

The system consists of 198 quartz fibers (200 μm diameter) held in place-behind the high-voltage membrane. The aluminized ends of the fibers enter a few mm inside the gas volume through 3 mm diameter holes drilled on the HV membrane. The nominal position of the fibers has been chosen in order to assess field distortions in the regions where we expect them to be more severe. These regions are those close to the spokes supporting the wire chamber and to the field cages [6]. The number of fibers has been chosen in order to have maximum redundancy without having superposition of signals onto any pad according to the PRF measured in the prototype. There are a total of 33 fibers per sector, covering essentially the sector boundaries, Fig. 1. The design distance between fibers is 49.5 mm in the radial direction and 29.25 (32.5) mm in the $r\phi$ direction for the innermost (outermost) row. The mounting and aluminization of the fibres is described in Ref. [1]. The real position of the fibers, once mounted, was measured by triangulation techniques (Fig. 1). The photoelectrons generated on the fiber tips drift inside the detector and produce the calibration signals. Since the photo-electrons are all produced at the downstream end of the detector volume, only integrated corrections can be determined. However, this information can be used to qualify distortions generated by the B field dis-homogeneity (cylindrical symmetry) or by the wire chamber structure. The technique allows to measure distortions, drift time, ion feedback and time stability in real time.

4. Results

In HARP, the laser data has been used to monitor the electron drift time, Fig. 1. After signal equalization and the correction of an undesired effect of cross-talk between certain electronic channels [1] it will allow to asses $E \times B$ distortions and to measure ion feedback and time stability.

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