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The HARP resistive plate chambers: Characteristics and physics performance

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Abstract

The HARP Resistive Plate Chamber (RPC) system was designed for time-of-flight measurement in the large-angle acceptance region of the HARP spectrometer. It comprised 46 four-gap glass RPCs covering an area of ~8 m^2. The design of the RPCs, their operation, intrinsic properties, and system performance are described. The intrinsic time resolution of the RPCs is better than 130 ps leading to a system time resolution of ~175 ps.

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Keywords: Resistive plate chamber (RPC); Glass RPCs; HARP; Time of flight; Particle detector

1. Introduction

The HARP experiment carried out a programme of systematic and precise measurements of hadron production by protons and pions with momenta from 1.5 to 15 GeV/c. The experiment was performed at the CERN Proton Synchrotron between May 2001 and October 2002 with a set of targets ranging from hydrogen to lead.

The main objective was to acquire adequate knowledge of pion yields for an optimal design of the proton driver of a neutrino factory, and to improve substantially the calculation of the atmospheric neutrino flux which is needed for a refined study of neutrino oscillations with atmospheric neutrinos. Further objectives were improving the input to Monte Carlo generators of secondary hadrons and better predictions of neutrino beam fluxes.

The HARP detector was designed to measure particle production over the full solid angle. It comprised a large-angle spectrometer and a forward spectrometer; the latter with a dipole magnet and drift chambers for momentum measurement, complemented by a threshold Cherenkov counter, a time-of-flight (TOF) wall, and an electromagnetic calorimeter for particle identification. The large-angle spectrometer consisted of a Time Projection Chamber (TPC) embedded in a 0.7 T solenoidal magnet, and two arrays of Resistive Plate Chambers (RPCs) around and downstream of the TPC. The purpose of the RPCs was to complement particle identification by TOF in particular for momenta for which the dE/dx measurement in the TPC cannot distinguish between electrons and pions (150–250 MeV/c).

The RPCs were designed for an intrinsic time resolution of ~200 ps and intrinsic efficiency close to 100%. Other

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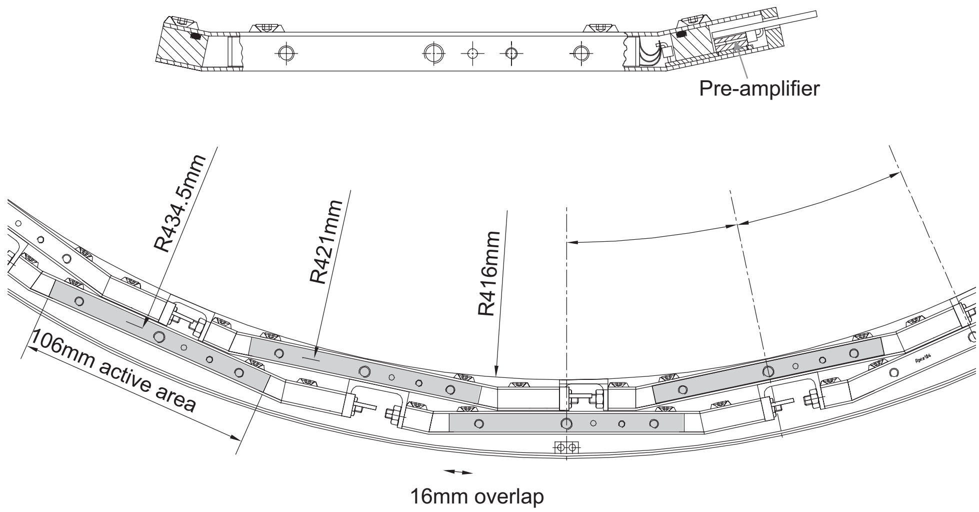

Fig. 1. Layout of a section of the barrel RPCs, looking upstream (bottom), and magnified view of one RPC (top).

constraints were an extremely short time for development and construction,[1] and low cost. The performance requirements were well matched by the multi-gap RPC concept [1,2] which we adapted to our needs.

The HARP RPCs was the first large-scale RPC system employed in an experiment for precision timing. Preliminary reports on its design and performance have been presented at several conferences [3–5].

This paper also sets the record straight with respect to the RPC performance reported in Refs. [6–8]. It justifies and details our criticisms thereof [9,10].

2. RPC layout, design, and readout electronics

The RPC system consisted of 46 identical chambers. Thirty of them, referred to in the following as barrel RPCs, were arranged in two partially overlapping layers around the TPC as shown in Fig. 1. The barrel RPCs provided for full coverage in azimuthal angle. The active volume of one RPC in the inner (outer) layer covered 14.4° (14.0°) in azimuth resulting in a ~16 mm wide overlap of the active volumes of neighbouring RPCs. In the z-coordinate the active volumes of the RPCs extended from -535 mm to $+1385$ mm and covered polar angles from 17° to 142° with respect to the beam axis, seen from the target whose centre was located at $z = 0$.

The other 16 RPCs extended the polar angle coverage in the forward direction from 16° to 6°. They were installed ~2.1 m downstream of the target centre, perpendicular to the beam and arranged in four groups of four RPCs each as shown in Fig. 2.

The active element of the RPC is shown in Fig. 3. It is a glass stack with four 0.3 mm wide gas gaps consisting of two sets of three glass plates each, placed symmetrically on both sides of the central readout electrode. The glass plates

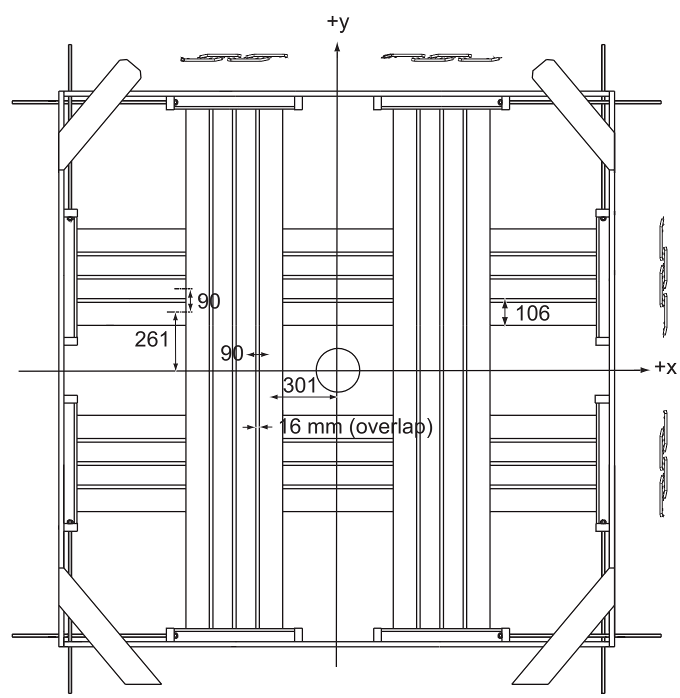

Fig. 2. Layout of the forward RPCs, looking upstream; the side and top views of the RPCs are also shown. Dimensions are in millimetres.

are 0.7 mm thick standard float glass[2] with a bulk resistivity of ~10^{13} Ω cm. No special precautions for rounding off the edges were necessary. The glass stack is 106 mm wide, 1930 mm long, and 7.8 mm thick. The narrow gaps are maintained by four 0.3 mm thick commercial fishing lines per gap, stretched longitudinally, assuring a mechanical precision of the gap width of better than 10 μm. The six glass plates and the fishing lines are kept in position by two machined Noryl end pieces, shown in Fig. 4.

[1]The complete system was developed, constructed, and installed in nine months.

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