Status of the HARP Experiment at CERN

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Abstract

Data collection at the CERN Hadroproduction experiment HARP is now complete. We present details of the experiment, the data collected and the status of the analysis. The data covers 3-15 GeV/c projectile momenta, the full range where resonance production is dominant, and both solid and cryogenic liquid targets.

1. Introduction

For the past decade or more it has been clear that the accuracy of atmospheric neutrino flux calculations (see for example [1,2,3,4]) are limited by knowledge of the primary cosmic-ray flux incident on the Earth's atmosphere and modelling of hadron-production. The hadron-production models are in turn limited by the availability of data in the relevant kinematic region. The HARP experiment is designed to provide sufficiently accurate data to improve models of the hadronic interactions relevant to modelling particle cascades in the atmosphere that produce neutrinos.

2. The HARP Experiment

The HARP experiment [5] was located in the East Hall at CERN, Geneva, and used a secondary beam generated by the CERN PS. This beam provided a flux of mainly pions and protons in a momentum range from 3 to 15 GeV/c. The flux of the beam could be tuned to the requirements of the experiment and typically provided around 10^4 to 10^5 beam particles per burst of 0.4 seconds.

The experiment progressed quickly from approval, in February 2000, to data taking, in 2001/2, and now on to data analysis in a very short time. During the rest of 2000 and the beginning of 2001 the experiment was constructed and physics data taking commenced during the summer of 2001 and then continued throughout 2002.

This quick progression to data taking was possible since many of the detector sub-systems in HARP are based on components from earlier experiments (e.g. the drift chambers are from the NOMAD experiment).

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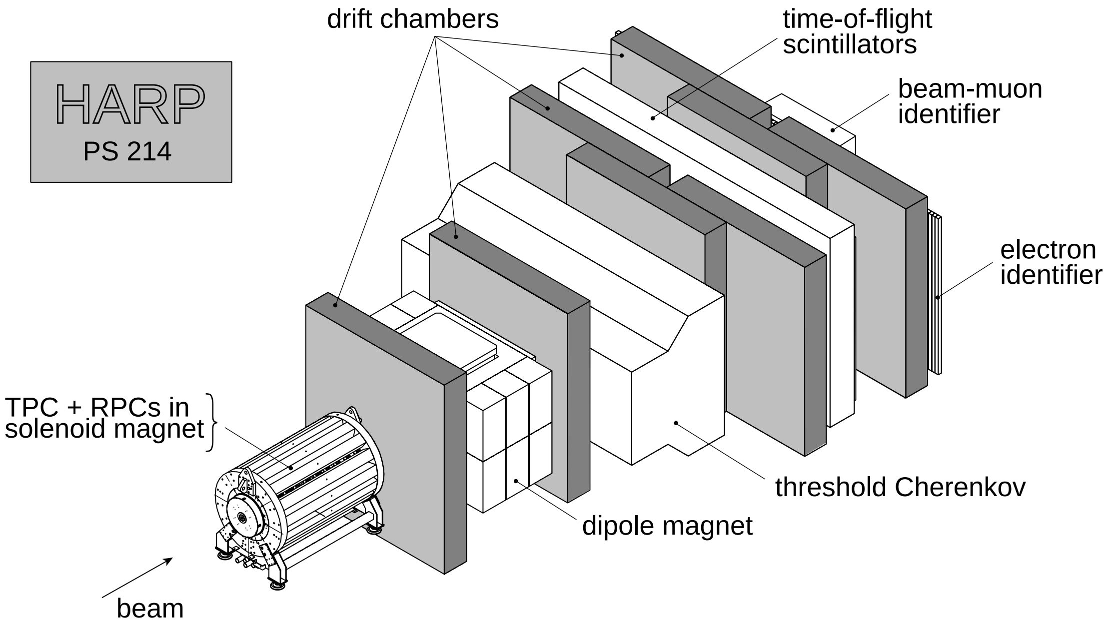

Fig. 1. Schematic of the components of the detector

Figure 1 shows a schematic of the HARP detector layout. The target sat inside the time projection chamber (TPC) allowing high transverse momentum and even backwards going particles to be measured. The TPC provides tracking, momentum measurement (due to the 0.7 Tesla solenoid magnetic field), and dE/dx particle identification. Particle identification was supplemented, in this large angle region, by a time-of-flight (TOF) system, based on resistive plate chambers (RPCs).

Downstream of the target and TPC particles entered the forward spectrometer, which consisted of a dipole magnet and drift chambers (for tracking and momentum measurements) and various particle identification detectors. Particle identification, in this small angle region, was performed using a combination of a TOF-wall a threshold cherenkov detector and an electron identifier based on an thin electro-magnetic calorimeter.

Another important component of the HARP detector was the beam instrumentation, which consisted of 4 multi-wire proportional chambers (MWPCs) for tracking, 2 TOF horoscopes and 2 threshold cherenkov detectors for particle identification, all in addition to a number of trigger scintillators.

Data were collected for a set of beam momenta (including 3,5,8,10,12,15 GeV/c) and for a wide variety of targets ranging from beryllium to lead. Data were also taken during 2002 with liquid cryogenic targets: hydrogen, deuterium, oxygen and nitrogen. Usually the hadroproduction data used for determination of the atmospheric neutrino flux uses an isoscalar target similar to nitrogen but

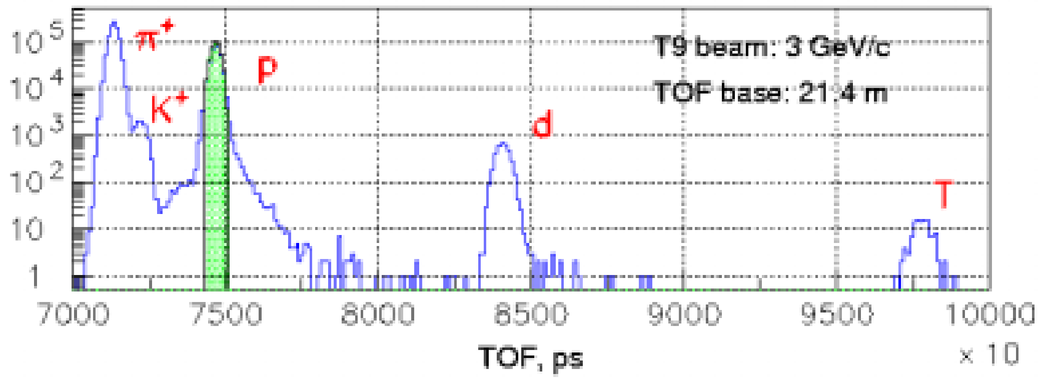

Fig. 2. Beam particle identification by time of flight.

more convenient to handle (e.g. carbon or beryllium). With the HARP data it will be possible to input data taken with a nitrogen target directly.

3. Results

3.1. Beam particle identification

As already discussed, HARP had beam instrumentation capable of identifying each beam particle that passes through the experiment. The performance of this particle identification is summarised in figure 2, which shows the beam particle time-of-flight (TOF) for a sub-set of the 3 GeV/c data. The highlighted region shows proton selection with almost 99% purity. The figure also shows that pions, kaons, deuterons and tritons have all been identified in the HARP beam. Electrons and pions were separated using the threshold cherenkov detectors while muons are separated during data analysis, on a statistical basis, using a beam muon identifier downstream of the forward spectrometer.

3.2. Interaction point reconstruction

Figure 3 shows the position of the interaction point (IP) in the target, reconstructed along the beam direction (z) using the large angle TPC tracks that match to an RPC hit. The left-hand panel shows the IP for data taken with a thin target, the right-hand panel shows the IP for data taken without a target. From the right-hand panel it is clear that the background from the empty target is small in the region of the target. The peak at 280 mm, in the empty target data, is due to the plastic at the end of the chamber, which contains the target inside the TPC, demonstrating that tracks from this can easily be separated from tracks from the target.

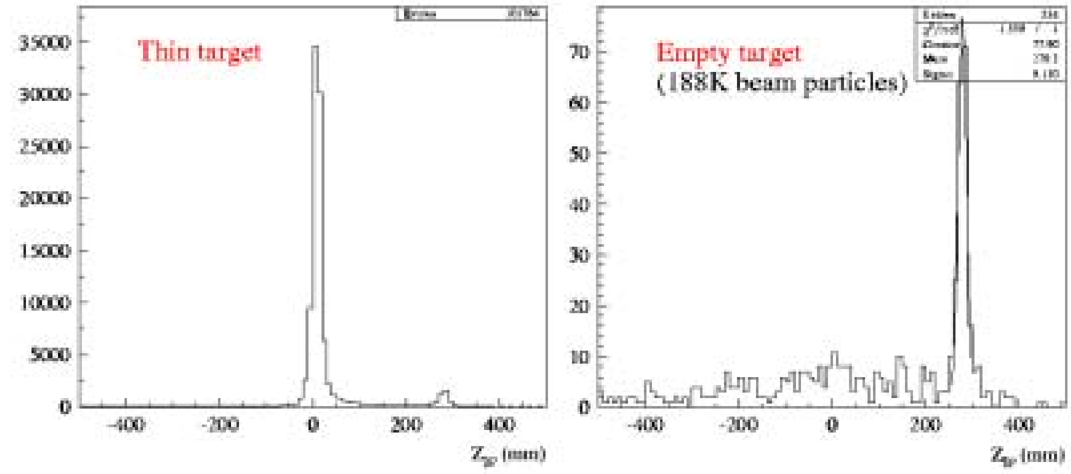

Fig. 3. Interaction point z positions reconstructed from TPC tracks that match to an RPC hit.

4. Conclusions

The results of the HARP experiment will be crucial for improving atmospheric neutrino flux predictions by providing data relevant to the hadronic interaction models. The analysis of this data is on going and the collaboration is dedicated to providing the results needed by the cosmic-ray community.

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