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Initial results from the HARP experiment at CERN

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Initial results on particle yields obtained by the HARP experiment are presented. The measurements correspond to proton–nucleus collisions at beam energies of 12.9 GeV/c and for a thin Al target of 5% interacion legth. The angular range considered is between 10 and 250 $mrad$. This results are the first step in the upcoming measurement of the forward production cross-section for the same target and beam energy, relevant for the calculation of the far–to–near ratio of the K2K experiment.

1. Introduction

The HARP experiment[1] was designed to perform a systematic and precise study of hadron production for beam momenta between 1.5 and 15 GeV/c and target nuclei ranging from hydrogen to lead. The detector was located at CERN, in the PS beam.The DAQ recorded 420 million events during the years 2001 and 2002.

The physics program of HARP includes: a) the measurement of pion yields for a variety of energies and targets relevant for he design of the proton driver of a future neutrino factory[2]; b) the measurement of pion yields on low Z targets as well as on cryogenic oxygen and helium targets, useful to improve the precision of atmospheric neutrino flux calculations[3]; and c) the measurement of pion and kaon yields, relevant for the calculation of the neutrino fluxes of experiments such as MiniBooNE[4] and K2K[5].

HARP (Fig. 1) is a large acceptance spectrometer, with two distinct regions. In the forward part of the apparatus (up to polar angles of about 250 $mrad$), the main tracking devices are a set of large drift chambers. Magnetic analysis is provided by a 0.4 T dipole magnet and particle identification relies in the combination of a threshold Cherenkov detector, a time-of-flight wall and an electromagnetic calorimeter. In the rest of the solid angle the main tracking device is a TPC, which is complemented by a set of RPC detectors for time-of-flight measurements. The target is located inside the TPC. In addition, sophisticated beam instrumentation (including three timing detectors and threshold Cherenkov detectors) provides identification of the incoming particle and allows the interaction time at the target to be measured.

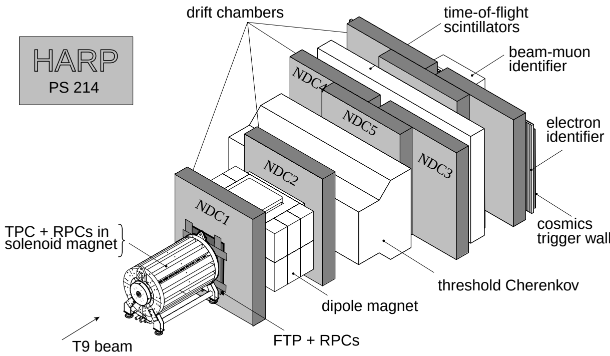

Figure 1. Schematic layout of the HARP spectrometer.

Given the immediate interest of the MiniBooNE and K2K experiments in a measurement

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of the production cross sections for pions and kaons at the energies and targets relevant for their beam setups, the HARP collaboration has given priority to the analysis of those particular data sets. In particular, we present in this article an initial result relevant for the K2K experiment. Specifically, we measure pion yields from proton-nucleus collisions, for a thin Al target ($5\%\lambda$) and a beam energy of 12.9 GeV. The K2K neutrino beam is produced from the decay of hadrons (primarily pions) emanating from a 2λ Al target, at the KEK PS proton driver energies of 12.9 GeV. Further details about the motivation of this analysis can be found in Ref. [6].

2. Forward Tracking and Particle Identification

2.1. Tracking

Tracking of forward-going particles is done by a set of large drift chambers(NDC) placed upstream and downstream of the dipole magnet. The chambers were recuperated from the NOMAD experiment and their properties have been described elsewhere[7]. Each NDC module is made of four chambers, and each chamber of three planes of wires with tilted angles -5^o, 0^o and 5^o. The single-wire efficiency is of the order of 80%, and the spatial resolution approximately 340 μm. The performance of the NDC is inferior to the one measured in NOMAD, where the hit efficiency was close to 95% and the resolution approached 150 μm. This is mainly due to the fact that, for HARP, the NDC used a gas mixture and voltage settings different from the ones in NOMAD[2].

Due to the low hit efficiency, the algorithm used in NOMAD, based in building up space points (with an efficiency of about $.95^3 = 85\%$) is not viable (for Harp we would obtain $.80^3 = 51\%$). Instead, the reconstruction builds $2D$ and $3D$ track segments in each NDC module (12 hits maximum), which are fitted to a straight line model via a Kalman Filter fit[9].

Next, the algorithm attempts all possible combinations (which include at least a $3D$ segment) to connect tracking objects in the modules downstream of the dipole magnet. Combinations such as $3D + 2D$ or even $3D$ + hits–not–associated are valid ways to build longer, $3D$ segments.

To measure the momentum it is necessary to connect a ($3D$) segment downstream of the dipole with at least one space point upstream of the dipole. Since one can impose the constraint that all tracks emanate from the event vertex[3]this point is always known and therefore the necessary and sufficient condition for a particle emanating from the target to have its momentum measured is that a $3D$ segment can be measured by the combination of downstream NDC chambers.

A measurement in the first NDC module is not strictly necessary to analyse the track momentum. Ideally, one would like, of course, to connect a $3D$ segment downstream with a $3D$ segment in the NDC1 *and* the vertex point. However, the tracking efficiency of the upstream module is sizeable lower than the efficiency of the downstream modules. This is due to, a) a higher hit density in NDC1[4] and b) the lack of redundance due to the fact that there is only a single module upstream of the dipole. A too restrictive condition to accept a track such as matching a $3D$ segment upstream of the dipole with a $3D$ segment downstream results not only in lower efficiency, but also in a systematic error, arising from the uncertainties in the hit density expected in NDC1 which would be hard to estimate (hit density depends on factors such as track multiplicity and opening angle, which are model-dependent). Instead, by building a track *always* when a $3D$ segment is present downstream of the dipole, one is practically independent of the tracking efficiency in NDC1.

In order to quantify these considerations, we have considered three different types of tracks, depending on the matching between the downstream and upstream modules. Type I is a $3D$-$3D$ matching. Type II matches a $3D$ (downstream) with a $2D$ (upstream). Type III are those where one has been unable to find either a $3D$ or a $2D$

[2] $Ar(90\%)-CO_2(9\%)-CH_4(1\%)$, a non-flamable gas mixture.

[3] for a thin target the vertex is known with a precision of about 1 cm In the case of thick target, a vertex algorithm will provide the event vertex to a comparable precision.

[4] the hit density decreases quadratically with the distance to the vertex, and therefore the effect is only significant for NDC1.