Hadroproductrion in Proton Carbon Collisions at the NA49 Experiment

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Abstract

We report on a special run of the NA49 experiment at CERN to obtain hadroproduction data specifically for improving the simulation of atmospheric interactions of cosmic rays. NA49 is a large acceptance detector based on time projection chamber spectrometers. Data were collected using a thin carbon target with proton beams of 100 and 158 GeV.

1. Introduction

The fluxes of atmospheric neutrinos have been of great contemporary interest due to their sensitivity to neutrino oscillations [3,4,5]. The neutrino fluxes are predicted (See review by Gaisser and Honda [2]), starting from the known fluxes of primary cosmic rays at the top of the atmosphere. Hadronic interactions are then simulated by Monte-Carlo as these particles strike the atmosphere and the cascades are tracked until the particles decay to produce neutrinos. Solar wind activity and geomagnetic effects are also included. This technique relies on a good knowledge of the production of hadrons in collisions with air molecules, and this element of the simulation dominates the uncertainty in the cosmic ray fluxes.

This paper describes measurements which were carried out specifically to improve the knowledge of hadroproduction for atmospheric cosmic ray shower simulation. The NA49 experiment at CERN [1] uses large time projection chambers (TPCs) to measure the momenta and identify the type of particles produced in high energy collisions. A one week run in which data were collected with a proton beam striking a carbon target (the closest convenient isoscalar nucleus to the nitrogen and oxygen in air) was carried out in the summer of 2002 and is described in this paper. The data are currently being analyzed.

2. The NA49 experiment

The NA49 experiment is situated in the SPS North Area at CERN on the H2 fixed target beam line. The beam for the experiment is produced from

pp. 1551–1554

collisions of the 400 GeV/c protons extracted from the accelerator with the T2 target situated in the main north target area at CERN. The particles which emerge from T2 are used to produce beams for several of the north area beam lines simultaneously. The H2 beam line is capable of transporting beams with momenta between 40 to 350 GeV/c. The beams contain a mixture of protons, pions and kaons. These are identified with a differential gas Cerenkov system which can be adjusted (by changing the pressure of the gas).

NA49 uses the particles which are transmitted down the beam line and causes them to strike the experiment target (in the case of these measurements, carbon) situated directly in front of the particle detection system described below. The SPS accelerator operates a slow extraction with particles being available with a flat intensity profile during a 4.8 s long 'burst' which is repeated every 16.8 s.

The experiment was designed to cope with the ∼1500 charged particles produced in central lead ion collisions striking lead targets. To date, the NA49 experiment has also collected appreciable datasets of proton-proton collisions (using a liquid hydrogen target) and proton$-A$ data (with mainly heavy nuclei A). Most of the data collected to date has been with a trigger to select central collisions.

The layout of the main detectors (Figure 1) comprises two vertex TPCs (VTPC1 and VTPC2) followed by two main TPCs (MTPCL and MTPCR). The two vertex TPCs are each inside a 1.5 Tesla super-conducting magnet which produces a p_T kick in the horizontal plane. This field bends most of the low momenta particles into the active TPC volume. A mixture of neon and CO_2 (10%) is used in the vertex TPCs and a mixture of argon, CH_4 (5%) and CO_2 (5%) is used in the main TPCs. The ionisation electrons produced along the particle trajectories drift vertically upwards to the readout chambers on the top of the detectors. The high granularity pad readout is shaped to follow the mean trajectory of the particles from the target. This is to aid in pattern recognition and to maximize the response for $\mathrm{d}E/\mathrm{d}x$ measurements. Where the $\mathrm{d}E/\mathrm{d}x$ response curves of the different particles overlap ($p \sim 4$ GeV/c), the particle ID is augmented with time-of-flight scintillation counters which were not used for the measurements described here.

The main detectors contain a vertical gap down the centre which limits acceptance for very forward going particles. The gap is necessary for lead-ion operation of NA49 where the very highly ionizing lead nuclei beam must not be transported through the detector. A 'gap-TPC' has been recently incorporated into the apparatus and was operational during the carbon-target run to register the tracks of particles in the gap.

Downstream of the main apparatus, leading particles can be identified to be either protons or neutrons using the ring calorimeter information in connection with the signals of two tracking chambers.

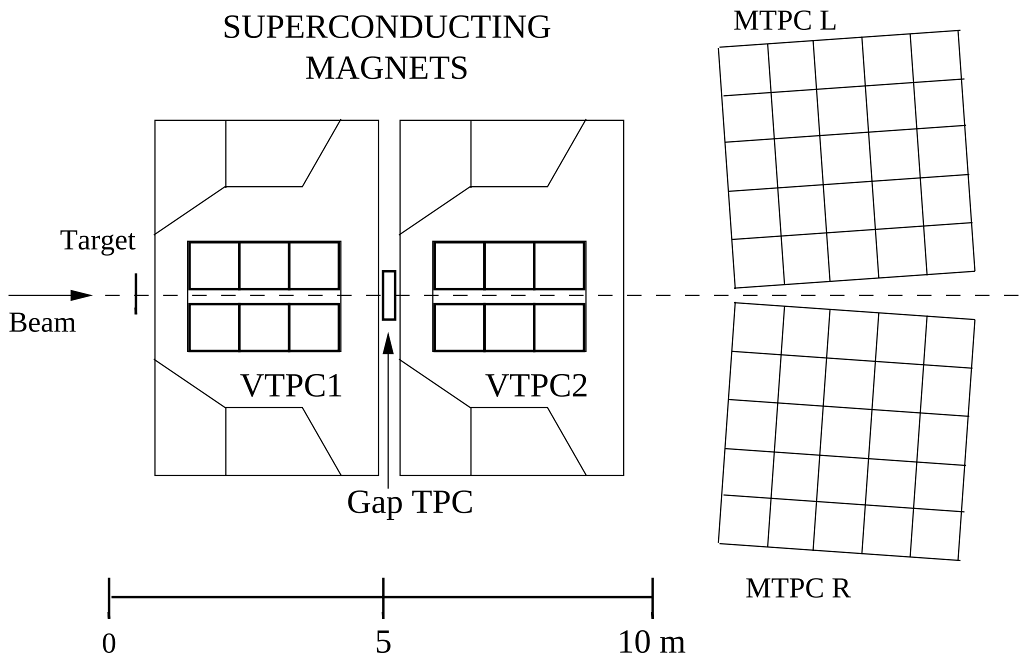

Fig. 1. Schematic layout of the main components of the NA49 experiment used in the hadroproduction measurement.

The target is positioned in front of the first TPC. A minimum bias trigger is formed in anti-coincidence with a small scintillation counter located on the beam trajectory 4 m downstream of the target. The signals from the 182,000 TPC pads are digitized at 10 MHz and a time window of 512 time buckets corresponding to the maximum drift time of 50 μs is read out for every event. The data acquisition system is capable of reading out the TPC information for 38 events per 4.8 s SPS burst.

3. The measurements with carbon

The data with the carbon target were collected in a one week period during 2002. The target was cylindrical, 6 mm in diameter and 6 mm long. Data were collected exclusively with the differential Cherenkov set to select protons. Two separate beam momenta were measured. The set with beam momentum 158 GeV/c contained 500,000 triggers and the second set at beam momentum 100 GeV/c contained 160,000 events. Approximately half of the triggered events contain real interactions. The energy deposition ($\mathrm{d}E/\mathrm{d}x$) of each track is computed using a truncated mean algorithm. Figure 2 shows a scatter plot of the energy deposition measured along the tracks as a function of momentum for positive tracks in a small fraction of the data.

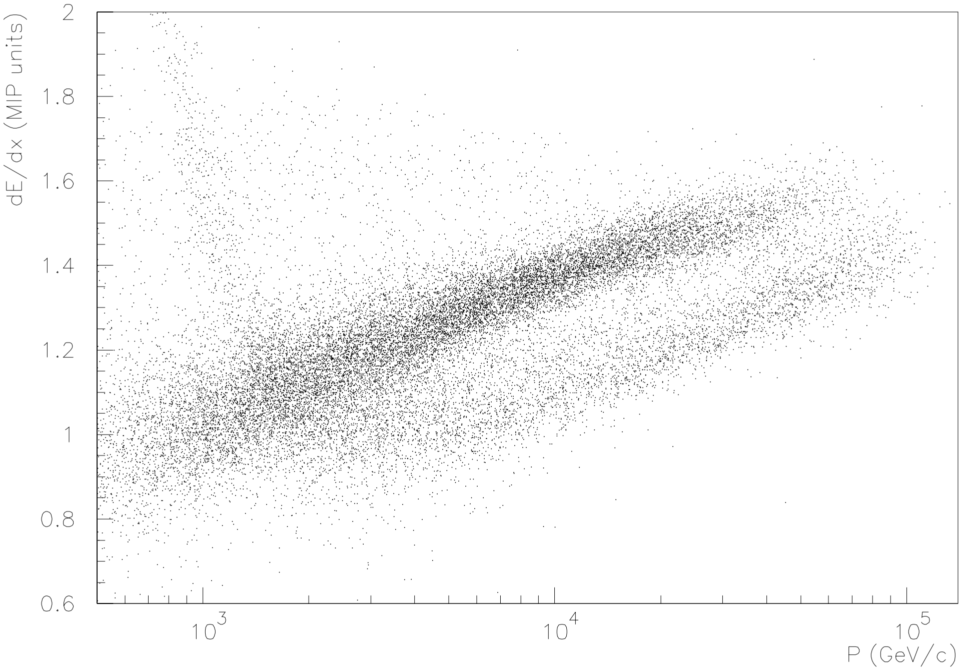

Fig. 2. dE/dx as a function of particle momentum for a small fraction of the positive tracks in the data sample.

4. Conclusions

New data have been obtained with a large acceptance experiment to measure hadron production from a carbon target. The data have been collected with the NA49 experiment at CERN with two beam momenta, 158 GeV/c and 100 GeV/c. These will be analyzed shortly and are intended to be used to make the hadron production models used in atmospheric neutrino flux calculations more precise.

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