ADAMO, an Altazimuthal Detector for Atmospheric Cosmic–Ray Observation

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Abstract

ADAMO is a composite particle detector that is being developed by a group of INFN and University of Firenze, Italy. The purpose of this detector is the study of the main charged components of cosmic rays at ground level, i.e. muons, electrons and protons, with momenta between about 100 MeV/c and 100 GeV/c. The measurement of these components allows a fine tuning of the propagation models of cosmic rays in the Earth's atmosphere. The core of the detector is a magnetic spectrometer composed of a permanent magnet and a tracking system based on silicon microstrip detectors. A Time–Of–Flight (TOF) detector system will be ready in a few months to be used as trigger and for the discrimination of the proton component up to 1 GeV/c momentum. A threshold aerogel Cherenkov detector and an electromagnetic calorimeter are also foreseen to improve the discrimination capabilities for both proton and electron components.

1. Introduction

A great amount of atmospheric cosmic–ray measurements has been performed since their discovery at the beginning of the XX century [5]. The existing data are used to calibrate the theoretical calculations of cosmic rays propagation in the Earth's atmosphere. The relevance of these calculations is mostly related to the study of the atmospheric neutrino problem put in evidence by several underground experiments [4]. The disagreement discovered by these experiments between the measured upward going μ–like neutrino flux and the calculated one could be explained by neutrino oscillations. While recent results from both solar and reactor neutrino experiments [2,3] confirmed the hypothesis of e–like neutrino oscillation, the situation for atmospheric neutrino experiments is less clear. The results seem to favor the hypothesis of $\nu_\mu \rightarrow \nu_\tau$ oscillations rather than other hypotheses (for example $\nu_\mu \rightarrow \nu_{sterile}$ oscillations). The greatest difficulty in the interpretation of atmospheric neutrino results is the comparison between the experimental data and the theoretical expectations, based upon the knowledge of particle propagation in the atmosphere. This requires a detailed information about the primary cosmic–ray spectrum, the interaction cross sections and the

pp. 3485–3488

structure of the atmosphere. The uncertainties in these calculations are still too big to constrain the oscillation parameters.

New accurate measurements of charged atmospheric cosmic rays on the ground at different altitudes and geographical locations can be used to test models of cosmic–ray propagation in atmosphere, thus improving the calculations of the neutrino fluxes.

2. The ADAMO detector

The first version of ADAMO (*Altazimuthal Detector for Atmospheric Muons Observation*) was developed during the years 1999 and 2000 with the aim of measuring the atmospheric cosmic–ray fluxes, at different angles and in different geographical locations. It consists of a magnetic spectrometer lodged on an altazimuthal mechanics that allows to vary the measurement direction. The spectrometer is composed of a permanent magnet and a tracking system based on the silicon microstrip detector technology (see left picture in figure 1.). The silicon sensors are used to track charged particles passing through the high magnetic field region produced by the magnet. The gathered spatial information, along with the knowledge of the magnetic field map, allows to determine the particle deflection (charge–to–momentum ratio), the sign of the charge and the incoming angles. The whole detector is compact and not very heavy (about 100 kg) so that it can be easily moved from one place to another. More informations are available at `http://hep.fi.infn.it/ADAMO/`.

2.1. *Magnetic system*

The permanent magnet is made of two magnetic modules kept 1 cm apart from each other. The blocks are assembled in such a way that the whole system forms a magnetic cavity $6 \times 6 \times 21\,\mathrm{cm}^3$ wide. The material used for the permanent magnet is a Nd–Fe–B alloy with a residual magnetization $\mathrm{B}_r \simeq 1.3\,\mathrm{T}$. The field in the centre of the cavity is about 0.6 T.

2.2. *Tracking system*

The tracking system is composed of five basic detection units (*ladders*) located two above, two below and one between the magnetic modules. The *ladder* is a structure made of two microstrip silicon sensors and a hybrid circuit to house the front–end electronics. The silicon sensors, the same used for the WiZard–PAMELA experiment [1], are produced by Hamamatsu and are double sided, with integrated decoupling capacitors and a double metalization on the ohmic side. Their measured spatial resolution are $\sigma_x \simeq 3\,\mu\mathrm{m}$ and $\sigma_y \simeq 13\,\mu\mathrm{m}$ on junction and ohmic sides respectively. The magnetic field strength and the spatial resolution of

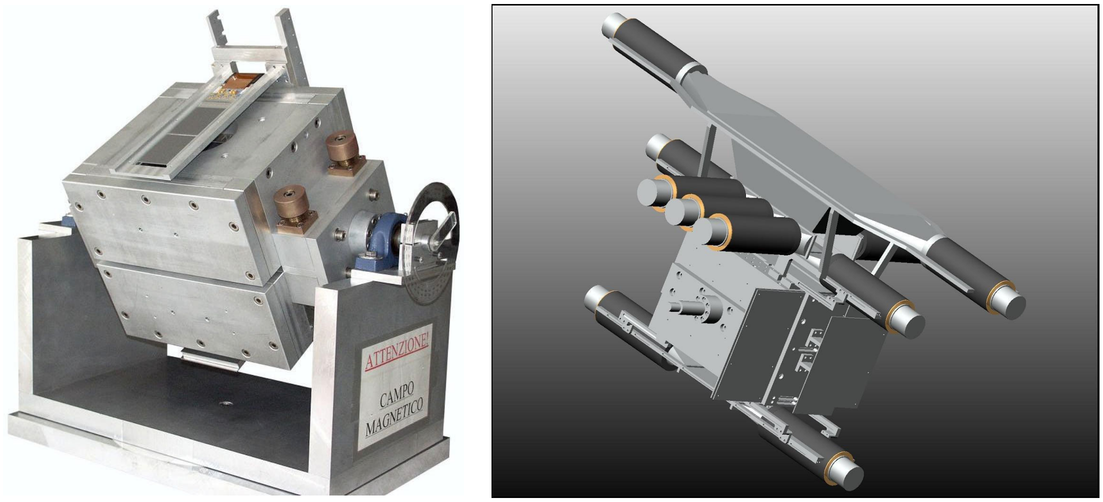

Fig. 1. The ADAMO detector in its present configuration (left) and its foreseen evolution (right). In the left picture the magnetic spectrometer is lodged on its altazimuthal platform. Only three *ladder*s are places in this photo; the upper one is visible at the top of the magnetic system. In the right picture the TOF system and the Cherenkov detector are drawn together with the spectrometer. The TOF planes are disposed two above and one under the spectrometer. The Cherenkov detector is placed between the two upper scintillators.

the sensors, arranged in this configuration, set the Maximum Detectable Rigidity[*] of the spectrometer to about 650 GV/c.
The whole system has a geometric factor[†] of $1\,\mathrm{cm}^2\,\mathrm{sr}$.

3. Upgrade of the apparatus

An upgrade of the ADAMO detector is in progress (figure 1.). The work is carried on following two main directions. First of all the apparatus will be provided with additional detectors for particle discrimination. Secondly, the magnetic cavity will be enlarged in such a way to reach a geometrical factor 8 times greater. This will allow to collect enough statistics to study the proton and electron/positron components (for example 1000 protons of momenta between 350 MeV/c and 1 GeV/c in one month). However this modification has also a drawback: the magnetic field intensity decreases of about 30%, resulting in a new

[*] The Maximum Detectable Rigidity (MDR) is the value of the rigidity at which the uncertainty is equal to the rigidity itself.

[†] The geometric factor of a detector is defined as the proportionality constant between the rate of particles passing through it and the incident differential flux integrated over the momentum, in the case of an isotropic flux.

MDR of 260 GV/c.

A Time–Of–Flight is under development to allow the identification of protons with momenta up to about 1 GeV/c. It consists of three BC–408 plastic scintillators each viewed by two fast photomultipliers (PMTs) Photonis XP2020 (right picture in figure 1.). The electronics of the TOF system is based on a time expansion method. The time interval (a few nanoseconds) between the arrivals of a relativistic particle on two scintillator planes, some tens of centimeters apart from each other, is expanded by a factor about 400, in such a way to be easily measurable. The expected TOF time resolution is better than 100 ps.

A threshold aerogel Cherenkov detector (figure 1.) has been studied to extend the proton identification above the TOF range. The thickness of the radiator will be 8 cm and the Cherenkov light will be detected by six 5" cathode PMTs. This configuration allows to discriminate protons out of muons up to about 6 GeV/c.

The apparatus will be provided in the future with an electromagnetic calorimeter to improve the discrimination performances. It will be used to identify e^+ and e^- between about 100 MeV/c and 100 GeV/c.

4. Conclusions

ADAMO is a cosmic–ray telescope, based on a magnetic spectrometer, for the measurement of the atmospheric charged particles at ground level, at different angles and locations. It is now being upgraded to have a greater geometric factor (about 8 cm^2 sr) and particle discrimination capabilities. The first subdetector to be added to the spectrometer will be a Time–Of–Flight, which will allow to discriminate the proton component for momenta up to 1 GeV/c.

5. References

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