ACORDE, a cosmic ray detector in ALICE. Firsts simulation studies

B. Alessandro,[1] E. Casimiro,[2] U. Cotti,[3] A. Fernández,[4] E. Gámez,[4] N. Jiménez,[4] R. López,[4] S. Román,[4] M. Sitta,[5] M. A. Vargas,[4] S. Vergara,[4] L. Villaseñor,[3] A. Zepeda[2].

(1) Instituto Nazionale di Fisica Nucleare, Torino, Italy
(2) Cinvestav, México DF, and IFUG, Leon, México
(3) Inst. de Fis. y Mat., Univ. Mich. de Sn. Nicolás de H., Morelia, México
(4) Facul. de Ciencias Fis-Mat., Univ. Autónoma de Puebla, Puebla, México
(5) Dip. Scien. e Tec. Avan., Univ. del Piemonte O., Alessandria, Italy

Abstract

ACORDE (A COsmic Ray DEtector in ALICE) will be part of the ALICE detector at LHC and its objective is to provide a cosmic ray trigger (level 0). ACORDE will consist of an array of plastic scintillators placed on the top sides of the ALICE magnet. We describe the measurements that can be done with these counters in conjunction with some other components of ALICE and we give the first results of the performances of ACORDE. A simulation program, which includes the environment of ALICE and the rock above it, has been developed within the AliRoot framework to study atmospheric muons and multimuon events. The momentum spectrum and angular distribution of muons at the ground surface and at the top side of the ALICE magnet are shown. Preliminary results on the momentum resolution of muons detected by the TPC encourage the proposed measurements.

1. Introduction

ACORDE will play a two-fold role in ALICE: a) It will act as the cosmic ray trigger for ALICE and b) it will detect, in combination with some detectors of ALICE, atmospheric muons and multi-muons events allowing studies on cosmic rays in the energy region of the knee in the cosmic ray spectrum. The underground location of the ALICE experiment, with 30 m of overburden above the ALICE cavern, is ideal for cosmic muon based experiments: the electromagnetic and hadronic components of the air showers are fully absorbed by the overburden and the muon momentum cut-off is around 15 GeV (see below). This is in contrast to deep underground experiments, such as Macro [1], where the momentum cut-off is of the order of TeV, as well as to surface experiments, such as Kascade [2] with a muon cut-off of 2 GeV. The ALICE TPC offers the opportunity to have magnetic

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analysis over a large volume which will provide precise determination of the muon directions as well as of their momenta up to order of TeV. The fine granularity of the TPC permits the measurement of a high density of muon tracks, the so-called muon bundles. A complete discussion on the ACORDE physics goals are presented at the ALICE Physics Performance Review, Chapter 6 [3].

In what follows we present details of the geometrical representation of the ALICE cavern, the calculation of the energy cut-off of (atmospheric) muons reaching the ALICE magnet, and of the corresponding angular distribution flux. We also calculate the geometric acceptance of the proposed ACORDE scintillator counter array to atmospheric muons. We generate muons at the surface level, pointing to the IP, with a uniform azimuthal angular distribution and parametric distribution functions for their initial momentum and zenithal angle. We have used GEANT3, under the AliRoot [4] framework, to transport the muons through 30m of molasse material above ALICE.

2. ACORDE simulation work

Because our main task is to study the propagation of energetic atmospheric muons traveling through the rock material above the ALICE cavern, it is important to have a good representation of the geometry of the cavern as well as of the volume and of the chemical composition of the rock material covering the cavern. About the rock material we will use the information provided by previous studies of the density and composition of the Sub-alpine molasse above the cavern [5]. Details of the geometric dimensions of the cavern, including the position of the three shafts, stairs, space between walls, floor, ceiling and some other civilian constructions, can be found in the CERN general layout architecture planes (LHC ring, Point 2). With this information in hand we were able to reproduce the ALICE cavern geometry for the simulation work presented here.

In order to study the characteristics of the atmospheric muons flux at the ALICE hall and the response of the ACORDE scintillator array we have developed an AliRoot module, named CRT, to simulate the travel of muons, crossing 30 m of molasse rock and reaching the ALICE detector. The simulation work also includes the calculation of the scintillator array detection efficiency.

Fig. 1. shows the angular distribution (zenithal angle vs azimuthal angle) of muons, generated at surface level and pointing to the Alice-IP, that reach the upper hemisphere of the magnet. The two bumps clearly seen in this plot correspond to the position of the PX24 and PM25 shafts. The third shaft is not very well seen because muons crossing this region do not reach the Alice hall. Muons, with uniform azimuthal angular distribution at ground level were generated according to the (initial momentum and zenithal angle) parameterization of atmospheric muons taken from a recent compilation of high energy atmospheric muons data at sea level [6].

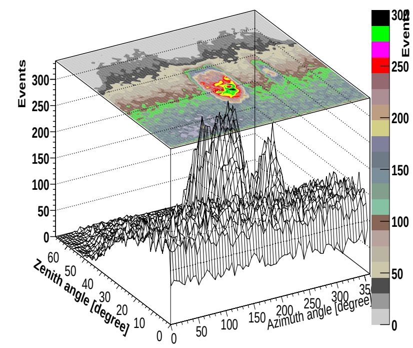
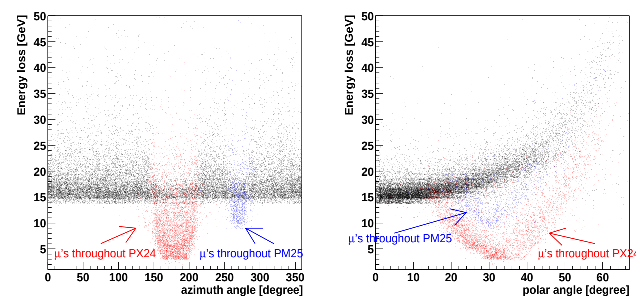


Fig. 1. Angular distribution (zenithal angle vs azimuthal angle) of atmospheric muons reaching the ALICE hall.

As we mentioned before, the underground location of the ALICE cavern fixes a natural energy cut-off for atmospheric muons. Fig. 2. shows the simulated energy loss by muons arriving at the ALICE cavern, crossing 30 m of molasse material. In this figure it is possible to see also two bumps (almost no energy loss) at $\phi = 180$ and 270 degrees , where the two shafts are located. This figure was obtained from the simulation of the ALICE cavern and of the rock material above the cavern previously discussed. Because some of the ALICE tracking detectors will be affected by the presence of atmospheric muons, it is useful to know the zenith and azimuth dependence of the muon energy loss. Fig. 2.left (right plot) shows this behavior.



captionLeft: Angle ϕ vs. Energy loss distribution of atmospheric muons reaching the ALICE cavern. The distribution of generated muons at surface level follows an exponential function taken from reference [6]. Right: Energy loss of (atmospheric) muons vs (initial) zenithal and azimuthal angles.

Given the performance of the plastic scintillator material available, the ALICE TPC acceptance and its high tracking resolution, we consider that it is not necessary to cover the whole area of the upper faces of the magnet to be able to reconstruct high multiplicity atmospheric muon events. The scintillator counter array that we propose to install is shown in Fig. 2. There, we will have 60 doublets (120 signal channels) of scintillator counters (previously used in the DELPHI Forward hodoscope [7]), with 20 doublets on each of the three magnet upper faces. Certainly, this amount of plastic scintillator material would be enough to put working ACORDE as the ALICE cosmic ray trigger.

We have calculated the geometrical efficiency of the proposed scintillator array. Having the atmospheric muon flux at the ALICE hall and the ratio (A1/A2) where A1 is the effective area of ACORDE array and A2 is the area of the three upper faces of magnet, we get a distribution of the geometrical efficiency in terms of the momentum of the muons in the ALICE hall. As we can see in Fig. 2. the geometric efficiency is 7.86%.

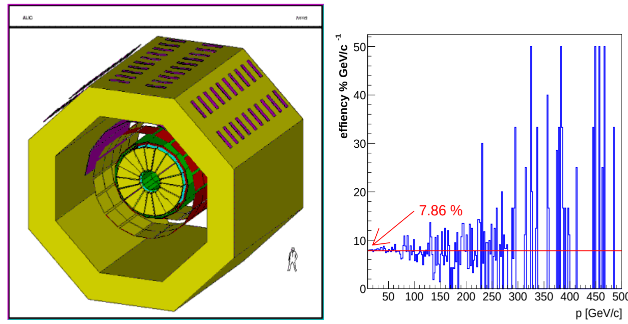


Fig. 2. Left: Scintillator counter modules placed on the three upper faces of the ALICE magnet. Right: Geometrical efficiency of the array (atmospheric muons) vs. muon momentum at the ALICE hall.

3. Conclusions

High precision apparatus and other excellent facilities of particle accelerator laboratories are providing a marvelous opportunity to develop cosmic ray experiments. In ALICE, it will be possible to detect atmospheric muon bundles with multiplicity higher than some hundreds. The high spacial resolution from the TPC and some other tracking detector, in combination with our ACORDE detector will provide profitable information from cosmic rays with energies around the knee region and higher.

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