DEASA STUDIES AND APPLICATIONS TO SPACE PHYSICS AND MUON TOMOGRAPHY

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Abstract

The high energy cosmic rays entering the Earth's atmosphere throw light upon many different aspects of Astroparticle Physics and Particle Physics. The work presented in this symposium outlines investigative learning about these high energy primaries based on a mini array DEASA in Agra, India. DEASA (Dayalbagh Educational Air Shower Array) consists of eight plastic scintillators each with an area of 1 square meter. This array covers an area of 260 square meters and is the first array in the northern part of our country. The real-life applications of the cosmic ray particles where the effect of cosmic rays in space has been studied and the best material has been found to protect the astronaut from the galactic cosmic rays. Poly materials were found to be the best material due to large amount of hydrogen (H) and low atomic number (Z). It is observed that equivalent dose is minimum (107 sieverts) for Polystyrene compared to the other materials. Finally the high energy muons have been studied to image nuclear caskets called muon tomography. In this study, a dry cask container has been simulated which contains the UO2 rods and the muon scattering has been observed.

1 Introduction

The cosmic rays come from radioactive decay inside the stars, explosive supernovae's, Sun and pulsars etc. The higher energy ones seem to be coming from super massive black holes at the heart of galaxies. On reaching the Earth's atmosphere, they produce showers of particles which pass through us almost 500 times in a minute. The cosmic flux is an important tool for calibrating particle detectors and this study is being done for DEASA detectors also. The muons entering our detectors do not have a constant flux but slightly more in summer and lower in winter. This is connected to pions which have decayed into muons in the shower. In summer the air warms and expands, leading to more gap between air molecules allowing pions to reach further so as to decay into muons. In winter the air is cold and dense resulting into higher collisions of pions leading to fewer decays into muons.
The cosmic rays before entering the atmosphere are mostly galactic energetic particles coming from inside the galaxy, extragalactic with energetic particles from the active galactic nuclei, quasars or gamma ray bursts. These energetic particles affect the human body in many different ways as published study [1] says that the twins physiology, memory abilities and genes

for one of the twin on Earth and other on ISS for 340 days.The study confirms that space time manipulates the genes, affects the human immune system. The exposed person suffers from loss in mental reasoning and memory and studies are going on for long term ailments. One of the stickiest problems for NASA is how to shield astronaut from energetic cosmic rays and solar flares.

The air shower developed by an energetic particle entering the atmosphere grows with depth into hadronic and electromagnetic particles at the sea level. These muons can look into the interiors of impenetrable structures in parallel to the x-ray imaging of our body. The difference being that X-rays have to be produced in the laboratory and muons are always available. This feature defines them as a good tool for imaging the impenetrable structures like pyramids, volcano's to nuclear reactor containers .Muons traveling through a structure will be stopped along the path or scattered depending on the thickness and density of the material. The plastic scintillator lights up when a charged particle passes through so we design the simulation with a nuclear casket surrounding by two plastic scintillators. This muon imaging technique has been used to image the interiors of the nuclear reactors at Fukushima Daiichi plant[2] also.

2 DEASA

The cosmic ray flux decreases rapidly with energy as $E^{-2.7}$ around 10^{14} eV, hence impossible to have direct measurements. At theses energies the secondaries produced at sea level increases with primary particle energy. The change in transverse momentum and scattering of the secondary particles with the atmospheric particles leads to their lateral spread on ground. This process of almost parallel arrival of the secondary particles reaching ground is called extensive air shower in which the spread is between $10^4 m^2$ to $10 km^2$.

This phenomenon gave insight into:

1. Particle Physics from air shower spread.
2. The direction of secondaries arriving on ground tells about high energy particles.
3. The cosmic ray energy spectrum.
4. Mass of primary cosmic rays.

DEASA is a mini array of eight plastic scintillators each with an area of 1 square meter, has been set up as shown in Figure 1. This array covers an area of 260 square meters and is the first array in the northern part of our country. The pulses from the eight detectors are being manually studied.The pulse amplitudes, Time over Threshold, rise time,fall time and Full width half maximum are being observed to study correlations between them. The calibration of the 12 dynode Photomultiplier tubes attached to each of the eight detectors has been completed and the flux measured is around 13500 counts per minute. Daily monitoring of the detectors is maintained in log book.

3 SPACE STUDIES

The real-life applications of the cosmic ray particles is the effect of cosmic rays in space to find out the best material to protect the astronaut from the solar energetic particles(SEP) and galactic cosmic rays(GCR) [3]. The water phantom was irradiated with primary proton following a galactic cosmic ray energy spectrum with different shielding materials. The secondary particles are created with interactions between protons and the shield material in Geant4.

Figure 1: The mini array

Poly materials were found to be the best material due to large amount of hydrogen (H) and low atomic number (Z). High H leads to fragmentation of the heavy GCR particles into small fragments and low Z produces maximum number of secondaries. Poly materials are 16 percent more effective than aluminum in reducing the dose equivalent with only 1.5148 g/cm2 of material. Polymeric materials are expected to play an important role in protecting the astronauts on future missions. It is observed that equivalent dose is minimum (107 sievert) for Polystyrene as compared to the other materials.

4 MUON TOMOGRAPHY

The second study defines the application of muons to identify nuclear wastage using plastic scintillation detectors [4] in muon tomography. In this study, a dry cask container has been simulated which contains the UO2 rods (varying in number) and the muon scattering has been observed [4]. This shows that when the dry cask is filled with the rods, muons scattered to the maximum angle and if the dry cask is empty, the muon will pass through it straight without getting scattered. The scattering of energetic muons of range 3 GeV – 10 GeV from these containers with dimensions from Narora Nuclear plant, Uttar Pradesh(U.P.). The parameters measured are energy loss, radiation length and scattering angle for different number of rods gives us patterns which describe the inside of the containers without opening them. The radiation length is the average distance required for an electron to lose 1/e of its energy and measured in cm. The multiple scattering of the muons is mostly due to Coulomb scattering of muons in the target with charge Z, calculated analytically.

Muon with energy 3 GeV looses 3.64 MeV/c energy in concrete and the scattering angle was found to be 4.14 mrad whereas the radiation length was 10.91 cm. These calculations have been done for different energy muons scattered from Iron, Lead and Uranium targets in this paper.

5 Conclusion

These studies prove that high energy quantum fields consciously assist us in applications beyond the accelerating sources from which they arrive and reach far beyond the human - machine interface. Neutrinos although being nearly massless give solutions to Dark matter, Dark energy in cosmology, muons being tiny particles can scan structures like nuclear plants, submarines etc. Hadron fields have applications in medical physics such as hadron therapy

and carbon ion therapy for the cancer patients.
The importance of cosmic ray studies at DEASA is that students can understand quantum sensors, the electronics for fast pulses and count rates analysis over the different seasons. Another important aspect of these studies is the Monte Carlo simulations in Geant4 and CORSIKA. These codes give a wide angle view to the user and applications in space physics, nuclear science and many other areas.

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