Development and Characterization of Prototype Electromagnetic Calorimeter

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Introduction

In high energy physics experiments, calorimetric information is of absolute importance to understand the data in terms of its physical processes involved. For the sake of full energy containment and compactness of the EM shower produced by the incident particles silicon and tungsten can be used as active and passive (absorber/converter) component respectively. Because of excellent energy/position resolution (Si), tracking capabilities (Si), high Z (W) it helps in discriminating one from other.

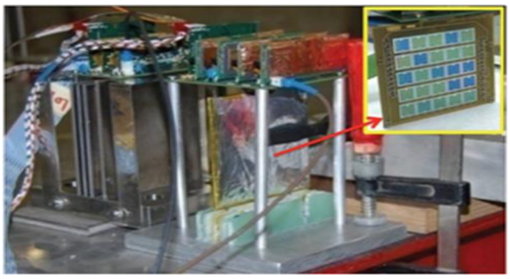

Fig.1 Test beam arrangement for prototype electromagnetic calorimeter.

Segmented structure of a calorimeter has number of advantages over the homogeneous structure in terms of energy and position resolution which need to be taken care for highly dense environment. Understanding particle production (PDF*IC*FF) in relativistic heavy ion collision is of primary importance to know parton (quarks and gluon) distribution in nucleon/nucleus. Parton Distribution Functions in nucleon are relatively better understood over a broad range of Bjorken-x (= $\frac{2p\_\{T\}}{\sqrt{s}} e^{\mp\eta}$) which is not the case in nuclei. Conventional pQCD is no longer valid for a new regime of parton distribution with small-x (down to 10^{-6}, gluon dominated). Measurements in this unexplored regime will help the understanding of physics such highly dense matter in terms explanations like CGC and others. Moreover it is equally important to disentangle initial state effect from those attributable to the hot high density partonic matter (final state effect). Recent results STAR experiment shows suppression of particle production as a function of P_T for different rapidities which could be explained using different phenomenon like CGC, multi-particle scattering, nuclear shadowing etc but with no certainty. So there is enough space to explore this small-x domain which can be done at LHC energies specifically in forward rapidities. In this abstract we had reported the performances and characterization of a prototype calorimeter, meant for proposed Forward Calorimeter for ALICE Experiment at CERN. The main purpose was to develop, test and characterize the detector array (1cm*1cm) along with front end electronics MANAS and newly developed ANUSANSKAR.

Design of the calorimeter

The newly proposed forward calorimeter (FOCAL), an upgrade to the ALICE experiment, is designed to measure prompt photons in the pseudo-rapidity range 2.5 ~ 3.0 < eta < 4.5 ~5.0 over the full azimuth and for a large P_T (few GeV/c to 100 GeV/c). The calorimeter needs to have highly granular layers of detectors consisting of 1 mm^2 as well as 1 cm^2 silicon detectors. Silicon (PIXEL) pad detectors are preferred for a number of reasons such as it has no inherent charge gain and intrinsically it is fast and also can operate under relatively low bias voltage. The relatively lower sensitivity to magnetic field is another attractive feature of this type of detectors. From simulation it has been found that for photons of energy range 1 to 200GeV the shower maximum in longitudinal profile will be in between 4 to 12 X_0 and 25 layers (each of 1 radiation length thick) are enough to minimize longitudinal leakage for the whole energy range. As a part of development of the calorimeter first try has been given in building a mini-prototype for the calorimeter with four layers of detectors (silicon of 1 cm^2 area) with tungsten plates in between. The Prototype calorimeter, shown in Fig-1, was to test the feasibility of using silicon as detector and to validate the electronics. Recently, four layers of 1cm^2 silicon pad detectors developed in collaboration with BARC and BEL have been tested in the laboratory at VECC and CERN PS beam line, quite successfully. Two types of readout systems, one based on MANAS and other based on ANUSANSKAR ASIC were used.

Result from Beam Test

The motivation behind building the calorimeter is to measure (direct/decay) photons with large momentum primarily.

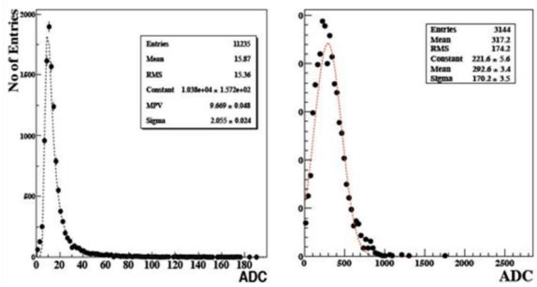

Fig.2 Responses of MIP (pion) and electron

The prototype with four layers of detectors was tested extensively first in laboratory with beta (Sr^{90}) source and then with pions and electrons in test beam at PS beam line at CERN. The momentum range of incident particles was in between 1 to 6 Gev/c. For the sake of finding the optimum operation voltage of detector, voltage scan had been performed both with lab set-up and test beam environment. It has been found that the detector could be operated at 60V safely with reasonably good signal to noise ratio.

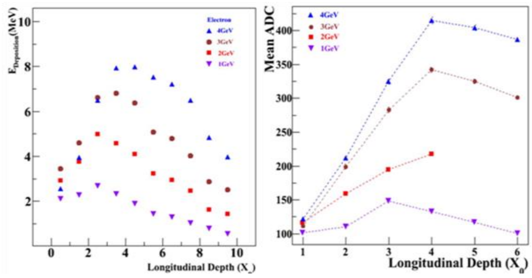

Fig.3 Longitudinal shower profile (left) Simulation, (right) Data.

A dedicated triggering detector (Cherenkov) was used to discriminate electron from other particles. The responses of the detectors to electron as well as to pions (Fig.2) had been tested at various energies. Minimum ionizing signal with mean (ADC) 15.8 has been obtained using the pions, whereas electrons create EM- shower which deposits large amount of energy (~ 317 ADC) in the detectors. Lab-test and Test-Beam data showed consistency in responses over a range of energies and with different types of particles. Though not exactly, but the trend of the shower profile (Fig.3) are seems to be as expected from the simulation. Details of the development and performances with test beam for the prototype calorimeter will be discussed in the presentation.

References

[1] "Physics and design studies for a Silicon-Tungsten calorimeter for the ALICE experiment at CERN, Sanjib Muhuri, Tapan Nayak", DAE Symp. On Nucl.Phys. 2011.

[2] "Simulation and design studies of ALICE Forward Calorimeter", S Muhuri,T. K. Nayak, DAE Symp. On Nucl.Phys. 2012.

[3] "Dynamic fuzzy c-means (dFCM) clustering and its application to calorimetric data reconstruction in high-energy physics", Radha Pyari Sandhir, Sanjib Muhuri, Tapan K. Nayak, Nuclear Instruments and Methods in Physics Research A 681 (2012) 34–43.

[4] "The electronics of ALICE Dimuon tracking chambers", V. Chambert, http://indico.cern.ch