Feasibility Study of a Forward Calorimeter in the ALICE Experiment at CERN

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Introduction

The ALICE experiment at the CERN Large Hadron collider (LHC) is devoted to explore the physics of strongly interacting matter and quark gluon plasma (QGP) formed in extreme conditions of temperature and density in nucleus-nucleus collisions. Besides the study of QGP, other aspects like parton distributions (PDFs) in nucleon and nuclei can be probed by the ALICE experiment. It has been established from Deep Inelastic Scattering (DIS) experiments that these PDF's depend on the Bjorken-x which is defined as $x = Q^2/2p.q = Q^2/2.M.nu = P_T e^{\varepsilon}/\sqrt{S}$ instead of depending on energy (E_{cm}) and momentum individually (known as Bjorken Scaling)[1]. At sufficiently high energy (small-x), one expects a new regime of QCD where gluon saturation occurs[2]. This is described in a picture of color glass condensate (CGC) where a saturation scale emerges naturally. At LHC energies, the ALICE experiment will probe a continuous range of low-x values from 10^{-3} to 10^{-5} at forward rapidities. The study of low-x regime, especially at forward rapidities, will be most appropriate for getting to know the early stage of nuclear collision.

Recent results from RHIC in terms of limiting fragmentation and suppression of hadron spectra at forward rapidity[3] support saturation phenomenon.

In the present configuration, the ALICE experiment has excellent capabilities in mid rapidity ($-0.9<=\eta<=0.9$) region both for charged particles and photons. But the capabilities in the forward rapidity region are limited. So a proposal for a forward electromagnetic calorimeter (FoCAL) is being considered as an upgrade of the ALICE experiment which is expected to have coverage from 2.5 to 5 in pseudorapidity. The capabilities of the detector should include photon measurements up to at least 200 GeV/c in momentum and excellent gamma to pi0 separation.

Such a forward calorimeter can provide excellent insight in terms of:

- Study of parton distributions in protons and nuclei down to $x=10^{-5}$ via the measurements of π^0 and γ,
- Study of single hadron and direct photon distributions to high P_T at forward rapidities as a test of pQCD predictions
- Study of gamma-jets at forward rapidities,
- Estimation of transverse energy, centrality and reaction plane.

In this abstract, we discuss the feasibility study of the forward calorimeter in ALICE.

Design of the Calorimeter

The calorimeter in the forward region of ALICE-Experiment is proposed to be installed at about 400 cm from the Interaction Point covering the pseudorapidity range 2.5 to 5.0. It is a proposed to have a sampling type electromagnetic calorimeter with Silicon (pixels or strips or pads) as Active medium and Tungsten as absorber. Detailed study is being performed using GEANT4 simulation package. According to the preliminary results, a depth of 22 radiation length (X0) is enough for the calorimeter which can give an energy resolution of about 18.9% for 22 sampling layers.

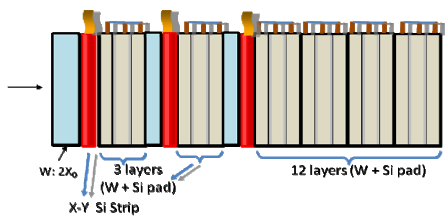

Fig 1: Prototype setup of one of the designs for ALICE Forward Electromagnetic calorimeter.

Fig. 1 shows a possible design which is being studied using GEANT4 simulation program. As shown in the figure, there are three highly silicon strip layers to track γs coming from π^0 (energy range of 1GeV to 200GeV) in the high multiplicity environment of ALICE. The strips are of 0.5cm width and 6cm long. Two back-to-back strips in transverse direction provide good position resolution for particle tracking. All other layers are made of silicon-pads of 1cmx1cm size and 0.5mm depth.

The location of the silicon strip layers have been decided from studying the longitudinal shower profile as shown in Fig. 2. It has been found that the shower-max position varies from $4X_0$ to $8X_0$ depending on the energy of the incident photons. Thus it has been found that the strip layers could be placed in the 1st, 5th and 9th layers.

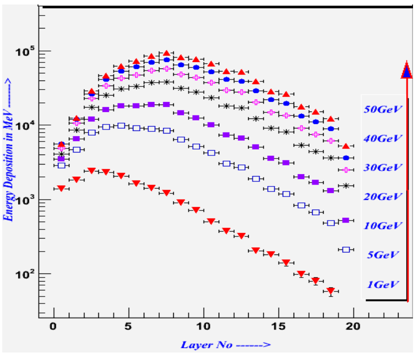

Fig. 2: Longitudinal shower profile for a sampling calorimeter with tungsten and silicon detectors.

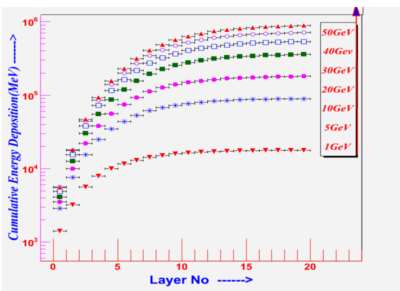

Fig. 3: Accumulated energy deposition for different layers in the sampling calorimeter.

The accumulated energy deposition has been plotted in Fig. 3. The calorimeter is found to have good linearity between the incident and deposited energies.

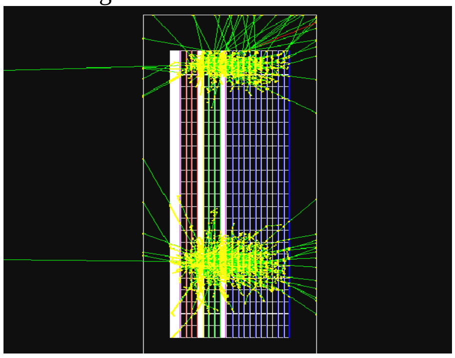

Fig. 4: Geant4 event display for pi0 decayed into two photons.

The pi0 decay to two gammas at different energies has been studied. From the response of the calorimeter to pi0 shows expected angular separation between two g's. Results of these studies will be presented.

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