R& D for Silicon detectors in India to probe low-x physics

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Silicon detector has drawn lots of attention in high energy physics experiments to characterize particles of various types and of wide incident energy range. An indigenous effort in India started back in 2010 aiming challenging task of measuring observable for possible gluon rich physics at LHC energies at forward direction at ALICE experiment. The R&D in India has successfully executed to design, fabricate and test of segmented silicon detectors towards this goal. The development is now matured in such a stage that the radiation hard silicon detector on large size wafer can be explored. A brief account of the R&D on silicon detector in India will be presented.

1. Introduction

High energy physics experiments demand high precession measurement with good position and energy resolution. Silicon detectors, being insensitive to magnetic field, become the obvious choice specially for vertex reconstruction, tracking and calorimetric measurements. The challenges get manifold when the measurements will be in forward direction (rapidity) of experiments like ALICE at CERN. The properties like high breakdown voltage, low leakage current etc. made Silicon detector as attractive choice for the sensitive medium for calorimeters. The introduction of a new calorimeter at forward rapidity of ALICE experiment will help in understanding the dynamics of gluon-rich domain of parton distributions (Fig. 1). The R&D for silicon detector fabrication in India is continuously evolving to meet the desired requirements.

2. Silicon Detector R&D in India

The effort towards the R&D for Silicon detector was perused keeping its uses in sampling type electromagnetic calorimeter which can measure high energy photons (1→200 GeV) and disentangle them according to their sources. The first attempt was with individual 1 cm^2 si-pixels, arranged in 5*5 array on a detector PCB and wire bonded for readout electronics (ref-2). There were four such layer (array) which were tested at laboratory and at beam line. 6*6 array of 1 cm^2 detector element on a 4-inch n-type wafer was explored in the next step which was the first of its kind in India. It was 300 μm thick single side polished wafers with (111) crystal orientation and has 3→5 kΩ-cm resistivity. The design consists of four mask sets, i.e., P+, contact, metal and passivation-layer-opening (ref-1&3). The metal routing tracks from the pad to the wire bond sites at the periphery were positioned in a single metal layer.

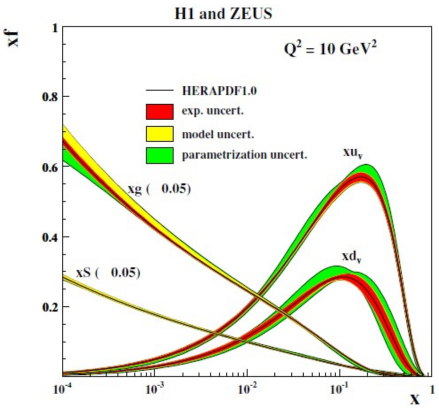

Fig. 1: Parton distribution function as a function of *Bjorken-x* ($(p_T/\sqrt{s})e^{-y}$). (JHEP01(2010)109 & ref-6)

The silicon pad array, diced from the fabricated wafer, was die-attached on a thin PCB (0.8 mm). The detectors were designed to achieve Leakage current at operating voltage ≤ 10 nA/cm^2, breakdown voltage of 500 V, Full depletion voltage (VDF) 45-50 V and Junction capacitance at VDF 45 pF.

3. Test and Results

After successful fabrication and packing of the detectors, series of test both at laboratory and high energy beam lines were performed. Basic wafer level tests were carried out at the foundry for I-V, C-V characteristics etc. The response of the detector to radioactive source (Sr^{90}) was studied. The ß-spectrum was well reconstructed and found separated from the noise floor. The minimum-ionizing-particle (MIP) response using 120 GeV pion beam as shown in upper panel of Fig. 2, was studied and well explained by the landau distribution as expected for thin detector.

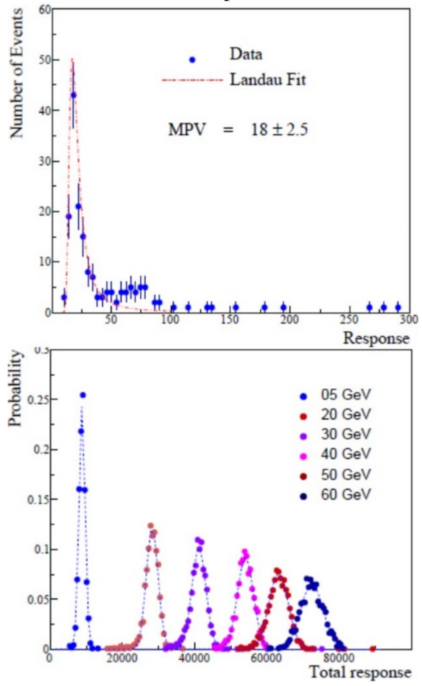

Figure 2: (Upper) Response to MIP, (Lower) Response to EM-Shower of different energies.

On the other hand, the response to electromagnetic showers, originated from incoming electron of incident energy range 5→60 GeV, was reconstructed as shown in lower panel of Fig. 2 .

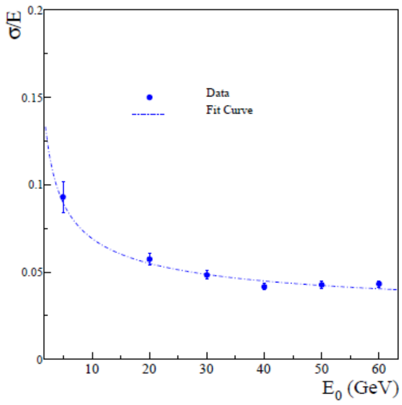

Figure 3: Energy resolution as a function of incident energy. The dashed line represents the fitting function.

The responses are well developed and separated from each other which depicts its good energy resolution. The energy resolution is plotted Fig. 3 in terms of relative width of each profile as a function of incident energy and is fitted with

$$\frac{\sigma}{E} = a \oplus \frac{b}{\sqrt{E_0/\mathrm{GeV}}}$$

with a = 0.020±0.0038 and b = 0.1536±0.023. However, there are scopes of improvement in terms of fabrication of radiation hard p-type silicon detectors and readout electronics with larger dynamic range. A brief account of the R&D effort in developing silicon detector for calorimeter will be discussed in the symposium.

Acknowledgments

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