CMOS strip sensor for the ATLAS phase-II tracker upgrade

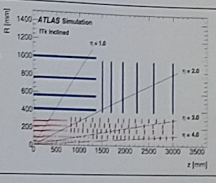
Yubo Han[1], Hongbo Zhu[1], Dionisio Doering[2], Herve Grabas[3], Pietro Caragiulo[2], Larry Ruckman[2], Camillo Tamma[2], Vitaliy Fadeyev[3], Su Dong[2]

1, Institute of High energy physics, China
2, SLAC National accelerator laboratory, U.S.A
3, University of California, Santa Cruz, U.S.A

Introduction

As the High Luminosity LHC (HL-LHC), the plan for current LHC starting in the middle of 2026 aims to improve the precision of the measurement of Higgs properties and enhance the sensitivity to search for new physics, was proposed. The detectors require to be operational with luminosity ten times of the original LHC design luminosity for 10 years to accumulate a total data set of 3000 fb^{-1}. Meeting this requirement presents numbers of challenges for the current Tracker. Thus an all-silicon Tracker consists of a pixel detector at small radius close to the beam line and a large area strip tracking detector surrounding it was chosen to be the new Tracker(ITK) for Phase-II upgrade.

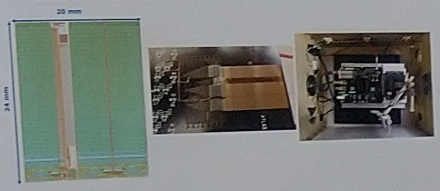
MAPS(Monolithic Active Pixel Sensor) has been studied as a potential candidate for the ATLAS Phase-II strip tracker upgrade as its capable of combining both silicon sensors and readout processing circuitry on one chip. HV/HR CMOS could also provide deep depletion region thus faster charge collection and better radiation hardness.



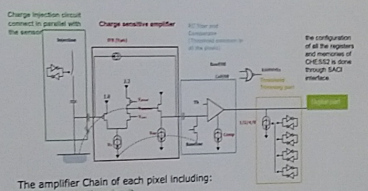
The CHESS2 sensor

CHESS2(CMOS HV/HR Evaluation for Strip Sensors)

- a full reticle monolithic high voltage CMOS sensor manufactured in the AMS-H35 high voltage process
- Designed to investigate the read-out architecture option of HV/HR CMOS technologies
- Follows and make use of the developments done for the CHESS1 ASIC



- CHESS2 in-pixel circuit



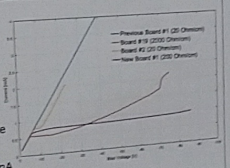
The amplifier Chain of each pixel including:

- Charge Injection circuit
- Charge Sensitive amplifier
- RC filter and Comparator
- Threshold Trimming

IV Curve measurement

IV curve

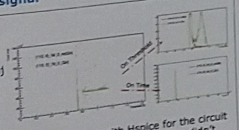
- One of the Basic characteristics of a CMOS sensor
- Enlarge the depletion volume and see how much the sensor could be depleted
  - The IV curves of different substrate resistance sensor have been tested
  - Only sensor with 200 Ohm/cm could hold up to ~ -90V at 0.8mA
  - Large leakage current observed



Tests with different input signal

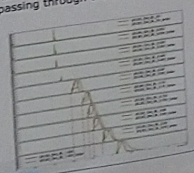
Test using Charge Injection

In our case an external pulser was taken as a controllable input signal generator. The Qinj circuit of the in-pixel circuit is responsible for changing input square signal into instantaneous current to "simulate" a real particle passing through the sensor



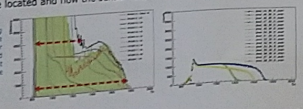
(Simulations with Hspice for the circuit has been done but the results didn't match with the test result)

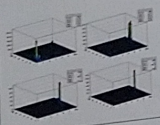
- The sensor could responding: More hits reported with Charge Injection on (with/without adding bias voltage)
- Correct timing information reported (corresponding to the input signal)
- BL & Threshold controllable in certain range: 0.6V – 0.9V
- More stable results with cooling module installed



Test and optimization pre-amp with Laser

The laser using in these tests could be focused to targeting few pixels in CHESS2 chip. Testing with laser will show us if the position of the signal could be located and how the sensor response to real photon injection





All the parameters of the pre-amp could be programmed by our software. To get a better signal with acceptable noise level, optimization of the pre-amp has been done.

- Correction position reported
- Improved signal and noise after optimization of the pre-amp

Summary and Next

Basic characteristic of CHESS2 chip and its response to different input signal have been tested; large leakage current observed with different chip; the chip response to Charge Injection and Laser, correct time and location information could be reported; The tests with Cd (20KeV X Ray) have been done but due to large amount of noise we didn't manage to see the signal; Lots of works including debugging the system, circuit simulation and firmware & software upgrades have been done; etc...

Next:

Debugging the test system and tests with Radioactive source in IHEP

More info:
https://twiki.cern.ch/twiki/bin/viewauth/Atlas/CHESSStripTestChip

Acknowledgment

Thanks for Institute of High Energy Physics and Chinese scholarship Council for providing fundamental resources for this work.