Testing Silicon Detectors for Outer Tracker of CMS

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Self Introduction

from Palestine

Bachelor In physics
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CERN summer Internship :
• EP-CMX
• Tracker DAC Group
Outline

• Introduction
  o Compact Muon Solenoid (CMS)
  o CMS Tracker Upgrade
• Physics
  o Silicon sensors
  o Readout from Tracker
• Contribution
  o Work bench
  o Results
• Conclusion
4 Detector Systems:
- Silicon tracker (particle tracking)
- ECAL (e/m particle energy)
- HCAL (hadrons energy)
- Muon system (momentum and trigger)

Tracker (Inner and outer)
CMS Tracker Upgrade

Detection principle using silicon sensors

Ref: The Phase-2 Upgrade of the CMS Tracker TDR, CMS Collaboration
1. Charged particle pass the material creating ionization in the silicon.

2. Electron/hole pairs created.

3. Holes Drift in an applied electric-field toward the p-type strips.

4. Charged induced on Aluminum strips.

5. Recording which read-out channel gives signal → we can determine where the charged particle passed through.

- **Depletion region** must be created to make bulk sensitive (by applying reverse bias voltage)
The signal amplitude is lost in turn losing the reconstruction of energy loss along the tracker.

CMS Binary Chip (CBS)

- Measures the charge generated by ionization and converts it to ‘Hit’ or ‘No Hit’

Ref: CBC3.1 User Manual CMS exp.

Above thresh. = 1
below thresh. = 0
Contribution:
- Work Bench + Source
- Noise vs Voltage
- Events Vs Voltage
Grounding Bracelet, to prevent buildup of electrostatic charge. (ESD Could damage the detectors)

Sensor Covered by black sheet to block photo current which increases the noise.

Control Computer (testing bench can be accessed remotely)

Voltage Output

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Source Americium-241

Am(241) decaying via alpha decay, weak gamma ray byproducts.

\[ ^{241}_{95}Am \rightarrow ^{237}_{93}Np + \frac{4}{2}\alpha^2 + \gamma \ (59.5409 \text{ KeV}) \]

Alpha
(stopped in the first layer)

Gamma
(Measured in both layers)

Warning Sign for radioactive source

Am-214

Sources locker
Noise Vs. Voltage Curve (No source)

- Noise ($N$) varies with a capacitance ($C$) related to the region between conduction and valance band ($t$).

\[
N = A + B \times C \\
C \propto \frac{1}{t} \propto \frac{1}{\sqrt{V}}
\]

- Thickness ($t$) of the region varies with high voltage until reaching full depletion voltage ($t = t_0$ "Thickness of sensor")

\[
t = t_0 \sqrt{\frac{V}{V_{FD}}}
\]

- Noise relation differ before and after depletion $x = \frac{1}{\sqrt{V}}$

\[
N = a + B' \times x \\
x > (\sqrt{V_{FD}})^{-1}
\]

\[
N = a + B \times x_{FD} \\
x < (\sqrt{V_{FD}})^{-1}
\]

From the curve can’t extract $V_{FD}$ directly $\rightarrow$ Do signal studies !!
Bias Voltage Scan (Source)

Bias voltage scan to measure the number of events of X-rays from source → measure the full depletion Voltage with signal processing.

If we assume that signal rate is directly proportional to the thickness of the depletion region → It is not achieved yet at 200 volts

Range needs to be increased → Further studies needed

Number of events Vs Voltage

\[ t = t_0 \sqrt{\frac{V}{V_{FD}}} \]
Conclusion

• Quality measurements have to be done to test the silicon strips.

• Noise and number of events measurements are done to acquire the full depletion voltage.

• Full depletion Voltage not achieved at 200 volts.

• Continue looking for $V_{FD}$.

• Future work: Insure a procedure that can be done to measure the full depletion voltage accurately.
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Thank you for your attention
شكرا جزيلا لانتباهكم 😊
Backup Slides
Design Concept for Outer Tracker

• Maintain efficient tracking capabilities under high luminosity conditions for the HL-LHC.

• The concept of outer tracker (OT) is based on $P_T$ module.

Figure: Illustration of tracker-triggered of correlated hits in closely spaced sensors.

Tracks are bent in the CMS magnetic field and clusters in both sensors are correlated to distinguish high and low $P_T$. 
Ref: The Phase-2 Upgrade of the CMS Tracker, CMS Collaboration
CMS Binary Chip (CBC)

- reads out the charge generated by ionizing events within the silicon strips of the CMS detector. It converts these events into a ‘hit’ or ‘no hit' binary value for each of the channels.

- The ionizing events are synchronous with the bunch crossing event interval of 25ns and the chip must store the data from each event, up to a maximum of 512 bunch crossing intervals (12.8s for a 25ns clock), in order to allow time for the external system to decide which event data should be read out. This time is known as the trigger latency.
Ref: The Phase-2 Upgrade of the CMS Tracker, CMS Collaboration
studying the behavior of the silicon strips with Voltage applied.

- Soft breakdown: gradual increase of the current after a certain point.
- Hard breakdown: sudden increase in the current
Threshold corresponds to the amount of charge carriers needed to receive a hit

Scan over the threshold on the silicon strips to measure the noise and signal