Testing Silicon Detectors for Outer Tracker of CMS

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CERN Summer Student Session

7th August 2019

Self Introduction

from **Palestine**

Bachelor In physics
An-Najah National university ,
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Master In Experimental particle physics
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CERN summer Internship :

- EP-CMX
- Tracker DAC Group

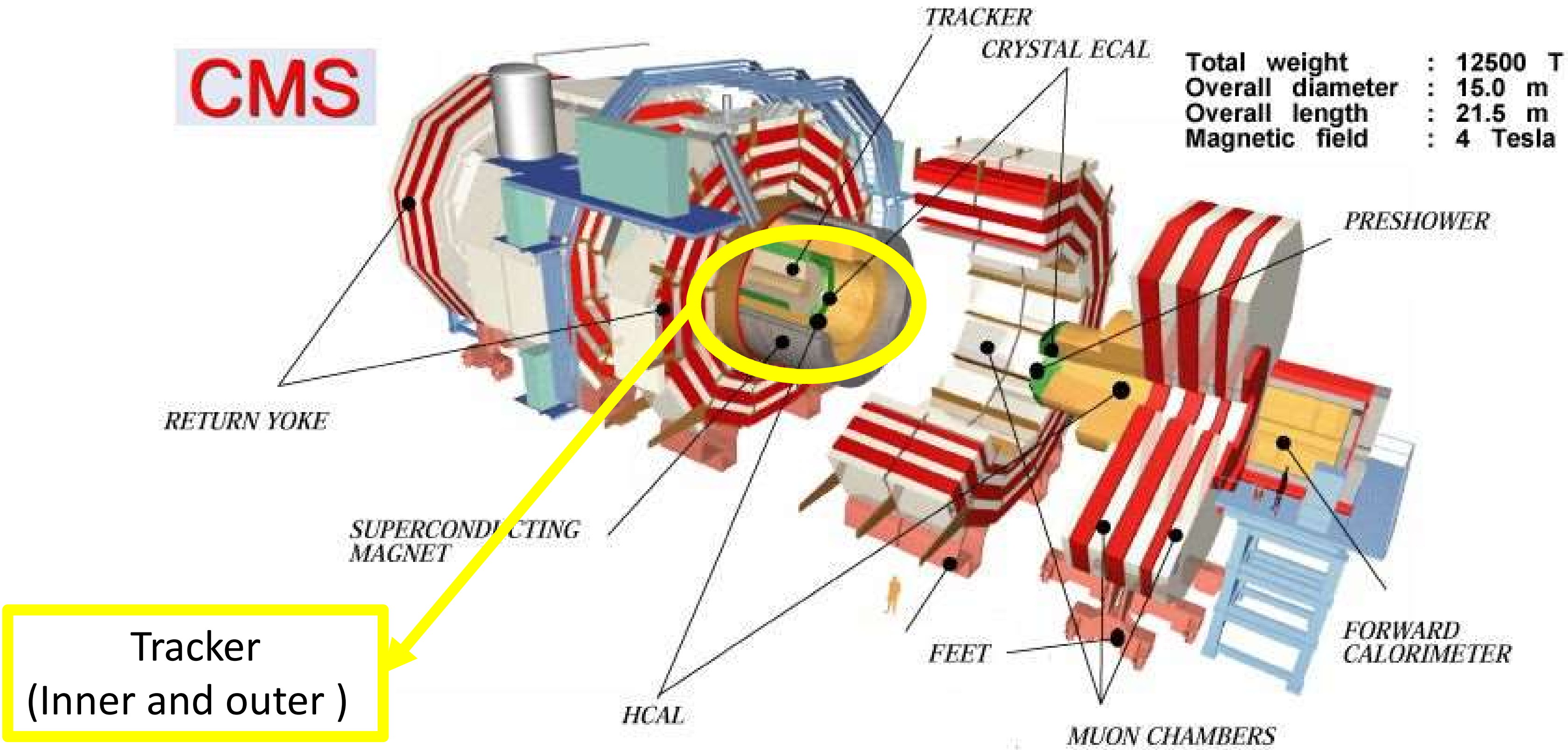
Outline

- Introduction
  - Compact Muon Solenoid (CMS)
  - CMS Tracker Upgrade
- Physics
  - Silicon sensors
  - Readout from Tracker
- Contribution
  - Work bench
  - Results
- Conclusion

Compact Muon Solenoid (CMS)

4 Detector Systems :

- Silicon tracker (particle tracking)
- ECAL (e/m particle energy)
- HCAL (hadrons energy)
- Muon system (momentum and trigger)



CMS Tracker Upgrade

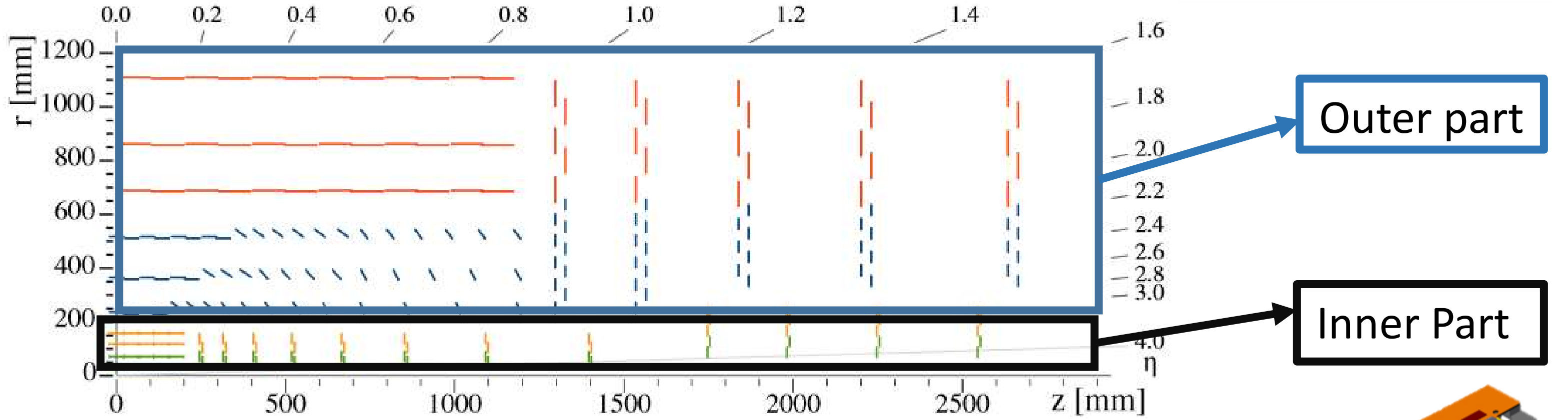


Figure : Layout of CMS tracking system for the HL-LHC

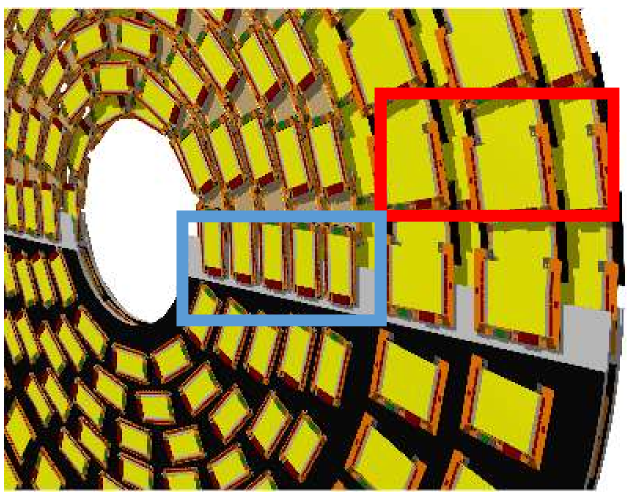
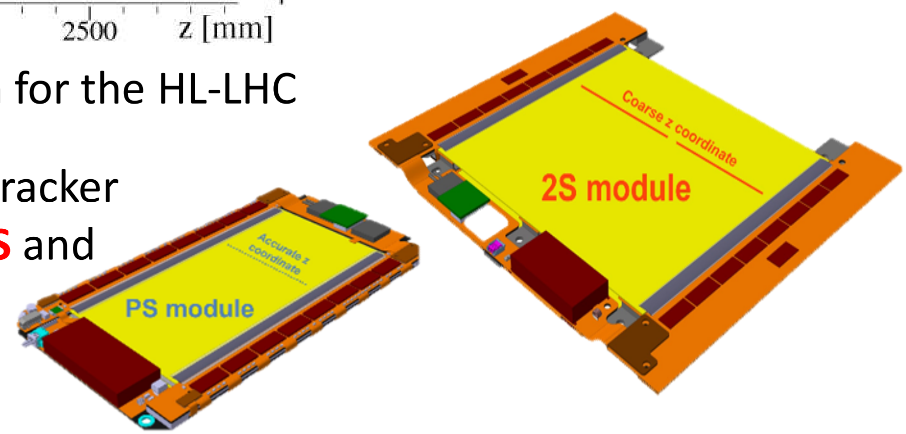


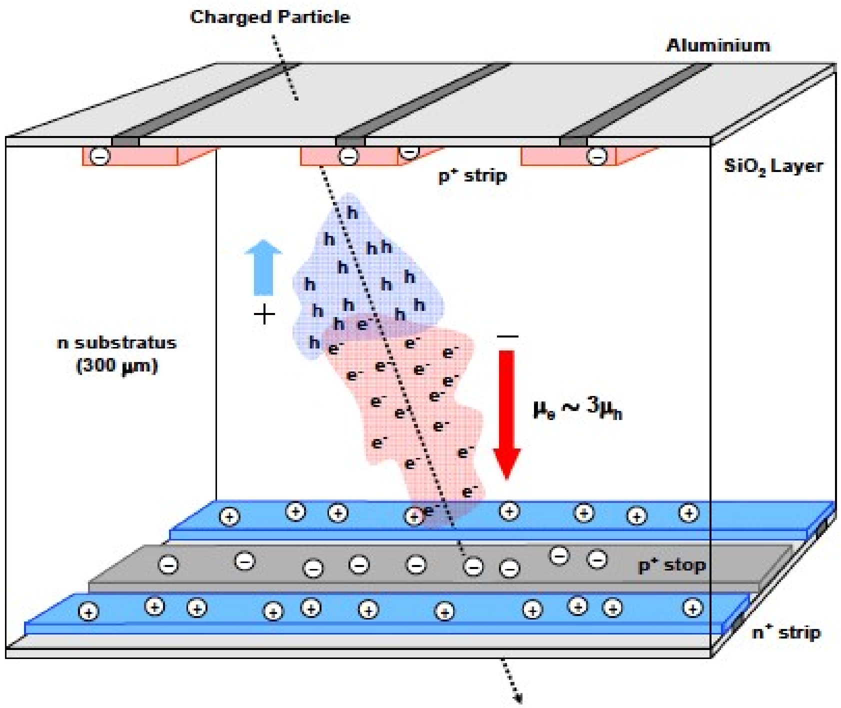
Figure : Outer tracker (Divided into **2S** and **PS**)



Detection principle using silicon sensors

Ref : The Phase-2 Upgrade of the CMS Tracker TDR, CMS Collaboration

How silicon Sensors Work ?



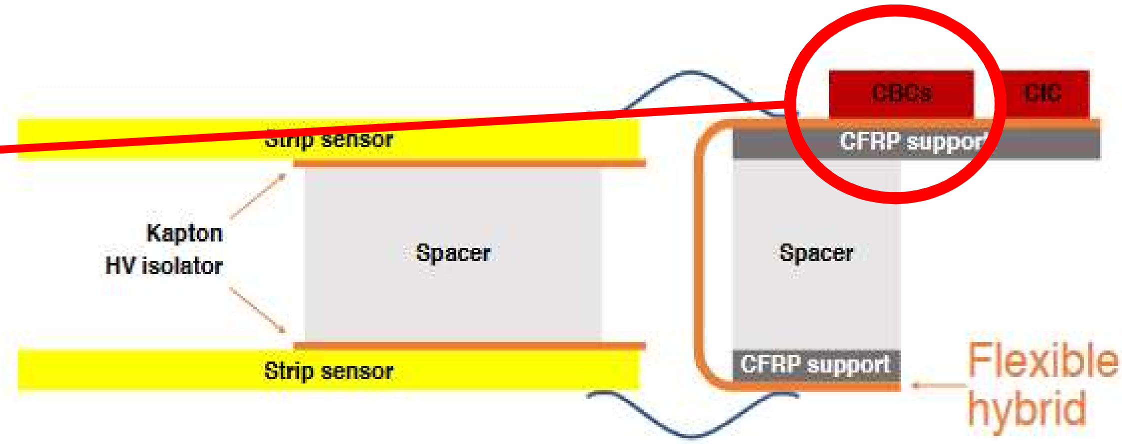
1. Charged particle pass the material creating ionization in the silicon.
2. Electron/hole pairs created.
3. Holes Drift in an applied electric-field toward the p-type strips .
4. Charged induced on Aluminum strips.
5. Recording which read-out channel gives signal → we can determine where the charged particle passed through.

- **Depletion region** must be created to make bulk sensitive (by Appling reverse bias voltage)

Readout Electronics

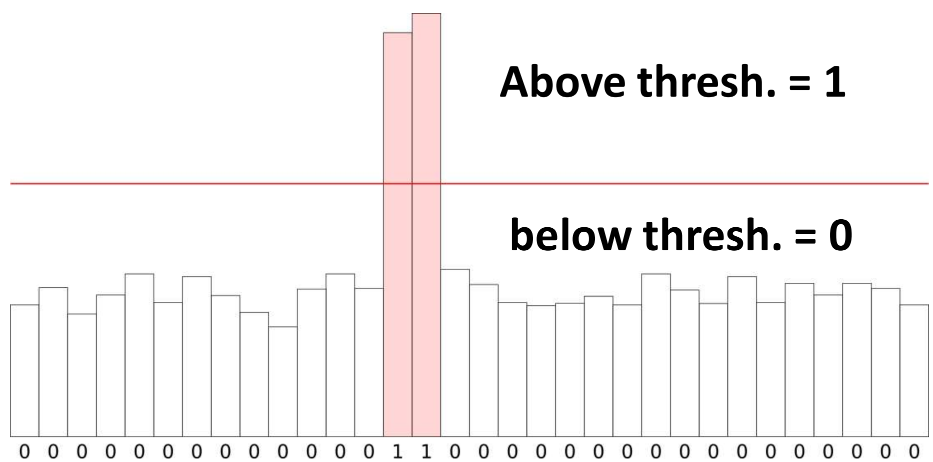
CMS Binary Chip (CBS)

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



sketch of the frontend hybrid folded assembly and connectivity. Ref: CBC3.1User Manual CMS exp.

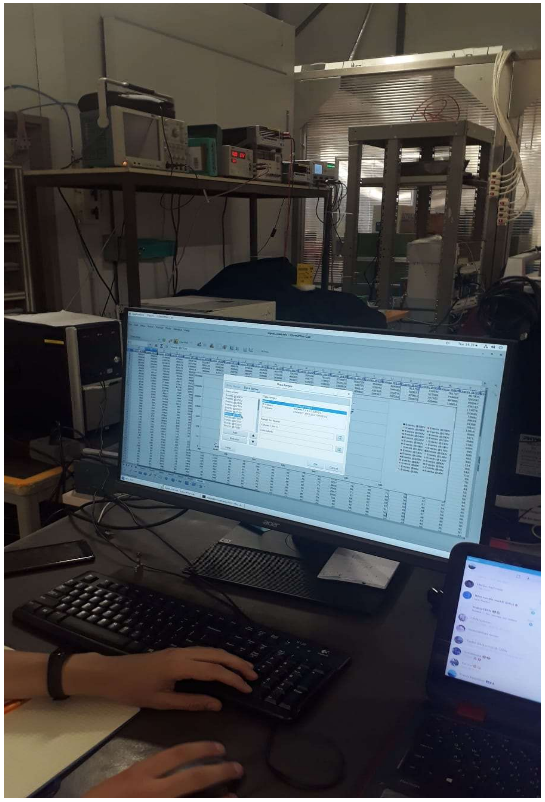
The signal amplitude is lost
In turn losing the reconstruction of energy loss along the tracker.



Contribution:

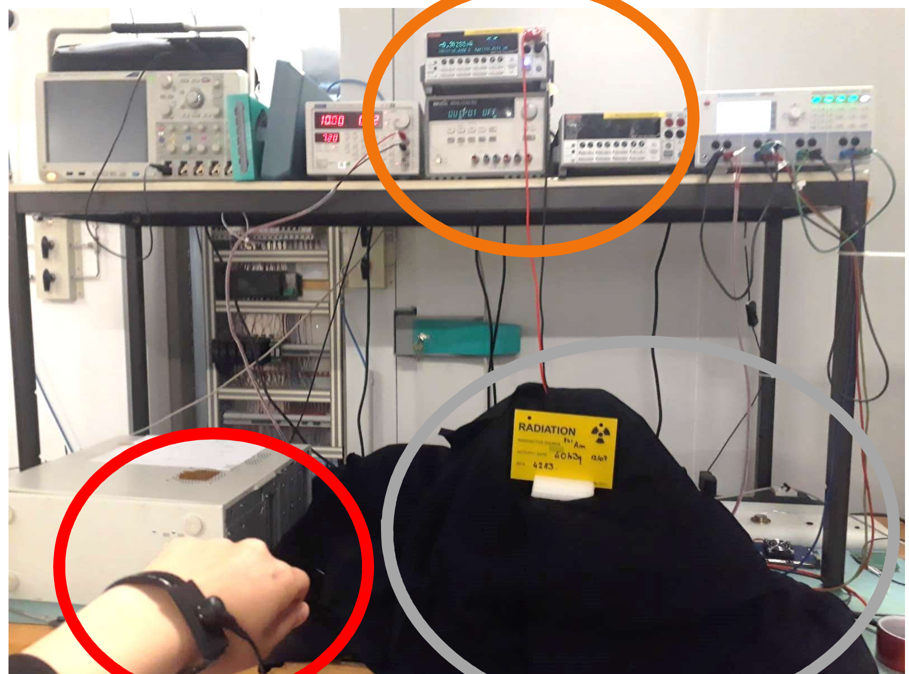
- Work Bench + Source
- Noise vs Voltage
- Events Vs Voltage

Work Bench



Control Computer (testing bench can be accessed remotely)

Voltage Output



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.

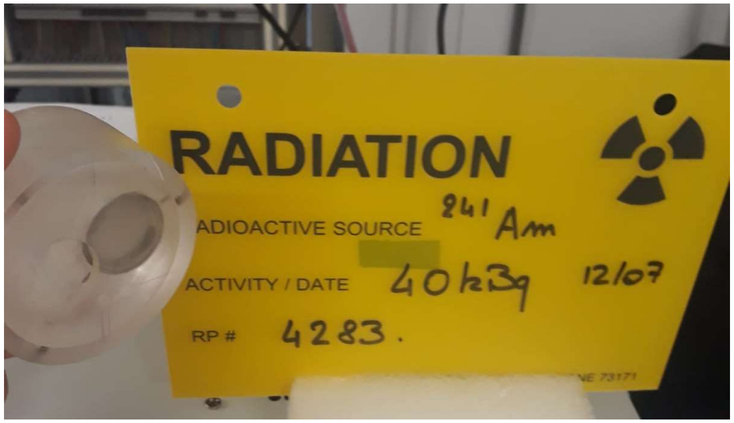
Source Americium-241

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

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

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).

$$\left.\begin{array}{l} N = A + B * C \\ C \propto \frac{1}{t} \propto \frac{1}{\sqrt{V}} \end{array}\right\} N = A + \frac{B'}{\sqrt{V}}$$

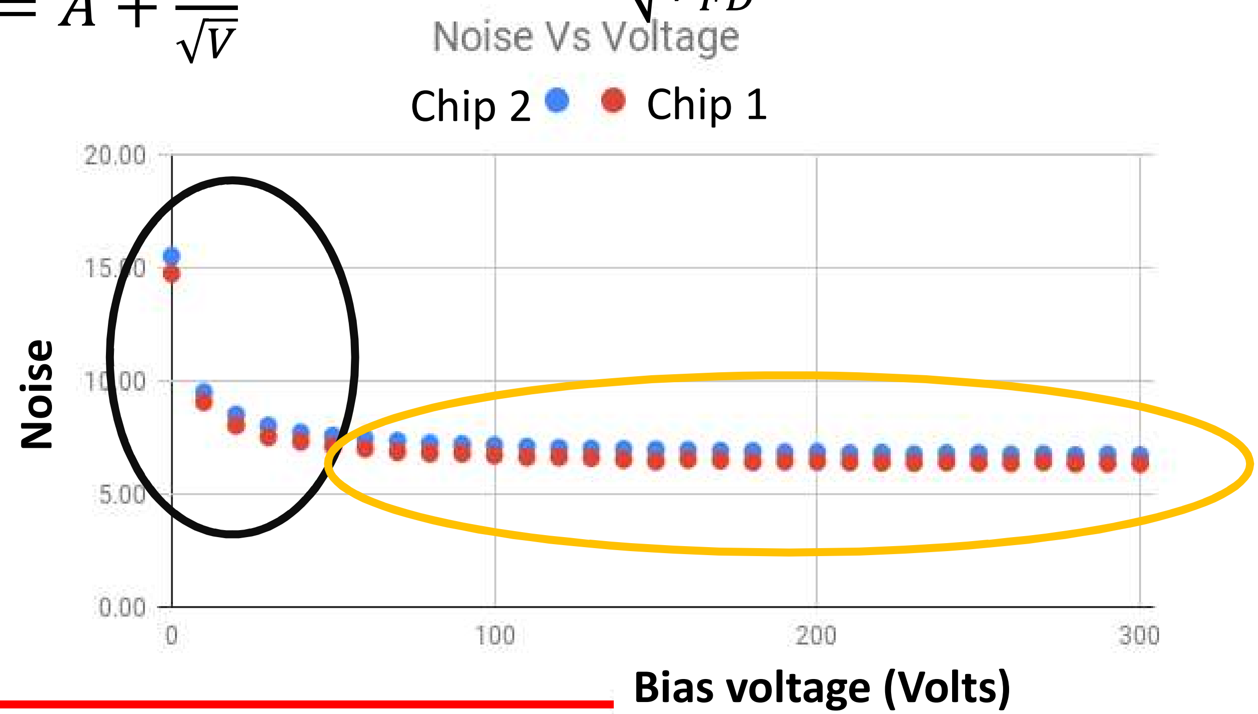
- Thickness (t) of the region varies with high voltage until reaching full depletion voltage ($t = t_0$"Thickness of sensor")

$$t = t_0 \sqrt{\frac{V}{V_{FD}}}$$

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

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

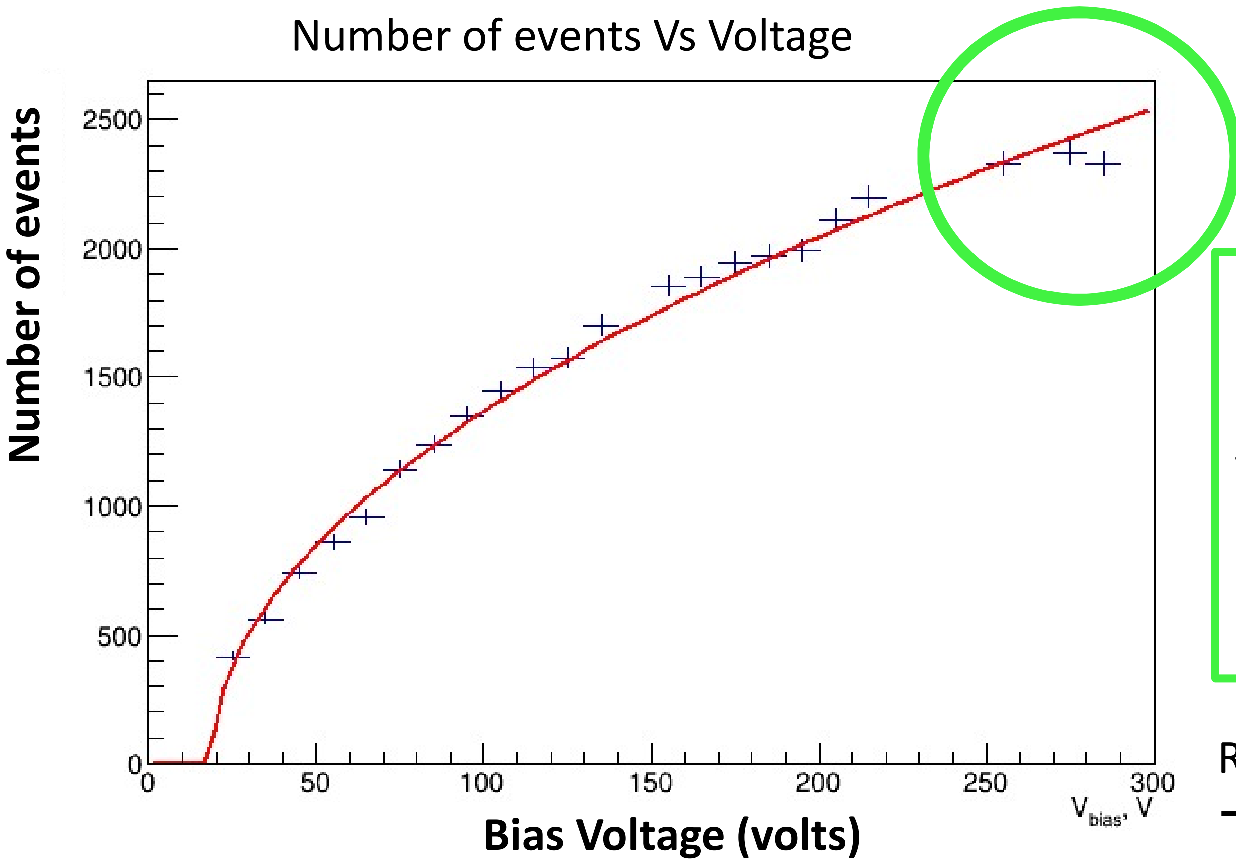
$$N = a + B\, x_{FD}$$
$$x < (\sqrt{V_{FD}})^{-1}$$



From the curve can't extract V_{FD} directly → 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 .**



$$t = t_0 \sqrt{\frac{V}{V_{FD}}}$$

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

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.

Thanks to:

CERN

Organizers

Supervisors

PhD students

Family

Students

Best summer ever

Thank you for your attention

شكرا جزيلا لإنتباهكم

☺

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 .

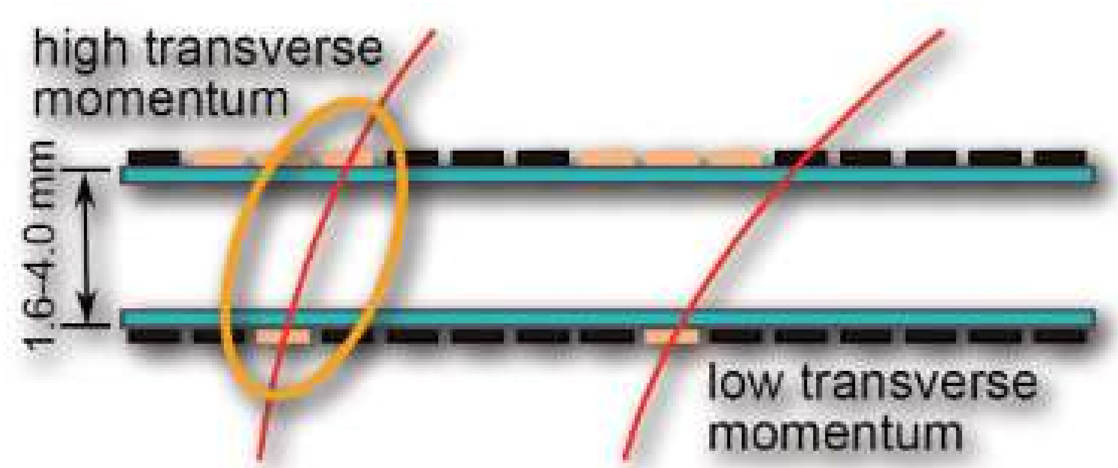
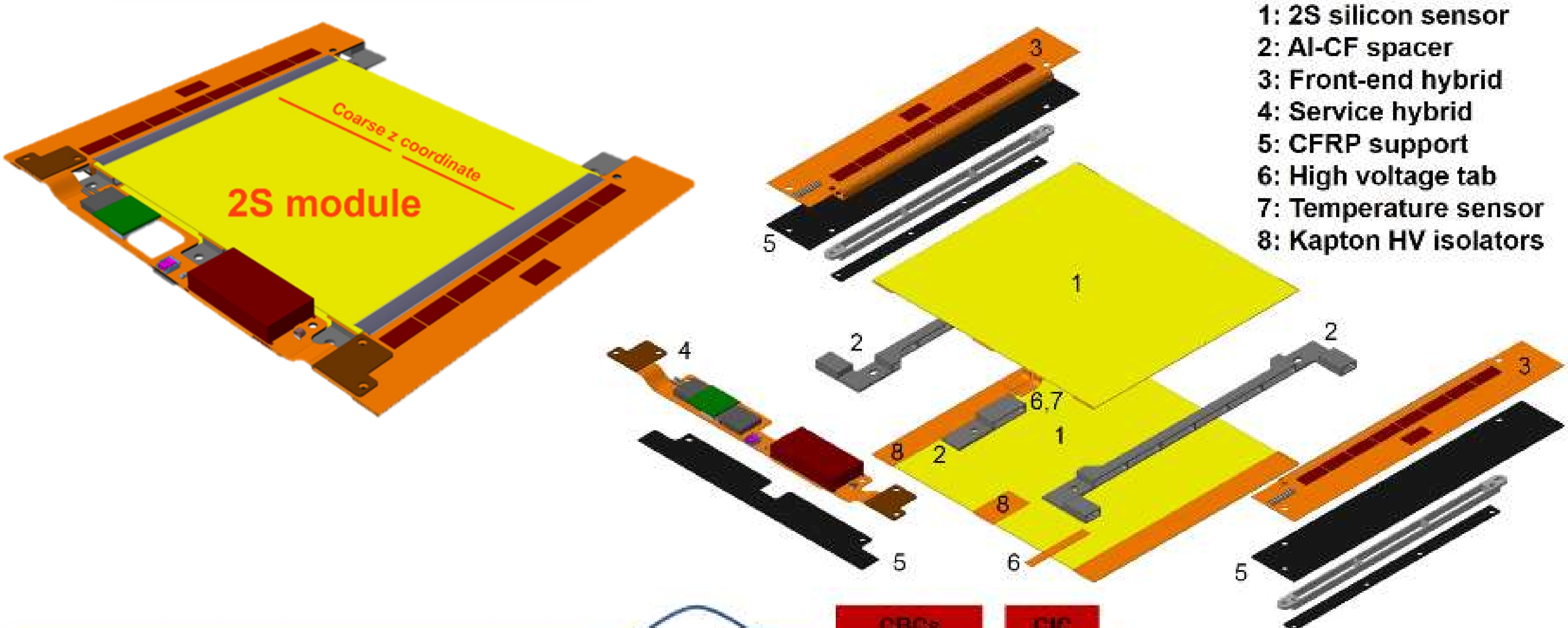
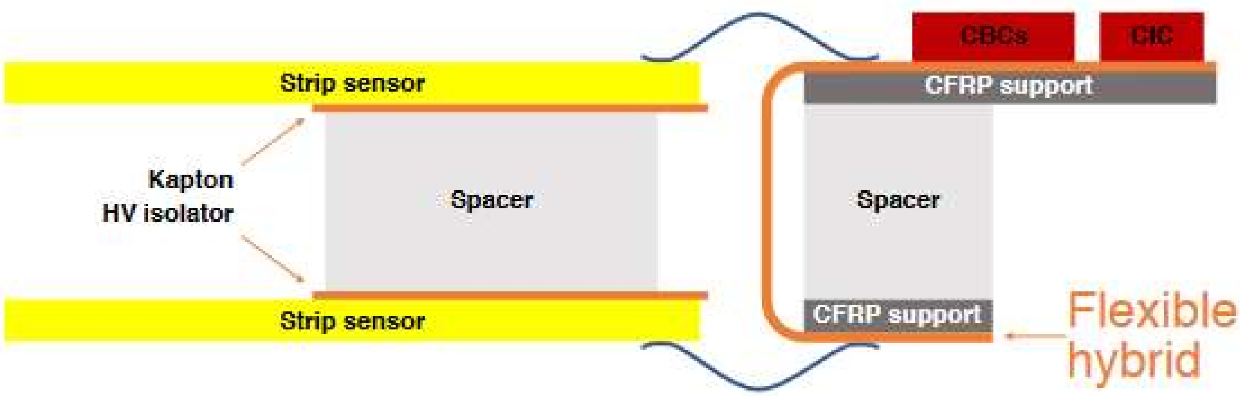


Figure : Illustration of tracker-triggered of correlated hits in closely spaced sensors.

Tracks are bent in the CMS magnetic field and clusters in both sensors are correlated to distinguish high and low P_T.

2S Module for CMS outer tracker





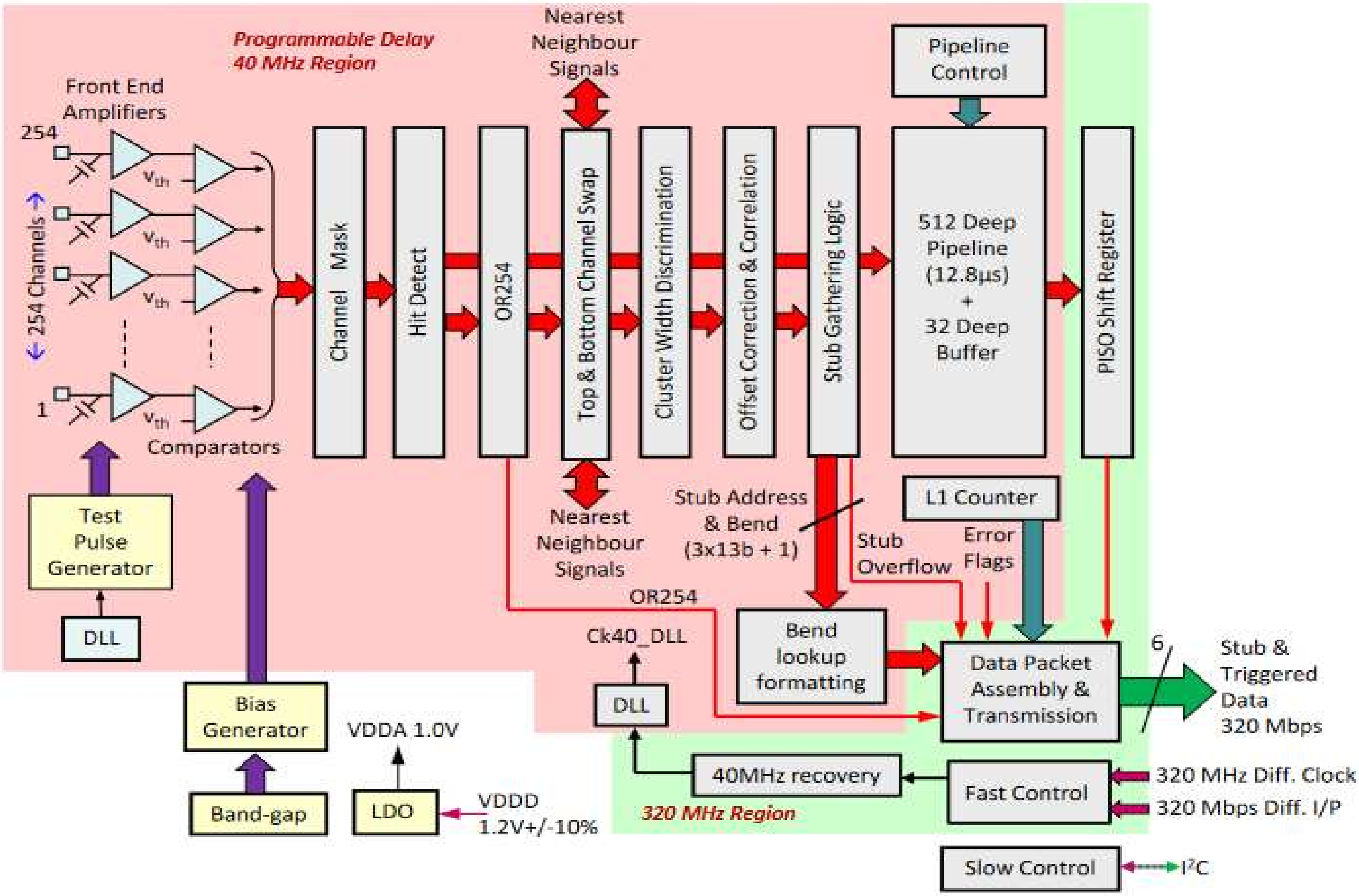
Ref : The Phase-2 Upgrade of the CMS Tracker, CMS Collaboration

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 512bunch 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.

Functional Block Diagram of the CBC



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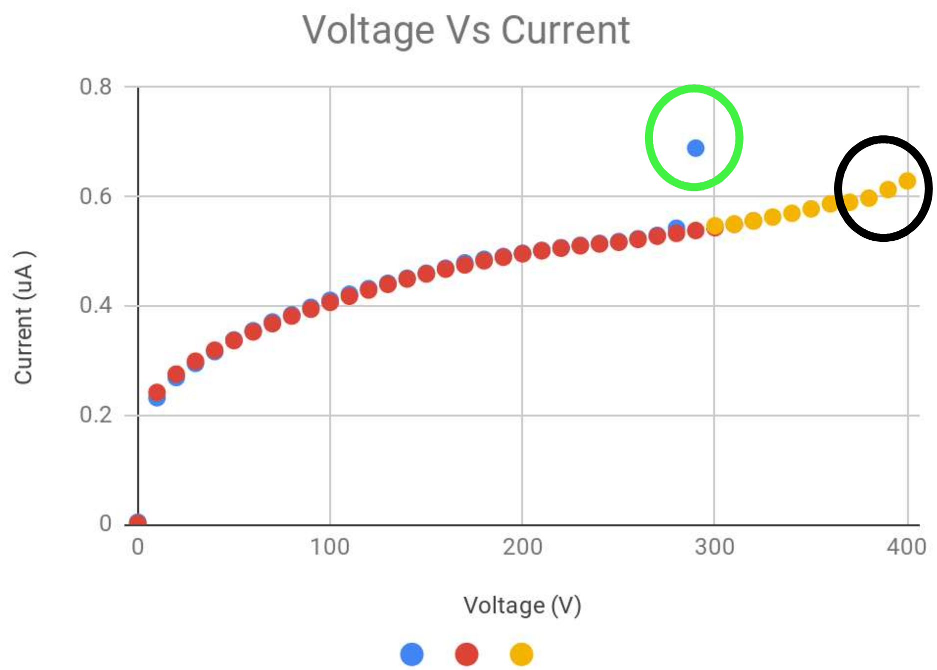
IV-Curve

studying the behavior of the silicon strips with Voltage applied.



Repeated scans for IV curve

- scan 1
- scan 2
- scan 3

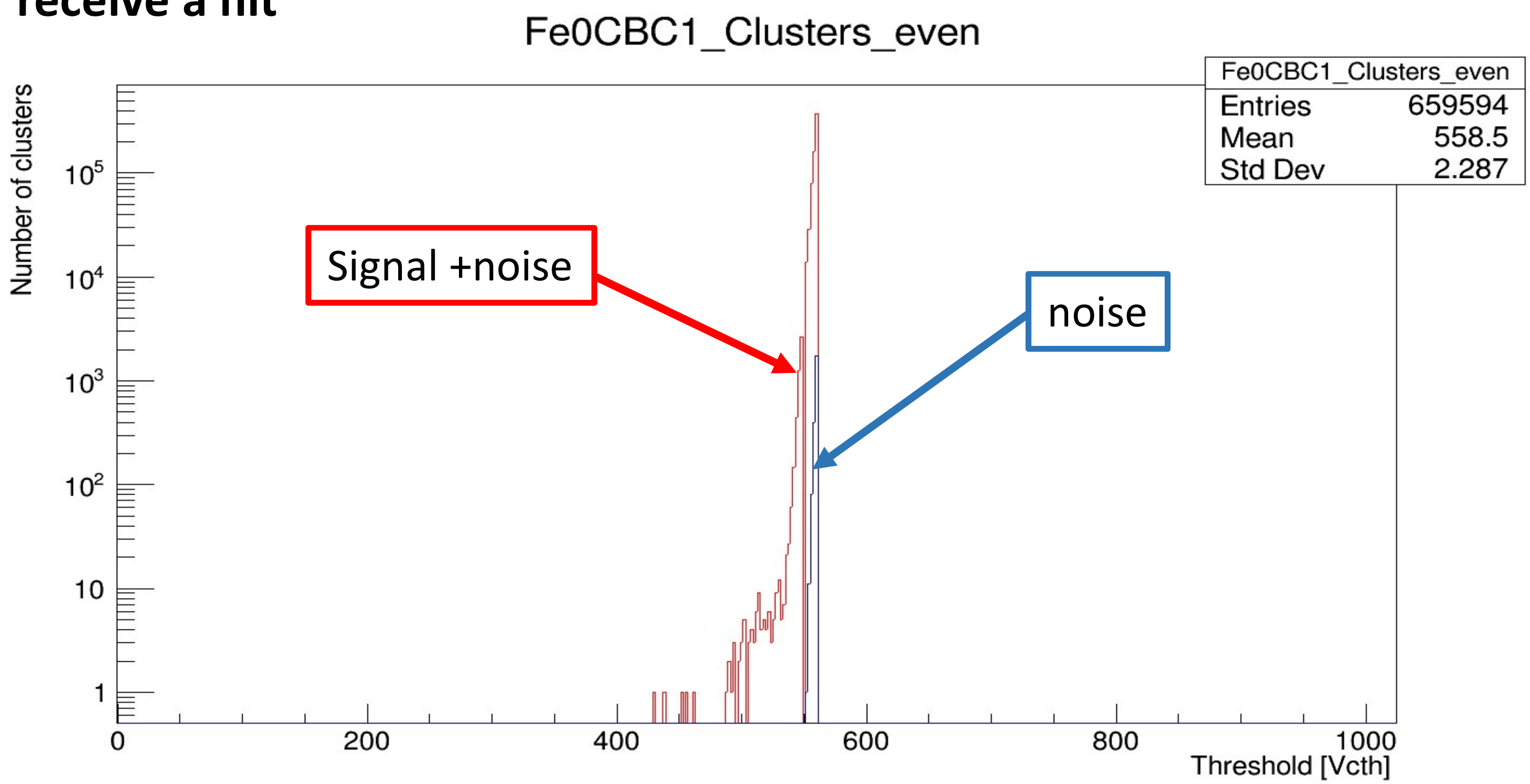
IV curves measured on 2S modules.

- soft breakdown : gradual increase of the current after a certain point.

- Hard breakdown : sudden increase in the current

Threshold Scan (Source)

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

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