Development of a characterization set-up for testing position sensitive silicon micro-strip sensors at the University of Delhi

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21st International Workshop on Radiation Imaging Detectors

Chania, Crete, Greece

(7-12 July, 2019)

Outline

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- *Silicon strip sensor*
- *Measurements results*
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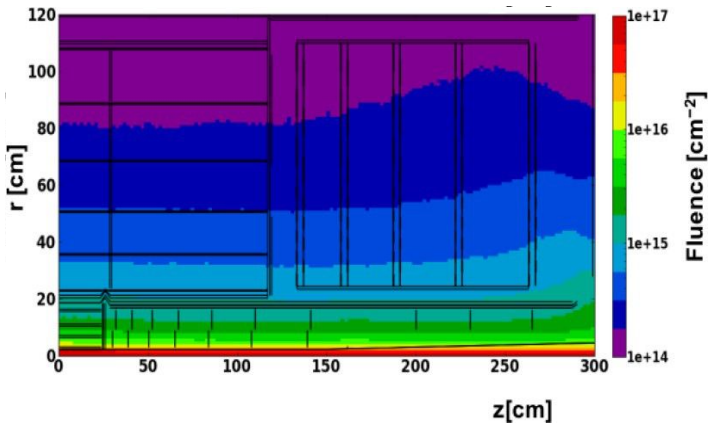
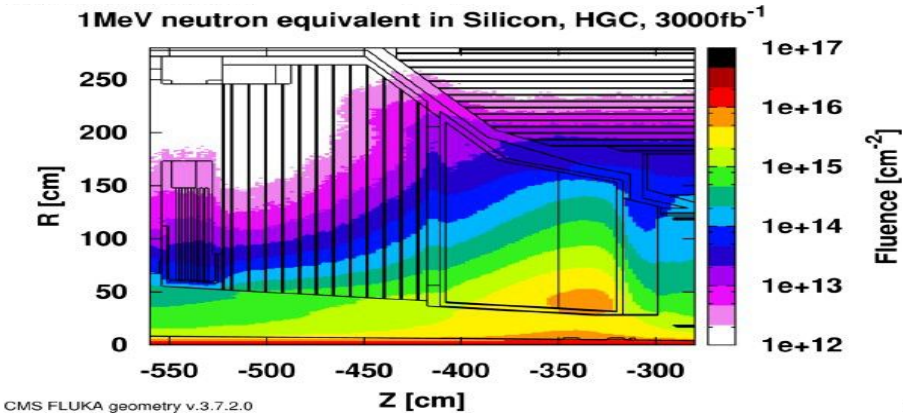
Motivation and Introduction

Predictions of the maximum 1MeV n_{eq} fluences normalized to 3000fb^{-1} of **HL-LHC**





Expected particle fluence in the ***Tracker volume***

Expected particle fluence in ***End cap calorimeter***

LHC Runs 1, 2 **L=Luminosity**

- **Peak L ~ 1.5 x 10^{34} cm^{-2}s^{-1}**
- **Expected Integrated L = 500 fb^{-1}(10 yrs of operation)**

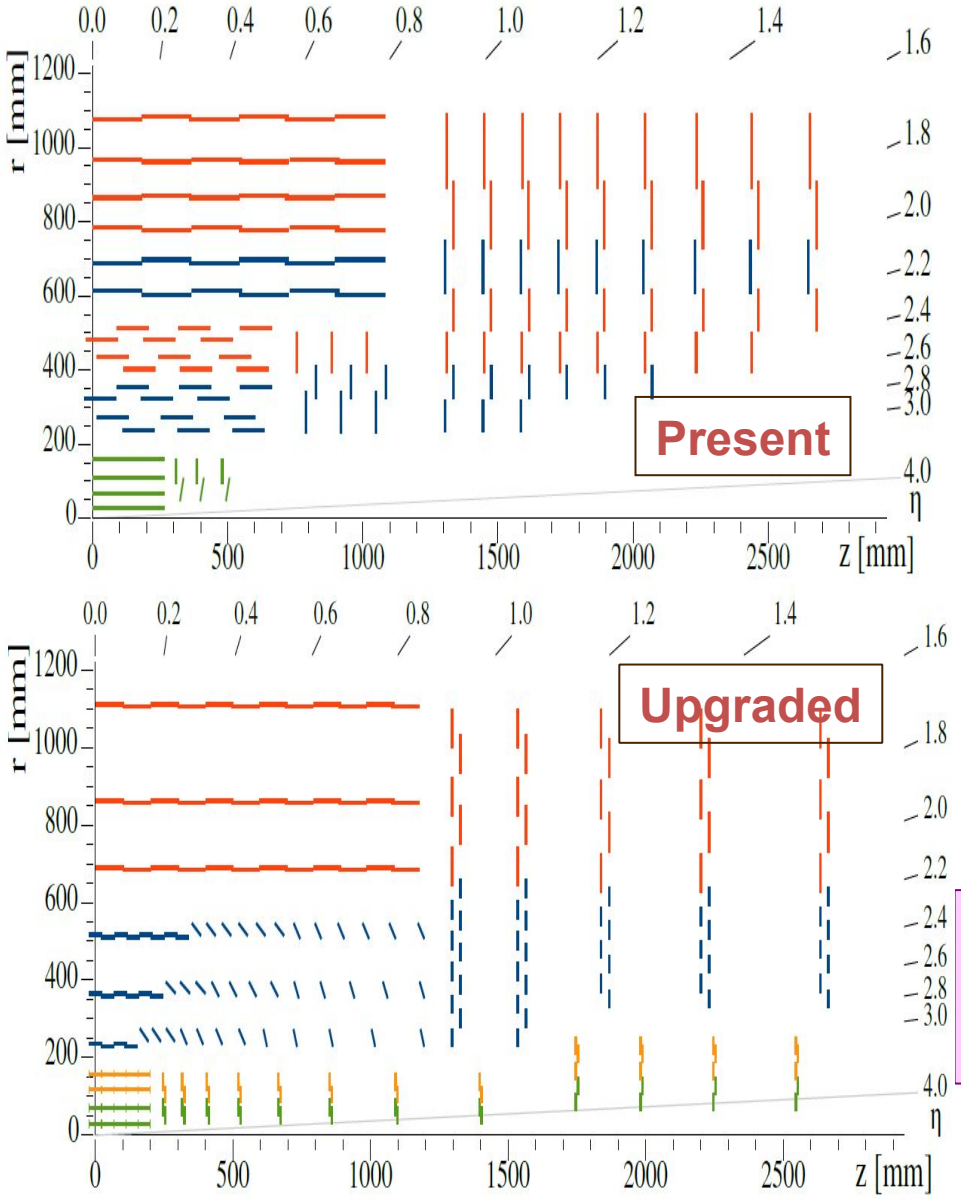
HL-LHC Phase

- **Peak L ~ 5-7 x10^{34} cm^{-2}s^{-1}**
- **Integrated L = 3000 fb^{-1} (10 yrs of operation)**

Need to upgrade the outer tracker by using more radiation hard silicon sensors !!

Region	Maximum Fluence (1 MeV n_{eq} cm^{-2})
Outer tracker	1.1 x 10^{15}
Endcap Calorimeter	1.5 x 10^{16}

Upgrade of tracker and endcap calorimeter of CMS experiment

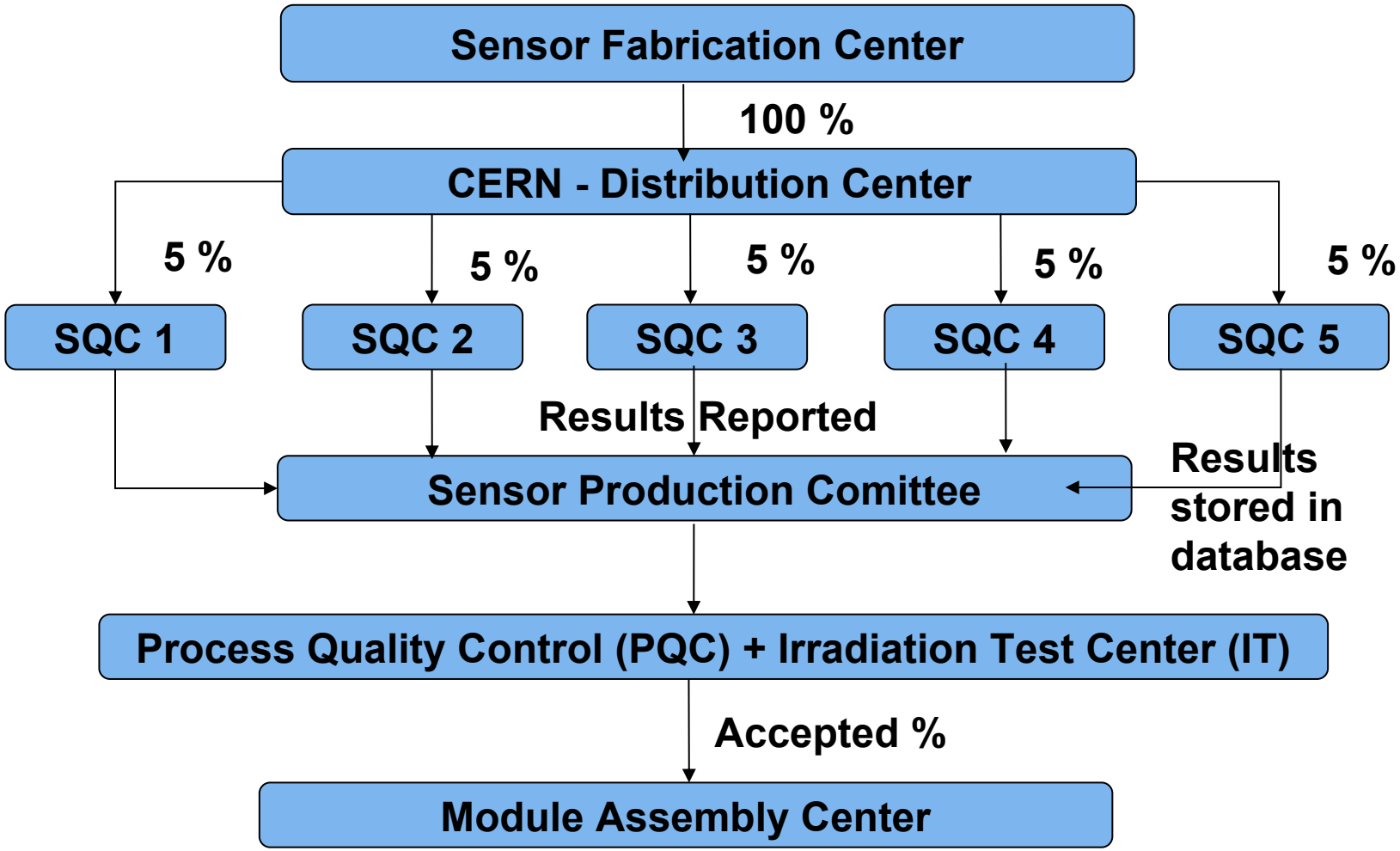


Present	Phase 2 Upgrade
p-on-n	n-on-p
3 Discs of Pixel	10 Discs of Pixel
~124 millions pixels ~10 millions Strip detectprs	~218 millions pixels ~50 millions strip detectors
Active area ~200 m^2 Pixels : 2 m^2 Strips : 198 m^2	Active area~215 m^2 Pixels : 4 m^2 2S & PS modeules : 150+60 m^2
$\|\eta\| < 2.7$	$\|\eta\| < 4.0$

These sensors have to be extensively tested, prior to their installation, under the controlled environment of SQC.

Sensor Qualification Center

Quality Assurance Scheme for OT strip sensors



100% of the accepted sensors are bonded

Preliminary Specifications*

- **Environmental conditions**
  - Have to be monitored during measurements and should be within the following range:
    - Temperature: 22±2˚C
    - Humidity: < 40% rH
- **Global measurements on sensors**
  - Extracted from I-V and C-V curves on the full sensor (bias voltage between bias ring and backplane) from 0 V – 700 V
    - Full depletion voltage Vfd: < 150 V for 200 μm (LCR settings: < 1 V and 1 kHz)
      < 300 V for 300 μm
    - Current @500V I_{500}: ≤ 2 nA/mm³ (< 5 μA for 100 x 100 x 0.2 mm)
    - Breakdown voltage Vbreak: > 700 V (un-irradiated), $I_{700} < 3 \times I_{500}$
      > 1000 V (for F ≥ 5e14neq/cm²), $I_{1000} < 4 \times I_{700}$
    - Long-term stability: $|\Delta I_{500}/I_{500}| < 48\%$ in 48 h @ 500 V bias
- **Measurements on each strip**
  - Measurements to be performed on each strip of a sensor at Vbias=300 V
    - Strip current I_{strip}: < 2 nA/cm
    - Bias resistor Rpoly: mean(Rpoly): 1.5 ± 0.3 MΩ RMS(Rpoly) : 5%
    - Coupling capacitance Cac: > 1.2 pF/cm μm
    - Inter-strip resistance Rint: > 10 GΩ cm
    - Inter-strip capacitance C_{int} < 1 pF/cm
    - Pinhole check: Idiel < 1 nA@10 V

- **Bad Strips : Max. Number of bad strips: < 0.5 % per sensor (10/2032) Strips are considered as bad strips if any of the criteria from Measurements on each strip are not fulfilled for the respective strip.**

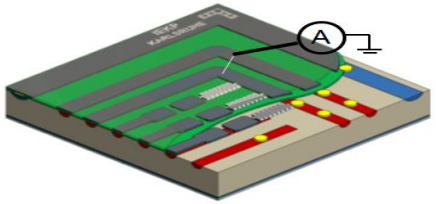
*These specs are getting evolved : CMS Technical Design Report

Measurements performed using the Qualification System

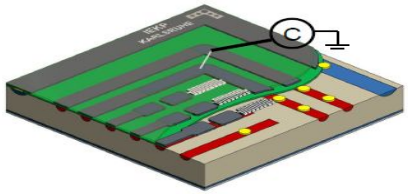
To ensure the performance and quality of each detector certain tests have to be performed on few samples on each batch.

Electrical Characterizations tests

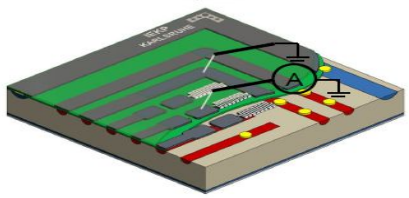
1. IV
Sensor current vs Bias



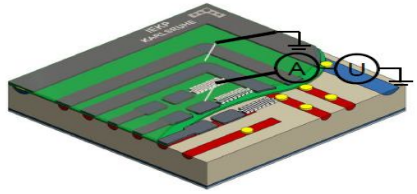
2. CV
Sensor capacitance vs Bias



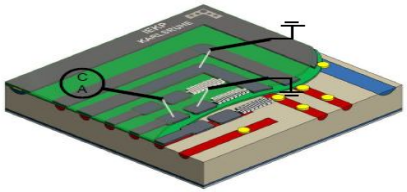
3. I_{leak}
Strip leakage current



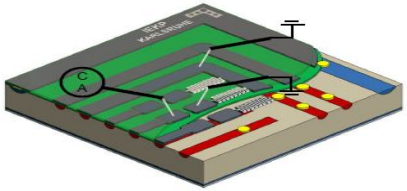
4. R_{bias}
Strip bias resistor



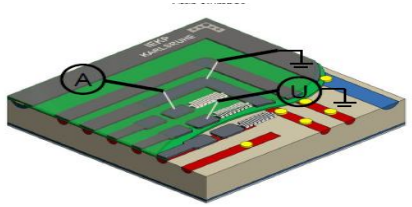
5. C_{Coup}
Coupling capacitance



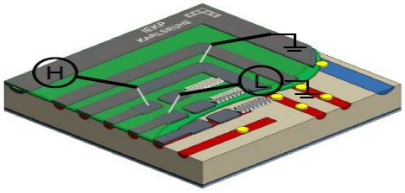
6. I_{diel}
Dielectric current



7. R_{int}
Interstrip resistance



8. C_{int}
Interstrip capacitance



Sensor Qualification Facility at DU

Basic Requirements for SQC (1/2)

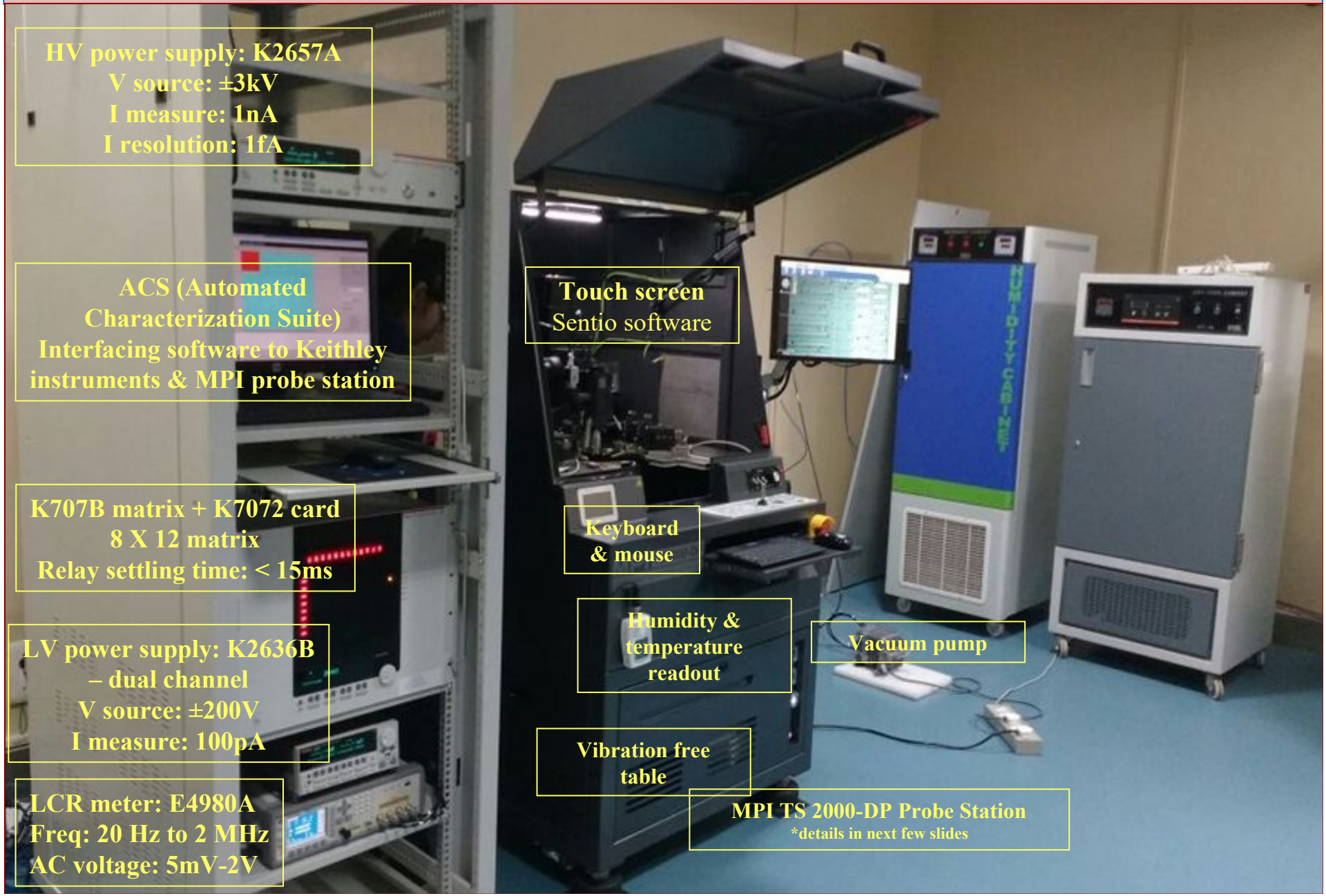
Clean Room	Class 10,000, Area ~40 m^2
Source Measuring Units	K2657A (single channel) Voltage range : 5 mV to 3 kV Current range : 30 fA to 120 mA
	K2636B (Dual channel) Voltage range : 5 μV to 200 V Current range : 20 fA to 10 A
LCR Meter	E4980A Capacitance : 1e-18 to 1e18 F AC Voltage : 100 μV_{rms} to 2 V_{rms} Frequency range : 20 Hz to 2 MHz DC Voltage : 330 μV to 40 V
Isolation Box	Customized from CERN

Basic Requirements for SQC (2/2)

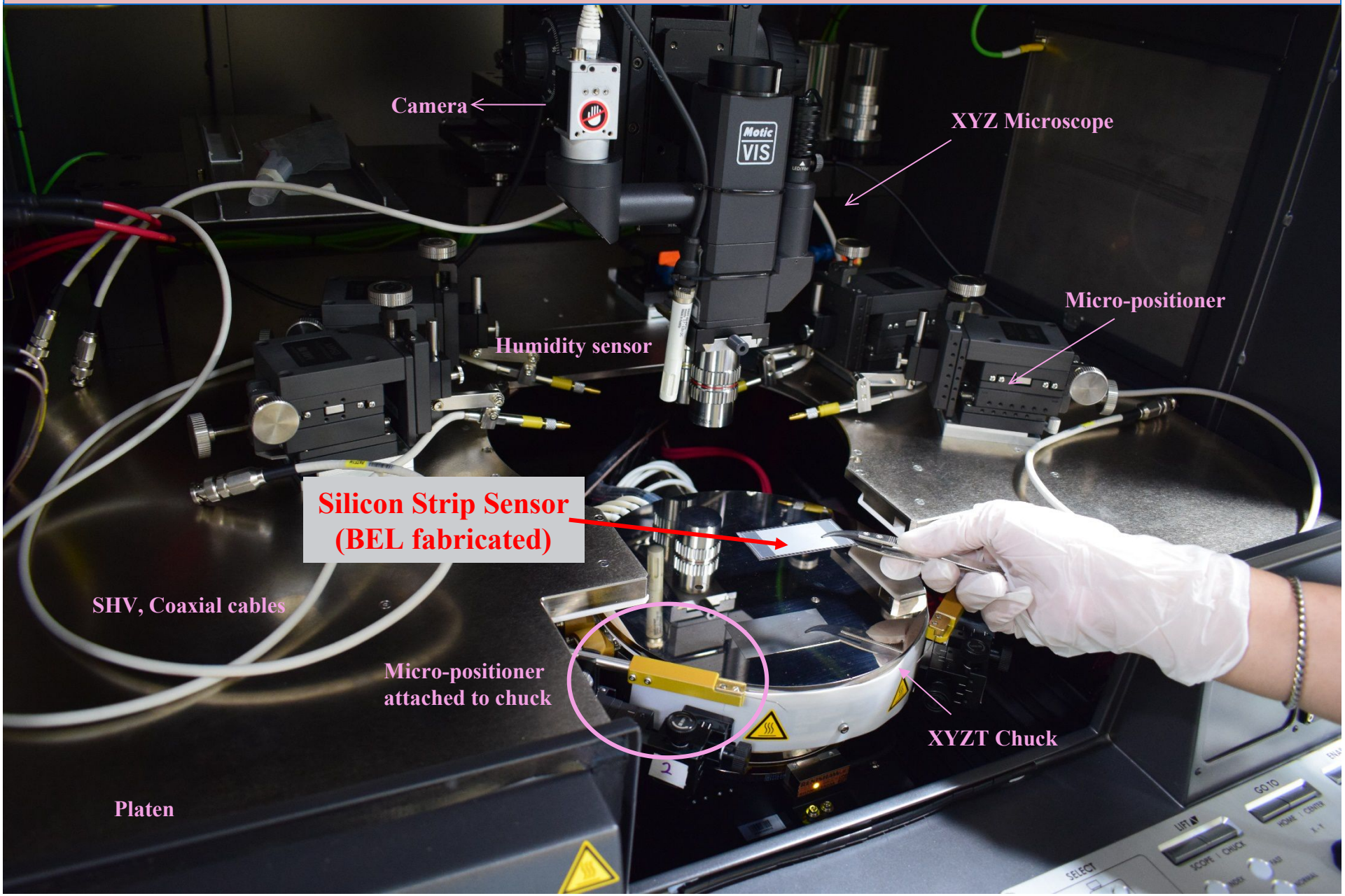
Light-tight humidity controlled chamber (MPI TS2000 DP)	
Chuck (200 mm)	Provision of Vacuum holes, temperature range : 13-200 ℃ XY stage : 210 X 340 mm (2 μm step) Z translation : 10 mm (1 μm step) θ stage : ± 5° (Resolution = 0.0004 ')
Microscope	2x, 5x and 10x magnification
storage cabinet	Low temperature cabinet, humidity Cabinet
Air Compressor	Anest Iwata SLPM-371EE (up to 1 Mpa or 10 bar)

Additional Equipments	
Protection Module	K2657A-PM-200
LO Interconnect Module	K2657A-LIM-3
Switching Matrix	K707B
Low voltage swtching card	K7072 Matrix card
High voltage swtching card	K7072-HV

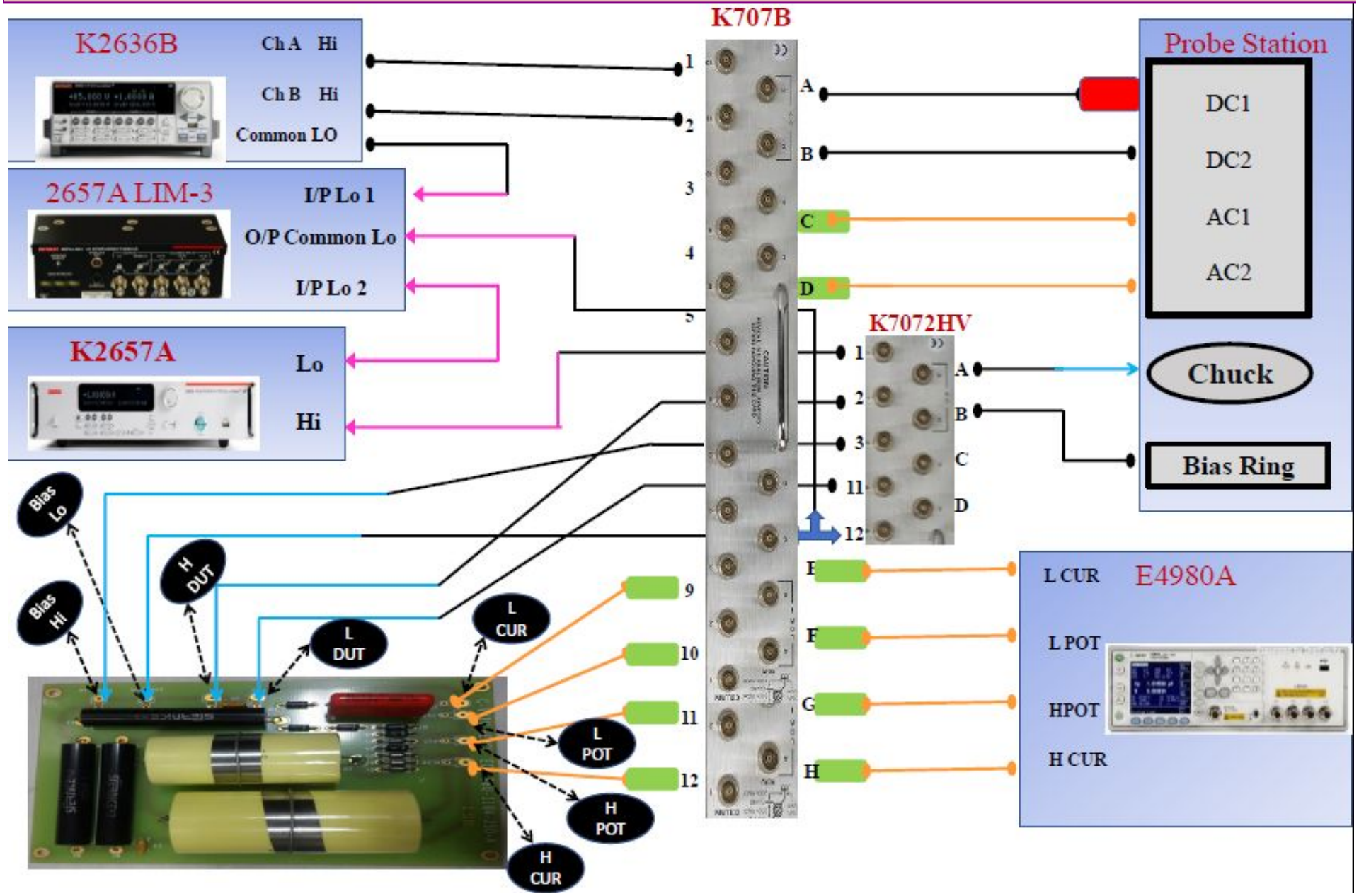
Electrical Instruments and Probe Station



Probe Station: In SQC lab



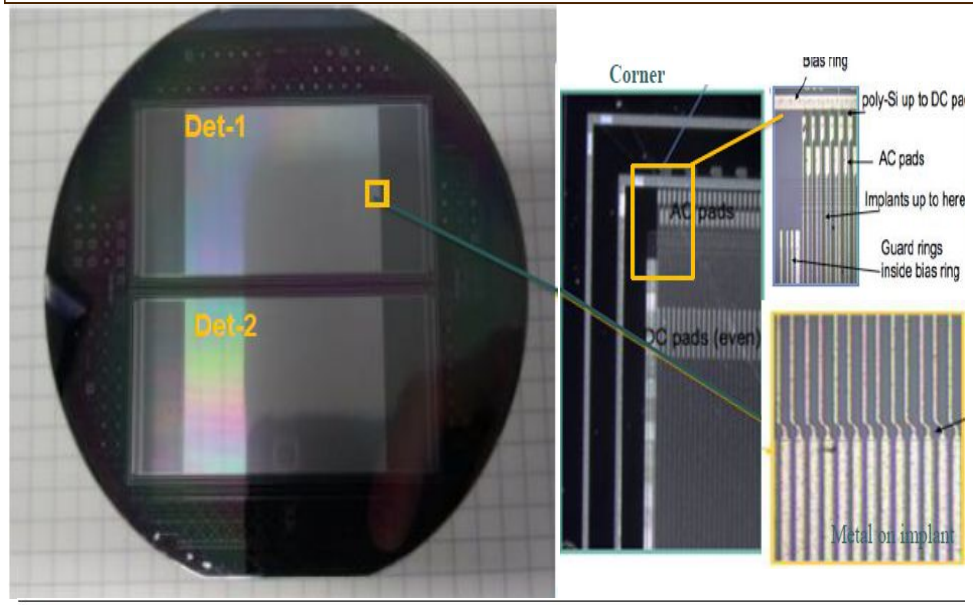
Master Connection Diagram



Measurements on strip sensor

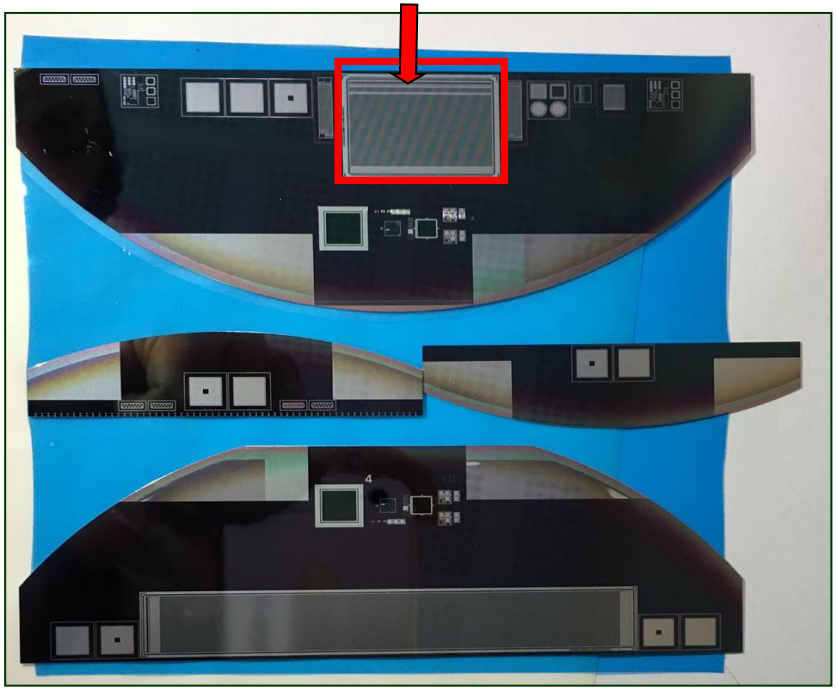
Silicon strip sensor

Indigeously developed in an Indian foundary*



Parameters	Value
Detector geometry	6.43 cm × 3.25 cm
Resistivity	2–5 kΩ · cm
Number of strips	512
Strip width	30 μm
Strip pitch	55 μm
Strip length	6 cm
Detector thickness	300 ± 20 μm
Metal overhang	5 μm on both sides of the strip
Number of guard rings	4
Width of guard rings	50 μm for innermost, 25 μm for others
Spacing between strip and guard ring	25 μm
Spacing between guard rings	25, 30,40 μm
Aluminium contacts	DC and AC pads

CMS Mini Strip Sensor for Phase 1



p-on-n
 # strips = 192
Strip Pitch = 120 μm

Measurements are shown in the next slides for CMS mini strip sensors from Phase 1

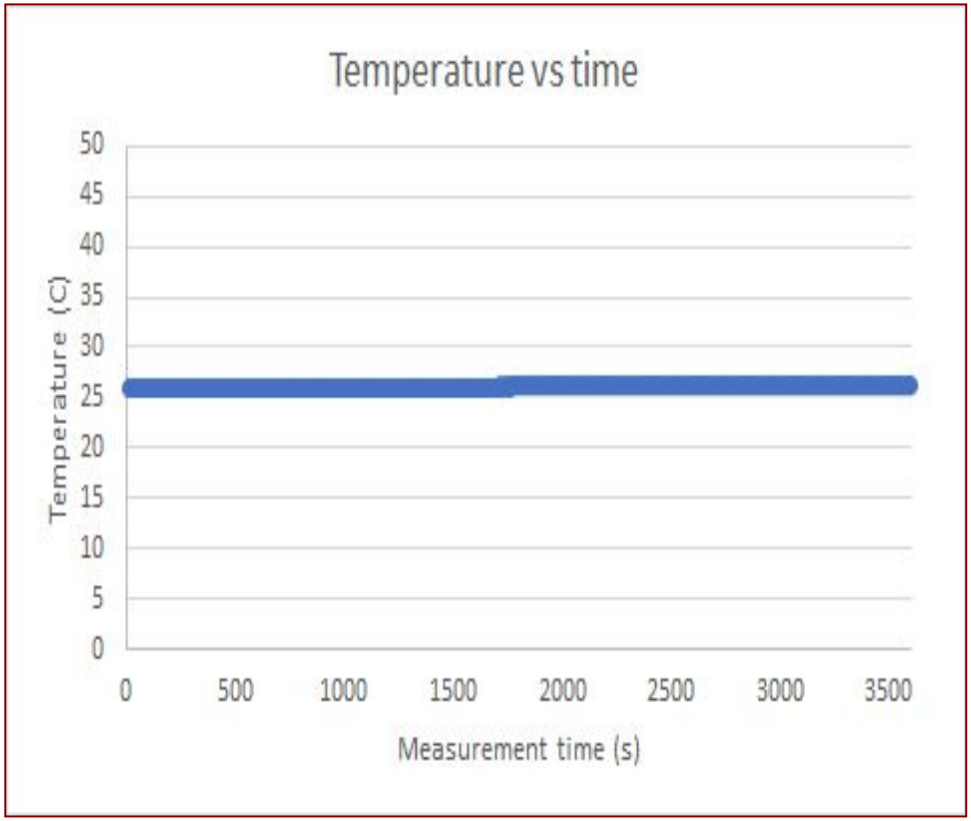
G. Jain, R. Dalal, A. Bhardwaj, K. Ranjan, Development of AC-coupled, poly-silicon biased, p-on-n silicon strip detectors in india for HEP experiments, NIM A 882 (2018)1–10.

Measurements using the Qualification System

Temperature = 20 ℃
Relative Humidity < 10 %

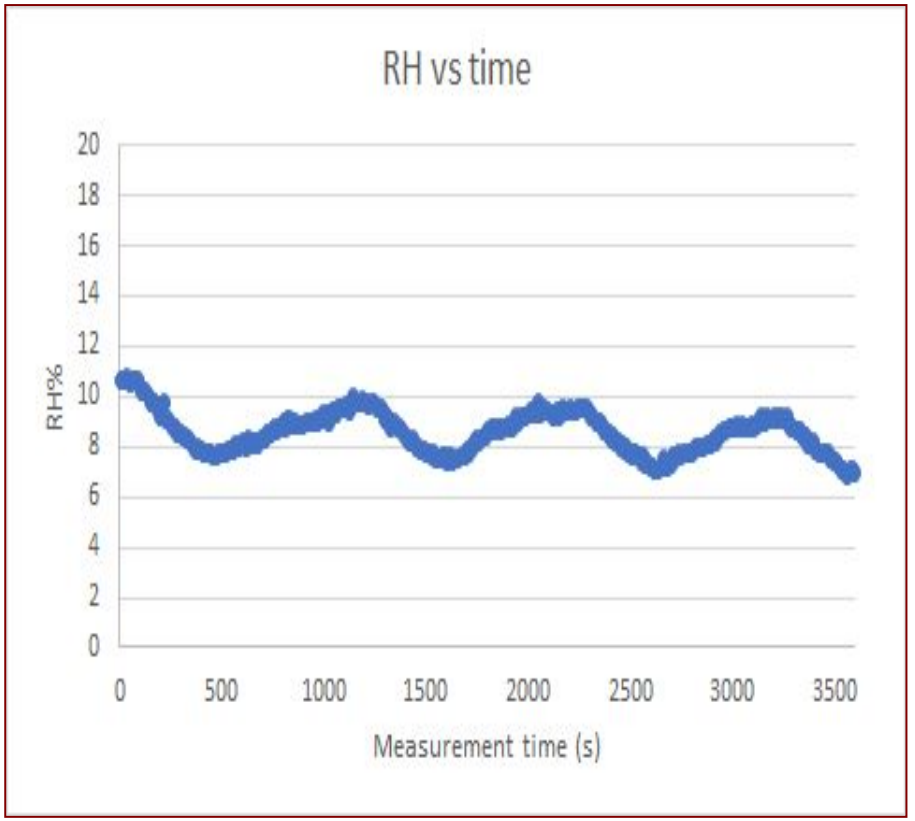
Environmental Conditions

Temperature vs Time



Stable temperature observed throughout the measurements

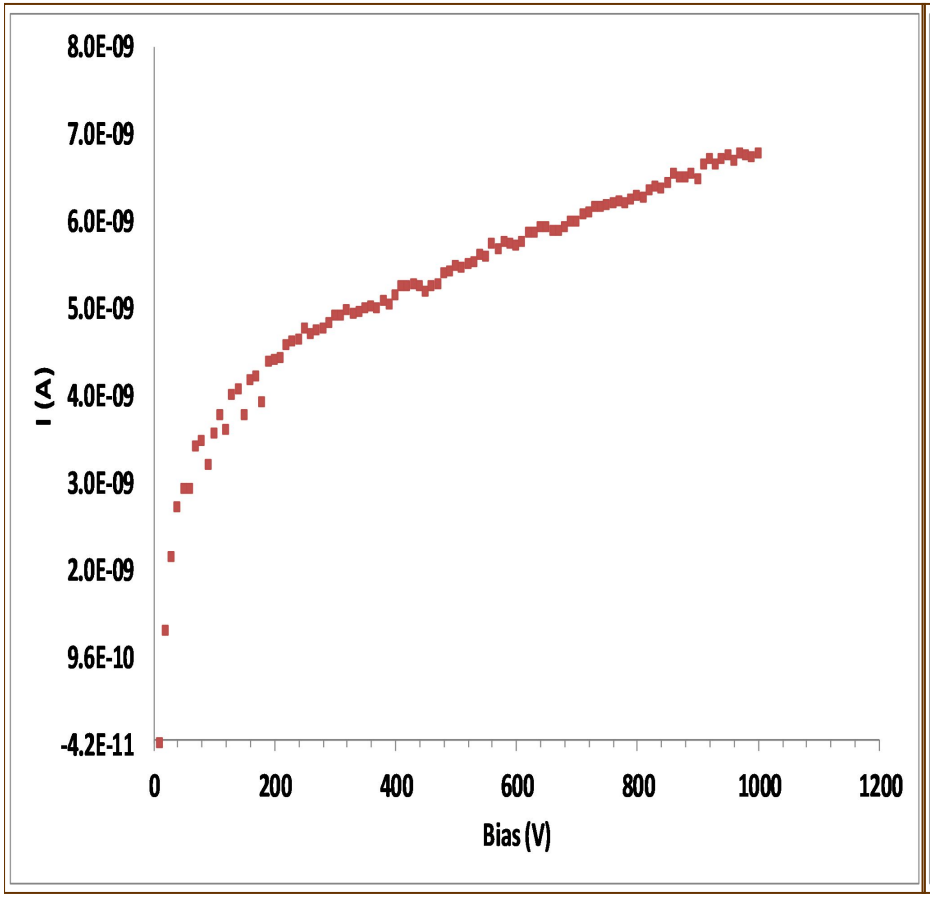
Relative Humidity vs Time



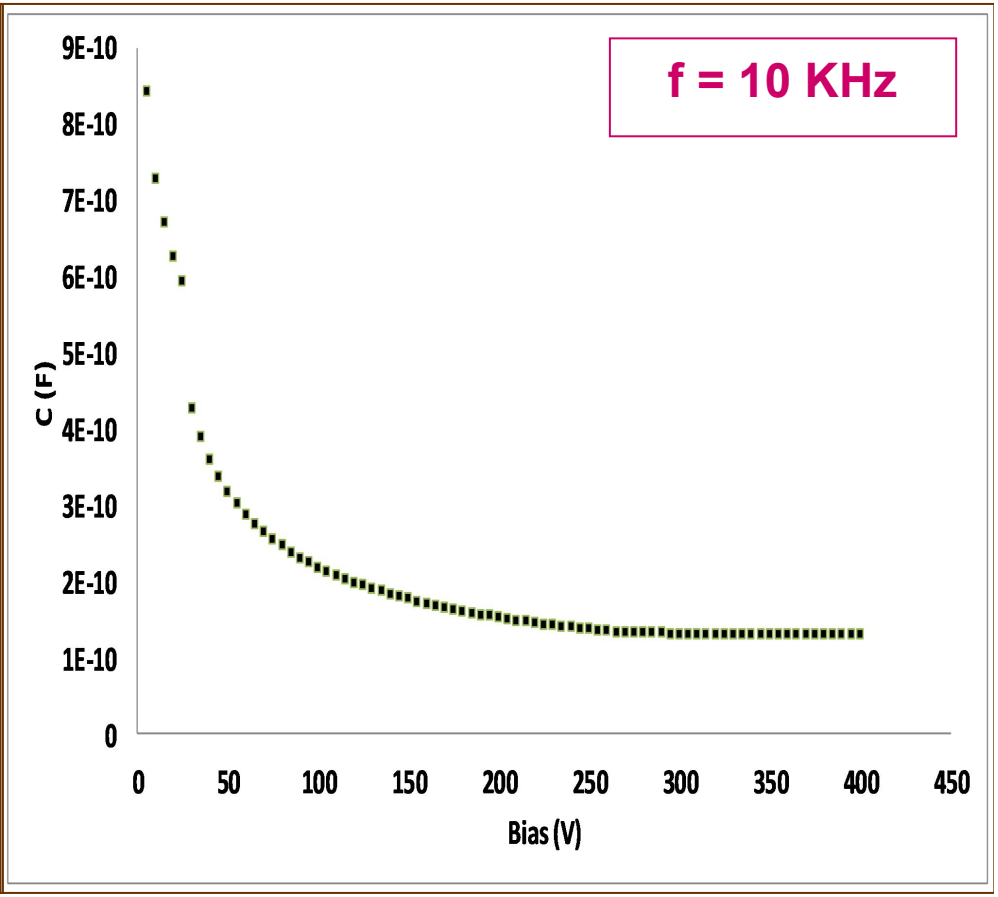
RH% of ~ 10% maintained during measurements

Global Measurements

IV Characteristics

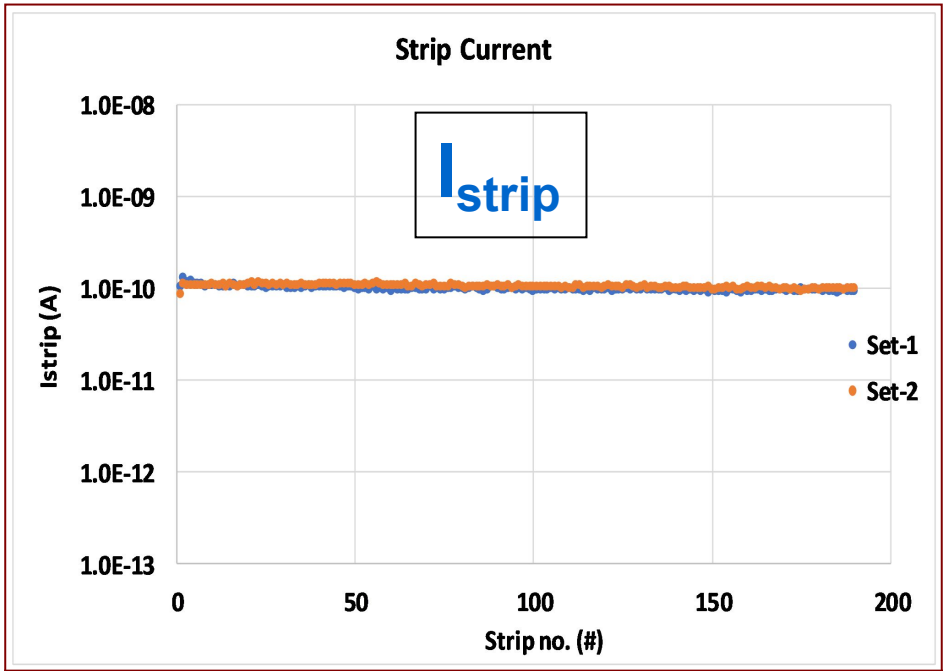


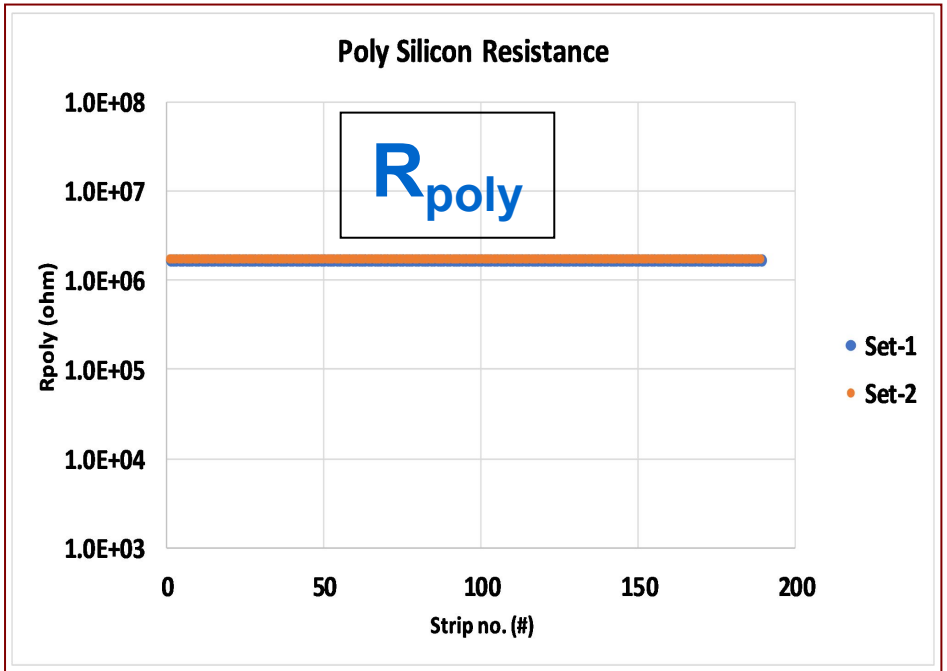
CV Characteristics

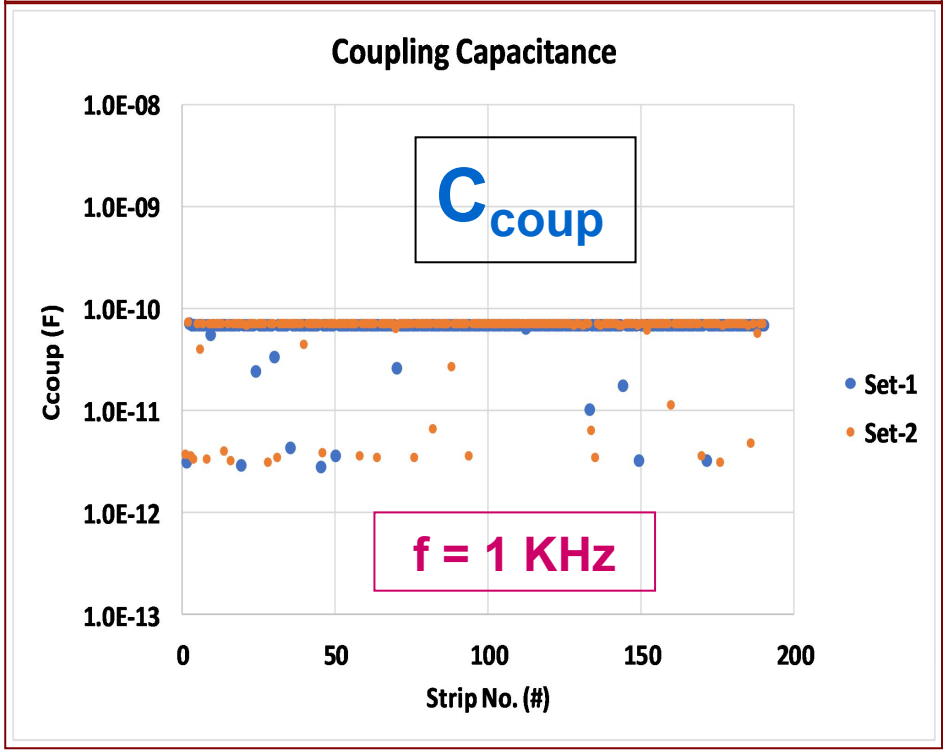


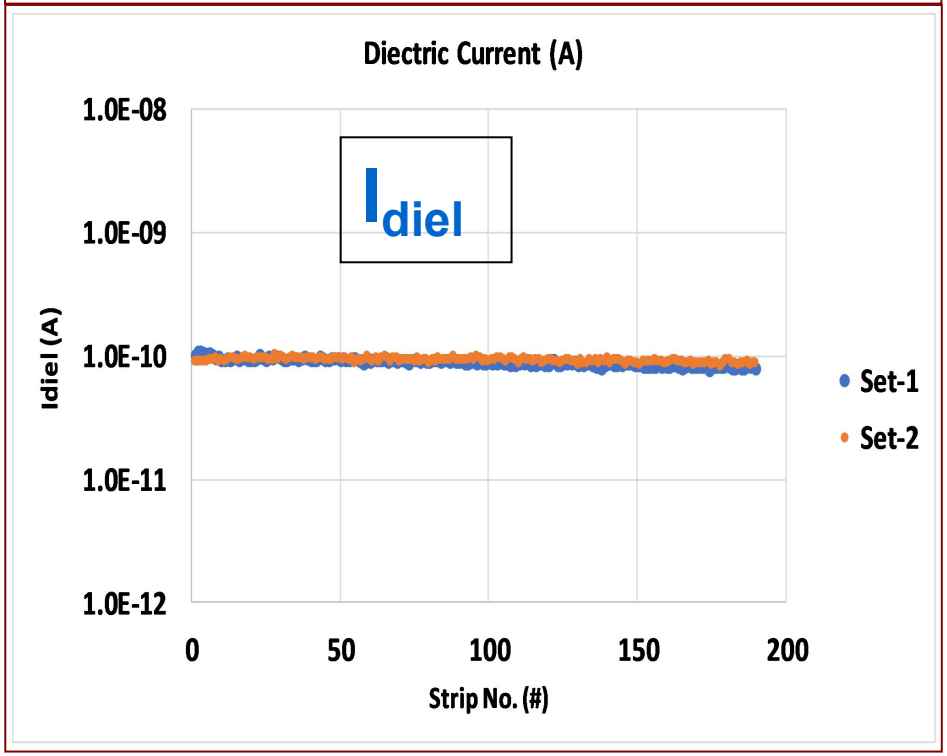
Strip Measurements

$V_{Bias} = 250$ V


Strip Current
Istrip
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
1.0E-13
Istrip (A)
0
50
100
150
200
Strip no. (#)
Set-1
Set-2

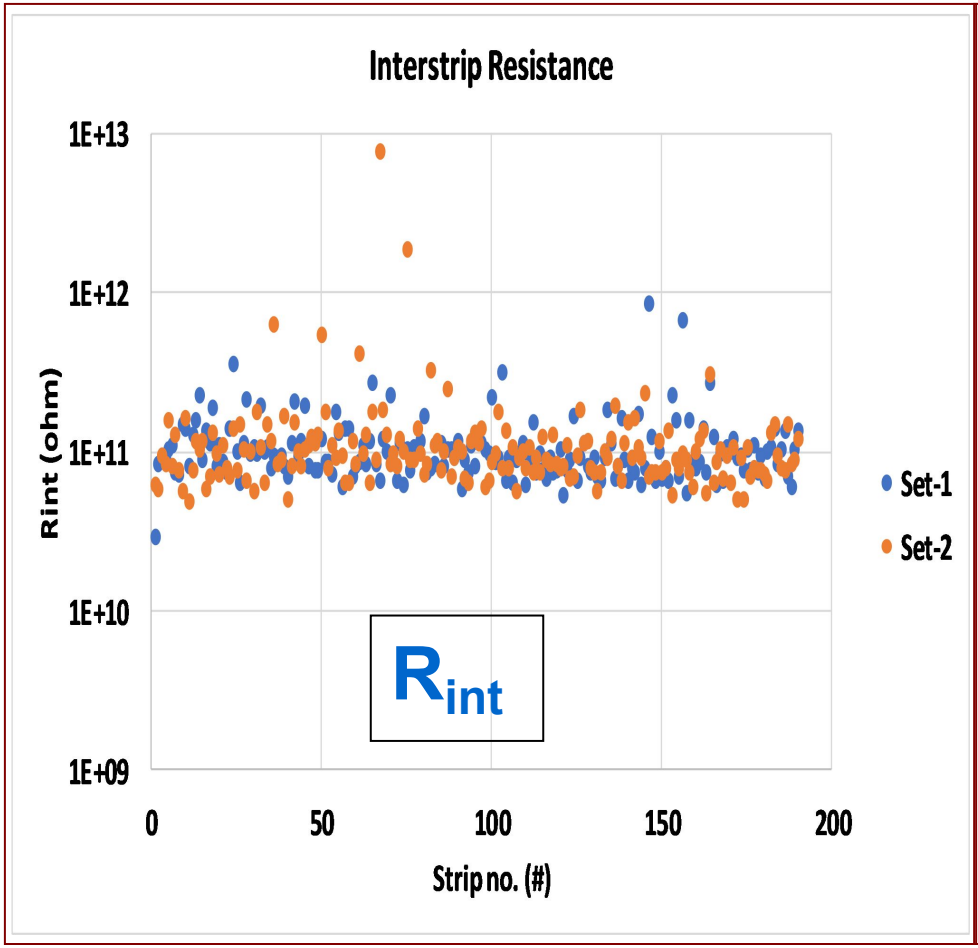

Poly Silicon Resistance
Rpoly
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
Rpoly (ohm)
0
50
100
150
200
Strip no. (#)
Set-1
Set-2

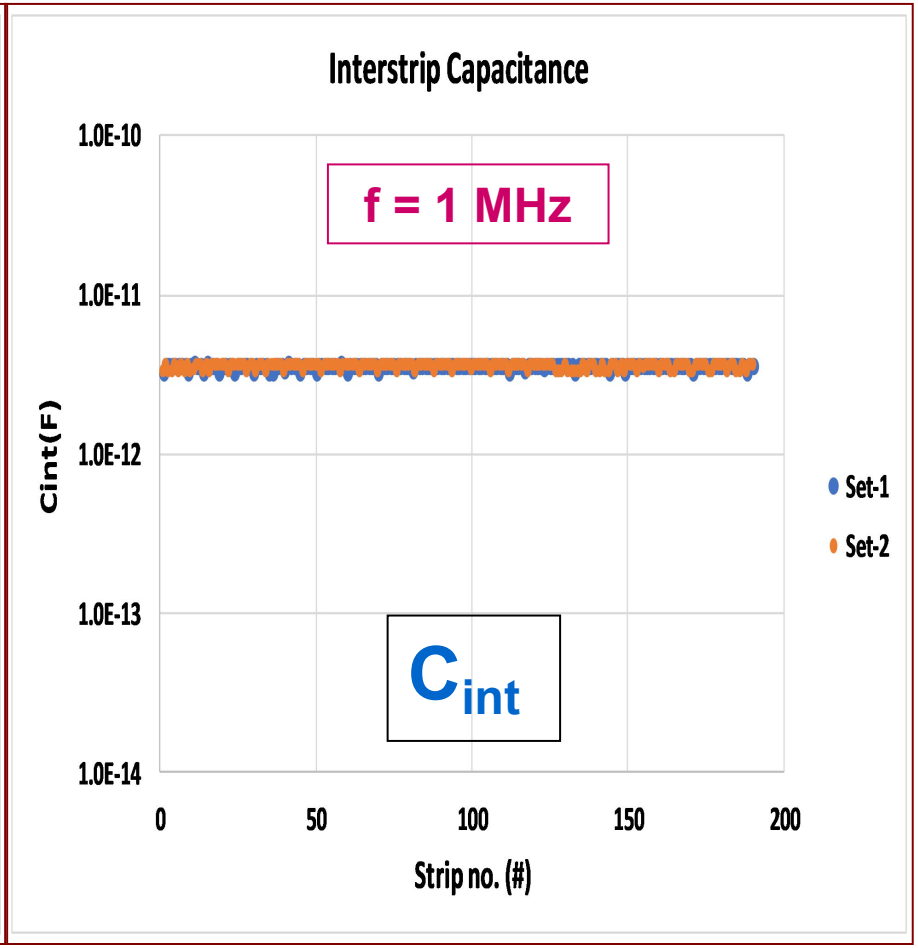

Coupling Capacitance
Ccoup
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
1.0E-13
Ccoup (F)
0
50
100
150
200
Strip No. (#)
f = 1 KHz
Set-1
Set-2


Diectric Current (A)
Idiel
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
Idiel (A)
0
50
100
150
200
Strip No. (#)
Set-1
Set-2

Inter-strip Measurements

V_{Bias} = 250 V





Expected Measurement Duration

2S	Measurement	Multiplicity	Duration (min)	Total (min)
	IV to 1000 V	1	0.84	0.84
	CV to 400V	1	1.33	1.33
	Strip (C_{Coup}, I_{strip}, R_{poly}, I_{diel})	2032	0.25	508
	Inter-strip (R_{int}, C_{int})	406	0.25	102
	Alignment	2	10	20

Total time~ 632 min (~10.5 h)

Summary and Future Outlook

- **The silicon sensor automated characterization facility is developed in the University of Delhi, India.**

- **Measurements are performed on strip sensors of CMS mini strip sensors.**

- **Measurement results are found to be reproducible and with in the tolerance limits for specific parameters.**

Future Outlook

- **This facility is proposed to be used for characterization and qualification of the 2S sensors during the production phase of the CMS Outer Tracker Phase II Upgrade in HL-LHC phase.**

Thank You