Quality Assurance of Silicon Microstrip Sensors for the CBM Experiment

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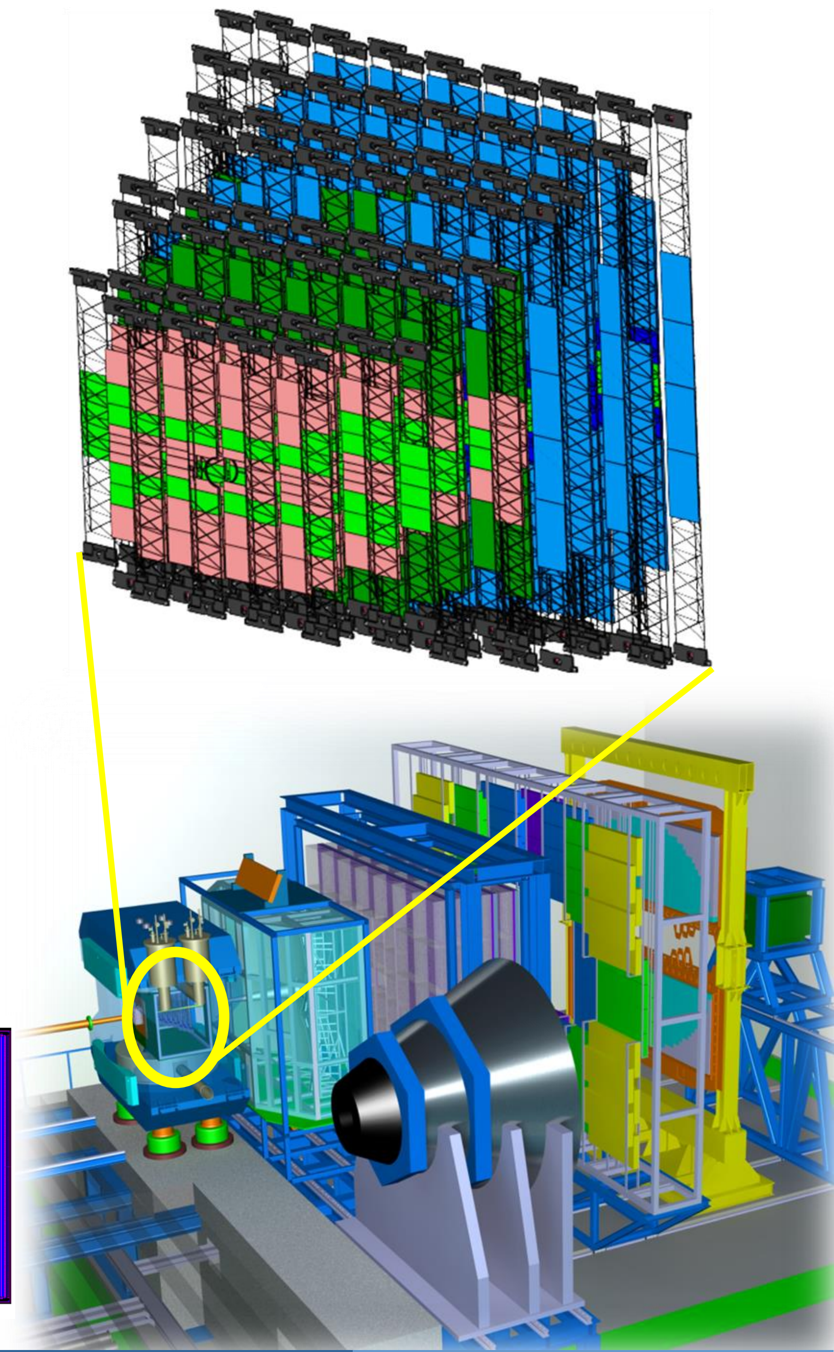
for the CBM Collaboration

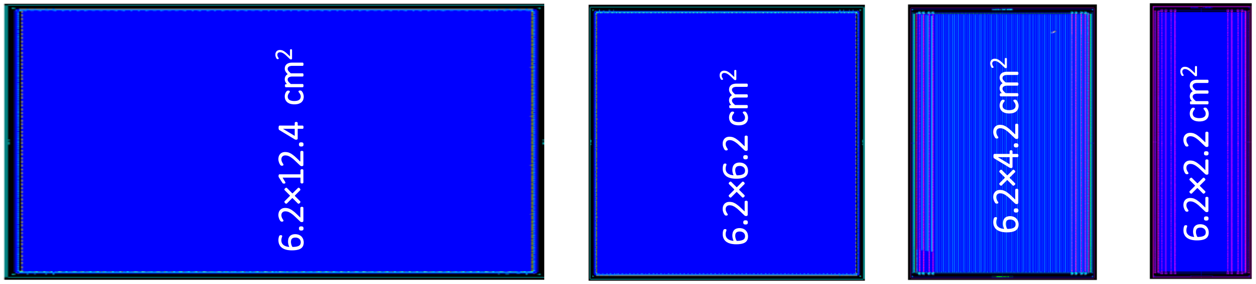
(Münster, DPG-2017)

STS

Silicon Tracking System (STS) – part of the CBM detector – 8 detection layers entirely covered by silicon microstrip detectors .

- Total silicon area 4.2 m^2
- Number of sensors – about 900 double-sided sensors in 4 sizes
- 1024 strips / side ≈ **1.8M strips** in total
- Ultra-thin long microcables
- Read-out electronics outside the detector acceptance

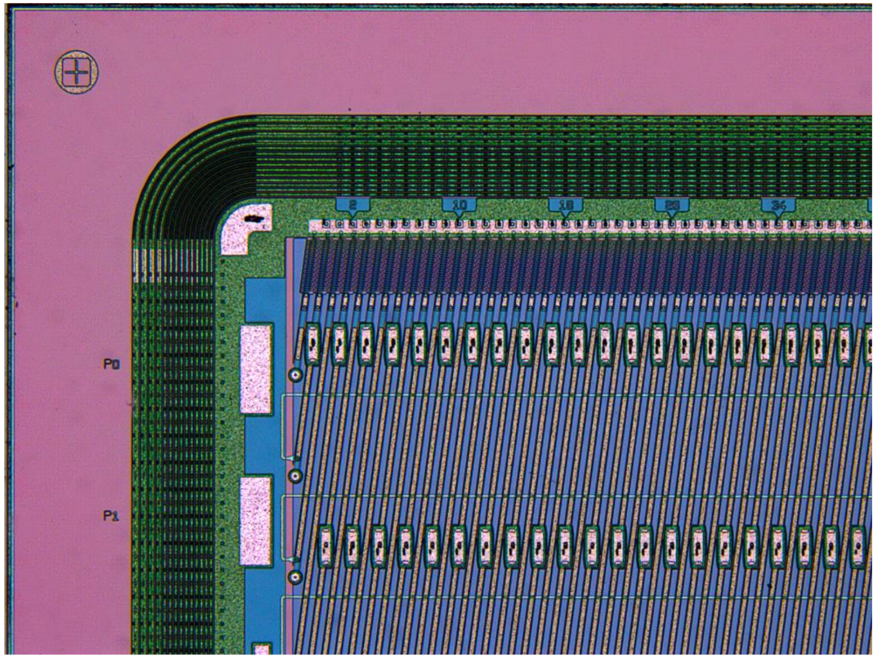


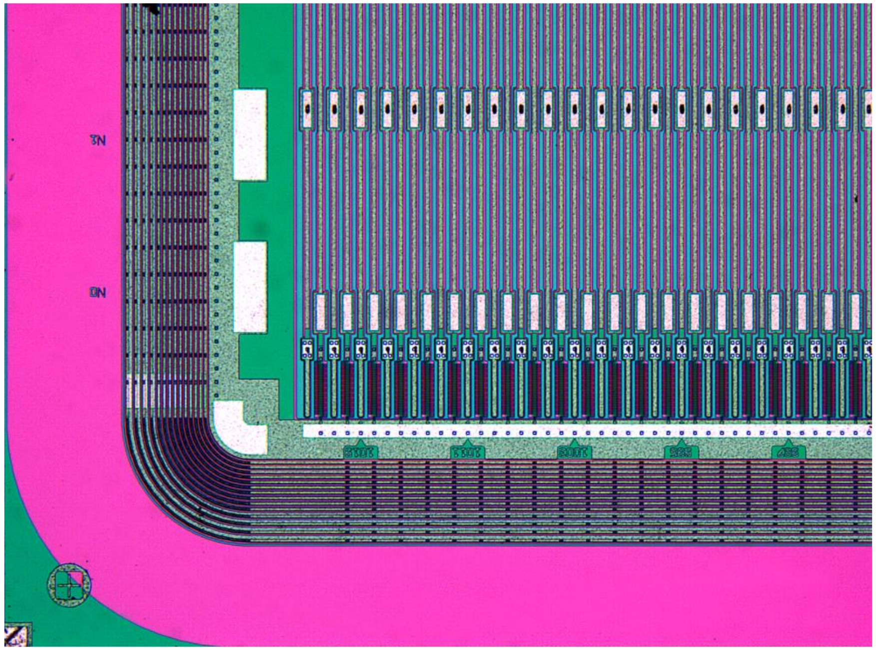


CBM MICROSTRIP SENSOR

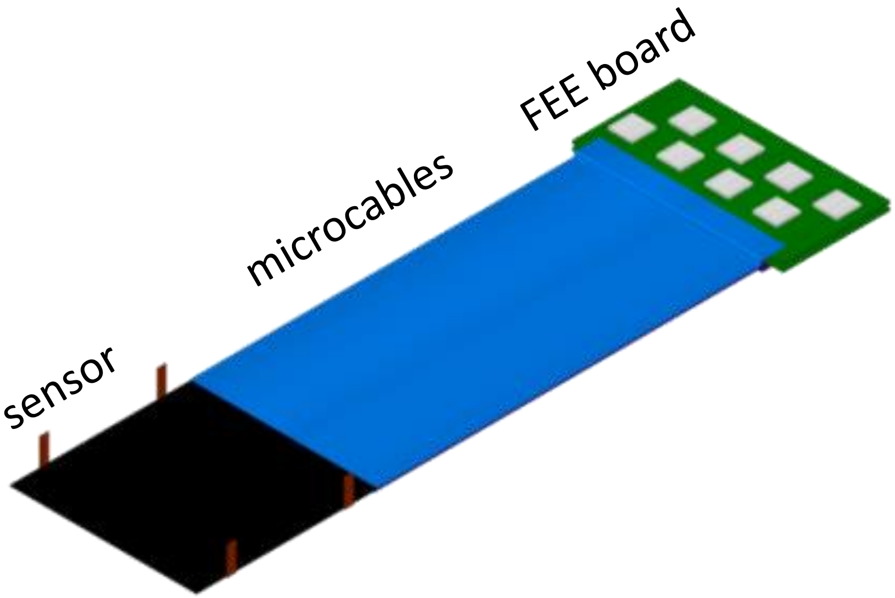
- n-type Si bulk
- thickness 285-320 µm
- double-sided
- **1024 strips** per side
- strip pitch **58 µm**
- strips under 7.5 deg angle on p-side
- double metallization on p-side:
  - AC coupled strips – 1st metal layer
  - routing lines for side strips - 2nd metal layer
- 4 rows of AC pads + 1 row of DC pads

Depletion Voltage	< 100 V
Leakage current	< 50 µA @ FVD+20 V
Junction breakdown	> 200 V
Coupling capacitance	> 10 pF/cm
Coupling capacitor breakdown	> 100 V
Interstrip capacitance	< 0.6 pF/cm
Polysilicon bias resistor	1.5 MOhm ± 20%
Defective strips	< 1% per sensor

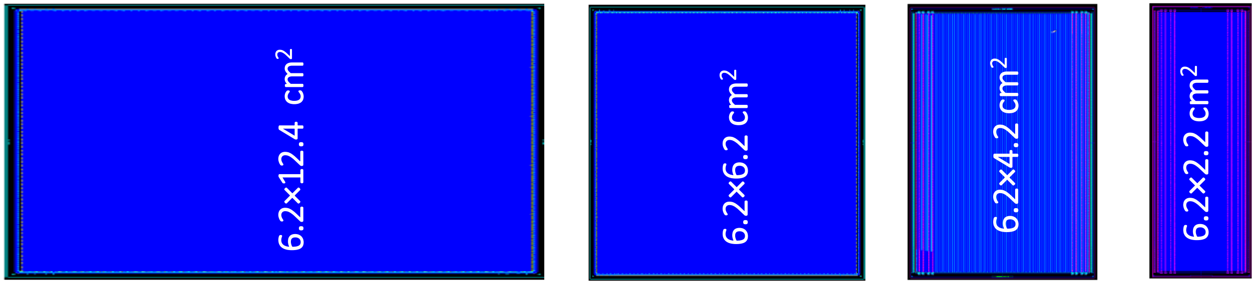




STS MODULE



Sensor' bulk and strip quality prior to module assembly



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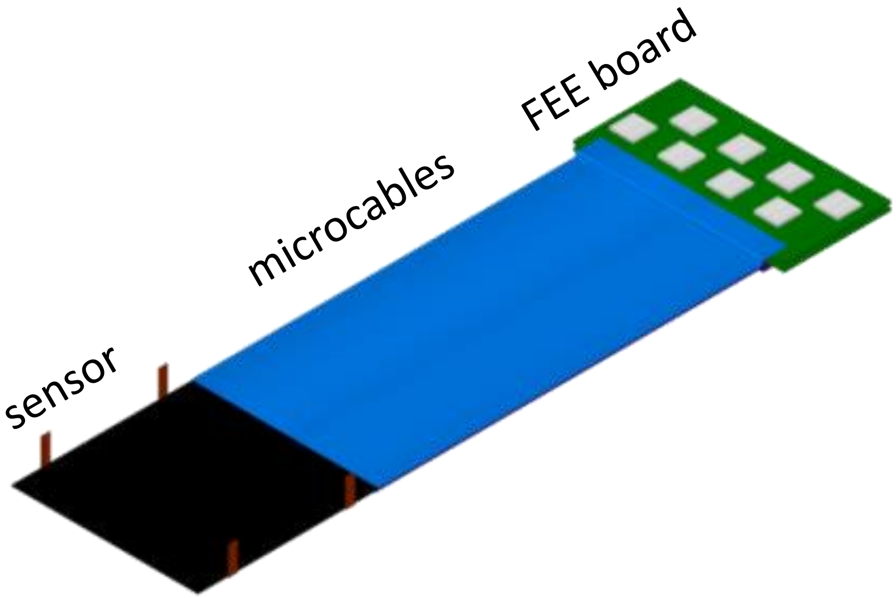
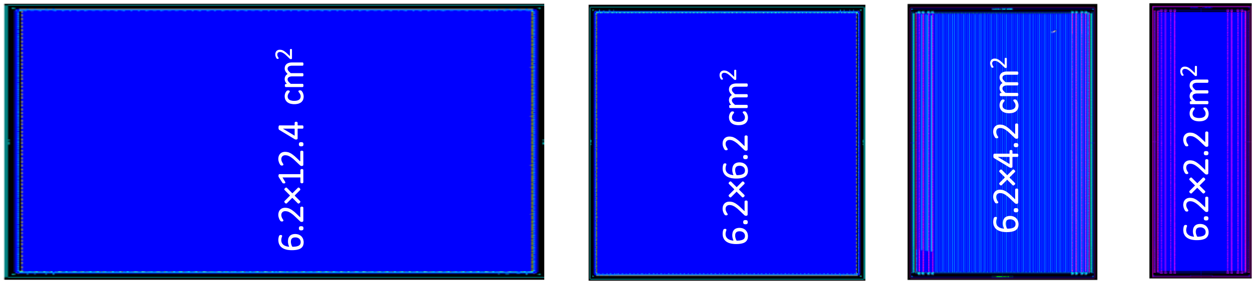


Sensor' bulk and strip quality prior to module assembly

- Efficient Quality Assurance is mandatory
- Determination of the electrical parameters of each strip requires:
  - Automated test system
  - Well-developed measurement techniques



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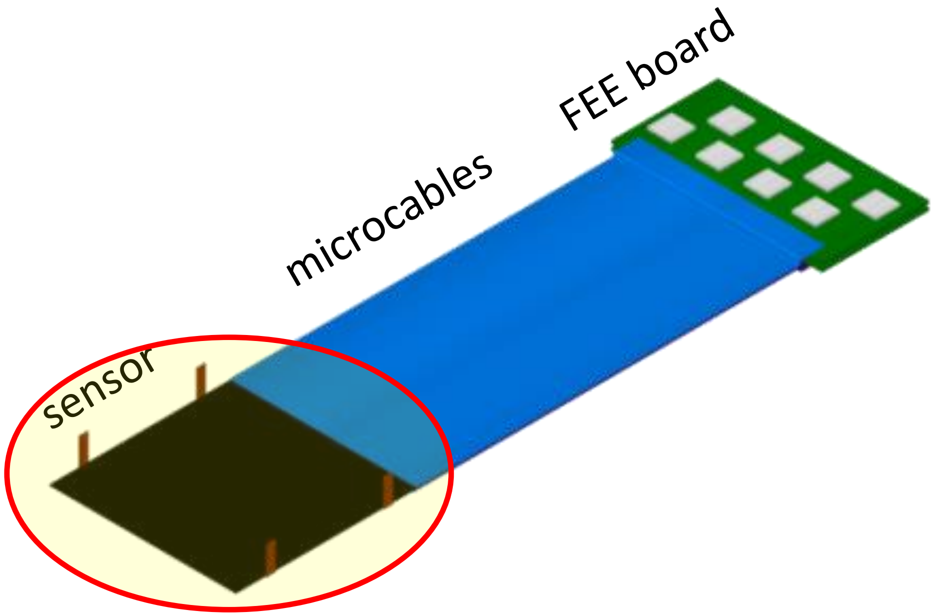

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⇩

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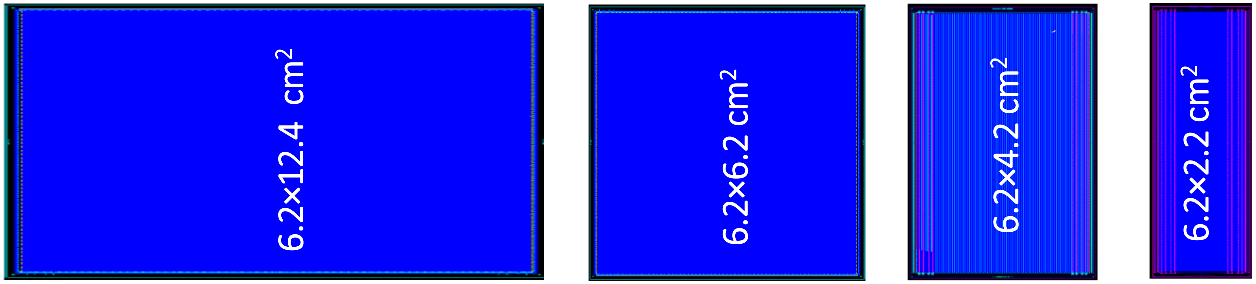

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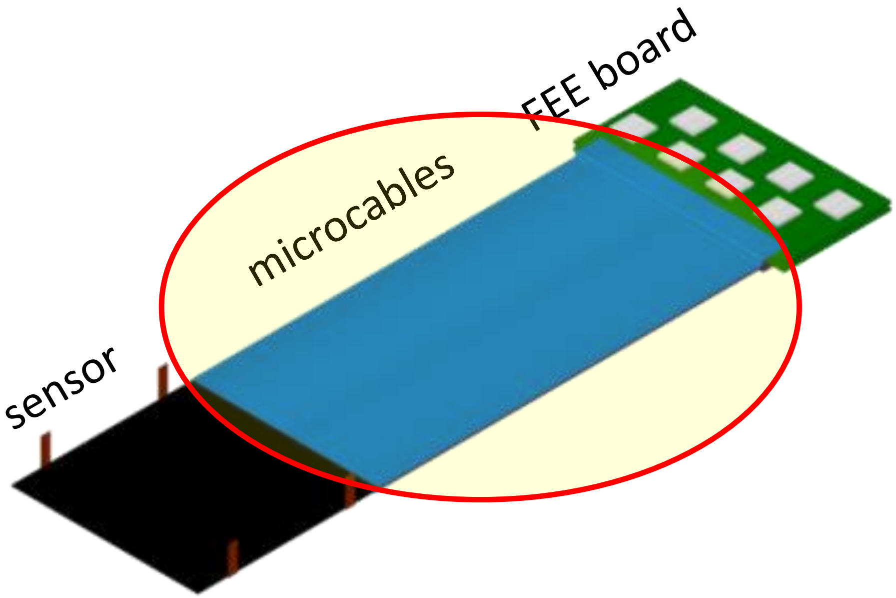

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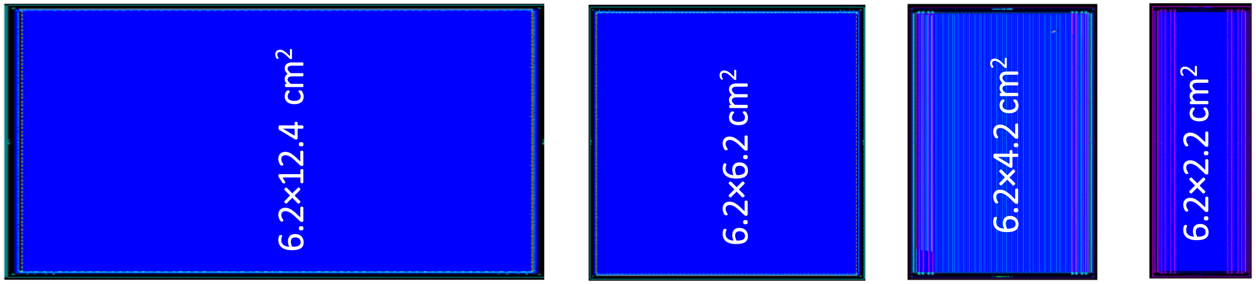


SENSOR CHARACTERIZATION

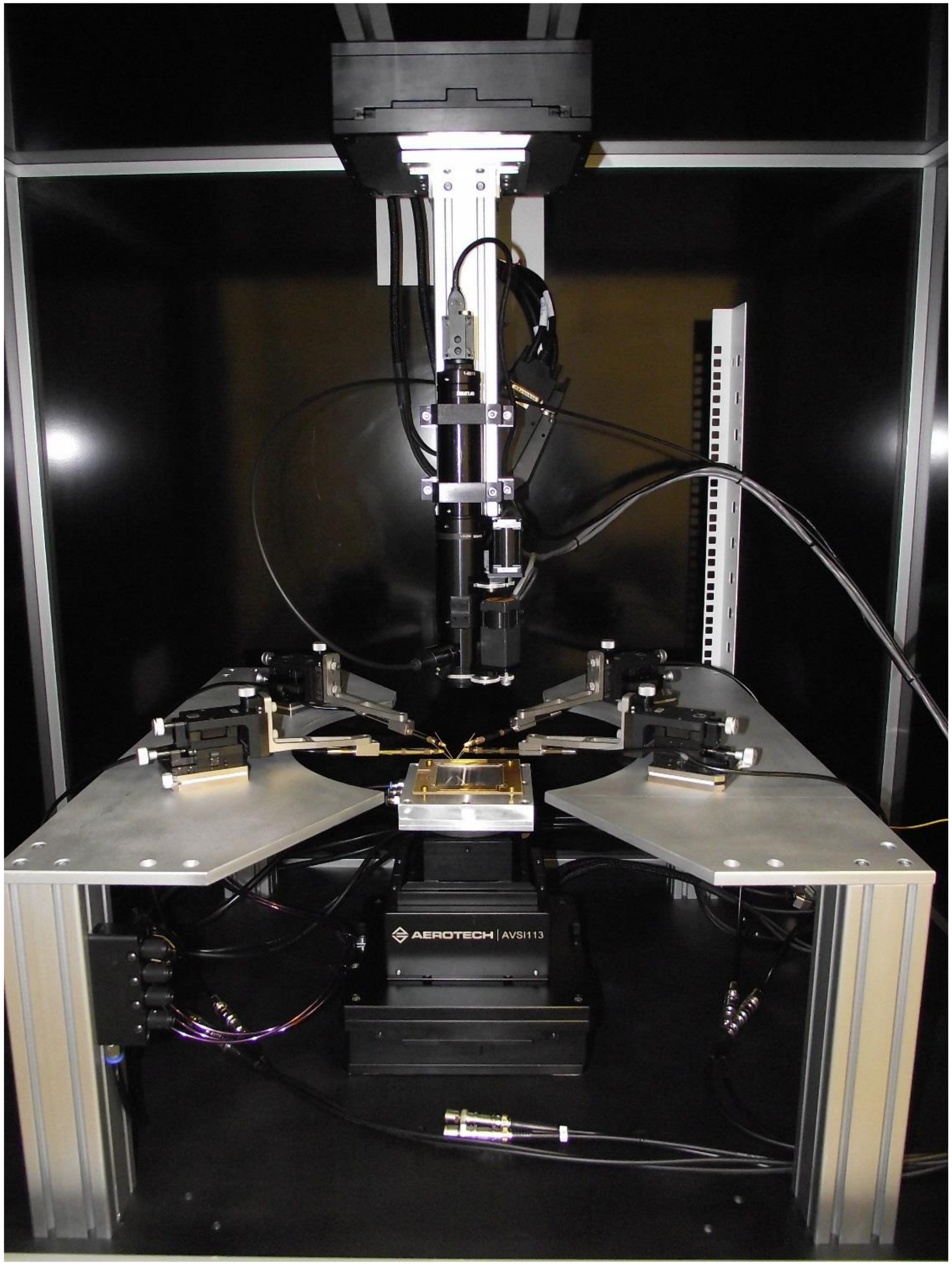
Bulk tests:

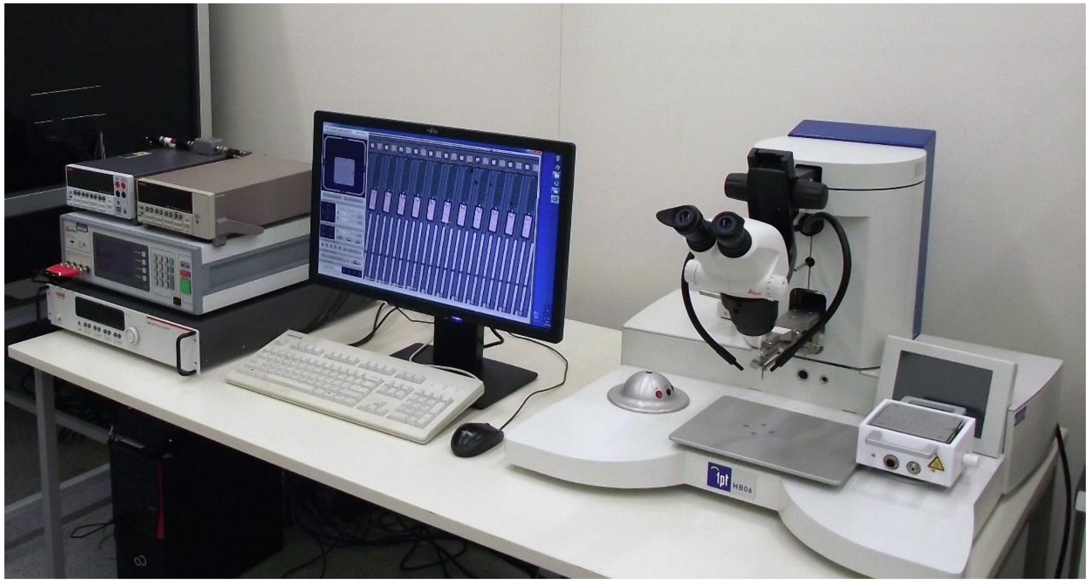
- IV-CV measurements

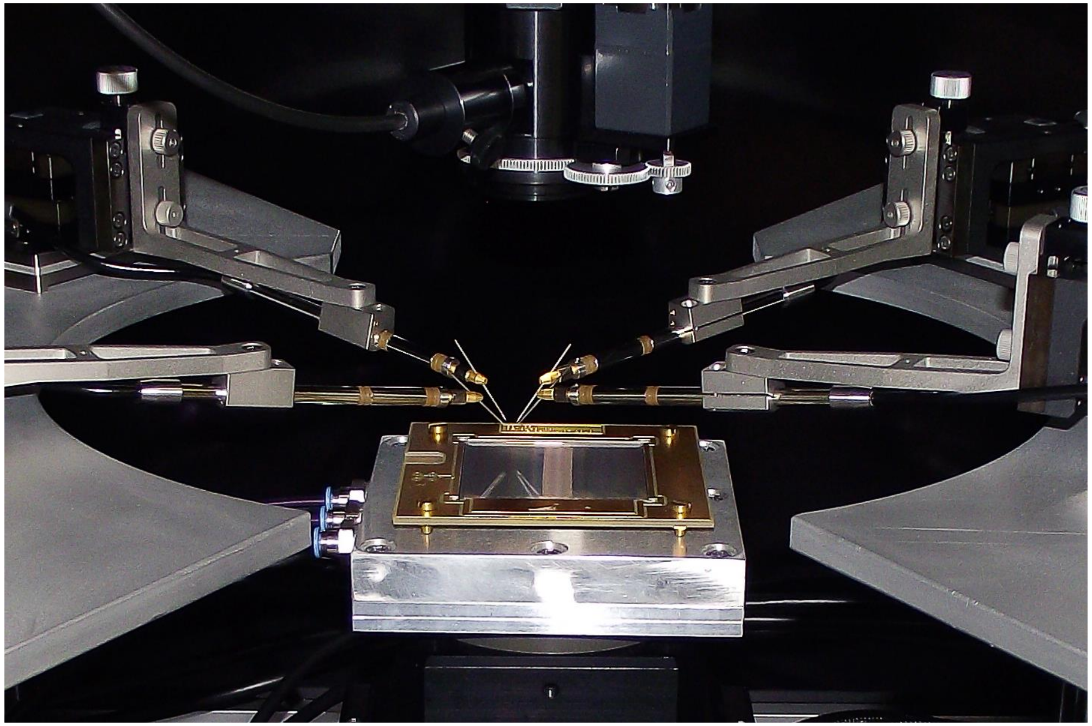
Strip tests:

- strip/implant breaks/shorts
- pinhole test
- strip leakage current
- coupling capacitance
- interstrip capacitance
- polysilicon bias resistance
- interstrip resistance
- …

CUSTOM PROBE STATION

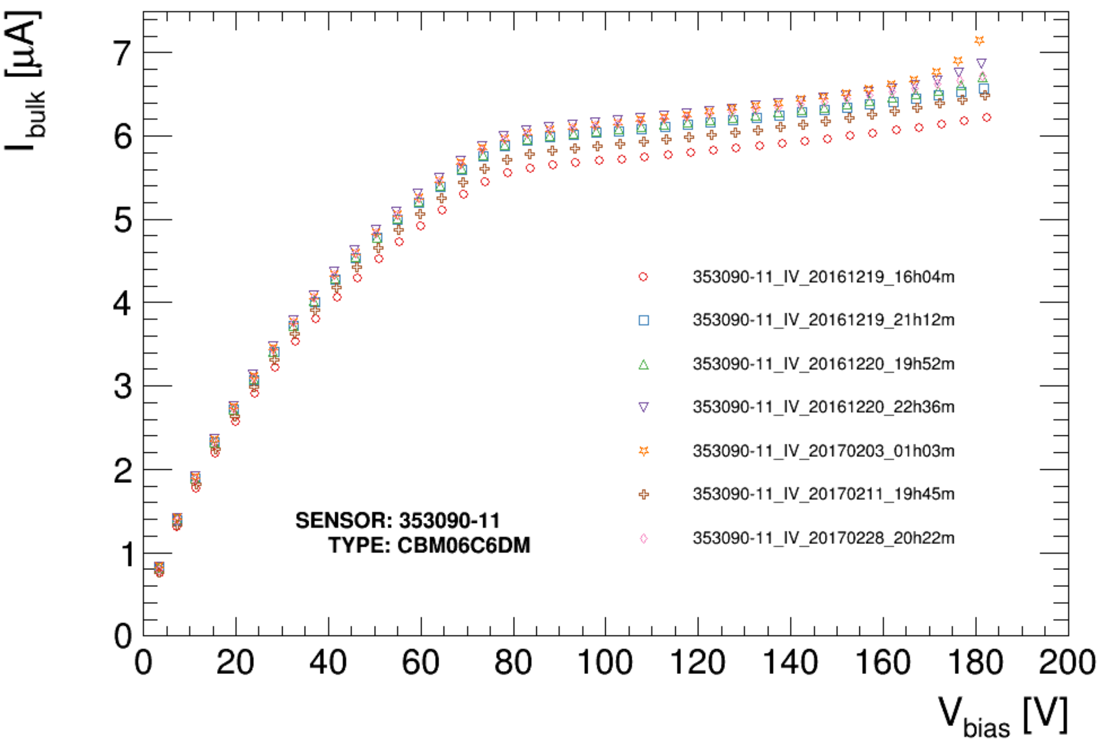






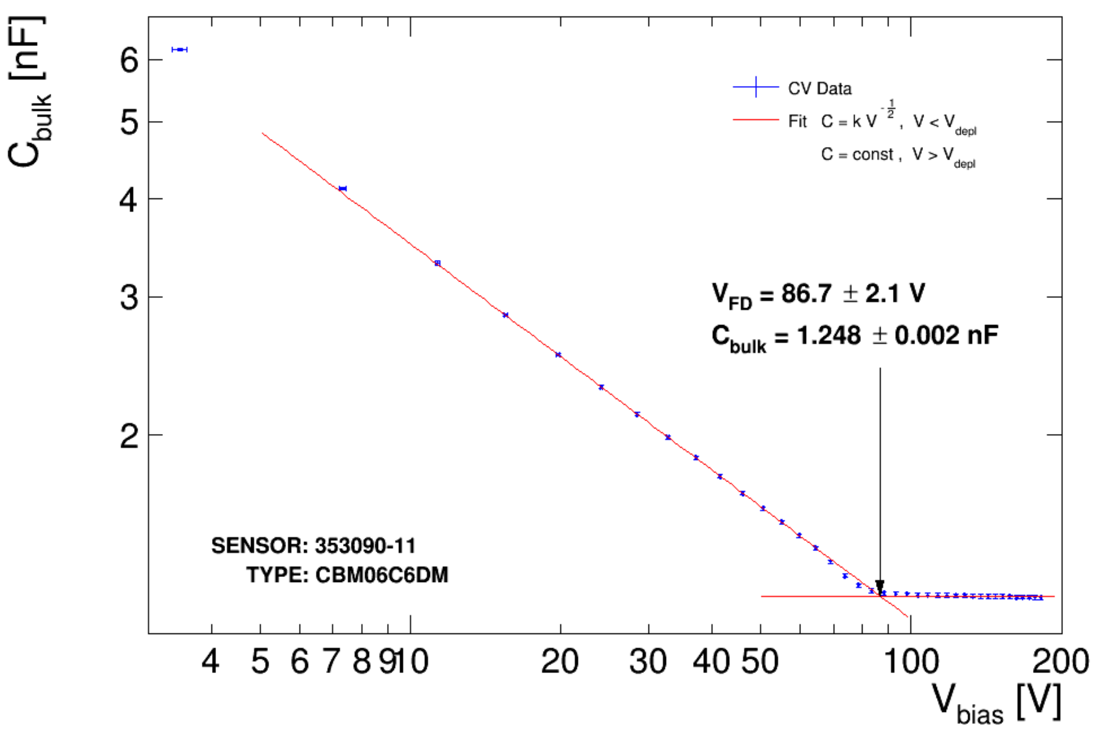
BULK MEASUREMENTS

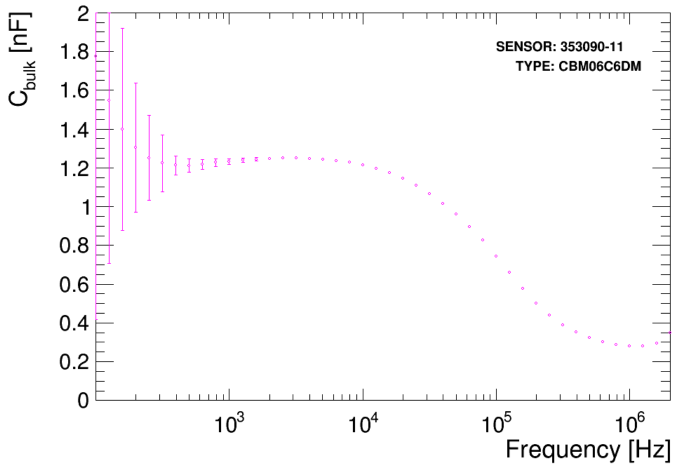
- 1^{st} and simple estimation of the sensor quality
- Magnitude of leakage current influences the noise performance
- **Leakage current < 10 uA @ 20^0 C**
- **No breakdown up to 200 V**
- Slope I (150 V) / I (100 V) < 2

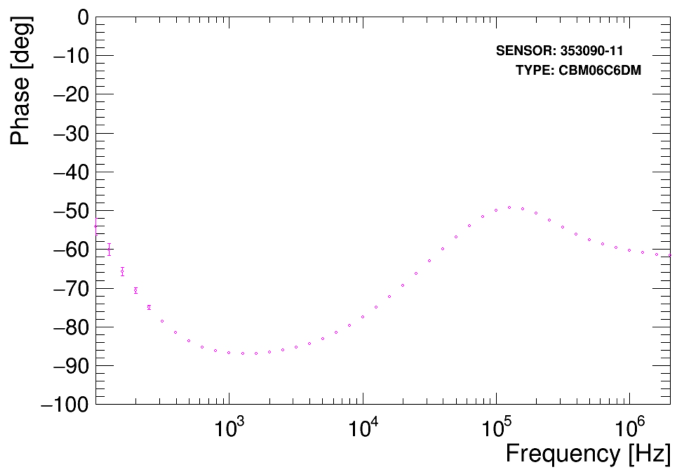


BULK MEASUREMENTS

- Bulk Capacitance is similar to parallel-plate capacitor
- Fully depleted detector capacitance is defined by geometric capacitance
- The full depletion voltage is the minimum voltage at which the bulk of the sensor is fully depleted
- **Full depletion is reached at ≈ 70-90 V**
- **Capacitance saturates at ≈ 1.25 nF**







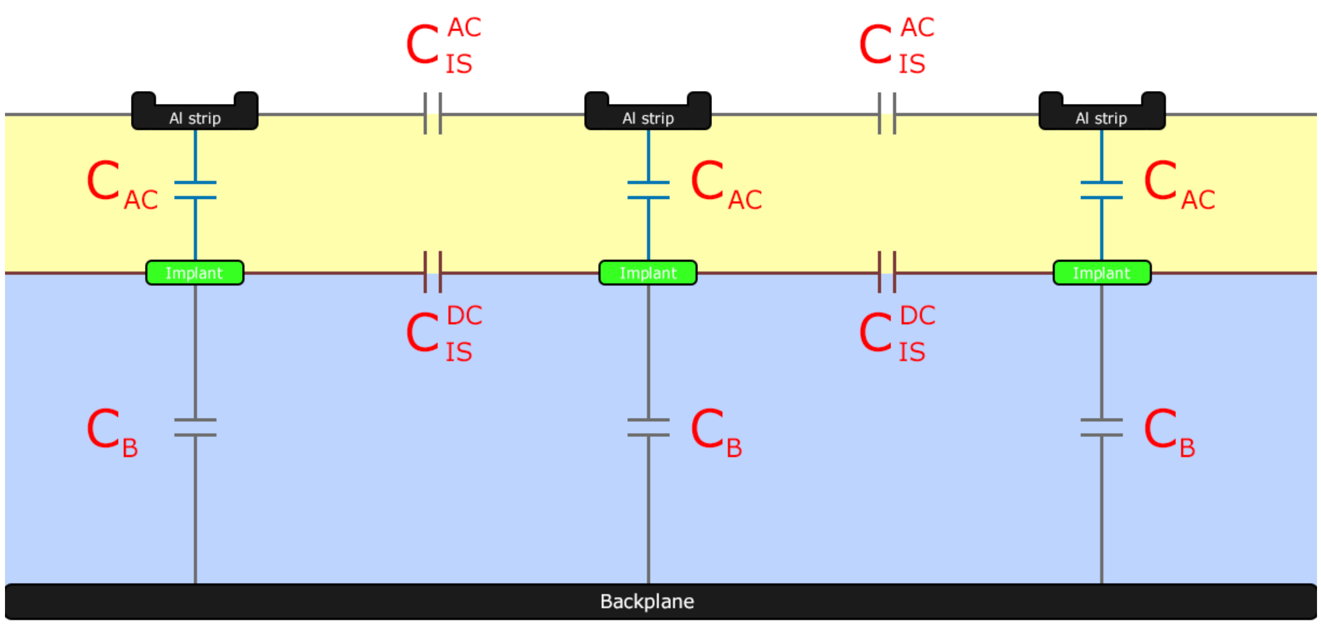
SILICON MICROSTRIP SENSOR

❖ Strip detector is a RC network.

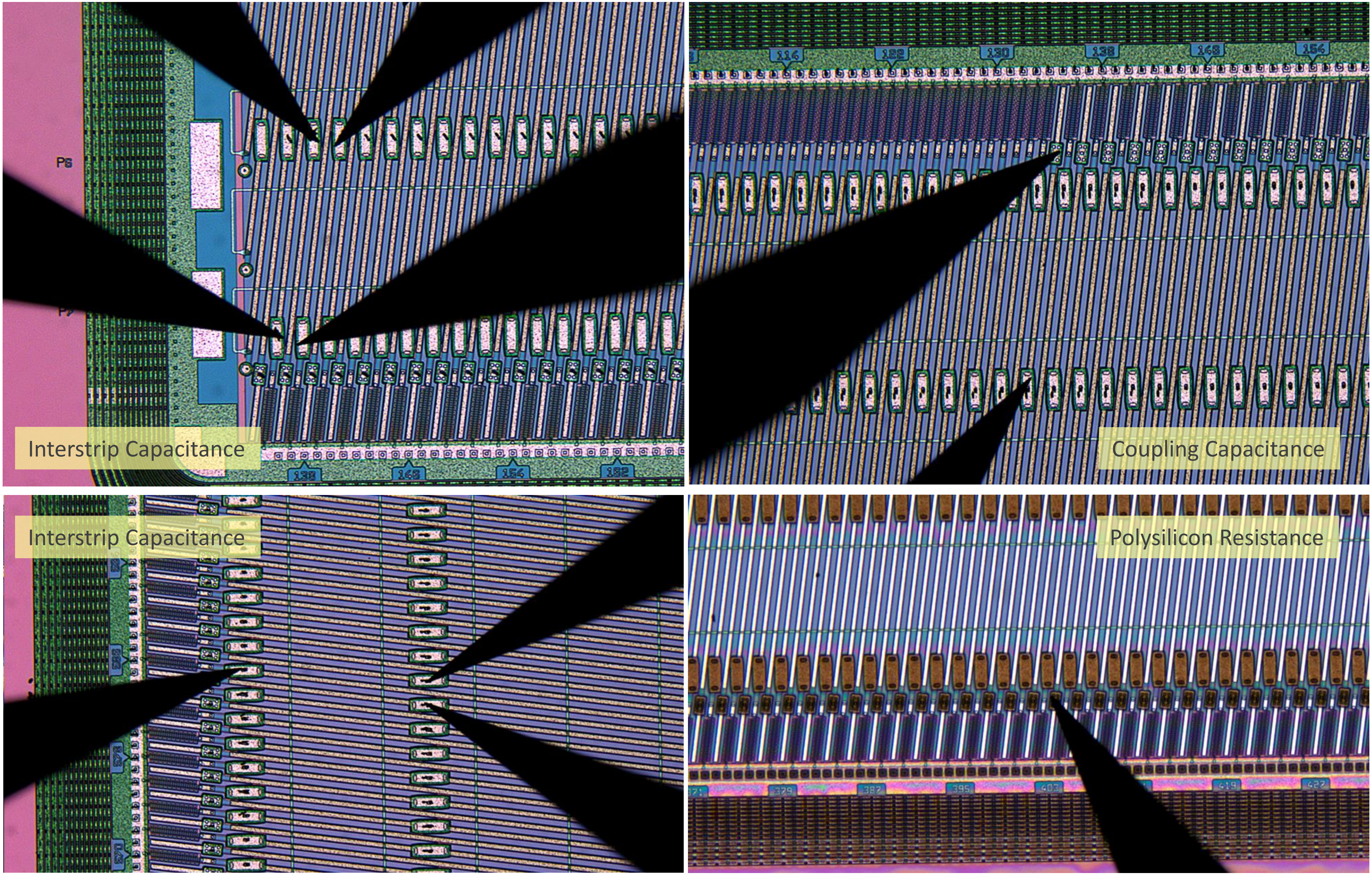
The peak amplifier signal V_s is inversely proportional to the **total capacitance at the input**, i.e. sum of:

- Strip backplane capacitance C_b (contribution to $C_{tot} \approx 20$ %)
- Interstrip capacitance C_{is} (contribution to $C_{tot} \approx 80$ %)

The coupling capacitance influences the signal strength.



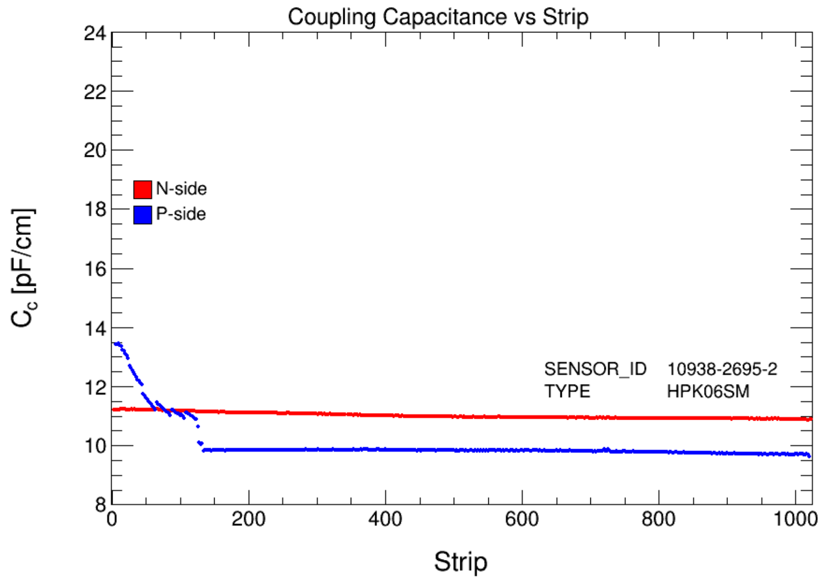
CONNECTION SCHEMES

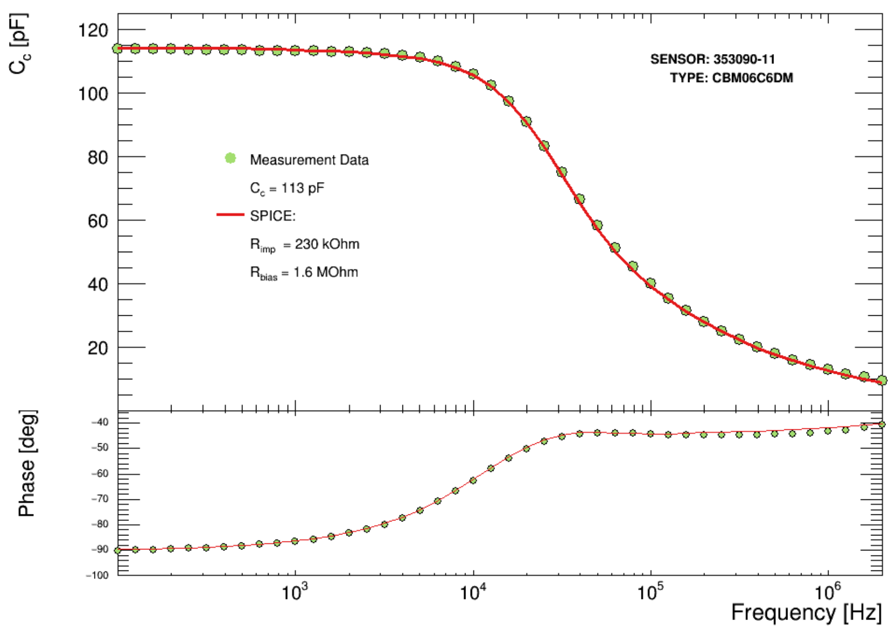


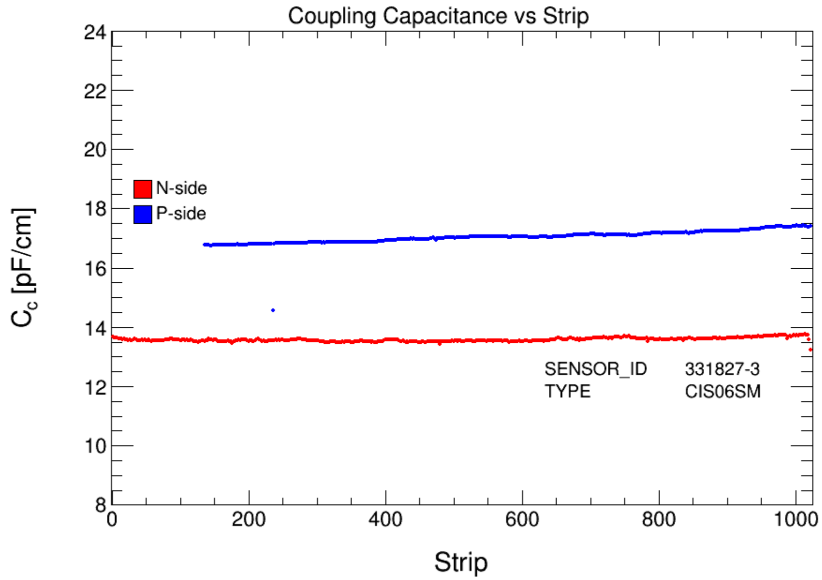
STRIP MEASUREMENTS

C_C – is a capacitance formed by the strip implant, insulation layer ($SiO_2 + Si_3N_4$) and the readout aluminum line.

In the strip scan C_C is measured by LCR meter between DC and AC pads.

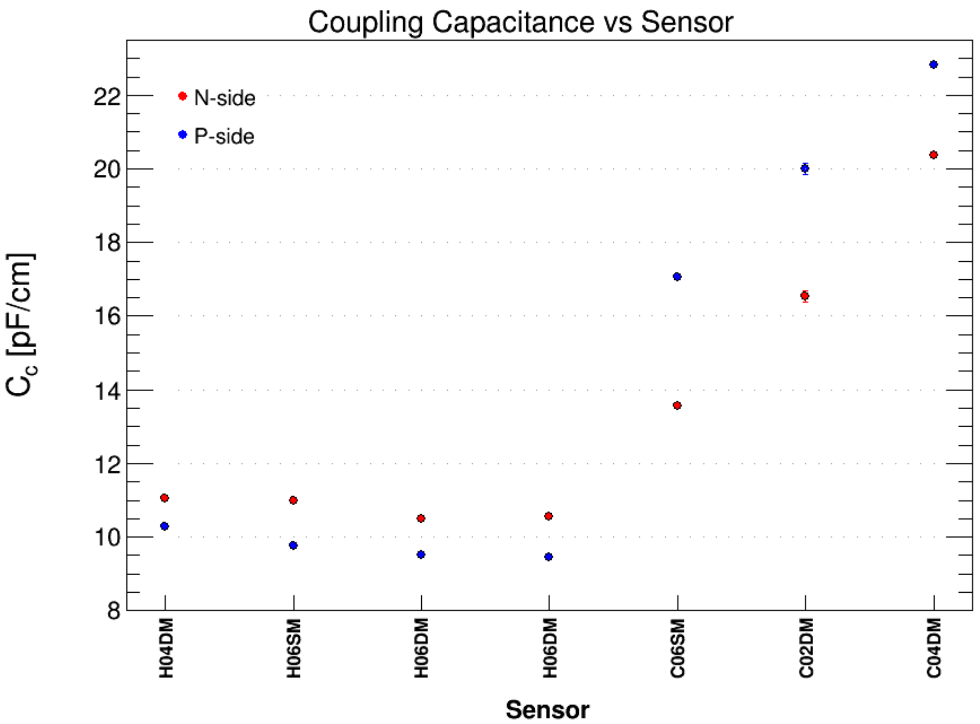






COUPLING CAPACITANCE

The coupling capacitance was measured for all 1024 strips on each side of 15 sensors (**30720** strips in total) for a moment…

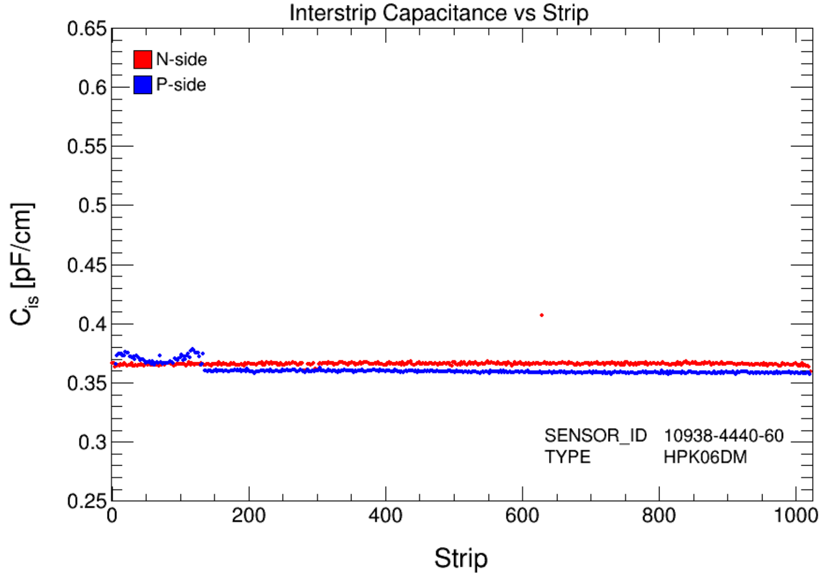


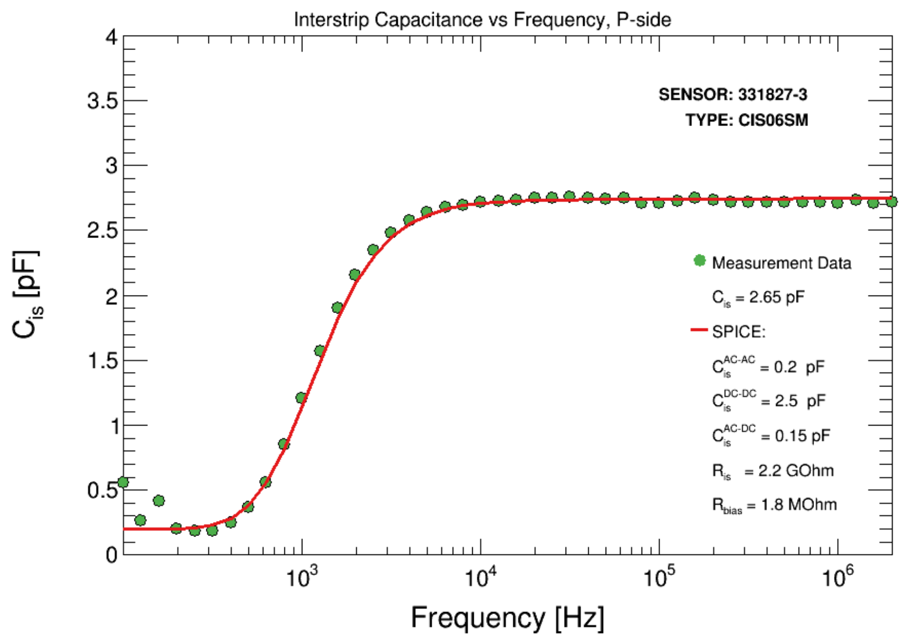
Sensor_ID	User friendly name	$C_c^{\ P}$ [pF/cm]	$C_c^{\ N}$ [pF/cm]
10938-1609-5	H04DM	10.29 ± 0.09	11.04 ± 0.09
10938-2695-2	H06SM	9.73 ± 0.07	10.99 ± 0.07
10938-4440-58	H06DM	9.52 ± 0.07	10.49 ± 0.07
10938-4440-60	H06DM	9.46 ± 0.07	10.56 ± 0.07
331827-3	C06SM	17.05 ± 0.06	13.57 ± 0.07
350714-06-1	C02DM	19.99 ± 0.16	16.54 ± 0.16
351139-23	C04DM	22.81 ± 0.09	20.38 ± 0.09

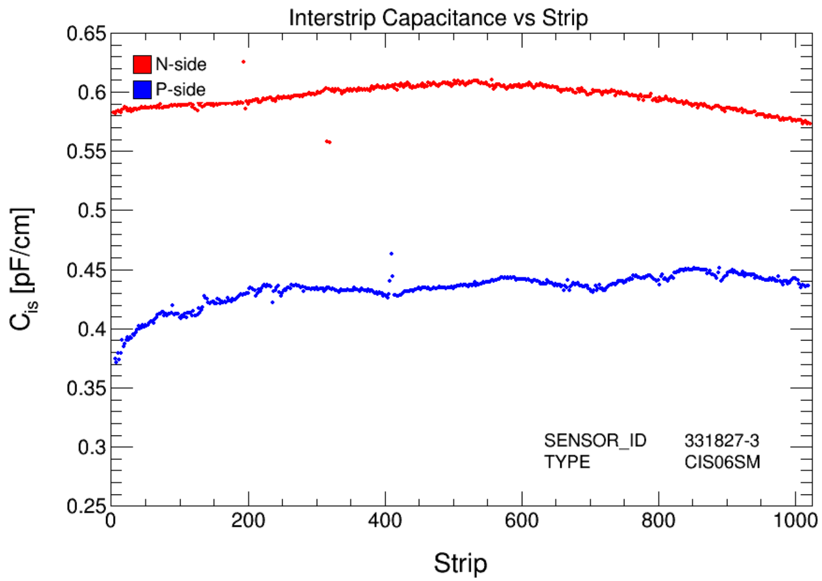
INTERSTRIP MEASUREMENTS

C_{is} – main contributor to the input capacitance of the FEE – defines its noise performance

C_{is} has to be significantly smaller than coupling capacitance in order to ensure a good charge collection.



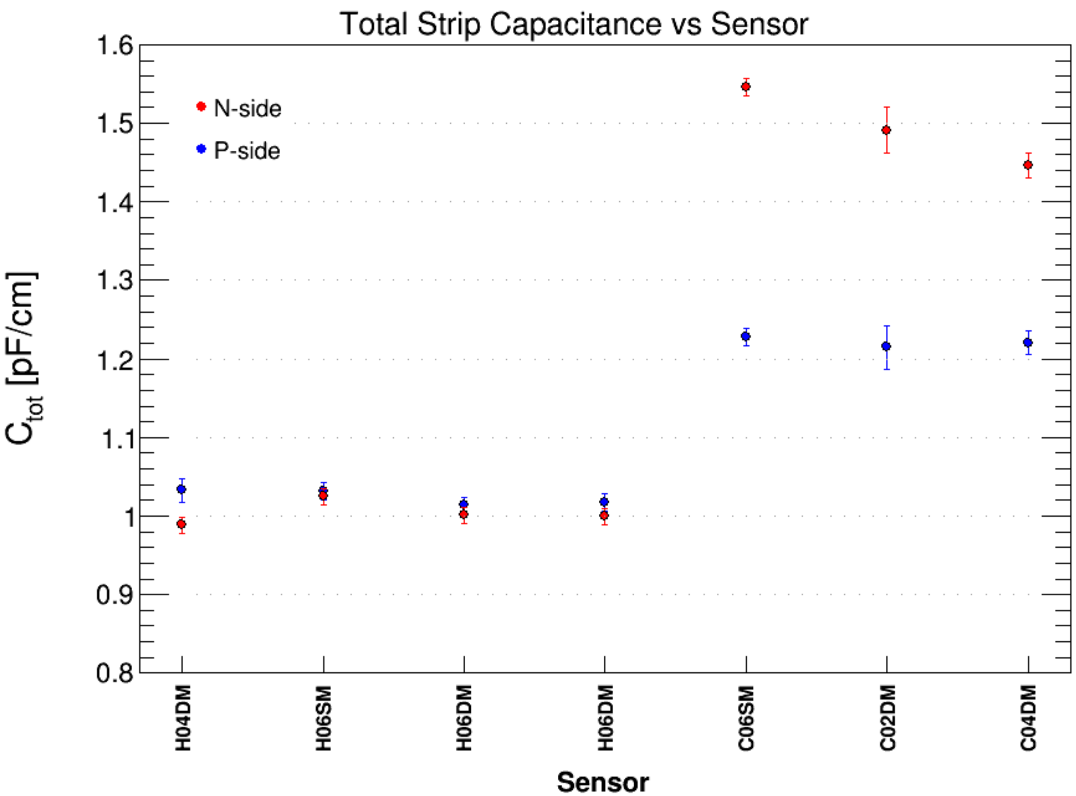




TOTAL STRIP CAPACITANCE

The total strip capacitance C_{tot} is defined as the sum of the capacitance of the strip to the backplane and the interstrip capacitance to adjacent strips:

$$C_{tot} = C_b + 2C_{is} + C_{rs}$$



Sensor_ID	User friendly name	C_{tot}^{P} [pF/cm]	C_{tot}^{N} [pF/cm]
10938-1609-5	H04DM	1.033 ± 0.015	0.988 ± 0.011
10938-2695-2	H06SM	1.032 ± 0.011	1.025 ± 0.011
10938-4440-58	H06DM	1.014 ± 0.011	1.001 ± 0.011
10938-4440-60	H06DM	1.017 ± 0.011	1.001 ± 0.011
331827-3	C06SM	1.228 ± 0.011	1.546 ± 0.012
350714-06-1	C02DM	1.215 ± 0.028	1.491 ± 0.029
351139-23	C04DM	1.221 ± 0.015	1.447 ± 0.016

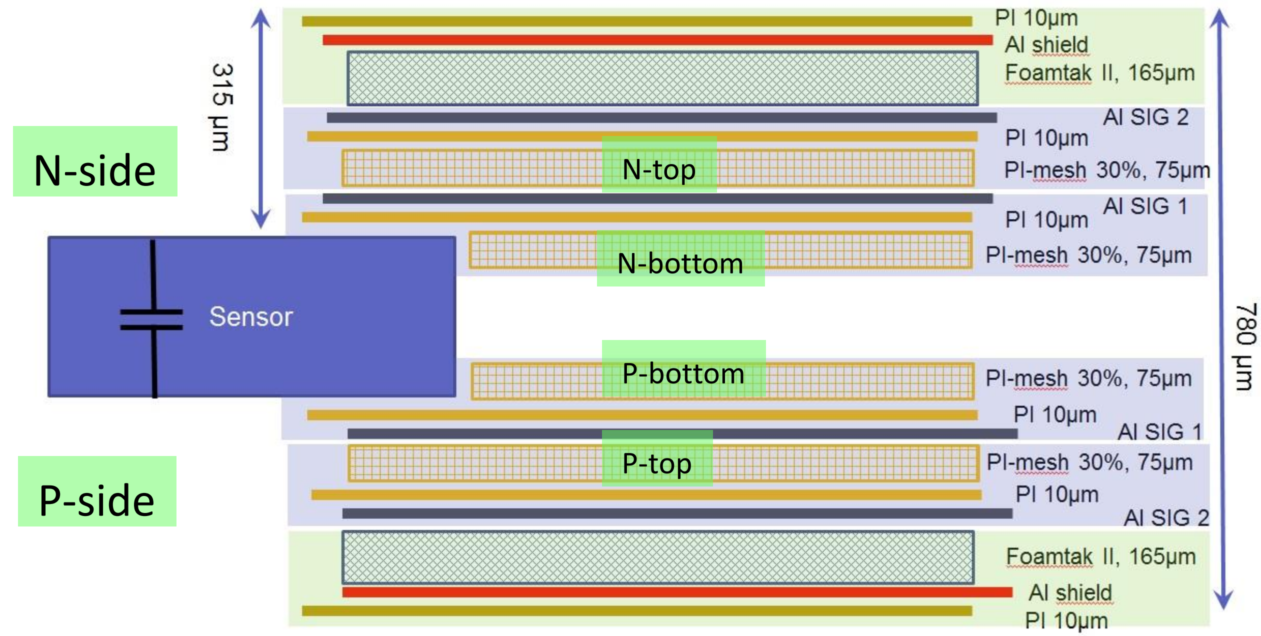
MICROCABLE STACK-UP

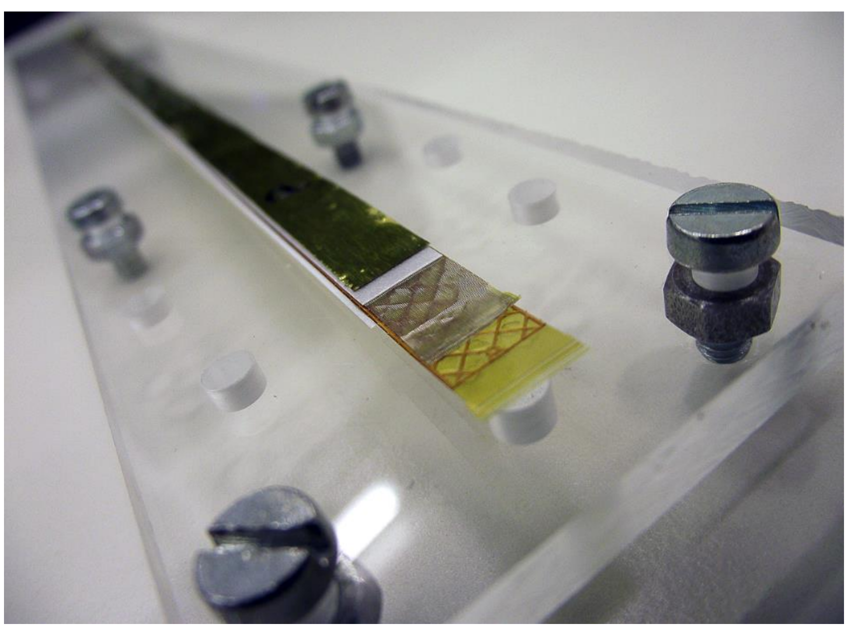
Goal : To measure capacitance of a single trace in micro-cable stack to everything ≡ C_{TOT}

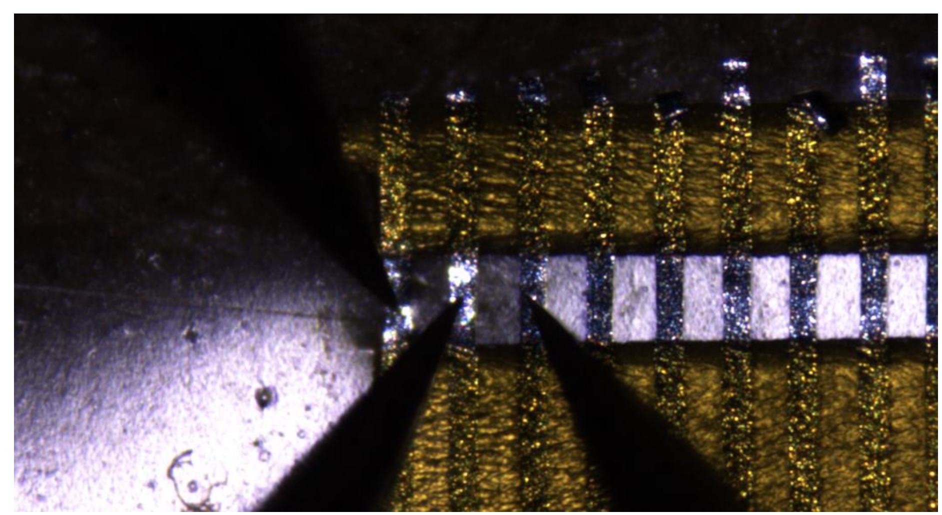
Layers Lengths:

- N-Top = 28.1 cm;
- N-Bot = 28.0 cm;
- P-Bot = 27.0 cm;
- P-Top = 27.1 cm.

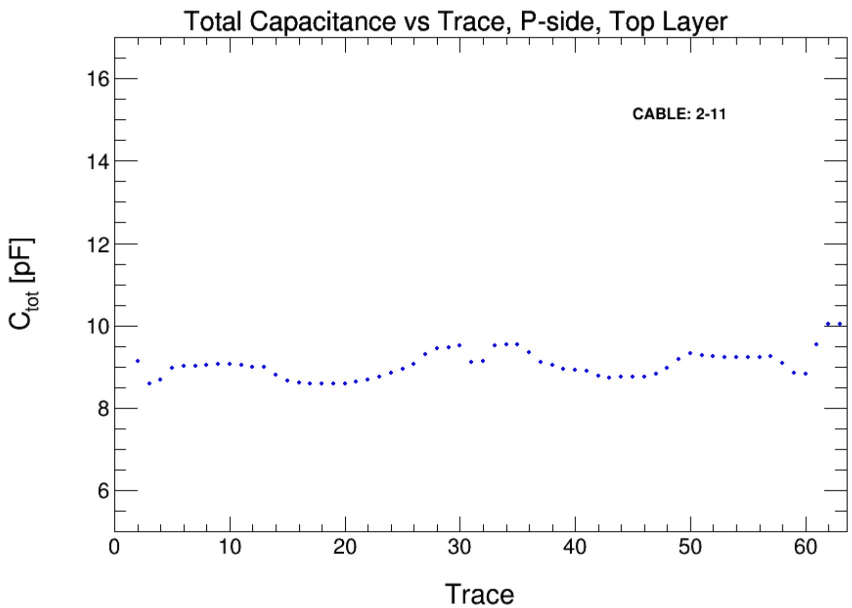
Number of Traces/layer: 64



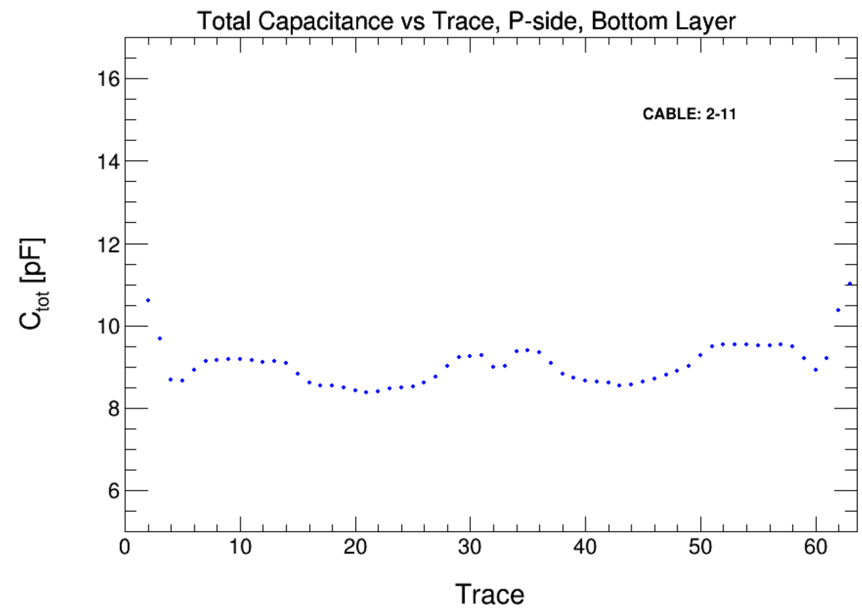




TRACE SCAN



Total Capacitance vs Trace, P-side, Top Layer
CABLE: 2-11
C_{tot} [pF]
Trace



Total Capacitance vs Trace, P-side, Bottom Layer
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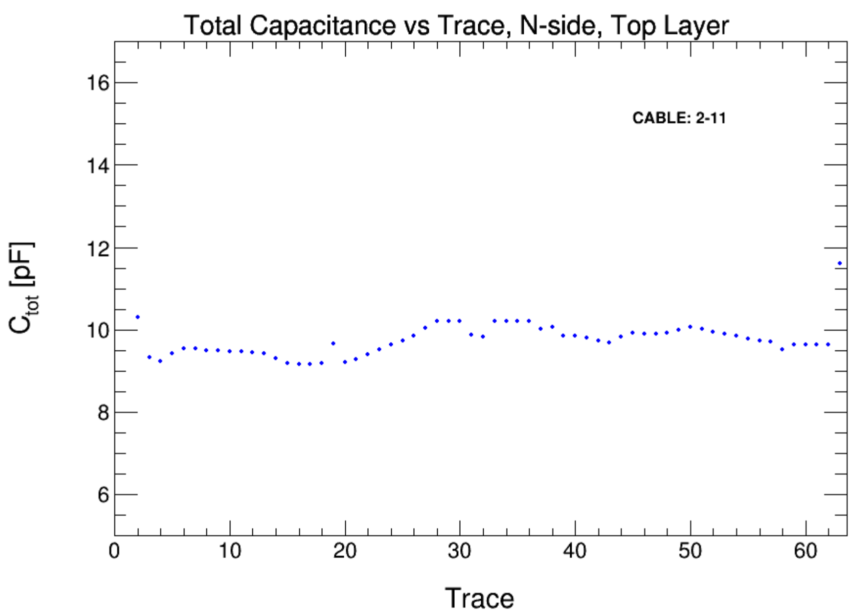
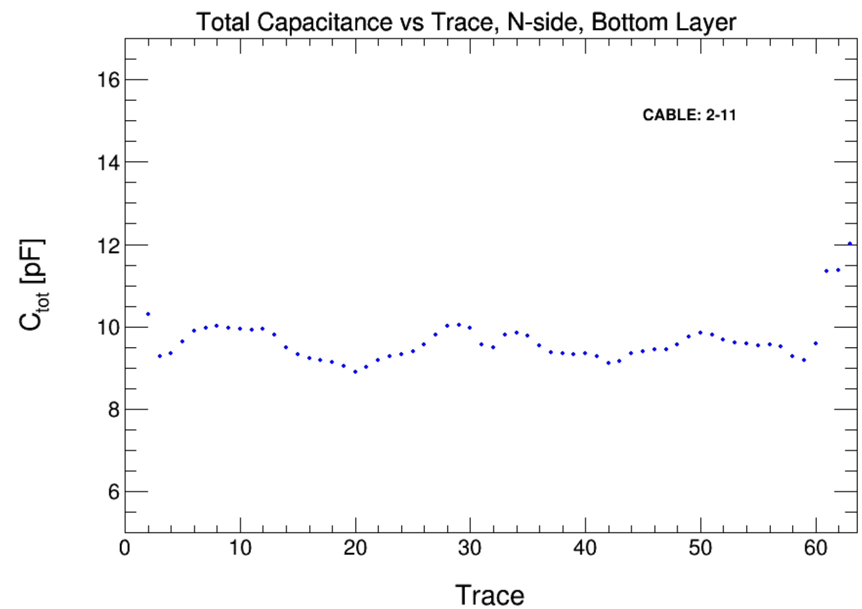


Total Capacitance vs Trace, N-side, Top Layer
CABLE: 2-11
C_{tot} [pF]
Trace

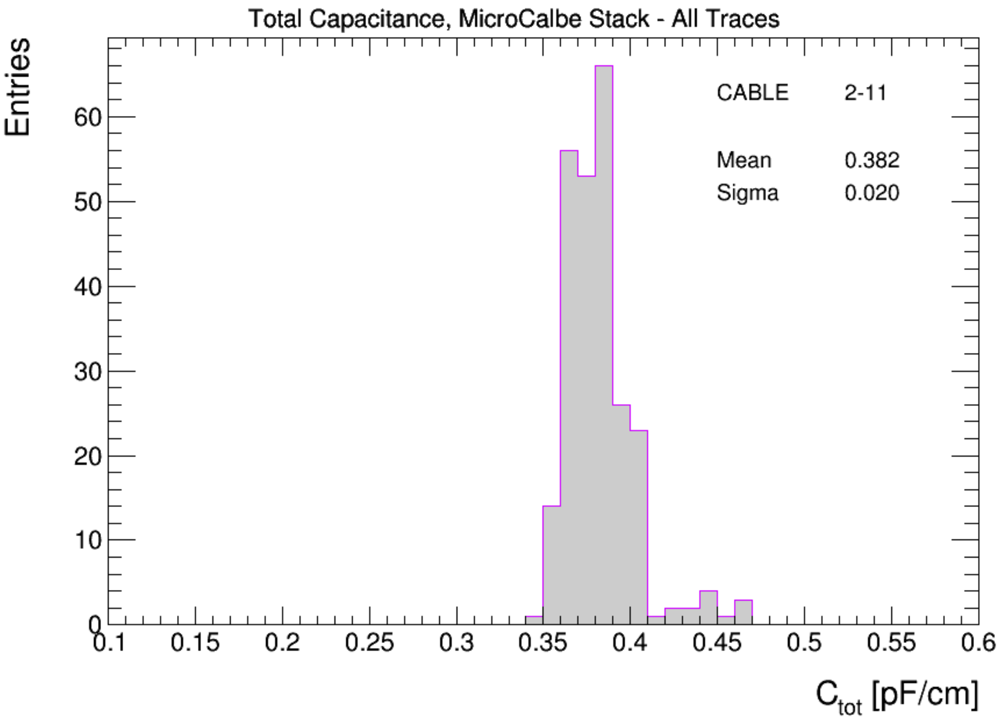


Total Capacitance vs Trace, N-side, Bottom Layer
CABLE: 2-11
C_{tot} [pF]
Trace

TOTAL TRACE CAPACITANCE

Total trace capacitance for #2-11 micro-cable stack-up

C_{TOT} **= 0.382 ± 0.020 pF/cm**



Total Trace Capacitance:

Design goal : **0.5 pF/cm**

Simulations:

D.Soyk et al., Capacitance studies of the CBM STS microcable stack-up, CBM Progress Report 2016, p.41

inner layer [pF/cm]	outer layer [pF/cm]
0.387	0.367

SUMMARY

- Prototype sensors for STS of CBM experiment were successfully tested using automated custom built probe station at University of Tuebingen.
- *Coupling Capacitance* **≥ 10 pF/cm** for both vendors and all sensor sizes.
- *Total Strip Capacitance* **≈ 1 pF/cm** for HPK sensors and higher for CIS sensors (see graphs).
- For both vendors *Total Strip Capacitance* is significantly smaller than *Coupling Capacitance* what ensures a good charge collection:

$$C_c / C_{tot} > 10$$

- Same methods were applied for microcable capacitance determination. Total trace capacitance for present micro-cable stack

$$C_{TOT} = 0.382 \pm 0.020 \text{ pF/cm}$$

- Developed capacitance measurement techniques are a powerful tool for sensor characterization.