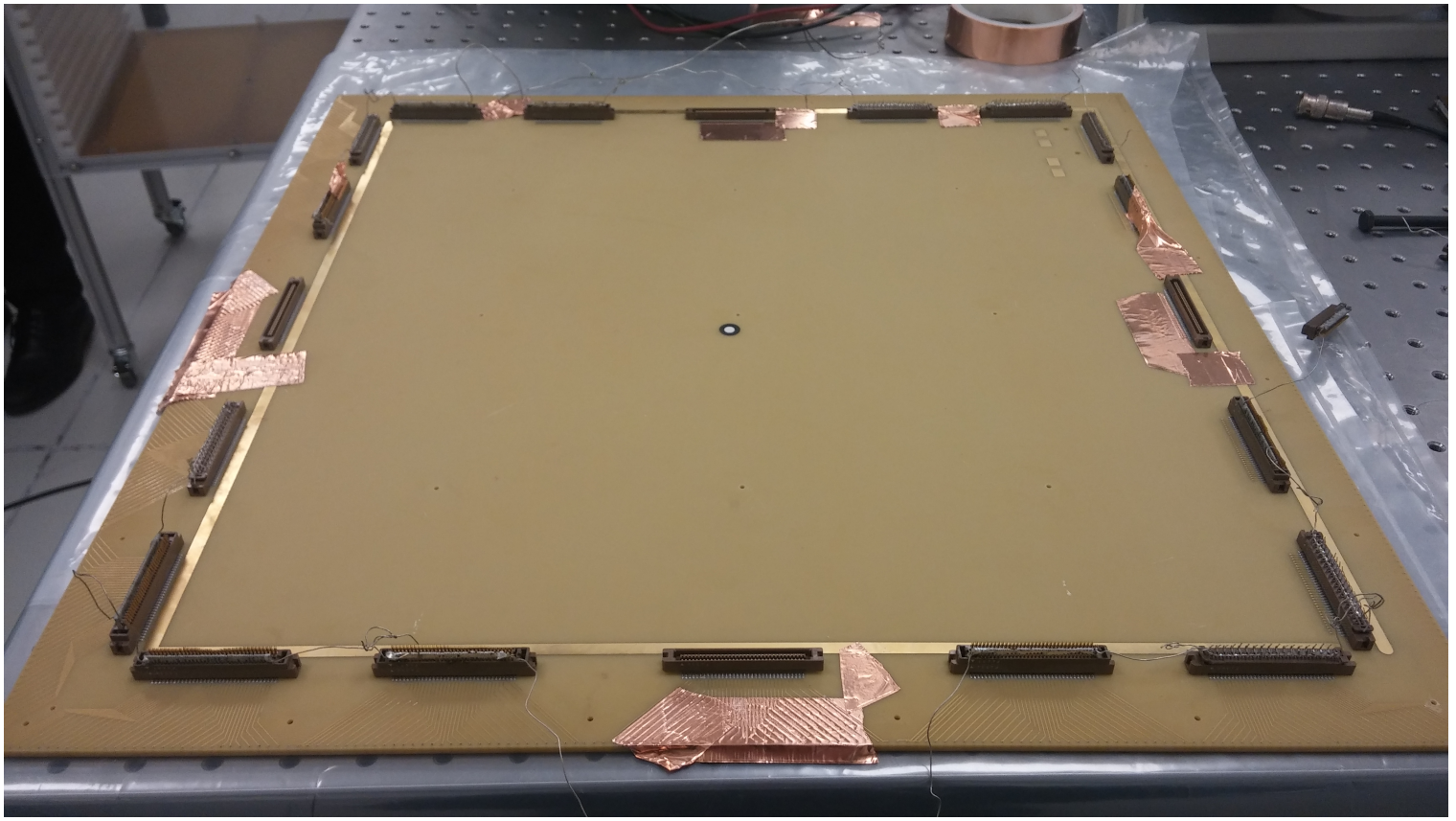
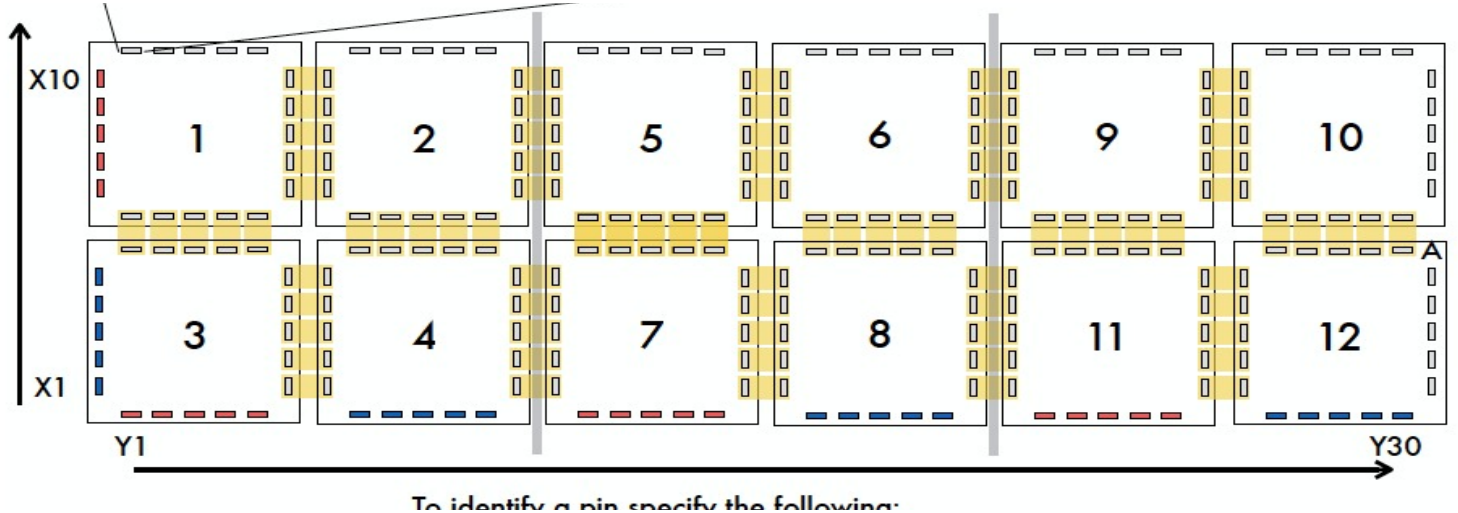
Capacitance/Inductance Measurements on the Anode

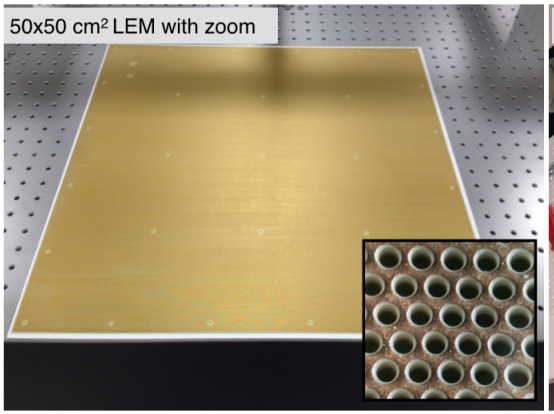


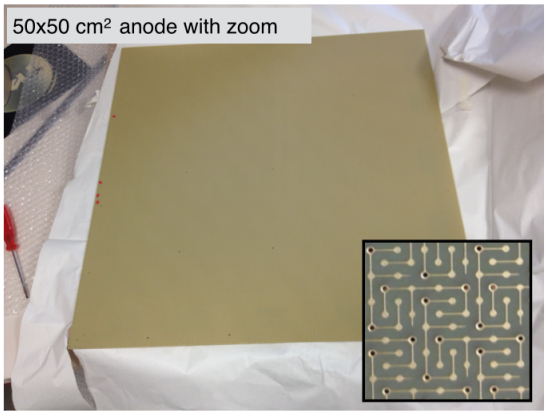
By Pin-Jung Chiu & Caspar Schloesser

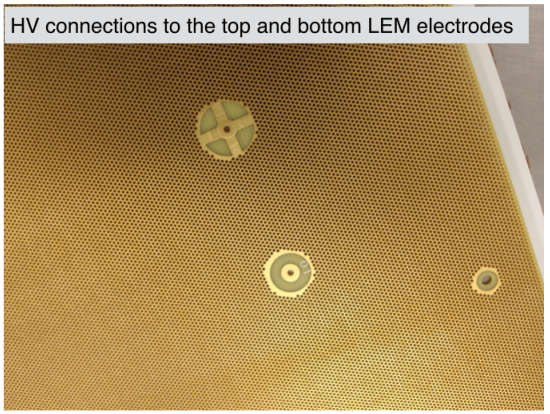
Charge readout plane in Detector

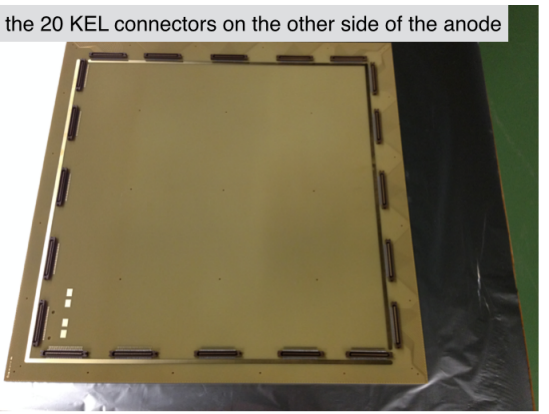


12 modules consisting of one anode and one LEM panel (2 mm from anode)

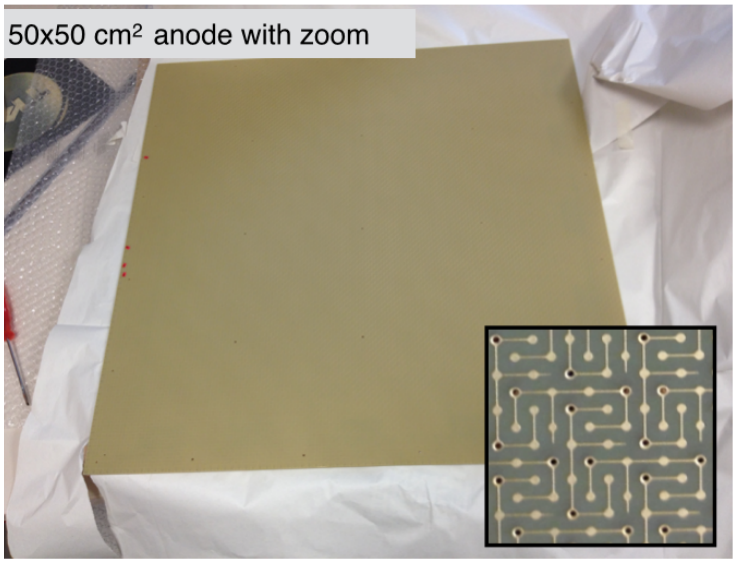


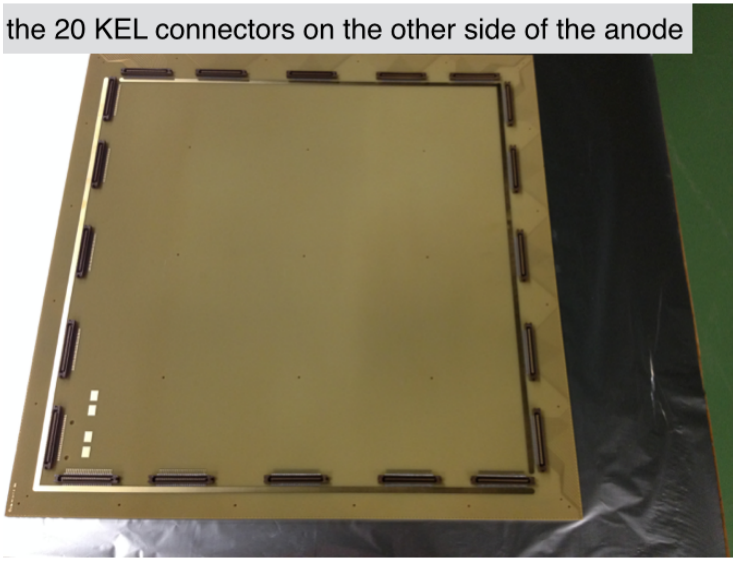




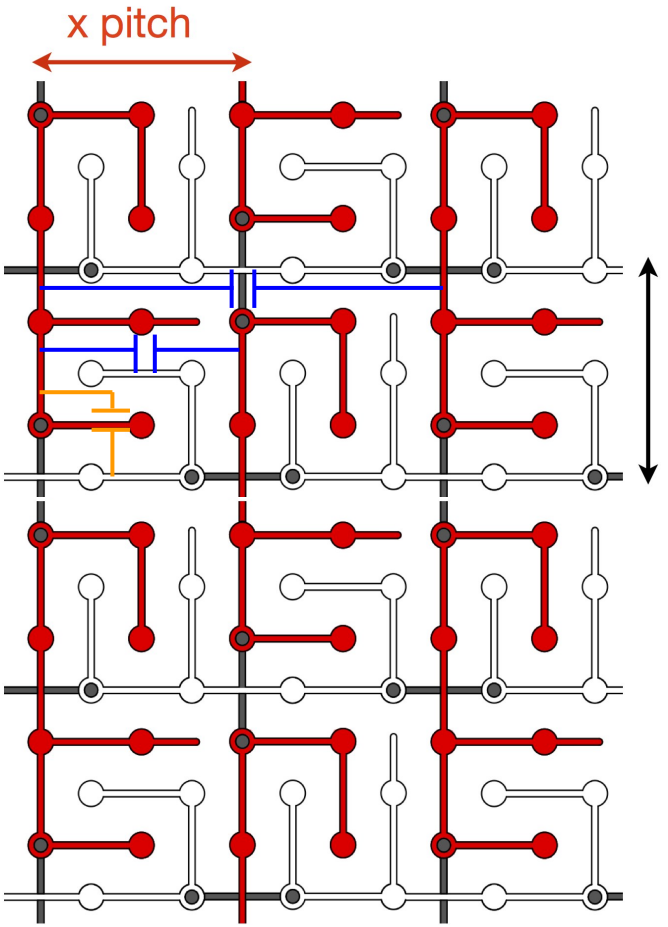


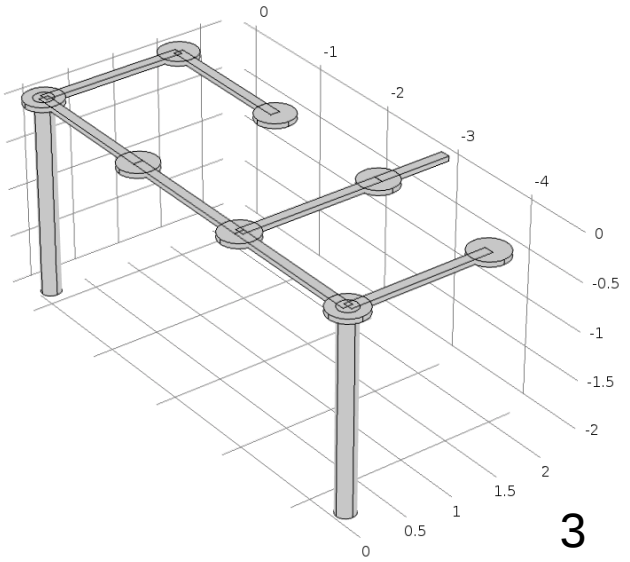
Structure of Anode



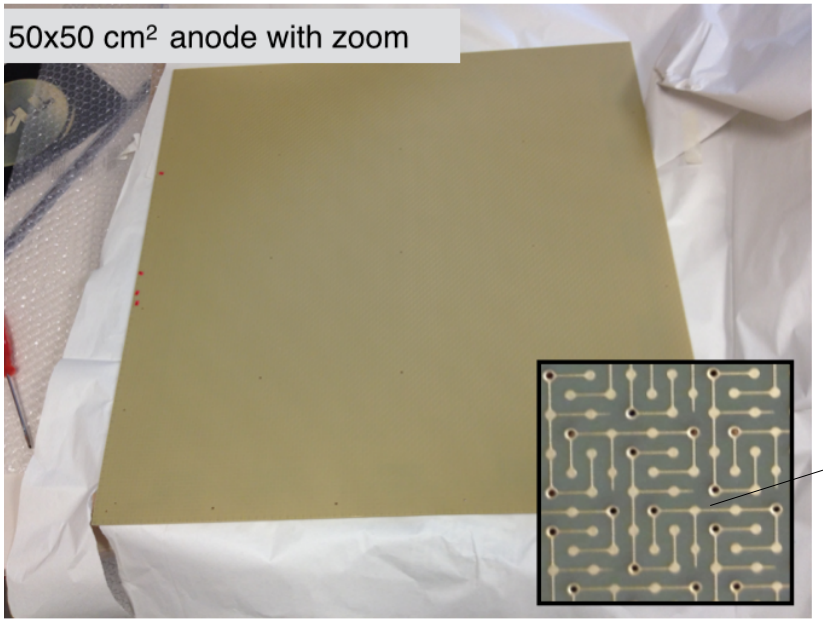


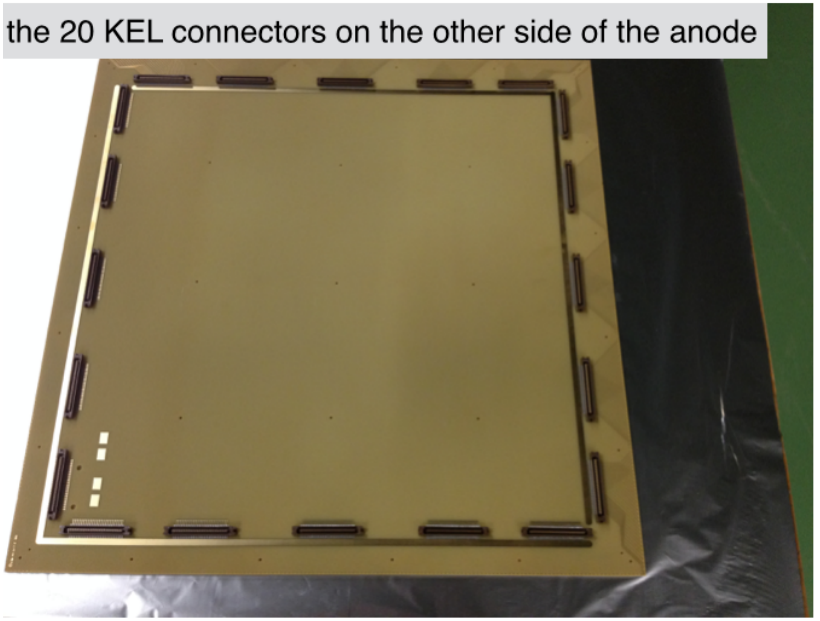
- Dimensions: 50 cm × 50 cm, thickness: 1.5 mm
- 160 strips in each view
- x pitch = y pitch = 3.125 mm
- pixels in each view are connected through connections one layer below (gray in figure)



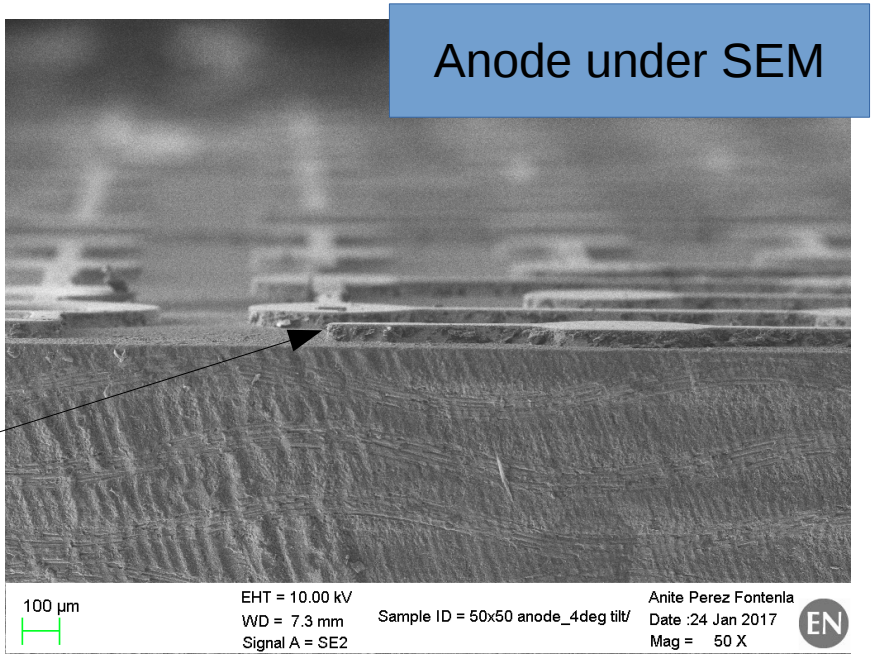


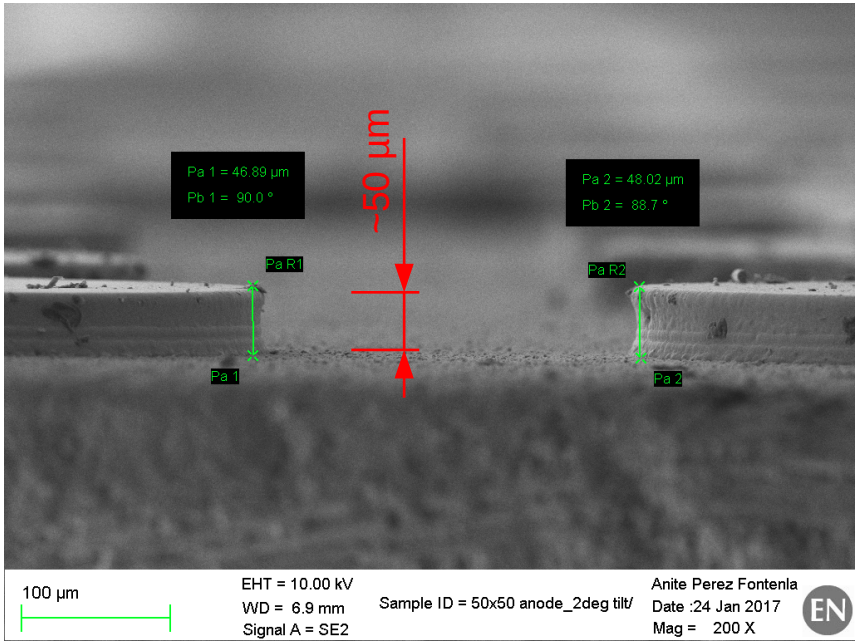
Structure of Anode





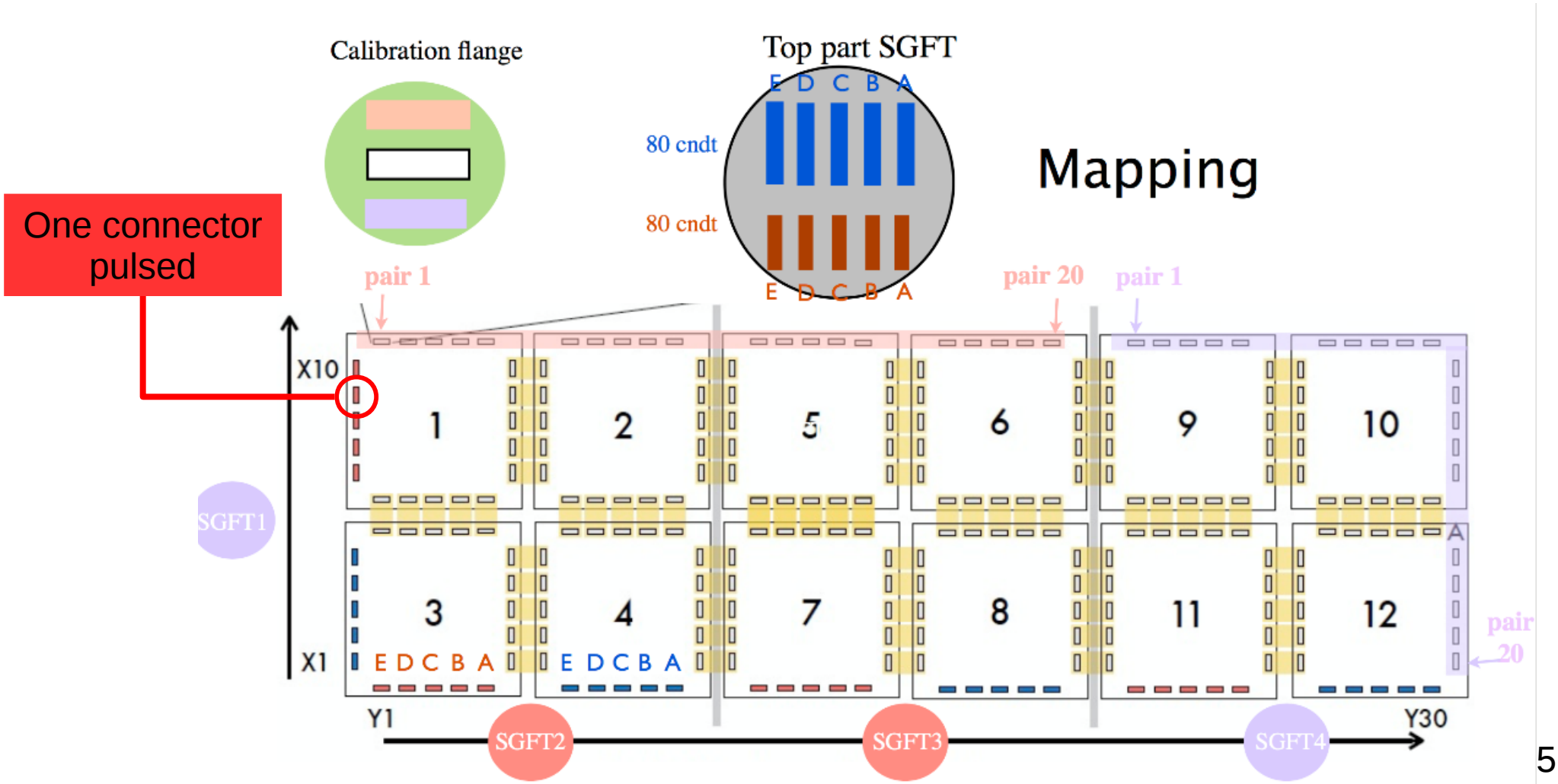
Anode under SEM





Pulsing measurements

- pulsing took place before Christmas last year
- 32 channels were pulsed simultaneously with 150 mV through a 1 pF capacitor ≙ 150 pC charge



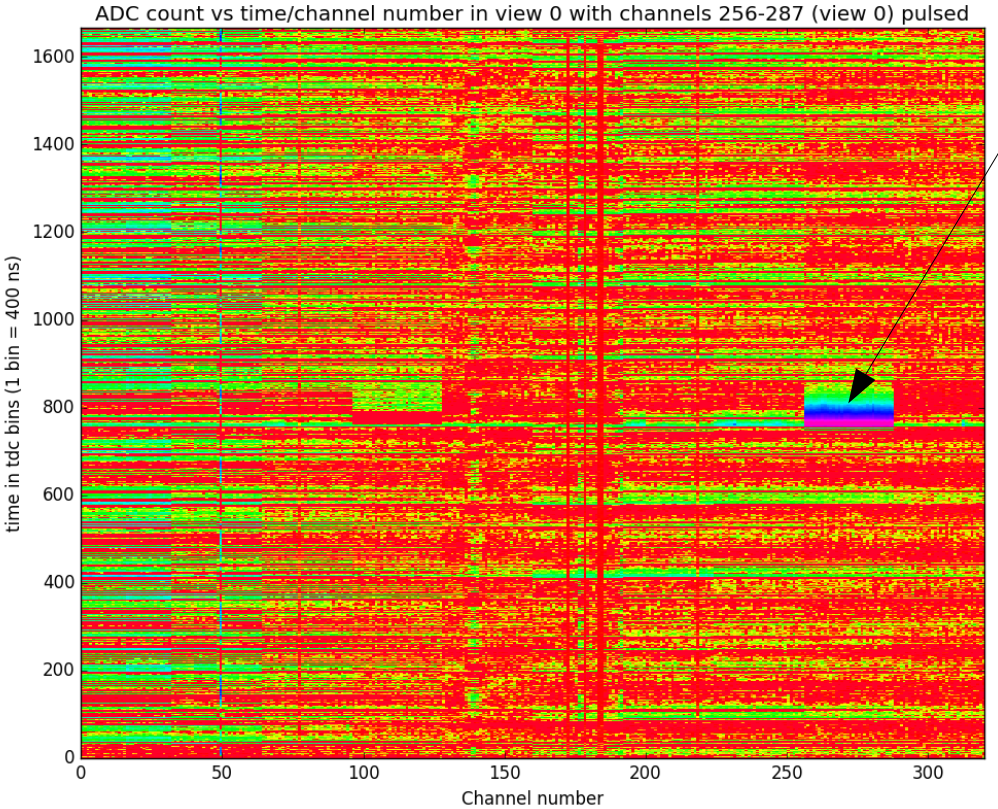
Pulsing measurements

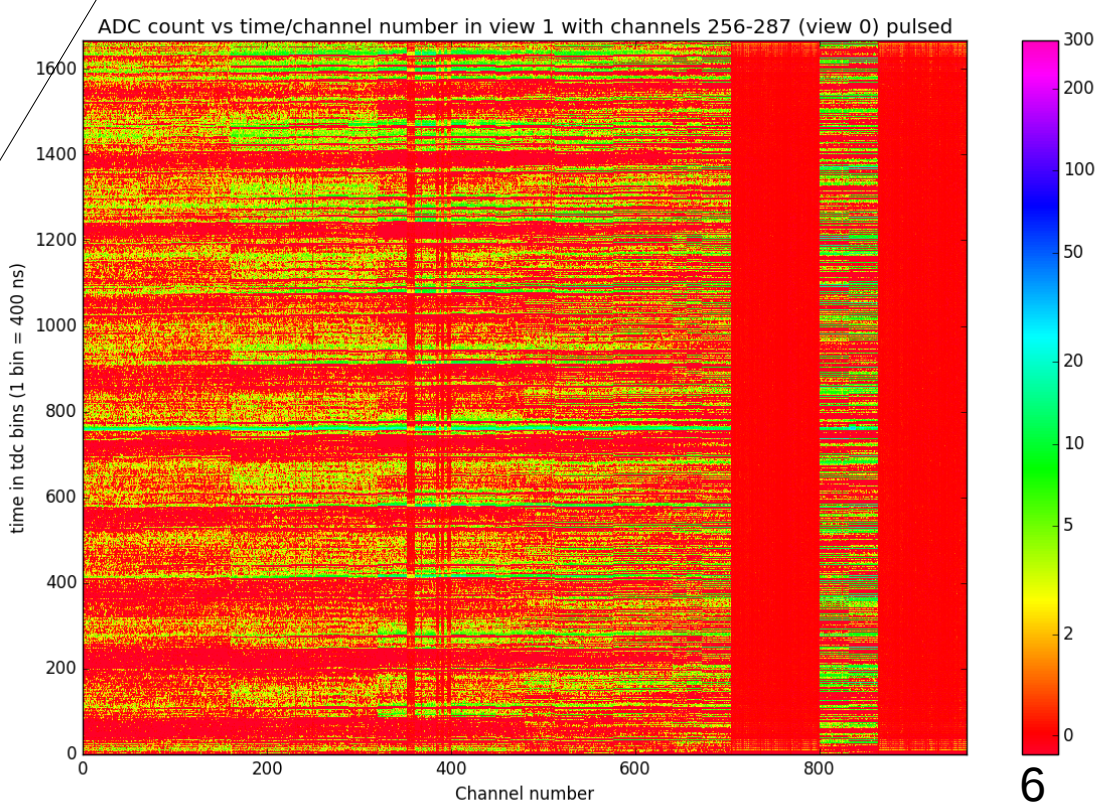
- pulsing took place before Christmas last year
- 32 channels were pulsed simultaneously with 150 mV through a 1 pF capacitor $\triangleq$ 150 pC charge
- pulse shape: square wave, rise/fall times ~100 ns
- Noise reduction: cuts in Fourier space for f > 0.5 MHz

view 0

32 pulsed channels in view 0

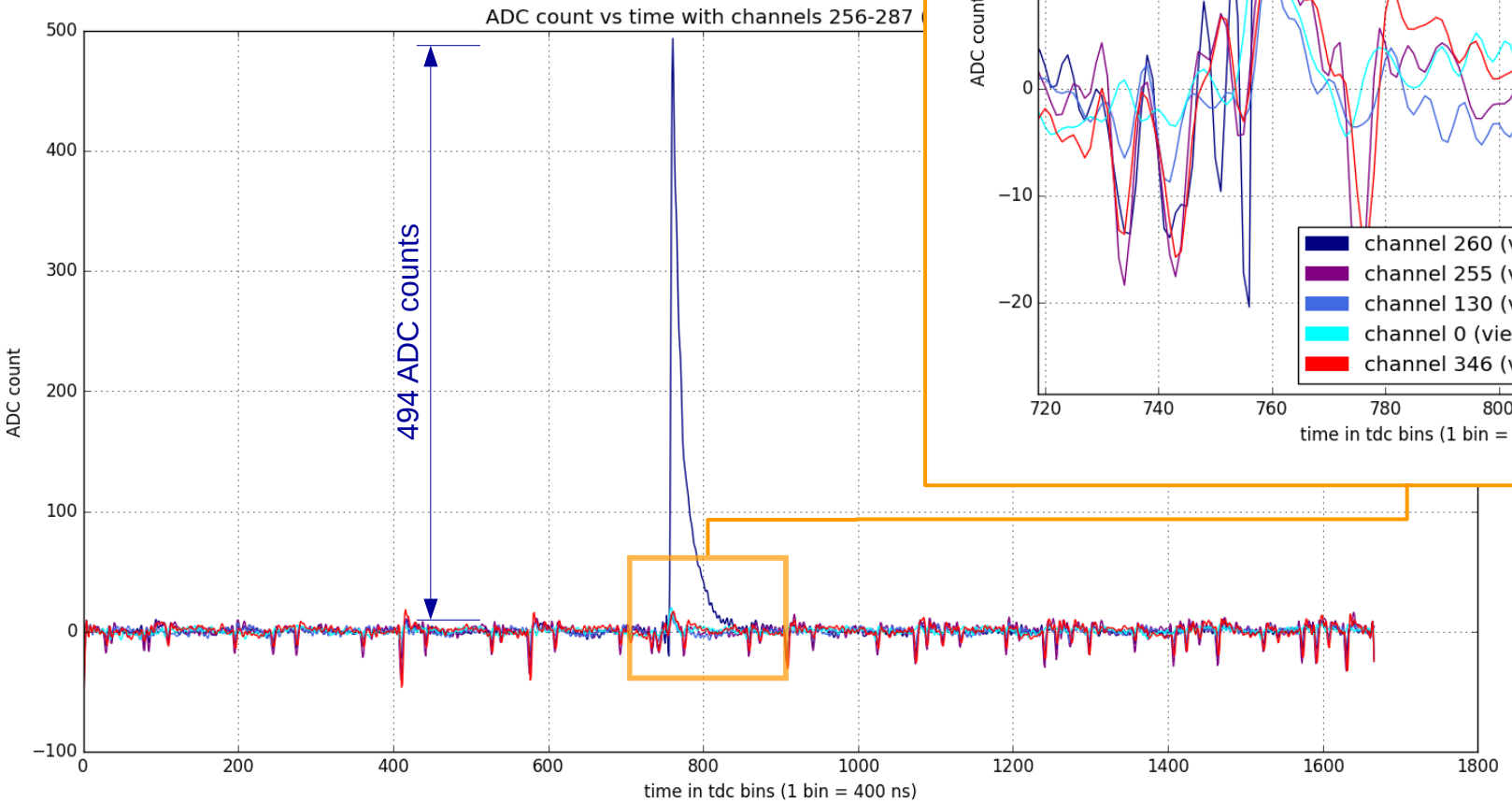
view 1

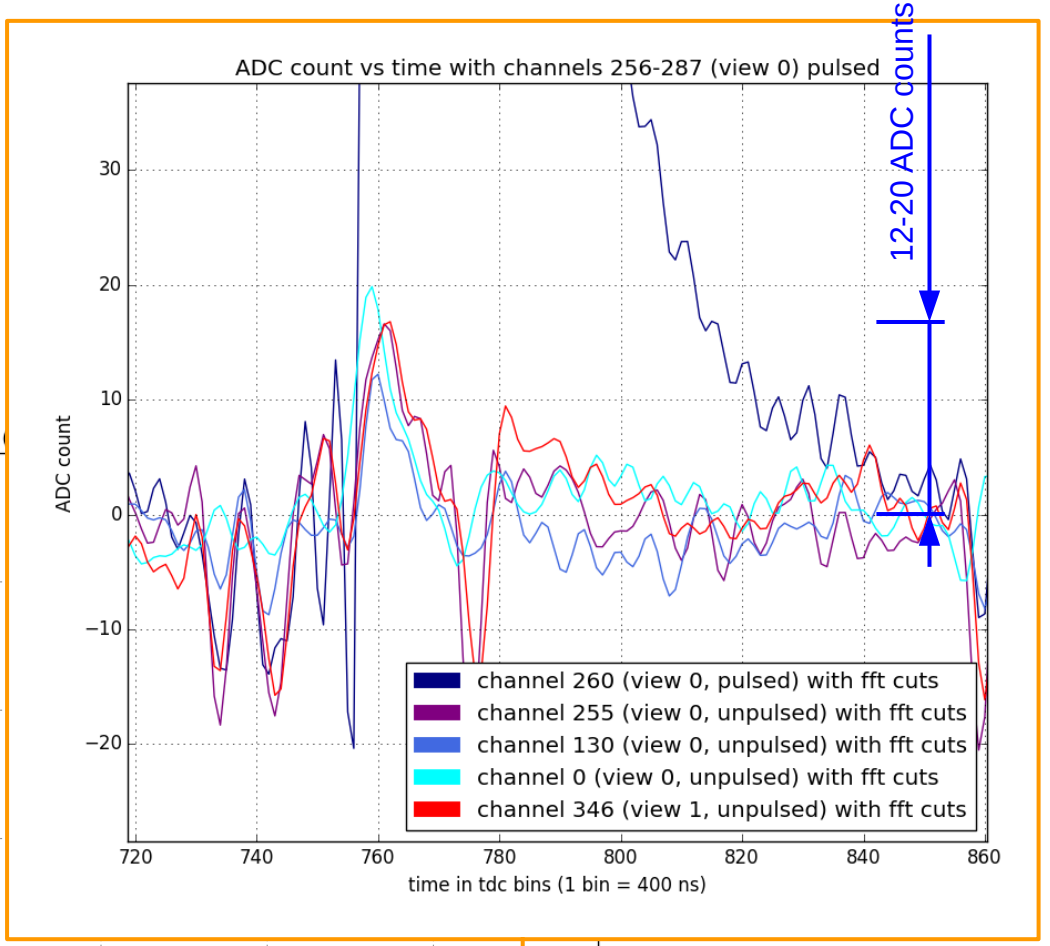




Pulsing measurements

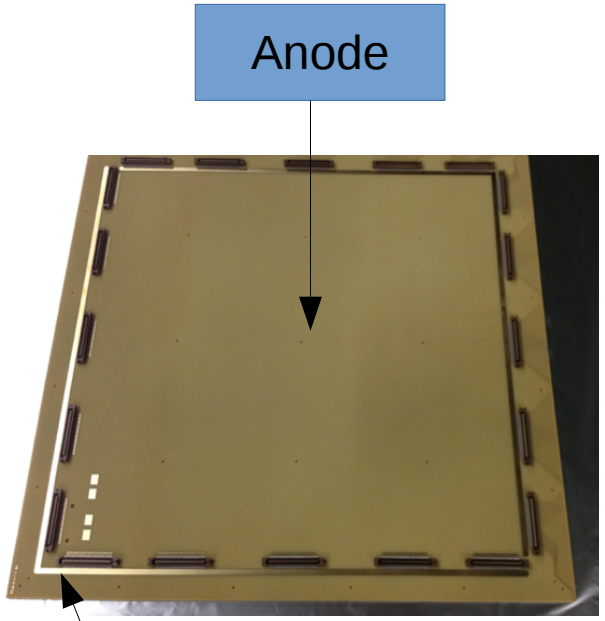
- induced signal on other channels: ~ 2.4-4.0 %
- little dependent on distance of non-pulsed channel to pulsed channel or view (parallel or perpendicular)

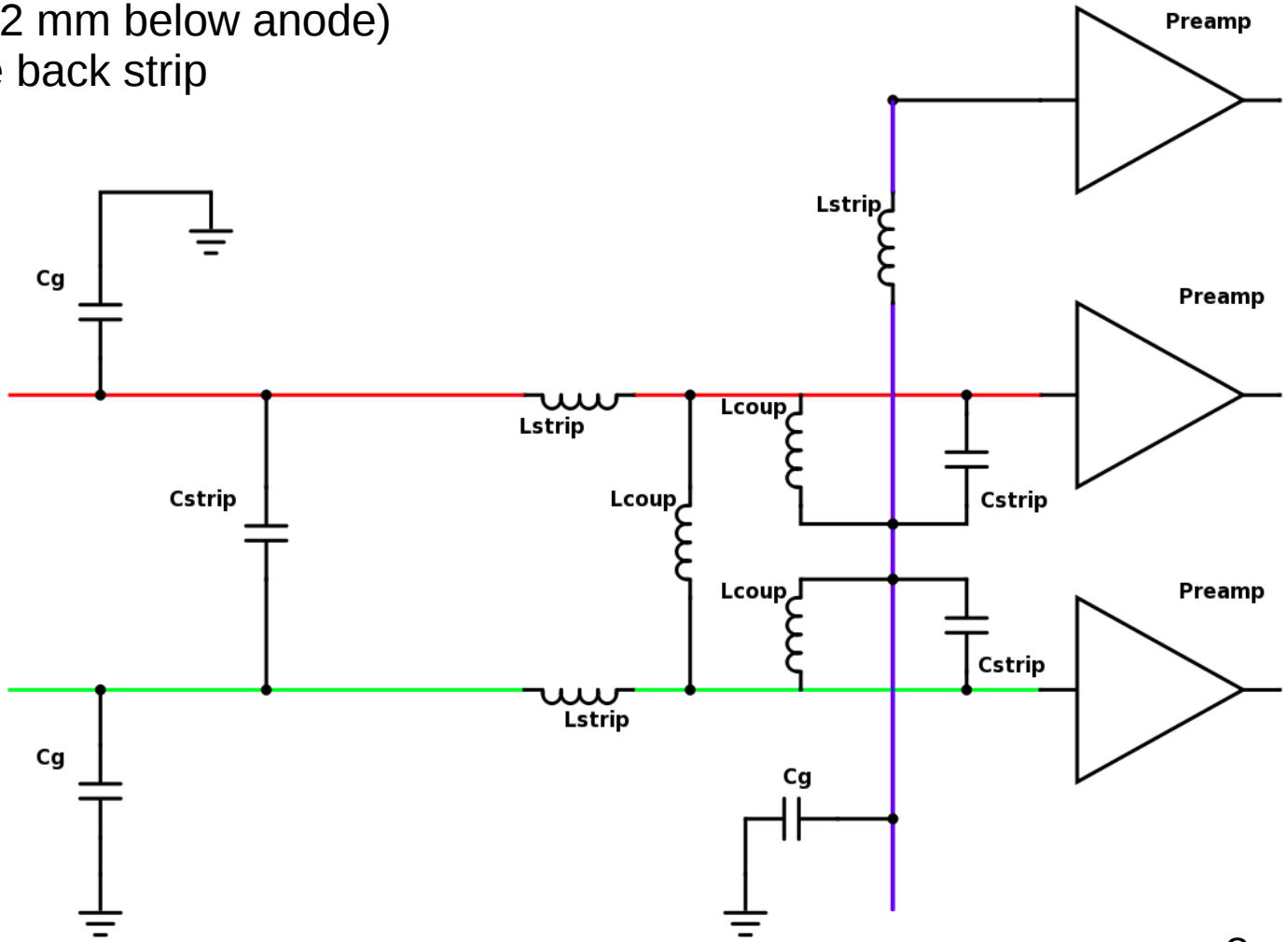




Circuit model of anode

- strips connected to preamp at one end (virtual ground), floating on other end
- capacitive/inductive coupling between strips
- capacitive coupling strip to ground consisting of:
  - capacitance strip to LEM (2 mm below anode)
  - capacitance strip to anode back strip





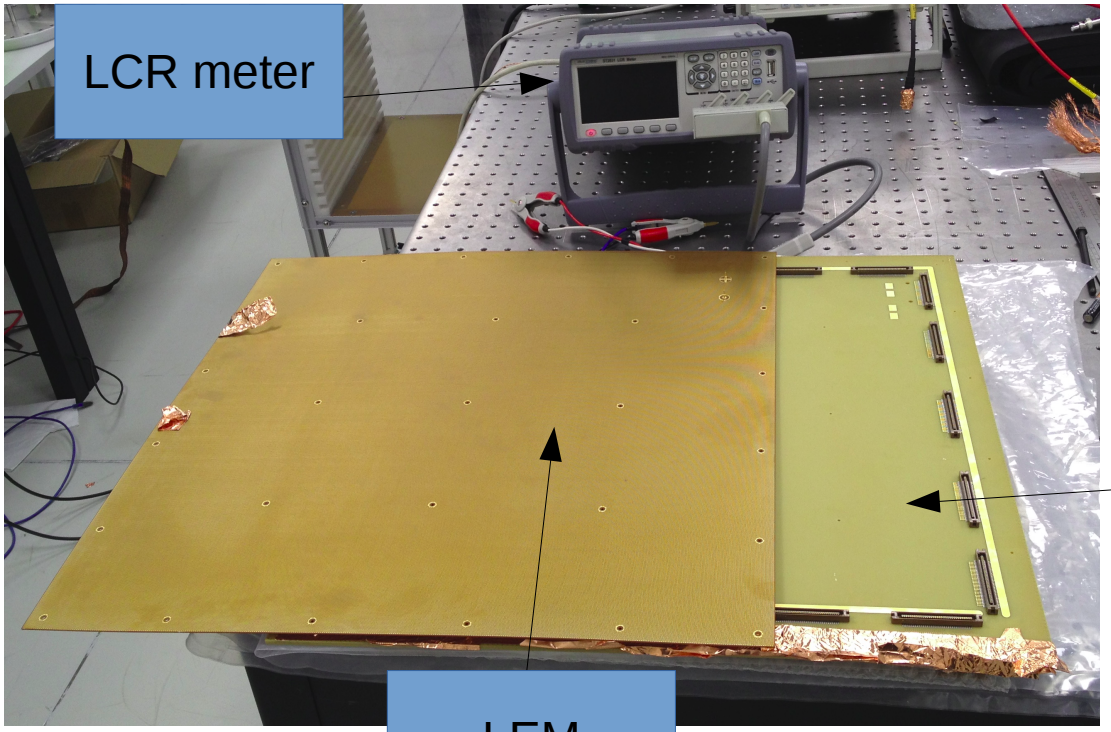
Measurements performed and scope

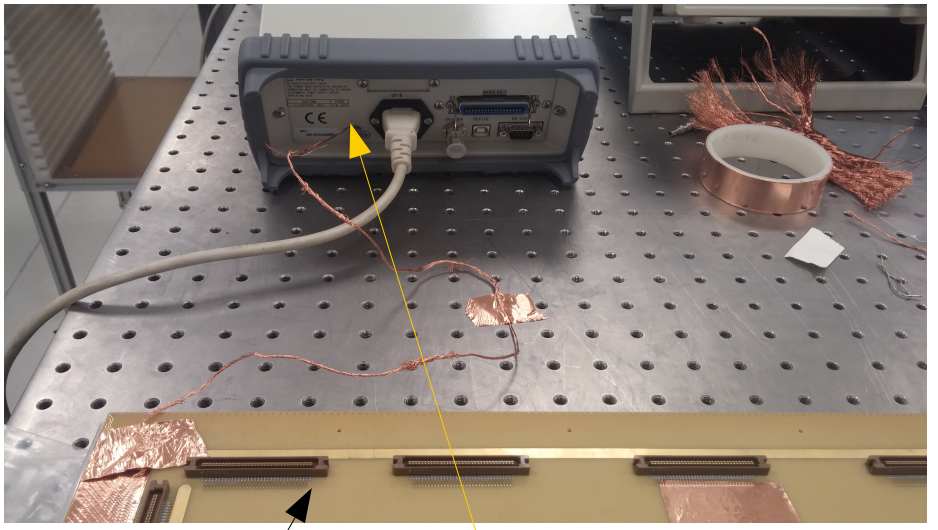
- Capacitance between 2 parallel strips at various distances
- Capacitance between 2 perpendicular strips
- Capacitance between 1 strip and ground:
  - Configuration 1 (without LEM): metal table at ground
  - Configuration 2 (with LEM): LEM at ground

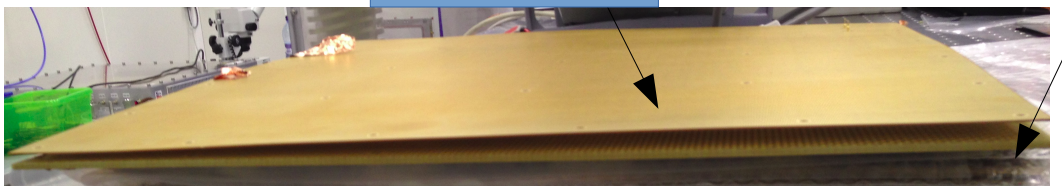
- Goal: quantitatively explain observed crosstalk in terms of equivalent circuit of the anode

Measurement setup

- Configuration 1: Anode on metal table without LEM
- Configuration 2: Anode on non-conductive surface with LEM 2 mm above

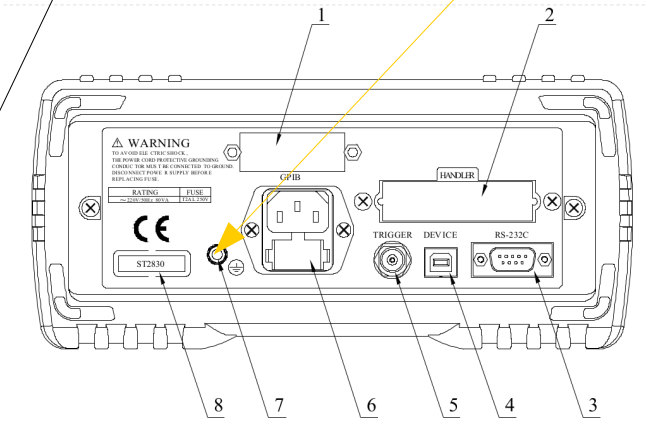






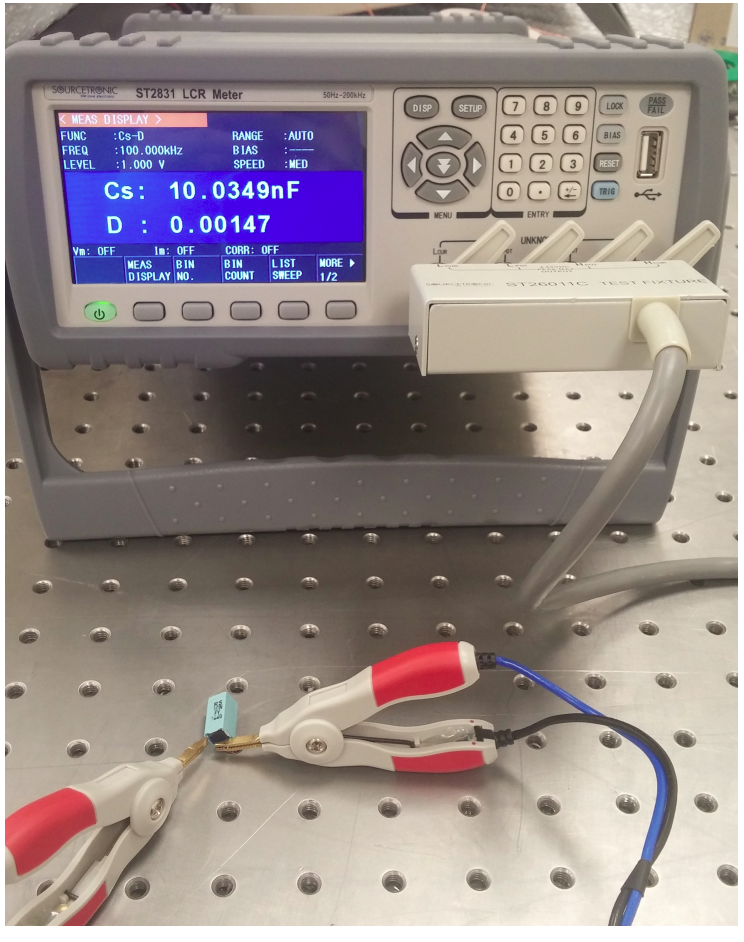
Anode

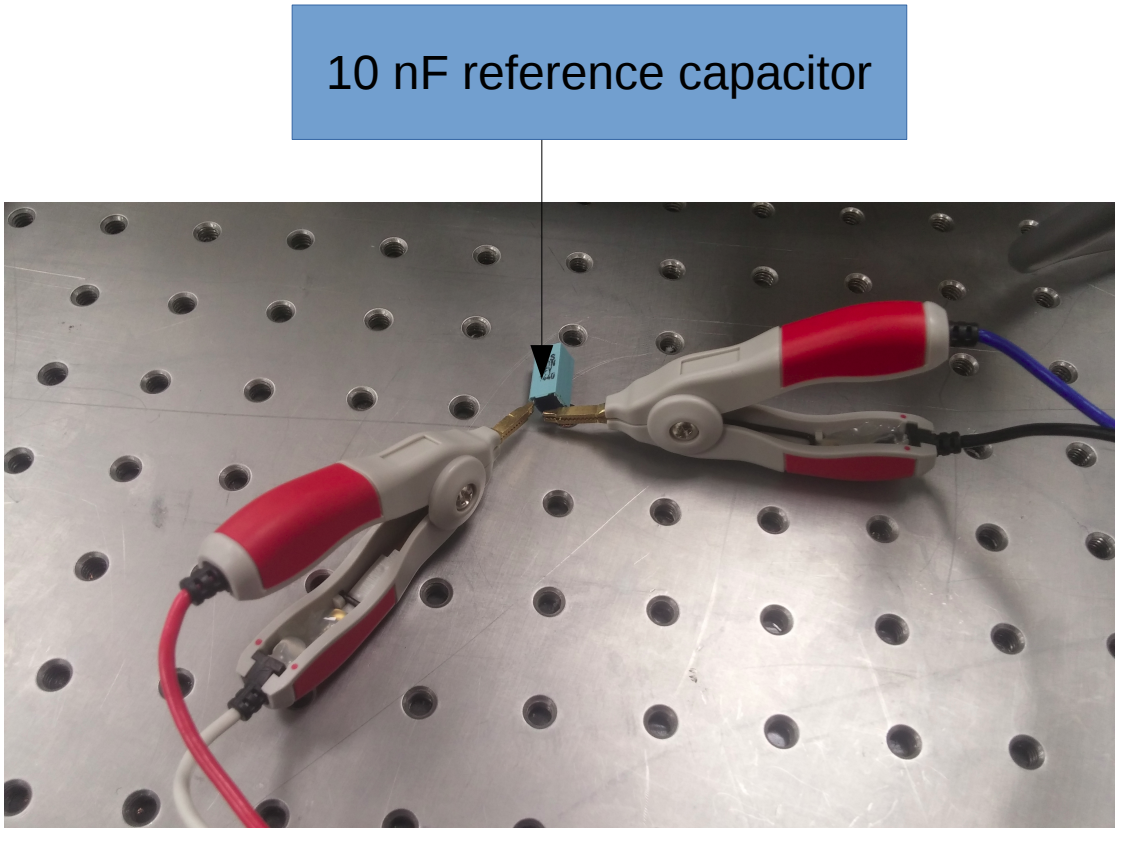
Ground terminal
LCR meter



LCR meter

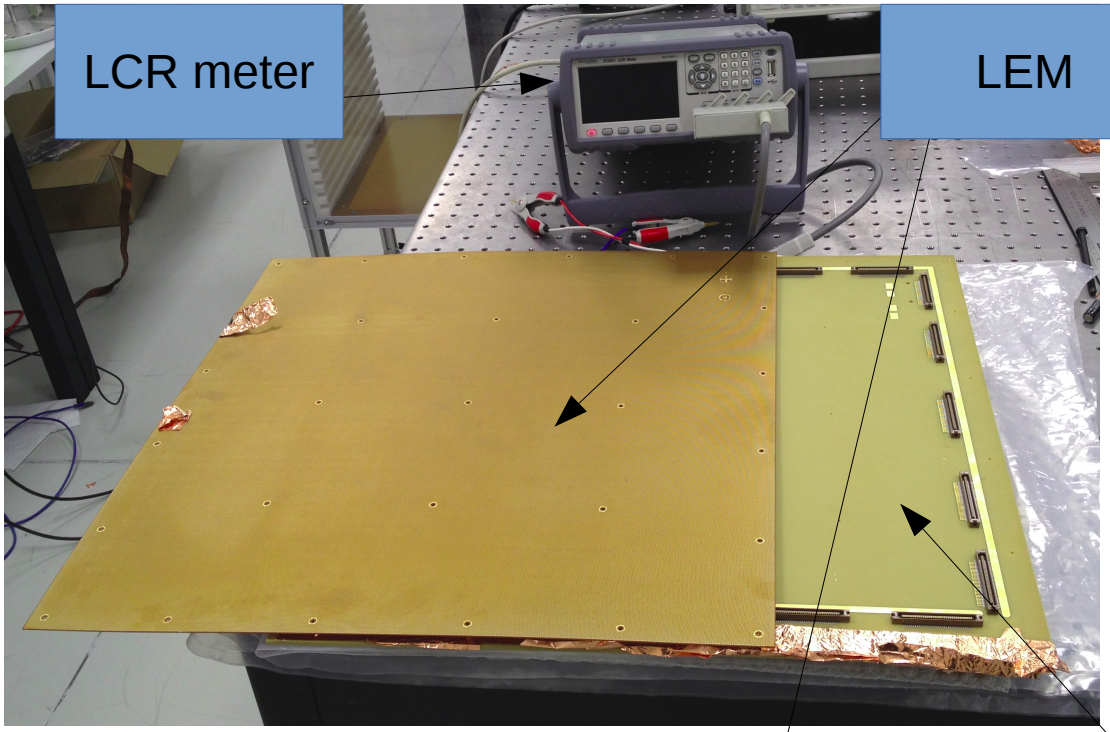
- Sourcetronic ST2831 LCR meter was used
- Calibrated by Sourcetronic on 30.01.2017
- independently checked with capacitor and resistor of known capacitance/resistance

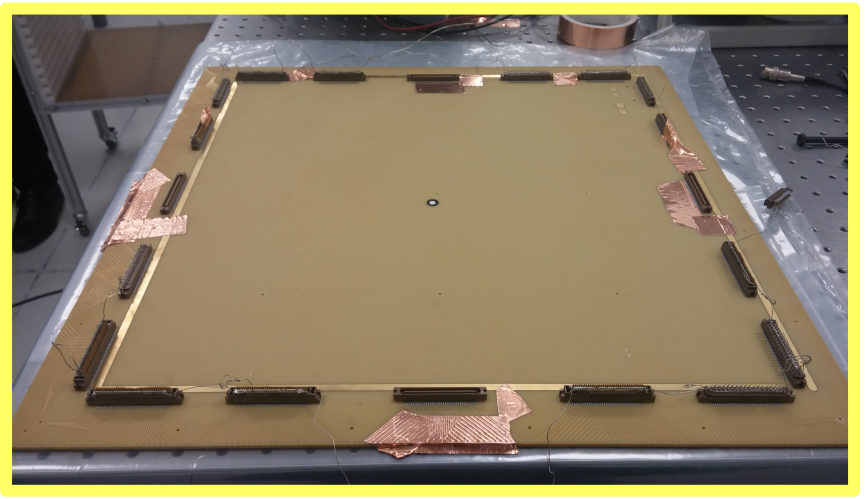


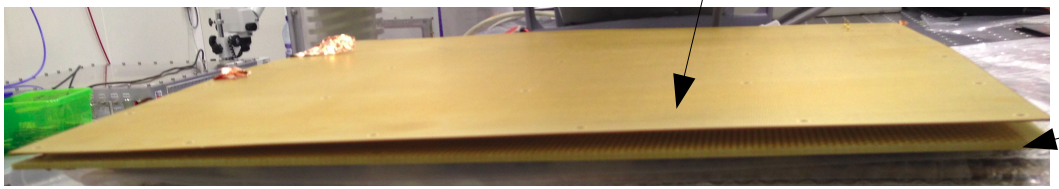


Measurement setup

- **Configuration 1: Anode on metal table without LEM**
- Configuration 2: Anode on non-conductive surface with LEM 2 mm above



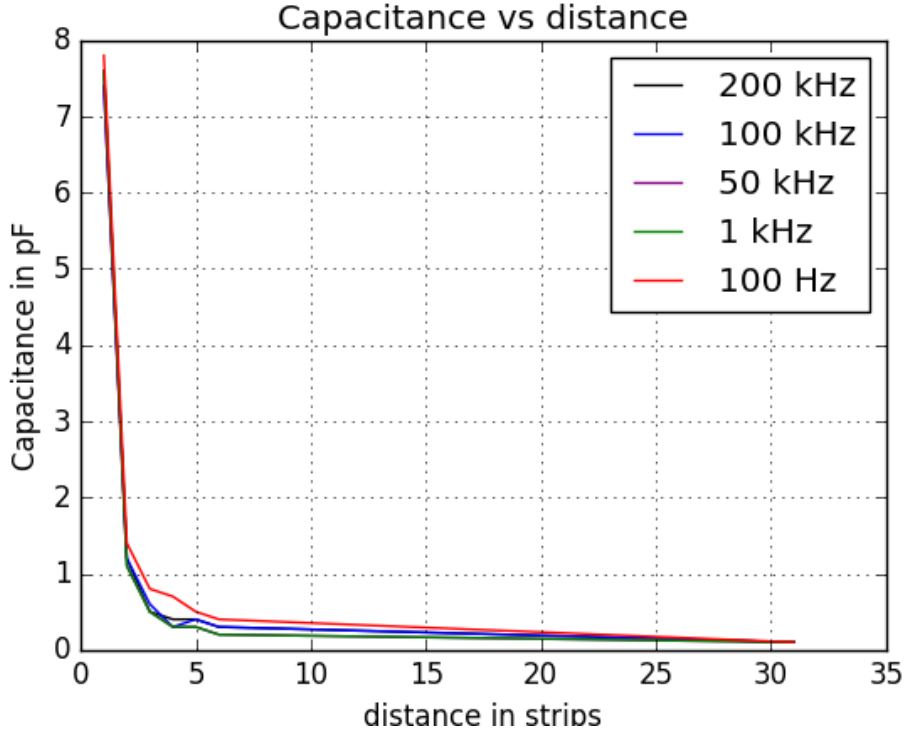




Strip-to-strip parallel capacitances with all strips grounded

Capacitances between parallel strips:

Frequency	Closest parallel	2nd closest	3rd closest	4th closest	5th closest	6th closest	31st closest
200 kHz	7.6 pF	1.2 pF	0.5 pF	0.4 pF	0.4 pF	0.3 pF	0.1 pF
100 kHz	7.4 pF	1.2 pF	0.6 pF	0.3 pF	0.4 pF	0.3 pF	0.1 pF
50 kHz	7.4 pF	1.1 pF	0.5 pF	0.3 pF	0.3 pF	0.2 pF	0.1 pF
1 KHz	7.6 pF	1.1 pF	0.5 pF	0.3 pF	0.3 pF	0.2 pF	0.1 pF
100 Hz	7.8 pF	1.4 pF	0.8 pF	0.7 pF	0.5 pF	0.4 pF	0.1 pF

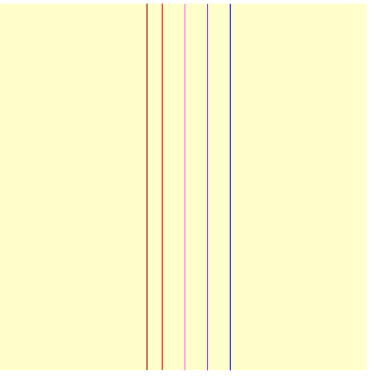


Configuration without LEM

Strip-to-strip parallel capacitance decreases rapidly with distance → no precise measurement after 6th closest strips

Measurement conditions:
Humidity: 39.8 %
Temperature: 19.4 °C

Capacitance measured between parallel strips with varying distance



All other strips grounded on both ends

Strip-to-strip perpendicular capacitances with all strips grounded

Very similar capacitances measured between all combinations of perpendicular strips

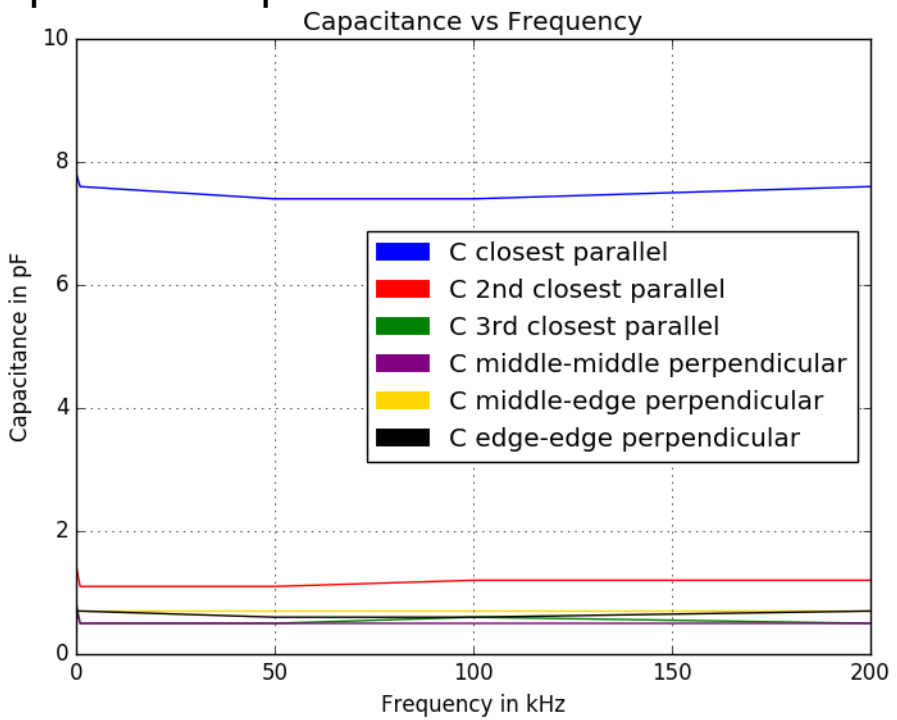
Configuration without LEM

Measurement conditions:
Humidity: 39.8 %
Temperature: 19.4 °C

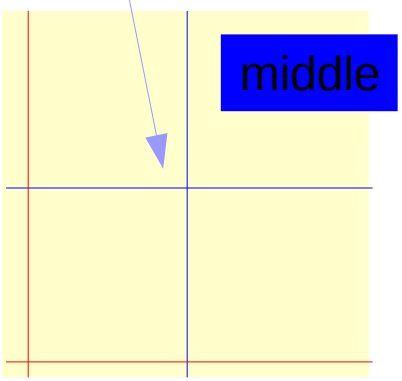
Capacitances between perpendicular strips:

Frequency	Middle-Middle	Middle-Edge	Edge-Edge
200 kHz	0.5 pF	0.7 pF	0.7 pF
100 kHz	0.5 pF	0.7 pF	0.6 pF
50 kHz	0.5 pF	0.7 pF	0.6 pF
1 kHz	0.5 pF	0.7 pF	0.7 pF
100 Hz	0.7 pF	0.7 pF	0.7 pF

Comparison to capacitances between parallel strips:



Capacitance measured between perpendicular strips



All other strips grounded on both ends

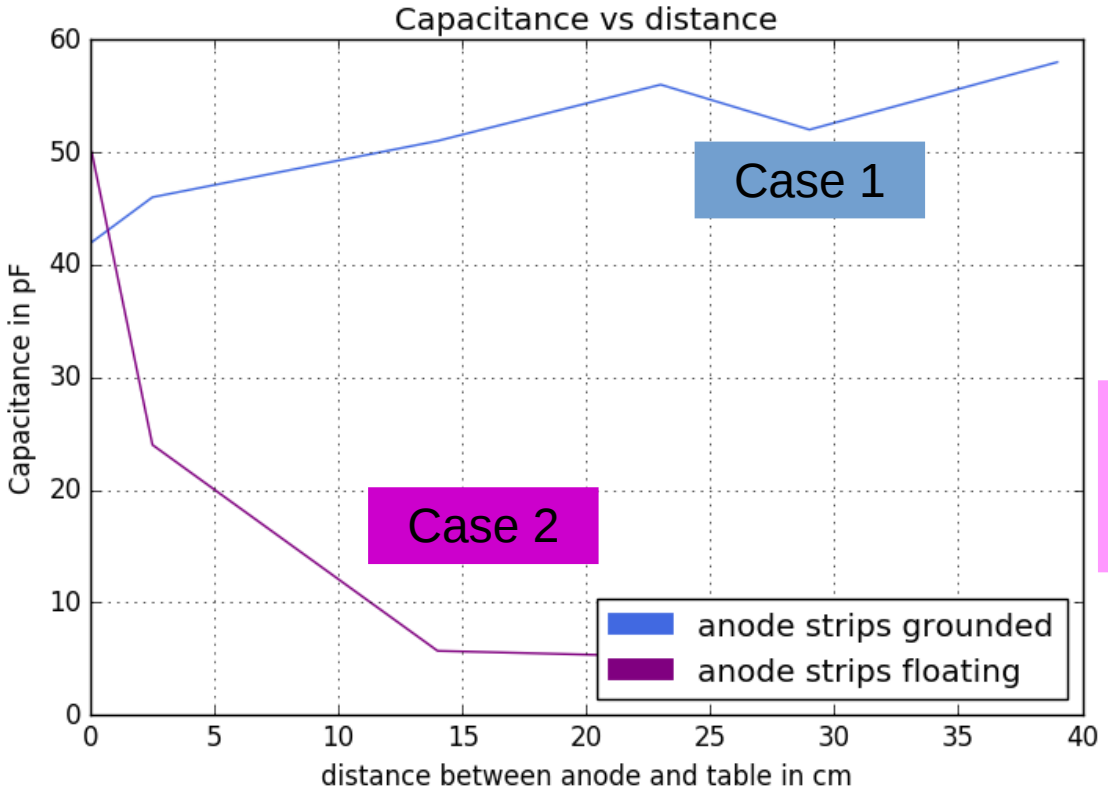
Strip-to-ground capacitances with varying distances from metal table

Case 1 (all strips grounded): capacitance to ground not decreasing with increasing distance to metal table
Case 2 (all strips floating): capacitance to ground rapidly decreasing with increasing distance to metal table

Configuration without LEM

Capacitance to grounded strips independent of distance to metal table → capacitance to other strips much larger than capacitance to ground

Capacitances measured by varying the distance of the anode to the metal table:



Capacitance measured between one floating strip and ground
Case 1: all other strips grounded
Case 2: all other strips floating

Measurement conditions:
Humidity: 22.6 %
Temperature: 20.7 °C

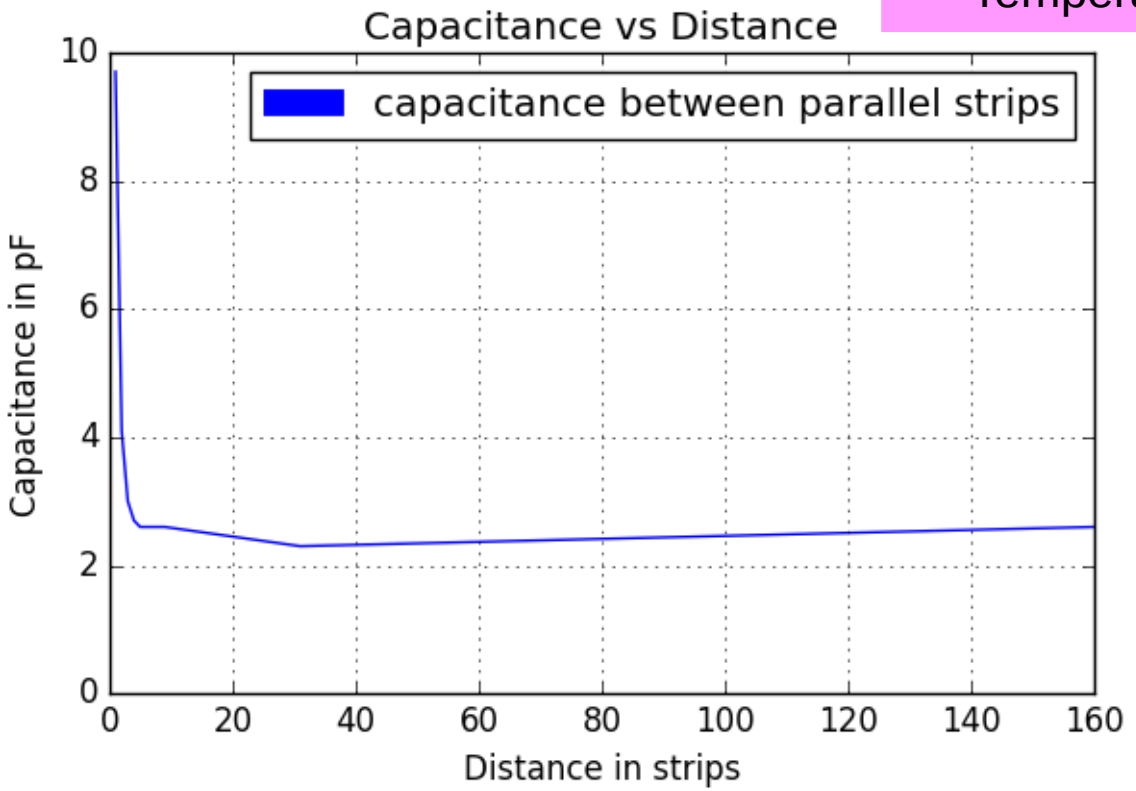
Capacitances with all strips floating

Configuration without LEM

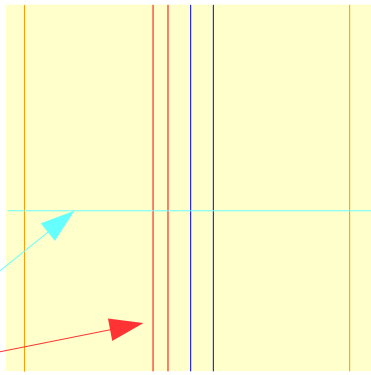
Closest parallel	2nd closest	3rd closest	4th closest	5th closest	6th	7th	8th	9th	31st	160th
9.7 pF	4.1 pF	3.0 pF	2.7 pF	2.6 pF	2.6 pF	2.6 pF	2.6 pF	2.6 pF	2.3 pF	2.6 pF

Capacitance between perpendicular strips: 2.4 - 2.6 pF

Measurement conditions:
Humidity: 25.1 %
Temperature: 21.3 °C



All strips floating

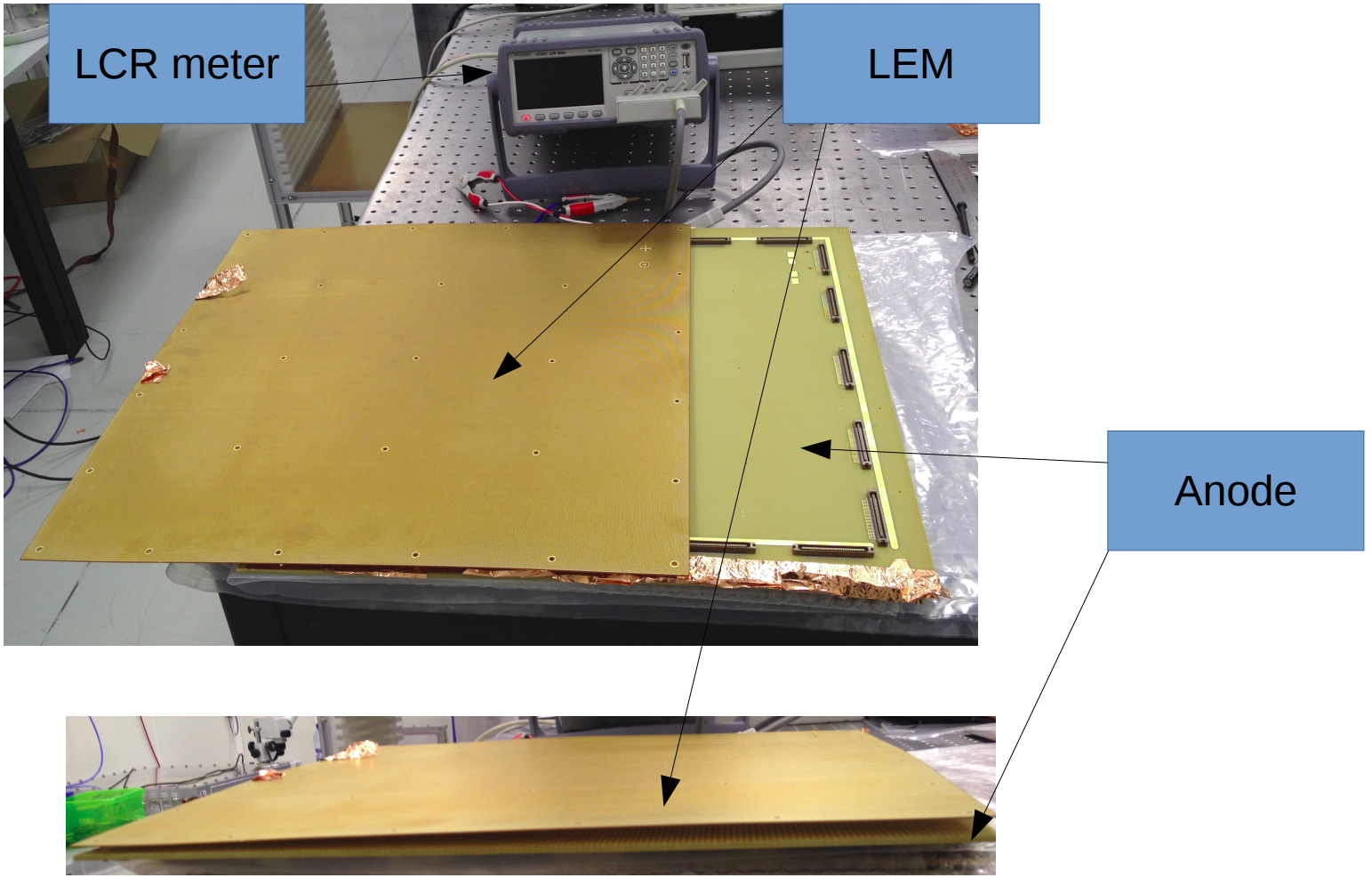


Capacitance between perpendicular strips

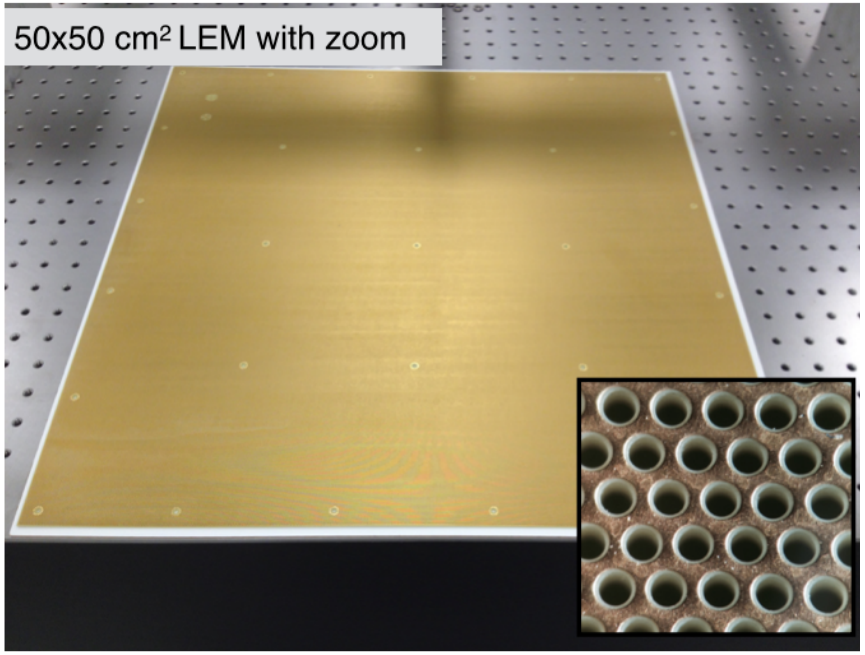
Capacitance measured between parallel strips with varying distance

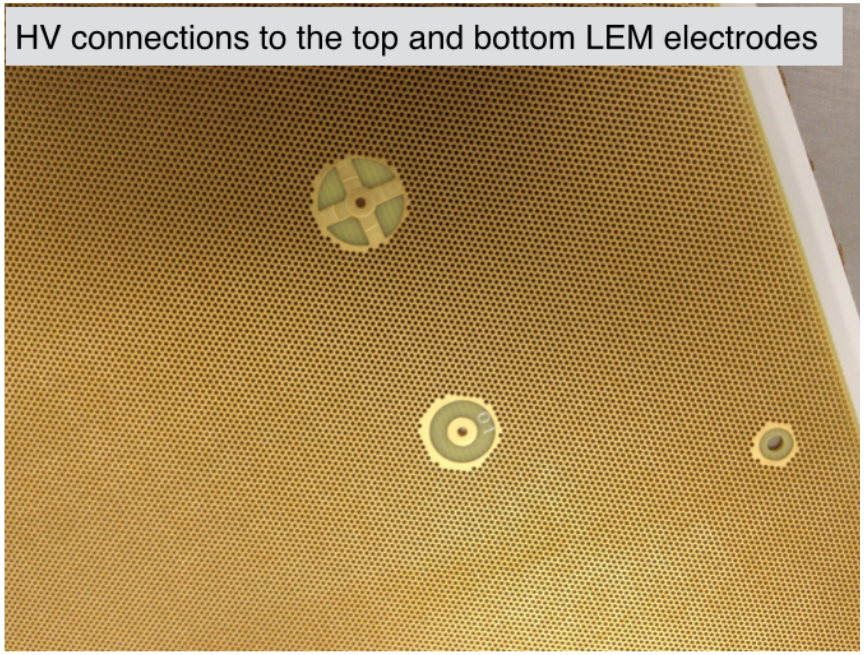
Measurement setup

- Configuration 1: Anode on metal table without LEM
- **Configuration 2: Anode on non-conductive surface with LEM 2 mm above**

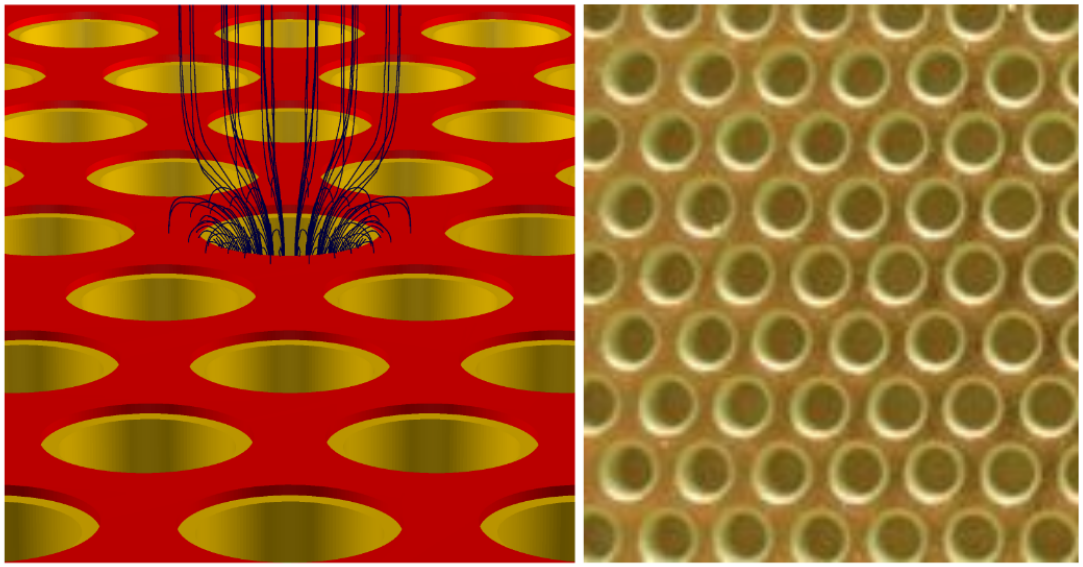


Structure of LEM



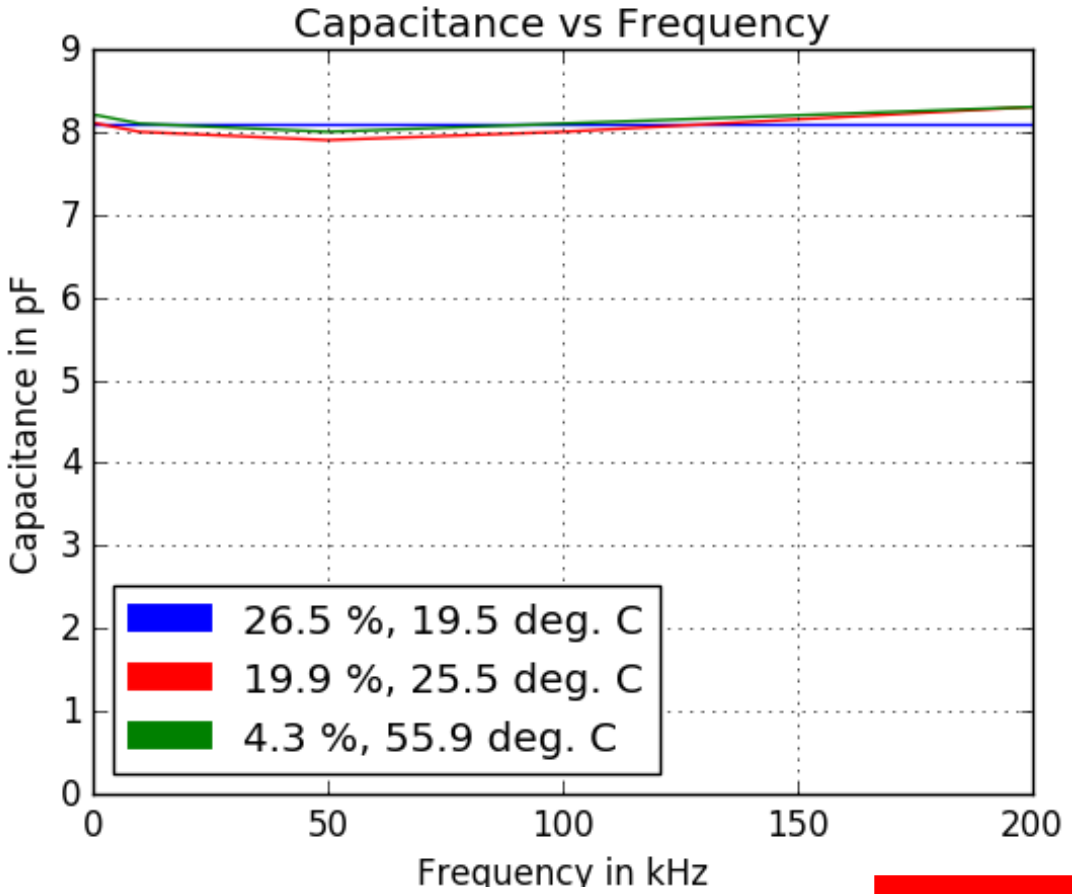


- Positioned 2 mm underneath anode
- Dimensions: 50 cm × 50 cm, thickness: 1 mm
- Consists of copper electrodes on both sides (red) and insulating material FR4 (yellow)
- cylindric holes spaced 800 µm from each other with diameter of 500 µm
- density of holes: , number of total holes:
- responsible for multiplication of ionization charges



Capacitances between 2 parallel strips

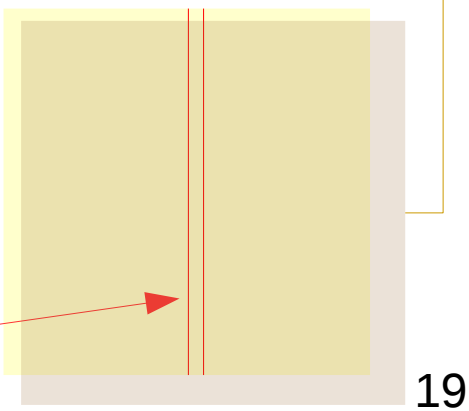
Capacitance between 2 neighboring strips not affected by different temperatures/humidities in range 19.5-55.9 °C / 26.5-4.3 %



Configuration with LEM

Anode and LEM heated up with hot air gun

LCR meter ground



Capacitance measured between parallel strips with all other anode strips grounded, at varying temperatures/humidities

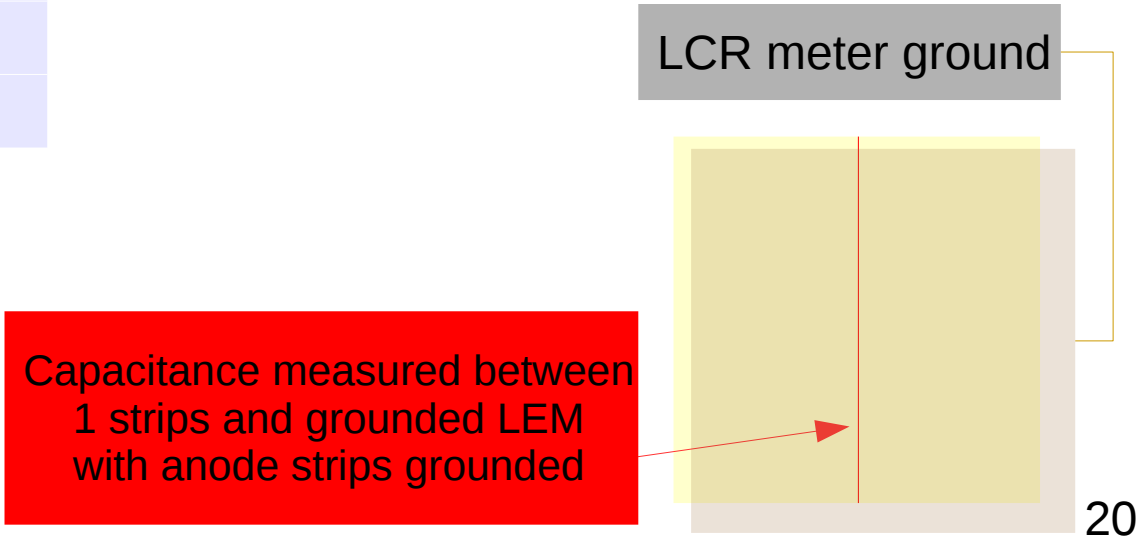
Capacitances between 1 strip and LEM

Capacitance between grounded LEM and floating strip: ~50 pF

Configuration with LEM

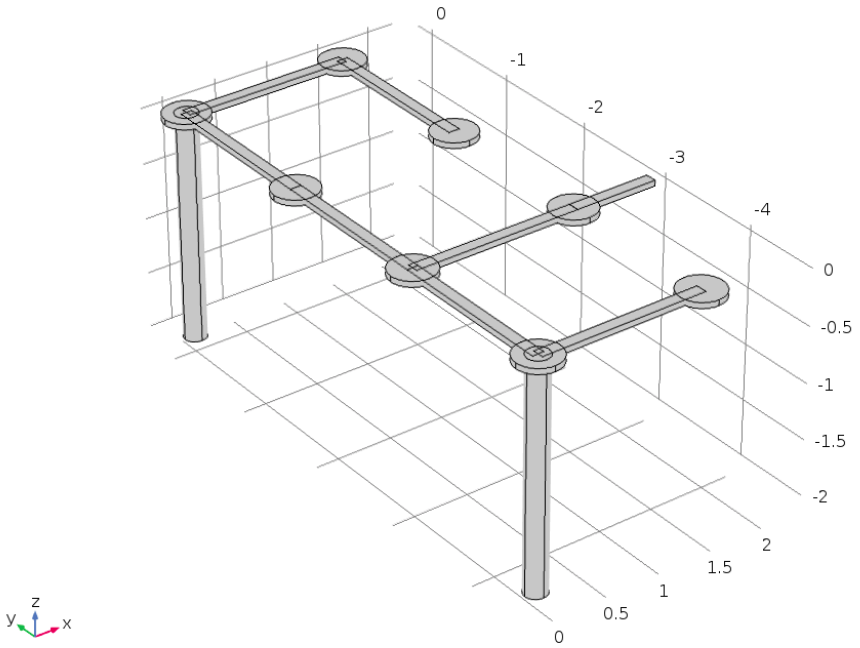
Measurement conditions:
Humidity: 26.5 %
Temperature: 19.5 °C

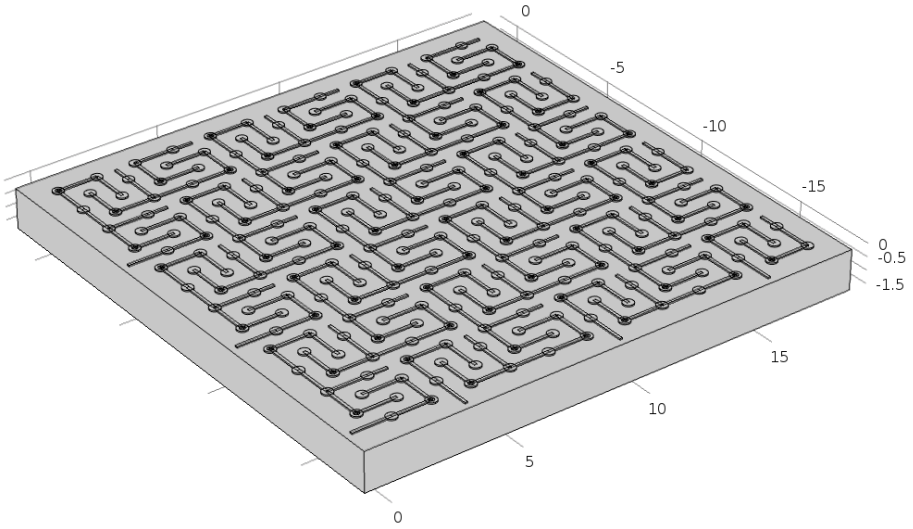
Frequency	Capacitance between grounded LEM and 1 strip
200 kHz	57 pF
100 kHz	53 pF
50 kHz	51 pF
10 kHz	47 pF
250 Hz	200-800 pF



Next steps

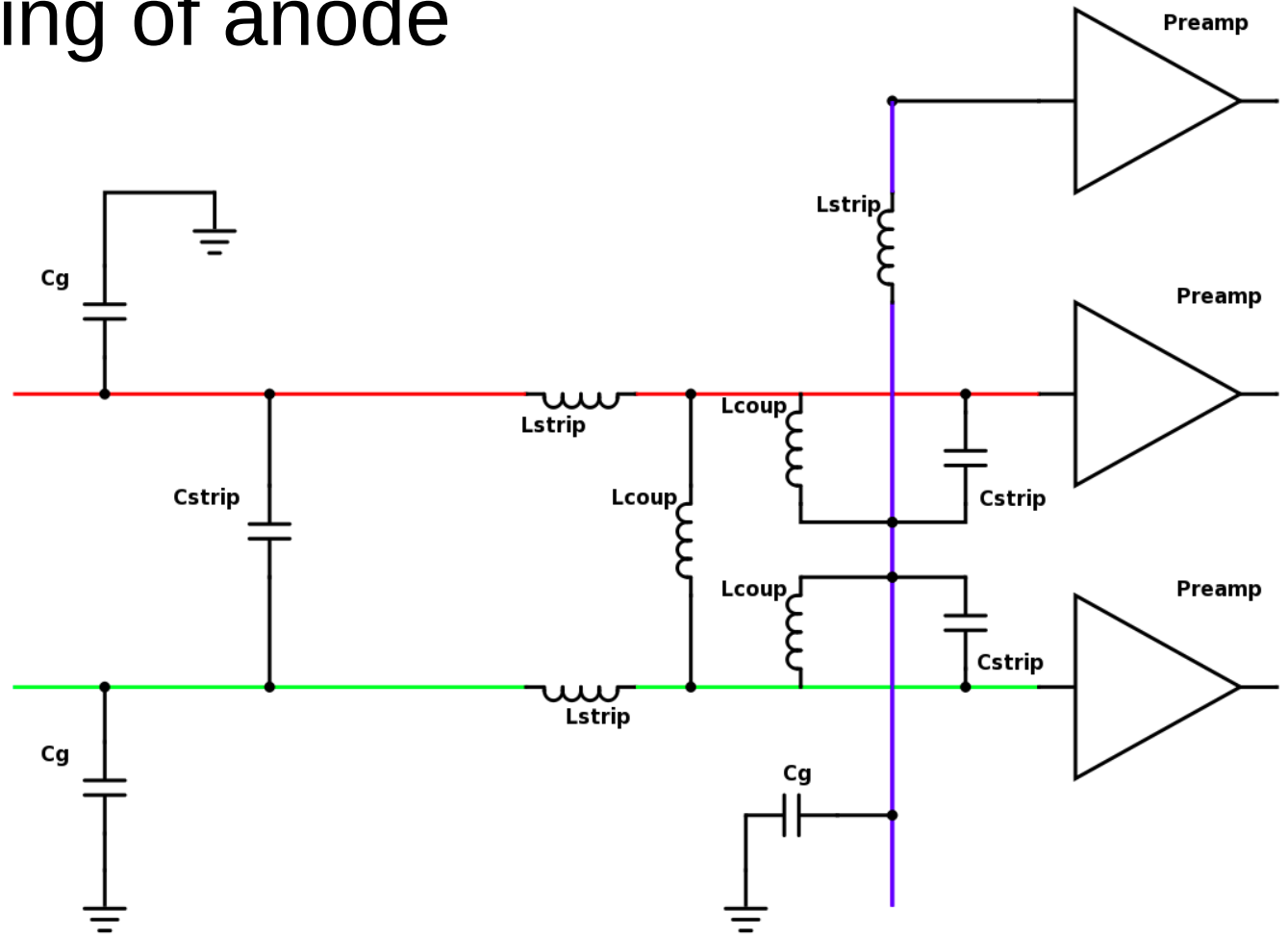
- simulate model of anode in Comsol to calculate capacitances between strips and compare to measured values





Next steps

- simulate equivalent circuit of multiple anode strips to compare to signals observed during pulsing of anode



Summary

- Capacitance between parallel strips decreases rapidly with distance → capacitance between 3rd closest strips (0.5 pF) less than 10% of closest strips (7.6 pF)
- Capacitance between 2 perpendicular strips (0.5 pF) ~ 10% of closest parallel capacitance (7.6 pF). Each strip couples to 160 perpendicular strips
- Capacitance of strip to ground significantly smaller than capacitances between strips
- With floating strips, higher order coupling through capacitance is not negligible (2.6 pF between furthest 2 strips) as seen in pulsing tests
- Capacitance between parallel strips independent of temperature/humidity in ranges 19.5-55.9 °C / 26.5-4.3 %
- Capacitance between LEM and anode strip ~ 50 pF
- Working progress: Comsol simulations & equivalent circuit simulations