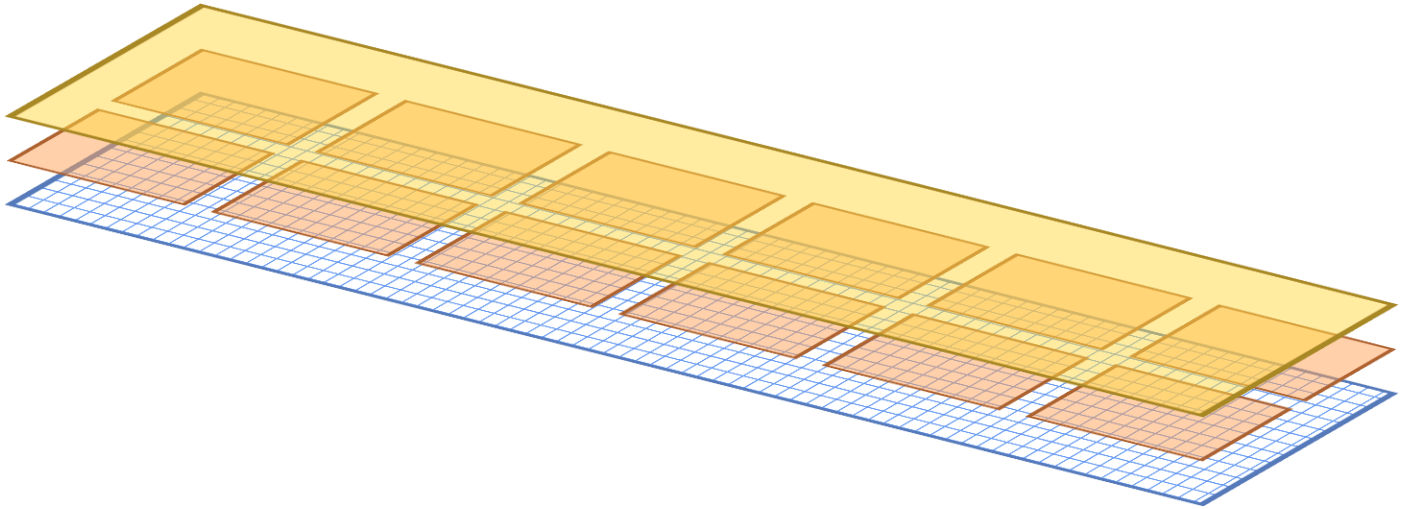
Anode impedance and grid/LEM capacitance measurements



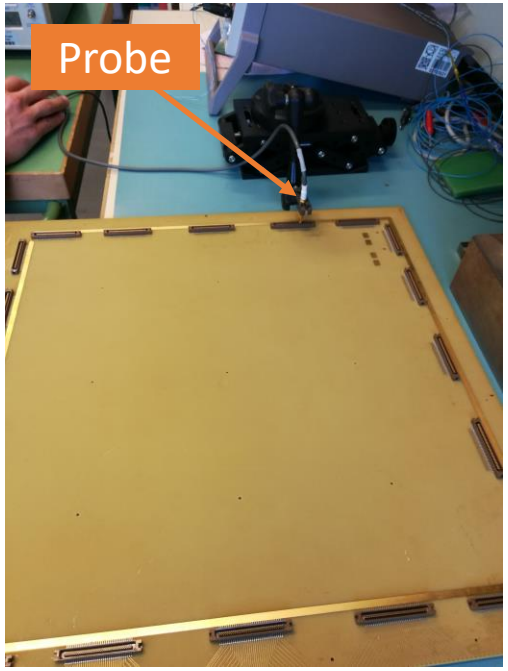
Caspar Schloesser

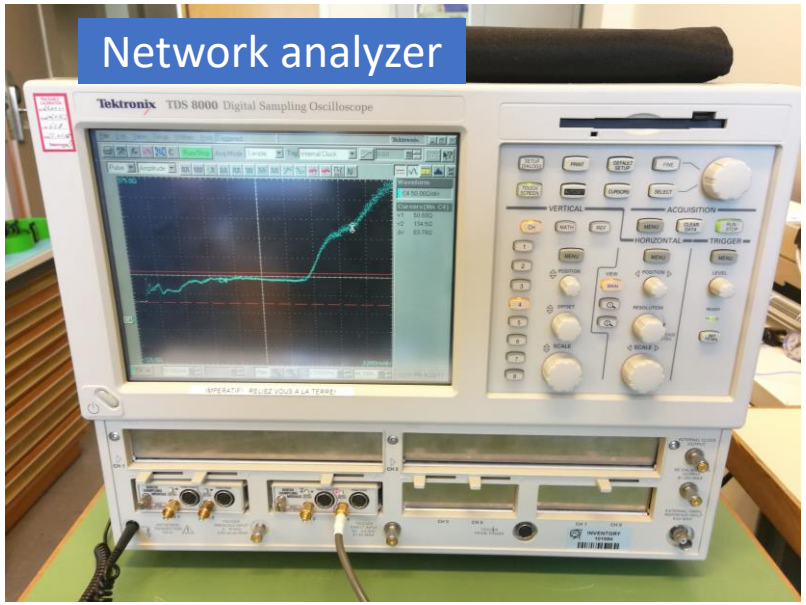
Summary

- Impedance measurements
  - 6x6x6 and 3x1x1 anodes
  - Different connectors and KEL cable
- LEM-grid capacitance measurements
  - For different LAr levels and CRP positions
  - Comparison to
    - Theoretical value
    - Levelmeter readings

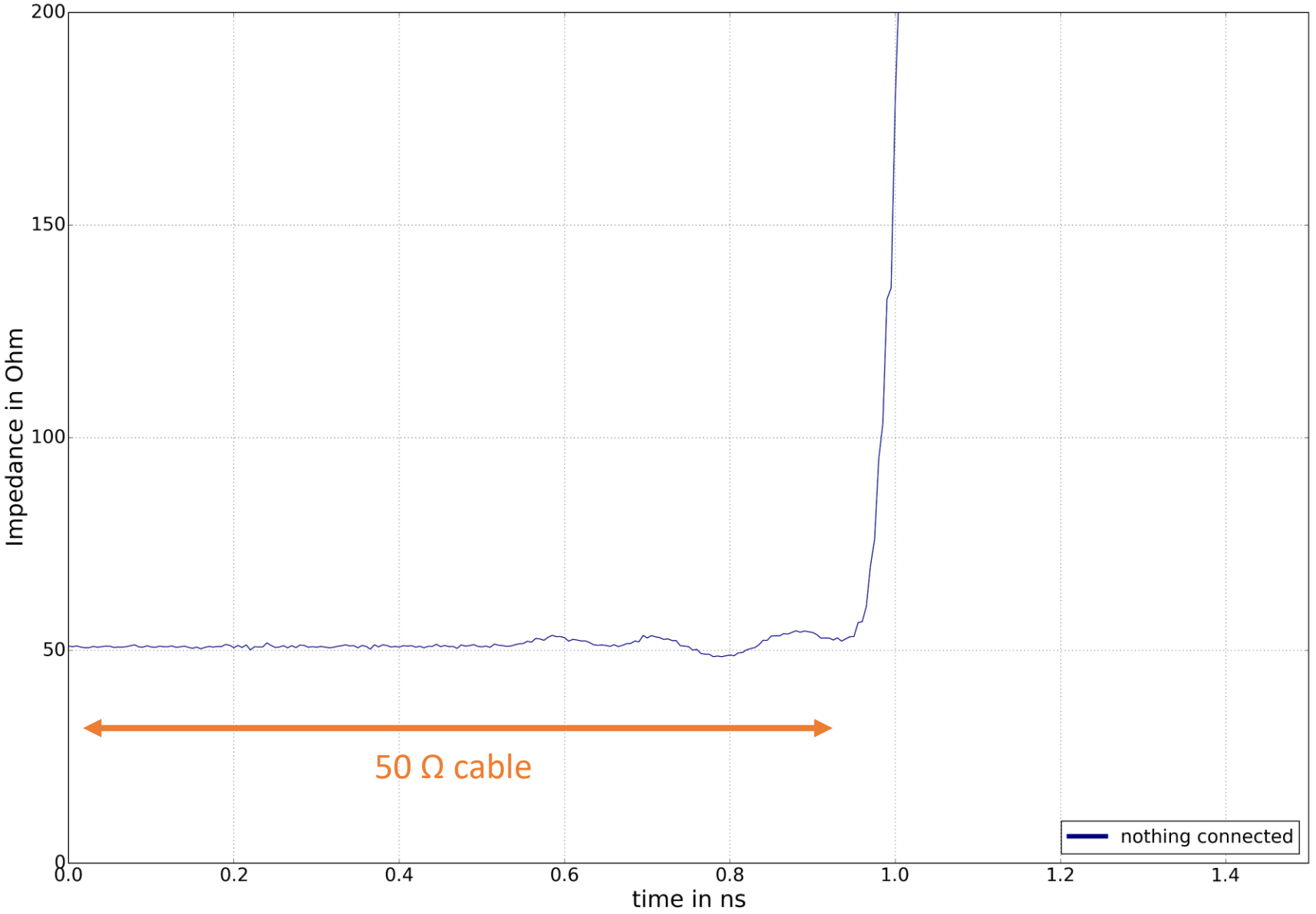
Measurement setup

- Impedance was measured with a Tektronix TDS 8000 Digital Sampling Oscilloscope for:
  - 3x1x1 anode module
  - 6x6x6 anode module
    - Strips at various positions and views
  - Anode + FEP/Kapton/PCB/KEL connectors
  - The 2 anode modules linked together
  - The 2 contacts of the probe were placed on the strip connection and the ground of the anode



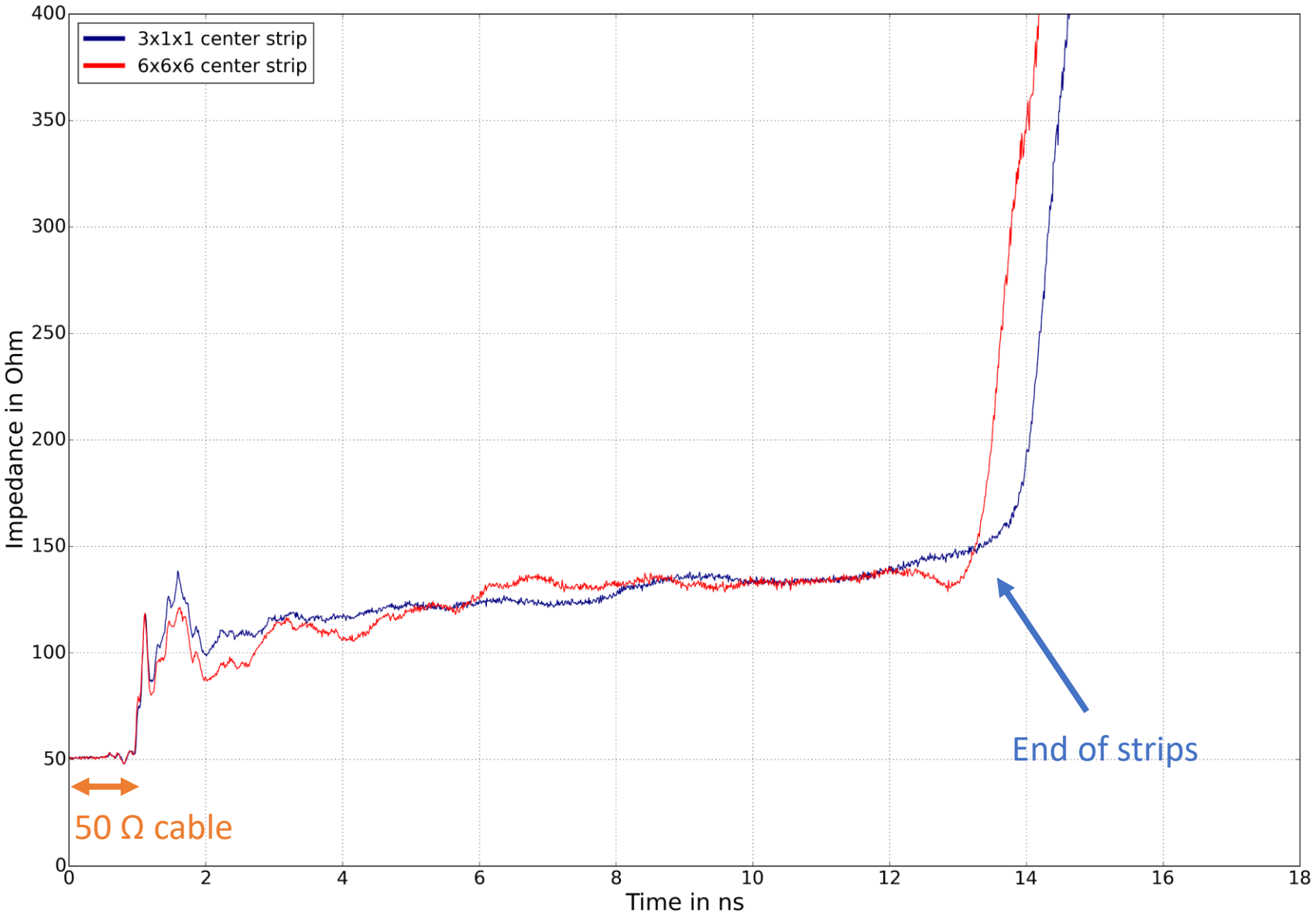


Nothing connected

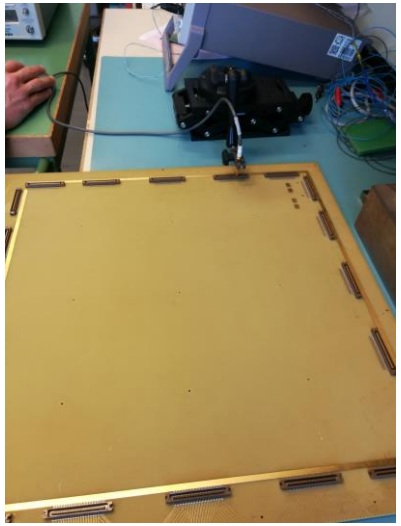


- With nothing connected to the probe, only the impedance of the 50 Ω cable is measured
  - At the probe connection it goes to ∞

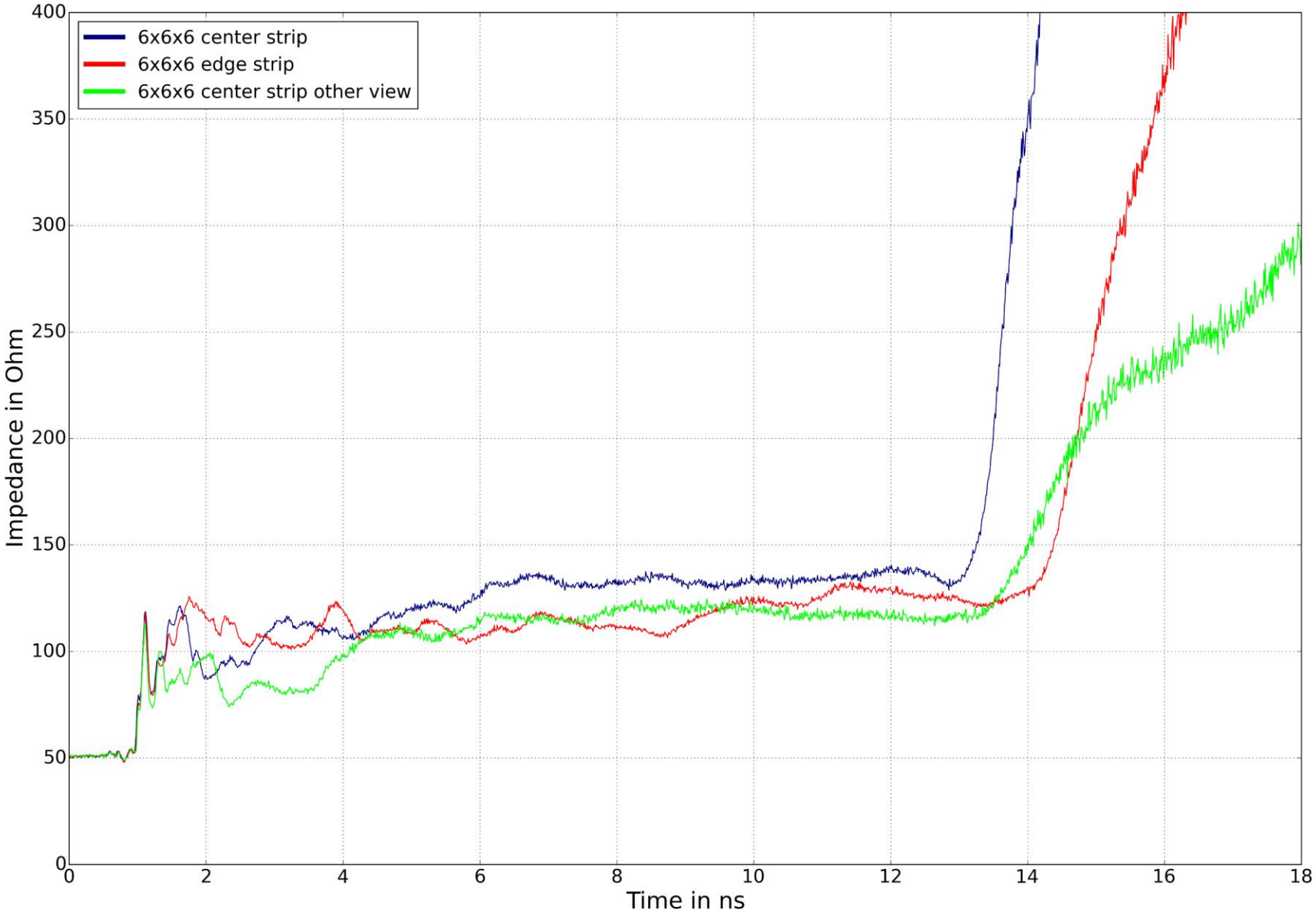
6x6x6, 3x1x1 anodes center strip comparison



- Impedance between 100 – 140 Ω for strips of both anode modules
- Contacts from connector to strips have slightly different lengths
  → slightly different durations for signals to traverse entire copper track



Comparison of different strips for 6x6x6 anode



- Contacts from connector to strips have slightly different lengths
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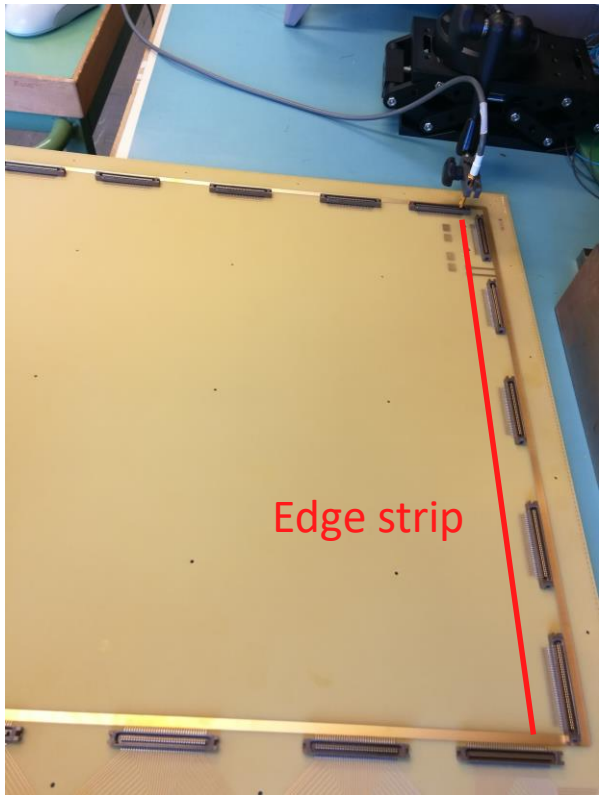
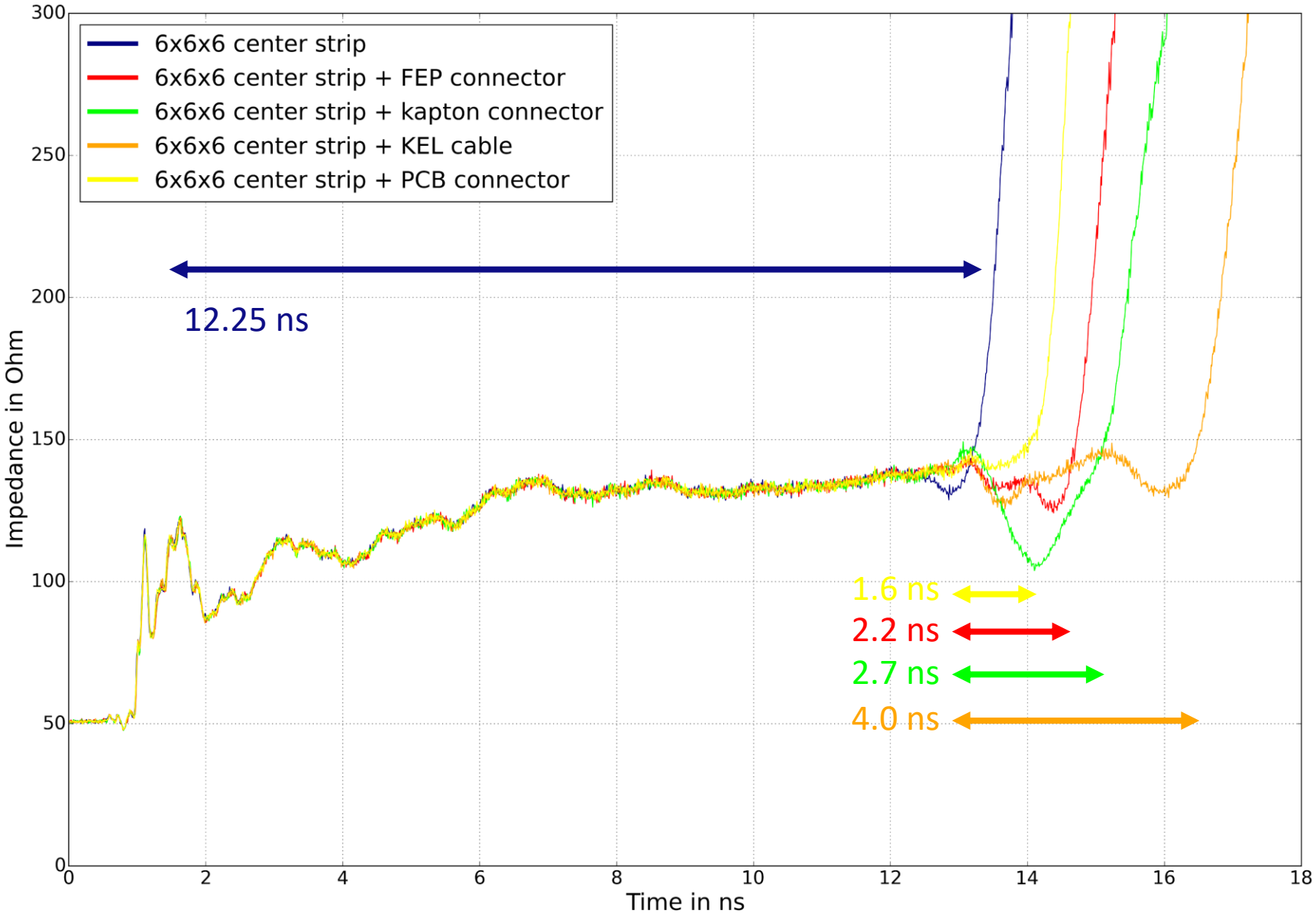
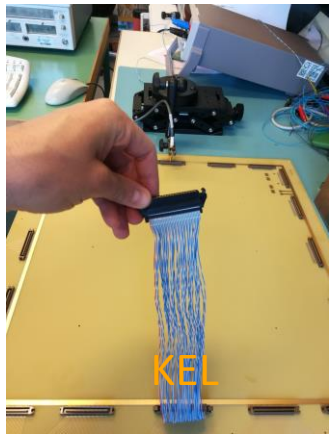
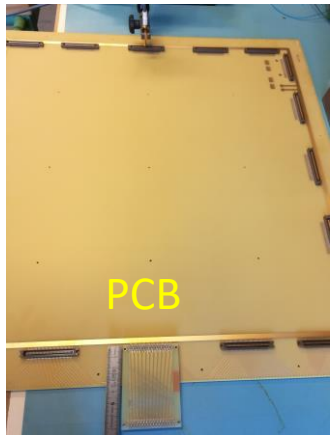


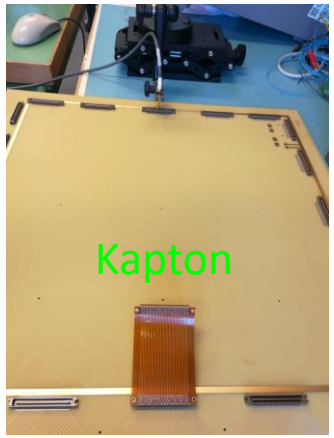
6x6x6 anode + connector

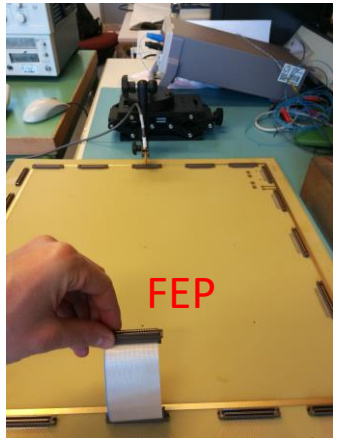


- Impedance not matched well for Kapton connector
- Impedance matched for KEL ribbon cables







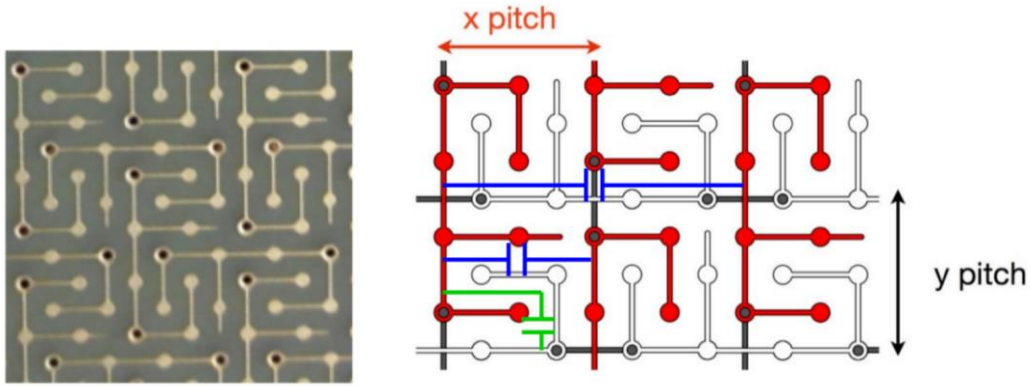


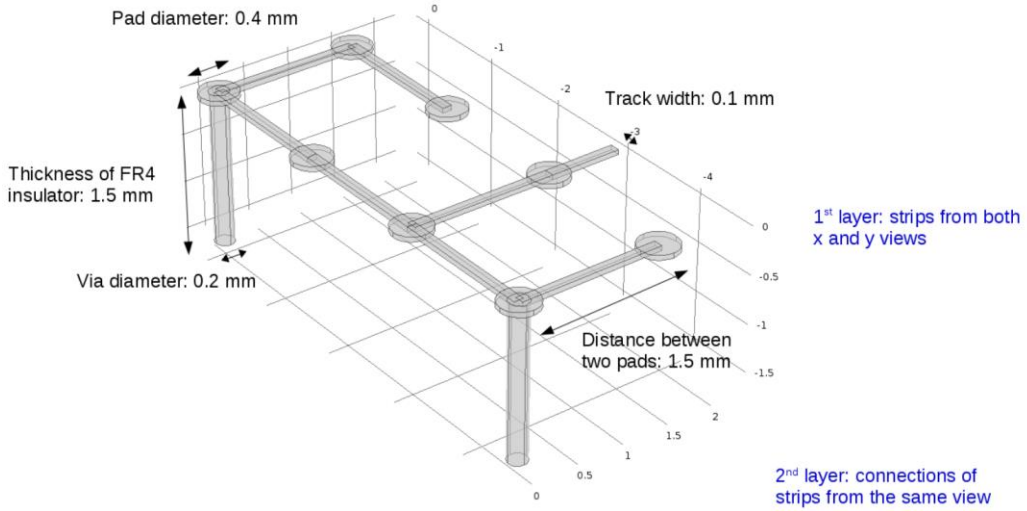
Signal speed in anode

- Effective length of 1 anode strip:

  50 cm + 80 * 2 * 1.5 mm = 74 cm

  (each strip passes 80 times below the perpendicular strips for 1 anode module)
- Time it takes signal to cross 1 strip: 12.25 ns
- Signal speed: 6.0e7 m/s = 0.20 * c_0

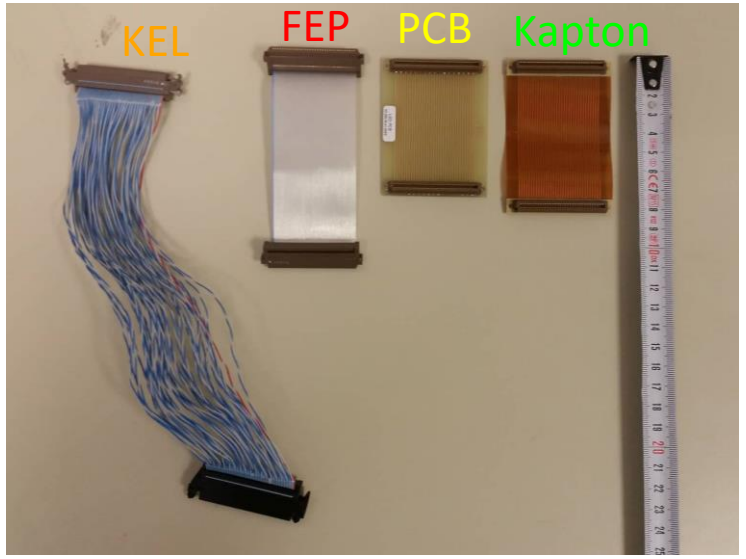


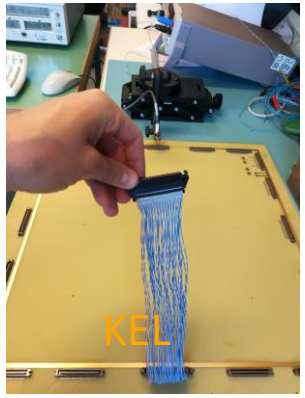


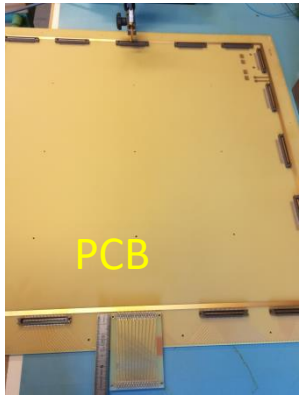
Taken from Pin-Jung Chiu

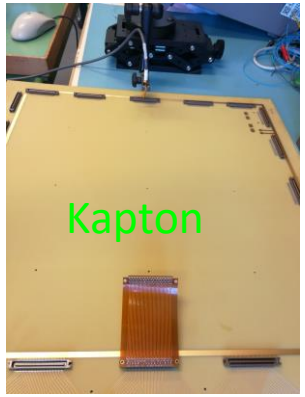
Signal speed in connectors

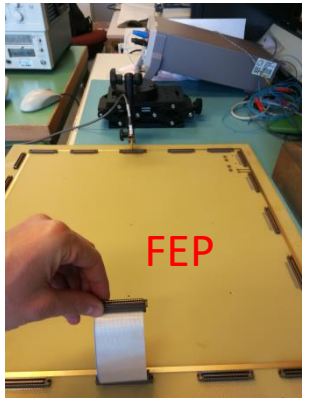
- PCB connector: 6.5 cm / 1.6 ns = 4.1e7 m/s = 0.14 * c_0
- FEP connector: 11 cm / 2.2 ns = 5.0e7 m/s = 0.17 * c_0
- Kapton connector: 7.5 cm / 2.7 ns = 2.8e7 m/s = 0.09 * c_0
- KEL cable: 25 cm / 4.0 ns = 6.3e7 m/s = 0.21 * c_0



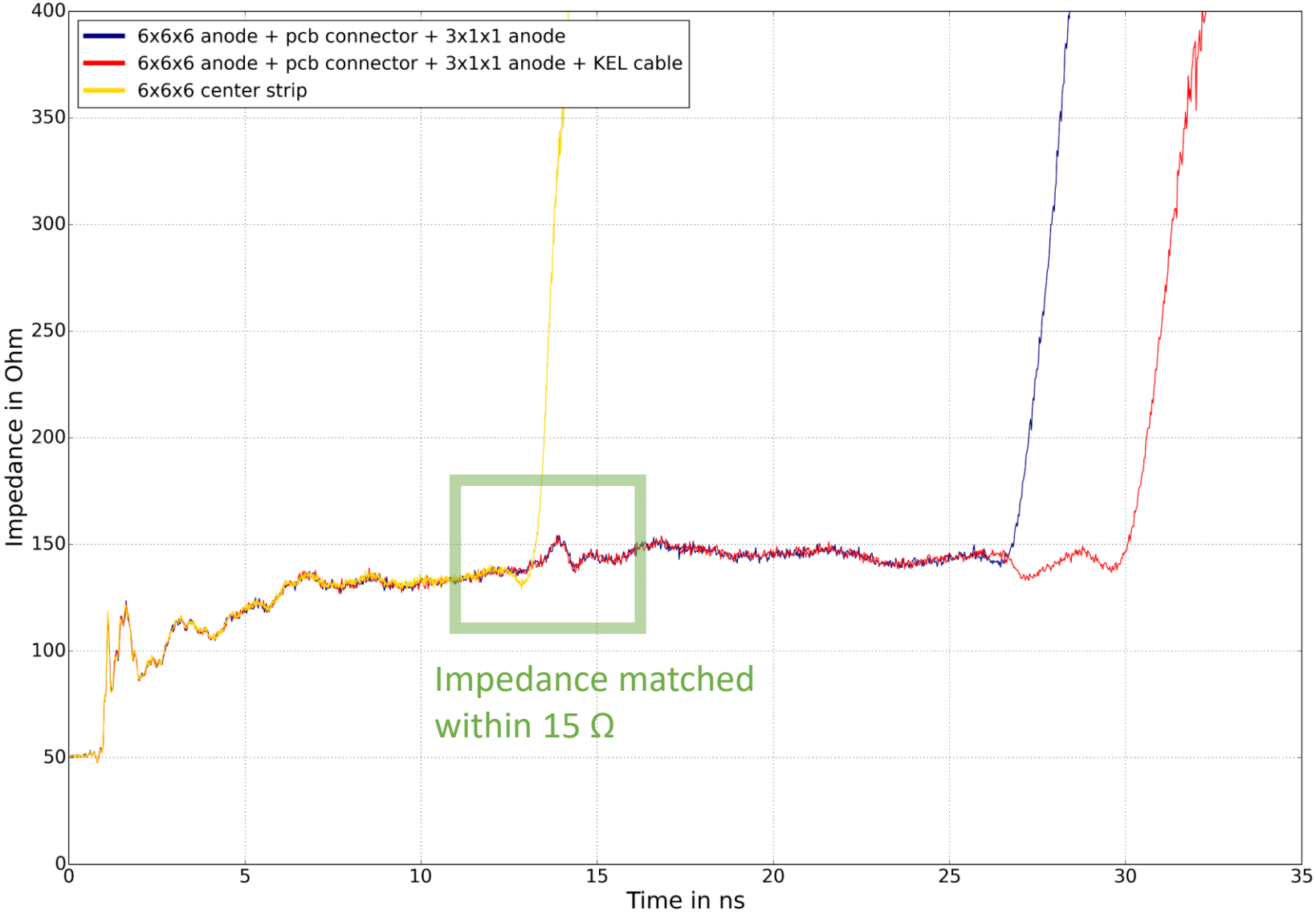




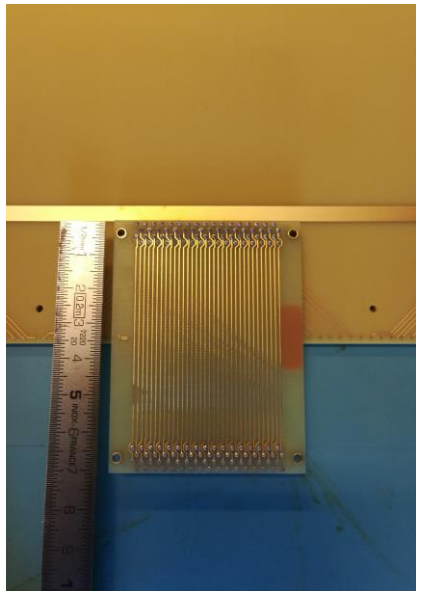


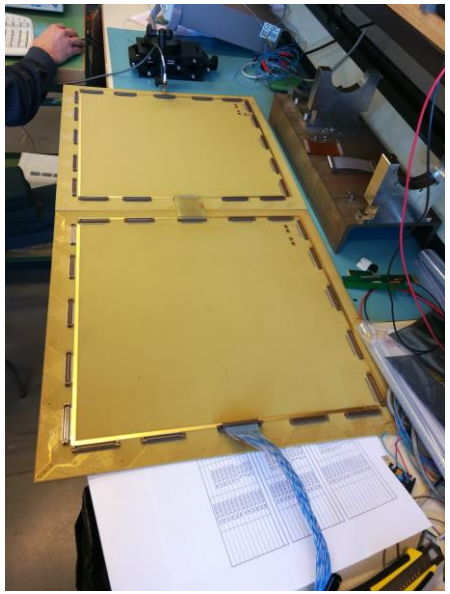


Anodes chained together



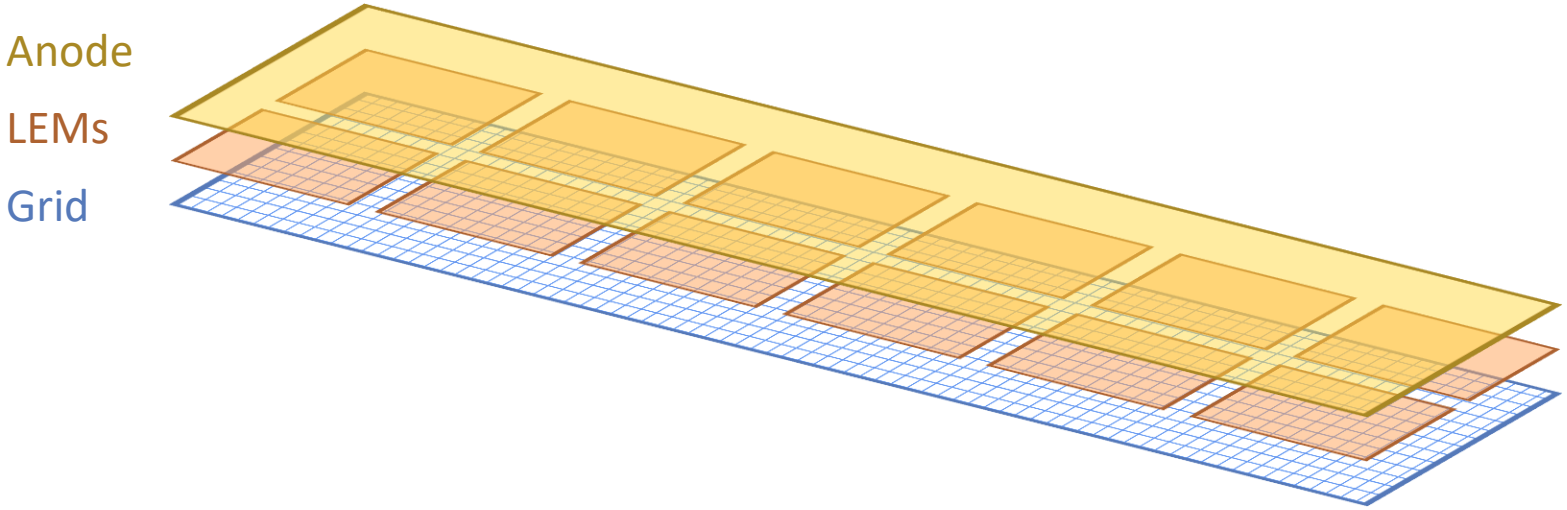
- Impedance matched for PCB connector within 15 Ω
- Impedance also matched for KEL cable, connecting anode to SGFT flange

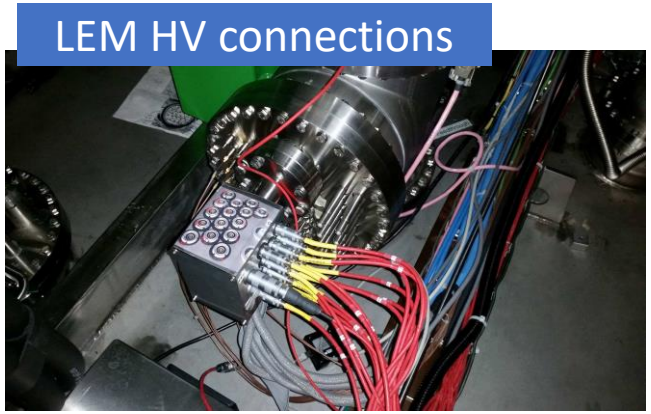




LEM-grid capacitance measurements

- Capacitance measured with Sourcetronic ST2831 LCR meter
  - Cs-Q mode
  - At 200 kHz
- Measured between grid connection on north flange and LEM up/down connections on SCFT HV flanges
- All other LEM cables were disconnected, LEMs floating

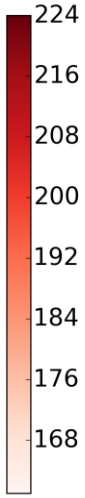




CRP level set at -0.5 mm

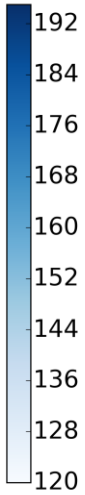
- Measured on Thursday, 05.Oct.2017 at 14:24
- CRP level set at -0.5 mm through SPFT motors

LEM 1 224 pF	LEM 2 165 pF	LEM 5 179 pF	LEM 6 191 pF	LEM 9 209 pF	LEM 10 212 pF
LEM 3 214 pF	LEM 4 161 pF	LEM 7 161 pF	LEM 8 208 pF	LEM 11 211 pF	LEM 12 190 pF



Capacitance LEM down / grid
Average: 193.75 pF

LEM 1 195 pF	LEM 2 131 pF	LEM 5 147 pF	LEM 6 170 pF	LEM 9 186 pF	LEM 10 188 pF
LEM 3 186 pF	LEM 4 120 pF	LEM 7 157 pF	LEM 8 185 pF	LEM 11 188 pF	LEM 12 169 pF

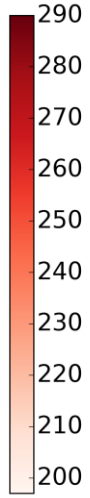


Capacitance LEM up / grid
Average: 168.5 pF

CRP level set at -4.5 mm

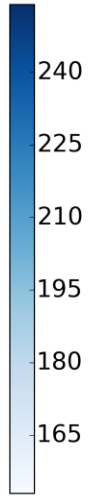
- Measured on Thursday, 05.Oct.2017 at 14:39
- CRP level lowered to -4.5 mm through SPFT motors

LEM 1 290 pF	LEM 2 201 pF	LEM 5 210 pF	LEM 6 223 pF	LEM 9 247 pF	LEM 10 249 pF
LEM 3 275 pF	LEM 4 202 pF	LEM 7 197 pF	LEM 8 252 pF	LEM 11 255 pF	LEM 12 222 pF



Capacitance LEM down / grid
Average: 235.25 pF

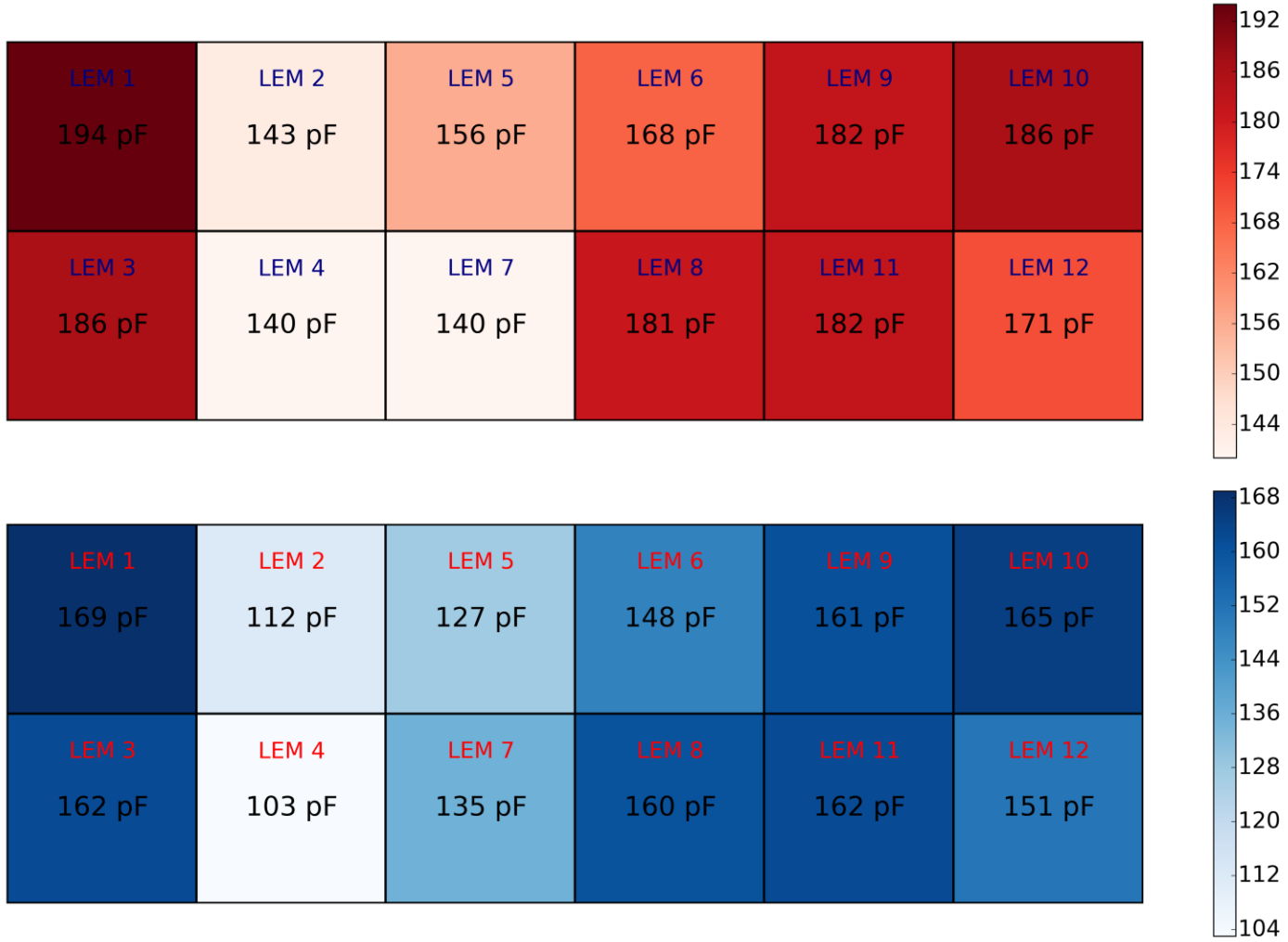
LEM 1 254 pF	LEM 2 161 pF	LEM 5 173 pF	LEM 6 197 pF	LEM 9 219 pF	LEM 10 221 pF
LEM 3 240 pF	LEM 4 153 pF	LEM 7 188 pF	LEM 8 224 pF	LEM 11 226 pF	LEM 12 196 pF



Capacitance LEM up / grid
Average: 204.33 pF

LAr removed and CRP level set to 0.0 mm

- Measured on Thursday, 05.Oct.2017 at 15:04
- 3 mm LAr removed and CRP level raised to -4.5 mm through SPFT motors

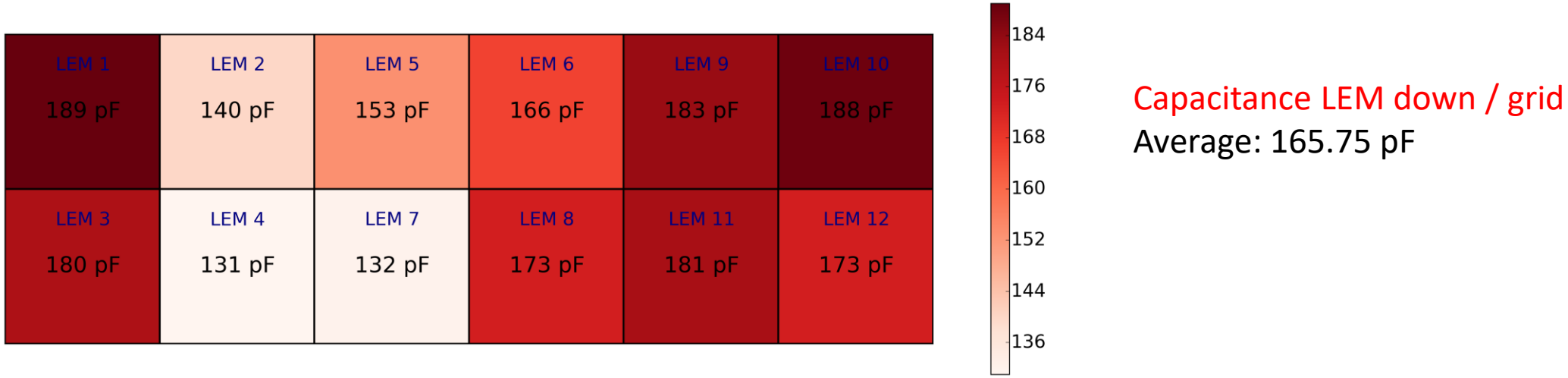


Capacitance LEM down / grid
Average: 169.08 pF

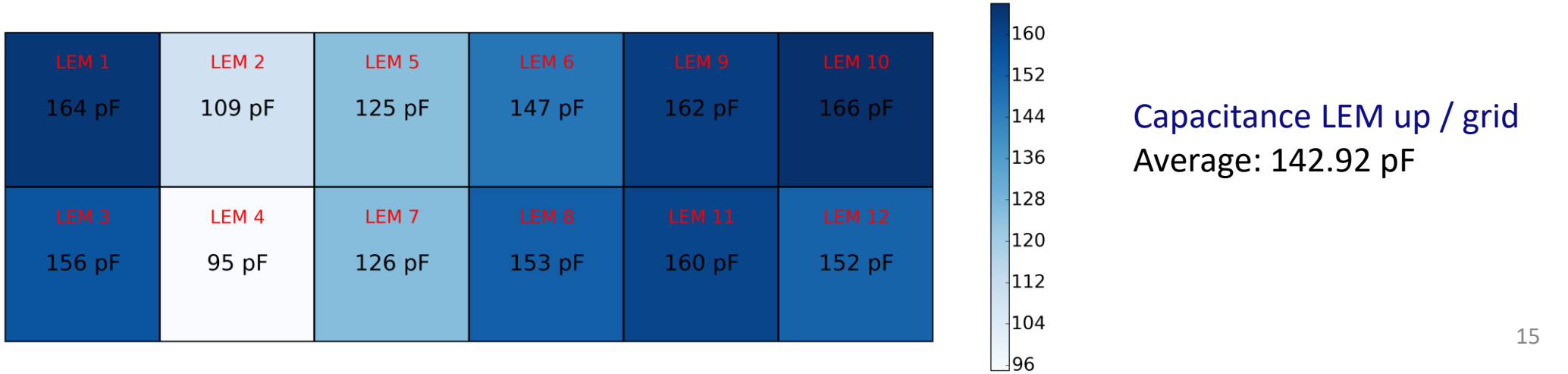
Capacitance LEM up / grid
Average: 146.25 pF

LAr added and CRP level set to 0.0 mm

- Measured on Friday, 06.Oct.2017 at 10:20
- 2 mm LAr added and CRP level set at 0.0 mm through SPFT motors



Capacitance LEM down / grid
Average: 165.75 pF

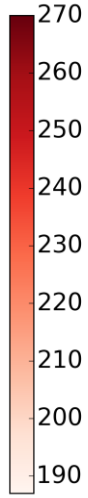


Capacitance LEM up / grid
Average: 142.92 pF

LAr added and CRP level set to -4.5 mm

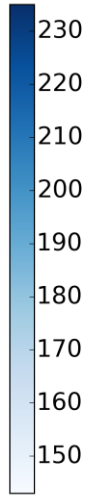
- Measured on Friday, 06.Oct.2017 at 11:58
- 2-3 mm LAr added and CRP level lowered to -4.5 mm through SPFT motors

LEM 1 270 pF	LEM 2 192 pF	LEM 5 203 pF	LEM 6 217 pF	LEM 9 239 pF	LEM 10 241 pF
LEM 3 252 pF	LEM 4 192 pF	LEM 7 187 pF	LEM 8 238 pF	LEM 11 242 pF	LEM 12 214 pF



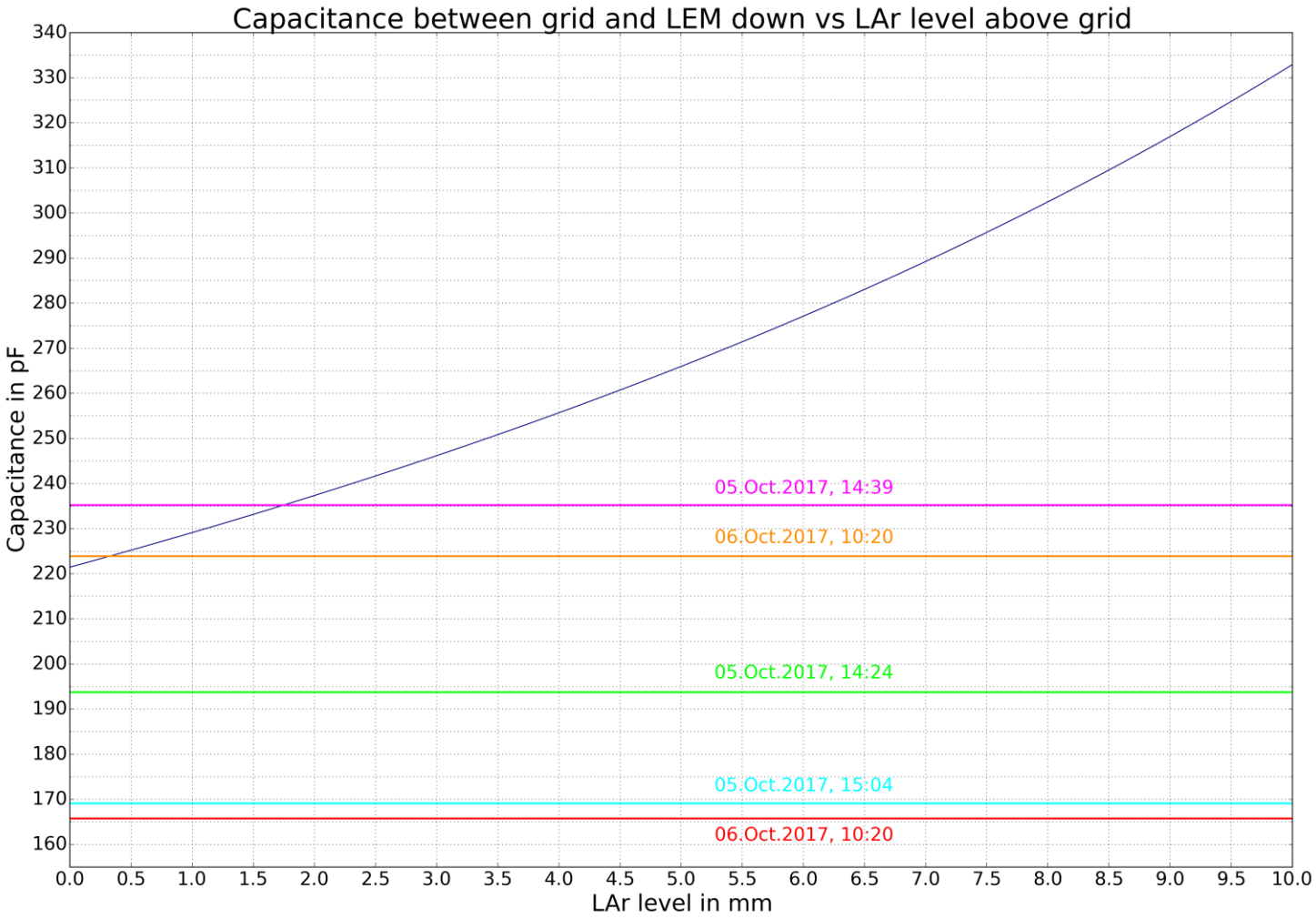
Capacitance LEM down / grid
Average: 223.92 pF

LEM 1 235 pF	LEM 2 153 pF	LEM 5 167 pF	LEM 6 192 pF	LEM 9 211 pF	LEM 10 212 pF
LEM 3 219 pF	LEM 4 143 pF	LEM 7 176 pF	LEM 8 211 pF	LEM 11 214 pF	LEM 12 189 pF



Capacitance LEM up / grid
Average: 193.5 pF

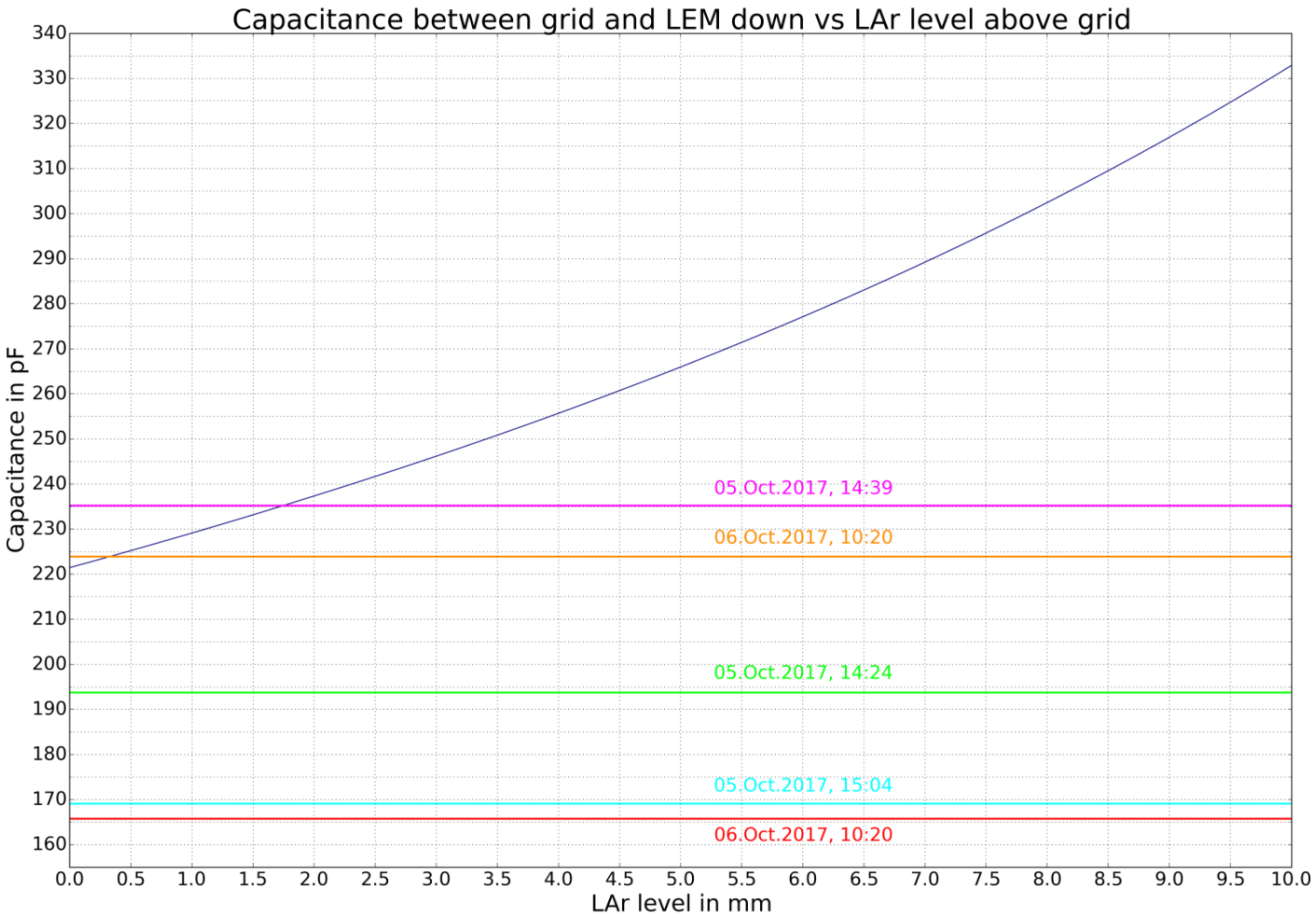
Theoretical capacitance



- Modelling the grid and LEMs as parallel plate capacitors, partially filled with a dielectric (LAr)
- Capacitance between grid and LEM down given by:

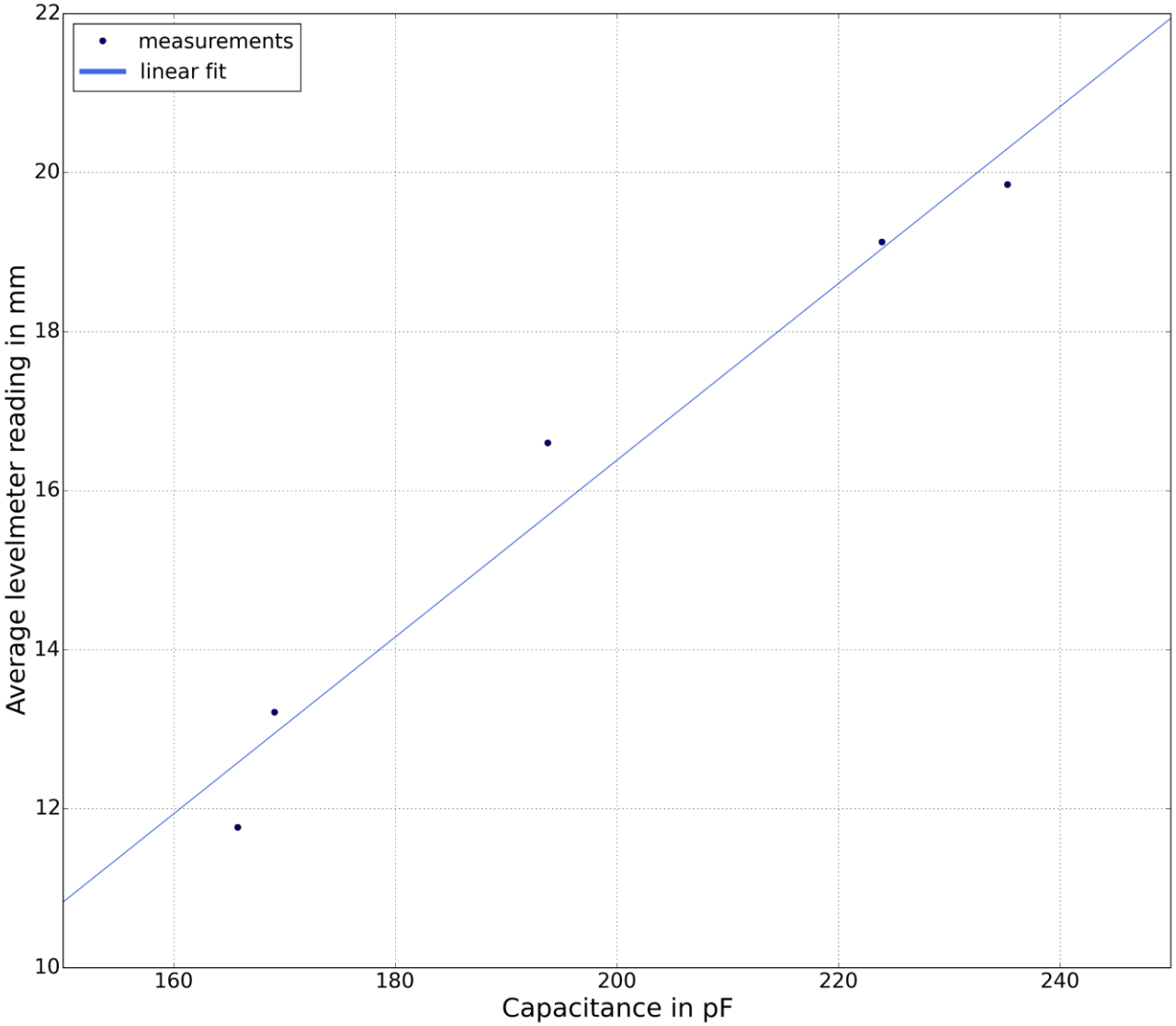
$$C_{grid/LEMbottom} = \left[\frac{1}{\frac{\varepsilon_{r\ (LAr)} \times \varepsilon_0 \times A}{d_{grid/LAr}}} + \frac{1}{\frac{\varepsilon_0 \times A}{d_{LAr/LEM}}} \right]^{-1}$$

Measurement deviations



- Capacitance is dependent on LCR meter frequency → indication of inductive component
- Stray capacitance from other components
- Theoretical capacitance calculated for parallel plate model
  - LEMs and grid are not perfect even surfaces
- Hard to remove effect of capacitance to ground
  - LCR meter gives different readings depending on which probe is placed on the grid

Comparison to levelmeters



- Average of all levelmeters was taken over given time period and plotted against capacitance measurements
- More measurements are needed to determine their exact relationship

Conclusion and next steps

- Impedance has been measured for strips of the anode modules and different connectors
  - Impedance matches for KEL cables and PCB connector
- 3L preamps have been set up in the clean room of Bldg. 185 and will be used to pulse the new anodes and connectors
- LEM/grid capacitance measurements reflect the level of LAr between them
  - Deviation from theoretical values due to stray capacitance, inductive components, etc.
  - Capacitance can be used to determine liquid level after initial calibration
- We will continue to measure capacitances as CRP is adjusted and/or level is altered to obtain the full relationship between capacitance and levelmeter reading