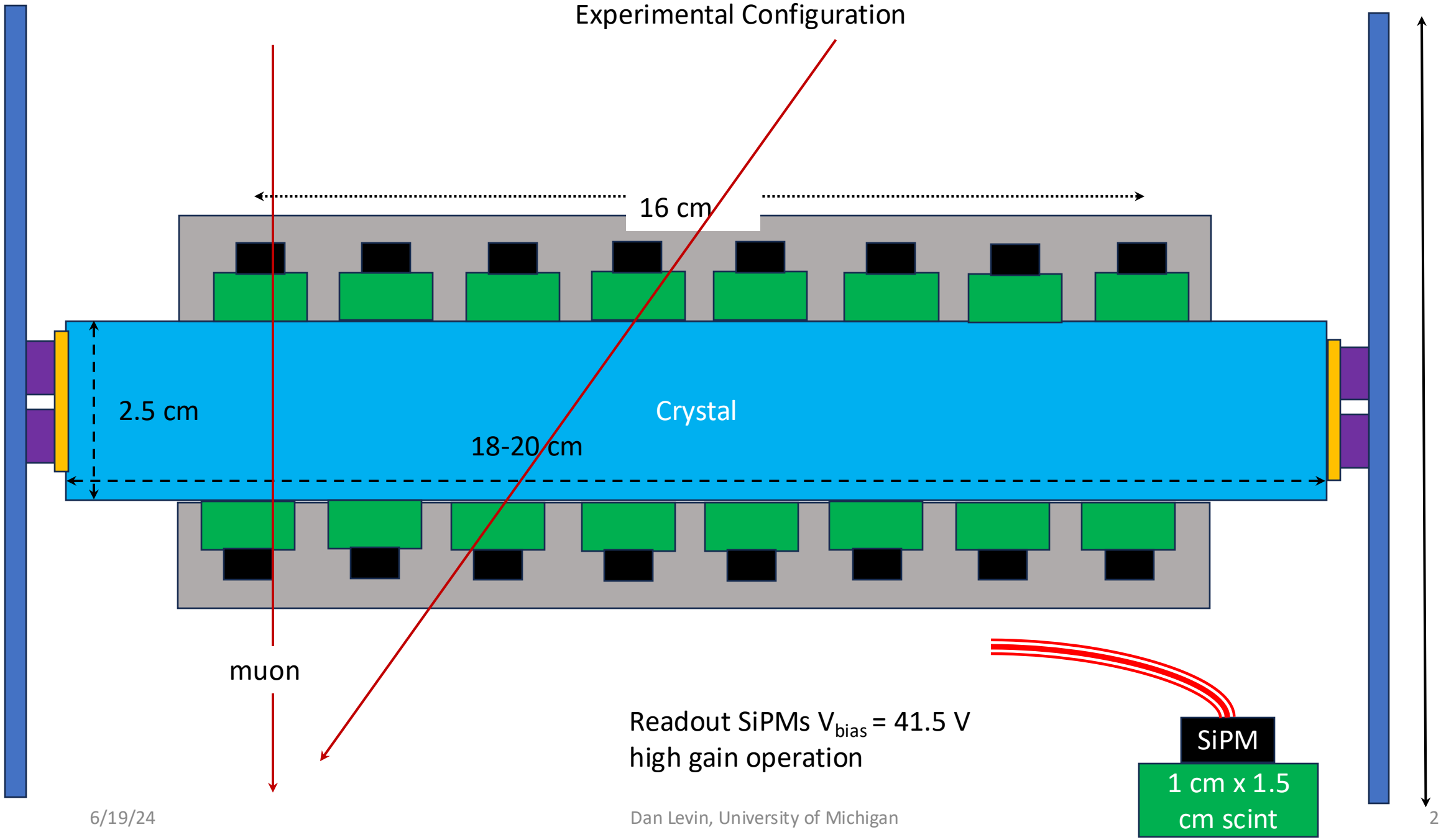
UM Cosmic Ray Test Bench

Evaluation of SiPM-to-crystal optical coupling compounds

Oct 21, 2024

Dan Levin on behalf of the Univ of Michigan group

Experimental Configuration

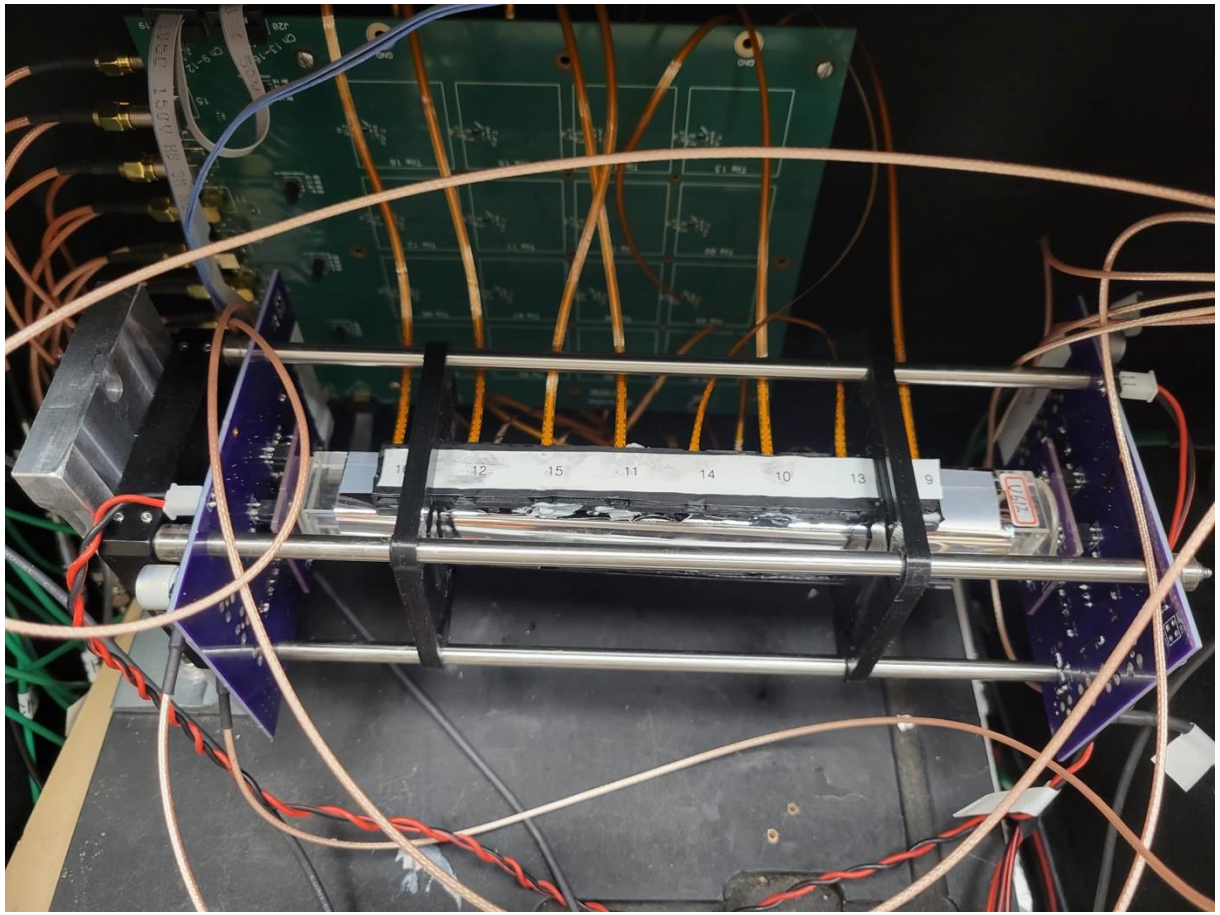


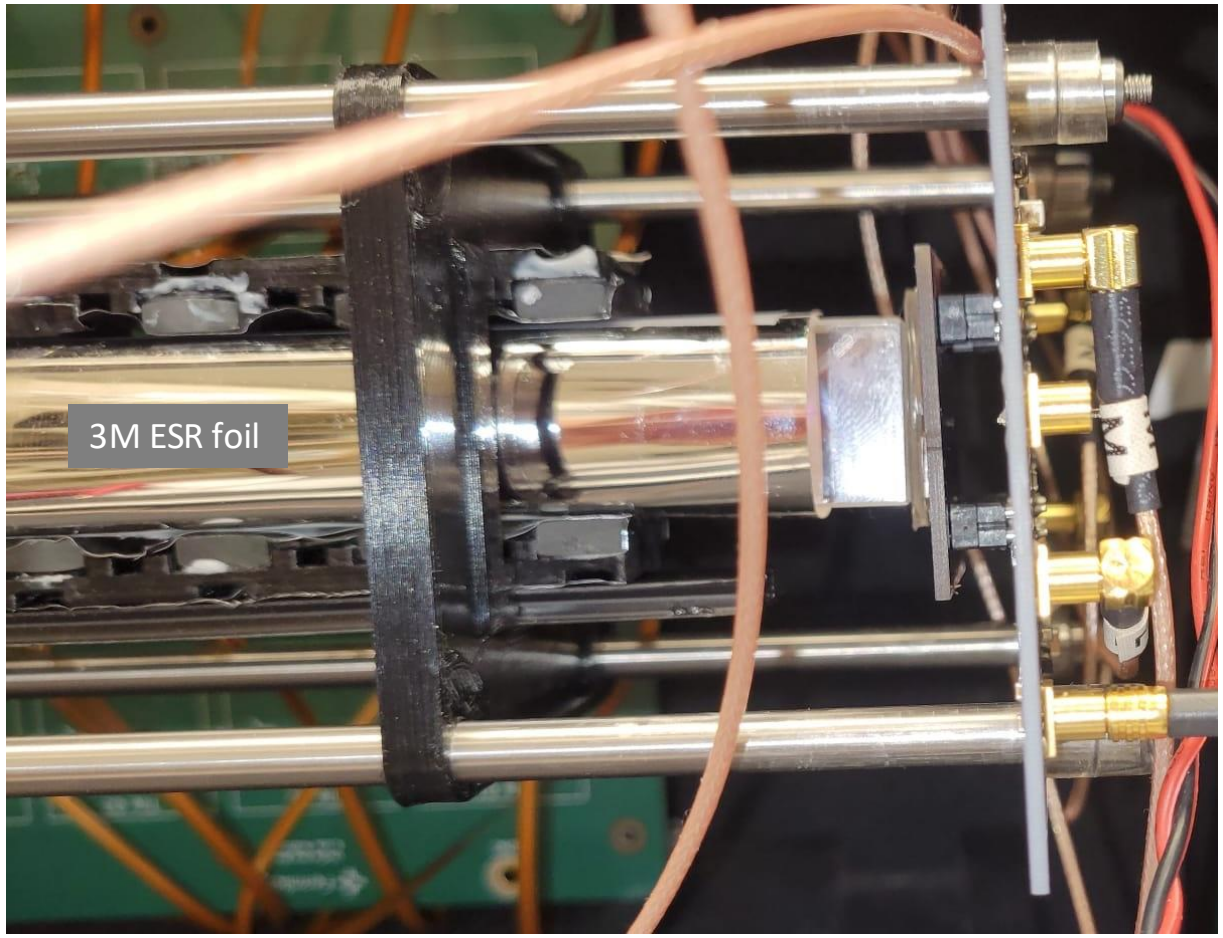
- Objective: establish the run-to-run reproducibility/stability of the CR test station
  Repeated disassembly and reassembly might introduce significant uncertainty- or other problems.

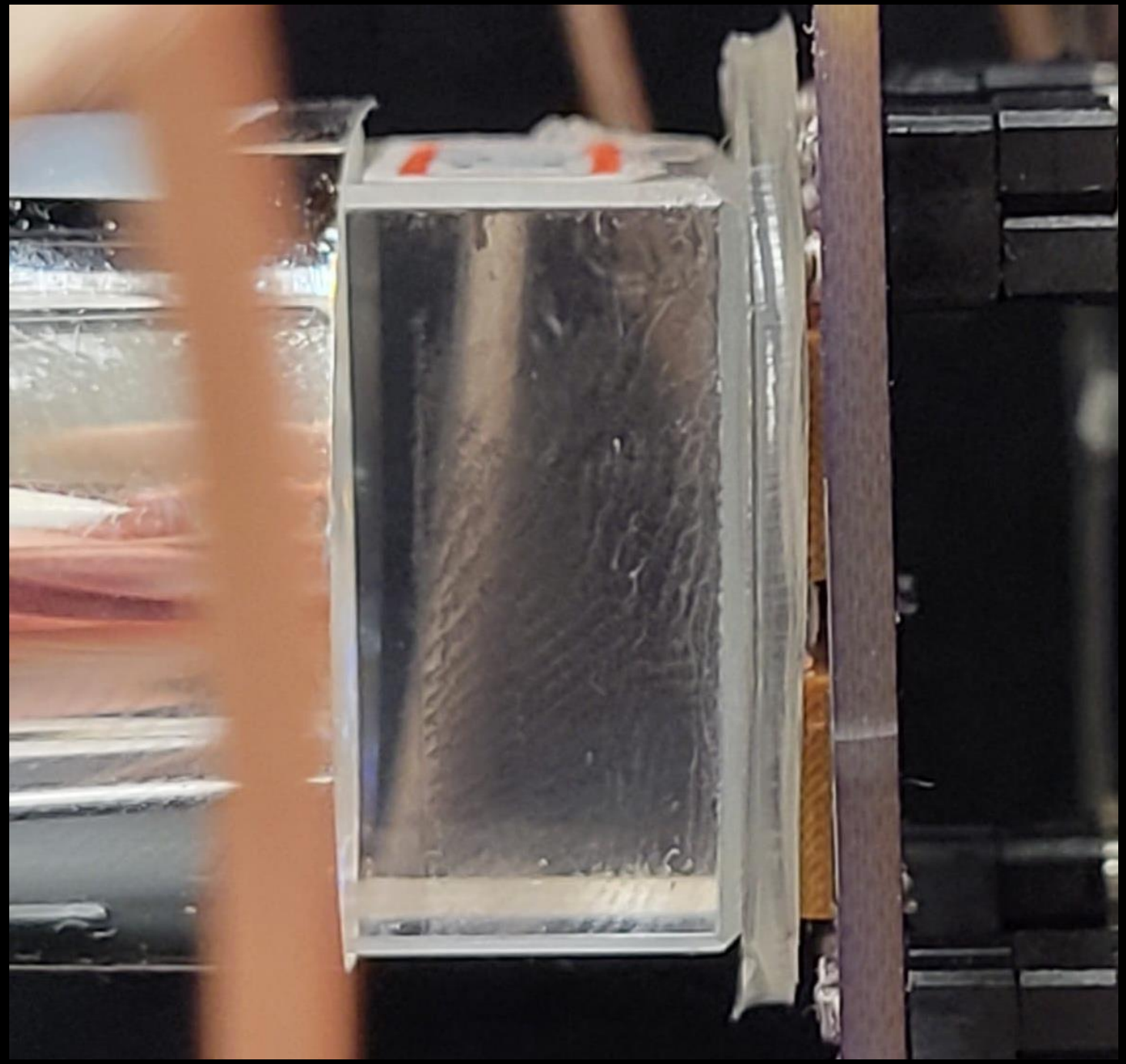
Four run sequences:

1. Baseline runs where:
   - SiPMs were cleaned of all grease and compounds
   - Silicone cookies as couplers on both sides
   - Mechanical disassembly/reassembly between runs
   - Use remaining “good” PWO crystal!

2. using Cargill gel (n=1.55), thin film application
3. using Cargill gel (n=1.55), thick film application
4. using Dowsil gel (n=1.43)




3M ESR foil

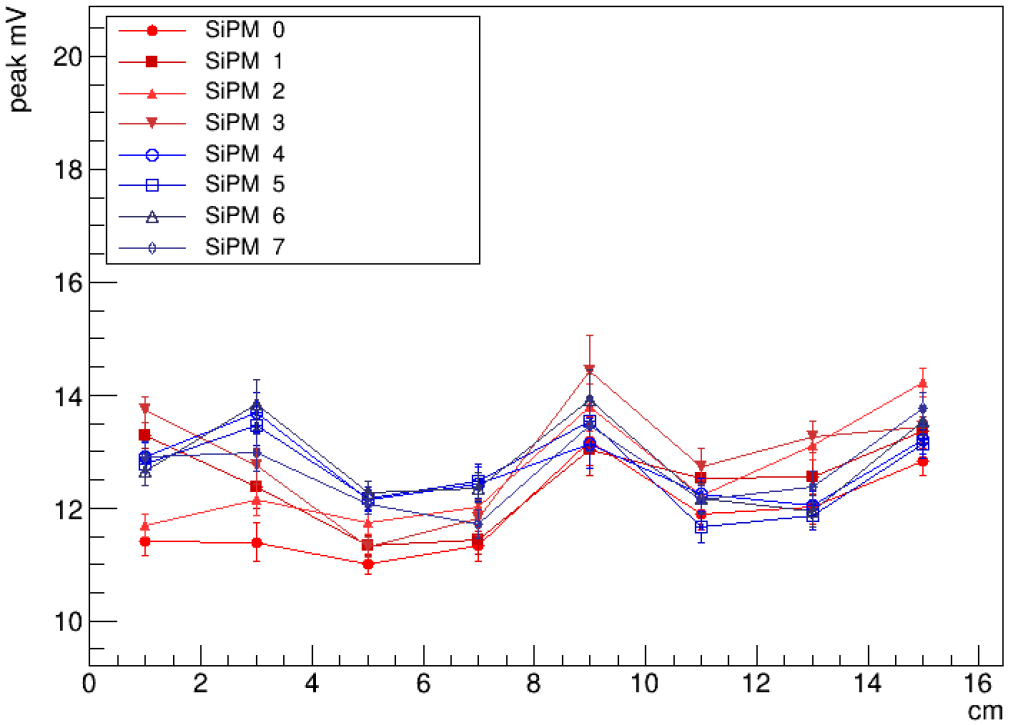


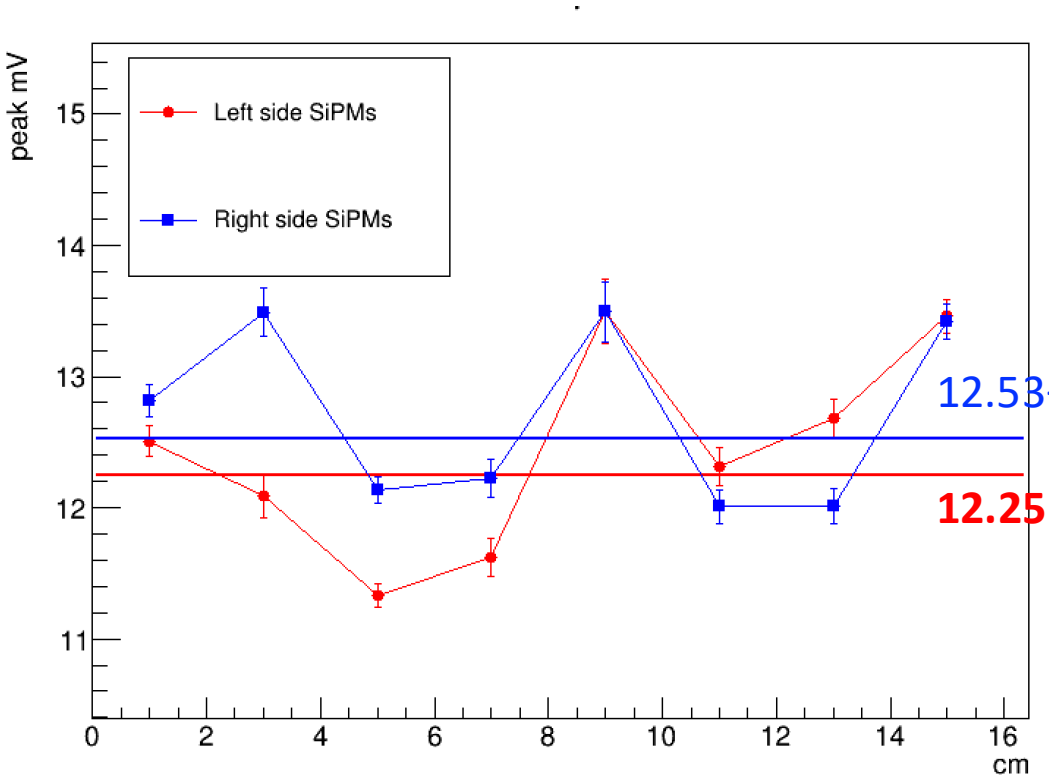
Detail:

Silicone cookie squished between SiPMs and crystal face

The pressure on the silicone interface is difficult to maintain equally over all 4 SiPMs

Reference run sequence Elgin silicone cookie on each side of the crystal. Run 228

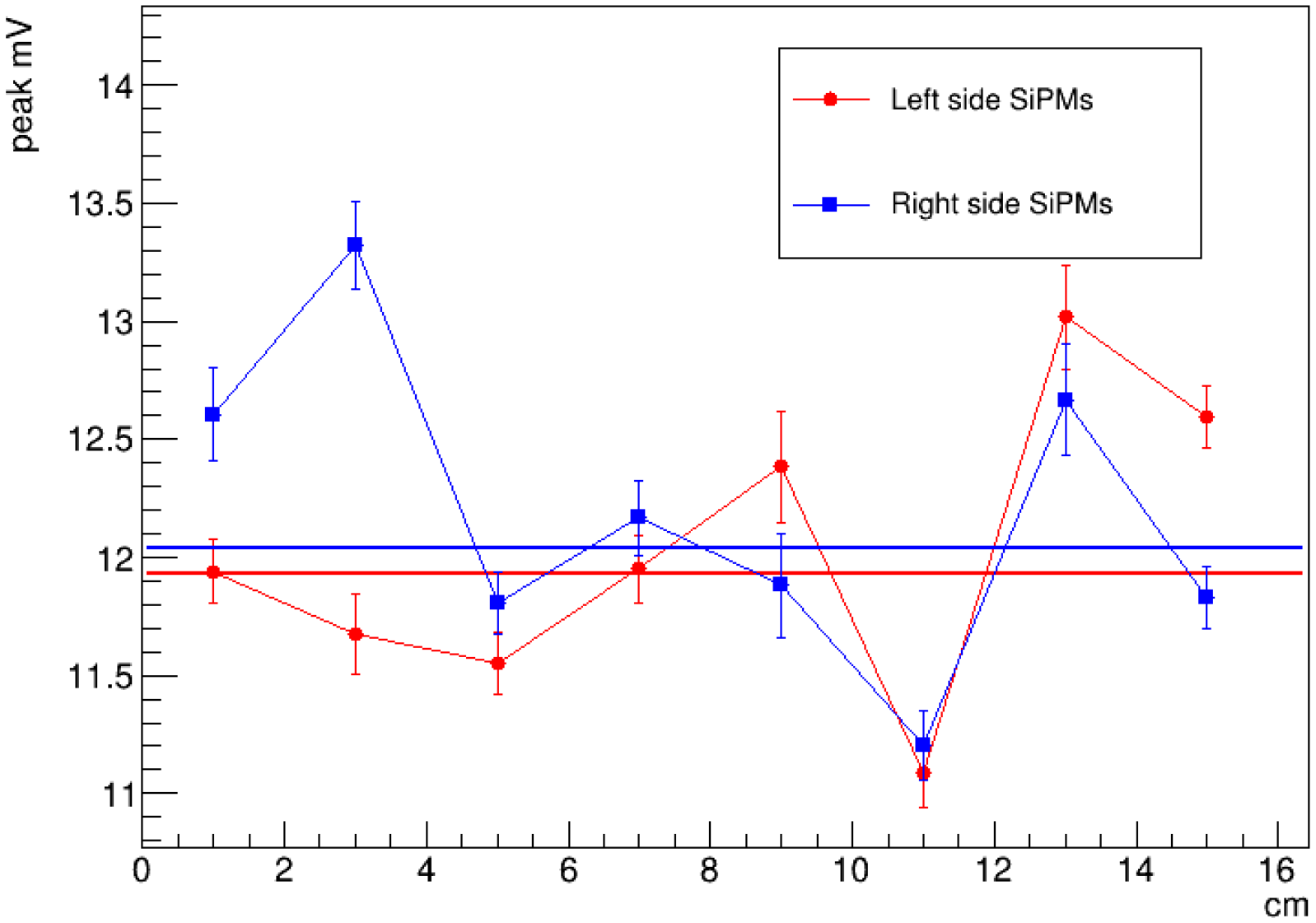




12.53+/- 0.05 mV

12.25 +/- 0.05 mV

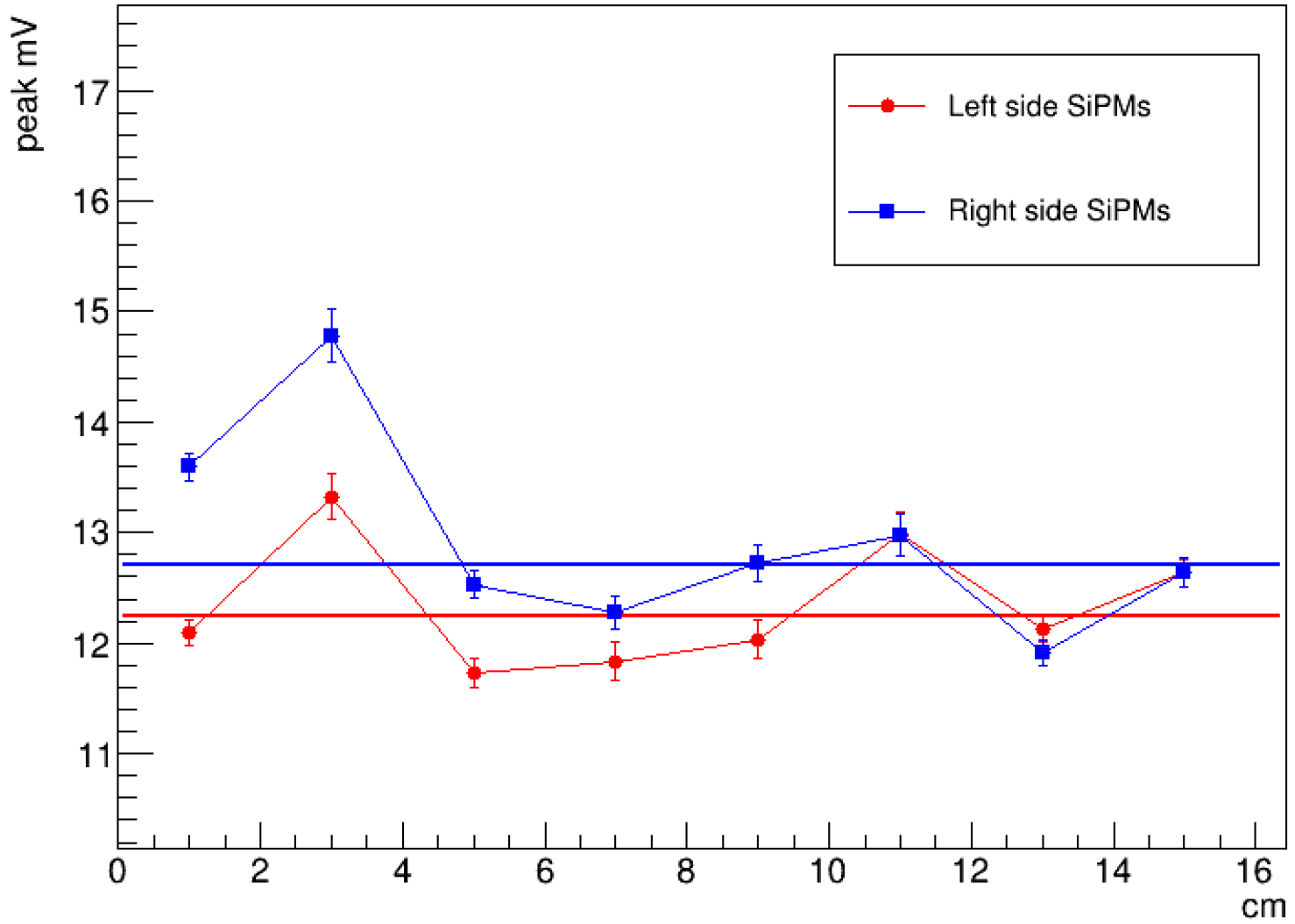
Reference run sequence Elgin silicone cookie on each side of the crystal. Run 229



Right 12.03+/- 0.06 mV

Left 11.9 +/- 0.05 mV

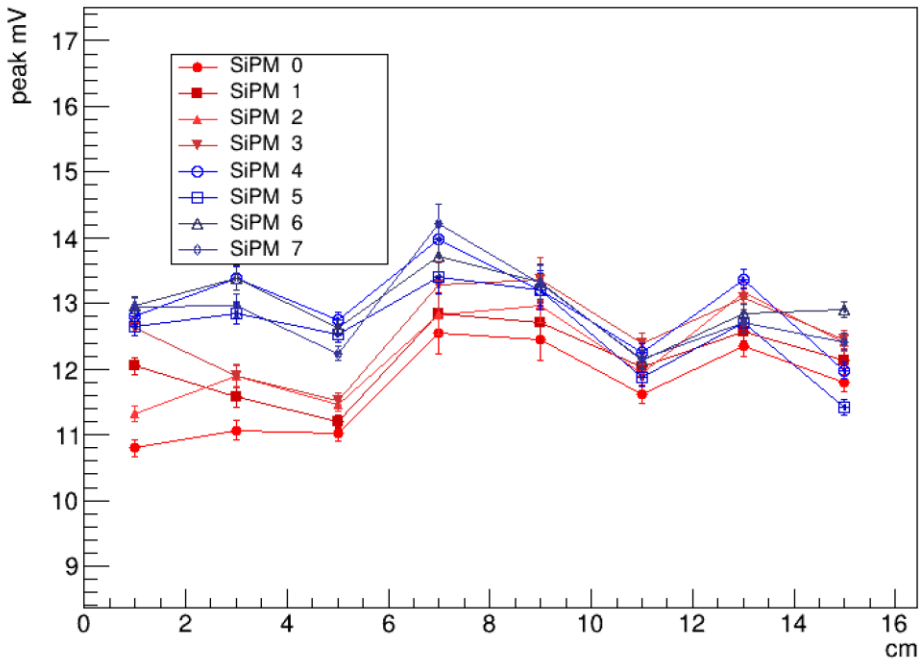
Reference run sequence Elgin silicone cookie on each side of the crystal. Run 230

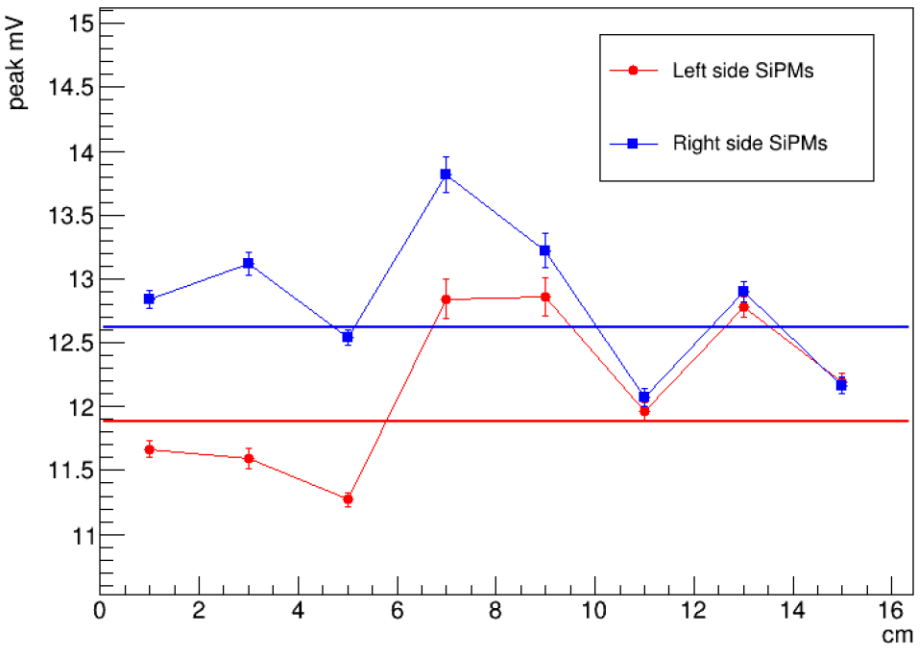


Right: 12.7+/- 0.06 mV

Left: 12.2 +/- 0.05 mV

Reference run sequence Elgin silicone cookie on each side of the crystal. Run 232





Right: 12.6+/- 0.06 mV

Left: 11.9 +/- 0.05 mV

Summary of reference run sequence: 228-232 (4 runs)

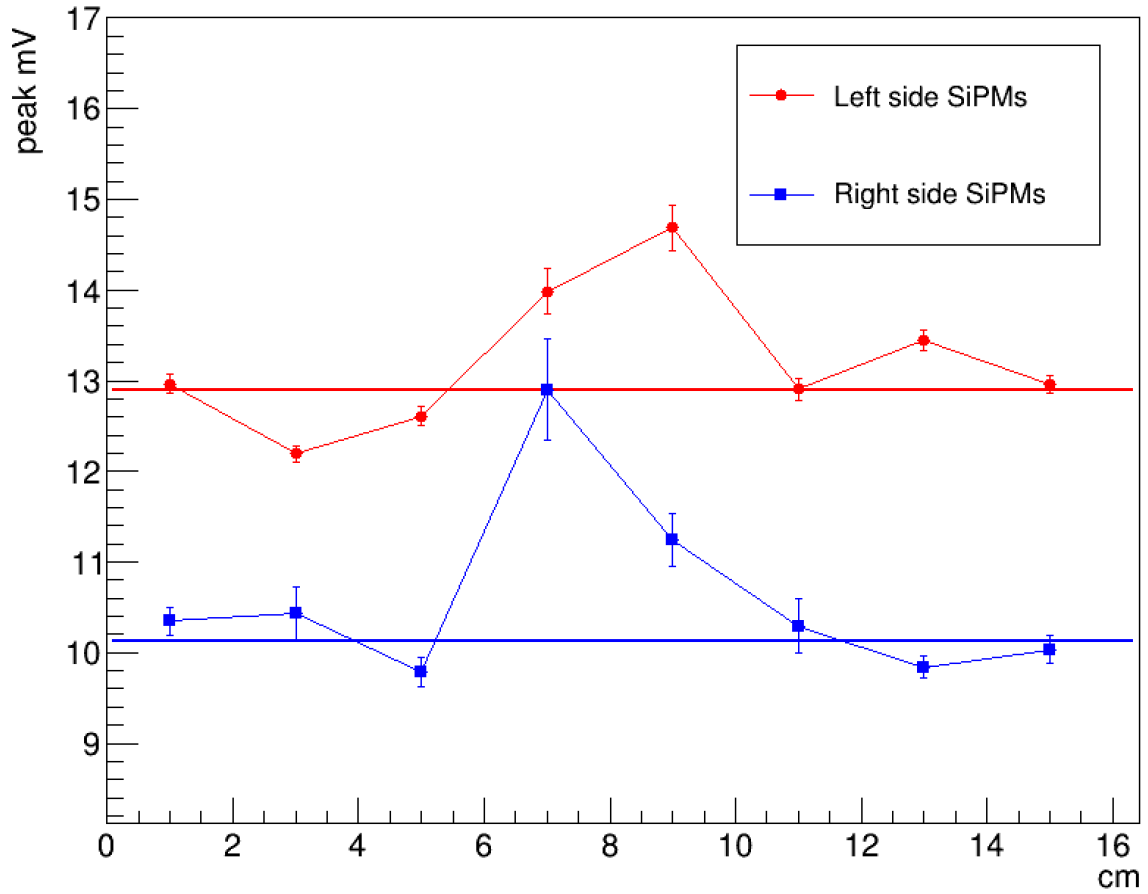
Run	Left Signal ± 0.1 mV	Right Signal ± 0.1 mV	Right/Left ± 0.014
228	12.5	12.2	0.98
229	12.0	11.9	0.99
230	12.7	12.2	0.96
232	12.6	11.9	0.94
avg	12.45 ± 0.15	12.0± 0.15	0.97 ± 0.016

Run-to-run uncertainty due to mechanical assembly
==>1.2 % reproducibility per side
==> 1.6% error on the L/R ratio

==> Rely more on the Right/Left ratio comparison method rather than the run-to-run comparison because small drifts in the SiPM bias voltage can affect both sides equally.

Cargill run sequence 1:

Elgin silicone cookie left side, *thin Cargill gel* right side of the crystal. Run 234

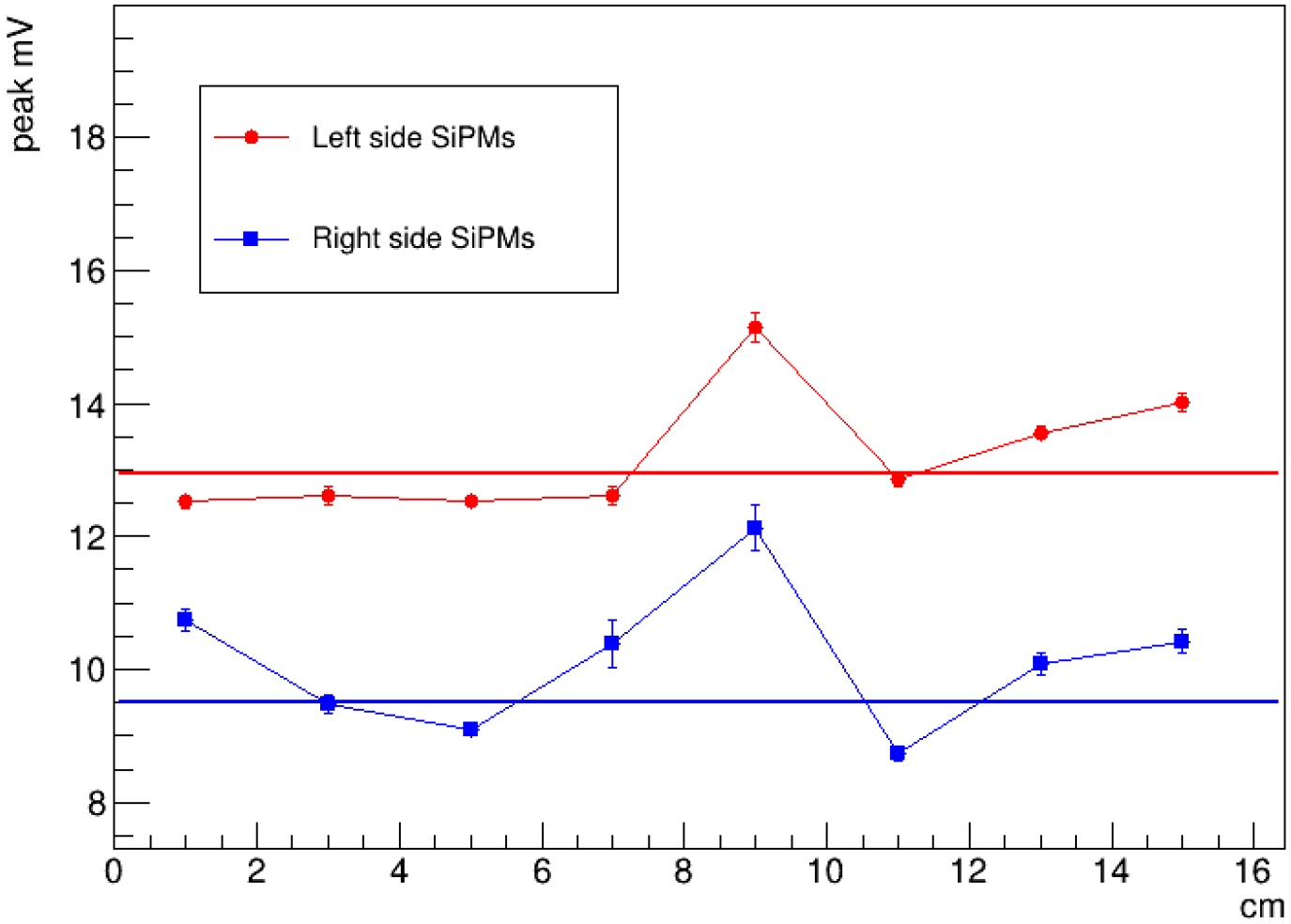


Left: 12.9 ± 0.04 mV

Right: 10.12 ±0.07 mV

Cargill run sequence 1:

Elgin silicone cookie left side, *thin Cargill gel* right side of the crystal. Run 235

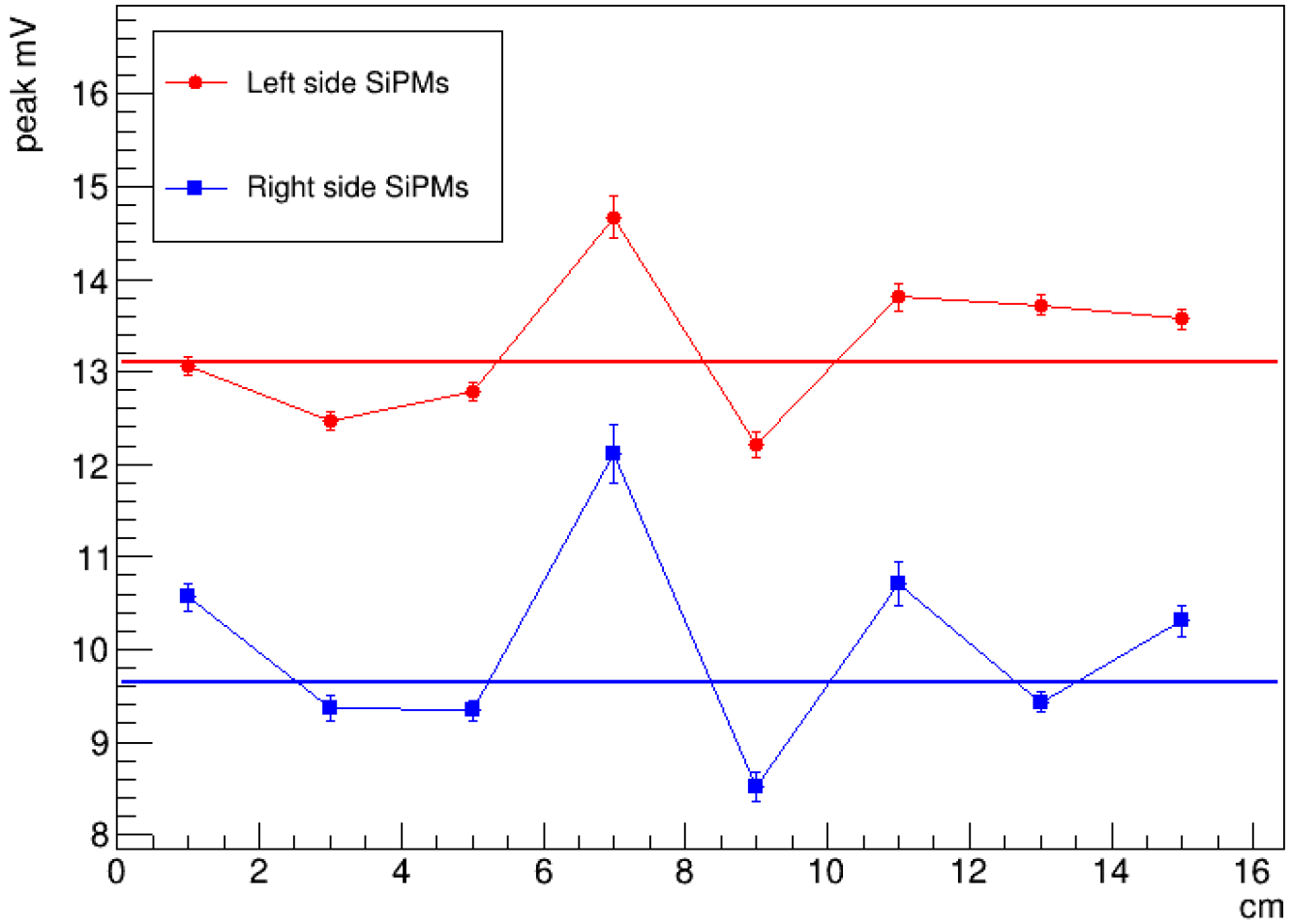


Left: 12.9 ± 0.04 mV

Right: 9.5 ±0.07 mV

Cargill run sequence 1:

Elgin silicone cookie left side, *thin Cargill gel* right side of the crystal. Run 236

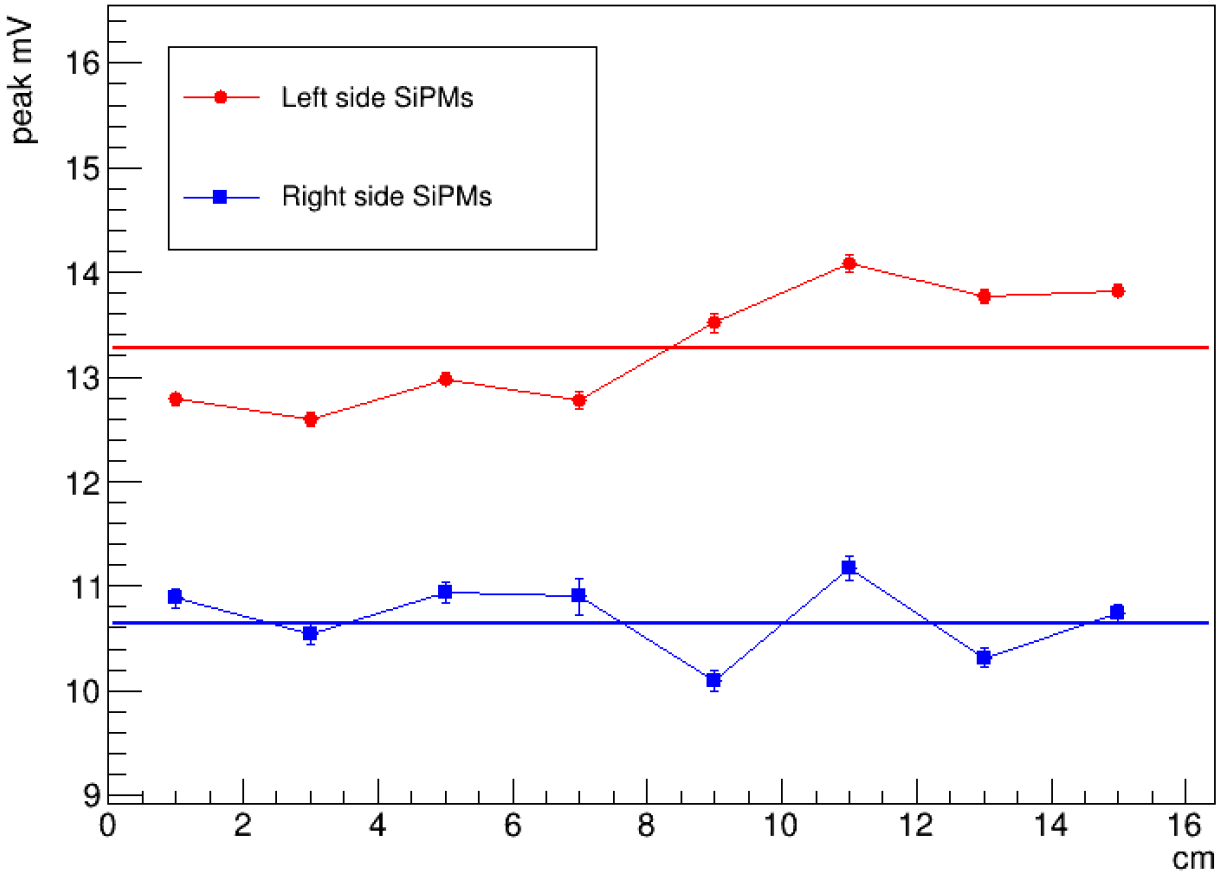


Left: 13.1 ± 0.04 mV

Right: 9.7 ±0.07 mV

Cargill run sequence 1:

Elgin silicone cookie left side, *thin Cargill gel* right side of the crystal. Run 237



Left: 13.3 ± 0.02 mV

Right: 10.7 ±0.03 mV

Summary:
Elgin silicone cookie left side
thin Cargill gel right side of the crystal.

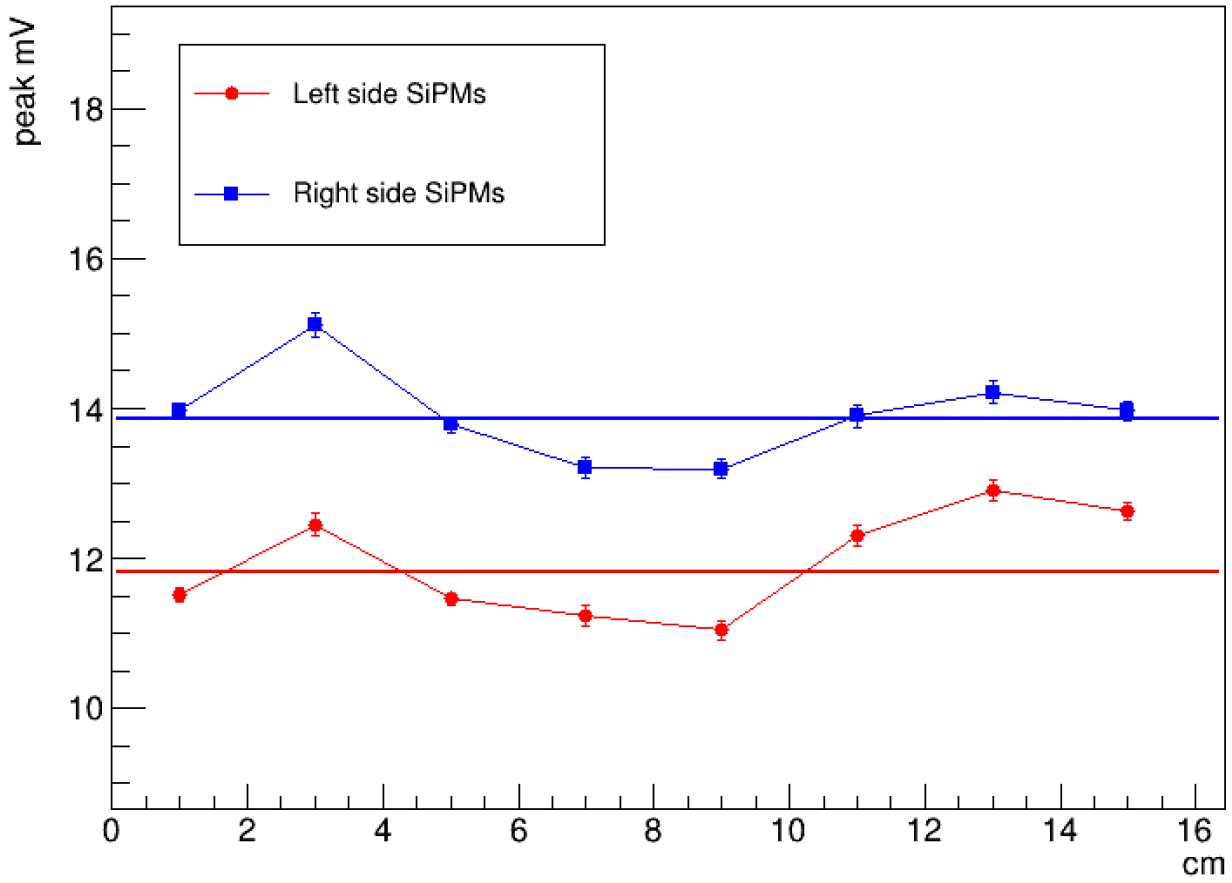
Run	Left Signal ± 0.1 mV	Right Signal ± 0.1 mV	Right/Left ± 0.014
234	12.9	10.1	0.78
235	12.9	9.5	0.74
236	13.1	9.7	0.74
237	13.3	10.7	0.80
avg	13.0 ± 0.09	10.0± 0.26	0.76 ± 0.015

Run-to-run uncertainty due to mechanical assembly
==>1.6 % reproducibility per side
==> 1.5 % error on the L/R ratio

Relative left/right ratio = 0.76/0.97 = 78%
==> 22% signal loss using thin Cargill gel

Cargill run sequence 2:

Elgin silicone cookie left side, *thick Cargill gel* right side of the crystal. Run 238

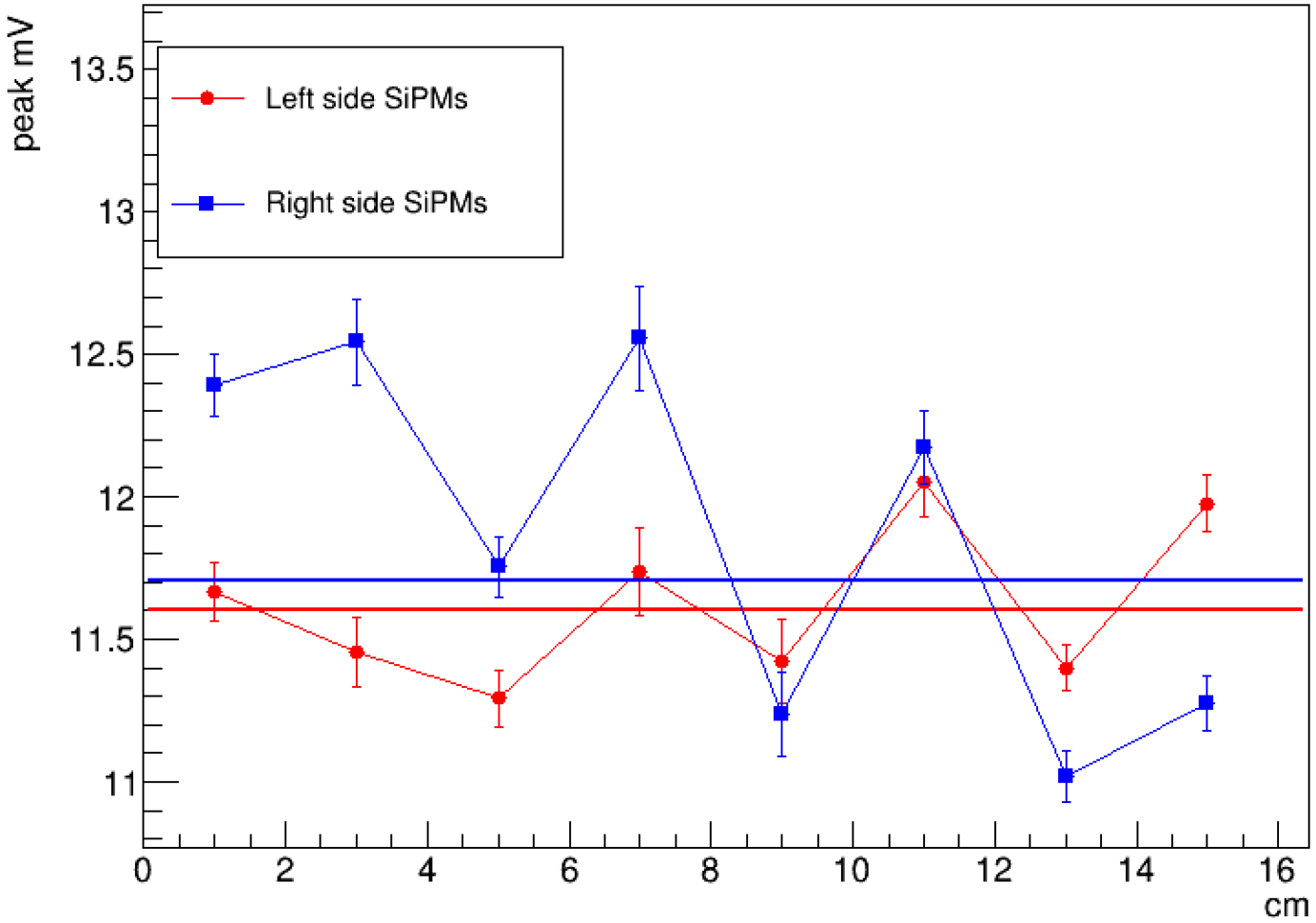


Right: 13.8 ± 0.07 mV

Left: 11.8 ± 0.04 mV

Cargill run sequence 2:

Elgin silicone cookie left side, *thick Cargill gel* right side of the crystal. Run 239

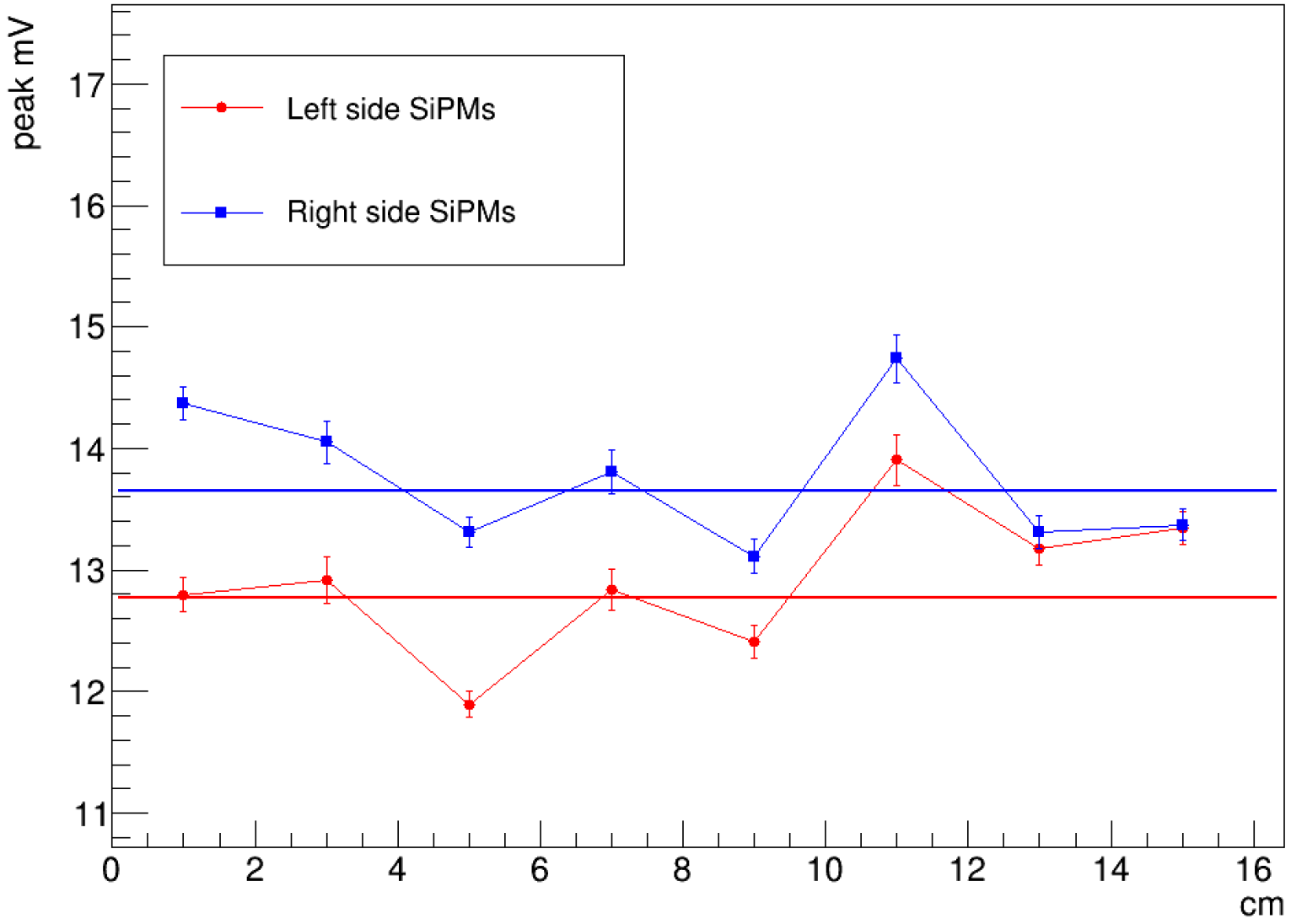


Right: 11.7 ± 0.07 mV

Left: 11.6 ± 0.04 mV

Cargill run sequence 2:

Elgin silicone cookie left side, *thick Cargill gel* right side of the crystal. Run 241

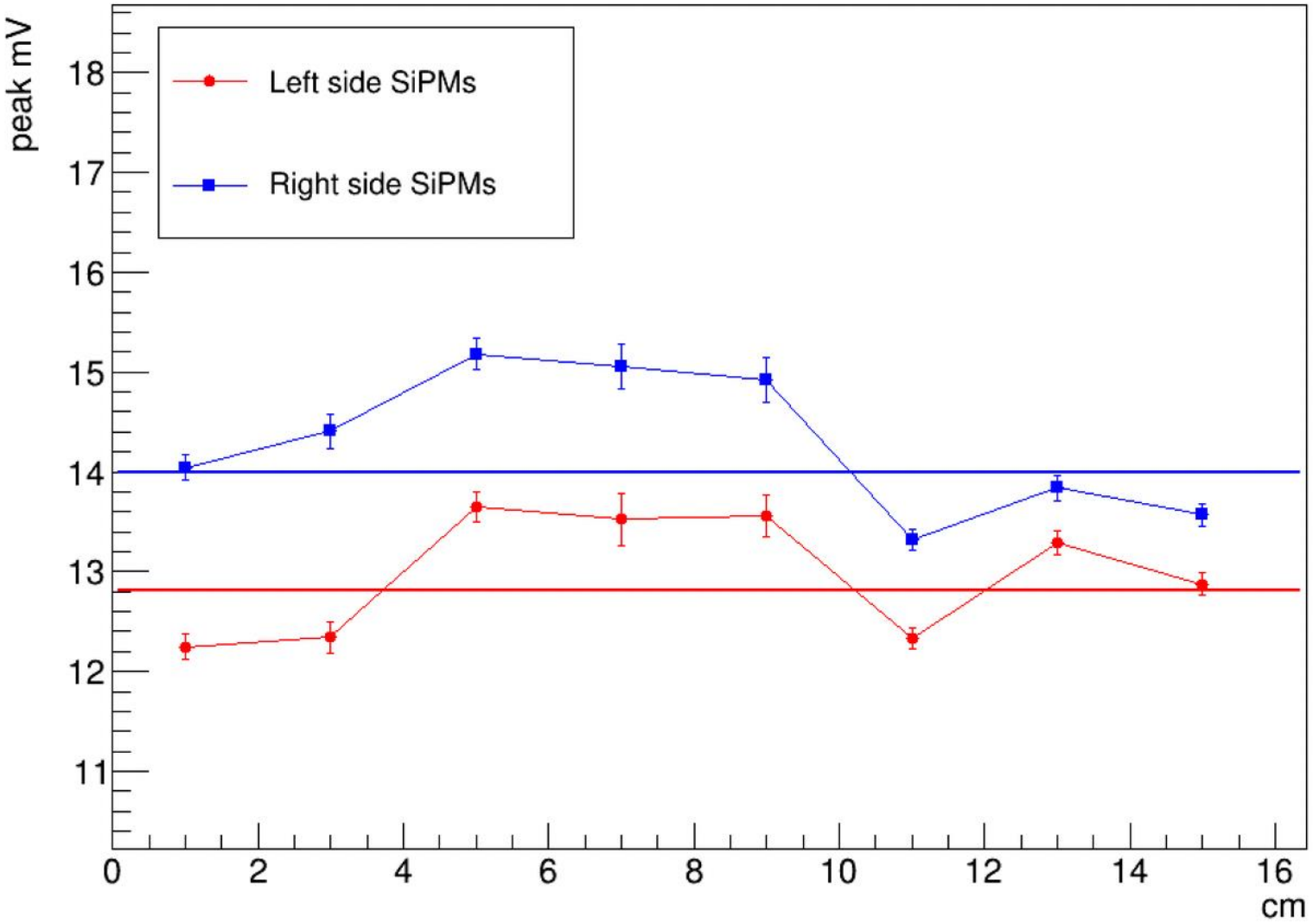


Right: 13.7 ± 0.07 mV

Left: 12.8 ± 0.04 mV

Cargill run sequence 2:

Elgin silicone cookie left side, *thick Cargill gel* right side of the crystal. Run 242



Right: 14.0 ± 0.07 mV

Left: 12.8 ± 0.04 mV

Summary:
Elgin silicone cookie left side
thick Cargill gel right side of the crystal.

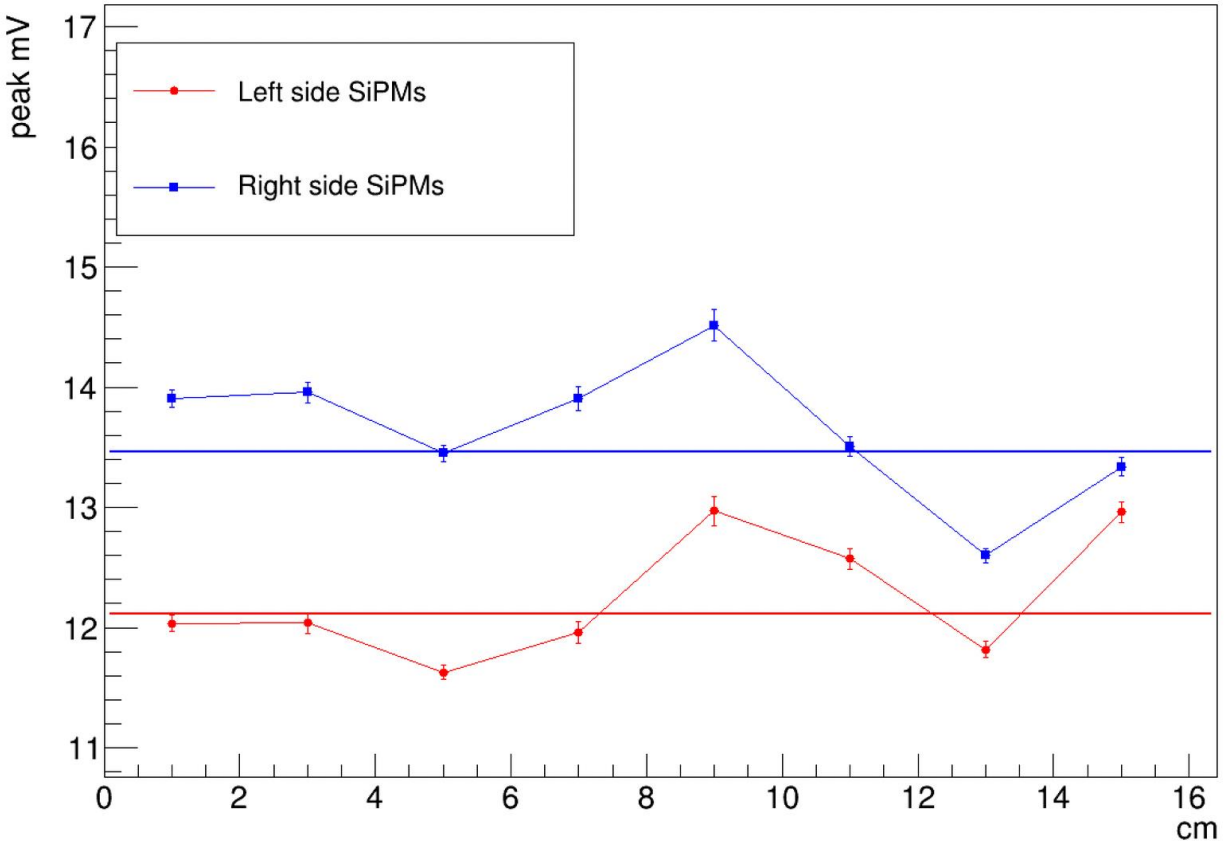
Run	Left Signal ± 0.1 mV	Right Signal ± 0.1 mV	Right/Left ± 0.014
238	11.8	13.8	1.17
239	11.6	11.7	1.008
241	12.8	13.7	1.07
242	12.8	14.0	1.09
avg	12.2 ± 0.3	13.7± 0.5	1.08 ± 0.03

Relative left/right ratio = 1.08 ± 0.03. (1.11 exlcuding outlier)

==> 8% signal gain using thick Cargill gel

Dowsil run sequence:

Elgin silicone cookie left side, *Dowsil optical coupling grease* right side of the crystal. Run 243

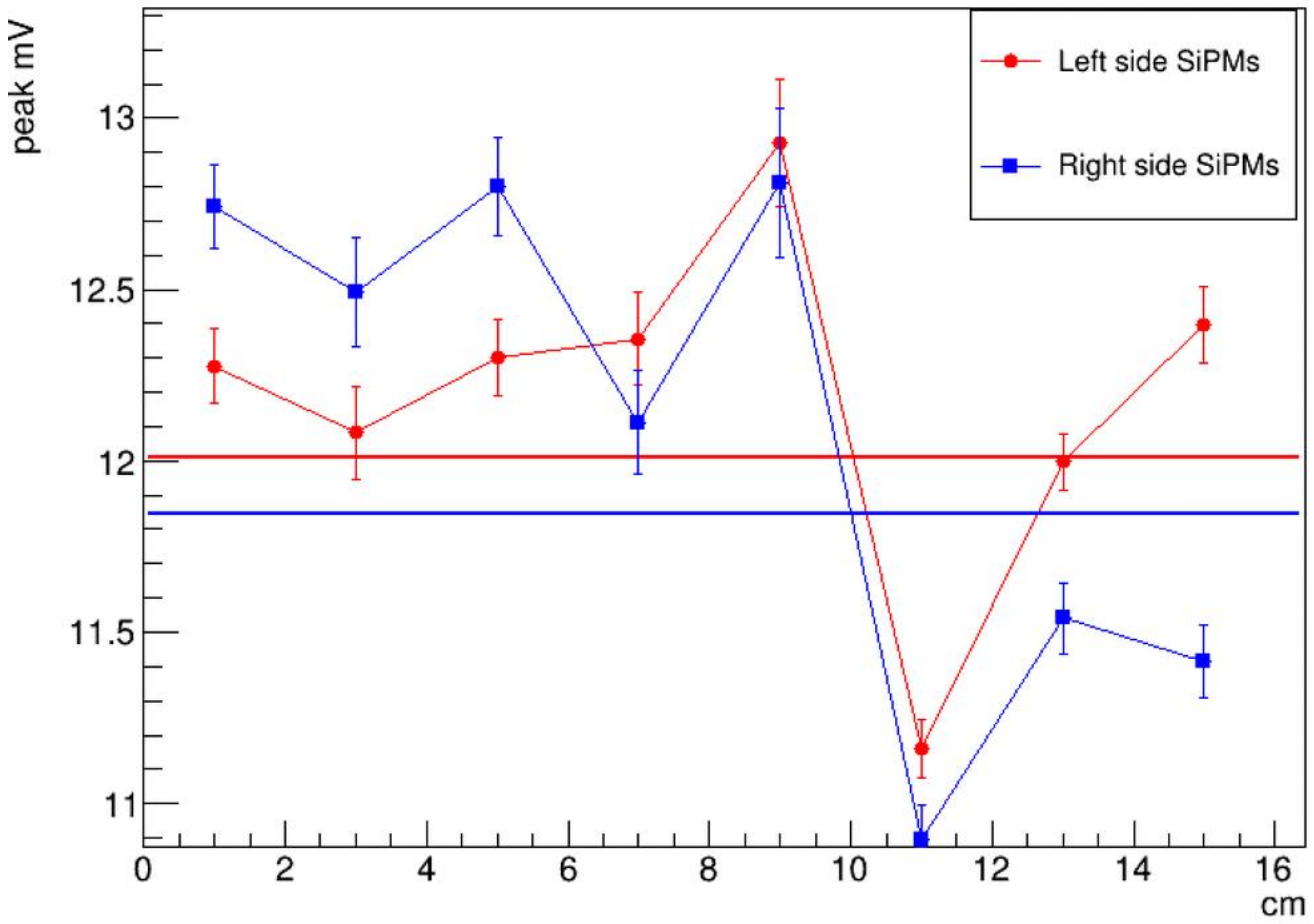


Right: 13.5 ± 0.07 mV

Left: 12.1 ± 0.04 mV

Dowsil run sequence:

Elgin silicone cookie left side, *Dowsil optical coupling grease* right side of the crystal. Run 244

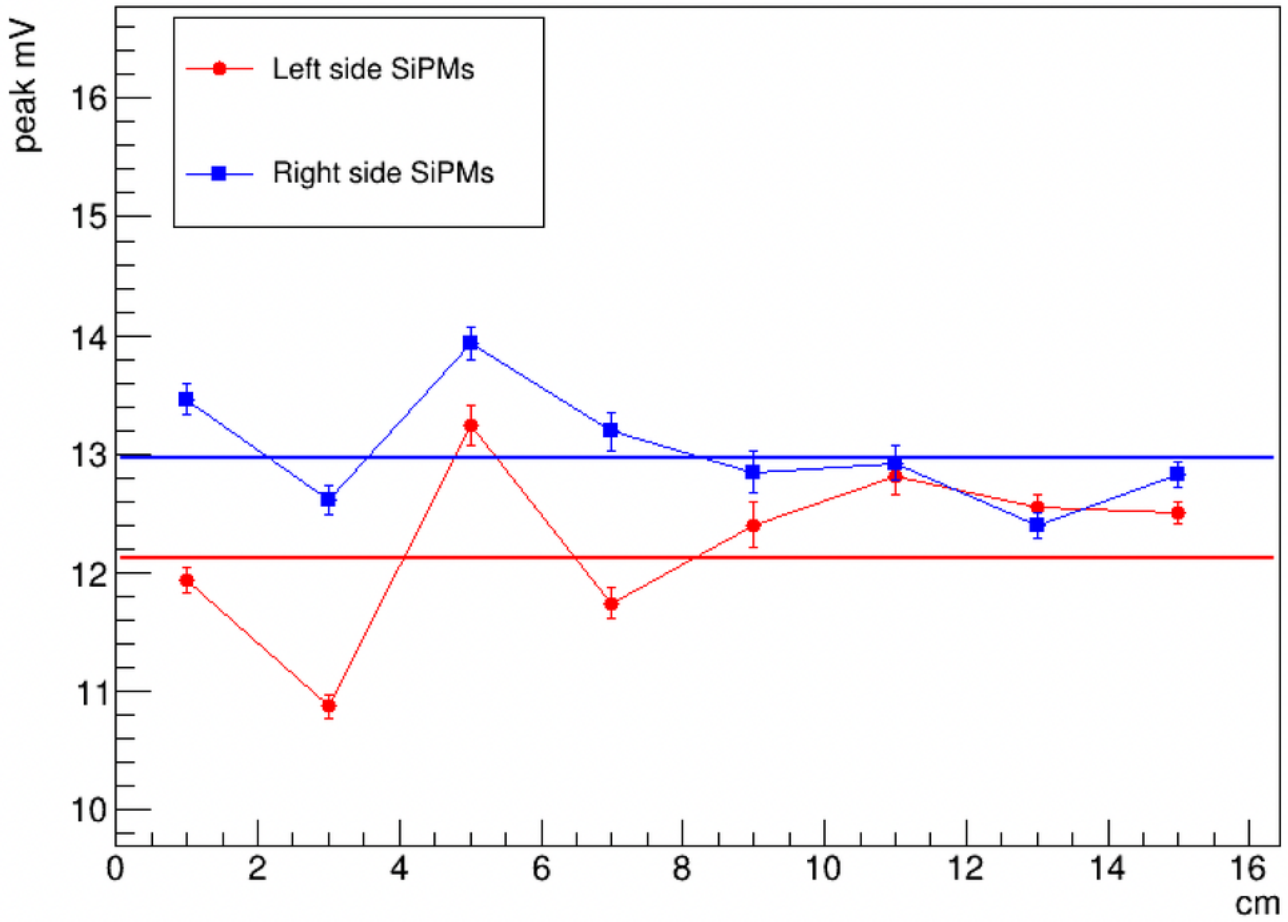


Right: 11.8 ± 0.07 mV

Left: 12.1 ± 0.04 mV

Dowsil run sequence:

Elgin silicone cookie left side, *Dowsil optical coupling grease* right side of the crystal. Run 245

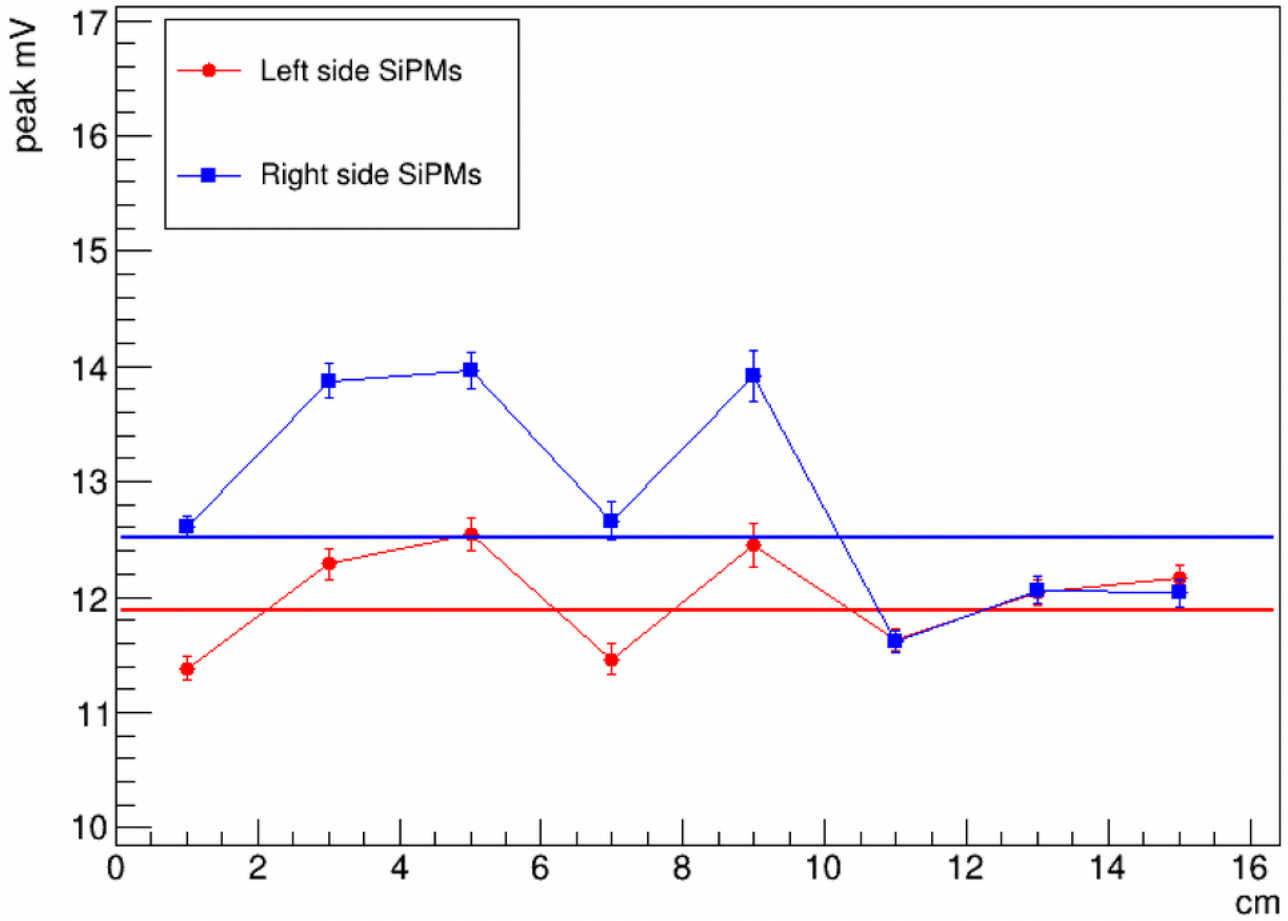


Right: 13.0 ± 0.07 mV

Left: 12.1 ± 0.04 mV

Dowsil run sequence:

Elgin silicone cookie left side, *Dowsil optical coupling grease* right side of the crystal. Run 245



Right: 12.5 ± 0.07 mV

Left: 11.9 ± 0.04 mV

Summary:
Elgin silicone cookie left side
Dowsil optical coupling. grease right side of the crystal.

Run	Left Signal ± 0.1 mV	Right Signal ± 0.1 mV	Right/Left ± 0.014
243	12.1	13.5	1.16
244	12.1	11.8	0.98
245	12.1	13.0	1.07
246	11.9	12.5	1.05
avg			

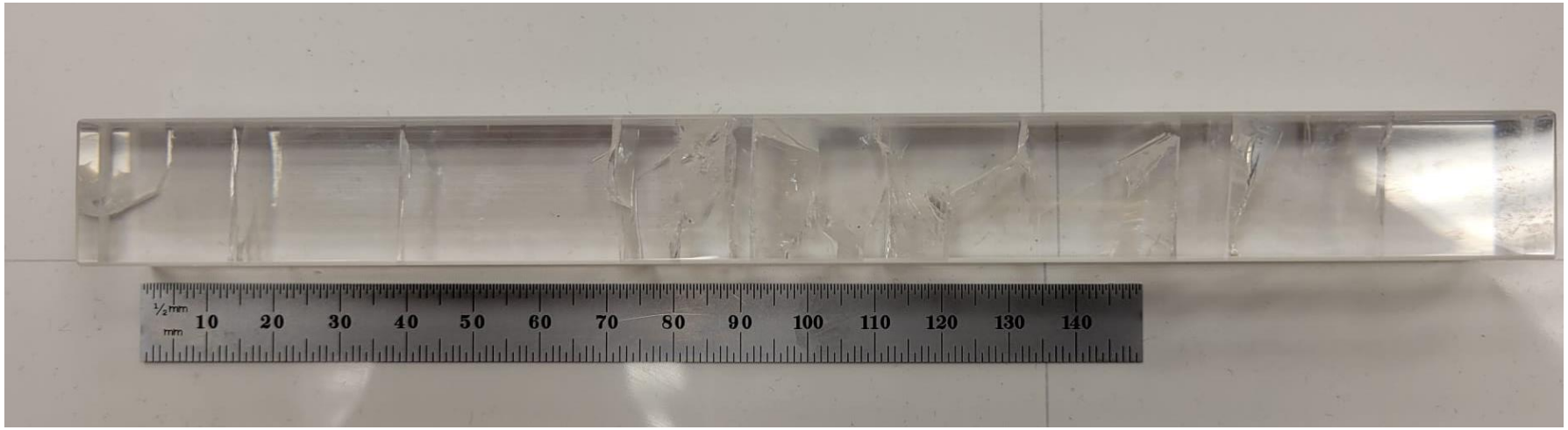
Relative left/right ratio = 1.09 ± 0.03 (excluding outlier)

==> 9% signal gain using Dowsil

Cleaning:

- The Dowsil silicone optical grease is difficult to remove.
- Special degreasing agents have been purchased- but not yet arrived.
- Attempt to clean ultrasonically
- The PWO crystal was immersed in an ultrasonic bath- using water and dish soap.
  The first 5 minute test worked very well but there was still a grease smudge.
  Set the timer for another 25 minutes.

➔ The crystal fractured at multiple locations, separated by ~2 cm along the length- presumably due to resonances set up along the crystal in the apparent vicinity of the transducer.



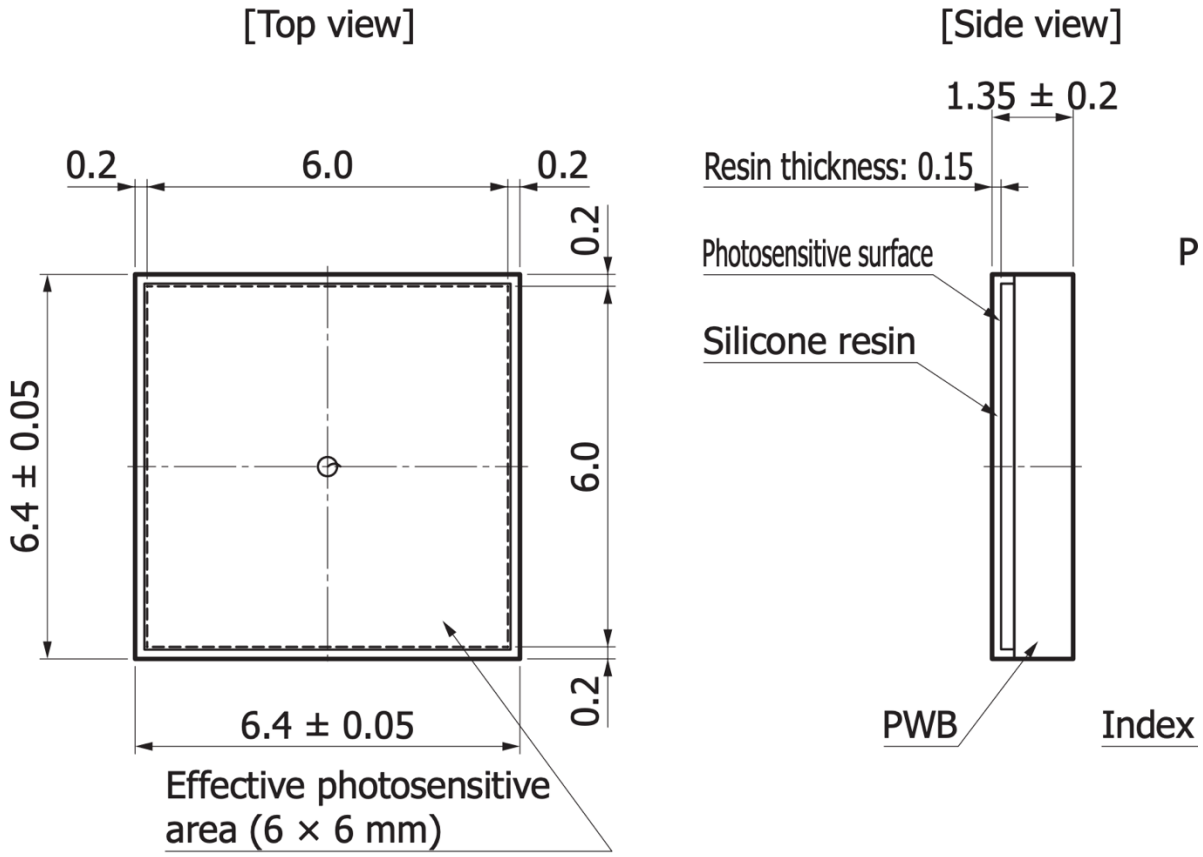
Cleaning Dowsil goo off of the readout SiPMs:

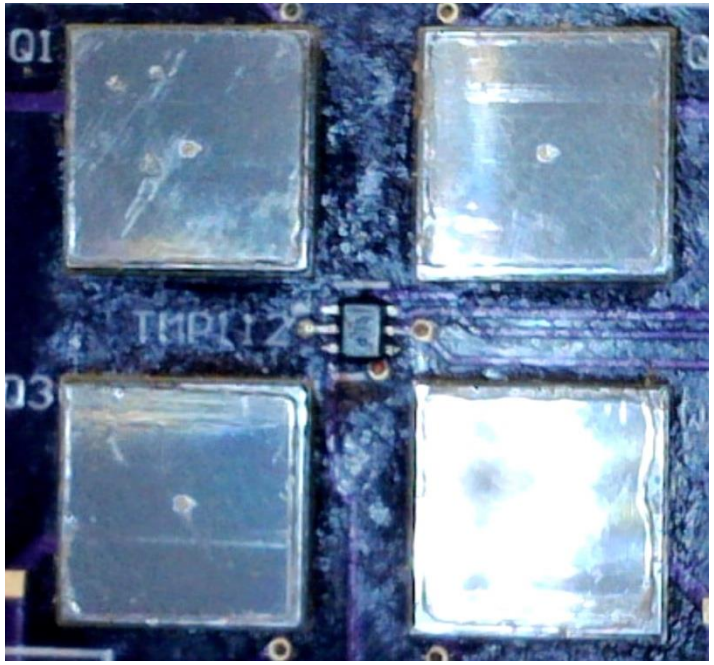
Leaves a horrid mess and is hard to remove.
But without 100% of the remaining grease film removal trials of other coupling agents are unreliable.

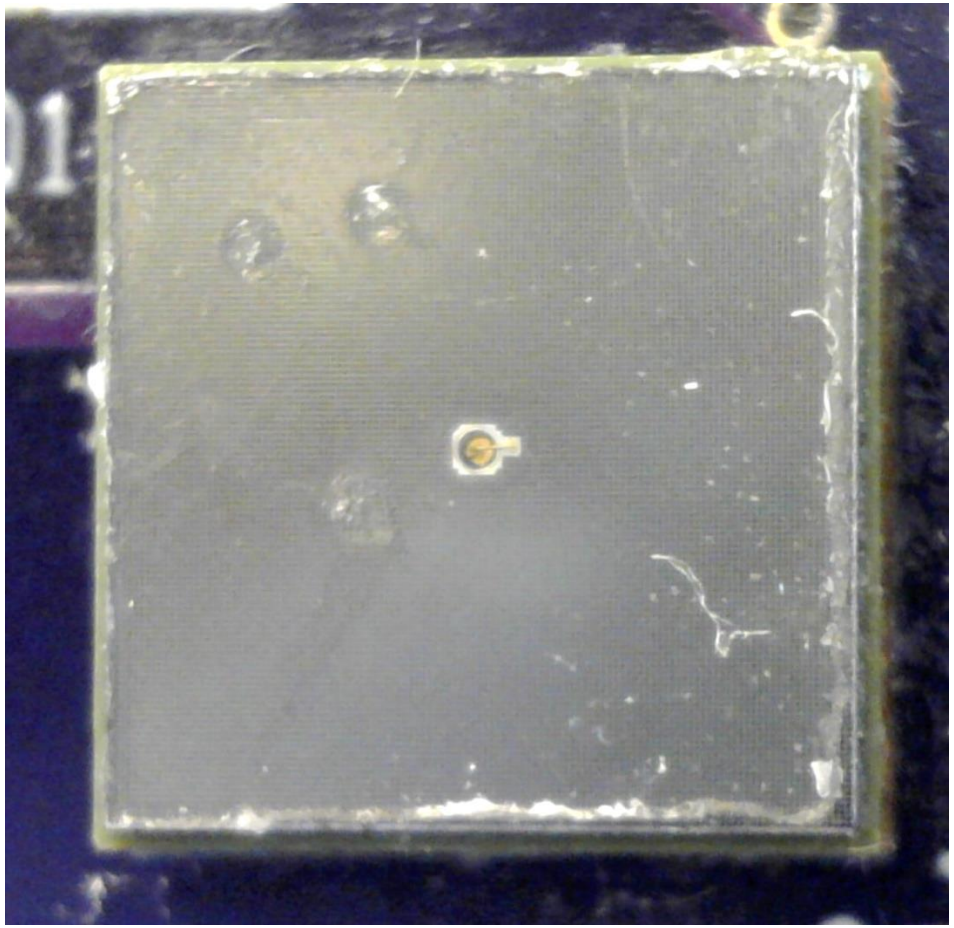
Also: RO SiPMs (Hamamatsu S14160 6 mm x 6 mm) has a caulk-like silicone seal around their perimeter. This covers 200 microns on each side.
But it also covers the photosensitive face.

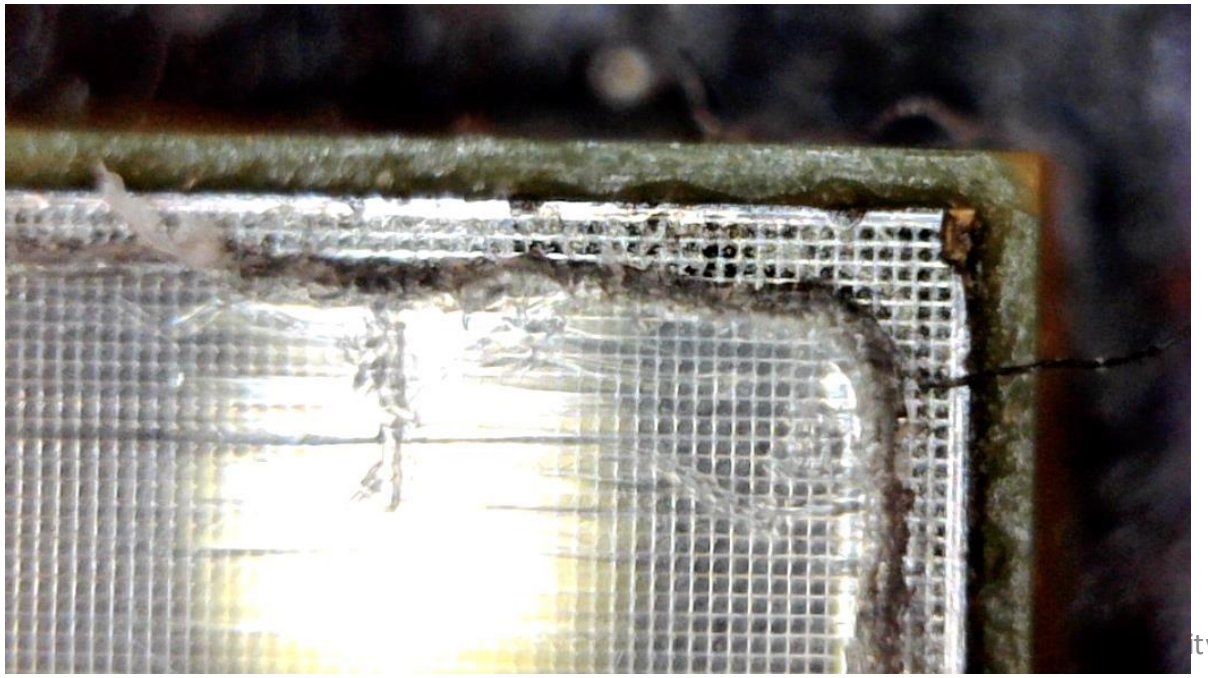
This is part of the SiPM construction:

During the cleaning process, some of this resin around the perimeter was removed.
It looks identical to the Dowsil.




Q1
TMP112
Q3





Main conclusions:

1. I've had a bad week
    - Broke a crystal.
    - Wrecked two SiPMs
    - New ones provided by Thomas Andersen very quickly– thanks!

2. Starting to gauge the reproducibility.
    - Using cookies on each side: Baseline right – left ratio is consistent with unity.
    - Coupling gel either Gargill or Dowsil both offer about 10% improvement.
    - Repeated mechanical assembly/disassembly reduces reliability
    - Need to carefully consider how SiPMs are mechanically coupled-
    - Probably need to use optical epoxy