

Plans for irradiation tests at the UC Davis Cyclotron

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Properties of UC Davis Cyclotron

- 76-inch cyclotron located in Crocker Nuclear Laboratory
- The cyclotron can deliver proton beams with energies from about 5-65 MeV. We would request proton a proton beam of 55-65 MeV to match the damage factor of 1 MeV neutrons.
- The cyclotron can deliver fluxes between 10^5 and $1.2 \times 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$. The total fluence (integrated flux) can be measured to the few percent level.
- The beam flux is uniform over a 6 cm diameter, and a collimator of this size will be placed upstream of the target.

Additional relevant info about the cyclotron

- The cyclotron only runs during business hours – 8 hours per day.
- New user approval and training is straightforward.
- The building that houses the cyclotron has space where we can perform pre-irradiation and post-irradiation characterization tests on the SiPMs and other irradiated components.
- The device being irradiated will be placed on a movable table during the irradiation.
- Transfer of the irradiated material outside of the cyclotron building requires some paperwork, but I was told it is not too complicated.

Radiation doses and beam time required

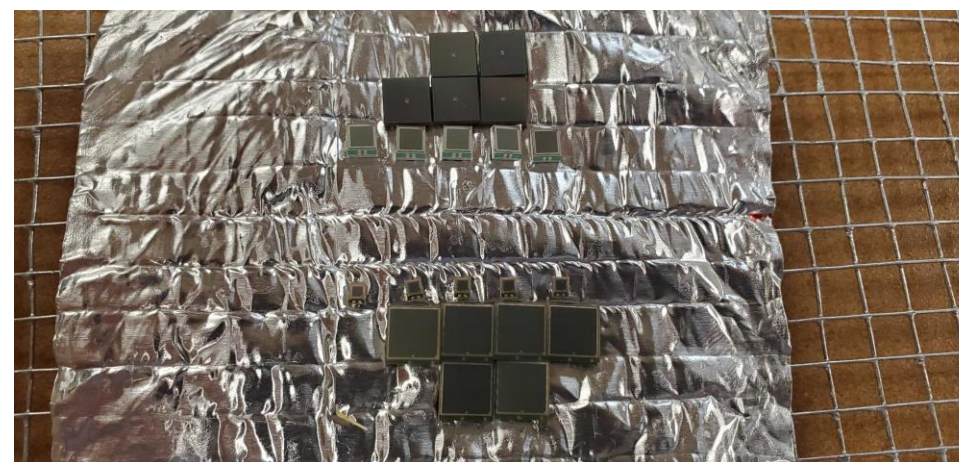
- The test is scheduled for **August 15th-16th 2024**. (16hrs total.)
- We plan to irradiate individual SiPMs with different total doses. See table on next slide for details.
- Total running time for the SiPM irradiation is 1 hour if $10^{10} \text{ cm}^{-2} \text{ s}^{-1}$ flux can be provided. If only $10^9 \text{ cm}^{-2} \text{ s}^{-1}$ flux can be provided, total running time will be about 4 hours. One hour of beam tuning is needed prior to the start of running. Between settings, about 10-15 minutes is needed to remove the SiPMs, install new ones, and restart the beam (total of 1-1.5 hours with 6 settings).
- This should give us time to irradiate other calorimeter-related components.

Radiation doses and beam time required

Beam Flux (cm ⁻² s ⁻¹)	Time (seconds)	Total Fluence (cm ⁻²)	Number of SiPMs
10 ⁶	100	10 ⁸	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch)
10 ⁷	100	10 ⁹	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch) 1 S14160-6015 (6mm, 15um pitch)
10 ⁸	100	10 ¹⁰	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch) 2 S14160-6015 (6mm, 15um pitch)
10 ⁹	100	10 ¹¹	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch) 2 S14160-6015 (6mm, 15um pitch)
10 ¹⁰	100	10 ¹²	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch) 2 S14160-6015 (6mm, 15um pitch)
10 ¹⁰	1000	10 ¹³	4 S14160-1315PS (1.3mm, 15um pitch) 4 S14160-3015PS (3mm, 15um pitch) 1 S14160-6015 (6mm, 15um pitch)

Mount for SiPMs

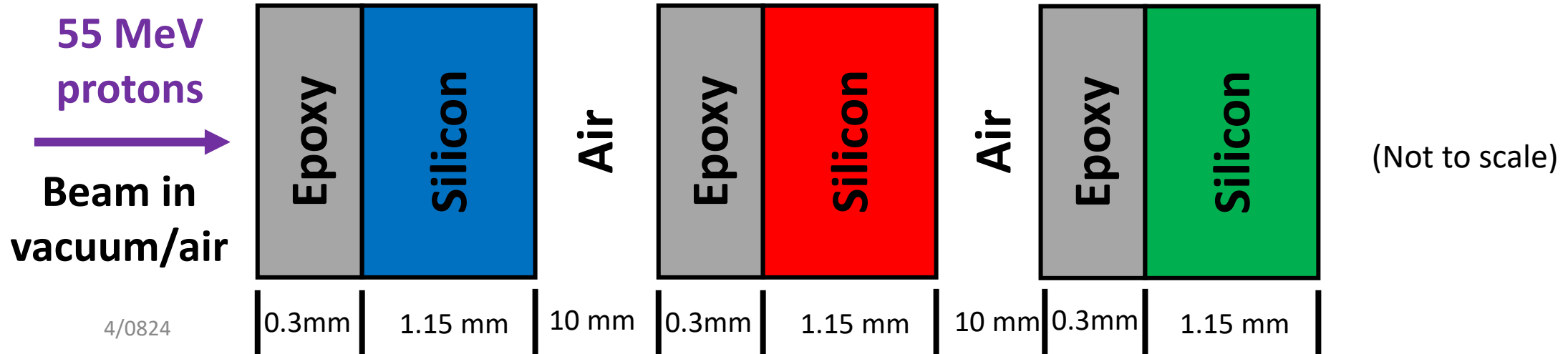
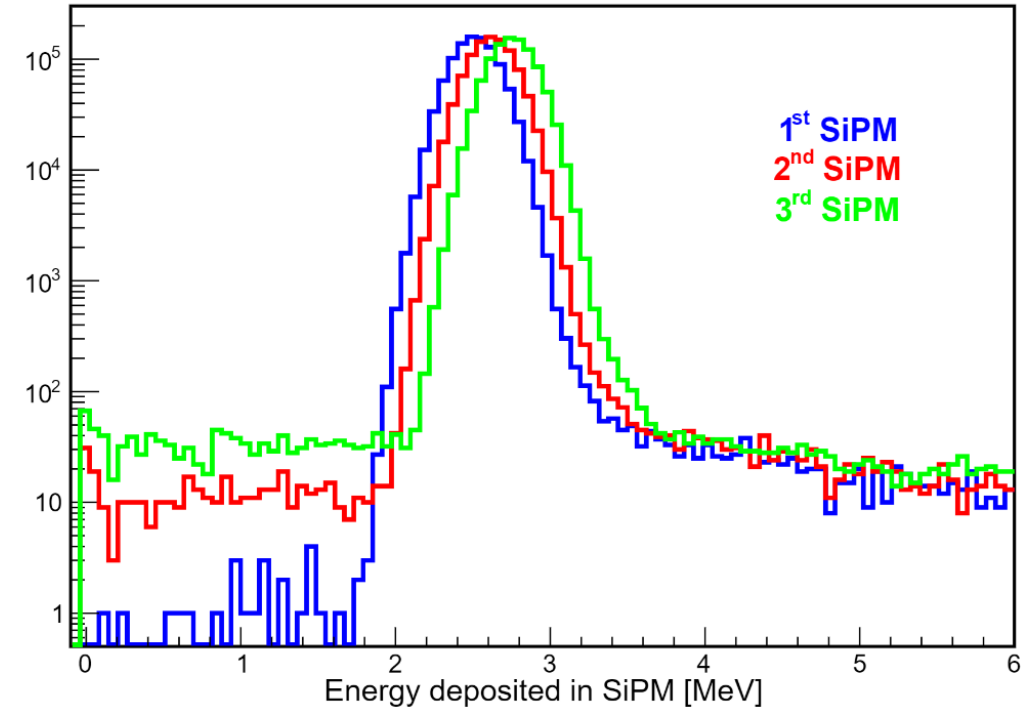
- Given the high proton flux, we were asked to use a mount that does not contain plastic.
- We will use the mount shown on the right. The structure is made from 80x20 bars, with the SiPMs mounted to a metal mesh grid and covered with aluminum.
- This setup allows multiple layers to be stacked in the beam simultaneously.
- In addition, it allows a layer of irradiated SiPMs to be removed quickly and replaced with a new layer on non-irradiated SiPMs



SiPM multi-layer Geant4 simulation

https://github.com/bschmookler/beamtests_dd4hep/tree/main/Sipm_RadTest

For 55 MeV Protons



Benchtop characterization tests for SiPMs

Setup for pre-irradiation and post-irradiation characterization tests



Example tests to perform:

- I-V characteristics before irradiation and at fixed times post-irradiation
- LED response – average signal charge, signal-to-noise ratio
- Waveform analysis
- Examples of SiPM irradiation tests:

<https://link.springer.com/article/10.1007/s10686-022-09873-6>

<https://arxiv.org/pdf/2001.10322.pdf>

Available hardware for SiPM characterization tests

SiPM bias unit (handheld)



Full waveform digitizer (handheld)



Annealing oven at UCR



Single channel board with an amplifier built in – goes to scope



Bias and digitizer unit with 64 channels (handheld)



Next steps

- I plan to meet with the UC Davis cyclotron staff this month to get details of the proton hall (cave) – such as distances to any patch-panels, power outlets, etc...
- For the SiPMs, we don't need to monitor the SiPMs during the irradiation. But some of the boards and electronic components suggested by Elke, Miguel and Gerard will want monitoring. (Zhenyu suggested also irradiating some tracking sensors if we have time.)
- Other than for the SiPMs, I need a comprehensive list of other components that we want to irradiate. I'll reach out to people in the next few weeks to get some specifics.
- Non-ionizing energy loss (NIEL) dose from 65 MeV protons should be almost equivalent to that of 1 MeV neutrons, but I need to understand the uncertainties on this conversion factor.