Plans for Silicon photomultiplier (SiPM) irradiation tests at the 88” Cyclotron

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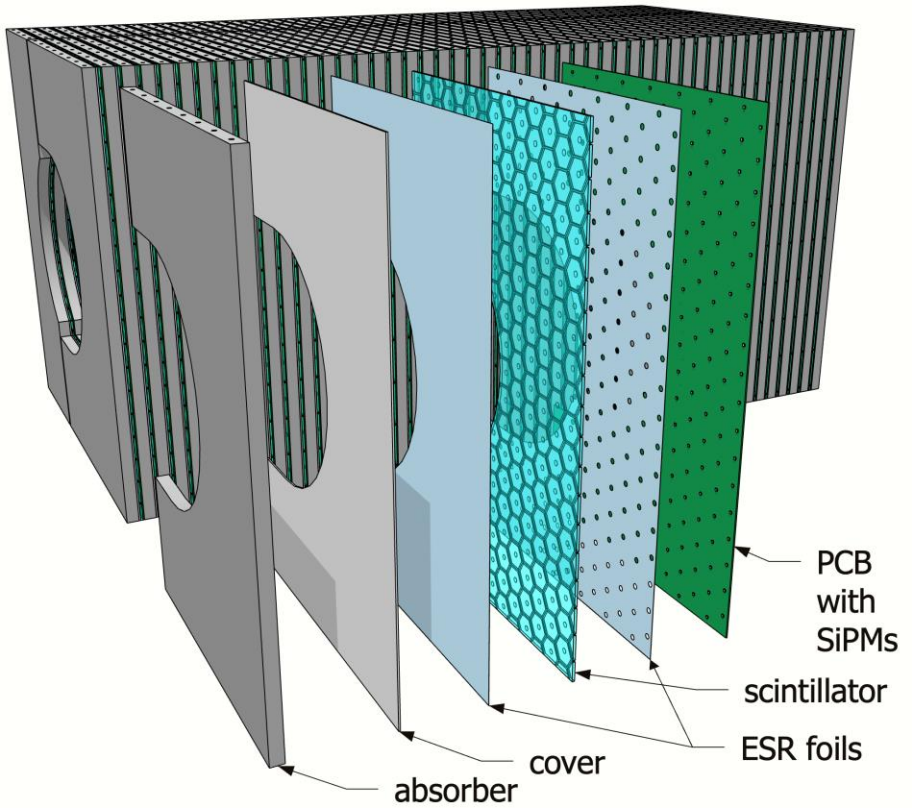
Motivation

High-granularity calorimeter insert
for the forward endcap



- Proposed insert has several thousand channels, each read out by a SiPM.
- Fluences in the insert region will be around 10^{12} /cm^2 n_{eq} per year.
- SiPMs give a high gain, a fast response time, are compact and economical, and are insensitive to magnetic fields. They can suffer from bulk and surface damage when exposed to radiation.

88-Inch Cyclotron at LBL

The 88-Inch Cyclotron is a 300-ton, K=140 sector-focused cyclotron with both light- and heavy-ion capabilities. Protons and other light-ions are available at high intensities (10-20 pμA) up to maximum energies of 60 MeV (protons), 65 MeV (deuterons), 170 MeV (3He), and 130 MeV (4He). Most heavy ions through uranium can be accelerated to maximum energies that vary with the mass and charge state.

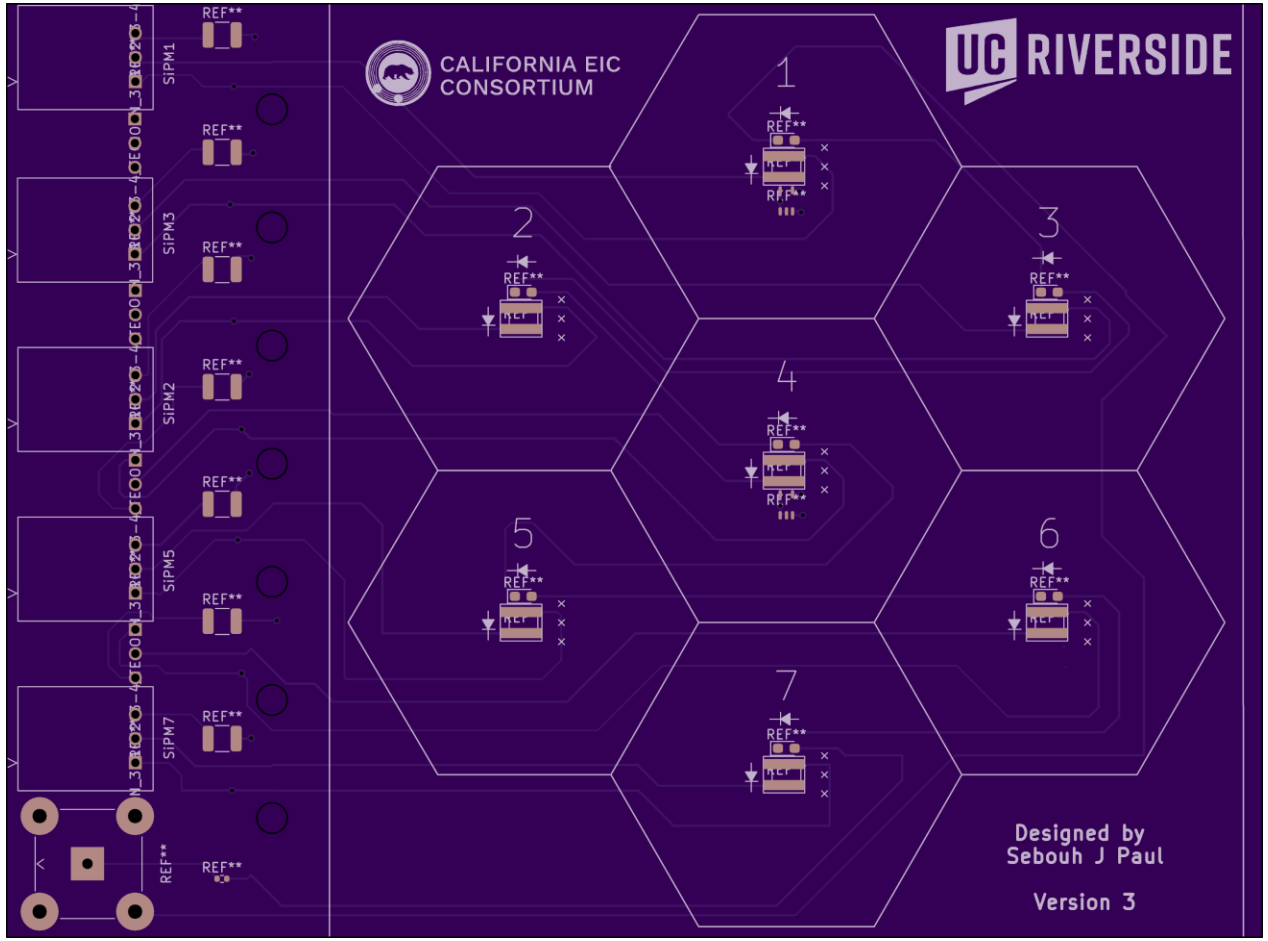
The BASE Facility is capable of providing fluxes of up to 1E9 protons/cm2-sec (the limit of our standard, continuously reading ion chamber dosimetry), but works best in the 1E7 to 1E8 protons/cm2-sec range. Higher levels of flux are monitored using intermittent faraday cup readings. Standard proton energies include 13.5, 20, 30, 40, 50, and 55 MeV,

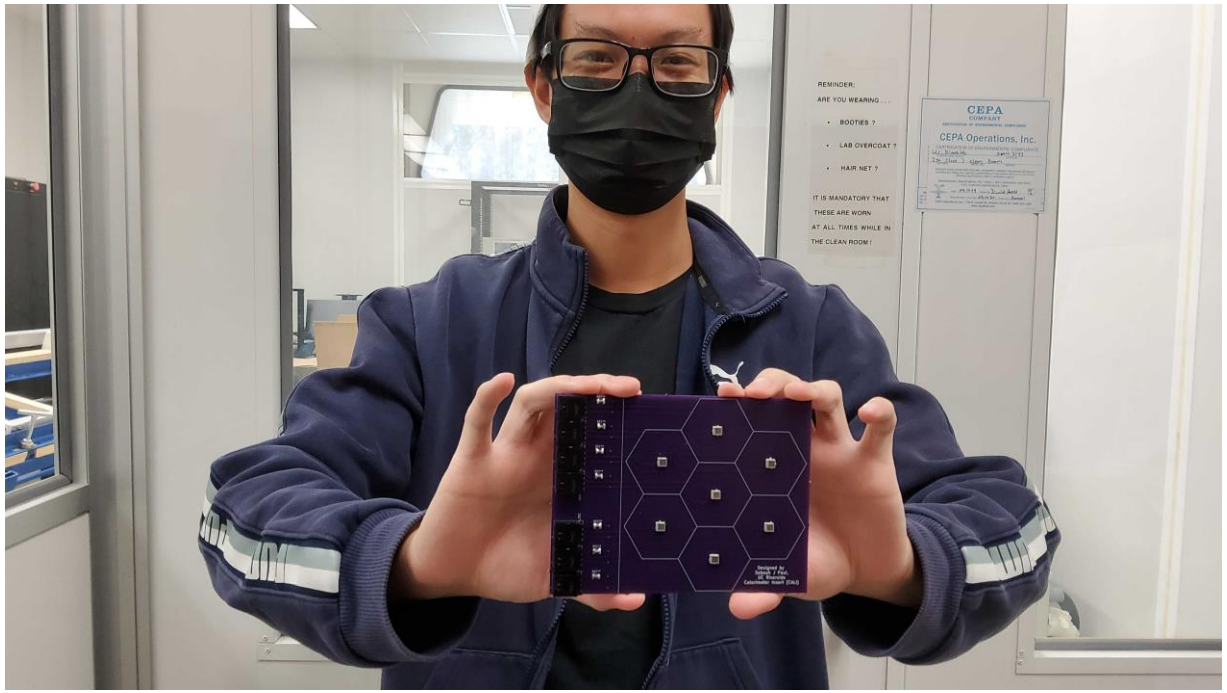
The ion chamber (pictured) monitors the beam continuously during the experiment. Five concentric rings (with diameters of 1cm, 2cm, 4cm, 6cm, and 8cm) and four quadrants are used to establish and monitor uniformity. Collimators are available with diameters of 1, 2, 3, and 4 inches. Beam particles traveling through the nitrogen-filled ion

Bias and digitizer unit with 64 channels (handheld)

https://cyclotron.lbl.gov/home

What would go into the beam

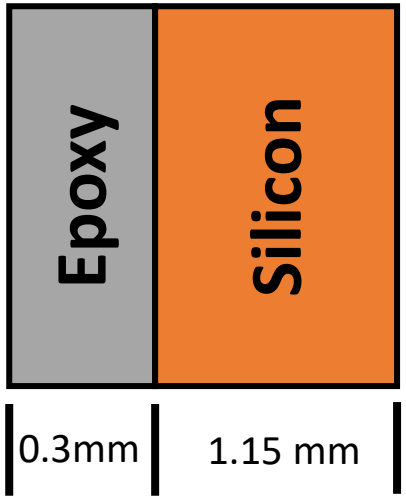




Simulation of energy deposition

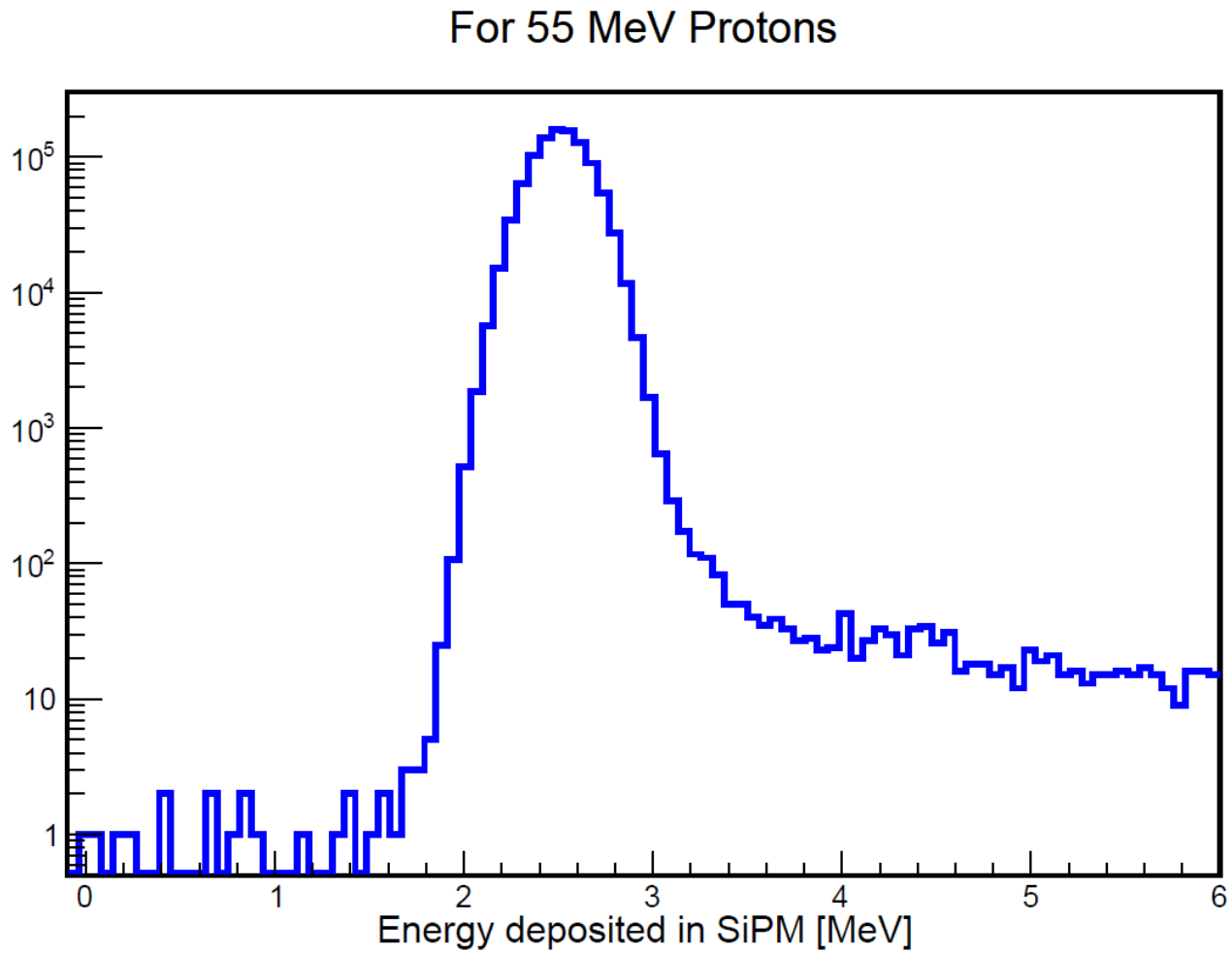
55 MeV protons
or
1 MeV neutrons

Beam in vacuum

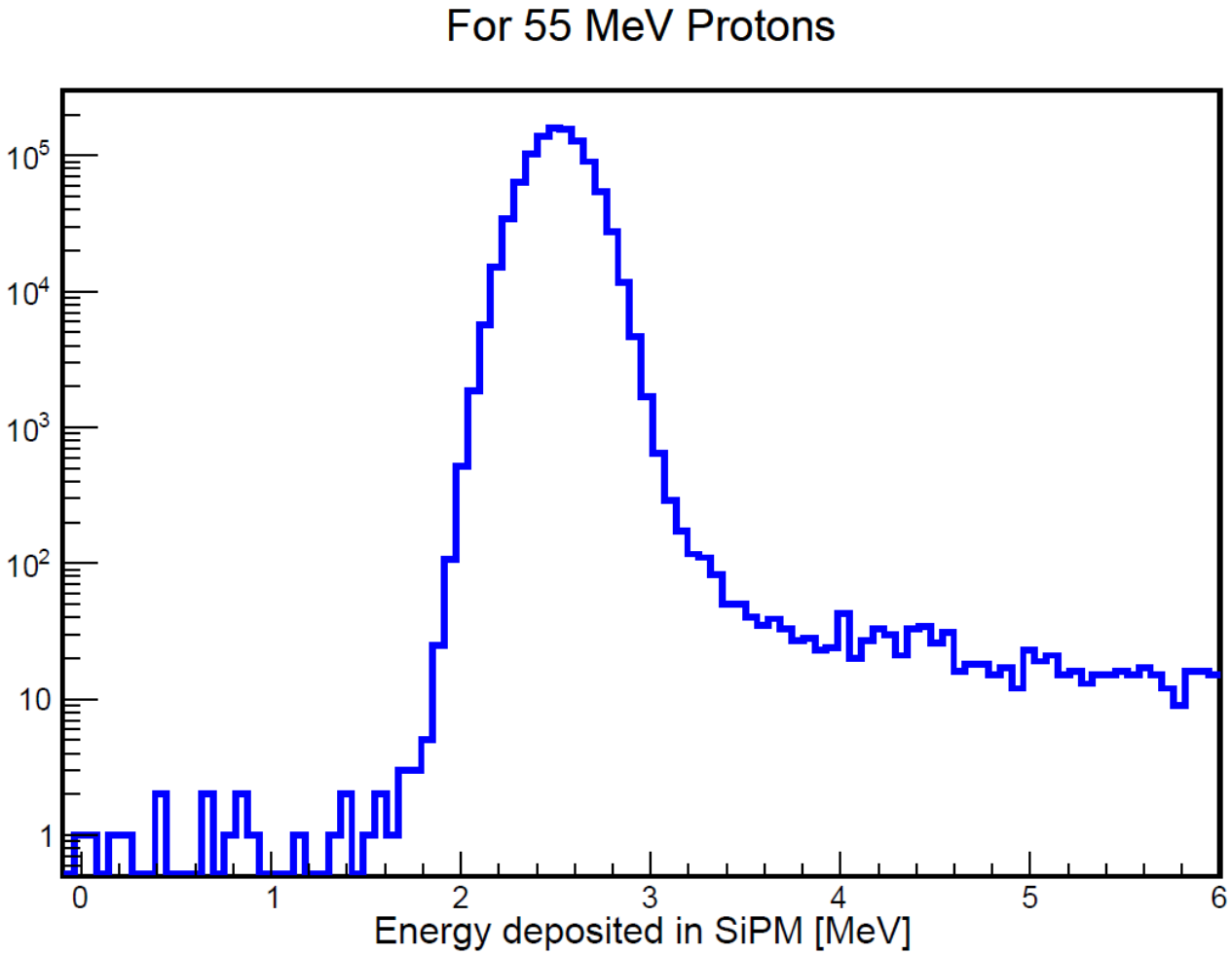


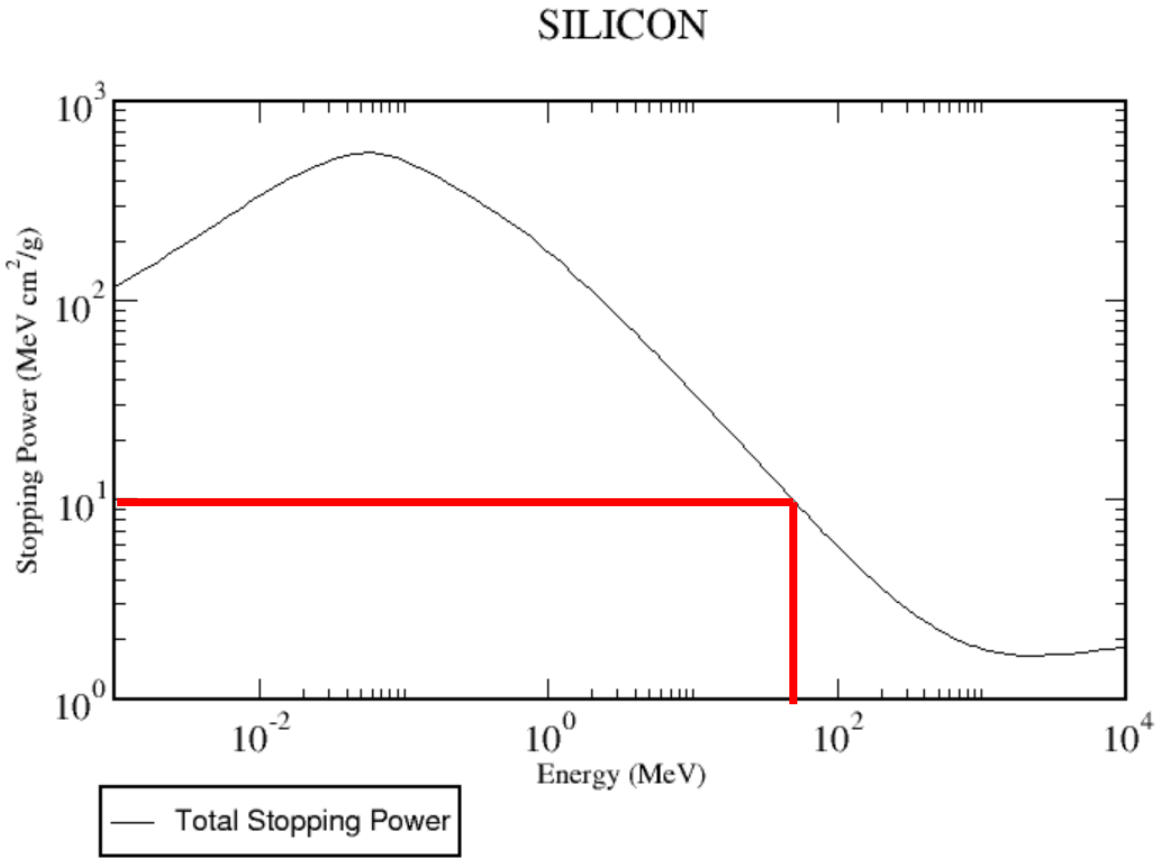
https://github.com/bschmookler/beamtests_dd4hep/tree/main/Sipm_RadTest

Energy deposited per beam particle – protons



Energy deposited per beam particle – protons

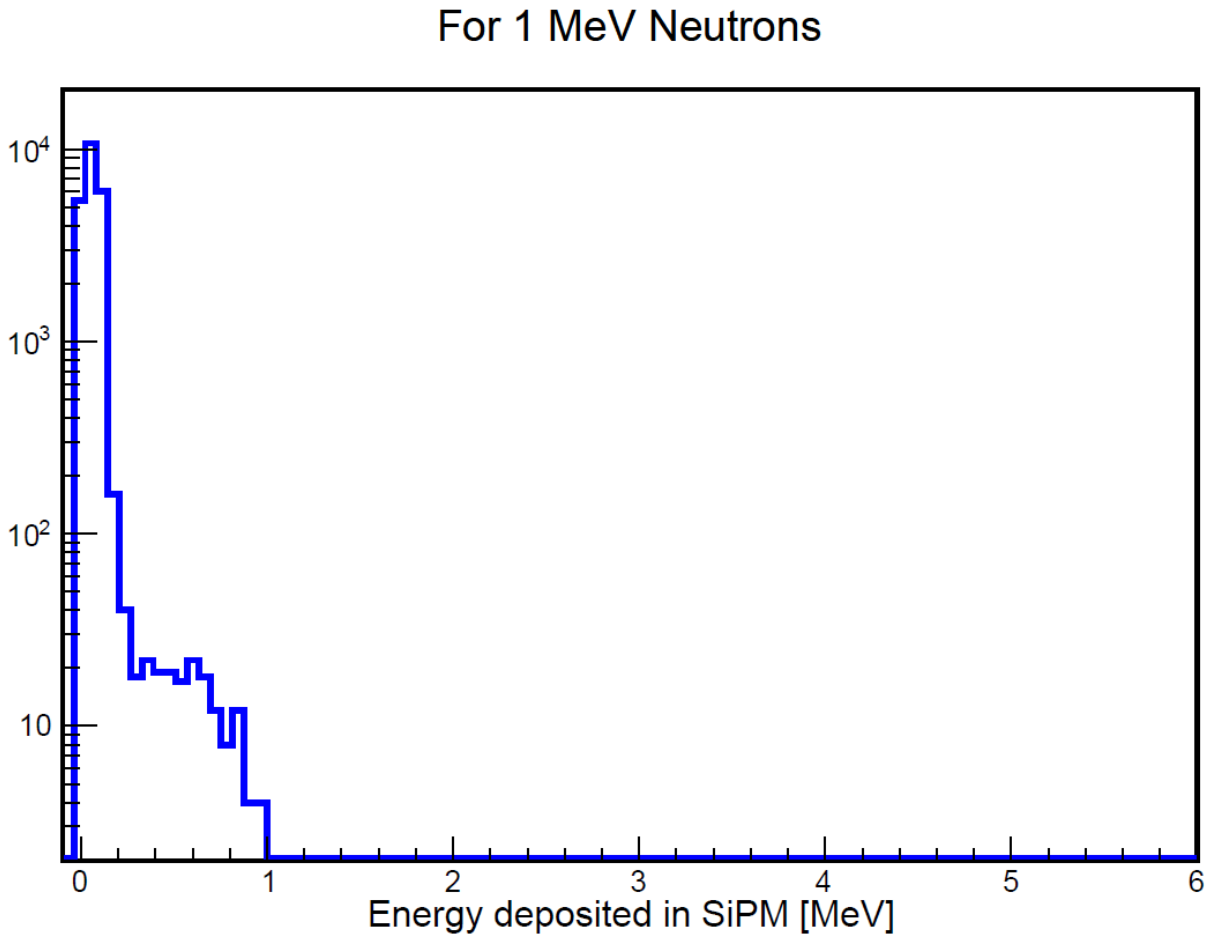




Calculated average energy deposit =
0.115 cm x 10 MeV cm^2/g x 2.33 g/cm^3 = 2.7 MeV

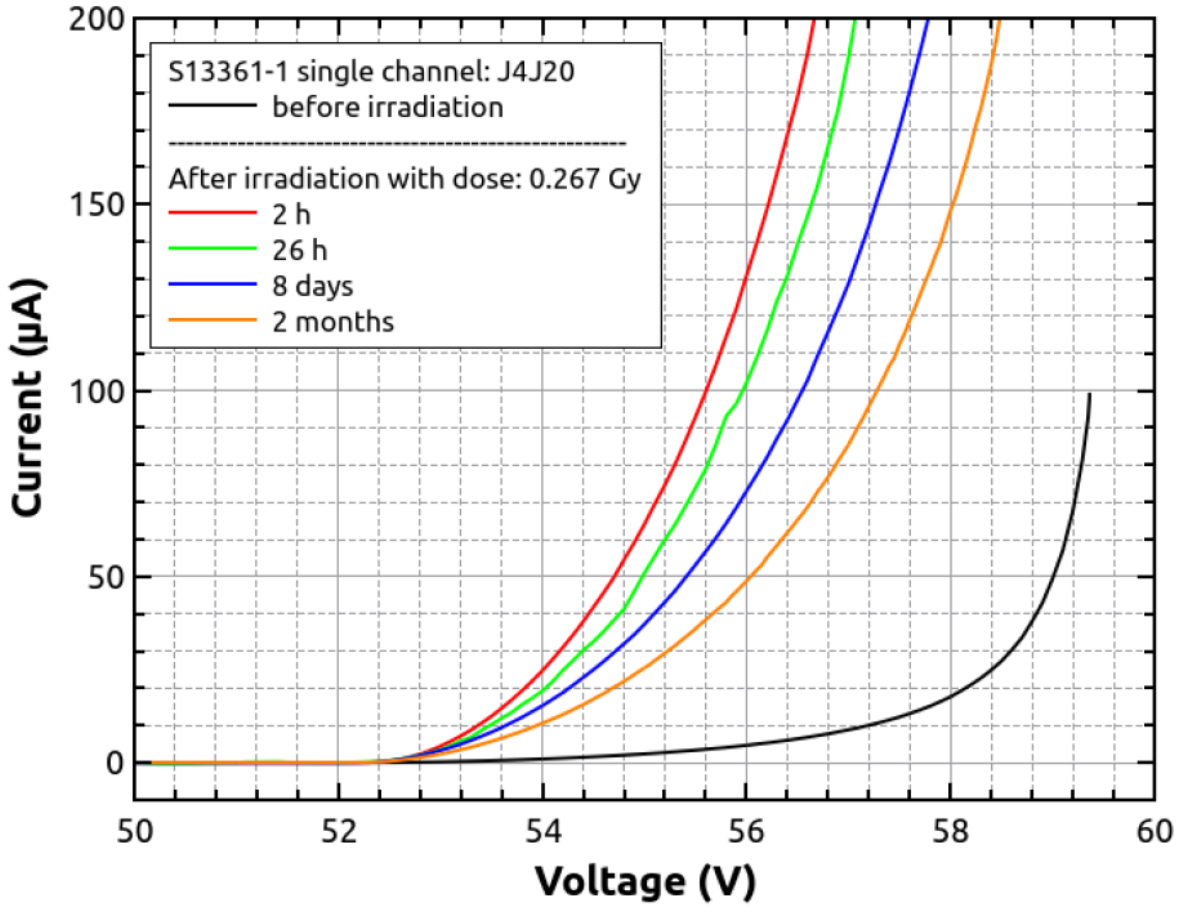
Seems consistent

Energy deposited per beam particle – neutrons



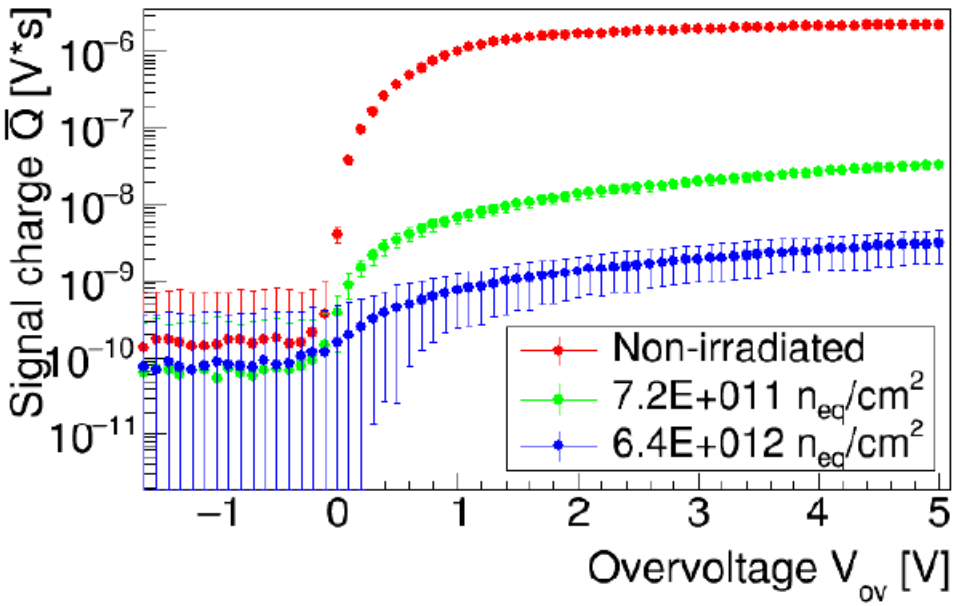
- 55 MeV protons have a similar radiation weight (i.e. damage factor) as 1 MeV neutrons.
- With a proton flux of $10^8/cm^2/sec$, we would need about 3 hours of beam to accumulate a fluence of $10^{12}/cm^2$ – which would be approximately $10^{13}/cm^2$ n_{eq}.

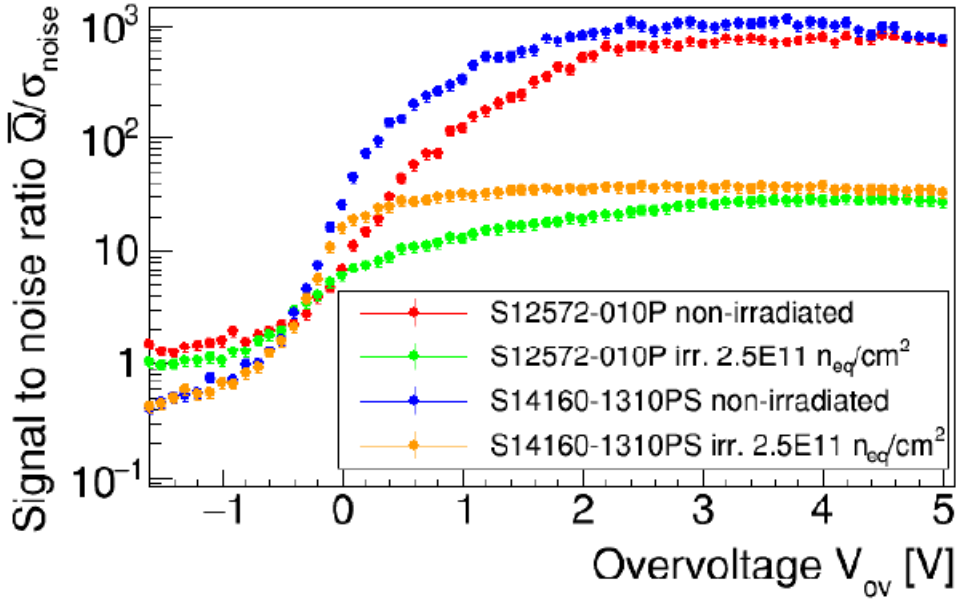
Example studies – I-V characteristics



Proton irradiation of SiPM arrays for POLAR-2. *Exp Astron* (2022). https://doi.org/10.1007/s10686-022-09873-6

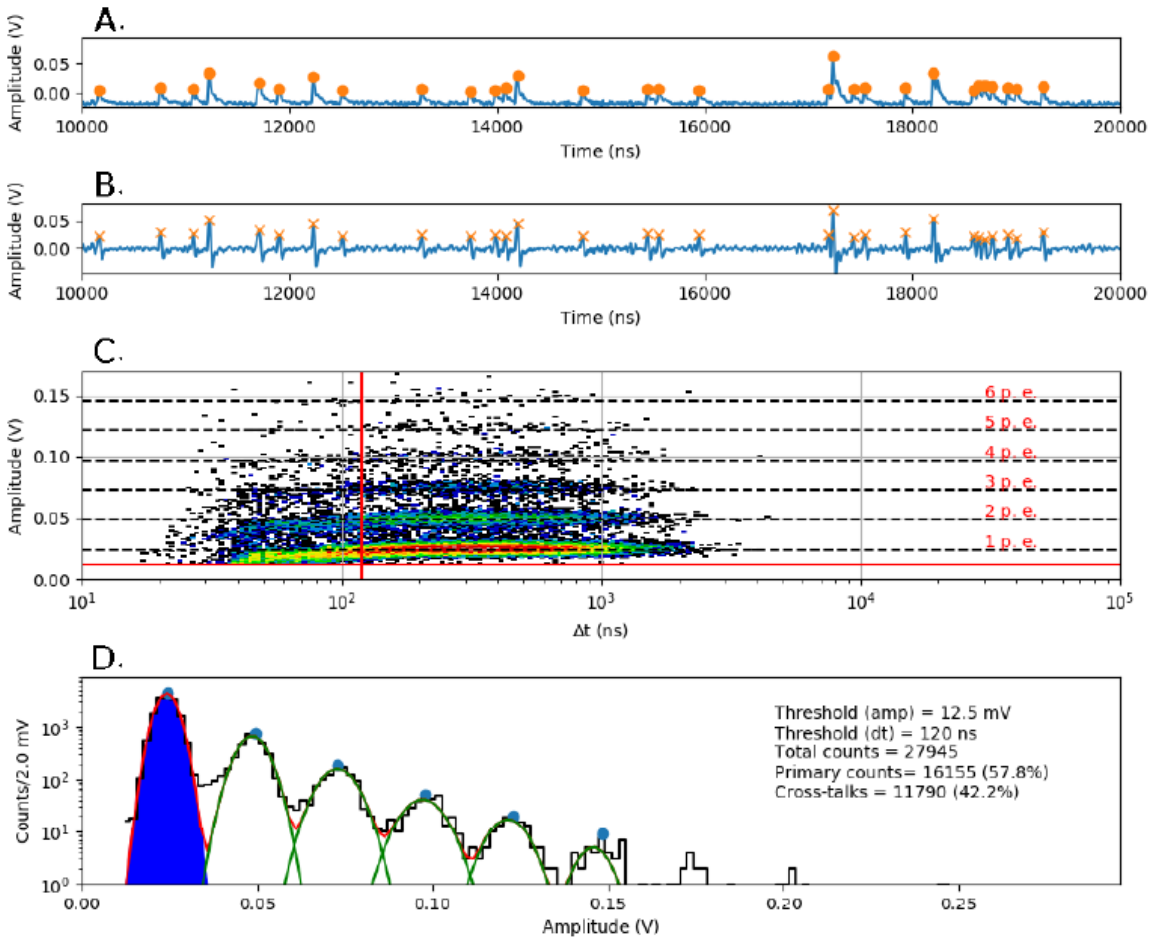
Example studies – LED response





arXiv:2001.10322v1

Example studies – waveform analysis



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Available hardware

SiPM bias unit (handheld)

Full waveform digitizer (handheld)

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

Bias and digitizer unit with 64 channels (handheld)

Available hardware

Annealing oven

Plans for test

- Plan to irradiate several SiPM arrays with proton fluences between 10^{10} and 10^{12} /cm^2. This is about 4 hours of actual beam time at 10^8/cm^2/s flux.
- Currently working on beam request form. Our goal is to perform this beam test in the next months.