

SiPM and FEB Considerations

Justin Frantz (Ohio University)

ePIC EEEMcal Readout Mtg

06/05/2024



Status of Irradiation Test/Data & Initial SiPM Decision

- I have all the single siPM's that were irradiated
 - Whole board was too hot to take, I emailed Crocker to have send board back to Larry last week, but haven't followed up with them.
 - Data is posted on google drive see email links.
-
- Initial purchase decision – 3015?

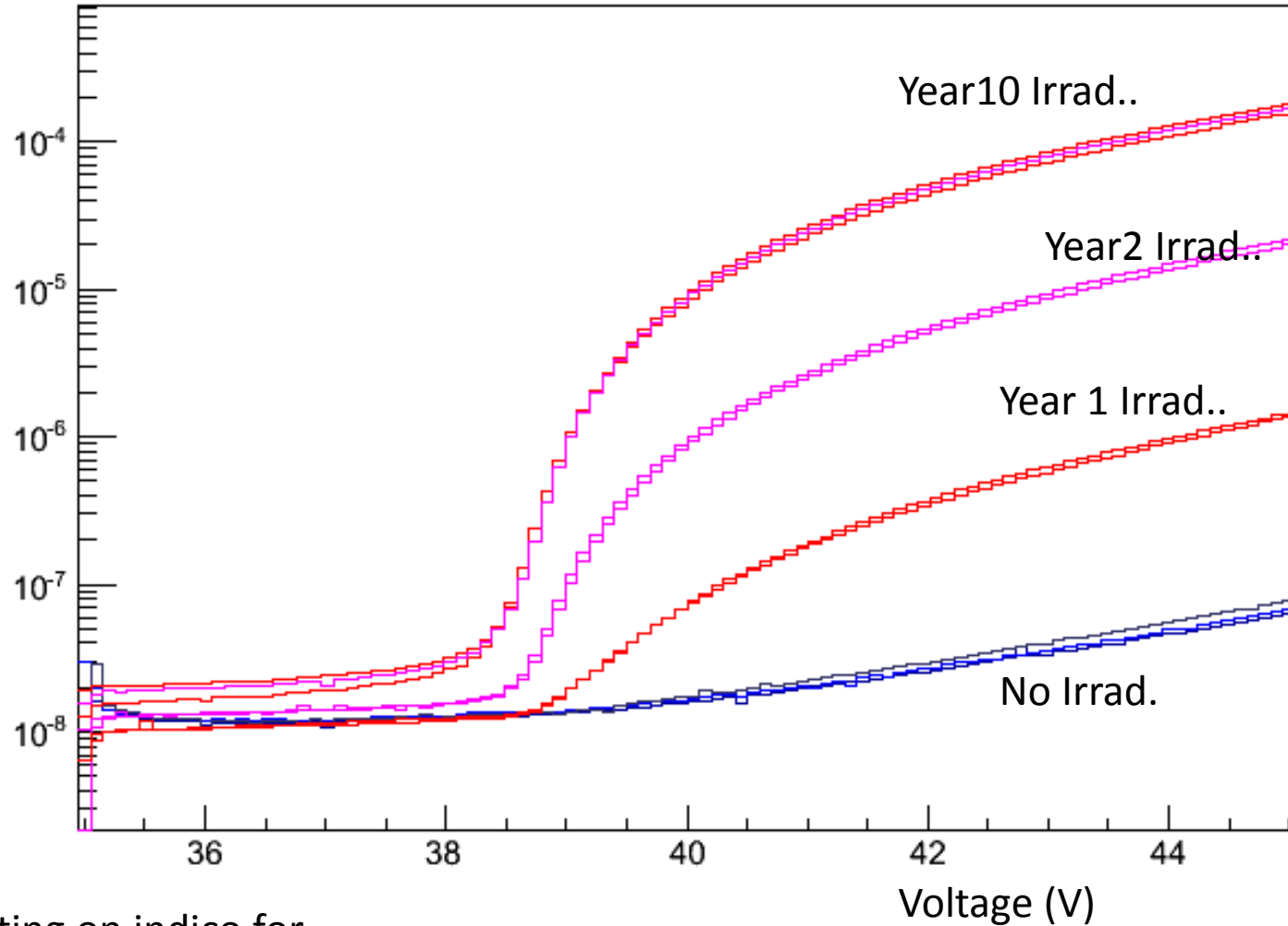
Initial Look at IV curves

- How to analyze?
- Find VBR for all curves, tabulate ?
- Anything else?

From UC Davis: 6015 ((6mm)², 15 μm pixel)

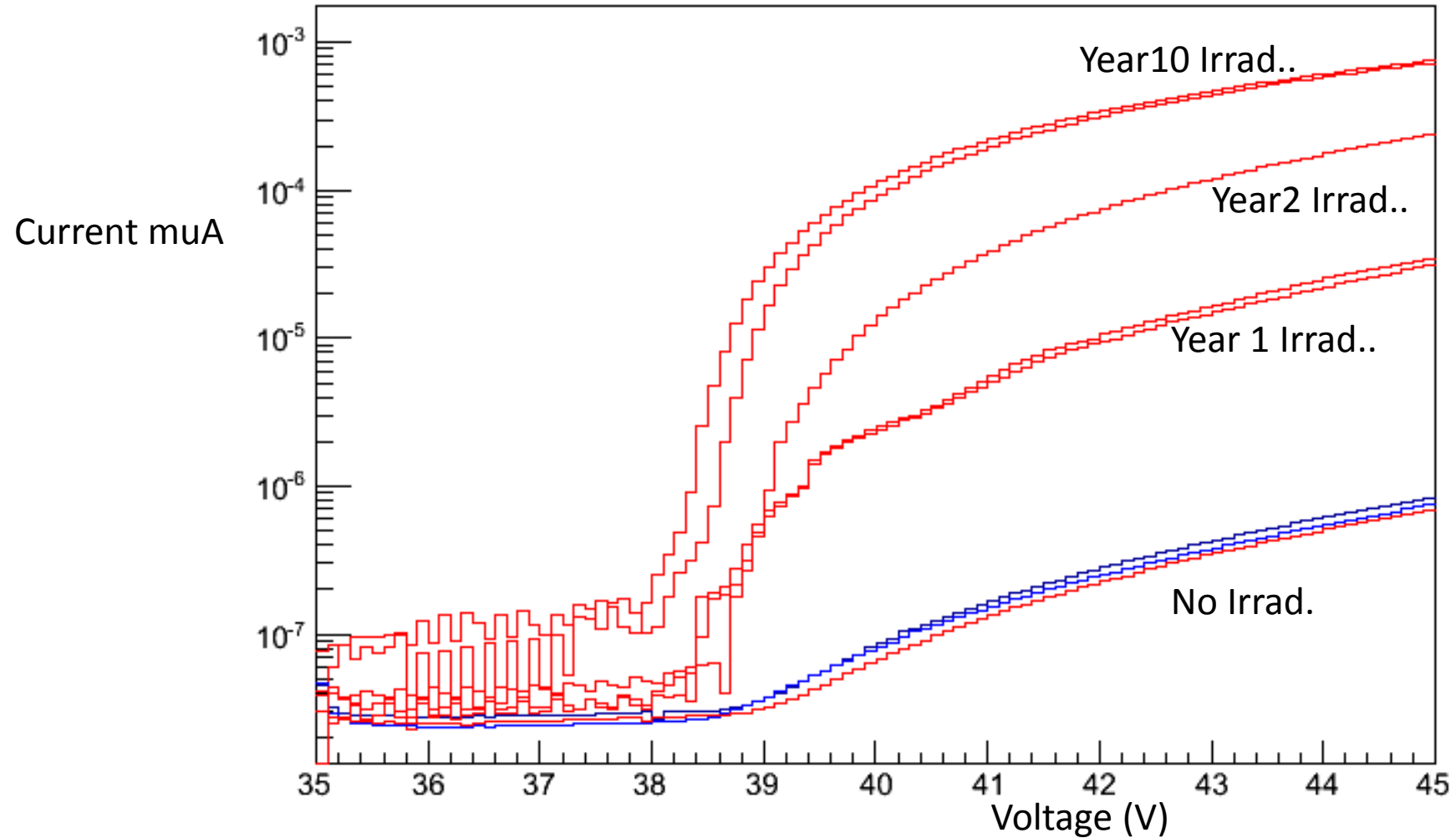
quick first
look

Current μA

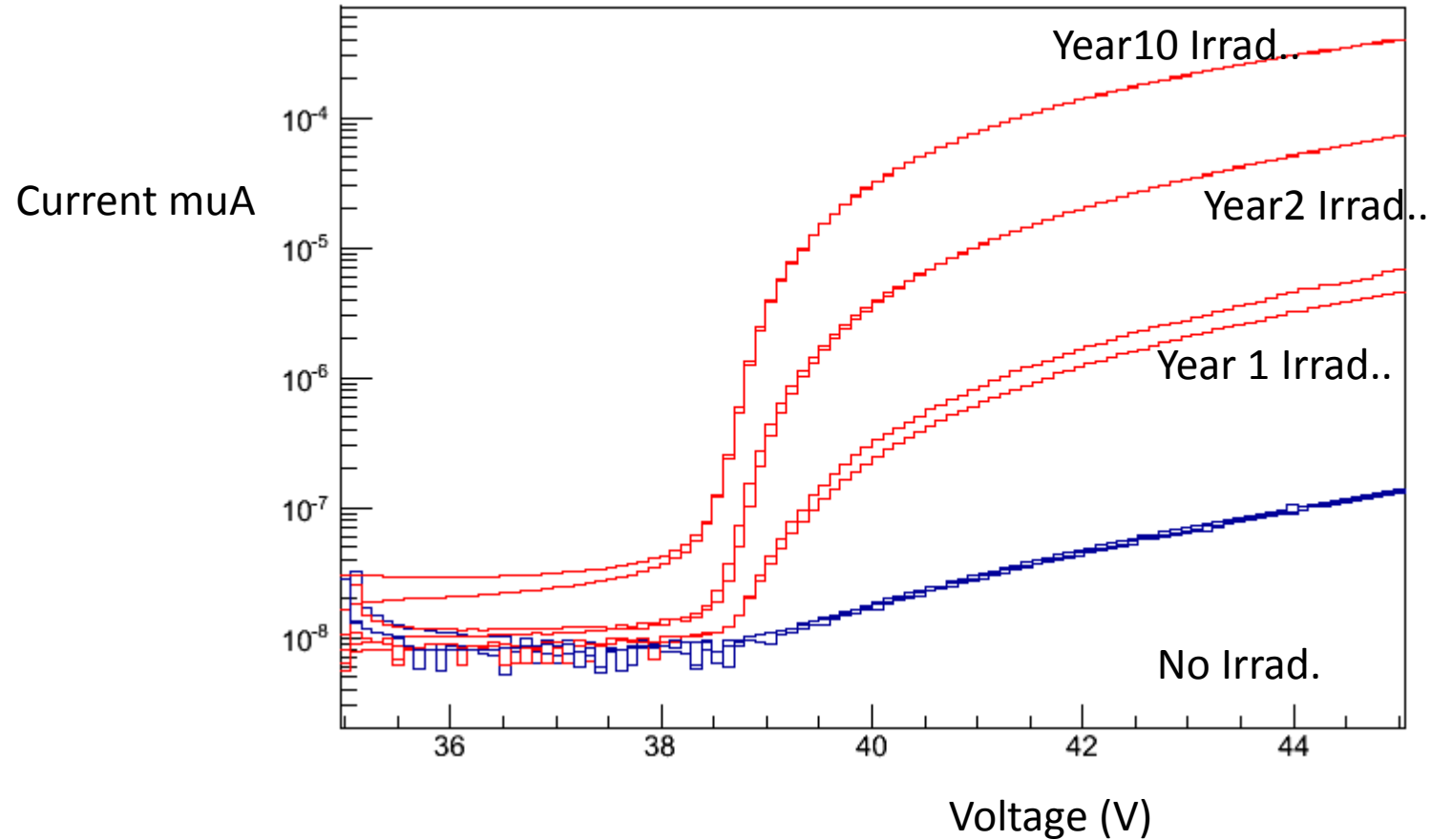


See last readout meeting on indico for
more detailed info about radiation doses

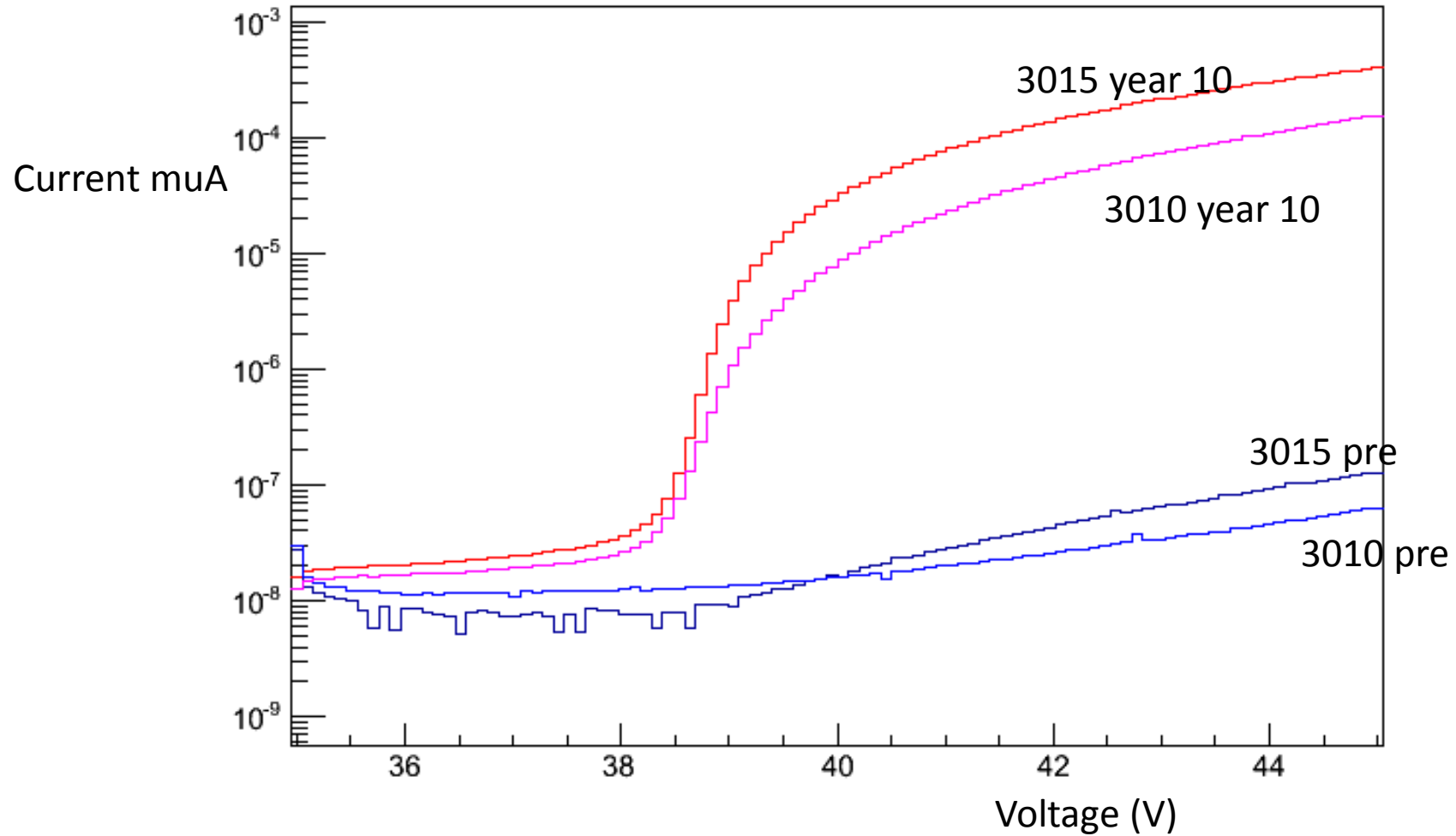
3010 ((3mm)², 10 μm pixel)



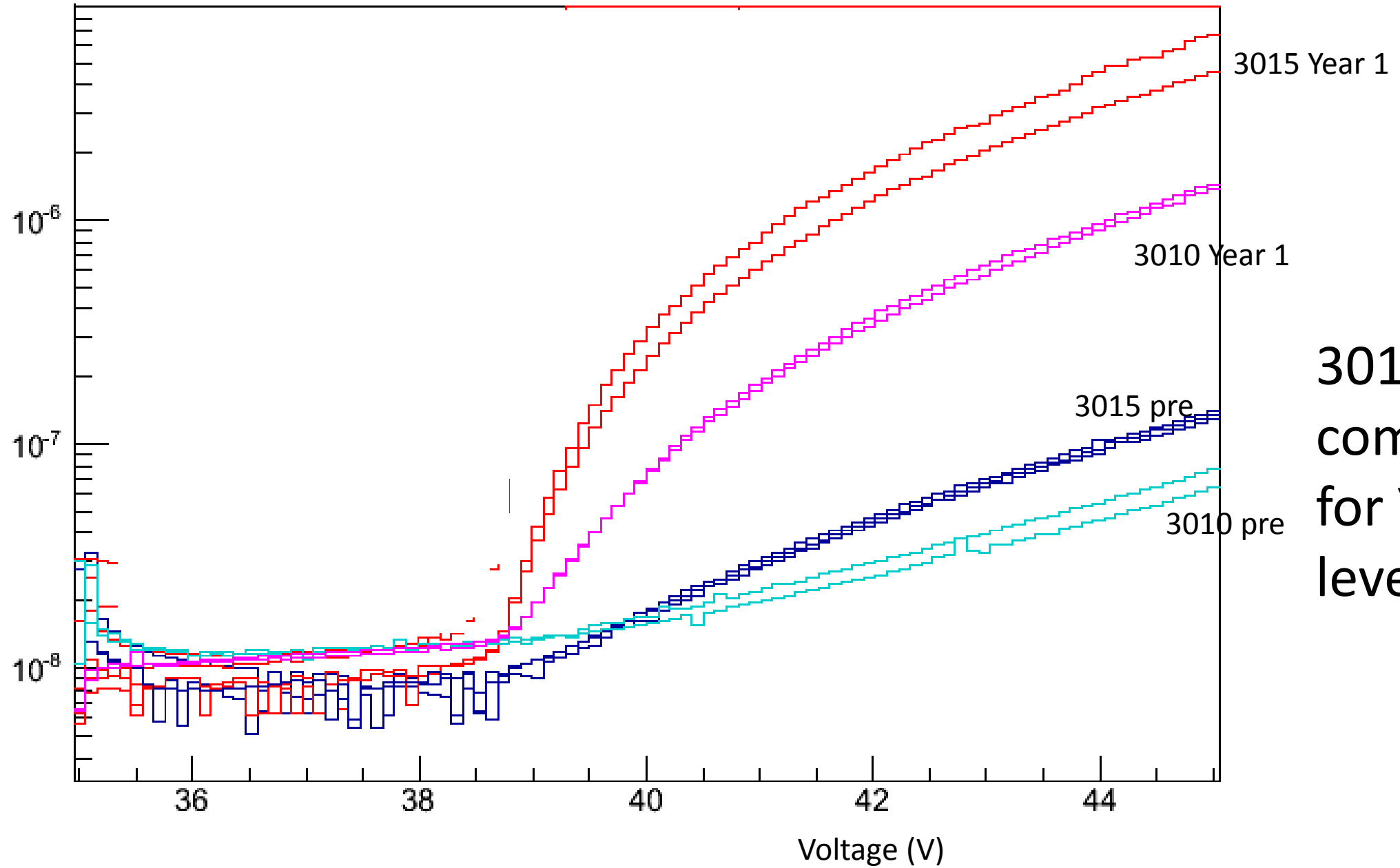
3015 ((3mm)², 15 μm pixel)



$(3\text{mm})^2$, $15\ \mu\text{m}$ pixel vs $10\ \mu\text{m}$



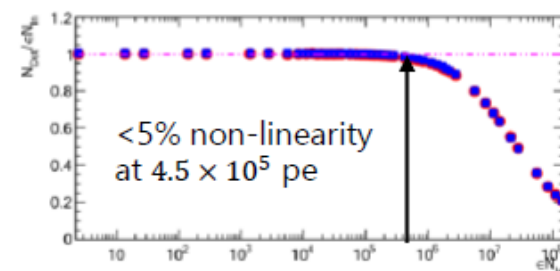
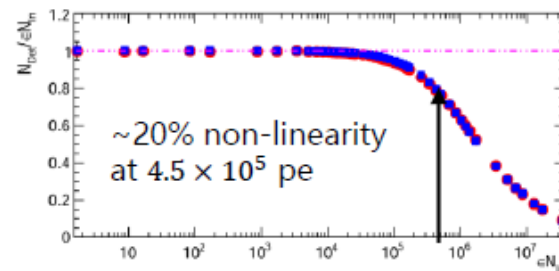
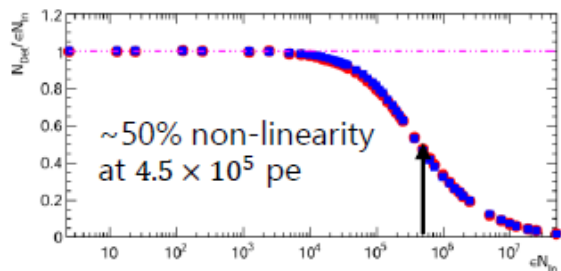
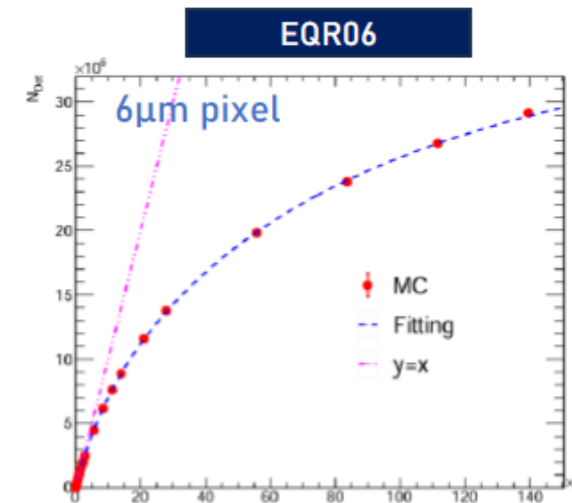
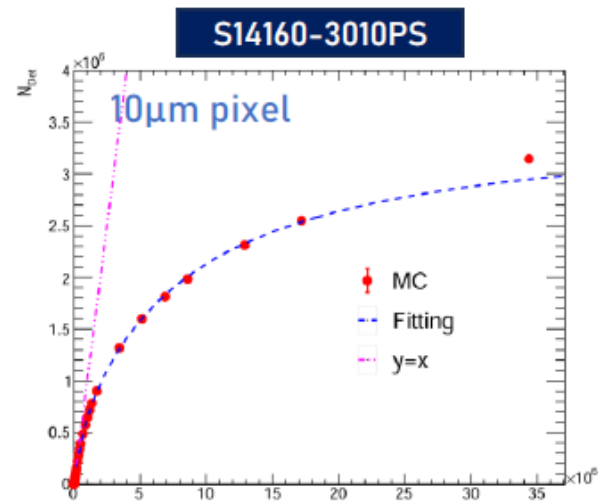
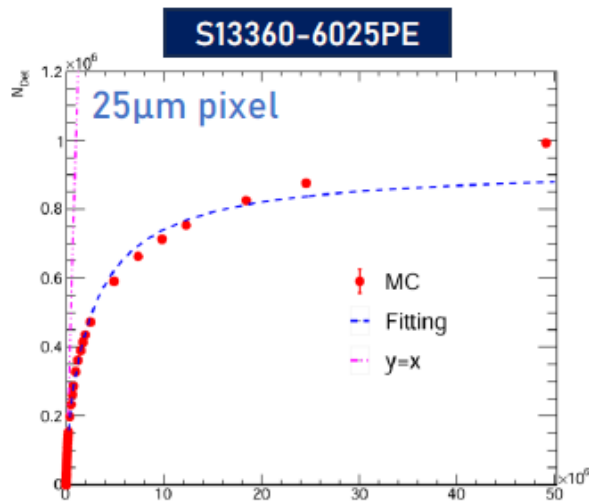
urrent r



3010/15
comparison
for Year 1
level dose

Linearity in Presentations at CALOR2024

- Olivier pointed to some slides
- Initial non-linearity worse with 6mm pixel, but better able to be corrected?
- <https://indico.cern.ch/event/1339557/contributions/5898510/>
- **Also one with beam tests , but non-linearity w/ 6mm models there was due to leakage?**
- <https://indico.cern.ch/event/1339557/contributions/5898480/>



Price Options Immediate Funds Needed

- Assume Sasha Bazilevsky Mechanism/Process gets needed funds for remaining needs, such as adapter board fab/assembly in late Aug/Sept timeframe
- Order siPM's ASAP
 - 3mm² siPM's came faster last time, still should be time to get in time, for 6015, order needs made ~now based on December order fulfillment times
- Costs: [10vs 15 mum always same]
 - 3mm : \$53/siPM, discount 100 unit: \$42/siPM, discount 300 \$19/siPM
 - 6mm \$125/siPM, discount 100 unit \$65/siPM
- discount level needs single buyer
- Some Options
 - Option 1) Single group buyer \$6500 – 100 6015 siPMs , \$7600 3015 500 siPM ALL new 25 channels worth
 - Other options : reuse some/all ones in hand, including some irradiated – maybe place on edges – expect some annealing – perhaps even baking could accelerate? 12-13 channels worth need ~12 more
 - Option 2) Many groups contribute, minimum, probably 3mm, around \$5500 (6mm is more expensive but similar)
 - Option 3) Many groups contribute, get more, probably 3mm, around \$8000- \$12K)
 - Option 4) Two groups contribute to get ~100 3mm's each 2 x 2980 = 6000

FEB Decision

- Status Carlos/HGCroc – should be ready by October beam test time
- Gerard not sure, but probably can't have everything ready: can other engineering help get more in time?
- Can generic Flash ADC tell us enough info anyway, work on getting that set up over summer?
 - Carlo's can provide board for this, but would want help developing the solution.
 - Work needs to be done by other group (ie in US probably)
- FUNDS FROM FERNANDO FOR FLASH ADC /other readout components if needed
- Jlab Flash ADC?s

Backup

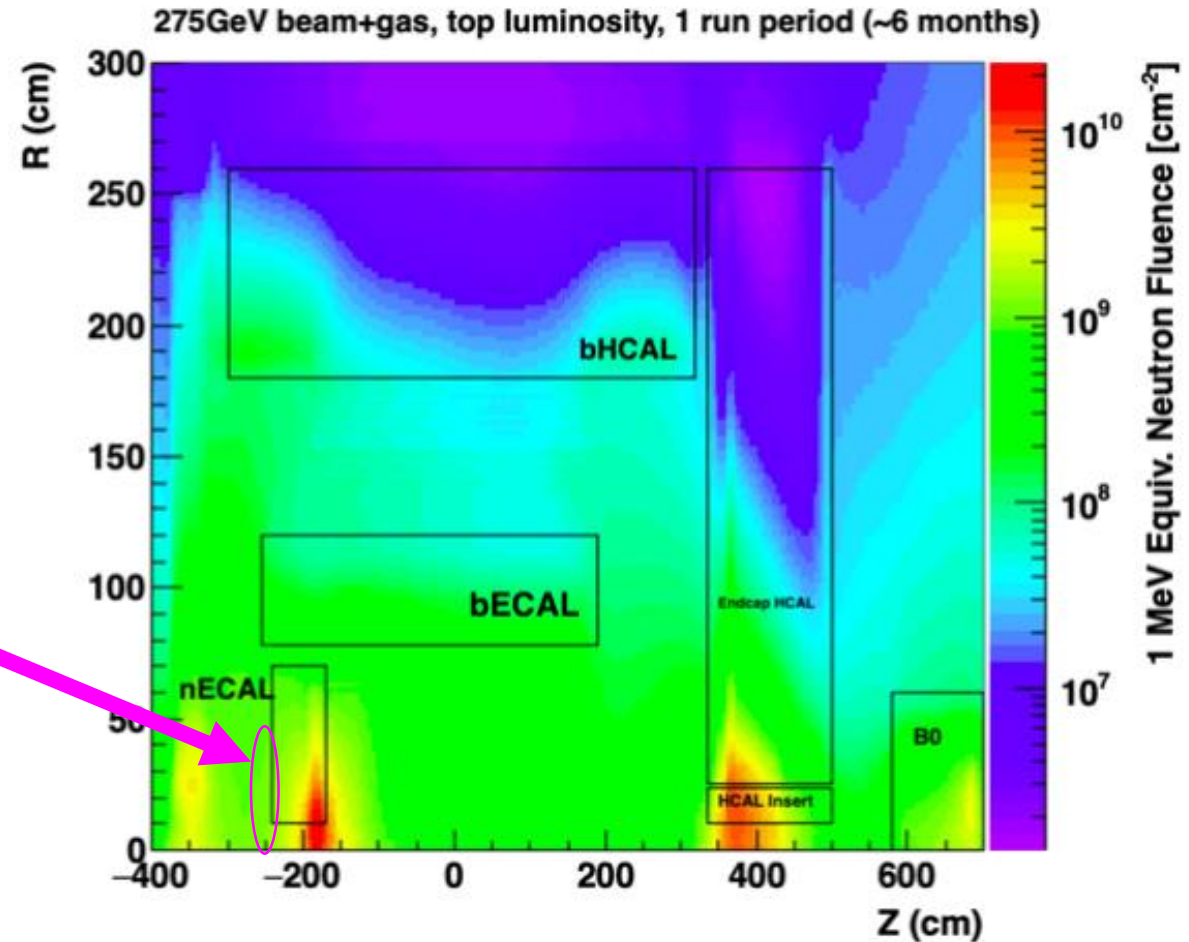
Backup

siPM's Irradiation Plan - Proposal

Beam Flux (cm ⁻² s ⁻¹)	Time (seconds)	Total Fluence (cm ⁻²)	MeV n equiv fluence	Number of SiPMs/board
1.00E+08	540	5.40E+10	8.10E+10	Whole board of 20-3015 sipms
1.00E+08	540	5.40E+10	8.10E+10	3 S14160-3010PS (3mm, 10um pitch)
1.00E+08	540	5.40E+10	8.10E+10	2 S14160-3015PS (3mm, 15um pitch)
1.00E+08	540	5.40E+10	8.10E+10	2 S14160-6015 (6mm, 15um pitch)
1.00E+07	540	5.40E+09	8.10E+09	3 S14160-3010PS (3mm, 10um pitch)
1.00E+07	540	5.40E+09	8.10E+09	2 S14160-3015PS (3mm, 15um pitch)
1.00E+07	540	5.40E+09	8.10E+09	2 S14160-6015 (6mm, 15um pitch)
1.00E+07	35	3.50E+08	5.25E+08	2 S14160-3010PS (3mm, 10um pitch)
1.00E+07	35	3.50E+08	5.25E+08	2 S14160-3015PS (3mm, 15um pitch)
1.00E+07	35	3.50E+08	5.25E+08	2 S14160-6015 (6mm, 15um pitch)
as carlos suggests if we can retest this last bunch, and then re-irradiate, then shoot for longer on these to make 4e ¹⁰ ?				

siPM's Irradiation Plan: Ingredients

- Also after carefully looking at [https://wiki.bnl.gov/EPIC/index.php?title=Radiation Doses](https://wiki.bnl.gov/EPIC/index.php?title=Radiation_Doses) Carlos and I arrived at 8×10^9 n/cm² for the inner most channels per standard year.
- 8×10^{10} for 10 years
- In first year, expect half design lumi : 4×10^9



siPM's Irradiation Plan: Ingredients

- First one point, UC Davis (Proton) Beam Energy 60 MeV
- Can provide in different fluxes (see next slide)
- Using this plot Gerard sent for conversion to MeV Equiv Neutron flux

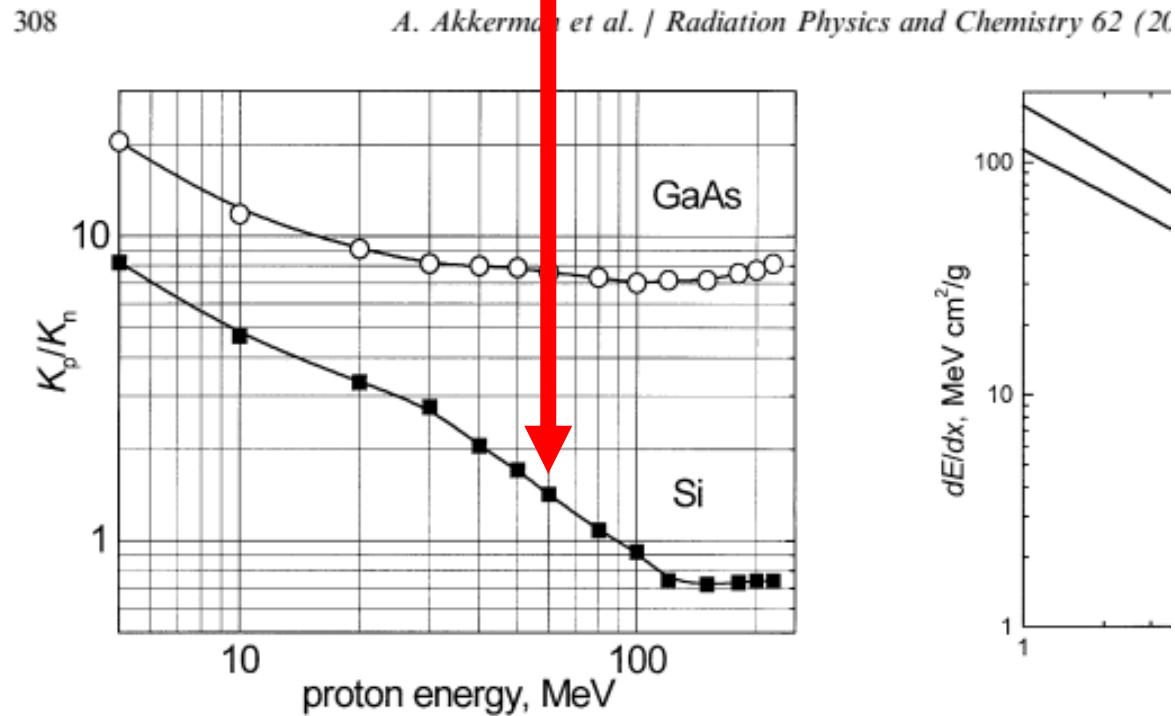


Fig. 6. The relative damage, K_p/K_n , as a function of proton energy where K_n is taken for 1 MeV neutrons.

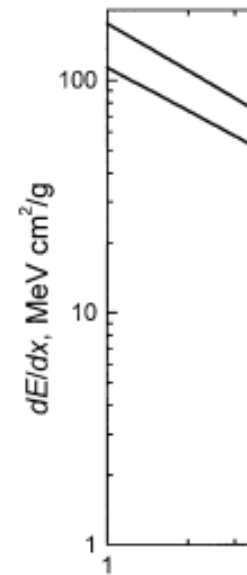


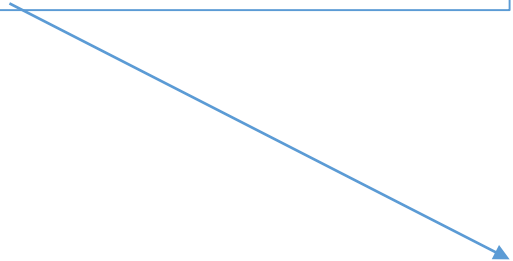
Fig. 7. The stopping power for GaAs as a function of proton energy (2000).

Assume 1.5 MeV/p as 60 MeV proton to MeV Neutron flux conversion factor

List of Needed Performance Parameters

- **Energy Resolution** (cluster) $2.5\%/\sqrt{E} + 1\%$
 - **Earlier 2023** $1\% + 2.5\%/\sqrt{E} [+ 1\%/E ?]$
- **Spatial resolution:** $1 + 3\%/\sqrt{E}$
- **Linearity** : correctable to 0.5%
- **Threshold (single tower)** : ~ 5 MeV [[Bazilevsky studies](#)]
- **Dynamic Range:** Tower level 2-5 MeV to ~ 15 GeV (x 7500-3000) (Cluster level -20-100 MeV – 20 GeV)
 - (assume $\geq 1-3$ ADCU per 5 MeV – which is threshold target.)
 - In pC : ~ 10 pC to 30-75 nC [?]- per channel : (min 10 pC from summer epic calo questionnaire document answer of “10-10000 pC”)
 - ADC : 14bit [?]
- **Rate Capability** : 20-100 kHz (highest [eta?] channels): Dominated by beam backgrounds, to be confirmed by further studies

This 20 is an old number?
YR: 50 MeV, later studies 100 MeV OK



List of Needed Performance Parameters

- **Waveform/timing:** All three of the below TBD
- *Timing resolution* : identify bunch crossing ~ 10 ns -- [can assume ≥ 2 tower measurements if needed $\rightarrow 14$ ns?]
- *Peak Time, N_samples* : $\geq 3-5$ in Peak + 2 pre-pedestal?
- *Sampling rate* : determined by above 40-80 MSPS
-
- **Noise Requirements** TBD by timing/resolution requirements: Pre-raddamage : DCR $\leq 3-10$ MHz Dark Current: ≤ 1.4 microAmps [Gerard's fEcal siPM presentation] Post-rad-damage

List of Needed Performance Parameters

- **Temperature/ Heating :**
- ***Temperature Sensitivity of siPM's*** - (Confirmation) tests of this would be good w/ w/o rad damage etc... look for opportunity
- ***Temperature Stability Requirement*** - tied to previous, later studies?
- ***Power consumption / Heating*** Pre-amp location [on adapter or preferably on IU adc board w/ 60 cm cable] - will be tested by Gerard IU.
 - TBTested with Dark current increase from Irradiation tests

• Adapter Boards

• **Designs:**

- Larry: Updated (finished?) designs for 4x4 6010 and 6010 independent readout[details on ind] [also 6015?] adapter boards]
- We currently don't have board designs for 3mmx3mm models? Can we again start with the 3x3 = 9 siPM boards (made for previous prototype testings)
- For sooner tests if siPM's delayed can we make a customized board for say four 3mm sipm - usefl?
- **Production of Testing Adapter Boards:**
- How much? Can Gerard/someone make cheap test boards?

- Gerard recent studies for fEcal w/ 6015 siPM's
 - Gerard presented study for fEcal Readout [last week at Calo mtg:](#)
 - Parts can be applied almost directly or done similarly for us to us?
 - LED testing for 4 6015 siPM's on test adapter board - different pre-amp expectation than for us?
 - Different dynamic range need (15 MeV threshold – 100 GeV) different light yield conversions
- Showed behavior of near threshold (for fEcal 15 MeV- ~20 pixel) and higher pulse and digitization characteristics
 - 13.5 pixel RMS 4.5 w/ simulated 100 μ A dark current rad damage RMS @ 13 is **18**
 - Timing resolution: assuming 14bit ADC digi-noise 39MSPS sampling need 5 ADCI pulses to achieve bunch crossing 10 ns resolution

Testing Proposals (who does them next)

- Repeat Gerard's last tests on all (other) siPM's models
Slide?)
 - mostly same stuff done , but for other siPM models (too much work?) x 3
 - Independent readout of 6015 board? + 1 or x2
 - do we need to better characterize the LED for PDE do we want cosmics/crystals?
 - Need calibrated comparison (e.g. PMT) setup – at least for cosmics?
- Not covered so far but to be added
 - same tests : sim rad damage → real rad damage – repeat same tests?
 - Timing resolution is a pure sim study, can be done by anyone – To be improved by real pulse shape [pulse shape can be adjusted by design of adapter board,etc.]

- # Who does testing?
- Gerard IU?
 - Backup: Ohio U?

Backup

https://wiki.jlab.org/cuawiki/index.php/OVERVIEW_OF_SPECIFICATIONS