Hit rates in forward EMC due to SiPM radiation damage
(a preliminary study)

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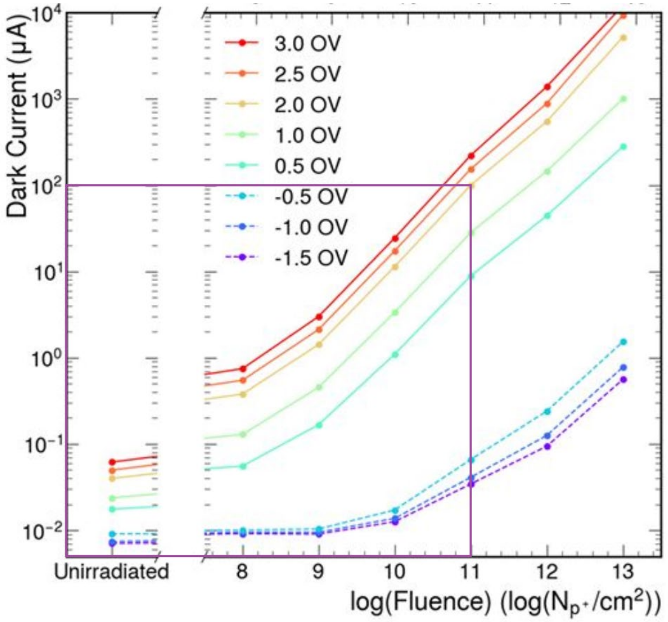
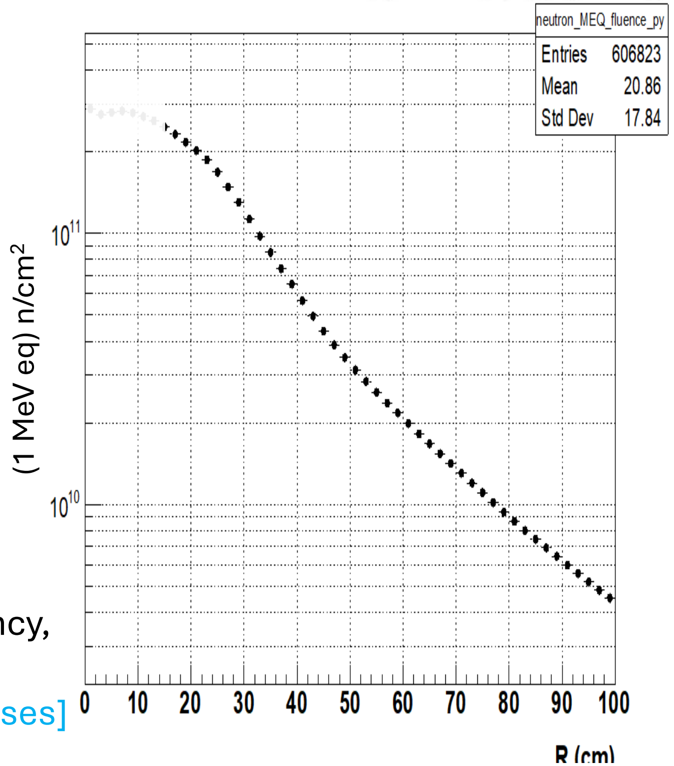
DCR estimation for FEMC

- assume (likely) overvoltage 2.0 V
- → gain 1.6E5 per datasheet
- From Miguel's presentation, dark current at V_{OV}=2.0 V **for 3×3 mm² SiPM** is **100 uA per 1E11 (64 MeV) p/cm²**
- **→ 3.9 GHz per 1E11 p/cm²**
- Adjust to 1 MeV eq. neutrons → **2.6 GHz per 1E11 n/cm²**
- That is for rapid damaging, allow for (RT) annealing (following Fig. 5.2 in Moll's thesis, see backup slide)
- → Factor of 0.33 for 3 years at RT relative to 1 hour. 3 years is *my WAG* of a timescale on which to get "a large portion" of total damage, 1 hour is *my WAG* of timescale relevant to the SiPM irradiation tests at UC Davis and the analysis of that.
  - **→ 0.86 GHz per 1E11 n/cm²**
- Adjust for area (4× 6×6 mm²) → **14 GHz per 1E11 n/cm²**
- Projected fluence (for 100 fb^{-1}) is **1E11 for R>32 cm, up to 2E11 innermost**
  - Side remark: 28 GHz is 720 μA, ~29 mW

I think, >>100 uA points in the I-V curves would need temperature compensation to be accurate. Was not done?



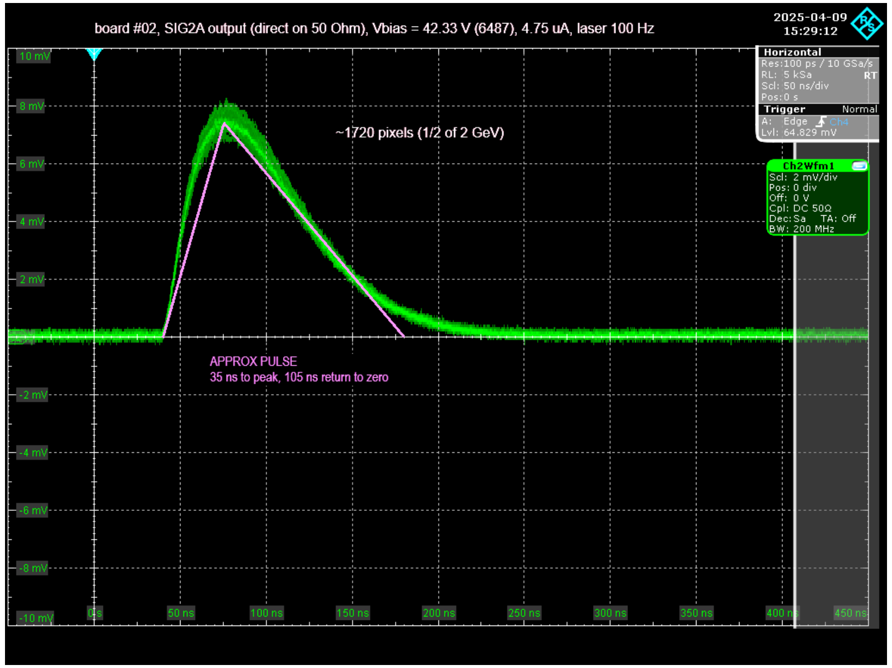


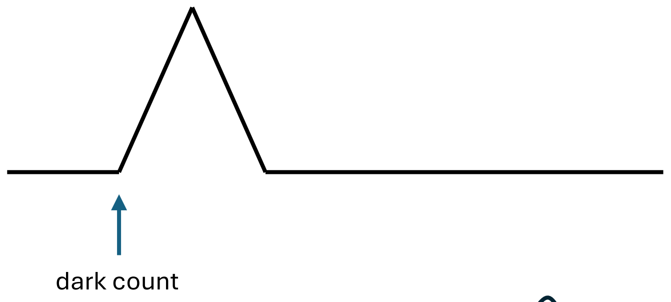
Integrated neutron fluence ePIC 10x275 top luminosity, 6 month running at 100 % efficiency, SiPM located at Z =3408 from IP

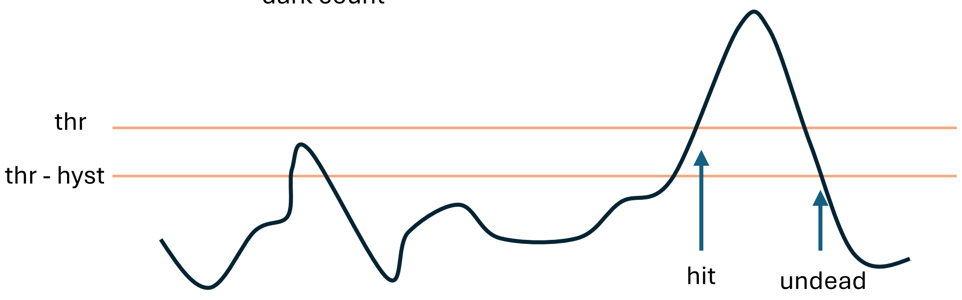
O.T. [Lifetime fluence for design purposes]

A simple simulation for “hits” detected due to dark counts (for “discrete” readout)

- Generate dark counts at a given Poisson rate
- Make a “waveform” pulse starting at each dark count time
  - For now, a simple-minded triangular pulse, with 80 ns peaking time (somewhat realistic)
- Sum all those pulses
- Sample at 98.5 MHz / 2 (the planned ADC sample rate)
- ~~Digitize to 14-bit~~ (NOT IMPLEMENTED YET)
- Discriminate when there is a hit or not
  - “Plan A”: Single waveform sample > threshold
  - Require single waveform sample < threshold-hysteresis to re-arm for next hit
  - Channel is dead when hit until re-armed
- (A range of waveform points is then read and processed around each discriminated hit, but that isn’t important at the moment and isn’t simulated.)
  - However, readout/processing imposes a limit ~50 kHz on the hit rate we can allow. (Can be improved a little, probably, but this is current specification.)

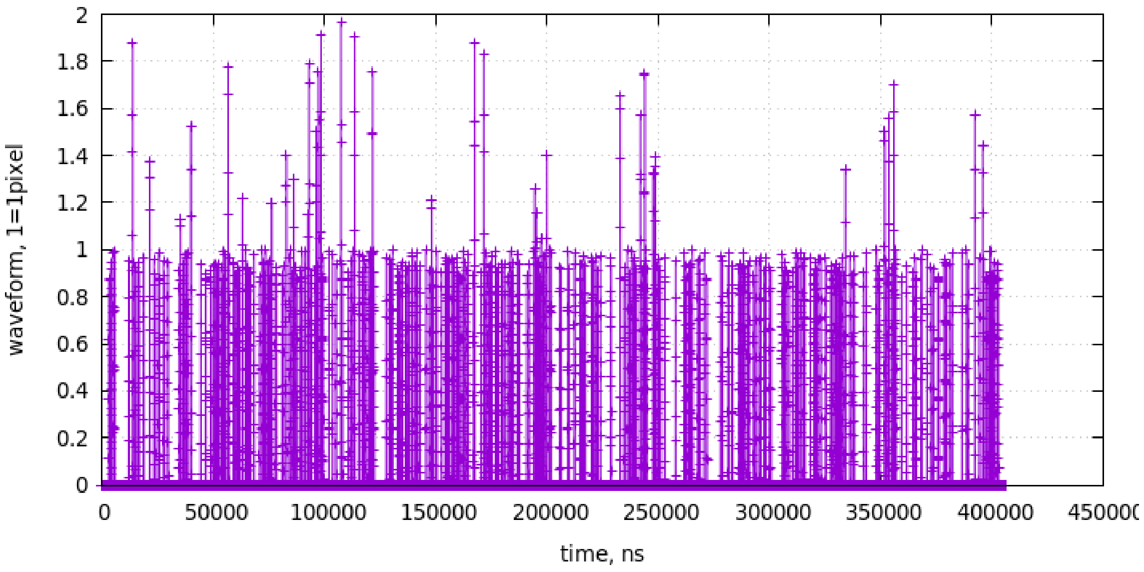


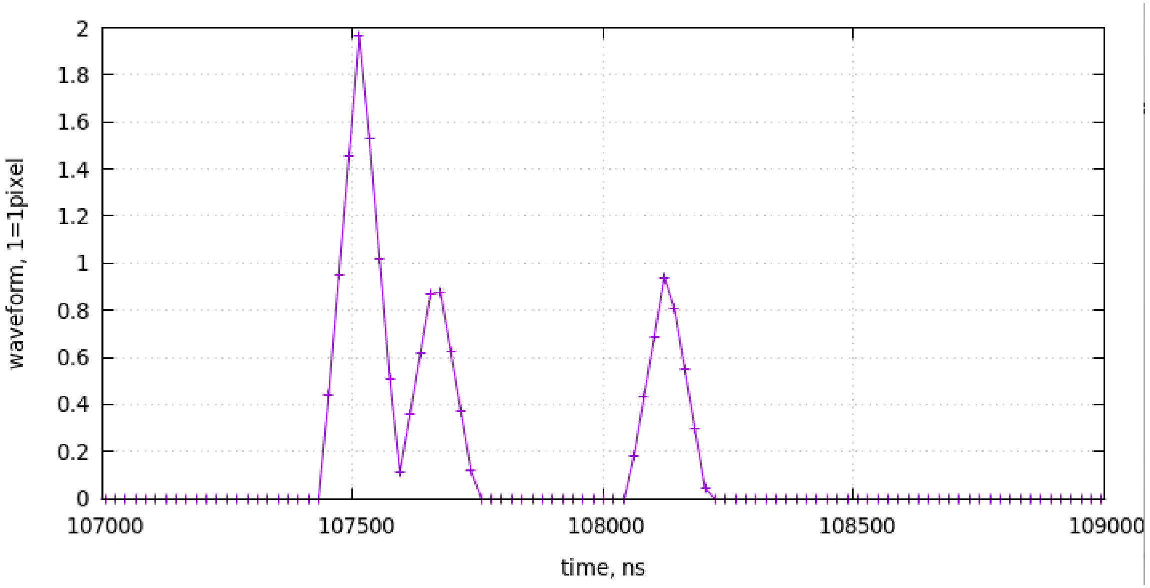




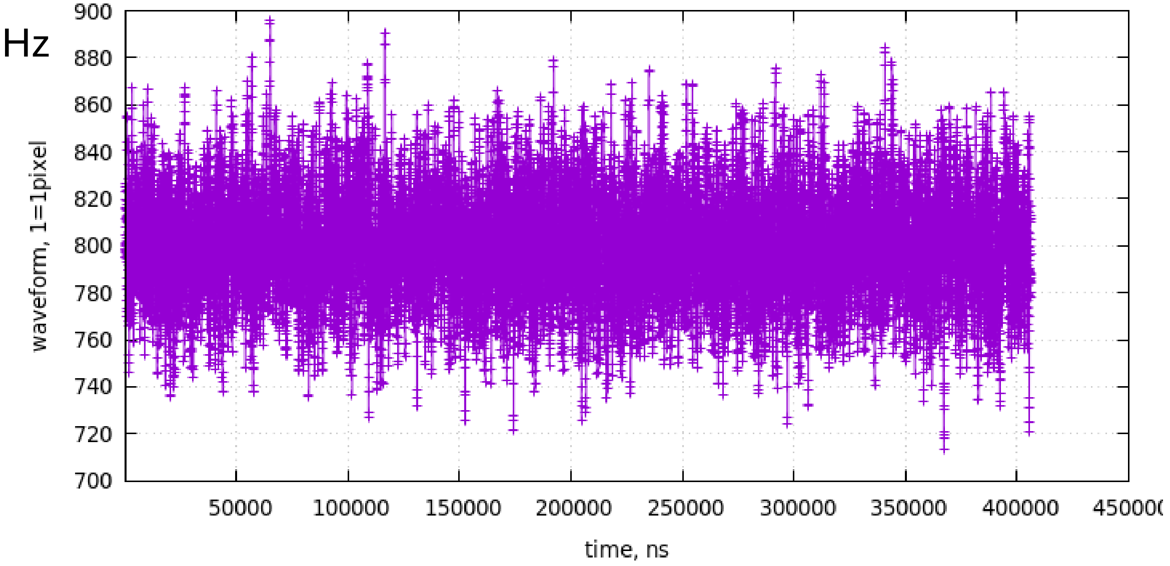
Waveform examples

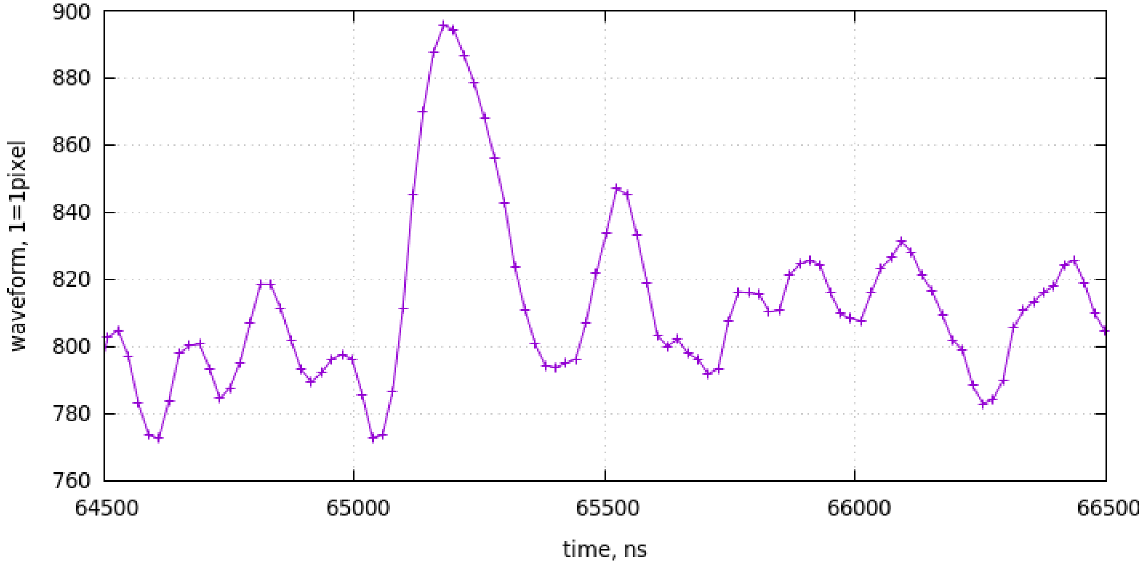
DCR=1MHz





DCR=10GHz





Results – hit rates and deadtime

triangular pulse model, peaking time 80 ns

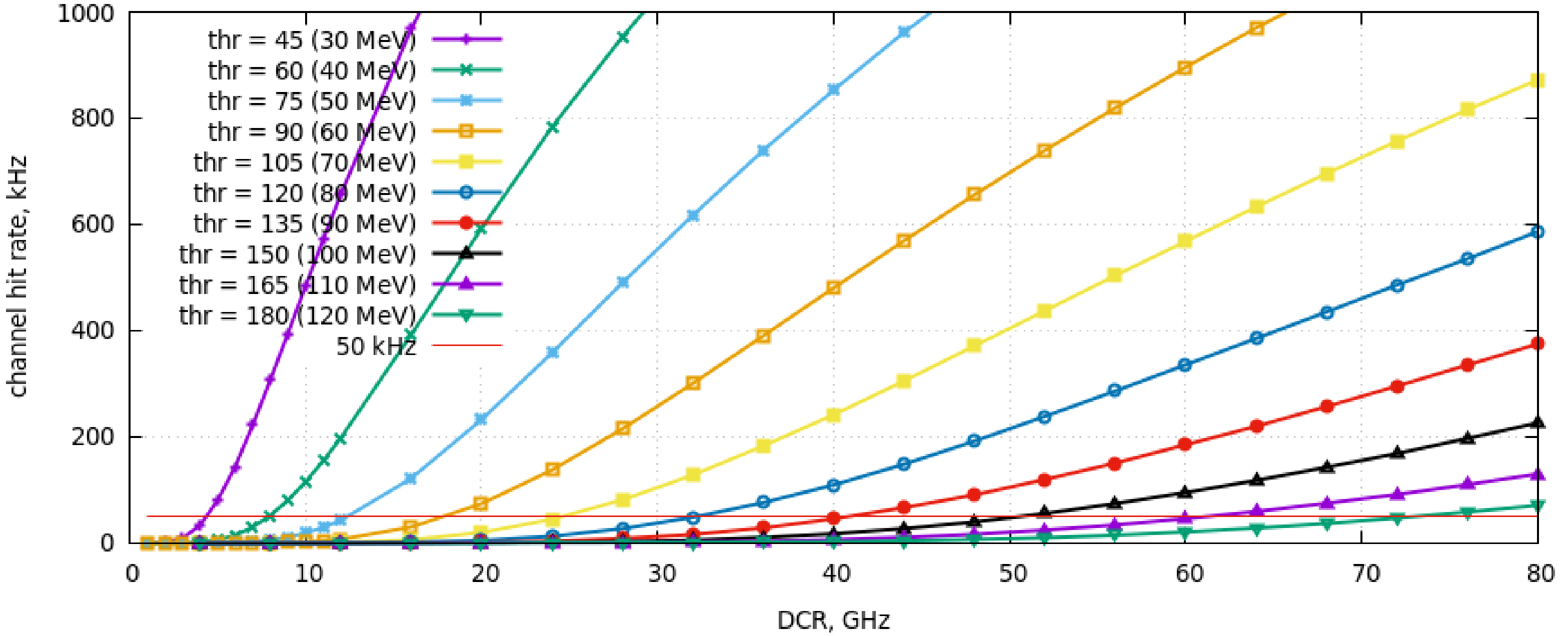
various thresholds, w/ hysteresis=5 (pixels)

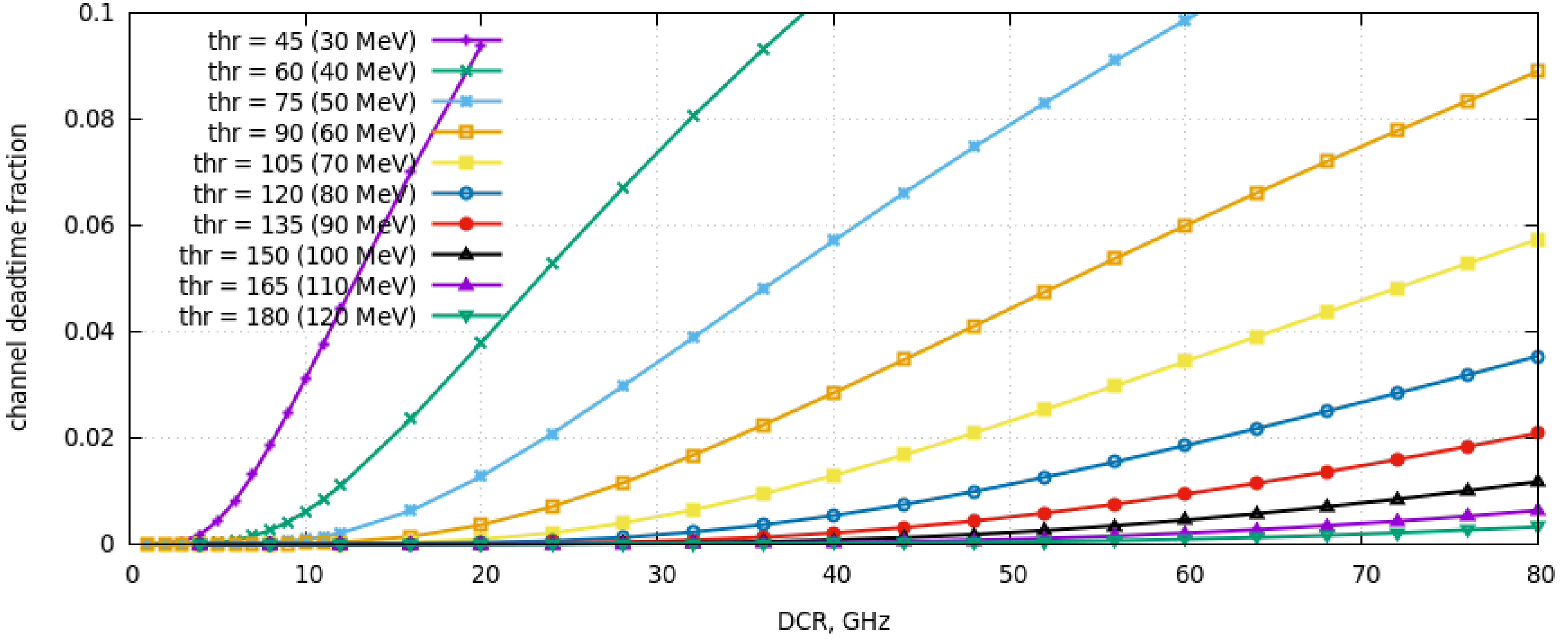
ADC sampling rate 98.5 MHz / 2

NO DIGITIZATION, just sampling

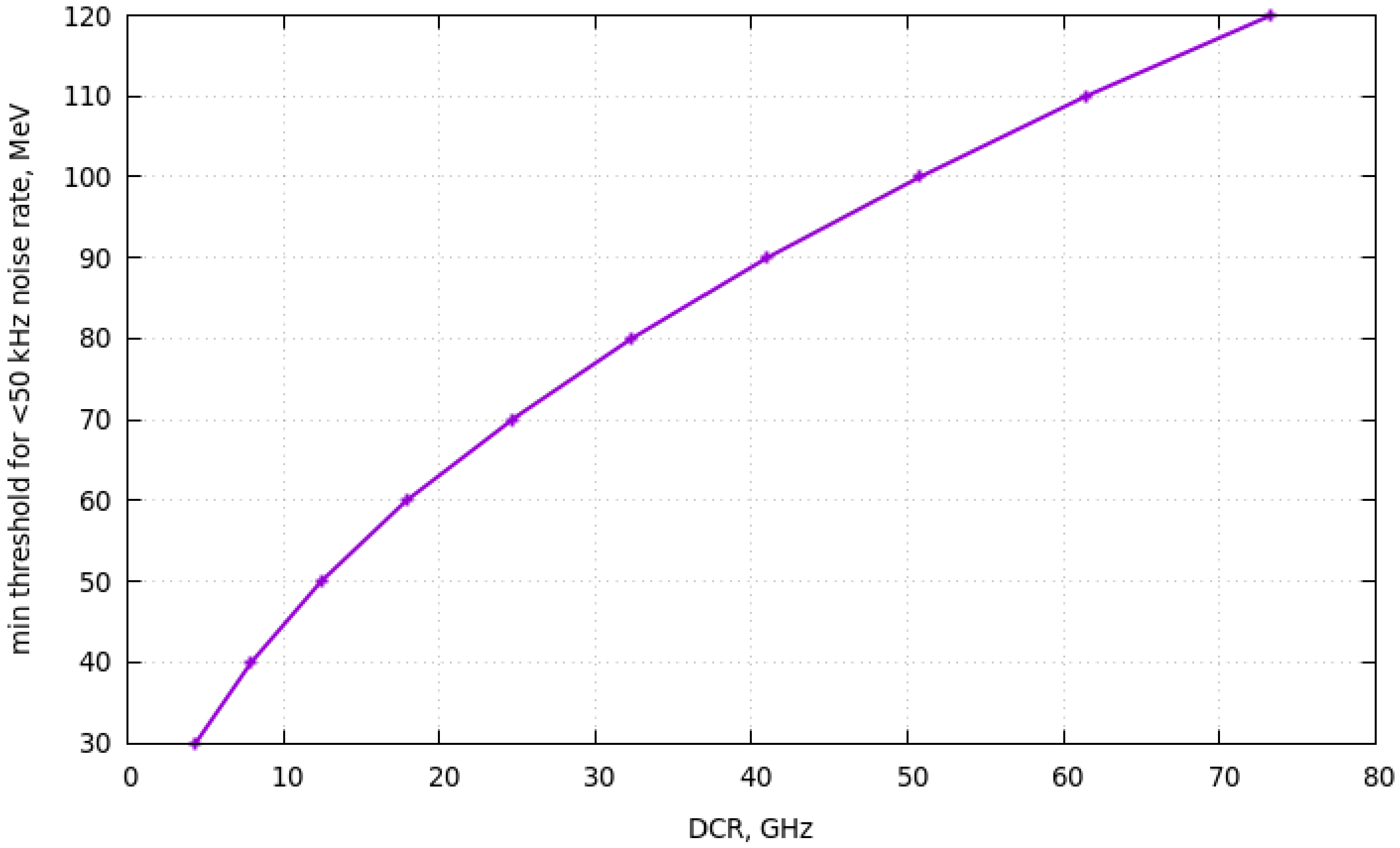
0.15 s simulation time

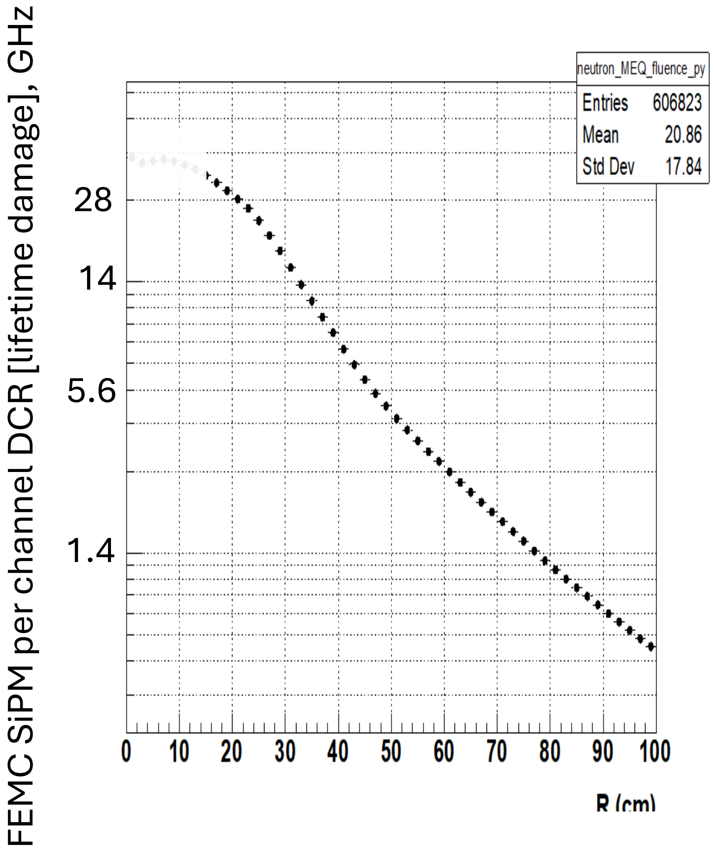
Assumed FEMC LY 1.5 pix/MeV (just to convert thresholds to MeV)





Required threshold vs. DCR
(Linearly interpolated from data set plotted on previous page)





Conclusions

- Projected threshold for 50 kHz noise hit rates
  - 30 MeV ok for R> ~48 cm
  - 40 MeV at ~42 cm
  - Up to a peak about 75 MeV at innermost towers
- Channel deadtime <1% whenever hit rate < ~200 kHz

To-do

- More realistic pulse shape – should only make a slight impact
- Digitization – probably no impact really
- Extract fit for allowable threshold as a function of DCR
  - → feed in to data rate simulation for whole detector
- How much of hit rate budget needed for real hits, needs study

Remarks on hardware rate limits

- On latest estimations the full raw data format should work up to 65 kHz
- With feature extraction on FEB, we might be able to work up to 190 kHz

BACKUP – annealing factor

Radiation Damage in Silicon Particle Detectors

– microscopic defects and macroscopic properties –

Dissertation
zur Erlangung des Doktorgrades
des Fachbereichs Physik
der Universität Hamburg

I assume that the UCR analysis results in dark current for irradiation on a time scale of roughly 1 hour, not in dark current for instantaneous irradiation.

Then the annealing factor we want to apply is that from 1 hour to, say, 3 years (arguably).

Drops from 7.5 to 2.5 ($\times 10^{-17}$ A/cm) on the plot here

→ SiPM DCR will similarly drop by factor of 0.33

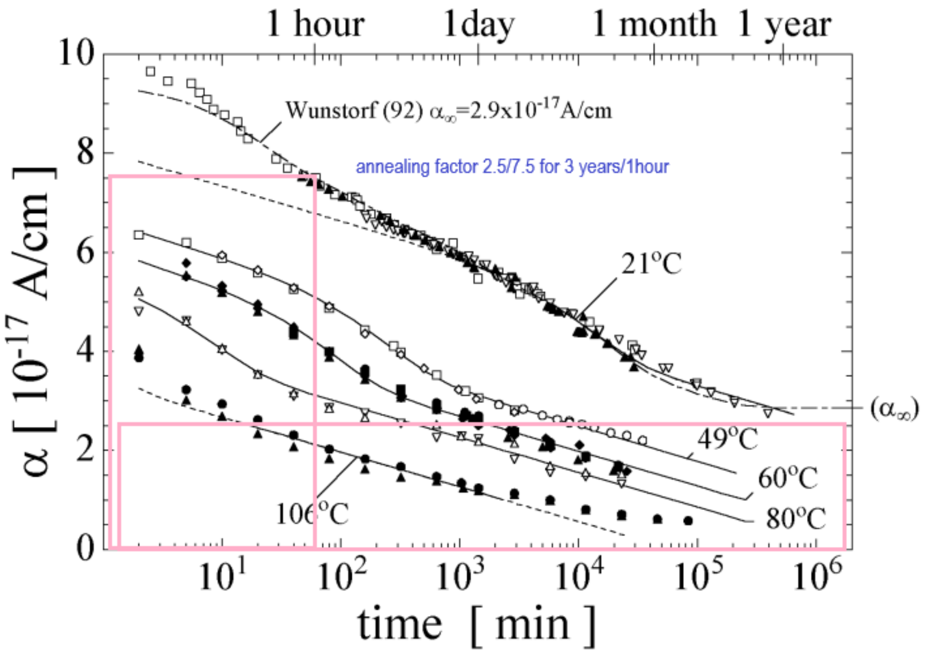


Figure 5.2: Current related damage rate α as function of cumulated annealing time at different temperatures. For each temperature at least one type inverted and one not type inverted sample has been used. The dashed–dotted line represents a simulation according to Eq. 5.3 with parameters as given in Tab. 5.1 and α_∞ as displayed in the figure. The solid lines