Quick Report on Silicon G-APDs (a.k.a. Si-PM) studies

XIV SuperB General Meeting
LNF - Frascati

Report of the work done in Padova

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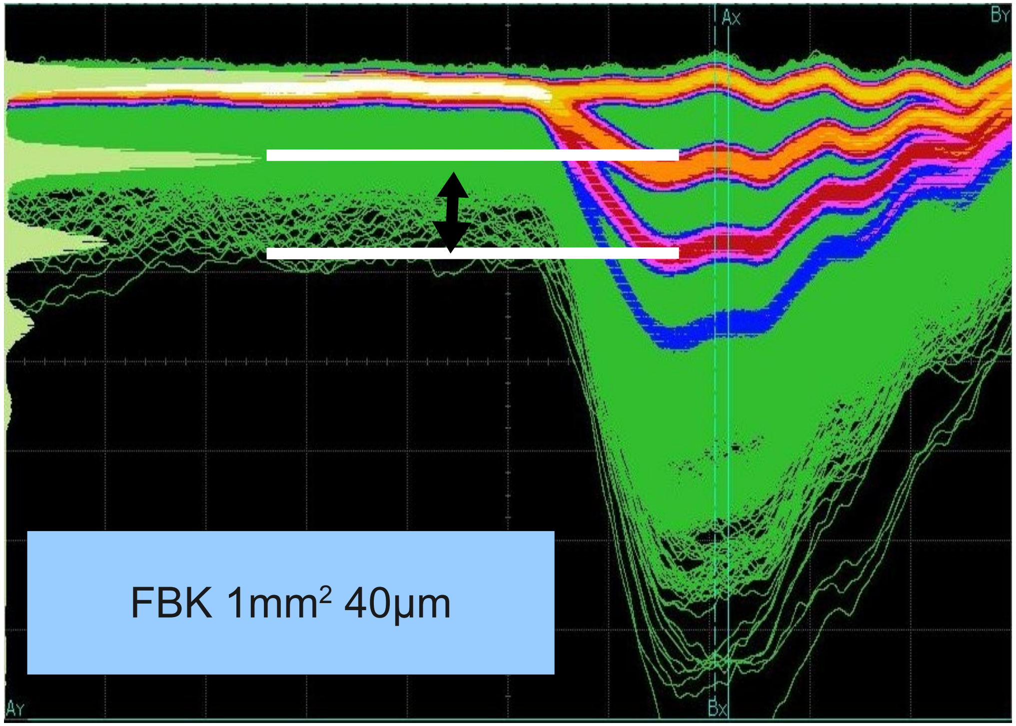
SuperB

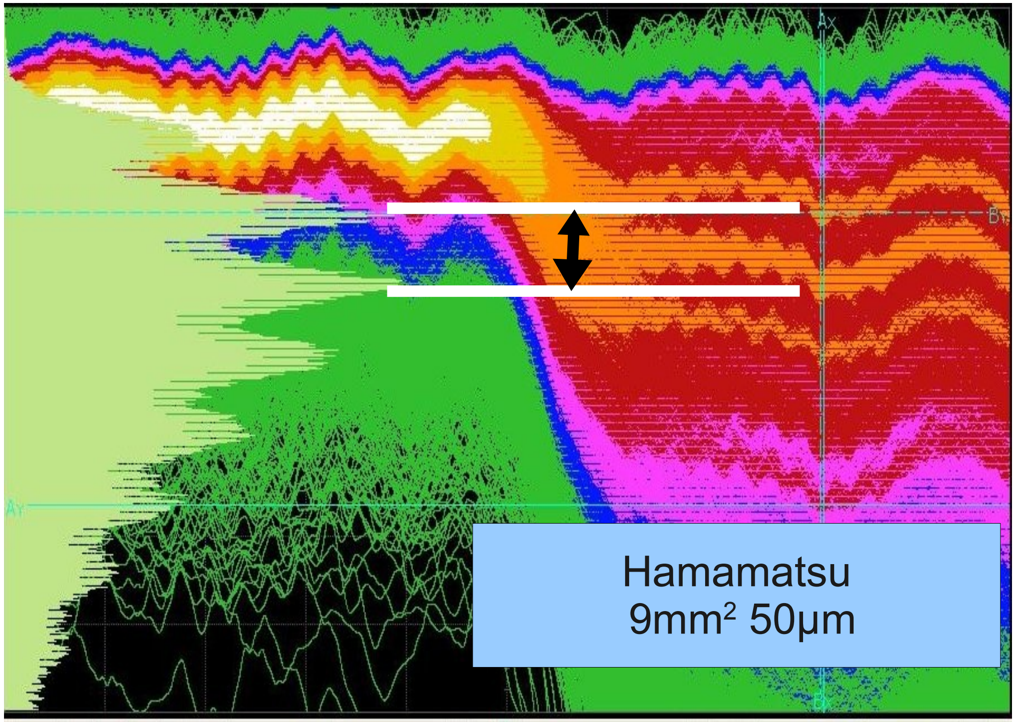
University & INFN Padova

Outline

- Studies on-going on different Silicon G-APDs
  - FBK (Irst), Hamamatsu, 1 mm^2 to 9 mm^2
  - Measuring the gain
- Radiation Tests @ LNL (INFN Legnaro National Labs)
  - Different energy, fluence and G-APDs
  - Preliminary Comparison
- Low Cost Power supply
  - Stability

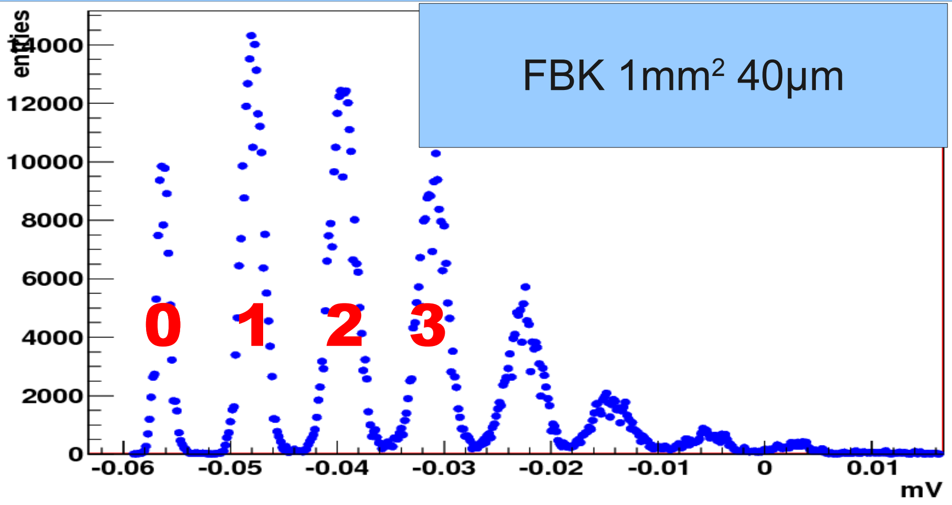
Measuring the gain





Measuring the distance between two photoelectrons peaks, but ...

Fitting the spectrum



FBK 1mm² 40μm

Gauss

Poisson

$$\sum_n \mathcal{G}(x; n\delta, \sigma_{tot}) \sum_{k=0}^{2k<n} \mathcal{P}(n-k, n)\mathcal{B}(k, n-k) \cdot k!$$

CrossTalk:
Binomial Probability

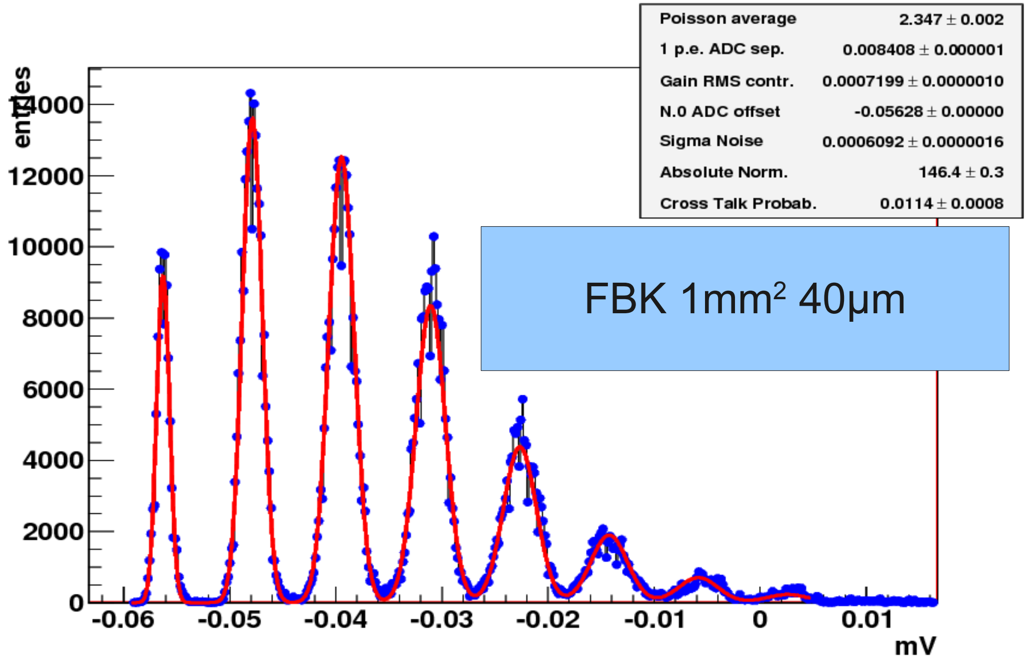
$x \rightarrow$ pulse height

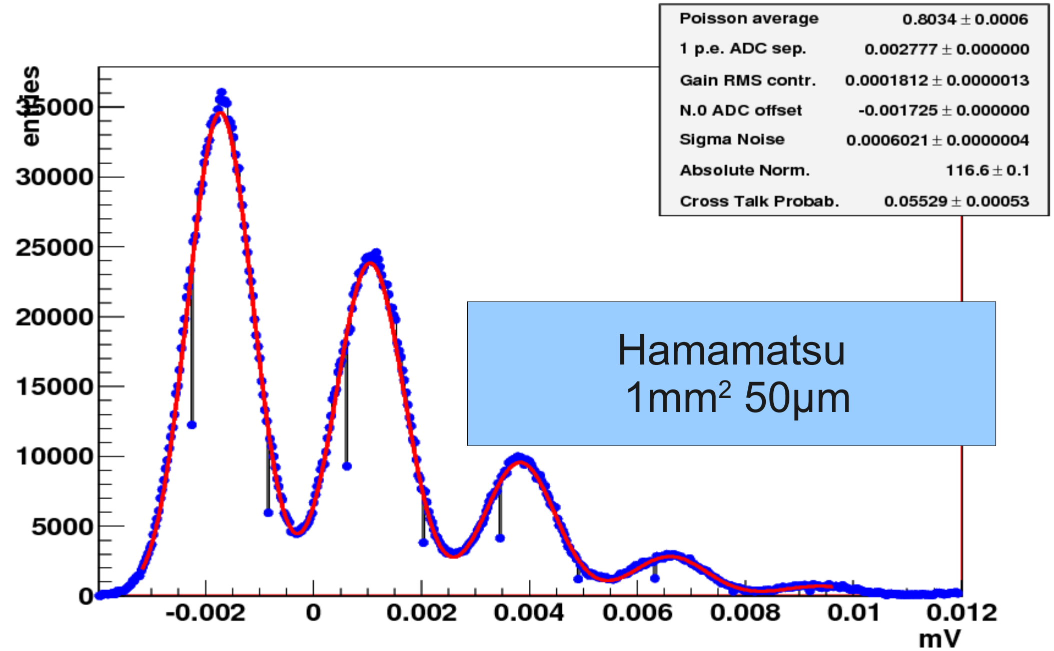
$n \rightarrow$ number of photons

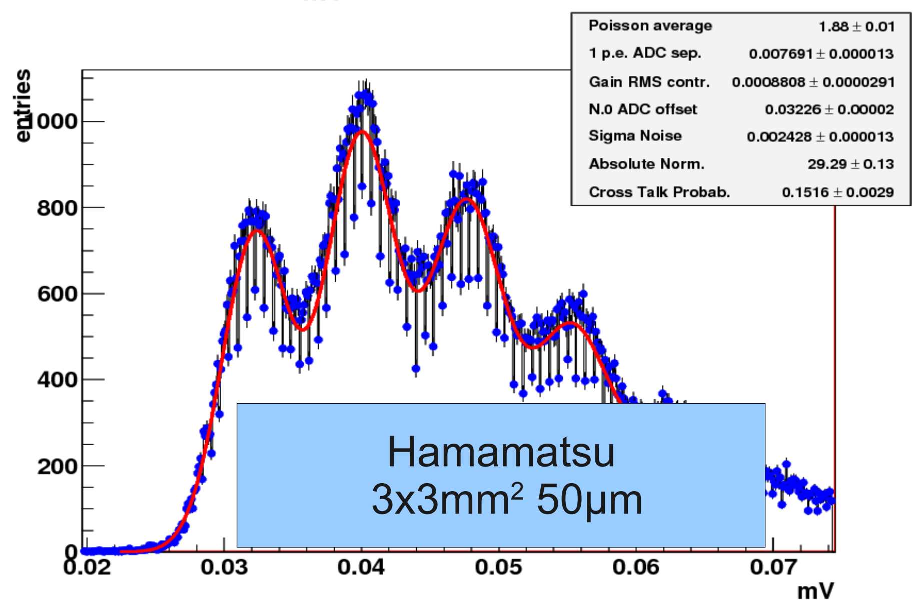
$\delta \rightarrow$ p.e. peak distance

$\sigma_{tot} \rightarrow$ electric noise and signal fluctuation

Fit Results







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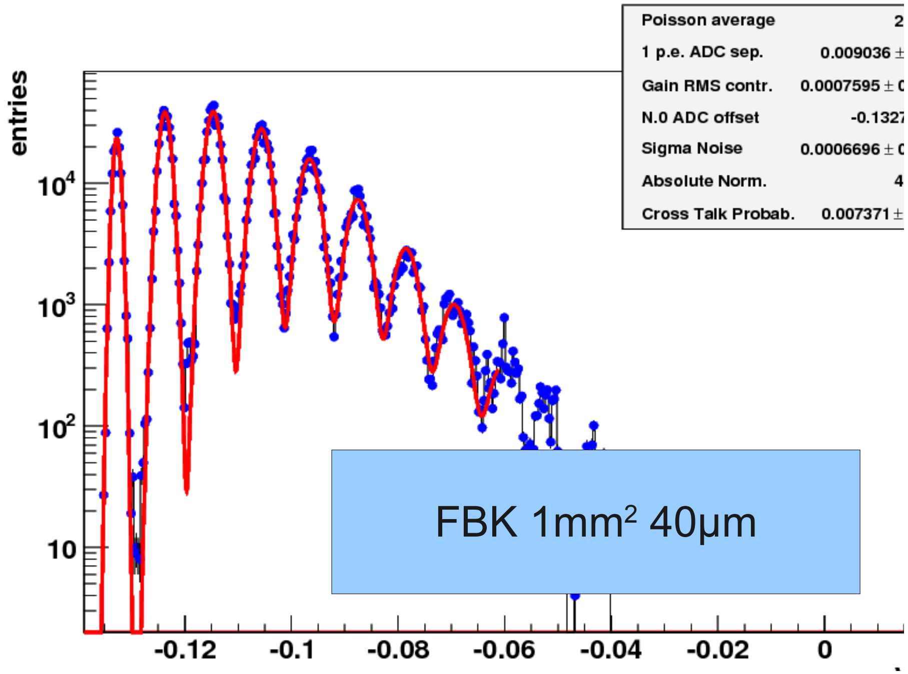
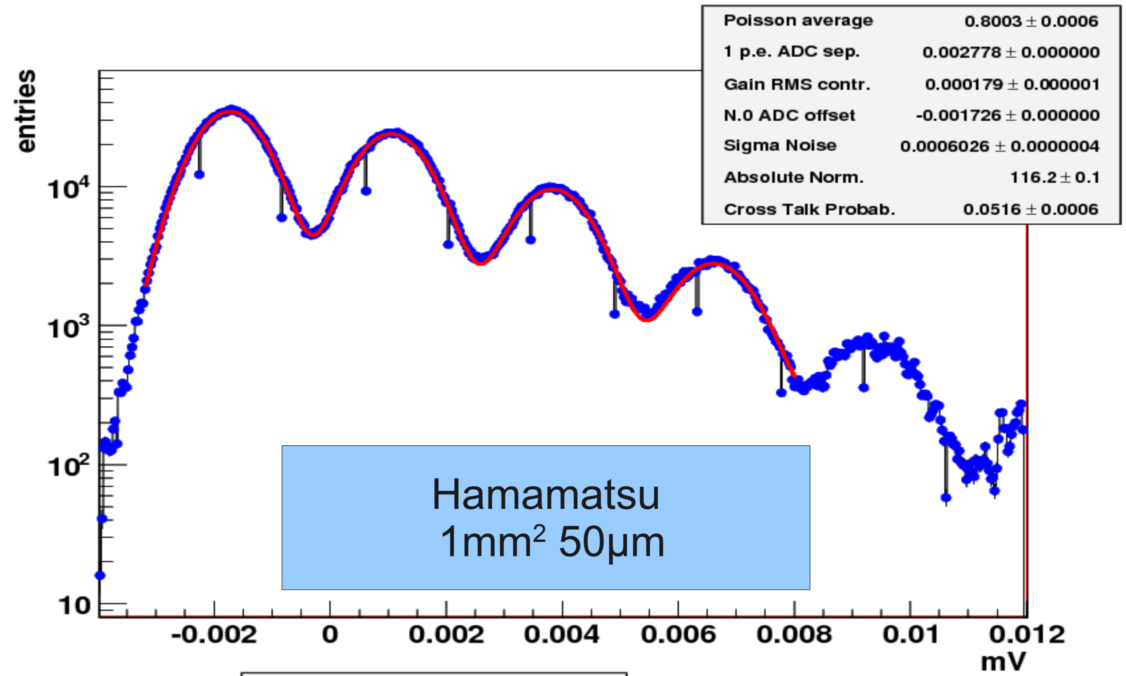
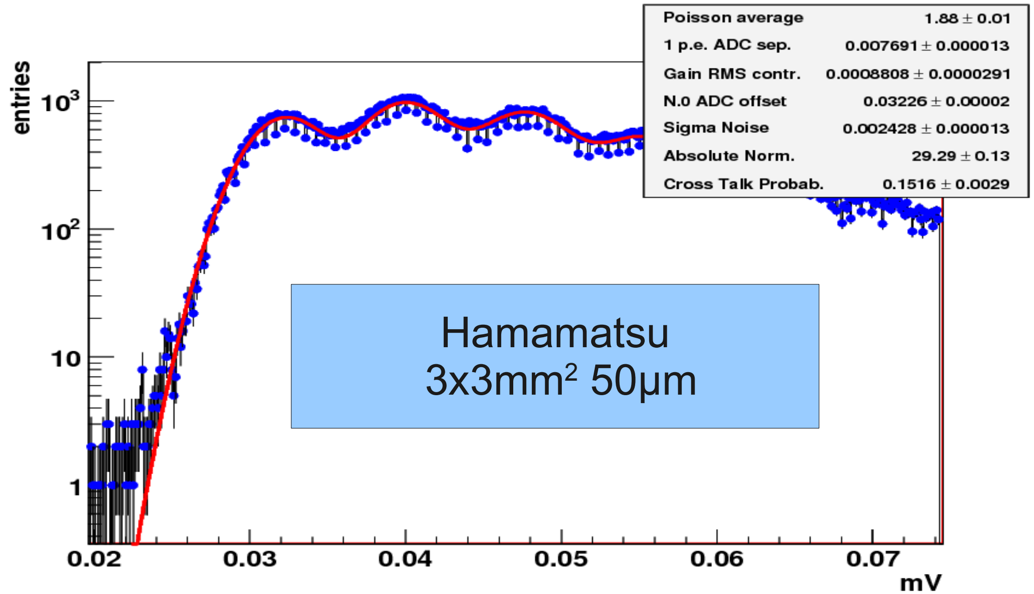
Fit Results: No AfterPulsing





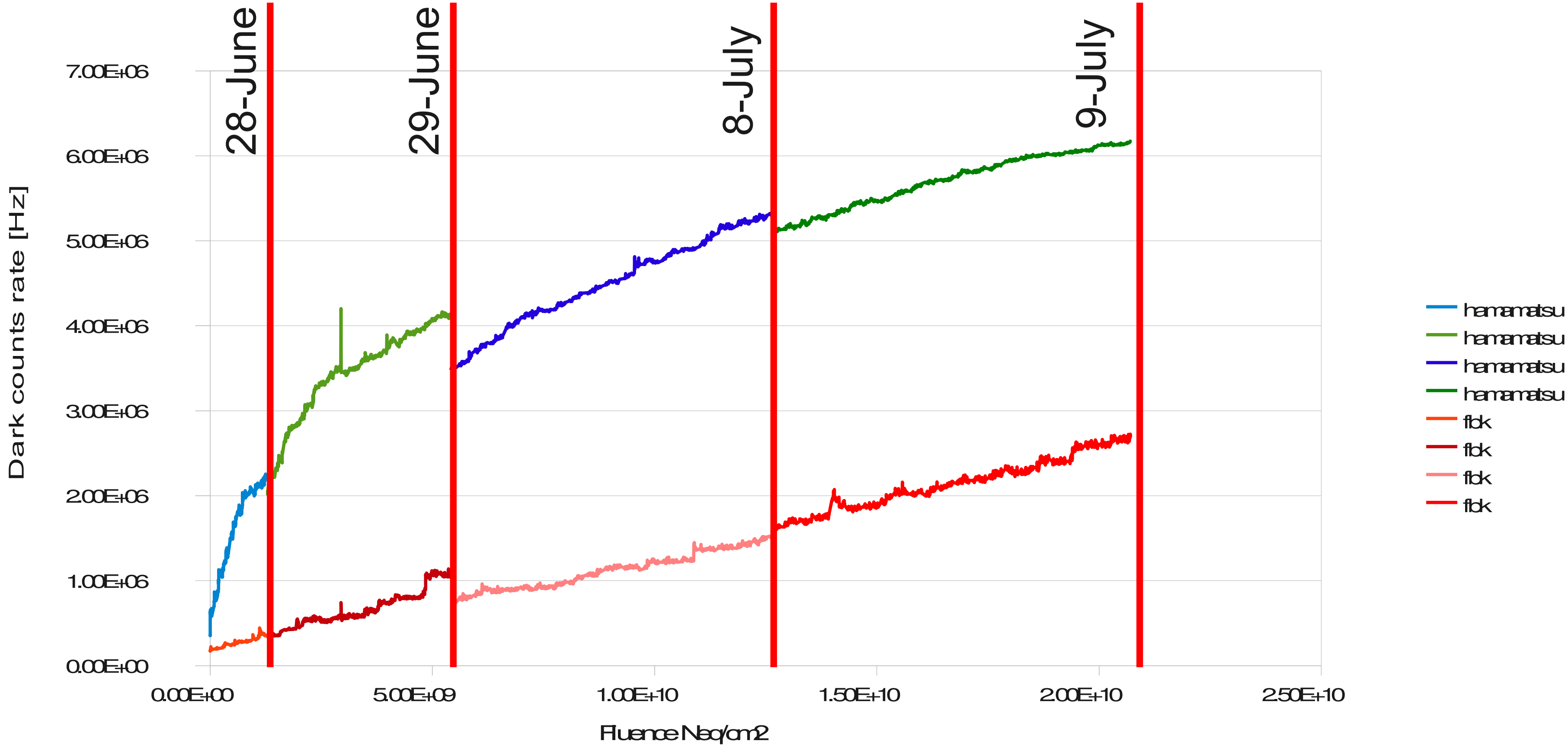


Neutrons irradiation tests @ LNL

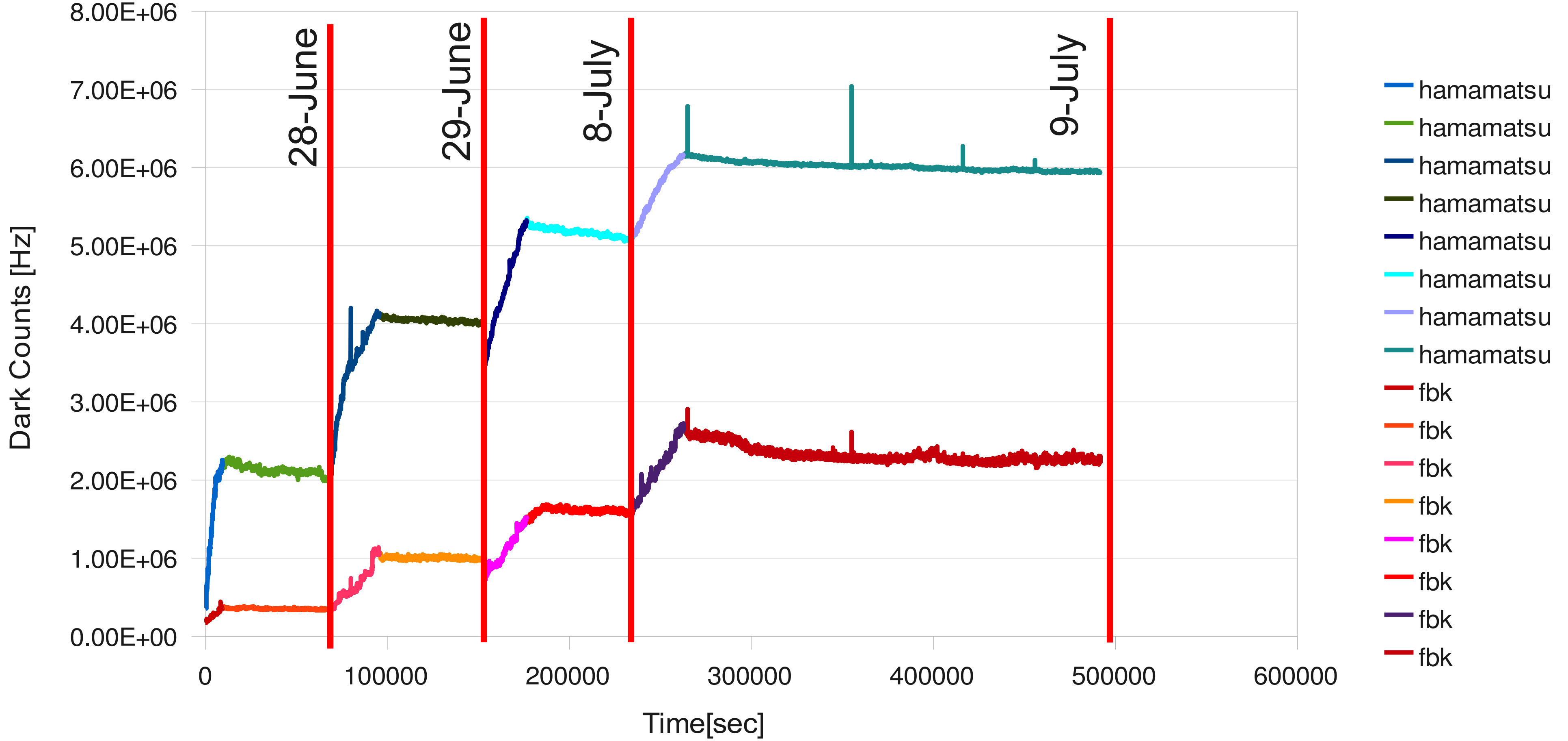
- Device irradiated during tests in June and July:
  - 2 G-APD (1 mm^2 - 50 μm pixel size – from Hamamatsu)
  - 1 G-APD (1 mm^2 - 40 μm pixel size – from FBK)
  - 1 G-APD (2x2 mm^2 - 50 μm pixel size – from FBK) .
- Deuteron beam over beryllium thick-target: $^{9}Be(d,n)^{10}B$
- E_d: 4 MeV
- Beam current: ~ 40 nA
- Temperature 20ºC
- 2 different sets of measurements
  - 28,29-June and 8,9 July 1 Hamamatsu & 1 FBK both 1 mm^2
  - 23 and 26 July 1 Hamamatsu 1mm^2 & 1 FBK 4mm^2

Neutron Fluence First set

- Reached Fluence of N_{1MeV} eq ~ $2x10^{10}$:

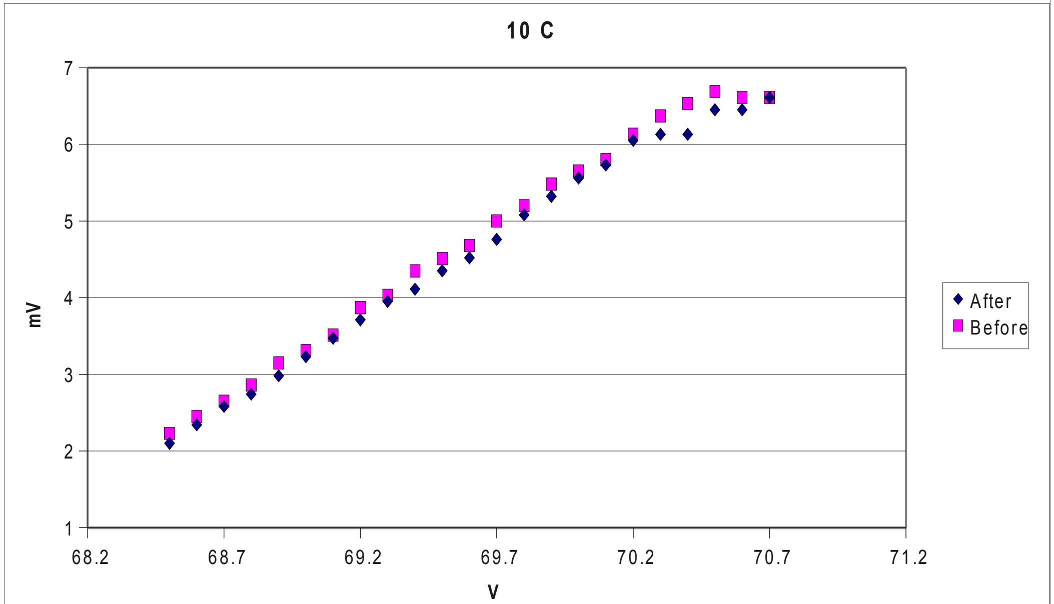


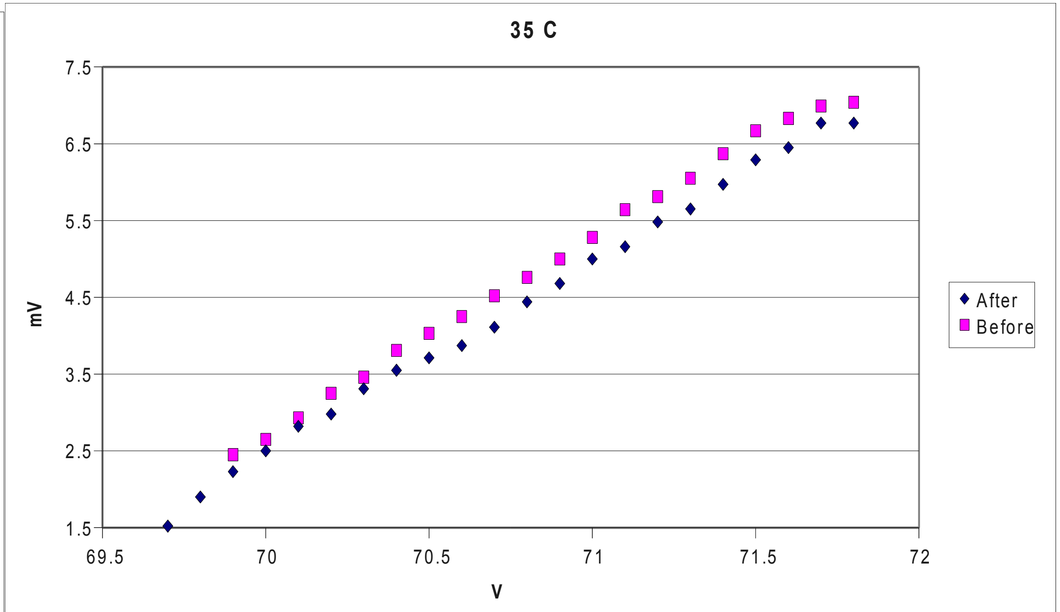
First sets: Dark Counts Rate vs Time

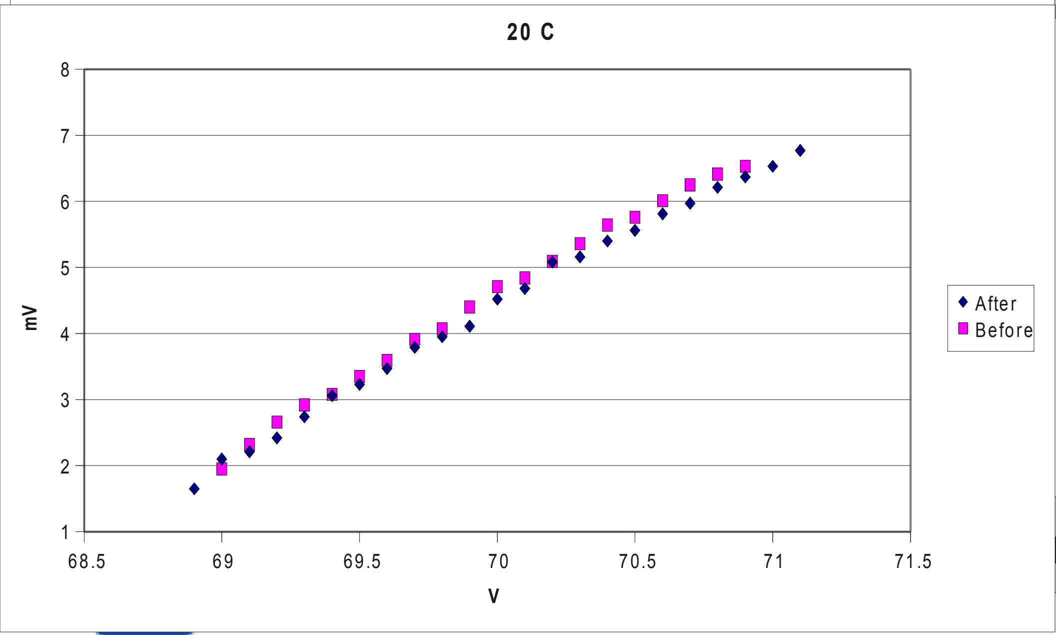


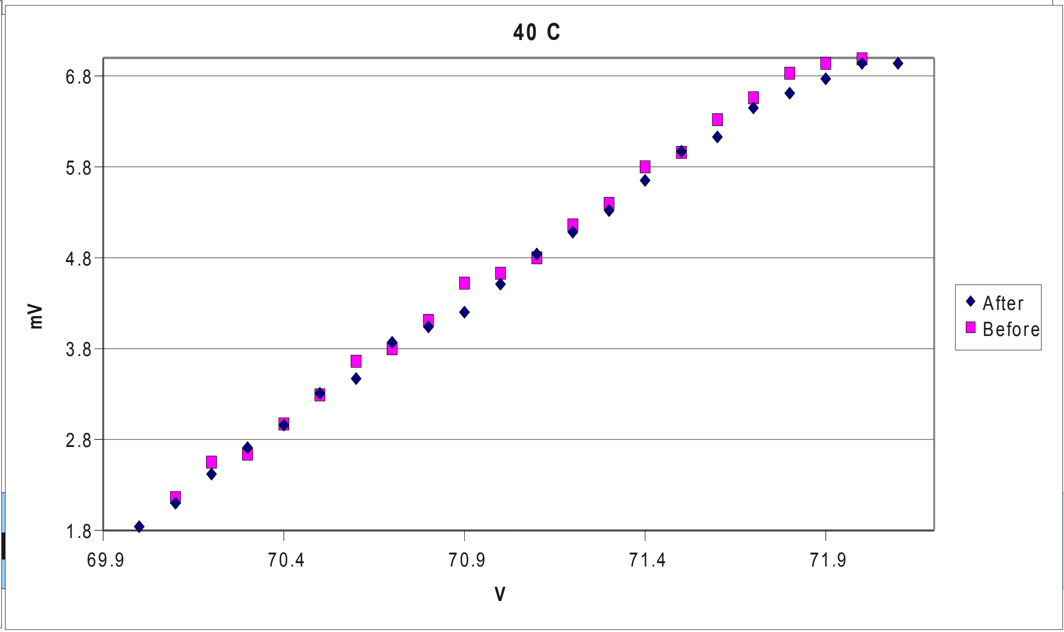
First Set Comparison: Before/After

- Gain, Hamamatsu Before and After the Irradiation for different temp.

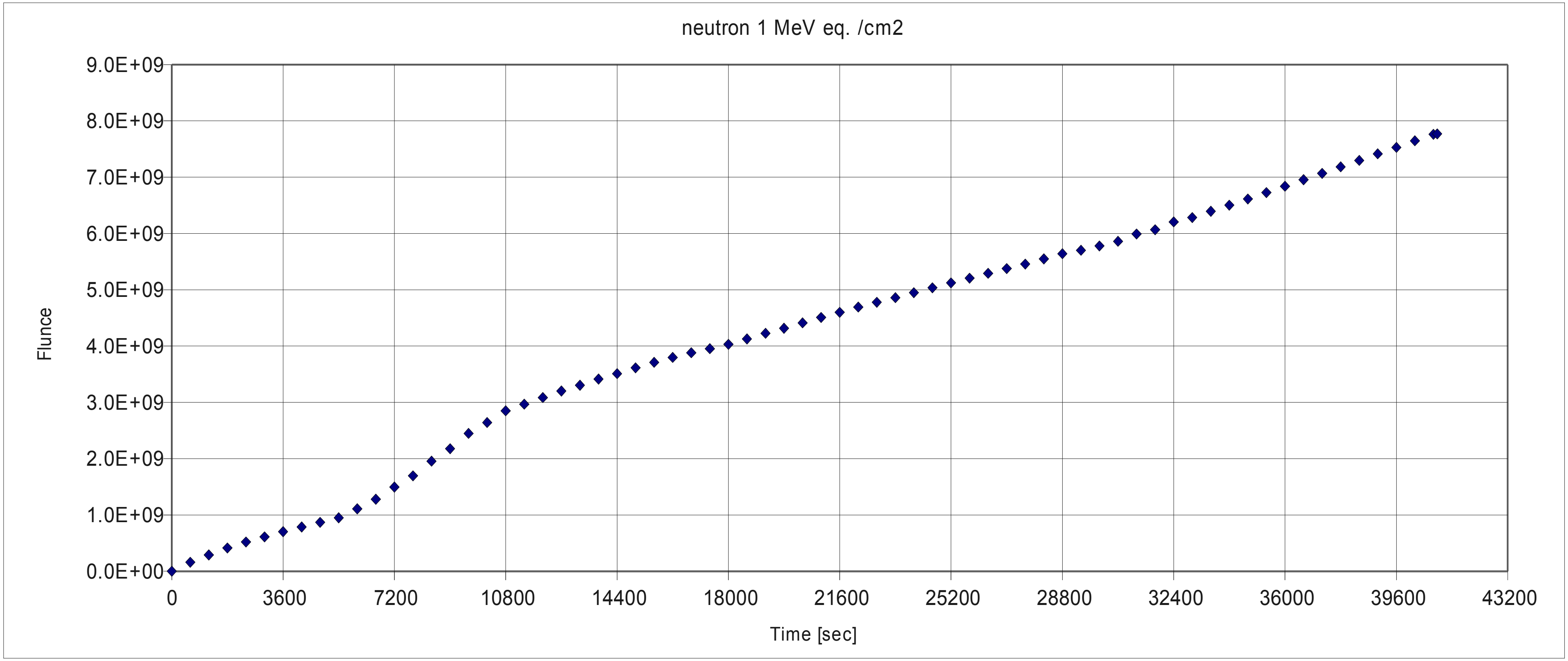




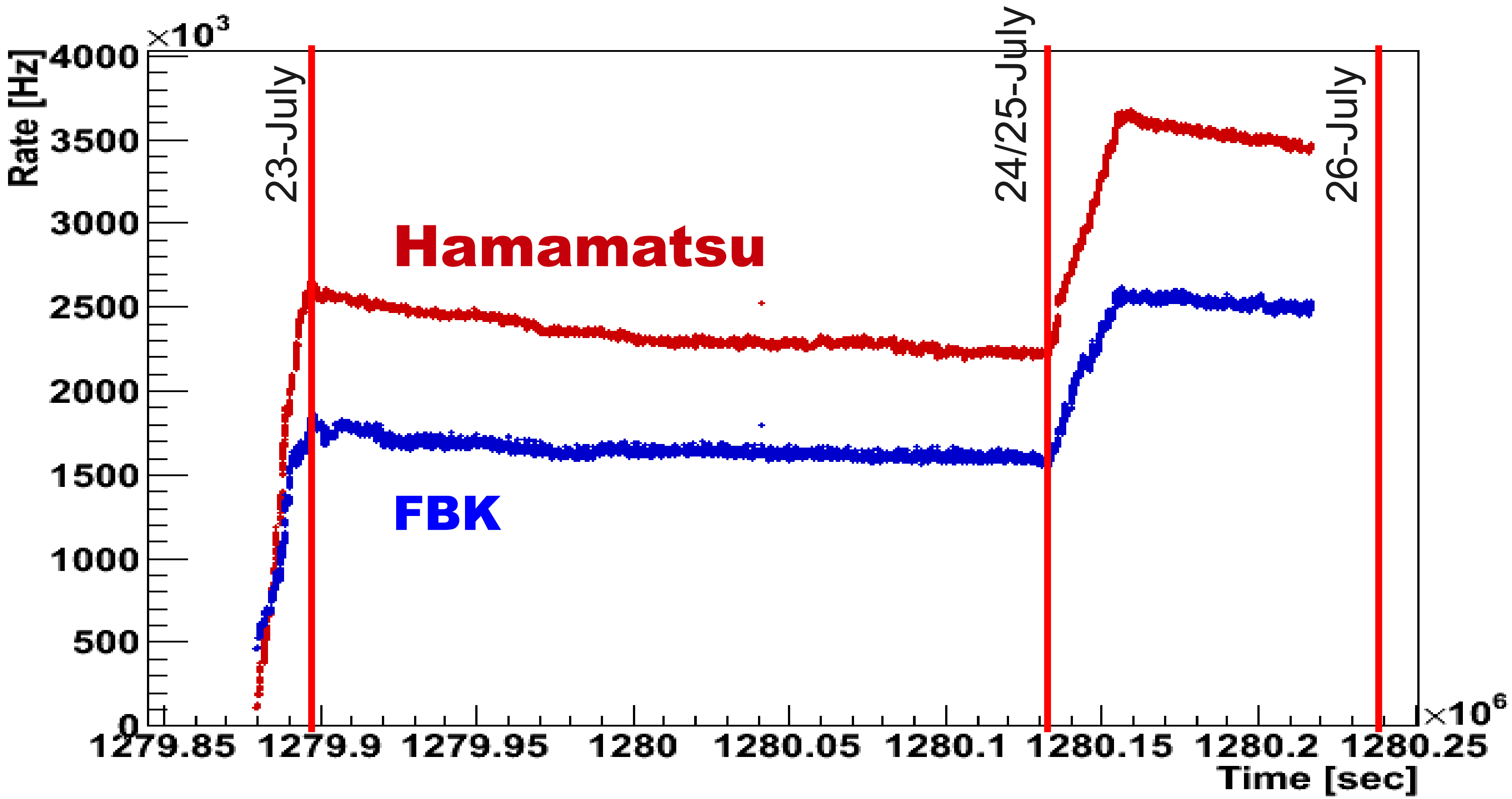




Neutron Fluence Second set

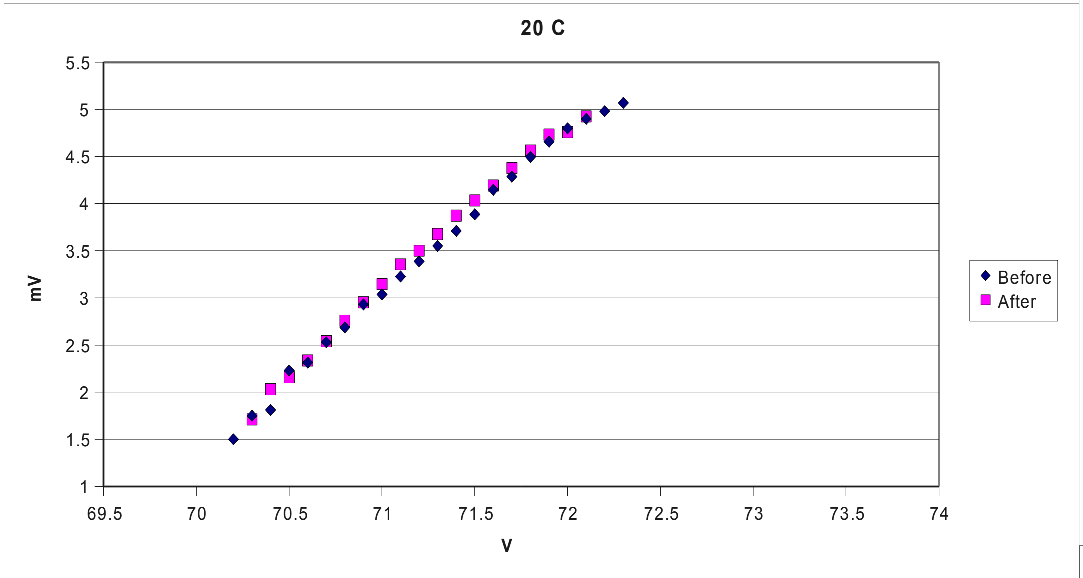


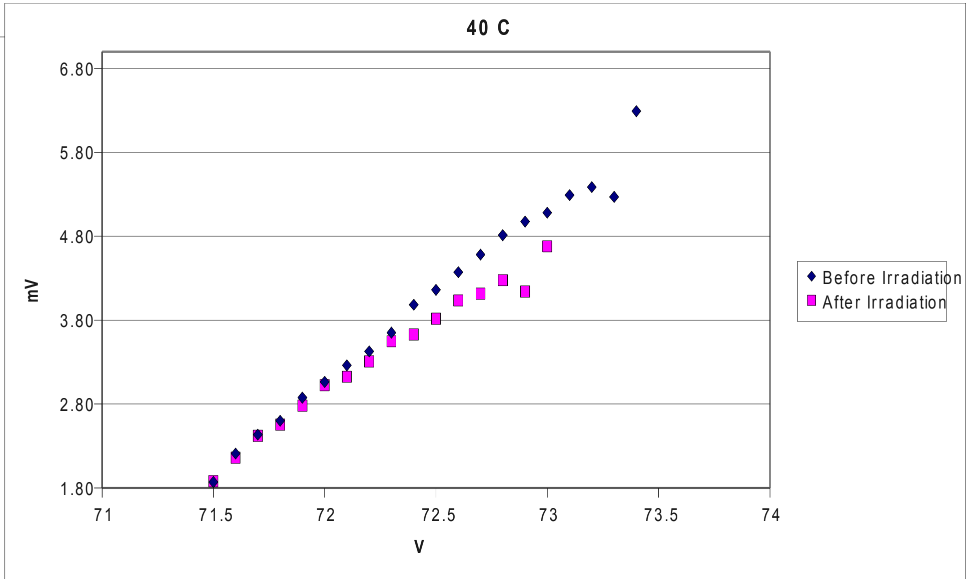
Dark counts rate

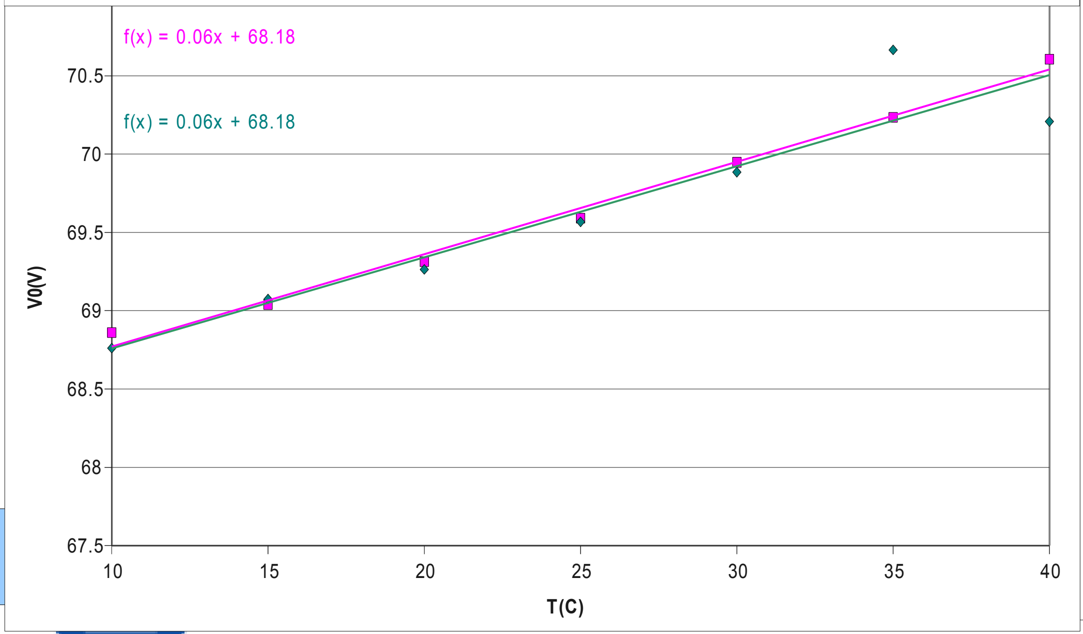


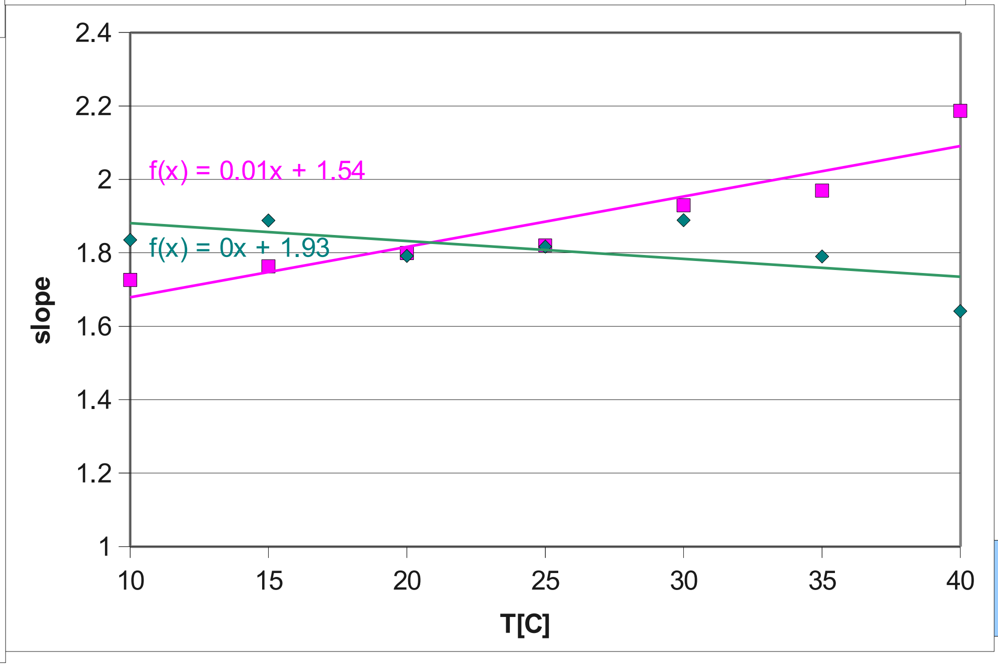
Comparison Before/After Second set

- Hamamatsu



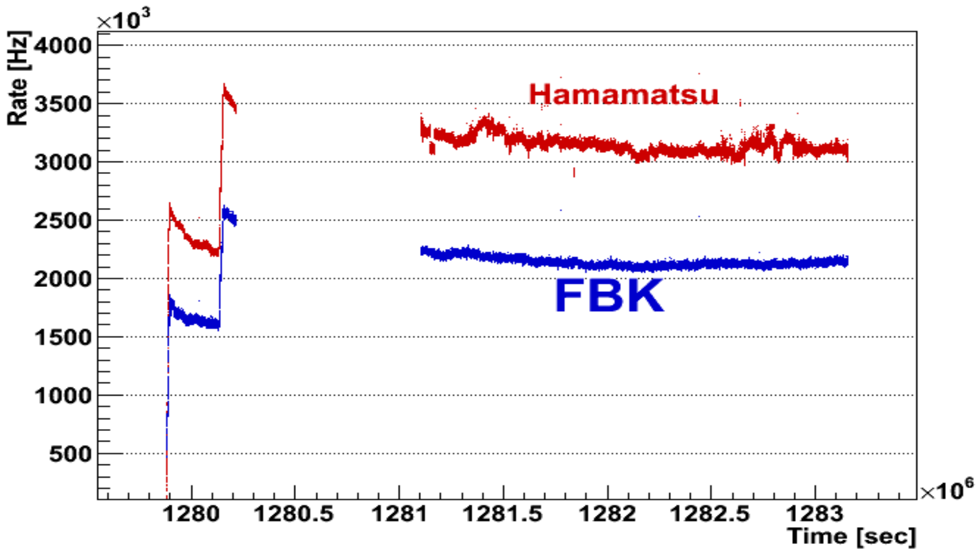


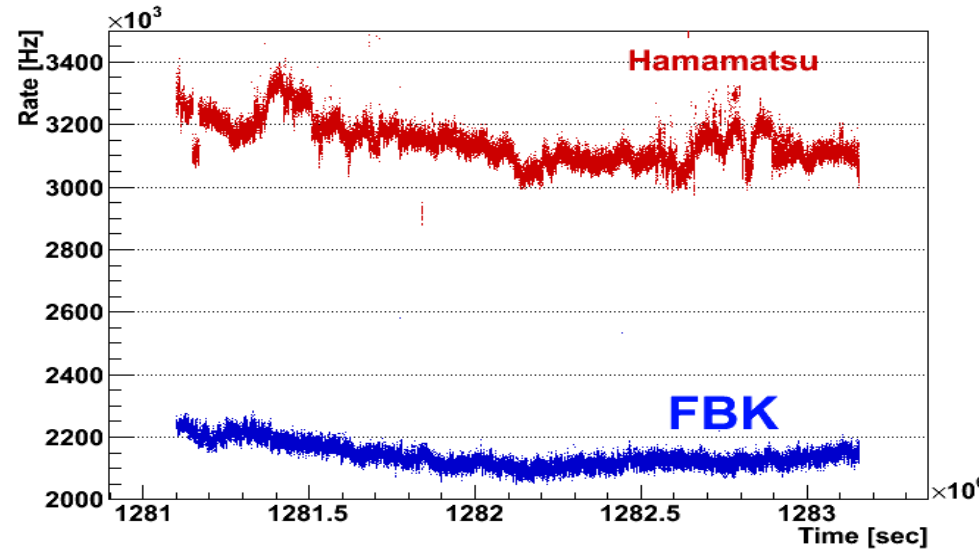


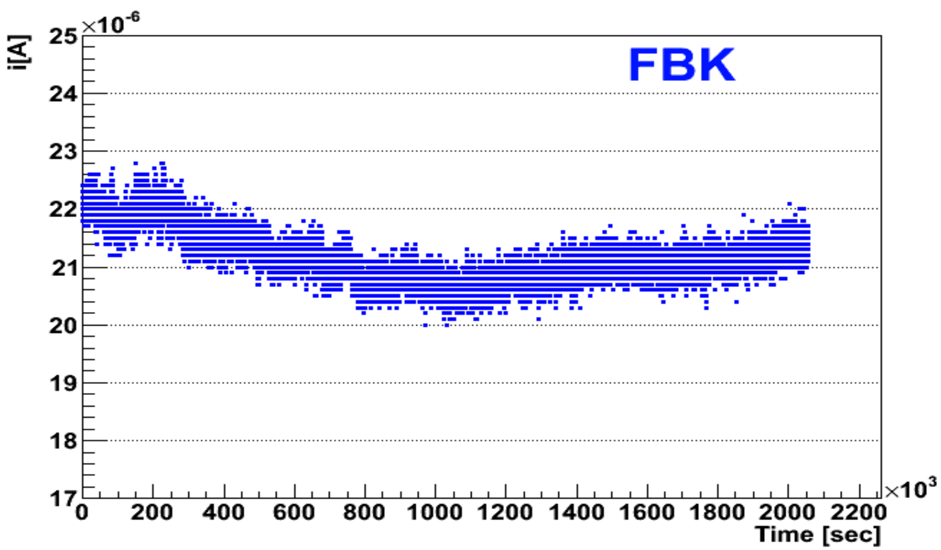


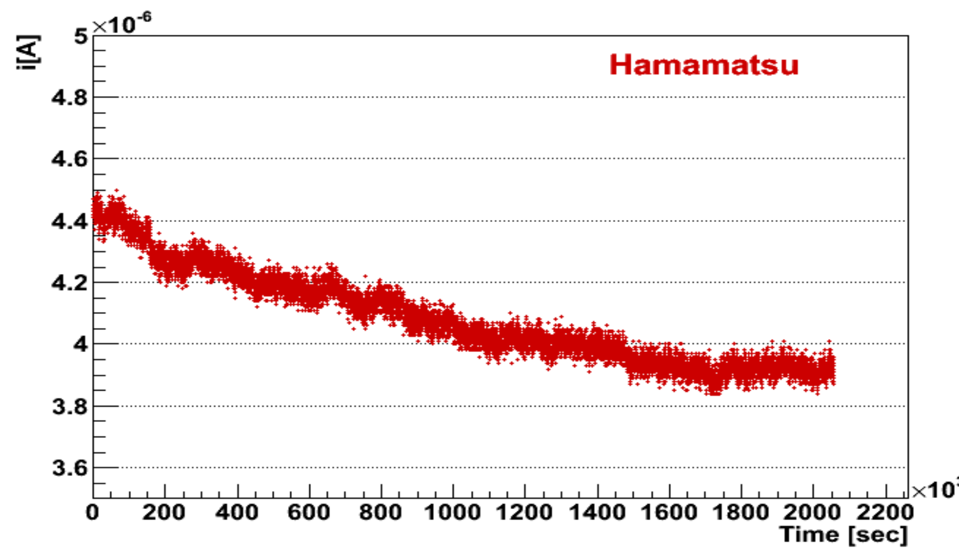
Healing

- These two devices have been monitored for more than a month







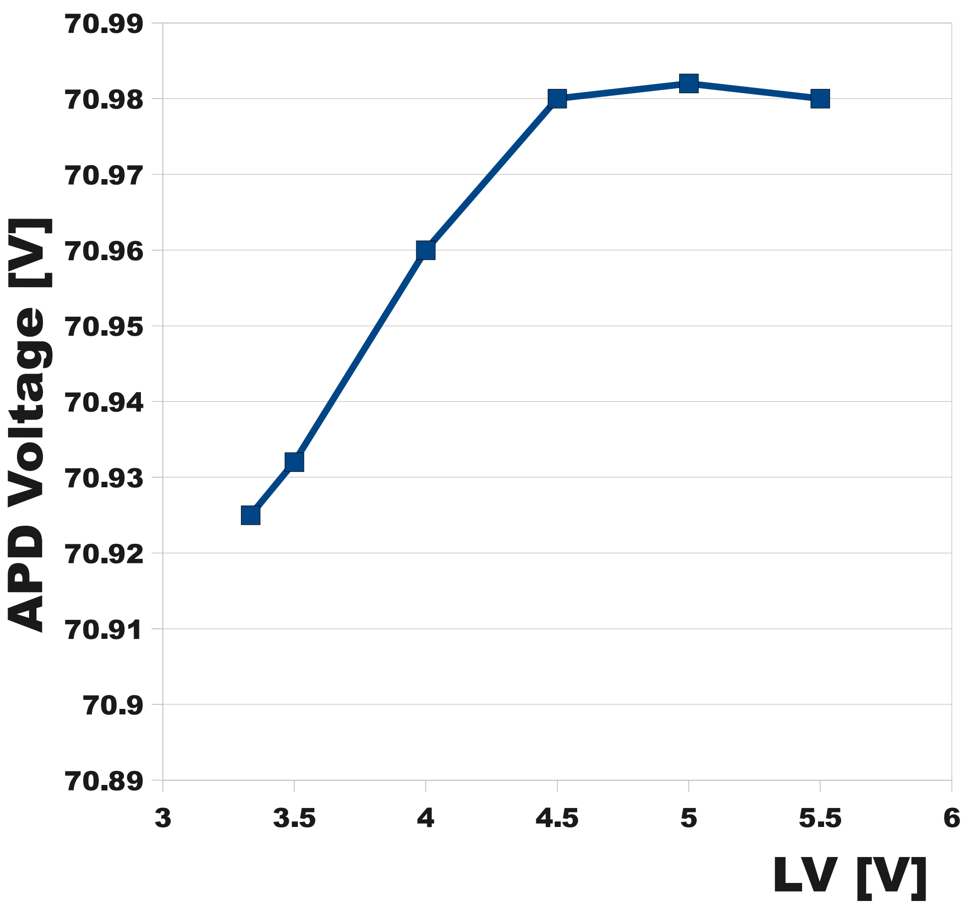


Extreme Low Costing G-APD Power Supply (35$ w/ PCB)

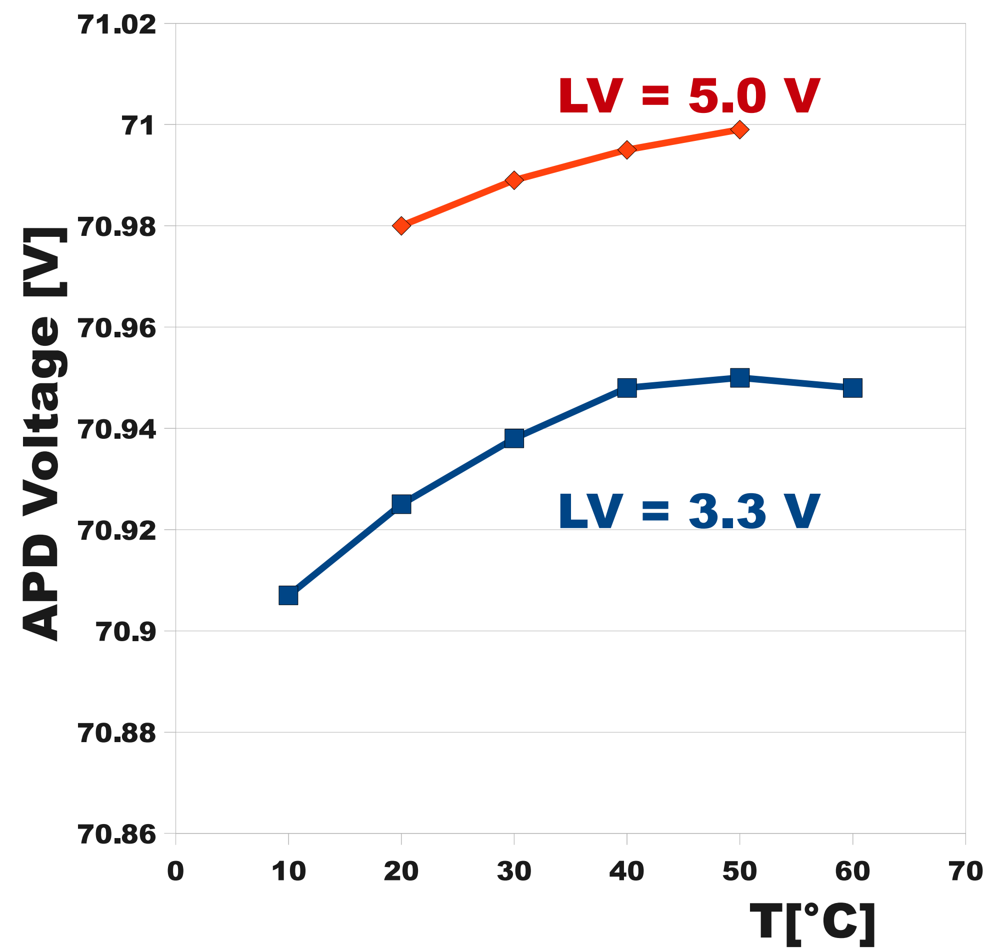
- Evaluated the Maxim MAX15031:
  - consists of a constant-frequency (400kHz) pulse-width modulating (PWM) step-up DC-DC converter
  - with an internal switch and a high-side current monitor with high-speed adjustable current limiting.
  - can generate output voltages up to 76V
  - provides current monitoring up to 4mA (up to 300mW)
  - operates from 2.7V to 11V
  - operates over the -40°C to +125°C temperature range
  - Very small dimension (Chip SMD) ~4mm^2

Maxim Stability

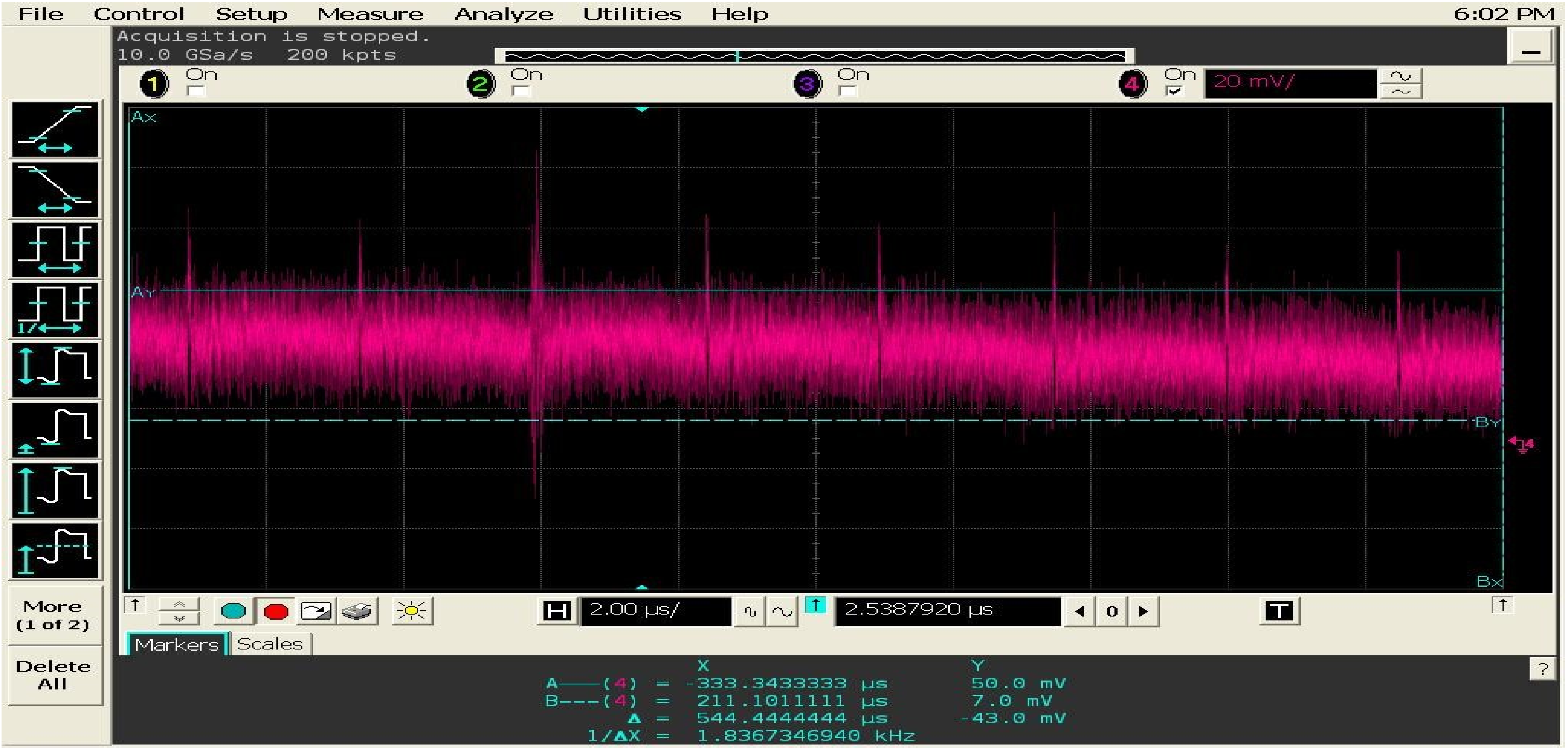
Variation of the Maxim APD Voltage as a function of the LV setting



Variation of the Maxim APD Voltage as a function of the Temperature for different LV setting



Switching Frequency



Summary/to-do

- Finish the comparison before/after irradiation for FBK G-APDs
  - Compare the noise too
- Setup a faster way to measure the gain (maybe with threshold scan?)
- Perform further irradiation test with neutron at LNL with different Si G-APDs
- Study the power supply noise induced by switching frequency

Backup

Backup slides

NIEL-scaling theory

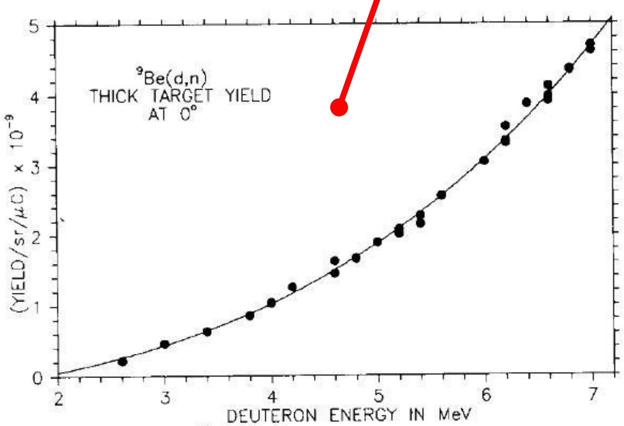
Any particle fluence can be reduced to an equivalent 1 MeV neutron fluence producing the same bulk damage. The scaling is based on the hypothesis that generation of bulk damage is due to non-ionising energy transfer to the lattice.

$$\Phi_{eq} = k \cdot \Phi_{abs}$$

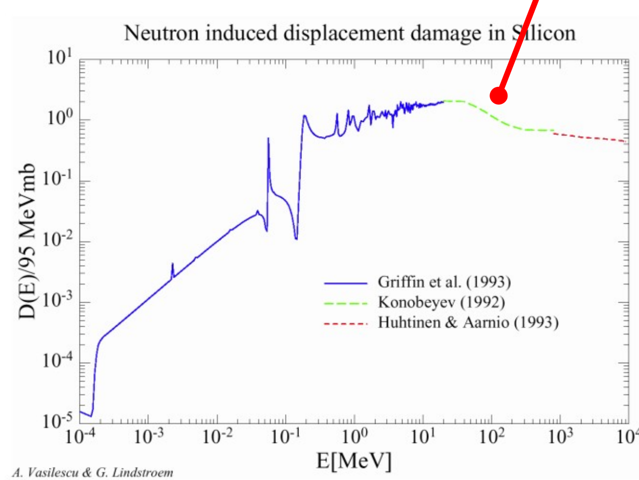
$k=k(E_d)$: "hardness parameter"

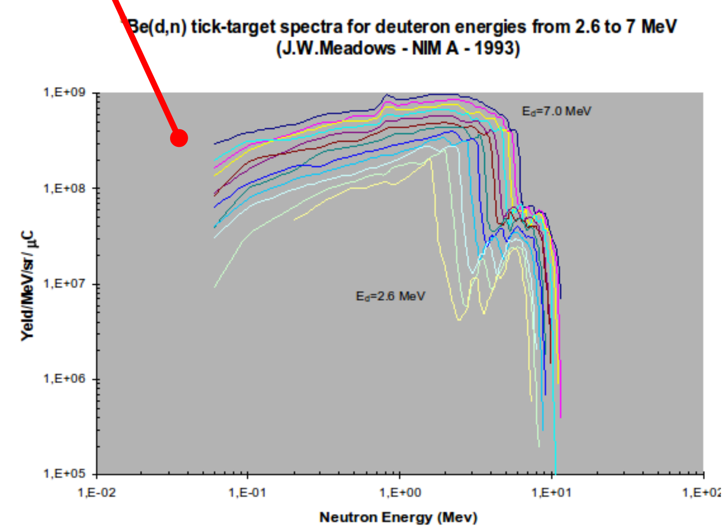
$$\Phi_{abs} = \frac{Y(E) \cdot sr \cdot \mu C}{S_{cm^2}}$$

$$k = \frac{\int D_n(E) \cdot \sigma(E) \cdot dE}{\int \sigma(E) \cdot dE}$$



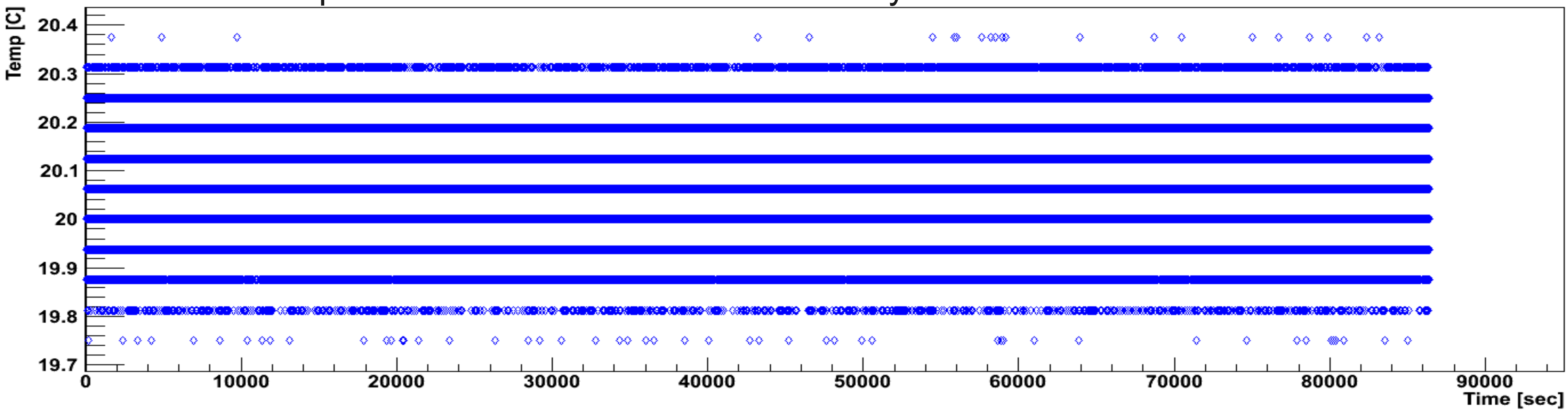
The 9Be(d, n) thick-target yield at 0°
J.W.Meadows - Nim A - 1993

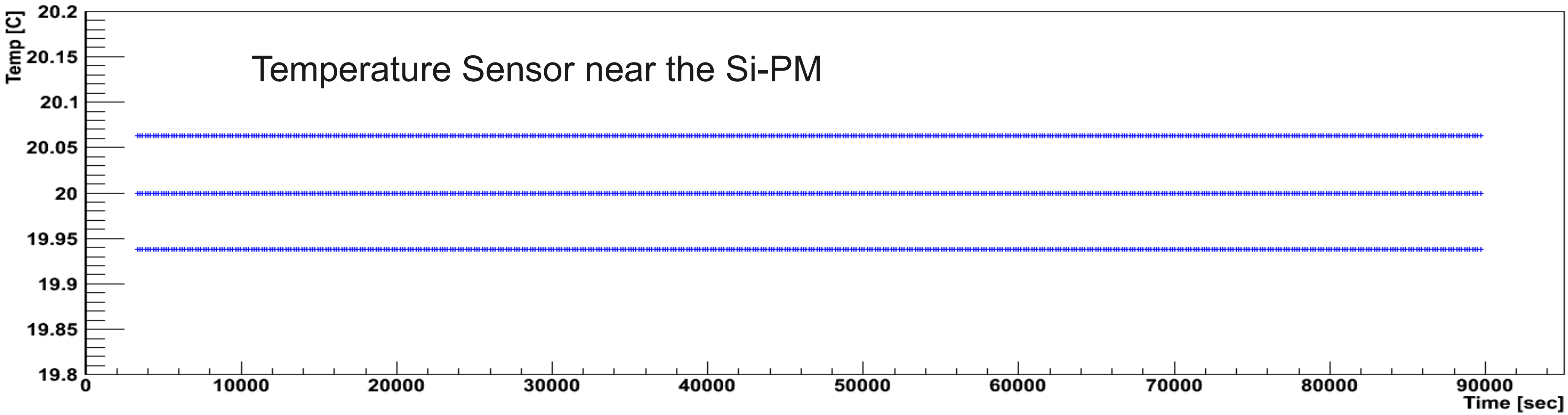




Temperature Stability during August Si-PM monitoring

Temperature Sensor on the inner box layer





Maxim Description

The MAX15031 consists of a constant-frequency pulse-width modulating (PWM) step-up DC-DC converter with an internal switch and a high-side current monitor with high-speed adjustable current limiting.
This device can generate output voltages up to 76V and provides current monitoring up to 4mA (up to 300mW).
The MAX15031 can be used for a wide variety of applications such as avalanche photodiode biasing, PIN biasing, or varactor biasing, and LCD displays. The MAX15031 operates from 2.7V to 11V.

The constant-frequency (400kHz), current-mode PWM architecture provides low-noise output voltage that is easy to filter. A high-voltage, internal power switch allows this device to boost output voltages up to 76V.
Internal soft-start circuitry limits the input current when the boost converter starts.
The MAX15031 features a shutdown mode to save power.

The MAX15031 includes a current monitor with more than three decades of dynamic range and monitors current ranging from 500nA to 4mA with high accuracy.
Resistor-adjustable current limiting protects the APD from optical power transients.
A clamp diode protects the monitor's output from overvoltage conditions.
Other protection features include cycle-by-cycle current limiting of the boost converter switch, undervoltage lockout, and thermal shutdown if the die temperature reaches +160°C.

The MAX15031 is available in a thermally enhanced 4mm x 4mm, 16-pin TQFN package and operates over the -40°C to +125°C automotive temperature range.