Quick Report on Radiation Hardness studies on Silicon G-APDs

XV SuperB General Meeting
Caltech

Report of the work done in Padova

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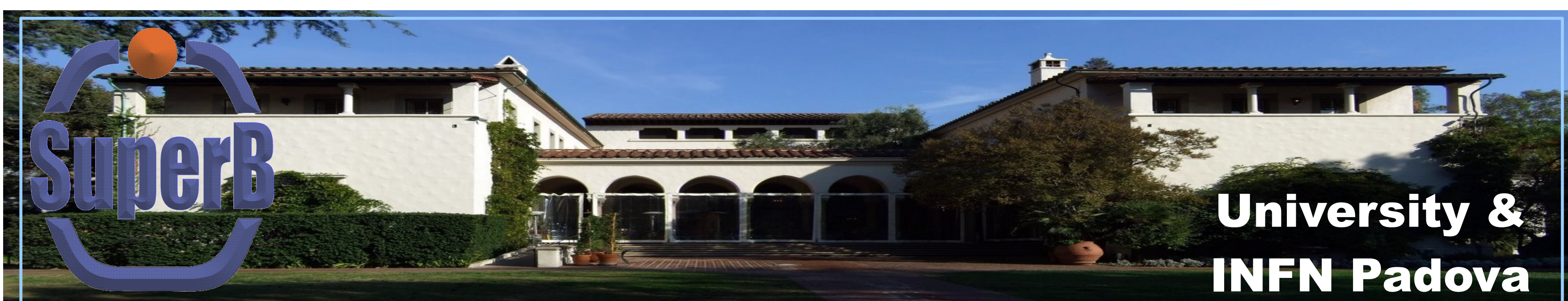


Outline

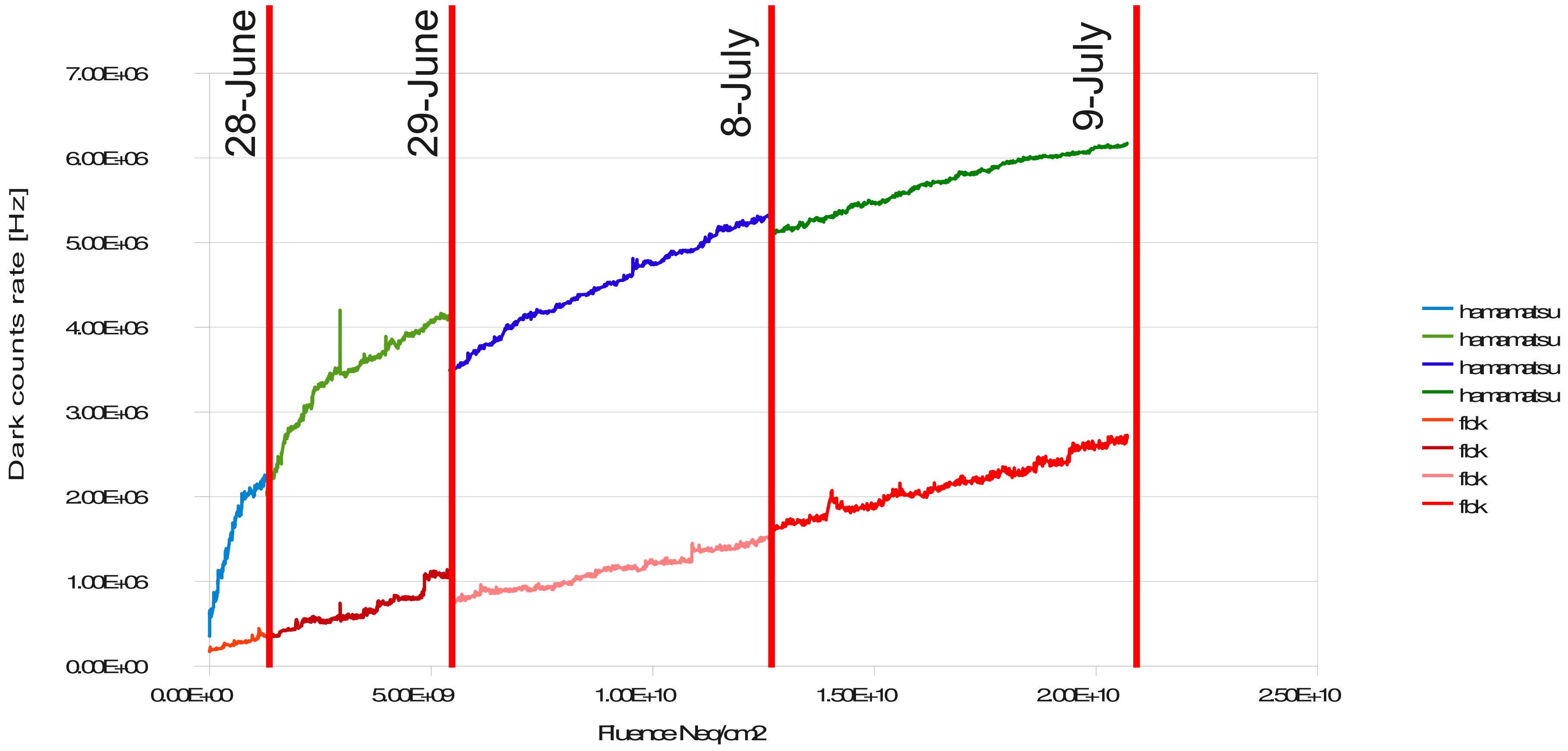
- Studies on-going on different Silicon G-APDs
  - FBK (Irst), Hamamatsu, 1 mm^2 to 9 mm^2
  - Measuring the gain
- Radiation Tests @ LNL (INFN Legnaro National Labs)
  - Different energy, fluence and G-APDs
  - Preliminary Comparison
  - New Setup: added a Neutron Moderator

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 (1 mm^2 - 50 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: 20-60 nA
- Temperature 20ºC
- 3 different sets of measurements
  - 28,29-June and 8,9 July 1 Hamamatsu 50 μm & 1 FBK 40 μm both 1 mm^2
  - 23 and 26 July 1 Hamamatsu 1mm^2 & 1 FBK 4mm^2
  - 8-9 Nov 1 Hamamatsu & 1 FBK both 1mm^2 and 50 μm

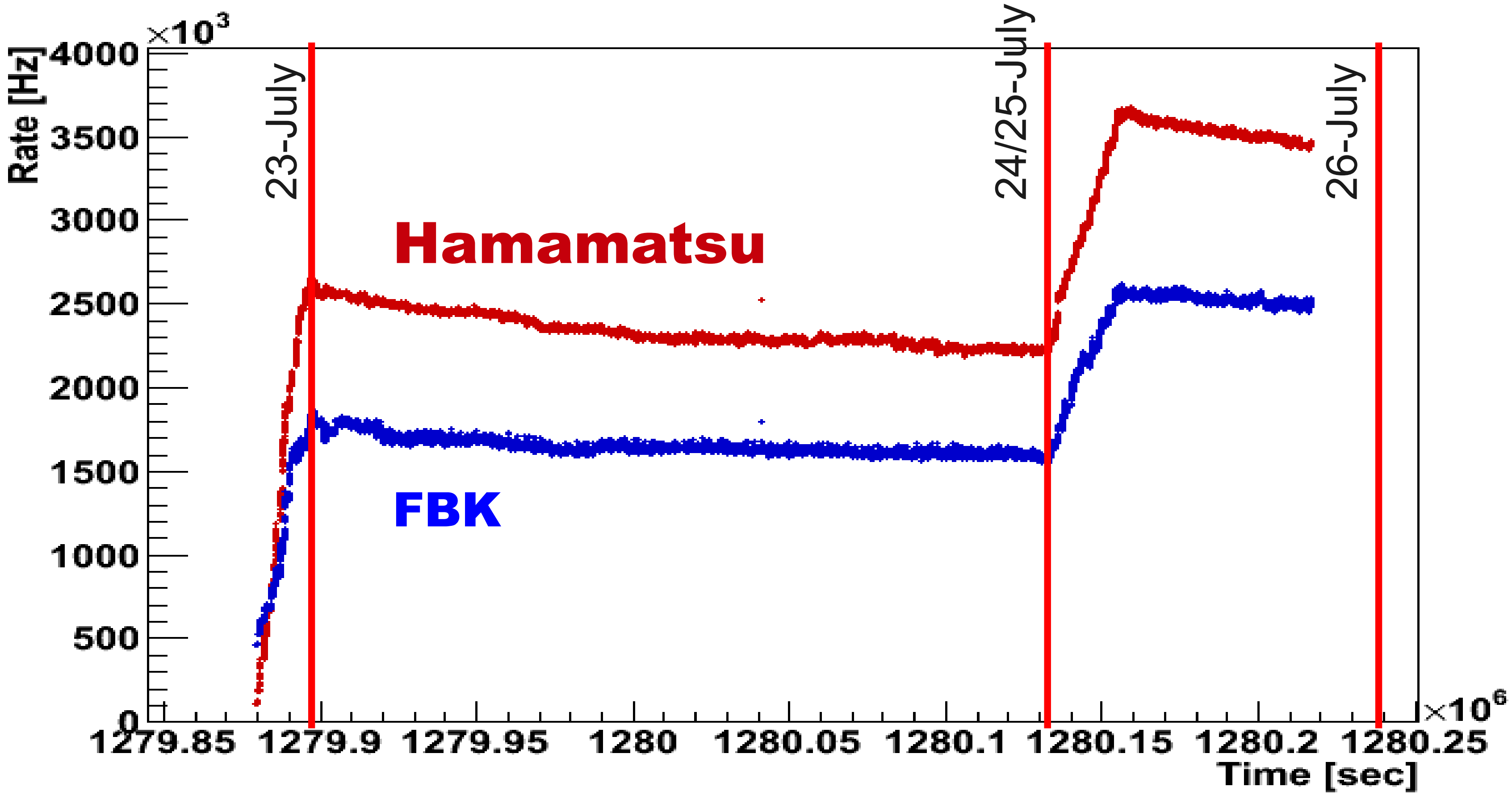
First sets: Dark Counts Rate @1.5p.e. vs N Fluence

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



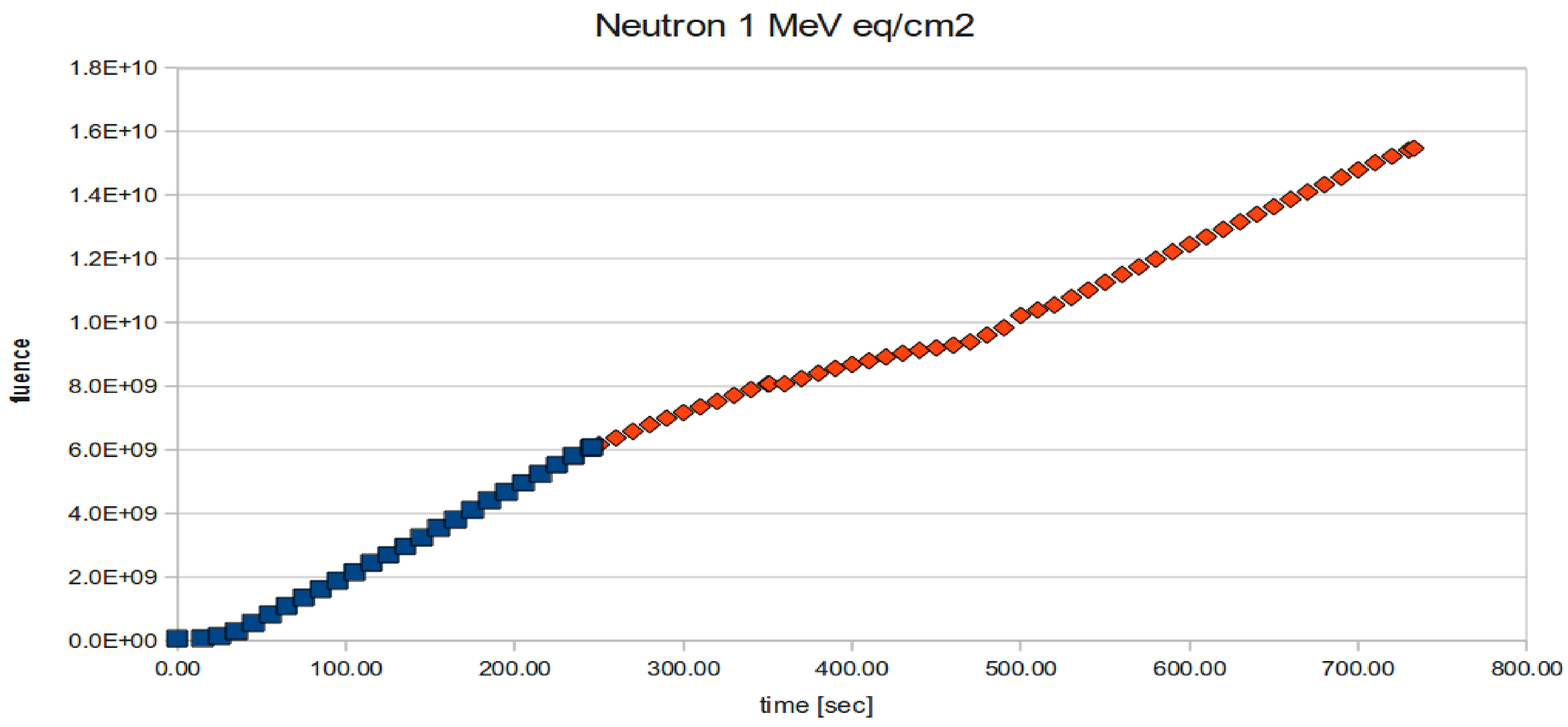
Second Set: Dark counts rate @ 1.5 p.e. Vs Time

- Reached Fluence of N_{1MeV} eq ~ $8x10^{9}$:

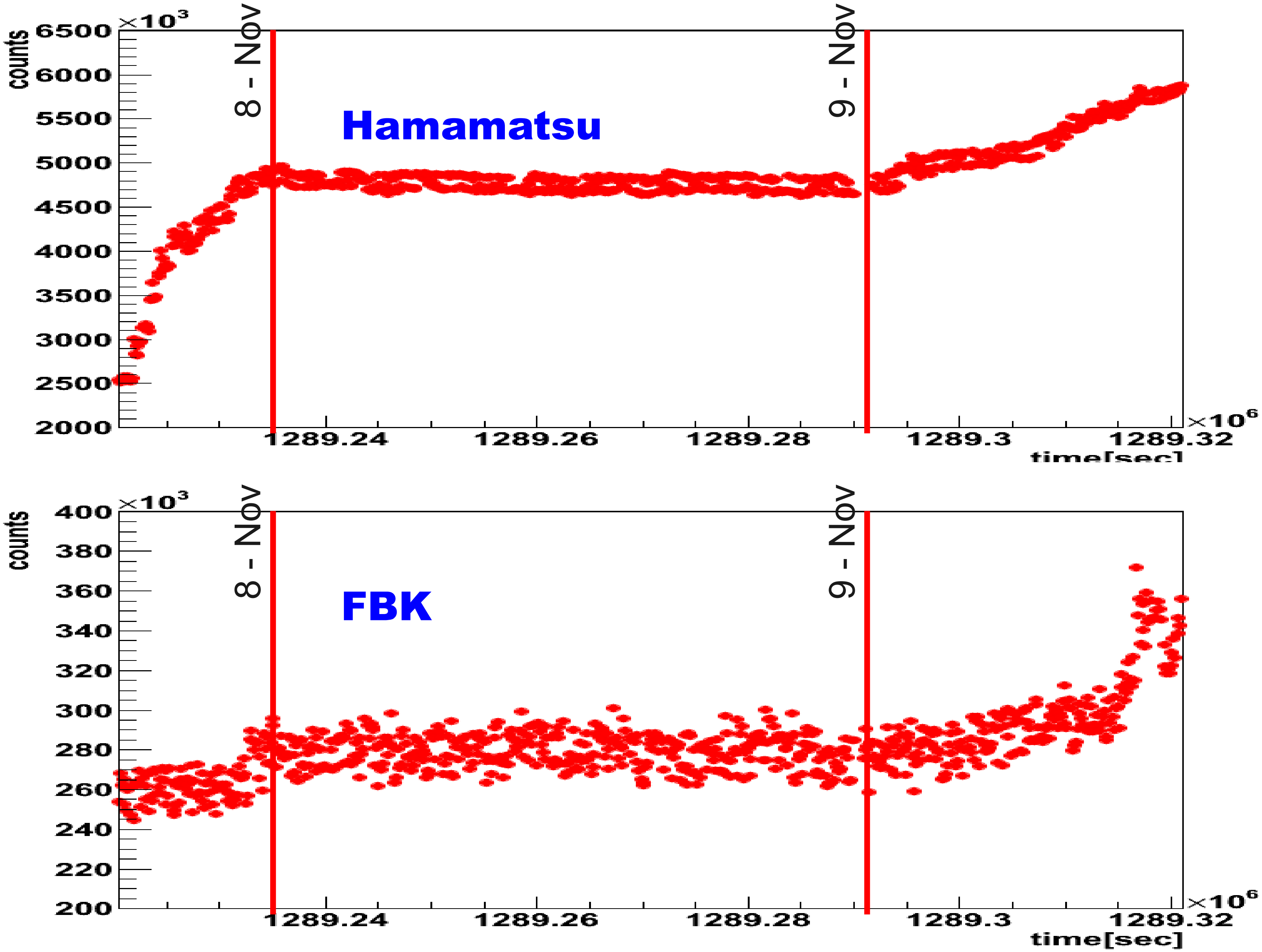


Third Set: added a Moderator

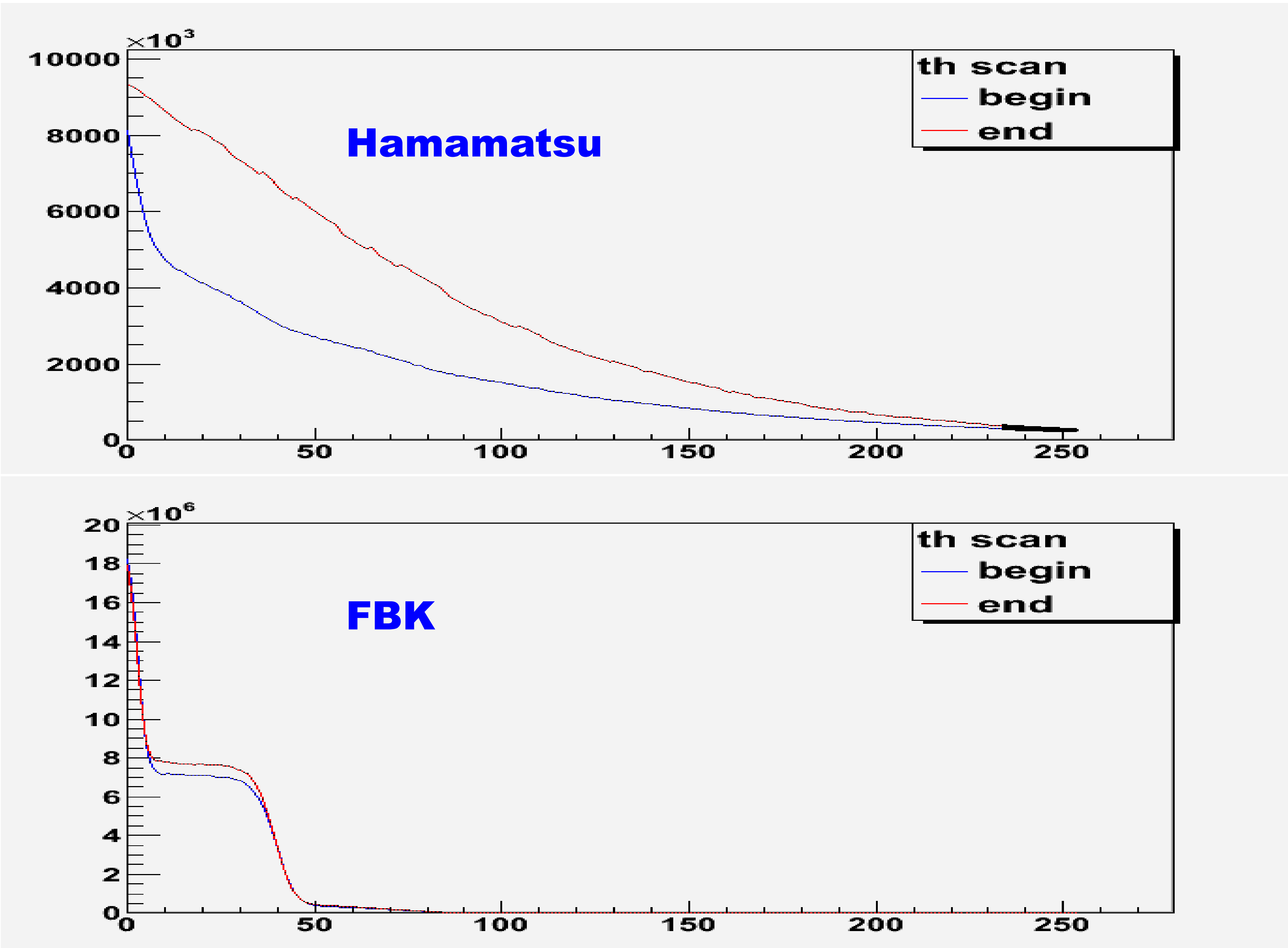
- Put 10cm of Neutron Moderator ("just" Water) between the neutron beam and the Silicon
- Reached Fluence of $N_{1MeV}eq \sim 1.6 \times 10^{10}$ on the moderator



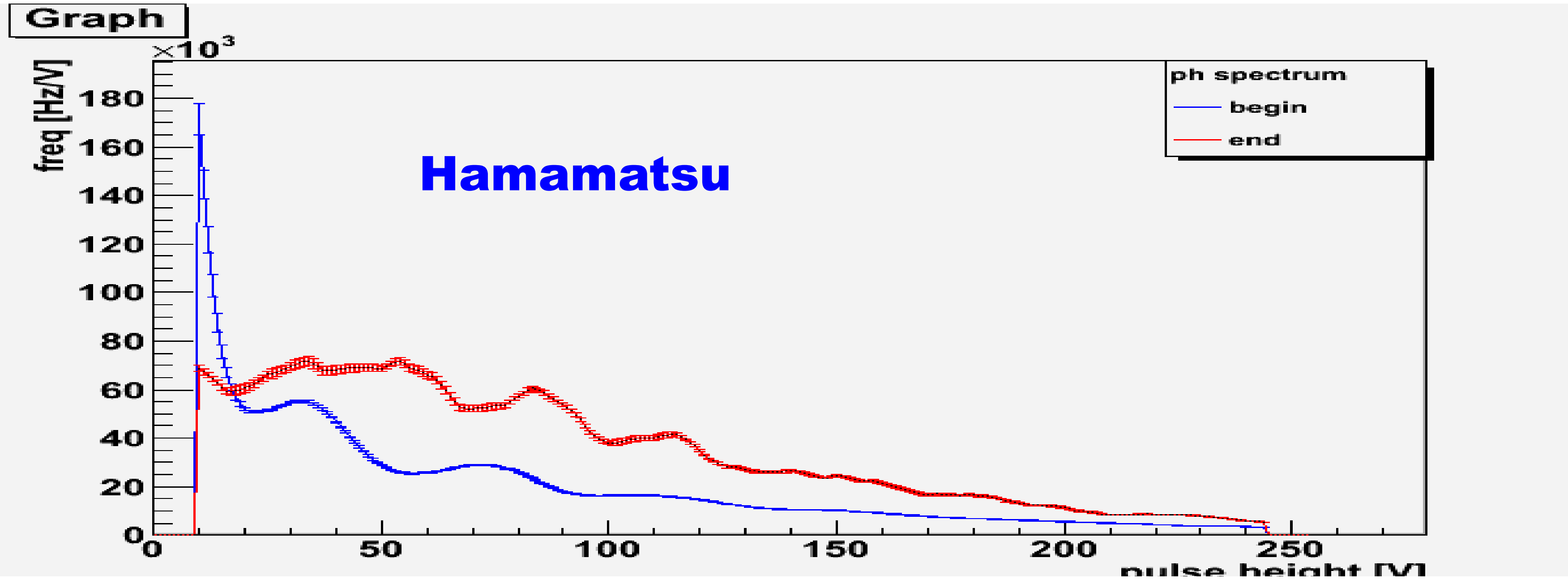
Third Set: Dark counts rate @ 1.5 p.e. Vs Time

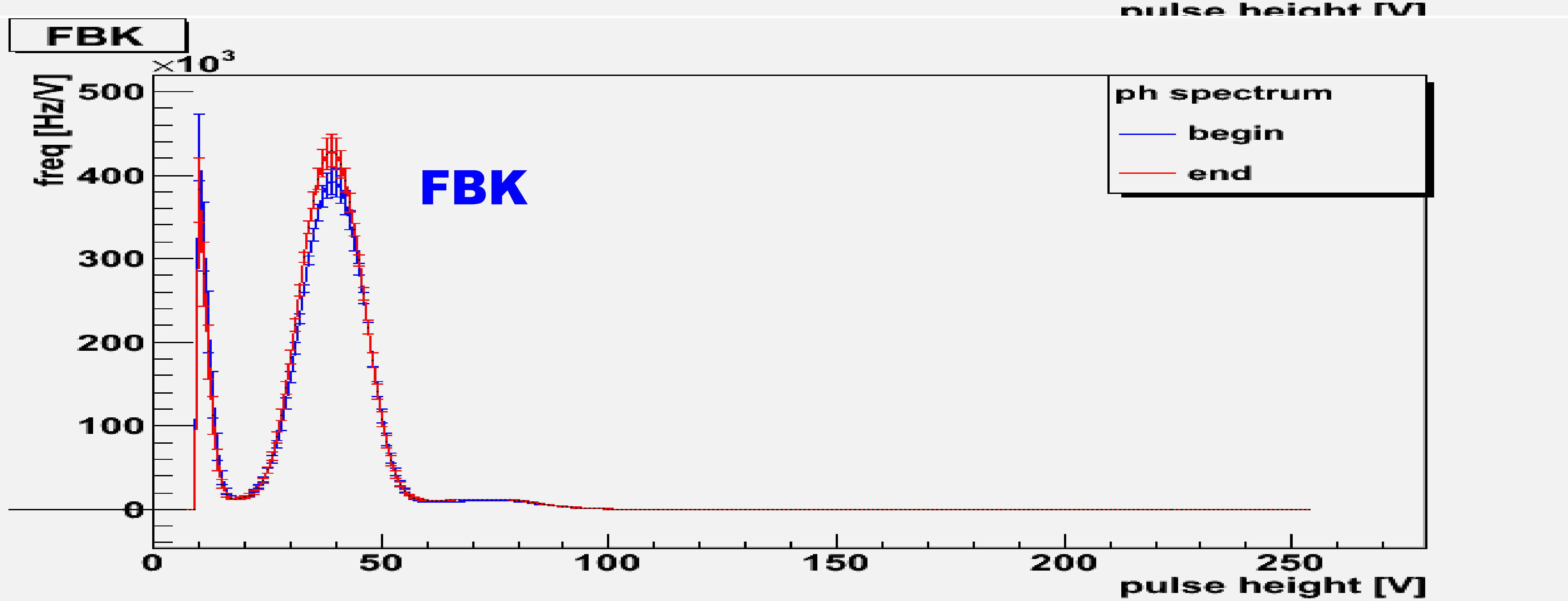


Third Set: Threshold scan



Third Set: Spectrum

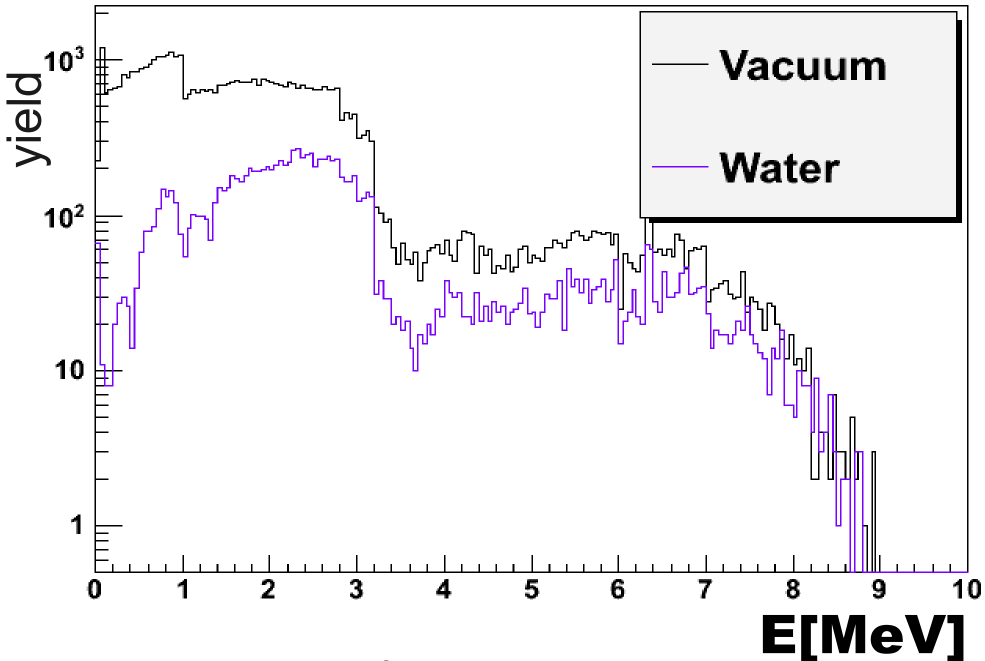


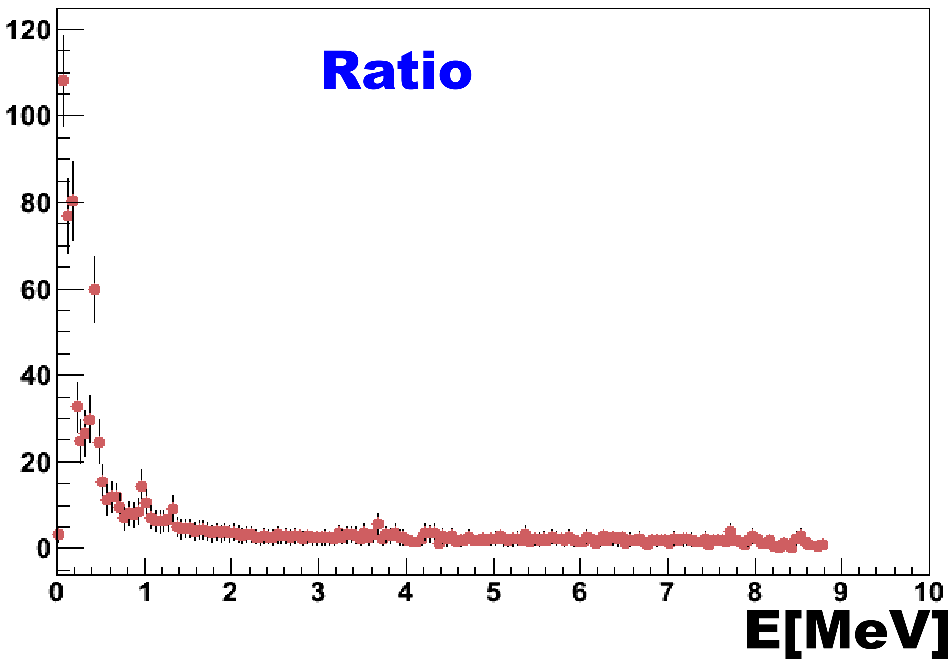


Third Set: Preliminary Simulation

Studies the neutron fluence using Geant4 simulation

- Using QGSP_BERT_HP physics list for hadron
- Standard EM & Optical
- Neutron Gun from a Paper of J.W. Meadows*





*Meadows, James W. Nuclear Instruments and Methods in Physics Research Section A, Volume 324, Issue 1-2, p. 239-246.

The 9Be(d, n) thick-target neutron spectra for deuteron energies between 2.6 and 7.0 MeV

Summary/to-do

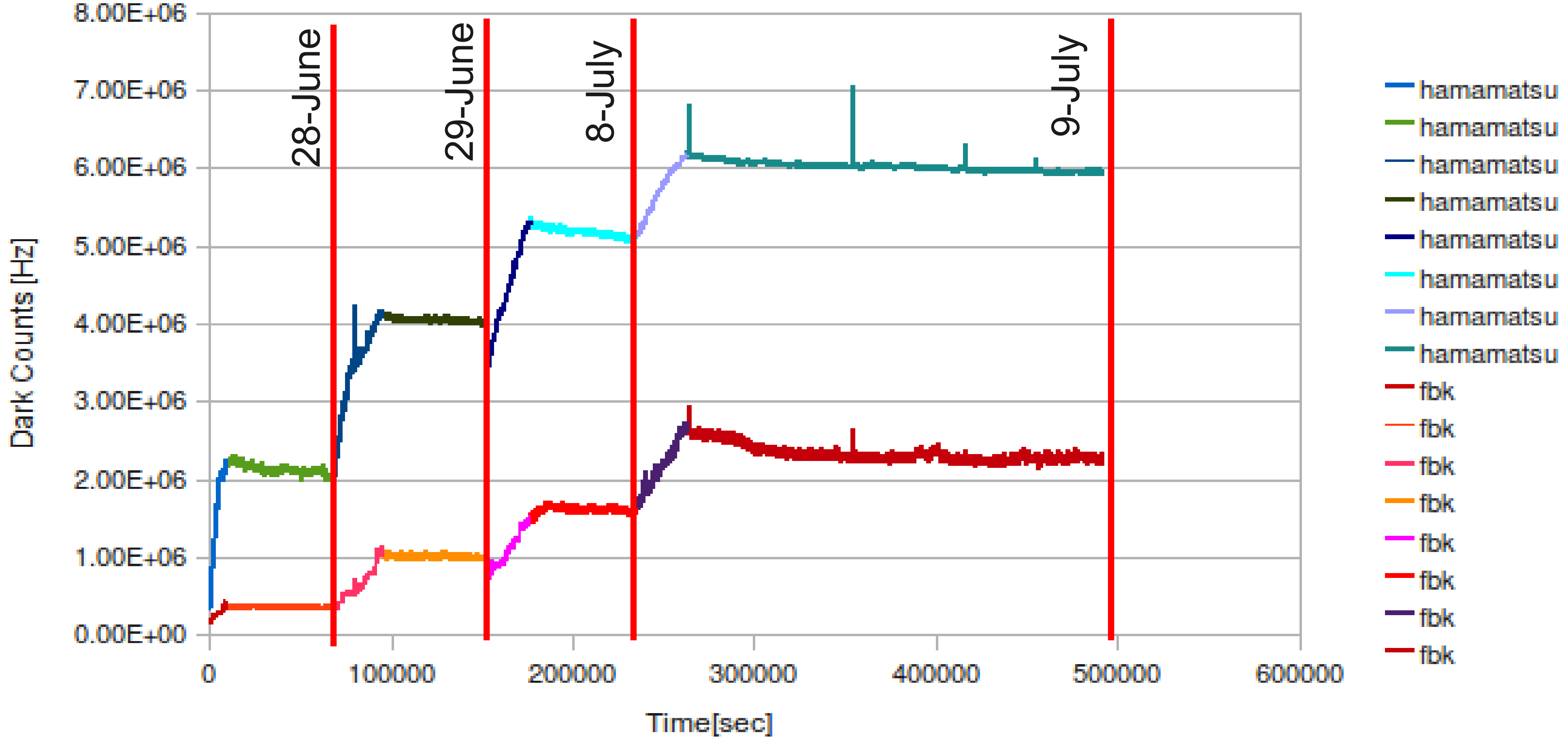
- Using a Moderator seems to give promising results concerning radiation hardness for FBK devices :-)
  - Work on the simulation to understand better what's going on
- Tests with other moderator (paraffin,graphite,...) have been planed
- Try to get in touch w/ MPI Munich to get a few samples of Si-PMs w/ bulk integrated quench resistors
  - no answer so far :-(

Backup

Backup slides

First sets: Dark Counts Rate @1.5p.e. vs Time

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



NIEL-scaling theory

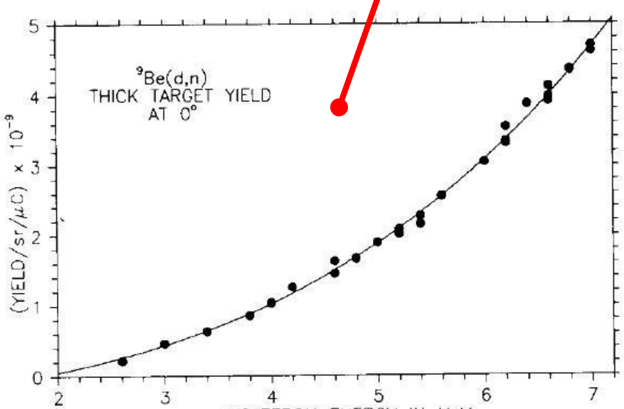
Any particle fluence can be reduced to an equivalent 1 MeV neutron fluence producing the same bulk damage. The scaling is based on the hypothesis that generation of bulk damage is due to non-ionising energy transfer to the lattice.

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

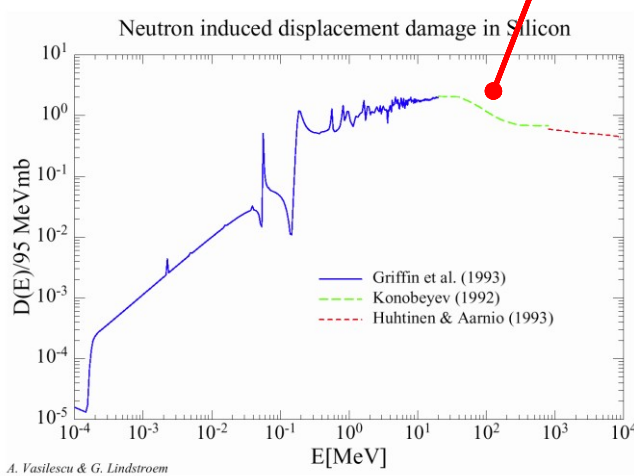
$k=k(E_d)$: "hardness parameter"

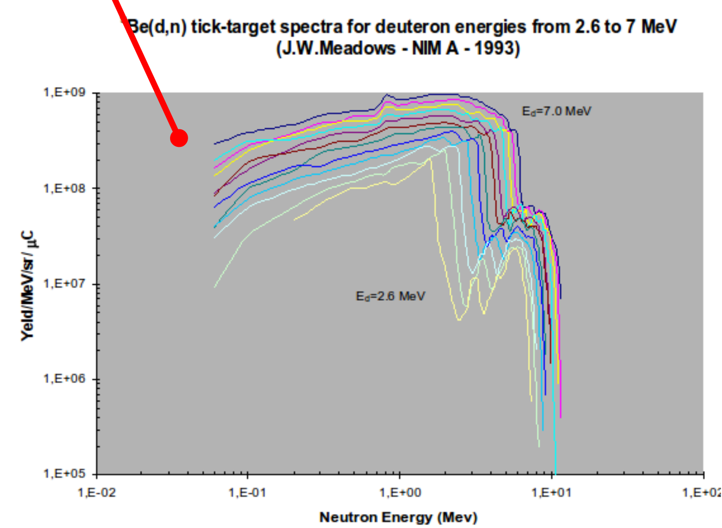
$$\Phi_{abs} = \frac{Y(E) \cdot sr \cdot \mu C}{S_{cm^2}}$$

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

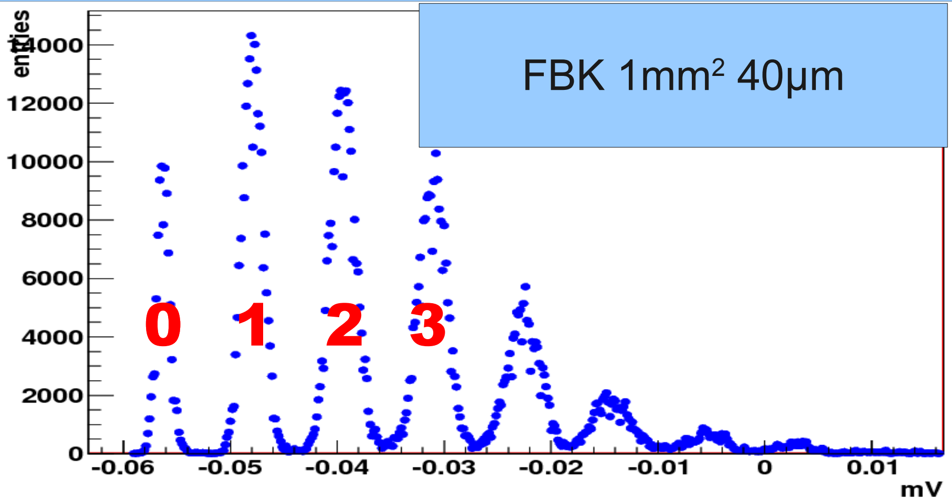


The ^{9}Be(d, n) thick-target yield at 0°
J.W.Meadows - Nim A - 1993





Fitting the spectrum



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

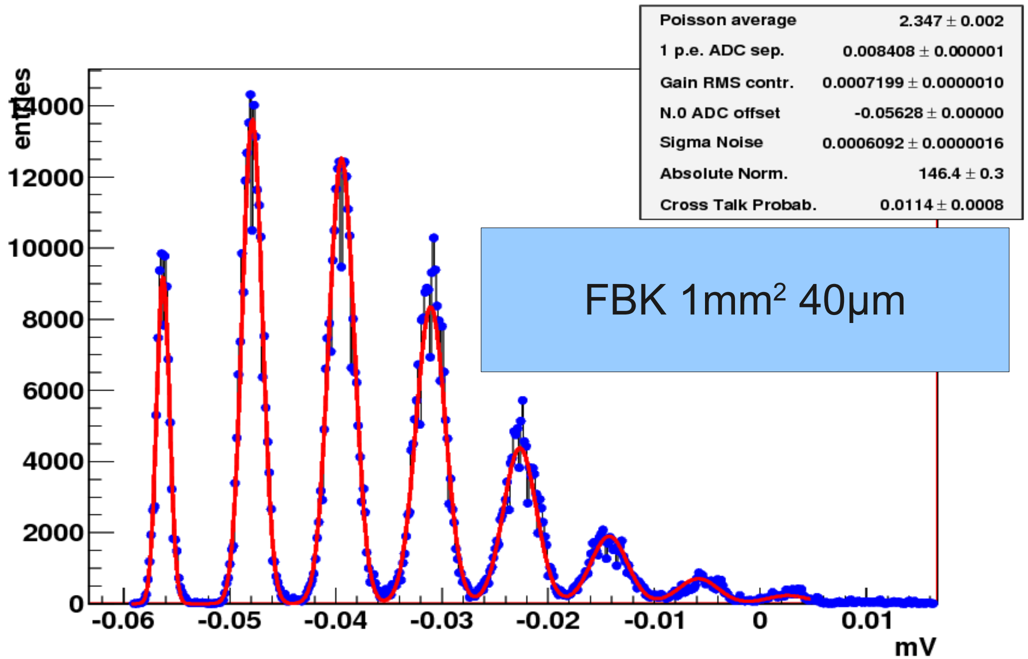
$x \rightarrow$ pulse height

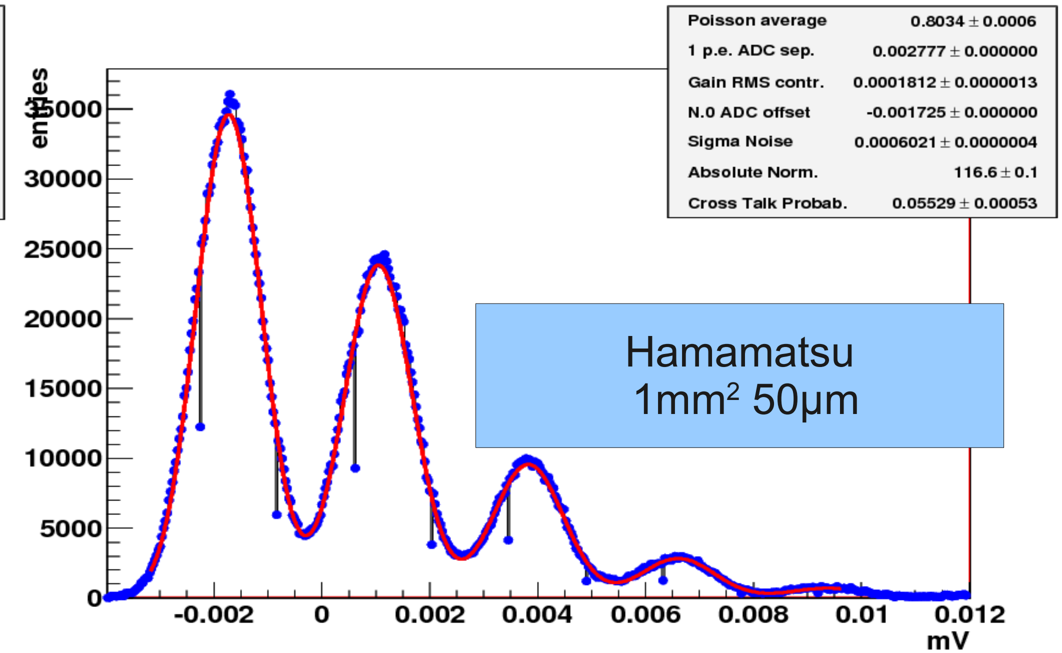
$n \rightarrow$ number of photons

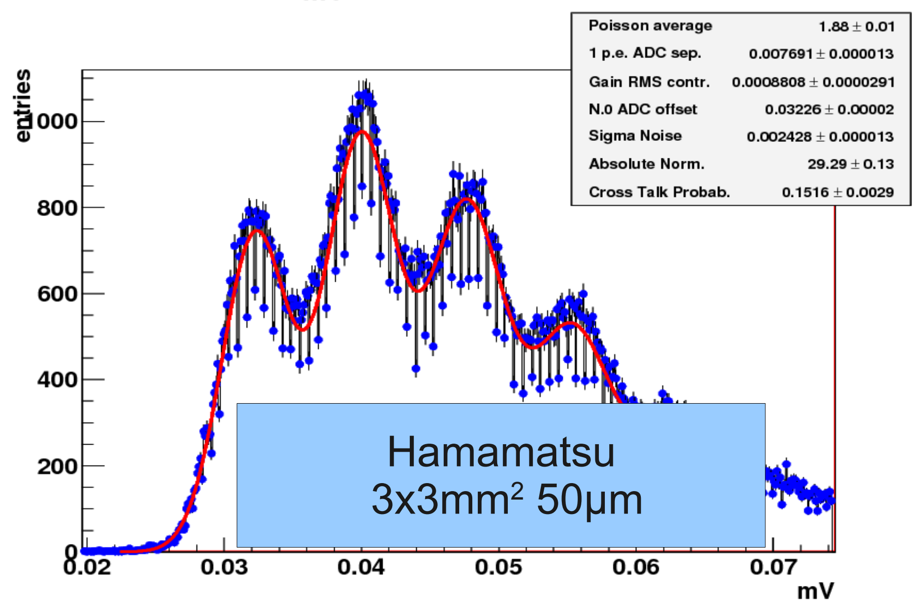
$\delta \rightarrow$ p.e. peak distance

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

Fit Results

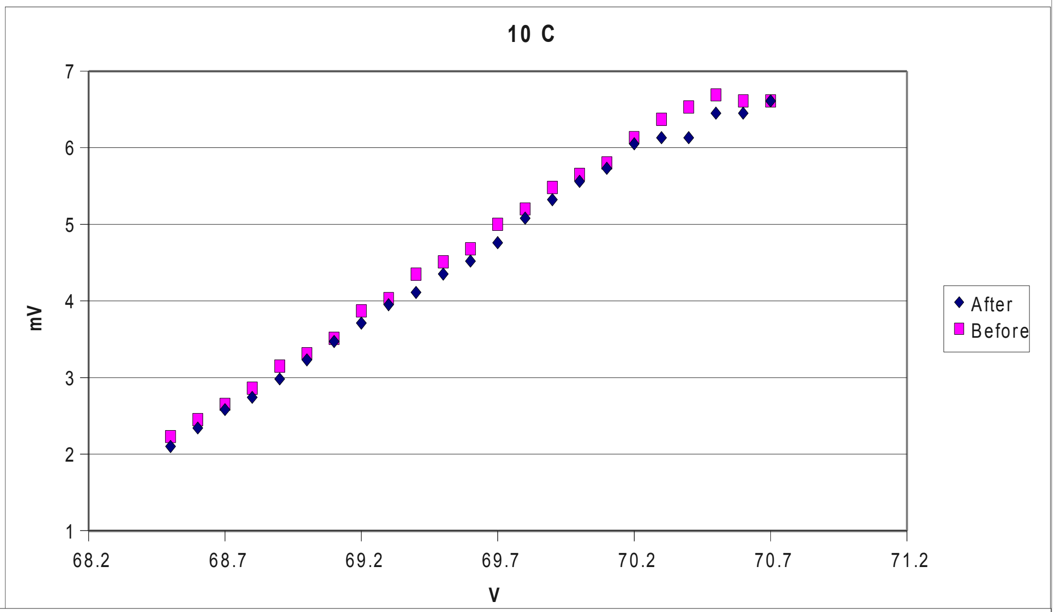

Poisson average 2.347 ± 0.002
1 p.e. ADC sep. 0.008408 ± 0.000001
Gain RMS contr. 0.0007199 ± 0.0000010
N.0 ADC offset -0.05628 ± 0.00000
Sigma Noise 0.0006092 ± 0.0000016
Absolute Norm. 146.4 ± 0.3
Cross Talk Probab. 0.0114 ± 0.0008
FBK 1mm² 40µm
entries
mV

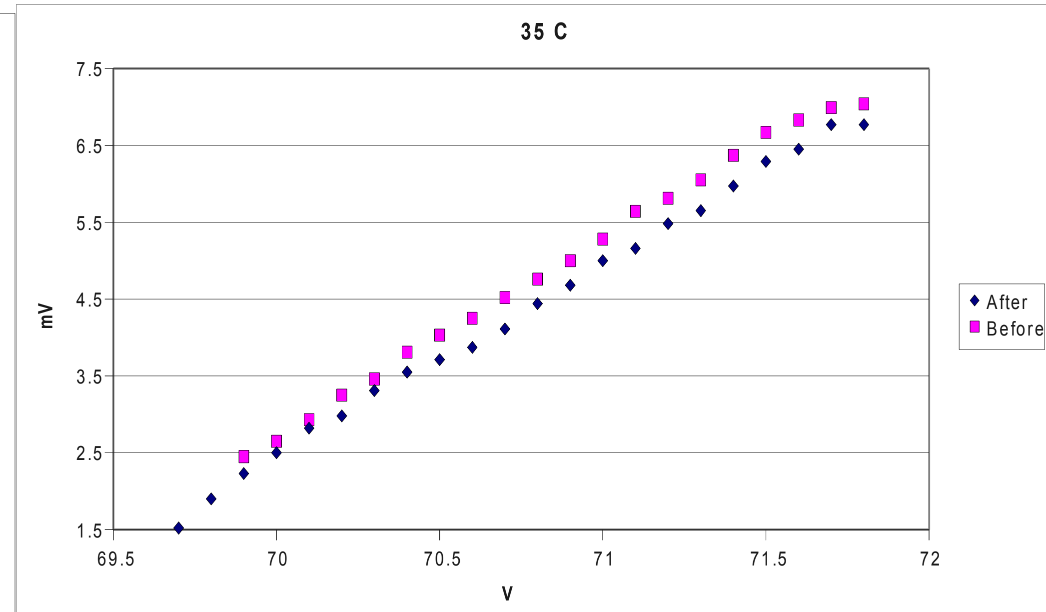

Poisson average 0.8034 ± 0.0006
1 p.e. ADC sep. 0.002777 ± 0.000000
Gain RMS contr. 0.0001812 ± 0.0000013
N.0 ADC offset -0.001725 ± 0.000000
Sigma Noise 0.0006021 ± 0.0000004
Absolute Norm. 116.6 ± 0.1
Cross Talk Probab. 0.05529 ± 0.00053
Hamamatsu
1mm² 50µm
entries
mV

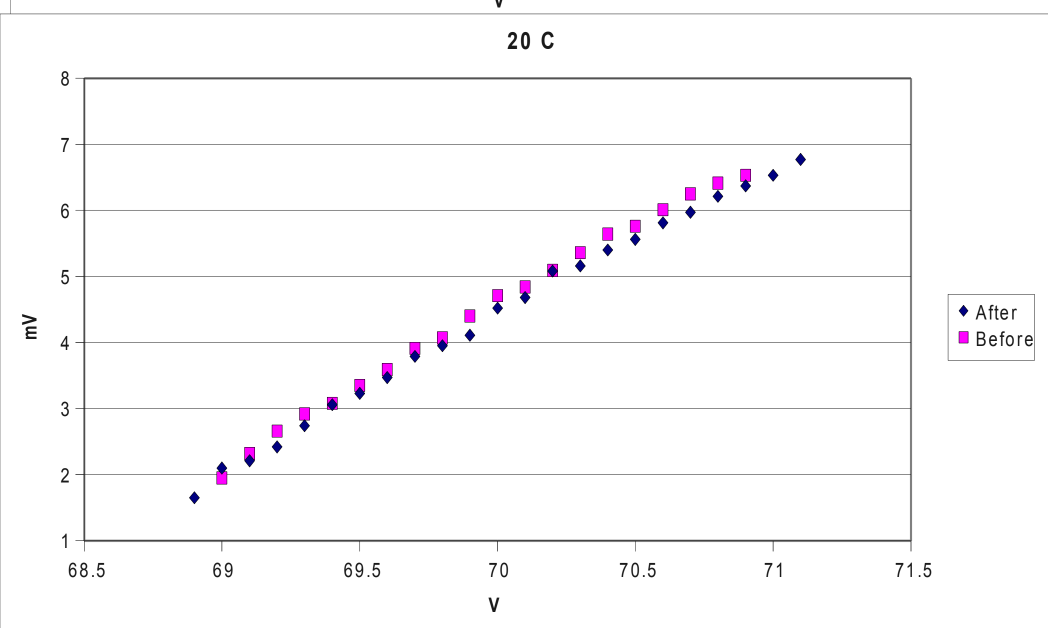

Poisson average 1.88 ± 0.01
1 p.e. ADC sep. 0.007691 ± 0.000013
Gain RMS contr. 0.0008808 ± 0.0000291
N.0 ADC offset 0.03226 ± 0.00002
Sigma Noise 0.002428 ± 0.000013
Absolute Norm. 29.29 ± 0.13
Cross Talk Probab. 0.1516 ± 0.0029
Hamamatsu
3x3mm² 50µm
entries
mV

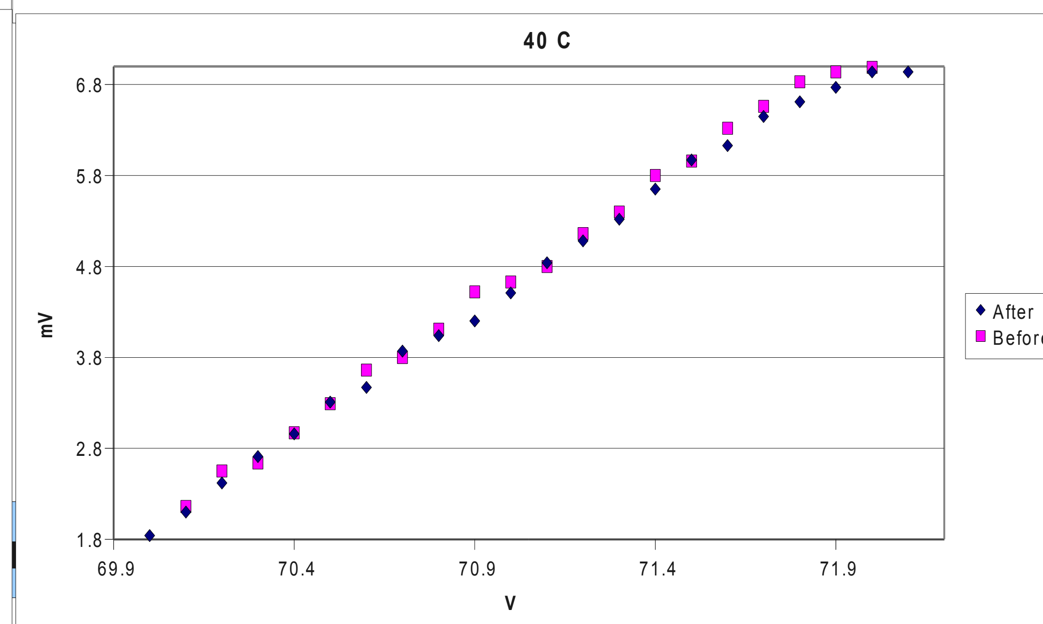
First Set Comparison: Before/After

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

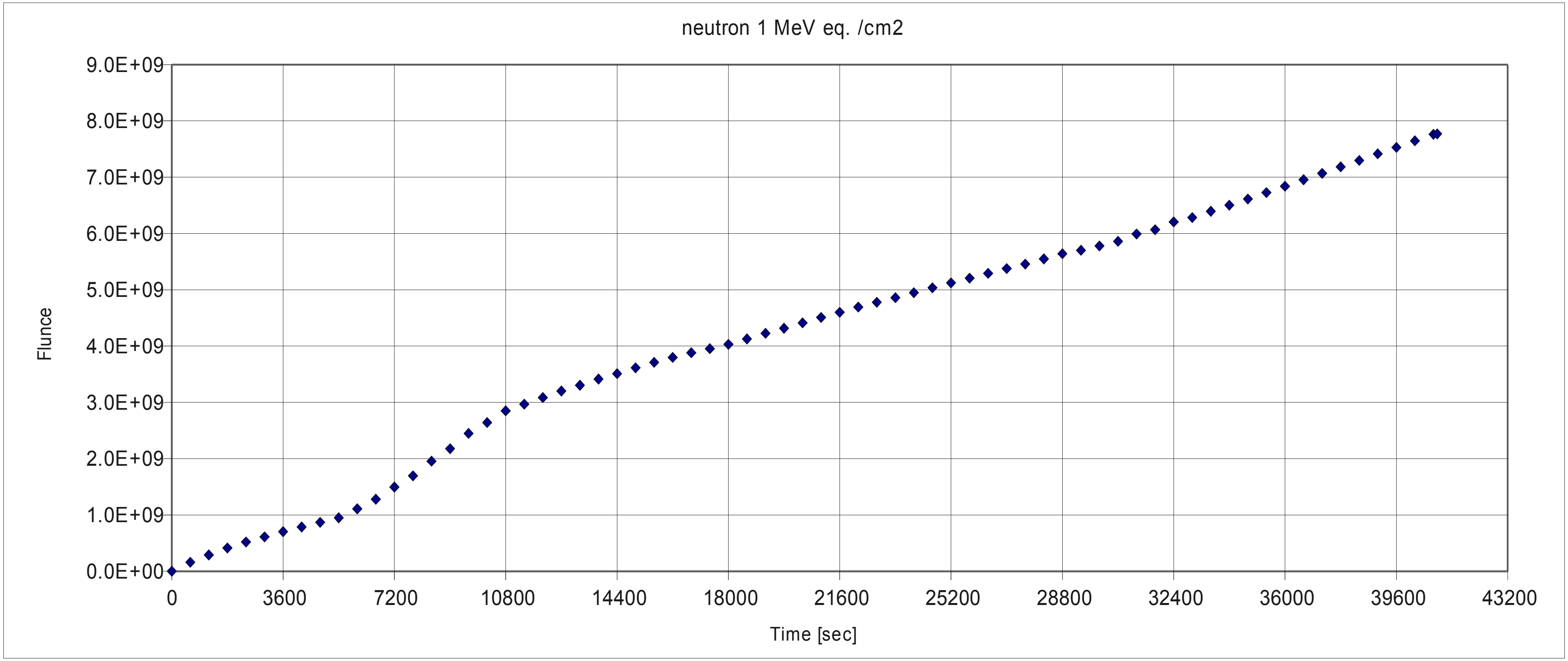






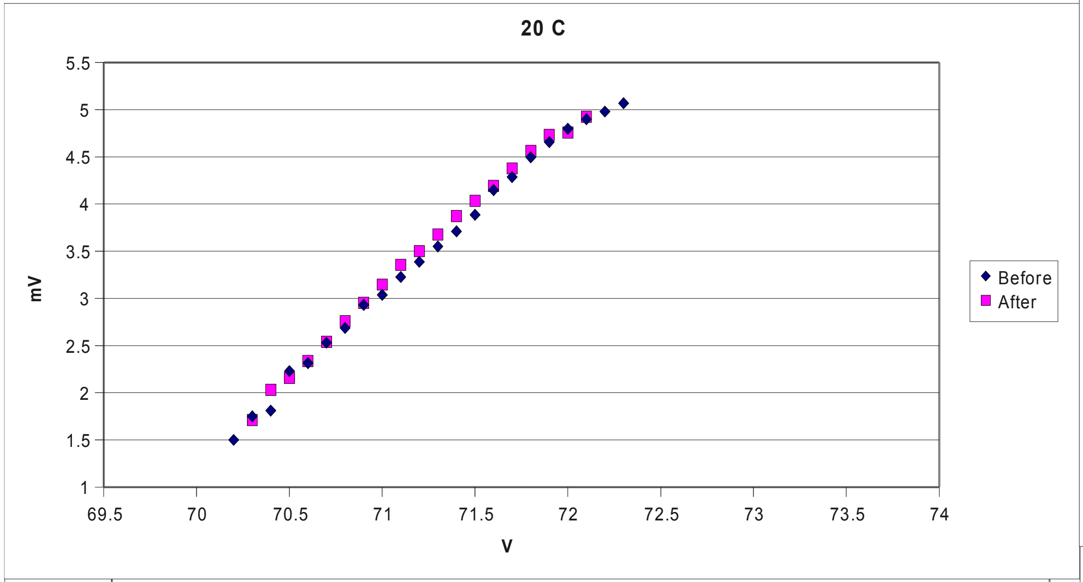


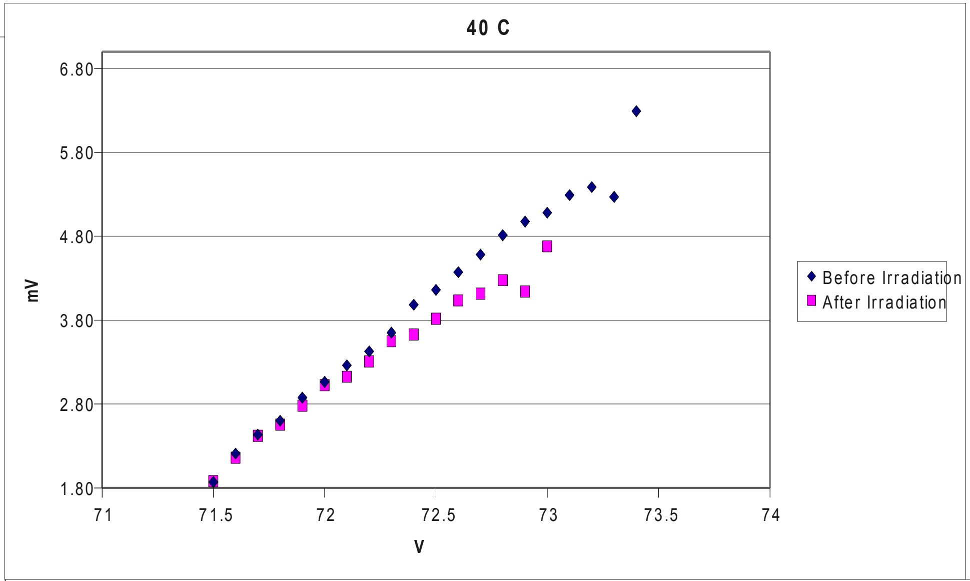
Neutron Fluence Second set

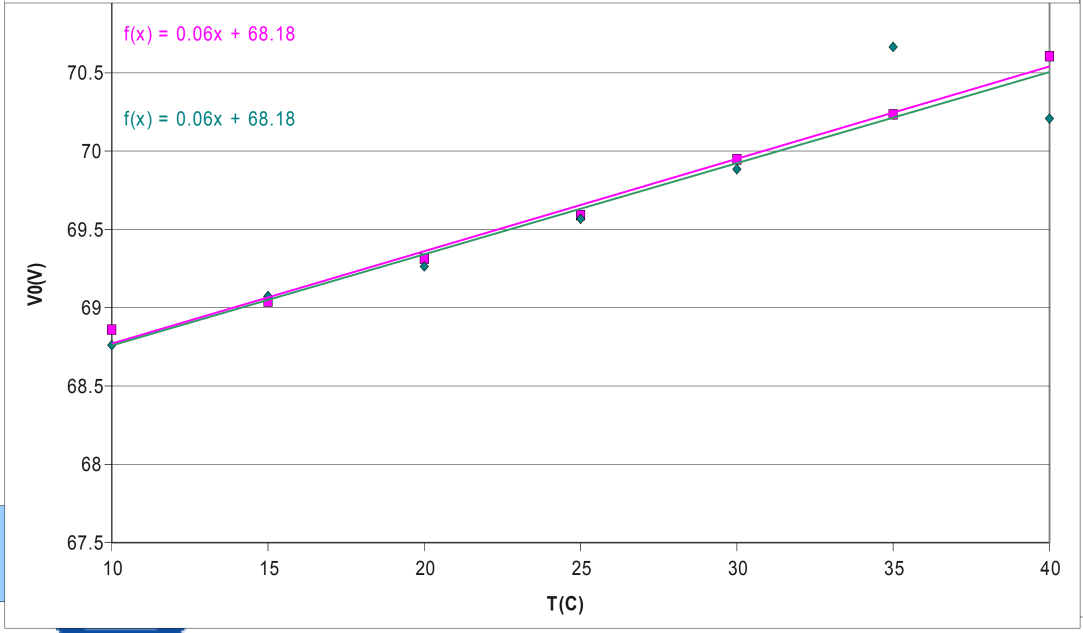


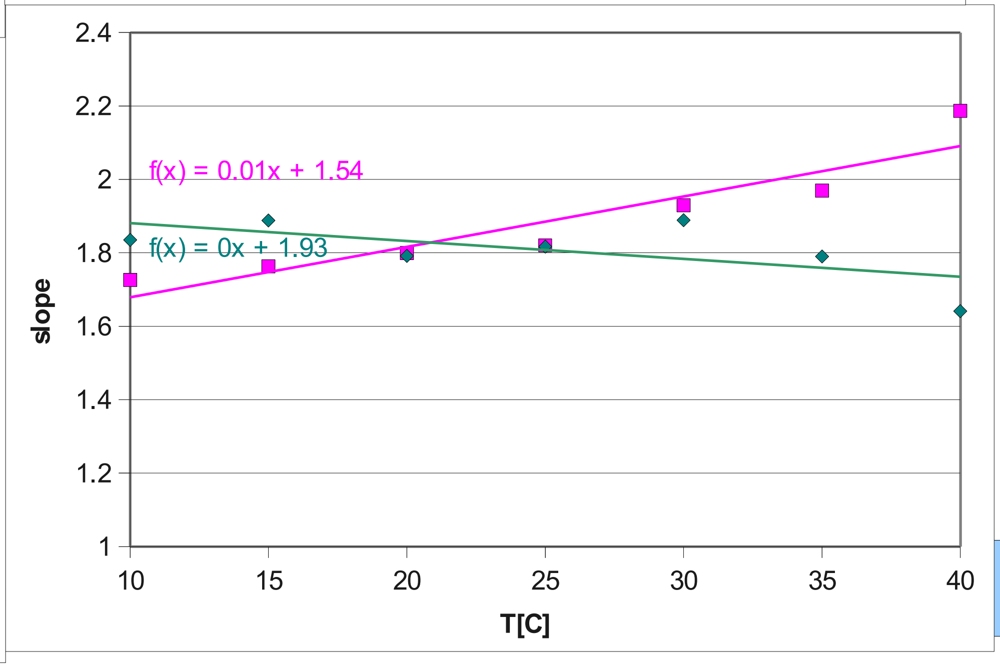
Comparison Before/After Second set

- Hamamatsu









Healing

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