Towards the pixel specifications

Torino MVD group

PANDA Collaboration meeting, GSI, 2-6 2009

Overview

- pixel readout specifications
- mechanics, cooling and constraints
- milestones
- results from epitaxial silicon tests
- results from ToPix_2 prototype

Pixel readout specifications

D. Calvo

Pixel readout specifications I

Work in progress !
Deadline to freeze the requirements : April (->June)

Parameter	**Requests**	**Different request ?**	**+ Safety factor**	**Final Specifications**
Pixel size	100 μm x 100 μm Chip: 1 cm^2, 10000 pixels	50 μm x 200 μm Chip: 1 cm^2, 10000 pixel		
dE/dx	ToT (Time over Threshold)			ToT
Charge dynamic range	100 fC (625000 e-, ~ 2.2 MeV) (90 fC for n, >100 fC for p)			
Clock	50 MHz	100 or 200 MHz		
Time resolution	5.77 ns rms @ 50 MHz (using one clock edge)	2.88 ns rm @ 50 MHz (using both clock edges)		
Time stamp	Clock defined	twice clock defined		
Data rate	800 Mbit/chip (50 bit/ev) 800 Mbit/chip (60 bit/ev) (12.3 Mhit/chip (1cm2)at max)	1.6 Gbit/chip	30% 8%	

Pixel readout specifications II

Parameter	**Requests**	**Different request ?**	**+ Safety factor**	**Specifications**
Analog gain	~ 40 mV/fC			
ToT gain	180 ns/fC @ rms 5.77 ns	90 ns/fC @ rms 2.88 ns		
ToT spread				
Max ToT	18 μs @ rms 5.77 ns	9 μs @ rms 2.88 ns		
Signal polarity	Either (freedom of sensor choice)			Either
Noise quantization	~ 200 e- rms			
Noise analogue	~ 200 e- rms			
Leakage current (sensor)	50 nA/pixel			
Saturation σ for SEU				
Threshold LET for SEU				
Total Ionizing Dose (Panda lifetime)	10 Mrad			
Neutron fluence (Panda lifetime)	$5 \cdot 10^{14}$ n 1MeV eq./cm^2			
Power to dissipate	~ 750 mW/cm^2		33%	

Pixel readout specifications III

Higher safety factors mean

- higher power (track width on the bus…)
- more cooling (larger pipe...)
- larger material budget

Parameters as pixel size, dE/dx, dynamic range, sensor type produce changes on electronic circuit in the pixel readout cell (analogue and digital sections) and then the ASIC layout
(Mazza, Rivetti, Kugathasan)

Parameters as clock, time resolution, time stamp, rate produce changes on digital electronic scheme on the pixel readout cell and the end column section,…, then the ASIC layout
(Mazza only!!)

After two ToPix prototypes for understanding the 130 nm technology and the pixel format issue, and for testing the circuit optimization with respect to the radiation damage….
…we need to freeze the specifications for the pixel readout

- not only to limit time-consuming iterations
- but also to fit in the 2009 budget for panda, in Italy
- and to have the needed time to study new prototypes before going into the production….and commissioning (any news concerning FAIR timescale?)

Mechanics, cooling and constraints

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Mechanics and constraints

From February meeting:

- ✓ the work is in progress on strips, pixel and external frame mechanics !
- ✓ request to freeze the external constraints:
  - ✓ beam pipe (angle, dimensions, flanges…)
  - ✓ target pipe (dimensions and flanges…)
  - ✓ tracker (straw) mechanics
- ✓ MVD mechanics meeting timescale: 2 months (next mvd mechanics meeting at the end of March in Torino)

My suggestions

- ✓ table (with date) to summarize the external constraints and other information, as temperature, mechanical stress…
- ✓ short report (e-mail) with the more important thing of these mechanics meetings

Pixel COOLING: First Test Results in the 2009

On behalf of Silvia Coli

- ✓ Quite a number of preliminary thermal simulations on pixel barrels and pixel disks have been performed.

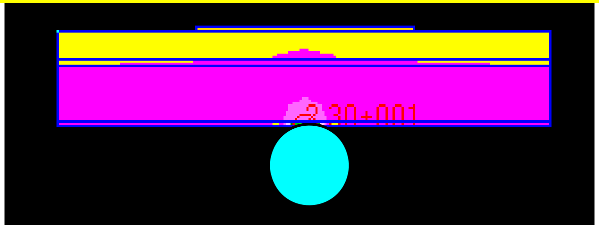
- ✓ Big differences in temperature and thermal efficiency show up introducing the glue layers.

- ✓ Large improvements of thermal efficiency can be obtained optimizing the contact with cooling tubes (to be tested).

- ✓ Tests started on first 4 prototypes.

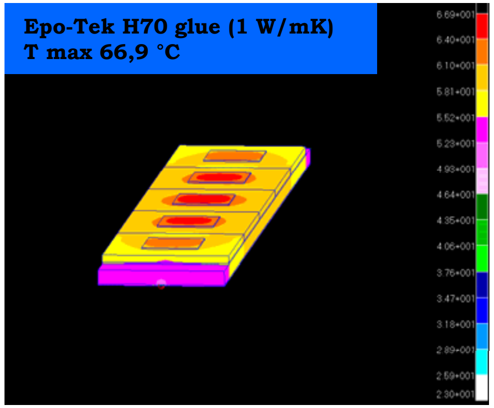
- ✓ Many tests are needed to tune and to verify the thermal simulations and to find out the most efficient configuration.

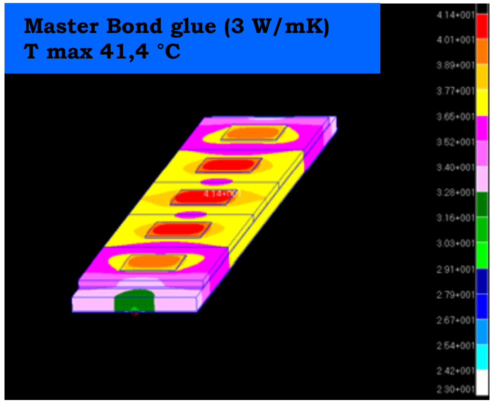
Thermal SIimulations of the Test Model:

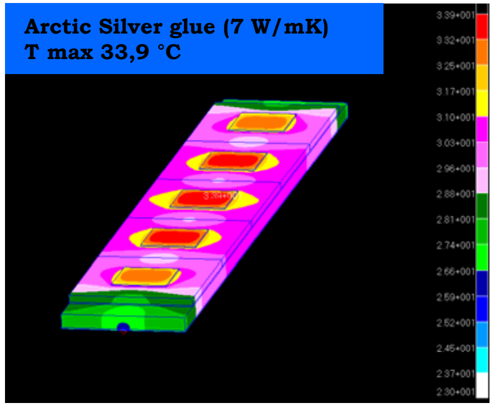


FIRST TEST MODEL:
Dummy FEE: 0,5 mm Alumina (20 W/mK) + 0,1 mm with Power: 5W
Glue layer: 0,1 mm (Epo-Tek H70, Master Bond EP30AN, Arctic Silver)
Carbon foam: 1 mm (40 W/mK)
Glue layer: 0,1 mm (Epo-Tek H70, Master Bond EP30AN, Arctic Silver)
Cooling water 18°C (about 23°C on the wall). Flow rate : 0,3 lit/min
MODEL LENGHT: 50 mm

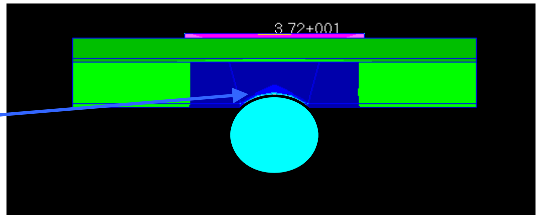
Different Thermal glues



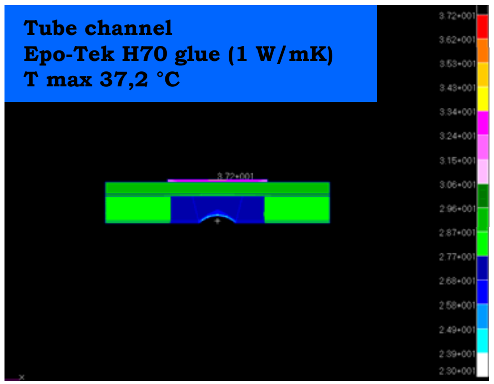


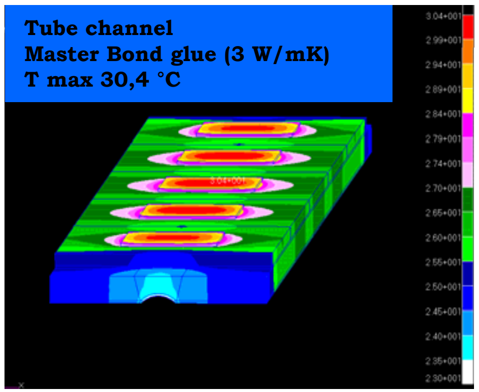


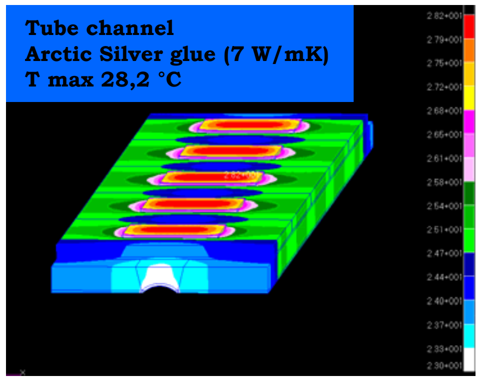
Improving contacts

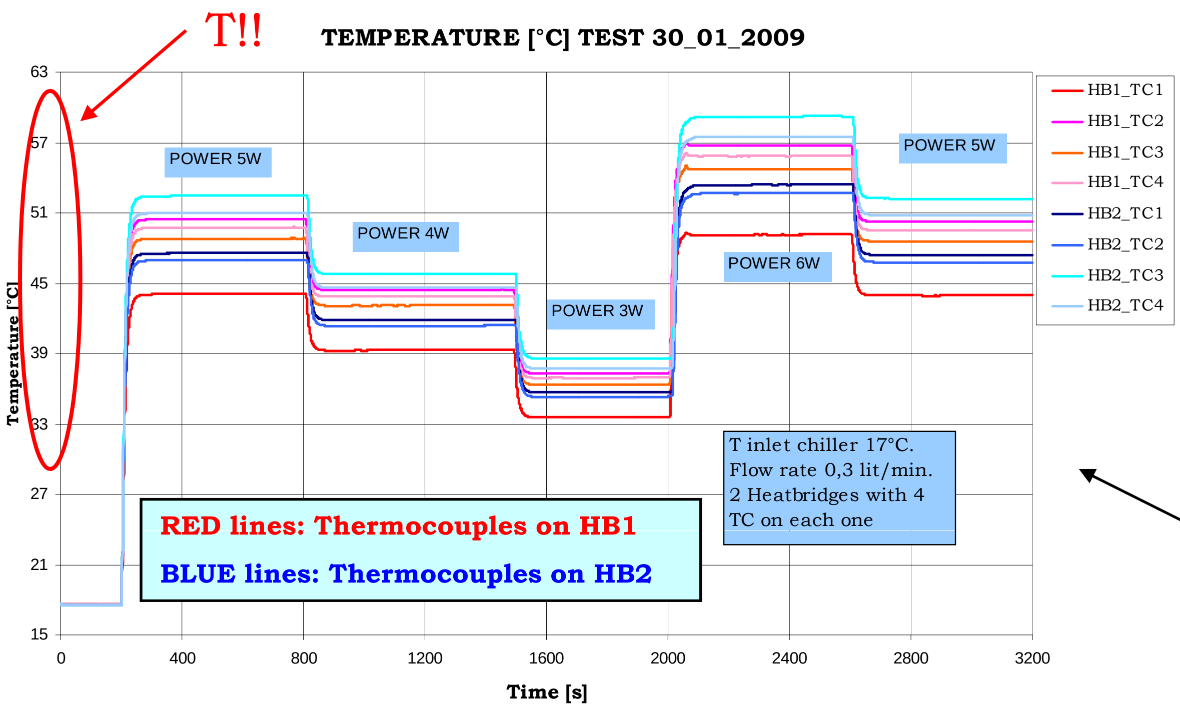


Better contact and different glues



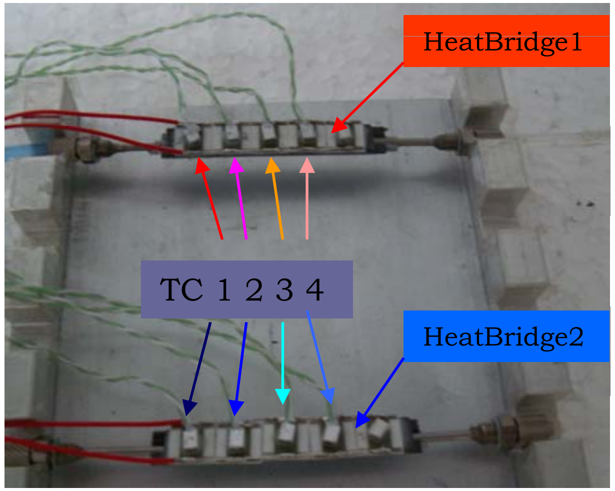


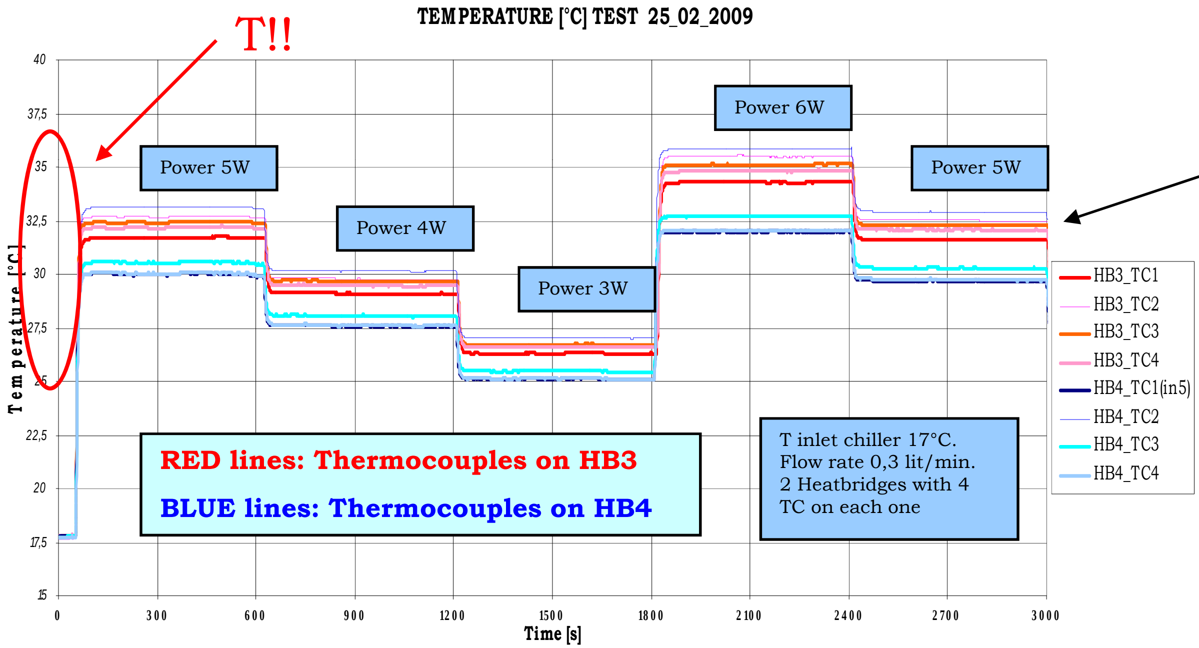




TEST RESULTS ON PROTOTYPES GLUED WITH MASTER BOND

HB1 and HB2: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D; carbon foam 1 mm; dummy chip in alumina.





TEST RESULTS ON 2 PROTOTYPES GLUED WITH ARTIC SILVER

HB3: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D.; carbon foam 1 mm; dummy chip in alumina. Problem with dummy chip2: probably damaged (HB3_TC2 instable).

HB4: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D.; carbon foam 1 mm; tube contact improved; dummy chip in alumina. Problems with welds in dummy chip 1 and 2 (HB4_TC2 higher T respect blue TC1(in5), TC2, or TC3).

Cooling Activity

A NUMBER OF MODELS HAVE TO BE REALIZED:

- To test different geometries to optimize the thermal efficiency: i.e. tube channels on Carbon foam have to be investigated (both for pixel disks and barrels) to improve the contact with cooling tubes.
- To test the thermal effects with different glues.
- To test the results repeatability.
- To test the thermal stability.
- To tune and to verify thermal simulations for the real pixel design.

AT PRESENT WE HAVE:

- The chiller which has been delivered.
- The hydraulic circuit now is ready.
- The equipped DAQ station.
- 4 Prototypes have been tested.
- Different glue
- Different carbon foam

Milestones for the 2009

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Milestones for 2009 in Turin

They depend from:

- ✓ the available INFN budget:
  - budget s.j. (ok for external frame of the mechanics and other parts to continue cooling test)
  - more budget connected to the CCS committee - answer expected by the end of March
- ✓ the time spent on this project by the people
- ✓ the freezing time of the major constraints needed to continue the project

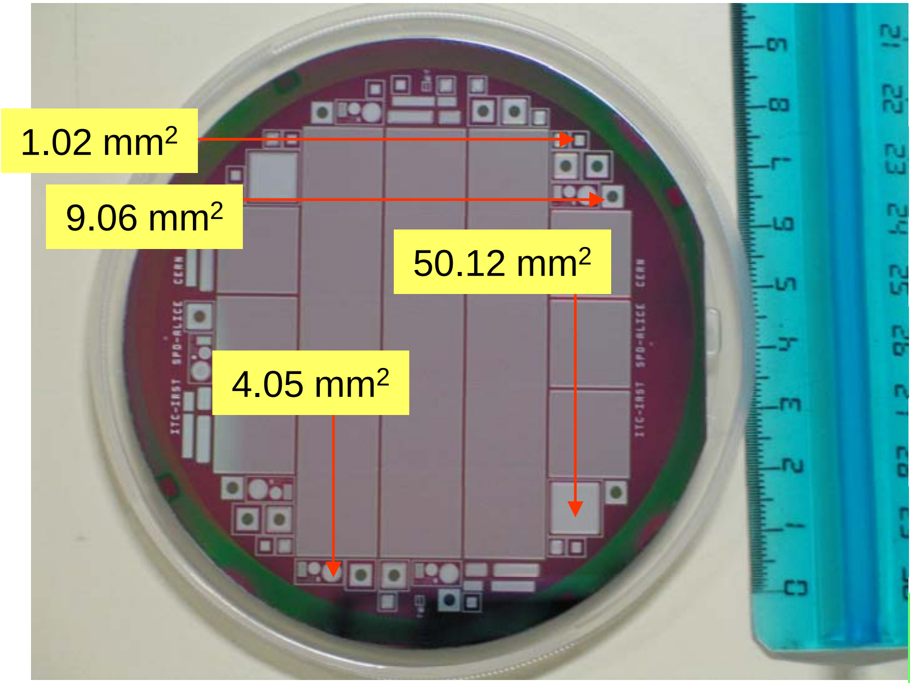
Milestones:

- ➢ mechanical design
- ➢ readout architecture: study of the next prototype and new ASIC submission
- ➢ first bus design
- ➢ other tests on radiation damage

Results from epitaxial silicon tests

D. Calvo

Diodes from epi-wafers



Epitaxial layer
49± 0.5 μm, 4060 Ω·cm, n/P
74± 0.5 μm, 4570 Ω·cm, n/P
98± 0.5 μm, 4900 Ω·cm, n/P

\+ Cz substrate
525 ± 20.0 μm,0.01-0.02 Ω·cm, n^+/Sb

= final wafers
Epi-50: 49μm Epi layer + Cz = 100 μm
Epi-75: 74μm Epi layer + Cz = 120 μm
Epi-100: 98μm Epi layer + Cz = 150 μm

Diodes from 300 μm FZ wafer have been used as reference

Test of epi-diodes with neutrons

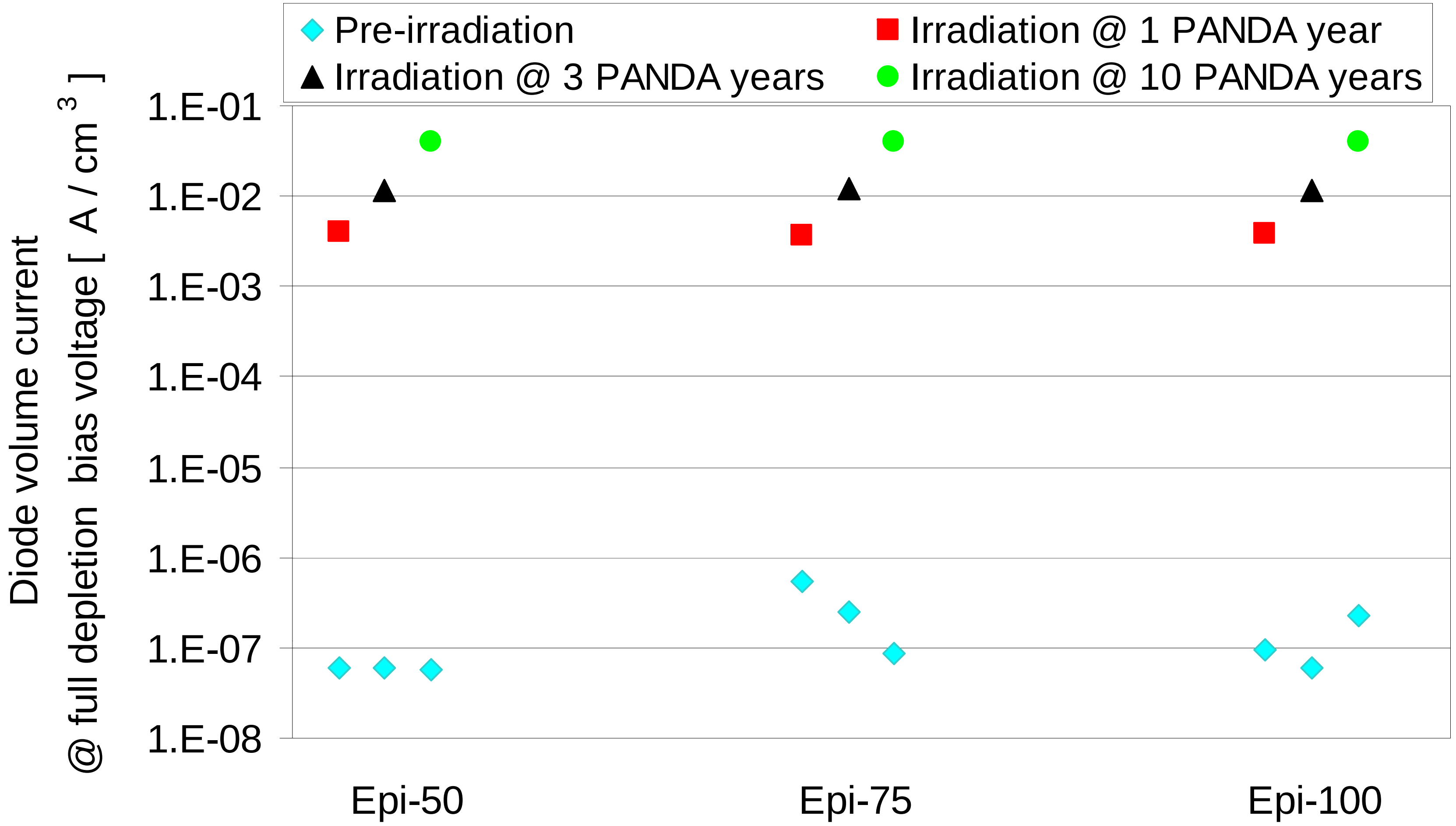
• in the central channel of the Pavia nuclear reactor the maximum neutrons flux can reach 1.87×10^{13} n/(s·cm^2) @250 KW nuclear reactor power

• taking into account the neutron energy distribution up to 18 MeV and the displacement damage cross section, a flux of 5.03×10^{12} n(1MeV$_{eq}$)/(s·cm^2) can be obtained for the displacement damage study of epitaxial diodes

• for our purposes, the irradiations were performed in 1000s at three nuclear reactor power values: 2.5 kW, 7.5 kW and 25 kW

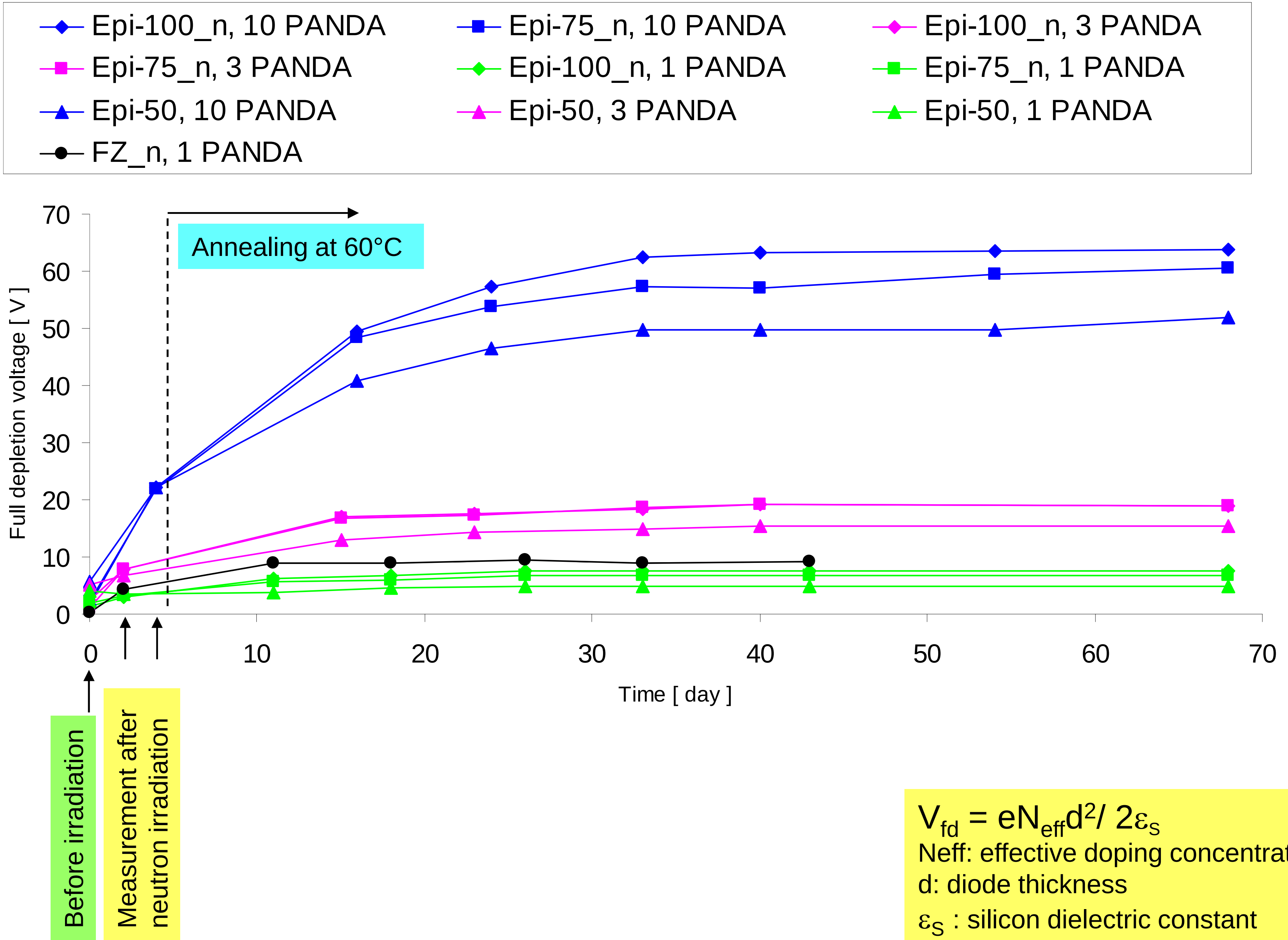
• the equivalent fluence values on the diodes were:
5.13×10^{13}, 1.54×10^{14} and 5.13×10^{14} n(1MeV$_{eq}$)/cm^2
corresponding respectively to 1, 3 and 10 years of PANDA lifetime

Results: the damage constant



The damage constant α is estimated as $\alpha=\Delta J/\Phi$.
ΔJ is the difference between the diode volume current before and after the irradiation, both measured once the full depletion voltage has been reached.
Φ is the corresponding equivalent fluence.
The radiation damage parameter defined above is $\alpha=7.6(\pm0.3)\times10^{-17}$ A/cm for all diodes.

Results: full depletion voltage normalized to epi50



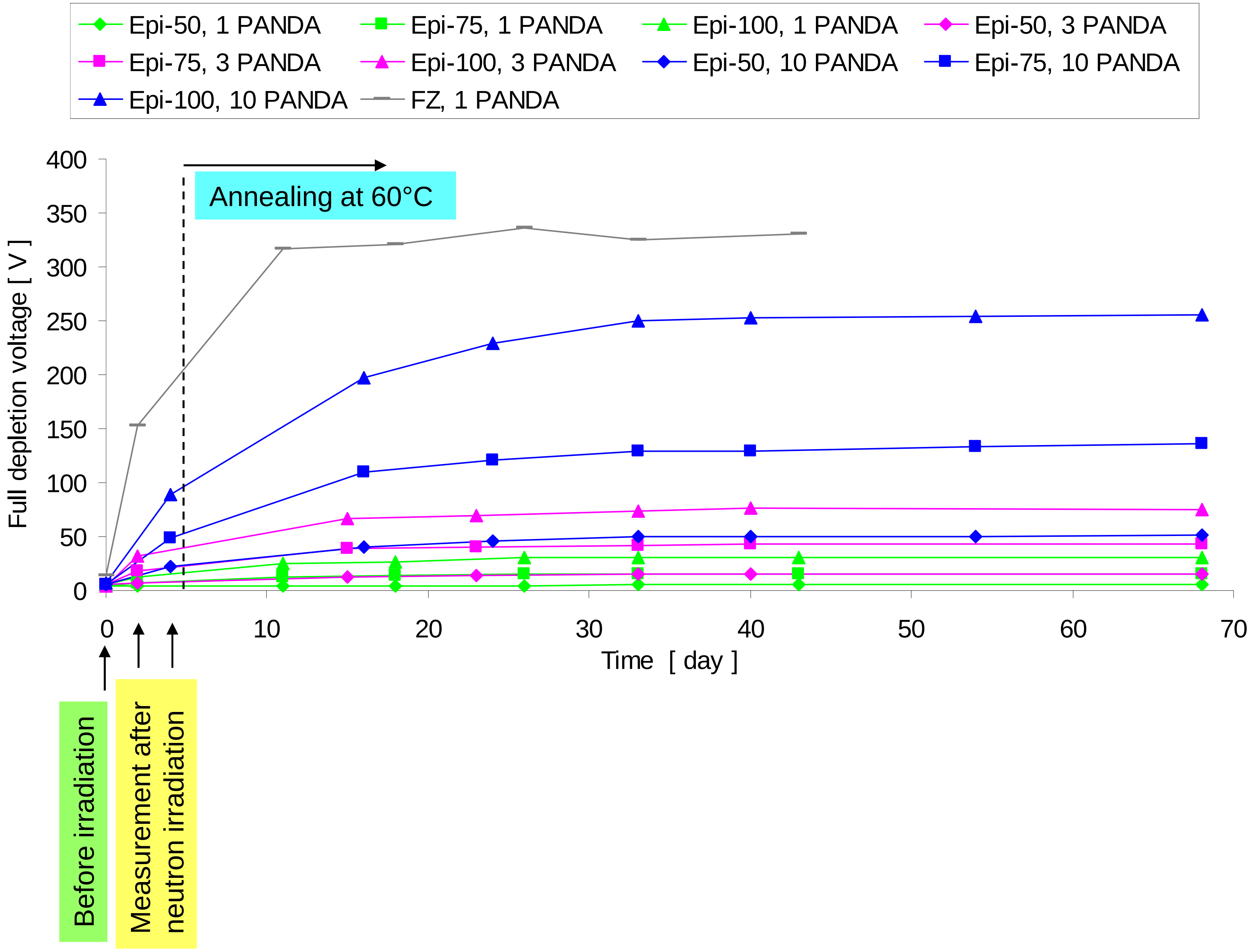
$V_{fd} = eN_{eff}d^2/\ 2\varepsilon_S$

Neff: effective doping concentration

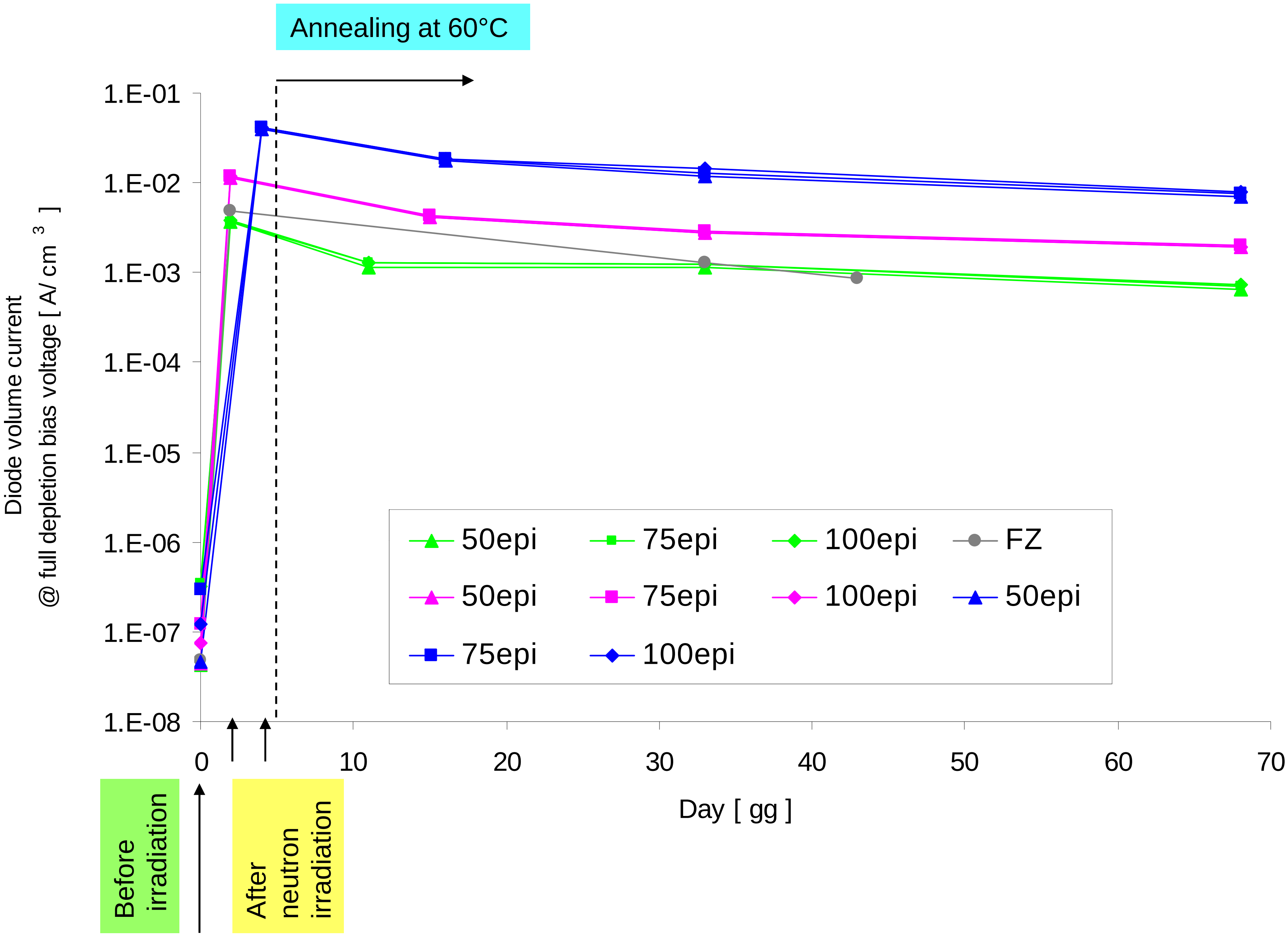
d: diode thickness

ε_S : silicon dielectric constant

Results: full depletion voltage



Results: diode volume current @ full depletion voltage



Results from electronic prototype

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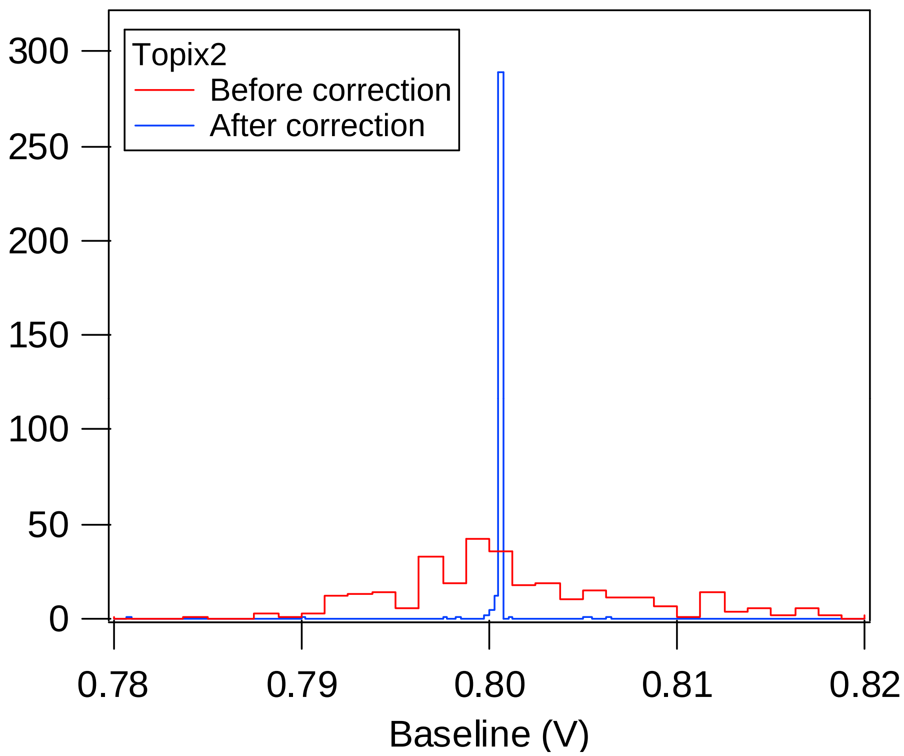
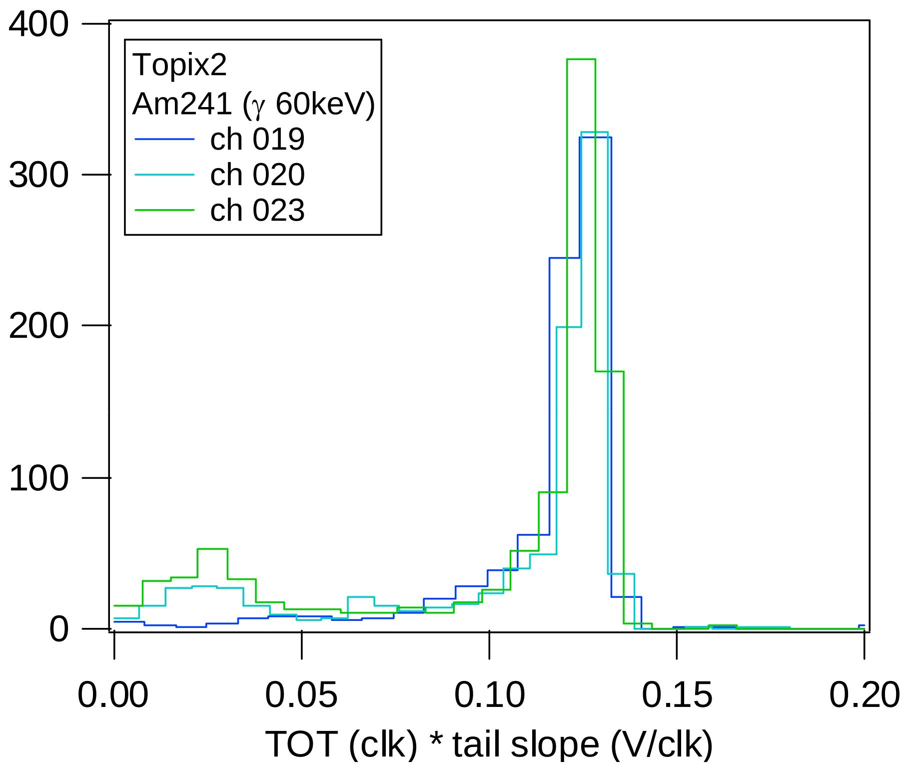
ToPix and sensor

- ToPix_2 - FZ diode (400µm x 400µm, 200 µm thick) connection using wire bonding
- test with gamma rays (60 KeV) from 241Am radioactive source



Individual pixel DAC baseline correction



TOT calibration