

Muse meeting

Plans for irradiation tests @ HZDR

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MUSE

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Talk Layout

Evaluate the MPPC behavior after 3 years of run:

- 1) New neutron test at FNG;
- 2) Innovative annealing procedure
→ still under investigation
- 3) Response / Resolution and Leakage current vs temperature;
- 4) CsI+MPPC test with CR vs Vbias to study the dependence of the PDE from Vbias;

Photosensors

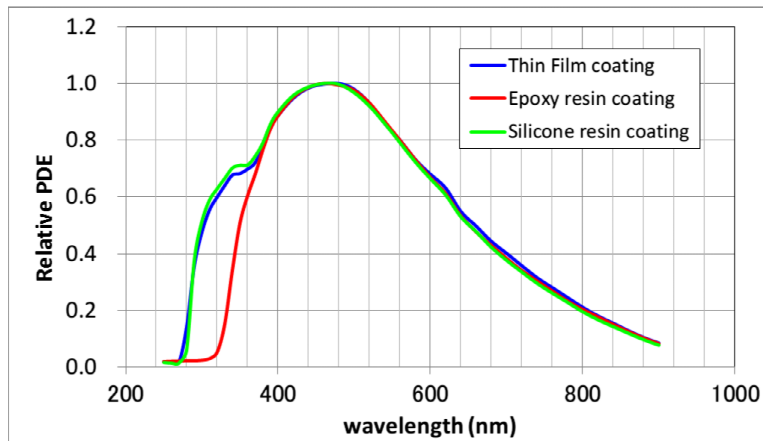
SPL and Thin Film MPPC

- We have tested the TSV MPPC (12x12 mm²) from Hamamatsu with SP and Thin Film protection layer. Both are ok coupled with pure CsI:

- ~ 30 (20)p.e./MeV with (without) optical grease and crystals wrapped with Tyvek
- Time resolution < 150 ps @ 100 MeV with 45 degrees e⁻ impact angle
- E.N.E ~ 100 keV

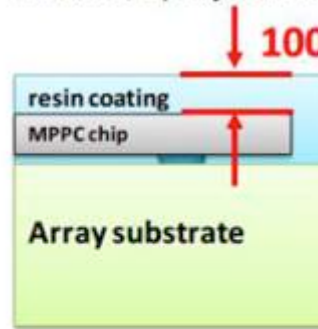
see docDB 5701-v6 and others

PDE comparison



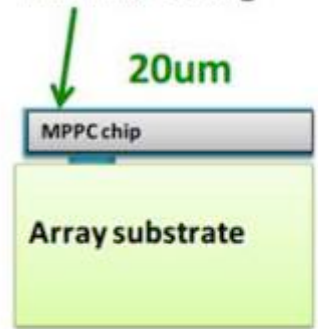
Thin Film coating and Silicon resin coating has PDE advantage in UV region.

Silicone, Epoxy resin coating



- merit
 - robust to the mechanical shock
 - easy handling (during assy.)
 - superior transparency in UV region
 - silicone resin coating type -

Thin Film coating



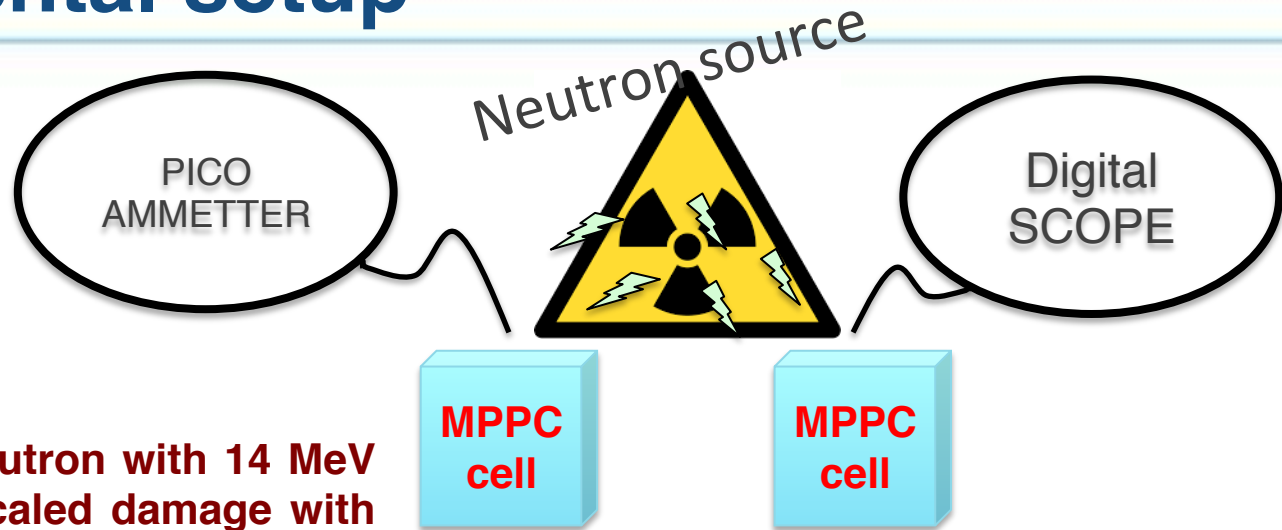
- merit
 - tough coating
 - (mechanical shock should be avoided)
 - superior transparency in UV region
 - cross-talk suppression in the coating
 - super flatness (minimum bending)

❑ Irradiation done @ FNG

→ Measurement of response and leakage current ..

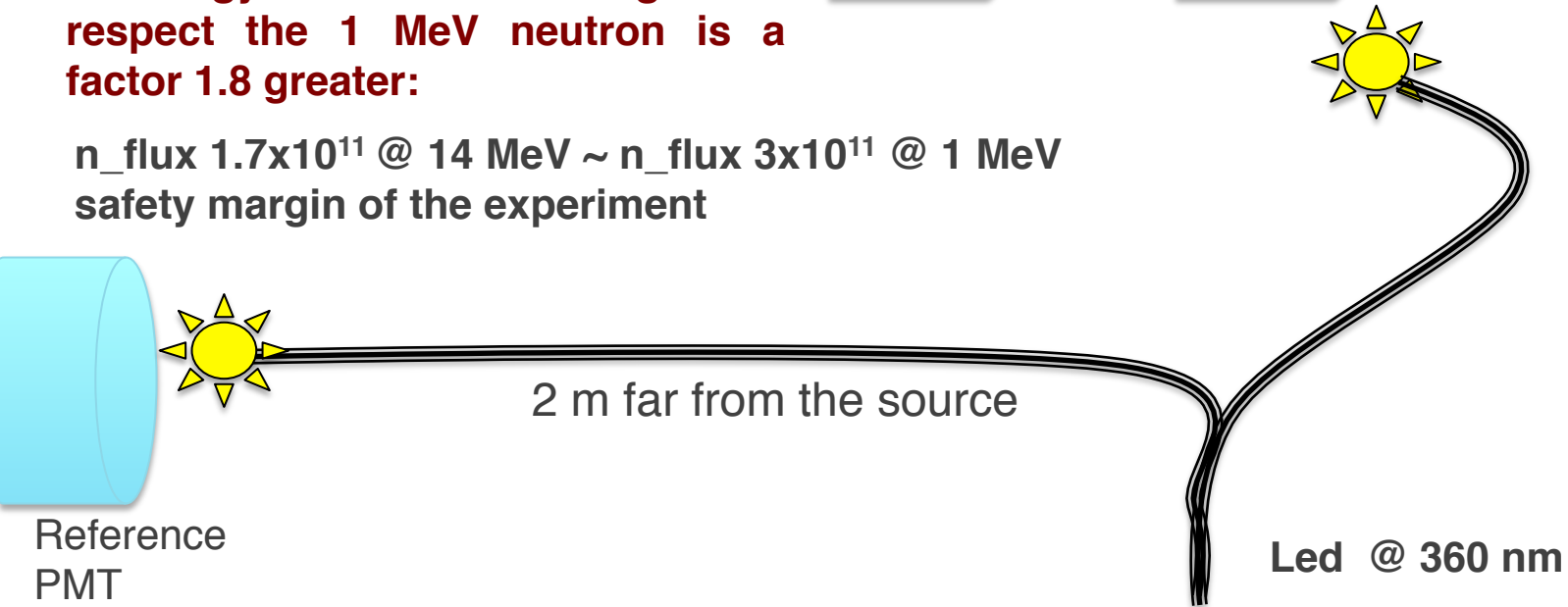
MPPCs and FBK at FNG

Experimental setup



FNG provides Neutron with 14 MeV of energy. The scaled damage with respect the 1 MeV neutron is a factor 1.8 greater:

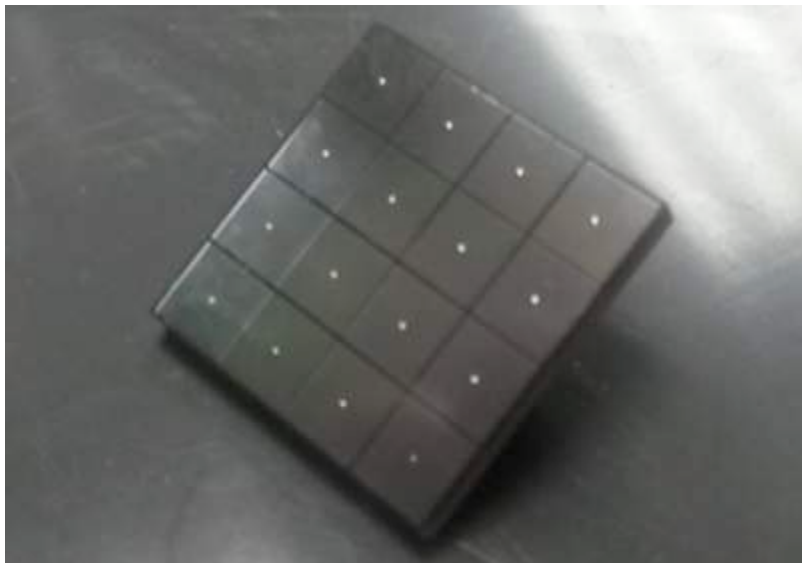
$n_{flux} 1.7 \times 10^{11} @ 14 \text{ MeV} \sim n_{flux} 3 \times 10^{11} @ 1 \text{ MeV}$
safety margin of the experiment



SiPMs tested

	V op (V)	Total flux (n/cm ²)	Total flux (n_1MeV/cm ²)
SPL 4 SiPM	53.9	2.2 x 10 ¹¹	4 x 10 ¹¹
Micro Film SiPM	53.95	2.2 x 10 ¹¹	4 x 10 ¹¹
FBK SiPM	32.5	2.2 x 10 ¹¹	4 x 10 ¹¹

SPL – Micro Film



16 MPPC of 3x3 mm²

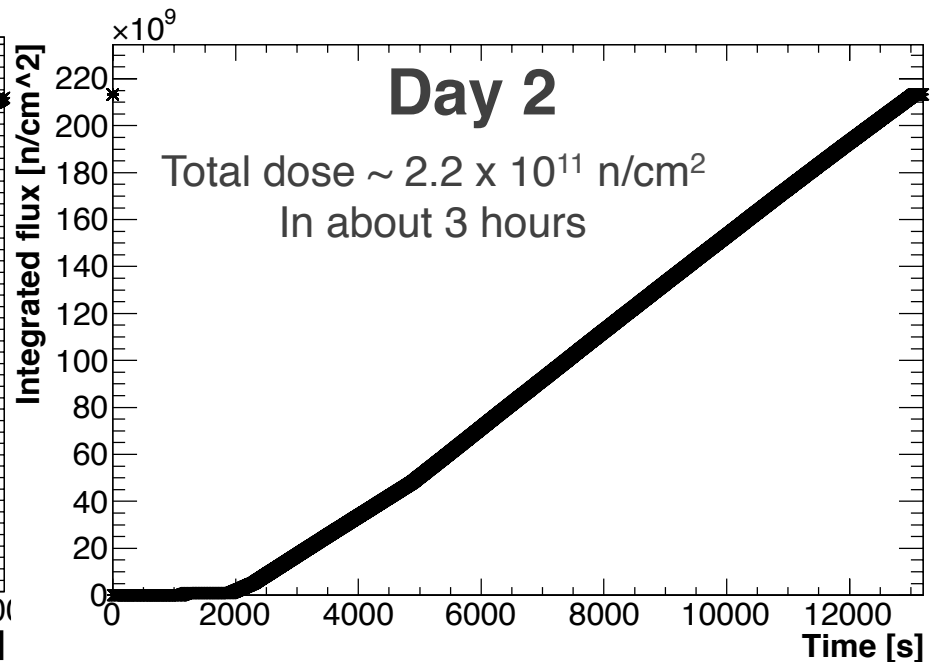
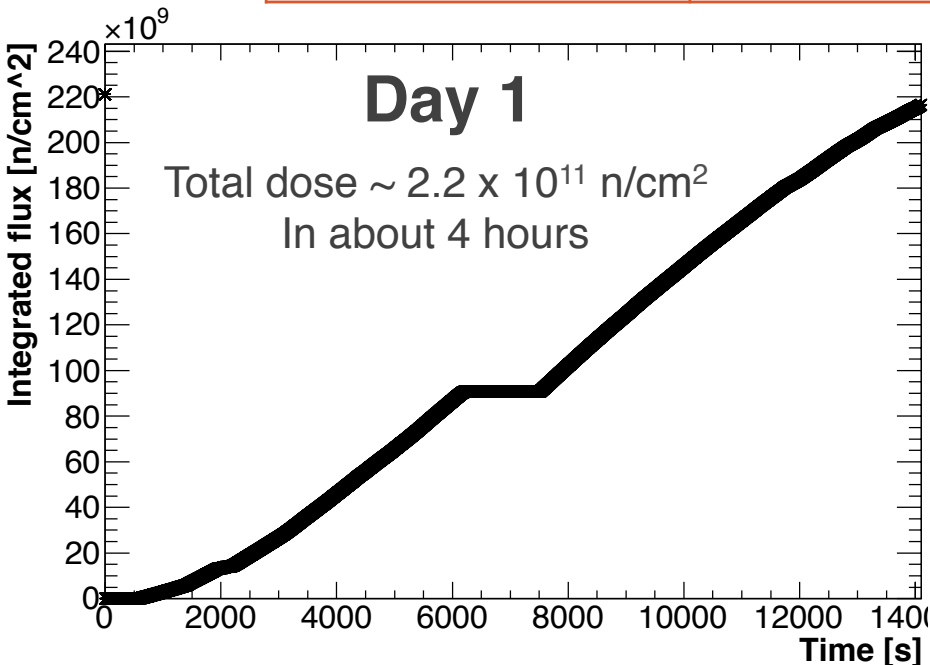
FBK



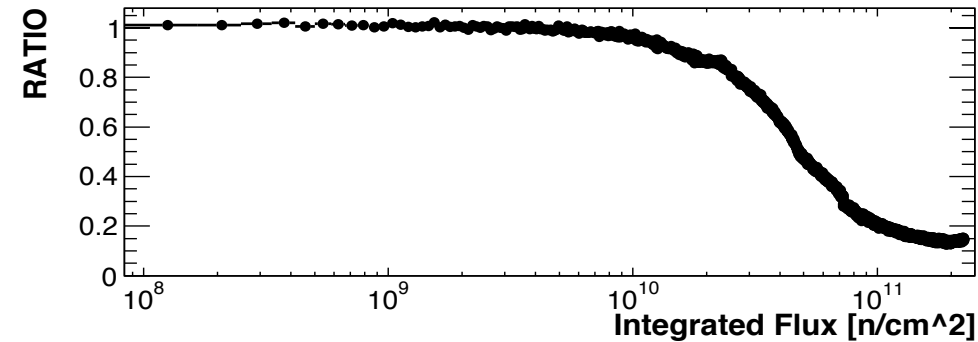
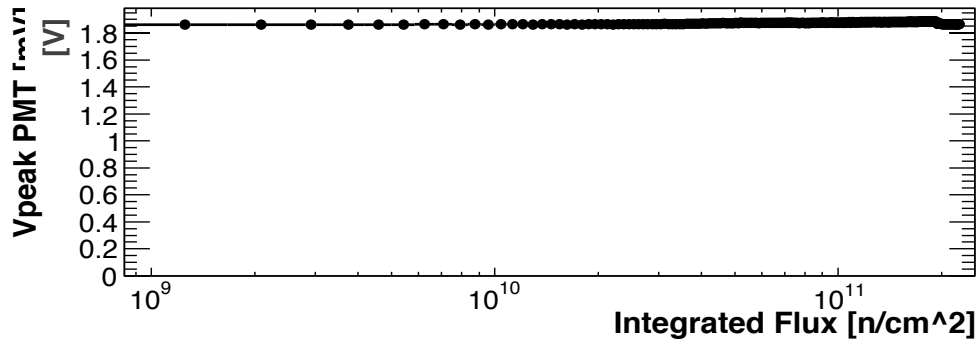
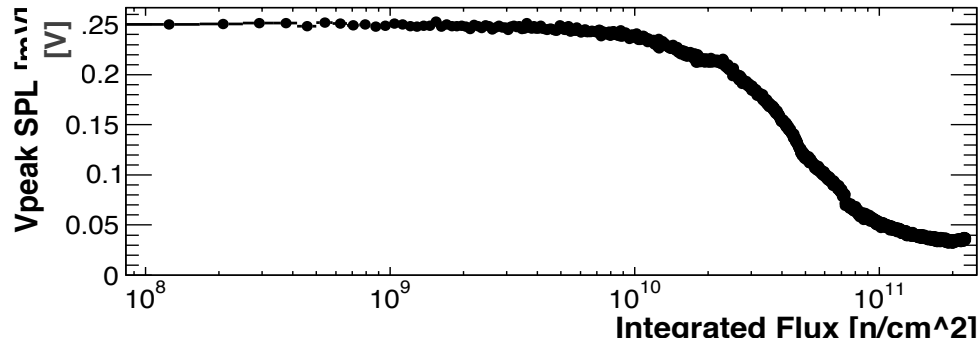
1 SiPM of 6x6 mm²

Irradiation plan

	Day 1	Day 2
Tot neutrons from source	1.36×10^{14}	1.3×10^{14}
Average flux (n/s)	1.09×10^{10}	1.16×10^{10}
Tot neutrons (14 MeV) on SIPM	2.2×10^{11} n/cm ²	2.2×10^{11} n/cm ²

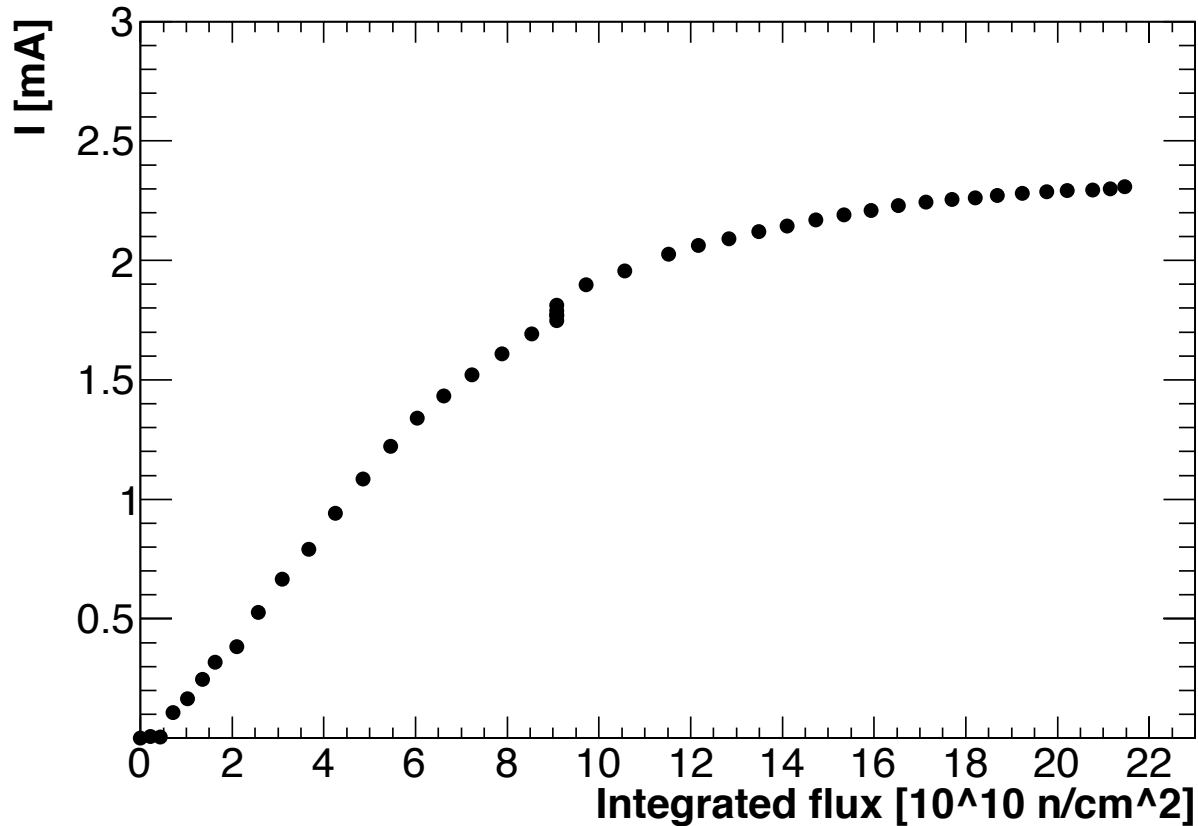


Day 1 – SPL 4 response (1)



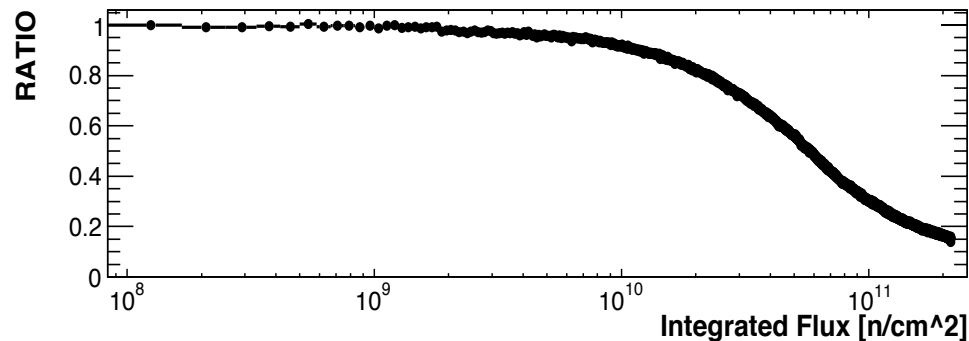
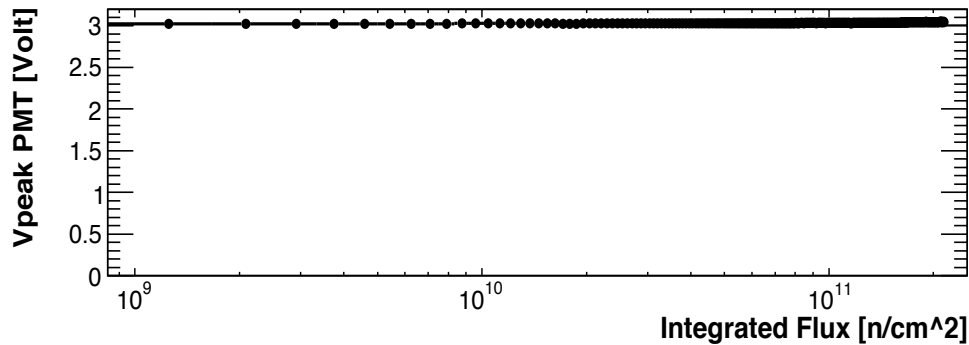
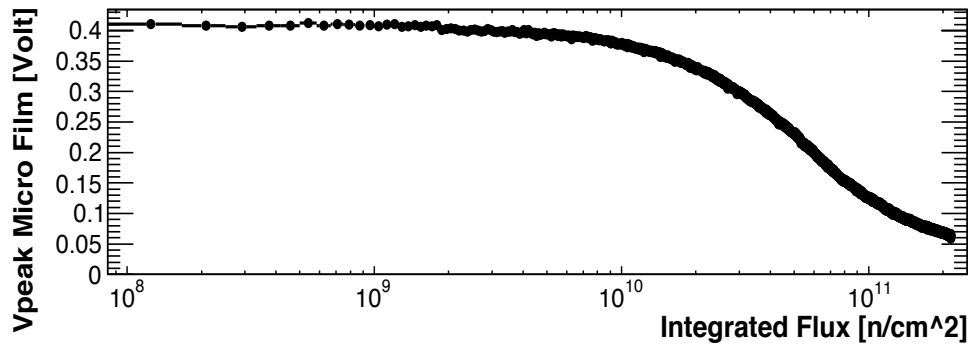
The signal peak decreases from 250 mV to ~ 30 mV

Day 1 – SPL 4 response (2)



The current increased from 100 uA up to ~ 2.3 mA

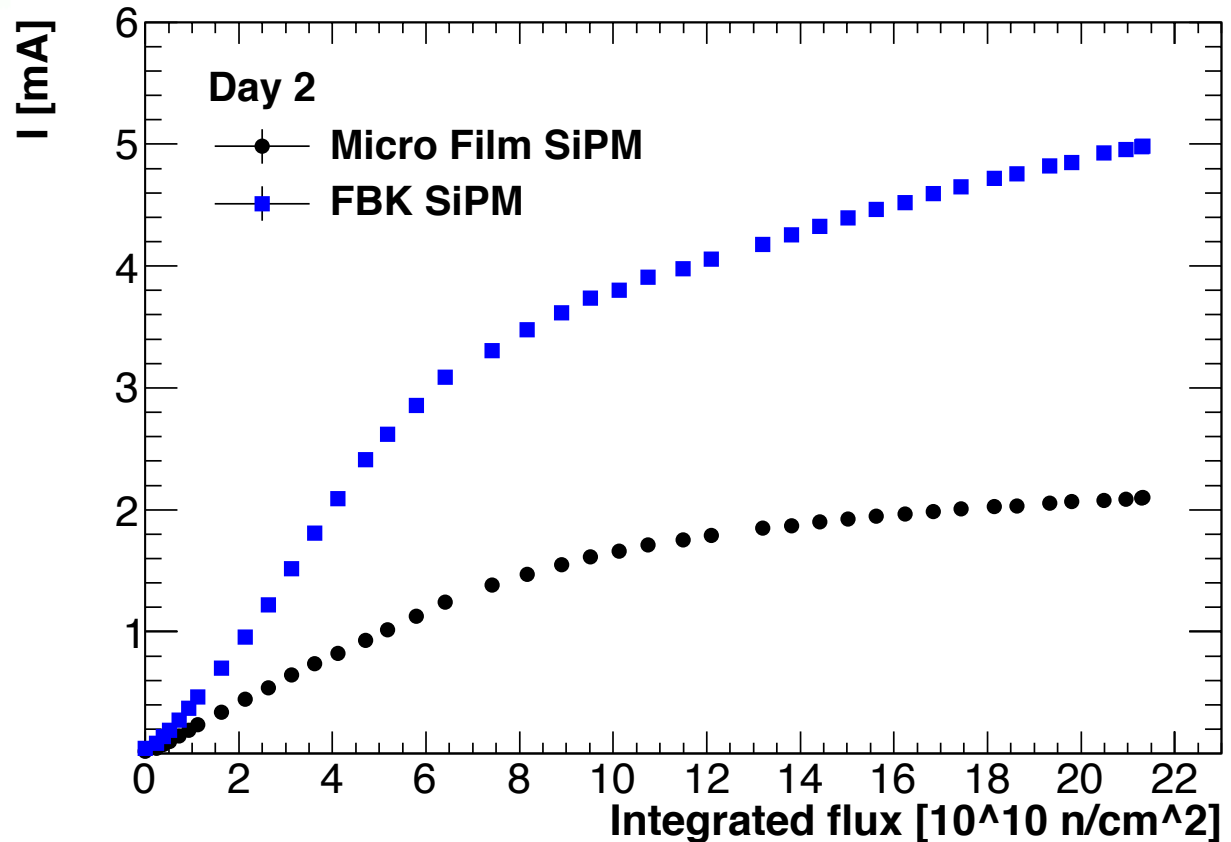
Day 2 – Micro Film Response



The signal peak decreases from
~ 400 mV to 50 mV

Day 2 – Micro Film and FBK responses

Reported current for FBK SiPM has been corrected by a factor of 4, due to the different active area.



The current increased from

- **16 uA up to 2.1 mA (Micro Film)**
- **86/4 uA up to 19/4 ~5 mA (FBK)**

Overview

Operating at V_{op} , not cooling the sensor after $2.2 \times 1.8 \sim 4 \text{ n/cm}^2$ [1 MeV eq.] (equivalent at more than 6 years of run \rightarrow more than the safety value)

- $\sim 2 \text{ mA} * 16 = 32 \text{ mA}$
- a factor 2 given by the natural annealing
- **$\sim 15 \text{ mA per device at 25 degrees}$**

a factor smaller than 3 on the leakage current value for the rest of calorimeter

Goal is to keep the I dark below 2 mA in order not to dissipate more than 100 mW on SiPM and keep the Bias Supply with a limit at 4 mA.

Annealing Induced

Annealing Induced

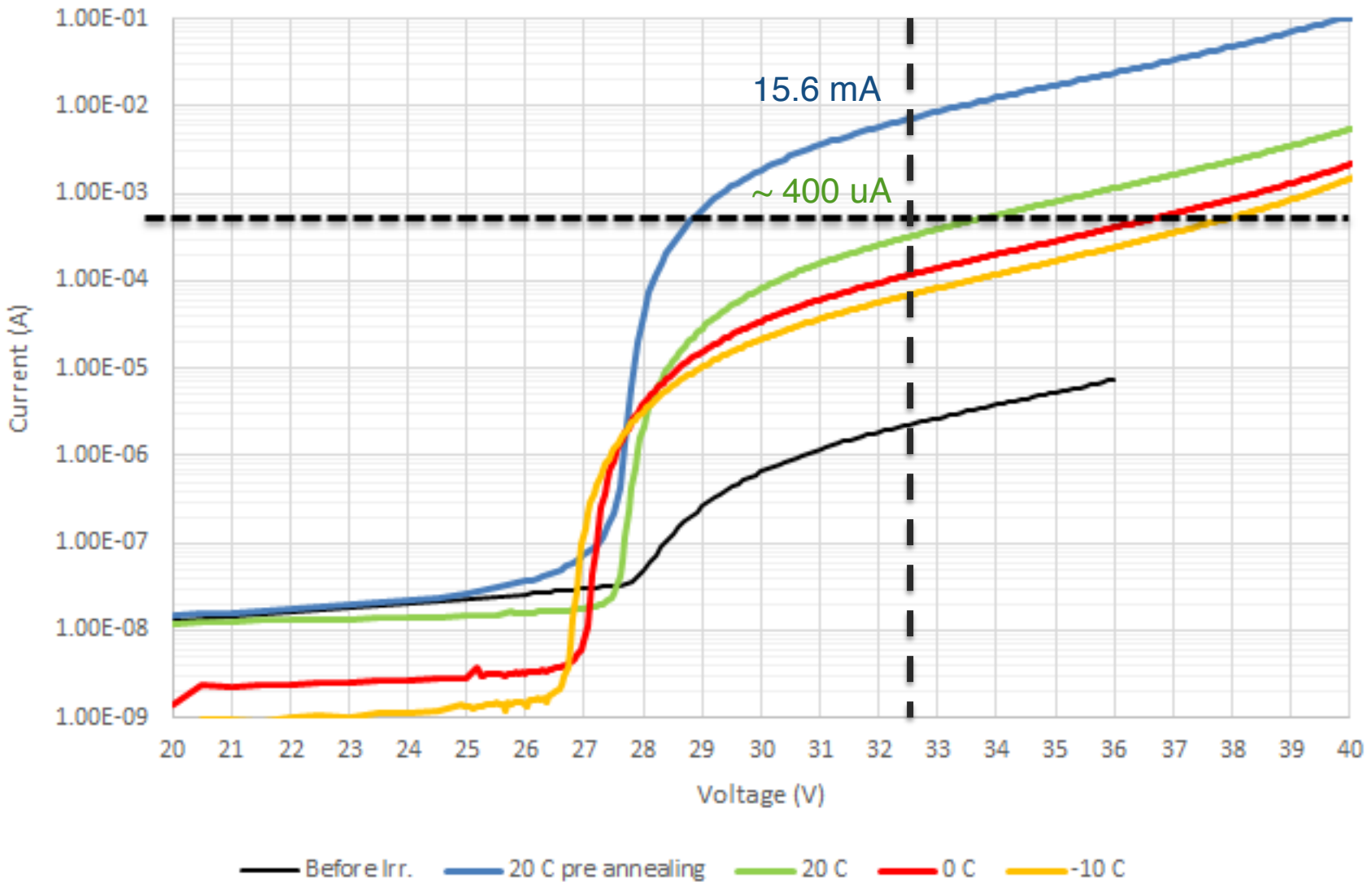
We have kept the 2 MPPCs and the FBK at 10 Volt over the Operational Voltage for ~ 30 seconds

- A huge current has been allowed to flow on the devices;
- A huge increase of the temperature has been measured on the devices: power dissipated on the quenching resistors

Leakage Current Variations
(measurment done in cleaning room):

	Before Annealing	After Annealing
	I (mA)	I (uA)
Micro film	1,72	134,2
SPL 4	2,07	220
FBK	15,6	450
Microfilm (irradiated in July)	0,8	210

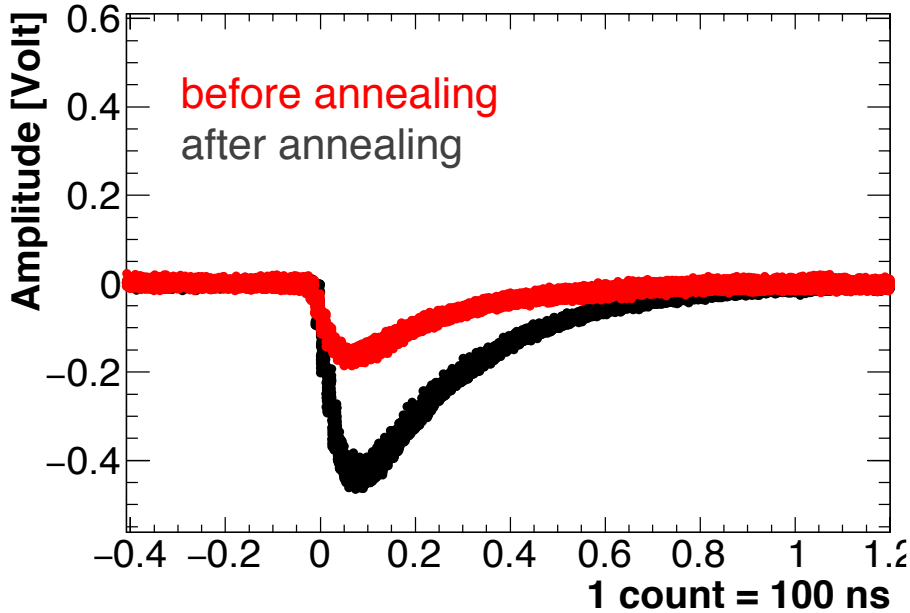
Annealing Induced – FBK measures



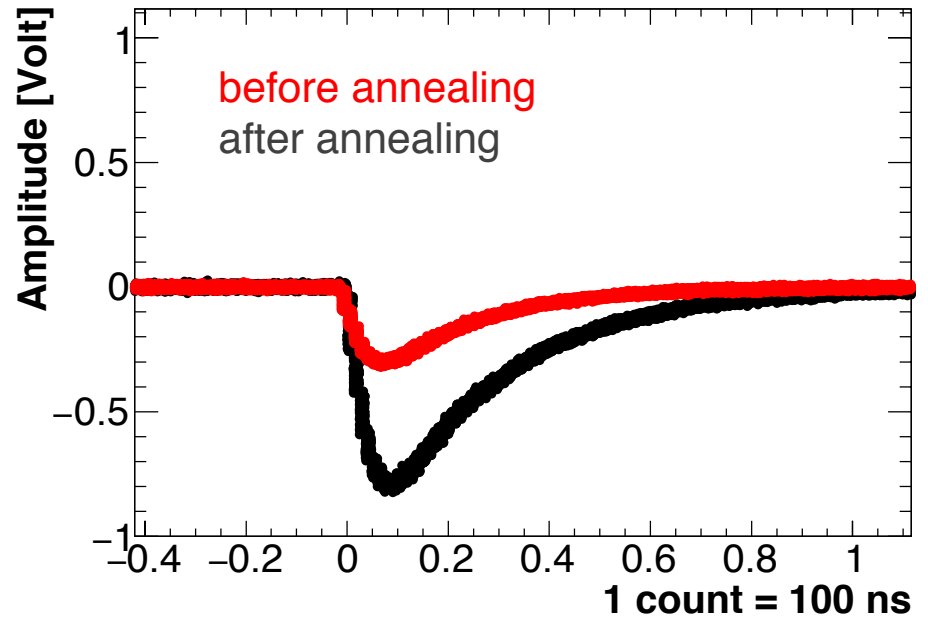
Annealing Induced -> Response Recovery

Also a huge recovery on the response at a blue laser has been observed

Thin Film



SPL



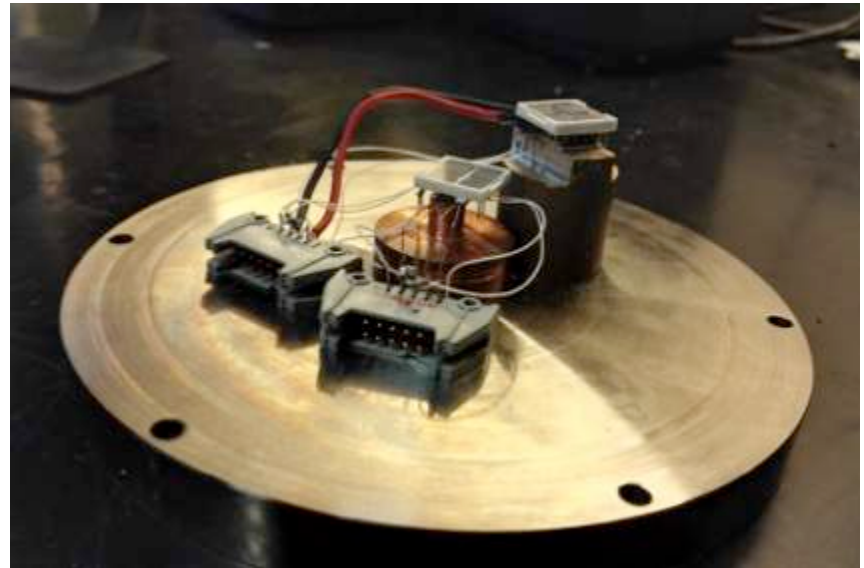
Gain and Leakage Current vs Temperature

Measurements of MPPC vs Temperature

- We have measured the MPPC in a cryostat in a $\sim 10^{-5}$ torr vacuum
- We could change the temperature using a Micro Peltier controlled system



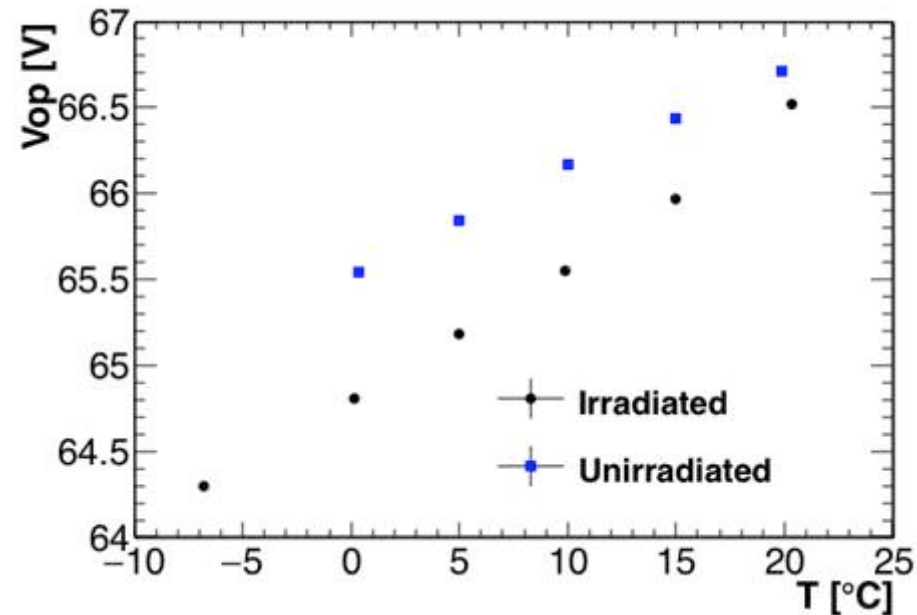
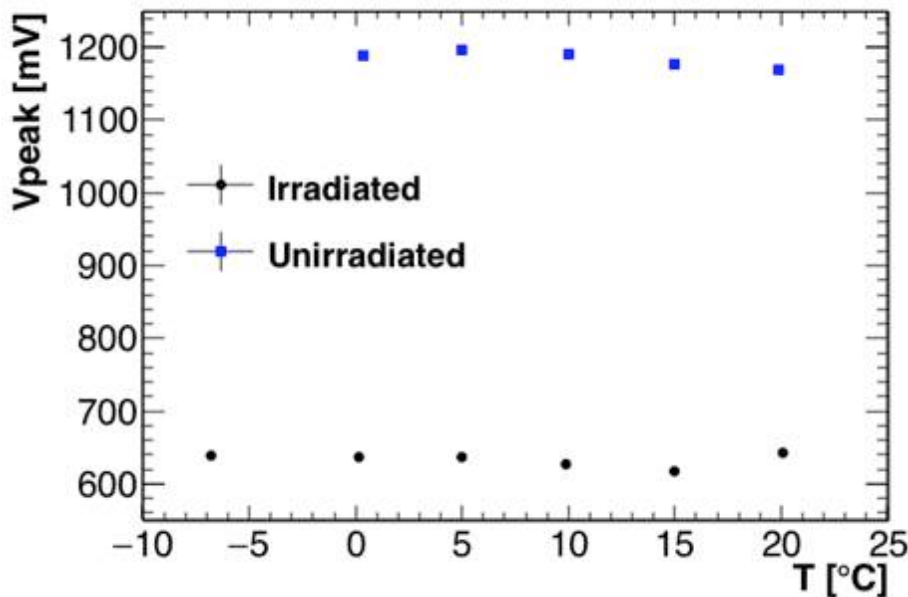
- 1) The response to a blue led has been measured
- 2) The leakage current has been measured using a Keithley Pico ammeter
- 3) We have tested two MPPC from MEG: one standard and one irradiated (1.5×10^{11} n/cm² @ 1MeV eq. \sim 3 years of run in the hottest regions)



Operational Voltage vs Temperature

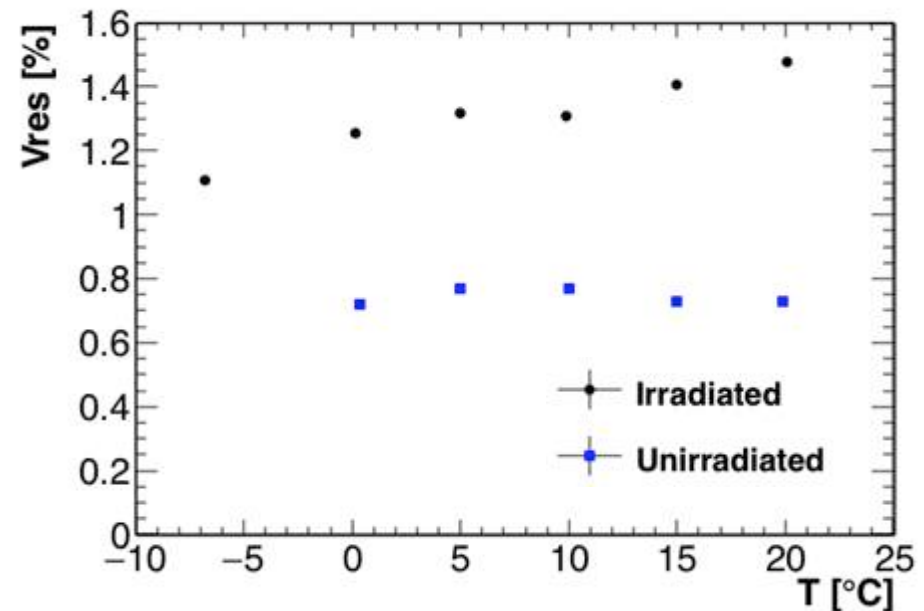
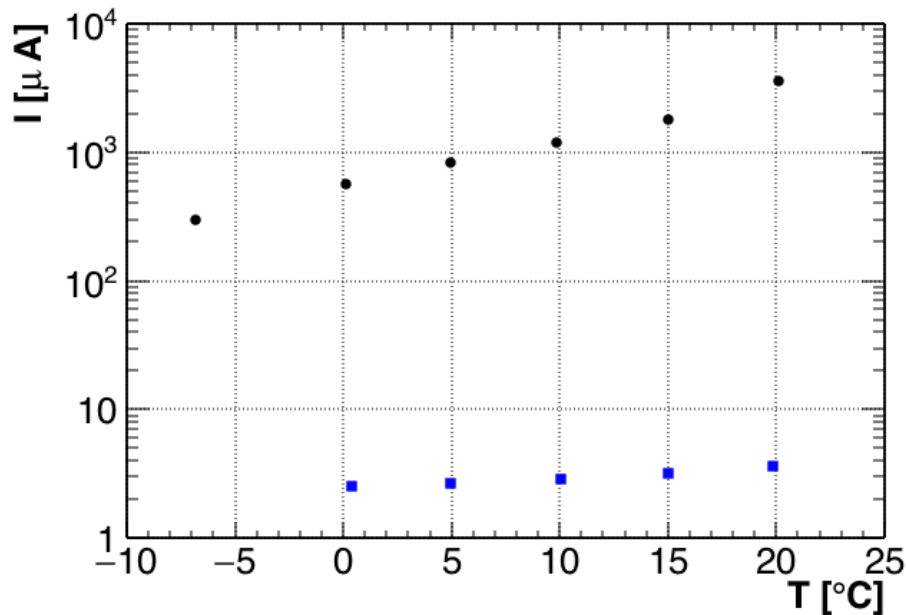
The operational voltage changes with temperature:

- We have re-equalized the operational Voltage keeping constant the led peak value;
- The data are related to a single cell (6x6 mm²).



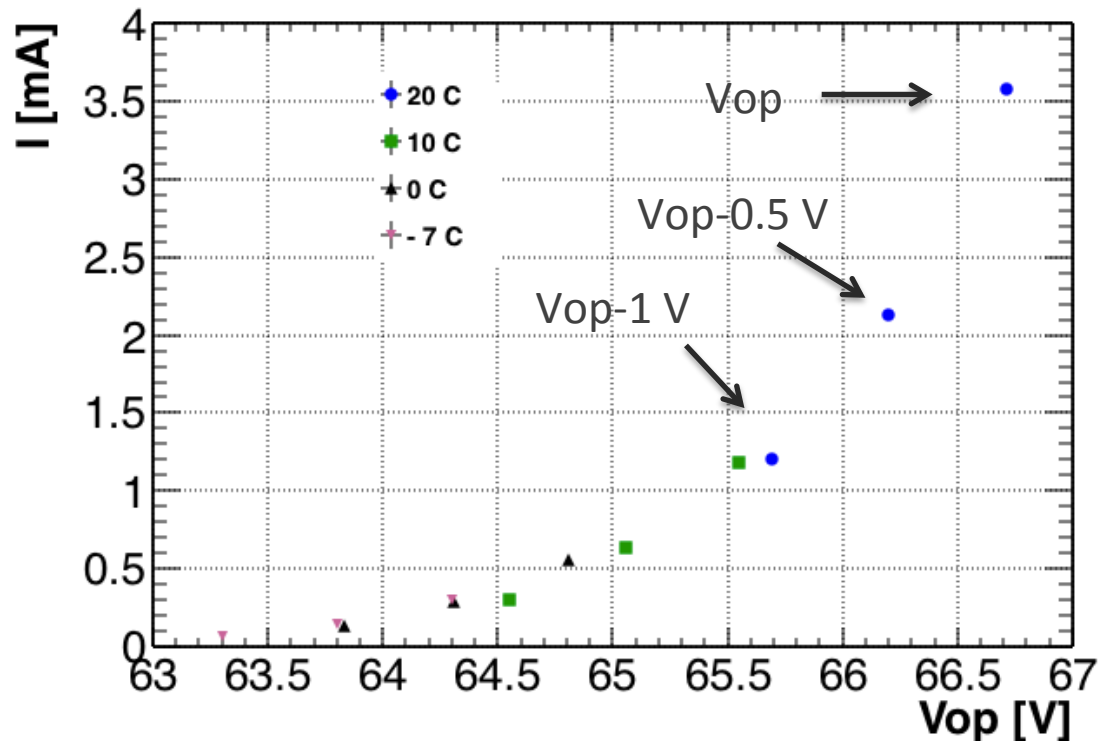
Leakage Current / Response vs Temperature

- We have measured the leakage current of the MPPCs changing the temperature;
- We have measured the response of the MPPCs to the blue led changing the temperature;
- The data are related to a single cell (6x6 mm²).



Leakage Current vs Temperature vs Vbias

- We have measured the leakage current of the MPPCs changing the temperature and three different set of Vbias: Vop, Vop-0.5, Vop-1 Volt
- The data are related to a single cell (6x6 mm²).



Summarizing

Irradiated MPPC

- ✓ The leakage current decreases of a **factor 5** from 20 to 0 °C
- ✓ The leakage current decreases of a factor ~ 5 (~ 2) from V_{op} to $V_{op}-1$ V ($V_{op}-0.5$ V)

Considering the MPPC current of ~ 15 mA per device in the hottest region, operating at **0 °C and $V_{op}-0.5$ V**, we expect: a leakage current of ~ 1.5 mA after more than 6 years of run **(without Induced Annealing)**

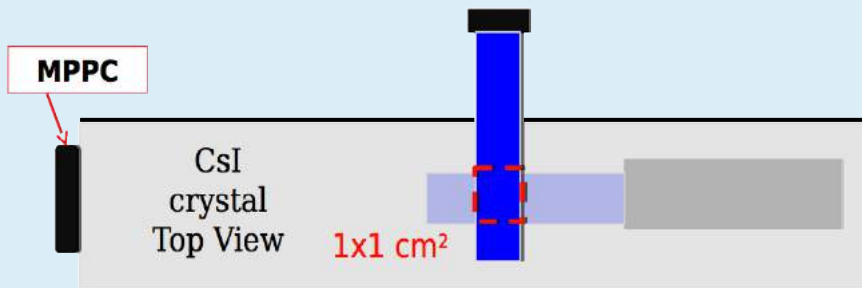
Cosmic rays with the Thin Film

Test of CsI + MPPC with CR

In order to evaluate the lost in the PDE decreasing the V_{bias} , we have performed cosmic rays test with three different operational voltages V_{op} , $V_{op}-0.5$ and $V_{op}-1$ V

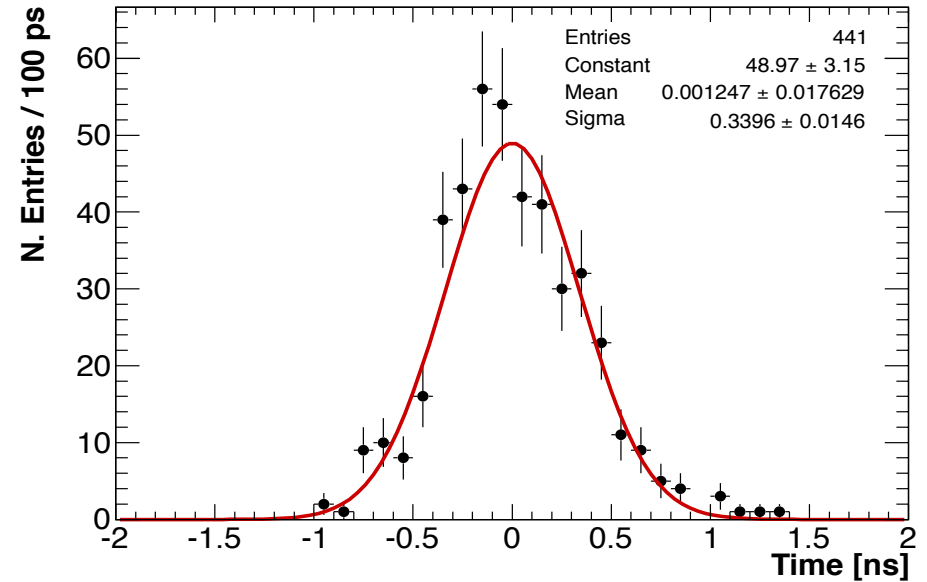
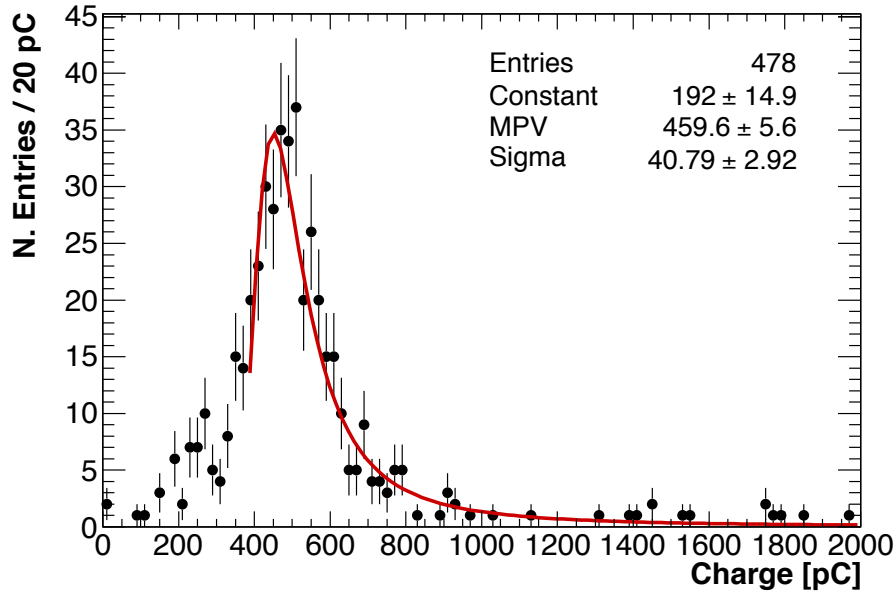
Experimental setup

- ◆ Crystals between two scintillation counters
- ◆ MPPC readout



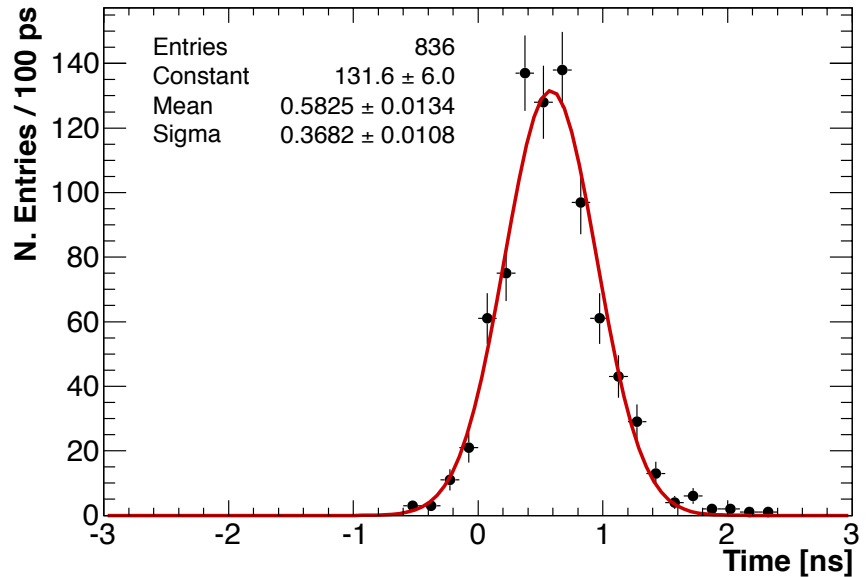
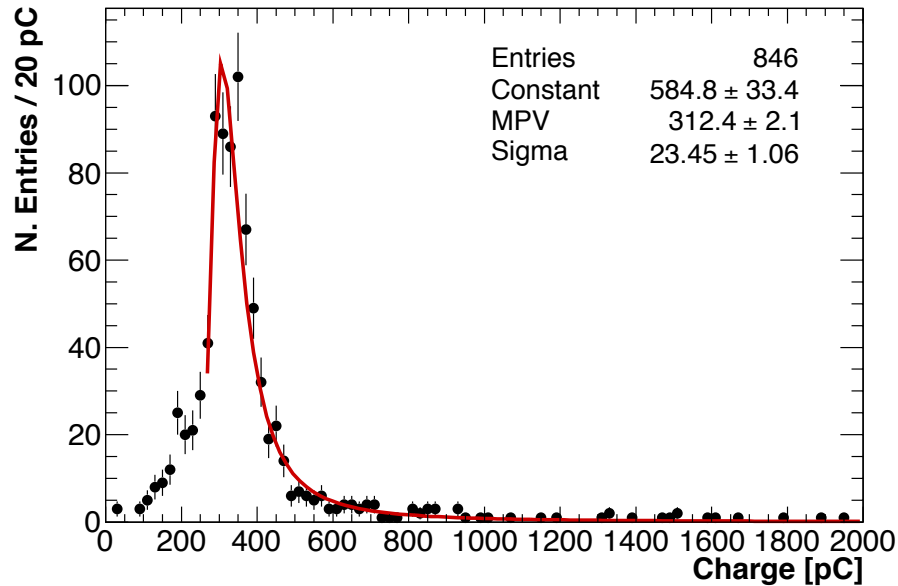
Analysis technique

- Fit function -> pol4
- Fit range: (0.1 – 85)% of the max amplitude
- Constant fraction method



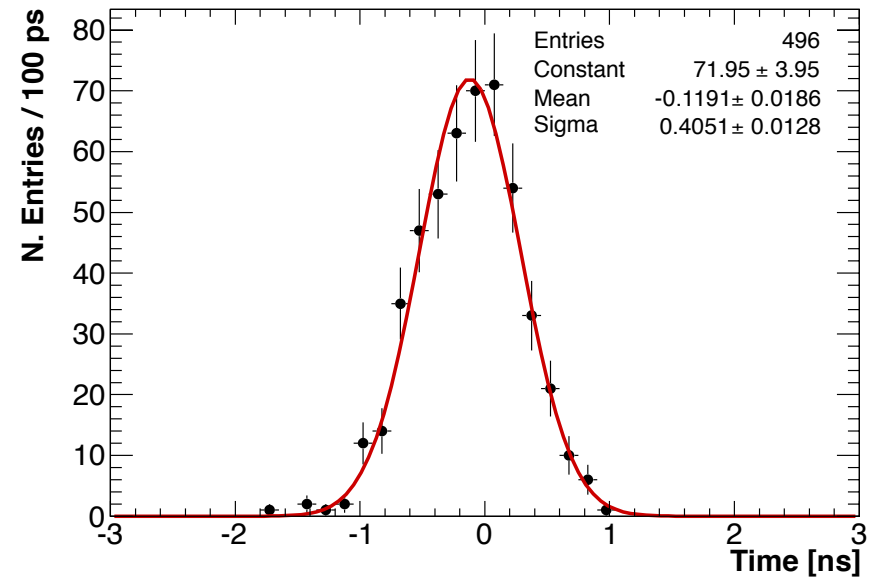
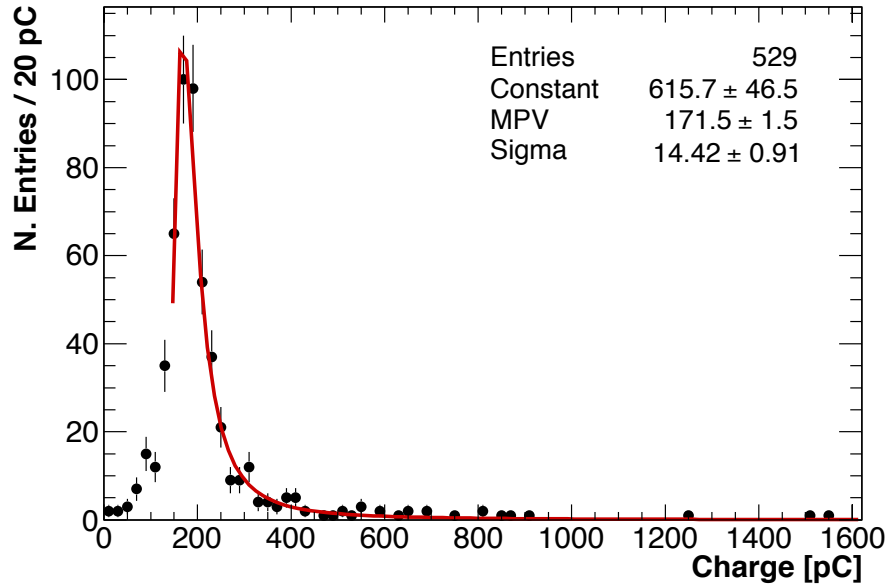
- ❖ Finger sigma($\Delta T_{\text{fingers}}$) = 180 ps
 - ❖ Final resolution for 1 MIP (~ 20 MeV) $\rightarrow \sim 290$ ps
- with Tyvek wrapping and optically coupled with Bluesil Past-7 silicon grease

Vop – 0.5 Volt



- ❖ Finger sigma($\Delta T_{\text{fingers}}$) = 180 ps
 - ❖ Final resolution for 1 MIP (~ 20 MeV) $\rightarrow \sim 320$ ps
- with Tyvek wrapping and optically coupled with Bluesil Past-7 silicon grease

Vop – 1 Volt



- ❖ Finger sigma($\Delta T_{\text{fingers}}$) = 180 ps
 - ❖ Final resolution for 1 MIP (~ 20 MeV) $\rightarrow \sim 360$ ps
- with Tyvek wrapping and optically coupled with Bluesil Past-7 silicon grease

Summarizing

The PDE decreases of:

- 20 % decreasing the operational voltage at $V_{op} - 0.5 \text{ V}$
- 35 % decreasing the operational voltage at $V_{op} - 1 \text{ V}$

- ✓ Operating at $V_{op} - 0.5 \text{ V}$ and $0 \text{ }^\circ\text{C}$ of temperature, we expect a total leakage current per MPPC of about **1.5 mA** and a loss of PDE of a about **20%** after more than 6 years of run (in the inner ring of the first disk);

For the rest of the calorimeter a factor three safety on the leakage current and running conditions is expected.