Aging studies of Micromegas prototypes for the HL-LHC

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on behalf of MAMMA collaboration

Outline

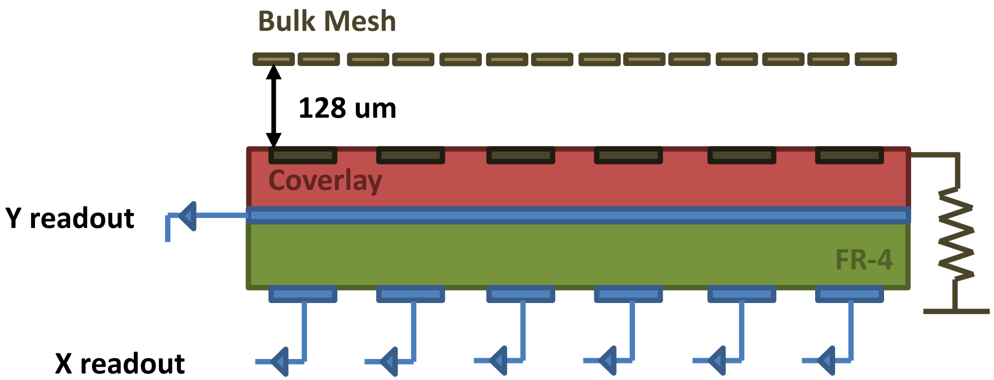
MAMMA micromegas resistive prototypes are beiong tested at Saclay for long term reliability.

Two types of aging radiation have been used

X-ray radiation tests already shown at MPGD2011 Poster

Neutron irradiation going on these last weeks.

Resistive prototypes under test (2D readout)



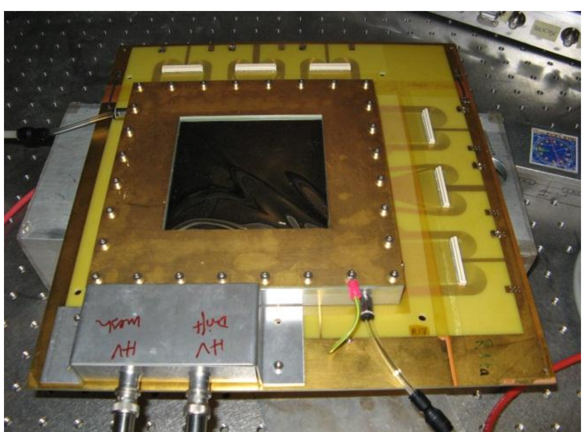
Two resistive prototypes (R17) were sent to Saclay for performing aging tests

17A
Resistance to GND: 80-140 MOhm
Resistance along strips: 45-50 MOhm/cm

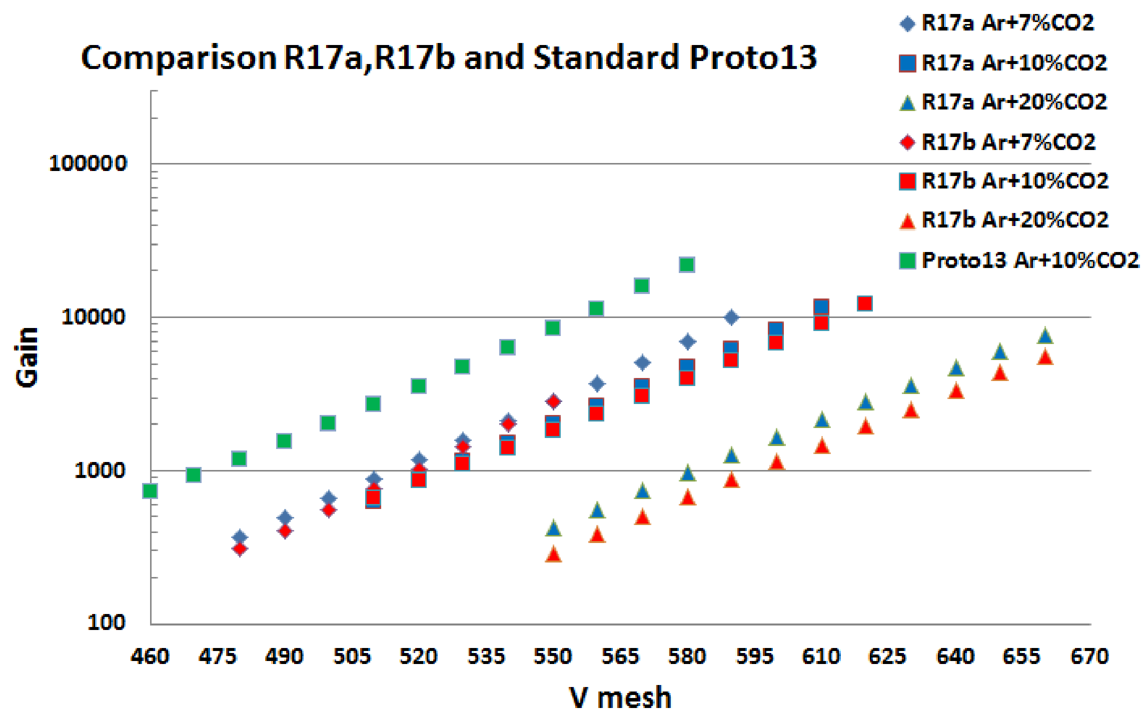
17B
Resistance to GND: 60-100 MOhm
Resistance along strips: 35-40 MOhm/cm

Geometrical properties

Strip pitch/width for all: **250 µm/150 µm**
Top layer (Resistive strips): **35 µm thick**
Insulation (coverlay): **60 µm**
Y strips (90 degrees to R strips): **9 µm Cu**
Insulation (FR-4): **75 µm**
X strips (same direction as R strips): **9 µm Cu**



Both detectors show similar gain properties
Re-characterized at CEA for different gas mixtures



Ageing tests

The idea is to <u>proof the capability</u> of these type of detectors (made of new resistive micromegas technology) <u>to operate in long data taking periods</u>.

X-rays radiation
Simulate detector charge operation
for long time equivalent period

Neutron radiation
proof invariability of detector material properties and ageing **due to nuclear interactions**

X-rays radiation

The X-ray ageing study includes

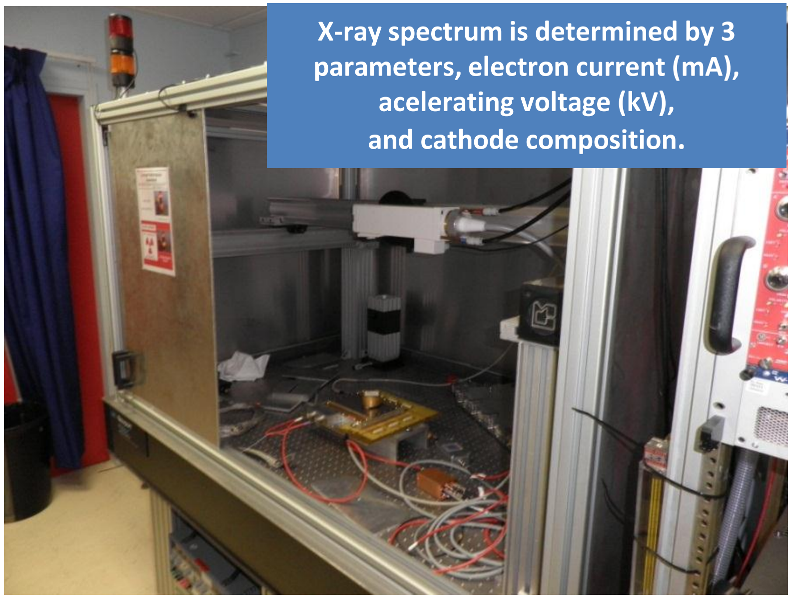
Characterization of X-ray gun rate and spectrum nature.

Estimation of exposure time required to validate the detector for long operating times.

Detector characterization before and after exposure.

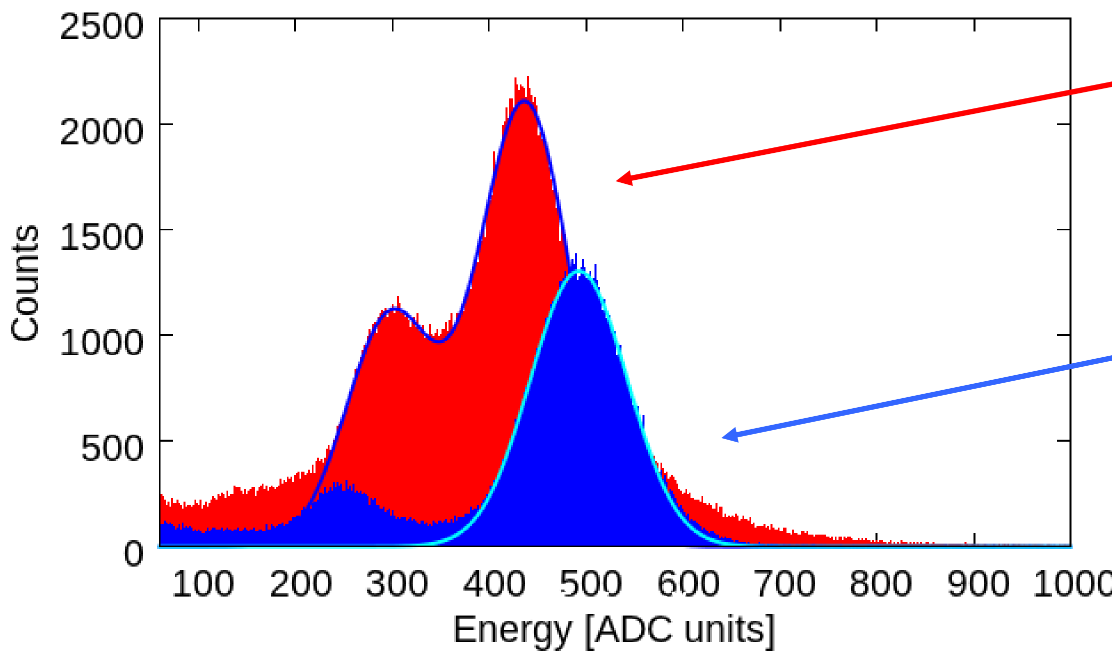
2 aging periods at two different regions of the detector

X-ray generator cage



X-ray spectrum is determined by 3 parameters, electron current (mA), acelerating voltage (kV), and cathode composition.

X-ray gun characterization : Low generator intensity and well collimated

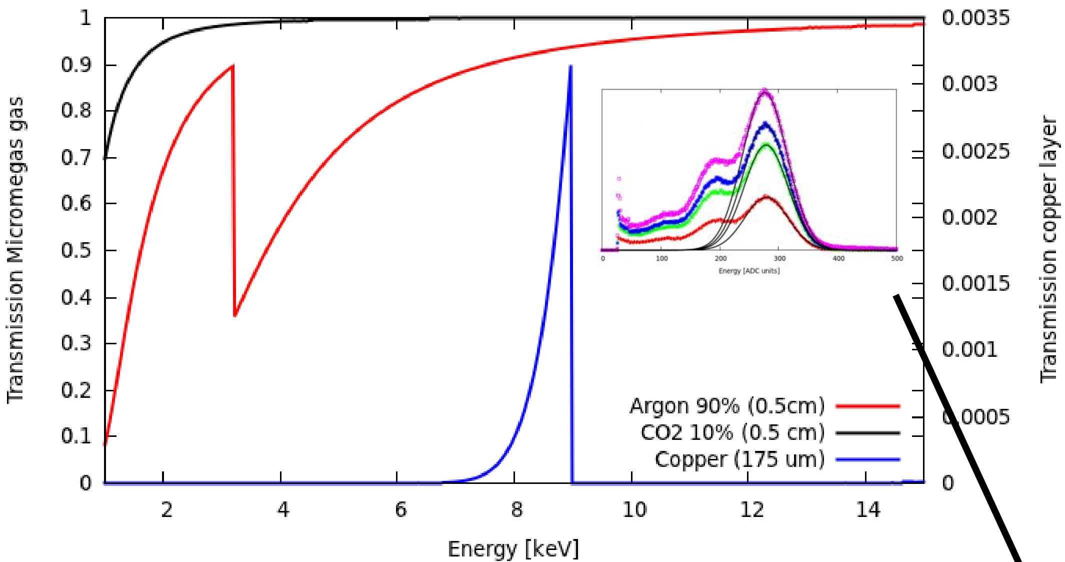


Double gaussian fit for X-ray gun sets up main peak energies and rates.

X-ray gun peaks	Energy	Interaction rate
Low energy peak	3.51 keV	500 kHz/mm2
High energy peak	5.28 keV	1.5MHz/mm2

Atom	Line	Energy	Decay Probability
Chrome	Ka1	5.415	17.1
	Ka2	5.4	8.7
Vanadium	Ka1	4.952	15.3
	Ka2	4.945	7.7
Calcium	Ka1	3.692	10.2
	Ka2	2.688	5.11
Potasium	Ka1	3.314	8.7
	Ka2	3.311	4.4

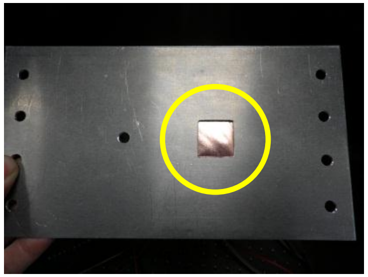
X-ray gun characterization : Using copper layer



5 layers of 3M copper tape (35um/layer) are used to screen the generated X-rays and produce fluorescence in the copper.

The copper transmission allows us to determine the original rate at 8keV.

The same mask as in the ageing exposure was used (4cm2 square).



The attenuated rate at the 8keV peak is related with the original rate at the detector at around the 8keV peak.

$$r_{meas} = \int_{1\,\mathrm{keV}}^{15\,\mathrm{keV}} \left(\frac{dr_o}{dE}\right) T_{Cu}(E) \cdot (1 - T_{Ar,CO_2}(E)) \cdot dE$$

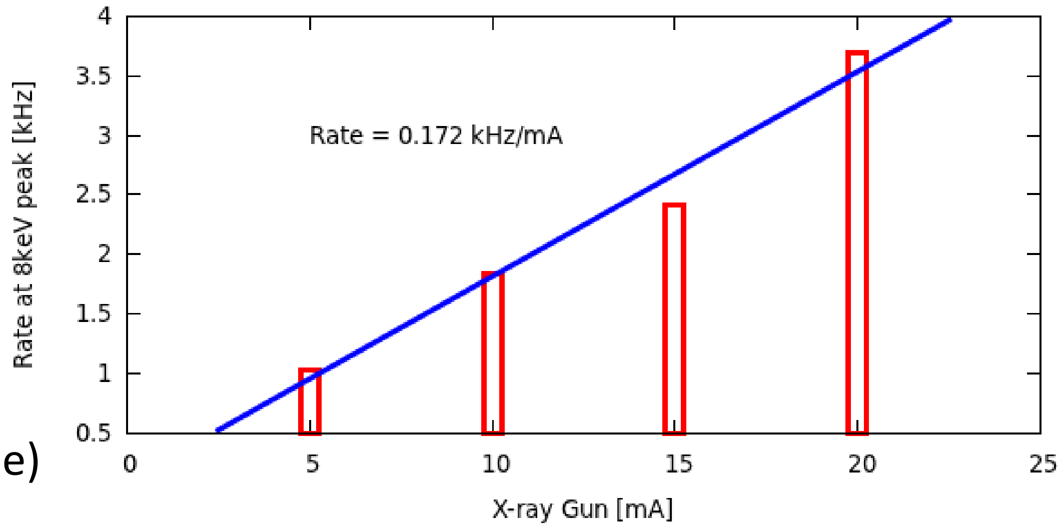
If the original rate around 8keV is considered constant the integrated transmission factor is

$$\left.\frac{dr_o}{dE}\right|_{8\mathrm{keV}} \simeq 9.62 \cdot 10^3\,\mathrm{keV}^{-1} \cdot r_{meas}$$

resulting 43 kHz/mm²/keV/mA at 8keV

Original rate (before reaching gas volume)

Rate measurements attenuated with Copper



Ageing tests : X-ray exposure

Equivalent charge generated during 5 years HL-LHC

Wi (Argon + 10% CO_2) = 26.7 eV
Gain = 5000
MIP deposit in 0.5 cm drift = 1248.5 eV

Charge per iteration = 37.4 fC

Expected rate at the HL-LHC : 10kHz/cm^2

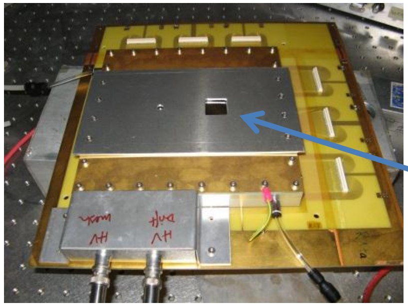
5 years of HL-LHC operation (200days X year)

Total detector charge generated during HL-LHC operation is estimated to be 32.5 mC/cm^2

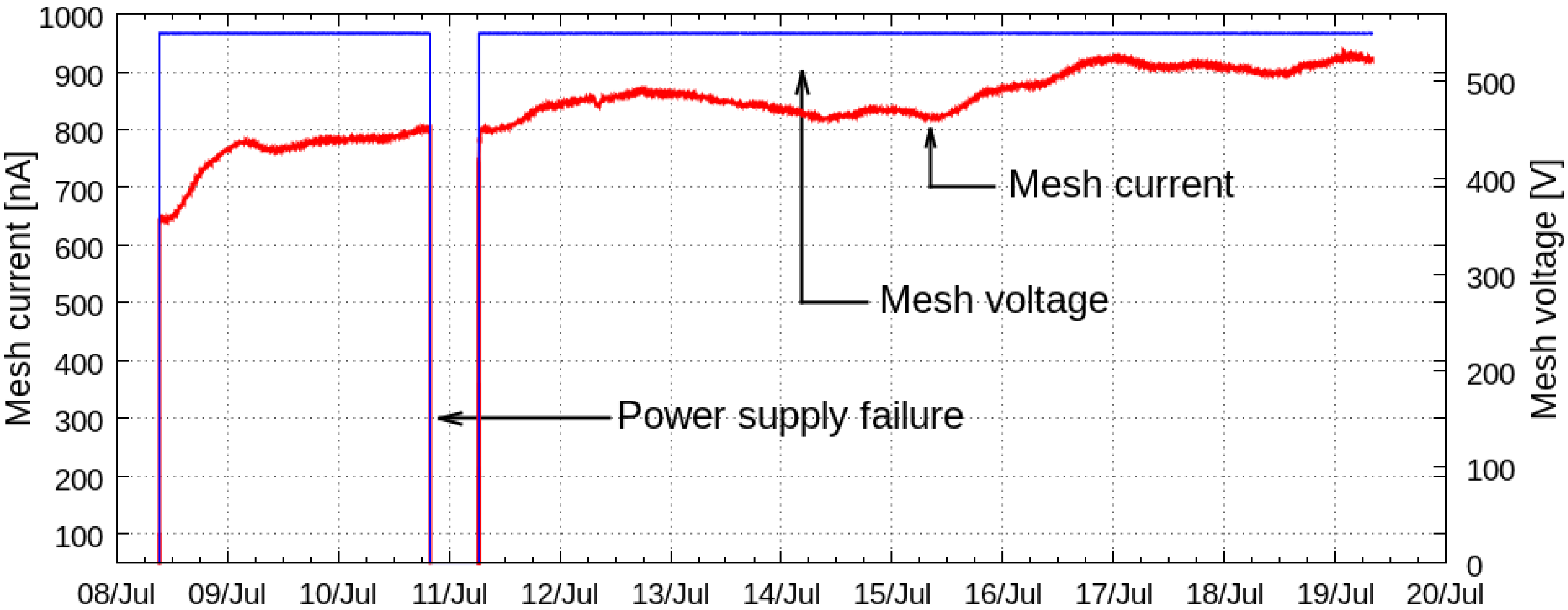
Detector operated in data taking conditions

Gas mixture : Argon + 10% CO2
Gas Flow = 0.5 l/h
Gain 3000
HVm = 540V
HVd =790 V

X-ray generator set-up at 10 kV 5 mA



X-ray exposure in a small active area region of 4 cm^2.



Ageing tests : First X-ray exposure (July 2011)

During the X-ray ageing test it was generated a total charge of

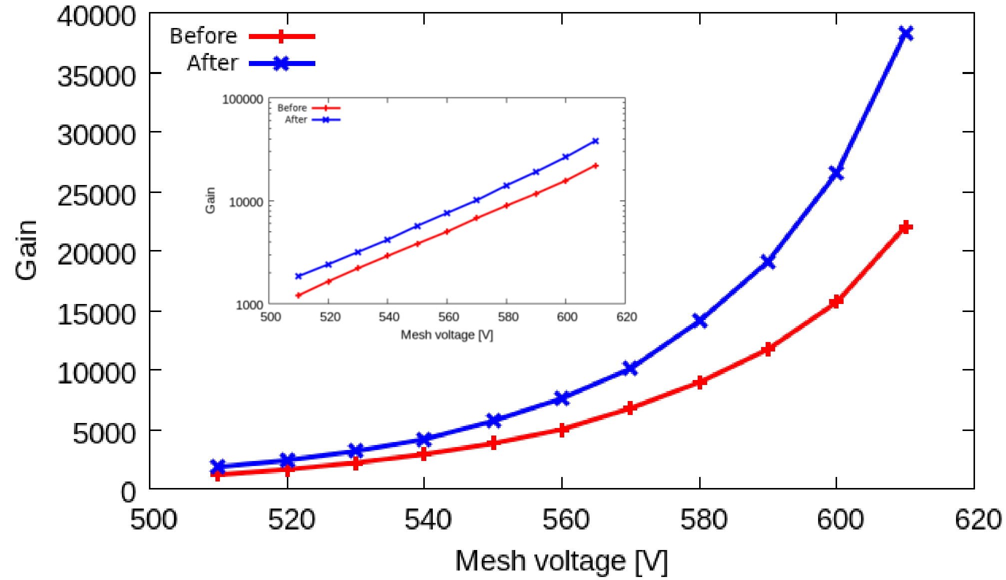
Q_{ageing} = 765mC in 4cm^2,

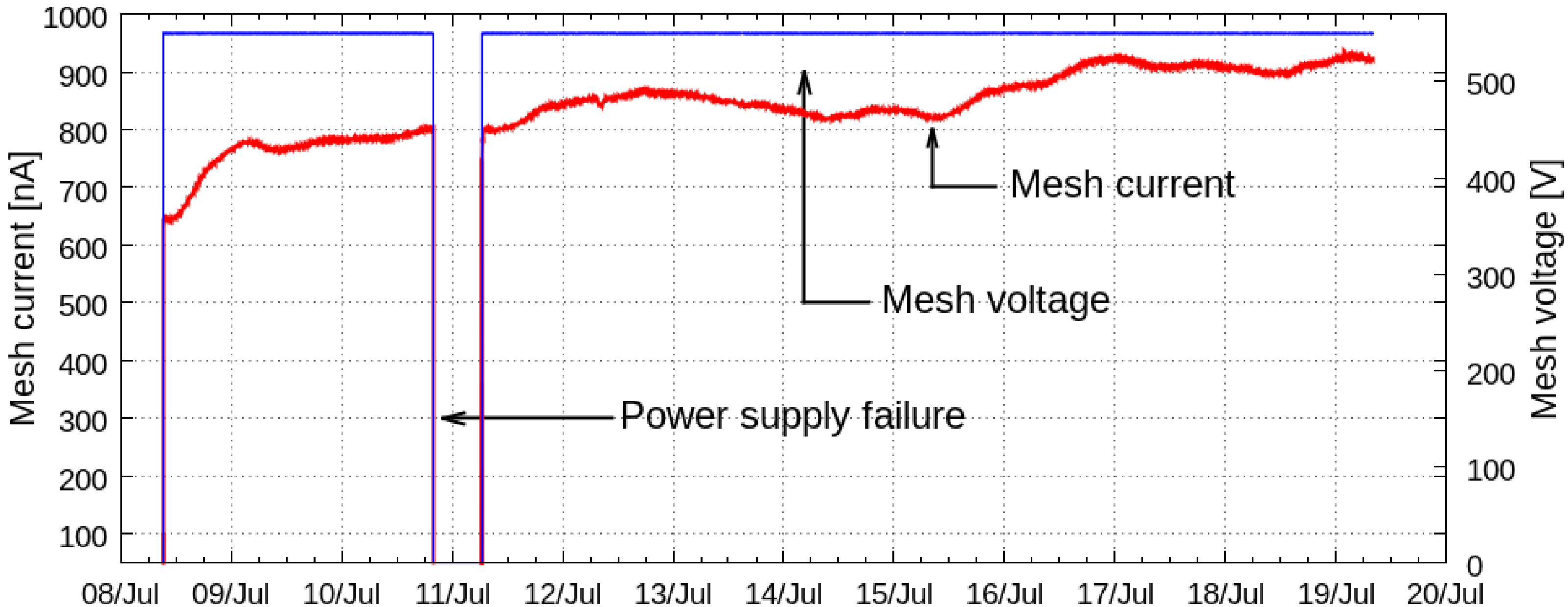
during a total exposure time of

$T_{exposure}$ = 11days 21 hours

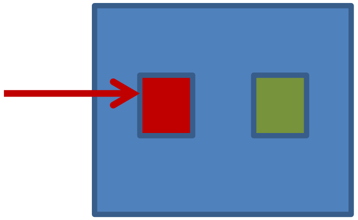
And therefore, the total charge to be generated at the HL-LHC during 5 years with more than a factor 5 of security factor.

Detector gain was not degraded at the area of X-ray exposure





Ageing tests : Second X-ray exposure (October 2011)



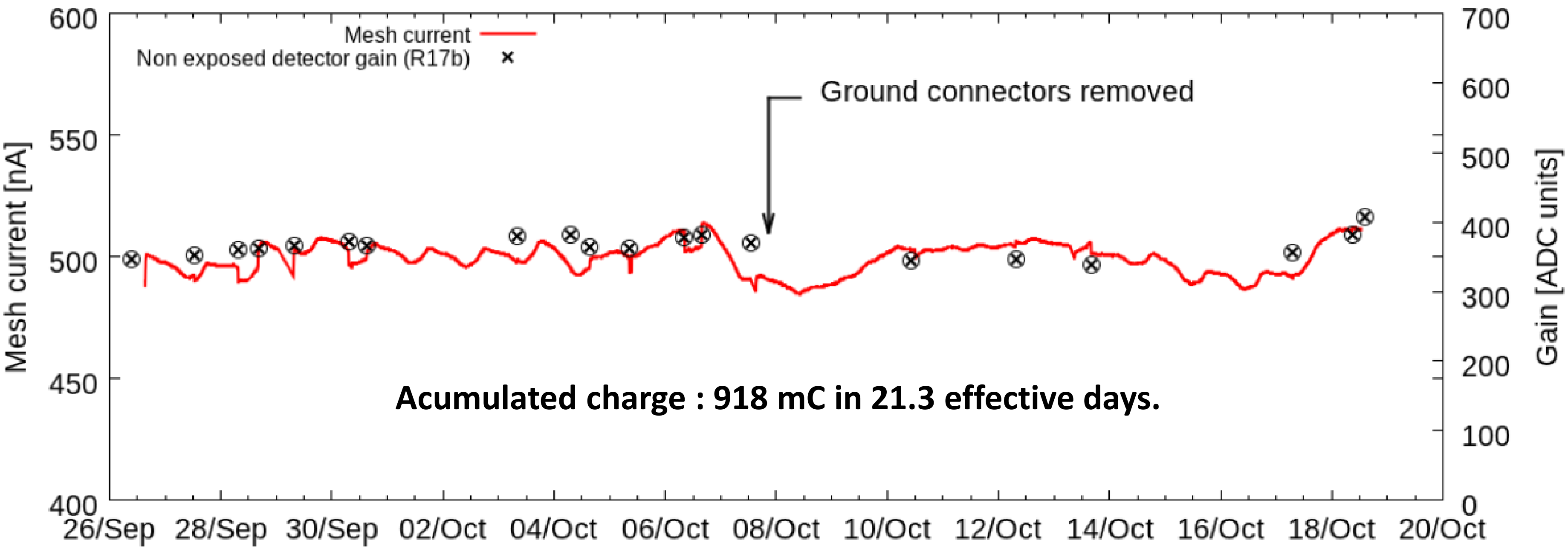
Second irradiation period had place at a different region of the detector

Tests were re-taken in order to verify the results obtained.

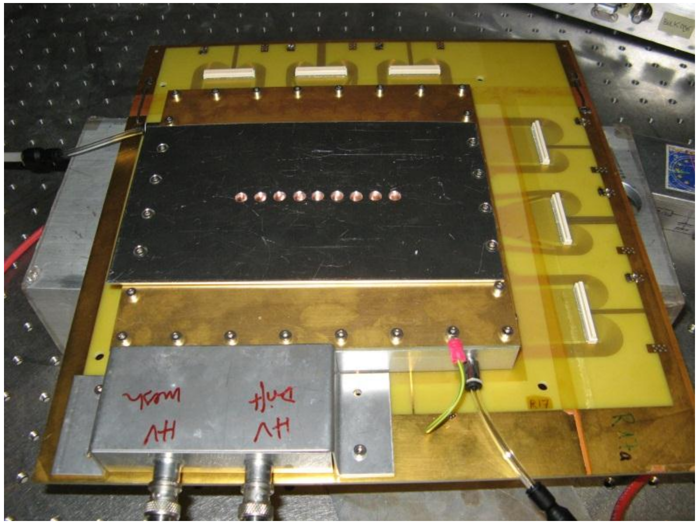
Due to the possible effect from non-grounded (to air) strips on the gain evolution.

Moreover, during the second aging period <u>the second detector (R17b) is connected in parallel</u> (without being exposed), and it is <u>used to do gain control measurements</u> to cross-check the gain changes coming from possible enviromental effects on gas mixture.

Additionaly, in this second period, <u>control gain measurements in the exposed detector (R17a) were done at different positions</u>, before and after the irradiation.



Detector characterization : Relative gain before,during and after second irradiation period

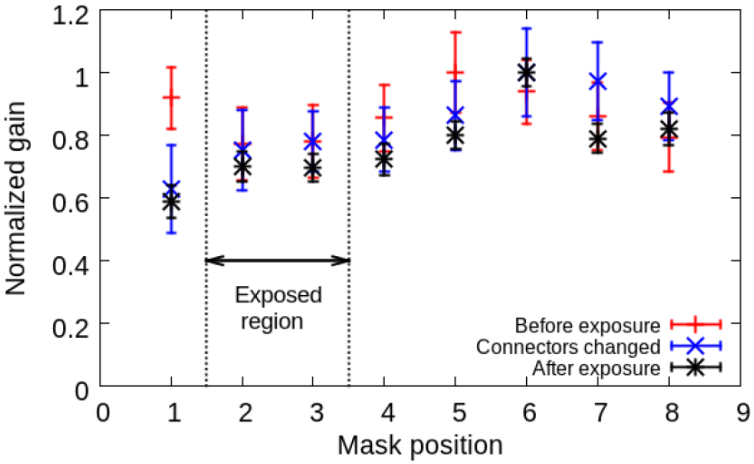


Measurements at different position were performed by using a mask with several equi-distant holes over the active region of the detector.

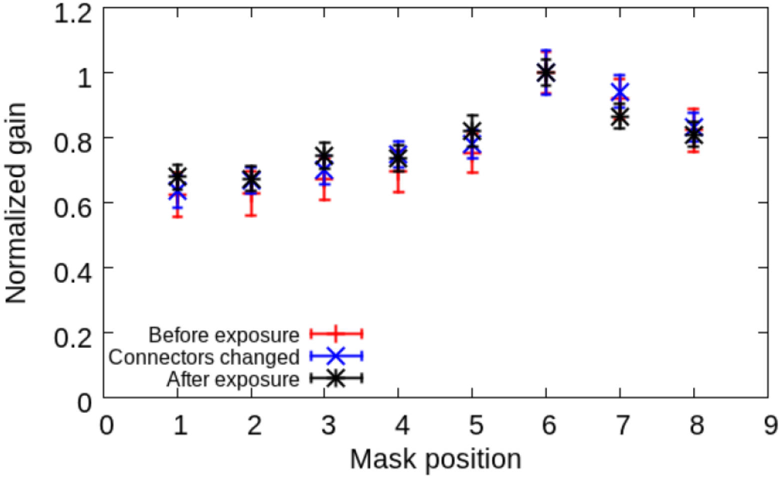
Normalized gain measurements show the relative compatibility with position.

The exposed region does not show a considerable change respect to the non-exposed regions.

Exposed detector R17a



Exposed detector R17b



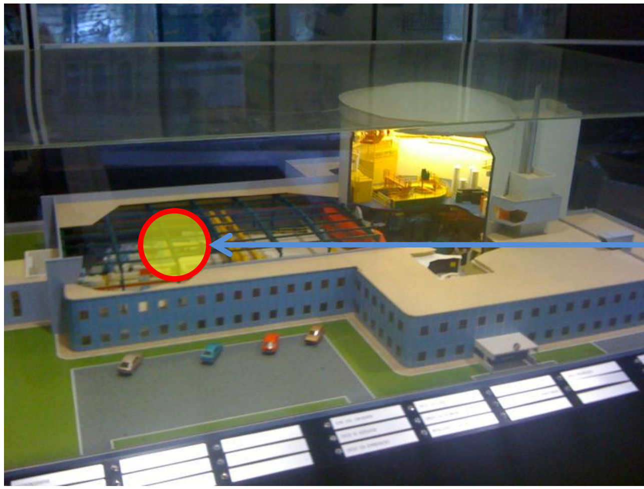
Neutron aging tests at Orphee reactor.

High intensity thermal neutron irradiation had place recently at C.E.A.

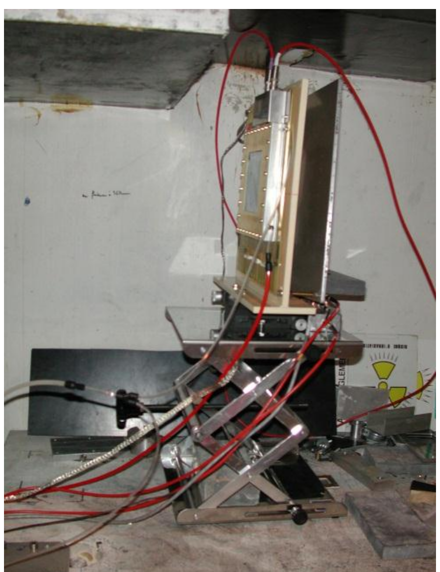
Several neutron research lines available.

Neutron flux : ~8.10^{8} n/cm2/sec

Neutron energy : 5 to 10 meV



Detector emplacement at Orphee reactor Neutron guide



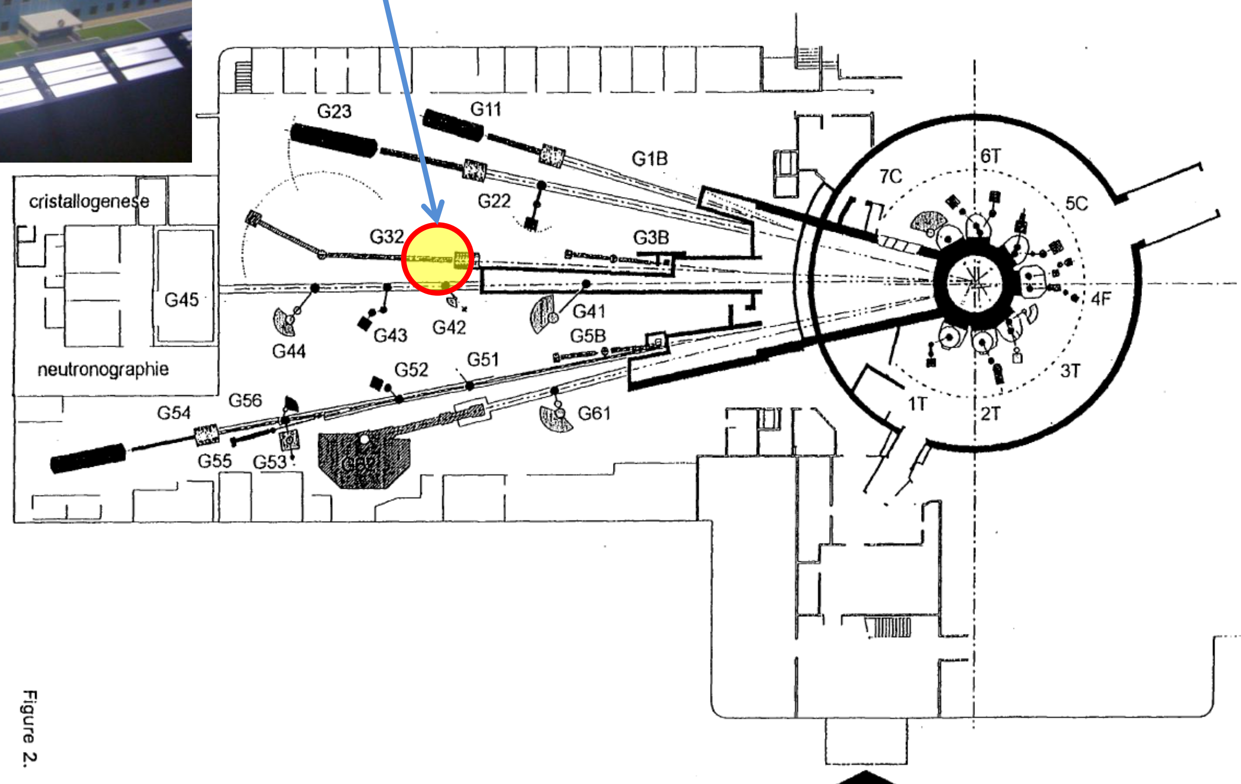


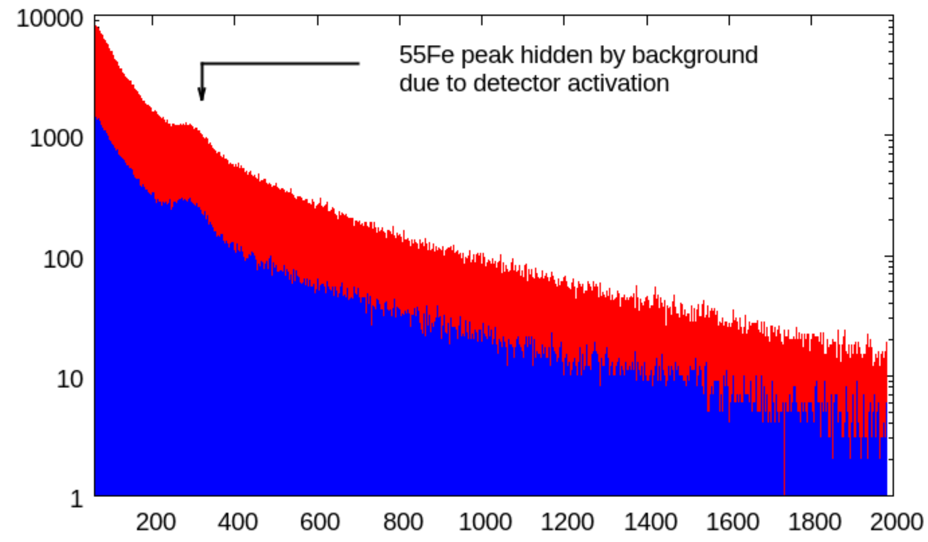
Figure 2.

Detector activation after neutron exposure

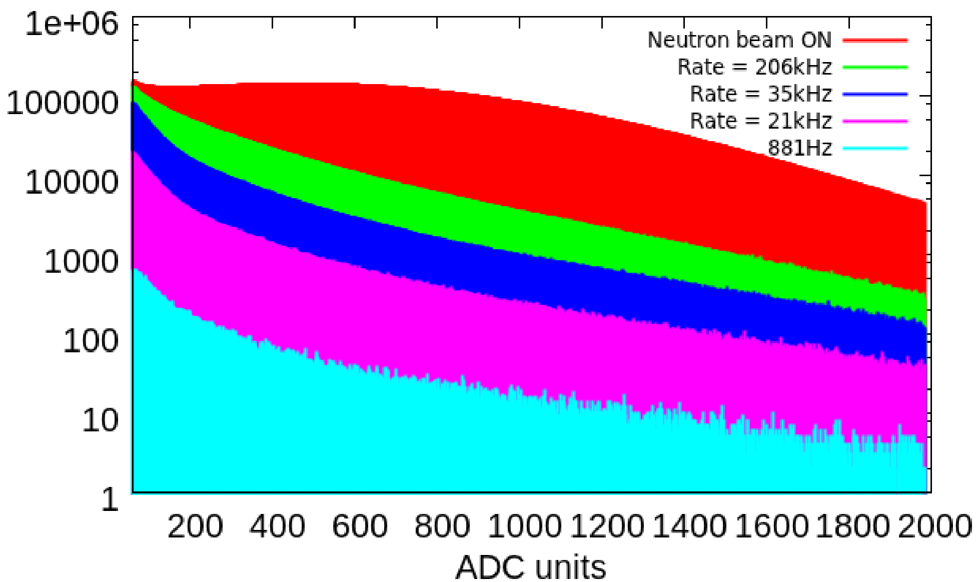
After a short irradiation period the detector is quickly activated and takes long time to deactivate.

The activation rate measured saturates and reaches a limit of about 250kHz which does not increase with exposures longer than 2 hours.

After 5 minutes neutron exposure



After a period of 2 hours exposure



Time	Rate
11h08	206 kHz
14h04	35 kHz
16h03	26 kHz
18h16	21 kHz
8h52*	881 Hz

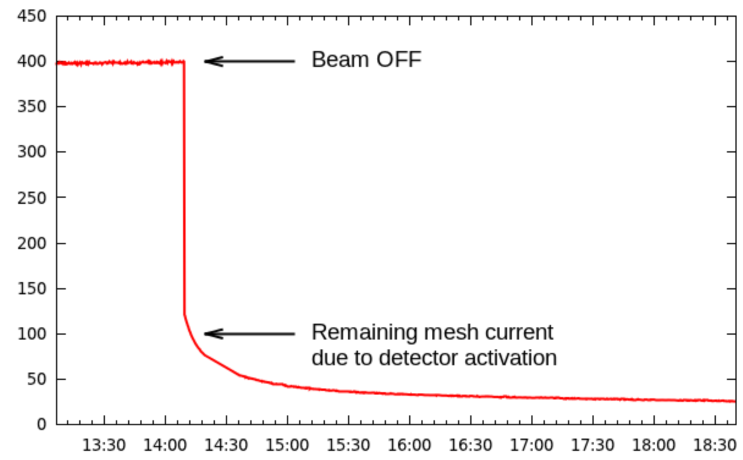
Detector aging history during neutron tests.

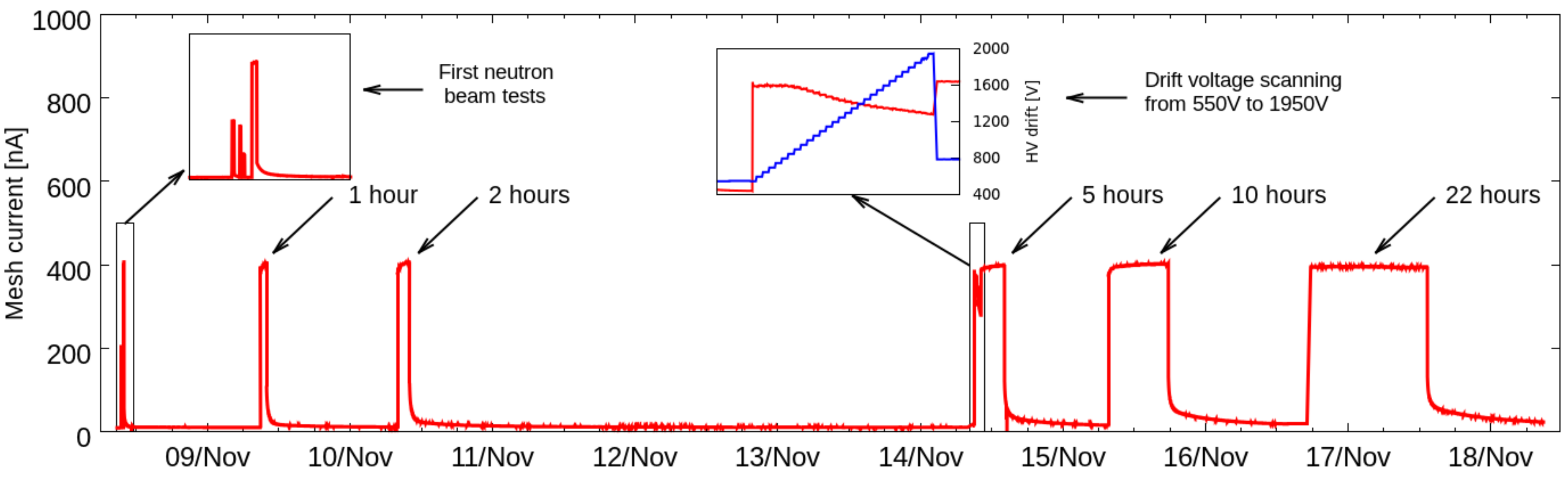
Neutron flux at the level of CSC in ATLAS ~3.10^4 neutrons/cm2/s

10 years at HL-LHC (=> $x10.10^7$ sec) with a security factor : x3

At the HL-LHC, we will accumulate $1{,}5.10^{13}$ n/cm2

At Orphee we have ~8.10^8 n/cm2/sec so in 1 hour we have : 8.10^8 x 3600 ~ 3.10^{12} n/cm2/hour which is about 2 HL-LHC years (200 days year).





Conclusions

Two X-ray irradiation periods had place at the detector in two different regions.

The operation charge accumulated during these periods is considerably higher than the total operation charge which would be obtained at the HL-LHC during 5 years.

No degradation of the detector was observed during or after the tests at the exposed regions. However, the increasing gain effect observed in the first period remains unexplained.

Several neutron irradiation periods had place during the last weeks and the detector will be evaluated during the coming weeks (once the detector has been completely de-activated).

First results show no degradation, since the current remained stable during each irradiation period.