New Dose and Loss monitor systems for SOLEIL

DEELS

18-19 April 2018

Diamond Light Source

Nicolas HUBERT on behalf of the SOLEIL diagnostics group

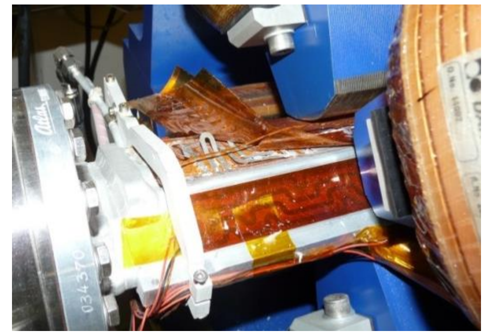
Objectives

- Dose monitoring
  - Estimation of the dose received by equipment (prematurely damaged)
  - Sensitive to all king of radiations (e-, X-rays…)
  - Compacity

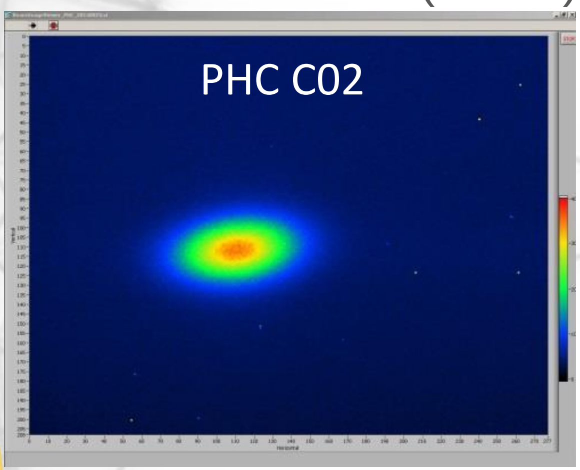
- Loss monitoring
  - Monitoring of the electron beam losses
  - Synchronized, good temporal resolution
  - Insensitive to synchrotron radiation
  - Relative calibration

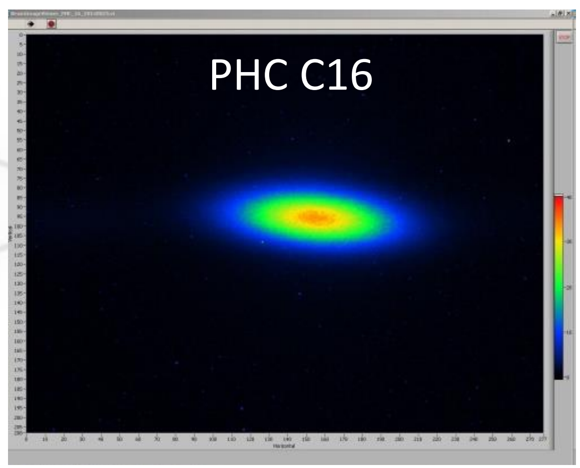
Dose Monitoring

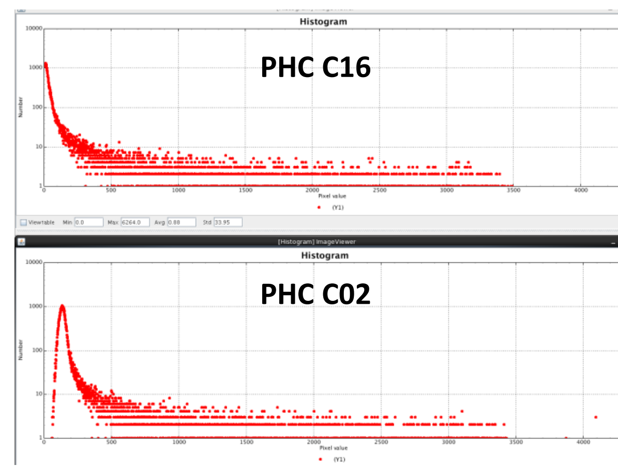
- Estimate the dose received by equipment to anticipate damages:
  - Insulators, baking films (glue)



  - Electronics (CCDs)







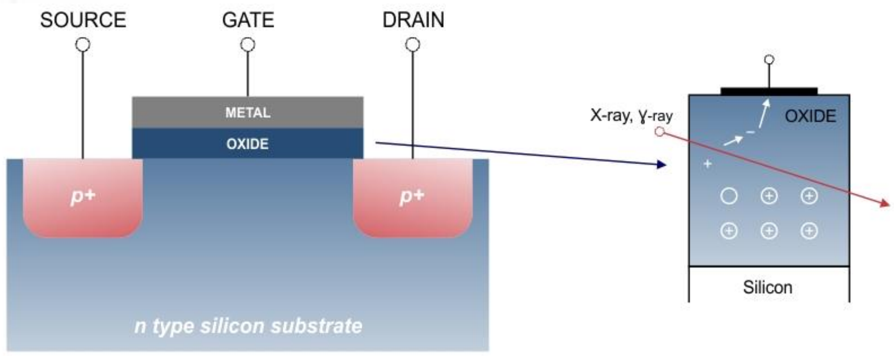
CCD Background histograms (wo beam)

  - Permanent magnets
    - Project to replace one dipole by a permanent magnet

Dose Monitoring

- Specifications
  - Small: to be installed as close as possible to the equipment
  - Estimation of the absolute dose value
  - Low cost

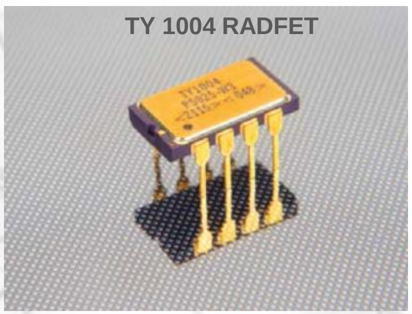
- RadFET Sensors
  - Metal Oxyde Semiconductor Field Effect Transistor (MOSFET) optimized for radiation sensitivity.
    - Generation of electron hole pairs in the gate (permanent modification)
    - Threshold voltage increases with the amount of radiation received.



RADFET Schematics (source: Tyndall)

Dose Monitoring

- RadFET Sensors
  - TY1004 from Tyndall Works (Tyndall National Institute, Ireland)
    - Two identical RadFET in the same chip



- Exposure Mode
  - All pins grounded (gate can be biased to increase sensitivity)
- Read Mode
  - 10 µA applied between ground and source
  - Threshold voltage @ 10 µA

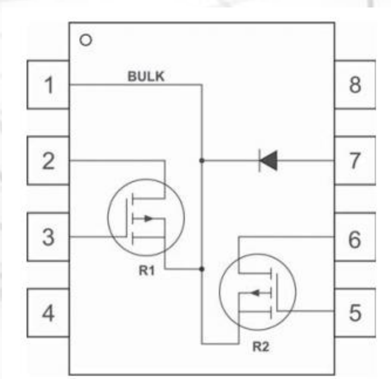
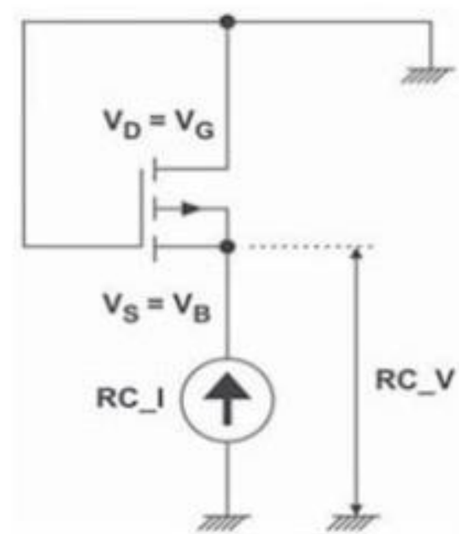


Figure 1: TY1004 pin-out drawing.

Table 1: TY1004 pin-out description.

Pin Number	Description
1	Source/Bulk (Common)
2	Drain of R1
3	Gate of R1
4	Not Connected
5	Gate of R2
6	Drain of R2
7	Diode
8	Not Connected



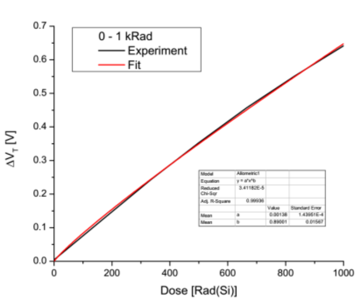
Dose Monitoring

- RadFET Sensors
  - Calibration curves provided by Tyndall based on irradiation with a Co60 source (RadFET from the same batch)

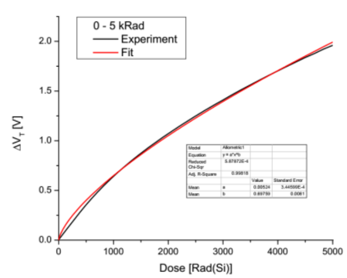
$$\Delta V = A \times Dose^{B}$$

Dose range	A	Sigma (A)	B	Sigma (B)	R-SQUARE
0 – 100 kRad	0.0659	1.020E-03	0.4117	1.400E-03	0.996
0 – 50 kRad	0.0478	1.500E-03	0.4438	3.050E-03	0.992
0 – 10 kRad	0.0090	4.546E-04	0.6306	5.780E-03	0.998
0 – 5 kRad	0.0052	3.446E-04	0.6976	8.100E-03	0.998
0 – 1 kRad	0.0014	1.440E-04	0.8900	1.567E-02	0.999

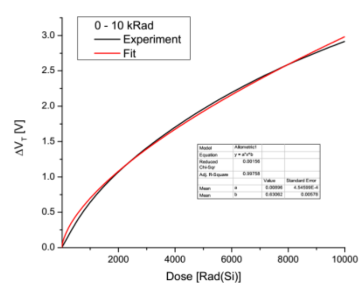
Calibration curve for dose range 0 – 1 kRad



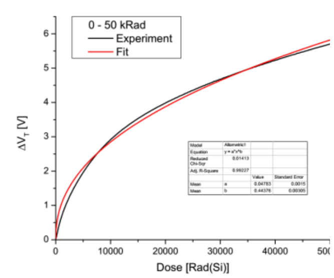
Calibration curve for dose range 0 – 5 kRad



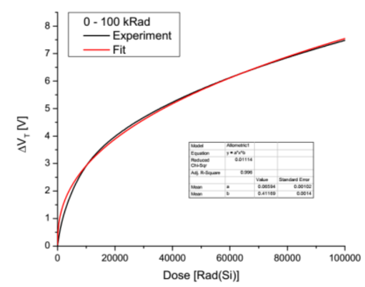
Calibration curve for dose range 0 – 10 kRad



Calibration curve for dose range 0 – 50 kRad

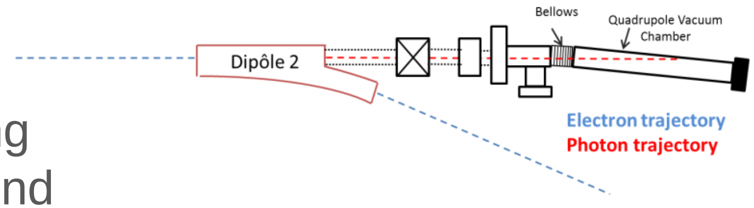


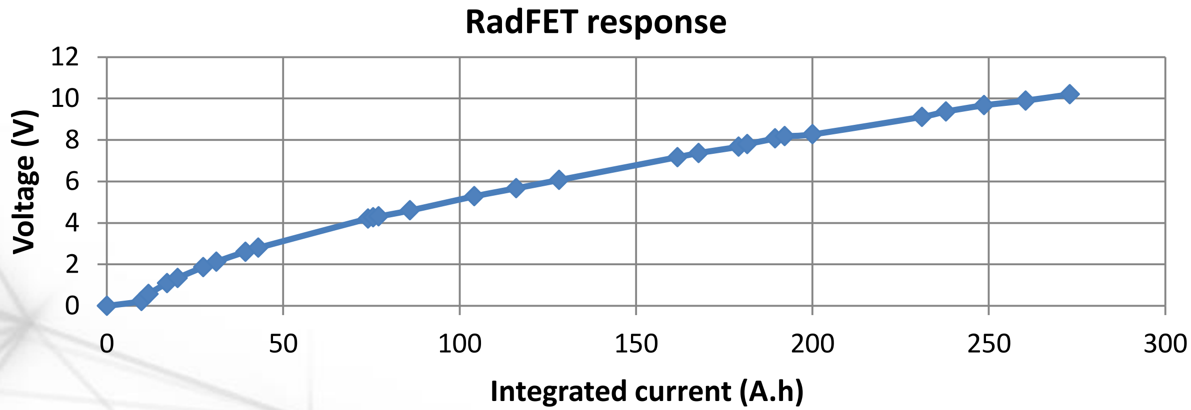
Calibration curve for dose range 0 – 100 kRad

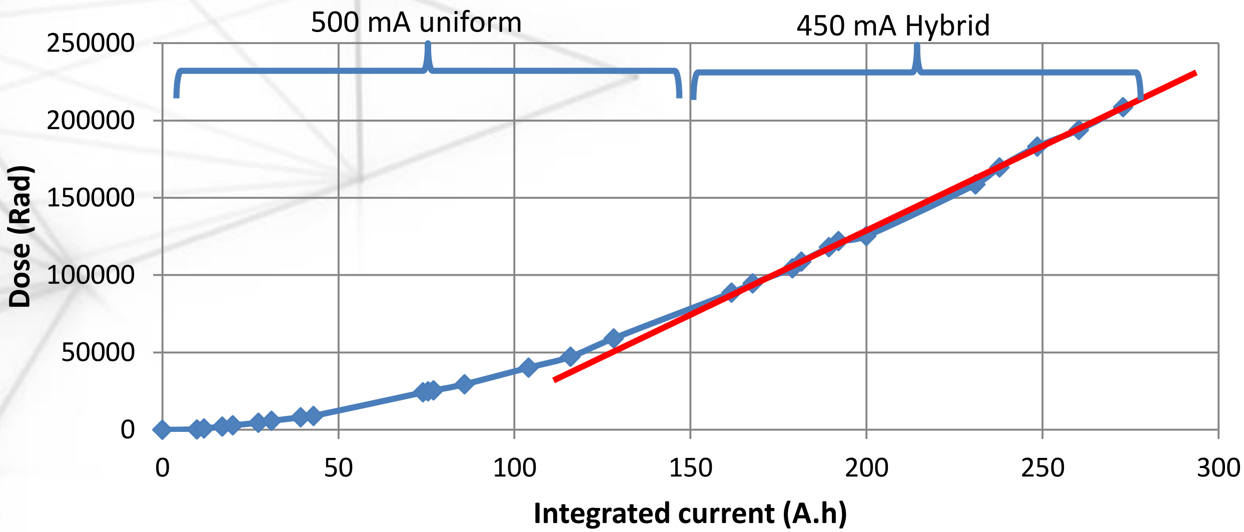


Dose Monitoring

- RadFET Sensors (testing)
  - Installed on a vacuum chamber intercepting synchrotron radiation on a beamline frontend

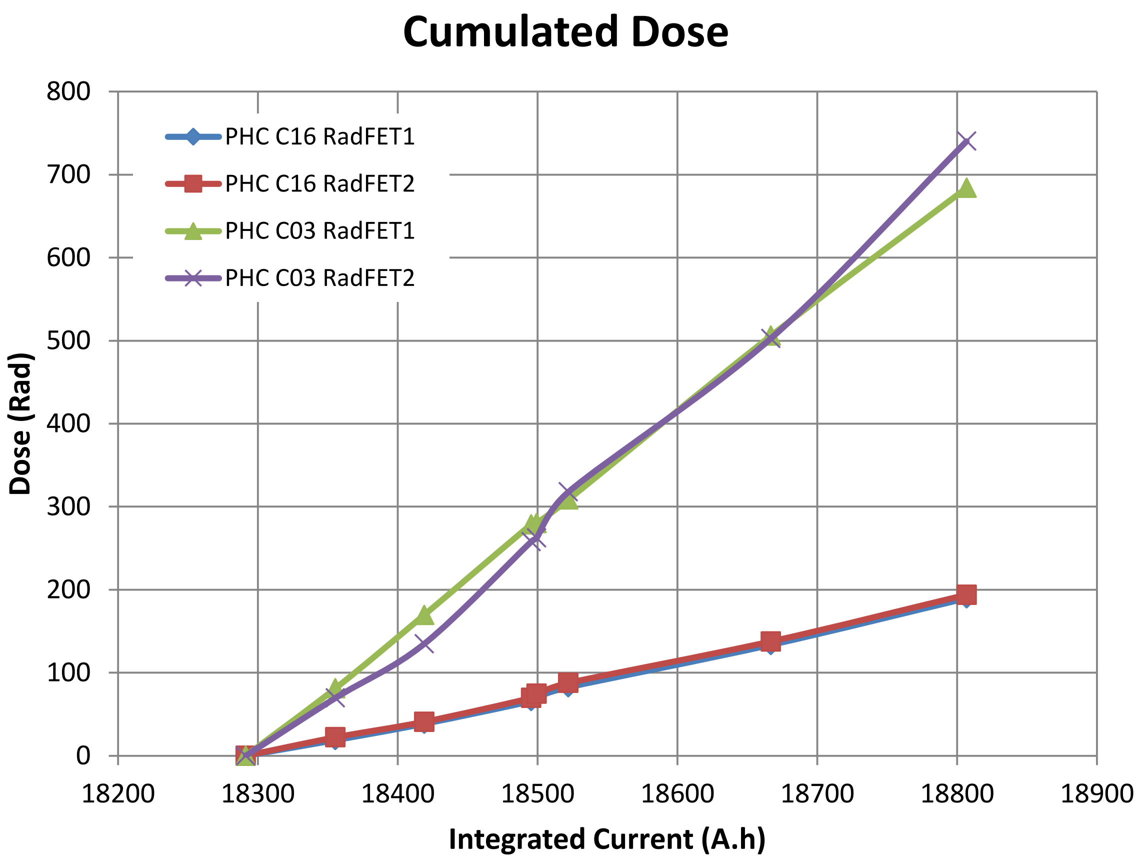


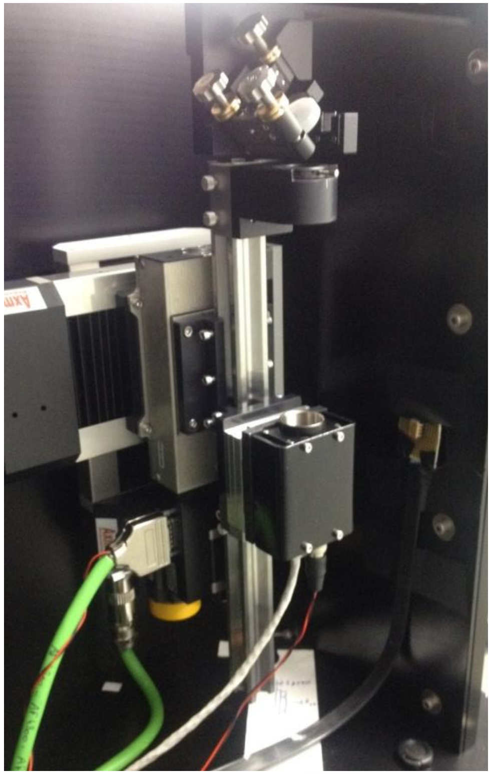




Dose Monitoring

- RadFET Sensors (testing)
  - Installed in the optic boxes of the PHCs





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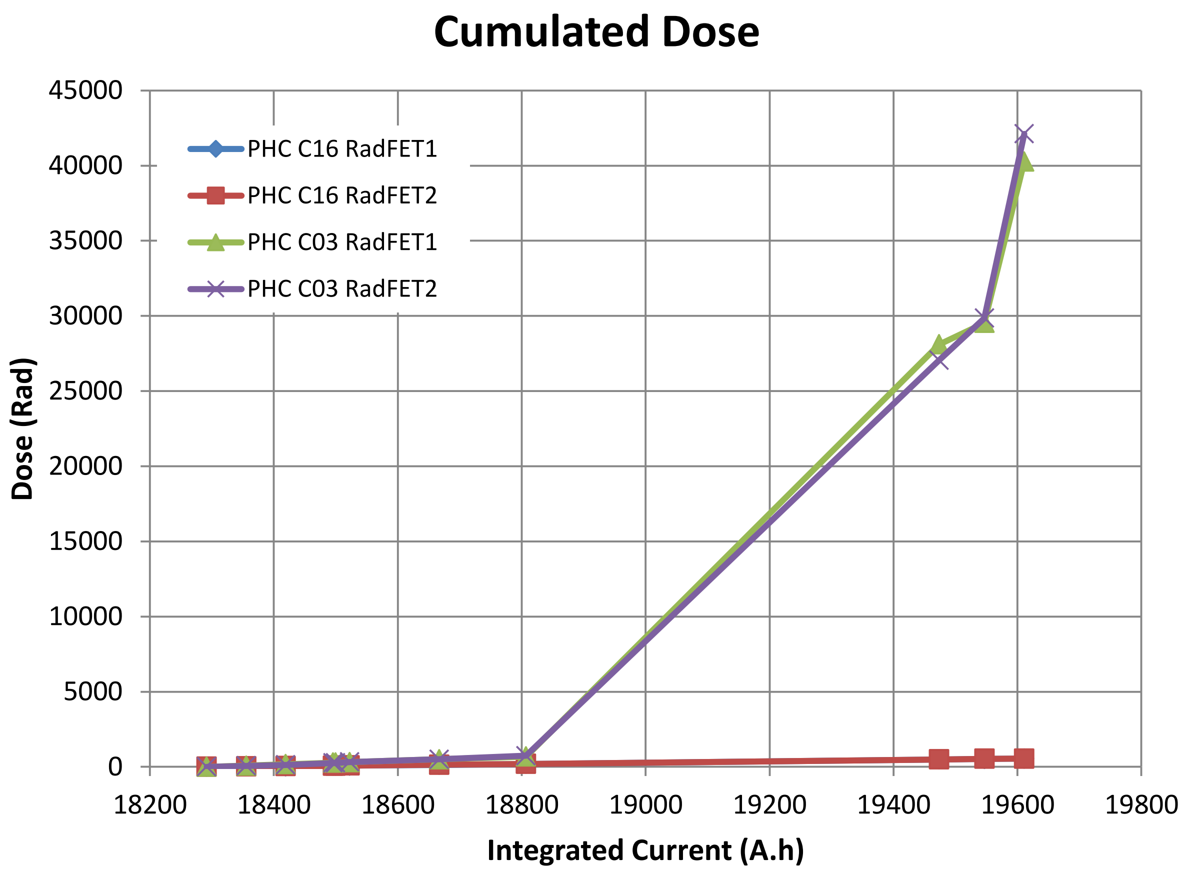
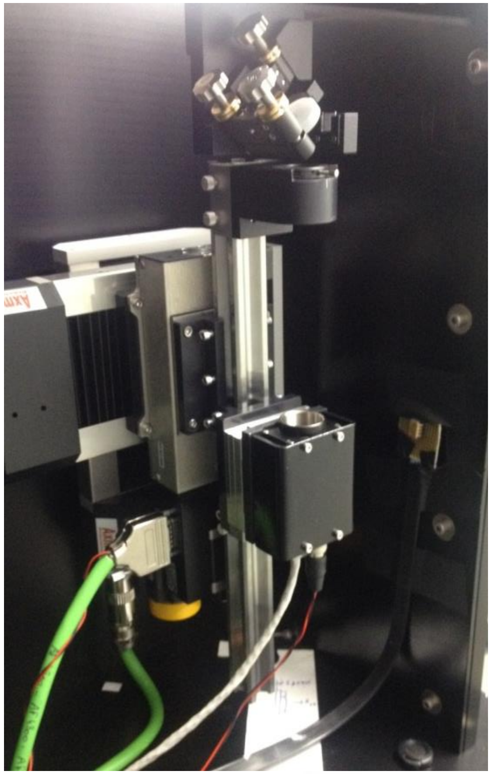
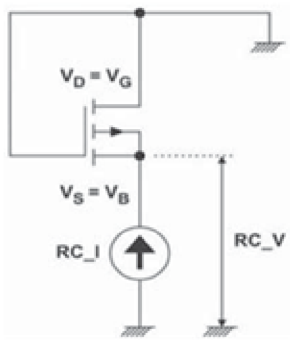
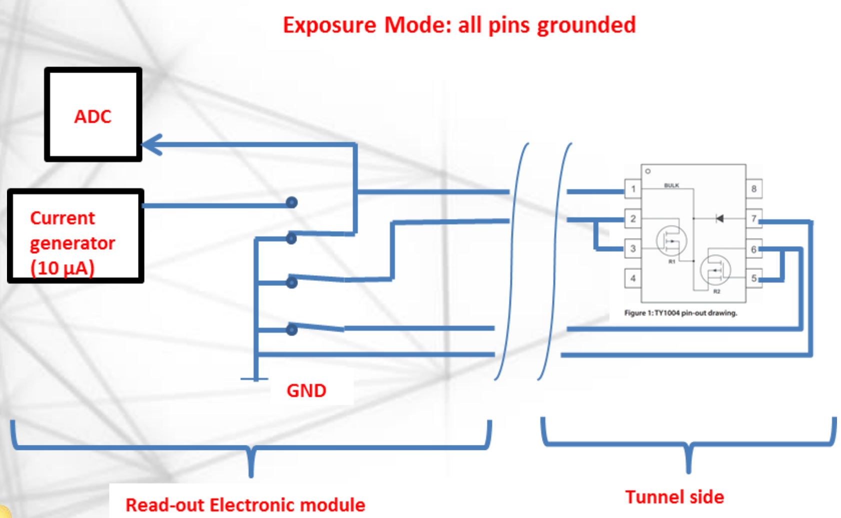


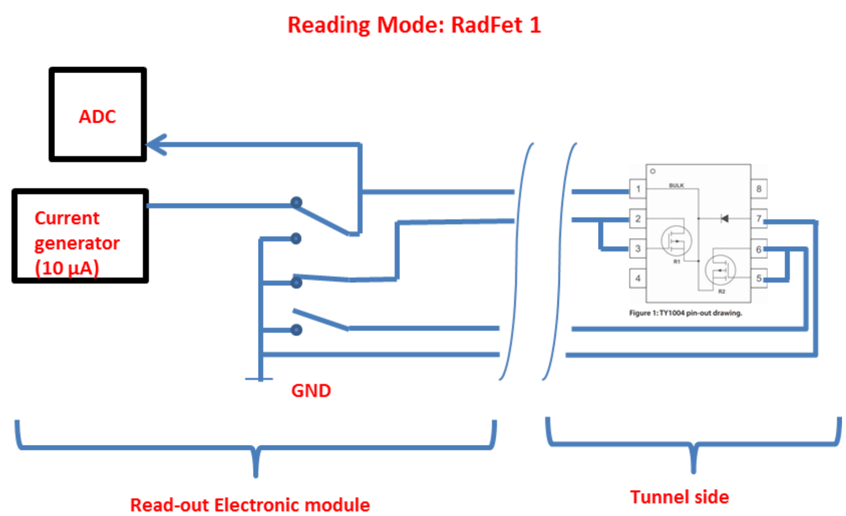


Dose Monitoring

- RadFET Read out electronics
  - Ongoing development of an electronic crate to integrate RadFET monitoring in the control-system.
    - Periodic automated reading (without beam)
    - Multiplexed to read several sensors with the same electronics (8 dual RadFETs)

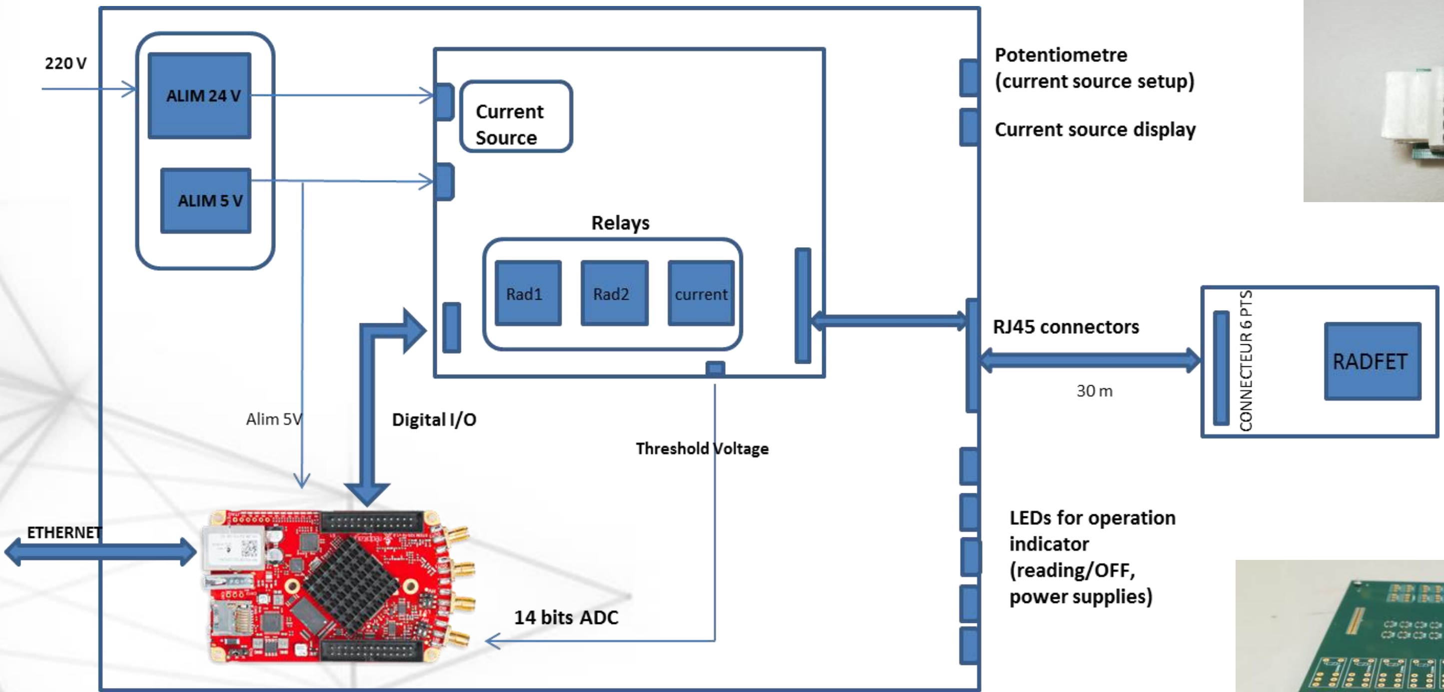




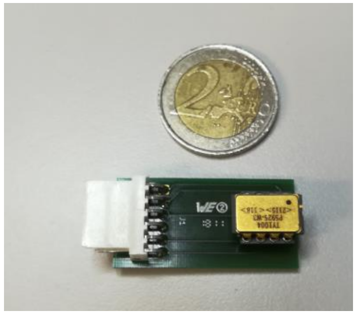


Dose Monitoring

- RadFET Read out electronics
  - Principle:



Simplified schematics of the RADFET readout electronics



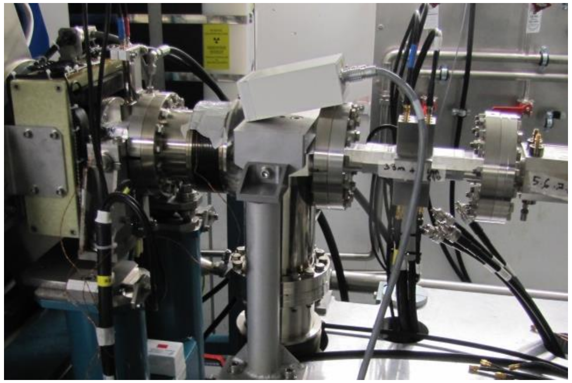
  - First prototype ready in the next weeks
  - Automatic measurements will facilitate the sensor characterization
  - Low cost

Dose Monitoring

- RadFET Conclusion
  - Monitor the dose received by critical equipment (outside vacuum)
  - Preliminary tests validated the principle
  - One prototype of read-out electronics is under assembly
  - To be done:
    - Fading measurement
    - Maximum dose, RadFET is given for 100 krad (1kGy) but can probably go higher

Loss Monitoring

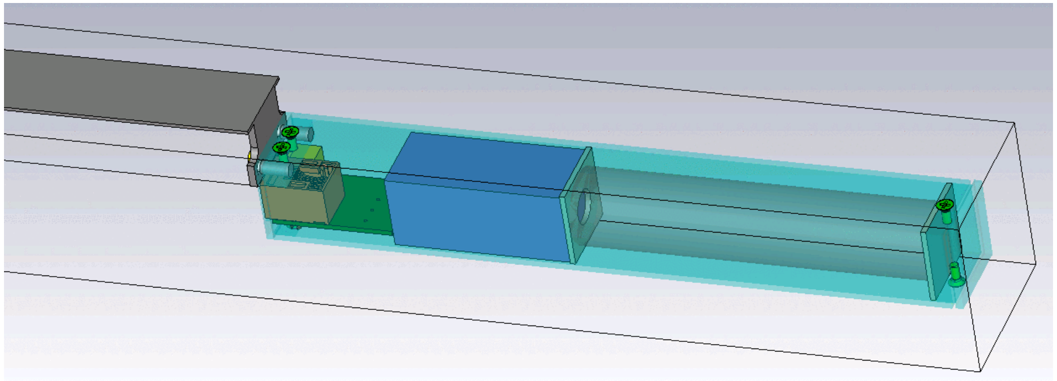
- Present Beam Loss Monitor System:
  - Coincidence pin diodes
    - Insensitive (by conception) to SR
    - Directive sensors -> small angle of detection
    - Counting mode only
    - Slow losses only



- Objective for the upgrade of the beam loss monitor system:
  - Relative calibration between monitors is needed
  - Slow and fast losses

Loss Monitoring

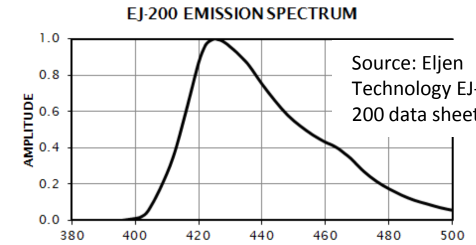
- Sensors:
  - Re-use of the ESRF design:
    - Plastic (scintillation)/Quartz (cerenkov) 100 mm rod
    - Compact Photosensor Hamamatsu H10721 series
    - Housed in a Al section

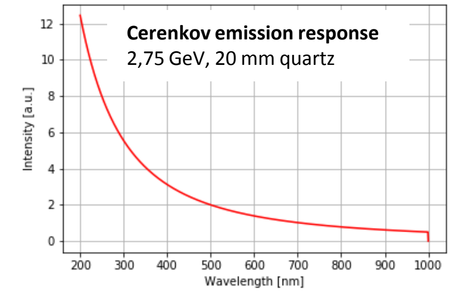


- Electronics
  - Libera BLM
    - 4x125 MHz digitizers (14 bits)
    - Several configurable data rates (ADC, TbT, averaged…)
    - PS for the detectors
    - Postmortem data

Loss Monitoring

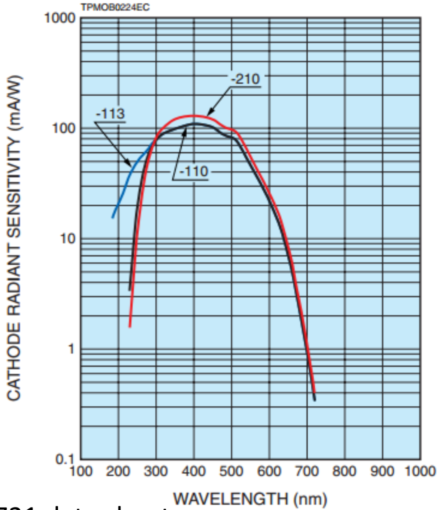
- Rods:
  - Scintillation: 5 x EJ-200 plastic scintillators
  - Cerenkov: 2 x quartz
  - Wrapped in Al foils





- Photosensor modules:
  - 2 x 210:Ultra bialkali photocatode, borosilicate glass
  - 2 x 110: Super bialkali photocathode, borosilicate glass
  - 2 x 113: Super bialkali photocathode, UV glass

Figure 1: Typical spectral response



Source: Hamamatsu H10721 data sheet

- Relative calibration:
  - However the modules are installed/configured on the machine, be able to compare their measurements
    - Scintillator/radiator yield
    - Photosensor sensitivity
    - Photosensor dependence to gain
    - Electronics dependence to attenuation
  - Can be compensated by the electronics:

Acal = Araw x BLDCalib x G x AT

Where:

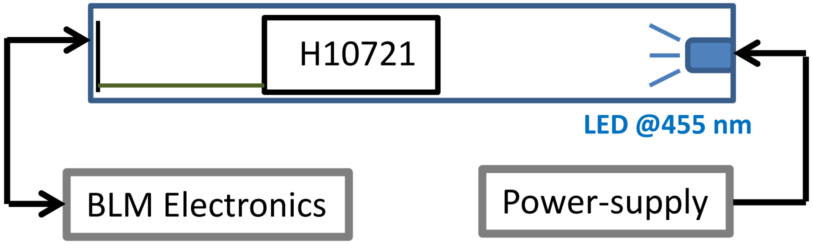
Acal	calibrated amplitude
Araw	raw amplitude (no correction)
BLDCalib	BLDCalib ... It is a calibration constant specific to each channel and the PMT.
G	It is a relative gain factor that depends on the setting of the gain control voltage.
AT	It corrects for the 10^(Att/20)

Source: Libera BLM user guide

Vgc ref	0.00	0.30	0.40	0.50	0.60	0.70	0.80	0.90
G	NaN	334.5	33.25	4.97	1	0.26	0.0825	0.0313

Loss Monitoring

- Diode calibration:
  - Addresses:
    - Photosensor sensitivity
    - Photosensor dependence to gain



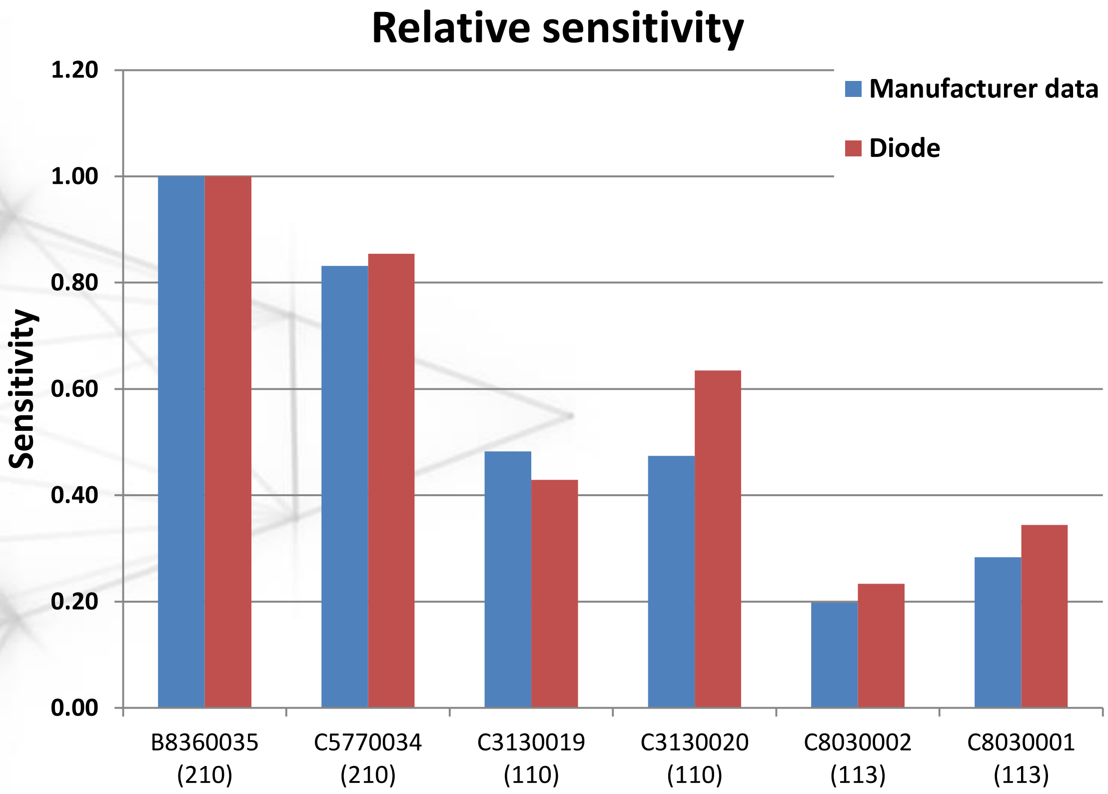
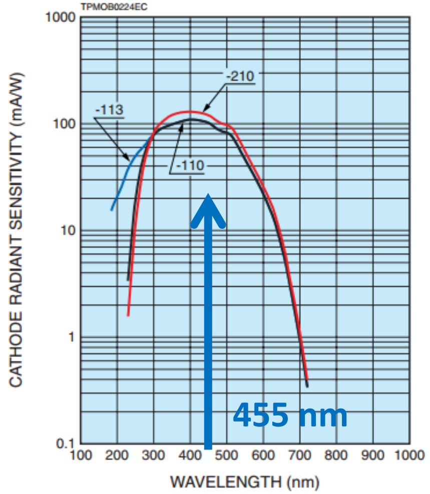
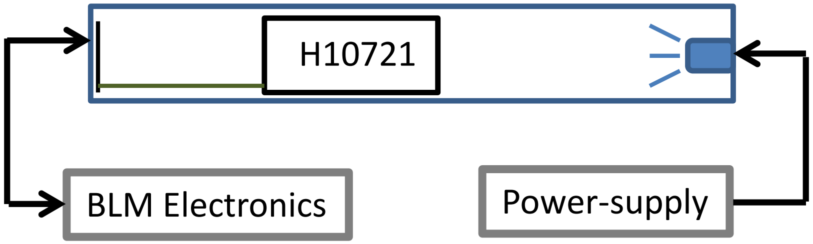


Figure 1: Typical spectral response



Loss Monitoring

- Diode calibration:
  - Addresses:
    - Photosensor sensitivity
    - Photosensor dependence to gain



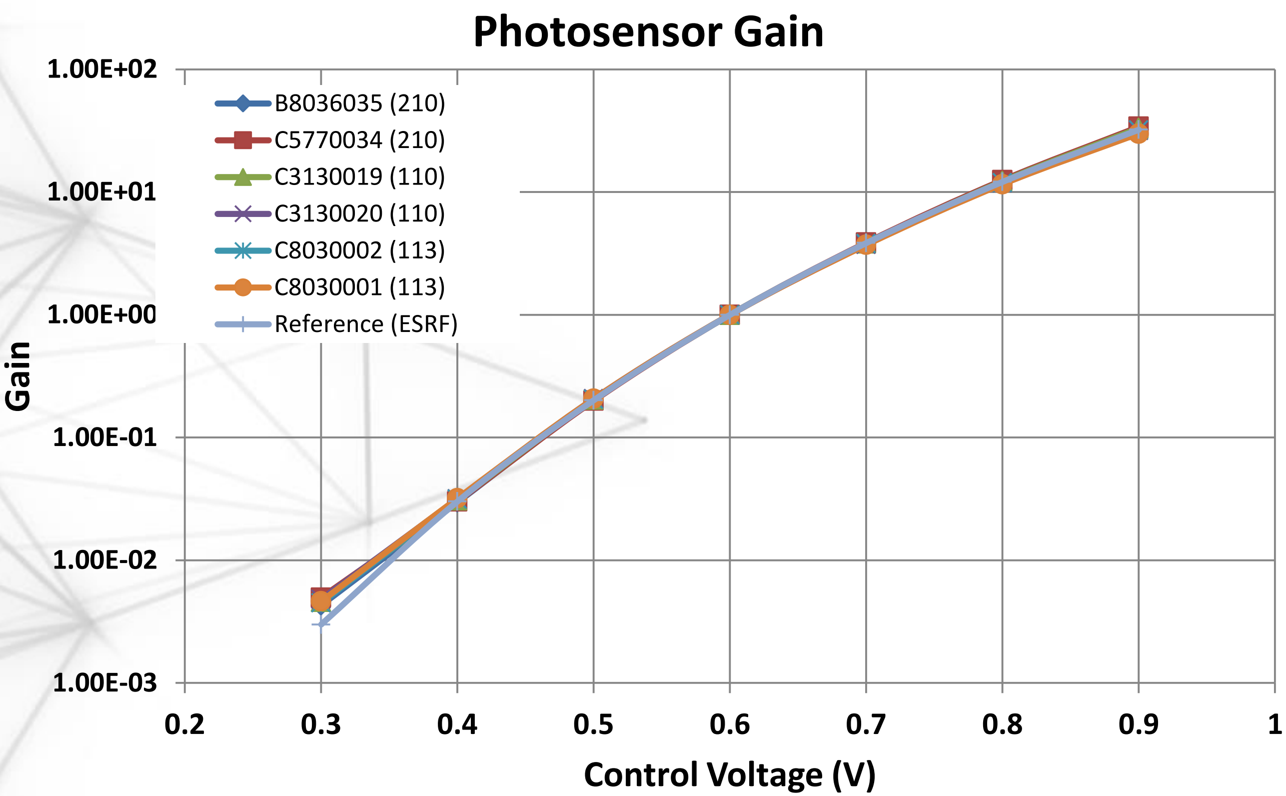
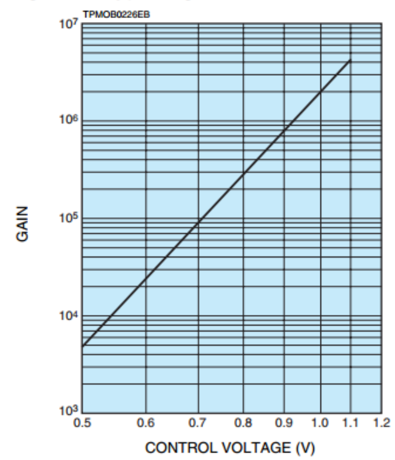
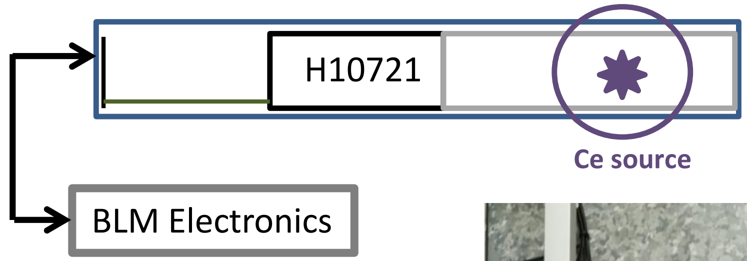


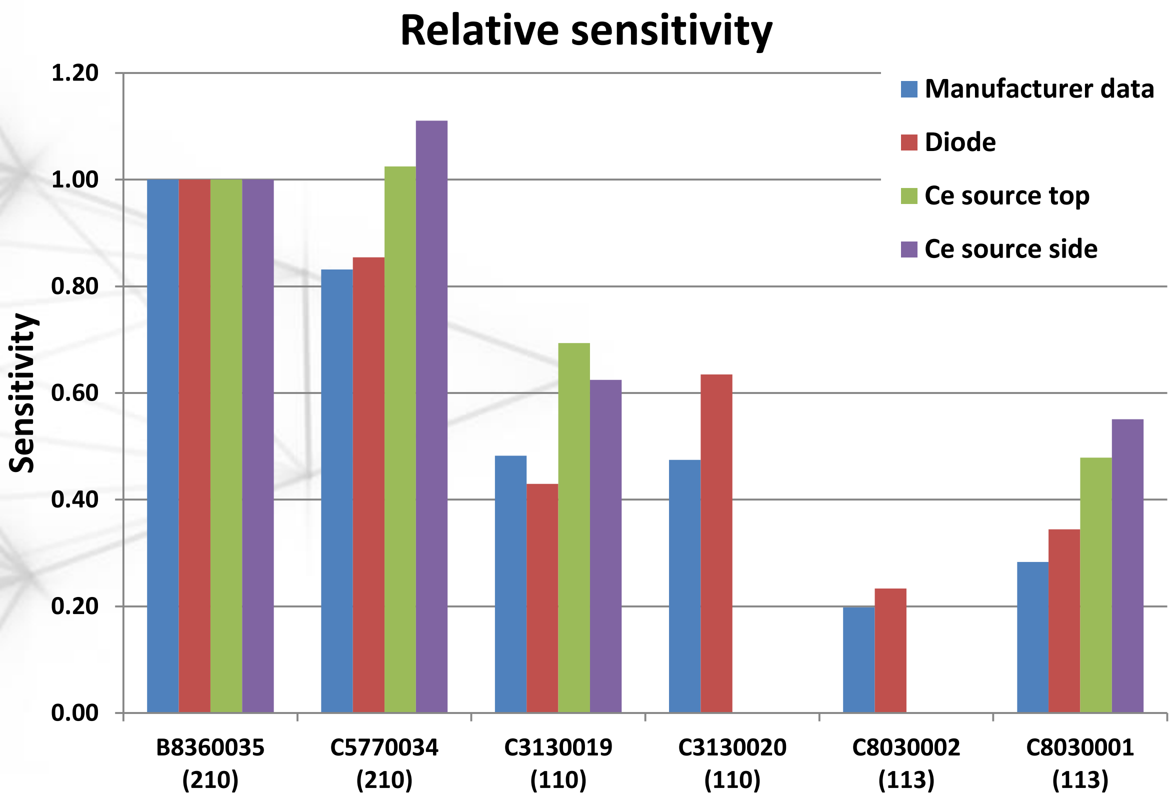
Figure 4: Typical gain



Loss Monitoring

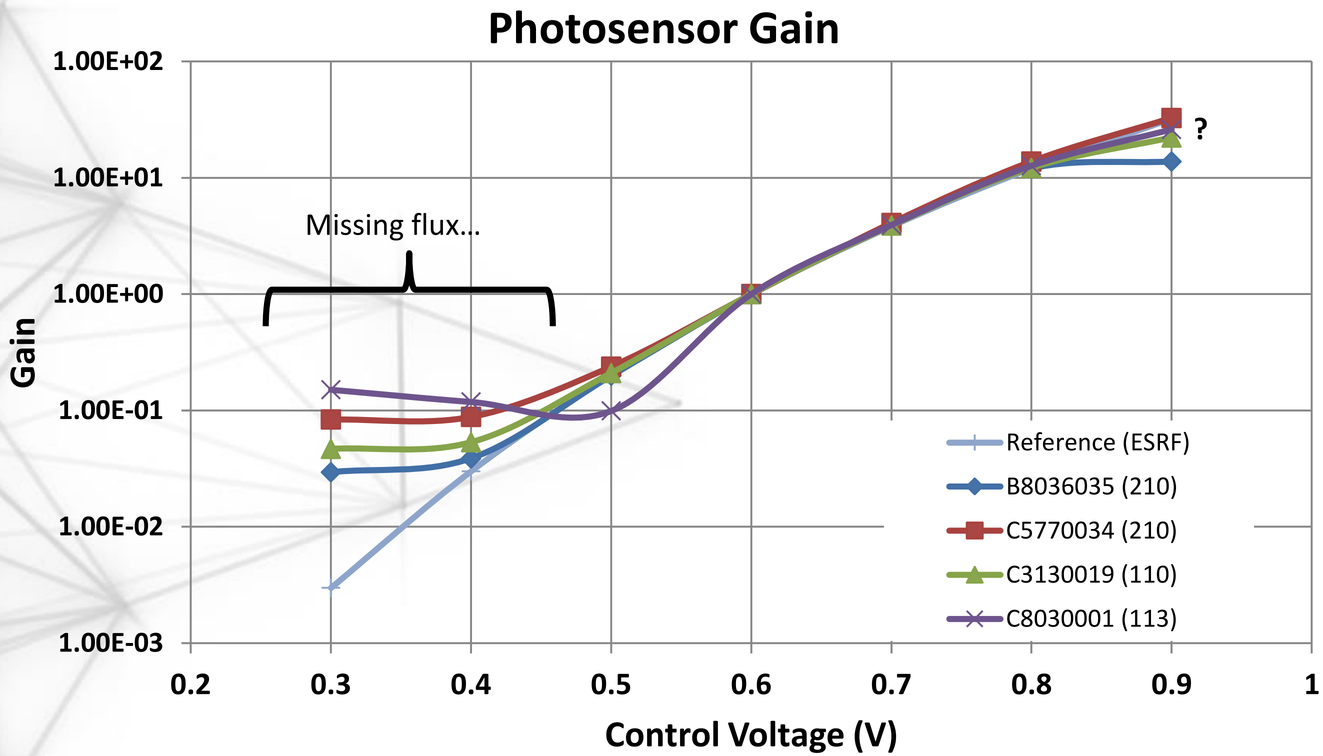
- Cesium source (gamma) calibration:
  - Addresses:
    - Photosensor sensitivity
    - Photosensor dependence to gain
    - Scintillator yield





- Effect of the scintillator yield?
- Sensitivity to the source position?

- Cesium source calibration:
  - Addresses:
    - Photosensor sensitivity
    - Photosensor dependence to gain
    - Scintillator yield

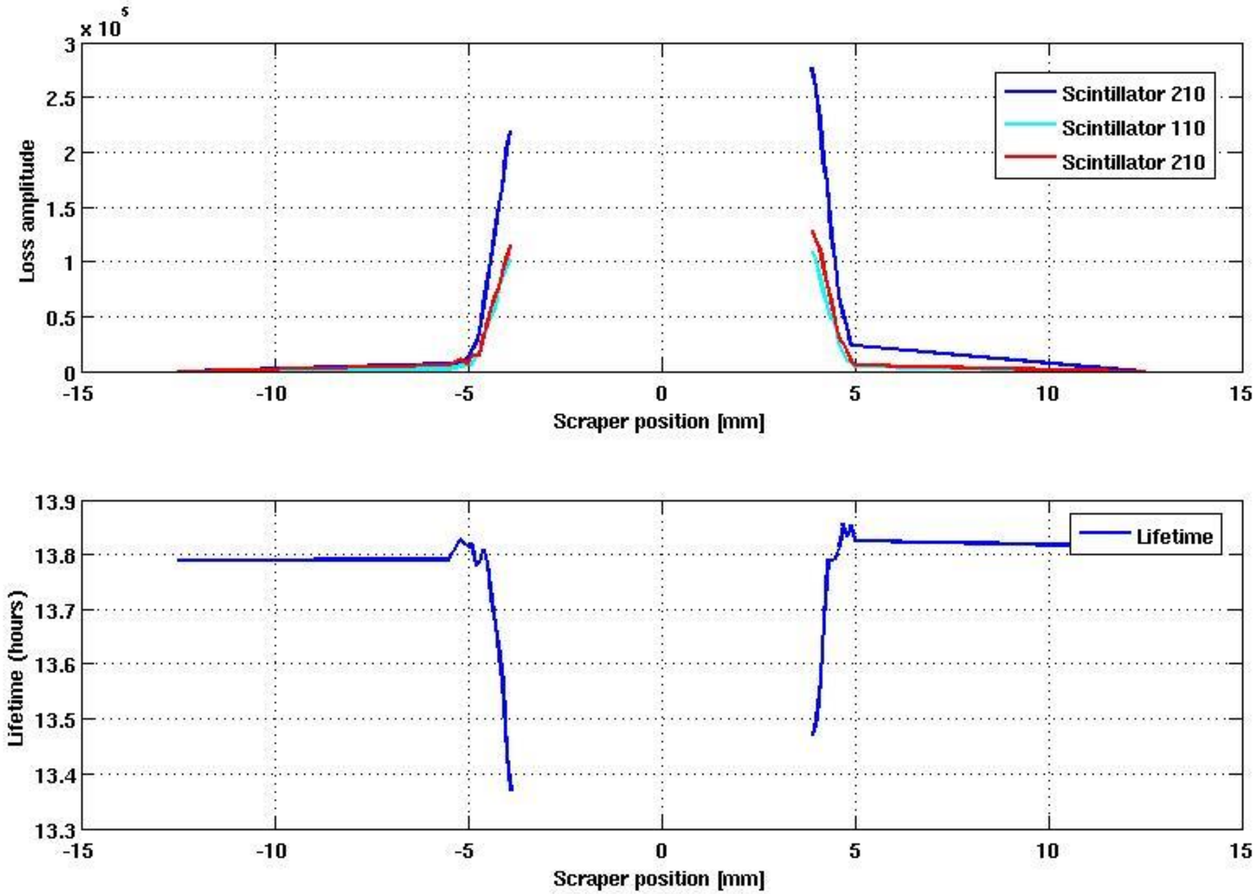


Loss Monitoring

- First observations with beam
  - 4 BLMs installed behind the vertical scraper
  - 3 different photosensors (210, 110, 113)
  - 3 scintillators, 1 cerenkov radiator
  - 3 thickness of lead shielding (1/2/3 mm)

Loss Monitoring

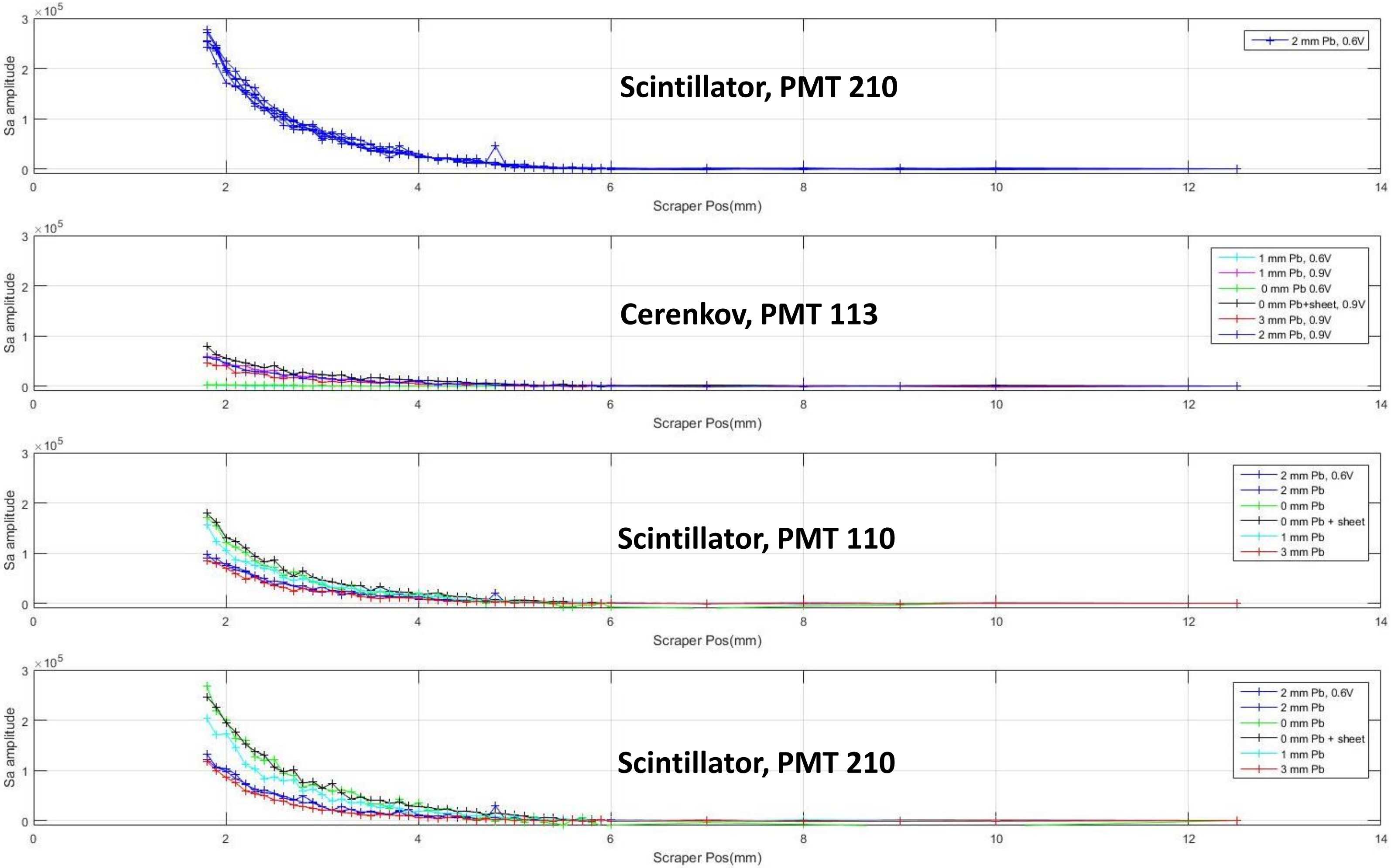
- Beam first observations
  - Vs scraper position



Definitely a really faster way of measuring the machine physical aperture compared to lifetime…

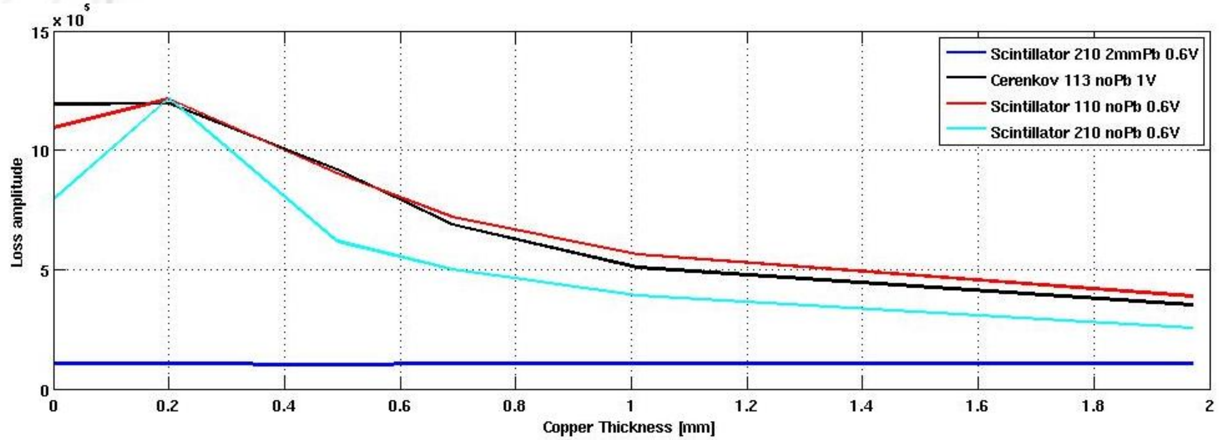
Loss Monitoring

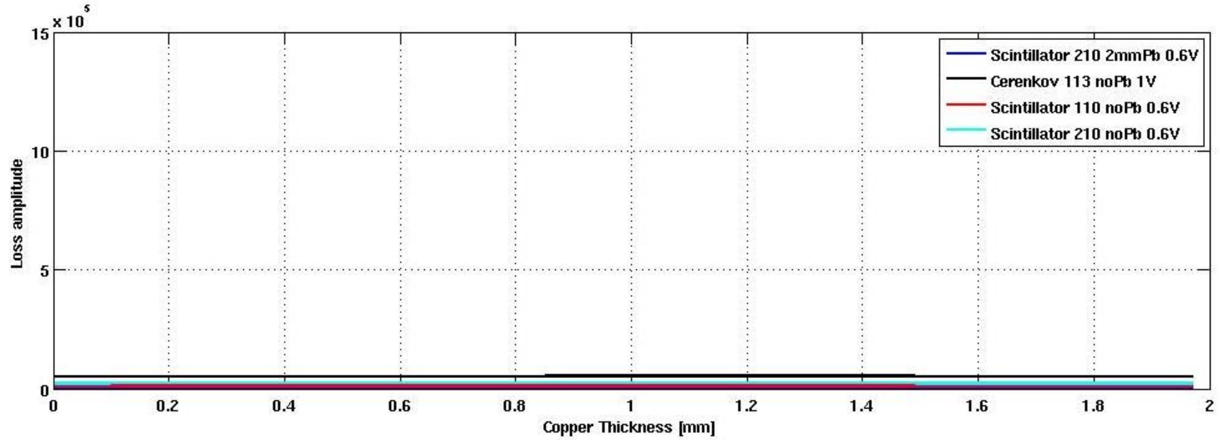
- Beam first observations
  - Vs scraper position (and lead thickness)



Loss Monitoring

- Others
  - Perturbation by the (nearby) pinhole operation

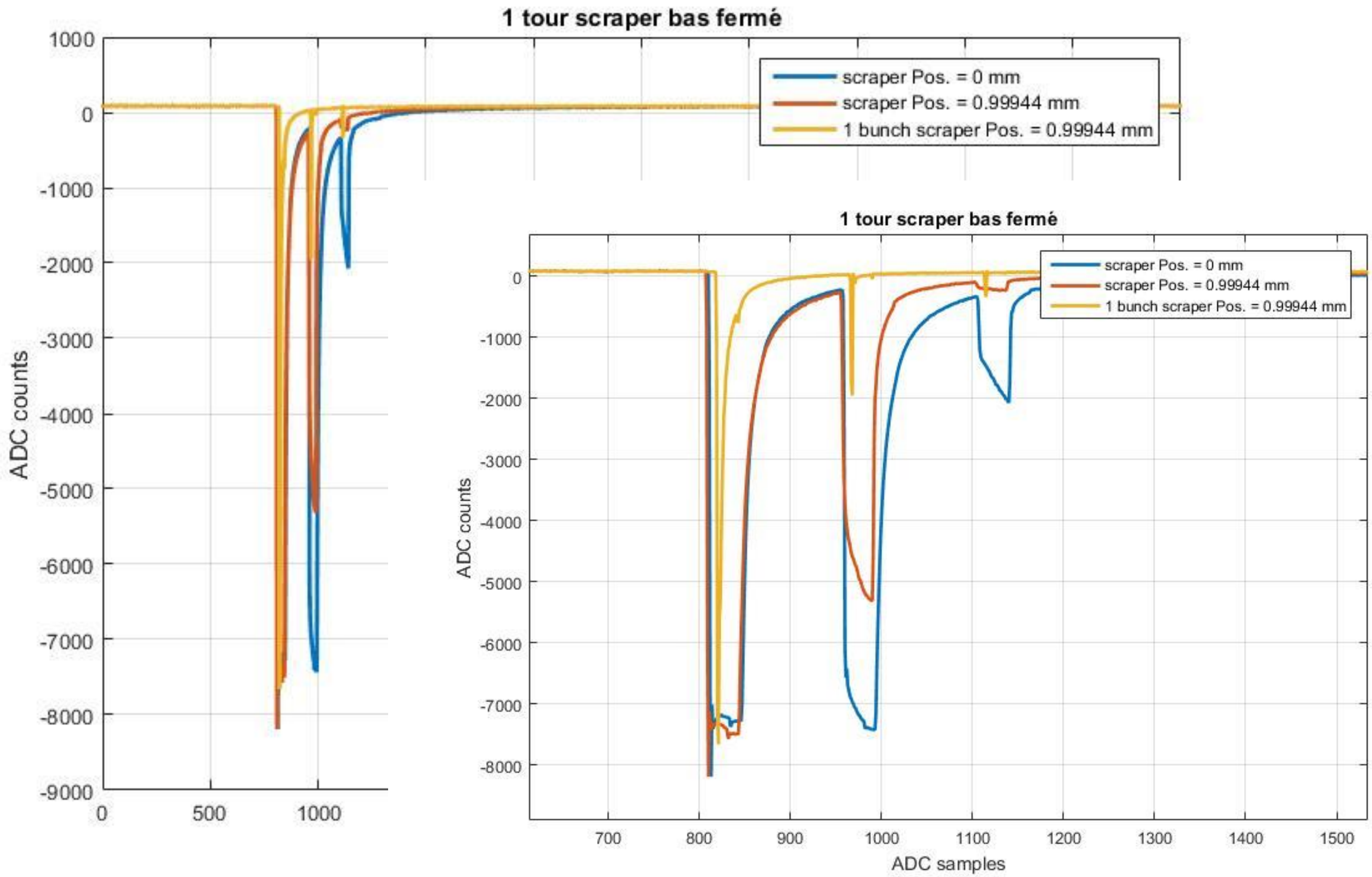




Loss Monitoring

- Beam first observations (fast losses, scintillator+ PMT210)
  - No beam, injecting on inserted scraper

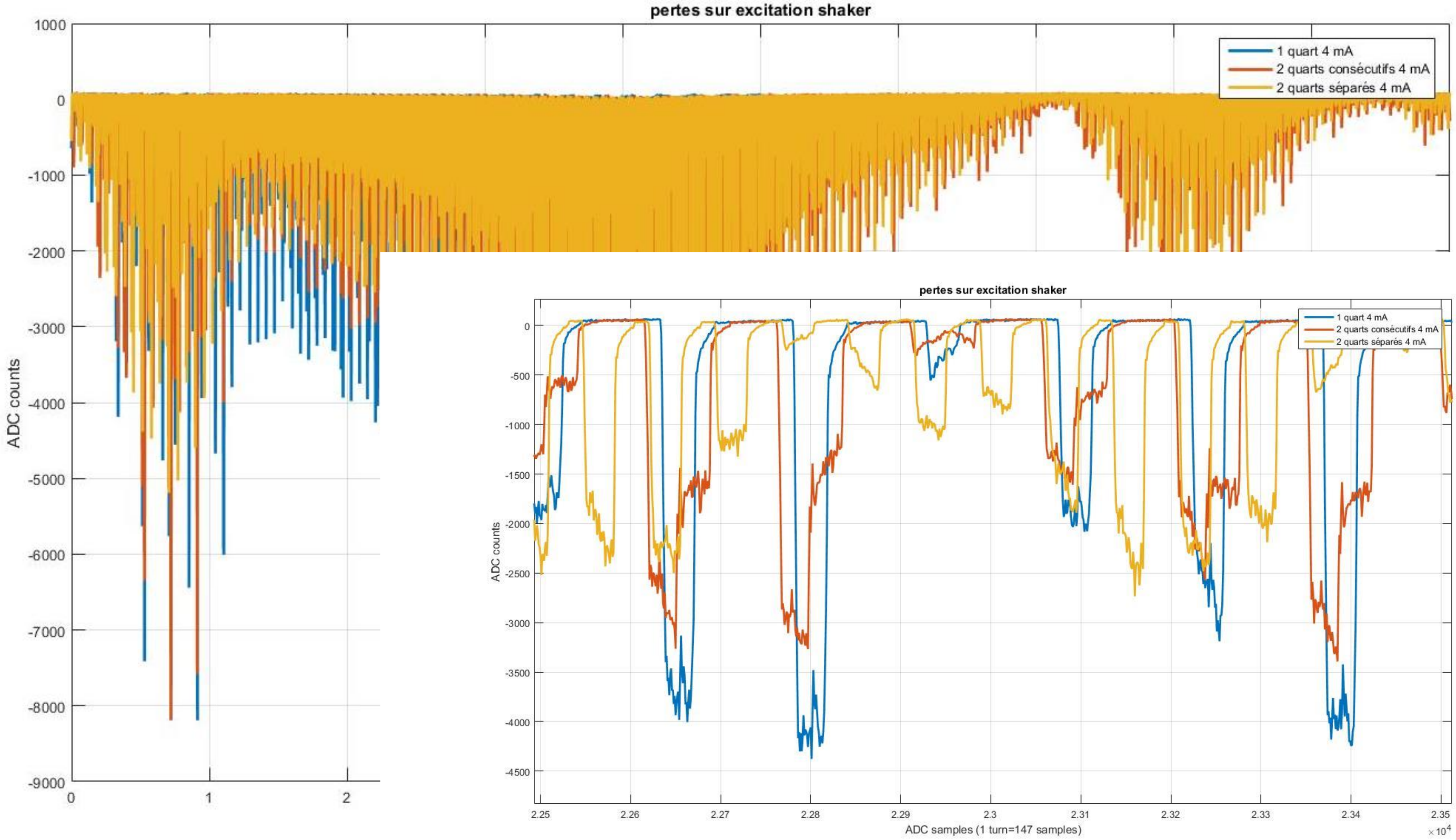
1 turn = 147 ADC samples



Loss Monitoring

- Beam first observations (fast losses, scintillator+ PMT210)
  - Stored beam, scraper slightly inserted, vertical excitation

1 turn = 147 ADC samples



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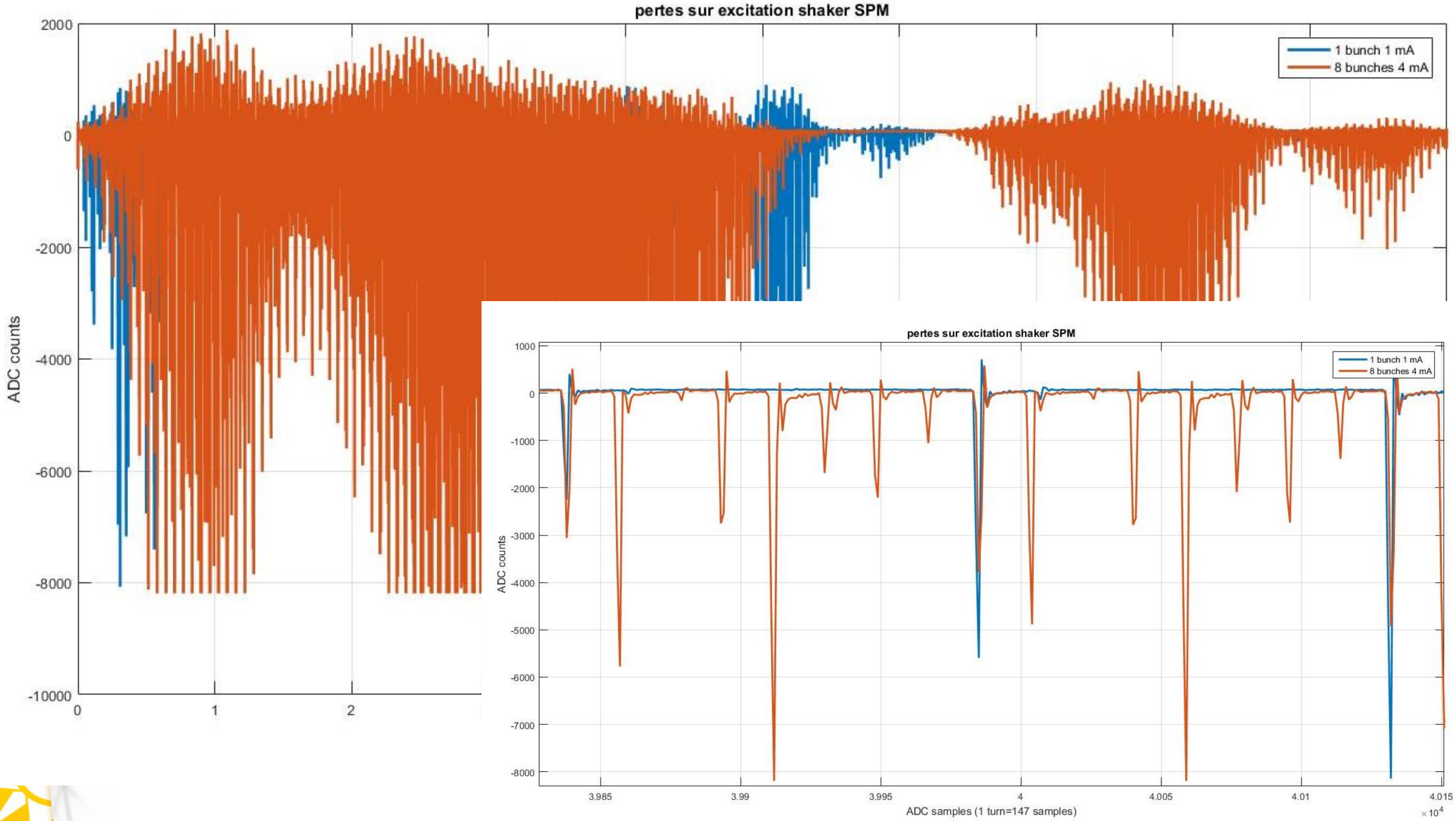
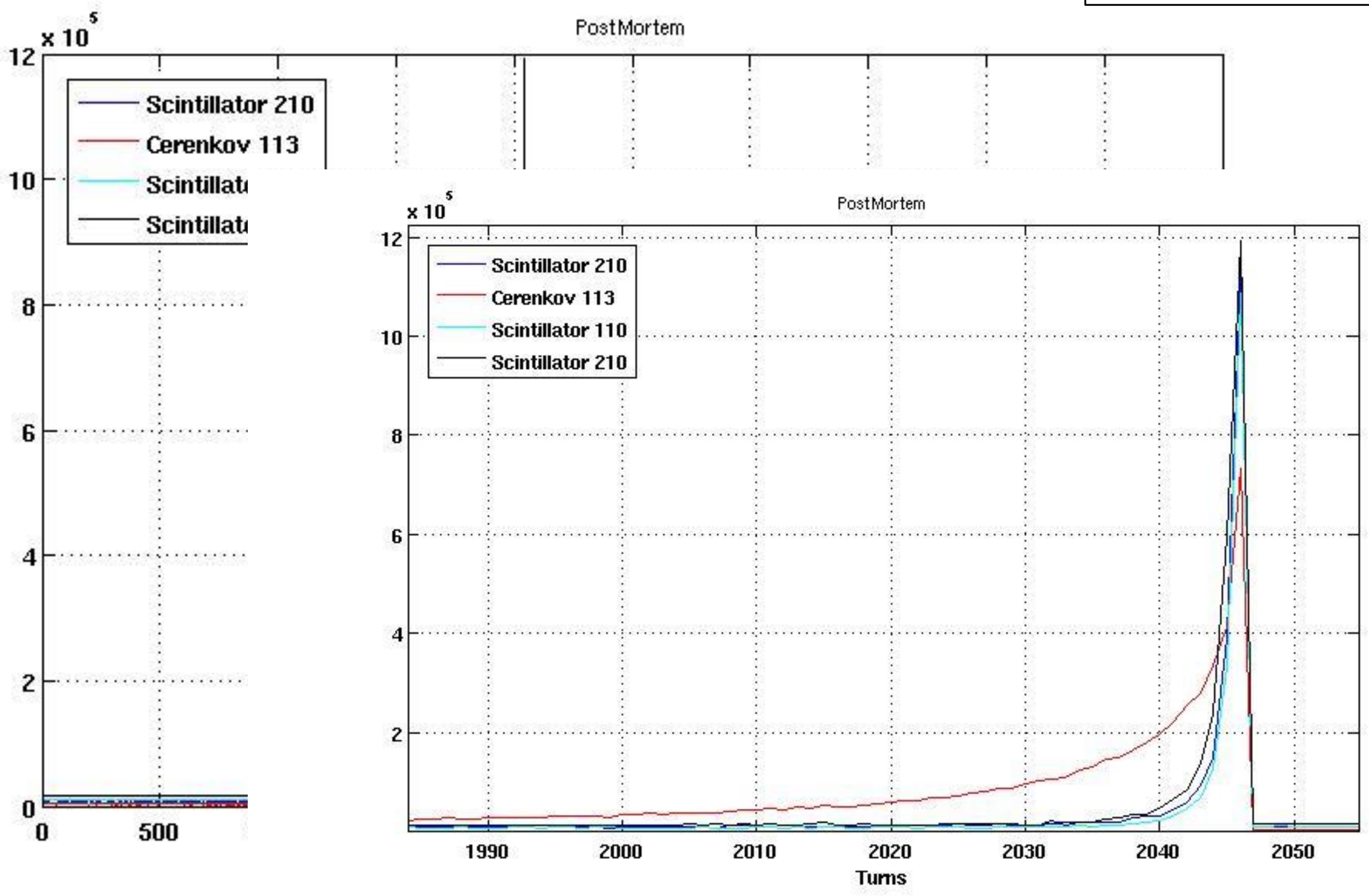


Loss Monitoring

- Beam first observations
  - Postmortem

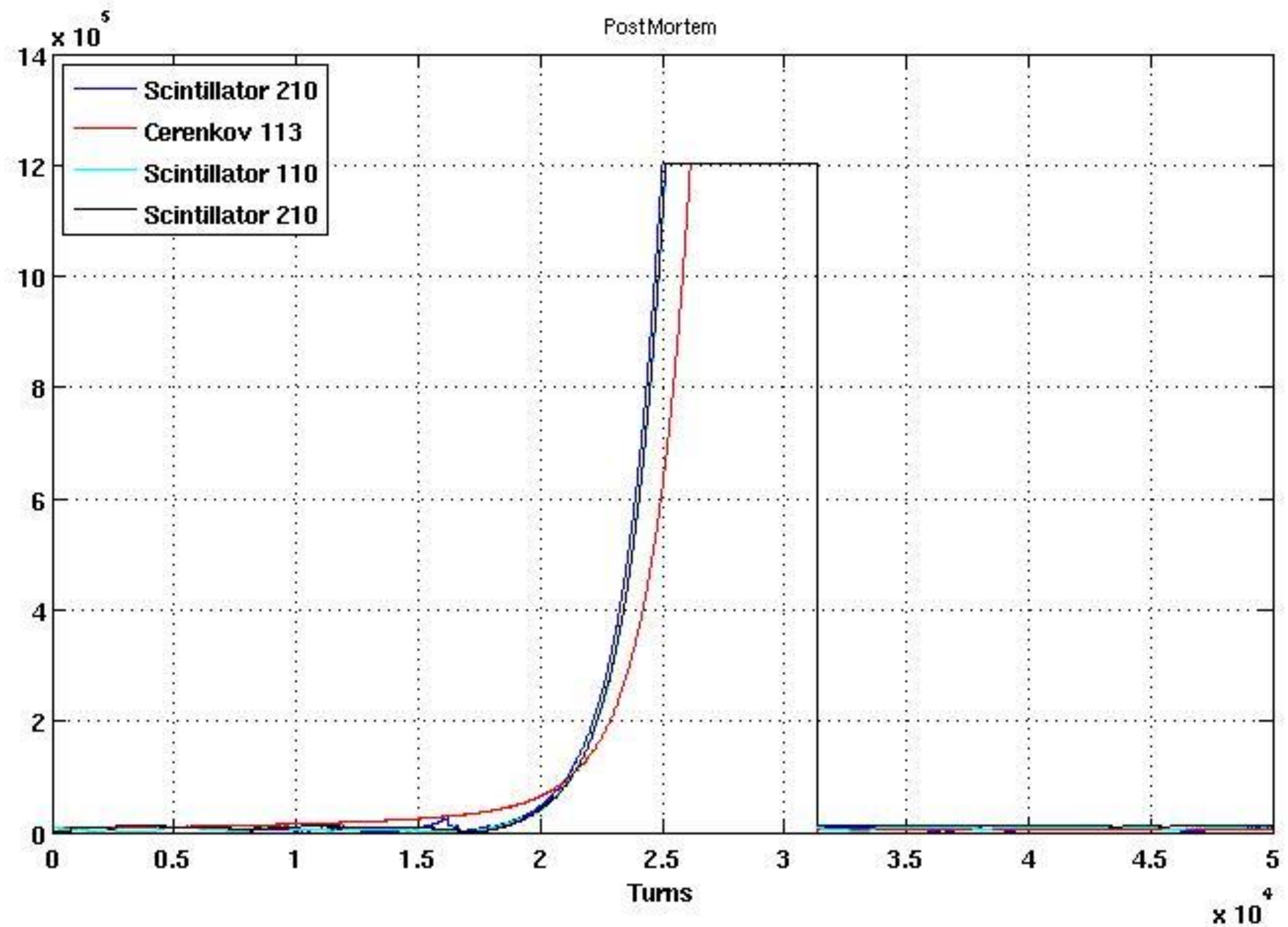
50 Ohms
Attenuation 10 dB
Vgcc= 0,6V (scintillators)
1V (Cerenkov)



Loss Monitoring

- Beam first observations
  - Postmortem

1 MOhms
Attenuation 20 dB
Vgcc= 0,6V (scintillators)
1V (Cerenkov)



Conclusion

- Two different systems for two different purposes
  - Dose measurement:
    - Have a rough estimation of the dose received by the equipment in the tunnel
    - Electronics readout prototype to be ready within the next month
    - Finish the RADFET characterization (fading, maximum measurement range…)
  - Loss measurement:
    - Localization and dynamic of the beam losses
    - Relative calibration
      - Operation and Machine physic studies
      - Results on witness cells will be used to validate radioprotection simulation codes
    - 2 cells to be equipped by the end of the year

- Back up slides

Loss Monitoring

- Others
  - ADC offset measurement vs PMT gain and tunnel light (no beam)