Radiation test at ENEA RC “Casaccia”

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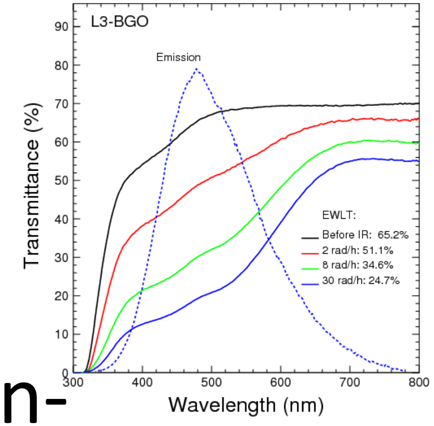
The issue



- LY loss due to appearance of radiation-induced absorption bands caused by color center formation
- There exists a trasmittance recovery mechanism → two types of crystals with significantly different issues
  - Slow recovery (e.g. LYSO, CsI?,…)
  - Fast recovery (e.g. BGO)

From R. Y. Zhu, "Radiation damage in scintillating crystals," Nucl. Instrum. Methods, vol. A413, pp. 297–311, 1998.

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Quantifying the "fast recovery" case

Fraction of absorption centers activated

$$D(t) = \sum_{i=1}^{n} \left\{ \frac{T_i}{T_i^R} D_i^{all} \left[1 - e^{-t/T_i} \right] + D_i^0 e^{-t/T_i} \right\}$$

$$T_i = \left(\frac{1}{\tau_i} + \frac{1}{T_i^R} \right)^{-1} \qquad T_i^R = \frac{1}{b_i R}$$

where

- The sum runs over all types of absorbtion centers
- R: dose rate
- b=sensitivity of a center to the dose rate

Asymptotically

$$D(\infty) = \sum_{i=1}^{n} \frac{1}{1 + T_i^R / \tau_i} D_i^{all}$$

Note: asymptotic value depends on R via the relative value of the characteristic times

Irradiation off

$$D(t) = \sum_{i=1}^{n} D_i^0 e^{-t/\tau_i}$$

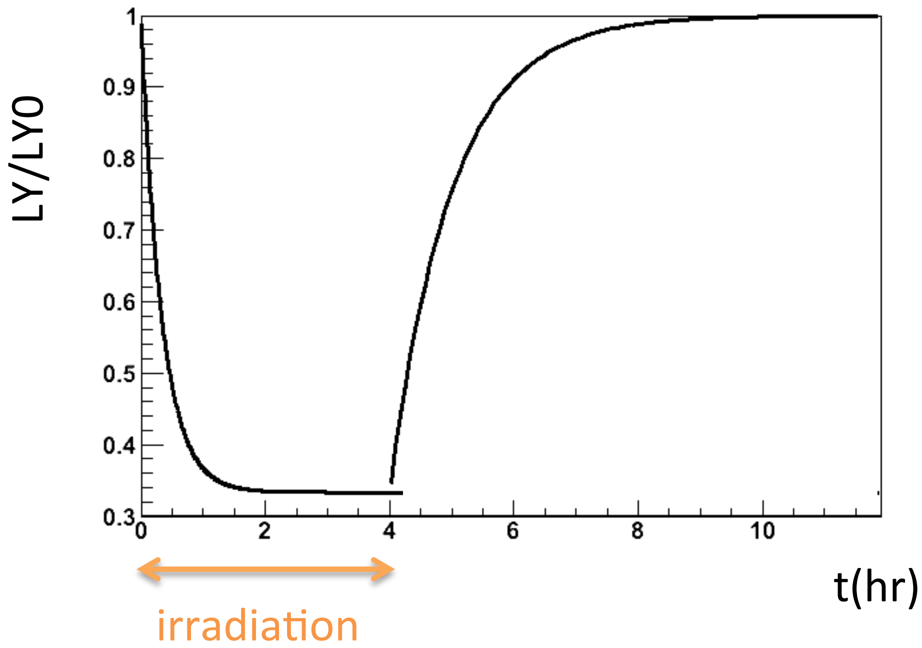
Note: recovery time (τ) longer than degradation time (T)

Example of LY

- To first approximation $LY \propto LT \propto 1 - \frac{D}{\sum D_i^{all}}$

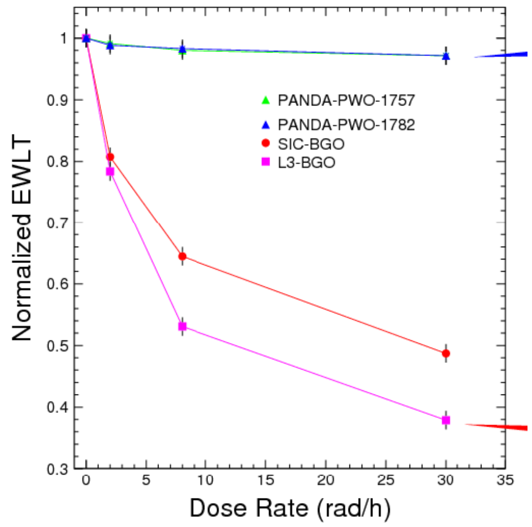
  ➔ expected behavior for reasonable values

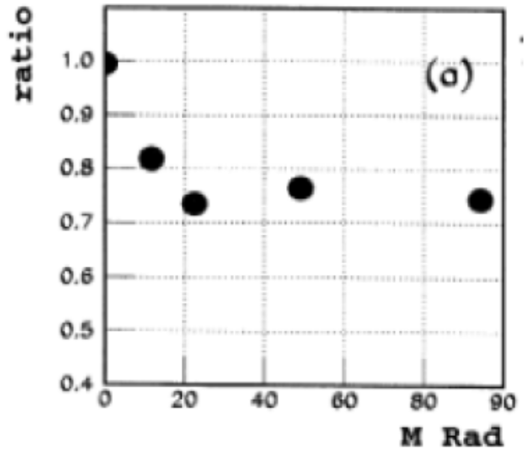
  (one color center, τ=1hr=2T^R)



Known facts

- LYSO and CsI undoped should be radiation resistant
- BGO should have recovery time ~1 hr
- LY(∞)/LY0 known for some productions





- Unclear statements about behaviour after Mrad doses

(insensitive to radiation?)

Goal of the tests

Assumed dose (rates) in SuperB

- 30krad total
- 3krad/year
- 10rad/day
- 0.5 rad/hr

- Measure properties of BGO at Dose rates comparable with SuperB ones and with time profiles comparable with the actual SuperB operation
- Further investigate the possibility to condition BGO to make it more resistent
- Verify stability of LYSO and CsI
- Setup a test stand for future studies

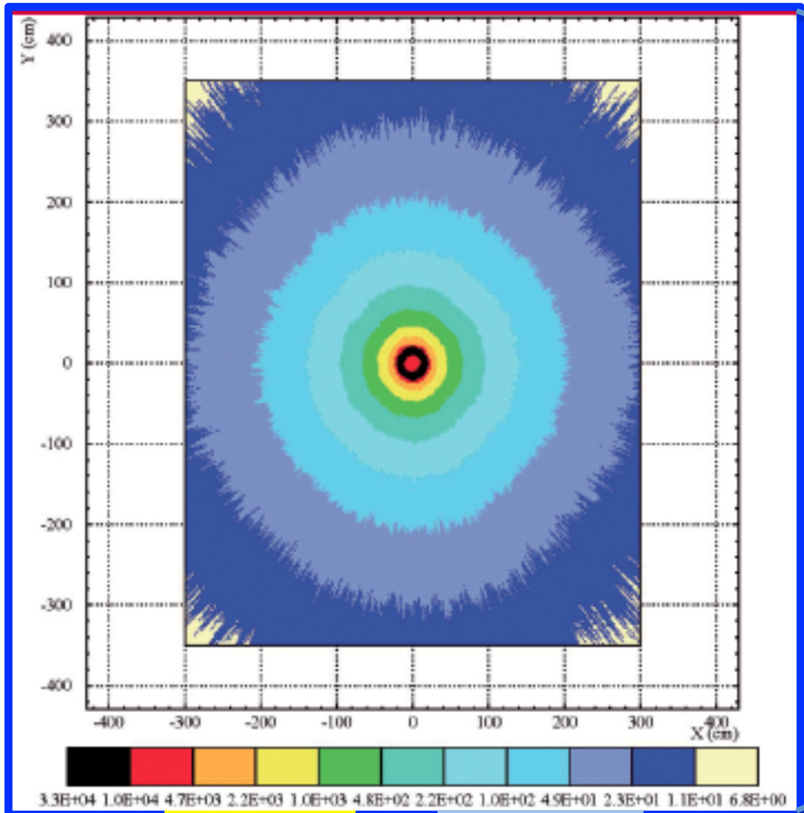
Crystals to be tested

- 1xLYSO (2x2x20)
- 2xBGO SICCAS new (2.5x2.5x16)
- 2xBGO L3 endcap (2.2x2.2x18)
- 1 CsI undoped (5x5x30)

Dose rates @ Calliope

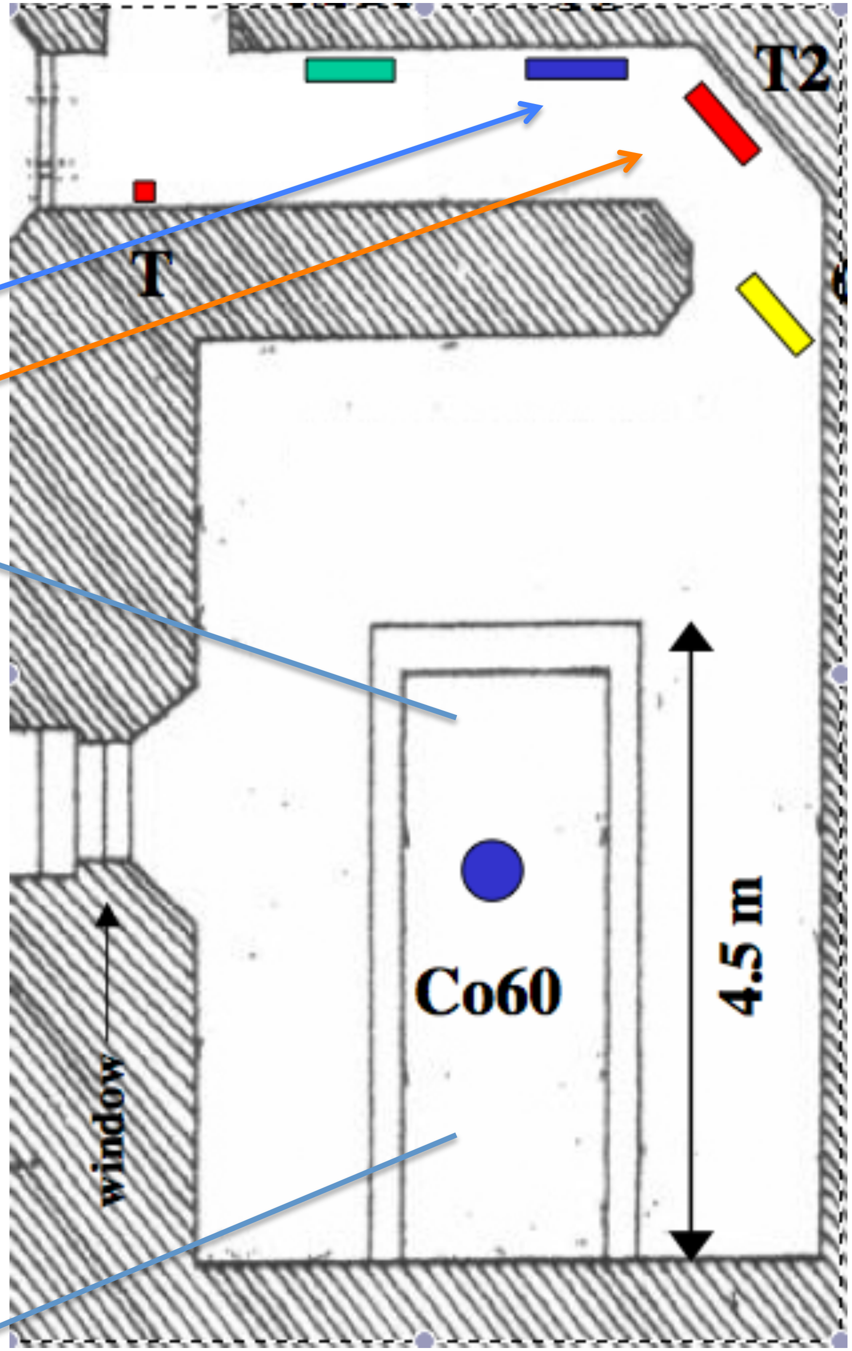
DR~9rad/hour

DR~30rad/hour



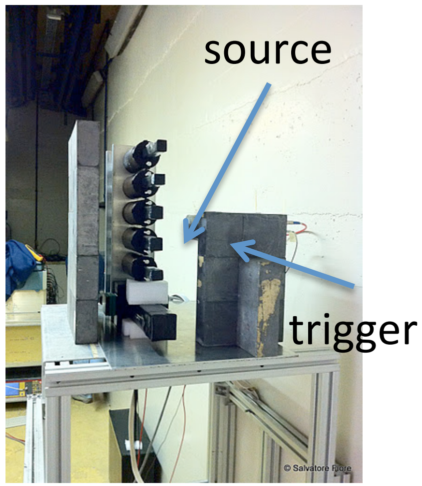
DR=0.1Mrad

DR=0.01Mrad



Measurements setup

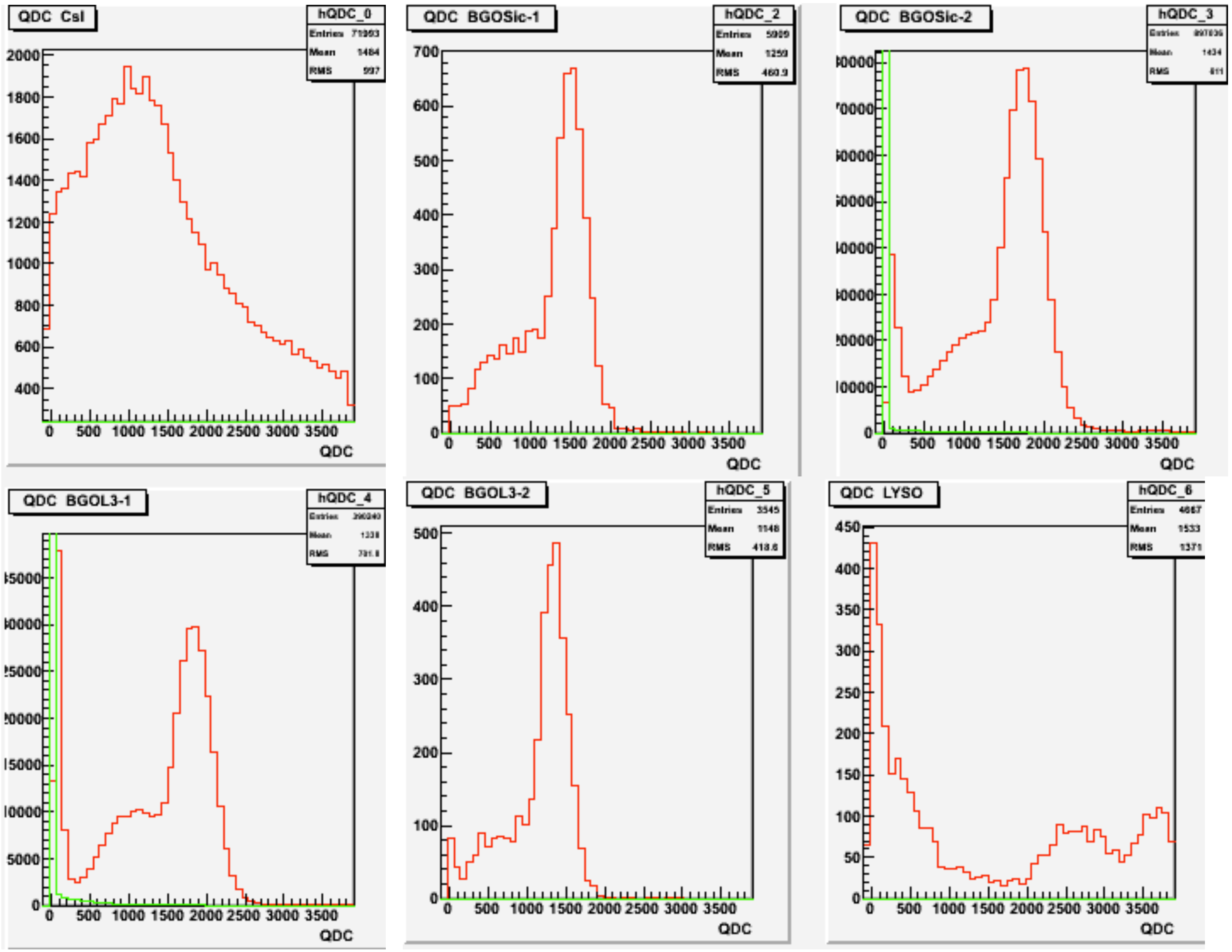
- Transmittance measurements with spectrophotometer located outside the cell (need to wait 10min before entering)
- LY measurement
  - Moveable test stand to be used in low rate region
  - 6 PMTs with mask to be able to easily extract and reposition crystals
    - Should be able to resist at tens of rad/hr
    - Crystals will be detached from the test-stand for the high dose irradiations
- Co Source coupled to NaI scintillator +PMT as an independent trigger with known geometrical efficiency: use one of the two simultaneous photons to tag the other, which is detected by one of the crystals



Problems (I)

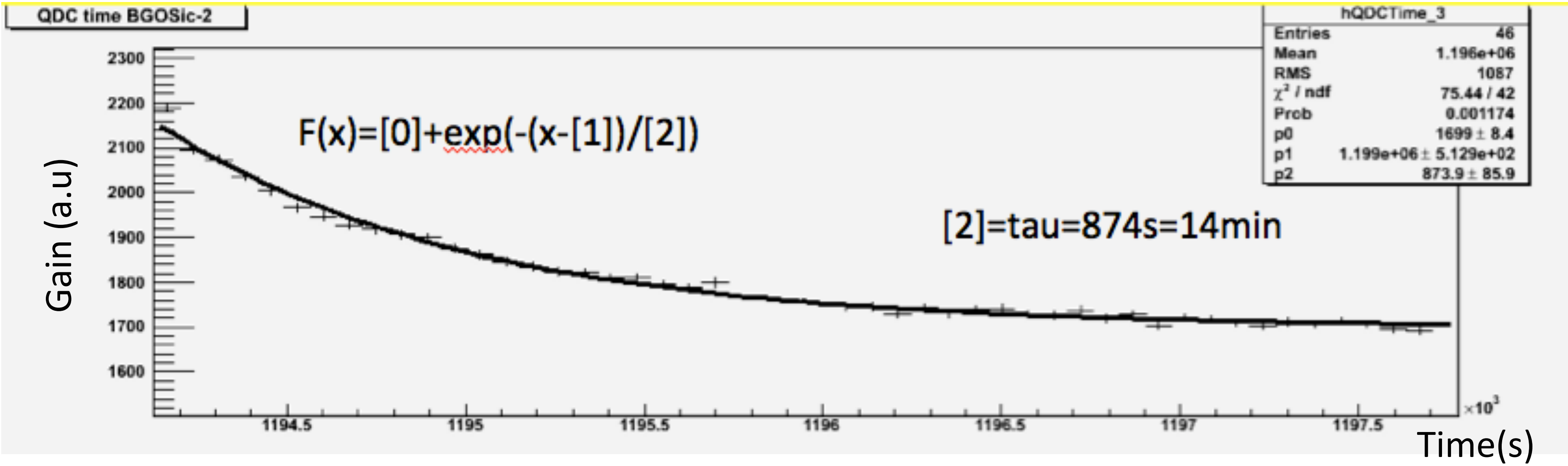
- NaI demonstrated to be a poor choice as trigger: very low resistance to radiation
  - →we had to use the or of two BGO as trigger
  - →Impossible to make fine monitoring of the other crystals
- CsI had a drop in LY after the first round of irradiation (1hr at 8 rad/hr) without ever recovering. We suspect a problem with PMT (different from the others) but we have not yet investigated.

Signals

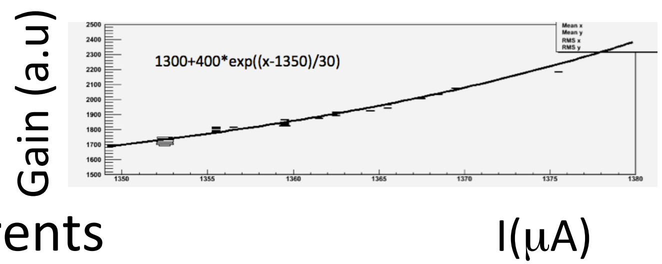

QDC CsI
hQDC_0
QDC BGOSic-1
hQDC_2
QDC BGOSic-2
hQDC_3
QDC BGOL3-1
hQDC_4
QDC BGOL3-2
hQDC_5
QDC LYSO
hQDC_6
Entries
Mean
RMS
QDC

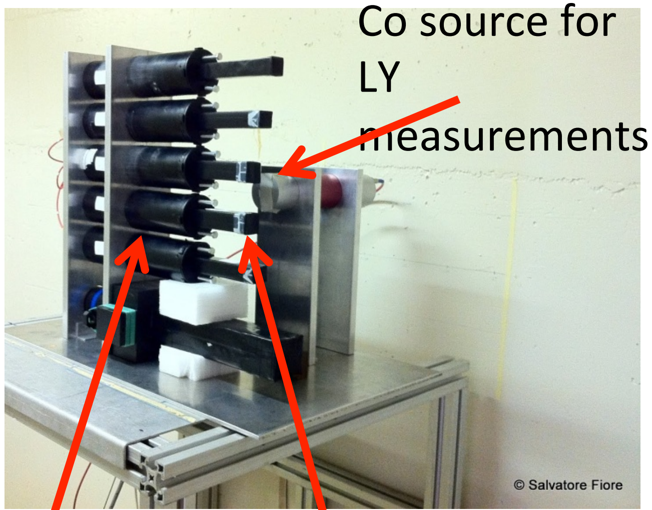
Problems(II)

- Found a long PMT gain drift even for short periods off



- Impossible to make "fast measurements" with LY setup in irradiation zone
- Study possibility to correct with currents



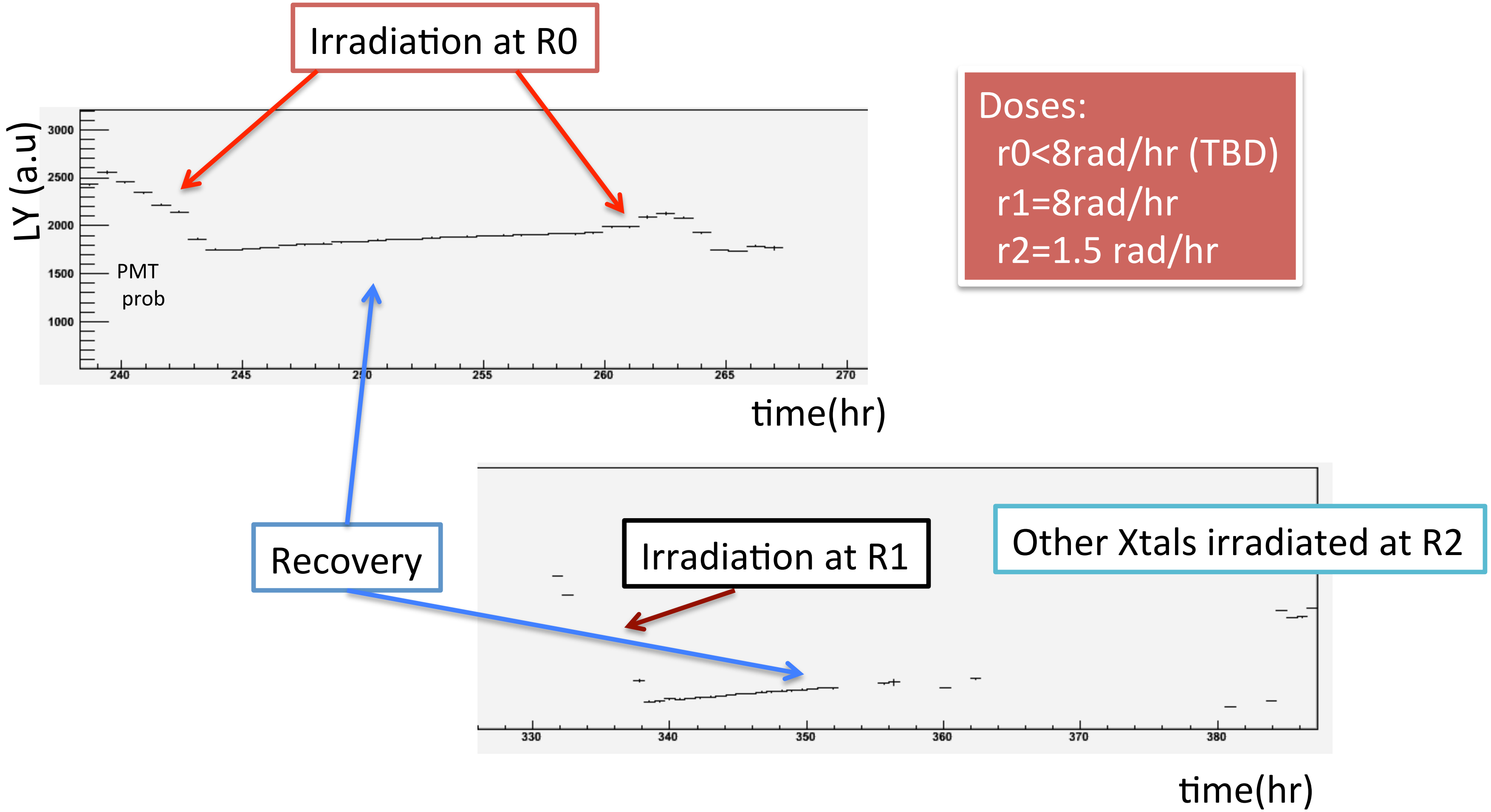


PMTs crystals

First measurement setup:
crystals on PMTs during irradiation,
HV ON during fast measurements between irradiations
HV standby during irradiation

specific gain drift for our PMTs implies a long gain stabilization time:
instead of leaving the crystals on the PMTs during irradiation, we had to irradiate the crystals alone and place the PMTs outside irradiation zone with HV ON.
Crystals were placed on PMTs during (longer) irradiation stops.
In this configuration the radiation dose was also precisely known.

Measurements summary

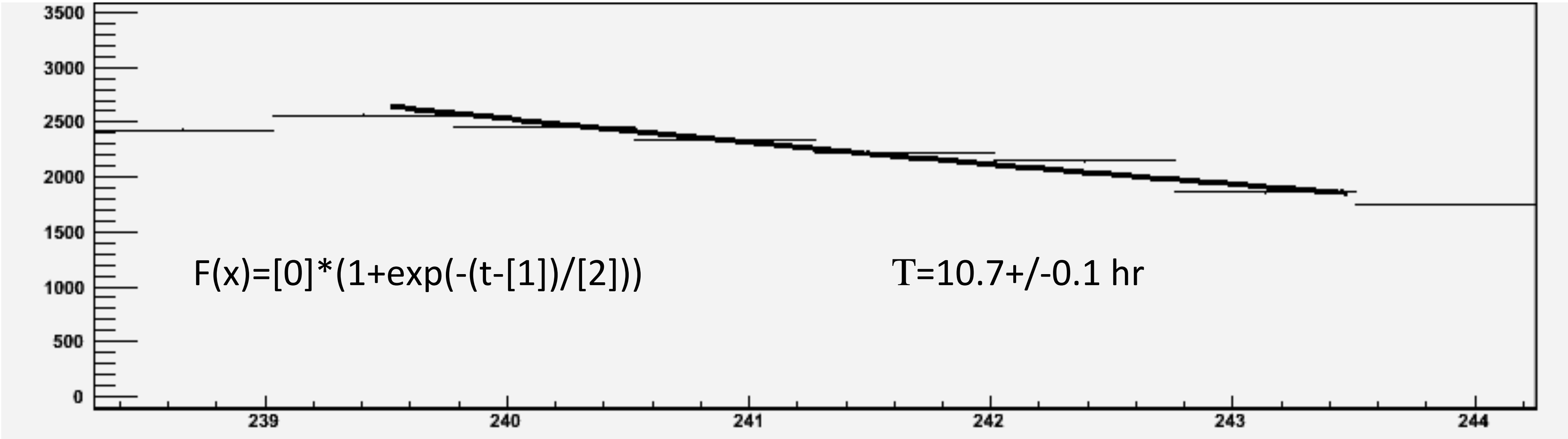


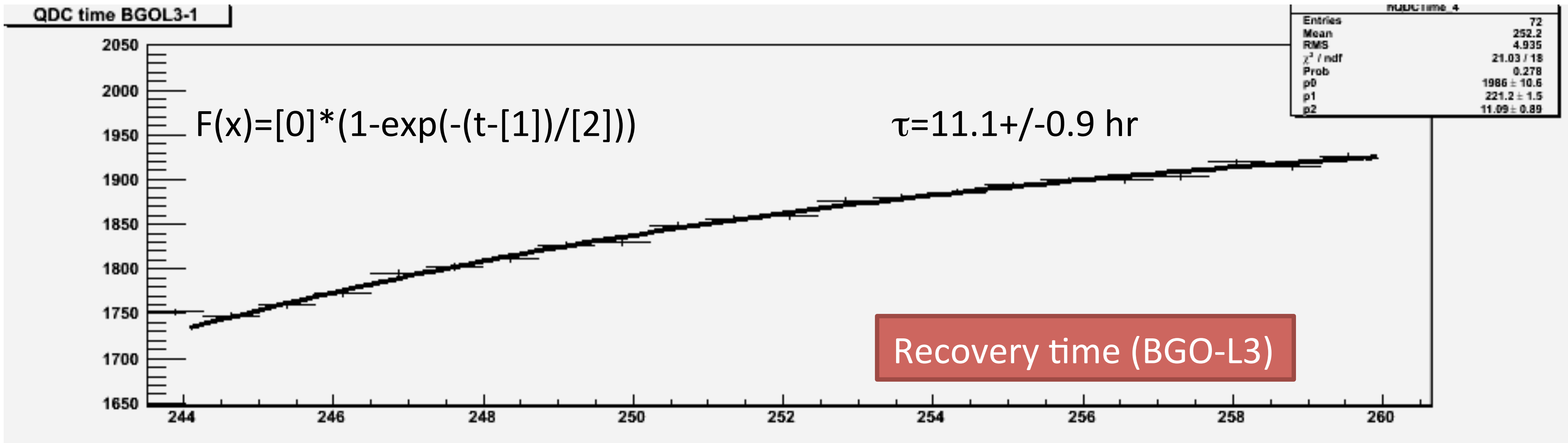
Doses:
- r0<8rad/hr (TBD)
- r1=8rad/hr
- r2=1.5 rad/hr

BGO-L3 crystal (#1)

BGO-L3 crystal (#1)

Time constant (rough) measurements

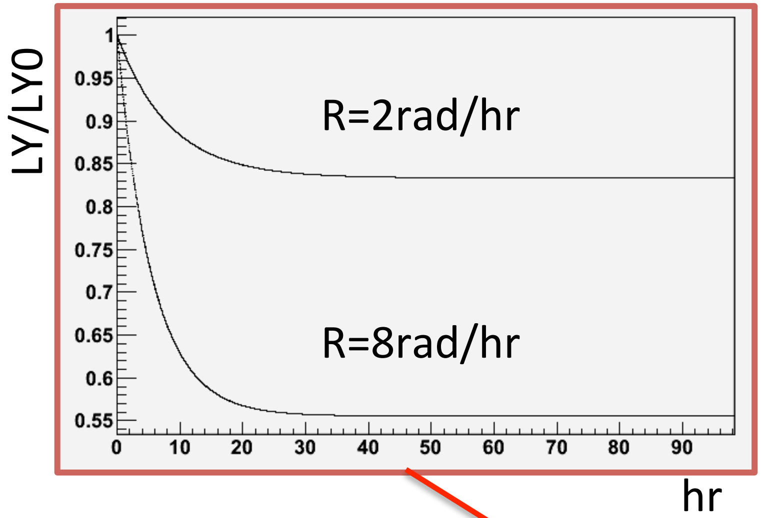


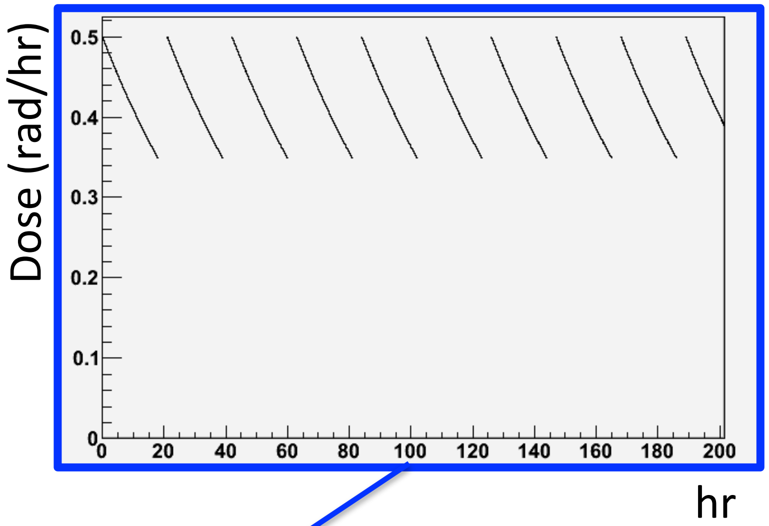


Lesson learned so far

- L3 BGO as good as the newly produced one
- measurement in a high radiation environment enhanced instrumental systematic uncertainties: Risk of masking irradiation effects with detector ones
- Recovery time seems to be rather ~10hrs → need to rethink strategy
- Significant drop (40% at 8rad/hr) seen, but saturation might not have been reached

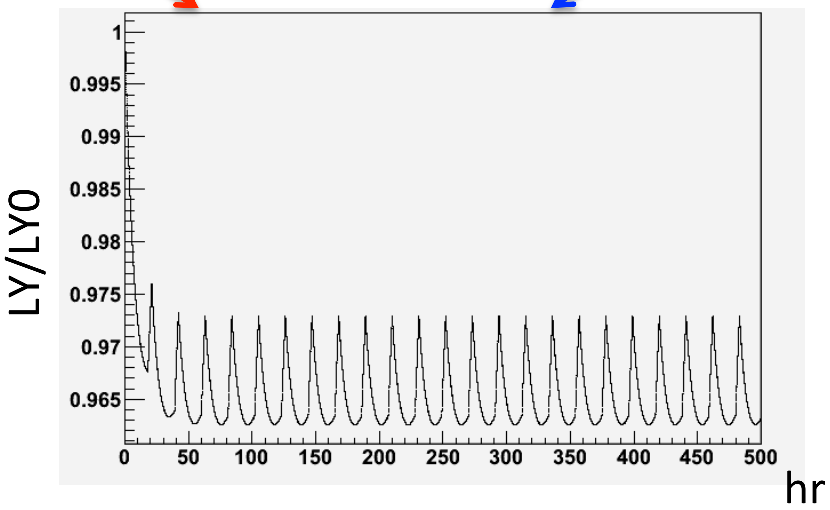
Impact on the experiment





LY model reproducing results from Ren-yuan and us

A naïve luminosity model



Naïve and preliminary

Situation could be better if there is a saturation effect

TODO

- Tests still ongoing: we have source time up to Christmas
- Understand problems with CsI and eventually perform a new set of measurements including it
- Test effect of irradiation at different rates on longer time scales
- Perform a Mrad irradiation and verify the behaviour of the crystals after it
- If we believe doses are significantly smaller (0.5 rad/hr) we could use another source in Frascati