Remembering PWO Radiation hardness studies at IHEP, Protvino

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Anything to learn?

- Main concerns of ours.
  - Any permanent damages in PWO which accumulate over time due to hadronic interactions?
  - Any damages to scintillation mechanism in addition to color center formations?
  - LO uniformity changed?

Irradiation facilities

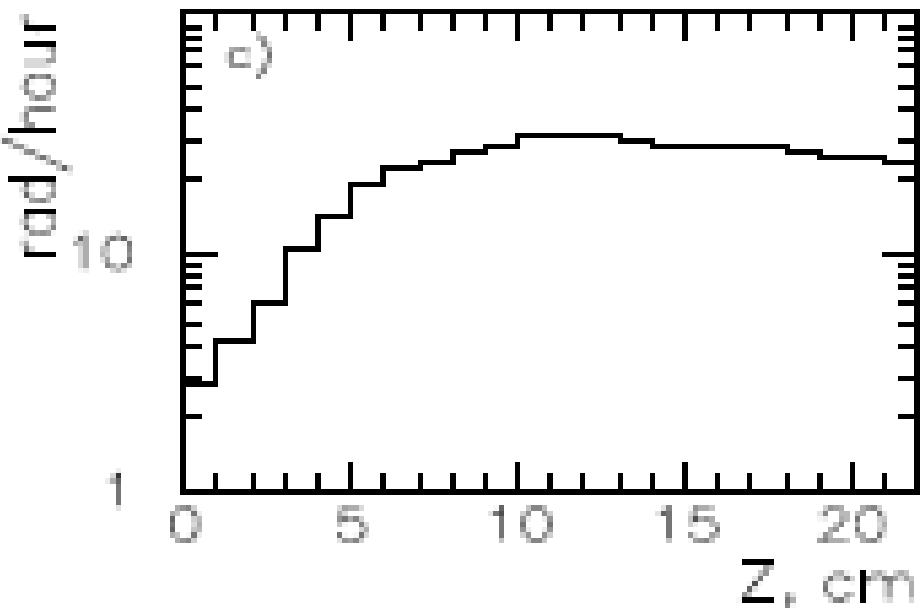
- Intensive electron beam (27 GeV)
  - ~0.25 Gy/h (10^6 e's/spill) spill~10sec
- Intensive pion beam (40 GeV)
  - ~0.6 Gy/h (10^7 pi's/spill)
- CsI source facility
  - ~0.5 Gy/h (?)
- Downstream of internal target
  - 1 kGy/h – normal U70 operation
  - 10 Gy/h – special U70 runs

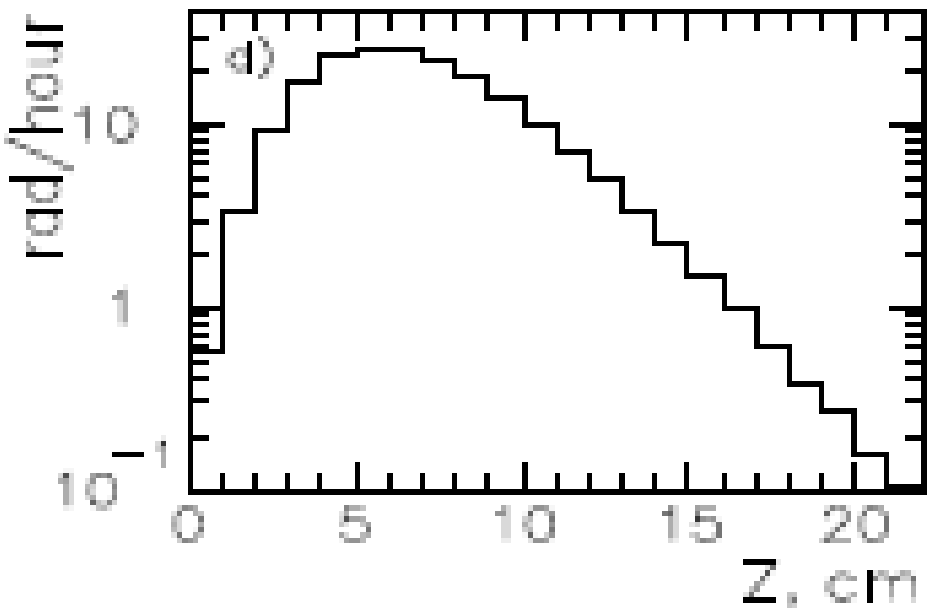
Uniqueness

- Beam-based irradiation facility used the beam to monitor the light output.
  - No wait time, no need for transport to make measurements
- PMTs were also exposed radiation, and could be affected by it.
  - No glue was use to avoid its degradation.
- PMT gains were changing depending on the beam rate.
  - Using stable red LED light source to monitor the gain changes and radiation effect on PMT (window).
  - Is the red light transmission in PWO really unaffected by radiation?

CMS barrel-like dose rate

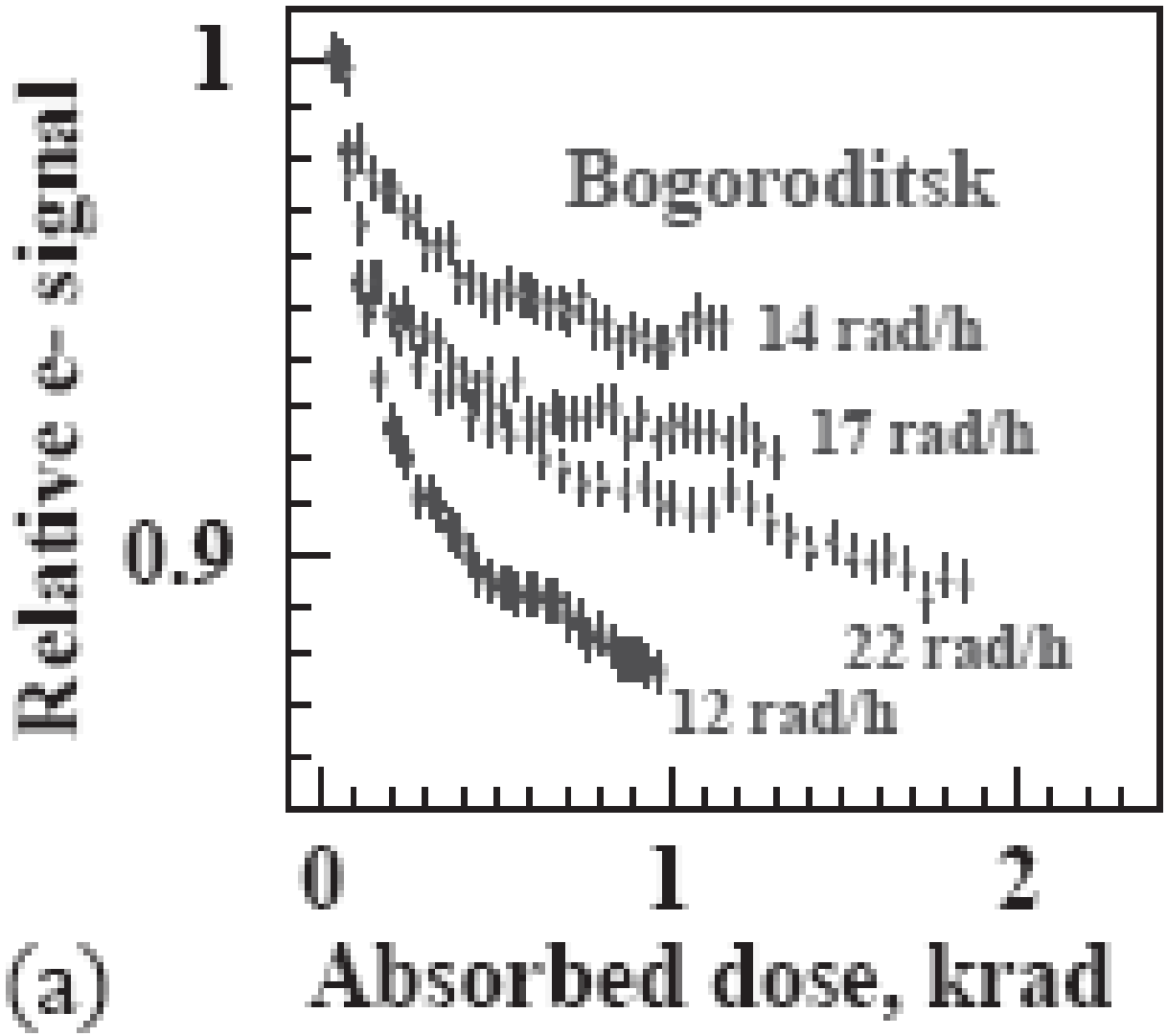
- Dose profile along the length of crystal.
- Pion beam
- Electron beam





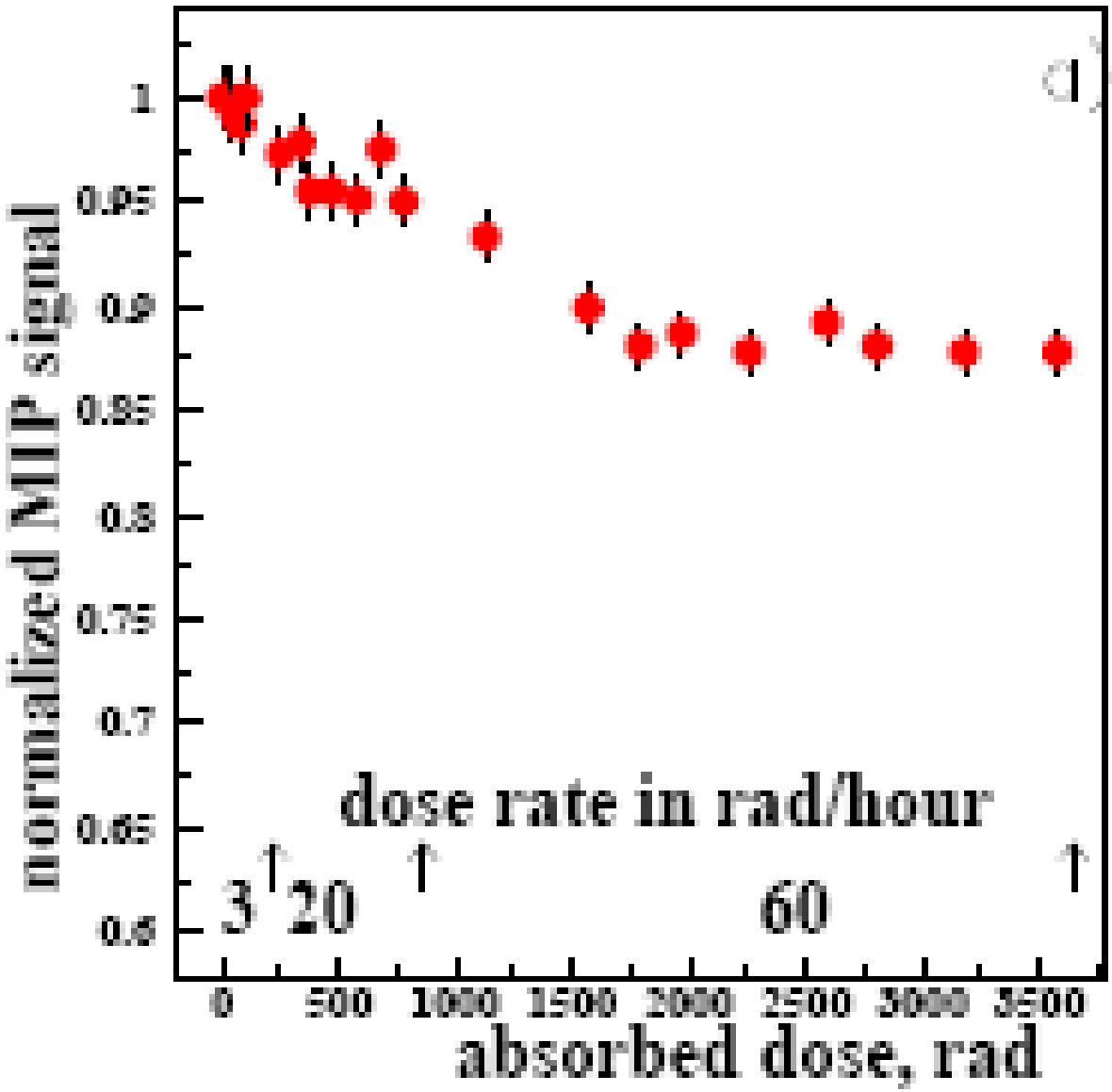
Electron irradiation

- Saturated LO loss as expected.



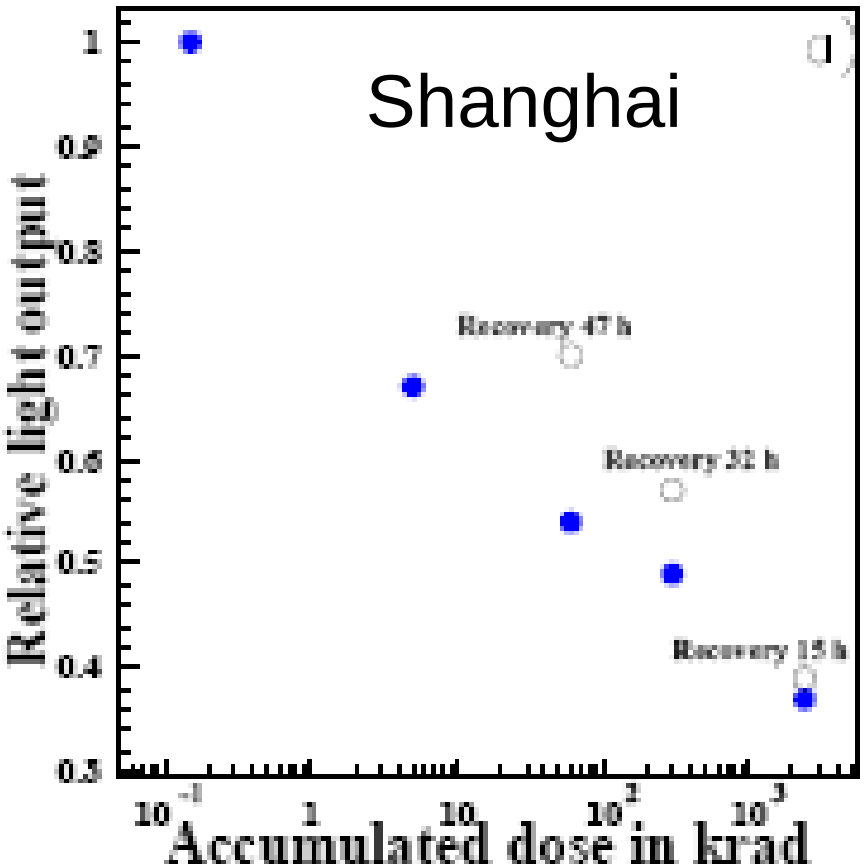
No cumulative damages from pions?

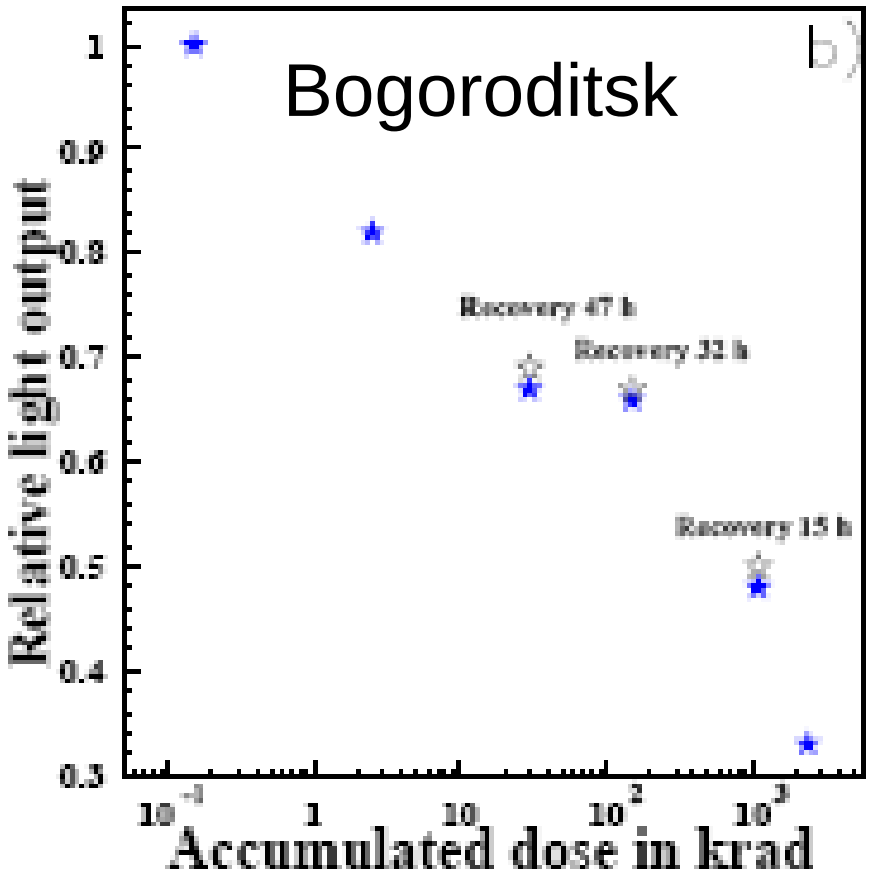
- Exposure to pions
- 0.6 Gy/h,
- 35 Gy total (about 10^{10} primary pions)



Very high dose rate 1 kGy/h

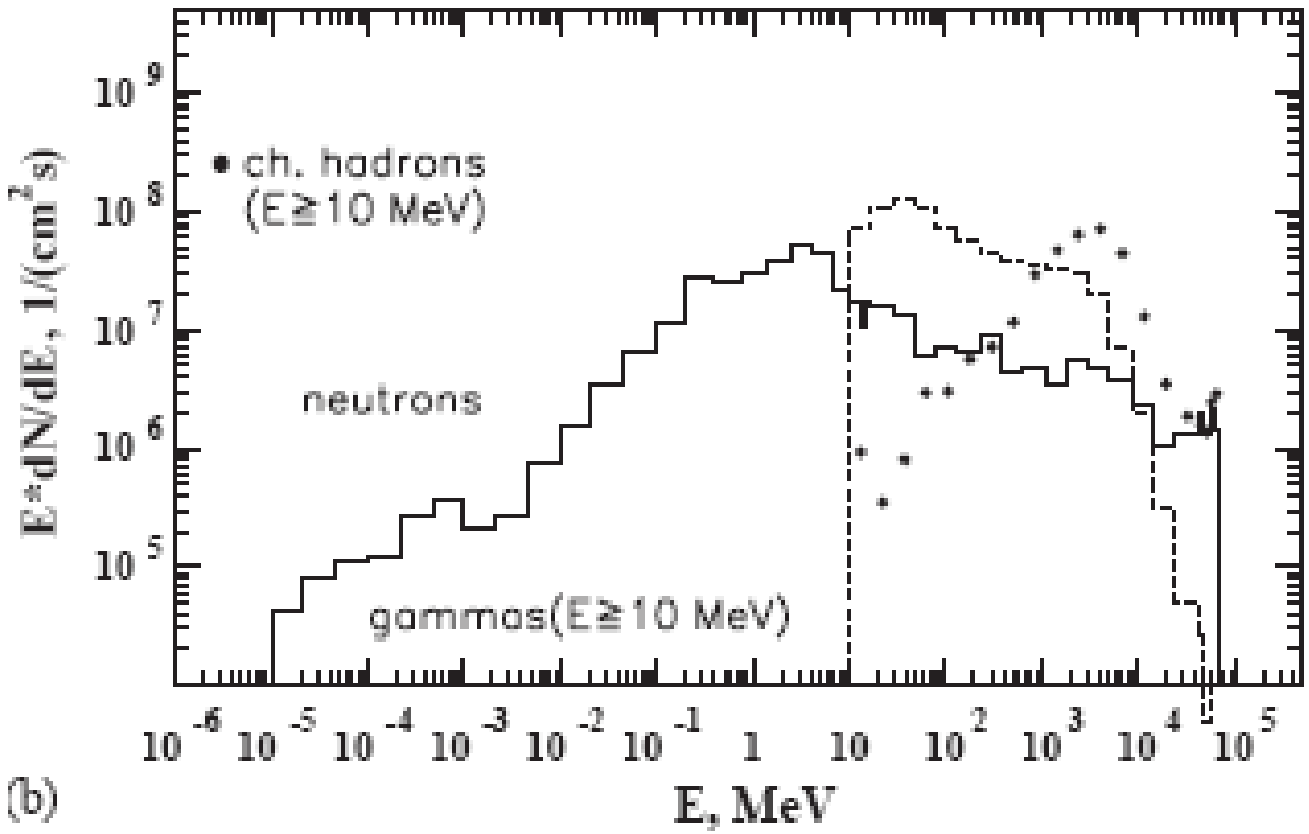
- Apparent cumulative effect at this extreme high dose rate.





Composition of 1 kGy/h

- MC (MARS) estimate of composition of particle flux.



10 Gy/h

- 4 crystals (2 BTCP, 2 SIC)
- 3.5 (SIC) – 7 (BTCP) Gy/exposure

The maximal values of the absorbed doses accumulated in Bogoroditsk B17, B9 and Shanghai S22, S18 crystals during the four exposures at the IHEP irradiation facility

Exposure (min)	Bogor. B17 (krad)	Bogor. B9 (krad)	Shanghai S22 (krad)	Shanghai S18 (krad)
25	0.7	0.7	0.35	0.35
72	2	2	1	1
60	1.7	1.7	0.8	0.8
60	1.7	1.7	0.8	0.8

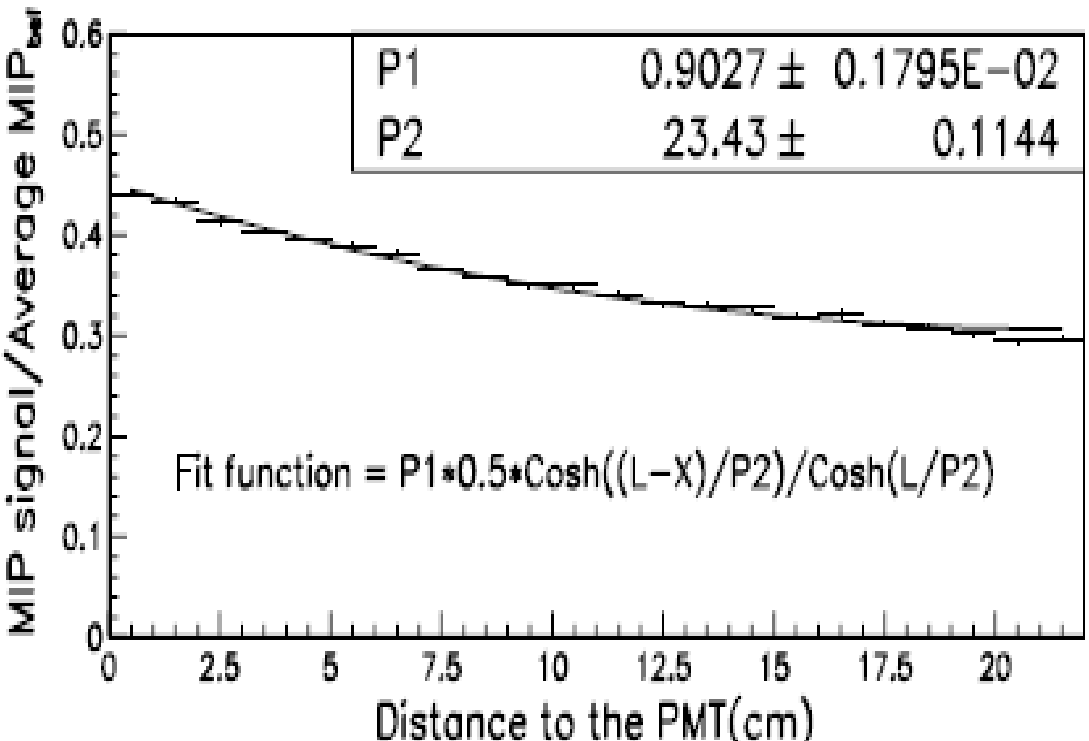
10 Gy/h (2)

- LO Loss of <10 % (SIC); ~ 25% (BTCP)
- 5 days of recovery – no significant change, however.
- Additional irradiation produced no further loss within a few % systematic errors

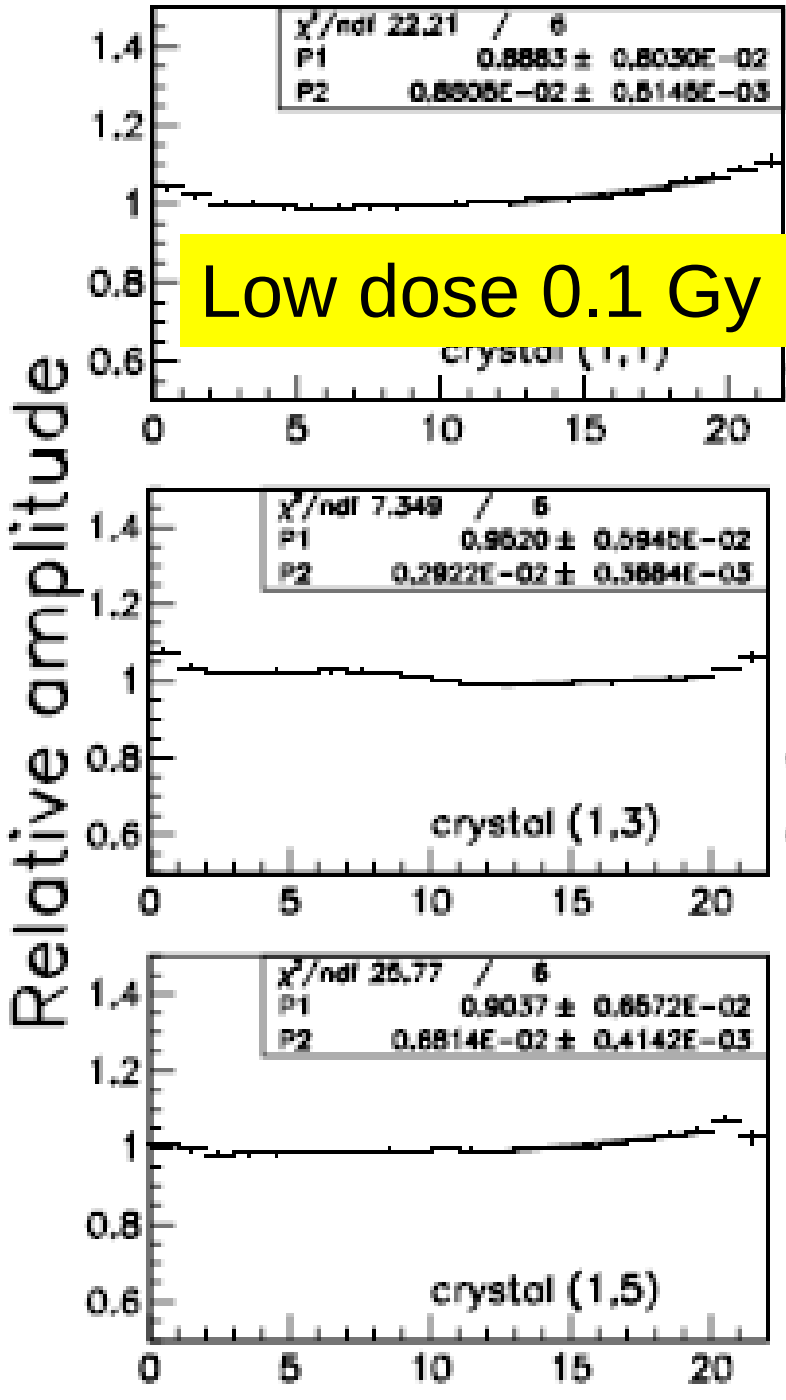
➢ Consistent with no cumulative damages.

LY uniformity changes

High dose (1 kGy)

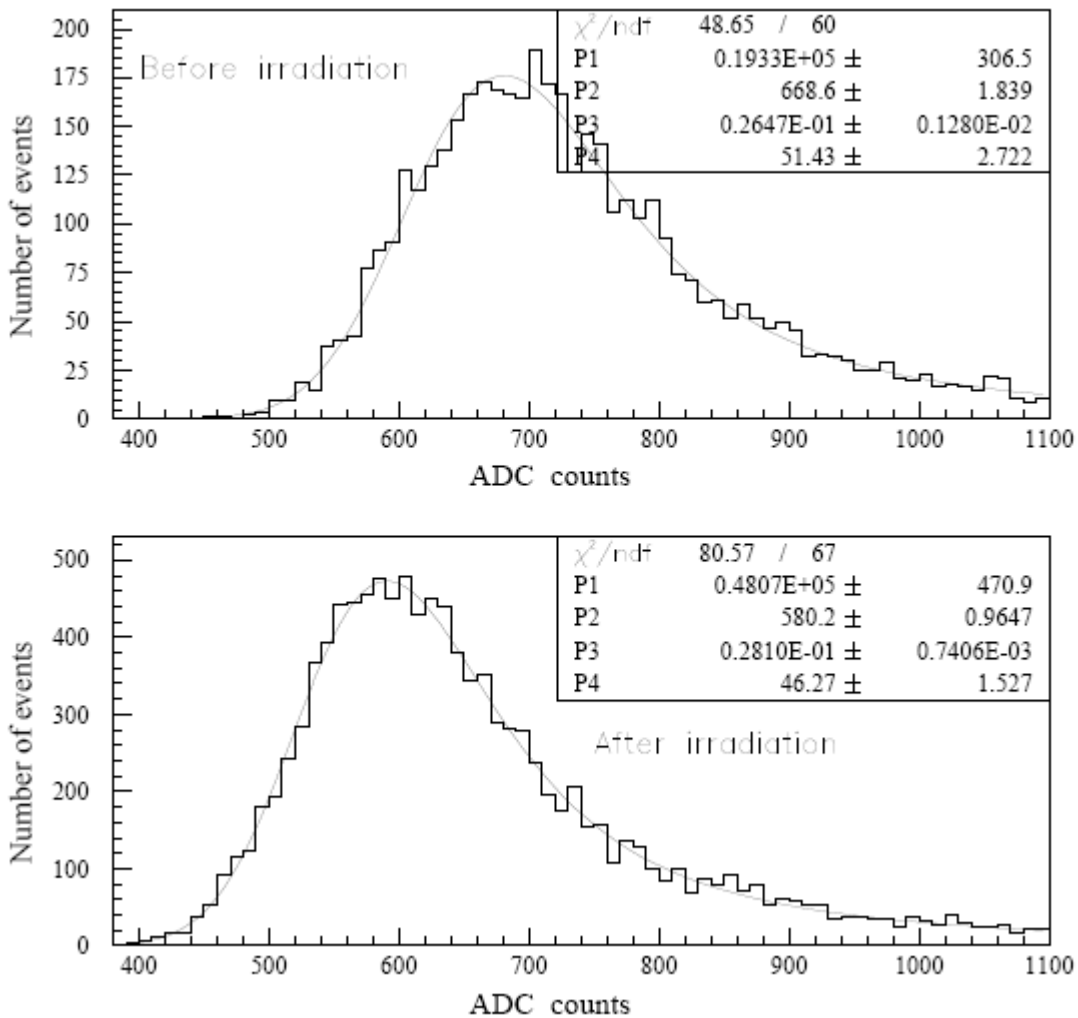


Low dose 0.1 Gy



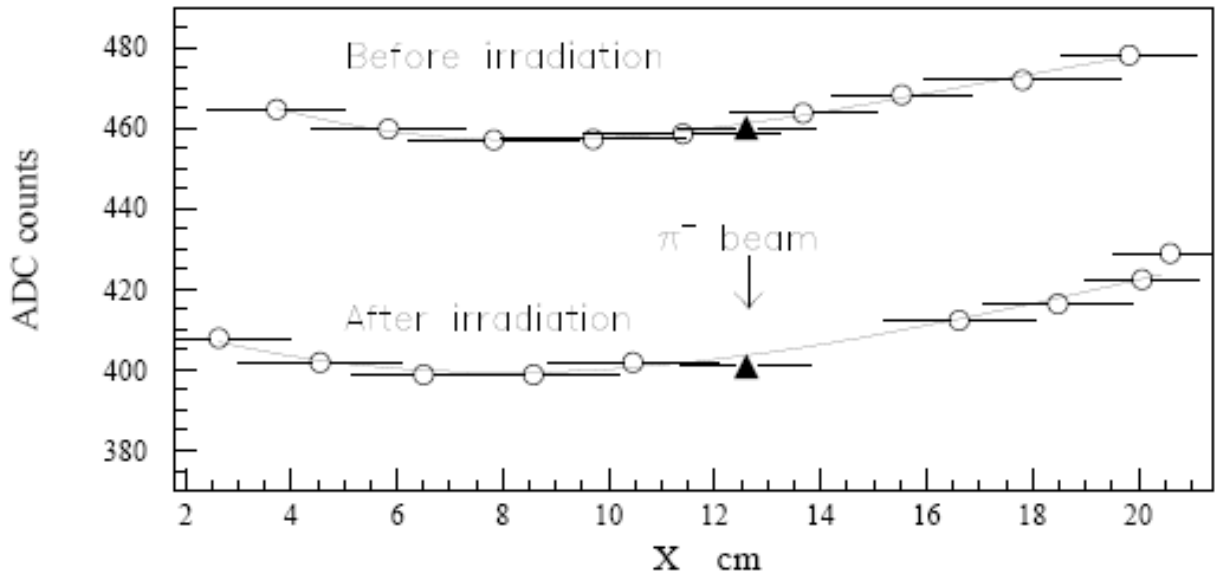
Scintillation mechanism damages?

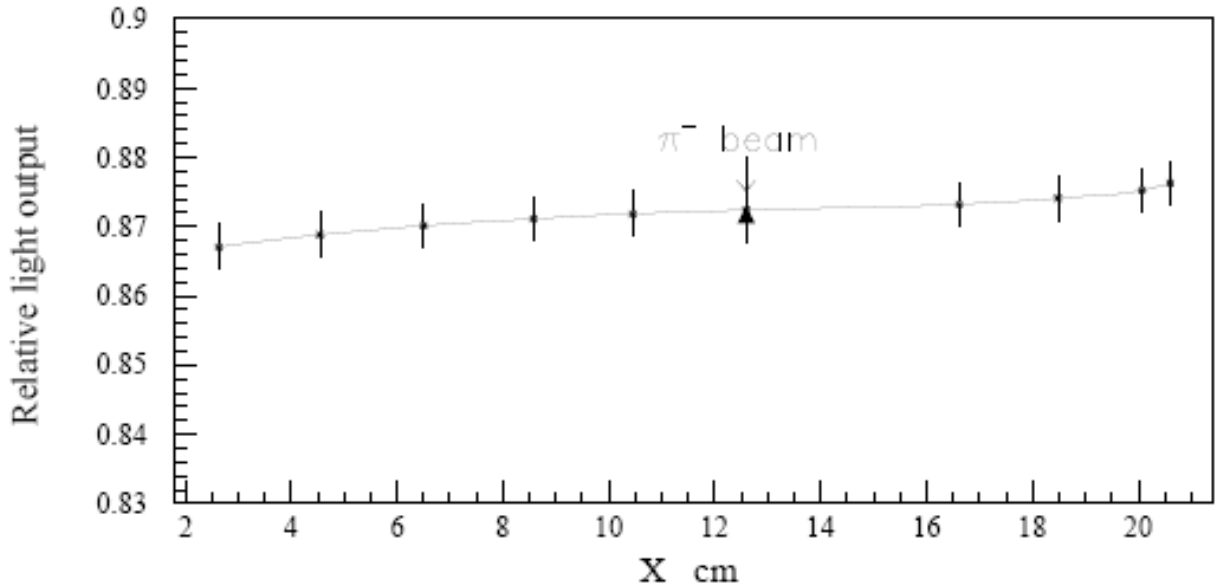
- 0.1 Gy/h, 30 hours
- using pion beam
- ~2 cm wide region in *z*



Uniformity

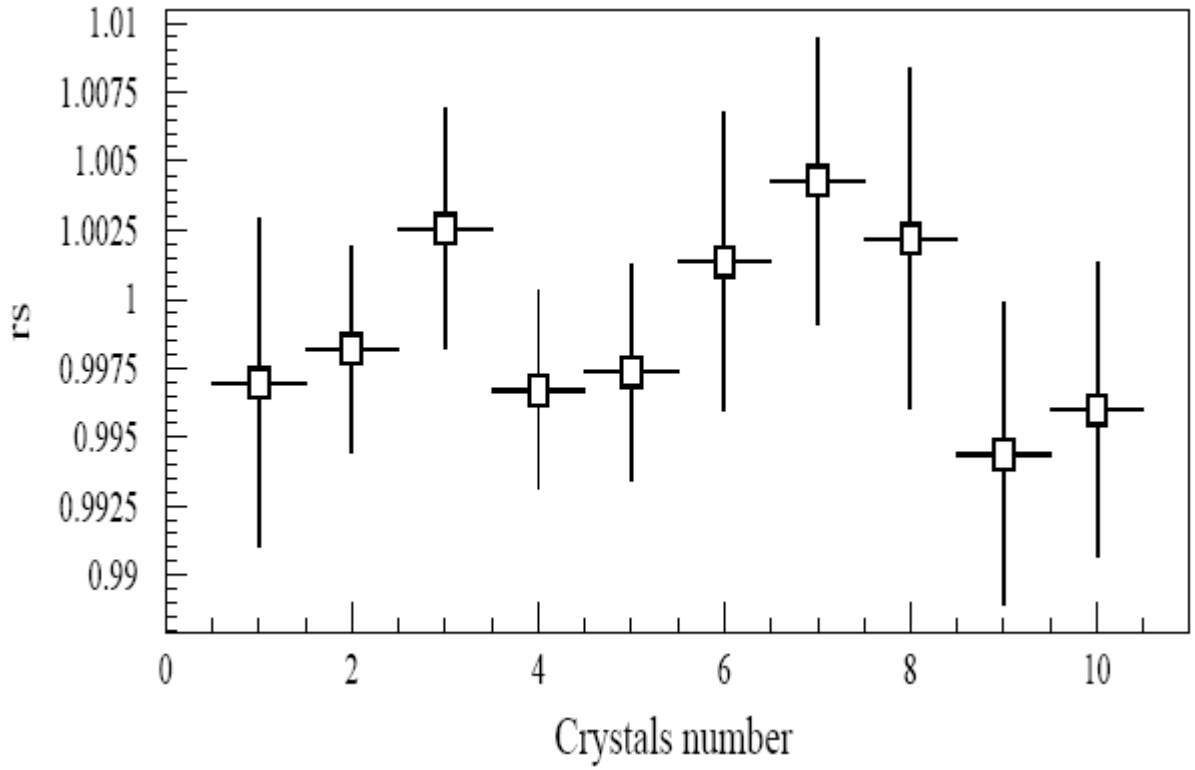
- LY uniformity was measured using MIP signal





Scintillation mechanism damage

- No effect seen at 1% level using 0.1 Gy/h, 3 Gy total radiation level.



Conclusions

- At 0.1 – 0.2 Gy/h, 10 Gy accumulated,
  - damage levels seem to saturate, and no cumulative effects seen.
  - No scintillation mechanism damage observed (1% level) – 3 Gy total dose
- At 1 kGy/h, 10 kGy total dose,
  - significant light loss,
  - uniformity changes and
  - likelihood of cumulative effect
- At 5-10 Gy/h, 30-60 Gy total dose,
  - no cumulative effect observed within 3% error.