A Systematic Study of Radiation Damage to Large Crystals of CsI(Tl) in the BaBar Detector

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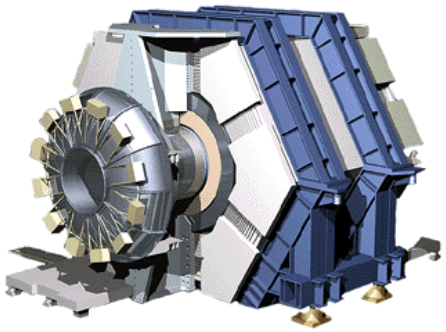
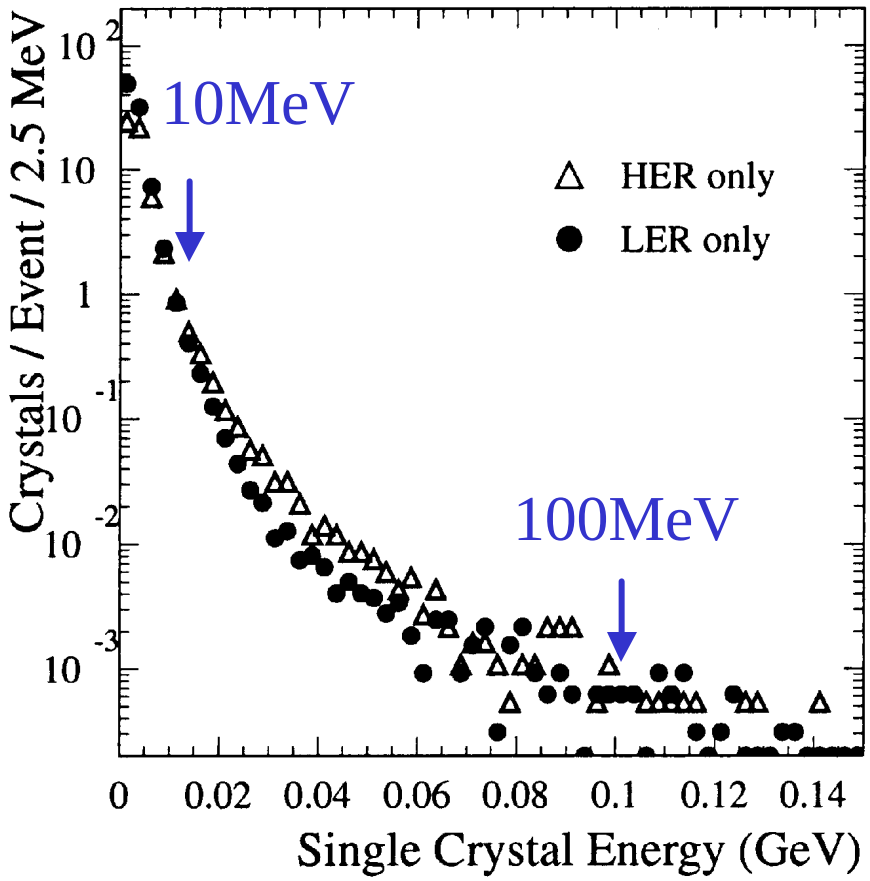
EMC Group of the BaBar Collaboration



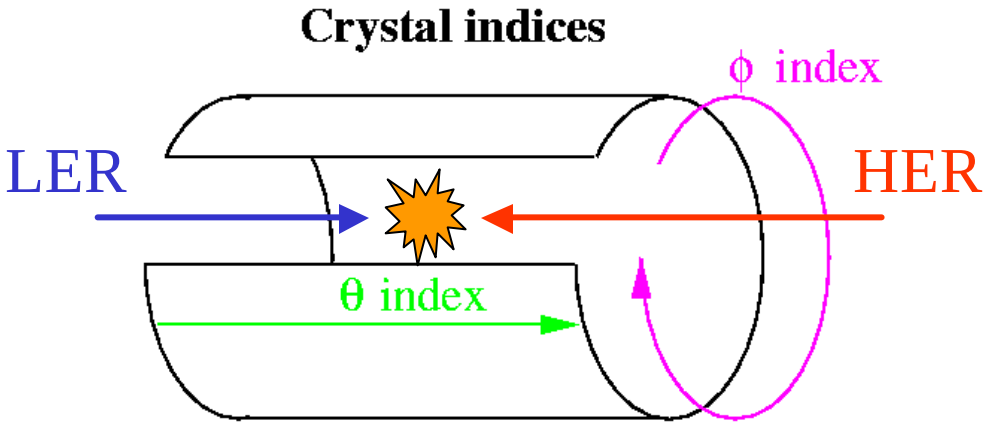
Calorimeter Backgrounds

- Single Beam Backgrounds
  - Lost primary beam particles
  - In fwd/bwd direction in horizontal plane
- Luminosity Backgrounds
  - Small angle Bhabhas
  - More uniform dose distribution
- Mostly photons up to 10MeV

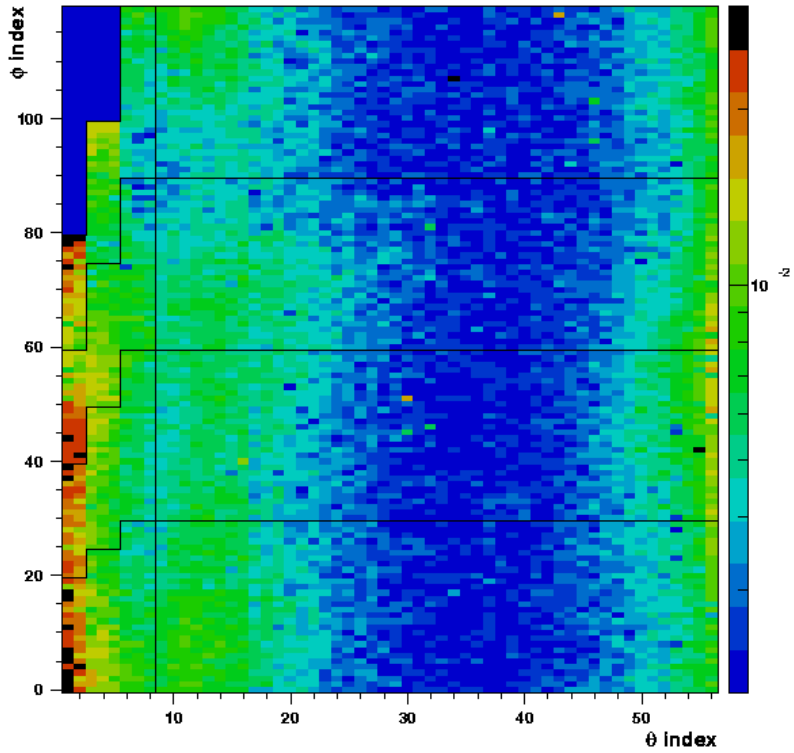


(plot by S. Robertson)

Background Distribution



Occupancy obtained using random triggers.



Different regions of the detector see different rates of photons.

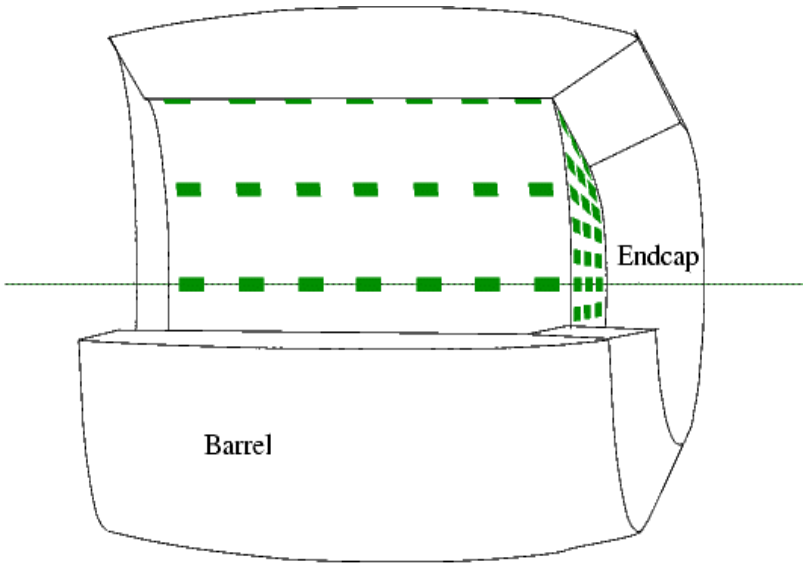
(plot by S.Robertson)

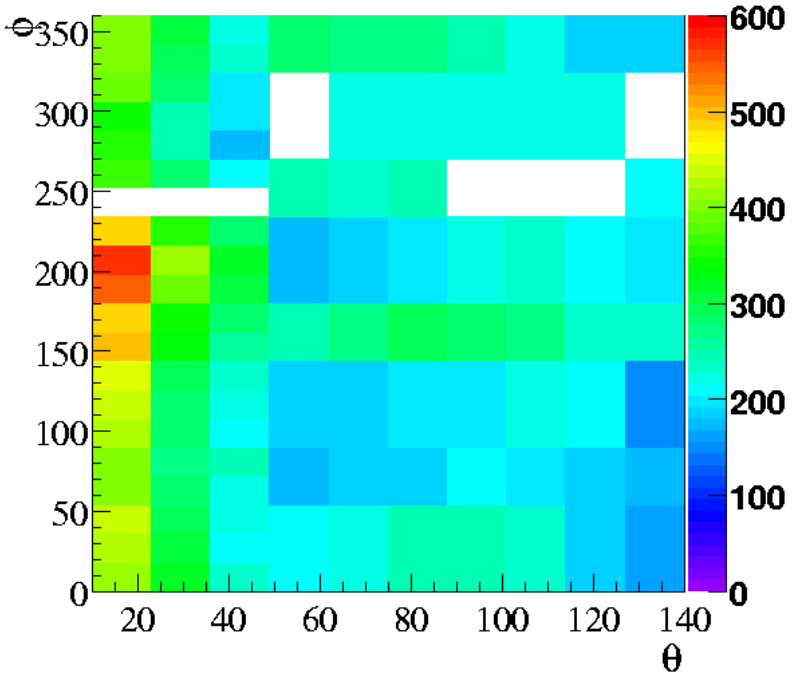
Radiation Damage

- Leads to formation of color centers and absorption bands, mostly in the front 10-15 cm of the crystal
  - ➢ Decrease in the light yield (LY)
  - ➢ Non-uniformity of the LY along the crystal length (worsens energy resolution)
- Caused by the impurities
  - ✓ Purity of the salt and recycle material was strictly controlled

Radiation Monitoring

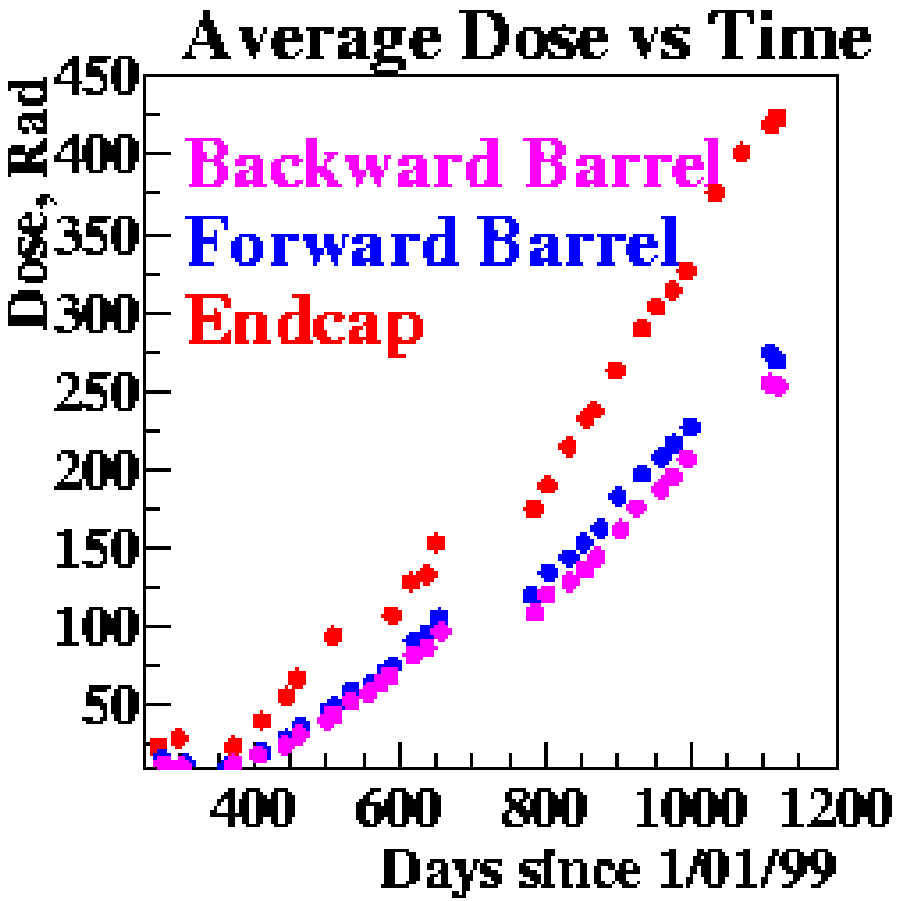
Array of 116 RadFETs distributed over the front face of EMC crystals





Dose map reproduces beam background pattern

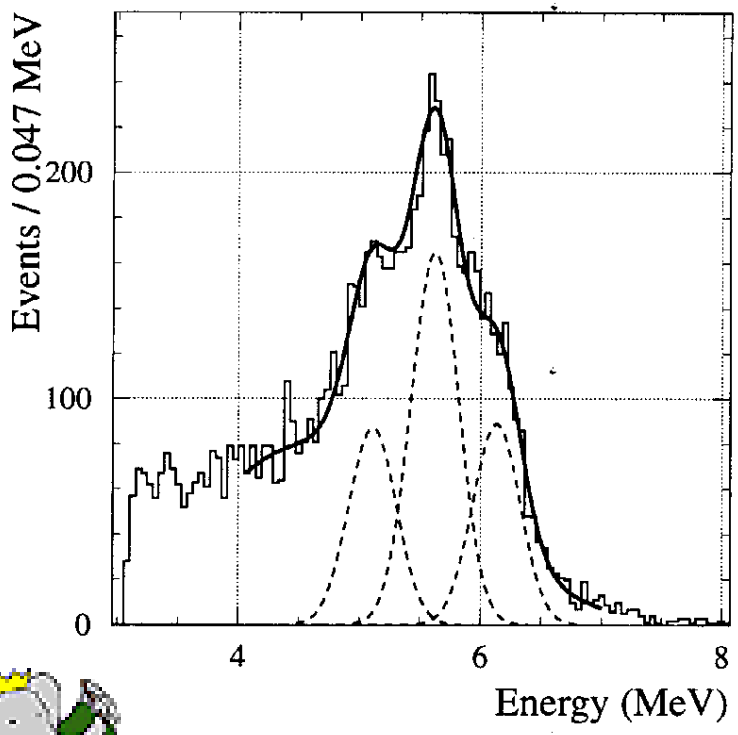
Radiation Monitoring

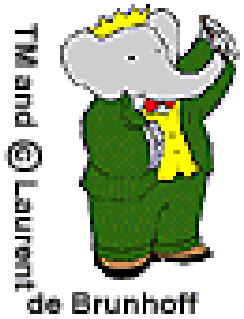


- Maximum dose is 700Rad in 2.5 years in the endcap
- Dose has a rate of 4-12 Rad/fb^{-1}
- Dose budget is 10 kRad over BaBar lifetime

Source Measurement of LY

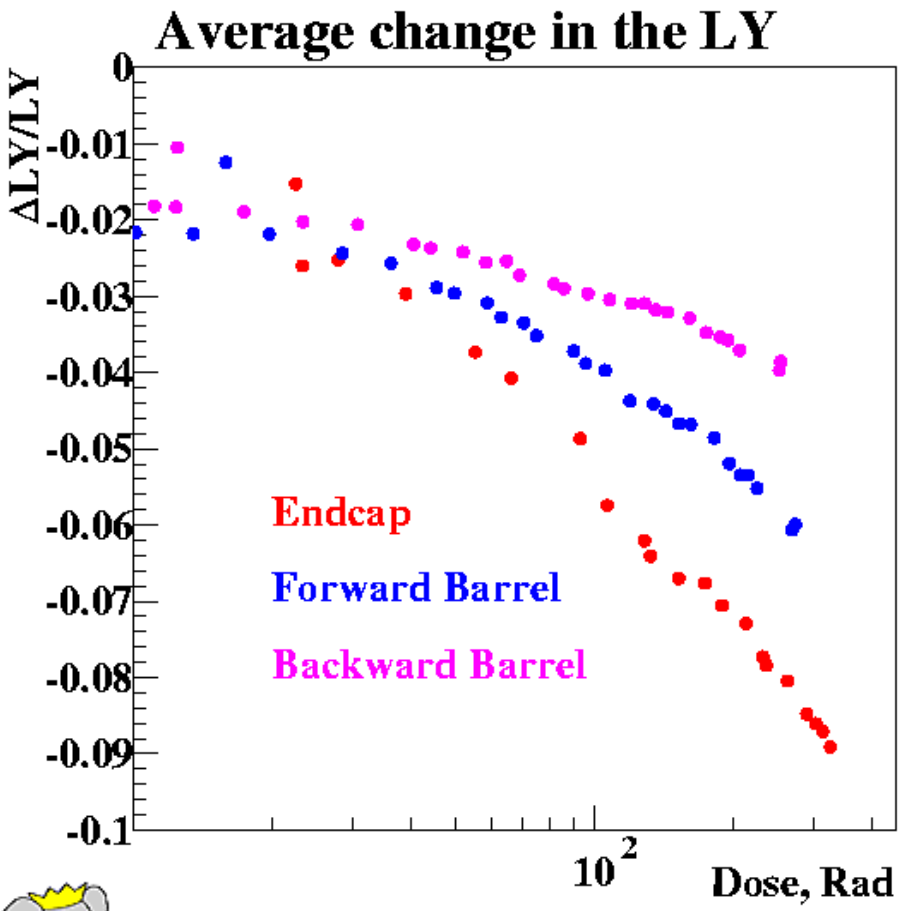
Typical source spectrum:





- Neutron generator activated fluid circulates on demand though a pray of thin tubes in front of all crystals
- 6.13MeV photons from $^{19}F \rightarrow {}^{16}N \rightarrow {}^{16}O^{*} \rightarrow {}^{16}O\gamma$
- ^{16}N lifetime is 7 sec
- Resolution of the light yields is 0.33%
- Measured every 2 weeks

Crystal Light Yield



- LY decreases with Dose
- Different change in BB and FB for the same Dose
- EC decreases faster

- ✓ Different Vendors/Growth Methods
- ✓ Different Production Times/ Salt Processing
- ✓ Dependence on the Rate of the irradiation?

Vendor Map

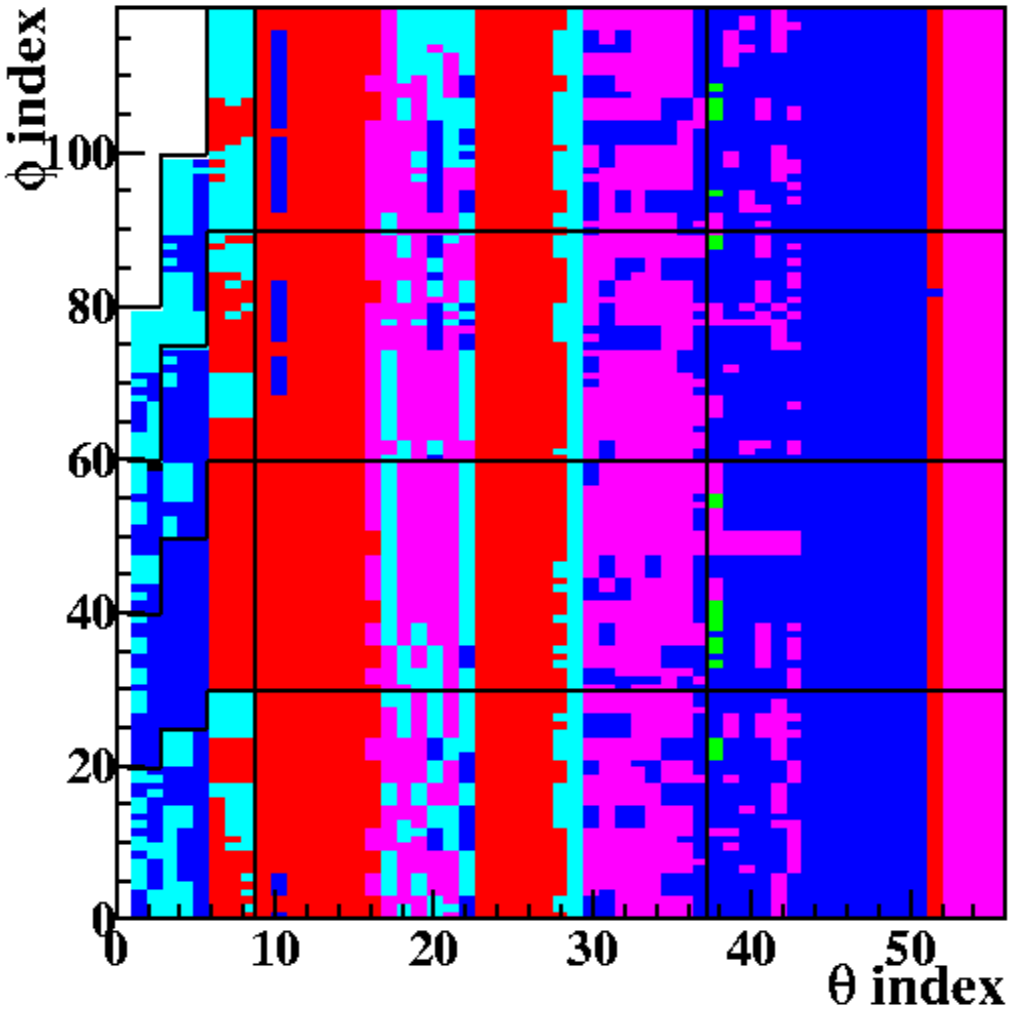
Crismatec

Beijing

Hilger

Kharkov

Shanghai



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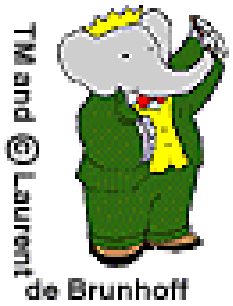
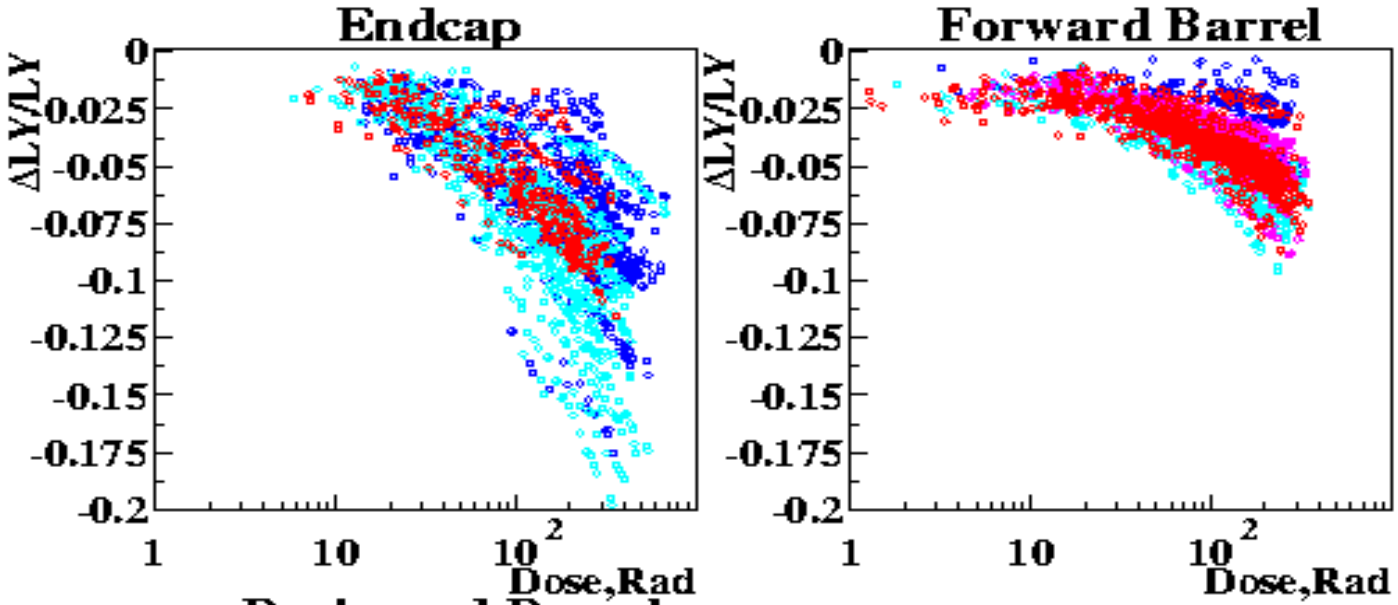
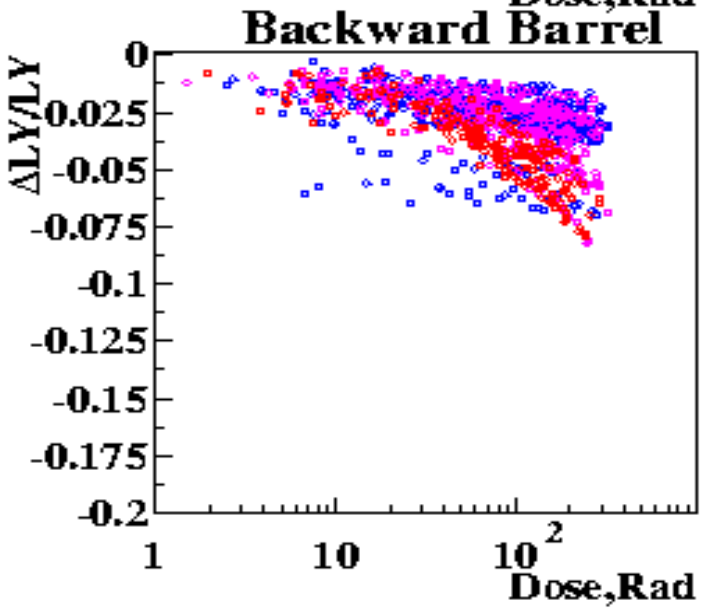


Crystal LY change by vendor





Crismatec

Hilger

Kharkov

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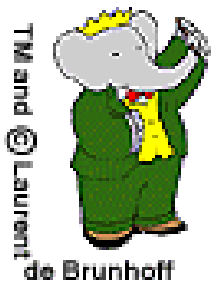
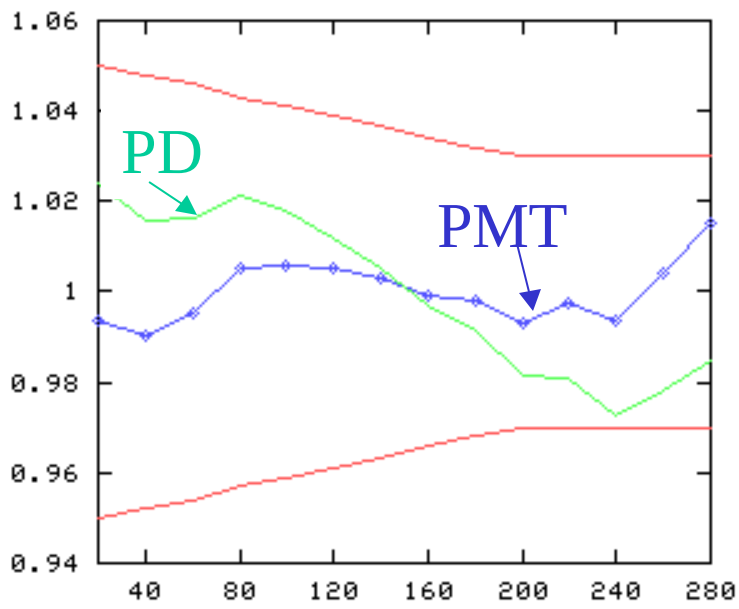


Uniformity

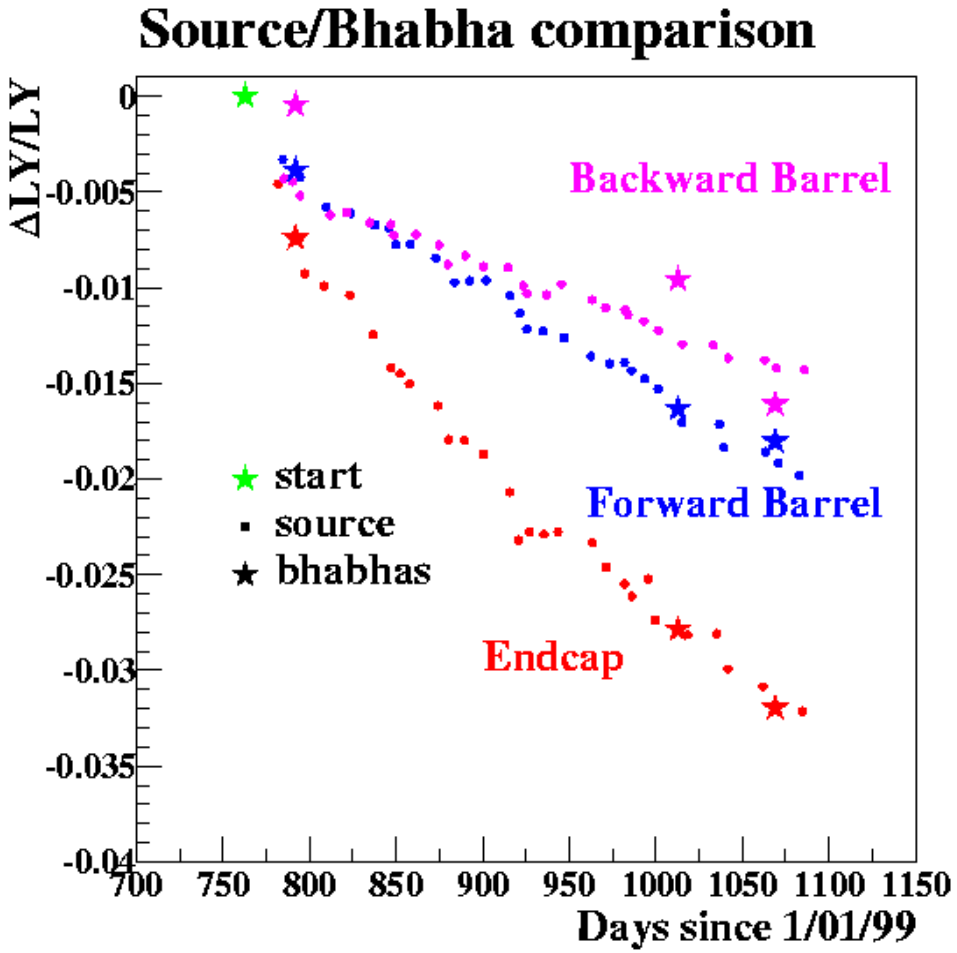
- Specifications of LY uniformity assume less then 0.5% contribution to σ_E/E for up to 5 GeV
- Enhanced by selective roughening of the surface and wrapping in TYVEK
- Is influenced if radiation damage is concentrated in the front of the crystal.

Acceptance envelope



Rear (±5%) Front (±2%)

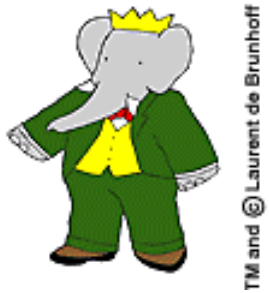
Checking the Uniformity



Gain changes obtained using the radioactive source and Bhabha calibrations: possible probe of LY uniformity along crystal length.

Statistical errors are:

- 0.33 % for the source
- 2 % for the Bhabhas



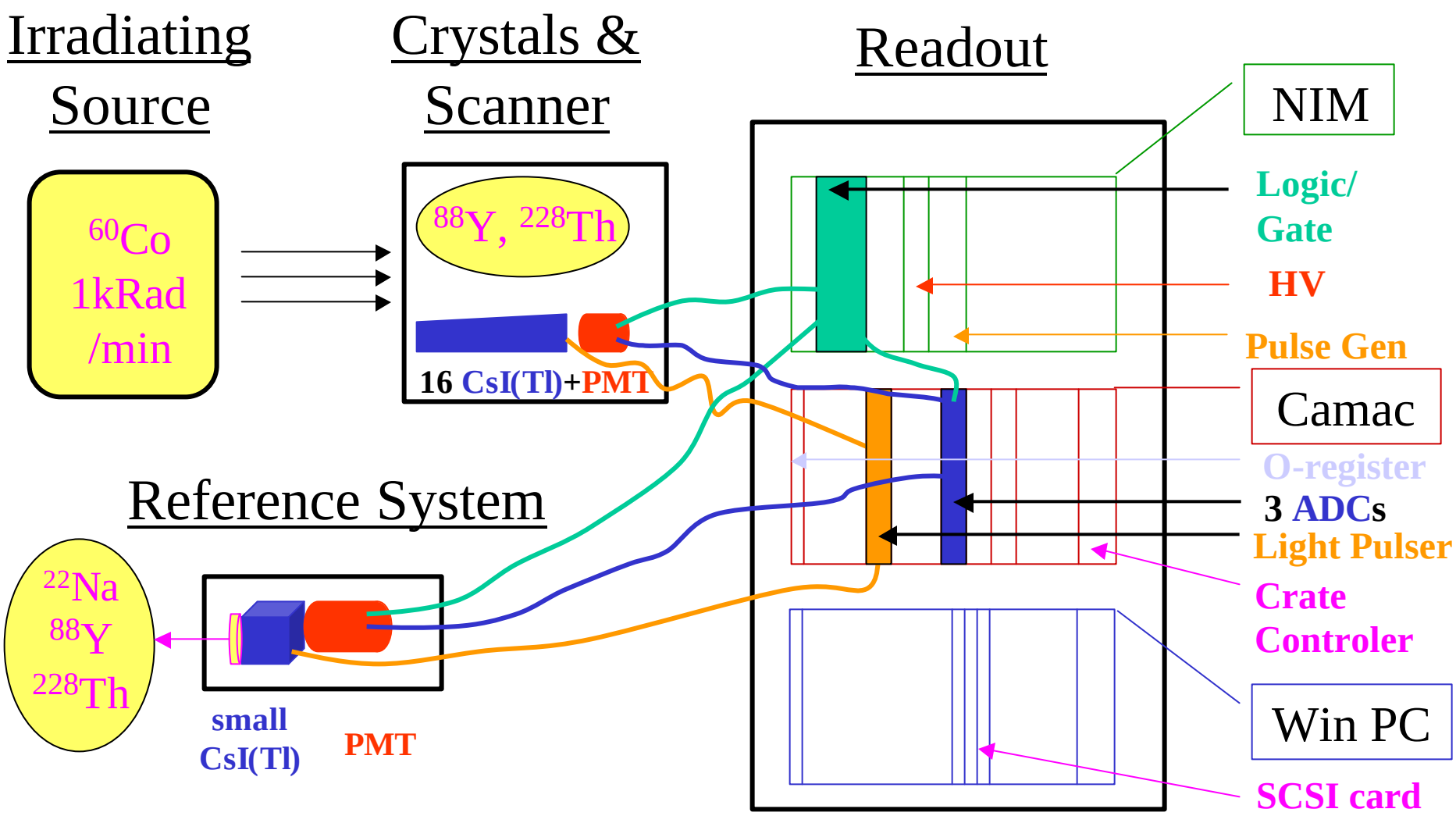
Crystal Scanner Test*

- Use 85 spare full size crystals of different vendors
- Closely model exposure of the crystals in BaBar
- Irradiation with 1.173 and 1.333 MeV photons from ^{60}Co source (2Rad/h)
- In-situ measurement of the total light loss & its change along length of crystals gives tight control of systematics

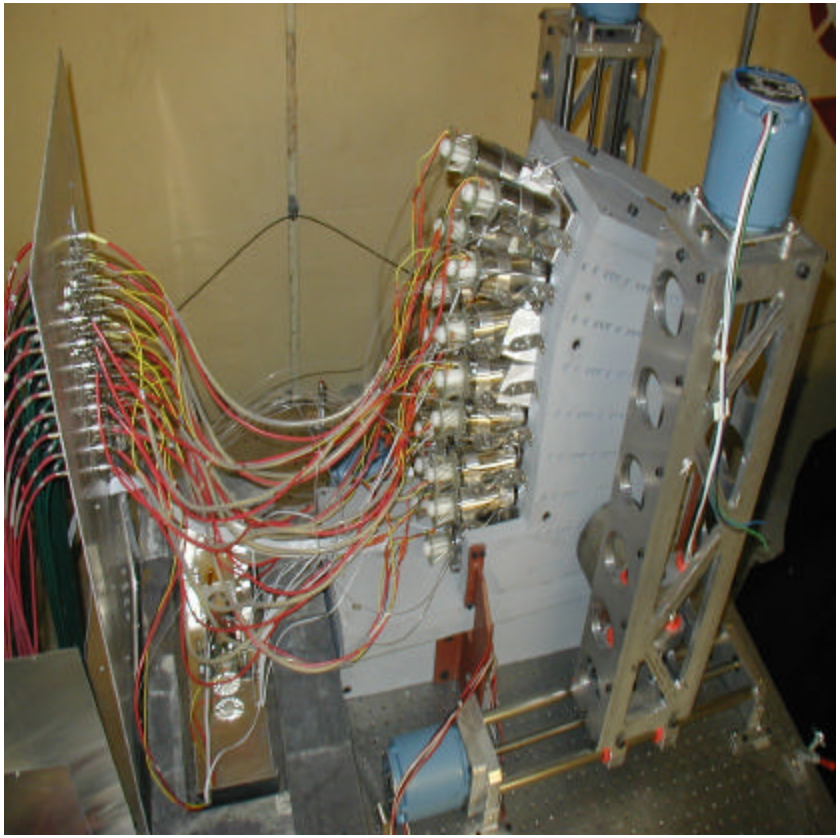
Goal: Develop a correction function to model crystal response to irradiation

* T.Hrynova, P.Kim, M.Perl,
K.Phillips, H.Rogers, R.Schindler,
W.Wisniewski

Crystal Scanner Setup



Crystal Assembly



- 16 CsI(Tl) crystals of different growers (SIC/Crismatec initially)
- 16 Hamamatsu PMTs
- 4 motors moving collimators with ^{88}Y and ^{228}Th sources in x&y

Reference System

Used as a standard reference to compensate for the drift of the electronics.

- Mirrors the main assembly
- Hidden behind 4in of lead (sees 0.1% of I_o)
- Sources: ^{88}Y, ^{22}Na, ^{228}Th

Control Systems

Radiation Monitoring

- 2 GM Tubes with a computer readout for the current dose monitoring
- 55 TLDs for the accumulated dose monitoring

Light Pulser

- Used for monitoring of the electronics
- Light fibers are connected to the face of each crystal

Temperature Monitoring

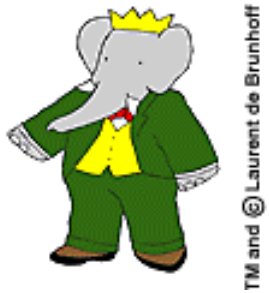
Used to reduce systematic errors on the measurements.

Crystal Scanner

- Data points are planned to be taken every 2-3 cm along the length starting from 4 Rad and doubling the dose until reaching 5 kRad.

- Measuring absolute change in LY and relative change of LY along the length.

- Ready to start running.



Outlook

- 6580 crystals in BaBar Calorimeter along with extensive (RadFET) dosimetry allow us to study impact of radiation damage on CsI(Tl) crystals with high precision
- Effects of radiation damage in the detector are visible but not problematic
- Additional studies like Crystal Scanner Test
  - improve our understanding of the changes in the detector, decreasing uncertainties in energy resolution
  - help to develop a correction function which may be applied to all crystals