ECAL: irradiation (#2) at PS and tests at SPS in 2012

The second irradiation was performed in June 2012, to the same dose as first time (~2 Mrad at maximum, so total of 4 Mrad). The flux was again verified with Al film: ~$9 \cdot 10^{12}$ p/cm^2 on average, with good uniformity.

The second beam test was conducted at the SPS electron beam in August 2012, only 2 months after irradiation, which may be too early. **The module performance is found not satisfactory any more:** the light yield had degraded now down to ~220 photoelectrons/GeV. The energy resolution (2.2% at 100 GeV) roughly agrees with the TDR expectations at 4 Mrad. However the light yield degradation from 2 Mrad to 4 Mrad (570→220 photoelectrons per GeV, factor 2.6) is worse than expected in TDR (factor 1.25); this may somewhat improve with further annealing, new test (November?) would be useful.

The summary table (tests after the 1st and 2nd irradiations, as well as the non irradiated one) are given in the table.

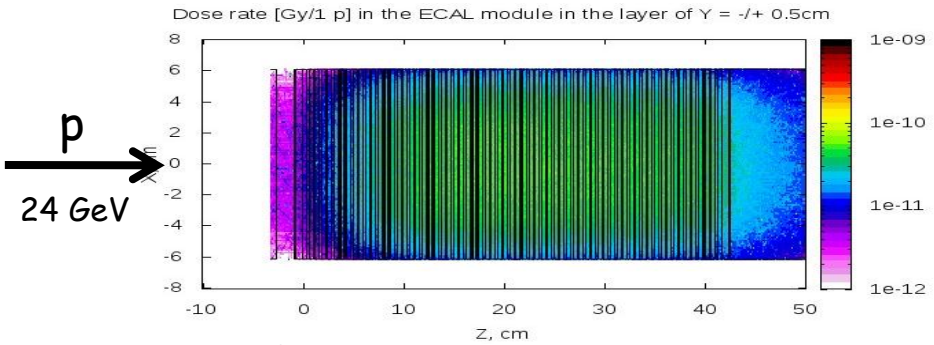
E beam, GeV	module #2, not irradiated		module #1, 2 Mrad		module #1, 4 Mrad	
	light yield, ph.el./GeV	resolution, %	light yield ph.el./GeV	resolution, %	light yield ph.el./GeV	resolution, %
50	2598±52	1.37±0.04	583±12	2.16±0.04	223±10	2.74±0.04
100	2611±52	1.01±0.03	576±12	1.57±0.03	221±10	2.26±0.05
120	2604±52	0.98±0.03	571±12	1.36±0.03		
125					220±10	2.06±0.05
150					219±10	1.77±0.05

Details: see spare slides

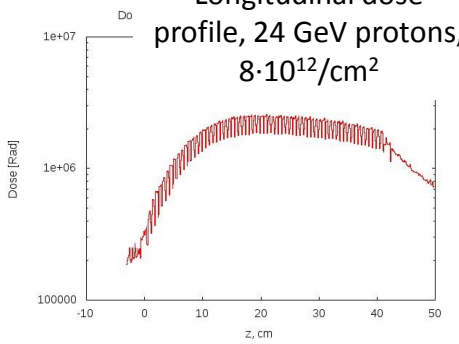
SPARES

irradiation at PS in 2010

The dose profiles and induced activity level were calculated using FLUKA (V. Talanov). It was found that in order to obtain ~ 2 Mrad inside the module we need ~$8 \cdot 10^{12}$ protons/cm^2.



Longitudinal dose profile, 24 GeV protons, $8 \cdot 10^{12}$/cm^2

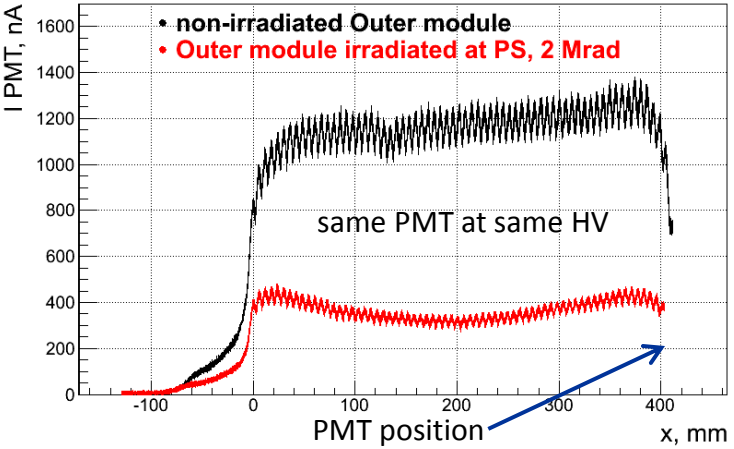


The 10x10 cm^2 central area of a Outer type (1 large cell) module's 12x12 cm^2 was uniformly irradiated, using the (x,y)-movable table. The irradiation took ~36 hours. The input proton flux was measured with Al film. It showed good dose uniformity; the input flux ~$9 \cdot 10^{12}$ p/cm^2 (requested $8 \cdot 10^{12}$, to have ~2 Mrad).

Tested in July 2011 at the SPS electron beam, along with a non irradiated module. **The module performance is satisfactory,** however the light yield degradation (factor of 5.5) is higher than expected from TDR results. The energy resolution roughly agree with the TDR expectations at 2 Mrad

E beam, GeV	module #1 (irradiated)		module #2 (not irradiated)	
	light yield ph.el./GeV	resolution, %	light yield, ph.el./GeV	resolution, %
50	583±12	2.16±0.04	2598±52	1.37±0.04
100	576±12	1.57±0.03	2611±52	1.01±0.03
120	571±12	1.36±0.03	2604±52	0.98±0.03

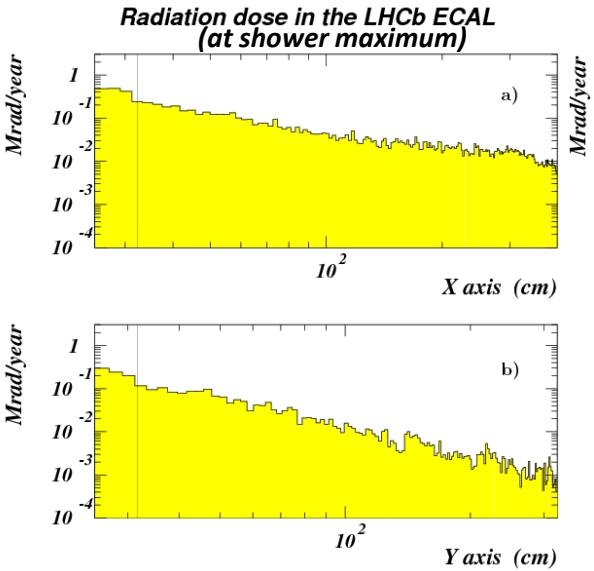
It would be interesting to study effect of higher dose ➔ second irradiation (performed in June 2012)

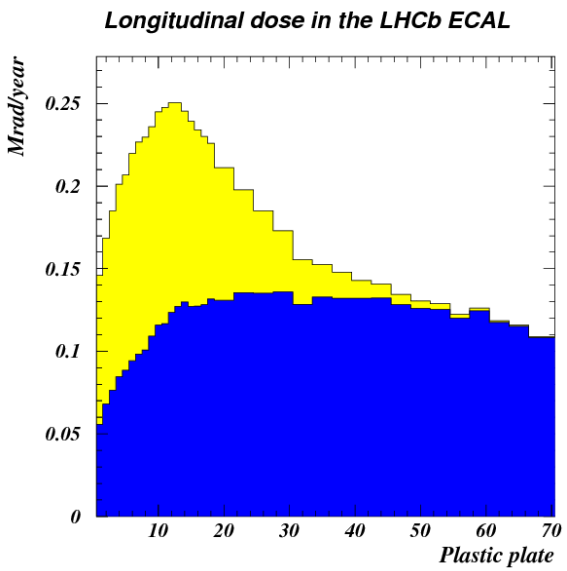


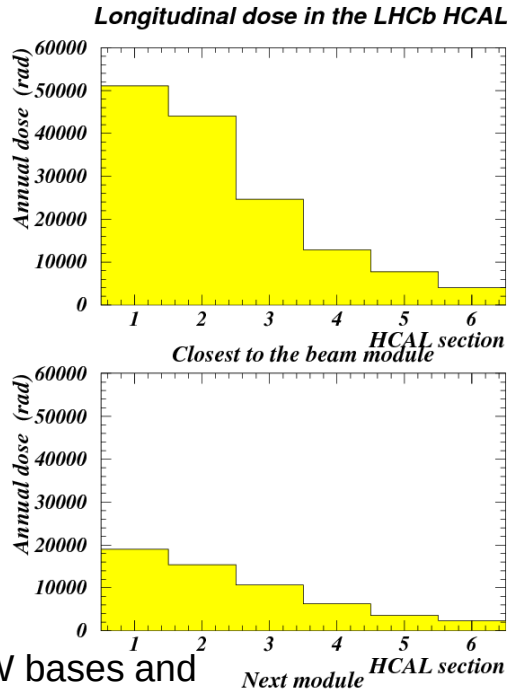
Results of the ^{137}Cs scan 15-Feb-2012. The light yield decreased over the whole module length ➔ effects of degradation of plastic and fibers are comparable.

The expected radiation dose in ECAL and HCAL (TDR)

from CALO TDR, per 1 year at $L=2\cdot10^{32}cm^{-2}s^{-1}$ (2 fb^{-1}) at $\sqrt{s}=14$ TeV (x20 for 4 years @ 10^{33} $cm^{-2}s^{-1}$)







The radiation tolerance is an issue for :

- ECAL modules: scintillator and fibers
- ECAL light readout elements
  - light guides
  - PMTs (entrance window)
  - CW boards
- HCAL plastic and fibers

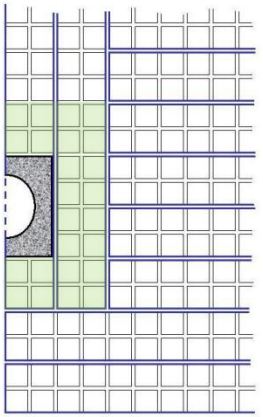
Not an issue for the HCAL light readout elements (lesser dose behind HCAL)

Replaceable are:

- ECAL (and HCAL) PMTs, CW bases and light guides
- 48 central ECAL modules (although not an easy task)
- WLS fibers of ECAL modules (check)

Not replaceable:

- other ECAL modules
- HCAL modules, plastic and fibers



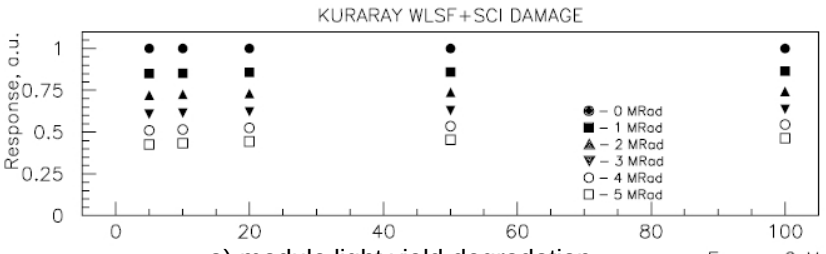
The radiation tolerance of ECAL modules: previous studies (TDR)

Studies performed in 1999.

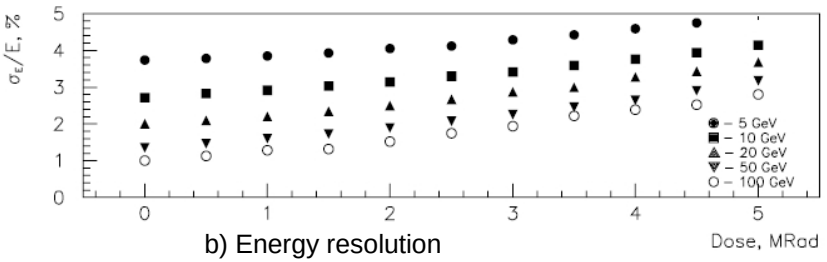
• scintillator tiles and fibers irradiated at LIL (LEP Injector LINAC) to doses reproducing the longitudinal dose profile at LHC

• the degradation of light yield and transparency of tiles and fibers were measured after irradiation (several times; significant annealing effect observed).

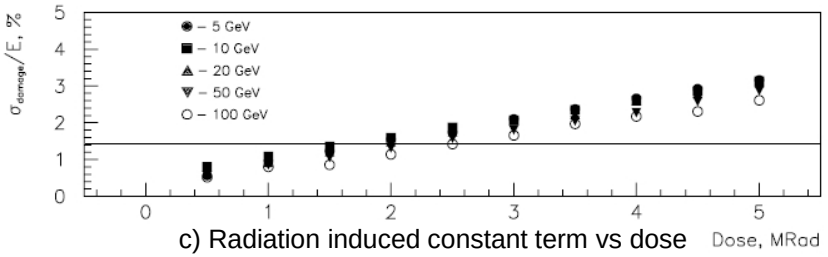
• degradation of light yield (N ph.el. /GeV) and energy resolution of ECAL modules obtained from simulation.



a) module light yield degradation



b) Energy resolution



c) Radiation induced constant term vs dose

However:

• not exactly the same type of scintillator and WLS fibers as in the present ECAL;

• only electromagnetic component in the irradiation;

• performance obtained from simulation and not by direct measurement;

➔ a new series of tests started

The radiation tolerance of ECAL modules: new tests - I

A. Make use of the LHC radiation field. Two modules were placed in the LHC tunnel at the opposite side from the LHCb interaction point.

• testing same type modules as in present ECAL;

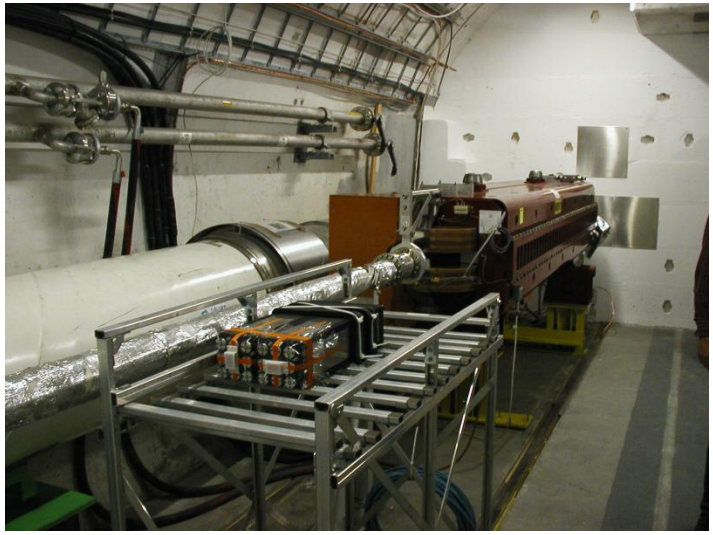
• same composition of the radiation field as in ECAL itself → reliable estimation of rad. damage;

• the dose rate is several times faster than at ECAL central modules;

• modules installed in September 2010, equipped with passive and active dosimeters;

• the test will last several years, with measurements with ^{137}Cs source scanner during shutdowns

• first scan performed 15-Feb-2012



B. Perform irradiation at the PS IRRAD facility, 24 GeV protons (Maurice Glaser)

– different composition of the radiation field

– different dose rate and longitudinal profile – different effect on the resolution

+ but quick answer; and

+ light yield degradation measurement is robust

November 2010 – irradiated to ~2 Mrad

July 2011 – tested at the SPS electron beam

February 2012 – scan with ^{137}Cs source

June 2012 – irradiated again, added other 2 Mrad

October 2012 – beam tests and ^{137}Cs scan planned