Radiation Sensor with transistorized HV divider

R2D-FBLM-0106

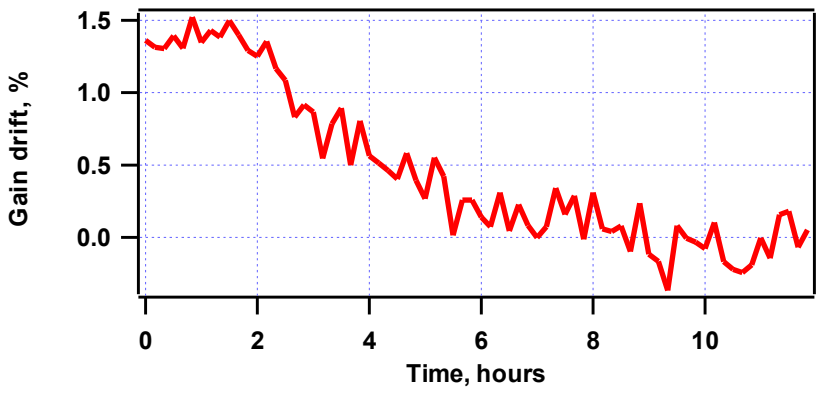
Fast Beam Loss Monitor

Highlights

- **Plastic scintillator: 6-inch long 2 inch diameter.**
- **Very gain stable photomultiplier**
- **Low-power embedded high voltage divider. Typical HV supply current: 15 µA @ 1000 V.**
- **Supports high anode currents (I > 100 µA)**
- **Embedded green, fast LED.**
- **Effective magnetic shield: 0.5 mm mu-metal housing without mounting flange**
- **Teflon-free construction**

Features

- This radiation sensor is a custom-built detector for operation as a fast beam loss monitor at a particle accelerator.
- The PMT type has been selected for high linearity and excellent gain stability.
- The embedded high-voltage divider employs a transistorized voltage divider for best linearity at the lowest power consumption. It only consumes 15 µA at HV=1000V
- The entire unit is hermetically enclosed in a 0.5 mm thick stainless steel magnetic shield (mu-metal).
- The SHV and BNC connectors use rexolite and valox for the insulation.



Gain drift measured over a 12-hour period, after an initial warm-up time of 30 minutes.

Specifications

Parameter	*Symbol*	*Min*	*Typ.*	*Max*	*Comment*
Performance					
Energy resolution at 478 keV			34.00%		Cs-137 Compton corner
PMT gain			385 k		HV = 1240V
PMT gain exponent			5.8		HV = 825V to 1225 V
Scintillator brightness			812 p.e./MeV		
Detector sensitivity	Sp		50.0 pC/MeV		HV = 1240V
			312 C/J		HV = 1240V
Detector sensitivity	Sp		45.2 pC/MeV		HV = 1225V
			282 C/J		HV = 1225V
Dose rate sensitivity	Sd		246 µA/(R/hr)		HV = 1225V
Max dose rate (I=50µA)	Dmax		0.203 R/hr		HV = 1225 V
Detector sensitivity	Sp		4.58 pC/MeV		HV = 825V
			28.6 C/J		HV = 825V
Dose rate sensitivity	Sd		25 µA/(R/hr)		HV = 825V
Max dose rate (I=50µA)	Dmax		2.00 R/hr		HV = 825 V
LED					
Type		IF-E93, green, fast LED			
Forward voltage			3.5 V		IF = 5mA
Ballast resistor	RB		1.0 kΩ		
HV-subsystem					
HV range	HV	700 V		1400 V	negative HV
HV supply current	I_{HV}		15 µA	18 µA	HV = 1000V
Anode resistor to GND	RA		100 kΩ		
Environmental					
Operating temperature		5ºC		60ºC	
Magnetic field				10 mT	Gain drift < 1%

Dose rate sensitivities have been derived from the measured Sp and have not been verified against a calibrated and certified radioactive source, nor have they been verified with a certified instrument.

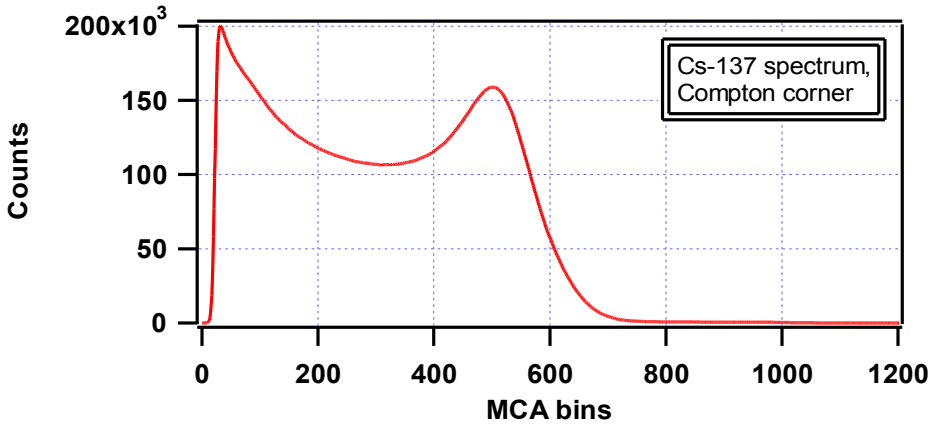


Figure 1: Cs-137 and LED pulser spectrum acquired over 15 hours. The energy resolution at the Compton corner of the Cs-137 (662keV) radiation is about 33% fwhm. The pulse-height resolution of the LED pulser signal (peak on the right) is dominated by photo-electron number statistics.

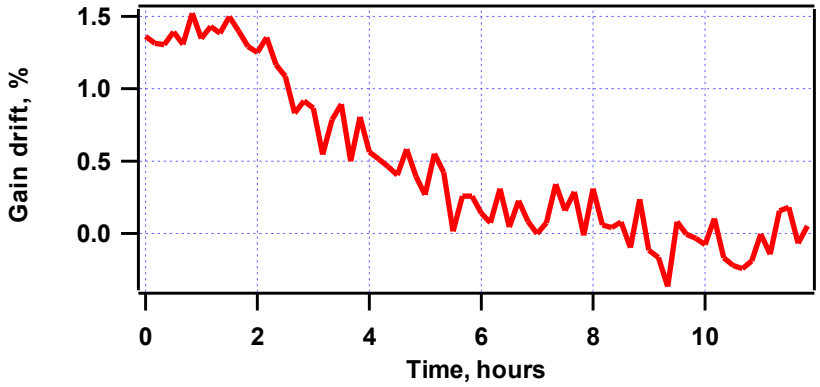


Figure 2: Gain drift measured over a 12-hour period, after an initial warm-up time of 30 minutes.

Detector components

This R2D-FBLM detector employs a plastic scintillator made of EJ-208 from Eljen Technology. It is 6 inches long and has a diameter of 2 inches. The scintillator rod is polished on all sides and wrapped in aluminum foil. It is glued to a linear-focus 2-inch photomultiplier. The photomultiplier type has been selected to ensure good linearity and very low gain drift (typically less than 5% in the first 24 hours after power on).

The detector is housed in a stainless steel magnetic shield made of 0.5 mm thick μ-metal. Unlike in "integral" detectors, this shield provides complete immunity to Earth's magnetic field and other weak magnetic fields of up to 10 mT (100 Gauss).

The photomultiplier is powered by a transistorized (active) high voltage divider with an extremely low power consumption, just 15 μA at HV=1000V.

Theory of operation

The PMT is powered using negative high voltage, and the anode is DC-coupled to its BNC connector. The last dynode signal is sent to its BNC connector via a 100 Ohm resistor and a 10 nF capacitor.

Anode current and dose rate

The DC anode current of the PMT can be related to the dose rate deposited in the plastic scintillator as follows:

$$I = S_P * m * \dot{D}$$

S_P is the energy calibration, expressed in pC/Mev for convenience when measuring energy spectra, or in C/J for dosimetry. Note, 50pC/MeV correspond to 312 C/J. The mass of the plastic scintillator is $m = 0.315$ kg, and $\dot{D}$ is the dose rate caused by the radiation field.

The R2D-FBLM will support anode currents up 50 μA DC with minimal gain shift, <2%. Hence the maximum dose rate, or full scale range, can be computed as

$$\dot{D}_{max} = I_{max} / (S_P * m)$$

and the dose rate range can be adjusted via the PMT gain and the high voltage setting.

Grounding

The R2D steel housing is connected to the HV ground of the SHV high voltage cable. The grounds of the anode and D10 signals are separated by a pair of 10 kΩ resistors. If both resistors were to fail a potentially hazardous voltage potential can develop on the anode and D10 grounds unless at least one of them is connected to a grounded receiver. It is advised not to use the unit if the resistance between the grounds measures more than 7.5 kΩ.

Revision history:

R1	**Aug 2007**	**Initial document**
R2	**Aug 2008**	**Added dosimetry data**