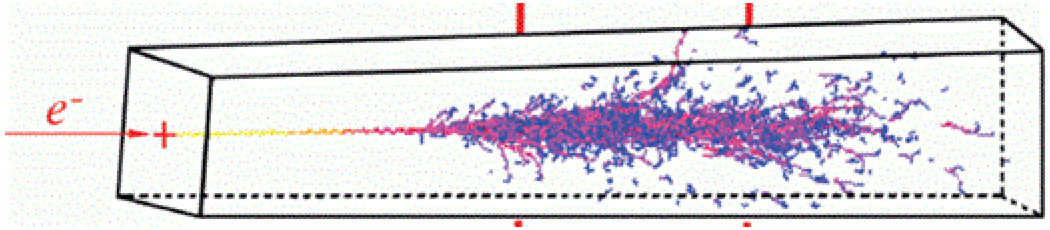
Calibration Methods for LYSO

Erik Swanson UW

PIONEER collaboration meeting

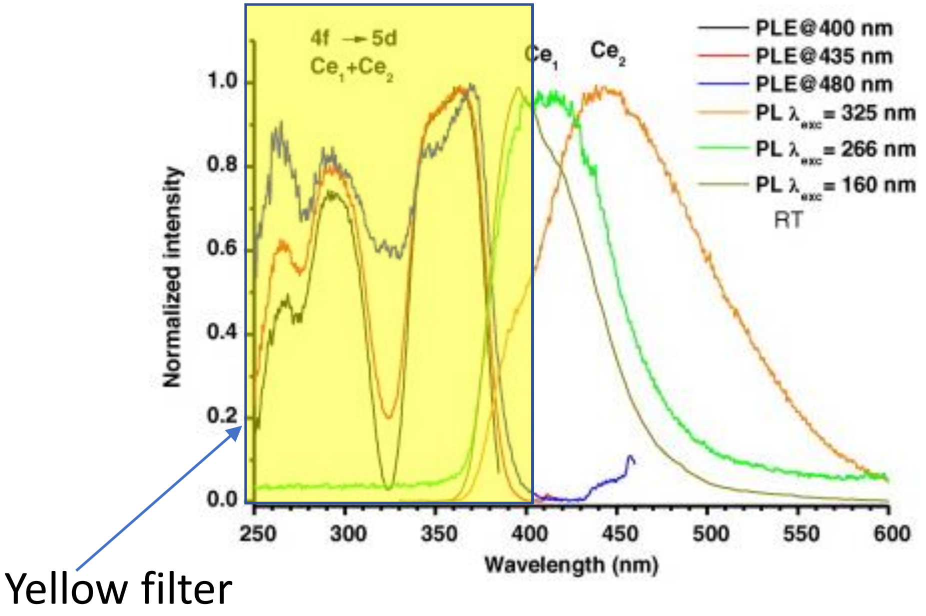
Calibration procedures – insights from LHC

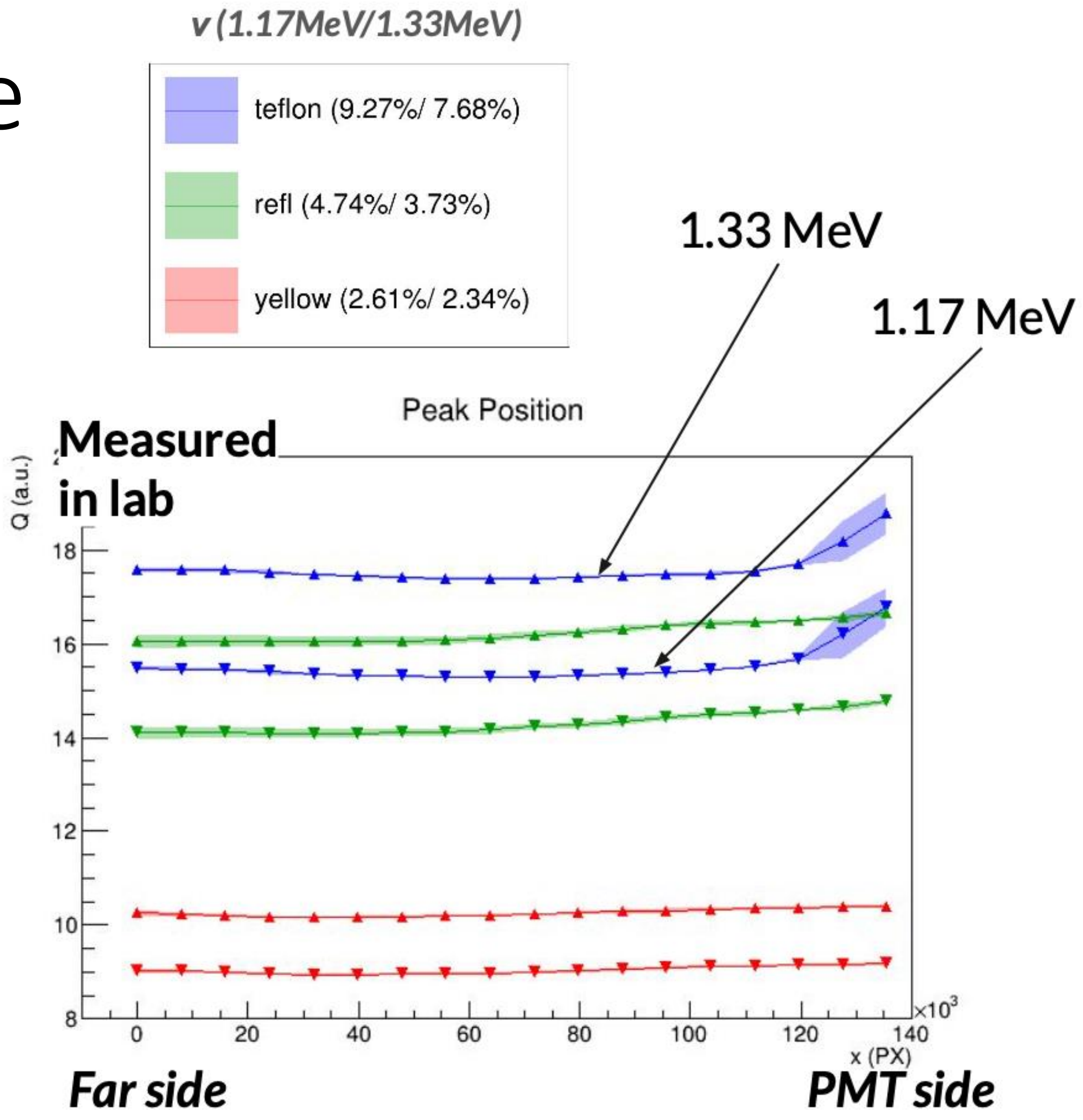
- Physics signals: electrons from W boson decay, electron pairs from Z boson decays
- Analysis of raw data to connect to physics signals
- Detector corrections: Monte Carlo, test beam
- CMS uses lead tungstate scintillation crystals
- Monitor light transmission: Blue and green laser light injected (scintillation emission wavelength)
- Response linearity along length



Longitudinal light response

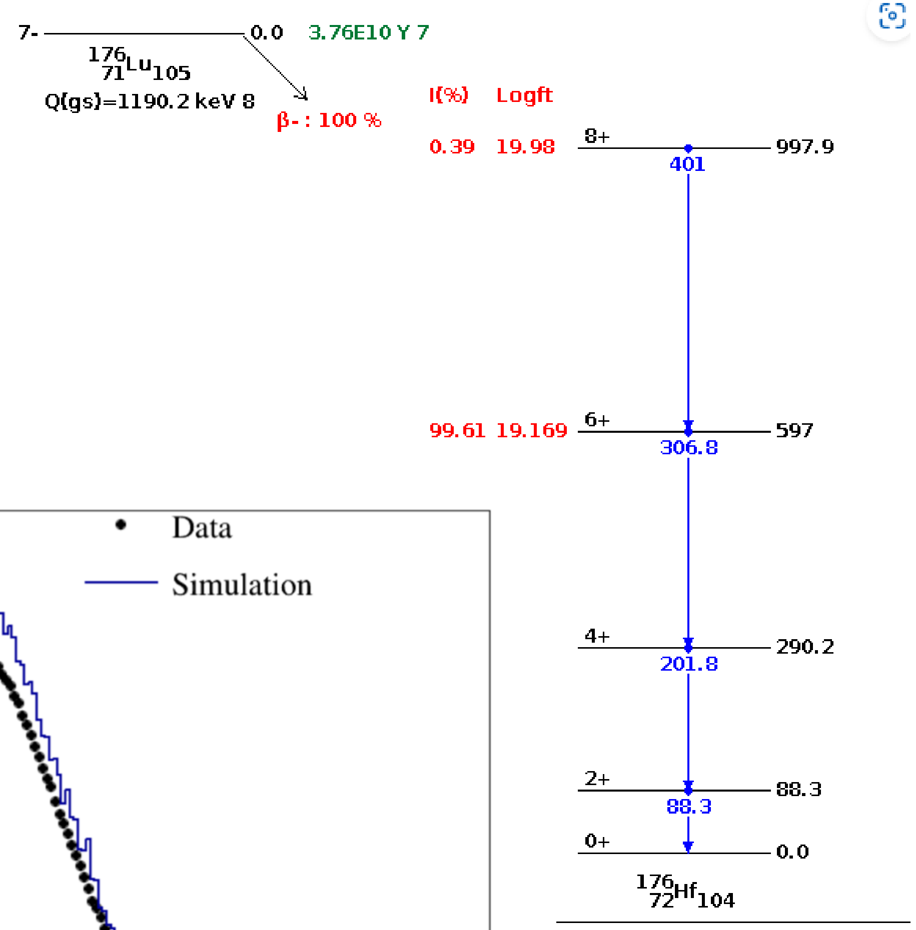
- LYSO grown by pulling seed crystal from melt
- Ce^{3+} ion concentration varies along length of boule
- Radioactive source scanned along length to measure light non-uniformity

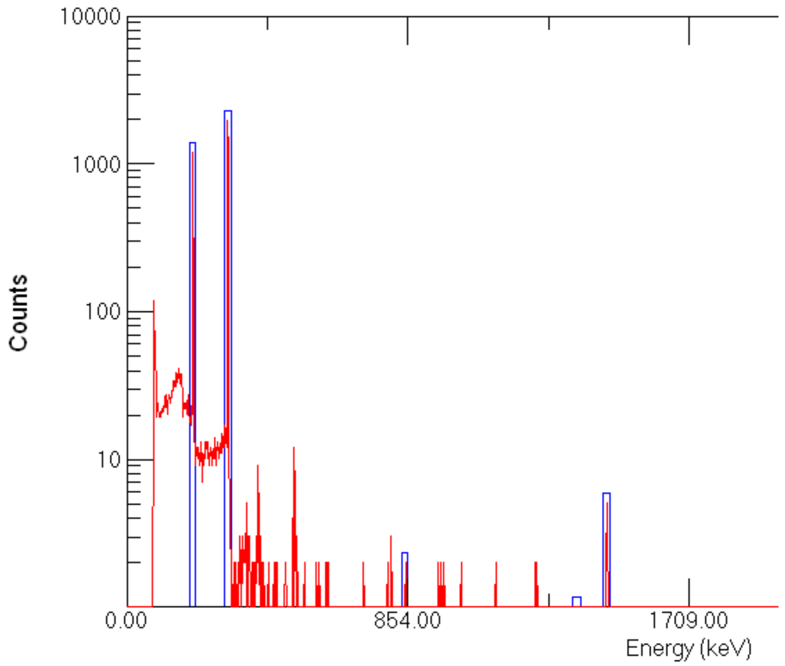


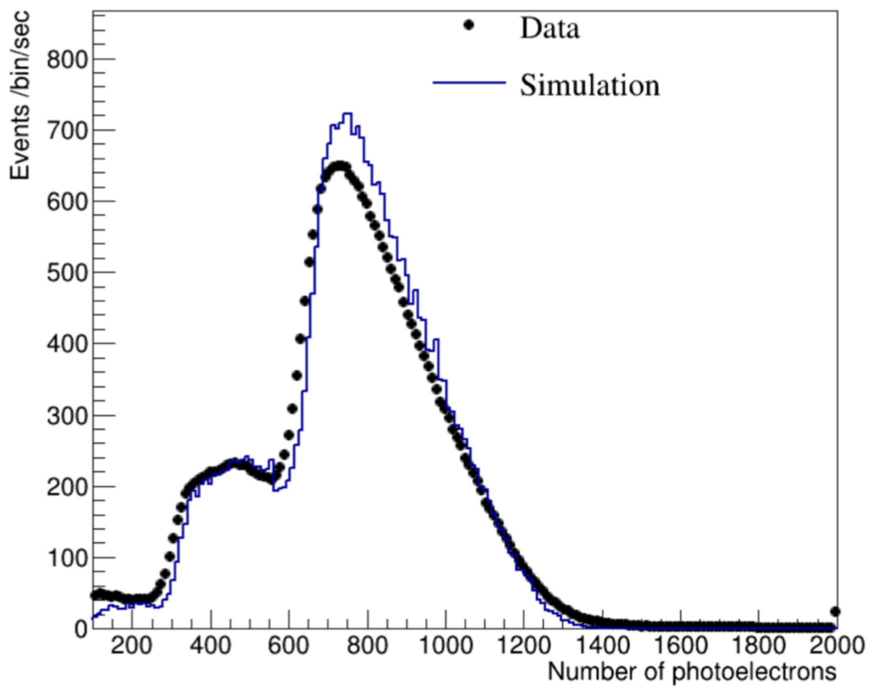


Calibrate using LYSO's intrinsic radioactivity?

- ^{176}Lu beta decays to an excited state of ^{176}Hf plus gamma rays
- Spectral shape is a beta decay spectrum with ~1 MeV endpoint overlayed with the same spectrum with 200 keV or 300 keV escape gammas subtracted
- The lack of spectral lines makes it less useful for calibration



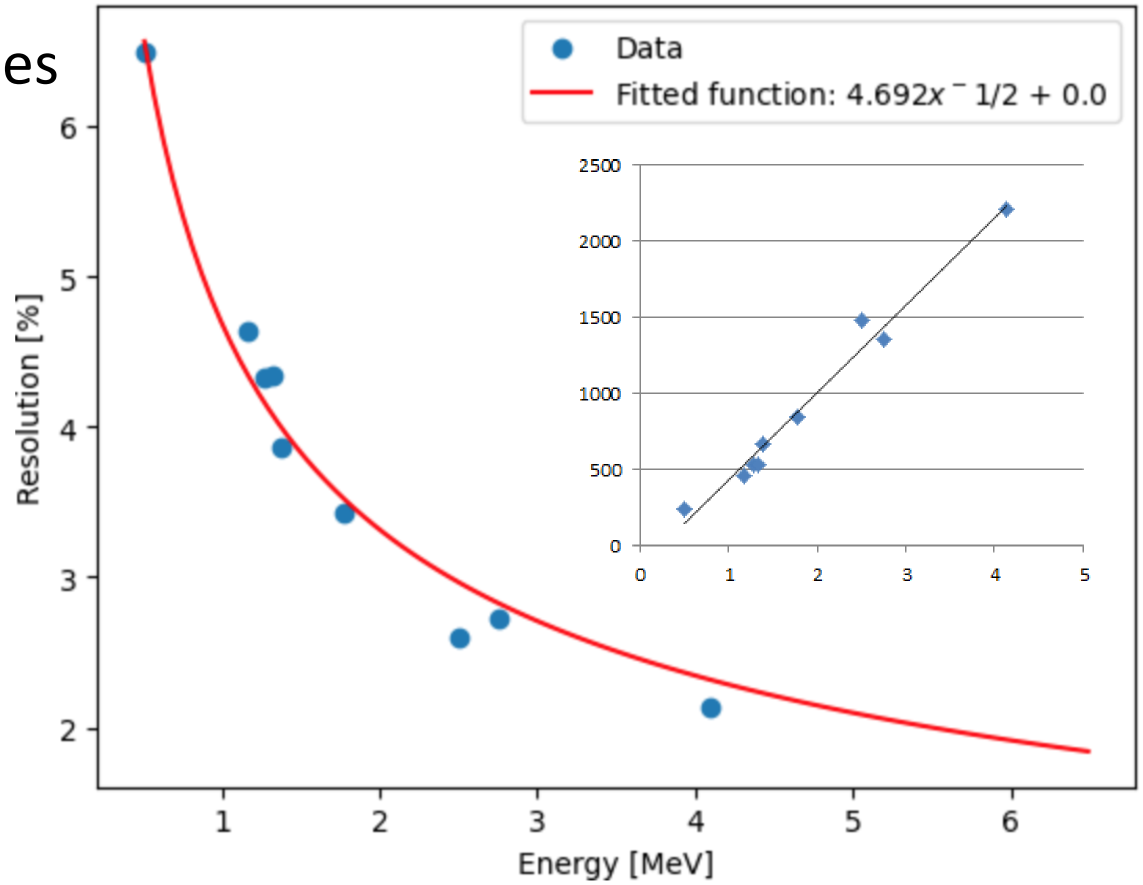




Measuring LYSO response with radioactive sources

Source	Energy[MeV]
Na-22	0.511, 1.274, 1.785
Na-24	1.38, 2.76, 4.14
Co-60	1.17, 1.33, 2.5

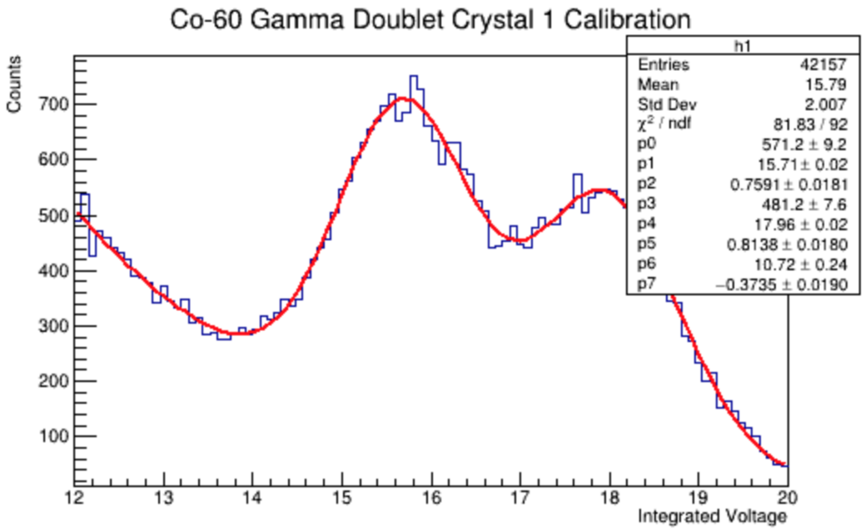
$\frac{\sigma(E)}{E}$ Resolution [%] at each source energy

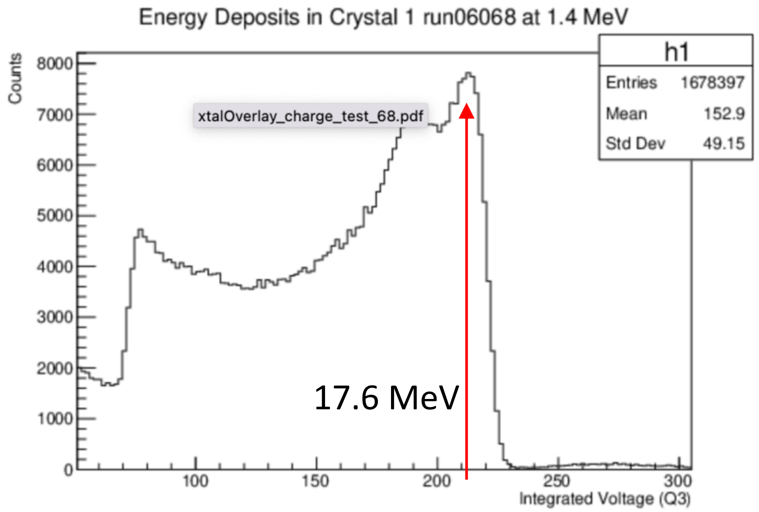


- Resolution Data *D* described by a Poisson distribution (red curve)
- Energy is proportional to the number of photons *N*
- *From Poisson stats N =* (D)$^{-2}$ *shown in the inset plot*
- *The theoretical light output for 1 MeV is 27,300 photons*

Scintillator	Calc. $n_{e\text{-}h}$ pairs per MeV	n_{ph} photons per MeV	Efficiency
LYSO : Ce	69,444	27,300	0.393

Calibrating the crystals for the CENPA test beam – practicing for PSI





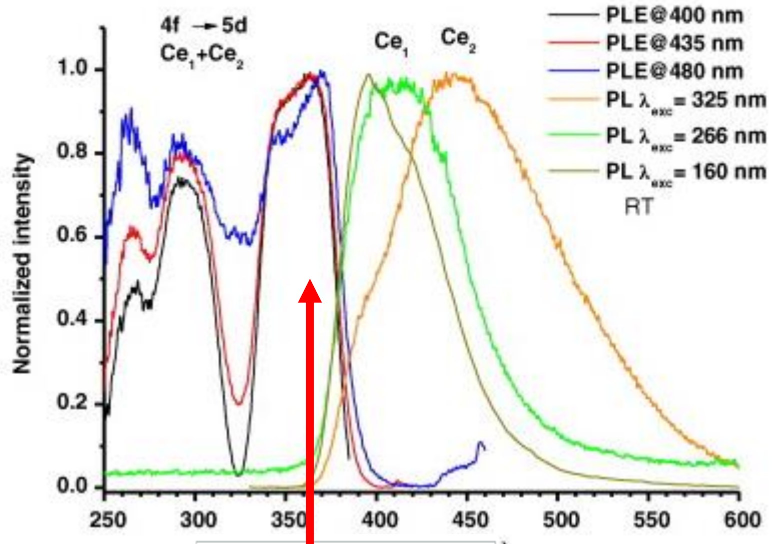
- The maximum input for waveform digitizers (WaveDream and Cornell) is 1 Volt
- First PM high voltage set high enough to resolve Co-60 lines and not saturate the digitizers at 20 MeV
- Co-60 data is fit for the integrated voltage for each line
- Estimate the integrated voltage for 17.6 MeV [245 V]
- With beam the 17.6 MeV line is fit for its voltage channel.
- A 3 point calibration can then be done for that crystal
- The remaining 3 crystals were then calibrated relative to the first one as shown in the table

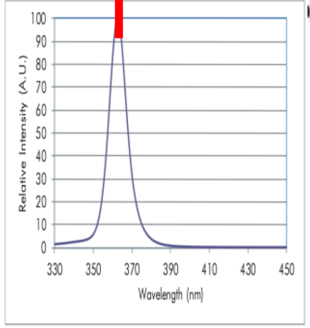
Crystal	1	2	3	4
High Voltage (kV)	1.127	1.124	1.092	1.250
Co-60 1.173 MeV Integrated Voltage Peak	15.7100	16.0871	15.4652	15.4259
Co-60 1.332 MeV Integrated Voltage Peak	17.9574	18.3404	17.6790	17.5650
Calibration Constant 1.173	1.00	0.97655886	1.0158291	1.0184171
Calibration Constant 1.332	1.00	0.97911714	1.0157475	1.0223399
Average Calibration Constant	1.00	0.97783800	1.0157883	1.0203785

The UV LED calibration system

- This system directly excites the Ce^{3+} ion and creates scintillation light just like high energy gammas and positrons/electrons
- The NIM pulser provides 15 nsec wide pulses to the UV LED and can drive large instantaneous currents
- The LED is rated at over 1 Watt DC
- Light is injected into the crystal along side the photomultiplier and relies on the nearly total internal reflection to sample the crystal volume
- Its purpose is to monitor relative changes in intercalibration constants between the crystals
- It also provides large light output signals for commissioning the detector and electronics

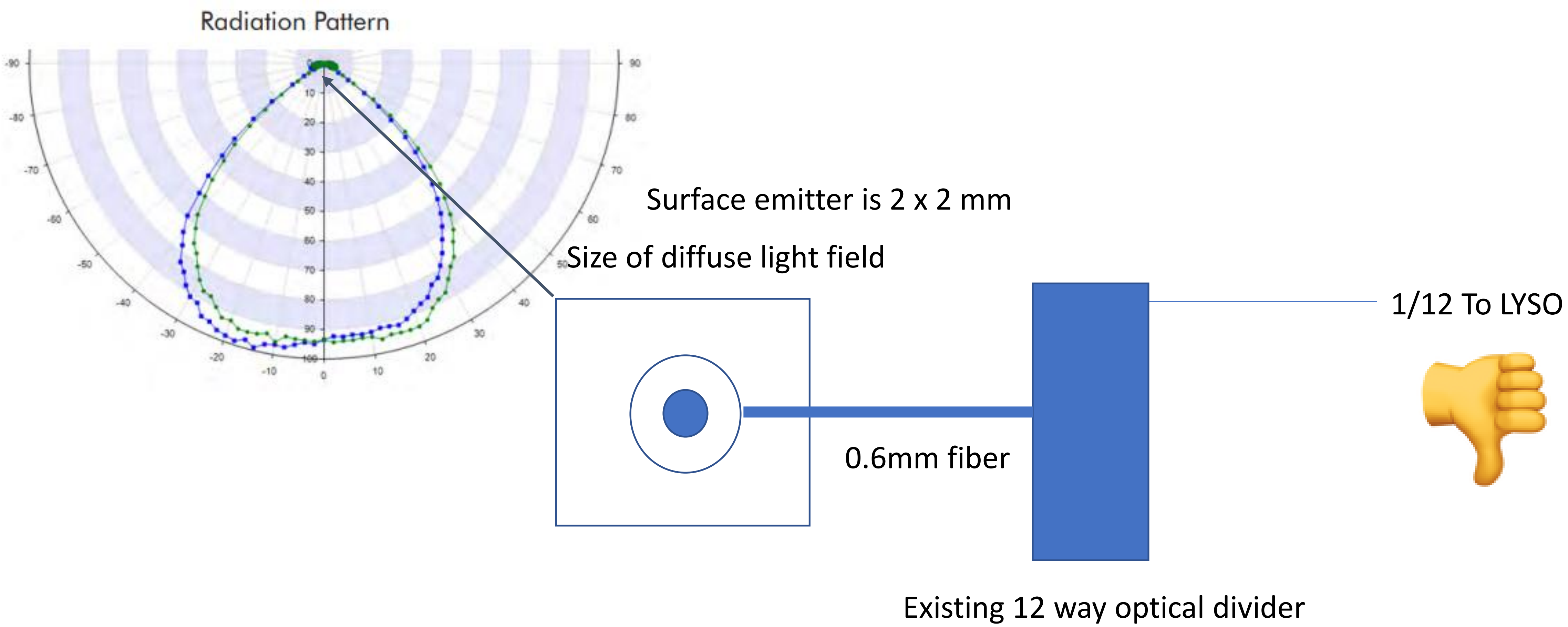
LYSO absorption and emission spectrum





UV LED spectrum

Coupling LED light output to optical fibers



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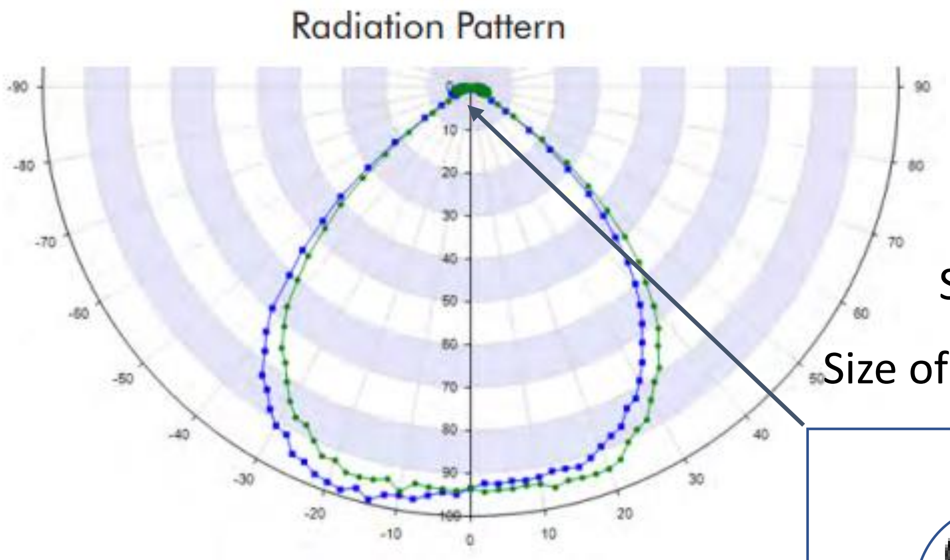
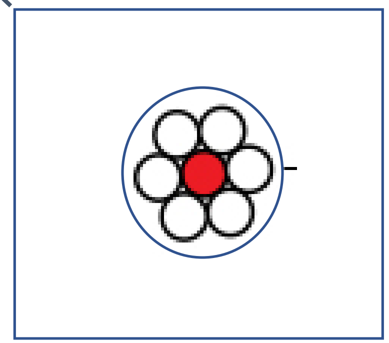


Surface emitter is 2 x 2 mm

Size of diffuse light field

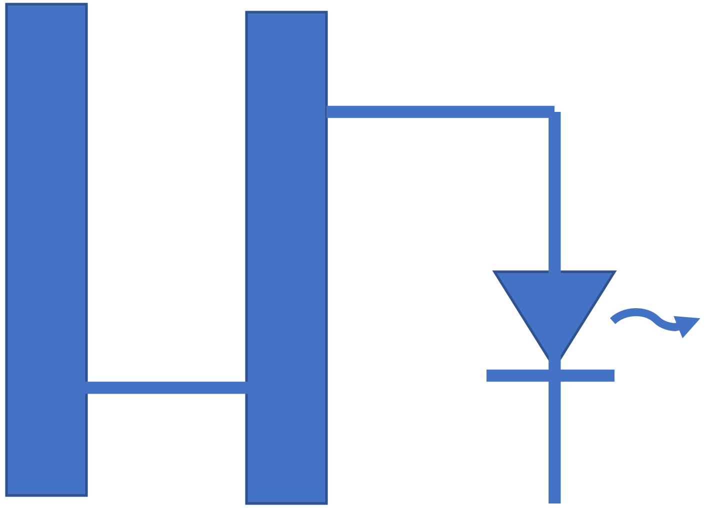


ThorLabs fiber bundle 1 – 7 fan out

0.4mm fibers directly to LYSO

The UV LED calibration system

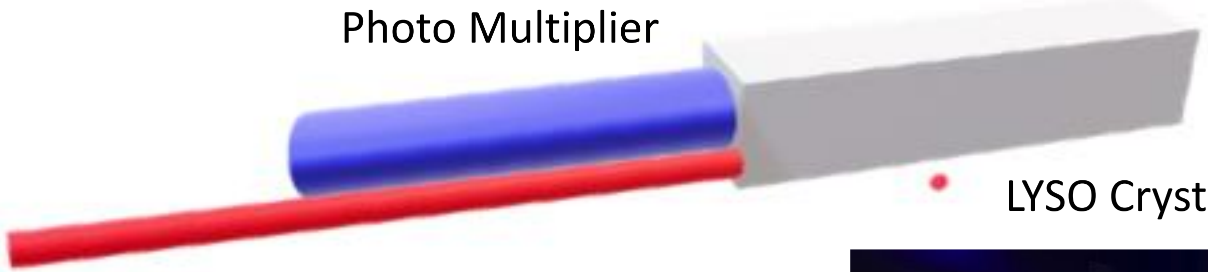
NIM Pulse Generator



NIM LED Driver

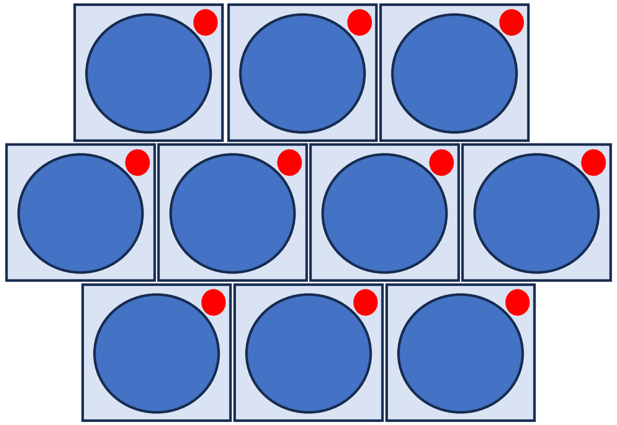
UV LED

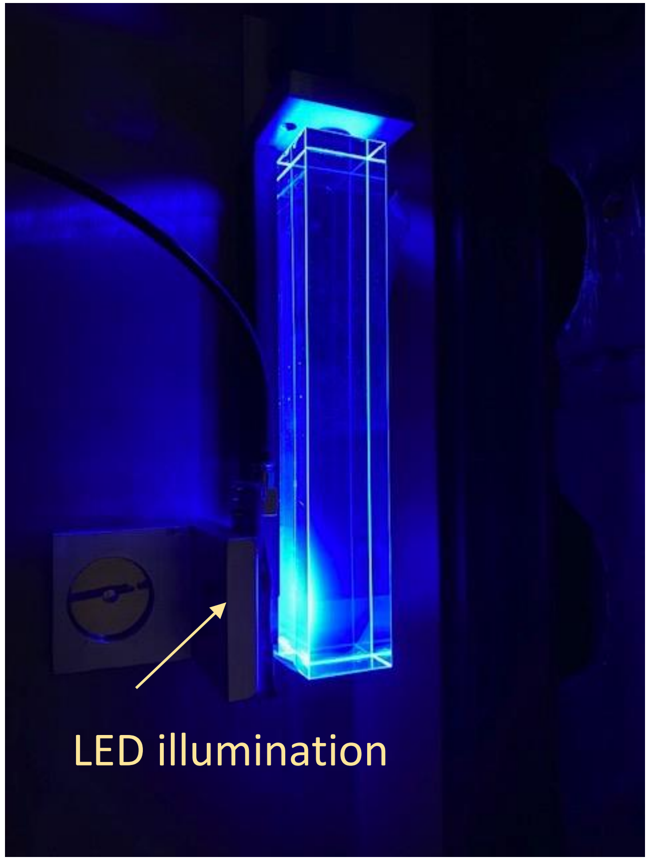
Photo Multiplier



LYSO Crystal

0.4 mm fiber





LED driver is triggered
By an external pulse generator

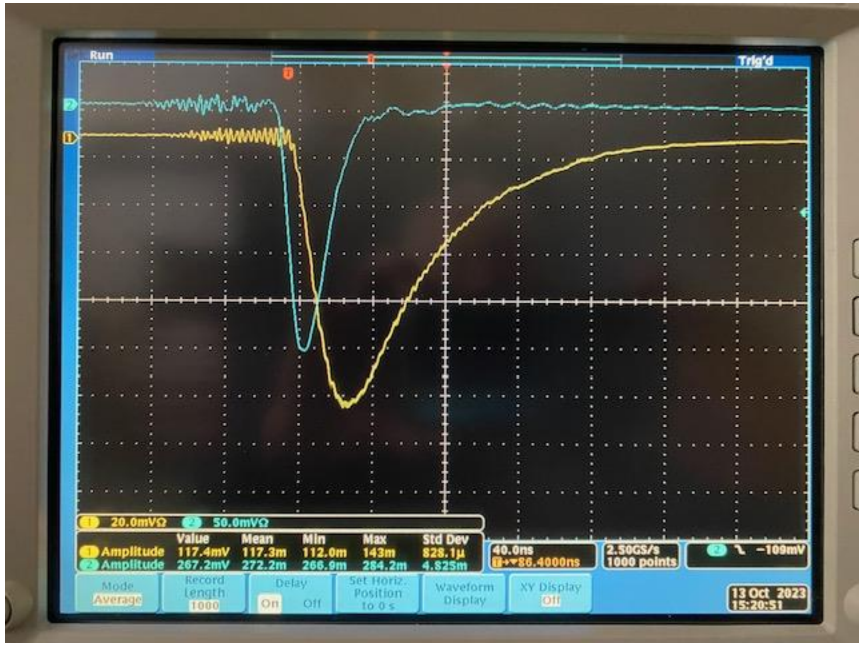
Two LEDs and fiber fan out bundles (1 – 7)
Are needed for the 10 crystal array

Photo shows LED beam divergence
and depth of penetration

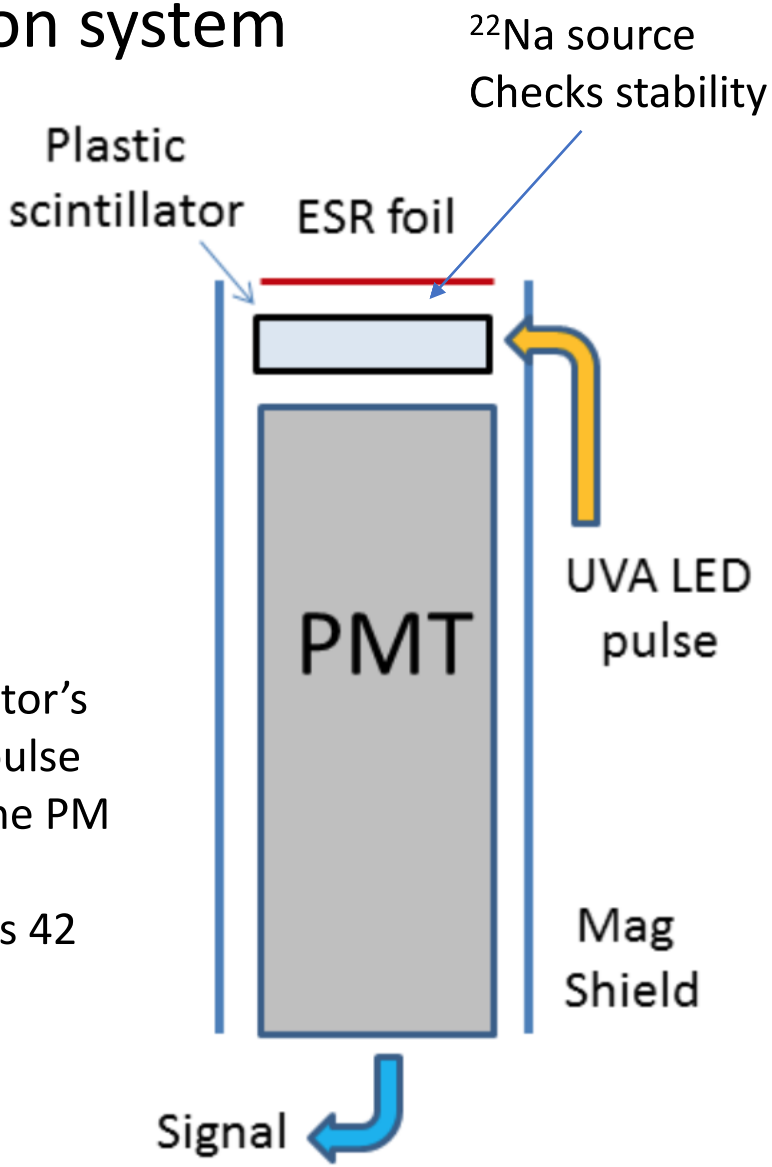
Near total internal reflection samples LYSO volume

Monitoring the UV LED calibration system

- LED light stability depends only on the driver electronics, there is no feedback to hold it constant
- Short term stability looks good
- A fiber from the fan out bundle injects light into the plastic scintillator of a monitor counter – scales with LYSO responses
- Consistency in the monitors response can be periodically checked with a radioactive source.



- Blue trace is the monitor's response to the LED pulse
- Yellow trace is from the PM on the LYSO crystal
- LYSO's time constant is 42 nsecs



Summary

- LYSO crystals resolve gammas from radioactive sources sufficiently well
- Up to 20 MeV sources can be used to calibrate energy scales, maybe more
- LED Light pulser system works well as pseudo standard candle at energies greater than radioactive sources