A Modular X-ray Detector for Beamline Diagnostics at LANL

P. M. Freeman[1†]

L. Malavasi[2], B. Odegard[1], R. Schmitz[1], D. Stuart[1], J. Yang[1]

1. University of California Santa Barbara, 2..Worcester Polytechnic Institute, †presenter

ABSTRACT

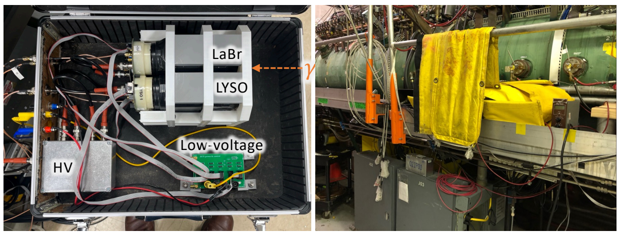
An X-ray detector is being developed for diagnostic measurement and monitoring of the Drift Tube LINAC (DTL) at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Lab. The detector will consist of a row of X-ray spectrometers adjacent to the DTL which will measure the spectrum of X-rays resulting from bremsstrahlung of electrons created in vacuum by the RF. Two types of spectrometer modules are being developed: a large number (near 100) of inexpensive LYSO+SiPM-based modules will be deployed to measure the rate and energy of gammas along the beam and at different azimuthal angles. A smaller number of LaBr+PMT-based modules (one or two per DTL tank) will precisely measure the energy of X-rays at specific drift tube gaps in addition to reporting event rates. An MFR proposal has been submitted for the funding of further development and deployment of this X-ray detector.

PROTOTYPE TESTING at LANSCE DTL

2 sets of tests:

- July 30-Aug 3 (presented here)
- RF conditioning April 2022.

PMT-BASED PROTOTYPE



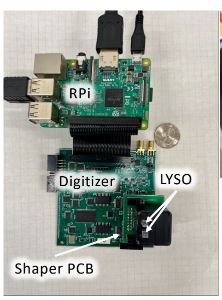
The PMT-based prototype at the LANSCE DTL with Pb blankets (yellow) for shielding.

Consists of 4 scintillator+PMTs:

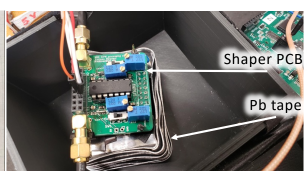
- LYSO+PMT (tagged γ-source)
- 2 NaI+PMT
- LaBr+PMT
  - Best energy resolution
  - Easiest to shield

SiPM-BASED PROTOTYPE

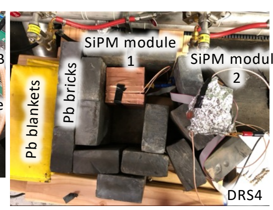
- Small => lightweight & inexpensive shielding
  - such as a Pb tape (see Fig.) or Tungsten-polymer.
- 2 SiPM-based prototypes at the LANSCE DTL:
  - Al foil-wrapped module w/ Pb tape
  - Cu-wrapped w/Pb bricks + blankets



Photograph of the X-ray detector module prototype with Raspberry Pi to control the SRAM digitizer and read out the (uncovered) LYSO+SiPM.



The SiPM-based prototype wrapped in Pb tape for radiation shielding inside its Faraday cage. There is no Pb tape on the front of the crystals.



CUSTOM-BUILT DIGITIZER

- samples signal with an ADC
- written to an SRAM at 33 MHz
- readout via a Raspberry Pi (RPi)
  - Can run over network, ssh
- trigger logic can run in hybrid AND/OR mode
  - i.e. calibration/data taking modes
- Custom-built electronics keep cost of modules low
- DRS4 evaluation boards [3] were used for these results

[1] M. S. Barrueta, J. T. M. Lysle, J. E. Zane, G. O. Bolme (retired), Pinsky and R. Z, "X-RAY Detector Array for Spatial and temporal Diagnostic at the LANSCE LINAC," in *NAPAC*, Lansing, MI, 2019. [2] G. O. Bolme, G. P. Boicourt, K. F. Johnson, R. A. Lohsen, O. R. Sander and L. S. Walling, "Measurement of RF Accelerator Cavity Field Levels at High Power from X-Ray Emissions," in *Proceedings of the Linear Accelerator Conference*, Albuquerque, New Mexico, 1990. [3] https://www.psi.ch/en/drs/evaluation-board

*Funded by "Advanced Accelerator Diagnostics" grant from UC Lab Fees program.

*BEAM*SSTRAHLUNG?

- Detectors will monitor field emission electrons and resulting bremsstrahlung X-rays
- Previous studies [1] demonstrated feasibility of creating a similar X-ray detector diagnostic
  - Used to help locate arc in tank 3

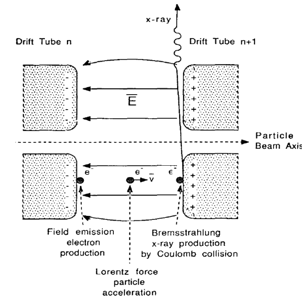
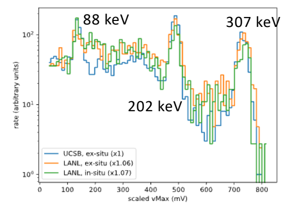


Diagram of Field Emission Electrons and resulting bremsstrahlung photons from [2].

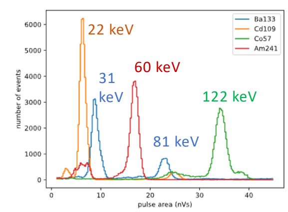
IN-SITU SELF-CALIBRATION

- LYSO used as tagged gamma source with 3 peaks
- Effective both ex-situ and in-situ (background RF on)



Scaled LYSO calibration spectra in-situ (at LANL DTL with background RF) and at ex-situ (labs at LANL and UCSB). The events are selected to have the 176Lu gamma rays tagged by a coincident hit in the LYSO.

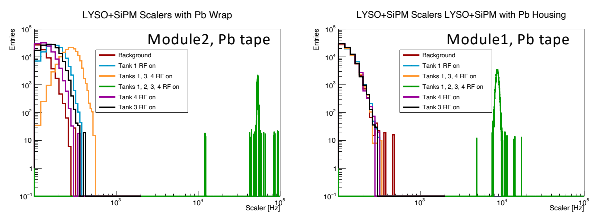
SOURCE CALIBRATION



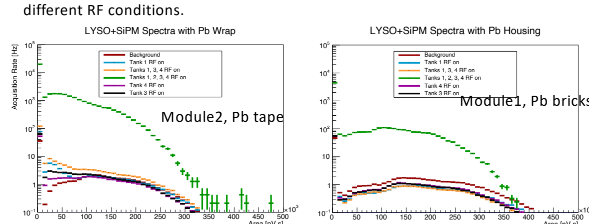
Spectra measured at UCSB with known calibration sources and the LaBr+PMT spectrometer.

SiPM SHIELDING COMPARISON

- Comparison of attenuation with different shielding: Pb tape vs. (Pb tape +Pb bricks)
- Acquisition rates ("Scalers") measured for different RF conditions
- Signal from tank 2 (target) dominates



Hardware scalers (trigger rate without dead time) for the LYSO+SiPM modules in different RF conditions.



Scaled pulse area spectra (uncalibrated) for the LYSO+SiPM prototypes for different RF conditions.

CONCLUSIONS & OUTLOOK

- The background of other tanks can be rejected while measuring tank 2 of the LANSCE DTL with relatively lightweight and inexpensive shielding around the LYSO+SiPM modules.
- A similar result would be expected for a smaller PMT-based LaBr/LYSO detector, which is to be developed.
- The feasibility of in-situ calibration with the PMT-based module was also demonstrated.

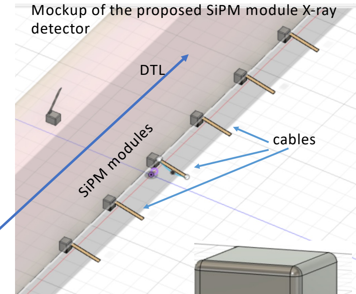
More testing at LANSCE and deeper analysis will explore:

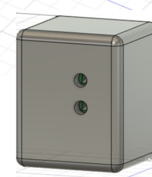
- Measurement with the custom-built readout electronics (digitizer)
- In-situ calibration with LYSO+SiPM modules
- Optimized mechanical and shielding design for both types of modules

An MFR proposal has been submitted for development of the X-ray detector as a diagnostic at LANSCE.

- A similar detector would be applicable to other DTLs, and possibly in diagnostics of other accelerator systems.

Mockup of the proposed SiPM module X-ray detector





Mockup of a single shielded SiPM module