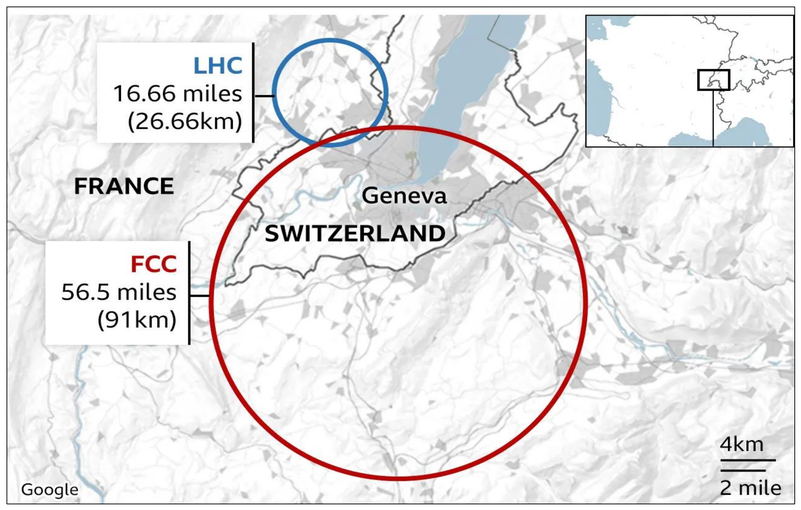
Crystal Characterization for Calorimetry at the Future Circular Collider

Bhavya Singhal[1], Shin-Shan Eiko Yu[1] ,Rachel Bartek[1], Aaron Dominguez[1], Harvey B. Newman[2], Liyuan Zhang[2]

[1] The Catholic University of America, Washington DC
[2]California Institute of Technology-Caltech

Introduction

- In particle physics, **"calorimetry"** refers to the detection of particles and measurement of their properties by complete absorption of the particle's energy in a bulk of matter, referred to as a calorimeter**.**
- Future Circular Collider (FCC) is a proposed future collider that would give access to a variety of new physics measurements. Precision measurements of visible energies via calorimeters hence play crucial role in probing physics at very high energy scales.
- **Calvision** is a consortium of universities and Department of Energy laboratories focused on advancing state-of-the-art calorimetric measurements for all types of particles. The program prioritizes the development of homogeneous calorimeters that maximize the use of available information.
- Key aspects of this program include, harnessing 'dual readout' of scintillation light signals and Cherenkov radiation (special radiation produced when a particle moves faster than the speed of light in that medium), utilizing timing to distinguish, and developing new algorithms to analyze the two signals.
- Scintillation is the process where a certain material media emits specific light signals upon absorbing energy from the particle shower produced in the particle collider



References

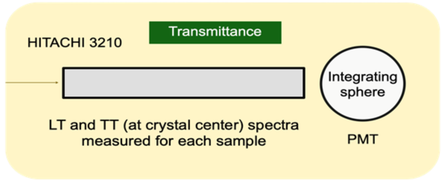
1. Ren-yuan Zhu 2009 J. Phys.: Conf. Ser. 160 012017
2. https://doi.org/10.48550/arXiv.2502.21223
3. https://doi.org/10.48550/arXiv.2408.10466
4. https://home.cern/

Methodology

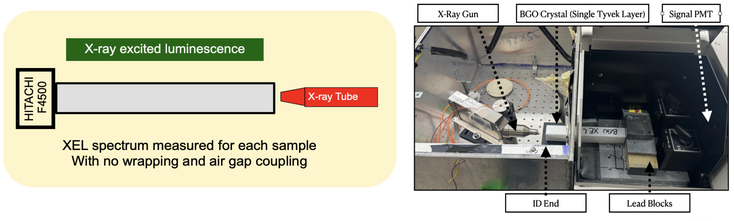
- As part of this initiative, CUA's high-energy physics group plans to establish a crystal testing facility to characterize candidate crystals to be used in the calorimeter.
- This classification involves studying the following properties of the crystal:
  - Transmission spectrum
  - X-ray excited emission spectrum
  - Pulse Height Spectra and Light Response Uniformity(LRU)
  - Light Output and Decay Time(**τ**) of scintillation
- Crystal samples of an inorganic scintillator, Bismuth Germanate ($Bi_4Ge_3O_{12}$) – BGO were tested in the Crystal HEP lab at Caltech as part of the knowledge transfer to CUA.

Setups

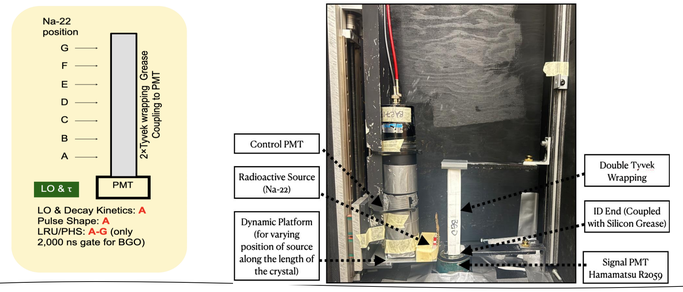
- Transmission Spectra



- X-Ray Excited Luminescence (XEL)

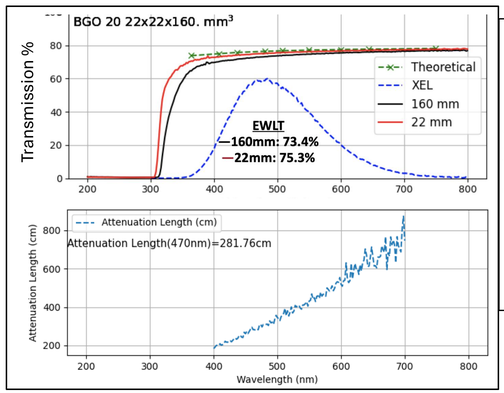


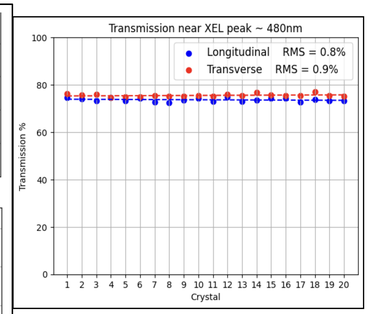
- Light Response Uniformity and Time Responsivity- Decay Time



Results

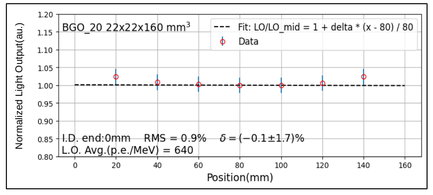
- Transmission Spectra, XEL and Attenuation Length

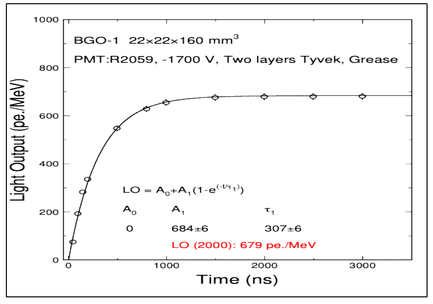


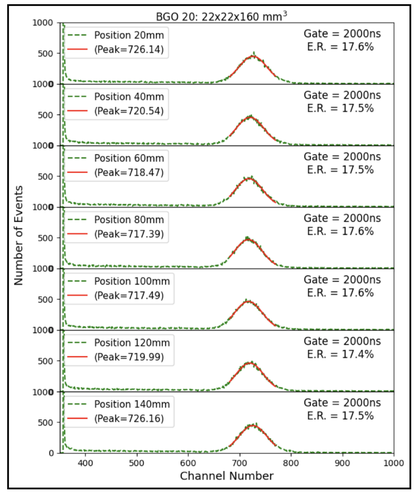


➢ Shows uniformity across the different crystal samples

- LRU, Time Decay and PHS







Discussions and Future Plans

- Successful testing of 20 good quality BGO crystals was done with
  - Scintillation peak(~480nm) measured by XEL spectrum
  - High EWLT and low RMS values for LRU along with theoretically accurate decay time ensures the quality of crystals.
- These crystals will be sent to the test beam at DESY for the crystal matrix tests
- We plan to test different scintillators samples and characterize them based on the properties studied to determine the scintillators best suited for dual readout calorimetry