URD Poster Script - Bhavya

Hi, my name is Bhavya Singhal, and I am going to talk on behalf of the High Energy Physics Group of the Physics department at CUA about our work on crystal characterization for electromagnetic calorimetry in the Future Circular Collider.

In particle physics, calorimetry refers to the detection of particles and measurement of their properties by the complete absorption of their energy in a bulk of matter, referred to as a calorimeter. The Future Circular Collider (FCC) is a proposed next-generation collider that gives access to a variety of new physics measurements. Precision measurements of visible energies via calorimeters play a 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 and Cherenkov radiation. Scintillation is the process where certain materials emit specific light signals upon absorbing energy from the particle shower produced in a collider whereas Cherenkov radiation is a blue glow produced when a particle moves faster than the speed of light in that medium. The challenge arises because the Cherenkov light spectrum overlaps with the scintillation light spectrum, and there is only a small UV window below the scintillation peak of the crystal. To address this, we utilize the time difference between these two signals, which is on the order of nanoseconds (ns). Thus, it is important to study the properties of these crystals in detail to develop the necessary methods and algorithms for analyzing these signals. As part of this initiative, CUA's high-energy physics group plans to establish a crystal testing facility to characterize candidate crystals for use 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.

To conduct these studies, we used three different experimental setups. To examine the transmission spectra, we used a HITACHI 3210 spectrophotometer, which measures the amount of light transmitted through the sample for wavelengths ranging from 200 nm to 800 nm. This test helps determine the wavelength range for which the sample is transparent. As seen in the plots, the transmission spectra for the BGO crystal match theoretical predictions for approximately 350 nm and above. This test was performed on 20 different BGO samples, yielding uniform results that confirm the reproducibility and high quality of the crystals.

We further measured the X-ray excited emission spectrum using a fluorescence spectrophotometer by exciting the sample with X-rays. This spectrum indicates the wavelengths at which we can observe quality scintillation signals for the BGO sample. The blue dotted plot in the same figure shows the relative luminosity of the X-ray emission, with peak luminosity at ~480 nm. Another plot shows the attenuation length of the crystal, which is over ten times the crystal's length.

Another important test is the study of light response uniformity (LRU) and the decay time of the scintillator. LRU ensures that the sample emits a consistent light output along its length since, inside a particle collider, the particle shower may incident at any position or angle on the scintillating crystal. To perform this study, we positioned the crystal vertically and moved the radiation source along its length while measuring the light output at predetermined locations using a photomultiplier tube placed beneath the crystal. The results show that the BGO crystal gives uniform light output with an RMS value of approximately 1% across its length. The figure on the far right shows the pulse height spectrum for BGO at different positions.

Lastly, we used the same setup to determine the decay time of the scintillator, which is the time it takes for the emitted light pulse intensity to decay to approximately 37% of its initial value after excitation. To measure this, we recorded the light output of the crystal at different time intervals while keeping the radiation source fixed. The results show that the light output follows a decay equation, giving a decay time of nearly 300 ns. This value aligns with previous studies on BGO crystals and is advantageous for our purposes, as it enhances the resolution of Cherenkov radiation, which, unlike scintillation, manifests as a brief pulse of light.

These results and their reproducibility across multiple crystal samples demonstrate the high quality of the crystals. As a next step, these samples will be sent to the test beam at DESY for crystal matrix tests.
Moving forward, we plan to test various scintillator samples and characterize them based on the studied properties to determine the most suitable scintillators for dual-readout calorimetry.

Thank you.