Compton calorimeter / NPS prototype beam tests

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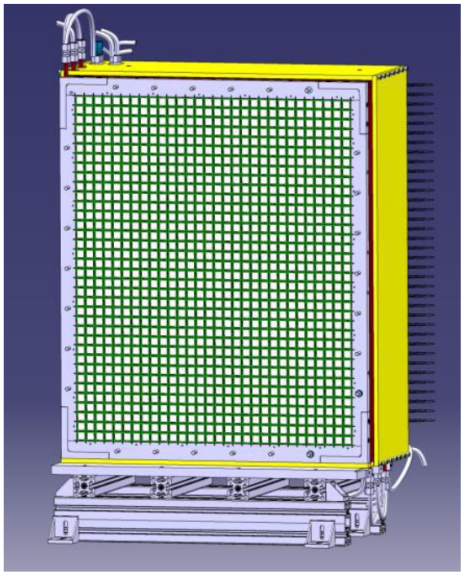
Detector-1 calorimetry weekly meeting
May 5 2022

Beam test motivation

Two PWO based calorimeters currently under construction at Jefferson Lab

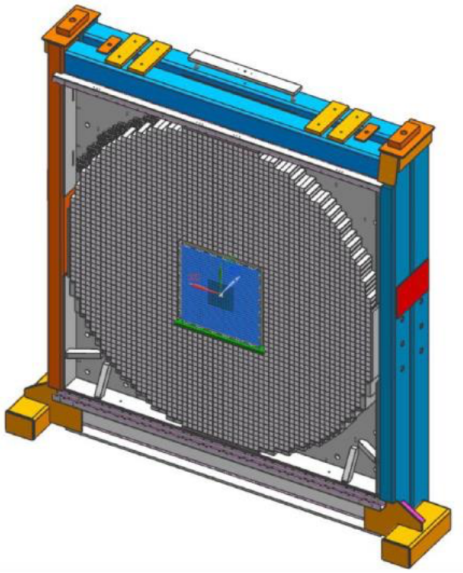
NPS (Hall C)

1080 PWO crystals



FCAL-2 (Hall D)

1600 PWO crystals



- Crystal size: 20.5 mm x 20.5 mm x 200.0 mm (~22 X0)
- Procured from two vendors: SICCAS (China) & CRYTUR (Czechia)
- Crystals of the same size considered for EIC EEEMCAL

Beam tests

- Crystal characterization for JLAB and future EIC
- Optimization of readout electronics
- Optimization of the calorimeter module design
- Study detector properties

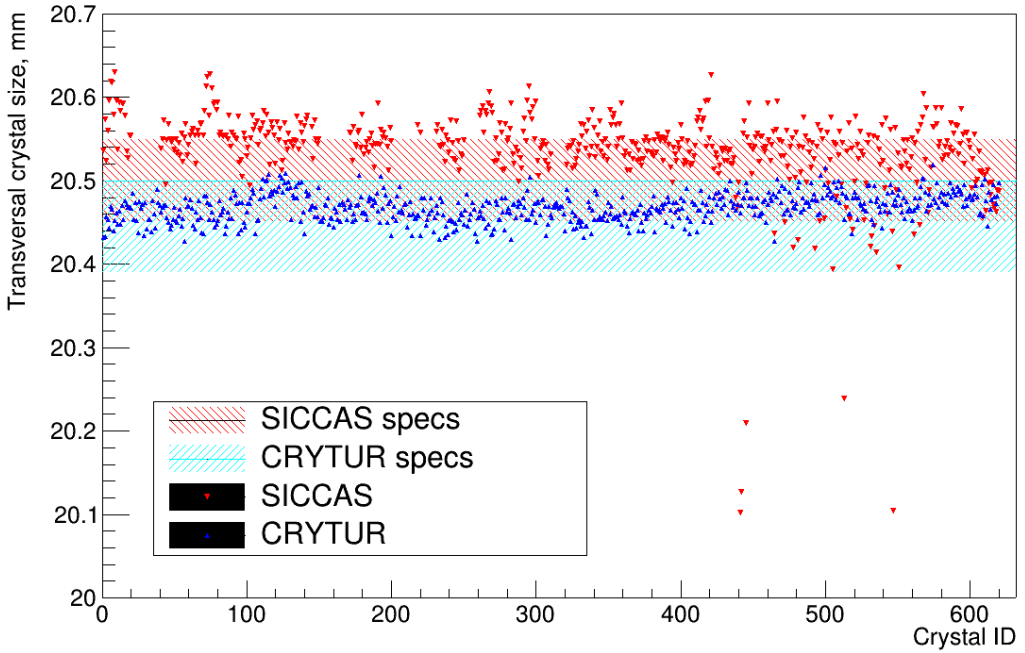
Test areas:

- Use leptons provided by Hall D pair spectrometer to check / study crystals and small prototypes
- Use Hall D photon beam. Constructed a large scale prototype (140 PWO towers). Detector used to reconstruct Compton scattering events in the PrimEx-η experiment during runs in 2019 and 2021

Beam tests timeline

- April 2018 - First test of the 3 x 3 prototype using PS test setup Study read out electronics, operation conditions (some features observed)
- October 2018 - Construction of Compton Calorimeter (140 modules). Installed in Hall D for the PrimEx-η experiment. Study electronics, detector resolution, performance at high rate
- Spring 2019 - first tests of crystals using PS setup. Method established and continue with the PS beam tests since then
- Fall 2019 - new tests of 3 x 3 prototypes using PS test setup (new electronics). Good agreement of the energy resolution with CCAL.
- Fall 2019 - optimize design of the FCAL 2 module. Study light guides.
  - **Nucl. Inst. Meth. A956 (2020) 163375**
  - **Nucl. Inst. Meth. A 1013 (2021) 165683**
- Fall 2021- CCAL 2 in the new PrimEx-η run (new electronics, updated LMS system)
- Fall 2021- test fabricated FCAL 2 modules using the PS setup
- Fall 2021 - various tests of calorimeter prototypes (PMT and SiPM readout), test scintillator glass modules using the PS setup

Characteristics of PWO crystals

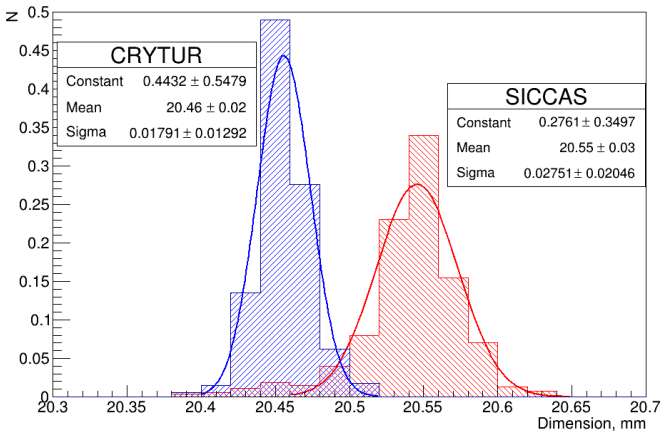


CRYTUR crystals are excellent quality

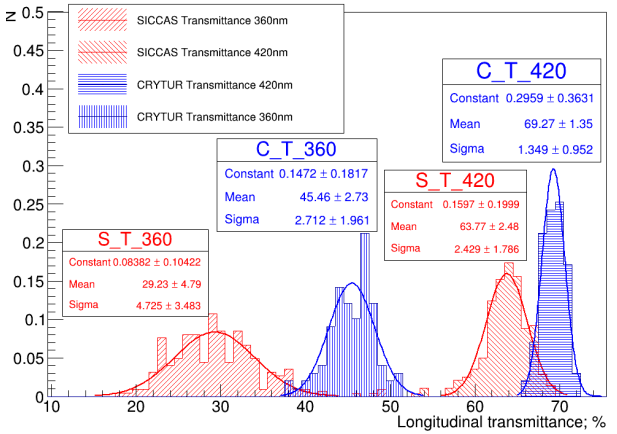
- Great transmittance
- Uniform LY and light collection
- Characteristics within specification
- Rejection rate 0%

SICCAS crystals are low medium quality

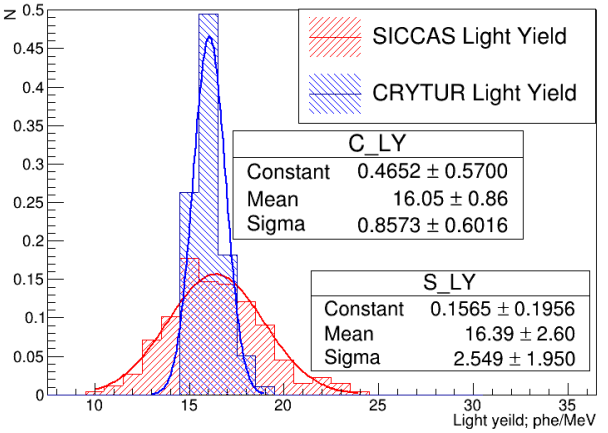
- Lower transmittance compare to CRYTUR
- Non-uniform LY and light collection
- Characteristics outside of specification for significant portion of crystals
- Preselection required
- Rejection rate 30%



Crystal size

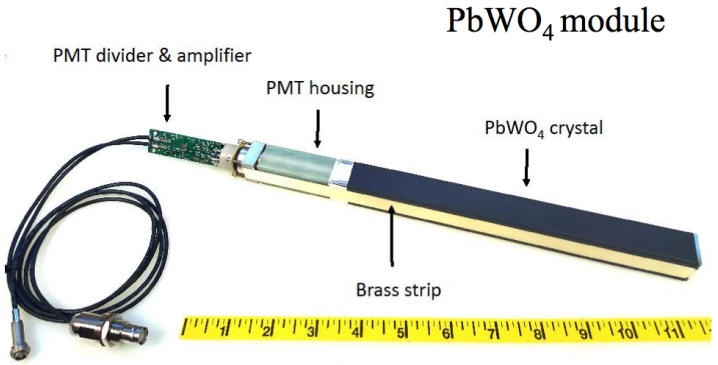


Transmittance



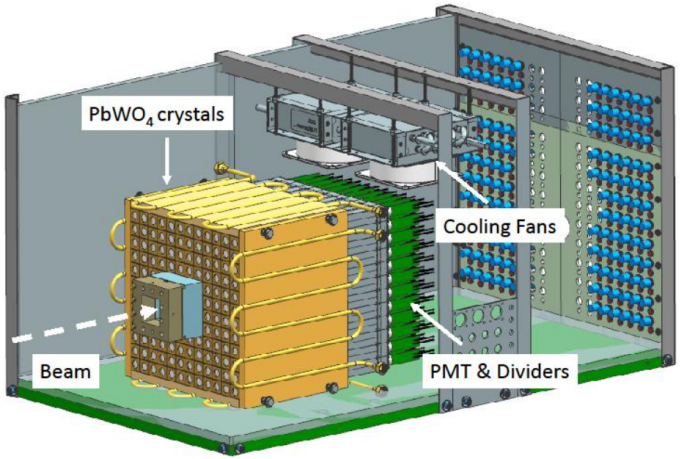
Light yield

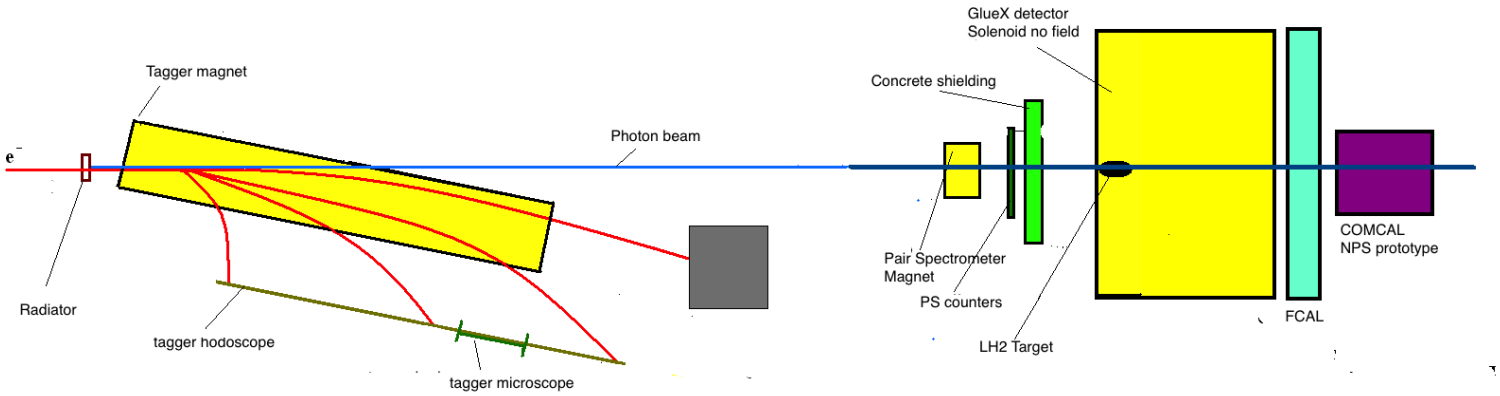
Compton Calorimeter in PrimeX-η



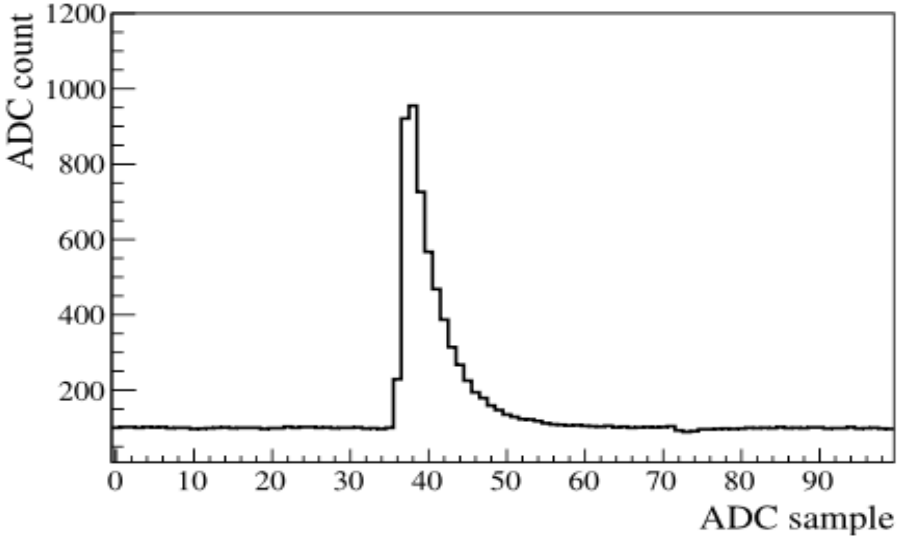
Nucl. Inst. Meth. A 1013 (2021) 165683

- 12 x 12 modules (SICCAS crystals)
- Used as a Compton calorimeter in PrimEx in 2019 and 2021
- Positioned in a movable platform (inserted into the beam for energy calibration)
  - initial calibration with respect to Hall D tagger (energy resolution 0.1 %)
- Temperature stabilization (17°± 0.2° during run)

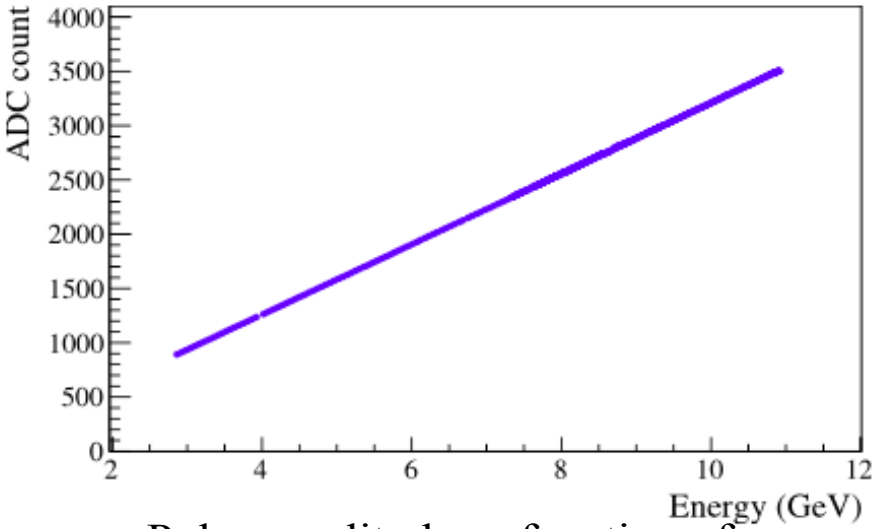




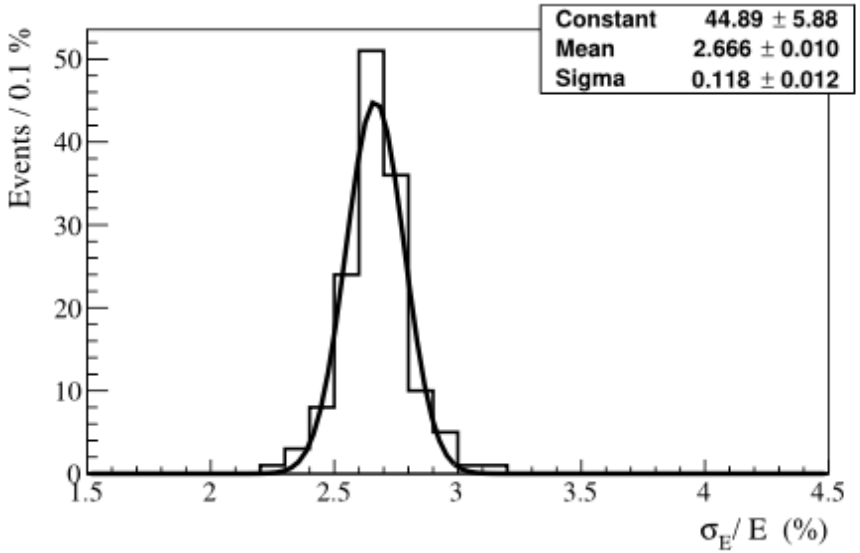
Compton Calorimeter performance



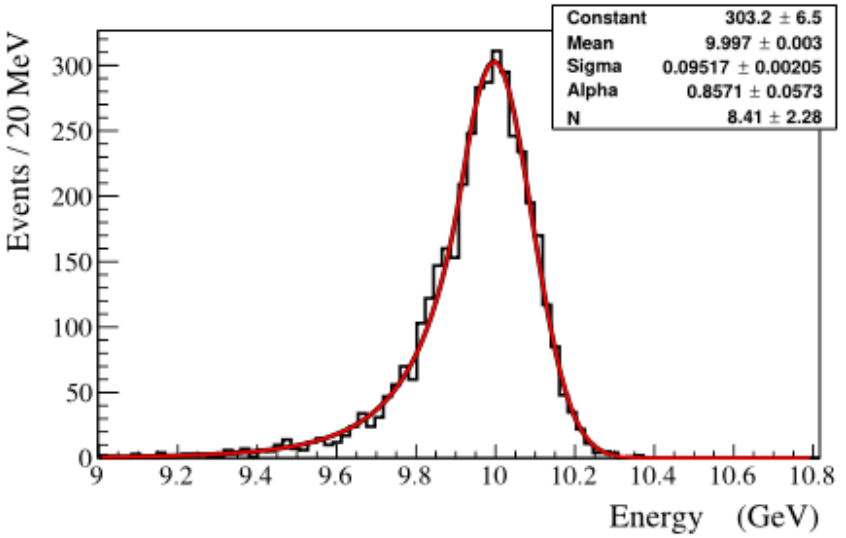
Typical fADC signal pulse



Pulse amplitude as function of energy

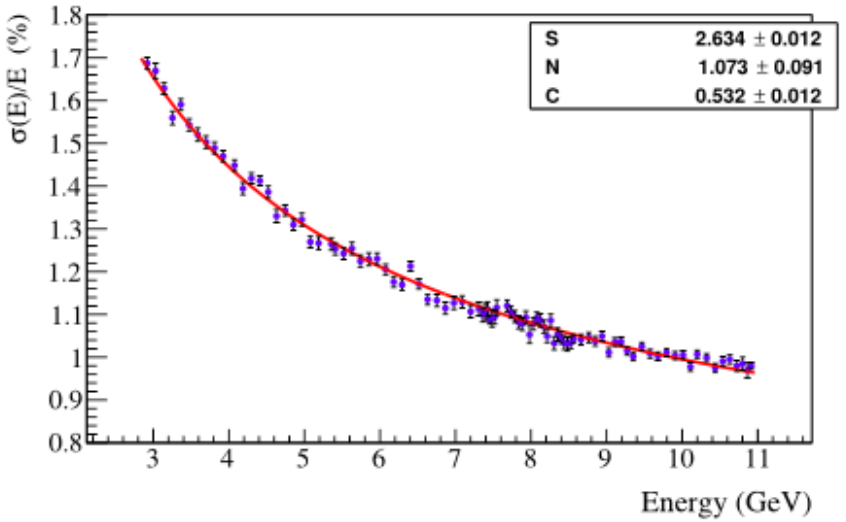


Relative energy resolution of
140 modules

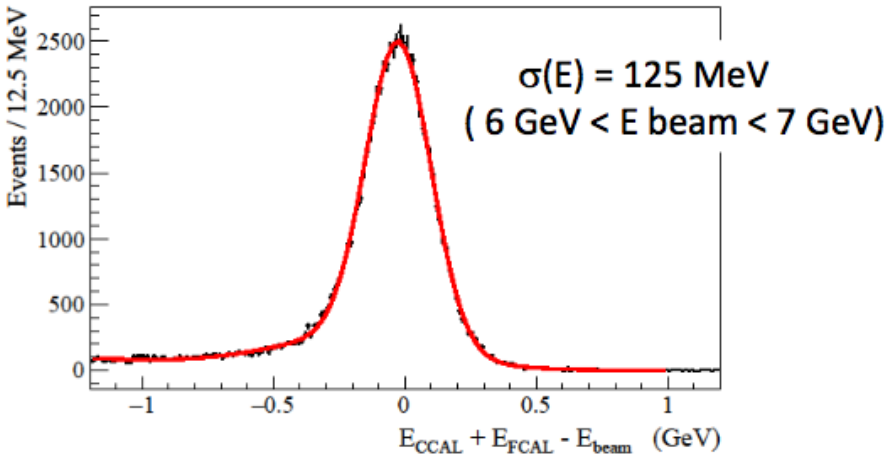


Energy distribution deposited
by 10 GeV beam photons

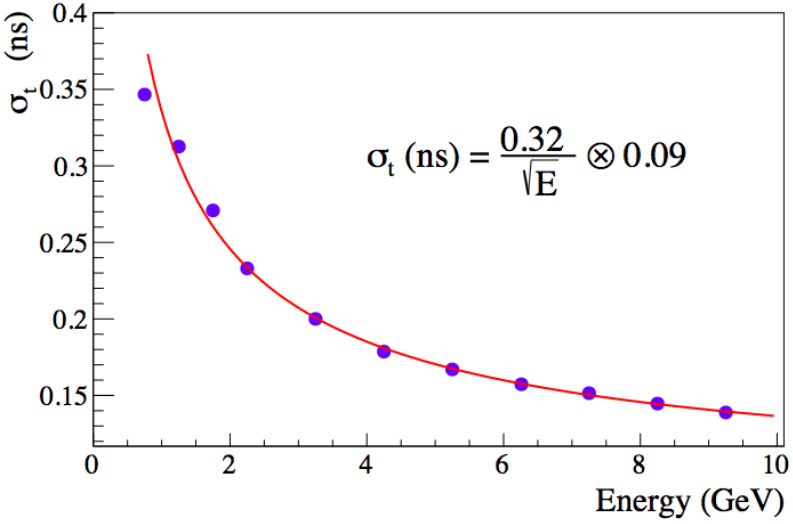
Compton Calorimeter performance



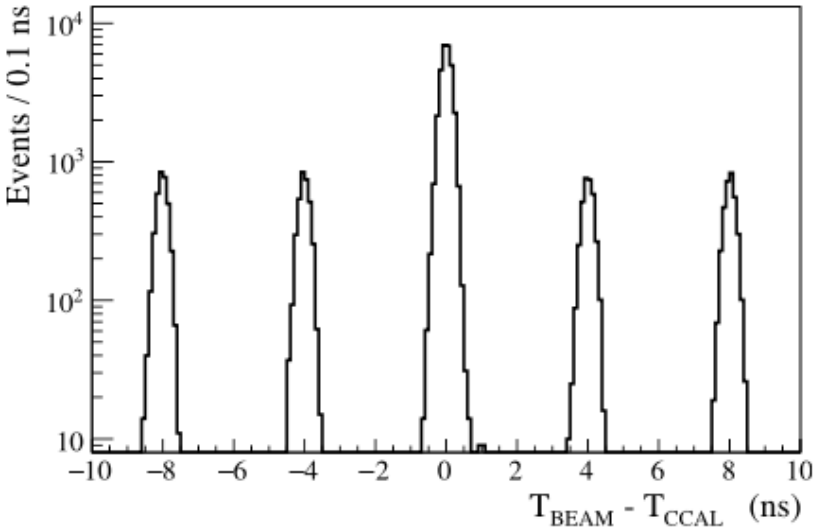
Energy resolution



Elasticity distribution (Compton candidates)



Time resolution



Separation of beam bunches

Summary

- Compton Calorimeter (CCAL) was constructed using 140 lead tungstate $PbWO_4$ crystals produced by SICCAS
- The calorimeter was successfully used in the PrimEx-η experiment in spring of 2019 for reconstruction of Compton scattering events
- The CCAL served as a prototype for two large-scale electromagnetic calorimeters based on the $PbWO_4$ crystals: the lead tungstate insert of the Forward CALorimeter (FCAL) of the GlueX detector and the Neutral Particle Spectrometer (NPS).
- Experience gained during construction and operation of the CCAL provided important information for finalizing the design of FCAL $PbWO_4$ modules and understanding the performance of PMT dividers and also served to further optimize the NPS calorimeter.
- Anticipate to use the CCAL in forthcoming GlueX runs in 2021–2022