# Compton Photon Detector Simulations

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EIC Polarimetry Working Group Meeting

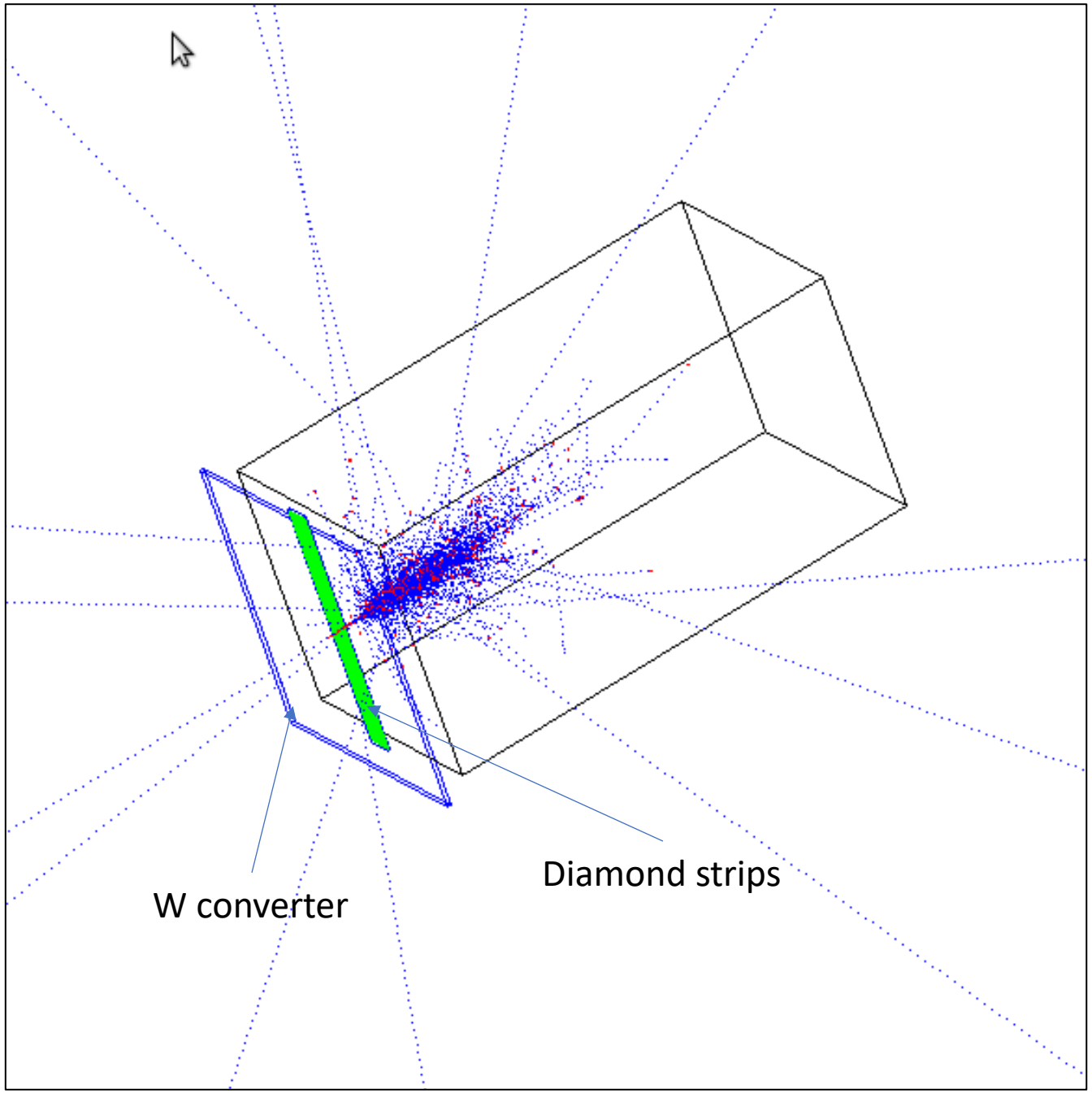
August 2, 2023

# Photon Detector Simulations

Adapted existing Hall C GEANT3 simulation of Compton polarimeter

18 GeV electrons, detector ~ 29 m from collision point

→ 20x20x40 cm PbWO4 crystal
→ 1 RL of tungsten
→ Diamond strips – 100 μm pitch, arranged horizontally to measure vertical positions

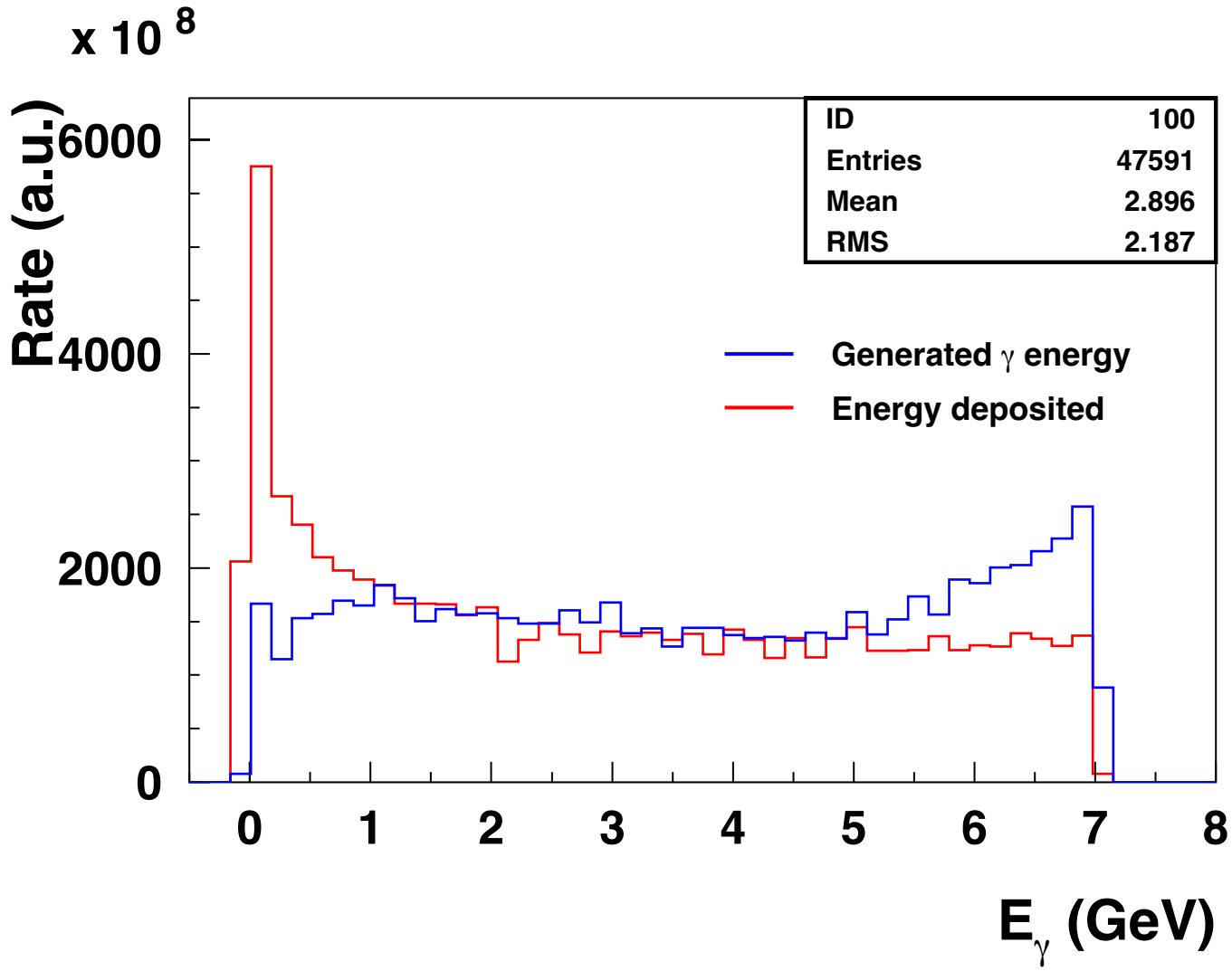


# Calorimeter response

Generated 50,000 backscattered photons

→ 47,591 gave at least one hit in the calorimeter (95.2%)
→ Clearly significant loss of lower energy events

Energy deposited in calorimeter (red) clearly influenced by W converter

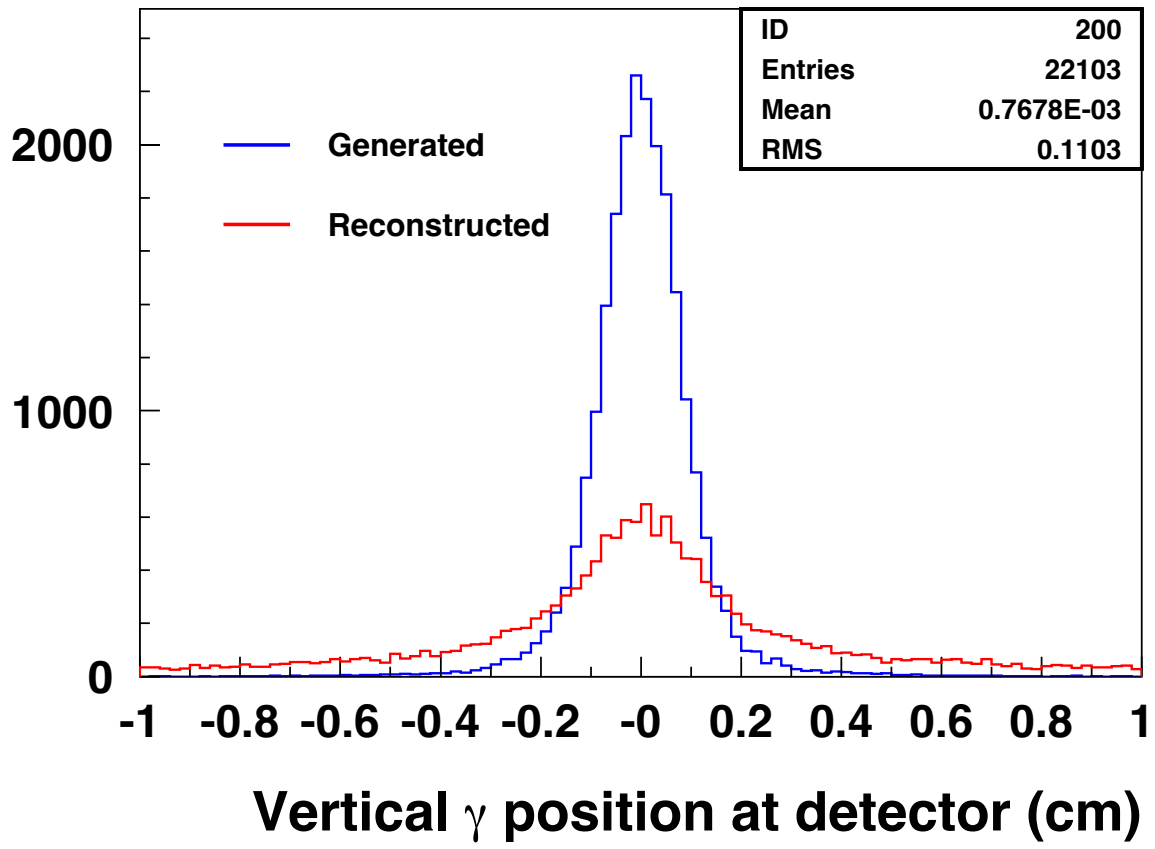


# Diamond detector response

Generated 50,000 backscattered photons

→ 22,103 events with at least one hit in the diamond strip detector – close to the ~50% efficiency I expected from 1 RL of material

→ Reconstructed position = average of all positions of strips that were hit

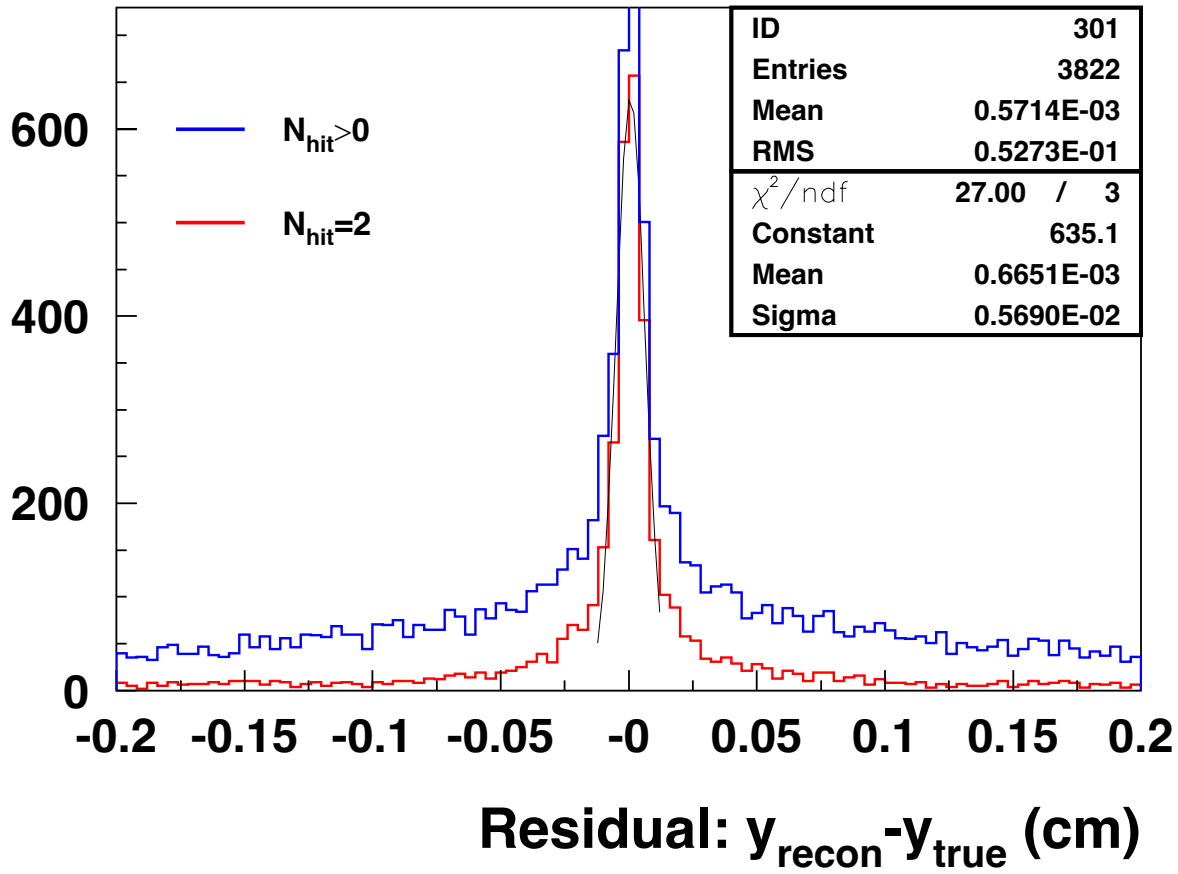


# Diamond detector response

Generated 50,000 backscattered photons

→ Large tails in distribution of residuals

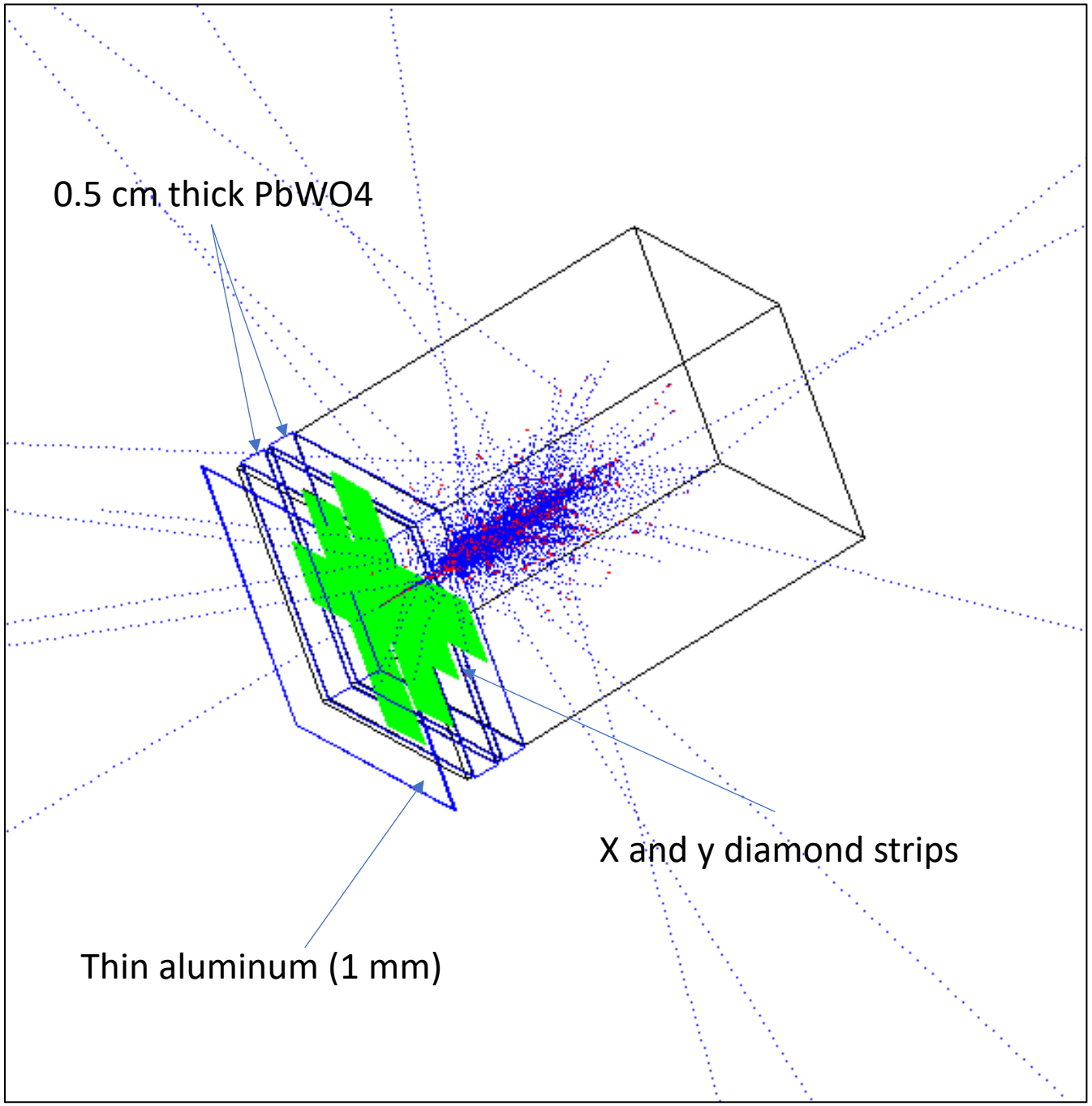
→ Tails are smaller when requiring exactly 2 hits, but then left with only ~3800 events out of 50,000



# Segmented calorimeter

→ 2 layers of lead-tungstate, 20x20x0.5cm, 2 cm gap between chunks
→ x-y diamond strips after each 0.5 cm thick chunk
→ 20x20x30 cm after last layer of diamond
→ Diamond strips – 100 μm pitch

RL of lead-tungstate = 0.89 cm, so detector in front of diamond is 0.56 RL

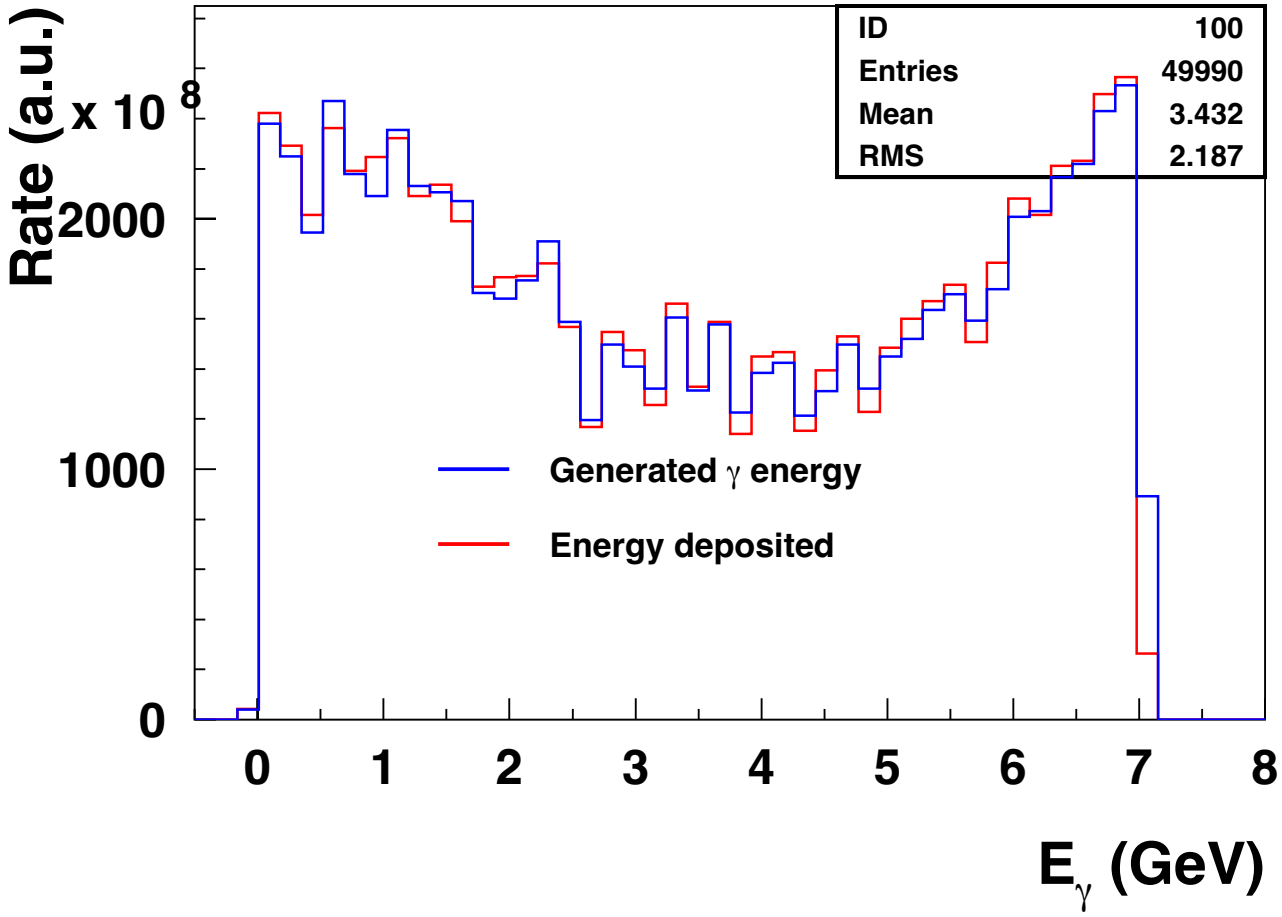


# Calorimeter response

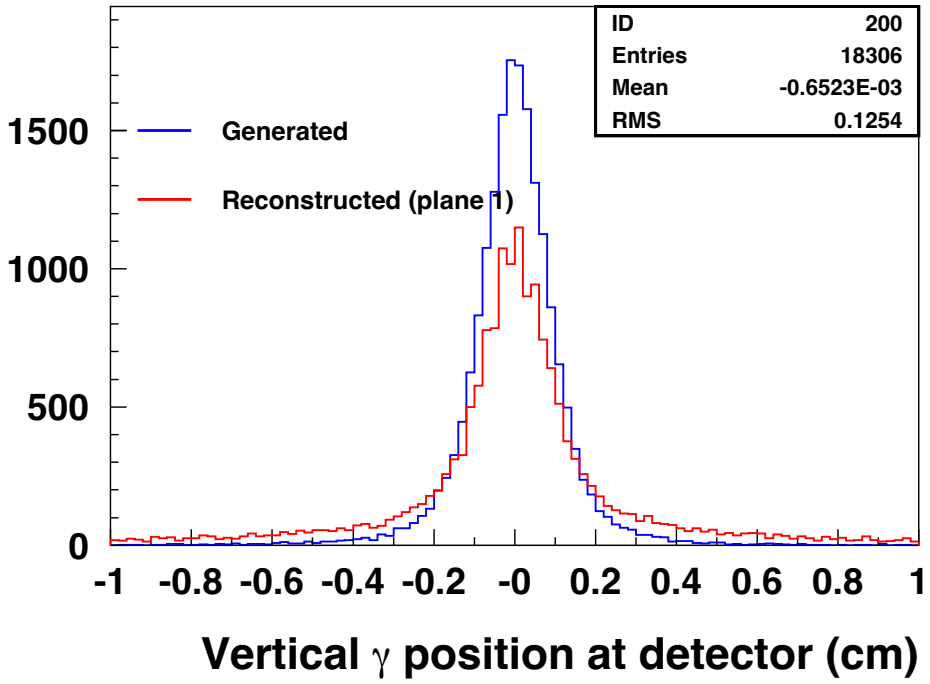
Generated 50,000 backscattered photons

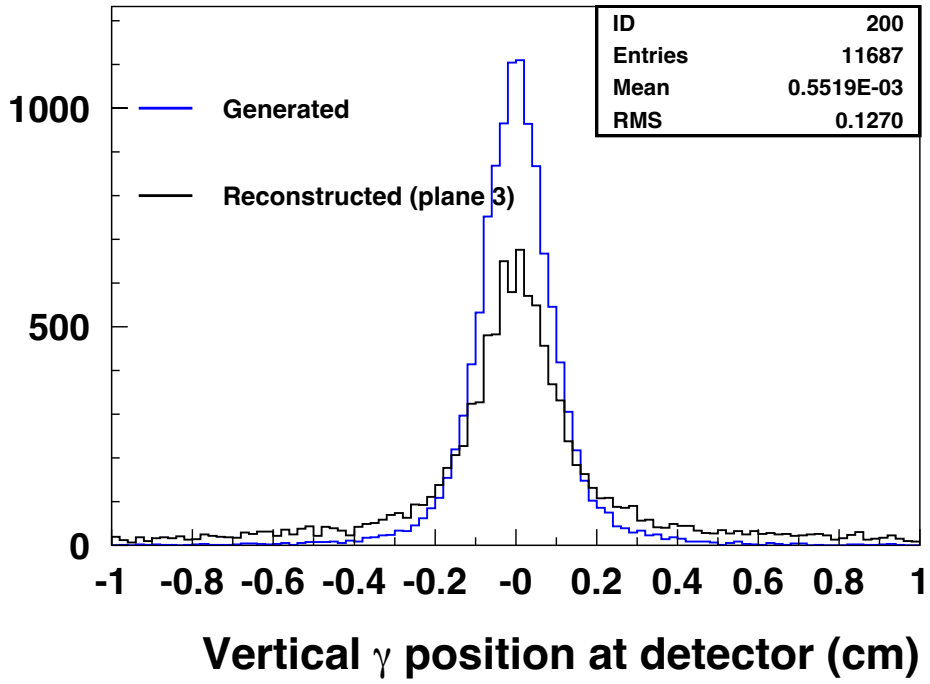
→ 49990 gave at least one hit in any of the calorimeter segments
→ Energy deposited = sum over all segments

Less distortion of Compton spectrum



# Diamond detector response




Generated 50,000 backscattered photons

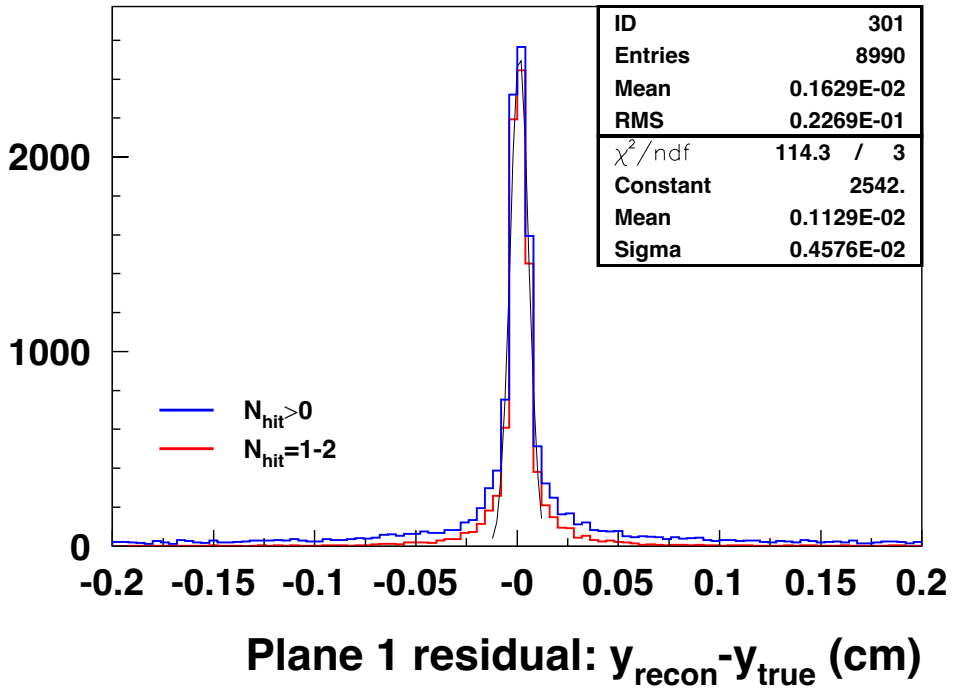
→ 18,306 events in plane 1 with at least one hit – this is maybe more than I expected

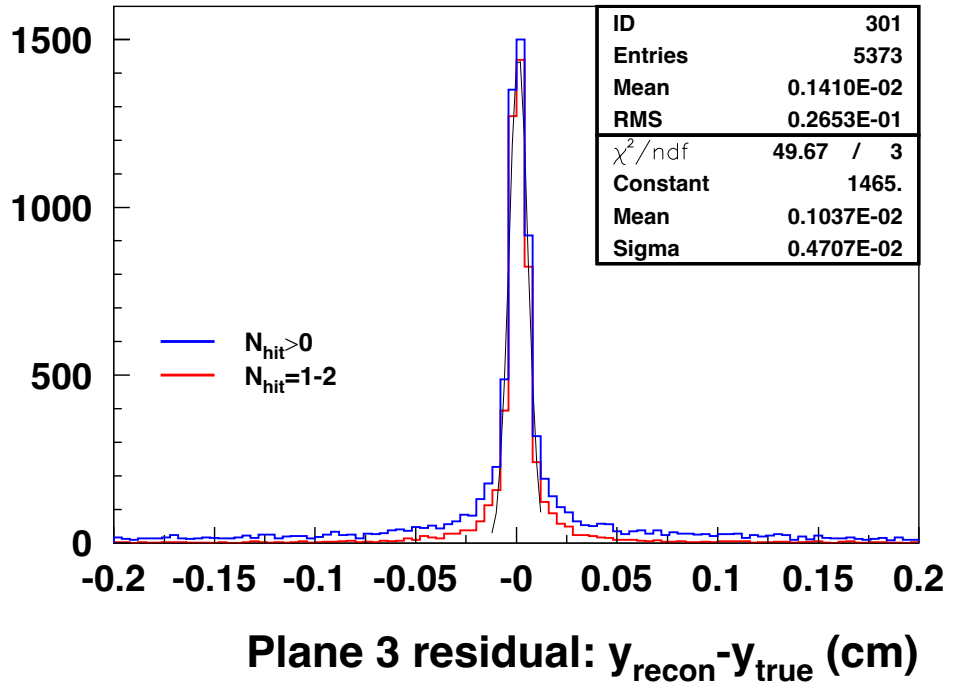
→ 11,687 events in plane 3 with at least one hit and no hits in plane 1 (avoid double counting)

→ Efficiency = 60%

→ Reconstructed position = average of all positions of strips that were hit

# Diamond detector position resolution



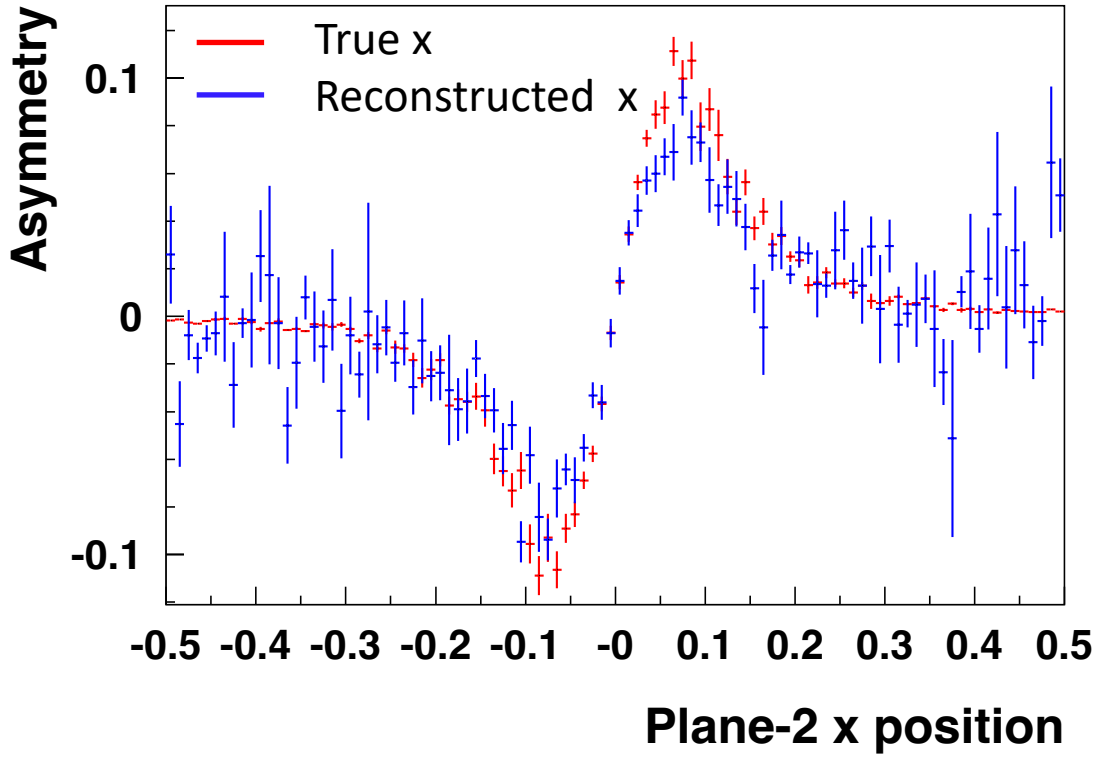



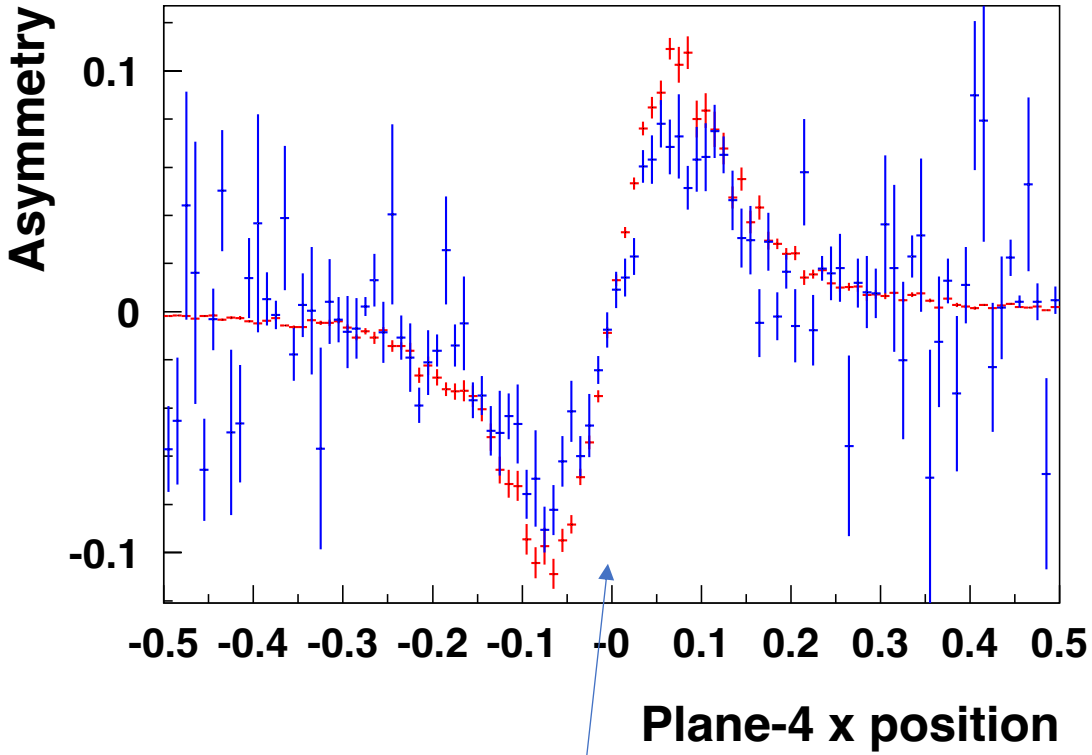

→ Resolution in peak pretty good

Require no hits in 1st plane

Limiting number of hits in each plane to 1 or 2

# Asymmetry vs. x



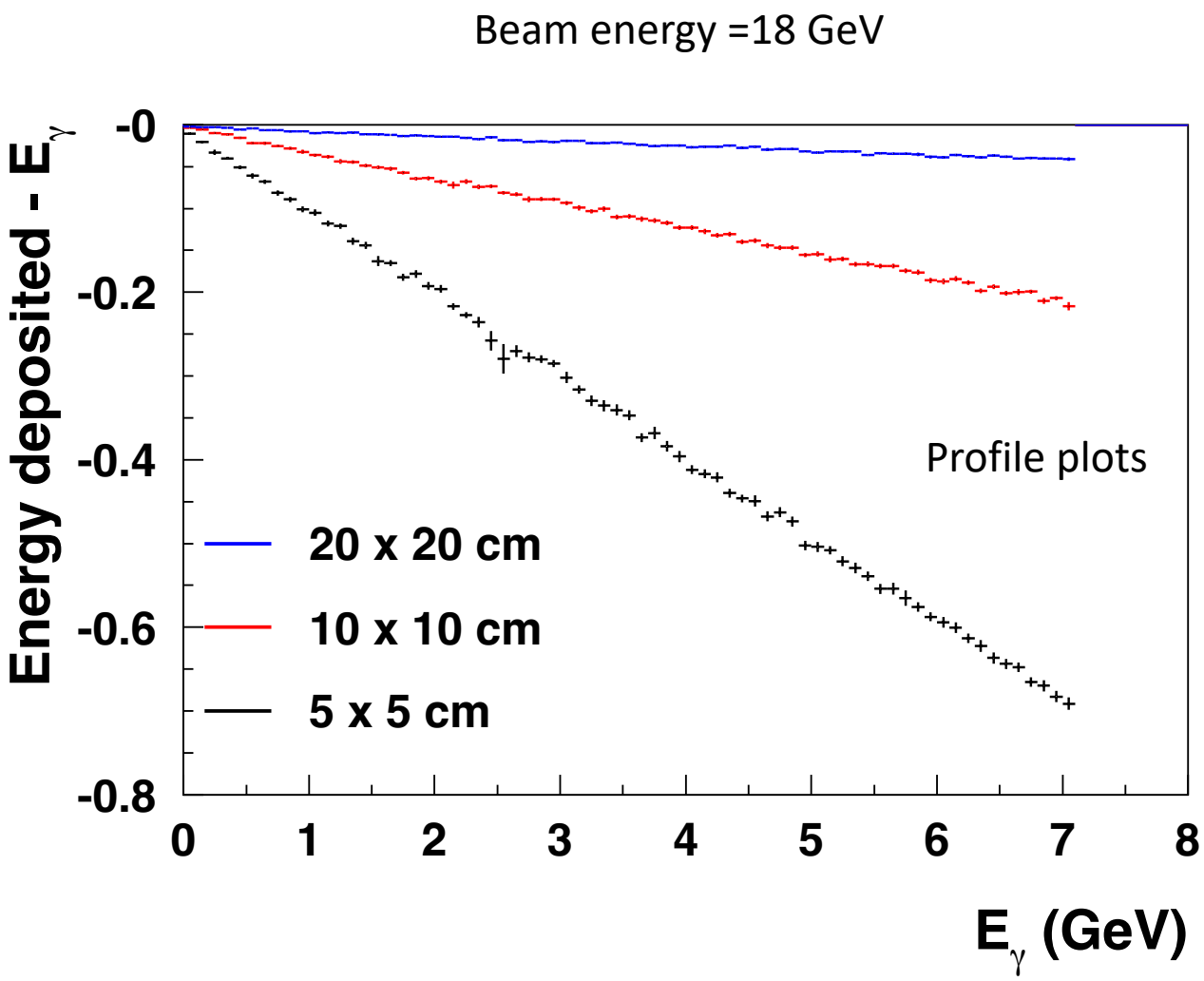

Require no hits in plane 2

Reconstructed asymmetries match true asymmetries very well → we can probably fit these with good precision

# Calorimeter response vs. size

Calorimeter = 2x0.5 cm long chunks + 1 30 cm long chunk

Transverse size = 20x20 cm, 10x10cm and 5x5 cm



# PbWO4 time response

Lead-tungstate has good energy resolution, but significant slow component

Recent paper (M. Follin et al 2021 JINST 16 P08040) suggests that at room temperature, slow component still pretty fast

→ But PE yield is smaller so resolution will suffer

→ Experience w/lead tungstate at room temperature in Hall A Compton suggests resolution good enough to allow high precision measurements

**Table 2**. Measured luminescence properties of doped $PbWO_4$ scintillator crystals on our apparatus for a mean energy deposited of 432 keV. $Y_{xx}$ stands for photo-electron yields, $\tau_{XX}$, for scintillation time constants. The Cherenkov contribution to yield, 0.80 photo-electron, is included in the total luminescence Yield. Second part: computed values of systematic errors on measurements (see paragraph 6)

| Temp. (°C) | $Y_{\text{Total}}$ (PE) | $Y_{\text{Fast}}$ (PE) | $\tau_{\text{Fast}}$ (ns) | $Y_{\text{slow}}$ (PE) | $\tau_{\text{slow}}$ (ns) |
|---|---|---|---|---|---|
| CRYTUR - Panda II | | | | | |
| 20 | 15.2 ± 0.5 | 8.45 ± 0.1 | 1.80 ± 0.06 | 6.0 ± 0.3 | 6.4 ± 0.2 |
| 5 | 22.3 ± 0.5 | 8.9 ± 0.1 | 2.20 ± 0.06 | 12.7 ± 0.4 | 8.0 ± 0.2 |
| −10 | 34.8 ± 0.5 | 7.6 ± 0.1 | 2.31 ± 0.06 | 26.4 ± 0.6 | 10.5 ± 0.2 |
| −25 | 54.5 ± 1.7 | 7.05 ± 0.2 | 2.8 ± 0.22 | 46.5 ± 1.9 | 16.5 ± 0.5 |
| SICCAS - CMS | | | | | |
| 20 | 14.1 ± 0.5 | 8.0 ± 0.1 | 1.71 ± 0.06 | 5.3 ± 0.3 | 5.8 ± 0.2 |
| 5 | 20.7 ± 0.5 | 7.8 ± 0.1 | 2.0 ± 0.06 | 12.1 ± 0.4 | 6.9 ± 0.2 |
| −10 | 31.7 ± 0.5 | 7.2 ± 0.1 | 2.33 ± 0.06 | 23.7 ± 0.6 | 9.8 ± 0.2 |
| −25 | 51.5 ± 1.7 | 6.5 ± 0.2 | 2.6 ± 0.22 | 44 ± 1.9 | 15.9 ± 0.5 |
| SICCAS - Y Doped | | | | | |
| 20 | 15.0 ± 0.5 | 8.75 ± 0.1 | 1.67 ± 0.06 | 5.4 ± 0.3 | 6.6 ± 0.2 |
| 5 | 22.2 ± 0.5 | 9.7 ± 0.1 | 2.06 ± 0.06 | 11.65 ± 0.4 | 7.9 ± 0.2 |
| −10 | 33.0 ± 0.5 | 8.8 ± 0.1 | 2.37 ± 0.06 | 23.4 ± 0.6 | 10.2 ± 0.2 |
| −25 | 53.5 ± 1.7 | 7.5 ± 0.2 | 2.65 ± 0.22 | 45.5 ± 1.9 | 15.5 ± 0.5 |
| Systematic uncertainities - All doped Crystals | | | | | |
| 20 | ±0.8 | ±0.55 | ±0.1 | ±0.9 | ±0.1 |
| 5 | ±1.1 | ±0.55 | ±0.1 | ±1.2 | ±0.1 |
| −10 | ±1.7 | ±0.5 | ±0.2 | ±1.7 | ±0.1 |
| −25 | ±2.7 | ±0.5 | ±0.2 | ±2.2 | ±0.1 |

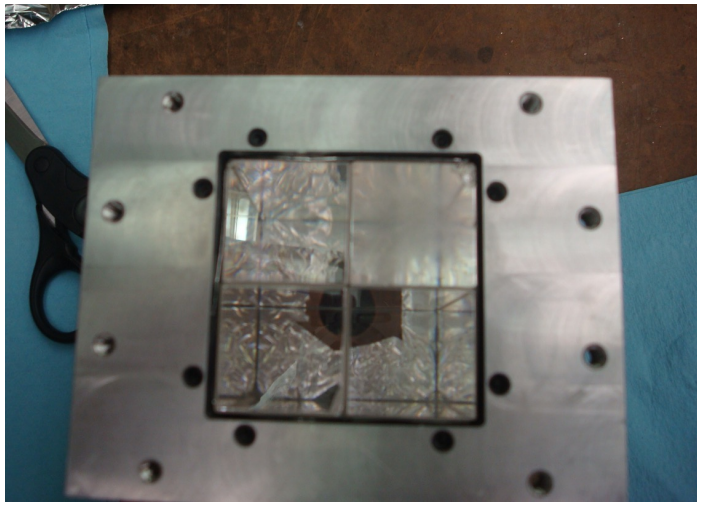
# PbWO4 in Hall A

Used PbWO4 at room temperature for Hall A Compton photon detector in 2016

→ DAQ optimized for integrating mode measurements, but also took event-mode data at lower rate

→ Fitted (approximately) asymmetry consistent with integrating mode measurements

→ Adequate energy resolution for high quality fit



4 crystals, crystal size = 3 x 3 x 20 cm