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Performance Study of BSO Crystal Bars for High-Granularity Electromagnetic Calorimeters

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on behalf of the CEPC-calorimetry team

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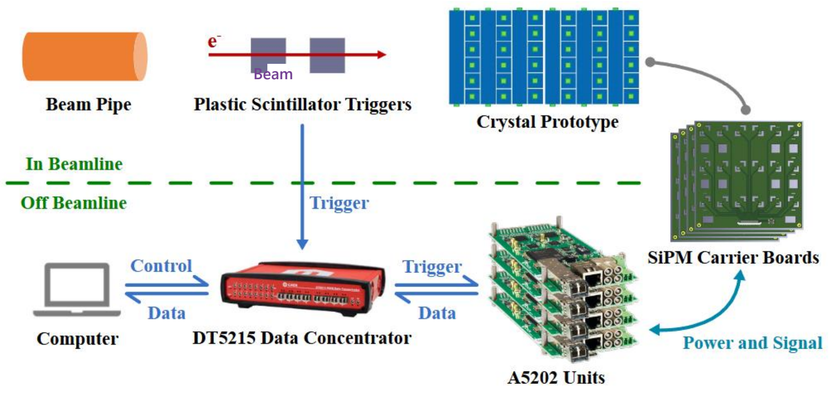
01 Motivation & Concept

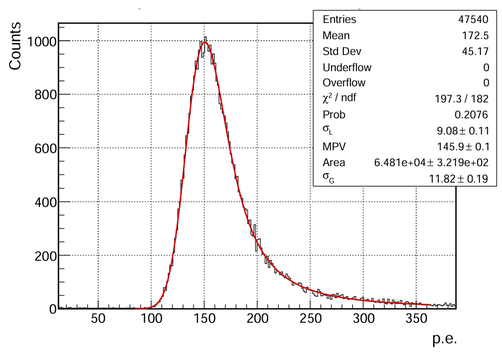
Crystal ECAL for future e^+e^- colliders

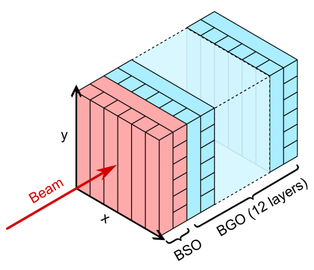
- **BSO as an alternative [1,2,3]**
  - Faster scintillation
  - Potential cost benefit
- **ECAL Design**
  - 15 × 15 × ~400 mm³ bars
  - Orthogonal layers with two-ended SiPMs

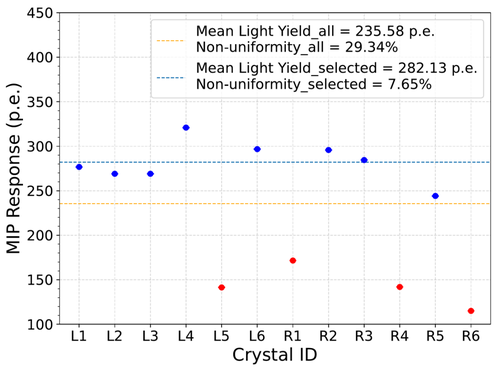
Typical crystal properties [4]

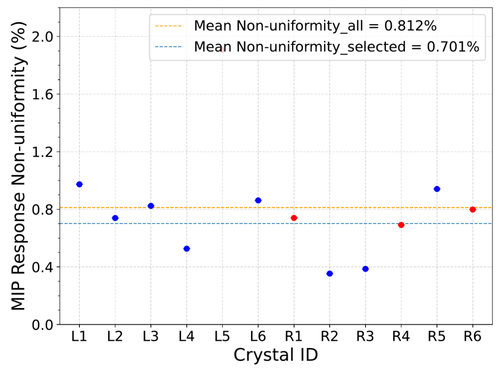
Property	BSO($Bi_4Si_3O_{12}$)	BGO($Bi_4Ge_3O_{12}$)
Density (g/cm³)	6.80	7.13
Radiation length (cm)	1.15	1.12
Decay time (ns)	100	300
Emission peak (nm)	470	480
Light yield (ph/MeV)	1/5-1/4 of BGO's	8000-10000











02 CERN PS-T9 Beam Test

- ✓ **12 BSO bars, 20 × 20 × 120 mm³**
- ✓ **10 GeV pion beam**
- ✓ **6 × 6 scan with 2 cm step**
  - MIP selection: one hit bar per layer
  - Fit: Landau function convolved with Gaussian
  - MPV as MIP response

➢ **Light yield: 282 p.e./MIP**

➢ **Non-uniformity**:

<1% intra-bar

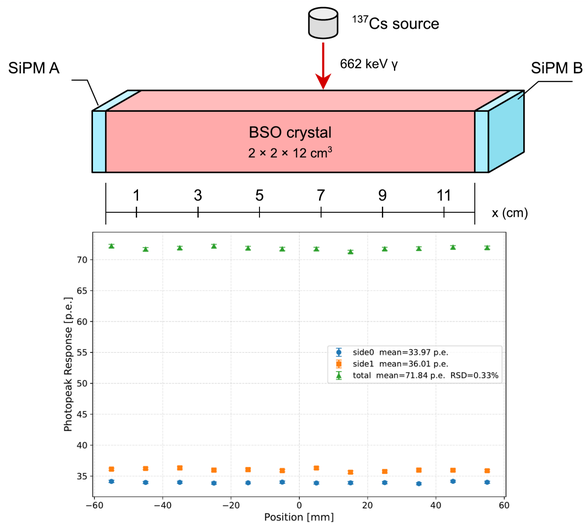
7.65% inter-bar

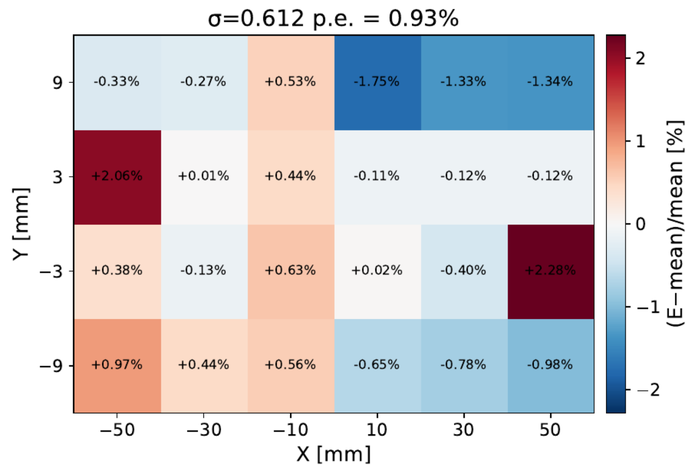
03 Laboratory Experiment

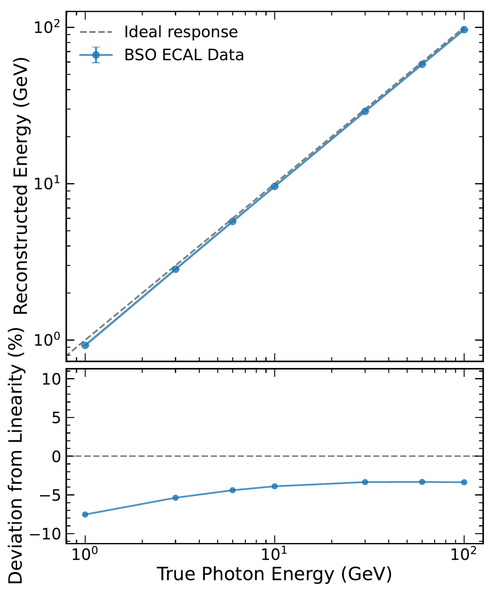
- ✓ Collimated ^{137}Cs · 662 keV γ
- ✓ Longitudinal scan: 12 positions
- ✓ Two-dimension scan: 6 × 4 positions

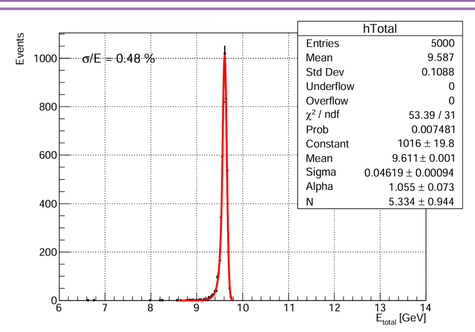
➢ **Non-uniformity < 1%**

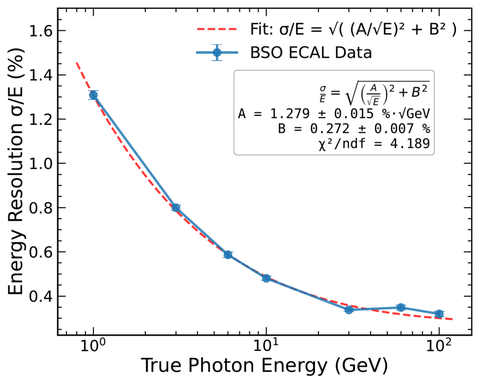
Consistent with beam-test, excellent uniformity!











04 Detector Simulation

- ✓ **Geant4 of BSO crystal ECAL with 405mm bars**
  Incident particle: 1–100 GeV photons
- ✓ **Digitization**
  - Light yield 282 p.e./MIP
  - Poisson statistics
  - 1% non-uniformity

➢ **Crystal Ball Fit → Energy Resolution (MC Truth)**

σ/E = 1.28%/√(E/GeV) ⊕ 0.27%

Excellent energy resolution for EMC!

Conclusions

- Sub-percent intra-bar non-uniformity of BSO
- Simulation supports BSO as an ECAL candidate

Outlook

- Crystal quality control & bar-by-bar calibration
- BSO ECAL prototype validation

[1] CEPC Reference Detector TDR, arXiv:2510.05260 (2025). [2] F. Yang et al., J. Phys.: Conf. Ser. 587 (2015) 012064. [3] M. Deng et al., IEEE Trans. Nucl. Sci. 73 (2026) 1535-1542.
[4] R.-Y. Zhu, Recent Progress on Inorganic Scintillators for Future High Energy Physics Experiments, SPIE (2021), slide 15.