R&D/test beam projects for HIKE: Calorimetry

Matthew Moulson

CSN1 referees – NA62

20 July 2022

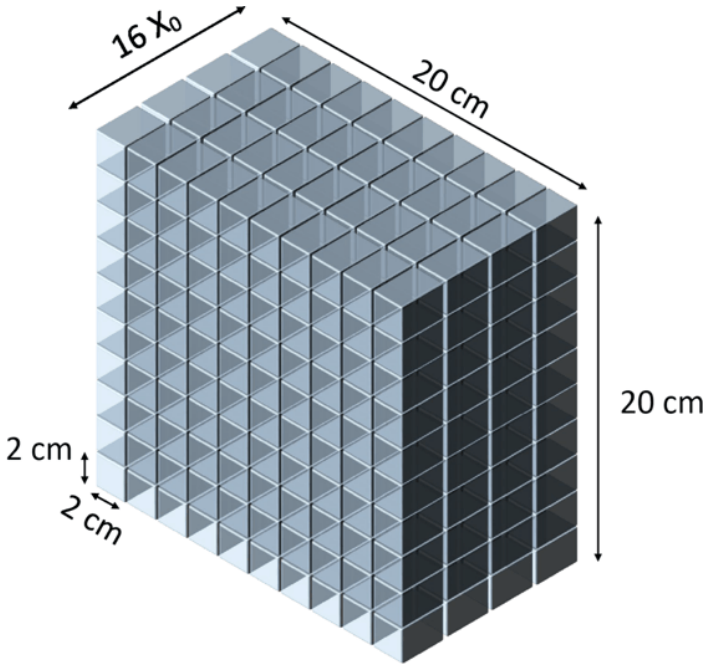
KLEVER SAC: Current status

Small-angle calorimeter system (SAC) operates inside neutral beam

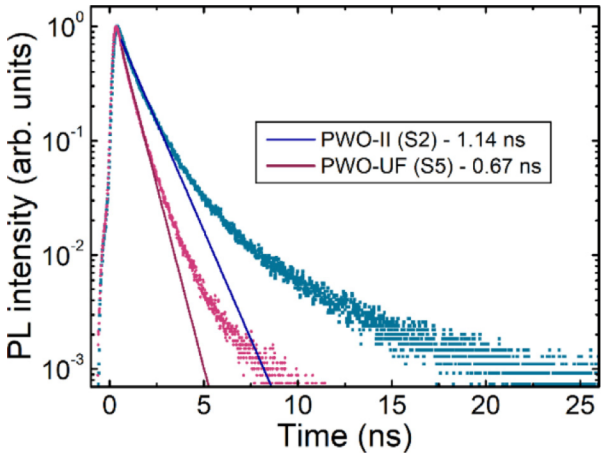
- Rejects γs from $K_L \to \pi^0\pi^0$ escaping through beam hole
- As insensitive as possible to 430 MHz of beam neutrons

Proposed solution:
Ultra-fast, high-Z crystal calorimeter

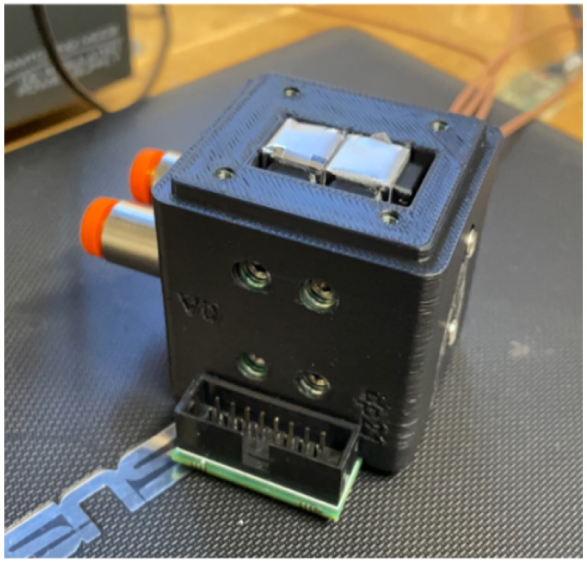
- Cerenkov radiator like PbF_2 or ultra-fast scintillator such as PWO-UF
- σ_t < 100 ps, 2-pulse separation at ~ 1 ns
- Photon inefficiency < 1% for E > 5 GeV, < 10^{-4} for E > 30 GeV
- Exploit coherent interactions in crystals to reduce thickness
- Transverse and longitudinal segmentation for γ/n discrimination
- Radiation hard to 10^{13}-10^{14} n/cm^2 and 10^5-10^6 Gy

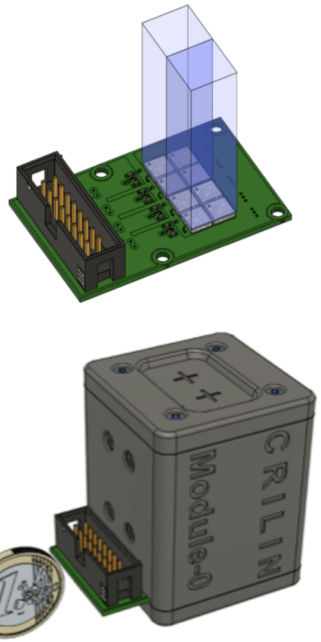


PWO-UF (ultra-fast):
Dominant emission with τ < 0.7 ns
M. Korzhik et al., NIMA 1034 (2022) 166781



KLEVER SAC: Current status





2021 tests at BTF and CERN H2 with single crystals:

- time resolution
- angular dep. of light yield

INFN Frascati, Torino, Ferrara, MIB Univ. Insubria, Legnaro

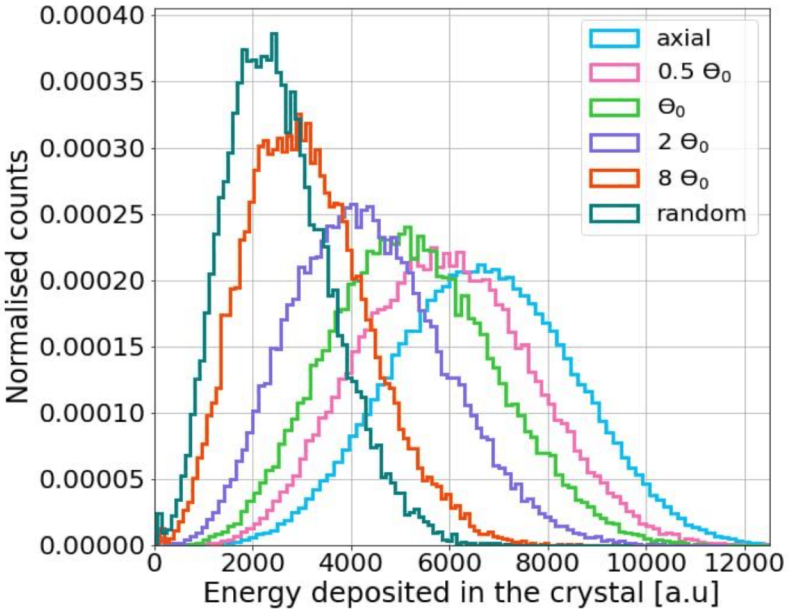
Collaboration with LNF Muon Collider group (CRILIN prototype)

Test goals:

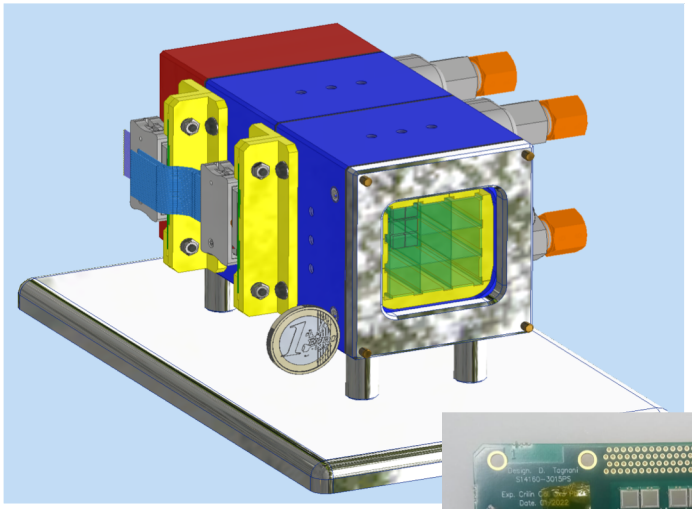
1. Measurements of response of **PbF_2** to **electrons**, including angular effects
2. Measurements of response of **PbF_2** to **tagged photons**, including angular effects
3. Measurements of response of **PWO-II(o)** crystal with SiPM readout to **tagged photons**, including angular effects

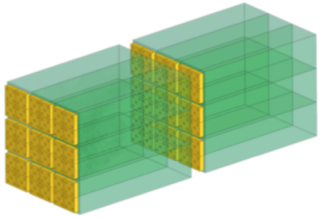
Light yield of 120 e^- in $2X_0$ PWO-II(o)

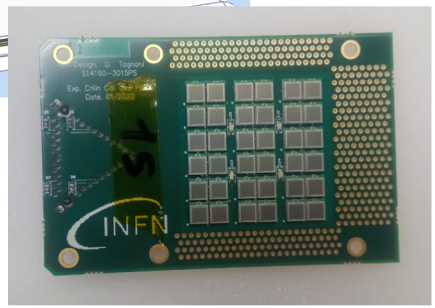
P. Monti-Guarnieri, ICHEP 2022

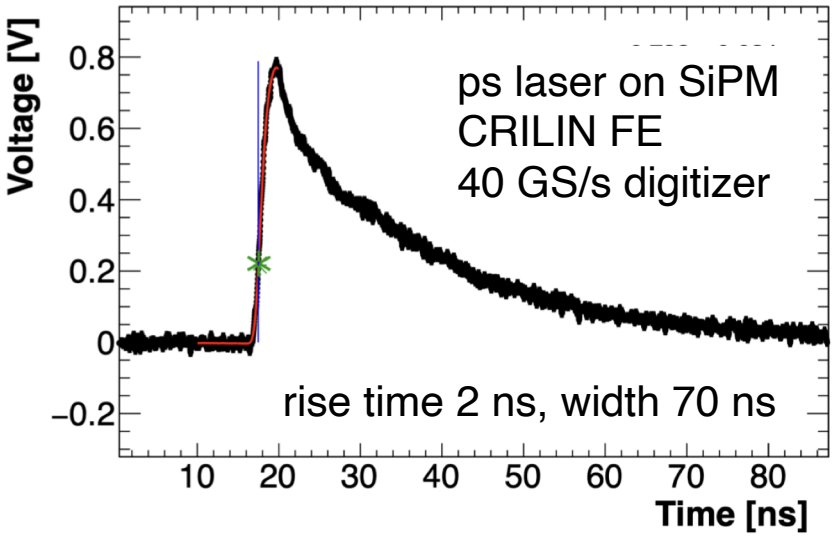


KLEVER SAC: 2022 beam test









Use CRILIN prototype (Muon Collider) as an engineering platform:

- 2 layers of 3 x 3 crystals (9 cm^2)
- Crystals 10 x 10 x 40 mm^3
- 2 readout channels per crystal
- 2 Hamamatsu 14160-3015 per channel
- Off-detector analog front-end
- 350 mW cooling (0C operation)
- No alignment yet

In 2022 use this platform to study:

- Time resolution: PbF_2 vs PWO-UF
- Conceptual test of longitudinal segmentation
- Angular dependence of response with center crystal aligned:
  - 18 unaligned PbF_2 from CRILIN + 4 aligned PbF_2 from NA62
  - 10 aligned PWO-UF from NA62

KLEVER SAC: Plans for 2023

Modify mechanics to align all crystals on a single plane:

- Obtain axis orientation by XRD or photoelasticity (PE) measurements
- Crystal coating with local ablation for precise static alignment
- Possible use of shims of calibrated thickness to assist alignment
- Explore use of piezoelectric actuators to allow adjustments in situ

Requests:

- Consumables for crystal coating and polishing: **1 kE FE**
- Manufacture of mounting brackets for XRD/PE measurements and test beam components: **2 kE FE**
- Piezoelectric actuators for design studies: **2 kE LNF**
- Adaptation of CRILIN front-end electronics with fast signal shaping and PCBs to integrate with new mechanics: **5 kE LNF**
- Travel to CERN test beams: **7.5 kE LNF** (4x2 person weeks) + **4 kE FE** (2x2 person weeks)

Synergies:

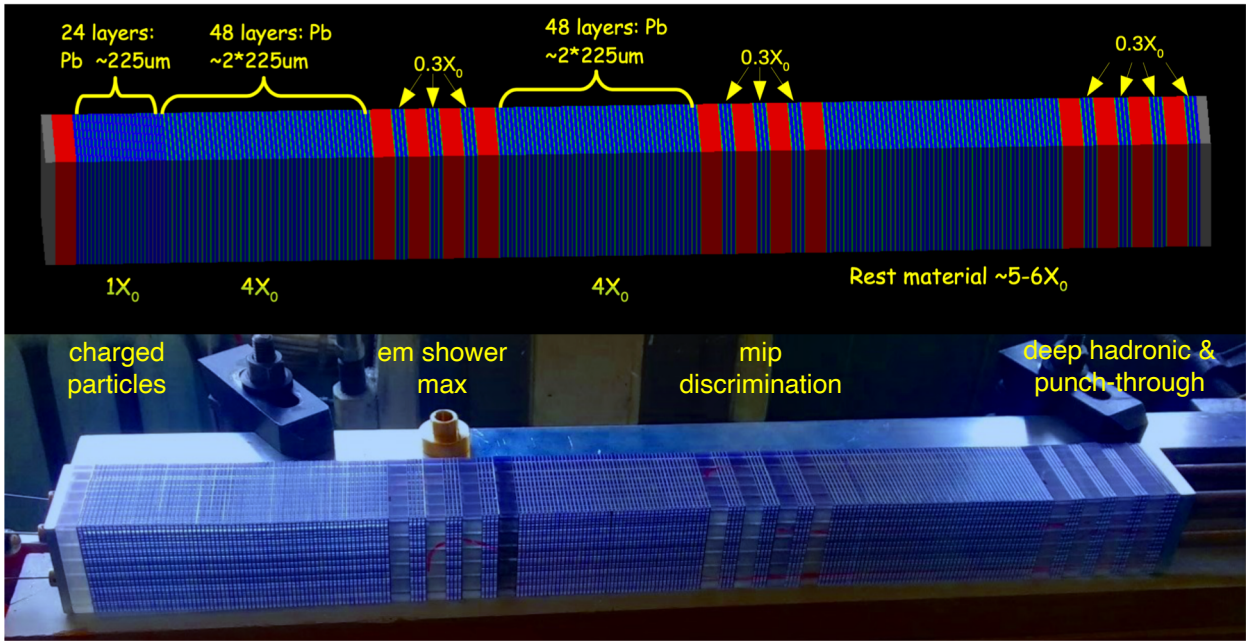
- OREO (CSN5): Development of a larger (56 cm^2) PWO calorimeter by 2024 with emphasis on effects of coherent interactions on transverse containment. OREO will contribute PS beamtime in 2023.

Shashlyk calorimeter with spy tiles

Requirements for main electromagnetic calorimeter (MEC):

Excellent efficiency, time resolution ~ 100ps, good 2-cluster separation

LKr calorimeter from NA62:
Photon detection efficiency probably adequate
Time resolution ~ 500 ps for π^0 with $E_{\gamma\gamma}$ > 20 GeV → requires improvement



Main electromagnetic calorimeter (MEC):

Fine-sampling shashlyk based on PANDA forward EM calorimeter produced at Protvino

0.275 mm Pb + 1.5 mm scintillator

PANDA/KOPIO prototypes:

$\sigma_E/\sqrt{E}$ **~ 3%** $/\sqrt{E}$ (GeV)

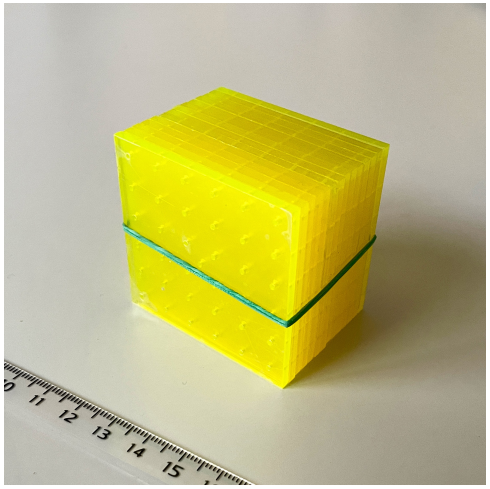
σ_t **~ 72 ps** $/\sqrt{E}$ (GeV)

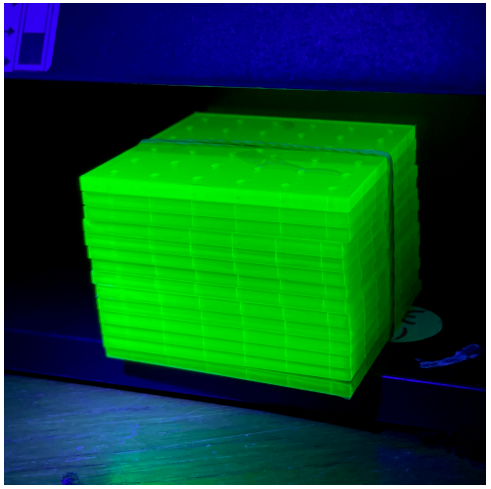
σ_x **~ 13 mm** $/\sqrt{E}$ (GeV)

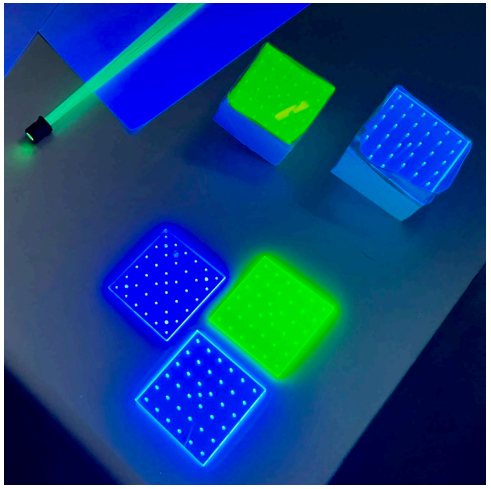
Longitudinal shower information from spy tiles

- PID information: identification of μ, π, n interactions
- Shower depth information: improved time resolution for EM showers

Nanocomposite scintillators for shashlyk







NanoCal project (AIDAinnova)

Realize first calorimeter with NC scintillators:

$CsPbBr_3$, 0.05% w/w in PMMA

- 50% of light emitted in components with $\tau < 0.5$ ns
- Radiation hard to O(1 MGy)

Excellent candidate for use in HIKE shashlyk!

Frist trial production of 14 shashlyk tiles in Protvino format (55 x 55 x 3 mm^3)

Progress:

- **2022:** Component test at CERN this summer/fall (fibers/tiles/SiPMs)
- **2023-2024**: Build compare full-scale prototypes with conventional/NC scintillator

NB: Development of FE electronics *not* specifically included in NanoCal grant

Summary: R&D requests for 2023

SAC project: 10 kE

- Consumables for fully-aligned 3x3 prototype: 2 kE LNF + 3 kE FE
- Adaptation of CRILIN front-end electronics: 5 kE LNF

Shashlyk project: 5 kE

- Development of readout electronics for NanoCal prototype: 5 kE LNF

Test beam (for both SAC and shashlyk): 11.5 kE

- 1 week H2 (electrons) + 1 week T9 (hadrons):
- 7.5 kE LNF (4x2 person weeks, incl. expenses for Como DAQ experts)
- 4 kE FE (2x2 person weeks, incl. expenses for Legnaro alignment experts)
- SJ approval beam time request