CCALT: a crystal calorimeter for the KLOE-2 experiment

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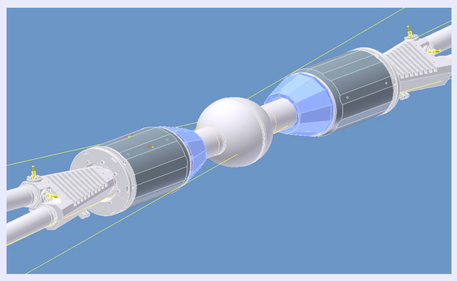
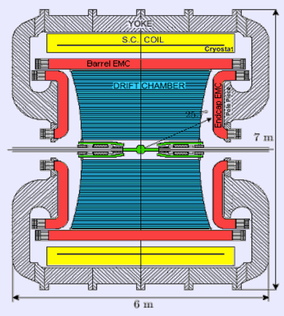
CCALT for the KLOE-2 upgrade

In the new machine layout of DAΦNE, the position of the inner quadrupole, 30 cm far from IP, reduces to 18 degrees the minimum polar angle of the central calorimeter photon acceptance





We are constructing a **Cristal CALorimeter with Timing, CCALT**, to improve the **acceptance** for prompt photons **down to 10 degrees**

Requirements

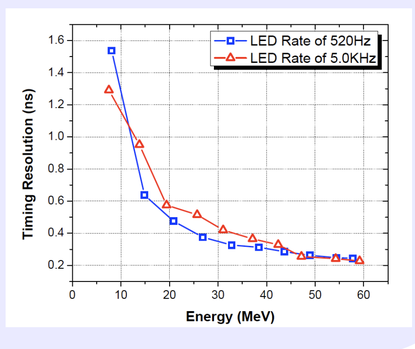
- Small X_0 and Moliere radius (limited available space)
- **Extremely accurate on timing: 300-400 ps @ 20 MeV** (needed to reject machine bckg of 100 kHz/channel)
- High efficiency for 20-300 MeV photons
- Able to work inside 0.5 T magnetic field
- Reasonable position resolution (2-3 mm at 15 cm from interaction region) to improve by kinematic fitting the poor energy resolution due to leakage

LYSO crystal is a perfect candidate

- High light yield: 27000 photons/MeV
- Emission time spectrum with τ of 40-42 ns
- X_0 = 1.1 cm , R_M = 2 cm, refraction index = 1.8
- Not hygroscopic
- Good optical match with APD-SiPM

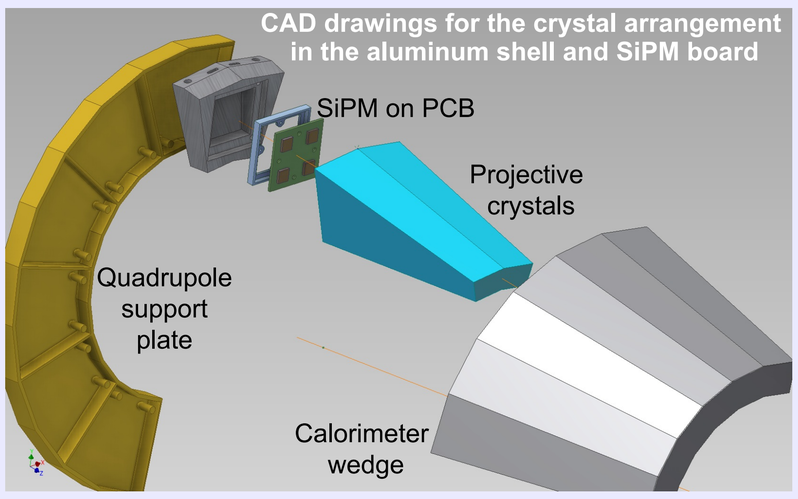
Test with SiPM readout

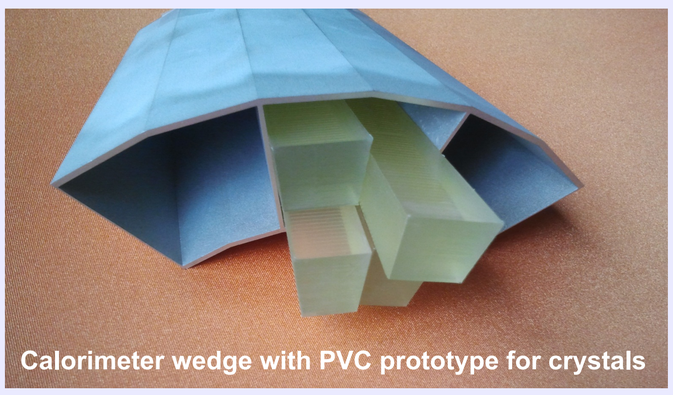
- Due to space constraints on thermal considerations, the final choice for the readout is Large Area ((4×4) mm^2) SiPM from ADVANSID. This results in a loss of 3 in time resolution, still satisfying detector requirements.This choice allows also to increase readout granularity
- First tests on single crystal (20×20×150 mm^3) with UV LED satisfactory
  - Energy calibration w/ MIPs
  - Time resolution and energy response tested for different LED rates. Good stability up to 100-200 kHz

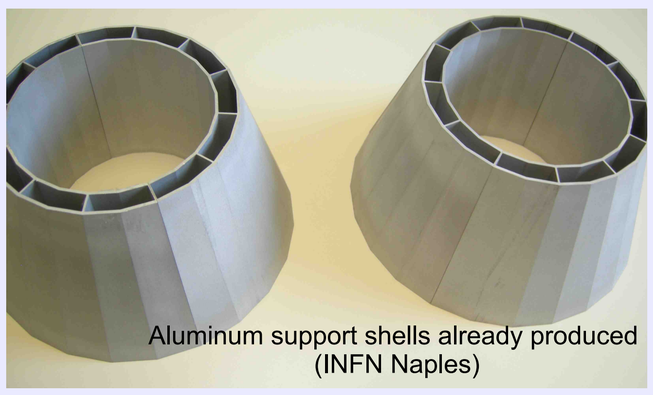


Mechanics

- Each calorimeter is composed by 4 wedges, each constituted by 3 sectors for a total of 12 modules in ϕ
- Each module has a granularity of 4 projective crystals, for a total of 96 read out elements
- Crystals have transversal dimension of ~ (1.5×2.0) mm^2 in the readout plane, ~ (0.5×1.5) mm^2 in the front side and a length of 8.5 cm (~ 8 X_0)
- Crystals are read out by a (4×4) mm^2 surface mount SiPM, mounted in groups of 4 on a home made designed PCB

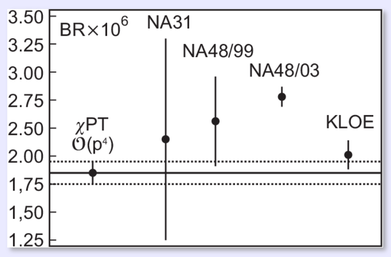



Calorimeter wedge with PVC prototype for crystals


Aluminum support shells already produced (INFN Naples)

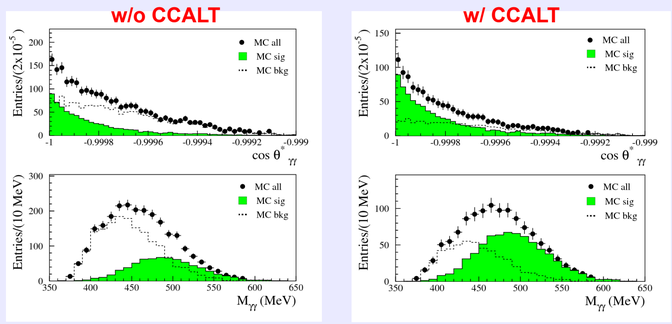
Physics motivations

Most precise measurements on BR($K_S \to \gamma\gamma$) show 3σ difference. KLOE confirms O(p^4) prediction of ChPT.



Major background in KLOE measurement is $K_S \to 2\pi^0$, with 2 lost photons

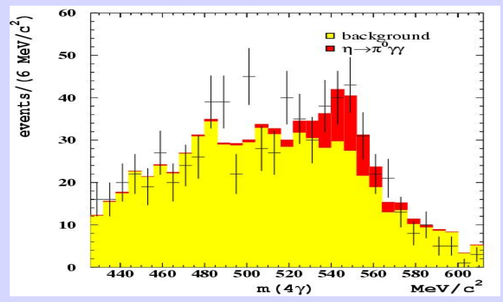
This background can be reduced by a factor of 3 by vetoing photons on CCALT



The $\eta \to \pi^0\gamma\gamma$ is a golden channel to test ChPT, being p^6 the dominant contribution

2.5σ discrepancy btw KLOE and Crystal Ball. Both measurements have large background contamination from $\eta \to \pi^0\pi^0\pi^0$

KLOE Preliminary: 3σ signal (1/5 of full statistics)



At KLOE, background contamination is dominated by $\eta \to \pi^0\pi^0\pi^0$, with 2 lost γ's

With CCALT we expect to reduce the $\eta \to \pi^0\pi^0\pi^0$ background by a factor of ≈2

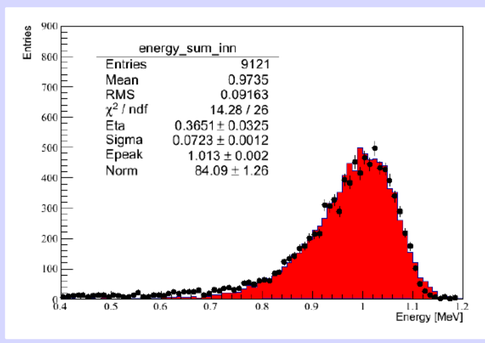
Test Beam Results

Calorimeter prototype:

- inner matrix of 9 LYSO (**20×20×150**) mm^3 crystals read out by (10×10) mm^2 APD S8664-1010 from Hamamatsu
- outer leakage recovery section of 30(40)×30(40) ×130 mm^3 $PbWO_4$ crystals read out by bialkali PMTs

Full Geant4 simulation of prototype construction details. Photon transportation and longitudinal response uniformity not simulated

Test beam @ Mainz Microtron with 40-300 MeV tagged photons: data-MC comparison for energy sum of the internal matrix, for 100 MeV γ' s



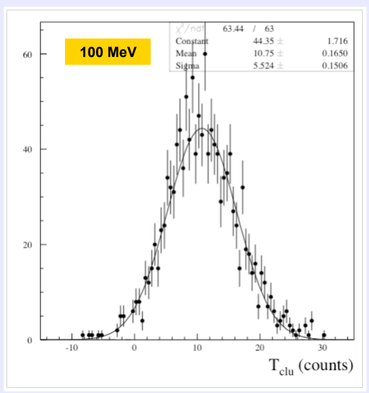
Timing test @ Beam Test Facility, Frascati with 100-500 MeV e^-

Each spill of 10 ns from LINAC consists of bunches separated by 200-300 ps

To eliminate the jitter of the start provided by the LINAC timing, we study the time difference between CCALT and the finger scintillators used to trigger: $DT = T_{clu} - T_{scint}$

Jiitter of the scintillator: σ(Tsc(1)-Tsc(2))/√2

σ_{scint} = 245 ps @ 500 MeV
= 265 ps @ 100 MeV

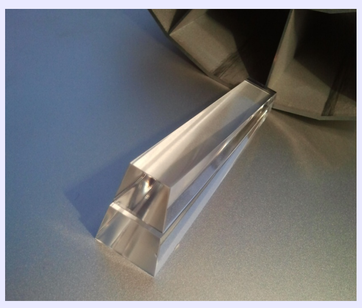


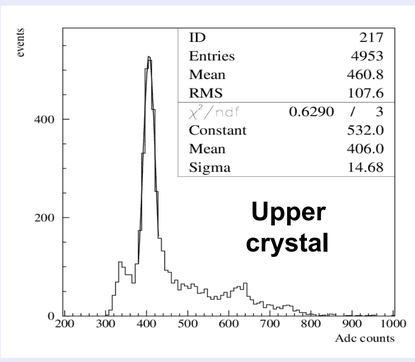
$\sigma(T_{clu})$ = **250 (49) ps @ 500 MeV**
= 291 (120) ps @ 100 MeV
} without (with) correction for trigger jitter

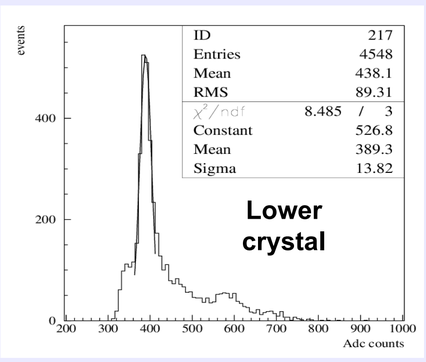
Test of delivered crystals

First two crystals delivered and under test using ^{22}Na source and PM readout:

- Pedestal = 253 ADC counts
- 10% energy resolution @ 511 keV







Construction schedule

- Final crystals under production from SICCAS. Delivery expected mid of June
- (4×4) mm^2 SiPMs from ADVANSID already produced. Expected by June
- PCB for mounting SiPM designed @ LNF. Delivery expected end of June
- Preamplifier and LED calibration driver under construction
- Standard read out with ADC and TDC boards from KLOE detectors