Quality Control of LYSO:Ce crystals for the CMS barrel MIP Timing Detector

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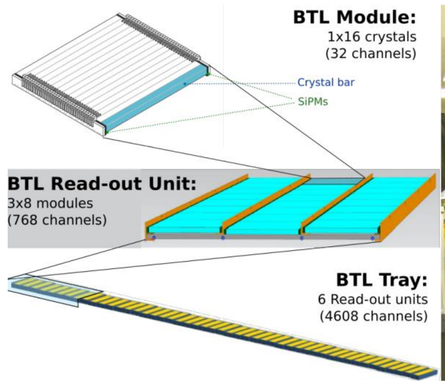
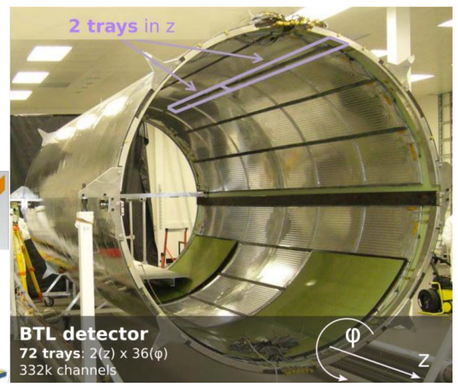
Barrel Timing Layer

- MIP Timing Detector (MTD) positioned between ECAL & tracker for High-Lumi phase of LHC
- Two regions – Barrel Timing Layer (BTL) & Endcap Timing Layers (ETL)
- BTL layout:
  - Cerium-doped lutetium-yttrium-orthosilicate (LYSO:Ce) crystal bars as scintillating material
  - Silicon photo-multipliers (SiPM) at both crystal ends as readout





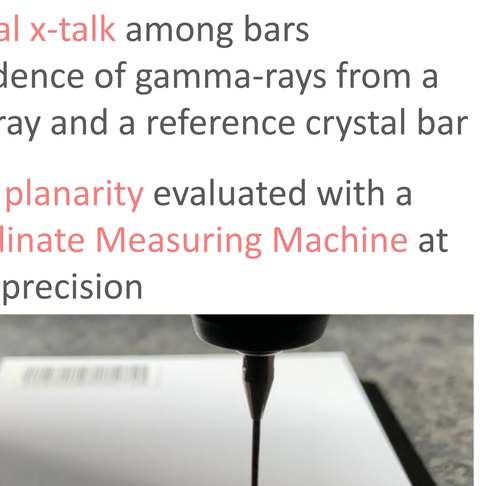
LYSO:Ce

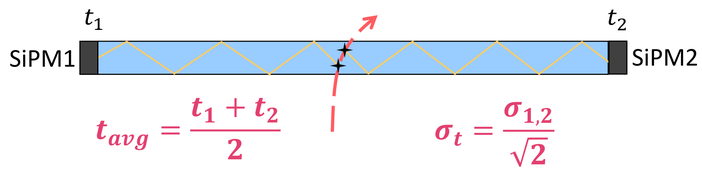
Optimal for radiation hardness & precision timing purposes

- High light yield ~ 40 000 ph/MeV
- High density ~ 7 g/cm3
- ~ 100 ps rise time, ~ 40 ns decay time

Quality control of crystal bars & arrays pre- & post-irradiation done in INFN-Roma1 lab

- 2 crystals extracted from top, middle & bottom part of each LYSO ingot
- Characterization of 5% of production arrays

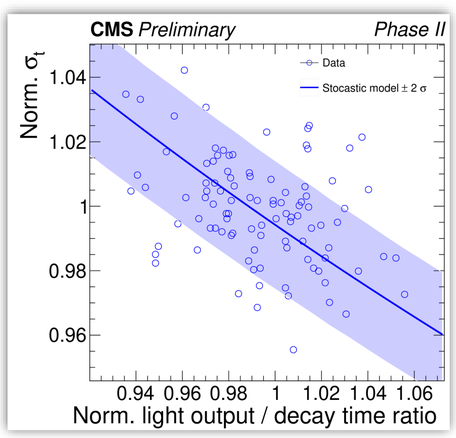




Crystal bar optical properties

Multi-anode PMT measurements:

- Light Output (LO) & Decay Time (DT) – highest possible LO in shortest possible time frame leads to better σ_t

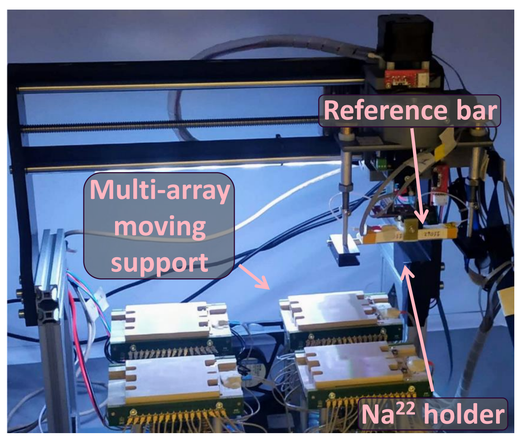


Correlation between normalized figure of merit ($\frac{LO}{\tau}$) & normalized time resolution σ_t - compatible with photostatistics model

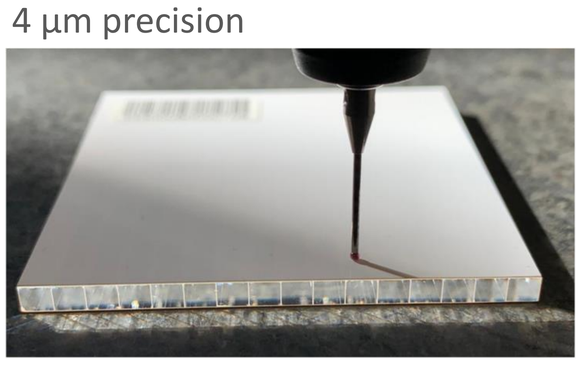
Array optical & mechanical properties

Measurements done using the TOFPET ASIC:

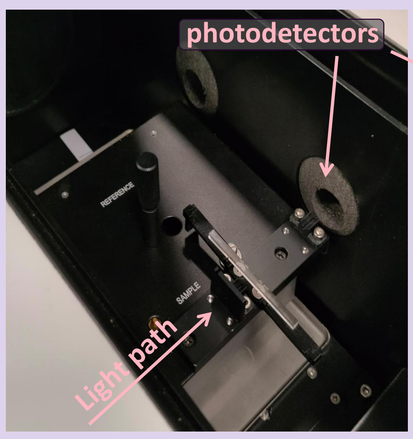
- Relative LO wrt reference array & optical x-talk among bars
- Time resolution measured using coincidence of gamma-rays from a Na^{22} beta decay, between crystals in array and a reference crystal bar



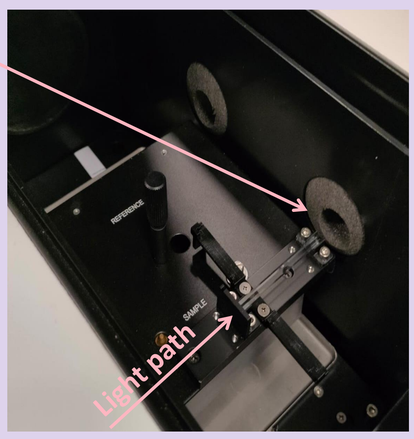
Array planarity evaluated with a Coordinate Measuring Machine at 4 µm precision



Light Transmission of LYSO:Ce crystals



Longitudinal

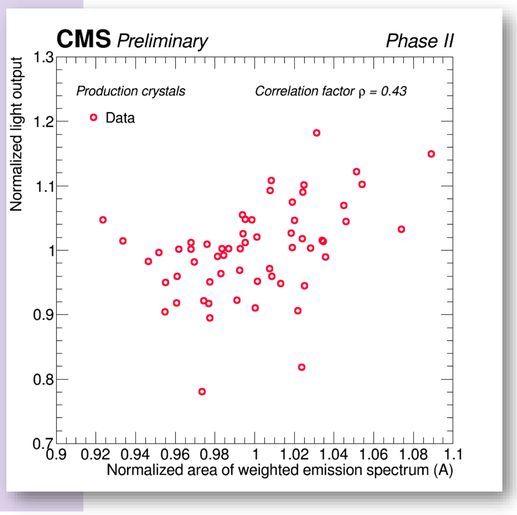


Transversal

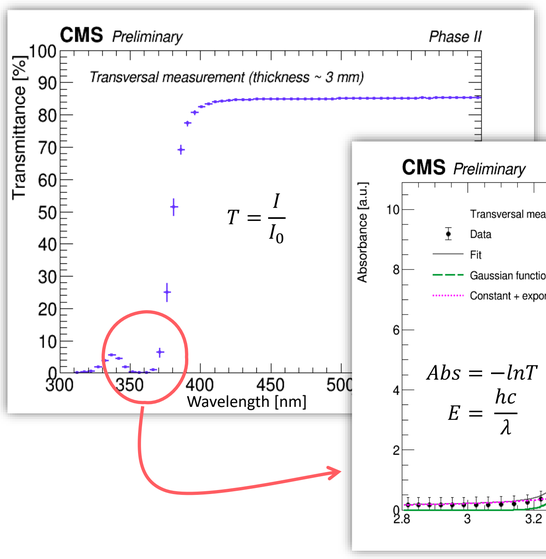
New lab activity!

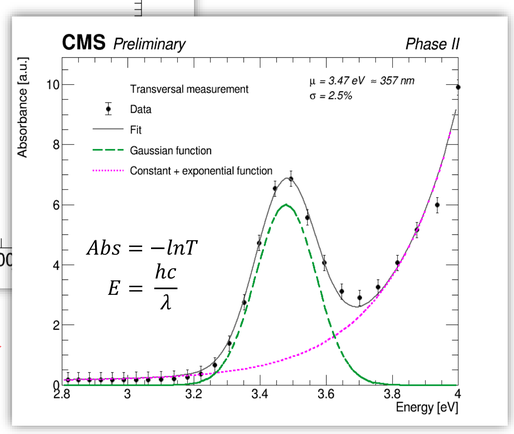
Measurements of light transmission done with a UV-Vis spectrophotometer

- Crystal transparency loss after irradiation – complementary to LO
- Dopant concentration studies

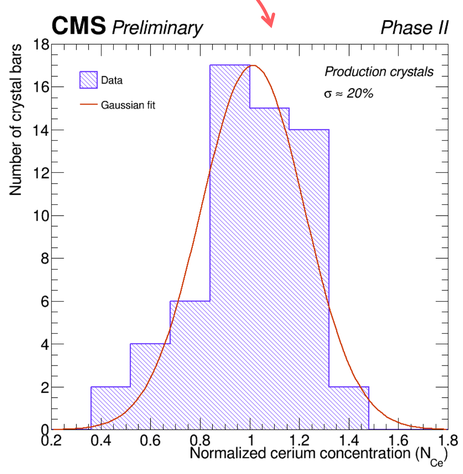


LO measured as described above in PMT bench

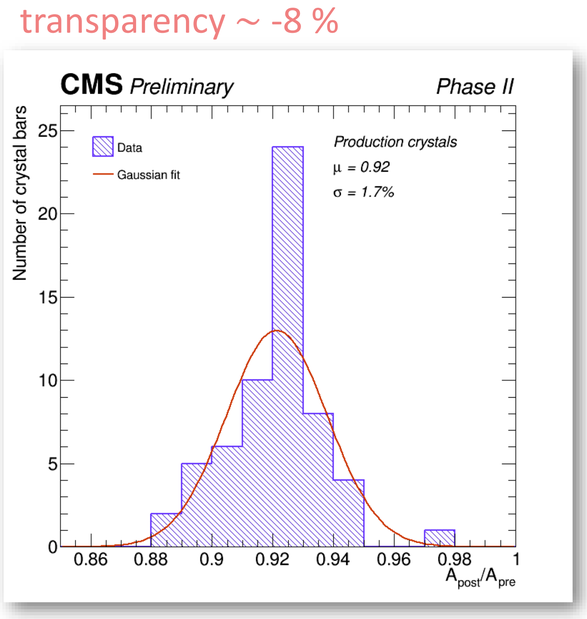




Area of the Gaussian peak ~ concentration of cerium dopant



Production crystals were irradiated with 50 kGy of photons from a Co^{60} radioactive source – reduction in transparency ~ -8 %



Area of weighted emission spectrum: integral of the LYSO:Ce emission spectrum multiplied by the quantum efficiency of the PMT & by measured longitudinal transmittance spectrum

Production ongoing with no issues so far - expected completion of LYSO:Ce validation by end of 2024 - aligned with BTL schedule!

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References

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