CMS–ECAL: Results on Crystal Measurements, Quality Control and Data Management in the INFN-ENEA Regional Center

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# CMS-ECAL: Why PbWO$_4$ (PWO) crystals?

<table>
<thead>
<tr>
<th>Physics Requirements</th>
<th>CMS-ECAL Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good resolution for high energy e/γ</td>
<td>Crystal calorimeter</td>
</tr>
<tr>
<td>High LHC lumin.: $10^{34}$ cm$^{-2}$ s$^{-1}$</td>
<td>PWO is radiation hard</td>
</tr>
<tr>
<td>LHC bunch separation: 25 ns</td>
<td>PWO is fast: 80% of light collected within 25 ns</td>
</tr>
<tr>
<td>Compact detector with high granularity</td>
<td>PWO has $X_0 = 0.89$ cm and Mol. Radius = 2.2 cm</td>
</tr>
<tr>
<td>Magnetic field inside CMS: 4T</td>
<td>Compact solid state photodetec. (APD’s) in the barrel (Endcaps: VPT’s)</td>
</tr>
</tbody>
</table>

PWO large scale production possible
PWO drawbacks:

- LY Temperature coefficient is -2%/°C
  Excellent temperature stabilization required

- Low Light Yield: \(~10\) pe/MeV
  (with PMT and tyvek wrapping at T=18 °C)
CMS-ECAL

APD’s internal gain: solution for PWO relatively low Light Yield:

2 APDs per crystal: 50 mm$^2$ active area
CMS-ECAL Construction

Barrel: 61200 PWO crystals
30600 measured and assembled in the
Rome Regional Center

➤ Distributed process
➤ Crystals are produced by BCTP (Russia)
➤ Measured and assembled into Modules (of 400 or 500 crystals each) at CERN and in Rome
➤ APD capsules qualified in Lyon
➤ Final supermodule assembly at CERN
➤ About 1/3 already produced: SM13 under construction
(out of 36 supermodules)
Assembly and test in Rome RC

Crystal measurements  17 x 2 different crystal types (8 x 2 in Rome)

Crystal + capsule = subunit  10 subunits \rightarrow submodule (10 crystals)
40 submodules \rightarrow module (400 crystals)
4 modules \rightarrow supermodule (1700 crystals)

Module assembly:
Crystal Measurements

Automatic measurements of:
• dimensions (minimize dead space and avoid mechanical stress among crystals)
• transmission (radiation hardness)
• light yield and LY uniformity

Dark room temperature: 20±0.5°C rel.
humidity: 50±10%

35 crystals/run
1 run time: approx. 6 hours

3D commercial machine
5 points on front and rear faces
8 points on lateral ones
Reproducibility ±2 μm
Transmission Measurements

Same apparatus for LT and TT

Single-beam array spectrometer coupled to an integrating sphere

Xenon lamp 300-700 nm

No crystal defects

Radiation hardness

LT (360nm) ≥ 25%
LT (420nm) ≥ 55%
LT (620nm) ≥ 65%

LT Slope at inflection > 3%/nm

Δλ (TT=50%) ≤ 3nm
Doping homogeneity
LY measurements

Photo-peak determination
scintillation spectrum of
γ-emitting $^{60}$Co source

21 spectra along the crystal:
• LY at 8 $X_0$ (shower maximum)
• Front non-Uniformity (FNUF)
in the light collection

Calibration with LED signal:
LY reference measurements

Five crystals measured every day to check ACCOR stability
Single crystal resolution ~1.5 %, same for the average

Crystal measurements are correlated due to the calibration procedure

Further improvement possible if rescaling by crystal average (stability over very long time scale under investigation)
LY measurements

Rejected crystals: about 0.2% for LY or FNUF, 0.3% in total

σ = 0.67 pe/Mev

σ = 0.16 %/X0
Data Management System: REDACLE

This HUGE amount of parts (order of 100000) and data (for each crystal about 500 measurements are stored) requires a fast and flexible DMS

- Fast and low resource demanding tool
- Easy to use for operators
- Open source software only. MySQL for the database structure
- Large flexibility: web interfaces with PHP, c++ programs for interaction with ACCOR, Java programs for computing crystal characteristics and quality checks, Labview programs for APD capsules quality checks, perl scripts for queries and data export
- The data are stored in tables (each part is identified by its unique barcode)
- Relationship between tables by internal pointers and identifiers
Data Management System: REDACLE

Definitions and instances decoupled: possible at any time to insert new characteristic definitions

REDACLE is in use since May 03: about 5000 crystals and 12 + 1 modules

Crystal measurements available for offline analysis with large statistics and to provide an initial intercalibration of the whole calorimeter at startup

Characteristic Definition Table:

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
<th>unit</th>
<th>actDefId</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>LY8X0</td>
<td>Pe/MeV</td>
<td>6</td>
</tr>
<tr>
<td>34</td>
<td>FNUF</td>
<td>%/X0</td>
<td>6</td>
</tr>
</tbody>
</table>

Characteristic Table with pointers:

<table>
<thead>
<tr>
<th>Id</th>
<th>charId</th>
<th>partId</th>
<th>actId</th>
</tr>
</thead>
<tbody>
<tr>
<td>235895</td>
<td>33</td>
<td>33101000020910</td>
<td>40275</td>
</tr>
<tr>
<td>235896</td>
<td>34</td>
<td>33101000020910</td>
<td>40275</td>
</tr>
</tbody>
</table>

Value Table with the real data:

<table>
<thead>
<tr>
<th>Id</th>
<th>x</th>
<th>characteristicId</th>
</tr>
</thead>
<tbody>
<tr>
<td>104995</td>
<td>9.2720</td>
<td>235895</td>
</tr>
<tr>
<td>104996</td>
<td>-0.2262</td>
<td>235896</td>
</tr>
</tbody>
</table>
Example: module assembly interface
Correlation between LY and LT

Transmission measurements can be used as additional and independent LY measurements

Does our knowledge of crystal intercalibration improve?
Comparison with test-beam data

LY from LAB

Entries: 58
Mean: 0.1609E-02
RMS: 0.4781E-01

χ²/ndf: 9.951 / 11
Constant: 6.452
Mean: 0.1610E-02
Sigma: 0.4782E-01

σ = 4.78%

LY from LT

Entries: 58
Mean: 0.9195E-03
RMS: 0.4346E-01

χ²/ndf: 13.04 / 11
Constant: 7.098
Mean: 0.9197E-03
Sigma: 0.4346E-01

σ = 4.35%
Correlations for crystal types 6-9 (module type 2)
Correlations for crystal types 10-13 (module type 3)
\[ \text{LY}_{\text{CALC}} = 4.64 + 0.128 \cdot T360 \]

LY difference = \[ \text{LY}_{\text{CALC}} - \text{LY}_{\text{MEAS}} \]

\[ \mu = 0.02 \text{ pe/MeV} \]
\[ \sigma = 0.44 \text{ pe/MeV} \]

No significant improvement with individual fits per type
Summary

- CMS-ECAL under construction. Half barrel being measured and assembled by the Rome RC
- Large statistics on crystal measurements
- Improved LY calibration and measurement precision
- Correlation between transmission and LY, could be used as independent measurements to improve the calibration

- Looking forward to statistically significant comparison with test-beam data