# EXL detector in E744

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**Abstract**

Run 302 and 339 contain the 60Co calibration. Run 347 contains the background overnight.

## Mechanical setup

The EXL detector comprises from 18 crystals in total, that are organized in pairs. Each crystal pair has a common pair of PMs. The PM come from **Photohis** XP14D5. There are no details on Photonis web now, however the information persists on internet.

**Crystals** The CsI crystal pair has a trapezoidal shape with $2.81^{\circ}$, 110mm long, faces $415\text{mm}^2$ and $718\text{mm}^2$[lefebvre]

**Photomultiplier (PM)** XP14D5 has two photocathodes that are behind the (probably) quartz glass of a (probable) thickness from 1mm (nearest) to 3mm (deep middle). These numbers come from a Hammamatsu drawing on the right panel. Also Peyre [peyre2008], who worked with these PMs claims the glass thicknesses 2-3mm for different types. The crystals are glued to the PM, the glue thickness is probably inferior to the quartz glass.

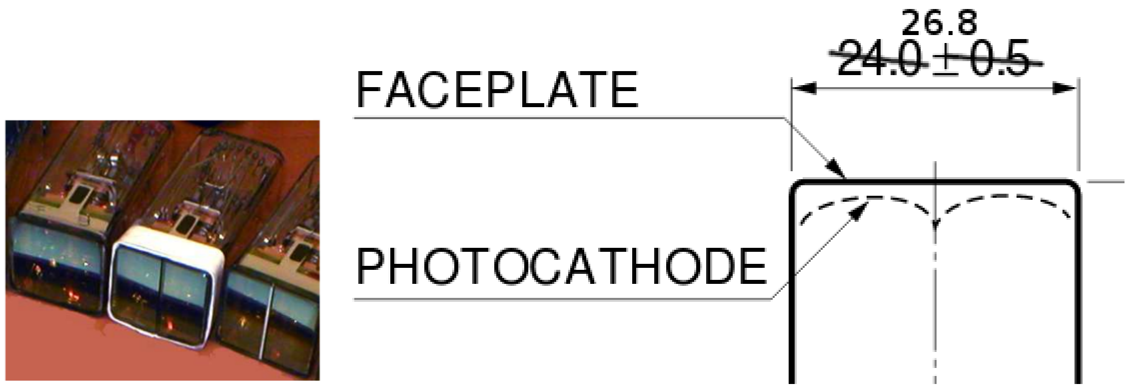


Figure 1: XP14D5

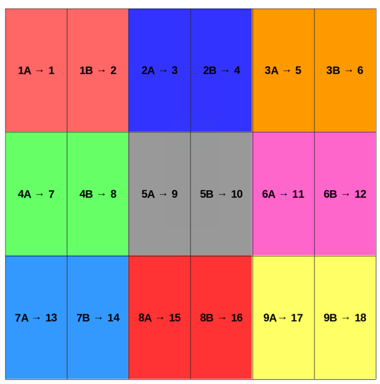


Figure 2: EXL crystals

## Collection effects

From the setup, it is evident, there are actually two (at least) effects that influence the measurement this crystal setup. **Energy sharing** (we mean a standard situation, where the energy of the gamma is deposited into two neighbouring crystals.) and **Light leak**.

### Light leak

The crystal pairs (1-2, 3-4, 5-6, ... , 17-18) have few milimeters of a common quartz glass and thus some light from (the photon deposited in) one crystal can travel into the PM of the other crystal. This effect was studied in [zamora] and [peyre2008].

An interesting insight is found in Zamora theses[zamora].

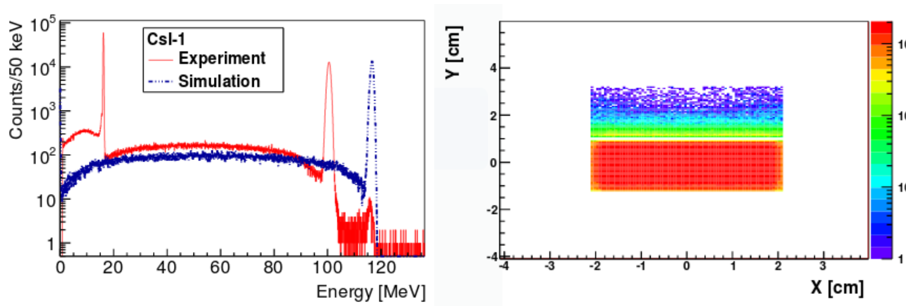


Figure 3: Zamora simulation (blue) and a real measurement (red) of energy deposition (120 MeV protons). Left: a simulation of the light collection, when the energy is deposited ONLY in crystal 1 (at 0 cm on y-axis).

Zamora shows the leak effect on protons 130 MeV. Zamora was able to reproduce this effect in a simulation by manipulation of ADC signals (N?) by a matrix

$$\begin{pmatrix} N1' \\ N2' \end{pmatrix} = \begin{pmatrix} 1-\alpha & \alpha \\ \alpha & 1-\alpha \end{pmatrix} \begin{pmatrix} N1 \\ N2 \end{pmatrix}$$

where $\alpha$is a light cross-talk percentage. $\alpha = \frac{R}{1+R,}$, where R is the ratio of the two **experimental** peaks in the Zamora spectrum (15 Mev and 100 MeV).

**Questions** However, the details of Zamora are not 100% clear - the values are summarized in the following table:

Table 1: Zamora xtalk values

| total light intensity leak - simulation | $R$- experimental ratio | $\alpha$- calculated xtalk |
|---|---|---|
| 0.02 | 0.15 | 0.13 |

**Note:** Zamora sees that the correlation between crystals are highly linear. And global gains were assumed to be the same (probably, see below).

## Peyre findings

Peyre [peyre2008]studied the XTALK of this XP14D5 double PM in three settings. His point of view included also the GLOBAL GAIN G of the system (number of photoelectrons are translated to the signal PMT+charge preamp+shaper gains). **We hope** that the global gains (G1 and G2) in the pair of PM system in our case are the same an thus G1/G2 will be always =1. Actually, the same was assumed by Zamora.

**Measurements** Peyre crosstalk was measured from signals S (obviously) and he describes XTALK as the ration of number of photoelectrons NbPhE. Here is crosstalk from crystal 2 into crystal 1.

$\frac{NbPhE2}{NbPhE1} = \frac{S2}{S1} * \frac{G1}{G2}$

He supposes that the both crosstalks are similar (variation 12%). Averaging the both cases G1/G2 factor disappears.

Table 2: Peyre xtalk values

| xtalk for 3mm glass | xtalk for 2mm glass | xtalk when saw line with Si present |
|---|---|---|
| 0.09 | 0.08 | 0.04-0.06 |

## Summary 1

The signal ratio of the light leak is estimated 13% in one 8-9% in the other study. Could be also affected by particle type. Every signal coming from CsI PM is lowered because of the light leak. The pairs might be compensated directly by addition.

## E744 data

We have analyzed the run 302. In all PAIRS - we observe a similar bidimensional picture (triangle like) for PM-pair as Zamora [zamora] had with protons 120 MeV (not presented here).

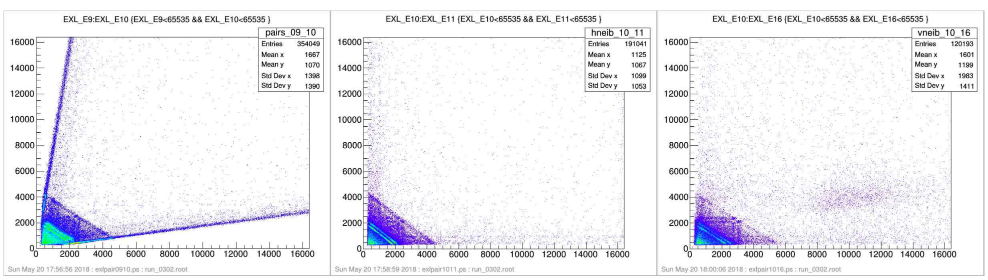


Figure 4: Run 302 - PM-Pair, horizontal neighbors and vertical neighbors. PM-pair has always the positive-slope lines, vertical neighbors have always a high energy dense area. As already discussed by Zamora, negative slope lines come from the energy sharing, the positive slope lines from light leak.

It is evident, that the **negative slope lines** are Compton-like events and true coincidences. The Comptons should be add-backed.

The **light leak** lines show that the leak is a constant fraction in all energies. It seems that addition should also restore the original energy.

# Single spectra vs. bidim - information loss

The evident thing is that bidim spectra have only a fraction of events of the single spectra (300k vs. 1.4M). That means that for a case of **low photon energy in one crystal** we loose the information about the light leaked to the other PM.

Solutions:

1. low energy threshold is too high - threshold decrease would show more bidim events (hard to control the total rate)
2. making OR of the PM-pairs for the acquisition would record also the leaked events
3. could be that during the experiment, MUST is a trigger and EXL is read without any threshold

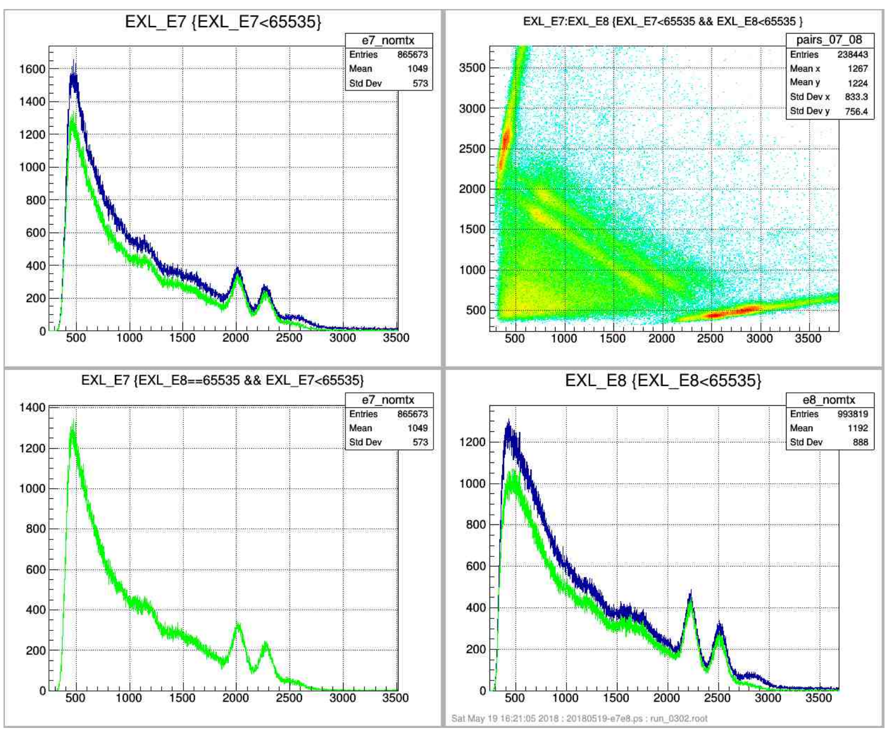


Figure 5: Example of single spectra 7 and 8 and the matrix 7-8. In blue - FULL single spectra together with green single spectra EXCLUDING bidim events. What seems to be penalized is a small 3rd peak, that we assume to be 40K 1462 keV.

In the previous figure there is shown how much we loose by throwing away all bidim events. Maybe the second crystal pair threshold (the one registering the leaked light) is just around this value (0.10 * 1332). For some unclear reason, we loose more of 1460 keV background line than 60Co.

## Two step calibration - step 1 - gain compensation

We know now, that the calibration done to singles do not really reflect the real gamma energies. But - at least it compensates the gains (see the mentioned G1/G2 ratio above - [peyre2008]). We did this "gain compensation" and that way new matrices (pairsCAL) PM-pairs were constructed - they look more rectangular. The 'positive slope' lines are much more similar for every PM-pair. We extracted the factor R - the signal leak ratio from the line's slopes.

Table 3: Deduced R - signal leak from the EXL data run 302 - after G1/G2 compensation (calibration with 60Co, histonames=pairsCAL). The values represent signal ratios and should be the same as R in Zamora thesis [zamora]. See 9% and 19% in the same PM pair 11-12

| R | 1-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-12 | 13-14 | 15-16 | 17-18 |
|---|---|---|---|---|---|---|---|---|---|
| lowline, second2first | 0.14 | 0.18 | 0.15 | 0.17 | 0.19 | 0.09 | 0.13 | 0.14 | 0.14 |
| highline, first2second | 0.13 | 0.14 | 0.12 | 0.12 | 0.12 | 0.19 | 0.15 | 0.22 | 0.13 |

The table sometimes shows HUGE differences like for the 11-12 pair. Not clear why (calibration error?). The light leak should be the same for both directions.

**compensation a la matrix $\alpha$ as in [zamora]......**

**Neighbor's matrices must Be Compensated for Light Leak by multiplication using the factors R .... The pairs are compensated by addition.**

### Question - what is the dense region in vertical neighbor pairs?

The crystal is longer in vertical direction, can something be seen in vertical direction that cannot be in horizontal? Cosmic ?

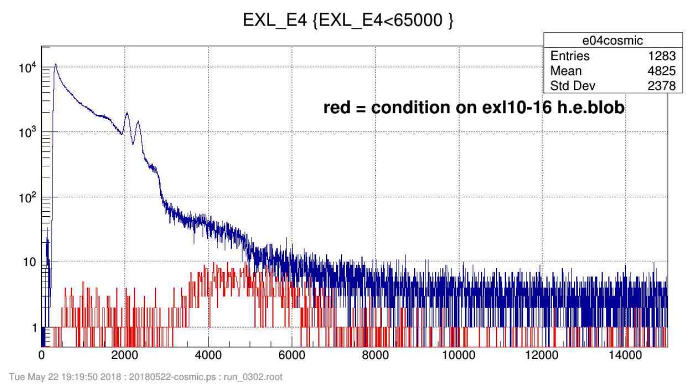


Figure 6: exl4 and the projection (red) of a high energy region from the 10-16 matrix in exl4 spectrum

# Summary 2

To summarize the previous:

1. Light leak compensation does not recover any events.
2. Light leak compensation recovers good energies in CsI, that are always recorded **partially**.
3. Three different cases are present in a matrix a) mtx of pairs, b) mtx of neighbors, c) singles
4. Pairs can get energy restored by adding both axes. Neighbors must be compensated using a coefficient, singles also.
5. Double counting should be avoided when adding the events from matrices to singles.
6. Everything can look nicer when trigger is MUST and validation is OR of CsI

# References


[zamora] http://tuprints.ulb.tu-darmstadt.de/5263/1/Zamora_thesis_final.pdf; Appendix A, page 87

[lefebvre] https://tel.archives-ouvertes.fr/tel-00875639/file/VD2_LEFEBVRE_LAURENT_20092013.pdf; page 123, page 77

[peyre2006] Jean Peyre, Measurements of CsI crystals, R3B Presentation Milano Oct 2006

[peyre2008] Jean Peyre, Goeteborg R&D on calorimeters - presentation, https://www.slideserve.com/lorie/ipn-orsay-r-d-on-calorimeters-jean-peyr-g-teborg-october-2008, October 2008

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