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ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Calibration on a beam line with POLAR, a satellite based astrophysical experiment to measure the polarization of gamma ray burst (GRB) photons.	**Experiment number**: MI-996
Beamline: ID15A	**Date of experiment**: from: 2 Dec 2009 to: 8 Dec 2009	**Date of report**: 26 Feb 2010
Shifts: 18	**Local contact(s)**: Dr. Veijo Honkimaki	*Received at ESRF:*

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Introduction:

POLAR [1] is a novel compact space-borne Compton polarimeter conceived for a precise measurement of hard X-ray polarization and optimized for the detection of Gamma-Ray Burst (GRB) photons in the energy range 50-500 keV. The flight model will consist of 25 modules, each built with an array of 8x8 plastic scintillator bars, and read-out by one multi-anode photomultiplier (MAPM). We have performed a systematic calibration of one modular unit of POLAR (dimensions ~5x5x20cm, total weight ~10kg including mechanical support and shielding; see figure 1) over a wide energy range (46keV-511keV) with a high-energy 100% polarized synchroton radiation source at the beam line ID15 at ESRF. The detector is placed inside an eulerian cradle, fixed on a translating table. The **experiment** consists of recording all pairs of bars that show a coincident energy deposition > 5 keV; one is the Compton scattering of the incoming photon, the other is the interaction by Compton or photoelectric effect of the secondary photon, usually in another region of the detector. The distribution of the azimuthal scattering angle ξ is referred to as **modulation curve**, which can be described with the following function: $C_M(\xi)= P_0[1+P_1 \cos (2\xi+P_2)]$. The angle of polarization (P_2) and the modulation factor ($\mu=P_1$) are obtained from the fit, while the degree of linear polarization is $\Pi=\mu/\mu_{100}$, where μ_{100} is the response of the instrument to a fully polarized photon flux. The **trigger** condition is fullfilled if the dynode signal is above the threshold; the event (the energy depositions in all 64 channels) is then saved on file. Only about 15% of the triggered events pass the quality cuts and are registered in the modulation curves.

The experiment:

In order to be able to calibrate the detector with unpolarized γ-rays from radioactive sources once back to our home institute, we have chosen during the beam test energy levels (except 200 keV) identical to the ones of available radioactive sources: 46.5, 59, 88, 122, 200, 288, 356 and 511 keV. Each time the monochromator was displaced in order to change energy range (it was done 3 times in 6 days), the detector had to be aligned on the beam, with a resolution better than 1mm. This was achieved each time in less than 2 hours (except the first time, which took longer), which demanded a large effort since the pixel size of the detector is 6mm. For each energy level we performed two main measurements:

- A scan of the 64 bars (20,000 triggers in the center of each bar) for polarization angles 0° and 90°. The detector was rotated along the beam axis (x axis) in order to achieve polarization angles different from 0°. At 4 energies the scan was performed also at 30°, 45° and 60°. These scans have provided a uniform illumination of the detector with photons at different polarization angles.
- A high statistics scan of 3 representative bars (one in the center and 2 close to the edges), for many polarization angles: 0°, 15°, 30°, 45°, 60°, 75° and 90°, with 200,000 triggers in each run. These measurements are aimed to study the differences between the center and the periphery of the detector, and also to study the influence of the different gain of the MAPM cells on the result.

For 2 energies, and on 2 bars only, very high statistics runs with 1,000,000 triggers for few polarization angles were performed, to study with good details very small variations in the modulation curves.

The data taking has proceeded smoothly with shifts over 24 hours for the whole period, and a total of ~90 million triggers have been collected. Figure 2 (left) shows the events collected as function of time.

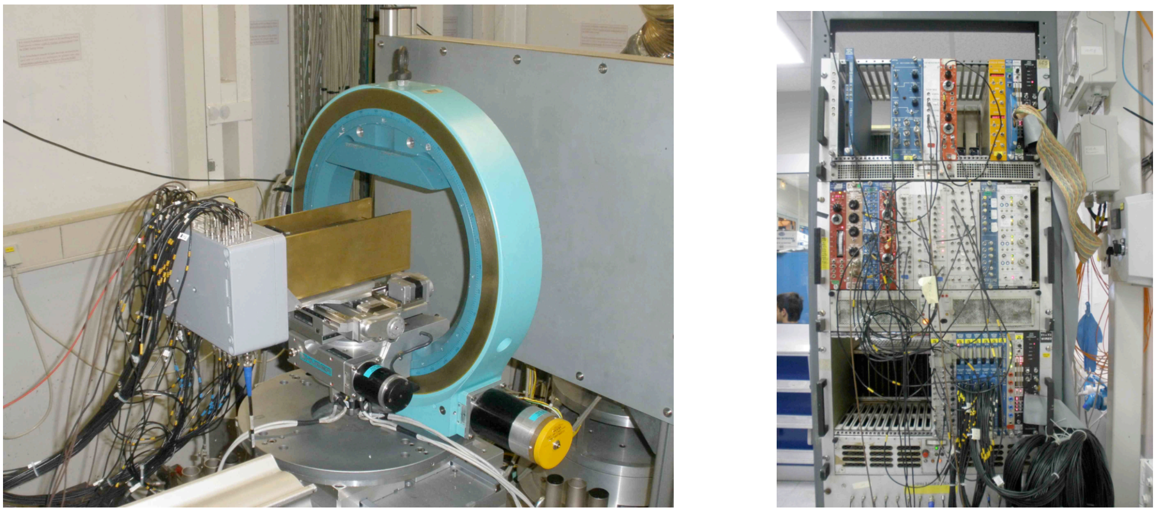

Figure 1: The experimental setup: the detector in the eulerian cradle (left) and the NIM-CAMAC read-out electronics (right).

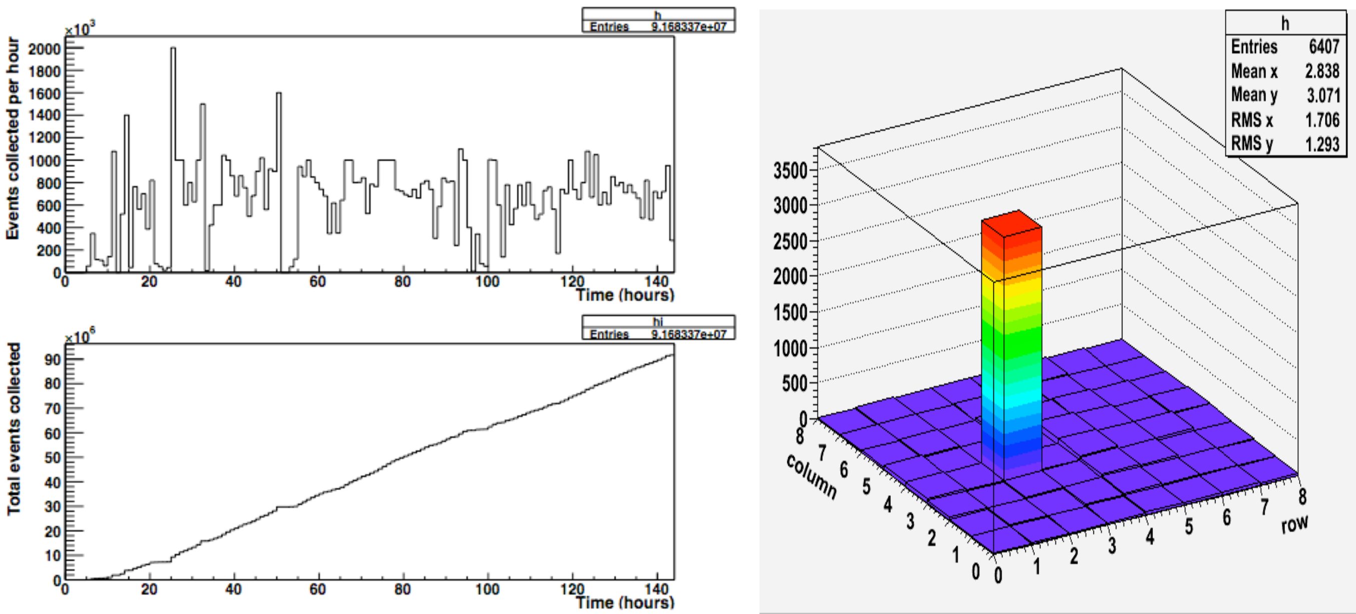

Figure 2: (Left) Number of events collected per hour during the test (top) and total number of events collected (bottom). (Right) Position of the bar with the highest energy release (photon energy 200keV) for one representative run.

Results:

Although the data analysis is ongoing (therefore all results are to be treated as preliminary), we can already show that there is good agreement between the experimental data and Monte Carlo simulations, performed with a GEANT4 package. Figure 3 shows the modulation curves obtained with data collected at ESRF for 100% polarized beam of photons with polarization angles 0° and 90°, and for an unpolarized beam. The curves are well reproduced by a fit function $f(x)=P_0[1+P_1 \cos 2(\xi + P_2) + P_3 \cos 4(\xi + P_4)]$, where one term describes the beam polarization (amplitude P_1 and phase P_2), and the other is due to the square geometry of the detector (double frequency, amplitude P_3 and phase P_4). The modulation due to geometry (P_3) is ~10%, while the modulation due to the polarization depends on the energy, and is ~30%.

The work described here is the subject of a scientific article in preparation [2].

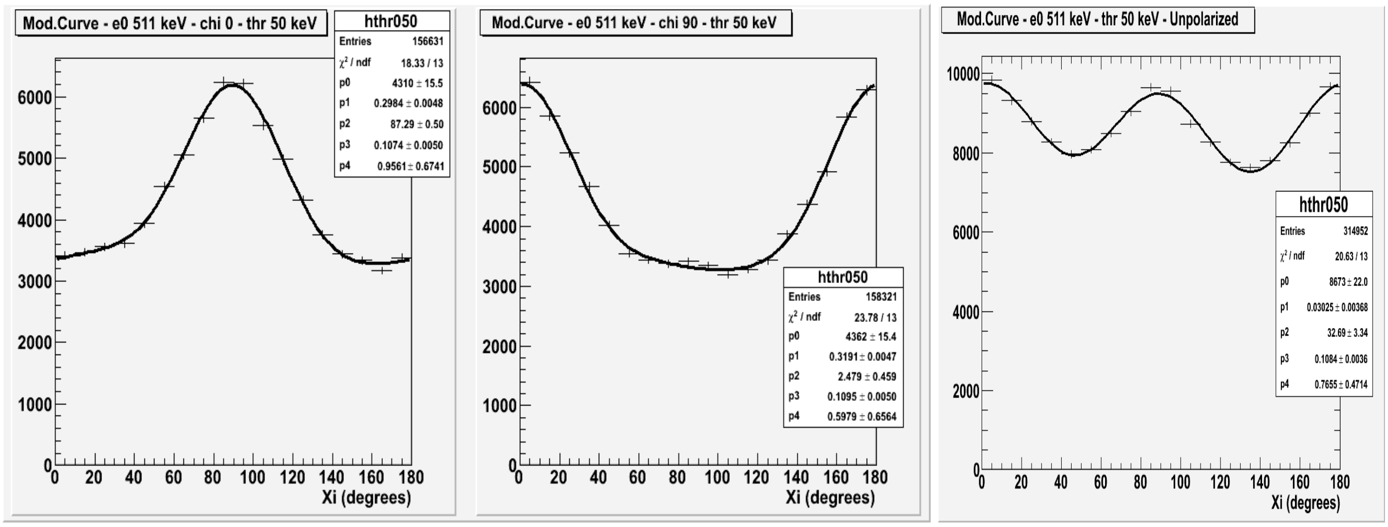

Figure 3: Modulation curves for 511keV photons with polarization angles 0° (left) and 90° (center), and for an unpolarized beam (right; obtained as the sum of runs with 0° and 90° polarization), all with a software threshold on the total deposited energy of 50keV.

Prospects for the future:

The limiting factor for the read-out speed has been the PC used for saving data on disk, that will be substituted for future tests by a custom read-out system, currently under testing, specifically built for POLAR. The new electronics is also able to trigger independently on each of the 64 channels, and to lower the trigger threshold to ~5keV.

In future experiments with synchroton radiation, the device under test will be the Engineering and Qualification Model of POLAR, which consists of 16 modules. These new measurements will allow us to test the trigger logic between various modules and address issues that could not be studied in the first beam test, such as a study of the modulation as function of the φ angle (rotation along vertical axis).

References:

[1] N. Produit et al., Nucl.Instrum.Meth. A550, 616 (2005)

[2] S. Orsi et al., "Calibration of the POLAR demonstration model with high-energy polarized photon beams", in preparation