SIDDHARTA Technical Note IR - 6

Tests of trigger on 30 mm^2 Silicon Drift Detector prototype performed at the Beam Test Facility (BTF) of LNF in the period 13 – 28 July 2004

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1. Introduction

The present work is a continuation of the tests performed in 2003 at the Beam Test Facility (BTF) of Frascati [1], on an array of 7 Silicon Drift Detectors (SDD), 5 mm^2 each. These detectors were the first prototypes used for tests in spectroscopic measurements in a triggered application. The results of this first measurements are reported in [2].

After this measurement, the work continued in the laboratory, with the use of various sources (Fe and Sr), with the same SDD array, having as a goal accurate measurements of the stability of electronics. For few months in the end of 2003 and in the beginning of 2004, tests were performed and high voltage power supply stability at few mV level by computer controlled feed back. The result turned out in a gain stability at the level of few eV at the Mn K_α line.

By March 2004 a new SDD prototype was delivered by MPE and PNSensors. The new prototype has an array of 30 mm^2 – so only a factor about 3 smaller than the final device (1 cm^2). The new device, which is different with respect to the previous one, being closer in design with respect to the final one, was equipped with a prototype electronics. A series of measurement then started. The first measurements, performed in the laboratory, showed that the SDD chip worked properly.

Consequently, a test on the trigger of this new device equipped with a prototype electronics, was performed at the BTF facility. The measurements were performed in parallel with the KLOE experiment, consequently the BTF efficiency was usually smaller than 40 %, still enough to perform valuable tests for triggering of the SDD. The setup which was installed at BTF, basically reproduced the one performing there in 2003. A brief description of the setup is given in Section 2.

The obtained experimental results are presented in Section 3, while their discussion is done in Section 4.

The performance of the used prototype electronics, as a function of the incident rate on SDD, is presented elsewhere [2].

2. Experimental setup

The basic experimental setup is schematically shown in Figure 1.

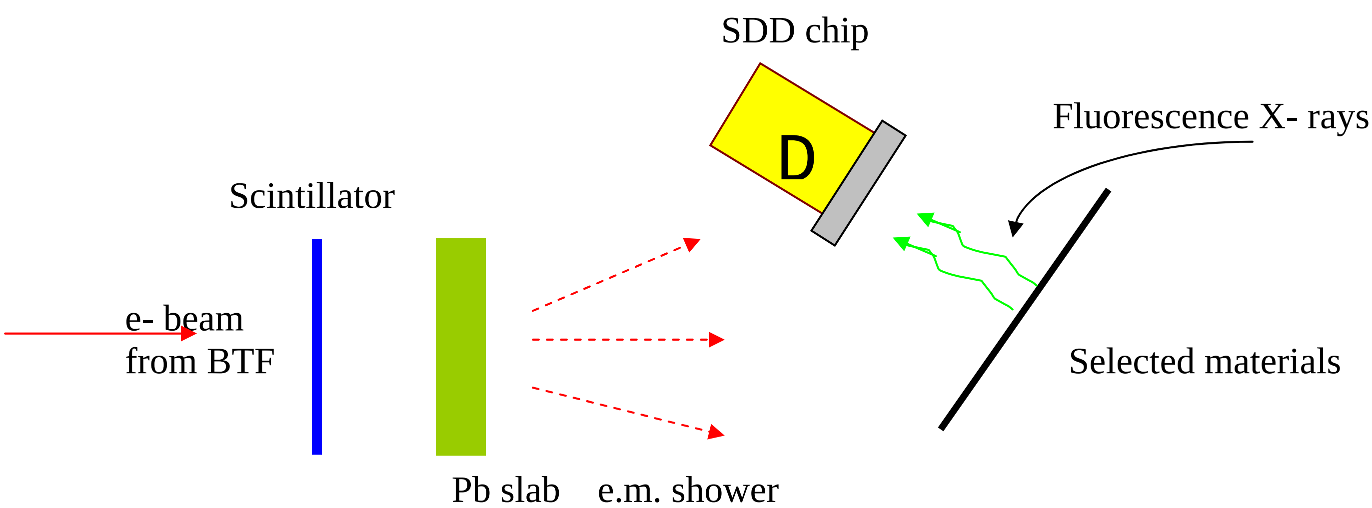

Figure 1. The basic test experimental setup mounted in the BTF area (D = SDD chip).

In order to degrade the preliminary electron energy, to excite fluorescence X-ray lines, a lead slab was put on the BTF beam, whose thickness was chosen by means of an e.m. shower MonteCarlo calculation to produce secondary particles continuously distributed in energy from few MeV to zero. A Pb layer of 2 cm turned out to be a good compromise between "energy softness" and particle intensity of such produced secondary beam. The secondary beam particles were let to impinge on a set of selected materials in the configuration shown in Figure 1. Before producing the e.m. shower in the lead slab, the primary BTF beam hit a thin scintillator, one of the two used for the Kaon Monitor in the DEAR experiment, to provide a fast triggering signal. The scintillator dimensions were (2 x 80 x 150) mm, thickness, height and length, respectively. The scintillator (NE104 type) was seen by two fast phototubes (PM), XP2020 type, mounted at the two (2 x 80) mm ends of the slab, by means of properly shaped light guides. The anode signals of each PM was sent to a CAEN ND235 NIM Constant Fraction and Mean Timer that produced a NIM output whose timing was independent on the particles hitting position on the scintillator. This output was then sent, after passing through a CAEN Dual Timer N93B to one of the input of an AND/OR CAEN Login Unit N455, the other input of which was fed by the SDD logic signal passing through a LECROY835 Discriminator. The output of this module was used to enable DAQ. Since the signal from the SDD had a jitter of about 1.2-1.4 μs, the width of the scintillator signal feeding the AND/OR unit was adjusted to 3 microsecond. The SDD chip was cooled to –50 C, by the use of a cryotiger system. More details can be found in [1].

The emerging secondaries from the e.m. cascade arrived to a set of foils of selected materials (Cu, Zr), disposed at about 45 degrees with respect to the primary beam flight line. Hitting these slabs, fluorescence X-ray transitions could be excited and the generated X-rays, traveling backward at about 45 degrees, opposite to the primary beam direction, reached the SDD and were detected ("reflection geometry"). The SDD itself was mounted oriented with the entrance window forming an angle of about 45 degrees with respect to the primary BTF beam axis, facing the material slabs but not being directly invested by the secondary particles. In such conditions, the SDDs could see the fluorescence lines generated on the selected materials, superimposed to a continuous background formed by the soft secondary electrons, positrons and photons created in the e. m. cascade and arriving on the detector window due to subsequent interactions and backscattering in the materials around the SDDs.

The spectrum of the fluorescence X-ray lines could then be measured. The continuous background spectrum, being generated by the same BTF primary beam, was synchronous with the "good" signal represented by the fluorescence lines .

To generate an asynchronous background, i.e. not time-correlated with the “signal”, we employed a radioactive source. The source, properly facing the SDD, could conveniently generate the wanted asynchronous background. In the test setup, we indeed inserted two sources. One, a Sr source, due to its beta spectrum of maximum energy 2.24 MeV, produced a continuous asynchronous background of soft electrons and photons and also an asynchronous structured background (Ni transitions). The other, a Fe source, produced the K_α and K_β X-ray Manganese lines.

In such a way, we were able to explore the SDD performance and the trigger effect in suppressing the asynchronous background, both continuous and in the form of unwanted X-ray peaks, which is exactly the situation occurring in DAΦNE.

The final test setup with the radioactive sources generating the asynchronous background, is shown in Figure 2.

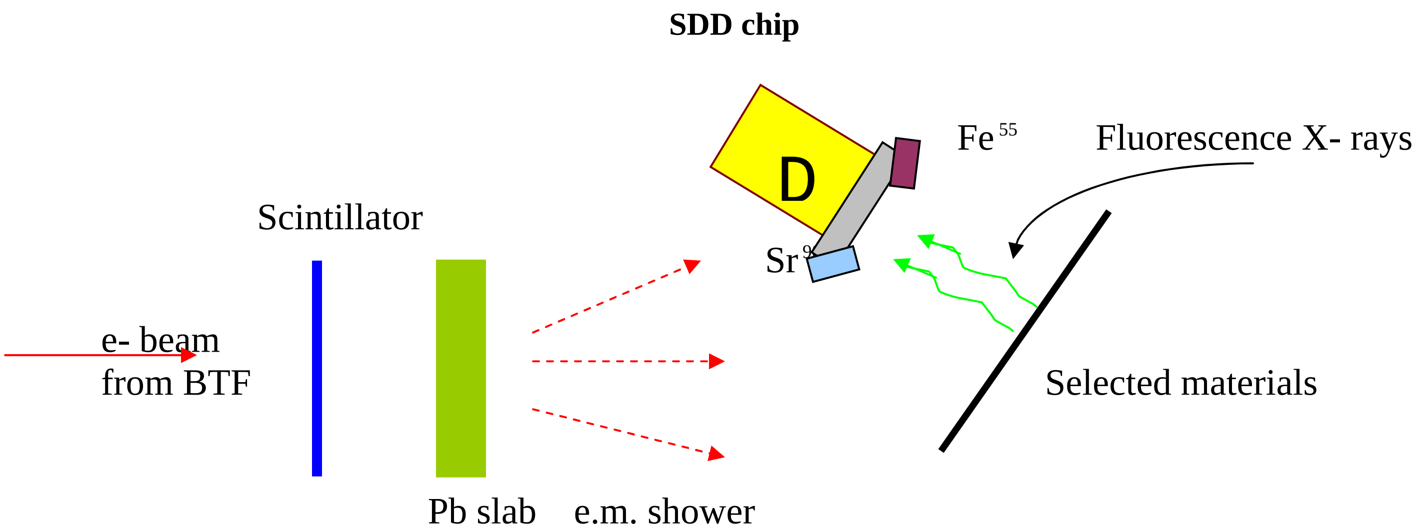

Figure 2. The final test experimental set up mounted in the BTF area (D = SDD chip).

Both the test setups of Figure 1 and 2 were used.

That of Fig. 1 was used to verify, first of all, the feasibility to generate with the BTF beam fluorescence X-rays on the selected materials, to be used as “signals” on the SDDs and to show that, in such a configuration, the spectra were, as expected, the same both triggering and not triggering the SDDs.

The configuration of figure 2 was used to show the capability of the trigger system. Without any trigger (AND/OR circuit working in OR mode) the fluorescence peaks generated by the BTF beam were non detectable, due to the much higher continuous background produced by the Sr beta source, while the background Mn peaks were clearly seen. On the contrary, triggering the SDDs with the scintillator (AND/OR circuit working in AND mode), the fluorescence peaks generated by the beam clearly appeared, being the continuous background produced by the Sr beta source and the X-ray background Mn peaks effectively suppressed, as will be shown in next Section.

Pictures of the setup as installed at BTF are shown in Fig 3 and (detail) Fig 4.

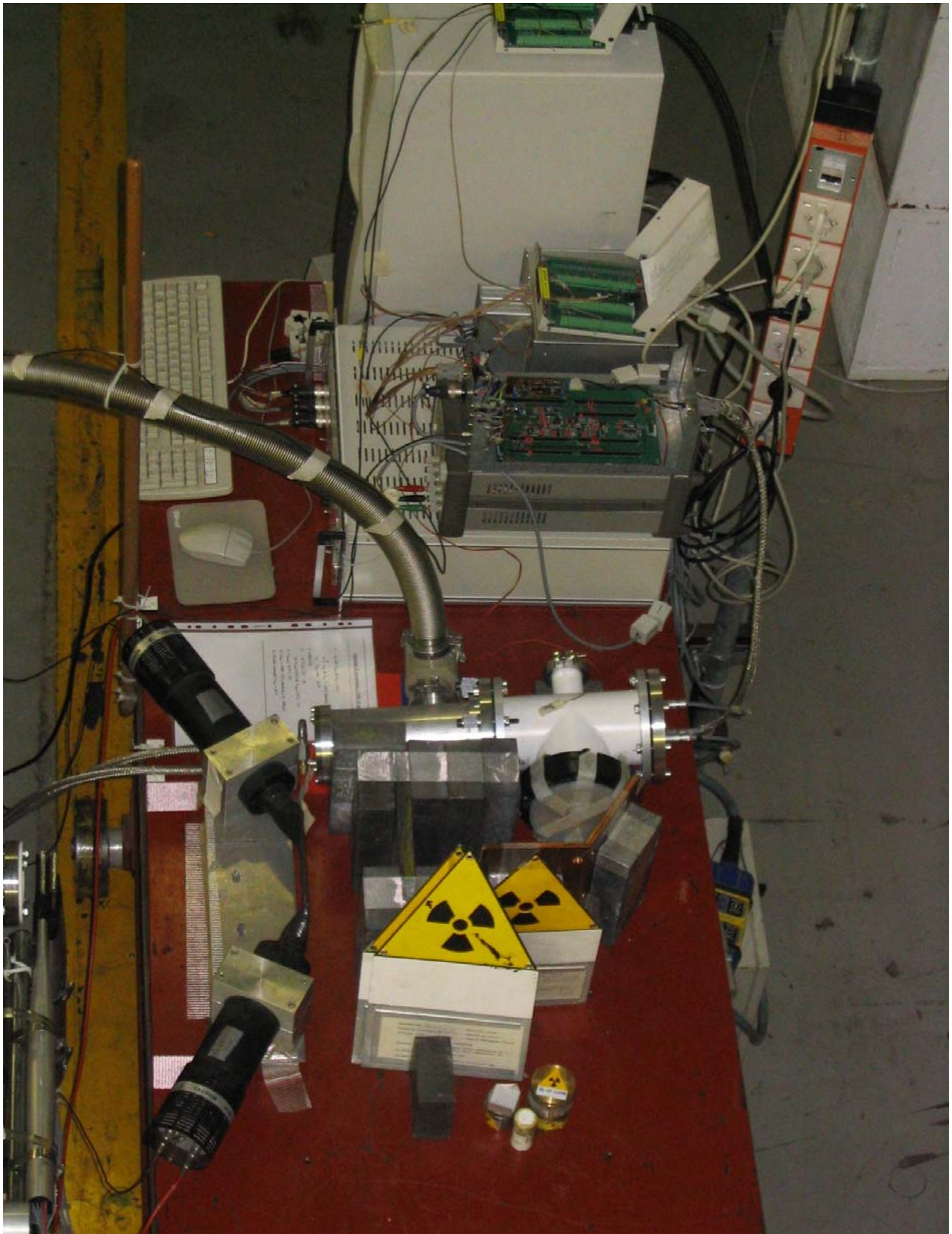

Fig 3: The test setup installed at BTF.

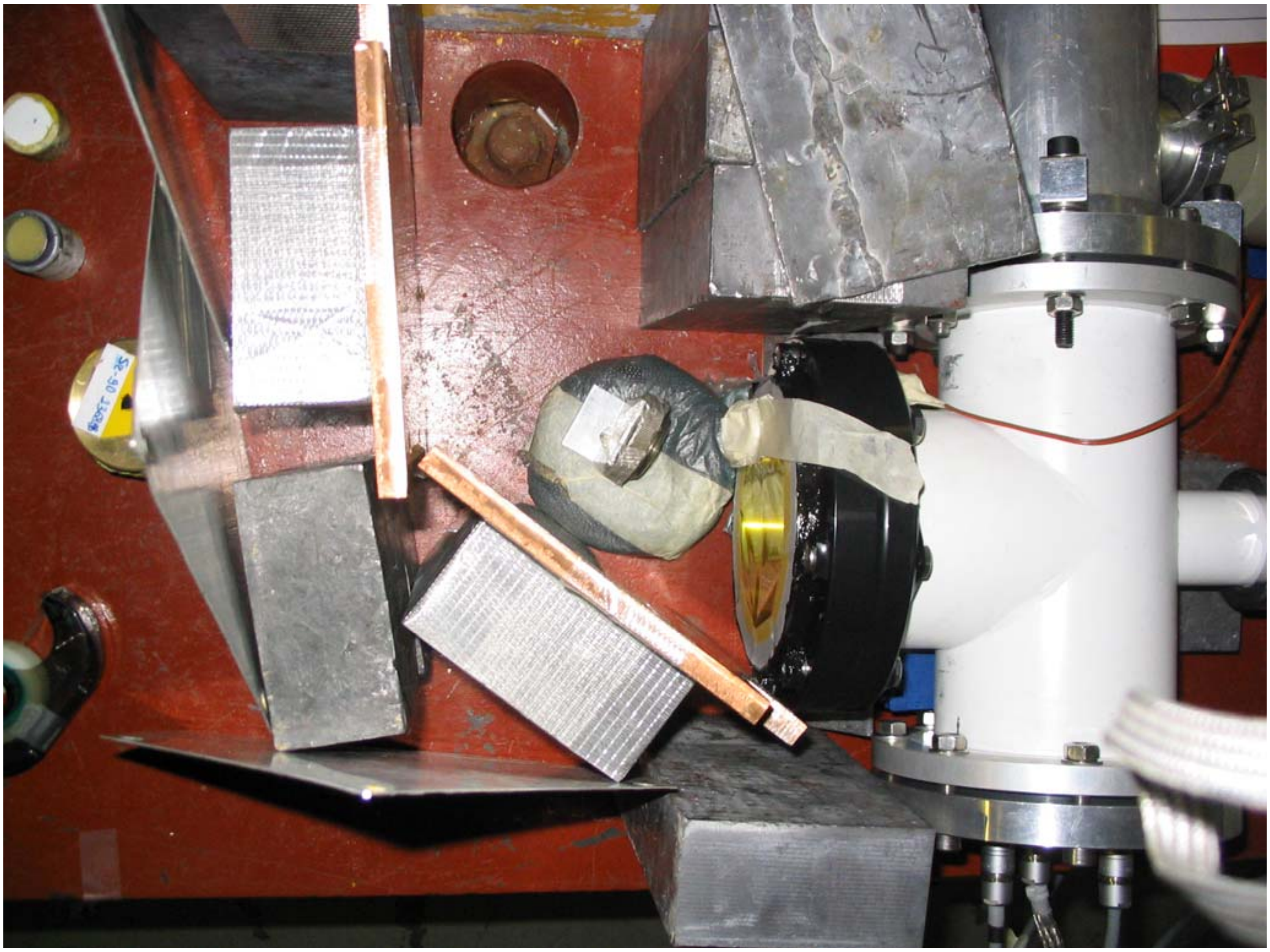

Fig 4.: The test setup installed at BTF (detail): the housing of the SDD chip is visible, together with the 2 Fe and Sr sources.

3. Experimental results

After a first period of optimization of the setup and measuring procedure, a series of measurements were performed, having as goal the understanding of the trigger capabilities applied to the SDD 30 mm^2 chip.

In order to do this, measurements with and without trigger were performed.

In what follows a short description of the most relevant measurements, together with the obtained spectra, are given.

a) Measurement without trigger, without Fe and Sr sources, for an equivalent of 601 minutes of the BTF beam on – used for reference – with an incident rate of 10 Hz - spectrum in Figure 5.

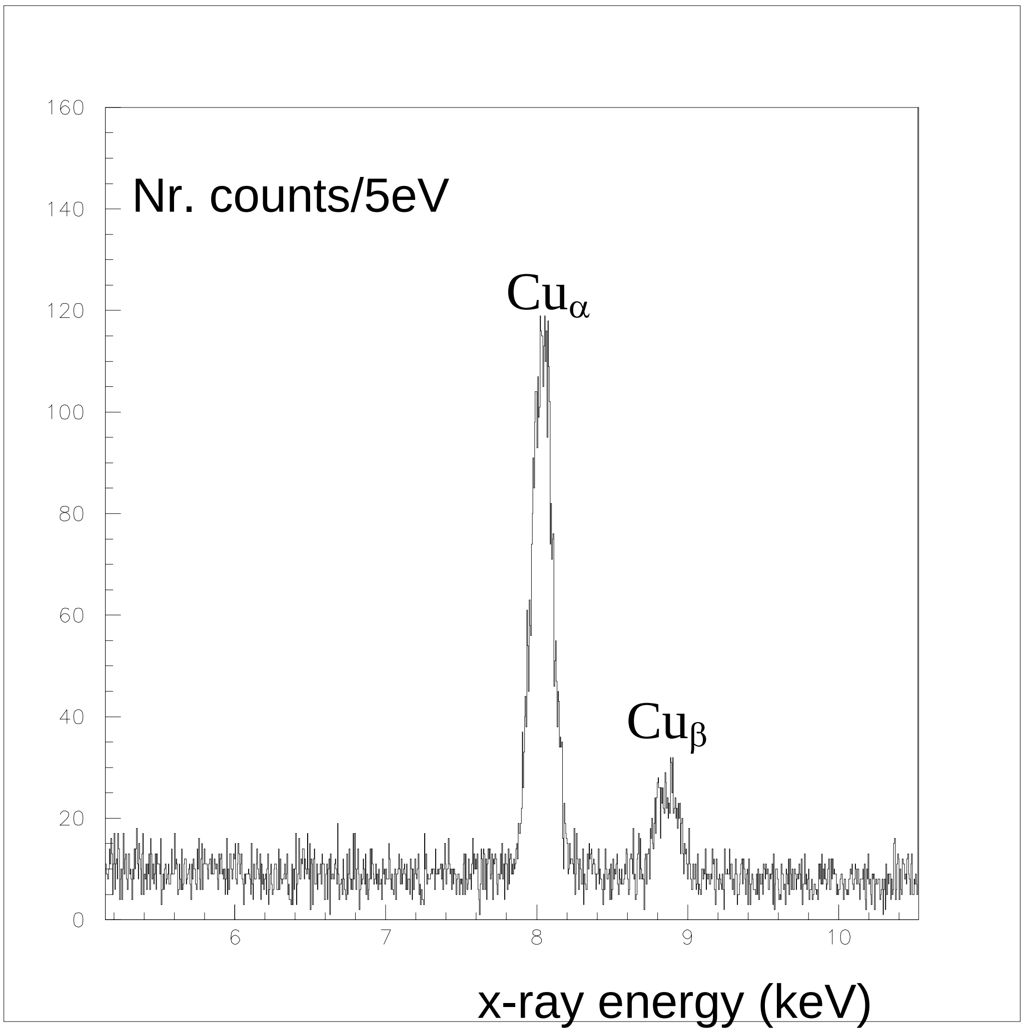

Fig. 5: Energy spectrum obtained without trigger., with BTF on (601 min), without Fe and Sr sources.

b) **Measurement with trigger (3 μs), without Fe and Sr sources, for an equivalent of 572 minutes of BTF beam on, with incident rate on SDD of 10 Hz – spectrum in Figure 6.**

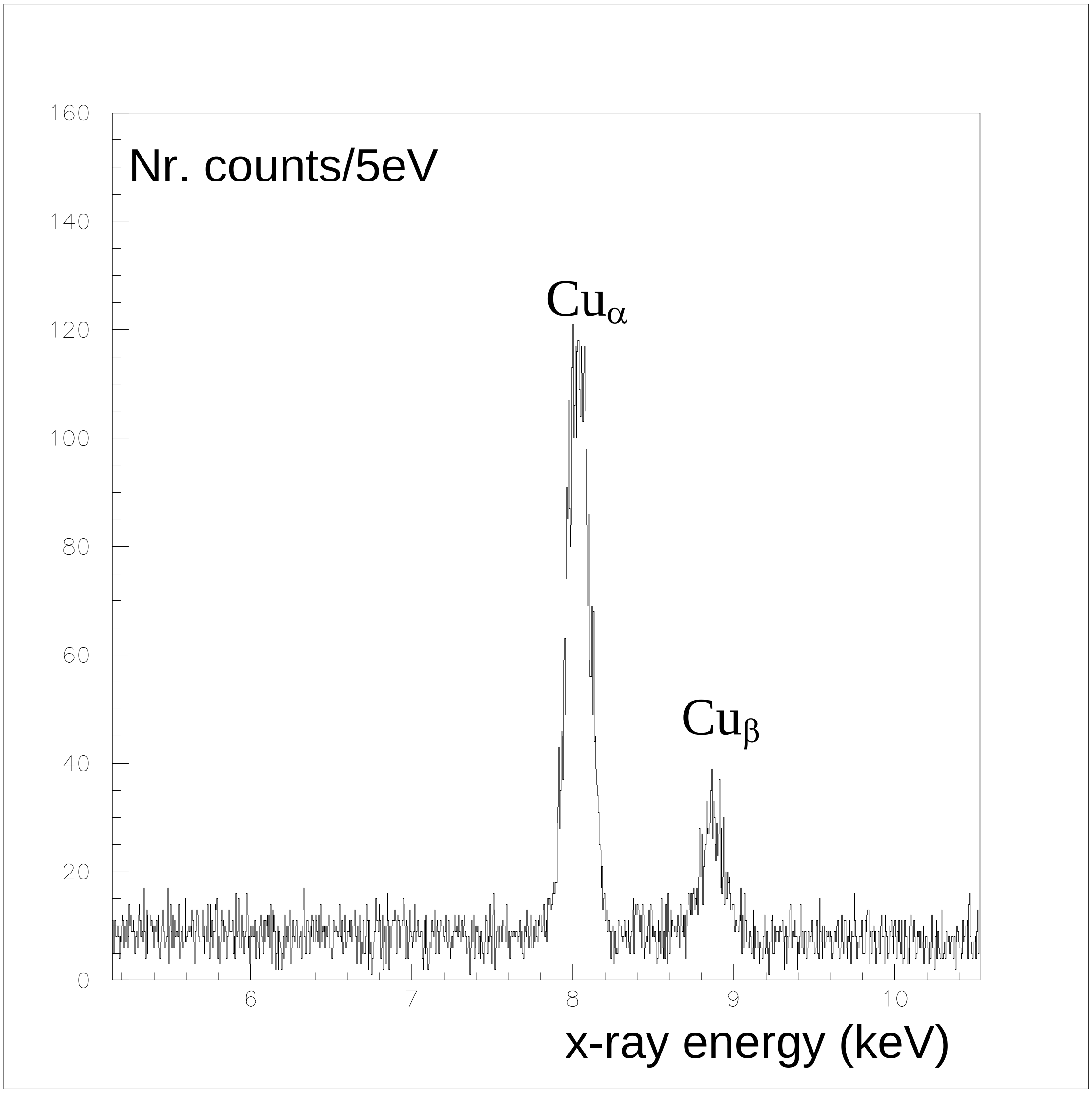

Fig. 6: Energy spectrum obtained with trigger (3μs), with BTF on (572 min), without Fe and Sr sources.

The triggered rate was of 10 Hz (as in measurement a)).

c) **Measurement without trigger, with Fe and Sr sources, with an incident rate of 190 Hz (160 Hz from Sr, 20 Hz from Fe and 10 Hz from BTF), for an equivalent of 110 minutes of BTF beam on – spectrum in Figures 7 and 8.**

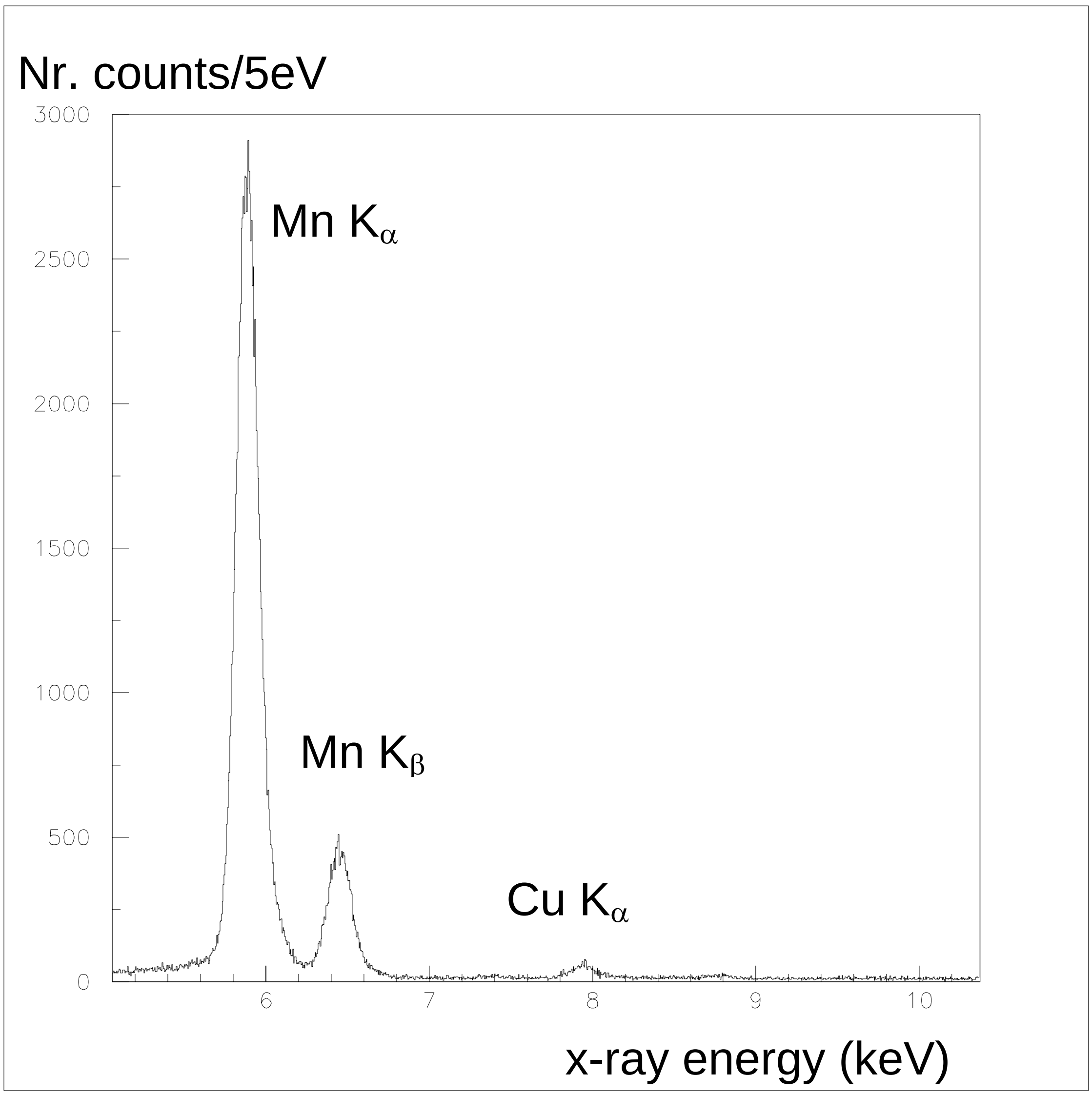

Fig. 7: Energy spectrum obtained without trigger, with BTF on (110 min), with Fe and Sr sources.

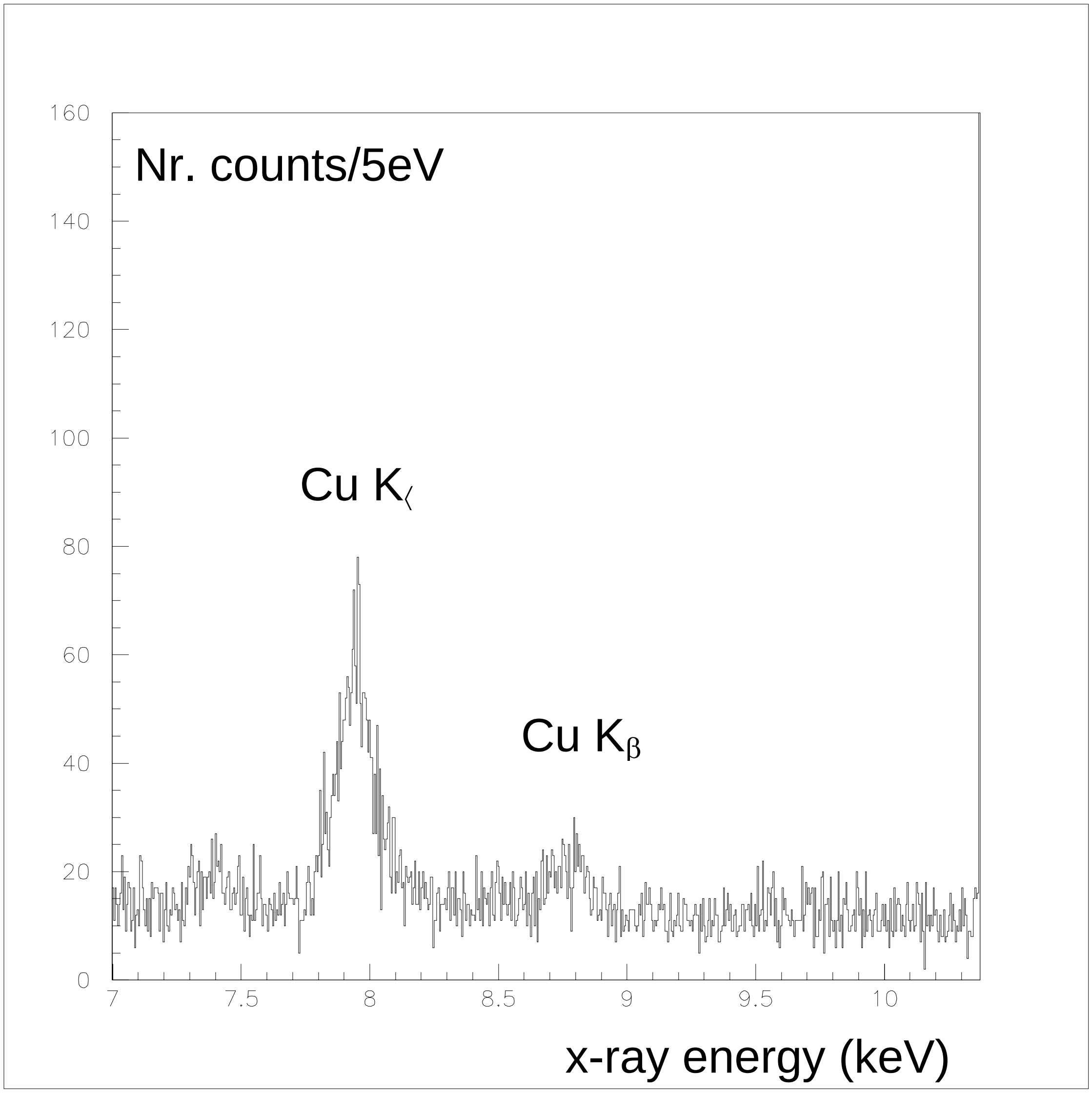

Fig. 8: Energy spectrum obtained without trigger, with BTF on (110 min), with Fe and Sr sources - detail.

d) **Measurement in same "beam conditions" as the measurement c),with trigger (3 μs), for 270 minutes equivalent BTF on– spectrum in Figure 9.**

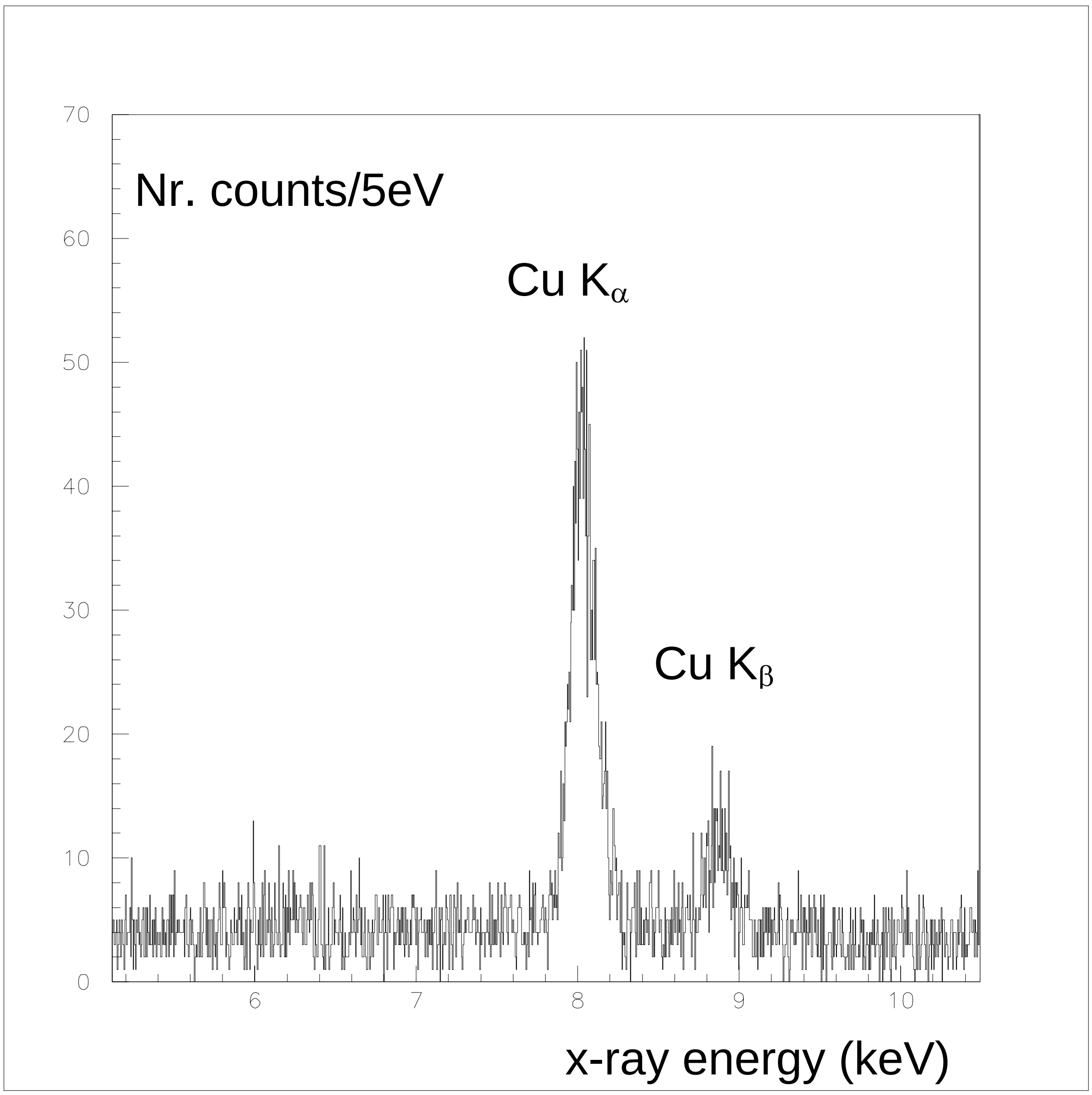

Fig. 9: Energy spectrum obtained with trigger (3 μs), with BTF on (270 min), with Fe and Sr sources .

The triggered rate was of 10 Hz.

4. Discussion of the experimental results

A discussion of the obtained results is done in what follows.

The spectra shown in Fig. 5 and 6 are measured in about the same amount of equivalent BTF time, and they are almost identical (about 4200 events in the Cu_α peak in both spectra). This ensures us that the trigger works correctly, in the sense that with an incident synchronous rate of about 10 Hz events are not lost when trigger is applied.

The analysis of the spectra shown in Figure 9 and Figures 5 (or 6) shows that they are (normalized) basically ***identical***. The first one was obtained ***with*** asynchronous structured (Mn) and unstructured (continuous) background, with trigger on (AND), with a time window of 3 μs, with an incident rate of 190 Hz, while the second one ***without*** asynchronous background, with the same trigger as before. The asynchronous background, shown in Figure 7 – where no trigger was used, is completely cut by the trigger condition.

The Rejection factor as measured by the present test at BTF, comes as follows:

a) Asynchronous structured and continuous incident background:
   R_B = ~ 180 Hz
b) Trigger rate from BTF facility:
   R_t= 50 Hz
c) Coincidence window:
   C_w = 3μs
d) “Good” synchronous event rate:
   Ev_{rate} = 10 Hz
e) Efficiency for good event production, i.e. number of events /number of triggers:
   Eff = Ev_{rate}/ R_t = 10/50 = 1/5
   so one “signal” event for 5 triggers;

f) Casual background event rate after trigger:

$R_{casual} = 50 \times 180 \times 3 \times 10^{-6} = 2.85 \times 10^{-2}$ Hz

With these numbers, one can calculate the ***trigger rejection factor R***:

$$R = R_{casual} / R_B = 1\underline{5 \times 10^{-5}}$$

The incident rate of asynchronous background of 180 Hz corresponds to a factor about 30 more than the incident rate expected as asynchronous background in SIDDHARTA.

Acknowledgements

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Bibliography

[1] DAFNE Technical Note: LC-2: DAFNE-Linac Test Beam and http://www.lnf.infn.it/acceleratori/btf/pubblications.html

[2] SIDDHARTA Collaboration: SIDDHARTA Technical Note IR-1 "Tests of prototype Silicon Drift Detectors to be used in **SIDDHARTA (S**ilicon **D**rift **D**etector for **H**adronic **A**tom **R**esearch by **T**iming **A**pplication) performed at the Beam Test Facility (BTF) of LNF in the period 21 – 31 July 2003, ***25 August 2003***