SIDDHARTA Technical Note IR - 9

Beam Test Facility (BTF) trigger tests of the SIDDHARTA 1 cm^2 Silicon Drift Detector chip performed in the period 19 March – 1 April 2007

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Content

1 Introduction

The present work is a continuation of the previous tests performed in 2003 [1] and in 2004 [2,3] at the Beam Test Facility (BTF) of Frascati on 5 and 30 mm^2 array Silicon Drift Detectors (SDD). These detectors were the first prototypes used for tests in X-ray precision spectroscopic measurements in a triggered application.

After these measurements, the work continued in the laboratory on the 1cm^2 SDDs to be used in SIDDHARTA experiment. The goal of the measurements performed in the laboratory, with Sr and Fe sources, was to check the stability of the SDD and readout electronics systems, and to characterize the performances of the SDDs (as the resolution). The results were very positive, showing that the system works properly and will allow to perform the high precision X-ray measurements planned in SIDDHARTA.

In order to check the effect of the trigger system on the SDDs in realistic conditions (i.e. similar beam as the one circulating in DAFNE) we have performed a test on a system containing final SDD chips and final readout electronics and power supply at the BTF facility, in the period 19 March – 1 April 2007. The results of these tests are object of the present report.

A brief description of the setup is given in Section 2, while the obtained experimental results are presented in Section 3,

2 The experimental setup

A test setup containing 3 SDD final chips of SIDDHARTA, together with a prototype of the final readout electronics and a final power supply module, was mounted in the BTF hall on March 19. In what follows we describe the setup as mounted in the BTF area.

Before going to the setup description, we briefly present the philosophy of the measurements: the electron beam coming from the BTF was firstly detected by a system of two scintillators, used to give the trigger signal to the SDDs; the BTF beam excited various materials (mainly Copper) of which X-ray transitions were measured by the SDD detectors. These X-ray transitions are the so-called “signal” X-rays, and are coming “in time” (i.e. triggered) with BTF electron beam. To these X rays we added non-correlated (in time) X-ray sources, as Fe and Sr, which created the asynchronous background which had to be discarded by our trigger system; we calculated in the end the rejection capacity of the system – reported in the next Section. This method is similar to what will happen in SIDDHARTA at DAΦNE: a system of scintillators will register the back-to-back kaons which are entering in the hydrogen target delivering kaonic hydrogen X-rays and will set the trigger for SDD measurement; the background X-rays (not correlated with the kaons) generated mainly by electrons and positrons lost from the primary circulating beams, should then be discarded by the trigger system – of course with a trigger rejection factor which depends on the timing capacity of the SDD system (SDD chips, plus readout electronics and DAQ system).

Let’s now go to the description of the system installed in the BTF hall. In order to degrade the preliminary electron energy to optimally excite fluorescence X-ray lines (those measured by SDD detectors), a lead slab was placed in 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 thickness of 5 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 material which delivered in the end the X-rays considered as “signal” (i.e. triggered) in the configuration shown in Fig.1

Before producing the e.m. shower in the lead slab, the primary BTF beam hit a thin scintillators system (see Fig. 1), similar to the one used for the Kaon Monitor in the DEAR experiment [4], to provide the 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. 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 SDDs and were detected ("reflection geometry"). The SDD chip itself was mounted oriented with the entrance window forming an angle of about 45 degrees with respect to the target foils, parallel to the primary BTF beam axis, at about 7 cm below the beam axis. 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 radioactive sources. The source, properly facing the SDD, could conveniently generate the wanted asynchronous background. In the test setup, we 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 Figures 1, 2, 3 and 4.

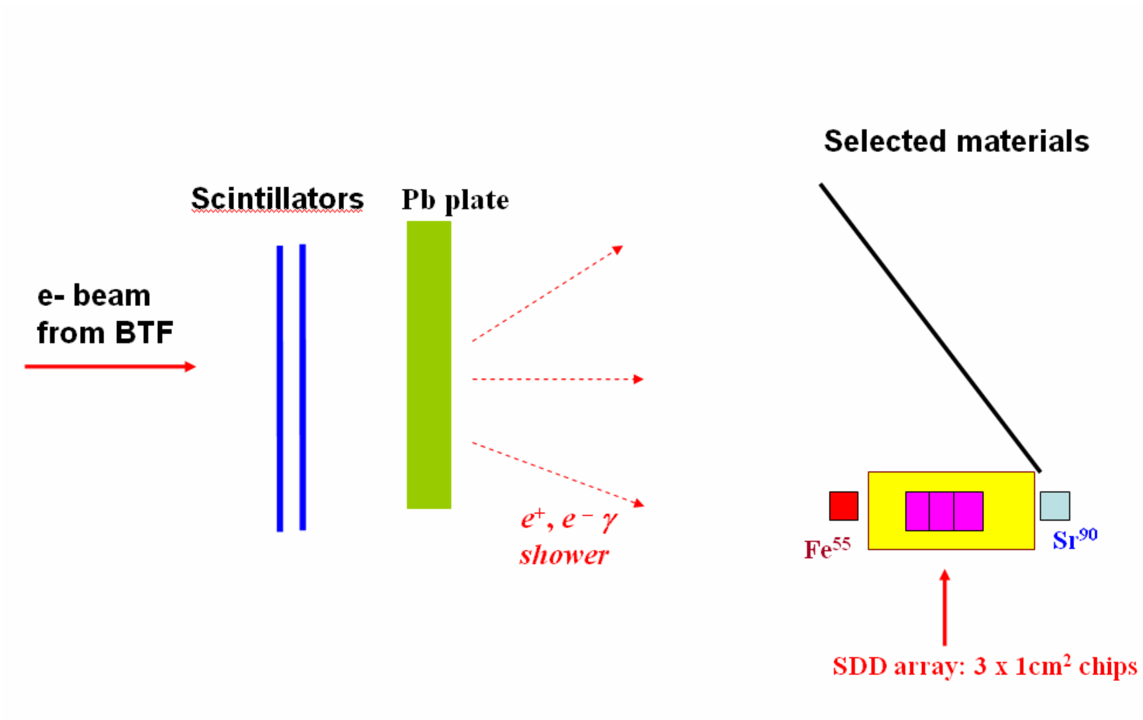

Fig.1 The experimental test setup mounted in the BTF area (side-view)

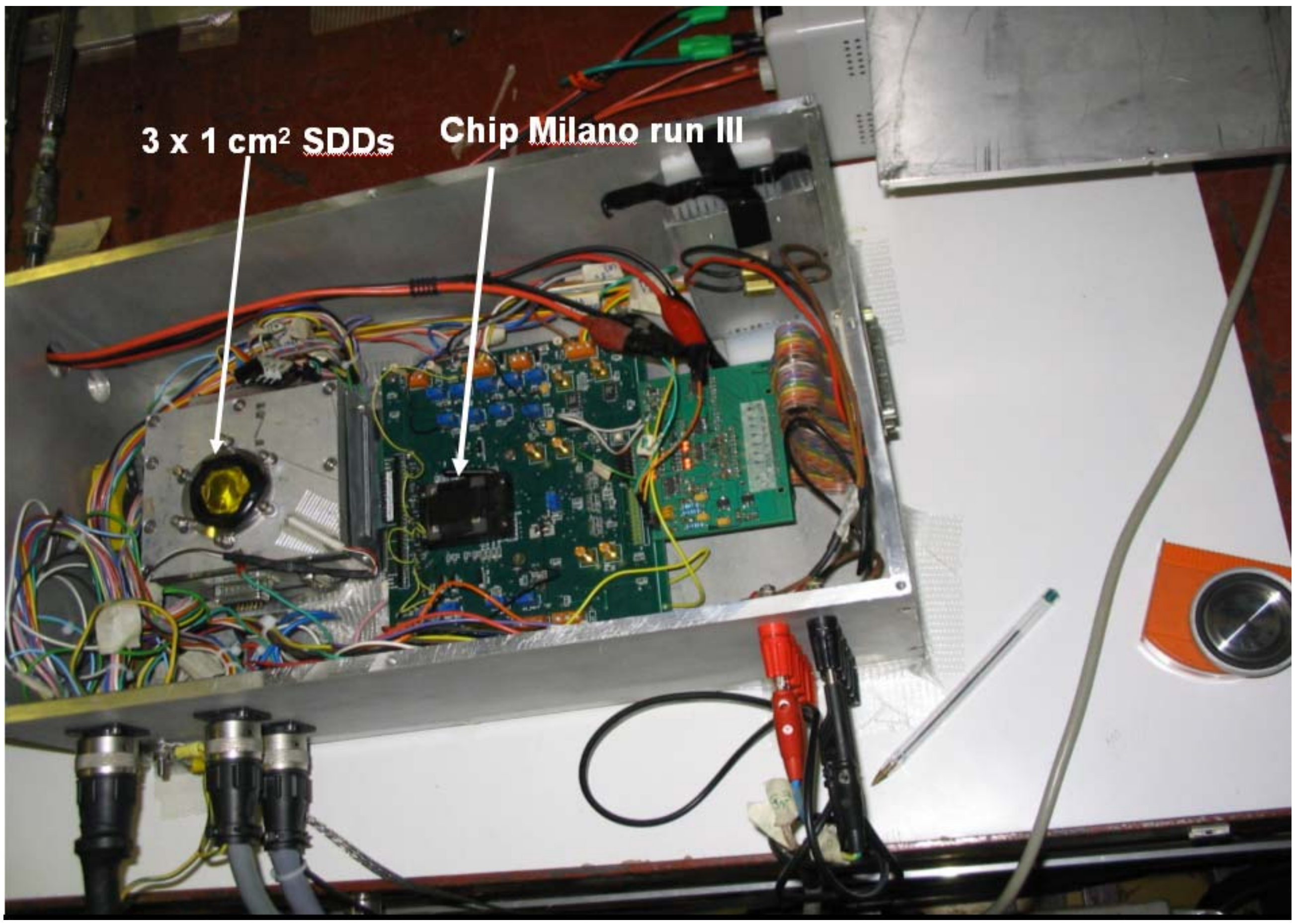

Fig.2 Picture of the experimental setup mounted in the BTF area (detail)

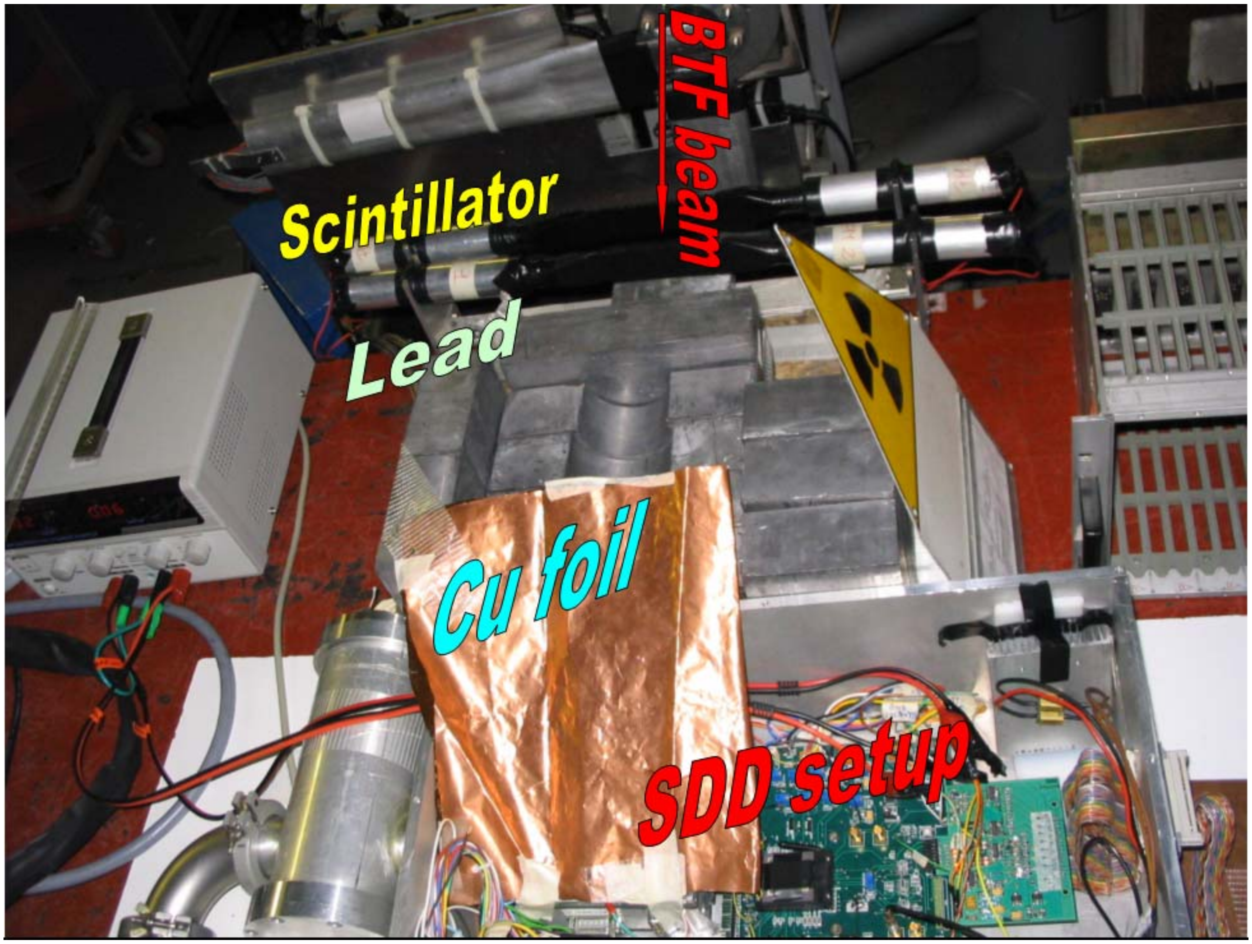

Fig.3 Picture of the experimental setup mounted in the BTF area (detail)

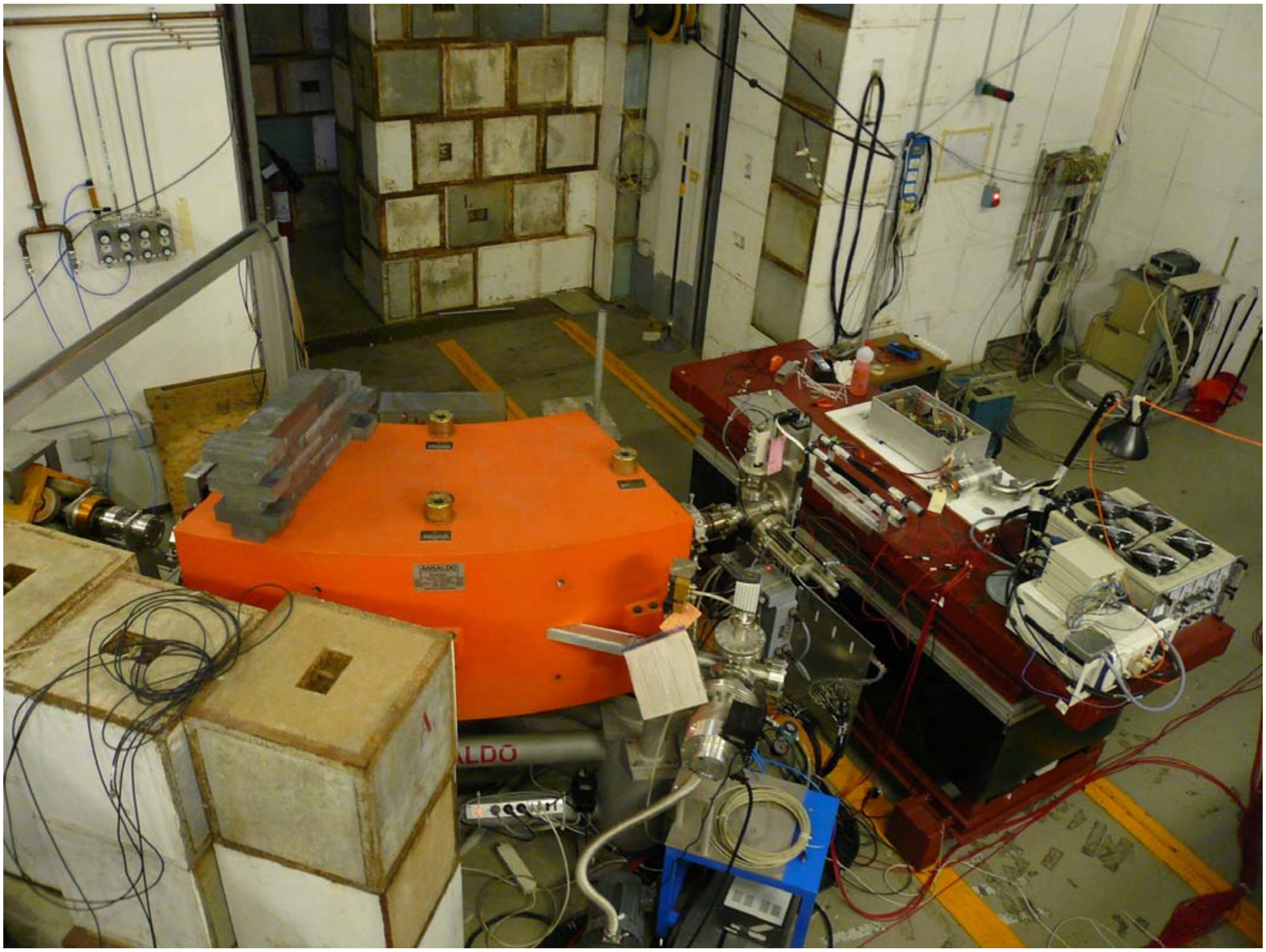

Fig 4 The setup as mounted in the BTF hall – global view

This configuration was then used to measure the capability of the trigger system. Without any trigger 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, 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, even at the greatest "illumination" possible of the SDD with such sources, as described in the following Section. The results of all measurements with the test setup are described in the next section.

3. Results of the measurements performed at the BTF

3.1. Performed measurements

The following measurements were done during the BTF testing:

- energy resolution of the SDD chips in the experimental hall;
- linearity of the energy scale: SDD channel versus energy;
- test of the triggering capability;

The results of these tests are presented in the next Subsections.

3.2 Energy resolution

In order to measure the energy resolution of the SDD chips of the test setup in the experimental BTF hall, a Fe X-ray source was used together with a Titanium foil activated by the Fe source. The two K_α and K_β transition of Manganese (at 5.899 and

6.490 keV) and Titanium (at 4.511 and 4.932 keV) were than used to obtain the calibration and to deduce the energy resolution.

The spectra of the 3 SDDs, obtained in a run lasting about 38 minutes, are shown in Figures 5, 6 and 7, while results are reported in Table 1.

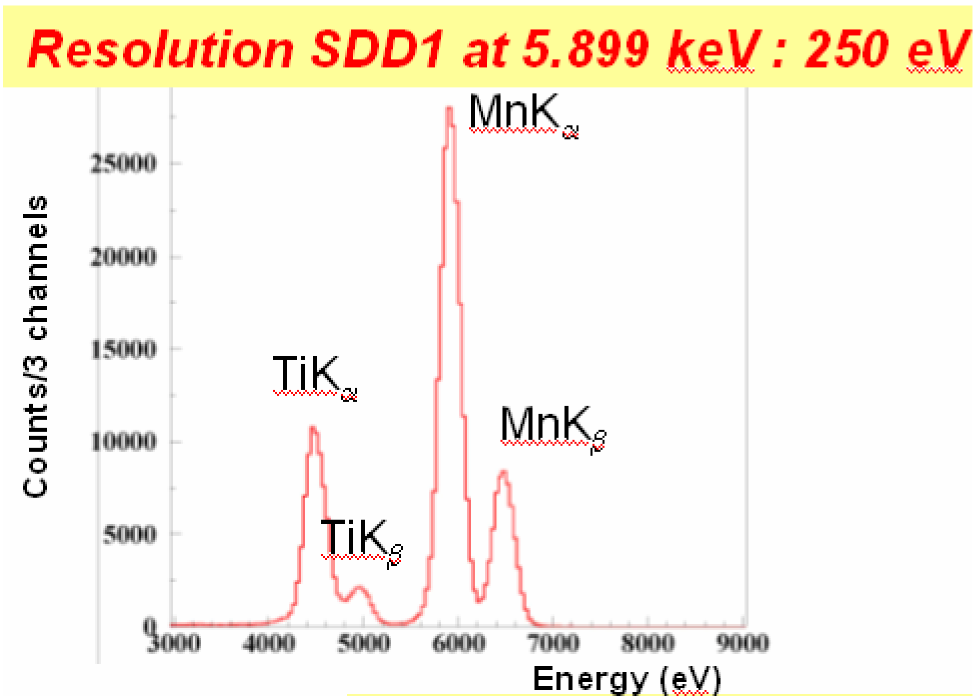

Fig.5 Calibration spectrum of SDD1 taken with Fe sources and Titanium foil as target

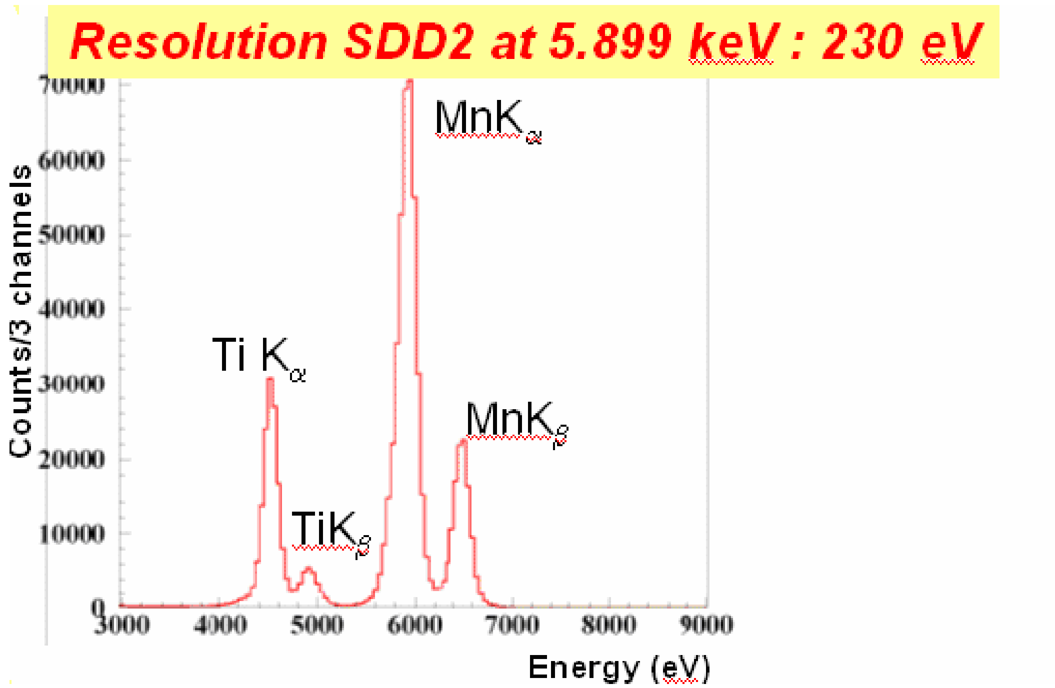

Fig.6 Calibration spectrum of SDD2 taken with Fe sources and Titanium foil as target

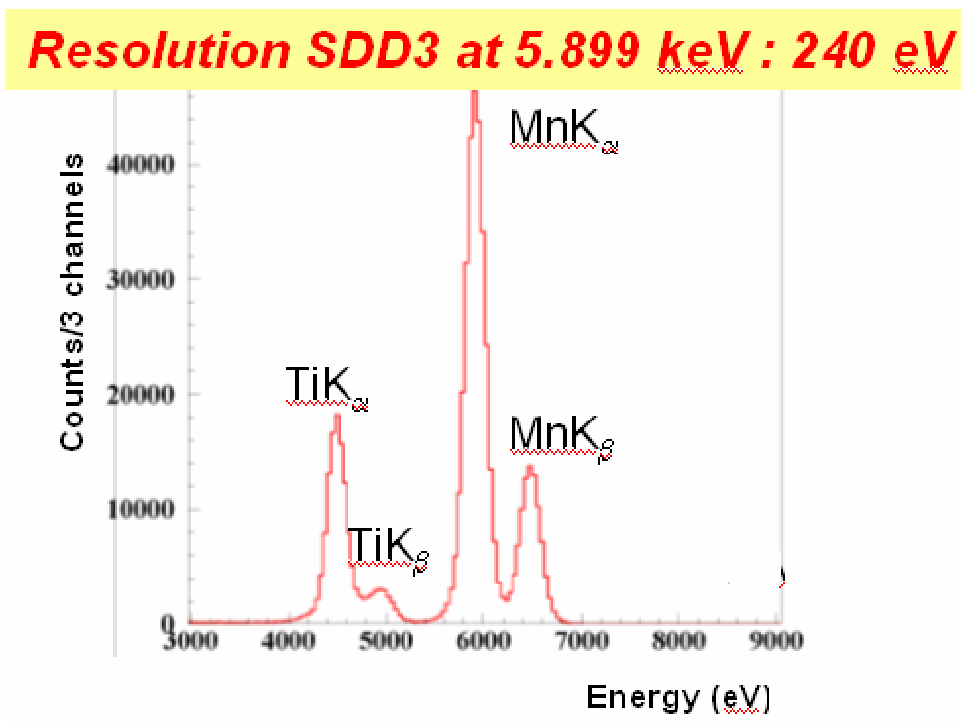

Fig.7 Calibration spectrum of SDD3 taken with Fe sources and Titanium foil as target

Table 1: Energy resolution of the SDDs at 5.9 keV

SDD	RESOLUTION
1	250 +/- 0.25 eV
2	230 +/- 0.18 eV
3	240 +/- 0.20 eV

As can be seen from Table 1, the experimental resolution of the 3 SDDs is varying between 230 and 250 eV at about 6 keV of energy.

These resolution values are higher then the ones reached in laboratory (140 eV at 6 keV), being this a direct consequence of the fact that we worked in the BTF without a proper filtering of the noise (lack of time for optimization)– showing that dedicated cure has to be addressed to this item for the final SIDDHARTA setup on DAFNE..

3.3 Measurement of the scale linearity

The linearity of the SDD answer – no. of channel as a function of energy - was checked by analysing a measurements with beam, with Sr (830 Hz) and Fe (40 Hz) sources, with TRIGGER OFF, lasting 2 hours, with an incident rate on SDDs of about 900 Hz (for example fig. 8 for SDD2).

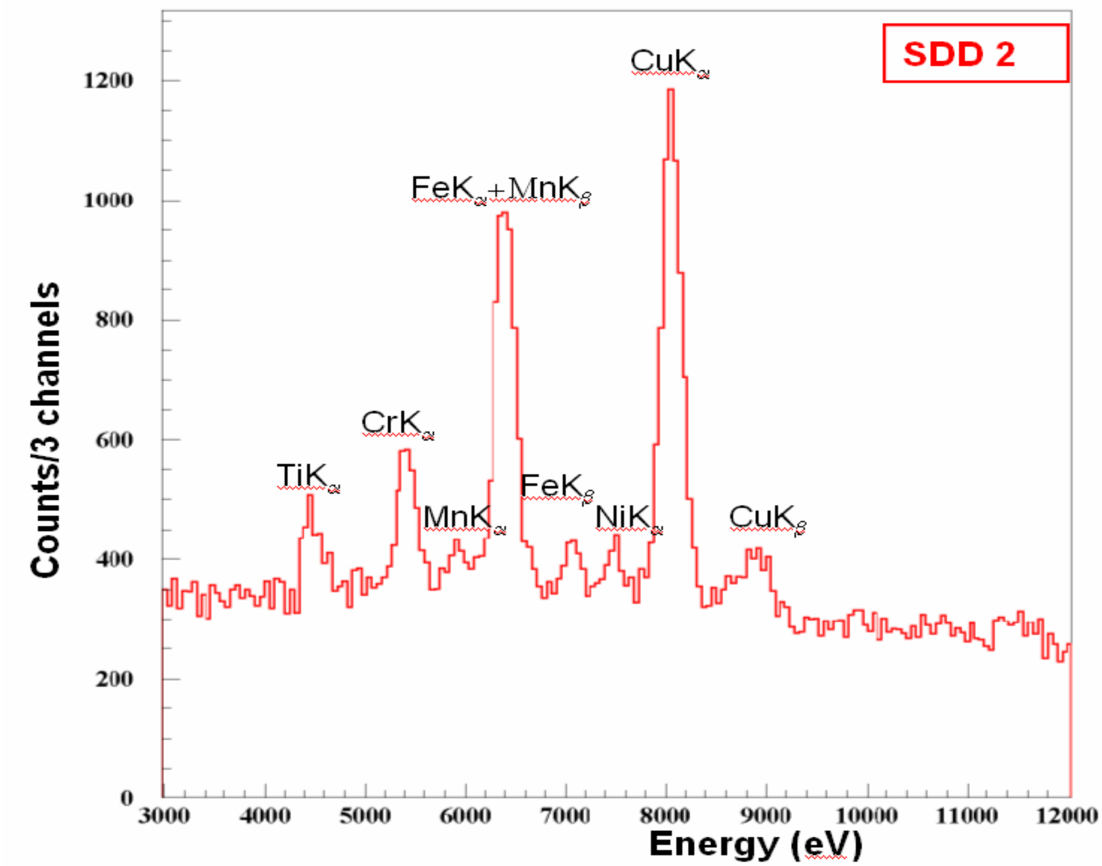

Fig. 8 Measurements with beam, with Sr (830 Hz) and Fe (40 Hz) sources, with TRIGGER OFF, lasting 2 hours, with an incident rate on SDDs of about 900 Hz

After having performed the fit of the spectra, the obtained results were used to check the scale calibration under the hypothesis of a linear or parabolic behavior (using MINUIT fitting procedure).

For the linear behavior the following function was used:

no. channel = a + b * energy (eV).

The linear fit gave a χ^2/NDOF of 2.96. The values of the fit parameters turned out:

a = 28.62+/- 0.78

b = 0.06219 +/- 0.00011 (eV^{-1})

For the parabolic fit: no. channel = a + b*energy + c * $(\text{energy})^2$ the χ^2/NDOF was the same as the one of linear fit and the c-term was compatible (within 1 σ) with zero (a and b were similar to the linear fit).

The result of the fit is shown in Fig. 9, where the experimental peak positions together with the linear fitting curve are shown.

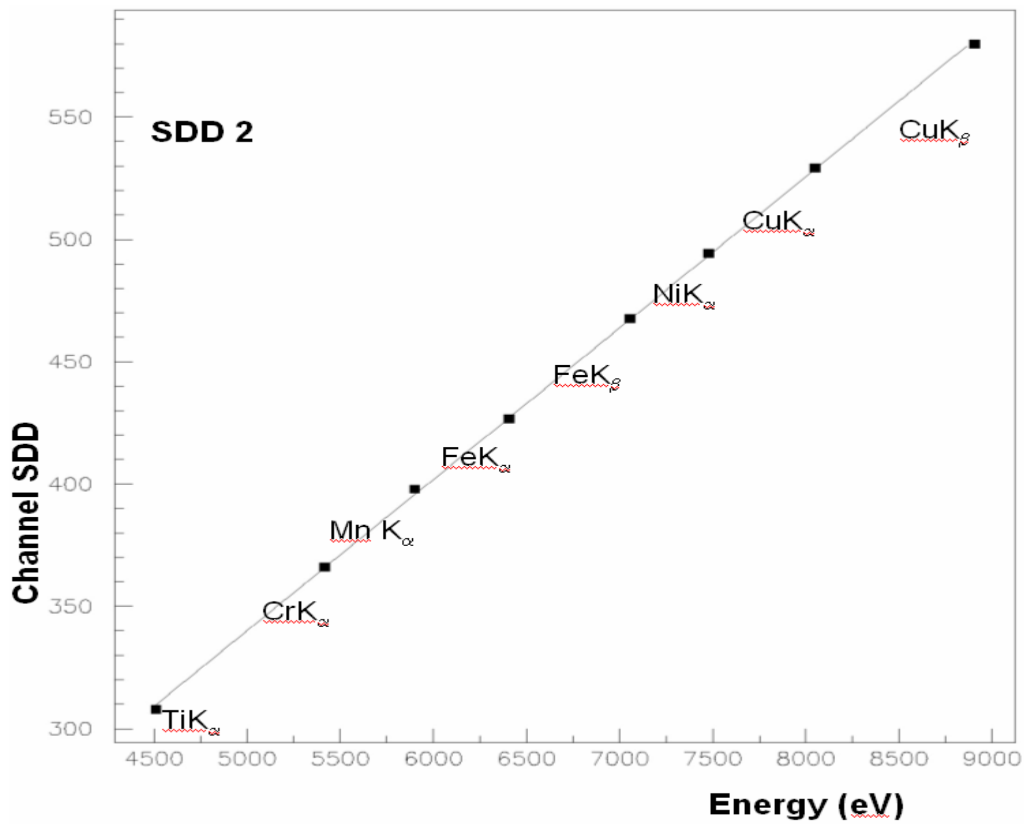

Fig. 9 Linear fit of the experimental peak positions versus energy of transitions (used for SDD linearity study)

In conclusion, the linearity of SDD behavior was checked at BTF at about 0.3% level; further tests – in order to arrive at 0.1% level, will be performed in the laboratory.

3.4 Trigger performance: test for an incident rate ~ 900 Hz with the Fe and Sr sources

The main goal of the measurements performed at BTF was to check the SDDs' answer under realistic beam conditions – in terms of types of particles and energy – and with a trigger system. The trigger was given by the coincidence between a thin scintillator slab hit by the primary BTF electron beam (see Fig. 6) and the SDDs.

In order to perform the test of the trigger performance the following series of measurements were performed:

- a measurements with beam, with Sr (830 Hz) and Fe (40 Hz) sources, with TRIGGER OFF, lasting 2 hours, with an incident rate on SDDs of 900 Hz (Fig. 10);
- a measurement with beam lasting 15 hours, the Fe (40 Hz) and Sr (830 Hz) sources, with the "signal" given by the Cu lines, with TRIGGER ON; an incident rate on SDDs of about 48 Hz was measured (Fig.11);
- a measurement lasting 11 hours, with no sources, with the "signal" given by the Cu lines, with TRIGGER ON; an incident rate on SDDs of about 48 Hz was measured (Fig.12).

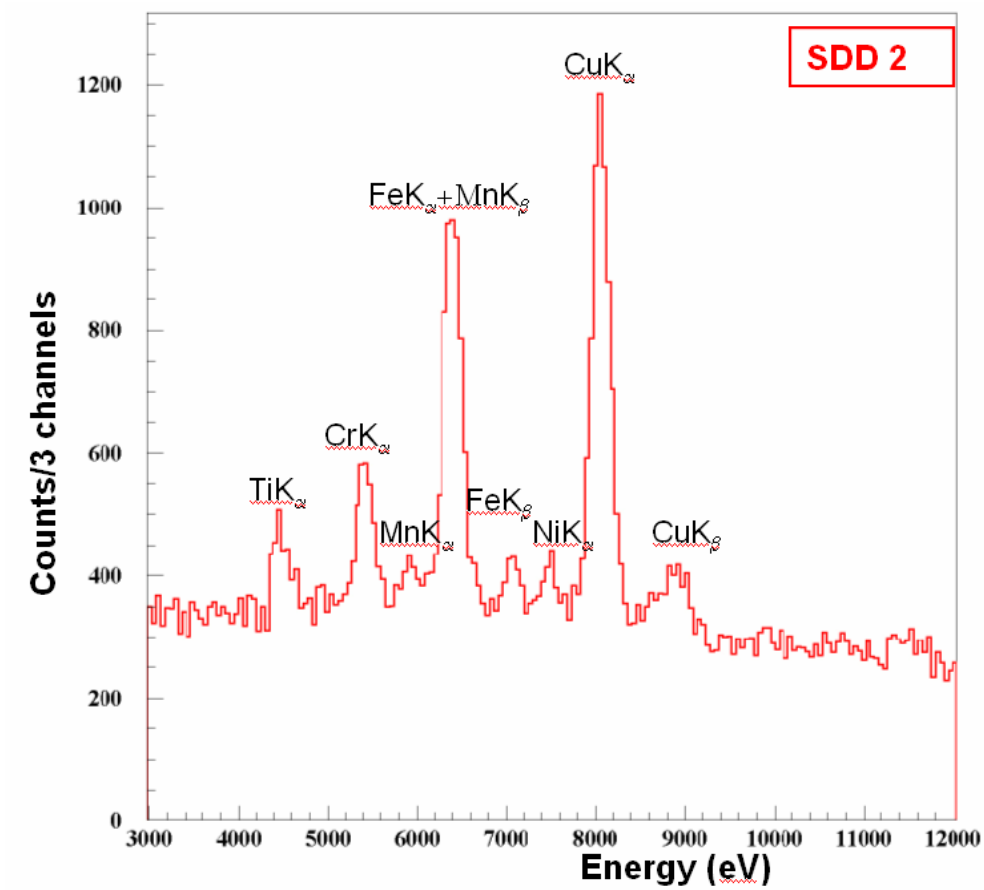

Fig. 10 The measurements with beam, with Sr (830 Hz) and Fe (40 Hz) sources, with TRIGGER OFF, lasting 2 hours, with an incident rate on SDDs of about 900 Hz

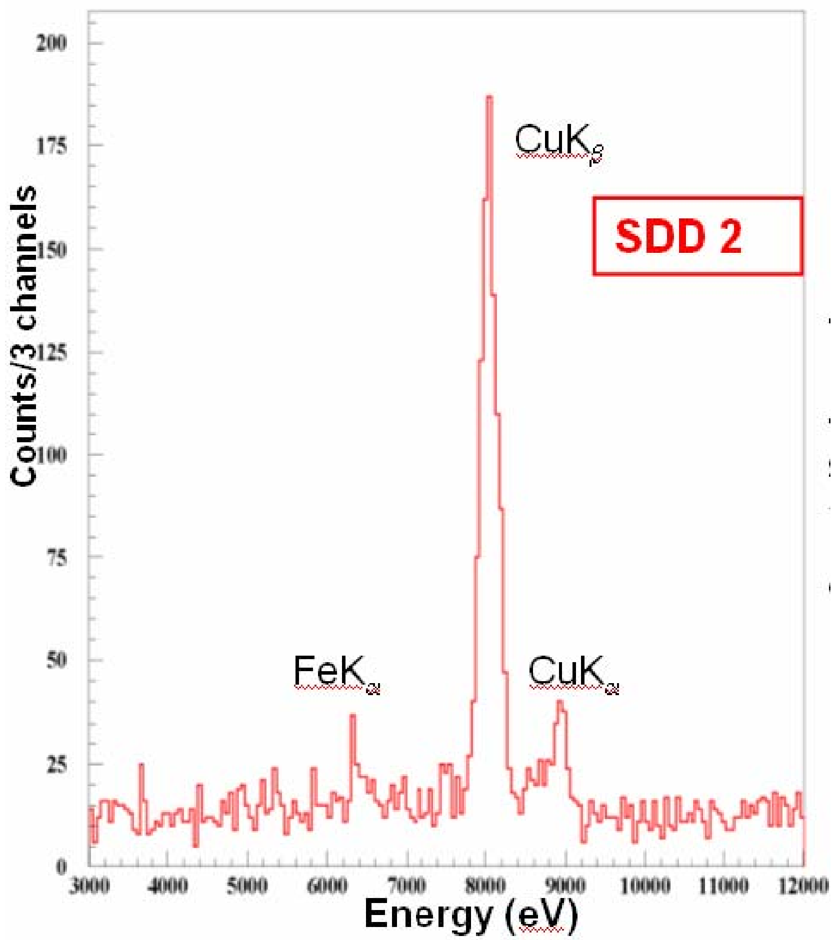

Fig. 11 The measurement with beam lasting 15 hours, the Fe (40 Hz) and Sr (830 Hz) sources, with the "signal" given by the Cu lines, with TRIGGER ON; an incident rate on SDDs of about 48 Hz was measured

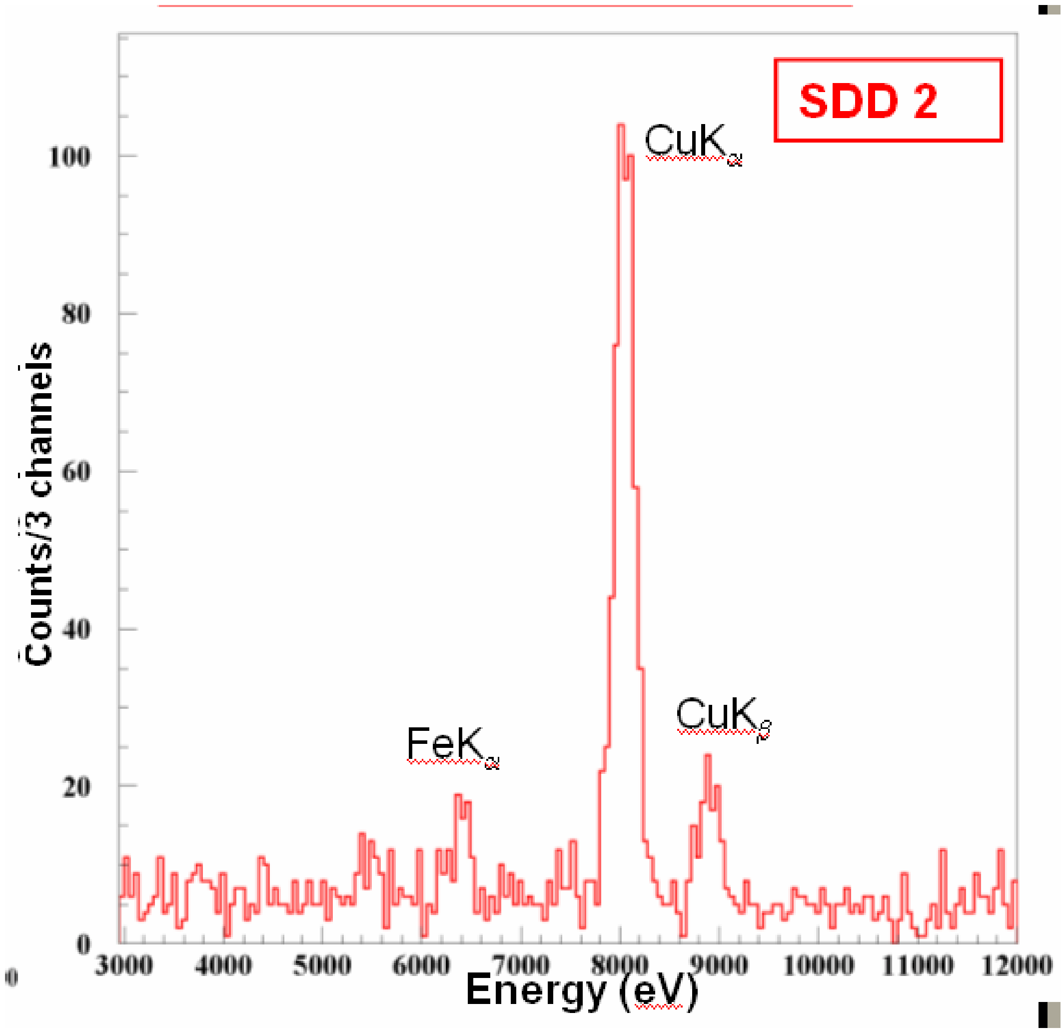

Fig. 12 The measurement lasting 11hours, with no sources, with the "signal" given by the Cu lines, with TRIGGER; an incident rate on SDDs of about 48 Hz was measured

As it can be seen from the figures, trigger completely cuts the background (structured and unstructured) given by the asynchronous sources. The synchronous background cannot obviously be eliminated by the trigger. One thing worth to be mentioned, is that in the energy range in which SDDs are sensible for this test (1–20 keV) only about 10% of the overall incident particles are detected; all the remaining ones, depositing more energy, are counted as overflows.

Numerically:

a) Asynchronous structured and continuous incident background:

R_B = 920-48 = 872 Hz

b) Trigger rate from BTF facility:

R_t= 48 Hz

c) Coincidence window:

C_w = 3μs

d) "Good" synchronous event rate:

Ev_{rate} = 48 Hz

e) Efficiency for production of one good event, i.e. number of events /number of triggers:

$Eff = Ev_{rate}/ R_t = 48/48 = 1/1$

so one "signal" event for 1 trigger;

f) Casual background event rate after trigger:

$R_{casual} = 870 \times 48 \times 3 \times 10^{-6} = 1.3 \times 10^{-1}$ Hz

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

$R = R_{casual} / R_B = 1.3 \times 10^{-1} /870 = 1\underline{5 \times 10^{-5}}$

Conclusion:

For a total incident rate of about 900 Hz on 3 SDD chips with a surface of 1 cm^2 each, the rejection factor measured at BTF, when the trigger rate is 48 Hz and the triggered good event rate 48 Hz, with the trigger coincidence window of 3 μs, is $\underline{15 \times 10^{-5}}$. This result confirms the very good results found in the previous BTF measurements, confirming the feasibility of the SIDDHARTA experiment.

Acknowledgements

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Bibliography

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