SIDDHARTA Technical Note IR - 2

The Preliminary **SIDDHARTA**

(<u>**S**</u>ilicon <u>**D**</u>rift <u>**D**</u>etector for <u>**H**</u>adronic <u>**A**</u>tom <u>**R**</u>esearch by <u>**T**</u>iming <u>**A**</u>pplication)

experimental setup

Johannes Zmeskal

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Content

1. Introduction

The setup for SIDDHARTA follows the successful way of the first stage of kaonic atom research at DAΦNE: the DEAR experiment [1].

As in the DEAR experiment, a cryogenic target cell will be used together with the detector inside a vacuum chamber [2]. A further development of the detector system has become necessary, because of the high beam correlated X-ray background of DAΦNE, *which has to be suppressed more effectively for the high precision kaonic hydrogen and the first kaonic deuterium measurement.* Therefore, a new detector is under development in cooperation with LNF Frascati, MPE Garching, PNSensor Munich, Politecnico Milan, IMEP Vienna and IFIN-HH Bucharest. This new SDD (Silicon Drift Detector) device has an energy resolution as good as the CCDs (Charged-Coupled Device) [3]: 150 - 180 eV at 6 keV, and in addition a timing resolution better than 1µs, necessary for the required background reduction [4,5].

Why is timing so important? The kaons at DAΦNE are produced by the decay of the Φ-mesons (decay channel for a K^+K^- pair has a branching ratio of 49.5%). This offers an excellent possibility to suppress the background using the kaon as trigger for the X-ray coming from kaonic atoms. A signal to background ratio of about 5:1 can be expected for the kaonic hydrogen experiment [6,7].

2. Setup Scheme

In general two different setup schemes are under consideration, depending on the availability of detector chips: size of the SDD array and total active detection area. Both schemes will allow to place detectors around the target cell with a total area between 100–200 cm^2.

In setup version V.1 the SDDs are placed on top of the target cell, while in version V.2 a similar system, as that already successful used in the DEAR experiment, is discussed.

A Monte Carlo simulation for version V.1 was performed [7]. This calculation has shown, that the new design leads to a very efficient target detector arrangement, approximately 12% of all generated kaons will stop in the target cell. In total we could expect about 400 X-rays (from the K_α transition of kaonic hydrogen) for a detector area of 200 cm^2 and an integrated beam luminosity of 1 pb^{-1}.

Common for both setup schemes is the use of a cryogenic target cell to achieve the necessary target gas density with a moderate gas pressure. This is important to minimize the target material and to avoid Bremsstrahlung generation close to the detector as well as the production of fluorescence X-rays.

The detector system has to be mounted as close as possible around the target cell to maximize the solid angle. The SDDs will be cooled to approximately 220 K to get a better energy resolution and to reduce the cooling power for the cryogenic target.

Both target cell and detector, including preamplifier boards, are mounted inside a vacuum chamber (insulation vacuum better than 10^{-6} mbar) to allow the cryogenic system to work: target cell at 25 K, detector at 220 K.

2.1 Setup Version – V.1:

In setup V.1 the SDDs are placed close to the top window of a cylindrical target cell. The 50 µm kapton window in direction to the detector will be reinforced by a honeycomb grid made of ultra-pure aluminum.

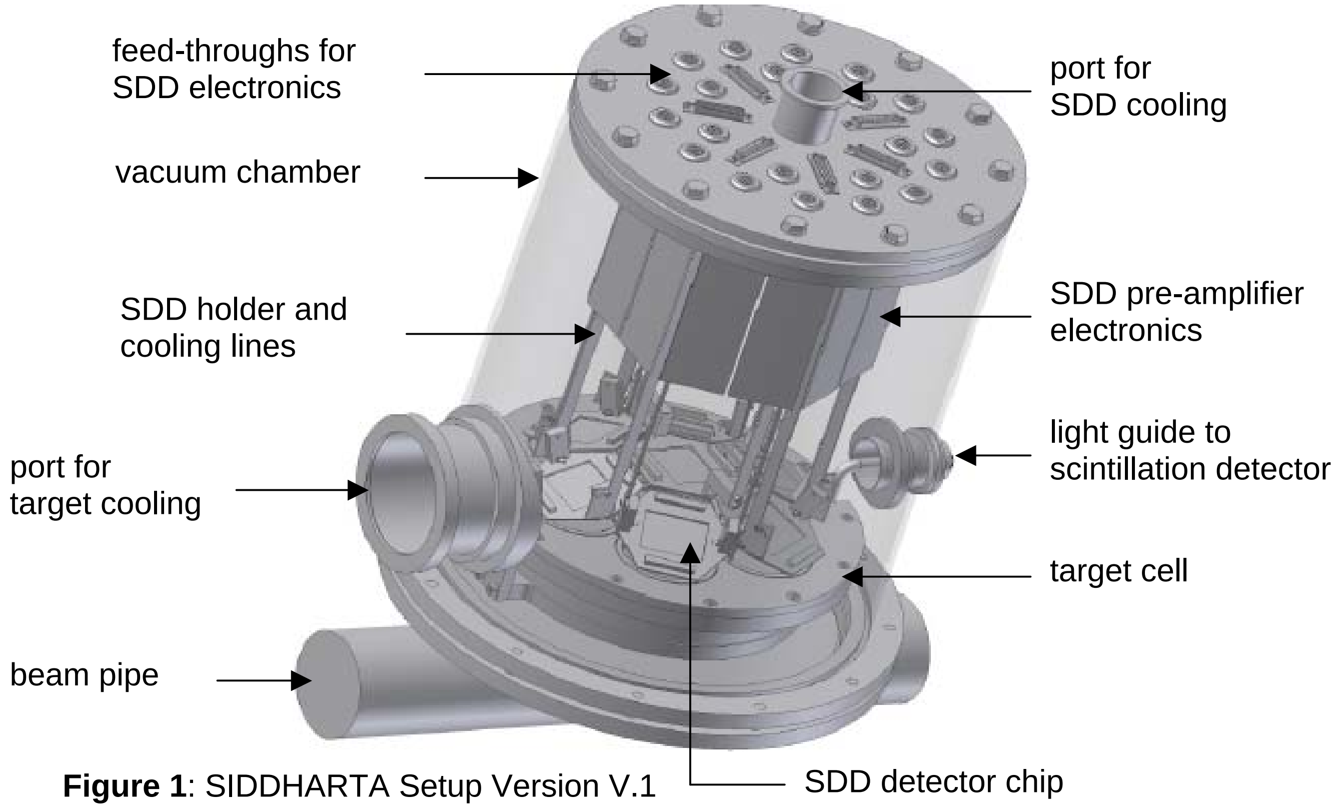

Figure 1: SIDDHARTA Setup Version V.1

The SDD-array is held in place by aluminum bars, which are also used for cooling the SDD-chips. Pre-amplifier boards are mounted also inside the vacuum chamber close to the top flange with the necessary electrical feedthroughs for the detector electronics, placed outside around the top of the vacuum chamber.

Below the target entrance window, 125 µm kapton, a plastic scintillator is foreseen. The scintillation detector with a thickness of 1 mm will be implemented in an auxiliary device used to trigger the SDD detector with the incoming kaons.

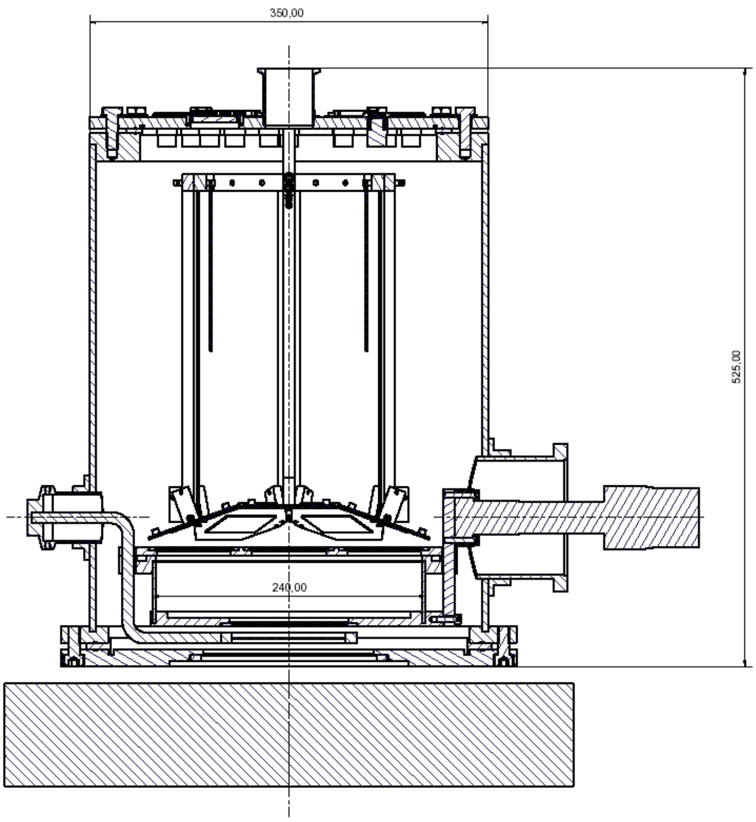

Figure 2: SIDDHARTA Setup Version V.1 – schematic drawing

The trigger system consists in a coincidence between the SDD signal and a signal associated to the production of the exotic atom, in this case, the production of a K^+K^- pair. The signal associated to the event is given by a device similar to the Kaon Monitor operating in DEAR, put, in this case, in vertical, instead of on radial plane. Two counters, one below the target entrance window, above the beam pipe, the second below the beam pipe, detect the back-to-back correlated pair from φ decay. The second counter, that below the beam pipe, can also consist in two scintillators, put in coincidence, to further clean the signal associated to the production of the exotic atom.

With this configuration the required background suppression will be made possible, an expected signal to background ratio of about 5:1 for the kaonic hydrogen measurement is feasible. Just for comparison, in the DEAR experiment done at DAΦNE, at the end of 2002 with the CCD detector, the signal to background ratio was in the order of 1:100.

2.2 Setup Version – V.2:

The design proposal of version V.2 follows the successfully installed DEAR setup.

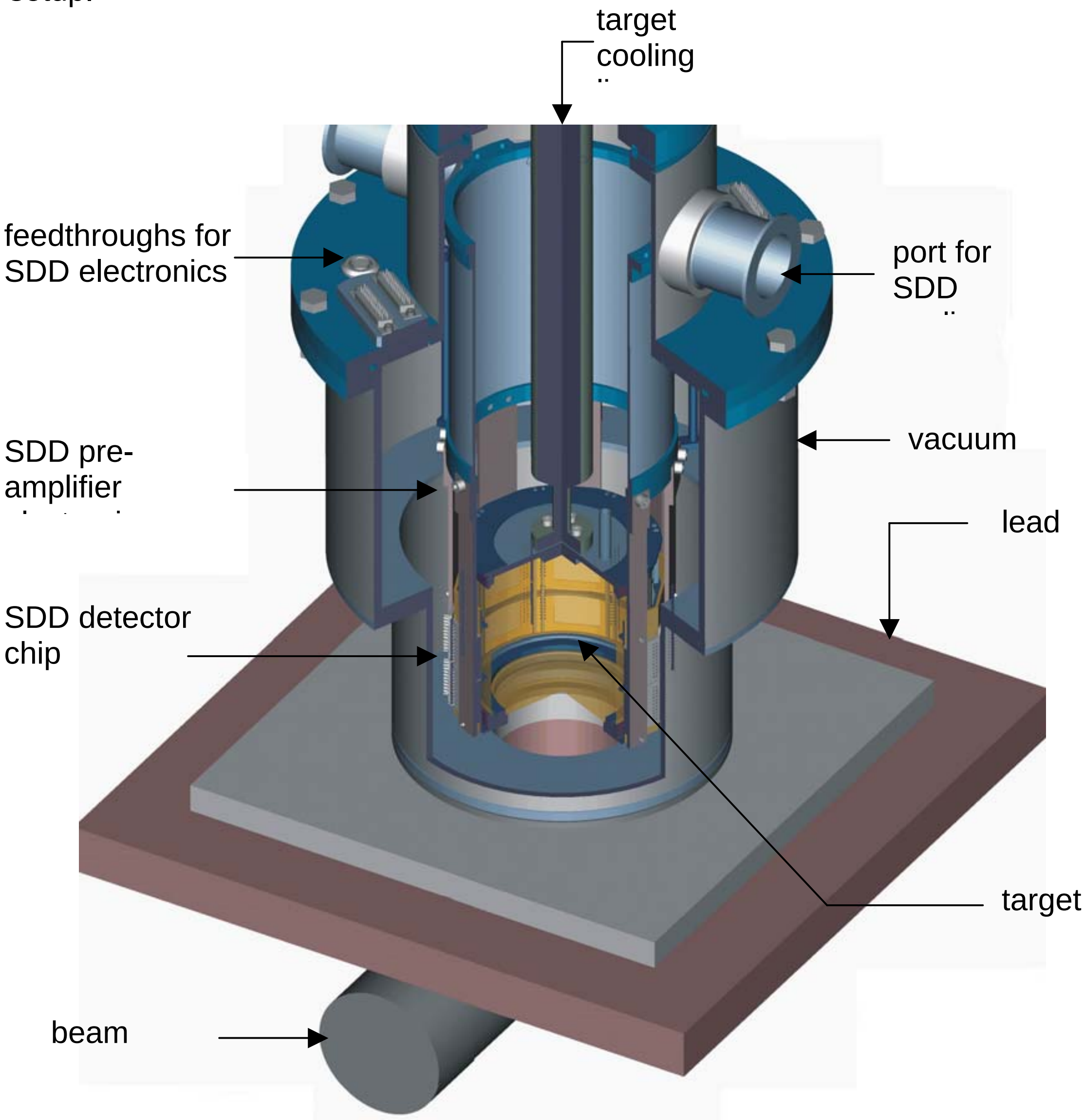

Figure 3: SIDDHARTA Setup Version V.2

The SDDs are placed around a cylindrical light weight target cell as shown in figure 3. The working conditions for the target cell are around 25 K, while the SDDs will work at 220 K. Target cell, detector and part of the detector electronics are inside a vacuum chamber, with a pressure below 10^{-6} mbar.

3. Target Cell

For both target types the materials in use will be carefully selected and the amount of materials minimized. To test the materials used in the construction of the target cell, a material test facility at VERA in Vienna will be established, using Proton Induced X-ray Emission (PIXE).

Each piece of the target material will be measured to determine the contamination with iron, manganese, and so on (all that produces fluorescence X-rays in the region of interest of the proposed experiment).

3.1 Target Cell Version – V.1:

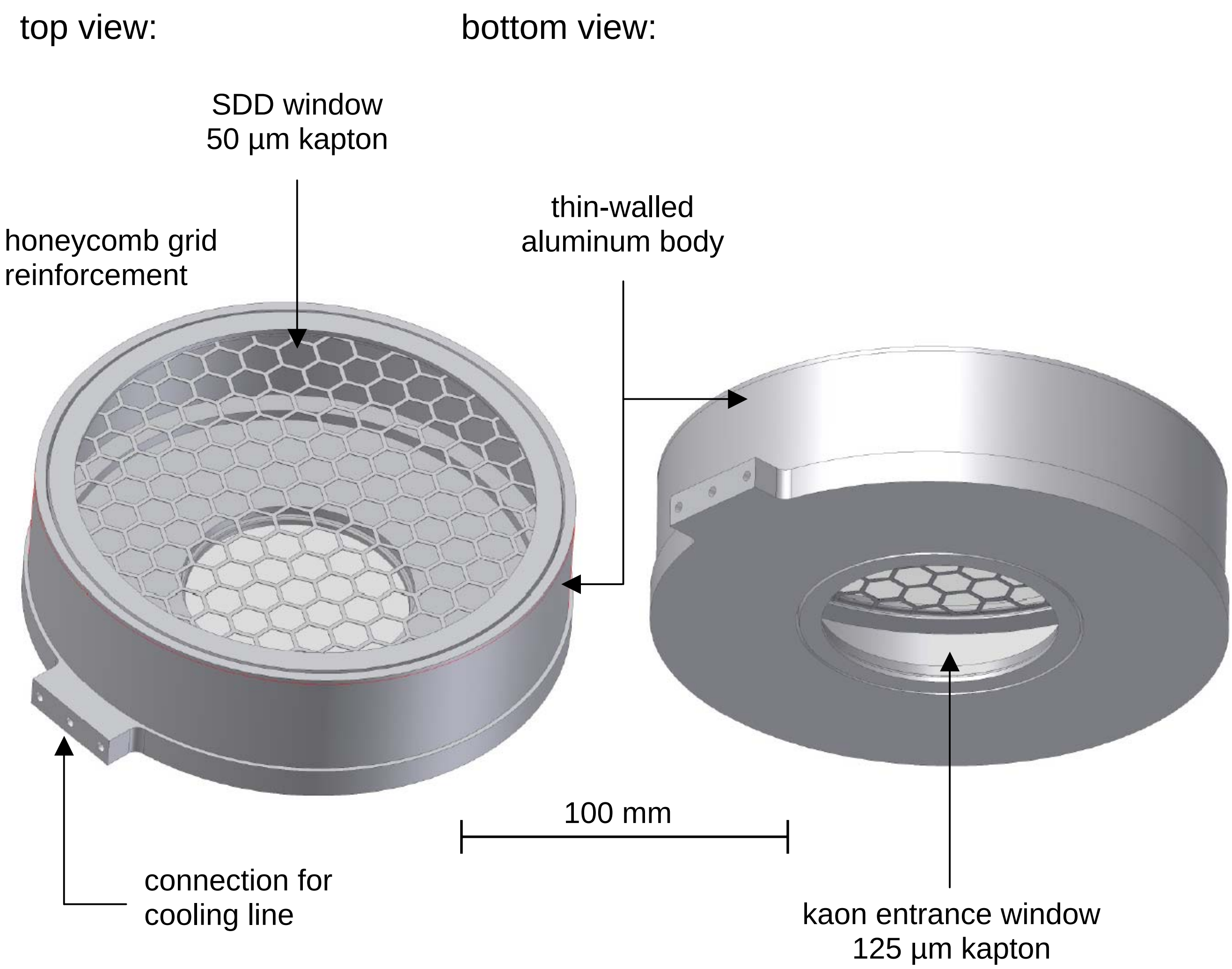

Figure 4: The target cell version V.1

The target cell will be made of three pieces:

- the top part, an aluminum ring with a 50 µm kapton foil, reinforced by a honeycomb grid of ultra-pure aluminum, glued together with a low temperature resin,
- a thin cylindrical aluminum wall,
- and a bottom part with the kaon entrance window, made of 125 µm kapton, glued in an aluminum ring with a connection to the refrigerator system.

3.2 Target Cell Version – V.2:

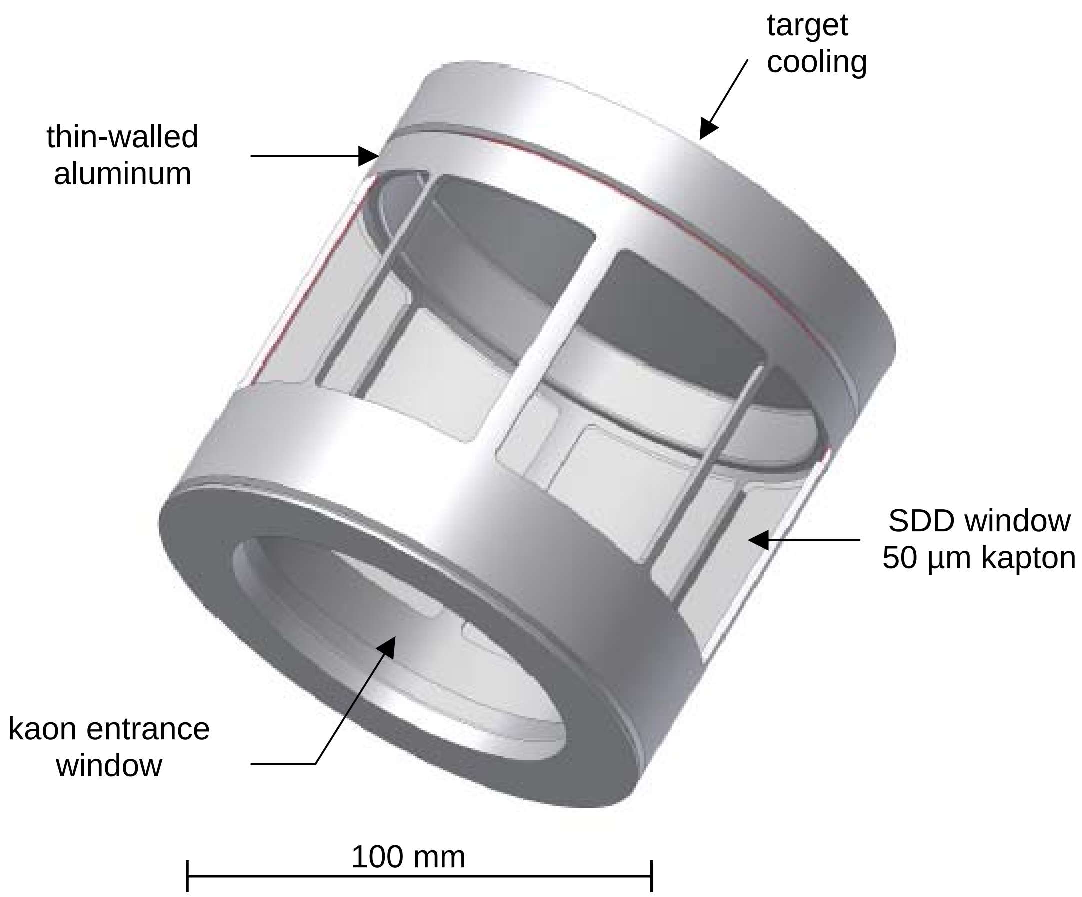

Figure 5: The target cell version V.2

4. SDD Detector System

The main advantages of the SDD are their timing properties, timing resolution below 1µs for 100mm^2 chips can be expected. Therefore, background reduction can be achieved with a coincidence between the signal of a kaon – creating the exotic atom - provided by the auxiliary detector described in Section 2.1 and the signal of the SDD.

First SDD devices (a 10 mm^2 single chip and a 7x5 mm^2 array) were already tested at IMEP in Vienna and at LNF Frascati.

In additon, a two-week beam time at the Beam Test Facility (BTF) of LNF (with a 500 MeV pulsed electron beam) was used to check the performance of this two different SDD devices under more realistic experimental conditions and under trigger (see details in [6]).

The energy resolution of a 10 mm^2 single chip is shown in figure 6, measured with an Fe-55 source. A comparable good energy resolution was measured with a CCD detector.

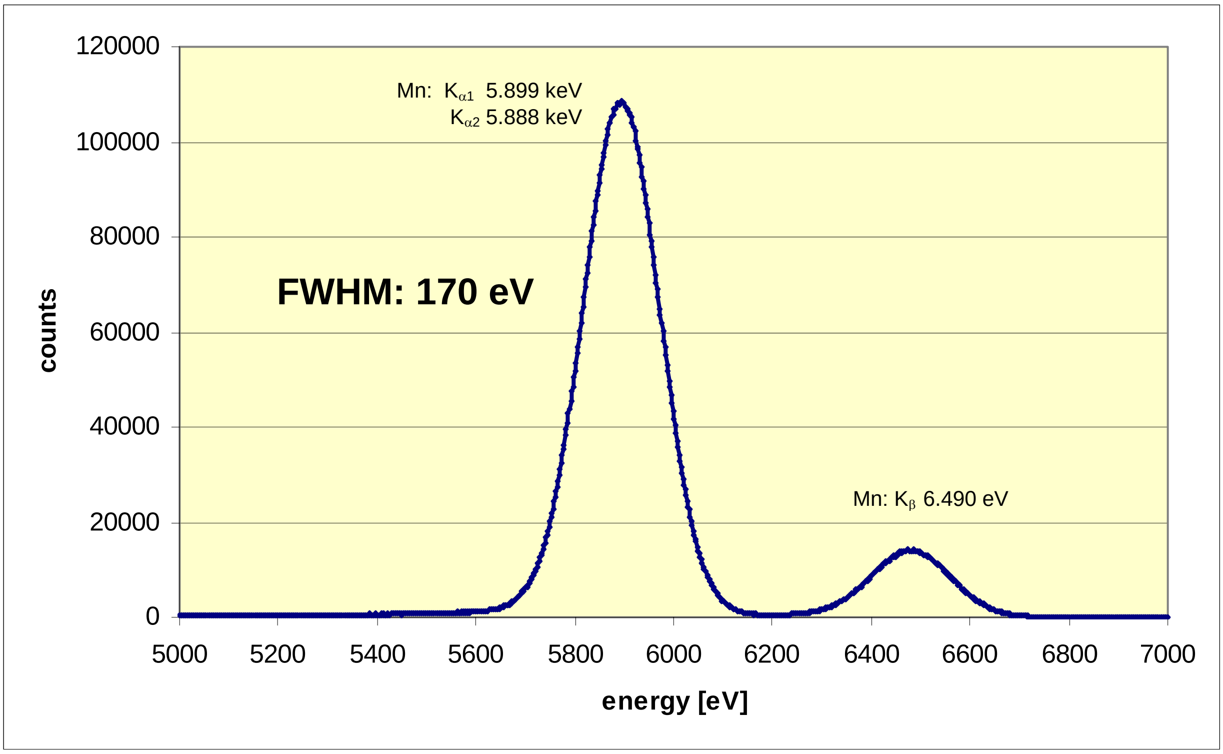

Figure 6: Energy resolution of a 10 mm^2 SDD chip measured with an Iron Source

5. Cooling System:

5.1 Target Cell

For the target cell a two-stage closed-cycle helium refrigerator with 8W at 20 K will be used. A copper bar connects the target cell and the cold end of the expander head of the refrigerator to transfer the heat. The temperature is measured with two carbon-glass sensors, one on top of the target cell, the other one at the cold-end of the refrigerator with an accuracy of about 20 mK. The target gas pressure will be measured with a piezo-resistive device with an accuracy of about 10 mbar. A PID-controller using the output of the pressure sensor will allow to stabilize the pressure to better than 50 mbar.

Figure 7 shows the stability of temperature and pressure of the DEAR target cell during data taking in Oct. 2002.

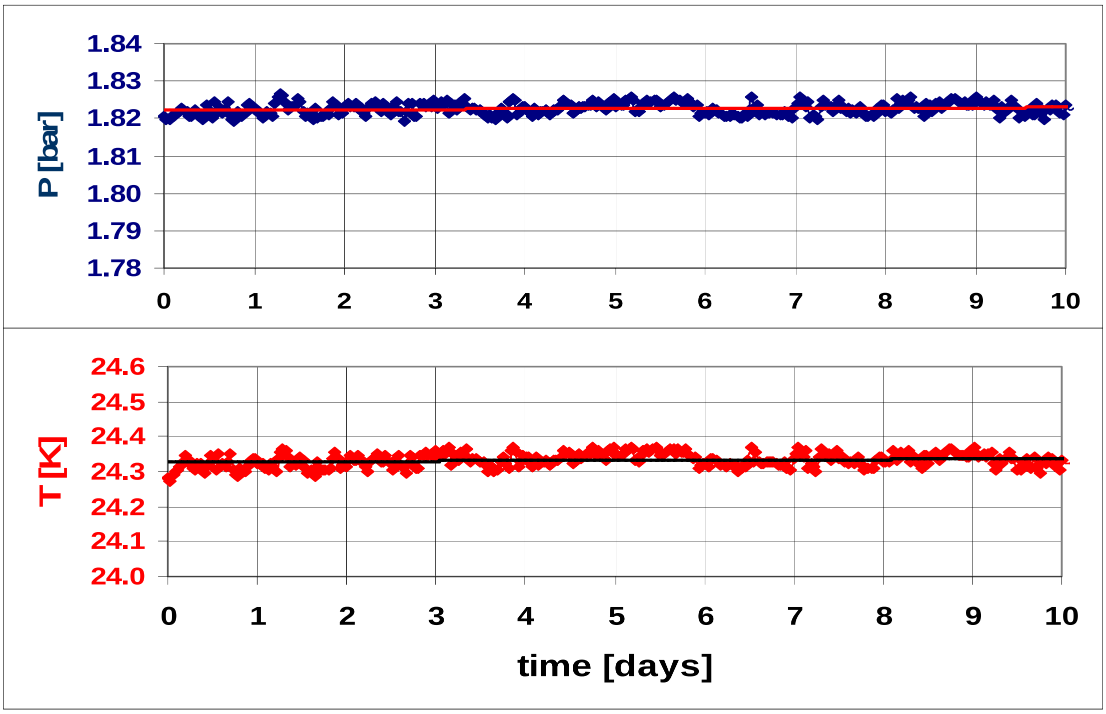

Figure 7: Pressure and Temperature stability during DEAR measurement in October 2002

5.2 SDD Detector

A closed-cycle refrigerator (CryoTiger, 20 W at 100 K) will be used to keep the SDD detector at a temperature of about 220 K. The temperature of the SDD frame will be measured using Pt-100 sensors. The temperature of the SDDs will be stabilized to better than 0.1 K with a Lake Shore controller.

References:

[1] J. Zmeskal et al., DAFNE Exotic Atom Research – Results and Future Perspectives; Proceedings EXA02 (2003) 113

[2] J. Zmeskal et al., Frascati Physics Series, Vol. XVI (1999) 355

[3] J.-P.Egger, Hyperfine Int. 119 (1999) 291

[4] J. Marton, et al., Target and Detector Systems for Exotic Atom Experiments; Proceedings EXA02 (2003) 223

[5] Proposta di nuovo esperimento SIDDHARTA (Silicon Drift Detector for Hadronic Atom Research by Timing Application), 14/07/03 – Commissione 3°, preventivo 2004, Modulo EN5.

[6] SIDDHARTA Collaboration, *SIDDHARTA Technical Note IR – 1,* "Tests of prototype Silicon Drift Detectors to be used in SIDDHARTA (Silicon Drift Detector for Hadronic Atom Research by Timing Application) performed at the Beam Test Facility (BTF) of LNF in the period 21st – 31st July 2003", 25 August 2003.

[7] Catalina Petrascu, SIDDHARTA Technical Note IR – 3, "Preliminary Monte Carlo simulation of the SIDDHARTA (Silicon Drift Detector for Hadronic Atom Research by Timing Application) setup and performance", 25 August 2003.