Commissioning of the ANKE Silicon Tracking Telescopes at the Polarized Internal Target

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Abstract

The ANKE collaboration asks for two weeks of beam time for commissioning of the Silicon Tracking Telescopes together with the Polarized Internal Target PIT. The first week should be scheduled right after the next PIT installation (Experiment 146.2). A second week is only conditionally needed depending on the outcome of this first week.

The Silicon Tracking Telescopes are an essential device for the future ANKE program Spin Physics from COSY to FAIR, COSY Proposal # 152, 2005. Within this program they will combine spectator proton detection, vertex reconstruction and polarimetry. A prototype has already shown its excellent performance together with the ANKE cluster-jet target and can be operated close as 20 mm to the COSY beam within the accelerator vacuum. The purpose of this week is to show that they can also be operated under PIT conditions with cooled and stacked beam through the storage cell at injection and stochastic cooling at a flat top momentum higher than 3 GeV/c

- 5mm close to the PIT storage cell, surviving the COSY beam-losses at injection,
- in presence of the PIT hydrogen atoms,
- not affected by the H-atoms from the electron cooler,
- unaffected by the vibrations induced by the Kryo-pumps in the ANKE target section,
- and later (2nd week) together with the PIT deuterium gas.

1 The ANKE Silicon Tracking Telescopes

Modular Silicon Tracking Telescopes, based on double-sided silicon strip detectors have been developed [1]. Serving in general for

- low energy spectator proton detection/tracking and
- vertex reconstruction into the ANKE target region and
- polarimetry.

The telescopes are optimized for the identification and tracking of low energy protons, providing their four-momenta. The identification and tracking of low energy protons allows to use the polarized deuteron gas as a polarized neutron target and e.g. to study reactions of the type $\vec{p}\vec{n} \to pnX$ or $\vec{p}\vec{n} \to dX$.

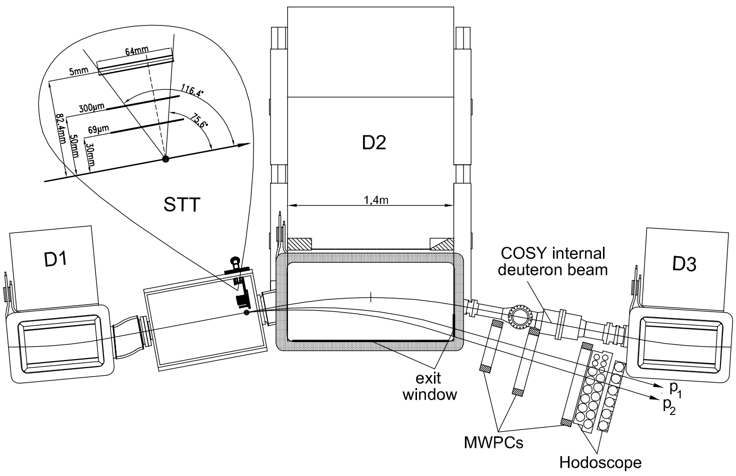

Figure 1: One Silicon Tracking Telescope within the ANKE target chamber.

These telescopes are installed close as 30 mm to the COSY beam inside the ultra high vacuum of the accelerator (s. fig. 1). Their basic features are ΔE/E proton-deuteron identification from 2.5-40 MeV and particle tracking over a wide dynamic range, either 2.5 MeV spectator protons or minimum ionizing particles. Especially the recent development of very thick (5-20 mm) double-sided micro structured Si(Li) and very thin (69 μm) double-sided Si-detectors provides the modular use of the telescopes for particle identification over a wide range of energies.

1.1 The Detection Concept

The basic detection concept of a telescope is to combine particle identification and tracking over a wide energy range. The tracking of particles is accomplished by the use of double-sided silicon strip detectors. The minimum energy of a proton to be tracked is given by the thickness of the most inner layer. It will be detected as soon as it passes through the inner layer and is stopped in the second layer. The maximum energy of protons to be identified is given by the range within the telescope and therefore by the total thickness of all detection layers. Measuring the energy losses in the individual layers of the telescope allows the identification of stopped particles by the ΔE/E method. So by tracking and subsequent precision energy measurements the telescopes provide the four-momentum for stopped particles.

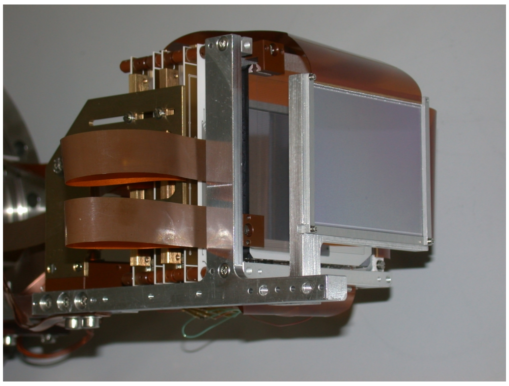

Figure 2: Telescope arrangement of double-sided silicon strip detectors: 69 μm thin, $51 \cdot 66\,\mathrm{mm}^2$ active area as first layer and 5100 μm thick, $64 \cdot 64\,\mathrm{mm}^2$ active area Si(Li) detector as second layer. For this arrangement protons with kinetic energies from 2.5 MeV up to 35 MeV will be tracked and identified.

Depending on the requirements of the individual experiment, four to eight telescopess can be equipped with different sets of silicon detectors and be positioned around the target region to serve for several purposes:

- **Spectator Detector** Low energy protons will be identified and tracked from 2.5-35 MeV. Each telescope covers about 10% of the geometrical acceptance.

- **Vertex Detector** One track in the Silicon Tracking Telescopes defines the vertex in two coordinates (along and vertical to the beam) with a precision of about 1 mm. The third coordinate (horizontal to the beam) can only be fixed with the spacial resolution of the ANKE detection system of about 10 mm. Only two tracks from the same reaction inside the telescopes allows a 3D vertex reconstruction with a precision to about 1 mm. In this case reactions on the walls of the storage cell can easily be identified.

- **Polarimeter** Two protons in the telescopes from the pp-elastic or pp quasi-elastic reaction allow to analyze the polarisation along the storage cell parasitically.

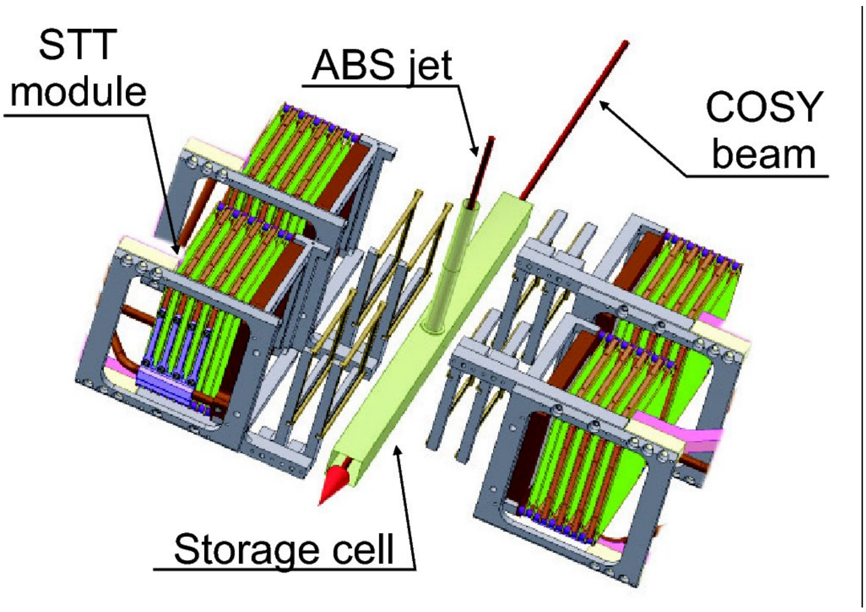

Figure 3: Possible arrangement of four telescopes around the 400 mm long storage cell.

1.2 The Detector Performance

Two telescopes have been assembled and checked together with the ANKE cluster-jet target to evaluate the performance of the choosen detectors. Three types of double-sided position sensitive detectors are arranged as silicon tracking-telescopes.

- The inner layer is 69 μm thick, has an active area of $51 \cdot 66\,\mathrm{mm}^2$ and an effective pitch of about 400 μm. Its thickness sets the detection threshold for protons in coincidence with the second layer to about 2.5 MeV.

- The second layer consists of a 300(500) μm thick detector with an active area of $51 \cdot 66\,\mathrm{mm}^2$ and a pitch of $\approx 400\,\mu$m. It stops protons of kinetic energies up to 6.3(8) MeV.

- The last layer is a 5500(10000) μm thick double-sided Si(Li) detector with a pitch of 666 μm and an active area of $64 \cdot 64\mathrm{mm}^2$ [4]. It stops protons up to 40 MeV and therefore covers most of the dynamic range of the telescope.

Especially the development of very thick (> 10 mm) double-sided micro structured Si(Li) [4] and very thin (69 μm) double-sided Si-detectors provides the use of the telescopes over a wide range of particle energies.

The ΔE/E performance of the detection system is demonstrated in figure 4 and figure 5. In addition to the experimental data the SRIM calculations [3] for the energy losses of protons and deuterons are drawn. With a careful calibration of the system they coincide to about < 3 %. The layout of these modular, self-triggering silicon tracking telescopes provides

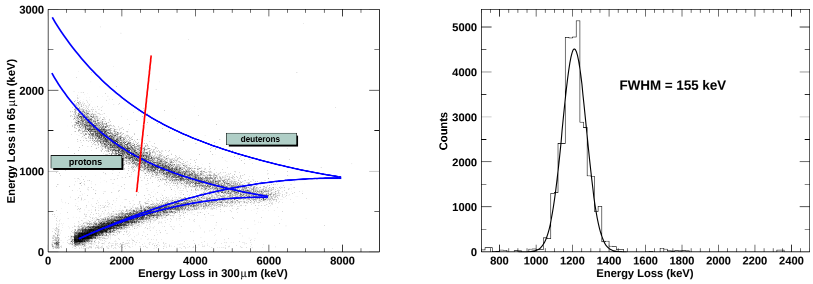

Figure 4: The energy loss in a 60 μm versus the energy loss in a 300 μm thick detector. Only the proton-band is seen. Deuterons can not be seen here because the detectors are placed in the backward hemisphere of the target. The right figure shows the energy resolution along the indicated slice orthogonal to the proton band.

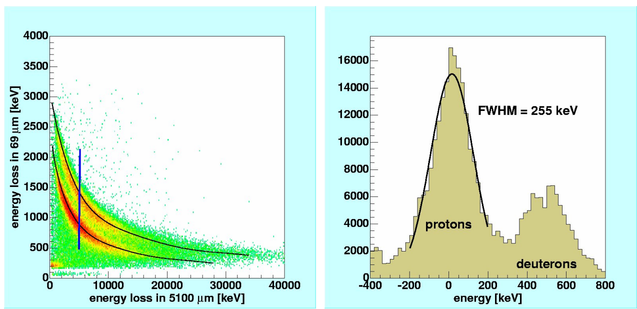

Figure 5: The energy loss in a 69 μm versus the energy loss in a 5100 μm thick detector. The right figure shows the energy resolution along the indicated slice orthogonal to the proton band.

- ΔE/E proton identification from 2.5 up to 40(50) MeV with an energy resolution of 150-250 keV (FWHM). The telescope structure of 69/300/500/5000 μm thick double-sided Si-strip detectors, read out by high dynamic range chips [5], allows ΔE/E particle identification over this wide dynamic range.
- Particle tracking over a wide range of energies, either 2.5 MeV spectator protons or minimum ionizing particles. The angular resolution varies from 1°-6° (FWHM). It is on the one hand limited by the angular straggling within the detectors and therefor also on the track inclination. On the other hand side (e.g. for minimum ionizing particles) it is limited by the strip pitch of about 400-700 μm and the distances between the detectors. A typical vertex resolution for two low energy protons in the telescopes is in the order of $\approx$ 1 mm.
- Self-triggering capabilities. The telescopes identify a particle passage within 100 ns and provides the possibility to set fast timing coincidences with other detector components of the ANKE spectrometer.

2 Requested Time For Measurements

We plan to install one Silicon Tracking Telescope already for Exp. No.: #125.2 ('The Polarised Charge-Exchange Reaction $\vec{d} + p \to (pp) + n$') together with the ANKE cluster-jet target. Studying the reaction $\vec{d} + p \to p + d$ by detecting the deuteron in the ANKE forward detection system and the proton in the telescope, it will parasitically serve as a polarimeter.
For Exp. No.: #146.2 ('Commissioning and Initial Research with the Polarized Internal Target (PIT) at ANKE' it will be de-installed.
The ANKE collaboration now asks the PAC for **ONE week** beam-time to commission the Silicon Tracking Telescopes together with the Polarized Internal Target PIT. This week should be scheduled right after the PIT commissioning (Exp. No.: #146.2). The purpose of this week is to show that the Silicon Tracking Telscopes can also be operated under PIT conditions with cooled and stacked beam through the storage cell at injection and stochastic cooling at a flat top momentum higher than 3 GeV/c

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- and later (2nd week) together with the PIT deuterium gas.

Studying the reaction $\vec{d} + \vec{p} \to p + d$, the performance at the polarized target can be directly compared with the data taken with the unpolarized cluster-jet target.
A second week is conditionally needed depending on the outcome of this first week.

References

[1] R. Schleichert et al., IEEE Trans. Nucl. Sci., vol. 50, no. 3 (2003) 301;

[2] G. Riepe, D. Protic, *Thick Silicon Strip Detectors*, Nucl. Instr. Meth., vol. 226, pp. 103-106, 1984

[3] The Stopping and Range of Ions in Matter, version 2000.24. Available: http://www.srim.org

[4] D. Protic, T. Krings, R. Schleichert, ”Development of Double-Sided Microstructured Si(Li)-Detectors” Contribution on RTSD Workshop, IEEE Conference 2001, San Diego, USA.

[5] The IDEAS/Norway homepage, http://www.ideas.no