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Silicon Detectors for Low Energy Spectator-Proton and Luminosity Measurements at ANKE

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Abstract

One of the physic goals of the ANKE spectrometer with the proton beam of the Cooler Synchrotron COSY-Jülich are studies of elementary reactions on an **effective neutron target**. By the identification of the low energetic spectator proton one can tag the reaction on the neutron using a thin deuterium target. For these measurements a dedicated **spectator detector** has been developed and was installed into the vacuum of the ANKE spectrometer. Its telescope-like structure of several layers of silicon-strip detectors provides the $\Delta E/E$-identification of protons and deuterons over a large dynamic range, as well as track information for these particles. Parasitically this setup proved to be capable to provide the luminosity, needed for the determination of any cross section at ANKE.

Meson production on the neutron

A proposal to measure the cross sections for pn→dω and pn→dϕ on the neutron of a deuterium target near threshold has been submitted by the ANKE collaboration and was accepted [1]. At first the reaction **$pd \to d\omega p_{sp}$** at a beam energy of 2.0 GeV, which is about 200 MeV above threshold for the ω-production on a free nucleon, is planned to be measured with an expected cross section of about 50 μb.

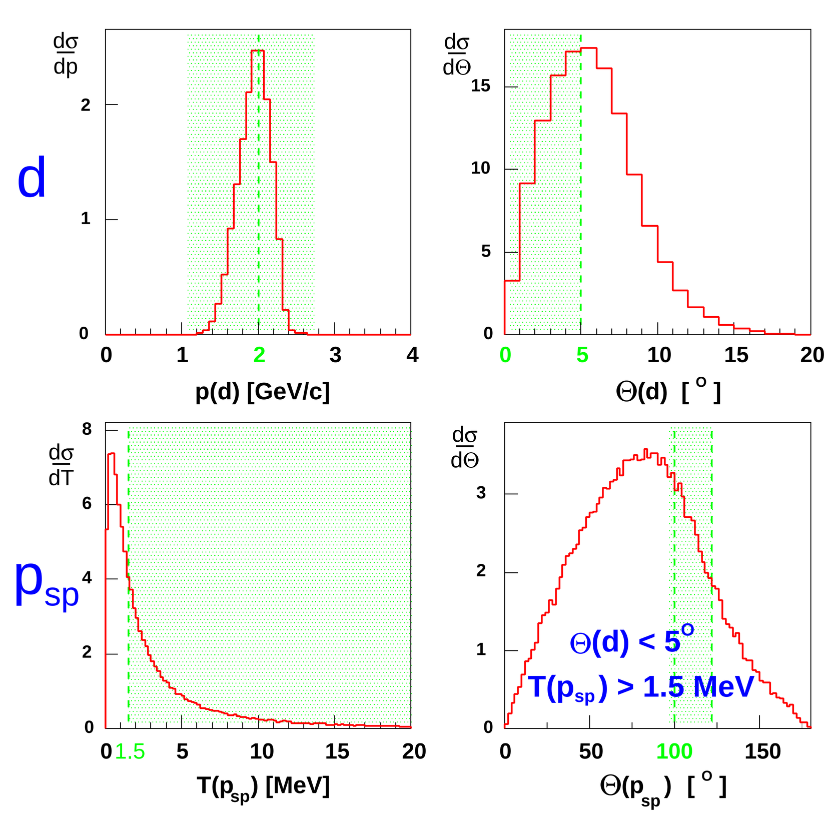

Figure 1: Momentum (energy) and angular distributions for deuterons and spectator protons at 2 GeV beam energy by simulations of ω-production [2]

Simulations [2] (see figure 1) show that deuterons with momenta of about $2\,\frac{\text{GeV}}{c}$ have to be detected under forward angles less than 10°, and spectator protons are isotropically distributed in an energy range peaked at 1 MeV[1]. The ANKE acceptance (marked in green) leads to a spectator proton distribution broadly peaked around 90°. Considering background, one finds the angular range from **100° to 120°** to be optimally suited for the detection of spectator protons.

Setup at ANKE

ANKE is a magnetic spectrometer installed in the storage ring of COSY. The proton beam interacts with the deuterons of the cluster-jet target at a luminosity of about $10^{30}\frac{1}{\text{cm}\cdot\text{s}}$. The deuterons from the ω-production will be detected in the forward detection system of the ANKE spectrometer. The spectator protons in an energy range of **1.2 to 30 MeV** can be detected in the **spectator setup**, which is sketched in a magnified detail in figure 3.

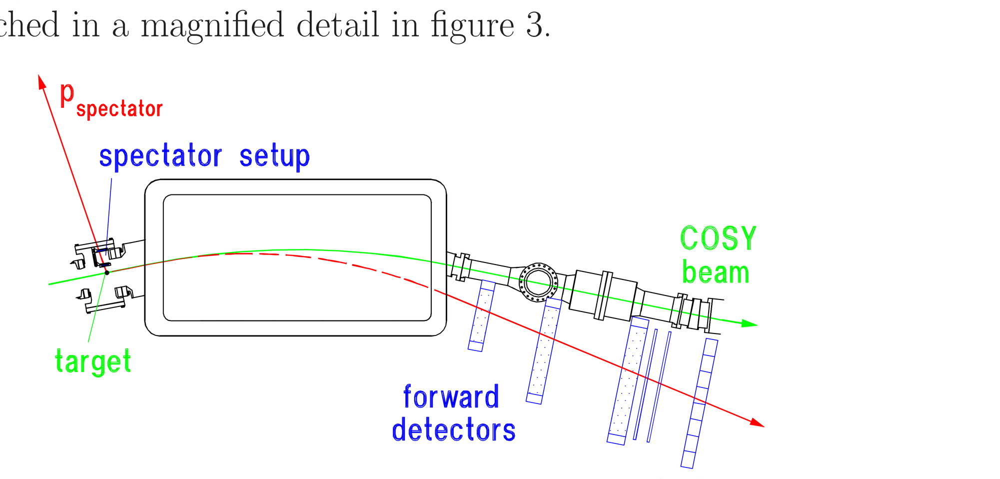

Figure 2: Detector setup at ANKE: Under forward angles 3 multi-wire proportional chambers define the track of a particle, whereas a scintillator hodoscope and Čerenkov counters are used for particle identification[2]

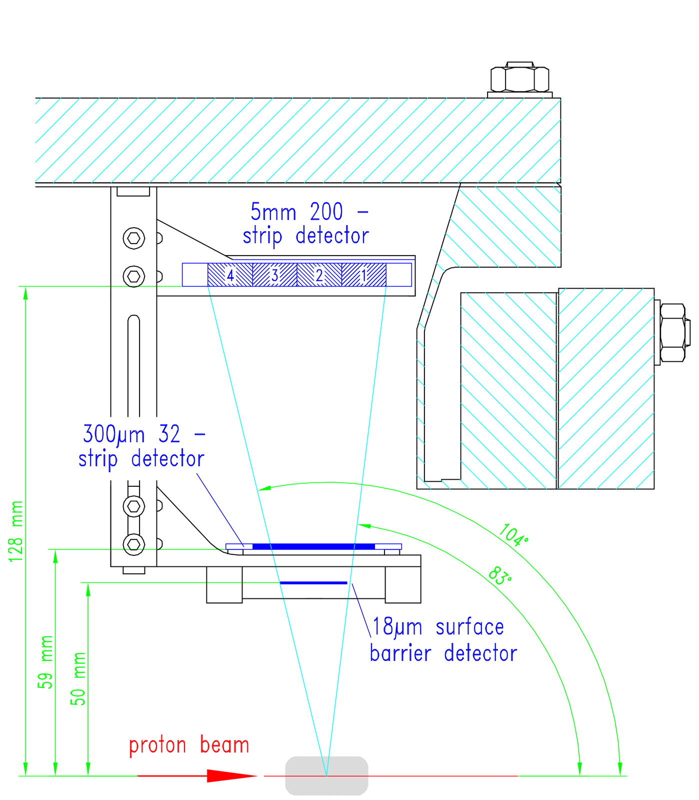

Figure 3: Spectator setup inside the target chamber of ANKE

[1]The ω-meson or its decay products can not be detected fully with the current ANKE setup, but its missing mass can be reconstructed.
[2]The side and backward detectors used at ANKE are not shown in this figure.
[3]The higher energetic particles can be easily identified as shown below.

Detector Tests at Cologne

A test of our setup with the well defined proton beam of the Cologne-Tandem accelerator has been performed. The Tandem-energy range from 2 to 18 MeV was ideally suited to check our detectors for the following properties:

Energy Resolution: The energy calibration of the detectors with an α-source has been checked with the Tandem beam. With the applied corrections the α-energy calibration reproduces these proton energies within **less than 1%**.

Spacial Resolution:

The 5 mm-strip detector could be precisely (≲ 1 μm) moved with respect to the beam profile. We can conclude, that the absolute position of a track in this detector can be determined within **less than 300 μm**.

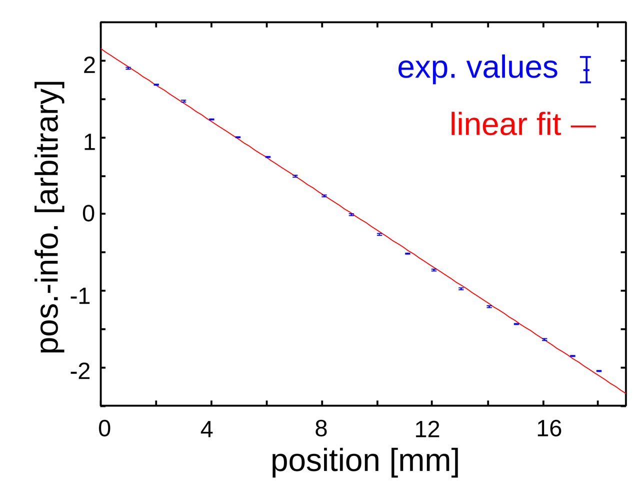

Figure 4: Position information from the detector vs. detector position

Limitation of the angular resolution by straggling:

At the ANKE setup an angular resolution of **less than 3°** is feasible for proton energies higher than **8 MeV**. With an 18 μm thick first layer a similar resolution is principally feasible for energies from **2 MeV** upwards.

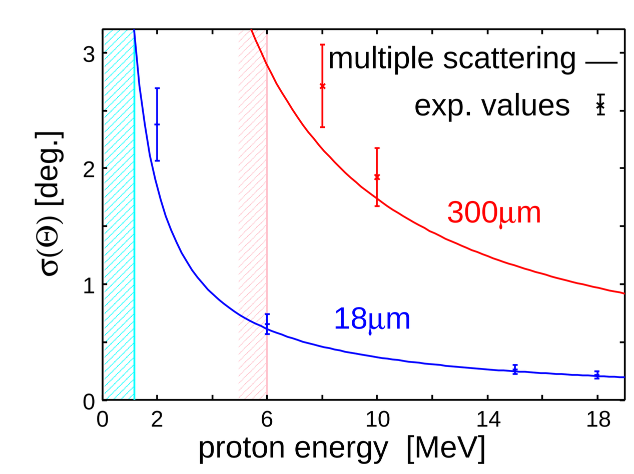

Figure 5: Calculated multiple scattering and experimental straggling

Particle Identification below 6 MeV:

Below 6 MeV protons can be in principal identified by the 18 μm thick surface-barrier detector and the 300 μm thick strip detector[3]. But the expected **proton-deuteron-band separation** for the $\Delta E/E$-identification is only **150 keV**. The **energy resolution** for this detector has been tested to be **130 keV**. In figure 6 this can be seen in comparison, which shows, that a particle identification with this detector is at the limits of its capability.

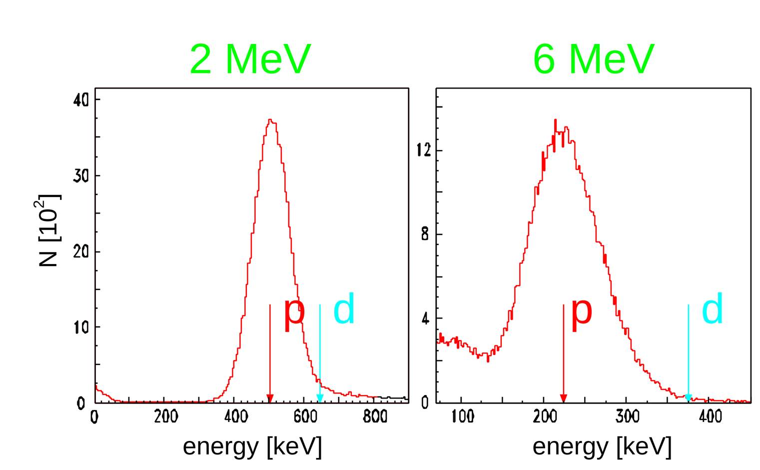

Figure 6: Measured energy losses for protons of 2 and 6 MeV in the 18 μm detector (arrows: expected mean values for p and d)

This leads to the conclusion, that the combination of a 300 μm thick strip detector and the 5 mm thick micro-strip detector is able to fulfil the requirements for the spectator and luminosity measurements at ANKE. The crucial energy resolution in the 18 μm thick surface-barrier detector should be cross checked at the experiment.

Luminosity at ANKE

In September 1999 first measurements with 2 GeV protons on a deuterium-cluster-jet target were performed at the ANKE spectrometer. In figure 7 the energy losses in the 300 μm versus the energy losses in the 5 mm thick detector are plotted. The elastically scattered deuterons are clearly seen under forward angles whereas under backward angles only protons can be seen. The deuterons can now be selected and used for the luminosity determination.

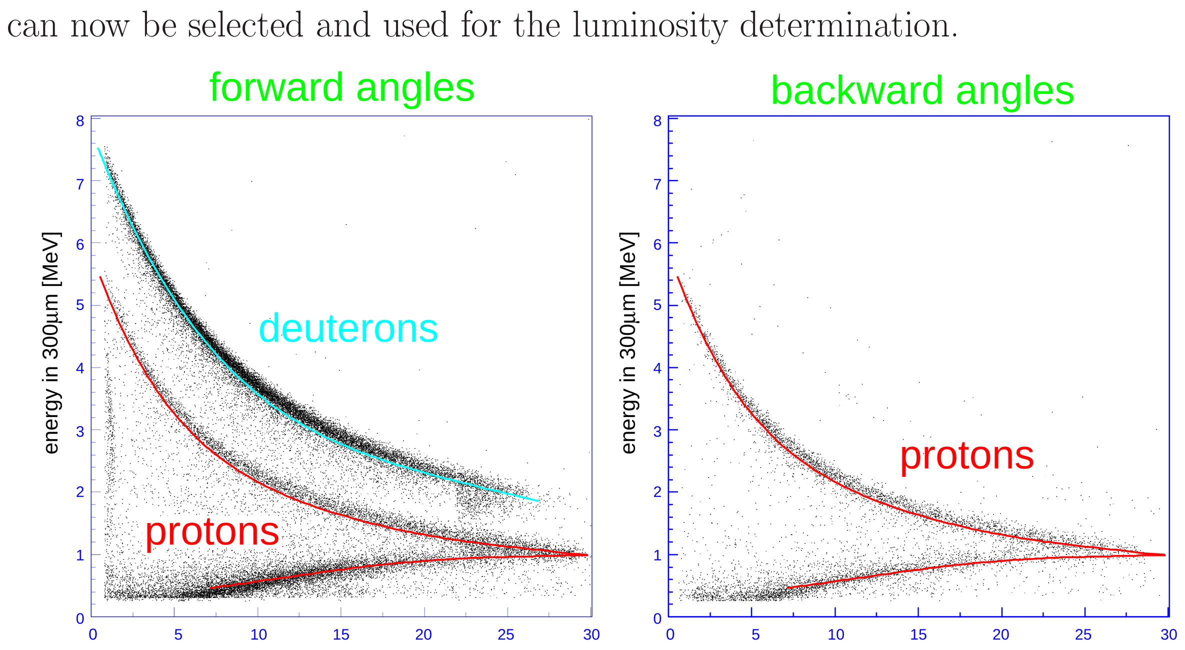

Figure 7: Particle identification and check of the α-energy calibration by comparison with the calculated energy losses (coloured lines)

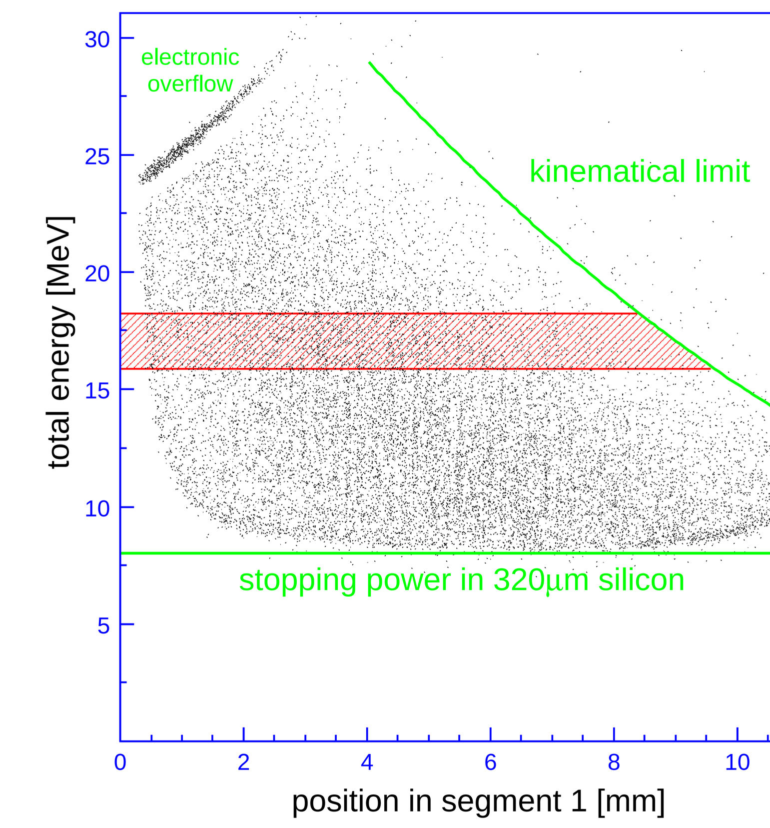

Figure 8: Total energy vs. position of elastically scattered deuterons showing the expected kinematical limitations

We selected pd-elastic scattering as a reaction with a known cross section at 2 GeV incident proton energy[3] and measured the scattered deuterons at large angles (close to 90°). The rate of deuterons from 16 to 18 MeV total kinetic energy (marked red in figure 8) has been used to calculate luminosity, minimising errors due to calibration, energy losses, angular straggling, efficiency and cross section.

Results: We were able to obtain:

- **the absolute luminosity within 18%**
- **the relative luminosity within few %**

The rather large errors have two main reasons:

- Available data on the cross-section of pd-elastic-scattering is unfortunately scarce and not very accurate.
- Only a part of the target can be used. Therefore we have to take into account inaccuracies in dimensions, position and homogeneity of the target, to determine the luminosity.

Contrary to $pd_{elastic}$ the cross section from pp-elastic scattering is very well known over the whole energy range of COSY. Together with forward tracking and identification of protons at ANKE, our setup would be able to yield the luminosity by quasi-free pp-elastic scattering much more accurately than with pd-elastic scattering. Unfortunately the forward detectors were mechanically restricted to angles greater than 7°. Therefore we were not able to measure any coincidence with quasi-free pp-elastic scattering of this forward system with our setup at 2 GeV beam energy, and the separation of background (break up, pd_{elasic}, etc) could not be done.

A setup is proposed, which would allow a much more accurate determination of the luminosity at all beam energies, combined with quite a few improvements for the proposed ω- and ϕ-production measurements. The question remains, weather we need higher accuracy on luminosity determination or not.

Spectator Protons at ANKE

Parasitically we proved that our setup is ready to identify and trace protons in an energy range **from 8 to 30 MeV at least**, with the required energy and angular resolution for the measurement of meson production reactions on the neutron.

The extension of this energy range to lower energies still seems to be a difficult task. In figure 9 the energy losses in the 18 μm versus the energy losses in the 300 μm thick detector are plotted. Due to the absence of deuterons under backward angles slight differences between d-, p-bands can be seen. But the small band separation together with the bad energy resolution (150/130 keV see above) in the 300 mm², 18 μm thick surface-barrier detector inhibits any reliable particle identification.

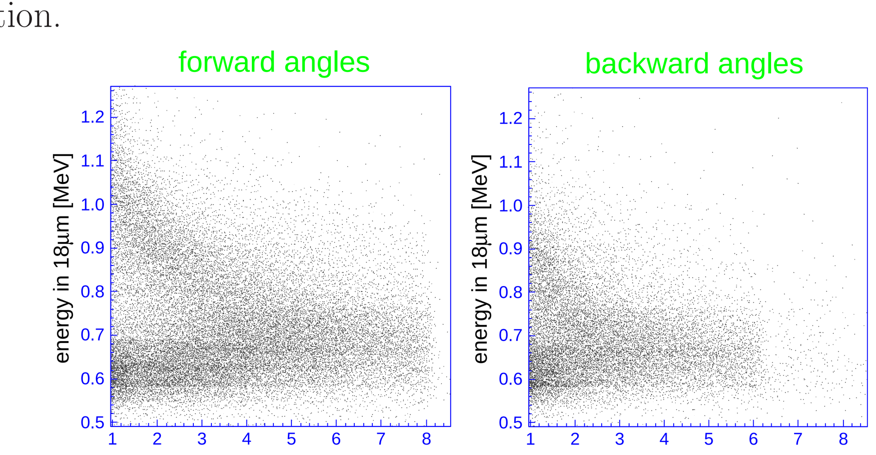

Figure 9: Energy loss spectra for low energetic particles showing no band separation

To improve this situation, we plan to reduce the capacity of this first detector and enlarge the band separation at the same time. For that 50 μm thick single sided silicon-strip detectors with a pitch of 1 mm are under discussion. The accessible energy range would then be restricted to proton energies above 2 MeV.

References

[1] Büscher M. et al. Study of ω- and ϕ-meson production in the reactions $pd \to dVp_{sp}$ at ANKE. COSY-Proposal #75, 1998.

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