Beam energy and STT position optimization for experiment #203

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In the proposal for experiment #203 [1], studies of the $pn \to K^+n\Lambda$ reaction close to threshold, two silicon tracking telescopes (STTs) were planned to be used for: (1) the determination of excess energy in the reaction, (2) the luminosity determination using pd elastic scattering, and (3) the reaction identification, in coincidence with the K^+ meson detected in ANKE positive side detector. From the experience gained in the operation of two STTs at ANKE during the studies of the $pn \to d\omega$ reaction [2], it is known that for the telescope position used (−12.5 mm from the centre of STT flange) the very high rate from the normalisation reaction can engender significant instabilities in the system. In the experiment in August 2008, regions of the silicon detectors that were subject to pd elastic events were excluded from the trigger in order to to reduce the high input rates and were only used for the collection of normalisation runs. During the preparation of the proposal for experiment #203, the same STT position as in August 2008 was used to optimize the energy for the data taking. In this short note, the effects of detector position and beam energy optimization are summarized. Conclusions are then drawn about the detector scheme and beam energy that are best suited for this particular experiment.

In the proposal [1] it was planned to use three different energies for the experiment, $T_p = 1.662$, 1.775 and 1.826 GeV. Data taking on a deuterium target was only planned at $T_p = 1.775$ GeV, which is optimal for studies of $pn \to K^+n\Lambda$ reaction with the STT installed at the August 2008 position. The other two energies are necessary for calibration on a hydrogen target to determine the range telescope efficiency as precisely as possible; for details please see Ref. [1]. In principle, in the spectator detector support construction it is foreseen to have the possibility to shift all three detectors together, backward and forward with respect to the centre of the flange, in steps of 10 mm, though with not more then three steps in either direction. The placing of the STT downstream is risky, due to a possible beam dump in the system. Hence, in our simulation, only three detector positions were considered: −12.5 (August 2008), −22.5, and −32.5 mm.

The differential cross sections for three elastic processes at $T_p = 1.826$ GeV are presented in Fig. 1. At all three positions considered, the spectator telescopes cover regions with $\vartheta > 60°$, so that the pd elastic reaction gives the main contribution to the count rate in the telescopes. The pd elastic rate, at the energies of interest, varies with increase of beam energy from 1.775

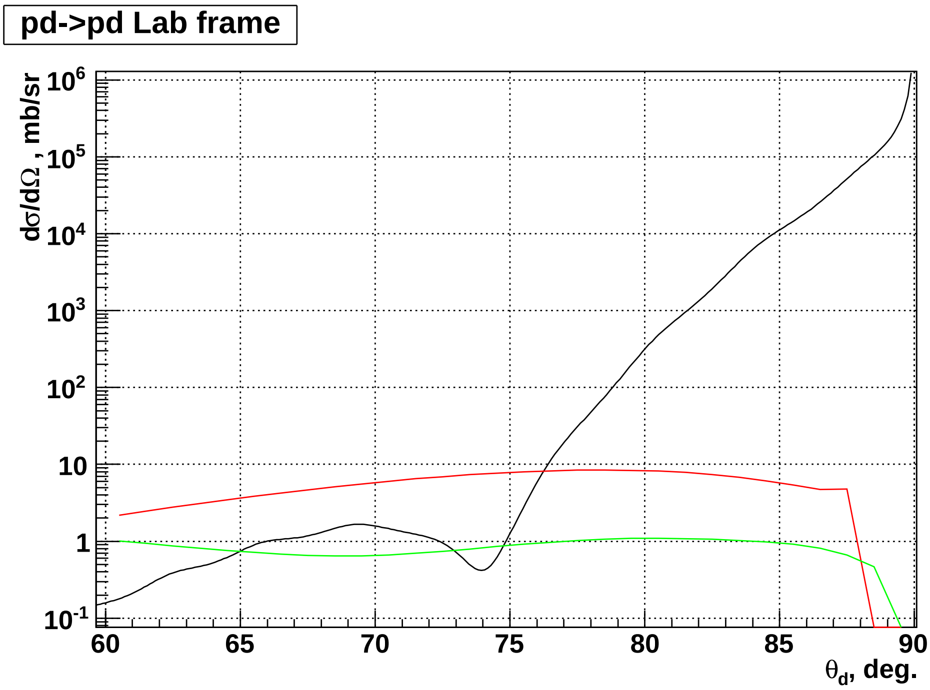

Figure 1: Differential cross sections at $T_p = 1.826$ GeV for three different reactions $pd \to pd$ (black line) [3], $pp \to pp$ (red line) [4], and $np \to np$ (green line) [4]. The pd elastic process gives the main contribution to the count rate above 60°.

to 1.920 GeV by only a few percent. We therefore restrict ourself to the consideration of only one energy.

Simulations of the pd elastic count rate in the ANKE STTs at $T_p = 1.826$ GeV are presented in Fig. 2 for three different detector positions. A shift from the August 2008 position by only 10 mm hardly changes the count rate from pd elastic, whereas a shift to the very backward position (-32.5 mm) reduces the expected load by almost an order of magnitude. The differential cross sections for the other processes shown in Fig. 2 suggest that the rates from other elastic processes should also be significantly suppressed. However, the displacement of the STT backward, with respect to the beam direction, changes the lower cut on the angular acceptance for the detected particles. As a consequence, a new optimal energy has to be selected for the reaction of interest.

Simulations for the expected numbers of $pn \to K^+ n\Lambda$ counts after three weeks of measurements are shown in Fig. 3 for three different telescope positions (solid, dashed, and dotted lines). A shift of the STTs downstream

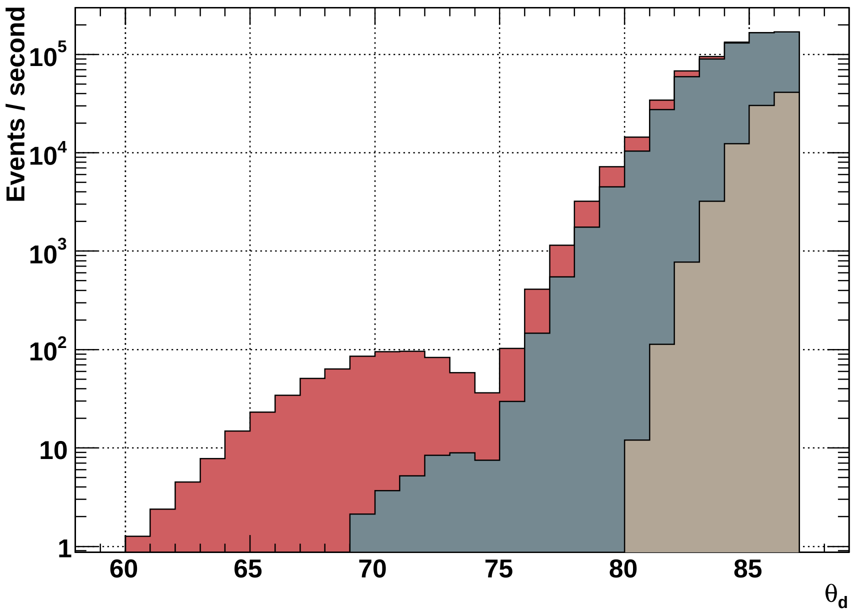

Figure 2: Simulations of the pd elastic count rate at $T_p = 1.826$ GeV for three different STT positions -12.5, -22.5, and -32.5 mm.

leads to a loss in the total numbers at all three energies. However, the count rate in the region with $Q < 60$ MeV does not change as significantly.

The total numbers of counts expected for the Λ reaction channel are shown in Fig. 4 at three different energies as a function of the STT position. The totals change by a factor of two when the STTs are moved from the -12.5 to the -32.5 mm position, as illustrated in the left panel of Fig. 4. For comparison, the change in the predicted numbers of pd elastic events, scaled by a factor 500, is also shown. Thus, the very backward position for the STTs gives a factor ten reduction in the elastic event load, whereas the loss in the total rate for the reaction of interest is only a factor of two.

In the right panel of Fig. 4 the numbers from the $pn \to K^+n\Lambda$ reaction for $Q < 60$ MeV at the three different beam energies are shown as a function of the STT position. From the August 2008 to very backward position the Λ rate at $T_p = 1.775$ GeV changes by $\approx 15\%$ and at the -32.5 mm position it is roughly equal to the rate at 1.826 GeV.

The simulations show that the simultaneous change of the STT position from -12.5 mm, which was used in the proposal, to the backward one (-32.5 mm) has the following consequences:

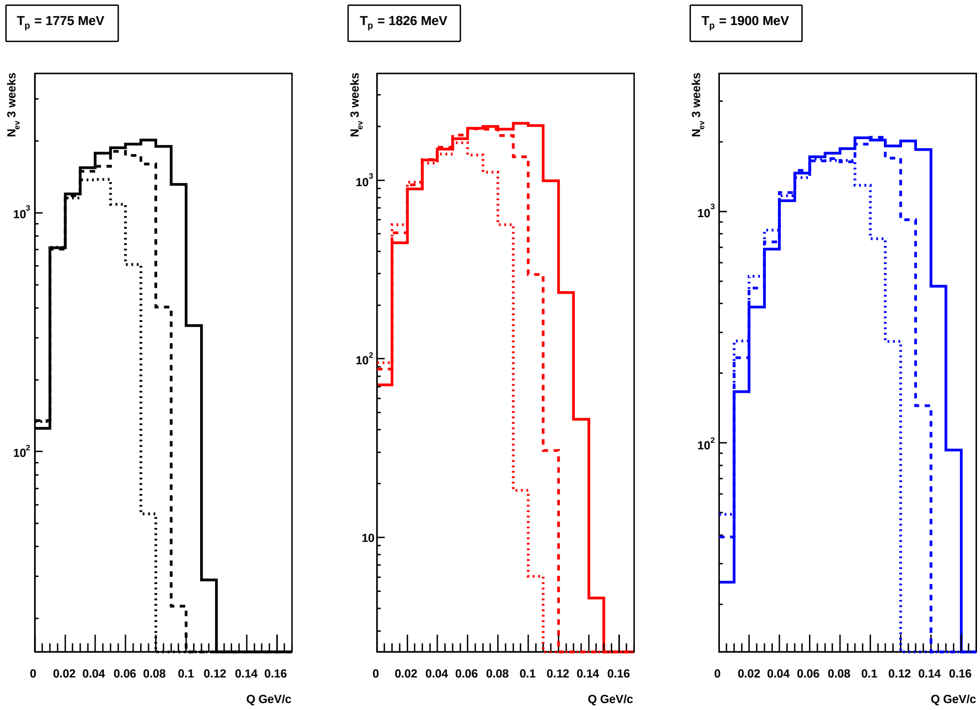

Figure 3: Simulations of the numbers of $pn \to K^+ n\Lambda$ counts at three energies. The estimations made for the -12.5, -22.5, and -32.5 mm positions are shown by solid, dashed and dotted lines, respectively.

- A factor of two lost in the total count rate for Λ production;
- A factor of ten reduction in the rate in the STT from the *pd* elastic reaction and, therefore, an order of magnitude reduction in the rates for the spectator detectors;
- The possibility of using the *pd* elastic rate for normalisation is **LOST**;
- A small change in the Λ production rate for $Q < 60$ MeV, where acceptance is maximal;

It is therefore worthwhile to change the spectator telescope position to -32.5 mm and increase the energy for the *pd* data taking up to $T_p = 1.826$ GeV. It this case, the Λ count rate for low Q, will be hardly affected by the change in the STT position, and will only change by $\approx 15\%$ compared to the numbers given in the proposal. This action should spare one day of machine development (only two instead of three energies will be needed) and reduce the rate in the STT by an order of magnitude, which should hopefully

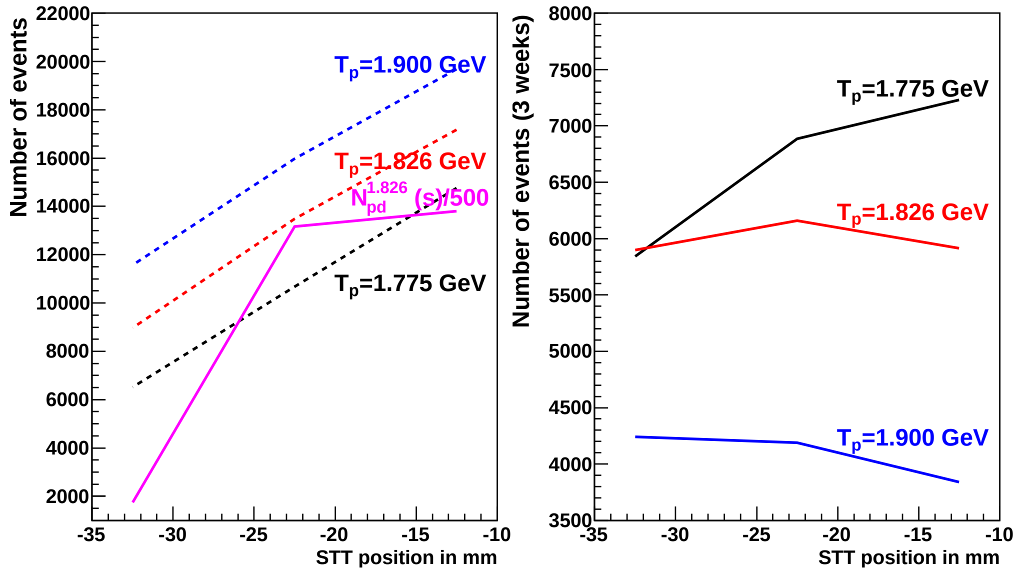

Figure 4: Left: Simulations of the numbers of $pn \to K^+ n\Lambda$ events expected at three energies as a function of the STT positions after three weeks of data taking. For comparison, the predicted reduction in the elastic counts, scaled by a factor 500, is show by the magenta line. Right: The Λ production numbers with a $Q < 60$ MeV cut.

give a more stable STT system and good conditions for using the time option of MATE chips.

On the other hand, *pd* elastic scattering will be almost completely removed from the detection system, which means that it cannot be used for normalisation. The Schottky method, together with the inclusive π^+ differential cross sections, and *pd* quasi-elastic calculations will be used instead. This should lead to a normalisation uncertainty of less than 20%, which is sufficient for purpose of the experiment.

References

[1] A. Dzyuba, V. Koptev and Yu. Valdau, COSY Proposal #**203** (2010).

[2] S. Barsov and R. Schleichert, COSY Proposal #**175** (2007).

[3] Yu. Uzikov, private communications.

[4] R. A. Arndt *et al.*, Phys. Rev. C **62** 034005 (2000); solution SP07 http://gwdac.phys.gwu.edu.