COSY Beam Calibration within the η Mass Measurement at COSY-ANKE

P. Goslawski*, M. Mielke*, M. Papenbrock*, T. Rausmann*, A. Täschner* and A. Khoukaz*
for the ANKE-Collaboration and the COSY-Crew+

Recent measurements on the η-meson mass performed at different experimental facilities (i.e. CERN-NA48, COSY-GEM, CESR-CLEO, DAΦNE-KLOE, MAMI-Crystall Ball) resulted in very precise data but differ partly by up to more than eight standard deviations, i.e. $0,5\,\mathrm{MeV/c^2}$ [1]. In order to clarify this situation a new high precision measurement using the ANKE spectrometer at the COoler SYnchrotron has been realised in March 2008.

Using the two-body reaction $d\ p \to\ ^3\mathrm{He}\ \eta$ at low excess energies the η-mass can be determined only from pure kinematics by the determination of the production threshold. Therefore, twelve data points at fixed excess energies in the range of $1-10\,\mathrm{MeV}$ were investigated. The final momentum p_f of the ^{3}He-particles

$$p_f\,(s) = \frac{\sqrt{\left[s-(m_{^3He}+m_\eta)^2\right]\cdot\left[s-(m_{^3He}-m_\eta)^2\right]}}{2\cdot\sqrt{s}}\ ,$$

measured with high precision using the ANKE spectrometer, is very sensitive on the value of the η-mass and the total energy $\sqrt{s}$ which is completely defined by the masses of the initial particles and the momentum of the deuteron beam. For a precise determination of the production threshold two quantities, the final momentum of the ^{3}He-particles and the beam momentum have to be measured with high accuracy.

To obtain a total precision of $\Delta m_\eta < 50\,\mathrm{keV/c^2}$ on the η-mass, which is comparable to other experiments, the beam momentum has to be determined with an accuracy of $\Delta p/p < 10^{-4}$, reached only in one test measurement at COSY [2]. This can be achieved by using an artificial spin resonance, induced by a horizontal rf-magnetic field from a solenoid to depolarize a vector polarized accelerator beam [3]. The frequency of the depolarizing resonance f_r depends on the kinematical γ-factor (i.e. the beam momentum $p = m\sqrt{\gamma^2-1}$) and the beam revolution frequency f_0 via the resonance condition:

$$f_r = (k+\gamma G)\,f_0\ ,$$

where k is an integer and G the gyromagnetic anomaly of the beam particle (for deuterons: $G_d = -0.142987272$).

To obtain the exact beam momentum for each energy the revolution frequency f_0 and the spin resonance frequency f_r have to be measured with high accuracy.

By studying the Schottky spectra, stored within four days, the revolution frequency for each energy was determined with an accuracy of $\Delta f_0/f_0 \approx 4\cdot10^{-6}$, with an uncertainty dominated by the systematic uncertainty of the Schottky measuring system.

The position of the resonance can be determined accurately by operating the rf-solenoid with fixed amplitude at several frequencies around the induced depolarizing resonance for a certain time and measuring the remaining polarisation with the EDDA-detector afterwards. For each energy the spin resonance spectrum was measured twice at a four days interval to investigate possible resonance frequency shifts over time. Between the two measurements the resonance frequency may vary up to 20 Hz, which is caused by a shift of the orbit length up to 3 mm. As an important by-product the spin resonance method enables for the determination of the orbit length for COSY (183.44 m) with an accuracy of less than 0.3 mm [4]. Figure 1 presents the spin resonance measurements for all twelve energies, normalized with respect to the polarisation as function of the solenoid frequency. The shapes of the resonance curves, especially

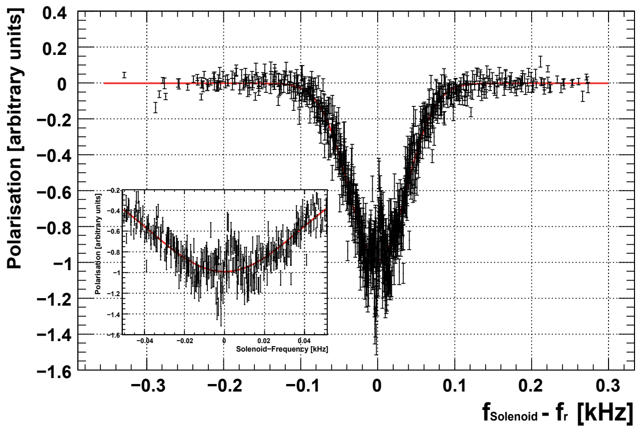

Fig. 1: Normalized spin resonance spectrum. The inlay shows the structure in the resonance maximum.

the structures in the resonance maximum are argued to be dominiated by synchrotron oscillations of the beam particles induced by the barrier bucket cavity. Despite this structure the achievable precision in beam momentum by analysing the spin resonance spectra is better than $\Delta p/p < 8\cdot10^{-5}$, i.e. the beam momentum in the threshold range of $3100-3200\,\mathrm{MeV/c}$ was estimated with an accuracy of less than $250\,\mathrm{keV/c}$ [4]. The uncertainty is dominated by the systematic shift in orbit length during the measurement. In comparsion to the usual momentum determination from the nominal orbit length and the revolution frequency the spin resonance method allwos for an improvement of $\Delta p/p$ of more than one order of magnitude.

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References:

[1] C. Amsler et al., Phys. Lett. B **667**, 1 (2008)
[2] H. Stockhorst et al., IKP An. Rep. 2007, **33** (2007)
[3] V.S. Morozov et al., Phys. Rev. Spec. Top. Accelerators and Beams **8**, 061001 (2005)
[4] P. Goslawski, Diploma thesis, Westfälische Wilhelms Universität Münster (2008)

* Institut für Kernphysik, Westfälische Wilhelms Universität Münster, 48149 Münster, Germany
+ Institut für Kernphysik, Forschungszentrum Jülich, Germany