EXTENSION OF THE 3-SPECTROMETER BEAM TRANSPORT LINE FOR THE KAOS SPECTROMETER AT MAMI AND RECENT STATUS OF MAMI*

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Abstract

The institute for nuclear physics (IKPH) at Mainz University is operating a 1.6 GeV CW microtron cascade (MAMI) for nuclear physics research [1, 2]. One of the vast experimental activities is electron scattering. A 3-spectrometer set-up is used for cross-section measurements of hadron knock-out and meson production.

The KAOS spectrometer magnet of GSI [3] is installed there in parallel to detect particles from (e,e'K) reactions under small forward angles. So the primary electron beam has to transit the spectrometer and after this it has to hit the existing beam dump. Because of the existing experimental set-up, this must be realized by deflecting the beam before the target that is rotated to be in line with the inlet of the KAOS spectrometer [4].

This paper will deal with the basic concept of a flexible beam transport line (BTL) magnet chicane for different KAOS forward angles, while keeping the forward beam direction for the 3-spectrometer set-up untouched. A survey concept for assembly and adjustment of the BTL will be introduced that is also useful for future adjustments of the target mount after target change. Results of the BTL commissioning and a general MAMI status will be presented as well.

INTRODUCTION

The aim of the new experiments with KAOS is to measure coincidence associated kaon production under small forward angles below 10°, therefore the primary electron beam has to enter the spectrometer magnet. This magnet causes a deflection of the primary electrons, so they will not hit the existing beam dump anymore. As the magnetic field of the spectrometer is changed with the energy range scanned, this deflection is also not constant. Installing a movable beam dump is not possible, so a chicane leading the beam back onto the existing dump was reviewed in [4]. Two solutions were possible, a chicane with two bending magnets preceding the KAOS dipole or two dipoles following it. The later was dismissed, since its bending radii demanded infeasible magnetic field strengths.

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BEAM TRANSPORT LINE CONCEPT

In the BTL concept discussed in [4], two bending magnets were placed in front of the target. Then the positions of the spectrometer and the second bending magnet would have to be moved quite precisely with every change of spectrometer energy. This means a large effort for the technical staff each time a change in energy is desired. So the machine division suggested a different chicane where only the bending magnet has to be moved:

The basic concept is keeping the distance between target and the bending magnet next to the target constant (Fig. 2). In this drift space two beam position monitors (XYMO) are inserted. Those XYMOs are mounted onto a common girder that can be moved to target angles from 10° to 22° in 1° steps centred around the target position. The second chicane magnet follows this swing, the first magnet is fixed. The precise beam position is determined by the two XYMOs. Thus the positioning accuracy of the second magnet can be low and orbit displacements are corrected by the magnetic fields. The chicane can be bypassed to allow

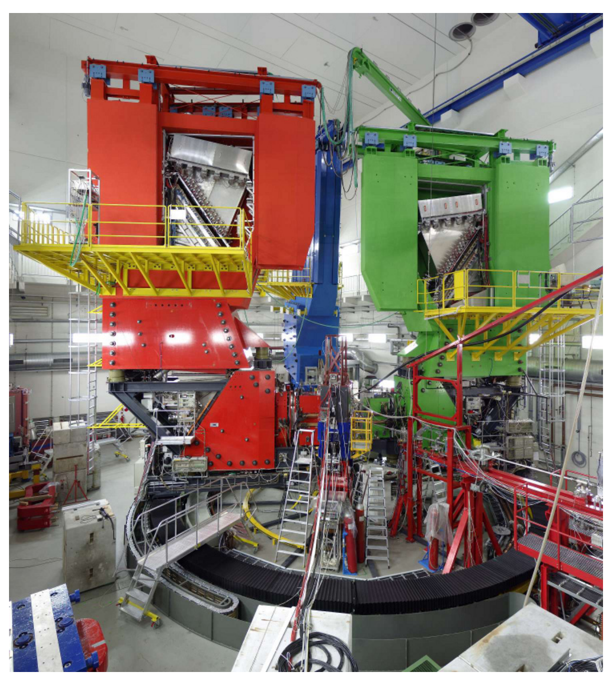

Figure 1: Photograph of the the 3-spectrometer set-up before reconstruction, spectrometers A, B and C can be seen. The beam is coming from the right.

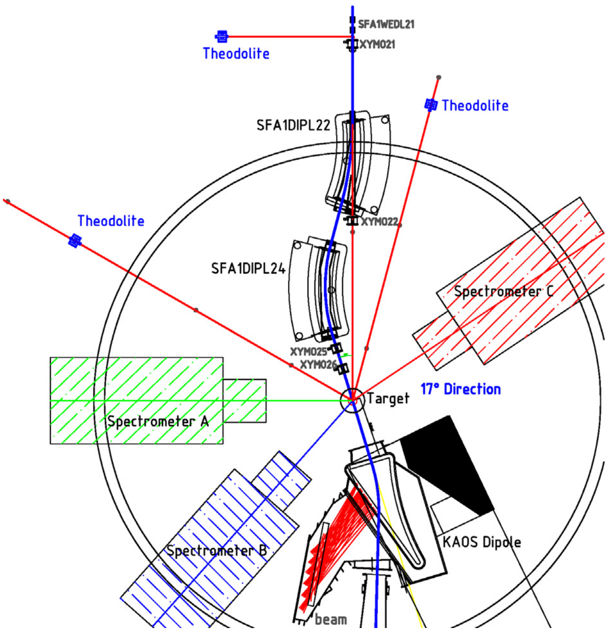

Figure 2: Overview over the KAOS chicane and the theodolite positions for target adjustment. The beam is coming from the top of the picture and is going to the bottom, following the blue line (17° target angle).

experiments in standard direction. In that case the XYMO girder is fixed at the $0°$ position.

The BTL is realized by the use of two bending magnets of the former Orsay DCI storage ring. Based on [5] gap widths of 34 mm and 30 mm were used for the first and second chicane magnet to achieve maximum fields of 1.1 T and 2.1 T with currents of 400 A and 800 A, respectively (DCI design: 110 mm gap, 1.66 T @ 1950 A). Because of the various target angles, the beam trajectories are covering most of the pole shoe area. The vacuum system takes this into account by having wide chambers covering nearly the whole pole shoe area (Fig. 3). Sets of adapter flanges are fitting the different angles. The use of dedicated sets of narrow chambers for each target angle that would have to be exchanged with every change of target angle was dismissed due to simplicity matters.

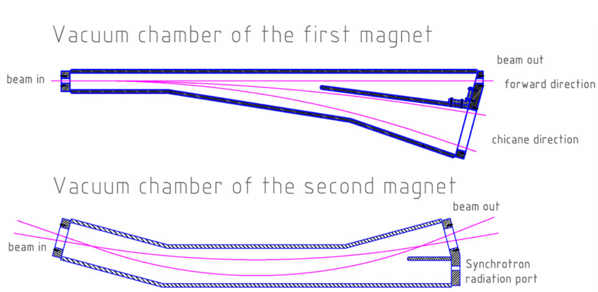

Figure 3: Technical drawing of the two chicane dipole chambers, with sketched in beam trajectories at maximum and minimum target angles.

Two ZnS-screen luminescence monitor (LUMO) were placed in the beam path. One at the entrance of the second chicane magnet for additional diagnostics, another large one in the exit chamber near the beam dump. Further a XYMO is located in forward direction at the exit of the first chicane magnet. A synchrotron radiation port is foreseen at the chamber of the second bending magnet.

ADJUSTMENT & SURVEY CONCEPT

The original target adjustment routine was oriented at wall marks under $0°, 90°, 180°$ and $270°$ centred around the target position and a XYMO (via marks, that fit into the aperture) in $\approx 2\,\mathrm{m}$ distance from the target. Therefore a theodolite was placed between XYMO and target mount to adjust the beam axis and then it was placed on target position for longitudinal positioning. Since that XYMO was moved upstream to the exit of the first chicane magnet and some lines-of-sight are blocked now (see Fig. 1 and Fig. 4), a new routine must be introduced.

With the new routine the target is adjusted from outside the spectrometer ring using two theodolites at the same time looking downstream. One is placed near the beam axis to check the lateral position, the other one is placed farther away from the beam axis to verify the longitudinal position. The target mount has a LUMO with a cross hair marking the centre of the mount. The position of the theodolites can be determined from referenced floor marks that form radial vectors from the target place under $165°$ backward angle counter-clockwise and under $120°$ backward angle clockwise. The marks were brought thoroughly in line using a theodolite at the target position (Fig. 2).

The routine to adjust the gas target is different: a small piece of chamber is taken out in front of the chicane, and a mirror is placed into that gap. Via this mirror a theodolite is directed through two XYMOs to determine the transverse target position. The beam axis is defined by centric pin holes and cross hairs, that fit into the apertures of the XYMOs. The longitudinal target position is found as mentioned in the original adjustment routine.

SET-UP & COMMISSIONING

To adjust the positions of the magnets and the movable XYMOs an absolute distance reference was needed. Thus a referenced floor mark was placed under $0°$ at a place visible from most positions in the cave. Then its absolute position was determined from the Leica Axyz V1.3 system [6]. This system computes absolute coordinates from the directions of two or more theodolites in a given coordinate system. In our case the coordinate system was linked to the beam axis with the target being the origin and a XYMO determining the axis vector. Later for recalibration after a change of the position of the theodolite this floor mark was used, since the line-of-sight to the target was blocked either by a chicane magnet or one of the 3-Spectrometer arms from most viewing angles. Two additional marks forming a perpen-

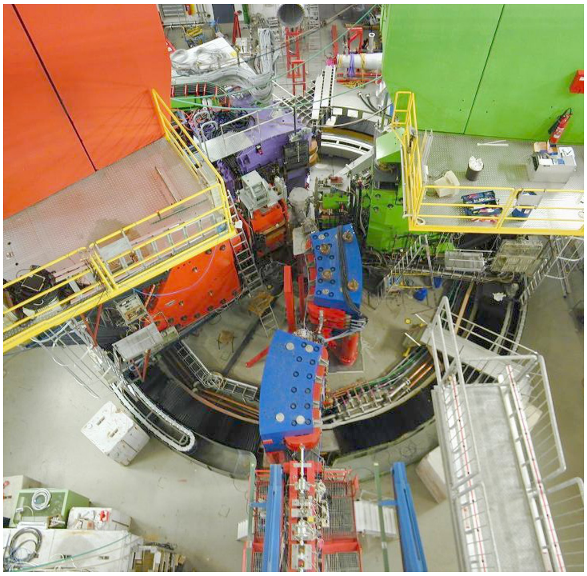

Figure 4: Photograph of the KAOS chicane inside the 3-spectrometer ring (black circle: inner radius of 5.7 m). Left and right, spectrometers A and C are visible, in violet the KAOS dipole can be seen. The small blue magnets are the former DCI bending magnets. The flange of beam dump is located in the top middle of the picture.

dicular that intersects the beam axis in this reference were also placed. This line is useful to monitor the position of the second magnet while moving it, the absolute end positions of the magnets were checked with Axyz. Also the position of the base plate of the two XYMOs on the girder was determined with Axyz before machining the bearings of the swing mechanism. This way an angle accuracy better than $0.1°$ was achieved.

The reproducibility of Axyz coordinates was better than 0.1 mm, but overnight stability due to thermal drift, etc. was poor: Though the coordinates were reproduced to again some 0.1 mm, the computed RMS error of the system rose to the order of 1 mm, so the system was recalibrated each morning.

The chicane was set into operation at a target angle of $17°$. Before the start of operation the function $B(I)$ was measured up to the maximum output current of the power supplies. The first magnet shows of course no saturation effects, while the second one does for fields exceeding 1.4 T (Fig. 5). From the measured B-field the currents for $17°$ operation were interpolated. Machine operation started at low beam currents of 10 nA for commissioning of the KAOS detectors on February 1st 2011. The beam was on the target LUMO right from the start, only minor adjustments of the chicane were necessary to put the beam into the centre of the screen. After this the beam was handed over to the experimentalists, who just had to adjust the field of KAOS to put the beam onto the beam dump.

The KAOS chicane is now in routine operations at beam currents $\geq 20\,\mu$A.

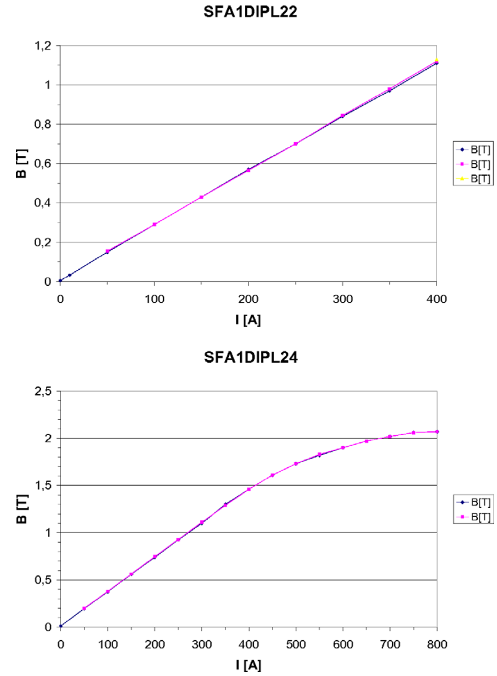

Figure 5: Plots of the B-fields of the chicane magnets as a function of current I.

STATUS OF MAMI C

The MAMI facility is a very reliable machine that is usually operated in a two weeks cycle, starting Tuesday at 7 AM and ending Monday at 6 AM, followed by 24 h of maintenance shut-down. The downtime due to machine failure in 2010 went down to only 2.6% of overall beam time. Compared to the past 10 years [7], the overall beam time decreased a little. The reconstruction of the KAOS chicane prevented one major user from accepting beam time for about four months. Further the detector of the parity violation experiment was altered, so also this group did not accept beam during that time. MAMI delivered in 2010 5888.5 h of operations, with more than 88% beam on target. Polarised beam was delivered at 68.8% of operational time and the portion of high energy operations ($\geq 1.5\,$GeV) was at 35.9%. For 2011 MAMI is expected to run again for more than 6000 h and again mostly at high energy.

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