Calibration of the New Analyzing Magnet

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With the installation of the new analyzing magnet [1] we faced the problem of its calibration. Although most of the heavy ion experiments nowadays do not require a precise knowledge of the beam energy, for measurements of the interaction barrier in fusion reactions [2] it is desirable to know the beam energy better than 10^{-3}. Traditionally analyzing magnets were calibrated using well known resonances e.g. in (p,γ) reactions. But these require a small proton energy. Even for the lowest energy of about 6 MeV obtainable with our Tandem there is hardly a precisely known resonance available and the magnetic rigidity of 0.25 Tm is only 1/10 of the maximum rigidity. Alternatively one could think of a resonance in inverse kinematics. The $p(^{58}\mathrm{Ni},\gamma)$ reaction e.g. has a narrow resonance at E/A= 1.844 MeV. But searching this resonance could be rather time consuming. Therefore we decided to use the Q3D magnetic spectrograph and to compare the magnetic rigidity of heavy ions from the Tandem with that of alpha particles from a radioactive source.

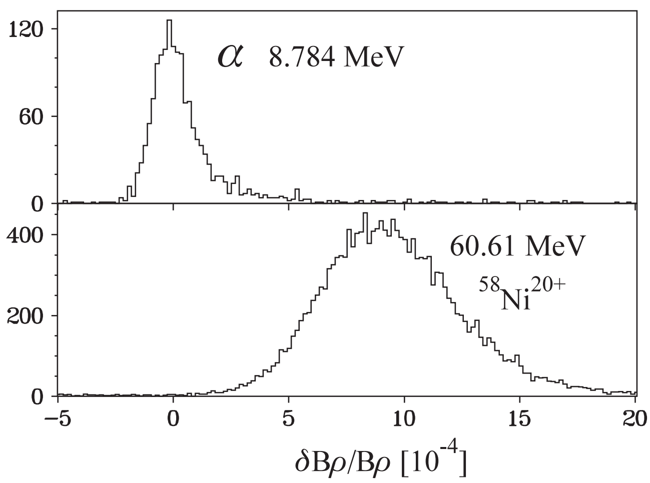

Fig. 1: Position spectra for the ^{212}Po α -particles (top) and for $^{58}\mathrm{Ni}^{20+}$ ions (bottom). The abscissa is calibrated as the relative difference in magnetic rigidity $(B\rho(\alpha)/B\rho(Ni)-1)$.

The alphas from the decay of ^{212}Po have a very well known kinetic energy of 8784.86 keV [3]). As a daughter product of ^{228}Th this activity can be deposited in a thin layer with little energy loss in the source [4]. Because these alphas have still a small magnetic rigidity we stripped the heavy ions in the scattering chamber of the spectrograph in order to have a higher rigidity through the analyzing magnet. We used ^{58}Ni ions in the charge state q=20+. With a kinetic energy of 60.718 MeV they have the same magnetic rigidity as the $^{4}\mathrm{He}^{2+}$ ions. Fig. 1 shows position spectra at the same magnetic field setting of the spectrograph. The upper spectrum is for the ^{212}Po alphas, the lower one for $^{58}\mathrm{Ni}^{20+}$ ions which were selected by the analyzing magnet in the 8+ charge state. The magnetic rigidities differed by only $9\cdot10^{-4}$.

The energy of the $^{58}\mathrm{Ni}^{20+}$ ions, measured with the Q3D as 60.610 MeV, has to be corrected for the energy loss in the stripper foil in front of the spectrograph. The thickness of this foil was determined from the energy loss of ^{241}Am and ^{212}Po alphas. The observed values were 40% higher than those expected for the optically measured thickness of 3.8 μg/cm^2 [6]. We attribute this increase to deposits of water vapour on both surfaces. Taking this into account we estimate the energy loss of the ^{58}Ni ions from our earlier measurements [5] as 220(25) keV. Another small correction of 7 keV comes from the loss of kinetic energy of the ions because of the decrease in mass due to the loss of 12 electrons. We also corrected the energy of the alpha line due to an energy shift from a finite source thickness. This energy loss was determined as 0.9 keV by tilting the surface of the source by 45^o and 60^o in either direction, thus increasing the thickness by a well defined factor.

If we now divide the magnetic rigidity, obtained from the precisely measured kinetic energy by the magnetic field measured with the NMR probe [1], we arrive at an effective bending radius of the analyzing magnet of $\rho = \mathbf{1667.4mm}$. The uncertainty is dominated by the uncertainty of the energy loss of the ^{58}Ni ions in the stripper foil and amounts to $2\cdot10^{-4}$. This could be improved by using a gas target as stripper.

As a test of the reproducibility of the magnetic field, we switched the analyzing magnet off and turned it on again, stabilized at the same magnetic field. The magnetic rigidity was within $5\cdot10^{-5}$ the same as before. To test the magnet at a higher field, 0.885 T, we analyzed the 60.8 MeV ^{58}Ni in the 6+ charge state and measured their energy again as 20+ ions with the Q3D. The resulting effective bending radius was again the same within $4\cdot10^{-5}$.

References

[1] L. Rohrer *et al.*, this report p. 2
[2] see e.g. C. Zotti et al., this report p. 11
[3] A.Rytz, At. Data Nucl. Data Tables **47** (1991) 220 (note that the most precise value was measured with our Q3D in conjunction with the time of flight system)
[4] The sources were provided by D. Grossmann, technological Laboratory LMU
[5] C. Frey, G. Dollinger, A. Bergmaier, T. Faestermann, and P. Maier-Komor, Jahresbericht 1994, p. 107
[6] P. Maier-Komor, G. Dollinger, and E. Hammann, Nucl. Inst. Meth. **A303** (1991) 88