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ION-OPTICAL CORRECTION ELEMENTS FOR ON-LINE MASS SEPARATORS

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ABSTRACT

To adjust on-line mass separators, variable magnetic or electrostatic multipoles are most desirable. Such elements were built and subsequently included in the ISOLDE-3 on-line mass separator at CERN. In first tests a mass resolving power $m/\Delta m$ 10000 > (FWHM) was achieved, which allowed the isobaric separation of ^{37}Ca from ^{37}K using a tungsten-surface ionization source.

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Abstract

To adjust on-line mass separators, variable magnetic or electrostatic multipoles are most desirable. Such elements were built and subsequently included in the ISOLDE-3 on-line mass separator at CERN. In first tests a mass resolving power $m/\Delta m > 10000$ (FWHM) was achieved, which allowed the isobaric separation of ^{37}Ca from ^{37}K using a tungsten-surface ionization source.

1 Introduction

Misadjustments of particle spectrometers or beam guidance systems can be categorized in different orders. Deviations of zeroth order here mean, that the optic axis of the particle beam does not pass through the middle of the foreseen aperture, deviations of first order mean that the focus point is shifted upstream or downstream from the foreseen position, etc. To compensate such misadjustments of n_{th} -order, n_{th} -order optical elements

are required, i.e. magnetic or electrostatic dipoles ($n = 0$), quadrupoles ($n = 1$), hexapoles ($n = 2$), etc. In all these cases care must be taken to position such elements at effective positions [1],[2]. Ideally one would employ for this purpose suitable placed multipole elements in each of which the different multipole strengths is individually adjustable [2],[3].

For the optic of the ISOLDE-3 on-line mass separator we have calculated and built adjustable magnetic correction elements to be installed inside of the 90° and 60° sector field magnets as well as computer controlled adjustable electrostatic multipoles placed in field-free regions. In ion-optical calculations we have simulated the properties of these elements and calculated optimal settings for them. We have demonstrated the drastic increase of the mass resolving power of ISOLDE 3 by switching these elements on and off, first in off-line tests using stable beams and finally in on-line tests to separate short lived nuclei of one isobar.

2 The magnetic correction elements

To compensate image aberrations of 2_{nd} - and 3_{rd} -order inside a magnetic sector-field two ways are possible. The first one is to shape the field boundaries of a homogeneous or inhomogeneous sector-field appropriately. Thus image aberrations of 1_{st} -order can be corrected using inclined field boundaries (effects of magnetic quadrupoles) while aberrations of 2_{nd} -order can be corrected by using curved field boundaries (effects of magnetic hexapoles). In both cases, these corrections are fix and not adjustable. The second way is to use a superposition of different multipole surface coils inside the magnet [3],[4],[5]. This method has the advantage that it is easily possible to adjust independently the correction elements of every order to correct the corresponding image aberrations. To produce such field distribution three ways are possible:

- use of wires of different widths, employing one power supply [3],[4],[5],
- use of wires of constant widths, employing different power supplies [6],
- use of wires of constant widths connected by a resistance network, employing only one power supply [7].

The first and third ways have the advantage, that only one power supply is required with the third one being able to work with quite high currents ($\approx 25\text{ A}$). As example for a magnetic octupole correction coil a radially quadratic increase of the current density distribution is required. As shown in Fig. 1, it thus is possible to approximate excellently the ideal current density distribution, i.e. the field distribution. Both sector-field magnets of ISOLDE-3 (90° and 60°) were provided with such separately adjustable hexapole and octupole surface coils [7]. Flat copper wires of $1\text{ mm} \times 3\text{ mm}$ were placed in milled notches (2.5 mm depth, 3 mm width) of a 3.5 mm thick epoxy-plate. Finally, these epoxy-plates were fixed on each pole face of the sector magnets. The power supplies for the correction coils can be adjusted and controlled from the ISOLDE-3 control room.

3 The electrostatic multipoles

Alternative to magnetic also electrostatic multipoles can be built [8]. The built multipoles, used a 32-wire 'squirrel cage' configuration in which each wire requires a separate power supply. The use of such elements for the correction of image aberrations of 2_{nd} - and 3_{rd} -order has already been described in ref.[8]. Such elements were inserted at three positions in the ISOLDE-3 on-line mass separator as shown in Fig. 2, allowing to rapidly vary the multipolarities, the orientations and the multipole field strengths. For this purpose electrostatic potentials of up to $\pm 750\text{ V}$ were required.

4 First tests and results

The electrostatic multipoles were tested earlier in off-line experiments using 25 Cs^+ beamlets of 4 keV energy [8]. The properties of the magnetic hexapoles and octupoles inside the 90° and 60° sector field magnets of ISOLDE-3 were first tested also off-line. Measurements of the field distributions as well as temperature effects inside the magnets were performed, showing good agreement with theoretical expectations. In a next step the influence of the magnetic correction coils on the mass resolving power of ISOLDE-3 was tested, using a stable $^{132}\text{Xe}^-$ and $^{14}\text{N}_2^-$ -beam. For this purpose a suitable beam observation system was installed (see in Fig. 3. In

addition variable slit-systems in all foci of the mass separator were used (see also Fig. 2).

In one of the last beam-times of the 'old ISOLDE-3' before moving the separator to the CERN booster, ^{37}Ca was separated from ^{37}K to investigate the ^{37}Ca β -decay and detect delayed $p\gamma$ -coincidences [9]. For this case a mass-separated ^{37}Ca -beam ($m/\Delta m \approx 7000$ FWHM) was required of 60 keV. To fulfil this request it was absolutely necessary to use the magnetic and electrostatic correction coils, achieve a very stable acceleration, replace the Hall probes with NMR probes inside the magnets and use a slit of variable width in combination with a beam observation system in the final focus of ISOLDE-3 (see also Fig. 3). A $3 \times 1 \text{ mm}^2$ slit type tungsten-surface ionizer was used. With precise adjustments of the standard beam elements of ISOLDE-3 a mass resolving power of $m/\Delta m \approx 7000$ (FWHM) was achieved. Adjusting the magnetic correction coils increased the mass resolving power to ≈ 9000 (FWHM) and using additionally the electrostatic multipoles a final mass resolving power of ≈ 10600 (FWHM) at 60 % transmission was reached. This allowed to separate the isotopes ^{37}Ca from the abundantly present ^{37}K by more than 3 halfwidths. The measured line-shape of ^{37}K is shown in Fig. 4 together with an assumed identical one normalized to the mass and intensity of ^{37}Ca [9].

With this good performance of the ISOLDE 3 separator the mass-separated ^{37}Ca beam was implanted into the entrance window of a gas proportional counter. This window formed the first element of a proton telescope. With the results of the measurements of $p - \gamma$ -coincidences a revised ^{37}Ca decay scheme could be obtained to compute the production of ^{37}Ar by the ^{37}Cl (ν_e, e^-) mirror decay.

5 Concluding remarks

Using the newly developed magnetic and electrostatic correction elements in the ISOLDE-3 mass separator the mass resolving power was drastically increased. After the move of the ISOLDE-3 (then called High Resolution Separator, HRS) to the booster of the CERN, additional tests and experiments are planned to use the HRS in future as standard on-line mass separator with a mass resolving power > 10000 .

References

- [1] K.L. Brown; in: Proc. Int. Conf. Magnet Technology; DESY, Hamburg (1970)
- [2] H. Wollnik; Optics of Charged Particles; Academic Press, Orlando, FL, 1987
- [3] H. Wollnik; NIM **103** (1972) 479
- [4] J. Camplan; NIM **187** (1981) 157
- [5] J.M. Wouters, D.J. Vieira, H. Wollnik, H.A. Enge, S. Kowalski, and K.L. Brown; NIM **A240**, (1985) 77
- [6] W. Wendel, P. Michner and H. Wollnik; Int. J. Mass. Spectr. & Ion Proc.; **90** (1989) 131
- [7] C. Geisse; Thesis Giessen (1987), unpublished
- [8] M. Antl and H. Wollnik; NIM **A274** (1989) 45-48
- [9] A. Garcia et al.; Phys. Rev. **C42** (1990) 765

Figure 1: Example of the wire-network used to simulate a magnetic octupole (1) and the resulting measured current distribution without (2) and with (3) additional resistances. Each resistance symbol in the network corresponds to one correction-wire, where the distance of the wire from the optical axis increases linearly with the sketched number.

Figure 2: Schematic drawing of the optics of the ISOLDE-3 on-line mass separator.

Figure 3: Principle of the beam observation system, used for off-line and on-line high-resolution measurements. The measurements with radioactive beams were performed with the available beam transport system.

Figure 4: Isobaric-separation with the ISOLDE-3 on-line mass separator. The mass resolving power was determined to be > 10600 at 60% transmission. The distance between two neighbouring points in the shown spectra correspond to one bit of the used NMR-system.