Development of Isobar Separation for ^{182}Hf AMS Measurements of Astrophysical Interest

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^{182}Hf with a half-life of 8.90 ± 0.09 million years [1] is an important nuclide for geo- and astrophysics. In addition to applications as an extinct radionuclide in geochemistry, live ^{182}Hf can be expected to be found on Earth today from recent and nearby nucleosynthesis events (e. g. supernovae). A positive signal would help to confirm the ^{60}Fe signal recently found in deep-sea Fe-Mn crusts [2] and to test nucleosynthesis models.

A first attempt to find live ^{182}Hf in deep-sea sediments using low-energy AMS based on a 3-MV tandem accelerator resulted only in an upper limit, mainly due to the high background of the stable isobar ^{182}W [3]. Although suppressed by chemistry and in the ion source by using $^{182}\mathrm{HfF}_5^-$, isobar separation at the final detector is necessary to reach the desired detection limit, which is only possible at high ion energies.

Due to the small difference in specific energy loss between ^{182}Hf and ^{182}W of a few percent, even at 200 MeV, conventional methods like an ionization chamber or a gas-filled magnet are not applicable. Thus we tried a new approach based on passive absorbtion and time-of-flight measurement (called ΔTOF [4]). Isobars loose different energy as they travel through a passive absorber. The different residual energy is measured with high resolution time-of-flight. As a passive absorber very homogeneous silicon nitride (SiN) foils (thickness of about 300 μg/cm^2) and special prepared carbon foils (about 200 μg/cm^2) [5] have been used. The setup is installed at beam line HI-20 which was adopted to achieve a good focus at the start MCP foil and the absorber foils. The flight path is about 1.8 m to the stop detector, which in this case is a silicon strip detector of about 25 cm^2 area. The large stop detector is necessary to achieve high co llection efficiency of the scattered ions.

The width of the peaks in the TOF spectra is dominated by the physics of energy-loss straggling, however high detector resolution (i. e. time resolution) is necessary to avoid additional broadening. With our setup sub-nanosecond resolution of the TOF measurement corresponds to an energy resolution better than 1%.

We used the stable isobar pair ^{176}Hf – ^{176}Yb to study the separation at ion energies from 150 to 200 MeV and various absorber thicknesses ranging from 900 to 1800 μg/cm^2. At the same thickness and energy carbon foils provide more separation compared to SiN foils, but also increases the FWHM of the peaks. On the other hand the high homogeneity of the SiN foils reduces energy-loss tails significantly.

The best results could be achieved at 200 MeV with about 1500 μg/cm^2 SiN foils (see Figure 1). By cutting at the maximum of the ^{176}Yb peak and loosing half of the counts the suppression of the isobar ^{176}Hf is about a factor of 400.

Alternatively to the ΔTOF method passive absorbtion in combination with the high resolution of the Q3D spectrometer was investigated. Isobars are bent according to their different momenta over charge after the passive absorber and focused to different positions at the focal plane detector. The position-sensitive detector allows a high momentum resolution of about 0.1%. However, long energy-loss tails and scattering from neighboring charge states reduce the separation capabilities of this method.

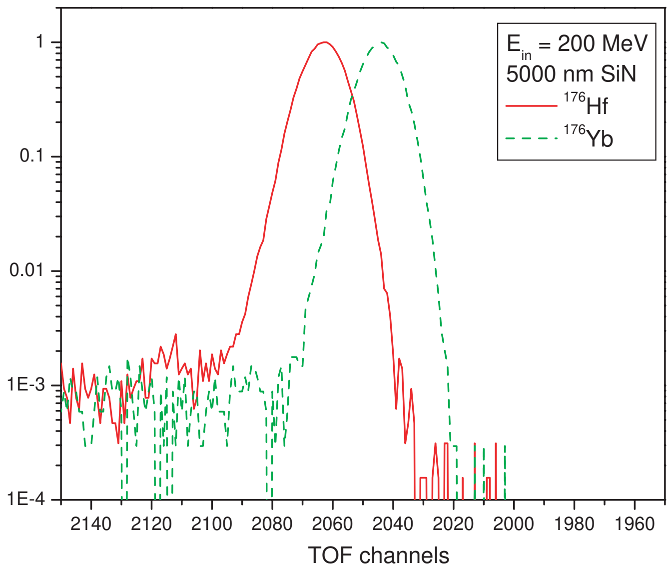

Fig. 1: Isobar separation at 200 MeV using 5000 nm SiN (=1500 μg/cm^2). The stable isobar pair ^{176}Hf – ^{176}Yb is used to simulate the case for ^{182}W – ^{182}Hf.

With improved chemical Hf-W separation and together with the suppression in the ion source by 3 to 4 orders of magnitude using $^{182}\mathrm{HfF}_5^-$ the additional suppression by ΔTOF by 2 to 3 orders of magnitude should result in an improvement of detection limit for a search for live ^{182}Hf.

References

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