## Energy Calibration with Secondary Beams


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The secondary beam method allows, in a relatively short period of time, the detection of a variety of charged particles of known energies in an angular range extending from the beam direction up to about 50 degrees. It is important to produce the secondary beams as far upstream as possible, so as to use the maximum magnetic selection, and to calibrate against a known primary beam. To do so, during the October 2000 run with the NIMROD multidetector in cave 4, a production target was mounted just downstream of the Faraday cup FC02, in the K500 vault area, upstream of the first magnet on the beam line, BM01. Since the beam lines cannot be set with nominal precise Bρ values as required for energy determination of secondary particles, primary beams must be used to set up the lines. For a wider variety of energies, a beam stripping foil has been mounted just in front of the production target; the latter is also used as a beam energy degrader. For the two primary beams intended for the calibration, $^{20}$Ne at 40A MeV and 30A MeV, the stripper was a 0.25 mil thick Al foil and the production target, a 59 mg/cm$^2$ carbon piece. The central Au target used in the scattering chamber was 10.3 mg/cm$^2$ thick.

The charge state selected for the primary beam, around 170 nA on FC02, was 7+ at 40A MeV and 6+ at 30A MeV. The figure shows a CsI(Tl) fast-slow energy spectrum, from NIMROD ring 2 detector. The beam line magnetic rigidity was 1.578 Tm with the carbon production target rotated at 35 degrees. There are peaks for protons, deuterons and alphas; $^6$Li and $^7$Li isotopes are also present. Maybe not clearly seen, but there are also F and Ne fragments detected each in two different charge states.

The same technique has been applied for HERACLES in cave 2, but with the production target mounted after the beam

**Table 1**: Setups for energy calibration of NIMROD with secondary beams

| Primary Beam Energy | Bρ Tm | Stripping Al Foil | Charge State | Production Target Yes/No | Angle | Time Hrs. | Remarks |
|---|---|---|---|---|---|---|---|
| $^{20}$Ne-40AMeV | 1.824 | Yes | 10+ | No | - | 0.5 | Elast.Rings 2,3,4 |
| $^{20}$Ne-40AMeV | 1.824 | Yes | 10+ | Yes | 15° | 15 | LCP, Fragments |
| $^{20}$Ne-40AMeV | 2.605 | No | 7+ | No | - | 0.5 | Elastic |
| $^{20}$Ne-40AMeV | 2.605 | No | 7+ | Yes | 15° | 3 | d,Forward Rings |
| $^{20}$Ne-30AMeV | 1.578 | Yes | 10+ | No | - | 0.5 | Elast.Rings 2-5 |
| $^{20}$Ne-30AMeV | 1.578 | Yes | 10+ | Yes | 35° | 16 | α,Z=5-9,weak Li |
| $^{20}$Ne-30AMeV | 1.3 | Yes | 10+ | Yes | 50° | 0.25 | Elastic |
| $^{20}$Ne-30AMeV | 1.3 | Yes | 10+ | Yes | 15° | 1 | Frags.Rings 2-6 |

magnet BM02. In consequence, there was only one dipole magnet left on the beam line before the scattering chamber at the end of line 2. The magnet BM03, bending the secondary particles at only 30 degrees, did not provide enough selectivity and primary beams and other particles were reaching the detectors after multiple scatterings in the beam line and its elements. However, with secondary particles and fragments generated just downstream of FC02, much cleaner contributing secondary beams should be available. Since the back hemisphere is not covered with charged particles detectors, during the data taking for energy calibration, a second target is mounted on a trolley near the entrance to the scattering chamber, in addition to the center target. So, almost all detectors are reachable with a smaller effective scattering angle and, therefore, can usually detect a wider variety of fragments and isotopes.

In the off-line analysis, peak coordinates of each isotope-energy combination will be used in conjunction with energy calibration functions (see for example [1-5]) to set effective parameters for each detector. The information collected with these short secondary beam runs is crucial in order to obtain a precise and self-adapted energy calibration of individual detectors in a large array heavy ion experiment.

**Table 2**: Time required for beam preparation and data acquisition

| Primary Beam | Bρ (Tm) | Preparation | Acquisition |
|---|---|---|---|
| $^{20}Ne^{7+}$ | 1,824 | 4 hours | 16 hours |
| 40A MeV | 2.605 | 2 hours | 4 hours |
| $^{20}Ne^{6+}$ | 1.578 | 2 ½ hours | 17 hours |
| 30A MeV | 1.3 | 2 hours | 2 hours |
| **TOTALS** | | **10 ½ hours** + | **39 hours** = **50 hours** |

## References

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