7 Mass separators and beam transport

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7.1 HRS (High Resolution Separator) upgrade: improved resolution

High-resolution operation of the HRS is crucial for a large number of experiments where isobaric contamination from more abundantly produced isotopes can seriously disturb the measurements. The requirements for successful suppression of unwanted contaminants vary from case to case; a relative mass resolution $\Delta M/M$ of between 8000 and 30 000 is needed.

The performance of the HRS is currently limited by three factors:

– Emittance of the ion source

– Second-order distortions in the magnetic dipoles

– Need for improved beam diagnostics and collimation.

For a significant improvement in HRS resolution, all three factors need to be addressed. A modest improvement in performance and ease of operation may be achieved by addressing just the second and third factors above.

The three factors above are also key requirements for the EURISOL high-resolution separator [1]. An upgrade of the ISOLDE HRS as suggested in this document would at the same time serve as a prototype of the EURISOL HRS.

7.1.1 Emittance of ion source: RFQ-BC

Construction of an RFQ beam-cooler is already under way at ISOLDE and is described in this report. In the first case it will be installed after the HRS (Fig. 7.1), where it will improve beam transport but will not have any effect on HRS performance. Once thoroughly characterized, one may consider installing the RFQ-BC before the first HRS magnet. The RFQ-BC is expected to reduce the beam emittance to ~3 π mm mrad, which would make resolutions of > 10 000 attainable. The RFQ will help HRS resolution only if beam distortions in the separator magnets are eliminated. However, the resolution could only be used if the beam diagnostics are upgraded. The RFQ also requires a pre-separator after the source, probably a Wien filter, and suitable beam-matching sections. To accommodate the new equipment, major modifications will be needed to the concrete and earth around the HRS. Altogether, this work entails a major rebuilding of the HRS.

7.1.2 Optical aberrations in magnetic dipoles

Beam distortion in the HRS may be eliminated by magnetic multipoles in the separator magnets. The existing multipoles have been shown to be ineffective, and it is proposed to modify the magnet pole faces to attain the correct field shape. This technique has not been used before, and an offline test is highly desirable before considering such a major modification to an operating machine.

A multipolar separator magnet should be built and tested offline. Essentially, a small isotope separator should be built. The prototype magnet could be of the same kind as proposed for the EURISOL HRS high-resolution separator, and a cost of 200 kCHF including design is anticipated. Vacuum chambers, beam-matching sections, and beam diagnostics will also be needed (see below). A ‘spare’ standard ISOLDE front-end could be used as a beam source and part of the beam matching. Once validated offline, the same principles may be applied to the HRS. With suitable preparation the magnet modifications could be done in a shutdown, without eating into the online running period.

7.1.3 Beam diagnostics

The existing slits and scanners are ill-adapted to the extremely narrow beams at the HRS foci. Moreover, they give no clue as to how to optimize the beam shape and they should be replaced with new slits, scanners and emittance meters. Suitable emittance meters are currently under development at ISOLDE. The existing fixed-needle beam-scanner (FNBS) could be copied and adapted slightly to make suitable scanners. A new development is needed for the slits. A new scanner/slit/emittance-meter box should be installed at the first and third foci of the HRS.

7.1.4 Planning

The three factors listed above are interdependent, and consequently the order in which they are carried out is important. A suggested outline plan follows:

- Install and test RFQ after HRS
- Build and install beam instrumentation boxes at first and third foci
- Build and test prototype EURISOL magnet (test of multipole concept)
- Replace HRS pole faces and add correctors, if necessary
- Test high-resolution mode using low emittance source and slits in first focus
- Major HRS rebuild:
    - Install RFQ before first focus
    - Install pre-separator (Wien filter) before RFQ
    - Add beam-matching sections (everything from the first focus onwards stays the same)

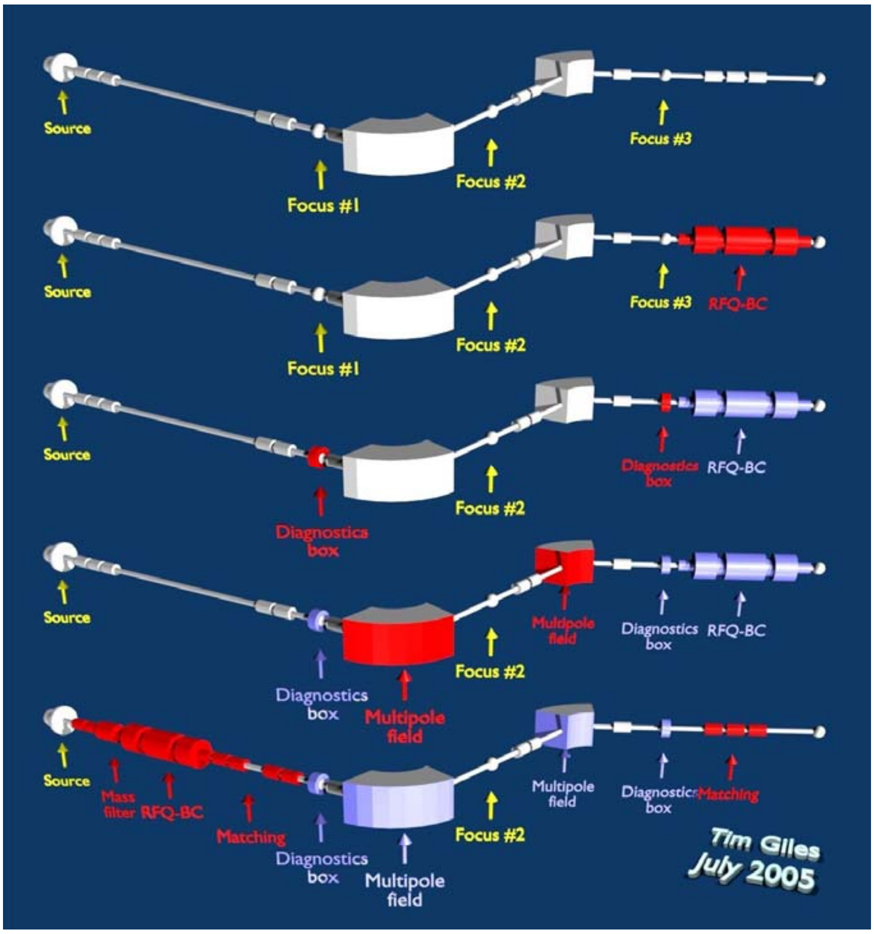

Fig. 7.1: Illustration of a possible sequence of upgrades to the HRS

The theoretical performance would be:

– Resolution of 1700 for 40 π mm.mrad beam (e.g. plasma ionizer)
– Resolution of 6700 for 10 π mm.mrad beam (e.g. surface ionizer)
– Resolution of 20 000 for 3 π mm.mrad cooled beam

Currently, a resolution of 4000–6000 from sources with emittances <~10 π mm.mrad (RILIS) can be achieved.

7.2 The CA0 bottleneck: parallel operation of GPS and HRS

The PS Booster permits pulse-to-pulse switching between the two separators, HRS and GPS, thereby raising the possibility of parallel operation. However, the beams from both the HRS and the GPS separators are delivered to the majority of the experimental installations at ISOLDE via a single central beamline. Consequently when the central beamline (CA0) is occupied by the HRS beam, the GPS can only deliver beam to the 'collection beamlines', GHM and GLM, upstream of CA0. When CA0 is occupied by the GPS beam, the HRS cannot run at all. There are two solutions to the CA0 bottleneck: building a second parallel beamline [2], or pulsing the existing beamline.

The first solution is heavily constrained by the existing beamline layout. A matrix-type switchyard, in the style of that proposed for EURISOL is not possible, because of the layout of existing beamlines: neither the incoming nor the outgoing beamlines can be moved more than a few centimetres without disrupting the whole layout of the hall. A very complex (and costly) switchyard could be imagined, but it is extremely difficult to create a design which, in the small space available, maintains efficient beam transmission without sacrificing operational flexibility.

Pulsing the CA0 beamline, on the other hand, would require almost no modifications to the hardware. The tape station would be accessible by either separator, even during parallel operations. The control system is already designed to deal with pulsed machines, so the software modifications are not expected to be dramatic. If necessary the pulsed control could be extended to beamlines downstream from CA0, opening up even more permutations for simultaneous operation of experiments. The CA0 elements which would need to be pulsed are labelled in red in Fig. 7.2.

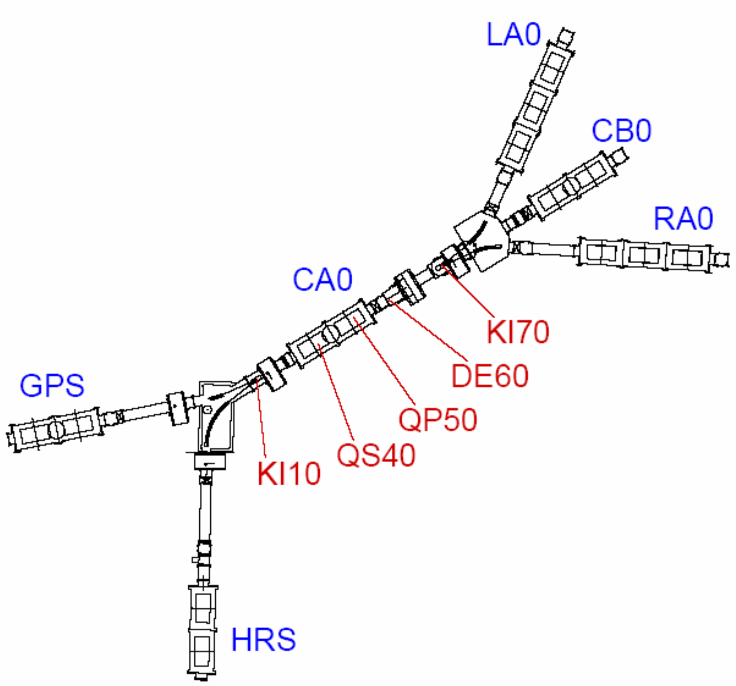

Fig. 7.2: Existing beamline layout around CA0

7.2.1 Modifications

- Two ‘contexts’ created: one for HRS and one for GPS
- Scanner and Faraday cup readout needs to be synchronized
- Switching time of the electrostatic supplies improved
- Timing hardware needed
- Synchronization of the beam gates
- Software control and visualization of timing

7.2.2 Limitations

- Cannot share a single separator between two experiments (if required, this could be achieved at the expense of more complicated controls).
- Cannot share beam between two experiments in the LA section, or two experiments downstream of CB0 (if this is a serious restriction, we could decide to pulse all ISOLDE beamlines; pulsing CA0 would be just a stepping stone before moving to fully pulsed beam transport).
- In the case of two experiments each using stable-beam or slowly-released, long-lived species, up to 50% of the yield is lost.
- Short time-slices may not give enough time for the beam diagnostics instruments to read out.

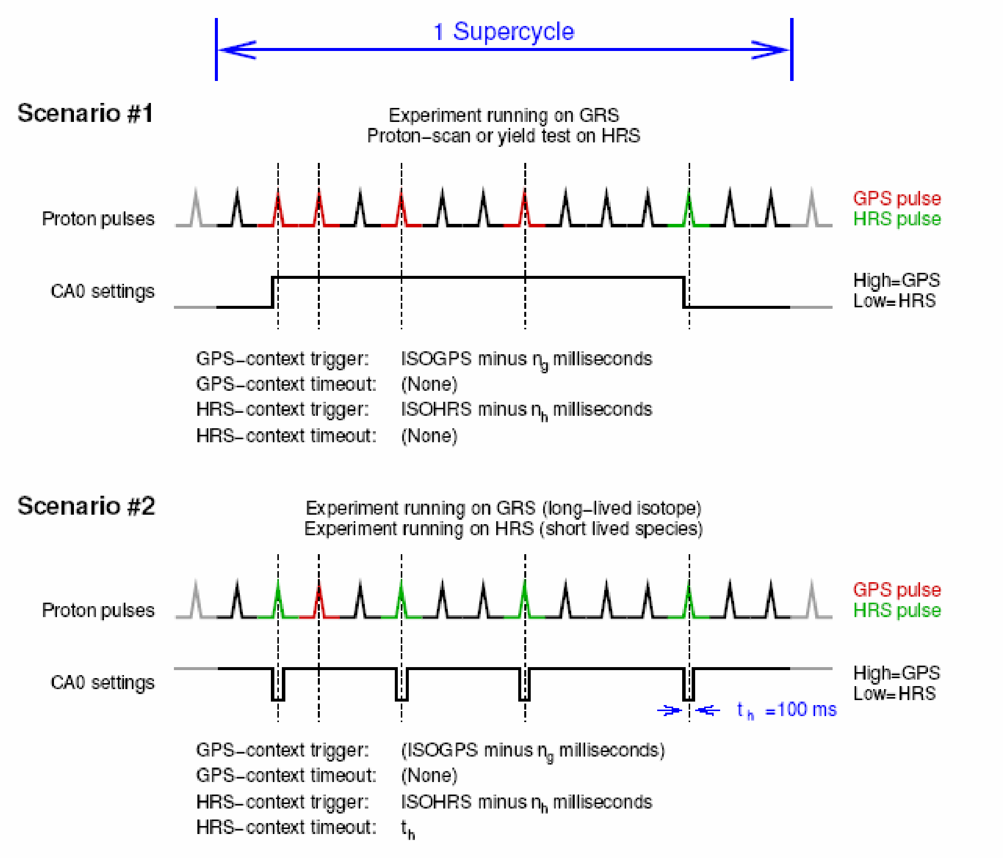

Fig. 7.3: Examples of beam sharing in CA0

Figure 7.3 shows two examples of beam-sharing in CA0. The settings for the CA0 elements are stored in two ‘contexts’. Switching between the contexts may be triggered by timing signals linked to the PSB cycle, or by timeouts. In the first scenario, the CA0-GPS context is loaded n_g ms before an ISOGPS pulse. Likewise the CA0-HRS context is loaded n_g ms before an ISOHRS pulse. In the second scenario the CA0-HRS context is loaded n_h ms before an ISOHRS pulse. At t_h ms later a timeout causes a switch back to the CA0-GPS context.

Triggers may be linked to any of the normal PSB signals (including ALL), and are sent a certain number of milliseconds before the proton pulse arrives to give the hardware time to react (does this time need to be adjustable, or can it be fixed?)

Timeouts are adjustable from 1 ms to 999-99 s, or set infinite (disabled).

Beam gates should open and close in synchronism, allowing for hardware reaction times, for example, the HRS beam gate is closed:

- 1 ms before an ISOHRS proton pulse arrives
- 5 ms after an ISOHRS proton pulse arrives
- if the HRS user beam gate signal is low (= closed)
- if the CA0-HRS context is not set.

To make things easy to tune, a number of standard timings should be set up for oft-repeated scenarios.

References

[1] The EURISOL Report, Ed. J. Cornell (GANIL, 2003).
http://www.ganil.fr/eurisol/Final_Report.html

[2] Ulli Köster, private communication.