An innovative Superconducting Recoil Separator for HIE-ISOLDE

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1. The HIE-ISOLDE facility and the recoil separator ISRS

The HIE-ISOLDE facility at CERN (Fig. 1) can accelerate more than 1000 isotopes of about 70 elements, at collision energies up to 8 MeV/A. Structure and dynamics of nuclear systems far from stability are being investigated by means of Coulomb barrier reactions, nucleon transfer, deep inelastic and fusion-evaporation reactions. The ISRS collaboration [1] has recently proposed the construction of a novel high-resolution recoil separator, the "ISOLDE Superconducting Recoil Separator" (ISRS). This instrument will extend the physics programme with the more exotic isotopes produced in the secondary target by means of focal-plane spectroscopy.

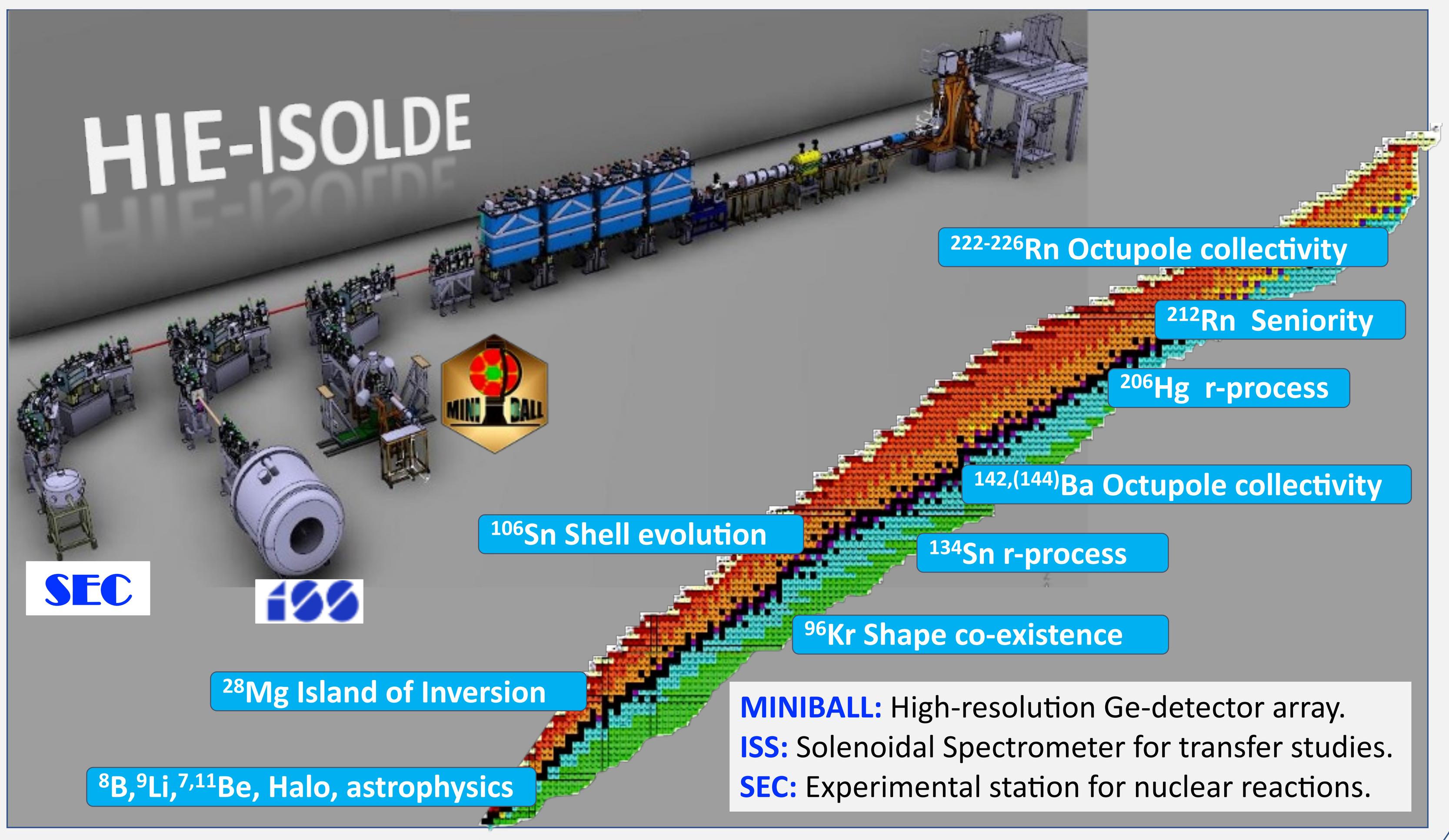

Fig. 1. The HIE-ISOLDE facility at CERN

2. Design studies of the ISRS

The design of ISRS is based on a circular particle storage ring with four 90° bending magnets (Fig. 2). When operating in the isochronous mode, the time-of-flight is a direct measurement of the M/Q ratio. Neighbouring masses can be separated by a suitable RF system synchronized to the duty cycle, regrouping charge states of selected isotopes and removing the rest.

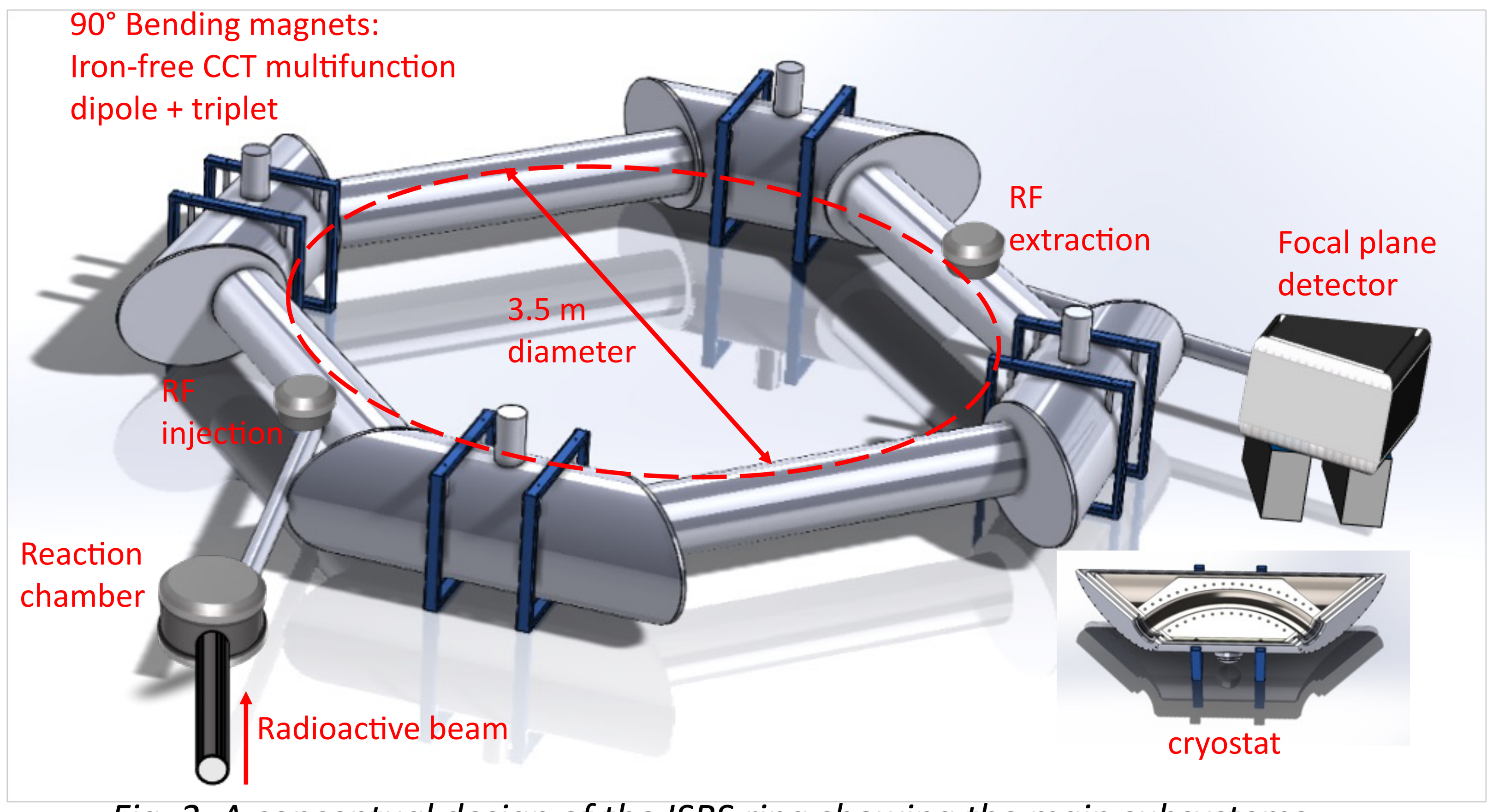

Fig. 2. A conceptual design of the ISRS ring showing the main subsystems.

3. Superconducting Canted-Cosine-Theta magnets

The ISRS ring can be made very light and compact (< 5 m² footprint), by the use of Multifunction Superconducting Canted-Cosine-Theta magnets (CCT) where magnetic fields are superimposed by nesting several tilted solenoids oppositely canted, so that the required multipolar fields are produced in the same magnet (Fig. 3). The present design has only four 90° CCT magnets of 1 m radius and 250 mm bore. The dipole field is 2.2 T with a peak field of 4 T, and three alternating quadrupoles with gradients of 13 T/m. [2].

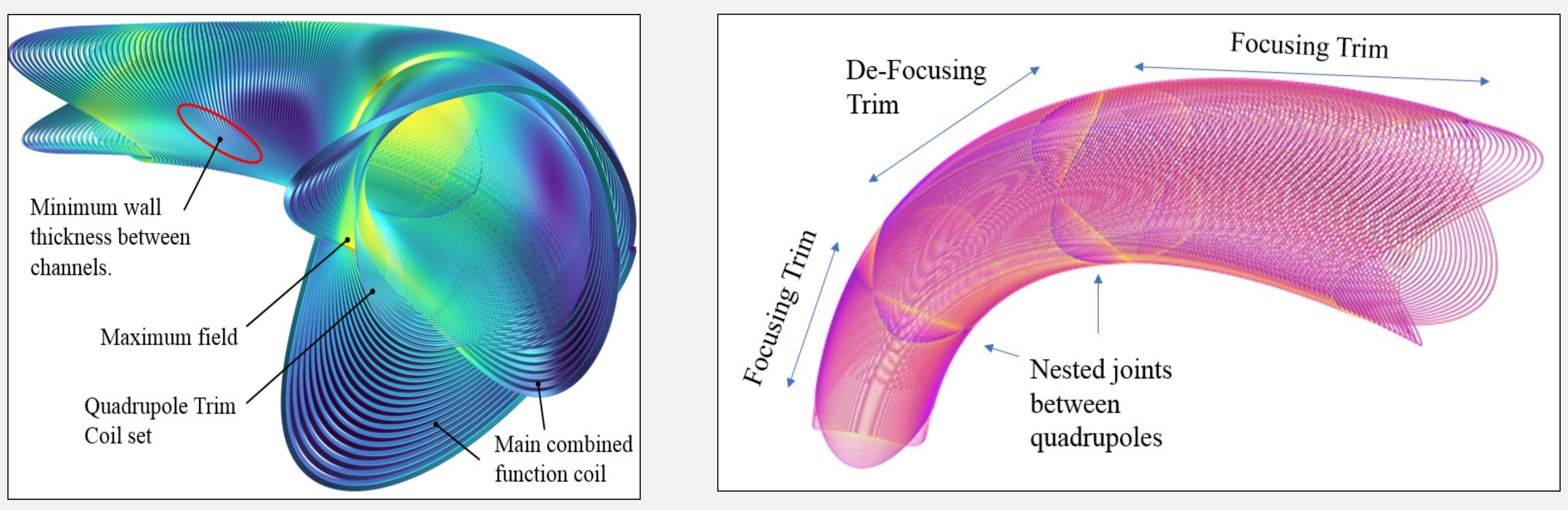

Fig. 3. Design model of a Superconducting Curved Canted-Cosine-Theta coil for ISRS

4. Beam dynamics

ISRS will operate as an isochronous non-scaling fixed-field alternating-gradient (FFAG) system (Fig. 4). The optical lattice allows the transportation and storage of an ion beam with large energy and momentum spread using fixed magnetic fields. Preliminary beam dynamics calculations predict large solid angles > 100 msr and momentum acceptances $\Delta p/p$ > 20% from ^{11}Li to ^{234}Ra @ 10 MeV/u, mass resolution better than 1/2000 and large storage efficiency ~ 100% [3].

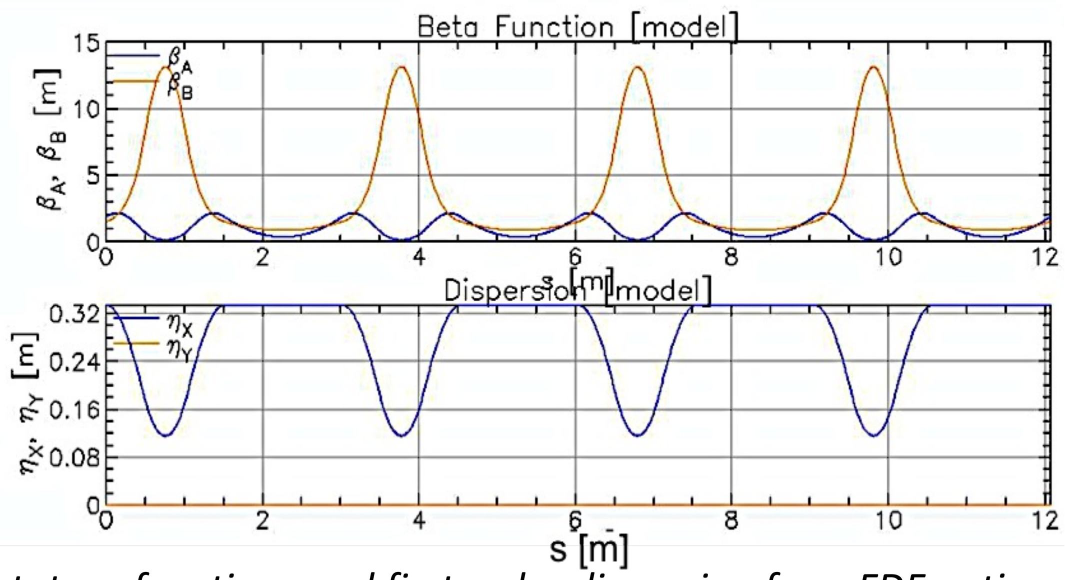

Fig. 4. Betatron functions and first order dispersion for a FDF optics configuration

5. CCT prototypes

The team is now working on a demonstrator (Fig. 5) of a combined-function iron-free 90°-curved CCT- SC magnet, which uses a cancellation coil for stray field suppression. This will remove iron non-linearities, solenoid weight, cooling power, thermal inertia and energy consumption. This provides also the possibility to implement a cooling system based on cryocoolers. First reduced scale pulsed-resistive models have been developed.

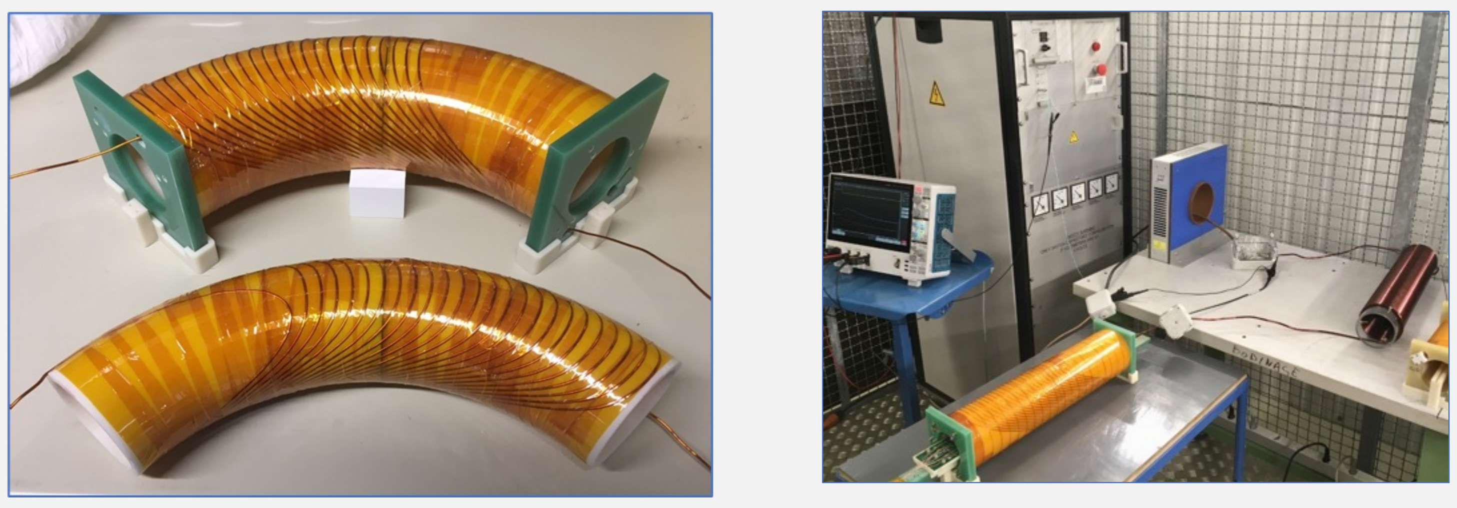

Fig. 5. Reduced scale pulsed-resistive models of the CCT coils and test bench at CERN

6. Injection/extraction systems

The design of the injection/extraction system and the bunching system needed to match the HIE-ISOLDE beam structure to the operation requirements of ISRS involve important technological challenges. An option for the injection/extraction system can be based on the SuShi system being developed for the HiLumi LHC phase [4]. The study of the low frequency multi-harmonic buncher system is already ongoing (Fig. 6).

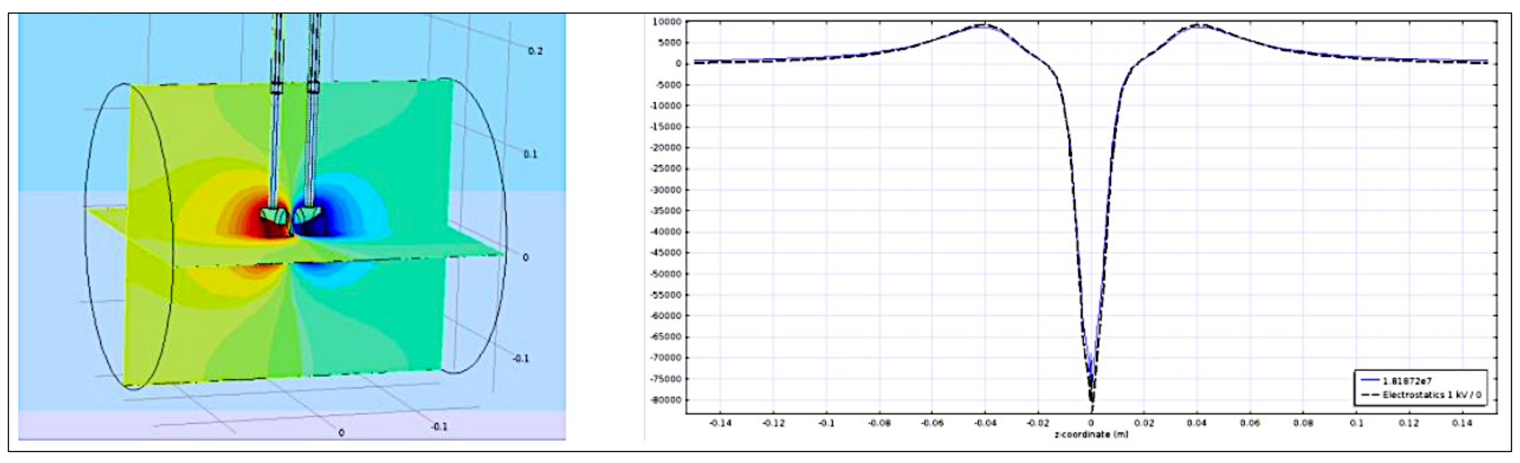

Fig. 6. Preliminary electromagnetic study of the MHB cavity, showing the electric field map produced by the two electrodes (left) and the field profile along the beam axis (right).

7. Summary and conclusions

The R&D program for the design of the Isolde Superconducting Recoil Separator is under development. Major advances include the beam dynamics and the design study of a curved multifunction coil with nested trim coils. First resistive models of CCT coils have been successfully developed and tested. Studies of the cryostats and the multi-harmonic buncher are already ongoing.

8. Acknowledgements

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