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Superconducting Curved Canted-Cosine-Theta (CCT) for the HIE-ISOLDE Recoil Separator Ring at CERN

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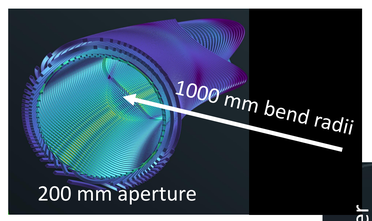
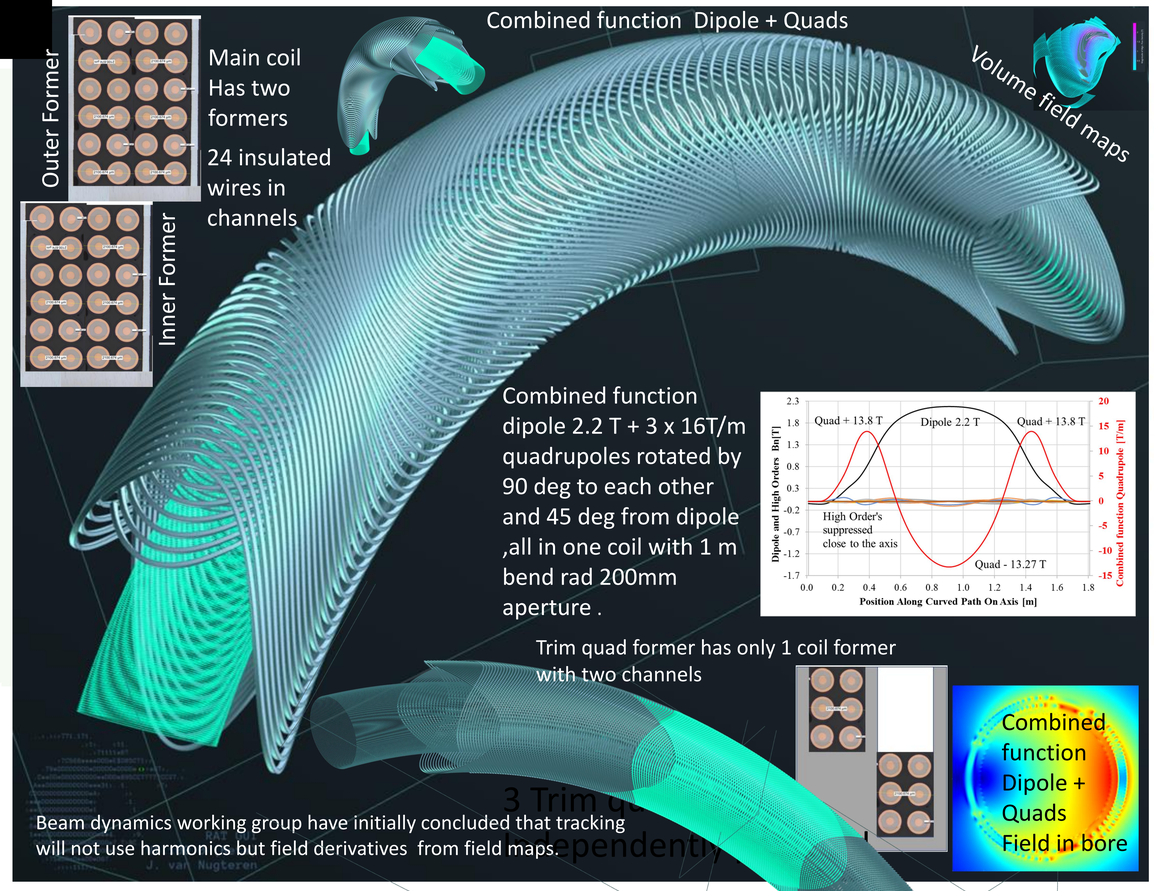


Abstract

The ISOLDE facility at CERN delivers the largest range of low-energy radioactive beams, exploited by several detector systems to investigate nuclear properties from the stable isotopes to the very exotic systems close to the neutron or proton drip lines. These studies can largely benefit from the use of a high-resolution fragment separator. To achieve this goal, an innovative spectrometer based on a compact superconducting (SC) ring, the Isolde Superconducting Recoil Separator (ISRS), is being studied. The ring will operate as an isochronous non-scaling fixed-field alternating-gradient (FFAG) system based on Canted-Cosine-Theta (CCT) magnets. These multifunction magnets have two alternating-gradient quadrupoles nested inside an outer dipole. According to preliminary beam dynamics studies, the dipole will need to generate a maximum field of 2.2 T. A maximum quadrupole gradient of approximately 14 T/m will guarantee orbit stability for heavy ions with a maximum kinetic energy of 10 MeV/u. Fine tuning of the CCT magnets and the FFAG optics will provide very large solid angles > 100 msr and momentum acceptances Δp/p > 20%.

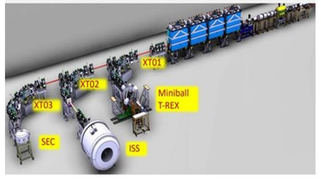
In this paper we present, the magnet designs and their optimisation. A cost-effective active stray field superconducting coil shield design has been introduced to be able to remove approximate 4000 kg of iron yoke and the complexity of building a tightly curved yoke.



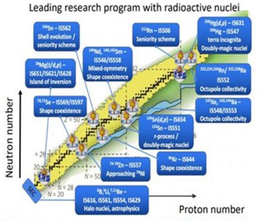
The HIE-ISOLDE facility at CERN

World-leading facility in radioisotope production and acceleration:

- Large range of radioactive beams: from ^{6}He – ^{236}Ra
- More than 1000 isotopes of about 70 elements
- Wide energy range from 0.45 to ~ 10 MeV/A



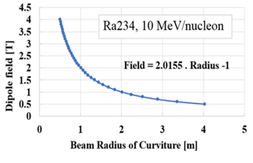
Leading research program with radioactive nuclei

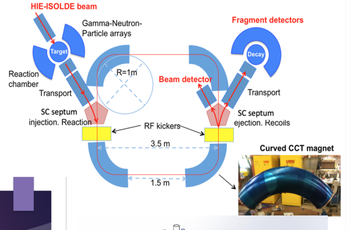


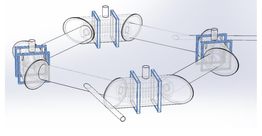
Recent physics cases investigated at HIE-ISOLDE (L. Gaffney, ISOLDE EPICS Workshop 2019).

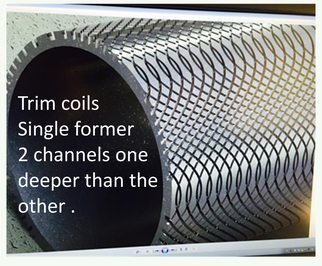
- The objective is to **carry out R&D program** to study the possibility to develop a compact fragment separator using **innovative** concepts and technologies: *(1) Mini-Storage ring, (2) CCT-Multifunction Superconducting solenoids, (3) FFAG, (4) Iron free magnets, (5) cryocooling*
- Unprecedent mass resolution, angular and momentum acceptance. Low cost.
- **Technological breakthrough for future fragment separators and mass spectrometers.**

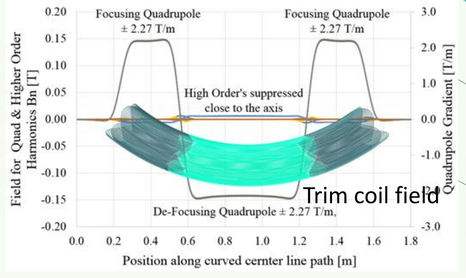
HIE-ISOLDE Ring curved CCT conceptual design development.

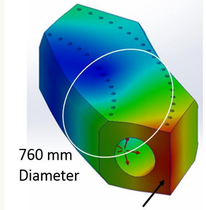


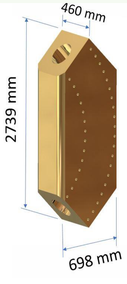


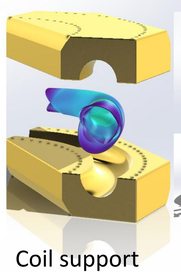


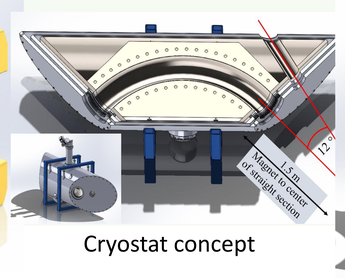


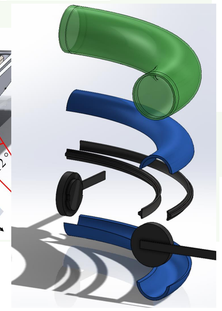


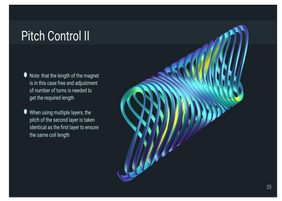


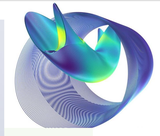


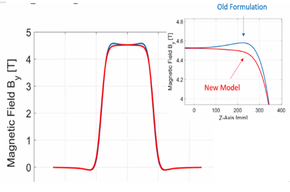




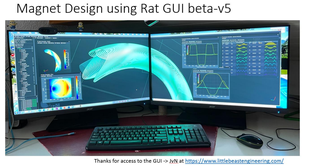


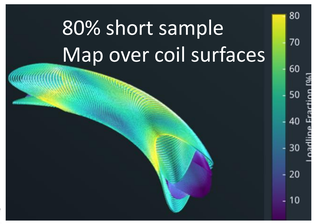






Magnet Design using Rat GUI beta-v5





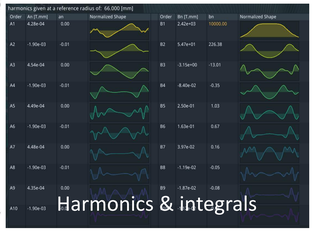
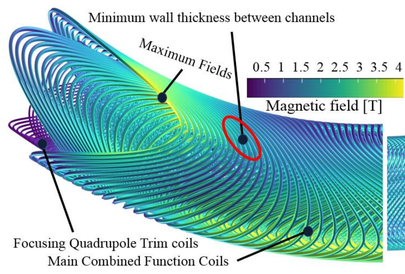


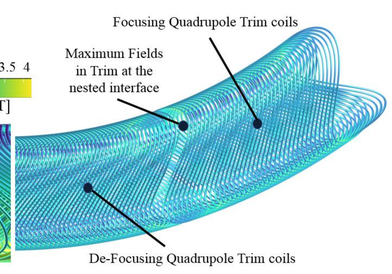
TABLE I
Magnet Perameters

Magnet Apertuer	200 mm
Radius of Curvitier	1000 mm
Magnetic Bend	90 deg
Total Matix Inductance	3122.223 mH
Total Energy	204.154 kJ
Superconductor	
Bare Strand Diameter	0.825 mm
Insulated Polyimed Strand Diameter	1 mm
Superconducting material	Nb-Ti
Cu:Su ratio	1.9 to 1.2:1
RRR	> 100 to 250
Total wire length: Main CF + Trims Q's	10.71 km *
Main Magnet Combind Function Coil	
Dipole field aperture	2.2 Tesla
Qaudrupole field	13.8 T/m
Nonimal Current	355 A
Max field with all coils powered (max in magnet)	4.252 T
Max field with just Main coil powered	4.157 T
Short Sample at Nominal currents in all coils	80.835 %
Number of wires in channel (Wide x High)	4W x 6H = 24
Number of layers/formers	2
Channel turns in formers	80
Coil Conductor lengh	9.199 km
Main Coil Inductance	3074.74 mH
Total number of joints in coil	23 + S&E

Trim Quadrupole Coils	Center Coil	End Coils
Max Quadrupole Gradient	± 2.27	± 2.27 T/m
Nonimal Current	(±) -132	(±) + 132 A
Max field with all coils powered	4.073	3.365 T
Short sample at Nominal Currents 4.5K	56	49&39 %
Number of wires in channel (Wide x High)	2W x 3H 6	6
Number of layers	2	2
Channel turns in formers	80	38
Magnetic Bend	33.1	28.2 Deg
Coil Conductor lengh	774	368 m
Coil Inductance	9.06	7.68 mH
Total number of joints in coil	5+S&E	5+S&E

* Coil is still subject to fine tuning so length may vary





V. Conclusion

A conceptual design of a curved multifunction coil with a nested set of trim coils mounted inside of the main curved magnet has been developed. The geometry of the magnet support former has been incorporated into a conceptual cryostat design. The coil technology follows closely the CERN orbit corrector MCBRD developed for CERN's High Luminosity upgrade. Further FEA work on the coil is needed. The Rat® program simulation package is a fundamental tool used in this magnets design. In conclusion This magnet will need further development to finalize the beam dynamics of the full ring, with injection and extraction elements incorporated in the ring design and their interaction with this magnet. This in turn will result in small changes to the field strengths. We are now waiting to start model building to finalize construction details.

Acknowledgment

The authors would like to thank J. van Nugteren at "Little Beast Engineering" for the interactive developing with the authors of the specialist software "Rat and its GUI". That was used in the design of this curved CCT magnets.