



Universidad
de Huelva

DESIGN STUDY OF THE ISRS CCT MAGNET DEMONSTRATOR MAGDEM LOI-INTC-228 (2021)

C. A. Gonzales Cordero¹, R. Berjillos¹, N. Deelen², C. Garcia-Ramos¹, A. Izquierdo³, T. Junquera³, G. Kirby¹, T. Kurtukian Nieto⁵, M. E. Page-Mason⁴, J. Resta-Lopez⁶, J. Van Nugteren², I. Martel¹

¹University of Huelva, Spain. ²Little Beast Engineering, Holland. ³Accelerator and Cryogenics Systems, France.

⁴Nottingham University, United Kingdom. ⁵Instituto de Estructura de la Materia-CSIC, Madrid, Spain. ⁶University of Valencia, Spain



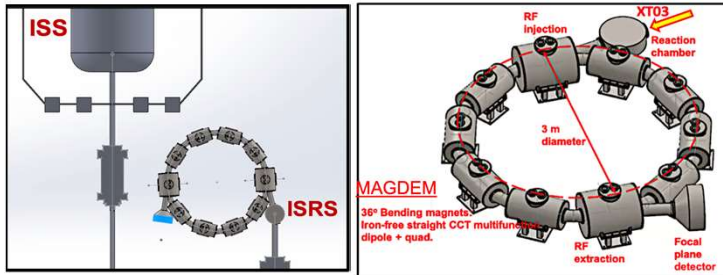
Abstract

The ISOLDE Superconducting Recoil Separator (ISRS) at CERN [1-3] is a high-resolution spectrometer for analysing the heavy fragments produced in reactions induced by ISOLDE's exotic beams. ISRS design is based on a compact FFAG particle storage ring composed of short straight multifunction superconducting magnets able to accommodate a wide range of momentum and energy spread. The team has developed a magnet prototype MAGDEM, a very compact, low current, large aperture Nb-Ti CCT superconducting magnet with both dipole and quadrupole functions. It features an innovative cryogen-free cooling system based on GM cryocoolers and a LN2 pre-cooling system [4].

HIE-ISOLDE

The HIE-ISOLDE facility at CERN is a world leading radioactive beam facility. Accelerates over 1300 isotopes from 70 elements, ~ 10 MeV/A.

Mission: Research on nuclear structure and reaction dynamics, astrophysics, and fundamental interactions.



ISOLDE Superconducting Recoil Separator

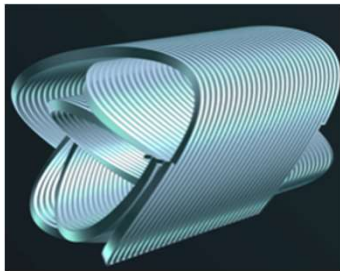
ISRS is a high-resolution fragment separator that combines focal plane decay spectroscopy and particle -gamma spectroscopy at the reaction target.

Mission: Expand the HIE-ISOLDE physics program.

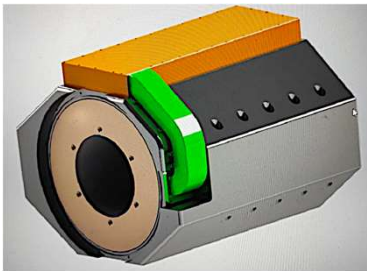
Design principles:

- (1) Particle storage ring: $R=1.5$ m, Aperture: 200 mm
- (2) NS Fixed Field Alternating Gradient (FFAG).
- (3) Superconducting Multifunction Nested coil (D + Q).
- (4) Canted Cosine Theta (CCT) Cryocoolers (no LHe bath).
- (5) Injection/extraction (RF kicker, Suchi, etc)
- (6) A/Q separation by cyclotron freq., RF, ToF
- (7) Dispersive/Synchronous operation modes

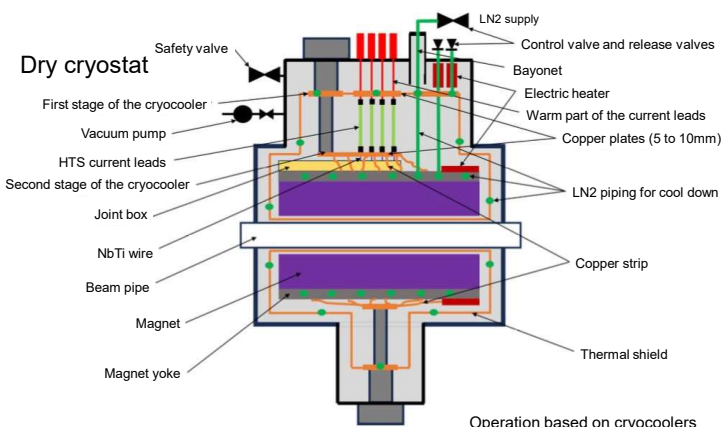
MAGDEM (MAGnet DEMonstrator)



Nested dipole & quadrupole functions



Integrated system



COIL Desing

The innovative design, operating at 100 A, features a dipole coil with a peak magnetic field of 2.2 T, integrated within a quadrupole coil with a field gradient of 9 T/m. The cross-section of the assembly consists of four aluminum layers, each with a 2 mm taper that forms a conical shape. The conical structure has a smaller aperture at the current lead end and a larger aperture at the layer jump side.

The winding channels are precisely machined using a 4-axis CNC system, and a glass insulation layer (~0.5 mm) is applied to each layer to help with resin flow during coil impregnation.

The coil deflection must not exceed 0.2 mm to keep magnetic field errors below 100 ppm. The dipole coil pack has 210 turns, and the quadrupole coil pack has 126 turns.

CRYOSTAT design

The MAGDEM magnet uses a dry cryostat with a single cryocooler to reduce costs while providing effective cooling, with mechanical supports and current leads being the main heat sources at 4K.

The dipole operates at ± 92 A and the quadrupole at ± 113 A. Copper leads are used for initial cooling, followed by high-temperature superconducting (HTS) leads to reduce the heat load.

The magnet has around 340 joints, each with a target resistance of 1-10 nOhms, achieved through soldering or ultrasonic techniques. The cooling process takes about 8 days with one cryocooler or 5 days with two, using LN2 pre-cooling.

References

- [1] I. Martel et al. "Design study of a Superconducting Recoil Separator for HIE-ISOLDE", INTC -I-228, 2021.
- [2] J. Resta-Lopez, et al. "Design and Beam Dynamics Studies of a Novel Compact Recoil Separator Ring for Nuclear Research with Radioactive Beams," Proc. of IPAC 2021, Campinas, SP, Brazil, 2021.
- [3] I. Martel et al. "An innovative superconducting recoil separator for HIE-ISOLDE. NIMB 541:176–179, 2023.
- [4] G. Kirby, et al., "Design and Optimization of a 4 Tesla 200 mm Aperture Helium-Free Nb-Ti Nested CCT Quadrupole / Dipole Superconducting Magnet", ASC2024 ID 4070214/1LOR1B-07, in press.



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CONTACT: imartel@uhu.es