ISOLDE Workshop and Users meeting 2025

ISRS project R&D status and plans for CERN LS3

Ismael Martel

University of Huelva

Universidad de Huelva

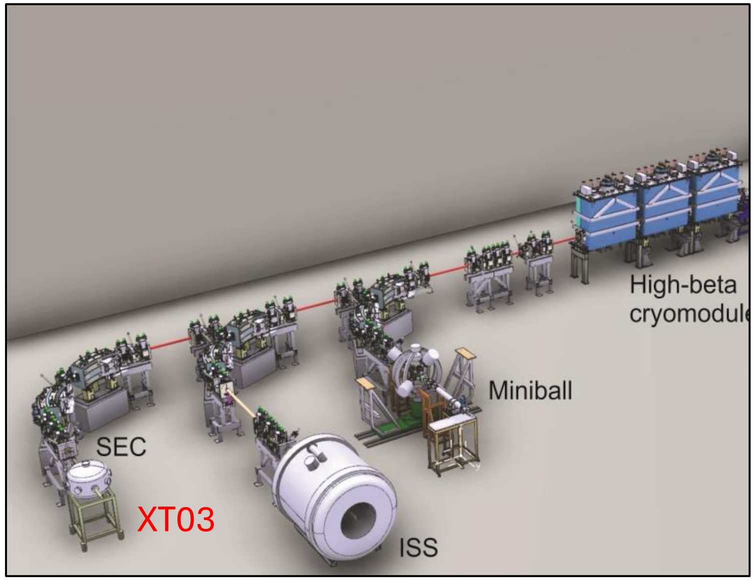
MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

ISOLDE Superconducting Recoil Separator

The ISOLDE Superconducting Recoil Separator (ISRS) is a high-resolution separator that combines focal plane spectroscopy with particle and gamma detection at reaction target. LOI-INTC-228 (2021). Spokespersons: I. Martel, O. Tengblad, J. Cederkall



Minimum spectrometer requirements

Parameters	Values
Momentum acceptance	$\pm 10\%$
Resolving power $p/\Delta p$	2000
Angular acceptance	$\pm 10°$
Angular resolution	$0.1°$
Solid angle	100 msr
Charge resolution $\Delta Q/Q$	1/70 (FWHM)
Mass resolution $\Delta M/M$	1/250 (FWHM)
Rotation	$0 - 70°$

R&D FUNDING 2023-2026

Spanish Gov grant (RRF/EU): 3 M€.

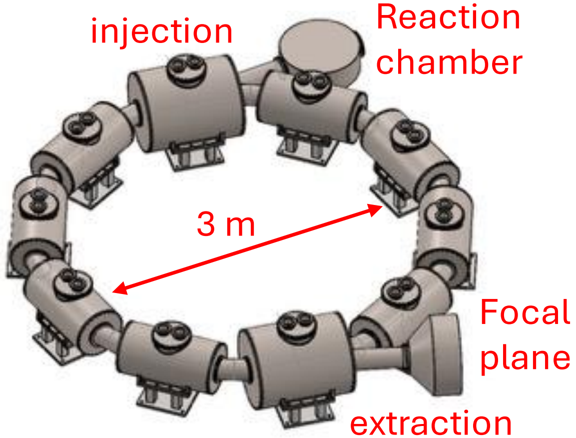
- Univ. Huelva (Coordinator)
- ESS Bilbao
- Univ. Valencia
- IEM-CSIC-Madrid

ISRS WEB SITE
https://www.uhu.es/isrs/

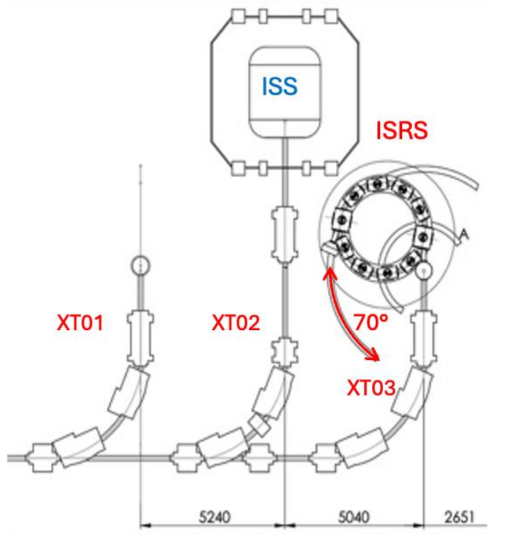
✓ Physics studies
✓ Beam dynamics
✓ SC Magnets
✓ Focal plane detectors
✓ Multiharmonic buncher
✓ Ion Test Bench

ISRS baseline design:

- Compact particle storage ring ~ 3 m diameter
- Fixed Field Alternating Gradient
- Nested dipole + quadrupole SC magnets, iron-free, Canted Cosine Theta (CCT) technology. → MAGDEM
- Cooling by Cryocoolers (no LHe bath)
- Injection/extraction (Kicker, Suchi, others)
- Focal plane detector
- Multi-harmonic buncher. → MHB



ISRS: 10 MAGDEM units



HIE-ISOLDE HALL

PHYSICS CASES

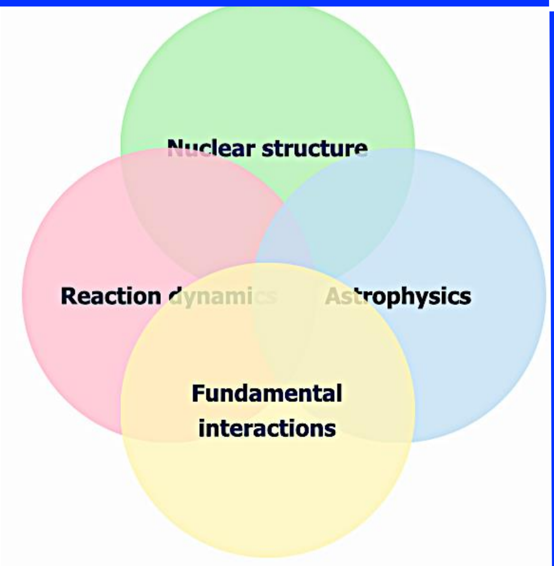
ISRS Physics Working Group

- Define sscientific roadmap that exploit ISRS’s unique capabilities

✓ ISRS White Paper

✓ ISOLDE Linear Spectrometer (ILS)

https://www.uhu.es/isrs/isrs-physics-working-groups/



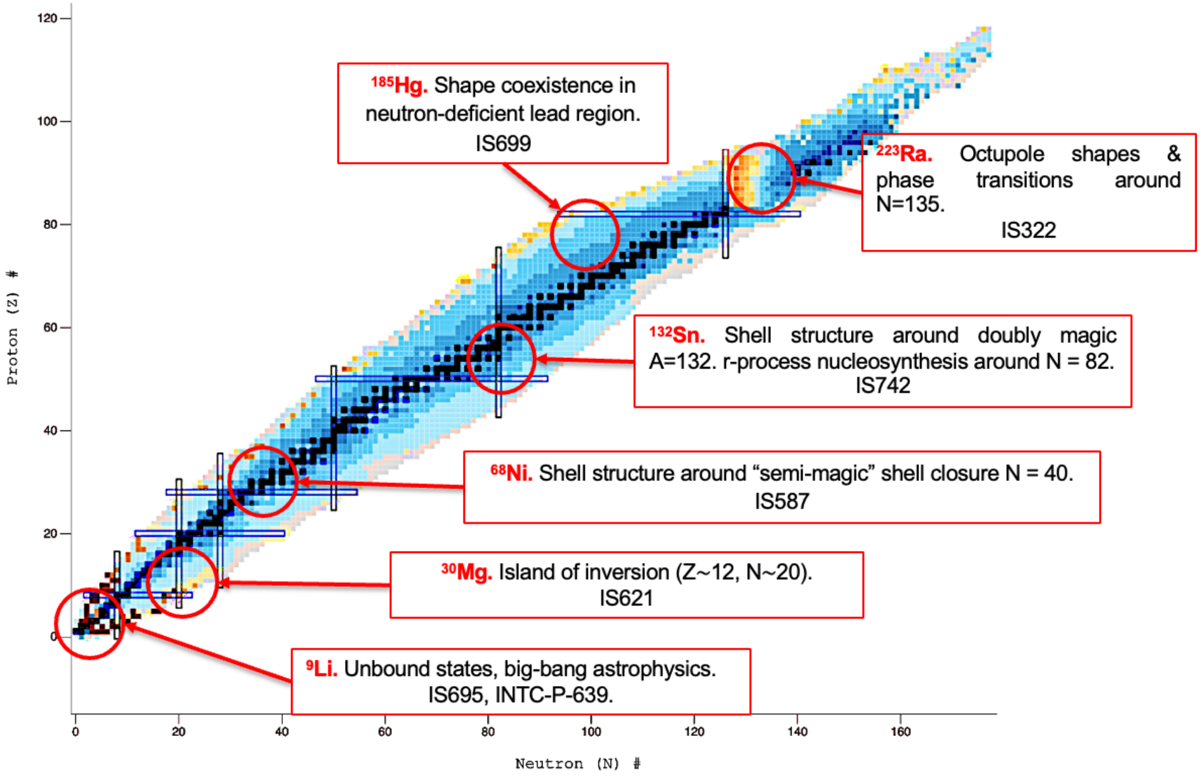
- First meeting October 29, 2025

https://indico.cern.ch/event/1602061/

- *Shape coexistence on regions around Z ≈ 40 and Z ≈ 82*
- *Structure and reactions of halo and skin nuclei, 11Li → 144Xe*
- *Structure of n-rich nuclei around and beyond N = 126 (MNT)*
- *Clustering in light and medium-heavy nuclei, 11Be → 21F*
- *Abundances of the elements in r-process peak: (α,n) reactions*
- *Spectroscopy and charged particle potentials on the proton-rich side → optical potentials for rp- and (p,γ)-process*

STAND ALONE – TAGGING – PRODUCTION & DECAY – PARTICLE GAMMA CORRELATIONS – ROTATION (MNT)

NUCLEAR REACTIONS CALCULATIONS



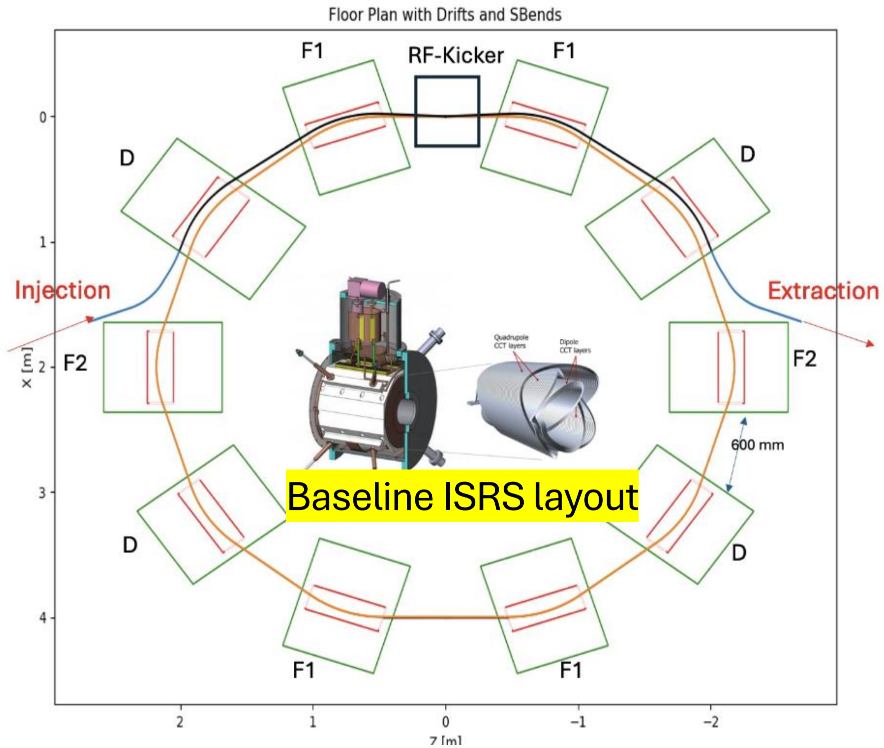
Nuclear reactions network

- Direct reactions
- Single & Multinucleon transfer
- Inelastic & Coulex scattering
- Compound nucleus

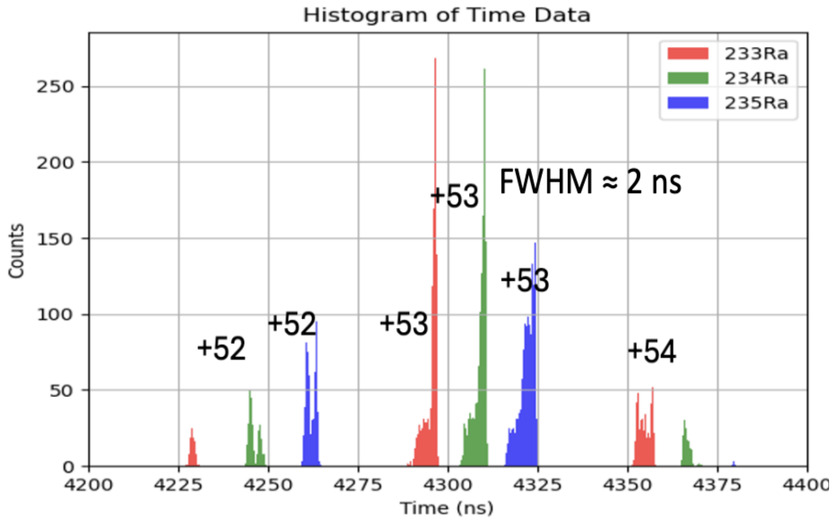
- EMPIRE
- FRESCO
- GRAZING
- GOSIA
- EXISTING DATA

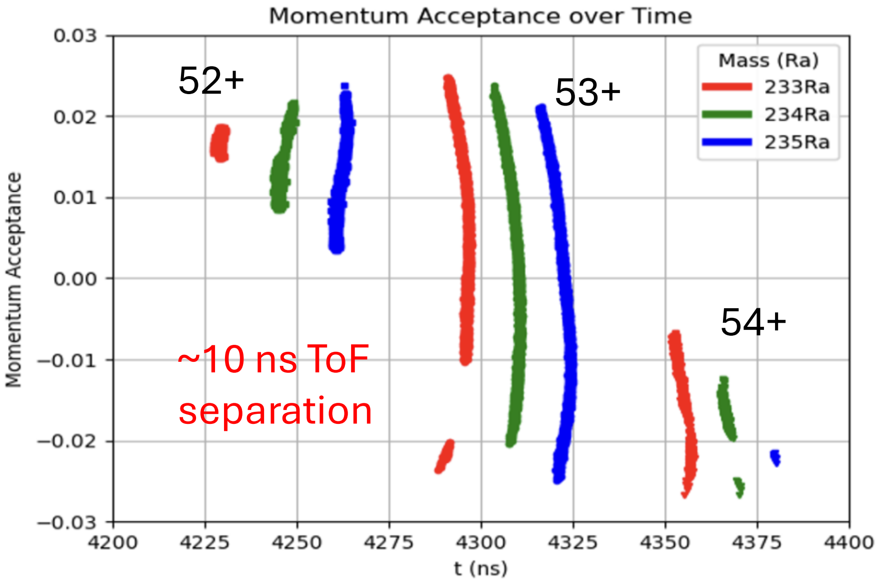
Provide cross sections, angular, and energy distributions for beam dynamics simulations → optimisation of ISRS configuration

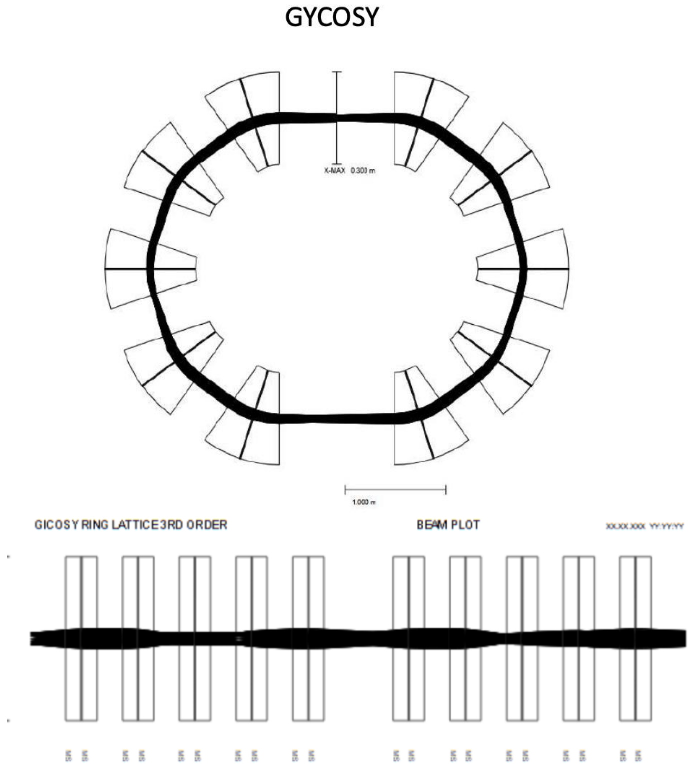
ISRS BEAM DYNAMICS



- OPTIMISATION: Configuration based on 10 x MAGDEM units
- BMAD, Xsuite code, RF-Track: first order beam dynamics.
- GYCOSY + COSY INFINITY: corrections up to third-order.
- Optimization to integrate the injection/extraction system
  - ✓ RF kicker
  - ✓ Truncated septum magnet
  - ✓ Superconducting CCT (K. Sugita et al. (GSI), IPAC2018)
- Isochronous & quasi-isochronous operation ~ compromise on momentum acceptance. (ISOCHRONOUS $\delta P/P$ ~1% FWHM)
- Mass resolving power (10 turns):
  - ✓ ISRS ~ 2100
  - ✓ PRISMA/LNL (300)
  - ✓ S800/SNCL-MSU (2000)



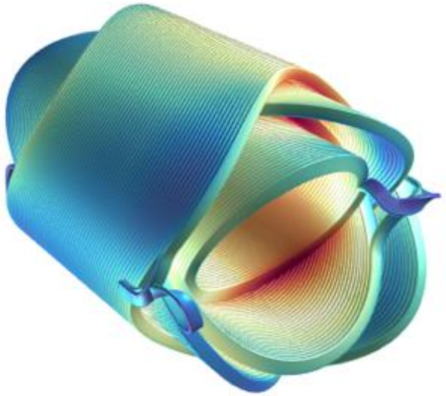




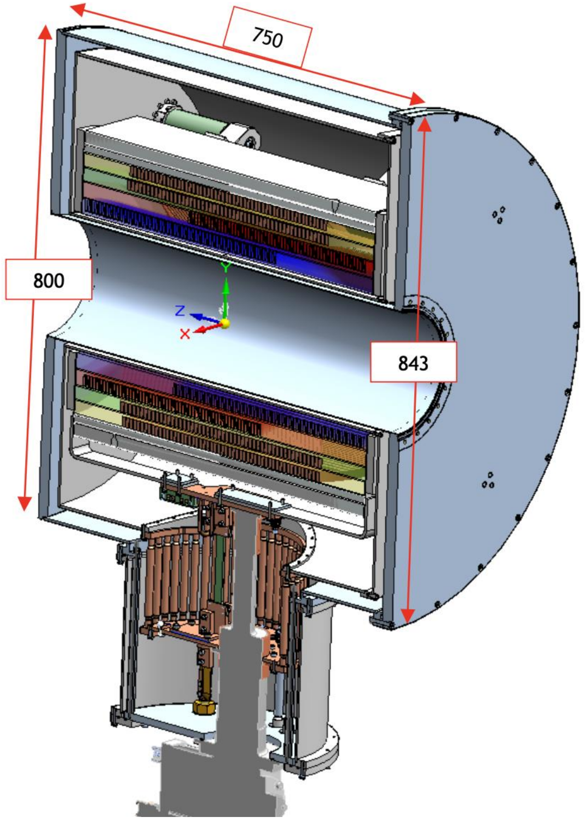
ISRS MAGNET PROTOTYPE: MAGDEM

MAGDEM: Cryogen-free, combined dipole/quadrupole Canted Cosine Theta (CCT) superconducting magnet cooled by a cryocooler.

- Solenoid and cryostat design completed
- One unit in production (industry contract)
- Delivery May 2026

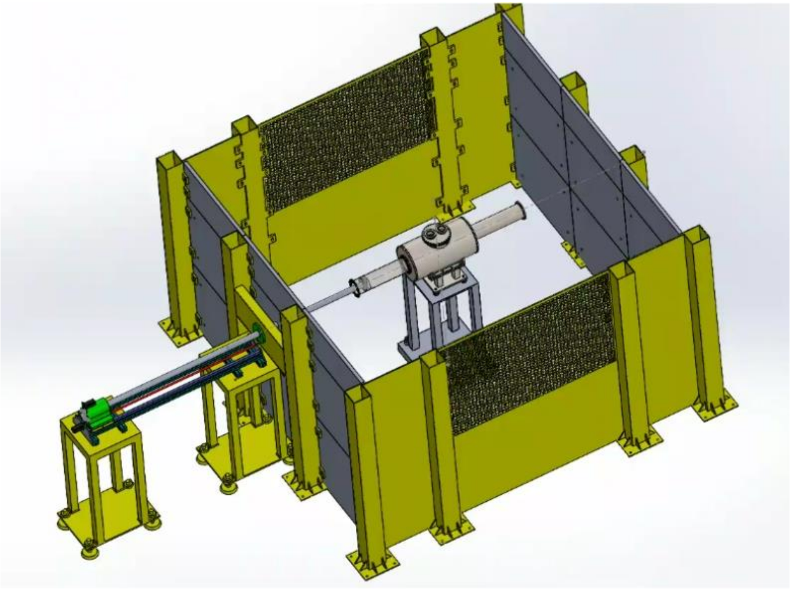


Aperture diameter	200 mm
Former length	606 mm
Magnetic bend	36 degrees
Magnetic length	1500 mm
Spiral pitch	5.7 mm
Peak dipole field at Inom	2.02 T
Dipole field integral at centre	0.75 Tm
Nominal dipole current	145 A
Peak Quadrupole field at r=100mm, Inom	0.92 T
Quadrupole integrated field at r=66.6mm	0.254 Tm
Nominal quadrupole current	141.6 A



Wire insulation process

MAGNETIC FIELD SCANNER SYSTEM – MFSS

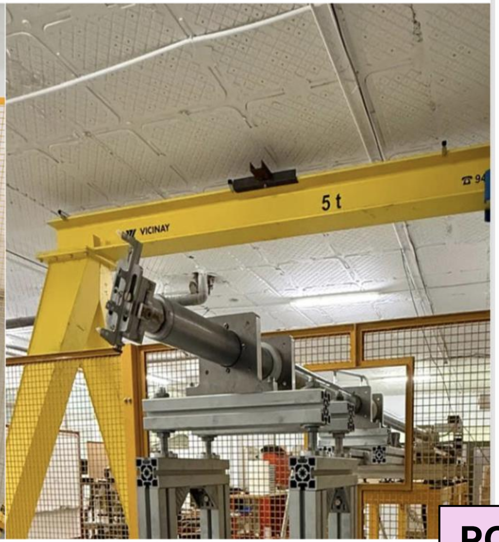


METROLAB probe HallinSight® 32×2

- 64 sensors in 2 rows of 32
- 3-axis Bx, By, Bz.
- Temperature Correction:
- Sensing area: 77.5 mm x 2.5 mm
- Resolution: ~ 100 μT for 2 T

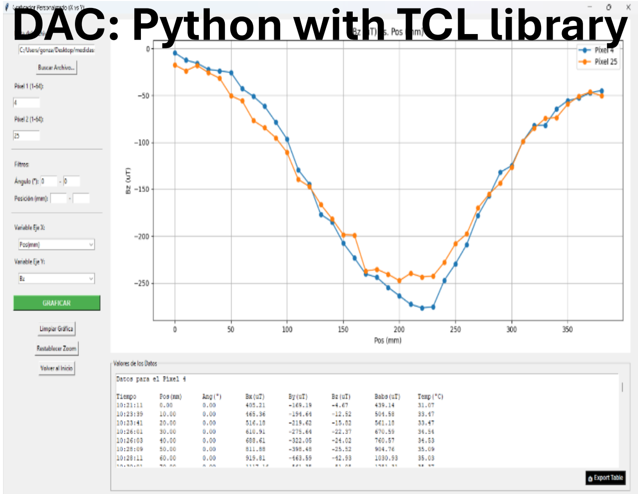
→ Reduce measurement time!!

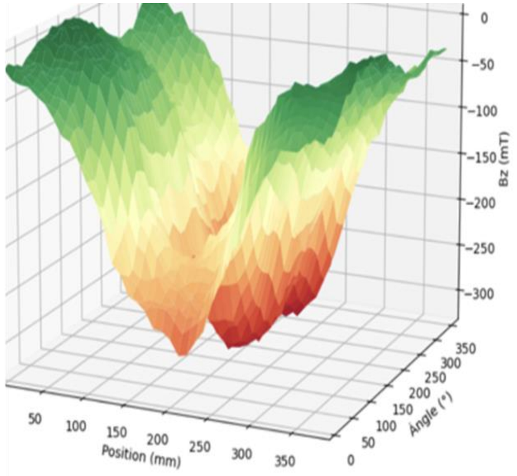
DAC: C# & Godot



Final MFSS to be delivered at ISOLDE, ΔL = 3500 mm, PLC

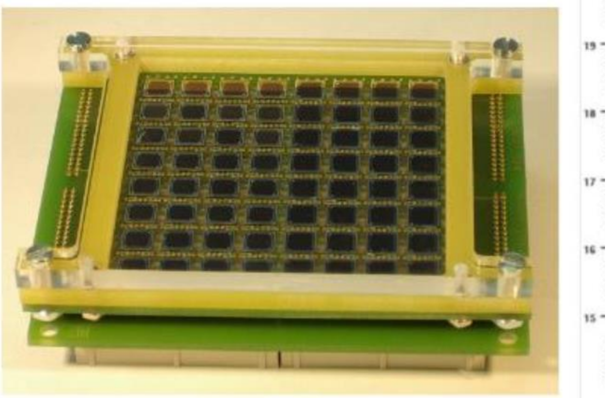
DAC: Python with TCL library



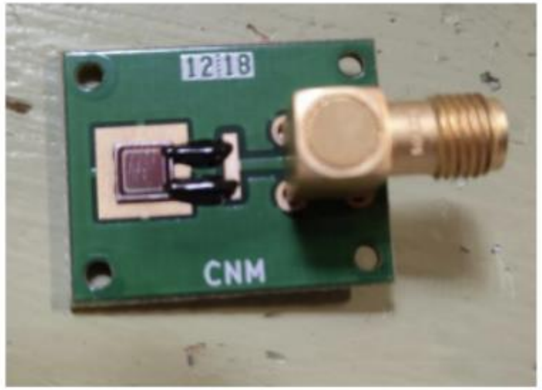


POSTER: *Magnetic field mapping and validation of the MAGDEM CCT superconducting magnet for ISRS.* Carlos A. Gonzalez-Cordero (Univ. Huelva)

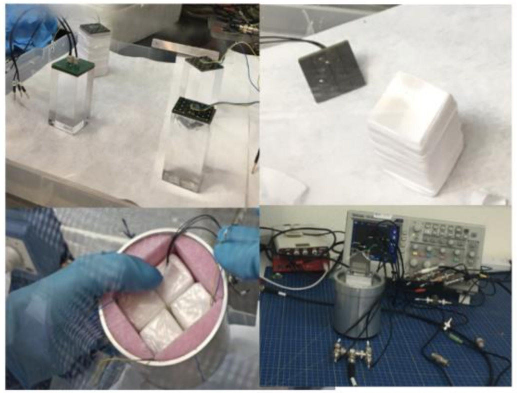
FOCAL PLANE DETECTOR



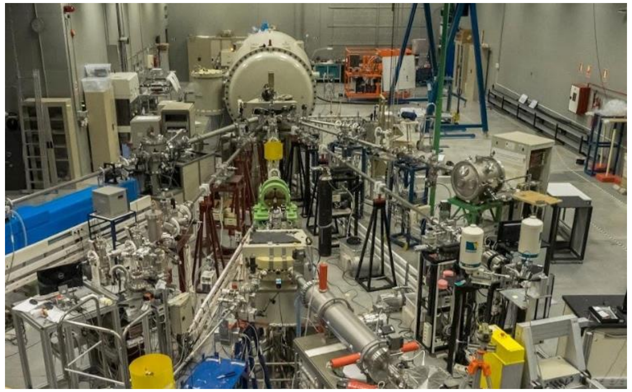
Monolithic detectors (1 µm) DE + (500 µm) E detector



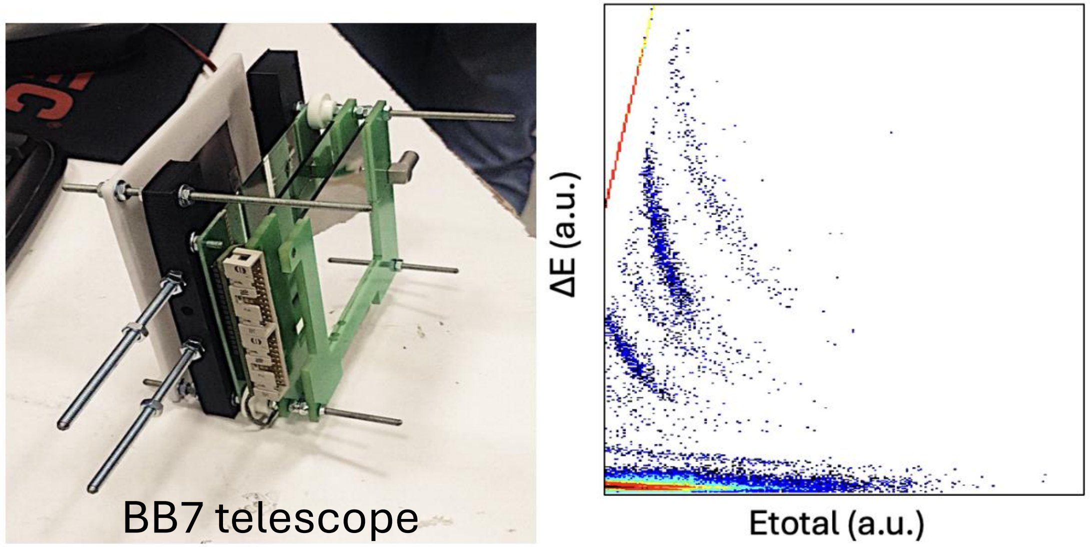
IMB -Barcelona - 64 SiC detectors of 50 and 100 µm



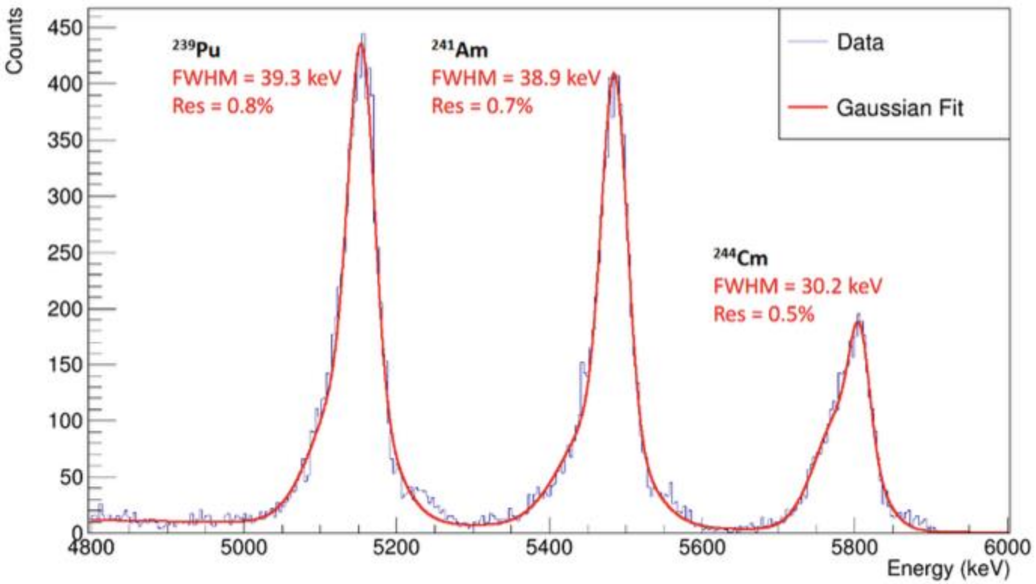
LaBr3 clover detectors developed at UWS



Experiments at CMAM (Madrid)



Test at CMAM (Madrid) of FPD based on Si DSSD telescope BB7



Energy spectrum for SiC detectors of 100 µm

MULTIHARMONIC BUNCHER -MHB

For optimal operation of ISRS, the present HIE-ISOLDE LINAC frequency of 101.28 MHz must be scaled down to 1/10 of the frequency1. To achieve this goal, a multi-harmonic buncher (MHB) must be placed at the medium energy beam line (MEB).

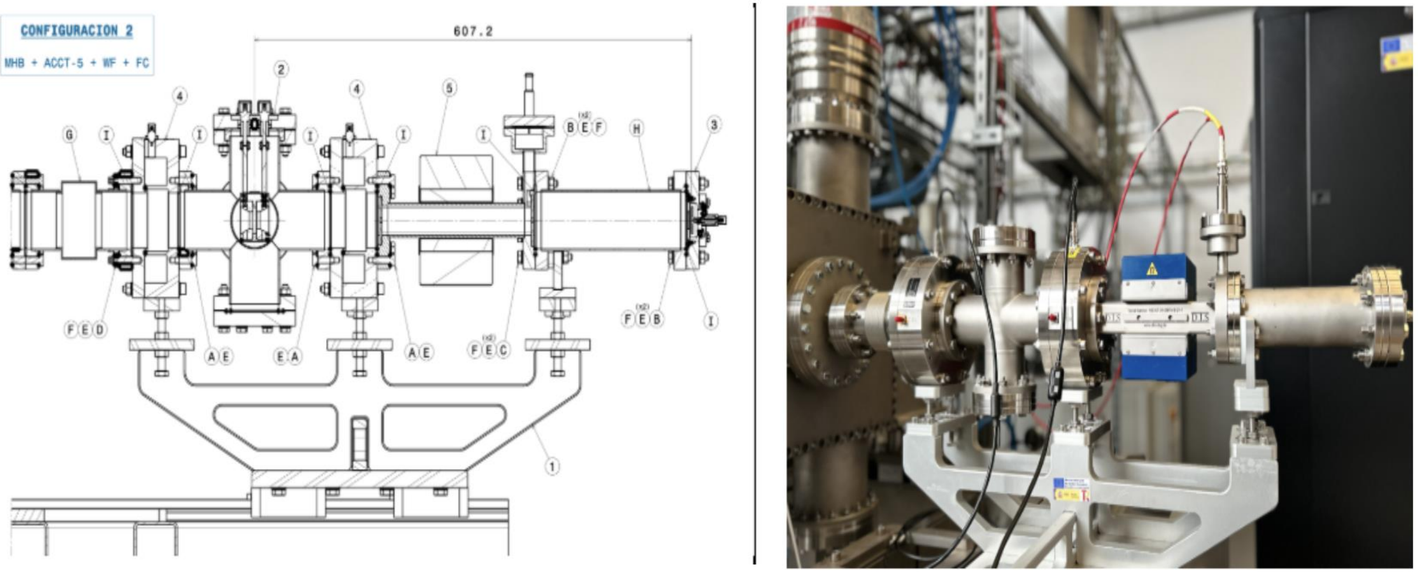
Parameters

- low energy dispersion (< 1%)
- high transmission (> 95%)
- bunch formation (< 5 m)
- Standard 4-way CF63 vessel
- To be placed before the REX RFQ.

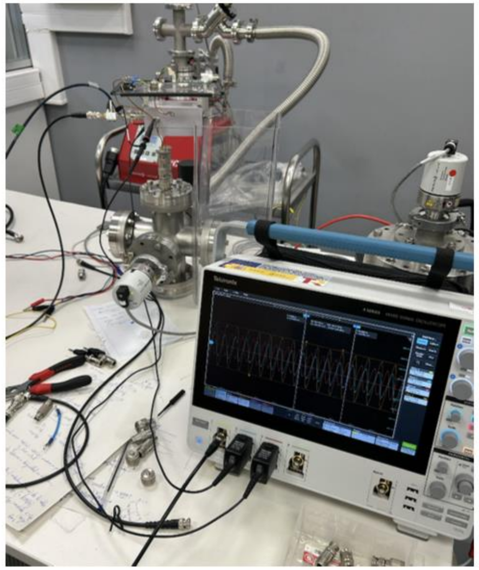
Ion Test Bench (ITB)

- ACCT for current measurements
- Fast Faraday Cup for the bunch-length measurements
- Wien filter

- **The multiharmonic buncher prototype is completed**
- Tests with H ions.
- RF characterization.



Ion test bench for MHB at ESS-Bilbao equipped with ACCT, Faraday Cup and Wien filter (10.09 keV H2+, ß=0.0328).

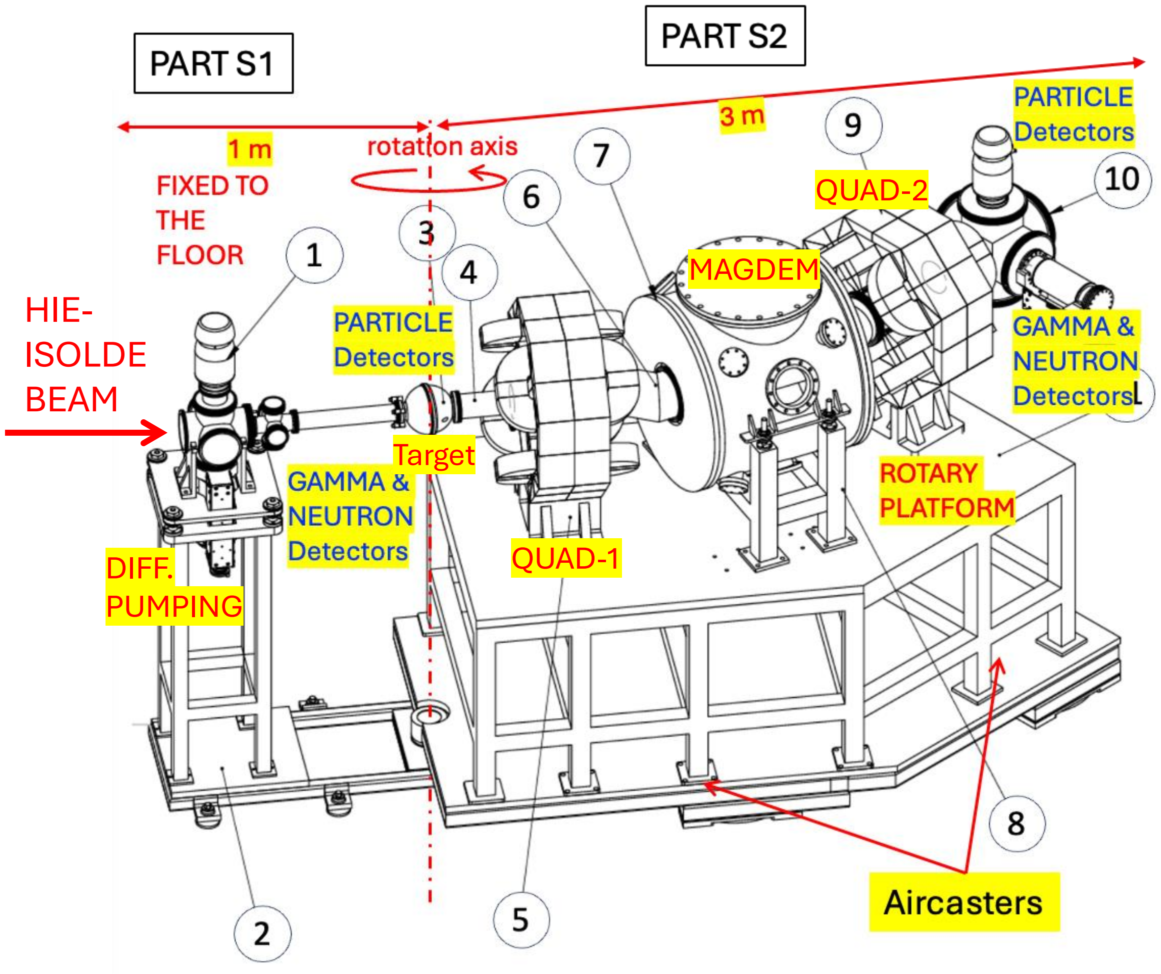


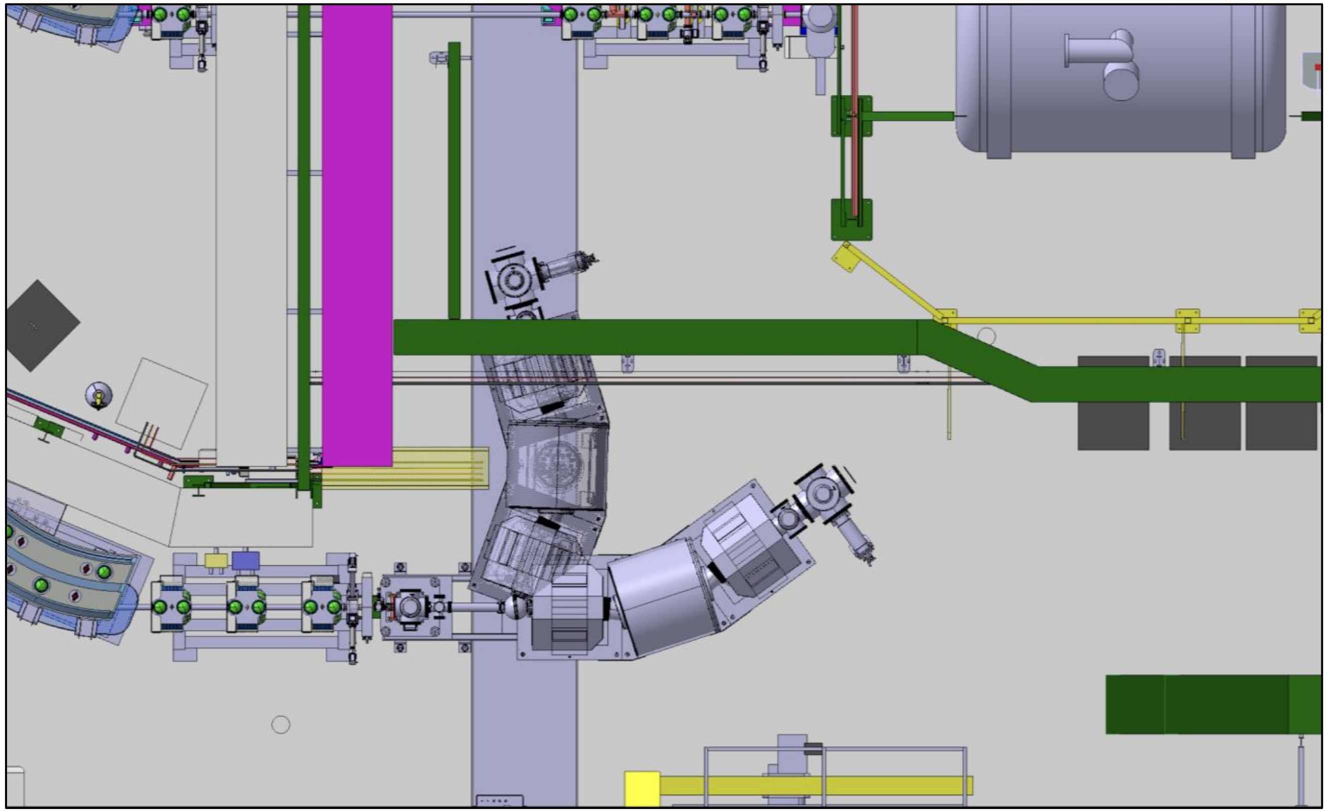
RF power characterisation in the lab

ION TEST BENCH – ISOLDE linear spectrometer (LoI INC-I-283)

Integrate prototypes developed for ISRS in an Ion Test Bench that can operate as linear spectrometer.

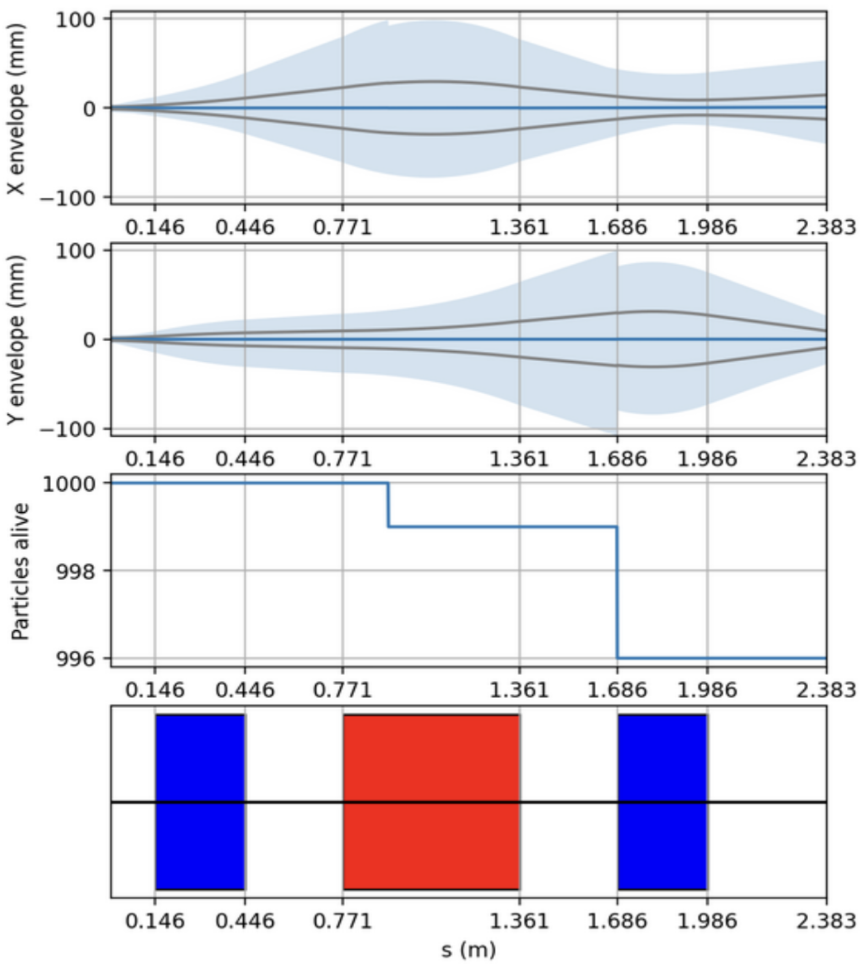
- Located at XT03.
- Do not disturb other experiments.
- Installation and test during LS3 (2026-2028).

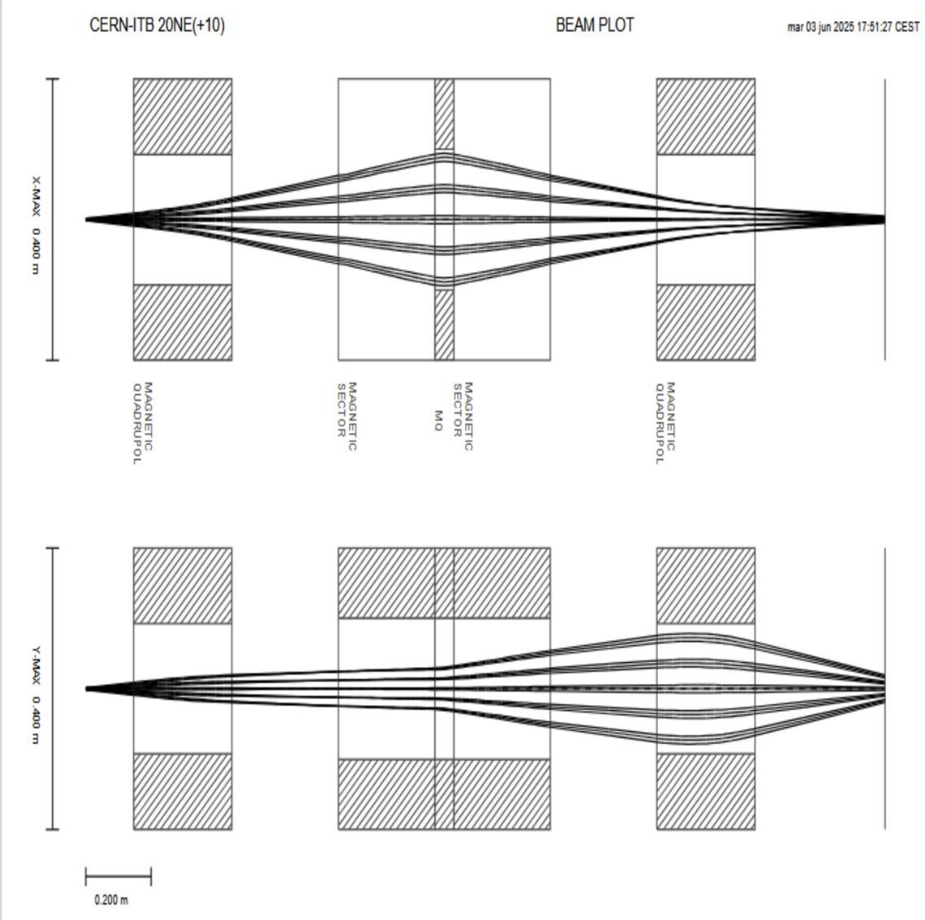


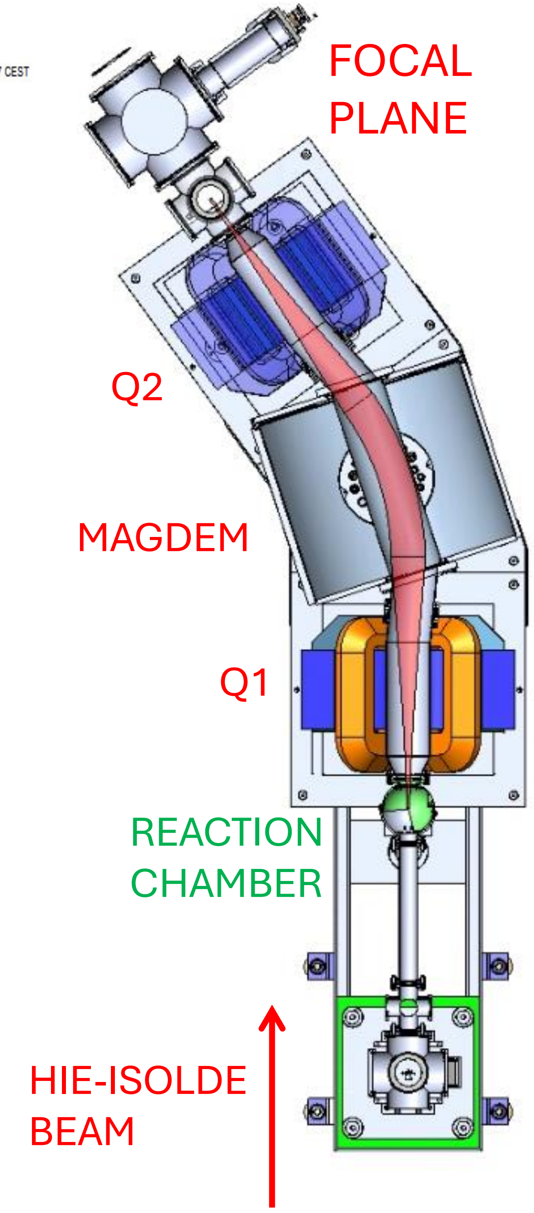


Integration studies at the XT03 beam line.
Courtesy of Vincent Barozier (CERN)

ISOLDE Linear Spectrometer – Beam optics studies







Beam transport simulations using BMAD and GCOSY. The mass dispersion obtained is ~ 0.6 cm/%. The simulations are consolidated and the configuration frozen.

ISOLDE Linear Spectrometer – First test experiment

^{19}Ne + d → ^{20}Na + n (1p capture)

$^{20}Ne + p\ (1n\ transfer)$ q= 6+

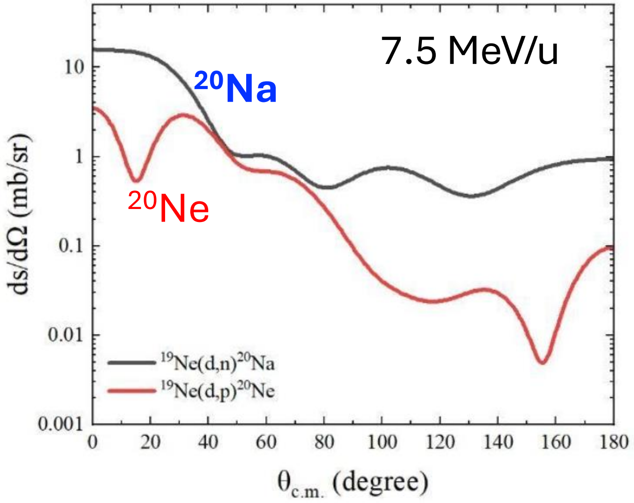
$^{19}Ne + d\ (elastic)$ q= 6+

$^{19}Ne\ (beam)$ q= 6+

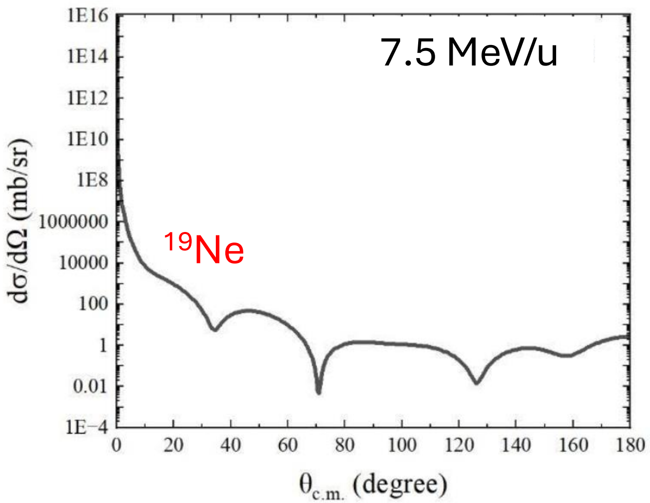
$^{20}Na\ (recoil)$ q= 7+

FRESCO
IJ. Thompson, CPR. 7(1988)167.

Proton and neutron capture

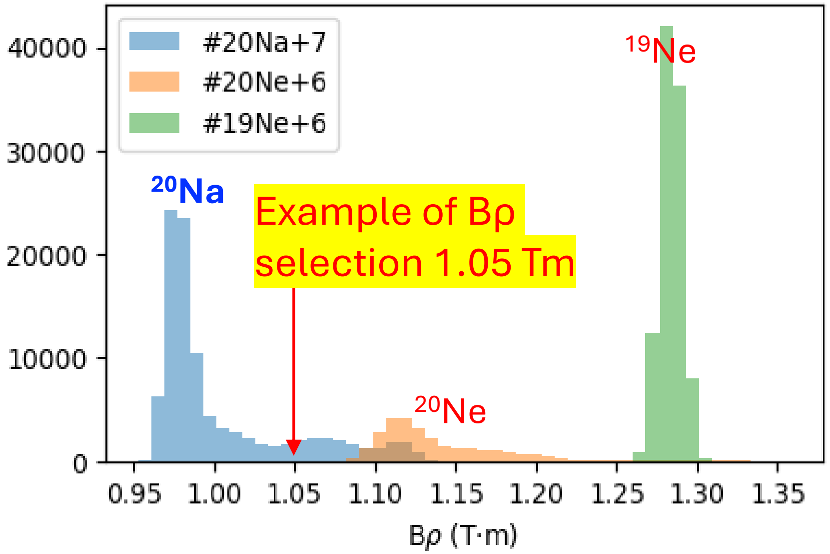


Elastic scattering

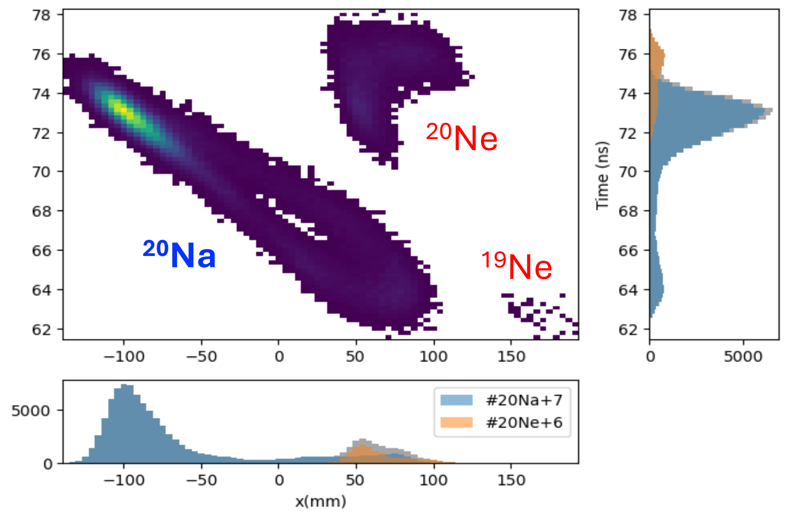


POSTER:
Theoretical predictions for transfer reactions supporting the ISOLDE Linear Spectrometer (ILS)
Fatemeh Torabi
(Univ. Huelva)

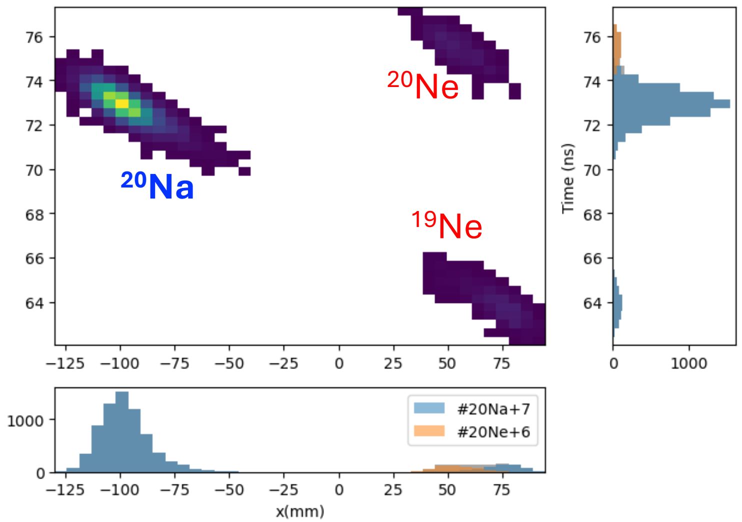
MAGDEM Bρ scan plot



TOF (ns) – Focal Plane position (mm)



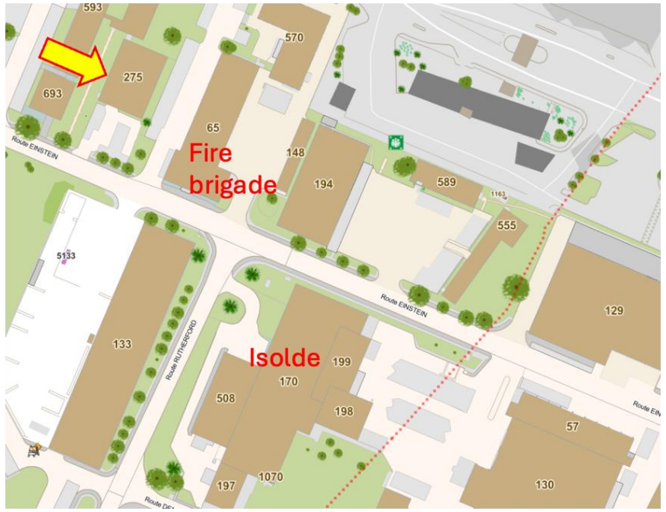
Scattering angle selection
θLab = **0** ±0.2 deg



ISOLDE Linear Spectrometer – Timeline

		2025				2026				2027				2028			
ACTIVITY	INSTITUTE	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. BEAM TRANSPORT AND INTEGRATION STUDIES	VALENCIA-MADRID-HUELVA																
2. ACQUISITION OF SUBSYSTEMS	HUELVA-MADRID																
3. INTEGRATION LAB-UHU	HUELVA																
4. OFF-LINE TESTS LAB-UHU	HUELVA											LS3					
5. TRANSPORT/COMMISSIONING CMAM	MADRID																
6. ON-LINE TESTS CMAM	MADRID																
7.TRANSPORT/COMMISSIONING HIE-ISOLDE	ISOLDE							Shipping to ISOLDE									

- Initial Safety Document.
- Interaction with other experiments (ISS).
- Engineering Change Request (ECR).
- Space at CERN Bat#275
- Funding: Spanish Grant 2025-2028 (LS3) Univ. Huelva – Univ. Valencia. Other resources from the collaboration.



SUMMARY AND CONCLUSIONS

ISRS

- Physics: ISRS Physics working group and Reaction Calculations framework consolidated.
- Beam dynamics: Frozen ISRS optical design, including Isochronous, Quasi-isochronous modes, high-order corrections. Realistic MC simulation tool including nuclear reactions. Injection/extraction concept developed.
- Magnets: MADGDEM prototype developed and in fabrication. Scanner system ready, software in progress.
- Focal plane: R&D on SiC and LaBr is progressing. Backup solution using DSSD.
- Buncher: system completed. Ion beam tests at ESS-Bilbao.

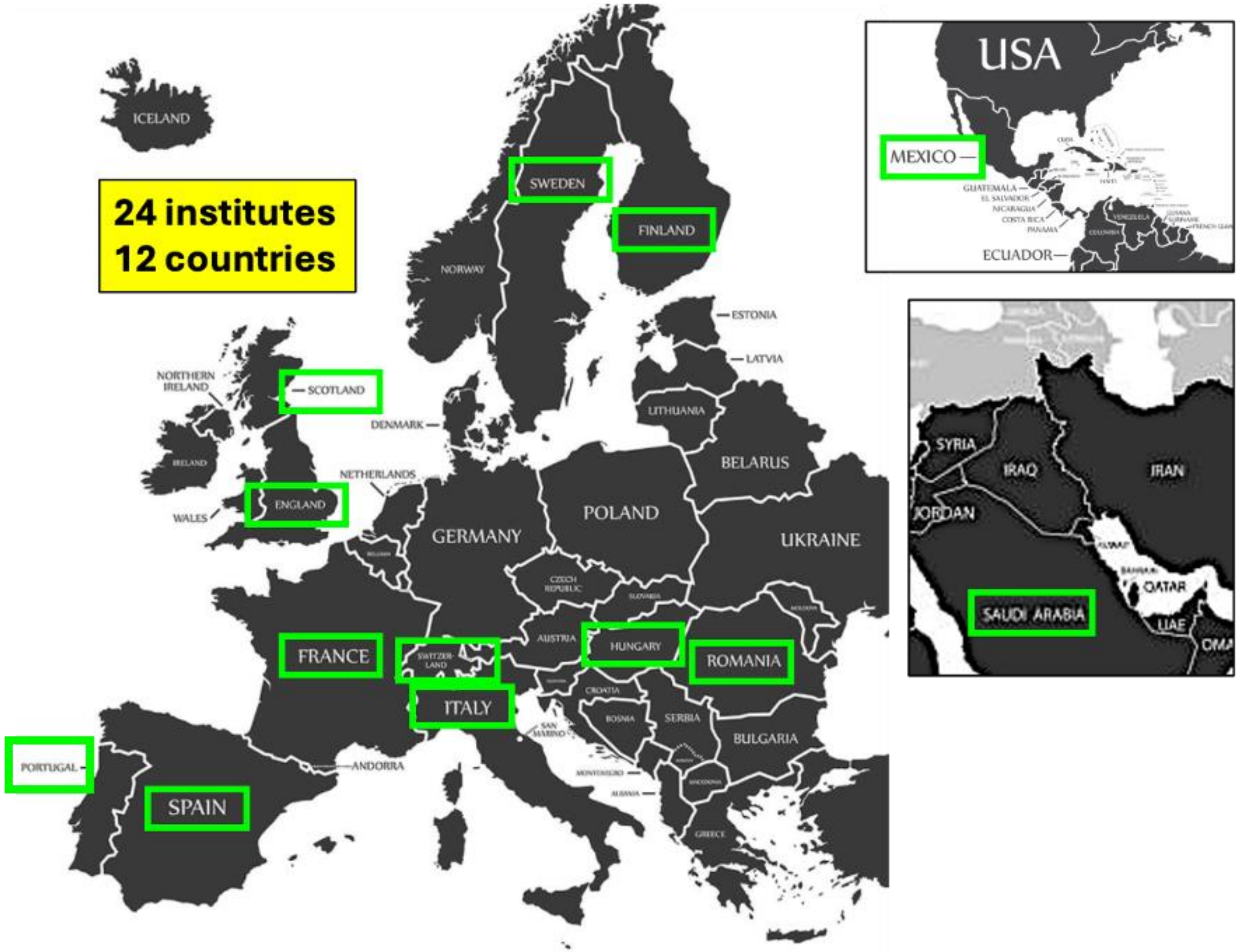
THANKS!!

IONTB- ILS

- Beam optics consolidated. Recoil separation power and physics program under study.
- Proposed first test experiment . ^{19}Ne+d → ^{20}Na + n (1p-capture).
- Installation. Procedures (ISD, ECR) in progress → first term of 2026.
- Funding during LS3. Spanish Grant 2025-2028 (LS3) Univ. Huelva – Univ. Valencia ☑ , other resources from the collaboration.

ISRS Collaboration

- Astroparticule et Cosmologie, Univ. Paris Diderot, Paris, France.
- CERN, Geneva, Switzerland.
- CENGB, Gradignan, France.
- Cockcroft Institute, Daresbury, UK.
- Dpt. Ciencias Integradas, Univ. Huelva, Spain.
- Dpt. of Physics and Astronomy, Aarhus Univ., Denmark.
- Dpt. of Physics, Chalmers Univ. of Technology, Göteborg, Sweden.
- Dpt. of Physics, Lund Univ., Sweden.
- Dpt. of Physics, Univ. Liverpool, UK.
- Dpt. of Physics, Univ. Surrey, UK.
- Dpt. of Physics, Univ. York, UK.
- ESS-BILBAO, Bilbao, Spain.
- Faculty of Mathematics and Science, Univ. Jyvaskyla, Finland.
- ICMUV, Univ. de Valencia, Spain.
- IFIN-HH, Bucharest, Romania.
- IPNO, Univ. Paris-Sud, Orsay, France.
- Inst. de Estructura de la Materia, CSIC, Madrid, Spain.
- Inst. de Física, UNAM, México.
- IMIS Univ. Riyadh, Saudi Arabia.
- Lab. Instrumentação e Física Exp. de Partículas (LIP), Portugal.
- LNL INFN, Italy.
- Univ. of West Scotland, UK.
- Univ. Edinburgh, UK.
- Uppsala Univ., Sweden.
- Wigner Research Centre for Physics, Budapest, Hungary.



MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
NextGenerationEU