ISRS STATUS & OPORTUNITIES

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University of Huelva

MINISTERIO DE CIENCIA E INNOVACIÓN
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU
CERN
ISOLDE

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- Beam dynamics
- Study of Injection/Extraction systems
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- Field Mapping System
- Ion test bench
- Focal plane detector
- Multiharmonic buncher
- Summary
- Opportunities/investments

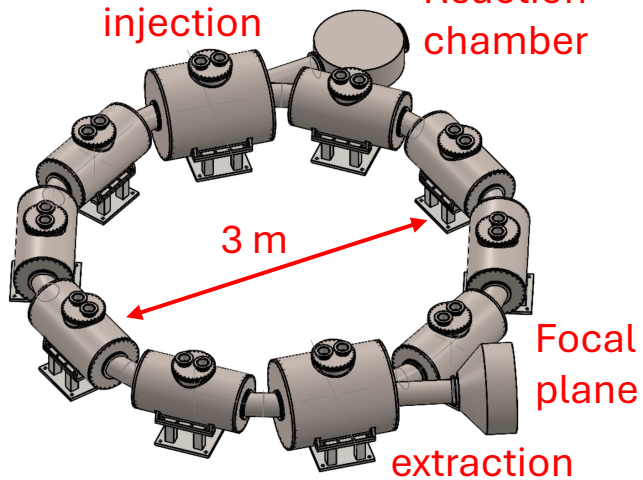
ISOLDE Superconducting Recoil Separator

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

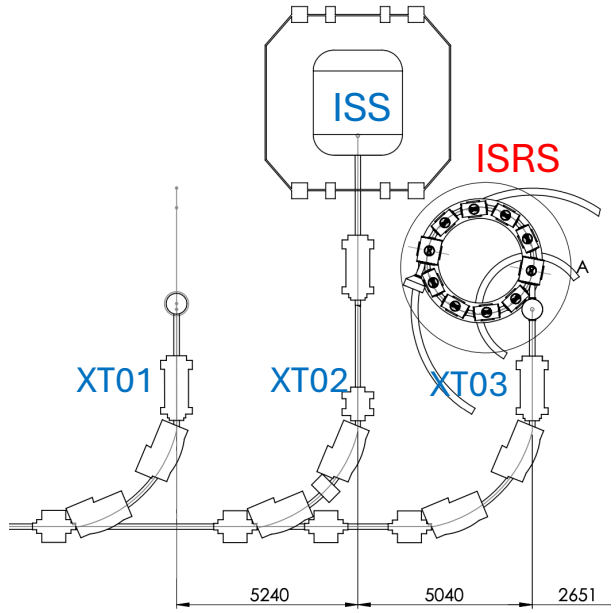
Mission: Expand the HIE-ISOLDE physics program.

ISRS conceptual design:

- Compact particle storage ring
- Beam dynamics: Fixed Field Alternating Gradient
- Magnets: Multifunction, nested dipole + quadrupole SC magnets, iron-free, Canted Cosine Theta (CCT) technology. FUSILLO(90°) & MAGDEM (straight)
- Cryocoolers technology (no LHe bath)
- Injection/extraction (Fast Kicker + Suchi, others)
- Reaction chamber, Focal plane detector
- Multi-harmonic buncher



ISRS: 10 MAGDEM units



HIE-ISOLDE HALL

Spanish grant (RRF/EU): 3 MEuro. July 2023 – Dec. 2025. → Scope of LOI activities was scaled to budget & timeline.

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

Website: https://www.uhu.es/isrs/ Linkedin: ISRS-ISOLDE X (twiter): ISRS-ISOLDE

R&D ACTIVITIES – Spanish grant

WP1. STUDY OF BEAM DYNAMICS, INJECTION AND EXTRACTION SYSTEMS

T1.1. Selection of physics cases
T1.2. Nuclear reaction calculations
T1.3. Study of beam dynamics
T1.4. Selection of configuration
T1.5. Injection/Extraction
T1.6. Non-interceptive beam diagnostics
T1.7. High-order corrections

WP Leader: UV
Collaborators: UHU, IEM/CSIC

WP2. CCT SOLENOIDS AND CRYOSTATS.

T2.1. Prot. of solenoid
T2.2. Prot. of sol. + cryostat (MAGDEM)
T2.3. MAGDEM focusing system
T2.4. Magnetic field meas. system
T2.5. Prot. of focal plane detector

WP Leader: UHU
Collaborators: IEM/CSIC, UV

WP3. MULTI-HARMONIC BUNCHER

T3.1. Multi-Harmonic Buncher
T3.2. RF distribution Control System
T3.3. Ion Test Bench Diagnostics

WP Leader: ESSB

Where we are?

1st July 2023 — 19 June 2024 — 31 Dec. 2025

	WORK PACKAGE	2023 1-3	2024 4-6	2024 7-9	2024 10-12	2024 13-15	2025 16-18	2025 19-21	2025 22-24	2025 25-27
WP1	STUDY OF BEAM DYNAMICS, INJECTION AND EXTRACTION SYSTEMS			40%						
WP2	CCT SOLENOIDS AND CRYOSTATS			50%						
WP3	MULTIHARMONIC BUNCHER			40%						

% COMPLETED

WP0: Coordination and communication

WP Leader: UHU

LOI – Spokespersons

Overall coordination of the project

- I. Martel, U. Huelva, Spain.
- O. Tengblad, IEM-CSIC, Madrid.
- J. Cederkall, U. Lund, Sweden.

LOI - Scientific Advisory Committee (SAC)

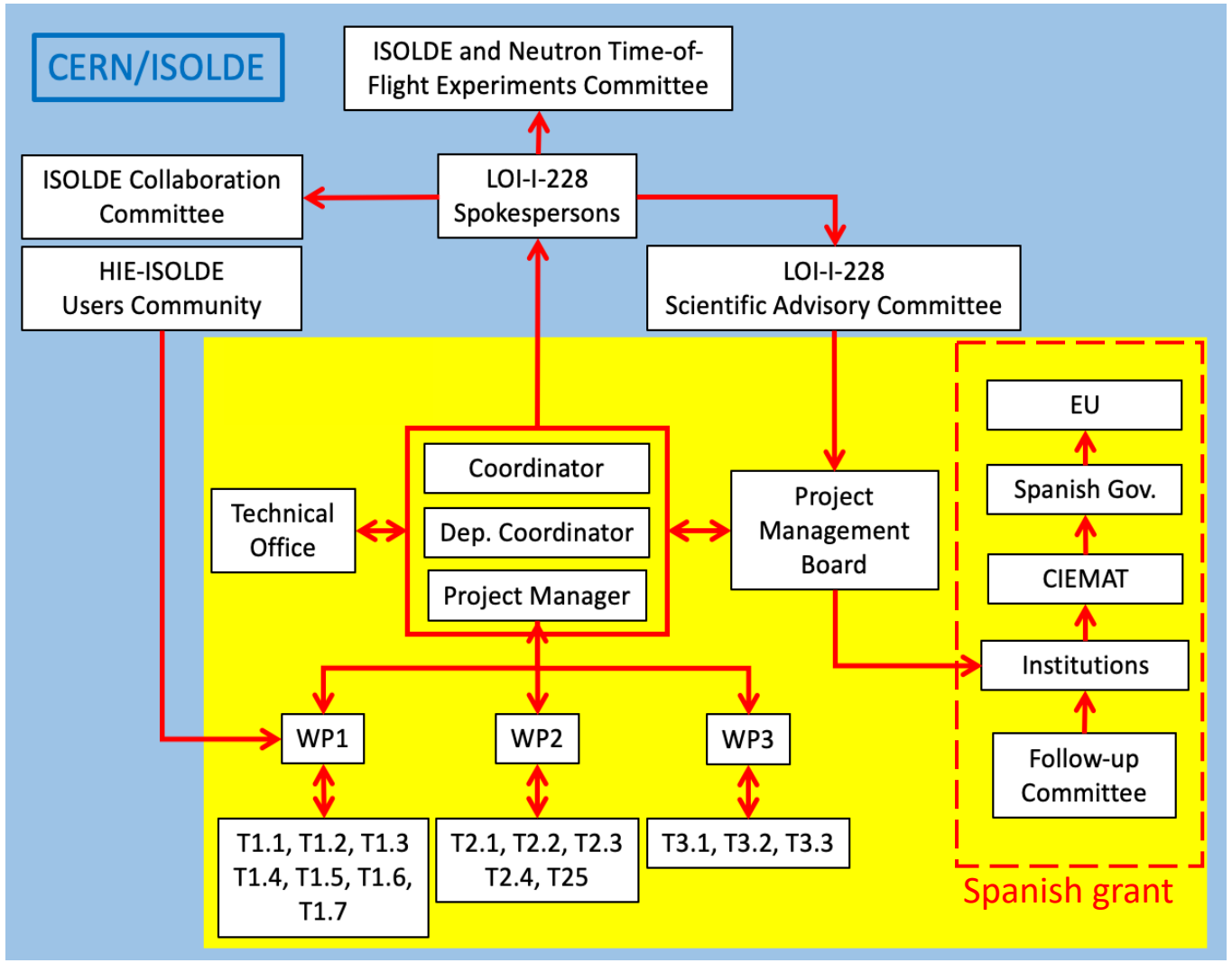
Monitor and review status of LOI activities

- ISOLDE Collaboration spokesperson: J. S. Freeman
- ISOLDE Technical group: J. A. Rodríguez
- ISOLDE Users community: G. de Angelis, INFN, Italy
- External experts: P. Delahaye, GANIL, France

Project Management Board (PMB) – Spanish grant

Monitor and review status of Spanish grant activities

- Univ. Huelva: I. Martel
- Univ. Valencia: J. Resta
- IEM-CSIC-Madrid: T. Kurtukian-Nieto
- ESS-Bilbao: I. Bustinduy



This structure can be replicated for additional grants

Physics program → ISRS performance requirements

Selection of physics cases → ISRS Collaboration meetings

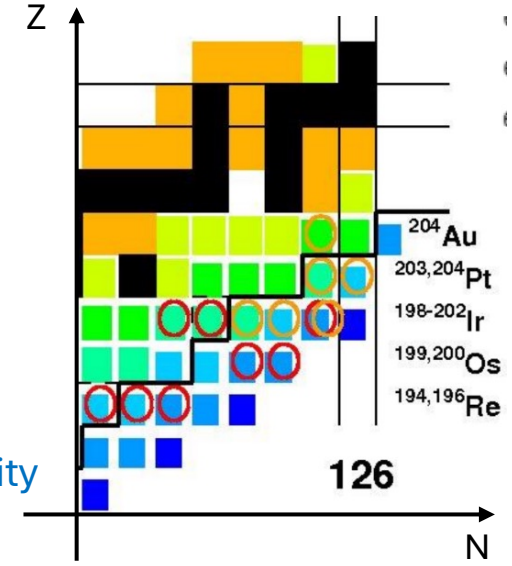
- ✓ Nuclear structure studies around N≈ 82, 126.
- ✓ Nucleosynthesis around Z ≈ 50 and Z ≈ 82.
- ✓ Neutron-rich nuclei in Terra Incognita (^{78}Ni, r-nuclei ~N=126).
- ✓ Shell-quenching and the r-process.
- ✓ Reaction dynamics studies, collective phenomena, nucleon-nucleon correlations.

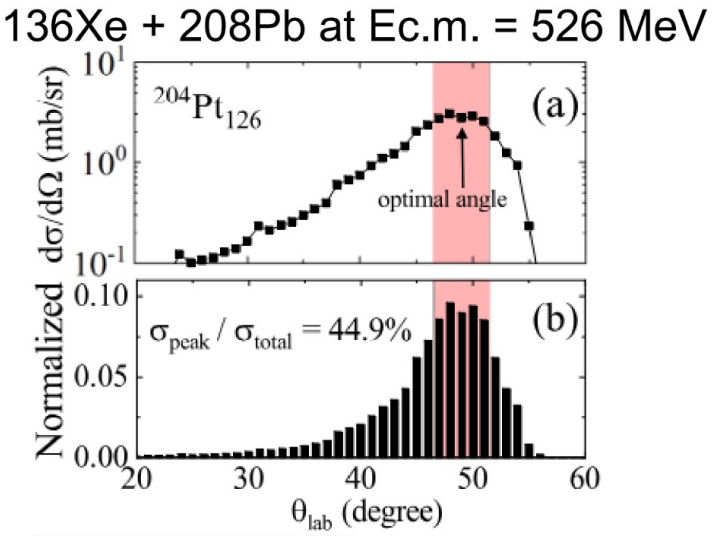
Nuclear reaction calculations → Reaction codes, theory community

- Coulomb breakup/dissociation
- Transfer reactions in inverse kinematics
- Fusion-evaporation reactions in inverse kinematics
- Low energy transfer, breakup and fusion reactions

→ Optimisation of ISRS configuration for selected physics cases

→ Recoil distributions for beam dynamics simulations





Example of physics case: study of r-process waiting point at N=126. Focal plane decay spectroscopy.

Courtesy of T. Kurtukian-Nieto, CSIC Madrid

Momentum acceptance	±10%
Resolving power $p/\Delta p$	2000
Angular acceptance	±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°

ISRS – coupled to detector arrays

- ISS
- MINIBALL
- SEC
- SAND
- AGATA

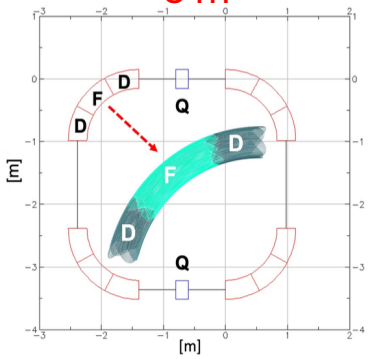
- Setup of nuclear reactions calculations framework. Eg. FRESCO, PACE4,…
- Selection of physics cases/calculations
  - (d,n), (d,p),(p,d),(p,n) transfer reactions, ^{11}Li, ^{68}Ni, ^{118}Ag, and ^{232}Ra
  - Multinucleon transfer (^{136}Xe+^{208}Pb -> 204Pt) and inelastic scattering
- ISRS PHYSICS WORKSHOP, SEPTEMBER 2024, HUELVA (SPAIN)

Beam dynamics → optimization of ISRS performance

- Selection of machine layouts and lattices
- Study of Injection/Extraction → It is a project by itself
- Beam diagnostics

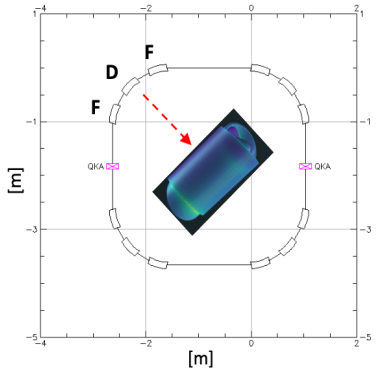
The ISRS Zoo

5 m



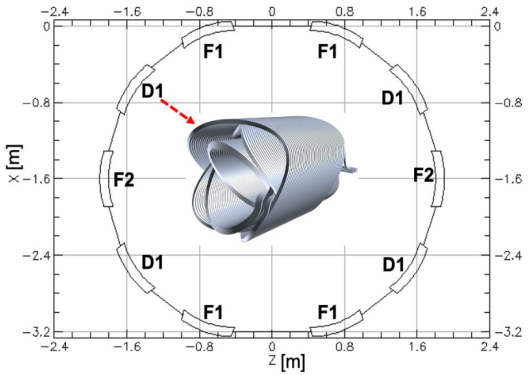
4 curved CCT magnets (90 deg. bend)

5 m

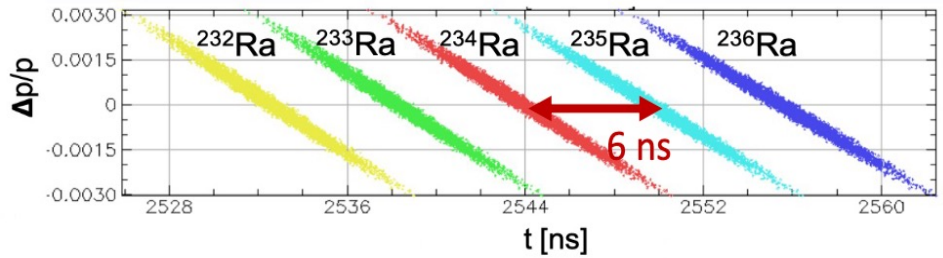


12 straight 350 mm magnetic length CCT magnets (30 deg. bend)

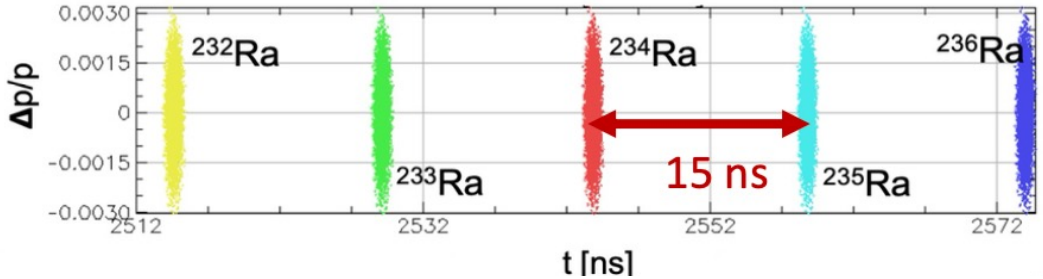
3 m



10 straight 580 mm magnetic length CCT magnets (36 deg. bend)



High-momentum

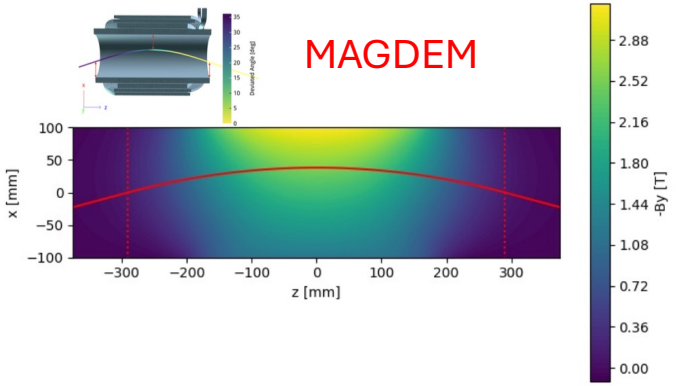


10 turns (2544 ns)

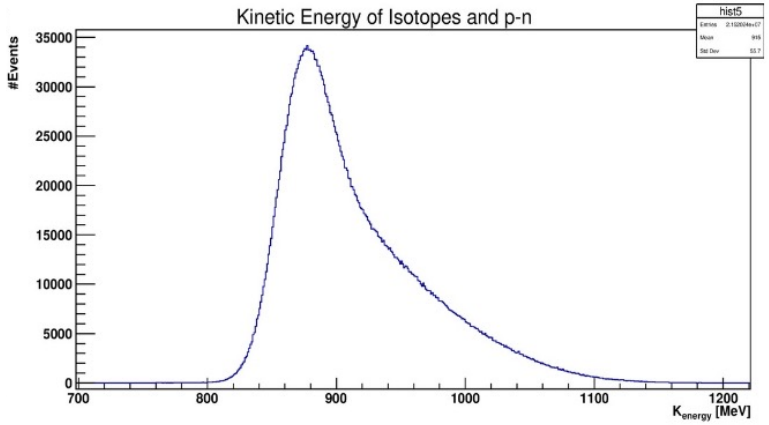
Isochronous

Realistic simulations using 3D magnetic field map

Multipolar optimisation for 36-degree curve trajectory



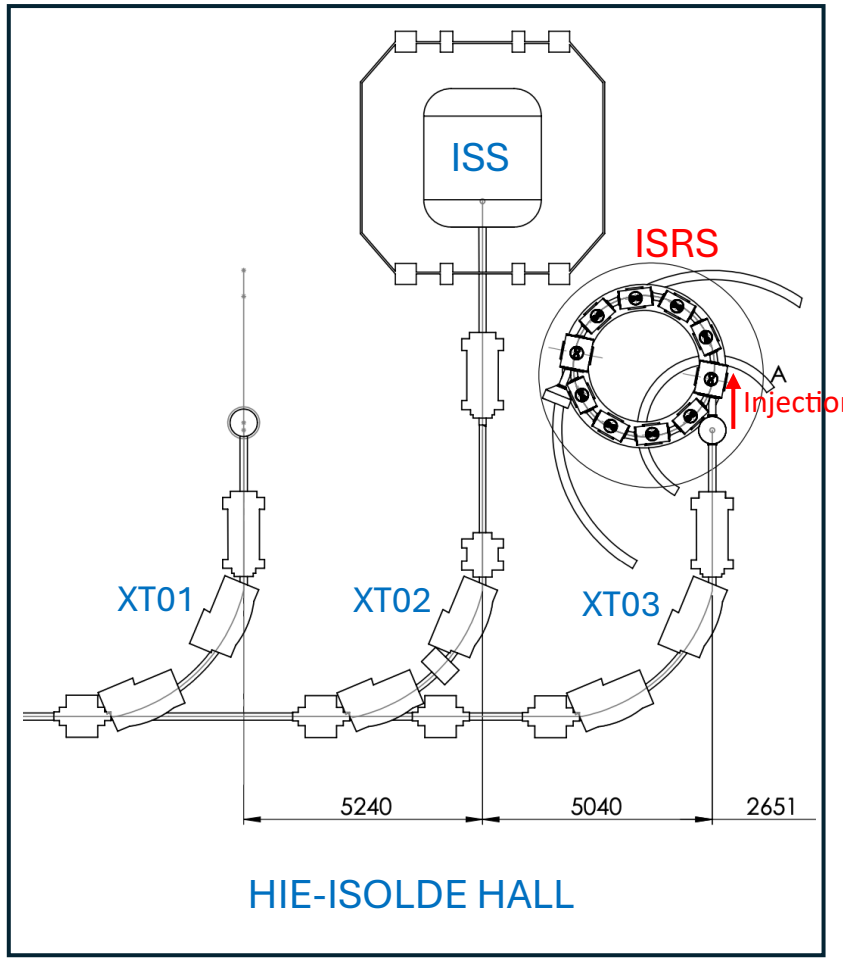
Simulation of beam bunch with reaction target. G4 Interaction modeling in SEC.



I. Martel. ISCC meeting, 21 June 2024

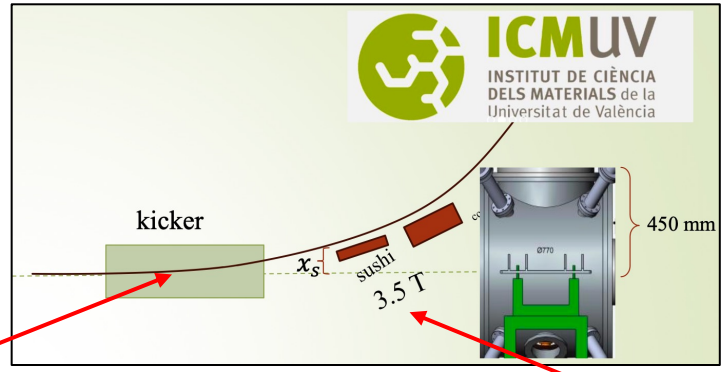
Study of Injection/Extraction systems

- Efficient injection/extraction system
- Activity just started !!

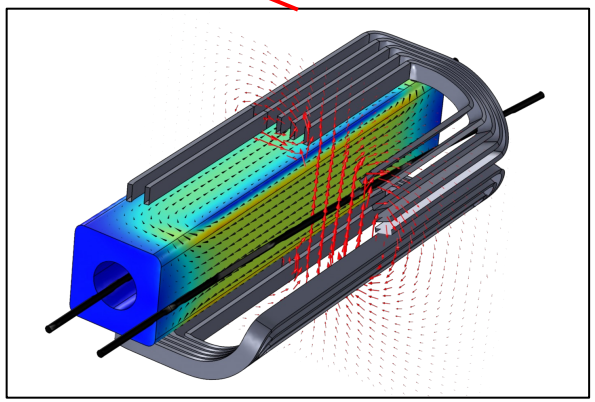


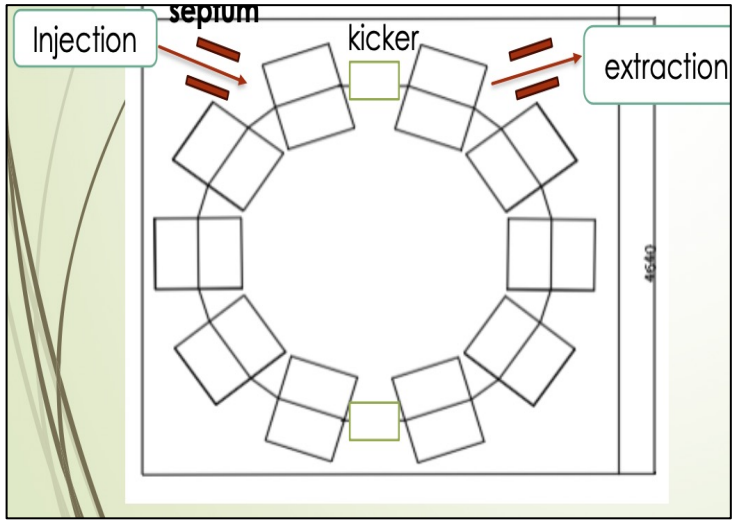
Properties of the ring	
ion	$^{234}Ra_{+53}$
E_{kin}/u	10 MeV/u
Rbend	2.1 T
rigidity	2.05 Tm
Revolution period	267ns
Straight section	750 mm
emittance	3 mm mrad

Combination of kicker+ SuShi magnet



Fast-kicker system for rare-RI ring
Y. Yamaguchi et al2015 Phys. Scr . 2015 014056
Stripline kicker for integrable optics test accel.
A. Sergey, 1607.00023 (arxiv.org)





SuShi SC magnet for the Future Circular Collider
D. Barna et al. IEEE Transactions in Applied Superconductivity 29 (2019), 4900108

Big challenge!

- Available space for injection ~ 700 mm
- Different options being considered, like e.g. “inbeam kicker” systems.

I. Martel. ISCC meeting, 21 June 2024

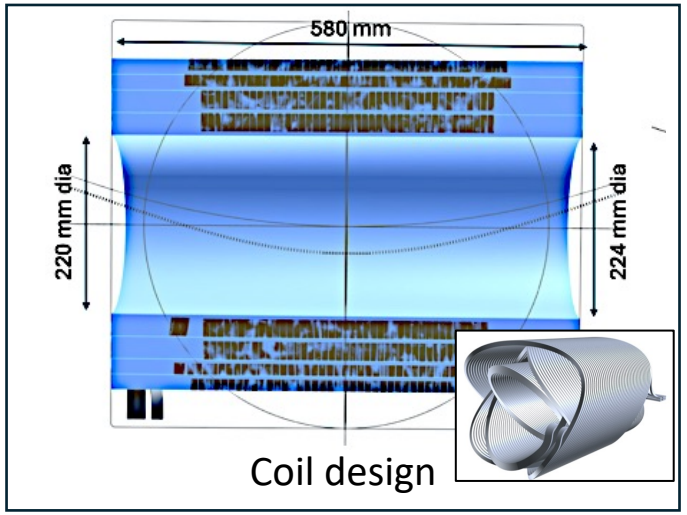
CCT magnets and cryostats → prototype of magnets and ion test bench

MAGDEM magnet

- Multifunction nested SC CCT straight magnet, dipole + quad, iron-free, cryocooler cooling (no LHe bath).
- Geometry/fields given by ISRS ring dimensions & beam dynamics.
- Contracts: Little Beast Engineering for solenoid design and ACS for cryostat design and integration.
- Minimum length, maximum beam aperture, minimum current.
- Magnetic forces – density map.
- Standard cooling time 6 days; LN_2 precooling to 2 days.
- Technical design report delivered last February 2024.
- Tender published (28/05/2024).

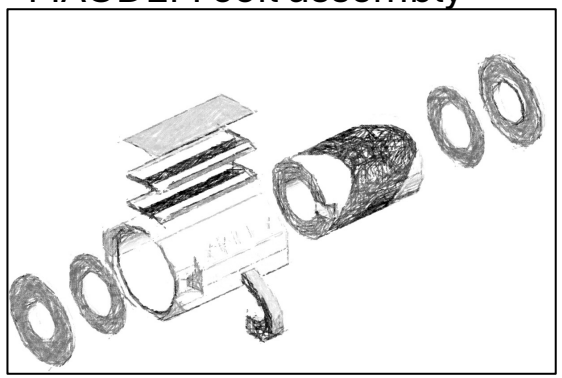
CCT parameters

Aperture	220 mm
Lenght	580 mm
Bdip (peak)	2.0
Bdip(integral)	0.742 Tm
Quad (peak)	10 T/m
Quad (integral)	0.238 Tm
Maximum current	90 A (D), 112 (Q)
	* 70% Load Line

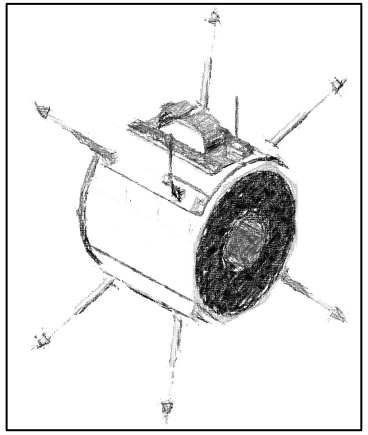


Coil design

MAGDEM coil assembly

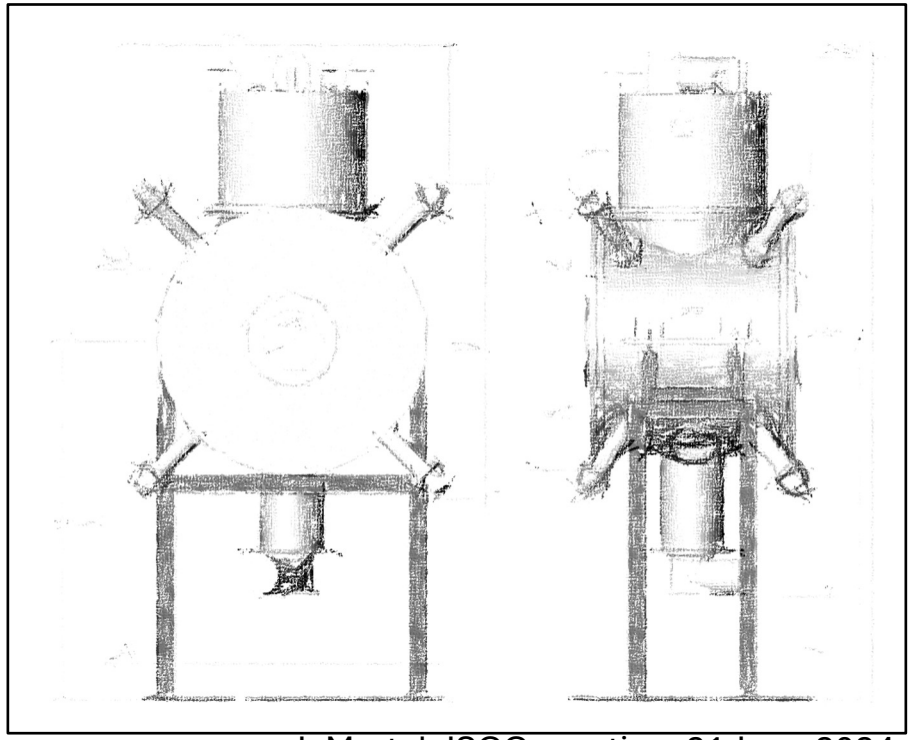


LN2 precooling



Cryostat

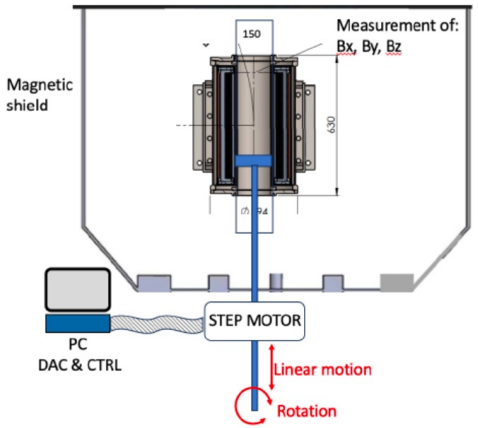
Aperture: 200 mm
Diameter: 900 mm
Length: 775 mm
Cryocoolers: 2 x 2 st Giord-McMahon.

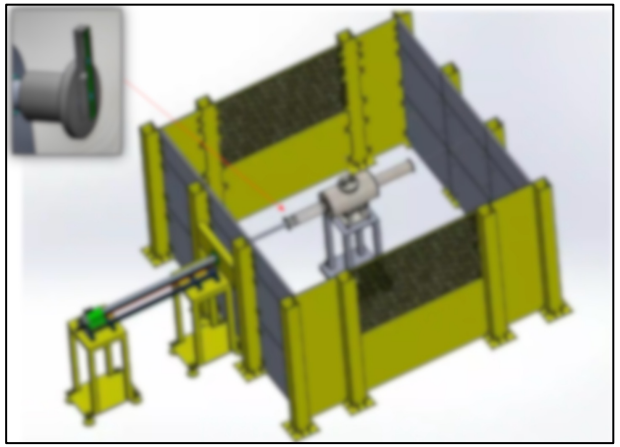


I. Martel. ISCC meeting, 21 June 2024

Field Mapping System (prototype)

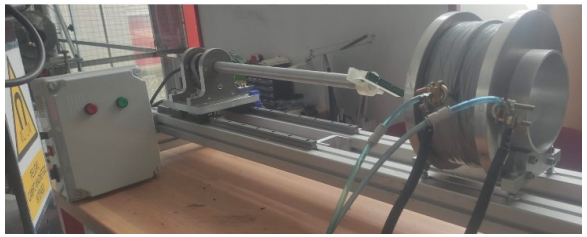
→ check MAGDEM magnetic field quality

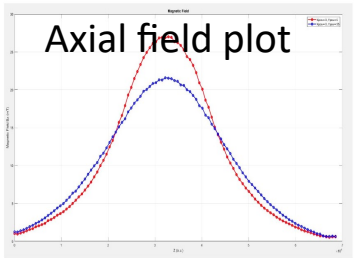


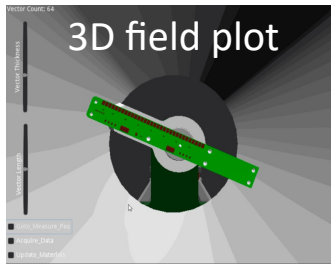


- 32x2 pixels Hall sensors array
- Axial displacement: 0.01 mm (programmable)
- Rotation: 0.01° (programmable)
- Magnetic field resolution: < 1/1000

Subscale system ready: → operation and software (control/field)







Full scale system:

→ Technical design ready

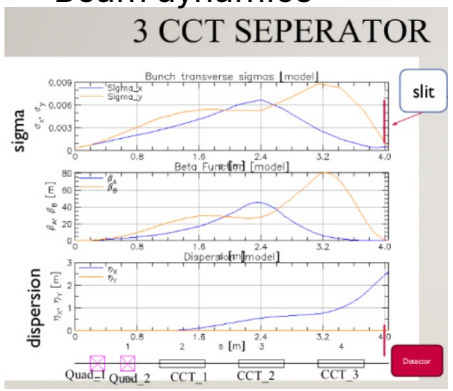
→ all components already purchased, waiting for delivery

Ion test bench

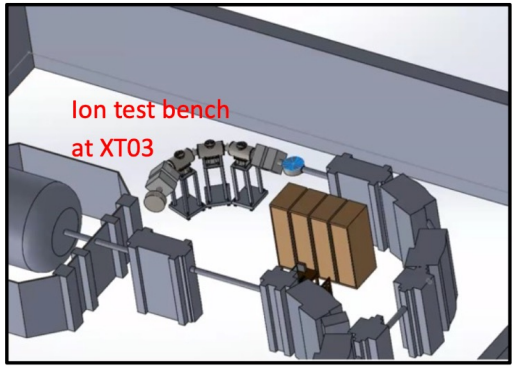
→ probe ISRS beam dynamics and operation principles

→ linear spectrometer (limited A/Q resolution)

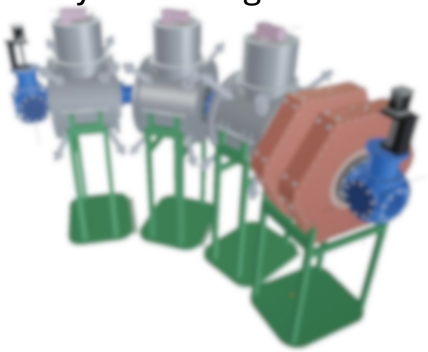
Beam dynamics



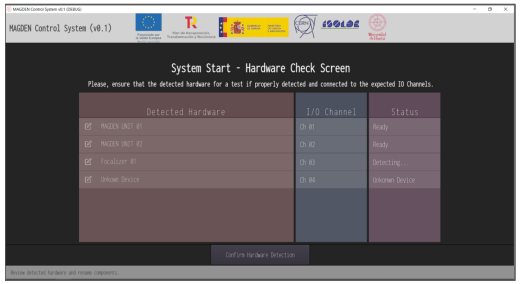
Installation at XT03



System integration



Control system



Reaction chamber

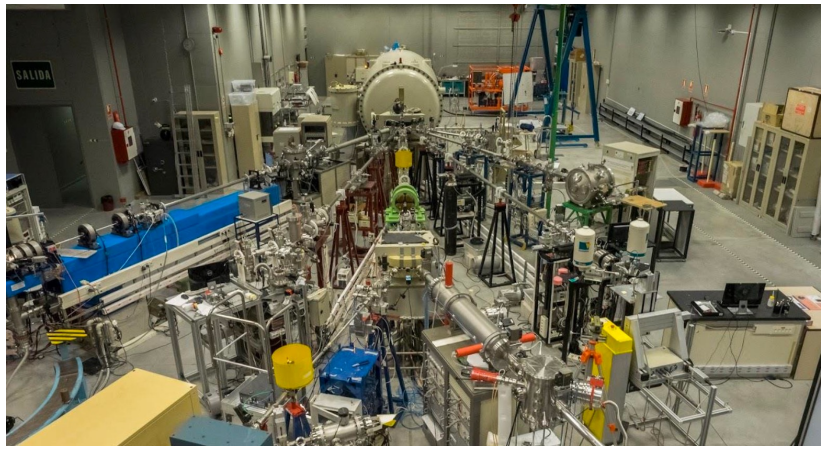
- Integration at UHU
- Test at CMAM-Madrid

Focal plane detector

- Needed for Z identification, energy and ToF
- Prototyping focal plane detectors:

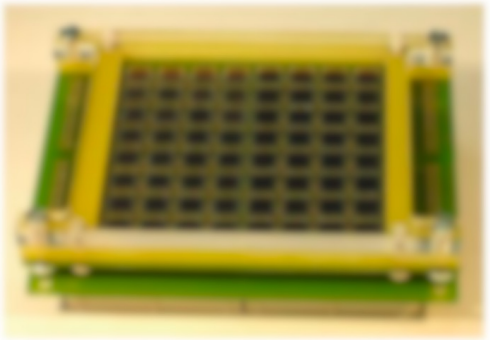
  Monolitic Si, SiC, LaBr3, BGO
- Collaboration with

  - IMB-CSIC
  - Politécnico di Milano
  - University of West Scotland, UK
- Development of new SiC detectors.
- Preliminary tests using standard electronics from MESYTEC.
- Ion tests foreseen at CMAM Madrid using pulsed beams.

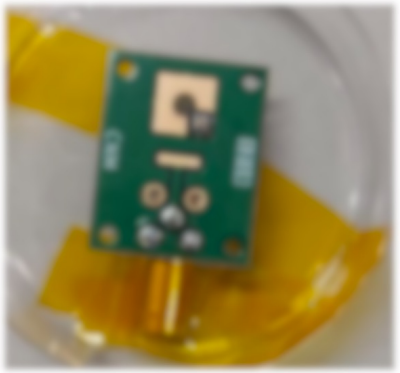


5MV Tandetron at CMAM, Madrid

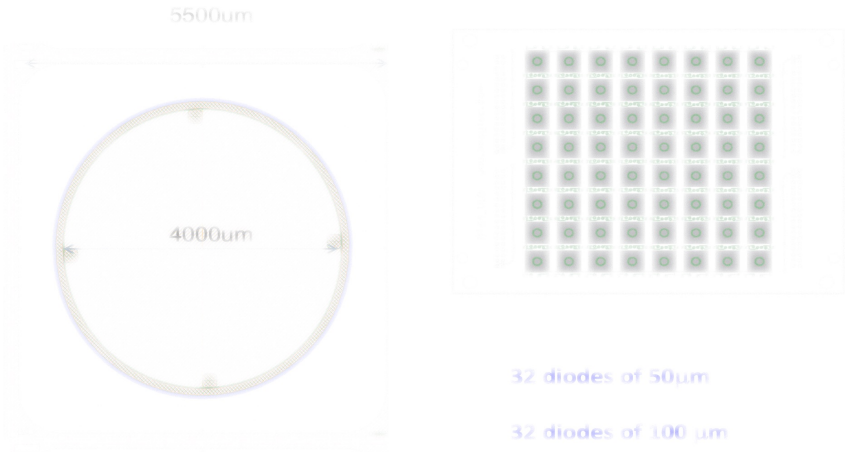
MESYTEC electronics chain



a) Photo of the monolithic detector.



SiC developed at IMB-CSIC



New SiC being developed at IEM-CSIC in collaboration with IMB-CSIC

Multiharmonic buncher

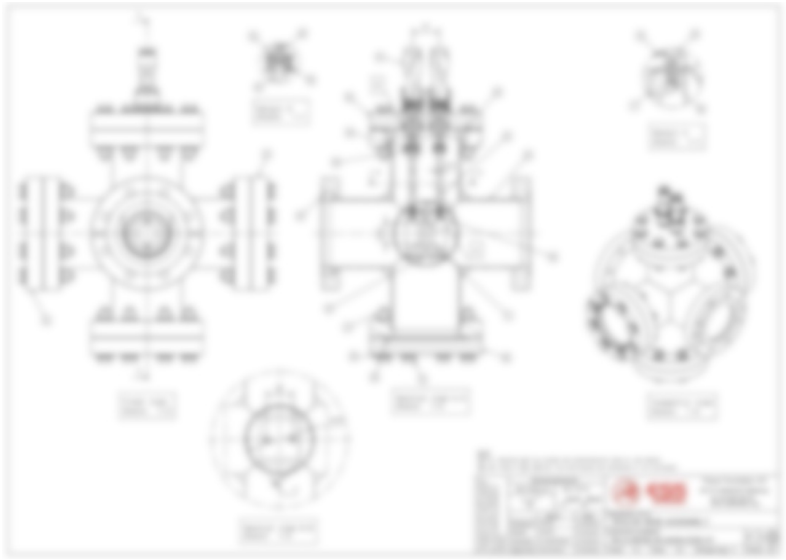
Reduce by a factor 10 the frequency of the HIE-ISOLDE LINAC. The objective is to develop a prototype of:

- Multi-Harmonic Buncher
- RF distribution Control System
- Ion Test Bench

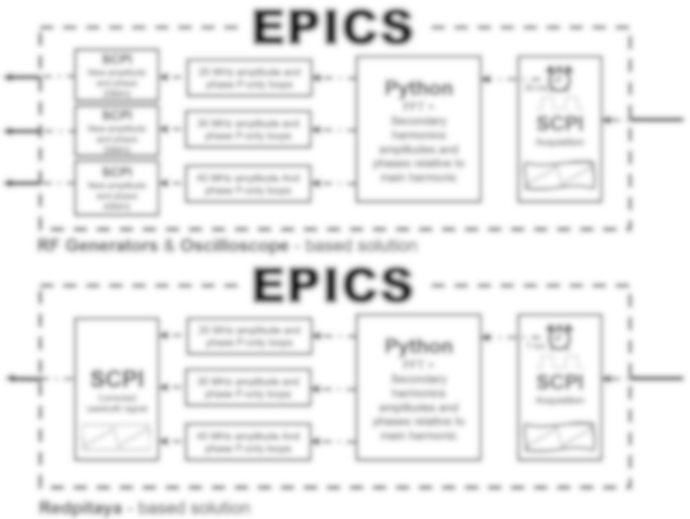
Operation combined with EBIS.

Status

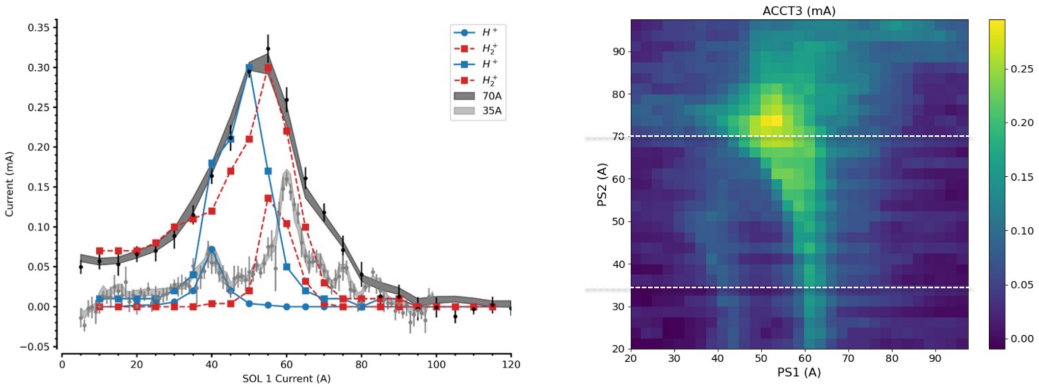
- MHB conceptual design is completed.
- ACCT (AC Current Transformer) was designed, fabricated and tested at ESSB (in-beam).
- Control system based on PyDev EPICS module is under development.
- Fast Faraday cup (FFC) prototype was developed.



MHB conceptual design



In-flange ACCT prototype



Test of ACCT with low energy beam at ESSB

Summary

- Spanish grant started in July 2023 and will finish by the end of December 2025
- Activities are being developed smoothly
- Expected outcomes:
  - Conceptual Design Report
  - Prototypes of:

  SC magnets - ion test bench - focal plane detector - MHB buncher - magnetic scanning system

Opportunities/investments

- Welcome to WPs → Personnel, Funds, Technical feedbacks – now, but also after 2025!!
- Injection/extraction system → big challenge! Prototyping not covered by Spanish grant.
- Additional detectors (MR-TOF), Plunger, LaBr3 array
- Ion test bench installation (during LS3, 2026-2028)
- Multi-harmonic buncher installation (during LS3, 2026-2028)
- Offline test site at CERN (during LS3, 2026-2028)
- Future construction/commissioning of ISRS (post LS3); ~ 10 MEuro

ISRS Collaboration

Inst. de Física, UNAM, México.
Dpt. CC Integradas, Univ. Huelva, Spain.
IPNO, Univ. Paris-Sud, Orsay, France.
Dpt. of Physics, Univ. Liverpool, UK.
IEM, CSIC, Madrid, Spain.
ESS- BILBAO, Bilbao, Spain.
CERN, Geneva, Switzerland.
Dpt. of Physics, Univ. Surrey, UK.
Dpt. of Physics, Lund Univ., Sweden.
Univ. Edinburgh, UK.
LNL INFN, Italy.
Uppsala Univ., Sweden.

Dpt. of Physics and Astronomy, Aarhus Univ., Denmark.
Dpt. of Physics, Chalmers Univ. of Technology, Göteborg, Sweden.
CENGB, Gradignan, France.
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