ISOLDE Workshop and Users meeting 2023

29 November 2023 to 1 December 2023
CERN
Europe/Zurich timezone

# Status of the HIE-ISOLDE Superconducting Recoil Separator (LOI-INTC-I-228)

Ismael Martel[1], Olof Tengblad[2], Joakim Cederkall[3]

[1] University of Huelva, Spain
[2] Instituto de Estructura de la Materia, CSIC, Madrid, Spain
[3] Lund University, Sweden

ISOLDE Superconducting Recoil Separator

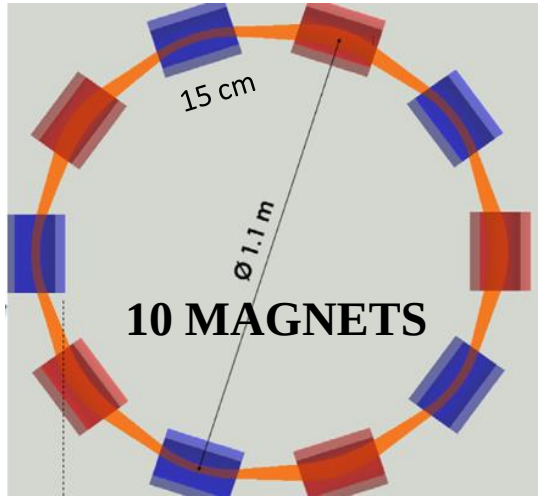
MINISTERIO DE CIENCIA E INNOVACIÓN
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

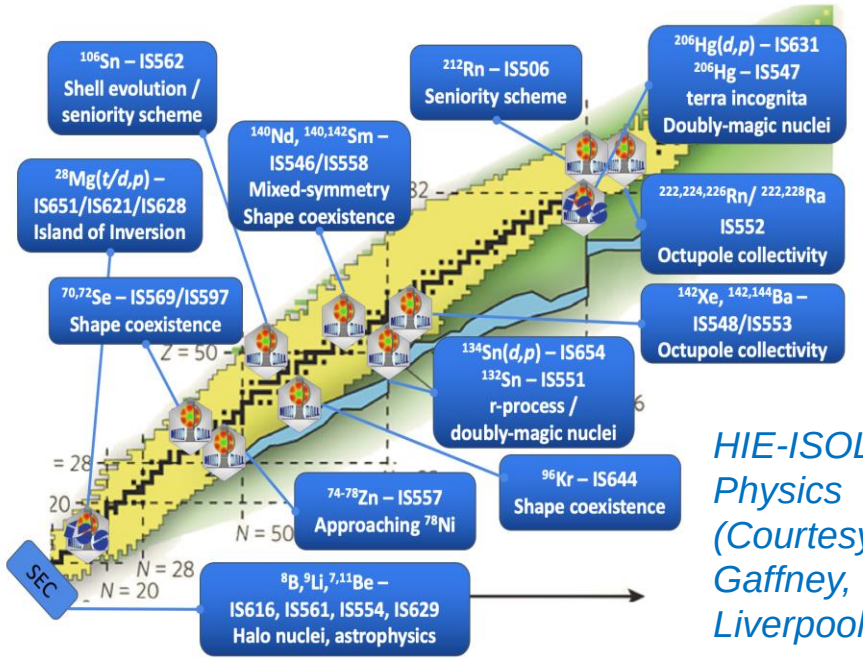
# ISOLDE Superconducting Recoil Separator

## *ISRS: a novel recoil separator for HIE-ISOLDE*

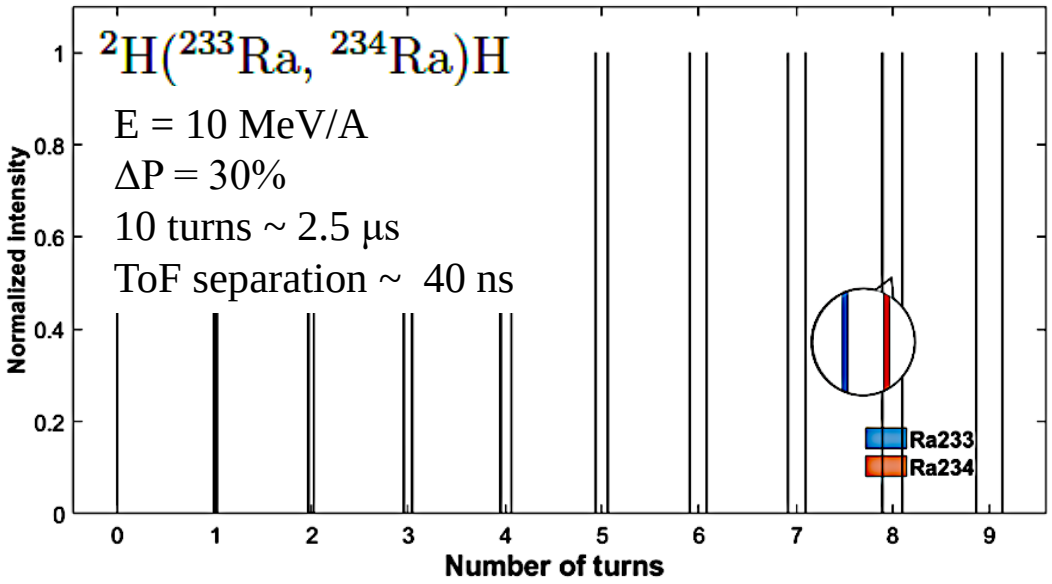
- ✓ Particle storage ring
- ✓ Nested multifunction superconducting magnets: quad + dipole
- ✓ FFAG (Fixed Field Alternating Gradient) beam transport system.
- ✓ Reaction fragments separated according to A/Q
- ✓ RF system for injection/extraction
- ✓ Focal plane detector: ToF, energy, charge (Z).
- ✓ Solenoids: Racetrack type or Canted Cosine Theta (CCT)
- ✓ Cooling: Hybrid LHe/cryocoolers/recondensing

*C. Bontoiu, J. Resta, V. Rodin, I. Martel, C. Welsch,* NIMA 969 (2020)164048




*HIE-ISOLDE Physics (Courtesy of L. Gaffney, Univ. Liverpool, UK).*



# Status of the LOI-INTC-I-228

**SHORT HISTORY**

- 2019: ISRS concept presented at 84th Meeting of the ISCC.
- 2020: First paper, C. Bontoiu et al., Nucl. Ins. Meth. A 969
- 2021: Letter of Intent for design study was approved – INTC-I-2283 (I. Martel, O. Tengblad , J. Cederkall)

The **mission** of the ISRS Collaboration (LOI INTC-I-2283), is

*"commit the resources needed to proceed with a Proof-of-Concept study and participate in national and EU funding programs."*

**Activities:**

- ✓ Participation in EU calls and national funding programs.
- ✓ Regular meetings (once/twice a year).
- ✓ Physics Cases
- ✓ Technical specs., Beam Dynamics, Multi-harmonic Buncher.
- ✓ **development of FUSILLO prototype -> 90° CCT solenoid with dipole function in collaboration with CERN.**
- ✓ Conferences/Publications.
- ✓ Close contact HT companies for possible developments.

Minimum ISRS requirements

| Parameters | Values |
|---|---|
| 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° |

# Status of the LOI-INTC-I-228

- **December 2021:** Spanish Gov. grants 6M€ to Spanish Institutions for R&D activities of CERN experiments.
- **July 2023**: R&D Project coordinated by CIEMAT.
- **Subproject ISRS ("ISRS-SPAIN"):** contribution of Spanish groups to the ISRS LOI. Budget 3M€.
- **December 2025**: budget deadline.

**Participants**

✓ University of Huelva, PI: I. Martel, **Coordinator**
✓ University of Valencia, PI: J. Resta
✓ IEM, CSIC, Madrid, PI: T. Kurtukian-Nieto, **Dep.-Coord.**
✓ Consorcio ESS-Bilbao (ESSB), PI: I. Bustinduy

**Four technical work packages**

✓ **WP0:** Coordination and Communication (not in LOI)
✓ **Technical WPs**: WP1, WP2, WP3.
✓ **WPs/Tasks:** Led by the Spanish institution receiving the funds.

| WP/TASK | LEADER |
|---|---|
| **WP1: STUDY OF BEAM DYNAMICS, INJECTION AND EXTRACTION** | **UV** |
| T1.1. Selection of Physics cases | UHU |
| T1.2. Nuclear reaction calculation | UHU |
| T1.3. Study of beam dynamics | |
| T1.4 Selection of configuration | |
| T1.5. Study of Injection/Extraction | |
| T1.6. Study of prototype of non-interceptive beam diagnosti | |
| T1.7. High order corrections to beam dynamics | |
| **WP2: CCT SOLENOIDS AND CRYOSTATS** | **UHU** |
| T2.1. Prototype of solenoid | |
| T2.2. Prototype of solenoid with cryostat (MAGDEM) | |
| T2.3. Study of elements of the magnetic field mesurement sy | |
| T2.4. MAGDEM focussing system | |
| T2.5. Prototypes of critical elements of focal plane | |
| **WP3: MULTI-HARMONIC BUNCHER** | |
| T3.1. Revision of critical designs | |
| T3.2. Test acceptance of manufactured protoypes | |
| T3.3. Prototype of multiharmonic buncher | |

Physics Cases Inputs for BD

Beam dynamics to optimize configuration & operation

Technology demonstrators

# WP0. COORDINATION AND COMMUNICATION

**Leader:** University of Huelva
**Objectives:**
- ✓ Project governance, management, coordination
- ✓ Quality assurance and risk management
- ✓ Communication and IPR

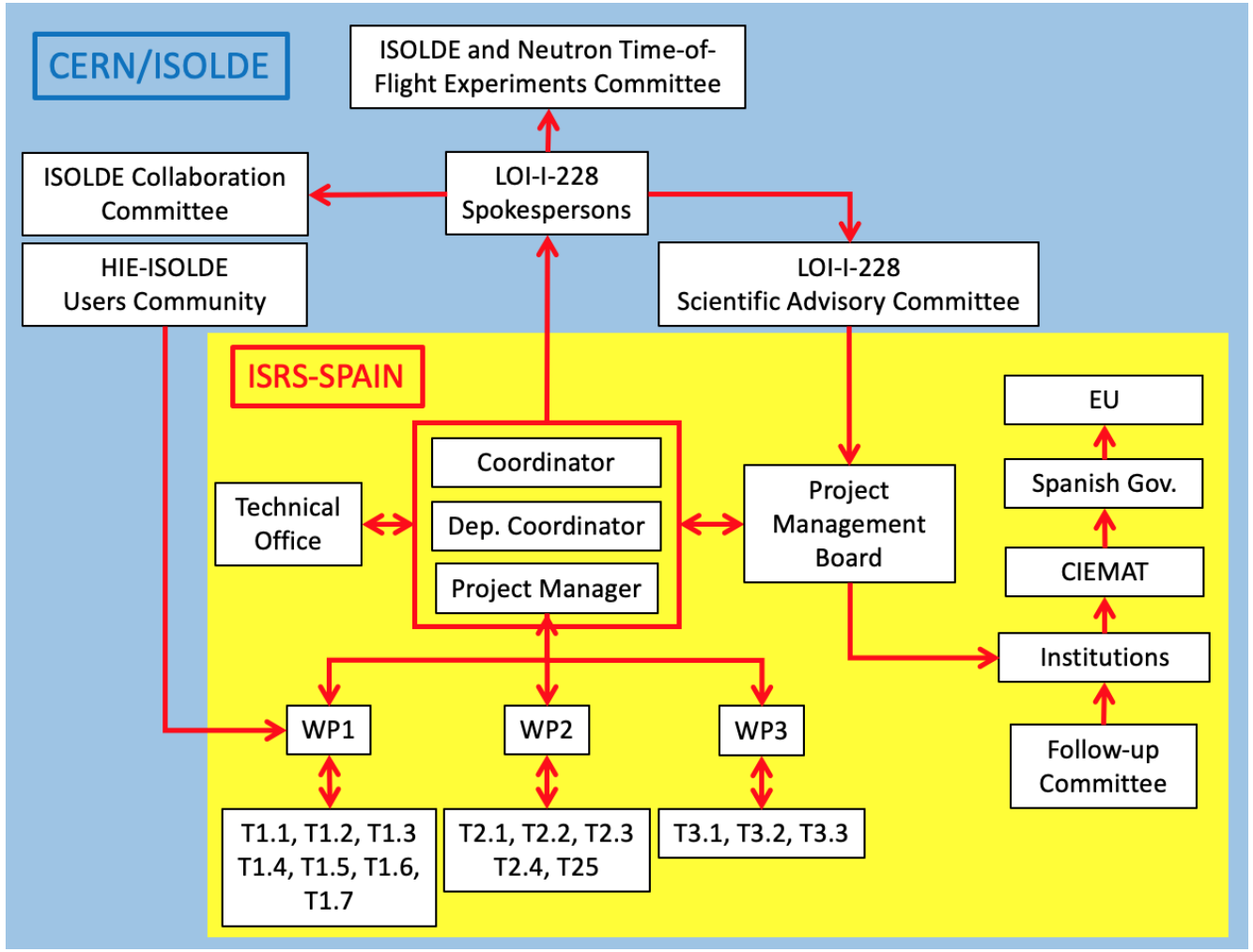
**Spokespersons**
I. Martel, U. Huelva, Spain.
O. Tengblad, IEM-CSIC, Madrid.
J. Cederkall, U. Lund, Sweden.

**Scientific Advisory Committee:** 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

**ISRS Web site** https://www.uhu.es/isrs/

Universidad de Huelva

## MANAGEMENT STRUCTURE: CERN/ISOLDE <--> ISRS-SPAIN



# WP1. Study of beam dynamics, injection and extraction

**Leader:** University of Valencia

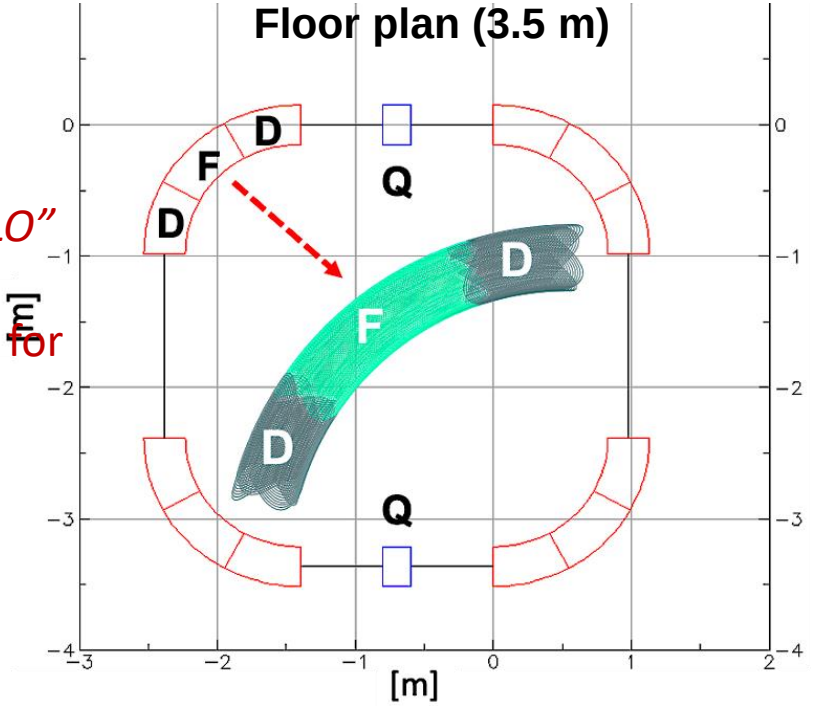
**Objectives:** Beam dynamics studies to optimize the layout and performance of the ISRS ring.

*Selection of physics cases -> Nuclear reaction calculations -> Study of beam dynamics -> Selection of configuration/operation*

- ✓ Injection/Extraction
- ✓ Non-interceptive beam diagnostics
- ✓ Corrections to beam dynamics

**Configuration - example**

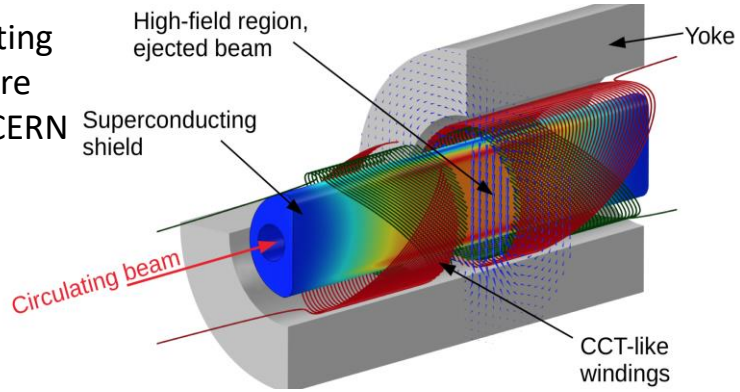
- 4 x 90° *"FUSILLO"*
- DFD sequence
- Two quads (Q) for matching.




## Injection/extraction - example

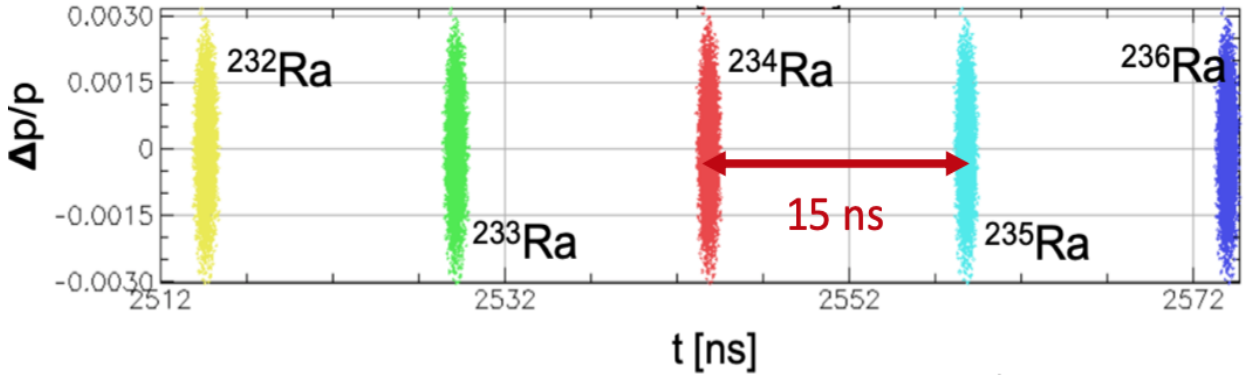
SuShi: Superconducting septum for the Future Circular Collider at CERN

D. Barna. Rev. Sci. Inst. 90 (2019)




Particle tracking study, isochronous solution

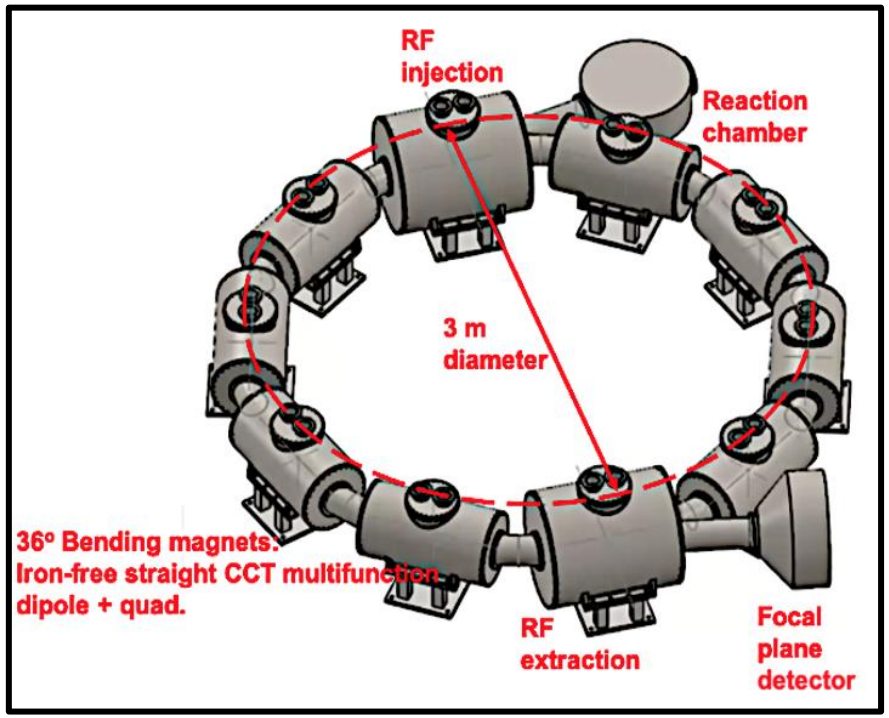
10 turns (2544 ns)



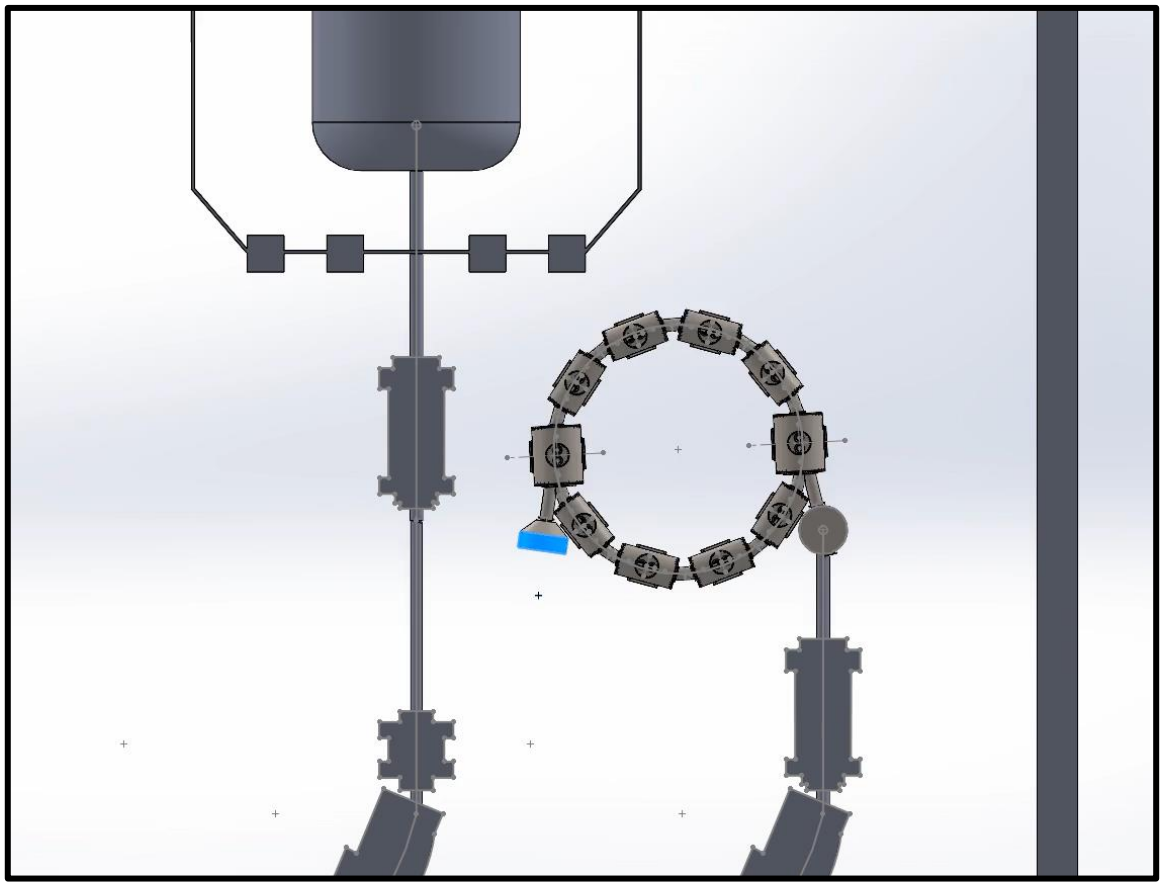
# WP1. Study of beam dynamics, injection and extraction

## Configuration - example

- 8 x straight CCTs
- 2 x SuShi type injection/extraction



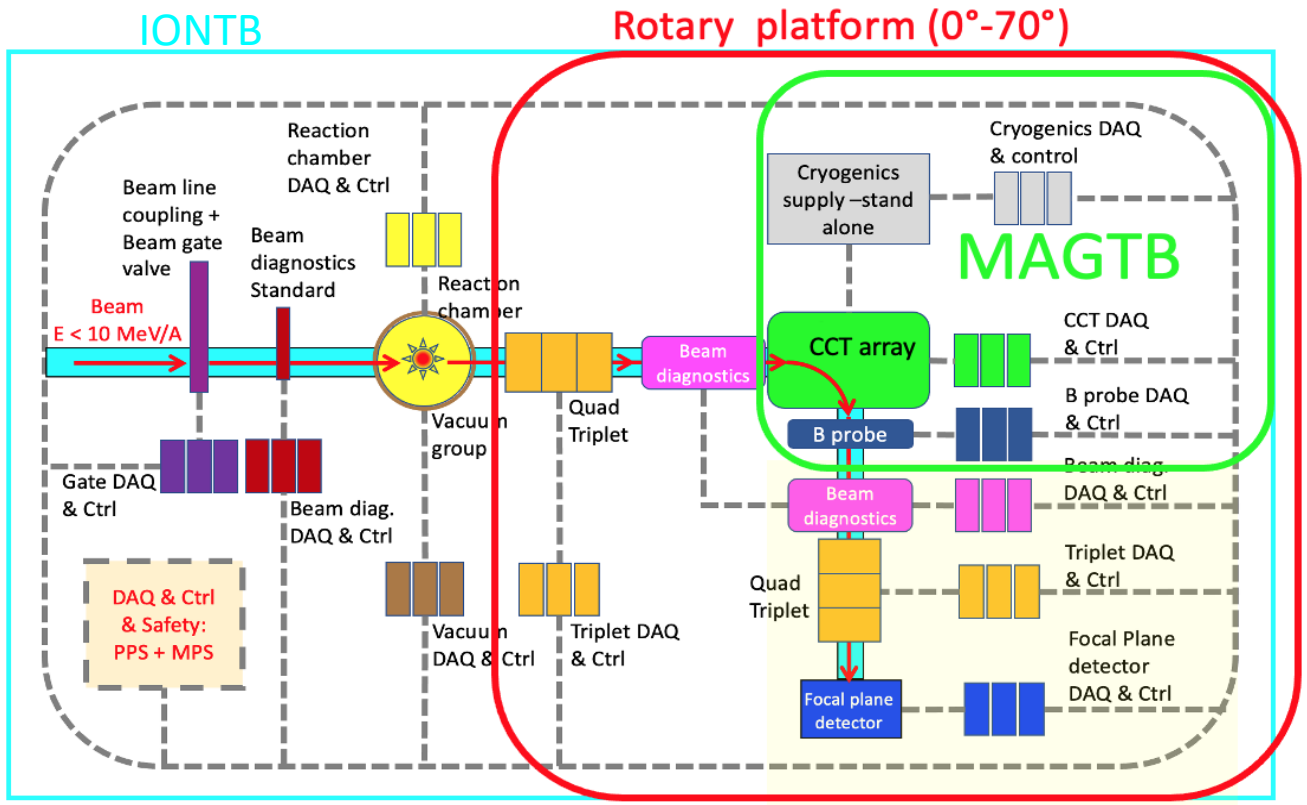

## Integration study at XT03



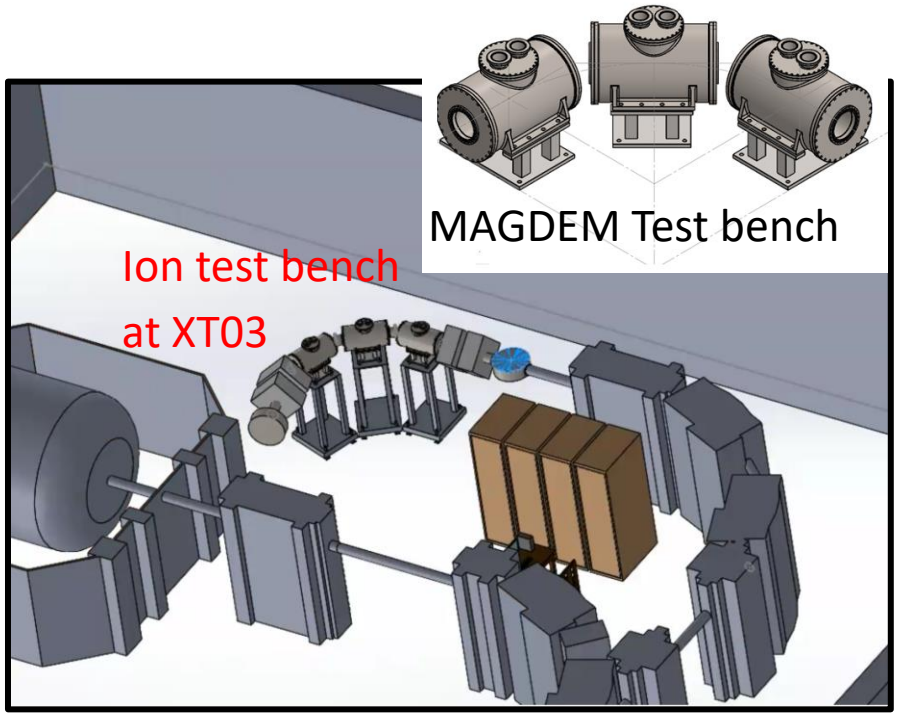
# WP2. CCT SOLENOIDS AND CRYOSTATS

**Leader:** University of Huelva

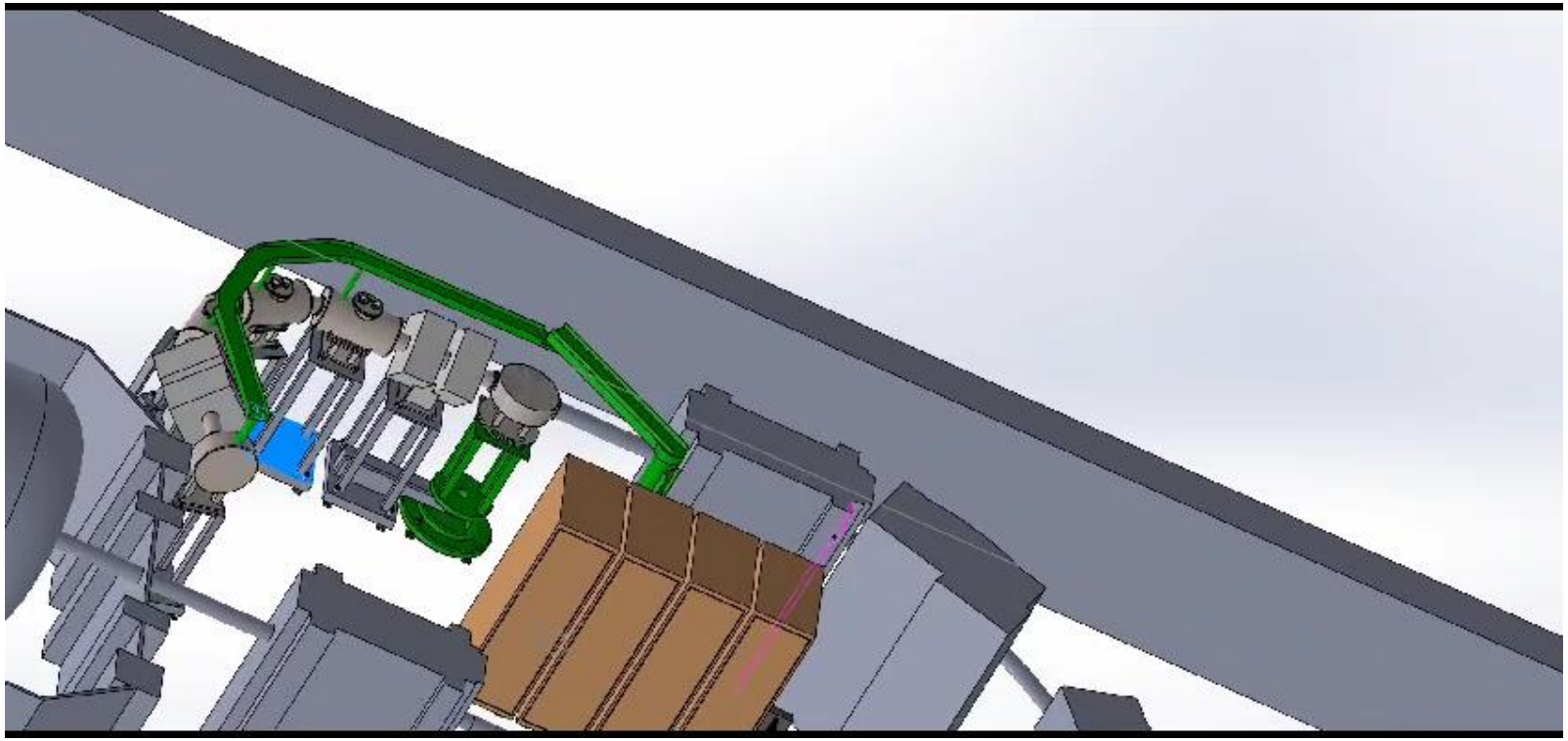
**Objectives:** Study technical challenges in the construction and operation of the ISRS spectrometer. Prototypes of critical elements.




- ✓ MAGDEM: Straight CCT magnet with dipole and quad functions, for ion beam circulation.
- ✓ 3D magnetic field scanner.
- ✓ Focal plane detector
- ✓ MAGDEM Test bench
- ✓ Ion test bench: Test concepts with ion beams
  - Linear spectrometer



# ION TEST BENCH at XT03

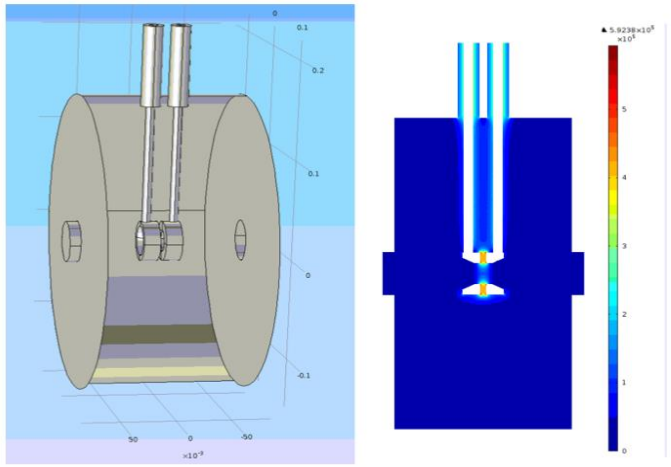


# WP3. MULTI-HARMONIC BUNCHER

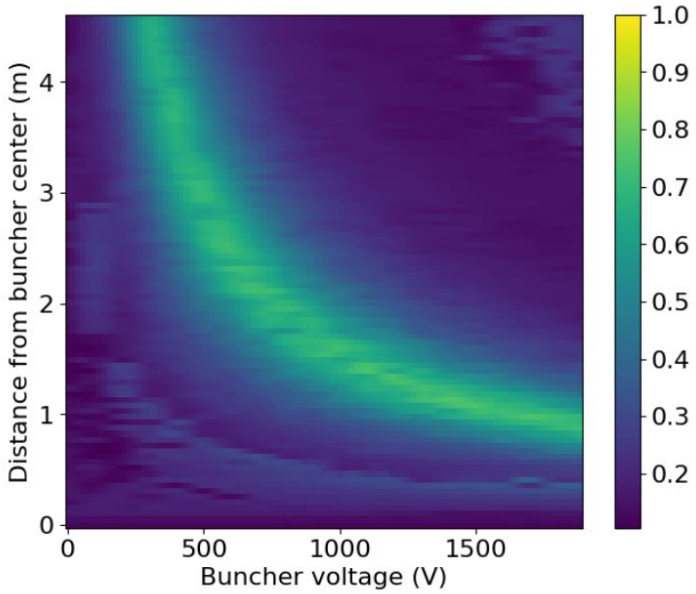
**Objectives:**

- Design and build prototype of multi-harmonic bucher for the operation of ISRS at HIE-ISOLDE.
  - ✓ low energy dispersion (< 1%)
  - ✓ high transmission (> 95%)
  - ✓ reduced space for bunch formation (< 5 m).
- RF power signal generation
- Test at ESS-Bilbao injector

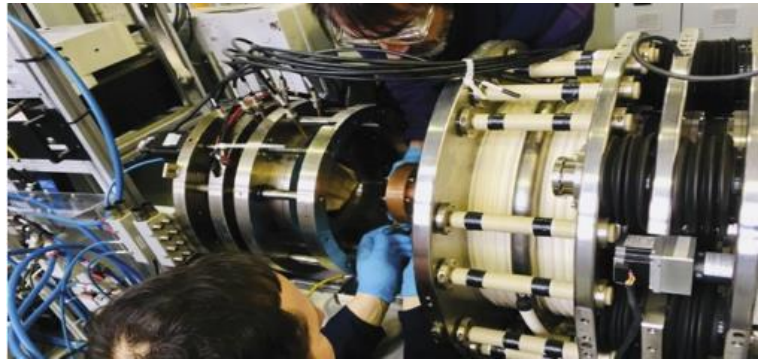
| | ESS-BILBAO INJECTOR |
|---|---|
| RF Frequency | 10.128 MHz |
| Macro-Pulse | 1-50 Hz, 50 - 3000 μs |
| Beam Energy | 5-45 keV/q |
| Ion Species | H+ / He+ / N+ |
| Beam Current | 0.1-40 mA |
| Vacuum Flange Interface | DN63CF |
| Maximum longitudinal space | 4.0 m |



EM model of the MHB with wedge electrodes. Frequency 10.128 MHz




Bunching efficiency as a function of distance and electrode voltage.



*ESSB plasma ion source*

# SUMMARY AND CONCLUSSIONS

- Funding from Spanish Gov. for R&D activities received. Deadline December 2025.
- Spanish Institutes: Univ. Huelva, Univ. Valencia, IEM/CSIC Madrid, ESS-Bilbao
- R&D covers the main activities of the LOI: beam dynamics, injection/extraction, beam diagnostics, CCT magnets, focal plane detector, beam diagnostics, multi-harmonic buncher.
- ISRS Spain focus on **straight CCT magnets**, complementary to **curved magnets** (CERN-FUSILLO).

**THANKS!**

## ISRS COLLABORATION

*Inst. de Física, UNAM,* ***México.***
*Univ. Huelva,* ***Spain.***
*IJCLab-Univ. Paris-Sud,* ***France.***
*Dpt. of Physics, Univ. Liverpool,* ***UK.***
*Wigner Research Centre for Physics, Budapest,* ***Hungary.***
*Inst. de Estructura de la Materia, CSIC, Madrid,* ***Spain.***
*ESS-BILBAO, Bilbao,* ***Spain.***
*Univ. Surrey,* **UK.**

*CERN, Geneva,* **Switzerland.**
Lund University, **Sweden.**
*Götenborg University,* **Sweden.**
*Univ. Edinburgh,* **UK.**
*LNL INFN,* **Italy**
*Uppsala Univ.,* ***Sweden.***
*Aarhus Univ.,* ***Denmark.***
*Chalmers Univ. of Technology,* ***Sweden.***
*CENGB, Gradignan,* ***France.***
*Univ. York,* ***UK.***

*Univ. of West Scotland,* ***UK.***
*ICMUV-Univ. de Valencia,* ***Spain.***
*The Cockcroft Institute,* ***UK.***
*Astroparticule et Cosmologie-Univ. Paris Diderot,* ***France.***
*Univ. Jyvaskyla,* ***Finland.***
*IMIS Univ. Riyadh,* ***Saudi Arabia.***
*IFIN-HH, Bucharest,* ***Romania.***
*Politecnico di Milano-DEIB & INFN,* ***Italy.***
*HIL-Warsaw University,* ***Poland.***

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

# PROJECT IMPLEMENTATION SCHEDULE (draft)

| | | WP/TASK LEADER | COLLAB. | 2023 | | | | | | 2024 | | | | | | | | | | | | 2025 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jul | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Ap | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Ap | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| | | | | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 | M14 | M15 | M16 | M17 | M18 | M19 | M20 | M21 | M22 | M23 | M24 | M25 | M26 | M27 | M28 | M29 | M30 |
| WP0. | COORDINATION AND COMMUNICATION | UHU | ALL MEMBERS | | | | | | ML1 D1 | ML2 D2 | ML4 TR1 | ML3 ML5 | D3 D4/D5 | ML2 | ML1 | | TR2 | ML2 | | | ML1 | ML2 | TR3 | | | ML2 | ML1 | | TR4 | ML2 | | | ML1/ML2 TR5(y26) |
| WP1. | STUDY OF BEAM DYNAMICS, INJECTION AND EXTRACTION SYSTEMS | UV | UHU, IEM/CSIC | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T1.1. | Selection of Physics cases | UHU | | | | | | | ML1 | | D1 | | | | ML2 | | D2 | | | | ML3 | | D3 | | | | | | | | | | |
| T1.2. | Nuclear reaction calculation | UHU | IEM/CSIC | | | ML1 | | | | | | | | | | | ML2 | | D1 | | | | ML3 | | D2 | | | | | | | | |
| T1.3. | Study of beam dynamics | UV | | | | | | D1 | | | | | | | | | | | | | ML1 D2/D3 | | | | | | | | | | | | |
| 1.3.1. | Design specification | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3.2. | Selection of machine layouts and lattices | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3.3. | Ring simulations | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3.4. | Error calculation and tolerance levels | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T1.4. | Selection of configuration | UV | | | | | | | | | | | | | | | | | | | ML1 D1 | | | | | | | | | | | | |
| T1.5. | Study of Injection/Extraction | UV | | | | | | | | | | | | | | | | | | | | | | | | ML1 D1 | | | | | | | |
| 1.5.1. | Injection/extraction specifications | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5.2. | Injection/extraction simulations | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5.3. | Beam detectors | UV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T1.6. | Study of prototype of non-interceptive beam diagnostics | UV | UHU | | | | | | | | | | | | | | | | | | | | | | | | | | | | ML1 D1 | | |
| T1.7. | High order corrections to beam dynamics | CSIC | UV | | | | | | | | | | ML1 | | | | | | | | ML2 | | | | | | | | | | | | D1 |
| WP2. | CCT SOLENOIDS AND CRYOSTATS | UHU | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T2.1. | Prototype of solenoid | UHU | SUBCO | ML1 | | | | | | ML2 | D1 | | | | | | | | | | | | | | | | | | | | | | |
| T2.2. | Prototype of solenoid with cryostat (MAGDEM) | UHU | SUBCO | ML1 | | | | | | ML2 | ML3 D1/D2 | | ML4 | | ML8 D3 | | | | ML5 | | ML6 | | | | | | | | | ML7 D4 | ML9 D5 | | | |
| T2.3. | MAGDEM focussing system | CSIC | | | | | | | | | | | | | | | ML1 D1 | | | | ML2 D2 | | | | | | | | | | | | ML3 D3 |
| T2.4. | Study of magnetic field measurement system elements | UHU | | | | ML1 | | | ML2 | | | | | | ML3/ML4 D1/D2 | | | | | | ML5 D3 | | | | | | | | | | | | |
| T2.5. | Prototypes of critical elements of focal plane | CSIC | | | | | | | | | | | | | | | | | | | ML1 D1 | | | | | | | | | | | | ML2 D2 |
| WP3. | MULTI-HARMONIC BUNCHER | ESSB | | | | | | | | | | | | | | | | | | | ML1 D1 | | | | | | | | | | | | ML2 D2/D3 |
| T3.1. | Revision of critical designs | ESSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T3.2. | Test acceptance of manufactured protoypes | ESSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T3.3. | Prototype of multiharmonic buncher | ESSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |