ISOLDE Superconducting Recoil Separator

ISRS Collaboration Meeting and Physics workshop 19–20 Jun 2025

Ion Test Bench and the New LOI for the installation of ISRS prototypes at ISOLDE (INTC-I-283)

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MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

CERN

HIE-ISOLDE

➢ LOI: Installation and commissioning of the ISRS Ion Test-bench and Multi-Harmonic Buncher at HIE-ISOLDE

- New LOI submitted to the INTC in January 2025

- Continue the ISRS R&D activity with the installation of MHB and IONTB at ISOLDE during LS3 period 2026-2028.

Status

- The LOI was approved by the INTC.
- The ISCC requires detail information of the setups and safety approval.

  - ✓ ISCC 6 March 2025
  - ✓ ISCC 18 June 2025
  - ✓ Next ISCC November 2025

Funding applications for 2026-2028 (LS3)

- Funding from ISRS collaboration is welcome!!

  - ✓ Spain Gov. application U. Huelva – U. Valencia ~ **1 MEuro**
  - ✓ INTERREG Spain –Portugal: UHU – LIP (Lisbon) ~ **4.5 MEuro**

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Installation and commissioning of the ISRS Ion Test-bench and Multi-Harmonic Buncher at HIE-ISOLDE

9 January 2025

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Local contact: Jose Alberto Rodríguez (alberto.rodriguez@cern.ch)

ISCC meeting, March 2025, minutes

*"The following **additional information is requested** so that the proposal could be discussed again at a future ISCC meeting:*

1. ***Additional technical details on the multi-harmonic buncher** and a planning scenario for implementing the device. The latter concerns the implementation and characterisation in the linac, as well as potential deployment strategies **should there be negative consequences** for certain beams/experiments that prevent its permanent inclusion in the machine.*
2. ***Whether the implementation of the Test Bench was permanent or for a limited duration**, and what **effect** this might have on the **use of flexible setups** that have been deployed at XT03 in the past.*
3. ***Any significant safety concerns** that might arise from an initial safety audit which must be undertaken. The proponents should contact **EP safety** about this issue as soon as possible.*
4. *A **better understanding** of the **hall space required and the estimated timelines."***

MHB:

- Do not present important issues
- It was suggested to be decoupled from IONTB so it could move forward

IONTB:

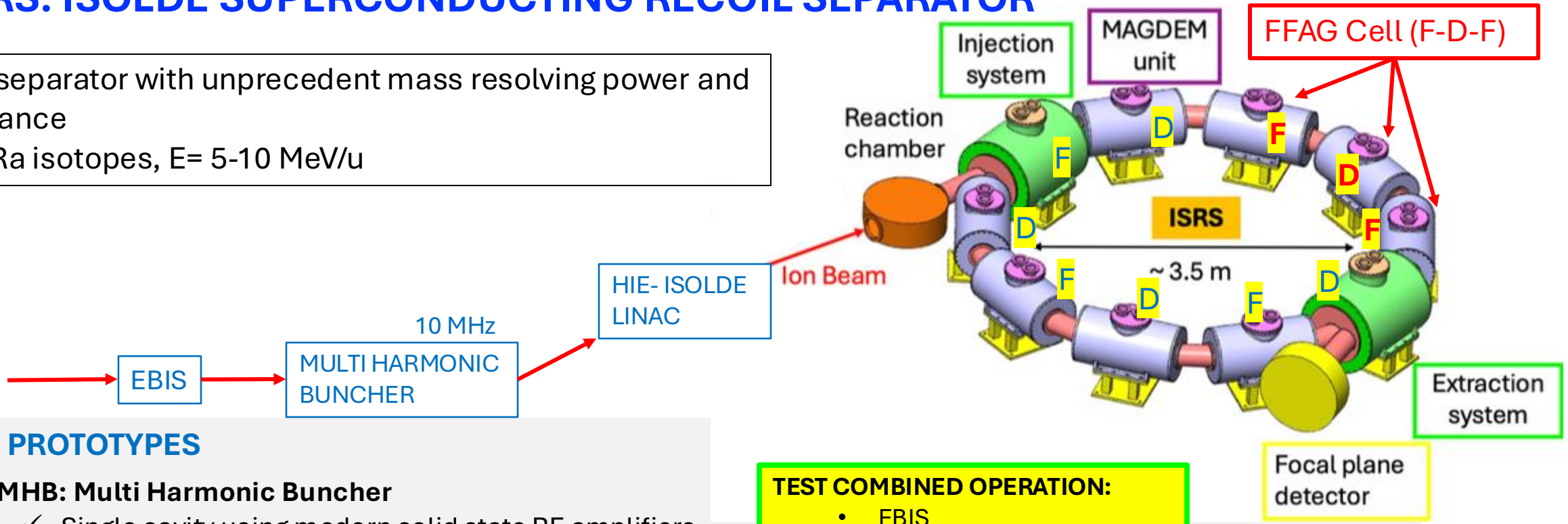
- Beam transport and mechanical integration completed
- Quads from CERN pool selected
- Initial Safety Declaration (ISD) – first draft sent last 13 June

Already in contact with ISOLDE team and preparing the information for next ISCC meeting in November.

➢ ISRS: ISOLDE SUPERCONDUCTING RECOIL SEPARATOR

Recoil separator with unprecedent mass resolving power and acceptance

- Li - Ra isotopes, E= 5-10 MeV/u



➢ ISRS PROTOTYPES

- **MHB: Multi Harmonic Buncher**
  - ✓ Single cavity using modern solid state RF amplifiers
  - ✓ Reduce HIE-ISOLDE frequency to < 10 MHz / 100 ns
  - ✓ Required for TOF experiments
  - ✓ Improve IONTB and ISRS (future) performance.

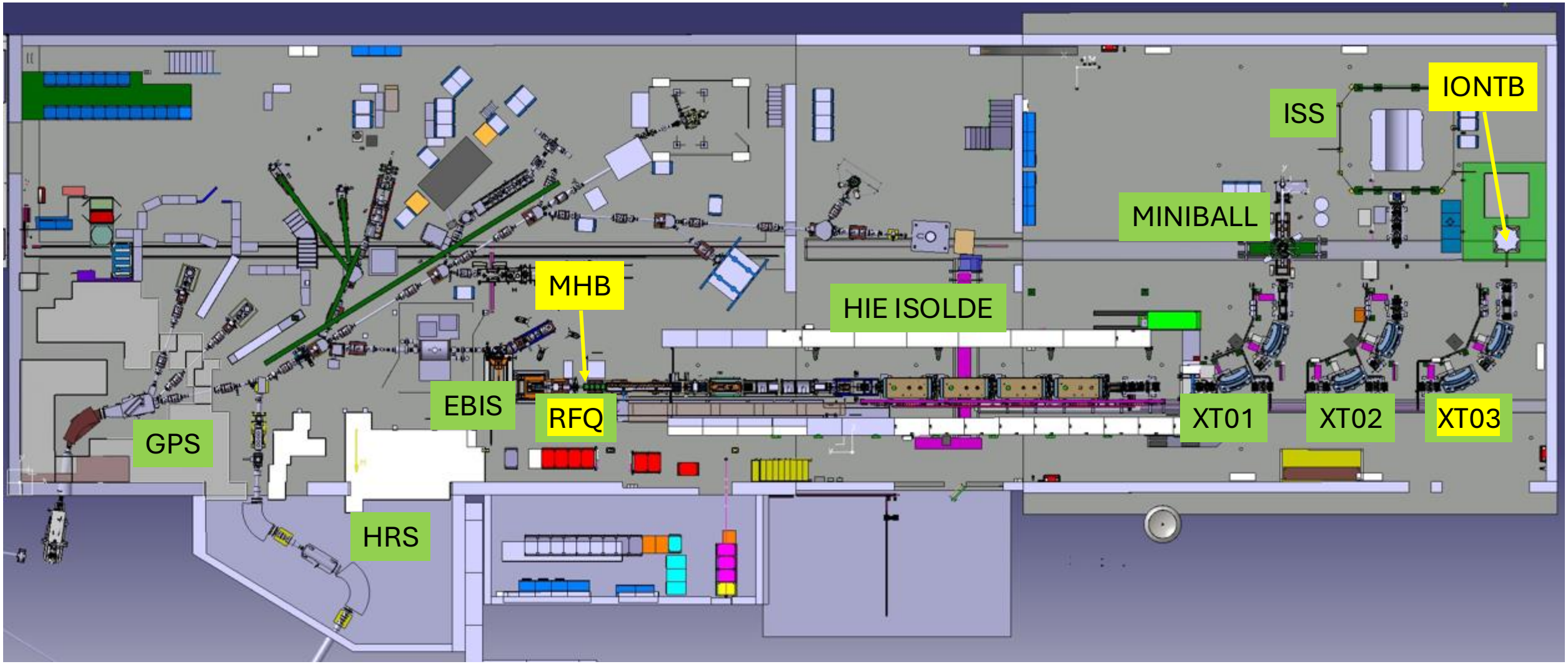
- **IONTB: Ion Test Bench**
  - ✓ MAGDEM: prototype of nested Superconducting Magnet for ISRS (dipole + quad)
  - ✓ IONTB: Complete bench including reaction chamber, MAGDEM, focusing system, focal plane
  - ✓ Prove MAGDEM performance & ISRS experimental concepts
  - ✓ Can operate as a linear spectrometer, but limited mass resolution and acceptance.

TEST COMBINED OPERATION:

- EBIS
- MHB
- HIE-ISOLDE linac
- REACTION CHAMBER
- MAGDEM
- FOCAL PLANE DETECTOR

IONTB: Can operate as a linear spectrometer → "ISOLDE Superconducting Linear Spectrometer" **ISLS**

➢ MHB & IONTB AT ISOLDE HALL

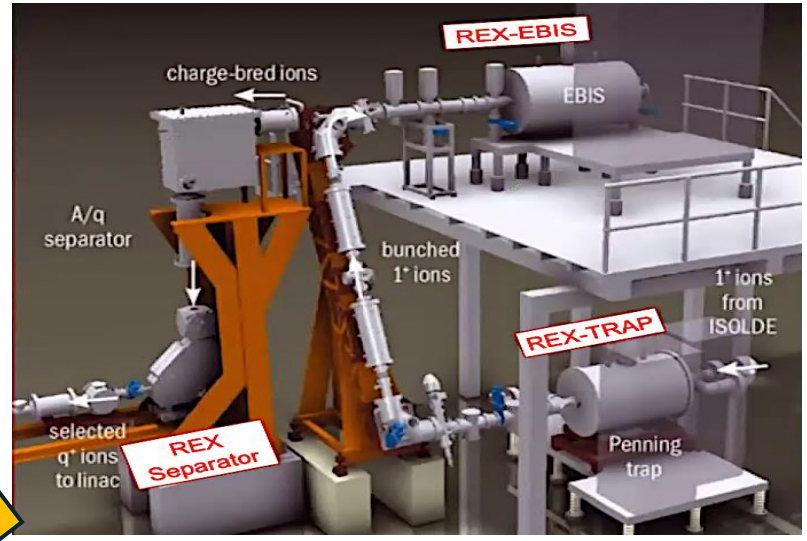


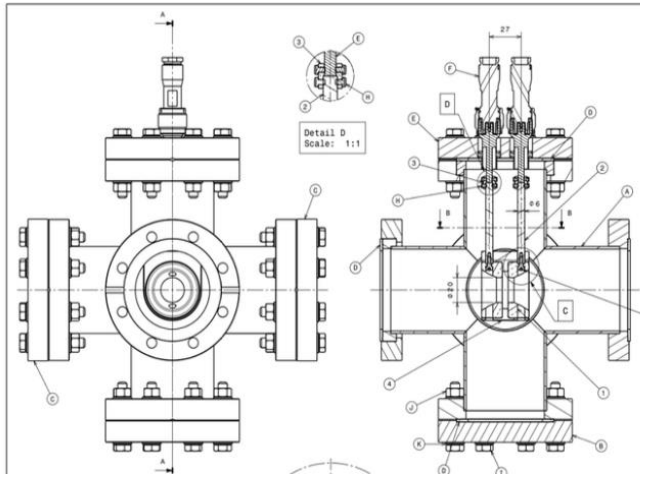
➢ MULTI HARMONICS BUNCHER

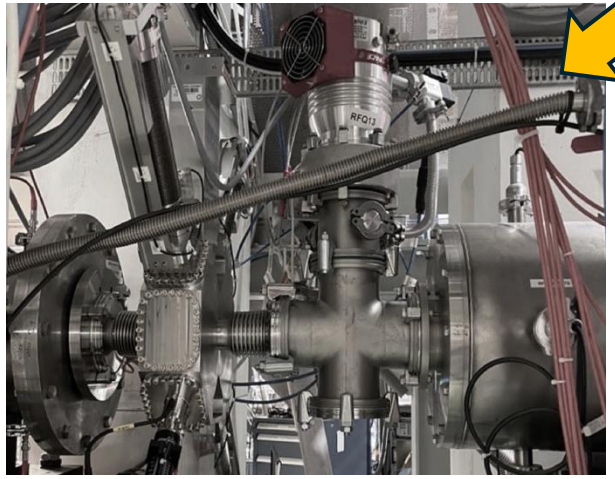
ACTIVITY	INSTITUTE	2025 Q1	2025 Q2	2025 Q3	2025 Q4	2026 Q1	2026 Q2	2026 Q3	2026 Q4	2027 Q1	2027 Q2	2027 Q3	2027 Q4	2028 Q1	2028 Q2	2028 Q3	2028 Q4
1. BEAM DESIGN AND INTEGRATION STUDIES	ESS-BILBAO																
2. COMMISSIONING at BILBAO	ESS-BILBAO																
3. MHB VALIDATION	ESS-BILBAO																
4. DOCUMENTATION	ESS-BILBAO																
5. ISOLDE STUDY SETUP	MADRID/HUELVA																
6. TRANSPORT/INSTALLATION	ESS-BILBAO																
7. COMMISSIONING HIE-ISOLDE	ISOLDE																

LS3

Detail plan Q3-Q4 2027



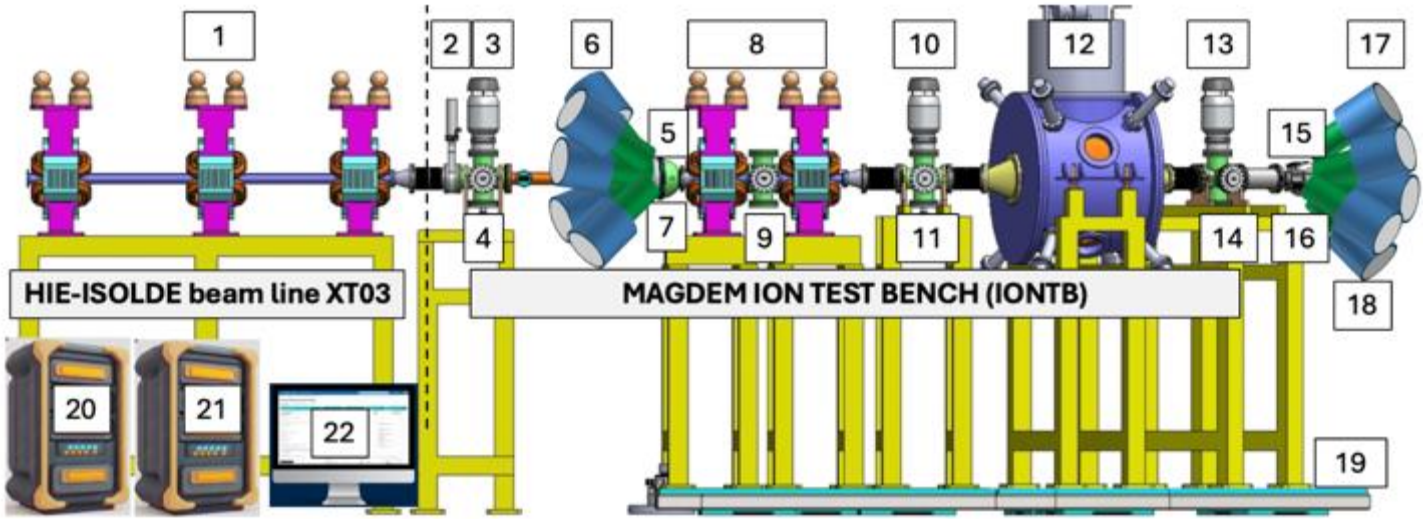




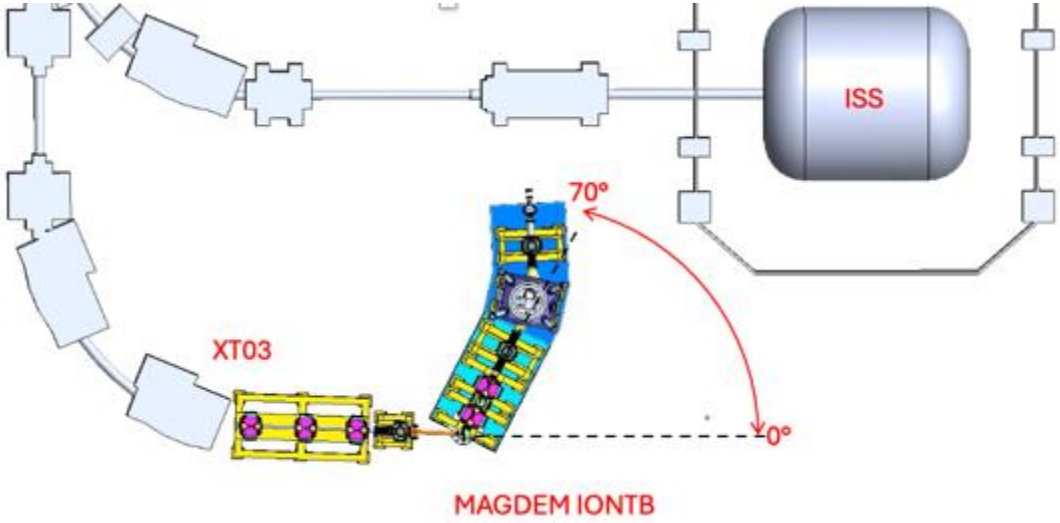
- **Already** of existing 4-way cross → MHB
- **MHB design:** electrodes can be removed → no beam obstacles/impact on experiments
- **Equipment:** 6-way cross + RF power amplifier
- **Space:** Elect. crate for RF power supply
- **Safety:** ISD submitted on June 13.
- **Installation plan**
  - ✓ Equipment first tested & commissioned at ESS
  - ✓ **ISOLDE: details** to be developed with local group (in progress).
  - ✓ **TDR** preparation
- **Test planned:** directly at HIE, during LS3.

➢ ION TEST BENCH, THE FIRST CONCEPT

MAGDEM



1. HIE-ISOLDE triplet/XT03
2. Beam valve
3. Diff. pumping < 10-7mb
4. Beam diagnostics
5. Reaction chamber (RC)
6. RC-Gamma array
7. RC-particle detector array
8. Quadrupole doublet
9. Beam diagnostics
10. Vacuum system
11. Beam diagnostics
12. MAGDEM (Dipole+ quad)
13. Vacuum system
14. Beam diagnostics
15. Focal plane chamber (FP)
16. FP-particle detector array
17. FP-Gamma array
18. Beam dump
19. Rotary platform
20. Data acquisition and control (DAC) hardware
21. Machine & personal protection system (MPS & PPS) hardware
22. DAC-Software



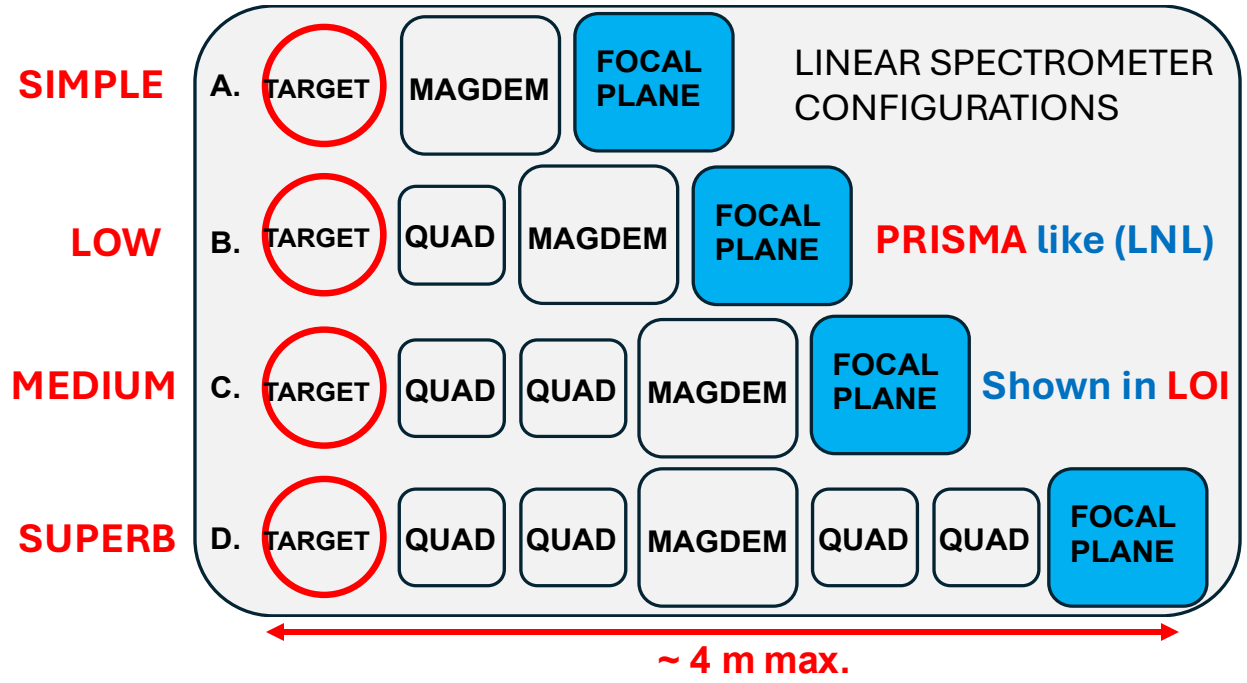
2. IONTB & MHB: Improvements gained

- **MHB** –> **TOF** experiments at HIE-ISOLDE
- **IONTB + MHB** – Physics experiments @ XT03 complementary to ISS and MINIBALL using **gamma-particle** correlations
- **Performance** better than previous HiFi project
- **Low, Medium and High** mass resolution configurations
- **Reduced footprint** to avoid interaction with ISS
- Possibility to **rotate up to 70°**
- **Most experiments:** zero degree

➢ ION TEST BENCH OPTIMISATION

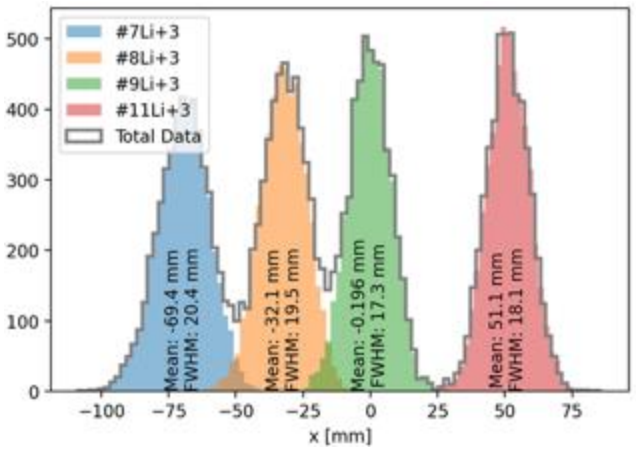
- **Optimisation work**
- BMAD (**Univ. Valencia**) + GICOSY (**IEM, CSIC, Madrid**)
- Small footprint ~ 4 m max (**Univ. Huelva**)
- **Rejection** of primary beam
- **Ancillary** detectors → gamma-particle correlations
- **Tagging** on selec. react. fragments/**Focal plane** decay
  - ➢ Isotopic separation
  - ➢ Acceptance – dP/P – $\delta\theta$
- **Most experiments at 0°,** rotate up to 70° possible
- Combine IONTB with **MHB for TOF** → improved PID

Example for (d,p) (d,n) (t,p) (t,d)… reactions

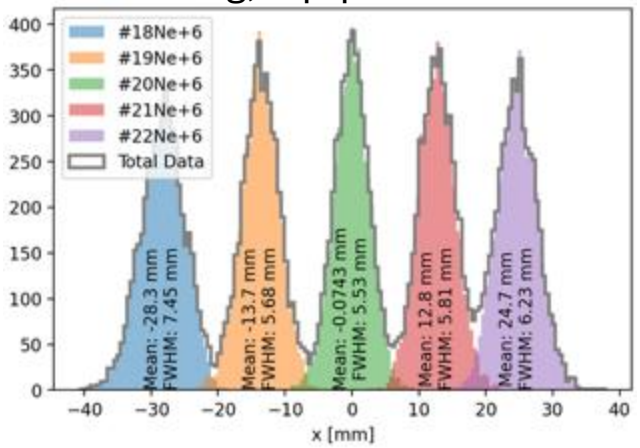


Config C. results BMAD- MEDIUM (0.3 cm/%)

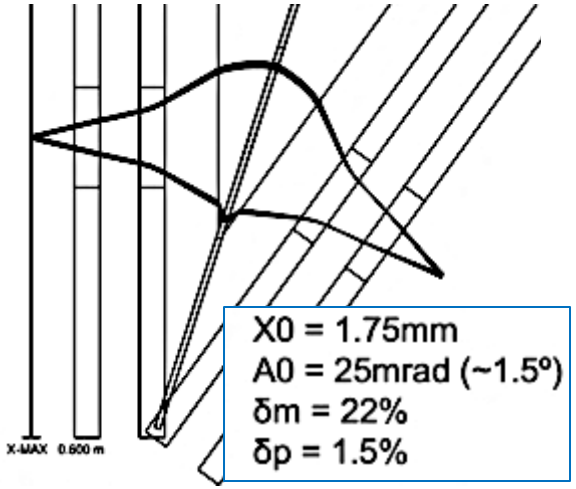
Lithium recoils
Div. ±1 deg, Δp/p = 3%



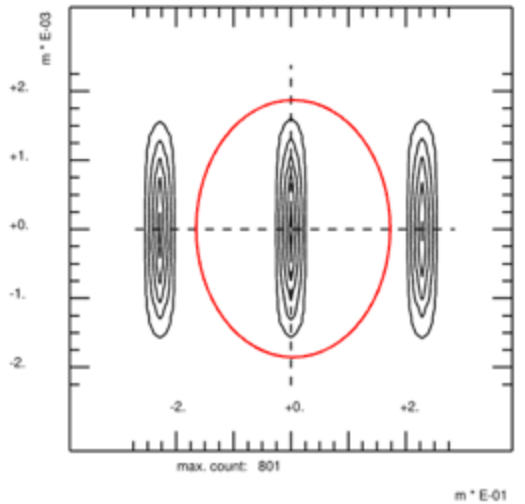
Neon recoils
Div. ±1 deg, Δp/p = 1%



Config D. results GICOSY – SUPERB (1 cm/%)



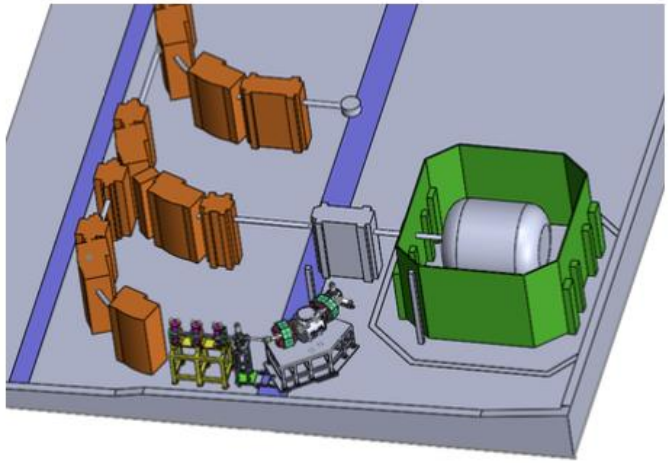
point-to-point X+Y fit with final dispersion 1cm/%



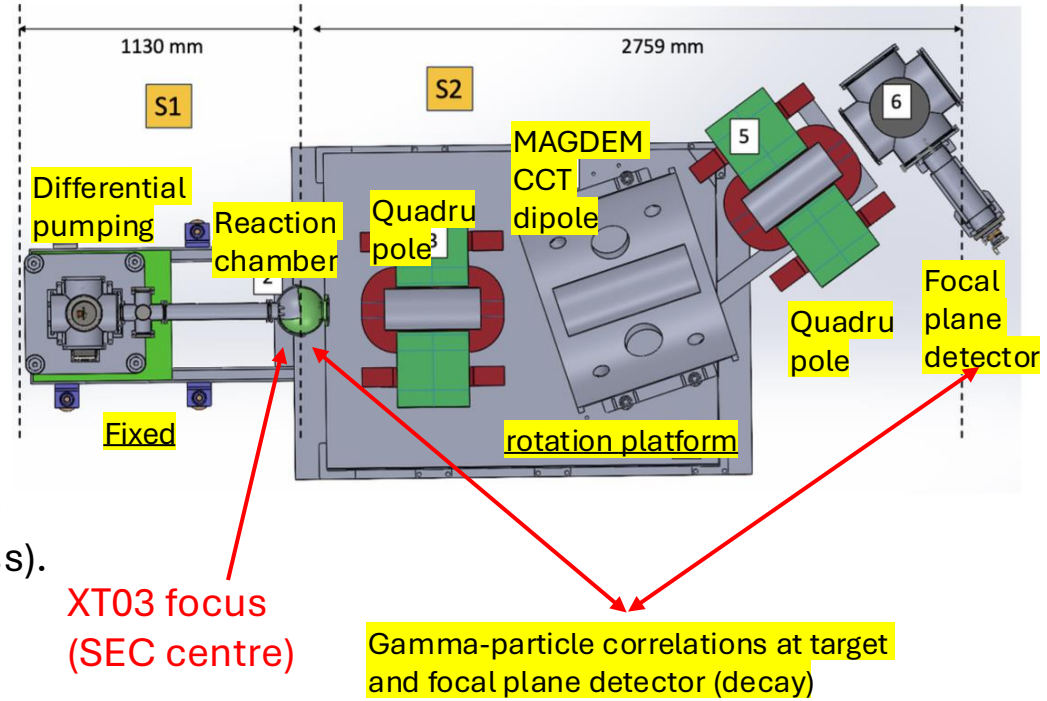
➢ ION TEST BENCH FINAL SETUP

ACTIVITY	INSTITUTE	2025 Q1	2025 Q2	2025 Q3	2025 Q4	2026 Q1	2026 Q2	2026 Q3	2026 Q4	2027 Q1	2027 Q2	2027 Q3	2027 Q4	2028 Q1	2028 Q2	2028 Q3	2028 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																

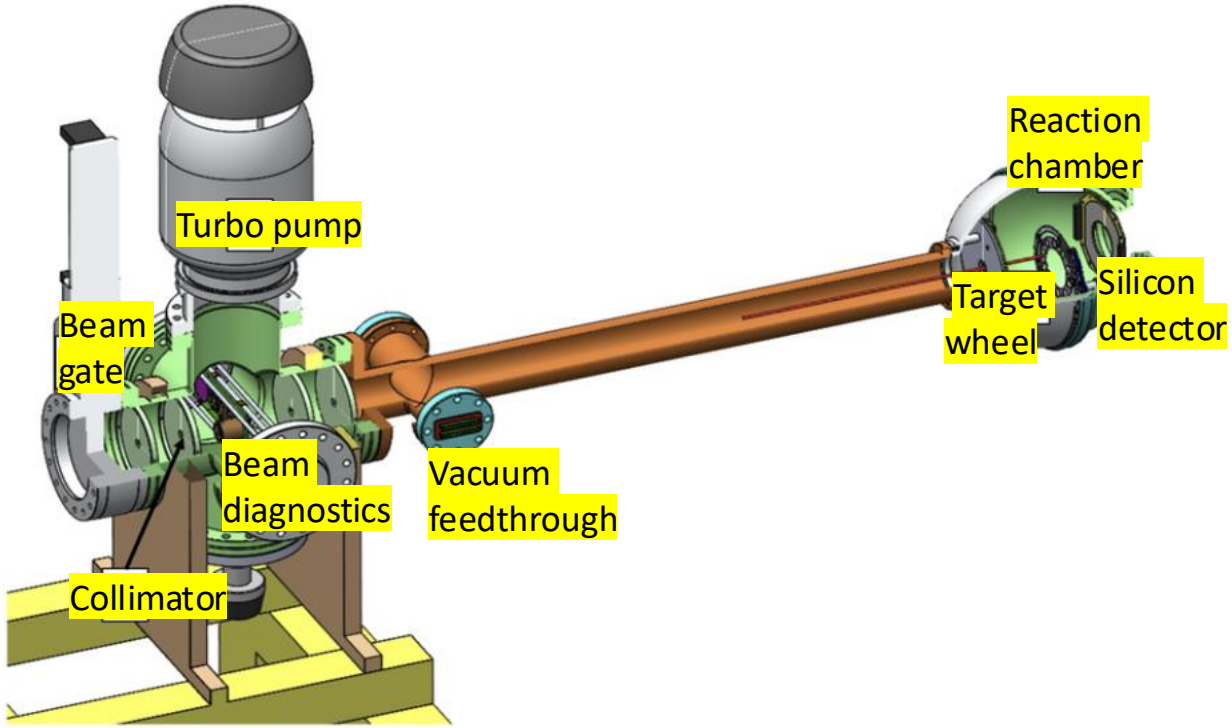
Detail plan
Q3-Q4
2027

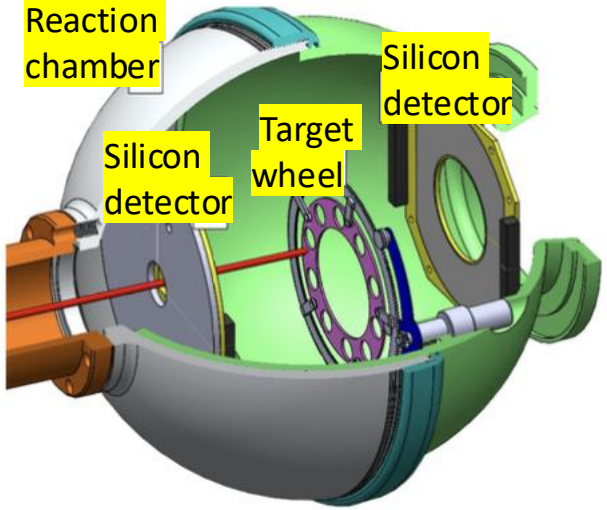


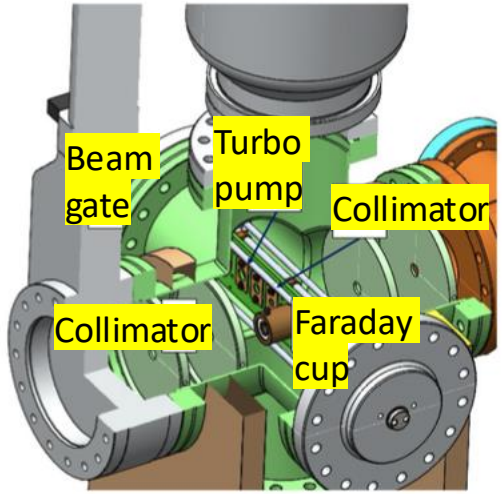
- **"PRISMA (LNL, Italy)" config.** Transport calculations (BMAD, GCOSY) and mechanical integration converged:
  - ✓ Quads from CERN-pool
  - ✓ Space: L 3 m; W 1 m; H 2.3 m + Elec. CRATE
- **Selectivity:** Scatt. angle (target) + **Bρ (dipole)** + (TOF(A) + E-loss (Z)). (Focal plane detector)
- **Aim for "permanent" setup** (ISOLDE SC Linear Spectrometer) ←→ **SEC**
- **Safety:** ISD submitted on June 13. → No LHe refilling needed
- **TDR** preparation→ Still purchasing equipment (June 2026)
- **Installation plan**
  - ✓ Equipment first tested/comm. at stable beam facility: CMAM (Madrid)
  - ✓ **HIE-ISOLDE: details** to be developed with the local group (in progress).
- **Day one test experiment**: ^{19}Ne (d,^{20}Na) in inverse kinematics
  - ✓ Reaction calculations
  - ✓ Detailed simulations

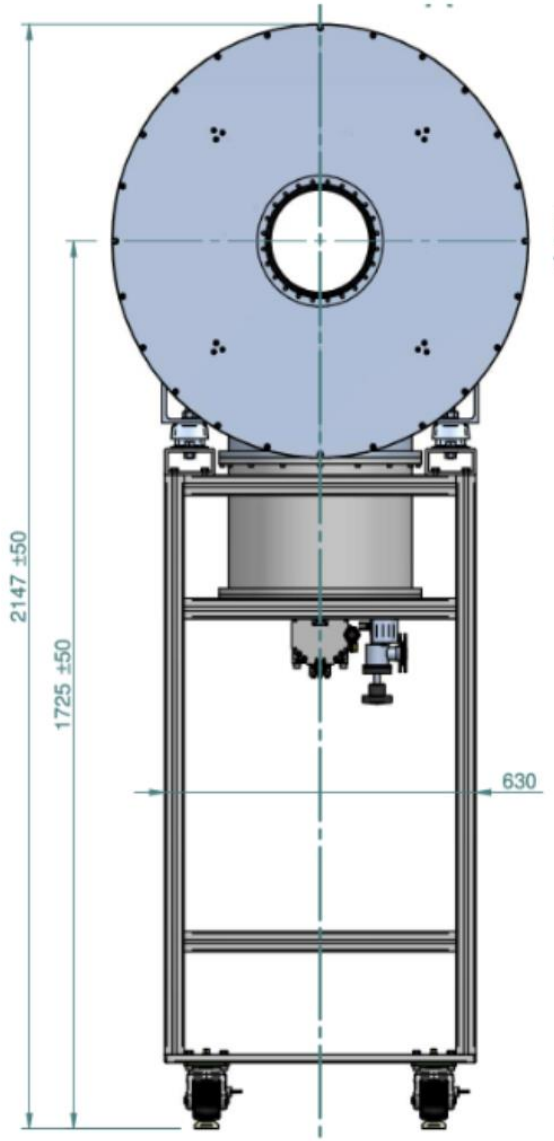


➢ SOME ION TEST BENCH SUBSYSTEMS









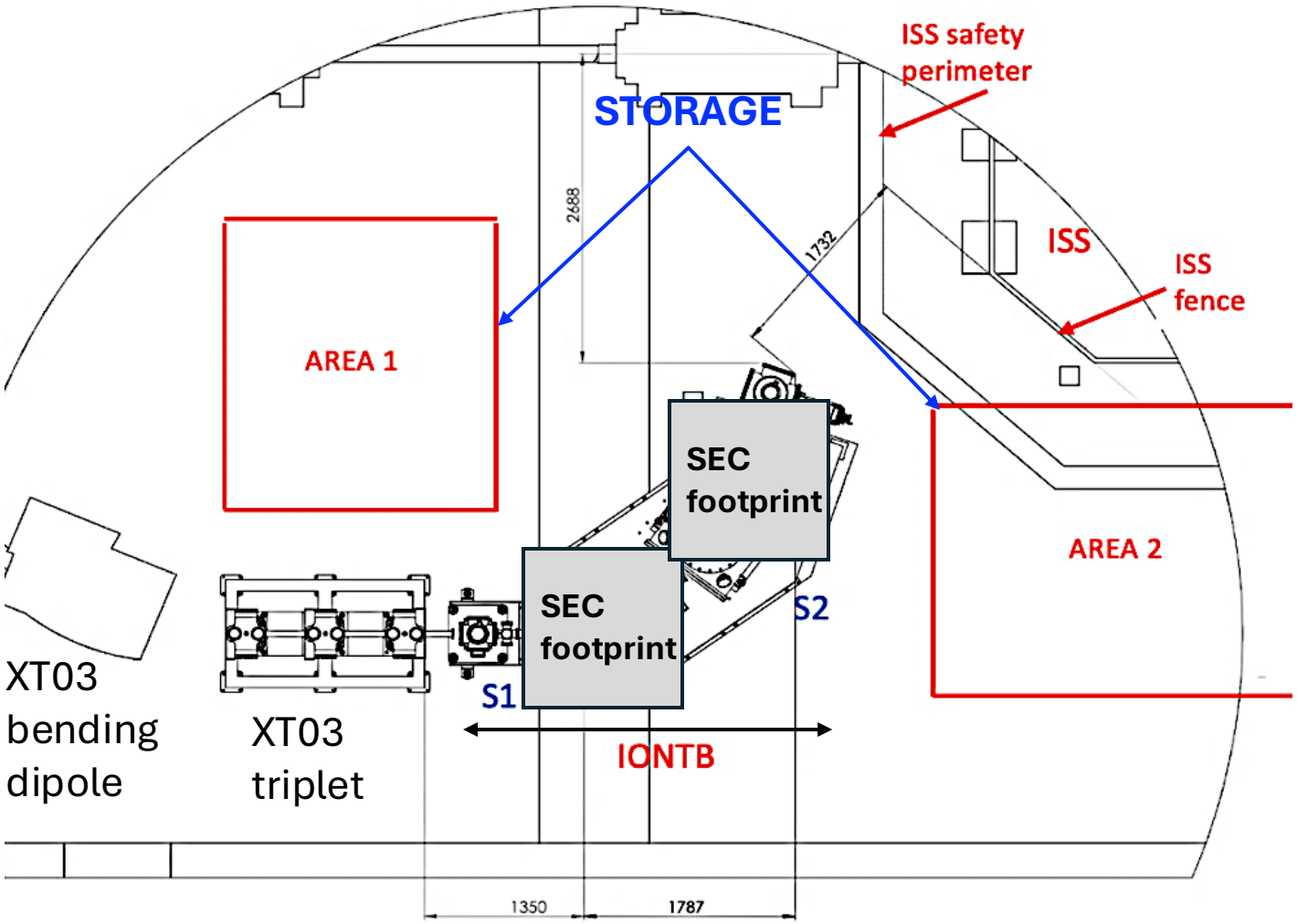
MAGDEM CCT SC DIPOLE + QUAD

WARM QUADS CERN pool

➢ IONTB footprint, interaction with experiments, storage

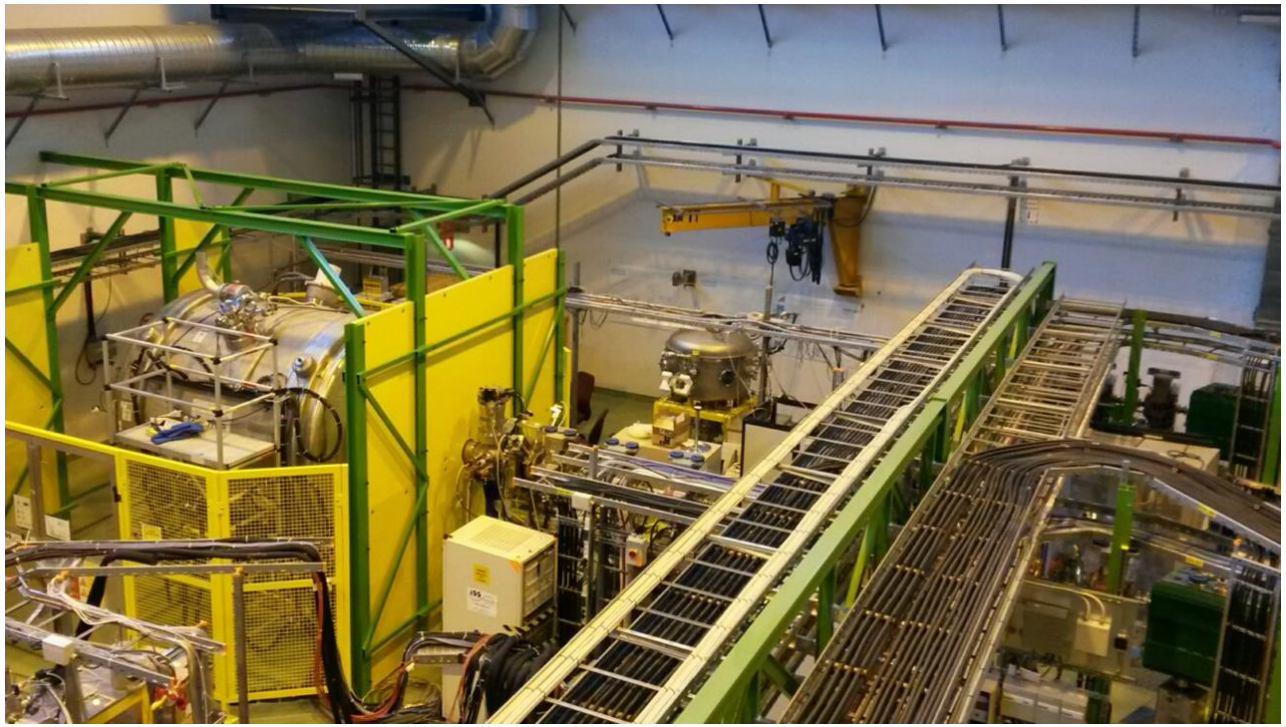
- **IONTB and SEC exchange/storage.**
  - ✓ Storage areas A1, A2 possible.
  - ✓ IONTB is provided with 4 aircasters.
  - ✓ SEC and IONTB can be moved using pallet jacks.
- **Detail drawings** of footprint can be provided.

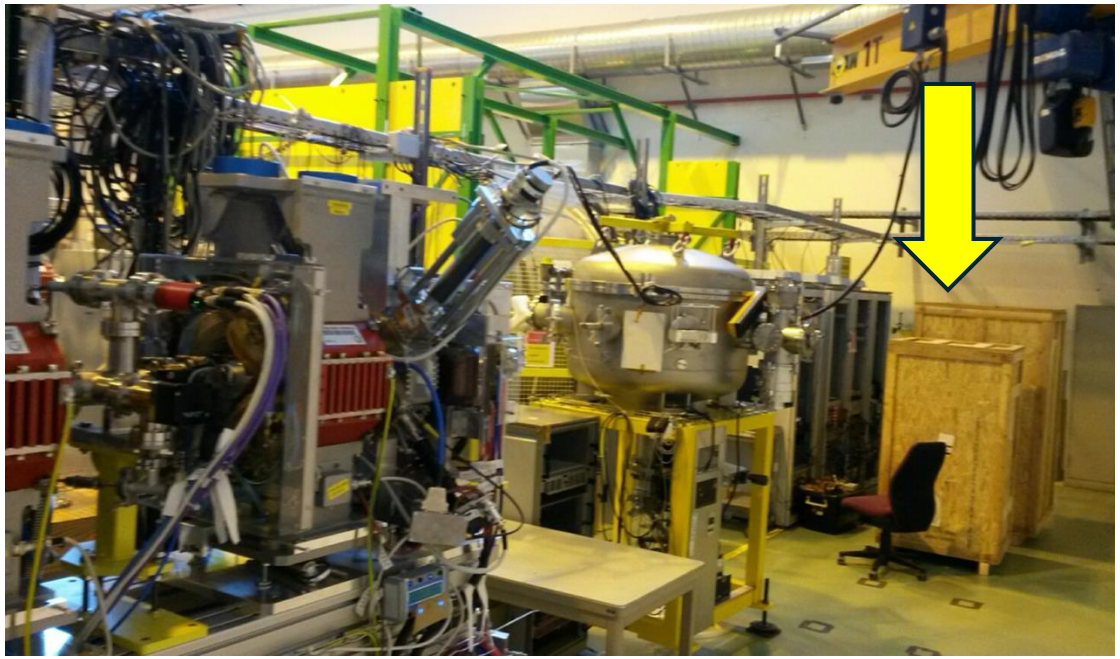
SEC reaction chamber

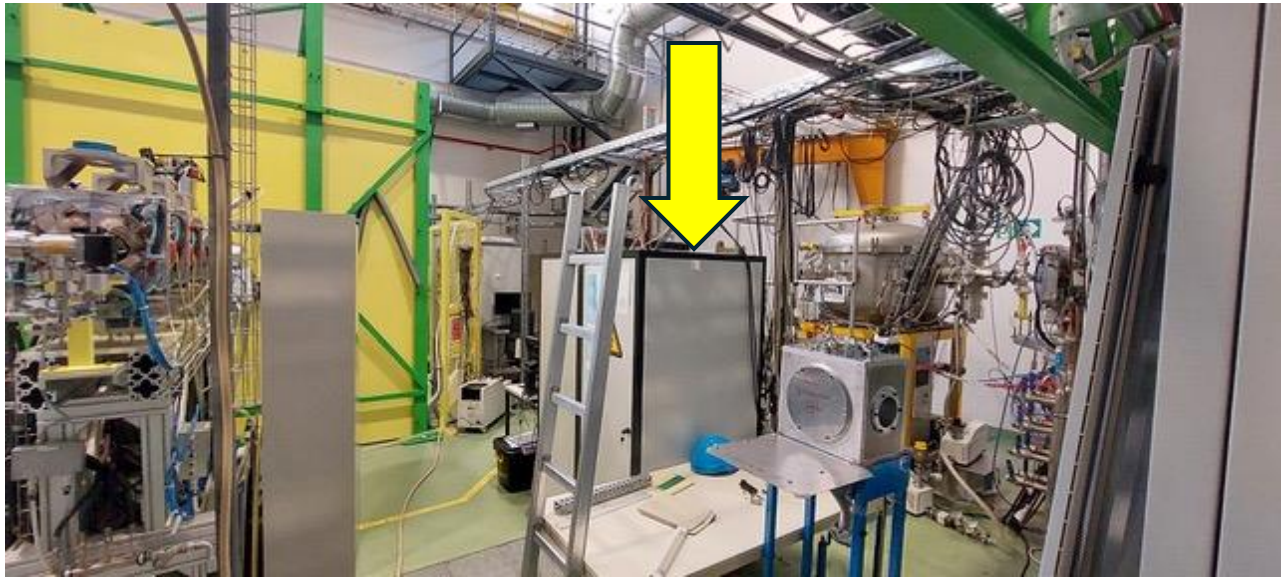


ALREADY ORDERED

Subsystem	Power	Cooling	Pressure
1. Differential pumping	2 kW	no	beam line < 10-6 mb
2: Reaction chamber	< 1 kW	no	beam line < 10-6 mb
3: Quadrupole magnet	5.2 kW	4 l/m	beam line < 10-6 mb
4: MAGDEM CCT magnet	10 kW	9 l/m	beam line < 10-6 mb
5: Quadrupole magnet	5.2 kW	4 l/m	beam line < 10-6 mb
6: Focal plane detector	2 kW	no	beam line < 10-6 mb
7. Rotary platform.	no	no	no







➢ Day-1 test reaction

$^{19}Ne + d \rightarrow {}^{20}Na + n$ (1p transfer)

	18Mg 115 kev 2p=100%	19Mg 3500 fs 2p=100%	20Mg 90.4 ms ε+β+=100% εp=29.9%	21Mg 120 ms ε+β+=100% εp=20.9% εα=0.115%	22Mg 3.87 s ε+β+=100%
	17Na p=100%	18Na 0.2 mev p=100%	19Na 40 kev p=100%	20Na 448 ms ε+β+=100% εα=19.9%	21Na 22.45 s ε+β+=100%
15Ne 0.59 mev 2p=100%	16Ne 80 kev 2p=100%	17Ne 109.1 ms ε+β+=100% εp=94.4% εα=3.51%	18Ne 1.66 s ε+β+=100%	19Ne 17.26 s ε+β+=100%	20Ne STABLE 90.48%
14F 910 kev p=100%	15F 0.38 mev p=100%	16F 23.1 kev p=100%	17F 64.368 s ε+β+=100%	18F 109.734 min ε+β+=100%	19F STABLE 100%

- **Proton rich nucleus at the drip lines**
  - ✓ Little experimental info about ^{20}Na ground state → SFs
  - ✓ Quenching factor around the drip lines
  - ✓ Role of $^{19}Ne(p,\gamma)^{20}Na$ in Explosive Stellar Phenomena
- **Good production** of $^{19}Ne > 10^6$ pps at ISOLDE → **^{19}Ne EU paradise!!**
- Cannot be done at **ISS, SEC, Decay Station**

Hot Topic

Coulomb excitation of the proton-dripline nucleus ^{20}Na

M. A. Schumaker[1], D. Cline[2], G. Hackman[3], C. J. Pearson[3], C. E. Svensson[1], C. Y. Wu[4], A. Andreyev[3], R. A. E. Austin[5], G. C. Ball[3] *et al.*

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Phys. Rev. C **80**, 044325 – **Published 22 October, 2009** | Erratum Phys. Rev. C **82**, 069902 (2010)

DOI: https://doi.org/10.1103/PhysRevC.80.044325

TRIUMF-ISAC 2010 PRC

Experimental Investigation of the $^{19}Ne(p,\gamma)^{20}Na$ Reaction Rate and Implications for Breakout from the Hot CNO Cycle

J. Belarge[1], S. A. Kuvin[1], L. T. Baby[1], J. Baker[1], I. Wiedenhöver[1], P. Höflich[1], A. Volya[1], J. C. Blackmon[2], C. M. Deibel[2] *et al.*

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Phys. Rev. Lett. **117**, 182701 – **Published 27 October, 2016**

DOI: https://doi.org/10.1103/PhysRevLett.117.182701

FSU-2016 PRL

Direct Measurement of the Key $E_{c.m.} = 456$ keV Resonance in the Astrophysical $^{19}Ne(p,\gamma)^{20}Na$ Reaction and Its Relevance for Explosive Binary Systems

R. Wilkinson[1], G. Lotay[1,2], A. Lennarz[3], C. Ruiz[3], G. Christian[4,5,6], C. Akers[3,*], W. N. Catford[1], A. A. Chen[7], D. Connolly[3] *et al.*

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Phys. Rev. Lett. **119**, 242701 – **Published 11 December, 2017**

DOI: https://doi.org/10.1103/PhysRevLett.119.242701

DRAGON-2017 PRL

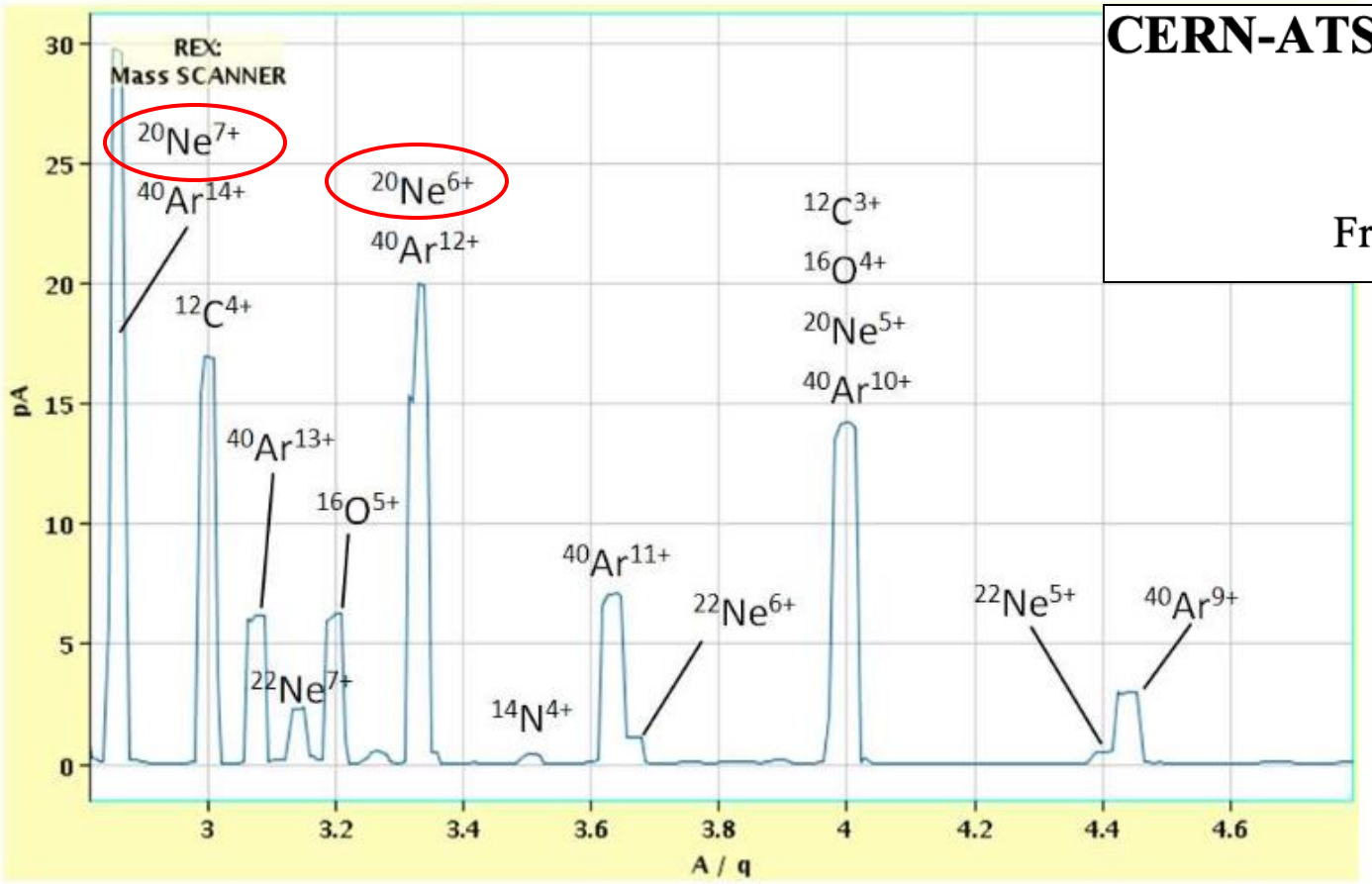
➢ ISOLDE yields

ISOLDE Yield Database

Version: 0.2.1.0 (30.11.2021 1

sotope	Half life	Driver	Yield / µC	Target
^{17} Ne	109.2 ms 6	PSB	4.00e+1	TiOx fibers
^{17} Ne	109.2 ms 6	PSB	1.00e+3	Mg Oxide
^{18} Ne	1672 ms 8	PSB	3.70e+2	U Carbide
^{18} Ne	1672 ms 8	PSB	2.30e+3	ZrO2 fibers
^{18} Ne	1672 ms 8	PSB	7.00e+3	TiOx fibers
^{18} Ne	1672 ms 8	PSB	4.20e+4	NaFLiF salt
^{18} Ne	1672 ms 8	PSB	2.00e+5	Mg Oxide
^{18} Ne	1672 ms 8	PSB	6.90e+5	CaO powder
^{19} Ne	17.22 s 2	PSB	1.50e+4	La2O3 powder
^{19} Ne	17.22 s 2	PSB	2.10e+5	TiOx fibers
^{19} Ne	17.22 s 2	PSB	9.60e+6	CaO nanostructured powder
^{19} Ne	17.22 s 2	PSB	1.20e+4	U Carbide
^{19} Ne	17.22 s 2	PSB	3.50e+6	Mg Oxide
^{19} Ne	17.22 s 2	PSB	1.40e+4	ZrO2 fibers
^{19} Ne	17.22 s 2	PSB	9.00e+3	SrO powder
^{19} Ne	17.22 s 2	PSB	2.30e+4	CeOx fibers
^{19} Ne	17.22 s 2	PSB	7.50e+6	CaO powder
^{20} Ne	stable	PSB	1.10e+6	U Carbide

➢ ISOLDE Neon charge states



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2011-10-21

Fredrik.Wenander@cern.ch

Figure 9. Extracted residual mass-spectrum from REXEBIS for optimal vacuum conditions. The Ne peaks are due to buffer-gas effusing from REXTRAP into the breeder. At the time of recording an electron beam current of 150 mA was used with a breeding time of 28 ms.

➢ DRAGON @ TRIUMF

Direct Measurement of the Key $E_{\mathrm{c.m.}} = 456$ keV Resonance in the Astrophysical $^{19}\mathrm{Ne}(p,\gamma)^{20}\mathrm{Na}$ Reaction and Its Relevance for Explosive Binary Systems

R. Wilkinson[1], G. Lotay[1,2], A. Lennarz[3], C. Ruiz[3], G. Christian[4,5,6], C. Akers[3,*], W. N. Catford[1], A. A. Chen[7], D. Connolly[3] *et al.*

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DOI: https://doi.org/10.1103/PhysRevLett.119.242701

(...) . In total, the average ^{19}Ne beam intensity was found to be $\sim 7 \times 10^6$ pps. However, it should be noted that ^{19}F was also present as an isobaric beam contaminant at a level of $\sim 2 \times 10^7$ pps. Nevertheless, reactions involving ^{19}F were easily separable from those involving ^{19}Ne in the ionization chamber.

Figure 1 shows the γ-gated MCP vs separator TOF results obtained for the incident beam energy $E_{\mathrm{beam}} = 486$ A keV. (...)

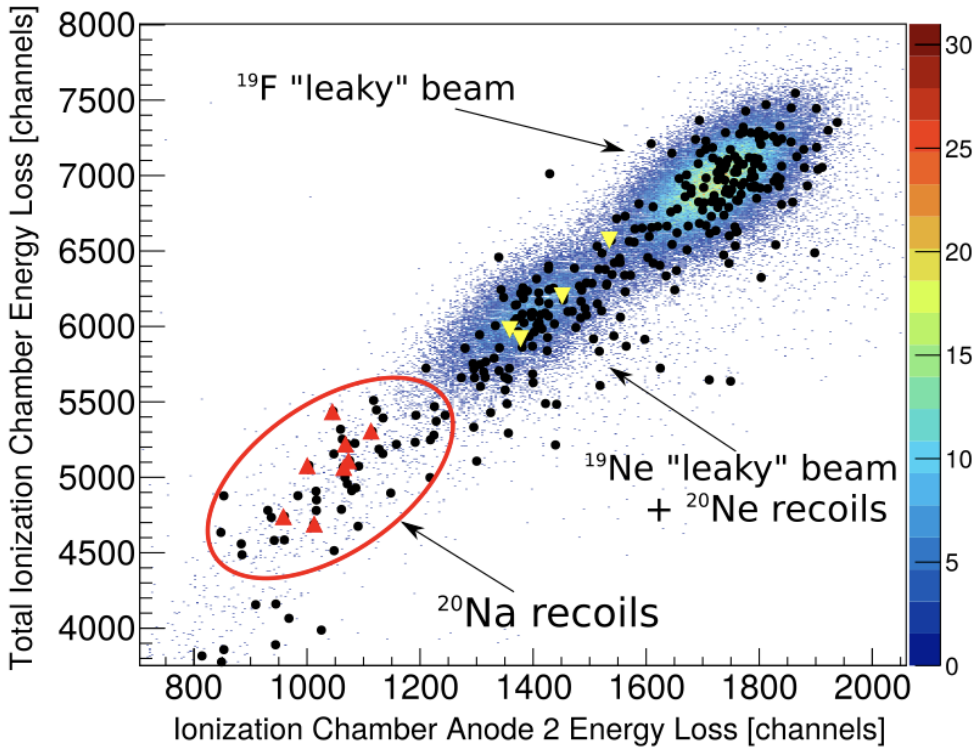


FIG. 2. Total energy loss in the ionization chamber vs energy loss in the second anode. Black dots indicate all singles events observed from all production runs. Attenuated beam runs are also included as shaded underlays, and two clear loci of F and Ne recoils are visible. Red triangles represent golden recoil-γ $^{19}\mathrm{Ne} + p$ resonance events, while the location of easily distinguishable contaminant $^{19}\mathrm{F} + p$ resonance events are highlighted by yellow triangles.

➢ Calculations and simulations for IONTB

Fatemeh Torabi, Huelva

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

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

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

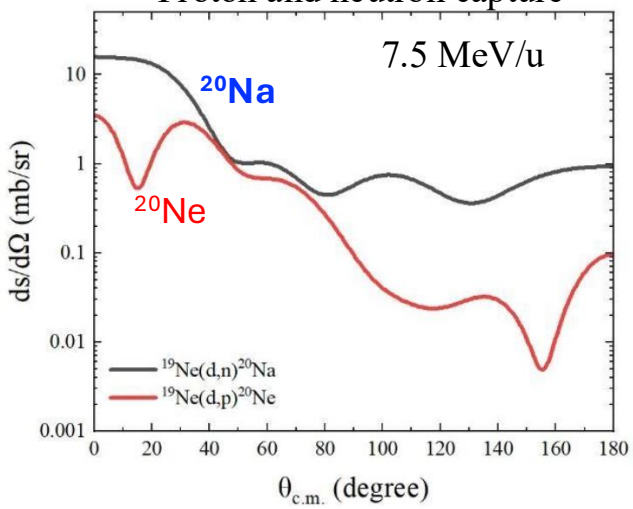
$^{19}Ne\ (beam)\ 6^+$

$^{20}Na\ 7^+$

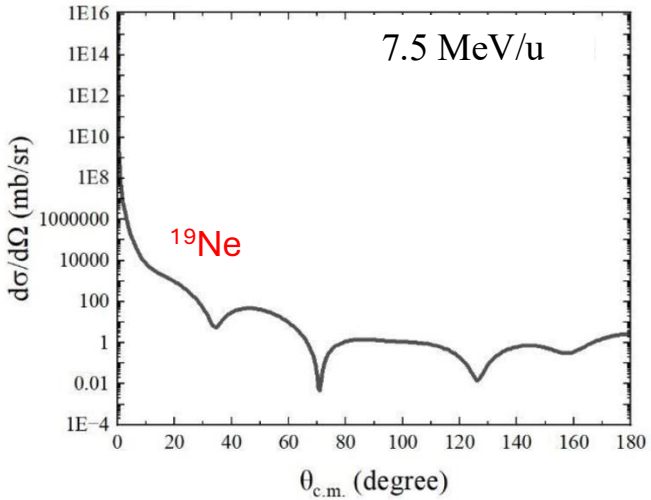
FRESCO

Ian J. Thompson, Comput. Phys. Rep. 7 (1988) 167.

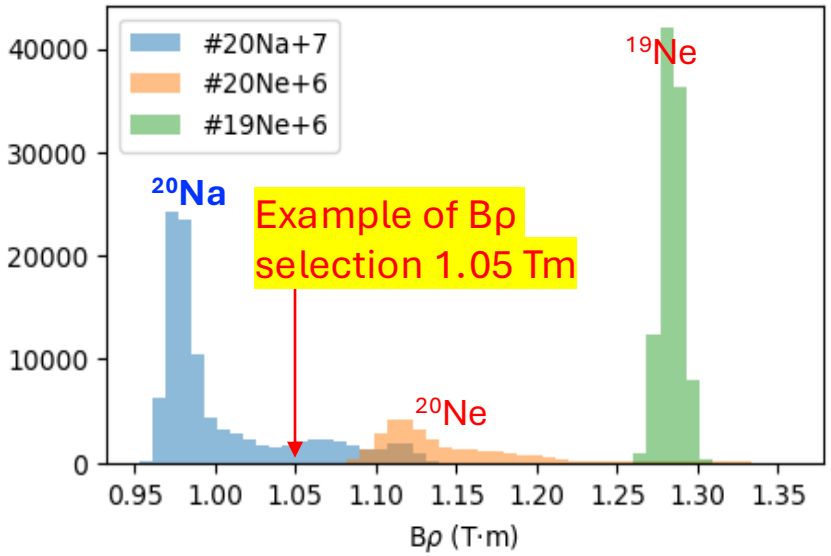
Proton and neutron capture



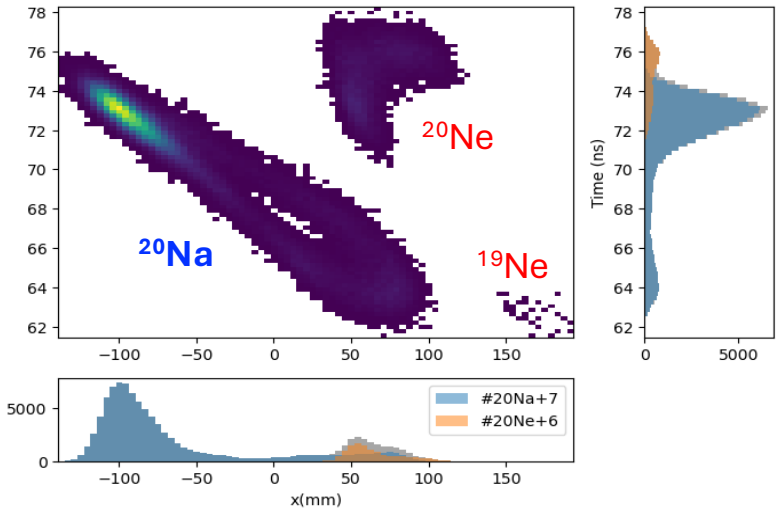
Elastic scattering



MAGDEM Bρ scan plot

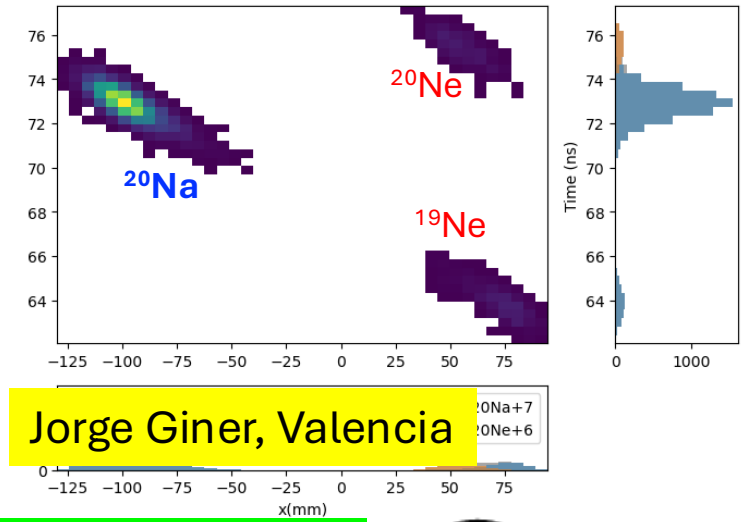


TOF (ns) – Focal Plane position (mm)



Scattering angle selection

θLab = **0** ±0.2 deg



Jorge Giner, Valencia

Final resolution will even increase!! → "DE-E" detector (DSSSD+PAD) → full simulation in progress → "ISOLDE Superconducting Linear Separator (ISLS)" **EMIS2025**

THANKS!!

ISOLDE Superconducting Recoil Separator

CERN

ISOLDE

Financiado por la Unión Europea NextGenerationEU

MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Installation and commissioning of the ISRS Ion Test-bench and Multi-Harmonic Buncher at HIE-ISOLDE

9 January 2025

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