WP12: Societal Applications

WP12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators (Rob Edgecock, HUD)

WP12.2 - Design of advanced electron accelerator plant for biohazards treatment (Andrzej Chmielewski, INCT)

WP12.3 - Design of Internal RF Ion Source for Cyclotrons (Daniel Gavela Perez, CIEMAT)

Presentation on behalf of all members of the WP

Status

- **Task 12.1: Completes in M48**
  - Report on progress
- **Task 12.2: Completed, final report in Trieste**
- **Task 12.3: Completed, final report**

Objectives

- **Task 12.1: A Strategy for Implementing Novel Societal Applications of Accelerators**
  - Study some new and important societal applications of accelerators with the aim of developing roadmaps for their innovation: novel forms of radiotherapy for cancer treatment, reduction of environmental pollution, new imaging techniques, improved methods for radioisotope production.
  - Develop a strategy to deliver these roadmaps.
  - Study the barriers which discourage the use of accelerators in industry.

12.1 Sub-Tasks

- Sub-task 1. Coordination and Communication
  (Rob Edgecock - HUD)
- Sub-task 2. Novel forms of radiotherapy
  (Angeles Faus-Golfe - CNRS)
- Sub-task 3. Environmental applications of electron beams
  (Toms Torims – RTU
  Andrzej Chmielewski - INCT)
- Sub-task 4. Accelerator imaging
  (Graeme Burt - ULANCS)
- Sub-task 5. Accelerator production of radioisotopes for imaging and therapy
  (Concepcion Oliver – CIEMAT
  Diego Obradors-Campos)
- Sub-task 6. Barriers to accelerator adoption by industry
  (Andrzej Chmielewski – INCT
  Andrea Sagatova – STU)

12.1 Deliverable and Milestones

D12.1	Strategy for Implementing Novel Societal Applications of Accelerators	HUD	R	M28	Done

MS57	Projects identification for development funding	12.1	M10	Abstract of proposals	Done
MS58	Completion of strategy documents for each application area	12.1	M40	Report	

WP12 - Societal Applications

Task 12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators

Sub-task 2. Novel forms of Radiotherapy

Angeles Faus-Golfe

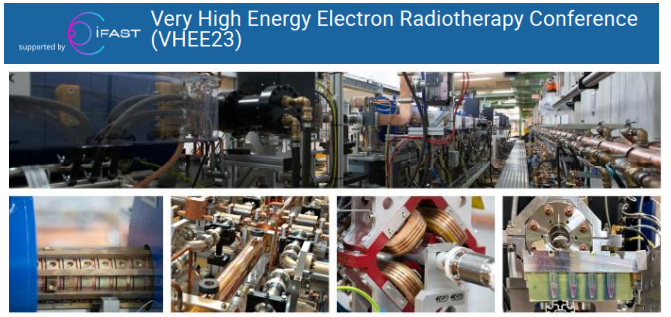
CNRS

Task 12.1
Sub-Task 2

Novel forms of Radiotherapy (CNRS)

A **follow up of VHEE2017 and VHEE2020**

- Study the **novel forms of RT** for cancer treatment with the aim of developing a roadmap for the innovation (Mini-beams with e-/p, FLASH RT, cost-effective ion RT, BNCT, combined RT, flexible machines..)
- Develop a strategy to deliver a **roadmap** (brainstorming writing meeting/workshop with identified experts, accelerator dedicated workshop…)
- Study the **barriers** which discourage the use of these **new techniques** in **industry** in collaboration with medical doctors as users



VH2023 @ DESY 11-13 July 2023

https://indico.desy.de/event/38194/

The list of topics explored:

- VHEE Current State of the Art
- Treatment Planning, Modelling and Imaging
- VHEE current conventional facilities at intermediate (Flastron IC , Antwarpen..) and high (CLEAR, CLARA, ARES, PITZ, ..) energies
- VHEE current non-conventional facilities LPA (DRACO, LOA)
- VHEE planned future facilities (DEFT, FRIDA,...)
- Accelerators R&D and Technologies: distributed coupling, cryogenic copper, millimetric waves or THz sources...
- Industries involved

Publication of a Research topic “Challenges in VHEE RT” in frontiers

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WP12 - Societal Applications

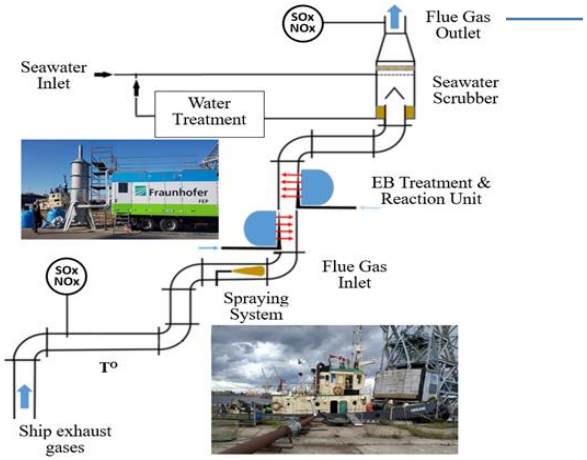
Task 12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators

Sub-task 3. Environmental Applications

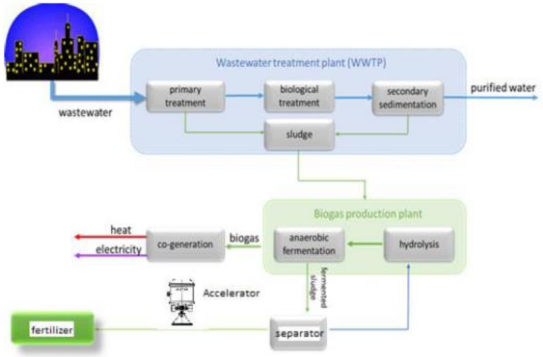
Andrzej Chmielewski (INCT) and
Toms Torims (RTU)

Environmental applications of electron accelerators

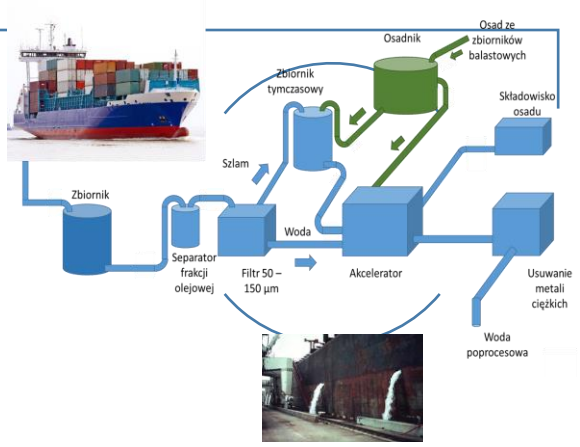
ARIES Diesel off-gas purification
TRL 5. Technology validated in relevant industrial environment



I.FAST Excess WWPT sludge hygenization
TRL 4. Technology is validated in lab



ARIES Balast water pur. & hygenization
TRL 4. Technology is validated in lab



What next with the results ?

1.Application of E-beam radiation for wastewater treatment may ensure future smart cities with sustainable water resources management.

2.Accelerators are needed for all these technologies.

Collaboration with China - „Advanced treatment for typical antibiotic pharmaceutical wastewater by electron-beam radiation (Acronim: TAPEB)" INCT - Tsinghua University (CHN), 36 months, 2024.01.04-2027.04.01; Total project cost: 1,032.746 EUR

China → **They are transformer accelerators manufacturers**

They built industrial eb wstwater treatment plant

EuroLabs - developing industrial application of electron beams of energy up to 10 MeV. – support of I.FAST – technology transfer

ID	Description	Key participants	Access Units (h)	Status(*)
1	Crosslinking of self-assambled fatty acids on copper by electron beam irradiation	Ruder Bośkovic institute, Croatia	**25**	Completed (December 2023)
	Crosslinking of self-assambled fatty acids on copper by electron beam irradiation	Ruder bośkovic institute, Croatia	**25**	Apporved (III Q 2024)
2	One-electron oxidation of S-adenosyl methionine	ICP, Univ. Paris Saclay, France	**25**	Completed (March 2023)
3	Effect of ionizing irradiation on dried fruits	National Centre of NuclearSciences and Technologies CNSTN, Tunisia	**15**	Completed (February2024)
4	One-electron oxida/on of S-adenosyl methionine	ICP, Univ. Paris Saclay, France	**15**	Completed (November 2023)
5	Irradiation engineering of biopolymer-based formulation for wound management and targeted drug delivery devices	University of Palermo, Italy	**50**	Submitted, planned May 2024
6	Bioactivity of irradiated foods by low energy e-beam	Instituto Superior Técnico, Universidade de Lisboa, Portugal	**25**	Submitted, planned June 2024
7	Influence of 10 MeV accelerated electrons on structure and properties of sheep wool fibres as a potential component for preparation of polymer-based composite materials	Institute of Chemical Physics, University of Latvia	**25**	Submitted, planned May 2024
		Total	**205**	

Other activities – BTS24 – I.FAST program support

EURO-LABS Basic Training School on Accelerators 2024 BTS24, June 18-27, 2024, to be organized at HIL and INCT, Warsaw, Poland.

Heavy Ion Laboratory with the U200-P cyclotron providing a heavy ion beam together with Institute of Nuclear Chemistry and Technology with electron accelerators invites students to BST24, which will take place in Warsaw on June 18-27, 2024. 15 - 20 students will be selected and will perform experiments with heavy ion and electron beams as well as with radioactive sources to get basic knowledge and develop skills on use of detectors, electron beam control and dosimetry.

Details will be published in February on the HIL website (https://www.slcj.uw.edu.pl/en/bts24/).

WP12 - Societal Applications

Task 12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators

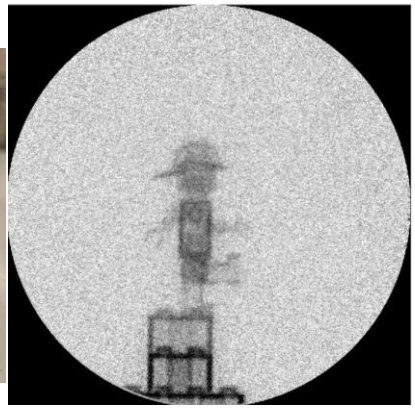
Sub-task 4. Accelerator Imaging

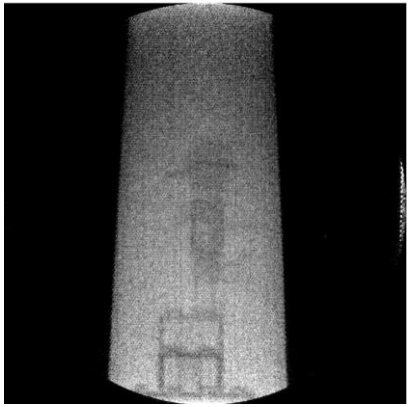
Graeme Burt

University of Lancaster

Task 12.1
Sub-Task 4

Accelerators for Imaging





- First mini-project has been completed
- **Project proposal: multi-energy fast neutron images(Dynaxion)**
  Fast neutron imaging is a growing field of interest for non-destructive testing (NDT) and security screening. Due to its high penetration capabilities and specificity for certain elements it is able to make images of items that no other imaging techniques (such as X-ray imaging) can.

This project has two main aims:

- Produce high quality fast neutron images of relevant objects to enhance the adoption of this imaging technique,
- Show that using multiple energies for the imaging of objects will provide additional information about the contents of the object, similarly as multi-energy imaging with X-rays.

Unfortunately, soon after this Dynaxion failed to find sufficient funding to build a prototype and declared bankruptcy

Top: Neutron image of the Lego man
Bottom: Neutron image of the lego man inside a steel casing

WP12 - Societal Applications

Task 12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators

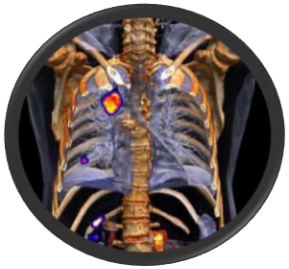
Sub-task 5. Accelerator production of radioisotopes for imaging and therapy

D. Obradors & C. Oliver

April 2023

Task12.1.5: Performed activities

- Attendance at the following seminars and meetings:
  - 2023 Isotope User meeting managed by U.S. Department of Energy Isotope Program focused in four sessions of the the following emerging alpha and beta emitters:
    - Cerium-134
    - Astatine-211
    - Lead-203/212



- Continuous market research/analysis to get a view of an important points related to the emerging radioisotopes, trends, and identify synergies with respect to the demand of these radionuclides and accelerator technology that will require innovations to reduce cost and increase the capability of production methods in an efficient manner. Important to note:

- **225Ac** stands out as a promising Targeted Alpha Therapy candidate due to its 9.9-day half-life, which makes it well-suited for antibody targeting.
- **There is a projected shortage of 225Ac supply**. Through the 229Th/225Ac generator system only a few select global research institutions have the required capacities. ORNL (USA), ITU (Germany), IPPE (Russia), no more than 70GBq per year.

Task12.1.5: Performed activities

- Several research efforts have been dedicated to exploring avenues to increase the production:

1. Moderate energy proton interactions with 226Ra (via nuclear transmutation).
2. Subjecting 226Ra to high-intensity gamma radiation (through photonuclear channels).
3. High-energy proton interactions with 232Th (via spallation).

- 226Ra targets for (1) and (2) purposes presents substantial challenges due to the scarcity of the isotope and associated safety risks, which complicate target fabrication, irradiation, and recycling. The issues of radon emanation and the emission of high-energy gamma rays from its descendants further exacerbate these challenges and is a significant disadvantage.

- (3) It does not carry excessively high radioactivity, presents fewer radiological risks, and is readily accessible as a target material. High-energy protons (60-140 MeV) have the potential to yield significant amounts of 225Ac, but **only a limited number of existing accelerators** can achieve this efficiently with the required current and energy for large-scale production.

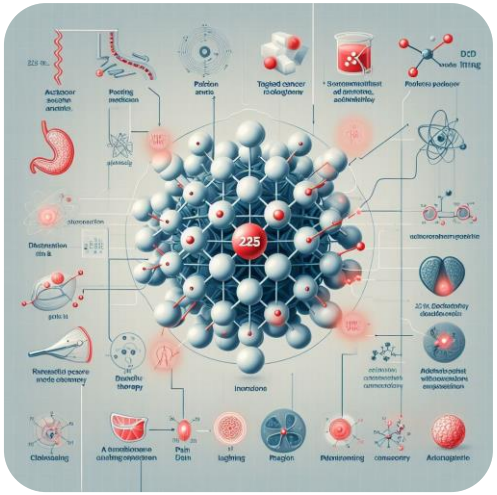
- **High-current and high energy superconducting H^+_3 cyclotron** has the potential to be a valuable tool in generating isotopes essential for medical treatments, research, and various other scientific applications.

Initial study has been done by TRIUMF Laboratory

TRIUMF

Task12.1.5: Next steps

- Continuous research/analysis of particle accelerators technology, programmes and projects related to emerging radionuclides into medical diagnostics and treatment.
- Regular monitoring and continuous analyses of the radiopharmaceutical market and needs, identifying new developments and trends.
  - 9th International Symposium on Medical Radioisotopes, April 26, 2024, Belgium
  - European Cyclotron Progress Meeting, ECPM2024



- RI users survey: To understand the isotope production needs and potential supply shortages in the next years. With this information we will gain a clearer understanding of future market demand and how the particle accelerators can better serve industrial and research entities by taloring isotope production to meet their expressed needs to define new challenges or common dificulties.

- Webinar / Workshop / (funding dependency) : ***Radiopharmaceutical market and future trends***. Several topics could be covered including development, production, and uses of diagnostic, therapeutic and theragnostic radioisotopes as well as issues related to their production.

- International cooperation is encouraged and collaborations are welcome.

WP12 - Societal Applications

Task 12.1 - A Strategy for Implementing Novel Societal Applications of Accelerators

Sub-task 6. Barriers to accelerator adoption by industry

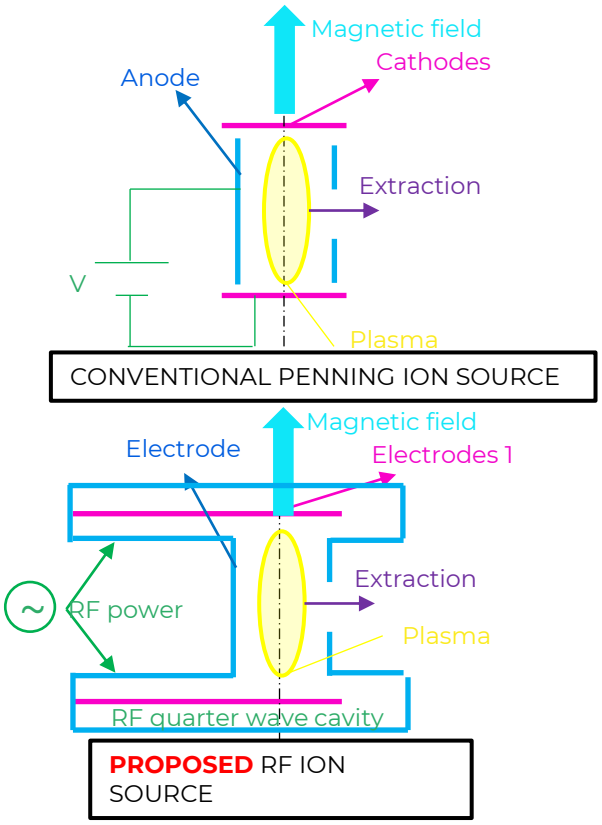
Andrzej Chmielewski (INCT) and
Andrea Sagatova (STU)

Sub-Task 6: Barriers to accelerator adoption by industry

- Ecological applications, that demand high power and great electrical efficiency, and inexpensive accelerators, are related to more complex situations. The solutions that use superconducting systems offered some optimism, but their benefits and drawbacks were not fully explored on an industrial scale. They may not achieve their predicted efficiency ratings because they require magnet cooling systems. The problem might be made better by using sources of clean energy to generate the electricity needed to power accelerators.
- No manufacturers of transformer or high energy efficiency accelerators in Europe.

Andrzej G. Chmielewski. Radiation technologies: The future is today.
Radiation Physics and Chemistry 213 (2023) 111233

IFAST Task 12.3. Internal Ion Source for Cyclotrons. Concept



A new concept of internal ion source based on RF for cyclotrons: Change DC voltage of conventional Penning ion source to a RF voltage

Expected advantages of RF ion source versus Penning:

- **Lower cathode wear** (sputtering). Less maintenance time, irradiation and cost. **Cathode** is **heated by RF currents**, no need for ions impact.
- Lower electron energies (~ 10 eV) -> **better efficiency** of producing H^-, leading to reduction of H_2 flow needed and **better vacuum** in the cyclotron.
- **No high voltage**

IFAST Task 12.3. Internal Ion Source for Cyclotrons. Concept

- Innovative concept
- Potential commercial application, mostly oriented to medical cyclotrons
- Simple concept, with relatively easy implementation on existing commercial products
- Partnership industry (General Electric, Cyclomed) – labs (Ciemat)
- I.FAST Task 12.3 objective:
  - Design & manufacture a first demonstrator prototype
  - Perform its experimental characterization (plasma production and beam extracted)

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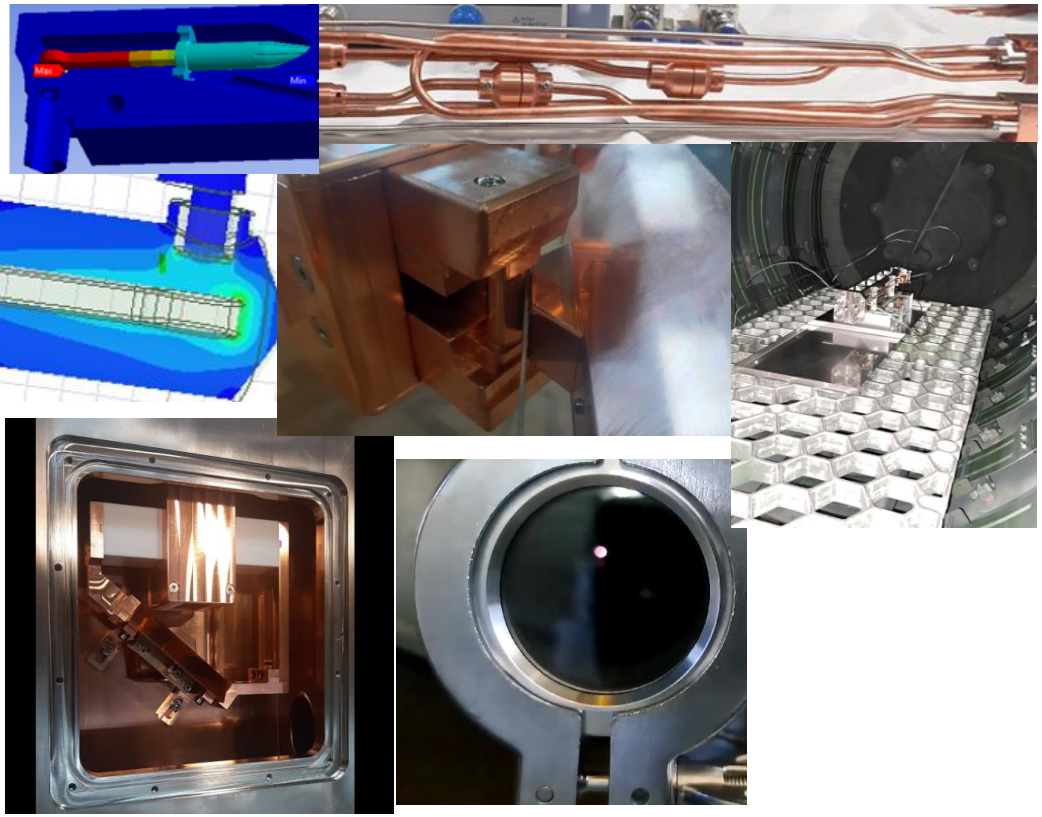
IFAST Task 12.3. Internal Ion Source for Cyclotrons. Progress



Task progress from may'2021 to nov'2023

- Definition of specifications for the ion source prototype
- Calculations and simulations to arrive at a conceptual design
- Development of a detailed mechanical design
- Welding tests
- Fabrication of all ion source components and toolings
- Bending of the cooling and hydrogen tubes for the ion source
- Brazing of the ion source
- TIG welding of the RF feedthrough
- Low power RF tests
- Development and fabrication of RF cable connections in vacuum side to correct connection problem.
- Fabrication and assembly of ion source test bench (IST)
- IST extraction cavity conditioning
- Ion source high power test on IST
- First plasma production
- Deliverable of the task (final report) submitted on nov'23

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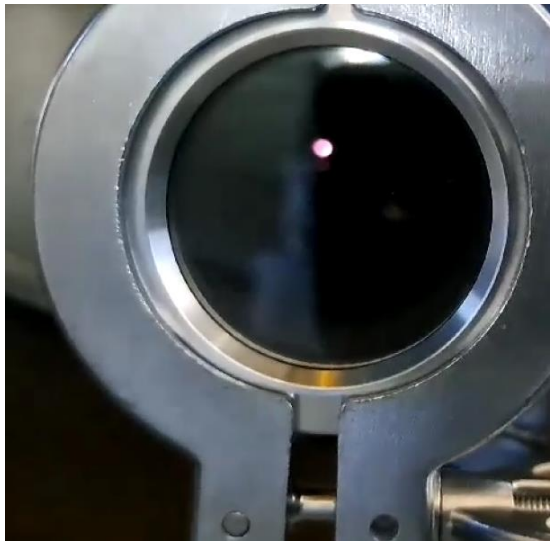
IFAST Task 12.3. Internal Ion Source for Cyclotrons. Plasma production

- An initial demonstration of plasma production was performed with copper cathodes, 0.8 Tesla dipole field
- RF power for plasma ignition: 70 W, 50% reflected power, 2 kV at each cathode
- Plasma is kept for long time, even stopping hydrogen Flow (no extraction), until RF power goes down to about 2 W, 400 V at each cathode



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IFAST Task 12.3. Internal Ion Source for Cyclotrons. Conclusions

- Task 12.3 was finished with the delivery of the final report
- Plasma ignition was demonstrated in the prototype
- Damaged connections in the ion source have been found due to overheating and not good connection. New connections have been redesigned and they are currently being fabricated
- When prototypoe is available again the plan is to perform:
  - Plasma characterization with spectroscopy análisis
  - Extracted beam analysis

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