This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

AM applications of refractory metals for ION Source

Beneficiaries:

- INFN – National Institute for Nuclear Physics (PD and LNL)
- CERN ISOLDE
- TANIOBIS GmbH

Industrial partners:

- GE UPPSALA
- SAES GETTERS S.p.A.
- EOS - Electro Optical Systems, Finland Oy
- TRIUMF

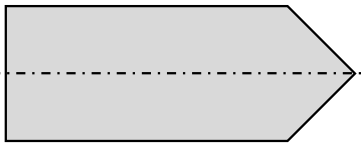
Eng. Adriano Pepato
Dirigente Tecnologo INFN

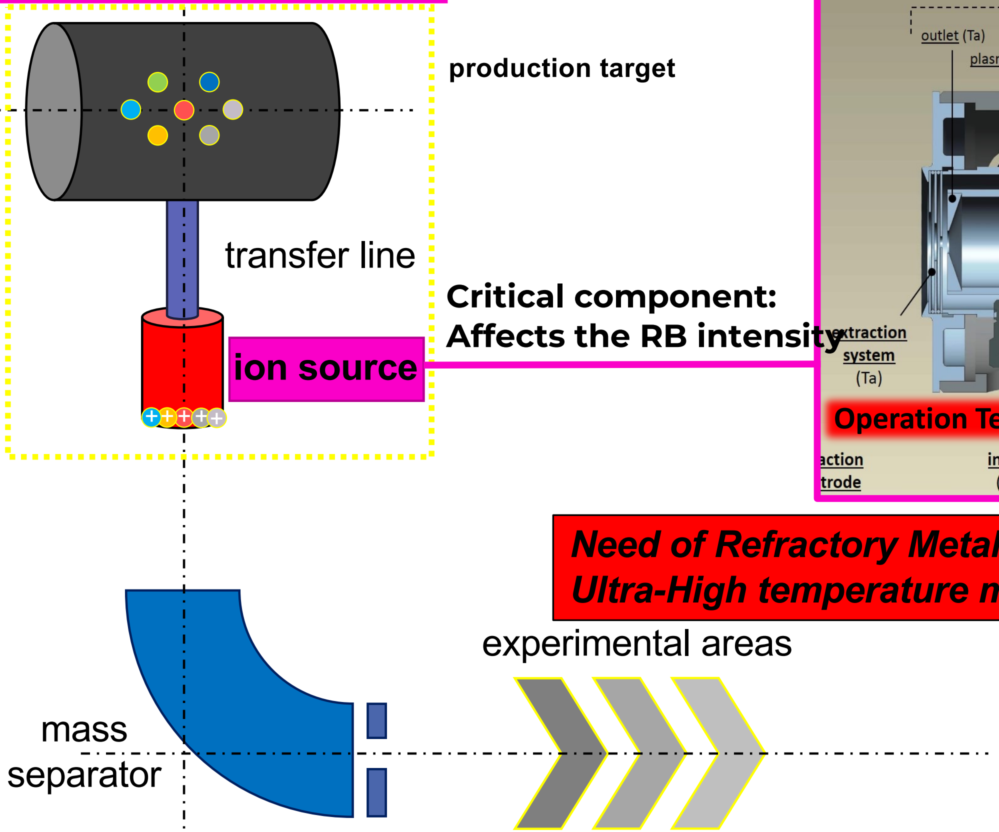
Project Evaluation, November 16th, 2022

SUMMARY

1. Introduction

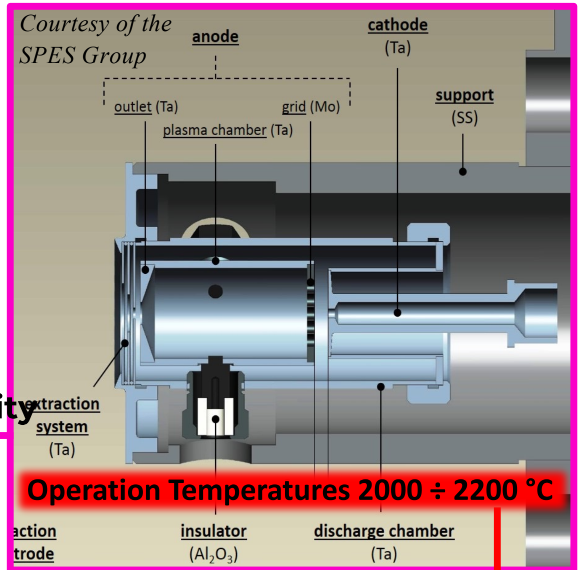
*Use of the **ISOL technique** for the production of radioactive ion beams*





Critical component:
Affects the RB intensity

Traditional FEBIAD Ion Source – SPES Project



Need of Refractory Metals
Ultra-High temperature materials

Nb 2470	Mo 2620
Ta 3000	W 3410

*Development and characterization of **AM Ref. Met.***

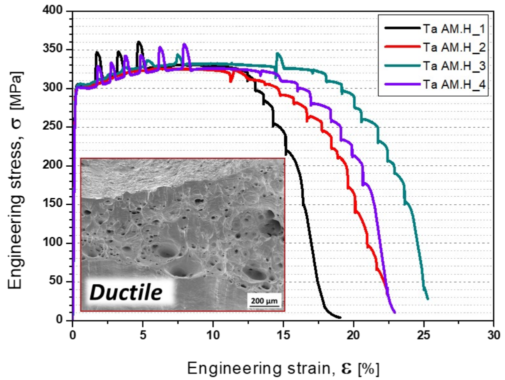
W and ***Mo*** → good for NON-STRUCTURAL components (anode)
→ susceptibility to crack when processed by LPBF

Ta and ***Nb*** → Perfect for STRUCTURAL components (cathode)
→ particularly suitable to be processed by LPBF

1b. AM Material Properties

Ta — TANiOBIS inspiring metal evolution

- High Density (> 99.8%)
- Mechanical properties higher than STD tantalum



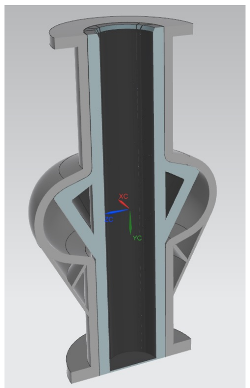
Sample	E [GPa]	σ_y [MPa]	UTS [MPa]	A [%]
Ta STD	173	155	210	> 50%
Ta AM	177	300	330	~22%

- Suitable for STRUCTURAL components (ex. Cathode)

AM Cathode - Ta

Nb — TANiOBIS inspiring metal evolution

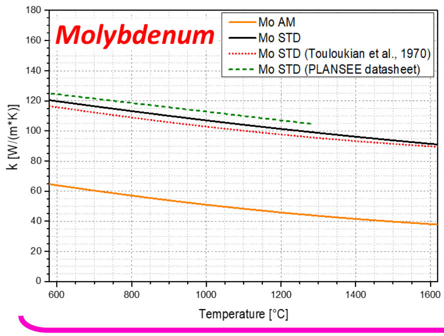
- High Density (> 99.8%)
- Extreme geometrical integrity during the production process



AM SRF 6GHz cavity - Nb

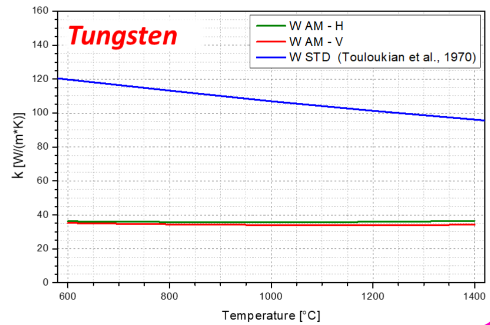
Mo

- High Density (> 99.9%)
- Thermal and mechanical properties lower than STD



W

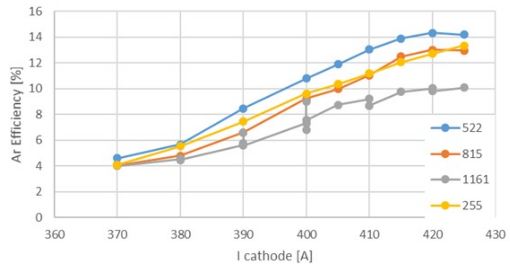
- High Density (> 99.6%)
- Thermal and mechanical properties lower than STD



- Suitable for NON-STRUCTURAL components (i.e. Anode)

AM Anode - Mo

Ionization efficiency using AM Mo Anode comparable to STD Ta Anode



2. Project Objectives

1. **Development of new Refractory Metals Alloys specifically Design for Additive Manufacturing DfAM** (LPBF process)
   → Define the best element choice in order to improve the physical performance of the ion sources (Ta-based and/or Nb-based alloys) or to solve the fabrication defects related to pure metals production (W-based and/or Mo-based alloys).

Production & Process Parameters tuning

<u>State of the Art</u>: Pure Mo and W characterization

DOI: j.addma.2021.102277 ; j.matlet.2021.130763 ; 10.1007/s00501-021-01109-y

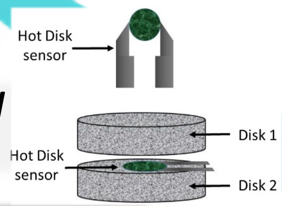
<u>Quantitative and verifiable output</u>:
Characterization of Refractory metals produced by LPBF
→ Metallurgical properties
→ Electrical & Thermal properties
→ Mechanical properties

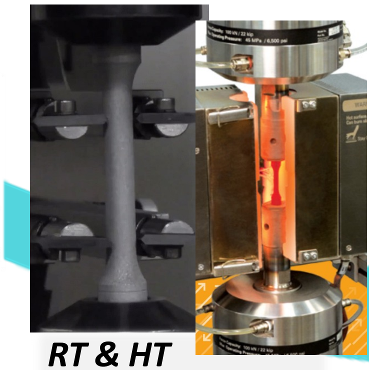
Microstructural & Surfaces morphology analyses

AM Mo Anode

AM Mo Cathode

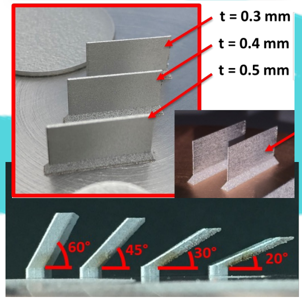
RT & HT Thermal & Electrical Characterization

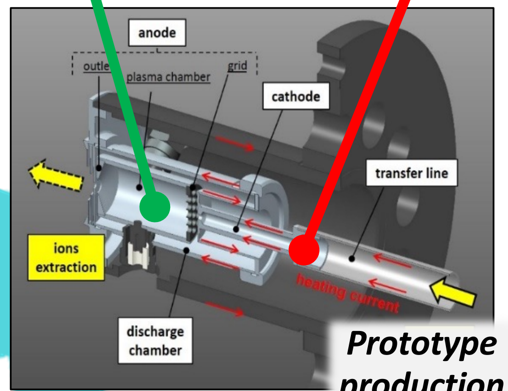




RT & HT Mechanical Characterization

Geometrical Characterization



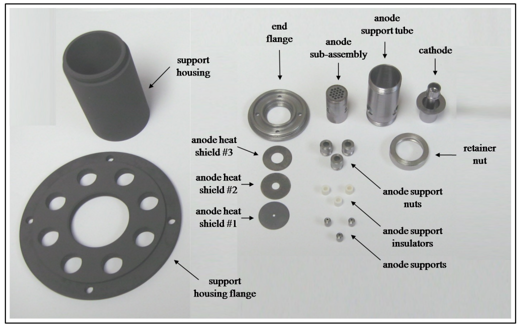


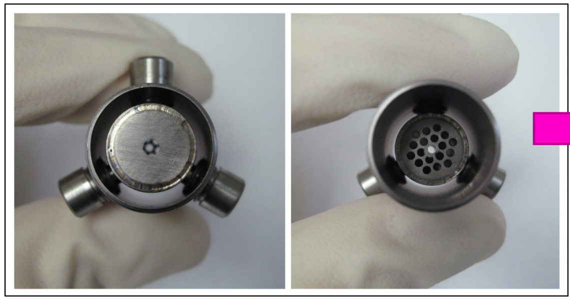
Prototype production & testing

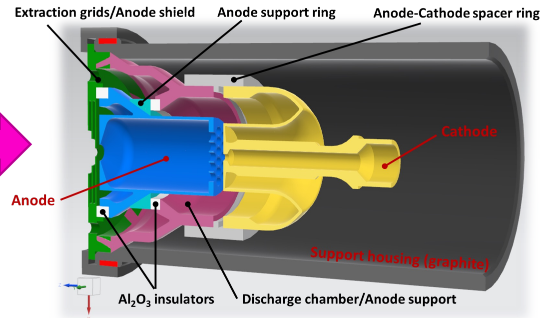
2. Project Objectives

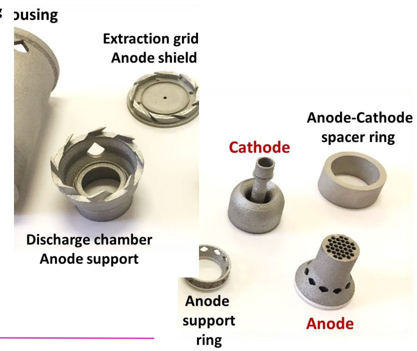
2. Development and Off-line/On-line test of a New ION source designed for Additive Manufacturing production in order to:

→ Improve the Assembly phase: components n° reduction (from n° components > 20 → to max 8 components)



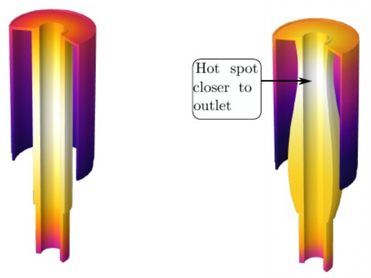




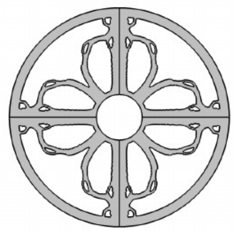


→ Develop a topological optimized design for the ION source physical performance improvement

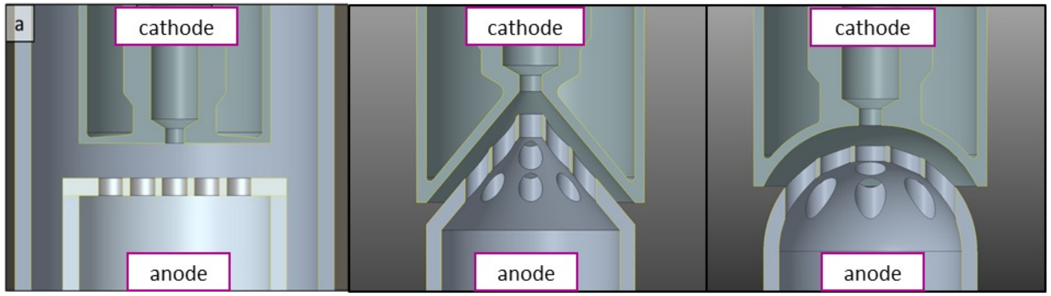
- Optimized Cathode shape
- Anode Grid generative design
- Optimized Cathode-Anode interface



(a) Nominal geometry (b) Optimized geometry



(c) Optimized geometry



***State of the Art*: Old traditional design of the FEBIAD Ion Source**
DOI: https://doi.org/10.1063/1.4933081

Quantitative and verifiable output:
AM ION Source → New DfAM Ionization efficiency estimation

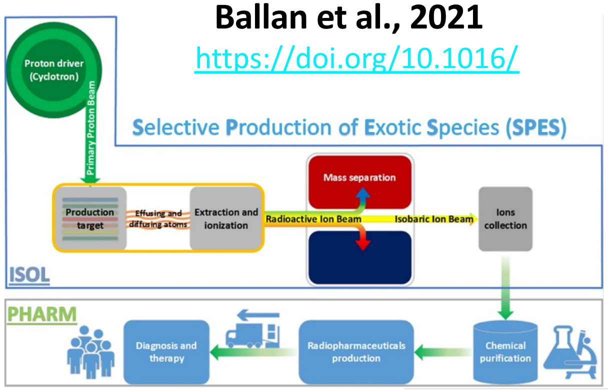
POTENTIAL APPLICATIONS of AM - ISOL Ion Sources

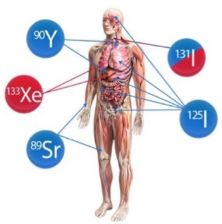
expected impact of the project in term of:
addressable and obtainable market

Palenzuela et al., 2021
https://doi.org/10.3389/fmed.2021.689281

SPES exotic beams for medicine

Ballan et al., 2021
https://doi.org/10.1016/





investigate the feasibility of using ISOL technology to produce radionuclides as radiopharmaceutical precursors.

Commercialization and Market Analysis:

The goal is to confirm the AM technology and the FEBIAD-like ion sources for the
- MEDICAL RADIO THERAPY
- RADIOACTIVE ION BEAMS

how the project addresses the
environmental challenges

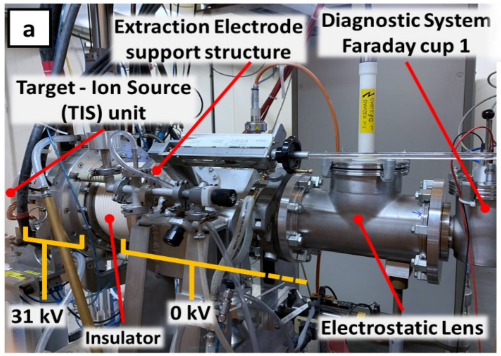
- **AM technology reduced the amount of wasted material**
- **The un-melted powder can be entirely recycled**
- **Post-processing, which involved material waste and high energy consumption, are almost completely avoided.**
- **ISOL technologies for production of medical radionuclides can become a green alternative to nuclear fission reactors.**

3. TRL status

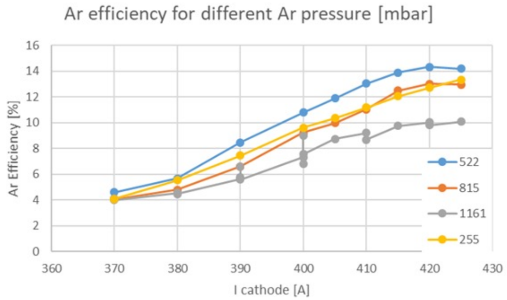
2022

The current TRL

→ TRL 4



Ionization efficiency using AM Mo Anode comparable to STD Ta Anode

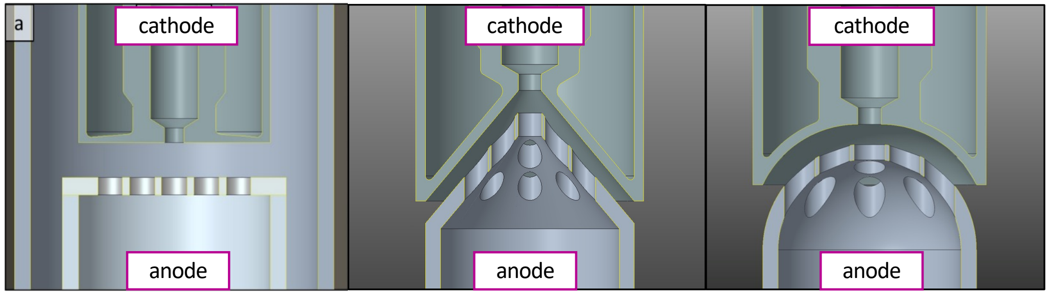


- **AM Ta Cathode and Mo Anode traditional geometry production**
- **Proof of Concept Test of the AM ION Source and Prototype production**
- **Off-line Test of the AM Mo Anode with the traditional geometry**

2025

The TRL at the end of the Project

→ TRL 5



- **Production and characterization of samples with innovative refractory metal alloys and/or composite powders.**
- **Development of a fully refractory metals Ion Source with new Design for AM for off-line / on-line tests.**
- **Radioactive ion beam production (on-line) with FEBIAD Ion Sources containing AM components at CERN and/or TRIUMF.**

Future

Estimated time for TRL 6

"Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)"

2026-2027

4. Project Organization

Organizational Expertise

Material Characterization & Product Development	Production & Supply of Refractory Metals	Product OFF-LINE and ON-LINE testing	Test on Potential application (Medical Radioisotope)	Commercialization and Market Analyses	Final component AM production
INFN DIAM Padova; INFN SPES LNL	TANiOBIS – inspiring metal evolution	INFN SPES LNL; ISOLDE; CERN; TRIUMF	ISOLPHARM – SPES exotic beams for medicine; Medicis Promed; Supporting company: GE Healthcare	saes group	eos – e-Manufacturing Solutions

WP1. Development and Characterization of Innovative Refractory Metals and their Alloys by AM Technology

WP2. Development of Additively Manufactured Ion Source Components

WP3. High Temperature Tests and Beam Production with Additively Manufactured Ion Source Components

5. Work Package and Timetable

WP1. Development and Characterization of Innovative Refractory Metals and their Alloys by AM Technology	year 1				year 2				End of IIF
	M3	M6	M9	M12	M15	M18	M21	M22	M26
T1.1. Production and characterization of Additively Manufactured Ta and/or Ta-based alloys.									
T1.2. Production and characterization of Additively Manufactured Nb and/or Nb-based alloys.									
T1.3. Identification and Development of refractory metal alloys and/or composite powders specifically designed for LPBF process.									MS.1
T1.4. Production and characterization of samples with innovative refractory metal alloys and/or composite powders.									
WP2. Development of Additively Manufactured Ion Source Components	year 1				year 2				End of IIF
	M3	M6	M9	M12	M15	M18	M21	M22	M26
T2.1. Multiphysics Simulation of Ion Sources with dedicated numerical models.									
T2.2. Redesign of specific Ion Source components for an improved assembly repeatability considering hybrid AM-traditional techniques.									MS.2
T2.3. Development of innovative Additively Manufactured free-form geometries to improve the performance of specific Ion Source components.									
T2.4. Development of a fully AM Ion Source prototype for off-line / on-line tests.									
WP3. High Temperature Tests and Beam Production with Additively Manufactured Ion Source Components	year 1				year 2				End of IIF
	M3	M6	M9	M12	M15	M18	M21	M22	M26
T3.1. High temperature tests of AM Ion Source components.									
T3.2. Thermionic emission tests of AM FEBIAD cathodes and anodes.									
T3.3. Stable ion beam production (off-line) with FEBIAD Ion Sources containing AM components at CERN and/or INFN-LNL.									MS.3
T3.4. Radioactive ion beam production (on-line) with FEBIAD Ion Sources containing AM components at CERN and/or TRIUMF.									

6. Milestone and Deliverable

WP1 milestones		Date
MS.1	Production and characterization of Additively Manufactured Ta and/or Ta-based alloys.	M26
	Production and characterization of Additively Manufactured Nb and/or Nb-based alloys.	
	Identification and development of refractory metal alloys and/or composite powders specifically designed for LPBF process.	
	Production and characterization of samples with innovative refractory metal alloys and/or composite powders.	

WP2 milestones		Date
MS.2	Development of Multiphysics numerical models for the simulation of FEBIAD Ion Sources.	M26
	Redesign of specific FEBIAD Ion Source components for an improved assembly repeatability.	
	Multiphysics Simulation of FEBIAD Ion Sources with innovative free-form geometries.	
	Production of free-form cathodes and anodes for ISOL FEBIAD Ion Sources.	
	Production of a fully AM FEBIAD Ion Source prototype.	

WP3 milestones		Date
MS.3	High temperature tests of AM Ion Source components.	M26
	Thermionic emission tests of AM FEBIAD cathodes and anodes.	
	First off-line ionization tests with a hybrid AM-traditional ion source prototype.	
	First off-line ionization tests with a fully AM ion source prototype.	
	On-line beam production at CERN-ISOLDE and/or TRIUMF with a FEBIAD Ion Source containing AM components.	

WP1, D1 (M24): Written report on the production and characterization of samples with innovative refractory metal alloys and/or composite powders.

WP2, D1 (M24): Production of a fully AM FEBIAD Ion Source prototype with related CAD documentation.

WP3, D1 (M24): Written report on test with FEBIAD Ion Sources containing AM components.

7. Budget

INFN-PD In-Kind Contributions

Item	FTE months	personnel costs (EUR)	capital costs (EUR)	type of capital cost	Sum (EUR)
AM Sample production for material characterization	3	8000	10000	Infrastructure consumables	18000
AM ion source components design	2	5000	0	None required	5000
AM ion source production	3	8000	10000	Infrastructure consumables	18000
Post-processing mechanical workshop	3	6000	4000	Infrastructure consumables	10000
Total	**11**	**17000**	**8000**		**51000**

INFN-LNL In-Kind Contributions

Item	FTE months	personnel costs (EUR)	capital costs (EUR)	type of capital cost	Sum (EUR)
Numerical Simulations	1.5	3000	0	None required	3000
Thermal-electrical characterization	1	4000	2000	Infrastructure consumables	6000
Mechanical characterization	1	4000	2000	Infrastructure consumables	6000
Offline Studies	2	6000	4000	Infrastructure consumables	10000
Total	**5.5**	**17000**	**8000**		**25000**

CERN In-Kind Contributions

Item	FTE months	personnel costs (EUR)	capital costs (EUR)	type of capital cost	Sum (EUR)
Numerical Simulations	1	10000	0	None required	10000
Offline Studies	2	20000	10000	two offline target assemblies and infrastructure consumables, computer tomography, material testing	30000
Online Studies	1	10000	10000	Online target assembly and tests	20000
Total	**4**	**40000**	**20000**		**60000**

TRIUMF In-Kind Contributions

Item	FTE months	personnel costs (EUR)	capital costs (EUR)	type of capital cost	Sum (EUR)
Numerical Simulations	2	14.800	0	None required	14.800
Offline Studies	3	22.200	17.760	two offline target assemblies and infrastructure consumables	39.960
Online Studies	3	22.200	21.830	Online target assembly, NRE	44.030
Online Material Irradiations	2	14.800	7.030	Irradiation sample holders, sample preparation consumables	21.830
Total	**10**	**74.000**	**46.620**		**120.620**

TANIOBIS In-Kind Contributions → **25000 EUR**

SAES-GETTERS In-Kind Contributions → **20000 EUR**

GE-UPPSALA In-Kind Contributions → **14700 EUR**

EOS In-Kind Contributions → **10000 EUR**

- ***TOTAL IN-KIND***: 326 k€

✓ ***THE FUNDING REQUIRED***: 100 k€

- **INFN-PD → 50 k€**
  - Personnel: 25 k€
  - Consumables: 15 k€
  - Travels: 10 k€
- **INFN-LNL → 25k€**
  - Personnel: 15 k€
  - Consumables: 4 k€
  - Travels: 6 k€
- **ISOLDE-FACILITY-CERN → 25k€**
  - Consumables: 20 k€
  - Travels: 5 k€

iFAST

Thank you for your attention!

Contact information

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This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

ISOLPHARM
SPES exotic beams for medicine

Legnaro, 28th June 2022

To Eng. Adriano Pepato
Head of DIAM workgroup – INFN Padua Division
To Eng. Mattia Manzolaro
ISOL targets and ion sources – Research Division – INFN-LNL

Dear Adriano and Mattia,

I have read the validity of the initiative made by your research groups for the I.FAST innovation fund proposal (https://ifast-project.eu/ifast-innovation-fund) in the context of the I.FAST project (https://ifast-project.eu/home).

Considering that the development of FEBIAD-like ion sources via Additive Manufacturing (AM) technology will have a strong influence on the ionization performance and consequently also on the future outlook of radioactive ion beams production for medical applications, we strongly encourage the research project activities proposed by your research groups and we are interested in participating to it.

Sincerely,

On behalf of INFN LNL – ISOLPHARM project

35020 Legnaro (PD) – Viale dell'Università, 2 – Tel. 049/80.68318 – Telefax 049/641925
Alberto.Andrighetto@lnl.infn.it
Codice Fiscale 84001850589

TRIUMF

University of Alberta
University of British Columbia
University of Calgary
Carleton University
University of Guelph
University of Manitoba
McGill University
McMaster University
Université de Montréal
University of Northern British Columbia
Queen's University
University of Regina
Saint Mary's University
Université de Sherbrooke
Simon Fraser University
University of Toronto
University of Victoria
Western University
University of Winnipeg
York University

July 1, 2022

To: Mattia Manzolaro and Adriano Pepato, Istituto Nazionale di Fisica Nucleare

RE: Expression of interest to participate in the I.FAST Innovation Fund project on additively manufactured ion sources for radioactive ion beams

This letter is to express TRIUMF's interest in the participation in the I.FAST Innovation Fund project initiative on additively manufactured (AM) radioactive ion beam ion source components, led by Adriano Pepato and Mattia Manzolaro, INFN, Legnaro.

TRIUMF is Canada's National Accelerator Centre, specialized in building particle accelerator infrastructure that enables cutting-edge multidisciplinary research. TRIUMF's flagship program is the delivery of radioisotope beams (RIB) to a wide range of research and applications. We are currently investing into an expansion of our RIB complex. Responding to a substantial oversubscription of experimental beam time, the ARIEL facility will allow to deliver three RIBs simultaneously to existing state of the art experimental end stations. However, even after decades of research and development, the dominating limitation of all international radioisotope beam programs is the low achievable instantaneous beam intensity. For thick target facilities, this is caused by low efficiencies of extraction and ionization of these exotic radioisotopes.
The proposed project has the potential to revolutionize the manufacturing process of RIB ion sources and to pave the way towards significant improvements of RIB intensity which will enable new scientific programs. Recent studies have shown, that more efficient and more reliable ion sources are in reach when more complex ion source geometries become available.
TRIUMF is conducting continuous research and development on new target and ion source designs, including the use of AM technology. Recently, the TRIUMF water-cooled hermetic target vessel has been replaced by an AM aluminum body, which enables greater performance at reduced manufacturing price. Also, composite target converter materials have been prototyped and studied under irradiation. These copper-tungsten, aluminum-tantalum, copper-beryllium layer composites are promising candidates that combine the design flexibility of AM with proven nuclear materials to enable unprecedented performance.

TRIUMF is excited to contribute to this I.FAST Innovation Fund project and will make design, prototyping, irradiation, numerical simulation and financial resources available to support the proposed activities.

Best regards,

Dr. Alexander Gottberg
Department Head, Targets and Ion Sources

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Ing. Pepato Adriano
Via Marzolo
8 - 35131 - Padova Italy

Paula Kainu
+358 40 75 14516
paula.kainu@eos.info
November 1, 2022

Expression of interest to participate in the I.FAST Innovation Fund project on additively manufactured ion sources for radioactive ion beams

Dear Ing. Pepato, Dear Ing. Manzolaro,

This letter is to express EOS' interest in the participation in the I.FAST Innovation Fund project initiative on additively manufactured (AM) radioactive ion beam ion source components, led by Adriano Pepato and Mattia Manzolaro, INFN, Legnaro.

EOS is leading supplier for responsible manufacturing solutions via industrial 3D printing technology. EOS GmbH was founded in 1989 and the company is a pioneer and innovator for comprehensive customer solutions in Additive Manufacturing. EOS' solution product portfolio of systems, materials and process parameters gives customers crucial competitive advantages in terms of product quality and the long-term economic sustainability of their manufacturing processes. EOS has over 30 years of experience in developing materials and processes for Additive Manufacturing and has brought tens of industrial AM solutions to the market. These solutions range across industries, from aerospace to automotive and from medical to turbomachinery.

One of the most successful AM solutions has been the development of tungsten for anti-scatter grids to improve CT image quality. During this development, EOS has generated extensive knowledge about processing of refractory materials (tungsten as well as molybdenum) in laser powder bed fusion. As fully dense microstructure is very hard to achieve, it is critical to define the exact requirement levels and tailor the development according to them. This way the utilization of AM refractory materials in further applications can be achieved and EOS is committed in supporting this development.

EOS is very excited about this project as it sees potential in this application area, to greatly enhance the performance of ion sources. EOS will support the project by consulting the development plans when & where needed, by updating the project on the relevant developments ongoing on EOS' side, and by building refractory material parts where possible.

With best regards
EOS GmbH
Electro Optical Systems

Paula Kainu
Business Development Manager

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IBAN: DE02 7016 0000 0020 1396 08 $
Management Dr. Florian Mes
Marie Niehaus-Langer
Nikolai Zaepernick
Company reg. in Munich HRB 87386
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GE Healthcare – MICT Cyclotron

Tomas Eriksson
GE Healthcare
Chief Cyclotron Engineer
Phone: +46 72 5103226
GEMS PET Systems AB
Box 15024
S-750 15 Uppsala
Sweden

To:
Eng. Adriano Pepato
Head of DIAM workgroup – INFN Padua Division
To Eng. Mattia Manzolaro
ISOL targets and ion sources – Research Division – INFNLNL

RE: Expression of interest to participate in the I.FAST Innovation Fund project on additively manufactured ion sources for producing ion beams

Dear Ing. Pepato, Dear Ing. Manzolaro

For General Electric (GE) the accelerator business is a most important part of our Healthcare division. In this case it is especially interesting in the scope of GE's Cyclotrons used for producing PET (Positron Emission Tomography) radioisotopes used for PET scanner diagnosing of e.g. cancer tumors.

GE Healthcare in Uppsala, Sweden, produces two types of cyclotrons for this purpose, PETtrace with 16.5 MeV proton and 8.4 MeV deuteron capability and MINItrace with 9.6 MeV protons.

For the medical PET radioisotope producing cyclotrons, it is most important to have a well-functioning, reliable as maintenance free as possible ion source. This is needed to reliably deliver the PET radioisotopes to the waiting patients. Reduced maintenance is also very important in order to reduce the radiation dose to maintenance personnel.

GE does from earlier experience believe that additive manufacturing techniques can provide great advantages in terms of freedom to mechanically design parts and to introduce new materials. For this reason GE has a great interest to participate in the I.FAST project (https://ifast-project.eu/home) as we see it as a stimulating and challenging opportunity to explore the manufacturability of key components and systems using alternative and innovative approaches.

Sincerely

Tomas Eriksson
GE Healthcare
Chief Cyclotron Engineer

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saes
SAES Getters S.p.A.

July 11th 2022

To Eng. Adriano Pepato
Head of DIAM workgroup – INFN Padua Division
To Eng. Mattia Manzolaro
ISOL targets and ion sources – Research Division – INFN-LNL

RE : Expression of interest to participate in the I.FAST Innovation Fund project on additively manufactured ion sources for radioactive ion beams

Dear Ing. Pepato, Dear Ing. Manzolaro

The scientific and technological accelerator community is one of the key area where SAES getters has been traditionally involved since decades. SAES provides high and ultra high vacuum pumps based on getter technology and integrated solutions for accelerators including Non Evaporable Getter coated vacuum chambers, complex components and scientific instrumentation for beam lines and accelerators. Through the recent acquisition of SAES RIAL Vacuum and Strumenti Scientifici Cinel SAES has further increased its focus on providing vacuum solutions based on advanced materials, innovative manufacturing techniques and novel designs.
We are therefore very interested in your initiative (https://ifast-project.eu/ifast-innovation-fund) in the context of the I.FAST project (https://ifast-project.eu/home) as we see it as a stimulating and challenging opportunity to explore the manufacturability of key components and systems using alternative and innovative approaches.

Due to this, SAES is very interested in participating to the activity proposed by your Group. As a manufacturing company with a strong focus on innovation, we can deploy R&D and engineering resources as well as competences in material science and vacuum technology. SAES can also leverage on its international commercial network to gather marketing and application information to more effectively capture the accelerator community needs.

Sincerely

Paolo Manini
Head of High Vacuum Division
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Mob. : +39 335 7375507
SAES Getters S.p.A.
Viale Italia, 77
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Extra. Personnel

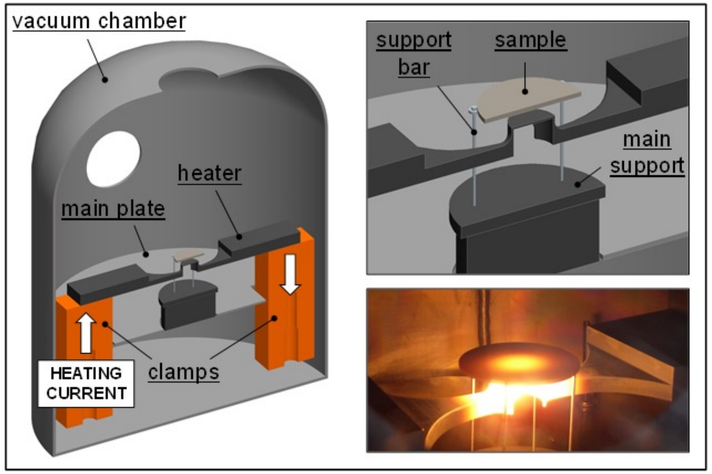
INFN - PD			
Name	**Expertise – Activity in the project**	**WP**	**FTE months**
Adriano Pepato	Project coordinator, DIAM technical coordinator	1,2,3	1
Matteo Turcato		1,2,3	2
Marco Romanato		1,2,3	2
Daniele Mazzaro		1,2,3	3

INFN - LNL			
Name	**Expertise – Activity in the project**	**WP**	**FTE months**
Mattia Manzolaro	FEBIAD-like Ion Source development, SPES ISOL machine management,	1,2,3	0.5
Michele Ballan	FEBIAD-like Ion Source development, thermal and electrical characterization, offline ion source studies	1,2,3	2
Lisa Centofante	FEBIAD-like Ion Source development, mechanical characterization, offline ion source studies	1,2,3	2
Alberto Monetti	FEBIAD-like Ion Source development, mechanical characterization, offline ion source studies	1,2,3	1

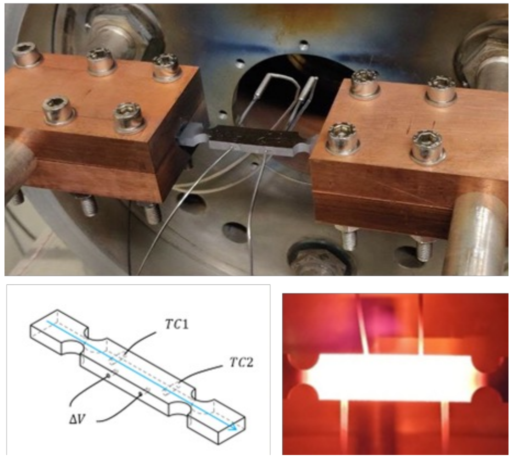
TRIUMF			
Name	**Expertise – Activity in the project**	**WP**	**FTE months**
Alexander Gottberg	Radioactive beam ion beam production, radiation damage in materials, TRIUMF coordinator	2,3	2
Thomas Day Goodacre	Radioactive beam ion sources, coordinator of offline ion source studies	2,3	3
Carla Babcock	Online radioactive beam ion beam production, coordinator of online ion source studies	2,3	1
Ferran Boix Pamies	Material irradiation studies, microstructure, mechanical properties, coordinator of irradiation studies	2,3	3
Fernando Maldonado	Numerical simulations (thermal, mechanical, electromechanical, electron and ion beam tracking)	2,3	2

INFN-LNL Contributions

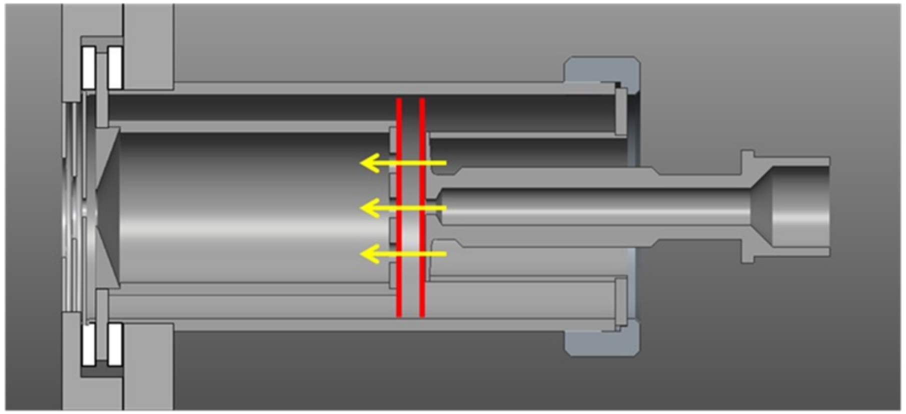
emissivity and **thermal conductivity** measurements



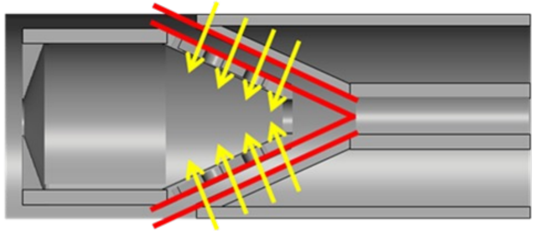
electrical resistivity measurements



planar interface and electron beam in the axial direction (STANDARD)

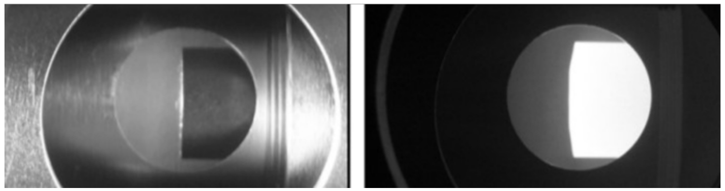


conical/spherical/free-form interface to improve the electron flux (AM)

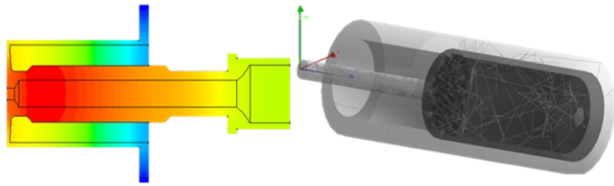


- bigger surface at high temperature for electron emission
- magnetic field not required
- simplified vacuum chamber design
- …

thermionic emission measurements



multiphysics simulations



TRIUMF Contributions

TRIUMF is Canada's Particle Accelerator Centre and is operating FEBIAD-type ion sources to produce radioactive isotope beams for fundamental research, as well as for medical and material applications. Summary of recent FEBIAD studies at TRIUMF: http://hdl.handle.net/1828/14082

Contributions to this project are in-kind and aligned with available expertise and priorities at TRIUMF

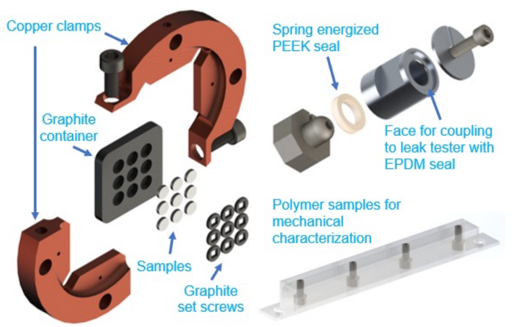
1. Support development of new ion source geometries through numerical **FEA and multi-physics simulations** to assess the temperature profile, the electron beam density, the electric field distribution inside of the anode and finally the ionization efficiency and ion beam emittance. This will result in qualifying a set of geometries for experimental studies.
2. Full ion sources of selected geometries will be manufactured by through this collaboration and integrated into dedicated TRIUMF radioisotope beam production target assemblies. These assemblies are used for **offline studies assessing the performance of the ion source** to ionize stable ion beam with high efficiency and reliability to validate the manufacturing processes, as well as the performance improvements predicted from the newly available complex geometries.
3. To qualify the AM methodology for this application, **material irradiation damage studies** will be conducted using an existing 500 MeV irradiation station. Different refractory AM materials will be qualified for high-energy and high-power particle irradiation by assessing their mechanical properties before, during and after irradiation.
4. After offline validation, a selected geometry will be integrated into an **online TRIUMF radioisotope production** target and submitted to 500 MeV proton beam. These online studies will act as TRL5 for the production of radioactive isotope beams using tailor-made AM ion source.

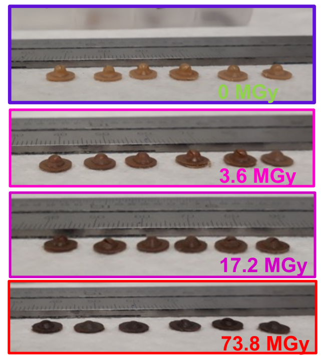
1. In-beam parasitic targets:

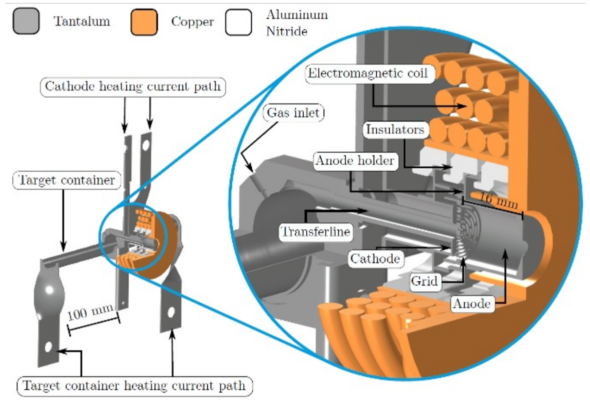
- 0.1-1 DPA/ISOL target (accumulative up to 5DPA/year)

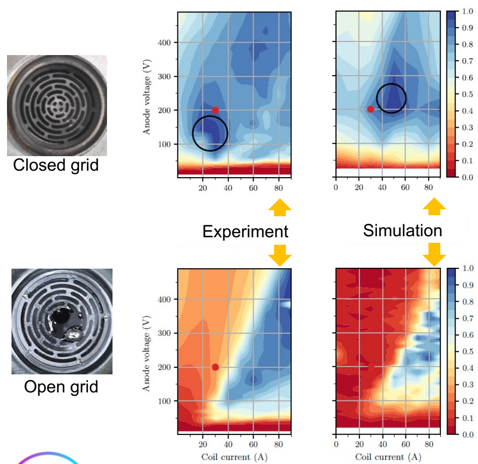
2.Scattered beam parasitic assemblies:

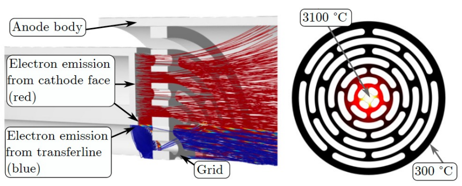
- 1-200 MGy/ISOL target



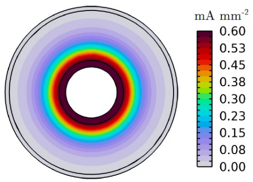






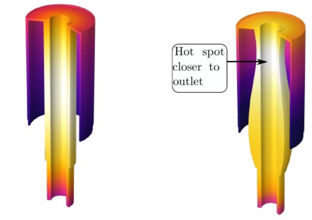


(a) Electron tracking and grid temperature

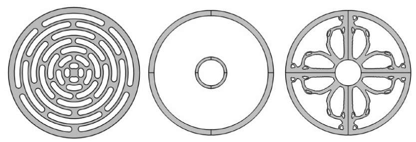


(b) Electron current density at the cathode

Cathode shape-optimization



(a) Nominal geometry (b) Optimized geometry



(a) Nominal geometry (b) Initial geometry (c) Optimized geometry

Grid generative-design-optimization

iFAST

SAES Getters contribution

saes

making innovation happen, together

- SAES getters is an Italian company with a strong focus on accelerator community to which it supplies NEG pumps since the 70s and more recently vacuum chambers, components and scientific instrumentation for synchrotron beamlines through SAES RIAL Vacuum and Cinel (both 100% part of the SAES Group).
- SAES is relatively new to AM but keen to explore the opportunities of this technology for accelerator components like the ion sources with improved efficiency and design.
- SAES will dedicate marketing and commercial resources to map the existing facilities, evaluate the applicability and advantages of the FEBIAD design, quantity the potential needs and the technical requirements. This should provide a clear perspective about the potential market, the requirements and also a viable route to the technology diffusion.
- SAES will also take care of exploring the IP matter through its internal IP office.
- As a manufacturing company, SAES is also potentially interested in manufacturing and selling the ion sources themselves. We will explore this opportunity in the course of the project.
- The project leader for SAES is Dr. Michele Mura, Head of the Divisional Development Lab. One senior technician and a sales/marketing expert will support the technical and market scouting activity, respectively.
- A total of 4 months (2 people for 2 months) over the span of the project will be deployed. The estimated cost is 20KEuro which will be fully absorbed by SAES as in kind contribution to the project.

The possible contribution requested to EOS:

- Production of samples for material properties evaluation (ex. Cubes for density measurement, samples for mechanical static test, cylinder of 40mm diameter and 20mm high for thermal properties) using one of the selected refractory metals alloy Mo-based (ex. TZM) as well as optionally Nb and/or Ta
- Production of non-structural components prototype of the ION Source (ex. Anode – about 30 mm high and 15 mm diameter) using one of the selected refractory metals alloy Mo or W-based aforementioned.

Requirements:

- Use of a LPBF machine that
  - allows the platform to be heated up to 450°C and/or 800°C
  - allows the application of a controlled cool down (ex. at a rate of 100 °C per hour).

Reference: the machine that EOS has supplied to PLANSEE (see the link of the paper below).

State of the Art: https://doi.org/10.1016/j.ijrmhm.2020.105369

What is provided to EOS:

- The powders, which will be purchased using the budget provided by the project (pre-processing step)
- The material characterization using the sample produced by EOS (post-processing step) as well as in-application (ion source) performance data
- Contribution/support for process parameters tuning based on INFN DIAM experience with pure refractory metals production and characterization.

In-kind contribution:

EOS will contribute by producing samples as described in this document

In-kind contribution elements:
- Engineering resources
- Machine operation resources
- Machine time (up to 5 jobs per system type)

- Total in-kind contribution: 8 000 – 10 000 €

•At EOS Finland, we only have a system that can go up to 450C. We have within our ecosystem another system that can go up to 800C,
•I need to check about the control on the cooldown, how this is managed
•We would potentially be interested in supporting the project in the Niobium efforts as well – if agreeable to the project, I'll discuss with our R&D
•In this project, besides the characterization data we would like to receive also detailed application performance data (I assume this is already part of the frame work?): FINE
•The in-kind contribution is 8-10k€ because of the uncertainty on the 800C trials and bringing in of Nb, as well as the amount of work finally involved for process settings finding for the higher temperatures

In-kind contribution: TANIOBIS

Markus Weinmann wrote:
we decided to provide you up to 50 kg of Ta or Nb and will support your project with a discount for the powder purchase and personnel efforts in the range of 25.000 €.