M.Losasso (CERN)

F.Carra (CERN), L.Notari (La Sapienza), M.Pasquali (L Sapienza), M.Tomut (GSI)

I.FAST Period 1 Review, 07.02.2023

WP4 - *Promoting Innovation -* objectives

- WP4 promotes innovation by structuring and implementing an internal funding (IIF) for financing cutting-edge innovations explored within I-FAST.

- The IIF is a competitive call for innovation-oriented projects in collaboration with industry. Performed starting from Y2 of the I.FAST. Its allocated budget allows supporting *5 - 10 projects.* WP4 shall manage the fund and monitor the advancement of the funded projects assessing results and properly allocation of resources according to established workplans.

- WP4 fosters collaboration within I.FAST and with other EC communities

- WP4 is engaged in collaborative R&D projects with industries:

  GRAPH&BEAMWIN: a project to develop beam windows for next generation of accelerators, and

  Innovative material industrial developments: a project to identify and manufacture sample of materials with extensive thermophysical characterization

WP4 - Summary of activities in P1

WP4 task 4.1 and 4.2- *CERN,CNRS,HUD,INFN* -has:

- defined the Internal Innovation Fund (IIF), its participation rules, timeline, evaluation procedure and committee, and has advertised and launched the Call for Proposal (CfP)
- started the selection among the 18 submitted projects

→ *These activities are objects of coming D4.1 (submitted) and D4.2 (in editing, will be submitted end of Feb. : 2M in advance)*

WP4 task 4.3 - CER*N, GSI,WWM, RHP, UDS-* has:

- Developed a study to identifying materials able to be used for beam windows in different accelerator applications.
- Irradiation tests have been carried out in GSI for selected beam windows samples materials

→ *These activities are objects of MS13*

WP4 task 4.4 – *CERN, NNK,RHP-* has:

- Defined the technical specification for new Carbon Composite Materials. Produced material samples
- Five plates of Molybdenum- Graphite and Chromium-Graphite materials produced and characterized.

→ *These activities are objects of MS14*

iFAST

WP4 - structure in 4 Tasks, 4 Deliverables - 4 Milestones

Partner number and short name	Task Leader
1 - CERN	
3 - RHP industry	M.Losasso
7 - CNRS	M.Losasso
14 - GSI	
20 - WWU	M.Tomut, M.Losasso
25 - INFN	
38 - NNK industry	F.Carra
44 - HUD	

UDS (Universita' della Sapienza)
added as collaborating institute after I.FAST start

Industries are partners of I.FAST directly working in Work Plan implementation

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	Evaluation criteria for IIF projects, and Evaluation Body	1 - CERN	Report (submitted)	Public	20
D4.2	IIF Projects awarding	1 - CERN	Report (in editing)	Public	24
D4.3	Beam-windows prototypes	1 - CERN	Demonstrator	Public	32
D4.4	Production of large-size CCM plates	1 - CERN	Demonstrator	Public	24

Schedule of relevant Milestones

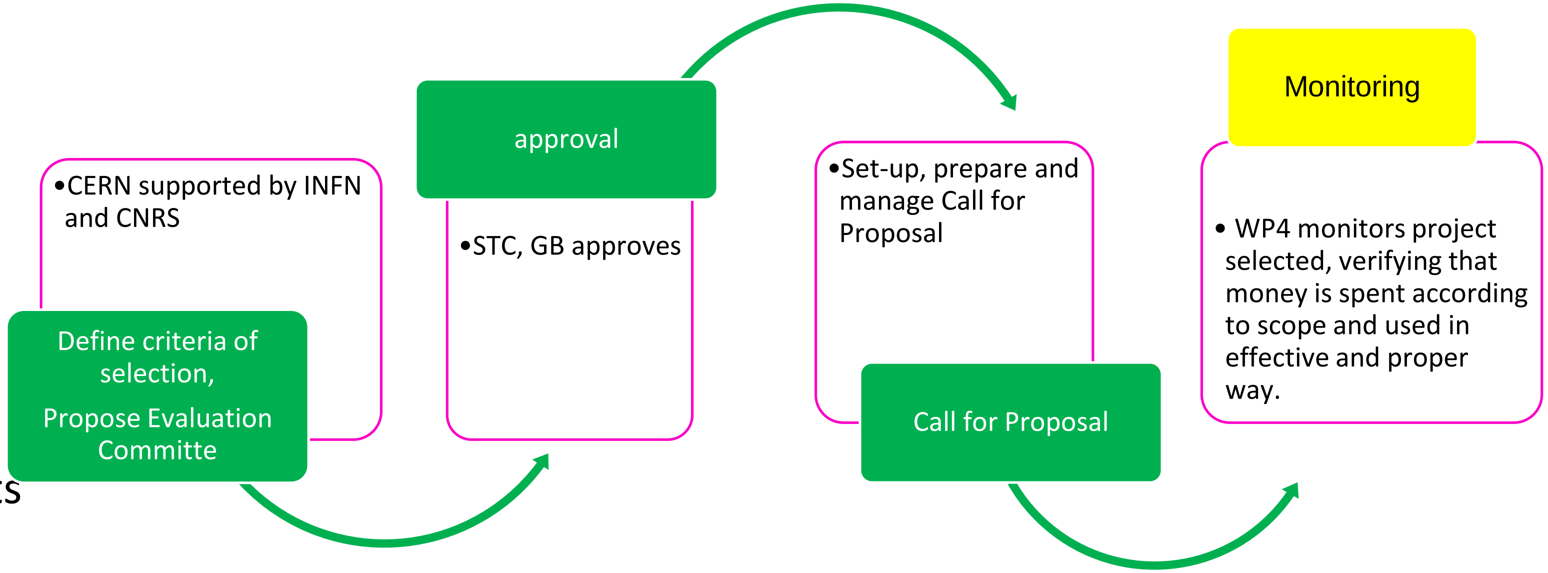
Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS11	IIF Projects interim progress	1 - CERN	36	Report (task 4.2)
MS12	IIF Projects final progress	1 - CERN	46	Report (task 4.2)
MS13	First characterisation of beam windows materials under thermomechanical load and extended radiation damage	14 - GSI (achieved)	16	Report (task 4.3)
MS14	Evaluation of a CCM alternative to Molybdenum-Graphite	1 - CERN (achieved)	12	Report (task 4.4)

iFAST

Task 4.1 / 4.2 Task leader: M.Losasso

Beneficiary:
CERN, HUD, CNRS, INFN

- Defined criteria for evaluation of projects for IIF – *presented and discussed in Feb and March 2022 STC*
- Appointment of an evaluation body (EvB) for IIF. *Proposal discussed in April STC, approved by GB in May 2022*
- Launch and Manage the *CfP*
- EvB has scored and proposed to GB projects for award. *Projects evaluated from Sept to Dec 2022, proposed for award to Jan. 2023 GB*



These activities are objects of submitted D4.1 and D4.2 (in editing)

IIF: aim and objectives

Based on ARIES acquired experience:

→ to promote innovative initiatives of I.FAST community in the phase 2 of project, connecting accelerator community and society at large

→ to sponsor fast-tracked, competitive and innovative projects directed towards the 8 thematic I.FAST areas

- IIF finances innovative projects: development and/or prototypes, contributing 100 to 200 K€, till the reaching of budget cap (1.2 M€)
- Managed in 2 rounds of evaluation, projects to start beginning of 2023
- Projects selected in round 1 that will not make to round 2 will be all the same advertised and promoted in IFAST community and in our networks

iFAST

IIF: rules of engagement, timeline, guidelines in web page

Requirements for eligibility

- Participants must include 1 IFAST beneficiary, at least 1 industry
- must have potential to attract resources
- Must be related to the key Thematic Areas of I.FAST
- Proposals must contribute to improve sustainability of future accelerators
- The idea or concept must have potential for industrial or commercial application
- Almost deployable-ready technologies: technical maturities at least TRL4 (validated in laboratory)

IFAST thematic areas

1. Novel particle accelerators concepts and technologies
2. High brightness accelerators for light sources
3. Innovative superconducting magnets
4. Innovative superconducting thin film coated cavities
5. Advanced accelerator technologies and materials
6. Sustainable concepts and technologies
7. Societal applications
8. Technology Infrastructure

https://ifast-project.eu/iif

- Submission form
- Pitch form to present
- Timeline
- Selection Criteria
- Guidelines to CfP

Disclose the call: IFAST AM and Industrial Workshop	May 2, 2022
Deadline for submission of proposals	August 31, 2022
Deadline for first round of evaluation	September 30, 2022
Deadline for second round of evaluations	November 30, 2022.

Selection Criteria & EvB

Quality with 3 sub-criteria

- Innovative Aspect of the proposal
- Clarity and Pertinence of the objectives
- state-of-the-art and demonstration of innovation potential

Impact with 3 sub-criteria.

- capacity to create new market opportunities, to reinforce competitiveness and growth of companies or bring other important benefits
- measures to disseminate and exploit the project results, including management of IPR
- How it is addressed sustainability and reduced environmental impact

Implementation with 3 sub-criteria.

- soundness of the concept, credibility of the proposed methodology in terms of meeting specific market needs. Credibility and soundness of the Industrialization /Business Plan.
- Quality and effectiveness of the work plan, including extent to which the resources assigned to work packages are in line with their objectives and deliverables: credibility and soundness of budget plan and schedule and of industries involvement.
- Capability to mobilize additional resources

EvB

C. Antoine/ CEA, WP9 Coordinator

G. Bisoffi/ INFN, WP4 member

M. Baylac/ CNRS, WP4 member

A. Faus Golfe/ IAB chair

P. Fork, GSI/ WP5 Coordinator

R. Geometrante/ Kyma SpA (Beneficiary)

Z. Melhem/ Oxford QS Ltd, IAB member

M. Losasso/ CERN, WP Coordinator, EvB chair

M. Morandin/ INFN, WP3 Coordinator

M.Vretenar/ CERN, I.FAST Coordinator

The use of:

- ***harmonized criteria in EvB***
- ***not-for-conflicting process***
- ***transparent methodology***

Has ensured a fair and effective competition

Task 4.3 GRAPH&BEAM project – M.Tomut, M.Losasso.

Beneficiaries: GSI,CERN,WWU, RHP, UDS

Achieved

Milestone/Deliverable Number	Title	Lead beneficiary	Type	Dissemination level	Due Date (in months)
MS13	First characterization of beam windows material under Thermomechanical load and radiation damages	GSI	Report	Public	16
D4.3	Beam windows prototypes	GSI	Demonstrator	Public	32

To come

D4.3 description

- Beam windows are exposed to extreme level of radiation, temperature, thermal stresses, dynamic pressure, and stresses conditions. WP4 tasked to develop beam windows able to sustain high intensity beams, to identify and characterize samples the best available materials in representative radiation environment

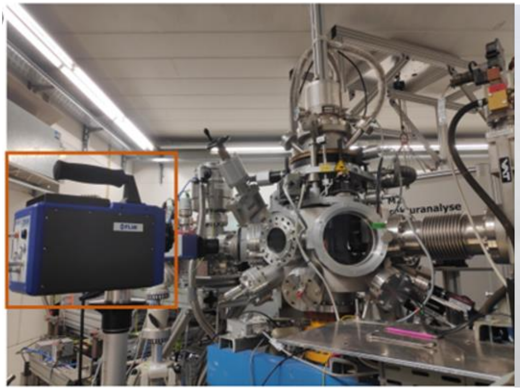
Status

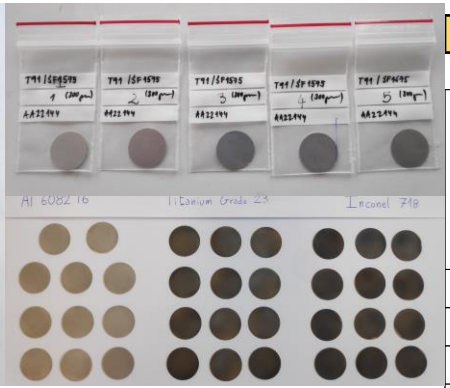
- L.Notari (La Sapienza University) hired to study materials eligible for application of beam windows, under supervision of M.Pasquali. Beryllium, Titanium and Titanium alloy, Steels, INCONEL 718, Aluminium alloys, and Graphitic materials have been selected. Thesis degree prepared and uploaded in Zenodo.
- Figure of Merit for beam windows defined, thermal structural analysis performed, irradiation experiment performed at GSI on material samples procured and manufactured.
- Results of the analysis compared with the measurement done during irradiation
- **Next step**: prepare samples of different materials and manufacture/characterize behavior under irradiation

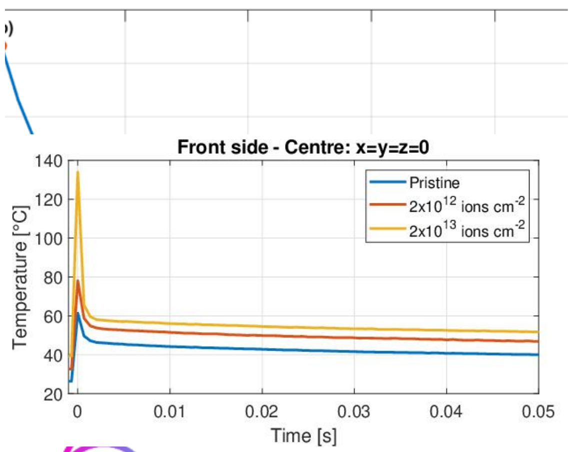
Task 4.3 : U beam irradiation experiments @ GSI - high T-load and transient stress

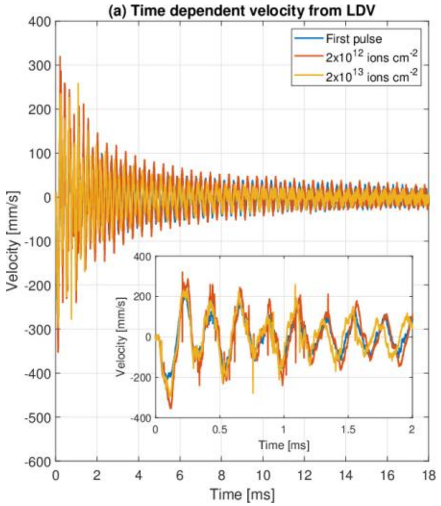
M-Branch, UNILAC, GSI – 4.8 MeV/u ^{238}U
high intensity, short pulses- 5x10^{9} i/cm^{2}s, 100 µs, 1 Hz

To better resist radiation and be “transparent” to the beam avoiding scattering effects, materials for beam windows application need to be leak-tight with high mech. strength, low thermal expansion, low atomic number. Thermal load induced by 4.8 MeV/u U beam









Lorenzo Notari , Master thesis, 2022

Peak temperature per pulse

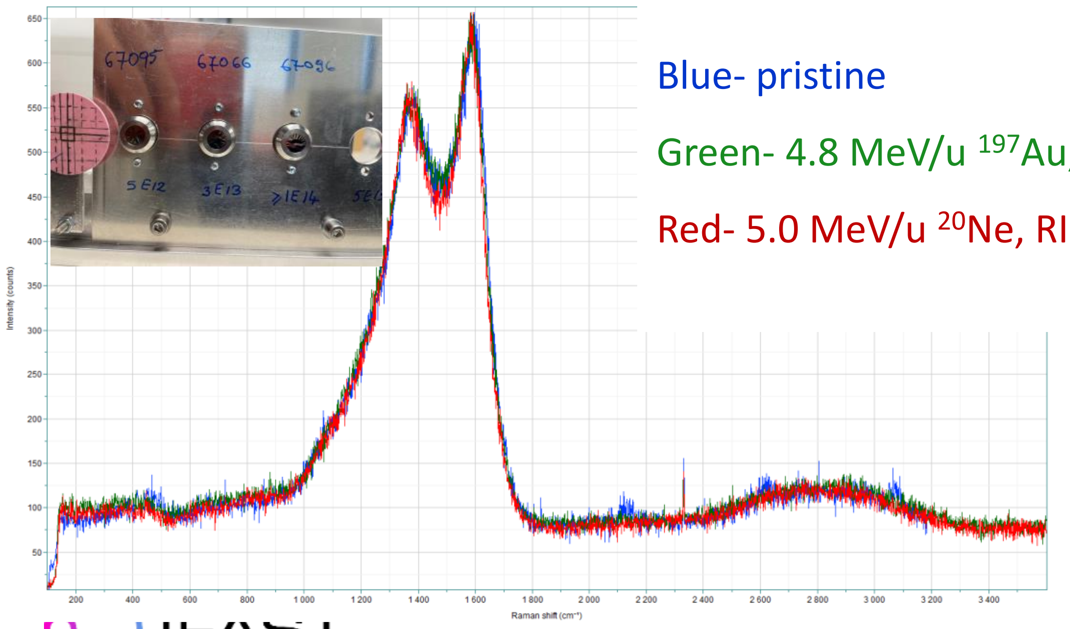
Materials	Density ρ [g cm-3]	Specific Heat c_p [J/kg K]	Penetration depth d_p	Peak temperature T_{max} [°C]	Melting temperature T_{melt} [°C]	Peak/Melting temperature ratio T_{max} [K]/T_{melt} [K]
Beryllium PF60	1.844	1925	58	108.90	1273	0.2471
Titanium Grade 2	4.51	540	58	149.58	1665	0.2181
Titanium Grade 5	4.43	526.3	58	155.35	1630	0.2252
T91 / P91	7.77	460	58	108.29	1370	0.2321
AISI 316L	8	500	58	98.89	1375	0.2257
AISI 316LN	8	500	58	98.89	1375	0.2257
AISI 304L	8	500	58	98.89	1425	0.2191
INCONEL 718	8.19	435	58	108.58	1298	0.2430
5052-H19	2.68	880	58	153.81	630	0.4727
A5083-O	2.66	901	58	151.67	570	0.5039
A6061 T6	2.7	896	58	150.45	616.85	0.4760
SIGRAFINE R6650 (isotropic)	1.84	700	58	265.01	3650	0.1372
SIGRABOND C-C 1501 G (anisotropic)	1.47	831	58	278.34	3650	0.1406
SIGRABOND C-C 1001 G (anisotropic)	1.36	831	58	299.23	3650	0.1459
Silicon Nitride (Si3N4)	2.81	886.5	58	146.68	2441.85	0.1546
Silicon Carbide (SiC)	4.6	580	58	138.28	1579.35	0.2221
Graphene	2.27	700	59	215.24	3697	0.1230

Task 4.3: GRAPH&BEAM project -Post irradiation of graphenic materials and pressure & leak tests on graphenic windows

No significant structural changes and material loss in the irradiated graphenic membranes, within beam spot

Raman spectra of pristine and irradiated graphenic membrane (Au @ GSI, Ne @ RIKEN)

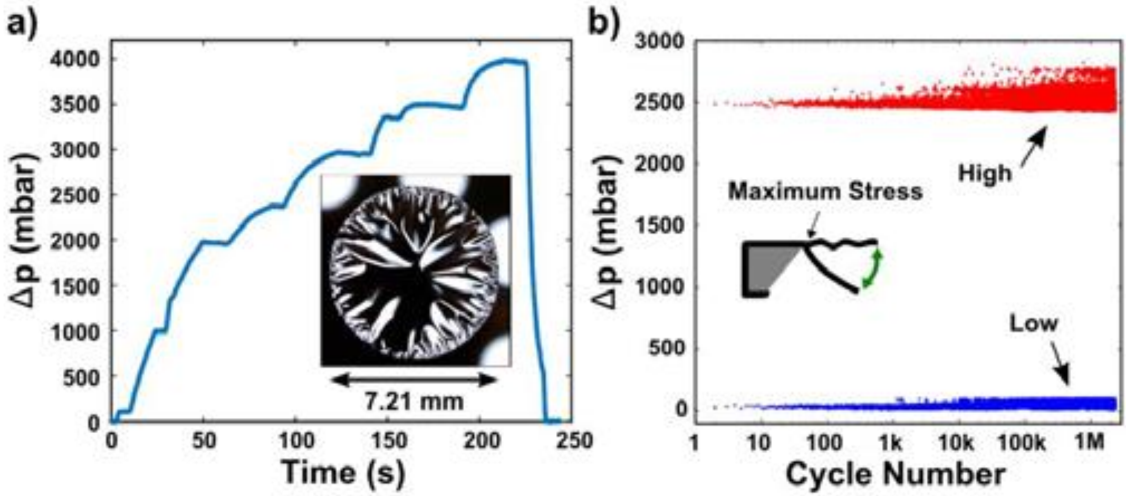
- no significant structural changes during irradiation with high dose and intensity beams



Blue- pristine

Green- 4.8 MeV/u ^{197}Au, GSI

Red- 5.0 MeV/u ^{20}Ne, RIKEN



GC window survives with no leak:

- Up to 4000 mbar differential pressure
- more than 2 million cycles with a differential pressure of at least 2400 mbar per cycle - *KETEK*

Task 4.4 – innovative materials industrial development /F.Carra

Beneficiaries: CERN, NNK, RHP

Achieved in month 13

Milestone/Deliverable Number	Title	Lead beneficiary	Type	Dissemination level	Due Date (in months)
MS14	Evaluation of a CCM (carbide-carbon material) alternative to Molybdenum-Graphite	CERN	Report	Public	16
D4.4	Production of large-size CCM plates	CERN	Demonstrator	Public	24

To come

D4.4 description

- Carbide-Carbon Materials (CCM) are a family of composites of wide interest for use in HEP facilities and, thanks to their high thermal conductivity and low density, they are of interest in aerospace, nuclear energy production.
- Scope: produce two large CCM plates (cross section >400 cm2) in a single sintering cycle at Nanoker (ES)

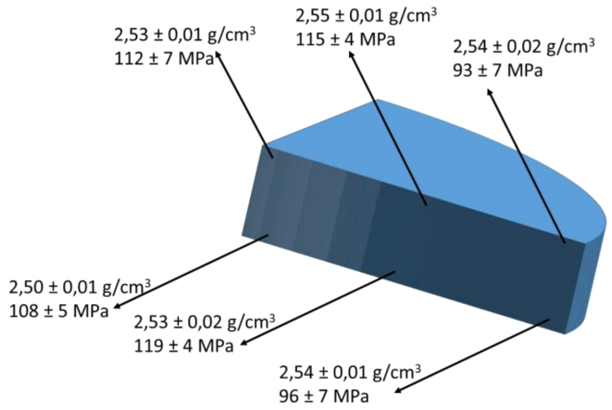
Status

- It was decided to target the 2 plate-in-1cycle production of Chromium-Graphite (CrGr) instead of Molybdenum-Graphite (MoGr)
- Reason: CrGr is the composite developed in the MS14, cheaper than MoGr thanks to lower required sintering temperature (lower machine energy consumption, saving consumables such as mould and electrodes) and at the same time, meeting the required tech specifications
- Next step: January 2022 sinter of a big size 1plate-in-1cycle of CrGr, if successful, Q1 2023 → 2-in-1 (deliverable!)

Year 1 Highlights – Molybdenum-Graphite

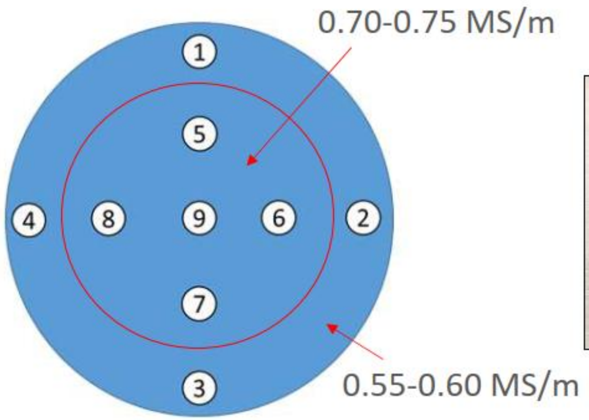
- **Molybdenum-Graphite** (sintered at 2640°C)

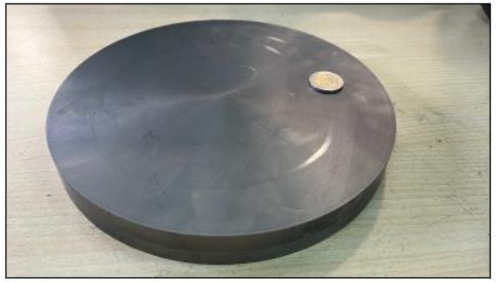
2 plates produced with 230 mm Diameter (2x bigger section than before IFAST)



Disk (230 mm diameter)	Density (g/cm³)	Electrical Conductivity (Mean values on each side) (MS/m)
Plate #1 (p=26 MPa)	**2,53**	**0,6 – 0,63**
Plate #2 (p=40 MPa)	**2,60**	**0,65 – 0,68**
Specification	**2,3 ÷2,6**	**>0,8**

Lower electrical conductivity values than in the 170 mm diameter disks





Pre-compaction of the green powder:

Maximum Applied Force Uniaxial Hydraulic Press ~ 900 kN

- 170 mm Ø → 40 MPa → 2,00 g/cm³
- 230 mm Ø → 21 MPa → 1,65 g/cm³

Next: increase the metal content, together with the higher sintering pressure

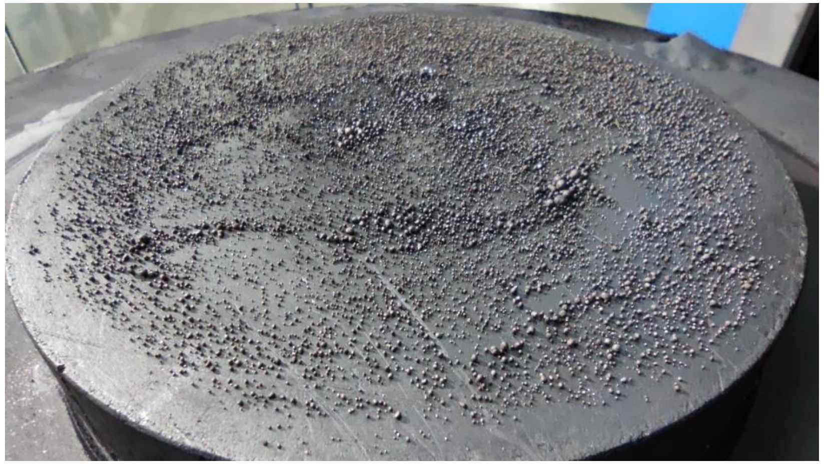
IFAST

Year 1 Highlights – Chromium-Graphite

- **Chromium-Graphite** (sintered at 2000°C – 1.3x lower T)
- Concept proposed by **Jorge Guardia** within ARIES WP14 & WP17, technically was not demonstrated yet (very poor mechanical properties)

3 plates produced with 170 mm Diameter

Disk (170 mm diameter)	Density (g/cm^3)	Electrical Conductivity (MS/m)
Plate #1	2,30	1,00 – 1,07
Plates #2 & #3	2,30	0.75/0.81
Specification	2,3 ÷2,6	>0,8



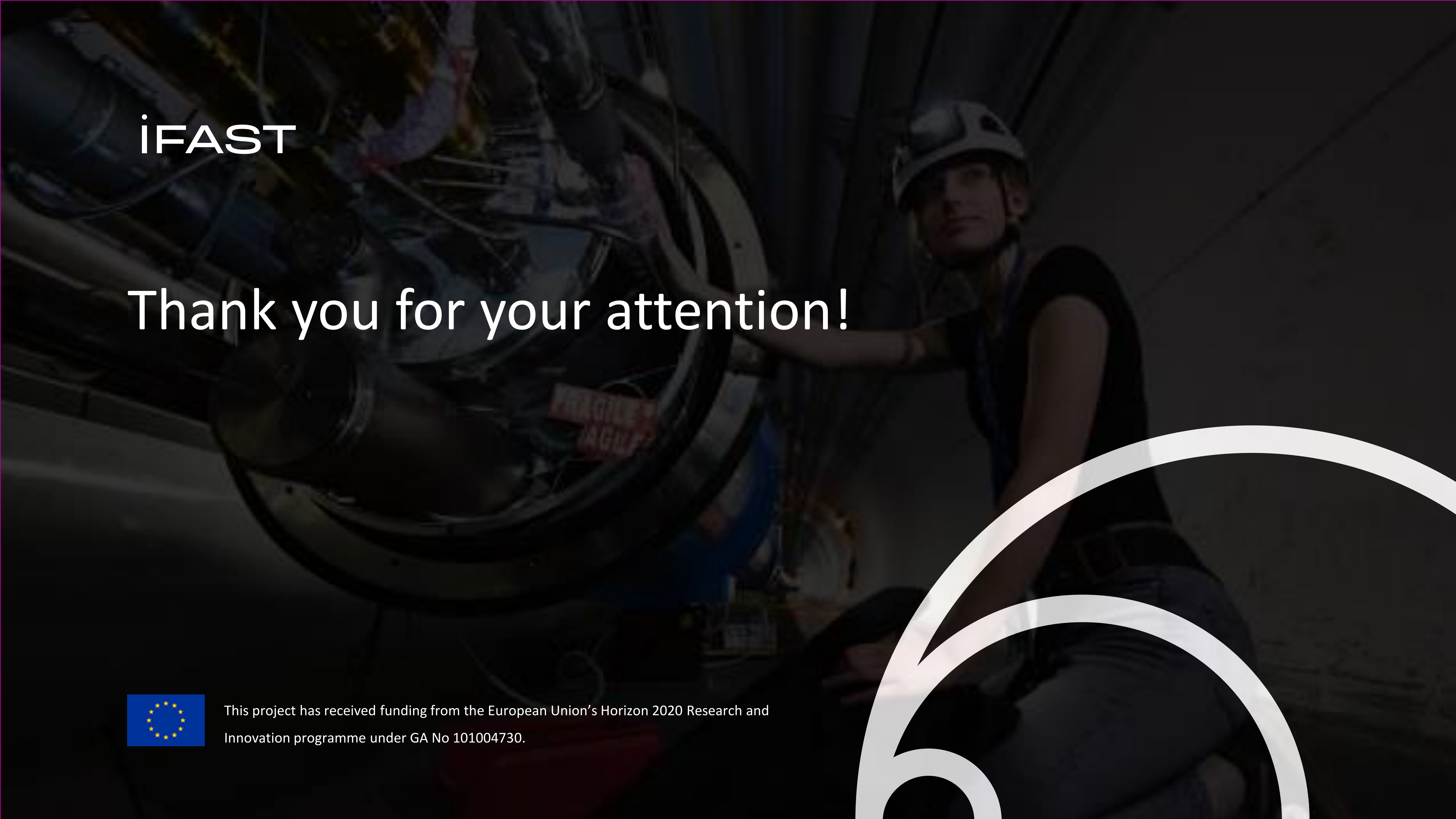
Reusable Mold and Parts → Important Cost Reduction

- **Plate #1 produced in a single plate per cycle**, very promising properties, decision for full characterization at CERN
- **Plates #2 and #3 double-plate per cycle**, losing a bit in conductivity → composition and cycle to be optimized

iFAST

Relevance of objectives and impact

- WP4 in P1 has met all the work planned objectives and deadlines, in some case advancing the schedule. For the future, the energy crisis may have an impact on the plan of irradiation campaigns for task 4.3.
- Relevance and scope is not changed: WP4 has provided support to innovative projects promising to produce energy savings for accelerators and reduce their environmental impact, while at the same time advancing developments in I.FAST tech areas.
- WP4, in collaboration with industries, has investigated new materials for use in application as diverse as nuclear, bio and medical.
- WP4, in collaboration with industries, has advanced researches resulting in thesis degree (published in Zenodo). A paper on scientific press is presently in review phase, a new paper will be prepared in the near future.



Thank you for your attention!

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