Prof. Toms TORIMS, Riga Technical University

I.FAST Period 1 Review, 09.02.2023

Task 10.1
Coordination and communication

- *Overall WP coordination, monitoring of progress and technical actions*
- *To **identify and promote novel technologies** to improve performance of particle accelerators*
- *Promote **communication strategies** on opportunities offered by new technologies for accelerators*

Coordination of WP10 *– how it works?*

- **Coordination** of the WP
  - Regular Task meetings (remote and in-person) – AM segment Tasks 10.2+10.3+10.4
  - Task 10.5, 10.6 and 10.7 meetings and liaison with the Task Leaders
  - 2 WP10 all Tasks meetings
- **Monitoring** of the progress
  - This is about Deliverables and Milestones of each Task
  - Every Task leader is fully aware of his D's and M's
- Technical **actions**
  - Tools are made available: Indico, I.FAST Collaborative Space
  - Regular communication, updates, follow-up and support
  - Organisation of events [Type1,2,3,4] and linking them with other I.FAST WP's
  - Coordination of publications and participation in the events

WP10 Milestones

MS43	Dissemination and communication plan	10.1	12	Report	Done
MS44	Survey on current AM applications in accelerators and expected new developments	10.2	30	Report	Ongoing – no difficulties noted
MS45	Survey on current AM repair technologies for accelerator and list of possible applications	10.3	24	Report	
MS46	Performance of Superconductive Cavities made by AM technology by Nb or Cu with Nb thin spattered film on the internal surface	10.4	12	Report	Ongoing – extension requested to M30
MS47	First NEG coated samples are installed on SR beamline at DLS and Soleil	10.5	12	Report	Done
MS48	ML model selection and implementation plan	10.6	18	Report	Done
MS49	Delivery of an electro-optic waveguide prototype for demonstration at RHUL test bench	10.7	12	Laboratory prototype in operation	Done

WP10 Deliverables

Deliverables related to WP10	
D10.1: Potential AM applications in accelerators. *Report on output of the survey on AM applications, further needs for the accelerator community, and perspective developments.* Ongoing – no difficulties noted	30
D10.2: Survey of AM applications and strategies for repairing accelerator components by AM. *Report listing possible strategies and technologies for repairing of parts.* Ongoing – no difficulties noted	24
D10.3: Additive-manufactured Superconductive RF cavities. *Production and tests of superconductive RF cavities, made by Nb and/or Cu coated by an Nb thin film.* Done	~~12~~ 18
D10.4: First PSD data from NEG coating. *First PSD data from NEG coating reported.* Ongoing – no difficulties noted	36
D10.5: Technical Report on machine learning at ESS. *Evaluation and verification results, architecture of the final implementation, and achieved performance at the ESS facility.* Ongoing – no difficulties noted	34
D10.6: Electro-optic performance report. *Final report on the performance of the electro-optic pick-up prototype with beam.* Ongoing – no difficulties noted	24

T10.1 summary of activities in P1
- some highlights only

- *53 meetings and events https://indico.cern.ch/category/13515/*

- *Dedicated **Workshop on Additive Manufacturing** applications at CERN globe during I.FAST annual meeting https://indico.cern.ch/event/1133254/sessions/439997/#20220505*

External dissemination of results:

- *Participation in the major **conferences***
- *10+ **scientific papers**, and counting*
- *Presence and **visibility** in the major AM exhibition*
- ***New** European industrial **partners** engaged*

Work is going-on!

Task 10.2
AM – Survey of applications and potential developments

- *Survey of **current** Additive Manufacturing (AM) **applications** in accelerators and identification of **needs for future** development and research actions*
- *Promote initiatives to identify **how AM can address** the needs of the accelerator community*
- *Define **strategic directions** for future AM technologies and foster their impact on accelerator applications (inc. societal), identifying technology barrier and challenges.*

Partners:
PoliMi, RTU, CERN, CNRS, CEA, INFN, TalTec + TRUMPF

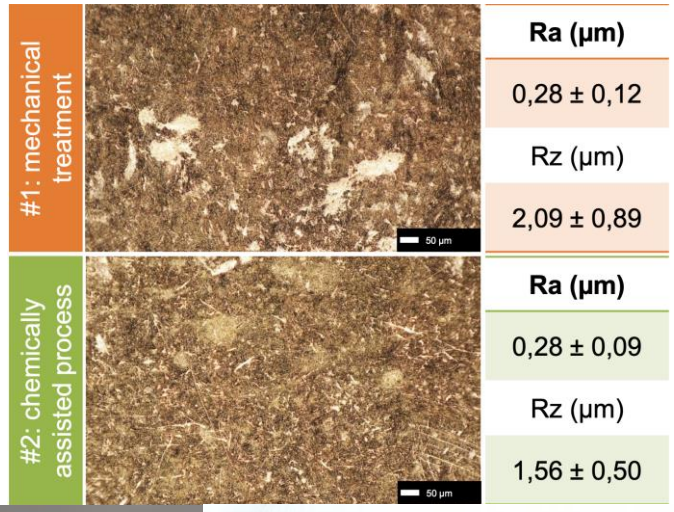
AM in the accelerator community - survey

Courtesy of Guntis Pikurs

Work is going-on!

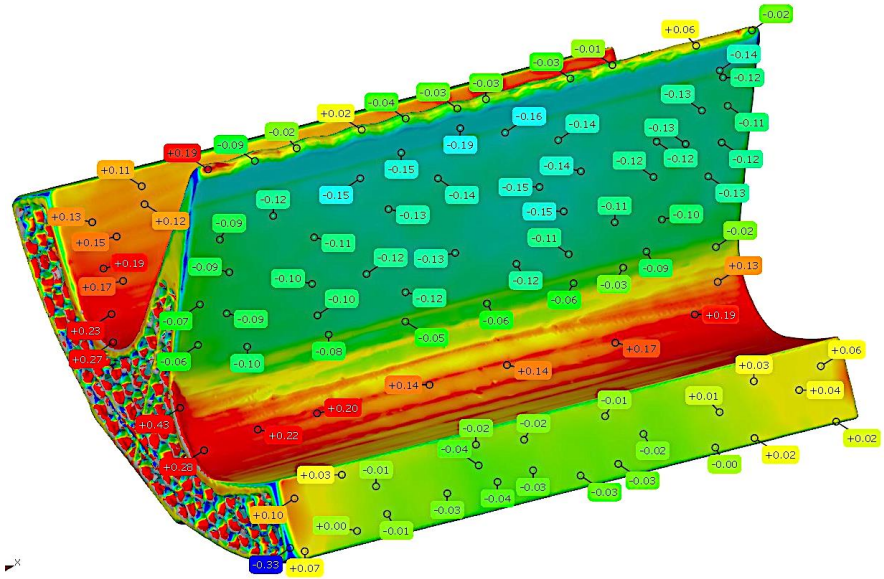
Indicative sample of RFQ

- *Promote initiatives to identify **how AM can address** the needs of the accelerator community*



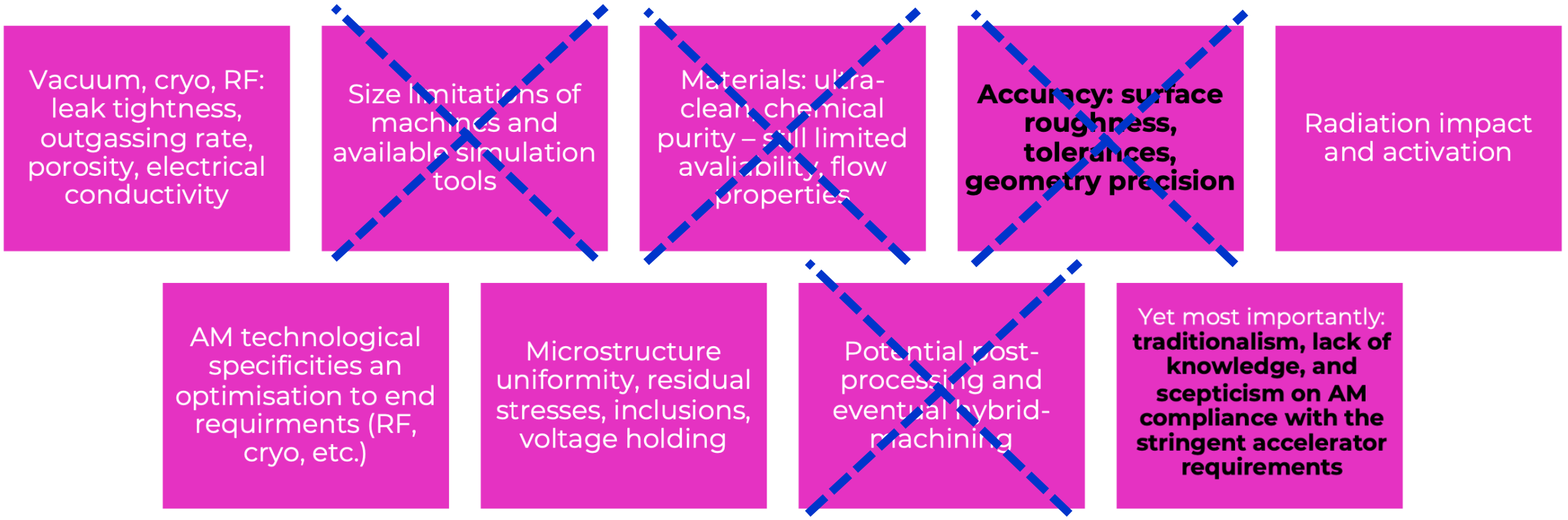
Ra (µm)
0,28 ± 0,12
Rz (µm)
2,09 ± 0,89

Ra (µm)
0,28 ± 0,09
Rz (µm)
1,56 ± 0,50




Preform
RFQ Particle Accelerator
Innovation Fostering in Accelerator Science and Technology
High-Frequency RFQ Prototype
World Premiere

T10.2 achievments during P1
- addressing challenges within accelerators



- *Define **strategic directions** for future AM technologies and foster their impact on accelerator applications (inc. societal), identifying technology barrier and challenges.*

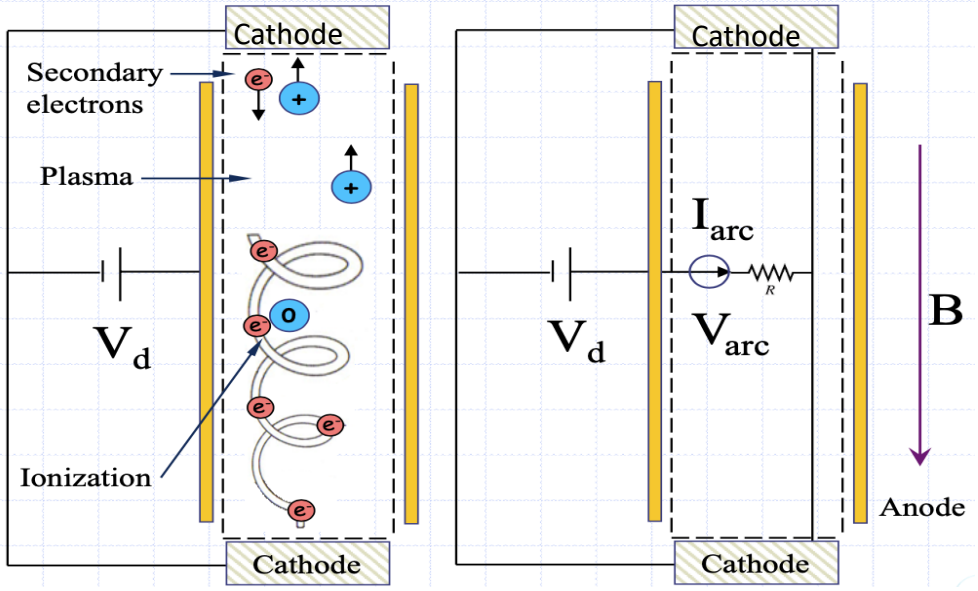
Work is going-on!

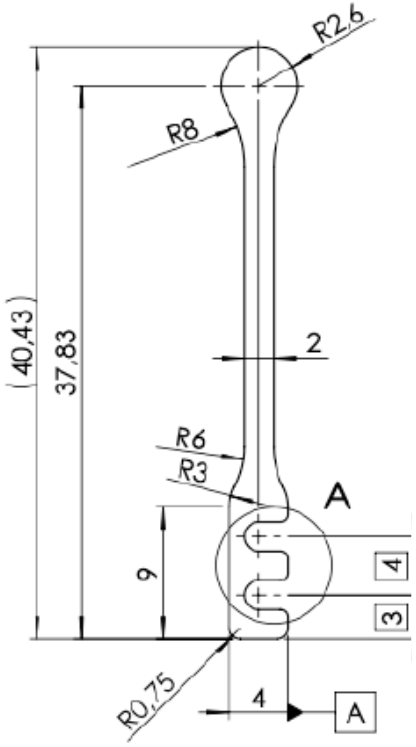
Task 10.3
Refurbishment of accelerator components by Additive Manufacturing (AM) technologies

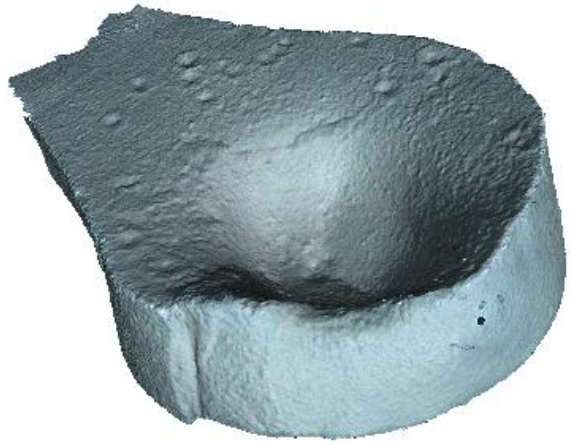
- *Definition of **applications and components for the repair** activities in the accelerator components by AM*
- *Identification of **AM strategies** that can be adopted to repair parts*
- *Study **post-processing methods** to control surface roughness and surface cleanliness of AM parts*
- *Identification of a sample **demonstration prototype** of AM repaired unit for an accelerator*

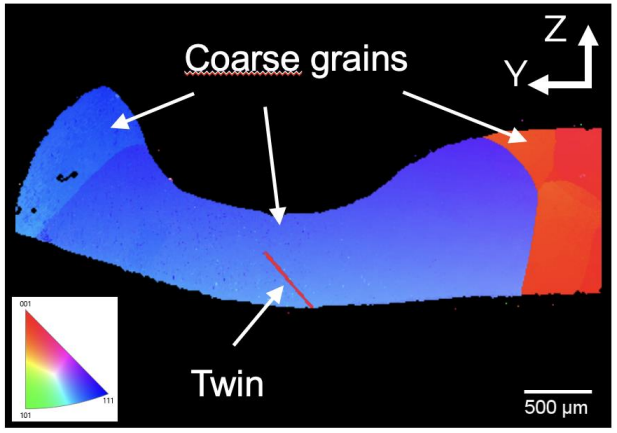
Partners:
RTU, PoliMi, CERN, CEA, INFN, CNRS, TalTec

Repaired - Cold cathode Penning Ionization Gauge (PIG) ion source







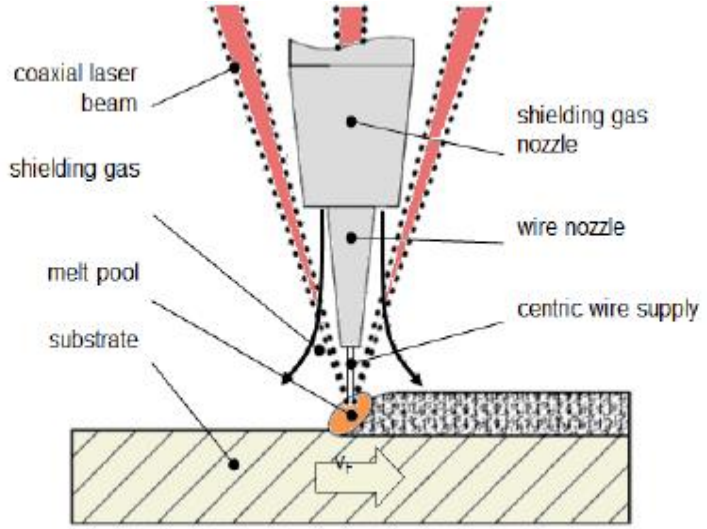


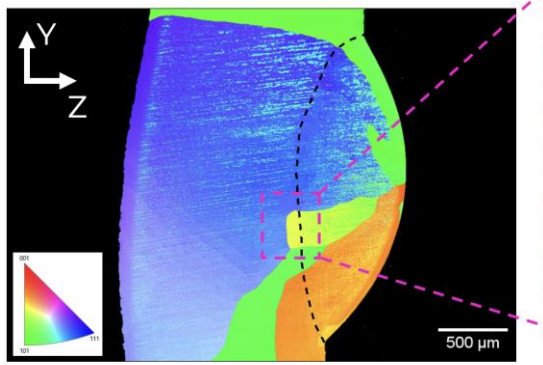
The cathodes sputtering by ions form the discharge which produces a crater

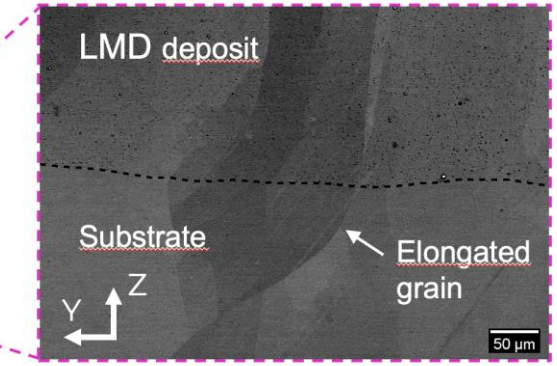
T10.3 achievments during P1

- **Demonstrated AM abilities** with exotic material
- Successfully used two DED AM technologies
- Parameters diapasons were determined
- Tested several **repair strategies**

Wire







Hardness: 315.3 ± 10.3 $HV_{0.05}$

Work is going-on!

Task 10.4: Development of AM-manufactured superconductive RF cavities

- *Develop the **design approach and test** relevant properties of **AM-manufactured Niobium RF cavities***
- *Develop the **design approach and test** relevant properties of **AM-manufactured Ultra-Pure Cu-made RF** body cavities - coated by a Niobium thin layer at the inner surface*
- *Both to be tested at room and at cryogenic temperature*

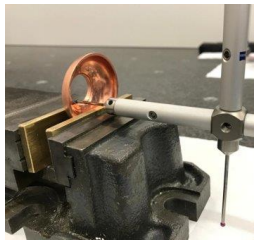
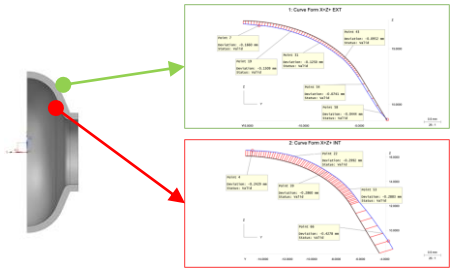
Partners:
INFN, CNRS

T10.4 achievments during P1
- Cavities produced by AM

Cu cavities

First prototypes:

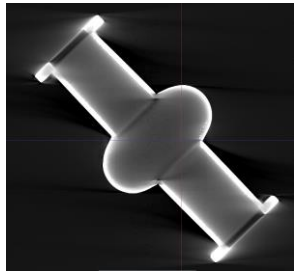
- Geometry verifications

6 GHz seamless cavities:

- Red laser
- Green laser

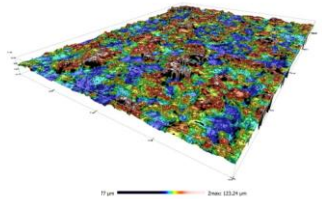




Nb cavities

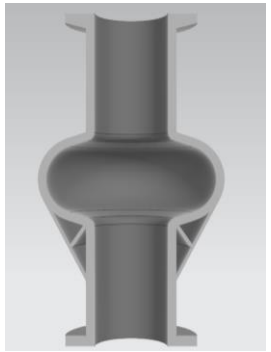
Material characterization and process parameters optimization:

- Density
- Critical angle
- Down-skin
- Contour


50° 45° 40° 35° 30° 25° 22° 20° 18°

6 GHz seamless cavities production

Surface treatments by Rösler

Cavities

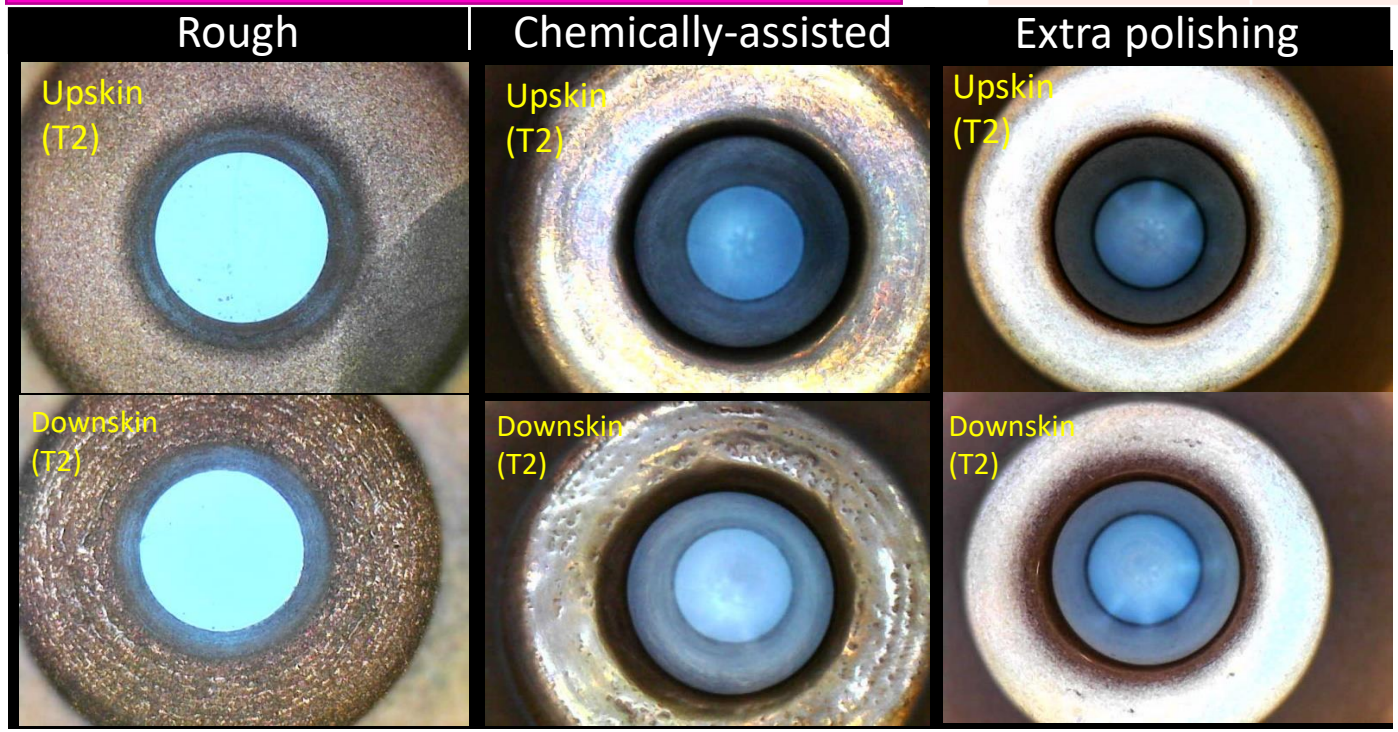
- P-shape →
- L-shape
- T-shape

Scrap parts for preliminary test

Samples to be treated

GOAL: Ra ≤ 1,0 µm

Treatments			
Type	**Mechanical treatment**	**Chemically-assisted treatment**	**Extra polishing step**
# of steps	10	5	2
media and compounds	*Rösler* media: Cu needles + synthetic diamond powder	*Rösler* ceramic media: ***RMBD1 05 G*** *Rösler* compound: ***CMP 03/21 L***	*Rösler* plastic media: ***RKH/4***
GOAL	Roughness reduction R_a from about 30 µm to 4 µm	Roughness reduction **R_a ≤ 1,0 µm**	Last defects removal Final cleaning **R_a ≤ 1,0 µm**



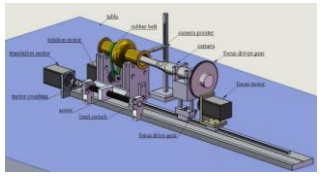
Average roughness at the end:

CAVITY	R_a µm	R_z µm
L2	0,48	2,32
L3	0,54	3,34
T2	0,48	3,39

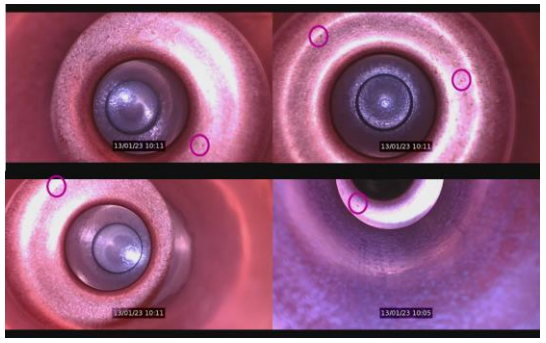
Morphology

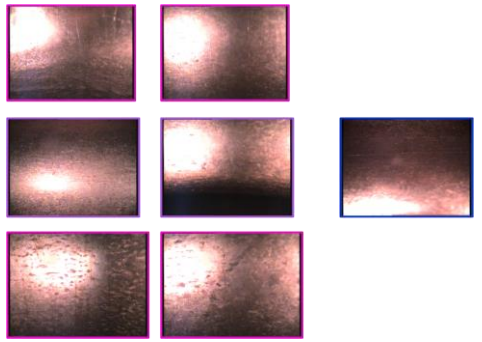
1 inspection

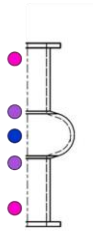
- ✓ Vacuum leak detection
- ✓ Frequency measurement



T 1 T2



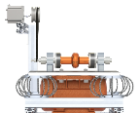




2 Treatment workflow

T 1

1Vibro-Tumbling at LNL

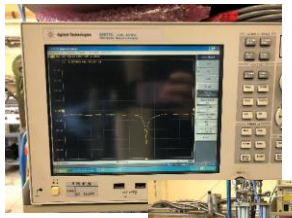


T 2

1Vibro finishing @Rösler

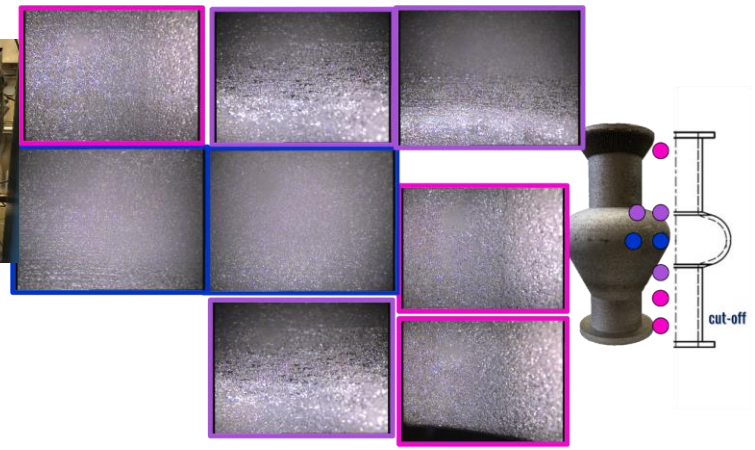
2 Electropolishing

3. Chemical polishing (SUBU)
4. Inspection
5. High Pressure Rinsing
6. Physical Vapour Deposition of Nb
7. SC measurements



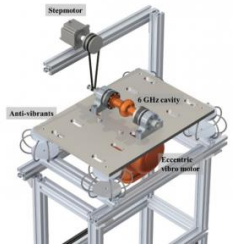
- ✓ Vacuum leak detection
- ✓ Frequency measurement

Nb



Nb

1Vibro-Tumbling at LNL



2 Electropolishing

3. Inspection
4. High Pressure Rinsing
5. SC measurements

Work is going-on!

Task 10.5: Photon Stimulated Desorption from NEG coating for accelerator vacuum chambers

- *Building facilities for photon stimulated desorption (PSD) yield measurement on beamlines.*
- *Obtaining and analysing the photon stimulated gas desorption (PSD) experimental data from Non-Evaporable Getter (NEG) coated prototypes under conditions similar to future light sources.*

Reported within WP9

Task 10.6: Machine Learning Techniques for Accelerator and Target Diagnostics

- *Long term mission:* ***Develop low-latency Machine Learning*** *(ML) techniques to improve performance and availability of high-power facilities at the intensity frontier.*
- *Goal: Identify signatures of potential* ***errant beam conditions***
- *Scope:*

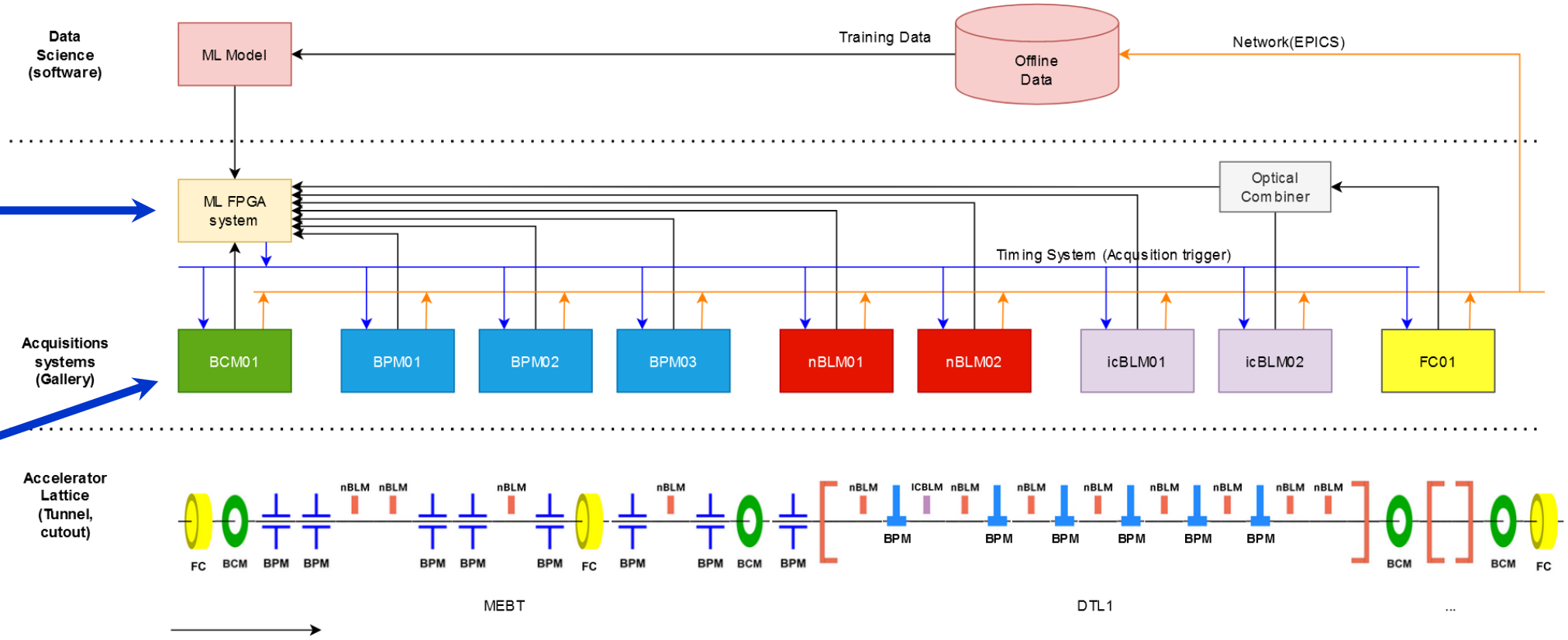
Assess the ***predictive capabilities*** *of selected ML models*

Prototype: ***proof of principle demonstration***

The most promising ML model to be implemented on a low- latency network of FPGAs processing signals from array of detector channels

ML prototype – ESS Normal Conducting Linac, Low Energy Section

- System covering Normal Conducting Linac (NCL)
- 2nd layer: **ML FPGA System** to detect "off normal" events and request readout via timing system (DoD extraction).
- 1st layer: **network of FPGAs** to acquire and process signal from detector channels.
- System could connect to beam interlock system (not shown).



T10.6. achievments during P1

- **Acquired data sets** during ESS beam commissioning run to DTL1 in July 2022
- Doctoral student from RTU engaged: performing **exploratory analysis** on data from beam commissioning run in July 2022
- Work on producing simulated **ESS data** for normal operation and anomalies - ongoing
- **Conceptual design** for the prototype demo prepared - FPGA system fed by low latency links from a set of instrumentation systems
- **Prototype** FPGA system **demonsrated** with the Xilinx SW toolchain and generic ML algorithm
- First version of **low latency link demonstrated** by transporting waveforms with sub-microsecond latency at multigigabit per second rates

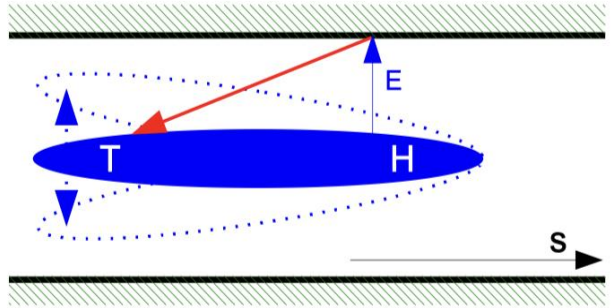
Work is going-on!

Task 10.7: Development of electro-optical waveguide sensors as beam electric field sensors

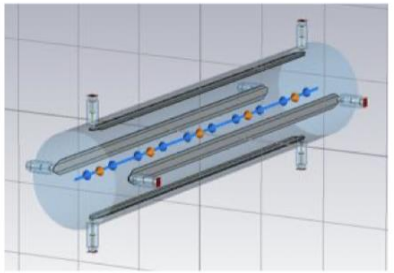
- ***Develop novel electric-field sensors*** *based on electro-optic waveguides to address new challenges in fast time response (<50ps) beam instrumentation*
- ***Demonstrate the capability*** *to optically measure the intra-bunch transverse displacement of a passing relativistic bunch, with a bandwidth that is beyond state-of-the-art*

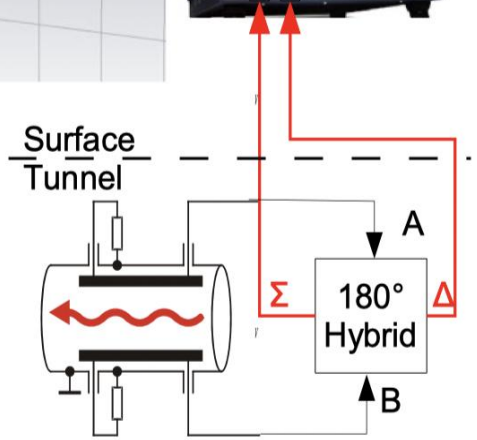
How to make beam Instrumentation FASTer?

- ***Challenge of rapid diagnostics***
  - Beam instrumentation at current and future particle accelerators would **benefit from an improved time response** in multiple areas:
    - Bunch arrival time/ ToF; crabbed bunch rotation; temporal longitudinal profiles; measuring rapid, intra-bunch transverse instabilities...
  - **Bandwidth** of conventional diagnostics is typically **limited** to a few GHz by the pick-ups, hybrid, cables and acquisition system.



Standard approach: stripline BPM





- ***A new technology is needed***
  - replace capacitive pick-ups with fast electro-optic crystals
  - replace electric cables by optical-fibre readout

Partners and facilities

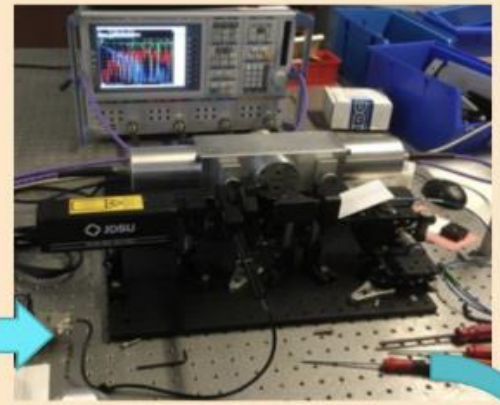
- **Pickup development and bench tests at RHUL**

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Waveguide fabrication in photonics industry

Inspection in new nanofabrication clean-room facility at RHUL

Precision manufacture & waveguide integration



Bench tests on RF coaxial line / laser labs

- **Beam tests of waveguides at CERN**

In collaboration with CERN BI, T. Lefevre et al

CERN

HiRadMat
High-Radiation to Materials

Beam test of waveguide signal

clear

Beam test of waveguide bandwidth

iFAST

T10.7 summary of activities in P1

Two successful beam test campaigns of electro-optics waveguide pickups:

- **HighRadMat 2021:**.
  - Benefit from short bunch length and train structure at CLEAR to **assess the time response** using an optical streak camera.
  - Improvements to the ata acquisition system to reach higher bandwidths.
- **CLEAR 2022:**.
  - Short bunch length and train structure at CLEAR used to **assess the time response**
- **Results in invited talk at International Beam Instrumentation Conference 2022, Kraków:**
  - IBIC22 proceedings: *https://ibic2022.vrws.de/papers/tu1i1.pdf*

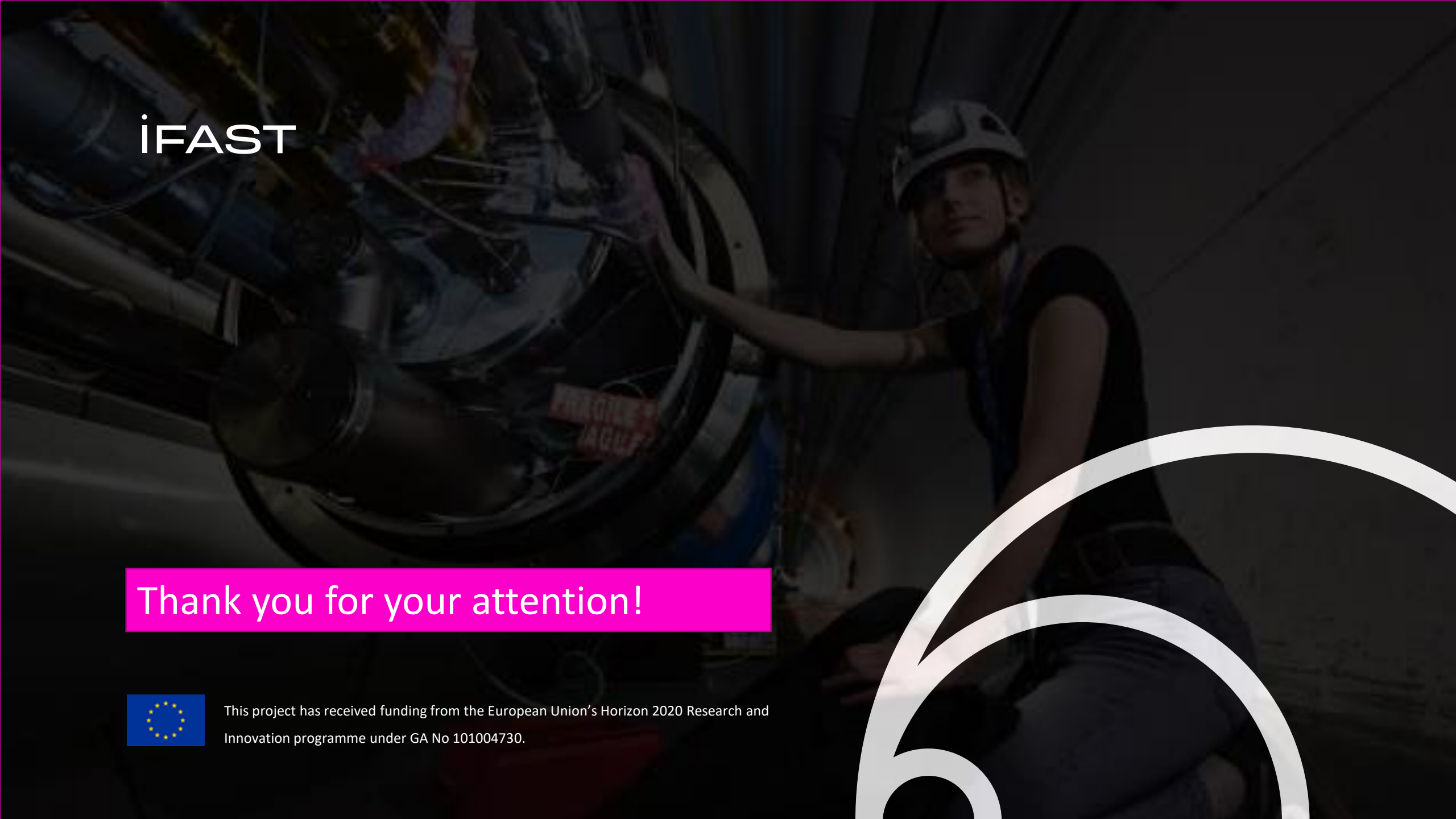
Waveguide design optimised in collaboration with photonics industry:

- Improve opto-mechanical design for handling, assembly and precise alignment of delicate components.
- Approaching final months of originally funded 24 month project on 10.7.

WP10 specific objectives

- ***Improve fabrication and repair techniques, reduce cost, and enhance performance for all accelerators.***

- *Identify applications of Additive Manufacturing (AM) in the accelerator.*
- *Develop and test AM-produced SRF cavities.*
- *Build facilities for measurement of Photon Simulated Desorption from coatings in accelerator vacuum chambers.*
- *Develop Machine Learning (ML) predictive algorithms with the capability to diagnose and protect high-power accelerators.*
- *Develop electro-optical waveguide sensors for beam monitoring.*



iFAST

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.

Back-up slides

WP10 perfectly relevant and are having impact

- Define strategic directions for the **use of AM** technologies on accelerator applications
- Identification of **AM strategies** that can be adopted to **repair parts**
- Develop the **design approach and test** relevant properties of AM-manufactured RF cavities
- **Build facilities** for photon stimulated desorption (PSD) yield measurement on beamlines
- Develop Machine Learning (ML) **predictive algorithms** to diagnose and protect high power accelerators
- Develop **novel electric-field sensors** to address new challenges in fast time response beam instrumentation

Workshops and meetings

How can AM address the needs of the accelerator community?

- Type 1: I.FAST meetings - project partners and community
- Type 2: “in situ” meetings with industry and other research institutions – relevant non-project partners and interested parties
- Type 3: “Horizontal Workshops” open to everyone (linked to project Annual Meetings) - transverse multidisciplinary Workshops and events involving two or more I.FAST WPs.
- Type 4: oral contribution to the international conferences and seminars

Workshops and meetings - in practice

- Type 1: I.FAST meetings
  - WP10 meeting, Task 10.1-10.7 meetings
  - Steering Committee, progress meetings, Annual meetings
  - I.FAST industrial workshop – Task 3.1
  - European Advanced Accelerator Concepts workshop – Task 6.1
- Type 2: meetings “in situ” with industry and other research institutions
  - Roesler, AM Solutions - current
  - meeting in Paris @ CNRS (Feb 2022) with designated workshop on AM applied to accelerators + series of other seminars in various locations
- Type 3: “Horizontal workshops” open to all (linked to project meetings)
  - I.FAST Annual Meeting @CERN (May 2022) - AM
- Type 4: conferences
  - special interest in IPAC23 @Venice (May 2023)