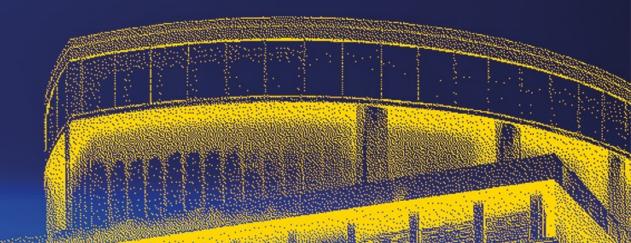


SVEDISH BIGSCIENCE FORUM



MATERIALS AND ADVANCED MANUFACTURING



Stefan Vikman

Head of Materials & Manufacturing
Technologies & Processes Group
Fusion for Energy

F4E



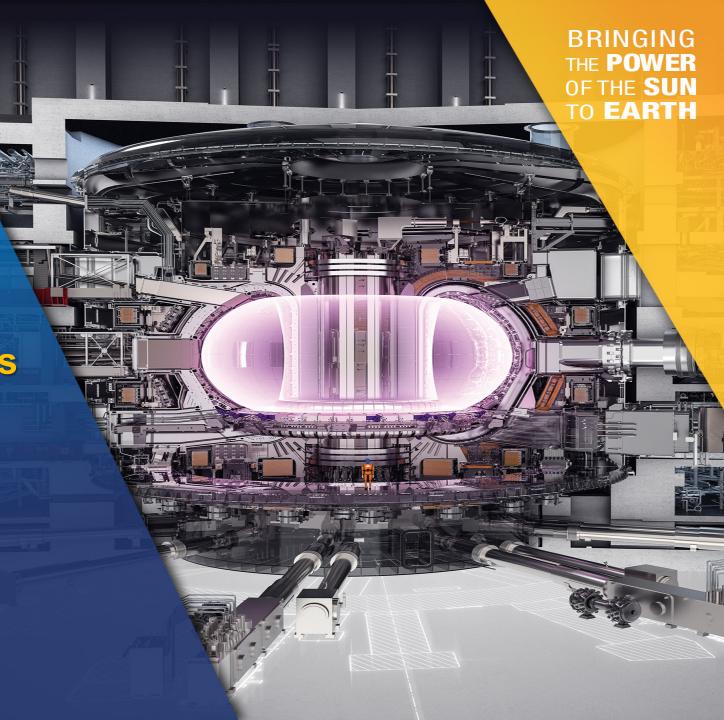
Rui Franqueira
Ximenes
Project Mechanical Engineer
CERN



Procurement and design challenges with materials exposed to high temperatures and neutrons

Stefan Wikman

Materials & Manufacturing Technologies & Process
Group Leader



F4E - The European Agency for ITER and the development of fusion energy



Headquarters: Barcelona, Spain

Offices: Cadarache, France

Garching, Germany

Rokkasho, Japan

▶ Staff: 460

▶ F4E is a public organisation set up in 2007 for 35 years

Budget:

Spent: €6.6 billion 2007-2020

Present package: €7.3 billion 2021-2027

F4E is responsible to deliver Europe's contribution to ITER (about 50% of the budget)

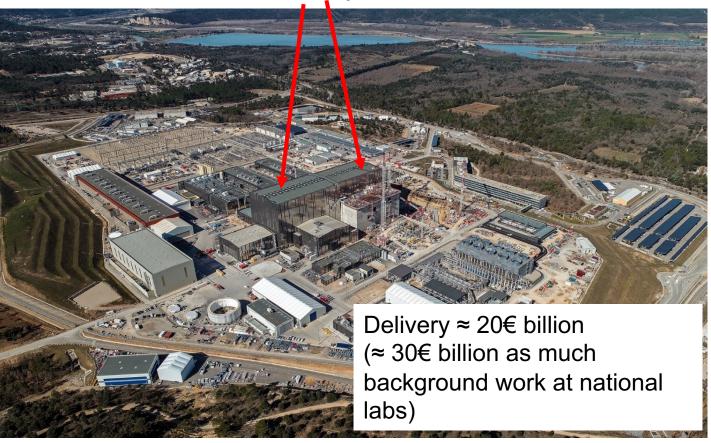


International Thermonuclear Experimental Reactor



Site: France Saint-Paul-lès-Durance

Tokamak Hall Assembly Hall

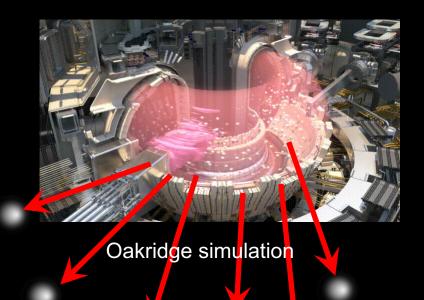


S. Wikman, Jan 2024

Produce a "little sun" on Earth



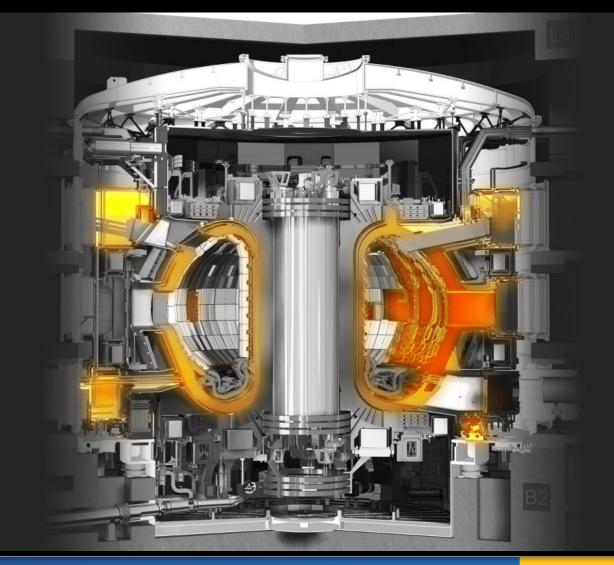




neutrons

High energy neutrons will collide with the walls and collisions generate gamma

Plasma Facing Components and Shields with complex coolant water system to slow down neutrons



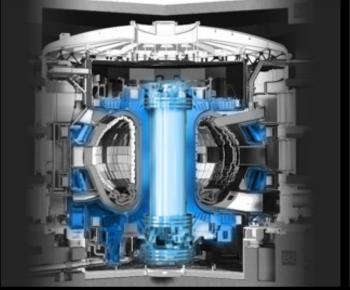
ITER - Any other particular challenges?



The most extreme temperatures side by side High magnetic loads (magnets need shielding) High mechanical loads

Machine systems difficult to manufacture Complex cooling systems





Magnets at -269 °C



Placema up to ~150,000,000 °C

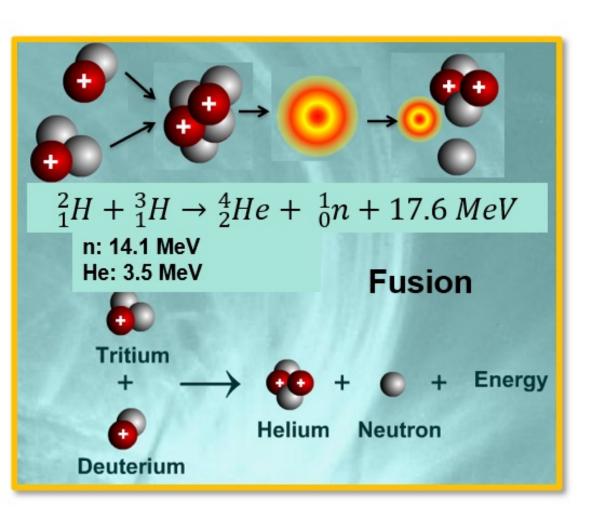
Plasma up to ≈150.000.000 °C

Toroidal field coils Magnetic energy 41 gigajoules Magnetic field of 11.8 Tesla

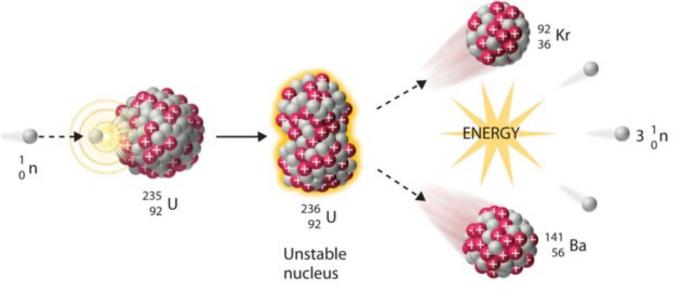
S. Wikman, Jan 2024

Fusion vs Fission





Fission



neutron energy in spectrum ≈ 0.7 – 2 MeV (moderated down to thermal neutrons for easier absorption to maintain chain reaction)

Thermal **n**: 2.2 km/s (0.025 eV)

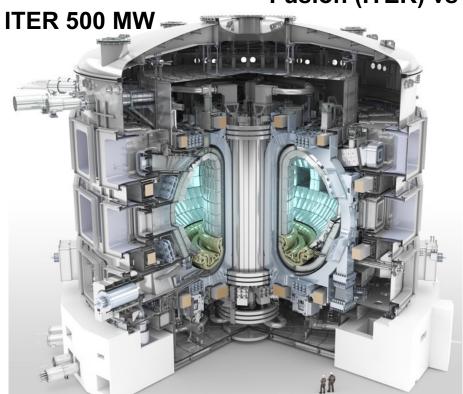
n at fission moment: "5000 – 20000" km/s

Fast fusion **n**: 52000 km/s "Speed of light 300000 km/s"

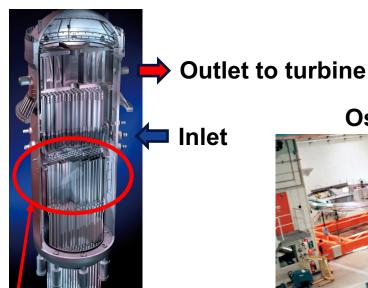
Fusion vs Fission



Fusion (ITER) vs Fission (BWR – Boiling Water Reactor)

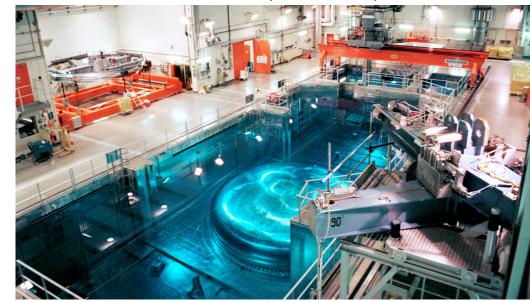


Ultra High Vacuum System Fuel: few single grams (≈ 5g)



BWR Core (fuel assembly 150 - 250 tonnes)

Oskarshamn O3, Sweden, 1450 MW



BWR immersed in water

- In a fusion reactor core the particles moves "freely" inside the vacuum vessel
- In a fission reactor core the particles are moderated (slowed down) by water

S. Wikman, Jan 2024

European contributions to ITER

Wide range of technical scope



Needs liaison with contractors and consortia

Contact network monitored via:

- F4E Business Intelligence Group
- Big Science Sweden

Most running Hot Cell Building- TBD



To be manufactured

Robotic Remote

Handling

120 MEUR, 20+ contracts

Neutral Beam

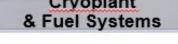
Injectors

To be manufactured

Several contracts

Contract signed





Contract signed



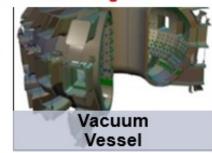






Facility in Padua (IT)

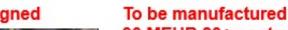
Contract signed

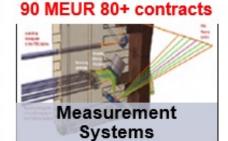


Manufacturing running 600+ MEUR, 20+ contracts Tungsten needed!









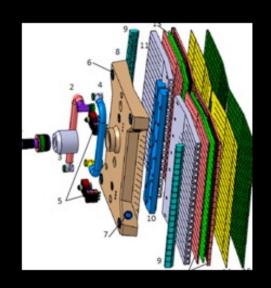
To be manufactured Several contracts + R&D



S. Wikman, Jan 2024

Major machine systems exposed to high temperatures and neutrons





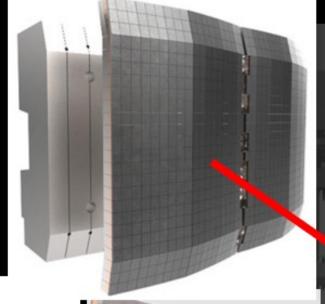
Steel pipes

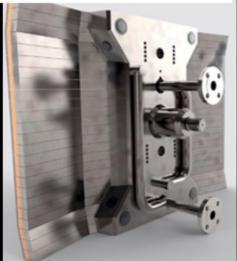
Steel drilled

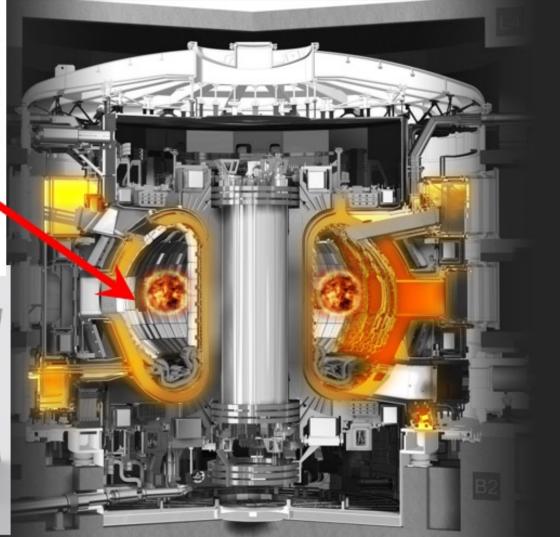
4Inner

Waterbox

structure







S. Wikman, Jan 2024

CuCrZr ?

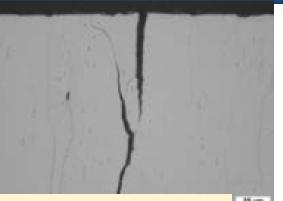
Be tiles

First Wall/Blankets - Procurement Needs

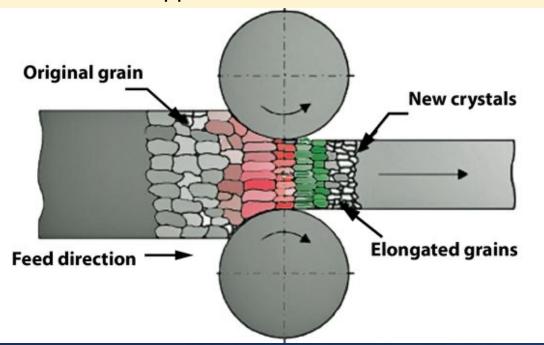
Tungsten







If we know W will eventually crack then design for it Conventional approach until now



75 – 150 tons of W

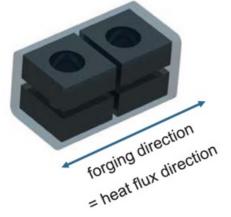
Assessment of design ongoing Qualification will follow



Many variants tested past decade:

- "3D" printing
- Sintering
- Forged
- Hot rolled
- Injection molding

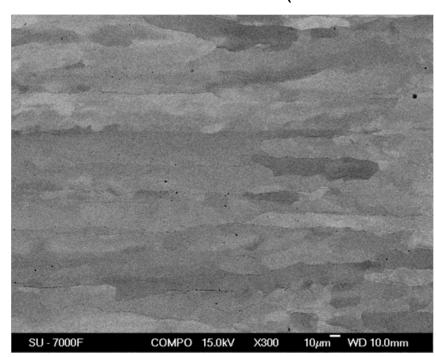
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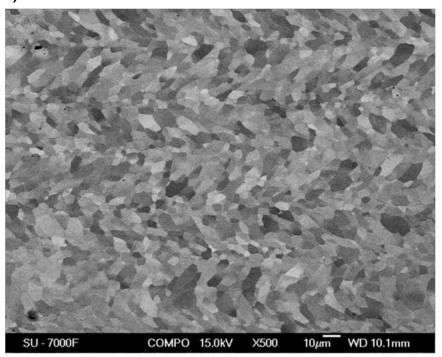


Example of trials with potential for W



Laser Sintered Surfaces (oriented structure)



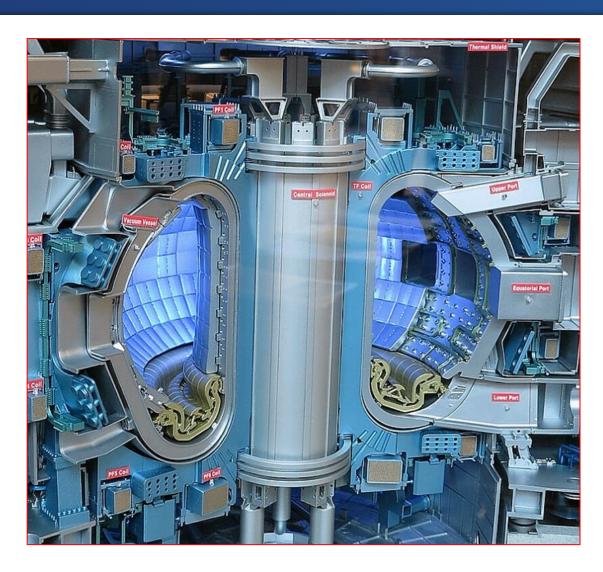


Non-polished W-surfaces due to high accuracy of laser beam (some months work to optimize by Ph.D. students – Stockholms University)

Now is the time for good ideas for Tungsten

Irradiation Shielding Materials





Shielding material needed Boron Carbide (B4C)

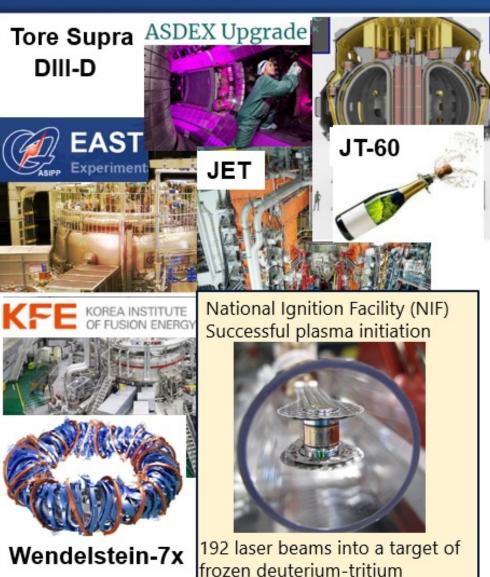
Larger order of about 20 m3 to shield from runaway irradiation (around the Tokamak) + 2 m3 ton customized B-10 grade

Several orders of tailor made shielding for use to protect electronics and sensitive machine systems

<u>Filling gaps</u> to reinforce bio shield for human interaction Likely it will be lots of need as work progresses and good to be ready to offer supply

FAQ: Successful plasma in media – why don't we have fusion power plants?







IFMIF DONES





Power Plant – still no defined concept

+ more experimental enterprises adding up





Fusion Energy

S. Wikman, Jan 2024

Engineering

Fusion Development Program – NEW Initiative



EU Funding to be coordinated via F4E

- > Aim is to support labs and small + medium size companies with key competence
- Beyond ITER

ITER is a "stepping stone" to fusion energy – build on lessons learnt towards power plants Implementation of new technologies that couldn't be used for ITER

Tailor made contracts to develop and qualify promising technologies

- Electrical Engineering diagnostics, plasma operation
- Materials Development New concepts that can manage long term exposure to fast neutrons and heat flux
- Manufacturing process development additive manufacturing, coating technologies, tailor made solutions for fusion, qualify existing materials for fusion
- Exposure qualification testing of new concepts to coolant medias and neutrons
- Much more to be decided

On the table now is a plan for 50 MEUR per year – launch 2024 and ramp up coming years

Qualification and readiness reviews



Solving material issues to verify performance

- ➤ **Definition of Design Criteria** What properties shall be met to withstand operational conditions?
- Definition of Acceptance Criteria What is an acceptable defect/performance?
- Qualification According to Codes & Standards Variants of tests.
- Irradiation Campaigns at ITER Relevant doses Variants of tests.
- Assessment of Corrosion in Heat Transfer Systems Corrosion is the main parameter determining the life time of any power plant!

Thereafter a Reality-Check

- Can targets on material properties be achieved by series production
- Manufacturability and inspection
- Based on testing which does not appreciably degrade the components?
- Acceptance programme can never fully guarantee actual performance
- The ease with which components can be replaced

Many material combinations never used before, or never interacted in this way before...

ITER & Beyond

Need of support coming 20 years!
ITER, DONES, DEMO and Fusion R&D

- Supply of materials
- Supply of machine systems
- Manufacturing processes
- R&D, Development and Testing



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F4E



Rui Franqueira
Ximenes
Project Mechanical Engineer
CERN



Materials And Advanced Manufacturing Swedish Big Science Forum 2024



Rui Franqueira Ximenes on behalf of SY-STI-TCD (CERN)

rui.franqueira.ximenes@cern.ch

31/01/2024

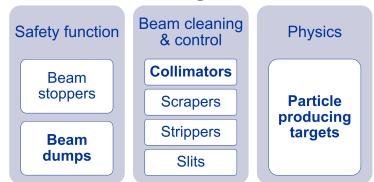


"Provides a unique range of particle accelerator facilities to researchers, to advance the boundaries of human knowledge."

- ❖ 17,500 people (2500 staff)
- ❖ 110 nationalities
- ❖ 23 member states
- ❖ > 60 km of tunnels
- A very wide range of technologies and services required

Sources, Targets & Interactions (STI) Target, Collimators & Dumps (TCD)

 In charge of designing, building, installing and operating all primary beam intercepting and their respective systems at CERN.



- Responsible for R2M studies
- Technical coordination of target areas.



Materials And Advanced Manufacturing

(some) Future needs for SY-STI-TCD



Supply, machining & HIPing of refractory metals

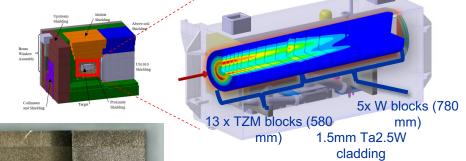
Large size W

- Supply of rolled and forged pure W
- D260, 10-100mm thick
- Mechanical and thermal characterization
- Supply of prototype block 2024-2025
- Series production (2027-2030)

Large size TZM

Refractories for prototype test

- Supply D80xL25-350 of W and TZM cylinders
- Supply of 1 mm Nb and Tantalum tubes & discs
- Hot-Isostatic Pressing of refractories
- Production end-2024 2025



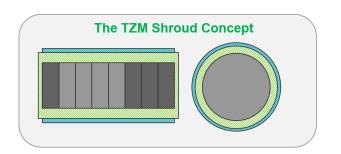


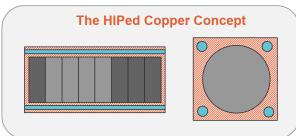


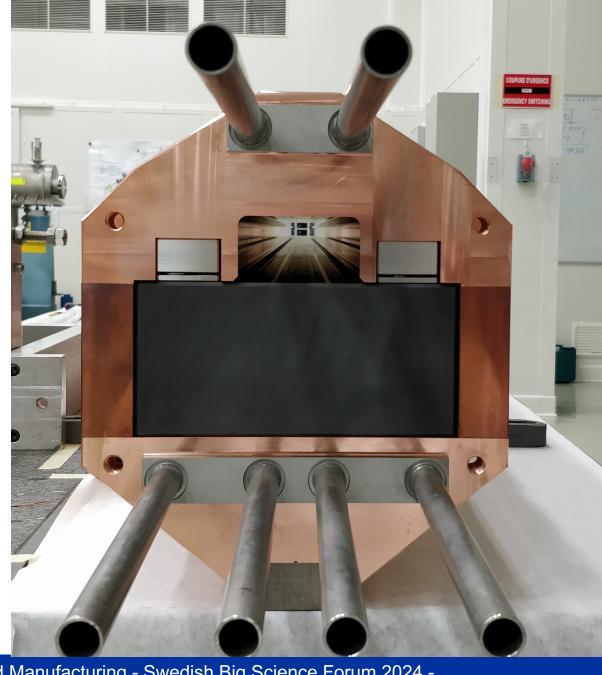
Bonding technology R&D with Cu-alloys, SS and refractories

Technology development

- HIPing of Cu-alloys with Stainless steel pipes
- R&D development for the bonding via HIPing of W and Cu-alloys
- Supply of Refractories
- 2024-2025









CuCrZr machining & marble

Deep drilling

- Deep drilling of CuCr1Zr plates
- Ø18 20 mm over 4000 mm length
- 2nd half 2025

Hot Isostatic pressing

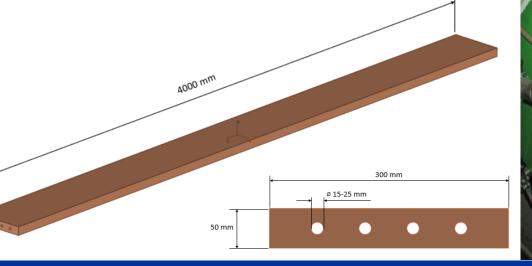
SS pipes HIPed on CuCrZr plates

Marble

 Supply of marble for radiation shielding







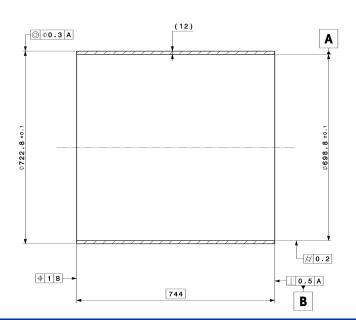




Vessel for the LHC Beam Dumps

Forged allow blanks

- 318LN forged hollow blanks
- Ti Gr 5 forged hollow blanks
- Market survey for one of the two materials coming in Q3 2024







EBW Titanium

Electron beam welding

- Circumferential full penetration welds
- Vessels having of 8.5 m
- Ti Gr 5 with 12 mm thickness
- First prototype 2024
- Final series 2026-2027



Crystal benders

Bender high precision machining

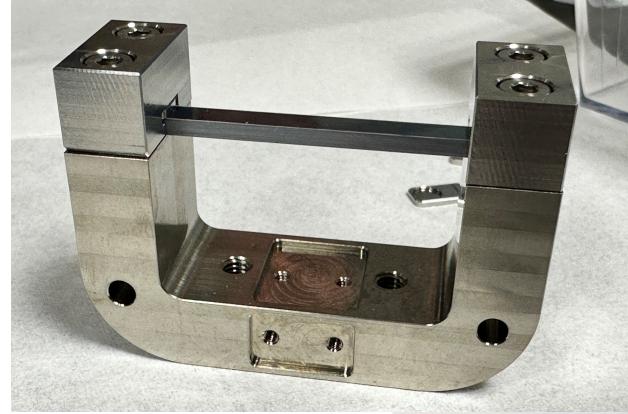
- Surface Ra <100 nm
- Angular orientation precision < 50 μrad
- Crystal relative orientation accuracy: 20 µrad

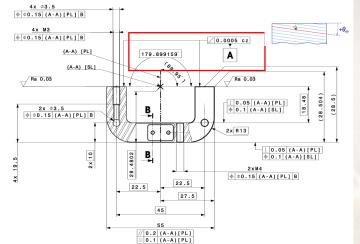
Benders in non-metallic materials

- Direct machining in non-metallic materials
- Bonding of a small metal layer on non-metallic bender

Crystal strip machining

- Surface Ra <50nm
- **Miscut <10 μrad** (require X-ray characterization)









LiH absorber

LiH absorber

- Supply of prototype block of LiH
- Solid discs produced from power via HIPing
- Coating (e.g. parylene)
- Characterization
- · 2024-2025



Conclusions

Current status & upcoming procurements

- Many projects in the pipeline (3y)
- MS, ITs, PO foreseen (and just looking at SY-STI-TCD)

Challenges (for us)

- Small production (few series) of high added value parts
- Joint R&D with industry

Required competencies & Capabilities of suppliers

- Supply/manufacturing of refractories, Ti-alloys, Cu-alloys, LiH, ceramics, and others
- Joining/welding technology
- Material characterization
- High precision machining
- R&D capabilities





Procurement @ CERN

Procurement process

https://procurement.web.cern.ch/home/procurement-process

Countries industrial return

Sweden is poorly balanced!



Open Market Surveys (MS) & Invitation to Tender (IT)

https://found.cern.ch/java-ext/found/CFTSearch.do

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BREAK

Swedish fika - refreshments with opportunities for informal networking and 1-to-1 meetings

