

Skills and fabrication facilities available in EN-MME

Jorge GUARDIA, on behalf of the EN-MME Main Workshop

RD51 Mini-Week, Topical Session on CERN Workshops

<https://indico.cern.ch/event/1242811/timetable/#20230228.detailed>

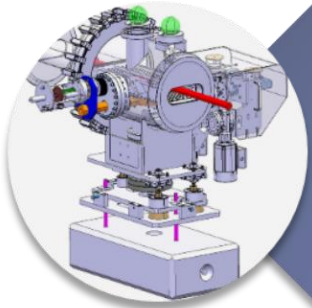
Outline

- **EN-MME group**
- **The EN-MME Main Workshop**
- **Subcontracting activities**
- **Fabrication examples**
- **Technology portfolio summary**

Mechanical & Materials Engineering (MME) Group :

domains of activities

<https://en.web.cern.ch/group/MME>



Design, Simulations and Measurements

- **Largest design office at CERN** using computer-aided design (CAD) software: 40 designers (Staff and Industrial Support).
- **Engineering Unit:** Advanced calculations, analyses and numerical simulations.
- **Mechanical Measurements Lab:** stress and strain, pressure, vibration and thermo-physical characterisation (4 K – RT – 2000 °C).

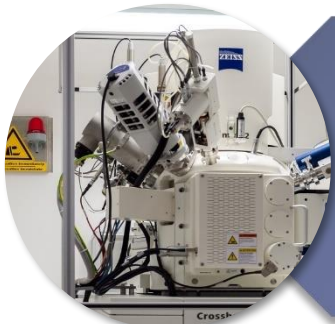


Fabrication

- Machining & Maintenance
- Preparation & Subcontracting
- Assembly & Forming

- 4000 m² of internal **workshop facilities with state-of-the-art equipment**, 50 technicians (Staff and Industrial Support): CNC machining, sheet metal work & welding, electron beam & laser, vacuum brazing, metallic additive manufacturing.
- **External subcontracting service.**

J. Guardia's presentation



Materials, Metrology & NDT

See presentation from S. Sgobba & K.E. Buchanan

- **Material selection, analysis & metallurgy:** optical microscopy, FIB, SEM, XRD, thin-film characterisation, mechanical testing (4 K – RT) and failure analysis.
- **NDT:** ultrasounds, radiography, micro computed tomography.
- 350 m² of **internal metrology facilities:** 3D Coordinate Measuring Machines (CMM)

MME Mechanical Workshop



Aerial view of bld. 100 (~1957)

A real **heritage of CERN** (1957-2023)

Guaranteeing 70 years know-how in **fabrication of mechanical components for accelerator and experiments**

Its core mission is to provide service to the Organization for:

- **Urgent needs** (repairing, tunnel interventions, urgent fabrication...)
- **Prototypes / proof of principle**
- **Multi-technology fabrication projects**

Knowledge Transfer to external collaborations and suppliers



Some numbers...

- Total workshop surface of ~**4000** m²
- Featuring **40+** conventional and unconventional machines
- ~**90** highly-skilled technical personnel
- Yearly turnover ~**2500** fabrication “jobs”

Fabrication Technologies: Portfolio

Sheet Metal Forming & Joining Tech.

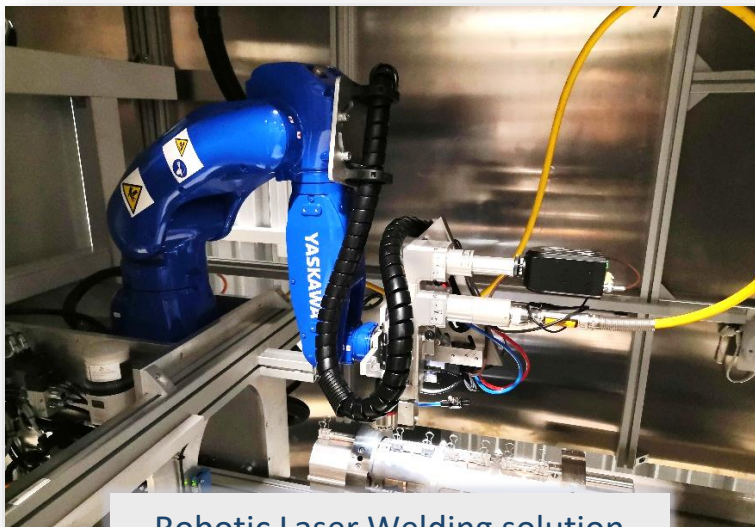
Ref. G. FAVRE
R. GERARD
D. FORESY

Wide **variety of technologies & equipment:**

- Rolling, Bending, Deep Drawing, Spinning
- Arc welding (TIG, MIG, Plasma), Beam welding (Electron Beam & Laser Beam)
- Vacuum Brazing & Thermal treatments

Strong emphasis on welding/brazing quality (ISO 3834 approach)

Specific know-how for on-site interventions in accelerator complex and Experiments



Robotic Laser Welding solution



High precision forming & welding



Sheet Metal Forming & Joining Tech

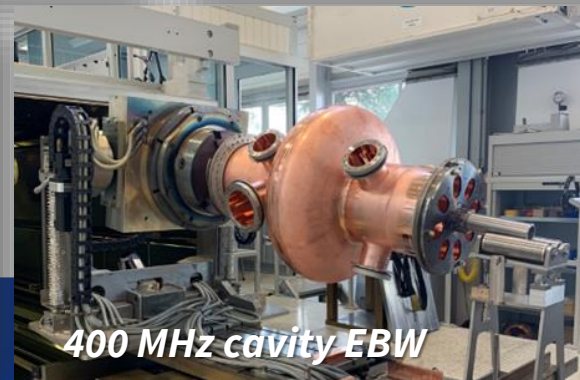
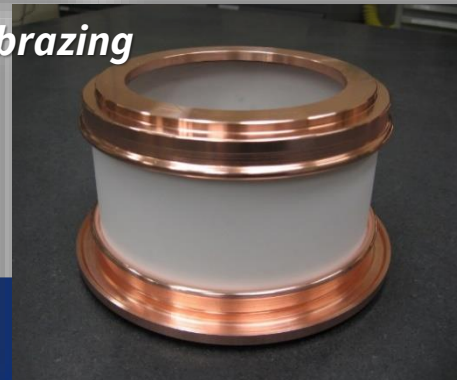
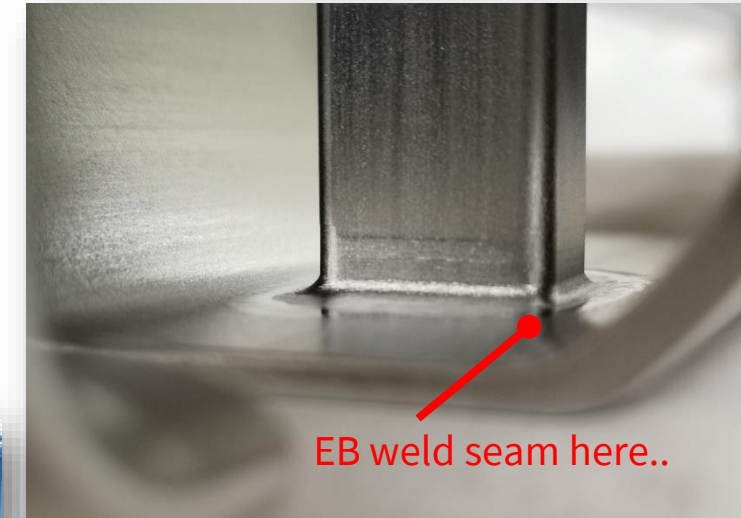
Ref. G. FAVRE
R. GERARD
D. FORESY

Wide **variety of technologies & equipment:**

- Cutting (Laser/Shear), Rolling, Bending, Deep Drawing, Spinning
- Arc welding (TIG, MIG, Plasma), Beam welding (Electron Beam & Laser Beam)
- Vacuum Brazing & Thermal treatments

Strong emphasis on welding/brazing quality (ISO 3834 approach)

Specific know-how for on-site interventions in accelerator complex and Experiments



Machining Technologies

Ref. M. GARLASCHÈ
J-M. GEISSER

Multi-axis machining: **5x Milling / 4x Turning**, Angled head

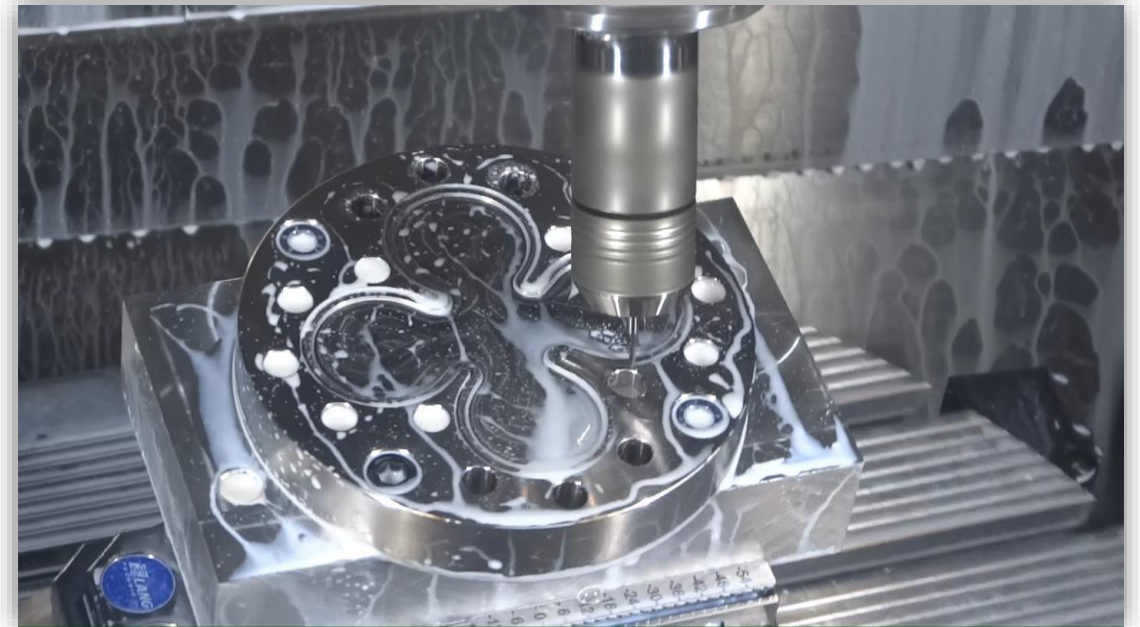
Attainable features : - accuracy : few μm

- roughness R_a : down to few nm

HIE Isolde Monoblock Cavity



5-axis Milling Conflat Flange Knife

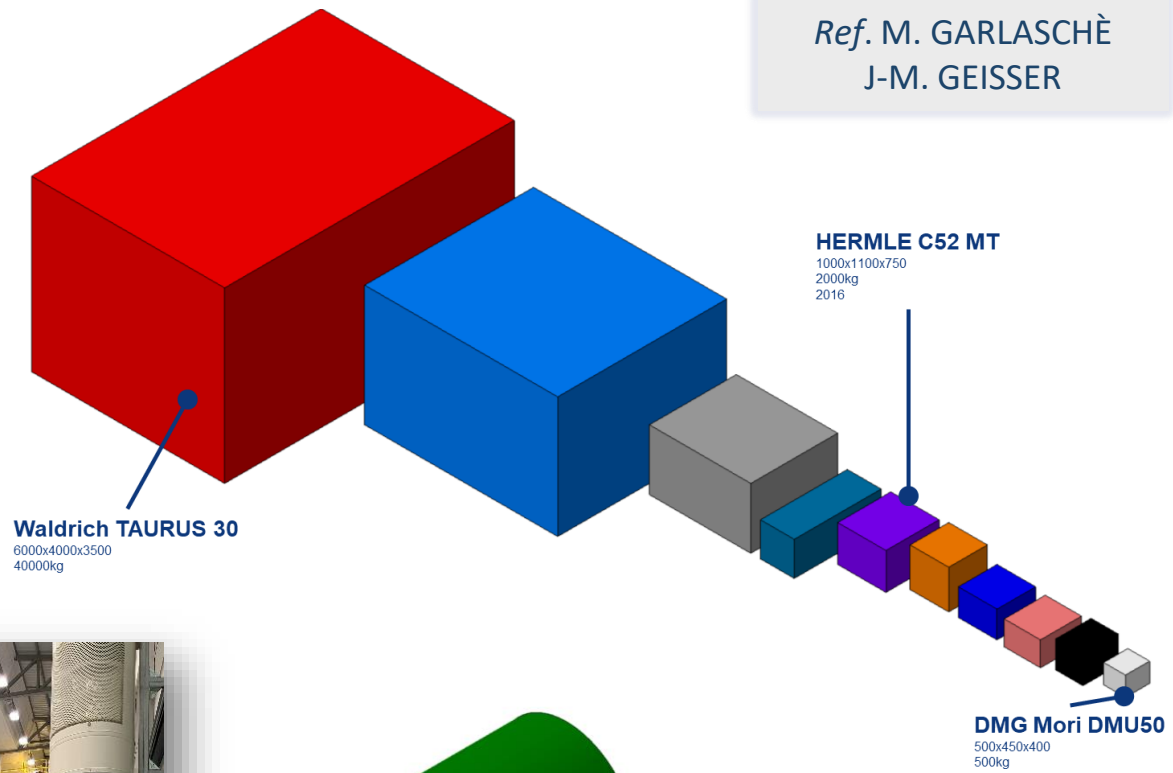


Machining Technologies

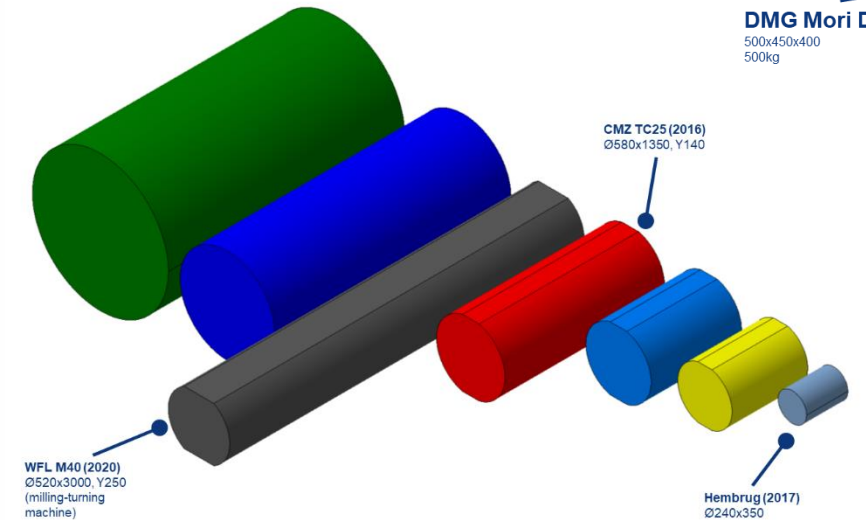
Multi-axis machining: **5x Milling / 4x Turning**, Angled head

Attainable features : - accuracy : few μm
- roughness R_a : down to few nm

Capable workpiece dimensions : **1cm³ → 6m×4m×3.5m** // up to 20 tons



Large Milling Centers Hall (bld. 156)



Machining Technologies

Multi-axis machining: **5x Milling / 4x Turning**, Angled head

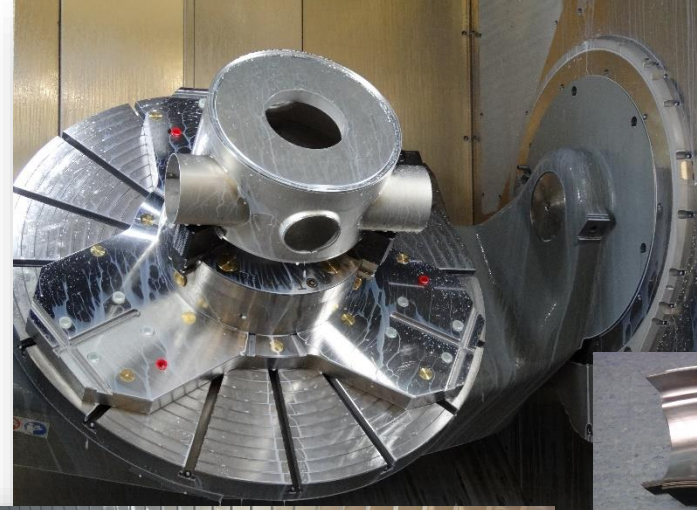
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Capable workpiece dimensions : $1\text{cm}^3 \rightarrow 6\text{m} \times 4\text{m} \times 3.5\text{m}$ // up to 20 tons

Machining **Radioactive Equipment** (bld.109)

Other Services : Open Workshop, Machine Maintenance

Ref. M. GARLASCHÈ
J-M. GEISSER
K. SCIBOR



TCLP Collimator
PROTO



HRMT Multimat2
Cylinder



Non-Conventional Technologies

Electrical discharge machining (EDM)

- **Wire EDM (5 axis) :**
 - Taper angle ($\pm 29^\circ$ max), Rotary axis ($\text{\O}120$ max)
 - Attainable features: Accuracy down to $\pm 5\mu\text{m}$, $R_a0.2$
- **Die-sink EDM**
 - Attainable features: $R_a0.8$



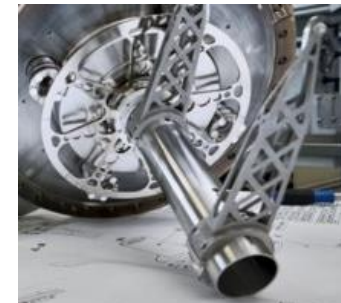
Additive Manufacturing (SLM)

- SLM 280HL (SLM Solutions)
- 400 W laser (1070 nm)
- Tri-axis scanning system
- $280 \times 280 \times 360 \text{ mm}^3$



Materials: Titanium (gr.5), Stainless Steel 316L, Niobium

Typical Applications:
Lightweight, Complex components, cooling channels, small series



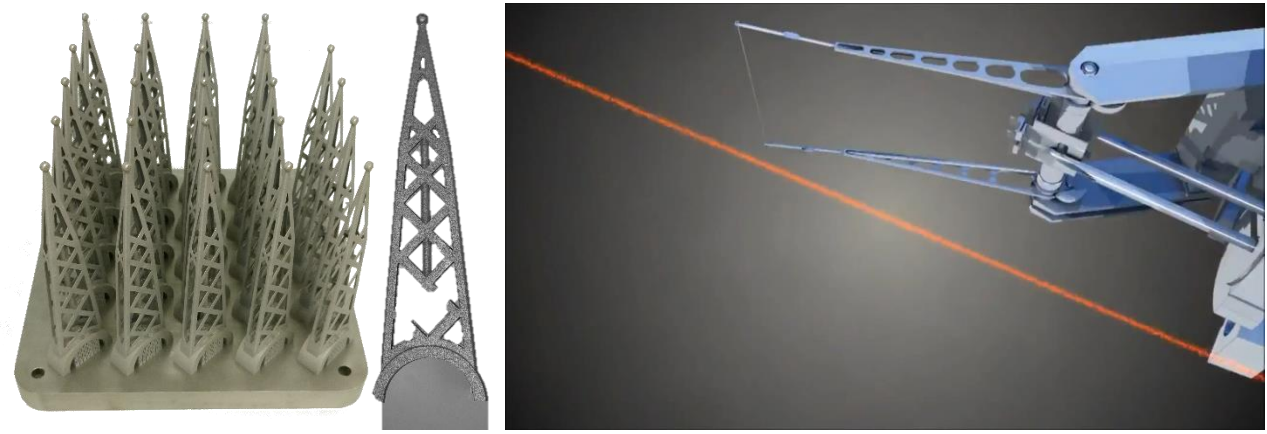
Fast Wire Scanner (Ti gr.5)



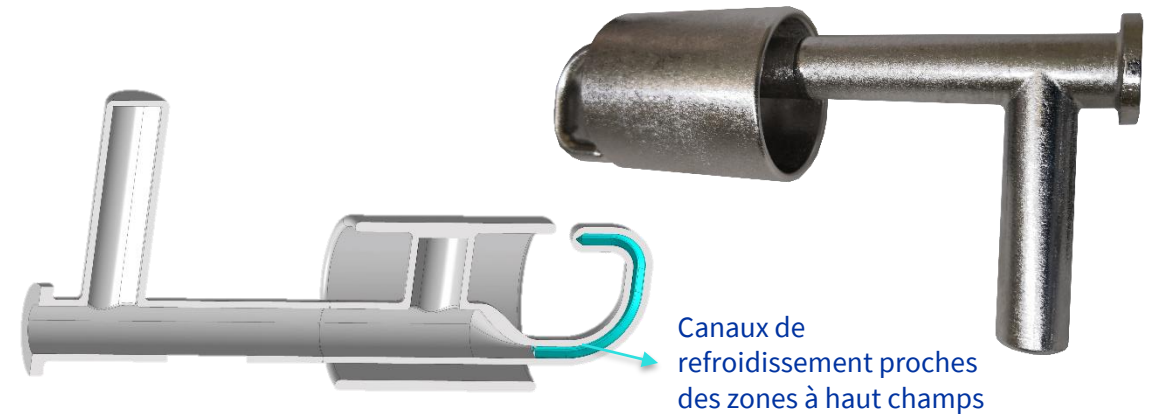
HOM Coupler DQW (Niobium)

Exemples d'applications au CERN

Fourche pour scanner de faisceau à fil
Légèreté et raideur par optimisation topologique

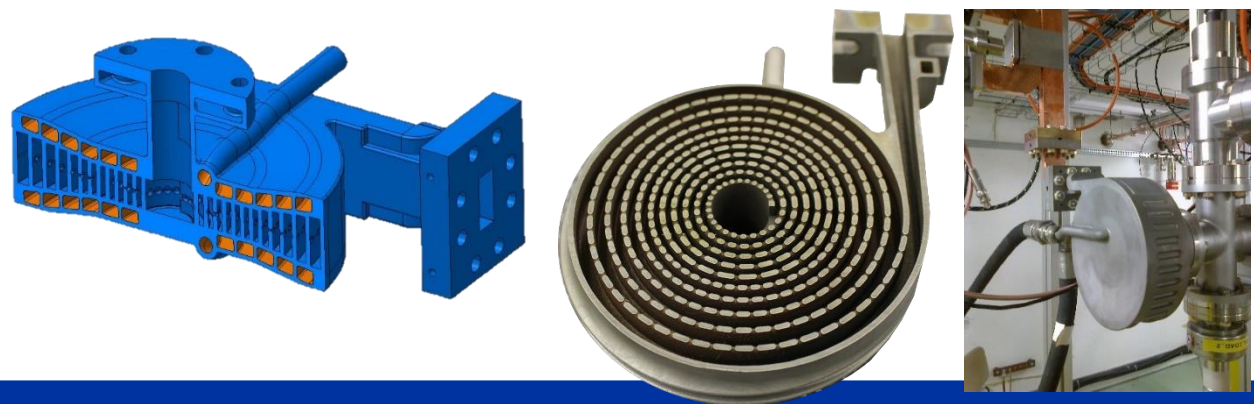


Coupleur HOM en niobium (application supraconductrice)
Ajout de complexité



Canaux de refroidissement proches des zones à haut champs

CLIC RF Spiral loads
Réseau de canaux (RF et de refroidissement)



SPS pumping port shields
Finition des pièces compatible UHV



Tribofinishing + EP

Technical Subcontracting



~40% semi-finished parts
~60% finished parts / turnkey products
900+ suppliers in all Member States

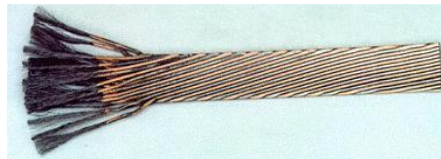
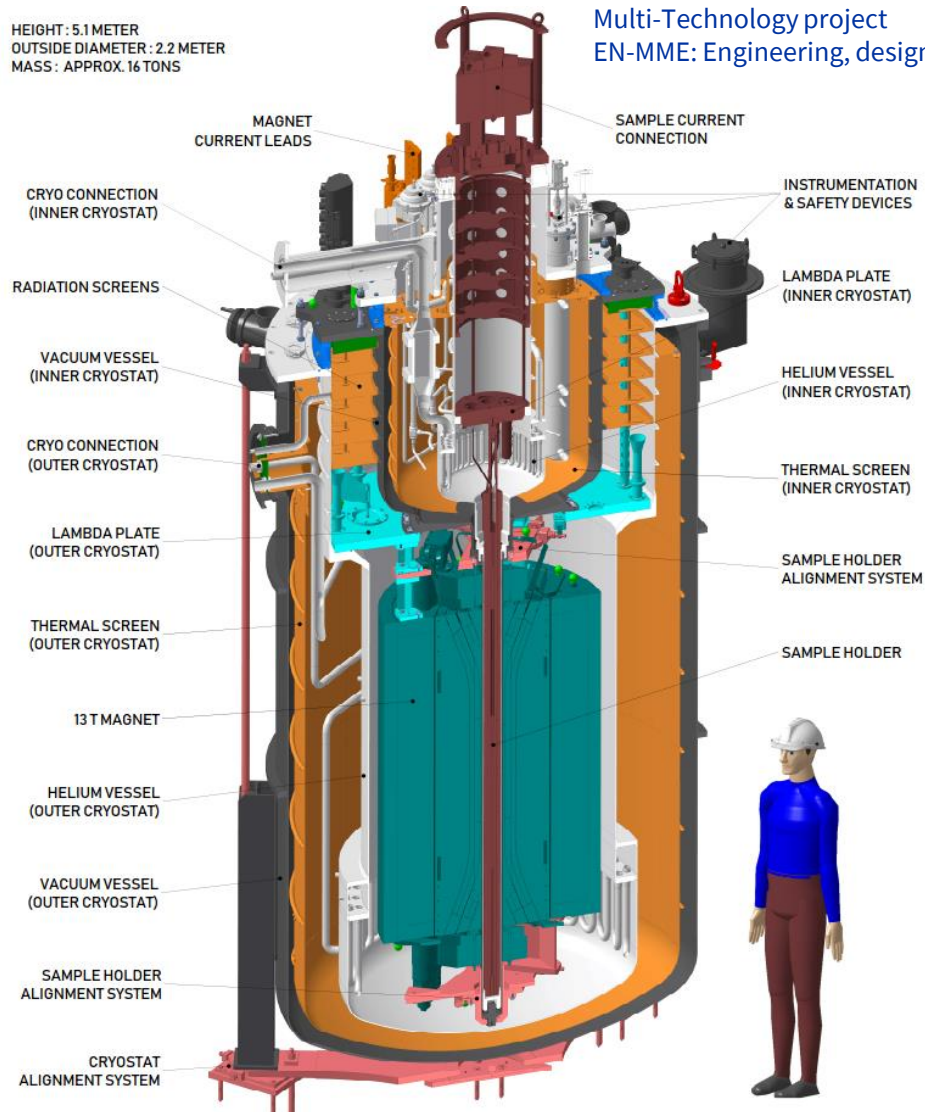
Full Complementarity with in-house portfolio...
...series... additional technologies

Fabrication Technologies: More examples

FRESCA2 double-nested cryostat for superconducting cable tests

Multi-Technology project
EN-MME: Engineering, design and **fabrication (in-house)** of the cryostat

HEIGHT : 5.1 METER
OUTSIDE DIAMETER : 2.2 METER
MASS : APPROX. 16 TONS



NOTE: This project has been successfully completed thanks to the excellent teamwork including all MME services with the valuable contribution of groups within the EN Dept. and across the whole ATS sector.

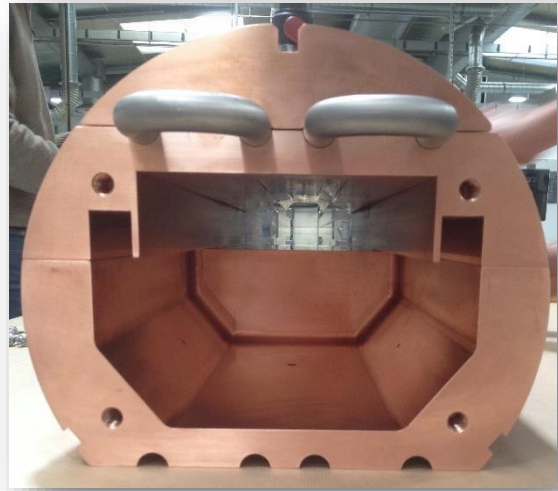
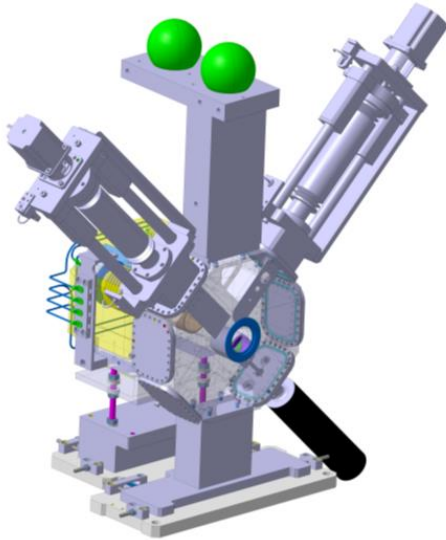
Beam Intercepting Devices: TIDVG4

Beam Diagnostic Components

- Complex bulk pieces with knife-edges for UHV applications
- Raw material from CERN (316LN 3D forged blanks)



Assembling ..welding and tests in house..



Copper blocks: Large CNC milling

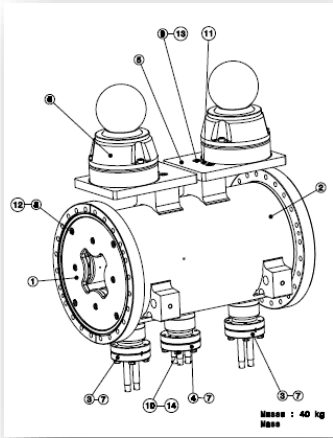


Assembly inside tunnel



Magnets

Prototypes & series of different magnets

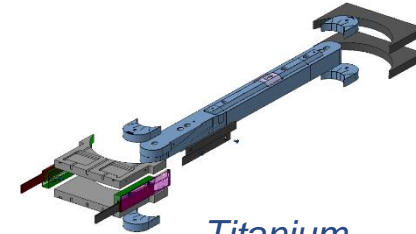
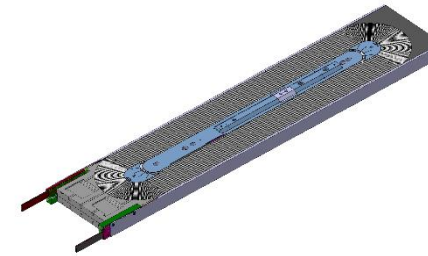


ELENA – Series production of electrostatic quadrupoles (x60). Synergy between EN-MME Workshop and EU suppliers.

- High precision CNC of small to large equipment
- Stamping, wire cut of laminations
- Cryostats

3x RMM prototype Coils for FCC project (R&D)

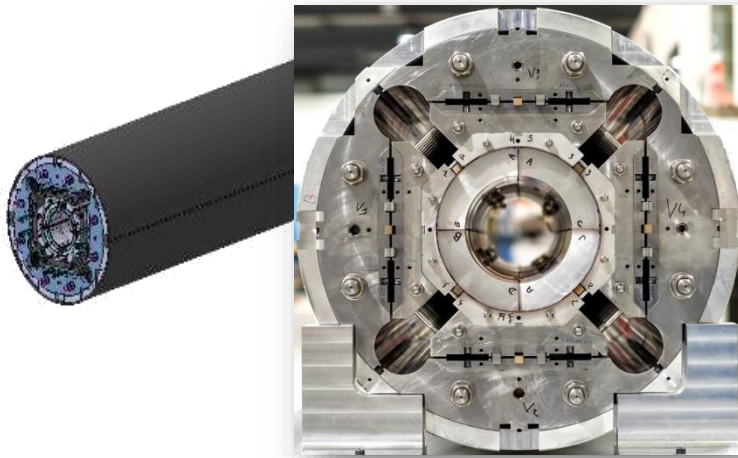
- High precision CNC machining
- EDM (wire erosion)



Titanium

MQXF Superconducting Magnet

..5 axes CNC machining, turning, EDM..



Titanium end spacers



Poles



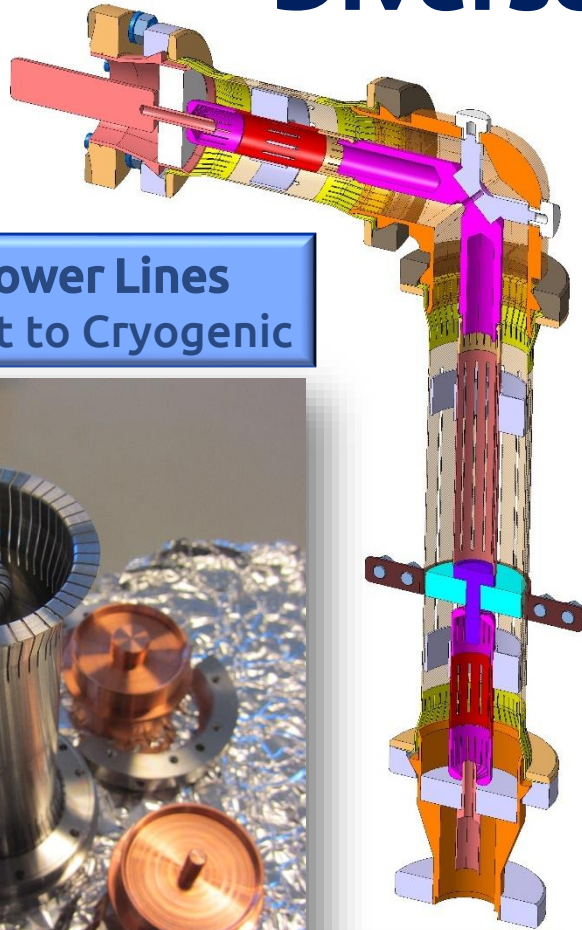
St. Steel 316L

St. Steel 316L



Diverse RF Equipment

RF Power Lines
Ambient to Cryogenic



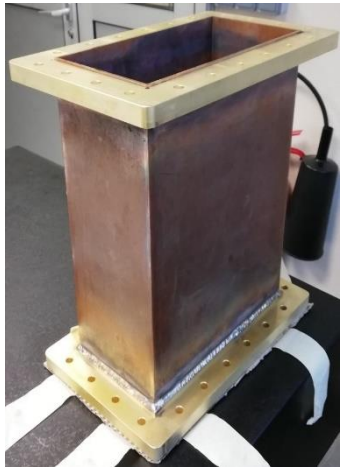
Crab Cavity:
RF Feedthrough



- *EB welding & Ceramic brazing in reduced volume*
- *Machining*

RF waveguides

Brass flanges



Handling, Lifting, Assembly Equipment



Handling Tool for
Chemical Etching

Remote Handling
System for LHC
Collimators



Bespoke Mechanical Lifting
Equipment

Lifting Equipment
for WOW Cavity



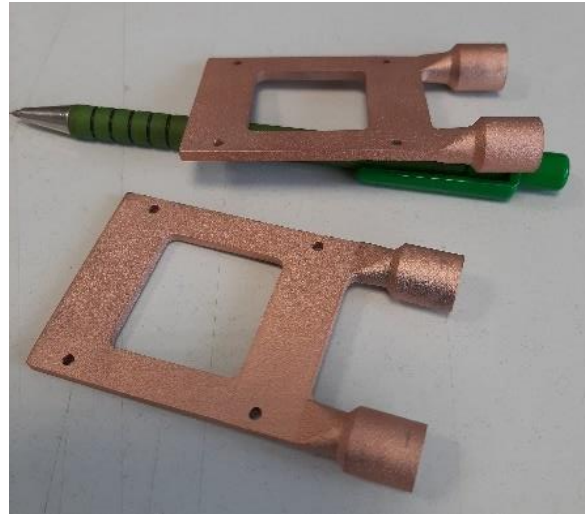
AD Remote
Handling
Trolley



Electronic /Power Racks



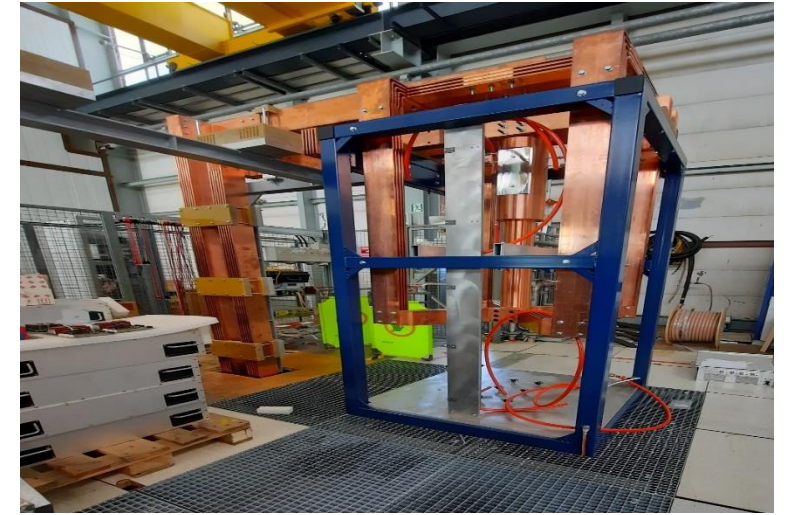
Custom electronic racks



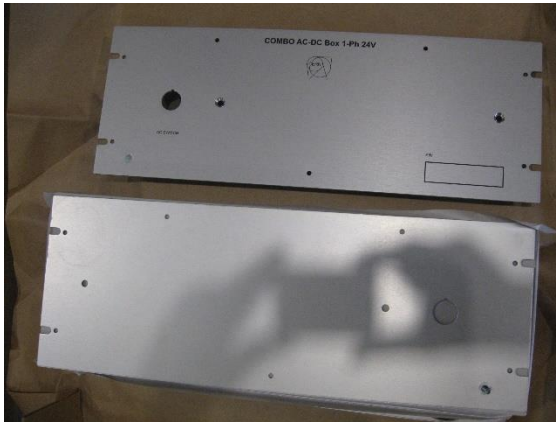
IGBT copper cooling system
(additive manufacturing)



Cu busbars +
Ag coating



Custom power racks, with busbars



Custom boxes/panels
+ paint/coating +
screen print / laser
engraving

Electronic and electro-mecanic parts



Electrical locks



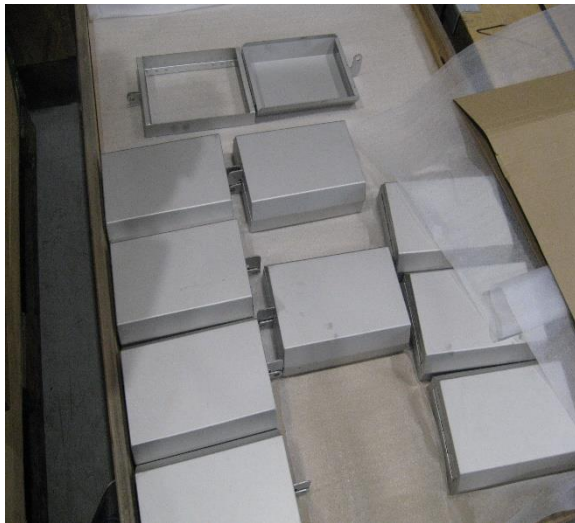
Magnets aluminium parts + gold coating



Polymer isolators



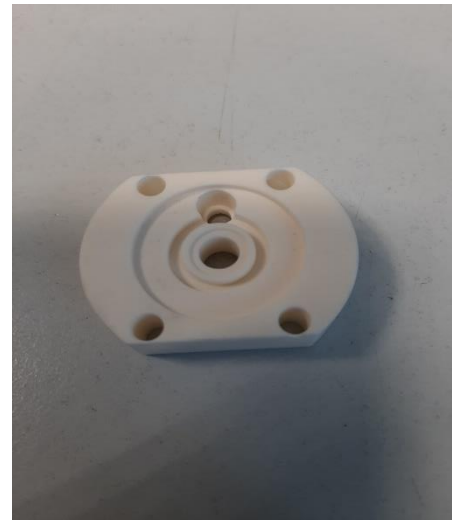
Micro screws



Faraday boxes



Cooling system



Ceramic isolator

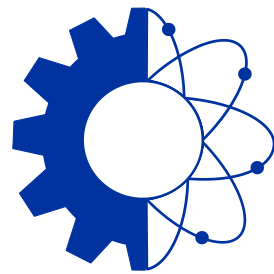


Micro Brass nuts

Technology portfolio summary

- **Machining Technologies**
 - Multi-axis machining: 5x Milling / 4x Turning, angled head
 - Accuracy : down to few μm . Roughness Ra : down to few nm
 - Capable workpiece dimensions : up to 6m \times 4m \times 3.5m // 20 tons
- **Sheet Metal Forming & Joining Tech.**
 - Rolling, Bending, Deep Drawing, Spinning
 - Arc welding (TIG, MIG, Plasma), Beam welding (Electron Beam & Laser Beam)
 - Vacuum Brazing & Thermal treatments
- **Non-Conventional Technologies**
 - EDM (wire and die-sink)
 - Additive manufacturing (SLM)
- **Technical Subcontracting**
 - Finished or semi-finished components
 - Complementary to in-house capabilities
 - Large series production

In-house



**ENGINEERING
DEPARTMENT**

Back-up slides

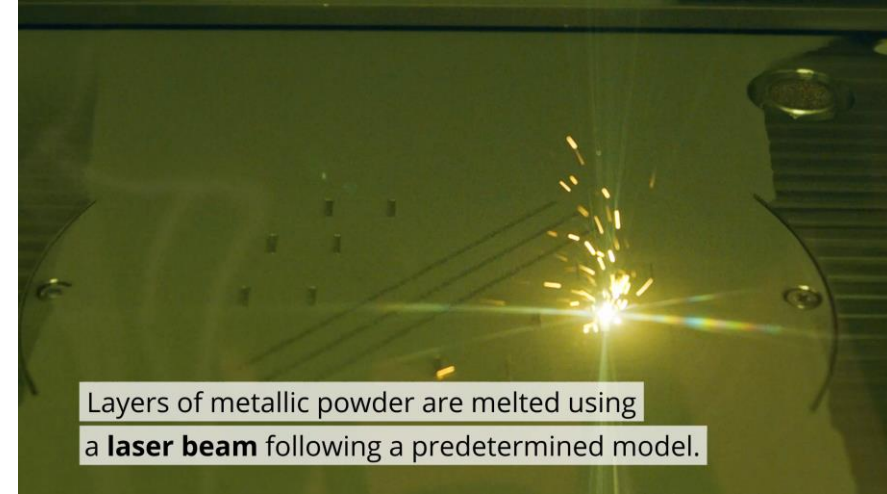
L'atelier de fabrication additive



Système:

- SLM 280HL (SLM Solutions)
- 400 W laser (1070 nm)
- Tri-axis scanning system

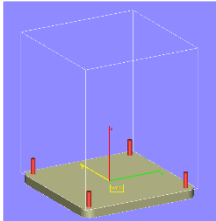
Ref. R. GERARD



Layers of metallic powder are melted using a **laser beam** following a predetermined model.

Volume de travail:

- 280 x 280 x 360 mm^3

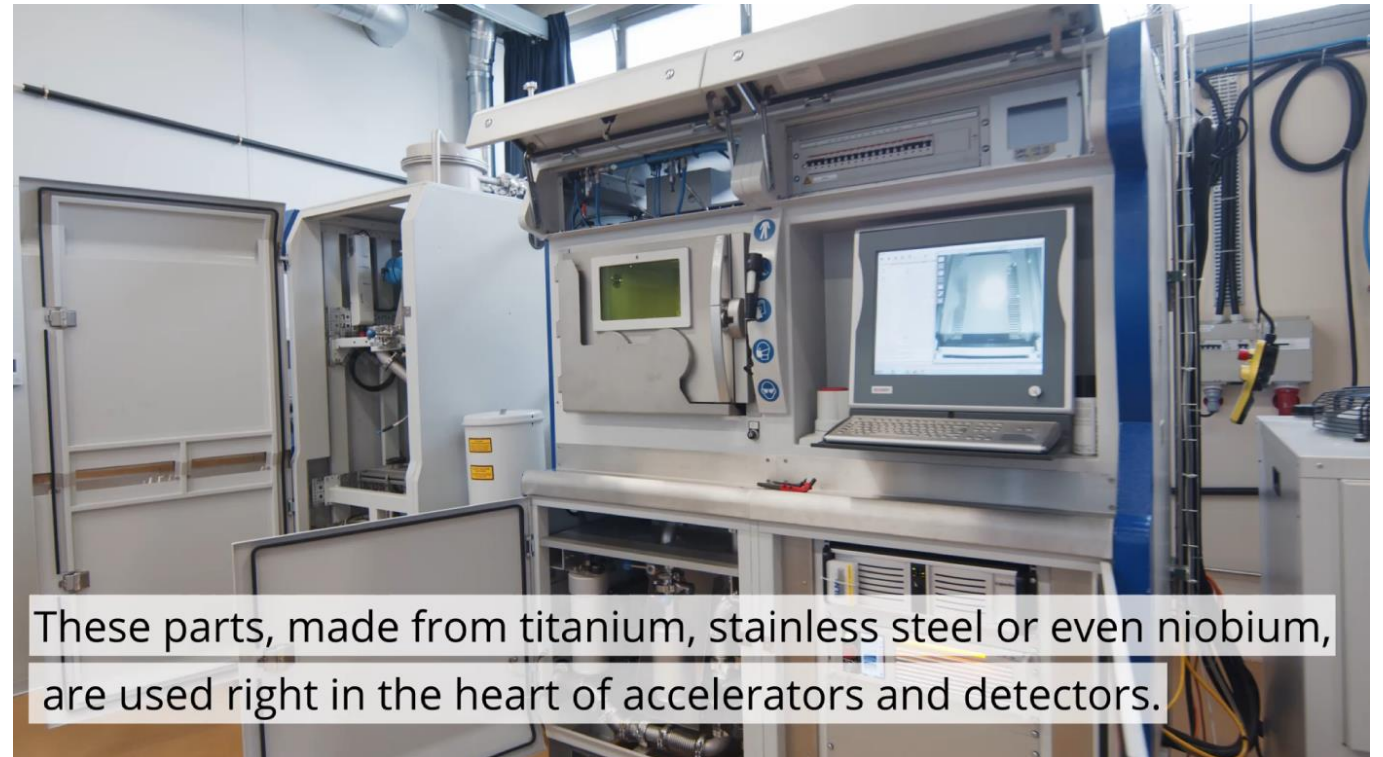


Matériaux:

- actuellement: niobium (R&D)
- autres: SS 316 L/ Titanium alloy gr.5

Localisation:

- CERN Meyrin building 156
- Suisse



These parts, made from titanium, stainless steel or even niobium, are used right in the heart of accelerators and detectors.

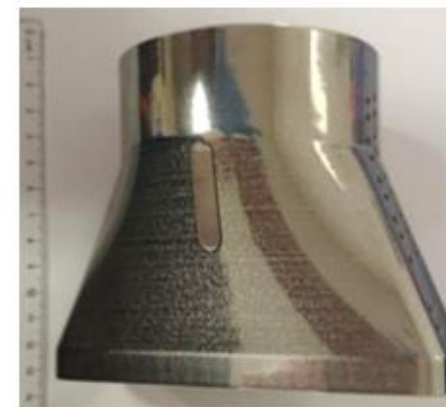
SPS pumping port shielding transitions

- 25 QD-MBB installées dans le SPS lors du Long Shutdown 2.
- Polissage et nettoyage en deux étapes (Tribofinition et électropolissage)
- Dégazage et RGA en accord avec le cahier des charges du SPS

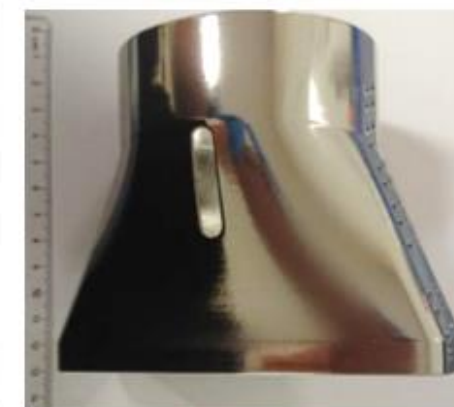
Matière: 316L



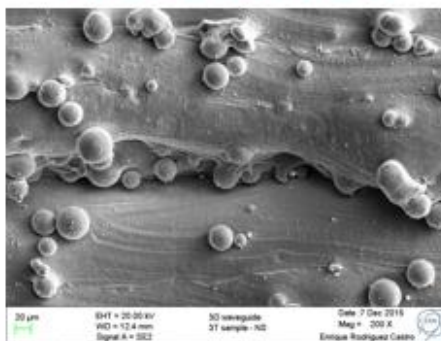
As-built surface
Surface brute de fabrication



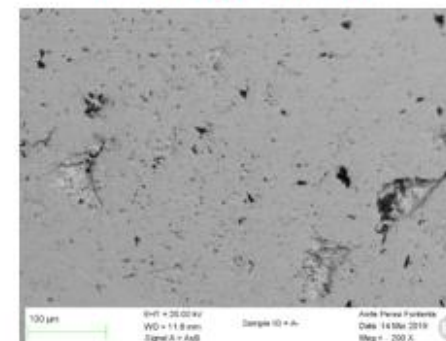
Vibratory polishing
Tribofinition par vibration



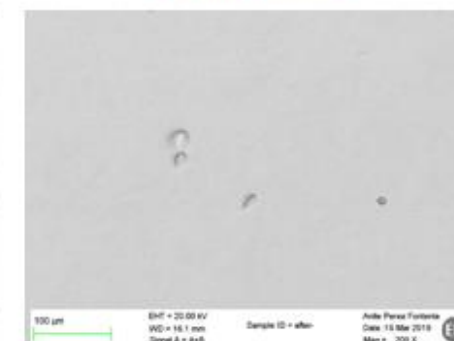
Electropolishing
Electro-polissage



Clean and rough surface, suitable for UHV
Surface rugueuse propre, compatible avec l'ultravide



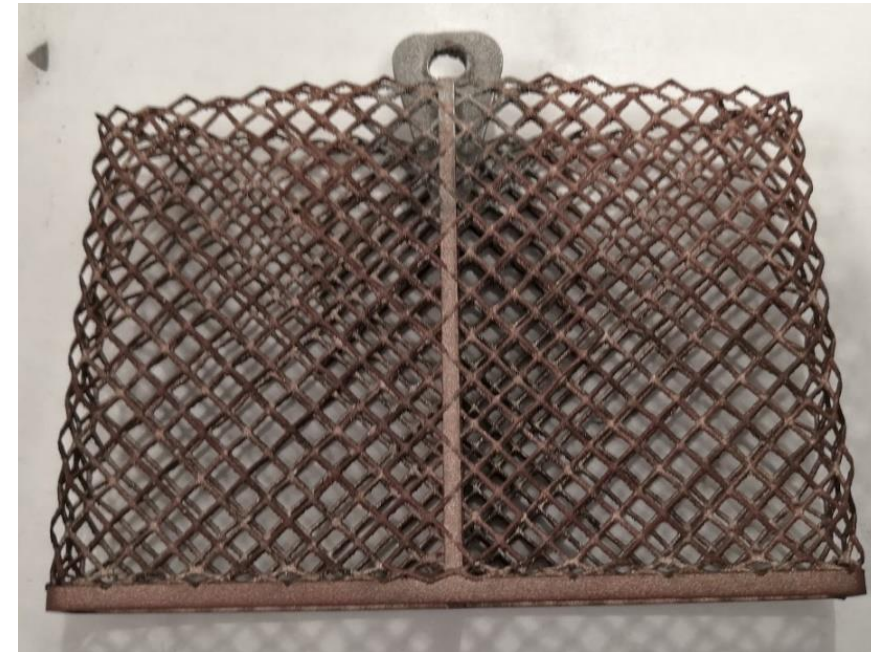
Smooth but contaminated surface
Surface lisse mais contaminée



Smooth and clean surface ideal for UHV and RF
Surface lisse propre idéale pour l'ultravide et RF

Electropolissage avec des cathodes en FA

Enlèvement de matière: 280 μ m en 10 min (surfaces extérieures)



Courtesy of M. Thiebert TE-VSC

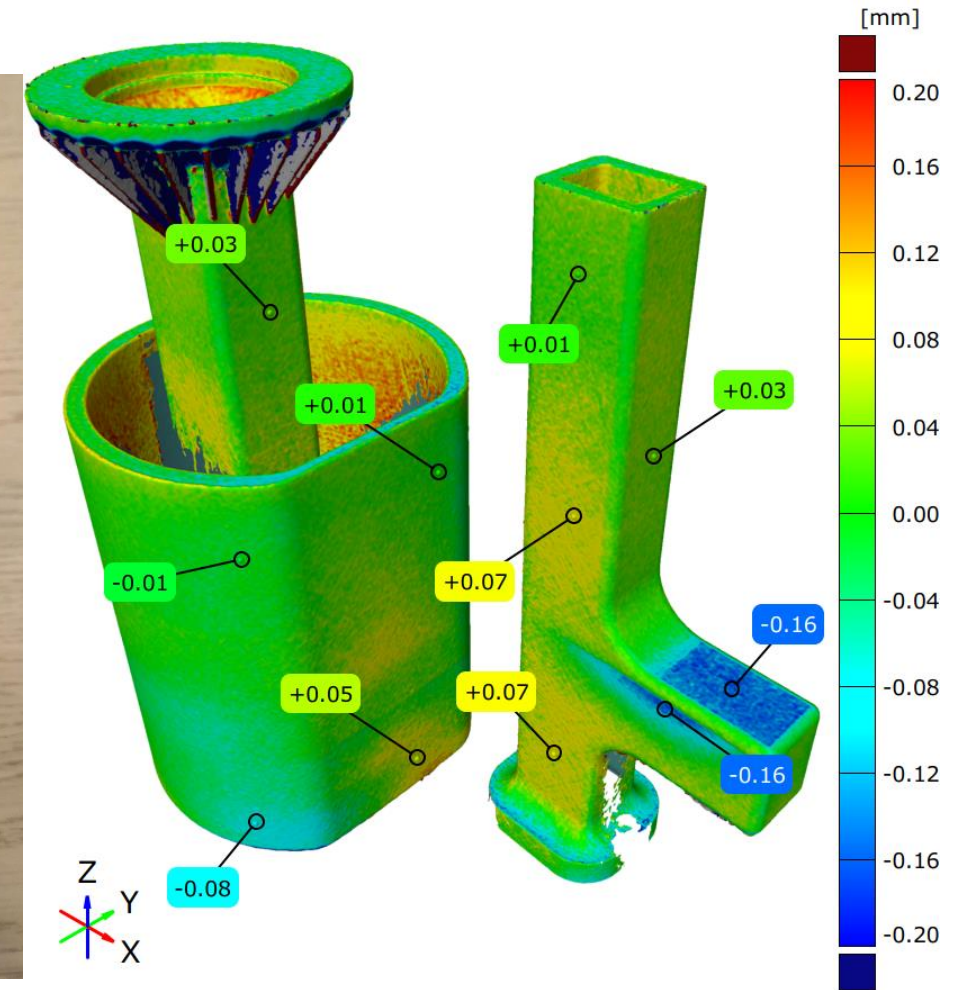
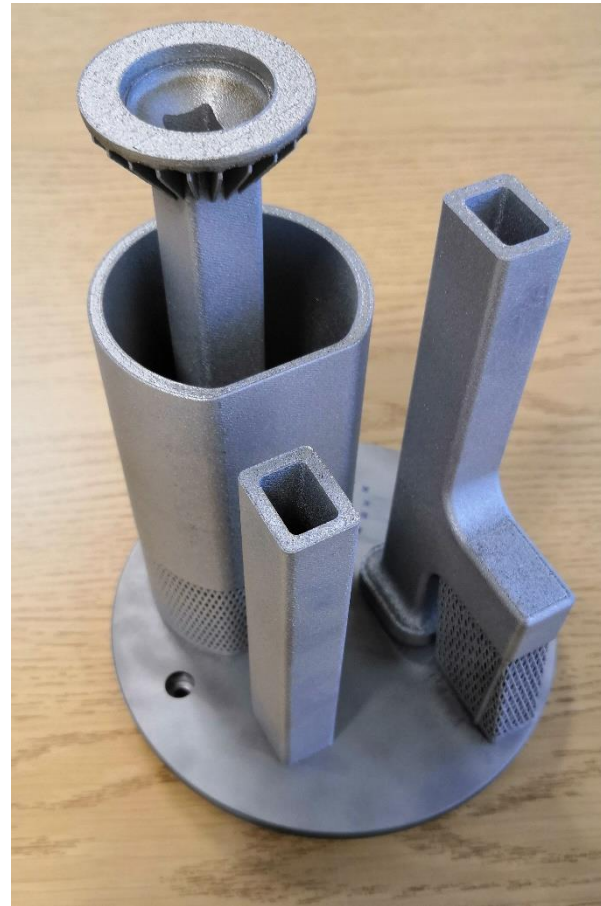
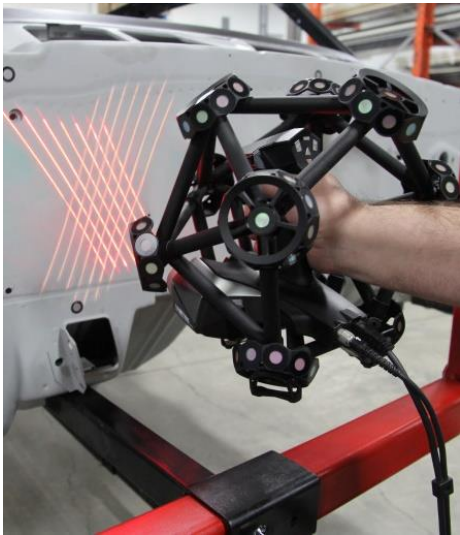
Précision dimensionnelle mesurée avec scanner 3D

SLM niobium:

Précision dimensionnelle: ± 0.2 mm

Après itérations: $\pm 0.10 - 0.15$ mm

Répétabilité entre pièces : ± 0.05 mm



Results courtesy of J.-P. Rigaud (EN-MME-MM)

MME Subcontracting Service: Core & Recent Activities

MME Subcontracting Service:

- in **close collaboration with the CERN Procurement Department**
- strong contribution to **balance the industrial return**
- **2000-2500** contracts/year
~**40% of overall production for mechanical components @ CERN**

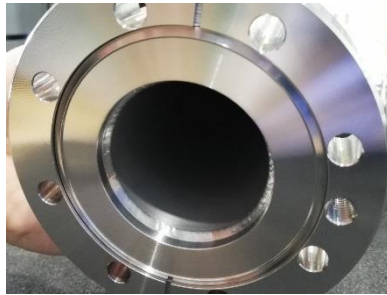
	Invoiced Jobs						
	2016	2017	2018	2019	2020	2021	2022
<i>Subcontracting MME-FS (MCHF)</i>	10	13	13,5	10,7	8	6	8

Subcontracting:

- ~ **40% of semi-finished** parts
- ~ **60% of finished / turnkey** components

High Vacuum Components

Pumping bypass for LHC



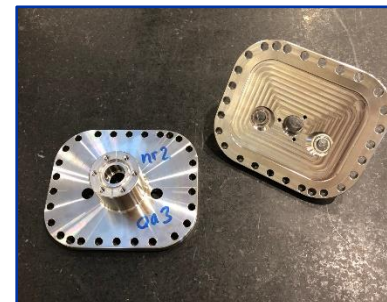
Collimator beam impact test

Technologies:

- Precision forming
(Rolling, Bending, Extrusions..)
- Vacuum brazing & heat treatments
- High precision CNC machining
- Bellows
- Electron beam welding / TIG welding
- Metrology
- UHV capabilities

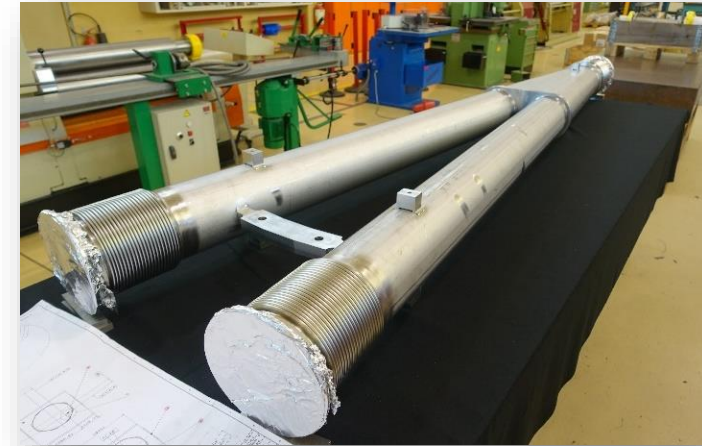
Materials:

- Stainless Steel
- Inconel
- Titanium
- Aluminium
- Copper alloys



ISOLDE UHV Flanges

Y-chambers



Cryocooler Test Chamber



Vacuum Chambers



PSB Ring



- Precise forming into chambers of different sizes
- Inconel & SS alloys
- UHV compliant fabrication

PSB Injection



Hippodrome edge-welded bellows

Pulled-nozzle chambers



Vacuum Vessels



Magnets Tooling

Large Precise Tools for Magnet assembly

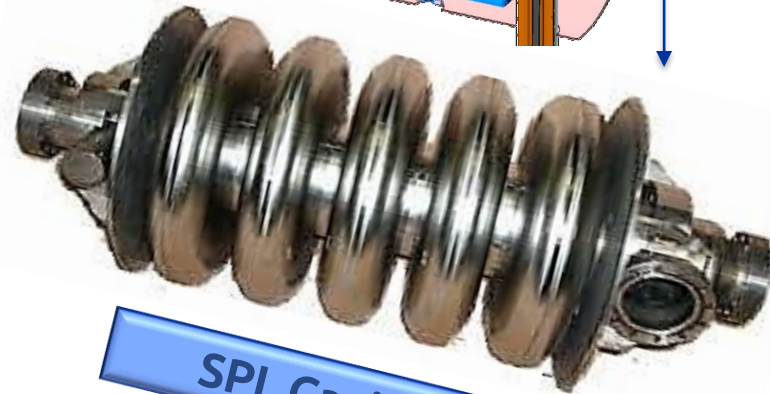
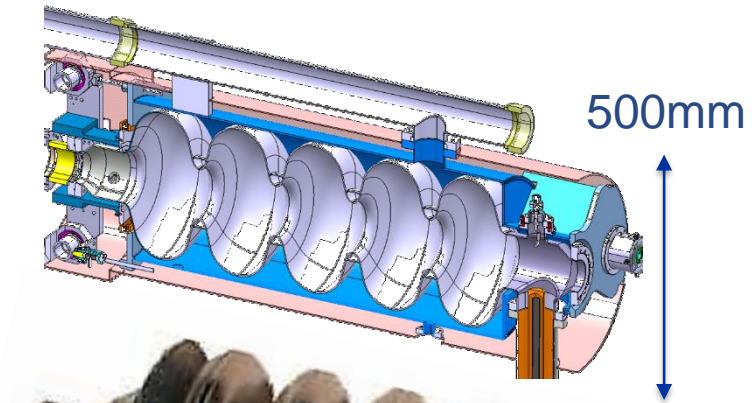
Rotating Table for SC magnets assembly



MQXF & FRESCA Magnet Impregnation & Curing Tools



Superconducting RF Cavities



SPL Cavity

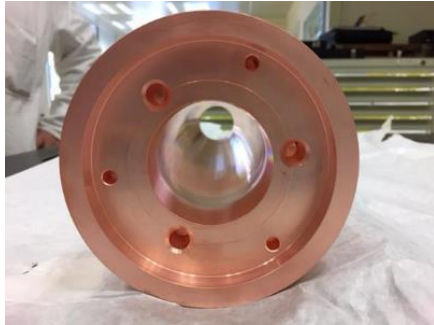
..Spinning..
EB welding

- Prototype: .. Precise forming & joining of Niobium sheets (in-house).. **Precise Tools**
- Series: 100% industry
- Precision and surface quality of utmost importance for cavity performance

CRAB Cavity

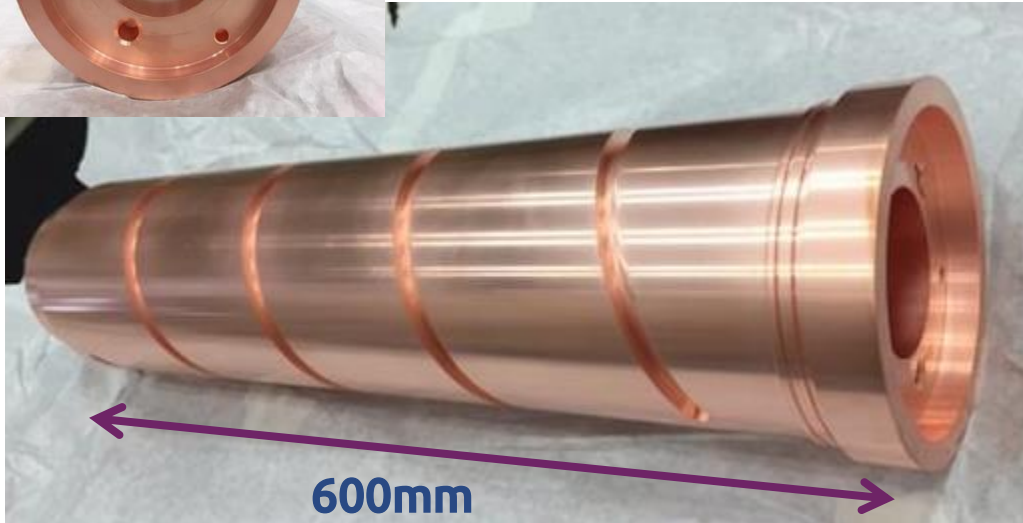


« Warm » RF Cavities

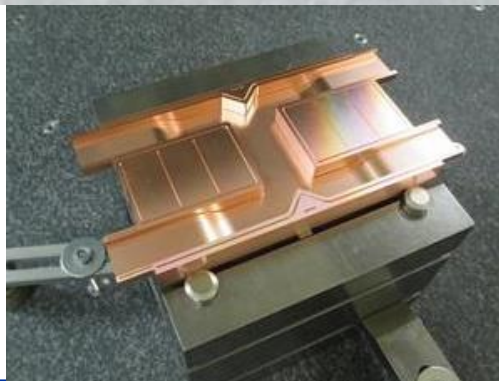


RF Pulse Compressor

*Turn/mill process on Cu
OFE 3D forged*

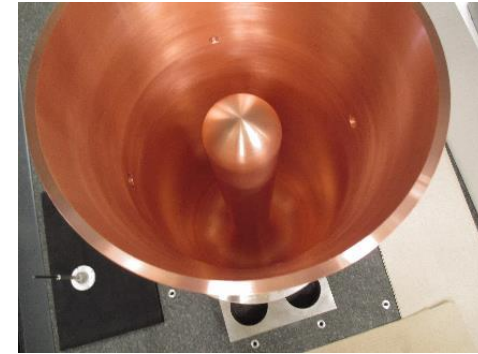


600mm



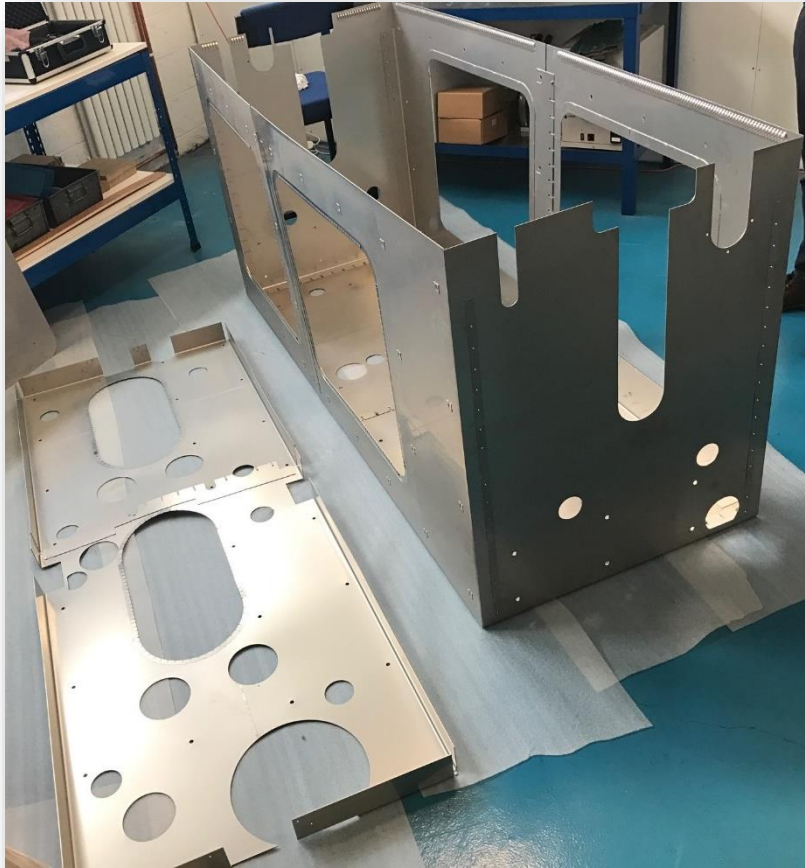
**Copper
Waveguide
Coupler**

HIE- Isolde Cavities



- *Long Overhang Machining from Monoblock Copper*
- *D320 x L900*
- *Tolerances in the tenth of mm..*

Magnetic Shields



Warm Magnetic Shield
MuMetal, 2m wide



Cryo Magnetic Shield
Cryophy, precise forming and thermal treatment