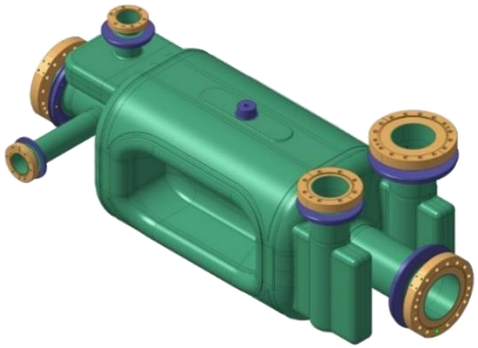
RFD Crab Cavity Manufacturing

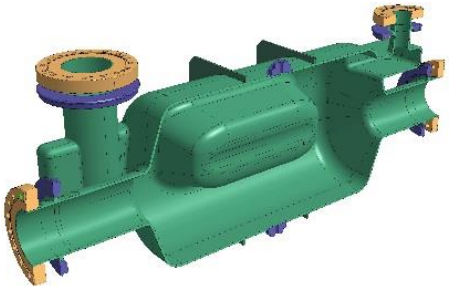
M. Garlaschè on behalf of RFD Prototype Manufacturing Team

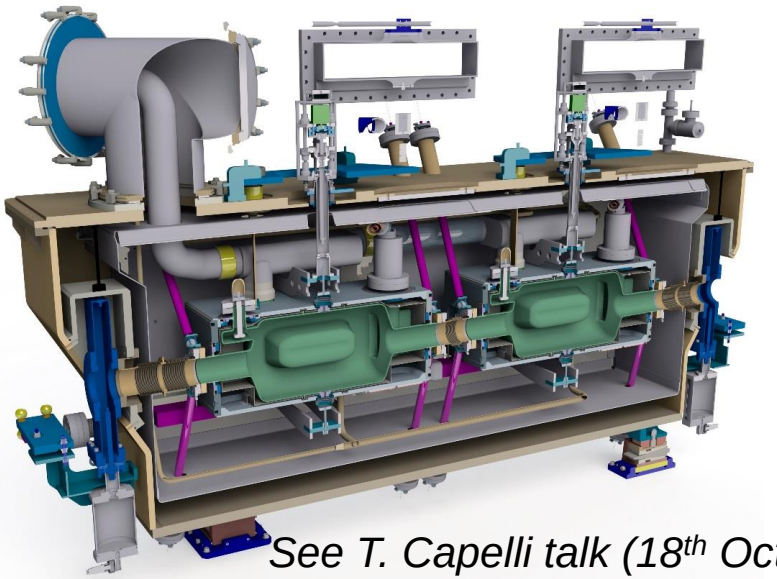
8th HL-LHC Collaboration Meeting – 18th Oct. 2018 (CERN, Geneva)

RFD Crab Cavity Prototypes

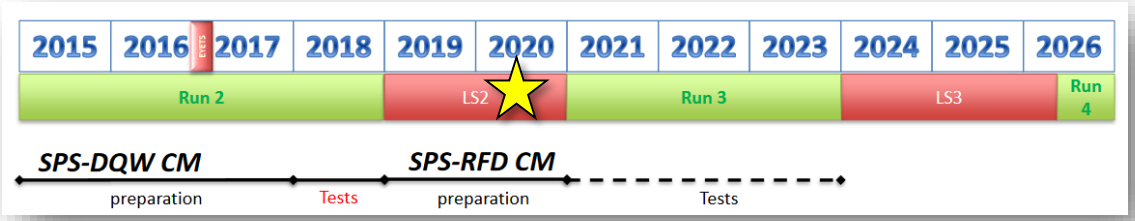
Manufacturing of **2x Jacketed Cavities**







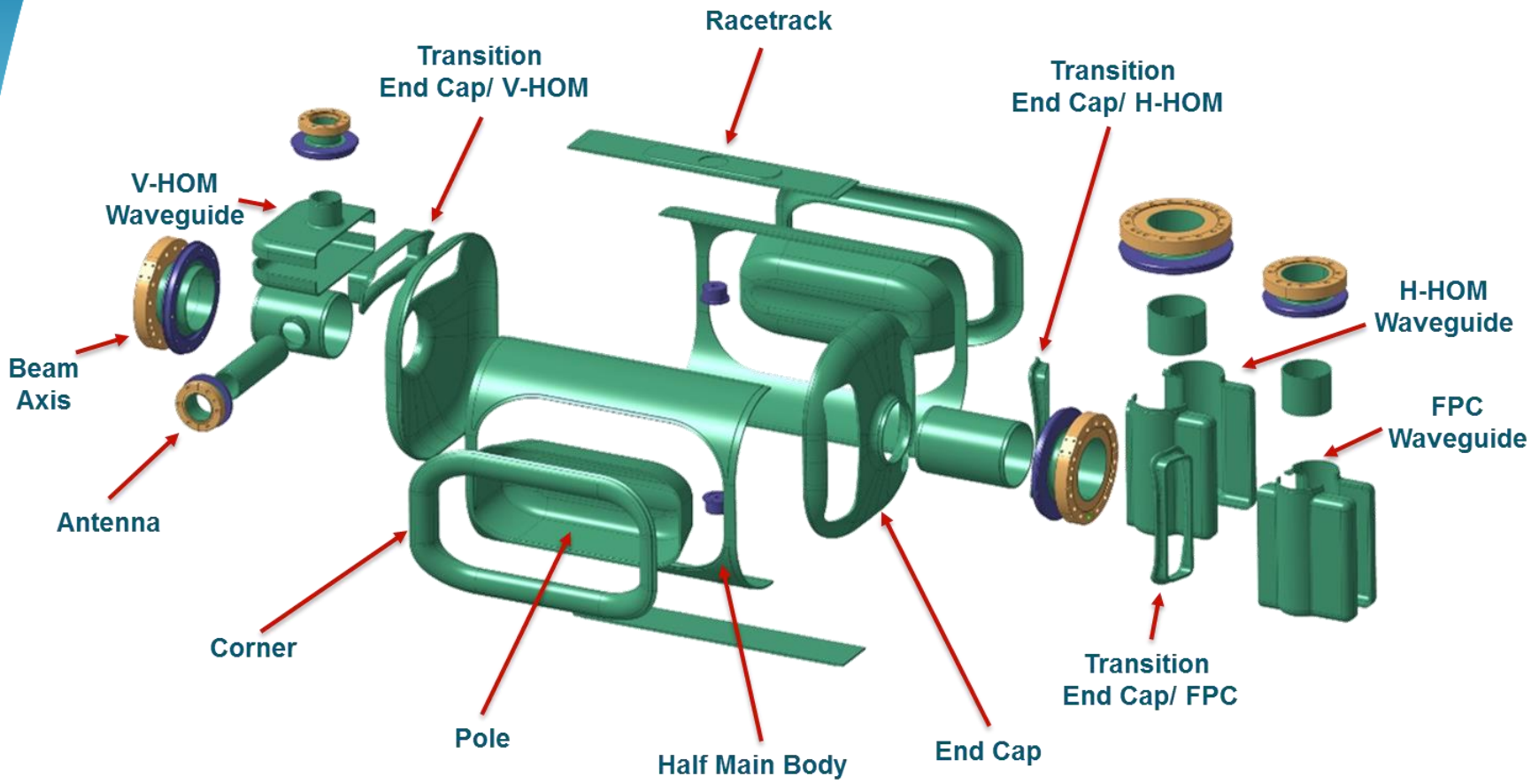
See T. Capelli talk (18th Oct.)



See R. Calaga talk (16th Oct.)

- RFD-SPS cavity fabrication started at CERN, cryostating to be performed at UK and the conceptual design in an advanced stage
- RFD-HL-LHC dressed cavities in-kind contribution from US-AUP with CD1 approval
- RFD-HL-LHC cryostating is approved to be an in-kind from Canada-TRIUMF

RFD Cavity: Manufacturing Cut Out



Rationale behind RFD prototype cut out:

- Favor high-added-value operations (EB welding, trimming)
- Shaping of easiest subcomponents
- Make use of DQW know-how and (tooling!)
- Optimize raw material cost VS. Process (Memento: 2x cavities)

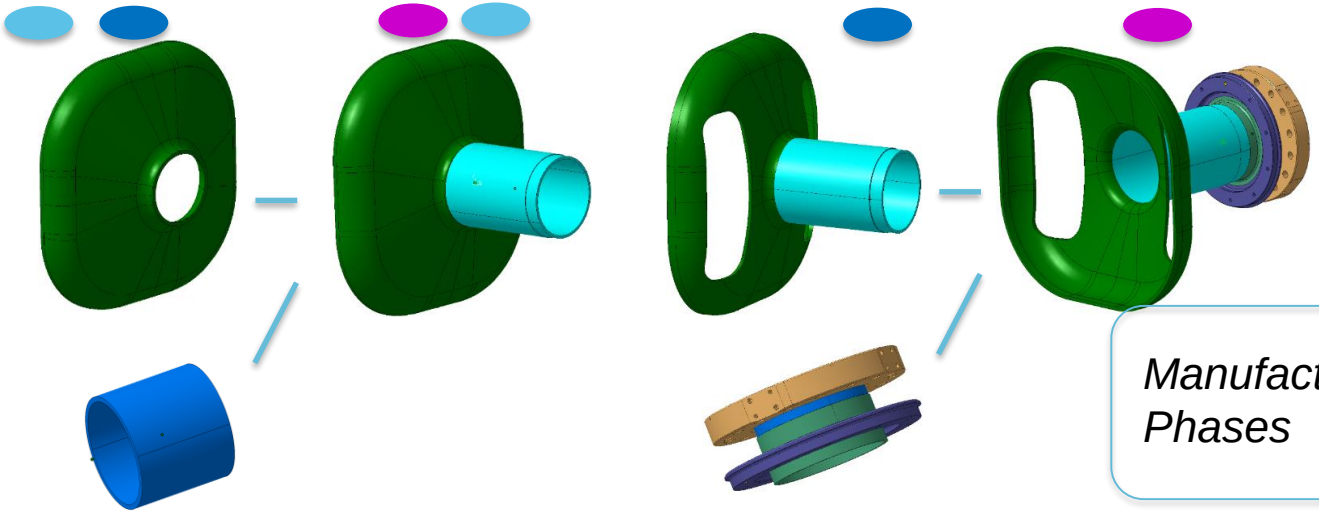
Cavity Build Up

Ports:

Manufacturing Phases

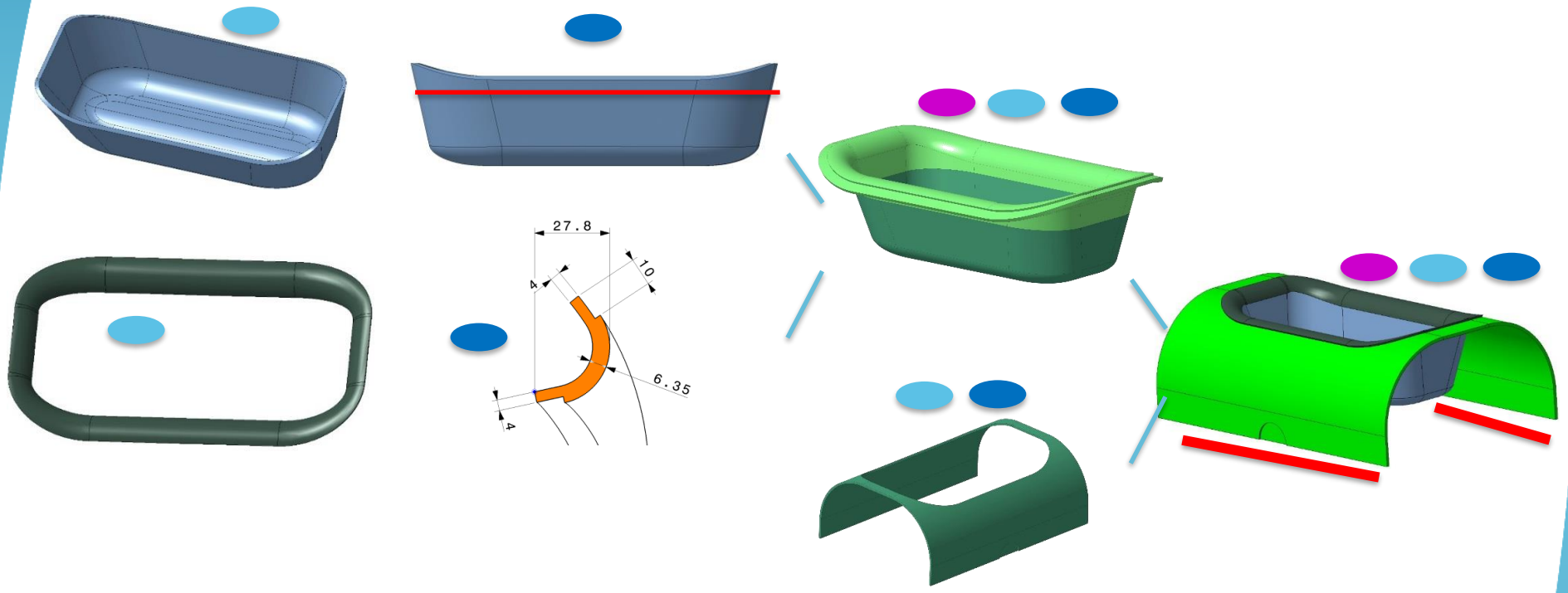
MECA
EB
TOL

Cap:



Manufacturing Phases

Cavity Build Up



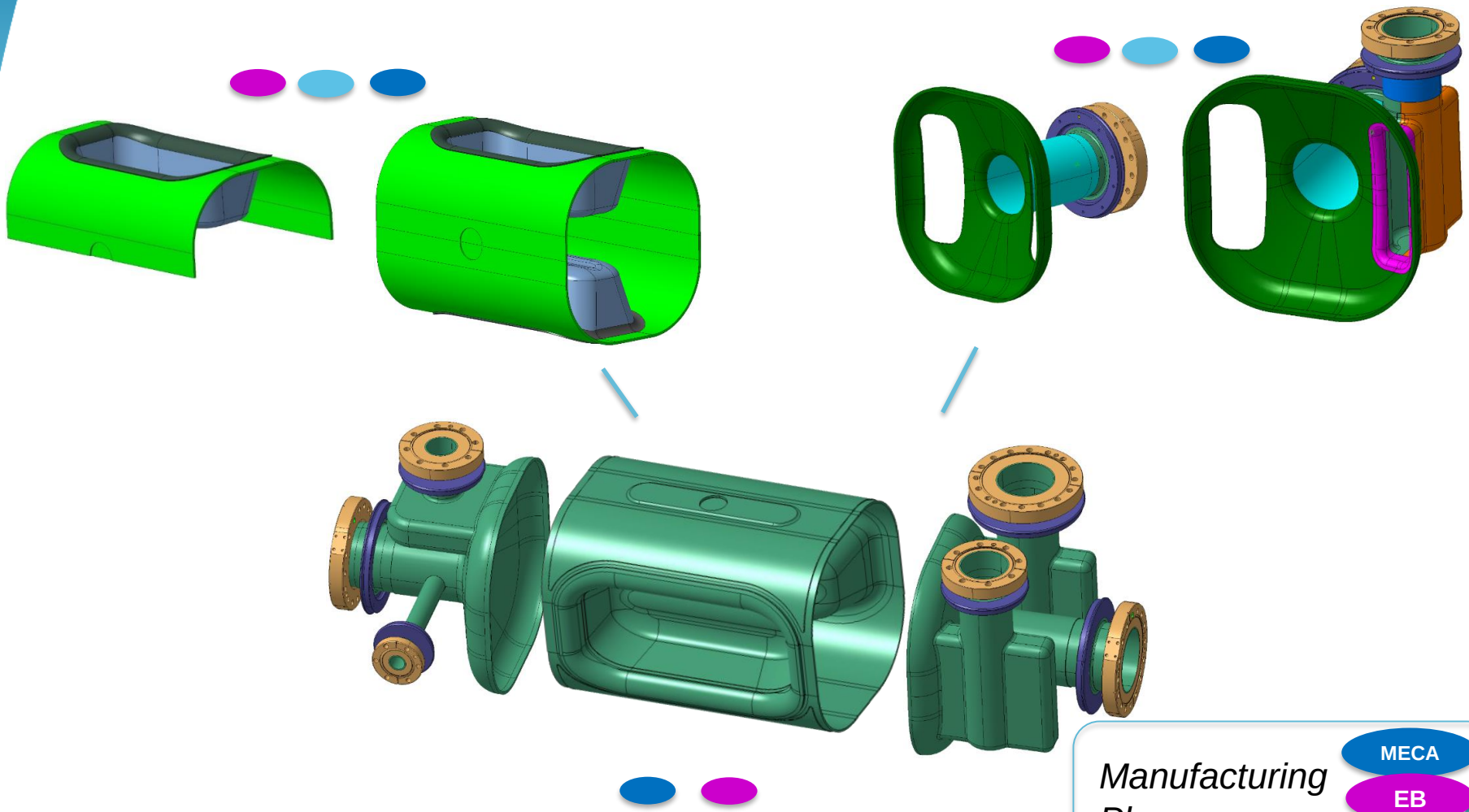
Manufacturing Phases

MECA

EB

TOL

Cavity Build Up



Manufacturing Phases

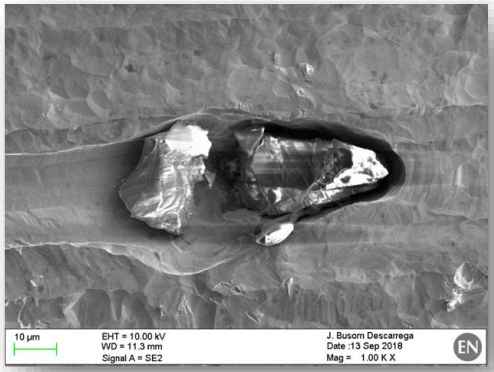
MECA

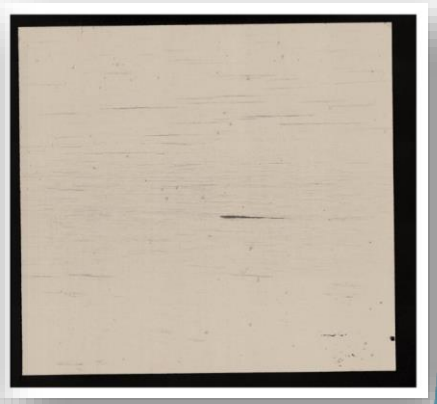
EB

TOL

RFD Cavity Manufacturing: Strategy

- **Extremities**: **same** procedure (and tools) as per DQW
- Initial tests in **annealed Cu** OFE, then Niobium
- **Material**:
  - Stainless Steels, Bronze (CuSn12), EN 1.2343, …
  - Highly attentive to Niobium and NbTi condition @ reception





Niobium:

- *Alumina inclusions*
- *Automatic inspection on samples of incoming material*

NbTi:

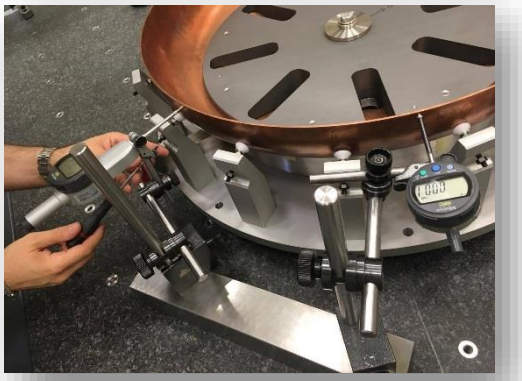
- *Niobium inclusions, not detected during supplier NDT*

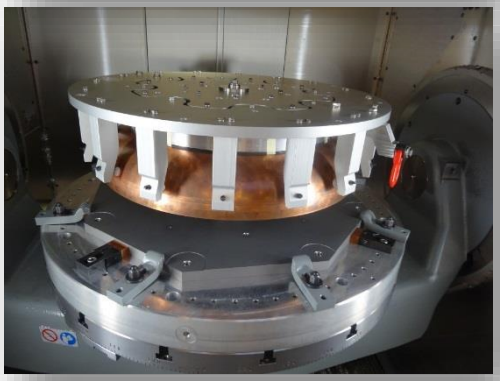
Experience is directly translated onto **ongoing discussions** with suppliers and into current updates of **corresponding CERN specifications**: (# 3300, # 3301, # 4055)

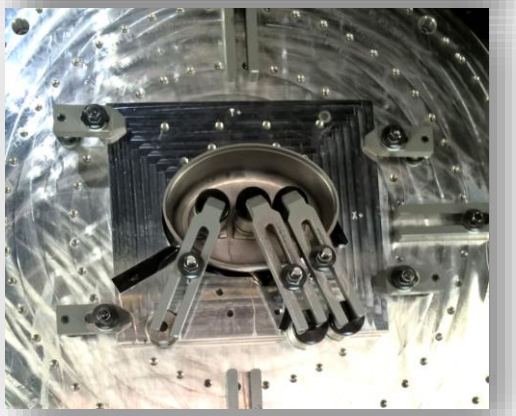
Manufacturing: Machining Strategy

How to handle unconventional shapes?

The real world...







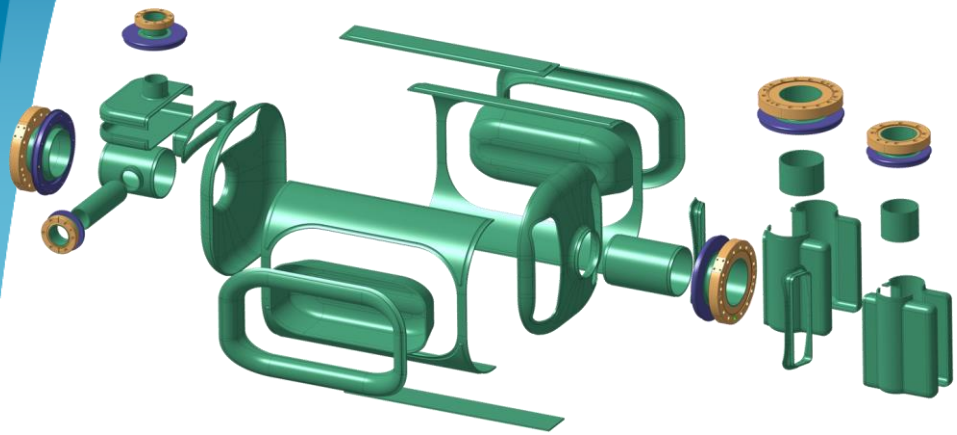
...**theoretical-shape** clamping…

- More indulgent on shaping and machining
- Advanced tools needed down to last weld

…VS. **free-state** (stress-free)clamping…

- Forming: must yield best shape possible (→ coining!)
- Machining: no easy referencing.. must go hand in hand with metrology
- Welding: no last minute surprises

Manufacturing : Welding Strategy



Butt welds (no key/slotted configuration):

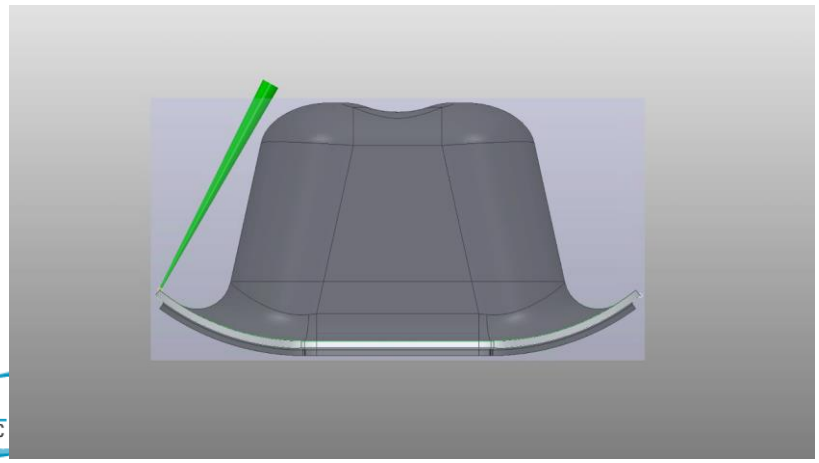
- Easy check for alignment and defects
- Easy RF trimming
- Multi-axis milling

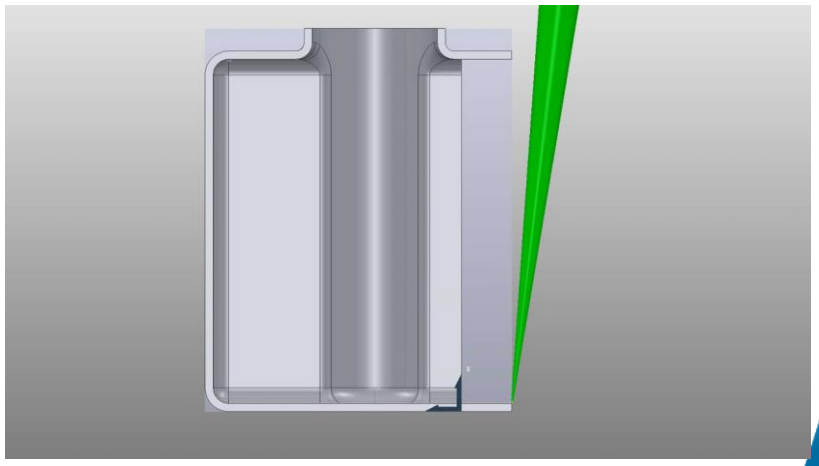
If **RF surface visible**:
4mm weld, smoothing on RF side.

If **RF surface not visible**: thickness reduction for critical welds (→lower energy input, less risky,..)

Backing Ring when remachining feasible

Corner-Pole smoothing

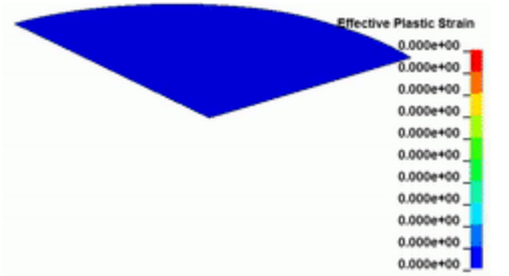




Finite Element Simulations

Why?

- Compare different manufacturing choices & steer strategy
- identify forming defects & highly stressed regions
- predict on the final thickness distribution

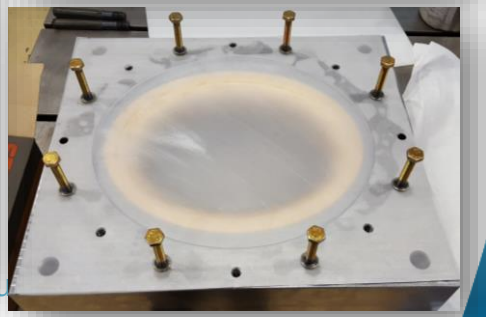


What?

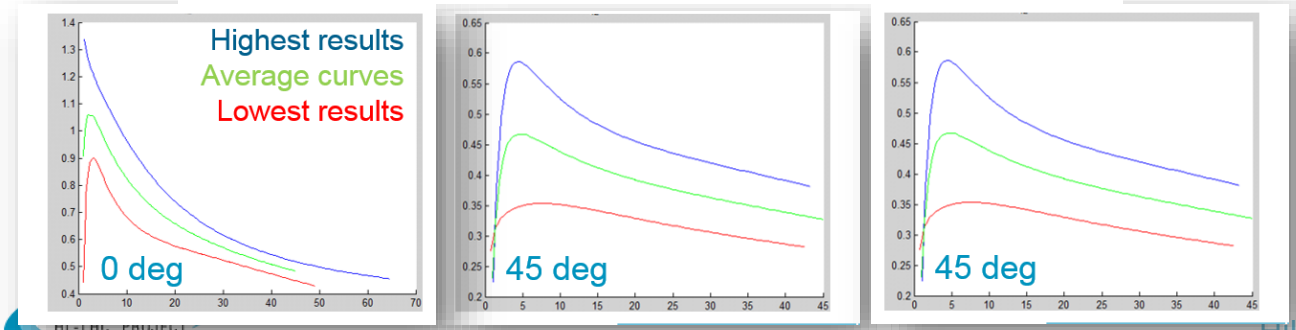
Shaping of: Pole, Main Body, H-HOM waveguide, End Cap, Corner

Working on **Springback** modelling and ongoing **material characterizations**:

- Anysotropy
- Niobium Frictional behaviour



r values curves for each direction and their averages



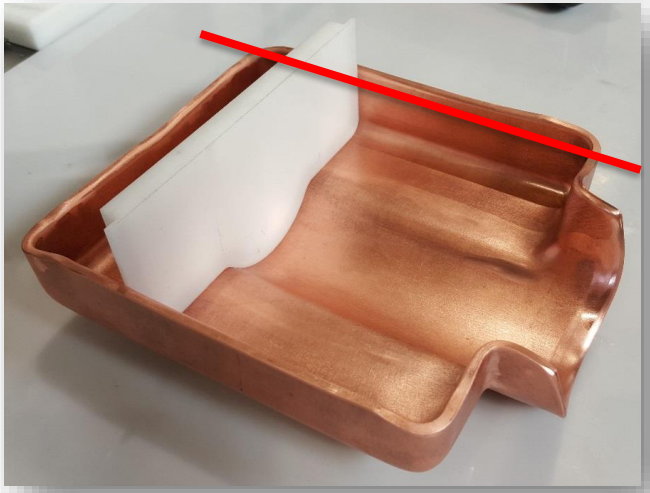
Waveguides

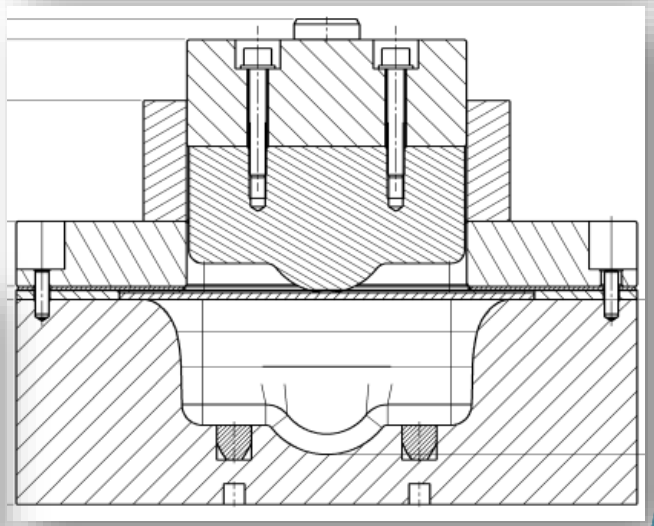
Deep drawing + coining of half-boxes

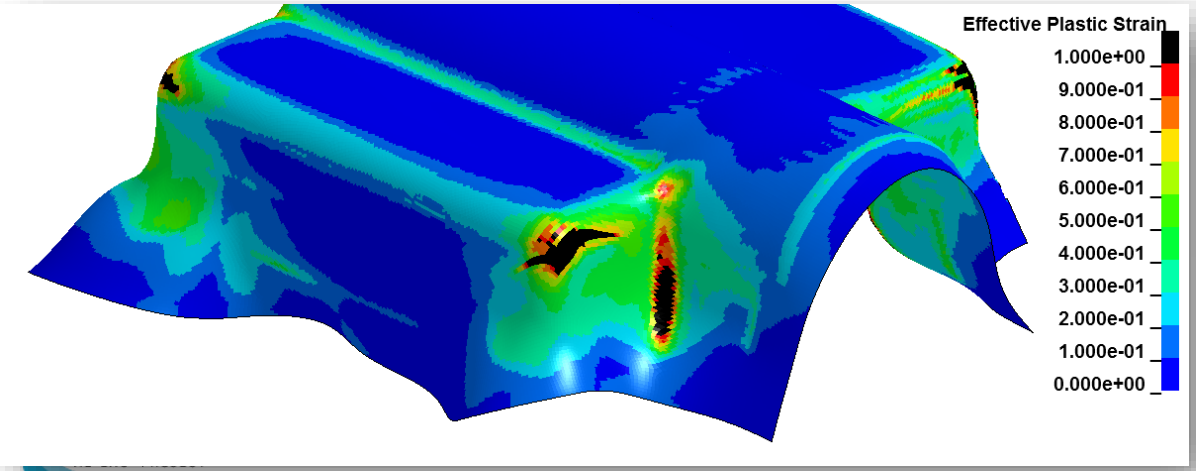
No extrusion of extremity interface

- Less forming steps
- High forming ratios and stretching in correspondance of extremity interface
- easier machining (only thickness & height for EBW)

- Challenging EBW due to sudden EB direction changes:
- RF side 100% accessible for smoothing & eventual repairs





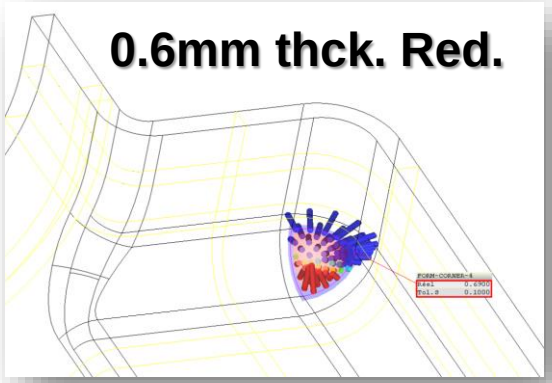


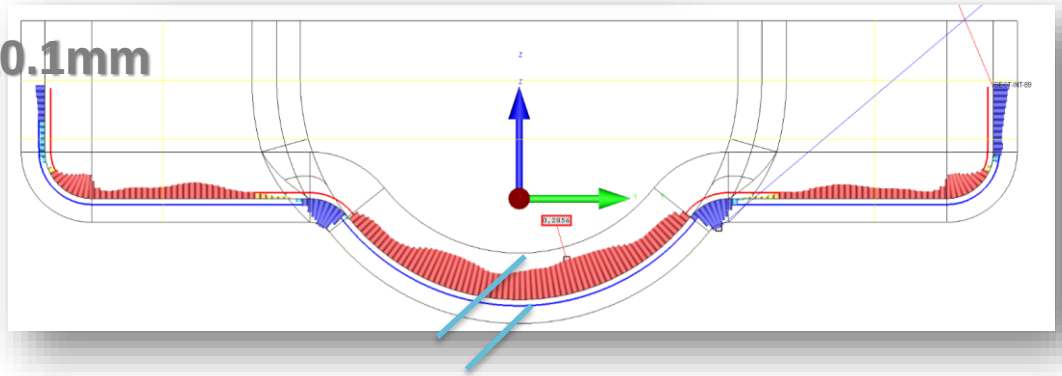
Waveguides: H-HOM Status

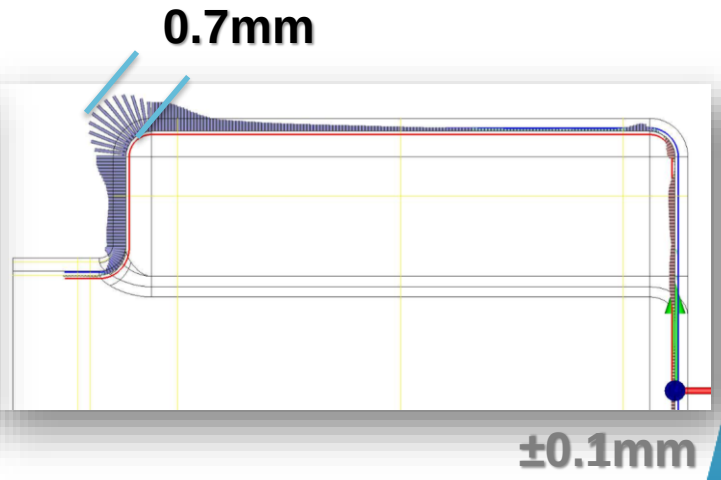
Good global shape tolerances achieved

Tool modification ongoing for improvement on:

- shape nonconformity due to springback
- thickness reduction @ angles







Corner

Shaping:

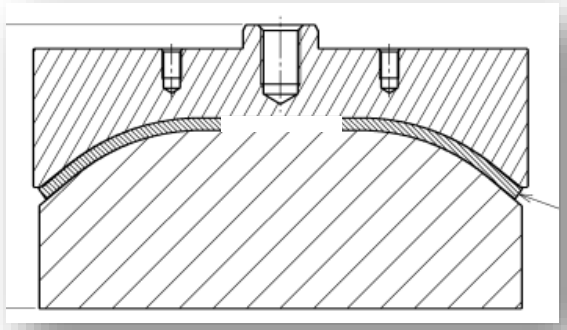
- Bending + Extrusion + Coining

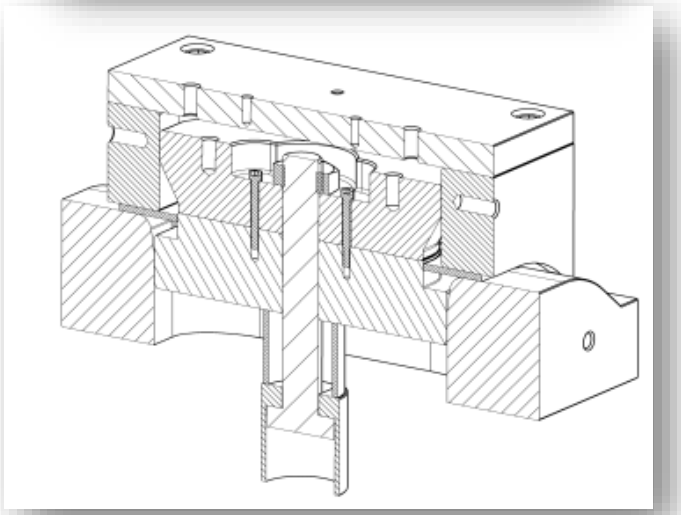
Machining

- multi-axial thickness reduction on both int & ext edges

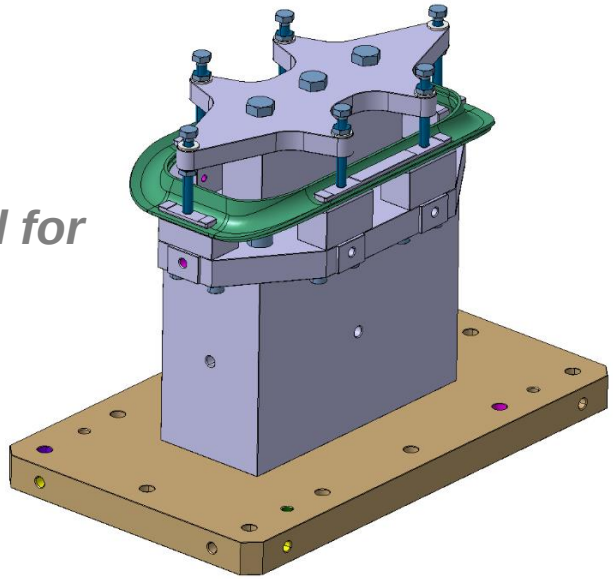
Rigid component (6.35 mm thickness)

- calibration after forming
- Stiffer during machining
- Shaping defects propagate to CNC machining





Universal tool for all machining steps

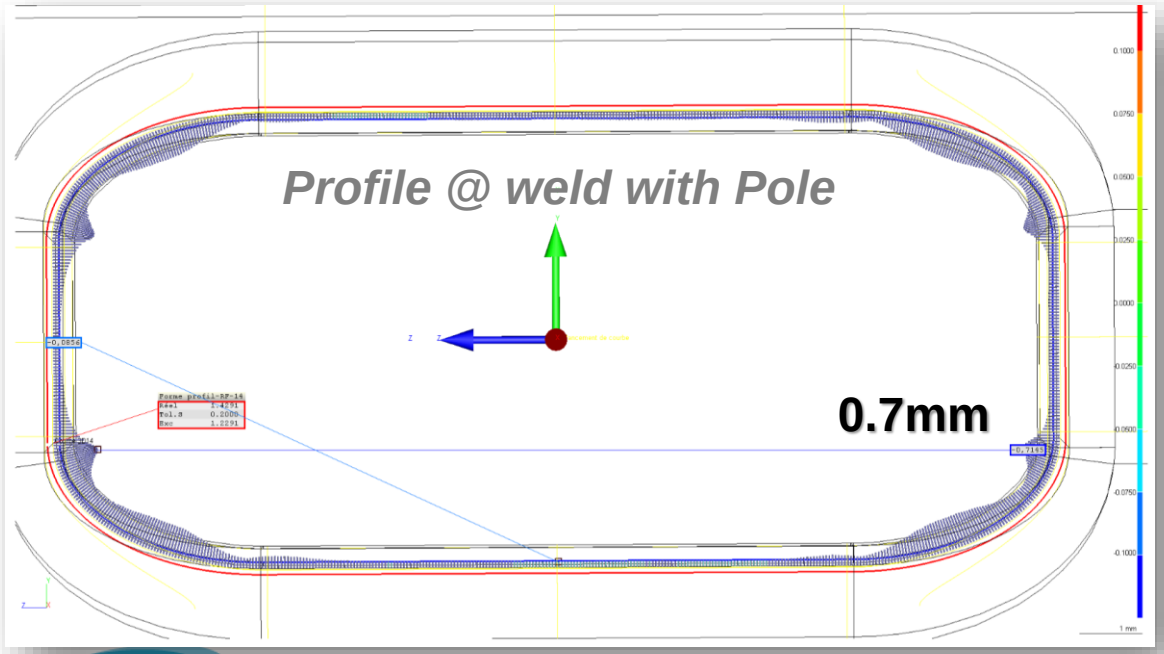


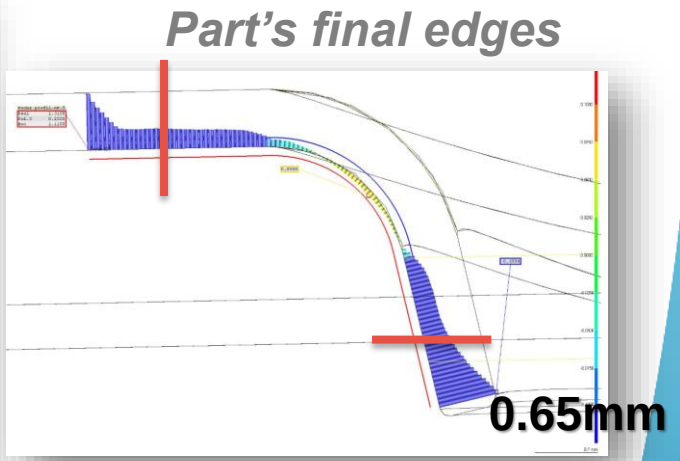
Corner: Status

Metrology (after shaping and coining):

- RF perimeter @ weld: **smaller in avg. 0.2mm** (per radius)
- Shape error peaks due to **thinning of material during extrusion**

Machining + re-coining should grant 0.1mm enlargement (per radius)
Local calibration for remaining nonconformities



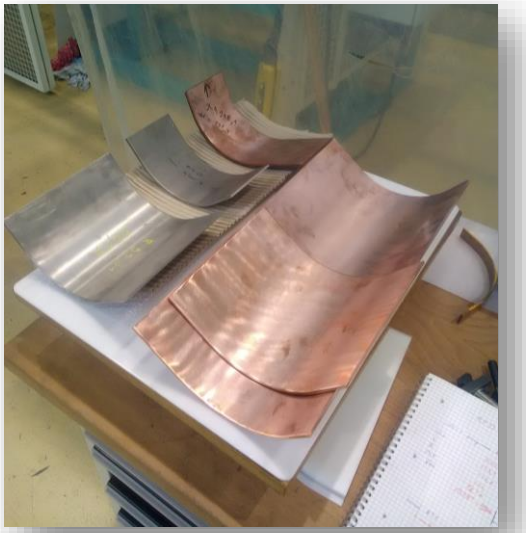


Main Body

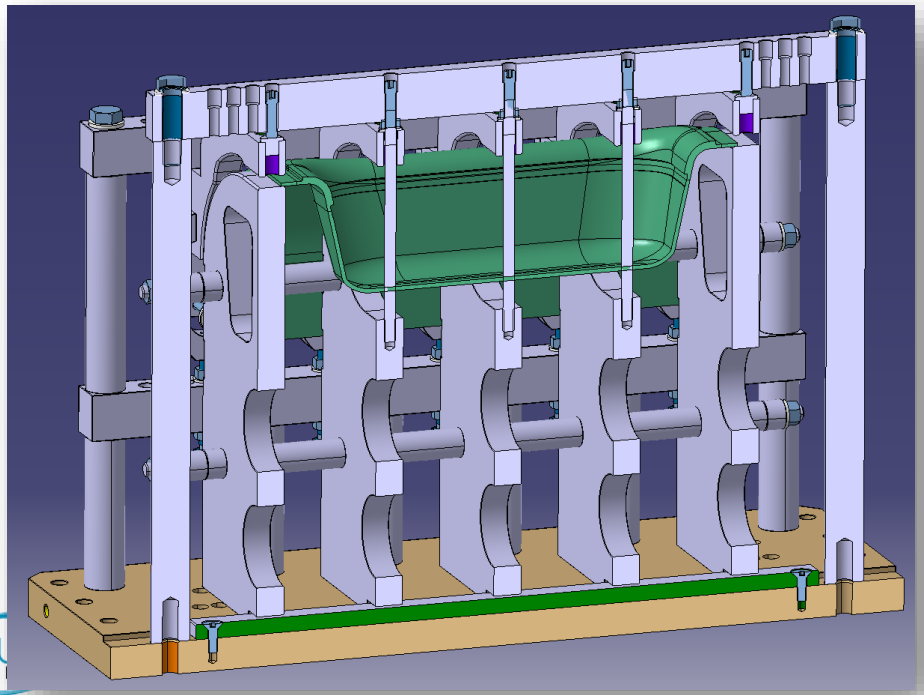
Shaping: standard process via press bend

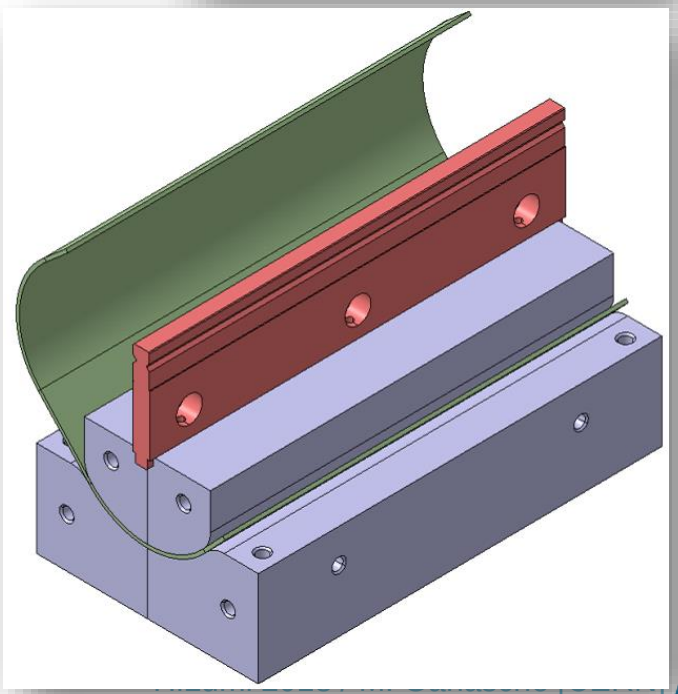
Multi-axis machining for interface with corner

Status: ready for shaping of cavity parts



Universal machining tool

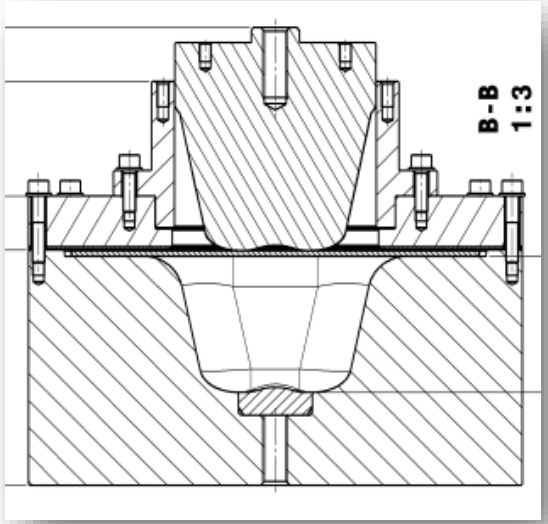


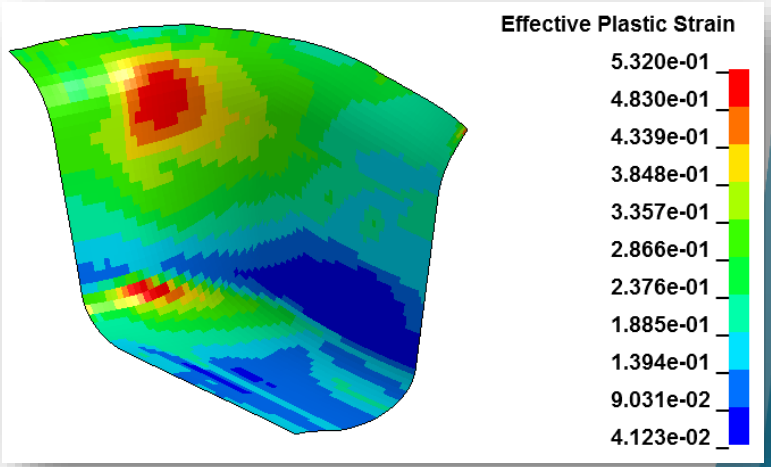


Pole

…With respect to DQW Bowl..
Shaping/machining/welding **strategy is in all similar**

Large **displacements** of sheet (friction)
RF surface open to the world
More **radical rates of strain** on the piece



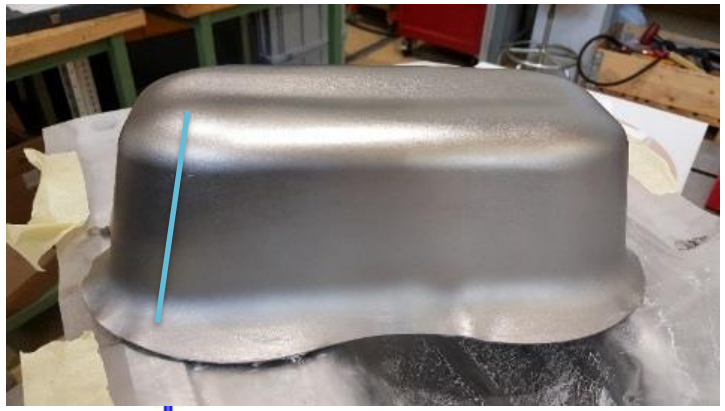


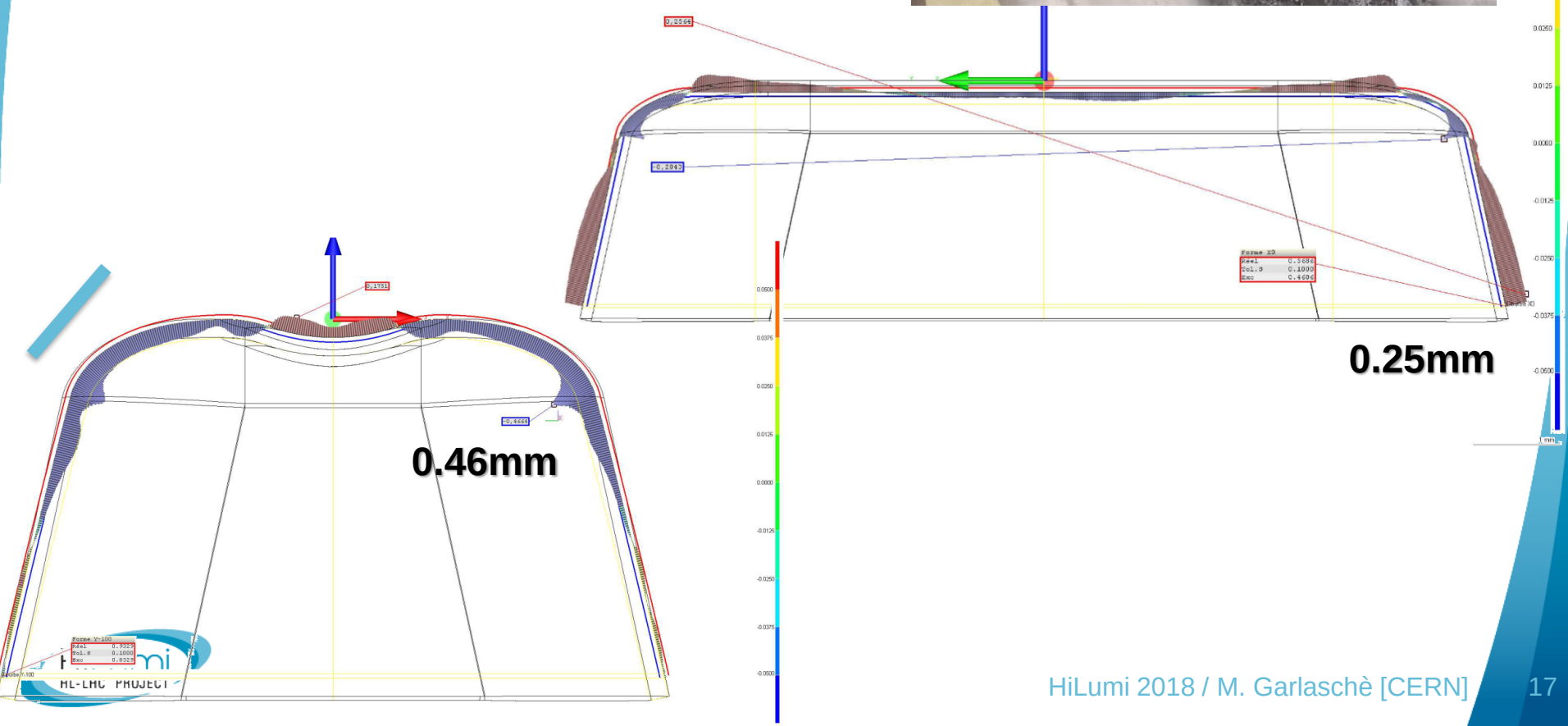
Pole: Strategy & Status

No scratches on RF surface

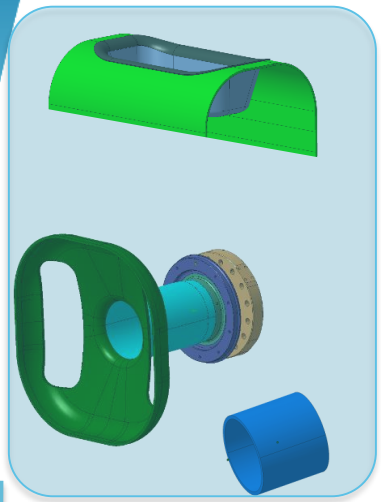
Shape inside specified tolerances, apart from local **peak at rounding (can be corrected)**

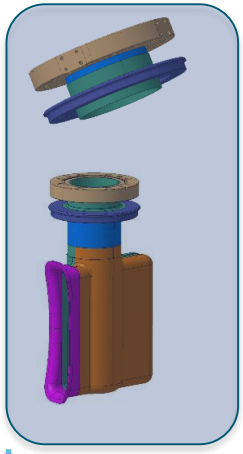
Shape at weld interface to further improve once final milling performed

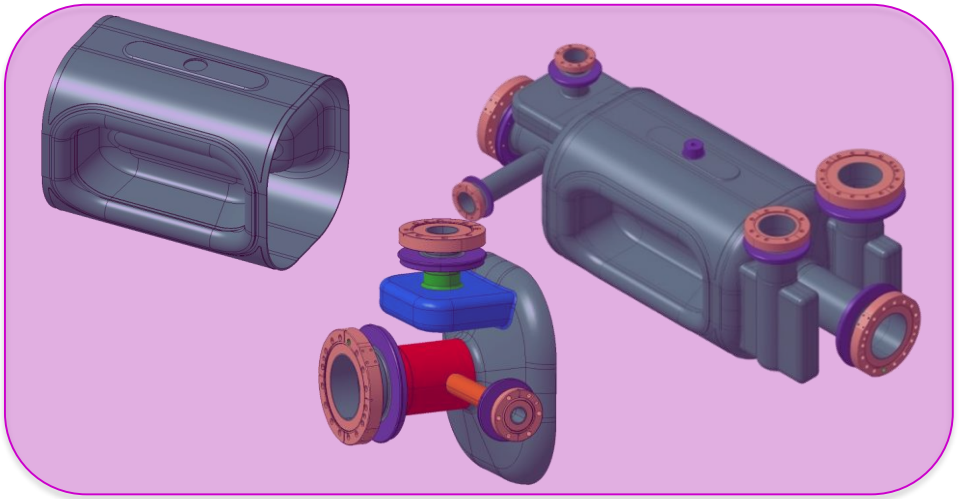




RFD Manufacturing: Sub-deliverables





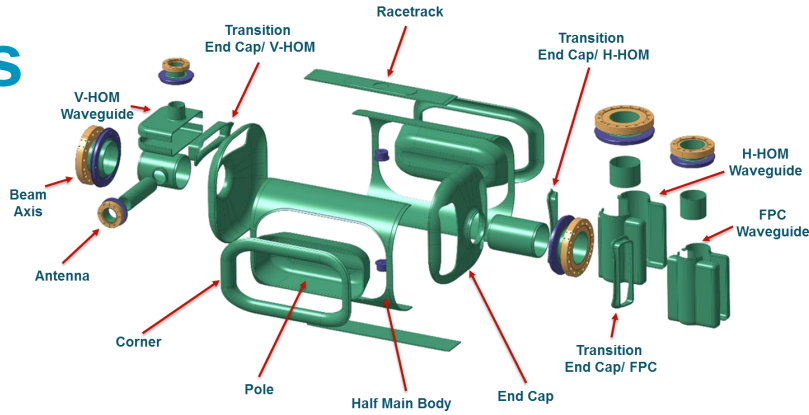


Deliverable #3:
Welding of major subassemblies onto 2x cavities.
Where provided subassemblies carry reduced Shaping-remachining interactions

Deliverable #2:
- Waveguides: ready for welding onto Deliverable #1
- Remaining extremities ready for welding with Deliverable #1

Deliverable #1:
- Main body ready for deliverable #3 (tuner + stiffener welding)
- End Cap ready for welding with Deliverable #2

Deliverable #1 & #2: Status



R&D phase to be finalized in Q4 2018

After Manufacturing Plan : welding tests, qualifications and prototypes production

Subc.	Material	Tools Forming	Tools Machining	Forming Test Cu	Forming Test Nb	Manuf. Plan
Extremity						
Waveguides						
Bulk Transitions						
Pole						
Corner						
Main Body						
End Cap						

Conclusions

- **DQW experience** instrumental for RFD manufacturing strategy
- **Interactions with Nb/NbTi material supplier**: small delay for missing Niobium, but instrumental for future series orders

- Feasibility check for initial processes to be finalized in upcoming weeks.
- Shaping **strategy** for all critical components **validated**.
- **First Niobium pieces** in sight.

- **Next**:
  - Launch production of extremities
  - Weld tests & qualifications

Thanks!