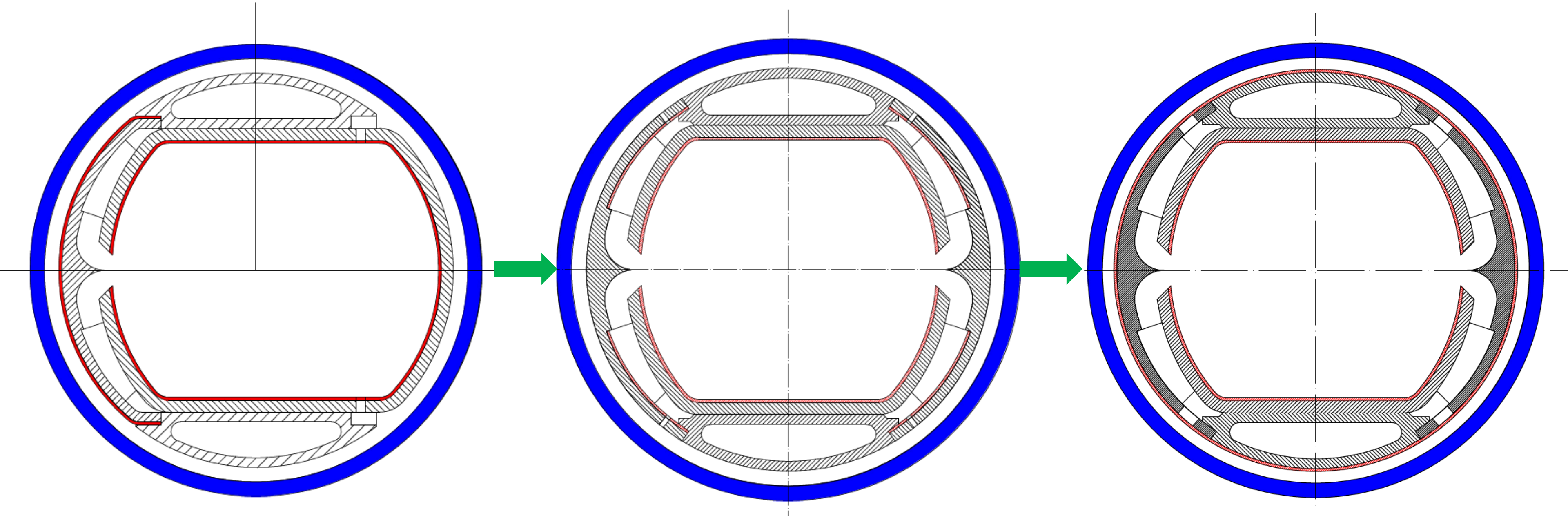
EuroCirCol
WP4 – Cryogenic Beam Vacuum

F. Perez & P. Chiggiato

WP4 – Beam Screen Desing

Design Updates



- Symmetrical design
  - → Better impedance
  - → Pumping holes hidden by the screen
- Thermal copper coating on the outer side
- Bigger pumping holes – no constraint for the distribution

Design – Main dimensions

Cold bore diameter: 44/47 mm

Beam screen wall:

- 1.25 mm P506 (high-Mn high-N st. steel)
- 0.3 mmcopper

Nominal aperture:

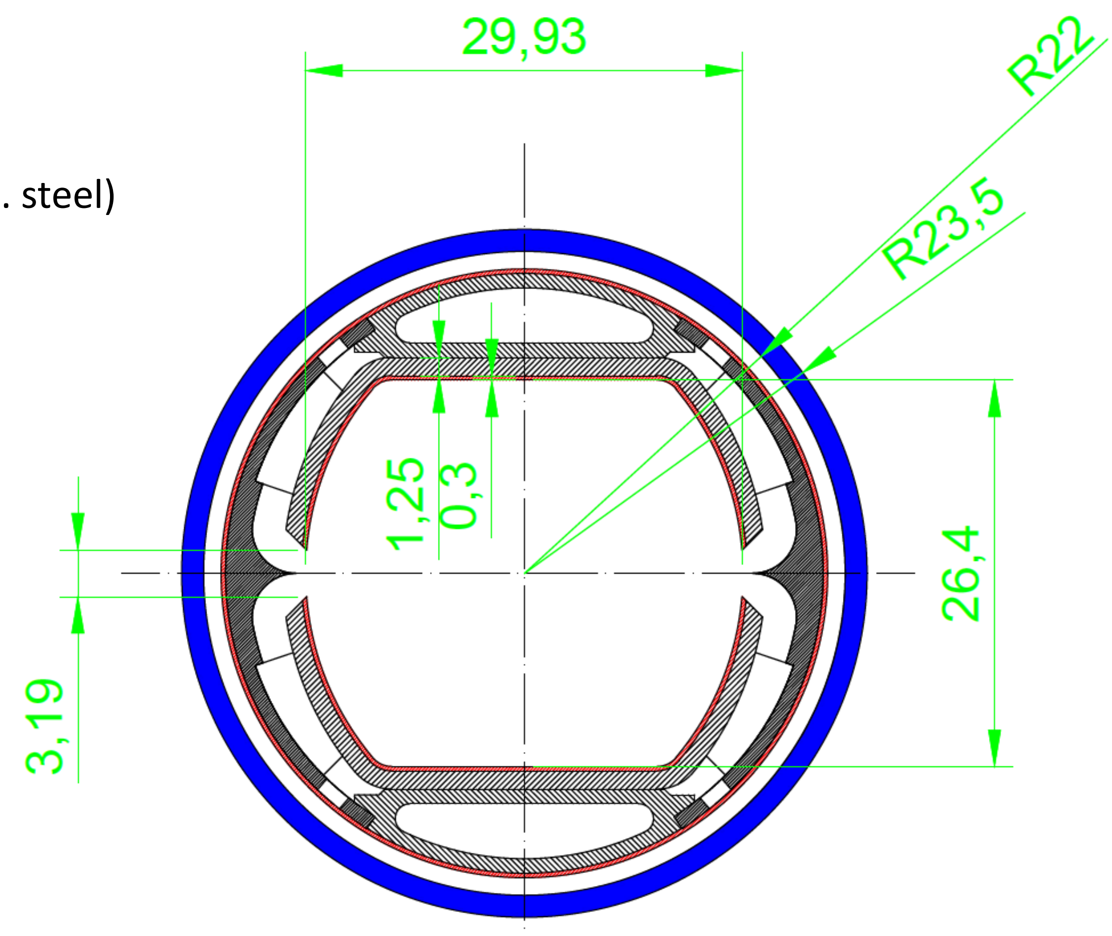
- H:~ 29.9 mm
- V:~26.4 mm

Slit height: ~ 3.2 mm

Cooling channel:

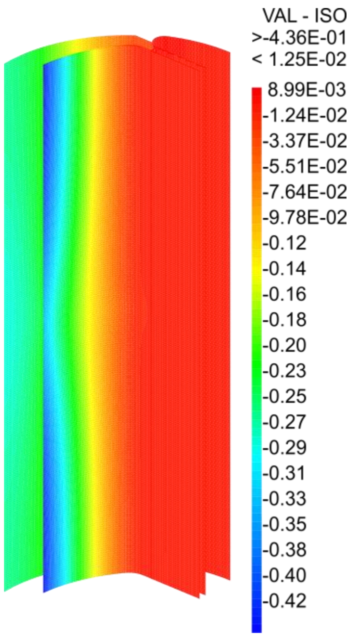
- Thickness 1 mm
- Internal 53.58 mm^2
- Hydraulic diameter: 5.61 mm

Copper for heat transfer: 0.3 mm

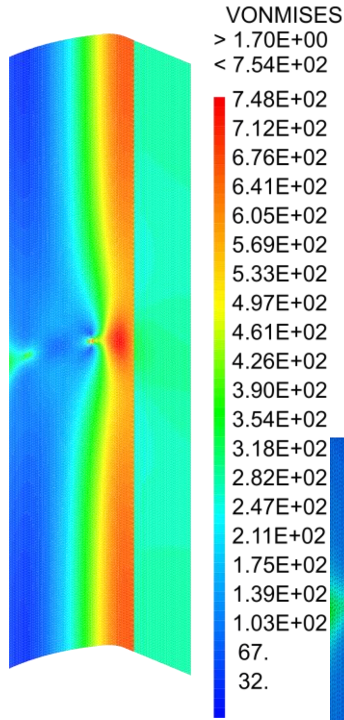


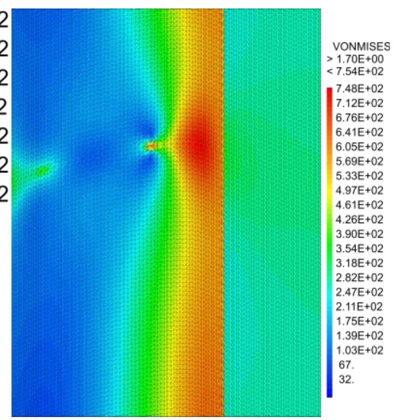
Mechanical analysis

Magnet quench

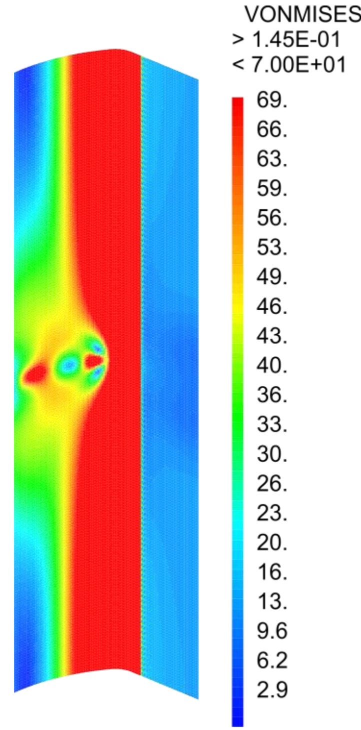


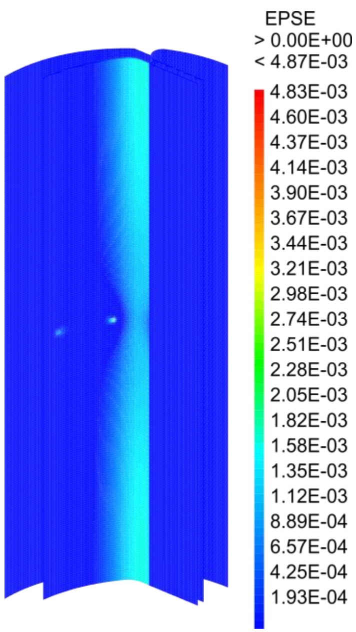
Horizontal displacement: ~ 0.5 mm





Maximum Von Mises stress in the beam screen: ~ 750 MPa



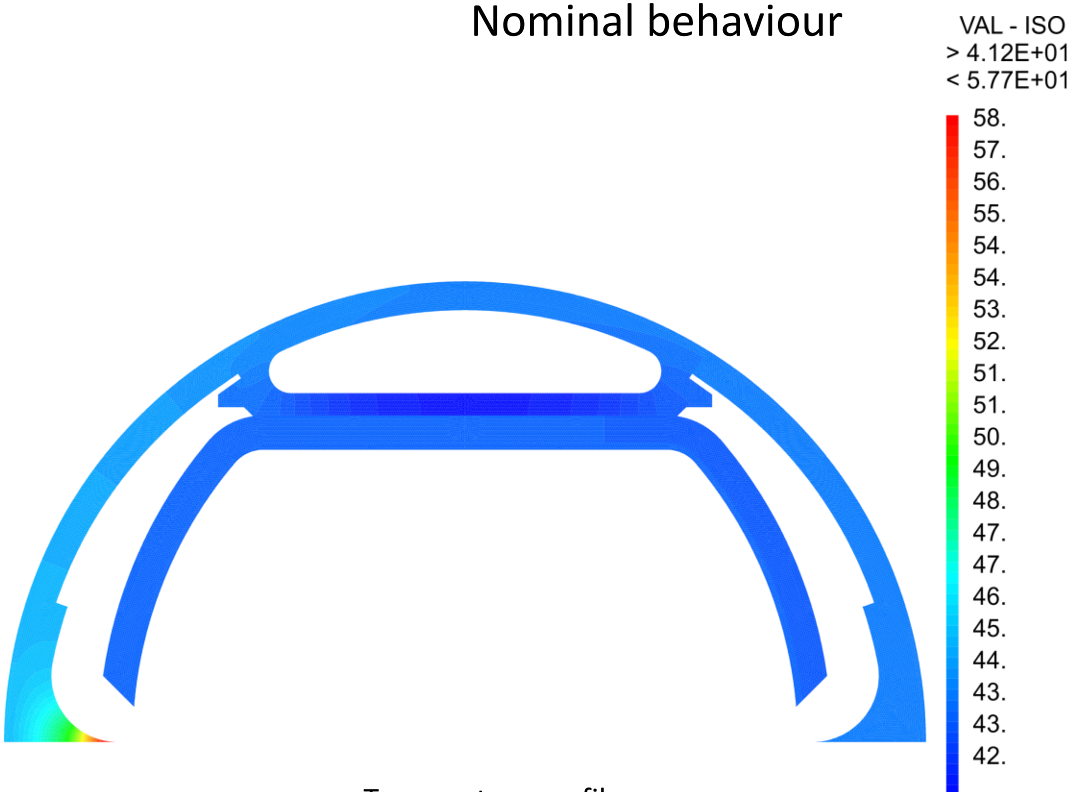


Plastic strain in the copper layer: ~ 10^{-3}

Even if the model has to be refined, results of the beam screen behaviour during a quench are promising.

Thermal analysis

Nominal behaviour



Temperature profile

Local temperature increase (reflector tip)

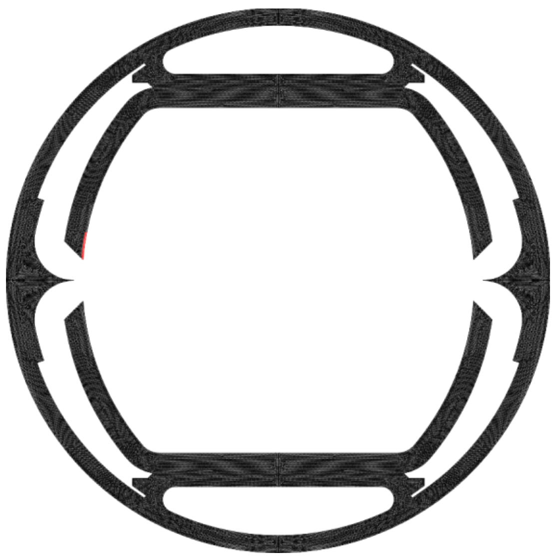
Screen temperature a few K higher than the helium temperature

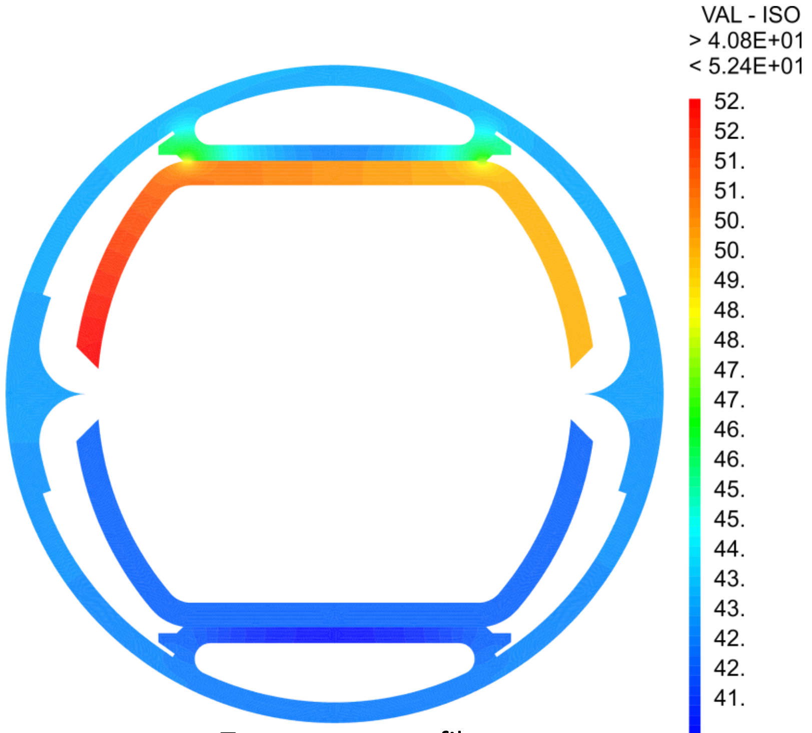
Thermal analysis

Nominal behavior

Model:

- 2D massive model
- Heat deposition of 31 W/m on one beam screen edge
- Thermal conductivity of copper estimated at 50 K and under 16T ~ 700 $W.m^{-1}.K^{-1}$ (need to be measured)
- Thermal conductivity of stainless steel at 50 K ~ 6 $W.m^{-1}.K^{-1}$
- Convection coefficient of 150 $W.K^{-1}.m^{-2}$

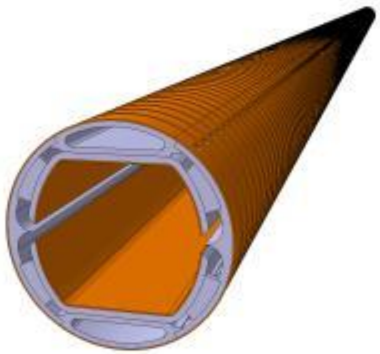

Heat deposition

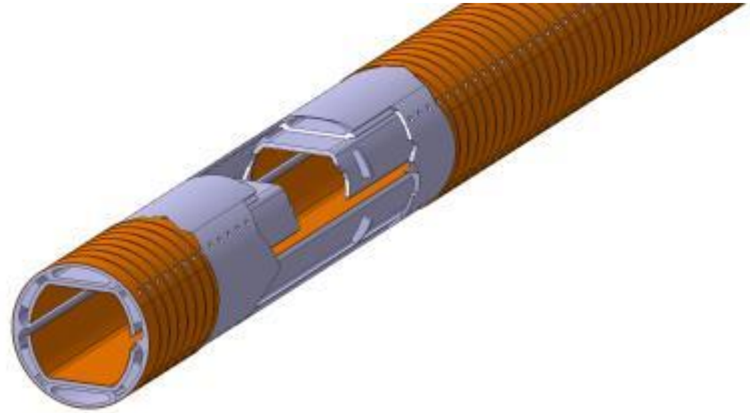


Temperature profile

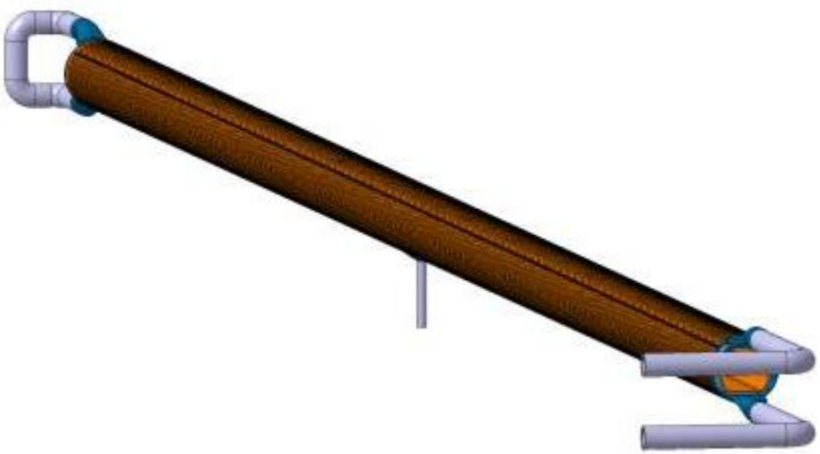
WP4 – Beam Screen Prototyping

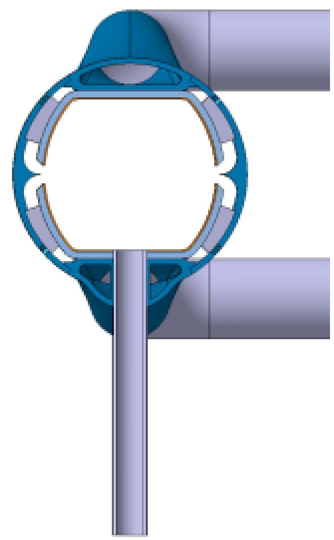
Beam Screen (15m long)

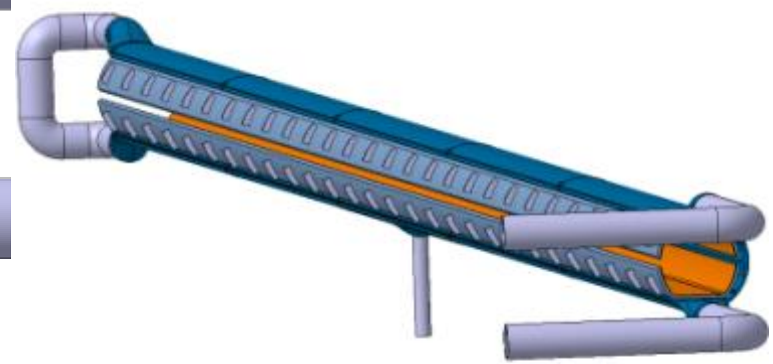




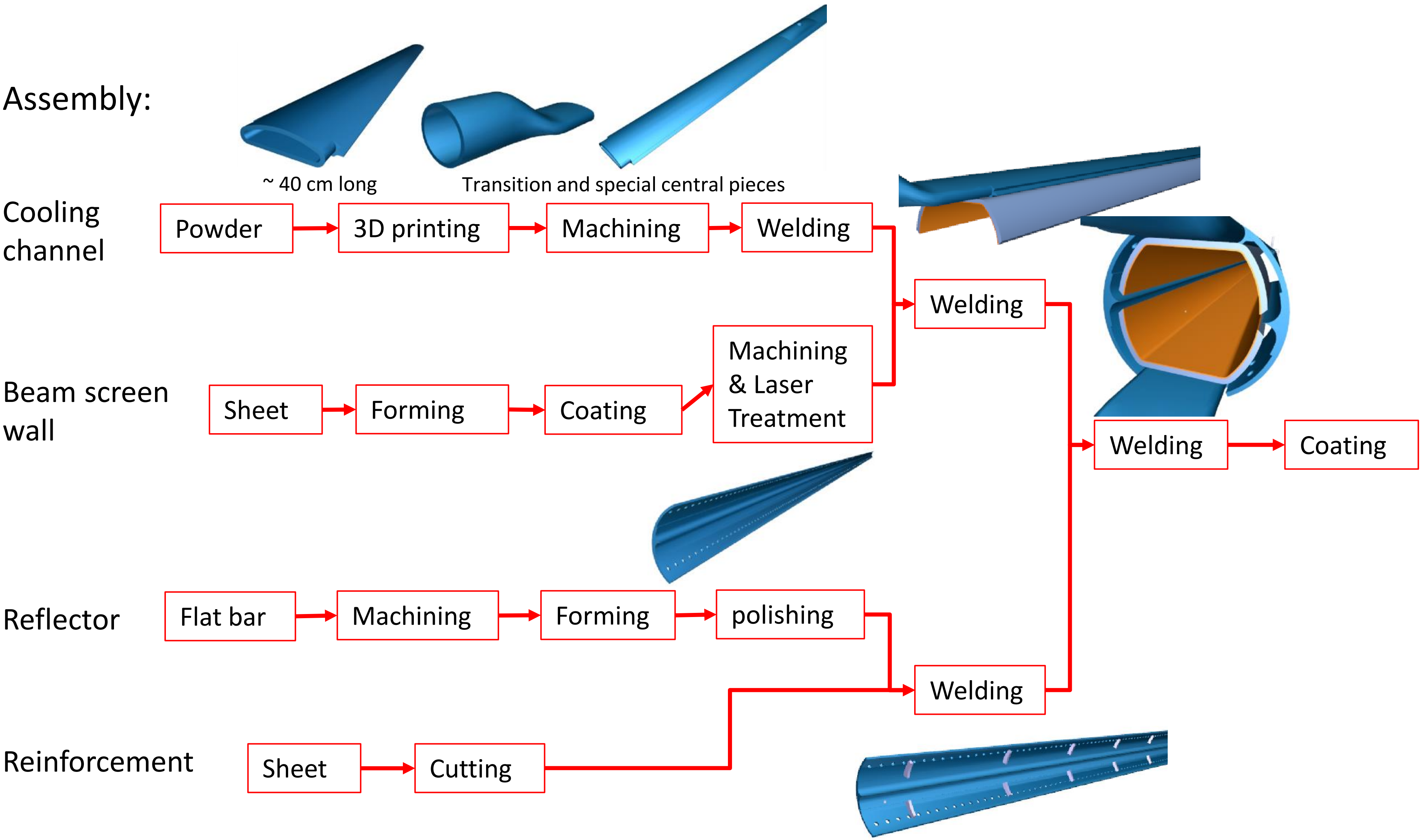
Beam Screen Prototype (≈2m)







Prototypes


Assembly:
~ 40 cm long
Transition and special central pieces
Cooling channel
Powder
3D printing
Machining
Welding
Welding
Beam screen wall
Sheet
Forming
Coating
Machining & Laser Treatment
Welding
Coating
Reflector
Flat bar
Machining
Forming
polishing
Welding
Reinforcement
Sheet
Cutting

Next steps

From the design point of view:

- Check the design of the cooling channels for pressure test conditions
- Refine the model for the quench analysis:
    - Joule effect
    - Influence of the copper strip (3D model for the current field)

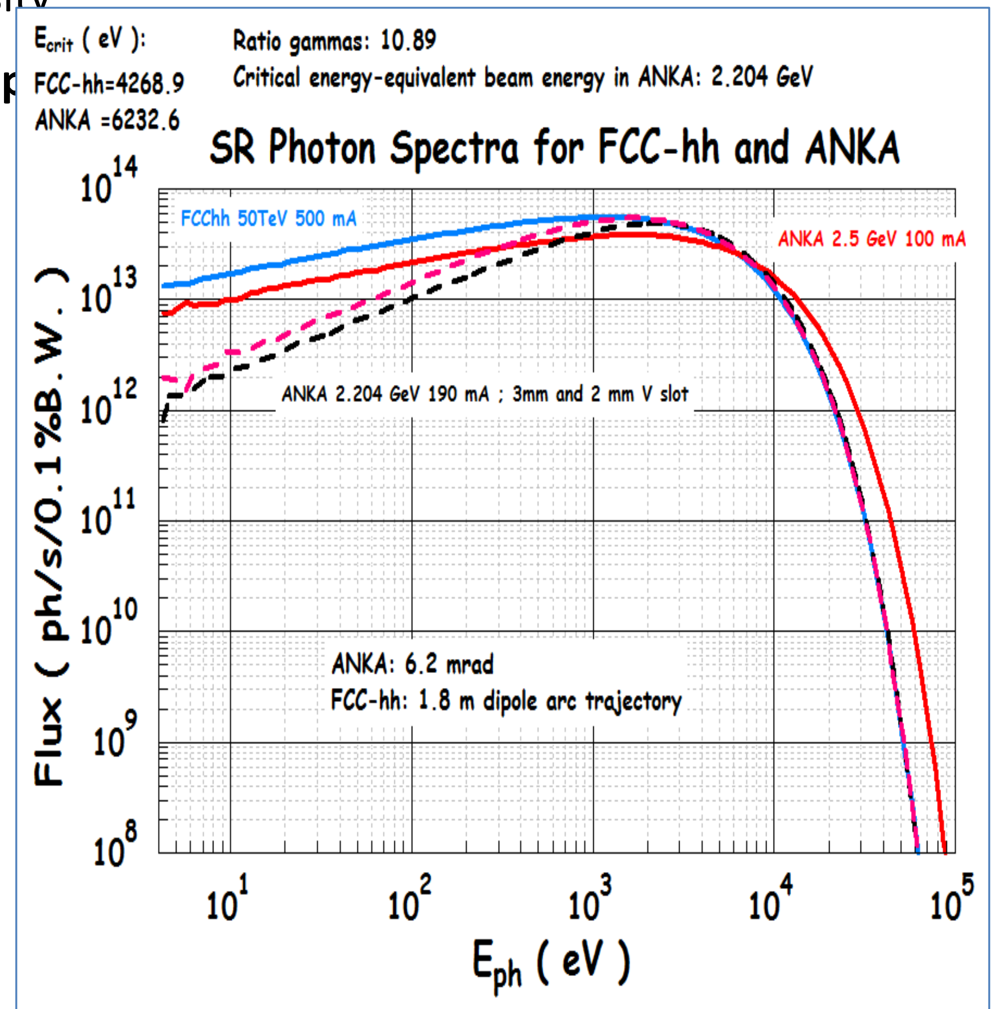
From the prototyping point of view:

- First samples to qualify the different processes involved in the manufacturing (Q1/2016)
- Manufacture ~2m long prototypes

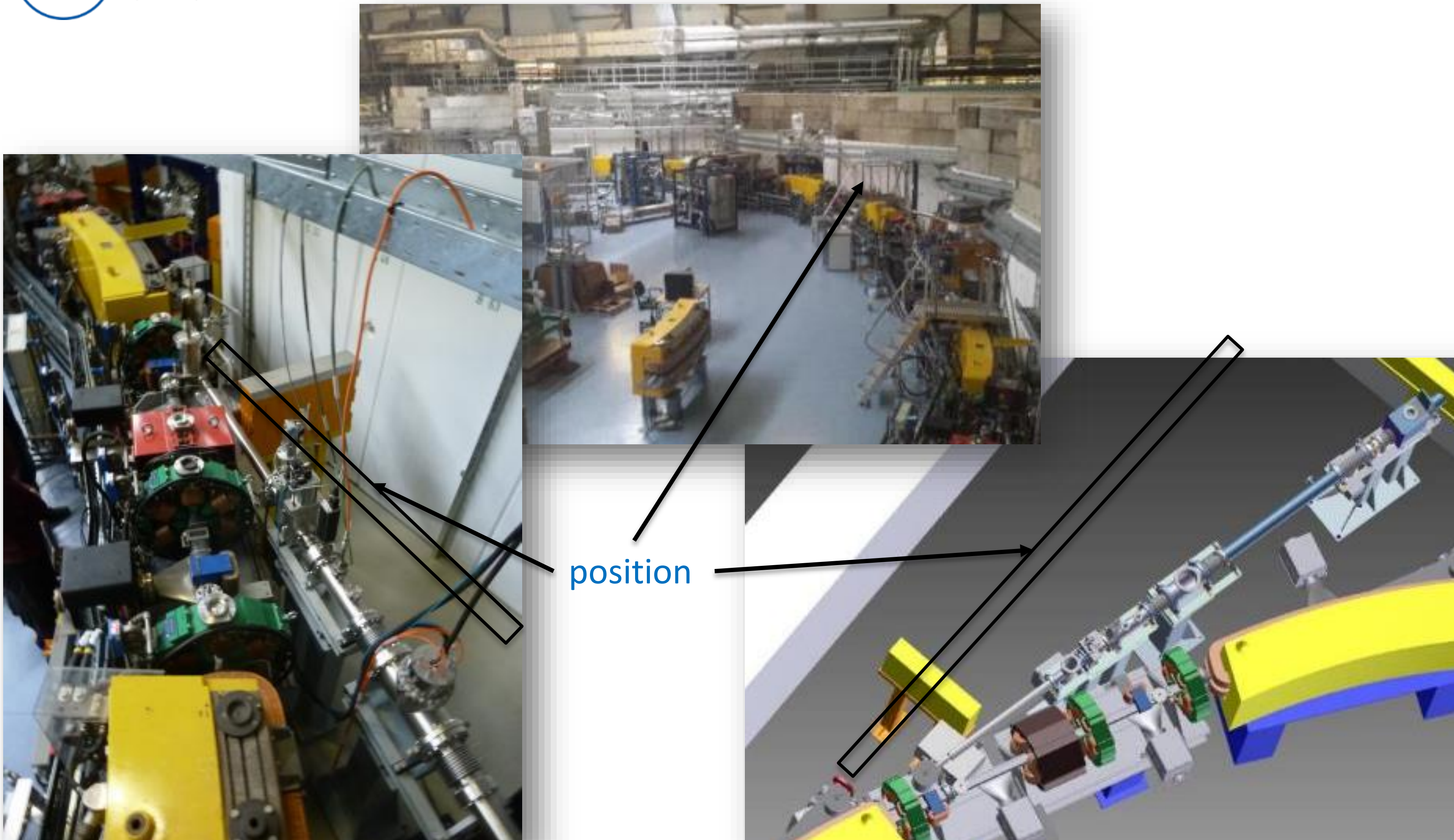
WP4 – Test Setp-Up in ANKA

- Contrary to the LHC, where the SR flux and power are marginal, the FCC-hh is a **powerful light source**; Its SR flux spectrum at 50 TeV is compared to that of the 3rd generation light source ANKA;
- A 1.8 m long arc of bending magnet trajectory corresponds, on average, to 2 m of BS length in the arc sections of FCC-hh (filling factor), giving the correct 31.5 W/m average SR linear power density

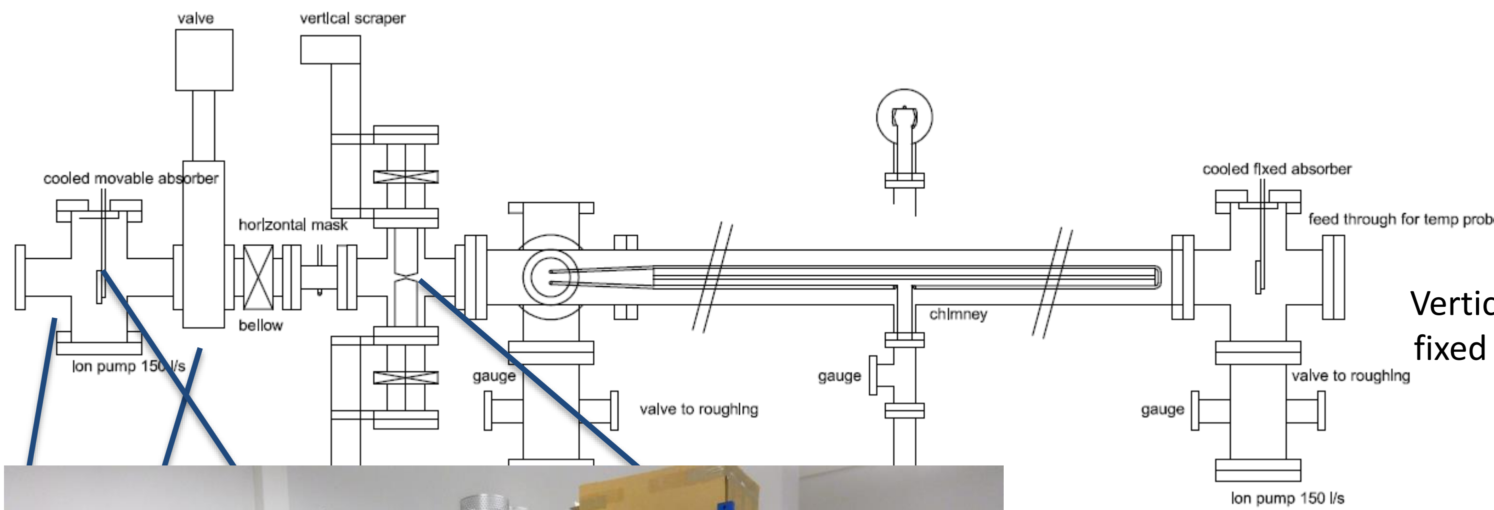
SR p ... **· K_F**

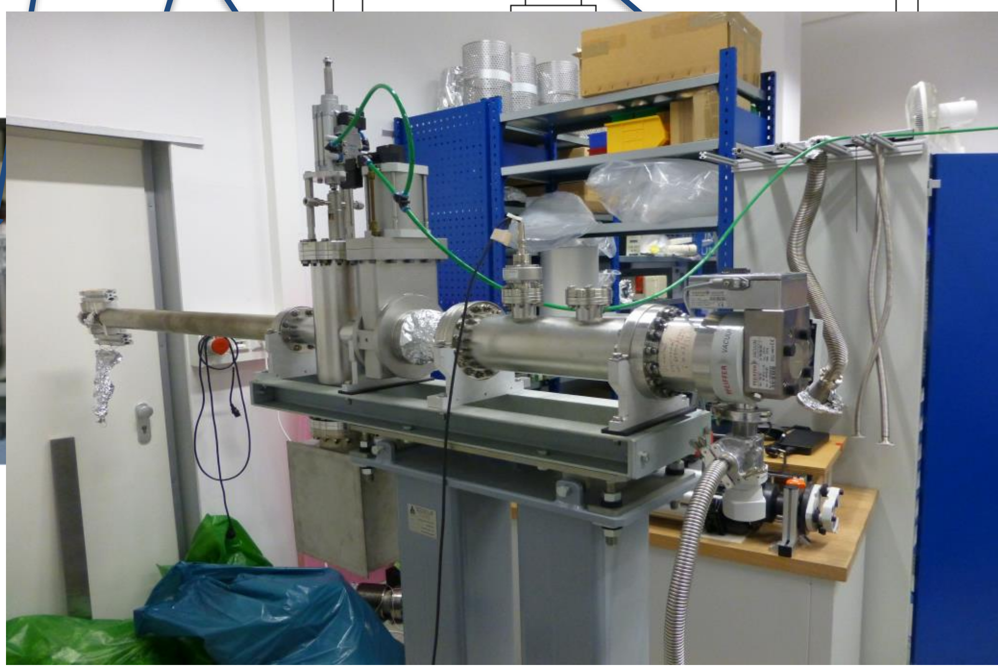


ANKA Facility

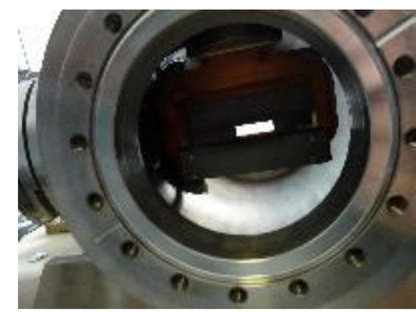


- Some components are available on site
- Proposition Sketch beam line + set up (thanks to E. Huttel)





Vertical scrapper with fixed horizontal mask

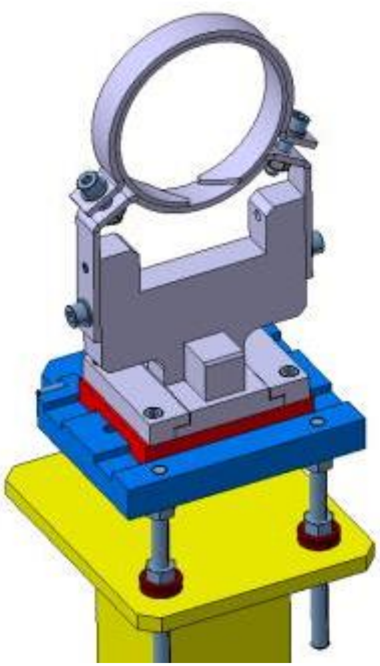


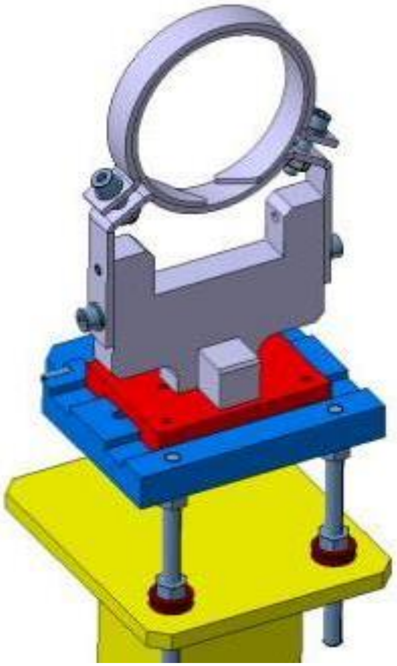
Schedule

Conclusion

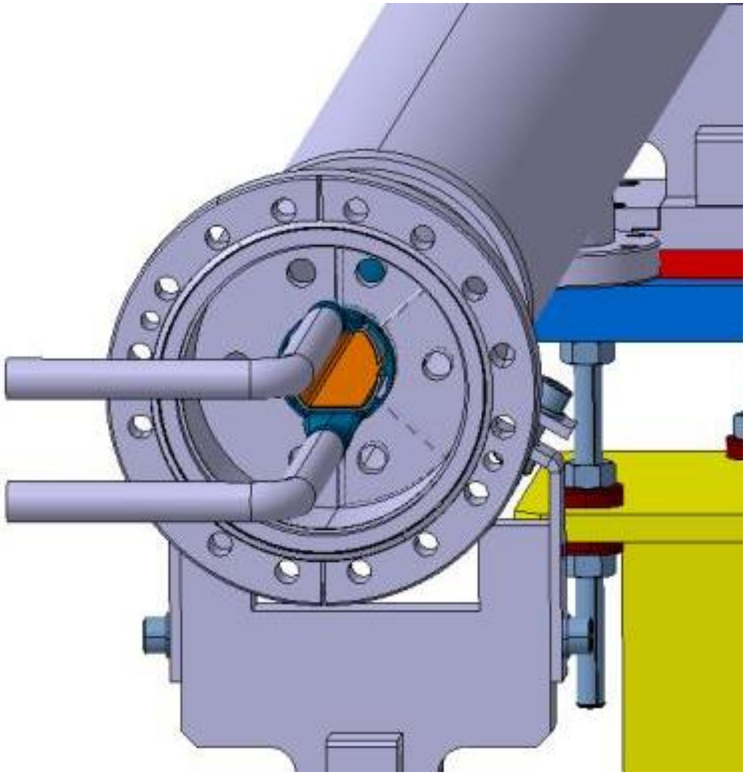
ANKA FCC Test Bench

- Supports adaptation from an existent design





- FCC Beam Screen Prototype Centring System



WP4 – Vacuum Stability

Conclusion and Tentative Plan:

- ✓ **Post DOC's will start next January**
- ✓ **maintenance and use of existing resources ongoing.**

- ✓ **Now: identify/prepare good samples (CERN)**
- ✓ **first part of 2016: first results with existing set up on available samples.**
  - ✓ SEY and TPD to contemporarily study physisorbed gas
- ✓ **Now: Clearly identify LNF contribution (other than what already agreed) to Anka project.**
- ✓ **Soon: If of interest officially plan/state any eventual co-funding. (needed to get INFN funds)**

Funding

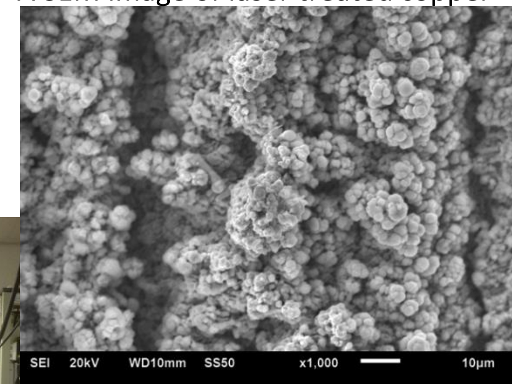
- In July 2015 we (LNF) applied for additional funding to support experimental activities @LNF for FCC-hh.
  - Maintenance, Consumables, Travel money for the 2016-2019 period (60k€ / Year).
  - Hardware for best performing LT desorption studies (~300 k€ total)
- In the October Meeting **no** funds have been allocated by INFN !
  - Different scientific priorities
  - Unclear Contribution and Co-funding from CERN.
- Hope in some reconsideration during 2016 !
  - Some lobbing and clearer co-funding would help!
- We are now forced to count on available resources (with very limited mobility etc.).
- No impact to our tasks but “only” on their quality!

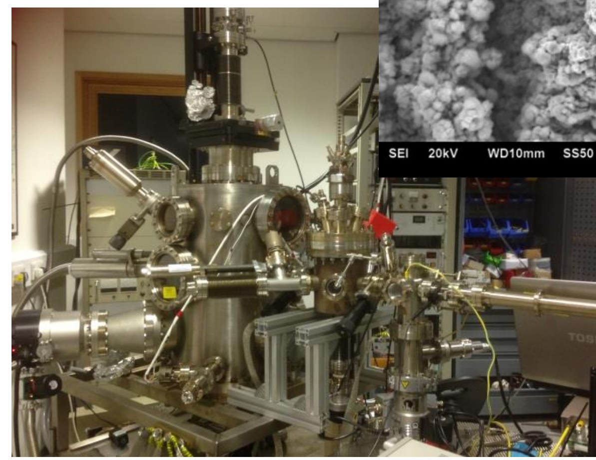
WP4 – Mitigation beam induced effects

Baseline: Low SEY laser surface treatment

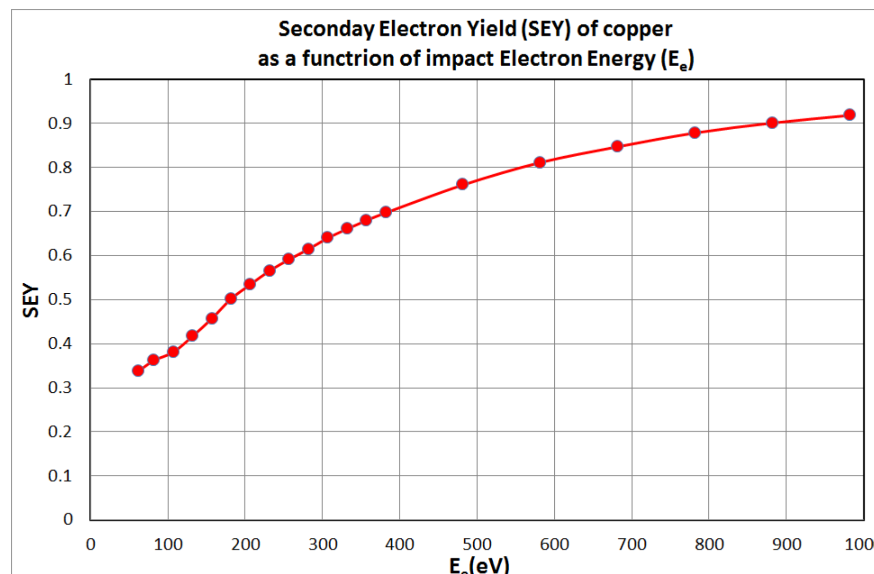
- Laser treated surface can provide $\delta<1$
- In addition it is compatible with other accelerator requirements: low impedance, low outgassing, low photon and electron stimulated desorption, etc.
- Cost effective (at least 10 times cheaper than other existing technologies)
- Nature friendly
- There is no need for vacuum or clean room facilities.
- The laser is capable of fabricating the desired micro/nanostructure in a single step process.
- Hierarchical structures containing both micro- and nanostructures can be created in a single machining step
- Machining is performed through a beam of light and thus contactless.
- The process is applicable to the surfaces of any 3D object.
- Many parameters can be easily adjusted resulting in a great variety of possible structures.
- It is possible to laser in many different environments, such as gases, liquids, or in a vacuum.

A SEM image of laser treated copper

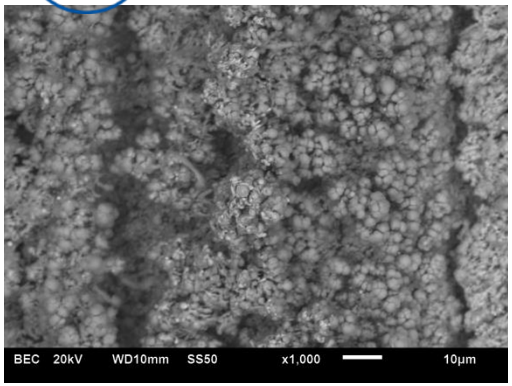


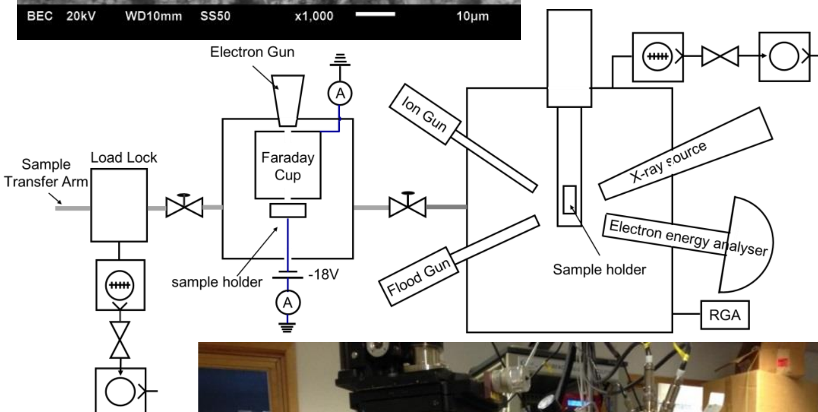


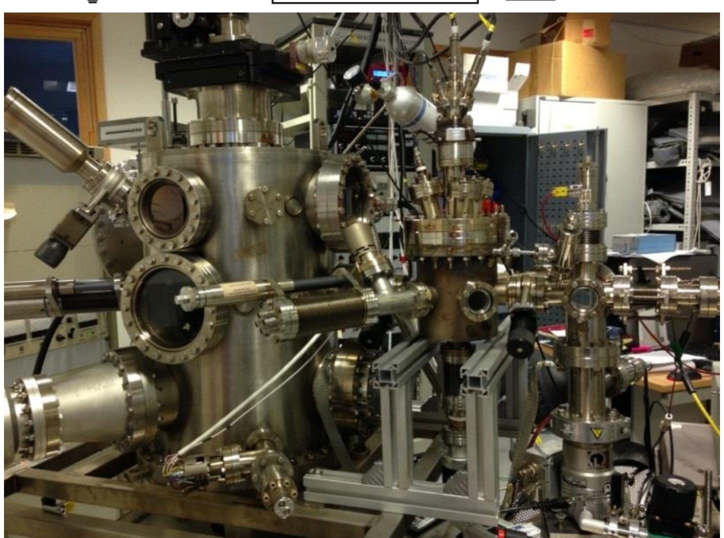
A facility for SEY studies



Baseline: Low SEY laser surface treatment







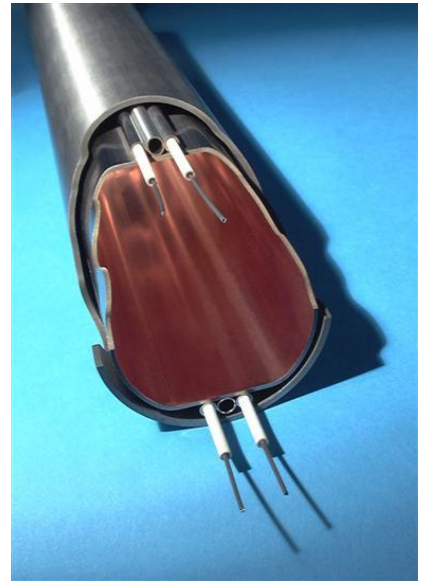
PhD student's (Taaj Sian) work:

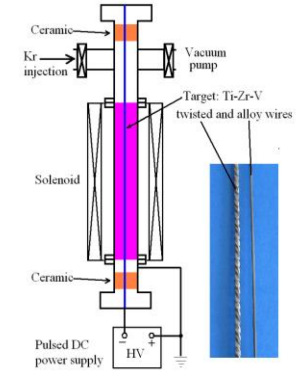
The main emphasis will be on the Laser Induced Micro/Nano Surface Structures (LIMNSS)

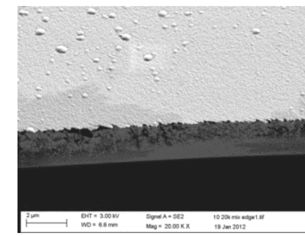
- Oct 2015 –Sep 2018
  - Studying various LIMNSS obtained with various lasers and their parameters at room temperature:
    - Measuring the SEY (as-received, after electron bombardment, after bakeout, after ion bombardment).
    - Measure surface resistance of LIMNSS
    - Measure ESD and thermal outgassing of selected LIMNSS with low SEY
    - Study the LIMNSS stability to ultrasound (measuring SEY before and after wash)
    - Study the particulates generation
  - Studying selected surfaces obtained by other techniques such as coatings, etching, etc., provided by sample exchange with other WP partners.

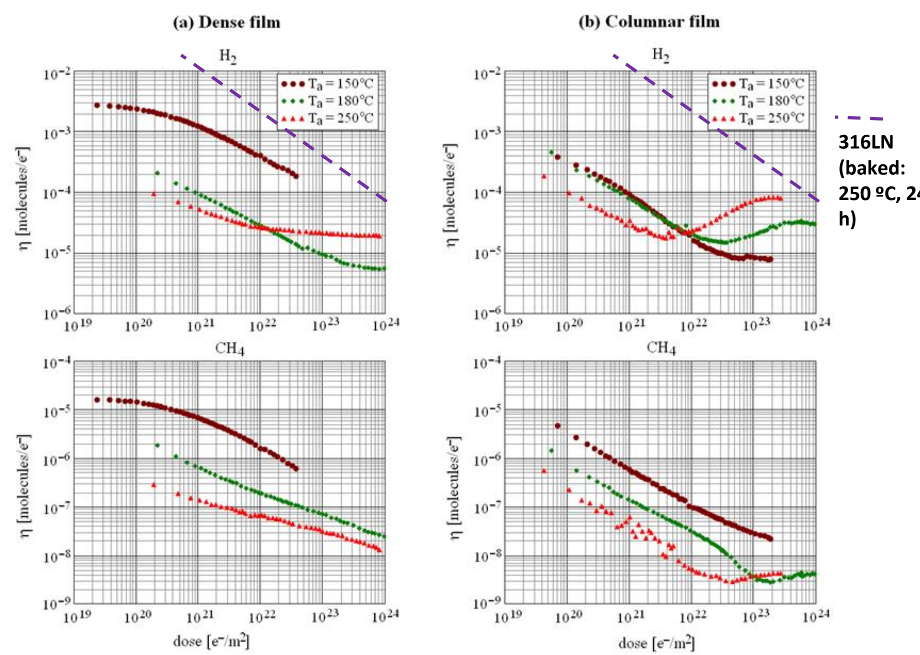
Optional: Non-evaporable getter (NEG) coating

- What NEG coating does:
  - A pure metal film ~1-µm thick without contaminants.
  - A barrier and/or getter for molecules diffusing from the bulk of vacuum chamber.
  - Distributed pumping speed after activation at 150°C
- Other highlights:
  - Photon stimulated activation
    - to be verified at cryogenic temperatures
  - NEG deposition on vacuum fired vacuum chambers allows to reduce PSD/ESD by another 10 times
- Benefits:
  - No additional pumping required
  - Beam vacuum is separated from magnet bore vacuum
  - Low SEY





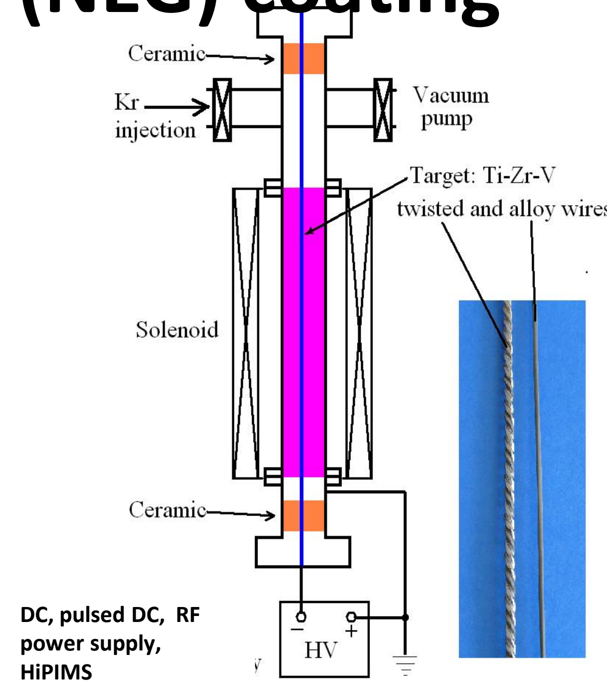


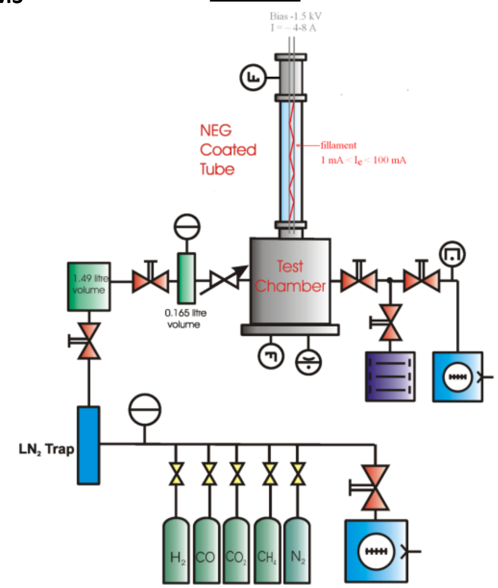


Optional: Non-evaporable getter (NEG) coating

PhD student's work:

- Jan 2016 – Mar 2016 – familiarisation with NEG depositions and evaluation facilities
- Apr 2016 – Mar 2017
  - Studying various NEG coatings and their parameters at room temperature:
    - Depositing NEG coating on standard ASTeC sample tubes (ID=38 mm, L=0.5m)
    - Analysing coupons deposited together with tubes with XPS, SEM, XRD.
    - Measuring the ESD as a function of electron dose after activation to 150, 180 and 200 °C, then measuring H_2 and CO sticking probabilities and CO pumping capacity.
- Measuring the ESD and pumping propertied for samples from CERN (if provided)





Reminder

Coordination needed for:

- Cold bore space
- Cold mass temperature: 1.9 vs 4.5 K
- Impedance issues
- E cloud
- Multipacting

Conclusion

- Work is progressing well
- Still some recruitment pending
- Design progressing towards prototyping
- ANKA Set-Up underway
- Laser surface treatment as baseline for e-cloud mitigation
- Some concerns on finding extra matching funding from National Institutes

WP4 – Cryogenic Beam Vacuum System

Task	Subtask	Members
Task 4.1. Coordination *Francis Perez* *Paolo Chiggiato*	*Task 4.2. Modeling* Carles Colldelram	Roberto Kersevan *Ianasi Bellafont* Raquel Monge Marcos Quispe *Joan Casas*
	Task 4.3. Mitigation *Oleg Malyshev*	Reza Valizadeh Pedro Costa Taai Sian *Open Doct* Peter McIntosh
	Task.4.4. Stability Roberto Cimino	Mauro Taborelli *Open PostDoc*
	Task 4.5. Design *Cedric Garion*	Miguel Costa → 4.6 Javier Munilla Elisa Garcia-Tavares → 4.4 *New PJAS - CIEMAT* Luis Garcia-Tavares Jose Manuel Perez
	Task 4.6. Test *Vicent Baglin* *Sara Casalbuoni*	*Open PostDoc* Erhard Huttel Anke-Susanne Mueller Sara Casalbuoni

FCC Week 2016 - Rome

- Overview WP4 – Paolo & Francis
- Screen Design – Cedric
- Vacuum Simulation – Roberto Kersevan
- ANKA Setup up – Sara
- Surface Laser Treatment – Reza
- Beam Screen Reflectivity - Roberto Cimino

ERC Advanced Grant 2015 by R. Cimino

(Submitted the 2-6-15).

GECO

Gr**e**en Circular C**o**lliders

GECO aims to bring to maturity the possibility offered by a **highly X ray reflecting beam screen**, to control and dissipate the SR induced heat load in the warm part of any future hadron accelerator at the energy frontiers. This will results in a much more cost effective accelerator. The proposed solution has to be solid, stable and validated to be compliant to all the functionalities required to a BS for optimum machine performance.

Rejected on 15-11

FYI:

The scientific base of GECO:

accepted yesterday for Publication in:

PHYSICAL REVIEW LETTERS

Potential remedies against the high Synchrotron Radiation induced heat load for future highest energy proton circular colliders.

R. Cimino,[1,2,*] V. Baglin,[2] and F. Schäfers[3]

[1] *LNF-INFN, Frascati, Italy*
[2] *CERN, Geneva, Switzerland*
[3] *Institute for Nanometre Optics and Technology, HZB BESSY-II, Berlin, Germany.*
(Dated: August 12, 2015)

We propose a new methodology to handle the high Syncrotron Radiation (SR) induced heat load of future circular hadron colliders (like FCC-hh). FCC-hh are dominated by the production of SR, which causes a significant heat load on the accelerator walls. Removal of such heat load in the cold part of the machine, as done in the Large Hadron Collider, will require more than 100 MW of electrical power and a major cooling system. We studied a totally different approach, identifying an accelerator beam screen whose illuminated surface is able to forward reflect most of the photons impinging onto it. Such a reflecting beam screen will transport a significant part of this heat load outside the cold dipoles. Then, in room temperature sections, it could be more efficiently dissipated. Here we will analyse the proposed solution and address its full compatibility with all other aspects an accelerator beam screen must fulfill to keep under control beam instabilities as caused by electron cloud formation, impedance, dynamic vacuum issues, etc. If experimentally fully validated, an highly reflecting beam screen surface will provide a viable and solid solution to be eligible as baseline design in FCC-hh projects to come, rendering them more cost effective and sustainable.

PACS numbers: 78.20.-e; 29.20.-c; 07.30.-t; 29.27.Bd

One referee said: "The method described in the paper has the potential to solve a critical outstanding problem and therefore to pave the way for notable progress in the field"