Design, Prototyping and Tests of the FCC-hh Vacuum Beam Screen

Francis Perez (ALBA) and Paolo Chiggiato (CERN)
on behalf of **EuroCirCol WP4**

Ciemat

Science & Technology Facilities Council

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FCC hh ee he

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A key to New Physics
WP4

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Outline

FCC-hh cryogenic vacuum requirement in the arcs

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More stringent gas density requirement than the LHC

Required gas density in the arcs **< 2x10^{14} H_2/m^3** (equivalent to 100 hrs nuclear beam-gas scattering lifetime, LHC **< 1x10^{15} H_2/m^3**) .

Much higher synchrotron radiation power density

	FCC-hh	Present LHC	
Proton energy [TeV]	50	7	
Temperature of cold mass [K]	1.9	1.9	
Number of bunches at 25 ns	10600	2808	E-cloud expected
Bunch population [10^{11}]	1	1.15	E-cloud expected
SR photon flux [ph $s^{-1}m^{-1}$] above cut-off at 4 eV	$1.34x10^{17}$	$2.02x10^{16}$	E-cloud expected
Arc SR heat load per beam [W m^{-1}]	**28.4**	**0.17**	Main issue
SR critical energy [eV]	**4300**	**44**	Main issue

FCC-hh cryogenic vacuum requirement in the arcs

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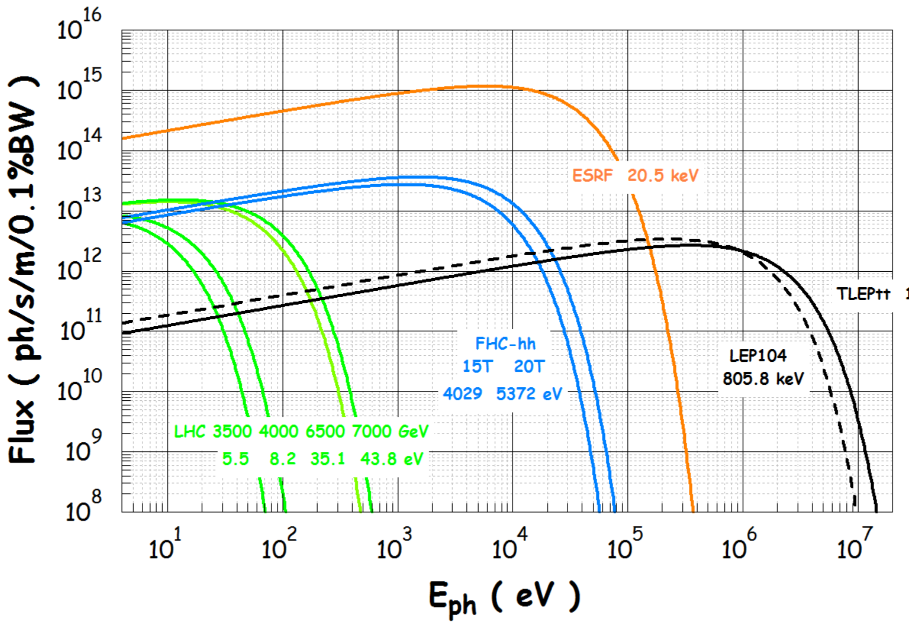
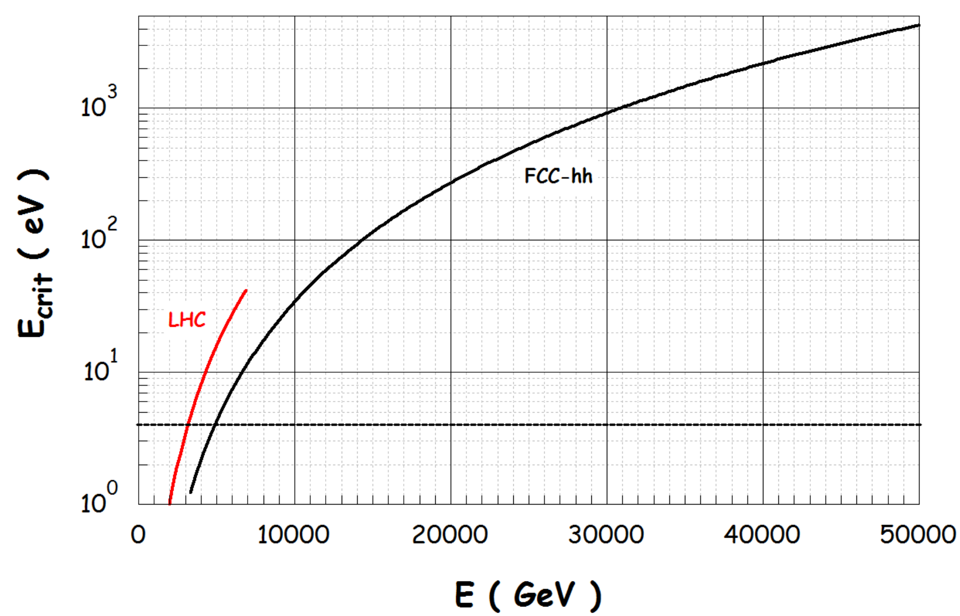
Spectral SR flux distribution



Critical energy vs Beam energy



Courtesy of Roberto Kersevan

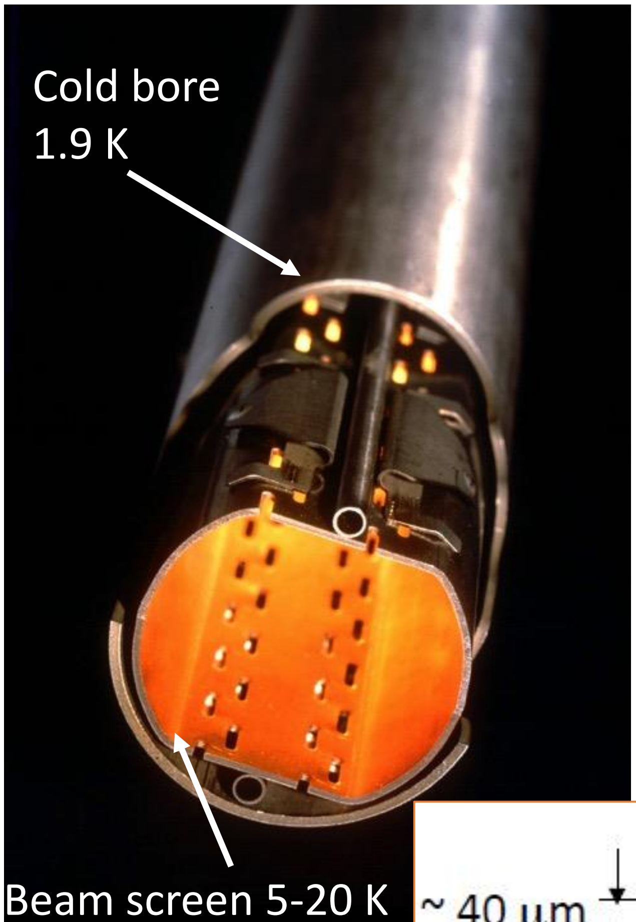
Beam injection at 3.3 TeV

At injection, critical energy much lower than the work function of metallic walls (≈4 eV); SR cannot generate photoelectrons nor photon-induced gas desorption.

Proposed design of the FCC-hh arc vacuum system

The LHC beam screen model

As in the LHC, a beam screen inserted in the cold bore intercepts the synchrotron light at temperatures in the 5 to 20 K range.

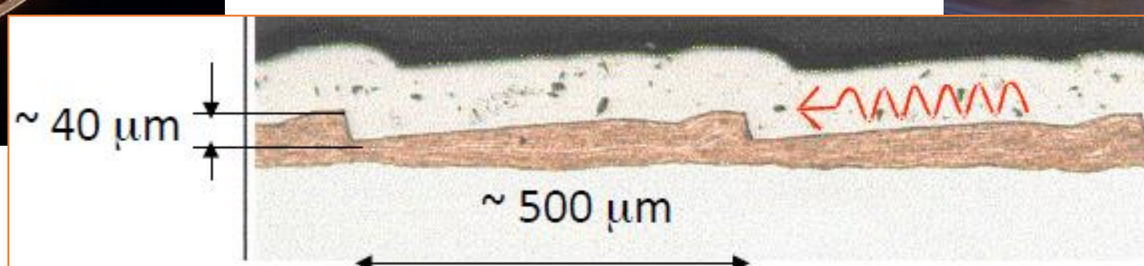


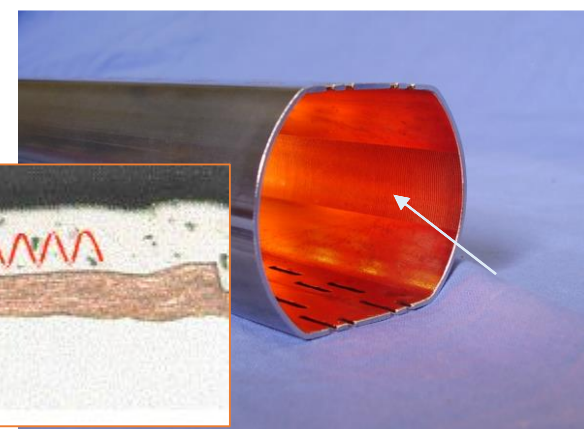
The heat load is evacuated by gas helium flowing in cooling channels.

Gas molecules are desorbed in the beam screen and, through pumping slots, are permanently cryo-pumped onto the cold bore (1.9 K).

Impedance is reduced by co-laminating a copper sheet on stainless steel and optimisation of the pumping slots.

Forwards reflection and photoelectron yield are reduced by increasing normal incidence on a saw-tooth profile engraved on the beam-screen side, where SR impinges.





The FCC-hh beam screen model

As a consequence of the **higher SR power density:**

- The **mass flow of gas** in the cooling channel must be increased. The diameter of the channel has to be increased to avoid too high pressure drop.

- The **beam screen temperature** must be increased in the range **40 to 60 K**, as compared to the 5 to 20 K in LHC, to reduce the needed cryogenic power. The higher temperatures have large repercussions on the vacuum due to higher ***equilibrium vapour pressures.***

- There is an increased photo-desorption due to an higher number of photons (x6 above cut-off at 4 eV). **Higher effective pumping speed** is needed.

Consequence: The present LHC beam is not adapted for the FCC-hh.

Proposed design of the FCC-hh arc vacuum system

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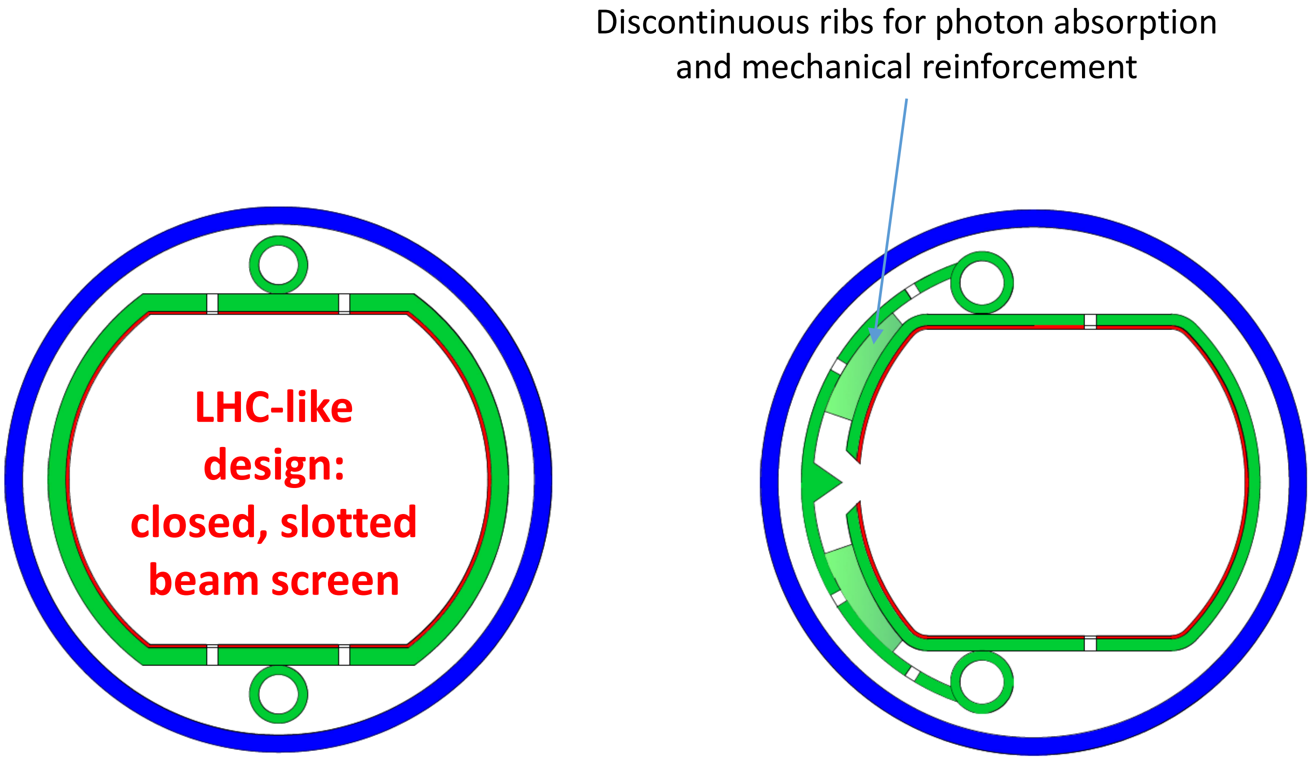
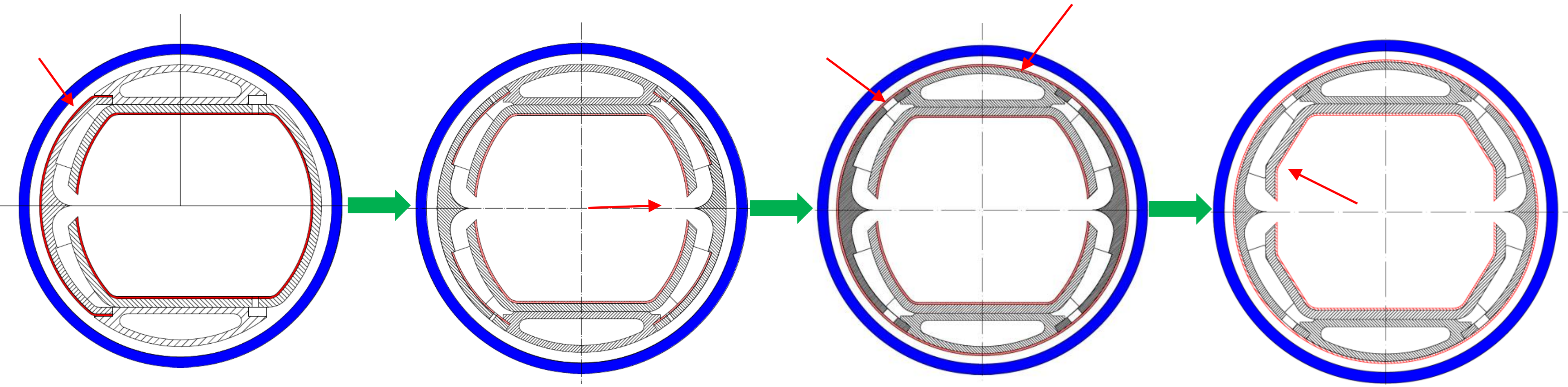


Original proposal at
"FCC Week Conference", Washington D.C., **March 2015**;
One-slot beam screen with reduced number of pumping slots (source of impedance)

Proposed design of the FCC-hh arc vacuum system



Improved heat transfer

- Increased He cooling channel
- Cold thermal sprayed copper coating on the outer side

Lower impedance

- Symmetrical design
- Pumping holes hidden by the screen

Better heat transfer

- Cold thermal sprayed copper coating on the outer side

Improved pumping

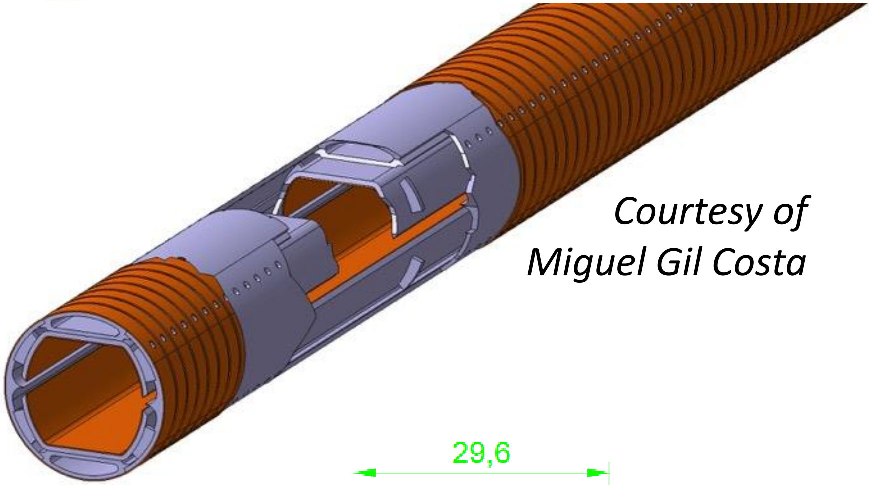
- Larger pumping holes (no impedance constraint)

Easier manufacturing

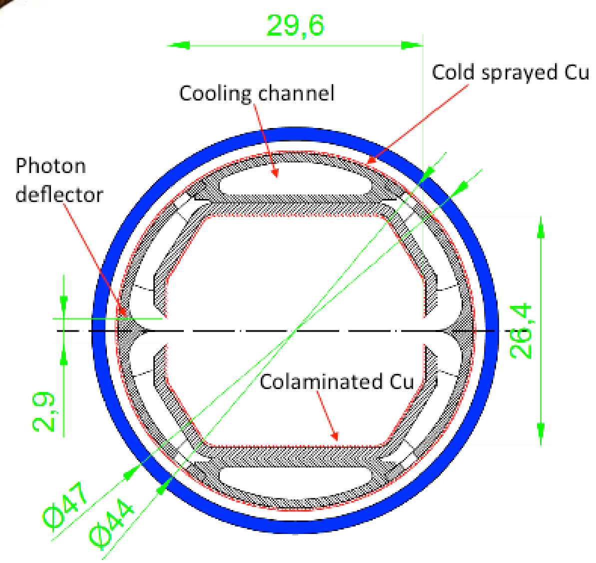
Polygonal shape of the screen

March 2015 → May 2015 → August 2015 → January 2016

The FCC-hh beam screen

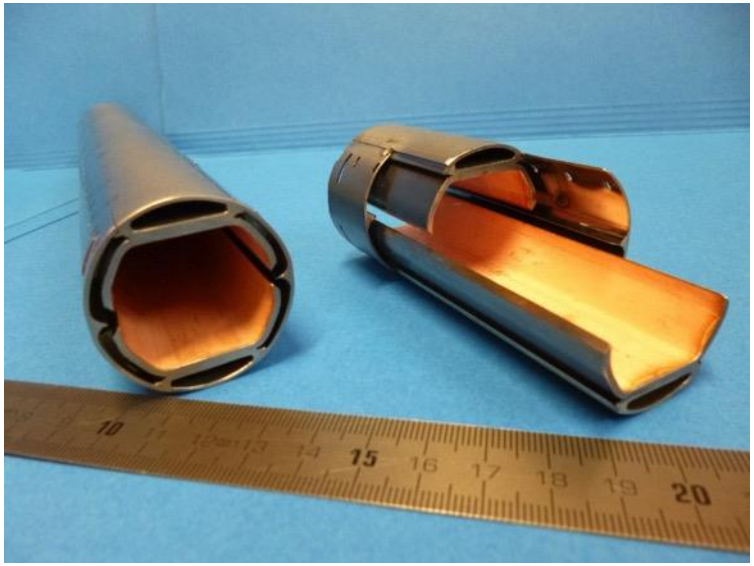


Courtesy of
Miguel Gil Costa



April 2016

Prototyping ongoing



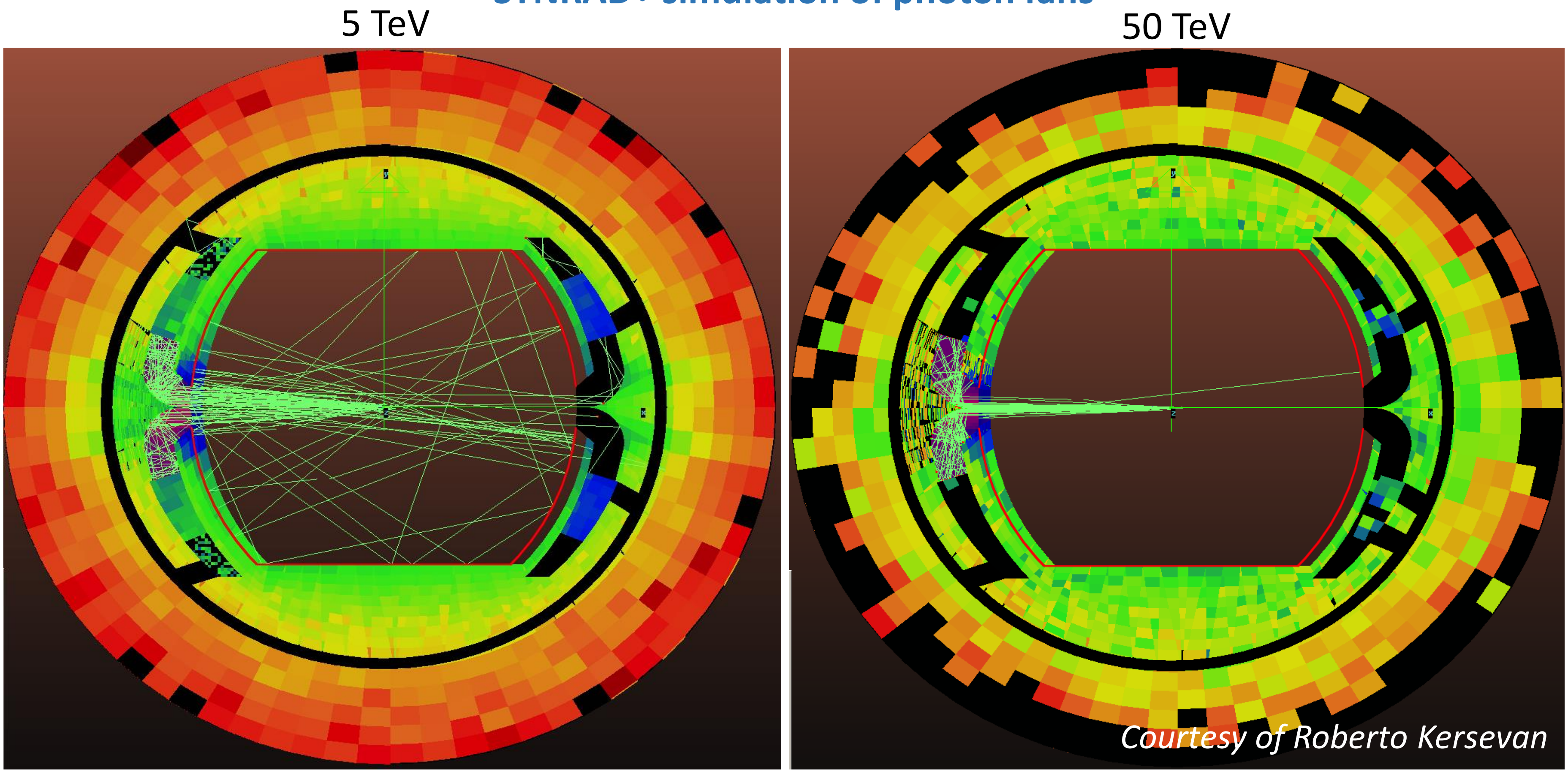
Large scale manufacturing process under investigation

See **Cedric Garion** contribution: FCC-hh beam screen studies and cooling scenario, Technologies R&D: Beam vacuum & cryogenics

Thursday AM 8:50

The FCC-hh beam screen

SYNRAD+ simulation of photon fans

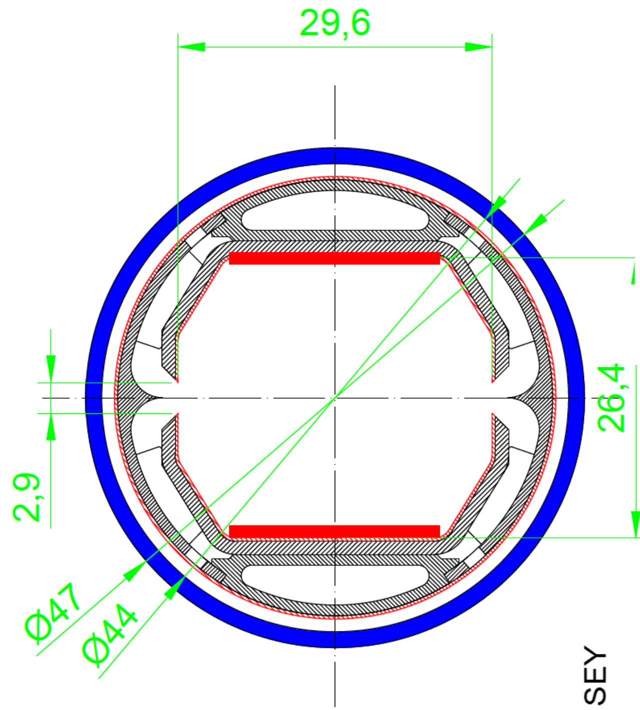


Gas density simulation by MolFlow+: strongly dependent on accumulated photon dose. Vacuum requirement attained after about 10 days at full current. Work in progress…

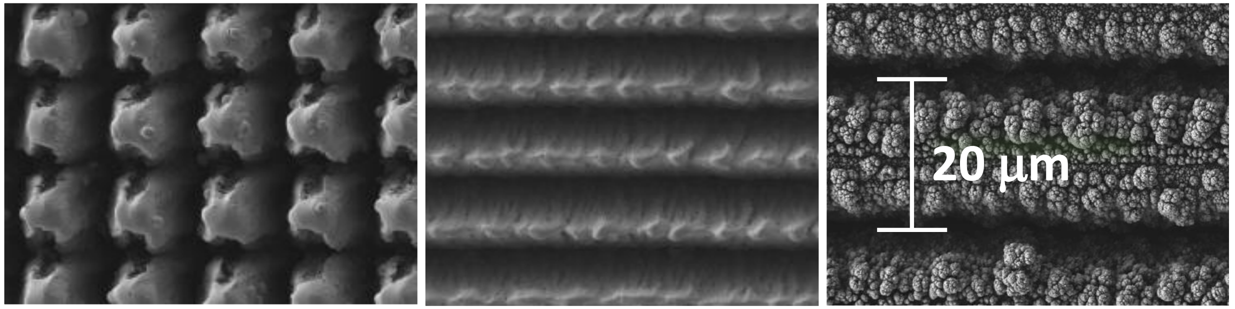
Ecloud mitigation integrated in the design

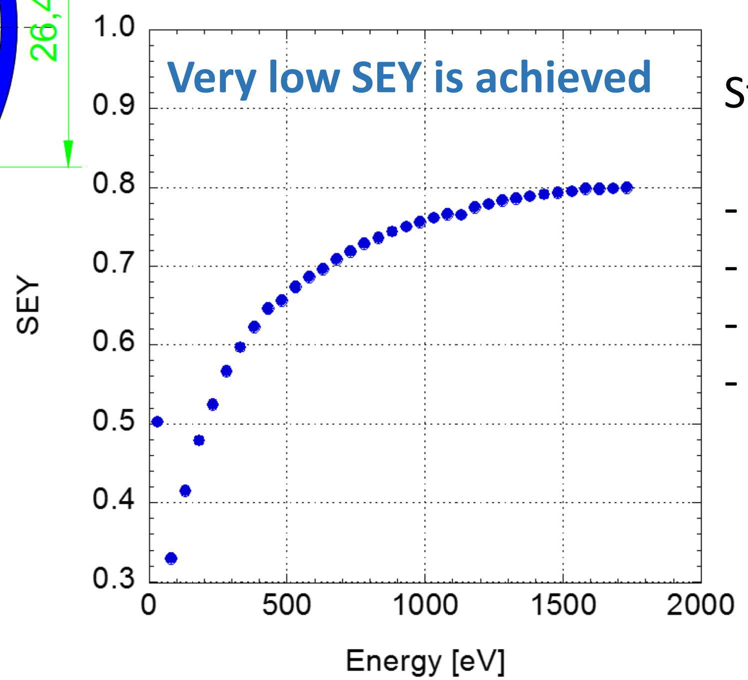
Present baseline

Laser treatment, just above the ablation threshold, of the top and bottom beam screen surfaces (ASTeC-STFC and Dundee University).



The morphology of the surface is modified





Very efficient to reduce photon reflectivity

Studies in progress:

- Morphology optimisation
- Impedance
- Dust generation
- Effect of magnetic field

See **Reza Valizadeh** contribution.
Wednesday PM – Poster section

The FCC-hh beam screen

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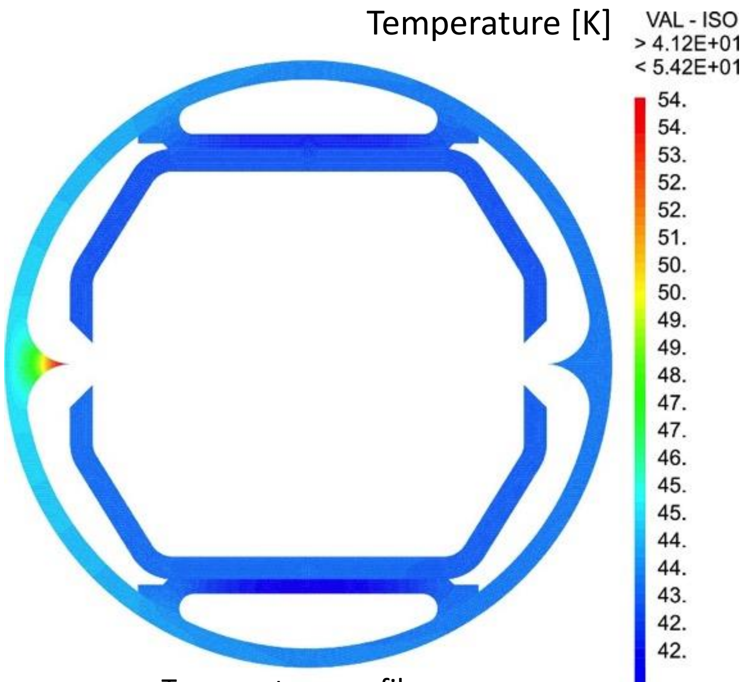
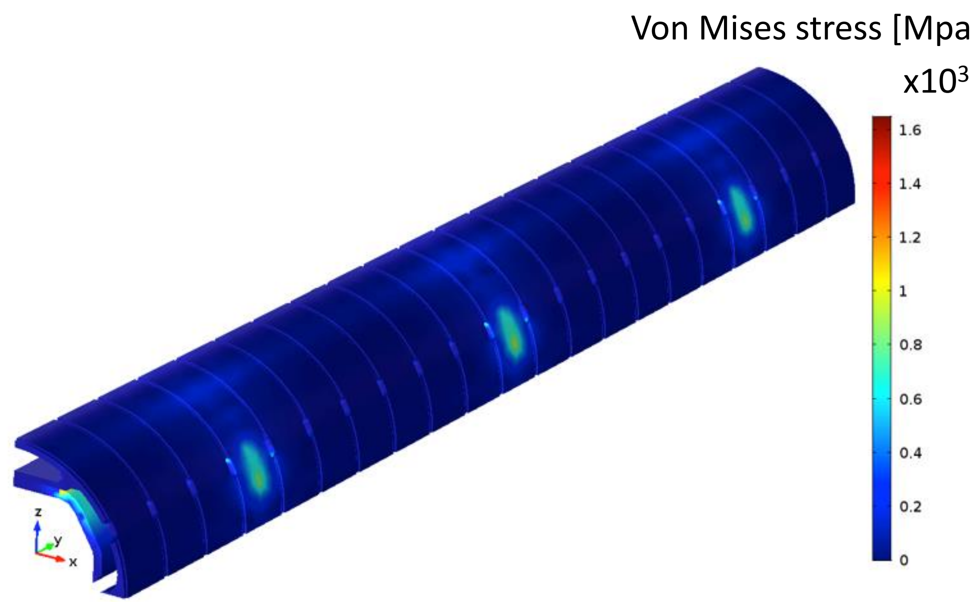
Thermal and mechanical simulation



Temperature profile

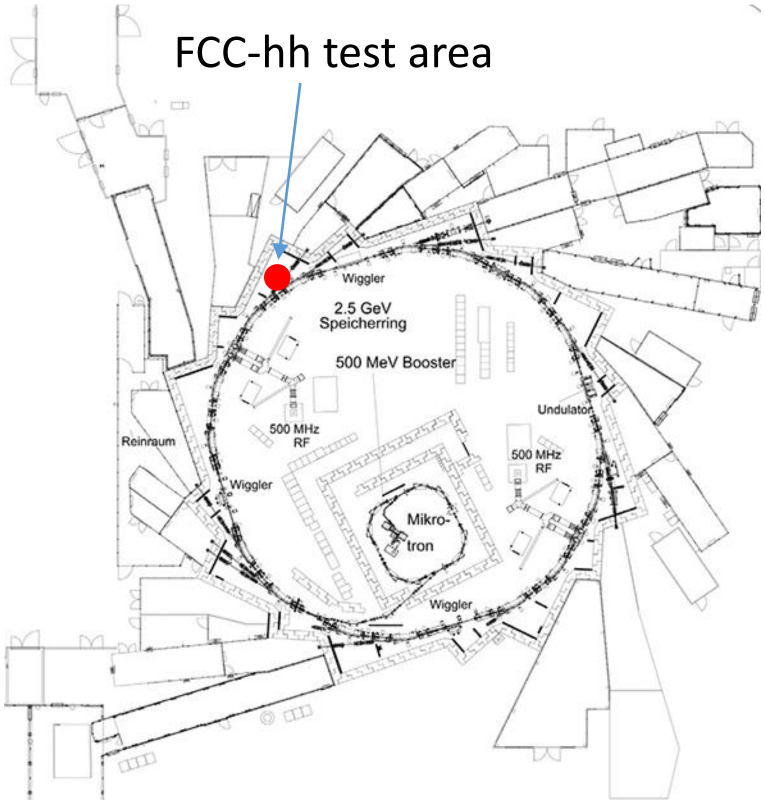


Screen temperature only a few degrees (<3K) higher than the cooling gas temperature. Maximum temperature at photon deflector: 54 K

Stress during magnet quench: the mechanical integrity is preserved.

Tests by synchrotron light at ANKA

The set-up



Emittance:	**40**	**nm rad**
Circumference:	**110.4**	**m**
Energy:	**2.5**	**GeV**
Current:	**200-100**	**mA**
Optics:	**4x2**	**DBA**
DP-field:	**1.5**	**T**

Dedicated shifts

Energy:	**0.5-2.5**	**GeV**
Current:	**< 200**	**mA**

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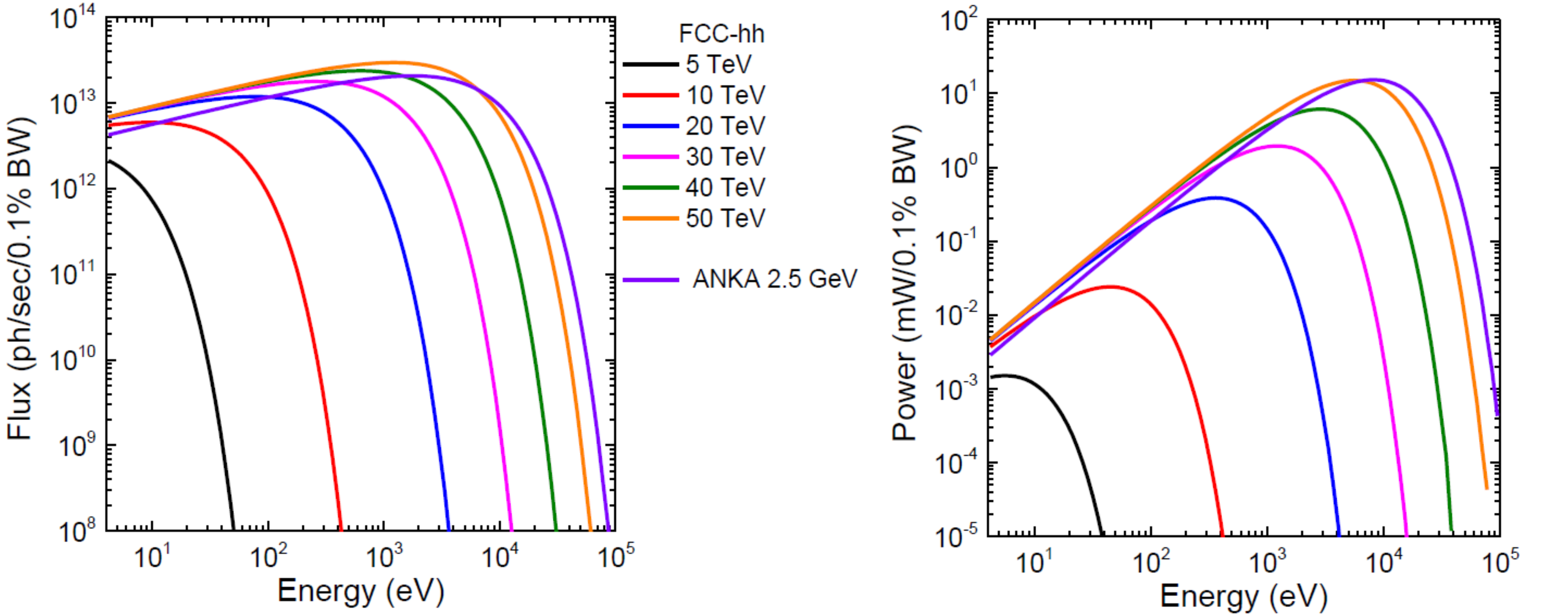
Good approximation of the FCC-hh photon spectra



Courtesy of Marton Ady

See **Sara Casalbuoni** contribution.
Section: Beam induced effects
Thursday AM 11:10

Tests by synchrotron light at ANKA

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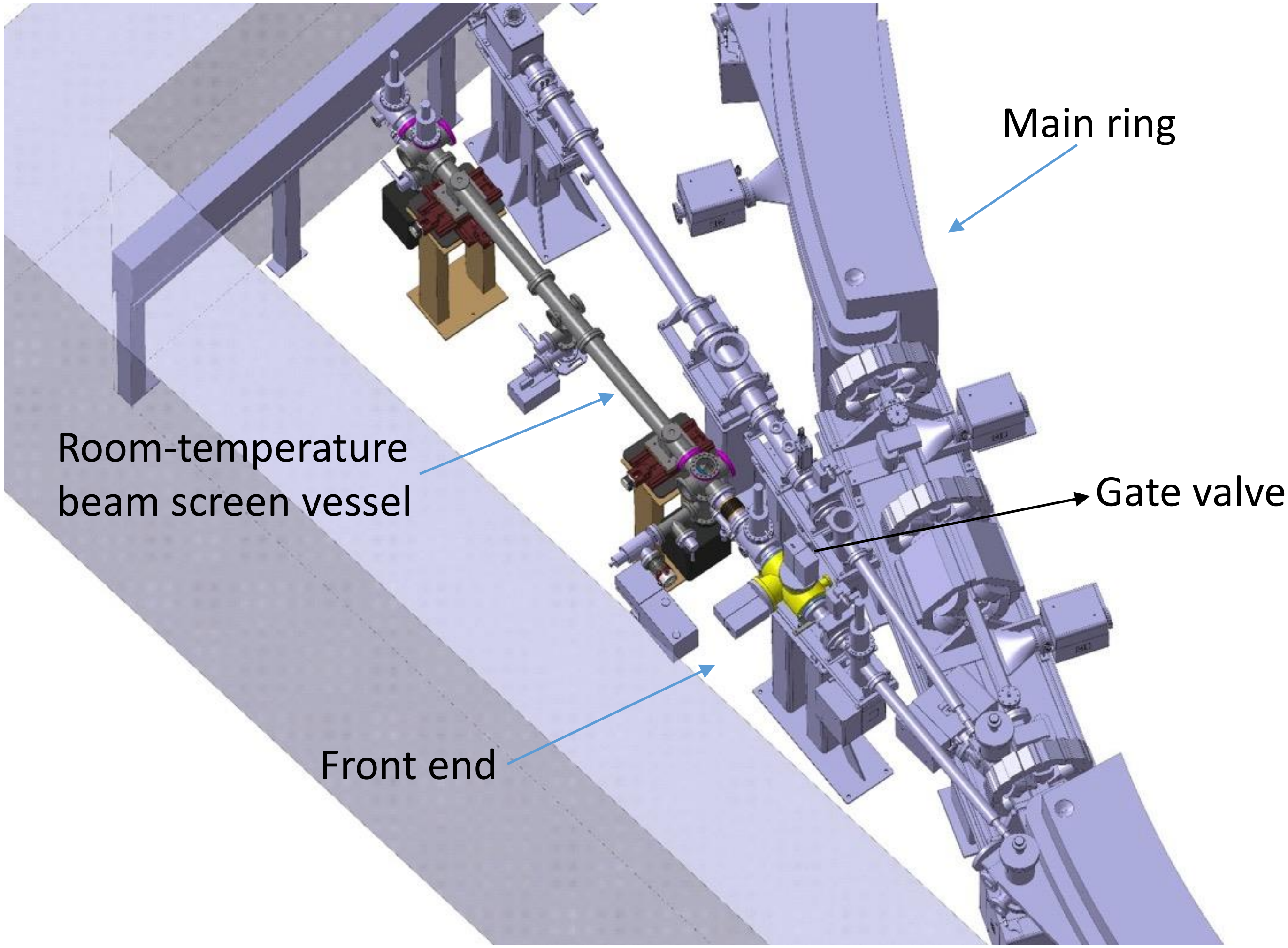
The set-up



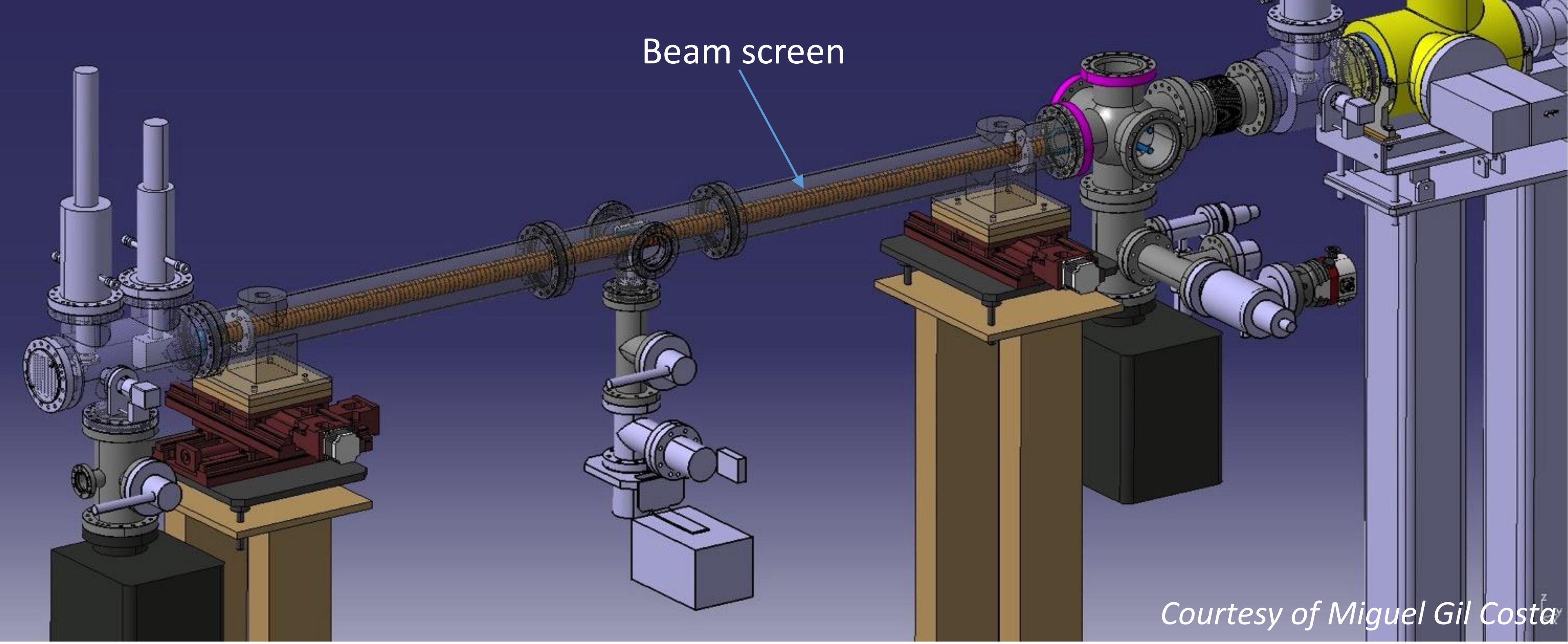
Courtesy of Miguel Gil Costa

Tests by synchrotron light at ANKA

The set-up

In the first step, the beam screen will be at room temperature; then, if possible, at liquid N_2 temperature.

First measurements in 2017



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What we can measure with the ANKA set-up

- Heat load distribution.
- Desorption yields as a function of photon dose.
- Photoelectron yield.

What we cannot measure with the ANKA set-up

- Electron cloud density.
- Beam impedance.
- Low temperature measurements.

Collaboration with Cornell University under study (CesrTA)

New COLDEX or COLDIAG?

Other tests to be planned

Opportunities for future tests:

a) Magnet quench measurements at CERN to verify **mechanical integrity**.

b) Low-temperature **gas adsorption on laser treated surfaces**.

c) Dust generation (**UFO**) and related issues.

d) …

Conclusions

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- For the FCC-hh, we have proposed a **new concept of beam screen** to :
  - fulfil the stringent vacuum requirements;
  - easily remove the much higher than LHC synchrotron light power;
  - integrate e-cloud suppression from the design
- The **preliminary design of the beam screen is ready**. It is being corroborated by:
  - mechanical and thermal simulation
  - gas density MC simulation
- The first **short prototype is ready**; a 2-m long version will be manufactured by end 2016.
- The **large-scale manufacturing** is presently under **investigation**: cost reduction is the main line of exploration.
- A new set-up under construction at **ANKA will provide in 2017 first measurements** under synchrotron light bombardment.
- Feasibility studies of **additional tests**, including confirmation of e-cloud eradication and integrity after magnet quench, are in progress.