FCC-hh beam vacuum concept: design, tests and feasibility

Francis Perez (ALBA)
on behalf of EuroCirCol WP4

EuroCirCol: 'The European Circular Energy-Frontier Collider Study (EuroCirCol) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 654305. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.'

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Outline

1. FCC-hh cryogenic beam-vacuum requirement in the arcs
2. FCC-hh beam screen design
3. Gas Density profile
4. Measurements of Prototypes
5. Progress with laser treatment for ecloud mitigation
6. Gas adsorption/desorption dynamics and SEY
7. Conclusions

FCC-hh cryogenic beam-vacuum requirement in the arcs

The challenge:
x100+ 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
Bunch population [10^{11}]	1	1.15
SR photon flux [ph $s^{-1}m^{-1}$] above cut-off at 4 eV	$1.34x10^{17}$	$2.02x10^{16}$
Arc SR heat load per beam [W m^{-1}] * Bending synchrotron emission power	**28.4***	**0.17**
SR critical energy [eV]	**4300**	**44**

E-cloud expected (number of bunches, bunch population, SR photon flux)

Main issue (arc SR heat load, SR critical energy)

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

Progress with the FCC-hh beam screen design

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** is needed.

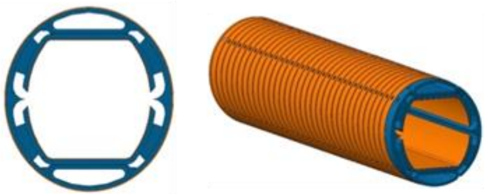
Consequence: The present LHC beam is not adapted for the FCC-hh.

Progress with the FCC-hh beam screen design

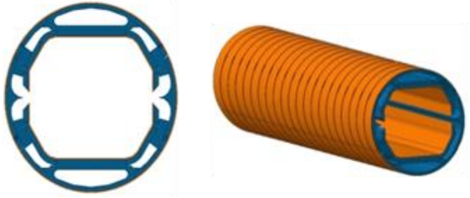
In the last three years, the beam screen design has been modified several times to attain:

- Improved **heat transfer** *(as cold spray copper ring in the outer surface)*
- **Reduced transverse impedance** *(symmetric cross section)*
- **Higher pumping** efficiency *(larger pumping holes)*
- **Easier manufacturing** *(polygonal shape)*

Orsay 09/2015
3th WP4 meeting



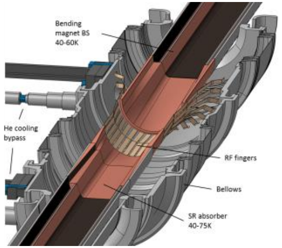
Geneva 06/2016
4th WP4 meeting



Barcelona 11/2016
5th WP4 meeting

Progress with the FCC-hh beam screen design

Last year a conceptual change was done, by going from **Reflection** to **Absortion** concept, in order to in order **reduce the undesired SR scattering** and in addition, **reduce the head load in the interconnection section**.

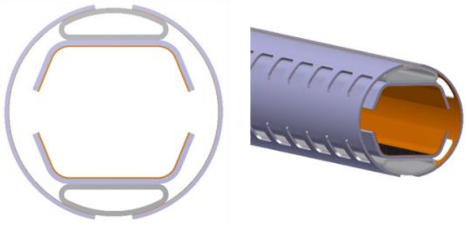


- **Remove the deflector**
- **Introduce Saw-tooth**
- **Re-design for simplification** *(remove rips, thickness)*

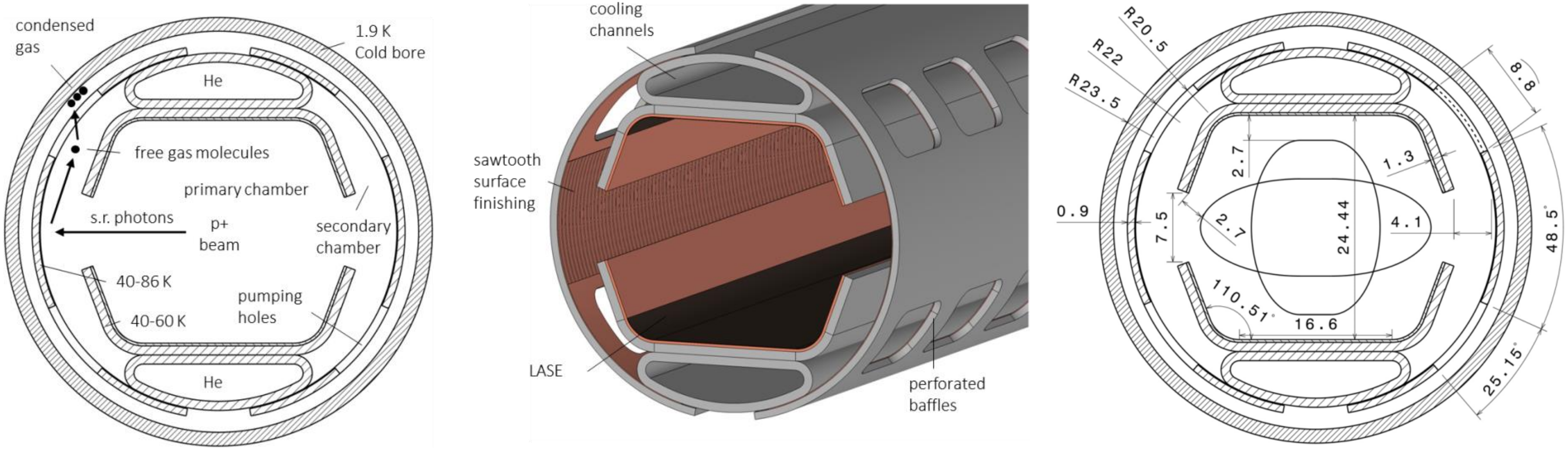
Berlin 05/2017
FCC week

Geneva 10/2017
8th WP4 meeting

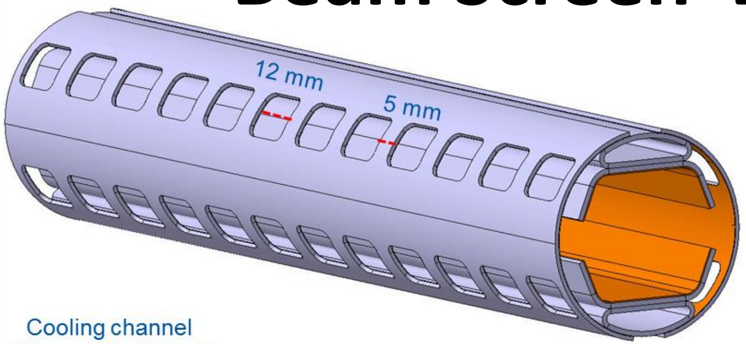
Frascati 3/2018
9th WP4 meeting

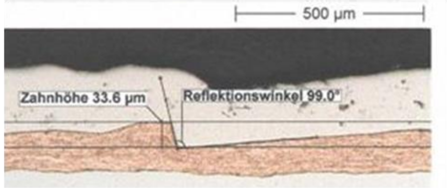


Amsterdam – April 2018
Beam Screen Design

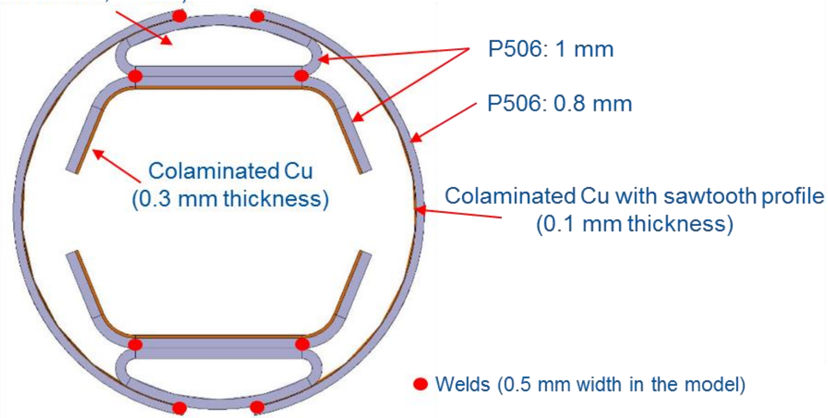


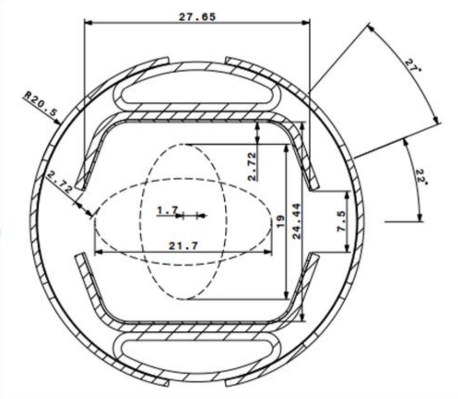
Amsterdam – April 2018
Beam Screen Design





Sawtooth profile





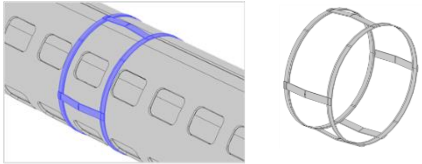
P506: High-Mn High-N Stainless steel

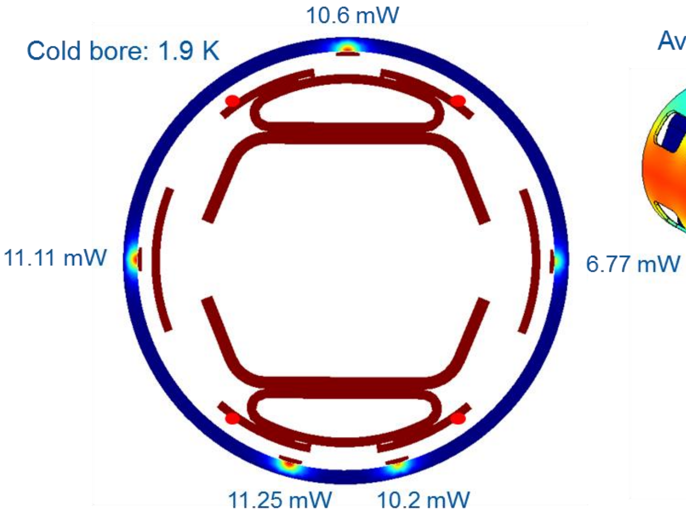
C. Garion, J. Fernandez Topham & C. Duclos

Progress with the FCC-hh beam screen design

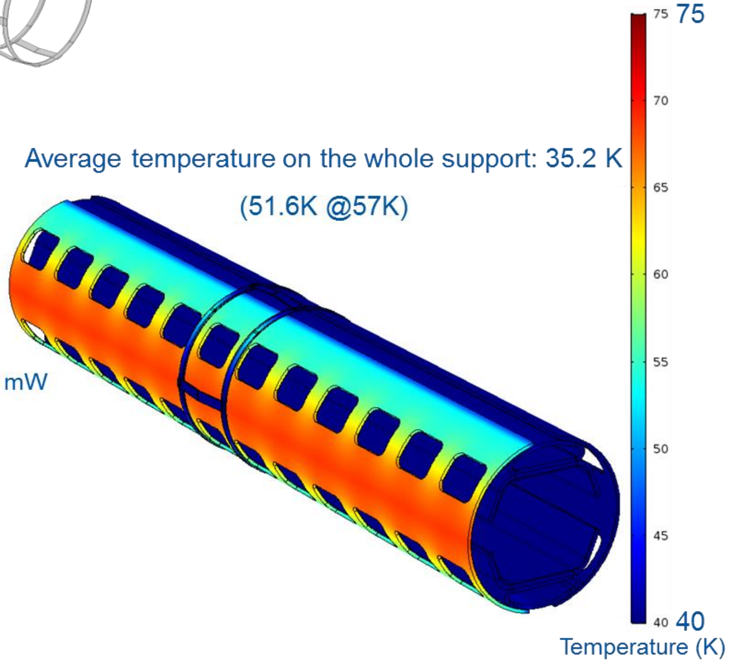
Optimisation of thermal load to the cold bore

Beam screen supports





Total heat load transferred: 49.9 mW/set

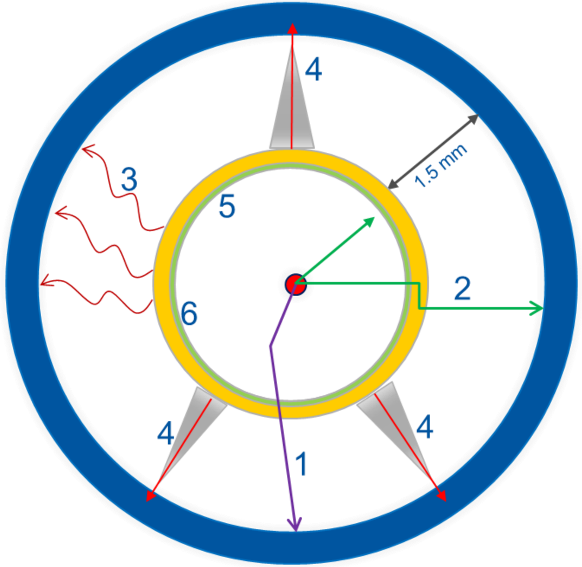


Assuming one set per 0.6 meter: 83.2 mW/m

FCC Week 2018
April 10th, 2018

Progress with the FCC-hh beam screen design

Heat transfer to the cold bore

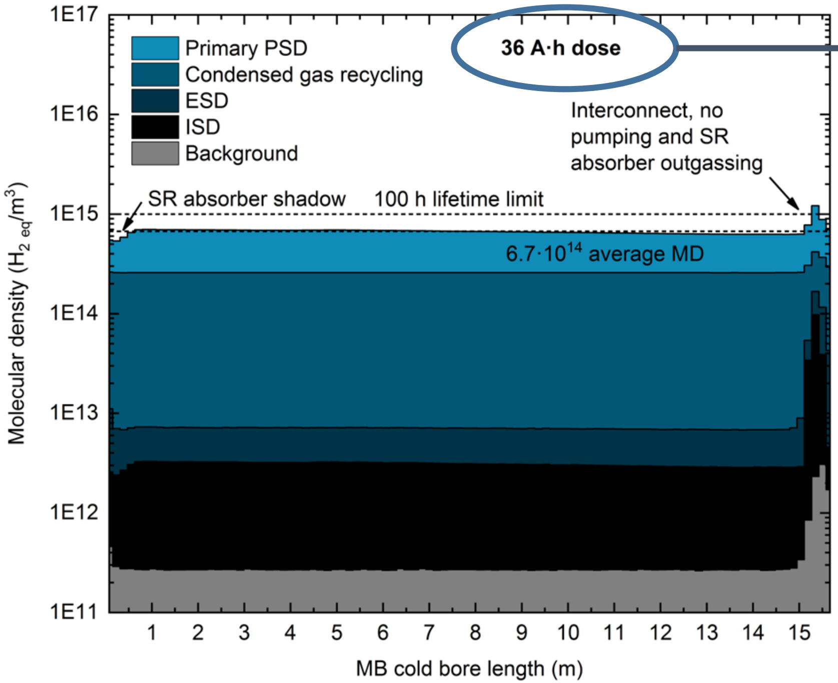


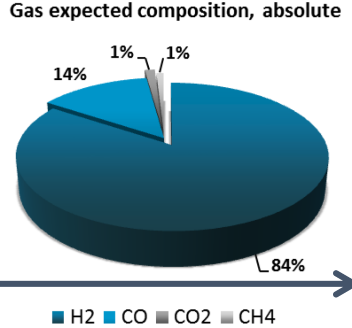
1 • Nuclear scattering: 191 mW/m
2 • Synchrotron radiation: 0.5 mW/m
3 • Thermal radiation: 2.3 mW/m
4 • Beam screen supports: 83.2 mW/m
5 • ~~Image currents~~
6 • ~~Electron cloud effect~~

Max power allowed: 300 mW/m

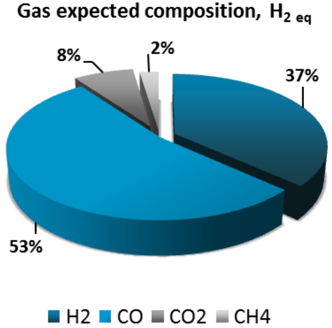
Total thermal load transferred to cold bore: <u>277 mW/m</u>

MB MOLECULAR DENSITY PROFILE



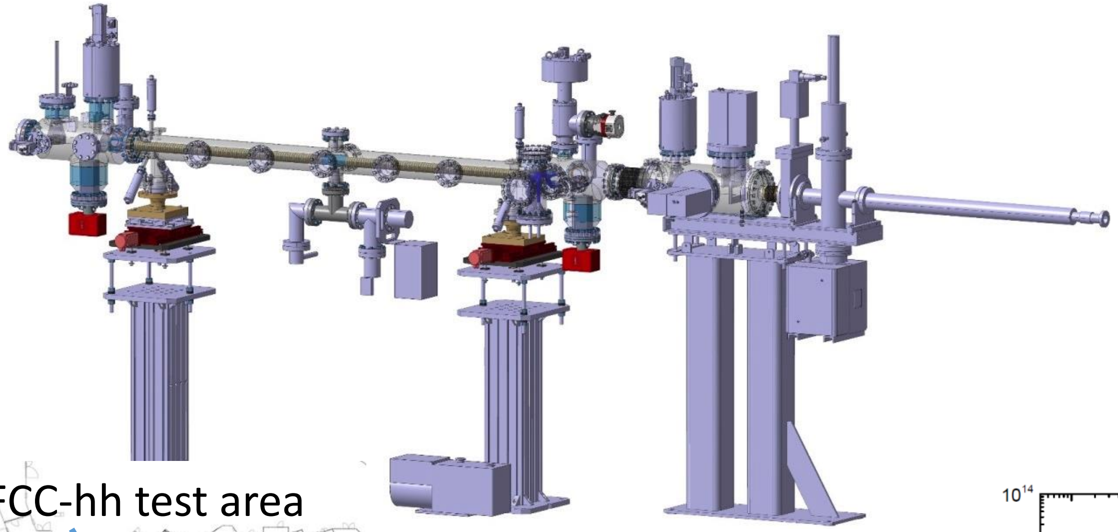


~ 3-4 months commissioning

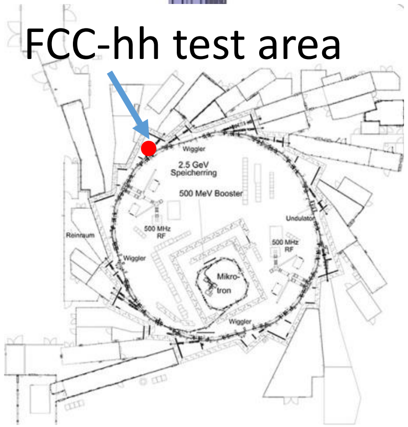


See Poster:
Photon tracing and gas-density profiles in the FCC-hh - Ignasi Bellafont

Prototypes measurements at KIT

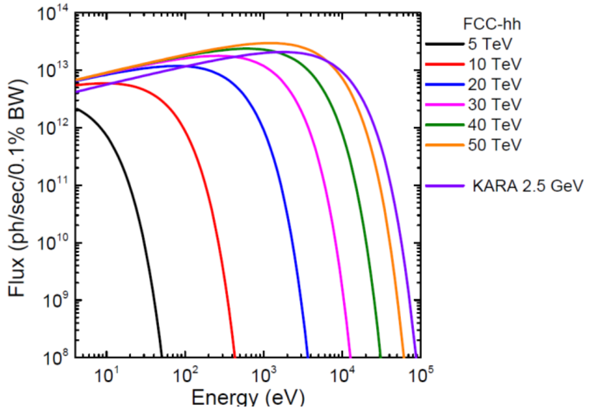


SR from KARA's dipole



FCC-hh & KARA set-up:

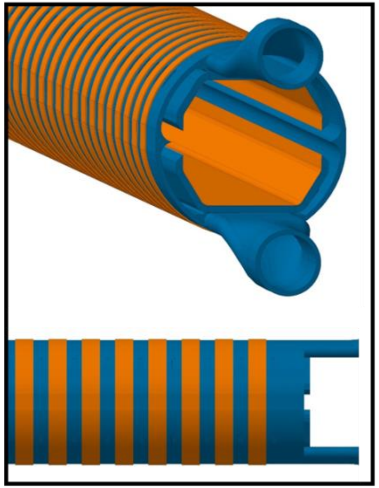
- **Identical power**
- **Similar ph. Spectrum**



FCC Week 2018
April 10th, 2018

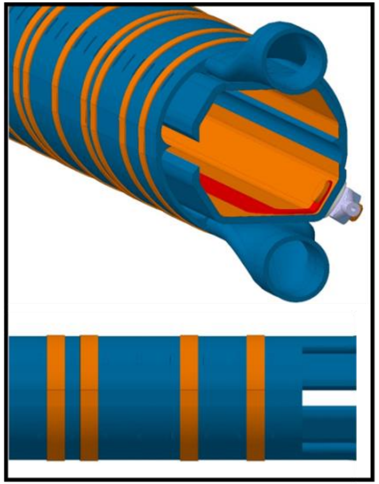
Prototypes measurements at KIT

Prototype #1 *July- Oct '17*



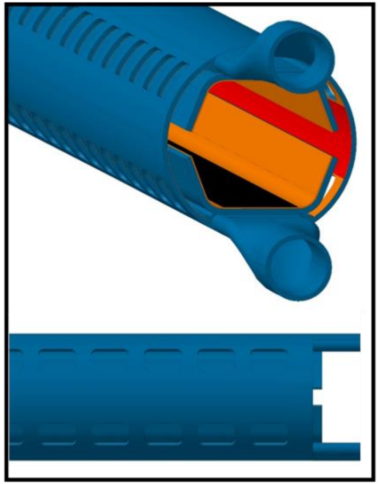
#1: Validation of temperature profile and **validity of photon reflector**

Prototype #2 *Jan- May '18*



#2: #1 + Electrode for **photoelectron current measurements**

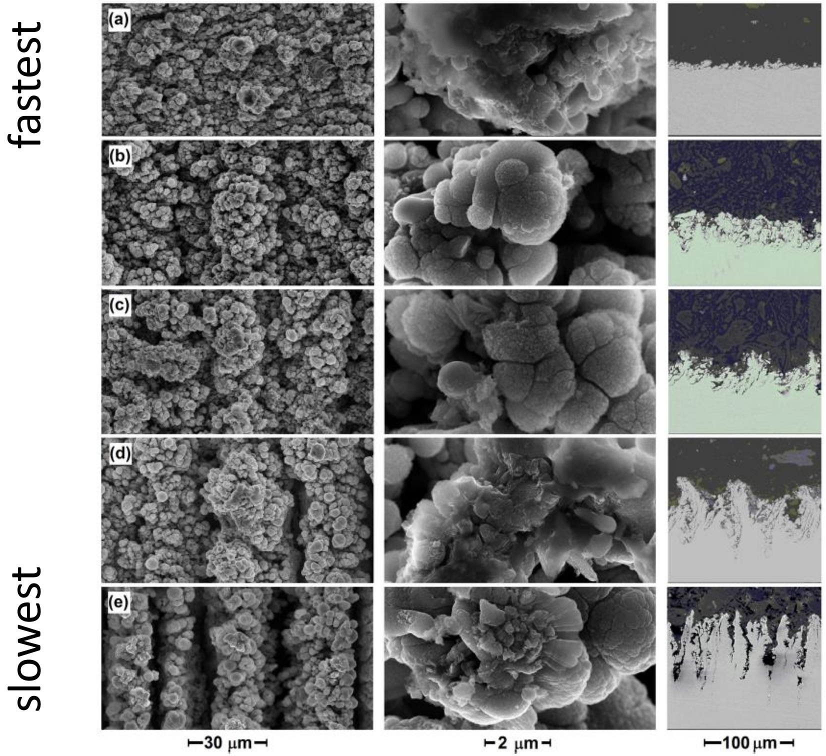
Prototype #3 *June-Aug'18*



#3: Surface treatments **as for baseline**. Updated internal screen and pumping slots. **Substitution Reflector for Sawtooth**

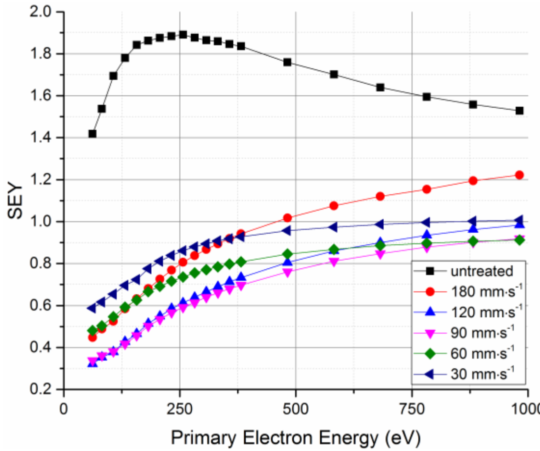
Attend Presentation, today at 8:50:
FCC-hh beam vacuum: Test results at KARA - Luis Antonio Gonzalez Gomez

Progress with NEG and laser treatment for e-cloud mitigation



Investigation at **STFC** includes:

- Laser scan speed
- Laser wavelenght



Attend Presentation, today at 10:50:

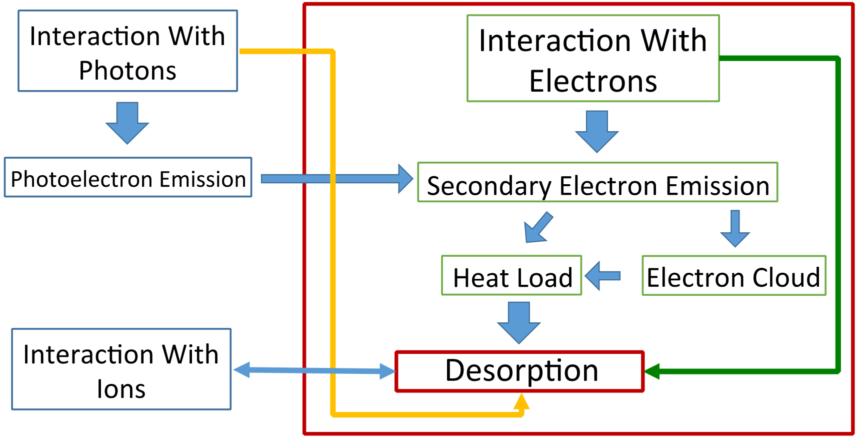
NEG Coatings LASE electron cloud mitigation techniques - Oleg Malyshev

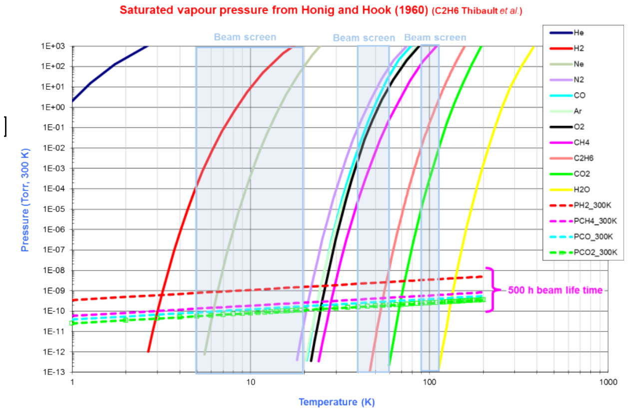
Progress with NEG and laser treatment for e-cloud mitigation

And **see posters**:

- A facility for studying SEY from LASE surfaces at cryogenic temperatures - Sian Taaj
- A progress with further developing of laser ablating surface engineering (LASE) for e-cloud eradication in particle accelerator - Reza Valizadeh
- NEG coating: associated problems and solutions - Oleg Malyshev
- New LASE surfaces obtained with various lasers and their parameters for e-cloud mitigation - Sian Taaj
- Vacuum Properties of Single Metal Zirconium Non-Evaporable Getter Coating - Ruta Sirvinskaite

Gas adsorption/desorption dynamics and SEY





Attend Presentation, today at 9:30:
Beam Screen surface characterisation for high energy beams: test results at Frascati - Roberto Cimino

And **see Poster**:
Study of Vacuum stability and desorption processes at low temperature for various FCC-hh candidate materials - Luisa Spallino

Conclusions

1. Design of the beam screen concept changed from Reflection (Deflector) to **Absorption (Saw-Tooth).**
2. The optimisation of the **beam screen is completed**; thermal, mechanical and vacuum behaviours are fully simulated.
3. The **dipole-end photon absorber** has been optimised and engineering design is in progress.
4. At the **KARA's set-up,** two prototypes have been measured and a third one will be tested in few months.
5. The optimisation of the **laser treatment** for the mitigation of electron cloud is ongoing. First samples have been produced. A beam screen prototype is being tested in the KARA's setup. **Impedance issues are under investigation.**
6. Study of **gas adsorption effects on SEY is progressing**. The laser treated surfaces are being measured.

Thanks for your attention!