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

Francis Perez (ALBA) on behalf of EuroCirCol WP4

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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: 
\( \times 100+ \) higher synchrotron radiation power density

<table>
<thead>
<tr>
<th></th>
<th>FCC-hh</th>
<th>Present LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton energy [TeV]</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>Temperature of cold mass [K]</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Number of bunches at 25 ns</td>
<td>10600</td>
<td>2808</td>
</tr>
<tr>
<td>Bunch population ([10^{11}])</td>
<td>1</td>
<td>1.15</td>
</tr>
<tr>
<td>SR photon flux [ph s(^{-1})m(^{-1})] above cut-off at 4 eV</td>
<td>1.34x10(^{17})</td>
<td>2.02x10(^{16})</td>
</tr>
<tr>
<td>Arc SR heat load per beam [W m(^{-1})]</td>
<td>28.4*</td>
<td>0.17</td>
</tr>
<tr>
<td>* Bending synchrotron emission power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR critical energy [eV]</td>
<td>4300</td>
<td>44</td>
</tr>
</tbody>
</table>

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*)
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 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*)
Beam Screen Design

condensed gas
1.9 K Cold bore
free gas molecules
primary chamber
s.c. photons
p+ beam
secondary chamber
pumping holes
He
40-86 K
40-60 K

cooling channels
sawtooth surface finishing

LASE
perforated baffles
Amsterdam – April 2018
Beam Screen Design

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

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Progress with the FCC-hh beam screen design

Optimisation of thermal load to the cold bore

Beam screen supports

Cold bore: 1.9 K

11.11 mW

10.6 mW

11.25 mW

10.2 mW

Average temperature on the whole support: 35.2 K

(51.6K @57K)

Total heat load transferred: 49.9 mW/set

Assuming one set per 0.6 meter: 83.2 mW/m
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: 277 mW/m
MB MOLECULAR DENSITY PROFILE

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

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Prototypes measurements at KIT

FCC-hh test area

FCC-hh & KARA set-up:
- Identical power
- Similar ph. Spectrum

SR from KARA’s dipole
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 wavelength

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 **Absortion (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!