SUMMARY WP4
Vacuum Screen

Francis Perez (ALBA)
on behalf of EuroCirCol WP4

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Outline

Task 4.2  Beam induced vacuum effect: Status report & next steps  
Speaker: Ignasi Bellafont

Task 4.3  Mitigate beam induced effects: Status report & next steps  
Speaker: Dr Oleg Malyshev

Task 4.4  Vacuum stability at cryogenic temperature: Status report & next steps  
Speaker: Luisa Spallino

Task 4.5  Design cryogenic vacuum beam-screen: Status report & next steps  
Speaker: Marco Morrone

Task 4.6  Test set-up at ANKA: Status report & next steps  
Speaker: Luis Antonio Gonzalez Gomez
Studies on the beam induced effects in the FCC-hh

Ignasi Bellafont
EuroCirCol WP4 Meeting
October 17th 2018

Contributions from C. Garion, L. A. González, R. Kersevan (CERN)
E. La Francesca, R. Cimino (LNF-INFN)
BEAM SCREENS COMPARISON

- See M. Marrone and C. Garion's presentation for details about the beam screen mechanical design.

LHC - 247 l/s/m for H₂ at 10 K
FCC-hh - 800-1000 l/s/m for H₂ at 50 K
With BESSY's measurements, the computed model of the BS has been refined. A real sawtooth profile has been drawn matching the reflectivity experimental data, above the theoretical one belonging to an ideal profile.

The SR scattering at the real sawtooth profile is still acceptable. If needed, it could be further lowered with the use of LASE, even beyond the one corresponding to an ideal profile.
Thanks to the high temperature, high BS p. speed and short length of the interconnect, ISD shouldn’t be a concern for the FCC-hh vacuum system.

\[ I_c(A, B^+) = \frac{e}{\eta_{A,B^+} \cdot \sigma_B} \]  
Partial \( I_c \) for an infinitely long tube

\[ \Delta P(\%) = \frac{100 \cdot J}{I_c - I} \]  
Partial P increment

\[ \sqrt{\frac{I_c \sigma}{e} \cdot \tan \left( \sqrt{\frac{I_c \sigma}{\eta} \cdot \frac{L}{2}} \right)} = \sqrt{C - \frac{I_c \sigma}{e}} \]  
\( I_c \) between BS’s, single gas (O.B. Malyshew, A. Rossi)

### Infinitely long tube, two gases system at He = 40 K

<table>
<thead>
<tr>
<th>Area</th>
<th>( \text{H}_2 + \text{CO} )</th>
<th>( \Delta P )</th>
<th>( \text{CO} + \text{CO}_2 )</th>
<th>( \Delta P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet BS</td>
<td>37 A</td>
<td>1.4 %</td>
<td>19 A</td>
<td>2.7 %</td>
</tr>
</tbody>
</table>

### Length w/o BS between BS’s, two gases at He = 40 K

<table>
<thead>
<tr>
<th>Area</th>
<th>( \text{H}_2 + \text{CO} )</th>
<th>( \Delta P )</th>
<th>( \text{CO} + \text{CO}_2 )</th>
<th>( \Delta P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnect</td>
<td>12.8 A</td>
<td>4.1 %</td>
<td>6.8 A</td>
<td>7.9 %</td>
</tr>
</tbody>
</table>

Gas coverage should not be allowed to grow in the area next to the RF fingers, since it would lower the \( I_c \).

* F.F. Rieke P.R. A5, 1507
** Estimated from LHC data
TOTAL PRESSURE EVOLUTION

For 50 TeV and 500 mA, the MD in the arcs is expected to be below the requirement of $1.0 \times 10^{15} \text{H}_2\text{eq/m}^3$ within 70 A·h. The current shall be kept lower than 500 mA if running at 50 TeV before the BS is conditioned, unlikely to happen if as in the LHC many years are necessary until achieving I and E conditions close to baseline.

- Residual gas is expected to be composed mainly by H$_2$, whilst the H$_2$ eq one is expected to be dominated by CO.
Progress with Laser Ablation Surface Engineering (LASE) and NEG Coating studies

O.B. Malyshev, R. Valizadeh, A. Hannah, T. Sian and R. Širvinskaitė

EuroCirCol Task 4.3: Mitigate beam-induced vacuum effects

ASTeC Vacuum Science Group, STFC Daresbury Laboratory, UK

4th EuroCirCol meeting, 17-18 October 2018, KIT, Karlsruhe, Germany
SEY studies in LASE samples
Measurements at room temperature

- Further surface analysis of the >100 samples has been undertaken using surface analysis techniques including:
  - SEM
  - XPS
- SEM was used to look at the surface topography
- XPS was used to measure the surface chemistry
- Results are being analysed
A new cryogenic temperature facility

Electron gun
Pumping, injection, gauge, RGA
Bellows
Test chamber
2nd stage
Conductor from 1st stage to heat shield
1st stage
Insulation vacuum

O.B. Malychev
4th EuroCirCol meeting, 17-18 October 2018, KIT, Karlsruhe
NEG coating studies
Modelled pressure ratio vs. sticking probability

- Low accuracy for $\alpha < 3 \times 10^{-3}$
- However in this case:

$$\alpha_M = \frac{S_M}{S_{M, ideal}} = \frac{4Q_M}{AV_M p_M}$$

Tube 1 – dense Zr

Tube 2 – dense Zr

Tube 3 – columnar Zr
Cryogenics

- All parts required to assemble the system + insulation materials have been received
- Silicon diode thermometers to be attached
- Needs to be tested with LN$_2$ flow to see what the lowest temperature can be achieved:
  - Without a heat
  - With a heat load during equal to one at the ESD measurements
Vacuum stability at cryogenic temperature

WP4 - Activity at LNF
Karlsruhe, 17/10/2018

Luisa Spallino, Marco Angelucci, Rosanna Larciprete and Roberto Cimino
Dose calibration

Different local pressure on the sample

1s@1.33x10⁻⁶ mbar corresponds to

Far from the sample

Near to the sample

1 Langmuir

= 5-10 Langmuir

Accurate Calibration in progress

Coverage calibration by SEY

Nominal 4L and 16L of Ar dosed in chamber correspond to a coverage of ~25L and ~100L on the sample surface

From here on, calibrated coverages are given

Temperature calibration

Same Desorption temperature of Argon Thick Film (TF) on different substrates

Ar TF desorbs at a unique T~30 K

From literature, CO and CH₂ TF desorbs at T~30 K a T~37 K respectively

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Fig. 1. Argon desorption spectra for increasing argon exposures onto various adsorbing substrates: 300 K Pressurized Ni and Ni substrate, 100 K Pressurized Ni and Ni substrate, and adsorbed Ar. The spectra show the desorption temperature dependence on the adsorbed Ar amount. The "valence" site was identified above 30 K, corresponding to the TPF spectra.

M. Stöckl et al., Surface Science 348 (1996)

Final Ar TPD results

- On flat Cu Ar adsorbs due to the weak Ar-Cu and Ar-Ar Van der Waals interactions and the desorption curve consists of the sharp peak at T~30 K.

- For the LASE-Cu substrate the Ar adsorption energy at the undercoordinated surface defect sites increases and desorption occurs at higher T. However, at high coverage, multilayer desorption at T~30 K is also observed.

CO TPD Measurements

- On flat Cu CO adsorbs due to the weak CO-Cu and CO-CO Van der Waals interactions and the desorption curve consists of the sharp peak at T~30 K.

- For the LASE-Cu substrate the CO adsorption energy at the undercoordinated surface defect sites increases and desorption occurs at higher T. However, at high coverage, multilayer desorption at T~30 K is also observed.

CH₄ TPD Measurements

- On flat Cu CH₄ adsorbs due to the weak CH₃-Cu and CH₃-CH₄ Van der Waals interactions and the desorption curve consists of the sharp peak at T~39 K.

- For the LASE-Cu substrate the CH₄ adsorption energy at the undercoordinated surface defect sites increases and desorption occurs mainly at higher T. However, on increasing the coverage, the multilayer desorption at T~39 K also increases.
General Considerations

Ar TPD curve from poly-Cu and LASE-Cu

LASE-Cu can accommodate a larger quantity of gas so as expected by its morphology

Highly porous and inhomogeneous surface with nanometric features (undercoordinated surface defect sites)

Morphology of LASE-Cu by SEM (G. Viviani @ LNF-INFN)

P2/(P1+P2) = (TPD Curve Area under P2)/(Total TPD Curve Area)

Gas desorption kinetics on LASE-Cu

Ubiquitous P2 contribution spreading in a broad temperature range

Gradually occupation of all available adsorption sites (pores wall included), up to saturation and ice thickening also on top surface

Saturated vapour pressure from Honig and Hook (1960)

Wide desorption contribution over 40 K due to the morphological structuring of the material (intrinsic broad distribution of adsorbing defective sites and pores)
FCC-hh beam screen design

Marco Morrone
Cedric Garion

4th EuroCirCol meeting
17-18 October 2018
KIT Campus North
Beam Screen Design
Recent design evolution at a glance

**Former version**
- Co-laminated Cu (thickness 100 µm)
- P506 outer shell (thickness 0.8 mm)
- Welding points (0.5 mm wide)

**Updated version**
- Co-laminated Cu (thickness 75 µm)
- P506 outer shell (thickness 1 mm)
- Edges reduced (thickness 0.4 mm)
- Welding points (0.5 mm wide)
- New welding points (0.5 mm wide)
Mechanical behaviour
Quench analysis

Variation of magnetic field at quench produces currents along the beam screen.

These currents generate Lorentz forces that might endanger the mechanical integrity of the beam screen.

3D simulations have been carried out taking into account the Joule effect coupling with the magnetic field \( \rho C_e \frac{dT}{dt} - \nabla (kVT) = Q_e = JE \).
Beam Screen Design

Beam screen supports

Maximum displacement and force along the horizontal plane during a quench:

- Former version: $\Delta x = 2.7$ mm, not 0.9 mm
  - $F_x = 61$ kN/m (per half outer shell)
- Updated version: $\Delta x = 0.65$ mm
  - $F_x = 43$ kN/m (per half outer shell)

Revision of the boundary conditions used to elaborate the results of the former BS version

Mechanical behaviour

Beam screen supports

Support on the horizontal plane

Optimisation of the beam screen supports to withstand a magnet quench with reduced plastic deformation

Residual deformation $20 \mu$m < 100 $\mu$m of pre stress

Maximum BS displacement $\Delta x = 0.65$ mm
Thermal behaviour
Temperature profile due to S.R.

Average synchrotron radiation power – 31 W/m
Beam intensity: 0.5 A, 50 TeV

Heat load deposited according to a Gaussian distribution on the saw-teeth

Surface Temperature 3D

Thermal contacts according to the spot weld pattern

T_{\text{MAX}} = 91.7 K
T_{\text{avg\_left\_side}} = 64.2 K

Heat to the cold bore: 2.18 mW/m²
Test set-up at KARA: Status report & next steps

L. A. Gonzalez, 1, 2

Task 4.5: Measurements on cryogenic beam vacuum system prototype

KARA, Karlsruhe. October 17th 2018
Installation of 3rd Prototype at KARA

July 2018

Test set-up at KARA: Status report & next stage
KARA, Karlsruhe. October 17th 2018
PSD

Sawtooth vs Inverted Sawtooth

- Similar evolution of dynamic pressure for both Sawtooths
- $P_{-Vessel}$ and $P_{-Middle}$ higher than $P_{-Front}$ and $P_{-Back}$
- In both cases $P_{-Vessel}$ and $P_{-Middle}$ cross at around $1E21 \text{ph/m}$

Test set-up at KARA, Status report & next steps
KARA, Karlsruhe. October 17th 2018

Luis Gonzalez
LNF-INFN/CERN TE-VSC
Test set-up at KARA: Status report & next steps

KARA, Karlsruhe, October 17th 2018

Luis Gonzalez
LNF-INFN/CERN TE-VSC
Reflectivity

- Slightly higher amount of photons reflected towards the photon collector for inverted Sawtooth
- Very noisy signal -> Large error bars
Reflectivity

\[ R = 100 \cdot \frac{I_{\text{In-sample}}}{I_{\text{Straight-Through}}} \]

- The ratio of Reflected/Straight-through currents is considerably lower for Sawtooth profile than for the Reflector geometry.
- Still higher than the electrodeposited Cu (Geom#4).
Future Steps

Requirement: Re-positioning of the Setup

Move the Setup in the vertical direction to irradiate upper LASE

Test set-up at KARA: Status report & next steps
KARA, Karlsruhe: October 17th 2018

Re-positioning of the Setup
Irradiation LASE
End of EuroCirCol Measuring Campaign
Beam Screen Design
Recent design evolution at a glance

Updated version

Thanks!