Amorphous carbon thin film coating of the SPS beamline: evaluation of the first coating implementation.

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Amorphous carbon thin film coating of the SPS beamline

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2. Carbon coatings to mitigate e-cloud
3. Implementation strategy
4. The coating setup
5. Results
6. Summary
1. Motivation

- SPS beam parameters

<table>
<thead>
<tr>
<th>Beam structure</th>
<th>P (GeV/C)</th>
<th>N_b (10^{11})</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 ns, 4x72b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal for LHC</td>
<td>450</td>
<td>1.2</td>
</tr>
<tr>
<td>High Luminosity LHC (HL-LHC)</td>
<td>450</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Performance will be limited by instabilities due to electron cloud
1. Motivation

How to mitigate e-cloud?

• Clearing electrodes.
• Axial magnetic fields to keep secondary electrons close to the wall.
• Decrease the Secondary Electron Yield (SEY) of the beam pipe walls.
1. Motivation

How to mitigate e-cloud?

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- Axial magnetic fields to keep secondary electrons close to the wall.
- Decrease the Secondary Electron Yield of the beam pipe walls.

Beam scrubbing coating
1. Motivation

LIU-SPS Scrubbing Review 8-9th September 2015: Conclusions and Recommendations

W. Fischer (BNL, review chair), Y. Suetsugu (KEK), K. Cornelis, J.M. Jimenez, M. Meddahi, F. Zimmermann (CERN)

Recommendation

Use a staged, partial deployment of aC coating to reach performance target:

- Take benefit of the impedance reduction activities to coat the corresponding elements (Quads and SSS)
- Replace any miss-functioning magnets by one with a aC coated chamber
- Make aC coating of MBB dipoles the baseline, until there is high confidence that scrubbing alone can establish LIU and HL-LHC performance goals
- Investigate feasibility of replacing standard drifts by coated chambers, with low impact

The following implementation timeline can be used: (E)YETS:

- Pilot run (1 arc) for QF+SSS aC coating and impedance reduction;
- MBB coating for limited cells;

1. Motivation

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  (E)YETS:
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  - MBB coating for limited cells;

2. Carbon coatings to mitigate e-cloud

- **2006**: Request of development
- **2007**: First coatings SEY$_{\text{max}}$ 1.3
- **2008**: SEY$_{\text{max}}$ 1.0 on sample
- **2009**: 3 dipoles in SPS
- **2010**: Second series of dipoles in SPS
- **2011**: 2m coating in hollow cathode
- **2012**: Dipole coating in hollow cathode
- **2013**: Development for in-situ coatings
- **2014**: Coating of MBB with 6m modular hollow cathode
- **2015**: Coating of QF with modular hollow cathode
- **2016**: Coating of 2x MBB dipole with 13.2 m train
2. Carbon coatings to mitigate e-cloud

<table>
<thead>
<tr>
<th>Machine element</th>
<th>Fraction of the machine</th>
<th>Multipacting threshold (SEY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBA dipole magnet</td>
<td>32.8 %</td>
<td>1.60</td>
</tr>
<tr>
<td>MBB dipole magnet</td>
<td>35.0 %</td>
<td>1.40</td>
</tr>
<tr>
<td>QF quadrupole magnet</td>
<td>4.8 %</td>
<td>1.30</td>
</tr>
<tr>
<td>QD quadrupole magnet</td>
<td>4.8 %</td>
<td>1.05</td>
</tr>
<tr>
<td>LSS</td>
<td>4.1 %</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Results of PyECLOUD simulations, courtesy of A. Romano, G. Iadarola, G. Rumolo and K. Li
2. Carbon Coatings to mitigate e-cloud

Electron cloud current in the SPS with an electron cloud detector

The B-field of 1.2 kGauss corresponds to the field of the SPS dipoles at injection energy (26 GeV)

2. Carbon Coatings to mitigate e-cloud

Electron cloud current in the SPS with an electron cloud detector

Beam Cross section

Proton beam

Coating
3. Implementation strategy

The Super Proton Synchrotron
3. Implementation strategy

Layout

1 cell = 63995 mm

Risk & cost optimisation:

• Ranking components by “e-cloud”
3. Implementation strategy

Risk & cost optimisation:

- Ranking components by “e-cloud”
- In-situ coating approach
- Minimize transport/removal of magnets from the tunnel
3. Implementation strategy

Layout

1 cell = 63995 mm

To do list for EYETS 2016-2017

• 4 MBB pairs
• 2 QD’s and adjacent SSS
• 9 QF’s and adjacent SSS
• LSS of sector 440 (27 m)

Totalling 33 coating runs
3. Implementation strategy

Logistics

1 cell = 63995 mm

Coating lab 1
+ new drift tubes

Coating lab 2 (radioactive)
4. The coating setup

MBB hollow cathode train

Coating setup

400 nm thick a-C coating

7.5 cm
4. The coating setup

MBB hollow cathode train

- 13.2 m long modular train for MBB
- 2 power supplies
- Continuous movement back and forward (A = 12 cm) during coating process
- Coating process takes 22 h
4. The coating setup

- 3.2 m long modular train for QF
- 1 power supply
- Continuous movement back and forward (A = 12 cm) during coating process
- Coating process takes 22 h
4. The coating setup

QF hollow cathode train

Coating setup

- 3.2 m long modular train for QF
- 1 power supply
- Continuous movement back and forward (A = 12 cm) during coating process
- Coating process takes 22 h

400 nm thick a-C coating

9.5 cm
4. The coating setup

QF hollow cathode train

- 3.2 m long modular train for QF
- 1 power supply
- Continuous movement back and forward (A = 12 cm) during coating process
- Coating process takes 22 h
4. The coating setup
5. Results

Start on Wed 04/01

End on Thu 23/02
5. Results

Specified $SEY_{\text{max}}$

E-cloud mitigation:

- **LSS + QD**
- **SSS**
- **MBB**
- **QF**

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**DC magnetron**
- Lab 1: $SEY_{\text{max}} = 0.97$, $\sigma = 0.03$
- Lab 2: $SEY_{\text{max}} = 0.99$, $\sigma = 0.03$
- Tunnel: $SEY_{\text{max}} = 0.98$, $\sigma = 0.02$

Accuracy on SEY measurement is $\pm 0.03$
5. Results

\[
\begin{align*}
\text{SEY}_{\text{max}} &= 0.97 \\
\sigma &= 0.03
\end{align*}
\]

accuracy on SEY measurement is ± 0.03
6. Summary

• First successful in-situ coating campaign in Jan & Feb of 2017.
• The a-C coating technique has proved its scalability to an industrial process.
• SPS is running smoothly since 24/04/2017.
• If scrubbing does not mitigate the e-cloud sufficiently, the coating technique is ready for full scale implementation.
Thanks to all teams and