Proposal 1602 – Cable Stack
HiRadMat Technical board

V. Raginel, D. Kleiven, D. Wollmann
CERN TE-MPE
Outline

- Scientific motivation
- Goals of the “Cable Stack” experiment in HiRadMat
- Overview of the experimental layout
- Operational aspects- Beam Pulse list
- Radiological risk
- Removal and Post mortem analysis
- Risk Assessment
Determination of damage limit of sc. magnets for instantaneous beam impact

- Original motivations coming from HL-LHC failure cases (injection, extraction)
- Several experiments planned without beam and with beam:
  1. Heat stacks of cables in an oven to different peak temperatures and measure dielectric strength of the insulation
  2. Heat insulation by a short current pulse and measure dielectric strength
  3. Heat a single strand by a current pulse and measure critical current
  4. Expose stacks of cables to radiation in HiRadMat at RT and measure dielectric strength and critical current
  5. Expose stacks of cables to radiation in HiRadMat at cryogenic temperatures and measure dielectric strength and critical current
Objectives

- Measure the degradation of the insulation
- Measure the degradation of critical current of Nb-Ti
- Check structural integrity of stainless steel plate to validate design of future HiRadMat experiment (cryostat)
Experimental Design Concept

- Six Cu/Nb-Ti cable stacks under compression in stainless steel moulds
  - 200 mm long cables
  - Mould: 60 x 85 x 120 mm³ (~ 4kg)
- Aluminium container
  - Air tight (to be tested up to 2 atm)
  - Filed with Argon (1.1 atm)
  - 250 x 300 x 600 mm³
- Stainless steel plate (thickness = 5 mm)
- Vertically movable table (reusing from HRMT24) stroke of 500 mm
- Diamond detector to be fixed on the container
Peak Temperature – Design choice

- Peak temperatures to be reach in sample based on results of experiments without beam

<table>
<thead>
<tr>
<th>Peak Temperature (°C)</th>
<th>Energy Density in Cu/Nb-Ti (kJ/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>950</td>
<td>3.2</td>
</tr>
<tr>
<td>800</td>
<td></td>
</tr>
<tr>
<td>650</td>
<td>2.4</td>
</tr>
<tr>
<td>500</td>
<td>1.6</td>
</tr>
<tr>
<td>400</td>
<td>1.2</td>
</tr>
<tr>
<td>300</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Energy Deposition and Temperature rise

Beam characteristics $FWHM = 0.5\,\text{mm}$, $E = 440\,\text{GeV}$

Max. Temp in $3^{rd}$ cable stack, stainless steel plate and container
Operational process - Beam Pulse list

- Single bunches for alignment (diamond detector)

<table>
<thead>
<tr>
<th>Beam Pulse List Template</th>
</tr>
</thead>
<tbody>
<tr>
<td>Created:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beam Pulse List</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1-80</td>
</tr>
<tr>
<td>81-96</td>
</tr>
<tr>
<td>87-92</td>
</tr>
<tr>
<td>92-98</td>
</tr>
</tbody>
</table>

- After each “high” intensity pulse, the target is moved vertically (moving the target ~1 to 2 minutes)
- Estimated beam time: 1 shift
Radiological risks – residual dose in proximity of the container

- Figures show spatial distribution of the residual dose rates in the horizontal plane
- Total intensity ~ 240 bunches, 1.15E11 p/b

<table>
<thead>
<tr>
<th>Cooling Period</th>
<th>Maximum residual dose rate at 40 cm ($\mu$Sv/h)</th>
<th>Maximum residual dose rate at contact ($\mu$Sv/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>&lt; 200</td>
<td>$1.4 \times 10^4$</td>
</tr>
<tr>
<td>1 week</td>
<td>&lt; 30</td>
<td>$4.5 \times 10^2$</td>
</tr>
<tr>
<td>1 month</td>
<td>&lt; 10</td>
<td>$1.3 \times 10^2$</td>
</tr>
<tr>
<td>6 months</td>
<td>&lt; 1</td>
<td>$3.5 \times 10^1$</td>
</tr>
</tbody>
</table>
Radiological risks – residual dose rate within/at contact with the cable stack

- Figures show spatial distribution of the residual dose rates in the horizontal plane
- $\frac{1}{2}$ of the total intensity (120 bunches, $1.15 \times 10^{11}$ p/b)

<table>
<thead>
<tr>
<th>Cooling Period</th>
<th>Maximum residual dose rate within cable stack ($\mu$Sv/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>$8.1 \times 10^4$</td>
</tr>
<tr>
<td>1 week</td>
<td>$9.4 \times 10^3$</td>
</tr>
<tr>
<td>1 month</td>
<td>$2.6 \times 10^3$</td>
</tr>
<tr>
<td>6 months</td>
<td>$4.8 \times 10^2$</td>
</tr>
</tbody>
</table>
Removal and disposal

After an appropriate cool down time to be defined in accordance with RP:

In BA7
- Removal of the container from the table
- Table will be left on the HiRadMat experimental table (to be used in future experiments)
- Transport container to an appropriate controlled area in B867 or in Radioactive WS (B109)

In Building 867/ Radioactive WS
- Opening of the container and removal of the cable stacks (procedure to be define with RP experts)
- Container to be stored as a single object in an appropriate controlled area – can be reused for future experiment. Request to be performed
- Cable stacks and stainless steel plate package in boxes for further analysis.
Post mortem analysis

Procedure for post mortem analysis will be defined with RP

Cable stacks:
- High Voltage test to be conduct either in building 867 or in the high voltage lab building 112
- Critical current measurement to be perform in external lab (to be perform)

Stainless steel plate:
- Structural analysis to be done in Microscopic Lab (B599) – (similar procedure as for the LPROT post mortem analysis)

After analysis the cable stacks, mould and the stainless steel plate become RP waste – request to be perform
Risk Assessment

• Melting of the samples
  ⇒ No contamination risk in HiRadMat

• Melting of the container due to too many bunches send on the target
  ⇒ Contamination risk
  ⇒ Low probability due to pre pulsing in the SPS

• Polyimide Film burning due to air contamination
  ⇒ Air tight test of the container at 2 atm.

• High Voltage for the Diamond detectors (100V DC)
  ⇒ The handling of high voltage equipment will be performed by trained CERN personnel.

• Radiological Risk
  ⇒ The experiment has been designed to include as little material as possible.
Thanks you for your attention!
Stress in Aluminium

\[ \sigma = \alpha \times E \times \Delta T \]

with \( \alpha \) the coefficient of thermal expansion \((2.5 \times 10^{-5} \text{ K}^{-1})\)

\( E \) the young modulus \((71 \text{ GPa})\)

\( \Delta T \) the temperature rise

- Yield stress of aluminium 90 to 280 MPa

<table>
<thead>
<tr>
<th># of bunches</th>
<th>( \Delta T ) (K)</th>
<th>( \sigma ) (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>26.5</td>
<td>43.2</td>
</tr>
<tr>
<td>12</td>
<td>53</td>
<td>86.4</td>
</tr>
<tr>
<td>24</td>
<td>106</td>
<td>172.8</td>
</tr>
</tbody>
</table>
Pressure in container due to beam pulse

- Energy stored in 24 bunches @ 440 GeV = 200 kJ
- Temperature rise in all volume less than 3 K
- Pressure rise < 0.1 mbar