18th BIS2 SMPv2 Reliability Study Progress Meeting

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New or updated end-user cases
LBDS, BLMs, BCCM & Collimators
Energy flag for LBDS

Failure consequences: **machine damage (TCDQ damaged)**.

Acceptable failure frequency: **1 in 10 years**

Initiating event:

\[
 f_{ie} = 2 \text{ per day} \\
 f_{ie} = 5,000 \text{ per 10 years}
\]

Upper boundary:

\[
 P_{SMP} < \frac{1}{5,000 \times 1\% \times 1\%} = 2
\]

Maximum allowed number of SMP failures per year:

\[
 0.1 \times 500 = 50 \text{ per year}
\]
Energy flag for BLMs

Failure consequences: **machine damage.**

Acceptable failure frequency: **1 in 1,000 years**

Initiating event:

\[ f_{ie} = 2 \text{ per day} \]
\[ f_{ie} = 500,000 \]

Upper boundary:

\[ P_{SMP} < \frac{1}{500,000 \times 6\% \times 1\%} = 3.3 \times 10^{-3} \]

Maximum allowed number of SMP failures per year:

\[ 3.3 \times 10^{-3} \times 500 = 1.67 \text{ per year} \]
Energy flag for BCCM

Failure consequences: **machine damage.**

Acceptable failure frequency: **1 in 1,000 years**

Initiating event:

\[ f_{ie} = 2 \text{ per day} \]
\[ f_{ie} = 500,000 \]

Upper boundary:

\[ P_{Smp} < \frac{1}{500,000 \times 6\% \times 1\%} = 3.3 \times 10^{-3} \]

Maximum allowed number of SMP failures per year:

\[ 3.3 \times 10^{-3} \times 500 = 1.67 \text{ per year} \]
Energy flag for Cleaning

Failure consequences: **machine damage.**

Acceptable failure frequency: **1 in 10 years**

Initiating event:

\[
f_{ie} = 2 \text{ per day} \]
\[
f_{ie} = 5,000 \text{ per 10 years} \]

Upper boundary:

\[
P_{SMP} < \frac{1}{5,000 \times 1\% \times 1\%} = 2 \]

Maximum allowed number of SMP failures per year:

\[0.1 \times 500 = 50 \text{ per year}\]
Questions regarding SMP-LHC flags

Remaining questions
Critical failure of the SPS Extraction BIS

Failure consequences: **machine damage** – **damage to transfer lines or devices of the LHC injection**.

Acceptable failure frequency: **1 in 100 years**.

- SPS extracting the beam to the LHC
  - Wrong safe value $P_{SMP}$
  - Beam above Setup Beam Limit 85%
  - Problem to circulate the beam at injection 12%

Initiating event: **SPS extracting the beam to the LHC**

$$f_w = 4 \text{ per day} = 4 \times 250 \text{ days} \times 100 \text{ years} = 100,000$$

It is assumed that extractions from SPS take place four times per day on average. Assuming 250 days in an operational year, this yields 100,000 extractions in one hundred years.

Upper boundary for the SMP system:

$$P_{SMP} < \frac{1}{100,000 \times 85\% \times 12\%} = 9.8 \times 10^{-5}$$

Maximum allowed number of SMP failures **per year** assuming that the probability of SMP critical failure is at the upper boundary derived above:

$$9.8 \times 10^{-5} \times 1000 = 9.8 \times 10^{-2} \text{ per year}$$
LHC Squeezing Factors for LHC Cleaning (Collimators)

Failure consequences: **protection dump**.
Acceptable failure frequency: **1 in a year**.

- **Wrong safe value** $P_{SMP}$ (seen by collimators which use beta* or Roman Pots)

**Conditions which must occur to constitute a risk of a critical failure:**

- Wrong value from SMP (incl. erroneous information from DCCT or BETS) $P_{SMP}$

**Initiating event:** beam squeeze

$$f_{ie} = 2 \text{ per day} = 2 \times 250 \text{ days} = 500 \text{ per 1 year}$$

**Upper boundary for the SMP system:**

$$P_{SMP} < \frac{1}{500} = 0.002 = 2 \times 10^{-3}$$

**Maximum allowed number of SMP failures per year assuming that probability of SMP critical failure is at the upper boundary selected above:**

$$2 \times 10^{-3} \times 500 = 1 \text{ per year}$$

Squeezing Factors are not involved in critical functions protecting the LHC therefore no damage can be provoked in case wrong values for the flag are generated.
<table>
<thead>
<tr>
<th>Flag</th>
<th>End User</th>
<th>Target [1 failure in x years]</th>
<th>Upper bound for $P_{SMP}$</th>
<th>Maximum allowed number of failures per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHC Setup Beam Flag</td>
<td>LHC Ring BIS</td>
<td>1,000</td>
<td>$2.7 \times 10^{-4}$</td>
<td>$1.3 \times 10^{-1}$</td>
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<tr>
<td></td>
<td>SPS Extraction BIS</td>
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<td>$9.8 \times 10^{-5}$</td>
<td>$9.8 \times 10^{-2}$</td>
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<tr>
<td>LHC Movable Devices Allowed In / Stable Beams Flag</td>
<td>Experiments</td>
<td>100</td>
<td>$7.8 \times 10^{-4}$</td>
<td>$3.3 \times 10^{-1}$</td>
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<td>LHC Energy</td>
<td>LBDS</td>
<td>10</td>
<td>$10^{-1}$</td>
<td>50</td>
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<td></td>
<td>MKI</td>
<td>1,000</td>
<td>$10^{-1}$</td>
<td>50</td>
</tr>
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<td></td>
<td>BLMs</td>
<td>1,000</td>
<td>$3.3 \times 10^{-3}$</td>
<td>1.7</td>
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<tr>
<td></td>
<td>BCCM</td>
<td>1,000</td>
<td>$3.3 \times 10^{-3}$</td>
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<td></td>
<td>LHC RF</td>
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<td>LHC Cleaning</td>
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<td>$10^{-1}$</td>
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<td>Beam Presence Flag</td>
<td>Extraction BIS</td>
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<td>$10^{-1}$</td>
<td>$2.5 \times 10^{-2}$</td>
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<tr>
<td>Max Bunch Intensity</td>
<td>LBDS TCDQ</td>
<td>100</td>
<td>$10^{-1}$</td>
<td>$10^{-1}$</td>
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<td>Link Mode</td>
<td>CIBDS</td>
<td>1</td>
<td>$7.8 \times 10^{-3}$</td>
<td>1.2</td>
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</tbody>
</table>
SMP-SPS
Hazard chains overview
# SMP-SPS Flags Reliability hazard chains

<table>
<thead>
<tr>
<th>Flag</th>
<th>End User</th>
<th>SMP Failure</th>
<th>Operator mistake (extraction when there should not be one)</th>
<th>LHC-SMP wrong safe state of the Beam Presence Flag</th>
<th>No beam in the LHC</th>
<th>Operator missing critical input to SPS BIS</th>
<th>Failure in the masked damsel</th>
<th>High intensity beam circulating in the SPS</th>
<th>Beam parameters causing damage to the TL equipment</th>
<th>Rel</th>
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<tbody>
<tr>
<td>Probe Beam Flag</td>
<td>Extraction BIS</td>
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<td>TRUE</td>
<td>TRUE</td>
<td>100 extractions per day</td>
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<td>Setup Beam Flag</td>
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<td>TRUE</td>
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<td>100 extractions per day</td>
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<td>LHC Injection BIS</td>
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<td>100 extractions per day</td>
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<td></td>
<td>SPS Ring BIS</td>
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<td>100 extractions per day</td>
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<td>Frequency of Wire Scanner use</td>
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<td>Intensity Flag</td>
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<td>Damage to the TL magnets</td>
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<td>Max Bunch Intensity BSRT</td>
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<td>TRUE</td>
<td>100 extractions per day</td>
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<td>Energy Flag</td>
<td>MKE</td>
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<td>1.50%</td>
<td>50%</td>
<td>85%</td>
<td>0.1%</td>
<td>100 extractions per day</td>
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<td>Energy_4X0 Flag</td>
<td>Extractions</td>
<td>TRUE</td>
<td>1%</td>
<td>0.11%</td>
<td>30%</td>
<td>1.50%</td>
<td>50%</td>
<td>85%</td>
<td>0.1%</td>
<td>100 extractions per day</td>
</tr>
</tbody>
</table>

| Probabilities | P_SMP | 1% | 0.11% | 30% | 1.50% | 50% | 85% | 0.1% | 100 extractions per day |

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Next steps

1. Distributing the SMP-LHC document
2. Further discussion and preparing a similar document for the SMP-SPS hazard chains
3. Component-level analysis
   - CIBG
   - CISX