Status of the Energy Deposition Studies in the Superconducting Links

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Abstract:
The status of the energy deposition in the MgB$_2$ Superconducting Links is reported. The almost definitive layout of the SCL in the tunnel has been established. The energy deposition and the dose in the SC with this layout and with a very detailed cable structure, but not with the final beam screen design, are presented. The dose and DPA in the links at P1 after 3 ab$^{-1}$ are about 0.1 MGy and $10^{-6}$ respectively. These values are well below the damage threshold. The same evaluations at LHC Point 7 (P7) are presented.
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<td>30/04/2015</td>
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</tbody>
</table>
TABLE OF CONTENTS

1. INTRODUCTION ........................................................................................................................................ 4
2. CONFIGURATION AT LHC P1 ................................................................................................................ 4
   2.1. SIMULATION RESULTS AT P1 (OPTION 1) ................................................................................................. 5
   2.2. SIMULATION RESULTS AT P1 (OPTION 2) ................................................................................................. 6
3. CONFIGURATION AT LHC P7 ................................................................................................................ 7
4. CONCLUSIONS ........................................................................................................................................... 8
REFERENCES ...................................................................................................................................................... 9
Executive summary

Here the status of the energy deposition in the MgB$_2$ Superconducting Links (SCL) in its almost definitive configuration is reported. Since the last documents, the new and almost definitive layout of the SCL in the tunnel has been established. The energy deposition and the dose in the SCL with this layout and with a very detailed cable structure, but not with the final beam screen design, are presented. The values are well below the damage threshold. Preliminary evaluation of the energy deposition and dose at LHC Point 7 (P7) are presented.

1. INTRODUCTION

The energy deposition in the Superconducting Links (SCL) has been evaluated since the beginning of the project. Continuous refinements of the geometry, materials and layout in the tunnel, according to the development of the project led to an almost definitive layout. The cable geometry for the simulations is very detailed and the layout of the SCL in the tunnel has been updated. A new beam screen, with a larger azimuthal extension than the one foreseen so far, is being implemented in the layout. The new beam screens are are tuned to better shield specific coil positions and they should not affect the energy deposition at the SCL locations. The values of energy deposition and displacement per atom (DPA) even in this not final (but anyway conservative) beam screen configuration are well below the damage limit and will not affect the SCL behaviour during the whole machine life.

Preliminary data for P7 are presented assuming a SCL cable geometry as the one at P1 and P5. The real cable geometry for P7 will be implemented in the future. The data presented for P7 assume a collimation configuration similar to the one for the operation of Run 1, the first working period of LHC reaching an integrated luminosity of 30 fb$^{-1}$.

2. CONFIGURATION AT LHC P1

Two possible routings of the SCL have been investigated:
1) to arrive from surface closer to IP1, with the SCL running aside the triplet and then connect to the Connection Module (CM), aside the beam pipe, as shown in Fig.1
2) to arrive from surface after D1, as shown in Fig.2.

Fig. 1 Superconducting Link routing option 1) as implemented in the FLUKA geometry.
2.1. SIMULATION RESULTS AT P1 (OPTION 1)

The Dose and DPA in the SCL for the routing option 1), scaled to 3000 fb⁻¹, as from FLUKA[1,2] simulations, are shown in Fig. 3a and Fig. 3b respectively. The plots show the dose and DPA averaged along the length of the SCL (10 m). The detailed internal structure of the cables is shown too [3].

As we can see the maximum dose is of the order of some 0.01 MGy, while the maximum DPA is about 10⁻⁶. According to [4] where a value of 1.1x10⁻² dpa causes a decrease of the critical temperature from 38.3 to 36 K and enhancement of the upper critical field, these values should be not endanger the SCL for all the machine operation.
2.2. SIMULATION RESULTS AT P1 (OPTION 2)

As it can be seen in Figs. 1 and 2 the SCL in the connection module (about 1 m aside the beam line) consists of a vertical part and a horizontal part. Very preliminary data (with a poor statistics) of the dose and DPA for the vertical part, averaged on the SCL length and scaled to 3000 fb$^{-1}$, are shown in Fig. 4a and Fig. 4b respectively.

![Vertical Dose](a)  ![Vertical Dpa](b)

**Fig. 4** Dose (a) and DPA (b) at 3000 fb$^{-1}$ for the vertical part of the SCL in the connection module as from FLUKA simulation.

In Fig. 5a and Fig. 5b the dose and DPA for the horizontal part (see Fig. 2) of the cable in the connection module are shown.

![Horizontal Dose](a)  ![Horizontal Dpa](b)

**Fig. 5** Dose (a) and DPA (b) at 3000 fb$^{-1}$ for the vertical part of the SCL in the connection module as from FLUKA simulation.
As we can see the mean dose and DPA are slightly higher in the vertical part, the peak value is almost the same. Their values should not represent any danger. A more detailed geometry description of the Links in the connection module is in progress. More precise data and plots are expected, without substantial changes in the dose and DPA evaluation.

3. CONFIGURATION AT LHC P7

The correlation between integrated luminosity and number of protons impacting the collimators, to evaluate the dose, can be extrapolated from the data available from LHC Run 1. In Fig. 6 the dose normalized to a number of proton losses in the collimators (10^{16}) that Run 1 data allows to tentatively correlate to 30-40 fb\(^{-1}\) is shown.

![Fig. 6 Dose in the collimators for beam 2 during Run 1 vs. the distance from IP7.](image)

The maximum dose occurs at z = 180 m so only this zone has been explored. The dose and DPA in this zone where the SC Links run at about 1 m aside the beam pipe (Fig. 7) is shown in Fig. 8a and Fig. 8b.

![Fig. 7 Layout of the SC Link in P7.](image)
For P7 the actual cable layout has not been implemented yet, so far in the simulations the same cable configuration as for P1 has been used.

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4. CONCLUSIONS

The simulation done so far indicates that the values of dose and DPA induced in the SCL should not represent any danger for the integrity and working of the SCL.

As a matter of fact if we set 50MGy as a dose limit, (value above which the kapton loses its insulating properties) [5,6] we find values well below this limit.

The DPA also should not represent any problem. As a matter of fact if we consider data from neutron irradiation [4] (being neutron the highest fraction of the radiation relevant to DPA production), we can extrapolate that the superconducting properties of MgB$_2$, at the foreseen working temperature (25 K) are not deeply affected. Values from literature indicate that the induced DPA increases the pinning effect [7] at the advantage of an increased performance.

In the next months a detailed layout of the MgB$_2$ SCL routing will be frozen, the new beam screen will be implemented in the FLUKA geometry and definitive simulations will be done.
REFERENCES


