AMT - Beam generated heat deposition and quench levels for LHC magnets

Report of Contributions

https://indico.cern.ch/e/408146

Contribution ID: **2** Type: **not specified**

Liquid helium heat transfer in superconducting cables insulation of accelerator magnets

The electrical insulation of superconducting cables poses the largest heat barrier between the heat exchanger and the cable for accelerator magnets.
This issue is of major importance for current accelerator magnets and undoubtedly will become a critical issue for magnets subjected to a higher heat deposition. We will first present a review of heat transfer studies on the LHC cable insulations in liquid helium pursued by CEA Saclay and by KEK, focusing on the key parameters involved in such heat transfer process. This will be followed by the overview of the NED program on heat transfer in light of these works.

Primary author: Dr BAUDOUY, Bertrand (CEA - SACLAY)

Presenter: Dr BAUDOUY, Bertrand (CEA - SACLAY)

Track Classification: Liquid helium heat transfer in superconducting cables insulation of accelerator magnets

Contribution ID: **3** Type: **not specified**

Quench levels and transient beam losses at HERAp

The talk recalls the main parameters which defined the expected beam loss generated quench levels (in 1985) and compares the results with measurements of loss induced quenches at HERA during 1994-2005. The parameters of the BLM system are discussed (like calibration, positioning, alarm level, etc.) and the response of the system to beam loss induced quenches with different time constants are analyzed.

Primary author: WITTENBURG, Kay (DESY)

Presenter: WITTENBURG, Kay (DESY)

Track Classification: Quench levels and transient beam losses at HERA

Contribution ID: **4** Type: **not specified**

Protecting Superconducting Magnets from Radiation at Hadron Colliders

The principal challenges arising from beam-induced energy deposition in superconducting magnets at hadron colliders are described. Radiation constraints are analyzed that include quench stability, dynamic heat loads on the cryogenic system, radiation damage limiting the component lifetime, and residual dose rates related to hands-on maintenance. These issues are especially challenging for the interaction regions (IR). Only with an appropriate IR layout, magnet design, materials, and a set of collimators and absorbers can one provide adequate mitigation of these problems that is desribed in details in this talk. Quench levels in the Tevatron, its collimation system performance and fast beam loss events are discussed.
A system to protect IR magnets at normal operation and unsynchronized beam abort is described for the LHC at a nominal luminosity as well as for possible upgrade scenarios.

Primary author: MOKHOV, Nikolai (FERMILAB)

Presenter: MOKHOV, Nikolai (FERMILAB)

Track Classification: Protecting Superconducting Magnets from Radiation at Tevatron, SSC, LHC and its upgrades.

Contribution ID: **5** Type: **not specified**

Thermal analysis and its experimental verification for the present and future IR triplets

The first generation of low-beta quadrupoles for the LHC IR inner triplets based on NbTi superconductor was developed by KEK and Fermilab in collaboration with CERN. The magnets were designed to achieve the nominal luminosity of 10ˆ34 cmˆ- 2sˆ-1. They provide a nominal field gradient of 200 T/m with a 20% margin at the high luminosity insertions with 70-mm coils, and operate at 1.9K under high radiation-induced heat load. Work on the second generation of low-beta quadrupoles based on Nb3Sn superconductor with larger aperture and larger operation margin for future IR triplets, which would allow reliable magnet operation at luminosity up to 10ˆ35 cmˆ-2sˆ-1, have also been started.
We present results of thermal analysis for the present and future IR triplets based on NbTi and Nb3Sn magnets with the expected radiation induced heat depositions in the magnet coils. The results of operation margin measurements for Fermilab-built NbTi IR quadrupoles using AC losses to simulate the radiation heat deposition in the coil will be presented. Possibilities of operation margin measurements of Nb3Sn IR quadrupoles will be also discussed.

*This work was supported by the U.S. Department of Energy

Primary author: Dr ZLOBIN, Alexander (Fermilab)

Co-author: NOVITSKI, Igor (Fermilab)

Presenter: Dr ZLOBIN, Alexander (Fermilab)

Track Classification: Thermal analysis and its experimental verification for the present and future IR triplets

Contribution ID: **6** Type: **not specified**

Experiment for energy deposition in a target

Material damage levels for LHC intensities and energies are in general derived from computer simulations calculating static energy deposition. A dedicated experiment was carried out to cross-check the validity of this approach: With a 450GeV proton beam extracted from the SPS in TT40, material was deliberately damaged in a controlled way. A simple geometry was chosen for the high-Z target comprising several typical materials that are used in the LHC, such as stainless steel and copper. Results of the simulations are presented and compared with the experiment.
General requirements to predict beam induced damage levels with computer simulations are discussed.

Primary author: KAIN, Verena (CERN)

Presenter: KAIN, Verena (CERN)

Track Classification: Experiment for energy deposition in a target

Contribution ID: **7** Type: **not specified**

Transient beam losses at injection and during beam dump

The injection and beam dump processes are designed to avoid any beam losses. However, situations will occur in which these processes are not carried out correctly, for instance with out of tolerance beam characteristics, wrong settings or equipment failures. In these cases beam losses can occur. Damage to accelerator equipment should be prevented by the Machine Protection systems, but it will not be possible to avoid quenches in all cases. The catalogue of different beam losses mechanisms is presented, with a summary of the studies made to date, the expected occurance rate and a discussion of outstanding areas of concern.

Primary author: Dr GODDARD, Brennan (CERN)

Co-author: KAIN, verena (cern)

Presenter: Dr GODDARD, Brennan (CERN)

Track Classification: Transient beam losses at injection and during beam dump

Contribution ID: **8** Type: **not specified**

Case study: Energy deposition in superconducting magnets in IR6

A diluter block TCDQ, with a collimator TCS and shield TCDQM, will be installed in front of the superconducting quadrupole Q4 magnet in IR6, to protect it and other downstream LHC machine elements from an unsynchronised beam dump. The system should also intercept particles in the abort gap to prevent quenches during regular aborts, and must also intercept the particles from the secondary halo during low beam lifetime without provoking quenches. The conceptual design of the system is briefly presented, and the FLUKA energy deposition simulations described. The results are discussed in the context of the expected performance levels for LHC operation, in particular for the problems associated with quenches. Options for improvement are elucidated and required future work is defined.

Primary authors: Dr PRESLAND, Andrew (CERN); Dr GODDARD, Brennan (CERN)

Presenter: Dr GODDARD, Brennan (CERN)

Track Classification: Case study: Energy deposition in superconducting magnets in IR6

Contribution ID: **9** Type: **not specified**

Ion operation and beam losses

The electromagnetic collisions of Lead ions can change the ions charge state due to electron capture via pair production (Bound-Free Pair Production).
Many electron-positron pairs are created in the intense electromagnetic fields of the nuclei. In some cases, the electron is created in a bound-state of one nucleus.
These wrongly charged ions are lost in the dispersion suppressor regions, and may lead to a magnet quench when LHC operates at the nominal luminosity and at collision energy. After a brief description of the Bound-Free Pair Production process, a first Monte Carlo evaluation of the energy deposition induced by such losses is discussed.

Primary author: Dr GILARDONI, Simone (CERN)

Co-authors: Mr , Bruce (CERN); Dr JOWETT, John (CERN)

Presenter: Dr GILARDONI, Simone (CERN)

Track Classification: Ion operation and beam losses

Contribution ID: **11** Type: **not specified**

Heavy ion interactions with matter

The effects of the interaction of heavy ions with matter caused by strong electromagnetic fields produced by ultrarelativistic ions are briefly reviewed. An important feature is that electromagnetic processes compete with hadronic reactions. Moreover, in certain kinematics, like in very peripheral collisions, electromagnetic dissociation processes become dominant. The pair production cross section starts to dominate over ionisation loss processes at the LHC energies. The status of development of the software adequate for simulating the beam transport at heavy ion colliders is presented.

Primary author: Prof. SMIRNOV, George (Joint Institute for Nuclear Research)

Presenter: Prof. SMIRNOV, George (Joint Institute for Nuclear Research)

Track Classification: Heavy ion interactions with matter

Contribution ID: **12** Type: **not specified**

Case Study: Energy deposition in superconducting magnets in IR7

The IR7 insertion of the Large Hadron Collider (LHC) is dedicated to beam cleaning with the design goals of absorbing part of the primary beam halo and of the secondary radiation. The tertiary halo which escapes the collimation system may heat the cold magnets at unacceptable levels, if no absorber is used. In order to assess the energy deposition in the sensitive components, extensive simulations were performed with the intranuclear cascade code FLUKA. The straight section and the dispresion suppressors of IR7 were fully implemented. A modular approach in the geometry definition and an extensive use of user-written programs allowed the implementation of all magnets and collimators with high precision, including flanges, steel supports and magnetic field. The talk will be focused on the number and location of additional absorbers needed to keep the energy deposition in the coils of the magnets below the quenching limit.

Primary author: Dr FERRARI, A. (CERN)

Co-author: Dr VLACHOUDIS, Vasilis (CERN)

Presenter: Dr VLACHOUDIS, Vasilis (CERN)

Track Classification: Case study: Energy deposition in superconducting magnets in IR7

Contribution ID: **13** Type: **not specified**

Heat load from beam

The circulating beam in the LHC generates heat loads which are dissipated onto the beam screen or in the cold masses of the elements operating at cryogenic temperature. The synchrotron radiation emitted by the proton beam is intercepted by the beam screens. These beam screens are also carrying the beam image current which dissipates power. Finally, the heat load induced by the electron cloud is also intercepted by the beam screen. The scattering of the protons onto the nucleus of the residual gas produce gerbs into the cold masses which dissipate heat load. The level of these heat loads are given for scenari which refer to nominal, ultimate and LHC luminosity upgrade.

Primary author: Dr BAGLIN, Vincent (CERN)

Presenter: Dr BAGLIN, Vincent (CERN)

Track Classification: Heat loads from beam

Contribution ID: **14** Type: **not specified**

Why do BLMs need to know the quench levels?

The LHC beam loss monitoring system is based of the detection of secondary shower particles, which depose their energy in the accelerator equipment and finally also in the monitoring detector. To protect the equipment and to prevent quenches the likely loss locations have to be identified by tracking simulations or by using low intensity beams. To keep the operational efficiency high, the calibration factor between the energy deposition in the coils of the magnets and the energy deposition in the detectors has to be accurately known.

The likely loss locations will de discussed and the envisaged detector location will be shown. The beam loss measurement system will be explained and the implementation of varying quench levels with loss duration and with beam energy will be pointed out

Primary author: DEHNING, Bernd (CERN)

Presenter: DEHNING, Bernd (CERN)

Track Classification: Why do BLMs need to know the quench levels?

Contribution ID: **15** Type: **not specified**

Heat transfer in superconducting magnets

Using the present LHC inner triplets, functioning in pressurized superfluid helium, I will classify the heat extraction paths from coil until cold source and identify the limits of the present design. This will be exemplified by the measurements made using the Inner Triplet Heat eXchanger (IT-HXTU). The areas in need for improvement, when going to higher heat loads, will be identified and where possible scaled.

Primary author: Dr VAN WEELDEREN, Rob (CERN)

Presenter: Dr VAN WEELDEREN, Rob (CERN)

Track Classification: Heat transfer in superconducting magnets

Contribution ID: **16** Type: **not specified**

Multi-turn Beam Losses

Due to the large amount of energy stored in the LHC ring, cleaning of the beam halo is necessary in order to avoid quenches of the LHC superconducting magnets.
We review the mechanisms of multi-turn beam losses and design parameters of the LHC collimation system, and present the cleaning performance for various beam lifetimes scenarios, both at injection and top energy.
Results of tracking simulations after cleaning process are presented: inefficiency curves and longitudinal/transvere loss maps, with and without machine imperfections.

Primary author: Mr ROBERT-DEMOLAIZE, Guillaume (CERN)

Co-authors: Mr ASSMANN, Ralph (CERN); Mr REDAELLI, Stefano (CERN)

Presenter: Mr ROBERT-DEMOLAIZE, Guillaume (CERN)

Track Classification: Multiturn beam losses

Contribution ID: **18** Type: **not specified**

LHC and magnet operation

The current of the main dipole and quadrupole magnets will ramp proportional to the momentum of the particles accelerated in the LHC, for protons from 450 GeV/c to 7 TeV/c. For those magnets, the quench margin will be largest at injection. For other magnets, the current could follow different ramps that needs to be considered for the quench margin.
When the beams are squeezed to reduce the beta function in the collision points, the current of some quadrupole magnets will increase, but for others the current will be reduced. In this presentation an overview of the various current functions during ramp and squeeze will be given.

Primary author: Mr SCHMIDT, Rüdiger (CERN)

Presenter: Mr SCHMIDT, Rüdiger (CERN)

Track Classification: LHC and magnet operation

Contribution ID: **19** Type: **not specified**

Review of past estimations of the induced quench levels by beam losses in the LHC dipoles

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Primary author: Dr LEROY, Daniel (CERN)

Presenter: Dr LEROY, Daniel (CERN)

Track Classification: Review of past estimations of the induced quench levels by beam losses in the LHC dipoles

Contribution ID: **20** Type: **not specified**

SPQR Approach for Predicting Realistic Quench Levels

The thermal and electrical equations implemented in SPQR code are presented and possible improvements underlined. The approach used to numerically solve them is briefly recalled and the technique adopted to calculate the minimum quench energy (MQE) clarified. Examples of MQE calculations are presented for different space and time perturbations and the minimum propagation zone (MPZ) introduced. The sensitivity to helium cooling is discussed using the enthalpy approximation and more realistic models for heat transfer in He II are proposed. Strand stability versus multi-strand cable stability is addressed and the differences in realistic beam loss scenario are discussed. Finally ideas for future systematic studies of quench levels in the LHC superconducting magnets are proposed.

Primary author: Dr CALVI, Marco (CERN, AT Department, MTM group)

Presenter: Dr CALVI, Marco (CERN, AT Department, MTM group)

Track Classification: SPQR –could it contribute?

Contribution ID: **21** Type: **not specified**

Introduction to the Session

The crucial role of quench limits in LHC is pointed out and some important workshop
and session goals are discussed.

Primary author: Dr ASSMANN, Ralph (CERN)

Presenter: Dr ASSMANN, Ralph (CERN)

Track Classification: Introduction to the session

Contribution ID: **22** Type: **not specified**

Thermal Modelling of IR Quadrupoles

Abstract –In this talk is presented the work carried out at LASA Laboratory in the years 1995 - 1999, related to the design of a new type of quadrupoles for the LHC low-beta insertion based on Nb3Sn technology.
The work deals of the power generated into the insertion quads from the reaction products of the 7TeV p-p collision in the high luminosity interaction point of LHC.
The simulation starts from the DTUJET event generator; the reaction products are then tracked along the magnetic structure of the insertions; the interaction with the accelerator beam pipe and the magnets is treated by the FLUKA code.
The keypoint of this work is the thermal analysis of the magnet under such energy deposition conditions. The simple evaluation of the energy deposed in the magnet cannot give any indication of the behaviour of the magnet in this operating conditions, what is really important is the thermal "response"of the magnet.
A 2 dimension finite elements thermal analysis (ANSYS) evaluate the temperature increase in the coils and the stability margin, considering the energy deposed inside the magnets

Primary author: Dr BROGGI, Francesco (INFN - LASA Lab.)

Presenter: Dr BROGGI, Francesco (INFN - LASA Lab.)

Track Classification: Thermal modelling of IR quadrupoles

Contribution ID: **23** Type: **not specified**

Modelling stability on Nb-Ti cables; R&D on stability planned in the Cern cable test facility FRESCA

A brief overview will be given of the possibilities of modelling stability in superconducting NbTi cables. It will be shown that in many cases the accuracy of the modelling is poor (due to limited knowledge on cooling and current redistribution phenomena), so that additional experiments are needed. In the coming years, such experiments will be performed in the CERN cable test facility FRESCA under conditions comparable to LHC operation. The set-up of these stability measurements will be presented as well as the type of results that can be expected.

Primary author: Dr VERWEIJ, Arjan (CERN)

Presenter: Dr VERWEIJ, Arjan (CERN)

Track Classification: Modelling stability on Nb-Ti cables; R&D on stability planned in the Cern cable test facility FRESCA

Contribution ID: **24** Type: **not specified**

LHC Insertion Magnets and Beam Heat Loads

The pp collisions in the LHC interaction points generate at nominal luminosity about
900 W carried away by secondaries to each side of an experimental insertion. This
energy is largely intercepted by the TAS and TAN absorbers, but a non-negligable
part ends up in the coils of the superconducting low-beta quadrupoles. These magnets
have to sustain and evacuate a load of typically 5 W/m, a factor of 10 larger than
in the arc. Other magnets in the insertions are also exposed to beam heat loads, but
of lower magnitude. In this talk, I will present the design of the various
superconducting magnets in the LHC insertions, and give an overview of the available
data on their expected performance in presence of beam losses.

Primary author: Dr OSTOJIC, ranko (CERN)

Presenter: Dr OSTOJIC, ranko (CERN)

Track Classification: Insertions magnets and IR radiation

Contribution ID: **25** Type: **not specified**

Understanding ac losses for LHC magnets

Brief comparison of results of the direct heat transfer measurement done on stacks of cables by B. Baudouy, L. Burnod, D. Leroy, C. Meuris, and B. Szeless with corresponding results based on the ramp rate limitation of the first LHC model dipoles by A. P. Verweij, in the period 1991-99.

Primary author: Mr RICHTER, David (CERN)

Presenter: Mr RICHTER, David (CERN)

Track Classification: Understanding AC losses for LHC magnets

Contribution ID: **26** Type: **not specified**

Quench-based magnet sorting at the MEB ?

The allocation of magnets at MEB is presently following guidelines on sorting derived from quench training curves. These guidelines are based on working assumptions rather than well established results. The presentation lists the open questions to be resolved for a sound sorting.

Primary author: Mr BOTTURA, luca (CERN)

Presenter: Mr BOTTURA, luca (CERN)

Track Classification: MEB and magnet sorting criteria

Contribution ID: **27** Type: **not specified**

Quench levels and experience from magnet tests at CERN

When does the magnet quench?
MQE and MPZ concept
Is it relevant for beam induced quenches?

Quench levels of various families of the main ring superconducting magnets
Outlook on further simulations and envisaged experiments
Conclusions

Primary author: Dr SIEMKO, Andrzej (CERN)

Co-author: Mr CALVI, Marco (CERN)

Presenter: Dr SIEMKO, Andrzej (CERN)

Track Classification: Quench levels –experience from magnet tests at CERN