123rd meeting of the LHC Collimation Study group

2011.04.04

Present: A. Rossi (chairman), R. Bruce (scientific secretary), R. Assmann, D. Wollmann, M. Cauchi, F. Brukart, G. Valentino, D. Deboy, G. Bellodi, V. Vlachoudis, G. Smirnov, V. Boccone, F. Cerutti, A. Ferrari, R. Versaci, J. Jowett, R. Losito, JPh. Thock, L. Lari, A. Dallochio, F. Caspers, H. Day, O. Aberle, G. Arnau, M. Zerlauth, S. Roesler, B. Goddard, T. Markiewicz

1 List of actions from this meeting

- Strategy for assessing the BLM response, necessary for LHC intensity reach calculation:
  - Estimate the impact distribution on the TCP during the crossing of the 3rd order resonance.
  - Run SixTrack simulations with this initial distribution.
  - Provide FLUKA team with starting distribution and SixTrack output. FLUKA simulations will then estimate the BLM responses, which can be compared to measured loss maps.
- Define failure scenarios with direct on beam impacts on the TCTs that should be studied (energy, emittance, impact parameters)

2 Topics presented

2.1 A. Rossi: Introduction

Adriana Rossi gave an introduction to beam-induced damage and accident scenarios for collimators.

A. Bertarelli's talk in Chamonix was summarized. Even with conservative beam parameters (up to 5 TeV, up to 1.3e11 p per bunch, down to half nominal emittance) a single bunch impact on the TCTs is not catastrophic. Eight bunches or more are needed to induce a water leak into the vacuum that will cause a longer downtime of the LHC.

As a follow-up of Chamonix, a scenario with realistic parameters compatible with the 2011 run should be simulated. Accidents could occur if the MKD kickers misfire during a collimation setup, when tungsten collimators (TCTs or TCLs) are moved in close to the beam outside the shadow of the dump protection.

A. Rossi raised a couple of questions:

- Can a metal collimator be hit during setup in case of a mis-kick? B. Goddard answered that this is possible.
- Can also the MKI kickers cause a hit on a sensitive collimator?
- Should accident scenarios be studied also at 450 GeV?

- A worst-case scenario has to be defined. Ralph Assmann points out that systematic simulations of many different scenarios will determine what is the worst case.

2.2 A. Bertarelli: Limits for Beam-Induced Damage: Reckless or too Cautious?

Alessandro Bertarelli shows a summary of his Chamonix-talk. If an impact of a high-energy beam on a material causes a phase transition, it cannot be simulated with standard structural codes like ANSYS, instead hydrocodes like AUTODYNE are needed. A problem is the lack of experimental material data, especially for alloys and compounds. This introduces uncertainty factors in the simulation results. Two collimator accident scenarios were considered:

- A single-bunch impact resulting from an asynchronous beam abort during ongoing collimation setup.
- A failure during standard multi-bunch operation, where an asynchronous abort occurs simultaneously with another machine error that exposes a sensitive collimator.

Several cases with varying emittance, beam energy, and number of impacting bunches were derived from the accident scenarios and simulated. All studied cases lead to permanent collimator damage. Damage was classified in three levels:

1. Collimator does not need to be replaced, enough to move to a spare surface. Oliver Aberle pointed out that this might not be possible remotely for all collimators and that a tunnel access is needed.
2. Collimator needs to be replaced.
3. Catastrophic: Long downtime of the LHC due to water leakage into the beam vacuum.

All single-bunch cases at 3.5 and 5 TeV were found to cause a level one damage. A. Rossi asked whether flatness is affected. A. Bertarelli answered that a permanent swelling of the jaw occurs and that particle sprays can alter the flatness of the opposite jaw only with several bunches impact. The beam size was found to have a relatively weak influence. The most important factor is instead the total deposited energy.

An impact of 2-4 bunches at 5 TeV was found to cause a damage of level 2. The only damage scenario causing level 3 damage was an impact of 8 bunches at 5 TeV.

A. Rossi asked whether an impact close to the surface is more dangerous than a deeper impact. A. Ferrari answered that the deeper impact is more dangerous, as a larger fraction of the shower stays in the material.

F. Caspers asked whether ultra-sound could be used to monitor over time if the collimator is about to crack and give an early warning. A. Bertarelli answered that this might not help during a fast accident although it could be useful to monitor a slow degradation of the material.

R. Bruce asked about the total uncertainty of the simulation results. A. Bertarelli answered that errors should be less than a factor 2 and that the main error source is the material database.

2.3 M. Cauchi: Preliminary ANSYS studies for Tungsten collimators

Marija Cauchi reported on ANSYS simulations of beam impact on the tungsten collimators. ANSYS can treat the behavior of the material up to the melting point.

Four different cases were simulated with varying beam energy (3.5-5 TeV), different normalized emittances (3.5-7 μm) and number of impacting bunches (1-4). An impact parameter of 2 mm was assumed for all bunches.

Transient thermal and structural analyses were performed on the timescales of 1 ns and 10 s. In case of a multi-bunch impact the bunch spacing was taken into account and additional transient analyses were carried out. Since the energy deposition was assumed to be symmetric around the x-z midplane, only the lower half of the jaw was simulated in order to gain in CPU time. The jaw was approximated as a pure tungsten body, thus neglecting the screws and the small fractions of nickel and copper.

The used mesh size was 1x1 mm in the transverse direction and 1.5 mm longitudinally. A. Ferrari pointed out that the transverse bin size is too coarse to capture the peak temperature rise, since with the real beam size the energy deposition from the hadronic shower varies significantly on much smaller scales. For the simulations presented by A. Bertarelli this effect was judged to be less important, because he looked at integral energy deposited rather than peak temperature.

The results indicate that for one bunch at 3.5 TeV, no melting occurs, while in the other cases it does. When melting occurs, the structural analysis is unreliable and other codes such as AUTODYNE should be used. Simulation have to be repeated with thinner mesh.

R. Assmann commented that the worst case might not yet be studied, since the crossing angles may change the impact angle.

2.4 B. Goddard (C. Bracco): Asynchronous dump studies

B. Goddard presented SixTrack simulations from C. Bracco , where a starting distribution was tracked with SixTrack from the beam dump protection in beam 2 to the TCTs in IR5. This type of simulation can be used as starting conditions to a FLUKA simulation of the energy deposition in the TCTs.

From simulation, one nominal bunch of 1.1e11 protons, 3.3e8 would hit the TCTs. Consistently, from measurements during asynchronous dump tests, a leakage from the TCDQ to the TCT of 2e-3 was found.

Possible worst-case scenarios were discussed for either a collimation setup or regular operation, which requires an additional error on top of an asynchronous dump. The question was raised whether the triplet aperture could be hit directly in any scenario.

R. Assmann raises a question about damage from ion beams. For ions the peak temperature is higher around the trace of the impinging beam, while the total energy deposition per incident energy is similar to protons. Thus, the AUTODYNE simulations should not show largely different results for ion beams.

A question about the onset of damage and the dependence on beam parameters was raised. As damage occurs already with 1 nominal bunch, by how much must the intensity be brought down in order to avoid damage? It was concluded that a 2D scan in intensity and emittance should be done.

2.5 Discussion on future studies with FLUKA

Two major topics for future studies were identified: Accident scenarios and the assessment of the intensity reach in the LHC. The second topic has the highest priority.

2.5.1 Accident scenarios

For future studies on accidents causing potential damage to collimators, the following steps have to be performed:

- Define a few accident scenarios to be studied (collimation team)
- Track particles to metal collimators with SixTrack (beam dump and collimation team)
- Simulate energy deposition in metal collimators with FLUKA (FLUKA team)
- Simulate temperature thermal and mechanical behavior with ANSYS (sufficient if final temperature is below melting point, M. Cauchi) or with AUTODYNE if a phase shift takes place (A. Bertarelli and team)

2.5.2 Intensity reach

FLUKA simulations are also needed to assess the intensity reach in the LHC. The actual cleaning efficiency depends on the ratio of the response of the BLM close to the TCP and at the cold bottleneck.

R. Assmann proposed FLUKA simulations to study the BLM signals in IR7. A. Ferrari pointed out that the BLM response is already well understood and benchmarked with FLUKA in the case of a well-defined initial loss (using a wire-scanner experiment) and expressed worries that the initial loss distribution in IR7 is less well-known so that a good agreement cannot be expected. V. Boccone mentioned that the FLUKA results are highly dependent on the accuracy of the geometry and the inclusion of machine imperfections and non-conformities such as the real shape of the vacuum chamber. R. Assmann argued that a FLUKA simulation could still be used as a starting point for understanding the intensity reach and that the impact distribution on a primary collimator during the lossmaps, when the third order resonance is crossed, can be simulated and given to the FLUKA team.