59th Meeting of the Machine Protection Panel

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1 Presentations

The slides of all presentations can be found on the website of the LHC and SPS Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 SLHCV3.1b: HL-LHC optics overview (R. de Maria / S. Fartoukh)

- The SLHCV3.1b optics contains a realistic, nearly complete, usable optics model. It is not a final version, as it depends on some working hypothesis (e.g. interconnect lengths, triplet correctors, phase advance between IR2/8/4/6, etc.).
- Beta* for IP1 and 5 goes to 15cm. No changes in IR3 and IR7. Right and left part of IR2, IR8 , IR4 and IR6 are changed.
- Chromatic aberrations in IR3 and IR7 are further reduced, i.e. minimizing off-momentum beta-beating.
- Spurious dispersion from the crossing scheme: Without correction this would rise to about 7-8m in the triplets. This is compensated by a bump structure in the arc, which creates a dispersion wave. Therefore the dispersion doesn't change compared to nominal. The feasibility of such a structure vs orbit feedback, etc. should be verified.
- Beta function around IR1 and 5 will be significantly higher than nominal.
- In IR6 the optics for the dump system is improved, so that the beam size at the dump region is bigger.
- The choice of beta* comes from the available aperture (N1) in the triplets, which limits the beta* to 15cm. Taking into account that we found more aperture in the real machine there is also an optics version available with beta*=10cm.

- The crossing angle was chosen to be 590 μrad at 25 ns, which means 12.5 σ and 11.4 σ at 50ns. This is due to the HL-LHC bunch intensity of ~2e11 at 25ns and ~3e11 at 50ns. The emittance for this case was assumed as 2.5 μm.
- The new crossing scheme is optimized so that the crab cavities don't see the crossing angle. This scheme requires significantly stronger orbit correctors, which also needs to be considered for machine protection.
- The latest estimate for the crab voltage at beta*=15cm is 9MV assuming a reduced crossing angle compatible with half of the bunch intensity.
- The optics is stored in /afs/cern.ch/eng/lhc/optics/SLHCV3.1b . The thin optics is ready for tracking with SixTrack and therefore also usable for collimation.

Discussion:

- Frank asks if the aperture in the triplet is final. Riccardo answers that there are some uncertainties in the aperture of the triplet, as energy deposition studies are still ongoing, which are the basis for the magnet design. A final decision is expected end of the summer by E. Todesko et al.
- Ruediger asks, if anyone is looking for machine protection issues at injection optics, as this is already delicate today. Riccardo comments that they try to be as close as possible to nominal LHC for injection. The beta-functions in the arcs will stay at ~180m. There will be no change in the dispersion. But the integer part of the tune is changed.
- Rama comments on new closed orbit with bumps to compensate the spurious dispersion: in the SPS the experience is, that a flat machine is preferred.
- Ruediger agrees that the spurious dispersion correction with bumps may complicate operation. Normally one wants to have as much as possible a zero closed orbit. It is much more difficult to maintain such structures. Clearly this is not a general show stopper, but it requires a substantial amount of work to be able to control this with orbit corrections. Rama comments that in addition IBS may also be strongly affected by this type of "zero" orbit. Frank adds that this depends only on the optics.

- Frank asks about the off-momentum beta beating in the new optics. Riccardo comments that this is improved wrt to nominal.
- Ruediger comments that due to the very high beta around the IRs one needs to look, if corrections can be maintained with the chosen power converters and magnets. There we enter into the scheme of power converter noise etc.
- Stefano comments that for IR6 we should also try to "optimize" the phase advance between MKD and triplet (mostly high beta IPs) in horizontal plane, to minimize the risk of an asynchronous beam dump. Frank comments that optimizing the phase advance between IR6 and IR1 / IR 5 symmetrically would probably cause a coherent adding of beam-beam instabilities.
- Frank comments that it is surprising that we need such a big crossing angle. Riccardo comments that the long range beam-beam interactions increase due to the higher bunch charges. Frank adds that indeed in his model he uses a wire compensator, which allows reducing the crossing angle (compensation of long range beam-beam encounters).

1.2 Crab-Cavity failures, LHC (R. Calaga)

- For HL-LHC it is planned to install 4 crab cavity modules per IP (1 / 5), to allow the beams to collide head-on instead of under a crossing angle.
- Basic parameters:
  - 3MV/cavity (each module contains about 2-3 cavities).
  - RF frequency: 400MHz
  - Qext= 10^6, R/Q~300 Ohm
  - Cavity tuning/detuning ~ 3 kHz
  - RF power source = 60kW (< 18kW nominal; for zero orbit) per cavity. In total the power would then be ~1.5MW.
- In 2010 Jorg made the point that we need to be able to survive at least 3 turns without damage to accelerator equipment in case of a failure in the crab cavities until the beam can safely be dumped. This requirement is the baseline of the presented studies. Still such crab cavity failures will be the fastest failure in the LHC machine. In comparison the current fastest

failure is the one of a warm separation dipole magnet D1, where beam losses reach damage threshold of the collimators after some 20-30 turns.

- Fast possible failures are cavity quenches or RF breakdowns, sudden discharge in the cavity couplers and fast orbit changes.
- Experiments with turning off the RF with and without beam were performed at KEKB (see K. Nakanishi et al. LHC-CC10).
- A cavity quench can cause significant phase changes (~50urad) within ~100 μs (measured in KEKB).
- Cavity quench: In case of a quench the RF power will be cut for all modules. The problem is to detect the quench. Thermal couplers are relatively slow in transient conditions. The transient cavity Q reacts very fast on a quench (~150 μs). This can be exploited to detect cavity quenches within a couple of LHC turns.
- Nb coated copper cavities seem to be more resistant against quenches. Some people even claim that these cavities will not quench.
- Currently first solutions on how to control the four cavity modules in view of a failure in one of them are being discussed.
- First tracking simulations have been performed with SixTrack to study limitations due to losses. The simulations are currently relatively time consuming, as a significant number of particles (~10M) has to be tracked for several turns without interaction to create the realistic particle distribution.
- Besides a single Gaussian distribution currently a double Gaussian distribution is used for the latest simulations, which were performed by B. Yee.
- Steps towards a crab specific option:
  - Fine tune optics for crabs.
  - Technological limits (power per cavity).
  - Impedance.
  - Long range beam-beam.
  - Work closely with the collimation team, e.g. to improve the statistic of the simulations.

Discussion:

- Markus asks how often the fast failures are expected to happen, as this is an important input for machine protection. Erk comments that the IOT power supplies for the SPS upgrade currently seem to trip after less than 100h, which is too often and certainly needs to be improved.
- Ruediger comments that there is a lot experience concerning magnet quenches especially in the TE department (e.g. A. Verweij), where we should consider asking for help with quench simulation for the cavities. In addition we should aim for quench tests with an external beam (e.g. in HighRadMat).
- Ruediger asks how long it takes to change the phase. Tobias comments 5 degrees within one turn.
- Ruediger asks why the simulation with 10M particles takes so long. Frank and Rama answer that a tracking over ~100 turns is needed to prepare the beam distribution with the crab cavities. Ruediger comments that it probably should be possible to analytically calculate an initial matched distribution, which then reduces significantly the tracking to a few turns.
- Daniel comments that the beam distribution measurements performed in the LHC (F. Burkart et al.) show that the tails are even more populated than expected from a double Gaussian distribution.
- Markus comments that it is clear, that anything which makes the failures from crab cavities slower will ease machine protection. One also needs to watch out, when using fast and strong feedbacks. These can help a lot, but in the case these fast feedbacks fail themselves this introduces additional concerns for machine protection.

1.3 Miscellaneous

- Markus mentions there will be a BI MD in the first MD block of 2012 next week. For this MD the injection of bunch intensities of 5-6e10p into the empty machine was requested. **Action:** This request will be distributed to the experiments in the beginning of next week. (MZ)