Minutes of the 19th Collimation Upgrade Specification Meeting

Participants: R. Bruce (RB), F. Carra (FC), M. Fitterer, R. de Maria (RdM), L. Lari (LL), R. Losito (RL), A. Marsili (AM) (scientific secretary), D. Mirarchi (DM), N. Mounet (NM), T. Pieloni (TP), E. Quaranta (EQ), S. Redaelli (SR) (chairman), T. Rijoff (TR), B. Salvachua (BS), H. Schmickler (HS), R. Steinhagen (RS), R. Veness (RV), F. Zimmermann (FZ).
Remote: T. Markiewicz (TM), SLAC; W. Fischer (WF), BNL.

Indico event here.

1 Scope of the meeting (S.Redaelli)

SR introduced the meeting by reminding that the HL–LHC study endorsed the prototyping and preparation of beam tests at the LHC to prove experimentally the feasibility of the long range beam-beam (LRBB) wire compensation scheme. The proposal brought forward by the BI team to achieve this goal foresees the installation of a wire into TCT and TCL collimators in IR1 or IR5. No better design could be found, also due to the tight space constraints in these IRs. Since the TCT and TCL collimators are used in standard operation, the proposal to replace these collimators with a new design can only be pursued after demonstrating that the standard collimator functionality is not jeopardized.

The scope of this meeting is to present to the collimation team the proposal to implement a wire for long-range beam-beam compensation into a standard collimator. As a follow up of this discussions, SR will prepare a list of studies that need to be addressed to demonstrate that the collimator functionality will not be jeopardized by this design.

SR also reminded that it has been agreed that the required studies will be followed by the existing teams within the collimation project.

2 Long-range beam-beam compensation at HL-LHC (F. Zimmermann)

Slides are available in pptx and pdf.

2.1 Summary of the presentation

FZ started by presenting how the long range beam-beam (LRBB) interaction can create operation issues with a large number of bunches. Long range effects can decrease lifetime by reducing of the dynamic aperture. At the LHC (up to 120 long range encounters), the aperture might be limited to $6\,\sigma$ for the nominal parameters at 25 ns. The LRBB wire compensator compensates the long range encounters and potentially gives up to a $2\,\sigma$ gain in dynamic aperture (nominal case, assuming perfect bunch-by-bunch compensation achieved with pulsed currents). Equivalently, it would allow operating with a smaller crossing angle (i.e. larger aperture margins). Optimum layouts for the wire compensation were shown. FZ also presented the simulated LHC tune footprint with and without correction by the wire to illustrate the benefit of such a scheme.

Various beam tests have been performed at RHIC and at the SPS to validate the LRBB wire compensation scheme. These tests used devices with three movable wires that can be approached to the beam. On the other hand, these beam tests cannot be considered fully conclusive. In the best case, at the SPS it was demonstrated that the effect of one wire can be compensated with a second wire. But there is no full demonstration in a LR beam-beam limited machine like the LHC.

At the LHC, space locations are reserved around IR1 and IR5 for LRBB devices. On the other hand, the implementation of such a scheme in the HL–LHC calls for a solid beam-based demonstration.

To achieve low $\beta^{\star}$ values at the HL–LHC, large crossing angle values are required, which induce large geometric luminosity reduction factors. The present baseline design relies on the crab-cavities to recover maximum peak luminosity values. Correcting the long range interactions would allow one to reduce the crossing angle, hence reducing the challenging requirements on crab-cavity voltage.

FZ also presented the results of recent simulations of tune footprint and Lyapunov stability diagrams by T. Rijoff. Simulations show the effect of the long range interaction and a clear improvement from the LRBB wire compensation scheme. Simulations were also performed for different beam test scenarios after LS1, considering scenarios where wire might be installed in TCT or TCL collimators (see next talk). Simulations indicate indeed that the proposed locations are suitable for conclusive beam tests at the LHC (tough not as good as the ideal case).

2.2 Discussion

SR asked whether the wires must be located in the inner space between the two beam in order to be effective. Having them on the outer side would simplify significantly the setup for beam tests. FZ confirmed that this is the case: a compensation on the outer side only would enhance the LR effects.

RdM asked which beam current is considered for the HL case. FZ replied that the the correction effectiveness is independent of beam current.

SR pointed out that the current Hi–Lumi target figures don't rely on the LRBB compensation. This would be the case only after a beam-based demonstration of the scheme.

SR asked what is the achievable gain if the LRBB compensation scheme worked as expected. FZ replied that in the best case it allows a crossing of 8 σ'. The nominal LHC crossing angle is 9.5 σ' so we would have a 15 % gain. For HL–LHC with a crossing of 12 σ' the gain would be 33 %. SR then asked why there is a change of design specifications for the HL case. FZ replied that this was specified by S. Fartoukh to leave margin for the larger bunch intensities. FZ stressed however that these gains are calculated for a perfect bunch-by-bunch compensation that required pulsed currents in the wire. This scheme can hardly be achieved in practice. FZ expects that constant powering current will still improve in average the bunch lifetime along one bunch train. But the real gains will be lower than the quoted figures.

TP asked if there is any effect on the beam core particles when the wire is powered. FZ replied that this will not be the case.

RdM pointed out that the validity of the Lyapunov approach to address beam stability is questioned in literature. Standard dynamic aperture simulations are considered more robust. FZ replied that several studies were performed in the past so he is fully confident that the proposed results are reliable. Lyapunov approach allows faster simulations and was the only appropriate strategy to probe in an exhaustive manner the parameter space for beam tests. SR recommended however that a complete simulation should be performed for the proposed parameter set for beam tests. FZ replied that there is no manpower to do this because the students working on this subject have moved to other projects.

3 Beam-Beam Compensator Prototype Parameters and possible Integration into the LHC Collimators (R. Steinhagen)

Slides are available here.

3.1 Summary of the presentation

RS presented the current state of design concept to install a beam-beam wire compensators in a LHC collimator for beam tests after LS1. This concept seems the only viable option to achieve in reasonable times a demonstration of the feasibility of the long range compensation scheme at the LHC: the nominal LRBB locations are not compatible with beam tests without major layout changes whereas the simulations indicate that two TCT and TCL locations are suited for this purpose (the two affected collimators would be the TCTH.4L5.B1 and the TCL.5R1.B1).

RS presented the specifications needed for a LRBB compensation wire at the LHC. Some acceptable compromises must be made compared to ideal design specs in order to achieve and integration the LHC collimator. For example, for first beam tests we would give up the possibility to power the wire with pulsed currents in favor of a DC powering scheme.

RS commented that the installation could be performed already before LS1 or otherwise in a short technical stop afterwards. SR corrected this statement: the installation in LS1 is essentially not possible considering that all the resources of the team are being employed for the production of the new collimators with embedded BPMs. SR also mentioned that the bake-out requirements make it not possible to install a collimator in a short technical stop: three weeks are needed. Therefore, the first possible installation date will be the Christmas stop in 2015.

RS presented first ideas of a wire-in-jaw design. RS claims that the impact on the existing collimator design is small. A minimum of 100 μm of tungsten would provide enough shielding to ensure that the wire would perturb the beams when not powered. First studies suggest that there would be no problem with the BPM buttons, and that the wire heating would be manageable without problems by the standard collimation jaw cooling system. A mock-up beam tests has been setup by the BI team (Raymond Veness, Axel Ravni) to see if the proposed concept will be able to cool efficiently the wire.

RS listed several points that remain to be followed up in his opinion: tests for mechanical feasibility, material and vacuum compatibility; evaluation of the impact of wire-in-jaw on machine impedance; beam cleaning performance simulations; wire-in-jaw robustness simulations. RS reminded that the necessary technical infrastructure for the cable powering are planned to be installed during LS1.

3.2 Discussion

SR pointed out that there are very tight constraints on the flatness of the collimator jaws. It looks difficult to implement the wire as proposed without affecting the jaw flatness, even for the proposed scenario with the wire offset with respect to the jaw centre. SR reminded that the tungsten past of the jaw is presently made by 5 tiles.

SR asked about the possible interferences between the wire and the BPMs buttons. RS answered that the wire's DC current would not affect the RF response of the BPMs. SR reminded however that the wire current will have to be ramped with beam in the machine. This aspect should be addressed by lab tests.

RL asked how the wire would be isolated electrically, and whether the insulator will be radiation hard. RS replied that the insulation material (ceramics, Al_2O_3) is the same material used in feed-throughs and vacuum equipment used elsewhere in the LHC and thus no major issue is being expected.

NM pointed out that the insulation can make a difference in impedance. RS answered that these components should be deeper than 10 skin depths behind the jaw surface, hence should not affect the beam. NM maintained that there could be impedance issues due to low-frequency components.

RL asked if HiRadMat tests should be performed on the new design. SR confirmed that HRM tests could be useful, and added that it could make it simpler to just test one jaw with a wire instead than building a full collimator. In addition, some months of tests in the SPS could be considered. RS added that some lab tests had been forecast from the beginning. SR also commented that the HRM tests in 2012 showed that the models used to address material behaviour under beam impacts have evolved significantly so the case should first be simulated.

SR asked for a list of proposed settings for the beam tests, knowing that the TCTs cannot go too close to the beam (min. $12\,\sigma$). HS agreed and stated that the definition of MD conditions should be an integral part of the approval procedure for the experiment. He stressed that a list of observables should be outlined in detail to ensure that meaningful beam tests can be carried out. [**Action: RS**].

RV asked which aspects are considered critical from the collimation point of view and which open questions should be addressed before having the validation from the collimation project. SR replied that he has already a list prepared after discussion with several people in the team. He will distribute this list and the minutes of this meeting to the responsible persons from the different teams to collect feedback and to get time estimates of when the required works could be performed. SR could mention the following items that need to be addressed before deciding on a possible installation in the LHC:

- Detailed design work in MME.
- Definition of a manufacturing technique that preserves the jaw flatness.
- Verification that the transverse collimator movement is available in the required range for the collimators considered.
- Is the TCT/TCL robustness jeopardized by the presence of the wire?
- Is the cleaning functionality affected?

- What is the impedance for the new design?
- Will the BPM measurements be affected when the wire is powered?
- The influence on the LVDT measurements when the wire is powered needs also to be addressed.
- The wire powering cables (that will have to be designed) are not part of the quick plug-in mechanism. Will this jeopardize the quick disconnection functionality of the present collimator design?

SR said that some of the questions are probably trivial but should be answered. He encouraged the people involved to send him feedback on this list and to think about other possible issues.

HS asked what will be the observables for MDs at the LHC. The MD program should be complemented with a detailed list of measurements. Most of the simulation results presented are not directly observable so we should define additional measurements for quantitative conclusions. RS indicated that presently mainly the beam life-time dependence on the crossing angle is being considered. HS commented that a halo monitoring (discussed already in the context of other collimation studies like to hollow e-lens) would certainly be useful. FZ commented that calculations of diffusion rates will be included in future simulations. [**ACTION: RS & FZ**].