

# BEAM-BEAM AND COMPENSATION SCHEMES: CONCLUSIONS

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## Abstract

This paper attempts at giving the important conclusions from this session.

## AGENDA OF THE SESSION

1. Summary of the SLAC beam-beam compensation workshop, W. Fischer, BNL
2. Head-on and pacman compensation with electron lens, V. Shiltsev, FNAL,
3. Beam-beam and emittance growth with wire compensation, U. Dorda, CERN & U. Vienna
4. Beam-beam and emittance growth with crab cavities, R. Calaga, BNL,
5. Beam-beam with a few long-range encounters at short distance, N. Abreu, BNL
6. Beam-beam with long flat bunches and large Piwinski angle, K. Ohmi, KEK.

## CONCLUSIONS OF THE SESSION

- **On the US-LARP beam-beam workshop:** In the US-LARP beam-beam compensation meeting, the accent was different and nicely complementary with this session: the phenomenology of the beam-beam limit had been reviewed, to better identify a possible hierarchy in phenomena needing compensation. Actually all three beam-beam issues (head-on, long-range and pacman) need be addressed. The experimental program of RHIC is the key to improve the understanding, taking advantage of the wire compensators newly installed in the machine. The MD results, together with the former SPS results, had been not only analysed but as well evaluated in terms of reliability of the conclusions. The beam-beam experiments are indeed notoriously known for their complexity and sensitivity to details. All results tend to give a coherent semi-quantitative picture. With more MD time, RHIC has all the potential to reach precise conclusions in a critical field limiting machine performances.
- **On the electron lens:** The electron lens has proven its reliability as abort gap kicker in the Tevatron. As a linear bunch-by-bunch tune shifter, it demonstrated both its usefulness and the high quality of the electron current control that causes no detectable emittance growth over long periods. With this solid basis, the efficiency of more complex compensations can be attacked: head-on, long-range. Experiments are strongly encouraged and results eagerly awaited. The electron lens is a good candidate for long-range beam-beam compensation in situations where the wire would be too close to the beam (possibly for the early separations scheme).
- **On the wire compensation:** With experiments and very detailed simulations using various criteria for testing the regularity of the motion, the ability to compensate the long-range beam-beam effect by wires appears now established. The significant gain of about 2 sigma in dynamic aperture is appreciable for a relatively modest investment. A simple dc system mitigating the compensation for normal and pacman bunches appears already very valuable and should be scheduled for installation in the LHC. For an exact compensation of pacman bunches, a promising research line has been identified by using an RF waveform, reducing significantly the requirement of synchronization accuracy that was otherwise extreme.
- **On the cross-talk between chromaticity and long-range beam-beam:** Simulations confirms the RHIC observations showing that the allowed chromaticity range is reduced by the presence of the long-range beam-beam interactions.
- **On the importance of the triplet length:** depending on the technology (Nb-Ti or Nb<sub>3</sub>Sn) and on the aperture requirements, the triplet length varies significantly. It was shown that the increase of the number of long-range beam-beam encounters at a given beam separation has a significant impact. For Nb-Ti and apertures of about 200 mm, the dynamic aperture becomes unacceptably small.
- **On the consequences of a large Piwinski angle:** Weak-strong simulation of the LPA (large Piwinski Angle) option for the LHC upgrade do not exhibit any evident pathology, except perhaps for horizontal-vertical crossing where the number of excited resonances is larger. To become conclusive, more studies and simulations are needed, e.g. **to take into account long range and imperfections.**
- **On the acceptable number of close encounters for an early separation scheme:** the experimental data collected seem to show that, contrary to what was feared, a small number of encounters at 5 sigma separation can be tolerated. Their exact number is not yet clear. Further experiments in RHIC are needed to establish quantitatively this number that is critical for the early separation scheme.
- **On crab cavities:** the potential in luminosity upgrade of weak angle crab crossing is very large and does not appear out of reach from the technology point of view. The various challenges (technology, collimation,...) will be addressed in a forthcoming US-LARP workshop.
- **Conclusion from the chairman:** for decades, the beam-beam effect had to be accepted as the ultimate limit of colliders. Since a relatively short time, three compensation concepts have been devised, simulated, partially implemented and experimented. Their potential is very high and they are thus of direct interest to the LHC upgrade, allowing a higher luminosity for a given beam current. Demonstrations in existing colliders are of highest value given the subtlety of the beam-beam effects.