

Presentation 60

Conclusions from the 8-Bunch Pretzel session

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60.1 The route to high luminosity

The aim of the Pretzel scheme is to increase the luminosity of LEP beyond the maximum value attainable in the present operating conditions in which four bunches per beam are used. Thanks to the considerable effort which is being made to understand the present limitations, the luminosity will eventually be pushed closer to its asymptotic value. This value is not known with precision, but is limited by many single bunch phenomena and by beam-beam effects, and will probably not exceed dramatically the design luminosity of $1.7 \cdot 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$. To go beyond this requires increasing the number of bunches while avoiding any additional beam-beam interactions : the beams have therefore to be separated at all unwanted crossings. This separation could be provided by inserting pairs of electrostatic separators around each additional crossing such as to generate a π orbit bump of opposite sign on the two counter-rotating beams. This gives the smallest perturbation to the particle dynamics but requires a large number of separators, and implies disturbing the magnet layout in the arcs. On the contrary the Pretzel Scheme discussed here can be implemented without a large scale disturbance to the layout of LEP, and at low cost by using separators recuperated from the SPS proton antiproton collider in which such a separation scheme has been successfully operated before. However, the Pretzel Scheme is much more demanding as far as beam dynamics is concerned since it imposes excursions of relatively large amplitude on the beams almost all around the machine. To master the already delicate LEP beam dynamics under these conditions will require an additional Machine Development effort.

60.2 Presentations at Chamonix

The following topics were successively exposed and discussed :

The 8 bunch Pretzel Scheme

The separation system

Protection of separator plates from synchrotron radiation

Orbit correction

RF implications

Feedbacks and LEP filling

J. Jowett

W. Kalbreier

G. von Holtey

J. Poole

G. Geschonke

E. Peschardt

Instabilities were not discussed during this session, but this topic was covered by B. Zotter during his general presentation in the session on intensity limitations.

60.3 The 8 bunch Pretzel Scheme

After about two years of study, a Pretzel Scheme allowing to collide up to 36 bunches in LEP was presented to the LEPC and summarised in a Yellow CERN Report on "High Luminosity LEP". The scheme which is discussed here is a low cost version of this proposal using electrostatic separators recuperated from the SPS and in which the number of bunches per beam is limited to 8, at least in a first phase. Four separators are now being installed, allowing Pretzel orbits to be established during 1991 between straight sections 4 and 6 and 8 and 2 respectively, for machine development purposes. The full complement of 8 separators will be installed in 1992 allowing further tests and possibly first operation with 8 bunches. It has been checked that with the minimum number of 8 separators it is possible to provide a sufficient separation up to the maximum LEP energy and with both 60° and 90° phase advance per arc cell. The scheme works if the phase advance between pairs of separators is fixed to $2n\pi$, and as a consequence the machine tune has to be adjusted in the insertions outside the Pretzel bumps. This has the favorable feature of assuring cancellation of optical differential effects between the two orbits within each Pretzel bump. However, the phase advance in the insertion is also subjected to severe constraints for other reasons (for instance to assure a proper action of the collimators). In order to introduce some flexibility into the scheme it is proposed to install four additional separators in the odd straight sections to be used as trimming elements. Simulations of the beam-beam interaction in the conditions of the 8 bunches Pretzel Scheme show that the extra bunch crossings introduce no harmful effects provided the separation at these points exceeds 5 to 6 r.m.s. beam width. The phase of the Pretzel orbits can be chosen such that the extra separation due to the energy sawtooth effect either adds (in the case of the 90° lattice which will be used at high energy where this effect is maximum) or subtract only marginally (for the 60° lattice) from the separation produced by the Pretzel orbits. It remains to be checked whether these nice properties are kept for the newly proposed optics with a 72° phase advance per cell.

60.4 Necessary Dynamic Aperture

The geometrical aperture of the LEP vacuum chamber is amply sufficient to accommodate the Pretzel orbits. However, particles oscillating around the Pretzel orbits sample the non linear fields at larger amplitudes than with a zero r.m.s. orbit and one expects the available dynamic aperture to be reduced in this case. With a zero r.m.s. orbit the dynamic aperture evaluated through computer simulation is much larger than needed for the 60° lattice, and just sufficient for the 90° lattice at high energy. Measurements performed on the 60° lattice with a zero r.m.s. orbit indicate that the real dynamic aperture is significantly smaller than expected. This is still unexplained and therefore should remain the subject of active investigation. First measurements at 20 GeV show that the introduction of a simulated Pretzel orbit reduces the dynamic aperture. However, even in these conditions the dynamic aperture around the Pretzel orbit is sufficient to accommodate the beam, and indeed the injection rate and the injected intensity were unaffected by the Pretzel Orbit, which is an encouraging result. Much more work is needed on this subject. Experiments should be pursued and simulations done around the Pretzel Orbit, taking into account the non-linear errors which are known to exist in LEP.

60.5 Fine tuning of LEP with Pretzel

The measurement and correction of the closed orbit, which is a very crucial operation in LEP, is not straightforward in the presence of the Pretzel. Experience gained in Cornell will be used when applicable. It is proposed to correct the orbit without Pretzel, then turn on the Pretzel and take the measured orbit as a reference to be used later for correction. Some 32 pick ups around the mid arc crossings will not be usable without a costly upgrading, because they see the two counter-

rotating bunches at a too small interval of time. However, it has been checked that discarding these pickups introduces only a marginal degradation of the corrected orbit. How to ensure that both beams have the same tune, chromaticity, etc... and that these parameters do not vary too much with the Pretzel amplitude (so called "Pretzicity" conditions) in LEP is still not a settled question. Additional sextupoles will probably have to be installed in the straight sections to control the tune differences, as has been done in the SPS. Coupling and dispersion, which are not yet understood completely in LEP will have to be studied around the Pretzel orbits. The effort invested for this purpose will certainly contribute to the general understanding of LEP.

60.6 Separators

Apart from the regulation of the High Voltage generators, which needs some improvement, the SPS separators have been satisfactorily adapted to the LEP environment after a few transformations. The main concern is the sparking rate, which must remain extremely low in operation. It can be minimised by working at a low value of the electric field, about 2MV/m. The electrodes must imperatively be shielded from the direct synchrotron radiation coming from the nearby bending magnets. The effect of back scattered synchrotron radiation photons and of Xrays produced by the RF cavities have to be studied. Another cause of sparking is an increase of the residual gas pressure induced by a temperature rise (above 200°C) of the separator plates due to heating by High Order Mode losses from the beam. According to present knowledge this problem should not be serious with 8 bunches, but measurements must be done to verify this point.

60.7 RF implications

Copper cavities have to be removed to make room for the separators, and this will reduce the available RF voltage in the units concerned by 12%. With 8 bunches, the storage cavities can still be used, all bunches crossing the cavities when the voltage is maximum on the accelerating gaps. For a larger number of bunches this is no longer true, and cavities must be fed with a single frequency. In this case the storage cavities are idle and the available RF voltage per cavity is reduced to 72% of its present value. With the superconducting cavities the problem of High Order Mode losses requires attention. Present wisdom indicates that the High Order Mode couplers which equip the cavities already installed can stand the losses of up to 8 bunches, but with not much safety margin. The next generation of cavities will be equipped with improved couplers. The main concern is the energy dissipated by the non trapped modes : temperature measurements will be done to check whether these can pose a problem to some parts of the structure. In order to fully exploit the voltage handling capabilities of the cavities, it will be necessary to install a second klystron per RF station. Variable power couplers are being studied to provide the best matching between RF generator and beam loaded cavity.

60.8 Feedback Systems

The new feedback system which is being built will be capable of damping all coupled bunch modes for up to 18 bunches.

60.9 Injection

After some improvements concerning the reliability and reproducibility of both the SPS at low energy and the transfer lines, and the implementation of the 100 MHz capture at 3.5 GeV followed by RF shaking to maintain long bunches during acceleration in the SPS, the injection complex will be capable of delivering 3 to 4 10^{10} particles per bunch with 4 bunches per SPS cycle. This should be amply sufficient to fill LEP in a reasonable time with 8 or even 18 bunches per beam. It is

proposed to inject the 4 SPS bunches into 4 LEP buckets as practiced now, and to rephase the SPS RF on the following cycle in order to fill the 4 other buckets.

60.10 Compatibility with polarisation

With a horizontal separation, polarisation is not excluded a priori. However, keeping a sufficient degree of polarisation in presence of Pretzel orbits could obviously prove more difficult than with a zero r.m.s. orbit.