DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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Note: **G-55**

Report by DAΦNE Machine Advisory Panel on 2nd Meeting held on 4-5 May 2000

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1. Follow up of previous Meeting

The first report by the DAΦNE Machine Advisory Panel (MAP) following the meeting held on 13-15 January 2000 made numerous recommendations related to the future performance of the machine. A list of these recommendations and the status of the work done in the meantime is given below.

1. *The detector should provide the measured beam parameters to the machine control system at as high a rate as possible.* This work is in progress and will be incorporated in the new control system.
2. *Every effort should be made to make the detector less susceptible to particle background. This will involve the use of the collimation system, aperture-limiting collimators and possibly changes in the operating conditions of the detector itself.* Little progress has been made on this recommendation as other activities were correctly given higher priority.
3. *The Panel proposes to investigate the empirical model, compare it with magnet measurements, try to systematically introduce the mutual ring-to ring distortions in order to arrive at a good machine more systematically. In this way, it is expected that the machine model will work for a larger range of optical solutions as well. Sufficient time should be scheduled in machine studies to test and verify the improved machine model.* A lot of progress has been made on this topic and is reported in Section 2 below.
4. *The Panel recommends returning to the optics with the nominal emittance of 1μm in order to avoid limitations of luminosity by the beam-beam effect.* This has been done and has proved successful.
5. *The Panel recommends the preparation of improved coupling compensation algorithms that should be tested on paper before start-up of the next run. These algorithms should be implemented for each of the two beams.* Enormous progress has been made as reported in Section 3 below.
6. *Dynamic aperture studies, both computational and experimental, should be given very high priority.* A lot of progress has been made on this topic and is reported below in Section 4.
7. *Improved understanding of single-particle dynamics may suggest that the sextupoles in the ring could be used either to adjust detuning with amplitude or provide compensation of resonances. If so, the appropriate knobs should be prepared for use.* This work has been successfully initiated and the results are very promising.

8. *Since the stability of such particles may however be relevant for the beam lifetime in presence of the strong Touschek effect, the chromatic properties of the optics should be checked carefully. If necessary, the additional sextupole magnets in the dispersion-free region may be used to optimise on- and off-momentum dynamic aperture and stability simultaneously.* This work has been started and looks promising.
9. *We therefore recommend that optical solutions with β_x^*<4.5m should be investigated, prepared, and optimised during machine studies to make them availabl for empirical optimisation of beam-beam operation.* This recommendation was made for the future and was not considered as high priority by the panel. This work should be foreseen as part of a general improvement programme when the machine is in smooth operation.
10. *An effort should be made to correct the horizontal dispersion at the interaction point.* This has been done successfully.
11. *The orbit correction algorithms should be upgraded to take into account the need for a minimum vertical dispersion. Such algorithms are available at other laboratories, in particular at CERN (LEP).* This work has not yet completed. There is some apprehension that existing algorithms may not be effective in DAΦNE.
12. *Although there is no clear over-riding need for a transverse feedback system, such a system is at present being studied. The panel fully supports the development and installation of this system, as it will allow much greater flexibility in the operation of the machine.* The development of the transverse feedback is well under way.
13. *The panel also suggests the installation of at least one, and preferably two wide-band pick-ups that would allow the measurement of phase plane trajectories. This is a very useful facility in general and is particularly important for the experimental studies of the dynamic or physical aperture.* The installation of these pick-ups is foreseen in the very near future.
14. *It was also considered worthwhile to provide sufficient temperature and vacuum logging in the region of the bellows suspected as the source of impedance for the quadrupole instability. This monitoring may allow identification of the offending object.* This instability has disappeared with the installation of the new injection kicker (see section 5)
15. *The extent to which the coupling compensation can be affected by the beam-beam force itself needs further investigation.* This work continues.
16. *The variation of tunes over a wider range that should include the tune-shift of the beam-core particles by the beam-beam interaction.* This very time-consuming work has been started and already shows excellent results for the new optics. (see Section 8 below)
17. *Another important input will be to deliberately increase the vertical beam emittance before the onset of the blow-up by the beam-beam interaction.* This work has been started by increasing the vertical beam size by betatron coupling. This technique was not successful, possibly because additional resonances were introduced. The study should be continued by increasing the vertical beam size using dispersion bumps.

The Panel was highly impressed at the progress made both theoretically (in only 4 months) and experimentally (in 2 short weeks of machine studies). The general opinion was that the machine is on the verge of being ready to substantially improve previous luminosity figures.

2. Linear Machine Model

2.1. Findings

A considerable effort has been made to improve and understand the linear optics of DAΦNE. An important step in the understanding of the complicated KLOE-IR orbits was the discovery of a misalignment of the low-β quadrupoles of about 1mm. This has been realigned and it has been made sure that the magnets stay aligned when the KLOE detector is closed.

The linear optics has been improved. The lattice is now approximately 4-fold symmetric and has a much more tractable behaviour. The momentum acceptance of the new optics has been increased and the higher order chromatic effects have been slightly reduced.

The two DAΦNE rings have been made more equal than in the 1999 configurations. This is another important step in the improvement of the general conditions. The theoretical β- and dispersion functions are now identical in both rings.

In addition, work is in progress to improve the linear machine model. For example, individual magnet measurements are taken into account to determine the quadrupole transfer functions. An elaborate sliced model describes the action of the permanent magnets in the solenoid field. End-field effects of dipole magnets and wigglers are taken carefully into account.

The linear machine model has been checked by careful measurements. Measurements and model calculations of β- and dispersion function are in good agreement. The difference between the positron and the electron ring is small and is within the precision of the measurement. The tunes are very similar for the same settings and differ only by 0.03.

The chromatic behaviour of the machine is not yet fully understood. The uncompensated chromaticity is larger than the natural chromaticity predicted by the linear model. The contribution of the sextupole magnets to the total chromaticity however is well predicted by the machine model. Thus there are additional contributions to the chromaticity, which are not yet included in the model. In addition, there is a strong contribution to the non-linear chromaticity, which is not described by the linear machine model.

2.2. Comments

The committee is pleased to see that the substantial effort to improve the linear machine model has been quite successful. The machine optical behaviour of DAΦNE appears to be quite transparent at this point.

2.3. Recommendations

The effort to understand the chromaticity and to find the sources of additional sextupole field should be pursued.

3. Coupling Compensation

A thorough and rigorous analysis of the coupling effects due the KLOE solenoid field has been successfully carried out. Solenoid field parameters could be related quite well to the coupling parameters of the machine. This was the basis of the new coupling correction iteration consisting of tuning the KLOE detector field. This method is very successful. The vertical to horizontal emittance ratio of the beams could be reduced to 0.5% This means that the machine is globally well decoupled.

The effect of all the skew quadrupoles on the tilts of the transverse beam envelopes has been analysed and carefully mapped. Beam-beam scans in longitudinal position varying collision points and for different skew quadrupole settings indicate that the machine is also locally well decoupled. In particular the tilt of the beam ellipse at the IP is small and is the same for both beams.

3.1. Comments

The coupling compensation has been very successful and is considered as a useful and necessary step in the understanding of the colliding beam behaviour.

3.2. Recommendation

In order to control the vertical emittance ratio of the beams, schemes alternative to global coupling should be explored. One possibility would be closed dispersion bumps, generated by one and closed by two or three bumps. This could be useful for beam-beam optimisation.

4. Dynamic Aperture

4.1. Findings

The Panel noted with satisfaction that a number of its recommendations had been followed up and that the dynamic aperture of the operational optics is now better understood.

4.2. Comments

Although the tune-variation with amplitude in collision will be dominated by the beam-beam effect up to moderate amplitudes, the single-beam effect may be important in determining the tails and lifetime of the beam. At large amplitudes it is better calculated by tracking rather than from perturbation theory.

The present model of the machine does not reproduce the measured chromatic behaviour, indicating that there is an unidentified source of non-linearity. The efforts to identify this are very worth while in order to reduce the uncertainties in this area.

It will soon be possible to measure the dynamic aperture and study the phase space structure with scrapers, beam-loss monitors and multi-turn beam measurements. If it turns out that beam lifetime is reduced significantly in collision, such measurements may throw light on the reasons.

4.3. Recommendation

Nevertheless, as mentioned in our previous report, the tracking data should be analysed in greater detail with more extensive use of phase space plots and other tools such as spectral analysis.

The physical model should be improved by tracking with inclusion of synchrotron oscillations.

5. Collective Effects

5.1. Findings

As expected from the study presented at the last meeting, the replacement of the injection kicker has successfully removed the quadrupole instability that limited the beam current in 1999. The accumulated beam current in DAΦNE has increased dramatically: the single bunch current limit has increased from 10—15˚mA to 40˚mA.

The Panel notes that the development of a transverse feedback system is under way; this is likely to be beneficial in the push towards higher intensities.

6. Beam-beam simulation

6.1. Comments

The beam-beam simulations presented are of the weak-strong type and provide only a guide to potentially good working points. The machine model in the simulations is being improved to take better account of the origin of coupling effects and it has been shown that the results depend strongly the way this is done.

6.2. Recommendation

The Panel recommends that the DAΦNE team should continue to devote some machine time to a careful search for better working points.

7. Control System Improvements

The control system of DAΦNE has been dramatically improved. The many useful features of the new system will evidently not improve the maximum luminosity performance but nevertheless these improvements will allow more efficient and easier operation of the machine which will result, in the longer term, in an overall increase in the integrated luminosity.

8. New Optics

The "new optics" with tune values of 5.10/5.14 has given spectacular results. In particular the beam-beam performance appears to be dramatically improved. On two separate weak-strong experimental situations

18mA/bunch (e^+) against 6mA/bunch (e^-) and

20mA(e^-) against 5mA(e^+)

there was no sign of blow up of the weak beam. This is highly significant as it indicates that beam-beam tune shifts of the order of 0.02-0.03 produce no significant increase in the vertical dimensions of the beam. The only doubt that remains about the new optics is that the single beam lifetime was observed to be rather low. However there was general consensus in the panel that, given some additional time, this problem will be solved by a careful choice of parameters in the region of the new tunes.

The parameters achieved with this new optics correspond very well to the design parameters with an emittance ratio of less than 1%, a horizontal emittance of 1µm.

9. Ambitious Performance Goals for Year 2000

Taking parameters, which have already been achieved on separate occasions but never simultaneously e.g.

20mA/bunch, 40 bunches, ξ=.02, κ= .01, ε_x =1µm

compared with design parameters of

40mA/bunch, 120 bunches, ξ=.04, κ= .01, ε_x =1µm (luminosity = 5×10^{32} $cm^{-2}s^{-1}$)

would yield a luminosity below design by a factor of 12 (4 due to the current per bunch and 3 due to the number of bunches). Hence the anticipated luminosity with these parameters would be 4×10^{31} $cm^{-2}s^{-1}$. This corresponds well to the luminosity per bunch of 1×10^{30} with 20mA that was already achieved in 1999.

Using this peak luminosity (for 2000) a reasonable integrated luminosity would be 200 to 400 pb^{-1} for the period up till the end of the year. These performance goals, although ambitious, do not seem to be out of reach since each parameter has already been achieved separately.

A pre-requisite for this performance is that the required single bunch performance be established as a basis for the physics running. This may take several weeks from the re-start of the machine after the vacuum incident in late April.