# Report by DAΦNE Machine Advisory Panel on 3rd Meeting held on 30-31 January 2001

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## 1. DAΦNE Operation

### 1.1. Findings

In May and June the machine was operated for machine studies to investigate new working points. The betatron coupling had been previously reduced to low levels by fine-tuning of the KLOE solenoidal field.

The first KLOE run produced a peak luminosity of $1.1\times10^{31}$ $cm^{-2}$ $s^{-1}$ with an integrated luminosity of 4 $pb^{-1}$. During this run the beam lifetimes were very low resulting in poor background conditions. This was followed by a DEAR run, which concentrated on the background seen in this experiment. These studies reduced the background seen by DEAR by a factor of 5.

The DAΦNE collider was operated from mid-September until 4 December on a schedule based on 5 weeks running followed by 5 days maintenance. During running, machine studies were interspersed with KLOE data taking. The peak luminosity achieved in KLOE was $1.8\times10^{31}$ $cm^{-2}$ $s^{-1}$. The integrated luminosity delivered to the KLOE detector during the year 2000 was 28 $pb^{-1}$ with a peak recorded daily luminosity of 0.830 $pb^{-1}$.

Operation was transferred to a DEAR run from 4 December till 21 December. This run was dedicated to the continuation of the background studies and the search for a suitable working point.

The subsequent operational performance of the accelerator showed that the most important discovery made during 2000 was the existence of very strong non-linear magnetic fields in the wiggler magnets. This crucial topic is given our full attention in the next section.

### 1.2. Comments

We were very impressed by the operational progress that has been made, particularly during the post-September period. The operational scenario of interspersed data taking and machine studies seems to be a very efficient way of making fast progress at this stage of the development of the collider. A significant increase in operational efficiency has been brought about by the "topping-up" procedure. This procedure was made possible by the transverse feedback system, optimisation of the injection process and, most importantly, an excellent collaboration effort between the machine and the detector physicists that resulted in a configuration that allowed the high voltage to remain on during injection.

Further operational improvements may exploit the new possibility to rotate the IR quadrupoles as part of the coupling compensation scheme. This may, in time, allow the solenoid field in the KLOE detector to be increased again.

## 2. Non-linear Distortions of the Magnetic Field in the Wigglers

### 2.1. Findings

The discovery of a strong, non-linear magnetic field component of the four DAΦNE wiggler magnets was discovered and investigated by the DAΦNE team. The direct observations were a strong decay or decoherence of coherent betatron oscillations and tune changes when a closed orbit bump is excited inside the wiggler magnets. This has been attributed to a strong decapole component of the wiggler field. Since the beam orbit passes off-centre through the wiggler magnets, the decapole feeds down to an effective octupole component that explains the observed phenomena. A new beam optics without the wigglers was implemented and it was confirmed that these non-linear effects disappear when the wigglers are turned off.

### 2.2. Comments

The analysis and the explanation of these very carefully executed measurements and the simulation of the tune changes appear to be plausible and sound. The Panel considers this an important step towards a better understanding of the DAΦNE beam dynamics and further improvement of performance.

Since there is reason to believe that the non-linear field distortions are in part caused by saturation effects, the DAΦNE team plans in the short term to explore whether this can be mitigated if the wigglers are operated with reduced fields. In the meantime it will be investigated whether the field can be improved by shimming. The ultimate solution would be to rebuild the magnet poles to suppress the decapole component. As a further backup solution, the installation of octupole magnets to compensate the average octupole is also under consideration.

### 2.3. Recommendations

We believe that this is a good strategy but want to point out that, while the DAΦNE team is concentrating on the secondary octupole component which produces the observable effects, the primary decapole component is even more undesirable and could have a detrimental impact on dynamic aperture. This decapole component should be removed from the accelerator. The secondary octupole however might even have the virtue of providing Landau damping and thereby suppressing coherent instabilities. For this additional reason, we support the plan to install octupole correctors in order to restore a desirable amount of Landau damping once the effective octupoles have been removed.

Before this is carried out, it is however important to understand the impact of the decapole and octupole field components on the dynamic aperture. The fields that have been derived from the tune measurements should be taken into account in tracking calculations. Some analytical analysis should also be performed in order to understand the harmonic content of the field distortions and possible generation of non-linear resonance driving terms. This analysis should also be extended to the planned octupole correction magnets and their impact on the dynamic aperture should be understood.

Some complementary measurement of the non-linear fields may be performed. The DA□NE team should consider measuring the residual closed orbit, which can be detected if an orbit bump is excited in the non-linear field.

Furthermore, since the measured field imperfections may interplay with the beam-beam effect, one should investigate whether the octupole terms from the beam-beam effects cancel the octupole from the wiggler field and at which beam-beam tune shift this cancellation occurs.

## 3. Background Studies

### 3.1. Findings

Background in the DAΦNE detectors is dominated by beam losses resulting from Touschek scattering. The tools available for reduction of this background are

- optimisation of the optics,
- working on the closed orbits, both locally and globally,
- increase of the dynamic aperture
- use of collimators (scrapers)

### 3.2. Comments

A concerted study (both experimental and simulations) by a LNF/CERN team has come to the conclusion that a new design of the collimators is needed. Predictions indicate a background reduction of between a factor of 3.5 and 10.

### 3.3. Recommendations

The newly designed collimators will be installed early in 2001. This experimental and simulation programme should be vigorously continued since the luminosity may ultimately be limited by the tolerable background in the detectors.

## 4. Dynamic Aperture

### 4.1. Findings

Some of our recommendations from earlier meetings have been followed up. In particular, the kicked-beam measurements of decoherence with and without the wigglers yielded one of the clearest demonstrations of the effect of the multipole fields in the wigglers. It was shown that the hypothesis of an octupole lens in the wigglers could account rather well for the measured chromatic tune-dependences. Some tracking studies have looked at the possibilities for correcting the tune-dependence on amplitude due to the wigglers with independent octupoles in various locations.

### 4.2. Comments

The tracking results are not yet comprehensive enough to provide enough understanding of the non-linear behaviour and dynamic aperture of DAΦNE.

### 4.3. Recommendations

We would like to re-iterate and amplify our earlier recommendations concerning the tracking studies. The model of the machine used in tracking should be refined and made to resemble the operational machine as far as possible, including all known multipole fields (in particular those in the bending magnets). Uncertainties in this modelling can be allowed for by Monte-Carlo procedures. More extensive coverage of phase space, including the longitudinal degree of freedom, is necessary. While the inclusion of synchrotron oscillations may not be strictly necessary given the low synchrotron tune in DAΦNE, some off-momentum tracking should at least be performed. Particles should be tracked, if not for a damping time, at least for a few thousand turns of the rings.

Experimentally, it is now possible to measure the beam distribution and dynamic aperture in the horizontal plane using scrapers and systematic measurements of this type are strongly recommended, with and without wigglers and with and without colliding beams. Kicked beam measurements, which are now readily performed, should be pursued to obtain more detailed information on dynamic aperture without colliding beams. The decoherence observed in these measurements can be analysed quantitatively to estimate of the strength of the effective octupoles.

The sensitivity of dynamic aperture to the machine settings should be explored. This may help to optimise the tunes with respect to $7^{th}$ order resonances.

## 5. Beam Lifetime Investigations

The Panel has been presented with a careful analysis of the beam lifetime in DAΦNE. The lifetime of the beam does not agree well with the expectations. The dominant mechanism for beam loss in DAΦNE is expected to be Touschek scattering. The calculated Touschek lifetime however is twice as long as the observed lifetime. It is unlikely that the uncertainties in the model used for these calculations account for the discrepancy (although this may be worth checking). Additional effects that reduce the lifetime have not been found.

The Panel suggests performing lifetime measurements with an artificially reduced aperture, e.g., by introducing scrapers, which could provide some clarification. The Panel also wants to point out that accelerator physicists at BESSY (Khan et al) have revisited the Touschek effect recently. It might be worthwhile to explore whether their formalism provides a better agreement with the observed lifetime.

## 6. Orbit and Dispersion Correction

### 6.1. Findings

The correction methods now implemented are satisfactory and effective in correcting orbit and vertical dispersion. Corrections are computed using the measured response matrices of the machine rather than depending on a model. It has been shown that the vertical emittance is mostly due to betatron coupling with little contribution from direct quantum excitation through the vertical dispersion.

### 6.2. Comments

The situation is well in hand, the origin of the vertical beam size is clear and tools are available to deal with any further problems in this area.

## 7. Beam-beam Effects

### 7.1. Findings

The space of possible working points has been well covered, both in simulation and in machine development studies. In the conditions of highest luminosity attained so far, with unequal tunes for the two rings, the intensities of single bunches are limited by a blow-up of the electron bunch and a reduced lifetime of the positron bunch. In multi-bunch mode, luminosity is limited by uneven filling of the bunch train, ion trapping effects and a transverse instability.

The blow-up of the electron beam has also been seen in strong-strong simulations.

### 7.2. Comments

Although it is difficult to compare directly all the experimental data while other parameters may be changing, the indications are that a change in the electron ring tune could be beneficial.

It is possible—and the simulations support the hypothesis—that the effective octupole fields in the wigglers may have had some beneficial effects through a partial compensation of the tune-dependences on amplitude from the beam-beam force or by providing Landau damping through a tune-spread. As mentioned before it is therefore important to be able to restore some octupole field in a controlled way after the wiggler multipoles have been compensated (see remarks about the octupole distribution above).

The transverse instability occurring in multi-bunch mode should be suppressed by the improvements to the feedback system (see below).

### 7.3. Recommendation

The combined detuning with amplitude from the lattice (with wigglers, octupoles, etc.) and from the beam-beam force should be calculated (probably by a combination of tracking and analytical estimates) and confronted with measurement in as many conditions as possible.

Measurements of the beam distribution with scrapers (as mentioned above) are also very important for understanding beam-beam effects.

To reduce the ion-trapping effects, the best approach, given that many clearing electrodes are broken, is to reduce the vacuum pressure. This will be worthwhile, as it should help to make the bunch train longer and increase luminosity. In time, beam cleaning will also contribute to reduce the ion density.

## 8. Transverse Beam Dynamics

### 8.1. Findings

The Panel was gratified to learn that the recommendations of the second MAP meeting were carried out, i.e., the "Dynamic tracking data acquisition system" was operational from May 2000 and the vertical feedback systems for positrons and electrons were installed in June and September 2000 respectively.

It is interesting to note from the second MAP "*Although there is no clear over-riding need for a transverse feedback system …The panel fully supports the development and installation of this system"*. In fact the feedback system was found to be very useful for the topping up scheme.

### 8.2. Comments

The "Dynamic tracking data acquisition system" has been successfully employed in the studies associated with the tune dependence on amplitude with wigglers on and off and has identified some resonances in the machine.

### 8.3. Recommendations

We fully support the upgrade of the transverse feedback system i.e.

- increased power in the final sections by improved amplifiers
- reduction of the electron bunch cross-talk (this is crucial with the increased power)
- avoidance of amplifier saturation by a bunch-to-bunch real time offset corrector.

In addition we encourage the continuation of the investigation and understanding of the driving mechanism behind the apparent bunch to bunch instability which occurs along the bunch train. It is also important, both for DAΦNE and for other accelerators, to understand why the predicted electron cloud instability has not yet been observed.

## 9. Third Harmonic Passive Cavity

The plan to use a third harmonic cavity for increasing the length of the bunch appears interesting. An average gain in Touschek lifetime of 50% is predicted. Of the two modes of operation studied, the passive cavity option appears the better. Although there is a non-negligible probability that other problems with beam dynamics (spread of synchronous phase along the train of bunches etc) may render the system inoperable, it is the opinion of the Panel that this is a worthwhile machine experiment.

The "parking" mode for the cavities may well allow restoration of the standard machine operating conditions; nevertheless all efforts should be made to allow fast replacement of the cavities with a blank beam pipe should this turn out to be necessary.

## 10. Future Plans

The Panel fully endorses the plans for running in 2001 as presented by the project team.

The scenario of five weeks operation followed by five days of maintenance appears effective, as does the interspersing of physics data taking with machine studies. The clear priority given to the study of the non-linearities of the wiggler fields is well justified.

The panel strongly recommends that the non-linearities in the wiggler fields be reduced by whatever means are the most effective. In parallel with this a design of suitable octupoles should be pursued in order to cover the possibility that the elimination of the fed-down octupolar field has a detrimental effect on the beam quality.

The efforts towards background reduction should be continued and it is hoped that the new collimators will greatly alleviate this problem.

The objectives of a steady 1 $pb^{-1}$ per day before the summer and a total integrated luminosity of between 100 and 200 $pb^{-1}$ this year appear achievable.

The panel was very impressed at the improved motivation of both the detector physicists and the accelerator teams. We are confident of their every success in 2001.