DAΦNE STATUS REPORT

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Abstract

The operation of DAΦNE, the 1.02 GeV c.m. e^+e^- collider of the Frascati National Laboratory with the KLOE experimental detector was successfully concluded in March 2006. Since April 2004 it delivered a luminosity > 2 fb^{-1} on the peak of the Φ resonance, > 0.25 fb^{-1} off peak and a high statistics scan of the resonance. The best peak luminosity obtained during this run was 1.5 10^{32} $cm^{-2}s^{-1}$, while the maximum daily integrated luminosity was ≈10 pb^{-1}. The KLOE detector has been removed from one of the two interaction regions and its low beta section substituted with a standard magnetic structure allowing for an easy vertical separation of the beams, while the FINUDA detector has been moved onto the second interaction point. Several improvements on the rings have also been implemented and are described together with the results of machine studies aimed at improving the collider efficiency and testing new operating conditions.

INTRODUCTION

The DAΦNE [1] lepton collider complex consists of two independent rings sharing two common interaction regions (IR), and of a full energy injector composed by an S-band linac followed by a damping/accumulator ring and beam transfer lines to the main rings. The main parameters of the collider are listed in Table 1.

Table1: DAΦNE Parameter list

Energy	0.51 GeV
Trajectory length	97.69 m
RF frequency	368.26 MHz
Harmonic number	120
Damping time, τ_E/τ_x	17.8/36.0 ms
Bunch length at full current e^-/e^+	2.8/2.2 cm
Beam currents e^-/e^+	2/1.4 Amps
Number of colliding bunches	111
Beta functions β_x/β_y	1.7/0.017 m
Emittance, ε_x (KLOE)	0.34 mm·mrad
Coupling at 0 current	0.3 %
Tunes ν_x / ν_y	0.091/0.166 e^- 0.109/0.191 e^+

Since year 2000 DAΦNE has been delivering luminosity to three experiments: KLOE, FINUDA and DEAR. The first interaction region (IR1) has been so far dedicated to the KLOE experiment, while FINUDA and DEAR detectors have shared, one at a time, the second interaction region (IR2).

An intense physics activity is also ongoing at the DAΦNE beam test facility (BTF), a dedicated transfer line delivering electron or positron beams from the DAΦNE Linac in the energy range 25-725 MeV with intensities varying from 10^{10} particle/pulse to a single-electron. Moreover, two separate beam lines from one wiggler and one bending magnet of the e^- ring deliver synchrotron radiation (SR) to a dedicated LNF facility.

In the last two years (from April 2004 to March 2006) the DAΦNE activity has been mainly devoted to the KLOE data taking. The details of the last KLOE run are shown in Figure 1.

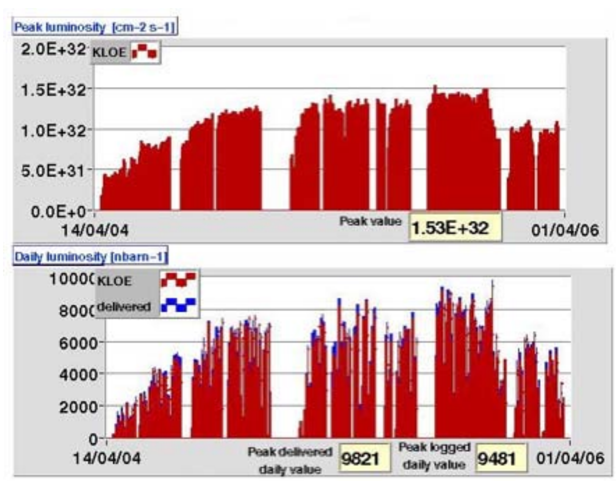

Figure 1: Last KLOE run peak and integrated luminosity.

LAST KLOE RUN

In the 2004-2006 KLOE run DAΦNE has delivered an integrated luminosity in excess of 2 fb^{-1} on energy (1019.4 MeV) and, in the last part of the run, > 0.25 fb^{-1} off-peak (1000 MeV). A high statistic scan of the Φ resonance has been also performed collecting more than 10 pb^{-1} per point at 4 different energies (1010, 1018, 1023 and 1030 MeV).

As shown in Fig. 1, the machine performances have been continuously improving during the on-energy run.

With respect to the past physics runs, the final obtained improvement in both peak and integrated luminosity is a factor ≈2.

The highest peak and daily integrated luminosities measured by KLOE have been $L_{peak} = 1.53 \cdot 10^{32} cm^{-2} s^{-1}$ and $L_{day} \approx 10\ pb^{-1}$, respectively. The luminosity has been optimized through many machine improvements, such as:

- Colliding current increase, due to the vacuum conditioning and the continuous improvements of the feedback systems, especially those fighting the electron cloud horizontal instability limiting the e^+ current;
- Coupling correction;
- Optimization of the β functions at the IP and of the tune working point;
- Improvements of the non-linear dynamics with octupoles and sextupoles optimization, monitored through the measurement of the de-coherence time;
- Closed orbit correction and control (very important also for background reduction);
- Adiabatic day-by-day tune-up of the machine

The machine performances have also benefited from some hardware upgrades implemented during the long shutdown of year 2003 [2] such as the new interaction regions, the modifications of the wiggler magnet poles, the reduction of the injection kicker pulse duration and the installation of additional feedback amplifiers.

The ultimate limits to a further luminosity increase in the run were:

- Positron beam instability limiting the maximum total current to 1.4 A;
- The increase of bunch length and transverse sizes with current in the μ-wave regime. This effect has been especially harmful in the e^- ring where the presence of Ion Clearing Electrodes (ICEs) in the wiggler chambers almost doubles the beam coupling impedance with respect to the e^+ ring.
- Vertical beam-beam blow-up of the beams;
- Lifetime degradation due to parasitic crossings.

As reported in the following, we are planning measures to alleviate all the above mentioned problems.

MACHINE PHYSICS ACTIVITIES

Several machine study shifts have been performed during the KLOE run, and especially in the last two weeks of operation (March 2006). They have been devoted to:

- Bunch length measurements with a large negative momentum compaction (α_c<0) optics;
- Test on the wires for Beam Beam Long Range interaction (BBLR) compensation;
- Test of the new transverse feedback in the e^+ vertical plane;
- Study of background to KLOE during injection and as a function of the scrapers position;
- Test on the new acquisition system for the single turn orbit measurements;
- Injection from the Linac switching off the chicane downstream the e^+ converter (towards a continuous injection scheme foreseen for the collider upgrade);

Negative α_c is a promising way to limit the bunch lengthening and weaken the effects of the μ-wave regime [3]. The short range wakefields are mainly focussing in this case, and the bunch starts lengthening only above the μ-wave threshold as a consequence of the energy spread increase.

In the DAΦNE IRs the beams experience 24 parasitic crossings (Beam-Beam Long Range Interactions) acting as a non-linear lens on both beams reducing their lifetimes, the maximum storable current and the integrated luminosity. Numerical simulations have shown that BBLR interaction can be compensated to a certain extent by current-carrying windings [4]. We have tested this principle in DAΦNE obtaining a significant lifetime improvement.

MACHINE SHUTDOWN FOR EXPERIMENT CHANGEOVER

Beginning from April 3rd 2006, machine operation has been stopped to allow the KLOE detector roll out from IR1 and the FINUDA detector roll in IR2. Meanwhile, maintenance of the various machine sub-systems and some hardware upgrades have been done.

The KLOE detector has been displaced from the beam line for the first time since spring 1999 when it was rolled in IR1 to begin its physics enterprise. The detector is now parked in a dedicated hall separated from the DAΦNE one by a dismountable concrete-block wall. It will undergo some maintenance, while future data taking runs are not planned yet. A new vacuum chamber has been installed in IR1 to replace the KLOE one, equipped with 4 electromagnetic quadrupoles allowing a flexible optics and an easy separation of the beams in IR1. Pictures of IR1 before and after KLOE roll out are shown in Fig. 2.

Figure 2: DAΦNE IR1 before and after KLOE roll-out.

The FINUDA detector is going to be rolled back in IR2 for a data taking run of approximately 9 months up to the delivery of 1 fb^{-1}. The collider operation restart is scheduled for July 17th, while the DAΦNE BTF operation has been already resumed on June 26th.

Among the various maintenance activities it is worth mentioning the substitution of all the cooling pipe spigots (≈150 per piece) in the 8 wiggler magnets, whose water leakages were responsible for a significant fraction of machine downtime in the past.

Hardware upgrades carried out during this shutdown are also relevant.

We decided to remove all ICEs from the wiggler vacuum chamber of the e^- ring, since they strongly contributed to the broadband impedance [5] making the

e^- bunches significantly longer than the e^+ ones and limiting the possibility of reducing the vertical β^* to increase the luminosity. Moreover, we have experimental observations of the vertical size increase of the e^- bunches above the μ-wave threshold, which also affected the luminosity and limited our possibilities to take full advantage from different collider regimes such as negative α_c. We estimate a luminosity gain of ≈ 20÷30 % from ICEs removal. To extract the ICEs from the chambers and to cut the metallic fingers keeping them in place, a special dedicated device remotely controlled through an endoscope has been designed and built. Two out of four electrodes have been already removed, together with some other shorter ICEs located elsewhere in the vacuum chamber that have proved to be broken or ineffective.

Other relevant hardware upgrades consisted in:

- Installation of wires for BBLR compensation in the IR2;
- Feedback upgrade (III generation digital bunch-by-bunch feedback designed for Super B-factory in the SLAC-KEK-LNF collaboration framework);
- New Beam Position Monitors (BPMs) for measurements of linear and non-linear optics parameters ($\nu_{x,y}$, $\beta_{x,y}$, κ, c_{11}, ...) based on turn-by-turn position tracking;
- TiN coating on a short straight section to allow the first direct e-cloud test measurement on the e^+ ring;
- Control System upgrades;
- Installation of a photon tagged source and of a pulsed magnet to improve the duty cycle from 40% to 80% in the Beam Test Facility

DAΦNE FUTURE PLANS AND UPGRADES

After the end of the FINUDA run, expected by mid 2007, a run of the SIDDHARTA experiment is already scheduled. Official programs beyond the SIDDHARTA run are not yet defined.

DAΦNE hardware improvements are planned in the near future. We intend to install in the machine new fast injection kickers designed at LNF to cope with the requirements of the ILC damping rings [6] which could be very fruitfully used in DAΦNE to leave all the stored bunches unperturbed during injection (with the only exception of the bunch selected for the injection plus the 2 adjacent ones). We have experimental evidence that the transient excitation of the bunches at injection is one of the mechanisms that drive the fast horizontal instability in the e^+ ring. Then we expect to increase the stored e^+ current by using the new kickers, which also provide better deflecting field uniformity and smaller beam coupling impedance with respect to the devices presently used at DAΦNE. The installation of a first set of new injection kickers is planned for the end of this year.

On a longer time scale there are proposals for more ambitious upgrades. The installation of new independent transfer lines to inject the two beams simultaneously (trickle injection) can keep the collider luminosity constantly at its maximum value, allowing also a better optimization of the collider parameters at the maximum currents. We have also a proposal to test the Strong RF Focusing (SRFF) principle at DAΦNE [7]. In this case the installation of a 1.3 GHz SC, TESLA-like cavity providing voltage in the 10 MV range, together with the implementation of a suitable lattice structure providing large or oscillating R_{56} functions allows the machine to explore the bunch length modulation regime. Short intense bunches (≈2 mm @ 10 mA) are obtainable, according to our simulations based on SPIDER [8], a tracking code purposely developed to study the bunch μ-wave behaviour in the SRFF regime.

The study of a crab crossing system to collide the beams head-on in spite of the finite crossing angle by properly tilting the bunch equilibrium distribution at the IP is in progress [9]. A basic design of the crab cavities has been defined, and the expected luminosity gain is of the order of ≈2.

Recently, the crabbed waist collision scheme [10] has been proposed to overcome the hourglass effect by increasing the crossing angle and decreasing the horizontal size of the bunch at the IP. A proposal to test in the near future this promising luminosity-boosting idea at DAΦNE by implementing a new dedicated IR is in preparation.

CONCLUSIONS

The Frascati Φ-factory DAΦNE has successfully completed the run of the KLOE experiment delivering $> 2\,fb^{-1}$ at the Φ resonance peak energy and $\approx 0.3\,fb^{-1}$ off-peak in the period from April 2004 to March 2006, with a luminosity increased by ≈2 with respect to the previous runs. Meanwhile, the machine continued to operate regularly also for the Beam Test Facility and for the Synchrotron Radiation Facility. After a 3 months shutdown for experiment changeover, machine maintenance and hardware upgrades, DAΦNE is ready for the 2^{nd} run of the FINUDA experiment.

There are many proposals to upgrade the machine and test new ideas to improve its performances: new fast injection kickers, new transfer lines, strong RF focusing, crab crossing, crabbed waist. Many of this items are of primary interest for the whole lepton collider community.

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