STATUS REPORT ON DAΦNE

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Abstract

DAΦNE, the Frascati LNF Φ-factory [1], is providing luminosity for the KLOE experiment since July 2000. A steady increase of daily integrated luminosity in KLOE has been obtained, due to interspersed machine physics studies. The main results are: increase of single bunch luminosity by reduction of the effects of nonlinear terms in the machine, background reduction, refill of the colliding beams while keeping the KLOE detector taking data and increase of stable stored current. A fraction of machine time has been used to tune luminosity and reduce background in the DEAR configuration. The luminosity delivered to DEAR was sufficient to conclude the first phase of the experiment.

1 INTRODUCTION

DAΦNE is an e^+e^- double ring collider at the Φ centre of mass energy. The KLOE experiment, dedicated to CP violation, is installed in Interaction Region 1 (IR1) since March 1999. The DEAR experiment, for exotic atoms studies, is installed in IR2.

A peak luminosity of 2.8 10^{31} cm^{-2} s^{-1} with currents of 730 mA e^+, 670 mA e^- in 47 bunches has been achieved. The maximum daily integrated luminosity is 1.4 pb^{-1}/day. The total luminosity delivered to KLOE since July 2000 is 50pb^{-1}. Time has been shared between KLOE (27%), DEAR (13%), Machine Development (30%), Shutdown (23%) and Maintenance (7%).

The collision parameters achieved in DAΦNE operation for KLOE are listed in Tab. 1. Continuos operation for KLOE started in July 2000 after machine development shifts dedicated at increasing the single bunch luminosity [2]. Thanks to strong reduction of machine coupling single bunch luminosity of 5-6 10^{29} cm^{-2} s^{-1} was obtained with a total luminosity of 10^{31} cm^{-2} s^{-1} with 350 mA in 30 bunches. At the beginning of operation the maximum luminosity could not be delivered to KLOE due to the high background level which limited the stored current below 250 mA per beam. From July to December machine shifts where interspersed with KLOE runs in order to optimise machine performance. In particular background reduction was obtained by tuning orbits and optical functions in the IRs and by optimising the scrapers configuration [3]. Improvement of peak luminosity and beam lifetime was obtained by tuning working point, machine coupling and sextupole configuration.

As soon as background was reduced, the stored currents were brought close to 1A, due to the good performance of the longitudinal and transverse feedback systems [4] as well as to the optimisation of the injection procedure. Furthermore all these actions allowed KLOE to stay fully operational during injection. This feature brought to a large increase in integrated luminosity because the average can be kept very close to the peak one by frequent refill of the rings.

In Fig. 1 currents and luminosity within two hours in a typical run are shown.

Table 1: DAΦNE Collision Parameters

Beam Energy [GeV]	.51
Crossing angle [mrad]	12.5
Luminosity [$cm^{-2}s^{-1}$]	2.8 10^{31}
Number of bunches	45
Harmonic number	120
e^+ current [mA]	730
e^- current [mA]	670
β_y*/β_x* [m]	.045/4.5
Minimum Coupling	0.3 %
Emittance ε_x [mm mrad]	0.8 - 0.9
IP rms beam size σ_y/σ_x [μm]	11/1900
Σ_y (low current) [μm]	12
Damping time τ_E/τ_x [ms]	17.8/36
Injection time (1full beam) [min]	3
Detector solenoid field integral [Tm]	2.4
Max integrated luminosity 24h [pb^{-1}]	1.3
Total integrated luminosity [pb^{-1}]	50

In November a nonlinear term in the wiggler magnets was measured [5]. After winter shutdown machine time has been dedicated to systematic studies of nonlinearities [6]. A new "detuned" optics (without low-β in the DEAR IR), allowing better separation in the second IP, has been designed [7]. This optics is less sensitive to machine nonlinearities and has achieved a single bunch luminosity of 10^{30} cm^{-2} s^{-1} at currents of ~ 20 mA.

Since April KLOE is taking data with the new optics and after ten days the daily integrated luminosity reached 1.3 pb^{-1}. The daily integrated luminosity since July 2000 is shown in Fig. 2. A continuous increase is evident.

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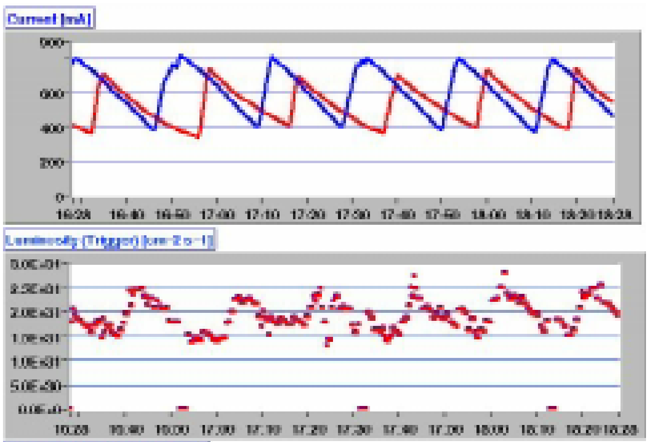

Figure 1: Luminosity and currents over 2 hours. Peak luminosity 2.8 10^{31} cm^{-2} s^{-1}, integrated luminosity 136 nb^{-1}.

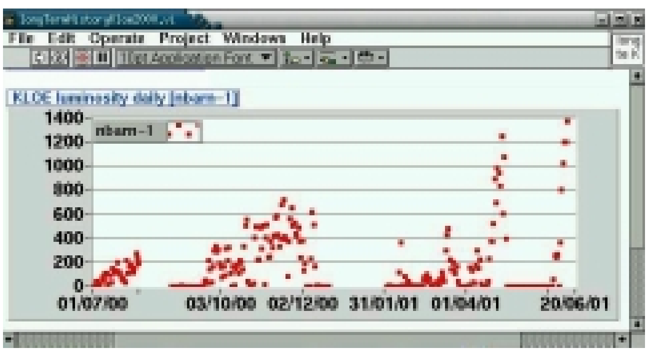

Figure 2: Daily KLOE Integrated Luminosity since July 2000

In the same period a smaller fraction of time has been dedicated to tune the DEAR optics. Due to the IR2 layout, to keep the chromaticity reasonably low the vertical β at the IP2 is twice the value used for KLOE.

A peak luminosity of 10^{31} cm^{-2} s^{-1}, with 600-800 mA in 45 bunches, has been achieved. The total integrated luminosity of 2.9 pb^{-1} has been sufficient to produce physics results and to conclude the first phase of the experiment.

During the winter shutdown, dedicated to maintenance of DAΦNE subsystems and cryogenic plant, some upgrades have been performed: remote helium refill of the compensating solenoids, scrapers upgrade [3] and new power amplifiers for the transverse feedback [4].

2 SINGLE BUNCH LUMINOSITY

To increase single bunch luminosity machine physics runs have been dedicated to measurement and reduction of the effects of nonlinearities, coupling reduction and working point tuning.

2.1 Machine Nonlinearities

Nonlinearities have been intensively studied in order to improve the beam lifetime (determined by dynamic aperture) and beam-beam performance.

A nonlinear term in the wiggler of the four arc achromats has been measured.

The measured tune shift on amplitude shows a parabolic well reproduced by an octupole term [5]. Tracking and simulation studies have been done to understand the effect of this octupole term on dynamic aperture[6] and beam-beam performance [8]. An optics with wigglers off has been designed and applied to both rings, and single bunch collisions have been performed. This optics had quite poor single bunch luminosity but was important for a better understanding of machine performance. The strong radiation damping of the wigglers is needed in DAΦNE to improve beam-beam performance and beam lifetime. Moreover the octupole term in the wigglers introduces a strong Landau damping which suppresses multibunch instabilities. Once turned off the wigglers a nonlinear component in the "C" corrector magnets was clearly individuated and found in agreement with magnetic measurements. This was responsible for the coupling introduced by the vertical separation orbit bump.

The new optics has been designed to reduce the effect of wigglers and "C" nonlinearities. In the wiggler this is obtained by lowering the β-function. The reduction of the octupole term increases the single bunch luminosity but reduces also the Landau damping which helps in suppressing multibunch instabilities.

In order to correct and optimise the effect of the octupole term on beam-beam and instabilities the installation of octupole magnets is foreseen for fall 2001.

2.2 Coupling and Working Point

To achieve the optimum luminosity performance the coupling has to be reduced as much as possible. The strong coupling introduced by the KLOE solenoid is compensated by two antisolenoids and by a rotation of the low β quadrupoles immersed in the solenoid field [9]. This system has demonstrated a strong efficiency in reducing the global coupling of the machine [10]. A further coupling reduction has been obtained by reducing the strengths of the "C" corrector magnets placed near IR2. Different working points have been tried, after tune scans. Small changes with respect to the working point adopted in June 2000 have given the best performance. Optimum luminosity, both for KLOE and DEAR, is obtained with (e^-: 5.12, 5.17; e^+: 5.15, 5.21).

3 MULTIBUNCH PERFORMANCE

A continuous improvement has been obtained by increasing total currents and number of bunches. At the beginning 1 bunch was filled every 3 buckets, injecting 30 bunches in non colliding buckets and bringing them into collision by "RF phase jump". The maximum number of bunches with this pattern would be 40 but a gap to avoid ion trapping in the e- ring is needed. At present we inject in collision 1 bunch every 2 buckets for a total of 49 bunches.

3.1 Feedback Systems

A longitudinal bunch-by-bunch feedback system has been operating in DAΦNE since the beginning of commissioning. A transverse bunch-by-bunch feedback system working in the vertical plane has been implemented in both rings. This produced an increase of the stable stored currents. A record of 1 A stable stored current in each ring, with the bunch pattern used in collision, has been achieved [4]. A similar system for the horizontal plane is ready to be installed when needed.

3.2 Vacuum System

The vacuum has been continuously improving because the high current operation for the experiments is very effective for beam conditioning. Desorption coefficient as a function of the integrated stored current is shown in Fig. 3. It can be seen that two vacuum breaks were rapidly recovered.

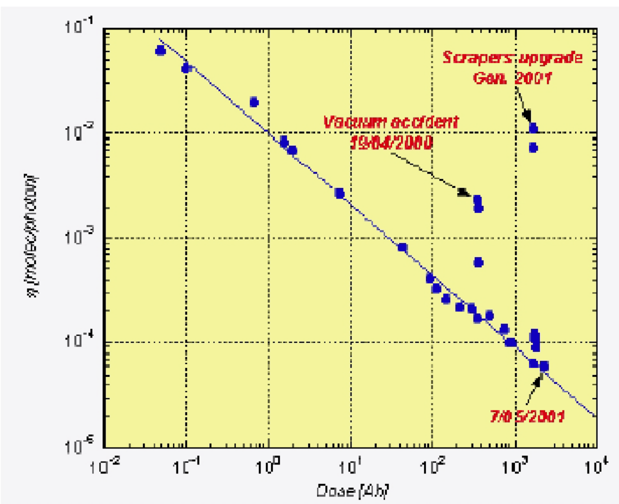

Figure 3: desorption coefficient vs. integrated stored current

3.3 Machine Background

Measurements and simulations have been performed to reduce the machine background in the detectors. A first reduction has been obtained by tuning orbits and optical functions in the IRs and by optimising the sextupole strengths. A further reduction is obtained by inserting the scrapers, thick tungsten targets, in the horizontal plane, to intercept large aperture particles upstream the two interaction regions. When the background is reduced stored currents and luminosity are increased.

At present KLOE is taking data with the same background level as in July 2000 but with an integrated luminosity per day 5 times larger.

For DEAR the signal to background ratio in September 2000 was 1/150, now has been reduced to 1/30.

The background reduction is both due to detector shielding upgrade and to improvement of machine performance.

5 FUTURE PLANS

We plan to deliver to KLOE 200 pb^{-1} by the end of the year. With the present integrated luminosity of 1.4 pb^{-1} most of machine time will be dedicated to KLOE, nevertheless a small fraction of time will be dedicated to machine physics studies on background reduction, beam lifetime increase and suppression of transverse instabilities. This has proven to be fruitful in increasing average luminosity. In autumn octupole magnets will be installed. They will be used to control tune shift on amplitude in order to find the best compromise between increase of single bunch luminosity and suppression of transverse instability.

Long term plans foresee major hardware modifications: correction of wiggler nonlinearities by means of pole shimming, installation of a third harmonic RF cavity to increase bunch length [11], and therefore beam lifetime and realisation of a new IR for KLOE.

The new mechanical design of the KLOE IR foresees independent rotation of the three low-β quadrupoles between zero and the design angle, in order to allow machine operation with the KLOE solenoid turned off. The same scheme is used for the design of the IR for the FINUDA experiment, which is planned for IR2 after the conclusion of DEAR.

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