ELECTRON CLOUD BUILD-UP STUDY FOR DAΦNE[*]

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Abstract

After the first experimental observations compatible with the presence of the e-cloud effect in the DAΦNE positron ring, a more systematic study has been performed regarding the e-cloud build-up. The measured field map of the magnetic field has been taken into account in the simulation for elements present in the four 10 m long bending sections, representing 40% of the whole positron ring. The obtained simulation results are presented together with the recent experimental observations performed on the vacuum behaviour of the positron ring.

INTRODUCTION

DAΦNE is an electron-positron collider with 1.02 GeV centre of mass energy (Φ-factory) [1]. The collider consists of two symmetric main rings, 97 m long, lying in the same horizontal plane and sharing two Interaction Regions (IR). Two experiments can be installed in the IRs and run separately: three detectors have been realized so far, KLOE, DEAR and FINUDA. KLOE (IR1) and DEAR (IR2) have taken data until December 2002, while FINUDA has been installed in September 2003 in the IR previously occupied by DEAR (IR2) and took data until April 2004. Starting from May 2004 the KLOE experiment is running again. For each circulating beam the maximum design current value is 5 A over 120 bunches, at an average dynamic pressure of 1 nTorr; up to now the maximum achieved current value is 2.4 A for the electron beam (not physical but administrative limit) and 1.3 A for the positron one.

After the 2003 shutdown for the FINUDA detector installation, and some optics and hardware modifications, the appearance of a strong horizontal instability for the positron beam at a current I ~500 mA, triggered the study of the e-cloud effect in the DAΦNE collider. Until 2003 the presence of the e-cloud induced instability was not clearly evident, due to the fact that even in the case it existed, other limitations to the luminosity were much stronger such as for example the beam-beam effect, parasitic crossings and so on. Nevertheless some different behaviour between the positron and electron ring were observed: a larger positive tune shift induced by the positron beam current [2], a fast horizontal instability whose rise time cannot be explained only by the beam interaction with parasitic HOM or resistive walls [3]; finally the comparison of the observed behaviour of the vacuum pressure vs. the total current between the electron and positron ring seems to provide a clearer evidence for the presence of the e-cloud instability as reported in the following sections. A more systematic study of the electron cloud build-up was started including the DAΦNE wiggler field map in the simulation code. Furthermore the first results of a measurement programme of the relevant surface parameters for the DAΦNE vacuum chamber were adopted in the simulation. The obtained results are presented in this paper providing the input for a detailed instability study.

THE DAΦNE POSITRON RING

The Main Ring vacuum chamber is designed in such a way that most of the Synchrotron Radiation that is emitted in the four arcs is stopped in the antechambers by water-cooled copper absorbers. Each arc is a single-piece only vacuum chamber, about 10 m long, hosting two dipoles and a wiggler magnet, together with three quadrupoles and two sextupoles. The vacuum vessel inside the arc actually consists of two chambers connected through a narrow slot [4]. The beam circulates in the first chamber, while the synchrotron radiation photons hit a system of copper absorbers located in the second one (antechamber) in such a way that more than 95% of the photon flux is intercepted in the antechamber. The arc vessel is made by two halves of Al alloy 5083-H321 plates, which, after machining, are welded along the middle plane. The inner surface is mirror finished (roughness = 0.2 Ra). The straight sections were made by extrusion of the same aluminum alloy, with a round cross section of Ø=88 mm. Four splitter dipoles bend the

Table 1: DAΦNE parameter list for FINUDA and KLOE experiment configurations.

	KLOE 2002	FINUDA 2003	KLOE 2004
E (GeV)	.51		
h	120		
N_b	49	100	108
ε_x (μrad)	.74	.34	.34
κ	0.003	0.003	0.003
σ_z (mm rms)	15÷25	10÷25	10÷25
I_{tot} (A)	1.8/1.1	2.4/0.8	2.4/1.3
L_{peak} (cm^{-2}s^{-1})	0.8×10^{32}	0.6×10^{32}	1.4×10^{32}

electron and positron beams nearby the entry/exit of the two interaction regions; the splitter chambers, 1.5 m long, were machined from the same Al alloy, with normal finishing. For the KLOE and FINUDA detectors two beryllium alloy (ALBeMet) vacuum thin chambers are provided, 70 cm and 50 cm long respectively. The parameter list for the KLOE and FINUDA experiment configurations are reported in Table 1.

PRESSURE RISE WITH CURRENT

After the first indications of the e-cloud build-up in the positron ring a signature was looked for in the vacuum behaviour for the two beams. A closer monitoring of the residual pressure was performed and the gauge readings were recorded every 15 s by the DAΦNE control system and logged in the daily data sheet together with the main operating parameters such as beam current, luminosity, beam lifetime and so on. In both the electron and positron rings 14 Bayard Alpert vacuum gauges are located, one in each of the two interaction regions, one per arc, and one upstream and down stream of each arc respectively. Looking at the gauge readings and comparing the observed behaviour between the electron and positron ring some relevant differences are found as it is shown in Fig 1. In this figure the pressure readings are plotted as recorded from the gauges located in the straight sections in both the electron and positron ring. Looking at the plots over a whole day acquisition the positron beam exhibits a non-linear behaviour of the pressure together with a blow-up for definitely lower current values than those circulating in the electron ring. It has to be mentioned that a typical worsening of the effect was observed at each machine operation resuming even after a short stand-by period (typically one maintenance week). Nevertheless the vacuum recovery takes less than two days while a steady overall improvement due to beam conditioning is
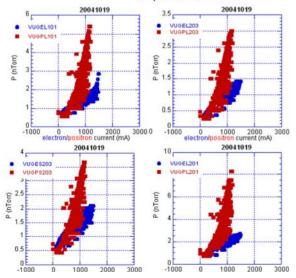

Figure 1: Vacuum pressure read-out vs. total current as recorded in four straight section locations for the electron (blue dots) and positron (red dots) rings.
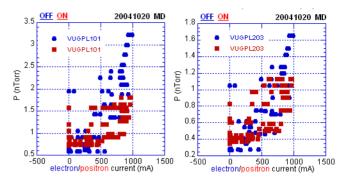

Figure 2: Vacuum pressure read-out vs. total current as recorded in 2 straight section of the positron ring where a 50 G solenoid field was turned on (red dots) and off (blue dots).

present. The pressure readings for the arcs are not reported due to the fact that in this case each vacuum gauge is located in the antechamber close to the pumping station, (Titanium Sublimation Pumps plus Sputter Ion Pumps), definitely far from the beam region. Later in the 2004 run, a small fraction of drift sections (about 2 m) were wrapped with a coil to provide a solenoid field of about $B_z \approx 50$ G. The vacuum pressure read-out is reported in Fig. 2 for the solenoid ON-OFF cases: quite a 50 % pressure burst reduction was locally obtained, but no remarkable effect showed up on the collider luminosity.

SIMULATION RESULTS

A more systematic study of the e-cloud build-up was started considering the stray and fringing magnetic field effect on the straight sections, including the magnetic field map in the wiggler simulation, and taking into account the recently measured surface parameters.

The wiggler magnetic field characterization was performed measuring the vertical magnetic field component B_y, over a 16x330 rectangular point matrix on the x-z plane [5]. Starting form the measured values a bi-cubic spline fit was performed with the help of the NAG FORTRAN subroutines, and the obtained coefficients were used for the field reconstruction. At the first order approximation the three components can be obtained from:

In Fig. 3 the field reconstruction result are reported

$$B_x = \frac{\partial B_{yo}(x,z)}{\partial x} y, \ Bz = \frac{\partial B_{yo}(x,z)}{\partial z} y,$$

$$B_y = B_{yo} - \frac{1}{2}\left(\frac{\partial^2 Byo(x,z)}{\partial x^2} + \frac{\partial^2 Byo(x,z)}{\partial z^2}\right)y^2.$$

showing the fit quality. The subroutine was included in the ECLOUD code [6] and the obtained e-cloud linear density is shown in Fig. 4 while in Table 2 the simulation parameters are reported. It has to be pointed out that in the case of wiggler the presence of the slot has been taken into account considering only the photons that hit the slot
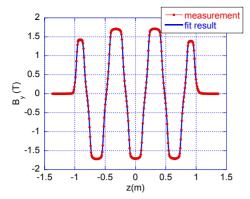
Figure 3: Wiggler magnetic field along the longitudinal axis as obtained from measurement (red dots) and fit reconstruction (blue line).

edges. The vacuum chamber photoelectron yield Y≈ .19 ÷

Table 2: Ecloud simulation parameter list

Bunch population	N_b	2.1×10^{10}
Number of bunches	n_b	100
Missing bunches	N_{gap}	20
Bunch spacing	L_{sep}	.8 m
rms bunch length	σ_z	18 mm
rms horizontal size	σ_x	1.1÷1.4 mm
rms vertical size	σ_y	0.05÷0.1 mm
Max sec. emission yield SEY	δ_{max}	1.9
Energy at max at SEY	ε_{max}	250 eV
Al eff. photoelectron yield	y_{eff}	0.2
Vac. chamber hor. aperture	$2 h_x$	88÷120 mm
Vac. chamber ver. aperture	$2 h_y$	20÷88 mm
Bending field	B	0÷1.7 T
Primary electron rate	$d\lambda_e/ds$	0.0088÷0.26
Photon reflectivity	R	50-60 %
elastic electron reflection	Cimino-Collins	

.2 and the reflectivity values have been obtained from the measurements performed by Mahne *et al.* [7] on an Al 5083-H321 sample with the same surface finishing as the actual vacuum chamber. The simulations for the drift sections, where most of the photons not intercepted by the arc slot hits the vacuum chamber wall, have also been performed adopting the measured parameters. The results are shown in Fig. 5 for three cases: simple drift, drift plus a moderate magnetic field of $B_y \approx$ .1 T, to take into account some residual fringing and stray field, finally drift with a solenoid of $B_z \approx$ 50 G.

CONCLUSIONS

After the first indications of the electron-cloud effect in the DAΦNE positron ring, more systematic measurement and simulation activity have started. A signature of the e-cloud build-up was found in the different vacuum behaviour of the electron and positron rings, as shown. The measured field-map for the wiggler magnetic field has been included in the simulation code, together with
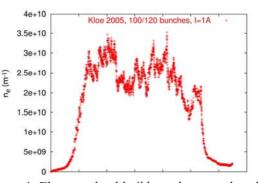

Figure 4: Electron cloud build-up along one bunch train for the wiggler. (Primary electron rate $d\lambda_e/ds$= 0.0088)
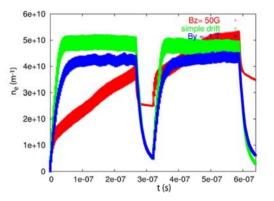

Figure 5: Electron cloud build-up along two bunch trains for the drift downstream of the arc: a) simple drift, b) drift with residual magnetic field of $B_y \approx$ .1 T, c) drift with a 50 G solenoid. (Primary electron rate $d\lambda_e/ds$= 0.26)

some DAΦNE surface parameters as come out from the measurements [7]. The simulation results, here shortly reported, show a significant value of the electron linear density for a beam current of $I_b \approx$ 1A. The study is underway in order to understand whether the obtained electron-cloud density can be related to the observed fast horizontal instability [3] and the large positive tune shift.

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