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$DA\Phi NE$ AND THE EXPERIMENTAL PROGRAM

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Abstract

The $DA\Phi NE$ ϕ-factory and the FINUDA and KLOE experiments are reviewed, and their status reported.

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1 Introduction

The e^+e^- collider facility, proposed in 1990 [1] and rapidly approved, it is now being built at the Laboratori Nazionali di Frascati of INFN. The $DA\Phi NE$ collider will operate at the center of mass energy of the ϕ meson with an initial luminosity $\mathcal{L} = 1.3 \times 10^{32} cm^{-2}s^{-1}$ and a target luminosity $\mathcal{L} = 5.2 \times 10^{32} cm^{-2}s^{-1}$.

The $\phi(1020)$[2] meson [$s\bar{s}$ quark assignment, mass $m = 1019.413 \pm 0.008\, MeV$, total width $\Gamma = 4.43 \pm 0.06\, MeV$, electronic width $\Gamma_{ee} = 1.37 \pm 0.05\, keV$, and $I^G(J^{PC}) = 0^-(1^{--})$ quantum numbers] is produced in e^+e^- collisions with a

$$\sigma(e^+e^- \rightarrow \phi) \sim 5\mu b$$

peak cross section, which translates into a production rate of

$$R_\phi = (5 \times 10^2 \rightarrow 2.0 \times 10^3)s^{-1}$$

from initial to target luminosity. The production cross section $\sigma(e^+e^- \rightarrow \phi)$ should be compared with the hadronic production, which, in this energy range and for $\beta \rightarrow 1$, is given by

$$\sigma(e^+e^- \rightarrow f\bar{f}) = \frac{4\pi\alpha^2}{3s} Q_f^2 = \frac{86.8 Q_f^2\, nb}{s[GeV^2]} = 83nb,$$

where Q_f is the charge of the fermion in units of the proton charge, i.e., with an integral S/N ratio of about 30:1.

The ϕ then decays at rest into K^+K^- (49%), $K_S^0K_L^0$ (34%), $\rho\pi$ (13%), $\pi^+\pi^-\pi^0$ (2.5%) and $\eta\gamma$ (1.3%). Therefore, a ϕ-factory is a unique source of monochromatic (110 and 127 MeV/c, respectively), collinear, quantum-defined and tagged neutral and charged kaons. Detecting one K out of the two produced in the ϕ decay determines the existence and direction of the other ("tagging").

Two experiments have been approved and are being built: FINUDA, for studying nuclear interactions of the kaons from the ϕ decay in a thin target; and KLOE, with the main aim of detecting CP violation in the K_SK_L system. These two lines of study have nothing in common but the exploitation of neutral and charged kaons produced in a unique environment. The description of $DA\Phi NE$ and its physics is very well-suited to the context of this Symposium.

2 DAΦNE

The $DA\Phi NE$ ϕ-factory machine [6][7][8] in construction at Frascati will make electrons and positrons to collide at the center-of-mass energy of the ϕ meson, with a phase I luminosity (begin 1997) of $\mathcal{L} = 1.3 \times 10^{32} cm^{-2}s^{-1}$ with at least 30 bunches, and a final design luminosity of $\mathcal{L} = 5.2 \times 10^{32} cm^{-2}s^{-1}$. To reach phase I luminosity itself is by no means a trivial task, since $1 \times 10^{31} cm^{-2}s^{-1}$ is the max routine luminosity ever attained at ϕ meson mass energy (VEPP-2M [9][10]), a one-order of magnitude improvement is necessary.

Table 1: $DA\Phi NE$ single-bunch collision parameters.

n bunches	120	ξ beam-beam tune shift	0.04
$\kappa \equiv \sigma_y/\sigma_x$ emitt. ratio	0.1	$< i_b >_{max}$ $[mA]$	43.7
σ_z $[m]$	0.03	E $[MeV]$	510
f_0 $[MHz]$	3.07	ϵ_{max} $[m][rad]$	10^{-6}
β_y $[m]$	0.045	$N_{max}/bunch$	8.9×10^{10}
θ_x $[mrad]$	$10\div 15$	U_0 $[keV]$ En. loss/turn	9.3

Under a number of simplifying assumptions [11], the luminosity $\mathcal{L}$ of a machine with two separate rings can be expressed as

$$\mathcal{L} = n\mathcal{L}_0,$$

where n is the number of bunches, and $\mathcal{L}_0$ is the single bunch luminosity given by the formula

$$\mathcal{L}_0 = \pi \left(\frac{\gamma}{r_e}\right)^2 f_0 \frac{\xi^2 \epsilon (1+\kappa)}{\beta_y} \tag{1}$$

where r_e is the classical electron radius, γ the beam particle energy in units of its rest mass, ξ the beam-beam tune shift parameter, κ the coupling factor, f_0 the revolution frequency, and ϵ the emittance. High luminosity $\mathcal{L}$ can be attained either by aiming at high $\mathcal{L}_0$ or by increasing the number of bunches n and keeping $\mathcal{L}_0$ relatively low. The strategy followed is to increase the number of bunches up to $n = 120$, while keeping the single-bunch parameters in eq. 1 quite conservative (table 1). The beam-beam tune shift parameter is, indeed, kept at a comfortable 0.04, which represents what has been achieved with the past and present colliders.

Increasing the number of bunches produces parasitic crossings outside the two interaction regions, which are circumvented by using two separate rings. In $DA\Phi NE$ the electron and positron rings are coplanar, and tangent in the two interaction regions.

The $DA\Phi NE$ complex is sketched in fig.1. $DA\Phi NE$ will be housed in the existing (formerly ADONE) buildings. Electrons and positrons are first accelerated by a linac, stored in an accumulator/damping ring, and finally injected through transfer lines into the main rings. A beam test area and a synchrotron radiation facility complete the accelerator complex.

The linac can deliver electron and positron beams at 50Hz. Manufactured by TITAN-BETA[12], it accelerates electrons to 800 MeV and positrons to 550 MeV. The linac was factory tested in August 1994, delivery was completed in January 1995, and it is now being assembled in Frascati. Full operation is expected to start in December. The beginning of linac operation is particularly interesting, since it will provide - by June 1996 - beams for the calibration of detector subcomponents in a dedicated test area.

The 32.56-m-long accumulator/damping ring stores at 50 Hz the particles in one RF bucket and also damps the transverse and longitudinal emittance of the linac beams. Ring assembly will start in September 1995, and commissioning is expected to begin in February 1996.

Figure 1: Layout of the $DA\Phi NE$ accelerator complex

Table 2: Beam particles lost by Touschek scattering.

Scraper aperture $[\sigma_x]$	Scraper aperture [mm]	Particles lost [part/(s bunch beam)]	Beam lifetime [min]
KLOE at IP=$\pm$ 43 mm			
9	25.0	0	161
10	27.8	7.5×10^3	184
∞	43.0	2.2×10^5	184
FINUDA at IP=$\pm$ 53 mm			
8	23.5	225	141
9	26.5	1.7×10^3	161
10	29.4	8.7×10^3	184
∞	43.0	1.0×10^5	184

Once inside $DA\Phi NE$'s main rings, electrons and positrons travel in two separated, coplanar storage rings, colliding at a half-angle of $\theta_x = 10-15\,mrad$ in two interaction points. The design is based on conventional technology, *albeit* pushed to technological challenges by the high-current requirement: the components allow operation at a maximum 5 A current. Each ring contains four normal-conducting wiggler magnets that increase the radiated energy and help tune the beam emittance. Delivery of all main ring magnets is expected within April 1996. Main-ring commissioning is expected to start in December 1996.

The two interaction regions will house the FINUDA and KLOE experiments. Both detector solenoids, with their $\sim 2.4\,T\,m$ integrated field, are a source of large perturbation to the beams. Therefore, three equivalent designs [13] for compensators have been developed to compensate for FINUDA, KLOE, and the so called 'day-one' configuration when the detectors have not yet been installed. Two pairs of permanent compact-size low-β quadrupoles and two pairs of conventional solenoids are used for FINUDA, while only permanent quadrupoles are used for the KLOE interaction region. The KLOE experiment requires (see §4) a spherical, large-aperture, Be vacuum chamber.

Particularly interesting from the experimental point of view are the control and limitation of machine background, as simulated in [14], and its connection with the machine lifetime. A scraper system allows one to reduce the rate of particles lost in the detector quadrupoles because of the Touschek effect and thus background such as beam particles showering in the quadrupoles. The number of beam particles lost per second per bunch per beam is shown in table 2 as a function of the scraper aperture in units of horizontal beam rms width, along with the beam lifetime. The rate is by no means negligible, since a fraction of the lost particles will interact inside the detectors and possibly overlap with triggered events. This was carefully studied by both FINUDA and KLOE, to make sure it only marginally affects event pattern recognition.