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A. Zallo:

TWO PHOTON PHYSICS AT DAΦNE

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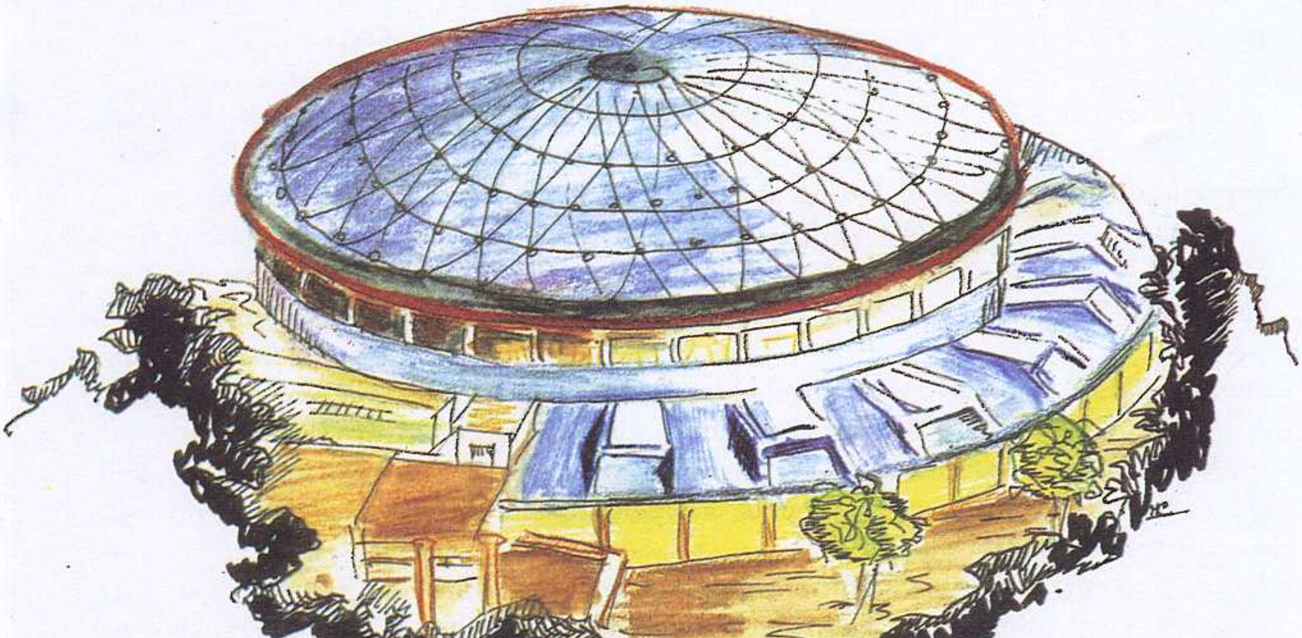

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TWO PHOTON PHYSICS AT DAΦNE

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Abstract

The $DA\Phi NE$ $\gamma\gamma$ physics program is reviewed.It is shown that although the phase space available at such machine is rather small, nevertheless it covers a region of great theoretical interest which gives the possibility to do very precise tests of Chiral Perturbation Theory.

1 Introduction

The $DA\Phi NE$ Φ factory is a e^+ e^- collider, with a target luminosity $\mathcal{L} = 1 \div 8 \cdot 10^{32} cm^{-2} s^{-1}$ at the $\phi(1020)$ production threshold [1].

The construction of this collider has started in January 1991; it is expected to be ready for the experimental activity at the end of 1995. The ϕ production cross section peaks at $\simeq 4.0 \mu b$. A one year data taking $(10^7 s)$ at a luminosity $\mathcal{L} = 1 \cdot 10^{33} cm^{-2} s^{-1}$ provides $\simeq 2 \cdot 10^{10}$ charged Kaon pairs, $\simeq 5 \cdot 10^8$ η and $\simeq 5 \cdot 10^7$ π^0 [2],[3].

In contrast to high energy e^+ e^- collisions the number of decay modes is low,the multiplicity of particles in the final state is small and also the particle species are limited.

The physics potential of a Φ factory has been recognized by many people and several proposals to build Φ factories have been considered[1],[2], [4], [5].

The main item is the study of CP violating phenomena. A measurement of the $Re(\frac{\epsilon'}{\epsilon})$ ratio with a total error $\Delta(Re(\frac{\epsilon'}{\epsilon})) \simeq 10^{-4}$ in 1-2 years running at $DA\Phi NE$'s luminosity seems to be possible.

CP violation does not exhaust the physics capabilities of a ϕ factory. Detailed studies of K mesons physics can be accomplished. Rare Kaon decays[3] with a $BR \simeq 10^{-6}$ are accessible to a ϕ factory, such as radiative decays $K \rightarrow \gamma\gamma, \pi\pi\gamma$, etc. Radiative ϕ decays are of big importance to clarify the problematic associated to $\eta - \eta'$ mixing, as well as to study scalar states such as $f_0(975)$, whose excessively small width has caused a bulk of hypotheses [6] ($K\bar{K}$ molecule, $q\bar{q}q\bar{q}$ states,gluon plasma).The $K_S K_L$ system offers also an ideal playground for the study of paradoxes concerning the foundations of Quantum Mechanics [7].

Finally the study of the low-energy processes $\gamma\gamma \rightarrow \pi\pi$ should provide an important testing ground for Chiral Perturbation Theory χPT[8].

Table 1: $DA\Phi NE$ design parameters at 510 Mev.

$L_0(cm^{-2}sec^{-1})$	4.510^{30}
ξ	.04
$\epsilon^{max}(m-rad)$	10^{-6}
κ	.01
$\beta_y(IP)(m)$	.045
$\beta_x(IP)(m)$	4.5
$N^{max}(particles/bunch)$	8.910^{10}
$h^{max}(N^{er} of bunches)$	120
$f_0(MHZ)$	3.17
$\sigma_x(IP)(mm)$	2.11
$\sigma_y(IP)(mm)$	0.021
$\sigma_z(IP)(m)$	0.03

2 The $DA\Phi NE$ machine

The $DA\Phi NE$ project foresees the construction of a two rings colliding beam Φ Factory and a 510 Mev e^+ e^- injector [1],[9].

The project has been approved and funded; the engineering design has started in January 1991;construction and commissioning is scheduled for the end of 1995.

The luminosity goals are $\mathcal{L} = 10^{32}cm^{-2}s^{-1}$ for the end of 1995 and a factor 10 higher for the end of 1996.

The design philosophy to achieve this goal has started from the experimental fact that the highest luminosity reached up to now at the ϕ energy,with flat beams and two interactions per turn, is $\mathcal{L} = 4.3 \cdot 10^{30}cm^{-2}s^{-1}$ obtained at VEPP-2M in Novosibirsk.Taking into account that

$$\mathcal{L} = h\mathcal{L}_0$$

($\mathcal{L}_0$ is the single bunch luminosity and h the number of bunches) ,the conservative approach has been chosen to construct a machine with many bunches since the increase of $\mathcal{L}_0$ requires the assumption of luminosities never achieved until now.

The choice of a low $\mathcal{L}_0$ should help in keeping the beam luminosity lifetime to a reasonable value (20 hrs). This solution forces to construct two separate rings in which electrons and positrons circulate in opposite directions and collide at a horizontal half angle θ_x=10 mrad.

The $DA\Phi NE$ design parameters are shown in Tab.1. Remembering that

$$\mathcal{L}_0 =\propto \frac{hf_0\xi^2\epsilon(1+\kappa)}{\beta_y}$$

(f_0 is the revolution frequency,β_y is the value of the vertical β function at the interaction point,ξ the linear tune shift parameter,ϵ the emittance and κ the coupling coefficient), we see that the $DA\Phi NE$ parameters are very similar to the VEPP-2M ones with the exception of f_0 , ϵ and the number of crossing.The beam-beam parameter ξ that enters quadratically in the luminosity formula has a value that is normally achieved in the e^+ e^- colliders. The value chosen for the emittance is very high and this implies a large physical and dynamical aperture of the lattice of the machine. Also the collision frequency has been pushed upward in order to gain luminosity. The very low β_y implies a small bunch length ($\sigma_z < \beta_y/1.5$);considering

Table 2: Pion electrical polarizability α

Process	$\alpha \times 10^4 (Fm^3)$
Theory (χPT)	2.7 ± 0.1
$\gamma\gamma \to \pi^+\pi^-$[10]	19.1 ± 4.80
$\gamma\gamma \to \pi^+\pi^-$[11]	17.2 ± 4.60
$\gamma\gamma \to \pi^+\pi^-$[12]	26.3 ± 7.40
$\gamma\gamma \to \pi^+\pi^-$[13]	2.2 ± 1.60
$\pi Z \to \pi Z\gamma$[15]	6.80 ± 1.40
$\gamma Z \to \pi Z$ [16]	20.0 ± 12.0

also the large values of h and f_0 this means that very high peak and absolute currents will circulate in the machine.

In conclusion the design of the machine is quite conservative for what concerns the optimization of the luminosity if we consider the single bunch luminosity; it is very demanding if we consider the necessity to maintain very high currents circulating in the rings. This requests a careful study of the multibunch instabilities that can be excited in the radio frequency cavities.

3 $\gamma\gamma$ Physics at low $M_{\pi\pi}$

The present data on $\gamma\gamma \to \pi\pi$ at low $M_{\pi\pi}$ are few,with large errors and contradictory. The total cross sections for

$$\gamma\gamma \to \pi^+\pi^-$$

from Pluto[10],DM1[11],DM2[12] disagree by a factor two the Mark-II[13] data and expectations from $\pi\pi$ phase shifts. The Mark-II data are in better agreement with Chiral perturbation theory (χPT).

The cross section of such processes can be parameterized in terms of the pion electric polarizability α[14] that measures the amount of electric dipole induced by an external electromagnetic field. In [14] the generalized polarizability function $\bar{\alpha}^*_\pi(s)$ has been introduced that in the limit of a vanishing center of mass energy $\sqrt{s}$ is reduced to the classical polarizability α. Data on the electric polarizabilities can be extracted also from $\pi\pi$ photoproduction interactions in the Coulomb field of the nucleus, by radiative scattering of pions in the Coulomb field [15] or in radiative pion photoproduction[16]. The available measurements of the pion electric polarizability α are contradictory as can be seen in Tab.2.

The most interesting channel is the production of a neutral pion pair, i.e. the study of the process

$$e^+e^- \to e^+e^-\pi^0\pi^0$$

In this channel the Born amplitude vanishes so the 1-loop contribution is finite and independent on the free parameters of the chiral lagrangian [17], [18].

In the threshold region ($\sqrt{s} \leq 0.5$ GeV), the Crystal Ball experiment yields results that are consistently higher than the χPT prediction [19]. This puzzling discrepancy could be reduced, within χPT, by calculating the 2-loop effects, which turn out to give a sizeable contribution to the cross-section in the threshold region [20].

Table 3: Events/year ($e^+e^- \rightarrow e^+e^-\pi\pi$)

Process	Number of events
$e^+e^- \longrightarrow \pi^0\pi^0$	1.4×10^4
$e^+e^- \longrightarrow \pi^+\pi^+$	1.8×10^6

The phase space available at $DA\Phi NE$ for the study of these processes ranges from the threshold to $\simeq 0.6\ Gev/c^2$. Although this range of phase space is rather small,nevertheless it covers the region of interest with high luminosity.In fact the events/year that can be collected at $\mathcal{L} = 5.0\ 10^{32} cm^{-2} s^{-1}$ (Tab.3[21]) should allow an improvement of almost an order of magnitude with respect to the Crystal Ball experiment [22].

For the process $\gamma\gamma \longrightarrow \pi^+\pi^-$ the cross-section is dominated by the Born amplitude and the contribution of the charged pion generalized polarizability is small (the Born contribution at *e. g.* $\sqrt{s} = 0.4$ GeV is 90% of the total cross section).So owing to the smallness of the correction the χPT corrections will be measured with no better accuracy than the $\pi^0\pi^0$ case [22].

4 Detection at $DA\Phi NE$ of the $\gamma\gamma$ processes

In order not to spoil the few % accuracy achievable in the measurement of $\bar{\alpha}^*_\pi(s)$ the detector must have fully acceptance,high efficiency in the detection of charged and neutral particles and high rejection power of the backgrounds. Simulations are in progress to see the improvements that should be applied to the recently proposed detector for $DA\Phi NE$ [23], expecially designed for the measurements of the CP violation processes.

KLOE is a standard general purpose collider's apparatus composed of a tracking device capable of some particle identification (through the cluster counting technique) and a lead-scintillating fibers electromagnetic calorimeter with very good measurement of the apex and time of the showers. These two detectors are inside a solenoid magnet at 0.6 Tesla. The main parameters of the tracking device and the electromagnetic calorimeter are summarized in Tab.4. Looking at this table it comes out that KLOE should be able to detect $\gamma\gamma$ processes with fully acceptance and very good efficiency.

The study of the background rejection is still on progress. For the process $e^+e^- \longrightarrow e^+e^-\pi^+\pi^-$ the main background comes from $e^+e^- \longrightarrow e^+e^-\mu^+\mu^-$ that has a cross section 20 times bigger. This background can be rejected using the cluster counting in the drift chamber and the difference in time of flight of the particles given by the electromagnetic calorimeter, taking advantage of the low momentum of the pions and of the large time base for the time of flight measurement. Work is in progress to get precise rejection factors.

For the neutral channel $e^+e^- \longrightarrow e^+e^-\pi^0\pi^0$ the main background at the ϕ energy comes from the process

$$e^+e^- \longrightarrow \phi \longrightarrow K_L K_S \longrightarrow K_L(undet.)\pi^0\pi^0$$

that has an effective cross section of $\simeq 100\ nb$ (assuming $\simeq 50\%$ for both the K_L probabilities to decay inside the detector and to interact in the electromagnetic calorimeter). This cross section is $\simeq 5 * 10^3$ times higher than the cross section of $e^+e^- \longrightarrow e^+e^-\pi^0\pi^0$; so a rejection factor of this order of magnitude is necessary. The KLOE electromagnetic calorimeter P_T resolution in the $\pi^0\pi^0$ plane comes out to be $\simeq 30 MeV/c$[24] and applying this cut to the background events, a rejection factor of only $\simeq 25$ has been obtained with a resolution in

Table 4: KLOE Detector parameters.

Tracking Chamber	
Radius	2 m
Length	4 m
$\sigma(r,\phi)$	200μ
$\sigma(z)$	4 mm
X_0	1400 m (Helium gas)
Number of layers	$\simeq 40$
acceptance	$\simeq 98$ %
Calorimeter	
$\sigma(apex)$	$\simeq 1\ cm$
$\sigma/E(Gev)*\sqrt(E(Gev))$	5%
σ_T	$87ps/\sqrt(E/1Gev)$
acceptance	$\simeq 98$ %

the $\pi^0\pi^0$ reconstructed invariant mass of $\simeq 50MeV/c^2$ [24];so we conclude that KLOE is unable to measure this process unless the outgoing leptons are detected.

It was pointed out at the 1991-Frascati workshop that at $DA\Phi NE$ energies tagging the electrons should not reduce too much the event rates [25] because the scattered electrons are produced at relatively large angles. In fact these angular distributions are peaked at $<\theta>\simeq m/E \simeq 1\ mrad$ (at PETRA/PEP they are peaked at $\simeq m/E \simeq 10^{-2}\ mrad$).

Limits on these acceptances are put by the magnetic structure of the quadrupole system and by the size of the split field magnet (the magnet that separates the e^+e^- primary beams). Study is under way to see the real possibility of the insertion of a tagging detector with high acceptance [26].

Finally as it was pointed out in [25] the tagging insertion opens the possibility to measure the outgoing electron azimuthal correlations.This study has never been done and could be used to test theoretical models [27].

5 Conclusions

Physics at $DA\Phi NE$ will start at the end of 1995 with as main physics item the measurement of $\frac{\epsilon'}{\epsilon}$. The measurement of $\gamma\gamma$ processes at threshold should allow the study of the loop structure of chiral lagrangian theories with much better accuracy; other tests of theoretical models could come from the study of azimuthal correlations.

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