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PHYSICS AT DAΦNE*

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The main physics items to be studied in the ϕ-factory DAΦNE under commissioning in Frascati are discussed. Experimental searches for CP violation, study of chiral structure of pseudoscalar and vector mesons, pion–pion phase shifts, hadronic e^+e^-cross-sections will be studied with the detector KLOE, nuclear physics with kaons will be investigated with the detector FINUDA, and formation of Kaonic atoms with the detector DEAR.

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1. Introduction

DAΦNE, Double Accelerator For Nice Experiments, presently under final commissioning in Frascati, is a high luminosity electron positron collider, which has been designed to operate at the ϕ-peak (E=1019 MeV) with a goal luminosity of 10^{33} cm^{-2}sec^{-1} and produce $\approx 10^{10}$ ϕ-mesons and more than 10^9 $K\bar{K}$ pairs per year. DAΦNE is a multibunch machine, with electrons and positrons circulating in two separate storage rings, colliding at a horizontal half angle $\Theta = 10 \div 15$ mrad in two interaction points. In the first phase the project effort will be concentrated to guarantee the accumulation of at least 30 bunches with luminosity per bunch $L_{\text{single bunch}} \approx 4 \times 10^{30}$cm^{-2}sec^{-1}, in the second phase the number of bunches will be increased up to a maximum of 120 bunches. In April 1998, there have been electron-positron collision, and the machine is expected to be soon in full operation. DAΦNE will have two interaction regions, which will be utilized by three detectors, namely KLOE for K Long Observation Experiment, FINUDA for nuclear physics experiments and DEAR for DAΦNE Exotic Atom Research. The high luminosity of the machine coupled to high resolution of the detector will

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allow for very precise measurements in K-meson physics, namely studies of CP-violation, rare K-decays, scalar, $f_0 - a_0$, and pseudoscalar meson spectroscopy through radiative ϕ-decays, vector meson spectroscopy and accurate measurements of $\sigma^{\rm had}_{e^+e^-}$, together with the study of KN-scattering near threshold, hypernuclei formation and decay, kaonic-atoms formation [1]. In Table I, we show the number of events expected at DAΦNE in some interesting ϕ-decays and which detector will make use of that particular final state.

TABLE I

ϕ-decays at DAΦNE with $\mathcal{L} = 5 \times 10^{32}\text{cm}^{-2}\text{sec}^{-1}$ from [2]

decay channel	branching ratio	events in 1 y	detector
K^+K^-	49%	1.1×10^{10}	KLOE FINUDA DEAR
$K^0_S K^0_L$	34%	7.5×10^9	KLOE
$\rho\pi + \pi^+\pi^-\pi^0$	16%	3.4×10^9	KLOE
$\eta + \gamma$	1.3 %	2.8×10^8	KLOE
$\eta' + \gamma$	1.2×10^{-4}		KLOE
$f_0\gamma$	$< 1 \times 10^{-4}$		KLOE

In the following sections, we shall briefly describe the main measurements which will be performed by the three detectors in the coming years.

2. High precision particle physics with KLOE

The main mission of the KLOE detector [3] has been from the very beginning the study of CP-violation in K-decays. Usually such measurements were done at hadron machines, where the higher cross-sections, of the order of millibarns, allowed for large statistics. At e^+e^-machines, the cross-sections are much smaller, but this can be compensated by the high luminosity, coupled with the low background when operating at a resonance. In addition, last, but not the least, the resonance being a special quantum state allows for tagged particle beams, $K_L - K_S$ or $K^0 - \bar{K}^0$, and the measurement can be thus become competitive.

The traditional classification of CP violation [4] in the neutral Kaon system distinguishes between CP-violation in the mixing matrix, the so called indirect CP-violation, and CP-violation in the decay amplitude, the so called direct CP-violation. The first is measured through the charge asymmetry in the semileptonic K_L decays, *i.e.*

$$\frac{\Gamma(K_L \to \pi^- l^+ \nu) - \Gamma(K_L \to \pi^+ l^- \nu)}{\Gamma(K_L \to \pi^- l^+ \nu) + \Gamma(K_L \to \pi^+ l^- \nu)} \approx 2\Re\,\varepsilon\,,$$

where ε is the amount of mixing in the mass matrix,

$$K_{S,L} \approx \frac{(1+\varepsilon)K \pm (1-\varepsilon)\bar{K}}{\sqrt{2}}\,,$$

while direct CP-violation could in principle be measured through

$$\frac{\Gamma(K \to \pi^+\pi^-) - \Gamma(\bar{K} \to \pi^+\pi^-)}{\Gamma(K \to \pi^+\pi^-) + \Gamma(\bar{K} \to \pi^+\pi^-)} \approx 2\Re\,\varepsilon'\,.$$

Actually, direct CP-violation is measured through processes in which there is interference between both mixing and decay. Defining

$$\eta_{+,-} = \frac{A(K_L \to \pi^+\pi^-)}{A(K_S \to \pi^+\pi^-)}\,, \quad \eta_{0,0} = \frac{A(K_L \to \pi^0\pi^0)}{A(K_S \to \pi^0\pi^0)}$$

and

$$\eta_{+,-} = \varepsilon + \varepsilon' \quad , \quad \eta_{0,0} = \varepsilon - 2\varepsilon'$$

direct CP-violation implies $\eta_{+,-} \neq \eta_{0,0}$ or $\varepsilon' \neq 0$ and a measurement of the double ratio

$$\left|\frac{\eta_{+,-}}{\eta_{0,0}}\right|^2 = 1 + 6\Re\,\frac{\varepsilon'}{\varepsilon}$$

can tell if there is CP-violation beyond the one in the mass matrix. The present knowledge, both theoretical and experimental, is summarized in Table II.

At DAΦNE a number of other measurements are planned to measure CP-violation, namely interferometry experiments [3, 11, 12] which measure the interference between decay into different final states with different decay times. Consider the decay of the ϕ:

$$\phi \to K\bar{K} \to (f_1, t_1) + (f_2, t_2)\,,$$

where (f_i, t_i) indicates that one of the two K-mesons has decayed into the state f_i after a time t_i and the other K into the other one. Given the relative ratio between the decays amplitudes $\eta_i = \frac{<f_i|K_L>}{<f_i|K_S>}$ one can measure the decay probability into (f_1, f_2) as a function of the time difference $\Delta t = t_1 - t_2$

TABLE II

ε'/ε Theory and experiment

Group	Theory $\Re\,\varepsilon'/\varepsilon \times 10^{-4}$	Experiment $\Re\,\varepsilon'/\varepsilon \times 10^{-4}$
A.J. Buras *et al.* [5]	$-1.2 \div 16.0$	
M. Ciuchini *et al.* [6]	$4.6 \pm 3.0 \pm 0.41$	
Bertolini *et al.* [7]	$1.7^{+1.4}_{-1.6}$	
E. Paschos *et al.* [8]	9.9 ± 4.1	
NA31 [9]		23 ± 7
E731 [10]		7.4 ± 5.9

measured through the distance crossed by the Kaons before decaying. The decay intensity is given by

$$\begin{aligned} I(f_1, f_2, \Delta t) &= \frac{1}{2\Gamma}|\langle f_1|K_S\rangle\langle f_2|K_S\rangle|^2 \times H \\ H &= \Big(|\eta_1|^2 \mathrm{e}^{-\Gamma_L \Delta t} + |\eta_2|^2 \mathrm{e}^{-\Gamma_S \Delta t} \\ &\quad -2|\eta_1||\eta_2|\mathrm{e}^{-\Gamma \Delta t/2}\cos\left(\Delta m \Delta t + \Delta\phi\right)\Big) \end{aligned}$$

with $\Gamma = \frac{\Gamma_L + \Gamma_S}{2}$ with obvious notation. A high precision measurement of this distribution allows for studies of the various Kaon-parameters like mass, phase differences, width and lifetimes. In particular, by properly choosing the final states (f_1, f_2) one can measure $\Re\,\varepsilon'/\varepsilon$ and $\Im\,\varepsilon'/\varepsilon$. In Fig. 1, we

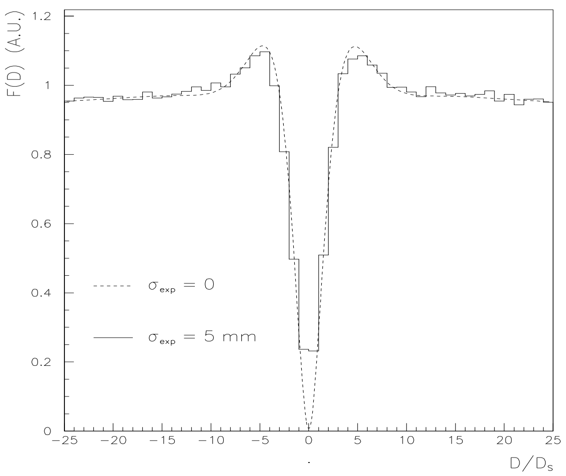

Fig. 1. Interference pattern for $f_1 = \pi^+\pi^-$ and $f_2 = \pi^0\pi^0$ from [12].

show one of the possible interference patterns: with $f_1 = \pi^+\pi^-, f_2 = \pi^0\pi^0$, the difference between $I(\Delta t)$ at large negative and positive Δt values, is proportional to $\Re\,\varepsilon'/\varepsilon$, whereas the width of the interference pattern around $\Delta t = 0$ is proportional to the imaginary part. At the design luminosity and with the expected characteristics of the KLOE detector, it is planned to obtain

$$\delta(\Re\,\varepsilon'/\varepsilon) = 1.8\times 10^{-4}\,, \qquad \delta(\Im\,\varepsilon'/\varepsilon) = 3.4\times 10^{-3}\,,$$

whereas with the method of the double ratio, the expected precision on $\Re\,\varepsilon'/\varepsilon$ can be further reduced to 1×10^{-4}.

In addition to CP and CPT physics, the detector KLOE can investigate an extensive array of other high precision measurements. In Table III we show the physics items which can be studied at DAΦNE in the various energy ranges.

TABLE III

The physics spectrum that can be explored by the e^+e^- DAΦNE collider in the next 10 years and physics results which can be expected. Estimates are based on a design luminosity of $5\times 10^{32}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$.

$\sqrt{s}$ in MeV	500÷1000	1020	1100÷ 1500
CP/CPT		ε'/ε	
K-decays precision		up to B.R. $10^{-8}\div 10^{-9}$	
η,η' physics		$\phi\to\eta,\eta'\gamma$	
$\pi\pi$ phase-shifts		$\phi\to K\bar{K}$ $K\to e\nu\pi\pi$	
Scalar and Pseudoscalar meson structure		$\phi\to a_0/f_0\gamma$ $\to\eta'\gamma\to(\rho,\omega)\gamma\gamma$	$\rho,\omega(1450)$ $\to(\eta,\eta',\eta^*)\gamma$
Light Vector mesons	VMD and ChPT refined	the $q\bar{q}$ content of ϕ,ω	
Higher Vector Mesons			decay width mass parameters
Scalar Glueballs		$\phi\to a_0/f_0\gamma$	
contribution to $(g-2)_\mu$	5% of the error the error (60%) comes from here	15%	

From Table I, we see that one expects to measure rare and very rare K-decays up to branching ratios of 10^{-9}, for which a comprehensive review can be found in [14]. Recently, in view of the observed $K^+ \to \pi^+ \nu\bar{\nu}$ event [13] at Brookhaven, it has been suggested [15] that DAΦNE and KLOE may have a chance to improve present experimental limits for the decay $K \to \pi^0 \nu\bar{\nu}$. Although there is no chance to positively observe this decay, whose B.R. in the Standard Model is a very small 3×10^{-11}, the special experimental conditions at DAΦNE and the characteristics of the detector may be able to exclude possible deviations from the Standard Model expectations.

As indicated in Table III, the high statistics expected at DAPHNE will allow very precise measurements of chiral dynamics in K-decays, in particular in connection with the semileptonic decays, K_{l3} and K_{l4} [16]. For the former, consider the decay channels

- $K^+(p) \to \pi^0(p')l^+(p_l)\nu_l(p_\nu) \quad [K^+_{l3}]$
- $K^0(p) \to \pi^-(p')l^+(p_l)\nu_l(p_\nu) \quad [K^0_{l3}]$

with matrix element [16]

$$T = \frac{G_F}{\sqrt{2}} V^*_{us} l^\mu F^{+,0}_\mu(p,p'), \qquad l^\mu = \bar{u}(p_\nu)\gamma^\mu(1-\gamma_5)v(p_l)$$

$$\text{and} \quad F^+_\mu = \tfrac{1}{\sqrt{2}}[(p+p')_\mu f_+^{K^+\pi^0} + (p-p')_\mu f_-^{K^+\pi^0}]\,,$$

$$F^0_\mu = \tfrac{1}{\sqrt{2}}[(p+p')_\mu f_+^{K^0\pi^-} + (p-p')_\mu f_-^{K^0\pi^-}]\,.$$

The four form factors $f_\pm^{K\pi}$, with $K\pi = K^+\pi^0$ or $K^0\pi^-$, contain the low energy dynamics of the decays, for which there exist predictions by Chiral Perturbation Theory (CHPT). In particular, the predictions for the so called vector form factor $f_+^{K\pi}$ are well in agreement with the experimental results whereas the situation is much confused for the scalar form factor, defined as

$$f_0^{k\pi}(t) = f_+^{K\pi}(t) + \frac{t}{M_K^2 - M_\pi^2} f_-^{K\pi}(t)\,.$$

The experimental analysis assumes a linear $t-$dependence of the form

$$f_{+,0}^{K\pi}(t) = f_+^{k\pi}(0)\left[1 + \lambda_{+,0}\frac{t}{M^2_{\pi^+}}\right]\,.$$

We show in figure 2 the status of the experimental situation compared with the theoretical predictions represented by the dashed band. The statistics of this measurement are dominated by the experiment by Donaldson [17] and can be remarbably improved by KLOE, as shown in Table IV from [16].

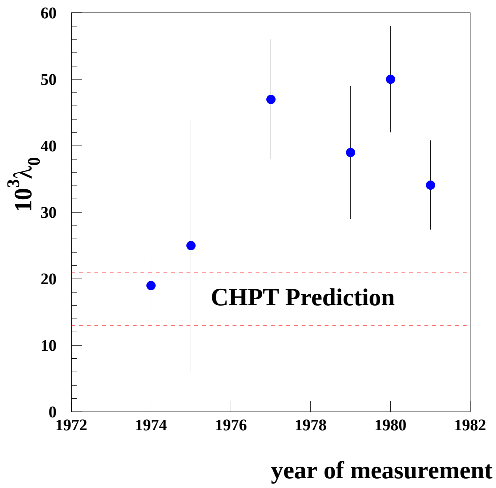

Fig. 2. History of determination of the slope of the scalar form factor in K_{l3} decays [16].

TABLE IV

Rates of K_{l3} decays. The number of events in the third column corresponds to those data which are of relevance for the determination of the slope λ_0 of the scalar form factor.

		♯ events		
	branching ratio	Particle Data Group	DAΦNE 1 year	improve-ment
$K^+ \to \pi^0\mu^+\nu_\mu$	$3.18 \cdot 10^{-2}$	10^5	$3 \cdot 10^8$	$3 \cdot 10^3$
$K_L \to \pi^\pm\mu^\mp\nu$	$27 \cdot 10^{-2}$	$4 \cdot 10^6$	$3 \cdot 10^8$	70

In addition to the possibility of clarifying the situation for the slope of the scalar form factor, the high statistics provided by DAΦNE should also help to investigate the possible existence of other than V-A interaction in the Lagrangian, notably scalar and tensor couplings. This can also be studied through the radiative K_{l2} decays, but in general higher order terms in the chiral expansion must be looked into before drawing any firm conclusions from the data. The measurement of the K_{l3} form factors will be one of the first to be performed by the KLOE detector and it is expected that already in the first three months of running one should be able to improve the present statistics.

Another interesting decay which can shed light on chiral dynamics and its loop structure is K_{l4} decays. Consider the decays

$$\begin{aligned} K^+ &\rightarrow \pi^+\pi^- l^+\nu_l \\ K^+ &\rightarrow \pi^0\pi^0 l^+\nu_l \\ K^0 &\rightarrow \pi^0\pi^- l^+\nu_l \end{aligned}$$

and their charge conjugate modes, with the letter l indicating either a muon or an electron. These processes will provide a measurement of $\pi\pi$ phaseshifts at threshold and hence of the pion–pion scattering length. Predictions from chiral perturbation theory up to the two loop contribution [18,19] are shown in figure 3. This figure uses the same inputs as the chiral perturbation

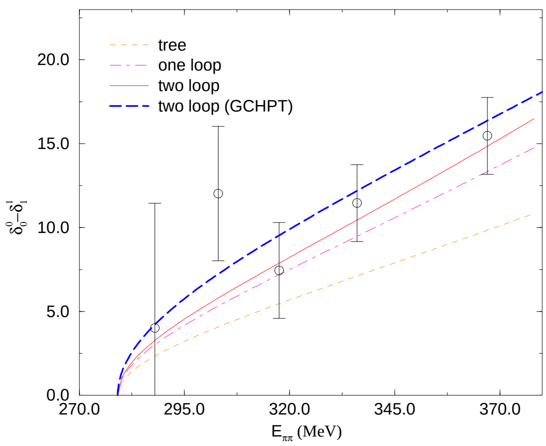

Fig. 3. Predictions for $\pi\pi$ phaseshifts in the threshold region from different theoretical calculations in Chiral Perturbation Theory in comparison with existing experimental data [20].

predictions for the S-wave $I = 0$ scattering length which up to two loops give $a_0^0 = 0.217$. It should be noted that K_{l4} decays are not the sole source of information on a_0^0 at DAΦNE : this information can also be extracted from the scattering $\gamma\gamma \rightarrow \pi^0\pi^0$ at threshold, for which we show in Fig. 4 various theoretical predictions [21, 22] in comparison with existing data [23]. At present there is no specific experiment planned to measure this process, but feasibility studies [24] indicate that DAΦNE could provide enough luminosity for a precision measurement of this process.

The figures discussed so far indicate the type of information concerning chiral perturbation theory predictions which one would like to obtain from

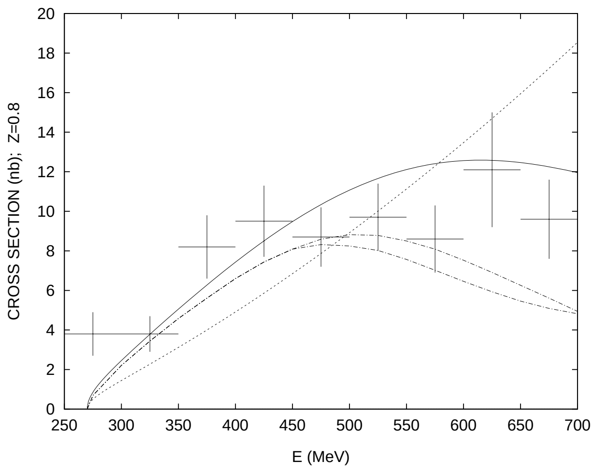

Fig. 4. The $\gamma\gamma \to \pi^0\pi^0$ cross-section ($|\cos\theta| \leq 0.8$) as a function of the c.m. energy E together with the data from the Crystal Ball Collaboration. The solid line is the full two-loop result [21] and the dashed line results from the one loop calculation. The band denoted by the dash-dotted lines is the result of the dispersive calculation by Morgan and Pennington [22].

DAΦNE. In addition, K-decays offer the possibility of a systematic study of the various constants appearing in the chiral Lagrangian and Ref. [1] contains an extensive discussion to which we refer the interested reader.

We shall now turn to a different type of high precision experiments, *i.e.* the measurement of the total hadronic cross-section where DAΦNE could significantly contribute to high precision tests of the Standard model, through a reduction of the present error on the determination of $\alpha(M_Z)$ and $(g-2)_\mu$. A serious problem for such tests is the fact that the low energy contribution of the light quarks cannot be reliably calculated using perturbative QCD. At the same time, the newly proposed Brookhaven experiment [25] expects to significantly reduce the error on $(g-2)_\mu$, thus opening up a whole new window in non standard model physics, provided one can reduce the uncertainties related to the hadronic contribution. We show in Table V the status of the present and planned experiments.

The theoretical situation is as follows [27–29] :

$$a_\mu^{\rm th} = \overbrace{116\ 584\ 706 \pm 2}^{a_\mu^{\rm QED}} + \overbrace{154 \pm 4}^{a_\mu^{\rm Weak}} + \overbrace{6882 \pm 154}^{a_\mu^{\rm had}} = \overbrace{116\ 591\ 742 \pm 154}^{\rm total},$$

TABLE V

Status of $(g-2)_\mu$ measurements. For E821 only the expected experimental error is given.

Laboratory	$a_\mu^{\rm EXP} \simeq (\frac{g-2}{2})_\mu$	precision	year
	$(1\ 162 \pm 5) \times 10^{-6}$	4300 ppm	1960
CERN [26]	$(116\ 616 \pm 31) \times 10^{-8}$	270 ppm	1970
	$(1\ 165\ 924 \pm 8.5) \times 10^{-9}$	7.3 ppm	1979
E821 at BNL [25]	$(\pm 0.45) \times 10^{-9}$	< 1 ppm	≥ 1998

where the numbers are in units of 10^{-11}. The contribution from QED has been calculated up to terms of order $(\alpha/\pi)^5$ [27, 30], that to $a_\mu^{\rm Weak}$ comes from W, Z and Higgs contributions and includes the two loop evaluation [29]. This is the term which is sensitive to new physics and which is potentially accessible by the next generation of planned experiments at Brookhaven. Apart from the fact that the two loop calculation gets contribution from light quark masse insertion which have substantial uncertainties, nothing can be said about this term until the error coming from $a_\mu^{\rm had}$, which is as large as the entire electroweak contribution, has been reduced. The overall hadronic contribution is given by

$$a_\mu^{\rm had} = a_\mu^{\rm vac-pol} + a_\mu^{l-l}\,, \tag{2.1}$$

where to the leading order $a_\mu^{\rm vac-pol}$ corresponds to the first of the graphs shown in figure 5, and a_μ^{l-l} to graphs, like the other three, which include light-by-light terms. Numerically the largest term, from whence there arises the main contribution to the error, comes from $a_\mu^{\rm vac-pol}$ and therefore all the efforts should be directed to reduce the error on the calculation of this term. Presently, the theoretical calculations for the leading order contribution are based on the expression

$$a_\mu^{\rm vac-pol} = \frac{1}{4\pi^3}\int_{4m_\pi^2}^{\infty} \sigma_{e^+e^-\to{\rm hadrons}}(s)K(s)ds\,, \tag{2.2}$$

where $K(s)$ is an energy dependent function strongly peaked towards small s-values. The most recent evaluation [28] of this integral using the measured hadronic cross-section from $e^+\ e^-$ has confirmed that the region below 1GeV contributes as much as 60% of the total error on $a_\mu^{\rm had}$. At DAΦNE an energy scan in the region between threshold and the ϕ resonance could easily reduce the statistical error on this cross-section [31], and hence on

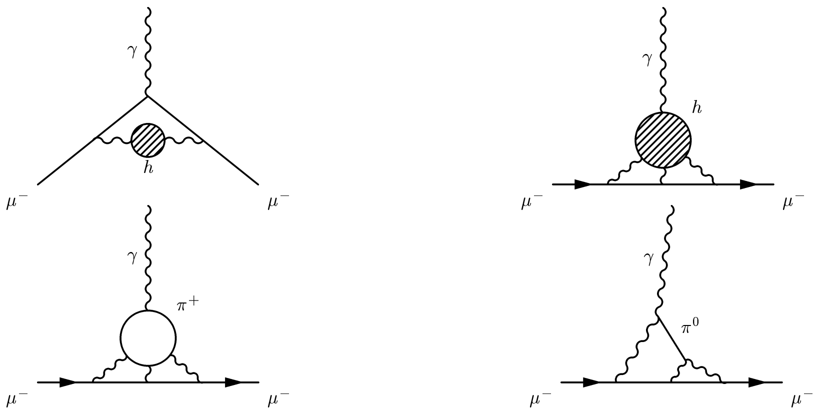

Fig. 5. Some of the hadronic contributions to $(g-2)_\mu$

$a_\mu^{\rm had}$, to the accuracy necessary to measure electroweak effects, provided that the radiative corrections and the remaining contribution from light-by-light graphs be kept under control. If, as it now appears likely, DAΦNE will operate at the ϕ peak for a substantial period of time, an energy scan in the region between the two pion threshold and below the ϕ-mass may not be coming soon. Recently, an alternative method has been proposed [32] in which, by triggering on Initial State Bremstrahlung, the e^+e^- cross-section into hadrons in this region could be measured through the processes shown in figure 6 *i.e.*, through the process

$$e^+(p_1)e^-(p_2) \to \gamma(k) + \quad \gamma* \to \gamma(k) \quad + \text{hadrons} \quad (p_1+p_2)^2 = M_\phi^2 \qquad (2.3)$$

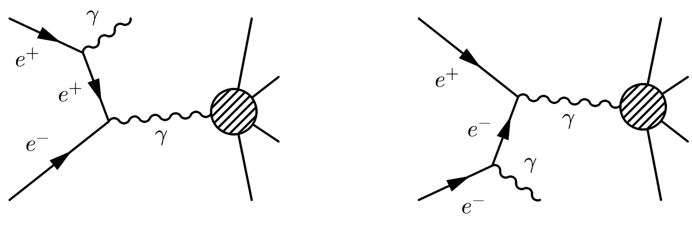

Fig. 6. Processes contributing to the measurement of the hadronic e^+e^- cross-section according to the method of Ref. [32].

with the photon emitted through initial state bremstrahlung and the hadrons coming through the subprocess $e^+e^- \rightarrow \gamma* \rightarrow$ hadrons. The relation between the above process and the fraction of hadronic contribution to $(g-2)_\mu$ from the vacuum polarization graphs in this energy region, is given by

$$a_\mu^h = \frac{M_\phi^2}{\pi} \int_{k_{\rm min}}^{k_{\rm max}} dk \frac{K(s(k))}{H(k, M_\phi^2, \theta_{\rm min})} \frac{d\sigma(k)}{dk}\,, \qquad (2.4)$$

where $d\sigma(k)/dk$ is the cross-section for the process (2.3), the function $K(s(k))$ is the function of Eq. (2.2) with $s = M_\phi^2 - 2kM_\phi$ and $H(k, M_\phi^2, \theta_{\rm min})$ is the radiative factor for emission of a photon of energy k at all angles larger than $\theta_{\rm min}$ relative to the beam direction. This differential cross-section is shown in figure 7 and is large enough to give a statistical error of 0.01810^{-9} in 3 months running time at a luminosity of $3 \times 10^{32}\text{cm}^{-2}\text{sec}^{-1}$. An initial evaluation of the possible background process indicates that the measurement as described is feasible and can give the desired precision, but more work is in progress. Before turning away from this argument, one should mention that, by measuring the total hadronic cross-section into e^+e^-, DAΦNE can help to reduce the error on $a_\mu^{\rm had}$ but also on α_{QED} although the contribution to a better precision on this quantity is only of a few percent.

Finally, scalar, pesudoscalar and vector meson spectroscopy will also be studied with great precision at DAΦNE . In particular, the large statistics should allow a precise determination of radiative ϕ-decays into scalar mesons and solve some puzzling questions about their nature. In a later phase, when

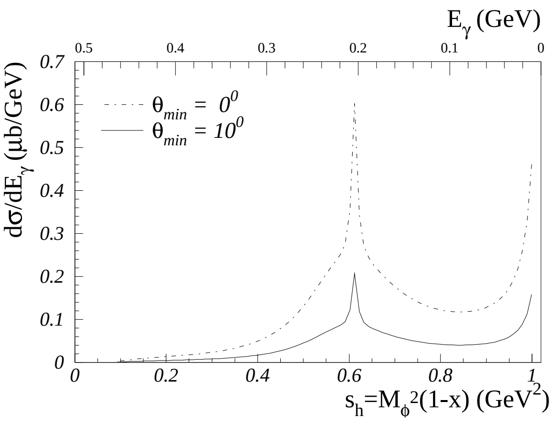

Fig. 7. Differential cross-section for the process Eq. (2.3). The energy scale of the photon is also shown [32]

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DAΦNE will operate at higher energies, vector meson recurrences and higher pseudoscalars will also be investigated.

3. Nuclear physics with kaons with FINUDA

Our present knowledge on hypernuclei is limited and cannot be compared with the one available on conventional nuclei ($S = 0$), yet it has already provided and can further provide important clues on nuclear structure; most importantly [34] it has much broadened the concept of nuclear physics itself.

FINUDA, FIsica NUcleare a DAΦNE, is a nuclear physics detector which will occupy the second interaction region at DAΦNE and will perform a unique hypernuclear physics experiment in ideal conditions [35]. At DAΦNE the large flux of slow K^- produced from ϕ decay, can be stopped in a nuclear target and undergo nuclear capture, forming hypernuclei whose formation and decay can be studied with very high precision. The main advantages with respect to the conventional beams rely on the monochromaticity of the Kaon-beam, the lack of hadronic background, the reduced straggling in the target due to the low energy of the Kaons and the possibility of tagging through the K^+. These advantages are summarized in Table VI. The detector FINUDA will study the reaction

$$K^-_{\rm stop} + ^A X_Z \to ^A_\Lambda X_Z + \pi^- \quad (250 \text{ MeV}/c \le p_\pi \le 280 \text{ MeV}/c) \qquad (3.1)$$

which combines the advantages of the two traditional processes of strangeness exchange and associated production reaction, *i.e.* $K^- + n \to \Lambda + \pi^-$ and $\pi^+ + n \to \Lambda + K^+$, with good intensity and quality of the Kaon beams coupled to a moderately, non-zero, momentum transfer to the produced Λ

TABLE VI

Hypernuclei at DAΦNE with respect to extracted Kaon beam

Low Momentum K^- (127 MeV/c)	Medium-high momentum K^- (500-600 MeV/c)
Monochromatic and background free K^-	Non-monochromatic K^- and not clean beam (π^- contamination)
Thin target (0.3 g cm^{-2}) Large acceptance detector (typical at a collider)	Thick target (several g cm^{-2}) Small acceptance (typical of fixed target)
Tagging capability with K^+	No tagging possible with K^+
Study of hypernuclei decay feasible	Study of hypernuclei decay not easy

particle, and a moderately high hypernuclear final state production rate. The latter is estimate to be $\approx 10^{-3}$ per stopped K^-.

The topics which can be studied with FINUDA can be summarized as follows:

- High resolution Λ-hypernuclei spectroscopy ($\Delta E \leq 700$ KeV)
- Λ-hypernuclei lifetime studies
- Studies of hypernuclei decays and possible violation of the $\Delta I = 1/2$ rule
- Production of hyperfragments through two-body decays
- Production of Λ-hypernuclei with a large neutron excess
- Study of K-N scattering at low energies
- Measurement of the $K_{\mu 2}$ decay
- Search for π^+ decay mode of hypernuclei.

4. The K-N interaction from kaonic hydrogen and deuterium transitions

According to Dalitz [36], "the most important experiment to be carried out in low energy K-meson physics today is the definitive determination of the energy level shifts in the K^-p and K^-d atoms, because of their direct connection with the physics of KN interactions and their complete independence from all other kinds of measurements which bear on thess interactions". The DAΦNE Exotic Atoms Research (DEAR) experiment, is an international collaboration [37] whose objective is the determination of the isospin dependent $\bar{K}N$ scattering lengths through a 1% measurement of the K_α line shifts, due to strong interactions, in kaonic hydrogen and kaonic deuterium. The strong interaction causes a shift of the lowest atomic level, whilst the absorption reduces the lifetime of the state. Precise measurements of the X-ray energy spectrum then allow to determine the energy shift ε and the width Γ associated with this final level. The energy shift ε and the width Γ in the $1s$ level in kaonic hydrogen can be related in fairly model independent way to the complex S-wave K^-p scattering length a_{K^-p} through the Deser–Trueman formula

$$\varepsilon + i\frac{\Gamma}{2} = 2\alpha^3\mu^2 a_{K^-p} = 412 a_{K^-p}\ \mathrm{eV/fm}\,, \tag{4.1}$$

where μ is the reduced mass and α the fine structure constant.

It follows that both ε and Γ can be obtained directly from X-ray measurements, or through the scattering length measured in low energy Kaon nucleon scattering experiments. This determination should bring about

- an understanding of SU(3) chiral symmetry breaking, through the determination of the KN sigma term. As in the case of the πN sigma term, one could eventually extract this quantity from accurate threshold KN scattering data. At present this not possible and only estimates of the KN sigma term are available until now;

- a measurement of the strangeness content of the nucleon since the KN sigma term is a sensitive and direct measurement of the strange-sea, unpolarized quark component in the nucleon at rest.

The principle of the DEAR experiment is very simple: kaons from the low momentum, monochromatic, high purity "Kaon beam" from the ϕ's produced in DAΦNE leave the beam pipe through a thin window, are degraded in energy down to a few MeV, enter a pressurized, low temperature, gaseous hydrogen target placed few centimetres above the pipe and are stopped there. A fraction of kaons is captured in an outer orbit of the hydrogen atom, thus forming an exotic atom. The kaon then cascades down through its own series of bound atomic states until it reaches a level where the short-range strong interaction acts on the particle, causing its absorption.

5. Conclusions

In the next few months, the ϕ-factory DAΦNE will start operating at the INFN facility in Frascati. In this talk, an overview of the physicsE821 results expected from the three detectors which will operate at DAΦNE has been presented, with special emphasis on results on ε'/ε , rare Kaon-decays, chiral dynamics and high precision tests of the Standard Model. The new determination of the direct CP-violation parameters from Frascati, together with the other new results expected from CERN [38] and FNAL [39], promise to give further insight into our understanding of CP-violation. Kaon decays will be studied to greater accuracy and the loop structure of Chiral Perturbation Theory will be tested through the measurement of a number of fundamental quantities, like the pion–pion scattering length, which can be measured with high precision from K_{l4} decays. The possibility that DAΦNE can contribute to high precision tests of the Standard Model through accurate measurement of the electron–positron hadronic cross-section and the consequent reduction of the theoretical error on the muon anomalous magnetic moment, has been discussed in connection with a recent proposal to use Initial State Bremstrahlung for the energy scan. Radiative ϕ decays, vector meson spectroscopy and two photon physics, although not explicitly described in this talk, are also expected to significantly contribute to our knowledge of elementary particle physics in this region.

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