INFN - Laboratori Nazionali di Frascati
Servizio Documentazione

LNF-91/034 (R)
17 Giugno 1991

PHYSICS ITEMS, DIFFERENT FROM ε'/ε, AT A Φ FACTORY

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ABSTRACT

Some physics items, different from ε'/ε, are briefly summarized with some emphasis on the experimental point of view, as they have been presented at this workshop. Namely: structure functions of weak and e.m. Kaon decays, radiative Φ decays into scalar and pseudoscalar mesons, spectroscopy of excited vector mesons, $\gamma\gamma$ interactions, Kaon-Nucleon and Kaon-Nucleus interactions at very low energies, hypernuclei formation with stopped Kaons, measurement of the hadronic contribution to the muon anomalous magnetic moment.

One of the purposes of this workshop was to look for and to develop other physics items to be studied at DAΦNE, different from ε'/ε, which remains the most important one. Some of these very interesting items are listed below:

- Structure functions of weak and e.m. Kaon decays, still unknown or contradictory, like in $K \rightarrow \pi\, \mu\, \nu$;
- Radiative ϕ decays into scalar and pseudoscalar mesons, to understand their still unknown nature and to produce also a relevant number of η' s;
- Spectroscopy of excited vector mesons, since the ϕ factory design allows for energies higher than the ϕ mass;
- $\gamma\gamma \rightarrow \pi\pi$ at threshold, predicted by the theory and badly measured at present;
- Kaon - Nucleon, Kaon - Nucleus interactions at very low energies, also badly measured and puzzling;
- High quality hypernuclei spectroscopy with stopped Kaons ;
- High precision measurement of the total annihilation cross section, to measure with better accuracy the hadronic contribution to the muon anomalous magnetic moment.

It is very likely that many of these open questions will be still unanswered and still topical when DAΦNE is operating. It is already a good start for their measurement if their requirements on the storage ring and the detector designs have been focused on. However their development was not fulfilled enough in this workshop and much more work is needed.

In the following these items will be shortly summarized with some emphasis on the experimental point of view.

Concerning open questions about the Kaon structure functions, very striking examples are the structure functions of the very large Kμ3 decay (as shown by J.Gasser(1)) , which are considered partially unknown even in the by now classical Okun book(2). Actually there is a prediction from the chiral perturbation theory(1), which is in agreement with the oldest high statistics measurement(3). Anyway more recent measurements disagree (see Fig. 1), refuting also the classical Callan-Treiman relation(2). This disagreement has been observed either looking at the Dalitz plot distribution(4) and looking at the muon polarization(5).

DAΦNE detectors should be able to measure such a structure function, since they are supposed to measure a small effect like ε'/ε. If the e.m. calorimeter is a tracking one also the muon polarization will likely be detected. Anyhow this is a hope, because there were no contributions on this subject in this workshop.

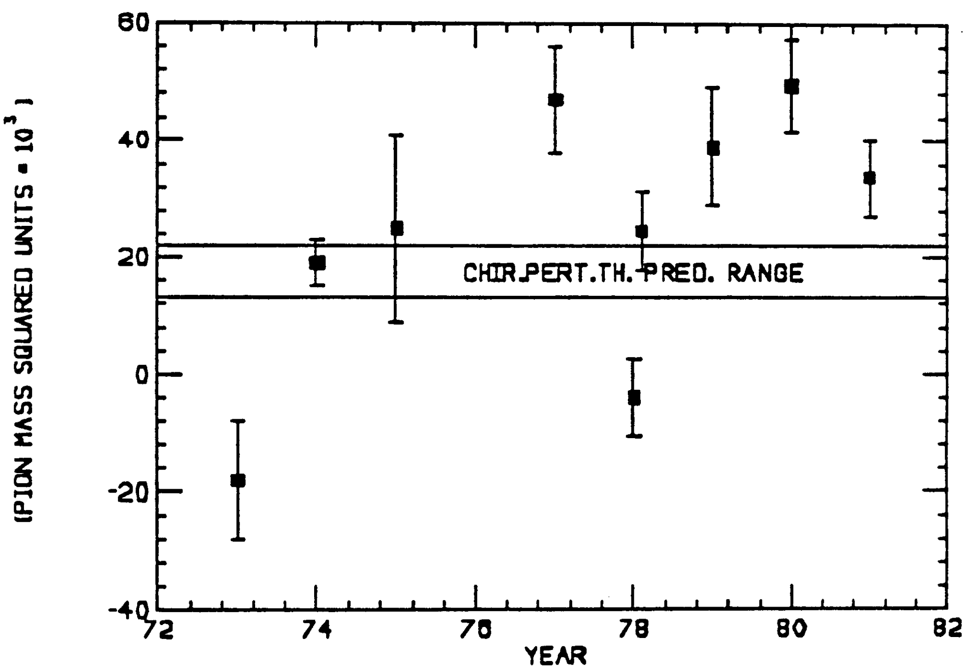

FIG. 1 - A compilation by Gasser of the measurements of the λ_0 parameter of the structure functions of $K \rightarrow \pi \mu \nu$, as a function of the year.

A ϕ-factory may be a very interesting tool also from the point of view of the hadron spectroscopy(6). The main search in hadron spectroscopy today is for states beyond $Q\bar{Q}$. However at present, in spite of many experimental candidates and theoretical suggestions, there are no definite evidences for states beyond $Q\bar{Q}$.

The ϕ radiative decays have unique features for that: the ϕ is a narrow $s\bar{s}$ state and the photon couples to the constituents even at low energies, as F. Close pointed out[6].

Puzzling scalar mesons exist just below the ϕ mass[7] (A_0 (980) and f_0 (970)) decaying into $\pi^\circ\eta$, $\pi\pi$ and $K\bar{K}$! Various convincing arguments suggest that these mesons in the end are not $Q\bar{Q}$ states, namely being $QQ\bar{Q}\bar{Q}$ states or $K\bar{K}$ molecules[8]. The main arguments for $K\bar{K}$ molecules are the masses, so near the $K\bar{K}$ threshold, the anomalously small widths and the degeneracy between the two different isospin states. However this interpretation is still controversial: for instance in this workshop[9] M. Pennington has presented an analysis, rather model independent, which is against it. In fact the poles structure should be different in the molecular hypothesis, but the various invariant mass distributions agree with Breit-Wigner behaviours. No matter how these states are certainly related to the strange quark (see Fig. 2) and qualitative arguments suggest that the ϕ radiative decay into them, being an electric dipole transition, should be much larger if they are multiquarks states[10].

At present there are only upper limits, but their detection should not be a hard task already at VEPP2M with CMD2, as J. Thompson pointed out[11], or at DAΦNE as a first measurement with CUSB , according to the proposal by J. Lee–Franzini[12]. By the way the radiative photon is in a suitable range for a detector optimized for CP violation.

The measurement of the radiative decays into $K\bar{K}$ is also important perse. In fact $\phi \rightarrow \gamma K_S K_S$ may be a background to the CP violation search in $\phi \rightarrow K_S K_L$ in the interference region. However such a background may be evaluated measuring $\phi \rightarrow \gamma K_L K_L$, which should be an easy task too.

Radiative decays into pseudoscalar mesons ($\phi \rightarrow \gamma\eta$ and $\phi \rightarrow \gamma\eta'$) are interesting to remeasure[6] the glue content of the η'. The η' is still a puzzling meson: for example it is a quite heavy meson and its width is 20 times smaller than the Φ, but no OZI rule has been invented for the η'.

Radiative decays into pseudoscalar mesons are also interesting to use DAΦNE as a suitable η factory. In fact at full luminosity it should be possible to produce~ 10^6 η per day. Actually B. Mayer has shown[13] that at Saclay an overwhelming number of η's are produced: 10^{10} η per day through $pd \rightarrow He_3\ \eta$, if there are 10^{12} proton per second. However there are some drawbacks: Saturne is not a dedicated accelerator and their apparatus has a few percent detection efficiency, detecting at present mostly $\eta \rightarrow \mu$ X. Therefore DAΦNE may be complementary to the η–factory at Saclay.

An interesting forbidden decay is $\eta \rightarrow 2\pi$, as L. Oliver pointed out[14], but background coming from ρ production and decay cannot be avoided. Still a good detector for neutrals as foreseen in DAΦNE may avoid this background looking for $\eta \rightarrow \pi^\circ\pi^\circ$ events.

DAΦNE is provided to achieve higher c.m. energies than the ϕ mass, probably 1.5 GeV already in the design optimized at the ϕ mass[15] . The pattern of the excited vector mesons is still puzzling and DAΦNE will be the only machine in the next future which may elucidate such a situation. For instance evidences for an exotic vector meson, C(1480) $\rightarrow \phi\ \pi^\circ$, has been presented in this workshop by D.G. Landsberg[16]. A detector suitable to detect ϕ decays should detect also these events.

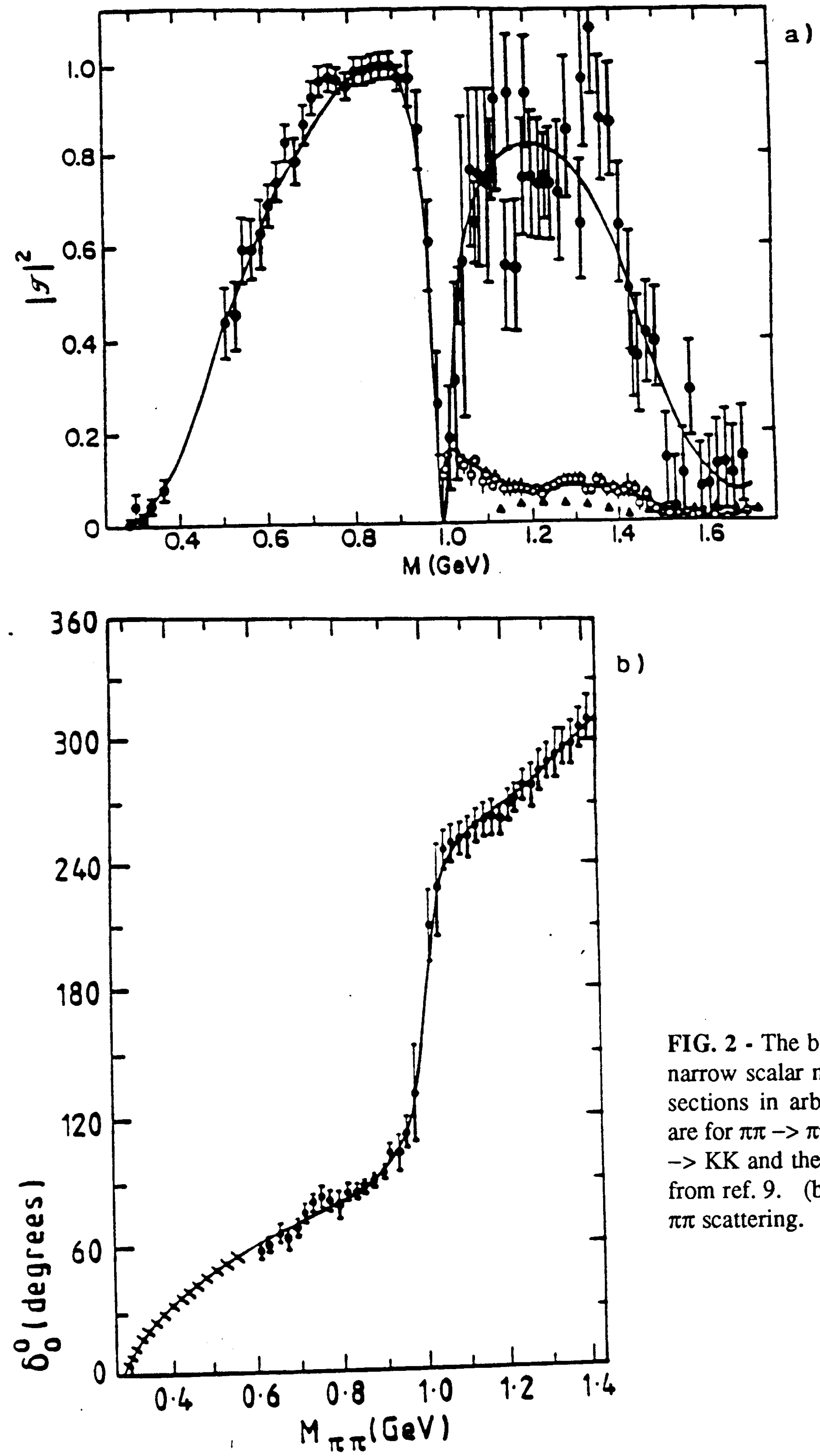

FIG. 2 - The best evidence at present for a narrow scalar meson, (a) I=0 S-wave cross sections in arbitrary units. The solid dots are for ππ -> ππ, the open circles are for ππ -> KK and the triangles are for ππ -> ηη, from ref. 9. (b) I=0 S-wave phase-shift for ππ scattering.

Of course a higher c.m. maximum energy, say 1.7 GeV, would be more convenient. In this case all the candidates we know at present [17] (ρ'(1250), ρ'(1450), ρ'(1700), ϕ(1650), ω'), would be accessible (see Fig. 3) and many tests could be done, as proposed by Y. Simonov,[18] A.Badalyan[19], K. Kalashnikova[20], P.E. Volkovisky[21] and A. Kudryatseev[22]. For example at present there are only circumstantial evidences to interpret the old ρ"(1600) as a superposition of two resonances and much more data are needed. In any case it cannot be accepted that the first excitation of the light quarkonia remains unknown.

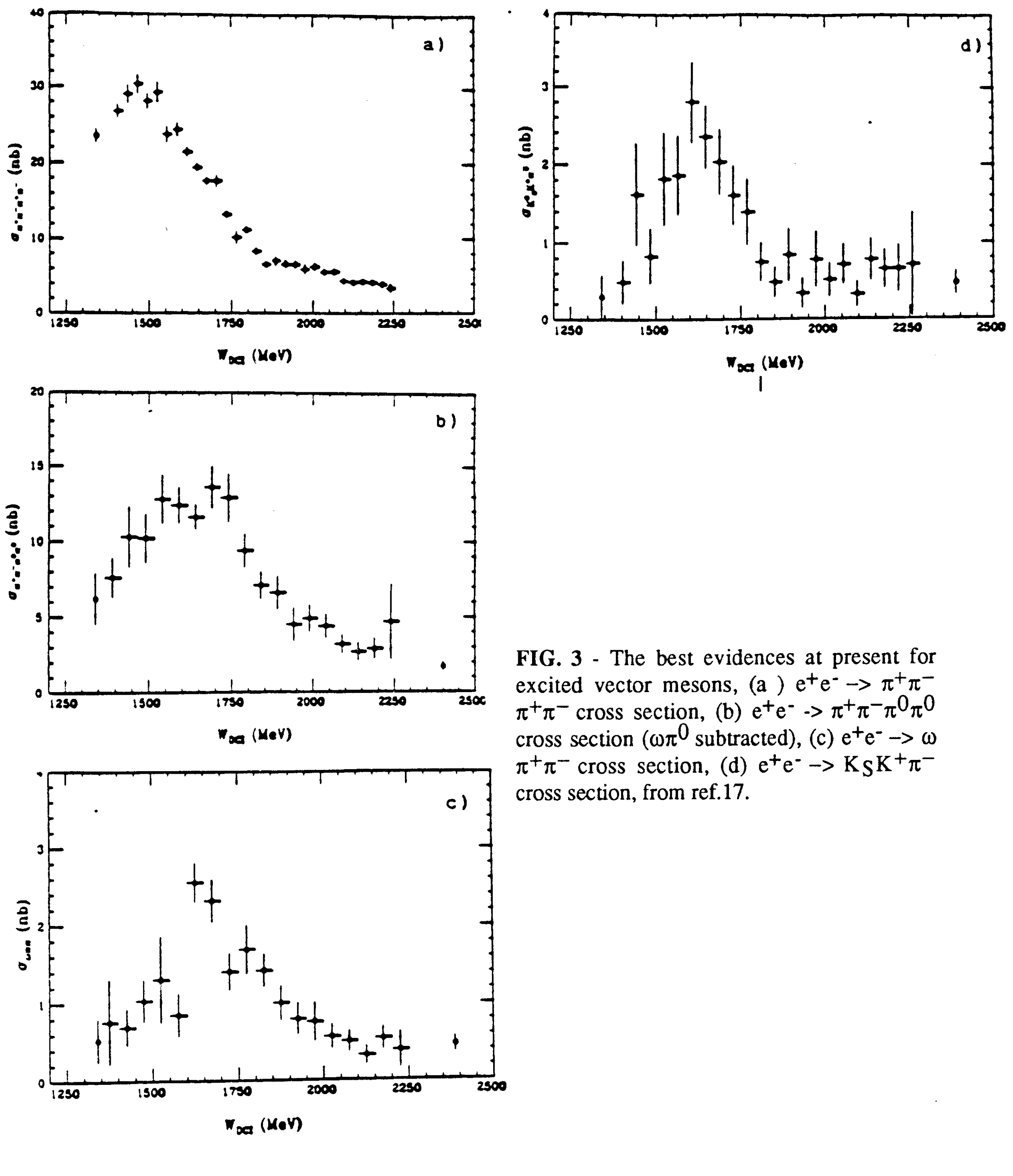

FIG. 3 - The best evidences at present for excited vector mesons, (a) $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$ cross section, (b) $e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$ cross section ($\omega\pi^0$ subtracted), (c) $e^+e^- \rightarrow \omega\,\pi^+\pi^-$ cross section, (d) $e^+e^- \rightarrow K_S K^+\pi^-$ cross section, from ref.17.

It has been shown in this workshop by S. Bellucci[23], A. Courau [24] and M. Pennington[25] that present data on $\gamma\gamma\rightarrow\pi\pi$ at threshold are scanty and contradictory. On the other hand $\gamma\gamma\rightarrow\pi\pi$ at threshold may be predicted from the first principles [26], if the chiral perturbation theory holds, and it is related to the pion electric polarizability [27]. Actually the available measurements of the pion electric polarizability are also contradictory, showing a trend similar to the $\gamma\gamma \to \pi\pi$ present measurements.

A.Courau has shown [24] that DAΦNE is suitable, respect to other e^+e^- storage rings to study $\gamma\gamma \to \pi\pi$ at threshold, in spite of the fact that the cross section increases with the energy, once realistic detection efficiencies are considered. Furthermore only DAΦNE has, perhaps, the possibility to tag forward electrons with enough efficiency. This is very important to identify better $\gamma\gamma \to \pi\pi$ events and it could allow to look for φ correlations between electron and positron forward emitted to disentagle the helicity amplitudes.

Unfortunately no realistic tagging proposal has been done in this workshop, but a device suitable for a tagging system has been presented by a Pisa group[28].

A very interesting and unexpected physics item for DAΦNE has been emphasized by R. Barrett; T. Bressani [29], W. Kluge [30], P. Gensini[31] and T. Yamasaki [32]. Namely they suggest to use DAΦNE as a unique, background free source of very low energy Kaons.

At the ϕ mass the Kaon momentum is 110 MeV/c and there are very few data, if any, for momenta lower than 300 MeV/c concerning elastic and total Kaon-Nucleon interactions.

There are relevant open questions in this low energy region. For instance the data on Kaon-Nucleon scattering lengths are puzzling [33]: the real part is positive according to the scattering data and negative according to the X rays emission from Kaonic atoms.

W. Kluge (30) and P. Gensini [31] have cleary shown that low energy Kaon-Nucleon data are needed for example to evaluate the Kaon–Nucleon σ term and to confirm or not if there is an anomalous strange quark sea inside the nucleon.

Concerning Kaon - Nucleus interactions the present data [34] on K^{+-} Nucleus total cross sections show evidences for a puzzling antishadowing, which apparently increases at lower Kaon momenta.

Furthermore in hypernuclei investigation, widely illustrated by T. Yamazaki[32], the ϕ factory should have performances an order of magnitude better than the present facilities. In fact one has to take into account the monochromatic Kaon flux at very low energies, which allow for thin targets, the absence of hadronic background and the possibility to tag the events by the other Kaon. From an experimental point of view to have a thin target is very important for studying hypernuclei in heavy elements.

The formation of deeply bound π^- states, predicted[35] but never obseved, from Λ decay in a heavy nucleus, like ^{208}Pb , is an example of an interesting search using a thin target, to be done at DAΦNE.

Another example shown by T. Yamazaki is the search for bound - Σ hypernuclei[36], which are controversial and rather unexpected. Also in this case the use of a thin target would allow for a large factor in rejecting background processes.

Hypernuclei weak decays are modified by the Pauli principle for the outgoing nucleons, therefore the hypernuclei decays are a mean to study weak interactions in a peculiar environment. There is a need of many more data, for instance it is not clear at present if the $\Delta I = 1/2$ rule is violated or not.

T. Yamazaki has also shown an amazing result they got at KEK[37], which is relevant when Kaons stop in He filled gas chambers, as it is likely to be the case for DAΦNE detectors: negative hadrons survive in He, with lifetimes comparable to their weak decays!

T. Bressani has sketched an apparatus[29] suitable for studying Kaon - Nucleon and Kaon-Nucleus interactions. It is rather complementary respect to any detector for the measurement of ε'/ε: a small volume with a high magnetic field is required, the target surrounding the beam pipe.

For studying Kaon-Nucleon interactions it would be useful to have also more energetic kaons, say up to $P_k \sim 300$ MeV/c, to join smoothly the present data. The DAΦNE designed luminosity and the Kaon form factor above the ϕ should be enough for that. Anyway the possibility of dissymetrising the two storage rings could be considered (may be it is an interesting possibility in itself) with some loss in luminosity of course.

No experimental contribution has been presented concerning the measurement of the total annihilation cross section. In the near future a new measurement of the muon anomalous magnetic moment is foreseen and therefore a measurement with lower statistical and systematical error of the hadronic contribution is worthwhile.

Of course a detector suitable for CP violation is also suitable for that. Yet a cheaper detector could be provided taking into account that the most relevant error at present is the systematical one and the target DAΦNE luminosity is not demanded.

Finally Quantum Mechanics paradoxes on a large scale will be observed at a ϕ factory. Unfortunately Bell inequalities cannot be tested, according to G.C. Ghirardi(38)and it should be possible in principle to conceive a hidden variables theory which may reproduce those paradoxes.

Nevertheless the paradoxes remain. For instance let us assume that a 1 cm Cu regenerator is brought close to the interaction region, say at 2 cm, and only neutral Kaons decaying downstream the regenerator are considered: some thousands of collinear K_S K_S events will be detected in few days, due to the K_S coherent regeneration in the Cu slab. However, if two regenerators are put simmetrically on both sides and still only neutral Kaons decaying downstream the regenerator are considered (see Fig. 4), collinear K_SK_S events will never be detected just due to the ϕ wave function(39). That is Quantum Mechanics is such that if a Kaon coherently interacts or not with some nuclei on one side the other kaon immediately interacts or not, exactly in the same way on the opposite site, no matter how far it is!

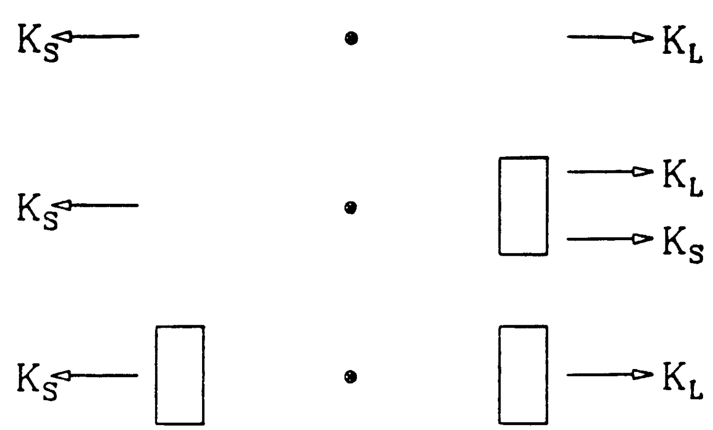

FIG. 4 - Illustrating the regenerators E.P.R. paradox .

I would like to thank L. Maiani and all the many people who partecipated to the search for other physics items, in particular D. Babusci, D. Bisello, T. Bressani, A. Courau, P. Dalpiaz,W. Kluge, A. Kudryatseev, B. Mayer, G. Matone, M. Pennington, T. Yamazaki, beside all the speakers.

I warmly acknowledge E. Iarocci , the conveners of the former study groups for a Φ–factory , M. Giorgi, M. Greco, M. Piccolo and all the people who allowed to continue the e^+e^- tradition in Frascati.

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