STATUS OF KLOE AND DAΦNE

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During the fall 1998 the KLOE experiment will start data taking at DAΦNE , the new ϕ-factory collider of the Laboratori Nazionali of INFN in Frascati, Italy. In this paper I briefly review its construction status and its physics program, giving more emphasis to CP violation studies which are its main mission.

1 DAΦNE

On March 1st 1998, the first collisions have been observed in DAΦNE , the newly built e^+e^- collider of the Laboratori Nazionali of INFN in Frascati, near Rome [1]. In DAΦNE electrons and positrons are accelerated to the energy of 510 MeV by a $\sim$ 60 m long LINAC, then stored in a small accumulator ring which finally fills up to 120+120 bunches of 40 mA each in the main accelerator. The machine is tuned to produce $\phi(1020)$ mesons resonantly with a maximum luminosity of $5\times10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$; the strategy to obtain this high luminosity is to inject huge currents in two separate rings, and let them collide in only two interaction regions, to minimize beam-beam interactions.

At present, collisions have been obtained in single bunch mode only. Multibunch operation has also been successfully tested, reaching 250 mA, limited by residual gas pressure in the vacuum chamber.

Although the physics program of DAΦNE covers several aspects of nuclear and particle physics, it is fair to say that its main mission is to shed light in the so far unexplained phenomenon of CP violation in the neutral kaon system. A dedicated detector, KLOE, has been built as explained in the following sections.

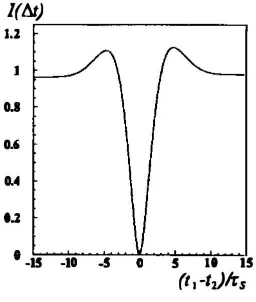

Figure 1: Interference pattern for the $\phi \to K_L K_S \to \pi^+\pi^-, \pi^0\pi^0$ decays. The real part of ϵ'/ϵ determines this pattern at large time differences, while the imaginary part dominates at $\Delta t \sim 0$.

2 The hunt for direct CP violation

After more than thirty years from the discovery of CP violation in K^0 decays we still do not know whether it is due to a small CP impurity in the mass eigenstates only, or if it is also present directly in the decay amplitudes. More precisely, we do not know whether the ϵ'/ϵ parameter, which measures the amount of direct CP violation in K^0 decays, is different from zero or not.

At DAΦNE this problem can be attacked in two, complementary, ways. When a ϕ meson decays into two neutral kaons (with a branching ratio of 34.1%) C-parity invariance forces the two kaons to be in a K_S-K_L state. The observation of a K_S, therefore, *tags* the presence of the K_L in the opposite hemisphere. Similarly, K_S decays can be selected by observing the K_L on the other side. One can then measure, almost without bias, all the possible branching ratios of K_L and K_S separately; in particular, by measuring the $\pi^+\pi^-$ and $\pi^0\pi^0$ decay modes, one can obtain the value of Re(ϵ'/ϵ) via the usual double ratio method.

On the other hand, since the K_S-K_L pair is produced in a well defined quantum mechanical state (described by the ϕ meson quantum numbers), one can measure ϵ'/ϵ performing a *quantum interferometry* experiment. Given two generic states f_1 and f_2 into which the two kaons can decay, the decay intensity into these states can be expressed, as a function of the difference of the times at which the two decays happen (Δt), by the following general formula:

$$\begin{aligned} I(f_1, f_2; \Delta t > 0) \;=\; & \tfrac{1}{2\Gamma} \times |<f_1|K_S><f_2|K_S>|^2 \\ & \times(|\eta_1|^2 e^{-\Gamma_L \Delta t} + |\eta_2|^2 e^{-\Gamma_S \Delta t} \\ & -2|\eta_1||\eta_2| e^{-\Gamma \Delta t/2} cos(\Delta m \Delta t + \phi_1 - \phi_2)) \end{aligned} \tag{1}$$

where $\eta_i = <f_i|K_L> / <f_i|K_S>$, $\Gamma=(\Gamma_L+\Gamma_S)/2$ and a similar expression holds for $\Delta t < 0$. By appropiately choosing the two decay channels one can measure 16 of the 17 parameters needed to completely describe the $K^0\overline{K^0}$ system[2][a]. In particular, if one chooses the two final states to be $\pi^+\pi^-$ and $\pi^0\pi^0$, the above formula becomes a function of both the real and the imaginary parts of ϵ'/ϵ. This interference pattern is shown in figure 1.

[a] If the validity of the $\Delta S=\Delta Q$ rule is assumed there are only 13 parameters to be determined. This rule, which is expected to be violated to only one part in 10^7 in the Standard Model, can still be tested at DAΦNE by using charged kaon pairs decays

3 The KLOE detector

The KLOE (KLOngExperiment) detector [3] has been designed and built with the primary goal of measuring ϵ'/ϵ with a sensitivity of the order of one part in ten thousand by the methods described above.

The detector consists of three main parts: a large tracking chamber, a hermetic electromagnetic calorimeter and a large magnet surrounding the whole detector, consisting of a surperconducting coil and an iron yoke.

The tracking chamber is a cylindrical *conventional* drift chamber with a number of *unconventional* features, determined by the specific requests of the KLOE experiment [5]. Firstly, the scale of KLOE is determined by the necessity of accepting the highest possible number of K_L decays whithin the detector (the average flight path of the K_L is 3.5 m at DAΦNE energies). Therefore the drift chamber is 3.7 m long and has a radius of 2 m, for a total number of wires exceeding 52000. Secondly, the drift chamber has to be as transparent as possible to photons and has to minimize the probability of regeneration of the K_L 's flying inside it. Therefore the plates at the two ends are made of a very thin (7 mm) carbon fiber epoxy and the chamber operates with a low-Z, He gas mixture. Thirdly, the uniform distribution of the K_L decay vertices and secondary tracks in the chamber volume requires a constant drift cell. This is achieved using *only* alternating stereo layers, with constant inward radial displacement at the chamber center.

For an expected resolution on any single measurement of $\sigma_{r\phi} \leq 200$ μm, confirmed by test beam results, the $K_L \to \pi^+\pi^-$vertex is expected to be reconstructed with accuracies $\sigma_{x,y} \leq 500$ μm, $\sigma_z \leq$ 1-2 mm. The resolution for the reconstructed K_L mass is $\sigma_M \sim 1$ MeV.

The chamber has been fully wired in eleven months of hard work, closed and succesfully tested with cosmic rays in the first months of 1998, and it is now placed in its final position inside the rest of the detector, where it is being equipped with the final front end electronics.

The electromagnetic calorimeter is a lead-scintillating fibres sampling calorimeter, divided in a barrel section and two end caps [4]. The 24 barrel modules and the 68 end cap ones are read-out at both ends by photomultipliers for a grand total of about 5000. The modules of the endcaps are bent *outwards* with respect to the decay region, so that photons produced inside the latter can never hit a dead zone of the calorimeter. With this simple, but effective, solution the coverage of the full solid angle for photons is kept at the level of 98% in KLOE.

The calorimeter allows the detection with very high efficiency of photons with energy as low as 20 MeV, measure their energy with a resolution of $4.5\%/\sqrt{E}$ and the time at which they reach it with a resolution of 50 ps/$\sqrt{E}$ (E in GeV).

This excellent timing performances allows one measuring the flight path of the K_L into neutral pions with great accuracy, thanks to the method shown in figure 2. This is a particularly important feauture, since a wrong definition of the fiducial volumes inside which K_L decays are accepted can introduce a relevant bias in the ϵ'/ϵ measurement.

The calorimeter has been installed in the fall of 1997 and is continuosly tested with cosmic rays since then.

At full luminosity, ϕ decays, Bhabha scattering and machine background events will produce sizeable energy deposits in the KLOE detector at a rate of several hundreths KHz. A two level trigger system has been developed, with the purpose of filtering the interesting part of this huge amount of data (about 10 KHz), keeping the efficiency on the CP violating channels above 99%, and selecting some useful calibration events [6].

This will represent nevertheless a very large load for the data acquisition system, which will have to handle about 40 MBytes of data per second. Data coming from ~ 25000 FEE channels are read-out by 10 independent chains housed in some 40 9U-VME crates. Sub-events coming from each chain are then put together by a computer farm through a FDDI GIGAswitch with bridge functionality. The required computing power of the online farm is 20000 MIPS at full

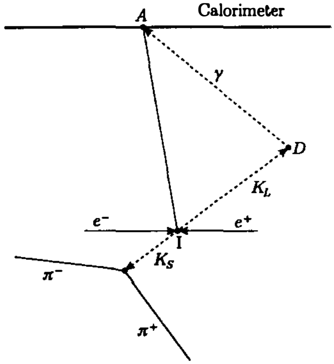

Figure 2: Measuring the K_L flight path in KLOE: I and A are known positions, while ID is a known direction. In addition the time at which the photon arrived at A is measured, and the speeds of the K_L and, obviously, of the photon are known.

luminosity [7].

4 Data Taking Plans

During the summer of 1998 KLOE is planned to roll-in and to eventually start data taking. Physics results are expected to come soon after.

Already with $\sim 10^8$ ϕ decays (which correspond to about two months of run at one tenth the nominal luminosity) KLOE can address important physics issues, such as the measurement of the K_{l3} decay form factors, or the observation of the $\phi \to f_0\gamma$ decay channel. For instance, KLOE can measure the slope of the scalar form factor λ_0 to an accuracy of $\sim 10^{-5}$; this will improve very much the present experimental situation which is rather controversial, as discussed in reference [8]. The $\phi \to f_0\gamma$ transition provides a unique opportunity to study the lightest scalar meson $f_0(975)$, which is poorly described by current models [9].

In general KLOE can be an excellent playground for testing chiral perturbation theory [10], by looking with unprecedented accuracy at a wide number of decay channels both of the neutral and the charged kaons. In particular the study of K_{l4} decays will provide a unique opportunity for the determination of the $\pi - \pi$ phase shift, a key quantity in low-energy QCD [8].

At maximum luminosity KLOE will accomplish its main mission, i.e. the measurement of ϵ'/ϵ at the 10^{-4} level. Together with this, a large number of rare K_S and K_L decay modes can be studied, measuring for the first time their branching ratios or setting new limits on them. For instance, KLOE can provide the first evidence of the CP violating decay $K_S \to \pi^0\pi^0\pi^0$ or set interesting limits on the "holy grail" of kaon physics i.e. the insofar undetected $K_L \to \pi^0\nu\overline{\nu}$ transition [11].

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