KLOE STATUS REPORT

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Abstract

During the fall 1998 the KLOE experiment will start data taking at DAΦNE, the new ϕ-factory of Laboratori Nazionali di Frascati in Italy. In this paper I briefly review its construction status and its physics program.

1 Introduction

The KLOE detector, at present under construction at the Frascati ϕ-factory DAΦNE, is a general purpose detector whose major aim is the study of direct CP violation in the neutral kaon system. Its ultimate goal is to reach an accuracy of $O(10^{-4})$ in the measurement of the parameter $\mathrm{Re}(\epsilon'/\epsilon)$. KLOE will also be capable of doing a whole spectrum of other measurements, such as tests of CPT in K decays, studies of chiral perturbation theory and detailed light hadron spectroscopy. The accelerator complex [1] consists of a LINAC, which accelerates electrons and positrons to 510 MeV, followed by an Accumulator Ring, which provides up to 120 bunches of each type of particles to the two separate Main Rings intersecting in two regions. The design peak luminosity is 5×10^{32} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which corresponds to a ϕ production rate of ~ 2.5 KHz.

2 Physics Program

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 $\mathrm{Re}(\epsilon'/\epsilon)$ 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's 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:

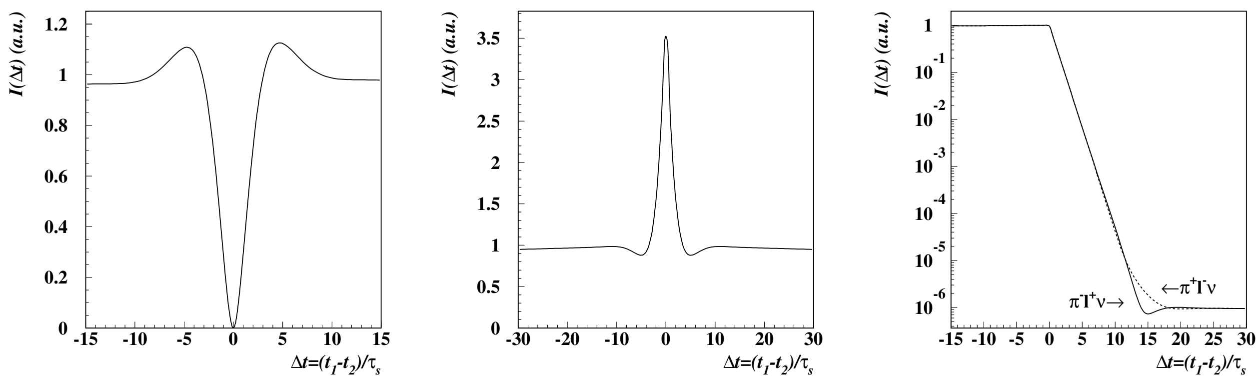

Figure 1: Interference pattern for $f_1 = \pi^+\pi^-$ $f_2 = \pi^0\pi^0$ (left); $f_1 = \pi^+l^-\nu$ $f_2 = \pi^-l^+\nu$ (center); $f_1 = 2\pi$ $f_2 = \pi^+l^-$ or π^-l^+ (right);

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

where η_i=$\langle f_i|K_L\rangle/\langle f_i|K_S\rangle$, Γ=$(\Gamma_L + \Gamma_S)/2$. A similar expression holds for Δt $<$ 0. By appropriately choosing the two final states one can measure 16 of the 17 parameters[1] needed to completely describe the $K^0\overline{K^0}$system [2]. One can thus perform a whole spectrum of precision *kaon-interferometry* experiments at DAΦNE by measuring the above decay intensity distribution for appropriate choices of the final states f_1 and f_2 (see also [3]). Some of these interference patterns are shown in figure 1. 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; the real part of ϵ'/ϵ determines this pattern at large time differences, while the imaginary part dominates at Δt$\sim$0.

[1] If the validity of the ΔS=ΔQ 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 (K Long Experiment) detector [4] has been designed and built with the primary goal of measuring ϵ'/ϵ with a sensitivity of the order of 10^{-4} by the methods described above.

The detector consists of a cylindrical drift chamber surrounded by a lead-scintillating fibre electro-magnetic calorimeter. Moreover, two small calorimeters cover the quadrupoles of the low-insertion β region which are located inside the detector. KLOE operates with an axial magnetic field of 0.6 T provided by a 2.5 m radius super-conducting solenoid.

4 The Electromagnetic Calorimeter

The electromagnetic calorimeter is a lead-scintillating fibres sampling calorimeter, divided into a barrel section and two end caps [5]. The 24 barrel modules and the 64 end cap ones are read-out at both ends by mesh 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 and allow to the photomultipliers to work axially to the magnetic field. 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 $4.7\%/\sqrt{E}$ and the time at which they reach it with a resolution of $\sim$ 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 allows us to reconstruct the $K_L$decay point using only one photon, making possible the systematics control trough the $\pi^+\pi^-\pi^0$ decay channel. This is a particularly important feature, 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 fully equipped has been installed inside the solenoid in the fall of 1997. In the beginning of 1998 the calorimeter has been fully read-out with the final Data acquisition system and is continuously tested with cosmic rays (see figure 2) since then, furnishing a powerful test system for the remaining part of the Kloe detector.

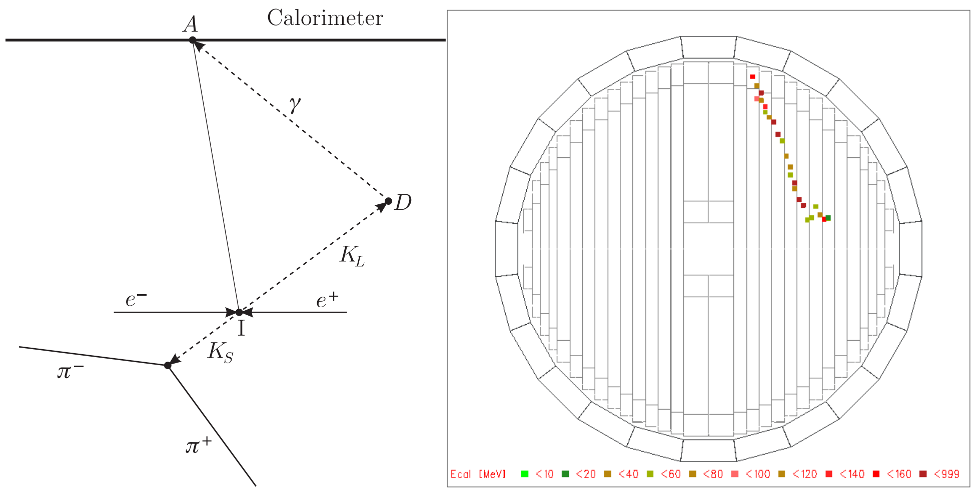

Figure 2: Left: Measuring the K_L flight path in KLOE: I and A are known positions, while ID is a known direction. Knowing the speed of K_L and γ, measuring the photon time of arrival in A, the point is measured with a precision of $\sim$ 1 cm. Right: A *muon stop* on one calorimeter endcap

5 The Drift Chamber

The tracking chamber is a cylindrical *conventional* drift chamber with a number of *unconventional* features, determined by the specific requests of the KLOE experiment [6]. Firstly, the scale of KLOE is determined by the necessity of accepting the highest possible number of K_L decays within 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 minimise 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 centre.

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 and $\sigma_z \leq$ 1-2 mm. The resolution for the reconstructed K_L mass is $\sigma_M \sim$ 1 MeV.

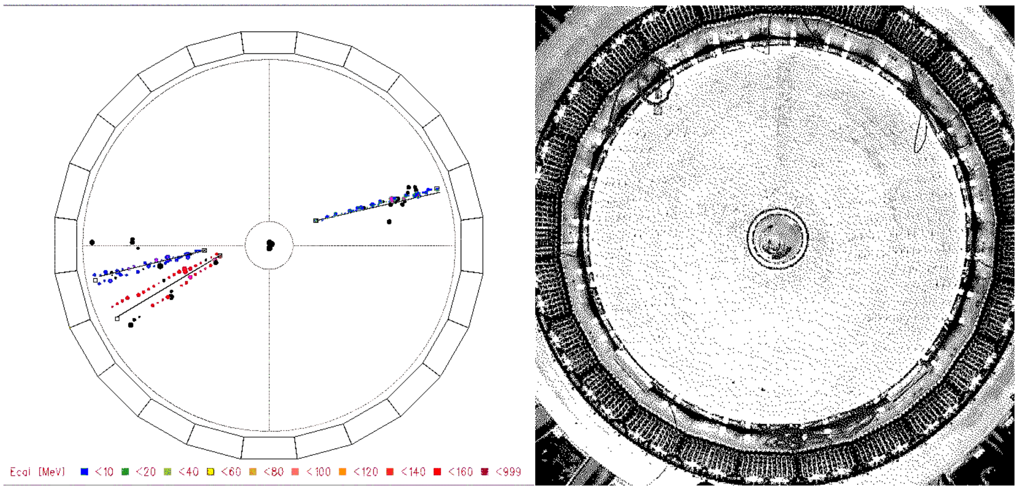

Figure 3: A cosmic ray tracked by the drift chamber and well reconstructed by the Offline (left). A view of drift chamber in the final position inside KLOE (right).

Its stringing started in November 1996 and is proceeding regularly towards its end on November 1997. In total, more than 52000 wires, both sense and field ones, has been strung.

After that the chamber was closed, the final gas system has been tested with a total leackage of only 5 l/day (over 40.000 l of total volume). In the first month of the year the chamber has been succesfully tested with cosmic rays (see figure 3).

Just after the test the chamber has been moved in the Kloe Hall and now is placed in its final position inside the rest of the detector (see figure 3) , where it is being equipped with the final front end electronics.

6 The Trigger and DAQ

The expected data rates together with the very high sensitivity required in the control of all possible systematic effects make the requirements on the trigger and data acquisyition system a real challenge in the field. Inefficiencies and error rates must be minimized to insure that no biases are introduced at these levels. Particular care must be taken in order to insure that the channels involved in the measurement of the CP violating parameters are triggered and acquired with very high and equal efficiencies. This is possible thanks to a very flexible trigger system, and a custom-designed DAQ system which allows us to handle data throughput as high as 50 MBytes/s. The FEE, DAQ and Trigger systems are done.

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 hundreth 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 useful calibration events [7].

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 luminosity [8].

7 Conclusions

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

Already with $\sim 100pb^{-1}$ (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 [9]. 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 [10].

In general KLOE can be an excellent testing for chiral perturbation theory [11], 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 [9].

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 $K_S \to \pi^0\pi^0\pi^0$.

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