FIRST RESULTS FROM $\phi \to K_L K_S$ DECAYS WITH THE KLOE DETECTOR

THE KLOE COLLABORATION [1]
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The KLOE experiment has collected 2.4 pb^{-1} of integrated luminosity during the commissioning of the DAΦNE ϕ-factory in 1999. The performance of the detector has been studied using the $\phi \to K_L K_S$ decays collected during this period, yielding also first measurements of relevant K parameters such as masses and lifetimes. A clean $K_S \to \pi^+\pi^-$ sample is used to select $K_L \to \pi^+\pi^-$ CP-violating decays and $K_L \to K_S$ regeneration events in the detector material. Results on the regeneration probability in a beryllium-alluminum alloy and carbon-fiber plus aluminum composite are presented.

1 Experimental setup

The DAΦNE ϕ factory [2] has come into operation in july 1999, delivering 2.4 pb^{-1} of integrated luminosity to the KLOE experiment during its commissioning period. Such data, taken at the energy of the ϕ resonance, allowed us to perform a careful check of the KLOE detector operation and performances [3]. Typical values of the beam parameters were 20+20 bunches, a current of 300 mA per bunch and a lifetime of 30 minutes. The average luminosity was $10^{30}\, cm^{-2}s^{-1}$. The beams cross with a period multiple of 2.7 ns and with an angle of 25 mrad in the horizontal plane, which implies a 13 MeV center of mass boost relative to the experiment.

The KLOE detector was described elsewhere[3]. The trigger requirement during most of the data taking was at least two calorimeter energy deposits, with an average efficiency of 90% for most ϕ decays and of ∼84% for $\phi \to K_L K_S$ events with kaons decaying in charged particles. The trigger rate was typically 1.5 kHz mostly due to cosmic rays. The luminosity was measured with an accuracy of ∼5% using Bhabha scattering events in the angular region $22^o < \theta < 158^o$.

About 7 million ϕ decays were collected during data taking. Data were filtered against cosmics and machine background, and classified using several tagging algorithms. This analysis used only events containing a candidate K_S charged decay, defined as: one vertex with two opposite curvature tracks, $\rho = (x^2 + y^2)^{1/2} < 4$ cm, $|z| < 8$ cm, two pion invariant mass $400 < m < 600$ MeV, and momentum $50 < p < 120$ MeV.

2 Measurement of the K_S lifetime

The position of the secondary vertex (SV) of $\pi^+\pi^-$ pairs from K_S decays, together with the knowledge of the average position of e^+e^- primary vertex (PV) allows the measurement of the K_S decay length in the ϕ frame, λ_S.

The PV position was reconstructed run-by-run from Bhabha scattering events with a typical resolution of $60 \div 70\,\mu m$ in x and y coordinates, and of $\sim 150\,\mu m$ in z. To avoid the systematic distortion of the λ_S distribution due to the SV resolution, λ_S is extracted from a fit to the distribution of its projection along the K_S momentum direction $\vec{p_S}$, and finally Lorentz-transformed to the ϕ system using the run-average ϕ boost as measured from Bhabha events.

This analysis was performed using only a subsample of events for which the position of the beam spot had been computed. The selection required the simultaneous presence of the K_S candidate vertex and of a second two-track vertex outside a sphere of 11 cm radius. If a third vertex was present the event was rejected. The mass and momentum cuts on

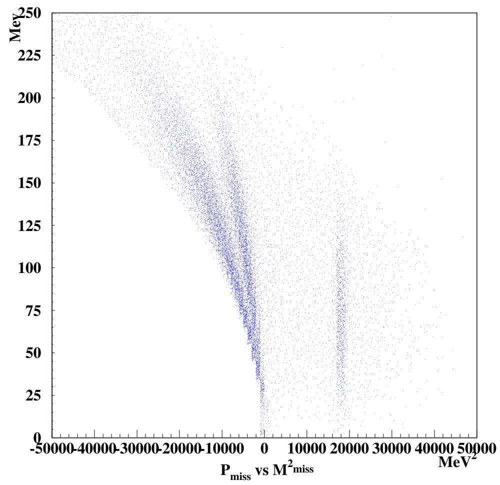

Figure 1. Correlation between missing momentum and squared missing mass for K_L charged decays

K_S candidates were tightened respectively in the interval (495,499) MeV/c^2 and (105,114) MeV/c, while the K_S polar angle had to l in the region above 45°. The final selected sample is 6866 decays. Their λ distribution was fit to four different functions: an exponential smeared with two or three gaussians, with or without an extra non-smearing gaussian modeling a zero-lifetime component. The fit statistical error on λ_S was taken as the largest fit error, while the fit systematic error was taken as half the spread of the four λ_S values. The preliminary result is then:

$$\lambda_S = 5.78 \pm 0.08\,(stat) \pm 0.10\,(syst)\,mm$$

3 Measurement of the $K_L \to K_S$ regeneration cross section

Due to the different absorbtion cross section of K^o and $\bar{K}^o$, a pure beam of K_L mesons will regenerate[4] K_S mesons when traversing the detector. Thus $K_L \to K_S \to \pi\pi$ is a potential source of background for the rare $K_L \to \pi\pi$ CP-violating decays. It has been shown [5] that for a thin regenerator, $t < \lambda_S$, the coherent regeneration is negligible. Inelastic regeneration can also be neglected in 110 MeV/c K_L-nuclei interactions.

$K_S \to \pi^+\pi^-$ candidates were selected as described in sect. 1 with the additional requirement of the presence of at least one more vertex, with two unlike sign tracks, and tighter cuts on K_S candidates mass and momentum. The ϕ vertex (the K_L origin) was defined as the distance of closest approach between the K_S direction and the beam line (z axis). A K_L associated charged decay was then defined to be any second vertex reconstructed with two unlike sign tracks found in a cone opposite to the K_S direction in the ϕ reference system. This cut selected 134997 events. Fig.1 shows the correlation of the missing momentum p_{mis} and the missing mass M^2_{mis} computed assuming the pion mass for all charged particles: $K_L \to \pi^+\pi^-\pi^o$ decays populate the region of $M^2_{mis} = m^2_{\pi^o}$; $K_L \to \pi\ell\nu$ decays are clearly separated in two bands with $M^2_{mis} < 0$; $K_L \to \pi^+\pi^-$ decays are peaked around $p_{mis} = 0$, $M^2_{mis} = 0$; $K_L \to K_S \to \pi^+\pi^-$ "elastic" events are expected to populate the band with $p_{mis} = (-M^2_{mis})^{1/2}$.

To select $K_L \to \pi^+\pi^-$ decays and $K_L \to K_S \to \pi^+\pi^-$ elastic events we first required the K_L vertex invariant mass to lie in the region $m = 497.7 \pm 4$ MeV, the measured K_L mass resolution being $\sigma_m = 1.1$ MeV. A further background rejection was obtained by requiring $-6 < \Delta|\vec{p}| < +12$ MeV, where $\Delta|\vec{p}| = |\vec{p}_S| - |\vec{p}_L|$. A sample of 930 events was obtained. Their radial distribution is shown in fig. 2, together with a control sample obtained from the sidebands of the K_L mass peak. The peaks around $r = 10$ cm and $r = 28$ cm are due to $K_L \to K_S$ regeneration in the spherical beam pipe (bp) and in the cylindrical drift chamber inner wall (cw). Two regions of interest were defined of width (-2,+4) cm around the regenerator positions. The number of regenerated events (background subtracted) is then: $N^{bp}_{reg} = 123 \pm 13$, $N^{cw}_{reg} = 122 \pm 12$.

Finally $K_L \to \pi^+\pi^-$ were separated from the semileptonic decays and regenerations by requiring the angle ω between the K_S and

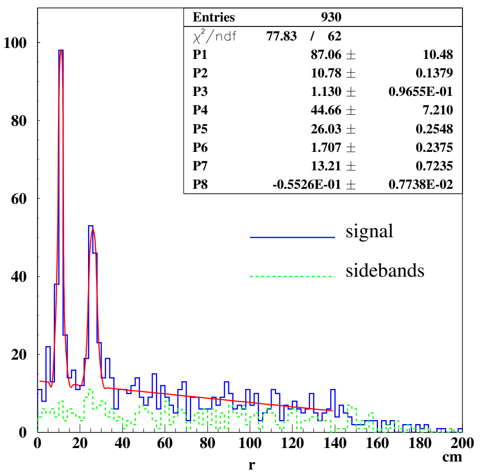

Figure 2. Radial distribution of for $K_L \to \pi\pi$ decays and regenerated events, and of the side bands sample

K_L momentum to be less than $75\,mrad$. A sample of 279 events was obtained.

3.1 Results

The number of $K_L \to K_S \to \pi^+\pi^-$ regenerated events is related to the regeneration cross section on nuclei, σ_{reg}, by

$$N_{reg} = N_L\ \varepsilon\ B_{S\pi\pi}\ \sigma_{reg}\ n\ t \qquad (1)$$

with $N_L = N_{SL}\ e^{-r/\lambda}$ the number of K_L mesons reaching the regenerator, ε the detection efficiency, $B_{S\pi\pi}$ the $K_S \to \pi^+\pi^-$ branching fraction, n the number of nuclei per unit volume, t the regenerator thickness. The spherical bp, of radius $10\,cm$, $0.50\,mm$ thick, is made of AlBeMet, an alloy of 61% Beryllium and 39% Aluminum: $(nt)^{bp} = 4.93\ 10^{21}\ cm^{-2}$. The cylindrical cw is made of Carbon 0.75 mm thick, 60%-fiber and 40%-epoxy and has a 0.20 mm thick Aluminum shield: $(nt)^{cw} = 6.97\ 10^{21}\ cm^{-2}$.

The detection efficiency for charged regenerated events is the same as for the selected $K_L \to \pi^+\pi^-$ sample, the only difference being the final ω cut. Such efficiency, expressed in terms of $dN_{L\pi\pi}/dr$, of the decay length in the laboratory λ_L, and of the number of $K_S K_L$ events, can be substituted in eq.1, giving:

$$\sigma_{reg} = \frac{B_{L\pi\pi}}{B_{S\pi\pi}}\ \frac{1}{\lambda\ dN_{L\pi\pi}/dr}\ \frac{N_{reg}}{\langle nt \rangle} \qquad (2)$$

Using the measured $dN_{L\pi\pi}/dr$ we got:

$$\sigma^{Be-Al} = 75.7 \pm 9.6_{stat} \pm 10.6_{syst}\, mb$$

$$\sigma^{C-Al} = 51.9 \pm 6.2_{stat} \pm 5.3_{syst}\, mb$$

Three main categories of systematic error sources have been considered: *a)* event counting method: regions of interest definition and background parameterization; *b)* efficiency evaluation: the assumption that the efficiency for regenerated K_S charged decays is the same as for $K_L \to \pi^+\pi^-$ decays (tested with monte carlo), and a possible contamination of regenerated K_S decays in the $K_L \to \pi^+\pi^-$ sample (checked in the data); *c)* knowledge of the regenerator thicknesses, which turned out to be the dominant contribution.

3.2 Discussion

With the present data it is not possible to evaluate separately the regeneration cross section on Beryllium, Carbon and Aluminun nuclei unless we make additional hypotheses on its dependence upon the atomic mass. However a reasonable agreement is observed with a previous measurement on Beryllium [7] made with the CDM-2 detector at VEPP-2M. On the other hand theoretical calculations [6] based on the eikonal approximation can hardly be accomodated.

References

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