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MEASUREMENT OF ϕ-MESON LEPTONIC WIDTH IN $e^+e^- \to e^+e^-,\ \mu^+\mu^-$ PROCESSES

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ABSTRACT

The ϕ-meson leptonic widths, Γ_{ee} and $\Gamma_{\mu\mu}$, are obtained from the $e^+e^- \to e^+e^-$ forward-backward asymmetry and the $e^+e^- \to \mu^+\mu^-$ cross section around the ϕ-mass energy. We find Γ_{ee} = 1.32± 0.05± 0.03 keV and $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$ = 1.320± 0.018± 0.017 keV. These results, compatible with Γ_{ee}=$\Gamma_{\mu\mu}$, provide a most precise test of lepton universality. Combining the two results gives $\Gamma_{\ell\ell}(\phi) = 1.320 \pm 0.023$ keV.

1 Motivations

The ϕ-meson leptonic width:
- determines the total ϕ production cross section in e^+e^- annihilation and the ϕ-decay BRs [1, 3];
- in VMD model provides photon-ϕ coupling constant $g_{\phi\gamma}$;

- plays an important role for hadronic contribution to photon vacuum polarization [2];
- provides test for universality of leptonic coupling constant and for quark charge assignment in ϕ meson.

2 Observables

In $e^+e^- \to e^+e^-$process (Fig. 1) the observable is the forward-backward asymmetry A_{FB} :

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}. \tag{1}$$

In $e^+e^- \to \mu^+\mu^-$ process (Fig. 1) the observable is directly the cross section. In both cases we have an interference term depending on $\Gamma_{\ell\ell}$:

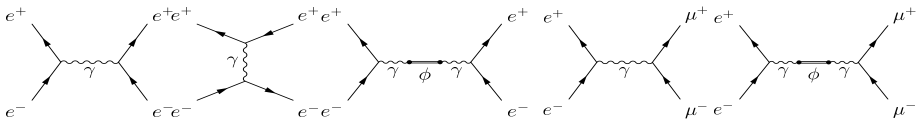

Figure 1: *Left: Amplitude for* $e^+e^- \to e^+e^-$ *process. Right: Amplitude for* $e^+e^- \to \mu^+\mu^-$ *process.*

$$\sigma_{\rm int} = \frac{3\alpha\Gamma_{\ell\ell}}{M_\phi}\,\frac{s - M_\phi^2}{(s - M_\phi^2)^2 + s\Gamma_\phi^2}\int_{\cos\theta_2}^{\cos\theta_1} {\rm d}\cos\theta f(\theta)_{\ell\ell} \tag{2}$$

where $\Gamma_{\ell\ell} = \Gamma_{ee}$ for $e^+e^- \to e^+e^-$, $\Gamma_{\ell\ell} = \sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$ for $e^+e^- \to \mu^+\mu^-$ and where θ_1 and θ_2 define our geometrical acceptance. Note that σ_{int} changes sign when s goes through M_ϕ^2. For this reason our analysis uses only 3 energy points: $\sim M_\phi, \sim M_\phi \pm \Gamma_\phi/2$

3 Detector and Data Sample

The KLOE detector [7] consists of a large drift chamber (DC) and an electromagnetic calorimeter (ECAL) surrounded by a superconducting coil with B=0.52T. The DC, a cylinder of about 4m radius and 3.3m length, filled with a $90\% He - 10\% iC_4H_{10}$ gas mixture and having ~13000 stereo sense wire, has a momentum resolution $\delta p/p \sim 0.4\%$, a hit resolution of $150\mu m$ (xy) and 2 mm(z) and a vertex resolution of ~1 mm. The calorimeter, a sample of alternate lead/scintillating fibers, consisting of a barrel covering $45^o < \theta < 135^o$ and two end caps, measures energy with a resolution $\sigma(E)/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$ and arrival times with a resolution $\sigma(t) = [54/\sqrt{E(\mathrm{GeV})} \oplus 50]$ ps. Luminosity and energy are obtained from Bhabha scattering. The CM energies and luminosities for the collected data are summarized in Table 1.

CM energy (mev)	integr.lum.(nb^{-1})
1017.17 ± 0.01	6966 ± 42
1019.72 ± 0.02	4533 ± 27
1022.17 ± 0.01	5912 ± 35

Table 1: 2002 ϕ-scan statistics

4 Analysis

Bhabha events are selected using DC and ECAL informations and, to enhance sensitivity, we measure forward-backward asymmetry (1). For $e^+e^- \rightarrow \mu^+\mu^-$ process we can measure directly cross section. While in Bhabha events background is almost negligible, in $\mu\mu$ production we have a strong contamination of $e^+e^- \rightarrow \pi^+\pi^-$ events. Initial state radiation (ISR), where one or both the initial colliding particles radiate a photon before interacting, changes the collision energy. ISR photons are mostly collinear to the beam, and therefore not detectable. The effective center-of-mass energy is so reduced from the nominal value, W, to a lower value, W'. Final state radiation (FSR), by interference with ISR, introduces an asymmetry in the angle distribution mainly in $e^+e^- \rightarrow \mu^+\mu^-$process. To enhance the ϕ-meson contribution, a lower cut on W'/W is imposed for both processes. All efficiencies are evaluated using the GEANFI Monte Carlo [6]. As fit function to our observables we use in both cases a Breit-Wigner cross section corrected for ISR [4, 5], FSR, and beam energy spread (BES) [8]. The fit parameters are $\Gamma_{ee}, M_\phi, A_{FB}(M_\phi)$ for $e^+e^- \rightarrow e^+e^-$ process and $\Gamma_{\mu\mu}, M_\phi, \sigma(M_\phi)$ for $e^+e^- \rightarrow \mu^+\mu^-$process. For bhabha the main systematic uncertainties on A_{FB} are the fiducial cuts on W'/W and polar angle ($\sim 80\%$) and the theoretical uncertainty on Γ_ϕ ($\sim 20\%$). For $e^+e^- \rightarrow \mu^+\mu^-$ process the main systematic contributions on $\sigma_{\mu\mu}$ come out from the fiducial cuts on W'/W and polar angle ($\sim 42\%$), from the theoretical uncertainty on Γ_ϕ ($\sim 50\%$) and from the event counting ($\sim 8\%$)(the number of signal counts comes out by fitting data to a linear combination of MC spectra for signal ($\mu\mu$) and background ($\pi\pi$)).

5 Results

Our results are: $\Gamma_{ee} = 1.32 \pm 0.05 \pm 0.03$ keV and $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}} = 1.320 \pm 0.018 \pm 0.017$ keV. They are consistent with lepton universality within our errors. Combining the two results we find for the leptonic width of the ϕ-meson $\Gamma_{\ell\ell} = 1.320 \pm 0.017 \pm 0.015$ keV, with a total uncertainty of less than 2%.

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