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MEASUREMENT OF NEUTRAL KAON MASS WITH CMD-2 DETECTOR

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1 Introduction

A preliminary result of the K^0_S mass measurement performed recently with the CMD-2 detector based on the precision of beam energy calibration at VEPP-2M collider and $K^0_S \to \pi^+\pi^-$ decay reconstruction technique is presented.

2 VEPP-2M collider and CMD-2 detector

The electron-positron collider VEPP-2M [1] has been running at Novosibirsk since 1974 up to 2000 carrying out experiments with the CMD-2 and SND detectors in the c.m. energy range $\sqrt{s} = 0.36 \div 1.4$ GeV.

The CMD-2 detector is described in more detail elsewhere [2]. Its tracking

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system consists of the cylindrical drift chamber (DC) surrounding the interaction point and providing precise particle momentum and dE/dx measurement and proportional Z-chamber (ZC) for precise polar angle measurement, both also used for trigger. Both chambers are inside a thin (0.38 X_0) superconducting solenoid with a field of 1 T. The barrel electromagnetic calorimeter placed outside the solenoid consists of 892 CsI crystals. The muon-range system of the detector, also located outside the solenoid, is based on streamer tubes. The endcap electromagnetic calorimeter based on BGO crystals makes the detector almost hermetic for photons.

3 Full two-body decay reconstruction technique

The measurement of neutral kaon mass performed with the CMD-2 detector is based on the full $K_S^0 \to \pi^+\pi^-$ decay reconstruction. A kaon mass value can be determined for each decay event using the following equation, derived from energy-momentum conservation:

$$\beta^2_{K_S^0} = \frac{1}{\eta^2}\left(1+\cos\psi\sqrt{1-\eta^2}\right)\left[1-\sqrt{1-\beta_m^2\eta^2}\right], \qquad (1)$$

where $\eta \equiv \frac{1-Y^2}{1+Y^2}$, $Y = p_+/p_-$, $p_\pm \equiv |\overrightarrow{p_\pm}|$, $\overrightarrow{p_\pm}$ are charged pion momenta,

$$\beta^2_{K_S^0} \equiv 1-(M_{K_S^0}/E_{K_S^0})^2, \;\; \beta_m^2 \equiv 1-(2M_{\pi^\pm}/E_{K_S^0})^2, \qquad (2)$$

$E_{K_S^0}$ is kaon energy and ψ is opening angle between pions in the c.m. frame. The main features of the technique are strong suppression of pion momentum measurement systematics and a requirement of precise beam energy calibration.

4 VEPP-2M collider beam energy calibration

In case of measuring $M_{K_S^0}$ via reconstruction of $K_S^0 \to \pi^+\pi^-$ decay in the process of kaon pair production $e^+e^- \to \phi(1020) \to K_S^0 K_L^0$ one needs to measure an average $\sqrt{s}$ value of the electron-positron system and then take into account beam energy spread and initial state radiation (ISR) effects.

The average beam energy of the VEPP-2M collider for a 355 nb^{-1} data set used for kaon mass measurement was determined by the resonant depolarization technique [3]. It was shown that the precision of single beam energy measurement was $\sigma_E/E \approx 10^{-5}$ corresponding to $\sigma_E \approx 5$ keV for the c.m.

energy near the $\phi(1020)$ meson peak. The typical duration of the CMD-2 experimental run was $T_{run} \approx 2$ hours so we had to study long term instabilities of beam energy.

The most significant instability was found to be the temperature drift due to variations of a collider ring perimeter caused by changing day/night temperature. Each bending magnet of VEPP-2M ring had a temperature probe and the data collected by these probes during the data taking allowed us to establish clear correlation between beam energy and average collider ring temperature. Recently the correlation was also studied via a technique based on measuring an average momentum of charged kaons in $e^+e^- \to K^+K^-$ process and full CMD-2 detector simulation. Combining both methods we managed to obtain average mean beam energy values for the data taking runs with $\sigma_E = 13 \div 19$ keV accuracy [4]. The total number of $e^+e^- \to K_S^0 K_L^0$, $K_S^0 \to \pi^+\pi^-$ events selected for further analysis is ≈ 45000 for the entire calibrated data set.

5 Event selection and visible mass values determination

Visible kaon mass values were obtained for each experimental run and then ISR radiative corrections (RC) and detector smearing corrections (NC) were applied. Pion charge dependent systematic effects of momentum measurements were taken into account for each run as well. In order to study the influence of pion energy losses (DE) in the CMD-2 drift chamber and vacuum tube material and effects of uniformity of detector magnetic field (MF) we separate all the experimental events into two "topological" classes. DE and MF corrections were applied event-by-event and it was found that these corrections do compensate all the experimentally observed systematic differences between average mass values measured for different event types.

6 Preliminary neutral kaon mass result

Performing the final fit over the K_S^0 mass values for all runs, we obtained

$$M_{K_S^0} = 497.634 \pm 0.016 \pm 0.019 \text{ MeV/c}^2, \tag{3}$$

where the first contribution to the uncertainty is the sum of beam energy dependent systematics and statistical error with a scale factor 1.7 included and the second is the sum of energy independent systematics (all the contributions

Table 1: $M_{K_S^0}$ *systematic error budget.*

Source of systematic	Correction, keV/c^2	Error, keV/c^2
Beam energy measurement		$13 \div 19$
Beam energy temperature drift		3
Radiative corrections to initial state	$-(80 \div 630)$	$2 \div 12$
Beam energy spread correction	$+3$	0.3
Radiative corrections to final state	-6	6
Detector smearing corrections	$+(60 \div 140)$	$6 \div 15$
Correction for pion decay in flight	$+4$	3
Background		4
Z-chamber thermal expansion		3
Selection criteria variation		6
Fit bounds variation		8
Charged pion mass uncertainty		0.04

are listed in Table 1). Our preliminary result is in good agreement with all previous measurements and has a total error of 24 keV/c^2 which is close to the uncertainty of the PDG2004 neutral kaon mass fit [5].

7 Conclusion

The mass of K_S^0 meson was measured with the CMD-2 detector at the VEPP-2M electron-positron collider by using total $K_S^0 \to \pi^+\pi^-$ decay reconstruction technique. The preliminary result obtained has the accuracy almost the same as the world average value at the moment, so an updated world average $M_{K_S^0}$ value can be used for precision beam energy calibration of ϕ-factories.

The mass measurement techniques developed could be easily adopted to other experimental conditions (e.g., KLOE at DAΦNE) in order to measure the $M_{K_S^0} - M_{K^\pm}$ value and CPT-violating quantity $M_{K^+} - M_{K^-}$ even without precision collider energy calibration technique available.

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