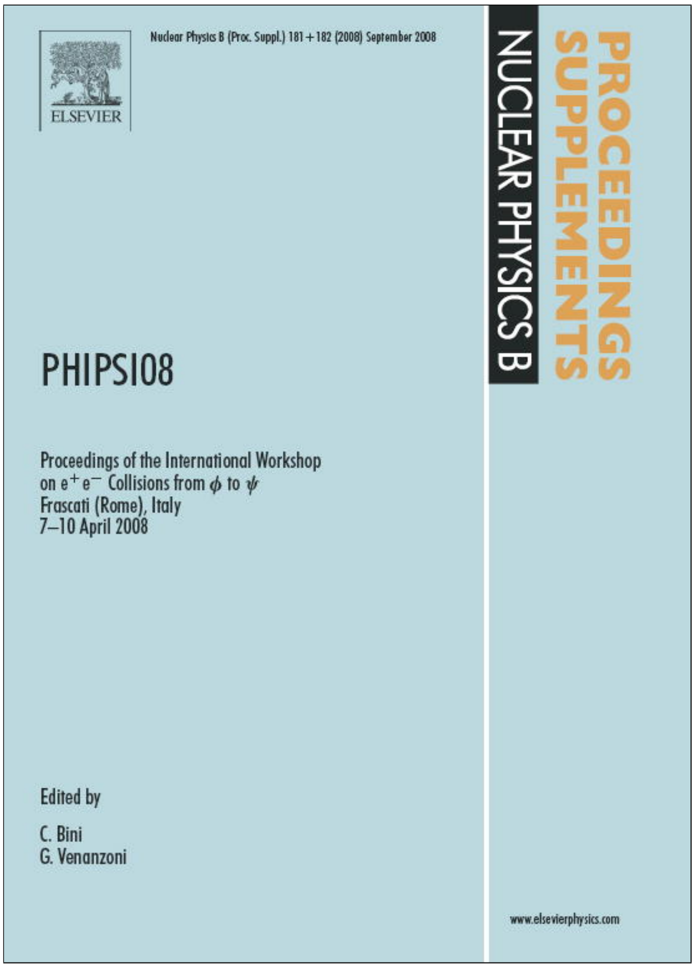

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Tau mass measurement at KEDR

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The status of the experiment on the precise τ lepton mass measurement running at the VEPP-4M collider with the KEDR detector is reported. The mass value is evaluated from the $\tau^+\tau^-$ cross section behavior around the production threshold. The preliminary result based on 15.2 pb^{-1} of data is $m_\tau = 1776.69^{+0.17}_{-0.19} \pm 0.15$ MeV.

1. Introduction

The τ lepton mass m_τ is one of the fundamental characteristics of the Standard Model. Together with the lifetime and the decay probability to $e\bar{\nu}_e\nu_\tau$ this value can be used to test the lepton universality principle which is one of the postulates of the modern Electroweak theory. The world average value $m_\tau = 1776.99^{+0.29}_{-0.26}$ MeV [1] is dominated by the result of the BES collaboration [2] which statistical analysis and uncertainty estimations were discussed in Refs. [3] and [4]. Thus, additional measurements are desirable to improve the mass accuracy and ensure future progress in the lepton universality tests.

The direct method of the τ mass determination is a study of the threshold behavior of the $\tau^+\tau^-$ production cross section in e^+e^- collisions as it was done in the experiments [5] and then [2]. The key question of such experiments is the precision of the beam energy determination. The important feature of the present work is an application of two independent methods of the beam energy measurement, while the previous experiments relied on the extrapolation based on the J/ψ and $\psi(2S)$ mesons as reference points.

The detailed description of the KEDR measurement of the τ mass is presented in [6] where the first 6.7 pb^{-1} of data have been analyzed. Below we remind the principal features of the VEPP-4M collider and the KEDR detector and present the preliminary result on the τ mass obtained using the full statistics of 15.2 pb^{-1}.

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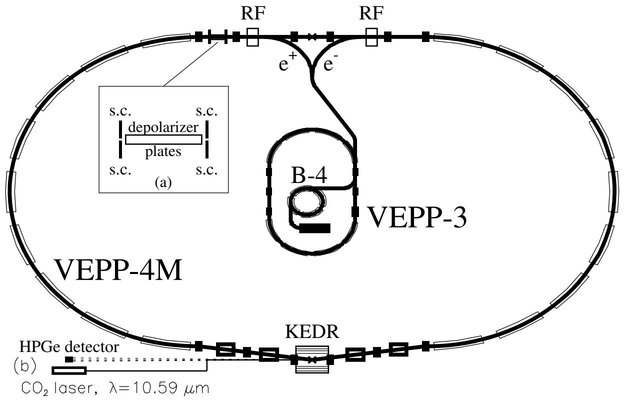

Figure 1. VEPP-4M accelerator complex in the energy calibration mode: (a) – Touschek polarimeter, (b) – Compton backscattering monitor.

2. VEPP-4M collider and KEDR detector

The VEPP-4M accelerator complex is presented schematically in Figure 1.

The VEPP-4M collider [7] has a circumference of 366 m and operates in a 2×2 bunches mode. The beam energy can vary in the range of 1÷6 GeV, the peak luminosity at $E_{beam} \approx 1.78$ GeV is about $2{\cdot}10^{30}$ $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (the τ production threshold).

Two different methods of the precise beam energy determination are implemented at VEPP-4M.

The first one is the resonant depolarization method [8] first applied for the ϕ mass measurement at VEPP-2 [9]. At VEPP-4M the accuracy of the instant energy calibration by the resonant depolarization is improved to about 10^{-6}. However, the depolarization results have to be interpolated on the data taking period as it was done in [10]. In the long term τ mass experiment the actual accuracy of the energy determination is $(0.5 \div 1.7) \cdot 10^{-5}$ (8÷30 keV).

The second method was developed at the BESSY-I and BESSY-II synchrotron radiation sources [11,12]. It employs the infrared light Compton backscattering and has worse precision (50÷70 keV at the τ threshold) but unlike the resonant depolarization, it can be used during the data taking.

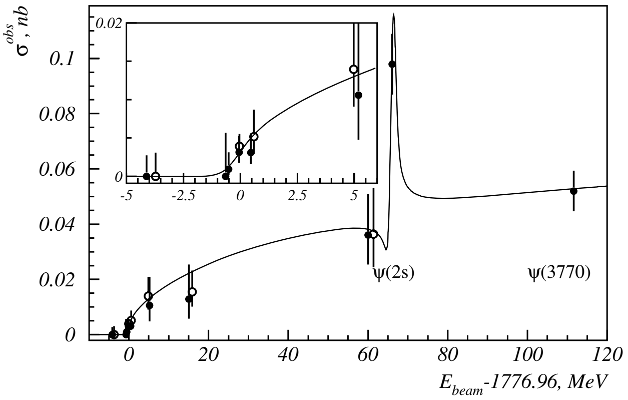

Figure 2. The measured cross section of $e^+e^- \to \tau^+\tau^-$ versus center-of-mass energy and the fit. Just for illustration the additional data points (open circles) are corrected to the difference of detection efficiencies and shifted in energy to avoid overlap.

The KEDR detector [13] is a classical type detector with the solenoidal magnetic field. It consists of a vertex detector, a drift chamber, aerogel Cherenkov counters, a liquid krypton calorimeter with the high spatial resolution in the barrel, CsI calorimeters in the endcaps, a time-of-flight system, a superconducting coil, a magnet yoke and a muon system inside it.

The longitudinal segmentation of the calorimeter provides good e/π identification used to select $\tau^+\tau^-$ events.

3. τ mass

To determine m_τ the full integrated luminosity of 15.2 pb^{-1} was collected at nine data points. The beam energy was varied from 1772 to 1889 MeV (see Figure 2). The first point at 1772 MeV containing 1.47 pb^{-1} of data is well below the threshold and is used to fix the background cross section σ_B. The next three points containing 7.46 pb^{-1} are in the vicinity of the threshold. They provide the main contribution to the mass determination. The last nonresonant points being well above the threshold are used to normalize the observed cross section and determine the detection efficiency ε. The data collected at the $\psi(2S)$ peak (about 0.8 pb^{-1}) were used to determine the product $\Gamma_{ee}\times\mathcal{B}(\psi(2S)\to\tau\tau)$ and to correct the cross section at the points at 1838 and 1889 MeV.

The two-prong $\tau^+\tau^-$ events were selected as described in the paper [6]. The number of events found in the vicinity of the threshold increased from 11 in [6] to 26. To take into account the difference in the detection efficiency between the old data and the new one collected in 2007, the additional parameter ε' was introduced in the fit.

The measured cross section and the five-parameter fit (σ_B, m_τ, ε, $\Gamma_{ee}\times\mathcal{B}(\psi(2S)\to\tau\tau)$ and ε') are shown in Figure 2. The fit gives

$$m_\tau = 1776.69^{+0.17}_{-0.19}\ \text{MeV}$$

and the background cross section is compatible with zero: $\sigma_B = 0^{+0.32}$ pb.

The conservative estimates of the systematic uncertainties are presented in Table 1. The detector related uncertainties still dominate.

Table 1
Estimates of systematic uncertainties of the τ mass.

Beam energy determination	35 keV
Detection efficiency variations	120 keV
Energy spread determination	20 keV
Background dependence on the beam energy	20 keV
Luminosity measurement instability	80 keV
Beam energy spread variation	10 keV
Cross section calculation (radiative corrections, $\psi(2S)$ interference)	30 keV
Sum in quadratures	150 keV

4. Conclusion

The τ–threshold experiment with the precise beam energy monitoring has been carried out at the VEPP-4M collider with the KEDR detector. The preliminary result on the τ lepton mass

$$m_\tau = 1776.69^{+0.17}_{-0.19} \pm 0.15\ \text{MeV}$$

agrees well with the world average [1]

$$m_\tau = 1776.99^{+0.29}_{-0.26}\ \text{MeV}$$

and with the recent result from BELLE [14]

$$m_\tau = 1776.61 \pm 0.13 \pm 0.35\ \text{MeV}$$

and also our result has better accuracy.

We plan to achieve accuracy of 0.15 MeV of the τ mass on completion of the data analysis.

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