POLARIZATION MEASUREMENT SYSTEM ON THE VEPP-4 COLLIDER AT LOW ENERGY RANGE[1]

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Abstract

For carrying out an experiment on a precision measurement of the tau-lepton mass near its production threshold of 1.8 GeV it is necessary exactly to know the energy of colliding particles. For measurement of beam energy a well known method of resonance depolarization with observation of a polarization degree on the effect of internal scattering of particles in a beam will be used.

For this purpose special systems including counters of scattered electrons and plates of the TEM wave depolarizer will be installed on the booster storage ring VEPP-3 and the collider VEPP-4M.

To control the measurement system we plan to use PC under Linux integrated into the VEPP-4 control system. Two CAMAC crates with recording units and CAMAC crate with the frequency synthesizer are connected to the PC. The step motors controlled via RS-485 regulate positions of the counters.

1 INTRODUCTION

The resonance depolarization method [1] for the particle energy calibration in storage rings is based on the measurement of the spin precession frequency Ω of beam electrons in the guiding magnetic field. The spin precession frequency in an ideal storage ring with flat orbits

$$\Omega = \omega_0(1 + \gamma\frac{\mu'}{\mu})$$

with ω_0 - the revolution frequency; μ', μ - anomalous and normal parts of the magnetic moment; γ - the relativistic factor to be determined.

The revolution frequency is known with a high accuracy, better than 10^{-6}. The value Ω is found by the resonance depolarization of the beam electrons.

2 SCHEME OF THE MEASUREMENTS

2.1 Polarization production

For the calibration of energy, the polarized electron beams are injected in the storage ring VEPP-4M from the booster storage ring VEPP-3 (see Fig. 1).

Radiation polarization of particles in VEPP-3 occurs with the characteristic time $\tau_p \approx 20$ minutes at the maximal energy of VEPP-3 E=2 GeV.
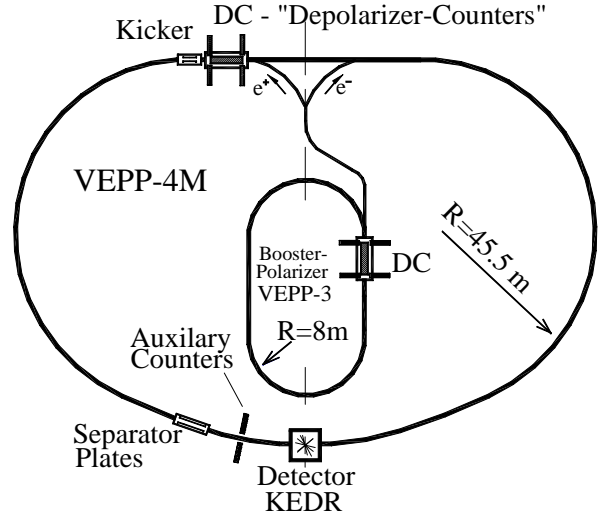

Figure 1: Layout of the VEPP-4 facility.

The peculiarities of obtaining the polarized beam in the VEPP-4M ring were described in [2].

Since the τ threshold stands in the vicinity of the intrinsic integer spin resonance $\gamma\mu'/\mu = 4$ (E ≈ 1763 Mev) the depolarizing effect of magnetic field imperfections in the storage ring is very strengthened at the energy of experiment.

Under these conditions the depolarization of the beam after its injection into VEPP-4M will occur during the spin relaxation time τ_r. The extent of depolarization is given by the factor $G = \tau_r/\tau_p < 1$, where τ_p is the polarization time for the ideal machine without any imperfections.

The value τ_p is quite great for the VEPP-4M near the τ threshold: $\tau_p \approx 85$ hours. By this reason even if with $G \ll 1$, the expected time τ_r may be comparable with the time of one beam run in the sufficient neighborhood of the τ threshold.

2.2 Mutual beam scattering polarimeter

The cross section of mutual scattering of electrons (Touschek effect) in the polarized beam is some less than in the unpolarized one. To observe the polarization one needs to depolarize the beam using an external spin resonanse and to detect the fact of depolarization by the jump in the counting rate of scattered beam particles [1].

The polarized beam is acted by an external oscillating e.m. field whose frequency is scanned. The polarimeter is needed to fix this frequency at the moment of polarization destruction.

Earlier, such a method was used in the measurements of the J/Psi- and Psi' mass at VEPP-4 [3].

To exclude the influence of changes in beam sizes, the closed orbit position as well as the beam lifetime dependence, the method of "two bunches" is applied. The value $1 - N_1/N_2$ is under observation, where N_1 and N_2 are respectively the counting rates of the polarized bunch and the unpolarized one spaced at one-half turn. Numbers of particles in the bunches must be equalized with an accuracy of a few percents.

Near the position of counters at a distance of $1 \div 1.5$ cm from the beam, the estimated counting rate makes up about 10 kHz with the jump of 3% at the beam current of ~ 4 mA in each bunch.

2.3 An accuracy of the measurement

The measurement accuracy was estimated in [2]. The expected value is about ~ 10^{-5}. The accuracy depends of many factors, such as the shift and broadening of the spin precession line by virtue of the guiding field non-linearities, the systematical shift of the spin precession frequency due to the influence of radial magnetic fields, et al.

3 MEASUREMENT SYSTEM

3.1 Depolarizer-Counters devices

The polarimeter devices "Depolarizer-Counters" are located on the booster storage ring VEPP-3 and the collider VEPP-4M (see Fig.1).

Each of them is based on a cylindrical section of vacuum chamber of length 830 mm. There is a pair of scintillation counters at the both ends of the section.

Counters of each pair can be moved from opposite sides of chamber into the aperture in the horizontal plane and register the Touschek electrons scattered at the most part of the ring.

The two matched striplines with the vertical gap of 60 mm are mounted inside of the polarimeter section to create the TEM wave. The power wide-band amplifier provides the amplitude of the voltage between striplines up to 400 Volts.

3.2 Scheme of counters

The two-fold/four-fold coincidence circuits are used to decrease the uncorrelated background influence. The circuit scheme is shown in Fig. 2.
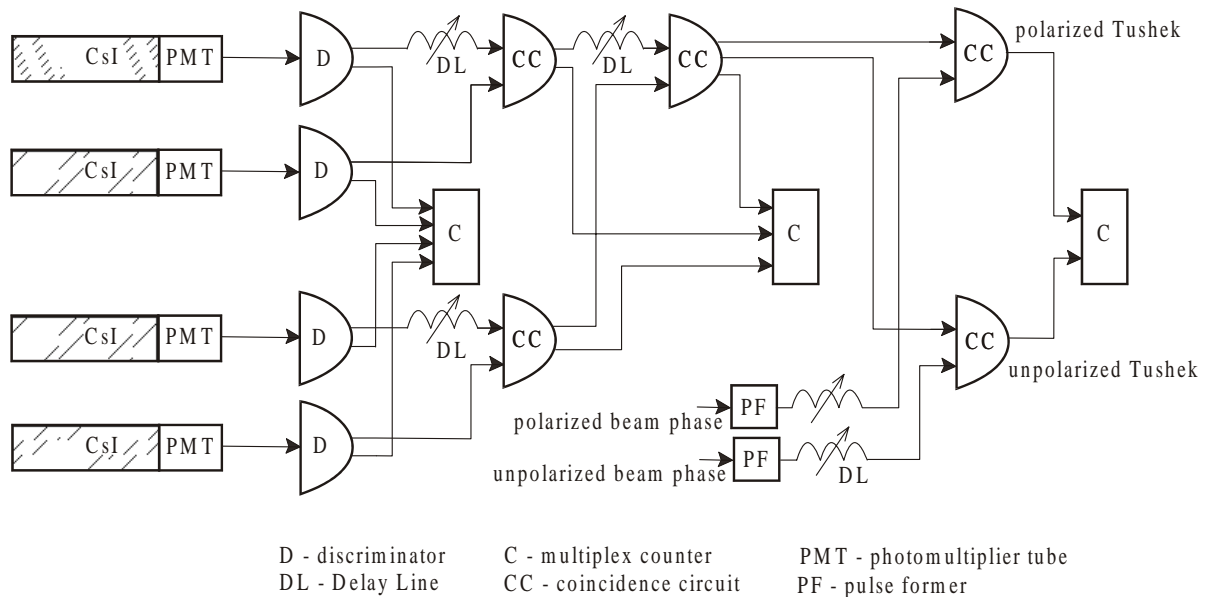

D - discriminator   C - multiplex counter   PMT - photomultiplier tube
DL - Delay Line   CC - coincidence circuit   PF - pulse former

Figure 2: The circuit scheme of counters.

3.3 Layout of the electronics

The current hardware configuration of the measuring system is depicted in Figure 3.

The system consists of one PC, three CAMAC crates, connected to the PC via special serial link, and 8 stepper-motor controllers, connected to the PC via RS-485 serial link.

The PC is physically located in the main control room. It provides the operator interface to the measuring system. The PC is integrated into the VEPP-4 control system.

All CAMAC crates are located in the radio control room. Two CAMAC crates include counter electronics, where all signals from counters are concentrated. One CAMAC crate includes the frequency synthesizer with

the minimal band width of $\Delta f_d \sim 1{-}10$ Hz and the rearrangement step of 1 Hz.

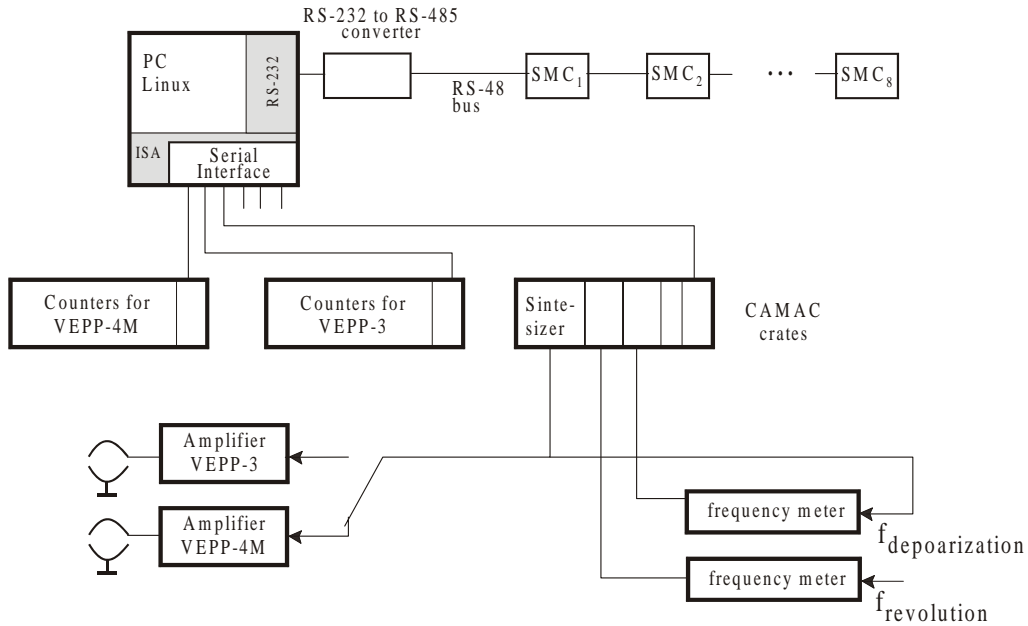The stepper-motor controllers are remotely located at the facility's two "Depolarizer-Counters" devices.

Figure 3: The layout of hardware.

3.4 Software

The software of the measurement system is based on ROOT package. The ROOT system was developed in CERN, and provides a set of frameworks with all the functionality needed to handle and analyze data in a very efficient way.

The software provides to control the frequency synthesizer, the stepper motors with window based tools, which prompts the operator to fill in the necessary values. Fields in the windows can be modified, and using values are displayed. The direction and moving of scintillation counters are controlled with arrows.

The operator can observe a visual representation of the data acquisition from the counters in different graphical windows, in which he can interactively process the data with curve fitting, minimization, graphics and visualization tools.

The software is linked with the VEPP-4 control system [4] for getting the status of the VEPP-3 and the VEPP-4M, the beam energy and the beam current values.

4 TEST RESULTS

We have tested the polarimeter system based on intra-beam scattering in the energy range of J/Psi peak using two auxiliary scintillation counters placed outside of the vacuum chamber (see Fig. 1). At this energy range depolarizing influence of the main intrinsic spin resonances is small at the VEPP-3 as well as at the VEPP-4M.

In spite of the low counting rate of ~100 Hz in this case, the accuracy achieved in the determination of the

depolarization frequencies (see Fig. 4) corresponds to the accuracy in energy of $\sim 10^{-5}$. The fact, that it is precisely the spin precession frequency, was sustained by the J/Psi peak position found with detector KEDR.
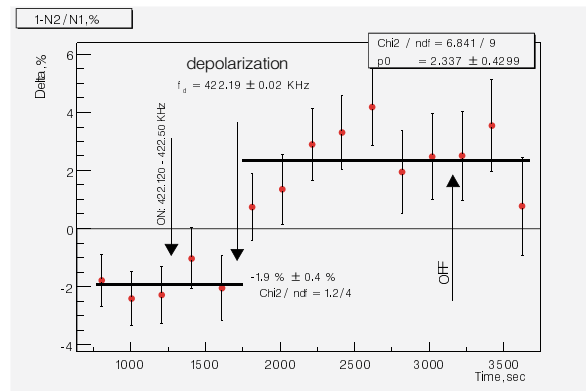
Figure 4: The observation of jump during one of the scanning of depolarizer frequency.

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