VEPP-4: APPLICATION BEYOND THE HIGH ENERGY PHYSICS

O.I. Meshkov (NSU, Novosibirsk, Russia) for the VEPP-4 team
BINP, Novosibirsk 630090, Russia

Abstract

The current status of the VEPP-4M electron-positron collider is described. During the fall of 2011 the accelerator was shut down because of the planned reconstruction of the KEDR detector. The next long run of the collider will be dedicated to the experiments in high energy physics within the range of 2-5 GeV.

Nevertheless, the experiments at booster VEPP-3 were continued. VEPP-3 operated as a SR source, besides, the experiment with internal target was performed and electron/positron scattering at proton was studied. The short runs of VEPP-4M were used both for commissioning of the new 3T wiggler that will be applied for SR experiments and for experiments with extracted electron beam. It was applied to test various high energy physics detectors.

The experiment on comparing of anomalous magnetic moment of electron and positron is being continued at VEPP-4M. The system of RF beam shifting is installed at the straight section of the accelerator. It is applied for elimination of parasitic interaction points of electron and positron beams. The first experiments with this system are described.

The KEDR detector reconstruction should be finished in the fall of 2013.The future experiments with the KEDR detector are discussed.

INTRODUCTION

Main parameters of VEPP-4M are given in Table 1. The layout of the complex is shown in Fig. 1.

Table 1: Main Parameters of VEPP-4M

Parameters	Values	Units
Circumference	366	m
Bending radius	34.5	m
Tunes Q_H/Q_V	8.54/7.58	
Mom. compaction	0.017	
Max. energy	5.5	GeV
Nat. chromaticity C_H/C_V	-13/-20	
RF-frequency	181.8	MHz
Harmonic number	222	
RF power	0.3	MW
RF voltage	5	MV
No. of bunches per beam	2	
Interaction point		
β_V function	0.05	m
β_H function	0.75	m
D_H function	0.80	m

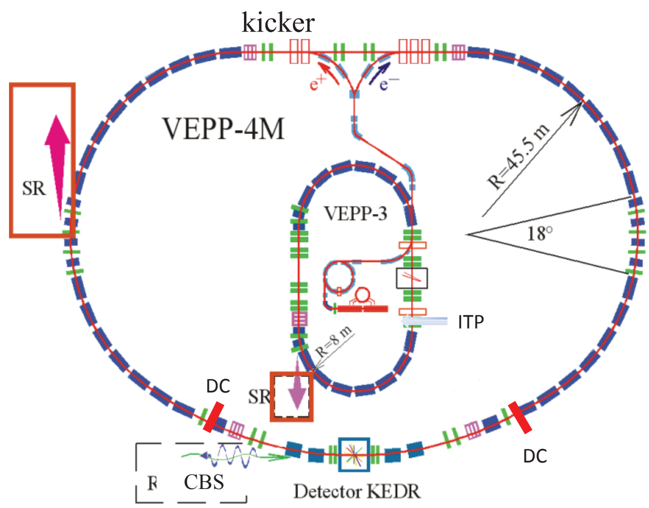

Figure 1: TheVEPP-4 layout with main HEP experimental set-up: detector KEDR, Compton backscattering (CBS) system, gas internal target (ITP), counters (DC) and kickers for precise polarization experiments.

Besides the particle physics there are other various experimental programs at VEPP-4 including studies with the synchrotron light, nuclear physics with polarized/unpolarized internal gas target, test beam of e^- or γ extracted from the vacuum chamber to the spectrometric equipment, etc.

NUCLEAR PHYSICS: DEUTRON EXPERIMENT AT VEPP-3

Nuclear physics experiments at VEPP-3 with internal gas target (proton or deuteron, polarized or unpolarized) have been carried out for many years [1]. Advantages of our installation include easy change of the beam energy, relatively high current (up to 150 mA of e^-), precise beam energy calibration (CBS technique is also applied at VEPP-3), use of e^+e^- beams in the same geometry (both rotate anti-clockwise).

Measurement of the ratio of cross-sections R of the elastic electron/positron scattering on a proton allows determination of the contribution of a two-photon exchange to this process. The necessity to take into account the two-photon exchange has been realized due to the contradiction in the results of measurements of proton electromagnetic form-factors.

In 2009 the measurement of R with the accuracy considerably exceeding the accuracy of the known world data

ISBN 978-3-95450-122-9

was performed at the storage ring VEPP-3. In 2011 the measurement of R in another kinematic area was started (Fig.2), this will allow us to double the achieved accuracy. These works were continued in 2012. By 1.04.2012 the planned integral of luminosity - over 100 kilocoulomb was obtained. Currently the experiment is finished and the collected data are under processing.

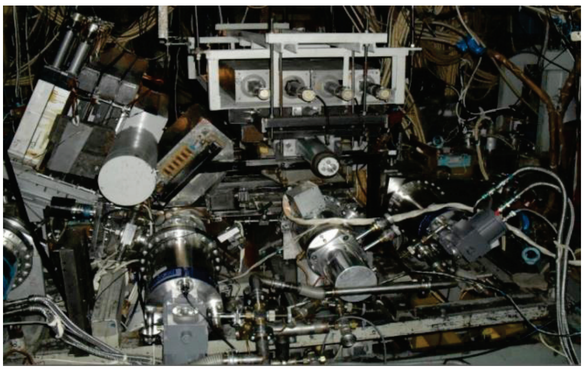

Figure 2: The DEUTRON experiment equipment at VEPP-3.

EXTRACTED TEST BEAM

Calibration of various systems of elementary particle detectors for the accelerators being under design and construction requires the beams of γ-quanta and electrons with certain properties. This type of beams are obtained at VEPP-4M via using the electron scattering either on the residual gas or on the tungsten converter specially inserted into the accelerator vacuum chamber. The produced secondary particles get to the equipped experimental hall through the collimator (Fig. 3). The design parameters of γ-quanta and electron beams are represented in Table 2.

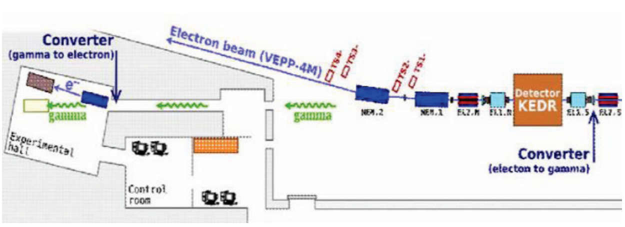

Figure 3: Test beam facility at VEPP-4M.

Table 2: Test Beams Parameters

	e^-	γ
E, GeV	0.1 ÷3.0	0.1 ÷3.0
$\frac{\sigma_E}{E}$**, %**	0.5 ÷5.0	~ 1
Intensity, Hz	10 ÷1000	1000
Resolution, mm	0.5	-

The applied experimental set-up allowed us, for the first time in Russia, to observe and measure the Cherenkov radiation focused by a four-layer aerogel with refraction index changing from layer to layer (Fig. 4).

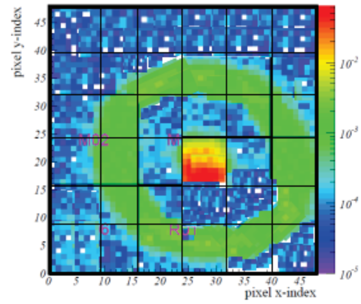

Figure 4: A Cherenkov-light ring observed at the VEPP-4M test beam facility.

Width of the focused Cherenkov-light ring (~1 mm) corresponds well to that theoretically predicted.

Besides, scintillating crystals for detector for the COMET experiment (JPark, Japan) were calibrated at the test beam bench in 2012.

Figure 5 represents the spectra of electrons separated from the extracted beam by bending magnet. The data are obtained with NaI calorimeter.

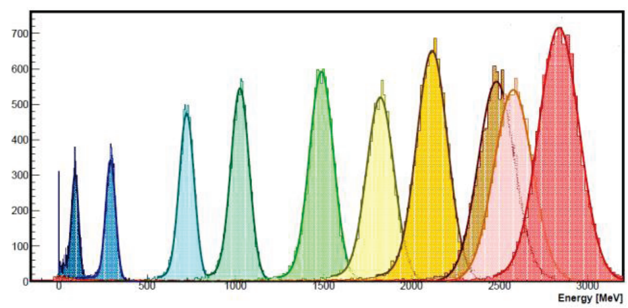

Figure 5: Spectra of electrons separated from the extracted beam.

SR EXPERIMENTS

Experiments with synchrotron radiation have been carried out at VEPP-3 for more than 30 years. Twelve stations are installed in the experimental hall providing study on X-ray lithography, high pressure and time resolving diffractometry, EXAFS, X-ray fluorescence analysis, X-ray microscopy, small-angle scattering, etc. For the details of numerous results we refer to [2].

Figure 6: Beamline "Detonation" at VEPP-4M.

Few years ago experiments in a new hall at VEPP-4M were started (Fig. 6). In 2011 a 7-pole electromagnetic wiggler was installed at VEPP-4M (Fig. 7) to enhance the radiation flux almost by one order of magnitude in comparison with the bending magnet radiation used before. As the wiggler magnetic field exceeds the field in the bend, the radiation wavelength decreases. These facts allow starting a new program on extremely fast time resolution experiments with different explosive materials.

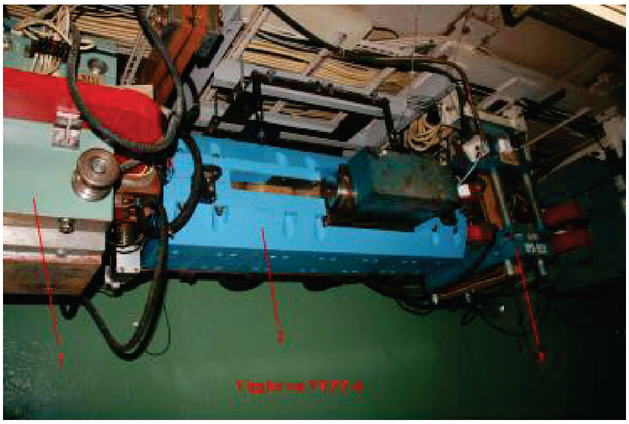

Figure 7: New wiggler installed at VEPP-4M.

PRECISE POLARIZATION EXPERIMENTS

A new system for extremely precise measurement of the beam polarization degree based on a Touschek electron pairs registration was recently applied at VEPP-4M. Number of counters installed in the ring vacuum chamber increases the registration efficiency by factor of 10 as compared to the previous set-up. The count rate for the scattered electrons is now 1.5 – 2.0 MHz for 2 mA beam current. An absolute record accuracy ($1.5 \cdot 10^{-9}$) of the measurement of depolarization frequency is achieved [3]. We hope that this possibility will open new horizons for the energy calibration experiments. Another interesting application is a search of CPT violation by comparison of the e^+/e^-spin precession frequency. Earlier such experiments were carried-out in BINP at the VEPP-4M collider and now we hope to improve the spin frequency resolution up to 10^{-8} .

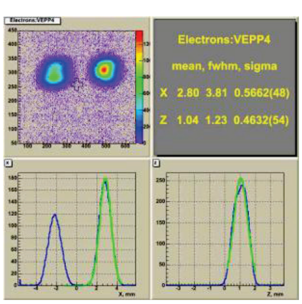

Figure 8: Separation of two electron bunches by means of RF-system, CCD-matrix data.

To eliminate the systematic errors in energy measurement, the solution of the problem of separating the beams in parasitic interaction points was required. The suggested method allows us to avoid using the systems of electrostatic separation of electron and positron orbits. The method is based on affecting the particle radial orbit by RF signal on the second subharmonic of revolution frequency. In this case electron and positron bunches run along the same orbit which is closed every two turns.

Bunches collide at the main interaction point, and at parasitic interaction point are always separated. The system for RF separation is installed in a technical area of VEPP-4M and is tested with electrons (Fig. 7).

FUTURE PLANS AND PROSPECTIVES

The HEP program at the collider VEPP-4M formulated for a decade in 2000 by the BINP scientific community is almost over. The last remaining item from that list is experiments with energy increase up to 4.5 GeV – 5 GeV, which relate to measurement of the hadron cross-section R in the wide energy range and $\gamma\gamma$-physics. We expect that this experiment will be completed in 2-3 years. The question arises: what kind of future studies can be carried out at our facility afterwards? The answer is not simple but one point is clear for us: experimental programs planning at VEPP-4M must be challenging, interesting and satisfy prospective demands of relevant scientific communities. Among them the following programs could be briefly mentioned:

Longitudinally polarized e^+e^- beams and HEP experiments with them. Future super-factories (SuperB in Japan, SuperCT in Novosibirsk, etc.) will essentially apply longitudinally polarized e^+e^- beams but the world experience on operation with such beams is very poor so production and study of longitudinally polarized electrons and positrons in circular colliders look rather attractive and actual. A strong point of the VEPP-4 complex is a possibility to polarize the beams in VEPP-3 in a reasonable time (~20-30 min). Longitudinally polarized beam can be obtained with spin rotator [4].

ACKNOWLEDGMENTS

This work is supported in part by the Ministry of Education and Science of the Russian Federation, RFBR (contract № 16.518.11.7003)

REFERENCES

[1] Nikolenko D. M. et. al., Phys Rev Lett. 2003 Feb 21;90(7):072501. Epub 2003 Feb 21.
[2] .Popov A. N. et. al.; Review of Scientific Instruments, Volume 60, issue 7 (July 1989), p. 2440.
[3] V. Blinov et al. ICFA Beam Dynamics Newsletter, No.48, April 2009, 207-217.
[4] S. A. Nikitin, E. L. Saldin. Preprint INP 81-19, 1981; Internal Report DESY L-Trans-290, April 1984.

ISBN 978-3-95450-122-9