XXVII Russian Particle Accelerator Conference (RuPAC-21),
September 26 – October 1, 2021, Alushta, Russia

VEPP-4M ELECTRON POSITRON COLLIDER OPERATION AT HIGH ENERGY

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VEPP-4

VEPP-4 team

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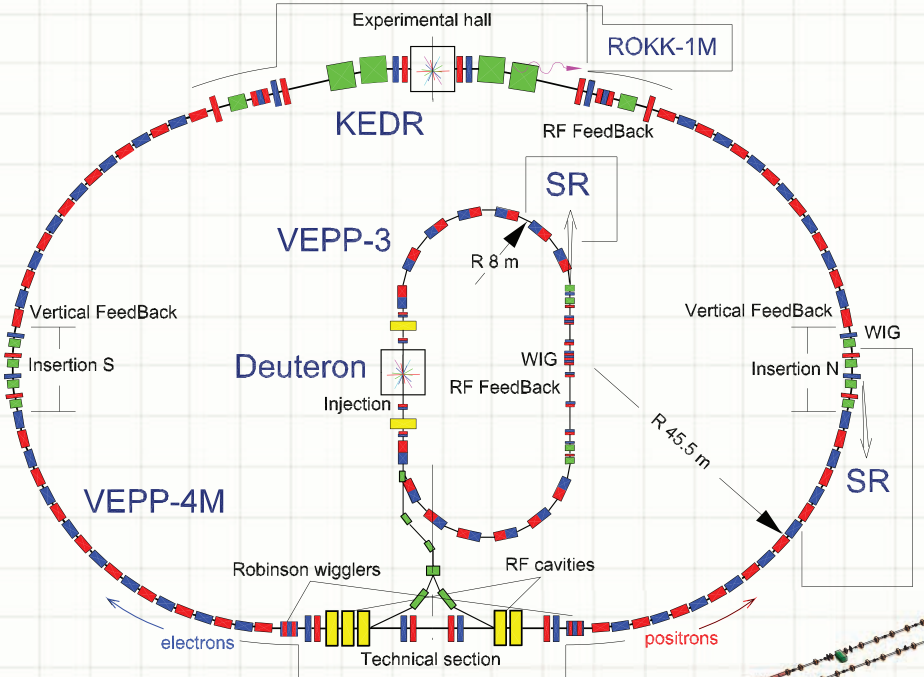
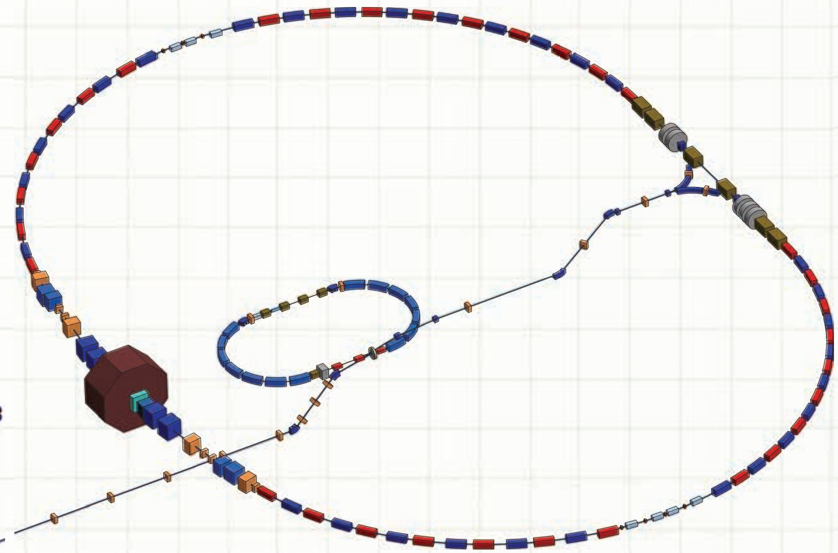
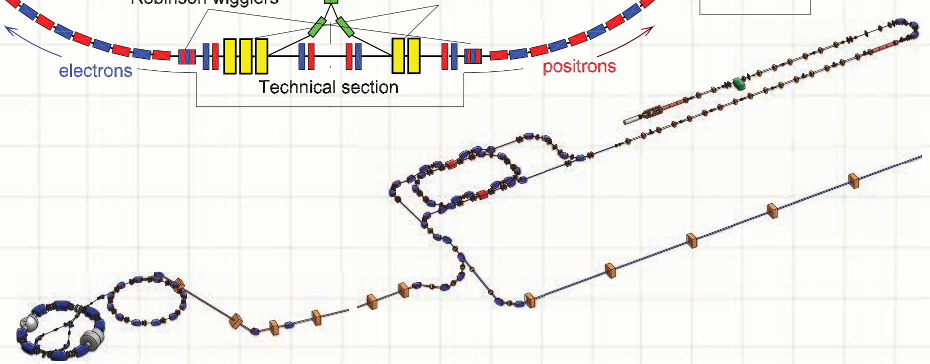
VEPP-4 facility



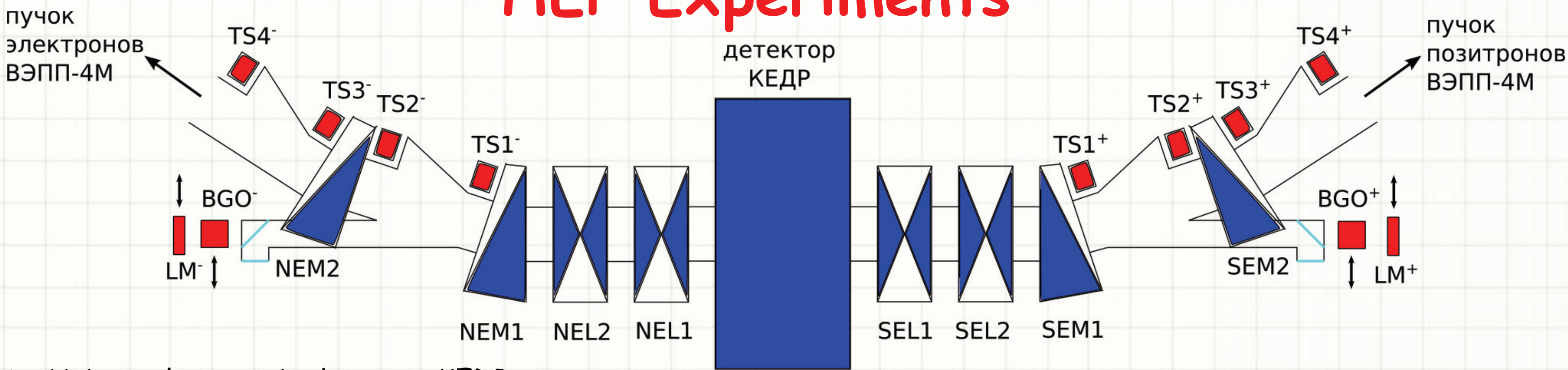




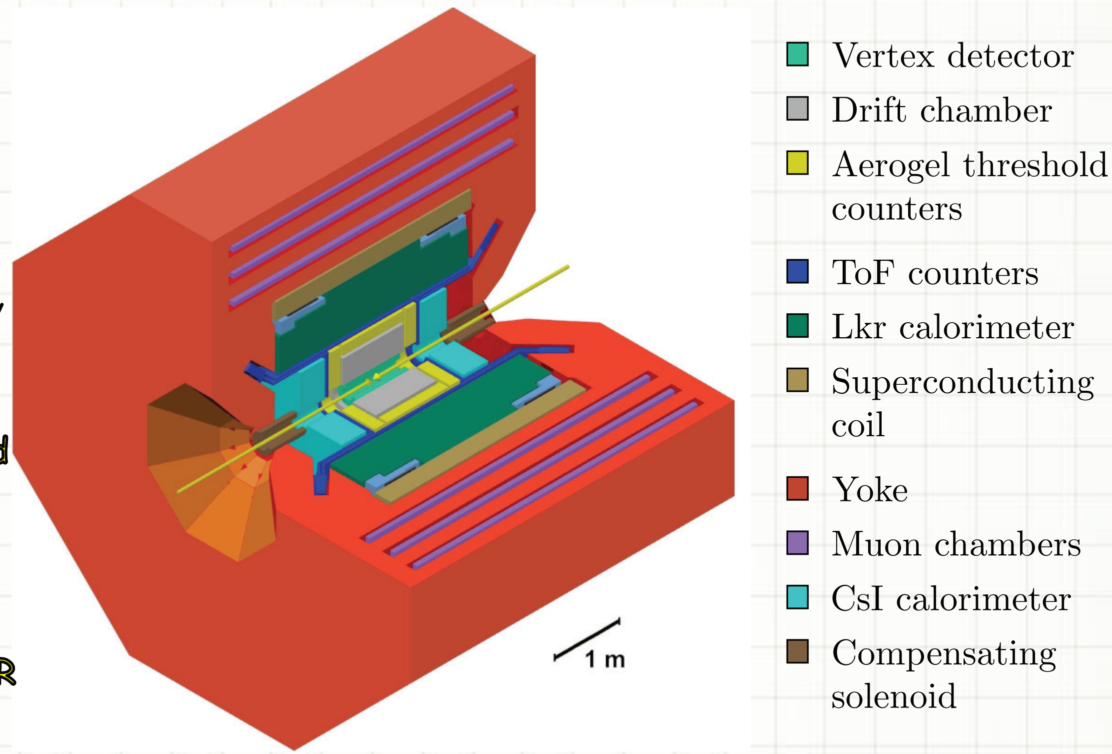
Energy	2.3	3.5	4.75	GeV
Betatron tunes		8.54/7.57		
Nat. chroms		–14/–20		
Comp. factor		0.0168		
Hor. emit.	42	100	180	nm·rad
Energy spread	3.7	6.5	7.5	$\cdot 10^{-4}$
Bunch length		4		cm
Beam	2x2	2x2	1x1→2x2	
Bunch current	6	9→12	9→12	mA
Luminosity	0.5	1.2→2.0	0.5→1.4	$\cdot 10^{31}$ cm^{-2} s^{-1}

- ★ High energy physics at VEPP-4M with detector KEDR
- ★ Synchrotron radiation at VEPP-3 & VEPP-4M
- ★ Nuclear physics at VEPP-3 with Deuteron facility
- ★ Test beam facility at VEPP-4M
- ★ Accelerator physics activity

HEP Experiments



- ★ Universal magnetic detector KEDR
- ★ Electron-positron tagging system
- ★ Wide energy range 0.9÷6 GeV
- ★ Energy spread control
- ★ Precision beam energy calibration by resonance depolarization
- ★ First collider with beam energy monitoring by Compton backscattering

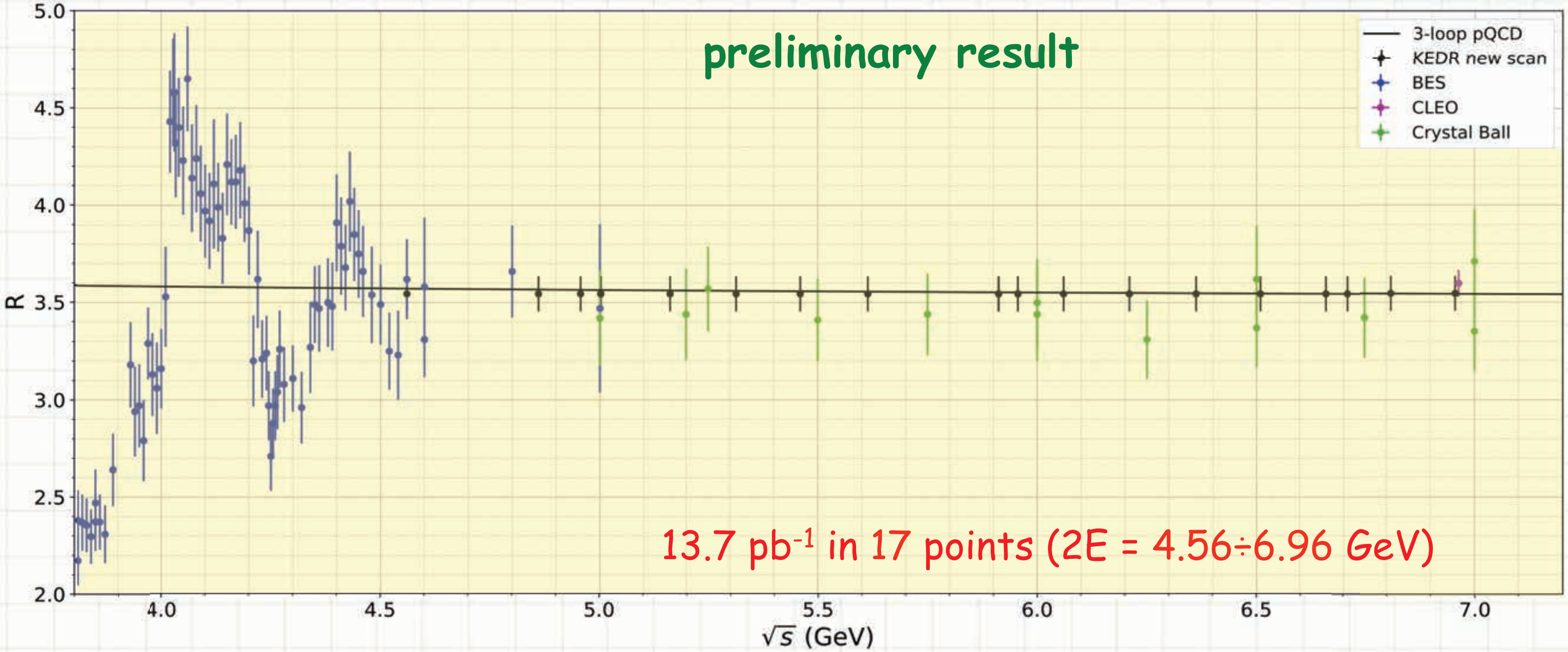


- ✓ J/ψ, ψ′ , ψ″, ψ(3770) meson masses **WR = World Record**
- ✓ τ lepton mass **WR**
- ✓ D^0 mesons masses
- ✓ $D^{\pm}$ mesons masses **WR**
- ✓ Search for narrow resonances 1.85÷3.1 GeV **WR**
- ✓ R-scan 1.85÷3.1 GeV **WR**
- ✓ Ruds- and R- scan 3.12÷3.72 GeV **WR**

From 2000 to 2018 HEP experiments at the VEPP-4M electron positron collider with the KEDR detector were carried out in the lower energy range from 0.9 to 1.9 GeV.

Hadron cross section scan from 2.3 to 3.5 GeV

Results of the experiments of R measurement in the energy range 2E=3.8-7.2 GeV with 13.7 pb^{-1} luminosity integral. KEDR R scan is shown by black points and fixed on pQCD (perturbative quantum chromodynamics) values. Errors correspond to expected statistical accuracy. Expected statistical accuracy ~ 2.5% will be best in the world.

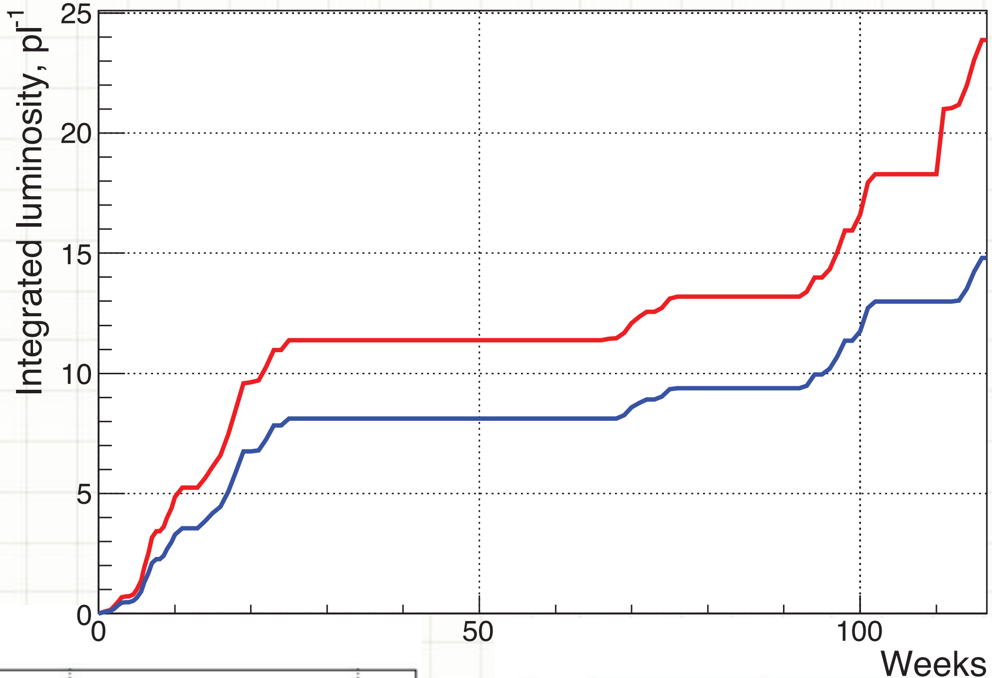


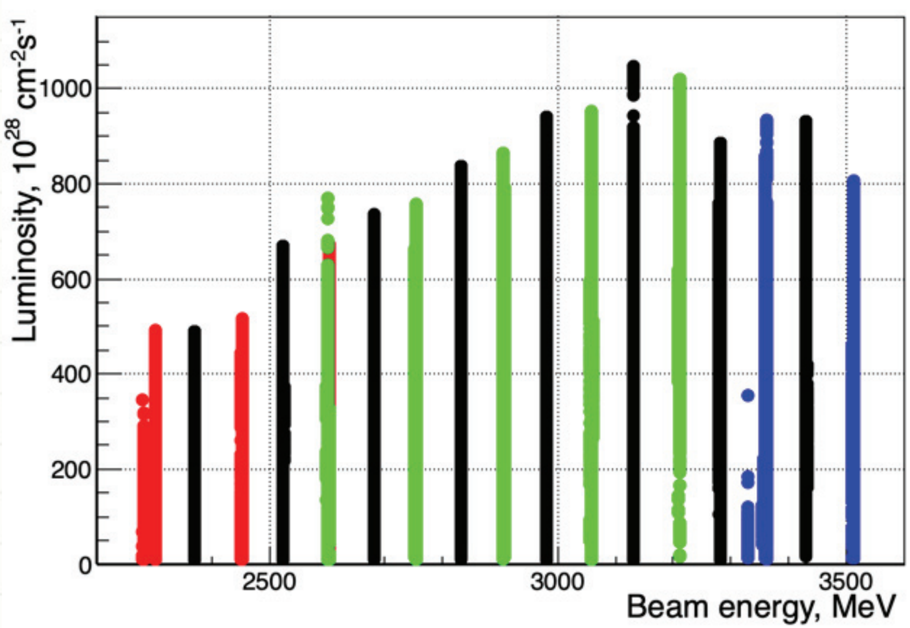
The R values are critical in various precision tests of the Standard Model. The energy region 4.6÷7 GeV, where KEDR data has been collected, gives small contribution to the anomalous magnetic moment of the muon, it is of about 1%.

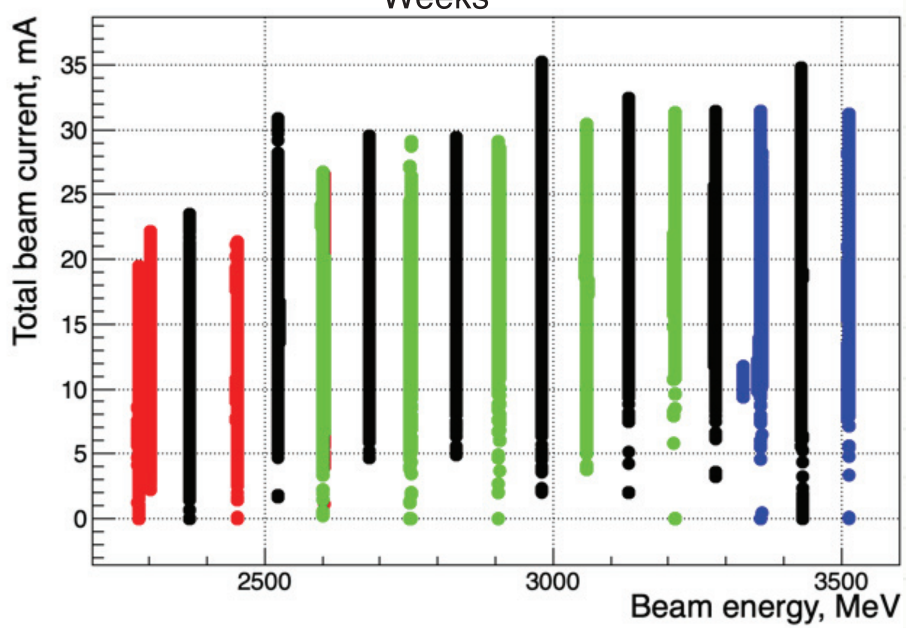
At the same time this energy range provides 10% into the hadronic contribution to the running the electromagnetic coupling constant $\alpha\left(M_Z^2\right)$ and the corresponding contribution of the uncertainty is about 15%.

In addition, when considering the energy region above 5.2 GeV and up to upsilon resonances, theoretical calculations based on pQCD are usually used. New measurements of KEDR will allow the use of experimental data up to 7 GeV.

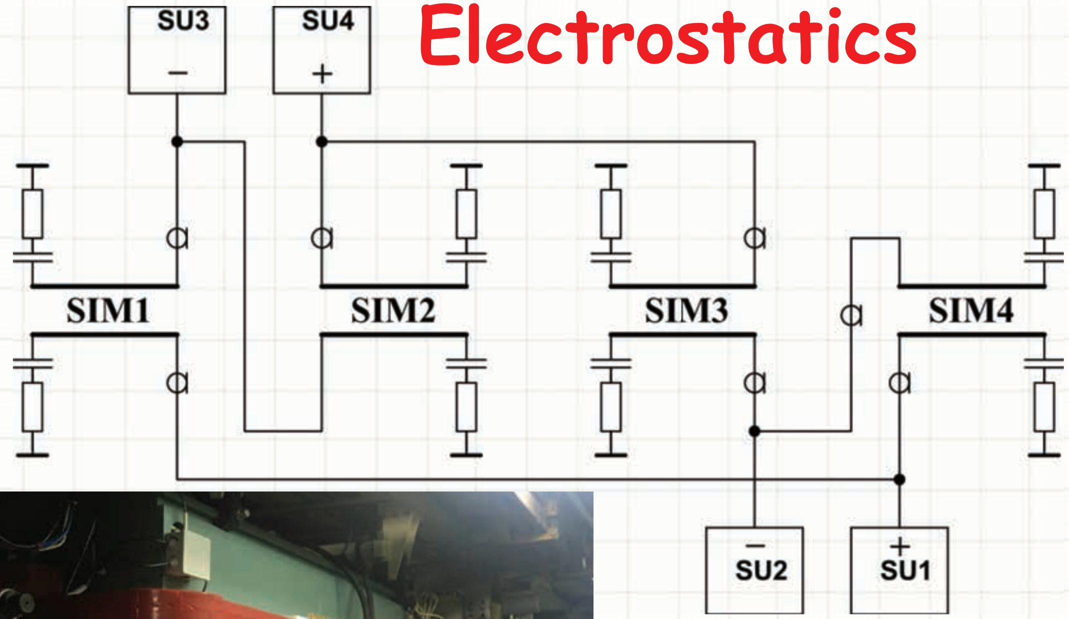
Hadron cross section scan from 2.3 to 3.5 GeV

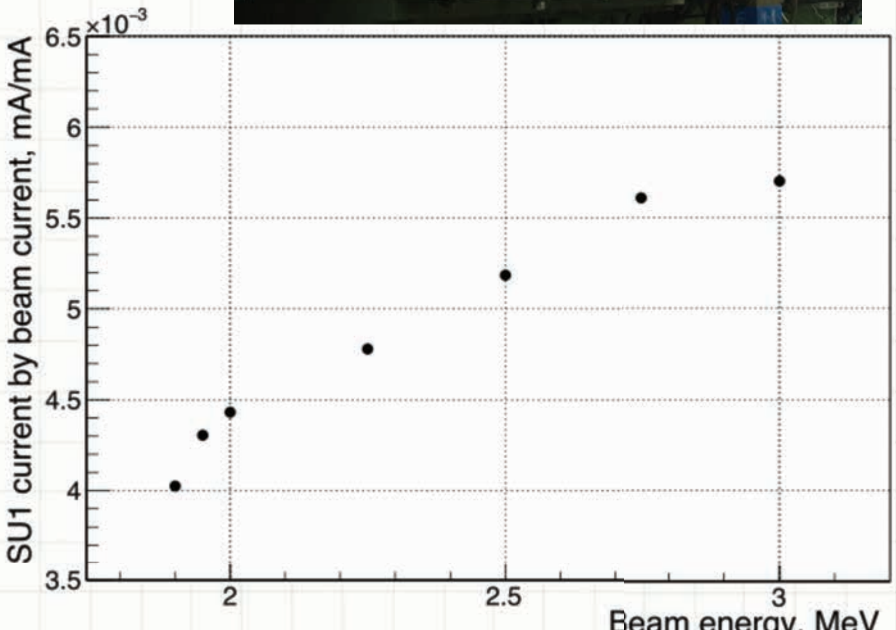


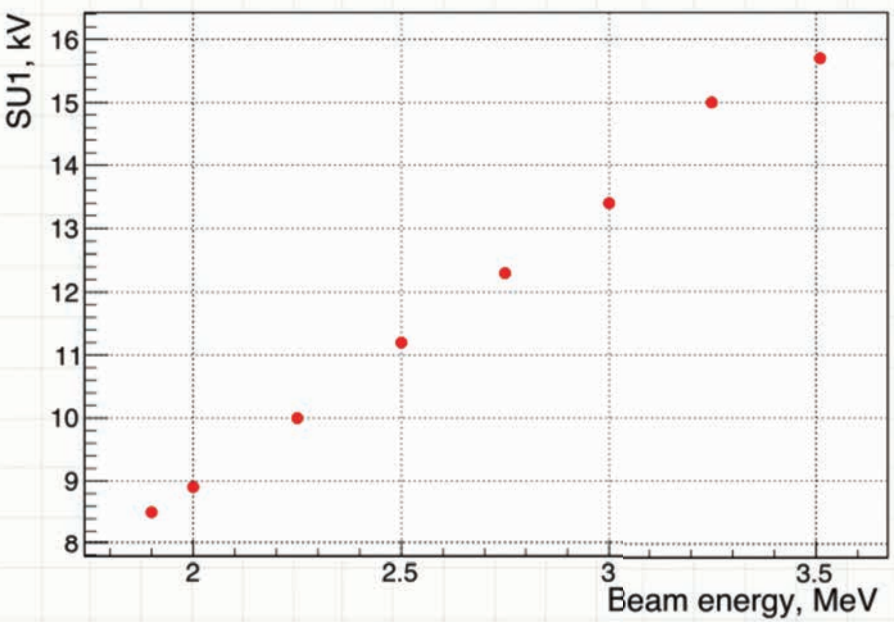




Electrostatics



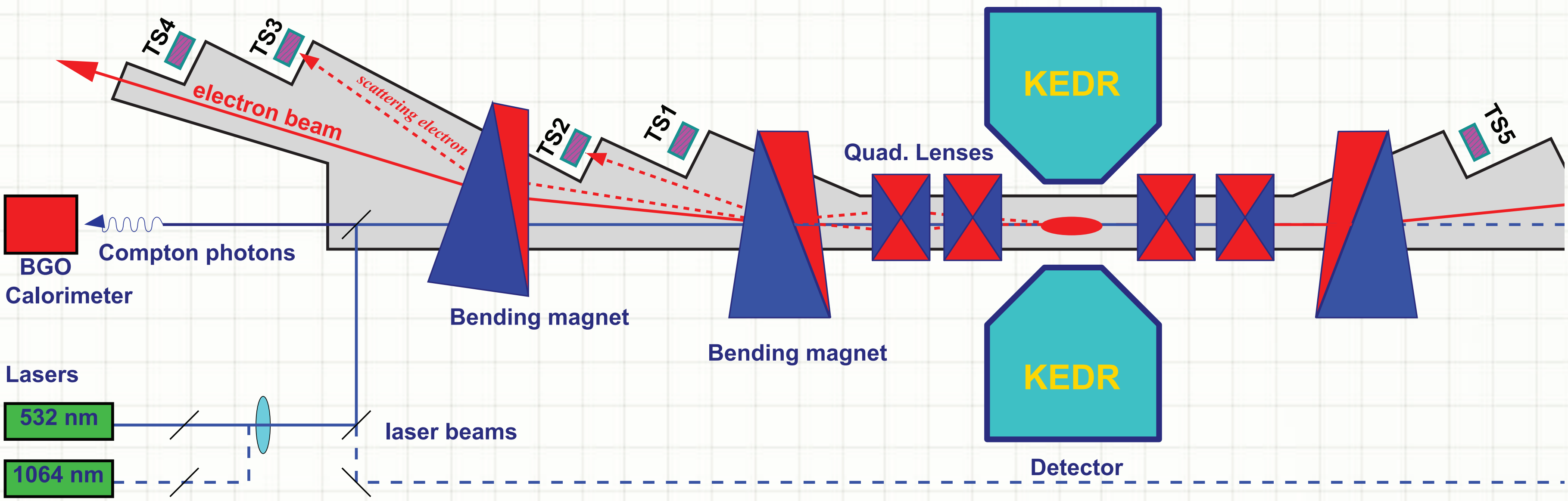




Gamma-gamma physics

In 2021 the luminosity run for gamma-gamma physics [2] was started. The main goal is the measurement of the cross section of gamma-gamma to hadrons.

The specific feature of the KEDR is the particle tagging system (TS). It allows registration of the scattered electron positron pair after two photons interaction. The first two quadrupoles and two special bending magnets of the collider form the focusing magnetic spectrometer. The scattered electrons or positrons with the energy loss from 0.02 to 0.6 of the beam energy are registered by one of the four modules of the TS. The module consists of six double layers of the drift tubes and the two-coordinate GEM detector in front of them.



The required luminosity integral for gamma-gamma is 200 pb^{-1}. The beam energy for this luminosity run is 3.5 GeV. We hope to achieve the maximum luminosity of VEPP-4M at this energy (~ $2\cdot10^{31}$ $cm^{-2}\cdot s^{-1}$). The luminosity acquisition scheme includes one background run with uncolliding beams for every seven signal runs. The beam energy measurement and the beam energy stability are not required.

Now the maximum peak luminosity is $1.2\cdot10^{31}$ $cm^{-2}\cdot s^{-1}$, the integral luminosity is 700 nb^{-1} per 12 hours and 1.4 pb^{-1} per a week. Now luminosity integral is 10 pb^{-1}.

Gamma-gamma physics

For the first stage we plan to collect $50 \div 100$ pb^{-1} at the energy range $3.5 \div 4.7$ GeV. With that we can:

- Provide the measurement of the total cross section for the process gamma-gamma → hadrons within the invariant mass range $1 \div 4$ GeV and study physical characteristics of events (multiplicity, spectra, etc).
- Study exclusive gamma-gamma processes at low invariant masses ($\lesssim 1$ GeV) which are approachless for B-factories due to the trigger conditions.

Based on the results of the first stage we will evaluate the possibility for the larger luminosity integral and further gamma-gamma investigations. In particular, the study of charmed resonances eta_c, chi_0,2, eta_ c(2S), etc.

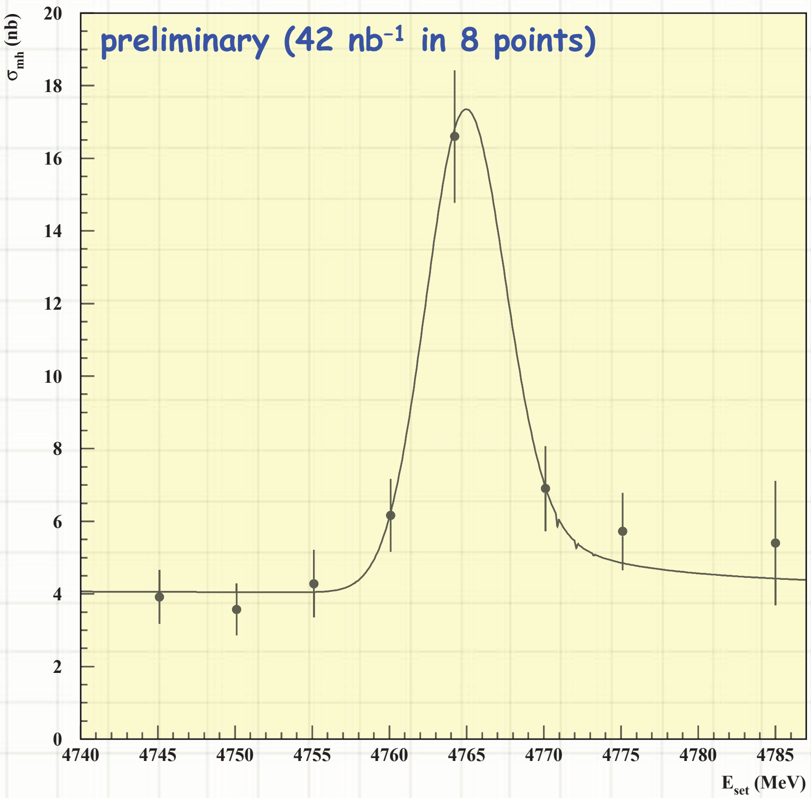
Υ(1S) meson scan
June 2021

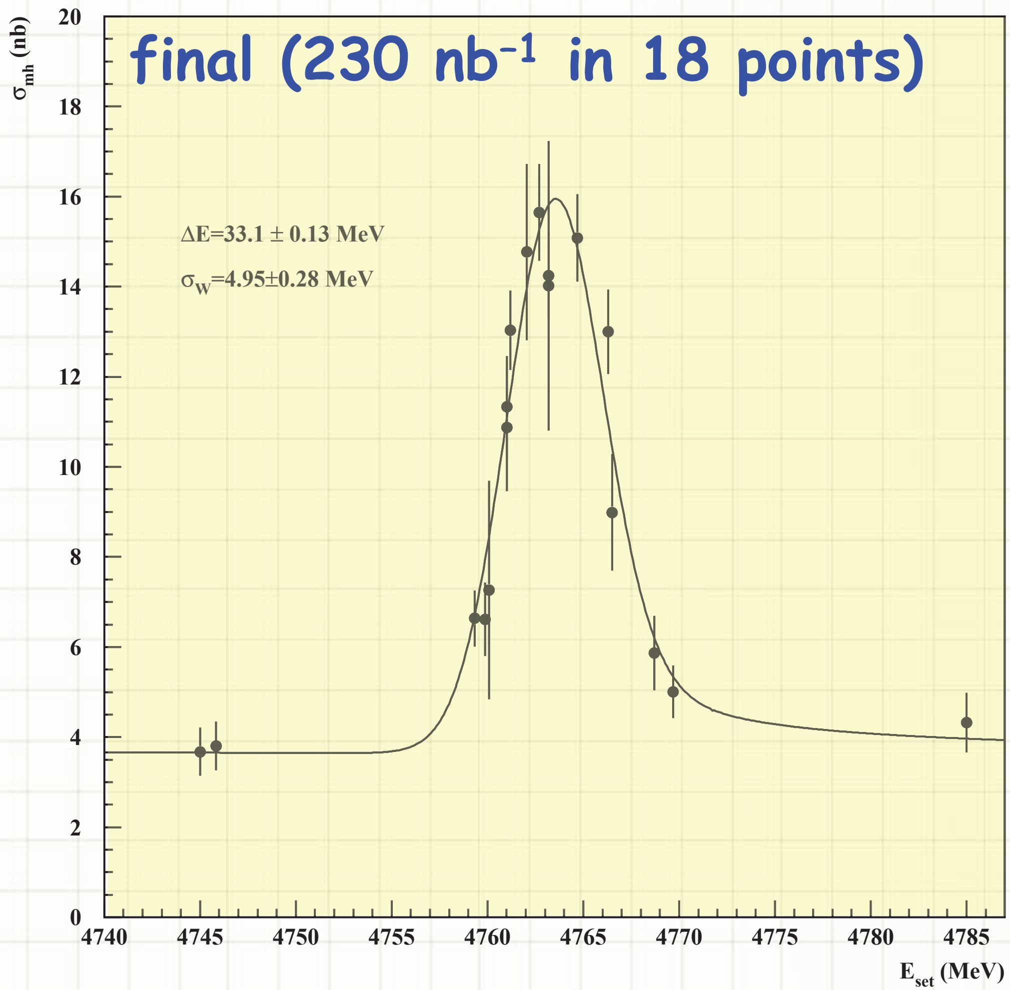
Υ(1S) pdg.lbl.gov $I^G(J^{PC}) = 0^-(1^{--})$

Υ(1S) MASS

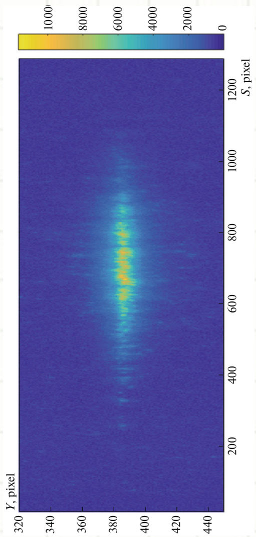
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
9460.30±0.26 OUR AVERAGE	Error includes scale factor of 3.3.			
9460.51±0.09±0.05	[1] ARTAMONOV	00	MD1	$e^+e^- \to$ hadrons
9459.97±0.11±0.07	MACKAY	84	REDE	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
9460.60±0.09±0.05	[2,3] BARU	92B	REDE	$e^+e^- \to$ hadrons
9460.59±0.12	BARU	86	REDE	$e^+e^- \to$ hadrons
9460.6 ±0.4	[3,4] ARTAMONOV	84	REDE	$e^+e^- \to$ hadrons

[1] Reanalysis of BARU 92B and ARTAMONOV 84 using new electron mass (COHEN 87).
[2] Superseding BARU 86.
[3] Superseded by ARTAMONOV 00.
[4] Value includes data of ARTAMONOV 82.





Beam energy spread measurement



ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2020, Vol. 17, No. 3, pp. 332–342. © Pleiades Publishing, Ltd., 2020.
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PHYSICS OF ELEMENTARY PARTICLES
AND ATOMIC NUCLEI. EXPERIMENT

Measurement of the VEPP-4M Collider Energy Spread in the Entire Energy Range

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Received December 1, 2019; revised December 16, 2019; accepted January 16, 2020

Abstract—The energy spread of the VEPP-4M electron–positron collider at the Budker Institute of Nuclear Physics was measured in the 1100–4750 MeV range (i.e., in the entire operating energy range of the collider) in two ways: based on the beam length and based on the envelope of betatron oscillations. The influence of the Touschek effect on this parameter was studied in the 1–1.5 GeV range. The results obtained using the two different methods agree well.

DOI: 10.1134/S1547477120030036

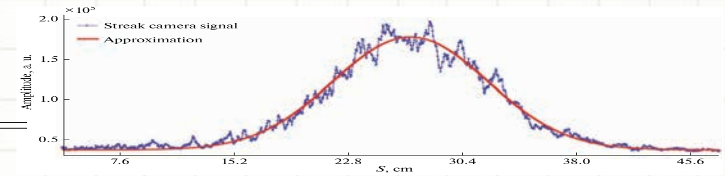


Fig. 3. Longitudinal beam profile. $E = 2.8$ GeV, $I = 0.3$ mA.

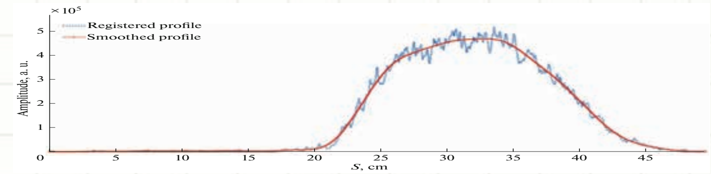


Fig. 4. Longitudinal beam profile. $E = 1.4$ GeV, $I = 2.6$ mA.

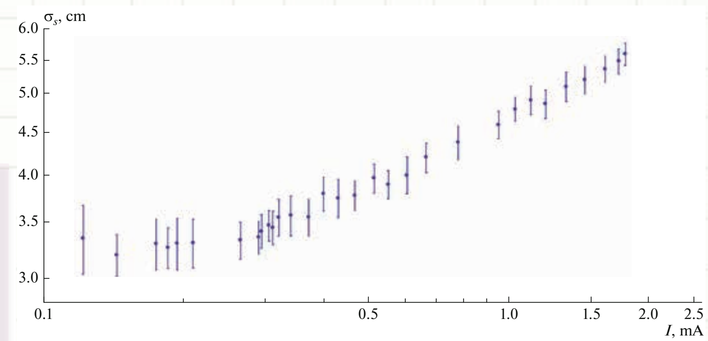


Fig. 5. Current dependence of the beam size. $E = 1.2$ GeV.

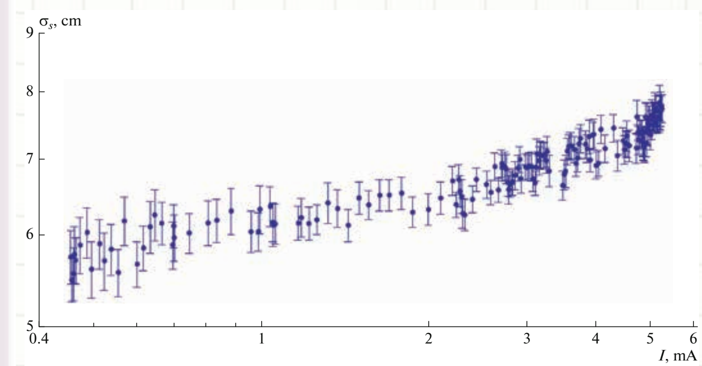
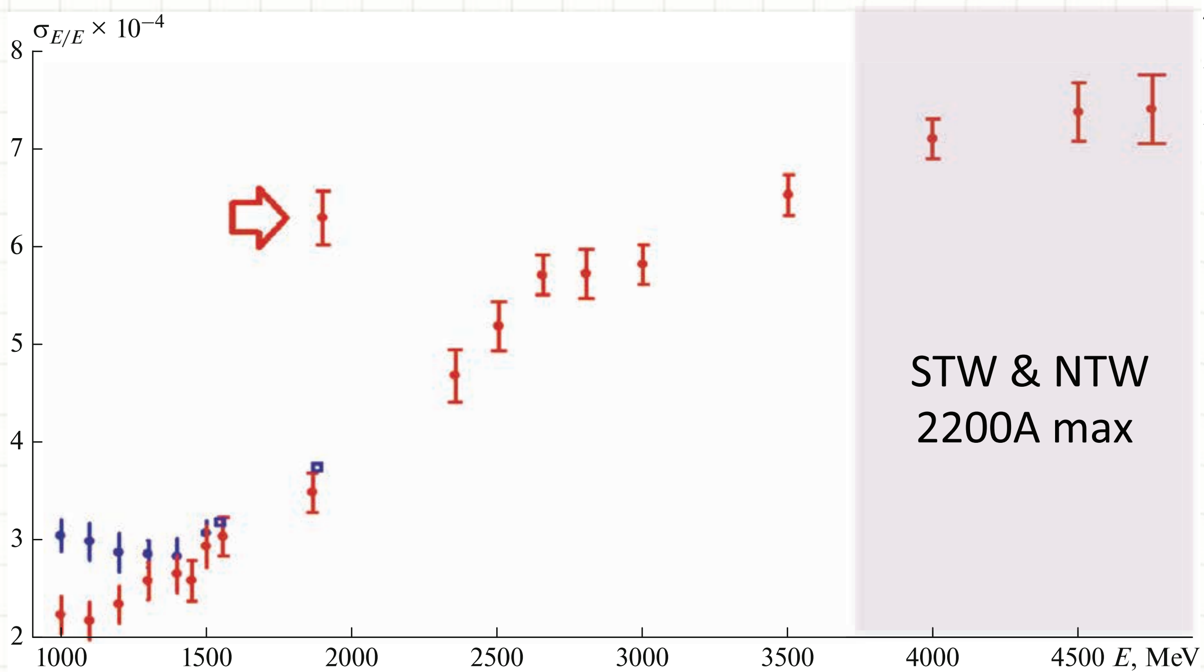
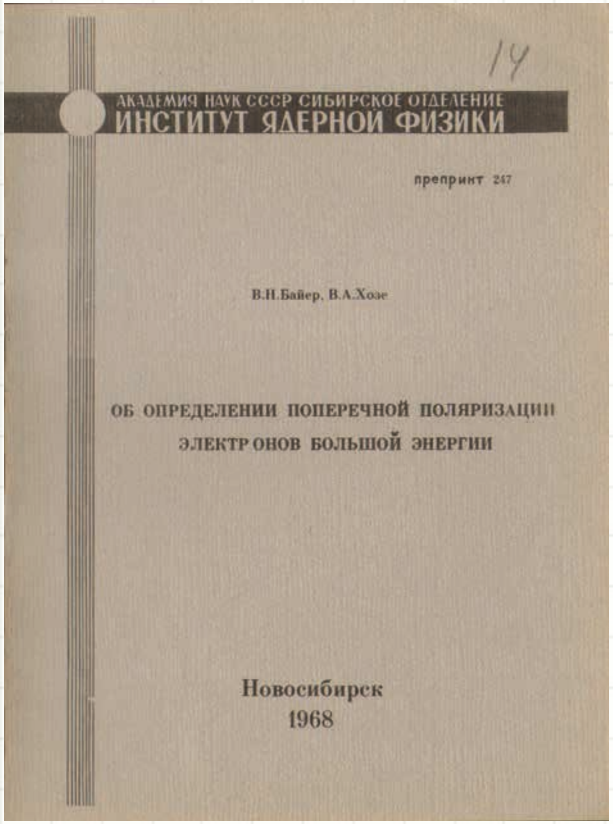


Fig. 6. Current dependence of the beam size. $E = 1.9$ GeV.



Beam energy measurement at high energy


14

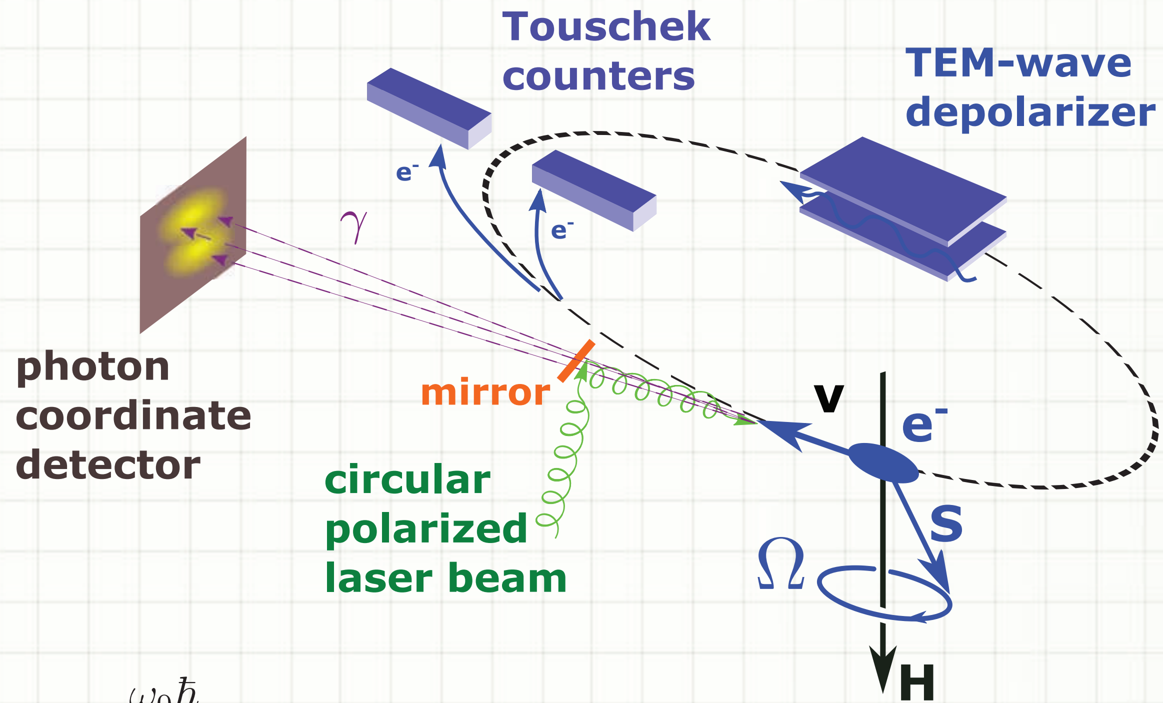
АКАДЕМИЯ НАУК СССР СИБИРСКОЕ ОТДЕЛЕНИЕ
ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ

препринт 247

В.Н.Байер, В.А.Хозе

ОБ ОПРЕДЕЛЕНИИ ПОПЕРЕЧНОЙ ПОЛЯРИЗАЦИИ ЭЛЕКТРОНОВ БОЛЬШОЙ ЭНЕРГИИ

Новосибирск
1968



$$\langle \Delta Y \rangle = \frac{\omega_0 \hbar}{2 m_e c^2} P L \Delta V \approx 0.1 mm \qquad (1)$$

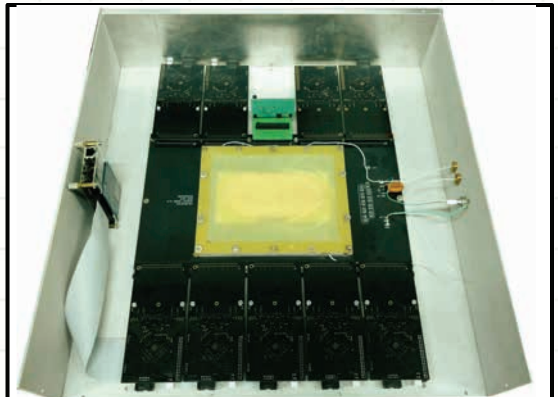
$\hbar\omega_0 = 2.35$ eV (527 nm) is the laser photon energy, m_e is the electron mass, P is the vertical polarization of electron beam, $\Delta V = V_{\rm left} - V_{\rm right} \approx 2$ is the difference in Stokes parameter of cirular (left/right) laser beam polarization. L is the flight length of γ-quanta

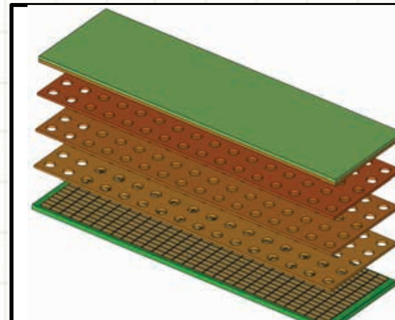
Spin precession and Resonance depolarization:

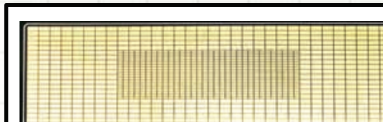
$$\Omega = \omega_{\rm rev}\left(1 + \frac{E}{m_e c^2}\frac{\mu'}{\mu_0}\right) = \omega_0 n \pm \omega_d \qquad (2)$$

Laser polarimeter

Two coordinate GEM detector
- Ar-CO2 mixture, 3.4 kV HV
- Sensitive area 128×40 mm^2
- Central area 64×20 mm^2 with 2x1 mm^2 pads
- Peripheral area with 4x2 mm^2 pads
- 10 front-end plates of electronics
- up to 4 kHz event rate


Detector view

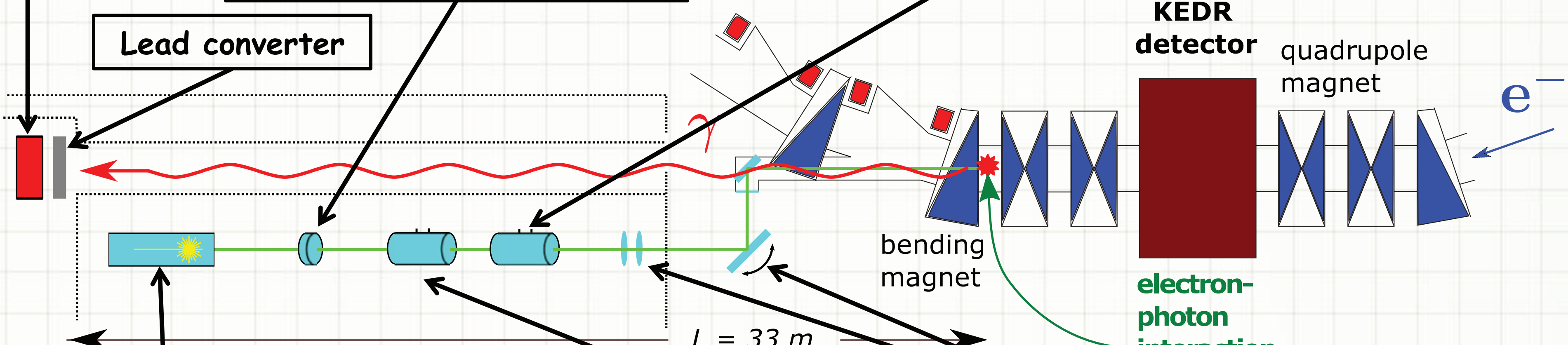

Triple Gas Electron Multipliers (GEM)


Readout pad structure

λ/4 phase plate
prepares circular polarization

Correction Pockels cell
compensates polarization degradation after reflecting on the air and vacuum mirror

Lead converter



Nd:YLF laser
- 527 nm wave length
- 2 W power
- 5 ns pulse duration
- 4 kHz pulse rate

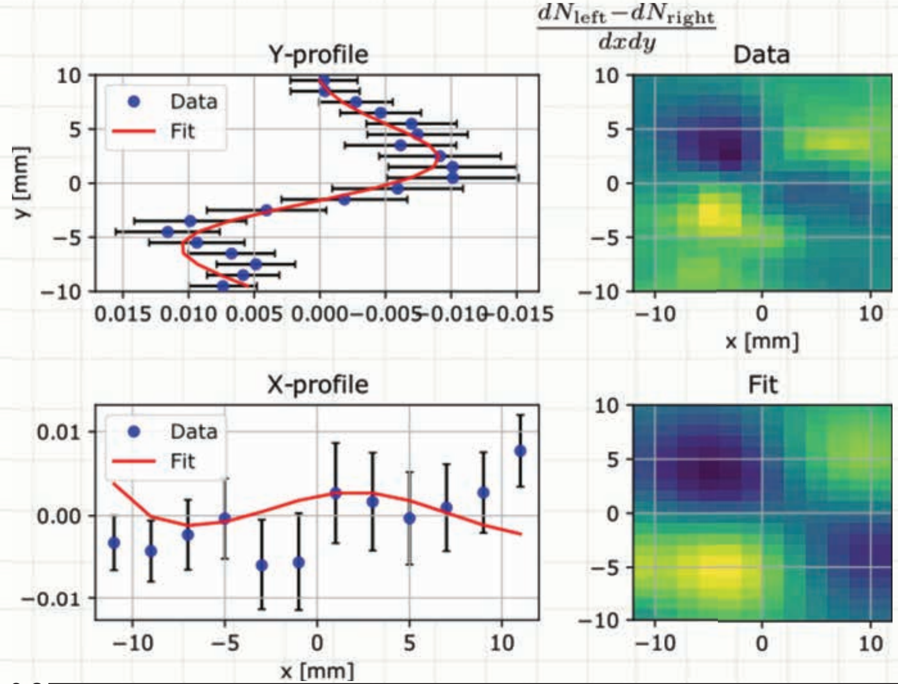
Main Pockels cell switch polarization from left to right
- 4 kHz switch rate
- random series of switching
- supress possible electron and laser beam orbit instabilities

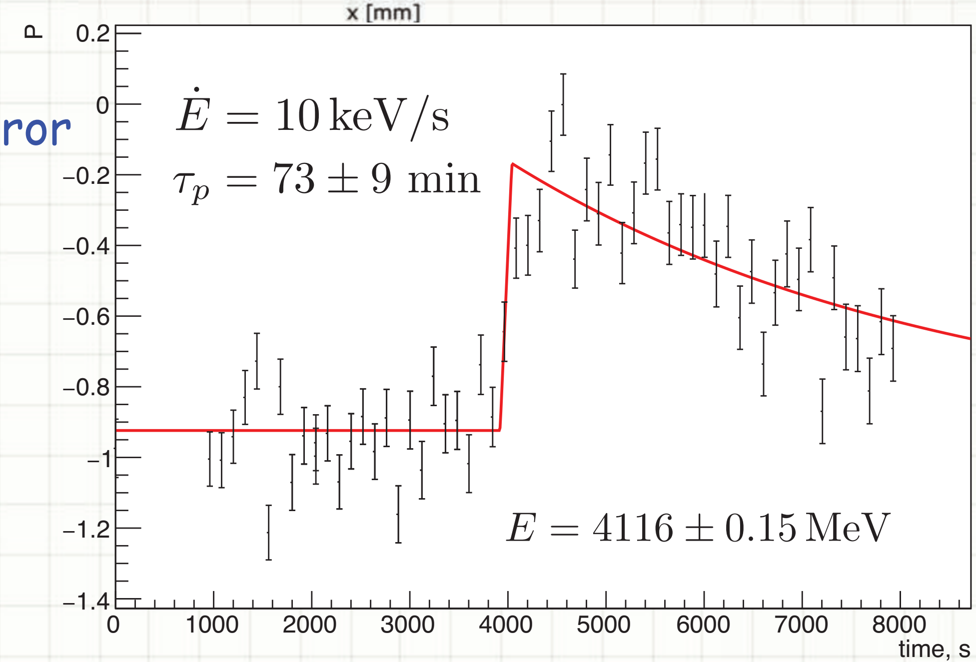
Expander and **Movable mirror** is focusing laser beam on the electron beam near close lenses where lower angular spread

Beam energy measurement @ 4.1 GeV

- ✓ 30 kHz event rate at 10 mA beam current with copper mirror
- ✓ Commissioning of the new detector
- ✓ Phase correction of laser beam by additional Pockels cell to compensate polarization degradation on mirrors
- ✓ New algorithm of the effect determination based on 2D fit
- ✓ Energy measurement at 4.1 GeV

- ✓ New water cooling vacuum copper mirror
- ✓ Noise suppression in detector electronics
- ✓ Polarization search and energy calibration at 4.7 GeV – Υ(1S)

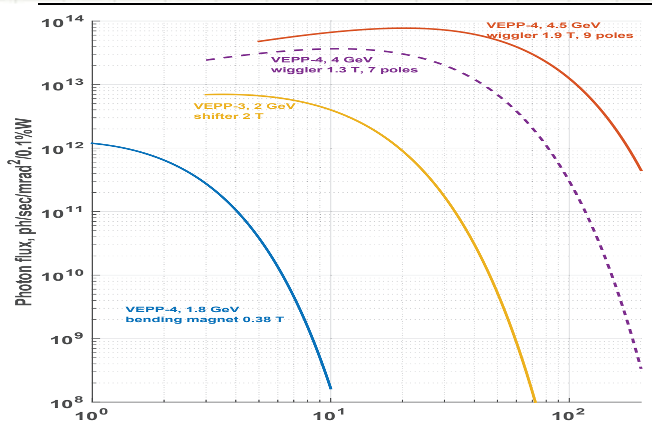


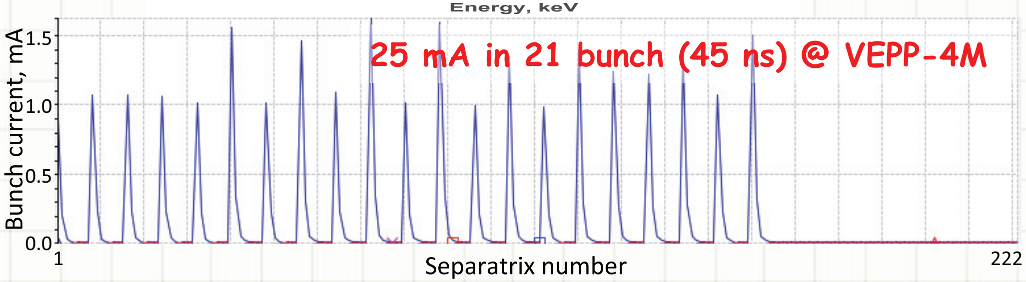


Synchrotron radiation

VEPP-3, 74 m		VEPP-4M, 366 m		
1.2 GeV	2 GeV	1.9 GeV	2.5 GeV	4.5 GeV
100 nm·rad	290 nm·rad	28 nm·rad	50 nm·rad	160 nm·rad
200 mA @ 1÷2 bunches		25 mA @ 1÷25 bunches		

1	LIGA-technology and X-ray lithography.	Metrology experiments.
2	Fast dynamic process.	Phase contrast microscopy, micro-tomography and hard X-ray fluorescence.
3	Precise diffraction and anomalous scattering.	Nanosecond spectroscopy of fast processes.
4	X-ray fluorescence analysis.	Material study under extremal conditions
5	High pressure diffraction.	Material study for thermonuclear applications
6	X-ray microscopy and micro-tomography.	
7	Time resolved diffraction.	
8	Time resolved luminescence.	
9	Precise diffraction.	





ISSN 1027-4510, Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques, 2020, Vol. 14, No. 1, pp. 150–154. © Pleiades Publishing, Ltd., 2020. Russian Text © The Author(s), 2020, published in Poverkhnost', 2020, No. 2, pp. 34–38.

Experiments with Synchrotron Radiation at the VEPP-4M

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Received May 25, 2019; revised June 10, 2019; accepted June 14, 2019

ISSN 1027-4510, Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques, 2020, Vol. 14, No. 6, pp. 1290–1293. © Pleiades Publishing, Ltd., 2020. Russian Text © The Author(s), 2020, published in Poverkhnost', 2020, No. 12, pp. 50–53.

Hybrid Nine-Pole Wiggler as a Source of "Hard" X-ray Radiation at the VEPP-4 Accelerator Complex

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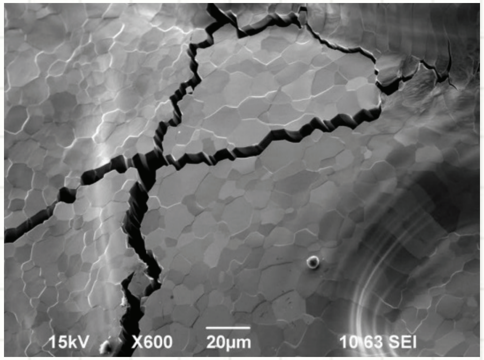
Received January 12, 2020; revised March 14, 2020; accepted March 17, 2020

Experiments using the hard X-ray range

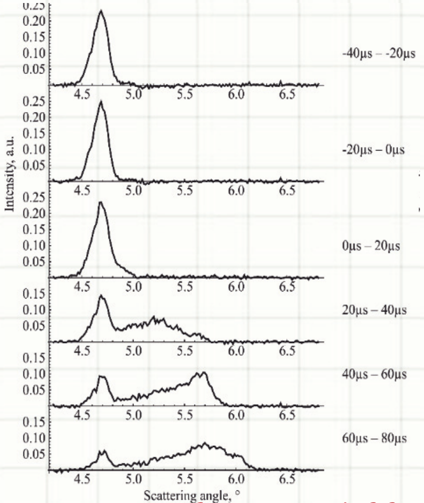
Investigation of the effect impulse heating on materials leading to deformation mechanical stress and mechanical destruction of materials.



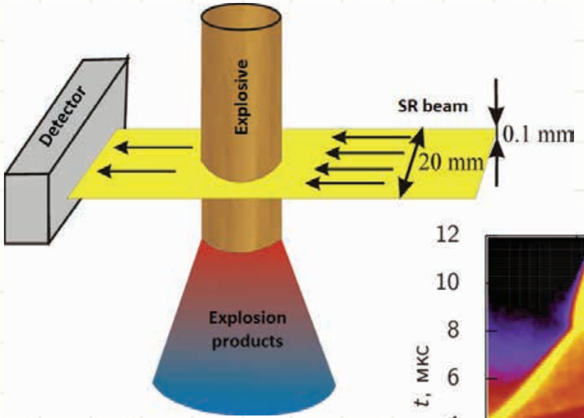
Cracks on tungsten after pulsed plasma loading.

High-speed temporal radiography of detonation processes

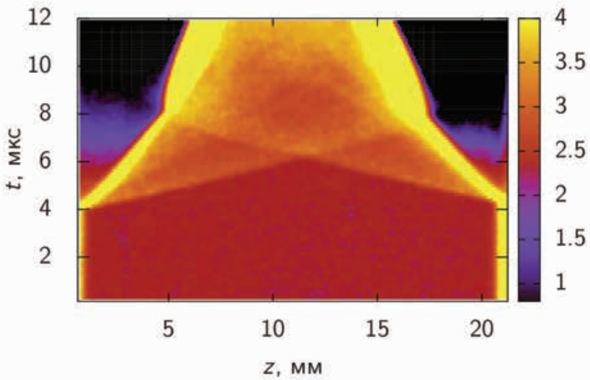
X-ray structural study of the phase transition and features of the formation of the microstructure during solidification metal alloys.

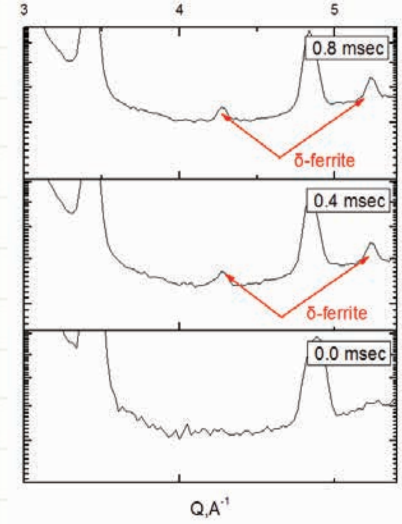


Dynamics of X-ray diffraction during pulsed heating of the tungsten structure.

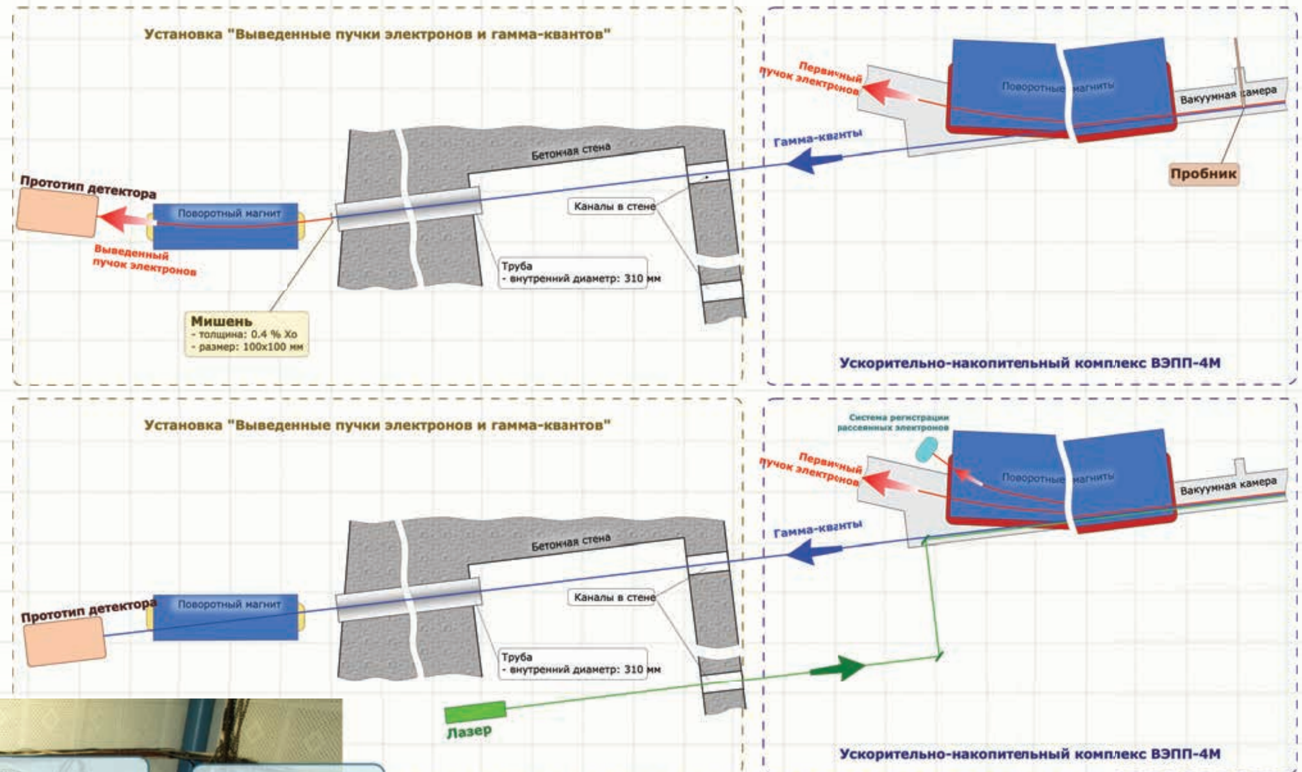


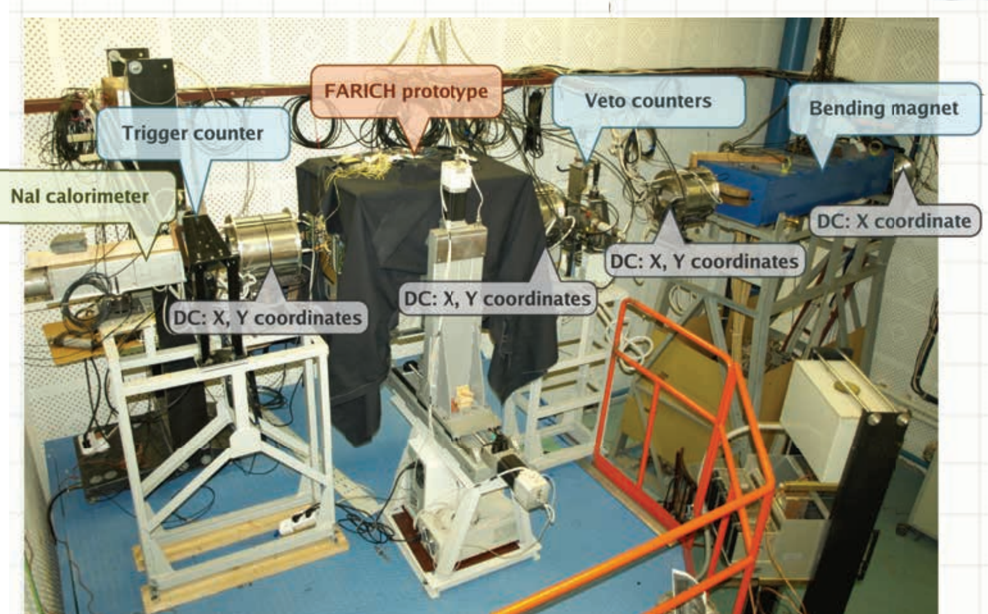
Converging shock wave in PMMA





Test beam facility





	electron	gamma	
Energy	0.1÷3	0.05÷1.5	GeV
$s_{DE/E}$	0.5÷1.5	~0.5	%
Intensity	10÷100	~1000	Hz

Beta functions measurement

ISSN 0020-4412, Instruments and Experimental Techniques, 2019, Vol. 62, No. 5, pp. 599–608. © Pleiades Publishing, Ltd., 2019.
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NUCLEAR EXPERIMENTAL TECHNIQUE

The Coherent Particle-Oscillation Excitation System at the VEPP-4M Collider

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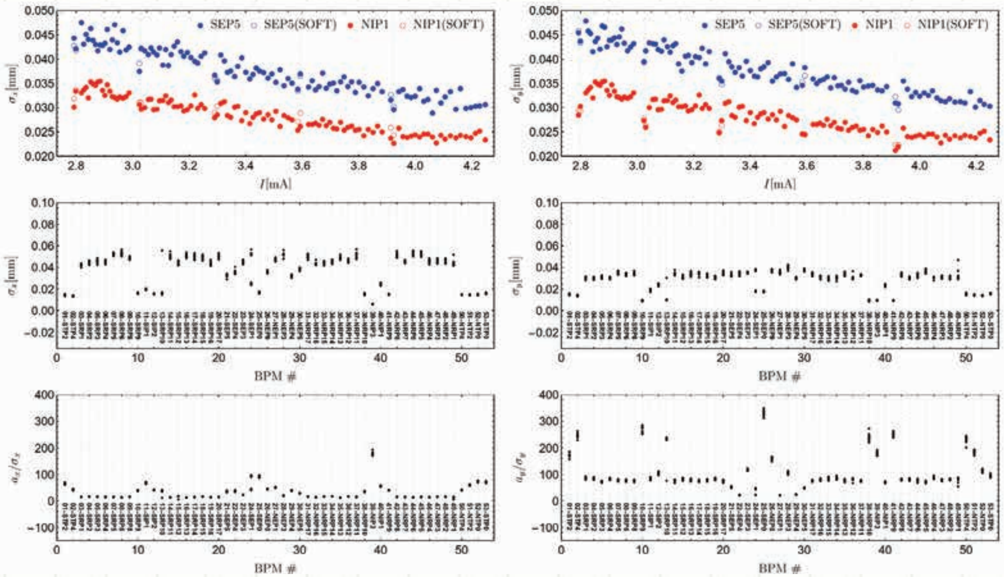
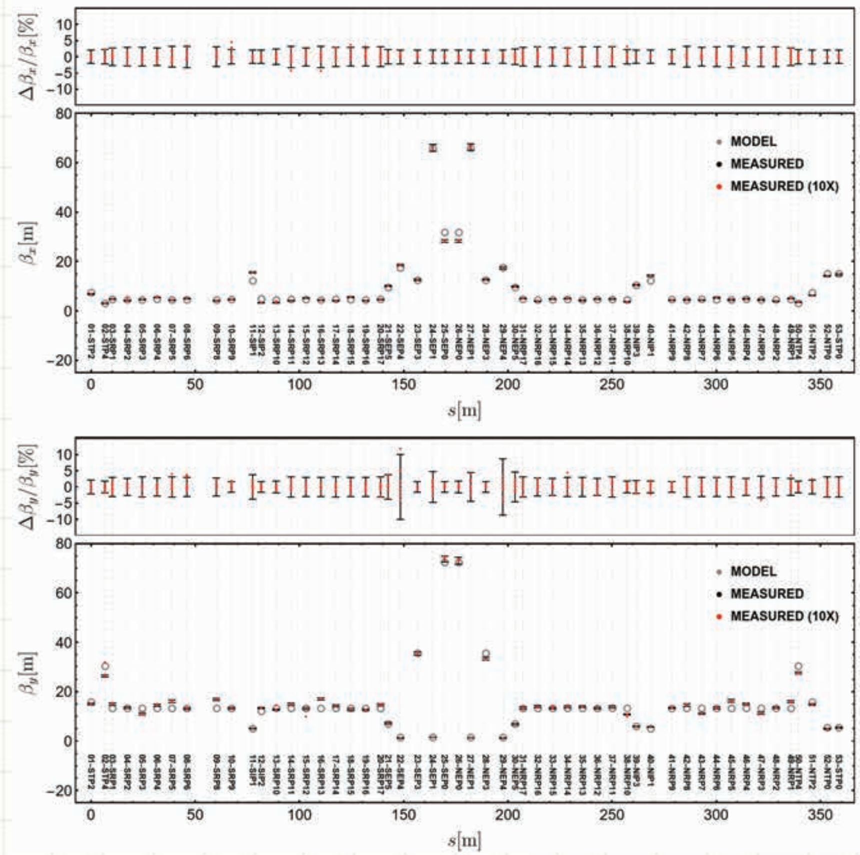
Received February 27, 2019; revised February 27, 2019; accepted March 24, 2019



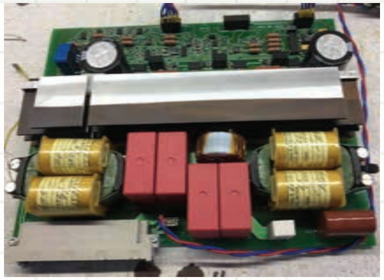


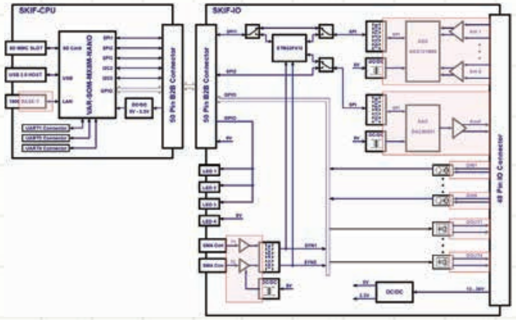
WED04 Oral talk „Precise analysis of beam optics in VEPP-4M by turn-by-turn betatron phase advance measurement" by Ivan Morozov (BINP SB RAN), 13:40 September 29, 2021, Wednesday

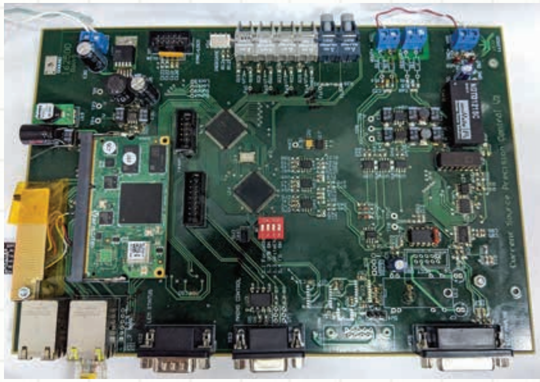
WEPSC40 Poster "Detection of Anomaly BPM Signals at VEPP-4M" by Ivan Morozov (BINP SB RAN), Poster session C at Wednesday

Upgrade

- ✓ Beam diagnostics upgrade has been completed
- ✓ RF system upgrade has been completed
- ✓ VEPP-3 & VEPP-4M main power supplies (PS) has no been finished
- ✓ Electrostatic separation system has being continuing
- ✓ Transfer feedback system has being developed
- ✓ Upgrade of 25A PS was started
- ✓ New ethernet processor for PS has being considered
- ✓ EPICS Control system has being developed







Conclusion

- ✓ VEPP-4M + KEDR HEP experiments at high energy were started
- ✓ Luminosity data for R-scan (2.3÷3.5 GeV beam energy) has been collected
- ✓ Gamma-gamma experiment at 3.5 GeV is continuing (10 of 200 pb^{-1})
- ✓ First luminosity run for Y(1S) meson 4.75 GeV has been finished successfully
- ✓ Beam energy spread measurement from 1 to 4.75 GeV has been made
- ✓ Laser polarimeter for absolute beam energy calibration with resonance depolarization method has being developed
- ✓ Radiate polarization and depolarization of electron beam at 4.1 GeV has been obtained
- ✓ Synchrotron radiation runs have been performed periodically (2 week per 2 month)
- ✓ Methods of optics measurement & correction has being developed
- ✓ Beam dynamics experiments are carried out
- ✓ Hard & Soft of facility has being upgraded

Thank you for your attention

VEPP-4