Budker Institute of Nuclear Physics, Novosibirsk

The VEPP-4M lab http://v4.inp.nsk.su

VEPP-4M

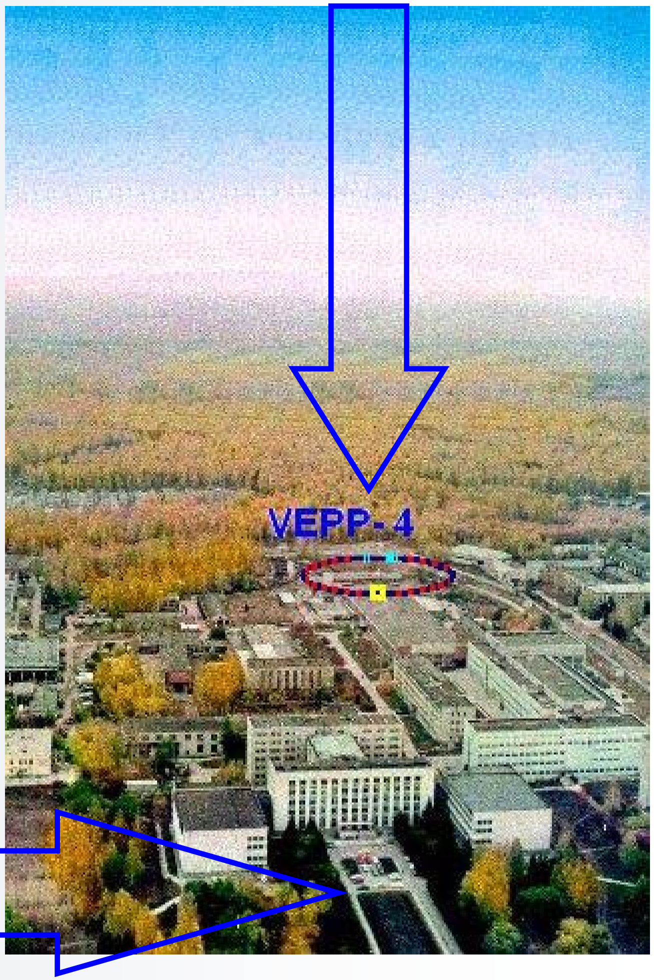
Status of VEPP-4M Collider at BINP

V. Smaluk, for the VEPP-4 team

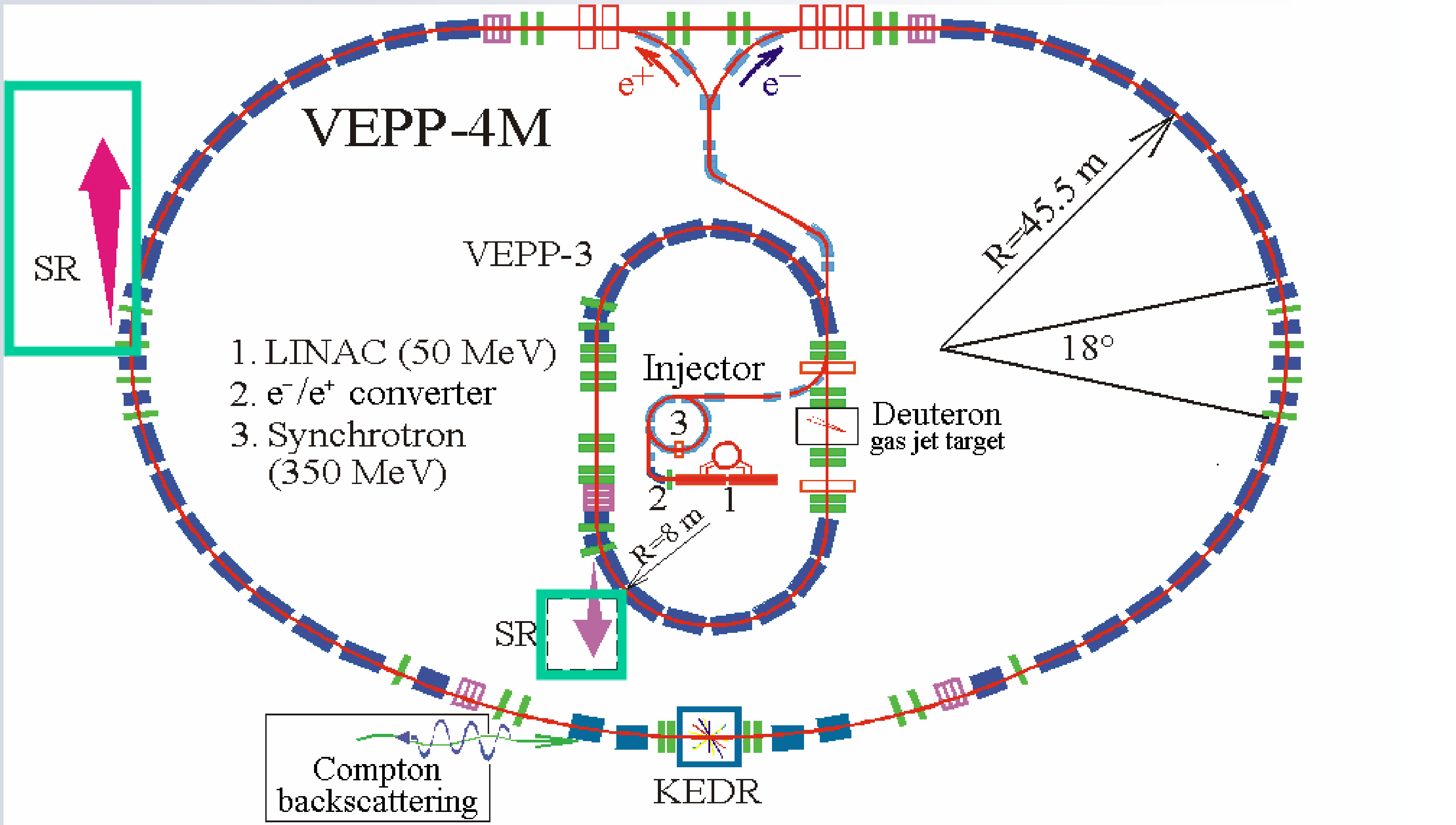
Contents

- The VEPP-4 accelerating-storage complex
- Operation time distribution
- High-energy physics experiments
- Beam and accelerator physics
- Working cycle automation
- Performance improvement

The VEPP-4 accelerating-storage complex

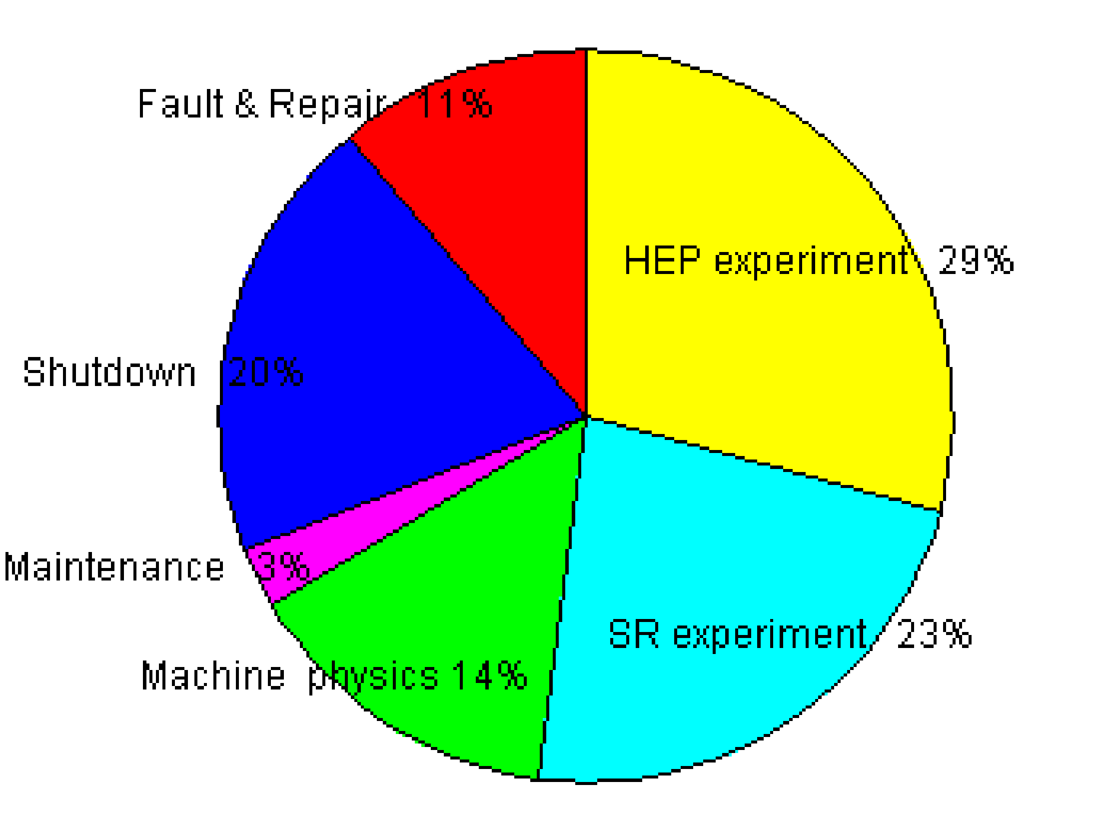


The VEPP-4 accelerating-storage complex



Distribution of the operation time

2004 - 2007



High-energy physics: history

Particle	E, MeV	Accuracy, $\Delta E/E$	Detector	Years
J/ψ	3096.93±0.10	$3.2\cdot10^{-5}$	OLA	1979-1980
ψ'	3685.00±0.12	$3.3\cdot10^{-5}$	OLA	1979-1980
ϒ	9460.57±0.09±0.05	$1.2\cdot10^{-5}$	MD-1	1983-1985
ϒ'	10023.5±0.5	$5.0\cdot10^{-5}$	MD-1	1983-1985
ϒ''	10355.2±0.5	$4.8\cdot10^{-5}$	MD-1	1983-1985
J/ψ	3096.917±0.010±0.007	$3.5\cdot10^{-6}$	KEDR	2002-2005
ψ'	3686.119±0.004±0.008	$2.5\cdot10^{-6}$	KEDR	2002-2005
ψ''	3772.9±0.6±0.8	$2.7\cdot10^{-4}$	KEDR	2002-2005
D^0	1865.43±0.60±0.38	$3.8\cdot10^{-4}$	KEDR	2002-2005
D^+	1863.39±0.45±0.29	$2.9\cdot10^{-4}$	KEDR	2002-2005
τ	$1776.69^{+0.17}_{-0.19}\pm0.15$	$1.3\cdot10^{-4}$	KEDR	2005-2007

High-energy physics: τ-lepton mass measurement

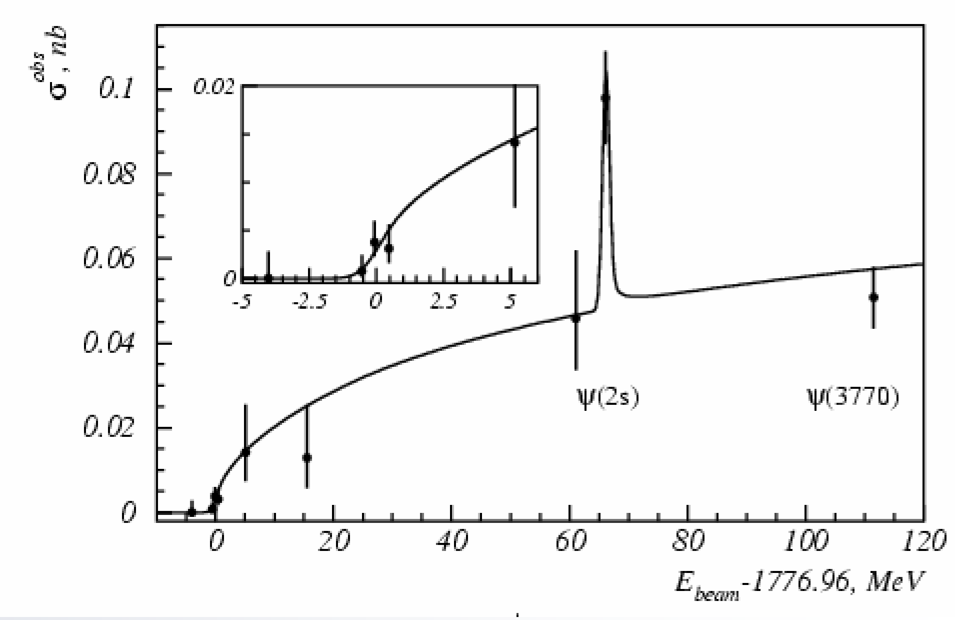
Precise measurement of the τ-lepton mass at the producing threshold is the principal high-energy physics experiment at the VEPP-4 accelerating-storage complex.

Exact value of the τ-lepton mass is required to verify the lepton universality principle which is one of the postulates of the Standard Model, the most complete theory describing fundamental properties of matter.

At present, measurement accuracy reached in this experiment is the best in the world.

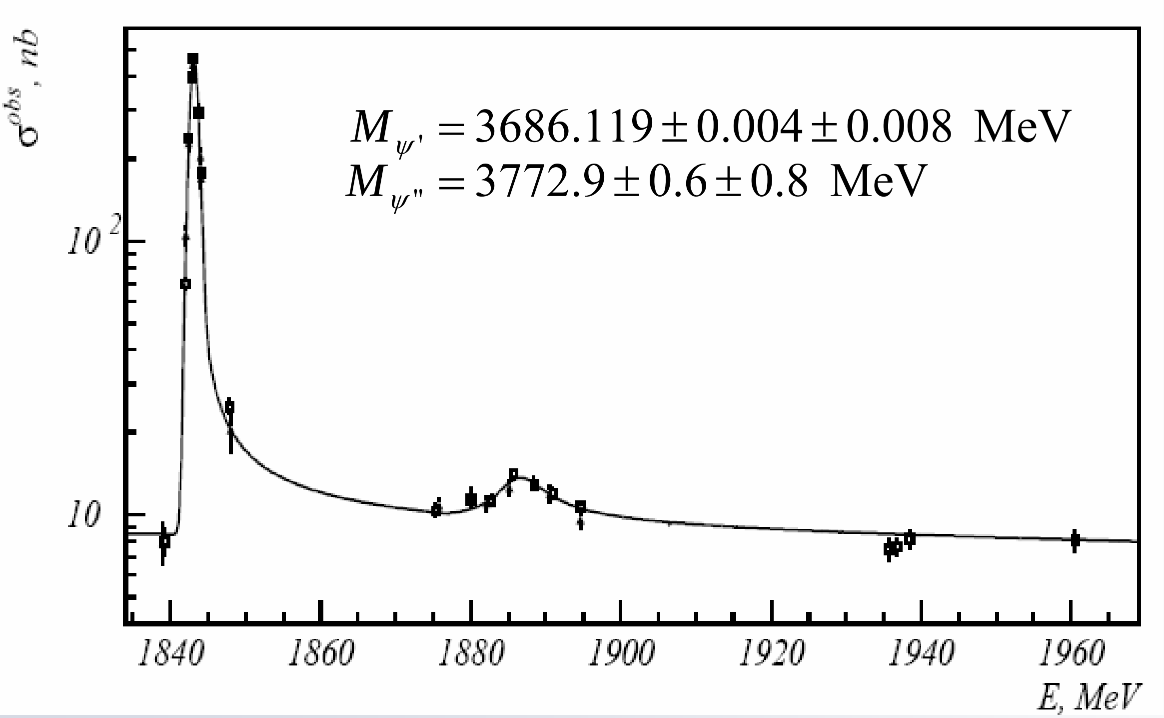
PDG 2006	$1776.90^{+0.29}_{-0.26}$ MeV
BES 1996	$1776.96^{+0.31}_{-0.27}$ MeV
BELLE 2006	$1776.77^{+0.35}_{-0.35}$ MeV
KEDR 2007	$1776.69^{+0.17}_{-0.19}$ MeV

http://kedr.inp.nsk.su



High-energy physics: ψ' and ψ''

Precise measurements of the ψ–family meson masses provide the energy scale in the range around 3 GeV which is a basis for accurate determination of masses for all charmed particles.



3 times improved

2 times improved

There are only 5 masses (e, p, n, μ, π) measured with higher accuracy

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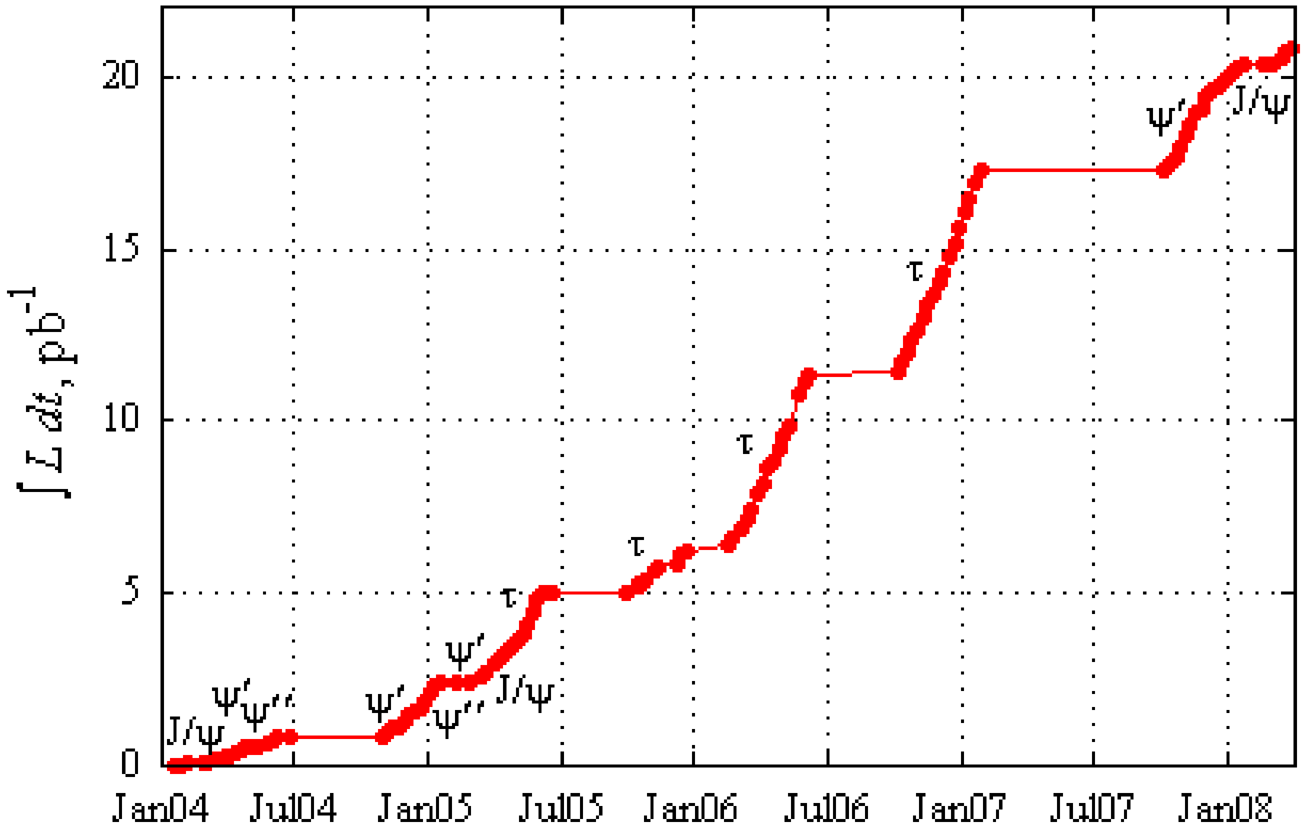
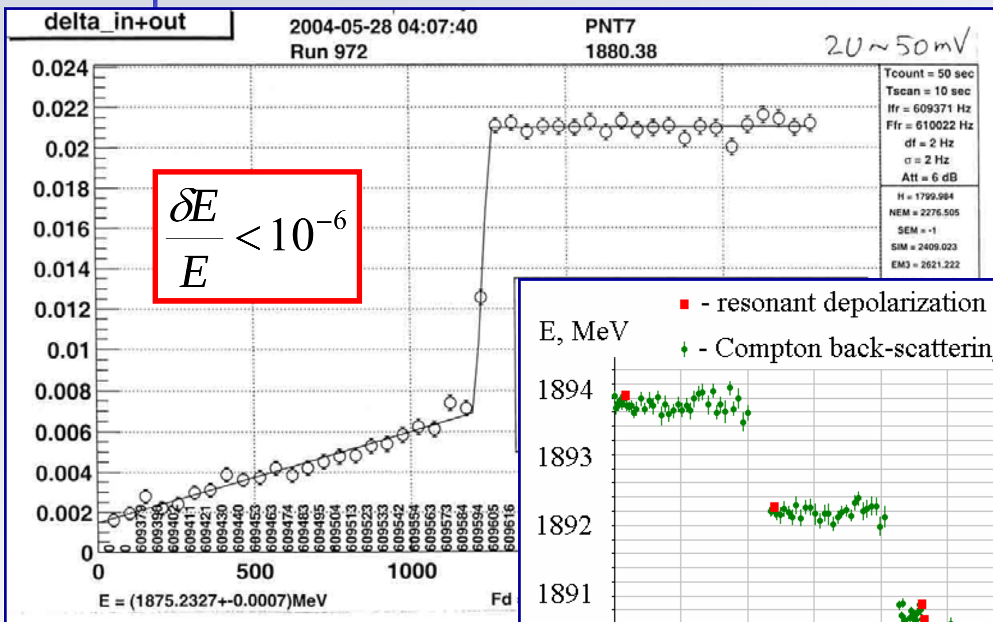
High-energy physics: luminosity integral 2004 – 2008



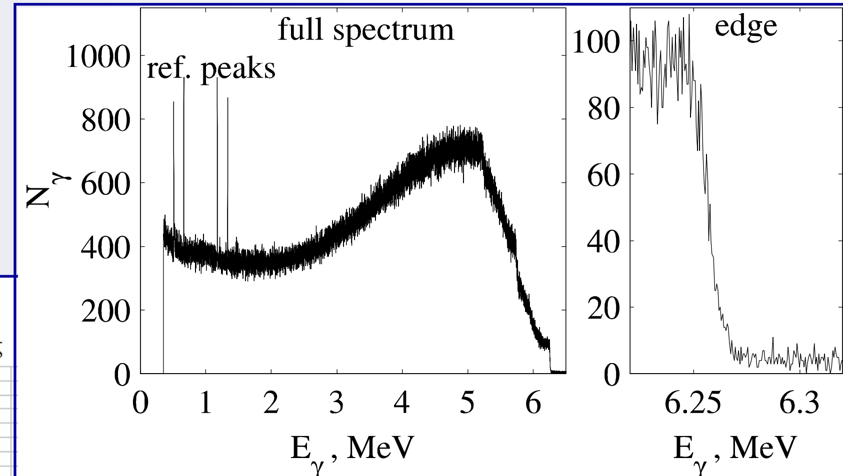
Beam energy measurement

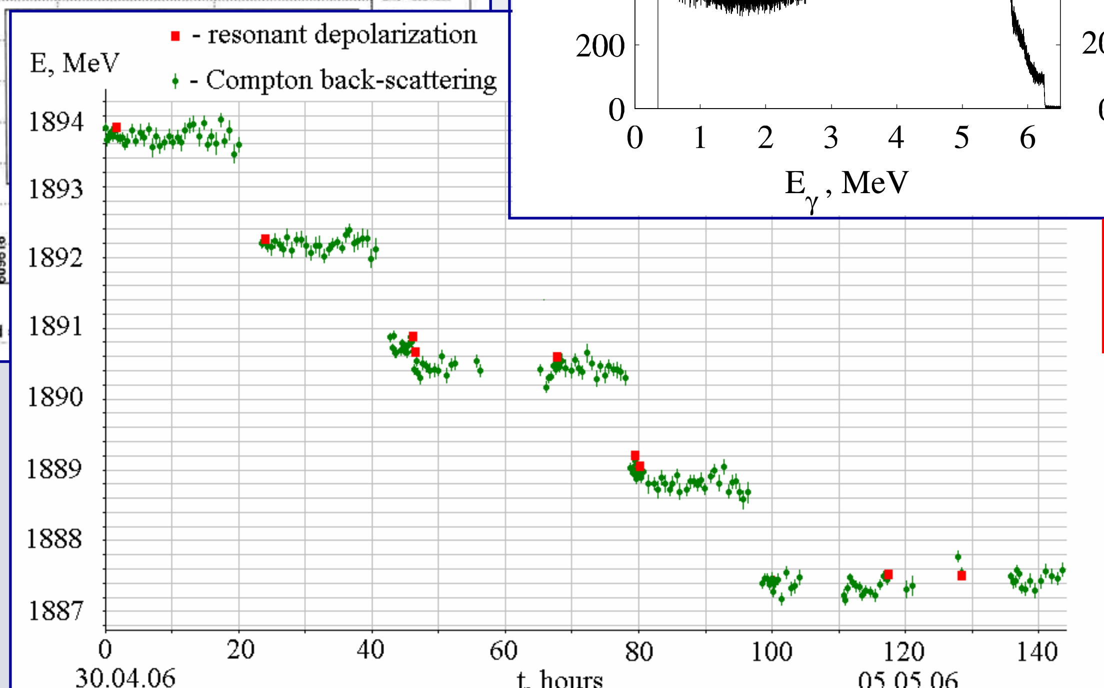
Resonant depolarization –
high-precision periodic calibration

Compton back-scattering – routine energy
monitoring during HEP experiment runs



$$\frac{\delta E}{E} < 10^{-6}$$





$$\frac{\delta E}{E} \approx 5 \cdot 10^{-5}$$

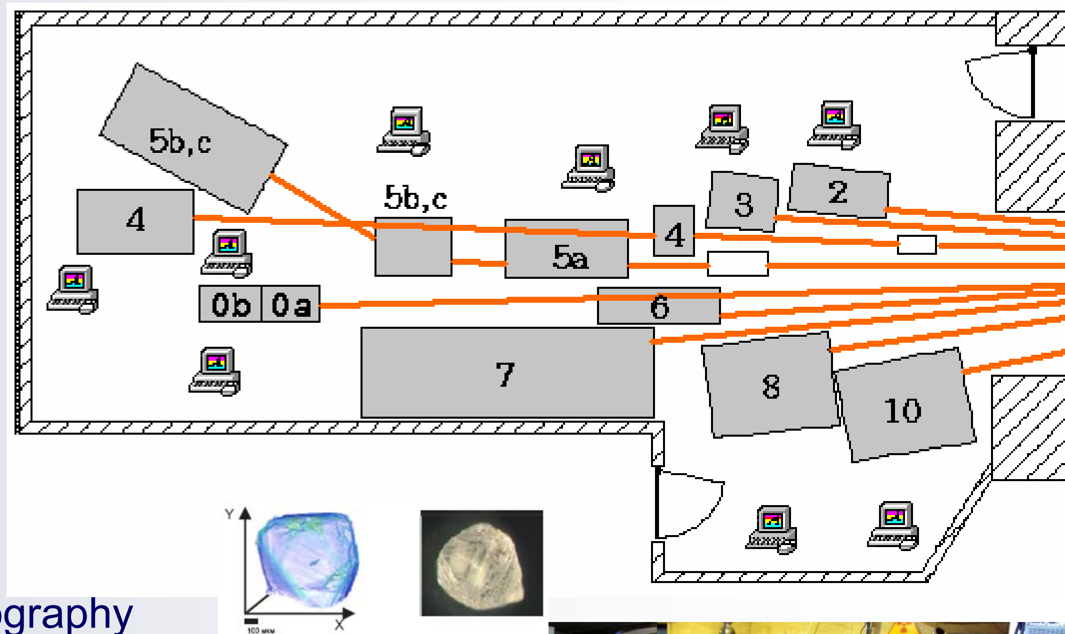
$$\Omega_s = \omega_0 \left(1 + \gamma \frac{q'}{q_0} \right)$$

$$E = 440.65\ \mathrm{MeV} \cdot \left(\frac{\Omega_s}{\omega_0} - 1 \right)$$

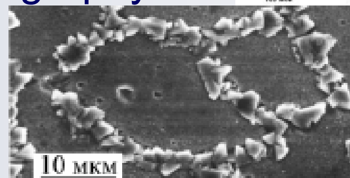
Synchrotron radiation experiments

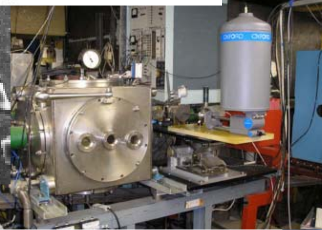
http://ssrc.inp.nsk.su

VEPP-3 SR channels and stations



- 0a – LIGA-technology and X-ray lithography
- 0b – “Explosion"
- 2 – Precision diffractometry and anomalous scattering
- 3 – X-ray fluorescence analysis
- 4 – High-pressure diffractometry
- 5a – X-ray microscopy and micro-tomography
- 5b – Time-resolution diffractometry
- 5c – Small-angle X-ray scattering
- 6 – Time-resolution luminescence
- 7 – SR beam stabilization
- 8 – EXAFS spectroscopy
- 10 – Metrology and EXAFS spectroscopy in soft X-ray band



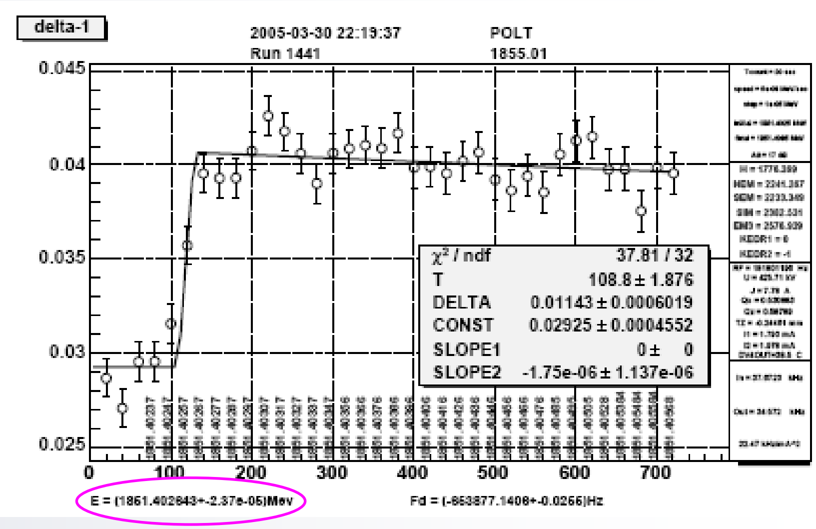


Accelerator physics: record-high resolution experiments on comparison of spin precession frequencies of electron bunches

S.A.Nikitin et al., Record-high Resolution Experiments on Comparison of Spin Precession Frequencies of Electron Bunches Using the Resonant Depolarization Technique in the Storage Ring, EPAC-2006, Edinburgh

The opportunity of performing an experiment on CPT theorem test based on high precision comparison of the spin precession frequencies of electron and positrons measured by the resonant depolarization technique in the storage ring is under study at the VEPP-4M facility.

- At the first stage of our experiments, we compare the spin precession frequencies of two electron bunches, simultaneously circulating in the VEPP-4M storage ring, with the aim to reach a minimal statistic error and to investigate some systematic errors.
- A record accuracy of $2 \cdot 10^{-8}$ has been achieved in the experiment on comparison of depolarization frequencies of two electron bunches.
- New RD techniques in the different multi-bunch mode have been proposed and mastered.
- Estimates of some sources of systematic errors which can affect an accuracy of the comparison of spin frequencies of electrons and positrons have been considered.



"Nano-resolution":
$2.5 \cdot 10^{-9}$ relative error was reached

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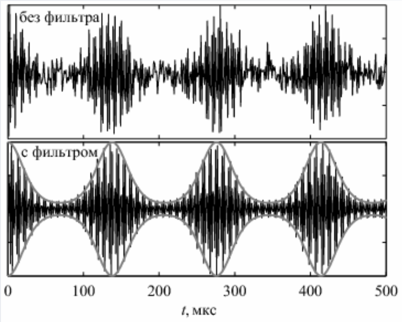
Accelerator physics: beam energy spread measurement

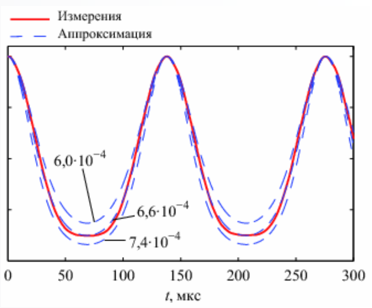
O.I.Meshkov et al., Beam energy spread measurement at the VEPP-4M Electron-Positron Collider, J. Inst. 2 No 06 (June 2007) P06001

1: Fit of the measured betatron oscillation envelope

$$A(t) \propto \exp\left(-\frac{t^2}{2\tau^2}\right)\cdot \exp\left(-\left(\frac{\partial \omega_\beta}{\partial E}\frac{\sigma_E}{\omega_s}\right)^2 \cdot \left(1-\cos(\omega_s t)\right)\right),$$

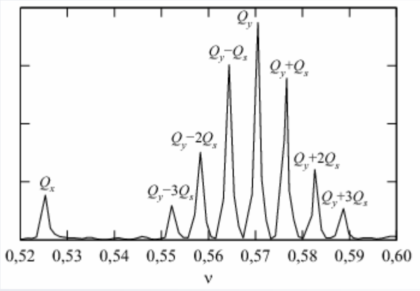
$$\tau^{-1} = 2\frac{\partial \omega_\beta}{\partial a^2} b \cdot \sigma_y$$

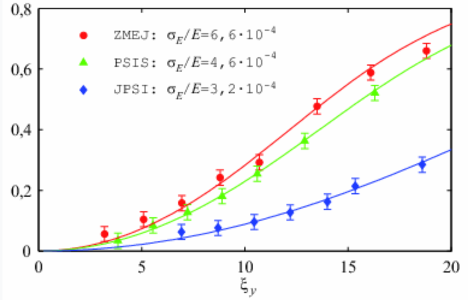




2: Measurement of amplitude ratio of synchrotron satellites to the main betatron peak in dependence of chromaticity

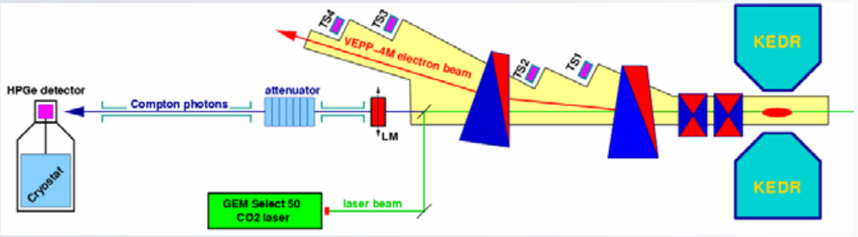
$$R_m(y) = \frac{1}{y^2}\int_0^\infty J_m^2(x) e^{-\frac{x^2}{2y^2}} x dx \qquad y = \left(\frac{\omega_\beta \alpha}{\omega_s} + \frac{\omega_0 C_y}{\omega_s}\right)\sigma_E$$

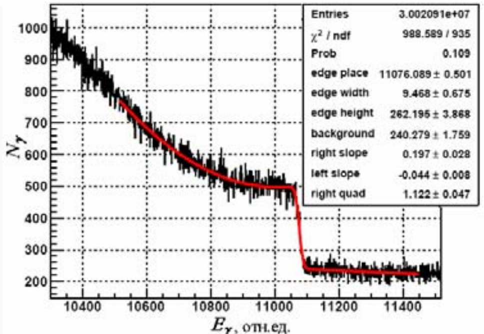




3: Fit of the edge of Compton back-scattering spectrum

$$E = \frac{\hbar\omega_m}{2}\left(1+\sqrt{1+\frac{m_e^2 c^4}{\hbar^2 \omega_m \omega_0 \sin^2\frac{\alpha}{2}}}\right)$$





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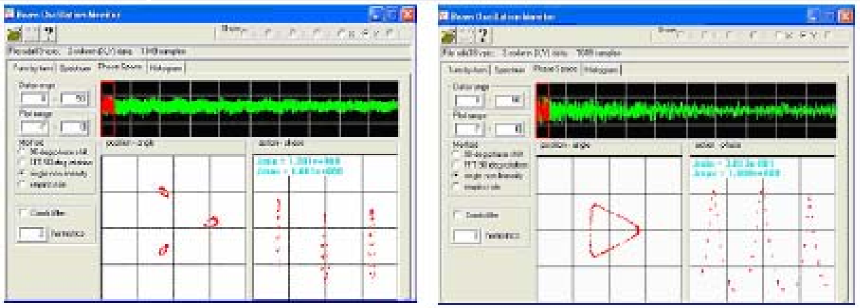
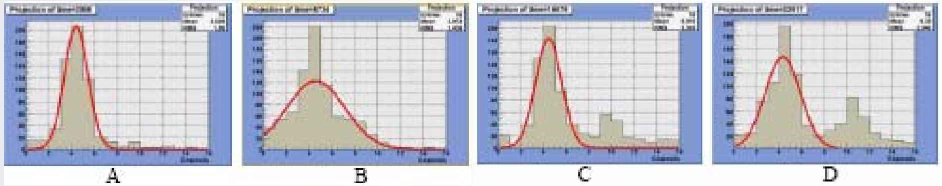
Accelerator physics: beam dynamics study during crossing of betatron resonances

V.Kiselev et al., Study of Beam Dynamics during the Crossing of Resonances in the VEPP-4M Storage Ring, Proc. of EPAC-2008, Genoa, 2008

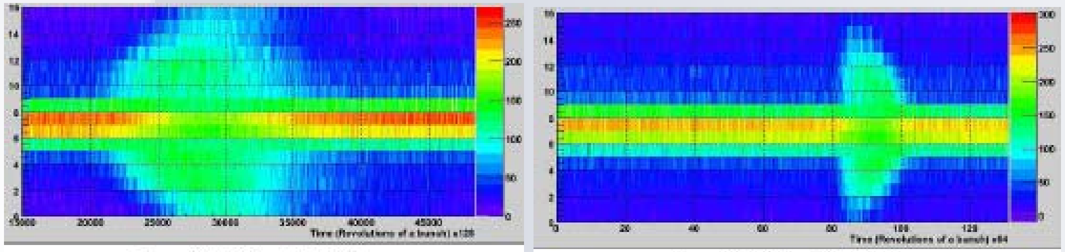
The influence of resonances on the beam dynamics in the storage rings is of a substantial interest for the accelerator physics. We have studied experimentally the crossing of resonance nearby the working point of the VEPP-4M storage ring. The observation of the beam sizes and particle losses has been done with a single-turn time resolution.



Phase trajectories at the resonance (left) and near the resonance (right), ν_z=0.6621

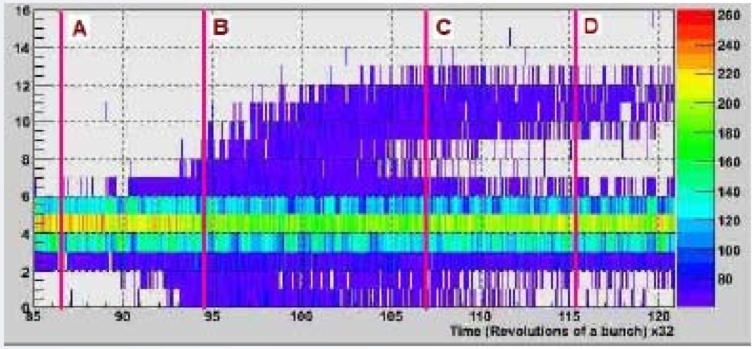


Creation of the resonance island and particles trapping in the adiabatic limit.



$\nu_z = 0.662 \to 0.674$ $\nu_z = 0.674 \to 0.662$

The vertical beam profile blowing up while crossing the resonance

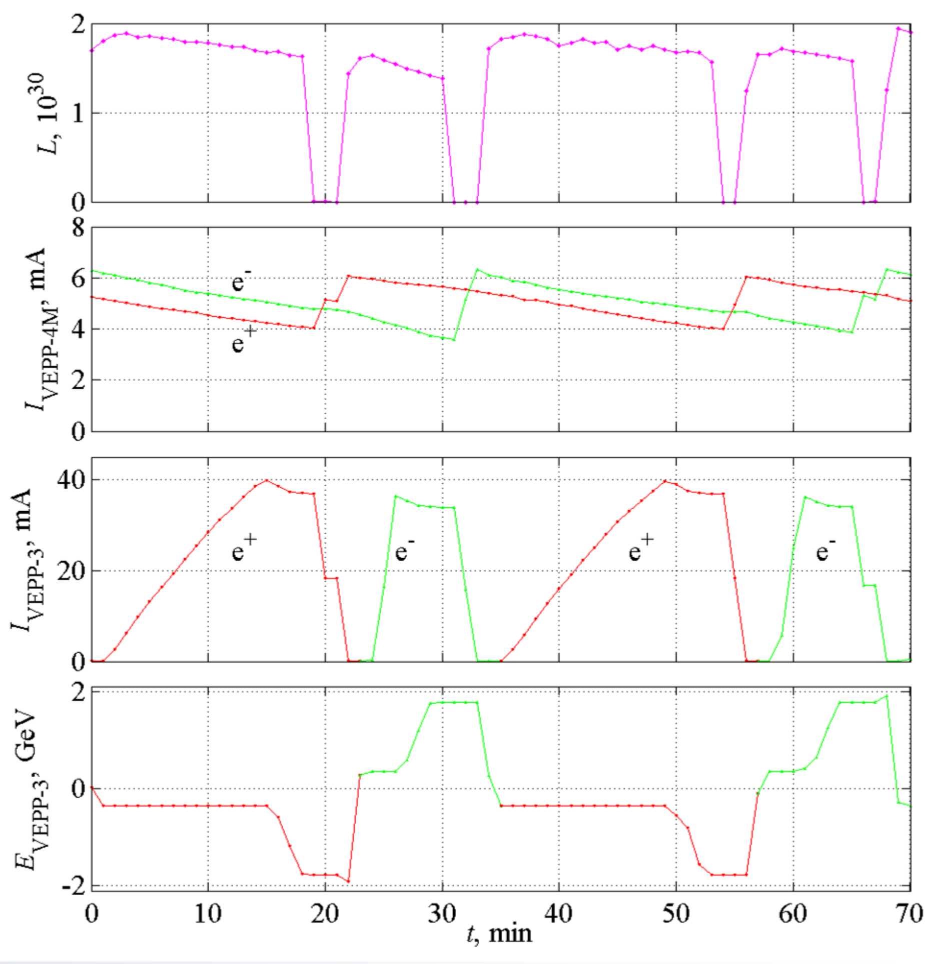


Time evolution of the vertical beam distribution in the case of the particle trapping in the resonance island

Working cycle in a HEP experiment

- accumulation of positrons in the VEPP-3 (15-20 minutes),
- acceleration up to the extraction energy (5 minutes),
- bunch-by-bunch extraction and injection into the VEPP-4M,
- magnetic cycle and polarity change of the VEPP-3 and Injector (5 minutes),
- electron accumulation (1-2 minutes), acceleration and injection into the VEPP-4M.

Total time required to refill beams in the VEPP-4M is 30-40 minutes.



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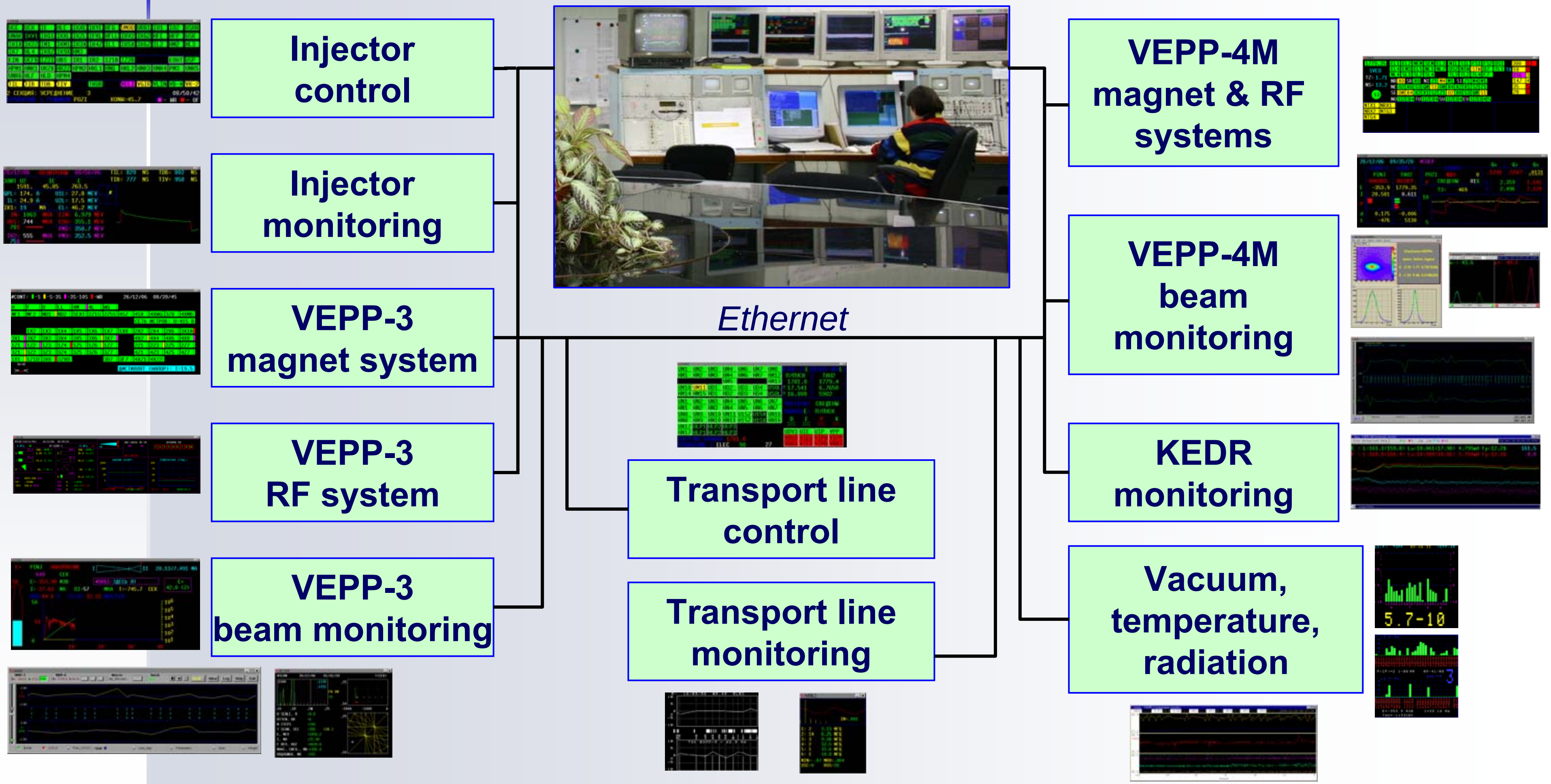
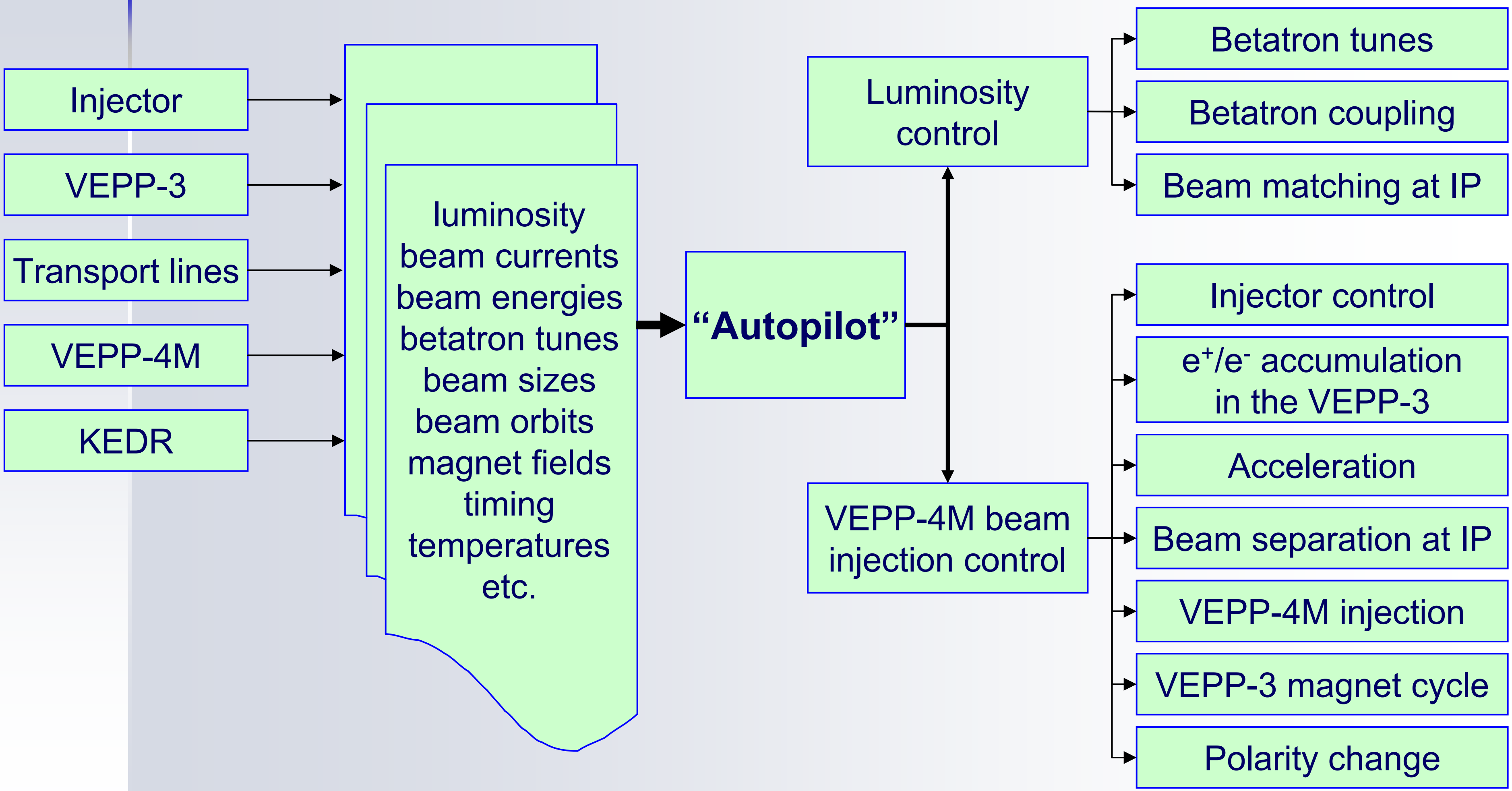
Machine control and monitoring

Control system layout

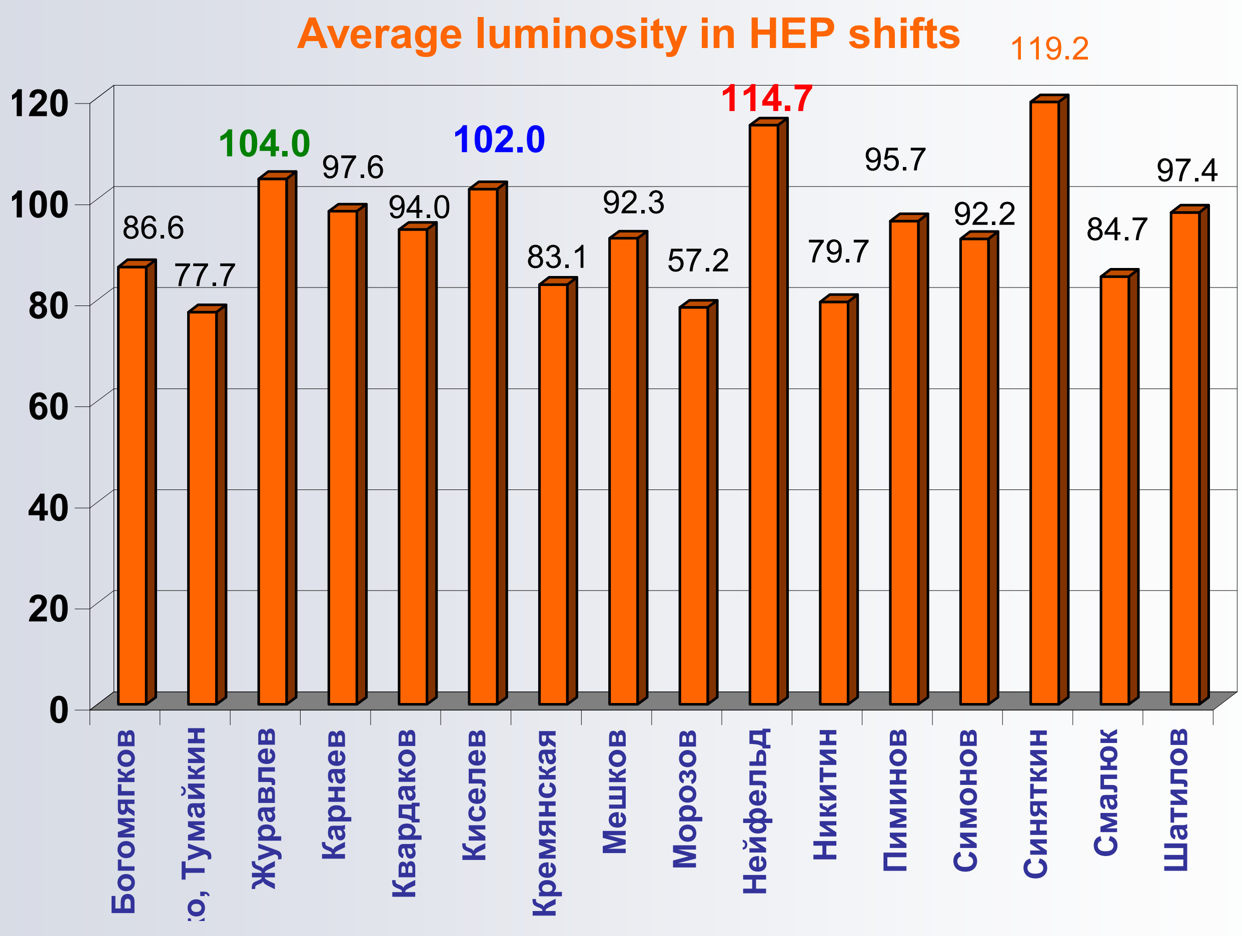


Working cycle automation



Results of working cycle automation

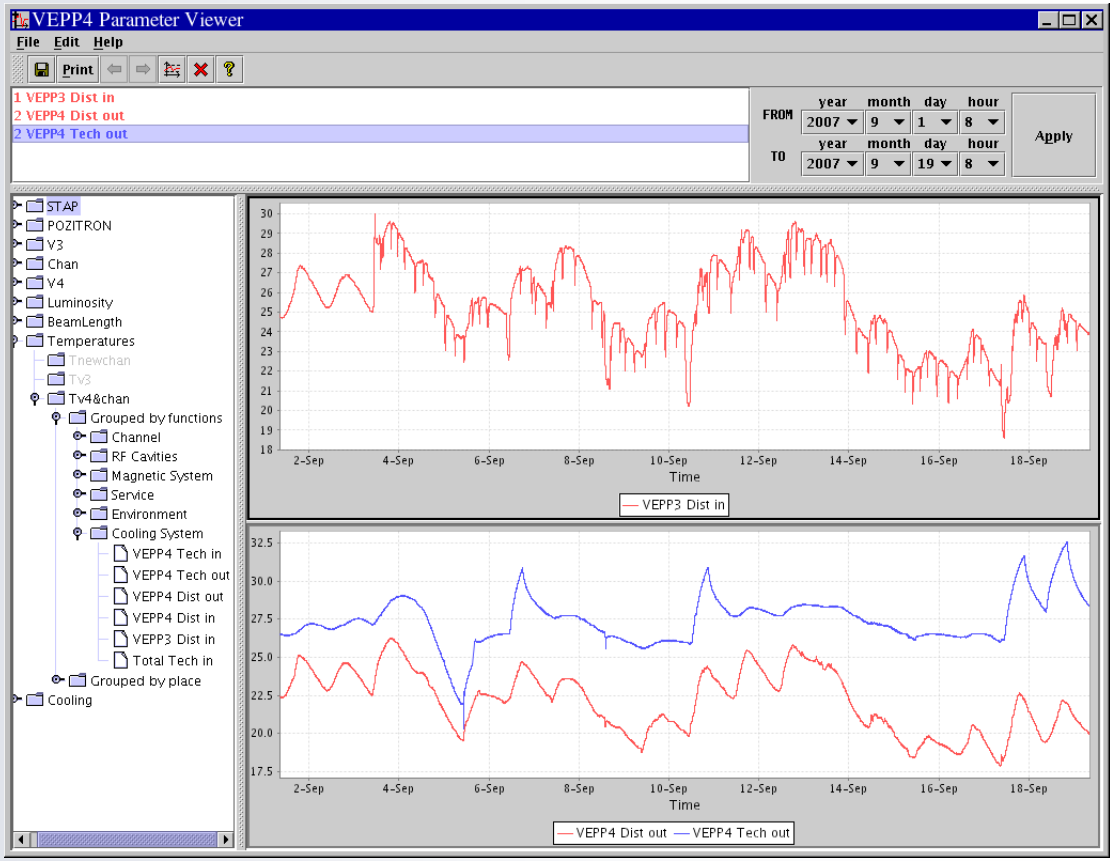
2005



Performance improvement: database

S.Karnaev, E.Simonov, E.Goman, O.Plotnikova, The Database of the VEPP-4 Accelerating Facility Parameters, to be presented at PCaPAC-2008, Ljubljana, October 2008

- PostgreSQL database
- more than 1500 parameters of beams and accelerators
- 1-second samples are available during last 24 hours
- 30-second samples are stored for 1 year
- older data are available from an archive storage
- a set of typical data request scripts is developed
- GUI



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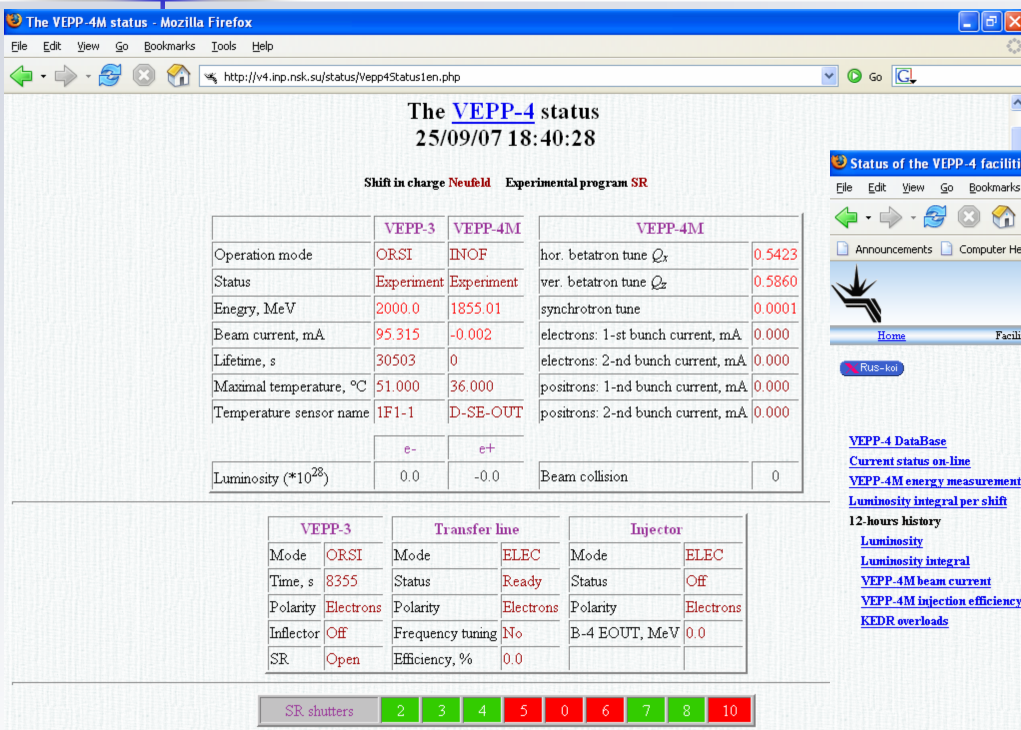
http://v4.inp.nsk.su

Performance improvement: on-line status in the www



The VEPP-4M status - Mozilla Firefox

http://v4.inp.nsk.su/status/Vepp4Status1en.php

The VEPP-4 status
25/09/07 18:40:28

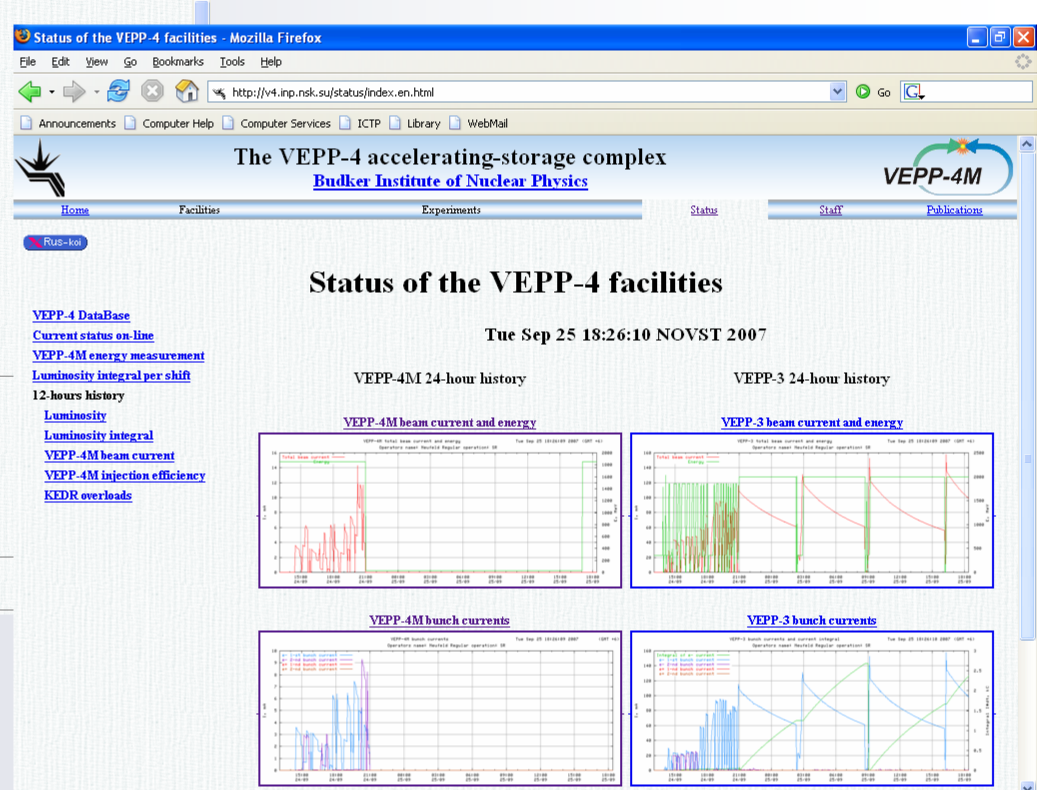
Shift in charge Neufeld Experimental program SR

	VEPP-3	VEPP-4M
Operation mode	ORSI	INOF
Status	Experiment	Experiment
Energy, MeV	2000.0	1855.01
Beam current, mA	95.315	-0.002
Lifetime, s	30503	0
Maximal temperature, °C	51.000	36.000
Temperature sensor name	1F1-1	D-SE-OUT
	e-	e+
Luminosity (*10^{28})	0.0	-0.0

VEPP-4M	
hor. betatron tune Q_x	0.5423
ver. betatron tune Q_z	0.5860
synchrotron tune	0.0001
electrons: 1-st bunch current, mA	0.000
electrons: 2-nd bunch current, mA	0.000
positrons: 1-nd bunch current, mA	0.000
positrons: 2-nd bunch current, mA	0.000
Beam collision	0

VEPP-3		Transfer line		Injector	
Mode	ORSI	Mode	ELEC	Mode	ELEC
Time, s	8355	Status	Ready	Status	Off
Polarity	Electrons	Polarity	Electrons	Polarity	Electrons
Inflector	Off	Frequency tuning	No	B-4 EOUT, MeV	0.0
SR	Open	Efficiency, %	0.0		

SR shutters	2	3	4	5	0	6	7	8	10



Performance improvement: new temperature monitoring system

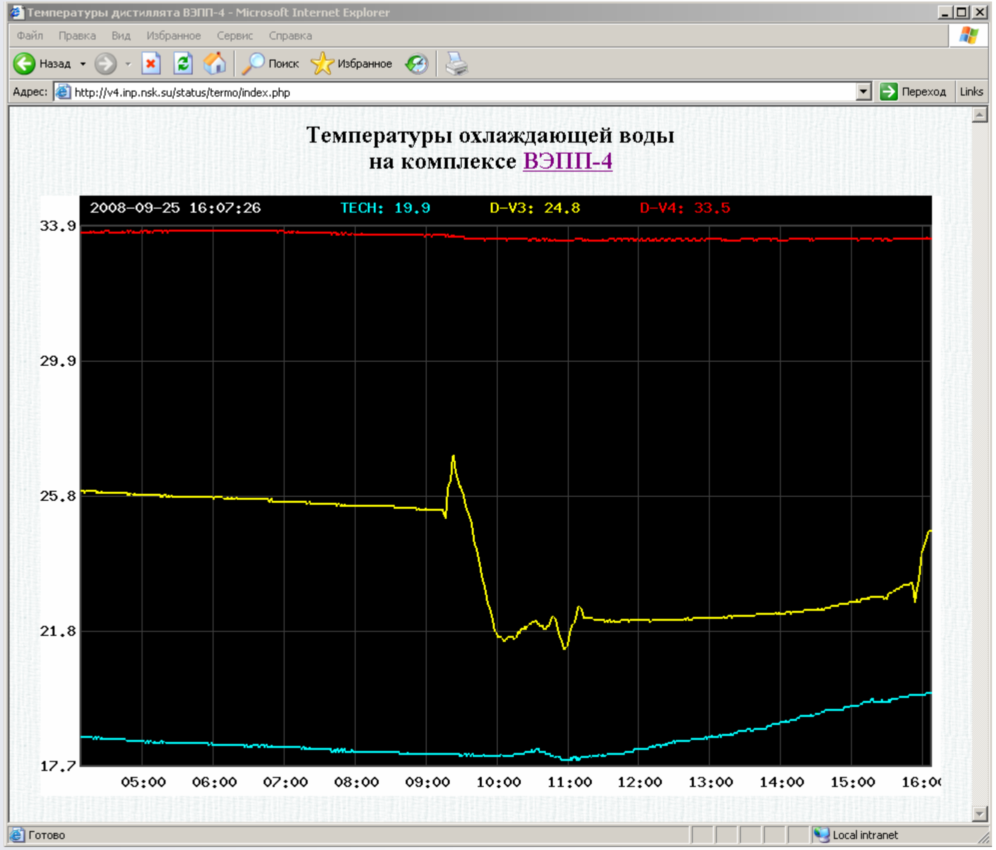
VEPP-4M
http://v4.inp.nsk.su

V.Kaplin, S.Karnaev, A. Kvashnin, I.Morozov, O.Plotnikova, The precision temperature measuring system of the VEPP-4M electron-positron collider, RuPAC 2006, Novosibirsk

Hardware:
High-Precision digital sensors DS1631 with the resolution of 0.0625°C and absolute accuracy of 0.5°C in the 0–70°C temperature range.

32-channel controller developed in BINP automatically scans the temperature sensors every second and write data into the internal memory. Relay interlock function is to prevent overheat.

Software:
Control program reads data from the all the controllers and writes it to a PostgreSQL database. GUI is also developed.



Controller and sensors:
1 – sensor board; 2 – sensor inside the protection case.

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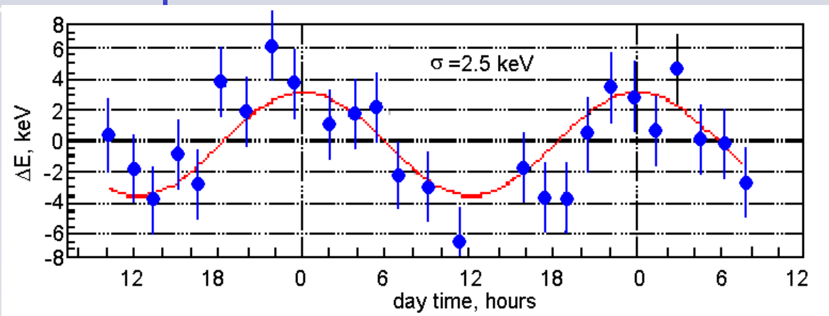
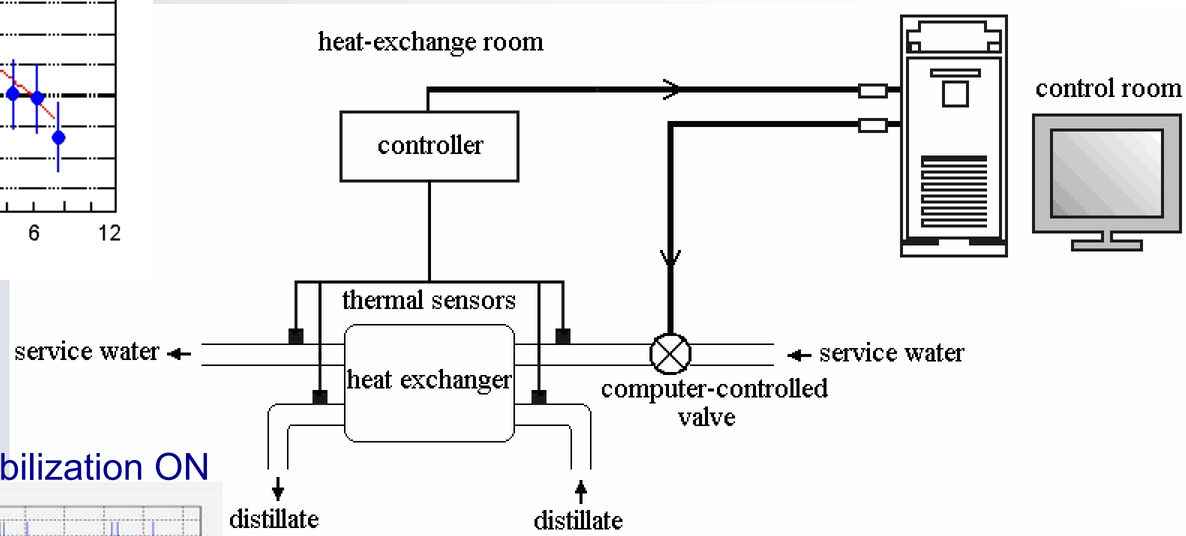
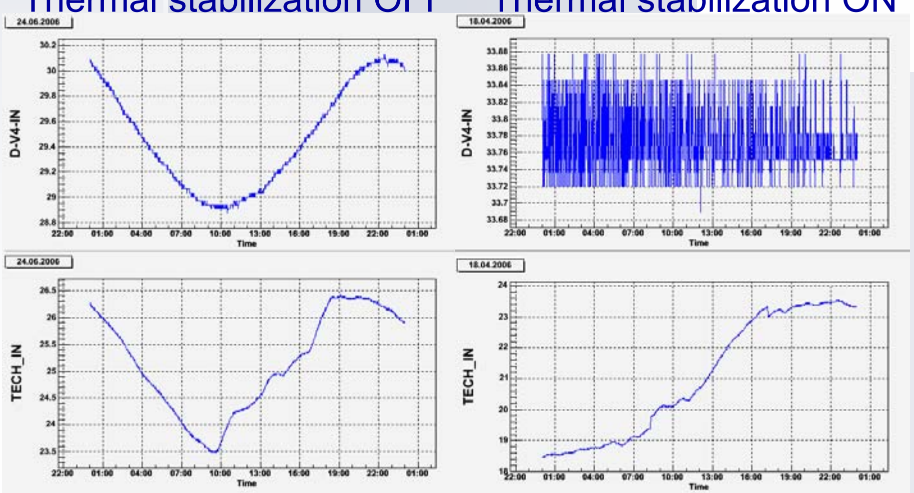
Performance improvement: thermal stabilization of the magnets



Diurnal variations of the VEPP-4M beam energy mainly results from temperature drift of the VEPP-4M magnets.



Thermal stabilization OFF   Thermal stabilization ON



Thermal stabilization system:

- double-loop water cooling
- high-precision thermal sensors
- computer-controlled valve

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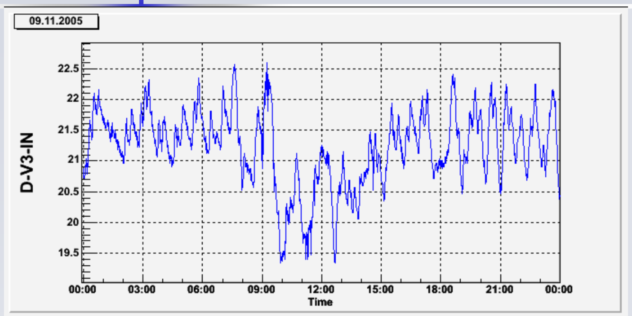
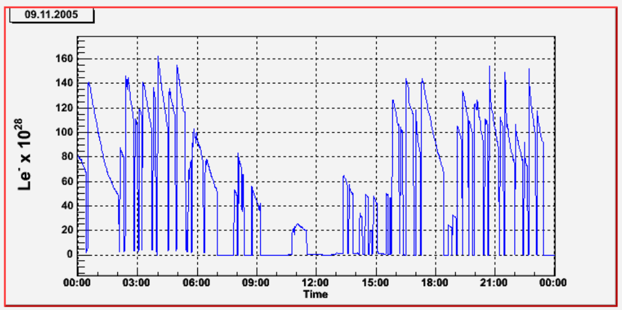
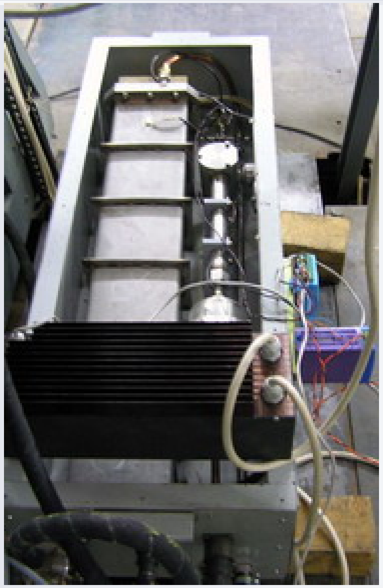
Performance improvement: thermal stabilization of the RF cavities

E.G.Miginskaya, I.I.Morozov, V.M.Tsukanov, A.A.Volkov, Temperature stabilization of RF-cavities of VEPP-4M Electron-Positron Facility, RuPAC 2006, Novosibirsk







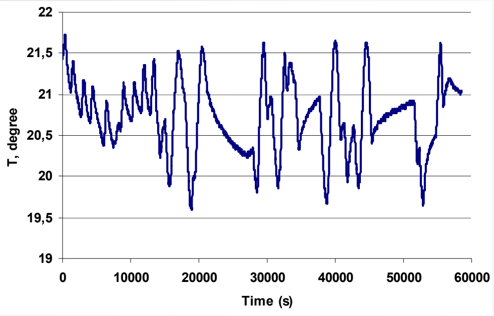
Temperature is measured by thermo-sensors with a sensitivity of 10 mV/^{o}C.

For each RF cavity, 5 kW flowing water heater is switched on/off by controllable electronic switches.

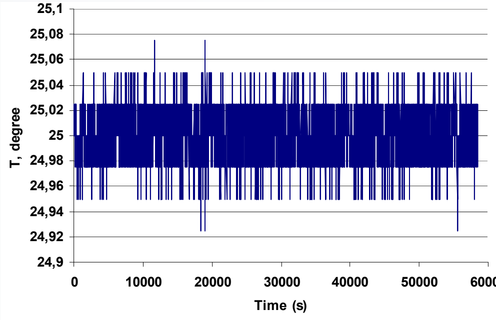
Temperature analysis and power control is provided by a microcontroller.

Longitudinal beam instability is one of the main efficiency decreasing factors, because it reduces luminosity drastically and can be dangerous for the KEDR detector.

RF cavity temperature variation results in the cavity deformation and then leads to a shift of working conditions away from a stable region of the high-order modes.

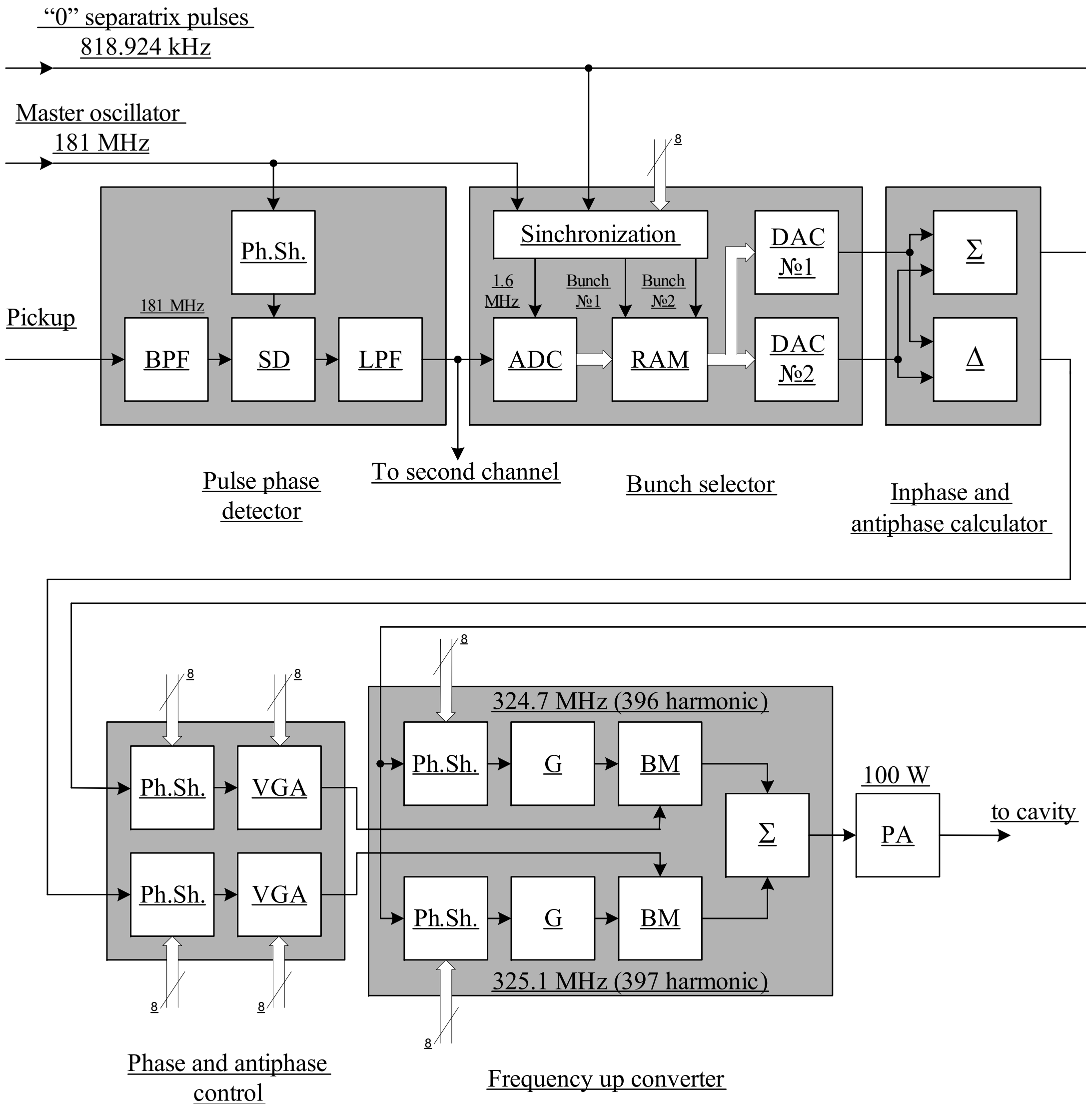


stabilization OFF, $\Delta T = 2^o$C



stabilization ON, $\Delta T = 0.1^o$C

Longitudinal feedback system



The system is designed to suppress longitudinal beam instability in 2×2 bunch operation mode.

- 2 systems for e- и e+ of 2 channels for synphase and antiphase oscillation modes;
- synchronous detector for beam phase measurement;
- analog superheterodyne modulator;
- 100 W output RF power;
- feedback decrement 500 s^{-1}

In 2007, the broad-band resonance kicker and signal processing electronics have been manufactured and installed.

In 2008, the system commissioning has been started.

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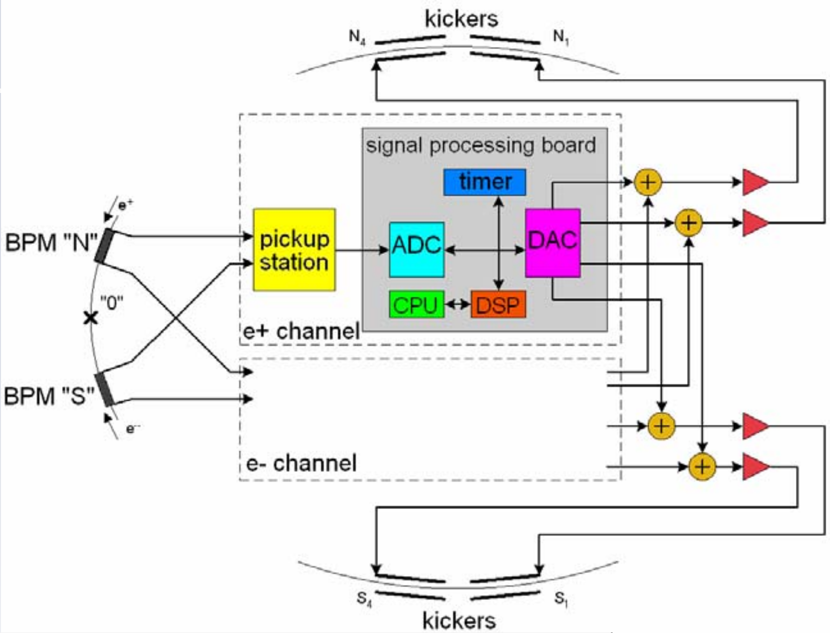
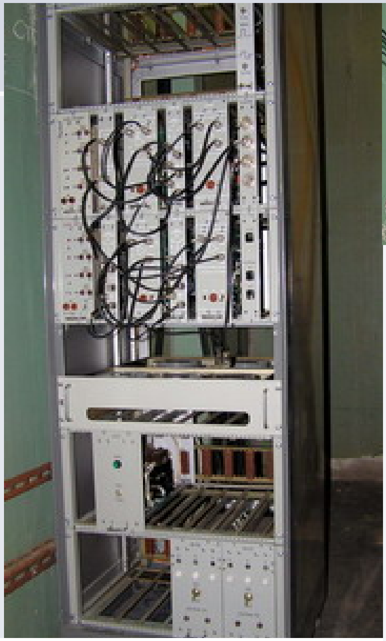
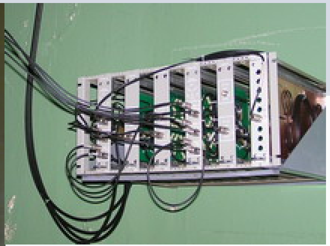
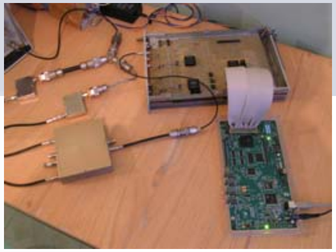
Transverse bunch-by-bunch feedback system



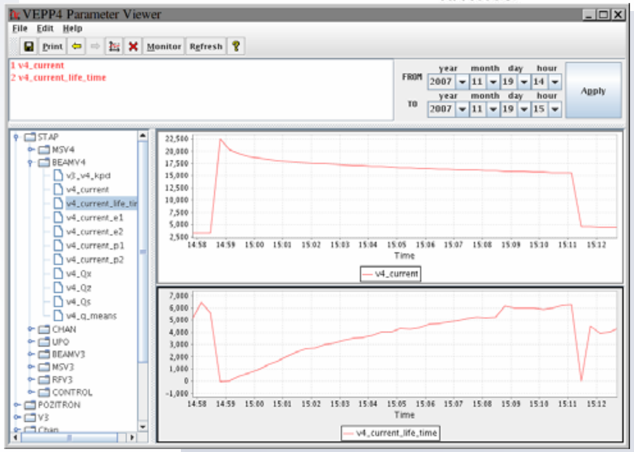


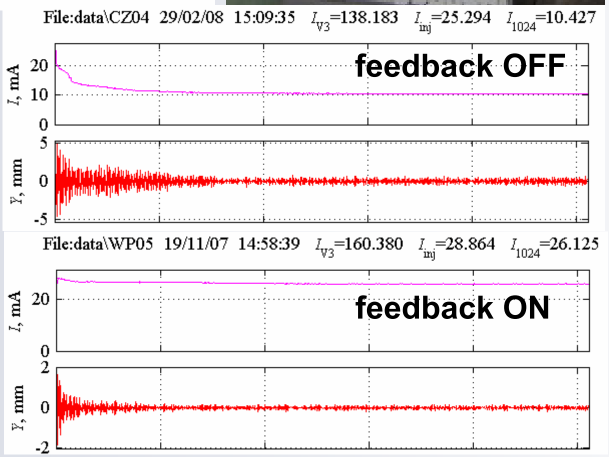




Transverse bunch-by-bunch digital feedback to suppress the fast head-tail instability limiting the VEPP-4M single-bunch current.

Energy, GeV	1.8 – 5.2
Number of bunches	2 x 2
Design bunch current	40 mA
Number of kickers	4
RF power per kicker	400 W





In 2007, one of four feedback channels has been commissioned.

With the feedback, beam current more than twice exceeding the threshold has been injected.

The VEPP-4 team

Physicist and post-graduate students	Engineers	Laboratory technicians
A.Aleshaev	O.Anchugov	A.Apanasenko
A.Bogomyagkov	I.Bannikov	G.Belyakov
S.Karnaev	M.Bokov	V.Bykov
V.Kiselev	M.Brovin	A.Kolesnikov
E.Levichev	D.Burenkov	G.Kurganov
O.Meshkov	S.Vasichev	P.Koshkin
S.Mishnev	Yu.Glukhovchenko	I.Lubyagin
I.Morozov	O.Gordeev	A.Maslov
N.Muchnoi	V.Erokhov	I.Mishin
S.Nikitin	A.Zhmaka	A.Petrov
I.Okunev	V.Neufeld	A.Poroshin
V.Petrov	O.Plotnikova	I.Romanov
P.Piminov	A.Polyanskiy	S.Rudakov
Yu.Pupkov	V.Sandyrev	P.Svischev
E.Simonov	V.Svischev	A.Soshilov
S.Sinyatkin	I.Utjupin	L.Stebailo
V.Smaluk	M.Fomin	N.Tur
E.Starostina	D.Shvedov	V.Turaev
G.Tumaikin		A.Chabanov
D.Shatilov		V.Shvaibovich
A.Zhuravlev		

Thank you for your attention