Overview prospects at BINP

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BINP, 630090 Novosibirsk, Russia

Phi Psi 13, Rome
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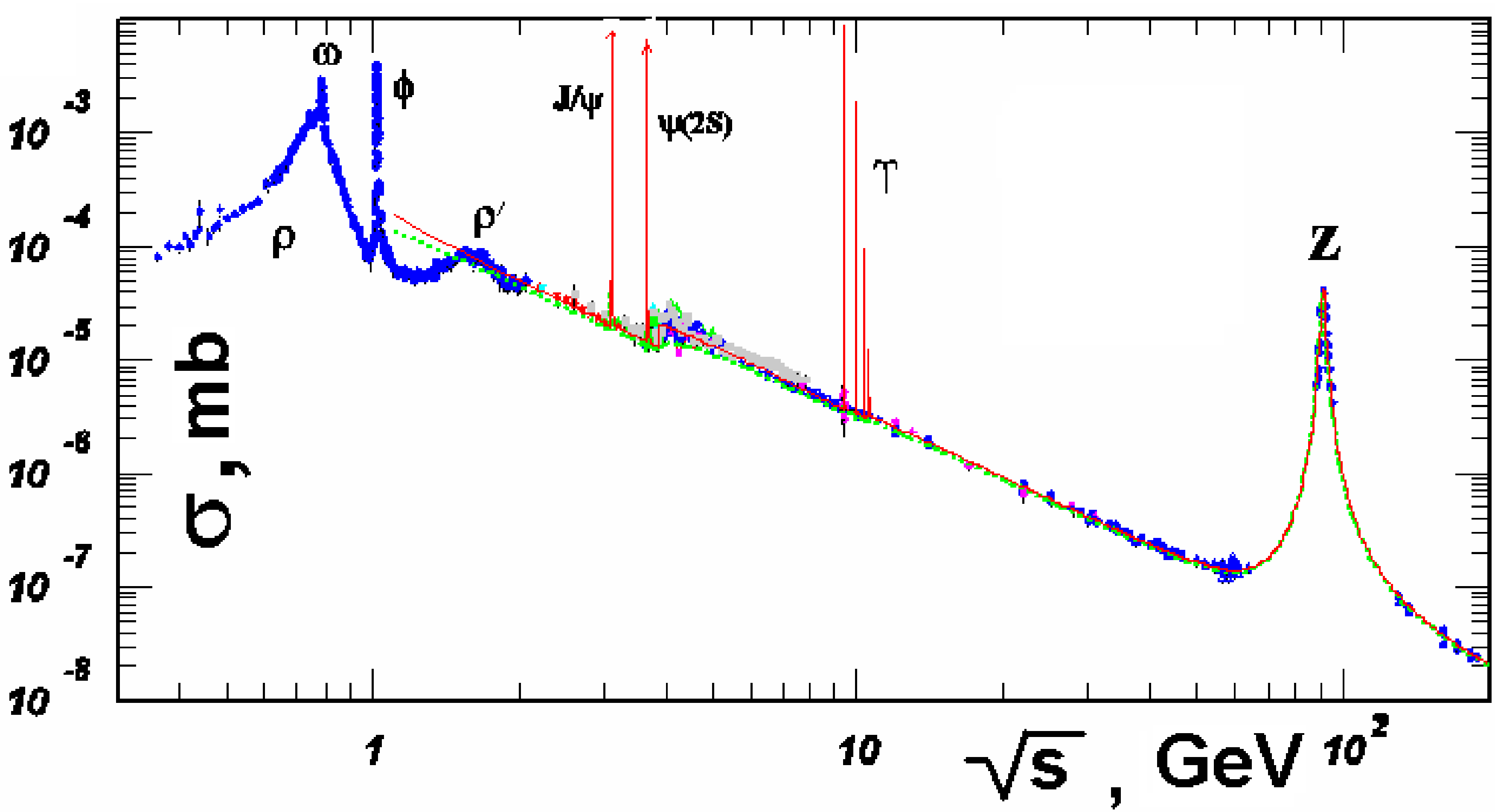
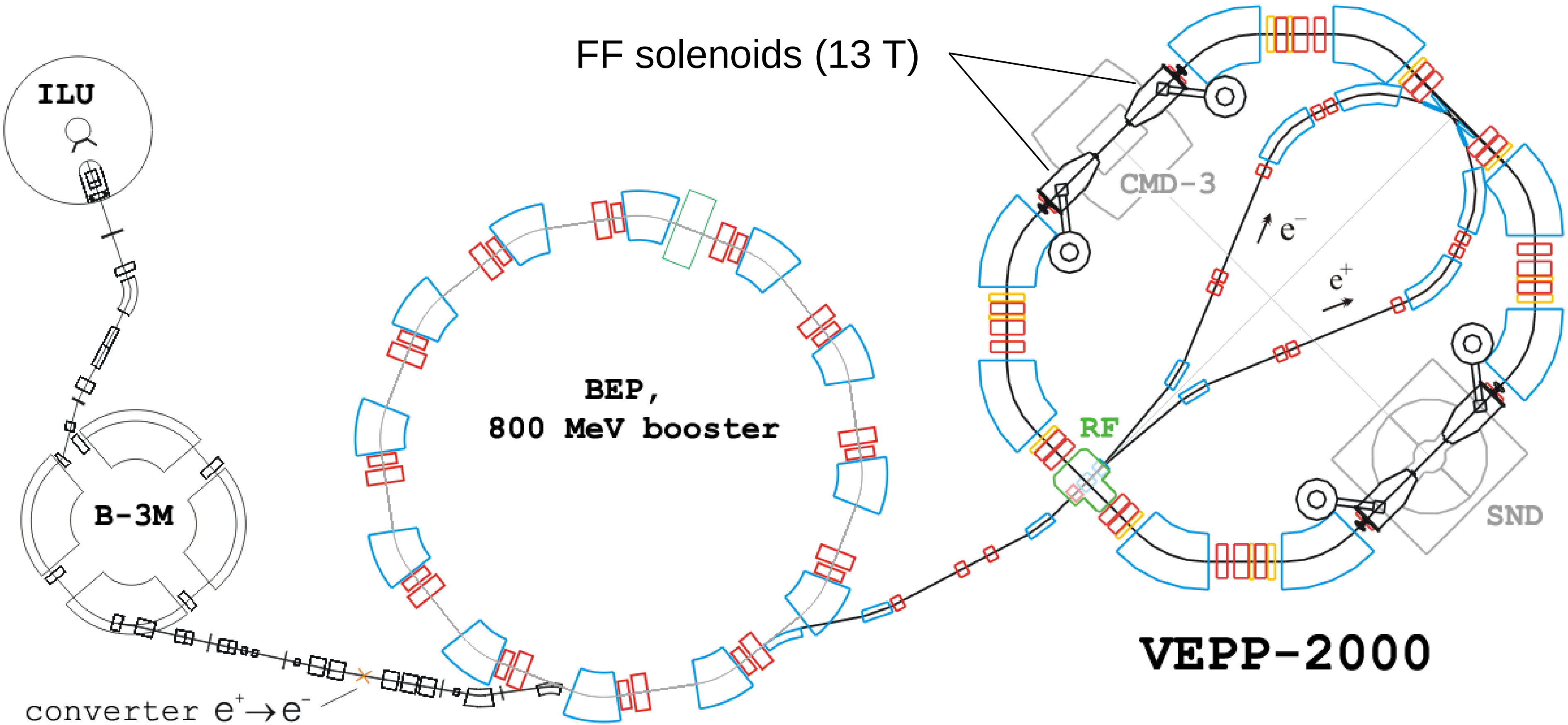
Outline

- VEPP-2000 results and plans
- BEP-booster ring upgrade to 1 GeV
- Positrons from new injector complex
- VEPP-4M
- Super tau/charm factory status
- Other proposals

Cross section $e^+e^- \to$ hadrons

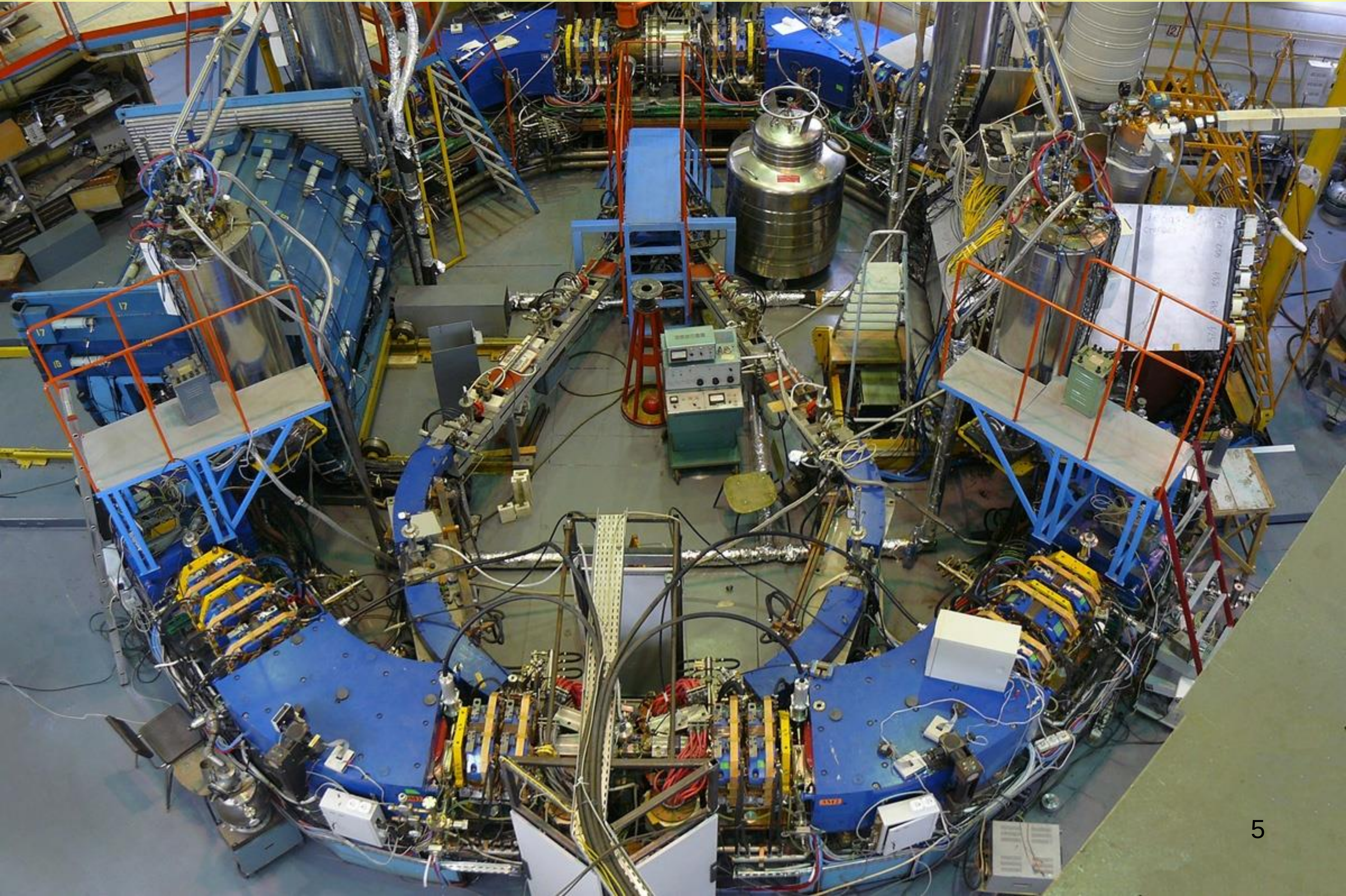


VEPP-2000 collider facility



Main parameters at 1GeV			
Circumference	24.388 m	Beam energy	160 ÷ 1000 MeV
Number of bunches	1	Number of particles	1×10^{11}
Tunes	4.1 / 2.1	Beta-function @ IP	8.5 cm
Beam-beam parameter ξ	0.1	Luminosity	1×10^{32} $cm^{-2}s^{-1}$

VEPP-2000 photo



Motivation for round beams

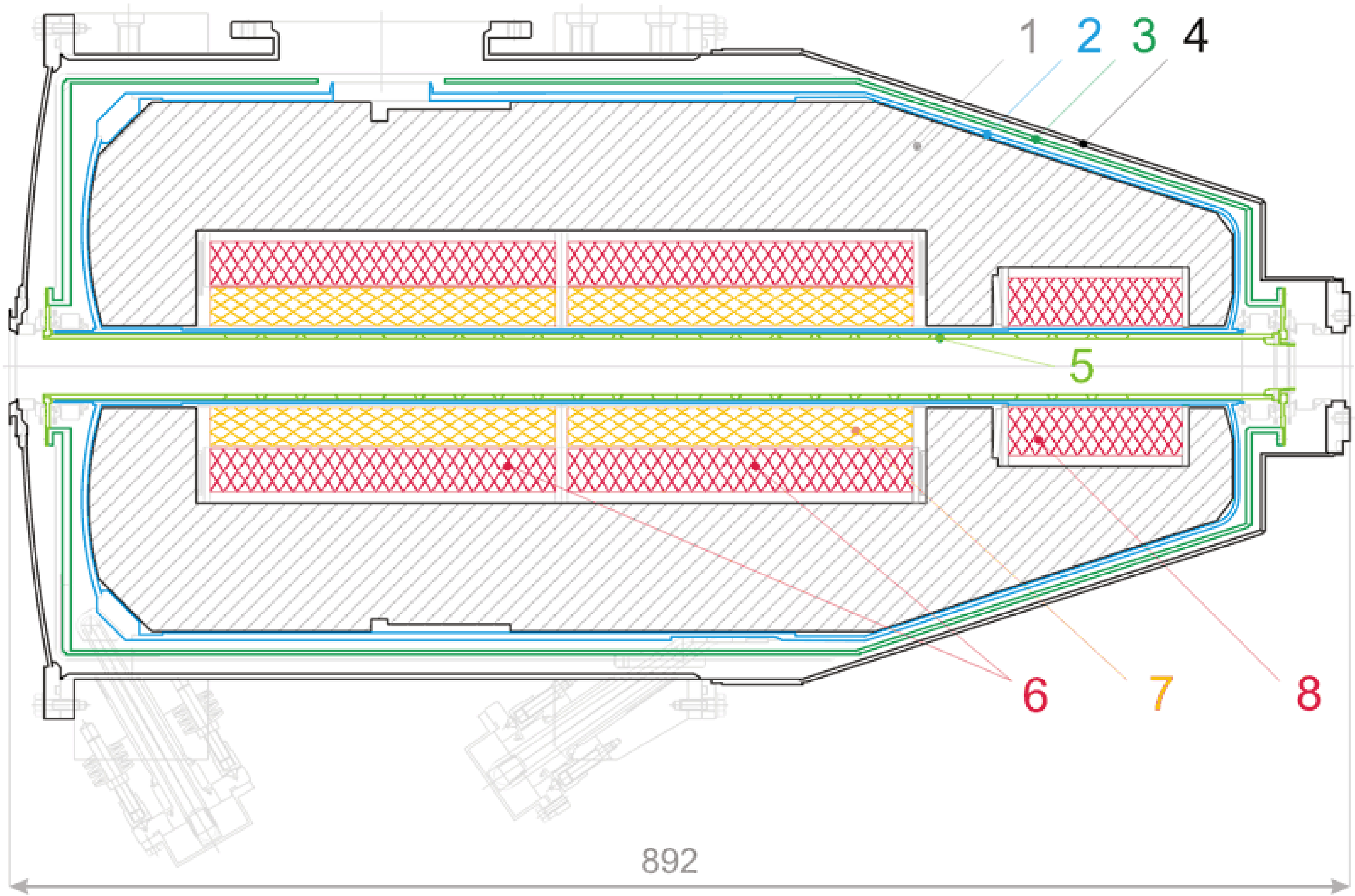
$$L = \frac{\pi\gamma^2 \xi_x \xi_y \varepsilon_x f}{r_e^2 \beta_y^*}\left(1+\frac{\sigma_y}{\sigma_x}\right)^2$$

Round beam:

$$L = \frac{4\pi\gamma^2 \xi^2 \varepsilon f}{r_e^2 \beta^*}$$

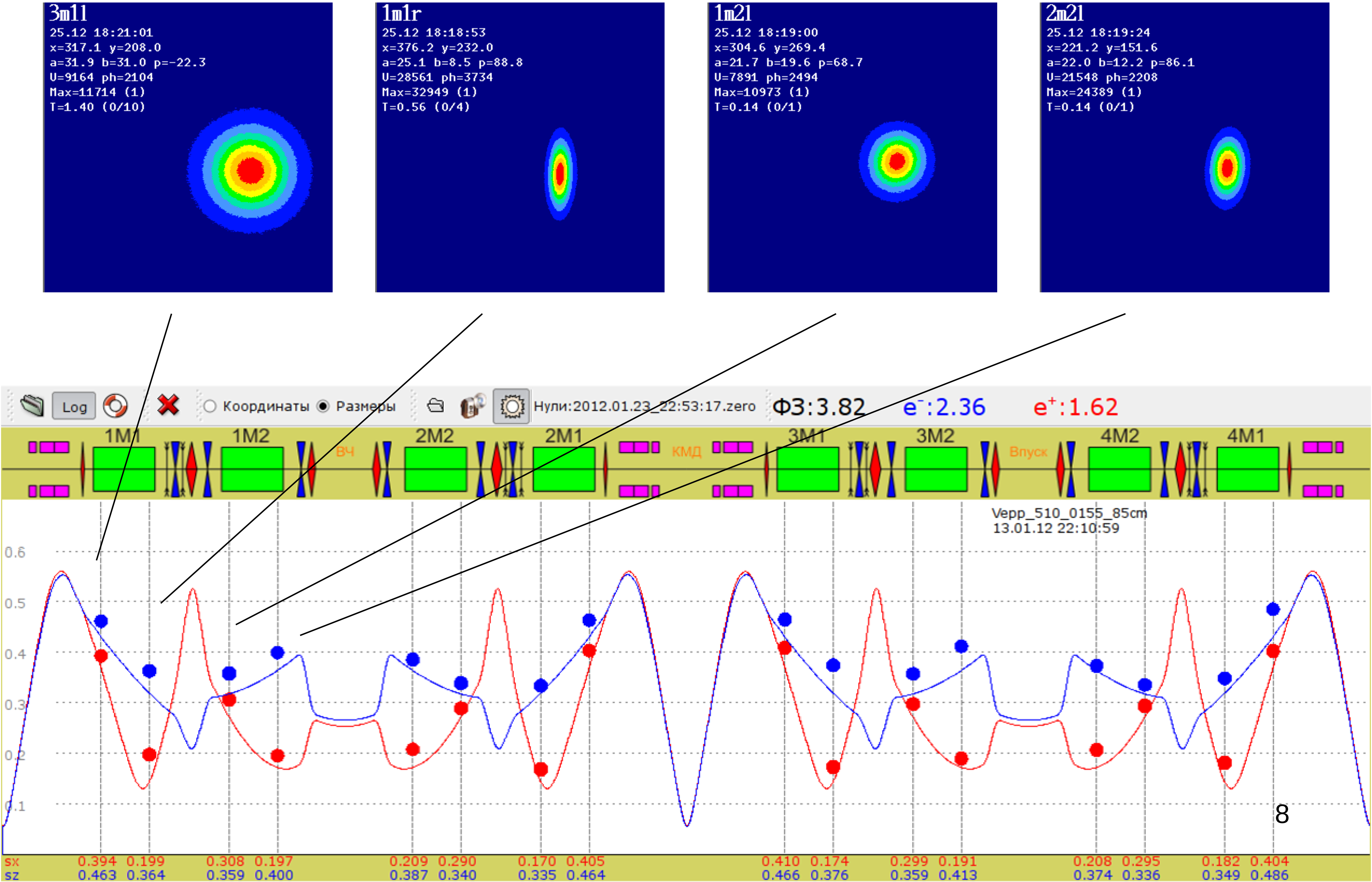
- ✓Geometrical factor: $\left(1+\sigma_y/\sigma_x\right)^2 = 4$
- ✓Beam-beam parameter enhancement(!): $\xi \geq 0.1$
- ✓Higher Touschek lifetime at low collision energies!

Solenoid of the Final Focus

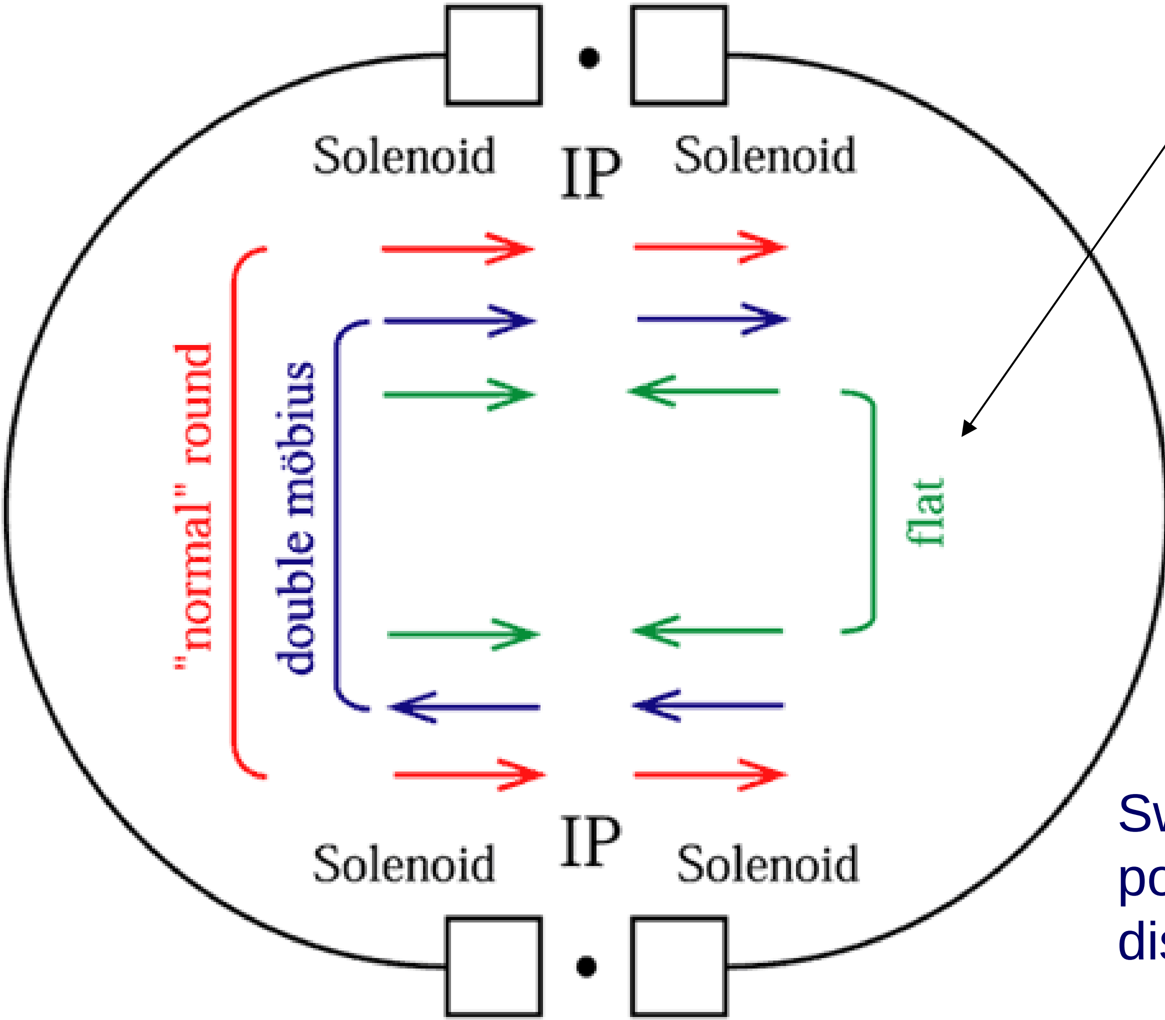


1 – iron yoke, 2 – LHe vessel, 3 – LN screen, 4 – room temperature wall, 5 – LN liner, 6 – NbTi coils, 7 – Nb_3Sn coils, 8 – NbTi compensating detector field solenoid

Beam Sizes measured by CCD monitors



Three options with different solenoids polarities (each twists plane by 45^0)



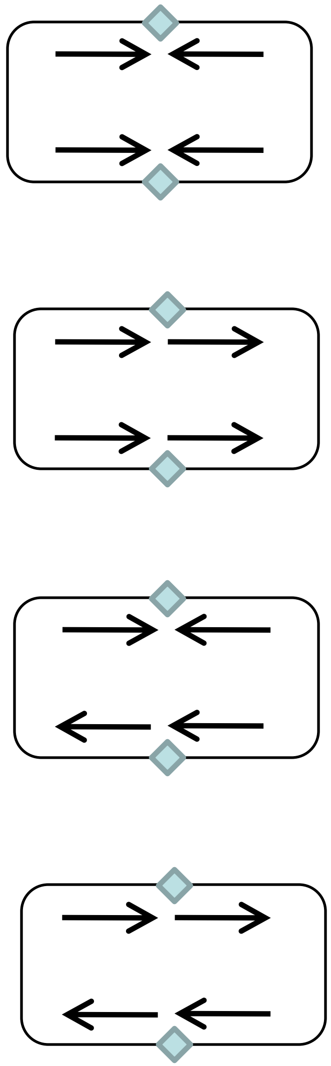
Round beams are made by choice of a working point on the linear coupling resonance. "Flat" option showed best beam-beam limit:

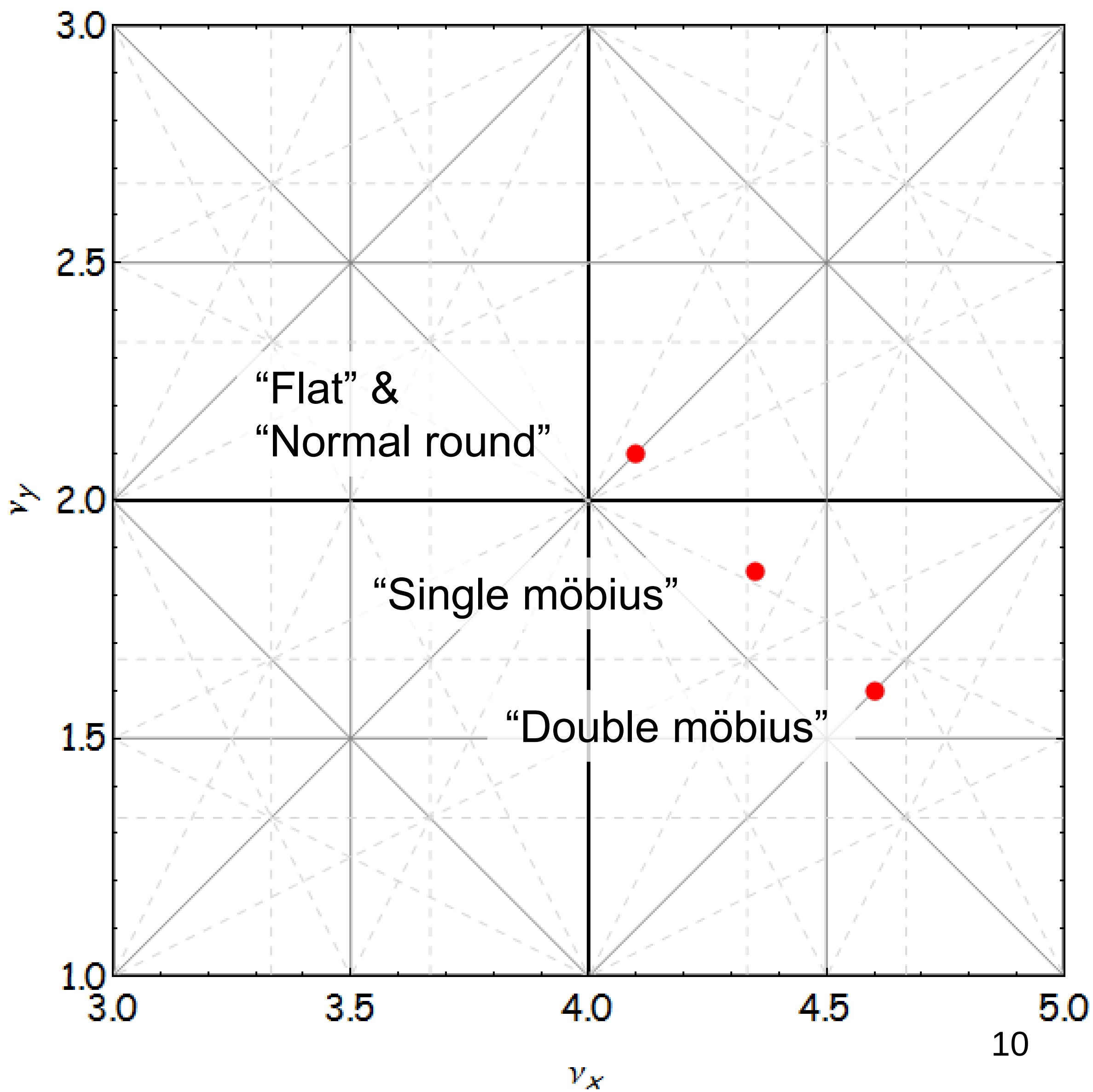
$$\xi > 0.1$$

while all others ~3 times lower due to DA problems.

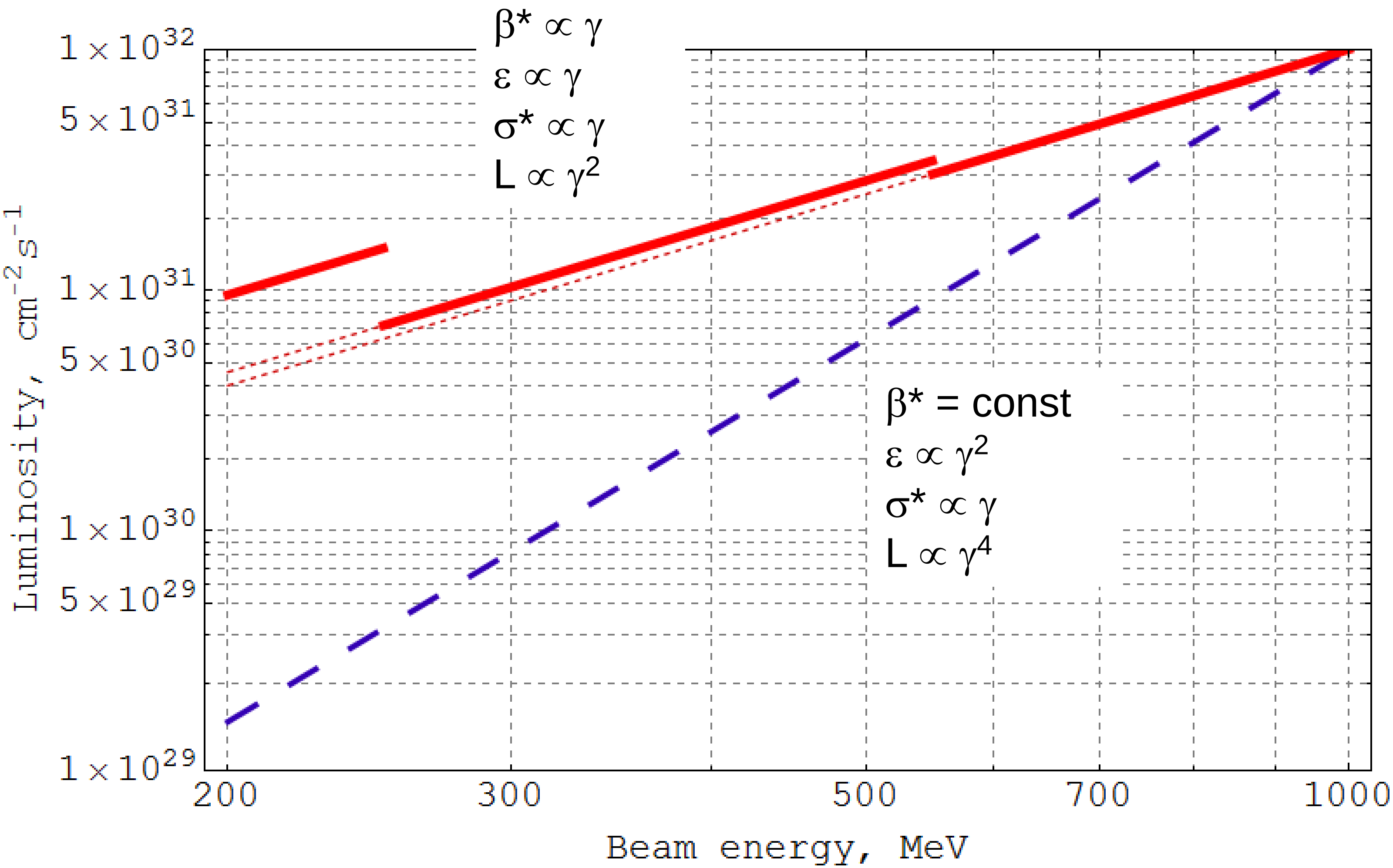
Switching between solenoid polarities causes large orbit distortions. Not easy to play!

Working point in different optics





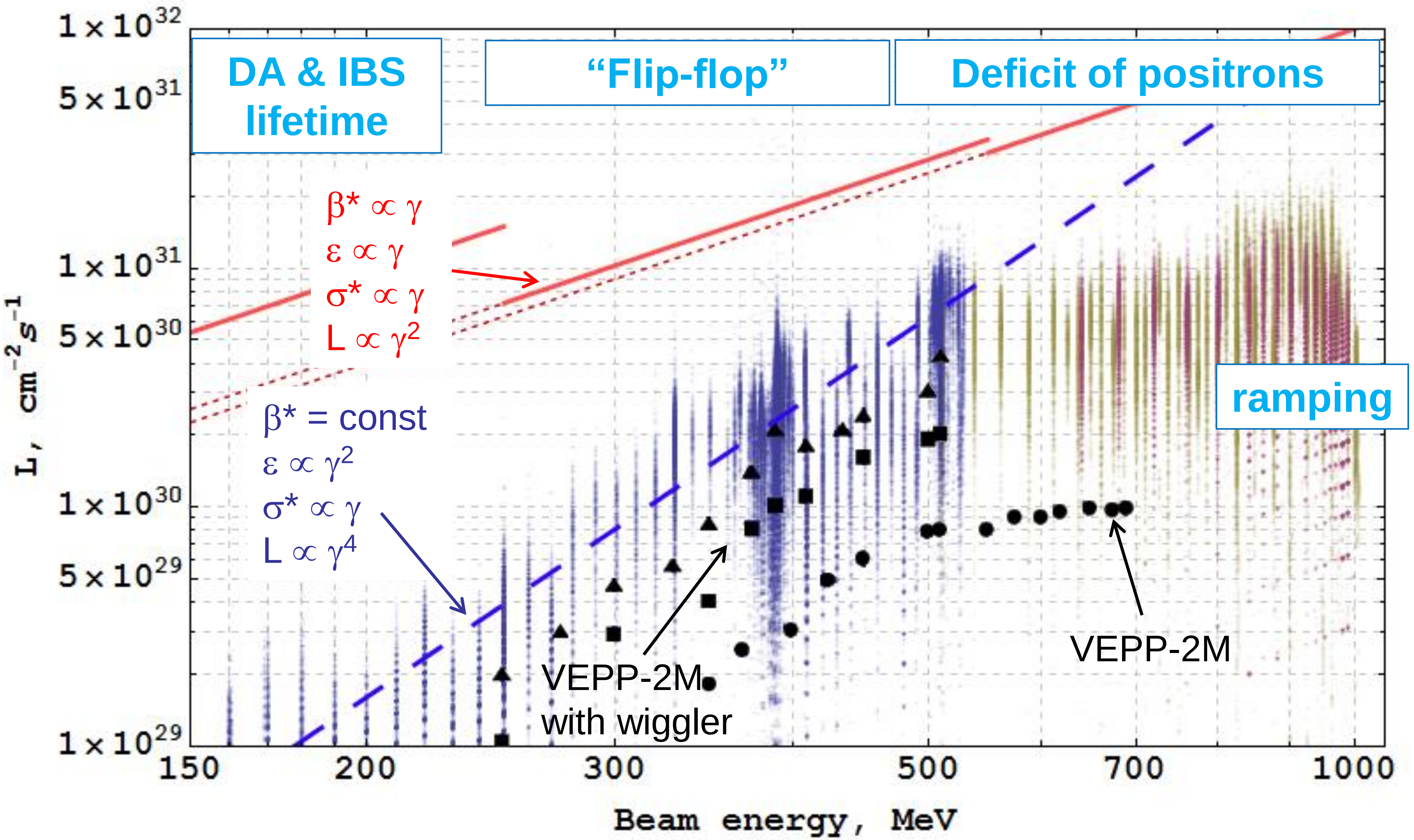
VEPP-2000: Luminosity vs.energy



$$L = \frac{4\pi\gamma^2\xi^2\varepsilon f}{r_e^2\beta^*} = \frac{4\pi\gamma^2\xi^2\sigma^{*2} f}{r_e^2\beta^{*2}}$$

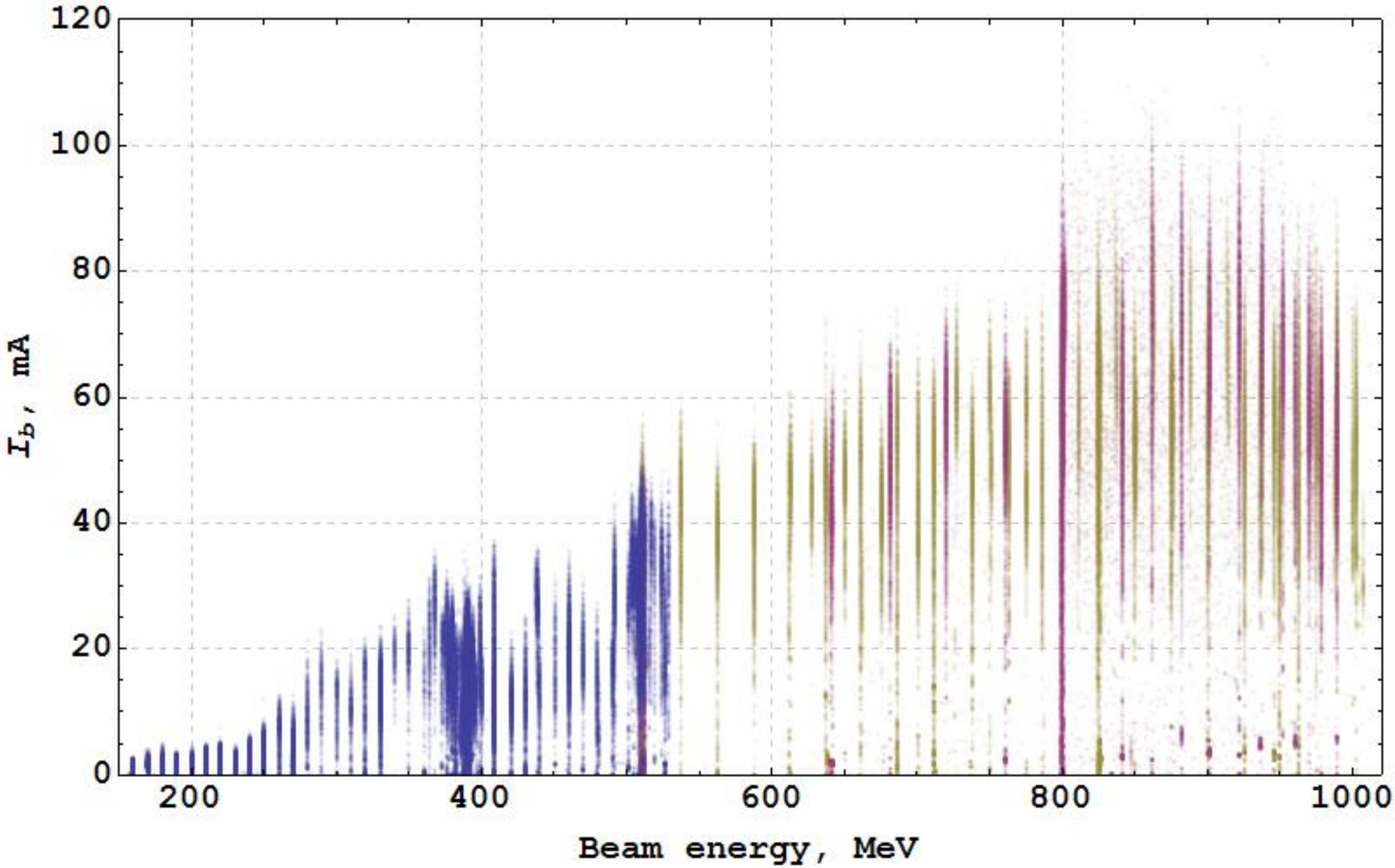
$$\sigma^{*2} = \varepsilon\beta^* = inv(\beta^*)$$

VEPP-2000: Luminosity energy scan

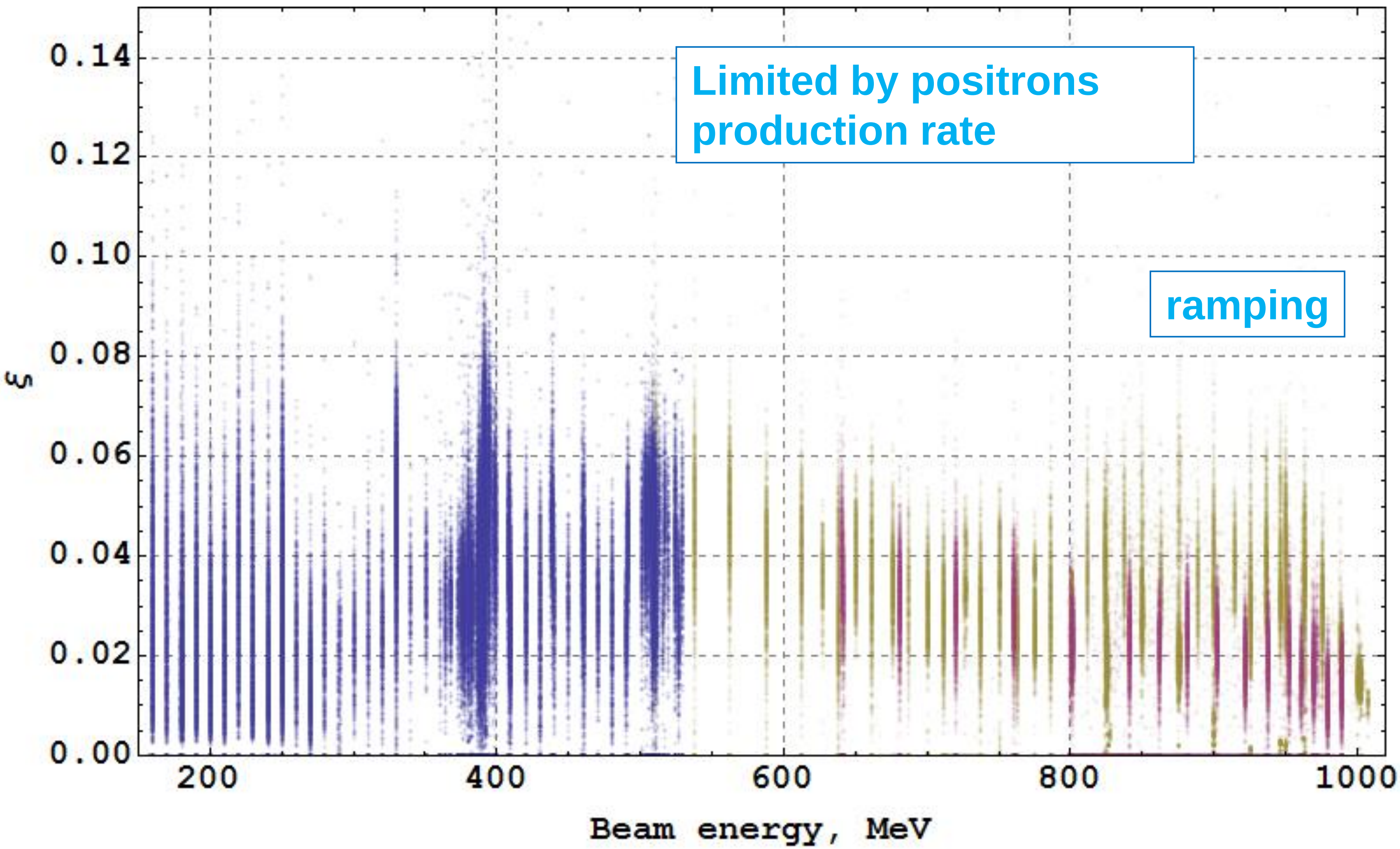


Seasons 2010-2011, 2011-2012, 2012-2013

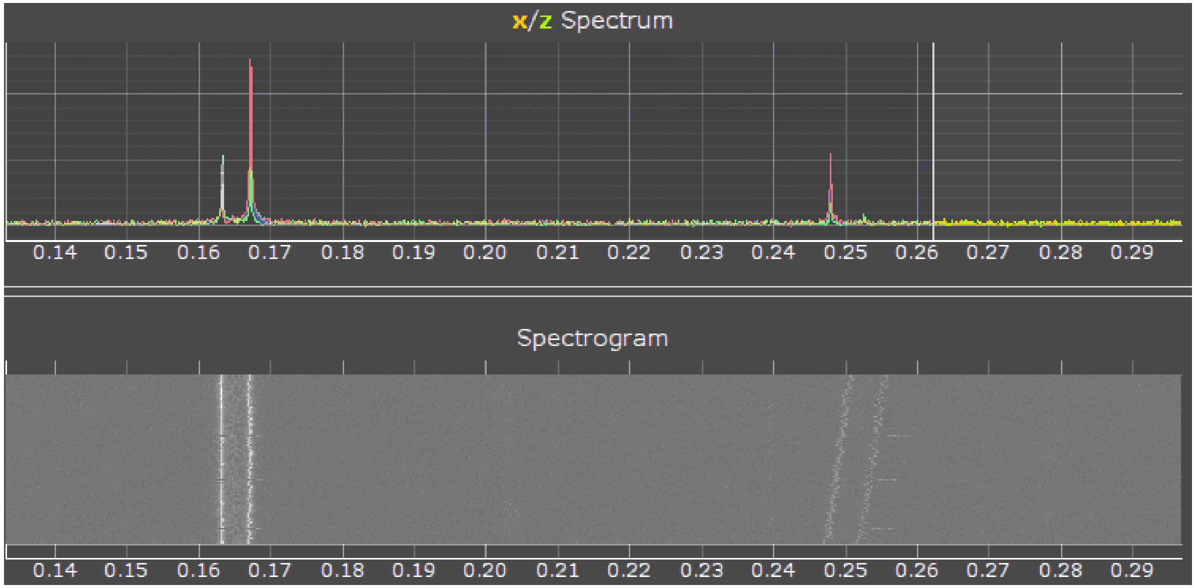
Beam current

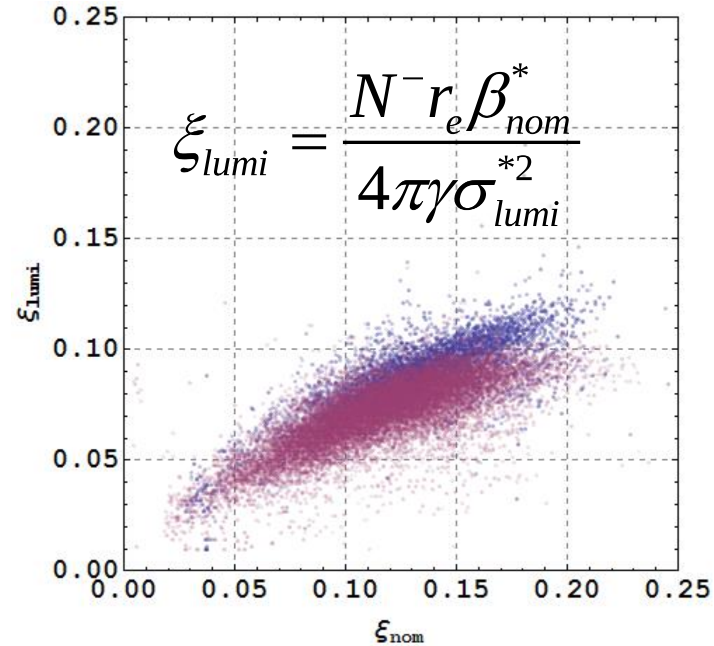


Beam-beam parameter vs. energy

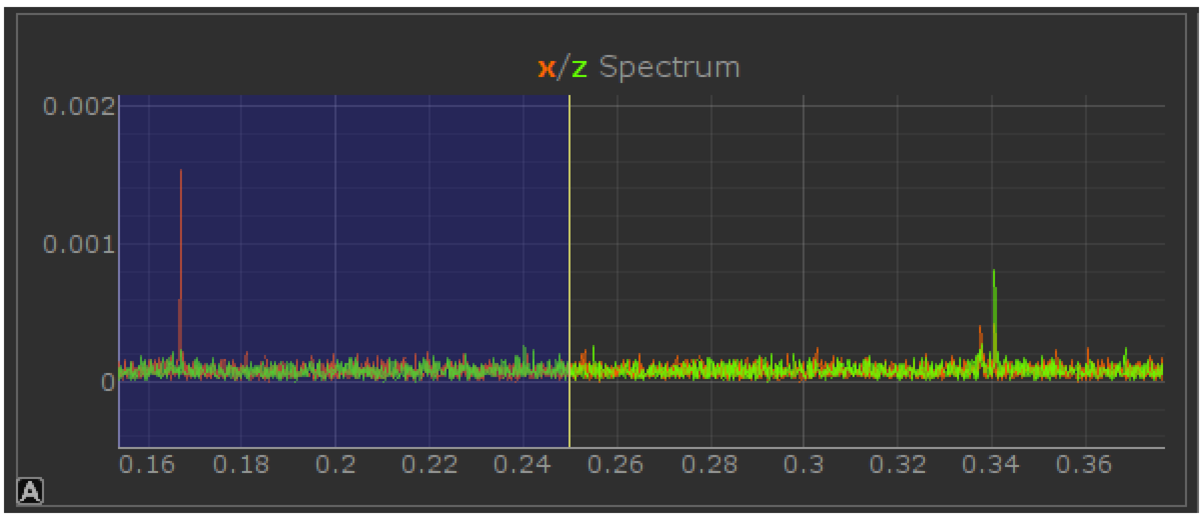


Beam-Beam sigma/pi-mode measurements





E= 392.5 MeV beam energy,
RF voltage 35 kV (violet poits)
and 17 kV (blue points).

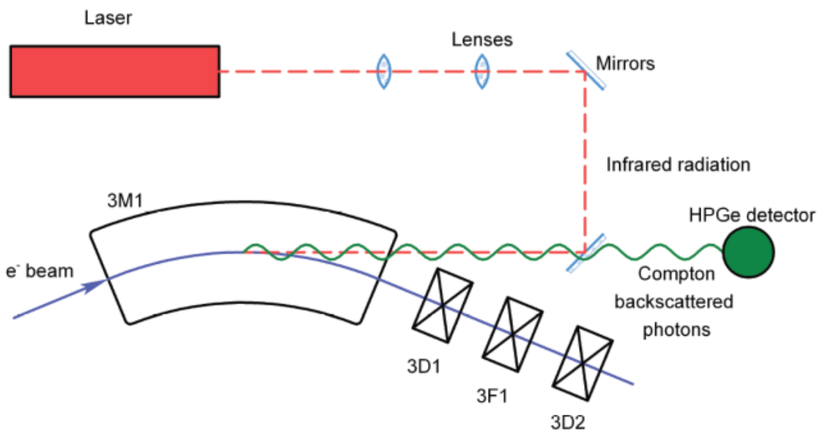


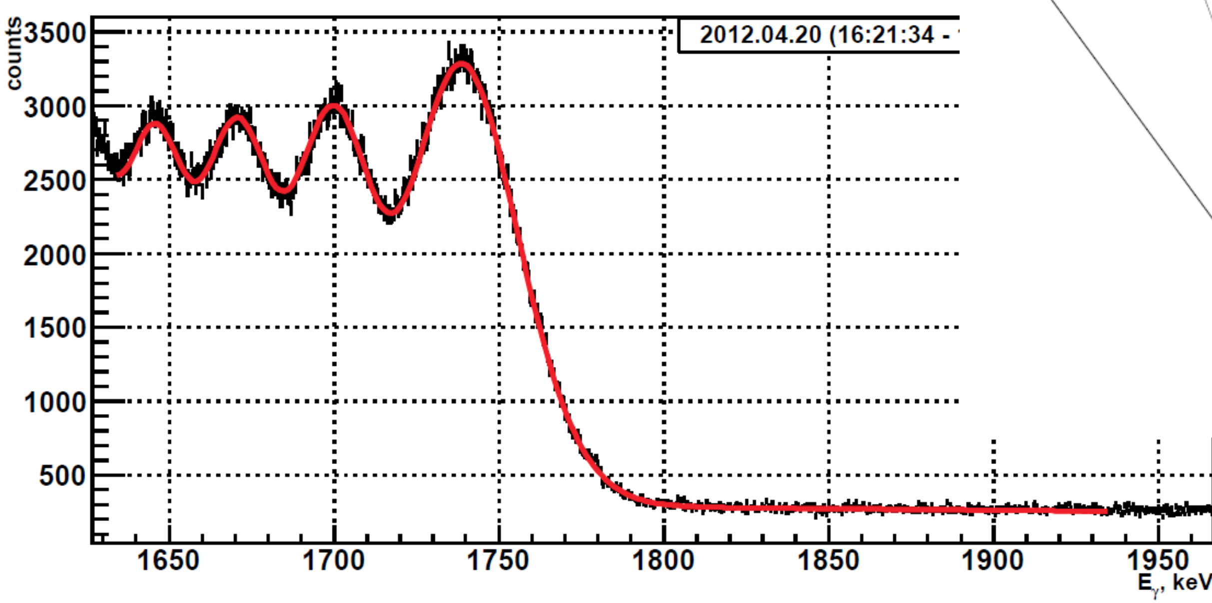
→ $\xi = 0.125$

$\Delta\nu = 0.087$

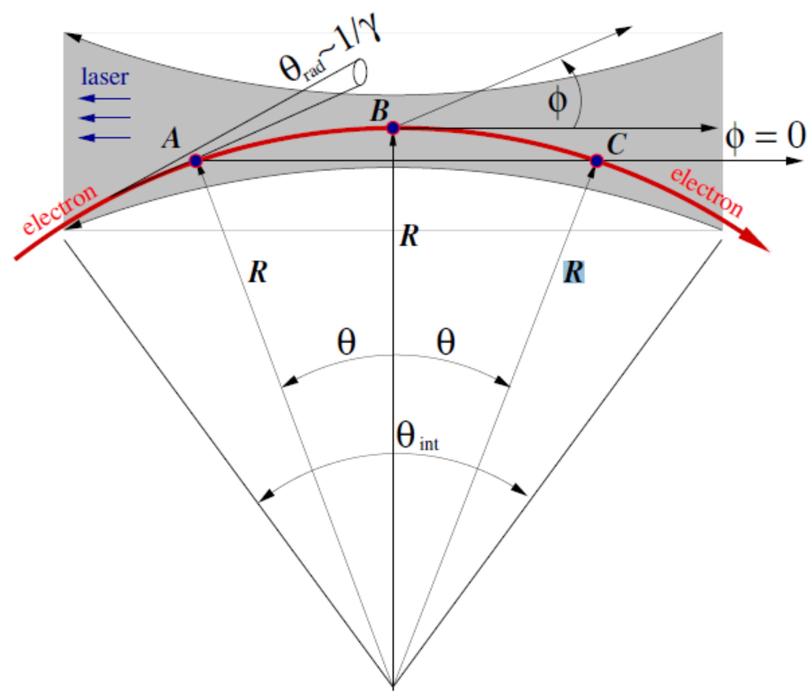
$$\Delta\nu = \arccos(\cos(\pi\nu_0) - 2\pi\xi\sin(\pi\nu_0))/\pi - \nu_0$$

Energy measurement: Compton Back-Scattering





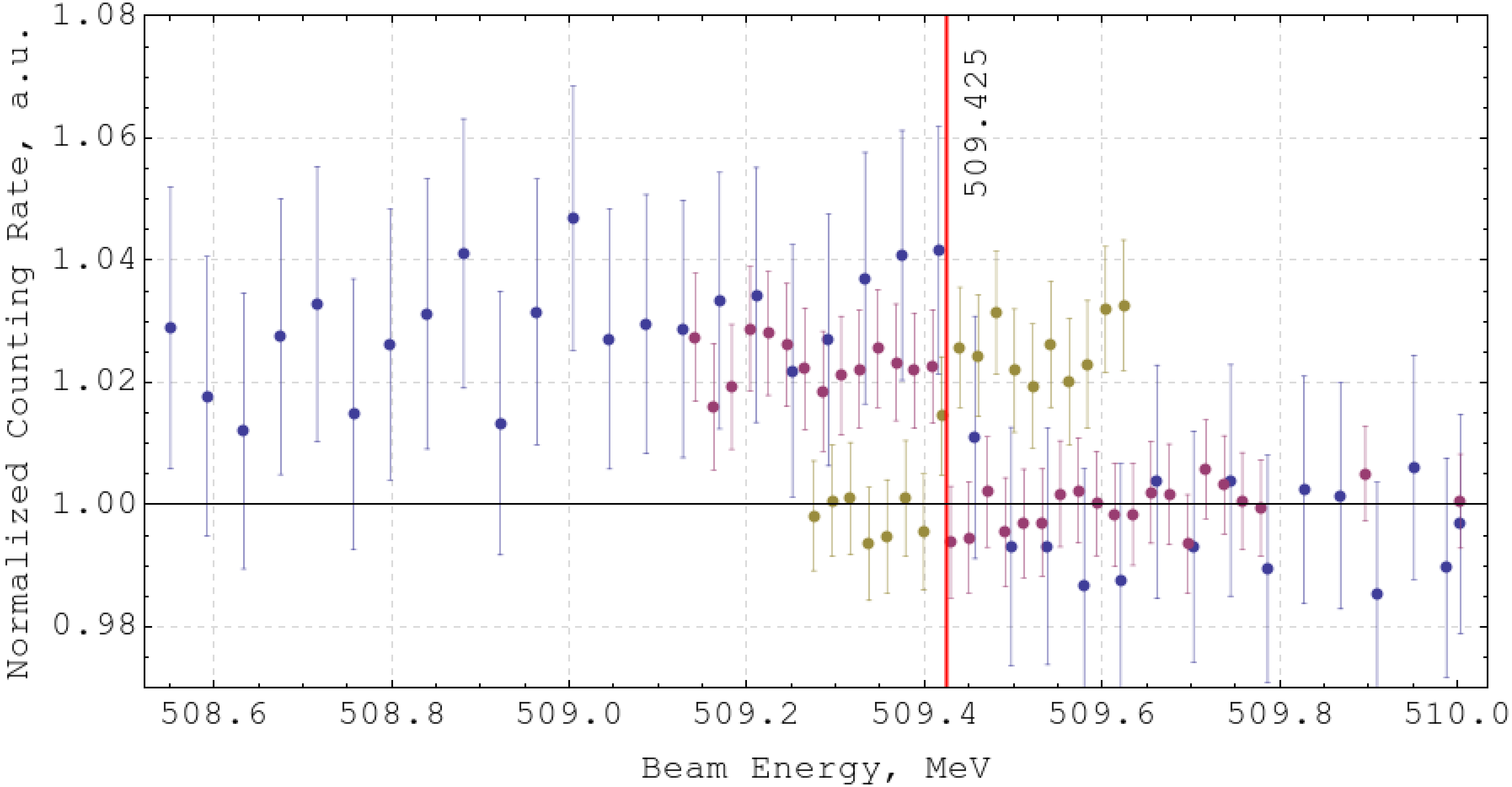
Interference of the scattered light emitted at φ = 0 along an arc A -C



E = 993.662 ± 0.016 MeV

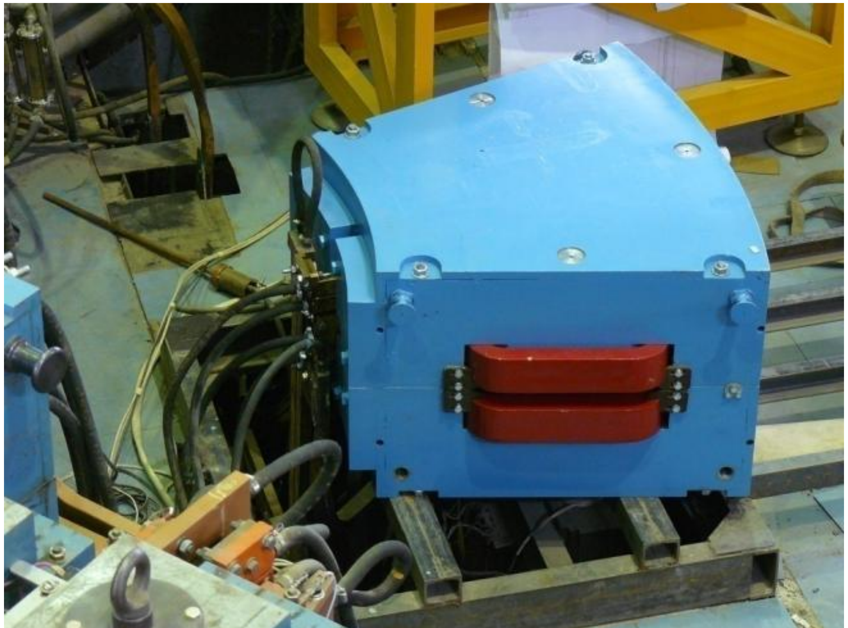
M.N. Achasov et al. arXiv:1211.0103v1 [physics.acc-ph] 1 Nov 2012

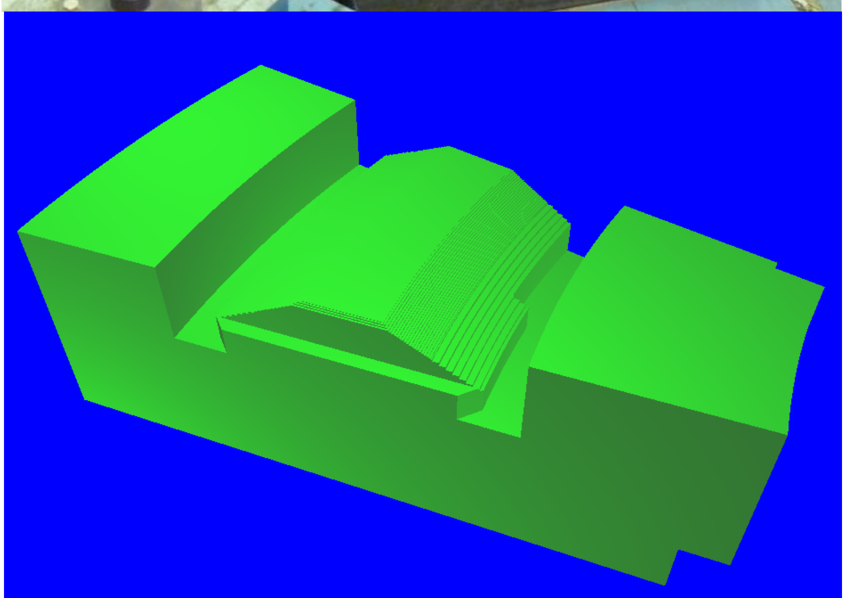
Energy measurement: resonance depolarization



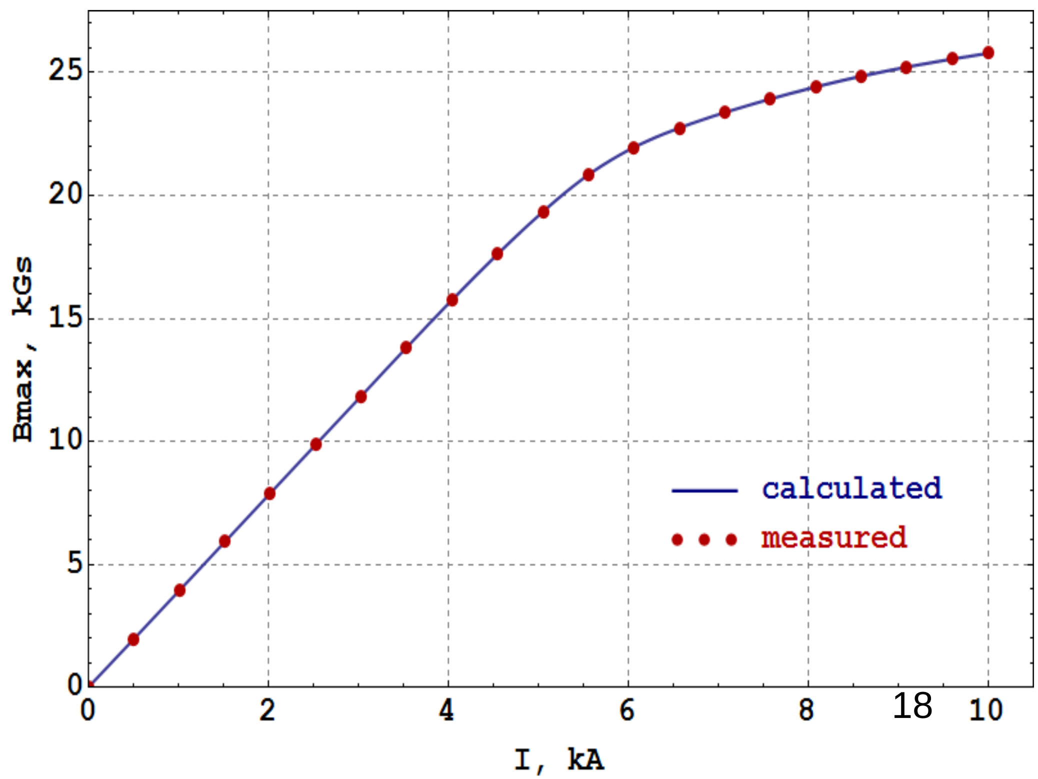
$$f_d = \left(\frac{E(MeV)}{440.6486} - 1\right) f_0$$

Upgraded to 1 GeV BEP's dipole (26 kGs)





Reduced gap: from 40 mm to 32 mm.
Narrowed width of the flat part of a pole: from 120 mm to 100 mm.
Increased width of a return yoke.



VEPP-2000 summary

- **Three seasons with data taking for physics have shown very good collider performance, limited only by positrons accumulation rate. Maximum luminosity achieved 1.3*10^{31} cm^{-2}s^{-1} at 0.51 GeV and 3*10^{31} cm^{-2}s^{-1} at 0.9 GeV.**

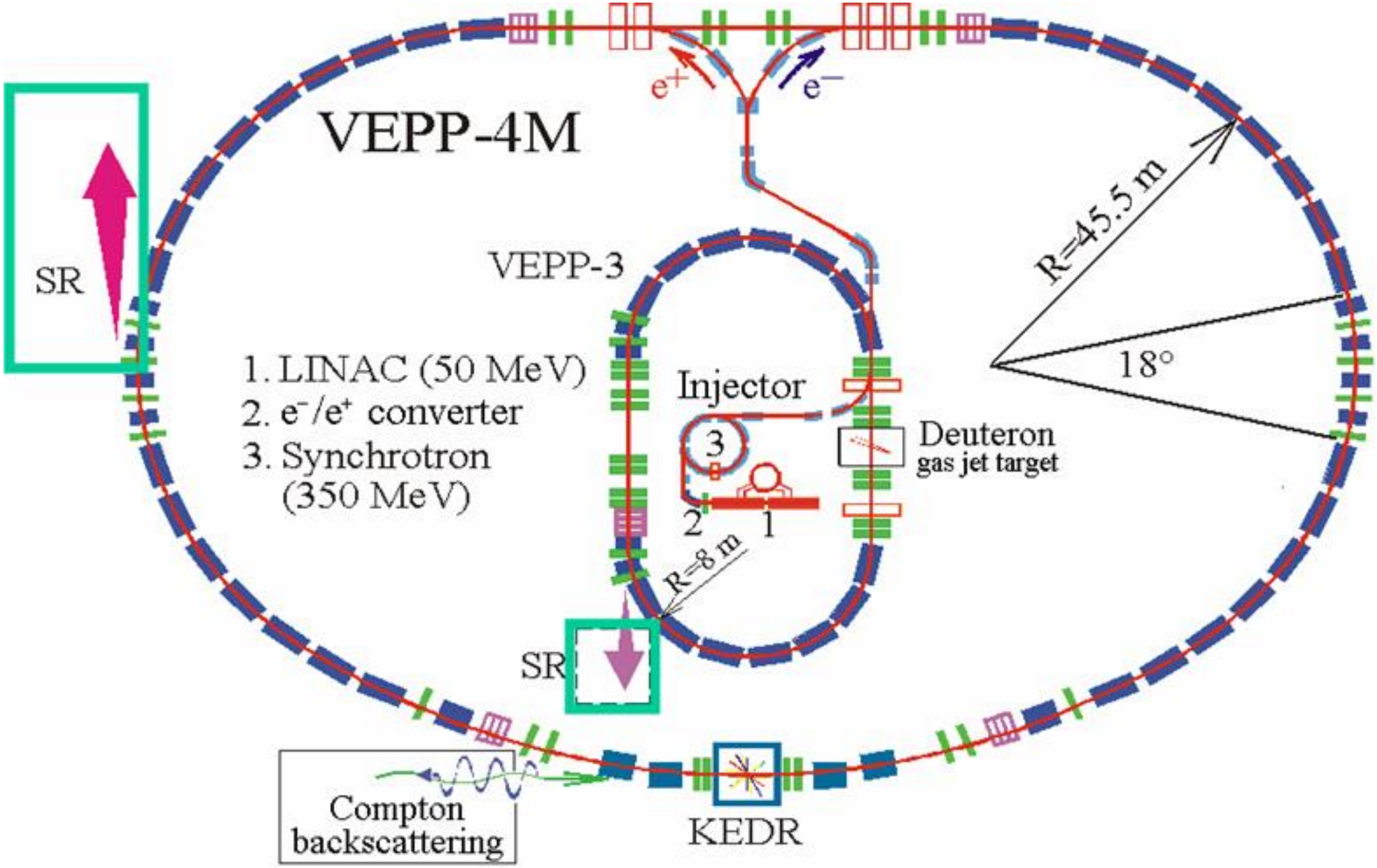
- **BEP's upgrade to 1 GeV and 10 times higher positron production rate, demonstrated recently at new injector complex VEPP-5, will ensure realization of the project luminosity goals in the full energy range.**

- **Next physics run is expected in the end of 2014.**

VEPP-4 near future plans

- **Beam-beam test experiment with smaller beta_x but larger D_x – to prove gain in collision currents and in luminosity**
- **R measurements and two gamma physics with increased beam energy up to 4.5-4.7 GeV (depends on RF)**
- **CPT test by resonance depolarization of two beams with 10^{-8} accuracy**
- **New transfer lines from VEPP-5 positron/electron injector complex commissioning**

VEPP-4 schematic view



VEPP-4 parameters and experimental facilities

Circumference, P (m)	366.075
Revolution frequency, f_0 (kHz)	818.924
Revolution period, T_0 (ns)	1221
Maximum energy, E (GeV)	5.3*)
Momentum compaction factor, α	0.017
Betatron tunes, Q_x/Q_z	8.54/7.58
Synchrotron tune, Q_s	0.012
Natural chromaticity, ξ_y/ξ_x	–14.5/–20.3
Parameters at 1.8 GeV	
Damping times, $\tau_x/\tau_y/\tau_s$ (ms)	70/35/70
Horizontal emittance, ε_x (nm-rad)	17
Energy spread, σ_E/E	4×10^{-4}
Bunch length, σ_L (cm)	6
Energy loss/turn, ΔU (keV)	16
IP optical functions, β_y / β_x / η_x (m)	0.05/0.7/0.78

- Detector KEDR for HEP experiments
- Electron tagging system at VEPP-4 for two-photon experiments
- SR experiments at VEPP-3
- SR experiments at VEPP-4
- Internal gas target for nuclear physics at VEPP-3
- Electron/gamma test beam facility for detector calibration
- Compton backscattering system
- High resolution polarization measurement system for CPT study
- Sophisticated beam diagnostics for accelerator experiments

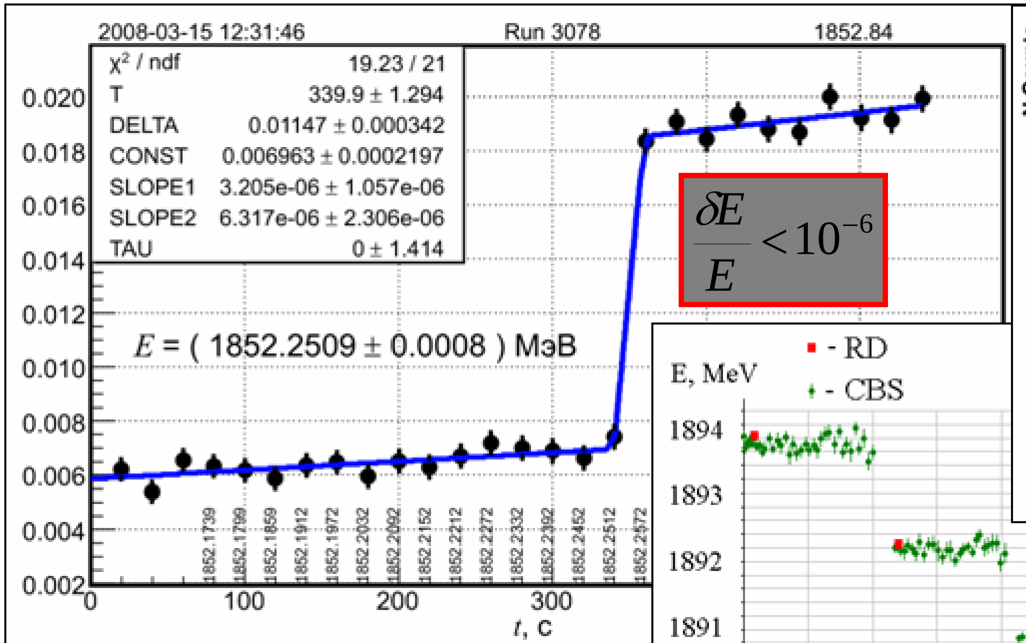
VEPP-4/KEDR features for HEP

- Beam energy range varied from 0.9 GeV up to 5.0 GeV
- Beam energy calibration using resonant depolarization method with the record accuracy of 10^{-6}
- On-line monitoring of the beam energy using the Compton back scattering method with the accuracy of $5 \cdot 10^{-5}$
- Universal detector KEDR comparable with modern detectors used for high-energy physics experiments at the electron-positron colliders:
  - system of registration of scattered electrons and positrons with the record resolution 10^{-3},
  - liquid-krypton electromagnetic calorimeter,
  - system of aerogel Cerenkov counters.

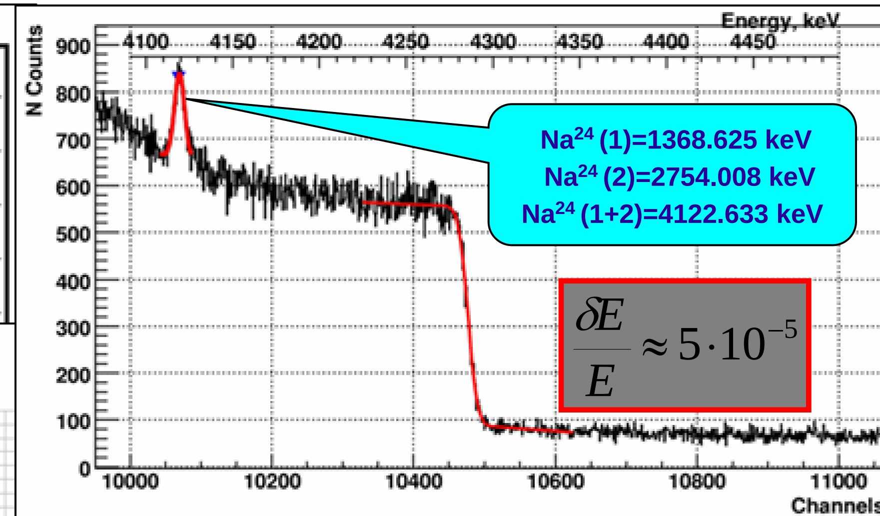
Beam energy measurement

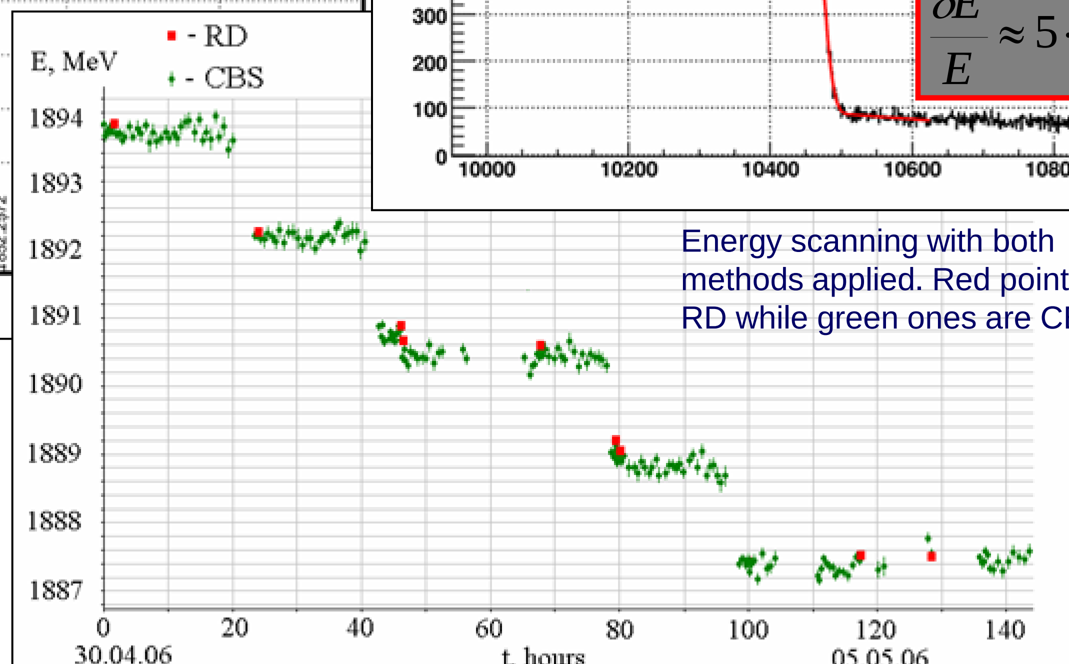
http://v4.inp.nsk.su

Resonant depolarization provides a record accuracy in energy calibration



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





Energy scanning with both methods applied. Red points are RD while green ones are CBS

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

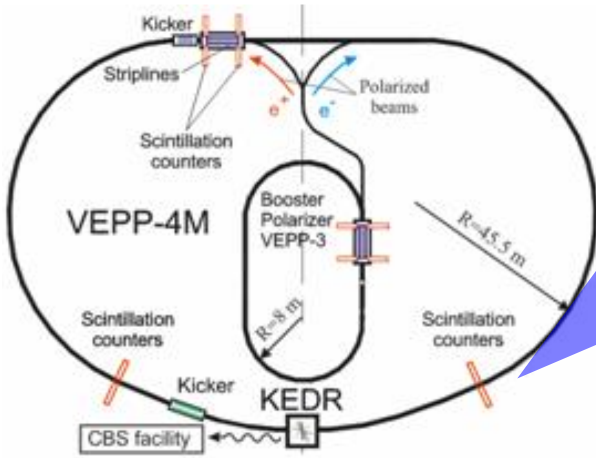
$$E = 440.65\,\mathrm{MeV} \cdot \left(\frac{\Omega_s}{\omega_0} - 1 \right)$$

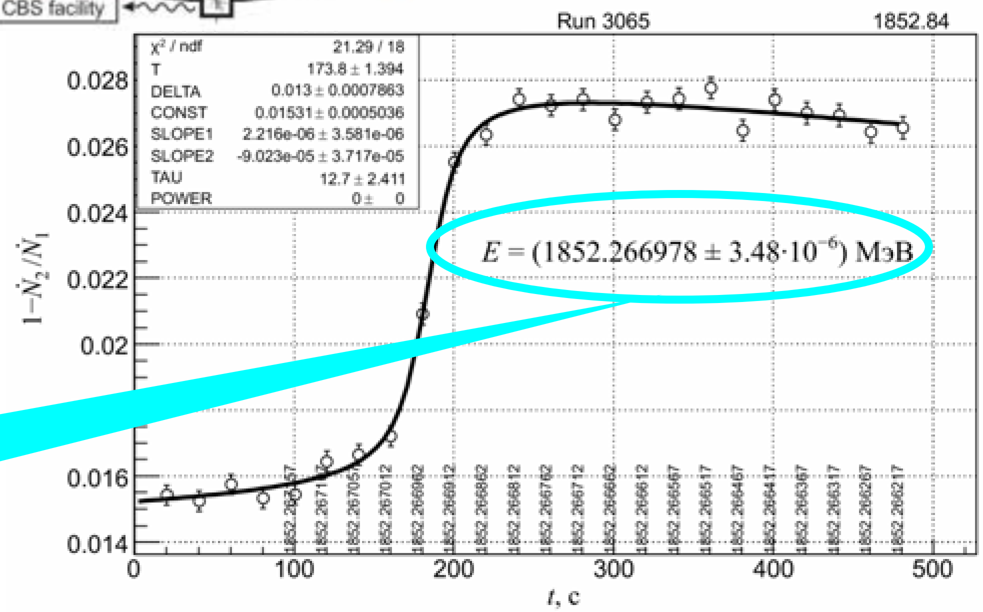
Particle mass measurements at VEPP-4

Particle	E, MeV	Accuracy, $\Delta E/E$	Detector	Years
J/ψ	3096.93±0.10	$3.2 \cdot 10^{-5}$	OLA	1979-1980
ψ'	3685.00±0.12	$3.3 \cdot 10^{-5}$	OLA	1979-1980
Υ	9460.57±0.09±0.05	$1.2 \cdot 10^{-5}$	MD-1	1983-1985
Υ'	10023.5±0.5	$5.0 \cdot 10^{-5}$	MD-1	1983-1985
Υ''	10355.2±0.5	$4.8 \cdot 10^{-5}$	MD-1	1983-1985
J/ψ	3096.917±0.010±0.007	$3.5 \cdot 10^{-6}$	KEDR	2002-2008
ψ'	3686.119±0.006±0.010	$3.0 \cdot 10^{-6}$	KEDR	2002-2008
ψ''	3772.9±0.5±0.6	$2.1 \cdot 10^{-4}$	KEDR	2002-2006
D^0	1865.43±0.60±0.38	$3.8 \cdot 10^{-4}$	KEDR	2002-2005
D^+	1863.39±0.45±0.29	$2.9 \cdot 10^{-4}$	KEDR	2002-2005
τ	$1776.69^{+0.17}_{-0.19} \pm 0.15$	$1.3 \cdot 10^{-4}$	KEDR	2005-2008

Precise polarization experiments

- New Touschek polarimeter is commissioned. The registration efficiency is increased by an order of magnitude.
- Total count rate at 2 mA beam current is now 1.5-2.0 MHz (was 0.1-0.2 MHz).
- An absolute record $1.5\cdot10^{-9}$ accuracy of the measurement of depolarization frequency is achieved.
- For CPT test experiment, the 10^{-8} accuracy of comparison of the electron and positron spin frequency is real now.





“Nano- resolution”:
scan rate = **2.5 eV/s**
relative error **$\sim10^{-9}$**

Increase in VEPP-4M luminosity at low energy (proposal)

We plan to test this proposal in a special experiment

Luminosity formulae (flat beam)

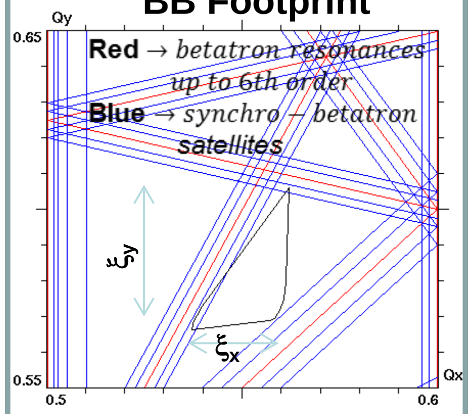
$$L=\frac{\gamma}{2er_e}\frac{I\xi_y}{\beta_y^*},\ \xi_x=\frac{Nr_e}{2\pi\gamma}\cdot\frac{\beta_x^*}{\sigma_x^2},\ \xi_y=\frac{Nr_e}{2\pi\gamma}\cdot\frac{\beta_y^*}{\sigma_y^*\cdot\sigma_x}$$

Monochromatization parameter

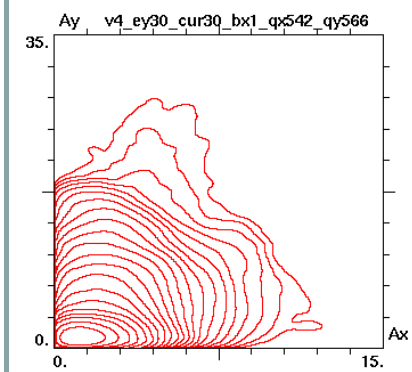
$$\lambda_m=\frac{\sigma_{xs}}{\sigma_{x\beta}}=\frac{\eta_x\sigma_E}{\sqrt{\varepsilon_x\beta_x}},\ \sigma_x=\sqrt{\sigma_{x\beta}^2+\sigma_{xs}^2}=\sigma_{x\beta}\sqrt{1+\lambda_m^2}$$

$$x=x_\beta+\eta_x\frac{\Delta E}{E}$$

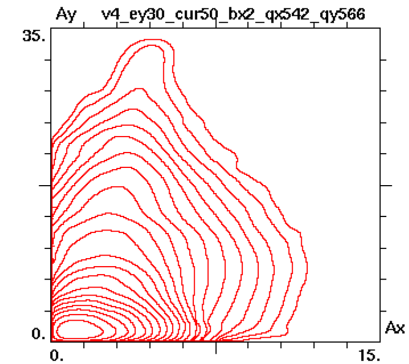
BB Footprint



Distribution in betatron amplitude plane



I_b=3.0 mA, β_x=65cm, ξ_y=0.036



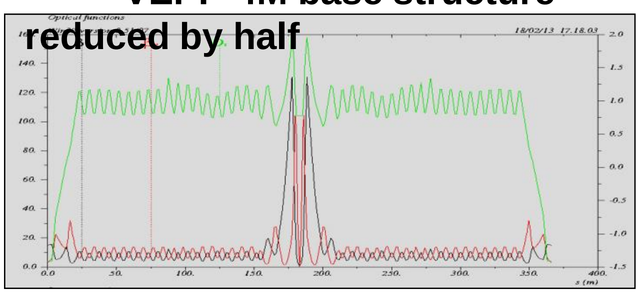
I_b=5.0 mA, β_x=32.5cm,

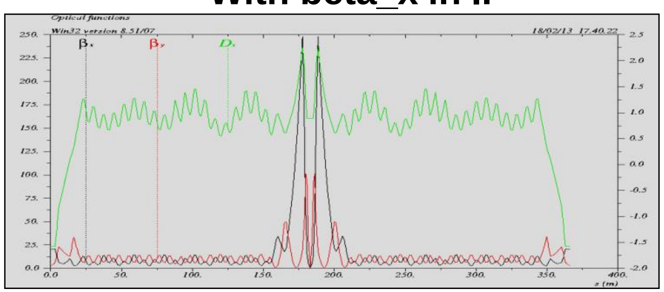
IP with dispersion

Increase in λ_m owing to reducing β_x (not ε_x – emittance!) results in:

- increase of critical current due to decrease of ξ_x
- Increase of critical ξ_y because of coupling resonance suppression

VEPP-4M base structure **With beta_x in IP reduced by half**

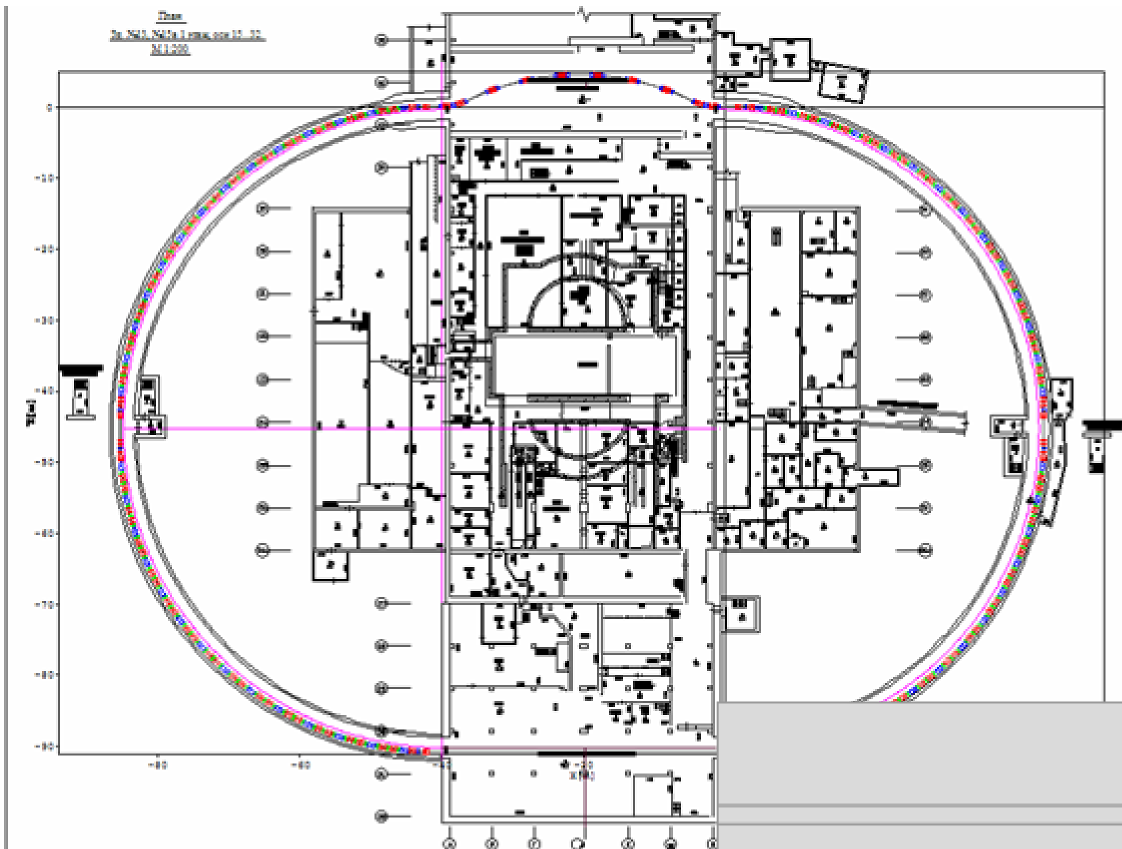




Resume

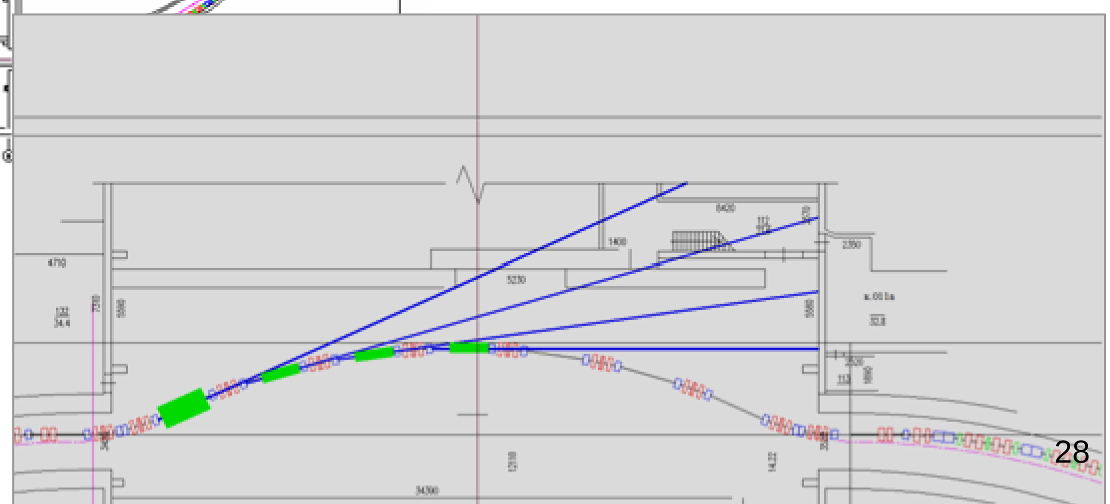
Reducing β_x by half yields increase of critical current from 3 to 5 mA

SR source in the VEPP-4 tunnel as an option



E = 3 GeV
Emittance = 1 nm
Current = 500 mA
RF 180 MHz exists

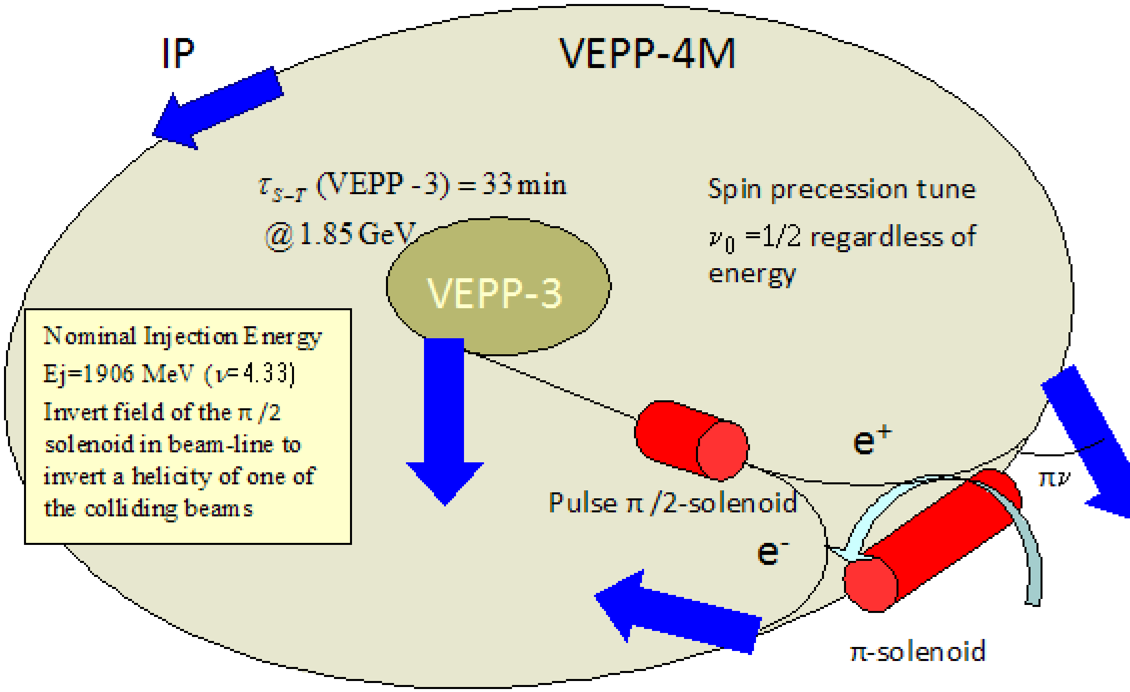
In a long (~70 m) straight section a set of IDs is located



VEPP-4M

Longitudinally polarized beams (wait approval)

(Project for VEPP-4: 1981, 1983)



Depolarization time with SS:

$$\tau_d \approx \frac{54}{11}\cdot\frac{\tau_{S-T}}{\pi^2\nu^2}\cdot B(\nu,\nu_x) \propto E^{-7}$$

$\nu = \gamma a$

$B(\nu,\nu_x)$ – betatron factor

VEPP-4M Sokolov-Ternov time:

$$\tau_{S-T}[h]\overset{\text{VEPP-4M}}{=}\frac{1540}{E^5[GeV]}$$

70 hours at 1.85 GeV

Estimate with $B(\nu,\nu_x)$ (no optimization):

$\tau_d = 160$ min at $E = 1777$ MeV

$\tau_d = 120$ min at $E = 1846$ MeV

$\tau_d = 425$ min at $E = 1548$ MeV

Siberian Snake (SS) insert with decoupling:

Two SC 124 cm × 72 kG solenoids (1.98 GeV)

Five 20 cm×(up to 2.8 kG/cm) quads

Total length=430 cm

Both electron and positron polarizations available in luminosity run.

Effects @ 1.85 GeV $\propto \langle \varsigma_+\varsigma_-\rangle_{time} = \frac{2\tau_d}{t_{run}} P_+P_-\left[\exp\left(-\frac{2t_{run}}{\tau_d}\right)-1\right] \approx 0.3,$

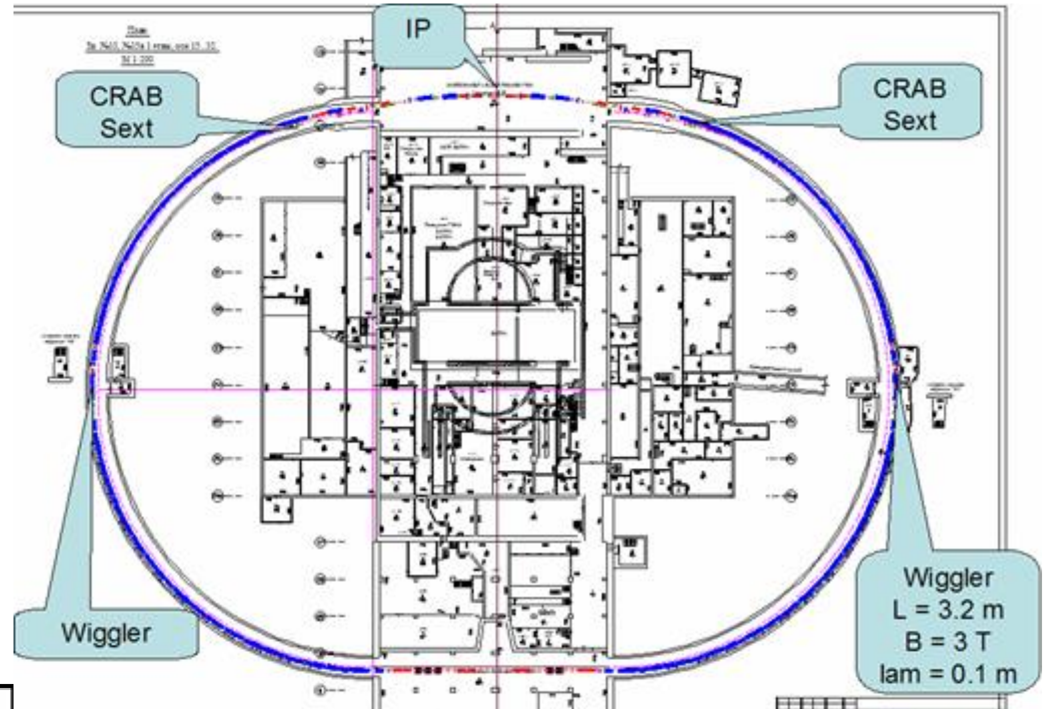
$t_{run} = 1$ h - run duration; $P_+ = 0.92\left[1-\exp\left(-\frac{t}{\tau_{p,VEPP-3}}\right)\right] = e^+$ initial degree for time $t \approx 3000$ s; $P_- = P_+\exp\left(-\frac{t}{\tau_d}\right) = e^-$ initial degree

VEPP-4M

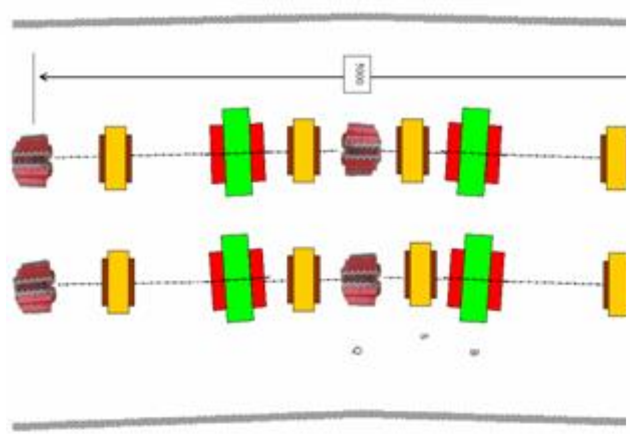
Super Cτ Factory Prototype (from ϕ to ψ)

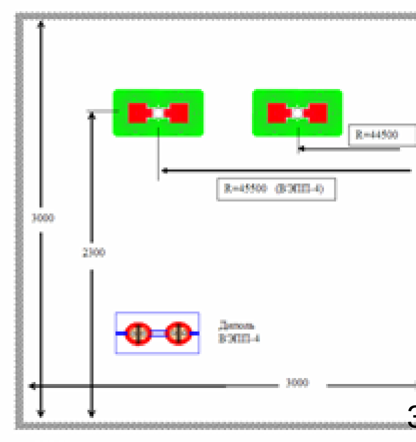
Crab Waist e^+e^- Factory providing in the energy range from 0.5 GeV to 1.55 GeV the peak luminosity from 10^{34} to $5\text{x}10^{34}$ $cm^{-2}s^{-1}$

10 times cheaper than SuperCτ Factory



Energy per beam E (GeV)	0.5	1	1.55
Emittance ε_x (nm)	10	4	2.5
Hor.damping τ_x (ms)	70	30	15
Bunch length σ_s (mm)	9	5	4
Energy spread $\sigma_E \times 10^3$	1.3	1	0.96
RF voltage U_{RF} (MV)	0.26	1	2.2
Particles per bunch $n_b \times 10^{10}$	1.4		
Lifetime Touschek τ_T	1000	2000	3000
BB parameter ξ_y	0.06	0.12	0.12
Luminosity ($cm^{-2}s^{-1}$) $\times 10^{34}$	1	5	6





VEPP-4 summary

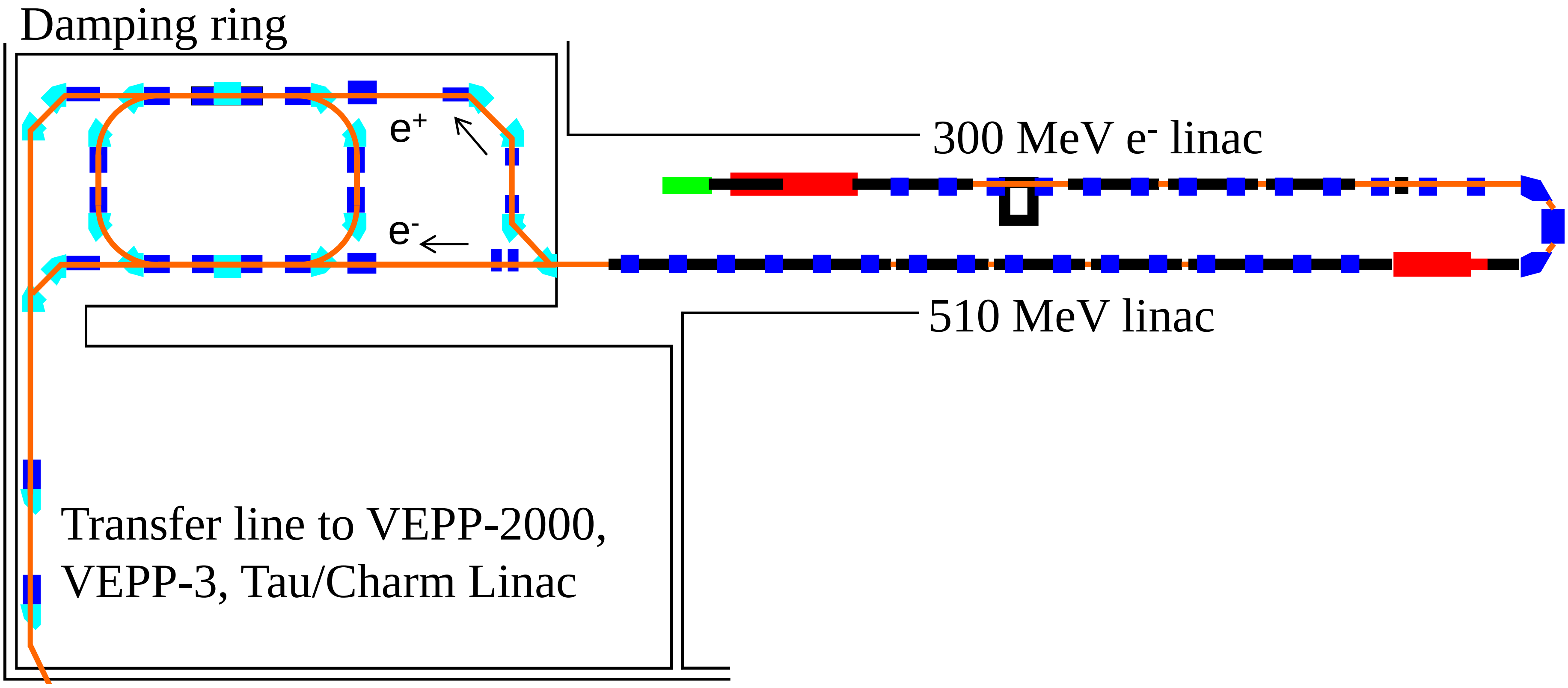
- Since 2002 VEPP-4M collider with detector KEDR provides world-class results for HEP community

- Many other experimental programs (SR, nuclear physics, test beams, accelerator physics study, etc.) are successfully performed at the accelerator facility

- Different scenarios of the future at VEPP-4 (or with the help of its infrastructure) are considered intensively

Positrons at VEPP-5 Injector complex

NEW INJECTOR COMPLEX FOR BINP's COLLIDERS



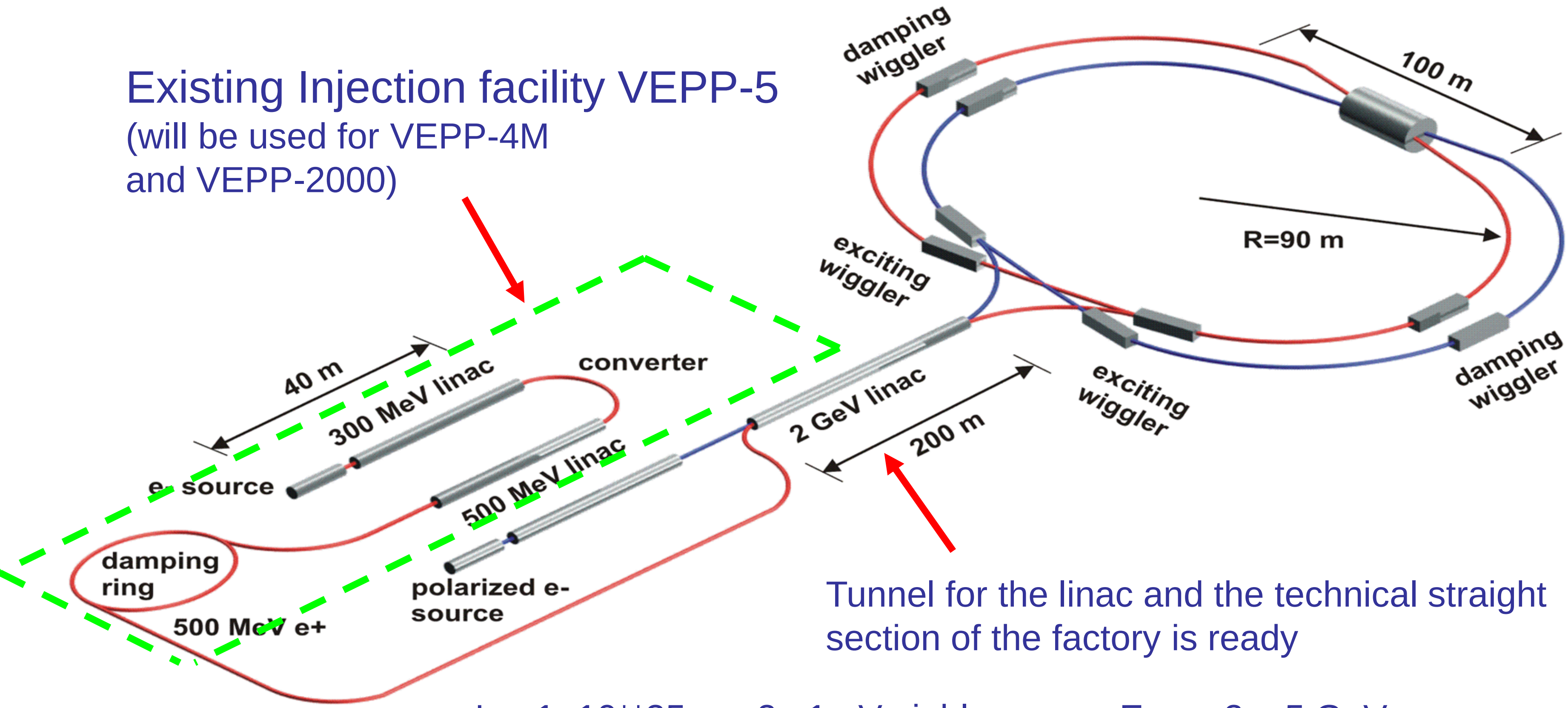
LINACS to GENERATE e^+ and ACCELERATE e^+ and e^- to 500 MeV.

DAMPING RING for STORAGE e+, e-

Transfer line to VEPP-2000 collider complex

Novosibirsk Super Tau-Charm factory

Existing Injection facility VEPP-5
(will be used for VEPP-4M
and VEPP-2000)



Tunnel for the linac and the technical straight section of the factory is ready

L = 1×10**35 cm-2s-1, Variable energy Ecm= 2 – 5 GeV

Status of the project:

- **Conceptual design of the machine and detector is complete**
- **Civil engineering and infrastructure design is complete**
- **Road map is ready (6 years for realization)**
- **Project is preliminary approved by the Russian government**

Super C/tau Factory at Novosibirsk

(physics)

- ► D-Dbar mixing
- ► CP violation searches in charm decays
- ► Rare and forbidden charm decays
- ► Standard Model tests in τ lepton decays
- ► Searches for lepton flavor violation $\tau \rightarrow \mu\gamma$
- ► CP/T violation searches in τ lepton decays

Requirements: $L > 10^{35}$ cm^{-2} s^{-1}, longitudinal polarization

(Polarization may increase sensitivity by several times!)

Project waits of final government's approval!