BINP colliders

Past & present

Yu.M.Shatunov

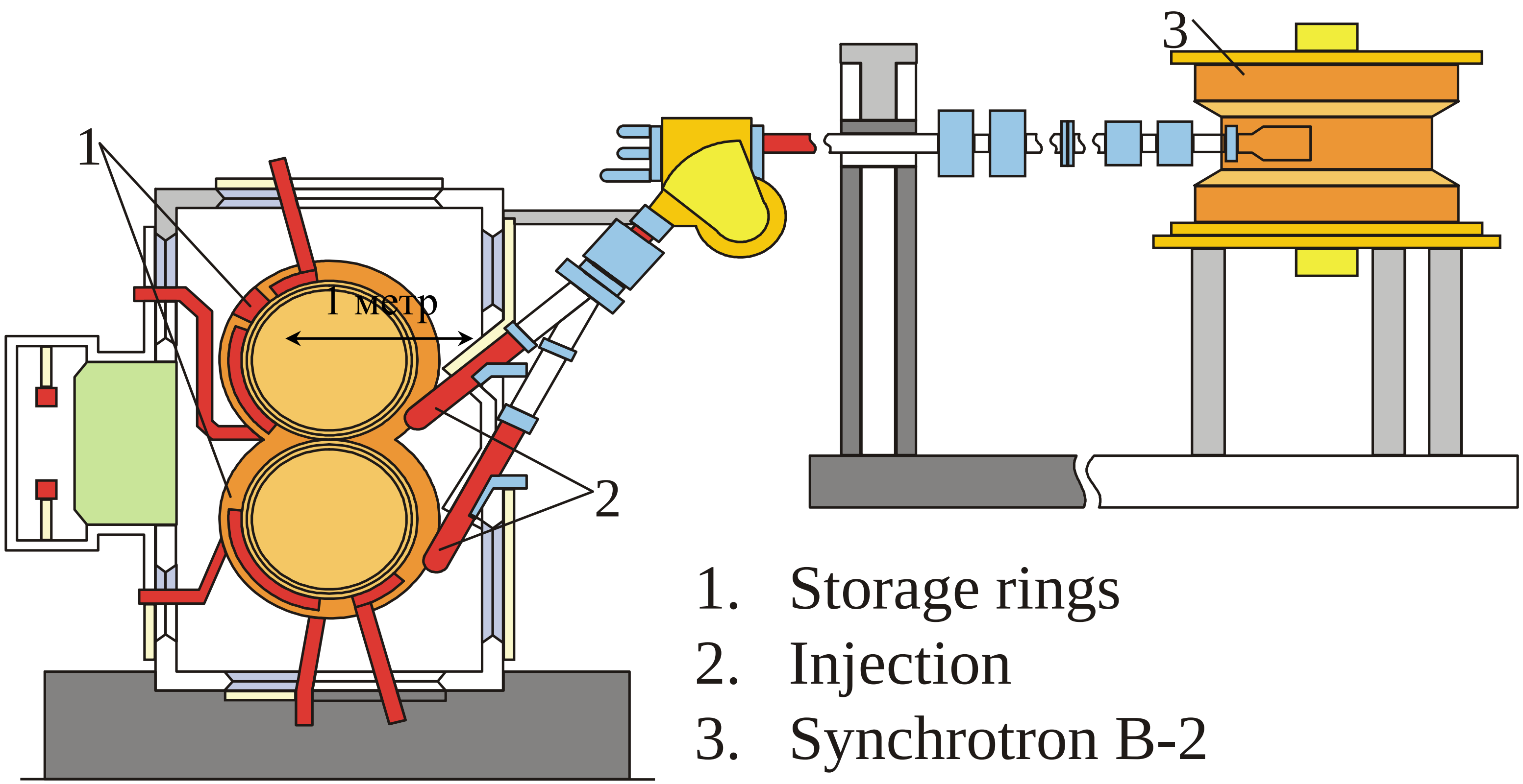
04.05 2018 Novosibirsk

1958 - 2018

VEP-1

Decision in1957 г.

E = 90 MeV - 160 MeV;   L= $5*10^{27}$ $cm^{-2}s^{-1}$



1. Storage rings
2. Injection
3. Synchrotron B-2

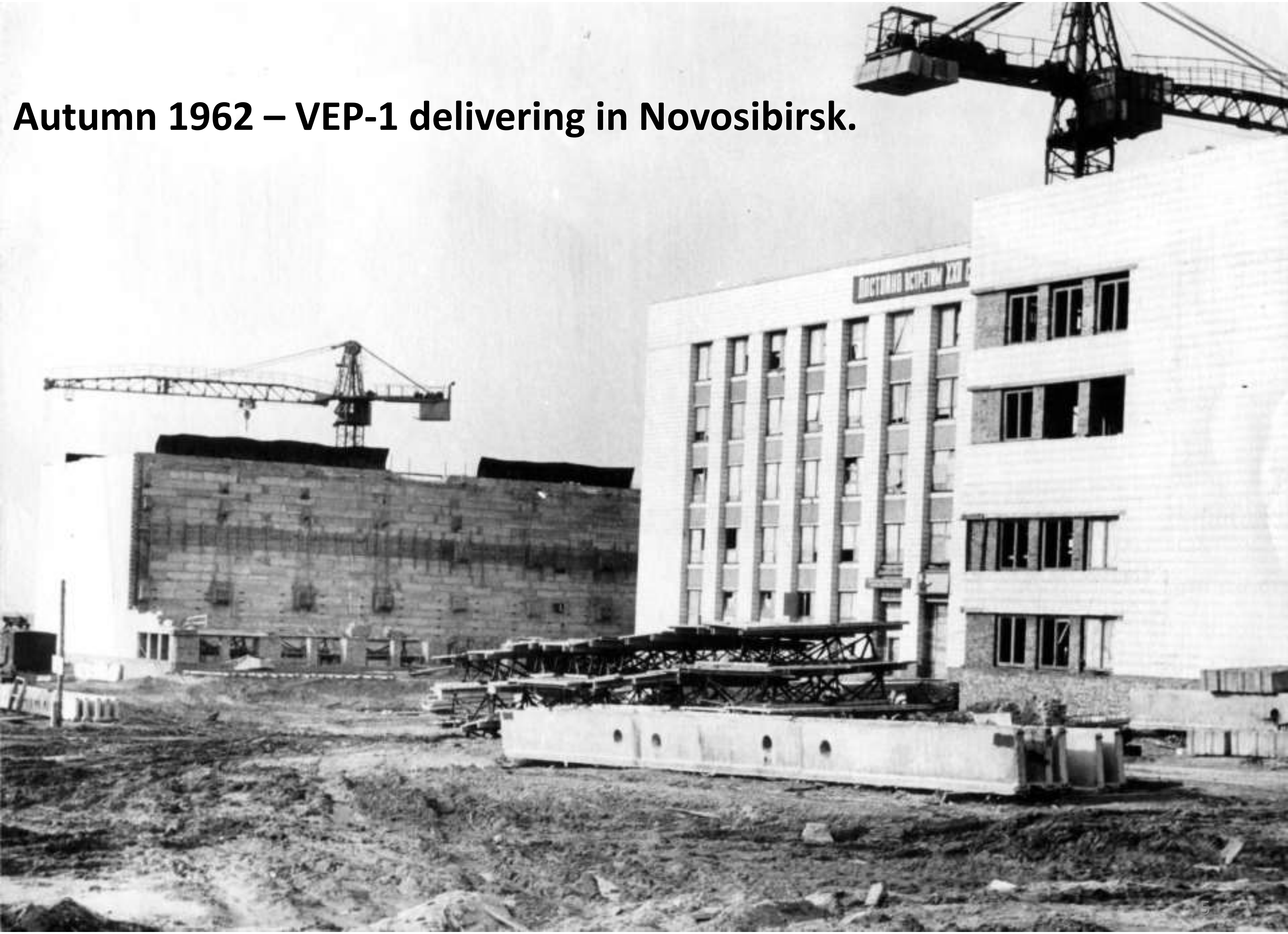
Start of discussions about electron-positron collider
(1959)

?

?

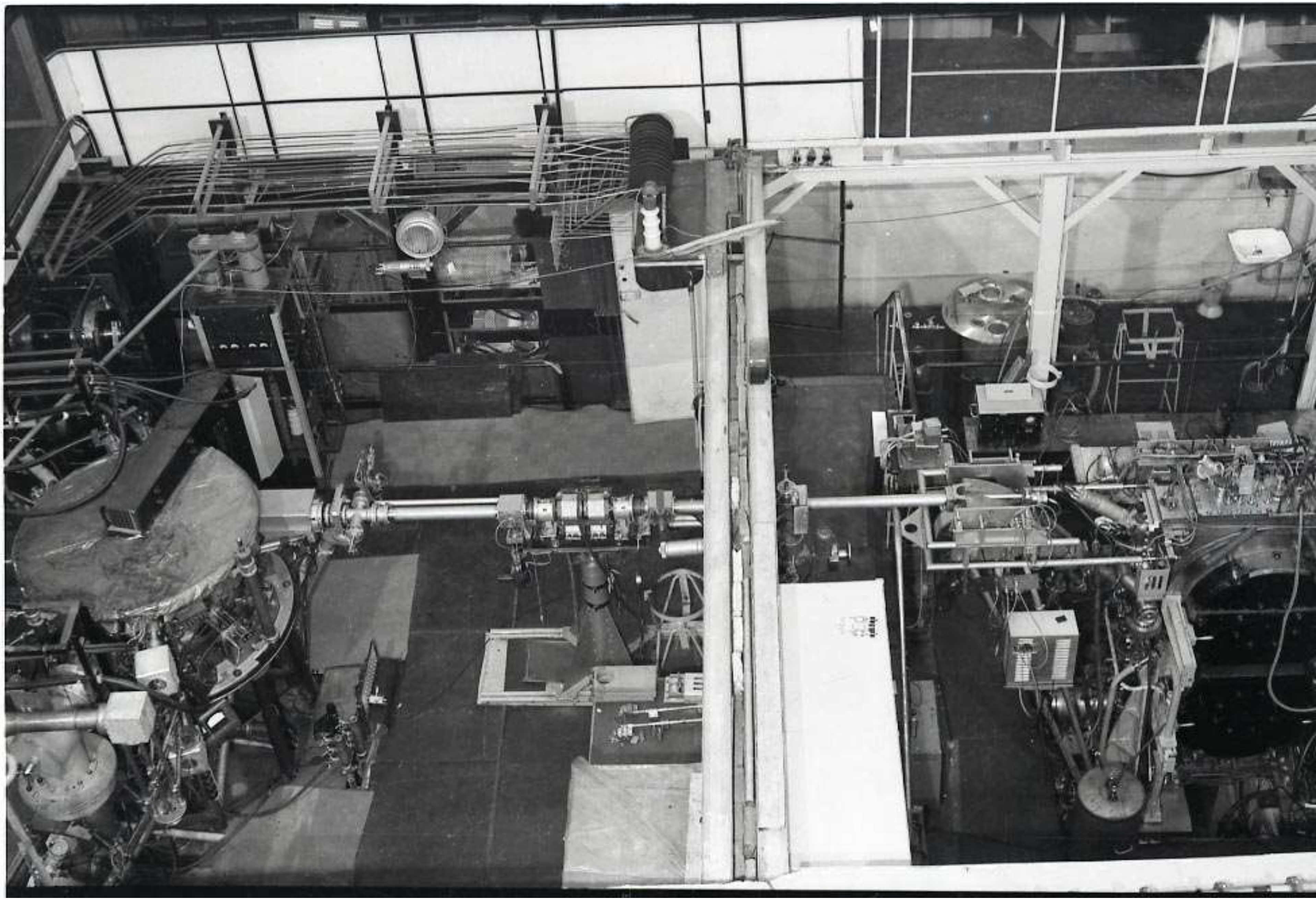
В.И.Векслер

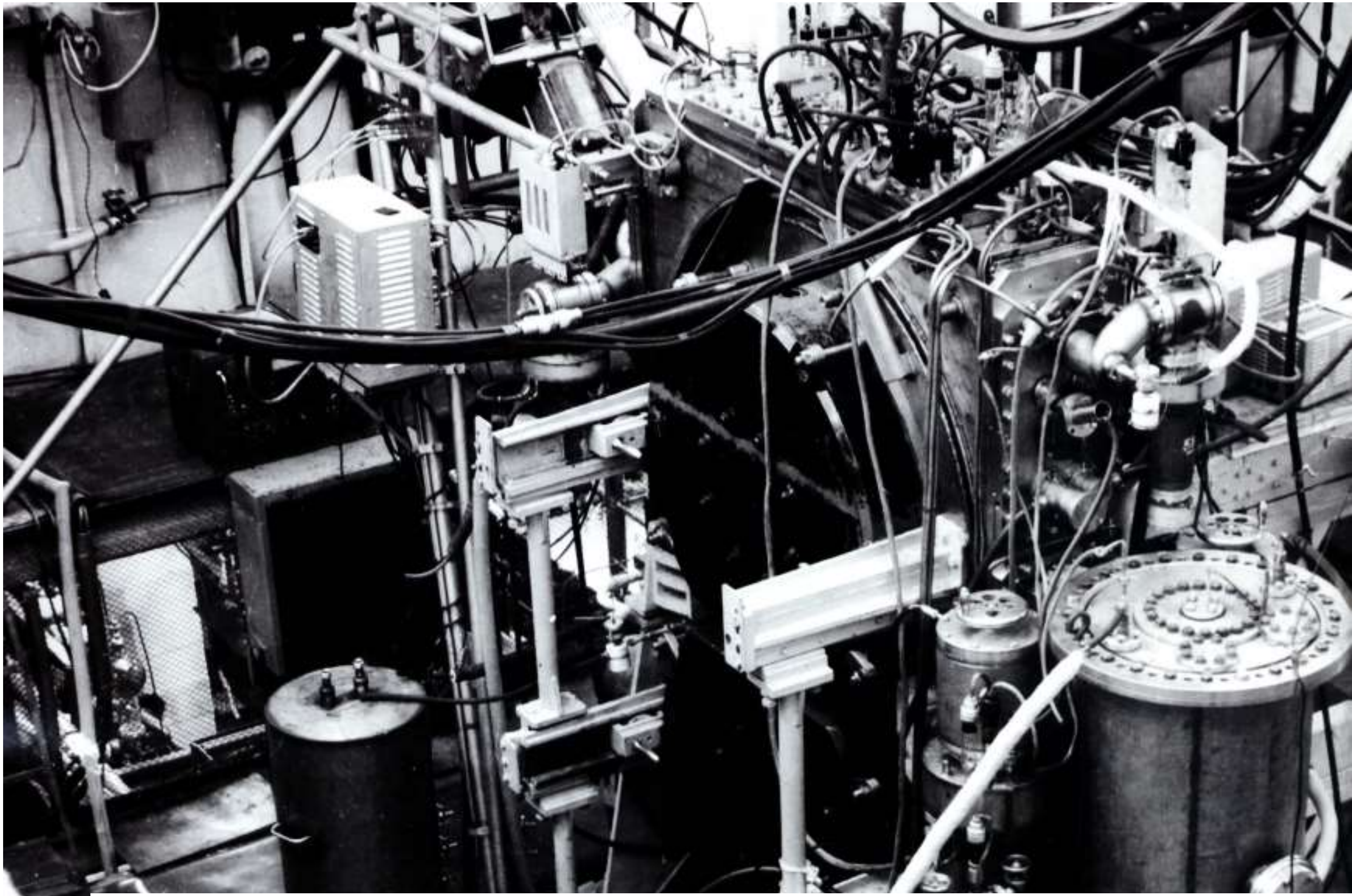
Autumn 1962 – VEP-1 delivering in Novosibirsk.



1963

VEP-1 bird's view

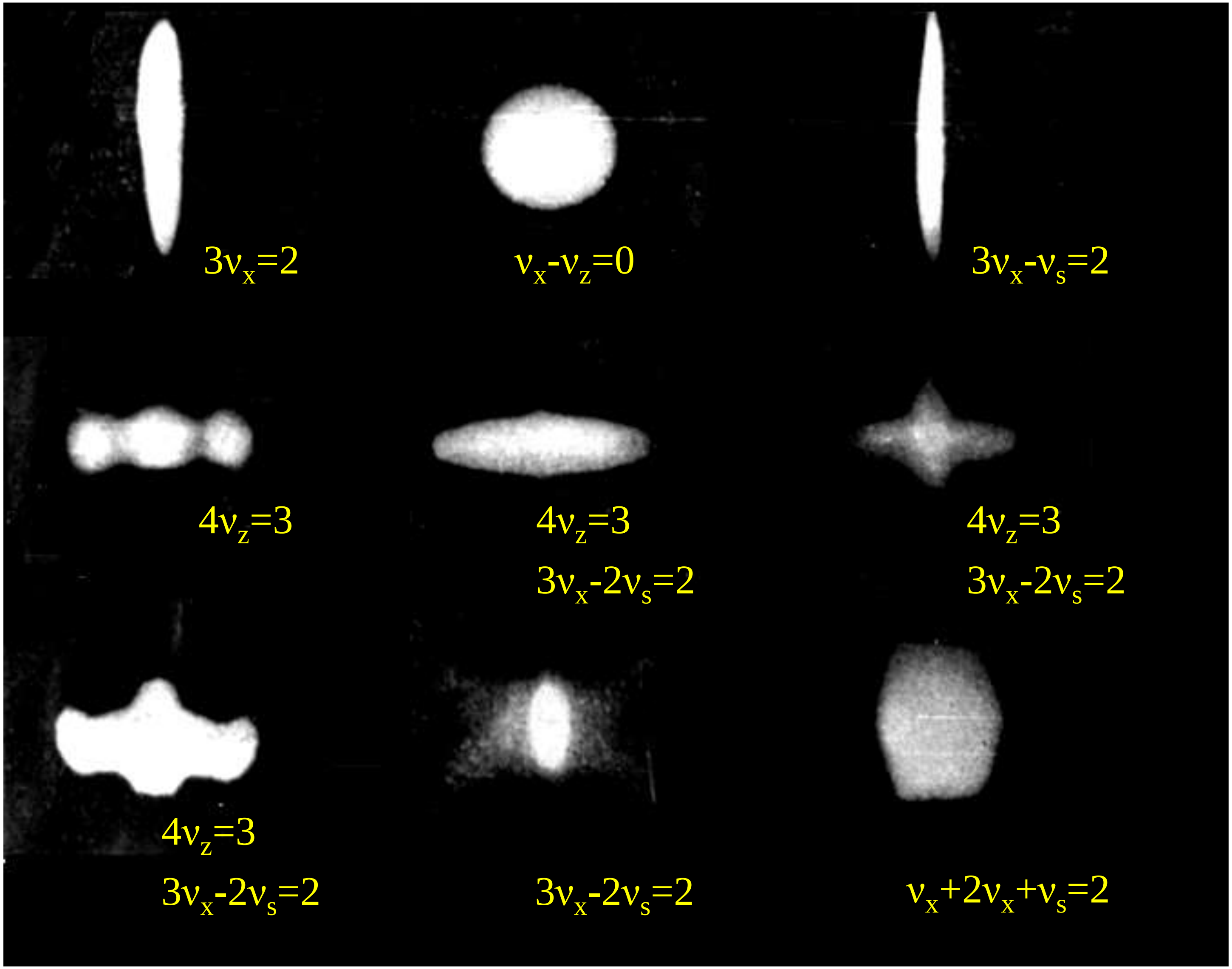




ВЭП-1
в работе

Experiments with colliding beams 1965-1967
simultaneously with Prinston-Stanford rings:
electron-electron scattering; discovery of double Bremstralung

Study of “beam-beam” effects and “machine” nonlinear resonances

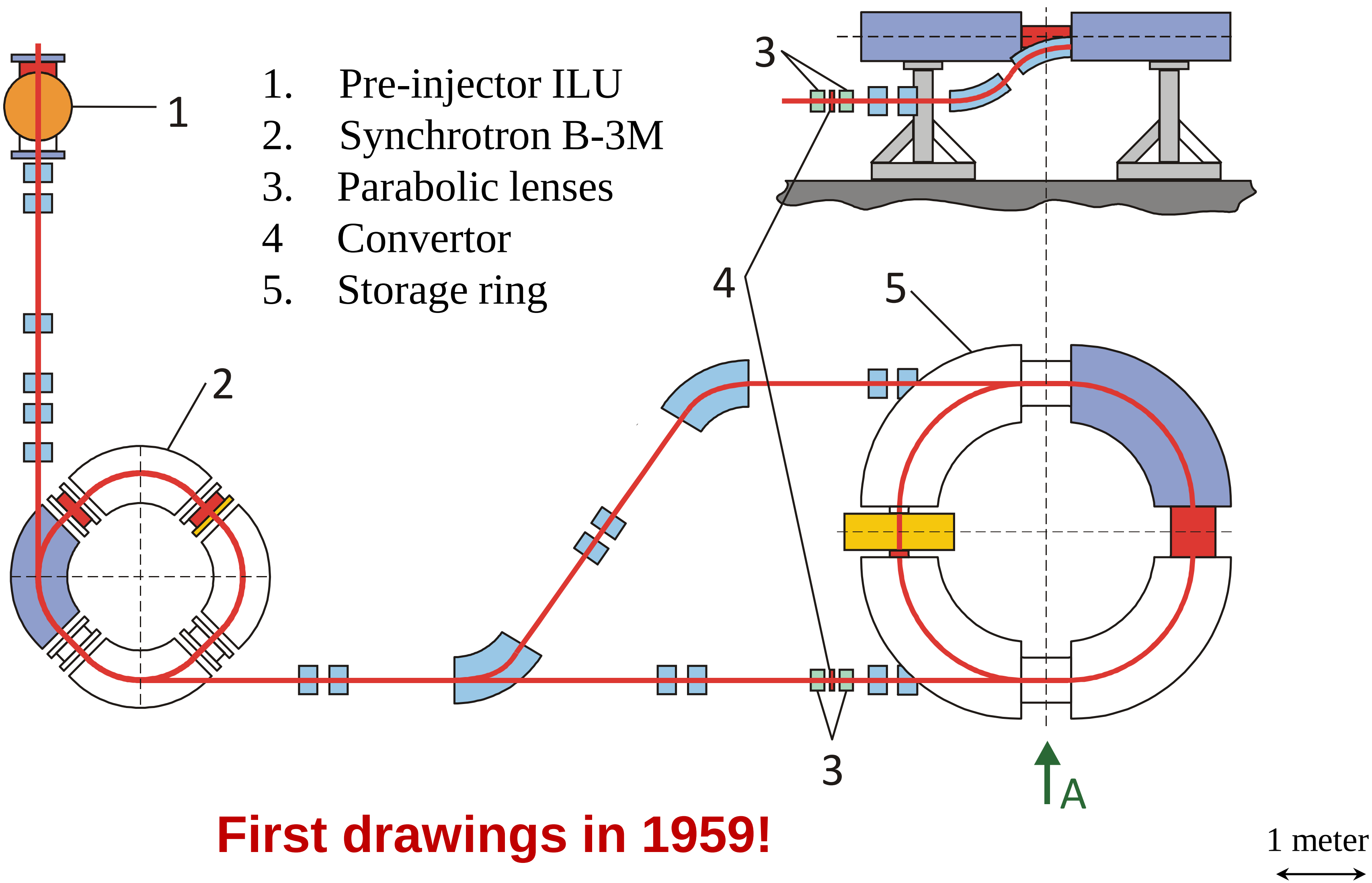


Layout of VEPP-2 complex

E=2×700 MeV

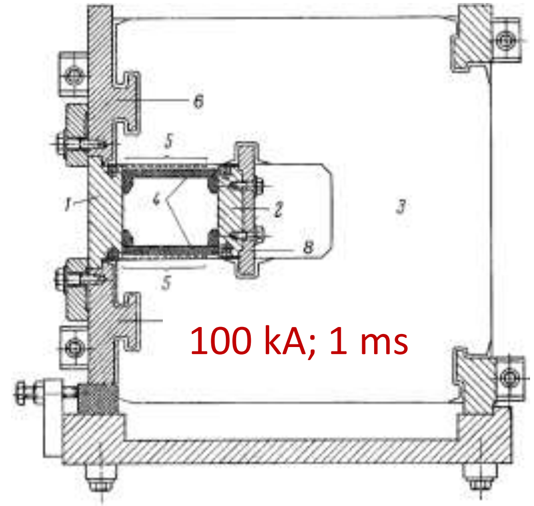
$L=4\times10^{28}cm^{-2}s^{-1}$

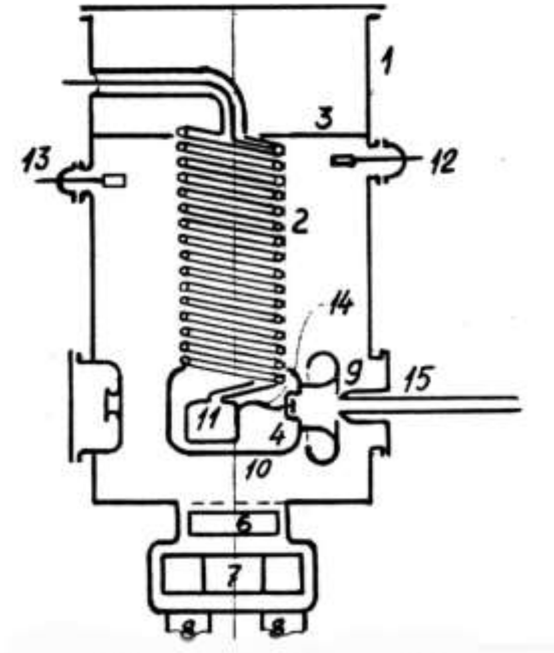
1. Pre-injector ILU
2. Synchrotron B-3M
3. Parabolic lenses
4 Convertor
5. Storage ring

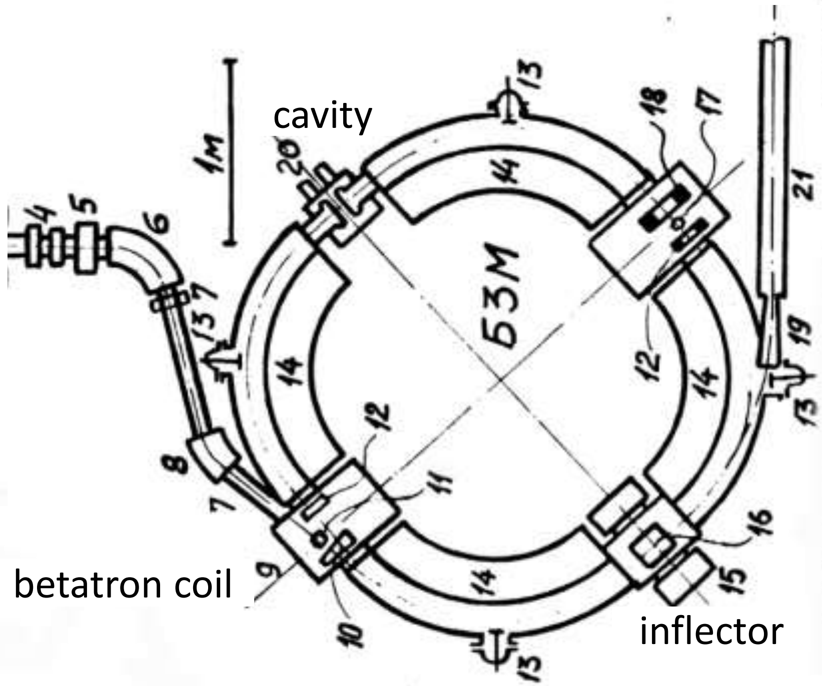


First drawings in 1959!

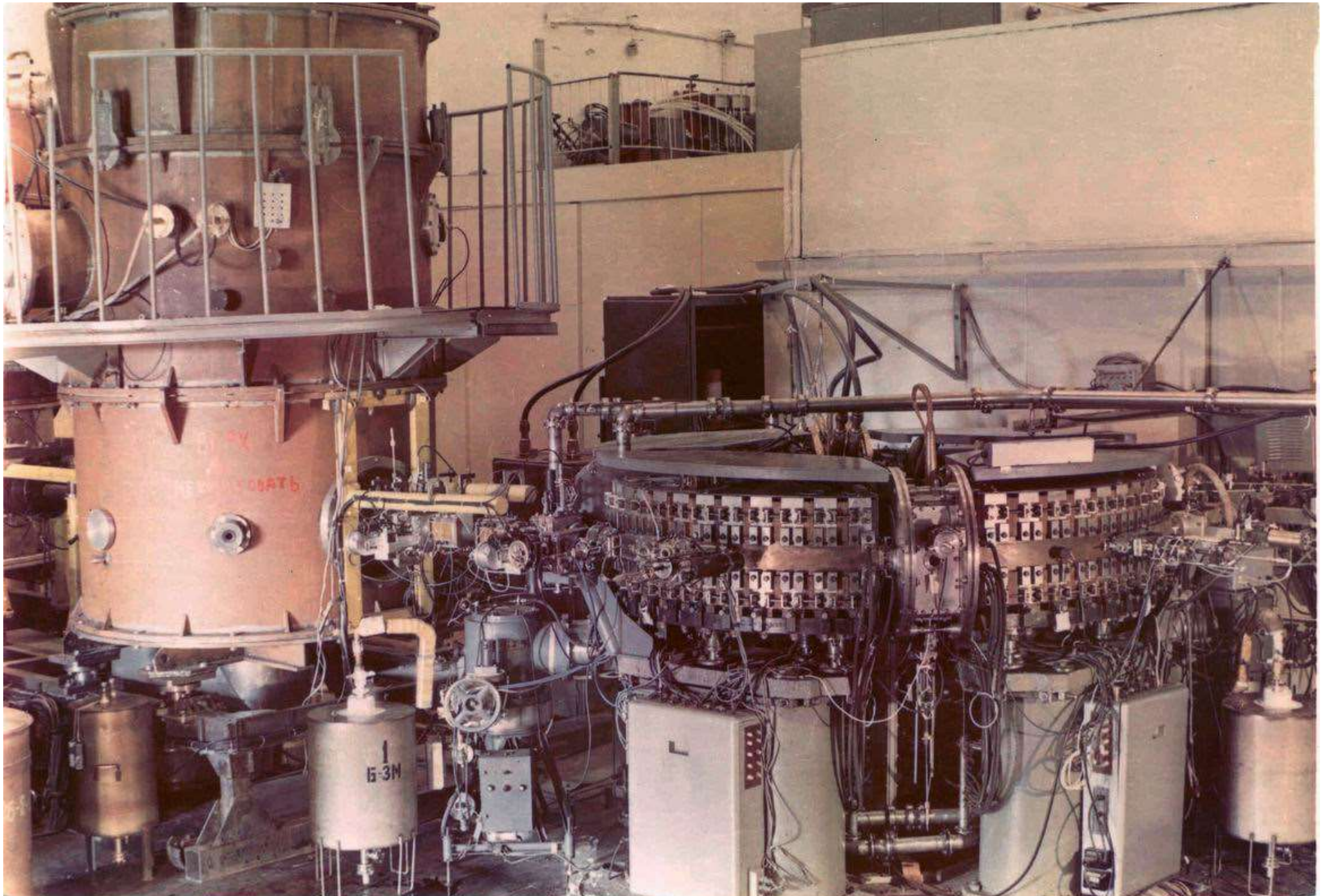
ILU+ B-3M





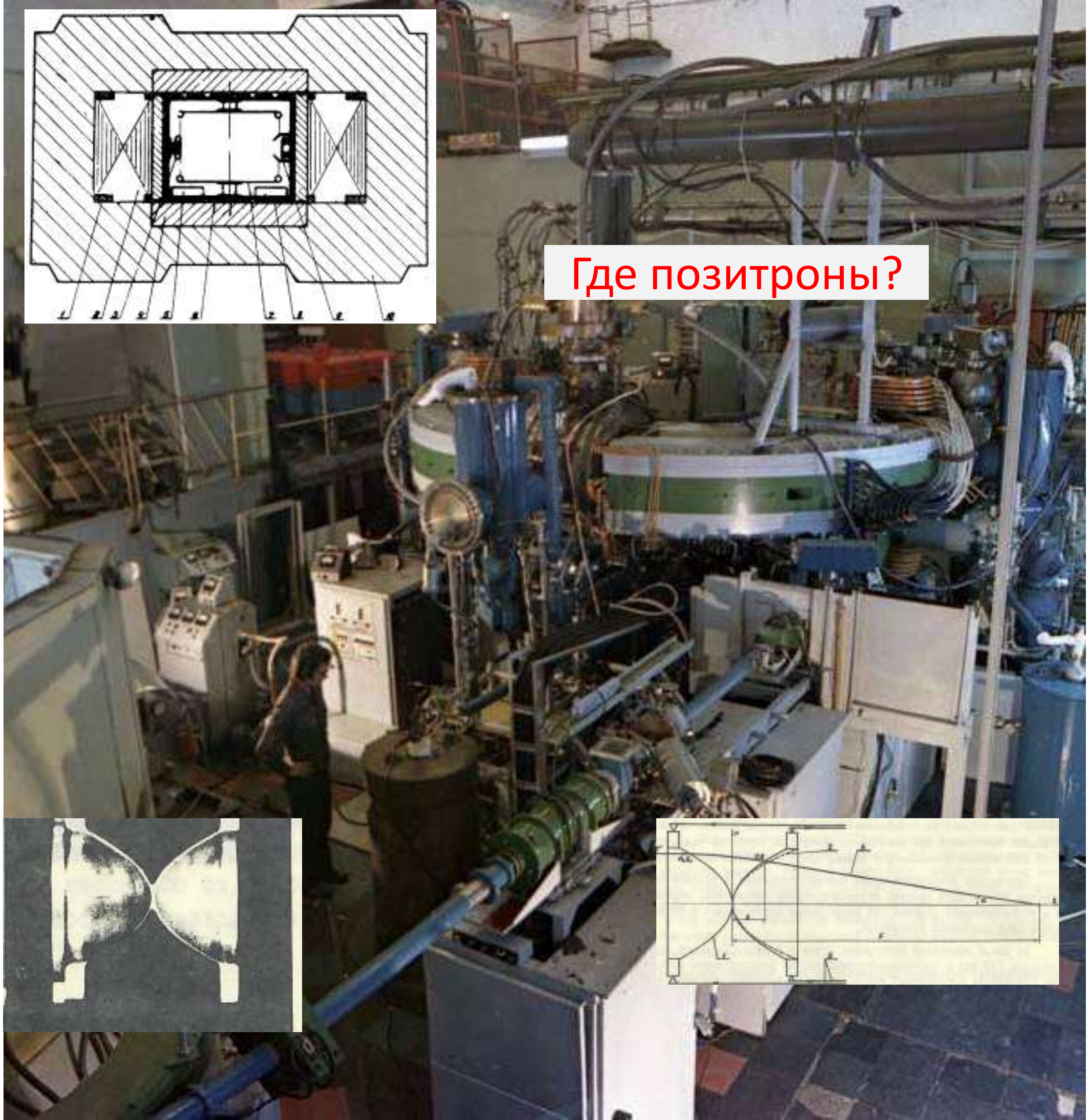


ИЛУ+Б-3М (1965-2014)



3 МэВ 5А

250 МэВ 1.2А



Где позитроны?

VEPP-2 main physical results

First observation vector meson production (ρ) in e+e- annihilation.

ρ, ω, and ϕ- mesons study.

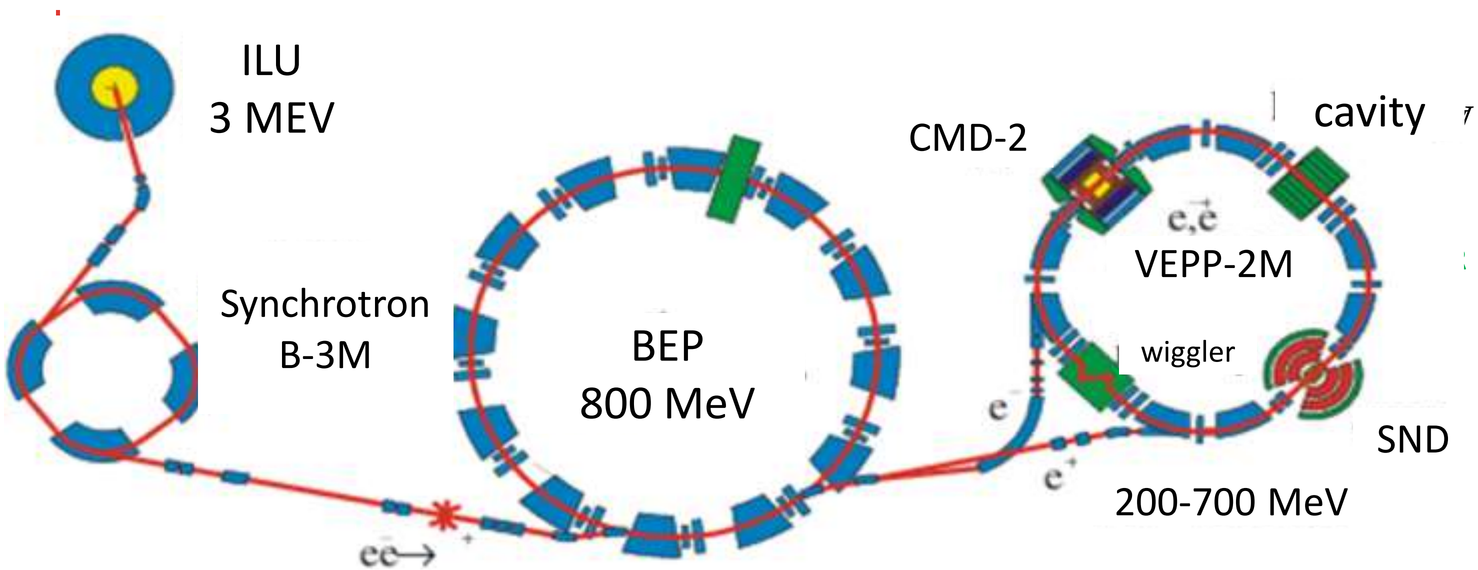
First observation of two-photons events.

<u>Discovery of multi-hadron production in e+e- annihilation.</u>

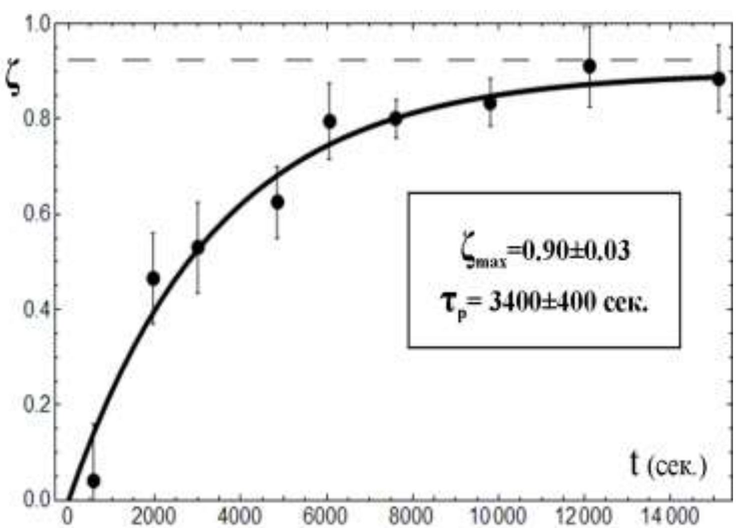
Observation of electron radiative polarization (simultaneously with ACO)

and absolute energy calibration by resonance depolarization.
(theory & experiment)

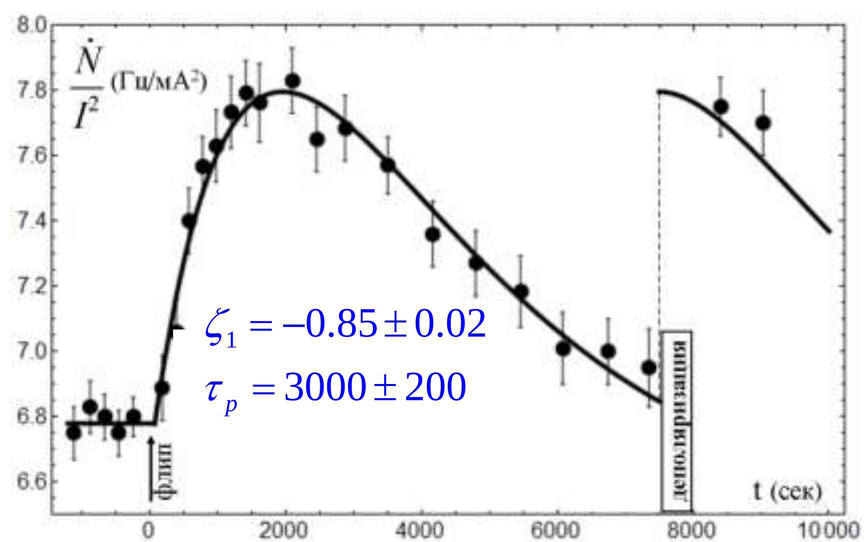
VEPP-2M (1972-2000)



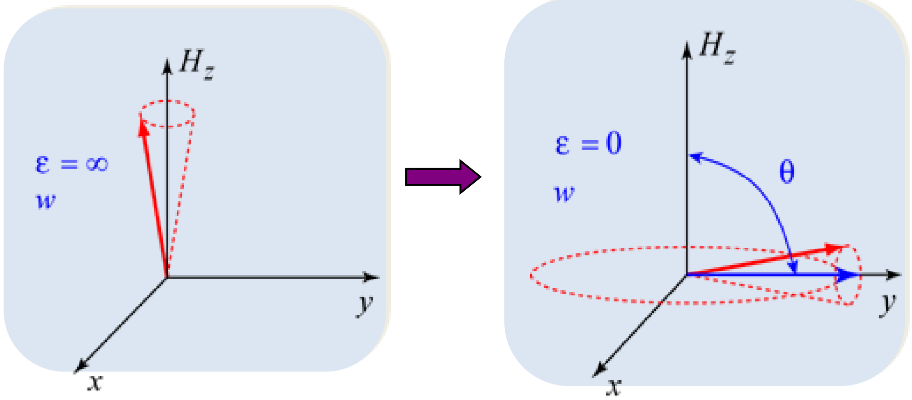
radiative polarization

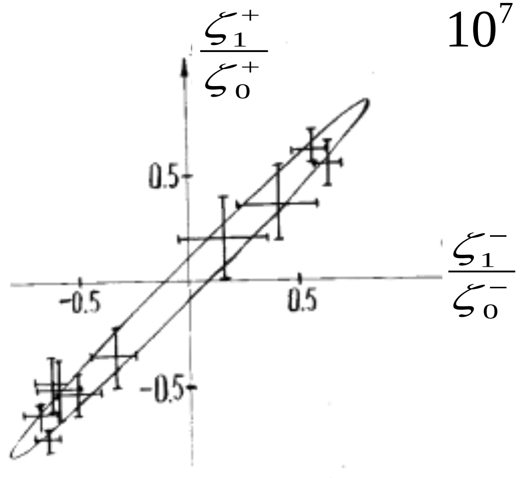


Spin-flip + radiative polarization



VEPP-2M Checkout of CPT theorem for e^+e^-

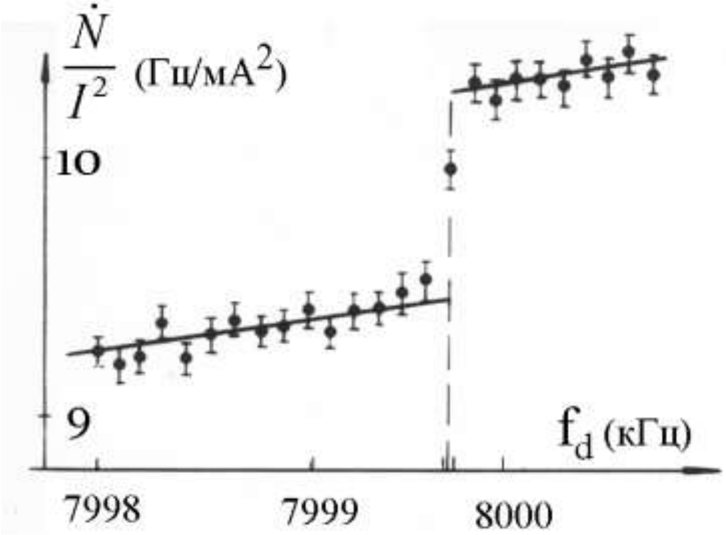




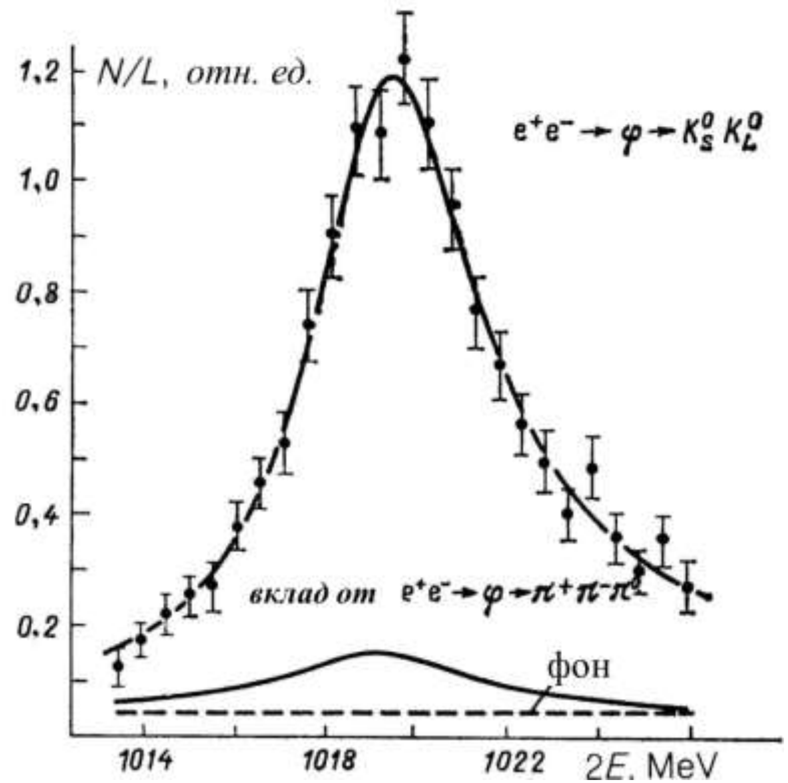
10^7 rotations

$$\frac{\gamma^- \mu'(e^-) - \gamma^+ \mu'(e^+)}{\gamma \mu_0} = a(e^-) - a(e^+) < 1 \cdot 10^{-11}$$

Energy calibration: **E=509.325±0.005 МэВ**

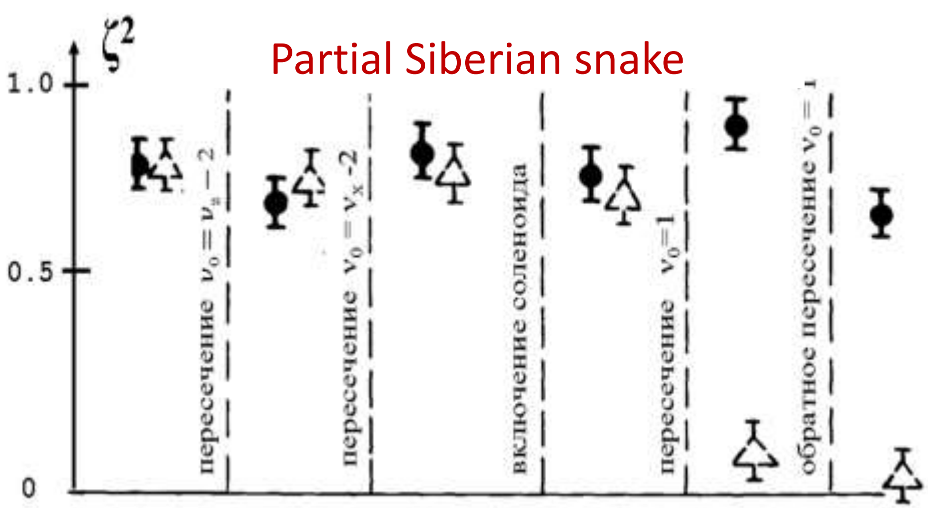


ϕ-meson mass measurement



$$M_\Phi = 1019.52 \pm 0.13$$

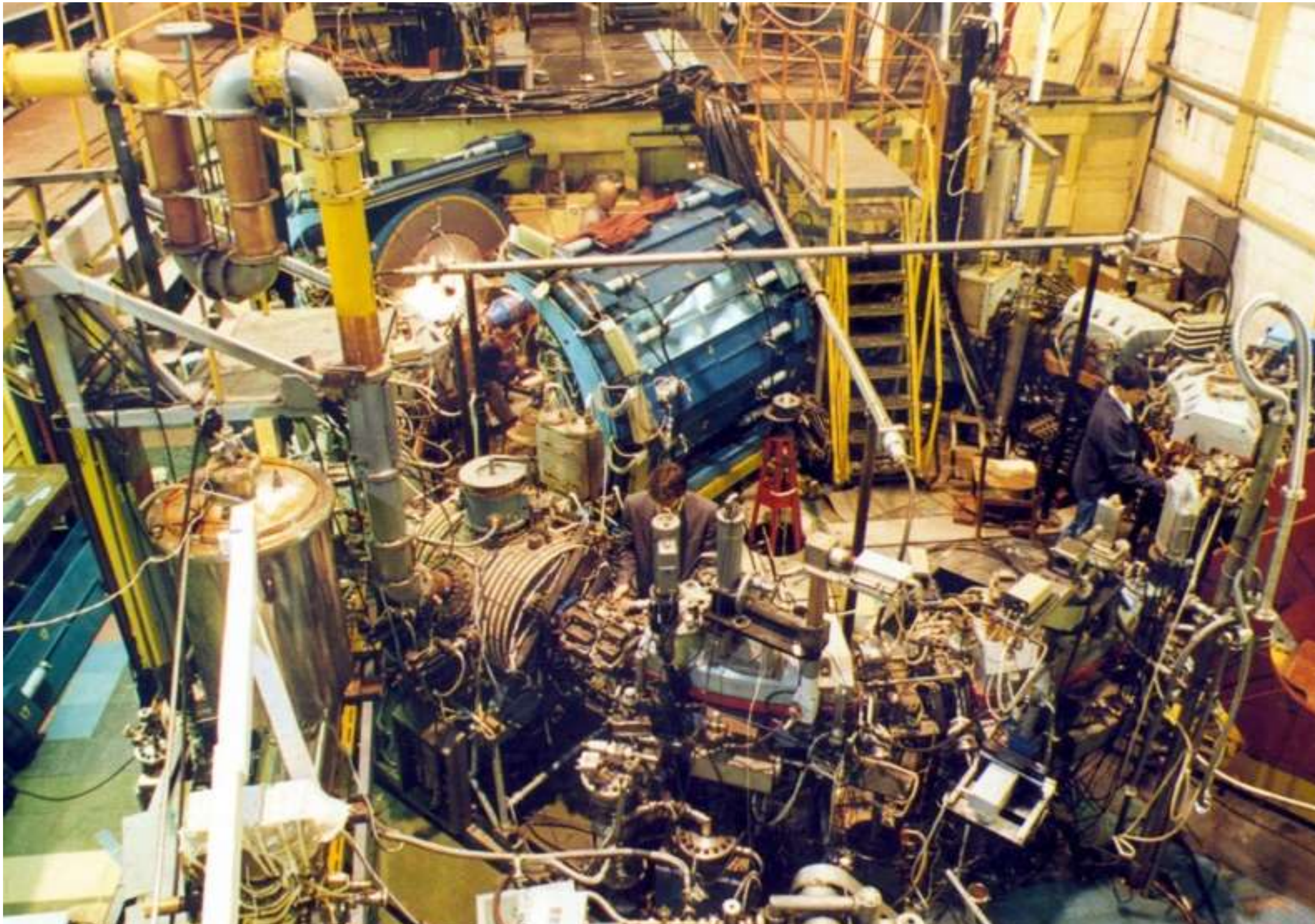
Partial Siberian snake



Particle mass measurements at VEPP-2M

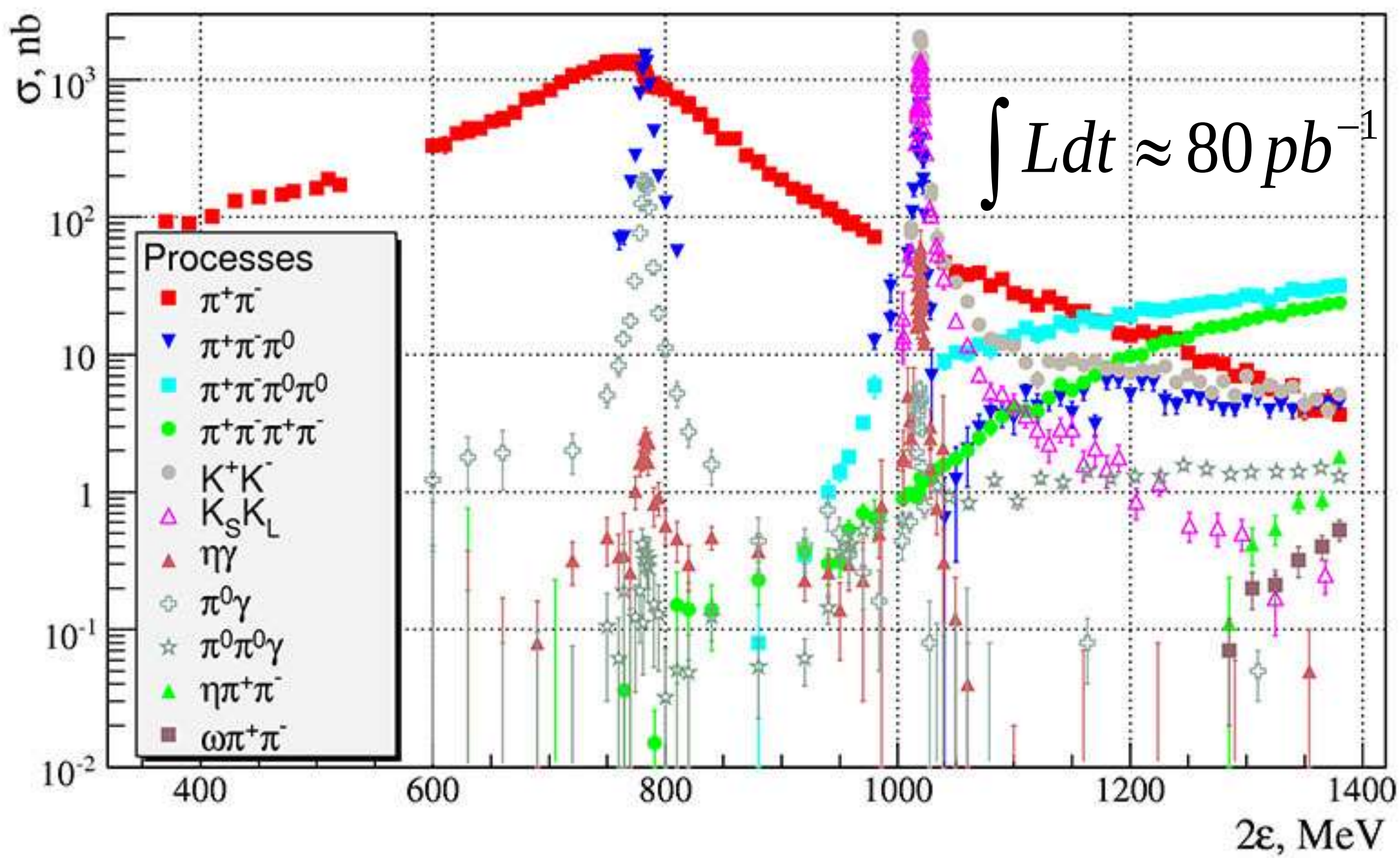
Particle	*E*, MeV	Accuracy, *ΔE*/*E*	Detector	Years
ω	781.78±0.10	1.2·10-4	CMD	1987
ρ	775.9±1.1	3.2·10–4	OLYA	1985
φ	1019.42±0.06	6·10–5	CMD-2	1995
K^0	497.661±0.033	1.5·10–5	CMD	1987
K^+	493.670 ±0.029	1.5·10–5	emulsion	1979

VEPP-2M



ВЭПП-2М results (world лидер during 25 years!)

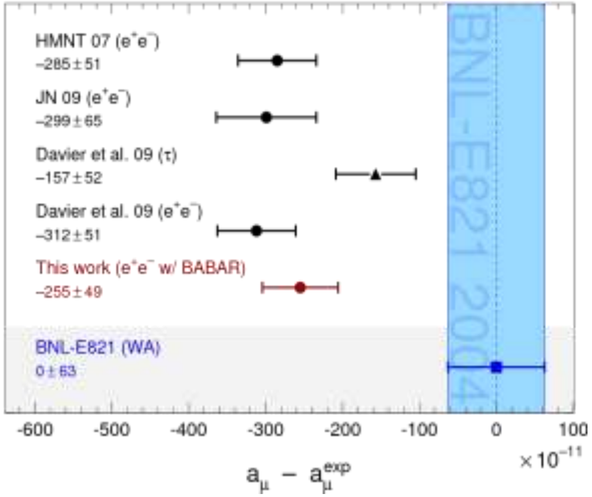
Hadron production in e^+e^- annihilation (detectors SND & CMD-2)



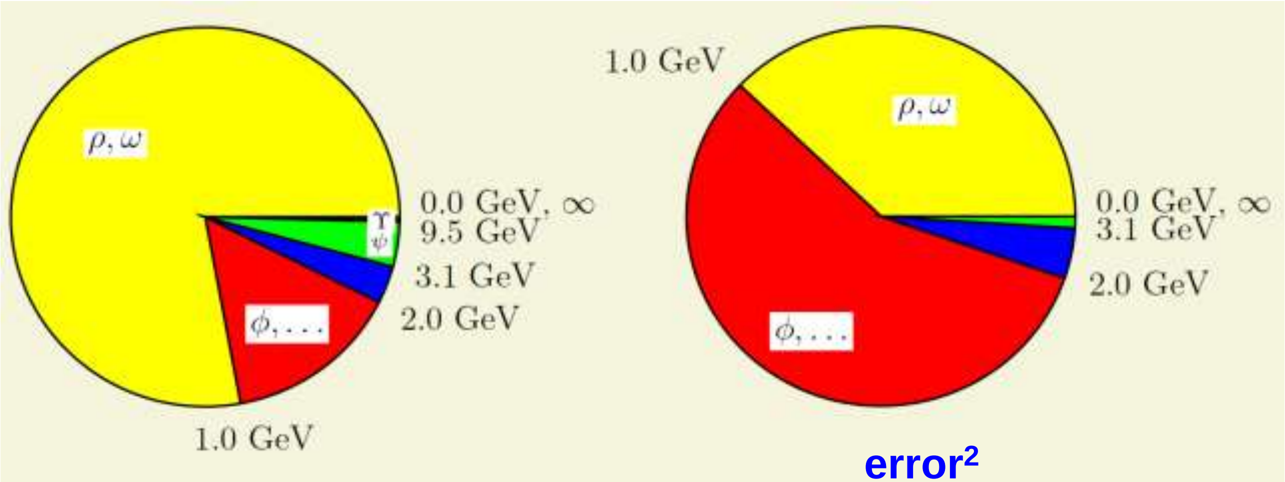
Hadron contribution in the muon (g-2)

$$a_\mu(\text{had}) = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{4m_\pi^2}^{\infty} \frac{ds}{s^2} K(s) \left(\frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}\right)$$

VEPP-2M, BaBar, KLOE reduced errors *Δ≈3.6 σ*



New (g-2) measurement FNAL
VEPP-2000 + detectors upgrade



contribution

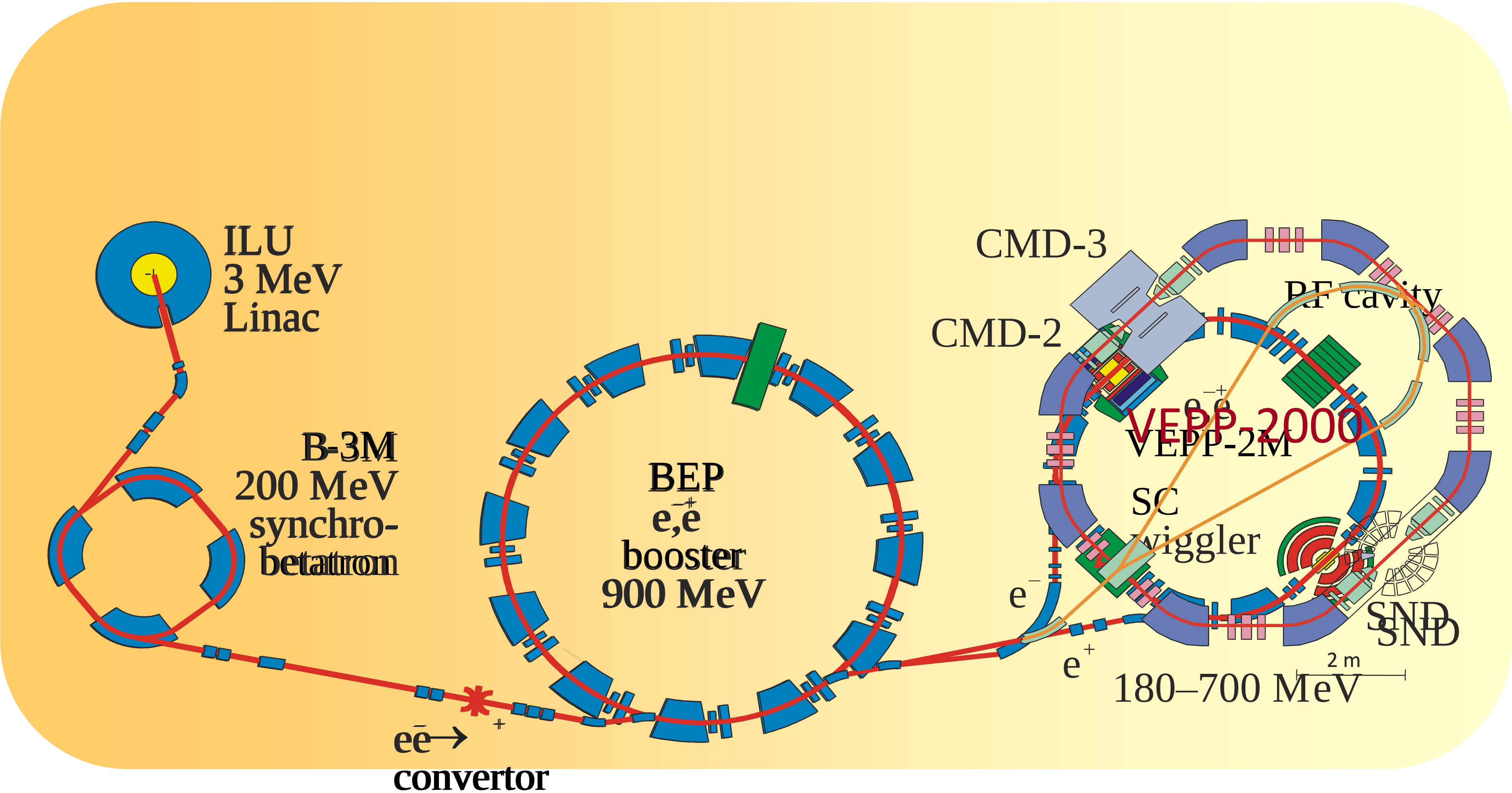
error^2

< 1% systematic error for most of the channels is needed!

Absolute energy calibration ≃10^{-4} must be done in whole energy range

VEPP-2M → VEPP-2000

(2001-2007)



- ♦ E ≈ 1 GeV (per beam)
- ♦ L ≈ 1×10^{32} cm^{-2} sec^{-1} (1×1 bunch)

Round beams - increasing of luminosity

- ❑ Number of bunches (i.e. collision frequency)
- ❑ Bunch-by-bunch luminosity

$$L = \frac{\pi\gamma^2 \xi_x \xi_y \varepsilon_x f}{r_e^2 \beta_y^*}\left(1+\frac{\sigma_y}{\sigma_x}\right)^2 \quad \rightarrow \quad L = \frac{4\pi\gamma^2 \xi^2 \varepsilon f}{r_e^2 \beta^*}$$

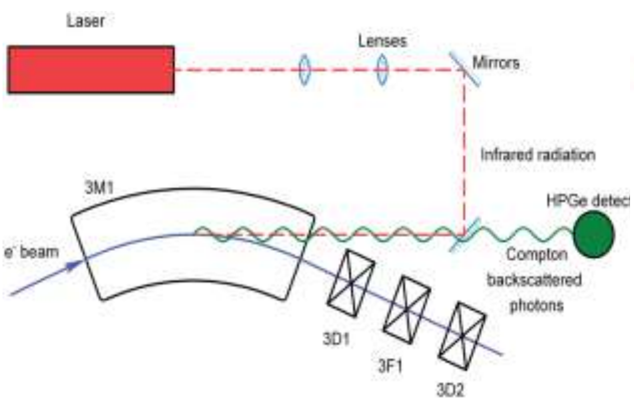
✓Geometric factor (gain=4)

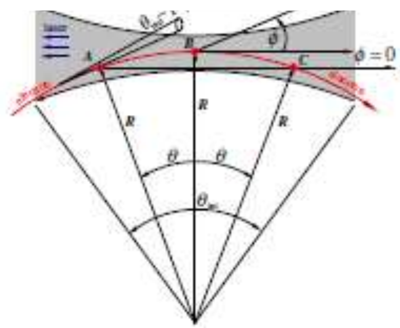
✓Beam-beam limit enhancement

✓IBS for low energy? worth life time!

$$\xi_{x,y}\ ;\ 0.2$$

Energy calibration





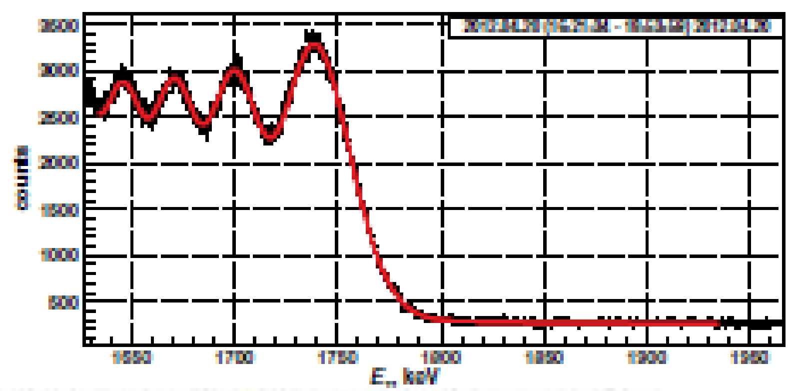
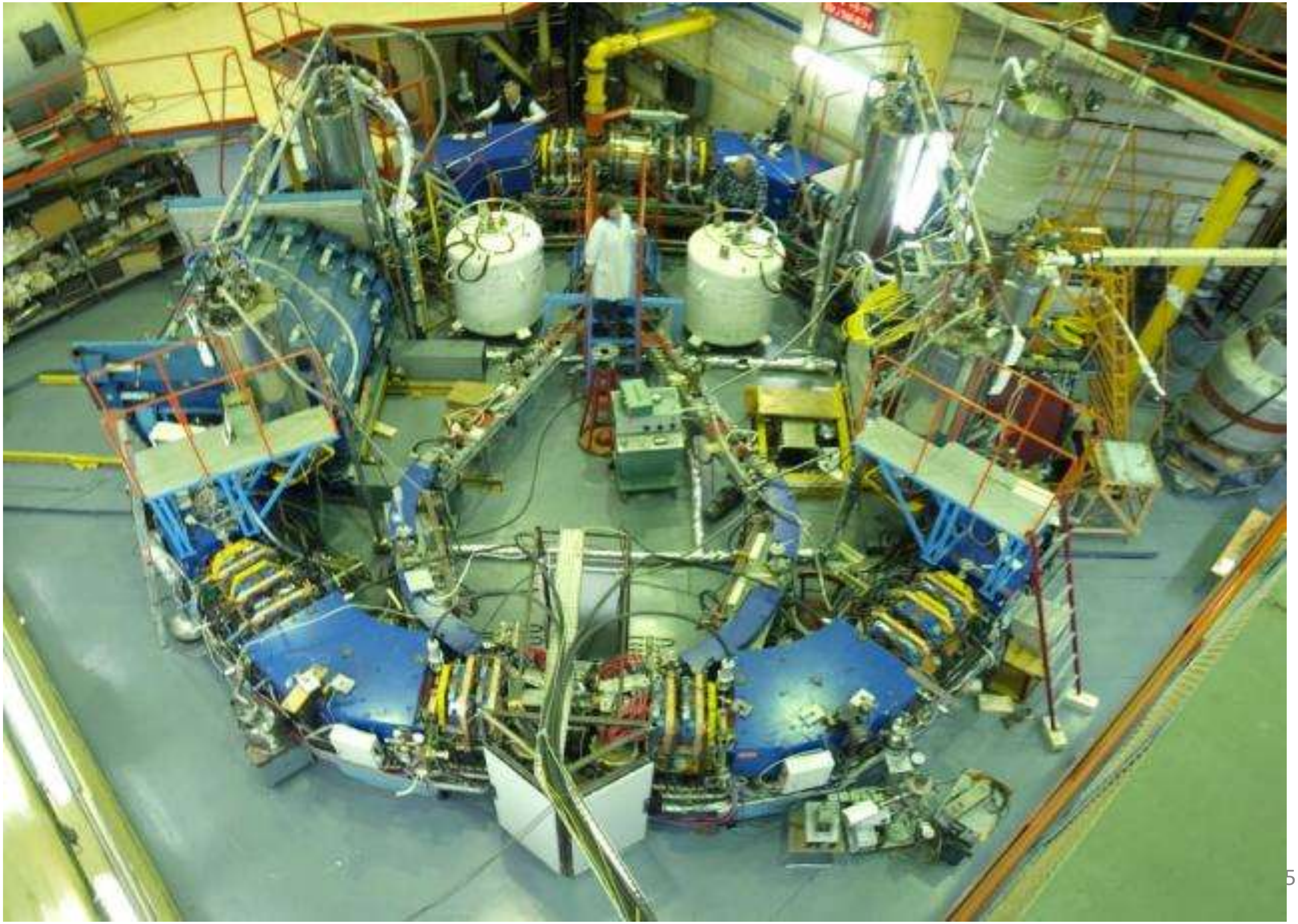


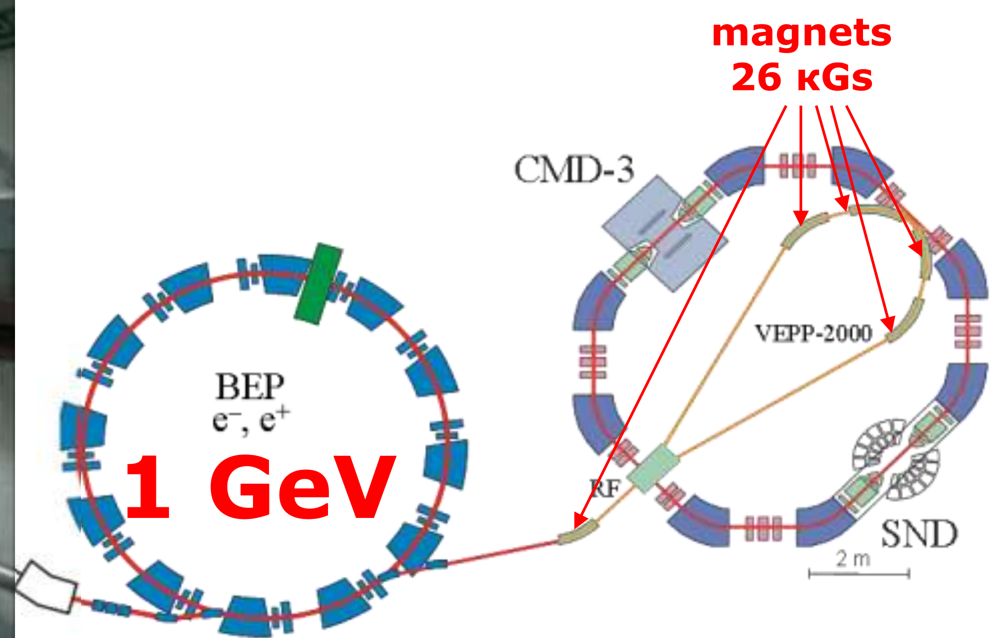
FIG. 5 (color online). The edge of the energy spectrum with the fit result: χ^2/d.o.f = 773.0/745, E = 993.662 ± 0.016 MeV, B = 2.3880 ± 0.0044 T, σ = 810 ± 40 ppm.

VEPP-2000 (2010-2013)

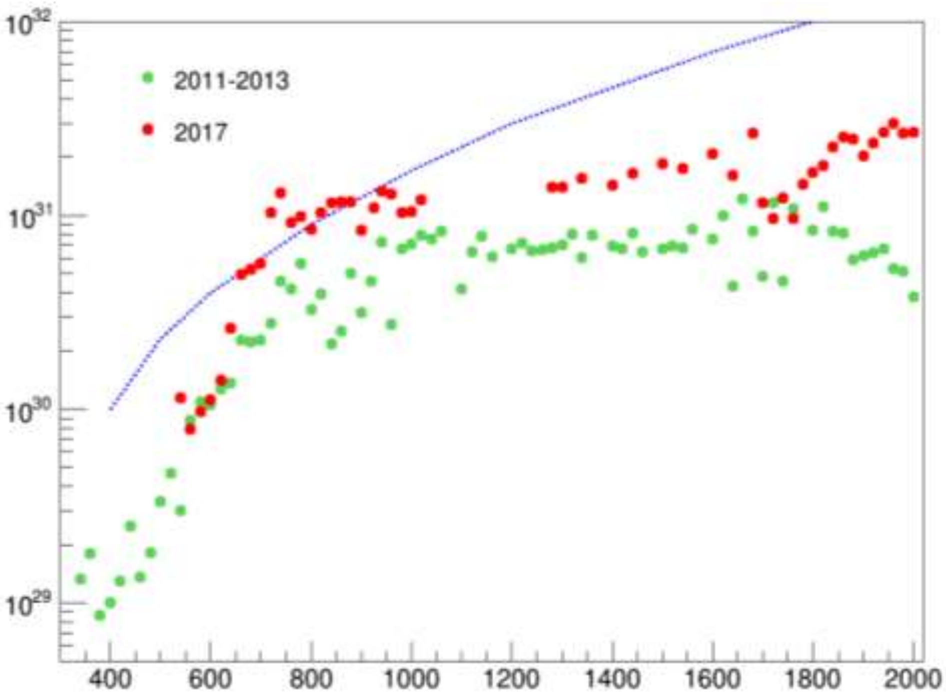


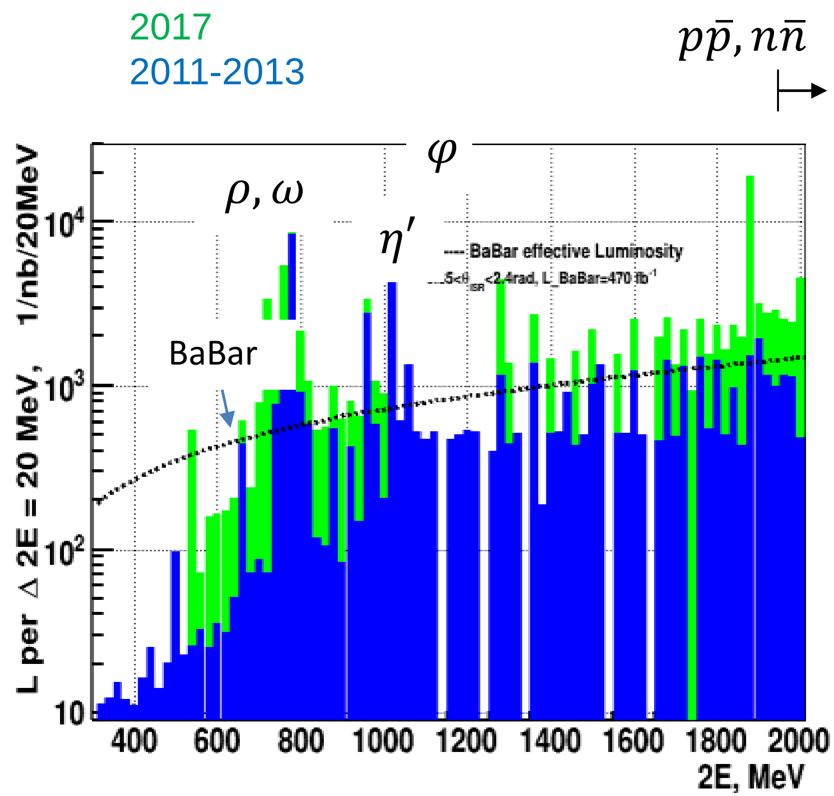
VEPP-2000 complex upgrade

(2014-2017)



Luminosity collection at VEPP-2000

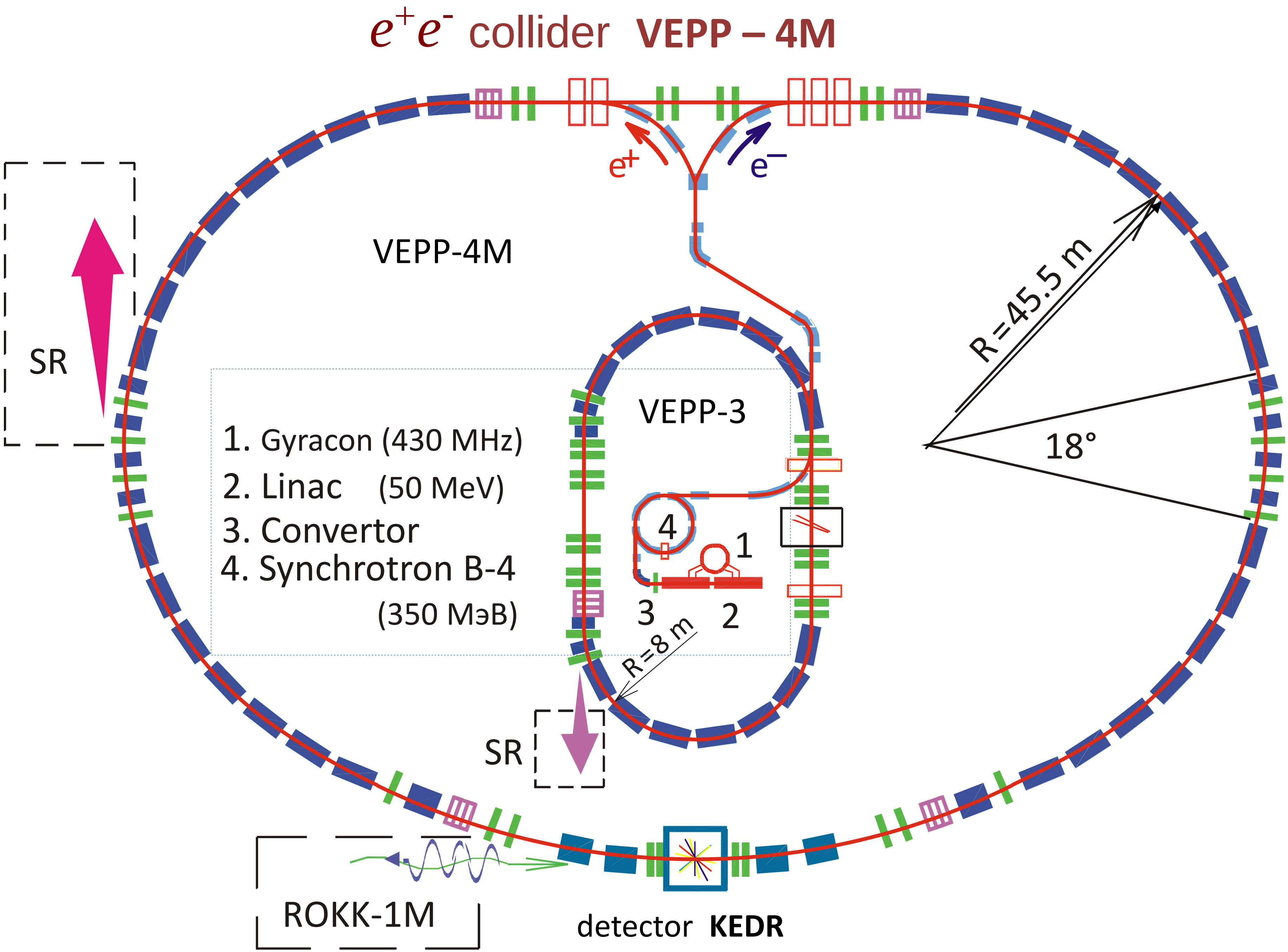




VEPP-4

-start up

1965



e+e- collider VEPP – 4M
e+
e−
VEPP-4M
R=45.5 m
SR
18°
VEPP-3
1. Gyracon (430 MHz)
2. Linac (50 MeV)
3. Convertor
4. Synchrotron B-4
(350 МэВ)
4
1
3
2
R=8 m
SR
ROKK-1M
detector KEDR

VEPP-3: first beam 1973; где позитроны?

Synchrotron radiation → G.M.Kulipanov

VEPP-4: first beam 1981; где позитроны?

Ψ and Ψ’ masses measurement;

Detector MD-1 (1983-1986)

RF, new positron source; Energy 1.8 – 5.0 GeV;

Υ –family mass measurement

Why mass measurement?

- **VEPP-4M has unique spin tune spread 10^{-7} at J/ψ energy**
- **Bench mark on the mass scale of elementary particles**
- **Bench mark on the energy scale of a given collider (J/ψ, ψ(2s) masses used in BEPC-II τ- lepton mass experiment**
- **Absolute calibration of momentum measurements in detector tracking systems**

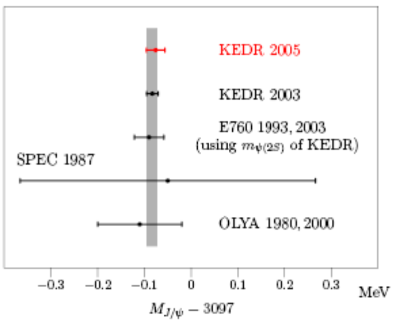
Particle mass measurements at VEPP-2M and VEPP-4:

USSR State award (1989) “Precise particle masses measurements at VEPP-2M and VEPP-4”
G.M.Tumaikin, Yu.A,Tikhonov, L.M.Kurdadze, V.A.Sidorov, I.Ya.Protopopov, A.N.Skrinsky, L.M.Barkov, A.P.Onuchin, V.V.Petrov, S.I.Mishnev, Yu,M,Shatunov, V.P.Smakhtin.

High precision particle mass measurements with KEDR at VEPP-4M

J/ψ mass measurement

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3096.916±0.011 OUR AVERAGE				
3096.917±0.010±0.007		AULCHENKO 03	KEDR	$e^+e^- \to$ hadrons
3096.89 ±0.09	502	[1] ARTAMONOV 00	OLYA	$e^+e^- \to$ hadrons
3096.91 ±0.03 ±0.01		[2] ARMSTRONG 93B	E760	$\overline{p}p \to e^+e^-$
3096.95 ±0.1 ±0.3	193	BAGLIN 87	SPEC	$\overline{p}p \to e^+e^-X$



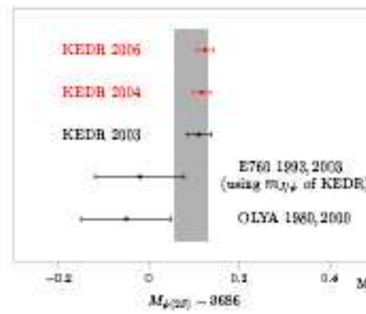
New result (preliminary)

$$M_{J/\psi}^{2005} - M_{J/\psi}^{2002} = 7 \pm 10 \pm 17\ keV$$

PLB573(2003) 63-79
Nuclear Physica B (Proc. Suppl.) 181-182 (2008)353

ψ(2S) mass measurement

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3686.09 ±0.04 OUR FIT Error includes scale factor of 1.6.				
3686.093±0.034 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.				
3686.111±0.025±0.009		AULCHENKO 03	KEDR	$e^+e^- \to$ hadrons
3685.95 ±0.10	413	[1] ARTAMONOV 00	OLYA	$e^+e^- \to$ hadrons
3685.98 ±0.09 ±0.04		[2] ARMSTRONG 93B	E760	$\overline{p}p \to e^+e^-$



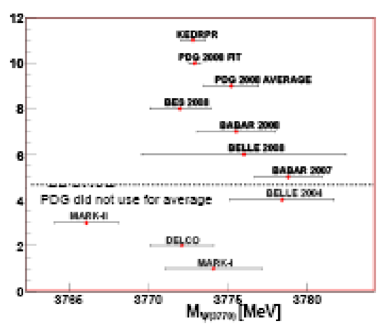
New result (preliminary)

$$M_{\psi(2S)}^{2004} - M_{\psi(2S)}^{2002} = 6 \pm 12 \pm 15\ keV$$

$$M_{\psi(2S)}^{2006} - M_{\psi(2S)}^{2002} = 14 \pm 10 \pm 15\ keV$$

PLB573(2003) 63-79
Nuclear Physica B (Proc. Suppl.) 181-182 (2008)353.

ψ(3770) mass measurement



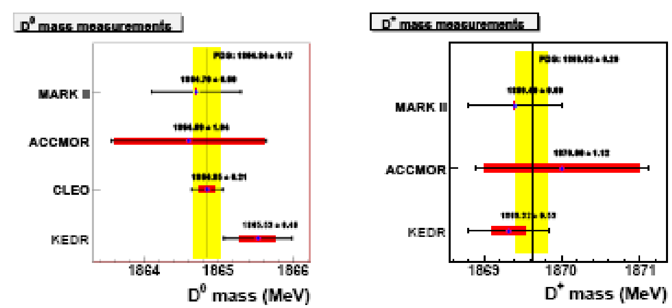
$$M_{\psi(3770)} = 3772.8 \pm 0.5 \pm 0.6\ MeV$$

(preliminary)

Nuclear Physica B (Proc. Suppl.) 181-182 (2008)353.

For compatibility, the resonance fitting form is same to that used in MARK1, MARK2, DELCO, BES(2005) experiments.

D± and D0 mass measurement



$$M_{D^0} = 1865.53 \pm 0.39 \pm 0.24\ MeV$$

$$M_{D^\pm} = 1869.32 \pm 0.48 \pm 0.21\ MeV$$

Nuclear Physica B (Proc. Suppl.) 181-182 (2008)353.

VEPP-4M

Detector KEDR (1991) + system of scattered electron and positron detecting with $\Delta p/p$ $0.05<0.5$ is advantage for study of two photon processes.
Luminosity with new injection complex?

Two next speakers know the answer……

Thanks for attention!