

INP Studies for a Tau-Charm Factory

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August 16, 1994

Three options:

1. Axially symmetric "round beams"

$$L = 1 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

- ultimate tau-pairs productivity!

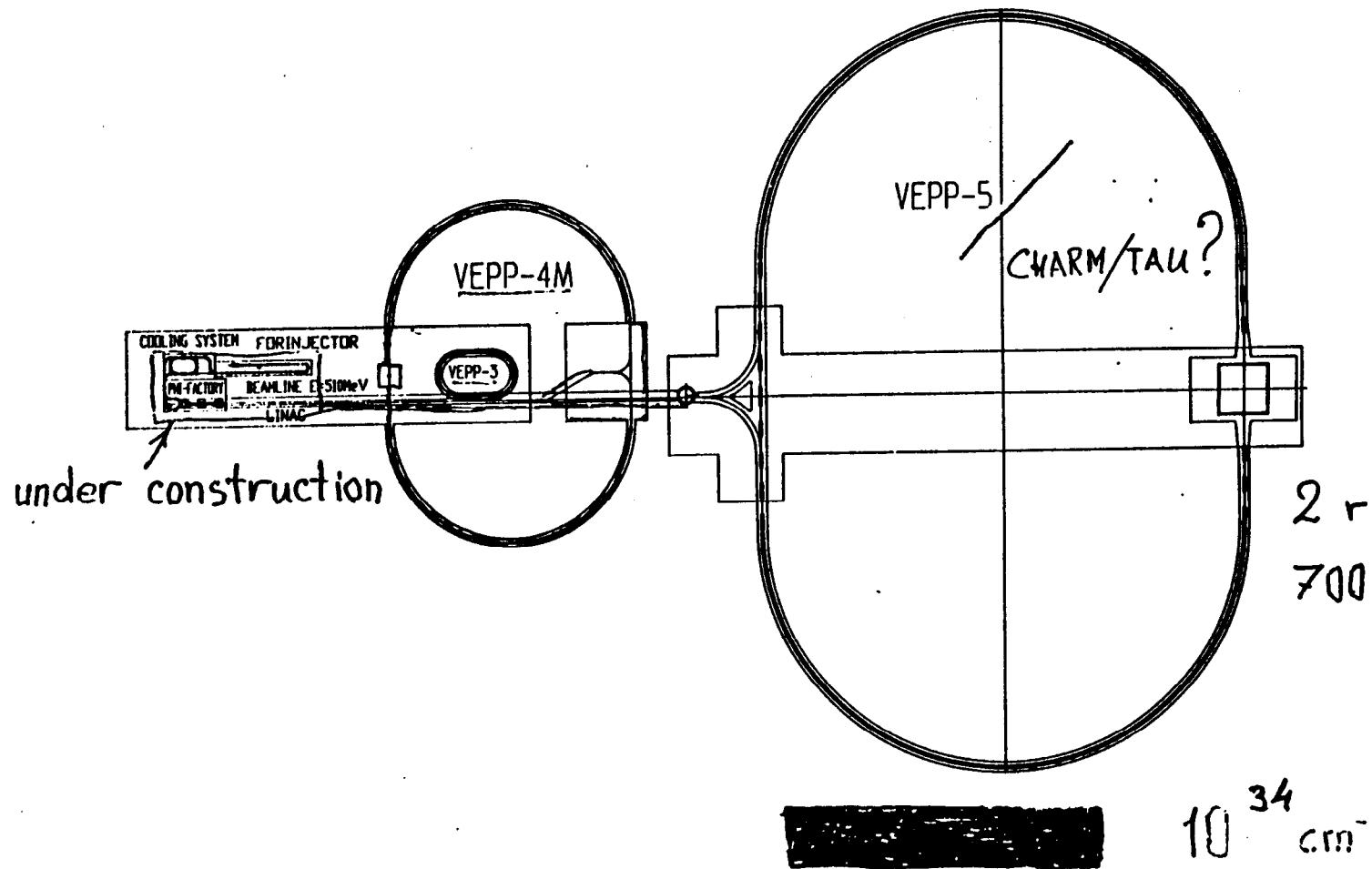
2. Monochromatic $\Rightarrow \sigma_{mass} \approx 20 \text{ keV}$

$$L_{20 \text{ keV}} = 1 \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$$

- ultimate productivity for narrow ccbar states;
- extremely good resonant-to-nonresonant ratio;
- clean & efficient tau-tau atoms production

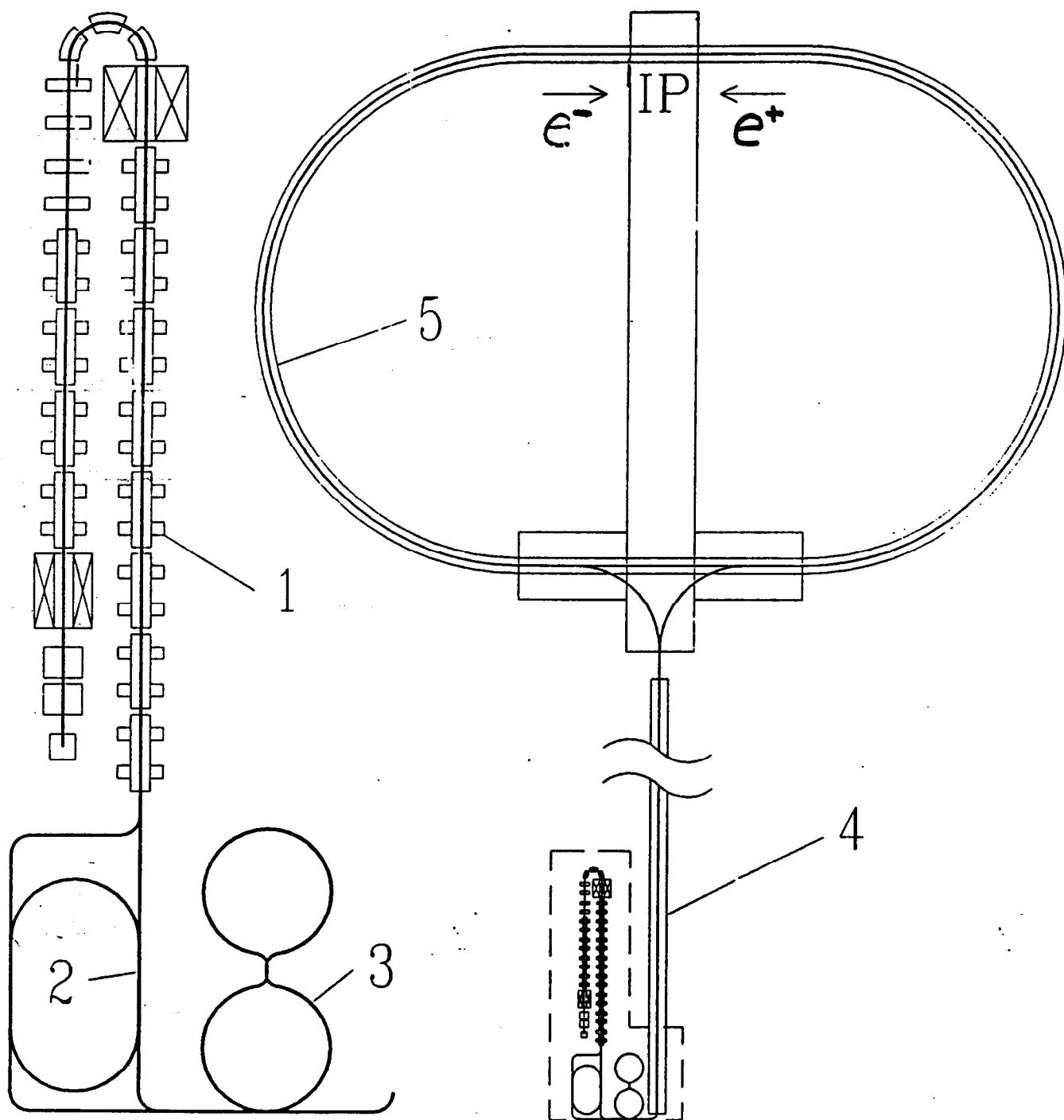
3. Longitudinal polarization

LAYOUT OF THE VEPP-5 COMPLEX



VEPP - 5

NOVOSIBIRSK



R.B.

$$L = \frac{c}{\epsilon_0} \cdot \frac{N_1 \gamma \xi}{D_b \beta_0} \quad (\beta_0 \approx \sigma_{long})$$

For $\gamma = 4 \cdot 10^3$

$$N_1 = 1.2 \cdot 10^{11}$$

$$D_b = 5 \text{ m}$$

$$\beta_0 = 1 \text{ cm}$$

$$\xi = 0, 1$$

$$I_{e^+, e^-} = 1.2 \text{ A}$$

$$L = 1 \cdot 10^{34} \text{ cm}^{-2} \text{s}^{-1}$$

$$\sigma_r^* = 30 \text{ microns}$$

(Novosibirsk Phi Factory project;
"Round Beams" at VEPP-2M - 1995)

"Round beams" for maximum luminosity:

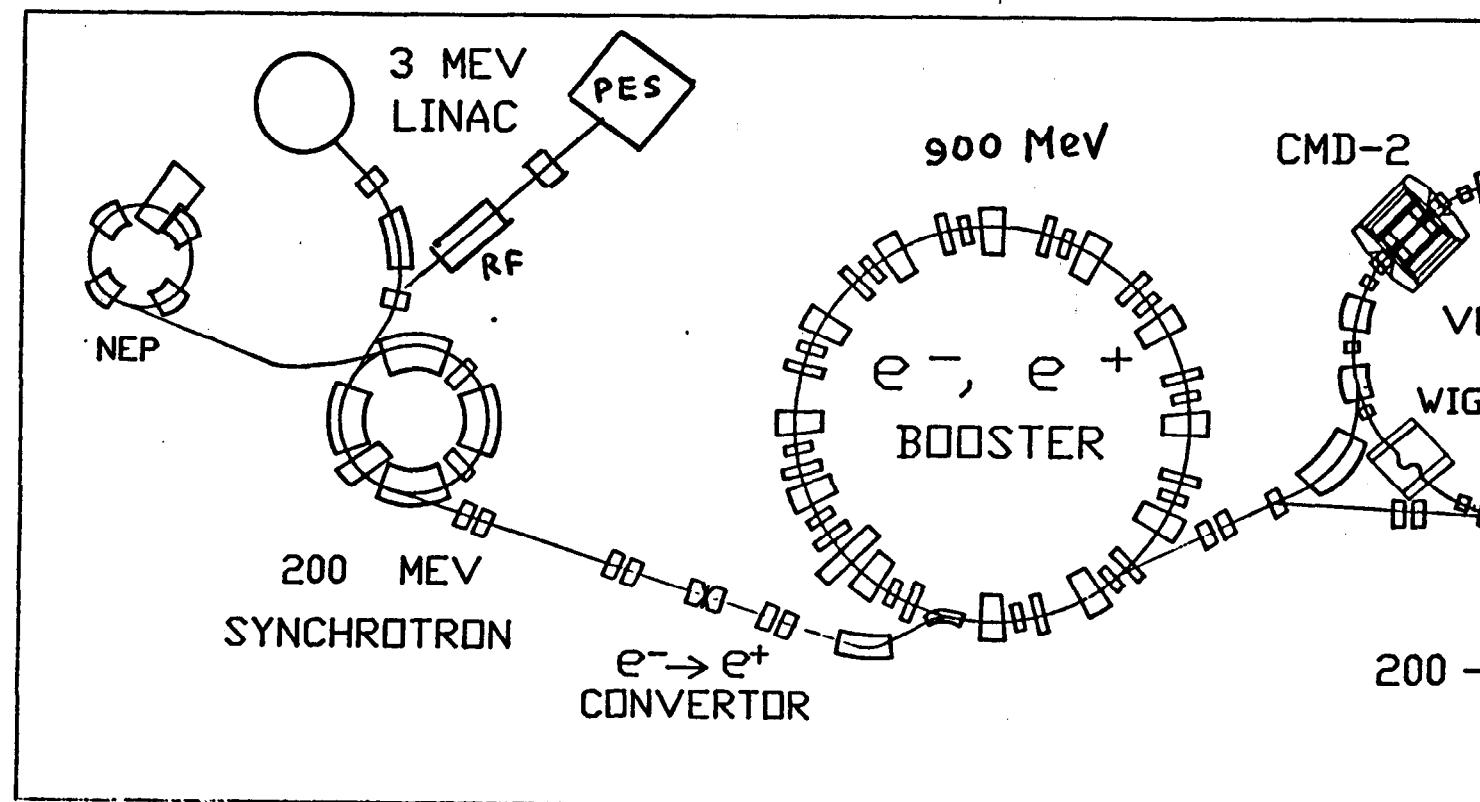
- * independent control/enlargement of transverse emittances, using quantum excitation in special separate wiggler sections;
- * resonant excitation/suppression of high enough dispersion functions in these wiggler sections (mechanical magnets/chamber position changes - to follow the orbit);
- * symmetric solenoidal final focusing;
- * arranging of large & equal x&z beta-functions at solenoid entrances;
- * zero dispersion functions at final focus region
- |* equal x & z tunes to reach higher ξ ;
|* low synchrotron osc. frequency for higher ξ
- * curing of spherical aberrations and chromaticity of FF solenoids;
- * suppression of coherent beam-beam instab. by the betatron tunes of rings separation,
by making $\sigma_{\text{long}} \approx \beta_0$,
by feedbacks;
- * "fastest" electrostatic separation of beam:
out of FF;
- * "joint" design of IR, FF solenoids & detector

This "Round Beams" option is prepared specifically for highest rate of

- τ -pair production at cross-section maximum - 100 per second,
and just below open charm threshold
- 25 per second;
- $D\bar{D}$ production at Ψ'' - 70 per sec
- $D_s\bar{D}_s$ production at Ψ''' - 70 per sec
- ... (charmed barions, ...)

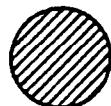
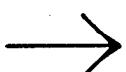
This option should be fully operational at lower energies

LAYOUT OF THE VEPP-2M COMPLEX

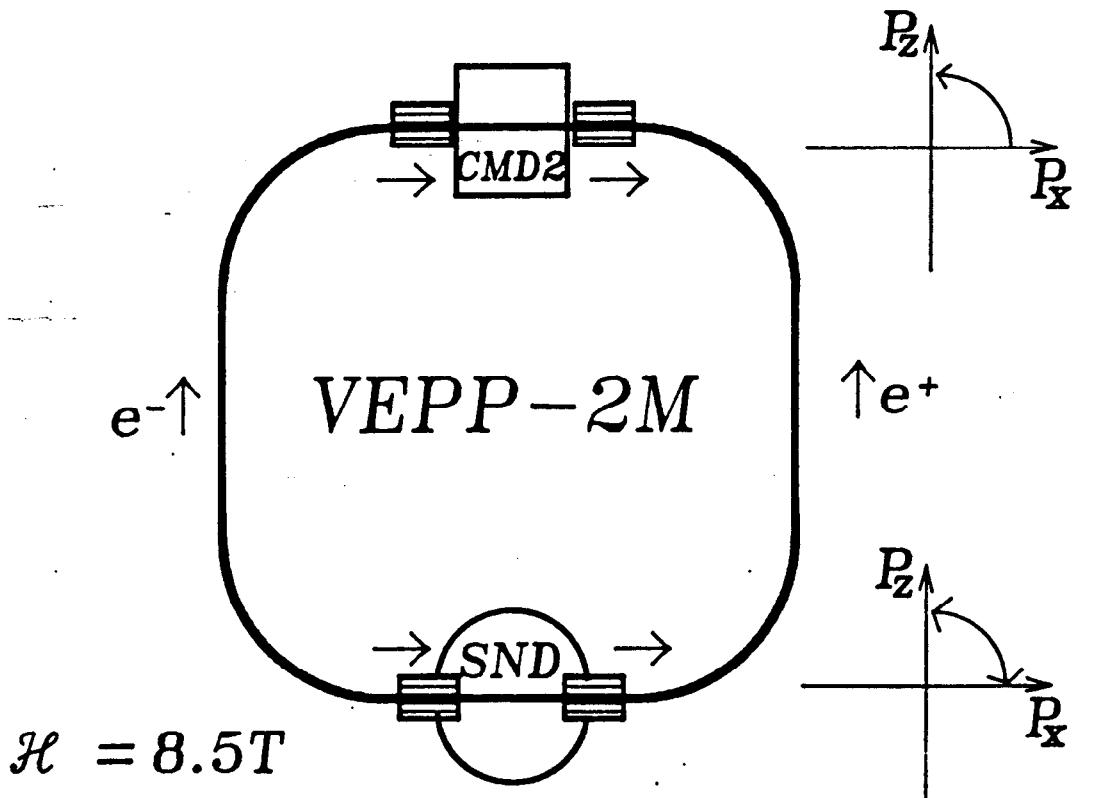


TEST OF ROUND BEAM IDEA AT VEPP-2M

$\sigma_z \approx 20\mu$
 $\sigma_x \approx 0.4\text{ mm}$



$\sigma_x^* = \sigma_z^* \sim 100\mu$
 $S_{\text{eff}} \sim \text{const}$



$\mathcal{H} = 8.5\text{T}$

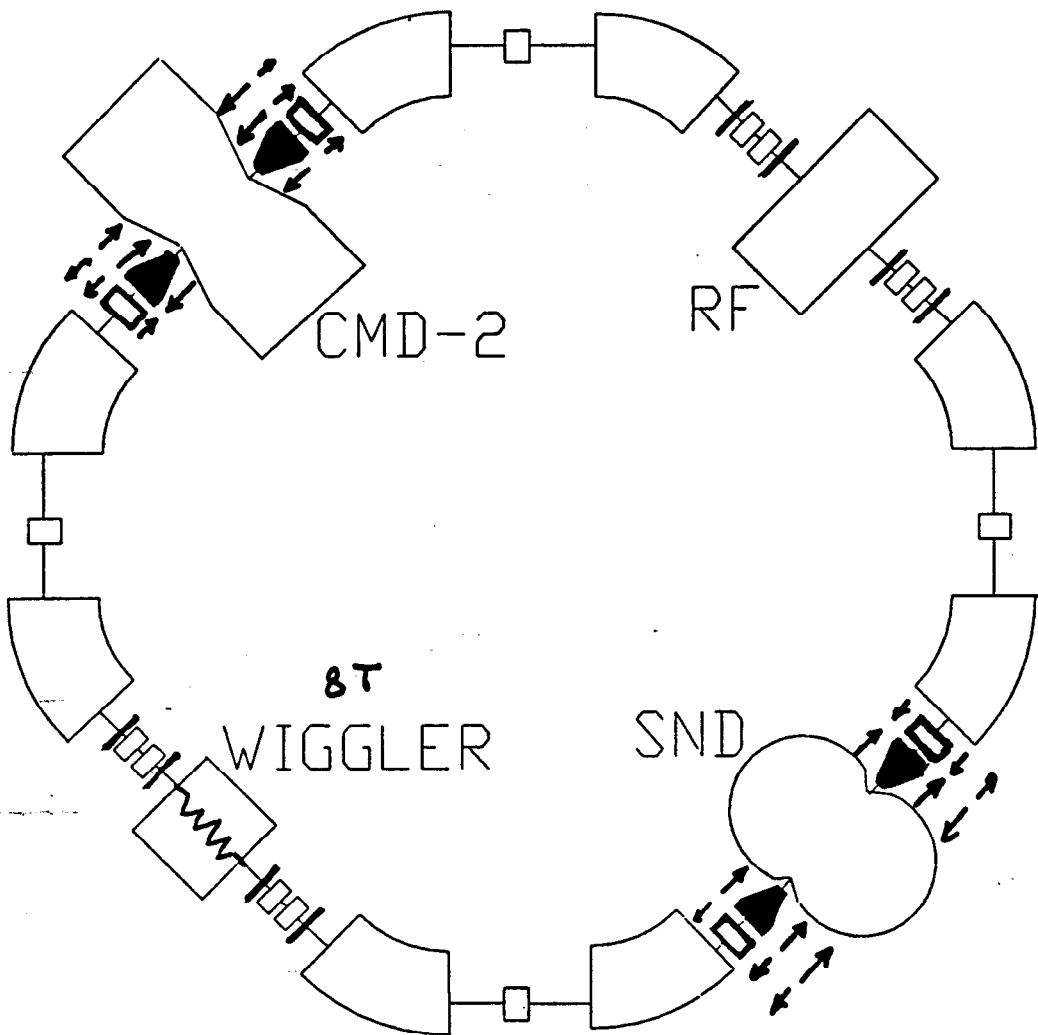
$\nu_x = \nu_z, \Delta\nu = 0.1 - 0.15$

$I \rightarrow 4I \sim 120\text{mA}, L \rightarrow 16L \sim 10^{32}\text{cm}^{-2}\text{s}^{-1}$

DEC.94 - End of construction

95 - TESTS

96 - Experiments at VEPP-2M

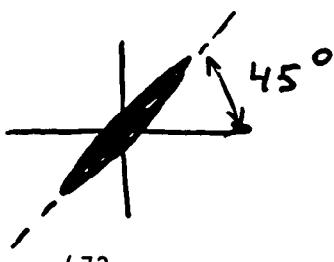


Layout of the VEPP-2M.Round beam.

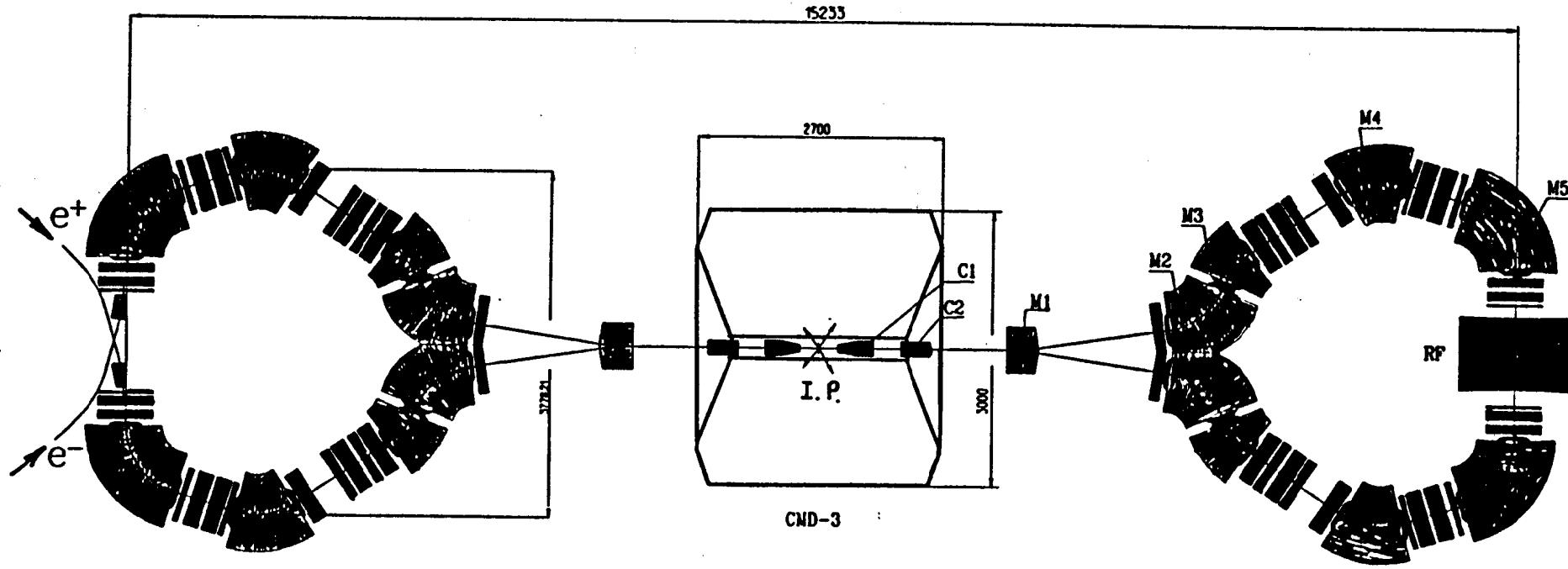
1. $\rightarrow \rightarrow$ round beams (linear eigen modes)

2. $\rightarrow \leftarrow$ round beams (circular eigen modes)

3. $\rightarrow \leftarrow$ flat beams



47



(2×2 bunches - an old dream)

TABLE 1. BASIC PARAMETERS OF THE ϕ - FACTORY

CIRCUMFERENCE, M	35.155
RF FREQUENCY, MHz	700
EMITTANCES, CM · RAD	$4.7 \cdot 10^{-5}$
	$4.7 \cdot 10^{-5}$
ENERGY LOSS, KEV	32.1
DIMENSIONLESS DECREMENTS	$1.6 \cdot 10^{-5}$
	$1.6 \cdot 10^{-5}$
	$3.4 \cdot 10^{-5}$
MOMENTUM SPREAD	$8.2 \cdot 10^{-4}$
BETAS AT IP, CM	1.0
BETATRON TUNES	6.08
NUMBER OF PPB, E^+, E^-	$2 \cdot 10^{11}$
SPACE CHARGE PARAMETERS	0,1
LUMINOSITY, $CM^{-2} s^{-1}$	$1 \cdot 10^{33}$

But to produce maximum of "narrow Psis"
— monochromatization!

$$L = \frac{\pi \cdot c}{r_e^2} \cdot \gamma^2 \cdot \frac{1}{D_b} \cdot \left(\frac{\sigma_E}{E}\right)^2 \cdot \frac{D_E^2}{\beta_D} \cdot \frac{1}{\beta_s} \cdot \xi_D \cdot \xi_s$$

For $\gamma = 3 \cdot 10^3$

$$D_b = 5 \text{ m}$$

$$\frac{\sigma_E}{E} = 0.6 \cdot 10^{-3}$$

vert. | $D_E = 35 \text{ cm}$
 $\beta_D = 5 \text{ cm}$

rad. $\beta_s = 1 \text{ cm}$

$$\xi_D = 0.015$$

$$\xi_s = 0.05$$

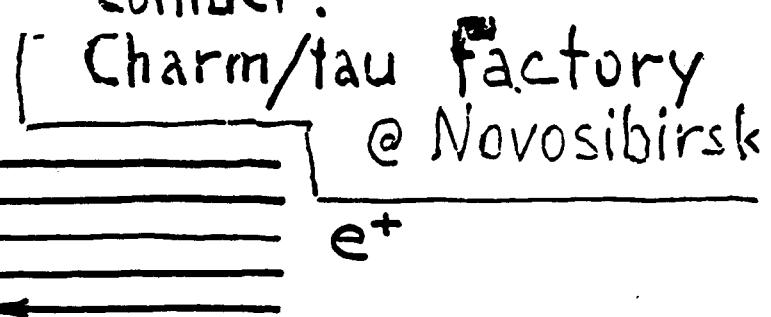
$L = 1 \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$	$\sigma_M = 20 \text{ keV}$
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$$N_i = 8 \cdot 10^{10} \quad \sigma_s = 6 \text{ fm} \quad \sigma_D = 200 \text{ fm} \quad \sigma_z = 3 \text{ fm}$$

$$\epsilon_s = 4 \cdot 10^{-7} \text{ cm} \quad \epsilon_z = 2 \cdot 10^{-8} \text{ cm}$$

Since 1974

"Monochromatized" collider:



If the energy dispersion size at IP is much larger than the size caused by betatron oscillations, than you proportionally gain in reaction energy spread.

Hence, you can measure masses of "narrow" states.

- Especially attractive (at least, for me) will be extreme accuracy tau-lepton mass measurement via clean $\tau\bar{\tau}$ atoms production @ C/τ Factory
 - 10000 atoms per day

$$e^+ e^- \rightarrow (\tau^+ \tau^-)$$

High monochromaticity & high luminosity problems and ways:

resonant excitation/suppression of vertical dispersion function with maximum at IR (to maximize D_z^2/β_z with minimal excitation of vertical emittance);

wiggler insertions for quantum excitation of energy spread and control of radial emittance (preserve vertical emittance!);

"fast" electrostatic separation of beams;

design of detector with analyzing magnetic field harmless for vertical emittance;

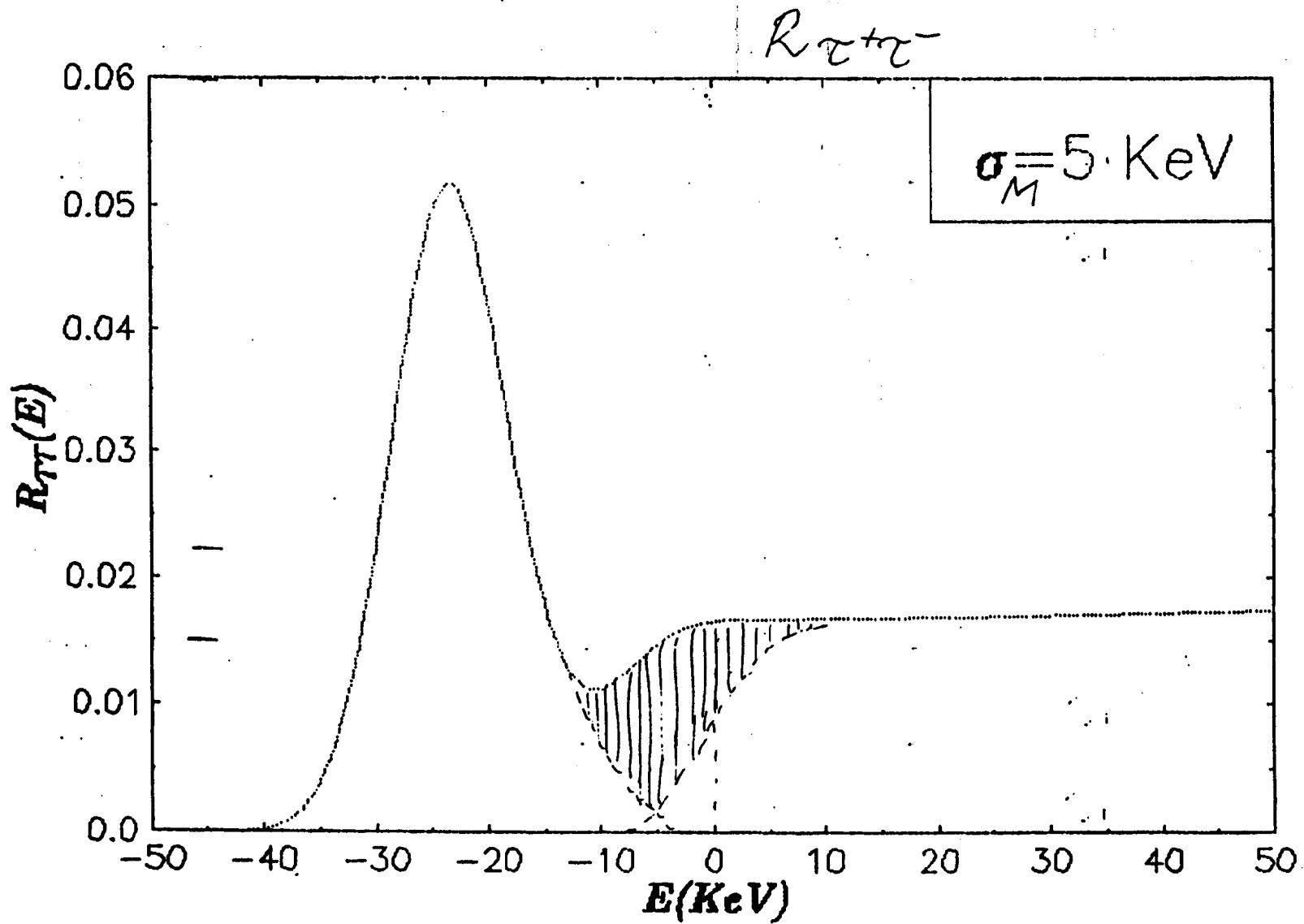
microvertex detector of high (2 microns) resolution for "monochromatic" D-meson.

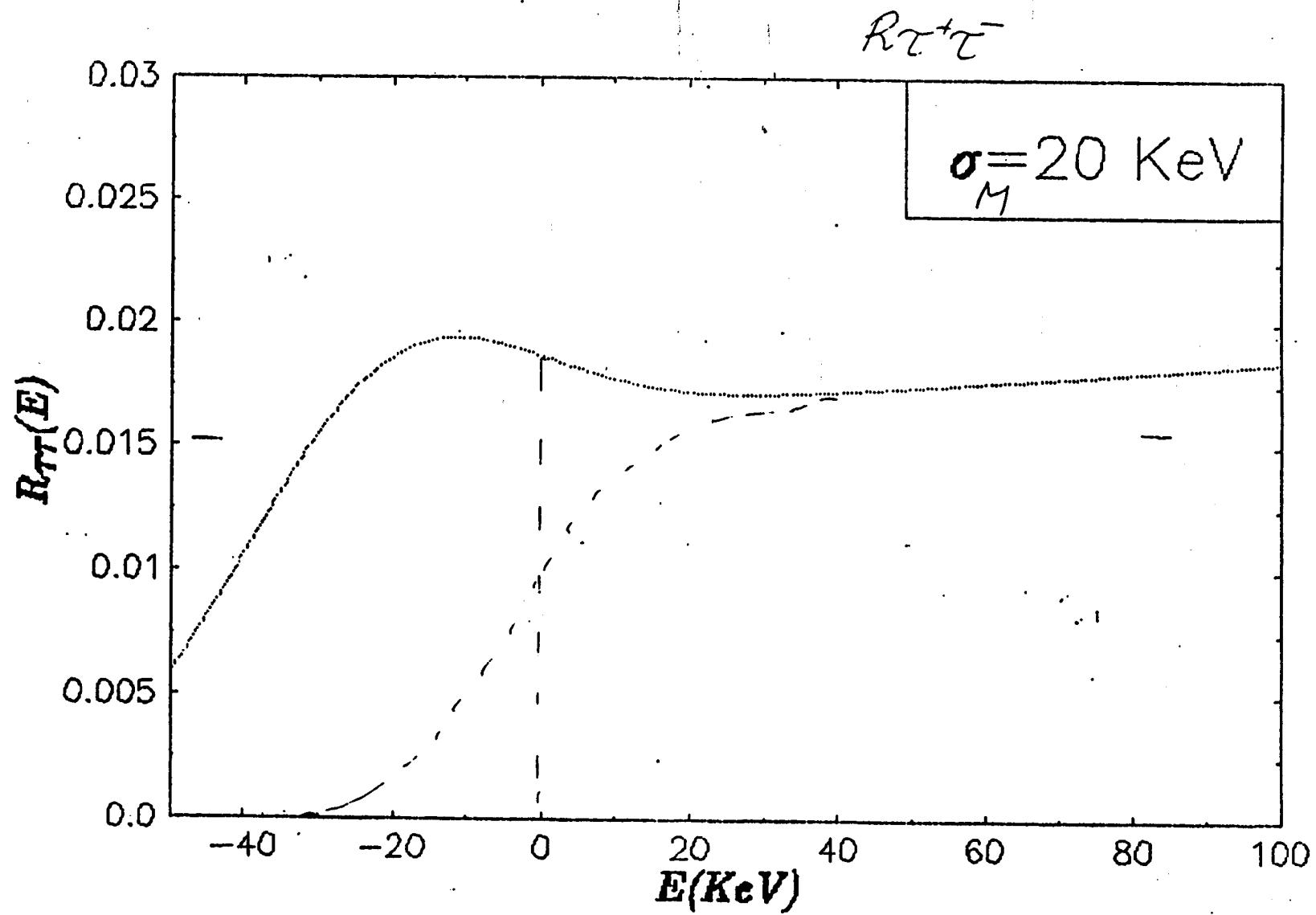
The monochromatic option:

- give possibility to produce narrow resonance with much lower non-resonant admixture - to study rare and "difficult" decays and to produce 400 clean η_c per second ($J/\psi \rightarrow \gamma \eta_c$)
- to search for and study of narrow charmonium states (via single- and double- photon annihilation)
- to study Ξ -pair production near thresh.

rare &	0.5 Ξ -pairs per sec at threshold,
"difficult"	
- Ξ -decays

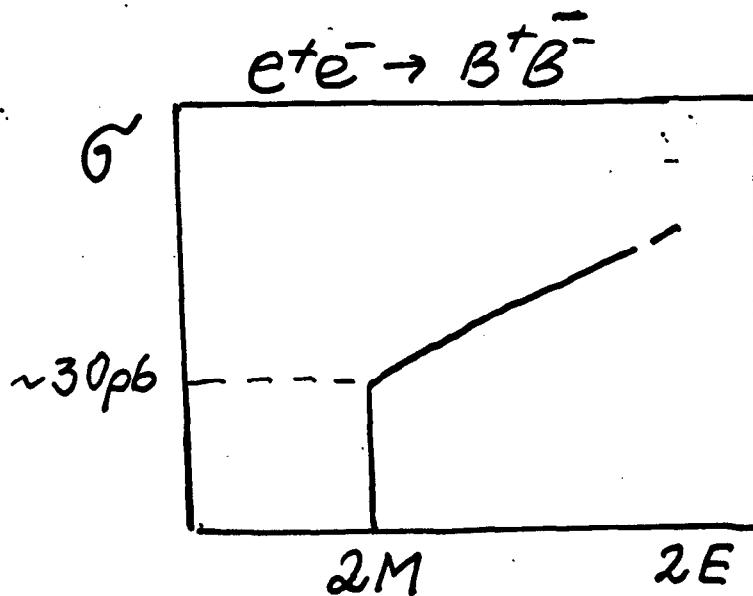
0.1 $\Xi^+ \Xi^-$ atom per sec
(sensitive to "New Physics"?)
- to measure Ξ -mass and "all" other masses with ultimate accuracy (using resonant depolarization)
- to set Ξ -neutrino mass limit lower than 1 MeV
- easier to study $D^0 \bar{D}^0$ mixing?





CHARMED PARTICLES MASSES

- D^\pm, D_s^\pm ; At threshold $\sigma(e^+e^- \rightarrow D^+D^-) \sim v^2$,
no steep rise like for $\tau^+\tau^-$
- D^+D^- - atom (e.m. bound state similar to $\tau^+\tau^-$)
 $\sigma_0(e^+e^- \rightarrow D^+D_{atom}^-) = 3\pi\lambda^2\Gamma_{ee}^D/\Gamma_t$
 $\Gamma_{ee}^D \sim 10^{-4}\Gamma_{ee}^\tau \sim 10^{-6} eV$ (P -wave!)
 $\sigma_{max} \sim 5 \cdot 10^{-39} cm^2$
- Λ_c, Σ_c - mass; $M_{\Lambda_c} = 2285$ MeV; $M_{\Sigma_c} = 2455$ MeV
 $\sigma(e^+e^- \rightarrow \Lambda_c \bar{\Lambda}_c) \sim const$ at threshold
 $\sigma \sim (\frac{m_\tau}{m_\Lambda})^2 \sigma_{\tau\tau} \cdot |\mathcal{F}|^2$;
 if $|\mathcal{F}|^2 \sim 0.2$ then $\sigma = 30 pb$;
 if $L = 10^{39} cm^{-2}$ $\mathcal{N}(\Lambda_c \bar{\Lambda}_c) = 3 \cdot 10^4$
 $\sigma M_{\Lambda_c} \leq \sigma_M \sim 30 KeV$



			MeV	keV		enh.	prospect
K ⁺	1979	INP	493.670	29	$5 \cdot 10^{-5}$	5	det.?
K ⁰	1987	INP	497.661	33			det.?
ω	1983	INP	781.72	100			3 keV
ψ	1975	INP	1,019.52	130			3 keV
η'	1981	INP	3,096.93	90			10 keV
η''	1981	INP	3,686.00	100			15 keV
γ	1986	INP	9,460.59	100	$1 \cdot 10^{-5}$	80	10 keV
γ'	1984	INP	10,023.6	500			
γ''	1984	INP	10,355.3	500			
Z	1993	CERN	91,187	4.000	$5 \cdot 10^{-5}$?

What are the prospects to improve accuracy in mass measurements even further - and the problems to be solved ?

- "Technical" problems -
 - need in long stability and suppression all higher frequency noises - 10^{-7} and even better
- Suppres depol. rate! \rightarrow "sharpness"!
- for "narrow" particles and states ($\Gamma \ll \Delta E$ in storage ring)
it useful to transit to
 - "monochromotized colliders"
- In e^+e^- colliders all masses are based on electron mass, and its accuracy is only 5 times better,
(relat.) $2 \cdot 10^{-6}!$

So, we need to proton mass the same way - to obtain universal relative scale

(be careful with beam-beam int.
caused difference

reaction energy vs beam energy:

$$\Delta E \approx e^2 \frac{N_b}{L_b} = r_e \cdot \frac{N_b}{L_b} \cdot m_e c^2)$$

Longitudinal polarization option (if interesting)

em 1: longitudinal polarization plans for VEPP-4
to study b-quark weak interactions.

em 2: VEPP-3M twenty years old project.

- ∴ "very easy" sub-option - only e^- polarized:
- to inject SLC-type polarized electrons;
- to install "gr-solenoid" (with correcting skew quadrupole)
at azimuth opposite to the interaction point;
"fast" exchange of electrons to prevent
polarization degree degradation;
arbitrary choice of each e^- bunch helicity
- to fight systematic errors;
interaction region & detector
- subject for optimization;
luminosity can exceed $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$.

II. for e^+, e^- both polarized:

to install at convenient azimuths

asymmetric high field polarizing w wigglers;

to install at symmetric azimuths

(corresponding to the energy chosen)

$\frac{\pi}{2}$ solenoids with correcting skew quads

possibility to choose any combination
of e^+, e^- helicities (two rings!);

possibility to control each bunch polarization
degree independently - to fight systematics;

luminosity can exceed $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

(easier to reach higher emittance!).

rem 3: Similar approach could be used at
B Factories;

it could be worth to inject in LER
polarized e^- .

LONGITUDINAL POLARIZATION

*"Common" opinion of 1960-th:
in storage rings transversal (e.g. along magnetic field H)
polarization can be stable - only:

$$\vec{S} = \text{constant.}$$

*1969:

for any closed orbit in storage ring special periodical
solution $\vec{n}(\theta)$ does exist - out of spin resonances:

$$S_n \text{ is constant.}$$

And it is possible to obtain any given angle between spin
and velocity of the particle at a given azimuth, particularly
longitudinal polarization
at the interaction region!

The stability of polarization is very much the same as
in "usual" case.

*Possible way to achieve (just an example):
to use radial magnetic fields and bend the closed orbit
vertically; at the point where the angle between the
orbit and the main orbit plane becomes equal to

$$\frac{\pi}{2} \cdot \frac{440}{E_{\text{MeV}}}$$

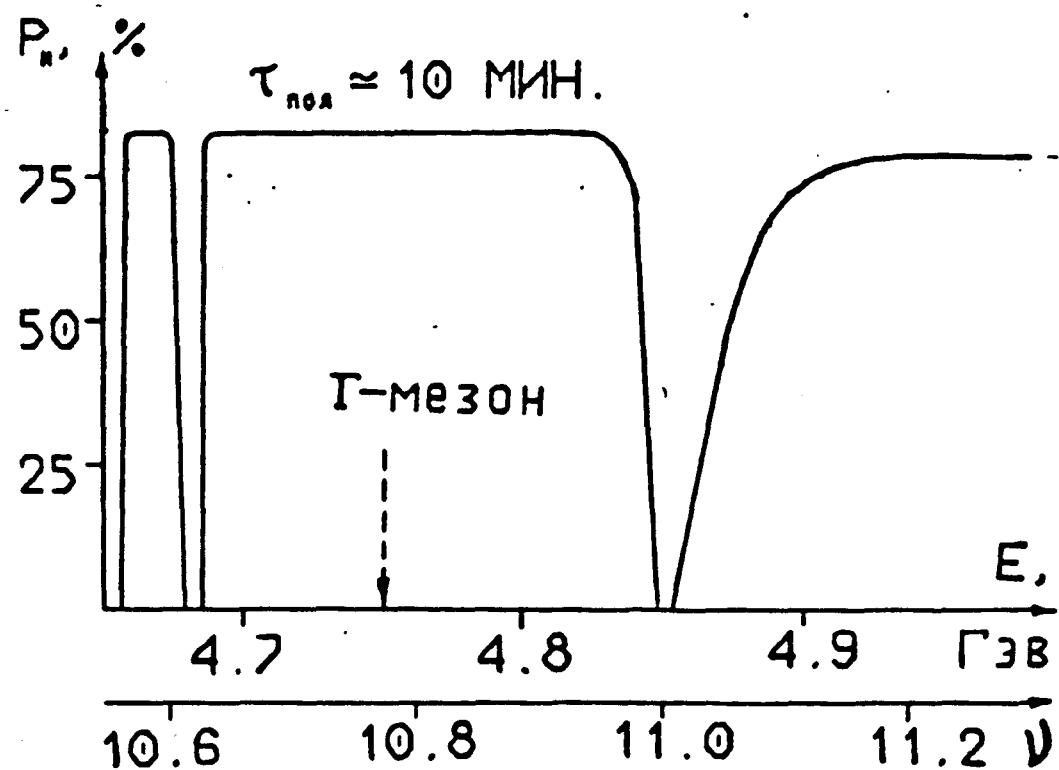
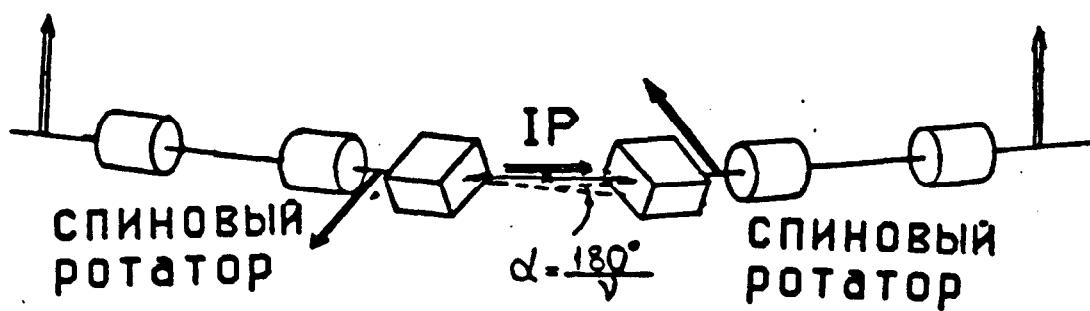
polarization becomes longitudinal.

Novosibirsk preprint #2-70 (1970)
Soviet Phys. Dokl. 15, 583 (1970)
Uspekhi Fiz. Nauk 105, 441 (1971)

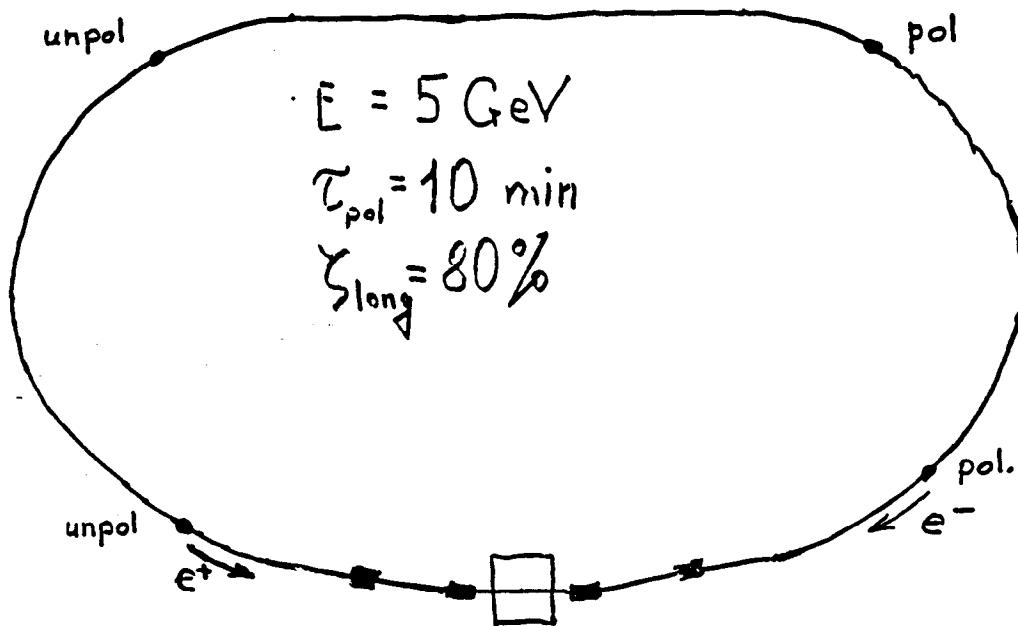
My seminar at SLAC - 1973

HERA & LEP

Продольная поляризация на ВЭПП-4М



Longitudinal polarization at VEPP-4M (experiment in design)



* b quark weak interaction (via helicity dependence)

$$e^+ e^- \rightarrow \gamma \rightarrow \text{hadrons}$$

$$\frac{\sigma_+ - \sigma_-}{2\sigma_0} \approx 1.5\%$$

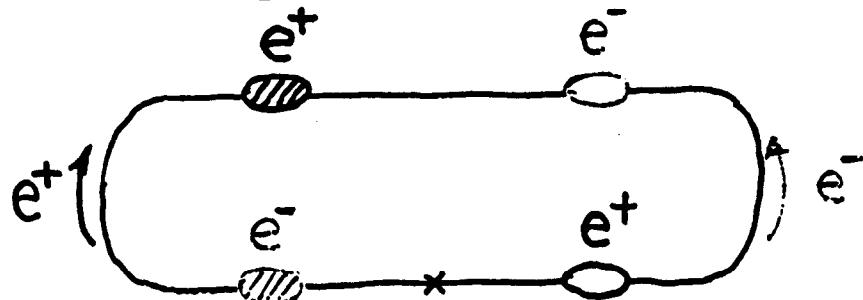
Main problem - to exclude systematic errors!

- 2×2 bunches
with arbitrary chosen helicities (+; 0; -)
- very equally populated bunches
- stationary conditions (inj., depol, ...)

Longitudinal polarization at VEPP-4M (experiments)

$T_{pol} = 10 \text{ min}$ + full energy injection
 $\xi_{long} = 80\%$

Main problem - to fight systematic errors!



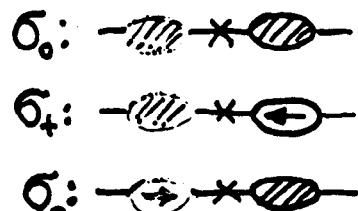
(any combination)

polarized bunch
 unpolarized bunch

* b quark weak interaction
 (via helicity dependence):

$$e^+ e^- \rightarrow Y \rightarrow \text{hadrons}$$

$$\Lambda = \frac{\sigma_+ - \sigma_-}{2\sigma_0} \approx 1.5\%$$



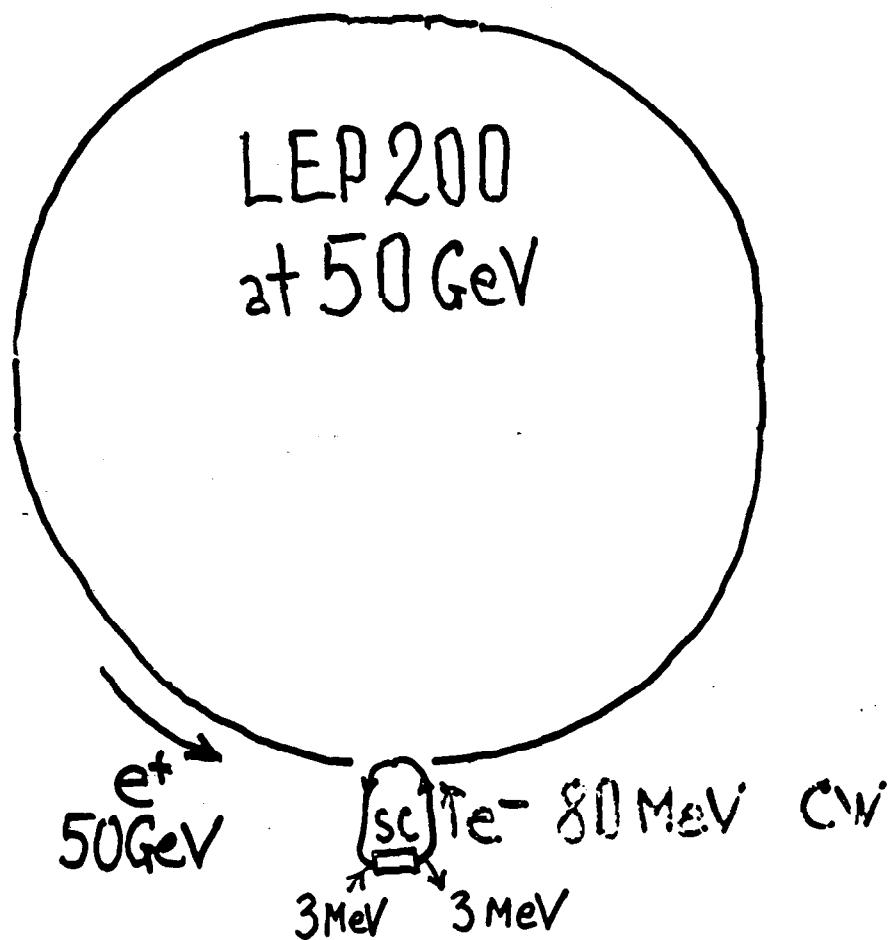
* Quasi-real $\gamma\gamma$ physics
 with longitudinally polarized ee

* ???

Call for collaboration
 (Dubna, ITEP + ???)

A remark:

Extremely asymmetric Charm/tau Factory



Luminosity $\rightarrow 10^{33} \text{ cm}^{-2} \text{s}^{-1}$:

e⁺ - "low" current, but high energy (\gg norm)

e⁻ - low energy, but single-pass!

Almost stationary target experiment,
but e⁺e⁻ cleanliness!