Status and Progress VEPP-2000

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OUTLINE

VEPP-2M  VEPP-2000

- Round beams - a way to increase luminosity.
- How to make beams round
- VEPP-2000 systems: magnets, RF, vacuum, control and diagnostics
- First beam
- Round beam
- Beam-beam study
- Detectors CMD-3 and SND
- Physics at VEPP-2000
- Conclusion
• High luminosity: $L=5 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$
• Radiative polarization
• Spin precession frequency measurements
• $\rho$, $\omega$, $\varphi$, $K^\pm$, $K^0$ mass measurements
• $e^+e^-$ anomalous magnetic moment comparison ($10^{-11}$)
Overview of VEPP-2M results

\[ \int L dt \geq 100 \text{ (pbarn)}^{-1} \]
ILU 3 MeV Linac

B-3M 200 MeV synchro-betatron

BEP e,e booster 900 MeV

CMD-2

vee -+ convertor

VEPP-2000

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

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

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

Round Beams:

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

- Geometric factor (gain=4)
- Beam-beam limit enhancement

$$\xi_{x,y} \geq 0.1$$
The Concept of Round Colliding Beams

- Angular momentum conservation: \( M_z = x'y - xy' \)
- Small and equal \( \beta \)-functions at IP: \( \beta_x = \beta_y \)
- Equal beam emittances: \( \varepsilon_x = \varepsilon_y \)
- Equal betatron tunes: \( \nu_x = \nu_y \)
- Small and positive fractional tunes

(V.V.Danilov et al., EPAC’96, Barcelona, p.1149, (1996))
Vertical size dependence on beam-beam parameter $\xi$

"Weak-Strong" Beam-Beam Simulations

$\xi = \frac{Nr_e\beta^*}{4\pi\gamma (\sigma^*)^2}$

Flat beams, fit on VEPP-2M experimental data

Round beams, simulation
"Strong-Strong" Beam-Beam Simulations
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference</td>
<td>24.38 m</td>
</tr>
<tr>
<td>RF frequency</td>
<td>172 MHz</td>
</tr>
<tr>
<td>RF voltage</td>
<td>100 kV</td>
</tr>
<tr>
<td>RF harmonic number</td>
<td>14</td>
</tr>
<tr>
<td>Momentum compaction</td>
<td>0.036</td>
</tr>
<tr>
<td>Synchrotron tune</td>
<td>0.0035</td>
</tr>
<tr>
<td>Energy spread</td>
<td>6.4 x 10^{-4}</td>
</tr>
<tr>
<td>Beam emittances (in the round mode)</td>
<td>1.29 x 10^{-7} m rad</td>
</tr>
<tr>
<td>Dimensionless damping decrements (x,y,s)</td>
<td>2.19 x 10^{-5}, 2.19 x 10^{-5}, 4.83 x 10^{-5}</td>
</tr>
<tr>
<td>Betatron tunes</td>
<td>4.05, 2.05</td>
</tr>
<tr>
<td>Betatron functions at IP</td>
<td>10 cm</td>
</tr>
<tr>
<td>Number of bunches per beam</td>
<td>1</td>
</tr>
<tr>
<td>Number of particles per bunch</td>
<td>1 x 10^{11}</td>
</tr>
<tr>
<td>Beam-beam parameter (x,y)</td>
<td>0.075, 0.075</td>
</tr>
<tr>
<td>Luminosity per IP (at 1 GeV)</td>
<td>1 x 10^{32} cm^{-2}s^{-1}</td>
</tr>
</tbody>
</table>
Practical Realization of Round Beams: Options for VEPP-2000
Cartoon of VEPP-2000 Collider
First “mile stones” of VEPP-2000
(14.05.2001)
Dipole Magnet (2.4 T)
Vacuum chamber and mirror
Single-Mode RF Cavity (172 MHz)
Solenoid 13.0 T
Solenoid 13.0 T at VEPP-2000
LHe consumption?
6 l/hour
Beam in Transfer Line
VEPP-2000 Lattice

Solenoids—"off"

\[ \nu_z = 1.38; \quad \nu_x = 2.44 \]
First injection (RF “off”)
Beam’s CCD pictures (RF "on")
CO and Beam Sizes (weak focusing)

E=508 MeV
Beam currents

Synchrotron B-3M

Booster BEP

VEPP-2000

\[ \tau(150 \, mA) \approx 500 \, \text{sec} \]

\[ \tau(1 \, mA) \geq 10 \, \text{hours} \]
Round beam operation

E = 508 MeV

Round beam lattice (solenoid field 10T+1T in anti-solenoid)

First injection (tune near one half)

CO + lattice symmetry corrections (tunes: 0.1 ÷ 0.15)

Orbit response matrices on dipole and quadrupole corrections + Singular values decomposition

$\beta^* = 4.5 \, cm, \quad \nu_1 = 2.12, \quad \nu_2 = 4.15$
Round beams  (solenoid field 10 T)

positron beam

#1 (1M2)  #2 (2M2)  #3 (2M1)
Round beam lattice

#3 (1M2)
#2 (2M2)
#1 (2M1)

\[ \text{ Beta functions, m} \]

\[ \text{Dispersion function, m} \]
"Weak-strong" beam-beam study

\[ I_{e^+} = 3 \text{ mA} \]

\[ I_{e^-} \approx 40 \text{ mA} \]

\[ \text{Positron life time} < 100 \text{ s.} \]

\[ \xi_{\text{lim}} \approx 0.08 \]

\[ \text{Positron life time} \approx 5000 \text{ s} \]

\[ \text{Luminosity} \approx 0.5 \div 0.7 \times 10^{30} \text{ cm}^{-2}\text{s}^{-1} \]

\[ \xi = 0.06 \]
CMD-3 DETECTOR

1 - Vacuum pipe
2 - Drift chamber
3 - BGO endcap calorimeter
4 - Z-chamber
5 - Superconducting solenoid
6 - LXe calorimeter
7 - CsI barrel calorimeter
8 - Yoke
9 - LHe supply
10 - Vacuum pumpdown
11 - VEPP2000 superconducting magnetic lenses
Physical program at VEPP-2000

- Precise measurement of the quantity $R = \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$
- Study of hadronic channels: $e^+e^- \rightarrow 2-3-4\ldots(\pi,K,\eta)$.
- Study of ‘excited’ vector mesons: $\rho’, \rho’’, \omega’, \varphi’, \ldots$
- CVC tests: comparison of $e^+e^- \rightarrow \text{hadr.} (T=1)$ cross section with $\tau$-decay spectra
- Study of nucleon-antinucleon pair production – nucleon electromagnetic formfactors, search for $NN\bar{\text{n}}$ resonances, ..
- Hadron production in ‘radiative return’ (ISR) processes
- Two photon physics
- Test of the QED high order processes $2\rightarrow4,5$
Conclusion

- Beam parameters of VEPP-2000 correspond to the project.
- All systems of VEPP-2000 are working.
- Vacuum life time exceeds 10 hours (I=1 mA).
- Round beam option was realized.
- First beam-beam study is done: $\xi_{\text{lim}} \approx 0.08$ is achieved.
- Further beam-beam study will continue soon.
- Detectors CMD-3 and SND are near to completion.
- Interesting physics can be done at VEPP-2000.