Recent results from CMD-3 detector

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(on behalf of CMD-3 Collaboration)

Outline

✓ Introduction
✓ Collider & Detector
✓ Preliminary Results
✓ Conclusion
Introduction

Measurement of the cross section $e^+e^- \rightarrow \text{hadrons}$ in the low energy range is interesting for:

- measurement of parameters of light vector mesons $\rho$, $\omega$, $\varphi$, $\rho'$, $\rho''$, $\omega'$, $\omega''$
- test of QCD sum rules, ... etc, search of exotics (light hybrids and glueballs)
- CVC test in comparison with spectral functions of tau decays
- measurement of $R(s)$:

  $$R(s) = \frac{\sigma(e^+e^- \rightarrow \gamma^* \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \gamma^* \rightarrow \mu^+\mu^-)}$$

is essential for the interpretation of precision measurements of: muon $(g-2)$ - good test of SM
The value and the error of the hadronic contribution to muon $(g-2)$ are dominated by low energy $R(s)$ ($<2\text{GeV}$ give 92%).
**VEPP-2000 $e^+e^-$ collider**

Main idea: Round Beams

**Table:**

<table>
<thead>
<tr>
<th></th>
<th>VEPP-2M</th>
<th>VEPP-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$ (MeV)</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>$\Pi$ (cm)</td>
<td>1788</td>
<td>2235</td>
</tr>
<tr>
<td>$I^+, I^-$ (mA)</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>$\varepsilon \cdot 10^5$ (cm rad)</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>$\beta_x$ (cm)</td>
<td>40</td>
<td>6.3</td>
</tr>
<tr>
<td>$\beta_y$ (cm)</td>
<td>5</td>
<td>6.3</td>
</tr>
<tr>
<td>$\xi_x$</td>
<td>0.016</td>
<td>0.075</td>
</tr>
<tr>
<td>$\xi_y$</td>
<td>0.050</td>
<td>0.075</td>
</tr>
<tr>
<td>$L$ (cm$^{-2}$s$^{-1}$)</td>
<td>$3 \cdot 10^{30}$</td>
<td>$1 \cdot 10^{31}$</td>
</tr>
</tbody>
</table>
CMD-3 Detector

1 – beam pipe, 2 – drift chamber, 3 – BGO calorimeter (680 crystals), 4 – Z-chamber, 5 – CMD-3 superconducting solenoid, 6 – calorimeter LXe (400 liters), 7 – calorimeter CsI (1152 crystals), 8 – iron yoke, 9 – solenoids of VEPP-2000, (not shown) muon range system (scintillation counters) and TOF system.
Collinear Events @ CMD-3

($E_{c.m.} = 1.95$ GeV)
The maximum luminosity is $2 \cdot 10^{31}$ cm$^{-2}$s$^{-1}$ at 1.7–1.8 GeV, falling much slower with decreasing energy than before the round beams. At high energies luminosity is limited by a deficit of positrons and maximum energy of the booster (900 MeV now).

In 2013 we reached $2 \times 160$ MeV, the smallest energy ever measured at ee colliders.

Collected Luminosity

Collected $L \sim 60$ pb$^{-1}$ per detector

- 8.3 pb$^{-1}$ \(\omega\) - region
- 9.4 pb$^{-1}$ \(< 1\) GeV (except \(\omega\))
- 8.4 pb$^{-1}$ \(\phi\) - region
- 34.5 pb$^{-1}$ \(> 1.04\) GeV
Energy measurement by Compton back scattering

\[ E = 993.662 \pm 0.016 \text{ MeV} \]

**Process** \( e^+ e^- \rightarrow 3(\pi^+ \pi^-) \)

We have very clean selection of 6 and 5 pions

**Other data for** \( e^+ e^- \rightarrow 3(\pi^+ \pi^-) \)

We study dynamics. Pure phase space doesn’t work, three models with JPC = 1^{−−}, each with one \( \rho^0/\text{event}: \)

- \( \rho(1450)(2\pi^+2\pi^-)_{S\text{-wave}} \rightarrow a_1(1260)\pi \pi \pi^+ \pi^- \rightarrow \rho^0 2(\pi^+ \pi^-) \rightarrow 3(\pi^+ \pi^-) \)
- \( \rho(770)(2\pi^+2\pi^-)_{S\text{-wave}} \rightarrow 3(\pi^+ \pi^-) \)

3 options for \( 2\pi^+2\pi^- \): phase space, \( f^0(1370), f^0(1500) \)
- \( \rho(770)E_2(1270) \rightarrow 3(\pi^+ \pi^-) \)

The best description is with one \( \rho(770) \) and 4 pions in S-wave
Process $e^+ e^- \rightarrow 2(\pi^+ \pi^- \pi^0)$

We have relatively clean selection of 2 and 1 $\pi^0$ in addition to four charged tracks.

$\omega$, $\phi$ intermediate states are seen, systematic errors are under study.
Look at the Process $e^+e^- \rightarrow 2(\pi^+\pi^-)\pi^0$

Example of $\omega f^0(980)$ signal in $\omega\pi^+\pi^-$ final state.

Detailed analysis is coming...
We confirm $a_1(1260)\pi$ dominance. Some other states ($\rho(770)f_0(600), \rho(770)f_0(980)$) are seen.

Statistical errors are at the level of 1–2% per point. Analysis of systematic errors is in progress.
Study of $e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$

In addition to dominant $\omega\pi^0$ and $a_1\pi$ we see $\rho^+\rho^-$, $\rho(770)f^0(600)$?, $\rho(770)f^0(980)$

We have statistical errors at the level of 1-2% per point. Systematic errors are under study.
Preliminary results on $e^+e^- \rightarrow pp$

Cross section

Ratio $G_E/G_M$ from analysis of angular distributions
**Process** \( e^+e^- \rightarrow K^+K^-\pi^+\pi^- \)

\( \pi K \) particle identification by dEdX in DC

Rich dynamics seen, many intermediate states:
- \( K_1(1270)K \rightarrow K^*(892)K\pi \)
- \( K_1(1400)K \rightarrow K^*(892)K\pi \)
- \( K_1(1270)K \rightarrow \rho KK \)
- \( K^*(892)K^*(892), \phi\pi\pi \)

**CMD-3**

**BaBar**
New accelerator principles put on the base of the VEPP-2000 collider were successfully proved. First three experimental runs generated considerable amount of data which analysis is in progress now. The second detector, SND, with very good photon detection collected similar statistics and has a lot of various results on hadronic cross sections, particularly on channels with neutrals.

The last experimental run ended in the middle of July 2013. Then a long shutdown for 1-1.5 years to increase the booster energy to 1 GeV and commission the new injection complex to reach $10^{32} \text{ cm}^{-2}\text{s}^{-1}$

Hopefully, in the next 5-10 years the VEPP-2000 will produce the integrated luminosity $\sim 1 \text{ fb}^{-1}$ which should provide new precise interesting results on the hadron production in $e^+e^-$ annihilation.

Stay tuned!
Thank You!
The maximum luminosity is $2 \cdot 10^{31}$ cm$^{-2}$s$^{-1}$ at 1.7–1.8 GeV, falling much slower with decreasing energy than before the round beams.

At high energies luminosity is limited by a deficit of positrons and maximum energy of the booster (900 MeV now).

In 2013 we reached $2 \times 160$ MeV, the smallest energy ever measured at ee colliders.
$e^+ e^- \rightarrow \pi^+ \pi^- \rightarrow CMD-3$

Clean collinear events (mostly without background).
Overall corrections at the level of a few percent.

Plans to reduce systematic error from 0.6-0.8% → 0.35%:
- Event separation will be checked by different methods (0.2%)
- More proof of Radiative corrections 0.3% → 0.1%
- Determination of fiducial volume controlled independently
  by LXe and ZC subsystems (0.1%)
- Beam energy measured by method of Compton back scattering of
  the laser photons ($\sigma_\gamma < 50$ keV) (0.1%)

Statistical precision of cross section measurement
$E_{cm} = 0.32 - 0.98$ GeV,
$\Delta E_{cm} = 0.02$ GeV,
100 nb-$1/point$