FIRST EXPERIMENTS AND PROSPECTS OF PRECISION HADRONIC CROSS SECTIONS MEASUREMENTS AT VEPP-2000 COLLIDER IN NOVOSIBIRSK

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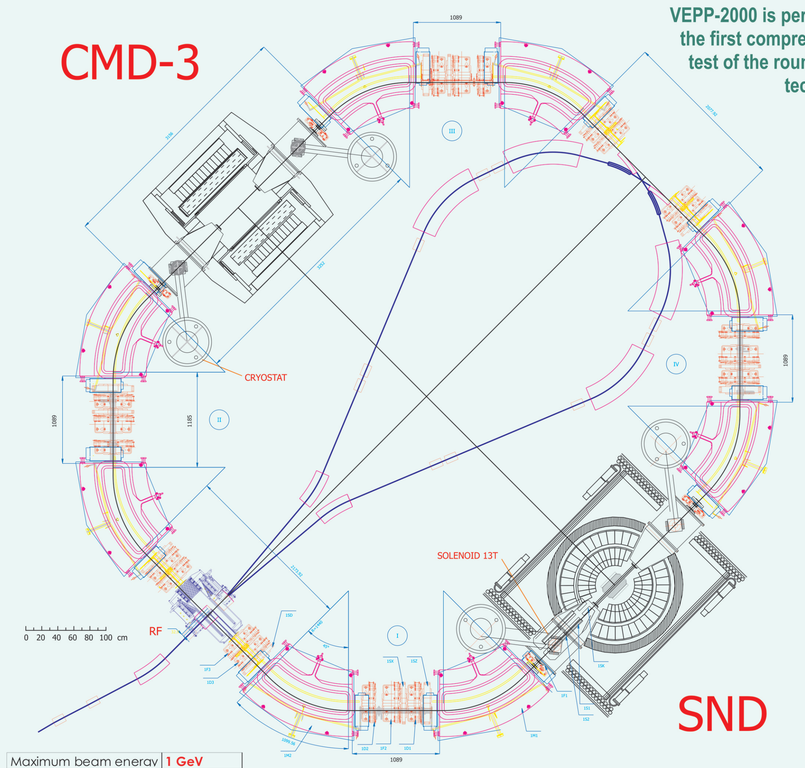
VEPP-2000 COLLIDER

HTTP://VEPP2K.INP.NSK.SU



Maximum beam energy	1 GeV
Perimeter	24.388 m
Time between collisions	80 ns

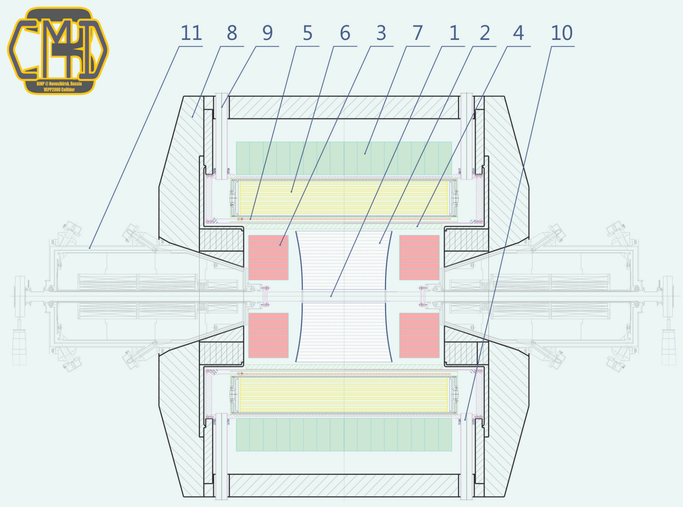
Parameters at E_{beam} = 1.0 GeV

Luminosity	$1 \cdot 10^{32}$ cm^{-1}s^{-1}
Beam current	200 mA
Number of particles in one bunch	$1 \cdot 10^{11}$
Bunch length	3.3 cm
Beta function at interaction point	$\beta_x = \beta_z = 6.3$ cm
Energy Spread	$\sigma_E/E = 6.4 \cdot 10^{-4}$

- In the middle of June, 2007 the colliding beam regime with round beams was obtained.
- The luminocity of $1.0 \cdot 10^{31}$ cm^{-2}s^{-1} was obtained at the beam energy of 500 MeV with currents $I^+ I^-$ = 1.0×25.0 mA^2 and tune shift of 0.08.
- Scans of $\phi(1020)$ and $\phi(1680)$ in the beam energy range of 510 – 950 MeV has been performed in 2010: 10 energy points with 400 nb^{-1} collected in each point

CMD-3 DETECTOR

HTTP://CMD.INP.NSK.SU

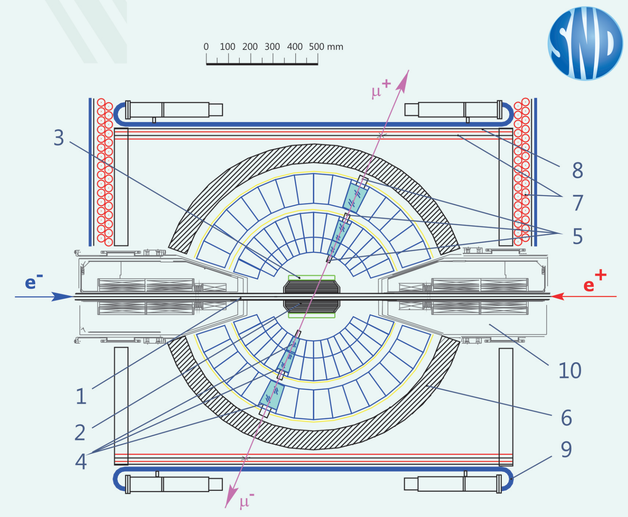


1 - Vacuum pipe
2 - Drift chamber
3 - BGO endcap calorimeter
4 - Z-chamber
5 - Superconducting solenoid
6 - LXe calorimeter
7 - CsI barrel calorimeter
8 - Yoke
9 - LHe supply
10 - Vacuum pumpdown
11 - VEPP2000 superconducting magnetic lenses

Current Status of the CMD-3 Detector:
- **CMD-3 detector is installed and operational at VEPP-2000 collider**
- **Magnetic field 1.0 T is obtained with the superconductive solenoid**
- **Data taking runs are being carried out**

SND DETECTOR

HTTP://WWWSND.INP.NSK.SU



1 - Vacuum pipe
2 - Tracking system
3 - Aerogel Cherenkov counters
4 - NaI(Tl) crystals
5 - Vacuum phototriodes
6 - Iron absorber
7 - Muon tubes
8 - Iron absorber (1 cm)
9 - Scintillation counters
10 - Solenoids

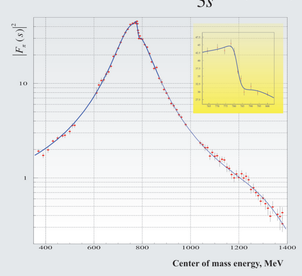
Current Status of the SND Detector:
- **SND detector is installed and operational at VEPP-2000 collider**
- **Muon system is under tests and partially assembled**
- **Data taking runs are being carried out**

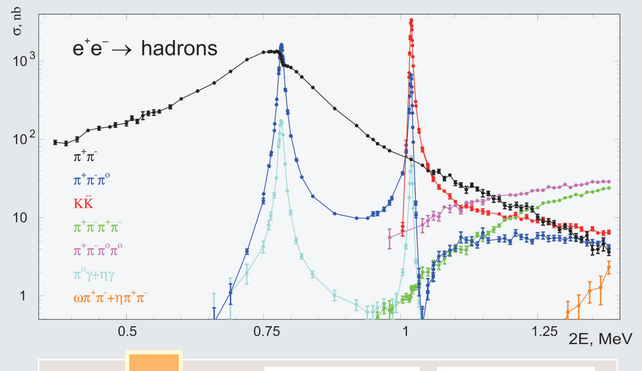
PRECISION CROSS SECTION MEASUREMENTS

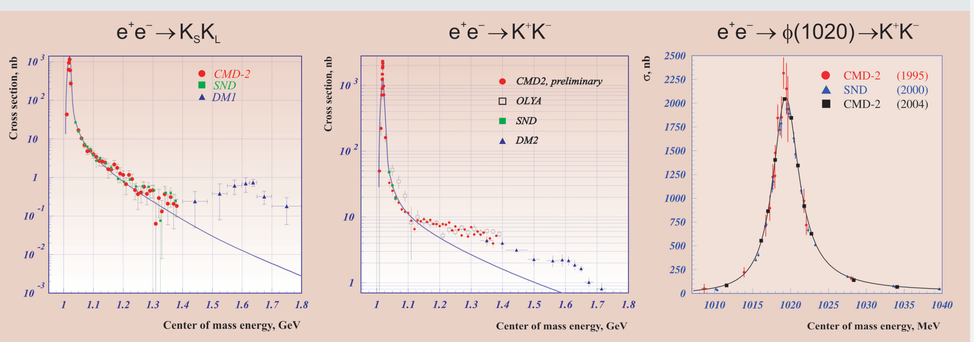
The uncertainty in a_μ(had) was decreased from 2% down to 0.6% as the result of VEPP-2M hadronic cross section measurements.

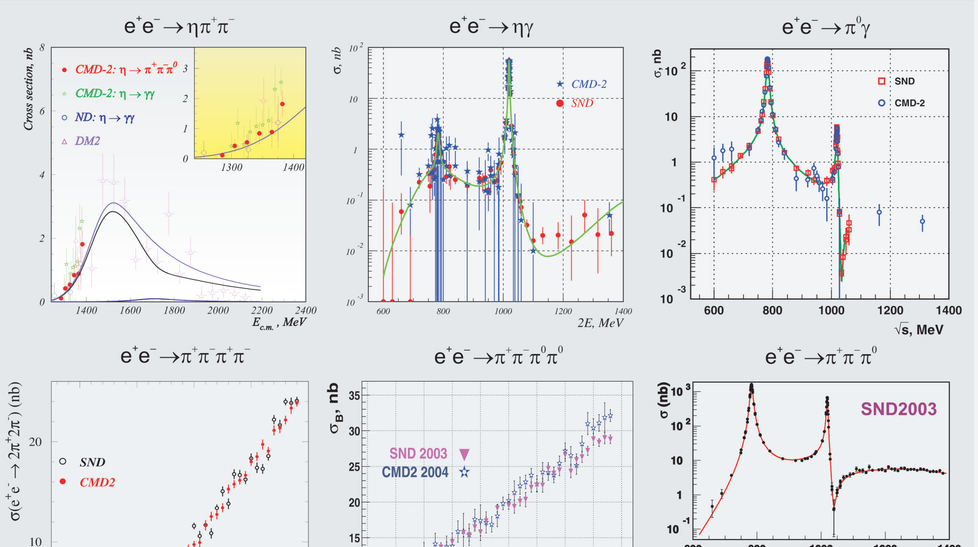
$$a_\mu^{had}(l.o.) = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{4m_\pi^2}^{\infty} ds \frac{K(s)}{s^2} R(s)$$

$$e^+e^- \to \pi^+\pi^- \quad \sigma_{\pi\pi}(s) = \frac{\pi\alpha^2}{3s}\beta_\pi^3 |F_\pi(s)|^2$$





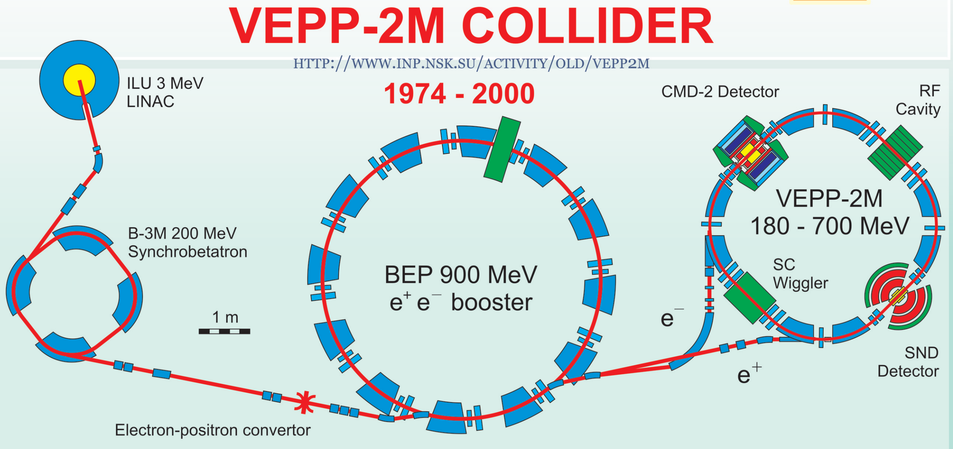




Measurements previously performed with CMD-3 and SND detectors at VEPP-2M collider

VEPP-2M COLLIDER

HTTP://WWW.INP.NSK.SU/ACTIVITY/OLD/VEPP2M



- New measurement of R with energy scan is one priority tasks for VEPP-2000.
- High luminosity of VEPP-2000, improved detectors and advances in calculation of the radiative corrections should allow to reach the low systematic error.
- The measurement will be preformed independently and concurrently at two detectors, CMD-3 and SND, providing important cross-check.
- With VEPP-2000 data, combined with ISR data from KLOE, Belle and BaBar (and, possibly, tau decays data), we expect to reduce uncertainty of the hadronic contribution to muon anomalous magnetic moment to the level, needed by the planned new (g-2) experiment.

Prospects for R measurement with CMD-3 and SND detectors

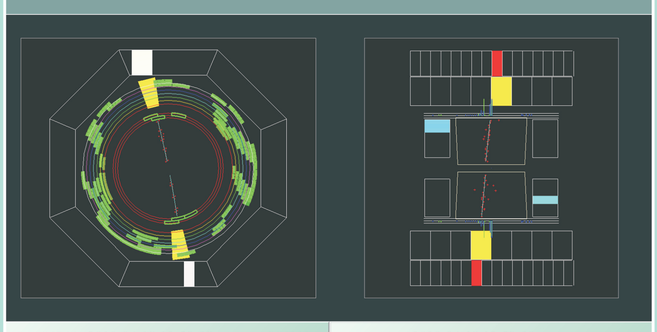
R measurement at VEPP-2M: systematic errors

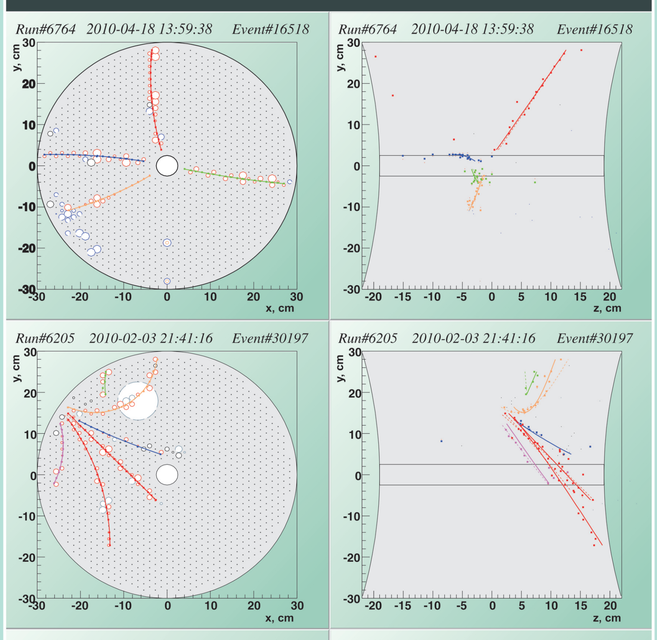
Source of error	CMD2, 2pi √s<1 GeV	SND, 2pi √s<1 GeV	CMD2, 4pi √s>1.1 GeV
Event separation	0.2-0.4%	0.5%	2% (cuts)
Fiducial volume	0.2%	0.8%	3% (model)
Energy calibration	0.1-0.3%	0.3%	1%
Efficiency correction	0.2%-0.5%	0.6%	2% (tr+bg)
Pion losses (decay, NI)	0.2%	0.2%	
Other	0.2%	0.5%	2%
Radiative corrections	0.3-0.4%	0.2%	1%
Total syst.	0.6-0.8%	1.3%	5%
Stat.+Syst.	0.7%	1.5%	7%

What systematic error can be achieved for R measurement at CMD-3?

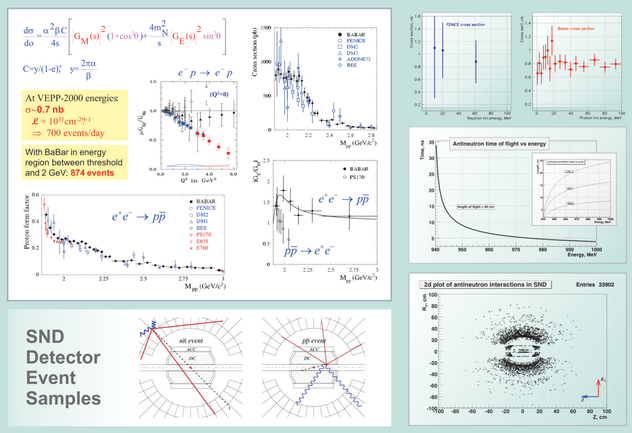
Source of error	CMD3, 2pi √s<1 GeV	CMD3, 4pi √s>1.1 GeV
Event separation	0.2%	1% (cuts)
Fiducial volume	0.2%	2% (model)
Energy calibration	0.1%	
Efficiency correction	0.1%	1% (tr+bg)
Pion losses (decay, NI)	0.1%	
Other		0.3%
Radiative corrections	0.1%	1%
Total	**0.35%**	**2.5%**

CMD-3 Experimental Event Samples



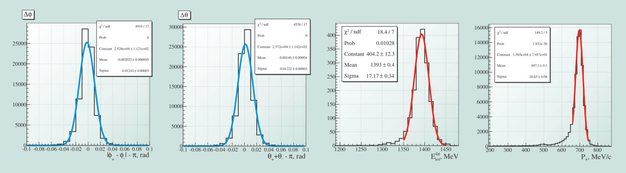


NN̄ and PP̄ Production Near Threshold



SND Detector Event Samples

CMD-3 Detector Resolution Obtained



VEPP-2000 Physical Program Overview

- Fundamental constants of particle physics and the quantity $R = \frac{\sigma(e^+e^- \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)}$;
- Exclusive channels of e^+e^- annihilation to hadrons: $e^+e^- \to 2h, 3h, 4h$, with $h = \pi, K, \eta$;
- Study of known and search for new vector mesons:

Quark content → / ↓ State ↓	$\sim u\bar{u} - d\bar{d}$	$\sim u\bar{u} + d\bar{d}$	$\sim s\bar{s}$
1^3S_1	$\rho(770)$	$\omega(782)$	$\phi(1020)$
2^3S_1	$\rho(1450)$	$\omega(1420)$	$\phi(1680)$
1^3D_1	$\rho(1700)$	$\omega(1650)$	–
3^3S_1	$\rho(2150)$	–	–

Evidence for 1^{--} mesons with mass below 2 GeV/c^2 in different channels of e^+e^- annihilation:

↓ Channel ↓	$\rho(1250)$	$\rho(1450)$	$\rho(1700)$	$\omega(1420)$	$\omega(1650)$	$\phi(1680)$
$\pi^+\pi^-$	+?	+?	++			
$\pi^+\pi^-\pi^0$				+?	+?	+?
$\omega\pi^0$		+?	++			
$\eta\pi^+\pi^-$		++				
$\omega\pi^+\pi^-$				+?	++	+?
4π		++	++			
K^+K^-			+?		+?	+?
K_SK_L			+?			++
K^*K			+?			++
$K^+K^-\pi^0$						+?

- Search for exotic hadrons:

state	description	candidates
gg	C^+ glueballs,	$f_0(1500)$
ggg	C^- glueballs	no
$q\bar{q}g$	hybrides	$\pi_1(1370)$, $\pi_1(1600)$
$q\bar{q}q\bar{q}$	4-quark meson	$f_0(980)$, $a_0(980)$
$q\bar{q}q\bar{q}q\bar{q}$	6-quark or $N\bar{N}$ states	$X(1870)$

- Study of $e^+e^- \to p\bar{p}, n\bar{n}$:
  1. nucleon formfactors
  2. $N\bar{N}$ resonances
  3. $p\bar{p}$ atom
  4. n absorbtion cross section
  5. collider energy calibration
  6. CPT tests: $m_p - m_{\bar{p}}$, $m_n - m_{\bar{n}}$
- CVC tests: comparison of $e^+e^- \to hadrons$ cross section with $\tau \to \nu_\tau + hadrons$ decay spectra;
- Hadronic processes with hard photon emission $e^+e^- \to \gamma^*\gamma$, $\gamma^* \to hadrons$;
- Two photon physics $e^+e^- \to e^+e^- + hadrons$: $\gamma\gamma \to \pi^0, \eta, \eta', a_0(980), f_0(980), 2\pi, 3\pi, n\pi, 2K, \eta\pi$, etc.
- Tests of high order QED:
  1. $e^+e^- \to 5\gamma$
  2. $e^+e^- \to e^+e^-\gamma\gamma$
  3. $e^+e^- \to \mu^+\mu^-\gamma\gamma$
  4. $e^+e^- \to e^+e^-e^+e^-$
  5. $e^+e^- \to e^+e^-\mu^+\mu^-$

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