Recent results from CMD-3 detector at VEPP-2000 collider

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Outline

- ❑ Motivation
- ❑ Collider & Detector
- ❑ Preliminary Results
- ❑ Conclusion

Motivation

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

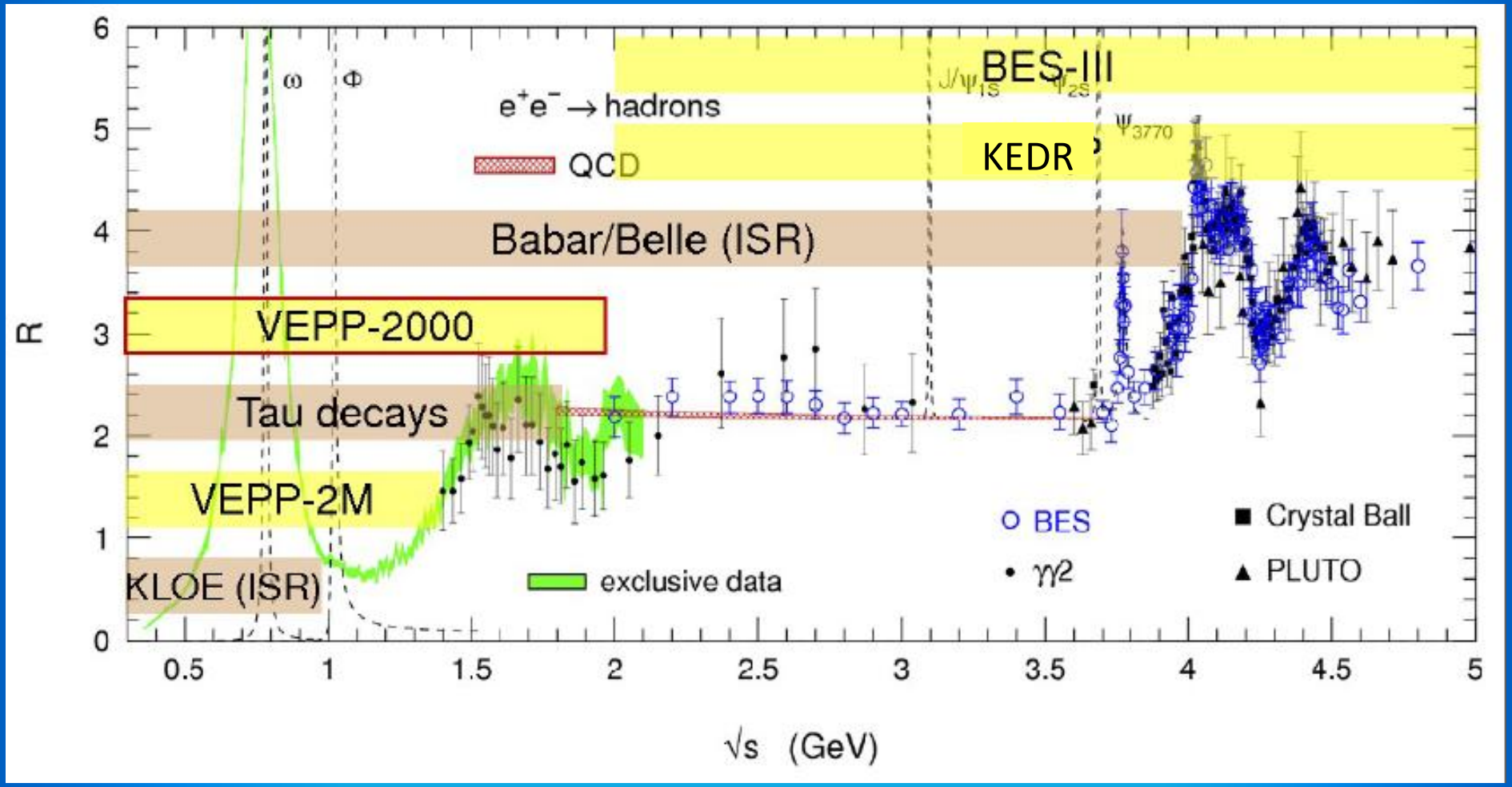
- determination of R(s) :

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

  - $\alpha_{QED}(M^2_Z)$ used for precise predictions in EW physics
  - the interpretation of precision measurements of muon (g-2)

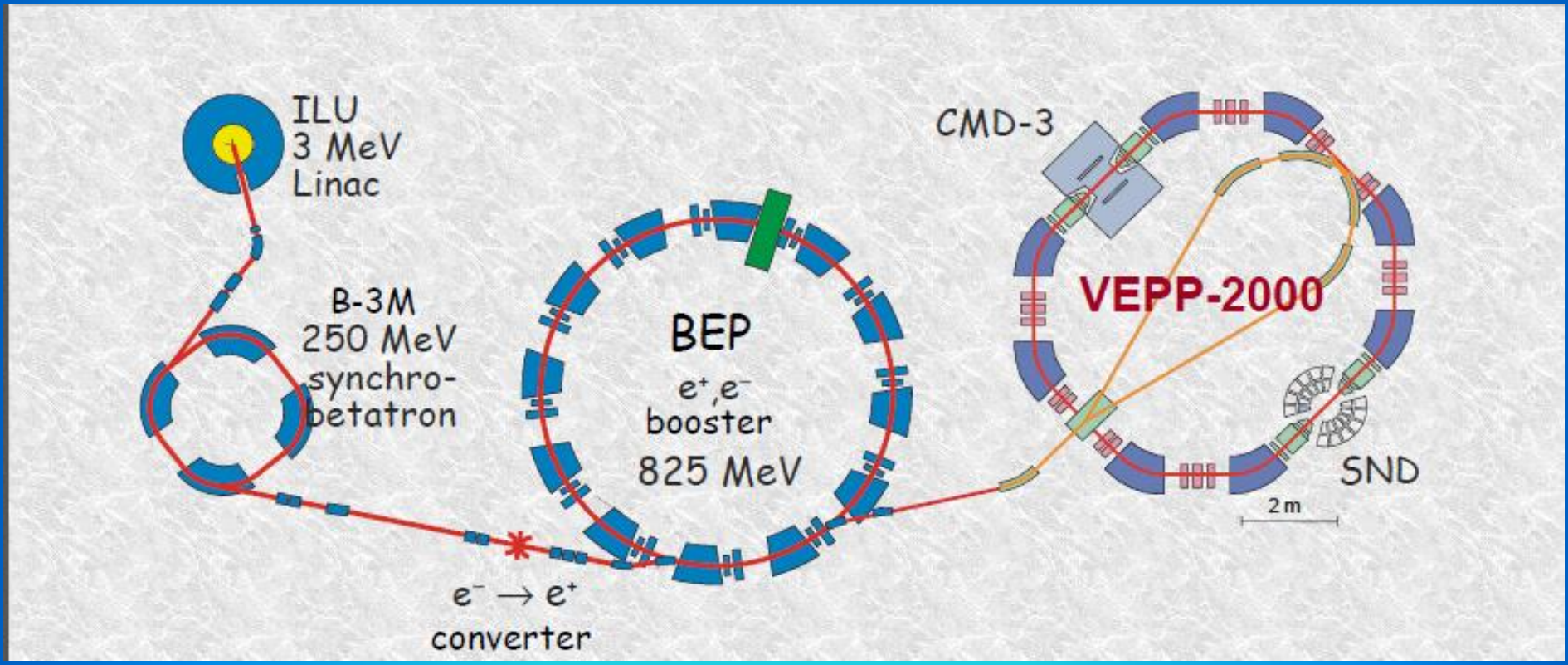
- measurement of parameters of light vector mesons $\rho(770)$, $\omega(782)$,$\phi(1020)$ and their excitations $\omega(1420)$, $\rho(1450)$, $\omega(1650)$, $\phi(1680)$, $\rho(1700)$, $\rho(1900)$
- test of QCD sum rules, ... etc, search of exotics (light hybrids and glueballs)
- CVC test in comparison with spectral functions of tau decays

R(s) measurement at low energies



The value and the error of the hadronic contribution to muon (g-2) are dominated by low energy R(s) (<2GeV gives 93%).

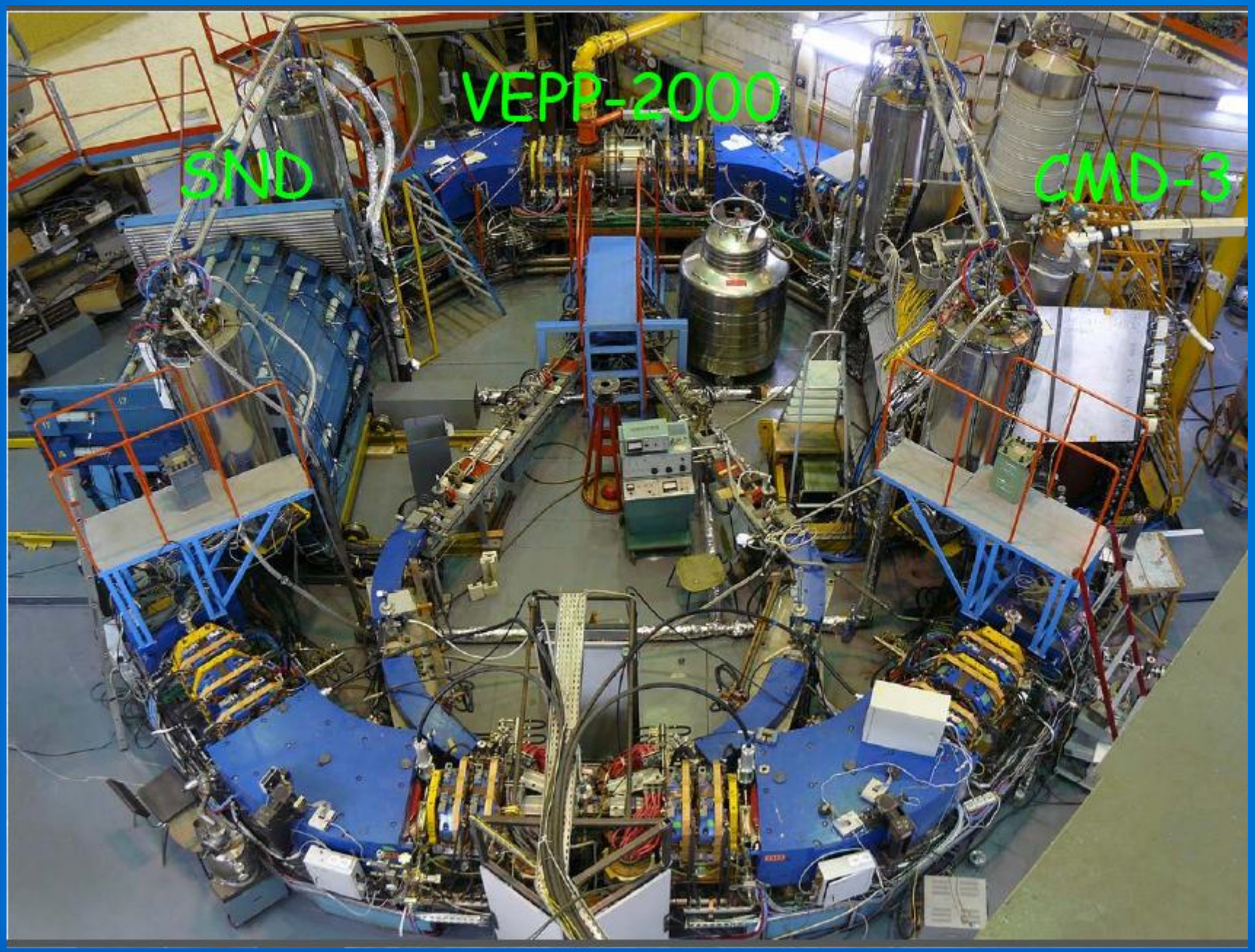
VEPP-2000 e^+e^- collider



- Up to 2 GeV c.m. energy
- VEPP-2000 uses unique "round beams" optics, which gives additional gain in luminosity
  $L = 10^{32}$ cm^{-2}s^{-1} @ 2 GeV

Status of VEPP-2000:
2001 – Start of construction
2010 – First physics run
2011 – 2013 – 60 pb^{-1} per detector
2013 – 2014 – Upgrade of injection facility and booster
Plans:
100 pb^{-1} per detector per year

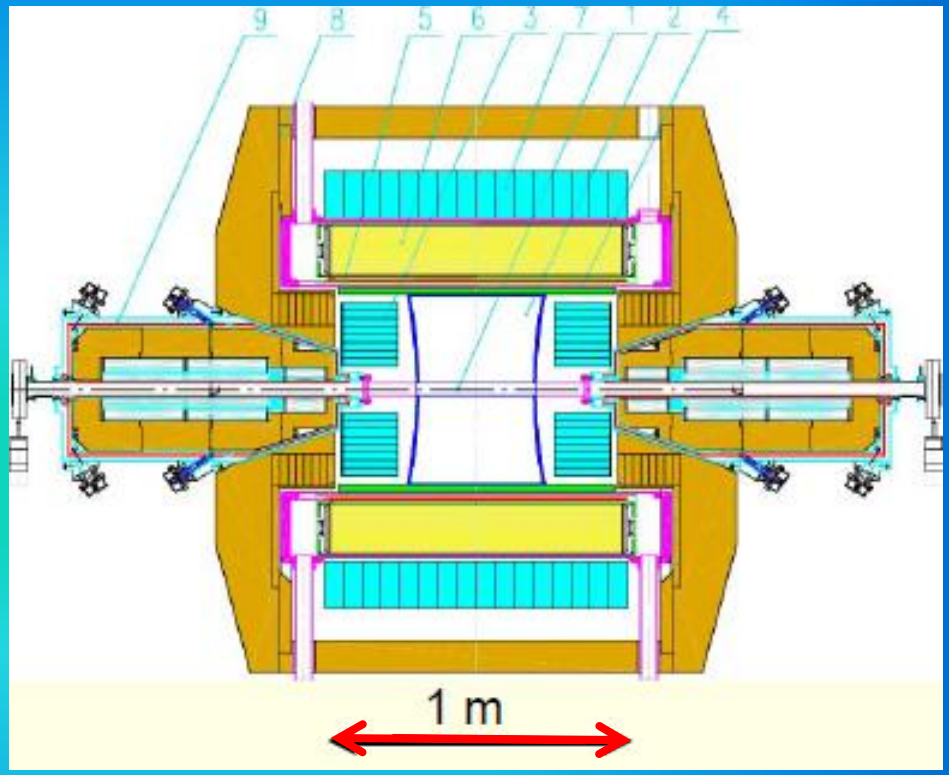
VEPP-2000 storage ring (2013)



CMD-3 detector

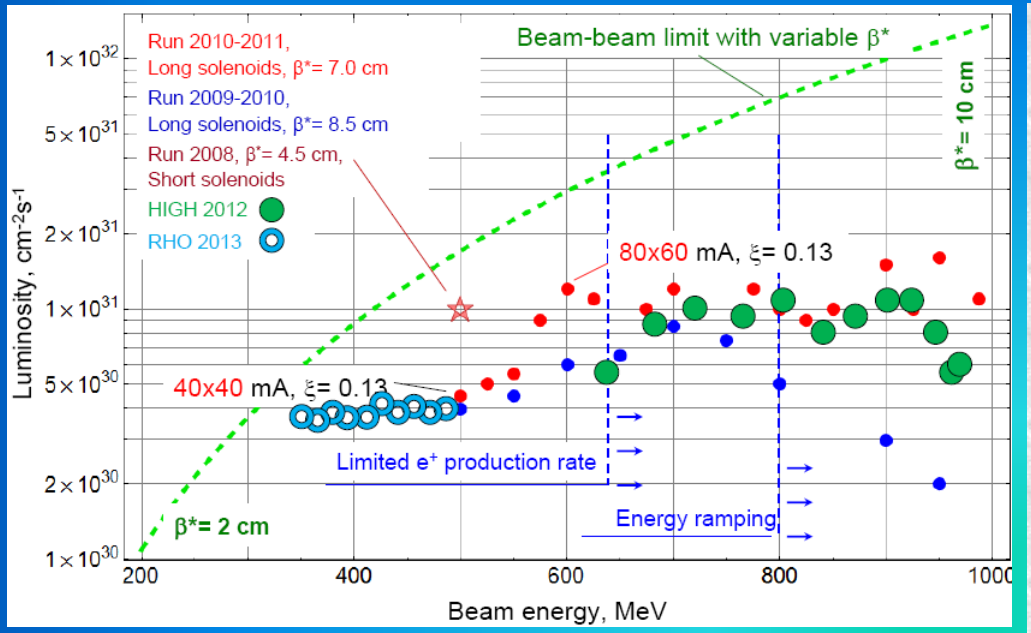
CMD-3 parameters:

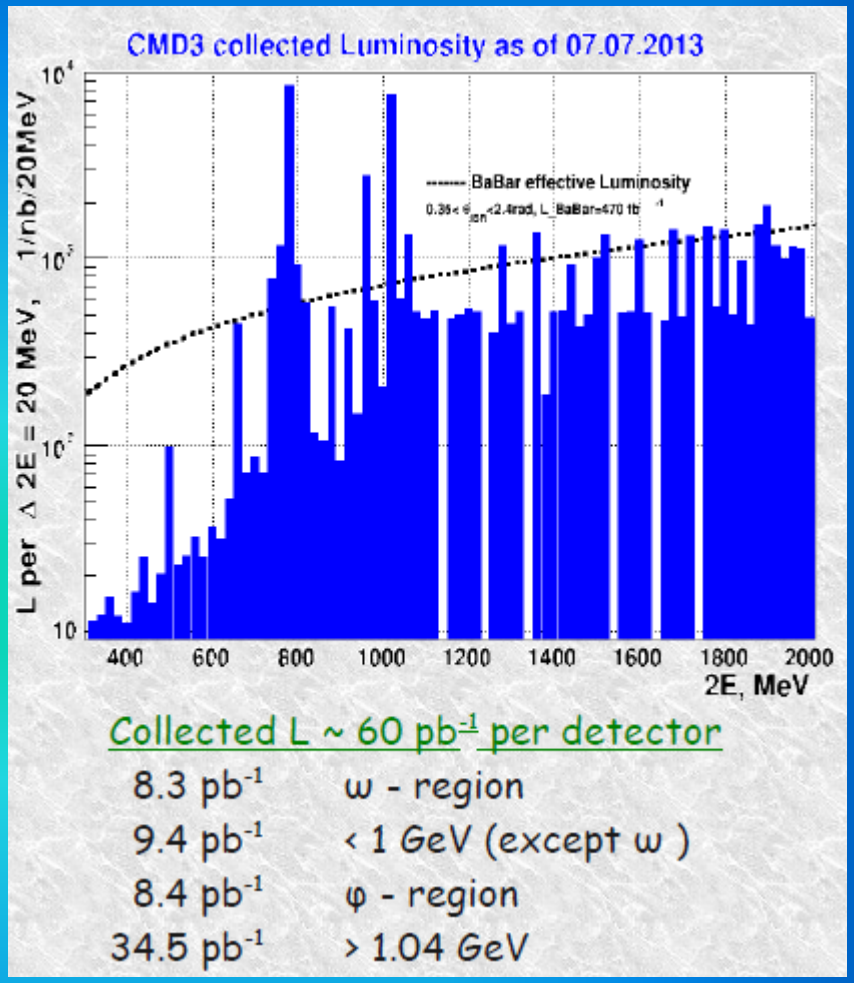
- DC:
  - 1218 hexagonal cells
  - 80% Ar + 20% iC_4H_{10}
  - σ_x=100μm, σ_z=2mm, σ_p/p = 3.3% @ p =1 GeV/c
- SC solenoid:
  - $0.38X_0$
  - B = 1.3T
- Barrel calorimeter (LXe+CsI):
  - $13.5X_0$
  - σ_E/E = 4% @ E_γ=1GeV
  - CsI calorimeter
  - 1152 crystals
  - LXe calorimeter
  - 400 Liters, 1.2 tons
- Endcap calorimeter (BGO):
  - $13.6X_0$
  - 680 crystals
  - σ_E/E = 4% @ E_γ=1GeV
- TOF system (after upgrade):
  - 168 counters
  - σ_τ = 0.7 ns



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.

Collected Luminosity





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)

Collected L ~ 60 pb^{-1} per detector

8.3 pb^{-1}	ω - region
9.4 pb^{-1}	< 1 GeV (except ω)
8.4 pb^{-1}	φ - region
34.5 pb^{-1}	> 1.04 GeV

In 2013 we reached 2 × 160 MeV, the smallest energy ever measured at ee colliders

$e^+e^- \to \pi^+\pi^-$ by CMD-3

Very challenging channel should be measured with the best systematic precision (a few per mil)

— Clean topology of collinear events (mostly without physical background)

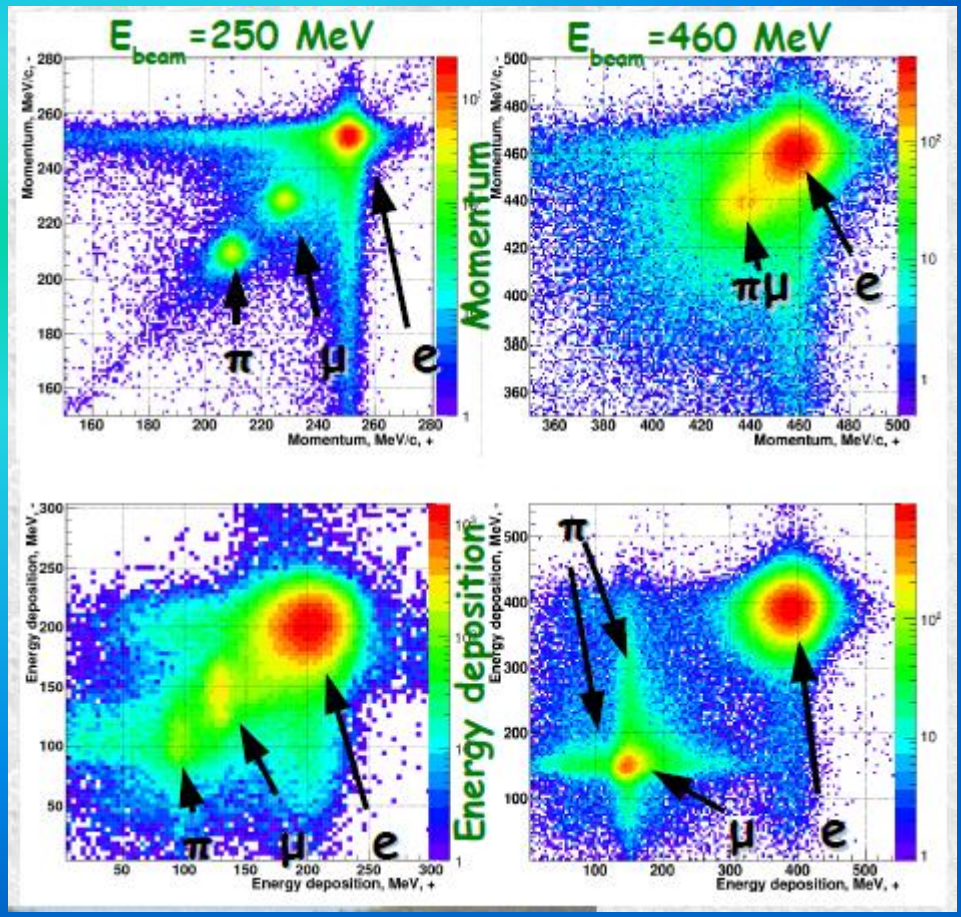
— Overall corrections at the level of a few percent

— Particle separation can be performed using momentum or energy deposition

Goal: To reduce syst. error 0.6-0.8% → 0.35%:

- ❑ Event separation can be checked by different methods (0.2%)
- ❑ Test of radiative corrections 0.3% → 0.1%
- ❑ Fiducial volume controlled independently by LXe and ZC subsystems (0.1%)
- ❑ Beam energy measured by the method of Compton backscattering of laser photons (σ_E < 50 keV) (0.1%)

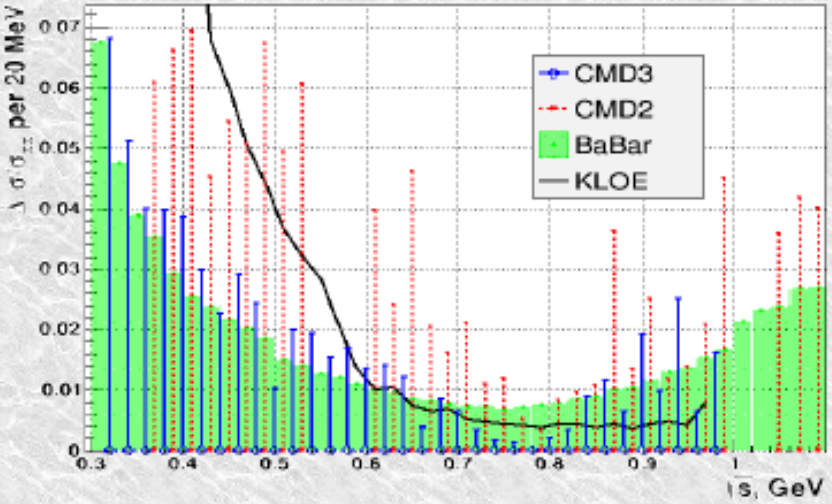
Many systematics studies rely on high statistics

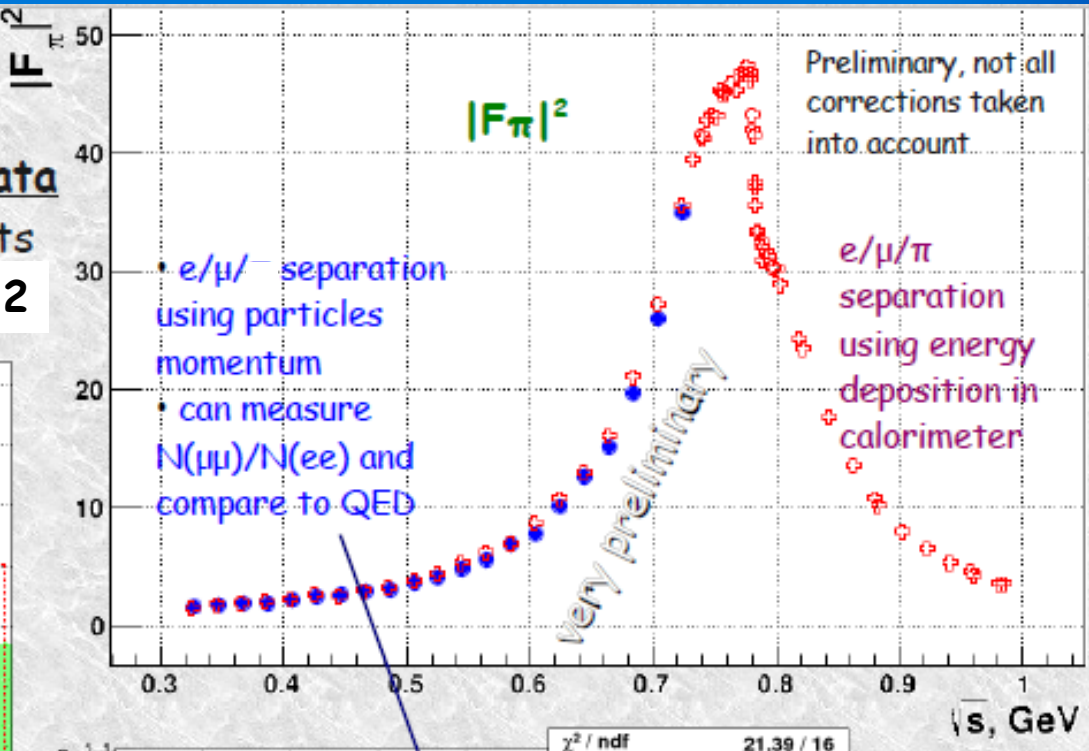


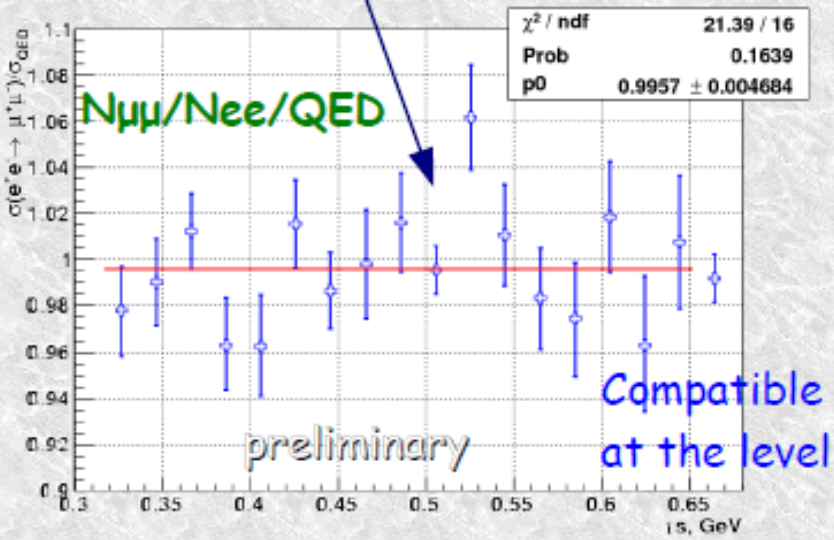
$e^+e^- \to \pi^+\pi^-$ by CMD-3

Statistical precision of cross section measurement for **2013 data** is at the same level as other experiments

and a few times better than at CMD-2





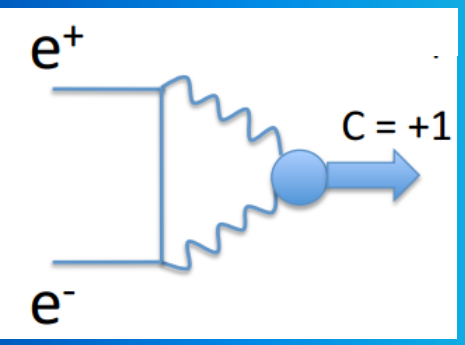


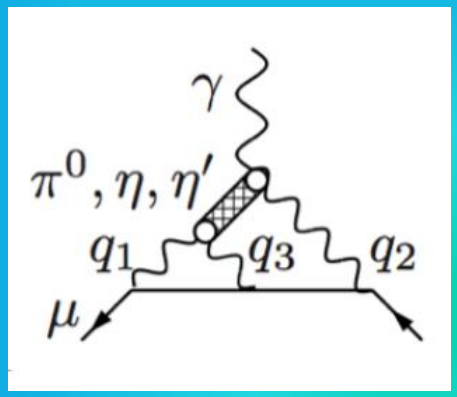
Compatible with QED at the level of 0.5 %

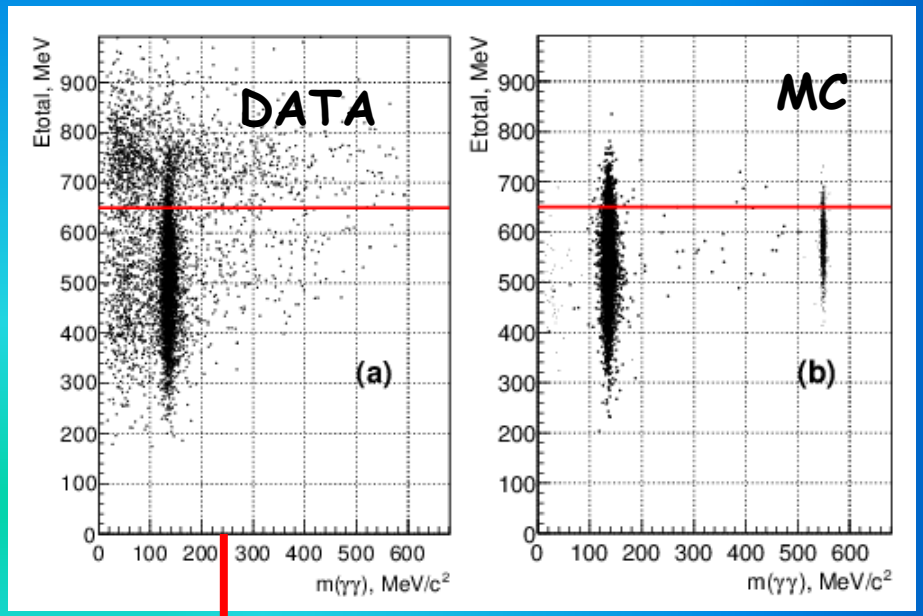
$e^+e^- \to \eta'(958)$ with CMD-3

ArXiv:1409.1664 [hep-ex]

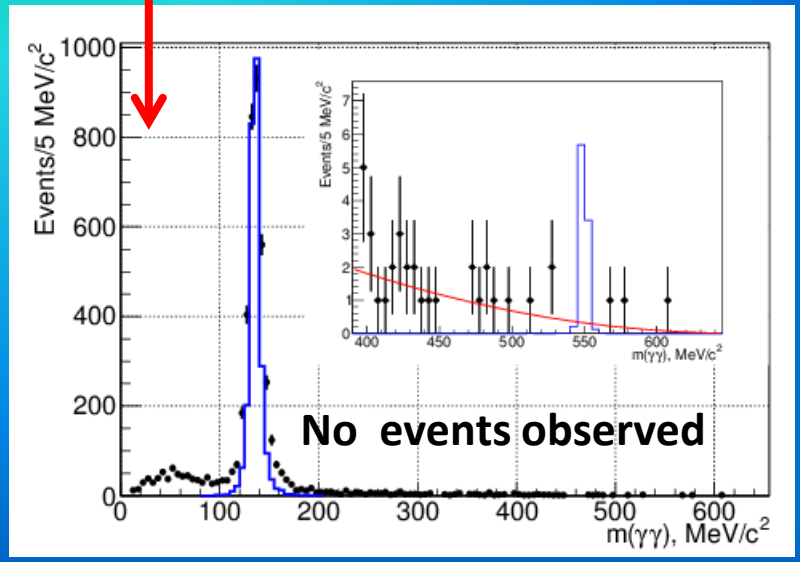
Dedicated physics run
@ $E_{cm} = M_{\eta'}$
Integrated Luminosity is 2.69 pb^{-1}
Decay $\eta' \to \eta\pi^+\pi^- \to \pi^+\pi^-\gamma\gamma$ was used







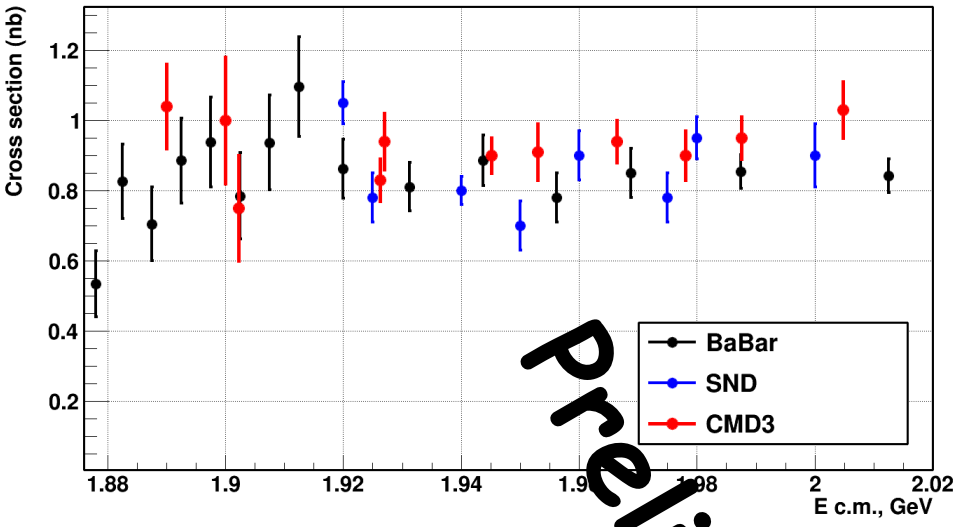
$$Br(\eta' \to e^+e^-) = Br(\eta' \to \gamma\gamma)\frac{\alpha^2}{2\beta}\left(\frac{m_e}{m_{\eta'}}\right)^2\left[\ln\left(\frac{1+\beta}{1-\beta}\right)\right]^2$$

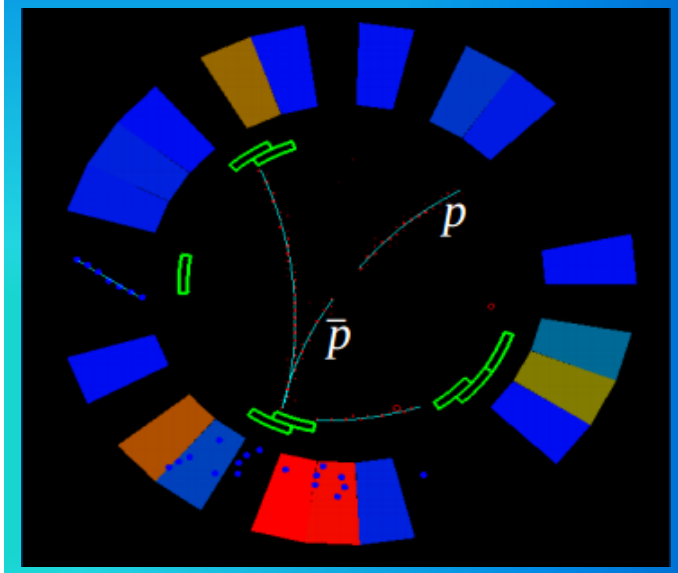


$B(\eta' \to e^+e^-) < 1.2\ 10^{-8}$ (90%CL) - CMD-3
$B(\eta' \to e^+e^-) < 2.1\ 10^{-7}$ (90%CL) - ND
$B(\eta' \to e^+e^-) = 3.7\ 10^{-11}$ - Theory

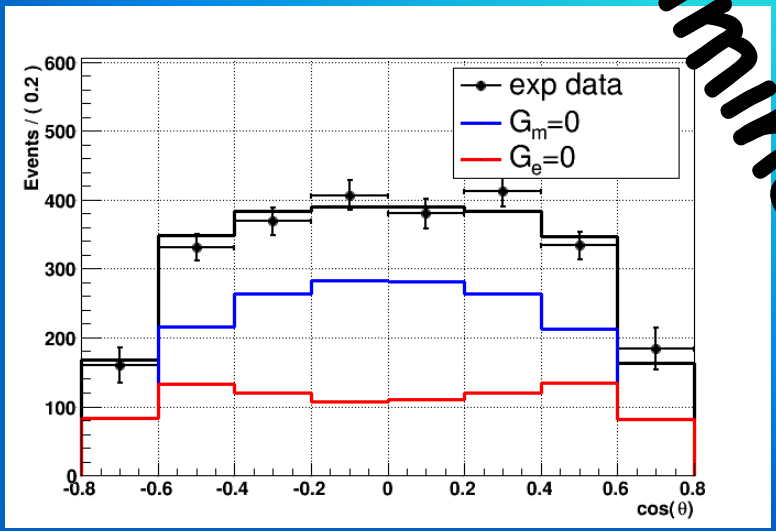
$e^+e^- \to p\bar{p}$ with CMD-3

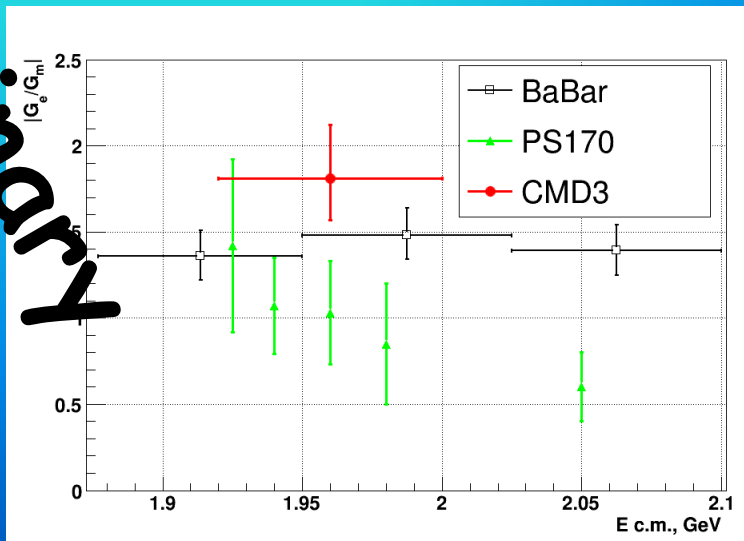
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta C}{4Q^2}\left[|G_M^p(Q^2)|^2(1+\cos^2\theta) + \frac{4M^2}{Q^2}|G_E^p(Q^2)|^2\sin^2\theta\right]$$





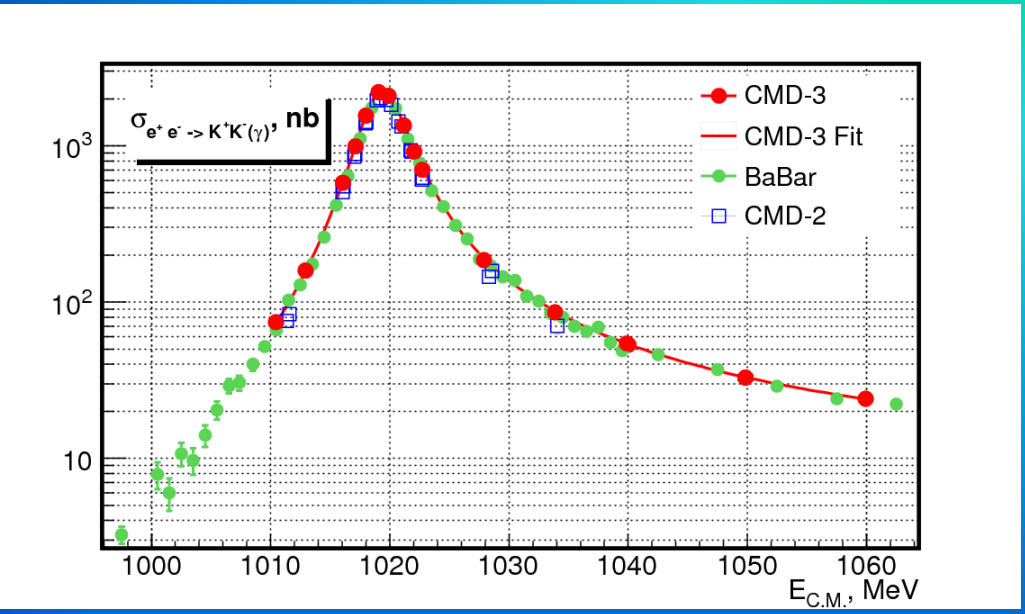
Preliminary





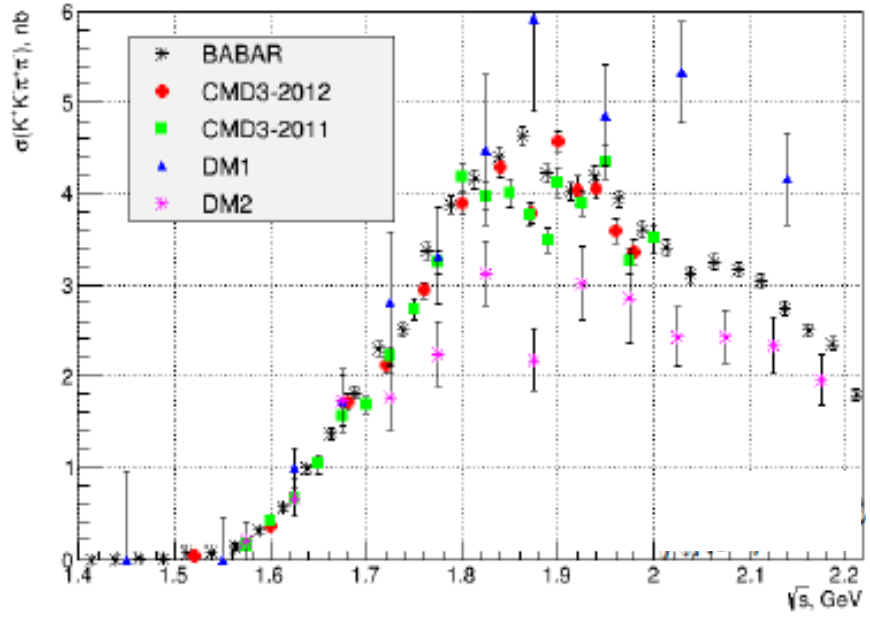
$e^+e^- \rightarrow K^+K^-$ with CMD-3

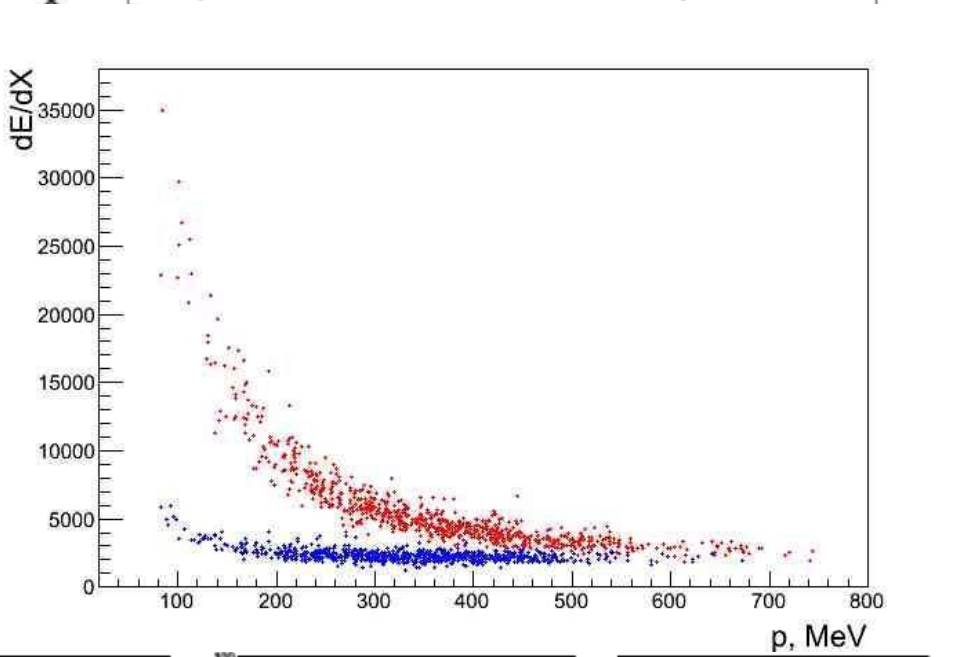
The study of K+K- production has been made also at energies of the φ-meson mass. The selection of events is made using information from the DC chamber where a pair of charged kaons is reconstructed. Kaons are selected by average energy losses dE/dx of tracks in DC and the average momentum of the pair of tracks.

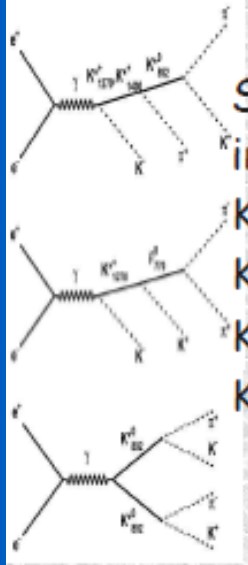


The measured cross section of the process e+e- → K^+K^- together with the results from CMD-2 and BaBar is shown near the ϕ-meson mass energy. The systematic error is of about 2.5%

$e^+e^- \to K^+K^-\pi^+\pi^-$ with CMD-3







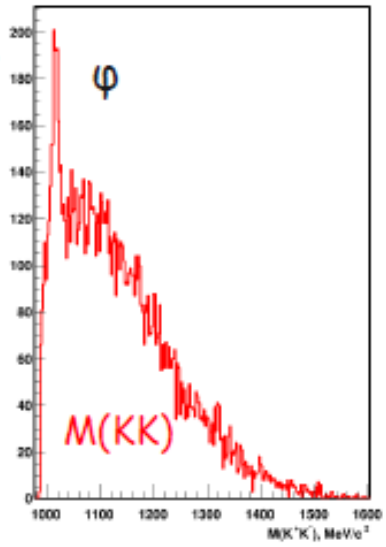
Seen rich dynamics, many intermediate states:

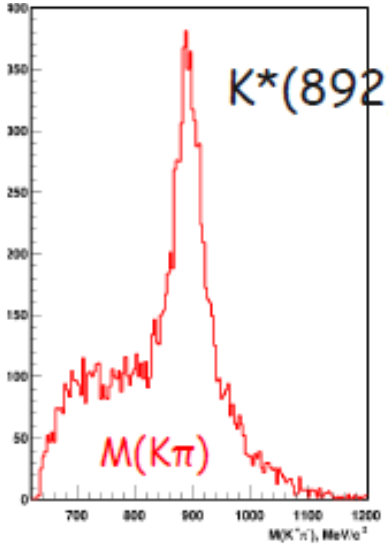
K*(1270)K->K*(892)Kπ

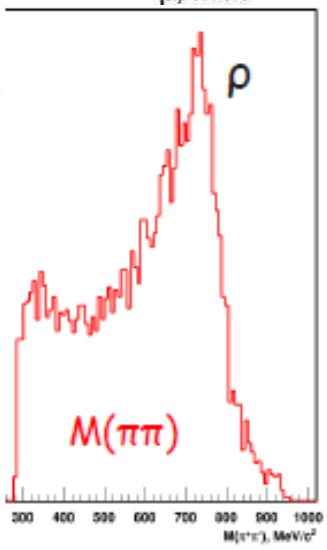
K*(1400)K->K*(892)Kπ

K*(1270)K->ρKK

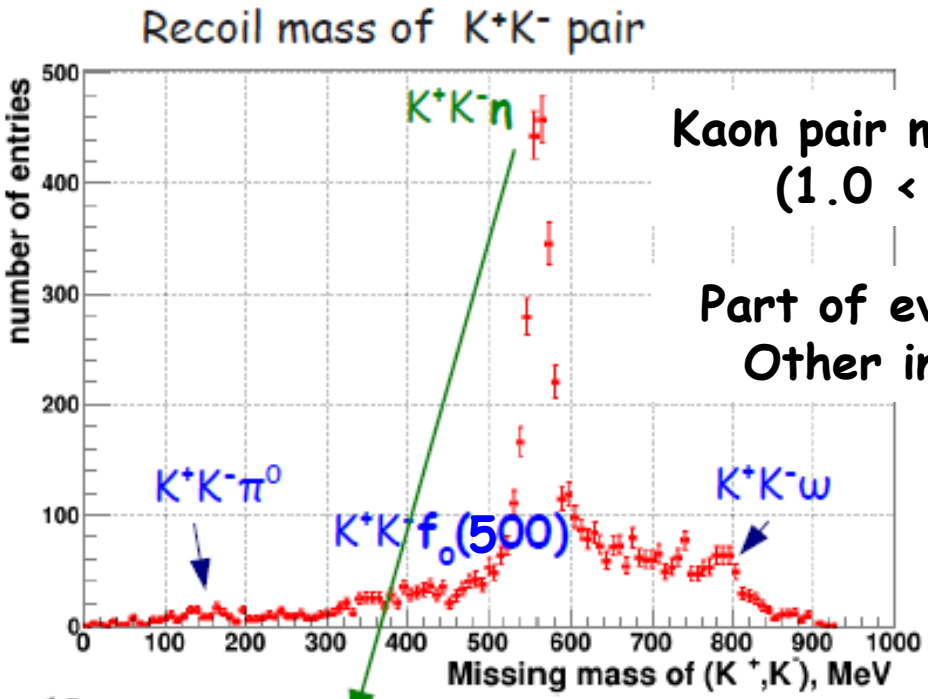
K*(892)K*(892), φππ

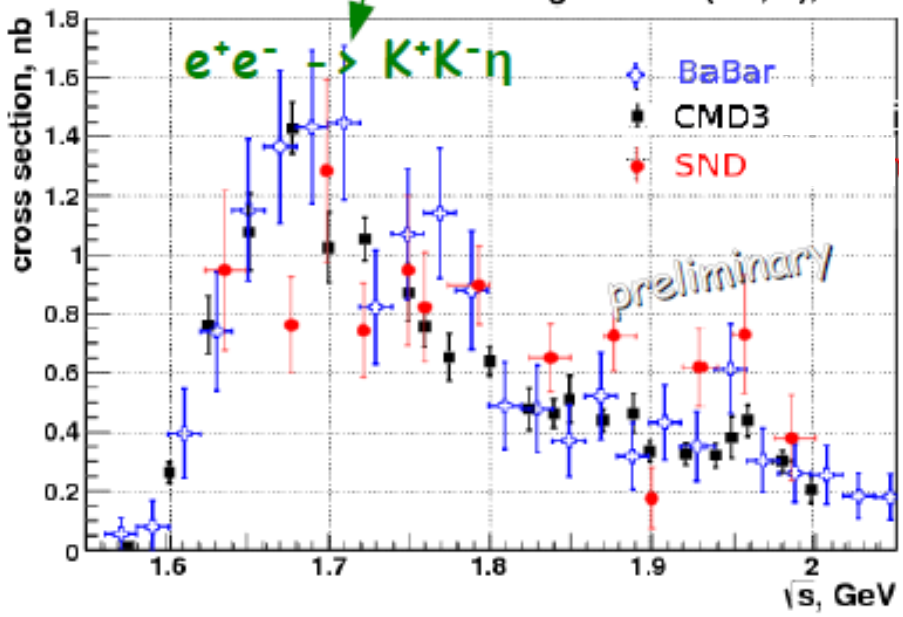






$e^+e^- \to K^+K^-\eta$ with CMD-3



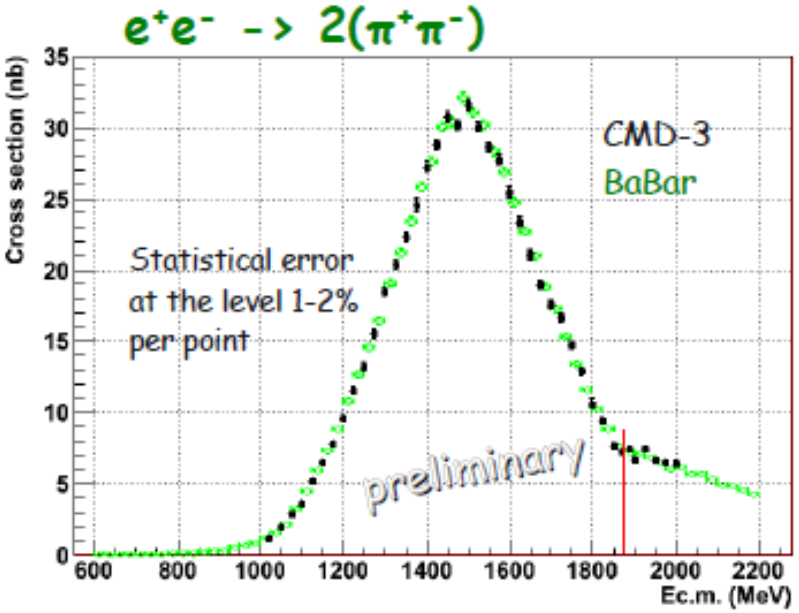


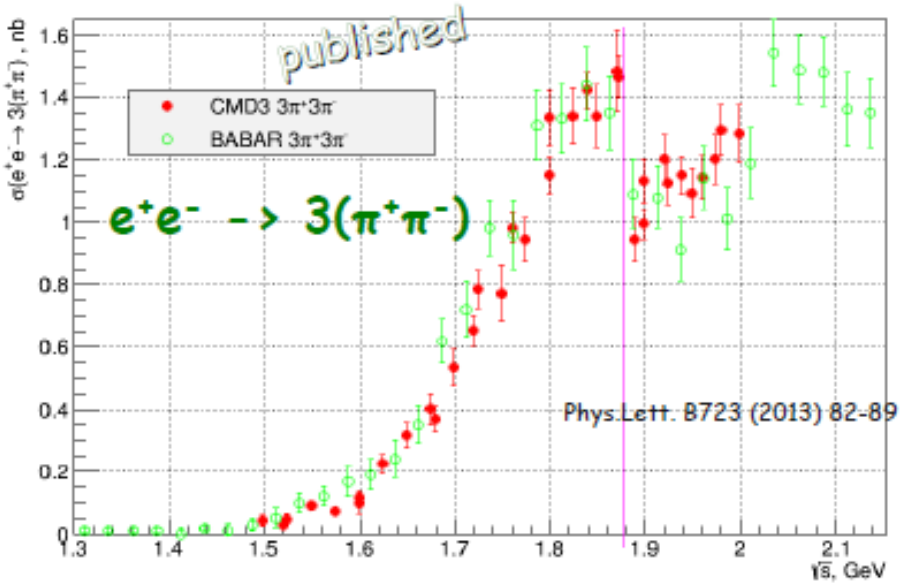
Kaon pair mass is in ϕ-meson window
($1.0 < m(K^+K^-) < 1.04$ GeV)

Part of events from $\phi f_0(500) \to K^+K^-\pi^+\pi^-$
Other intermediate states are seen

For $(g-2)_\mu$ and $a_{QED}(M^2_Z)$ all possible $KK\pi$, $KK\pi\pi$ ($K=K^+,K^0$) channels should be measured

$e^+e^- \to 4\pi, 6\pi$ with CMD-3

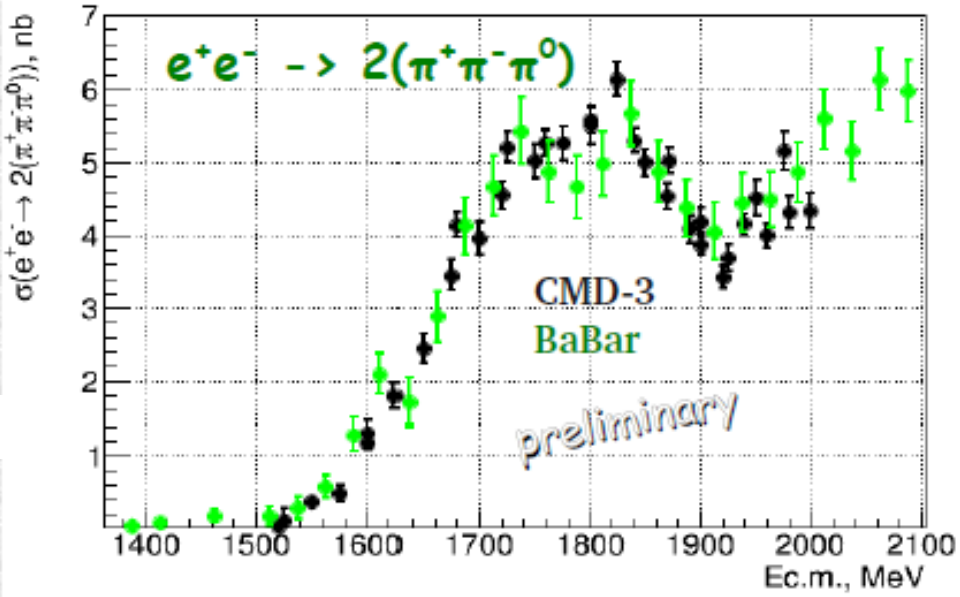




The **dominant** source of systematic error is model uncertainty
High statistic will allow much better dynamics study

$3(\pi^+\pi^-)$ are mainly produced through $\rho(770)$ + 4π (phase space or f_0)

Interesting feature: sharp dip at $p\bar{p}$ threshold
(dip in sum of 6π roughly as $p\bar{p}+n\bar{n}$ cross section)

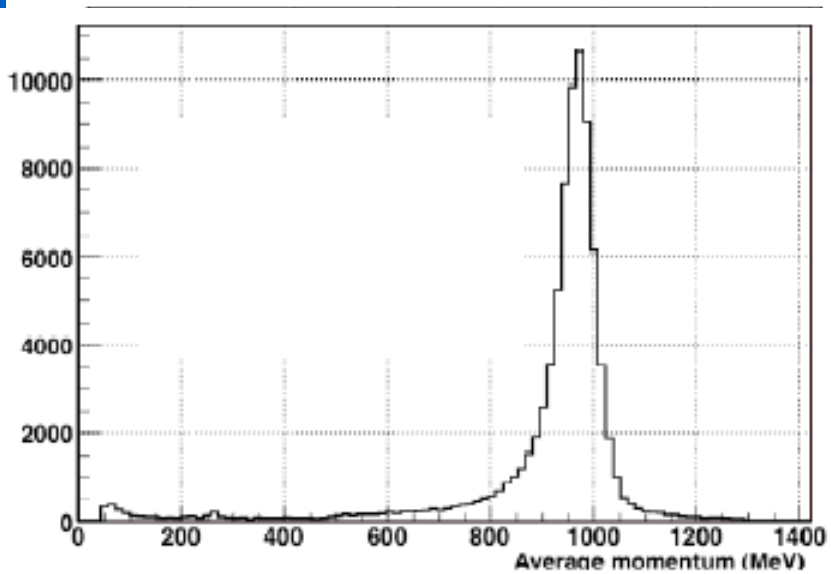


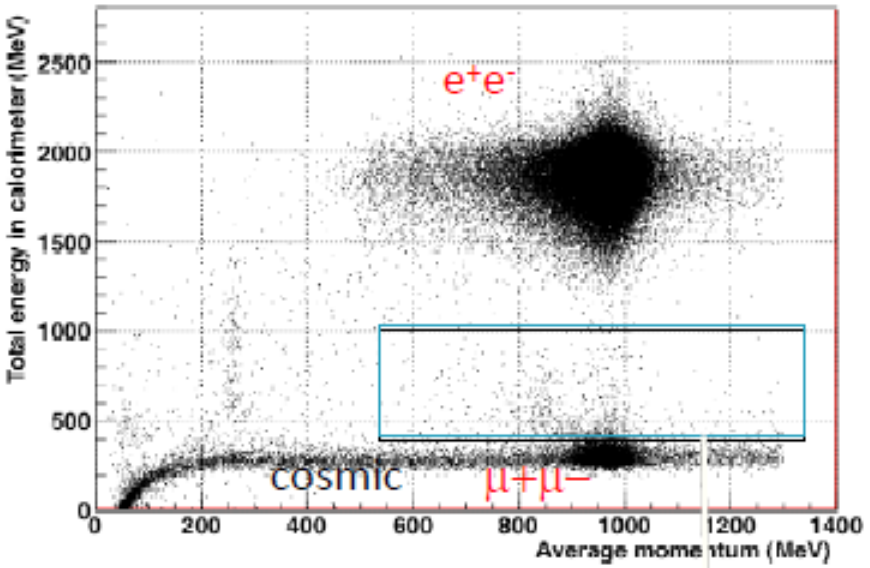
Conclusion

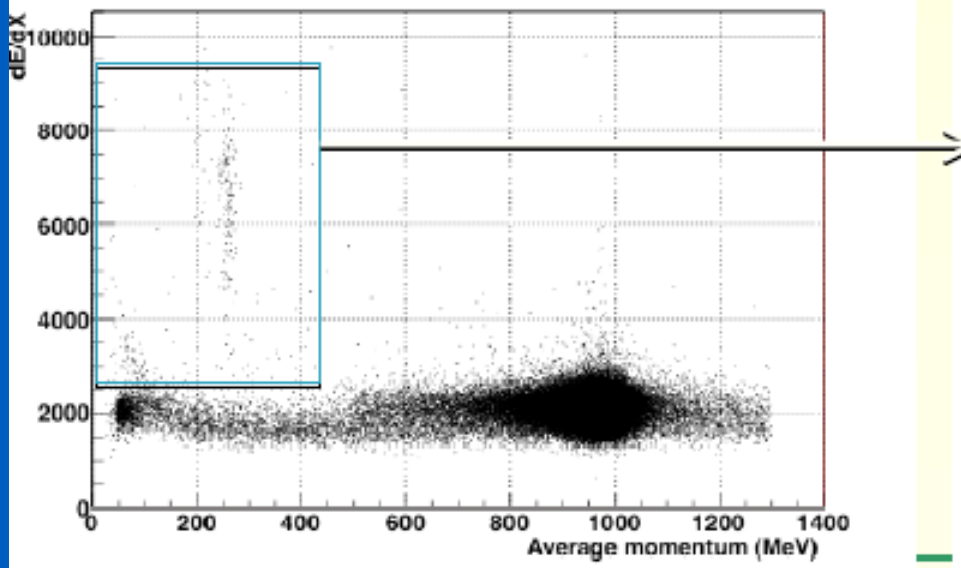
- VEPP-2000 collider successfully operates at $\sqrt{s} = 2m_{\pi} - 2$ GeV with $L_{max} = 2 \times 10^{31}$ cm^{-2}s^{-1} with a goal to get 1 fb^{-1} in 5 – 10 years, which should provide new precise results on the hadron production
- CMD-3 detector has good enough performance and monitoring of different detector subsystems
- Cross sections measured have the same or better statistical precision than ones from previous experiments
- VEPP-2000 upgrade is underway with new positron injection facility and upgraded booster, which will increase luminosity by factor of x10 at 2E = 2 GeV

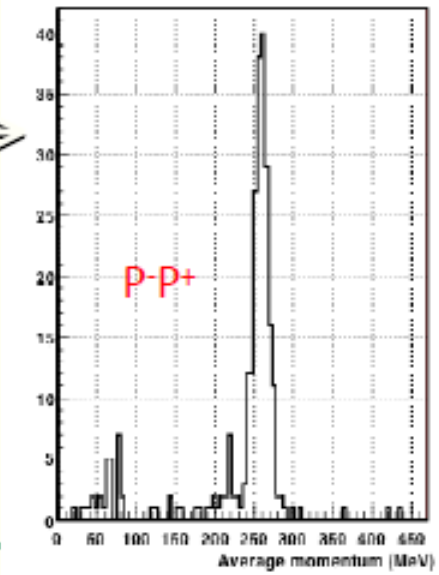
Backup Slides

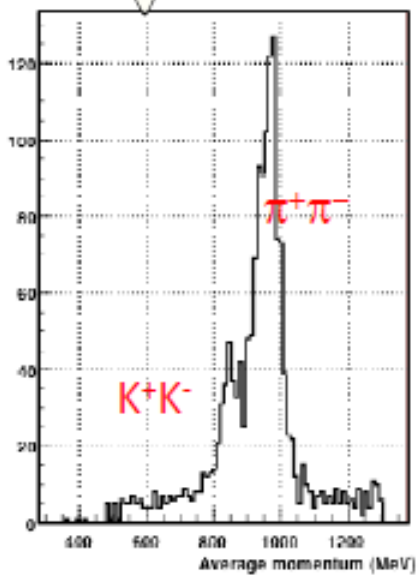
Collinear events @ CMD-3 ($E_{c.m.}$ = 1.95 GeV)



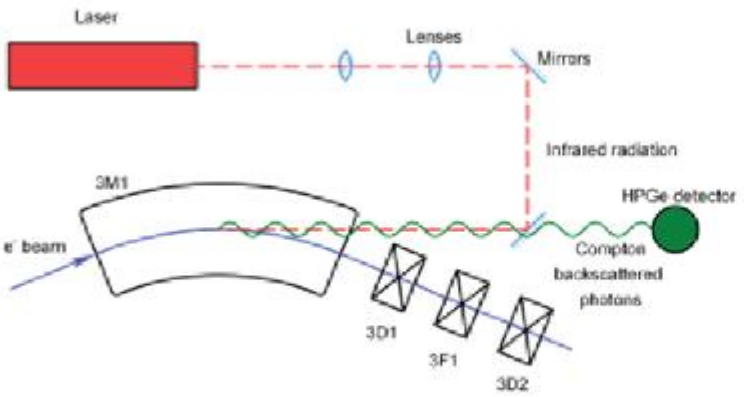




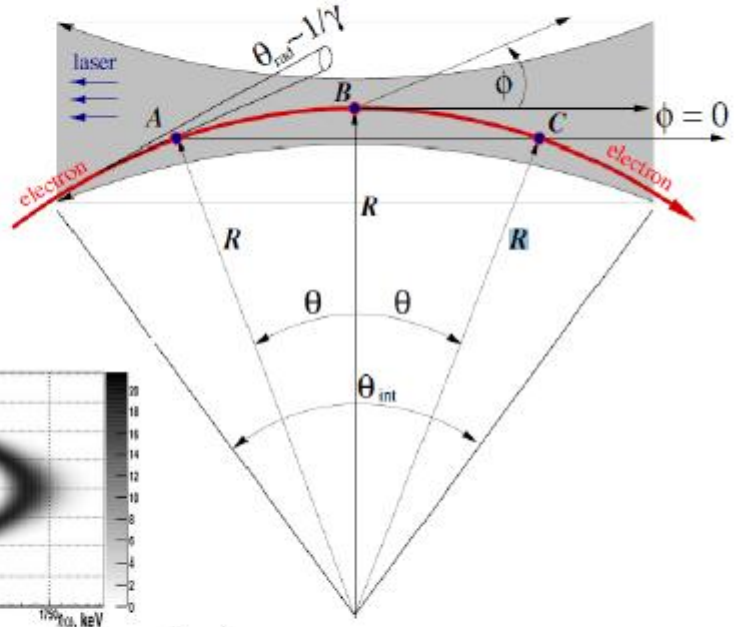


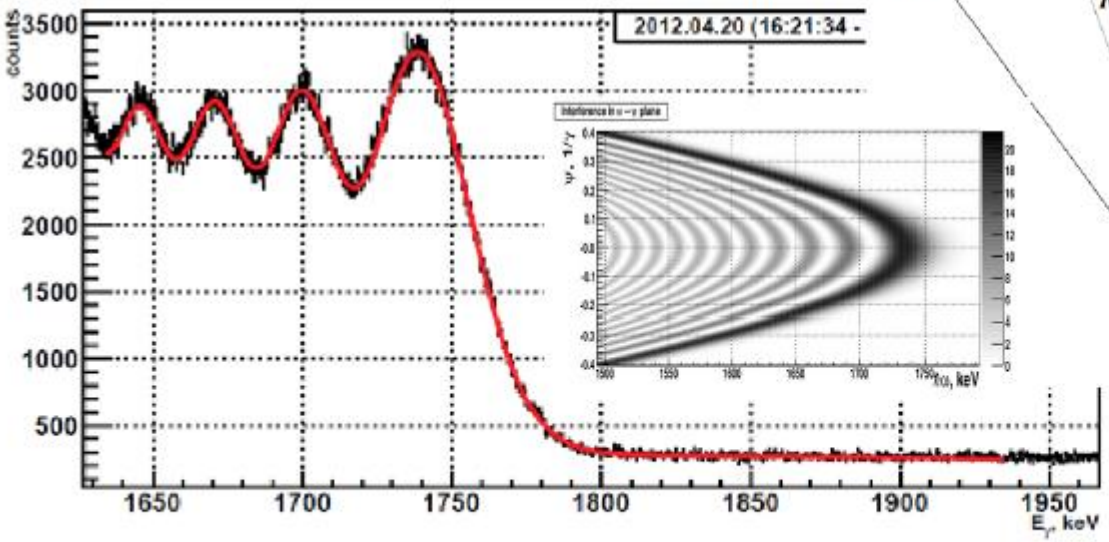


Compton backscattering energy measurement



Излучение из точек A и C под углом φ = 0 интерферирует

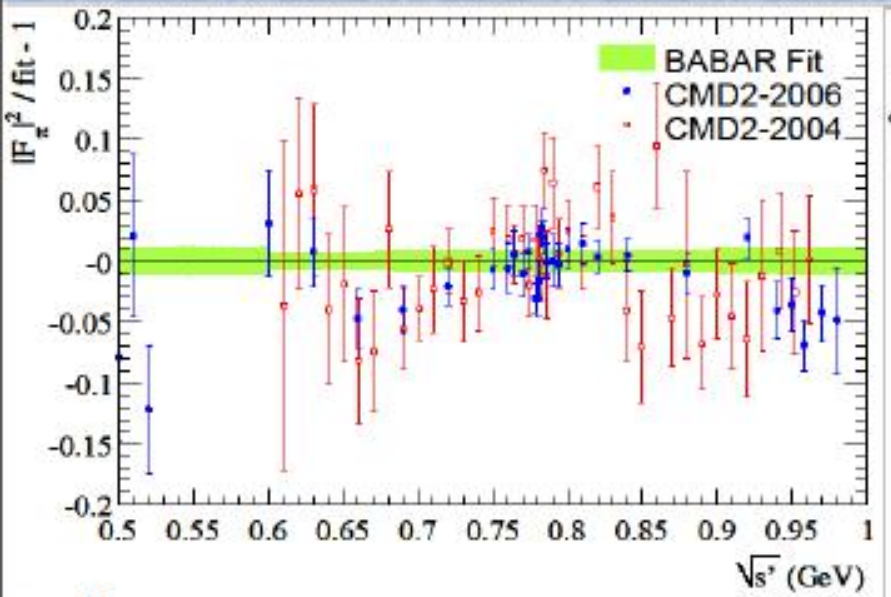


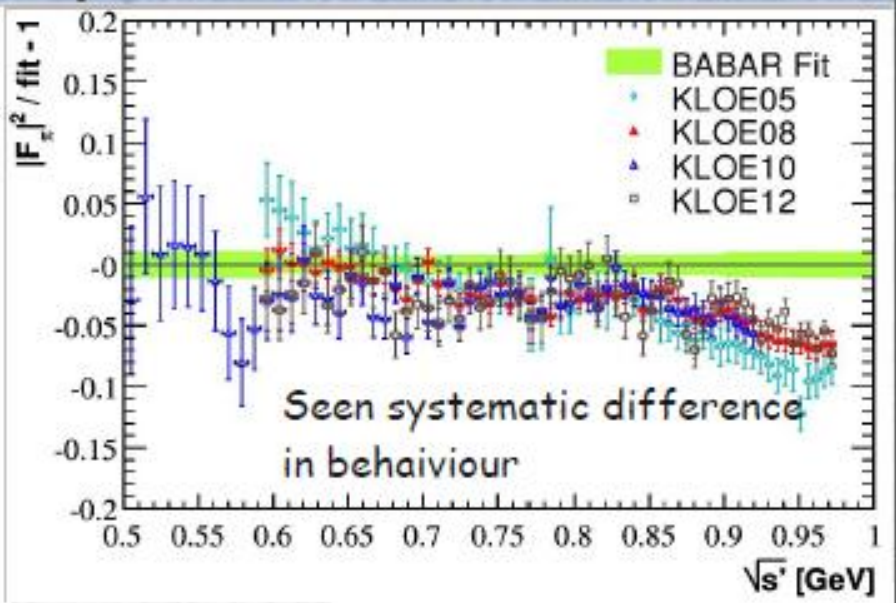


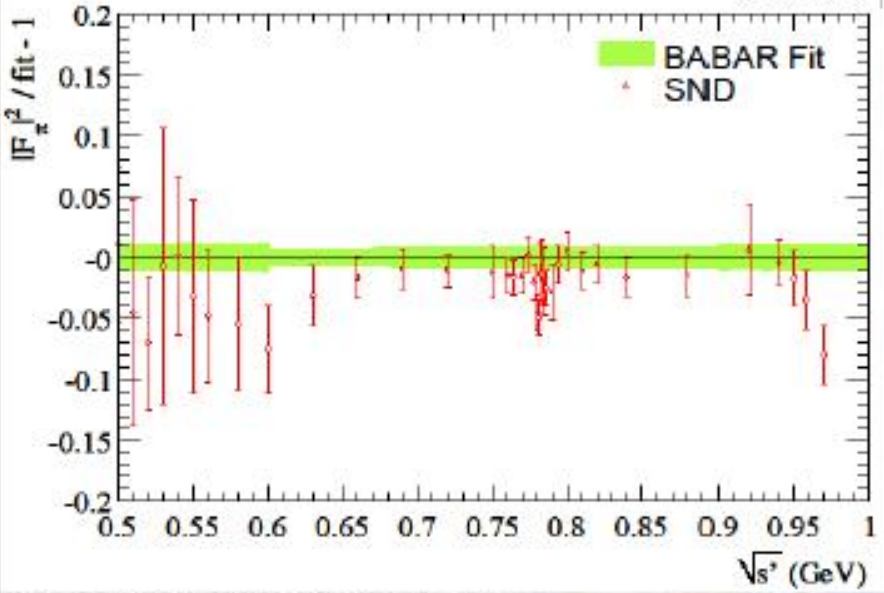
E = 993.662 ± 0.016 МэВ

M.N. Achasov et al. arXiv:1211.0103v1 [physics.acc-ph] 1 Nov 2012

e+e- -> π+π- published data

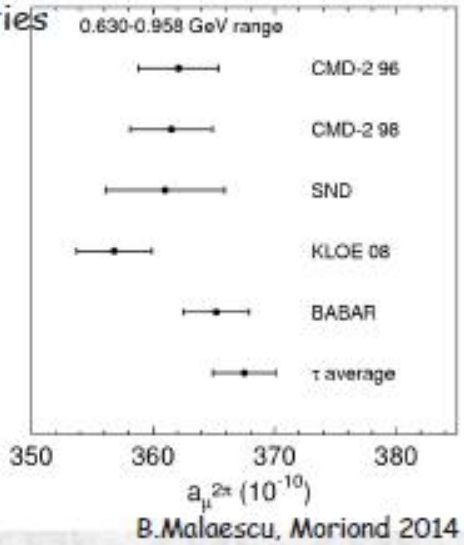






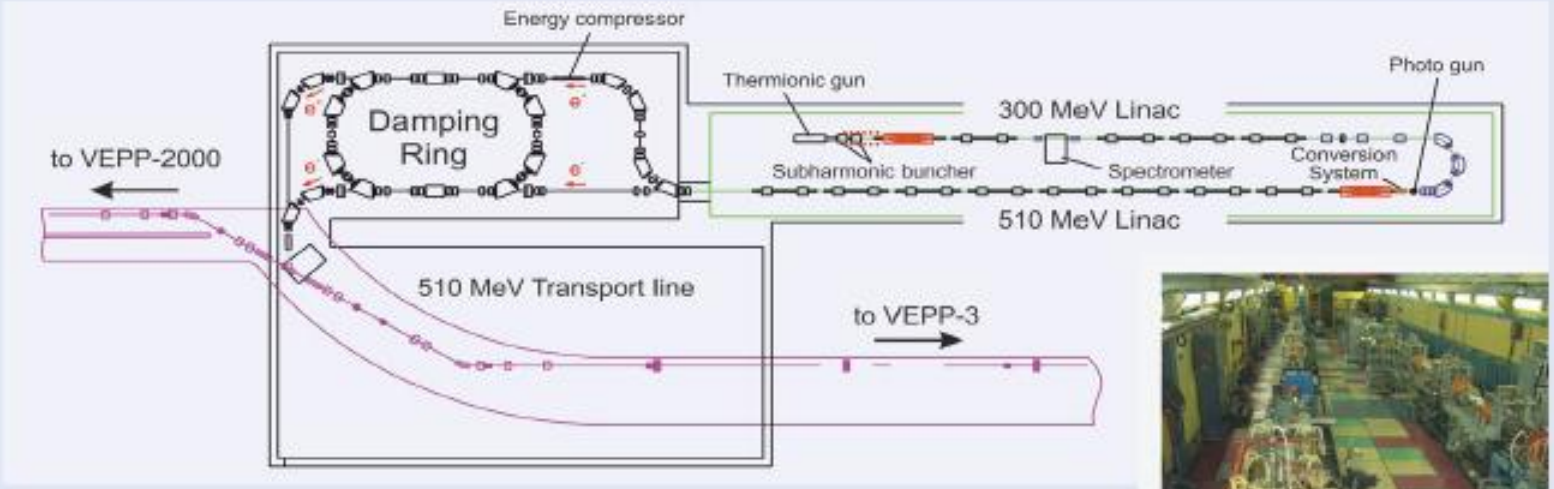
Systematic Uncertainties
(ρ-region)

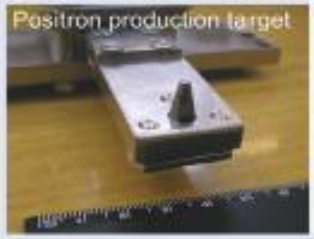
B A B AR :0.5%
CMD2: 0.6-0.8%
SND: 1.5%
KLOE: 0.8%



VEPP-5

VEPP-5 INJECTION COMPLEX





Parameters at E_{beam} = 510 MeV

Number of electrons per bunch	$2 \cdot 10^{10}$
Number of positrons per bunch	$2 \cdot 10^{10}$
Repetition rate	1 Hz
Electron bunch energy spread	0.07%
Positron bunch energy spread	0.07%
Vertical emittance	$5 \cdot 10^{-9}$ m·rad
Horizontal emittance	$23 \cdot 10^{-9}$ m·rad