

High-Precision Measurements of $\sigma(e^+e^- \rightarrow \text{hadrons})$ at VEPP-2000

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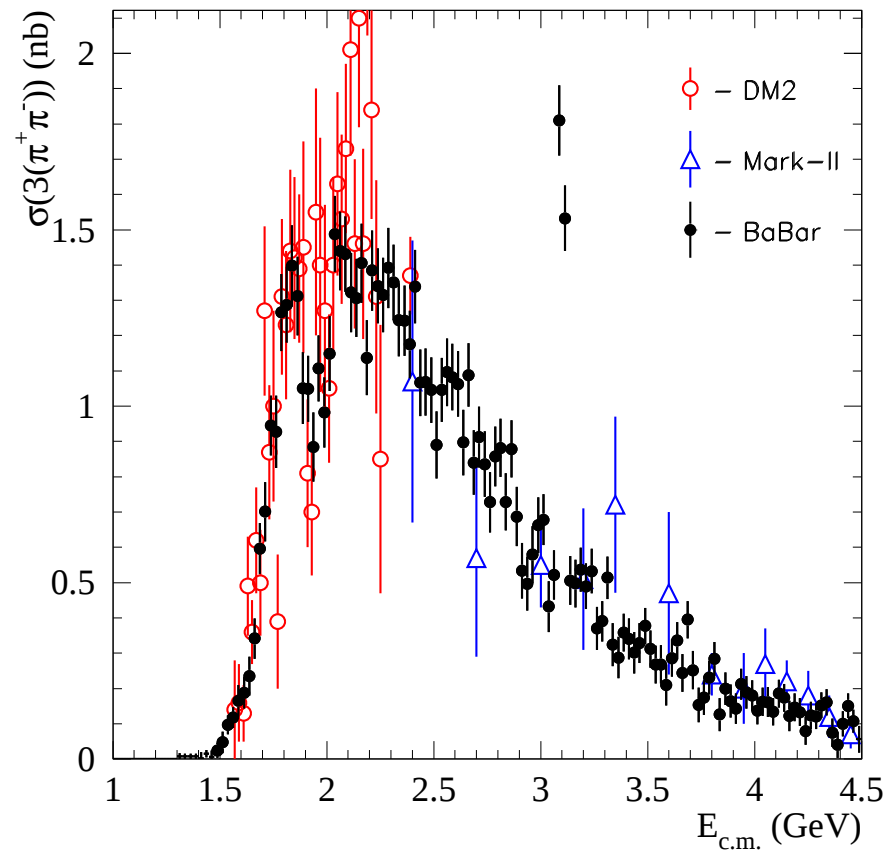
Outline

1. VEPP-2000
2. Super-tau-charm factory
3. Conclusions

Physics at VEPP-2000 – I

- VEPP-2000 – e^+e^- collider in Novosibirsk, $\sqrt{s}$ from threshold to 2 GeV
- Total and exclusive cross sections of $e^+e^- \rightarrow$ hadrons:
 1. Interactions of light quarks
 2. Spectroscopy of light vector mesons – ρ' , ω' , ϕ'
 3. Study of mesons with other J^{PC}
 4. F/f measurement in various two-body channels
 5. $p\bar{p}$, $n\bar{n}$ production near threshold
 6. Search for various exotics

$$e^+e^- \rightarrow 3\pi^+3\pi^-$$



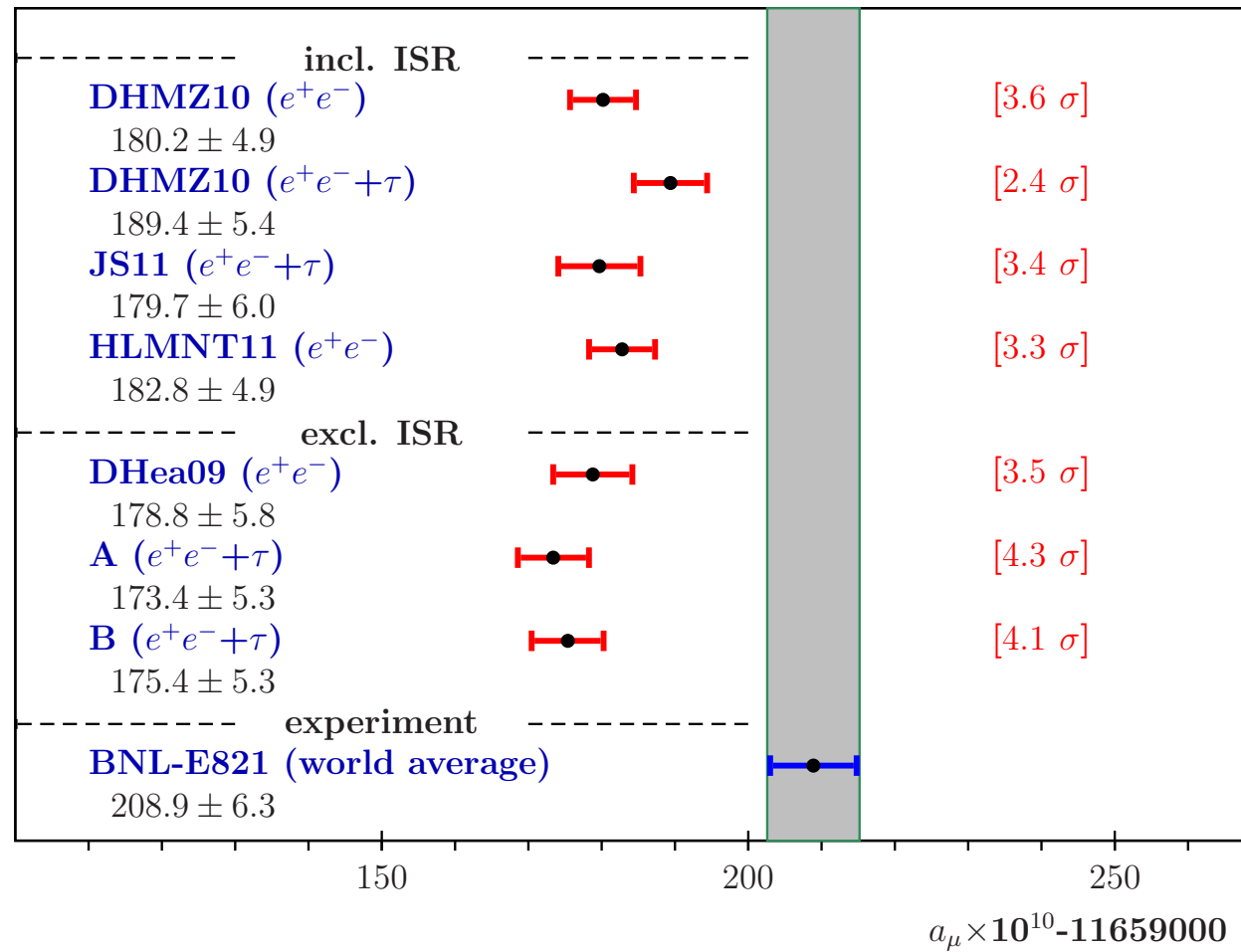
A new dip structure around 1.9 GeV – baryonium or $\rho(1900)$?

Physics at VEPP-2000 – II

Implications of low energy cross sections
for various fundamental quantities:

- Muon anomalous magnetic moment, a_μ , where a more than 3.5σ deviation is observed from the SM prediction
- 92% of $a_\mu^{\text{had,LO}}$ is saturated by $\sqrt{s}$ from threshold to 2 GeV
- 73% of $a_\mu^{\text{had,LO}}$ is saturated by $e^+e^- \rightarrow \pi^+\pi^-$ at $\sqrt{s} < 2$ GeV
- $\gamma\gamma \rightarrow \pi^0, \eta, \eta'$ is important for $a_\mu^{\text{had,LBL}}$
- Hadronic contributions to running α
- $m_{u(d)}$ and quark /gluon condensates from QCD sum rules
- Test of CVC by comparing e^+e^- and τ

Status of the muon anomaly $a_\mu^{\text{had,LO}} = (g_\mu - 2)/2$

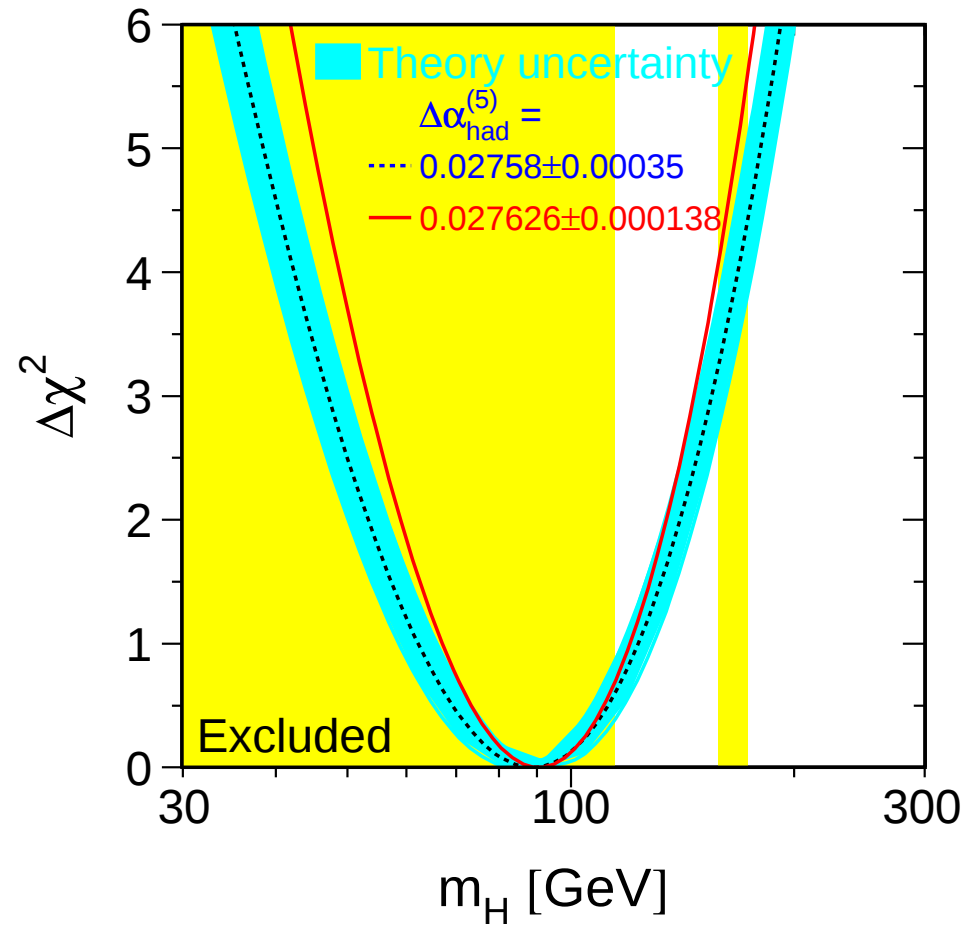


Status of $\Delta\alpha_{\text{had}}^{(5)}(M_Z^2)$

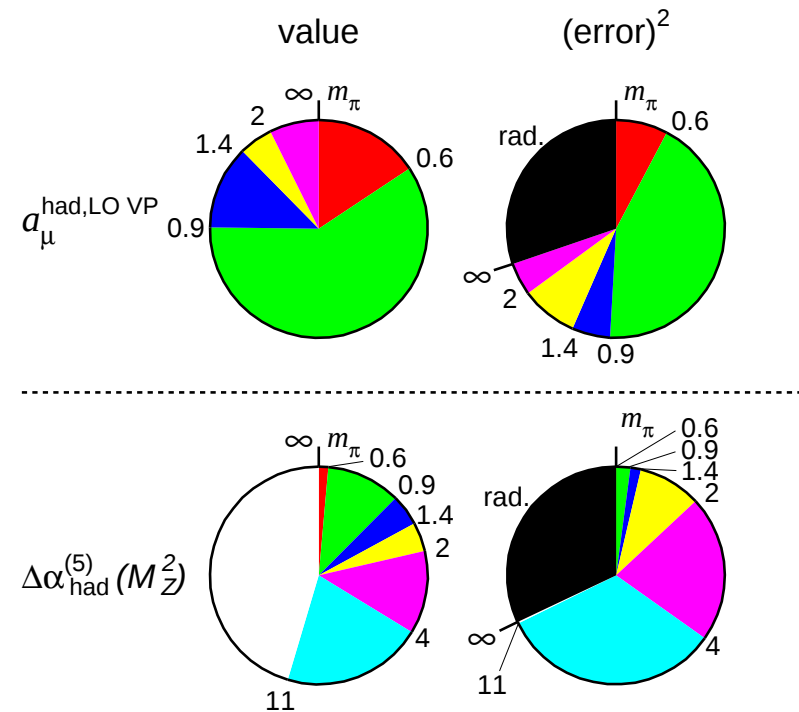
Because of the vacuum polarization effects
the charge gets shielding and e/m interactions
vary with distance $\Rightarrow 1/\alpha(M_Z^2) = 128.6$

Group	$\Delta\alpha_{\text{had}}^{(5)}(M_Z^2), 10^{-4}$	Date
S.Eidelman and F.Jegerlehner	280 ± 7	1995
M.Davier et al.	275.7 ± 1.0	2011
H.Burkhardt and B.Pietrzyk	275.0 ± 3.3	2011
K.Hagiwara et al.	276.26 ± 1.38	2011

Bounds on Higgs Mass

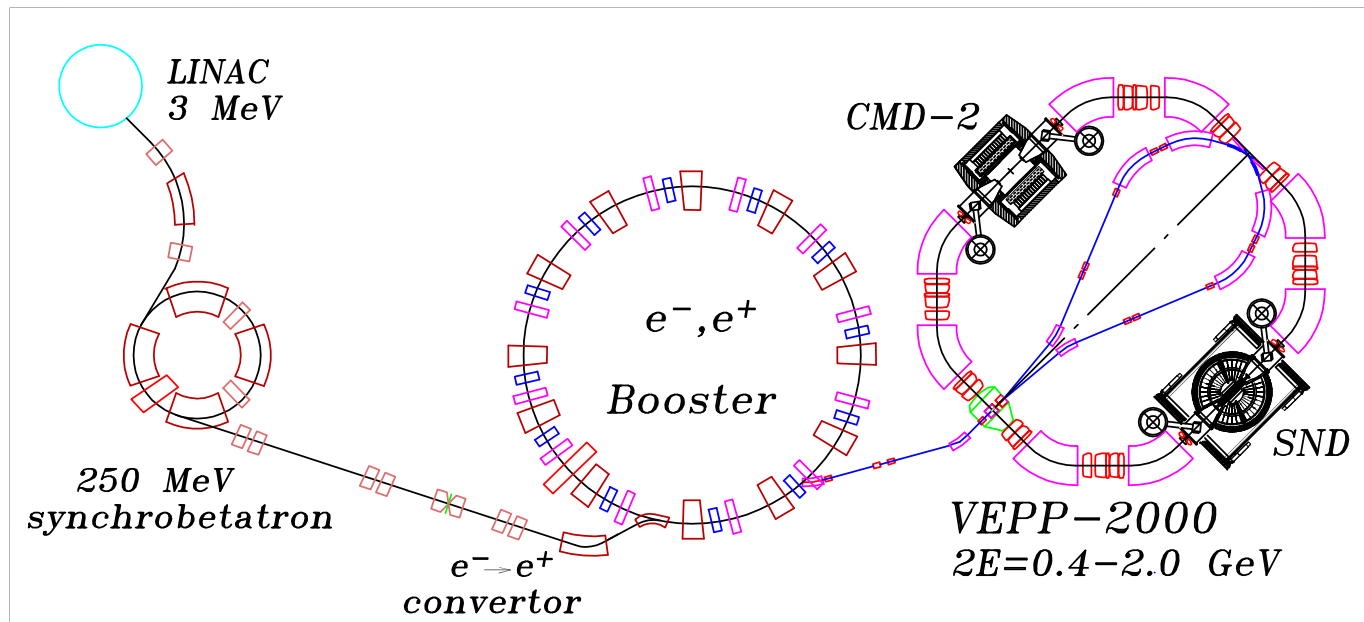


Impact of R Measurements on $(g_\mu - 2)/2$ and $\Delta\alpha_{\text{had}}^{(5)}(M_Z^2)$



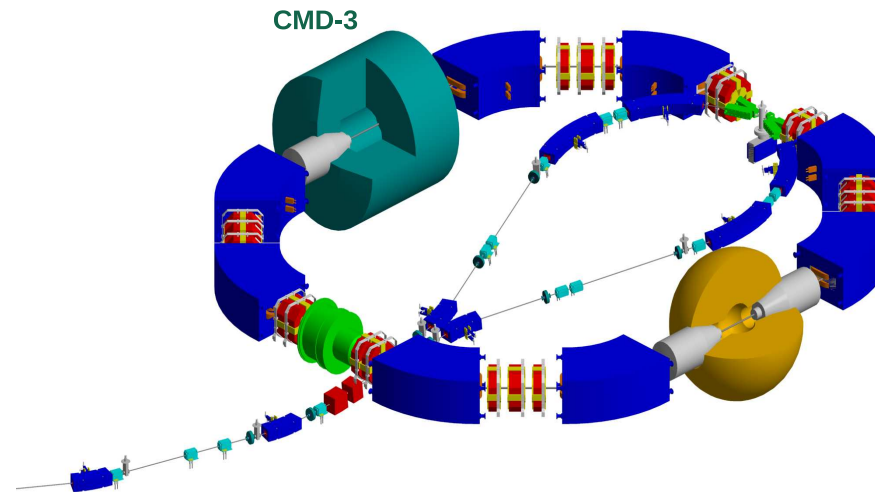
VEPP-2000 Accelerator Complex

Layout of the VEPP-2000 complex



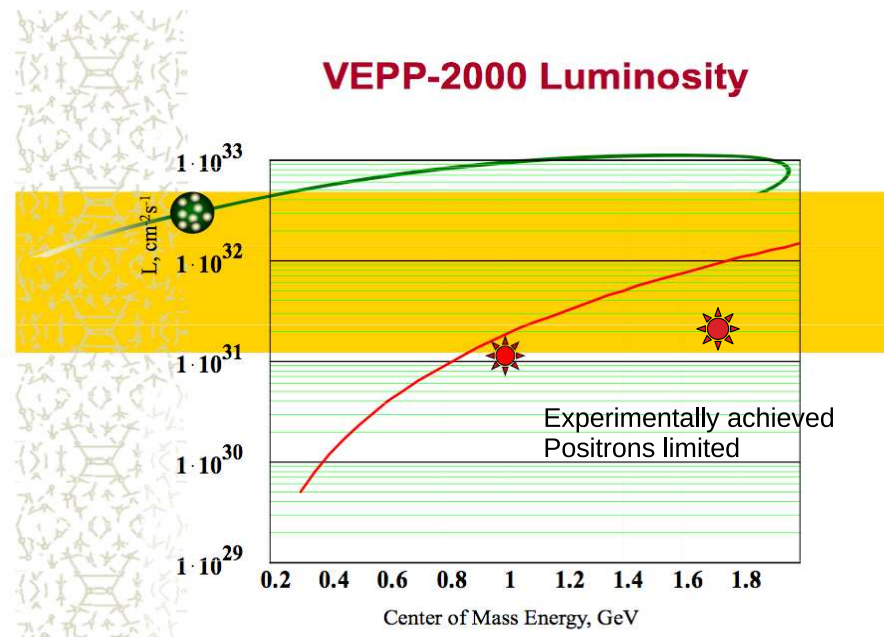
Machine	Physics	$\sqrt{s}$, MeV	$\mathcal{L}_{\text{max}}$, $10^{30} \text{ cm}^{-2} \text{ s}^{-1}$	$\int \mathcal{L} dt$, pb^{-1}
VEPP-2M	1975 – 2000	360–1400	3	~ 60
VEPP-2000	2010 – 2020	300–2000	100	~ 3000

VEPP-2000 Collider



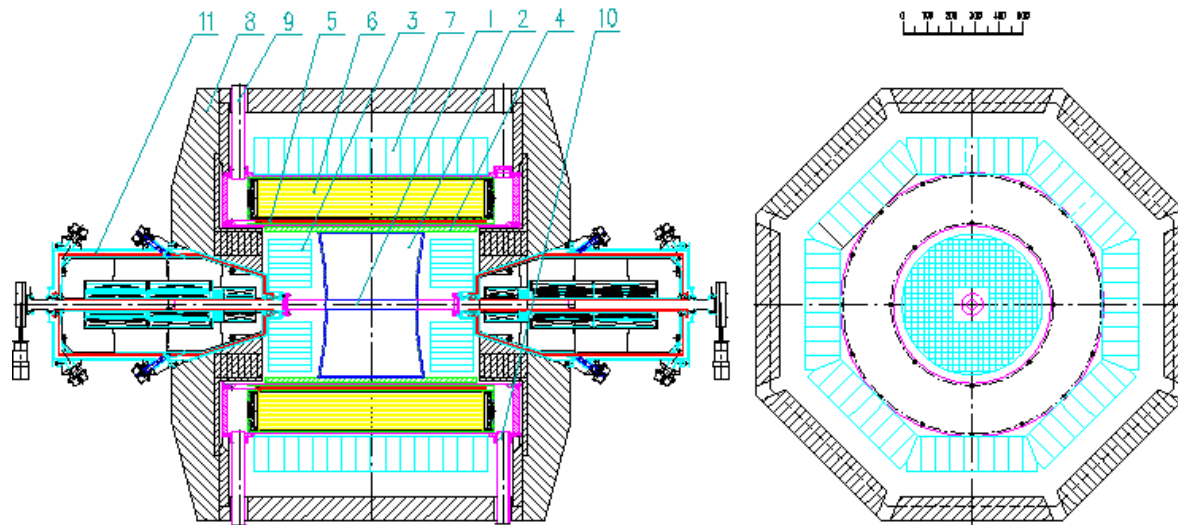
Round beams: 1×1 bunch, $\epsilon_x = \epsilon_y$, $\sigma_x^* = \sigma_y^*$, $\nu_x = \nu_y$

Luminosity at VEPP-2000



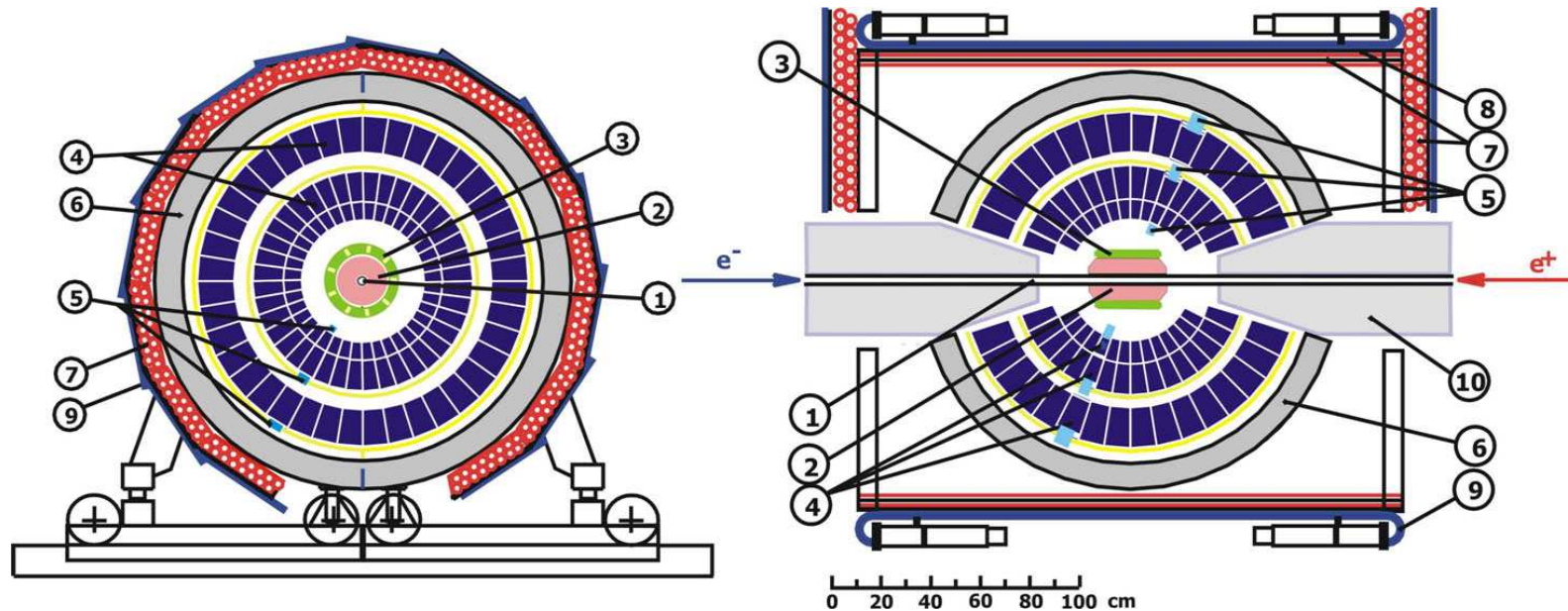
Design luminosity should be achieved after
the new injection complex is commissioned in 2012

CMD-3 Detector



- 1 Beam pipe
- 2 Drift chamber
- 3 BGO calorimeter
- 4 Z chamber
- 5 SC solenoid
- 6 LXe calorimeter
- 7 CsI calorimeter
- 8 Flux return
- 9 LHe supply
- 10 Vacuum pumpdown
- 11 SC focusing solenoids

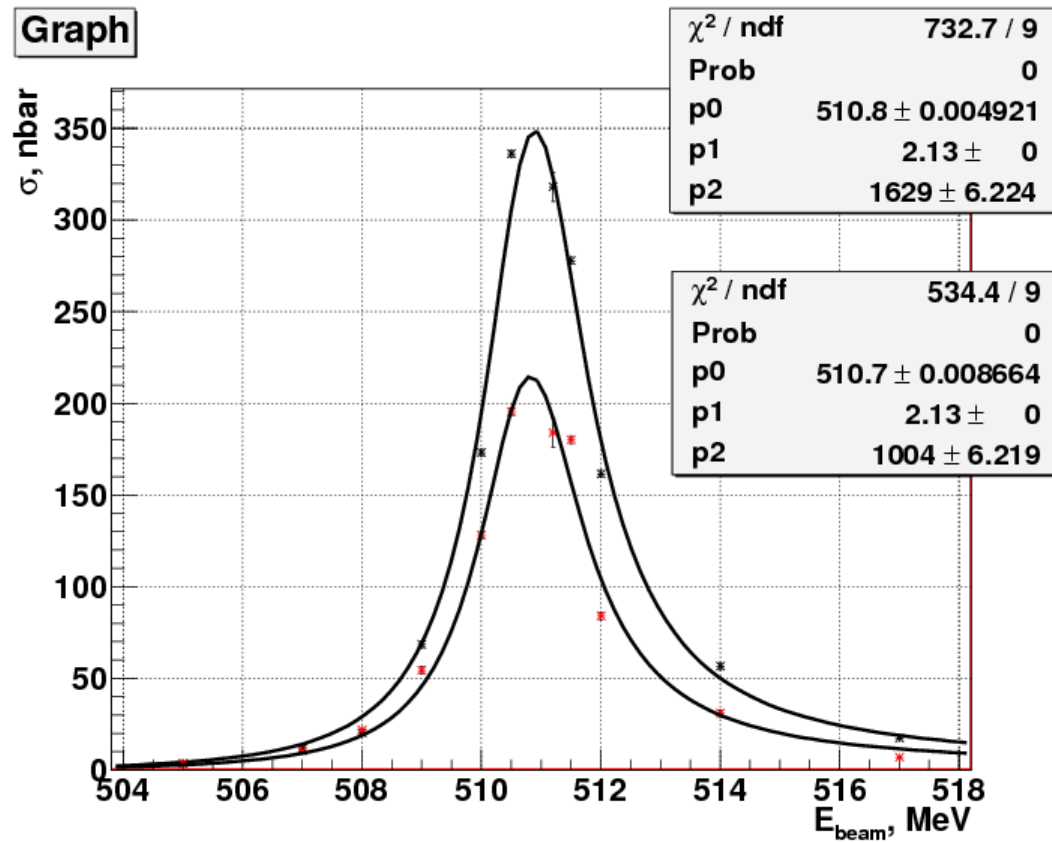
SND Detector



- 1 Beam pipe, 2 Tracking (drift and proportional chamber), 3 Aerogel Cherenkov counters, 4 NaI calorimeter, 5 Vacuum phototriodes, 6 Absorber, 7 Streamer tubes, 8 Iron filter, 9 Scintillation counters, 10 SC focusing solenoids

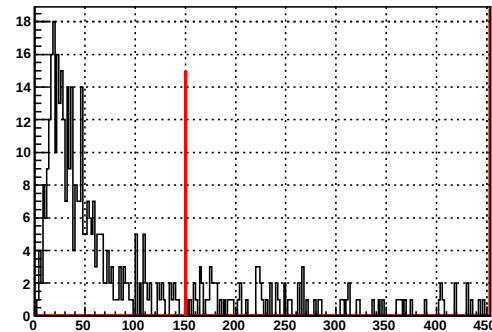
Data Taking

- In 2010 a scan was performed from the ϕ meson to 2 GeV with a step of 100 MeV and $\sim 5 \text{ pb}^{-1}$ in total
- Two scans (up and down) were performed from the ϕ meson to 2 GeV with a step of 25 MeV and $\sim 500 \text{ nb}^{-1}$ per point
- A step was smaller near the $p\bar{p}$ threshold
- ϕ meson, 1050, 1075, 1100, 1125, ..., 1800, 1825, 1850, 1870, 1890, 1900, 1925, 1950, 1975, 2000
- 56 points $\Rightarrow \sim 22 \text{ pb}^{-1}$
- 15 points at the ϕ meson from 1010 to 1034 MeV, 1.9 pb^{-1} in total for detector studies and software tests

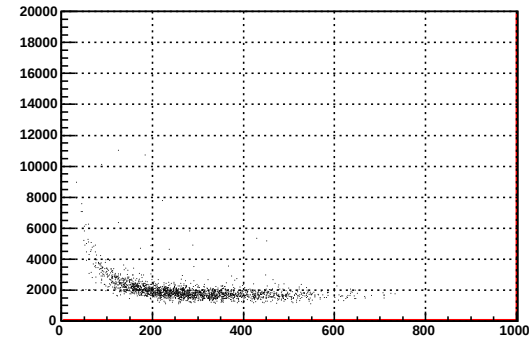
$$\phi \rightarrow K^+ K^-, K_S K_L \text{ at CMD-3}$$


Selection of $3\pi^+3\pi^-$ Events at CMD-3 – I

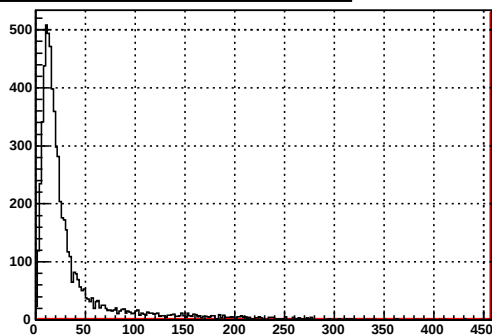
Total momentum for 6 good tracks - data



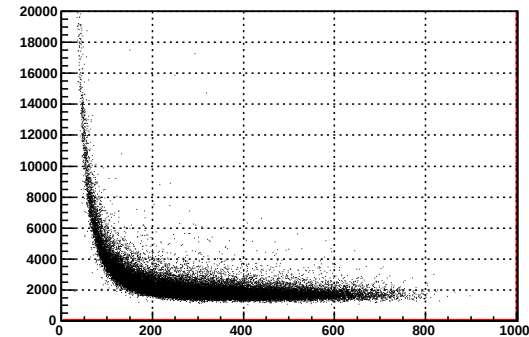
Six Good Track Momentum vs dEdX - data



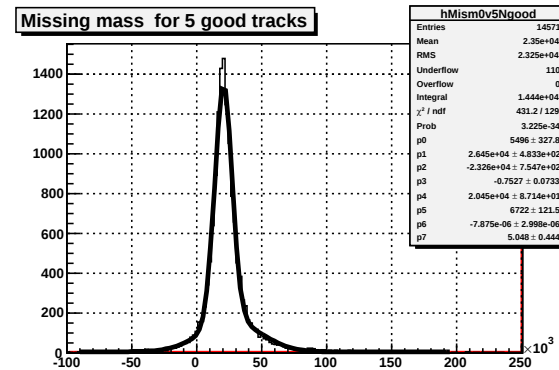
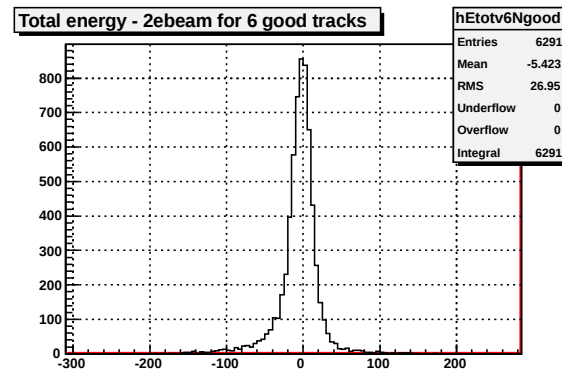
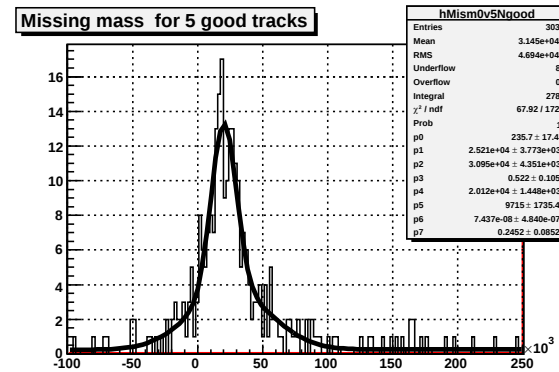
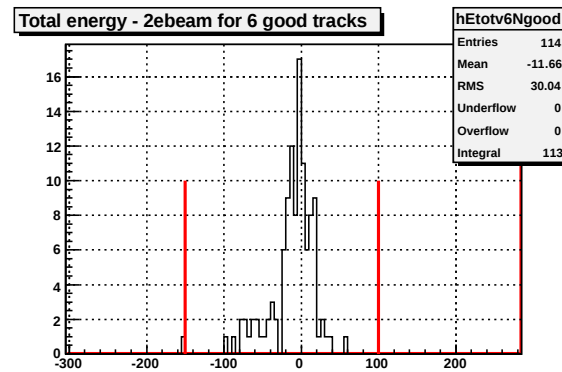
Total momentum for 6 good tracks - MC



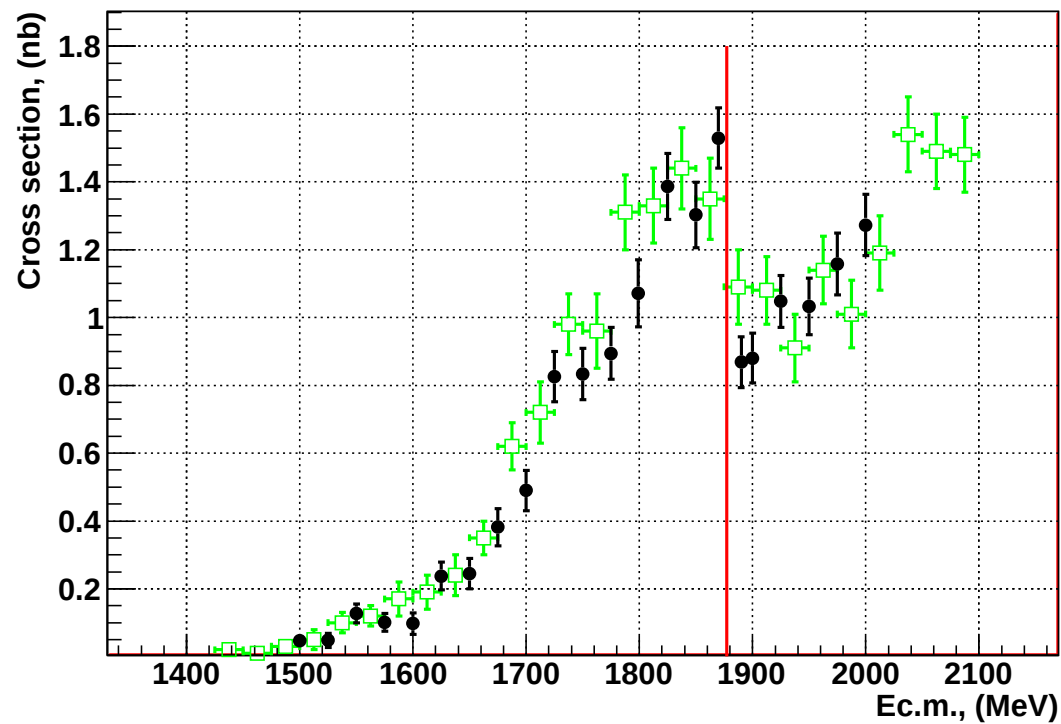
Six Good Track Momentum vs dEdX - MC



Selection of $3\pi^+3\pi^-$ Events at CMD-3 – II

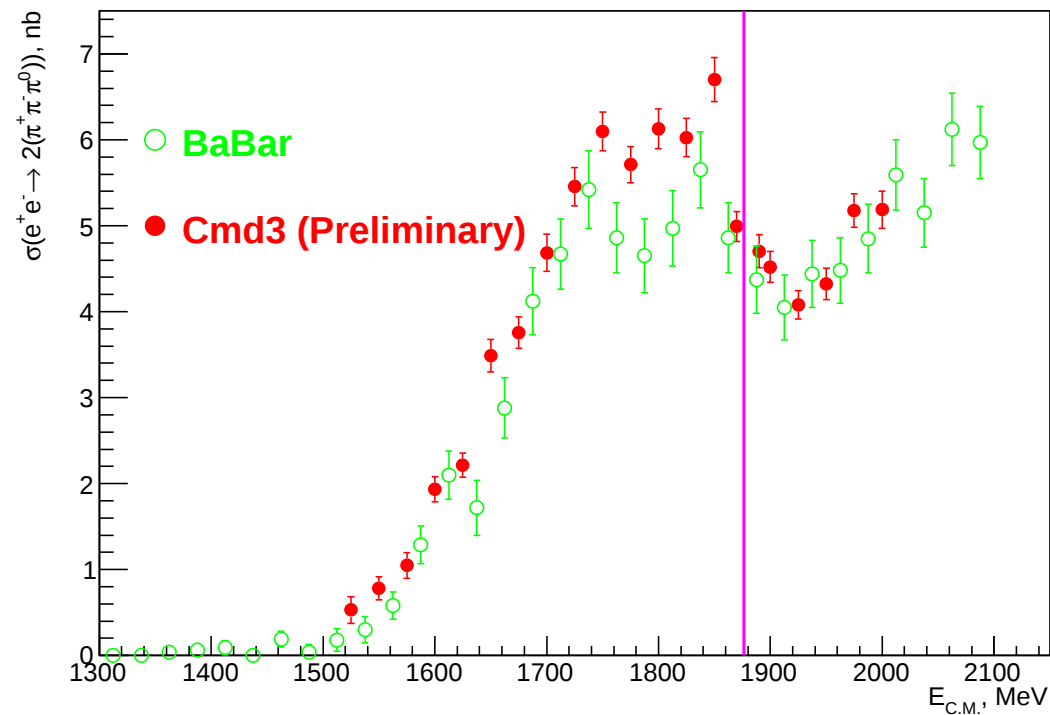


Cross section of $e^+e^- \rightarrow 3\pi^+3\pi^-$ at CMD-3



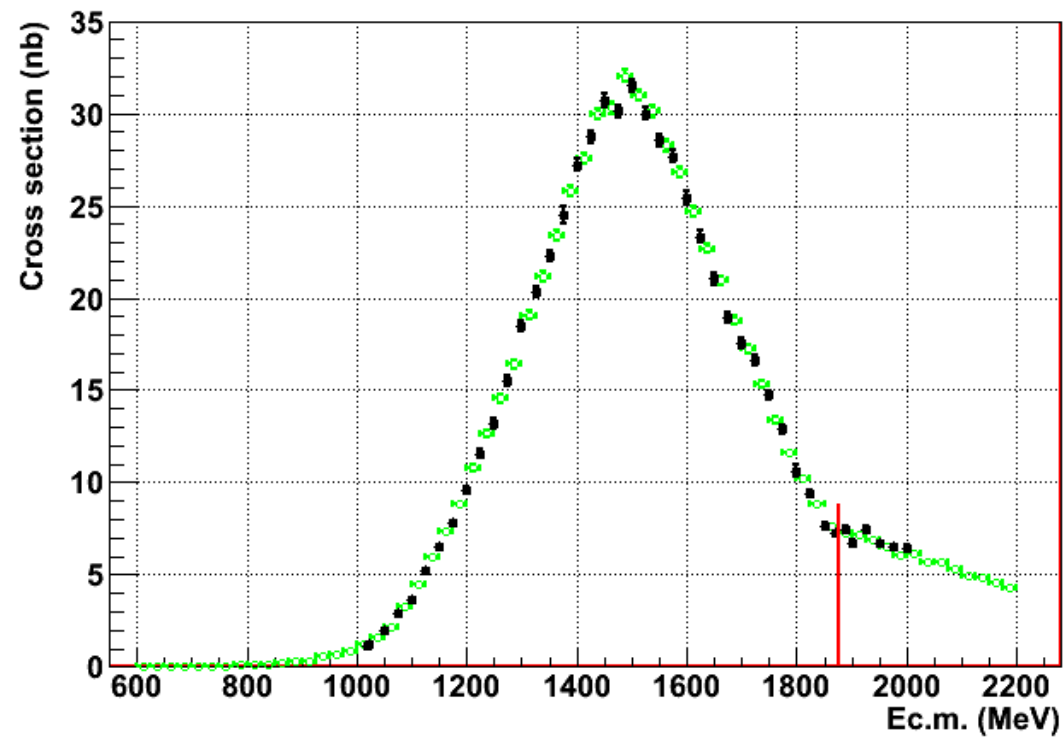
Good agreement and comparable precision to BABAR,
A dip at 1900 MeV confirmed, baryonium or $\rho(1900)$?

Cross section of $e^+e^- \rightarrow 2\pi^+2\pi^-2\pi^0$ at CMD-3

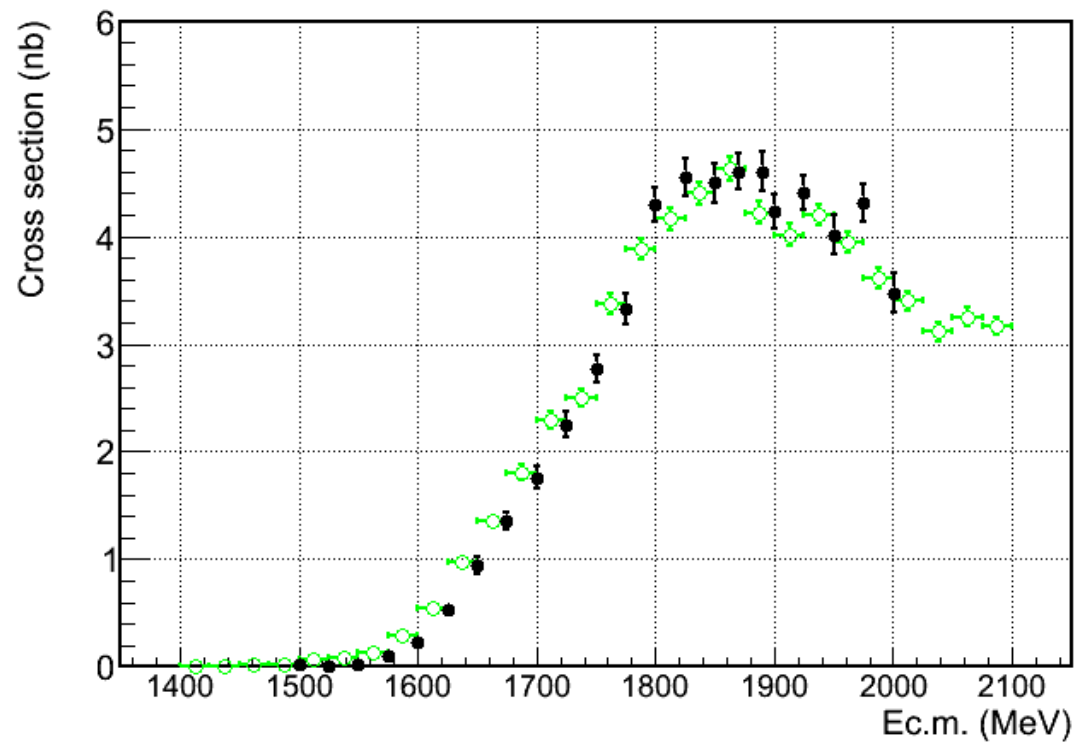


As for $3(\pi^+\pi^-)$, good agreement and comparable precision to BABAR,
A dip at 1900 MeV confirmed, baryonium or $\rho(1900)$?

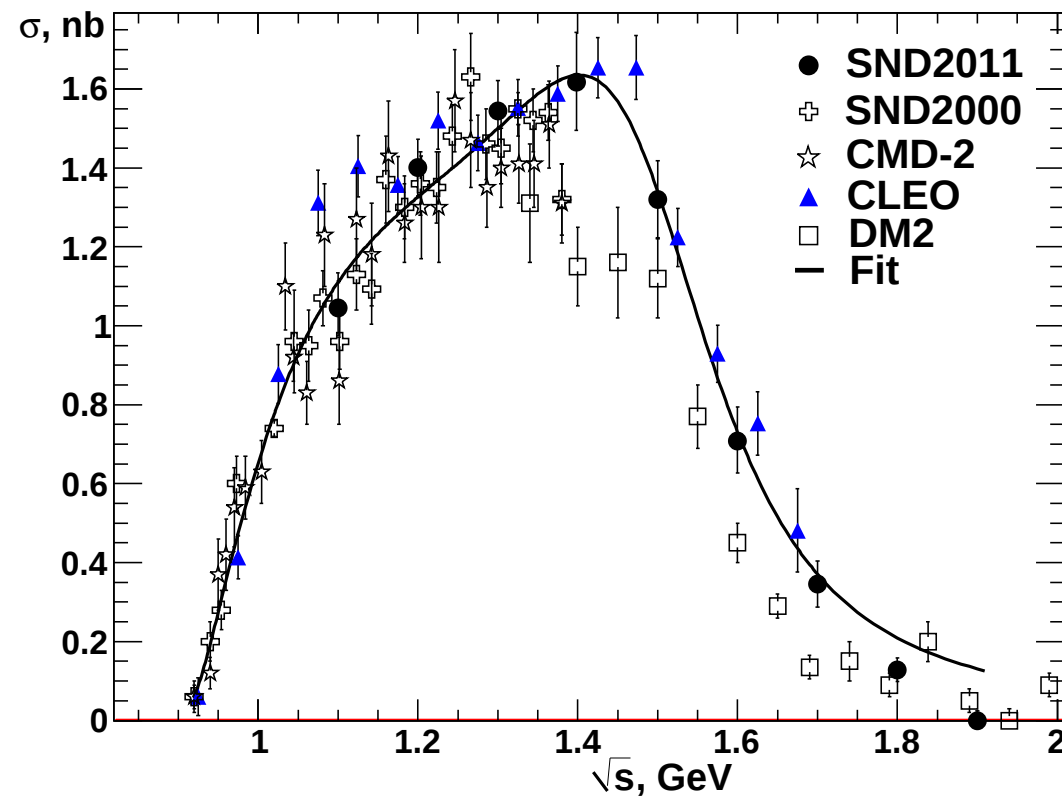
Cross section of $e^+e^- \rightarrow 2(\pi^+\pi^-)$ at CMD-3



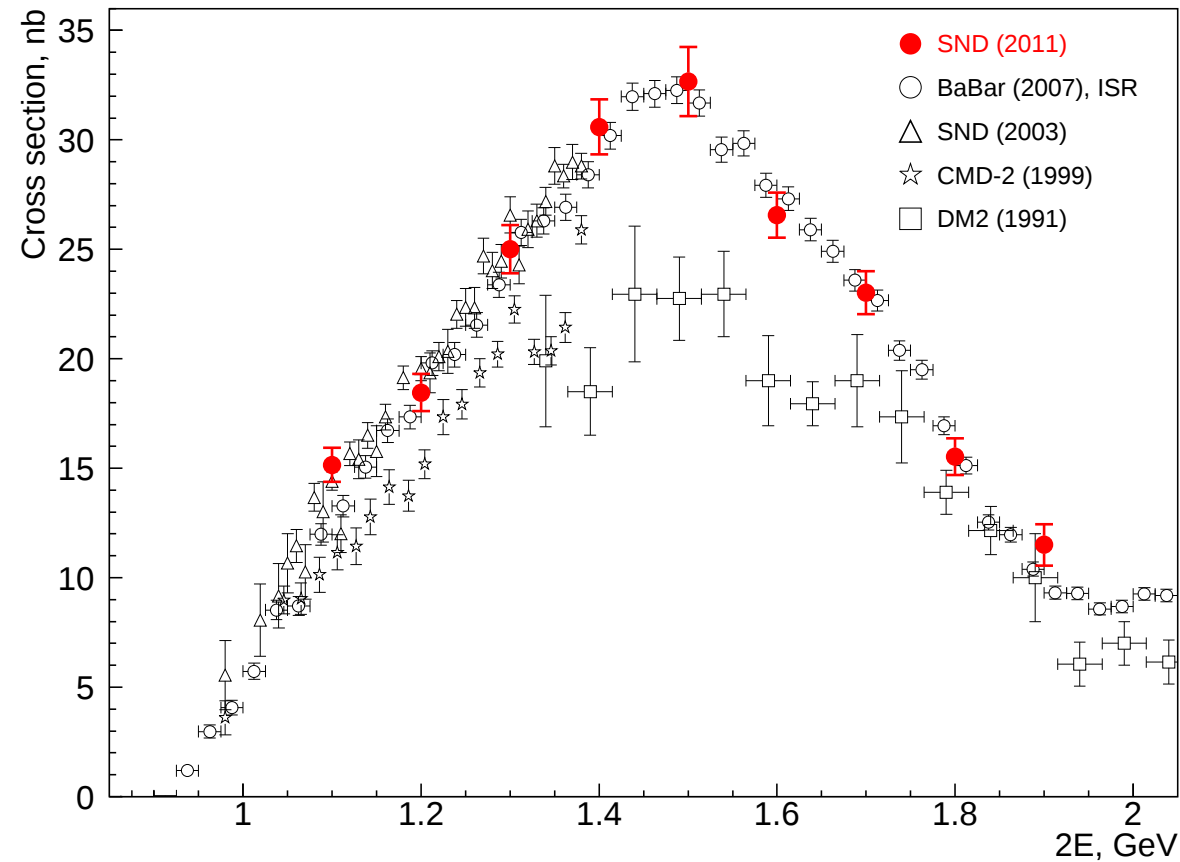
Cross section of $e^+e^- \rightarrow K^+K^-\pi^+\pi^-$ at CMD-3

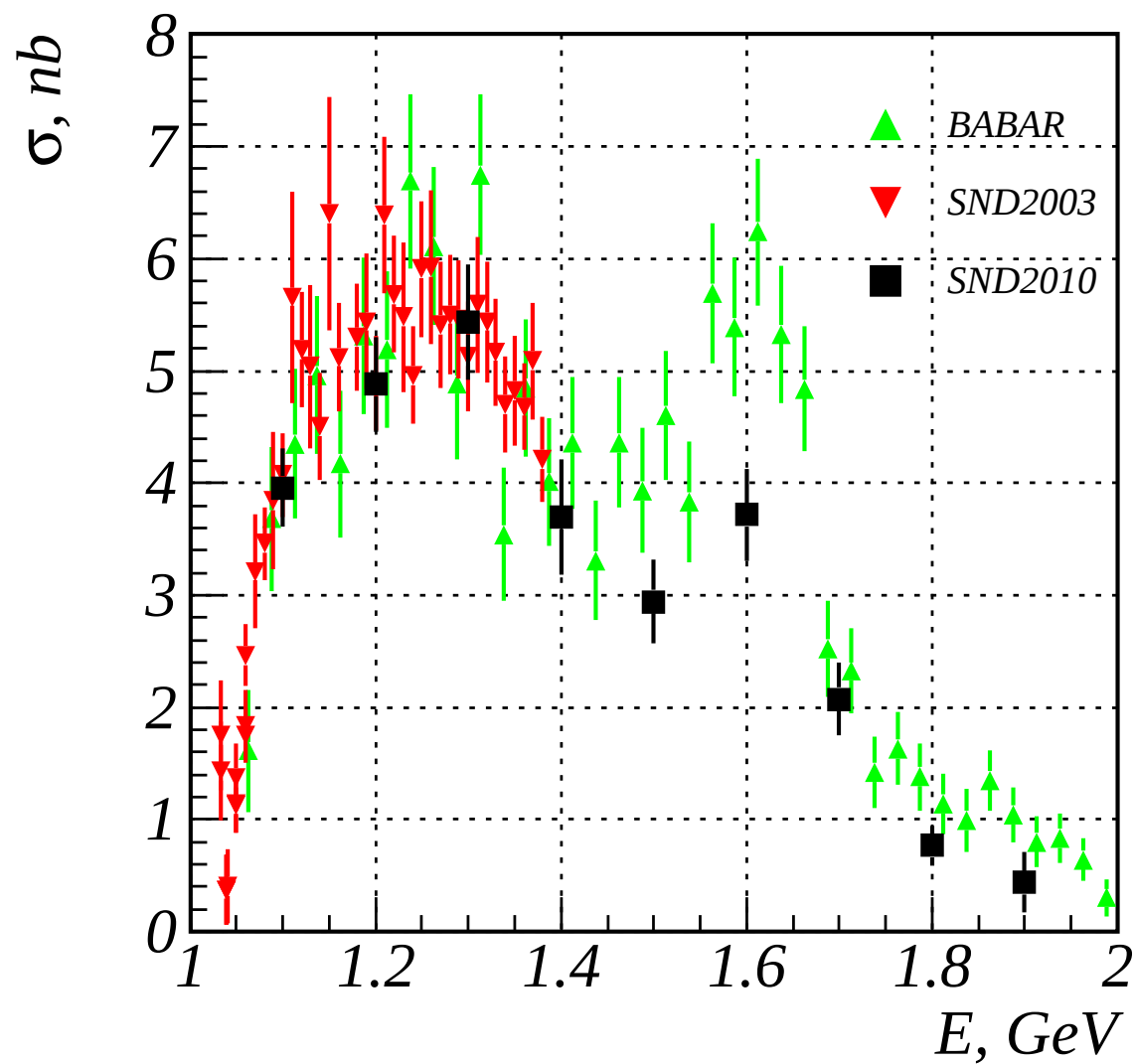


Cross section of $e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$ at SND

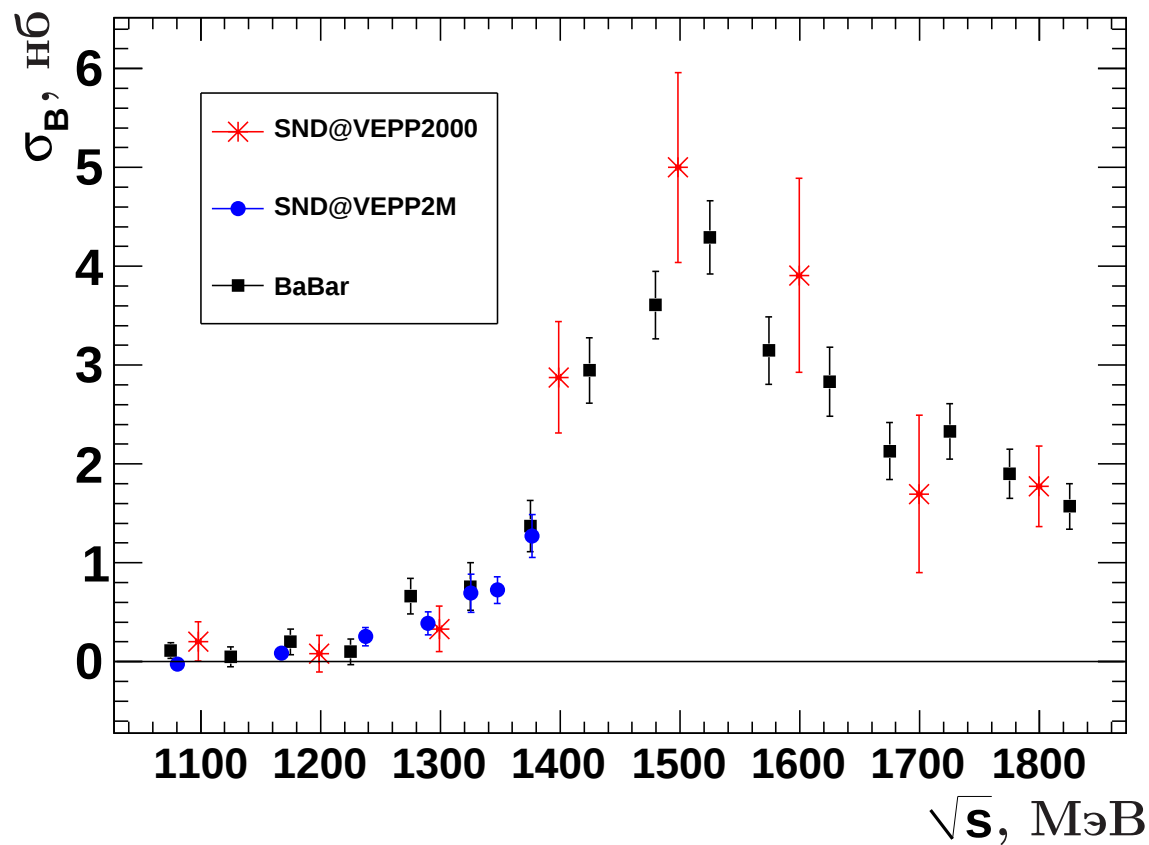


Cross section of $e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$ at SND

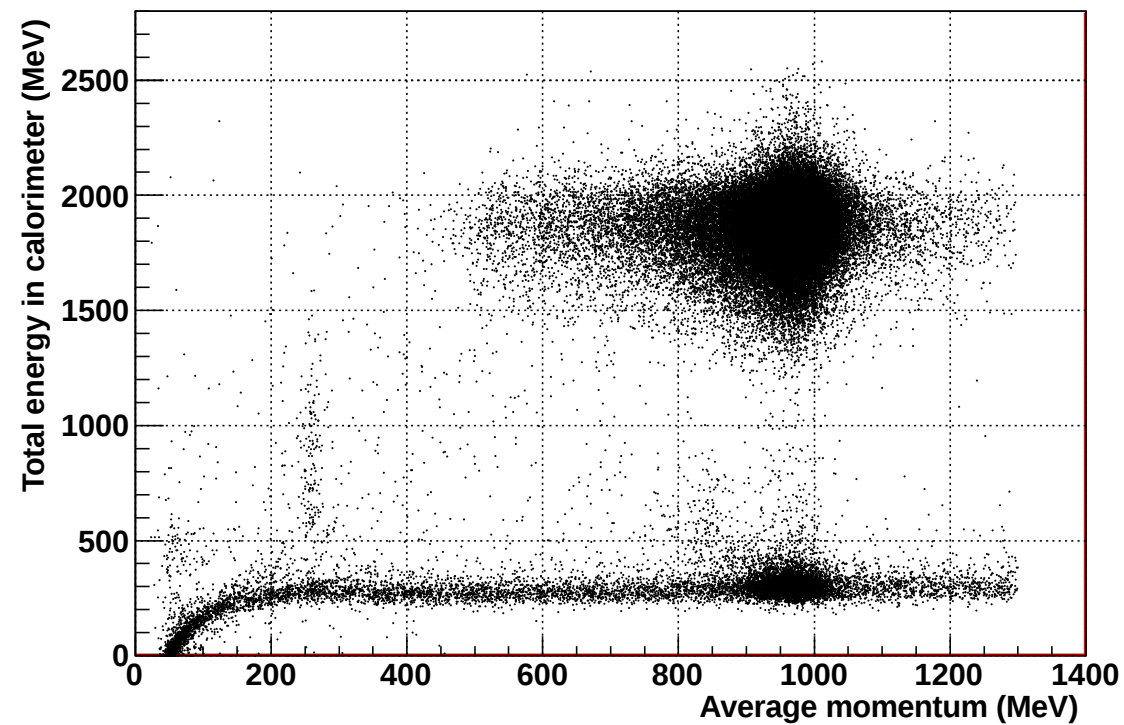


Cross section of $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ at SND

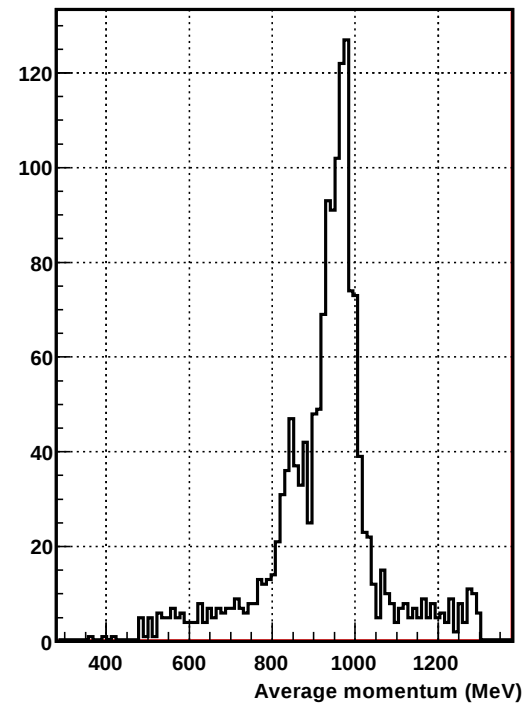
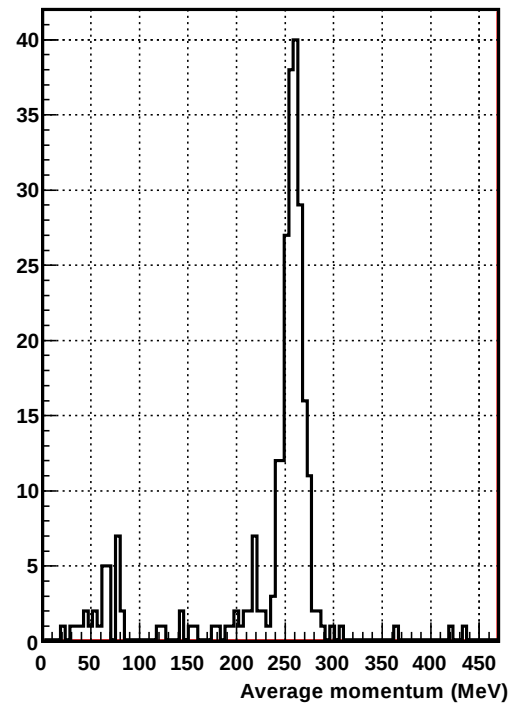
Cross section of $e^+e^- \rightarrow \eta\pi^+\pi^-$ at SND

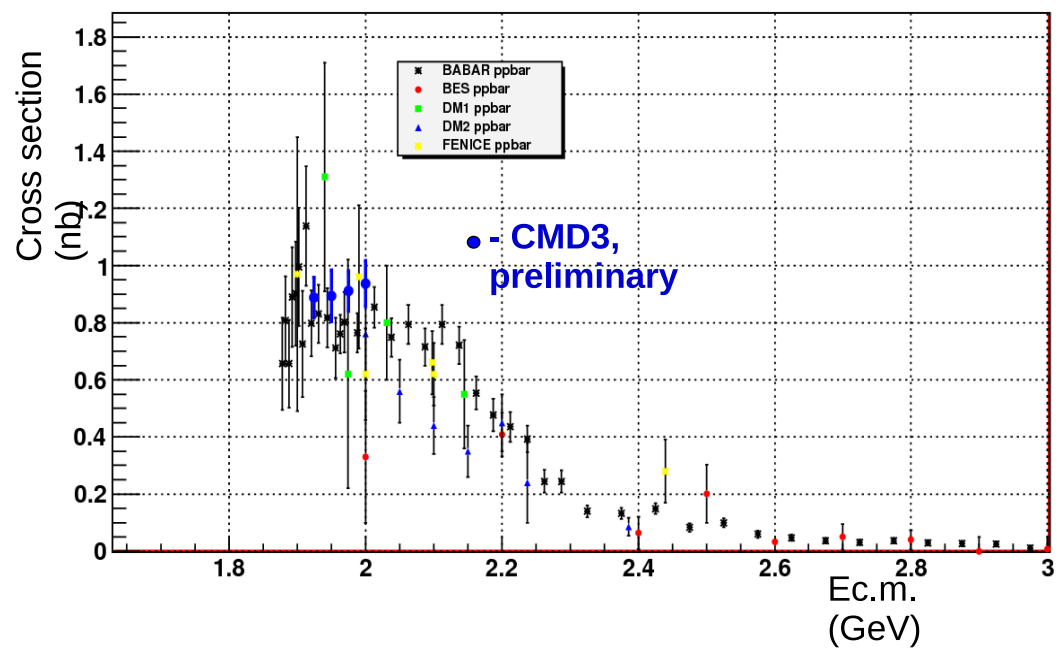


Selection of $e^+e^- \rightarrow p\bar{p}$ Events at CMD-3 – I



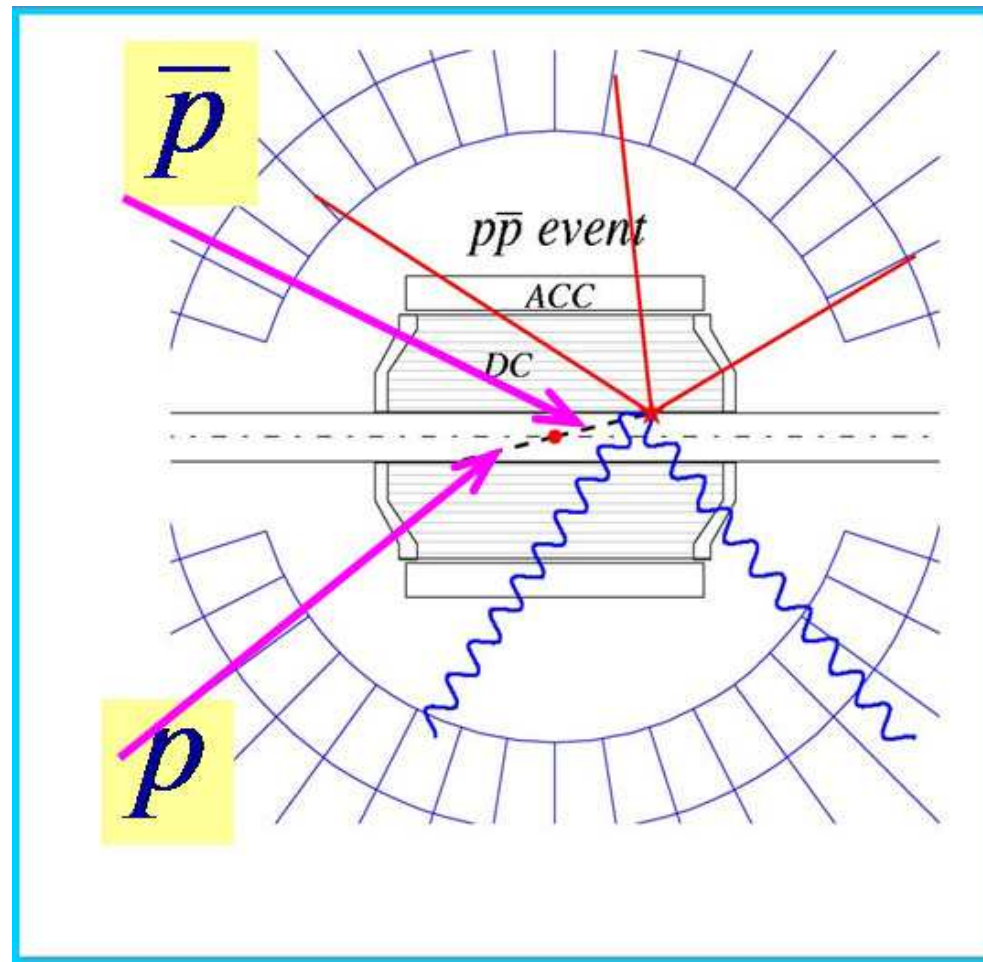
Selection of $e^+e^- \rightarrow p\bar{p}$ Events at CMD-3 – II



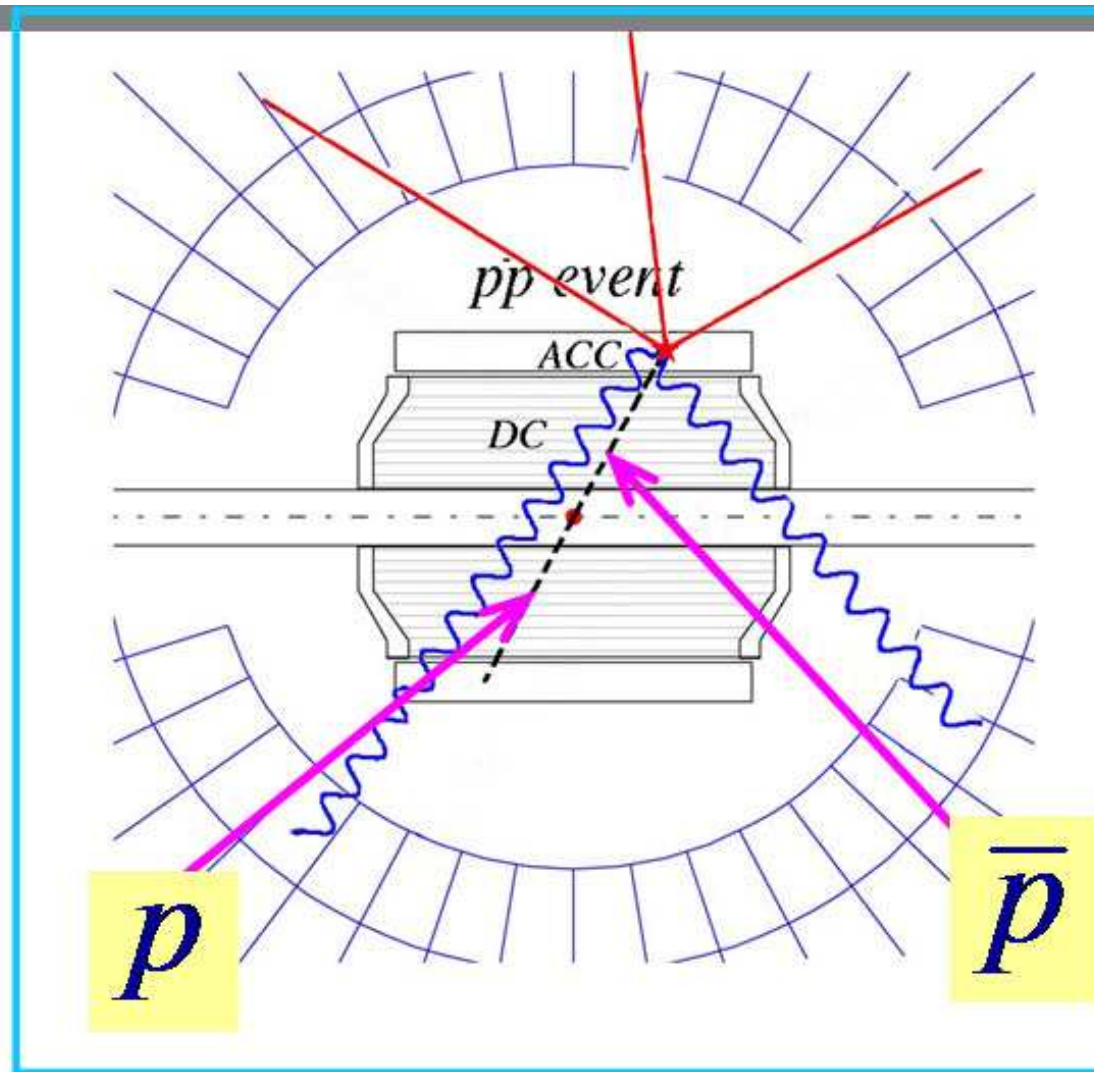


$\sigma(e^+e^- \rightarrow p\bar{p})$ is consistent with that of BABAR and older measurements

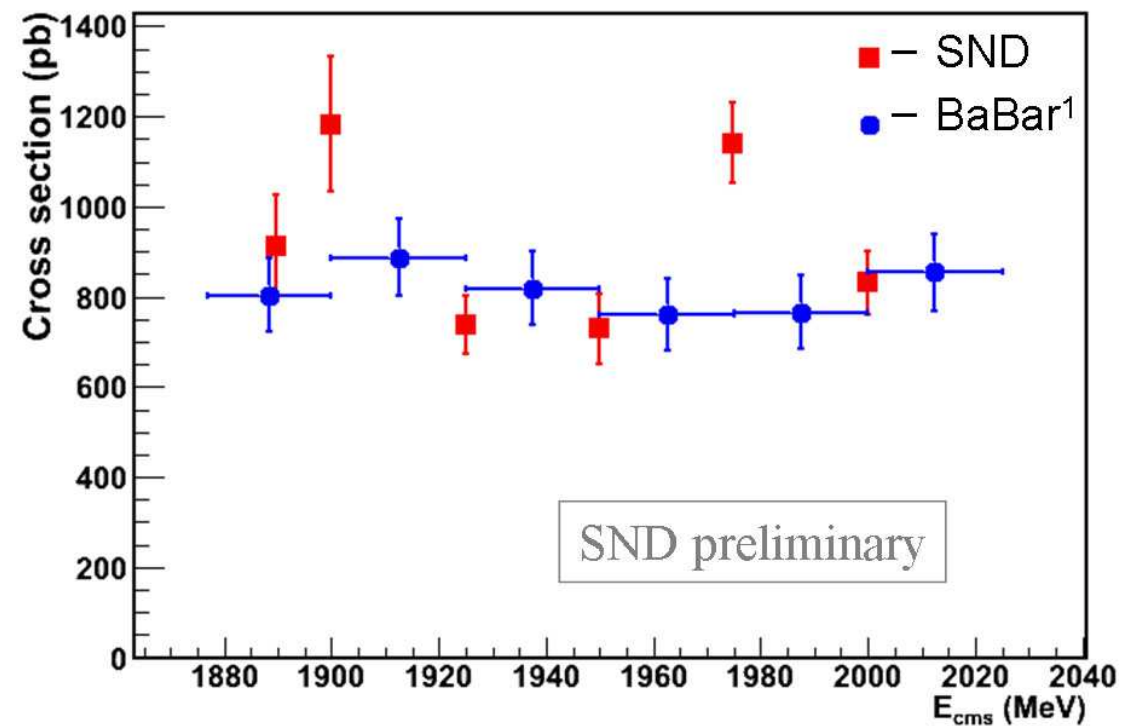
An $e^+e^- \rightarrow p\bar{p}$ event at SND - I



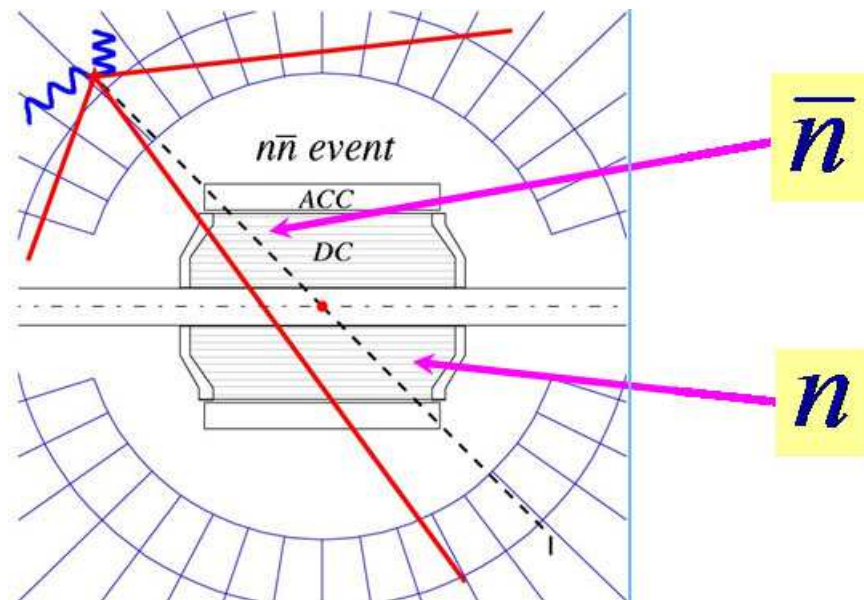
An $e^+e^- \rightarrow p\bar{p}$ event at SND - II



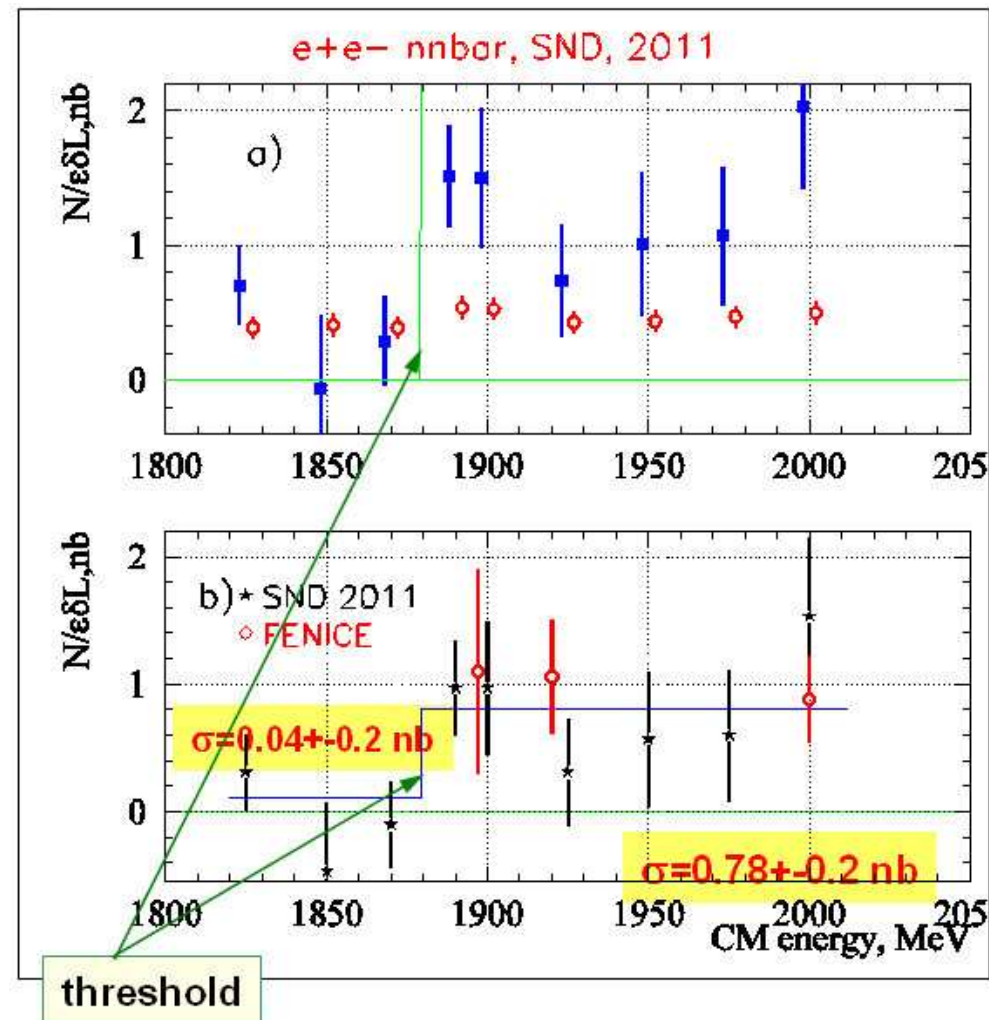
Cross section of $e^+e^- \rightarrow p\bar{p}$ at SND



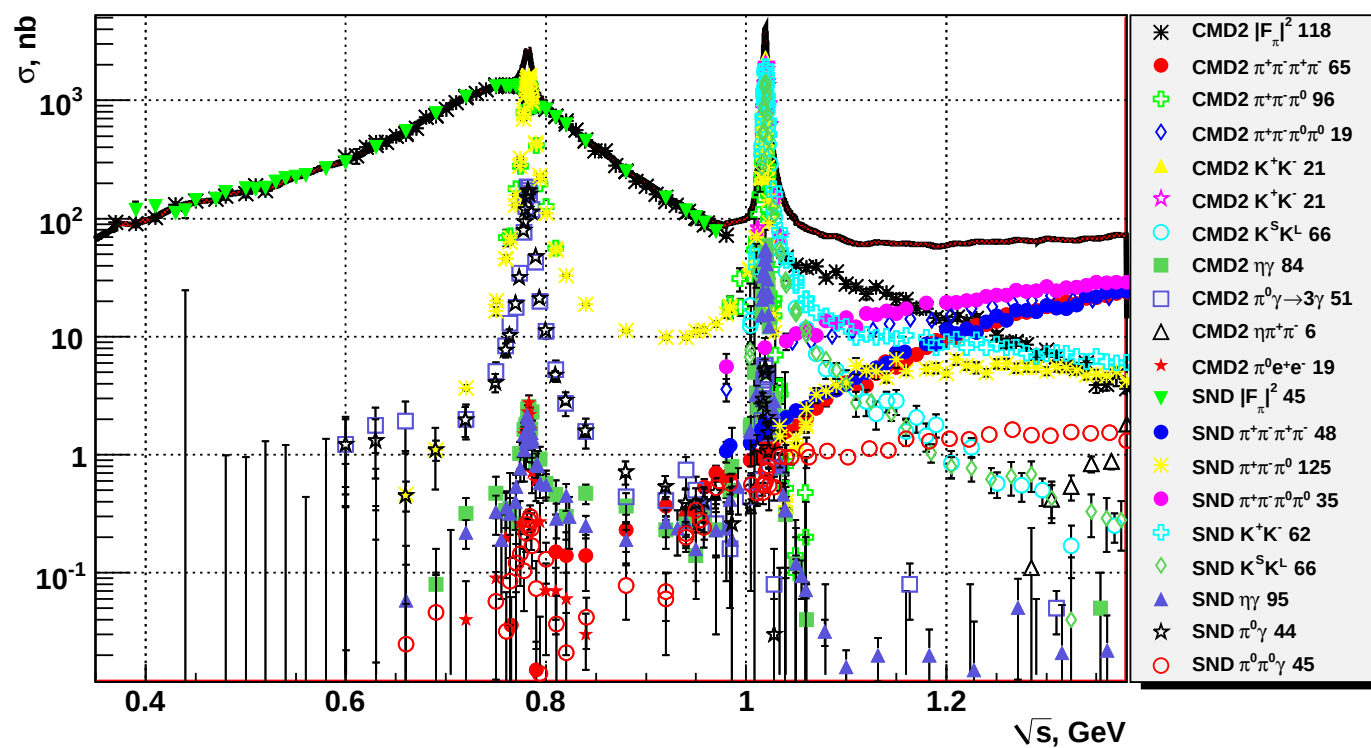
An $e^+e^- \rightarrow n\bar{n}$ event at SND



Cross section of $e^+e^- \rightarrow n\bar{n}$ at SND



All cross sections from VEPP-2M



Conclusions on VEPP-2000

- VEPP-2000 has been successfully commissioned with a luminosity of $2 \cdot 10^{31} \text{ cm}^{-2}\text{s}^{-1}$ achieved
- Two detectors, SND and CMD-3, are taking data, we start understanding their performance
- The integrated luminosity collected between 1 and 2 GeV already exceeds the one previously achieved in direct scans with precision close to BABAR
- CMD-3 measures $\sigma(3\pi^+3\pi^-, 2\pi^+2\pi^-2\pi^0)$ and confirms a dip at 1900 MeV
- Hundreds of $e^+e^- \rightarrow p\bar{p}, n\bar{n}$ events observed near threshold
- In a few years we hope to measure $\sigma(e^+e^- \rightarrow \text{hadrons})$ with high accuracy and significantly improve the precision of $\alpha_{\mu}^{\text{had,LO}}$ and $\alpha_{\text{had}}^{(5)}(M_Z^2)$

Super- τ – c factory – basic features

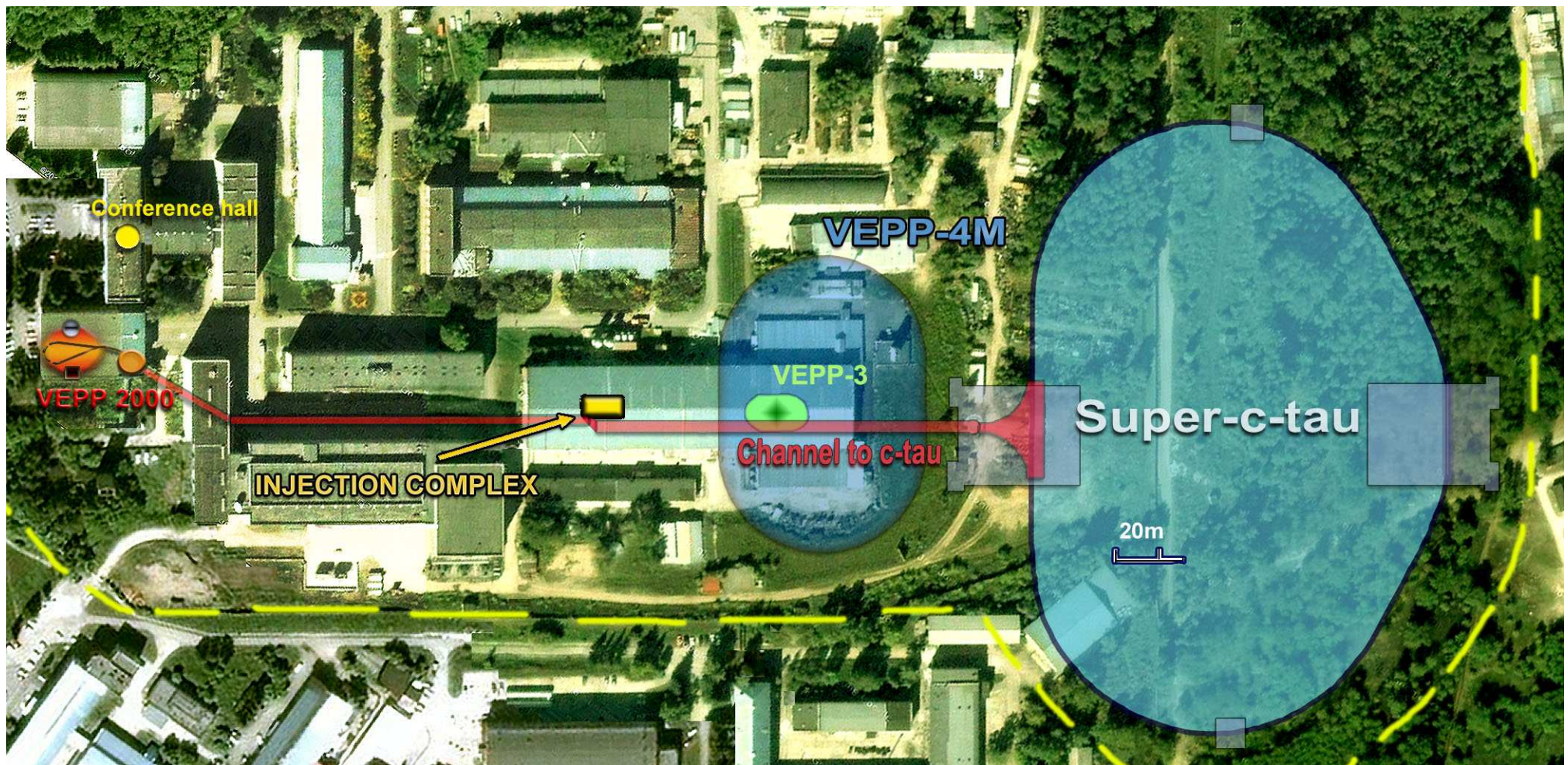
A new Crab Waist collision scheme successfully tested at DAFNE is a base for both Super-B factories and allows $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ to be reached $\Rightarrow$ unprecedented number of $c\bar{c}$ and $\tau^+\tau^-$ pairs produced with low background

- Center-of-mass energy W from 2 to 5 GeV
- Superconducting wigglers provide optimal luminosity at all W
- $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ at 2 GeV to $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ at the $\tau^+\tau^-$ production threshold
- Longitudinal polarization of the e^- beam
- The W calibration with $(5 - 10) \times 10^{-5}$ accuracy

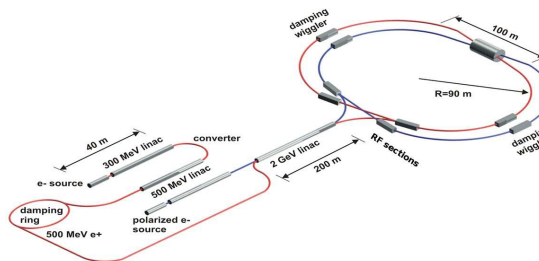
Super- τ – c factory – physics issues

- $D\bar{D}$ mixing
- Search for CPV in charm decays
- Rare and forbidden decays of the open charm mesons
- Study of standard charmonia and charmonium-like states
- Tests of SM in τ decays
- Search for CP/T and LF violation in τ decays
- Study of light mesons between 1 and 3 GeV, scan and ISR
- Production of polarized antinucleons
- A high chance to get funds from the budget, collaborators are very welcome!!!

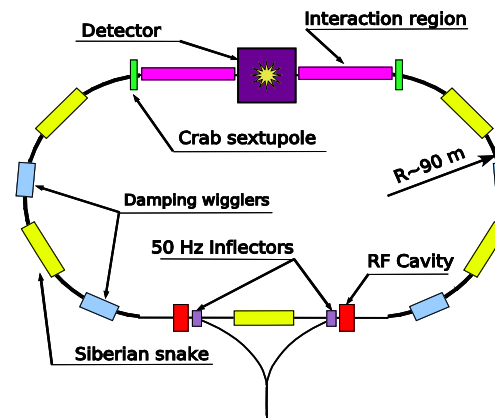
The general view of BINP



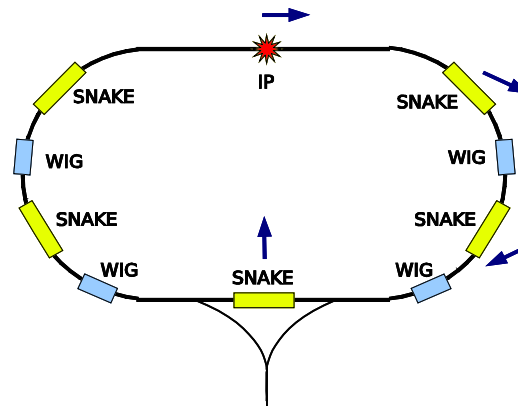
Scheme of the Super-tau-charm factory



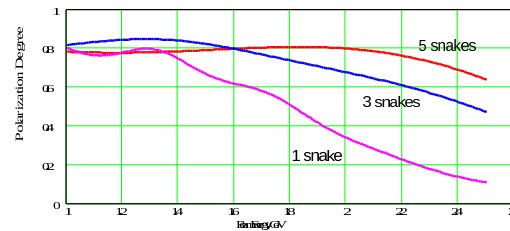
The new collider



Obtaining polarization – I



Obtaining polarization – II



Conclusions

- The new e^+e^- collider VEPP-2000 is running with two upgraded detectors (CMD-3 and SND) at a maximum W of 2 GeV and $\mathcal{L}$ of $2 \cdot 10^{31} \text{ cm}^{-1}\text{s}^{-1}$. Multihadronic cross sections are measured with precision comparable to BaBar. Cross sections of $p\bar{p}$, $n\bar{n}$ have been determined near threshold
- An ambitious project of the Super-tau-charm factory with W between 2 and 5 GeV, $\mathcal{L}$ of $10^{35} \text{ cm}^{-1}\text{s}^{-1}$ and longitudinal polarization of the e^- beam has been developed. There are good chances of its support by the Russian government.