Recent results from the SND detector

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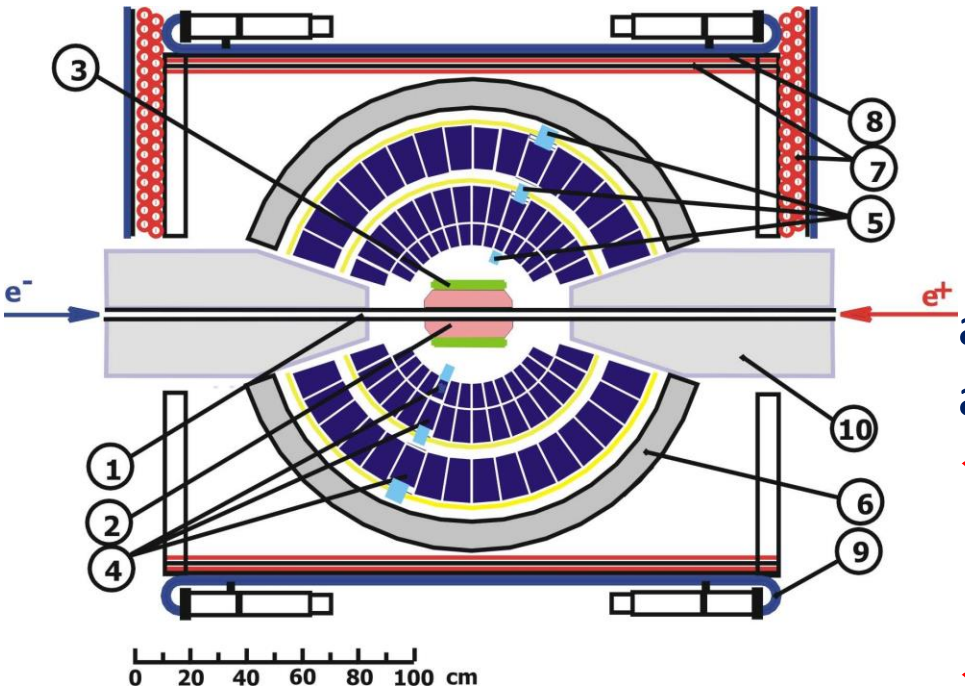
SND detector



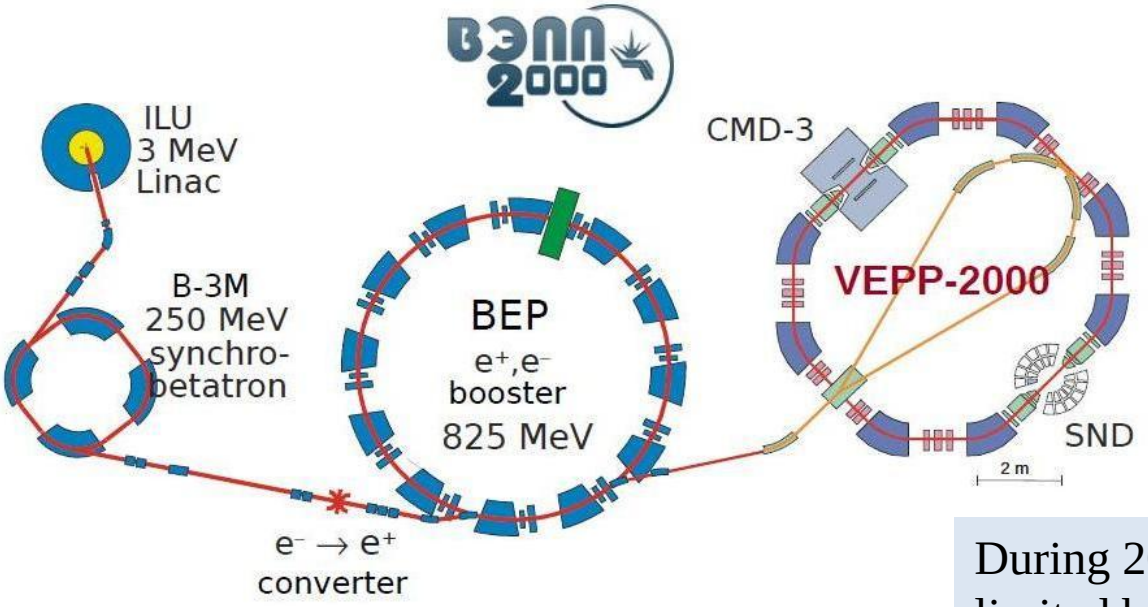
1 – **beam pipe, 2 – tracking system, 3 – aerogel Cherenkov counter , 4 – NaI(Tl) crystals, 5 – phototriodes, 6 – iron muon absorber, 7–9 – muon detector, 10 – focusing solenoids.**

SND collected data at the VEPP-2M (1996-2000) and VEPP-2000 (2010-2013,2016-…)

Main physics task of SND is study of all possible processes of e^+e^- annihilation into hadrons below 2 GeV.

- ✓ The total hadronic cross section, which is calculated as a sum of exclusive cross sections.
- ✓ Study of hadronization (dynamics of exclusive processes).
  - Properties of excited vector mesons of the ρ, ω, ϕ families
  - Development of MC event generator for $e^+e^- \rightarrow$ hadrons below 2 GeV.

VEPP-2000 e^+e^- collider



VEPP-2000 parameters:

- c.m. energy E=0.3-2.0 GeV
- circumference – 24.4 m
- round beam optics
- Luminosity at E=1.8 ГэВ

1×10^{32} cm^{-2} sec^{-1} (project)

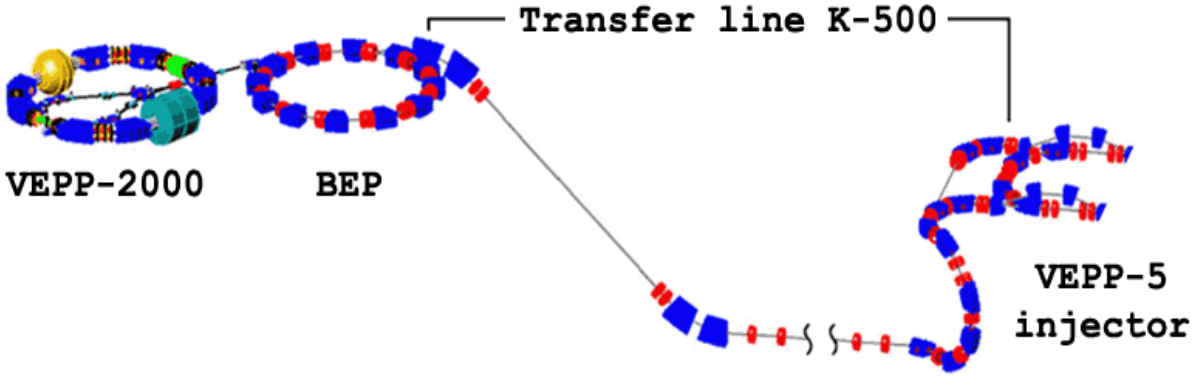
4×10^{31} cm^{-2} sec^{-1} (achieved)

During 2010-2013 the luminosity was limited by the deficit of positrons

✓x10 more intense positron source

✓Experiments at upgraded VEPP-2000 was restarted by the end of 2016.

✓About **50pb^{-1}** of integrated luminosity has been already collected during the 2017 run



SND data

~15 hadronic processes are currently under analysis

VEPP-2M

	Below ϕ	Near ϕ	Above ϕ
IL, pb^{-1}	9.1	13.2	8.8
E_{cm}, GeV	0.36-0.97	0.98-1.06	1.06-1.38

VEPP-2000

	Below ϕ	Near ϕ	Above ϕ
IL, pb^{-1}	15.4	6.9	100.0
E_{cm}, GeV	0.30-0.97	0.98-1.05	1.05-2.00

Precision measurements:

- $e^+e^- \to \pi^0\gamma$ (VEPP-2M data)
- $e^+e^- \to K^+K^-$

First measurements

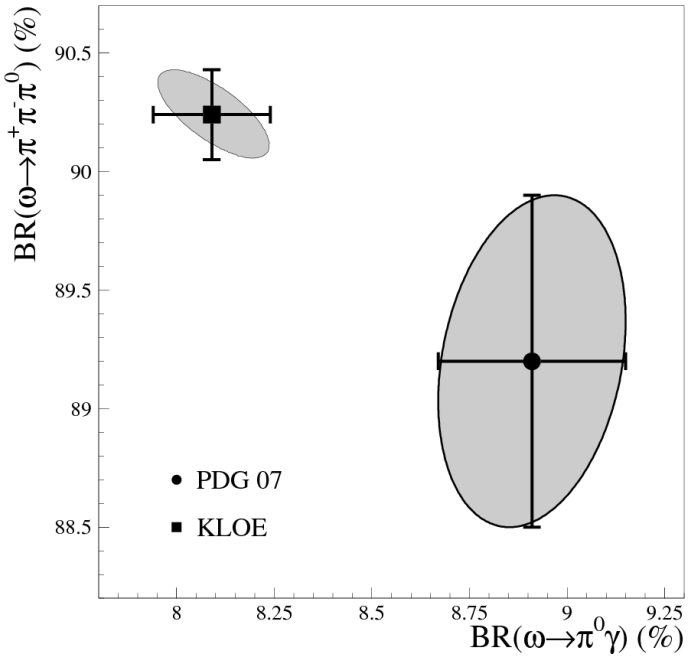
- $e^+e^- \to \pi^+\pi^-\pi^0\eta$
- $e^+e^- \to \omega\pi^0\eta$

$e^+e^- \to \pi^0\gamma$ (VEPP-2M data)

- Third largest cross section (after 2π and 3π) below 1 GeV
- Measurement of the $\pi^0\gamma^*\gamma$ transition form factor
- Measurement of the radiative decays $V \to \pi^0\gamma$, $V=\rho, \omega, \phi$ …
- There is a tension between the KLOE measurement of the ratio $\Gamma(\omega \to \pi^0\gamma)/\Gamma(\omega \to \pi^+\pi^-\pi^0)$ and other measurements of ω-meson parameters.

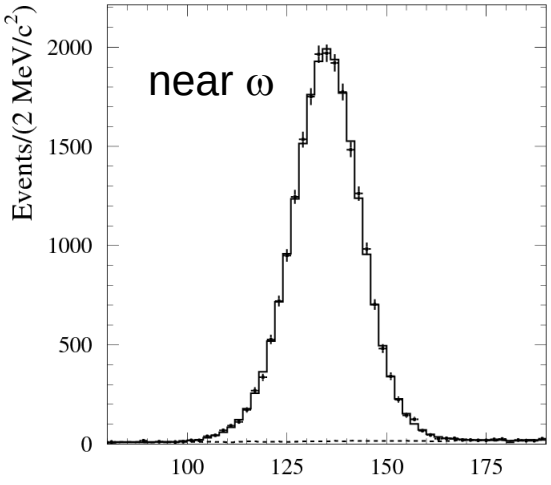
KLOE studies the $e^+e^- \to \omega\pi^0$ process near the ϕ-meson resonance in two ω decay modes.

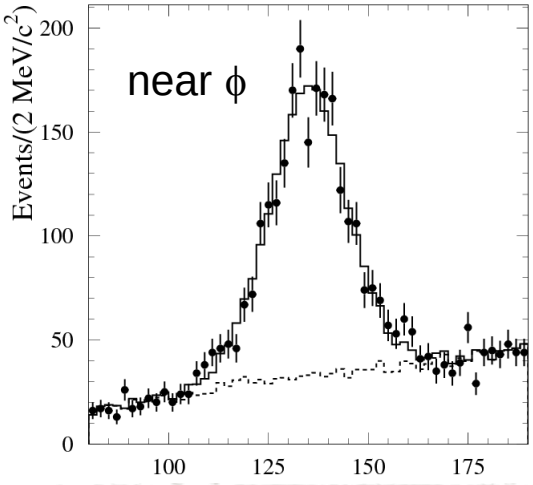
The KLOE measurement led to a large shifts of the previously measured ω-meson parameters, especially for $\omega \to \pi^0\gamma$.

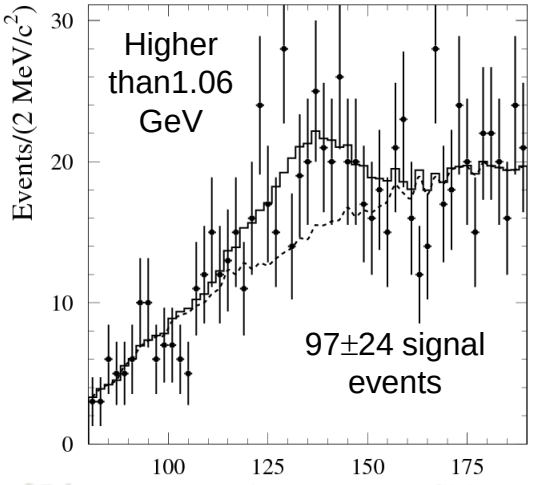


Analysis features

- The process $e^+e^- \to \gamma\gamma$ is used for normalization. Many selection criteria are common for 2γ and 3γ.
  - trigger, absence of charged tracks, cuts on the total energy deposition and event momentum, muon system veto.
- Final selection is based on 4C kinematic fit ($\chi^2_{3\gamma} < 30$, $36^\circ < \theta_\gamma < 144^\circ$, $80 < M_{rec} < 190$ MeV, where M_{rec} is the mass recoiling against largest energy photon).
- The number of $e^+e^- \to \pi^0\gamma$ events is determined from the fit to the M_{rec} spectrum







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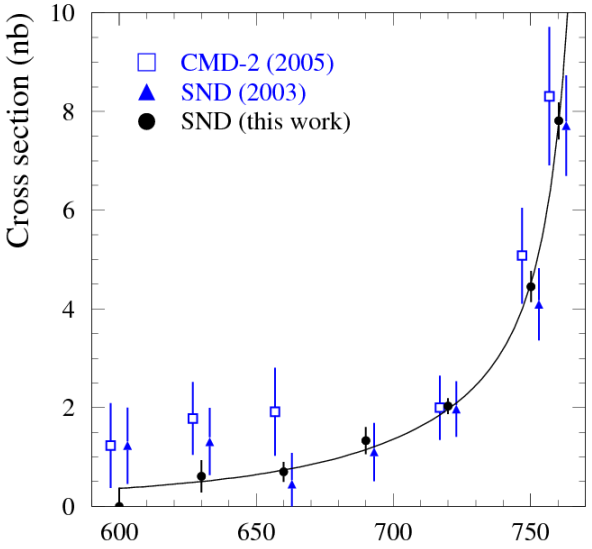
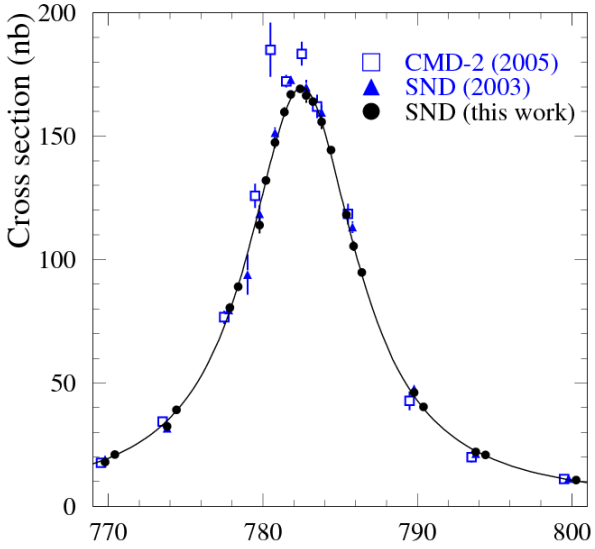
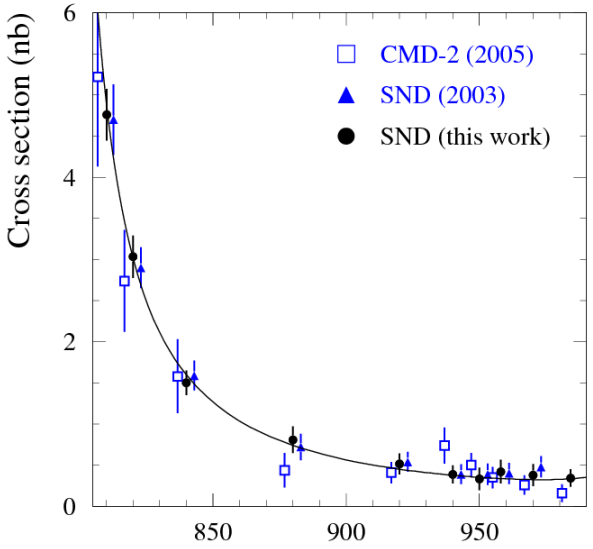
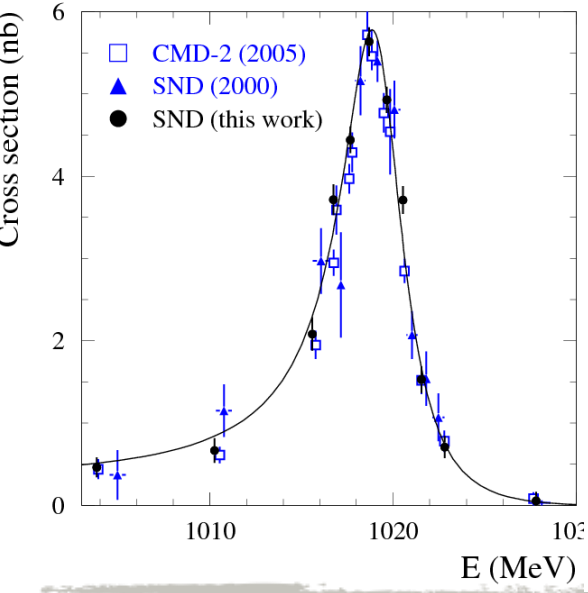
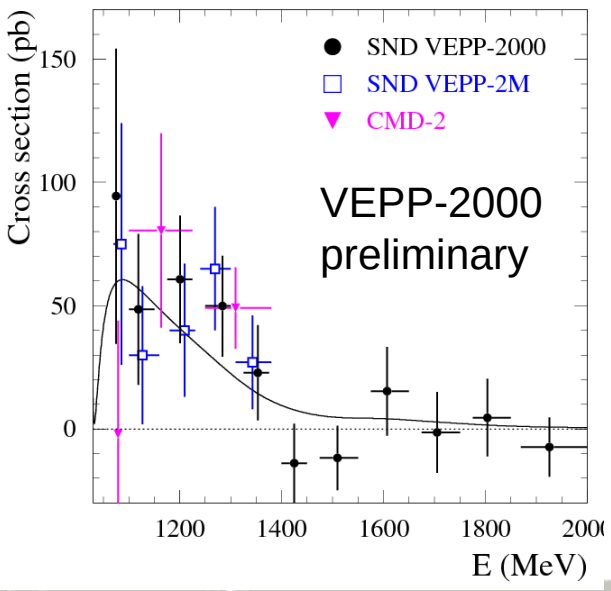
Born cross section











✓ The most precise measurement of the cross section

✓ Systematic uncertainty at the ω peak is 1.4% (1.2% from luminosity and 0.6% due to selection criteria)

Results on radiative decays

- $B(\omega \to \pi^0\gamma)B(\omega \to e^+e^-) = (6.336 \pm 0.056 \pm 0.089) \times 10^{-6}$

  Using PDG value for $B(\omega\to\pi^+\pi^-\pi^0)$ $B(\omega\to e^+e^-)$ we obtain $\Gamma(\omega\to\pi^0\gamma)/\Gamma(\omega\to\pi^+\pi^-\pi^0)$ =0.0992±0.0023, which is higher than the KLOE value 0.0897±0.0016 by 3.4σ

- $B(\rho \to \pi^0\gamma) = (4.20 \pm 0.47 \pm 0.22) \times 10^{-4}$

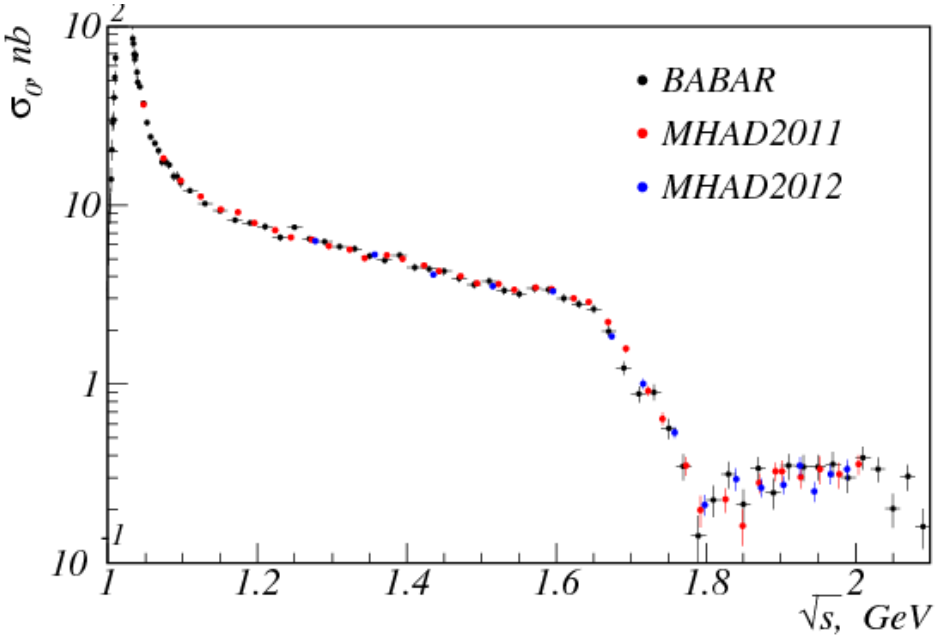
  By 1.8 σ lower than the current PDG value $(6.0\pm0.8)\times10^{-4}$, but agrees with the branching fraction for the charged mode $B(\rho^\pm \to \pi^\pm\gamma) = (4.5\pm0.5)\times10^{-4}$

- $B(\phi \to \pi^0\gamma)B(\phi \to e^+e^-) = (3.92^{+0.71}_{-0.40} \pm 0.51) \times 10^{-7}$

  The model uncertainties of the previous measurements (~8%) were underestimated. For φ_ϕ fixed at the value (163±7)° obtained in the VMD fit to $e^+e^-\to \pi^+\pi^-\pi^0$ data

$$B(\phi \to \pi^0\gamma)B(\phi \to e^+e^-) = (4.04 \pm 0.09 \pm 0.19) \times 10^{-7}$$

$e^+e^- \to K^+K^-$



Our measurement agrees with the BABAR data and has comparable or better accuracy.

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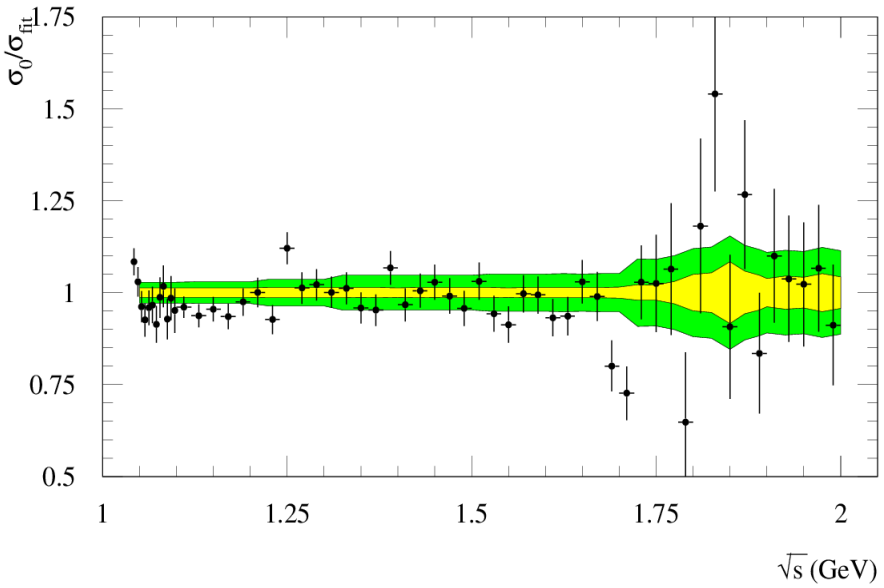
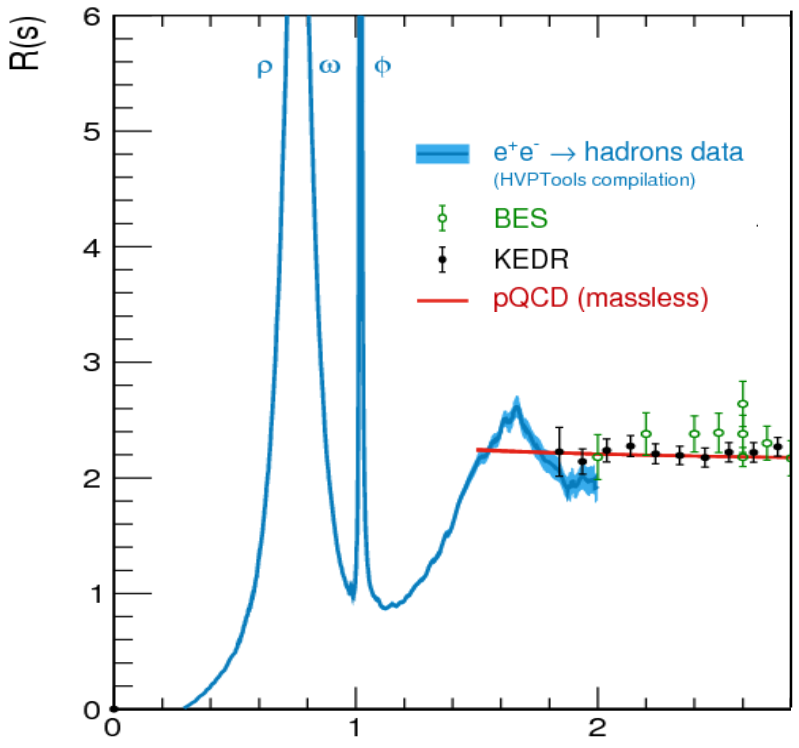
(BABAR data)/(SND fit) ratio



The green and yellow bands represent the BABAR and SND systematic uncertainties

Exclusive vs inclusive measurements

DHMZ , TAU 2016, arXiv:1612.02743

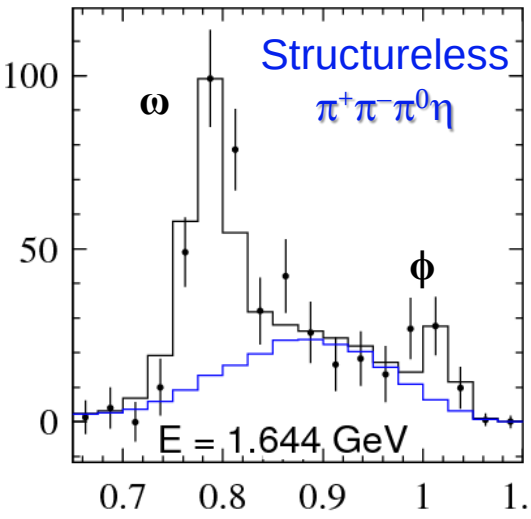


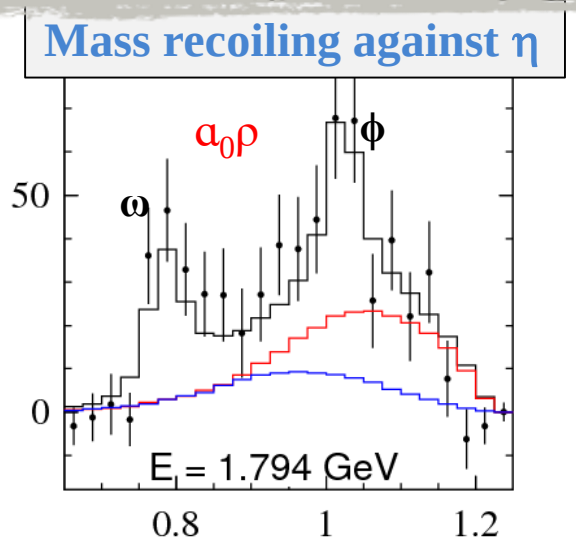
$$R(s) = \frac{\sigma(e^+e^- \to \gamma^* \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)}$$

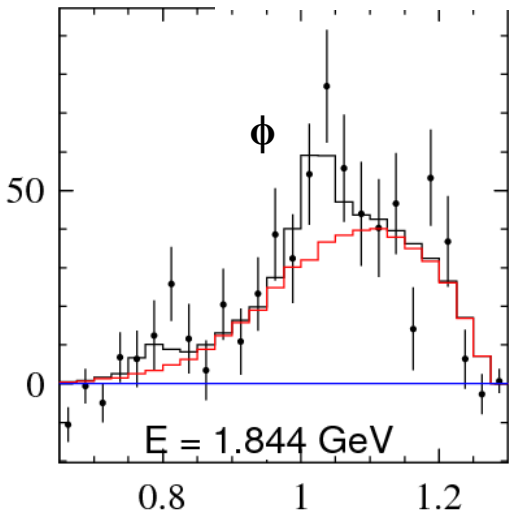
- At E < 2 GeV the total cross section is calculated as a sum of exclusive channels.
- The exclusive data are incomplete in the region 1.6<E<2.0 GeV.
- There is no experimental information on the final states $\pi^+\pi^-\pi^0\eta$, $\pi^+\pi^-\eta\eta$, $\pi^+\pi^-\pi^0\,\pi^0\pi^0$, $\pi^+\pi^-\pi^0\pi^0\eta$ …)
- The important experimental task is to measure all significant exclusive channels below 2 GeV, and perform comparison with inclusive measurements and pQCD prediction.

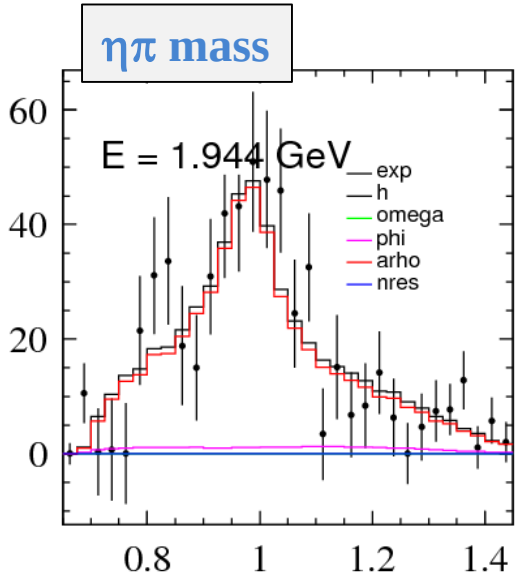
$e^+e^- \to \pi^+\pi^-\pi^0\eta$

preliminary



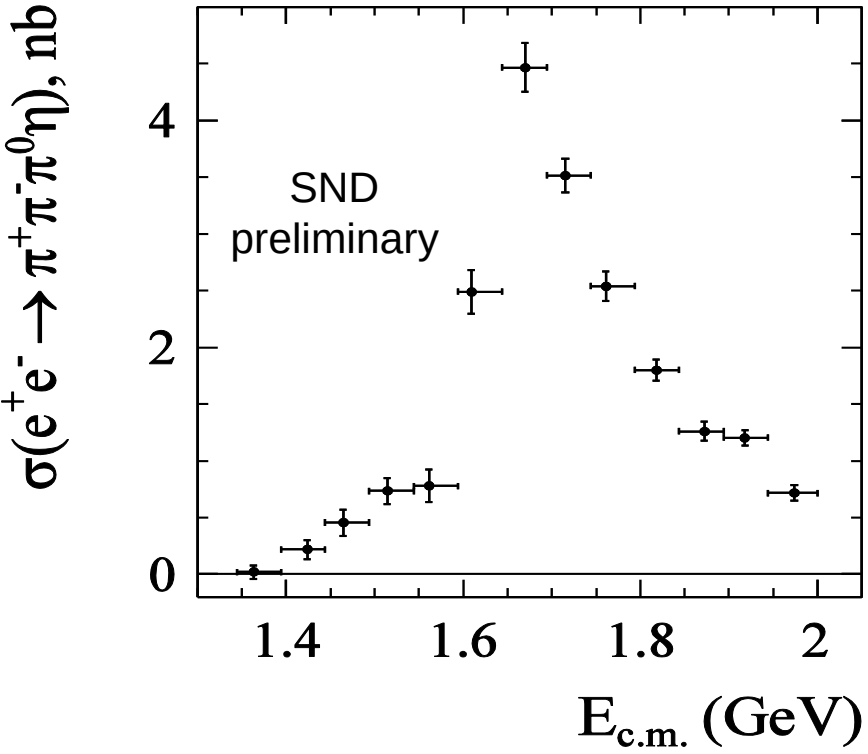




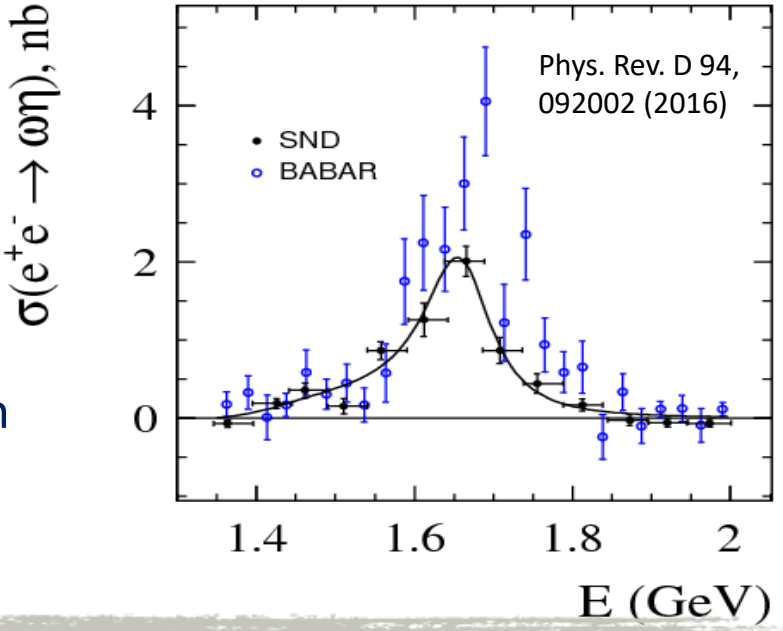


- **ωη** and **φη** intermediate states are clearly seen in the spectrum of the mass recoiling against **η**
- **a_0 (980)ρ** intermediate state is seen in the **ηπ** spectrum
- Some fraction of events at E below 1.8 GeV do not have any clear structure.

$e^+e^- \to \pi^+\pi^-\pi^0\eta$



- First measurement of this process
- The intermediate states are **ωη**, **φη**, **$a_0\rho$** and structureless $\pi^+\pi^-\pi^0\eta$
- The known **ωη** and **φη** contributions explain about 50-60% of the cross section below 1.8 GeV.
- Above 1.8 GeV the dominant reaction mechanism is **$a_0\rho$**



- The process $e^+e^- \to \omega\eta$ has been measured separately.
- There is a significant difference between our result and the previous BABAR measurement.

$e^+e^- \to \omega\pi^0\eta$ @ SND

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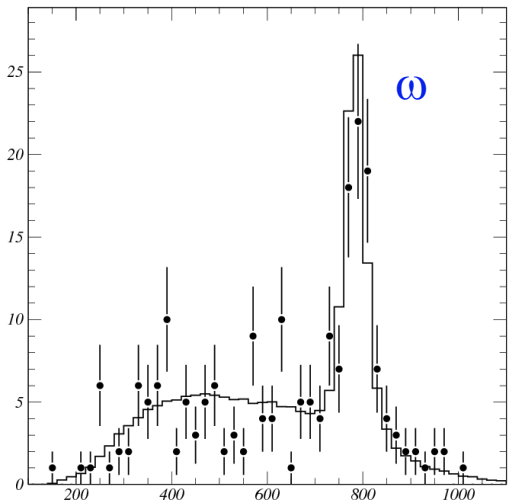
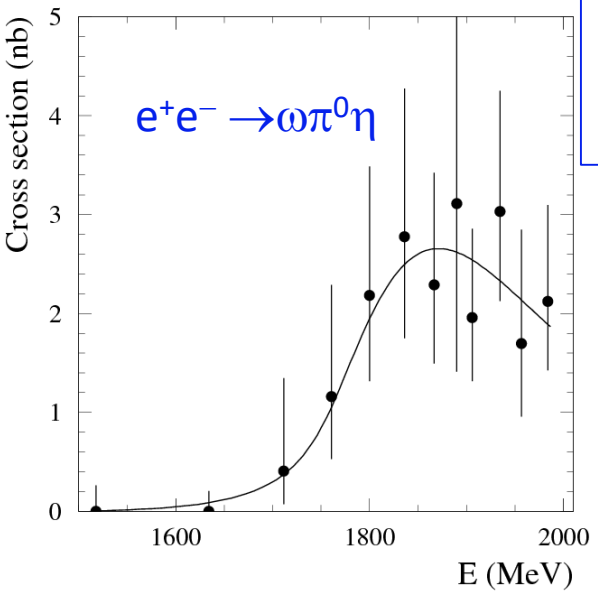
7 photon final state

$e^+e^- \to \pi^0\pi^0\eta\gamma \to 7\gamma$

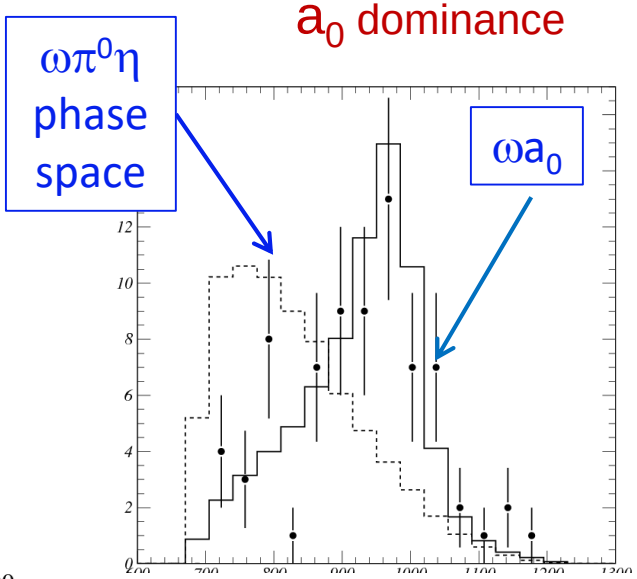


$\pi^0\gamma$ mass

Total cross section



a_0 dominance



$\eta\pi^0$ mass

- First measurement of the $e^+e^- \to \omega\pi^0\eta$ cross section.
- The dominant mechanism is $\omega a_0(980)$.
- The cross section is about 2.5 nb, 5% of the total hadronic cross section

Summary

- ✓ The SND detector accumulated ~120 pb^{-1} of integrated luminosity at the VEPP-2000 e^+e^- collider in the c.m. energy range 0.3 – 2 GeV.
- ✓ Data analysis on hadron production is in progress. The obtained results have comparable or better accuracy than previous measurements ($\omega\pi^0$, $\pi^+\pi^-\pi^0$, $\pi^+\pi^-\eta$, n anti-n, $\pi^0\gamma$, K^+K^-)
- ✓ For several processes the cross sections have been measured for the first time ($\eta\gamma$, $\pi^+\pi^-\pi^0\eta$, $\omega\pi^0\eta$)
- ✓ After VEPP-2000 upgrade, data taking was resumed, with a goal of ~1 fb^{-1} of integrated luminosity.