Recent results from SND detector at VEPP-2000 collider.

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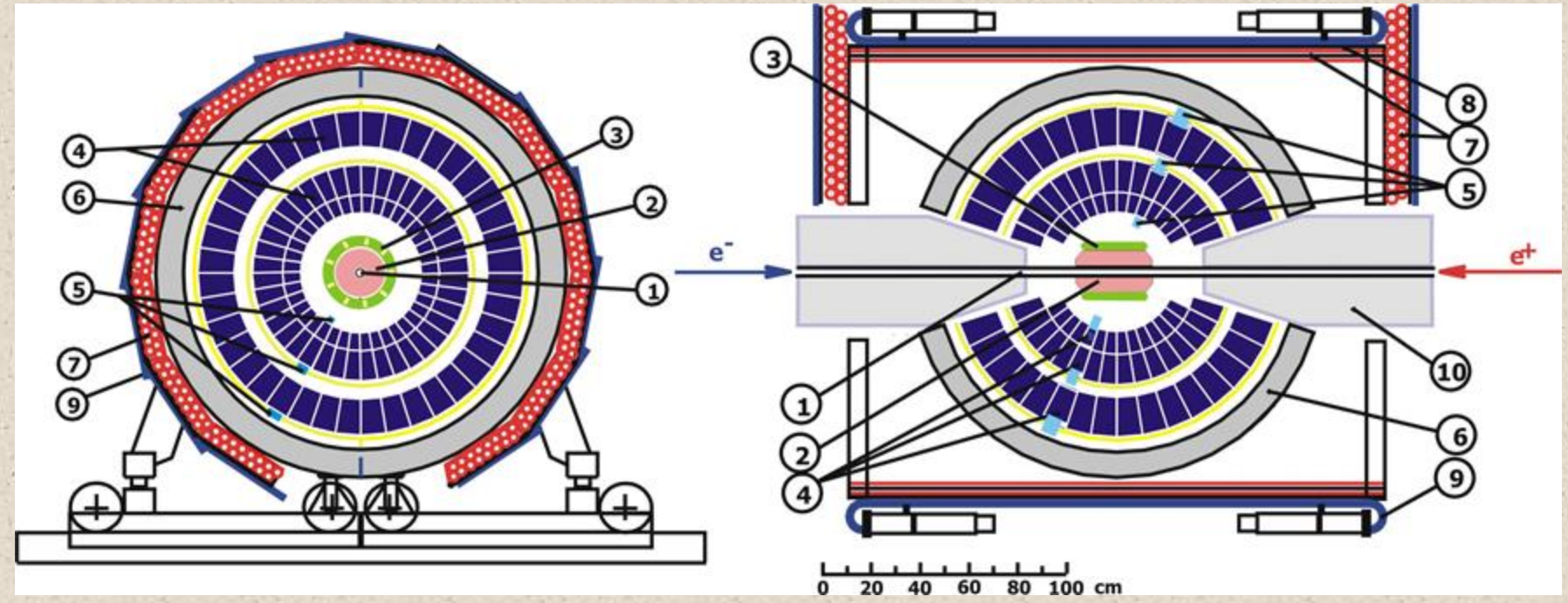
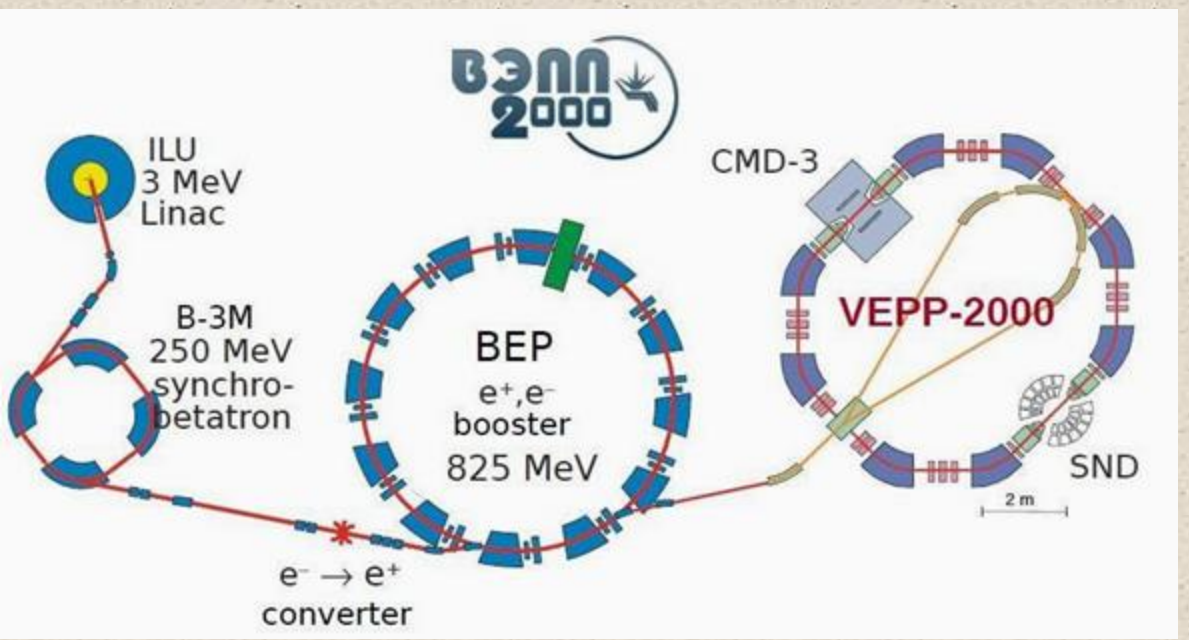
SND detector



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 VEPP-2M (1996-2000) and at VEPP-2000 (2010-2013)

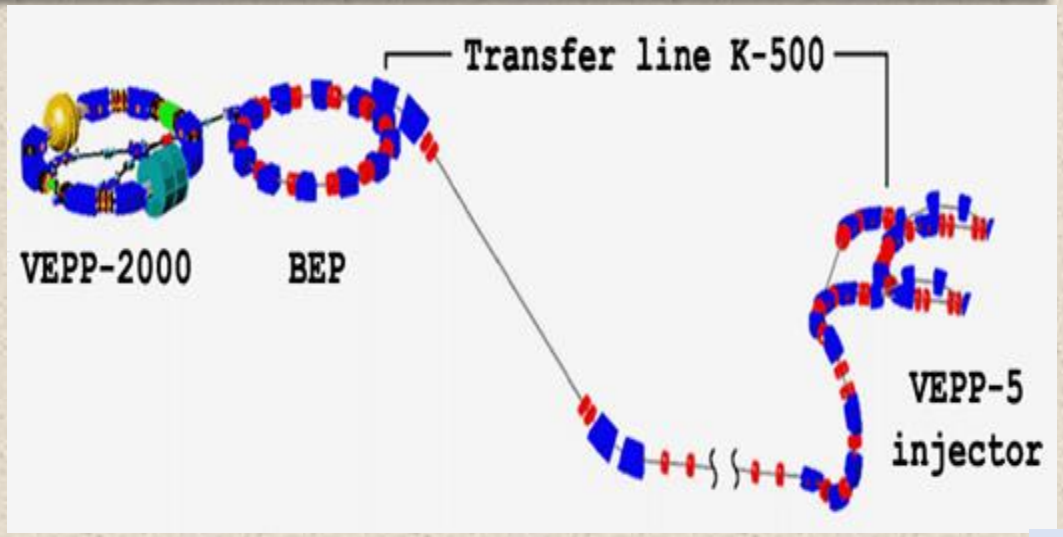
VEPP-2000 e^+e^- collider



- **VEPP-2000 parameters:**
- c.m. energy 0.3-2.0 GeV
- circumference – 24.4 m
- round beam optics
- Luminosity at 2 GeV
- $1´10^{32}$ cm^{-2} sec^{-1} (project)
- $2´10^{31}$ cm^{-2} sec^{-1} (achieved)

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

- ✓ Currently the VEPP-2000 complex is upgrading.
- ✓ Electrons and positrons are transported from the VEPP-5 injection complex through 250 m beamline.
- ✓ Experiments at upgraded VEPP-2000 are expected to be started in the end of 2016.



SND data

About 15 hadronic processes are currently under analysis.

VEPP-2M			
	Below φ	Arround φ	Above φ
IL, pb-1	9,1	13,2	8,8
√s, GeV	0,36 – 0,97	0,98 – 1,06	1,06 – 1,38

VEPP-2000			
	Below φ	Arround φ	Above φ
IL, pb-1	15,4	6,9	47,0
√s, GeV	0,30 – 0,97	0,98 – 1,05	1,05 – 1,38

Here we report the four results

Precision measurements

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

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

First measurements

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

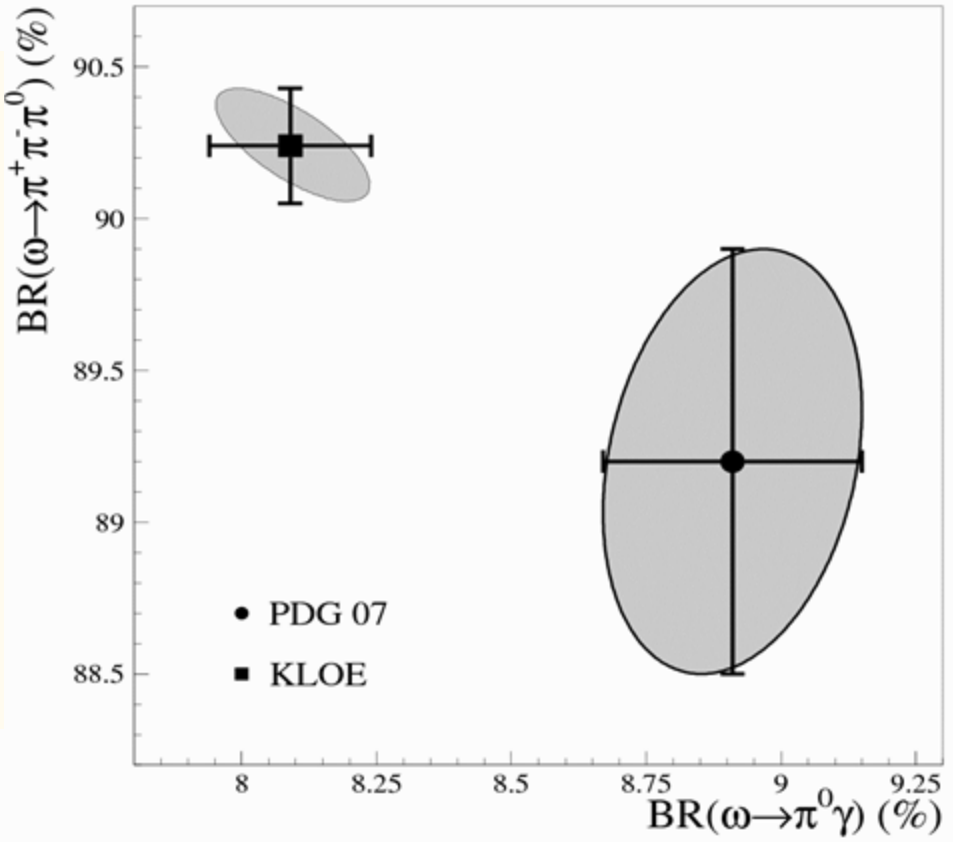
$e^+e^- \to \omega\,\pi^0\eta$

$e^+e^- \to \pi^0\gamma$ (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 $V \to \pi^0\gamma$, $V = \rho, \omega, \varphi, \ldots$
- 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 have studied the $e^+e^-\to\omega\pi^0$ process near the φ -meson resonance in two decay modes $\omega\to\pi^+\pi^-\pi^0$ a nd $\omega\to\pi^0\gamma$

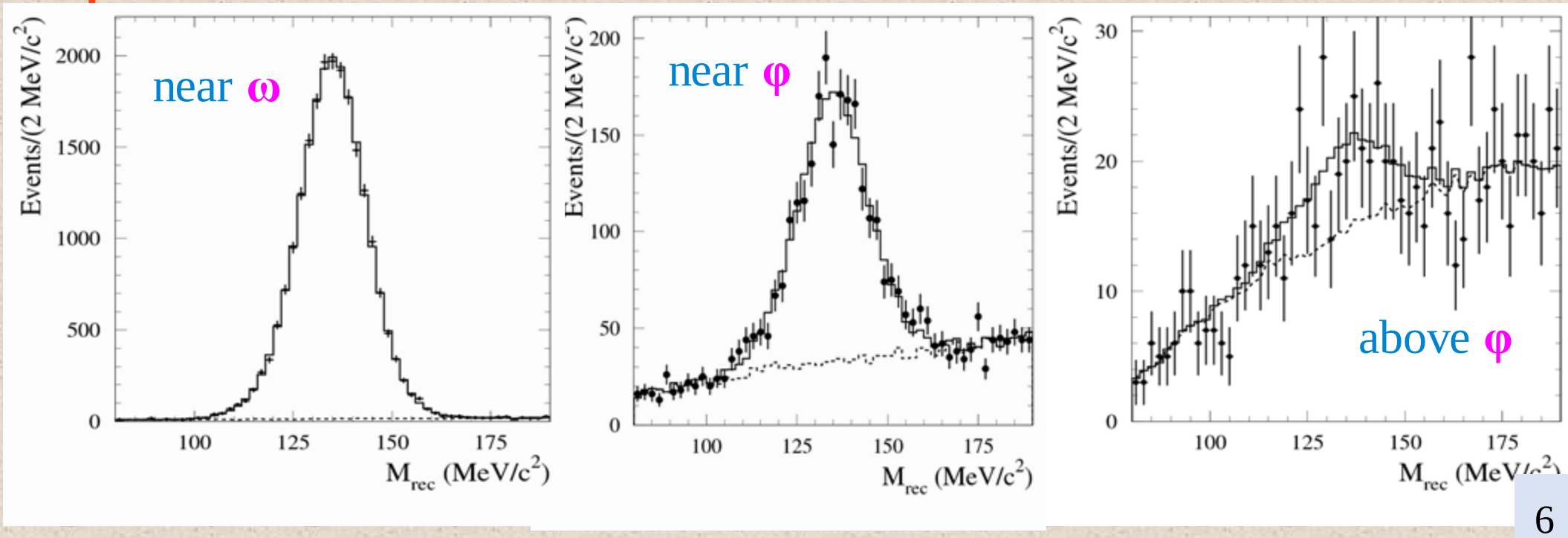
The ω -meson parameters obtained through KLOE studies have a large shifts from the previously measurements, especially for $\omega\to\pi^0\gamma$ decay.



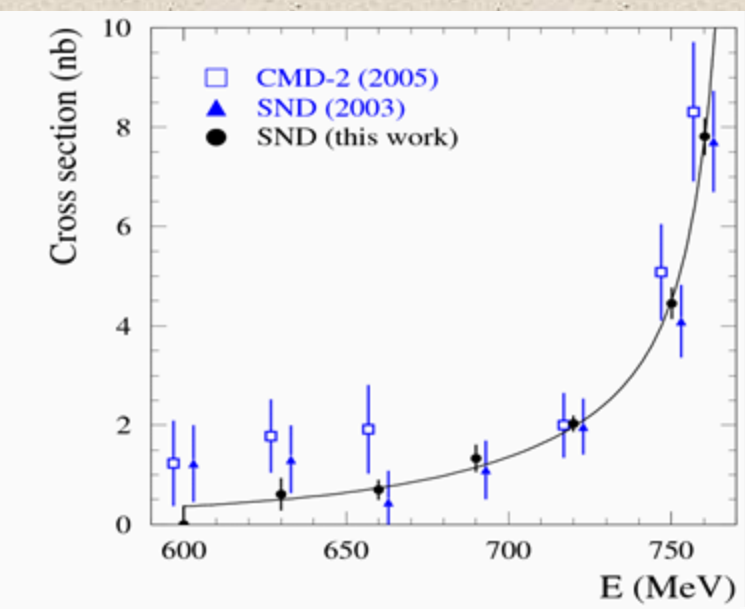
F. Ambrosino, et. al.,
Phys. Lett. B 665 (2008) 223-228

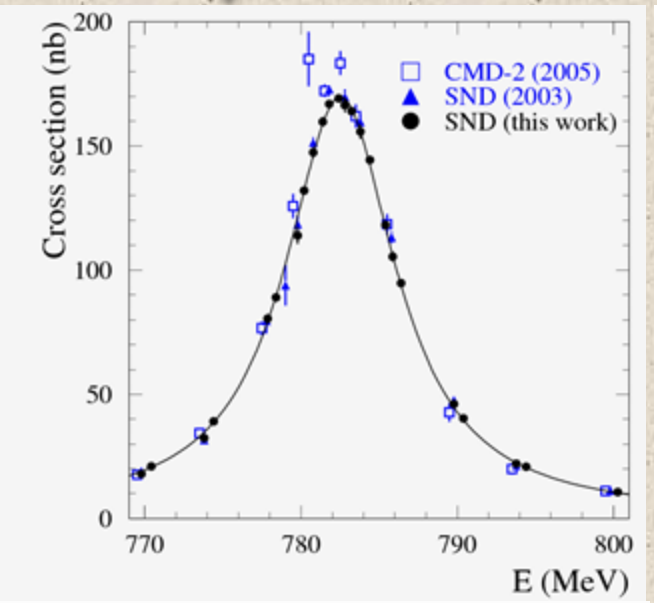
Analysis features

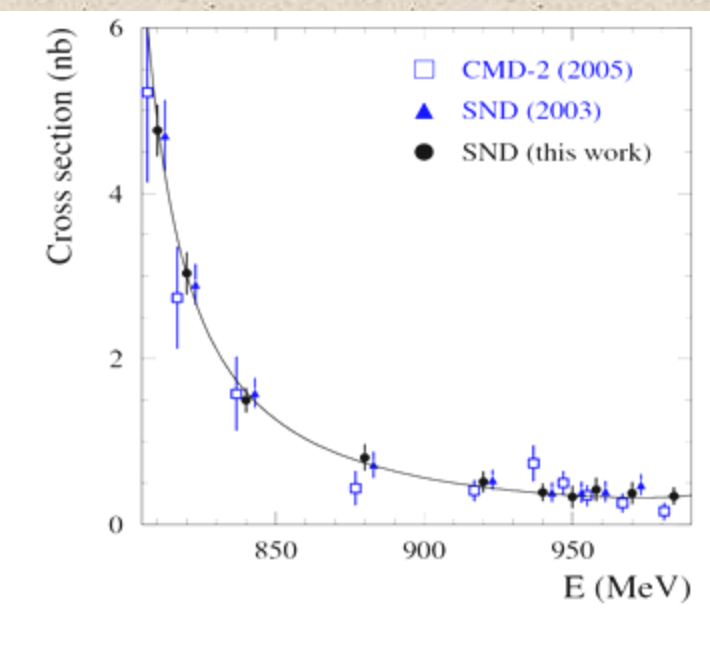
- The process $e^+e^- \to \gamma\gamma$ is used for normalization. Many selection criteria are common for 2γ and 3γ final states:
  - trigger, absence of charged tracks, cuts on the total energy deposition and event momentum, muon system veto.
- Final selection is **based on 4C kinematic fit : $\chi^2_{3\gamma} < 30$, $36° < \theta_\gamma < 144°$, $80 < M_{rec} < 190$ 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 of M_{rec} spectrum.**

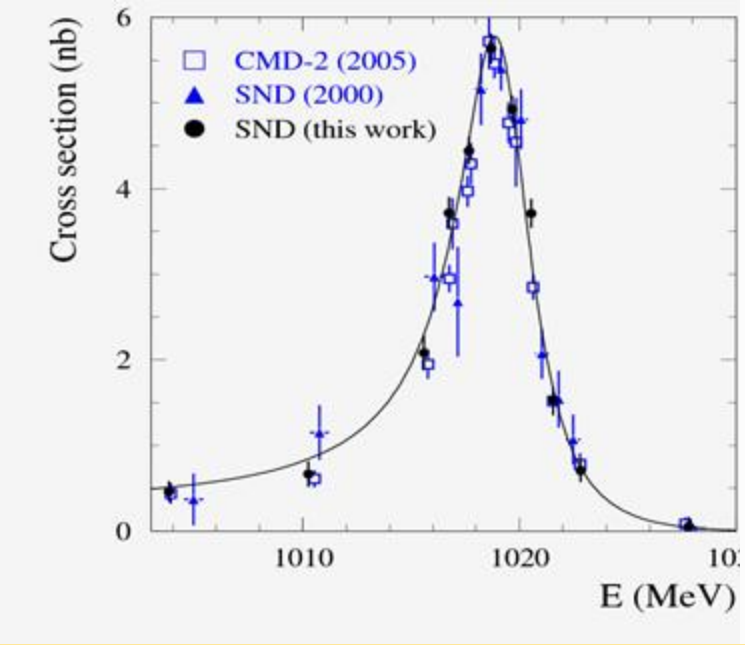


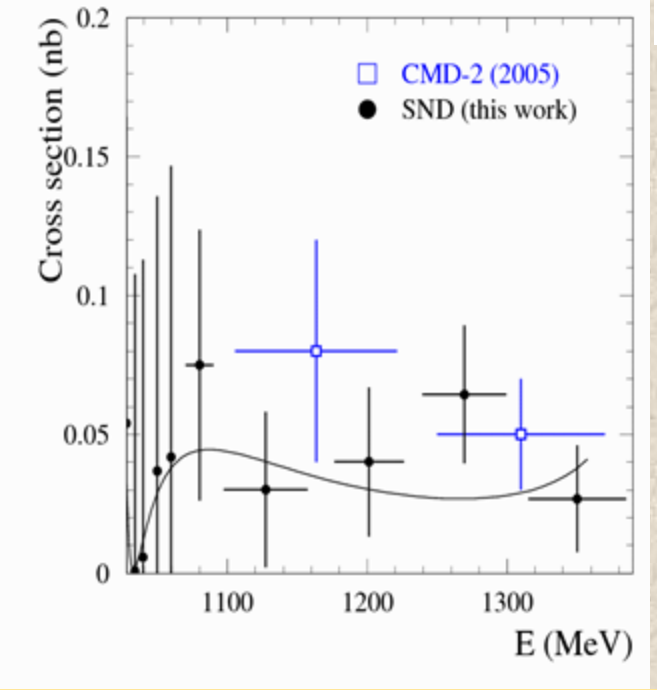
$e^+e^- \to \pi^0\gamma$ cross section











- The most precise measurement of the $e^+e^- \to \pi^0\gamma$ cross section.
- Systematic uncertainty at the ω peak is **1.4%** (**1.2%** from luminosity and **0.6%** due to selection criteria)

M.N. Achasov, et. al., Phys. Rev. D 93 092001 (2016)

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 have obtained $\Gamma(\omega\to\pi^0\gamma)/\Gamma(\omega\to\pi^+\pi^-\pi^0)=0.0992\pm0.0023$, which is higher than the KLOE value **0.0897±0.0016** by **3.4σ .**

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

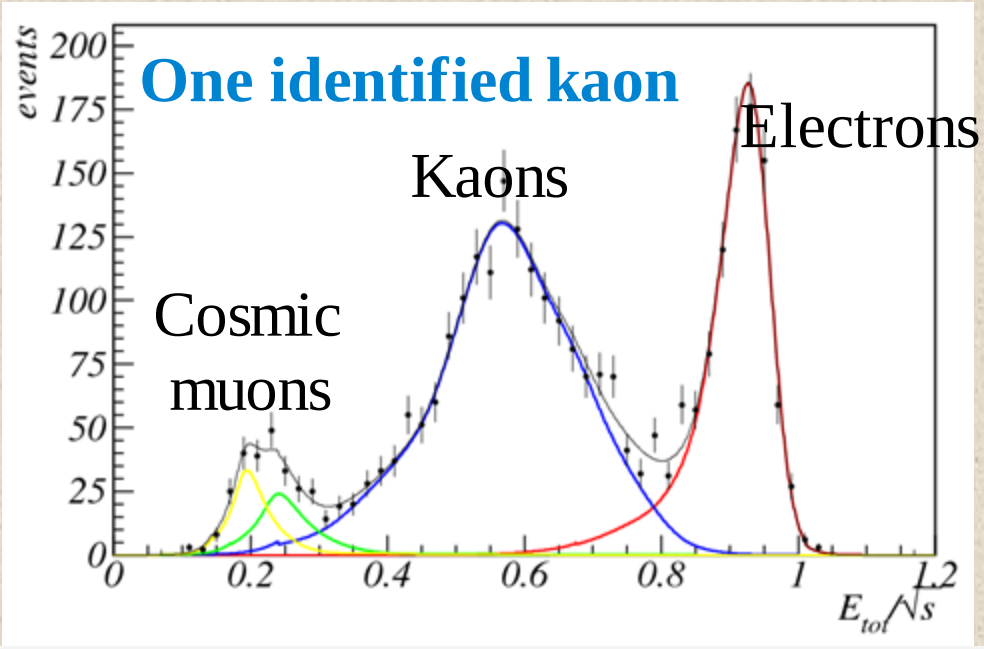
By **1.8σ** lower than the current PDG value $(6.0\pm0.8)\times10^{-4}$, but agrees with the branching fraction for the charged mode $B(\rho^\pm \to \pi^\pm\gamma) = (4.5\pm0.5)\times10^{-4}$.

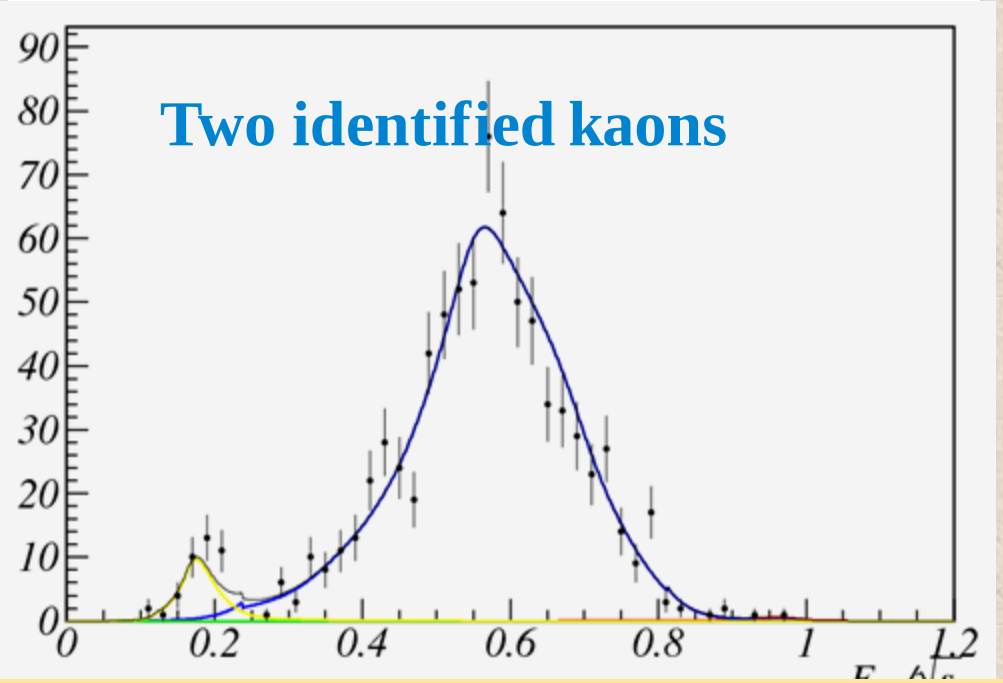
$$B(\phi \to \pi^0\gamma)B(\phi \to e^+e^-) = (3.92^{+0.71}_{-0.40} \pm 0.51) \times 10^{-7}$$

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

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

$e^+e^- \rightarrow K^+K^-$

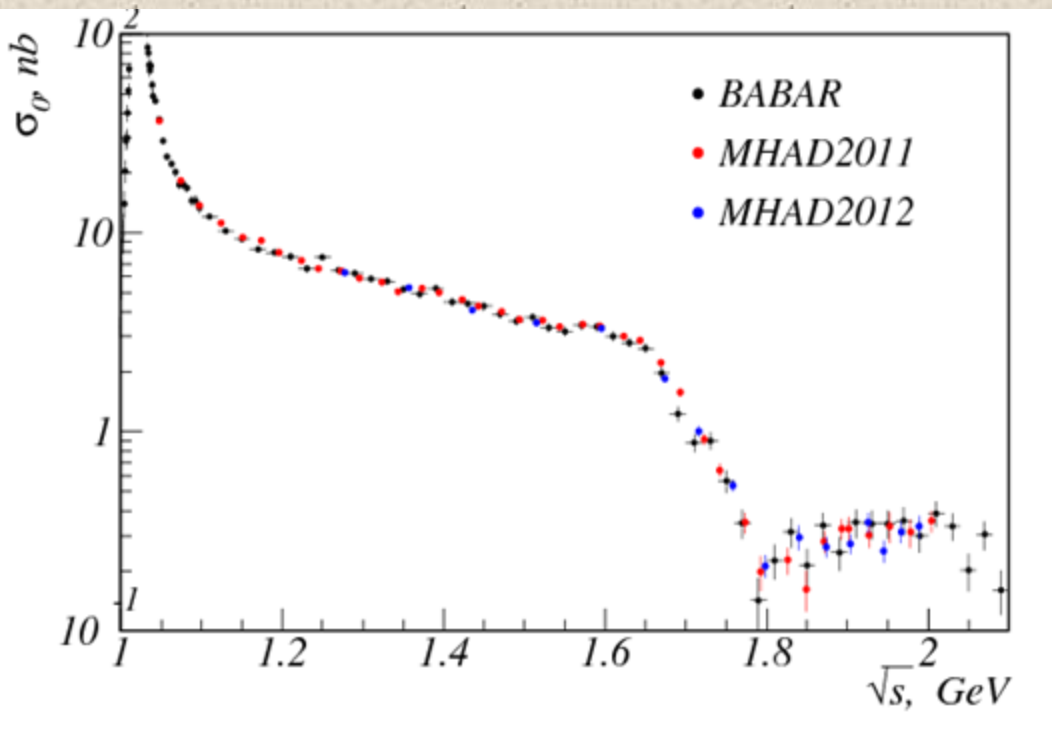




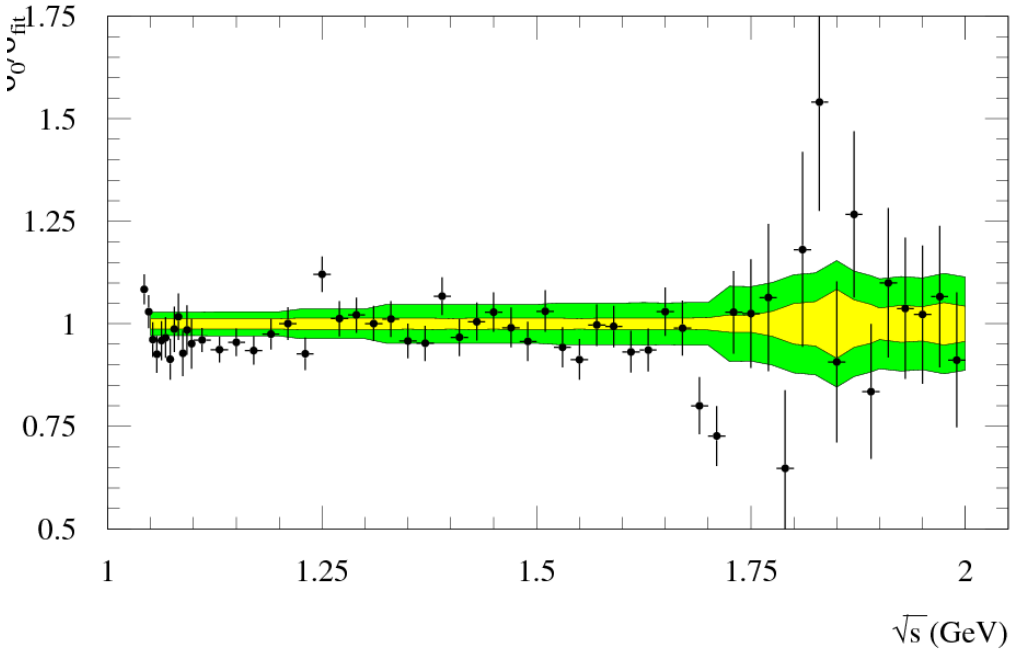
Total energy deposition in calorimeter normalized by c.m. energy

- Kaon identification is based on information from Cherenkov aerogel counters.
- Kaons do not produce Cherenkov signal in the counter, while electron, muon and pions do.
- The kaon ID requirement suppresses background from $e^+e^- \rightarrow e^+e^-$ by a factor of 300.

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



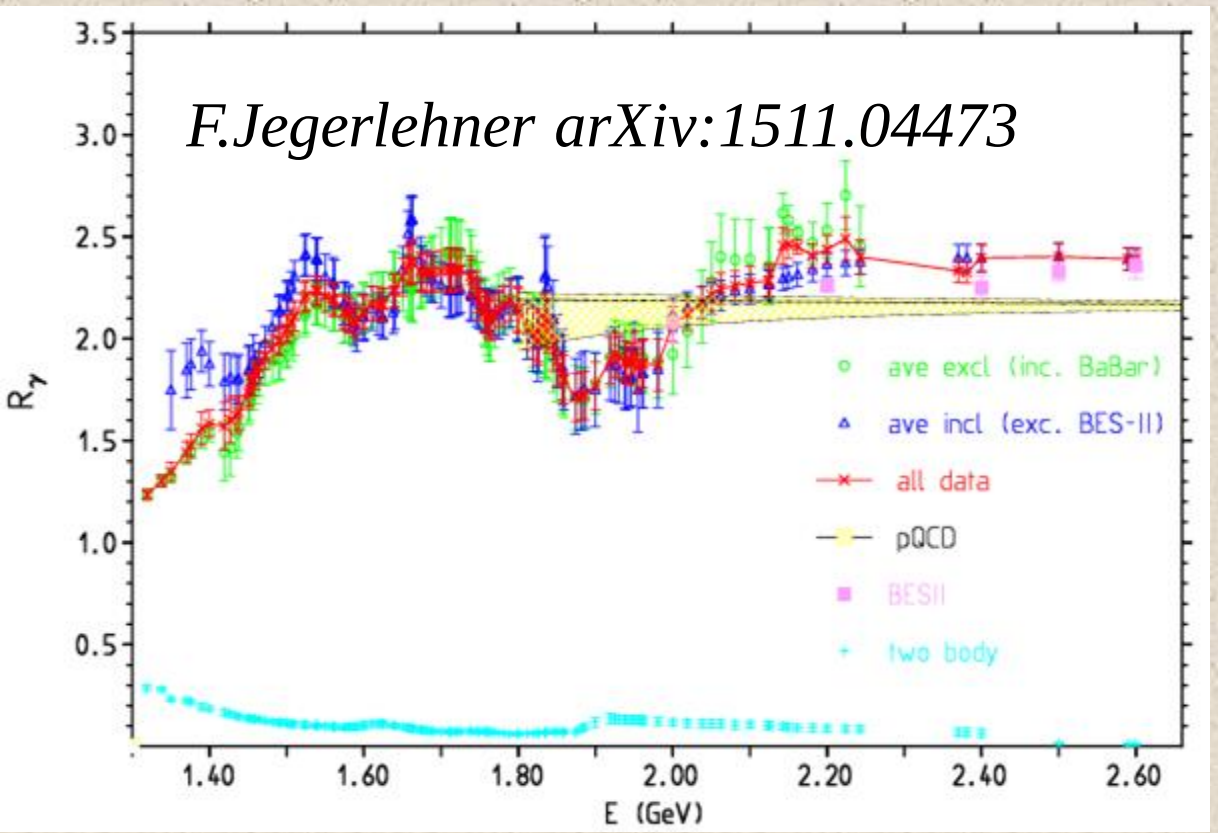
SND measurement agrees with the BABAR data and has comparable or better accuracy.



(BABAR data)/(SND fit) ratio

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

Exclusive vs inclusive measurements

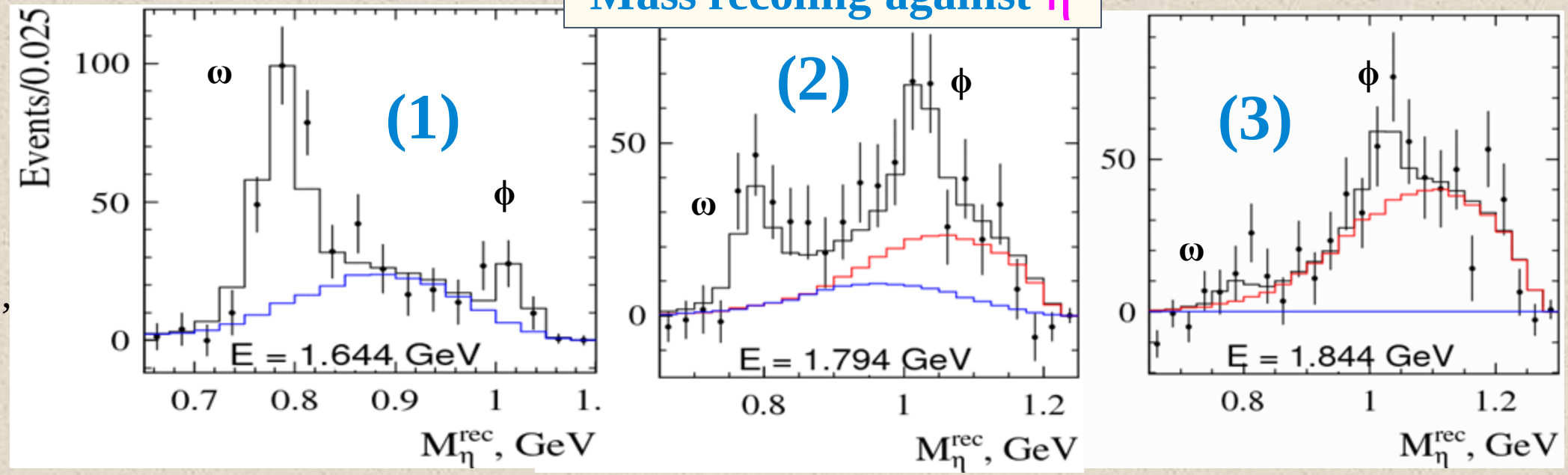


- Below **2 GeV** the total hadronic cross section is calculated as a sum of exclusive cross sections.
- Currenly the exclusive and inclusive data below **2 GeV** are in reasonable agreement.

In the energy region 1.5-2.0 GeV exclusive data are incomplete. There is no experimental data on the final states $\pi^+\pi^-\pi^0\eta$, $\pi^+\pi^-\eta\eta$, $\pi^+\pi^-\pi^0\,\pi^0\pi^0$, $\pi^+\pi^-\pi^0\pi^0\eta$ …

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

Mass recoling against η



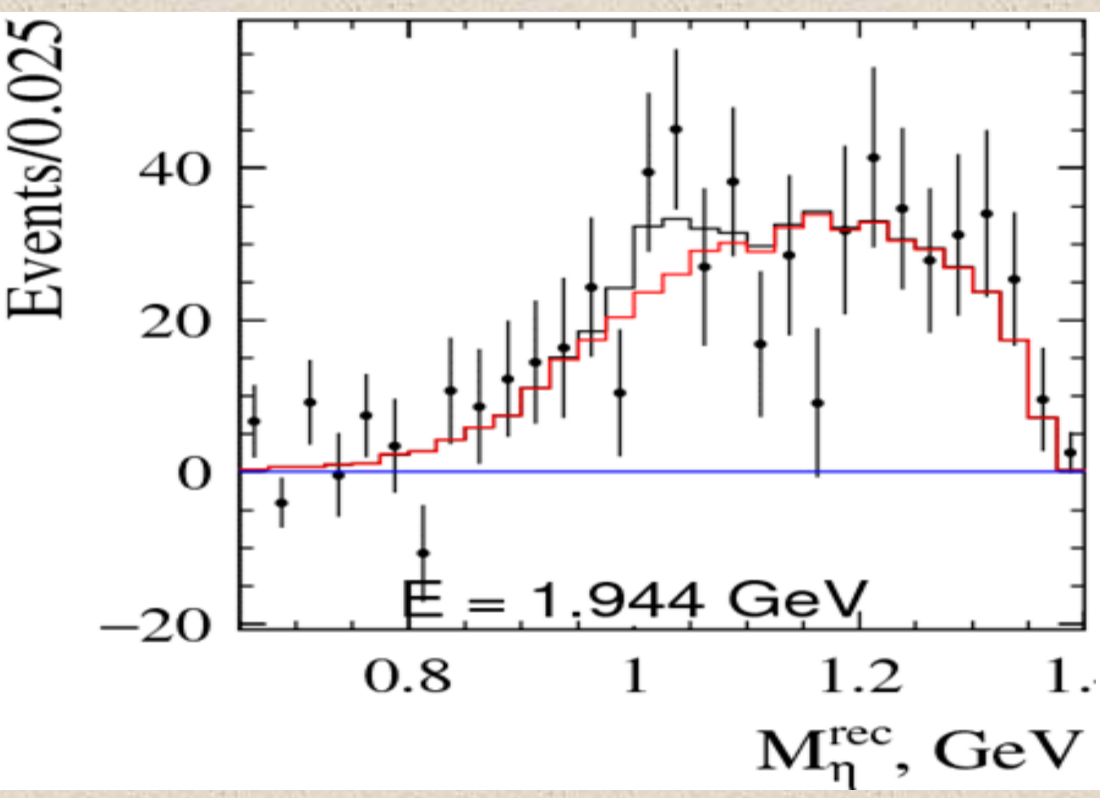
(1) The spectrum can be fitted by sum of **ωη, ϕη** and structureless $\pi^+\pi^-\pi^0\eta$ (blue histogram) contributions.

(2) The spectrum can be fitted by sum of **ωη, ϕη** structureless $\pi^+\pi^-\pi^0\eta$ and $\mathbf{a_0(980)\rho}$(red histogram) contributions.

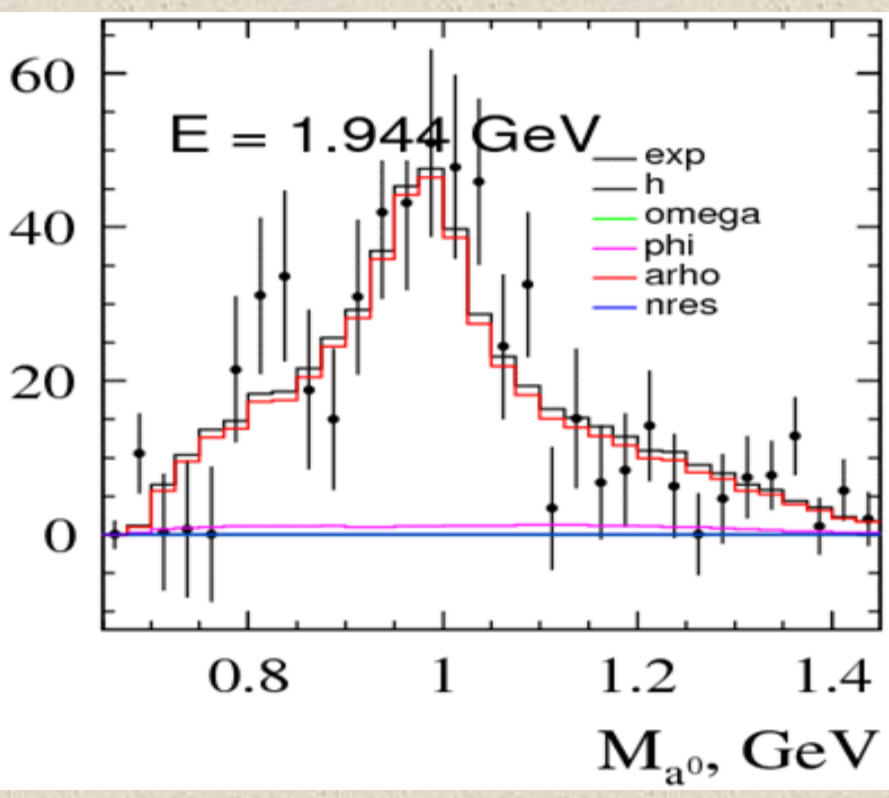
(3) The spectrum can be fitted by sum of **ϕη** and $\mathbf{a_0(980)\rho}$ contributions.

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

Mass recoling against η

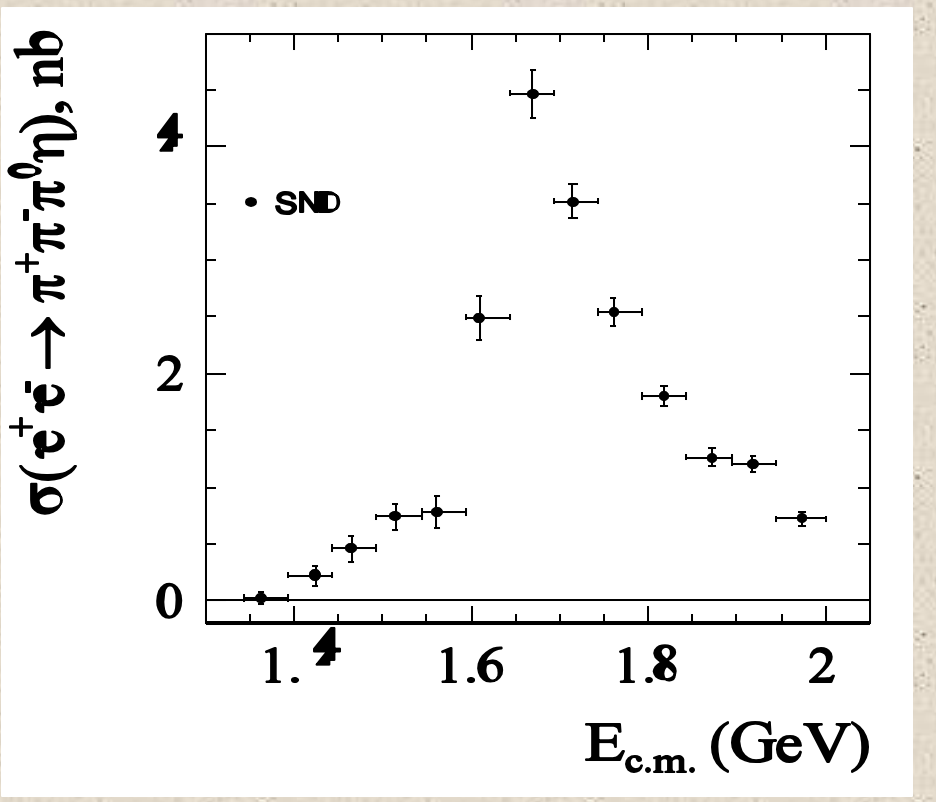


$\eta\rho$ invariant mass.



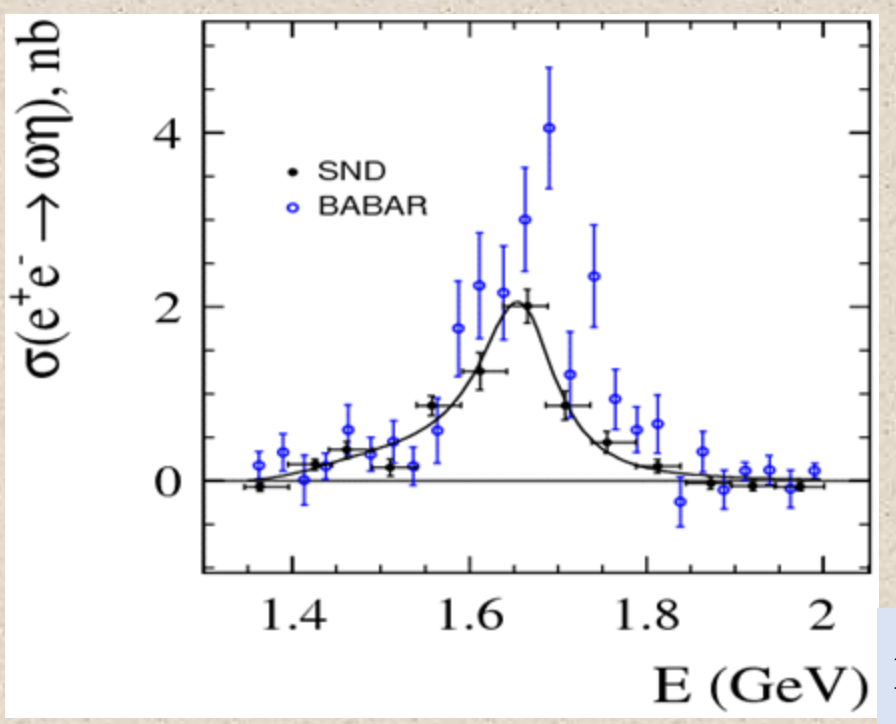
Above **1.8 GeV** the dominant reaction mechanism is **$a_0(980)\rho$.**

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

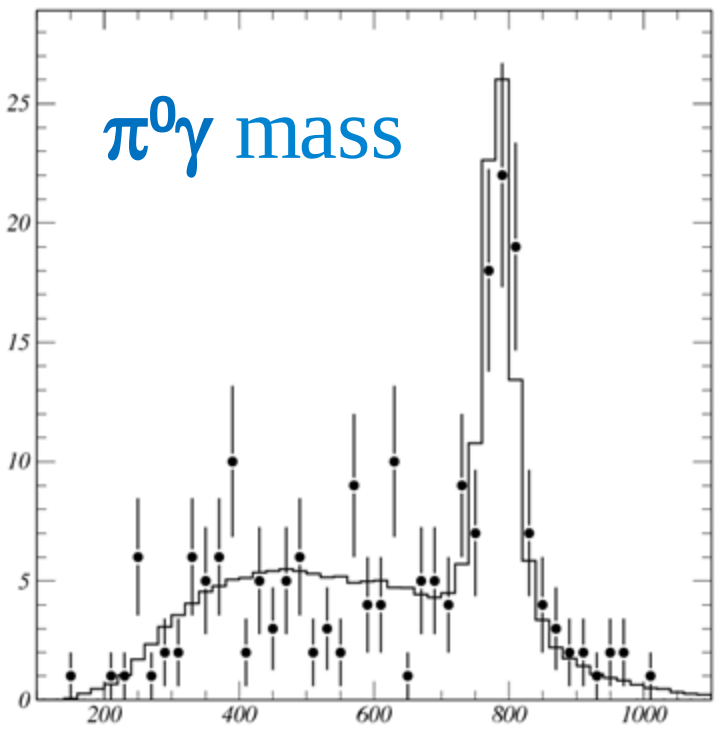


- First measurement of this process.
- Intermediate states are $\omega\eta$, $\phi\eta$, strucureless $\pi^+\pi^-\pi^0\eta$ and $a_0(980)\rho$.
- The known $\omega\eta$ and $\phi\eta$ contributions explain about 50-60% of the cross section below **1.8 GeV**.
- Above **1.8 GeV** the dominant reaction mechanism is $a_0(980)\rho$.

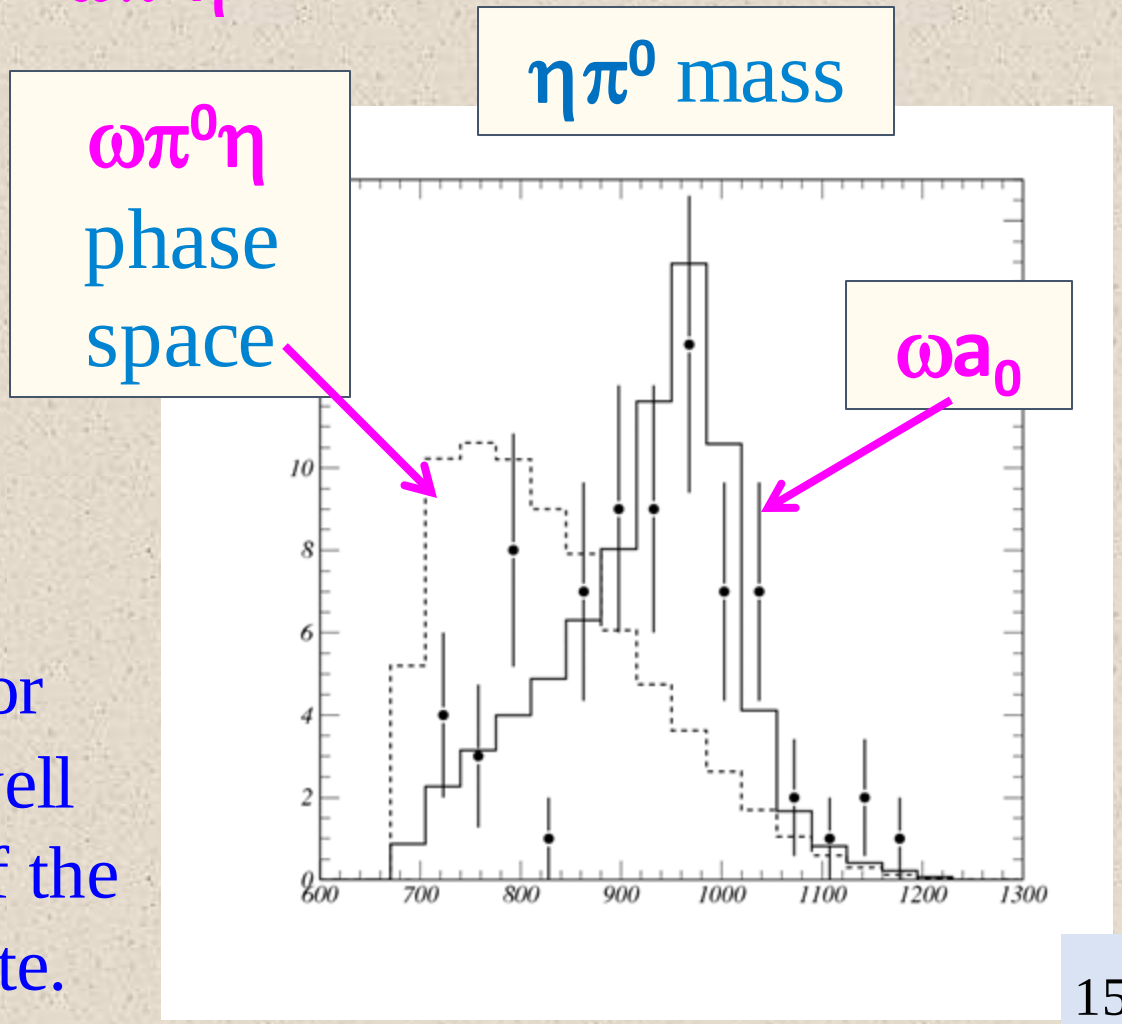
- The process $e^+e^- \to \omega\eta$ has been measured separately.
- There is a significant difference between **SND** result and the previous **BABAR** measurement.



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

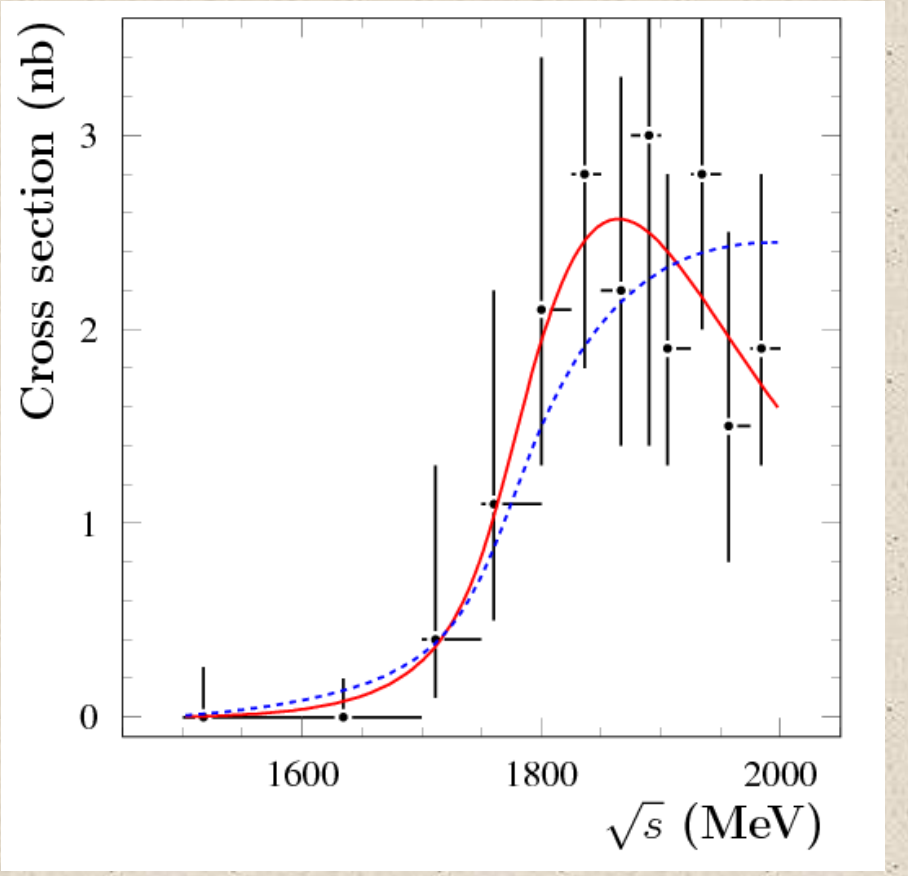


- Events of the $e^+e^- \to \pi^0\pi^0\eta\gamma \to 7\gamma$ process are selected.
- The dominant intermediate state is $\omega\pi^0\eta$



The $\eta\pi^0$ mass spectrum for selected $\omega\pi^0\eta$ events is well described by the model of the $\omega a_0(980)$ intermediate state.

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



- First measurement of the $e^+e^- \to \omega\pi^0\eta$ cross section.
- The dominant reaction mechanism is $\omega a_0(980)$.
- The cross-section energy dependence is fitted by **two** models.
- **Red** line corresponds to a single-resonance model. The resonance's parameters are consistent with those for $\rho(1700)$.
- **Blue** line corresponds to $\omega a_0(980)$ phase space model.
- **Both** models are consistent with data.

The cross section is about **2.5 nb**, **5%** of the total hadronic cross section in the energy region **1.8 – 2.0 GeV**.

Conclusions

- During **2010 – 2013** the **SND** detector accumulated **~70 pb^{-1}** of integrated luminosity at the **VEPP-2000** electron-positron 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 the data taking runs will be continued with a goal of **~1 fb^{-1}** of integrated luminosity.