Recent results from the SND detector
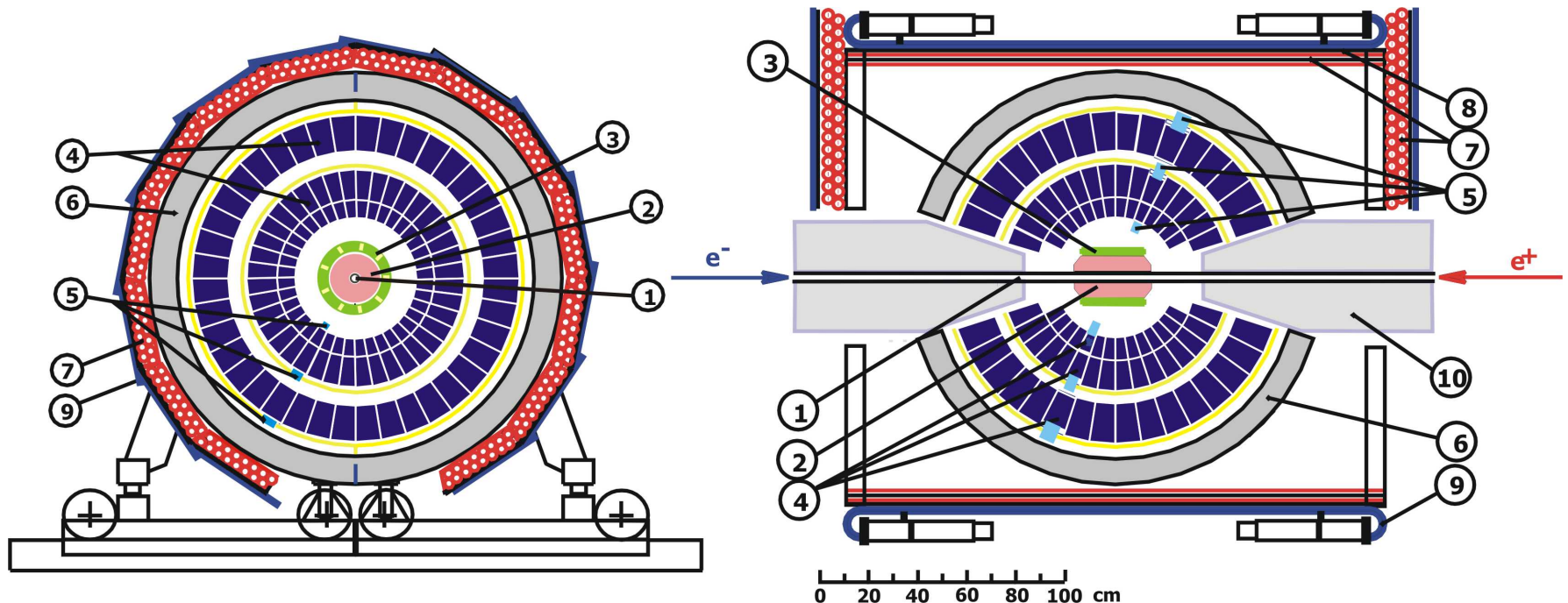
Aleksandr Korol
Budker Institute of Nuclear Physics, Novosibirsk
(on behalf of the SND collaboration)

27.10.2016

Advances in Dark Matter and Particle Physics
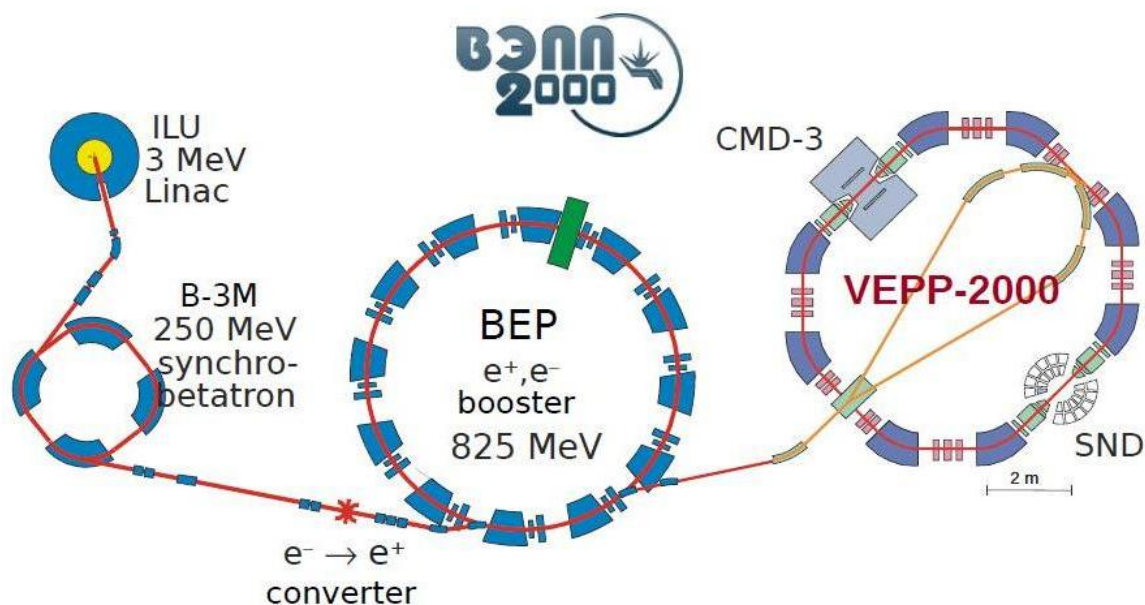*Messina, Italy*

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.

Calorimeter: 0.95×4π, 13.4X0, δE/E= 0.042/$\sqrt[4]{E(GeV)}$, δφ=1.5°. Tracking system: 0.94×4π, δφ=0.45°, δθ=0.8°

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

VEPP-2000 e⁺e⁻ collider

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

Upgrade of the VEPP-2000 complex:

- Electrons and positrons are transported from the VEPP-5 injection complex through 250 m beamline.
- Experiments at upgraded VEPP-2000 are expected to begin by the end of 2016.
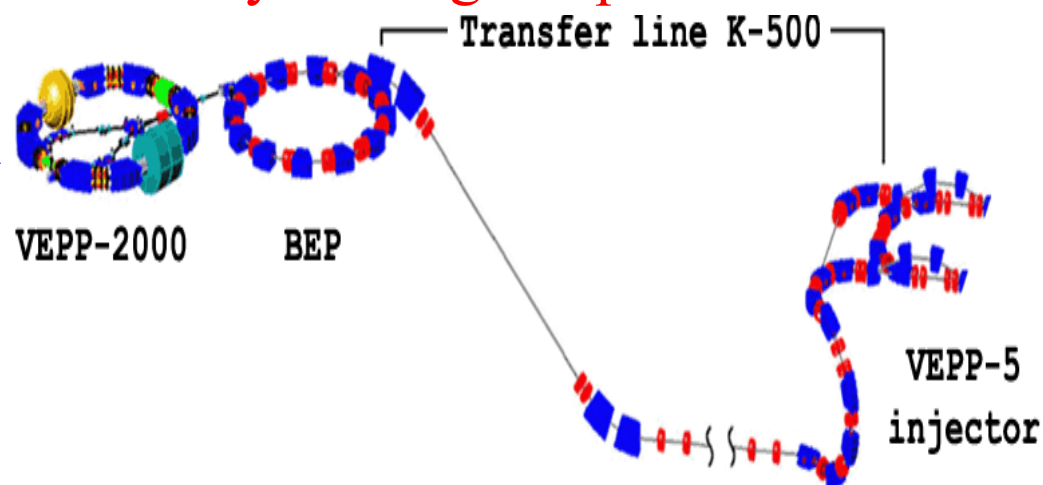
SND data

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			
IL, pb-1	15.4	6.9	47.0
√s, GeV	0.30 – 0.97	0.98 – 1.05	1.05 – 2.00

About 15 hadronic processes are currently under analysis.

Here we report the four new measurements and one update.

Precision measurements

$e^+e^- \to \pi^{\circ}\gamma$ (VEPP-2M data)

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

$e^+e^- \to \omega \to \pi^{\circ}\pi^{\circ}\gamma$ (update)

First measurements

$e^+e^- \to \pi^+\pi^-\pi^{\circ}\eta$

$e^+e^- \to \omega\pi^{\circ}\eta$

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

- Third largest cross section (after **2π** and **3π**) below **1 GeV**
- Measurement of the **π°γ*γ** transition form factor
- Measurement of the radiative decays **V→ π°γ** , **V= ρ, ω, φ, ...**
- There is a tension between the **KLOE** measurement of the ratio **Γ(ω→π°γ)/Γ(ω→π⁺π⁻π°)** and other measurements of **ω**-meson parameters:

KLOE have studied the **e⁺e⁻→ωπ°** process near the **φ**-meson resonance in two decay modes **ω→π⁺π⁻π°** and **ω→π°γ**.

The **ω**-meson parameters obtained through KLOE studies have a large shifts from the previously measurements, especially for **ω→π°γ** decay.

F. Ambrosino, et. al.,
Phys. Lett. B 665 (2008) 223-228
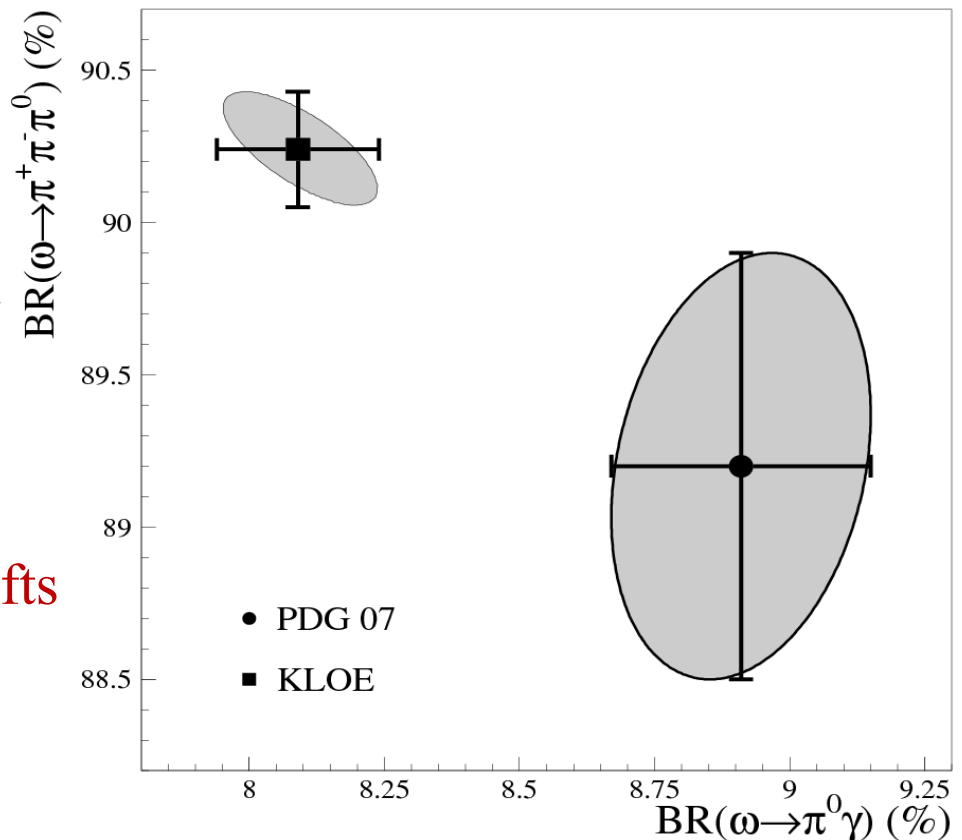
$e^+e^- \rightarrow \pi^\circ\gamma$: analysis features

The process $e^+e^- \rightarrow \gamma\gamma$ is used for normalization.

Common selection criteria for 2γ and 3γ final states:
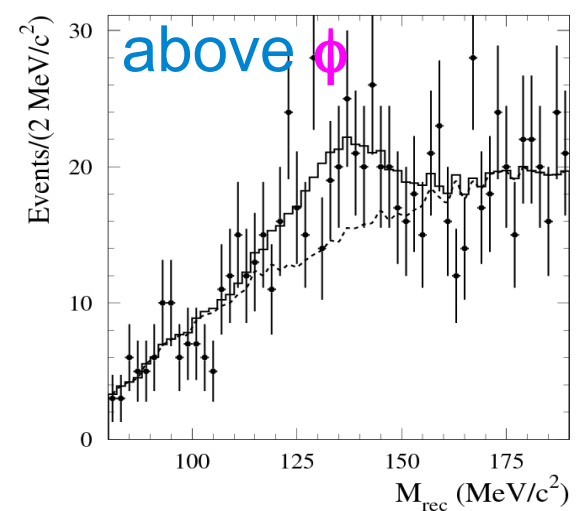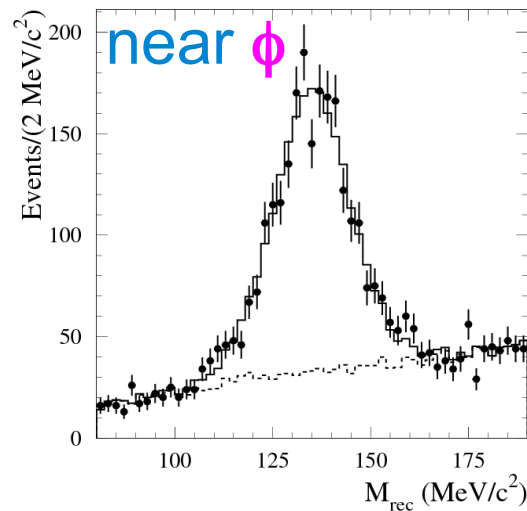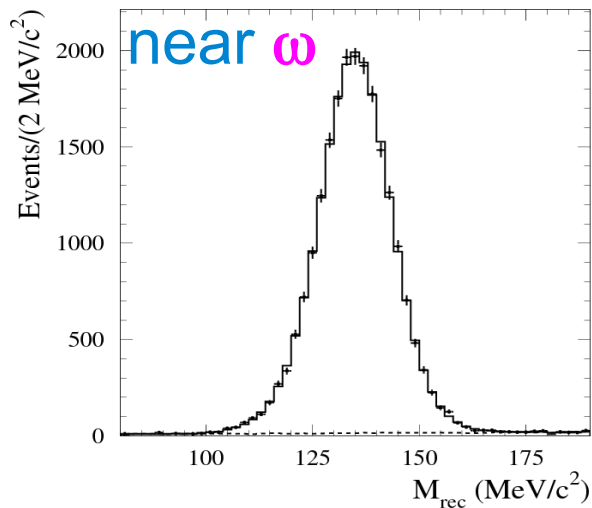
trigger, no charged tracks, total energy deposition and momentum, muon system veto.

Final selection is **based on 4C kinematic fit:**

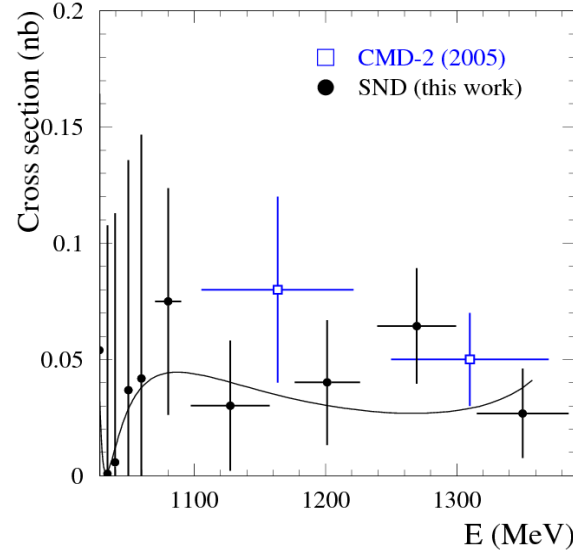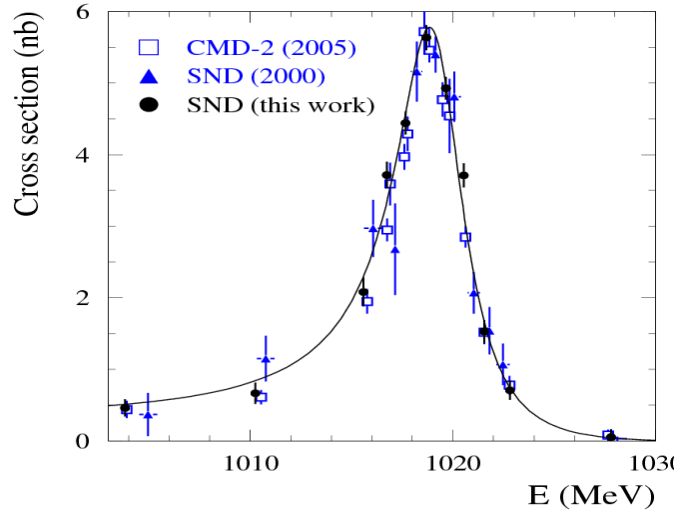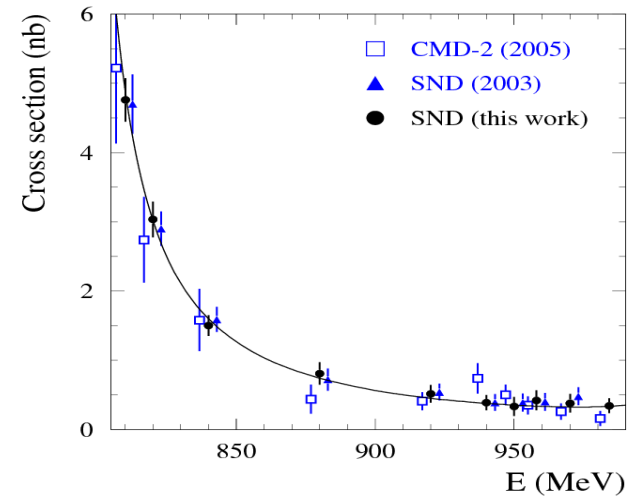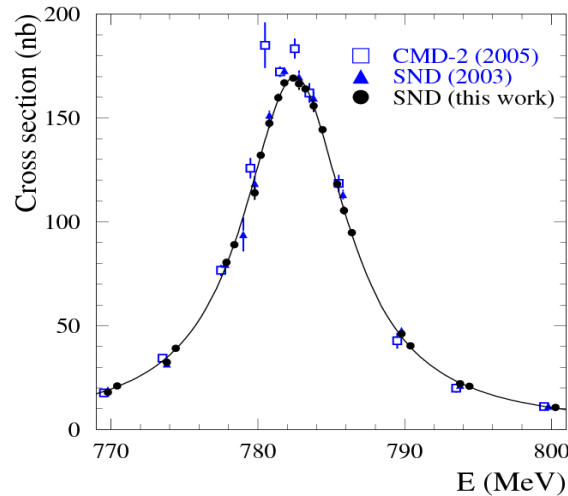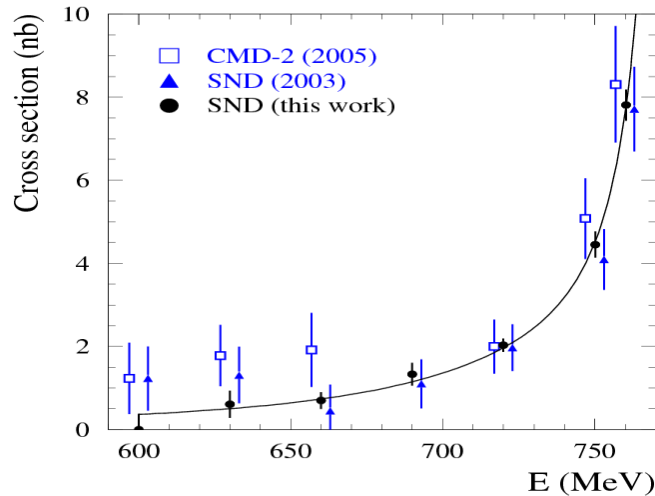$$\chi^2_{3\gamma} < 30,\ 36^\circ < \theta_\gamma < 144^\circ,\ 80 < M_{rec} < 190\ \text{MeV},$$

here M_{rec} is the mass recoiling against largest energy photon.

The number of signal events is determined from **the fit of π° in M_{rec} spectrum:**

e⁺e⁻ → π°γ: cross section

The most precise measurement of the e⁺e⁻→π°γ cross section.

Systematic uncertainty at the ω peak is **1.4%**:
- luminosity **1.2%**
- selection criteria **0.6%**

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

Results on radiative decays

Using PDG value for $B(\omega\to\pi^+\pi^-\pi^0)\times B(\omega\to e^+e^-)$ 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 .

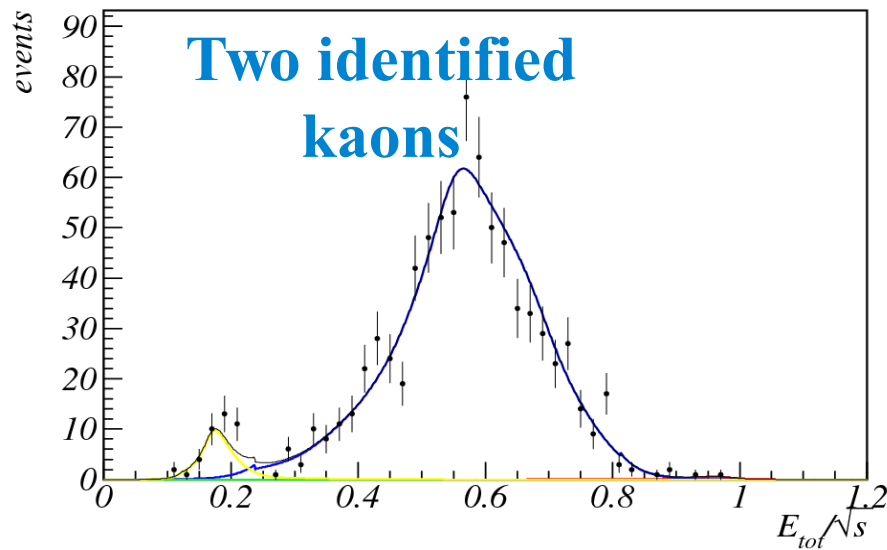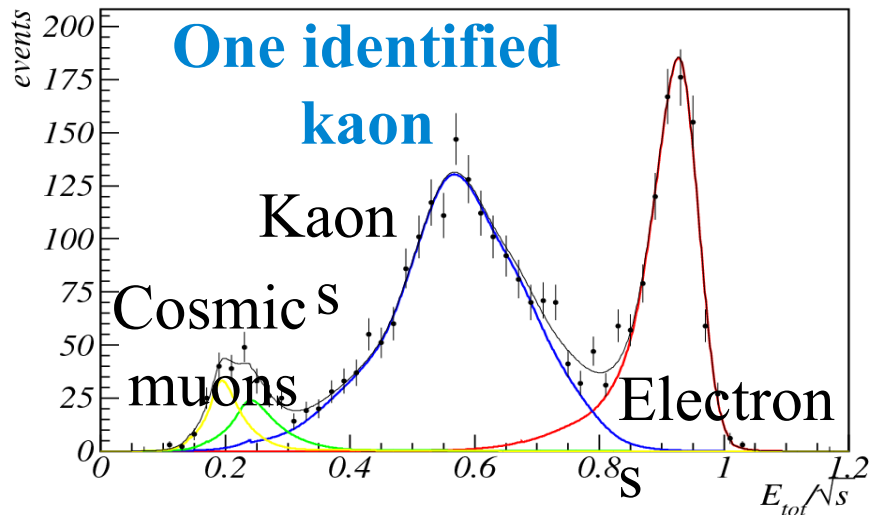$$B(\rho \to \pi^0\gamma) = (4.20 \pm 0.47 \pm 0.22) \times 10^{-4}$$

It is 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 $(163\pm7)^\circ$ obtained in the VMD fit to $e^+e^-\to\pi^+\pi^-\pi^0$ data

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

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

One identified kaon

Cosmic
muons

Kaon s

Electron
s

$E_{tot}/\sqrt{s}$

Two identified kaons

$E_{tot}/\sqrt{s}$

Preliminary events selection:
- trigger
- 2 back-to-back central tracks in DC

Normalization with $e^+ e^- \rightarrow e^+ e^-$

Information from Cherenkov aerogel counters:

- Kaons do not produce Cherenkov signal in the counter, while electron, muon and pions do.
- The kaon ID (one particle) requirement suppresses background from $e^+ e^- \rightarrow e^+ e^-$ by a factor of 300.

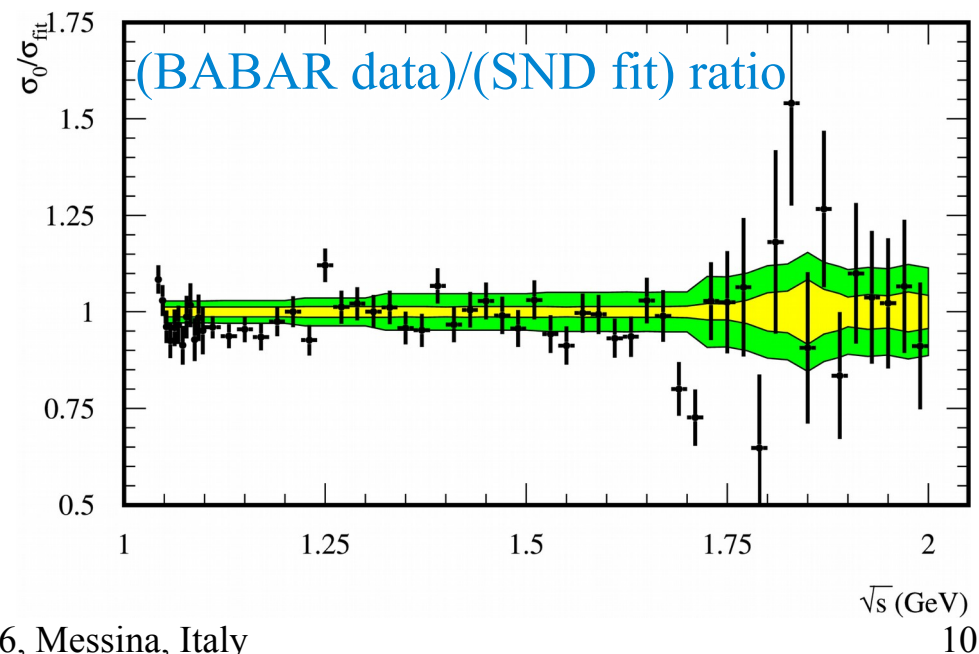Finally collinear background substracted fitting $E_{tot}/\sqrt{s}$

$e^+e^- \rightarrow K^+K^-$: cross section
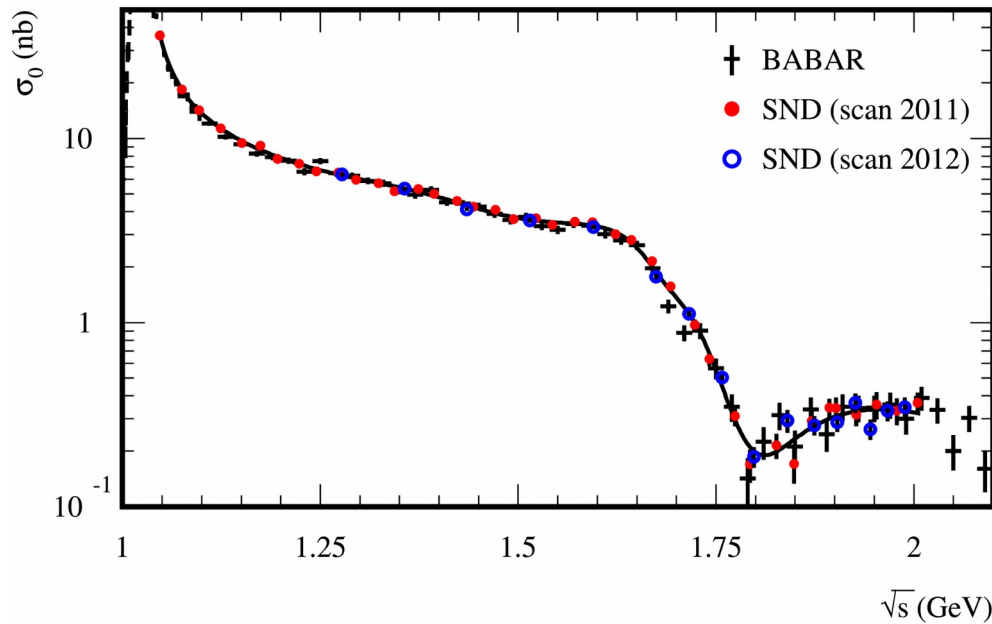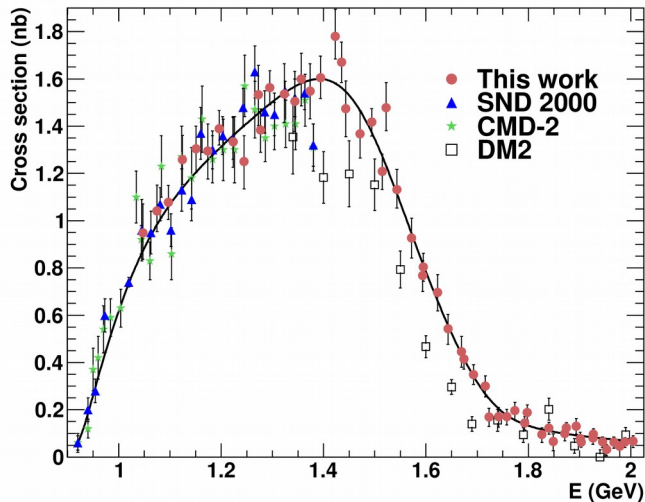

SND measurement agrees with the BABAR data and has comparable or better accuracy.

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

arXiv:1608.08757 [hep-ex]

(BABAR data)/(SND fit) ratio

Updated $e^+e^- \rightarrow \omega\pi^\circ \rightarrow \pi^\circ\pi^\circ\gamma$

Analysis is very close to described earlier:
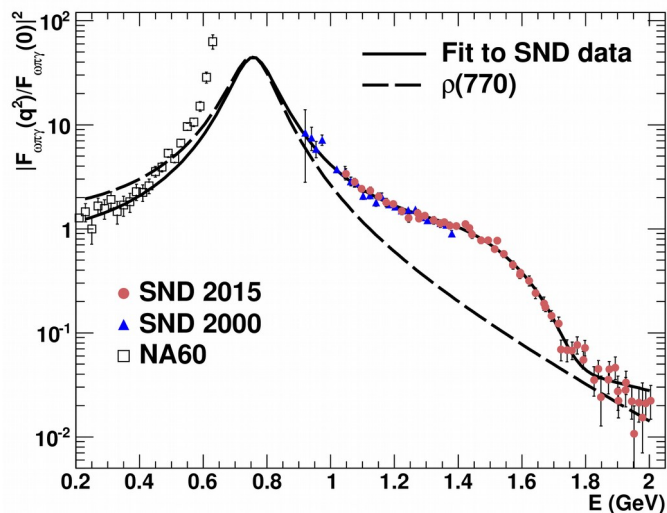
Phys. Rev. D 88, 054013 (2013).
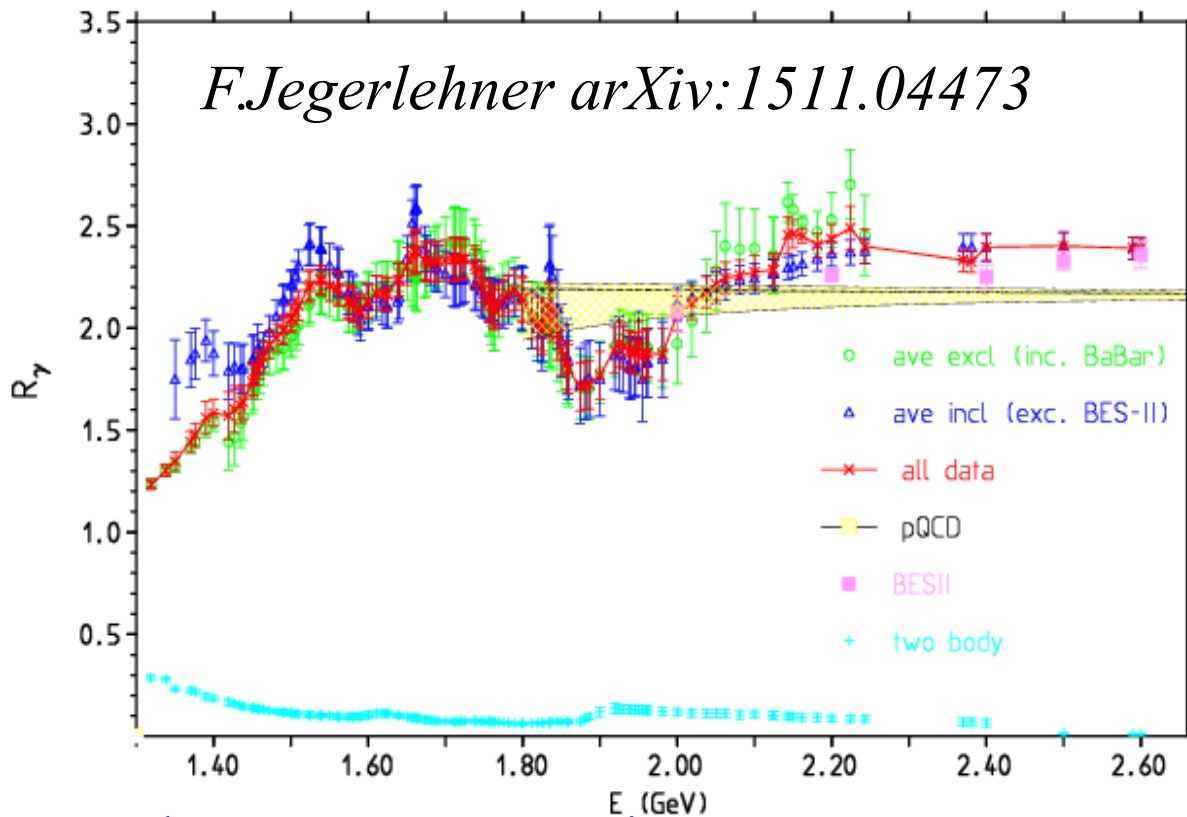
The radiative correction calculation has been fixed.

Additional data are taken into account:

- 25 pb^{-1} → 37 pb^{-1}

arXiv:1610.00235 [hep-ex]

# Exclusive vs inclusive measurements

F.Jegerlehner arXiv:1511.04473

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 are no experimental data on the final states $\pi^+\pi^-\pi^0\eta$, $\pi^+\pi^-\eta\eta$, $\pi^+\pi^-\pi^0\pi^0\pi^0$, $\pi^+\pi^-\pi^0\pi^0\eta$, ...

Process $e^+e^- \rightarrow \pi^+\pi^-\pi^\circ\eta$
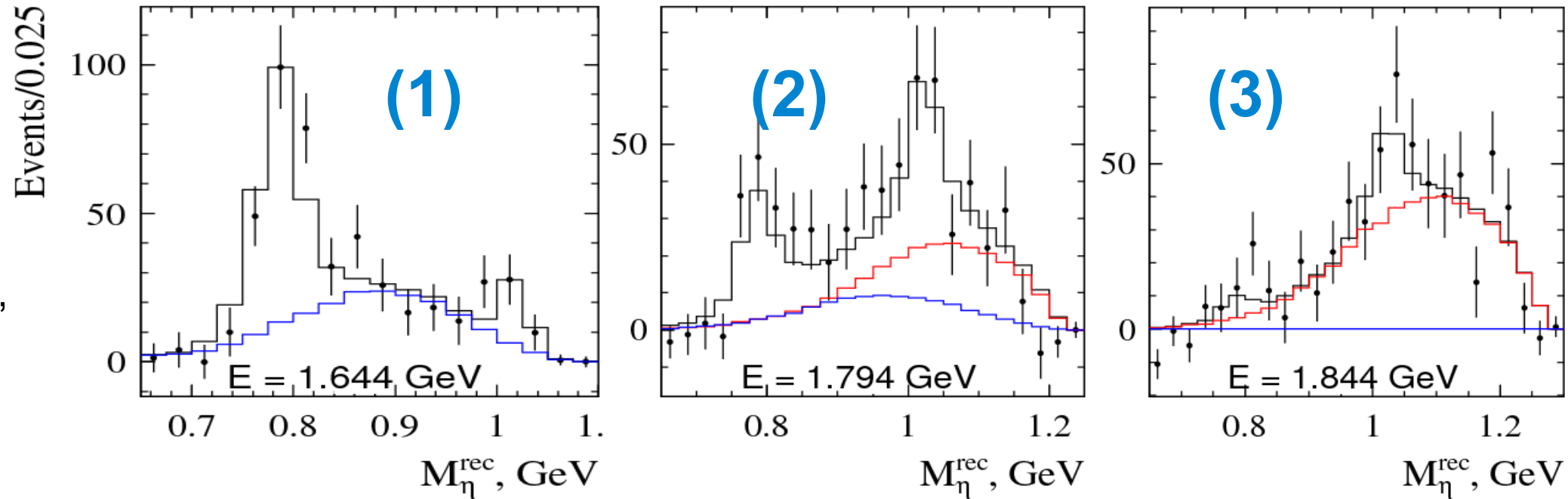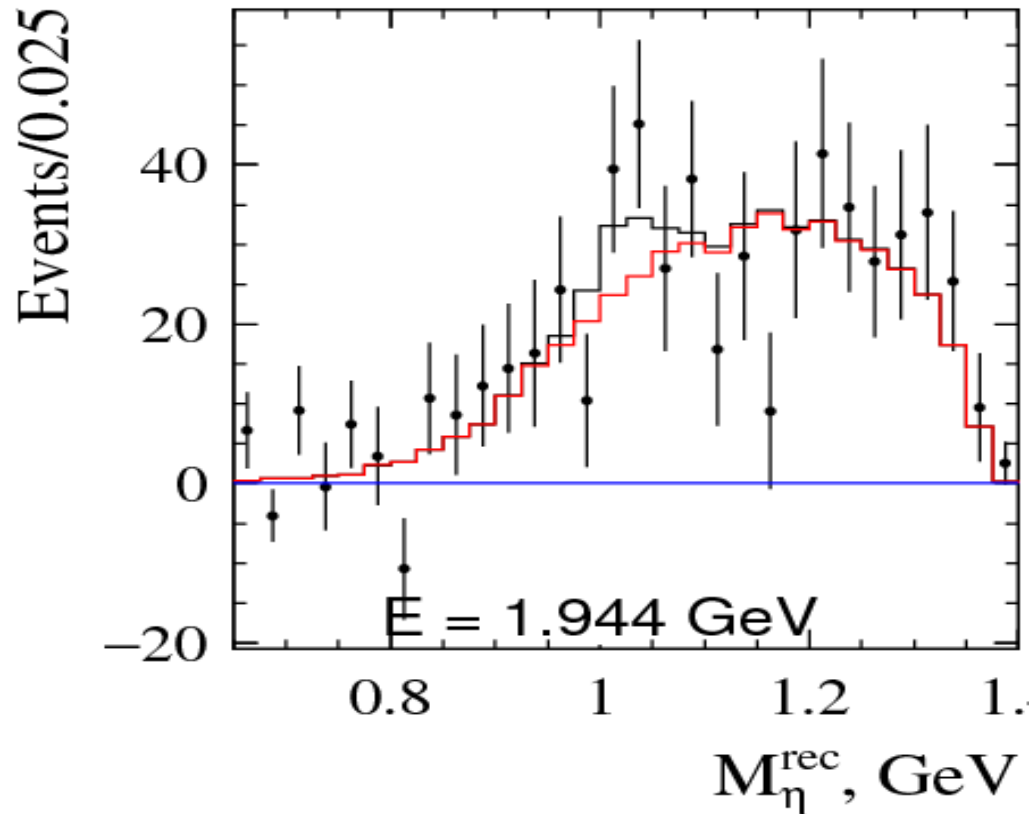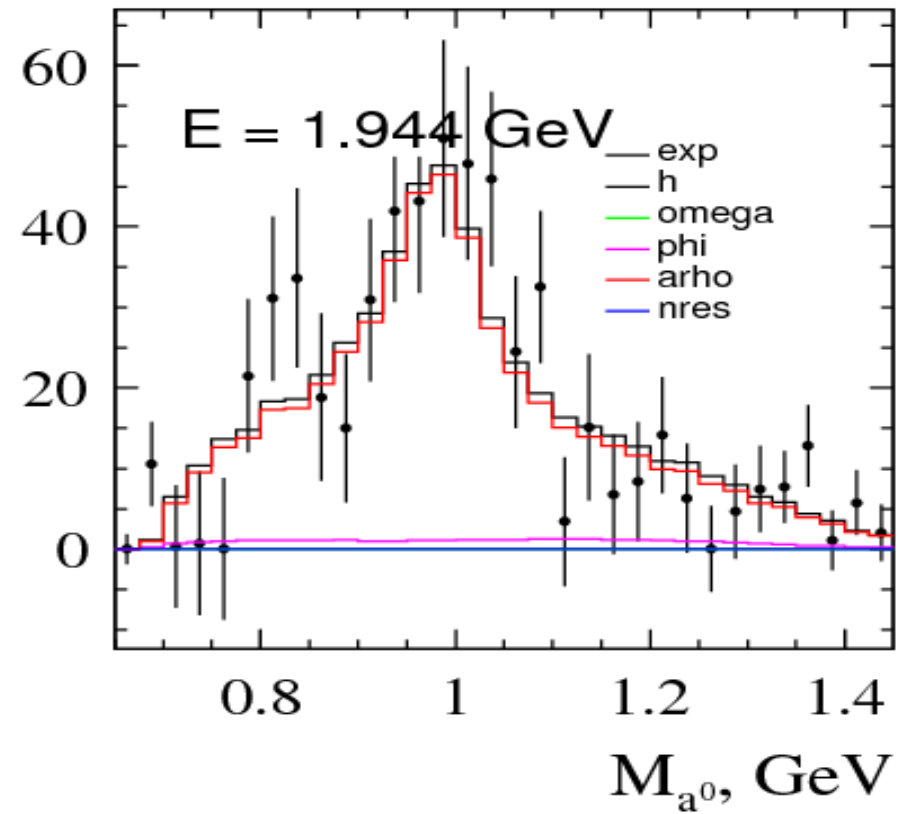

Spectrum contributions:
   (1) sum of $\omega\eta$, $\phi\eta$ and structureless $\pi^+\pi^-\pi^\circ\eta$ (blue);
   (2) sum of $\omega\eta$, $\phi\eta$, structureless $\pi^+\pi^-\pi^\circ\eta$ and $a_0(980)\rho$ (red) ;
   (3) sum of $\phi\eta$ and $a_0(980)\rho$ contributions.

$e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta$: **mass spectrum**
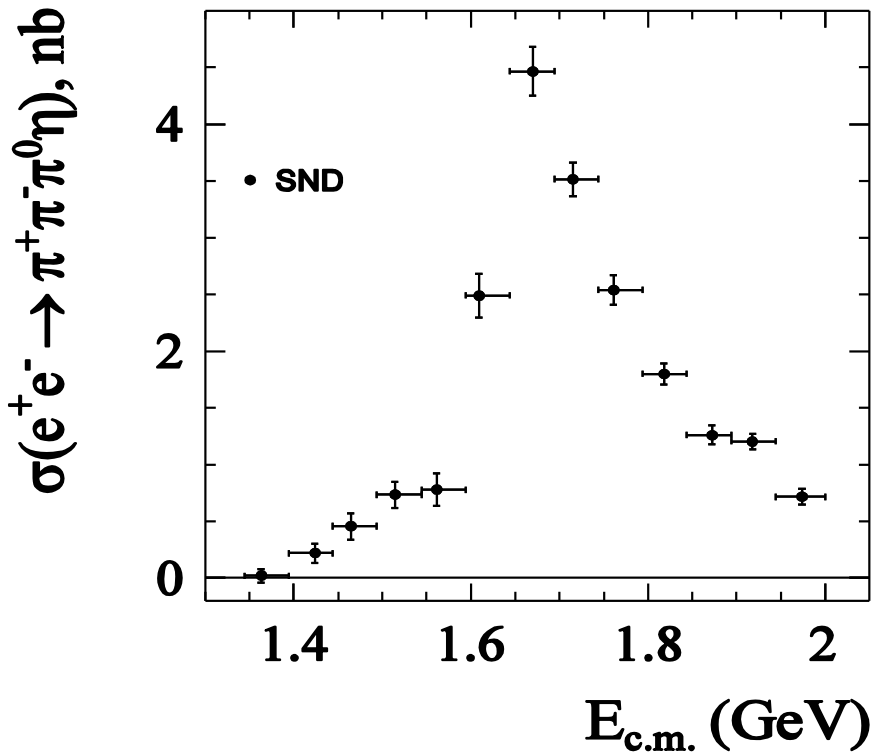
Mass recoiling against η.

$\eta\pi^0$ invariant mass.

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

$e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta$: cross section

- First measurement of this process.
- The intermediate states are $\omega\eta$, $\phi\eta$, structureless $\pi^+\pi^-\pi^0\eta$ 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**.
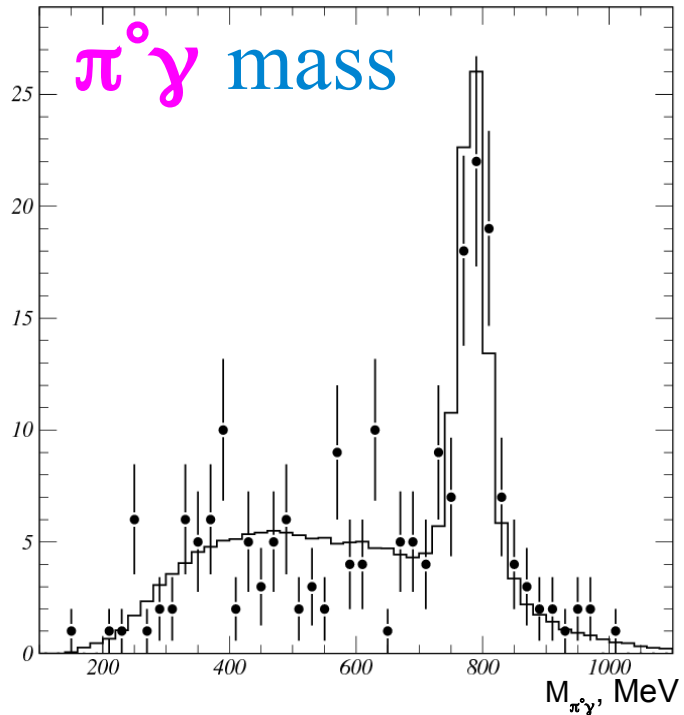- Above **1.8 GeV** the dominant reaction mechanism is $a_0(980)\rho$.

- The process $e^+e^- \rightarrow \omega\eta$ has been measured separately.
- There is a significant difference between **SND** result and the previous **BABAR** measurement.
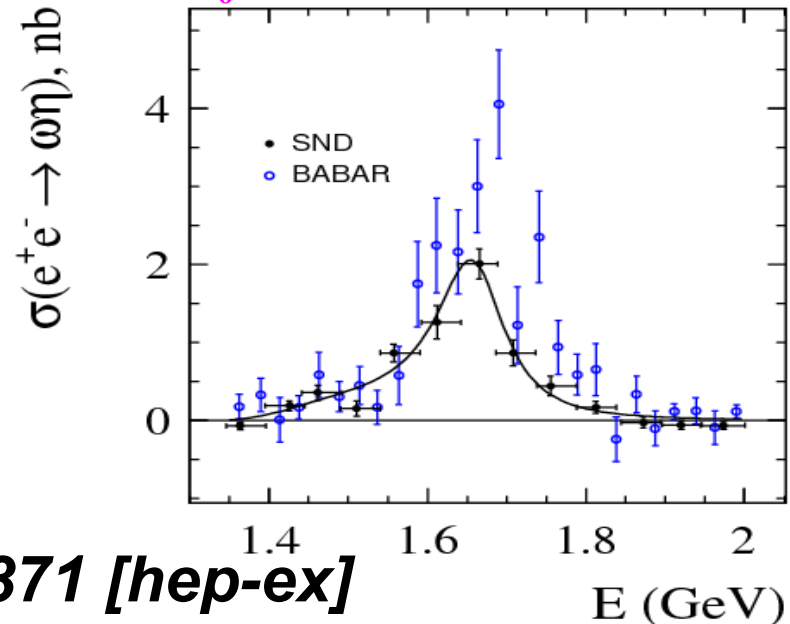
arXiv:1607.00371 [hep-ex]

Process $e^+e^- \to \omega\pi^\circ\eta$

$\pi^\circ\gamma$ mass

Events of the $e^+e^- \to \pi^\circ\pi^\circ\eta\gamma \to 7\gamma$ process are selected. The dominant intermediate state is $\omega\pi^\circ\eta$. No noticeable $\eta'\gamma$ signal observed.

$\eta\pi^\circ$ mass

$\omega\pi^\circ\eta$ phase space

ωa_0

The $\eta\pi^\circ$ mass spectrum for selected $\omega\pi^\circ\eta$ events is well described by the model of the $a_0(980)\omega$ intermediate state.
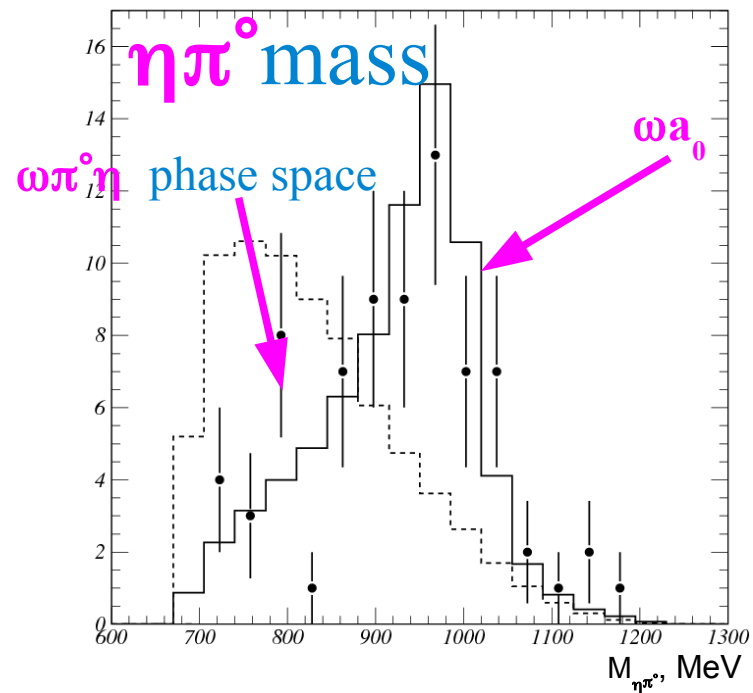
$e^+e^- \rightarrow \omega\pi°\eta$: cross section
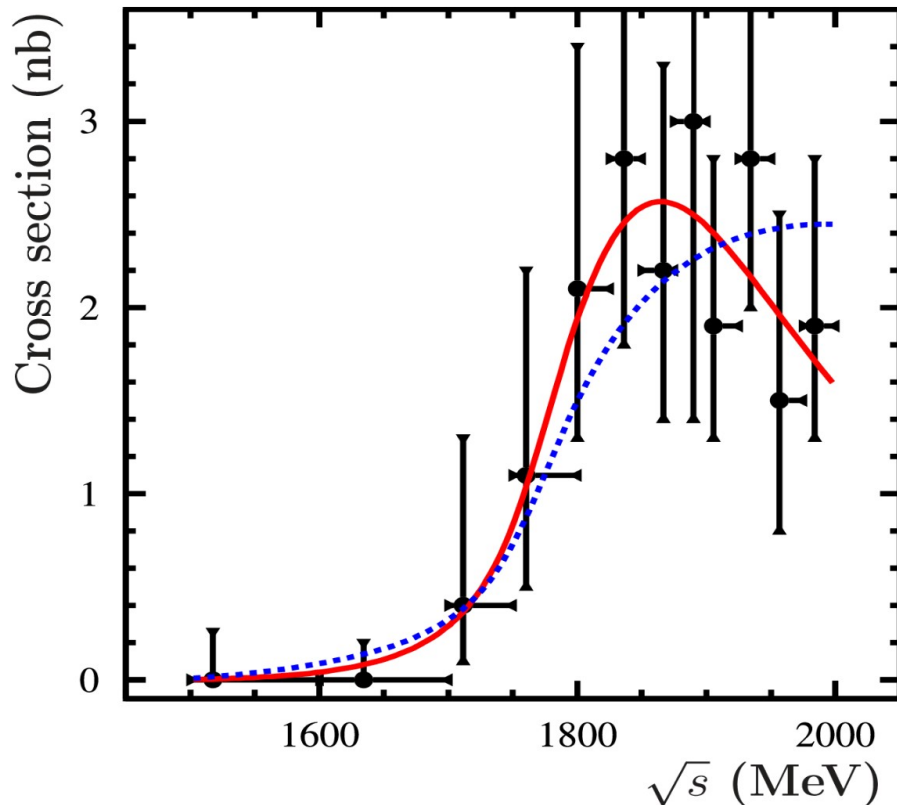
- First measurement of the $e^+e^- \rightarrow \omega\pi°\eta$ cross section.

- The cross section energy dependence is described by a single-resonance model.

- The resonance mass and width are consistent with those for ρ(1700)

  better than non-resonant at 1.2σ

Phys. Rev. D 94, 032010 (2016)

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 (**$\pi^{\circ}\gamma$, K^{+}K^{-}, $\omega\pi^{\circ}$**).

- For some processes the cross sections have been measured for the first time (**$\pi^{+}\pi^{-}\pi^{\circ}\eta$, $\omega\pi^{\circ}\eta$**).

- After **VEPP-2000** upgrade the data taking runs will be continued with a goal of **~1 fb^{-1}** of integrated luminosity.