Light Hadron Production in Experiments with SND Detector at the e+e- Collider VEPP-2000

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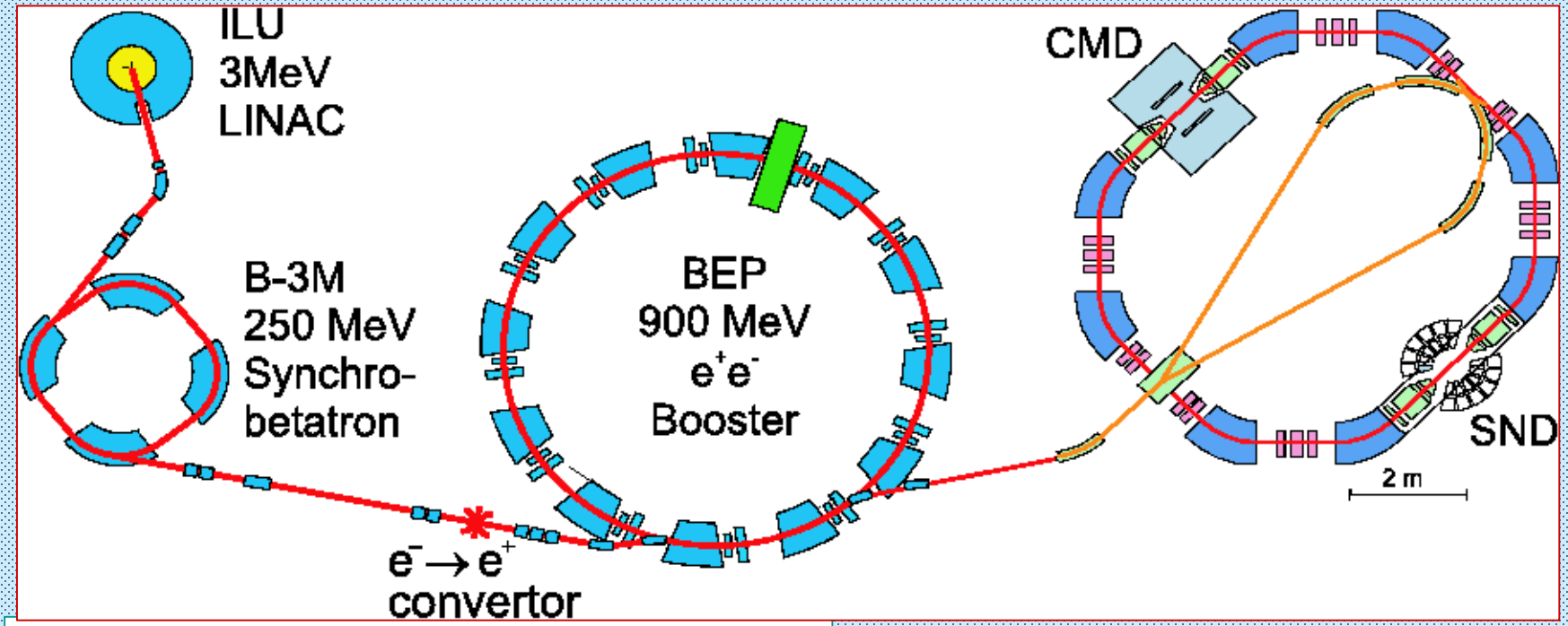
BINP, Novosibirsk

Outline

1. Experiment
2. e^+e^- -> mesons
3. e^+e^- -> nucleons
4. Conclusions

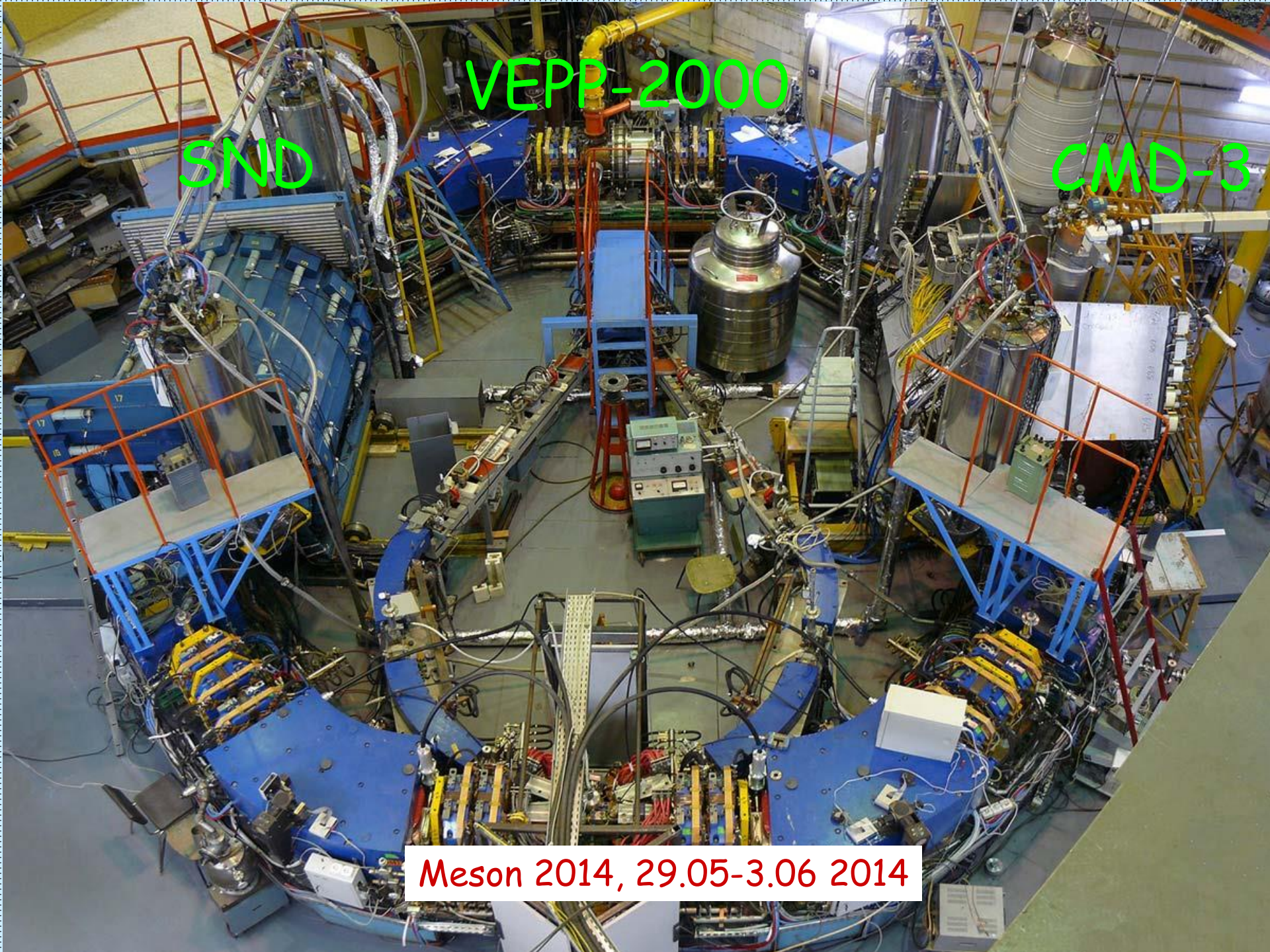
VEPP-2000 complex , in operation since 2010



VEPP-2000:

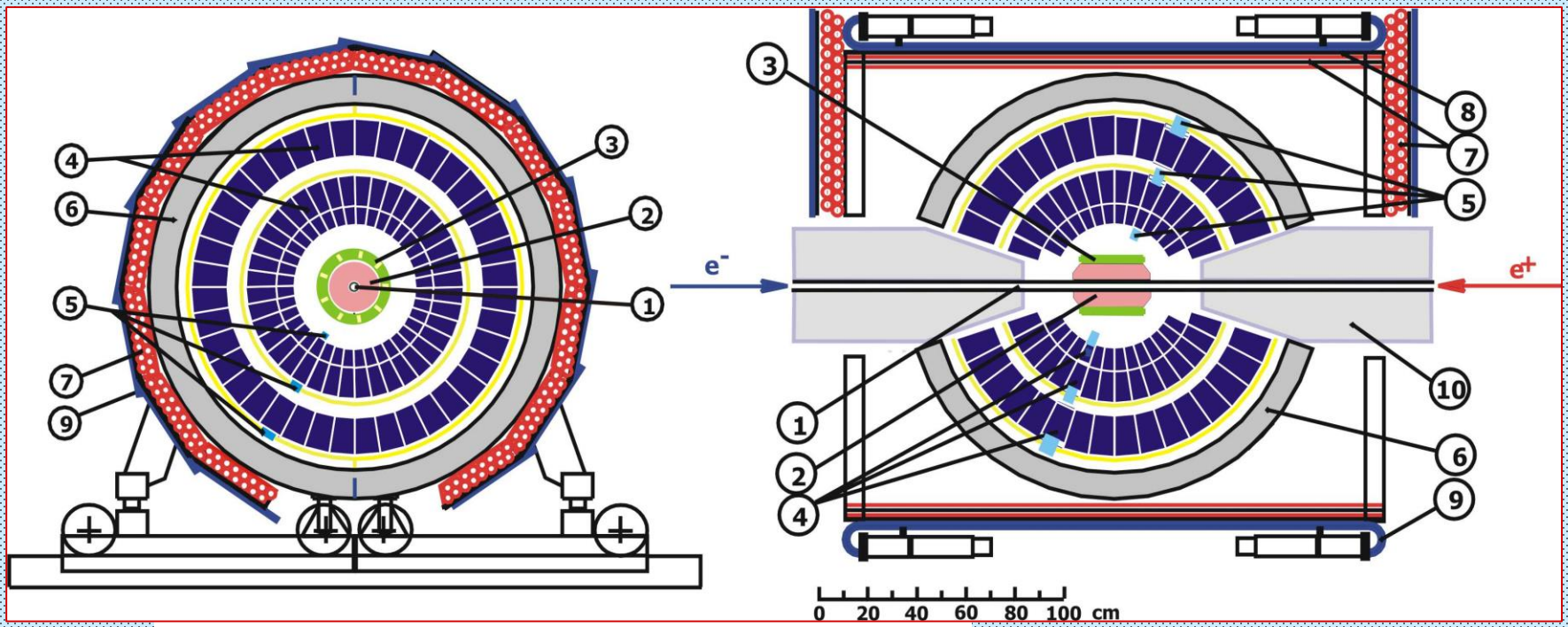
- **revolut.frequency – 12 MHz**
- **current – 0.2 A**
- **beam length – 3.3 см**
- **energy spread – 0.7 МэВ**
- **L ≃ 1.10^{32} at 2E=2.0 ГэВ**
- **L=2.10^{31}cm^{-2}s^{-1} at 2E=1.0 ГэВ**

Meson 2014, 29.05-3.06 2014


VEPP-2000
SND
CMD-3
Meson 2014, 29.05-3.06 2014

SND, in operation since 1995

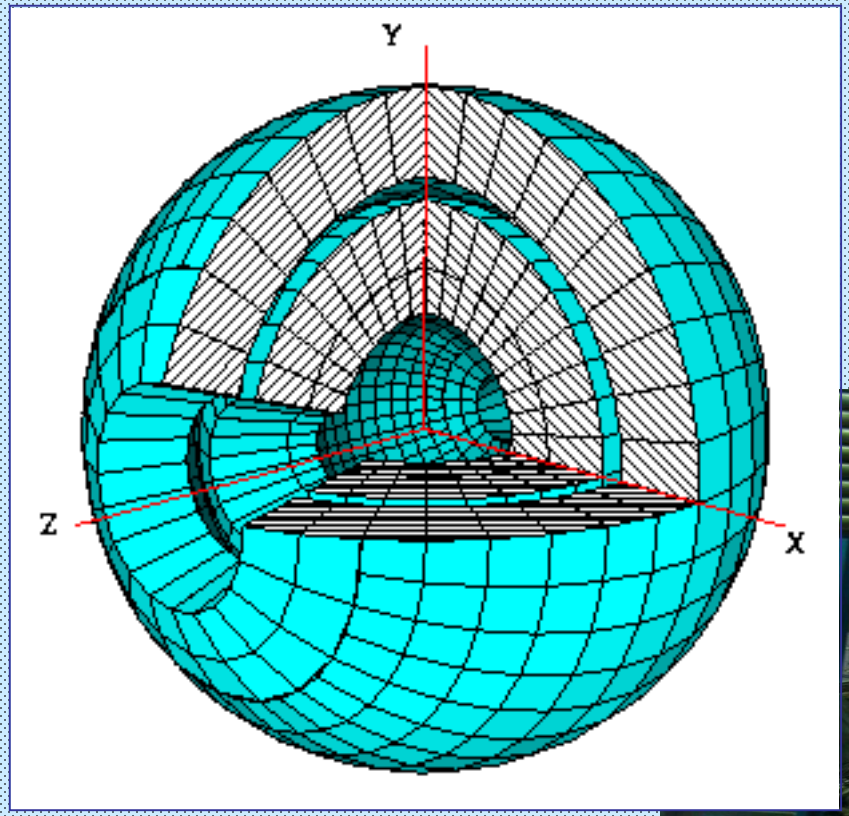
NIM A449 (2000) 125-139

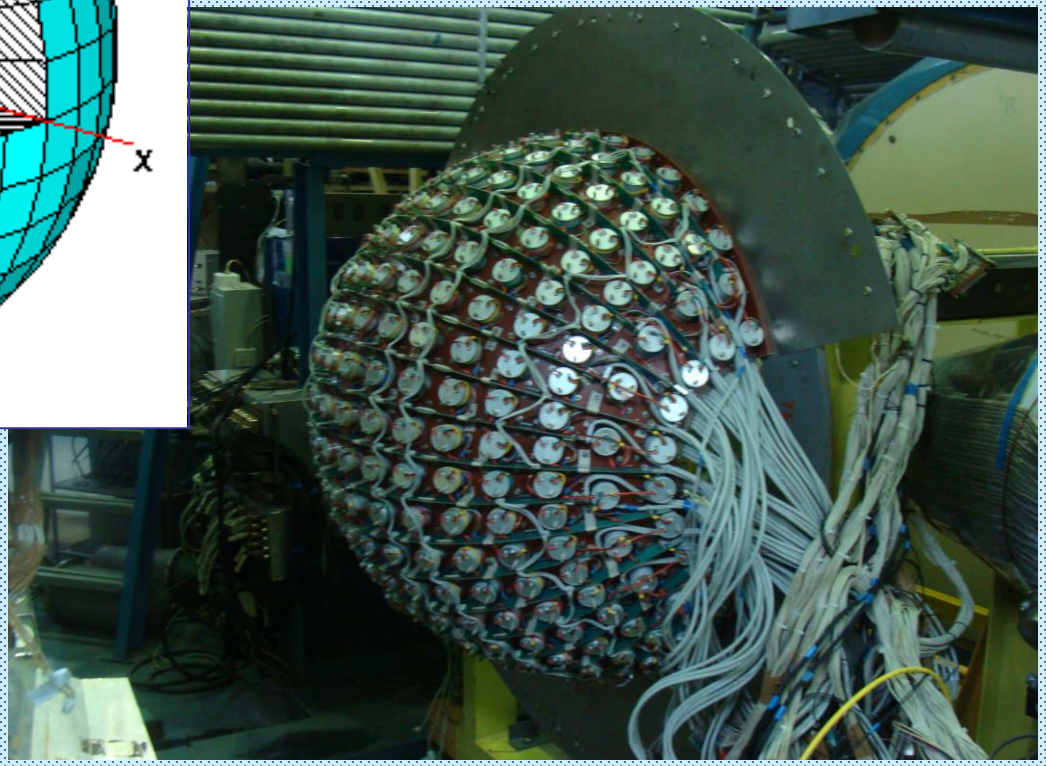


- 1 – **beam pipe, 2 – tracking system,**
- **3 – aerogel cherenkov counter ,**
- **4 – NaI(Tl) crystals, 5 – phototriodes,**
- **6 – iron muon absorber, 7–9 –**
- **muon detector, 10 – focusing solenoids.**

Meson 2014, 29.05-3.06 2014

SND





Experiments 2010 - 2012

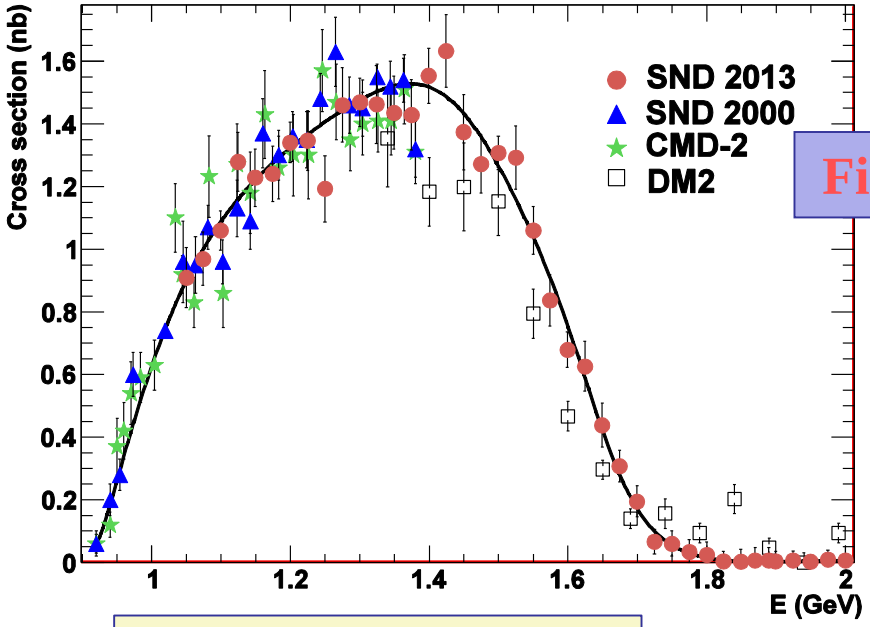
Experiment/year (1.05 – 2.0 GeV)	Integrated luminosity	$\sqrt{s}$ > 1.88 GeV
MHAD 2010	5 pb^{-1}	71 nb^{-1}
MHAD 2011	25 pb^{-1}	3.8 pb^{-1}
MHAD 2012	17 pb^{-1}	4.9 pb^{-1}
Total	47pb^{-1}	8.8 pb^{-1}

Experiment 2013

Energy region ($\sqrt{s}$, GeV)	Integrated luminosity, pb^{-1}	ρ - ω region, pb^{-1}	η' - meson region, pb^{-1}	φ - meson region, pb^{-1}	non-resonant, pb^{-1}
0.32–1.06	32	15.5	3.5	7.5	5.5

$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$ (1)

(arXiv:1303.5198[hep-ex])
Phys.Rev. D88 (2013) 054013



Fit: ρ(770), ρ′(1450), ρ″(1700)

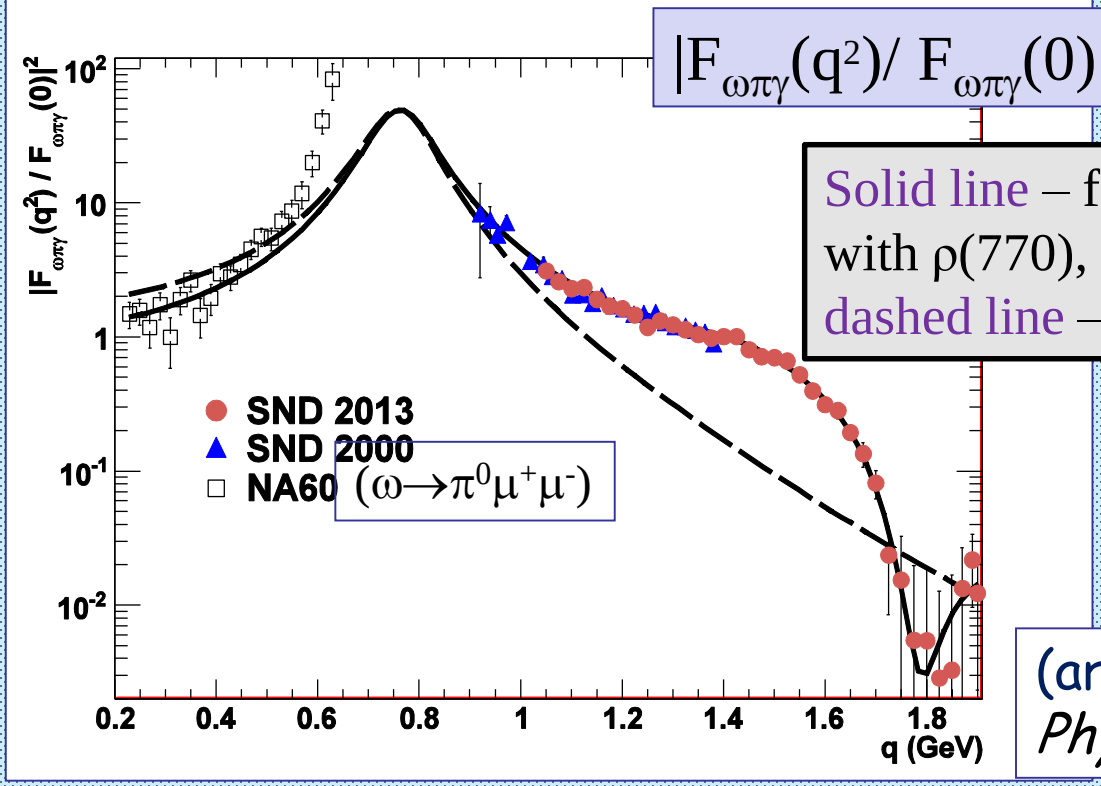
CVC test: SND :
$Br(\tau^- \to \omega\pi^-\nu_\tau) = (1.96 \pm 0.02 \pm 0.10)\%$
PDG:
$Br(\tau^- \to \omega\pi^-\nu_\tau) = (1.95 \pm 0.08)\%$

- **Systematic error: 3.4%**
- **(2E<1.55 GeV)**

$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$ (2)

(Transition form factor $\gamma^* \to \omega\pi^0$, $F_{\omega\pi\gamma}$)

$$\sigma_{\omega\pi^\circ} = \frac{4\pi\alpha^2}{E^3}\left|F_{\omega\pi\gamma}(E^2)\right|^2 P_f(E),\ P_f(E) - \text{phase space factor}$$

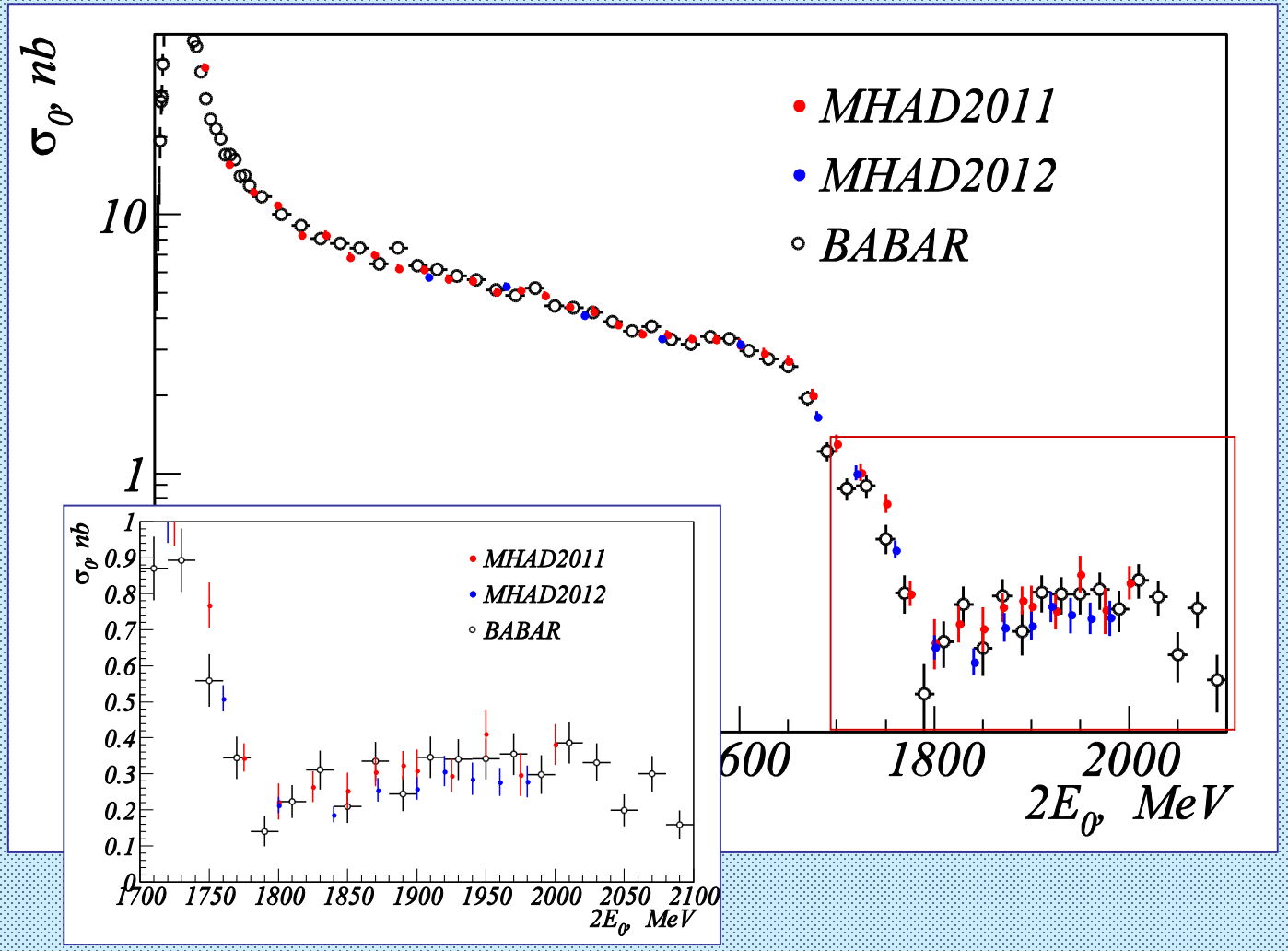


Solid line – from cross section fit with ρ(770), ρ′(1450), ρ″(1700), dashed line – ρ(770) contribution.

(arXiv:1303.5198[hep-ex])
Phys.Rev. **D88** (2013) 054013

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

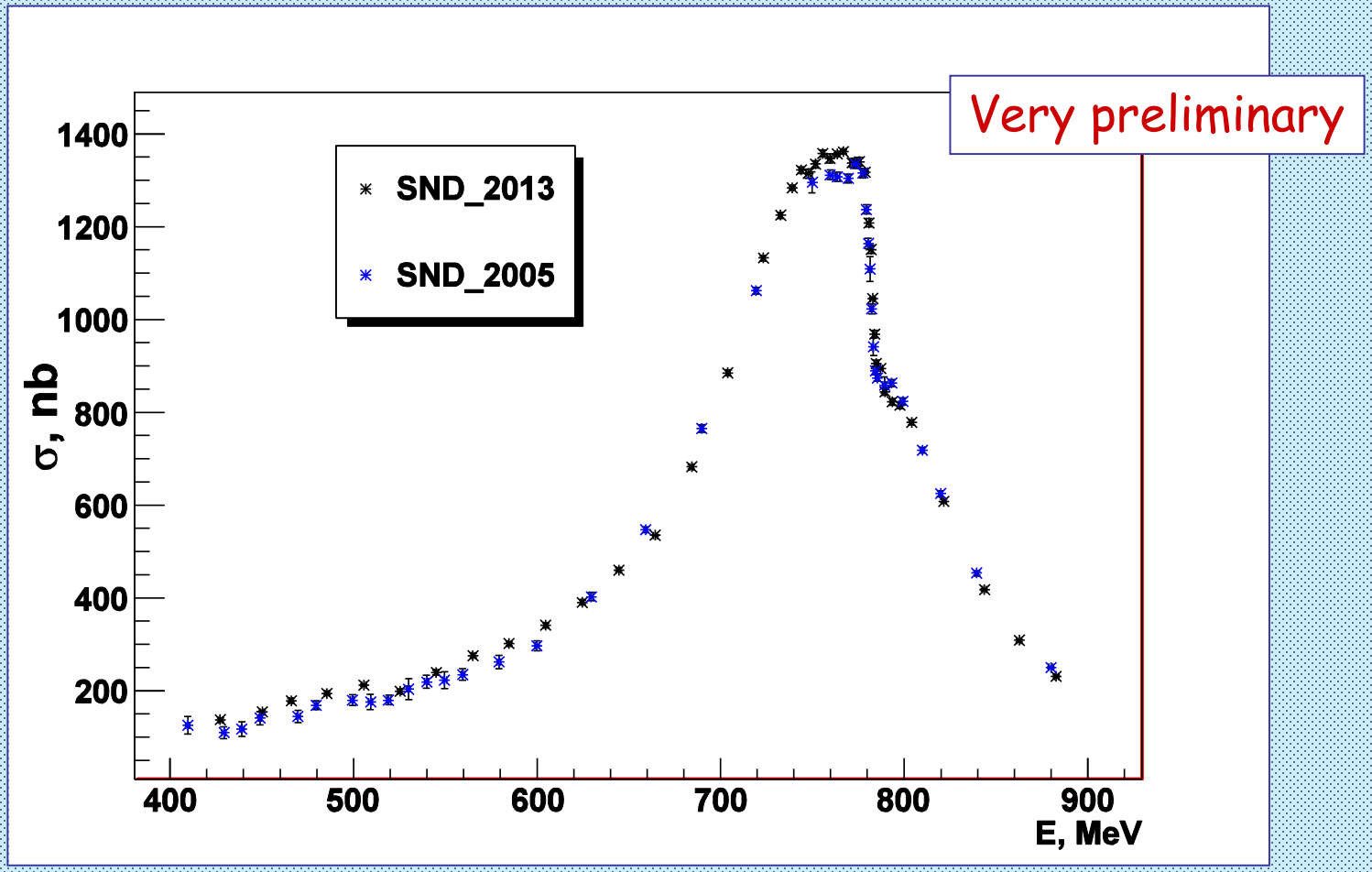
New SND measurement after Babar



Aerogel Cherenkov
--- kaon ID

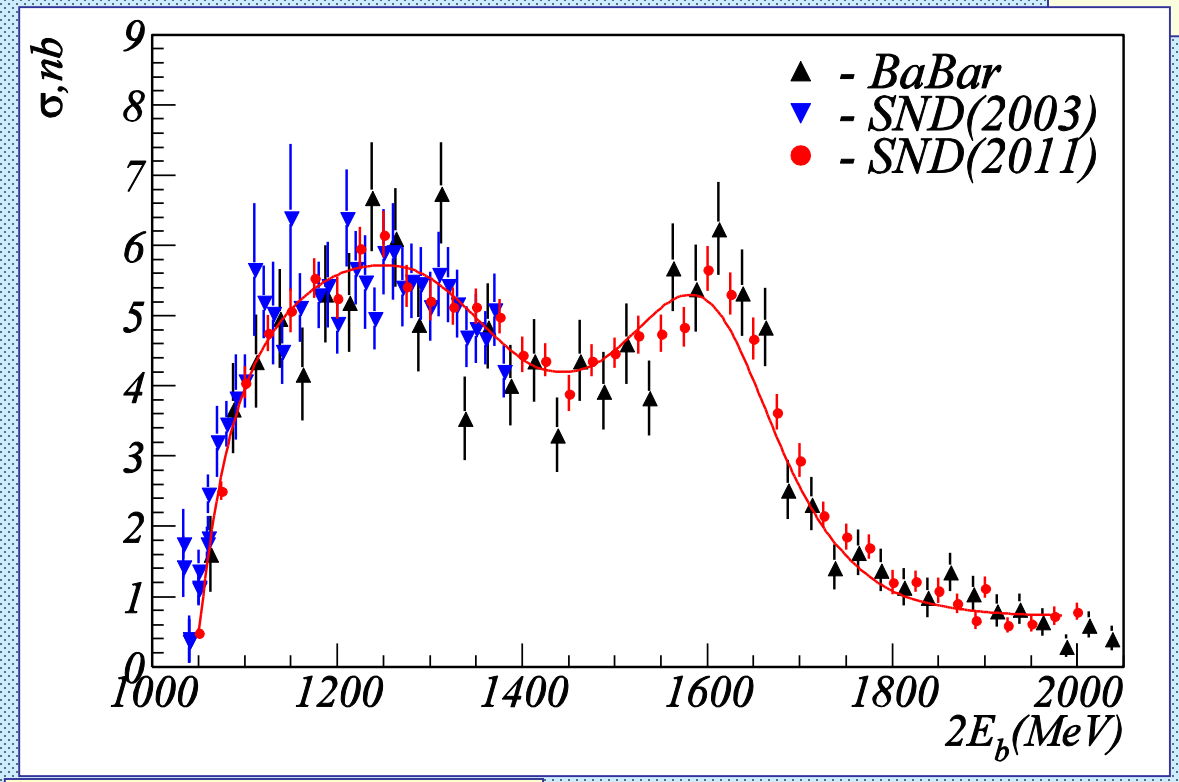
$e^+e^- \to \pi^+\pi^-$

Beginning of the analysis, 5 pb^{-1}



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

Close to the end of analysis



Contributions - ω(783), ω′(1420), ω″(1650).

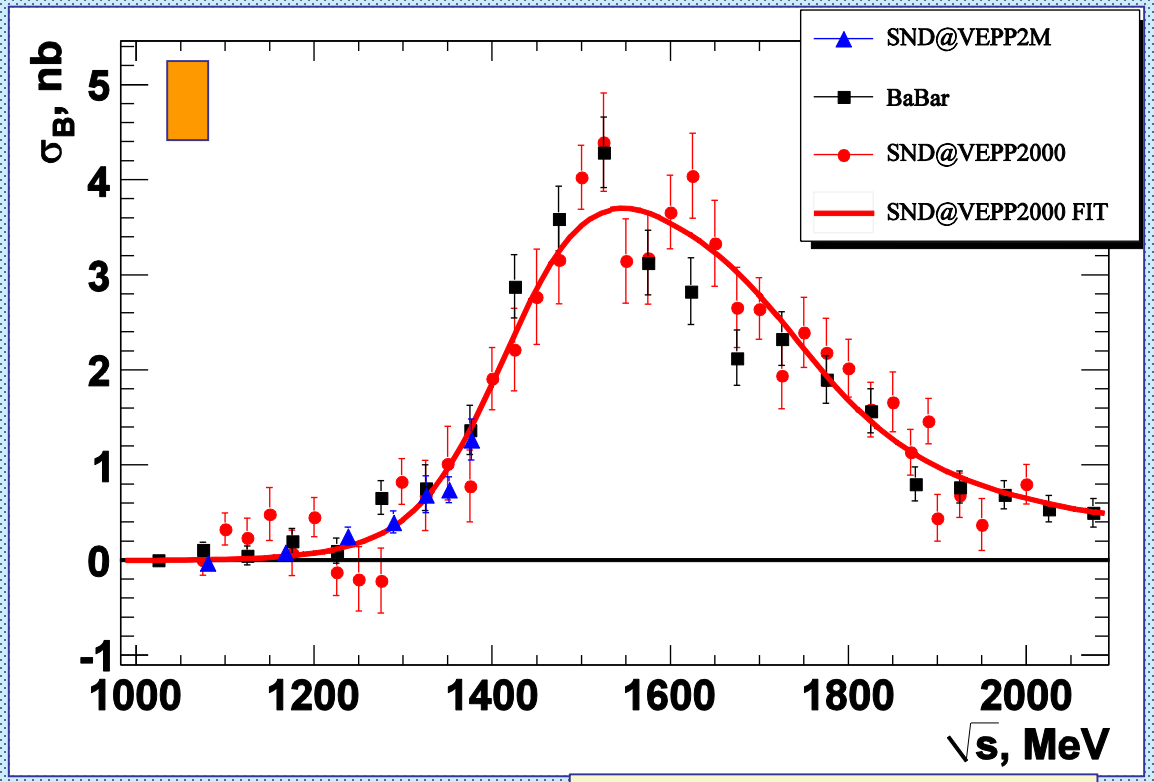
Only half of statistics

•**Systematic: ~5%**

The most precise measurement !

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

Ready to submit to journal

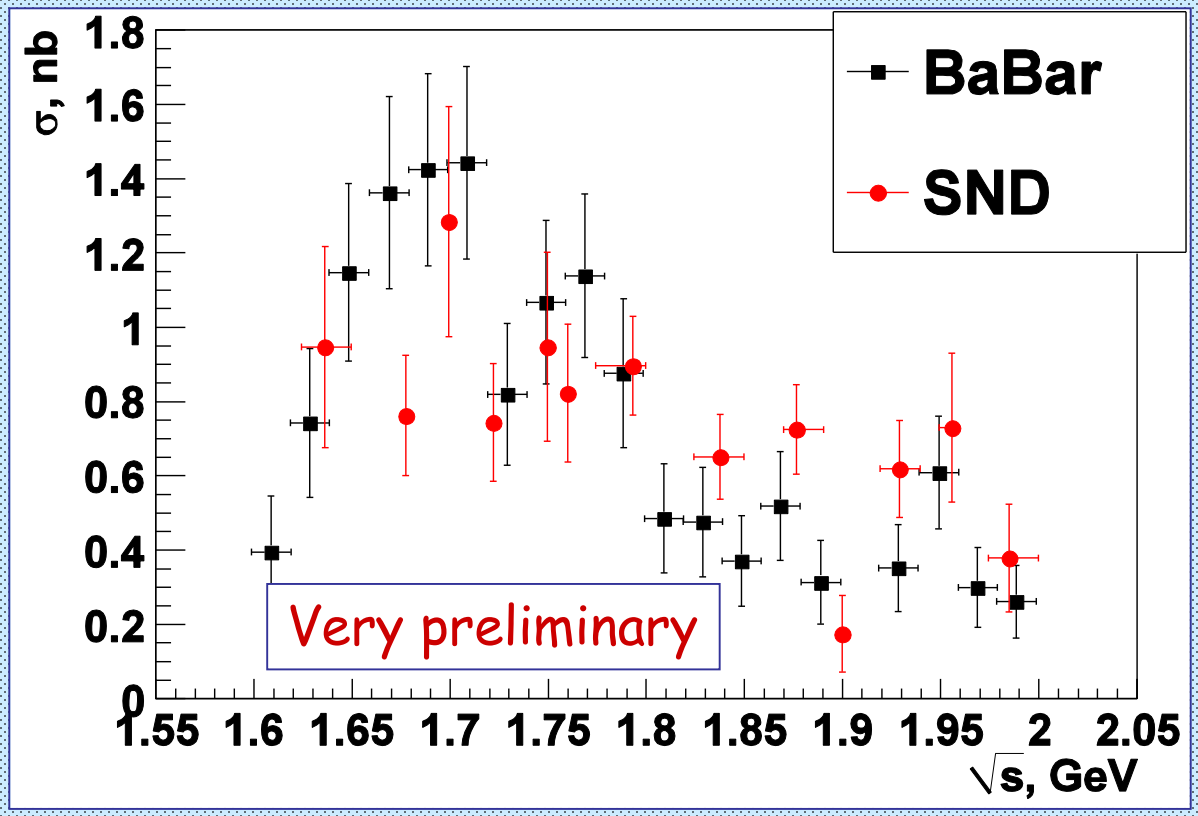


Fit:
ρ(770), ρ′(1450), ρ″(1500)

- **Systematic error: 4.7%**
- **(1450–1700 MeV)**

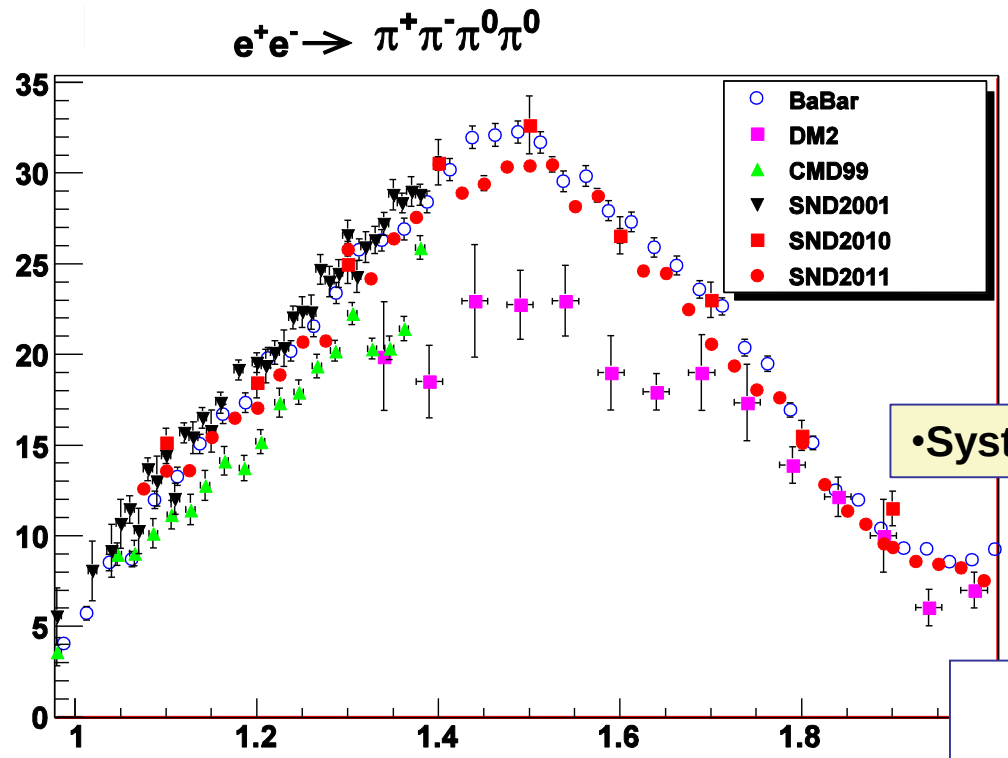
CVC test: SND :
$Br(\tau^- \to \eta\pi^-\pi^0\nu_\tau)$= (0.188+0.058-0.057)%
PDG:
$Br(\tau^- \to \eta\pi^-\pi^0\nu_\tau)$ = (0.139±0.01)%

e+e− → ηK+K−



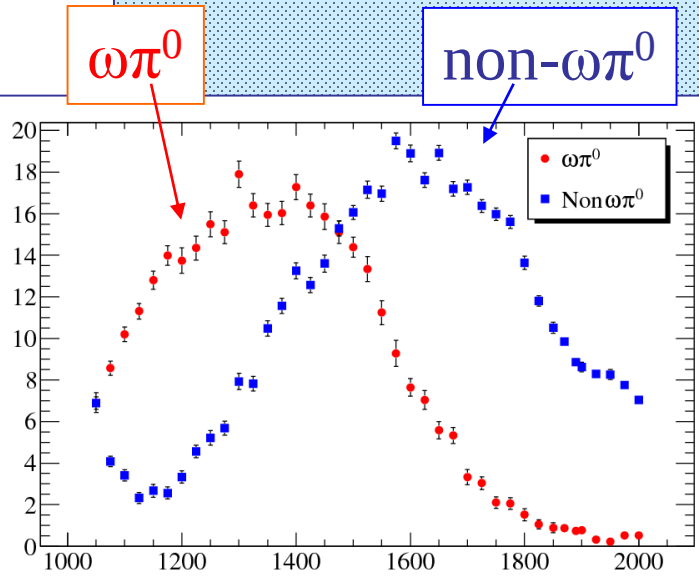
Meson 2014, 29.05-3.06 2014

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



Close to the end of analysis

•Systematics ≤ 10%

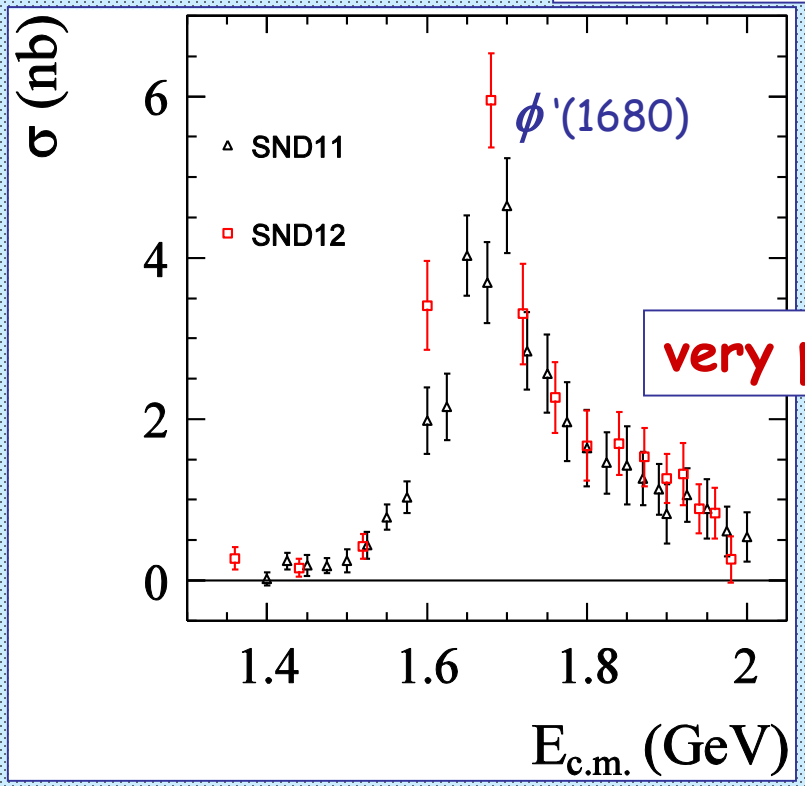


•The bump comes from ρ(770), ρ′(1450), ρ″(1700).

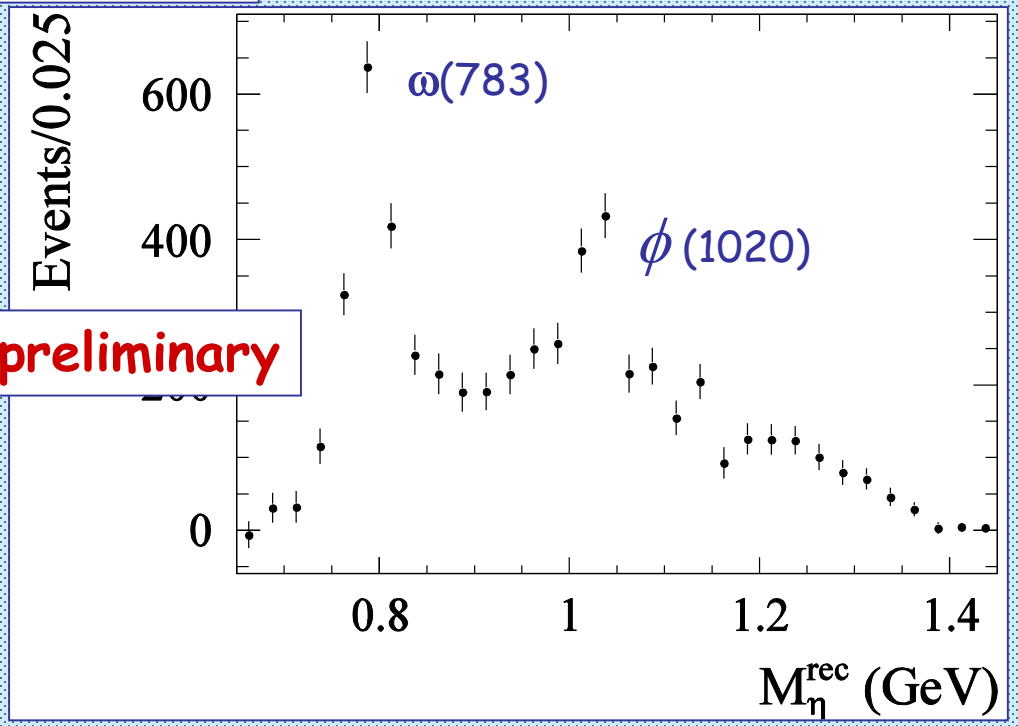
Main feature – many intermediate states: $\omega\pi^0$, $a_1\pi$, $\rho\pi\pi$, $\rho^+\rho^-$ of.

$e^+e^- \to \eta\pi^+\pi^-\pi^0$ ($\eta \to 2\gamma$)

first measurement



very preliminary



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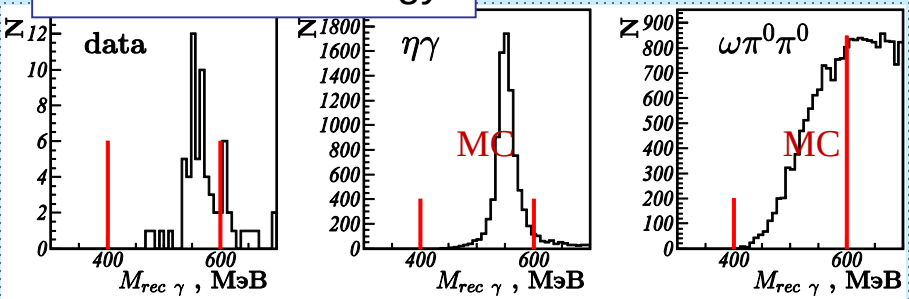
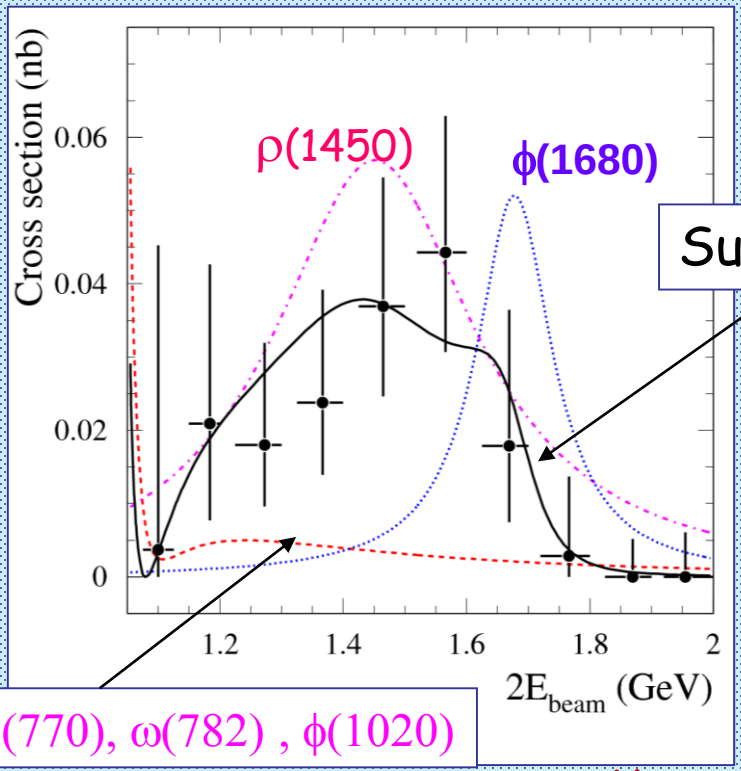
$e^+e^- \to \eta\gamma \to 7\gamma$,
first measurement for $\sqrt{s}$ >1.4GeV)

Photon recoil energy



arXiv:1312.7078 [hep-ex]
Submitted to PRD

Evidence of magnetic dipole decays of excited vector mesons



ρ(770), ω(782) , ϕ(1020)

The SND data are described By r(1450) and f(1680) states

$e^+e^- \to N\bar{N}$ cross section

Differential cross section:

$$\sigma(e^+e^- \to B\bar{B}) = \frac{\alpha^2 \beta C^2}{4m^2}\left(|G_M|^2(1+\cos^2\theta) + \frac{4m_B^2}{m^2}|G_E|^2(1-\cos^2\theta)\right)$$

Total cross section:

$$\sigma(e^+e^- \to B\bar{B}) = \frac{4\pi\alpha^2 \beta C}{3m^2}\left(|G_M|^2 + \frac{2m_B^2}{m^2}|G_E|^2\right)$$

Effective form factor

$$|F|^2 = \frac{|G_M|^2 + |G_E|^2/2\tau}{1+1/2\tau}, \quad \tau = \frac{m^2}{4m_B^2}$$

Two measurable values:
1 - effective FF,
2 - G_E/G_M

C for protons : $C = y/(1-e^{-y}),\ y = \pi\alpha/\beta$

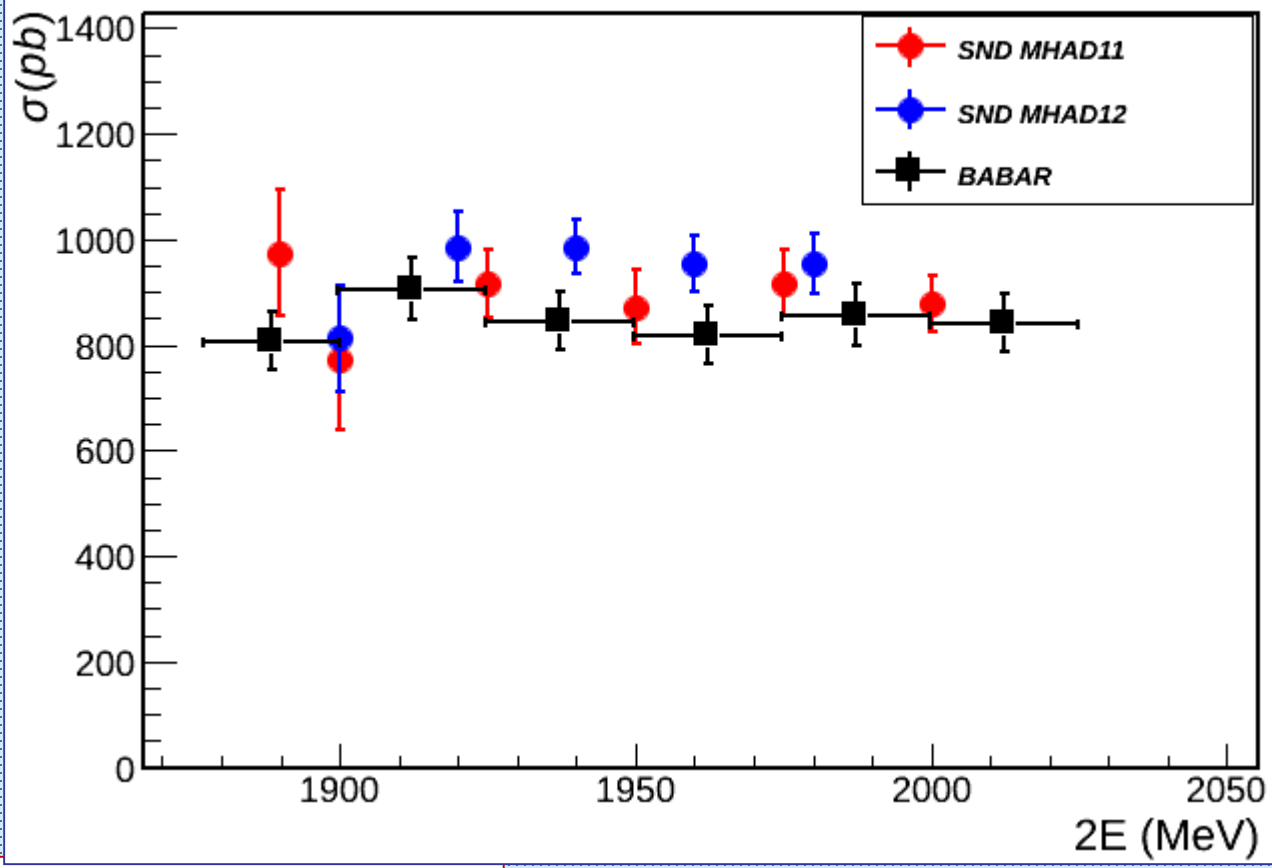
C=1 for neutrons

At threshold : $s=4m_B^2 \to |G_E| = |G_M| = |F|$

Asymptotic prediction: $F(+\infty) = -F(-\infty) \sim 1/s^2$

$e^+e^- \rightarrow pp$, SND

preliminary



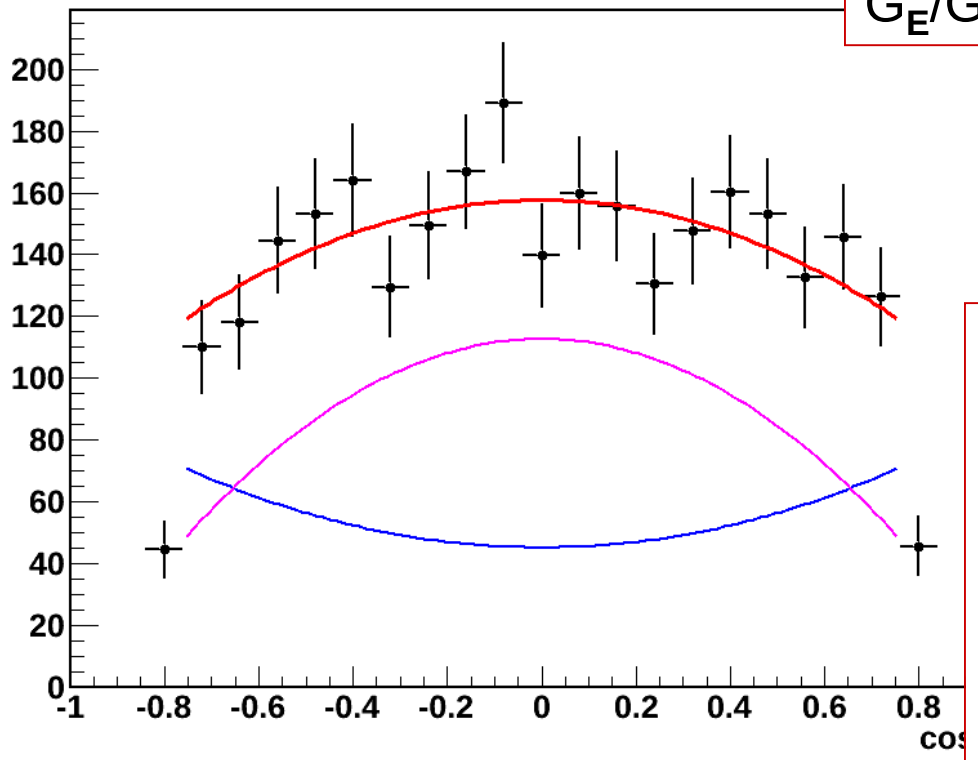
$\sigma_{\text{systemat.}}$ ~0.05 nb

Cos θ, $e^+e^- \rightarrow p\bar{p}$, SND

Preliminary

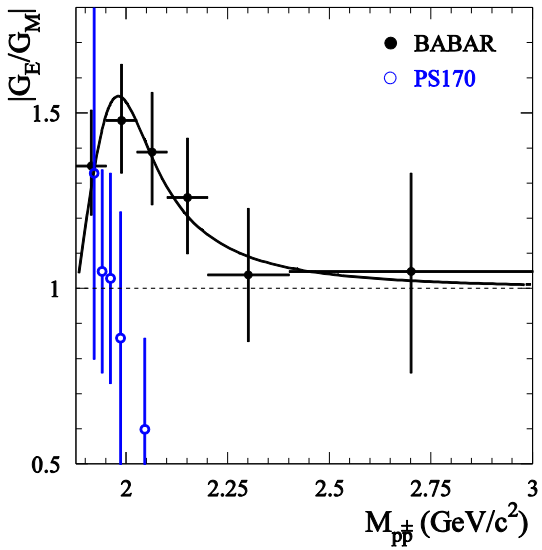
E_{beam}=960 – 1000 MeV

G_E/G_M= 1.64 ± 0.26



Babar :

G_E/G_M= 1.42 ± 0.09



Second measurement after Babar, confirmed Babar

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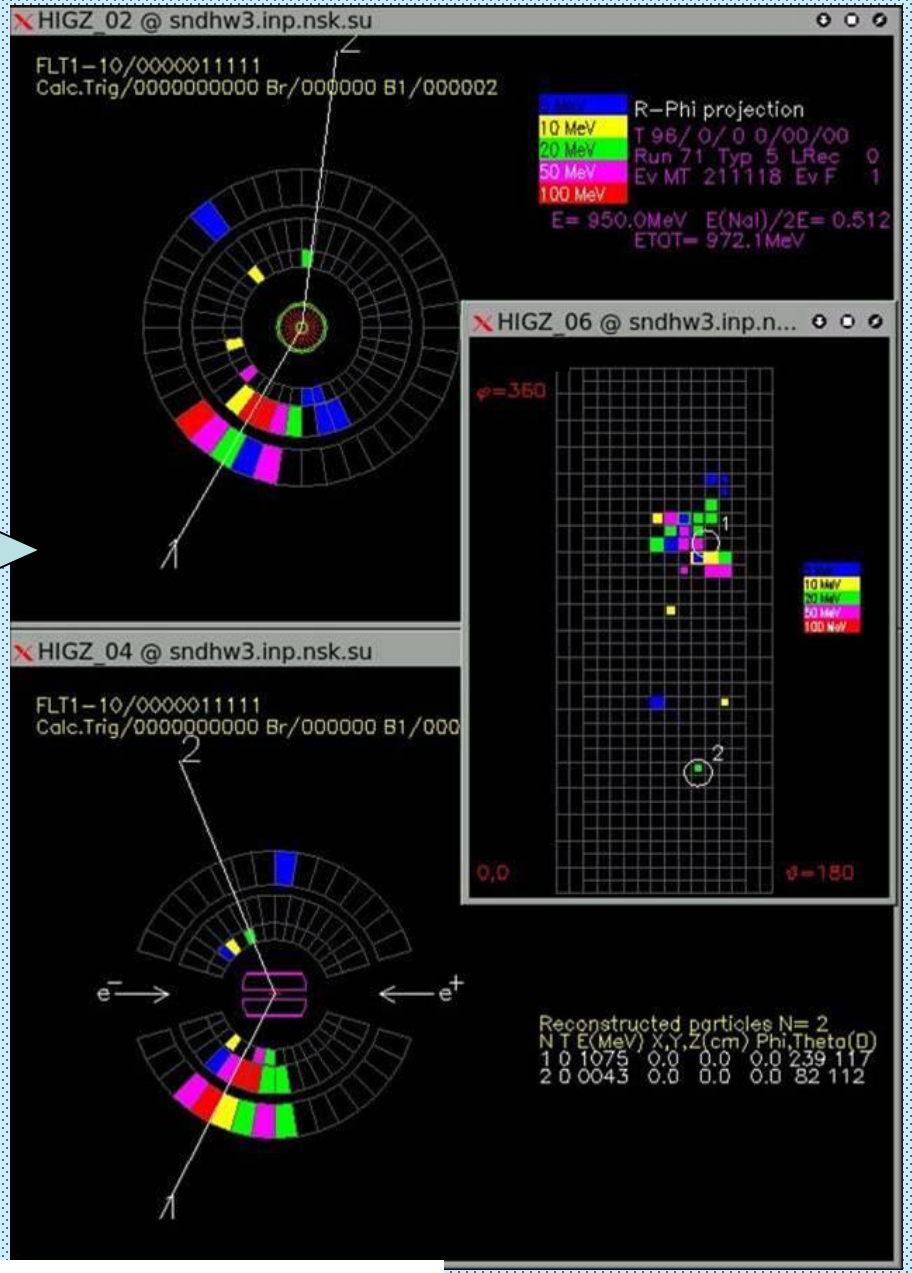
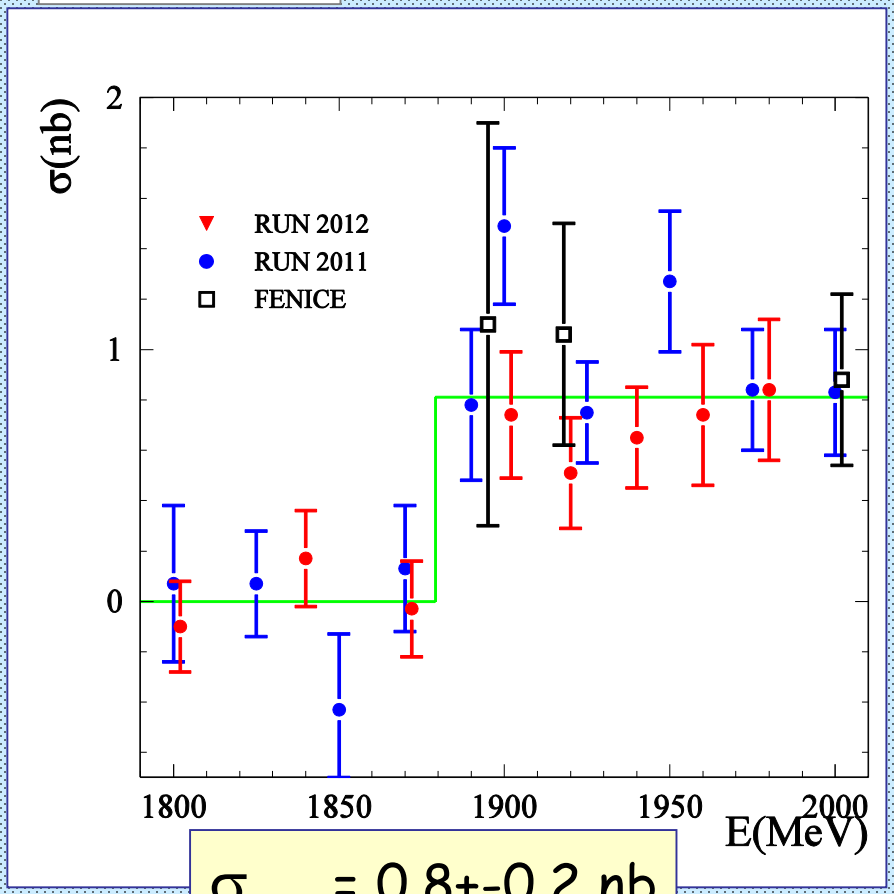
$e^+e^- \rightarrow n\bar{n}$

$n\bar{n}$ candidate event, $E_{\mathbf{beam}}$=950MeV



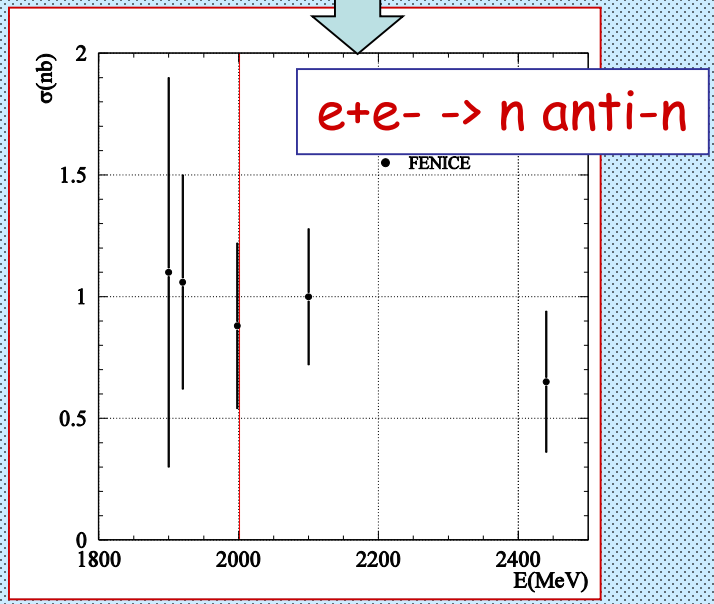
$e^+e^- \to n\bar{n}$, SND

preliminary



σ_{aver} = 0.8+-0.2 nb

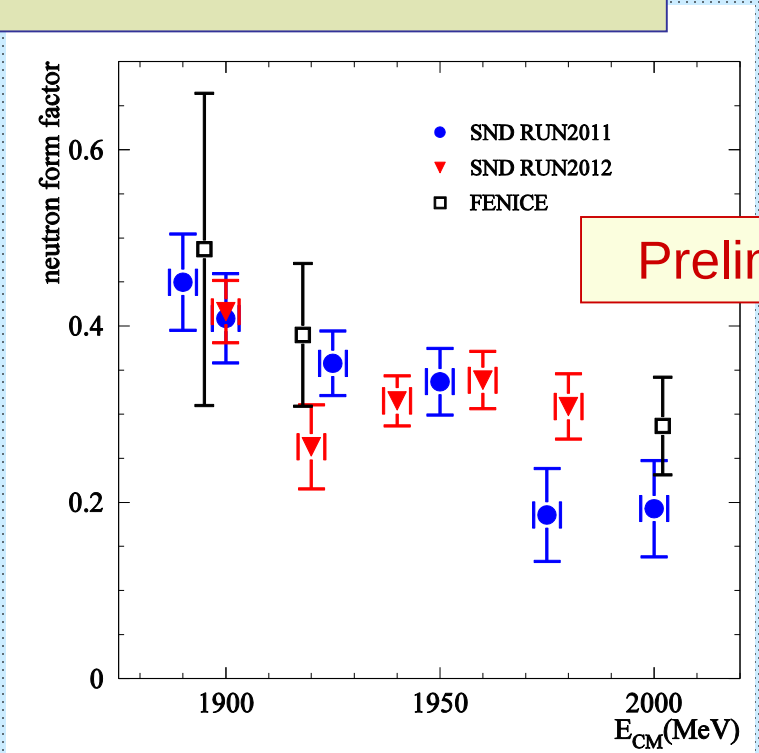
Second measurement after FENICE (1998)



Neutron and proton form factors

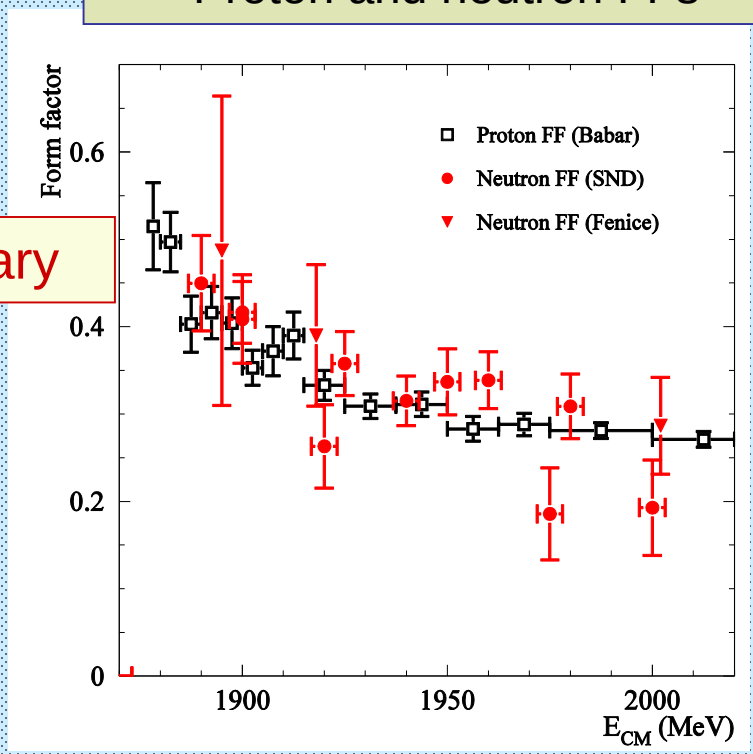
Effective form factor: $$|F|^2 = \frac{|G_M|^2 + |G_E|^2 / 2\tau}{1 + 1/2\tau}, \quad \tau = \frac{s}{4m_N^2}$$

Neutron effective FF

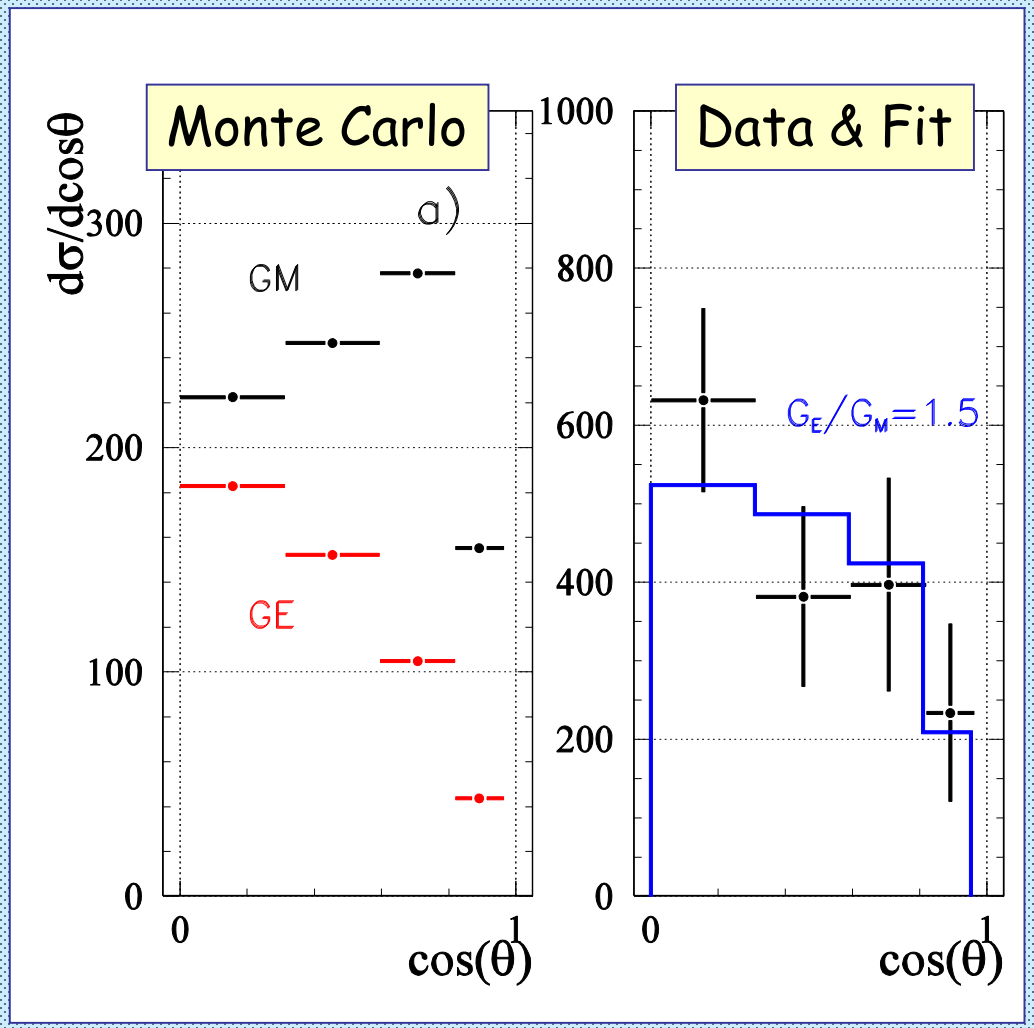


Preliminary

Proton and neutron FFs



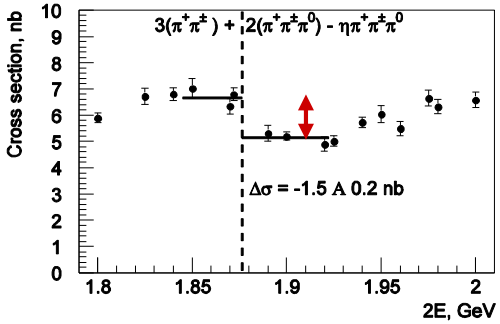
Cos θ, $|G_E/G_M|$, $e^+e^- \to n\bar{n}$, SND

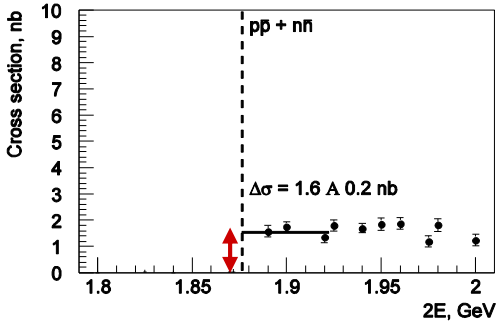


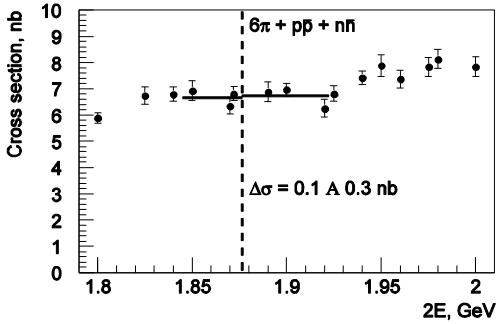
$G_E/G_M>0$, 90% CL

Compensation effect in total e+e- -> hadron cross section at the nucleon threshold

arXiv:1402.5225v1 [hep-ph] 21 Feb 2014







- Negative jump in $e^+e^- \to 6\pi$
- Positive jump in $e^+e^- \to N\ \bar{N}$
- No jump in total cross section
- No explanation, why in 6π ..

Meson 2014, 29.05-3.06 2014

List of analysis, E=1.05 – 2 GeV

1*. $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$

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

3-. $e^+e^- \to \pi^+\pi^-$

4. $e^+e^- \to \pi^+\pi^-\pi^0$

5. $e^+e^- \to \eta\pi^+\pi^-$

6-. $e^+e^- \to \eta K^+K^-$

7. $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$

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

9*. $e+e- \to \eta\gamma \to 7\gamma$

10. e+e- -> p anti-p

11. e+e- -> n anti-n

12*. e+e->6π * N anti-N

Possible applications of VEPP-2000 data

1. $g\text{-}2_\mu$
2. $\alpha_{em}\ (s=M_Z^2)$
3. CVC ($e^+e^- \to \tau$)
4. V * -> ρ', ω', ϕ', …
5.

Conclusions

1. VEPP-2000 e+e- collider since 2011 had accumulated ~70 inv.pb data with each SND and CMD-3 detectors in the range E=0.3 – 2 GeV. First results are published.

2. At SND the data analysis on meson and nucleon production is going on. The results for more than 10 processes are presented at MESON 2014 Conference.

3. After VEPP-2000 upgrade in 2015 the data taking runs will be resumed with the goal of ~ 1 inv.fb of integrated luminosity.

4. We hope to reach about ~3-5 % accuracy for the most of e+e- -> hadrons cross sections.

Thank you for attention