Measurement of the neutron timelike form factor in the process $e^+e^- \to n\bar{n}$

Sergey Serednyakov

Budker Institute of Nuclear Physics
Novosibirsk State University

Outline

1. Description of nucleon Form Factors
2. Collider, detector, data
3. $e^+e^- \to n\bar{n}$ cross section
4. $|G^E/G^M|$ ratio
5. Conclusions, perspectives

$e^+e^- \to N\bar{N}$ 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 : $c = y/(1-e^{-y}),\ y = \pi\alpha/\beta$

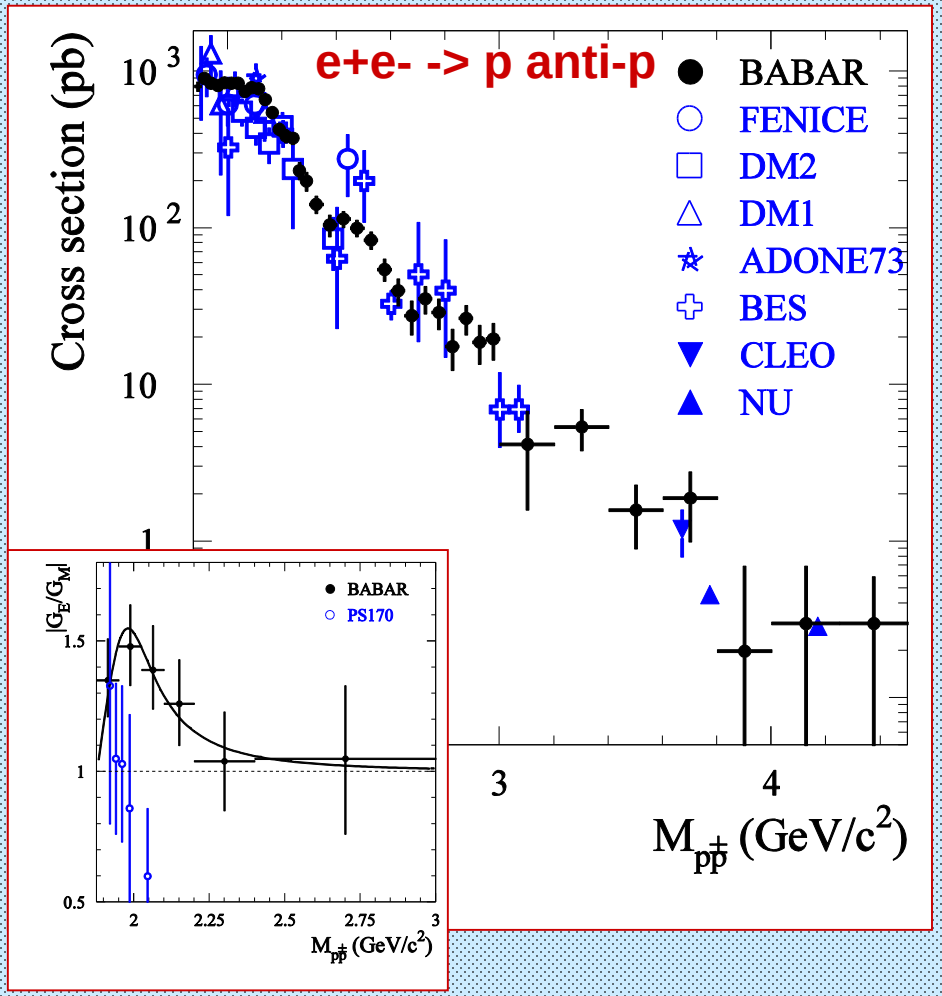
C=1 for neutrons

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

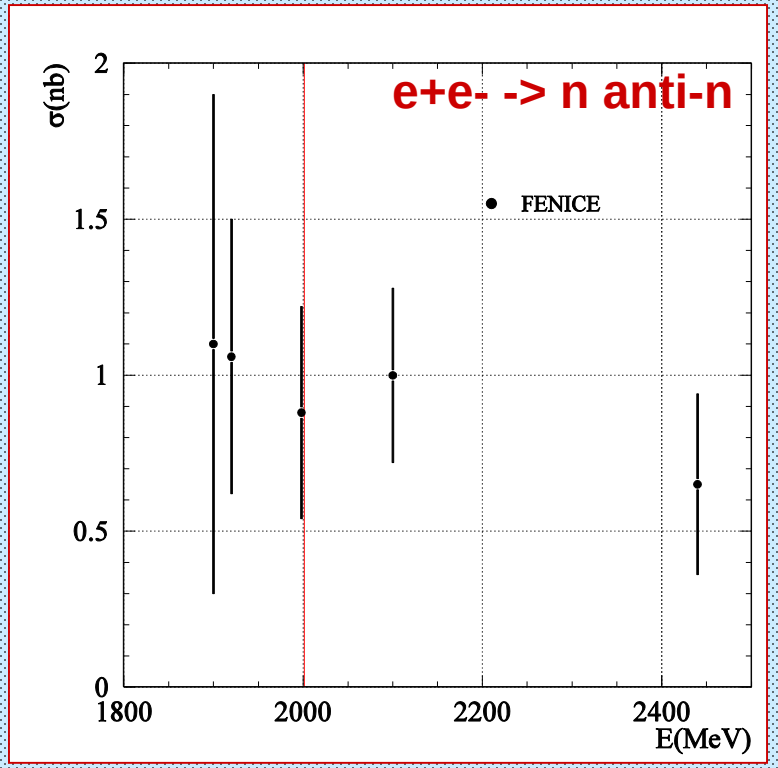
Asymptotic prediction: $F(+\infty) = -F(-\infty) \sim 1/s^2$

Existing data on TL FF and GE/GM for proton and neutron

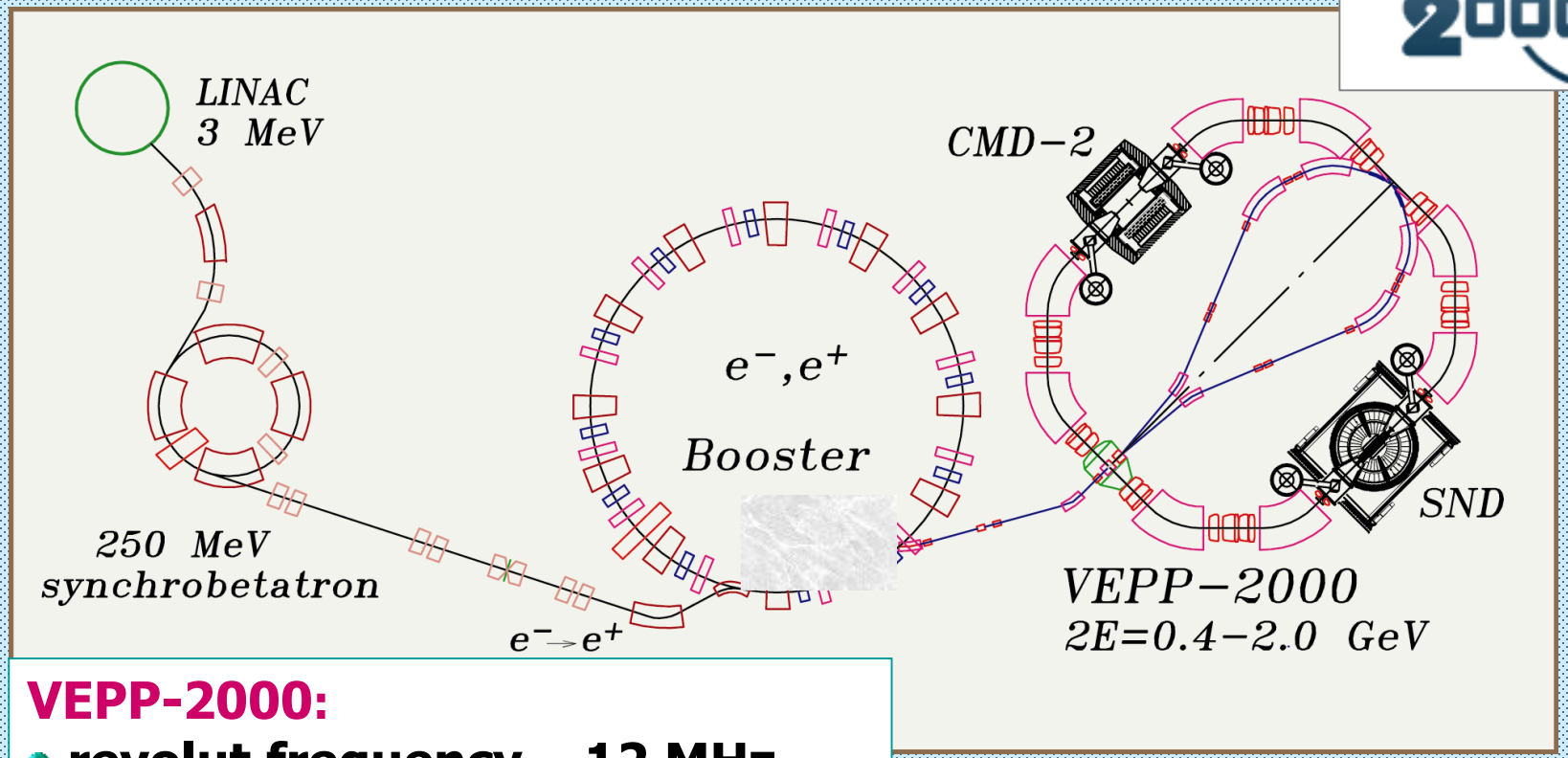
Babar: PRD 87,092005(2013)



FENICE: NP B517, 3(1998)

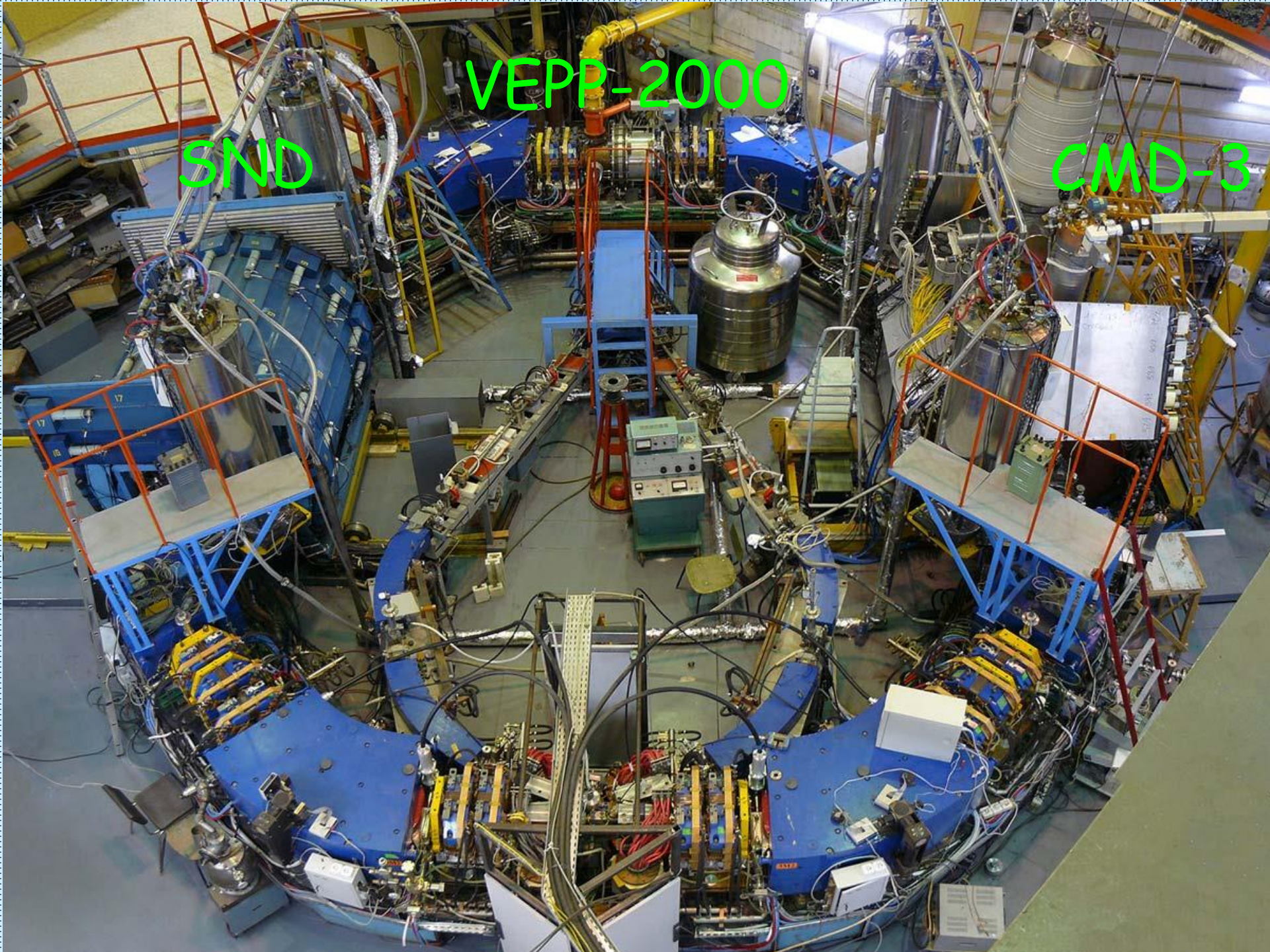


VEPP-2000



VEPP-2000:

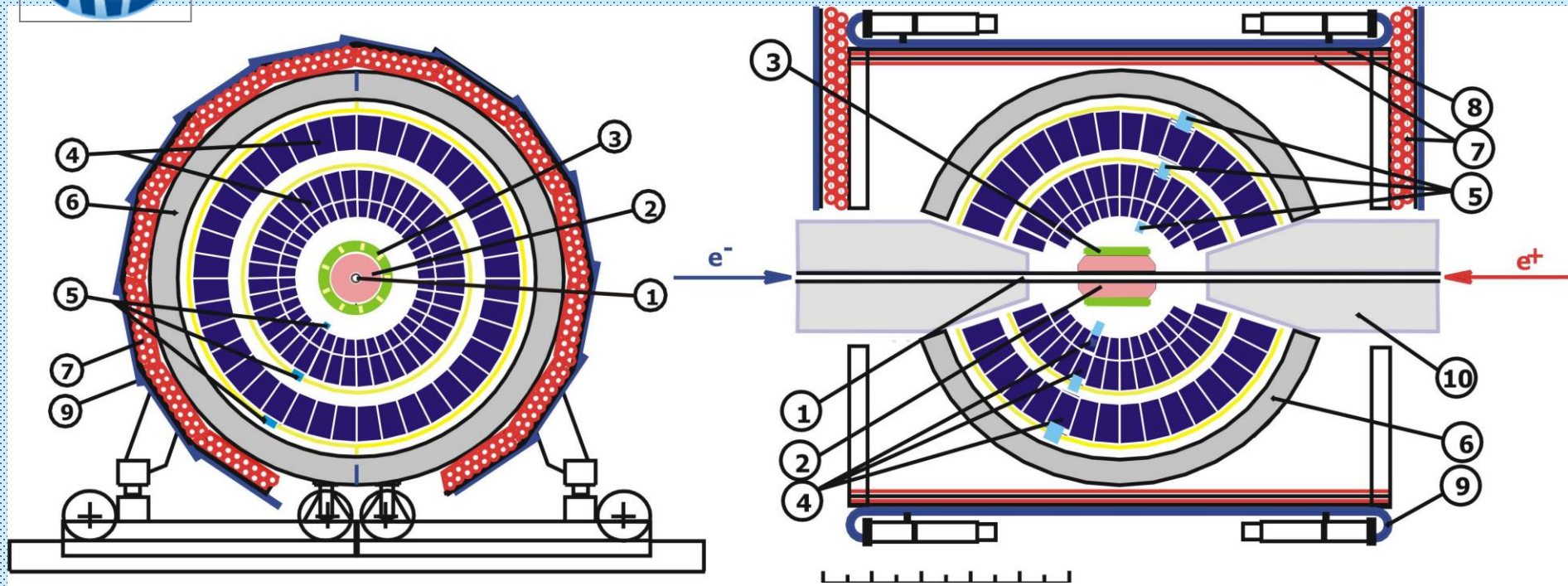
- **revolut.frequency – 12 MHz**
- **current – 0.2 A**
- **beam length – 3.3 см**
- **energy spread – 0.7 МэВ**
- **L ≃ 1.10^{32} at 2E=2.0 ГэВ**
- **L=2.10^{31}cm^{-2}s^{-1} at 2E=1.0 ГэВ**


VEPP-2000
SND
CMD-3

Data, 1.8 – 2.0 GeV (SND)

2011- 4.5 pb^{-1}
2012 - 5.8 pb^{-1},
Above N $\bar{N}$ threshold – 5.7 pb^{-1},
L_{av} – 5. 10^{30} $cm^{-2}s^{-1}$,
L_{max} – 10^{31} $cm^{-2}s^{-1}$,

SND



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

NIM A449 (2000) 125-139

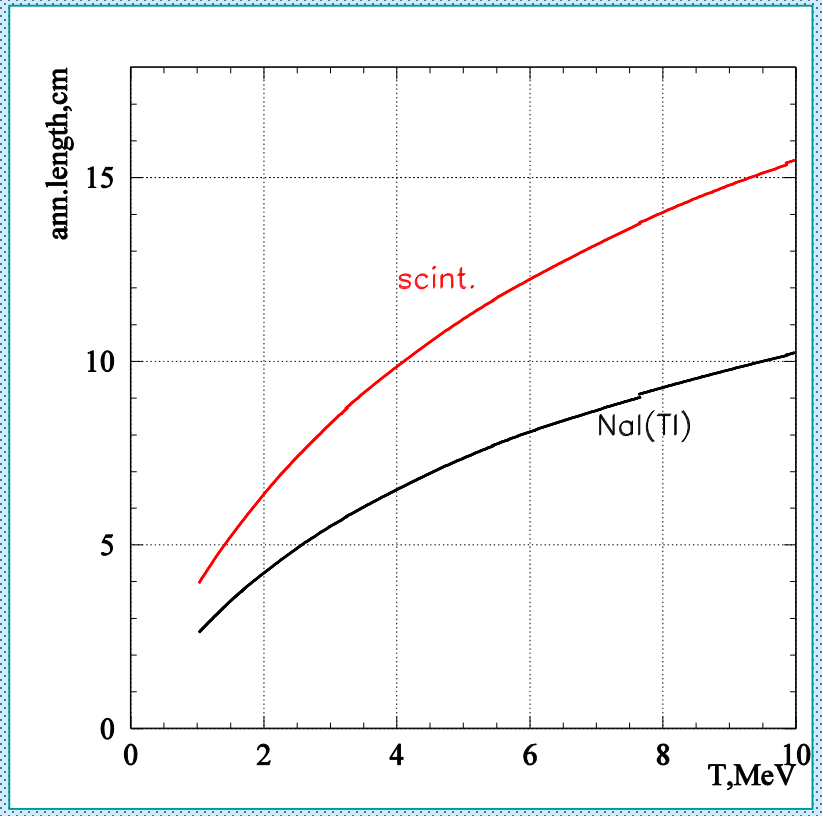
Advantages for VEPP-2000:

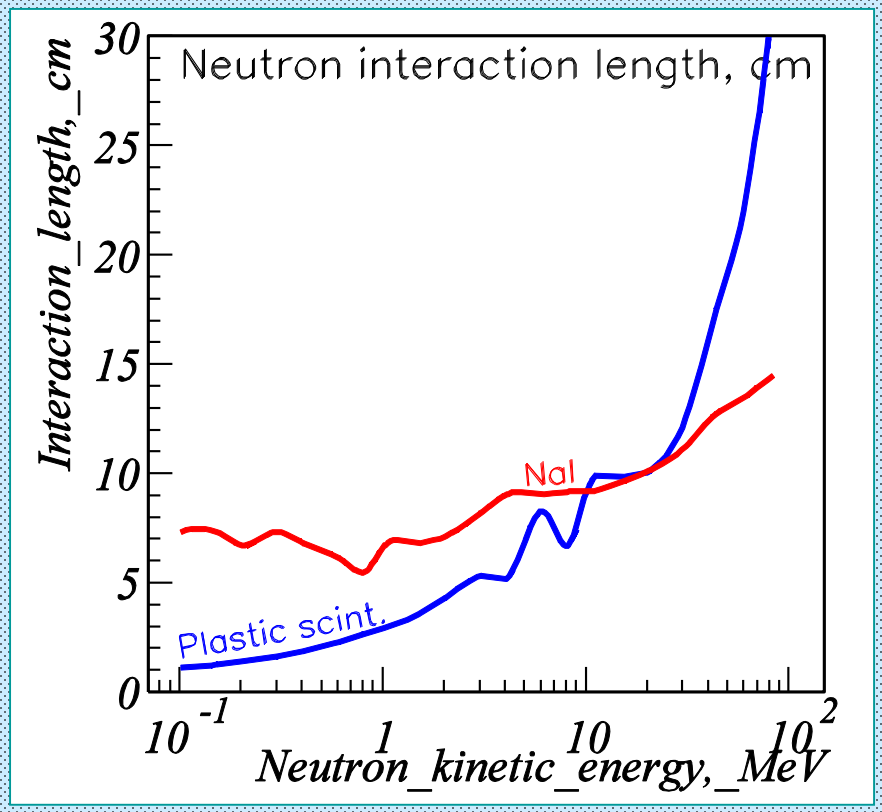
1- cherenkov counter, n=1.05, 1.13 – e/πseparation E<450 MeV, π/K separation E<1 GeV,

2 –drift chamber – better tracking,

3- time of flight in ECAL (будущий)

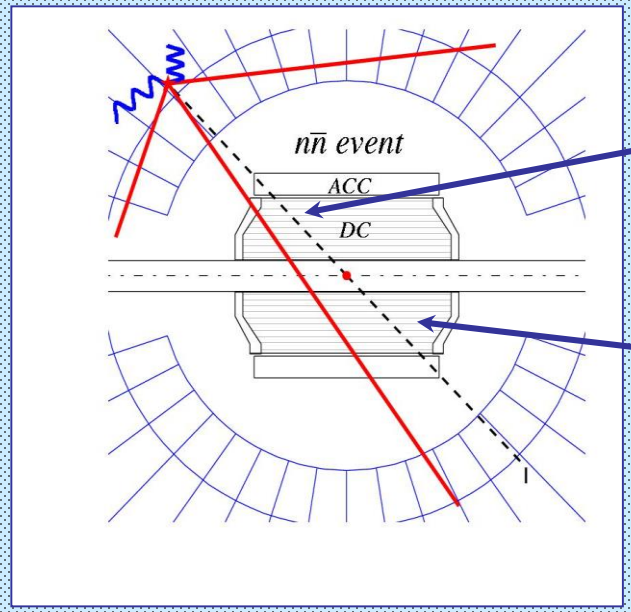
Взаимодействие нейтронов и антинейтронов





$e^+e^- \to n$ анти-n, данные 2011 и 2012 гг.

Ожидаемый вид события



Особенности событий:
- нет центральных треков, но могут быть непучковые треки;
- нет центральных фотонов;
- дисбаланс энергии-импульса

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

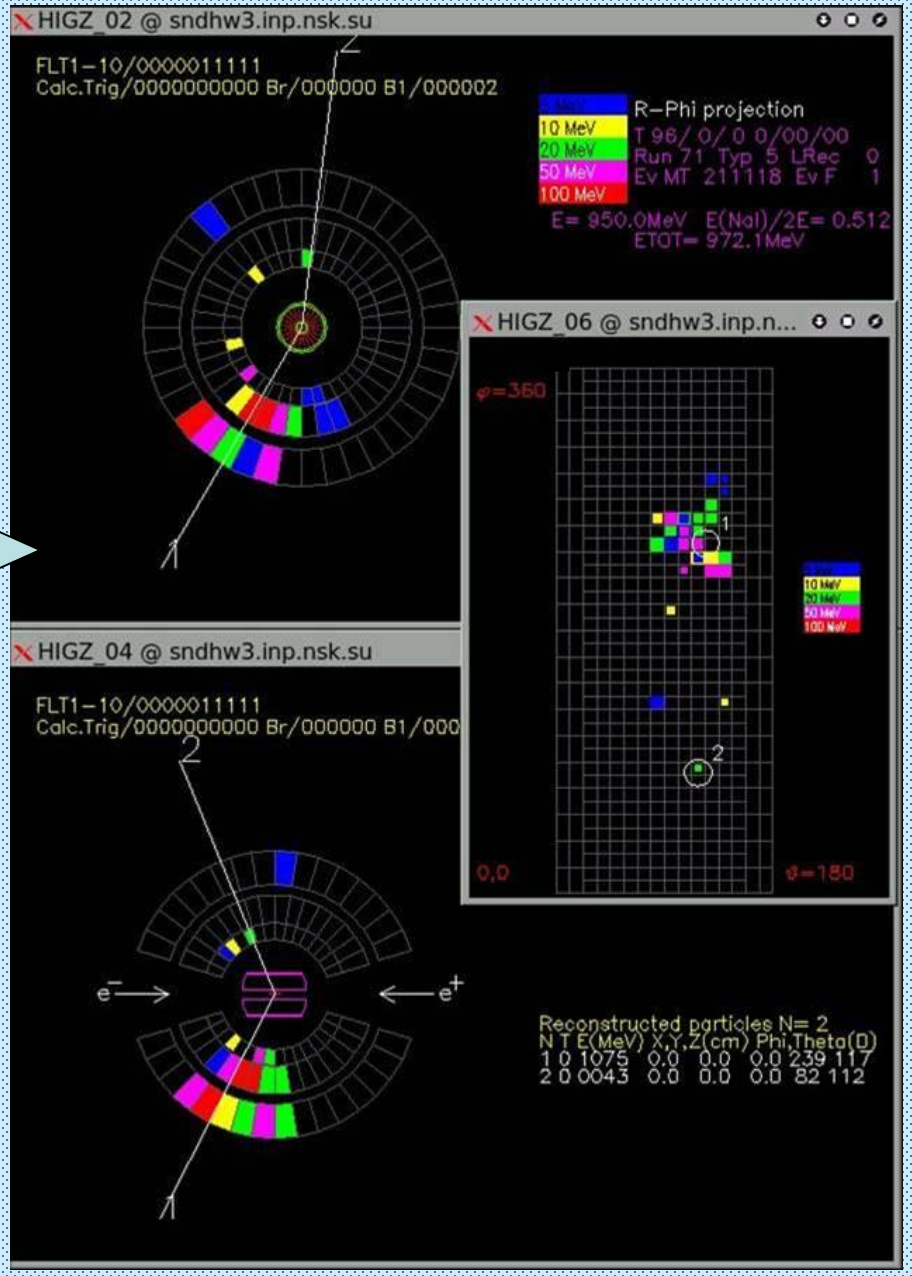
Both n, $\bar{n}$ are alike photon or K_L,
$\bar{n}$ gives huge energy release ~ $2M_n$,
$\bar{n}$ absorbtion length in NaI(Tl) ~5-15 cm,
EMC calorimeter thickness =35 cm,
Most n, $\bar{n}$ interact in EMC

Events types:	Suppression cuts
- All e^+e^- interactions,	- no tracks, photons from centre
- e^- or e^+ bkgd,	- $E_{tot} > E_{beam}$, in EMC
- Cosmic	- muon system veto,
- n n events	- no cosmic tracks in EMC

Detection efficiency 18-25%

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

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



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

$$\sigma = \frac{n - xT}{\varepsilon \delta L} - \sigma_{th}$$

n – number of events

σ – cross section,

X~1.5 10^{-3} Hz - cosmic

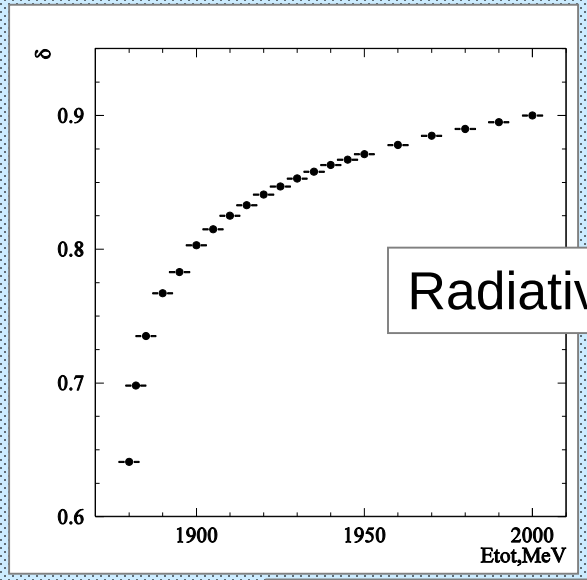
T – run time,

ε – detection efficiency,

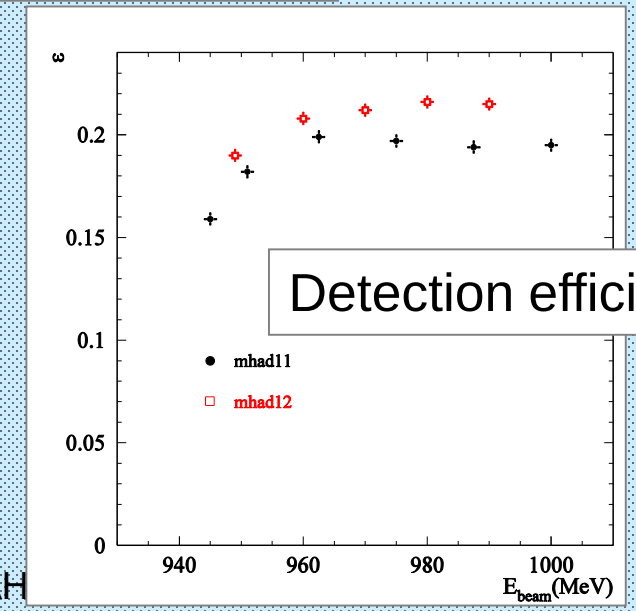
δ – radiative correction,

L – luminosity,

σ_{th} ~0.2 nb - threshold cross section



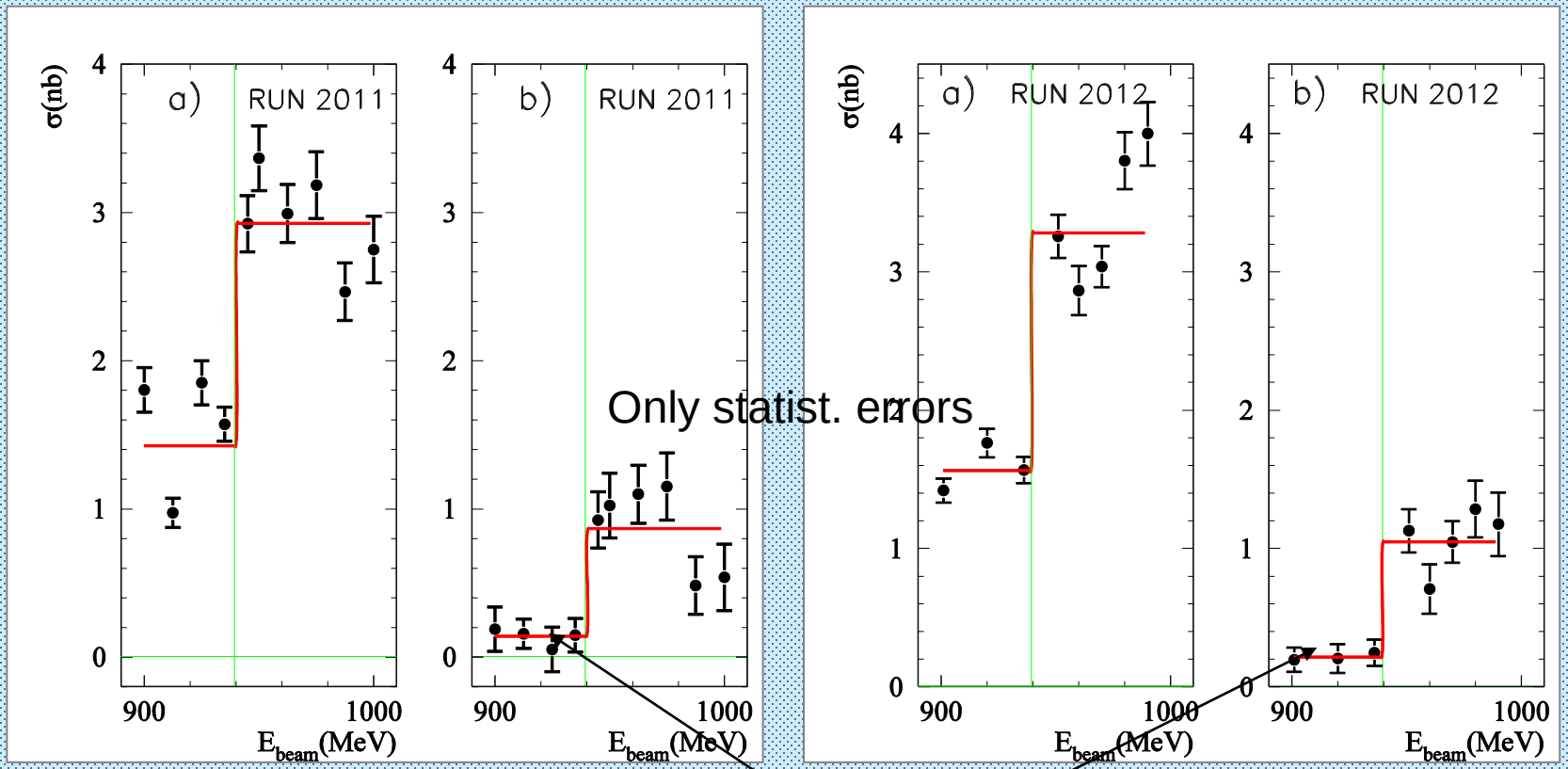
Radiative correction



Detection efficiency

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

Cross section before and after cosmic subtraction

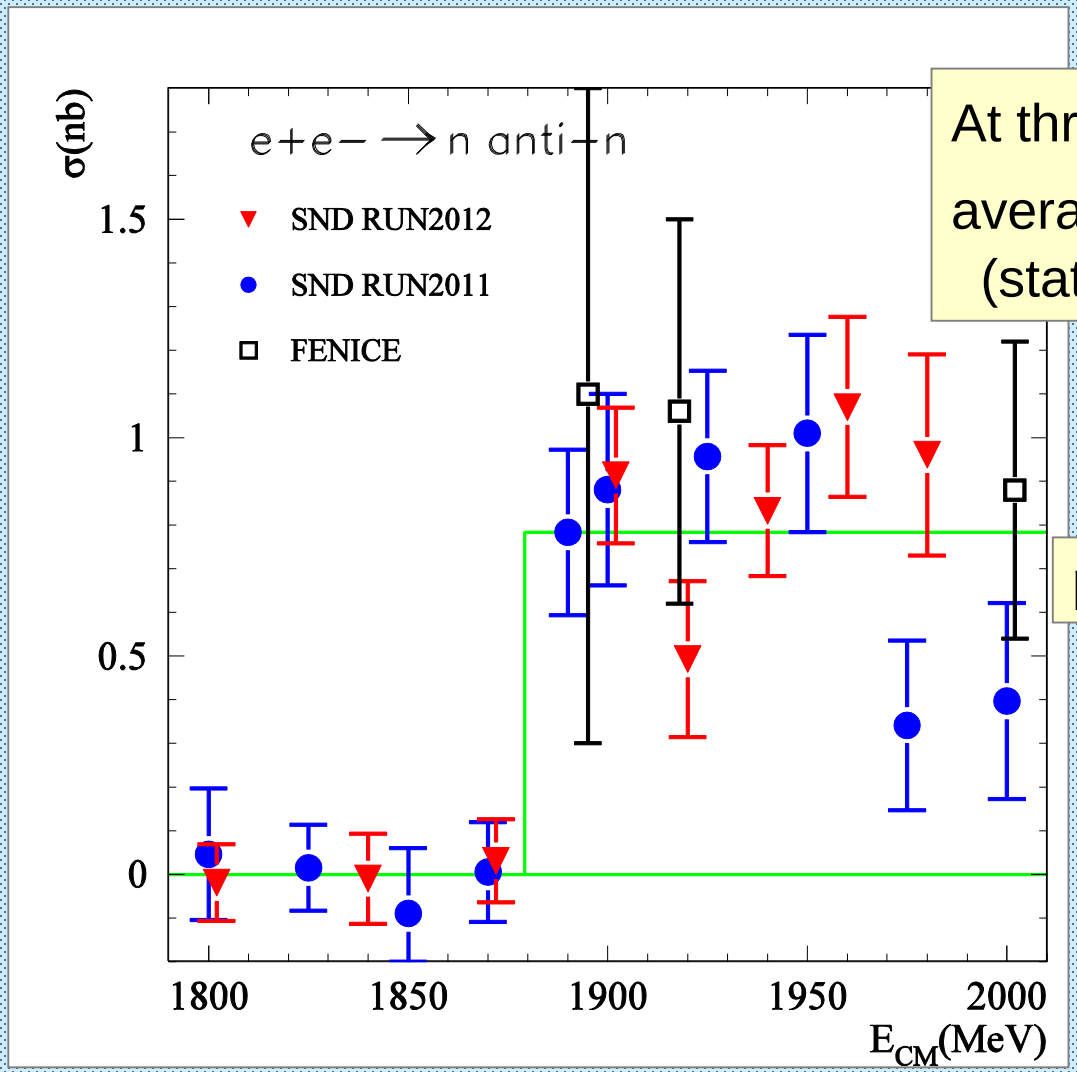


$e^+e^- \rightarrow n\bar{n}$, systematics

1. Cosmic subtraction ~ 0.1 nb
2. Detection efficiency ~ 0.2 nb
3. Threshold background ~ 0.1 nb
4. Luminosity – 3%

Total error 0.25 nb (~30%)

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



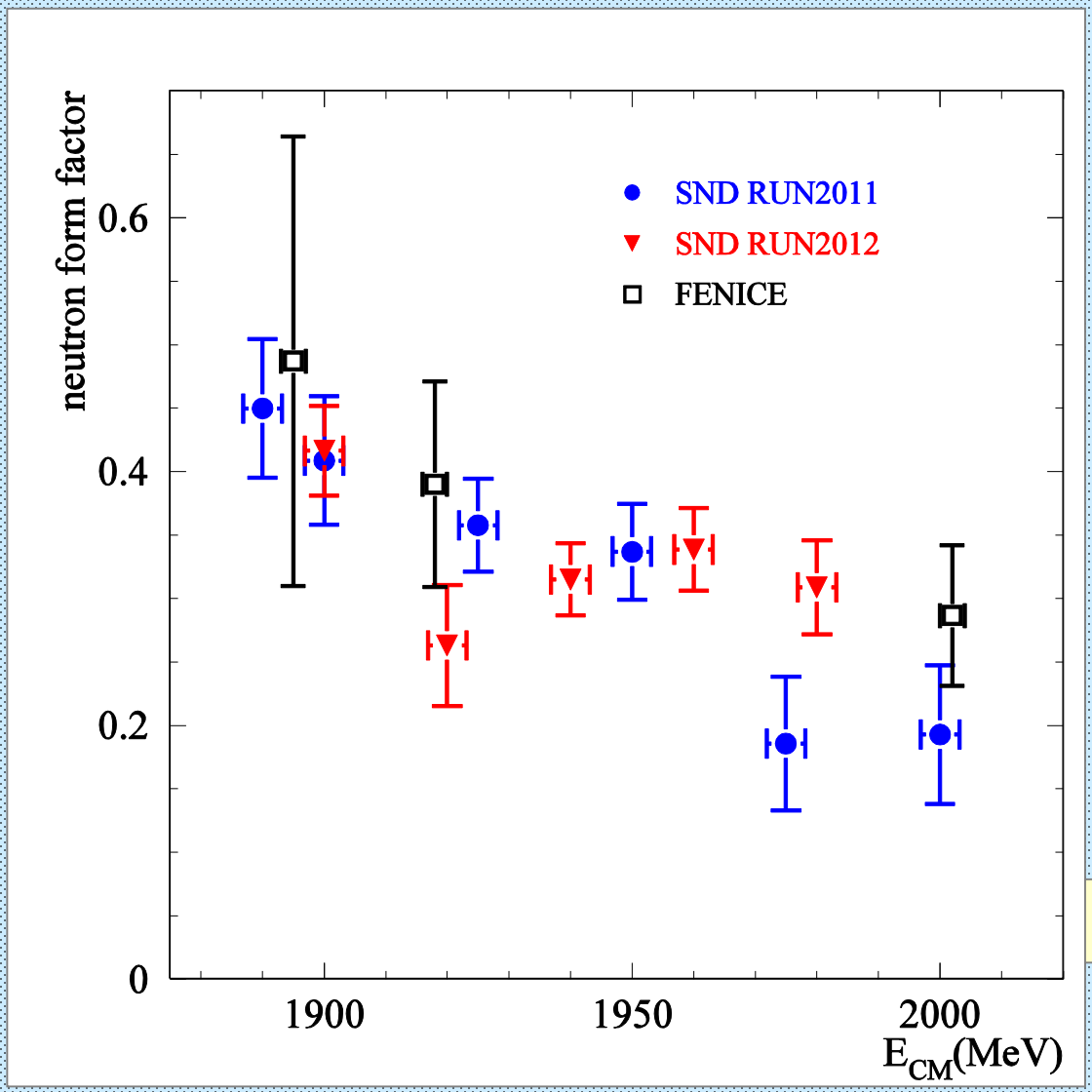
At threshold $\sigma \sim 1$ nb,

average $\sigma = 0.78 \pm 0.08$ nb
(stat.error only)

preliminary

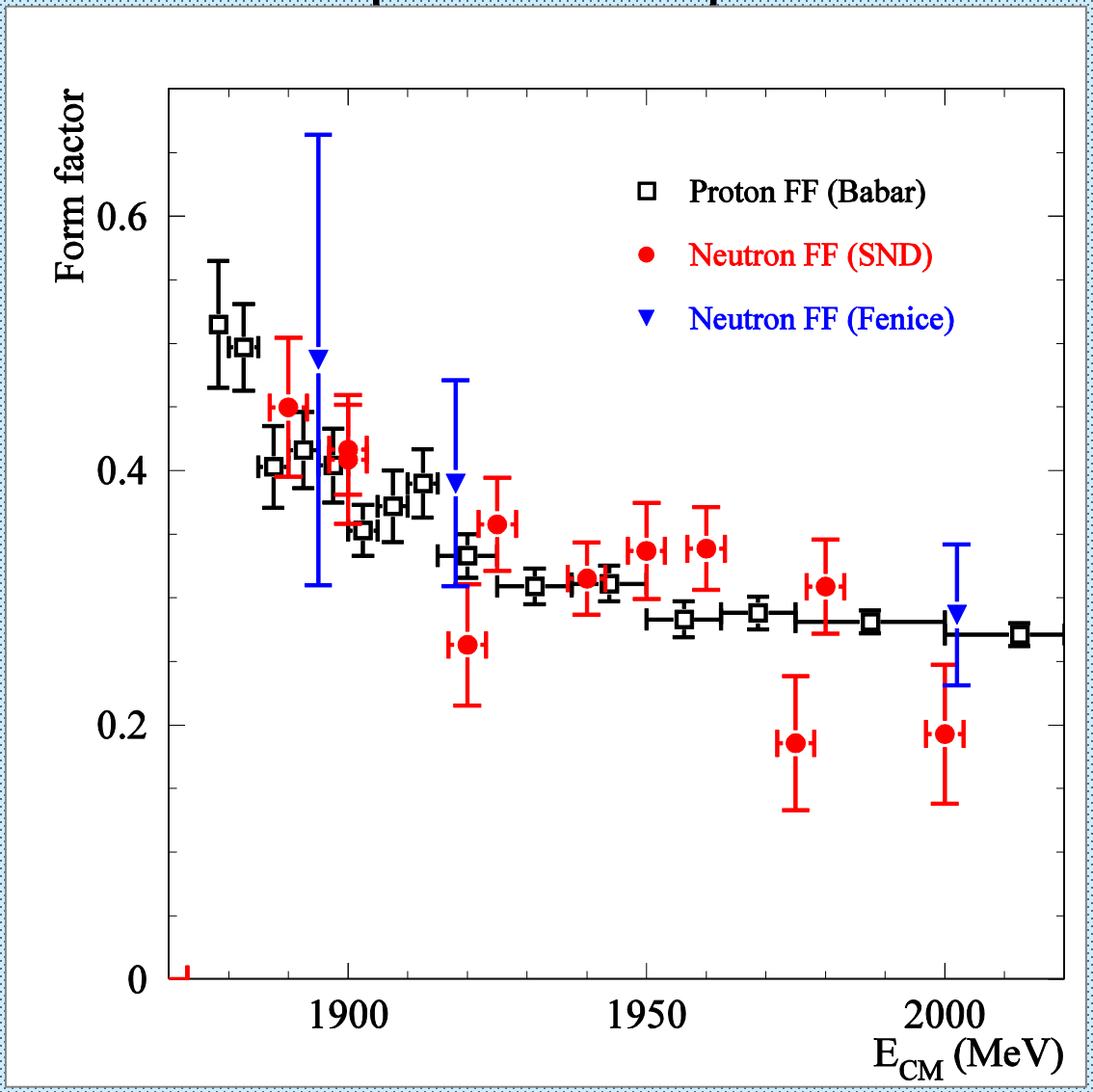
No contradiction with FENICE data

Neutron effective TL form factor



preliminary

Comparison of proton and neutron FFs

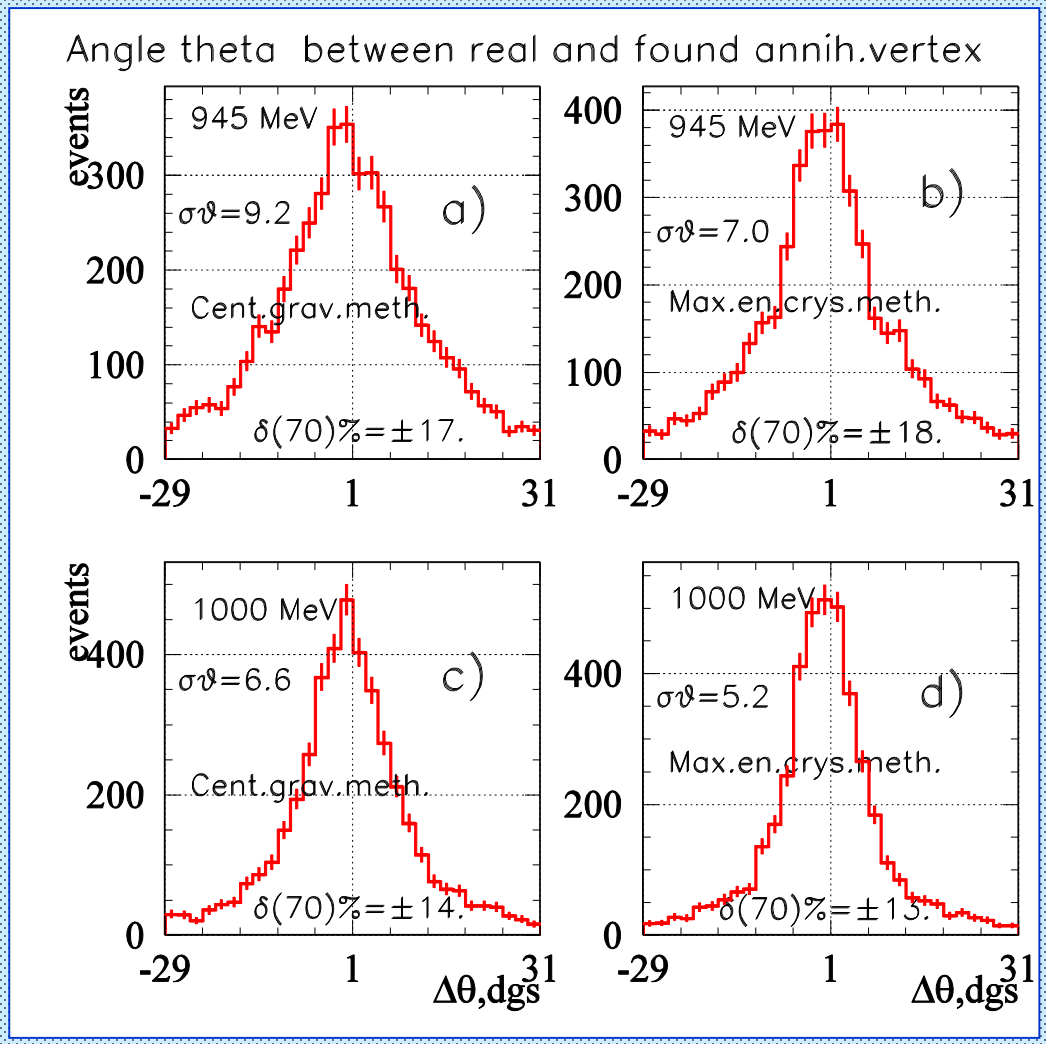


Preliminary

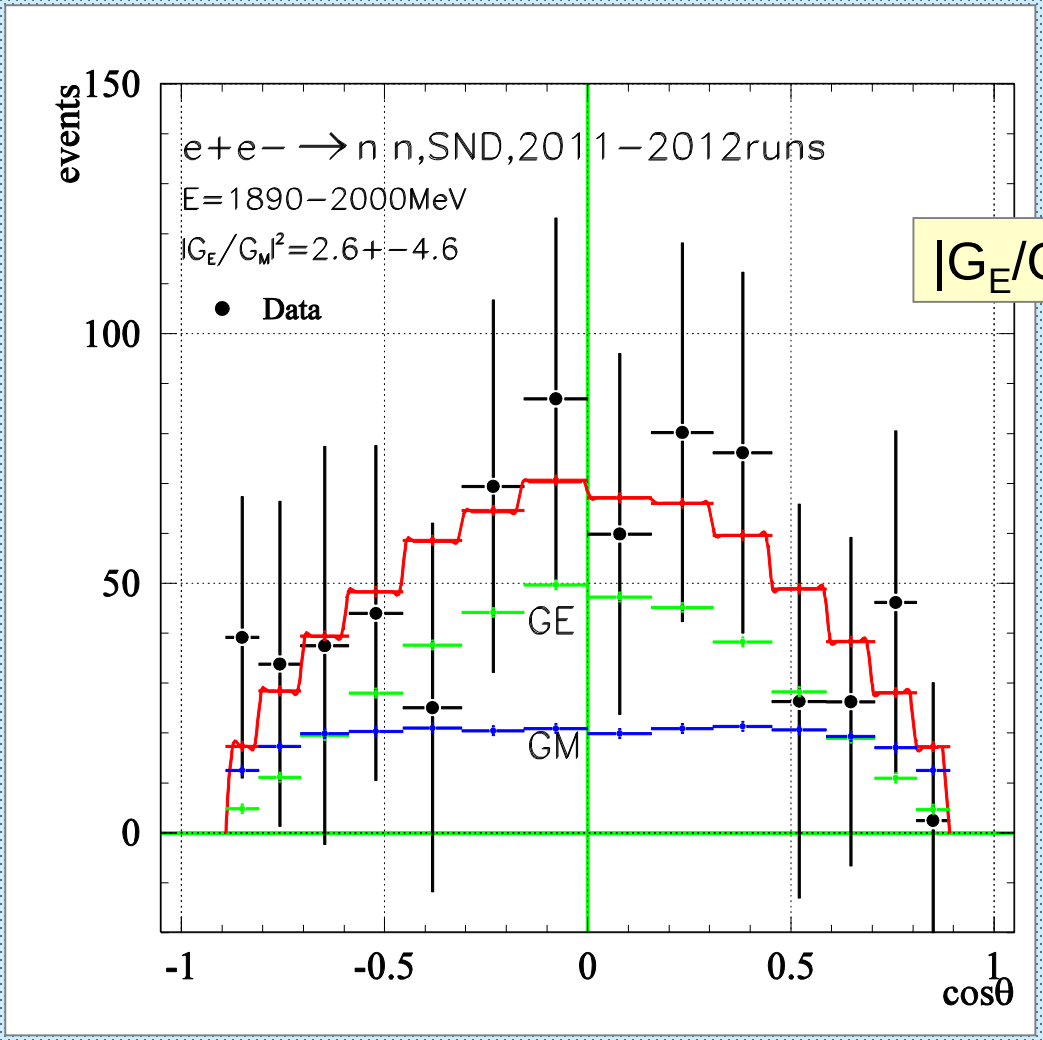
Only statist. error

Asymptotic QCD :
$F_n = - F_p/2$

Угловая точность по θ в Монте Карло.



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



$|G_E/G_M|^2 = 2.6 \pm 4.6$

Blue – G_M contribution
Green – G_E ontribution
Red – best fit

Conclusions

In 2011, 2012 runs SND has measured:
-- $e^+e^- \to n\bar{n}$ process cross section,
-- effective neutron e.m. form factor,
-- the neutron $|G_E/G_M|^2$ ratio

Perspectives

1. Final results on nucleons form factors are expected soon
2. New laser calibration energy with ~ 0.1 MeV precision is ready
3. New positron source will provide integrated luminosity higher than 100 pb^{-1}.

Спасибо за внимание