Measurements of nucleon form factors in the time-like region with DAΦNE at 2 GeV

Alessandra Filippi, INFN Torino

Outline of the talk

- Open problems in e^+e^- annihilation around $\sqrt{s}$ = 2 GeV (close to $\overline{N}N$ threshold)
  - Measurements of nucleon time-like form factors
  - Existence of anomalous structures in multihadronic production

- Study of feasibility with FINUDA
  - $e^+e^- \rightarrow \overline{N}N$ annihilation and form factors evaluations
    - Apparatus' changes
    - Expected topologies and detection efficiencies

Measurements of the nucleon form factors in the time-like region

- Based on total and differential cross sections:

$$\sigma = \frac{4\pi\alpha^2\beta}{3s}\left[\left|G_M(s)\right|^2 + \frac{2M_N^2}{s}\left|G_E(s)\right|^2\right]$$

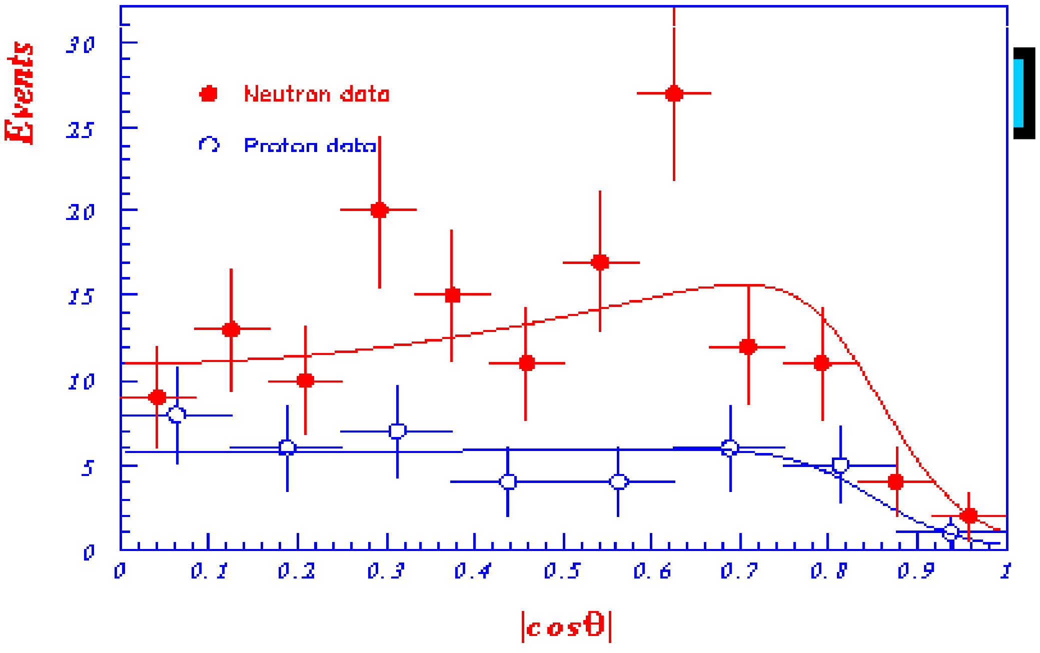
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2\beta}{4s}\left[\left|G_M(s)\right|^2\left(1+\cos^2\vartheta\right) + \frac{4M_N^2}{s}\left|G_E(s)\right|^2 \sin^2\vartheta\right]$$

- $G_E = F_1 + (s/4M^2_N)F_2$ $G_M = F_1 + F_2$ (Sachs FF)
- G_E vs G_M can be discriminated via the angular distributions
  - $s >> M^2_N$:   only $G_M(s)$ counts
  - $s \approx 4\,M^2_N$ (threshold): $G_E(s) \approx G_M(s) \Rightarrow$ isotropic distribution

FENICE data: the differential cross sections

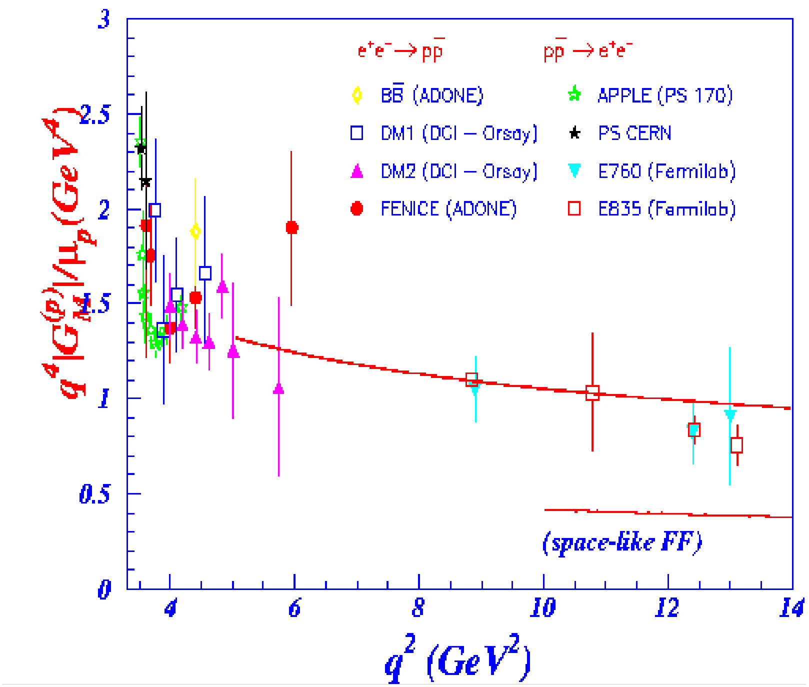
- General cross sections features:
  - $\sigma \approx \beta$
  - $\sigma \approx |G|^2$
  - Only $|G|^2$ can be measured, not G
  - $\Delta|G|/|G| = ½ \, \Delta\sigma/\sigma$

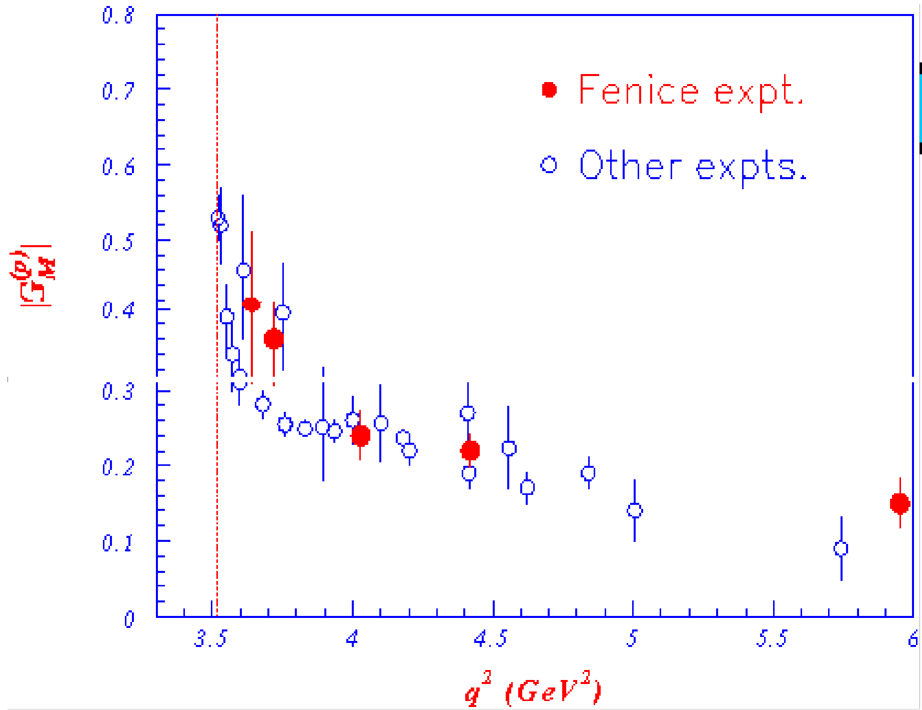
- Neutron: dominance of the $(1+\cos^2\theta)$ term
  - $|G_E| < 0.1\ |G_M|$ @ 90% C.L.
- Proton: isotropic distribut'n
  - $|G_E| \approx |G_M|$



FENICE data: the proton magnetic form factor

$\sqrt{s}$ (GeV)	L(nb^{-1})	$N_{cand} - N_{bckg}$	ε	σ(nb)
1.90	34.2 ± 2.0	7 ± 3	0.21 ± 0.07	0.97 ± 0.53
1.92	79.6 ± 4.8	16.0 ± 4.5	0.21 ± 0.02	0.96 ± 0.27
2.00	93.9 ± 5.6	18.0 ± 4.7	0.31 ± 0.03	0.62 ± 0.17
2.10	99.9 ± 6.0	28.0 ± 5.3	0.45 ± 0.03	0.62 ± 0.12
2.44	57.1 ± 3.4	7.0 ± 2.6	0.44 ± 0.03	0.28 ± 0.12

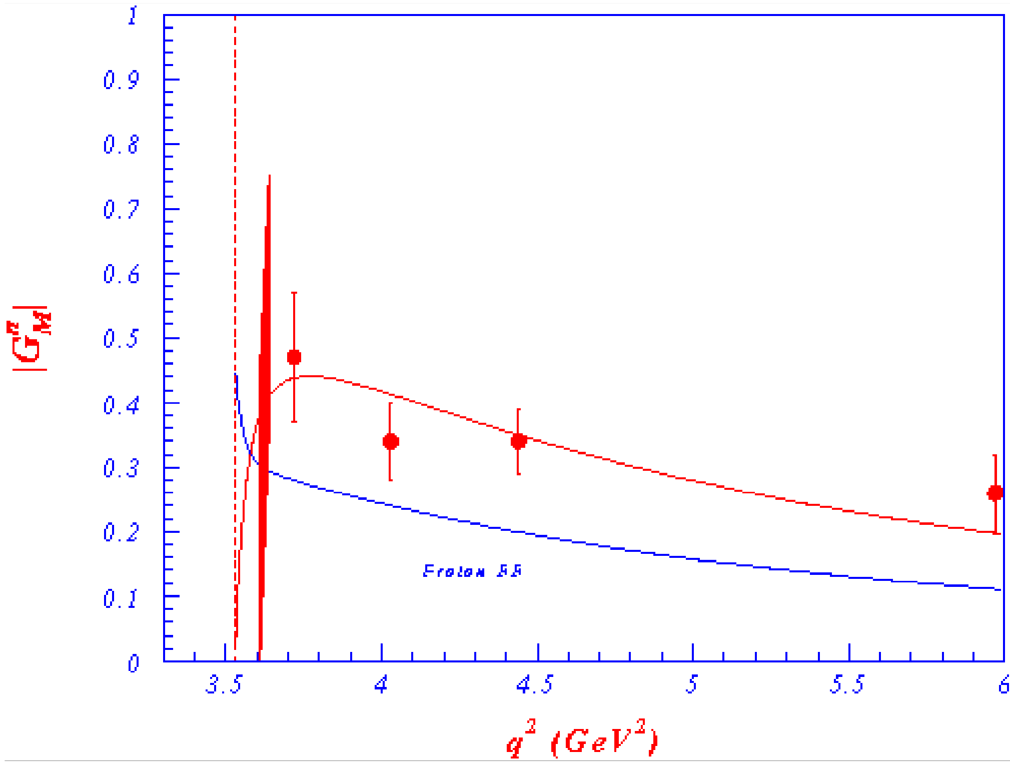




FENICE data: the neutron magnetic form factor

- Assuming $G_E = 0$ $|G_M|$ can be obtained as a function of s

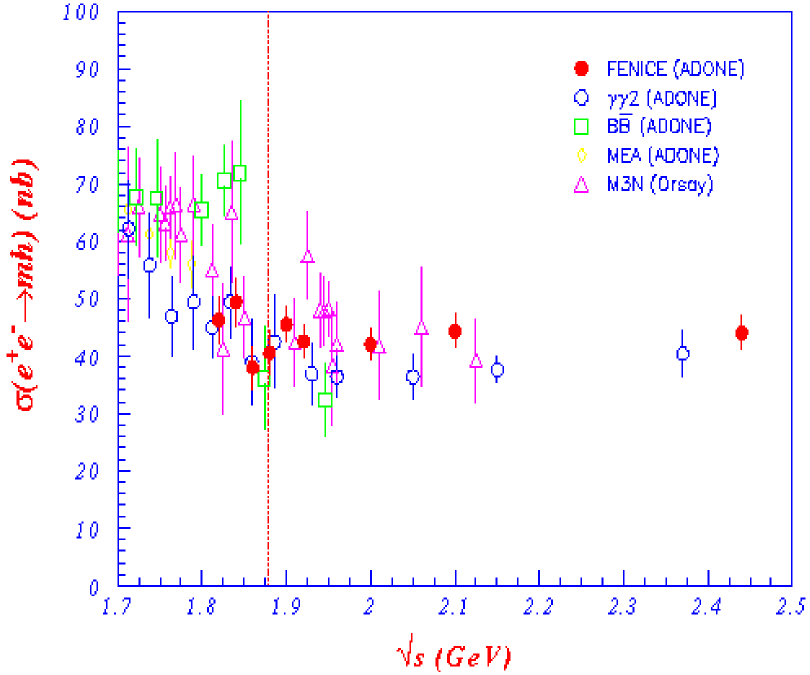
- Peculiar behaviours:
  - $|G_M^{(n)}| \approx 1.5\ |G_M^{(p)}|$
  - $|G_M^{(n)}$ time-like$|$ > $|G_M^{(n)}$ space-like$|$
  - Indications for an anomalous behaviour close to threshold (where must be $G_M \approx G_E$)

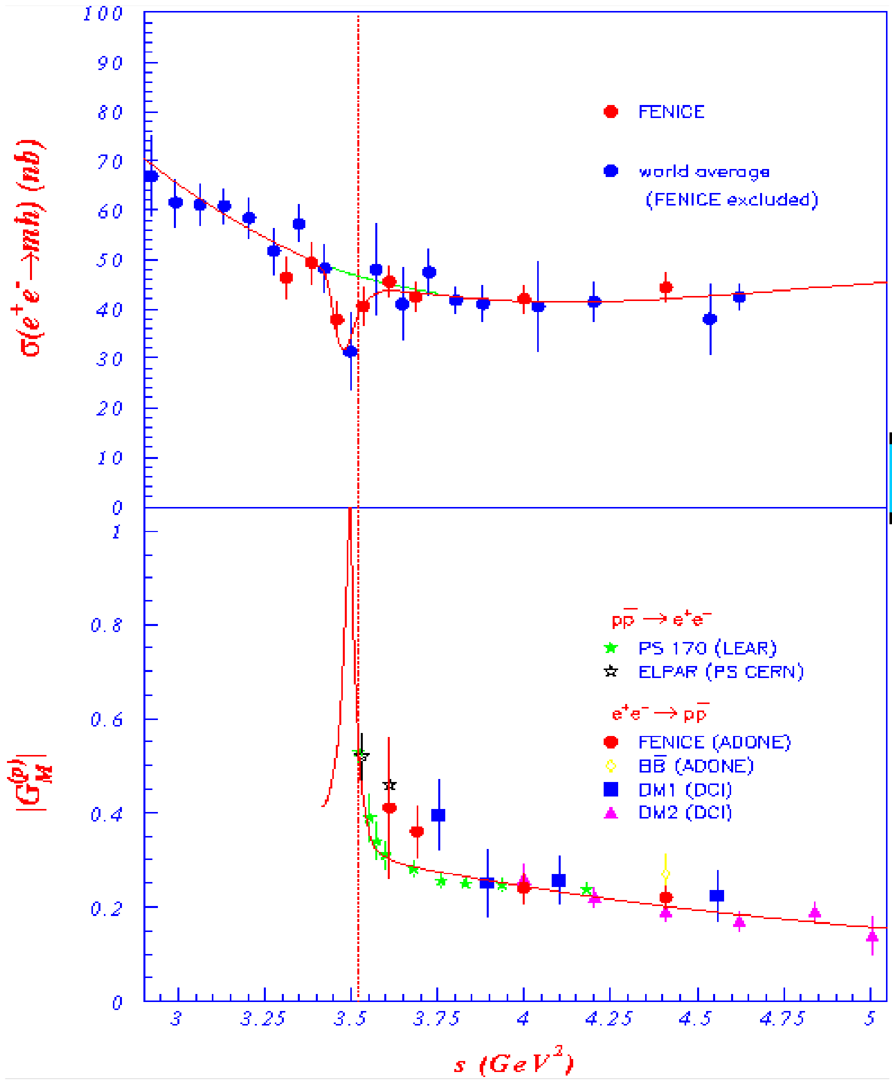


According to all theoretical predictions: G(p) > G(n)

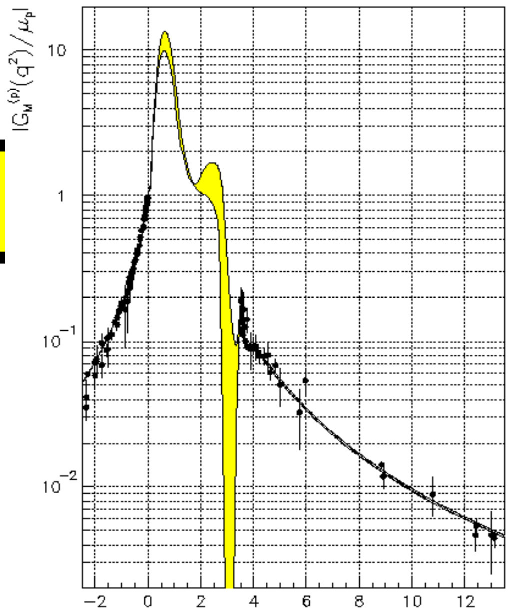
FENICE: multihadron cross section 1.82-2.44 GeV

- Hints for a dip close to threshold corresponding to a rise in $|G_M^{(p)}|$
- From a combined fit:
  - $M = 1870 \pm 10$ MeV
  - $\Gamma = 10 \pm 5$ MeV

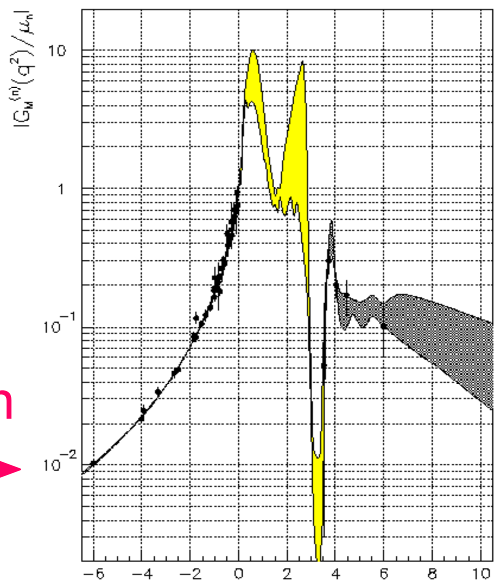




Open problems left by FENICE



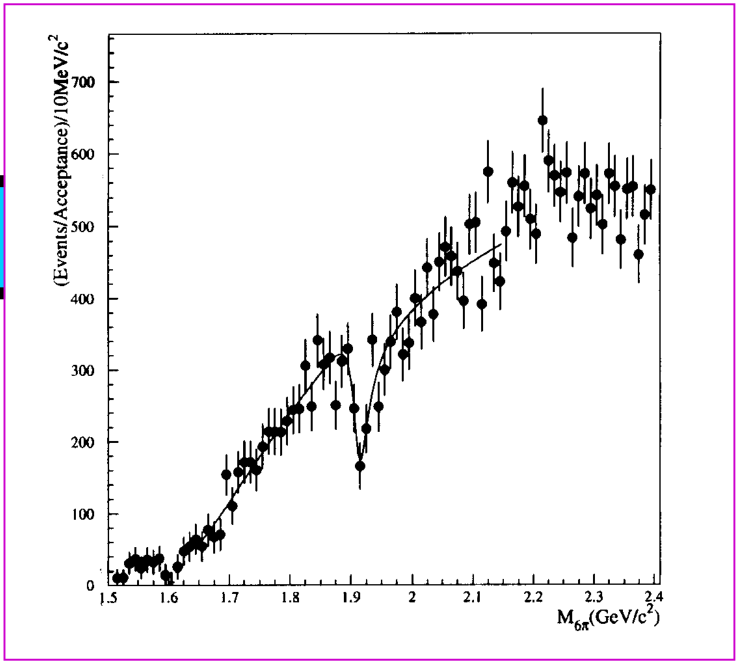
proton



neutron

- Why $G^{(n)} > G^{(p)}$?
- $G_E^{(n)} << G_M^{(n)}$
- Why $|G_M^{(n)}$ time-like$| >$ $|G_M^{(n)}$ space-like$|$?
- Form factors in the unphysical region (dispersion relations)?
- Only modules can be measured
- Is there a structure close to NN threshold?
- No infos on other baryons FF

Another anomaly at 1.9 GeV: observation in diffractive photoproduction and $e^+e^- \to 6\pi$

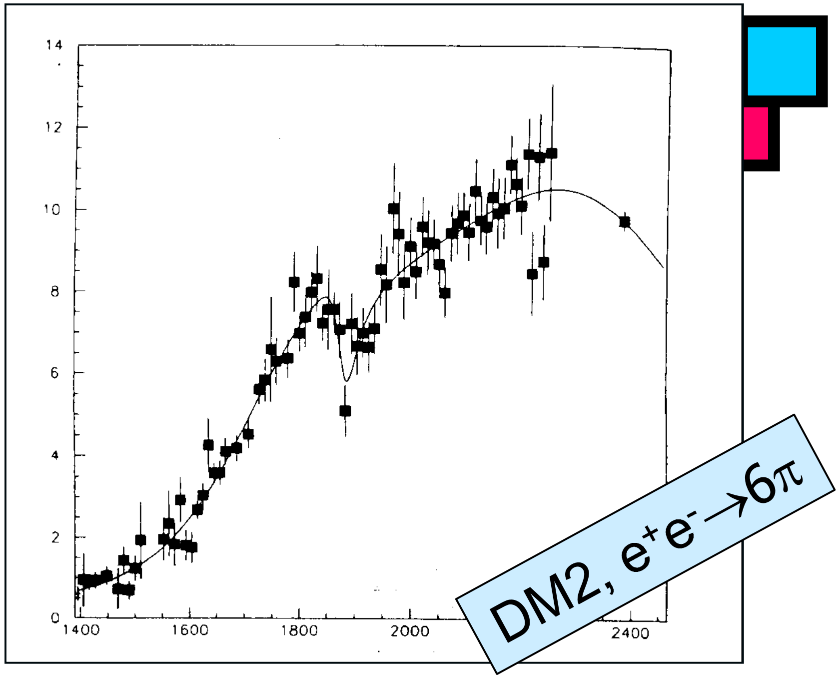


- Evidence for a narrow state at 1.9 GeV found by E687 in the diffractive photoproduction of 6π final state, interfering destructively with the continuum background

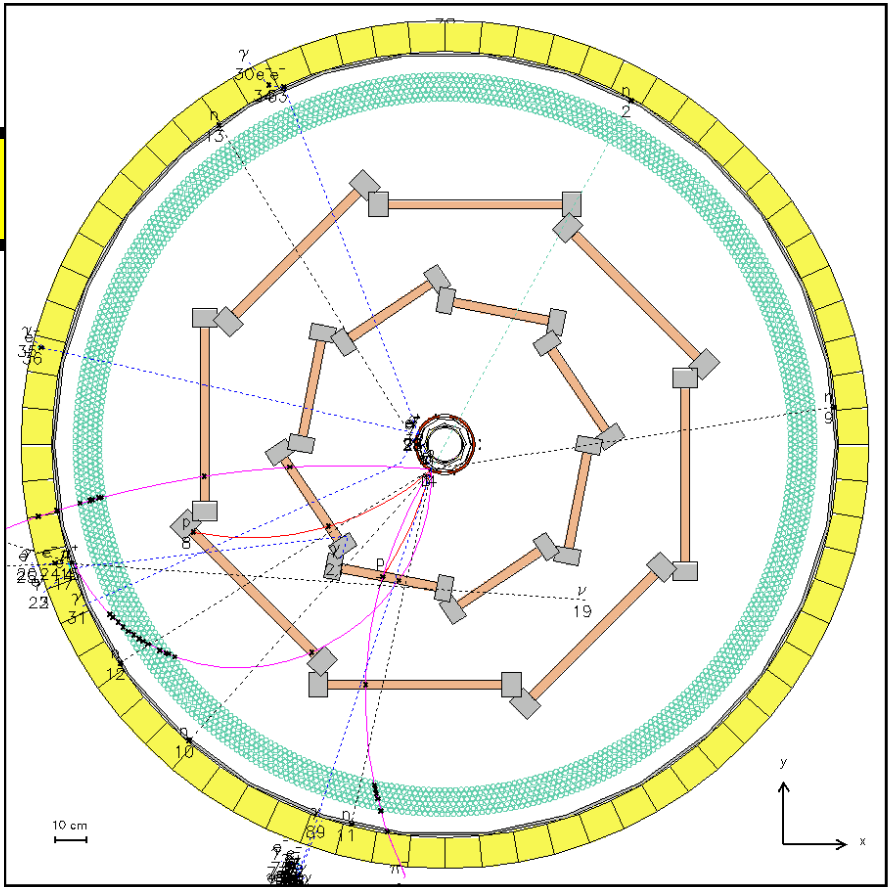
$m = (1.911 \pm 0.004 \pm 0.001)$ GeV

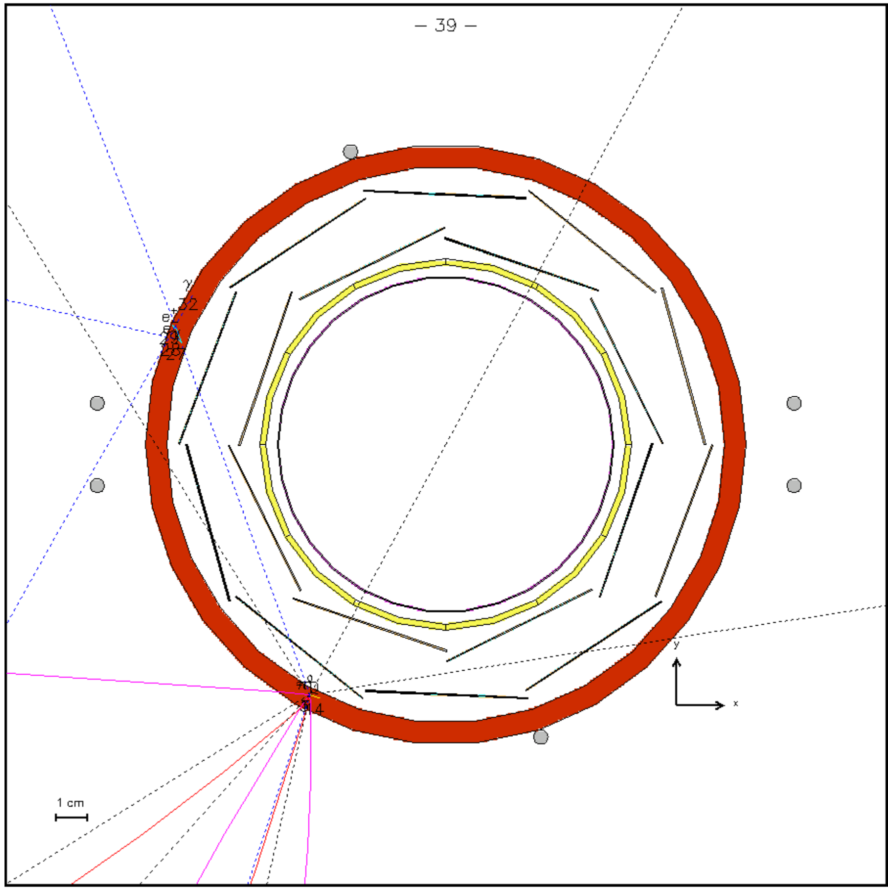
$\Gamma = (29 \pm 11 \pm 4)$ MeV

$J^{PC} = 1^{--}$, $I^G = 1^+$



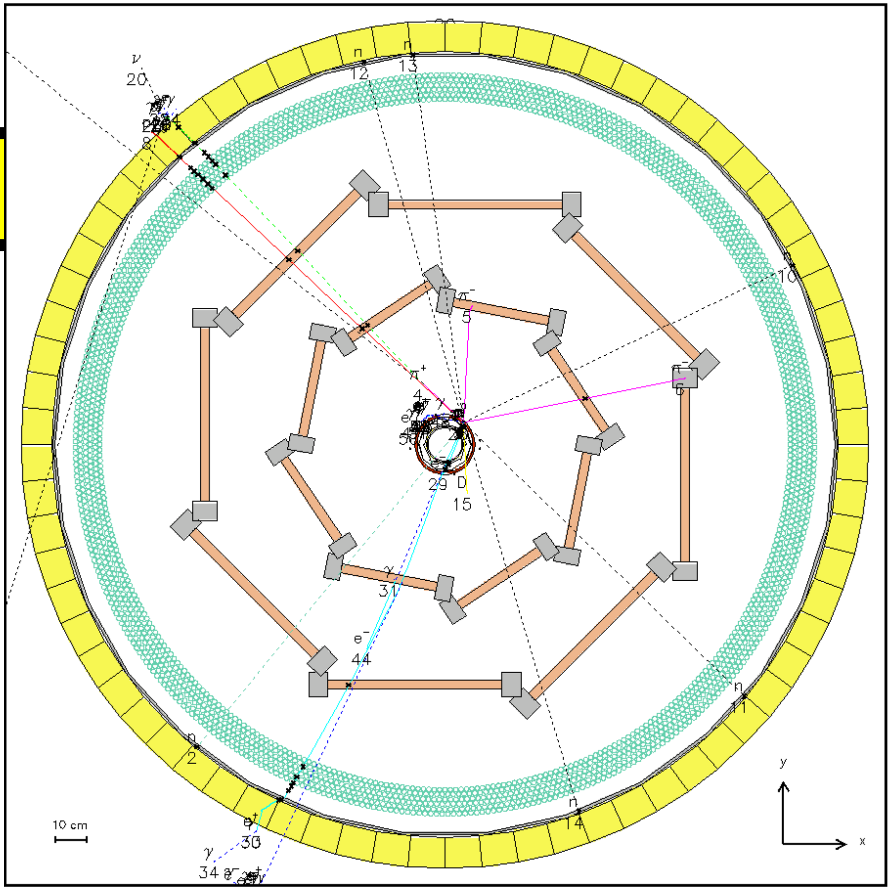
$e^+e^- \to \bar{n}n$: typical topologies

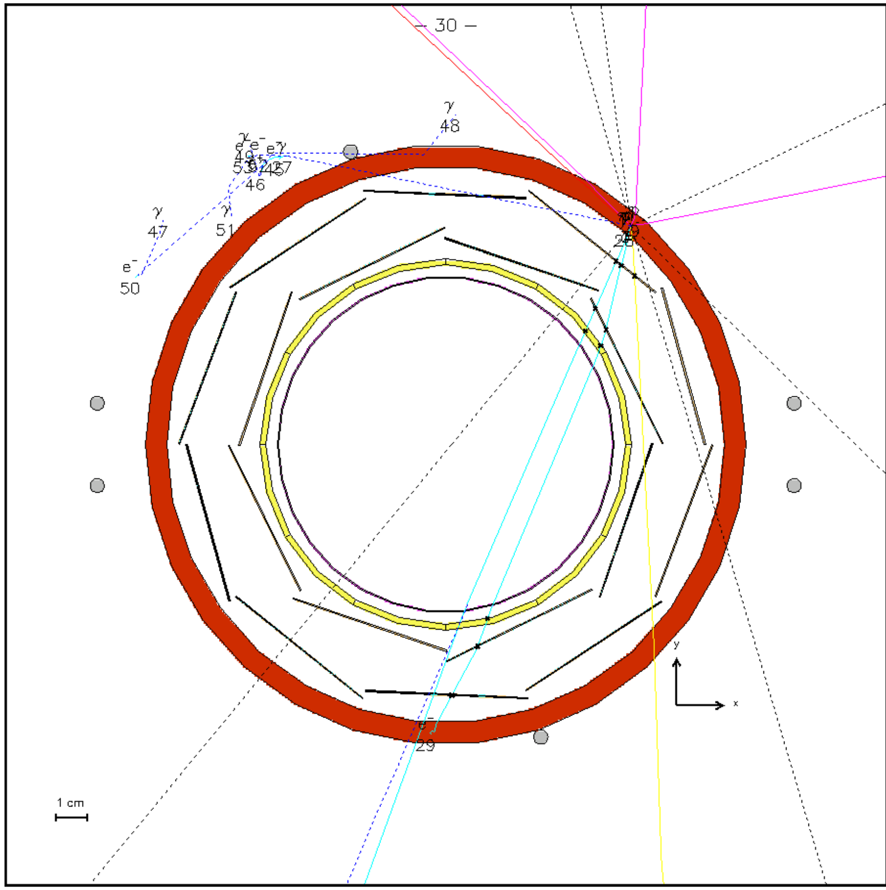




$\sqrt{s}$ = 1900 MeV, B = 0.5 T

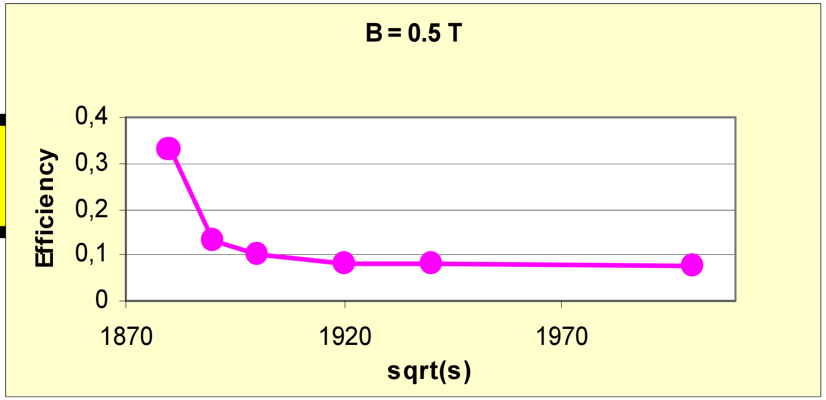
$e^+e^-\to\bar{n}n$: typical topologies





$\sqrt{s}$ = 1880 MeV, B = 0. T

Tentative events yields/day, $e^+e^- \to \bar{n}n$



$L \approx 5\times10^{31}\ cm^{-2}\ s^{-1}$

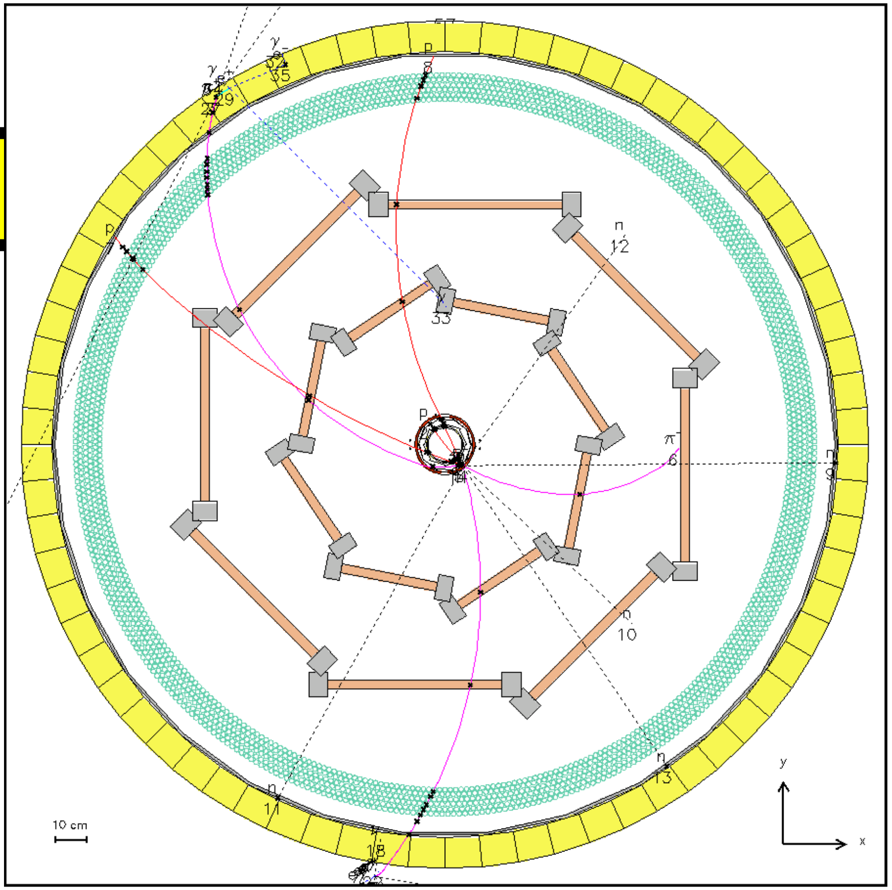
$L_{day} \approx 4\ pb^{-1}$; $\sigma_{Ann} \approx 1\ nb$

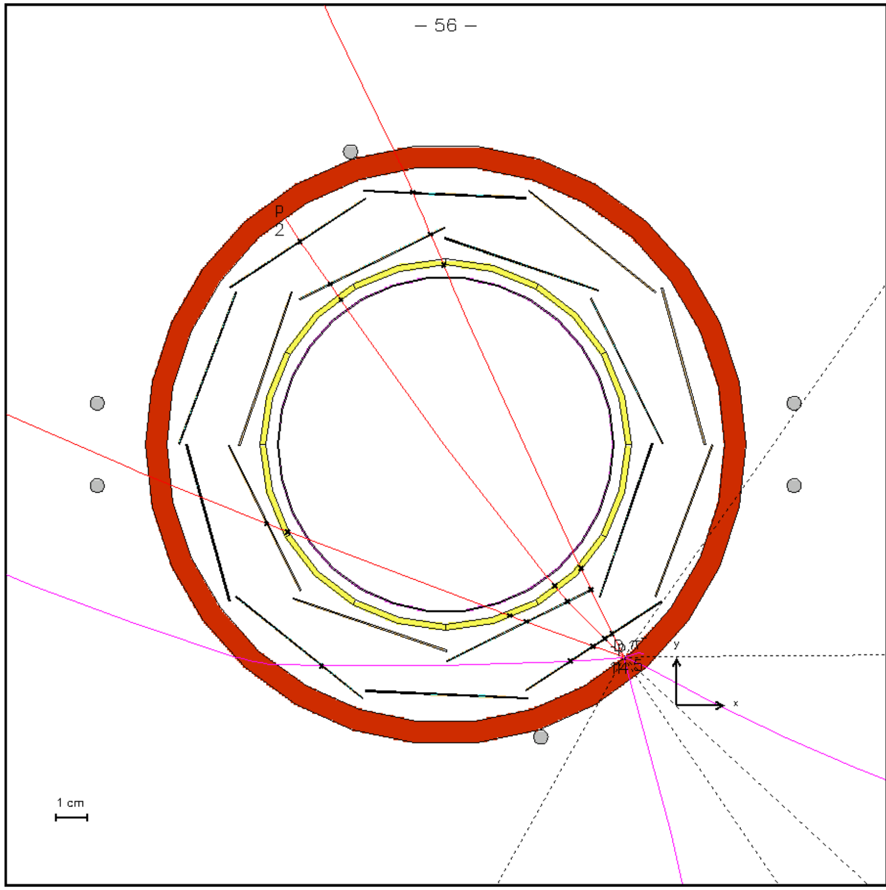
B = 0.5 T

Chamber transparency: 85%

$\sqrt{s}$ (MeV)	ε	$L_{day}(pb^{-1})$	# events	# events w. n coincidence
1880	.34	4	1156	173
1900	.10	4	340	51
1920	.08	4	272	41
1940	.07	4	238	36

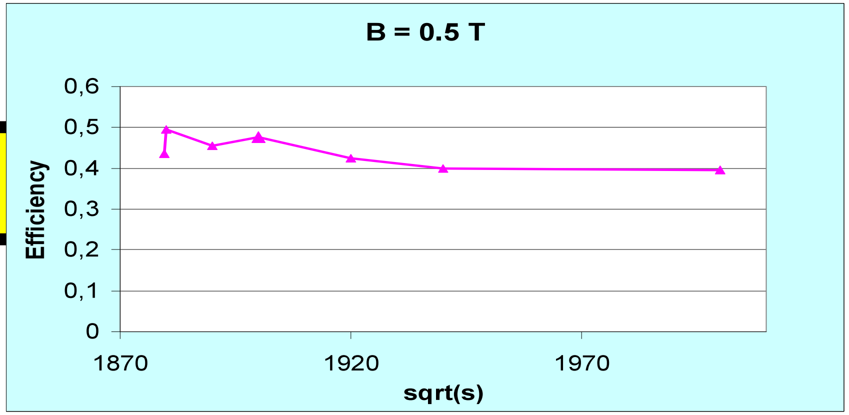
$e^+e^- \to \bar{p}p$: typical topologies





$\sqrt{s}$ = 1900 MeV, B = 0.5 T

Tentative events yields/day, $e^+e^- \to \bar{p}p$



$L \approx 5\times10^{31}$ cm^{-2} s^{-1}

$L_{day} \approx 4$ pb^{-1}; $\sigma_{Ann} \approx 1$ nb

B = 0.5 T

$\sqrt{s}$ (MeV)	ε	L_{day}(pb^{-1})	# events
1880	.50	4	1700
1900	.48	4	1632
1920	.43	4	1462
1940	.40	4	1360

Advantages and drawbacks with FINUDA

- Total cross sections can be measured with "decent" efficiency
- Some problems for the differential cross sections due to the apparatus' limited acceptance
  - Some more thoughts about a better angular coverage needed
- Further studies: possibility to measure the proton polarization
  - Tool to get the relative phase and infer something more about G_M and G_E, that in the time-like region are complex

Conclusions

- The cross section measurements for both $e^+e^- \to \bar{n}n$ and $e^+e^- \to \bar{p}p$ seems to be feasible
  - maximum efficiency: 30% close to threshold
  - Most important problem: reduced FINUDA angular acceptance!!
- $\gamma\gamma$ background rejection enough strong if event recognition requires
  - A more-than-two-prong annihilation star
  - A signal on TOFone by a neutron within a definite time gate
- $e^+e^- \to 3\pi^+3\pi^-$ cross-section feasible with an about 20% efficiency
  - Reduced efficiency due to apparatus' angular covering
  - Momenta reconstruction can help to identify events with 5 prongs only