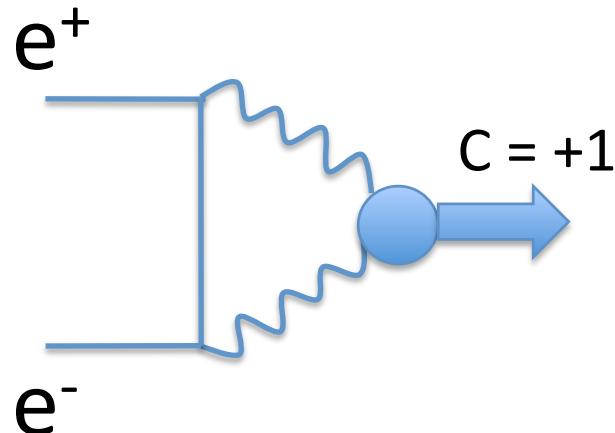


Search for $e^+e^- \rightarrow \eta(958)$ reaction with CMD-3 at VEPP-2000

E. Solodov

CMD-3 Collaboration

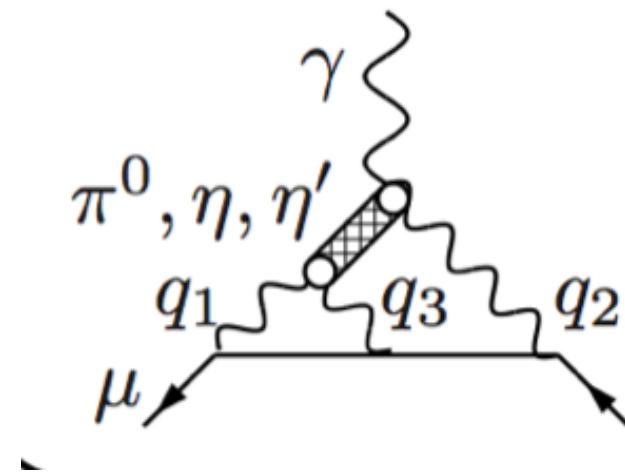
Why



C-even states can be produced in e^+e^- collision via two-photon reaction.

$(\pi^0, \eta(547), \eta(958), f_0(980), a_0(980), f_2(1270), f_0(1500) \dots)$

Observation of these reactions
could help to calculate
light-by-light contribution to g-2 of muon.



Theory (η')

In unitarity limit, when two photons are real, the electronic width of C-even state is in α^2 lower, than two-photon width, but for pseudo-scalars there is additional helicity suppression:

$$Br(\eta' \rightarrow e^+ e^-) = Br(\eta' \rightarrow \gamma\gamma) \frac{\alpha^2}{2\beta} \left(\frac{m_e}{m_{\eta'}} \right)^2 \left[\ln \left(\frac{1+\beta}{1-\beta} \right) \right]^2,$$

$$\beta = \sqrt{1 - 4 \left(\frac{m_e}{m_{\eta'}} \right)^2} \quad Br(\eta' \rightarrow \gamma\gamma) = 0.0218 \pm 0.0008$$

Unitarity limit $Br_{unit}(\eta' \rightarrow e^+ e^-) = 3.75 \times 10^{-11}$

For $\Gamma_{\eta'} = 0.199 \pm 0.009$ MeV, $Br_{unit}(\eta' \rightarrow e^+ e^-) = 7.5 \times 10^{-6}$ eV

Photons virtuality and form factor can significantly (?) increase these numbers

Previous measurements

Only data from ND at VEPP-2M (1985) are available.
No candidate events were found and upper limits:

$$\Gamma(\eta' \rightarrow e^+e^-) < 0.06 \text{ eV}$$

$$\Gamma(f_0(980) \rightarrow e^+e^-) < 8.4 \text{ eV}$$

$$\Gamma(a_0(980) \rightarrow e^+e^-) < 1.5 \text{ eV}$$

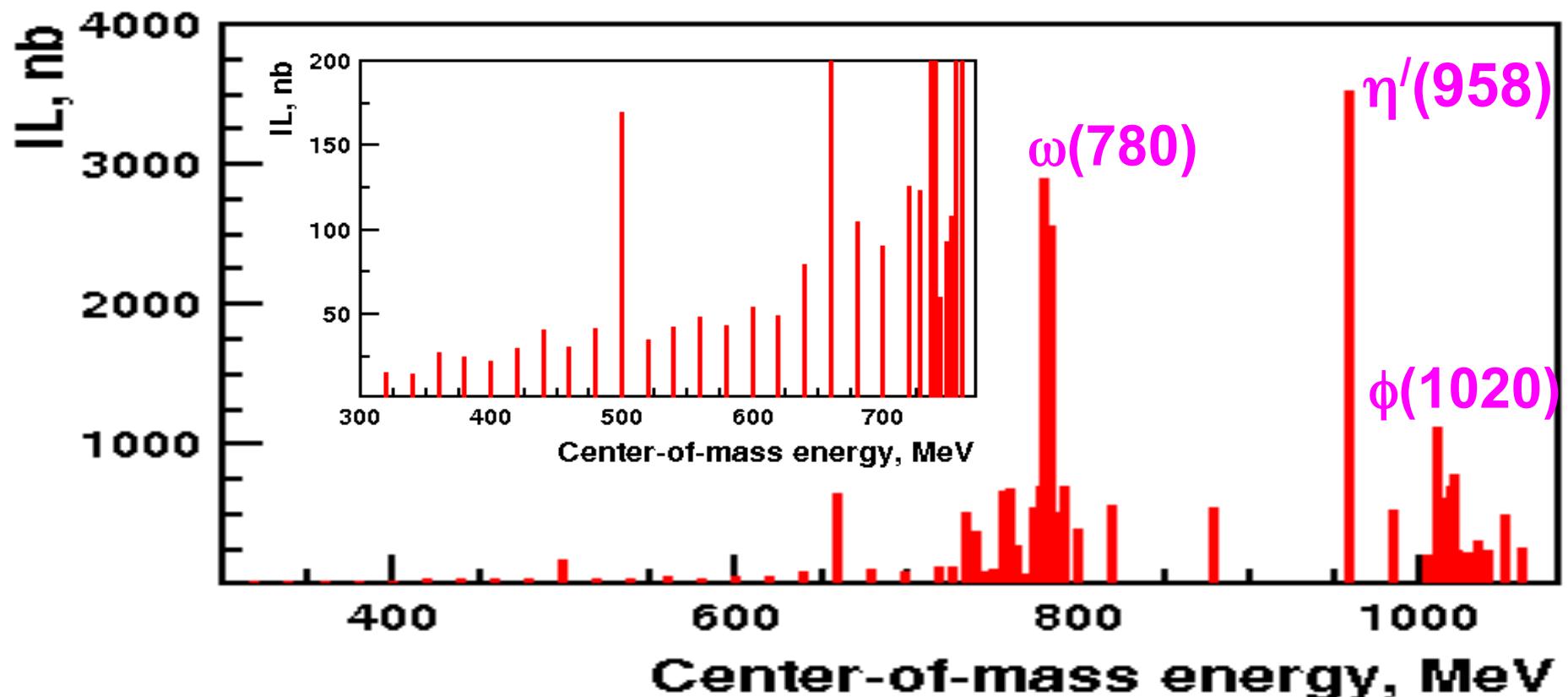
$$\Gamma(f_2(1270) \rightarrow e^+e^-) < 0.11 \text{ eV}$$

$$\Gamma(f_0(1300) \rightarrow e^+e^-) < 20 \text{ eV}$$

$$\Gamma(a_2(1320) \rightarrow e^+e^-) < 0.56 \text{ eV}$$

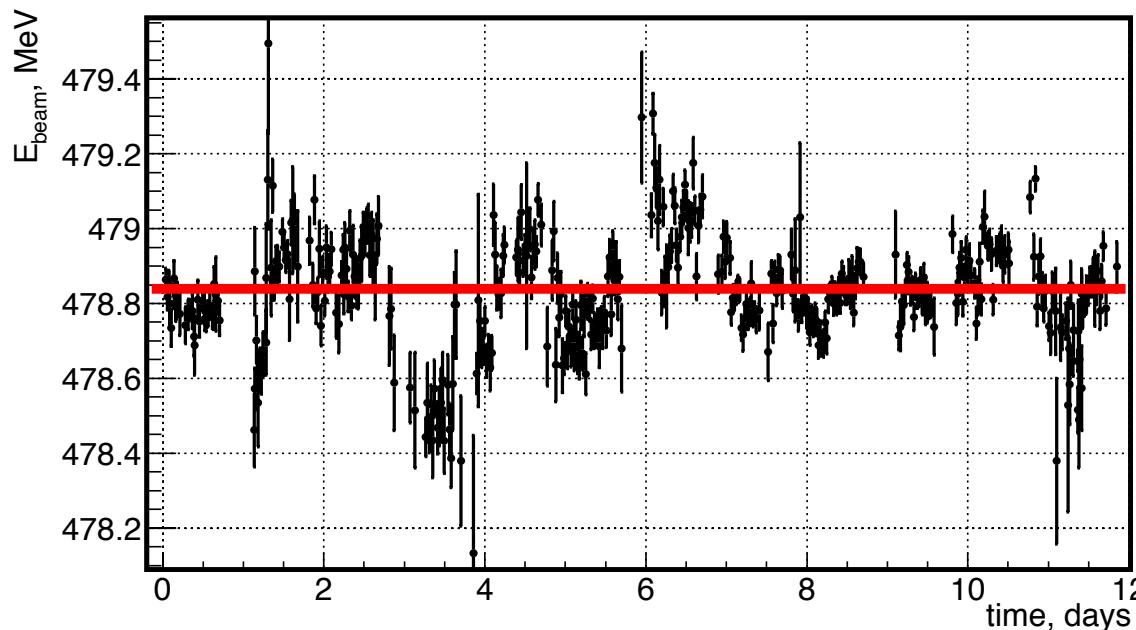
were obtained.

VEPP-2000 experiment (2013)



Energy distribution of collected integrated luminosity

Beam energy control



Beam energy was
continuously monitored with
Laser-Back-Scattering System.

$E_{c.m.} = 957.678 \pm 0.014$ MeV, to be compared with $m(\eta') = 957.78 \pm 0.06$ MeV
Deviations are at the level of beam energy spread.

$E_{c.m.}$ energy spread

For VEPP-2000 collision energy spread is related to longitudinal collision points distribution σ_z and RF voltages on the cavity V_{cav} as

$$\sigma_{E_{c.m.}} = 4.05\sigma_z \sqrt{V_{cav} E_{c.m.} \sin(a \cos(63.2 E_{c.m.}^4 / V_{cav}))} = 0.246 \pm 0.030 MeV$$

For this experiment $\sigma_z = 2.3$ cm (using BhaBha events) and $V_c = 15$ kV.

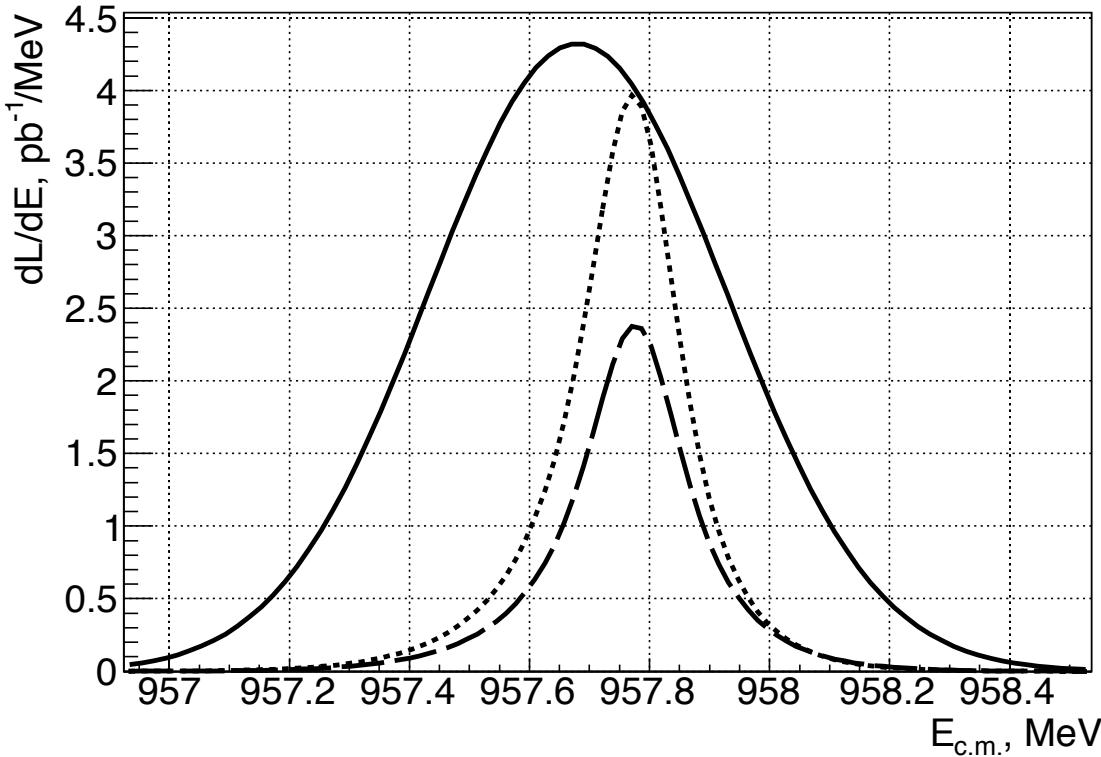
2.36 $\sigma_{E_{c.m.}}$ significantly larger, compare to $\Gamma_{\eta'} = 0.199 \pm 0.009$ MeV , and integrated (over width) cross section is calculated as

$$\sigma_{int} = \int_0^{E_{beam}} \int_0^1 \frac{1}{\sqrt{2\pi}\sigma_{E_{c.m.}}} e^{-\frac{(E_{c.m.} - av) - E)^2}{2\sigma_{E_{c.m.}}^2}} \cdot F(x, E) \cdot \sigma(E(1-x)) dx dE$$

where x is fraction of energy taken by soft photons according to radiator function $F(x, E)$, and $\sigma(E)$ is a Breit-Wigner for η'

$$\sigma(E) = 4\pi \frac{C\Gamma_{\eta'}\Gamma_{\eta' \rightarrow e^+e^-}}{(m_{\eta'}^2 - E^2)^2 + E^2\Gamma_{\eta'}^2}$$

Integrated cross section



$$\sigma_{\text{int}} = 6.38 \Gamma(\eta' \rightarrow e^+e^-) (\text{eV}) \text{ nb} \text{ and } \sigma_{\text{int}}^{\text{unit}} = 4.8 \times 10^{-5} \text{ nb.}$$

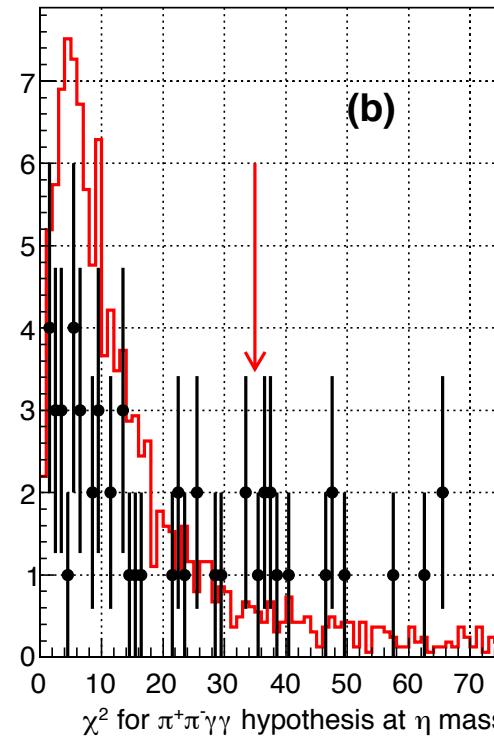
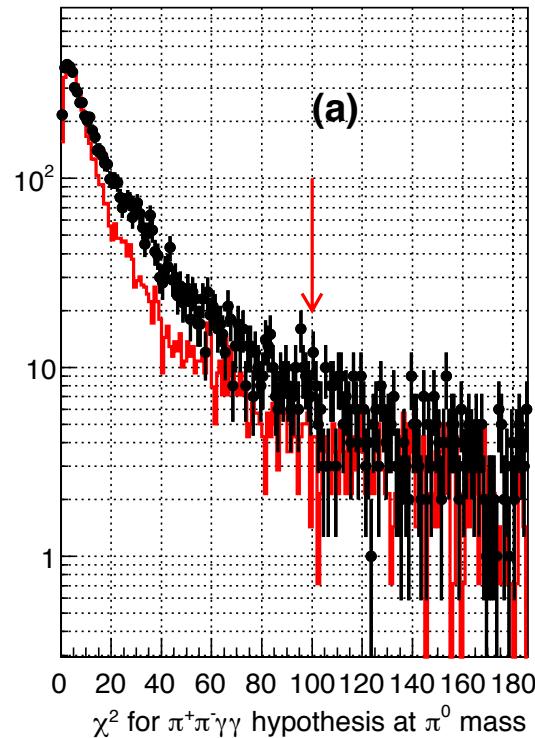
If we observe N events, we measure

$$\Gamma_{\eta' \rightarrow e^+e^-} = \frac{N}{6.38 \cdot \epsilon \cdot L} \text{ eV.}$$

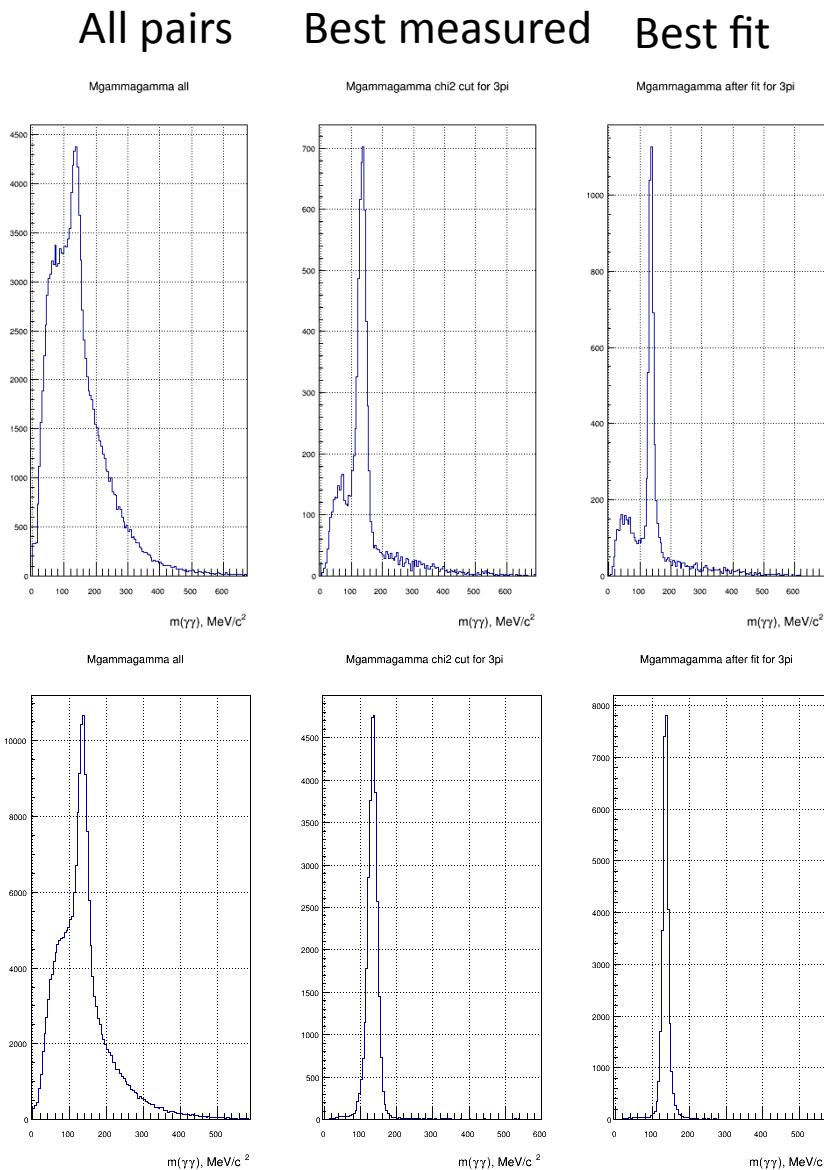
Event selection

We search for the reaction: $e^+e^- \rightarrow \eta(958) \rightarrow \pi^+\pi^-\eta \rightarrow \pi^+\pi^-\gamma\gamma$

- we select events with two “good” tracks and >2 photons
- we perform a kinematic fit in the $e^+e^- \rightarrow \pi^+\pi^-\gamma\gamma$ hypothesis
- if more than 2 photons, the best χ^2 combination is used



How $m(\gamma\gamma)$ looks like?

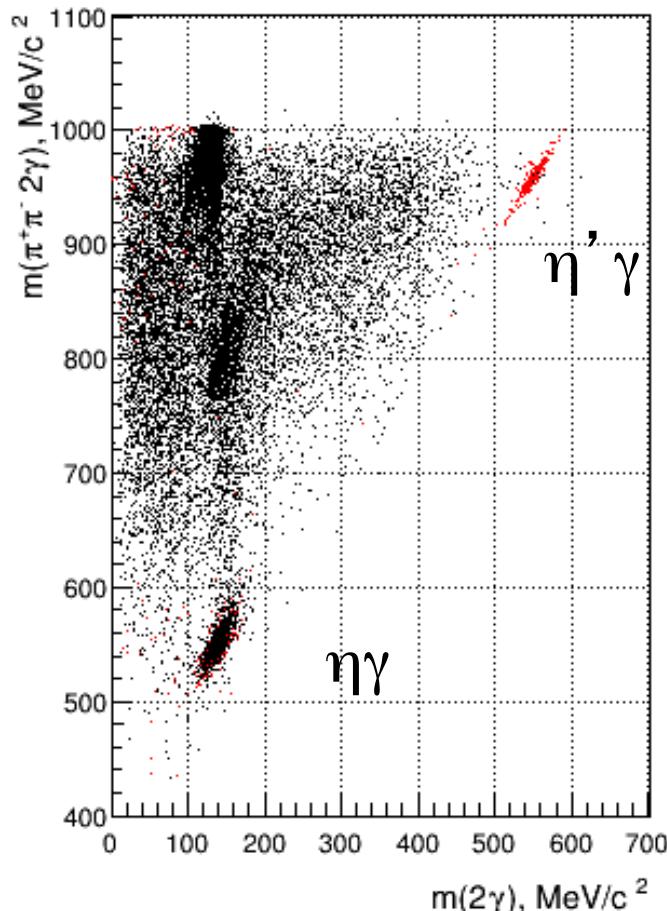


$E_{\text{beam}} = 479 \text{ MeV}$

$E_{\text{beam}} = 509.5 \text{ MeV}$

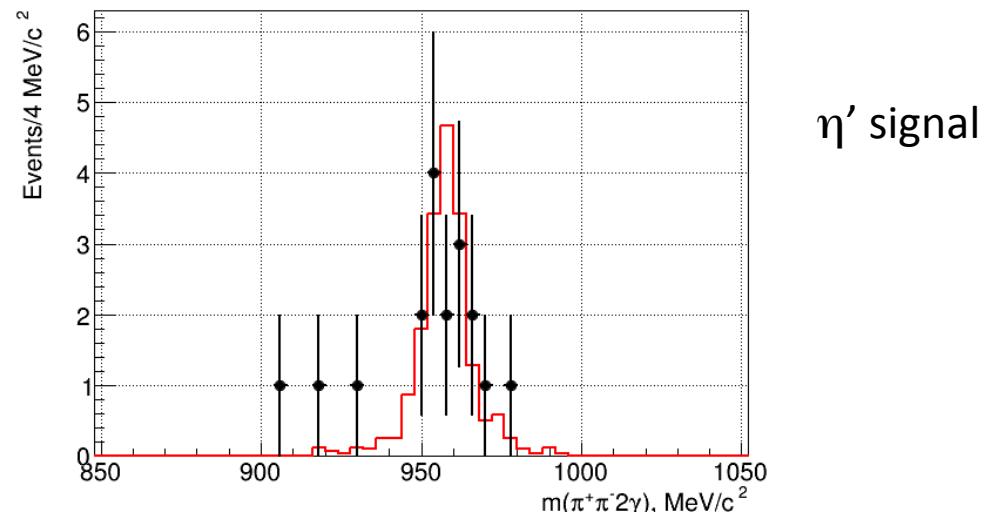
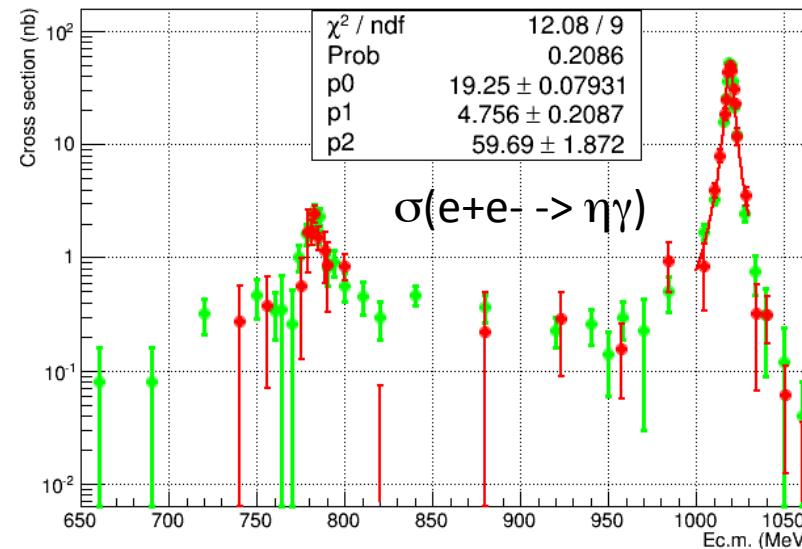
Check with $\pi^+\pi^-\pi^0(\eta)\gamma$

$E_{\text{beam}} = 509.5$



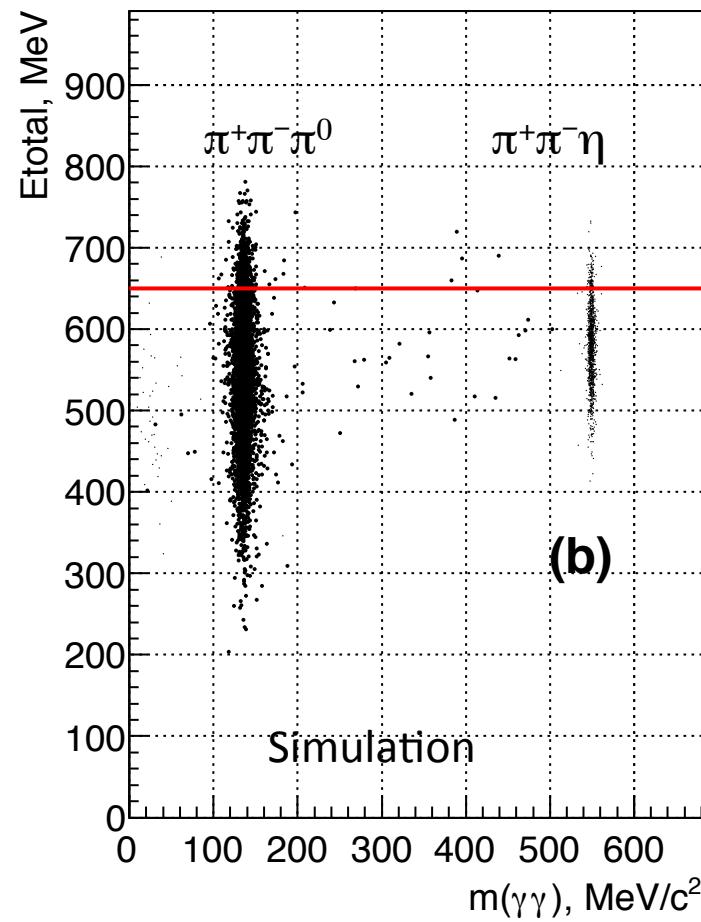
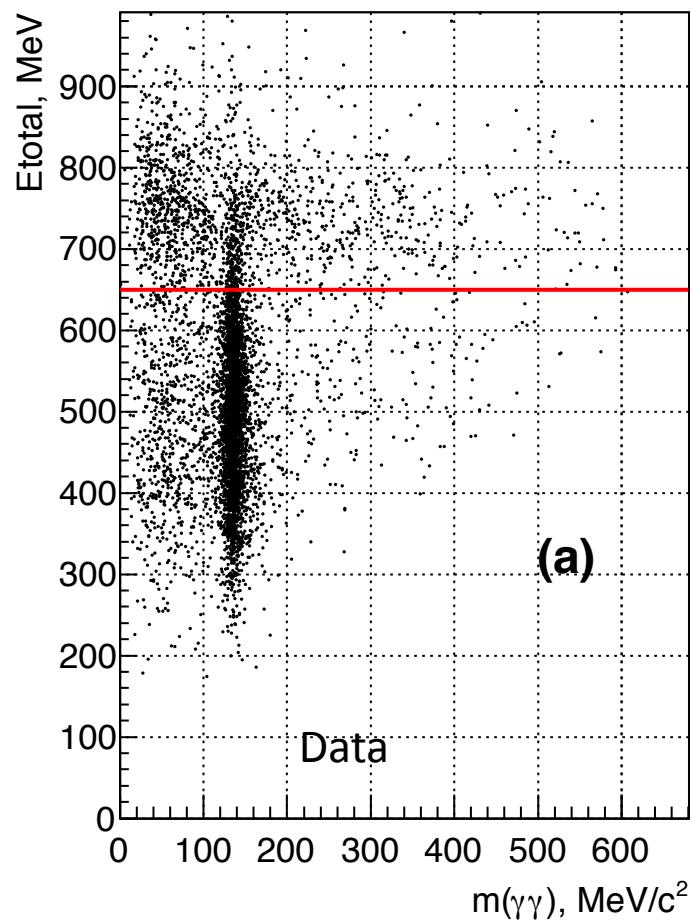
red points - simulation

Green – CMD-2, red – CMD-3 (part of data)

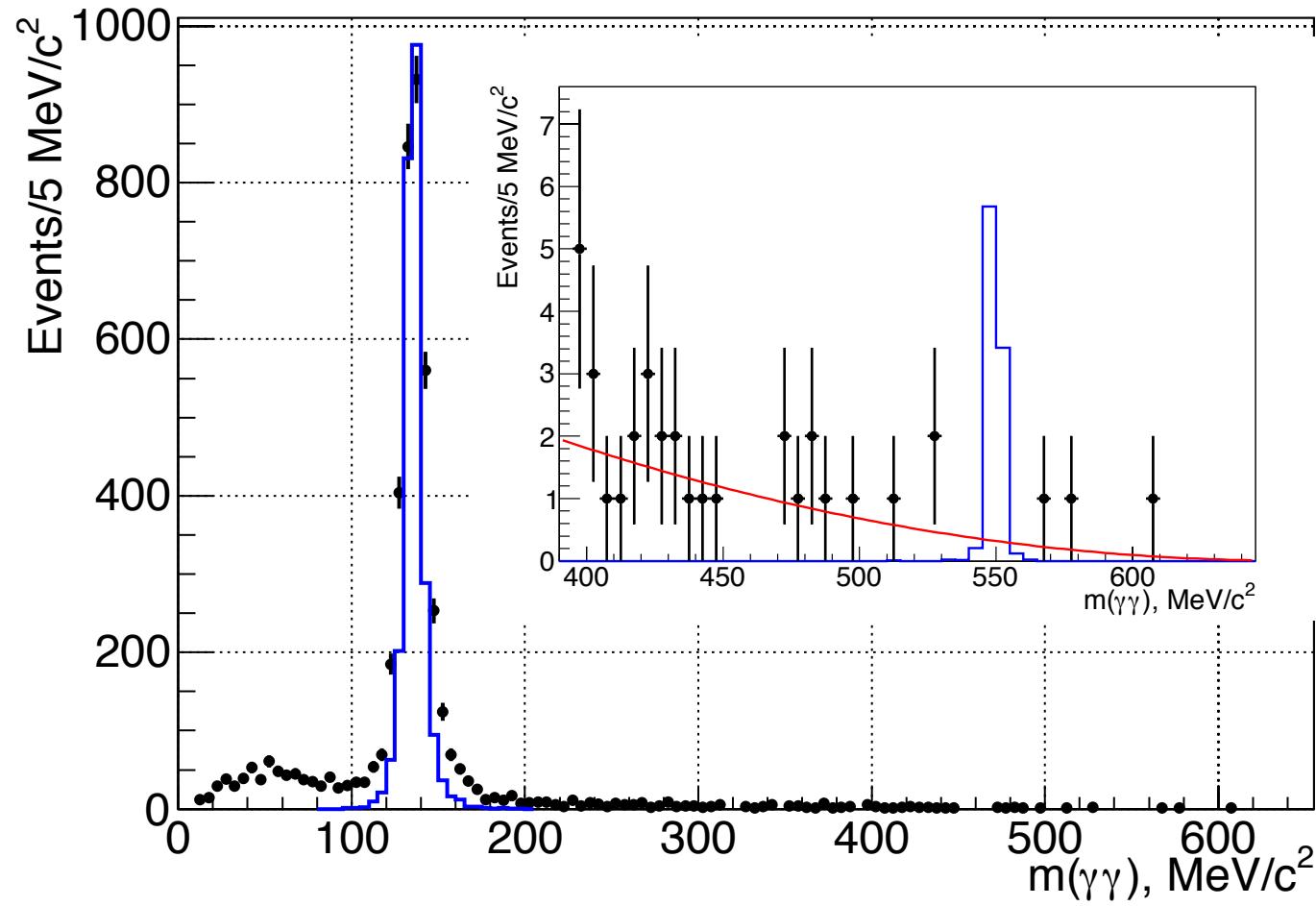


η' signal

Remove QED background



NO signal



$N < 2.5$ at 90% C.L.

Result

Efficiency $\varepsilon = 2.5\%$ (includes all decay modes of η and η')

$L = 2676 \text{ nb}^{-1}$

Our **PRELIMINARY** result is:

$$\Gamma_{\eta' \rightarrow e^+ e^-} < \frac{2.5}{6.38 \cdot 0.025 \cdot 2676} = 0.006 \text{ eV.}$$

$$\mathcal{B}_{\eta' \rightarrow e^+ e^-} < 3.0 \times 10^{-8},$$

to be compared with ND result

$$\Gamma(\eta' \rightarrow e^+ e^-) < 0.06 \text{ eV}$$

$$\text{Br}(\eta' \rightarrow e^+ e^-) < 2.1 \times 10^{-7} \text{ (used 0.3 MeV width on 1985)}$$

and with $\Gamma_{\text{unit}}(\eta' \rightarrow e^+ e^-) = 7.5 \times 10^{-6} \text{ eV}$ - still 3 order of magnitude lower!

Plans: - use more decay modes to increase efficiency

- factor of 10-100(?) in luminosity, decrease energy spread(?)
- how large is form factor ?