Study of the $e^+e^- \to \eta\gamma$ process with SND detector

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Outline

- Introduction
- Experimental setup
- Selection of $e^+e^- \to \eta\gamma$ events
- Luminosity measurements
- Detection efficiency
- Cross section parametrization
- Results and discussion

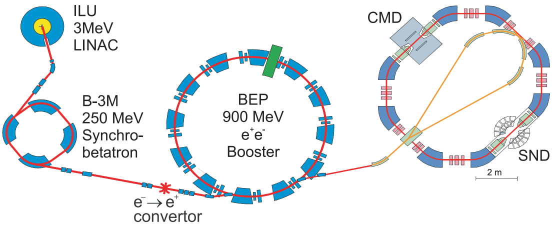
Introduction

This work is devoted to study of $e^+e^- \to \eta\gamma$ process in $\eta \to 3\pi^0$ decay mode. Our data is:

- collected with SND in 2013 and 2018
- 32 energy points near ϕ meson resonance
- 23 pb^{-1} of data: 6 pb^{-1} (2013) and 17 pb^{-1} (2018)

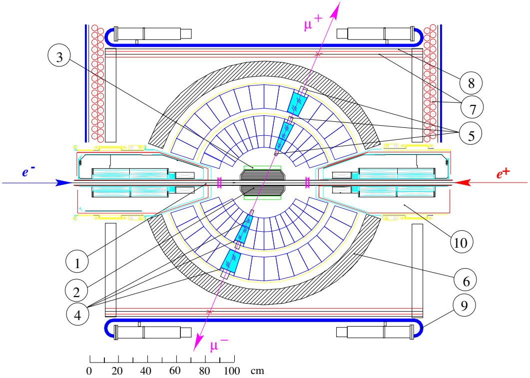
VEPP-2000 e^+e^- collider

- Collides electrons and positrons with the center-of-mass energy range 0.3—2 GeV
- The design luminosity L is 10^{32} cm^{-2} s^{-1}



VEPP-2000 scheme before modernization in 2013-2016

Spherical Neutral Detector



SND scheme (cross section along the beam axis): 1 — vacuum chamber, 2 — tracking system, 3 — aerogel cherenkov counters, 4 — NaI(Tl) crystals, 5 — vacuum phototriodes, 6 — absorber, 7 — proportional tubes, 8 — iron filter, 9 — scintillation counters, 10 — VEPP-2000 focusing solenoids.

Selection of $e^+e^- \to \eta\gamma$ events

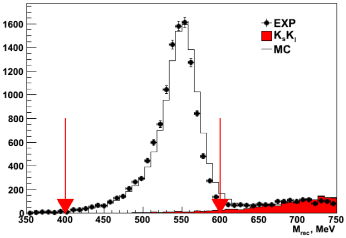
$e^+e^- \to \eta\gamma$ events were selected using the following conditions:

- No charged particles
- 6 or more neutral particles
- $0.7 \leq E_{tot}/E \leq 1.2$
- $P_{tot}/E < 0.2$
- $(E_{tot} - P_{tot})/E \geq 0.7$
- $400\ \text{MeV} \leq M_{rec} \leq 600\ \text{MeV}$
- $\chi^2_{n\gamma} \leq 30$

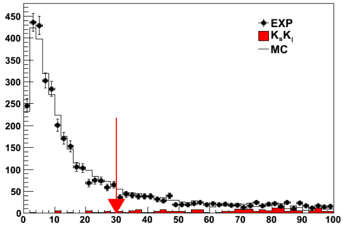
Selection of $e^+e^- \to \eta\gamma$ events

Under these selection conditions, the background processes are:

1. $e^+e^- \to K_s K_l,\ K_s \to \pi^0\pi^0$
2. $e^+e^- \to \pi^0\pi^0\gamma$ $(\chi^2_{\pi^0\pi^0\gamma} \geq 20)$
3. $e^+e^- \to 2, 3\gamma$ $(\chi^2_{3\gamma} \geq 20)$



The recoil mass of the most energetic photon



The $\chi^2_{n\gamma}$ distribution

Selection of $e^+e^- \to \eta\gamma$ events

The contribution of the $e^+e^- \to K_sK_l$ process was determined using simulation:

$$N_{K_sK_l} = N_{K_sK_l}^{DATA}(0.6\text{ GeV} < M_{rec} < 0.8\text{ GeV})\times \\ \times\frac{N_{K_sK_l}^{MC}(0.4\text{ GeV} < M_{rec} < 0.6\text{ GeV})}{N_{K_sK_l}^{MC}(0.6\text{ GeV} < M_{rec} < 0.8\text{ GeV})}$$

Luminosity measurements

Integrated luminosity was measured using the $e^+e^- \to \gamma\gamma$ process. $e^+e^- \to \gamma\gamma$ events were selected using the following conditions:

- No charged particles
- 2 or more neutral particles
- $E_{tot}/E \geq 0.65$
- $P_{tot}/E \leq 0.3$
- $0.3 \leq E_\gamma/E \leq 0.75$
- $||\phi_1 - \phi_2| - 180^\circ| \leq 15^\circ$
- $|\theta_1 + \theta_2 - 180^\circ| \leq 20^\circ$
- $0.5 \cdot (180^\circ - |\theta_1 - \theta_2|) \geq 36^\circ$

Luminosity measurements

Under these selection conditions, the main contribution to background comes from $e^+e^- \to \pi^0\gamma$ events. We subtract them using known $\sigma_{\pi\gamma}$ and $\epsilon_{\pi\gamma}$ derived from simulation:

$$L = \frac{N}{\epsilon_{\gamma\gamma}\sigma_{\gamma\gamma}} / (1 + \frac{\sigma_{\pi\gamma}\epsilon_{\pi\gamma}}{\epsilon_{\gamma\gamma}\sigma_{\gamma\gamma}})$$

Detection efficiency

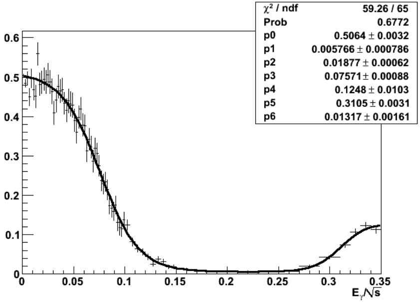
The visible cross section σ_{vis} can be written as

$$\sigma_{vis}(E) = \int_0^{x_{max}} \epsilon_r(E, \frac{xE}{2}) F(x,E) \sigma(\sqrt{1-x}E) dx, \quad (1)$$

where $\sigma(E)$ – Born cross section and F – Fadin-Kuraev function. The equation can be rewritten in the traditional form:

$$\sigma_{vis}(E) = \epsilon(E)\sigma(E)(1+\delta(E)), \quad (2)$$

where $\epsilon(E) = \epsilon_r(E, 0)$ and $\delta(E)$ is the radiative correction.



Cross section parametrization

Energy dependence of the $e^+e^- \to \eta\gamma$ Born cross section was parameterized according to the Vector Meson Dominance (VMD) model:

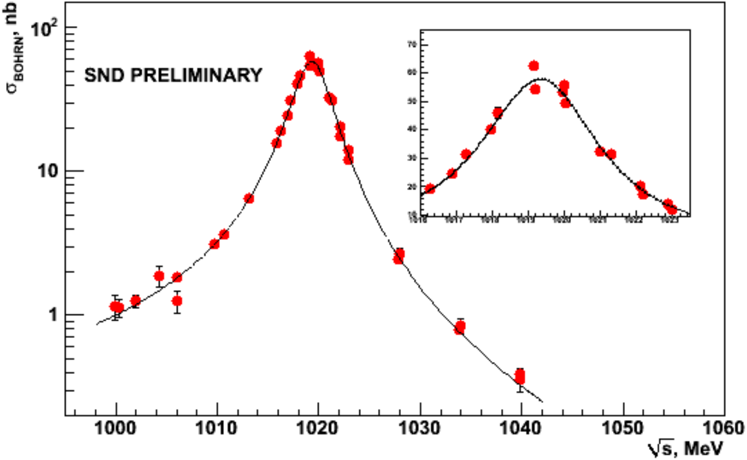
$$\sigma_{\eta\gamma}(E) = \frac{q(E)^3}{E^3}\left|\sum_{V=\rho,\ \omega,\ \phi,\rho'} A_V(E)\right|^2,$$

$$A_V(E) = \frac{m_V\Gamma_V e^{i\varphi_V}}{D_V(E)}\sqrt{\frac{m_V^3}{q(m_V)^3}\sigma_{V\eta\gamma}},$$

$$D_V(E) = m_V^2 - E^2 - iE\Gamma_V(E),$$

$$q(E) = \frac{E}{2}\left(1 - \frac{m_\eta^2}{E^2}\right)$$

At approximations of the data, the free parameters are $\sigma_{\rho\eta\gamma}$, $\sigma_{\omega\eta\gamma}$, $\sigma_{\phi\eta\gamma}$ and the phases φ_ω, φ_ϕ.



Born cross section of the $e^+e^- \to \eta\gamma$ process

Results and discussion

Results

- Preliminary results for the cross section of $e^+e^- \to \eta\gamma$ near ϕ meson resonanse

Outlook

- Add data near ρ and ω meson resonanses for 2013 (approximately 9 pb^{-1}) and 2018 (approximately 70 pb^{-1})
- Extract VMD model parameters using the approximation of cross section vs. energy dependence
- Study systematic uncertainties