Search for $\phi \to \eta\pi^0\gamma$, $\eta \to 3\pi^0$ decay with the KLOE detector at DAΦNE

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- Present situation and perspectives at KLOE.
- Signal selection criteria.
- Signal efficiency and background rejection.
- Preliminary results.
- Conclusions.

Present situation

Theory:
Several mechanisms may contribute into $\phi \to \eta\pi^0\gamma$ decay:

1. $\phi \to V\pi^0$, $V \to \eta\gamma$, V=vector meson: BR $\sim 5 \times 10^{-6}$
2. $\phi \to a_0\gamma$, a_0=scalar meson:
   - $K\overline{K}$ molecular model, $q\bar{q}$ scheme: BR $\sim 10^{-5}$
   - $q\bar{q}q\bar{q}$ model: BR $\sim 10^{-4}$

Experiments: Measurements of $\phi \to \eta\ \pi^0\gamma$, $\eta \to \gamma\gamma$ decay rate have been performed at SND/CMD-2 experiments:

- BR=$(0.83 \pm 0.23)\times 10^{-4}$ (Phys. Lett. B 438 (1998))
- BR=$(0.89 \pm 0.14 \pm 0.06)\times 10^{-4}$ (presented at DAΦNE '99 (SND))

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KLOE perspectives

- **Statistics:** 2.4 pb^{-1} collected in the 1999 data taking, 1.84 pb^{-1} (N$_\phi \sim 6 \cdot 10^6$) analysed.
- **Signal signature:** $\phi \to \eta\pi^0\gamma, \eta \to 3\pi^0$ is a fully neutral channel with 9 prompt photons final state.
- **KLOE Calorimeter:** Pb-scintillating fibers, energy resolution $\sigma(E)/E \sim 6\%/\sqrt{(\mathrm{E(GeV)})}$, time resolution $\sigma_t \sim 110$ ps$/\sqrt{(\mathrm{E(GeV)})}$, solid angle coverage of $\sim 93\%$ of 4π, angular resolution of $\sim 0.6°$ degrees $\to$ high performances for multi-photons final states.

Channel	Final State	BR	BR$_s$/BR
$\phi \to \eta\pi^0\gamma$, $\eta \to 3\pi^0$	9 γ	$2.8 \cdot 10^{-5}$	-
$\phi \to K_S K_L \to 5\pi^0$	10 γ	$2.3 \cdot 10^{-2}$	$1.2 \cdot 10^{-3}$
$\phi \to \eta\gamma, \eta \to 3\pi^0$	7 γ	$4.2 \cdot 10^{-3}$	$7 \cdot 10^{-3}$
$\phi \to \eta'\gamma, \eta' \to \eta\pi^0\pi^0, \eta \to 2\gamma$	7 γ	$9 \cdot 10^{-6}$	3.1
$\phi \to \eta'\gamma, \eta' \to \eta\pi^0\pi^0, \eta \to 3\pi^0$	11 γ	$8 \cdot 10^{-6}$	3.5

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Search for $\phi \to \eta\pi^0\gamma, \eta \to 3\pi^0$: signal selection

- **Signal selection criteria:**

  - fully neutral event with 9 prompt clusters.
  - $|T - R/c| < 2 \cdot \sigma_t$, $\sigma_t \sim 110\ \mathrm{ps}/\sqrt{(E(GeV))}$;
  - $21^\circ < \theta_\gamma < 159^\circ$. $\to \epsilon^{acc}_{\eta\pi^0\gamma} \sim 52\%$
  - 10 MeV $< E_\gamma <$ 340 MeV. $\to$ plot

- Signal efficiency and background rejection estimated using Monte Carlo with realistic detector simulation.

$\boxed{\epsilon_{(\eta\pi^0\gamma)} = 26\%}$ $\boxed{\epsilon_{(K_S K_L \to 5\pi^0)} = 1.4 \cdot 10^{-3}}$ $\boxed{\epsilon_{(\eta\gamma \to 7\gamma)} = 4 \cdot 10^{-4}}$

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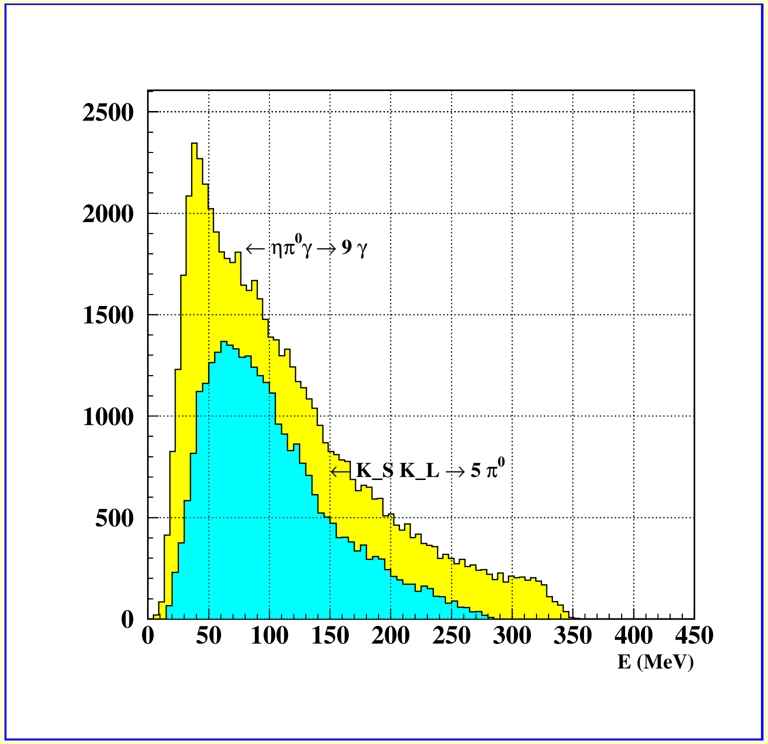
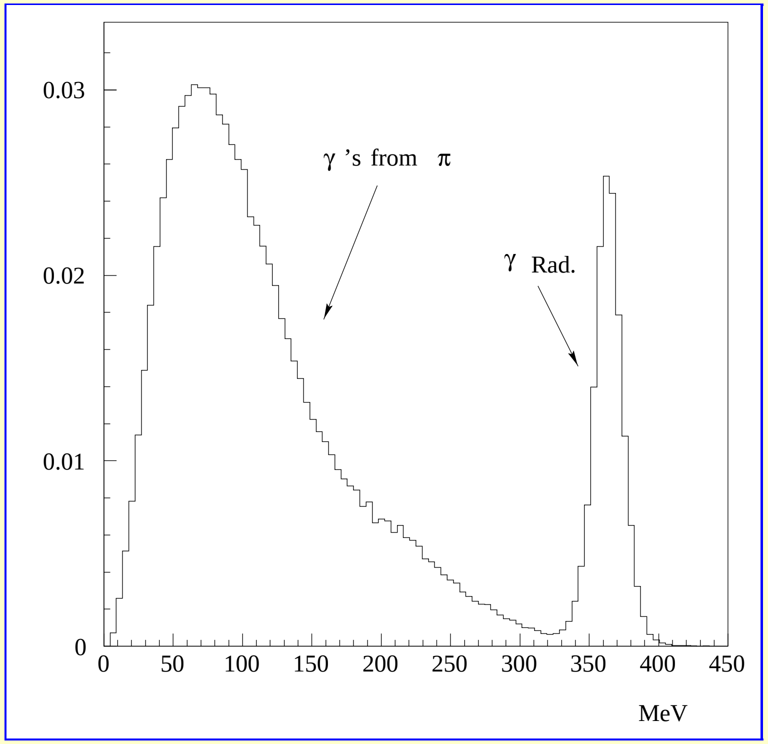
Search for $\phi \to \eta\pi^0\gamma, \eta \to 3\pi^0$: signal selection (II)

$\phi \to \eta\pi^0\gamma \to 9\gamma$



$\phi \to \eta\gamma \to 7\gamma$



10 MeV $< E_\gamma <$ 340 MeV $\to$ | $\epsilon_{sig} \sim 100\%,\ \epsilon_{\eta\gamma} \sim 10^{-3} \to$ | $S/B \sim 7$

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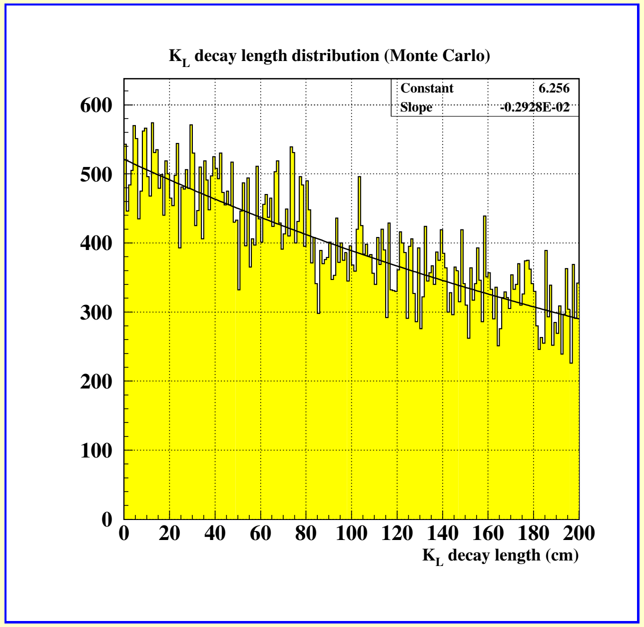
Signal selection (II)



$\phi \to K_S K_L \to 5\pi^0$ background:

- $|$T-R/c$|_\gamma <$ Time Window $=$ 2 σ_t
- $\sigma_t \sim 600$ ps at 30 MeV.
- Time Window $\sim$ 1.2 ns.
- l_{K_L}(max) $= \beta\gamma c t_{\mathrm{max}} \sim$ 8 cm.
- P(K_L decays in 8 cm)$\sim$ 2.3 %.

|T-R/c| $< 2\sigma_t \to$ $\epsilon_{K_L K_S} \sim 2.3\% \to$ $S/B \sim 0.05$

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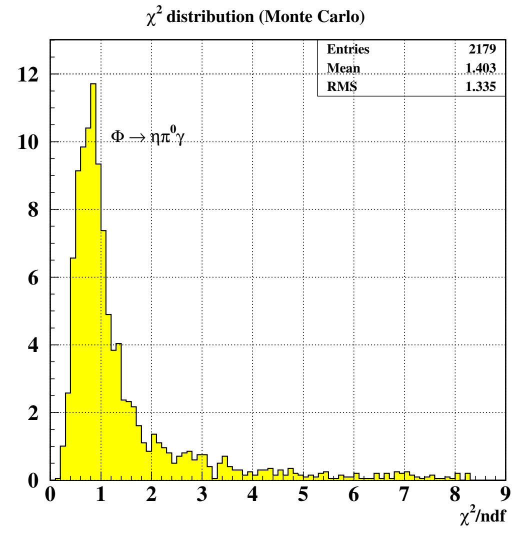
Search for $\phi \to \eta\pi^0\gamma, \eta \to 3\pi^0$ decay: signal selection (II)

- To achieve a better S/B ratio a constrained kinematic fit is performed.

- **50 measured quantities:**
  - E,T,x,y,z for each photon;
  - IP position;
  - Beam energies.
- **18 constraints:**
  - $|T - R/c|_\gamma < 2 \cdot \sigma_t$ for each γ;
  - total 4-momentum conservation;
  - $M_{\gamma\gamma} = M_{\pi^0}$ ($\times$ 4);
  - $M_{\pi^0\pi^0\pi^0} = M_\eta$.



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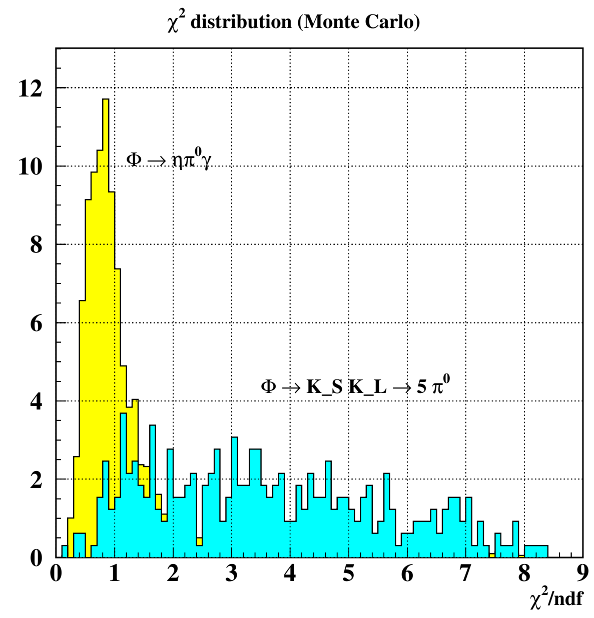
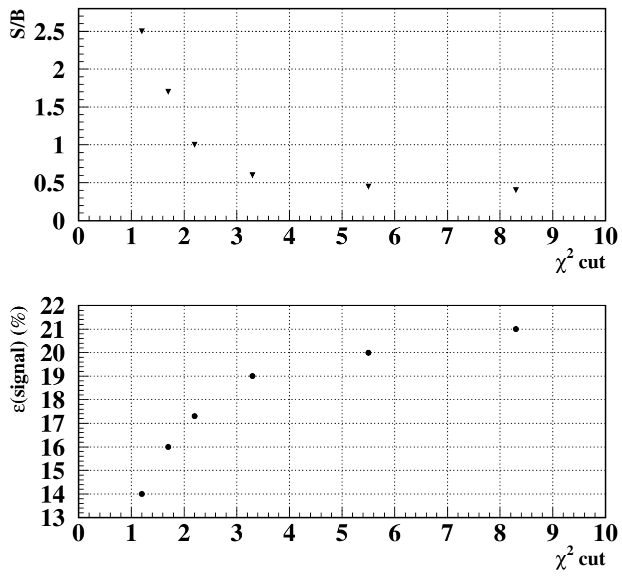
Fit results:
signal efficiency and background rejection

χ^2 distribution



S/B ratio and signal efficiency



$\chi^2 < \chi^2_{cut} = 1.7$

$\epsilon_{\eta\pi^0\gamma}(fit) \sim 54\%$ (95% CL)

$S/B \sim 1.8$

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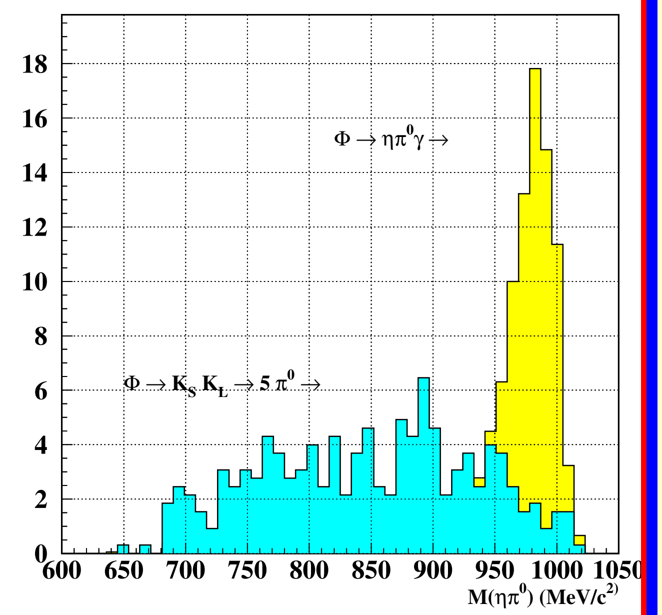
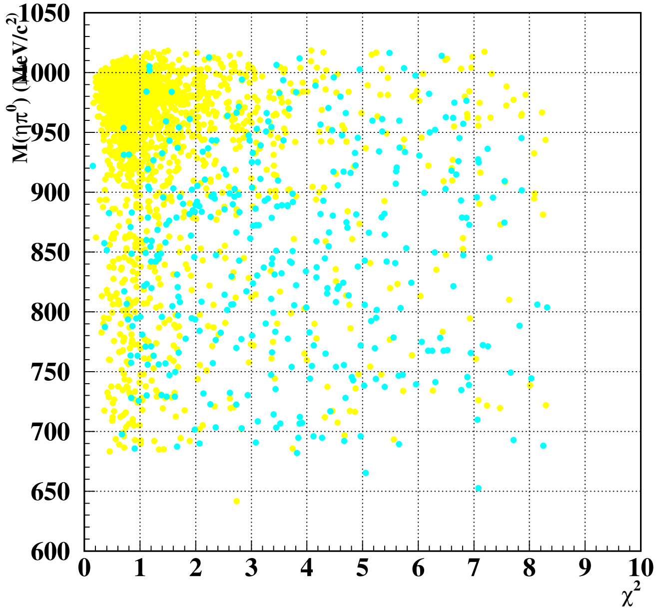
Fit results:
signal efficiency and background rejection (II)

$\eta\pi^0$ invariant mass distribution



$\eta\pi^0$ invariant mass vs χ^2



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Fit Results:

Signal Efficiency and Background rejection

$\epsilon_{\text{comb}} = \epsilon_{\text{trg}} \cdot \epsilon_{\text{event filter}}$ $\epsilon_{\text{sel}} = \epsilon_{\text{acc}} \cdot \epsilon_{\text{selection cuts}}$

Channel	ϵ_{comb}	ϵ_{sel}	ϵ_{fit}	ϵ_{tot}	S/B
$\Phi \to \eta\pi^0\gamma,\ \eta \to 3\pi^0$	71%	42%	54%	16%	-
$\Phi \to K_S K_L \to 5\pi^0$	54%	$1.4 \cdot 10^{-3}$	14%	$\sim 10^{-4}$	~ 1.8
$\Phi \to \eta\gamma, \eta \to 3\pi^0$	62%	$4 \cdot 10^{-4}$	-	$< 10^{-4}$	> 10
$\Phi \to \eta'\gamma \to 7\gamma$	69%	$\sim 8 \cdot 10^{-3}$	-	$< 10^{-4}$	$> 10^3$
$\Phi \to \eta'\gamma \to 11\gamma$	45%	$\sim 18\%$	11%	$< 10^{-3}$	$> 10^2$

$\epsilon_{\text{sig}} = 16\%$ $S/B \sim 1.8$

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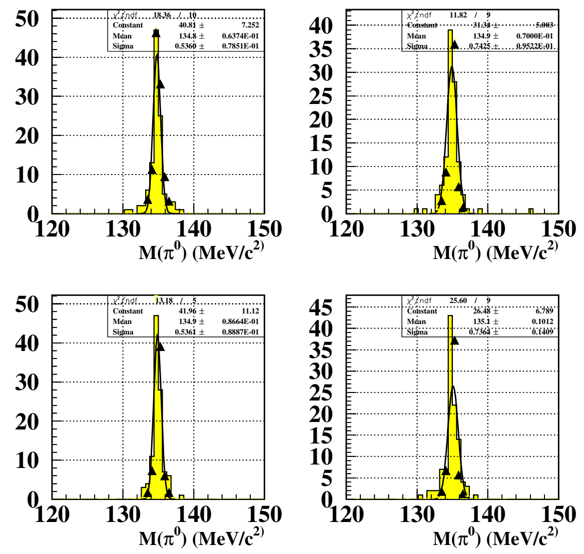
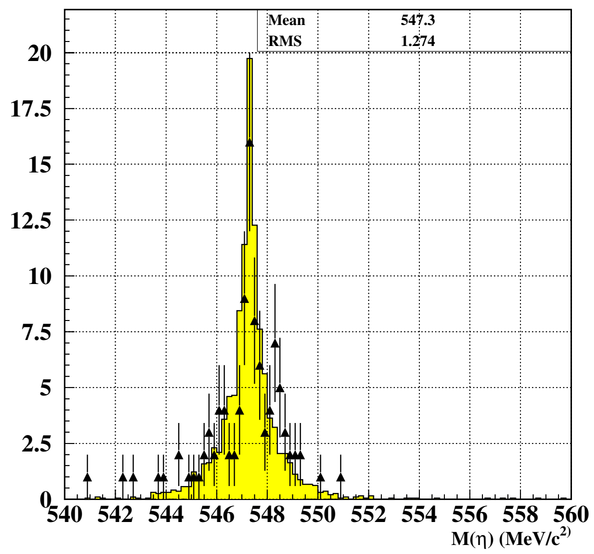
Data Analysis: Preliminary Results

- Selection cuts are applied to 1.84 pb^{-1} data sample.
- Surviving events are fitted in the $\phi \to \eta\pi^0\gamma$ hypothesys.

π^0's invariant masses



η invariant mass



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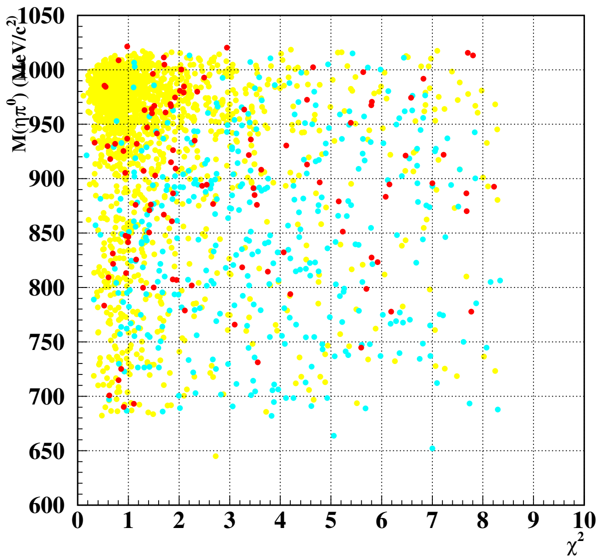
Data Analysis: Preliminary Results (II)

- $\chi^2 < 1.7 \rightarrow$ S/B ~ 1.8
- $N_{obs} = (41 \pm 6.4)$
- $N_{bck}^{est} = (14.6 \pm 3.8)$
- $N_{sig} = (26.4 \pm 7.4)$



$BR(\phi \rightarrow \eta\pi^0\gamma,\ \eta \rightarrow 3\pi^0) = (9.1 \pm 2.4_{\mathsf{stat}}) \cdot 10^{-5}$ (KLOE)
$BR(\phi \rightarrow \eta\pi^0\gamma),\ \eta \rightarrow \gamma\gamma = (8.9 \pm 1.4_{\mathsf{stat}} \pm 0.6_{\mathsf{syst}}) \cdot 10^{-5}$ (SND)

Evaluation of systematic error is in progress.

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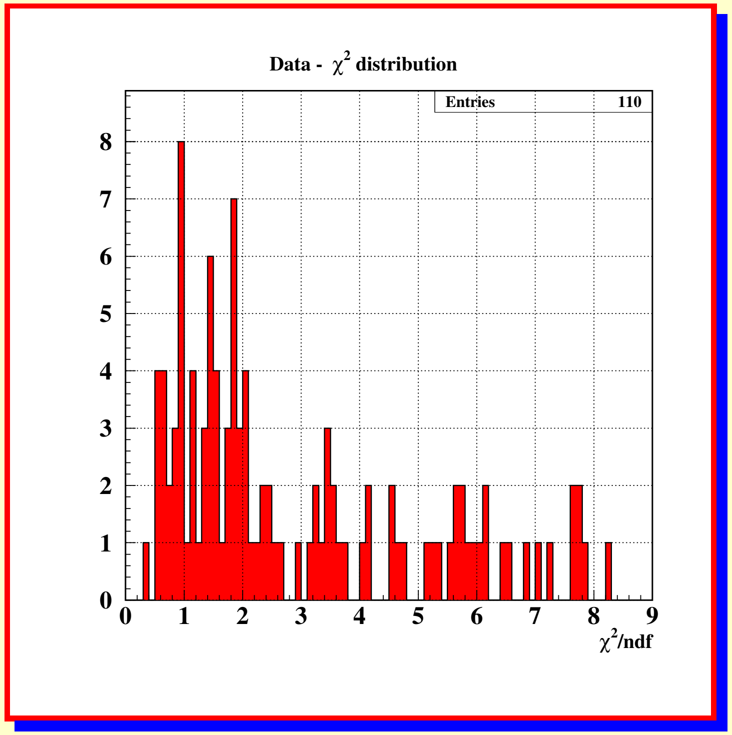
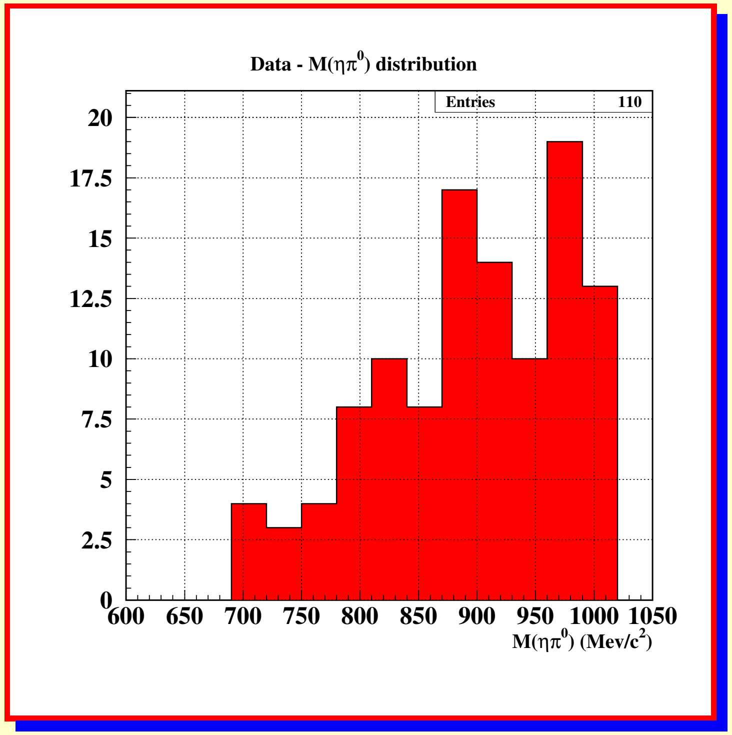
Data Analysis: Preliminary Results (II)

- 110 events survive the selection cuts $\oplus$ fitting procedure.

$\eta\pi^0$ hypothesis: χ^2 distribution



$\eta\pi^0$ invariant mass distribution



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Conclusions

- KLOE has collected $L = 2.4$ pb^{-1} in the 1999 data taking.
- Search of the $\phi \to \eta\pi^0\gamma$, $\eta \to 3\pi^0$ decay has been performed in a $L = 1.85$ pb^{-1} data set.
- An enhancement of data not compatible with background and compatible with the signal at 95% CL is observed in the 600 MeV $< M(\eta\pi^0) <$ 1020 MeV region.
- A preliminary result: $BR(\phi \to \eta\pi^0\gamma) = (9.1 \pm 2.4_{\mathrm{stat}})10^{-5}$ is in agreement with the SND measurement at 1 σ level.
- For $L = 100$ pb^{-1} a $\delta(\mathrm{BR})_{\mathrm{stat}} \sim 4\%$ is expected.
  Main goal: decrease systematic errors to the same level.

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