

Charged η decays with KLOE

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on behalf of the KLOE Collaboration



Outline

$$\eta \rightarrow \pi^+ \pi^- e^+ e^-$$

$$\eta \rightarrow e^+ e^- e^+ e^-$$

$$\eta \rightarrow \pi^+ \pi^- \gamma$$

$$\eta \rightarrow \pi^+ \pi^- \pi^0$$

$$\eta \rightarrow \pi^+ \pi^- e^+ e^-$$

Event selection

1 high energy prompt neutral cluster ($E_{cl} \geq 250$ MeV)

≥ 2 positive and ≥ 2 negative tracks are requested

Tracks are required to come from a cylinder around the IP:

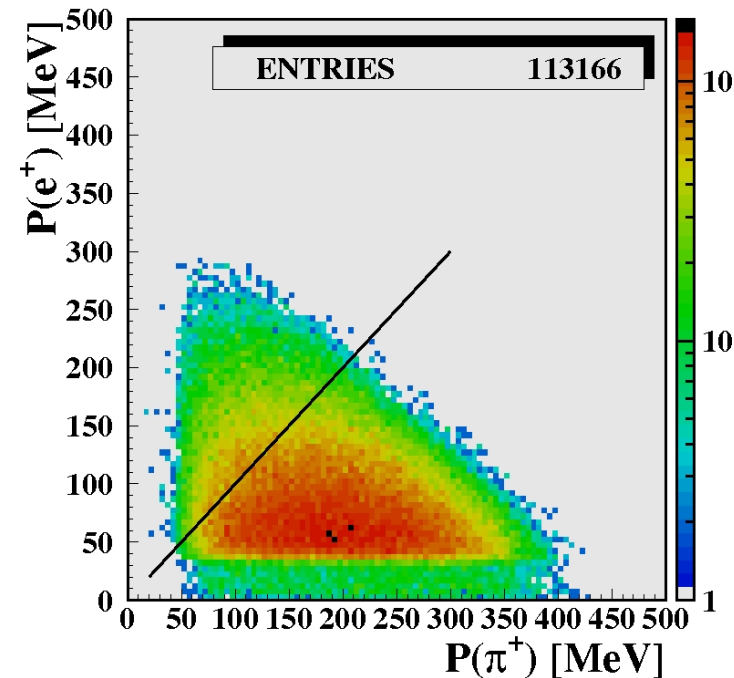
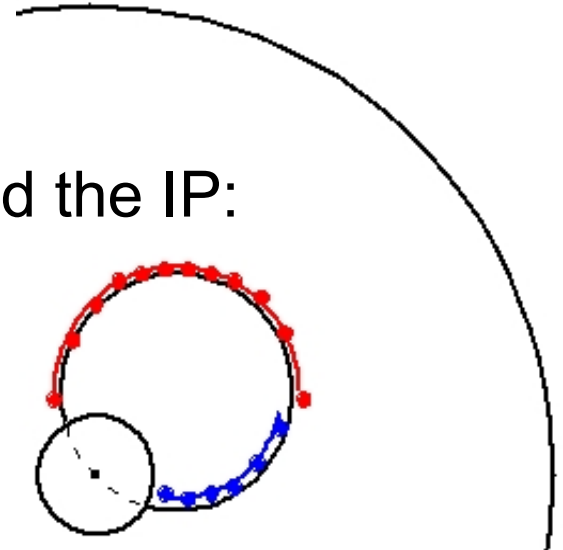
($R \leq 4$ cm, $h/2 = 10$ cm)

Check on broken tracks is applied:

($\Delta P_T < 4.5$ MeV , $\Delta P_Z < 3$ MeV)

Tracks are ordered by momentum

(Higher momentum tracks usually are pions)

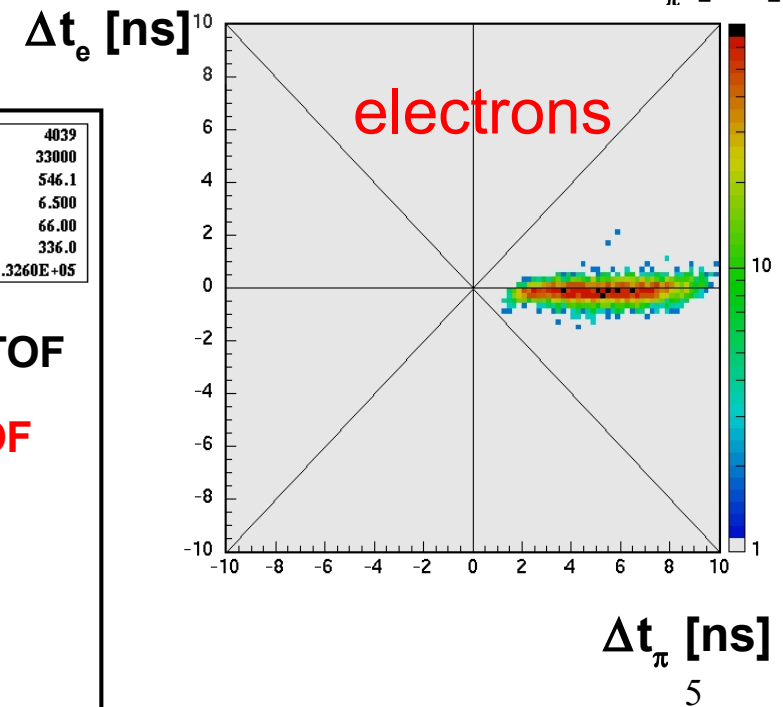
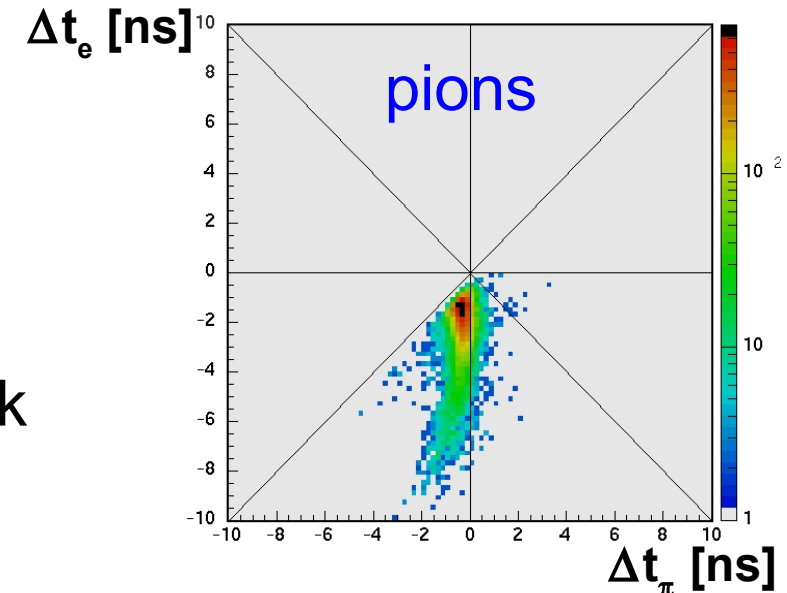
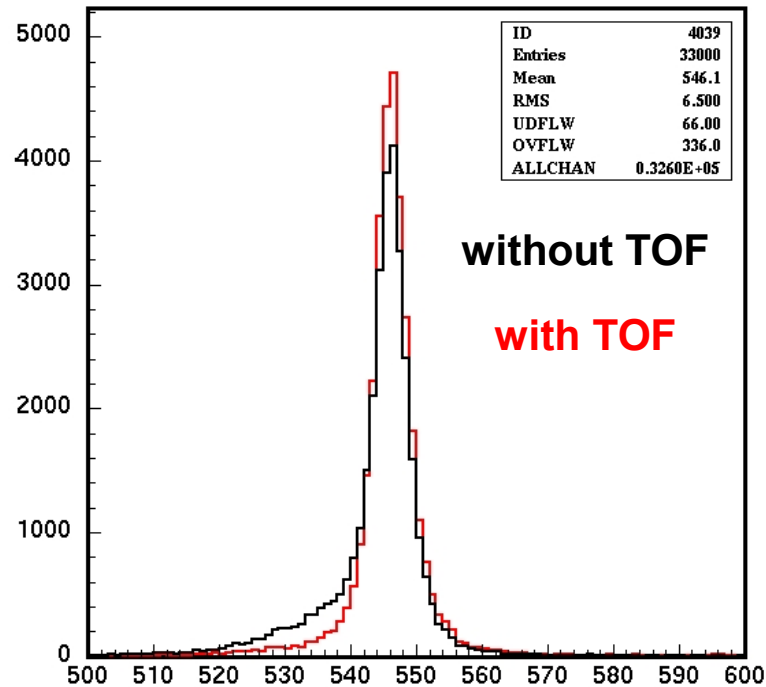


Particle Identification with TOF

We evaluate $\Delta t = t_{\text{track}} - t_{\text{cluster}}$ in both
electron (Δt_e) and pion (Δt_π) hypothesis

We also look for decay vertex along the track

Wrong mass assignment
leads to a distortion
of the $\pi\pi e e$ invariant
mass spectrum

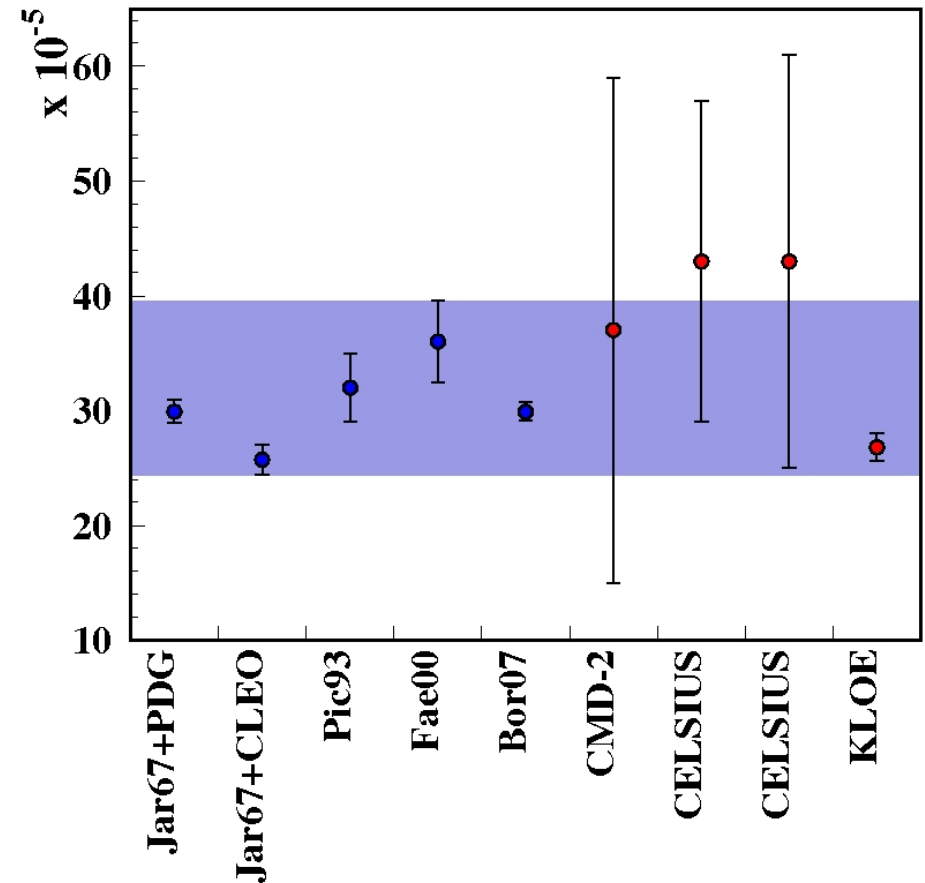
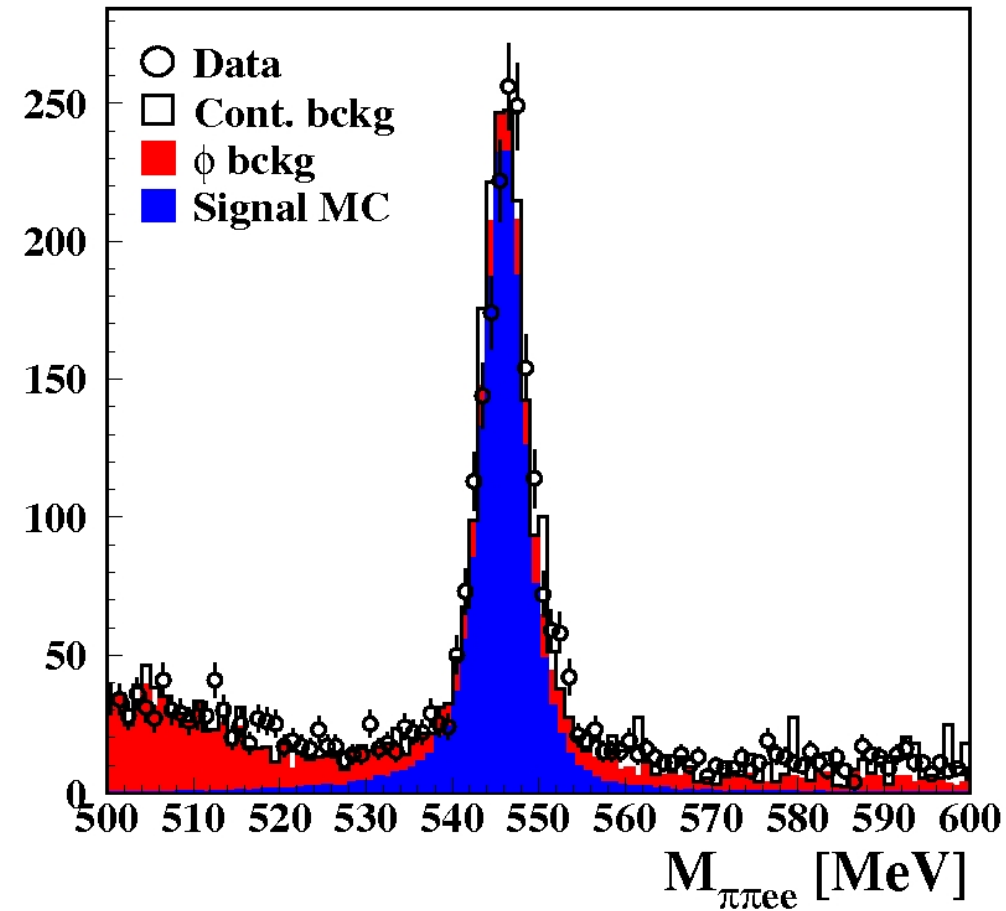


Important steps in the analysis

1. Event selection with PID (≥ 4 tracks and 1 good neutral cluster)
2. Kinematic fit to the ϕ meson: 22 inputs, 5 constraints, $\chi^2_{\text{KF}} < 4000$
3. Fit to $M_{\pi\pi ee}$ sidebands for background scale factors
4. Conversion rejection based on M_{ee} and D_{ee} at beam pipe
4. Continuum rejection $\cos\theta_f < 0.85$ and $\cos\theta_b > -0.85$
5. Cut on $M_{\pi\pi ee}$ $535 < M_{\pi\pi ee} < 555$ MeV

Signal counting at this level

Calculation of the branching ratio

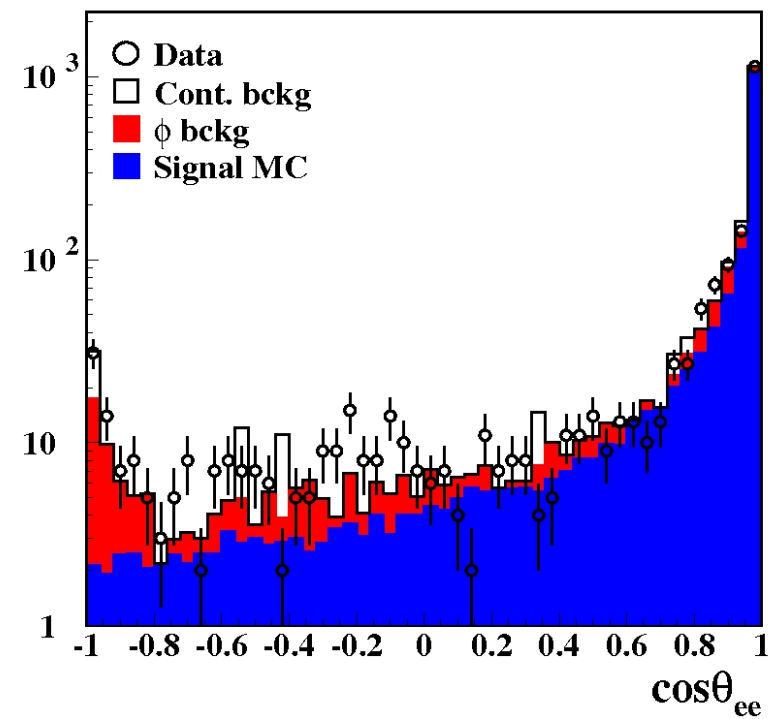
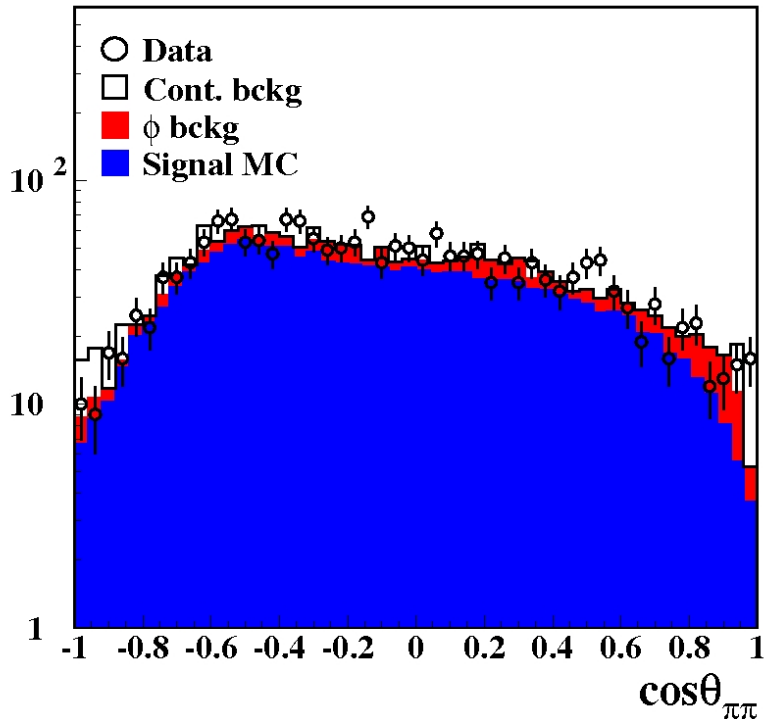
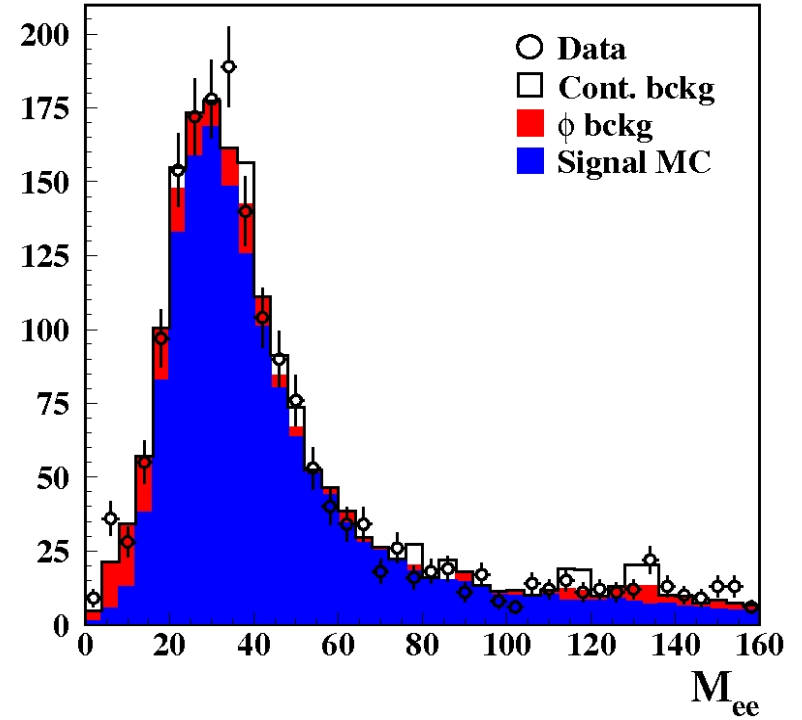
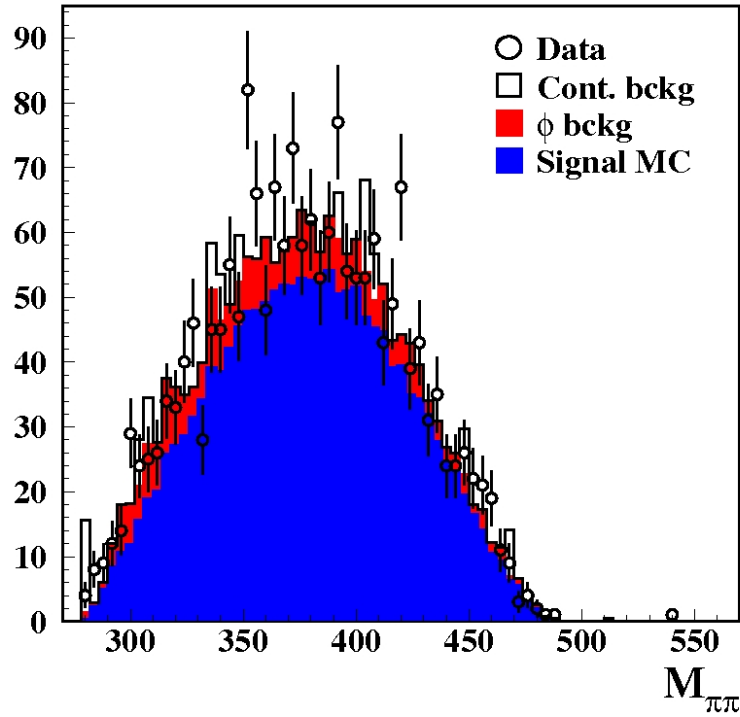


$$\text{BR}(\eta \rightarrow \pi^+ \pi^- e^+ e^- (\gamma)) = (26.8 \pm 0.9_{\text{Stat.}} \pm 0.4_{\text{Norm.}}) \cdot 10^{-5}$$

Number of events: 1555 ± 52
 Efficiency: 0.0803 ± 0.0003

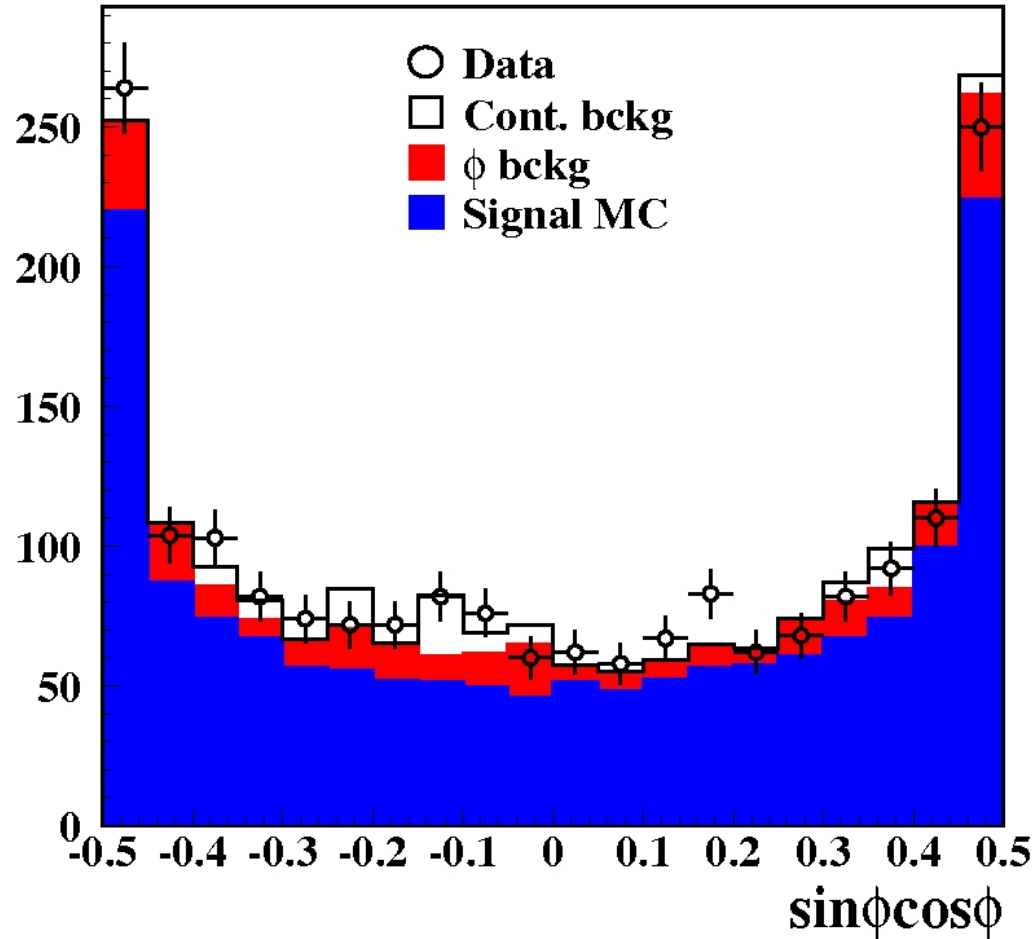
Luminosity: $(1733 \pm 10) \text{ pb}^{-1}$
 Cross section: $(41.7 \pm 0.6)^7 \text{ nb}$

Experiment – Simulation comparison



Asymmetry

First measurement!



$$A_{\phi} = (-0.6 \pm 2.5_{\text{Stat.}} \pm 1.8_{\text{Syst.}}) \cdot 10^{-2}$$

$$\eta \rightarrow e^+ e^- e^+ e^-$$

$\eta \rightarrow e^+ e^- e^+ e^-$ analysis

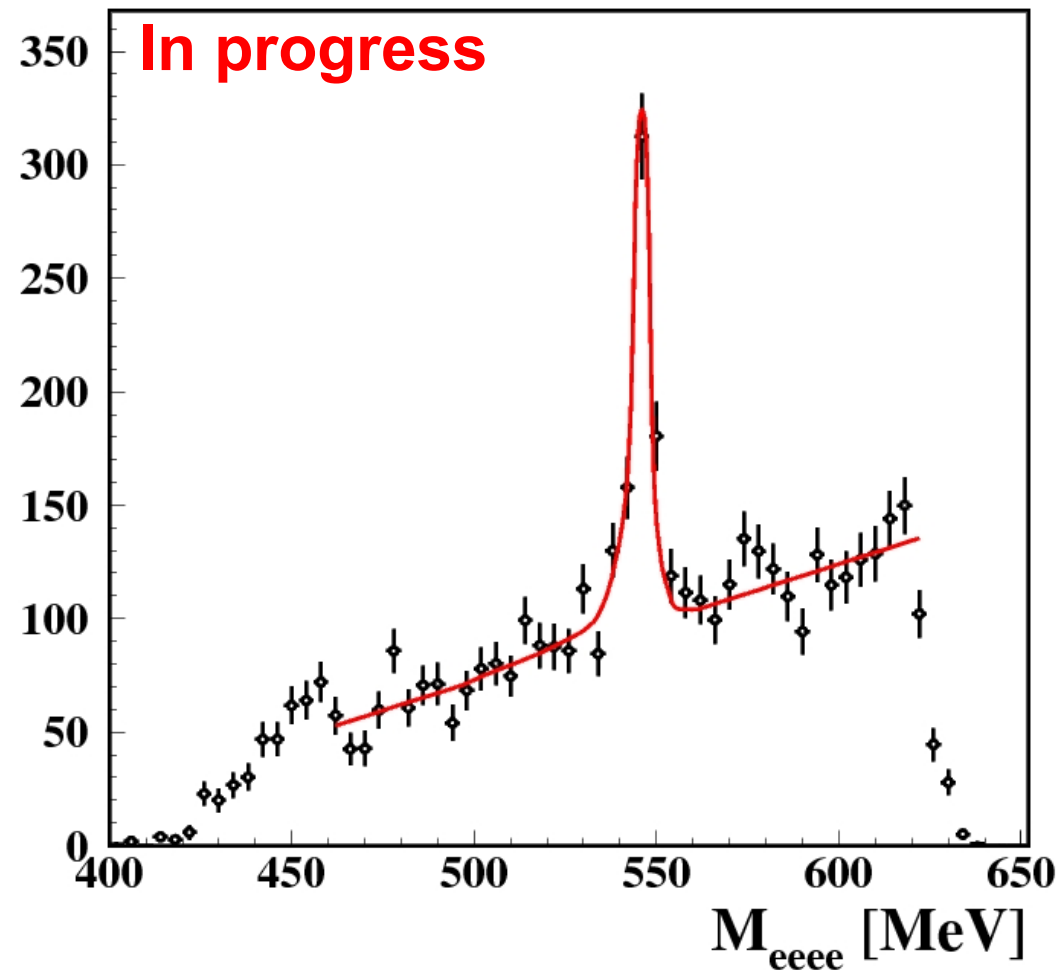
- Experimental data sample: 1.7 fb^{-1}
- MC simulation according to J. Bijnens and F. Persson, arXiv:hep-ph/0106130
(courtesely provided by J.Bijnens)

FSR included

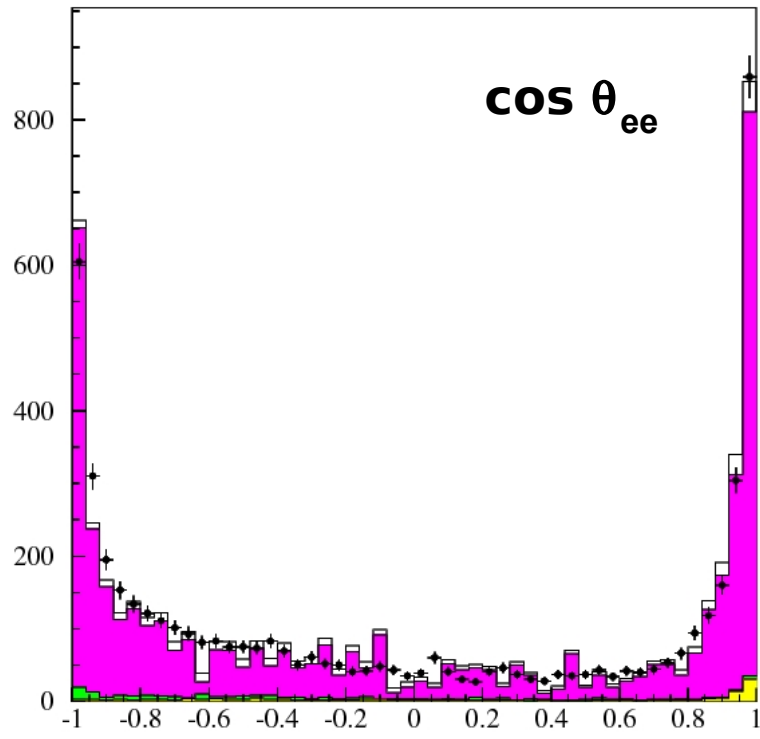
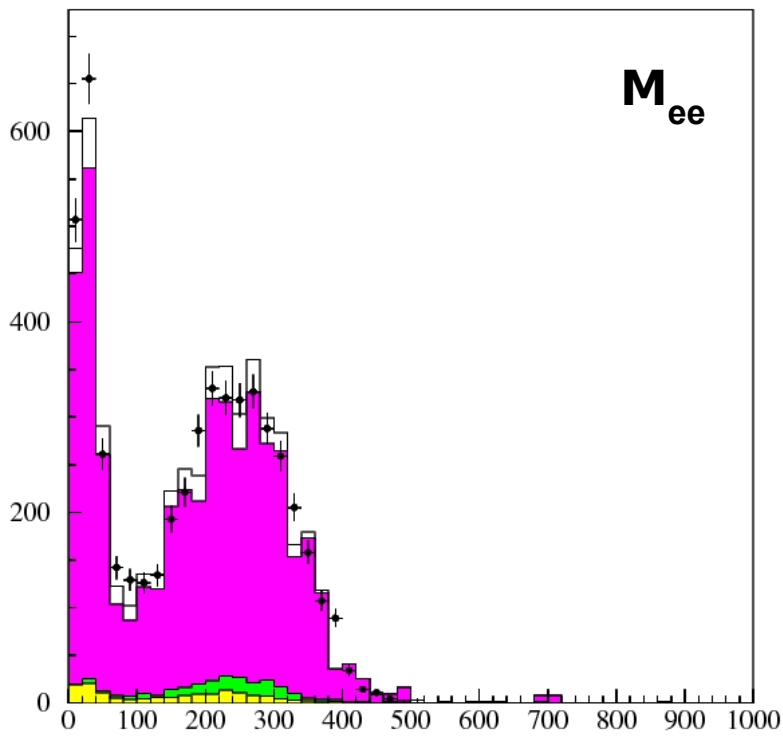
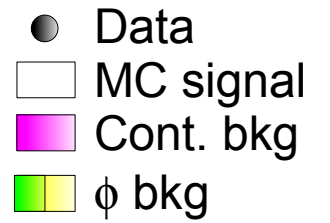
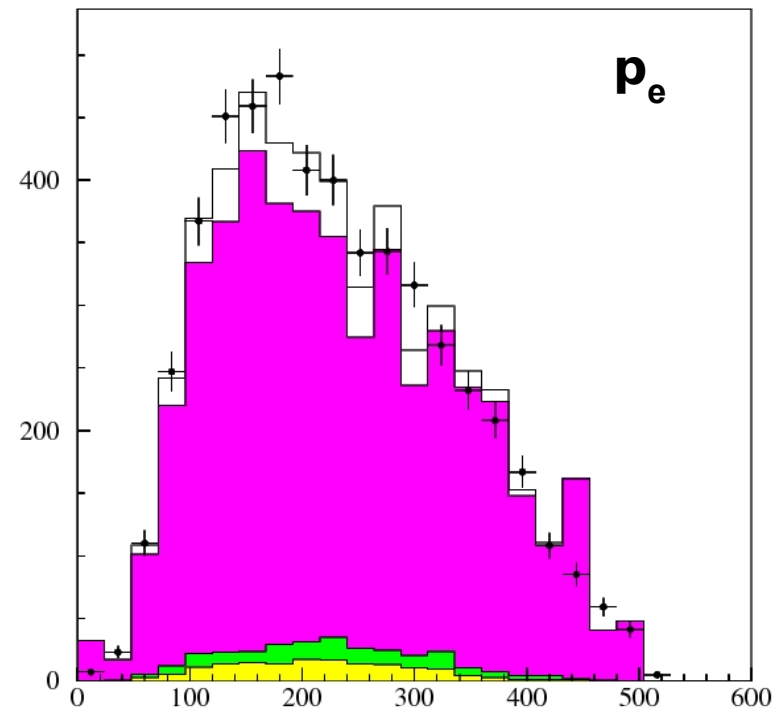
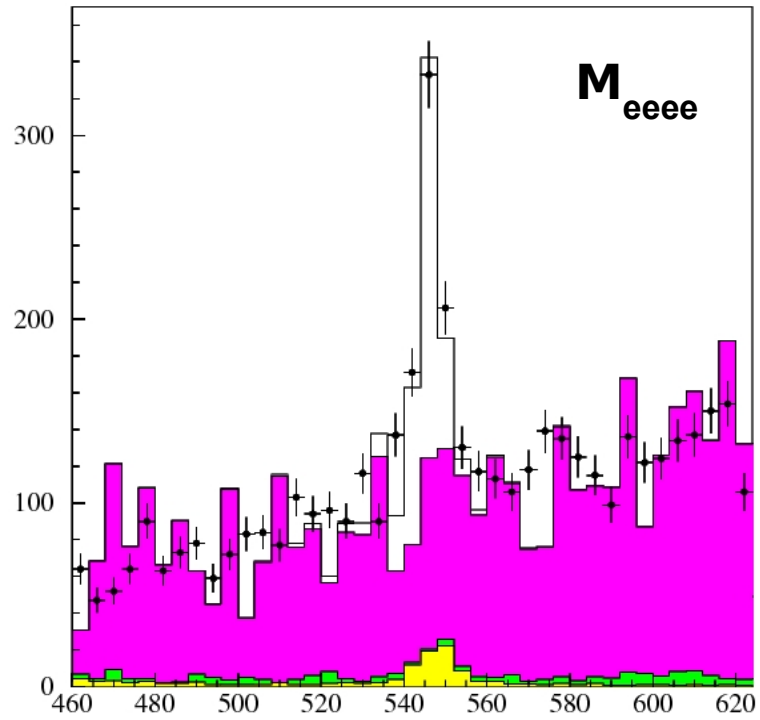
- e^+e^- pairs from photon conversion on Beam Pipe and Drift Chamber wall rejected
- Remaining background from ϕ decays is subtracted

Preliminary fit to M_{eeee} distribution with MC signal + continuum background shapes yields:

$N_{eeee} = 413 \pm 31$
First observation!



Experiment - MC comparison



$$\eta \longrightarrow \pi^+ \pi^- \gamma \quad \text{and} \quad \eta \longrightarrow \pi^+ \pi^- \pi^0$$

Motivations

Existing data [Gormley, Phys.Rev. D2 501 (1970),Layter, Phys.Rev. D7 2565 (1973)]

Low in statistic and not acceptance corrected

Not sufficient for unambiguous theoretical interpretation

Latest results from CLEO on the ratio of charged decays

BRs differ $> 3\sigma$ from old results

$$\Gamma(\eta \rightarrow \pi^+ \pi^- \gamma) / \Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)$$

value	events	author	year
0.203 ± 0.008	PDG average		
$0.175 \pm 0.007 \pm 0.006$	859	Lopez	2007
0.209 ± 0.004	18 k	Thaler	1973
0.201 ± 0.006	7250	Gormley	1970

Selection: $\underline{\eta \rightarrow \pi^+ \pi^- \pi^0}$ and $\eta \rightarrow \pi^+ \pi^- \gamma$

No kinematical fit, signal selection with help of kinematical constraints from consecutive decays i.e.

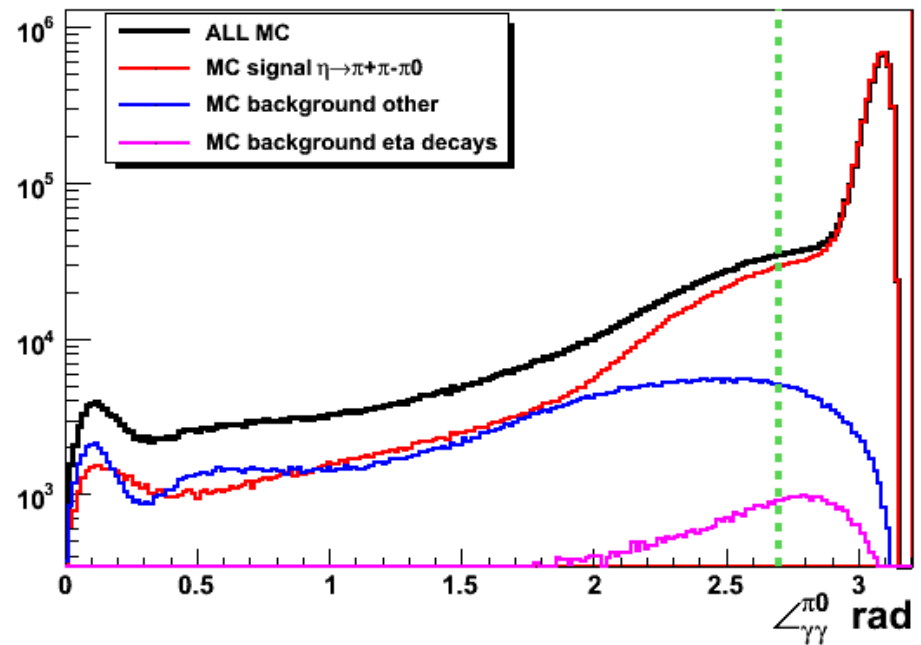
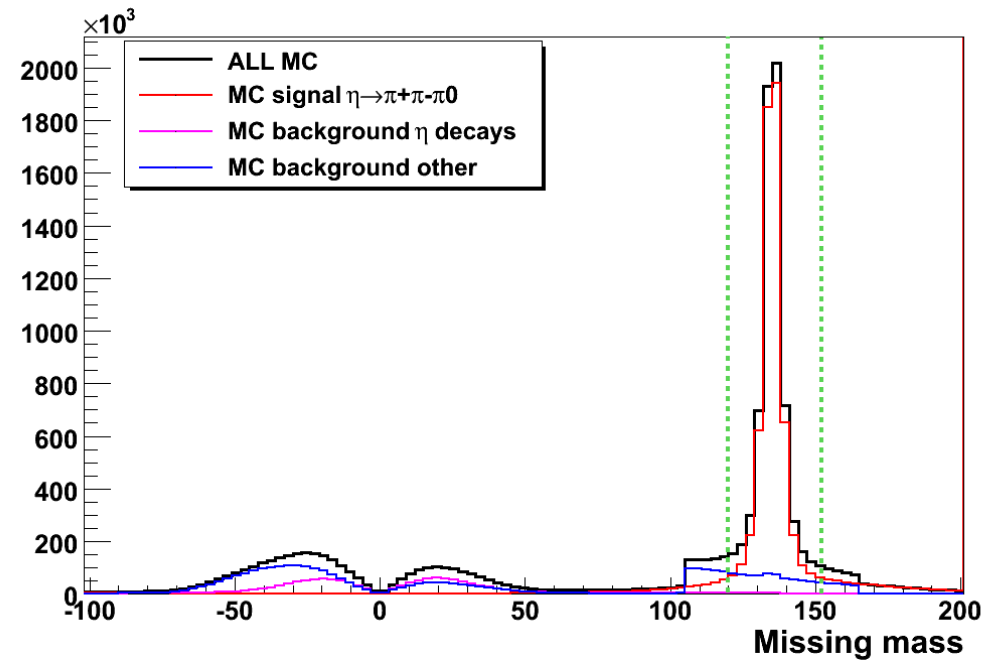
$$\phi \rightarrow \eta \gamma, \quad \eta \rightarrow \pi^+ \pi^- \pi^0, \quad \pi^0 \rightarrow \gamma \gamma$$

$$\phi \rightarrow \eta \gamma, \quad \eta \rightarrow \pi^+ \pi^- \gamma$$

For $\eta \rightarrow \pi^+ \pi^- \pi^0$:

- Missing mass to $(\phi - \pi^+ - \pi^- - \gamma_\phi)$ system
- Opening angle $(\gamma_\eta^1 \gamma_\eta^2)$ in the π^0 rest frame

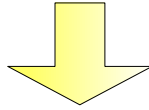
Eff = 40 % with BKG/SIG = 0.5 %



Selection: $\eta \rightarrow \pi^+ \pi^- \pi^0$ and $\underline{\eta \rightarrow \pi^+ \pi^- \gamma}$

For $\eta \rightarrow \pi^+ \pi^- \gamma$:

- Similar cuts ($(E_\gamma - P_\gamma)$) instead of missing mass, angle selection)

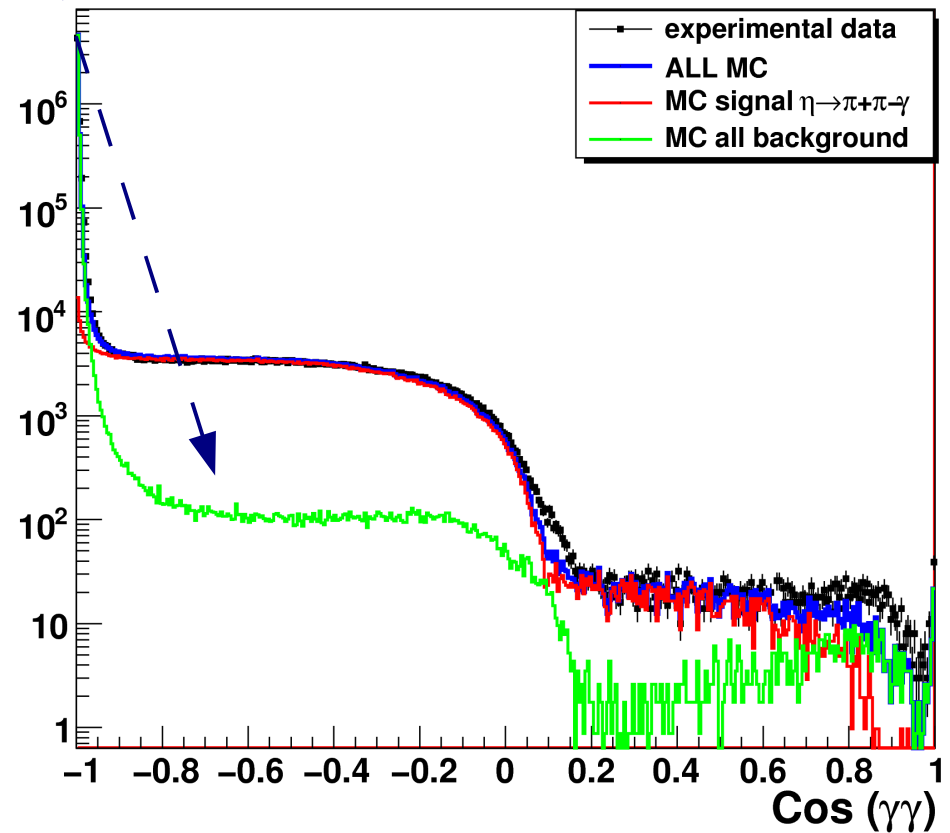
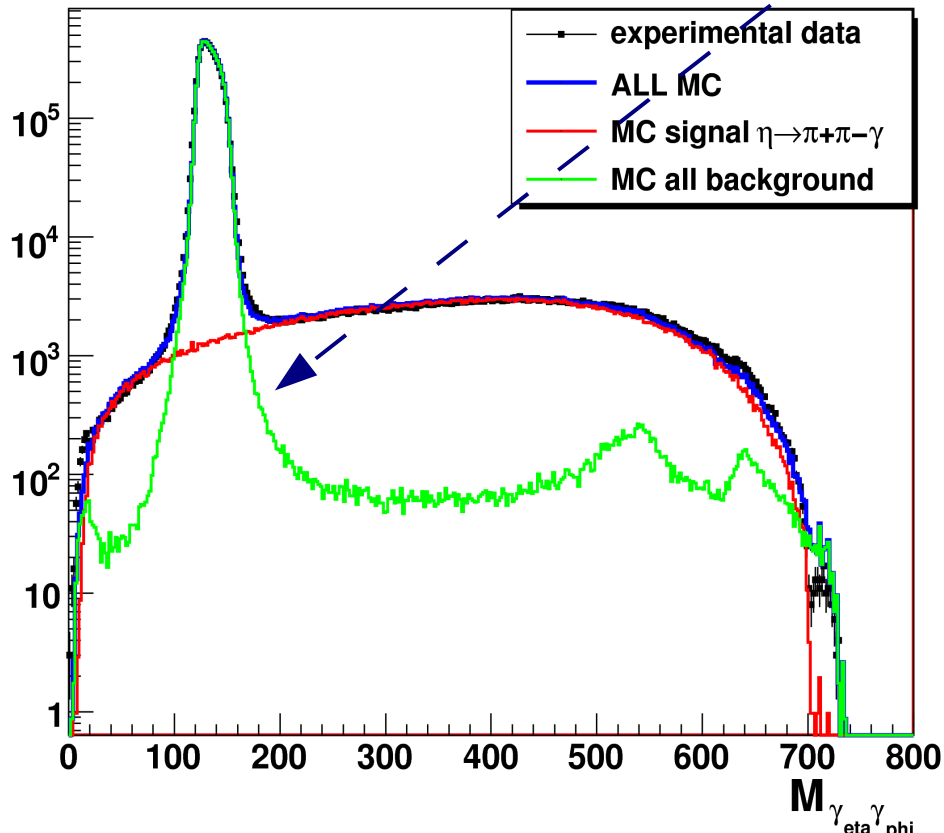


Eff = 29 % , BKG/SIG = 10:1

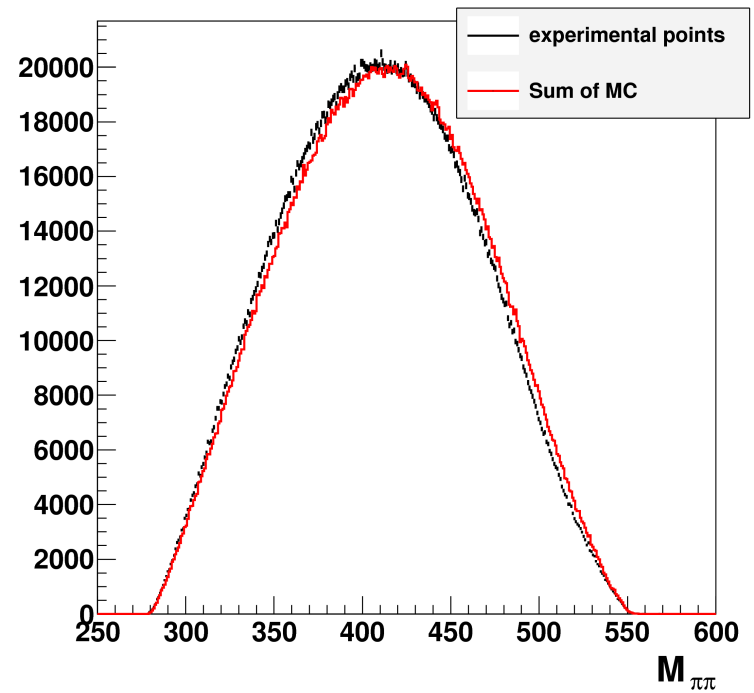
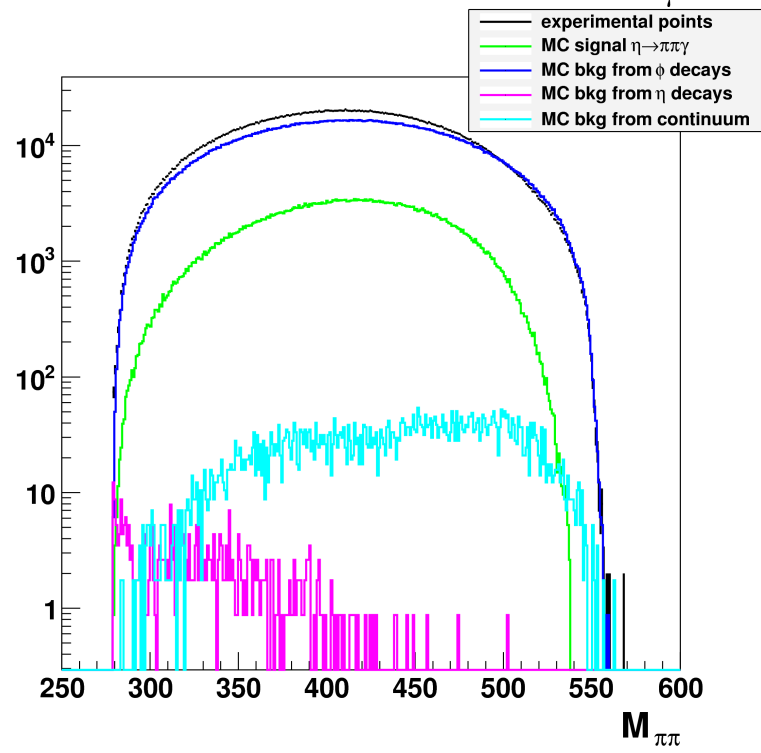
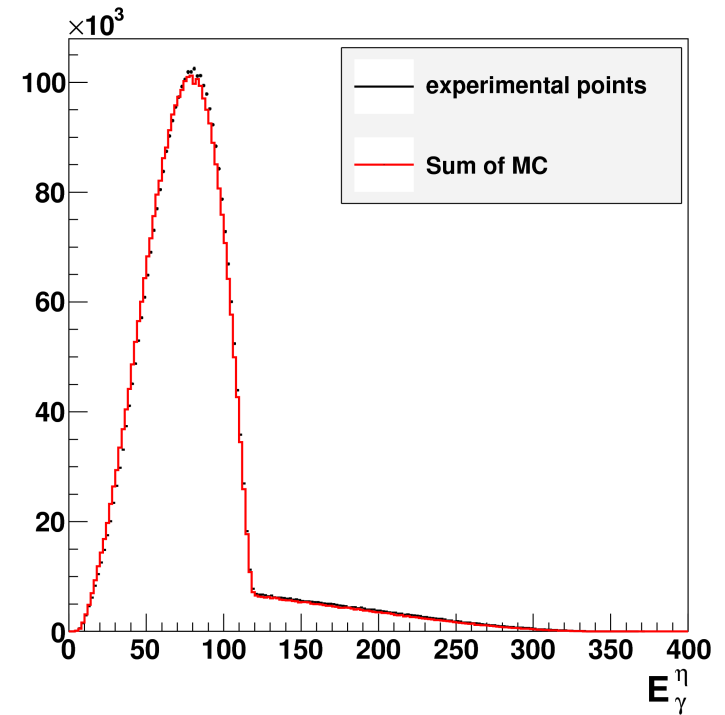
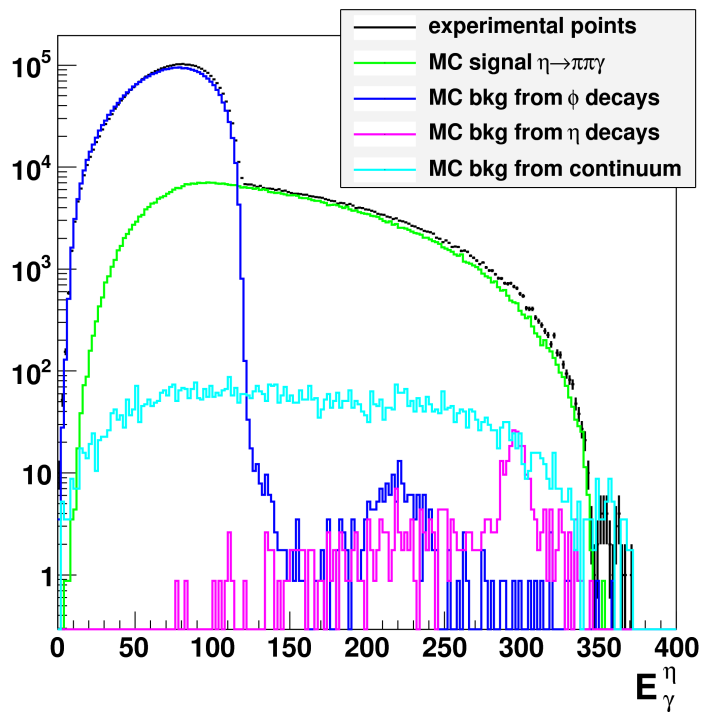
surviving background $\phi \rightarrow \pi^+ \pi^- \pi^0$

different topology in $\gamma\gamma$ distributions

simultaneous fit to both spectra



Exp. data – MC comparison



PRELIMINARY RESULTS:

$$\Gamma(\eta \rightarrow \pi^+ \pi^- \gamma) / \Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)$$

(based on 1.2 fb⁻¹ data set)

$$\frac{\Gamma(\eta \rightarrow \pi^+ \pi^- \gamma)}{\Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)} = 0.2014 \pm 0.0004_{\text{stat}}$$

*

value	events	author	year
0.203 ± 0.008		PDG average	
0.175 ± 0.007 ± 0.006	859	Lopez	2007
0.209 ± 0.004	18 k	Thaler	1973
0.201 ± 0.006	7250	Gormley	1970
0.2014 ± 0.0004	611 k	KLOE preliminary 2009	

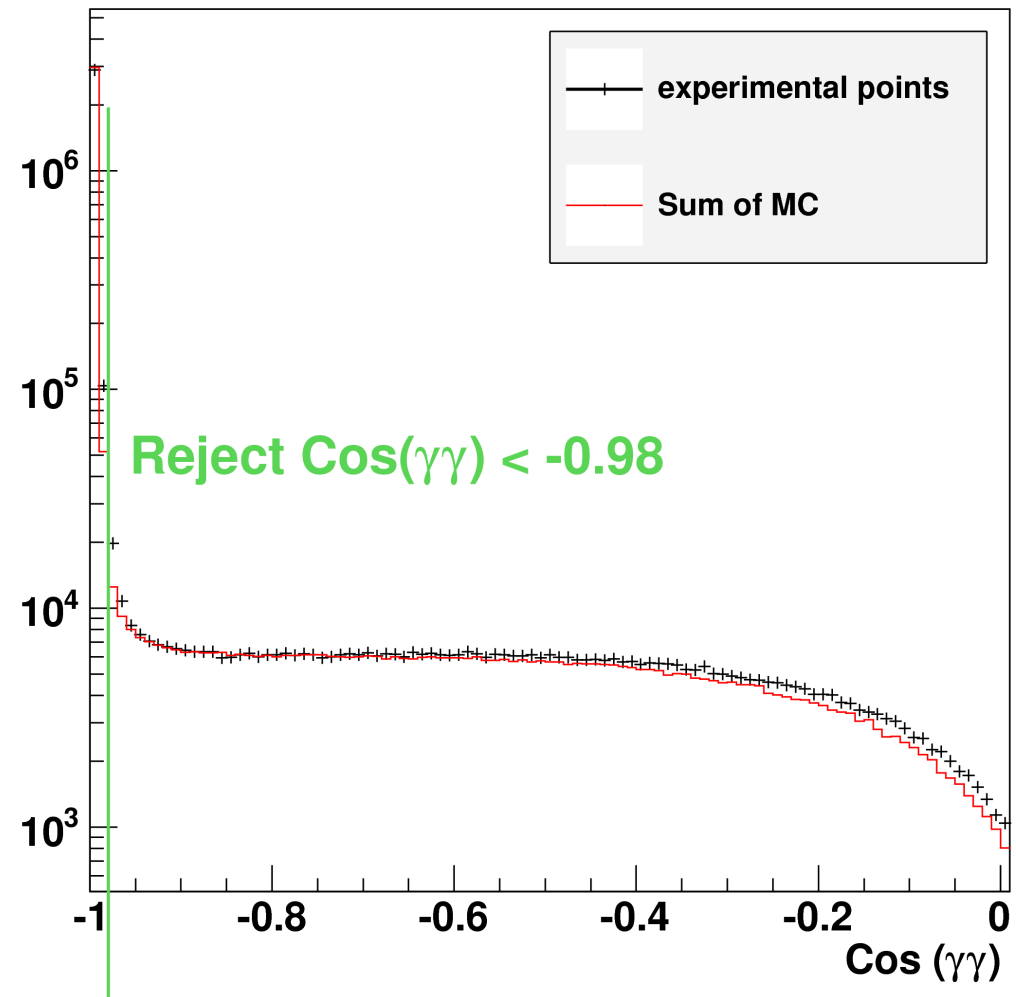
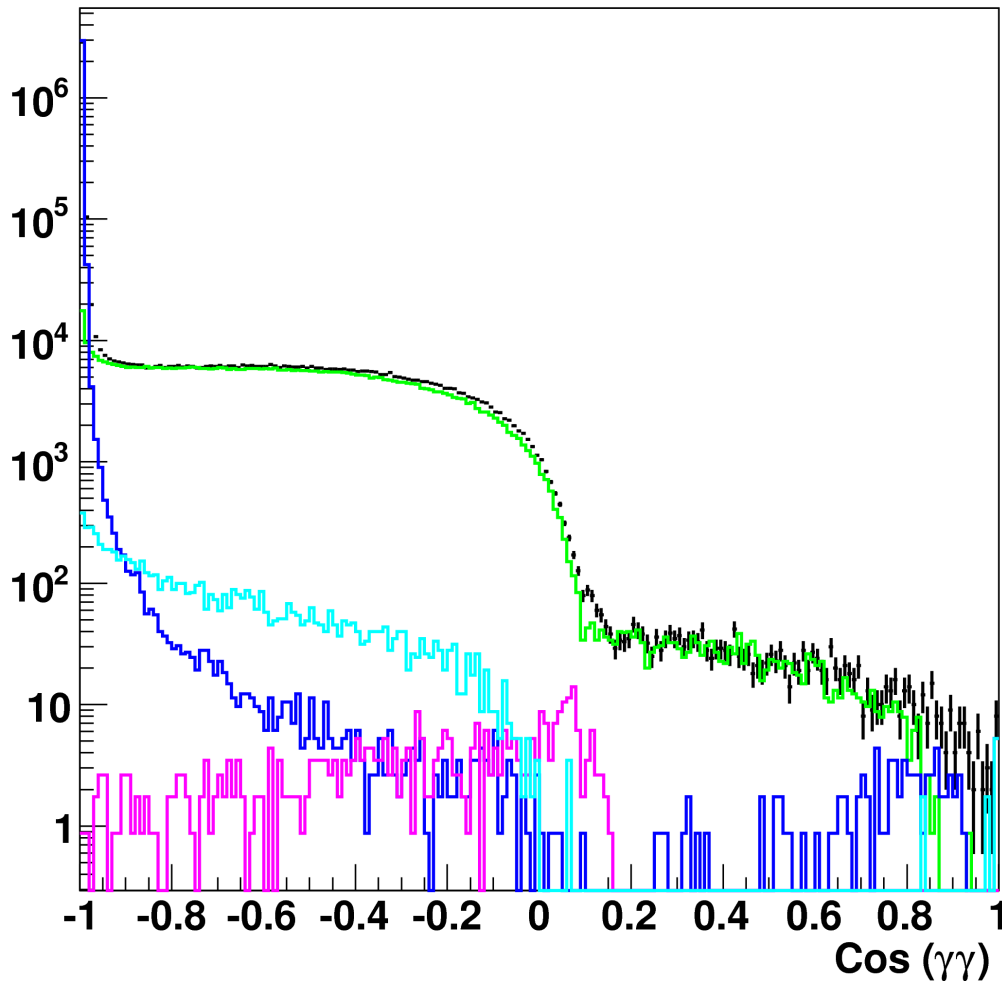
* systematic errors under evaluation

OUTLOOK – CURRENT STATUS

- Our preliminary results agrees with PDG values, confirming old results from '70s.
- We are evaluating systematics, aiming at value $< 1\%$
- Plan to use full KLOE data set (*statistical precision* $\sim 0.15\%$) and investigate in detail the $\pi^+\pi^-$ invariant mass distribution and photon energy spectrum in order to disentangle non-resonant contributions and settle the inconsistencies of previous measurements.
- Cuts on $M_{\gamma\gamma}$ and $\cos(\gamma_\phi \gamma_\eta)$ in the π^0 rest frame will allow for significant background reduction

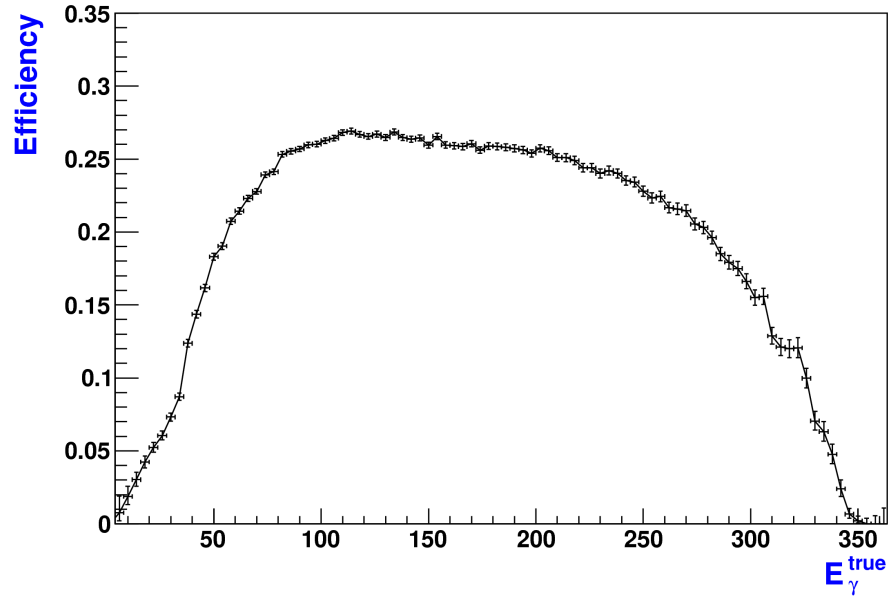
Further background rejection

- Particle Identification with TOF (continuum)
- Rejection based on $\text{Cos}(\gamma\gamma) > -0.98$ ($\phi \rightarrow \pi\pi\pi$)



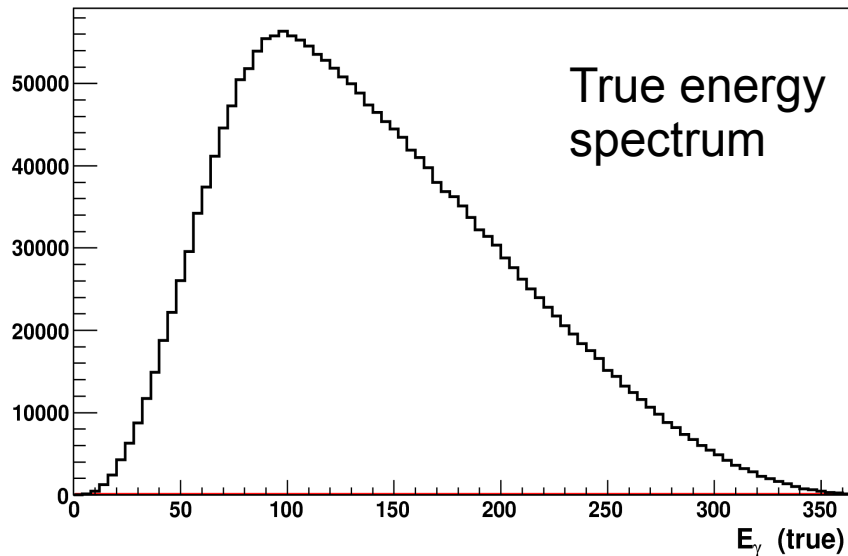
Efficiency after background reduction

Study based on 1.2 fb⁻¹ data set



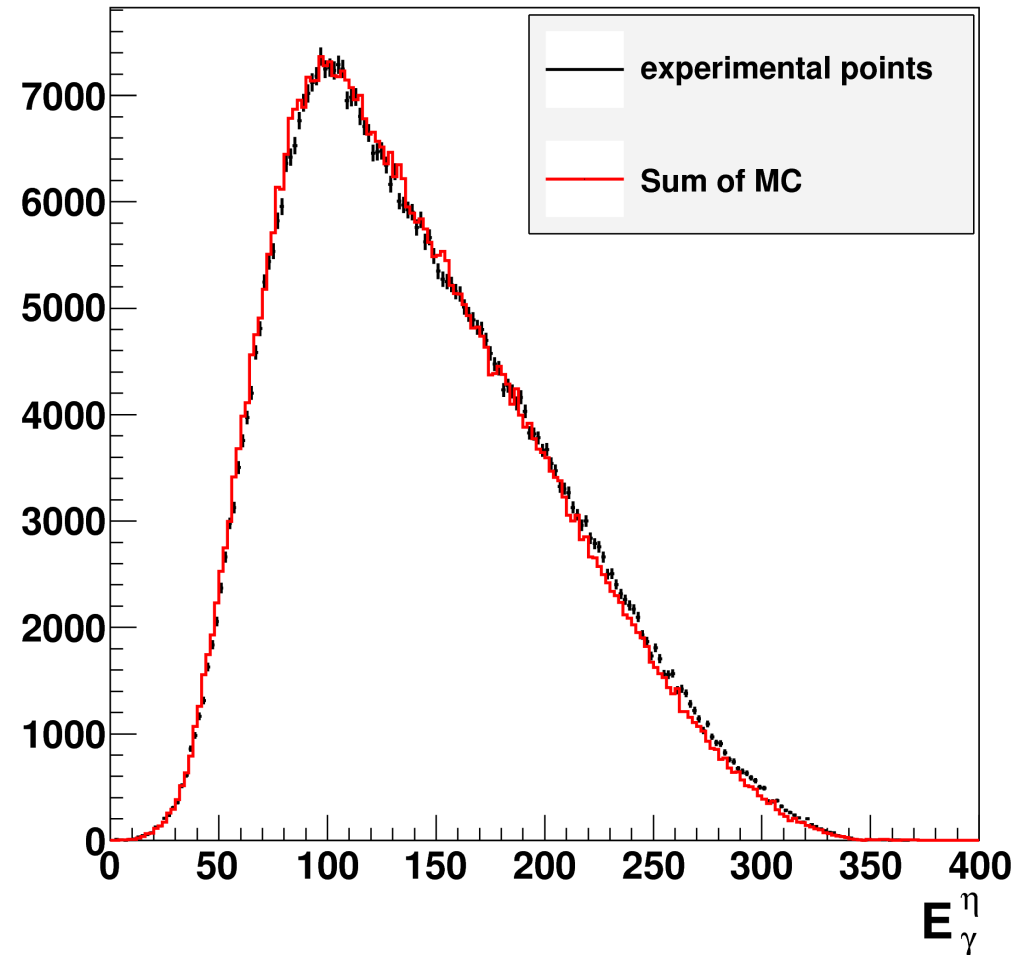
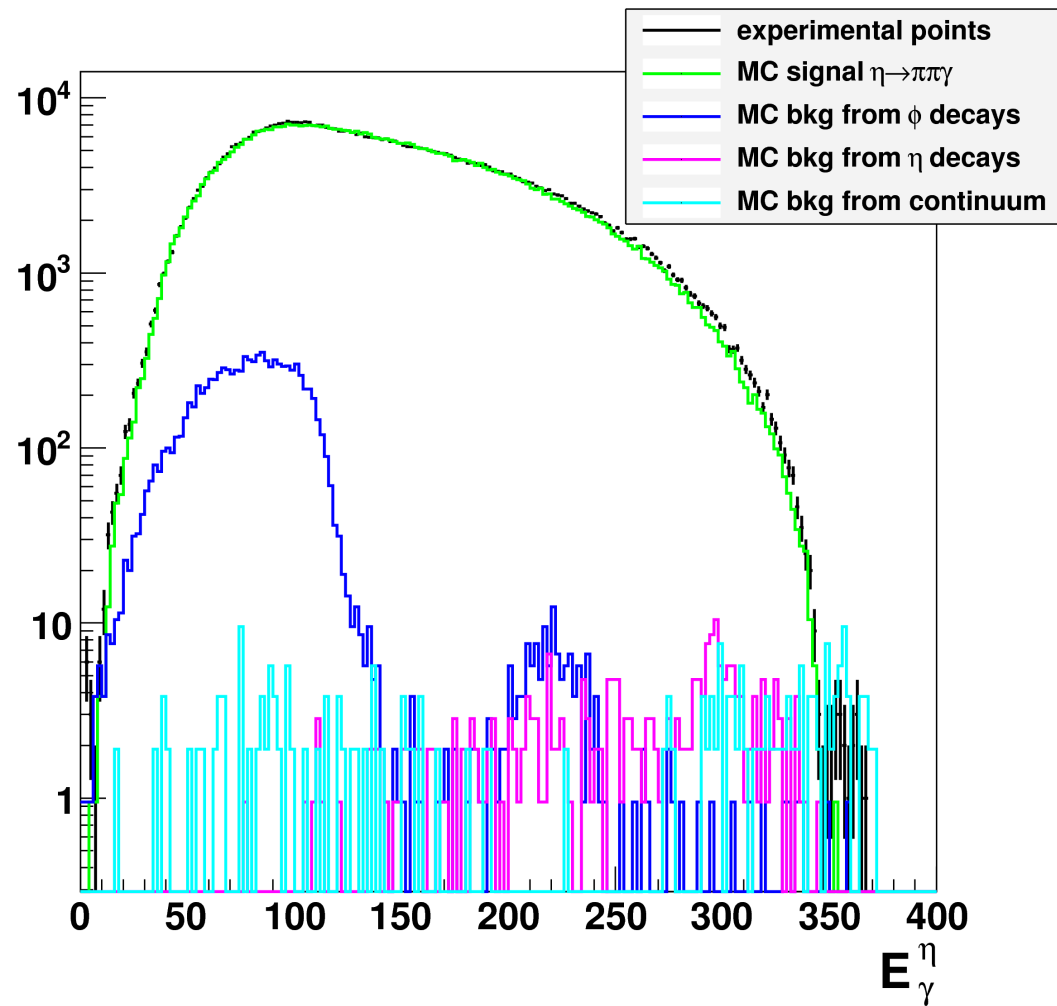
Signal 534 k events
All background 11 k events (2%)

Efficiency = 24.3 %



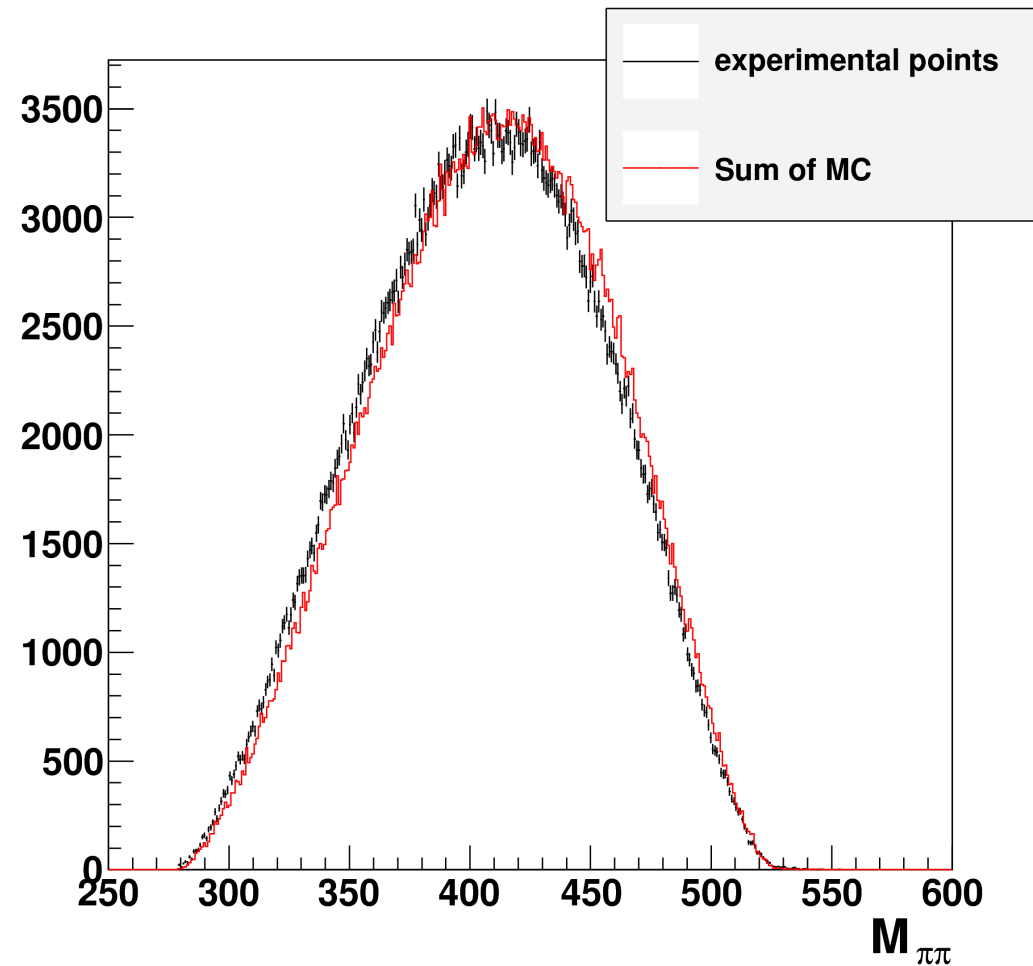
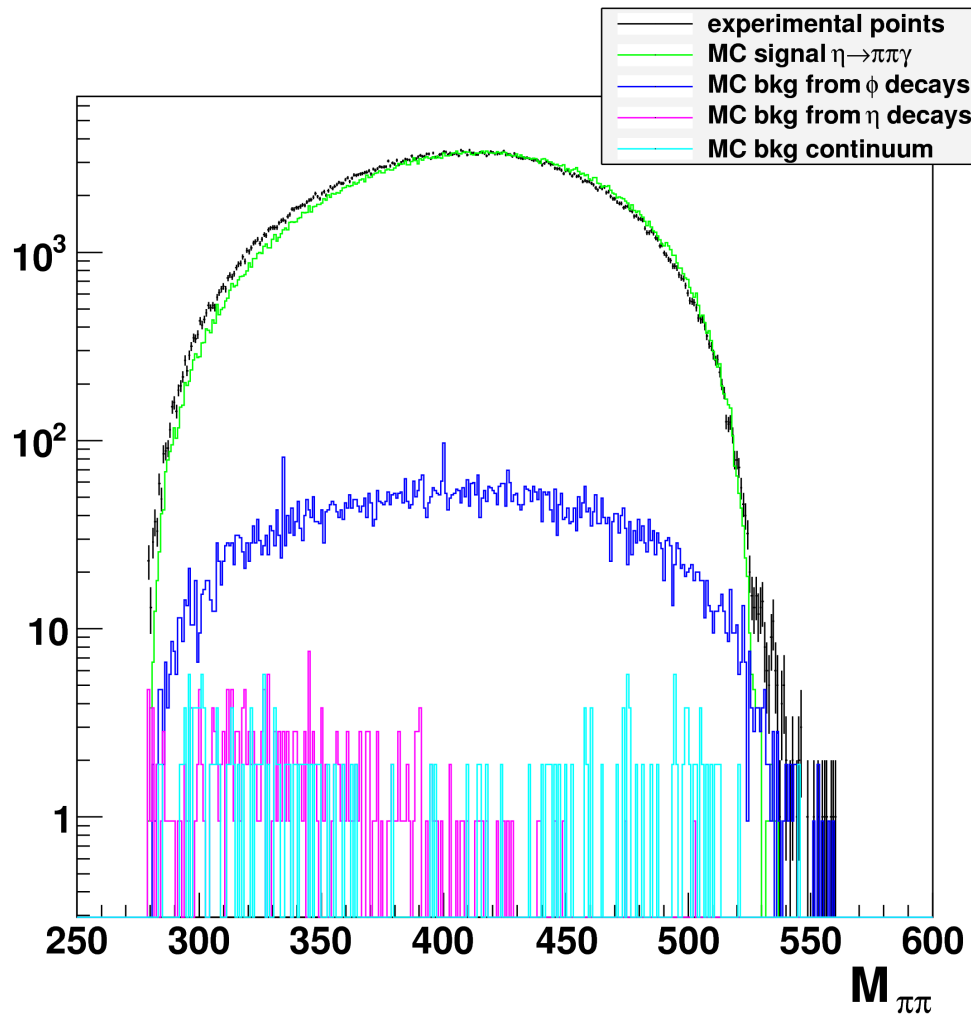
Exp. data – MC comparison

energy of γ_η E_γ^η



Exp. data – MC comparison

$\pi^+\pi^-$ invariant mass



SUMMARY

- BR and the first measurement of asymmetry in $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ decay:

$$\text{BR} = (26.8 \pm 0.9_{\text{Stat.}} \pm 0.7_{\text{Syst.}}) \cdot 10^{-5}$$

$$A_{\phi} = (-0.6 \pm 2.5_{\text{Stat.}} \pm 1.8_{\text{Syst.}}) \cdot 10^{-2}$$

- First observation of the $\eta \rightarrow e^+ e^- e^+ e^-$ decay ~ 400 events
- Analysis has been started on $\eta \rightarrow \pi^+ \pi^- \gamma$. Preliminary

results on the ratio of BRs: $\frac{\Gamma(\eta \rightarrow \pi^+ \pi^- \gamma)}{\Gamma(\eta \rightarrow \pi^+ \pi^- \pi^0)} = 0.2014 \pm 0.0004 (stat)$

- $\eta \rightarrow \mu^+ \mu^-$ analysis in progress

SPARES

Perspectives for $\eta \rightarrow \mu^+ \mu^-$

- Motivation
 - Study of the form factor
 - Possible physics beyond the SM (searching a candidate for the light dark matter)
 - $\text{BR}_{\text{PDG}} = 5.8 \pm 0.8 \times 10^{-6}$ (2 experiments: 114 and 28 events)
- Situation for KLOE
 - $\sigma(\eta \rightarrow \mu^+ \mu^-) = 0.23 \times 10^3$ [nb]
 - Expected $N_{\eta \rightarrow \mu^+ \mu^-} \approx 500$
 - Severe background from continuum