XCII Congresso della Società Italiana di Fisica

Recenti risultati dell'esperimento KLOE a DAϕNE

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Torino, 20 settembre 2006

Outline

The KLOE experiment at Daϕne

Kaon physics

Bell-Steinberger relation : $K_S \to \pi\, e\, \nu$, $K_s \to \pi\, \pi$, $K_s \to \pi^0\, \pi^0\, \pi^0$, and $K_L \to \pi^+\, \pi^-$

V_{us} extraction : K_L, $K^\pm$ BRs, lifetimes and semileptonic form factor slopes

Hadron physics

Light scalar study: $f_0(980)$

η-η' mixing : $BR(\phi \to \eta' \gamma) / BR(\phi \to \eta\, \gamma)$

Outlook

Physics with KLOE at Daϕne

Precision measurements

in the kaon and eta-meson sector,

of the hadronic cross section via radiative return

of the light scalars f_0 and a_0

Exploiting

the kinematic constraints on the events

the low-background levels

at the ϕ-factory

Thanks to the experimental setup

Good tracking resolution

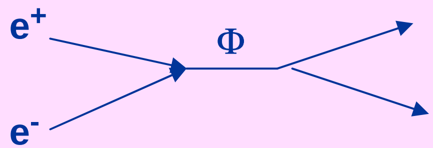
Excellent hermeticity and time resolution of the calorimeters

Excellent stability of the detector performance

Open trigger

Physics at the ϕ factory

ϕ production – Visible cross section 3.1 μb → $3\ 10^6\ \phi$ / pb^{-1}



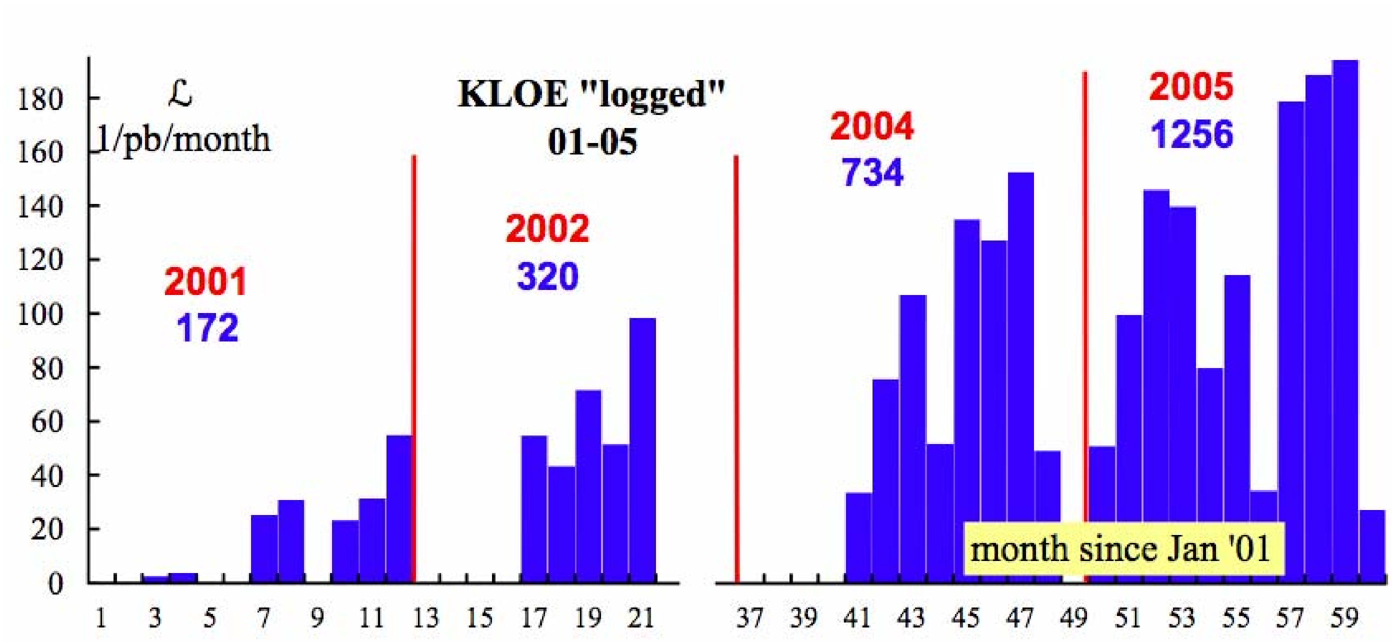
K^+	K_S	ρ	η	π^0	…	f_0	a_0	η'
K^-	K_L	π	γ	γ	…	γ	γ	γ
49%	34%	15%	1.3%	0.12%	…	0.044%	0.008%	0.006%

Almost monochromatic kaons, η, η'
Particle momenta and primary vertex position precisely measured by Bhabha-scattering events
Reconstruction of one kaon tags the other providing P
Monochromatic γ's tag η /η' events

Achievements limited by statistics - $2.6\ 10^9$ Kaons per fb^{-1}
$4\ 10^7$ η and $1.9\ 10^5$ η' per fb^{-1}

Open trigger provides a variety of control samples for optimizing systematics thus also limited by statistics

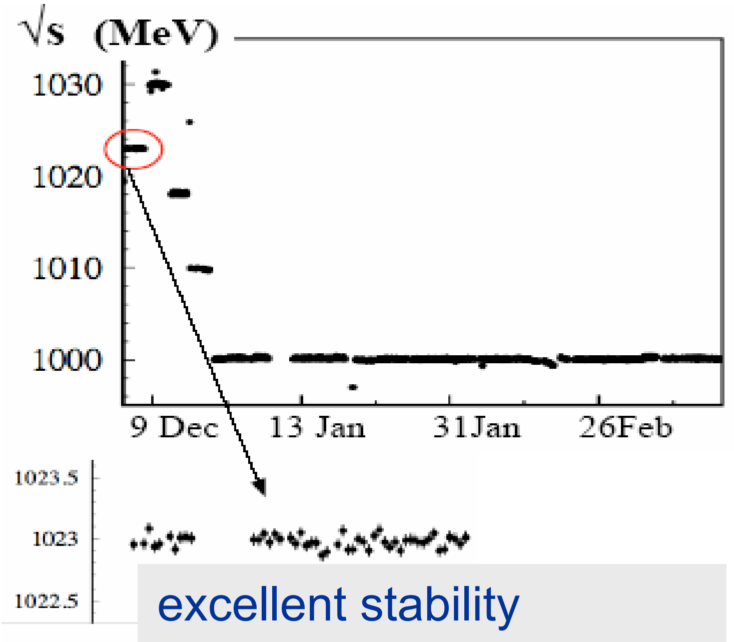
KLOE integrated luminosity at the ϕ peak



- **2001-2005** **$L_{int} = 2482\ pb^{-1}$**
- **2004-2005** **$L_{int} = 1990\ pb^{-1}$**
- **Best conditions: Sept/Oct/Nov 2005 $\Rightarrow$ 179/189/194 pb^{-1}**

  stable luminosity, beam energy and backgrounds
- **Dec 5th end of run at 1020 MeV, start off peak run**

Off-peak data taking



excellent stability
in Daϕne operation and
also excellent data quality

Data acquisition Dec 5 - Mar 16, 2006

$\sqrt{s}$ (MeV)	**1023.**	**1030.**	**1018.**	**1010.**	**1000.**
L_{int} (pb^{-1})	**10.4**	**11.4**	**10.2**	**11.0**	**233.5**

- 4 points (10 pb^{-1}) in the 1010-1030 MeV region:
  - Calibration of KLOE energy scale, line shape
  - Model dependence of the f_0 production vs $\sqrt{s}$
  - **$\sigma(e^+e^- \to \omega\pi^0)$**, ϕ leptonic widths
- 200 pb^{-1} at $\sqrt{\mathbf{s}}$ =1000 MeV:
  - **Measurement of the $\sigma(\pi^+\pi^-\gamma)$ down to $2m_\pi$**
  - Two-photon physics with KLOE: $\gamma\gamma \to \eta$, $\pi\pi$

Kaon Physics: results from 2001-2002 data

$K_S K_L \to \pi^+\pi^-\pi^+\pi^-$	Quantum Interference	**Submitted to PLB**	
$K_S \to \pi^0\pi^0\pi^0$	UL on BR at 10^{-7}	**PLB 619 (2005) 61**	**PDG06**
$K_S \to \pi e \nu$	BR to 1.3%, form factor slope, charge asymmetry	**PLB 636 (2006) 173**	**PDG06**
$K_S \to \pi^+\pi^-, \pi^0\pi^0$	$\Gamma(\pi^+\pi^-)/\Gamma(\pi^0\pi^0)$ to ~0.25%	**Accepted by EPJC**	**PDG06**
$K_L \to \pi l \nu, \pi\pi\pi$	Absolute BR's to ~ 0.5%	**PLB 632 (2006) 43**	**PDG06**
	K_L lifetime from Σ(BR)=1		
K_L lifetime	from $K_L \to \pi^0\pi^0\pi^0$ to ~ 0.5%	**PLB 626 (2005) 15**	**PDG06**
$K_L \to \pi e \nu$	Form factor slopes	**PLB 636 (2006) 166**	**PDG06**
$K_L \to \pi e \nu \gamma$	BR to ~ 2 %	**Preliminary**	
$K_L \to \pi^+\pi^-$	BR to 1.1%	**PLB 638 (2006) 140**	**PDG06**
$K_L \to \gamma\gamma$	$\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\pi^0)$ to 1.1%	**PLB 566 (2003) 61**	
$K^+ \to \pi^+\pi^0\pi^0$	BR to 1.4%	**PLB 597 (2004) 139**	
$K^+ \to \mu^+\nu$	Absolute BR to ~ 0.27%	**PLB 632 (2006) 76**	**PDG06**
$K^\pm \to \pi^0 l^\pm \nu$	Absolute BR's to ~ 1.5%	**Preliminary**	
$K^\pm$ lifetime	two independent measurements	**Preliminary**	

$K_S \to \pi e \nu$: BR and A_S

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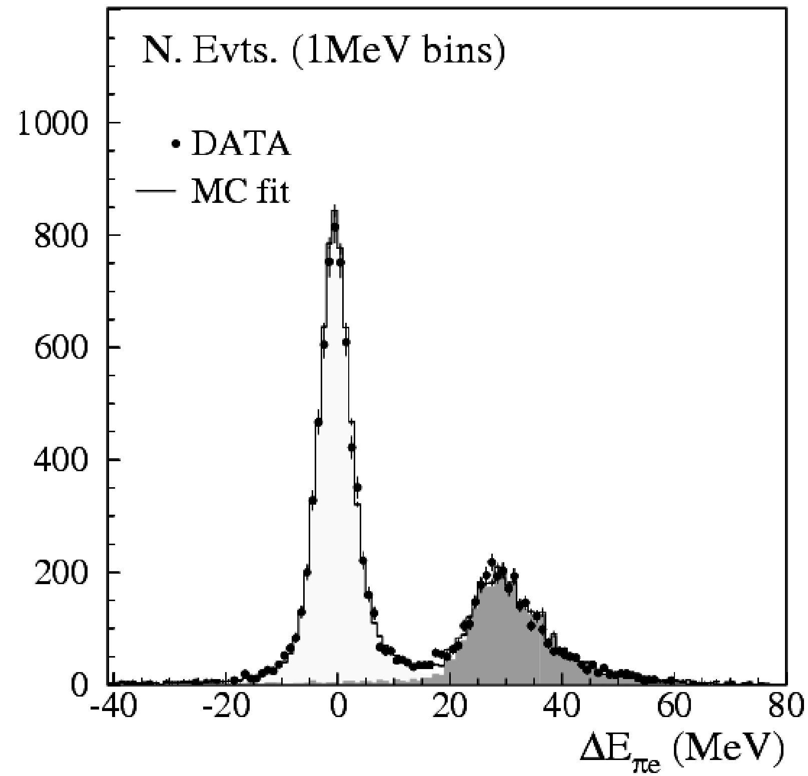
TOF e/π ID,
fit to $E_{miss} - p_{miss}$ spectrum

$K_S \to \pi^+\pi^-$ events in the same sample for K_S counting



Branching ratio

$$\boxed{BR(\pi e\nu) = (7.046 \pm 0.077 \pm 0.049)\times 10^{-4}}$$

fractional error: $1.3\% = 1.1\%_{stat} \oplus 0.7\%_{syst}$

Charge asymmetry

$$\boxed{A_S = (\,1.5 \pm 9.6 \pm 2.9\,) \times 10^{-3}}$$

first measurement
$\delta A_S \sim 3\times10^{-3}$ with 2.5 fb^{-1}

$$1 + 4\,Re(x_+) = \frac{\Gamma_S}{\Gamma_L} = \frac{\overset{13\,10^{-3}}{BR(K_S \to \pi e\nu)}\ \overset{6\,10^{-3}}{\tau_L}}{\underset{4\,10^{-3}}{BR(K_L \to \pi e\nu)}\ \underset{10^{-3}}{\tau_S}}$$

$$\boxed{Re\,x_+ = (\,-0.5 \pm 3.1 \pm 1.8)\ \ 10^{-3}}$$

$K_S \to \pi e \nu$: CPT test

1) Re $x\_$: CPT viol. and $\Delta S \neq \Delta Q$

$$A_S - A_L = 4\,(\,\mathrm{Re}\,x\_ + \mathrm{Re}\,\delta\,)$$

A_L	KTeV	$\sigma=0.75\times10^{-4}$
Re δ	**CPLEAR**	$\sigma= 3.4\times 10^{-4}$

$$\boxed{\mathrm{Re}\,x\_ = (\,-0.8 \pm 2.5)\;\;10^{-3}}$$

Factor 5 improvement w.r.t. current most precise measurement (CPLEAR, $\sigma= 1.3\times 10^{-2}$ **)**

2) Re y: CPT viol. and $\Delta S=\Delta Q$

$$A_S + A_L = 4\,(\mathrm{Re}\,\varepsilon - \mathrm{Re}\,y)$$

Re ε from PDG not assuming CPT

$$\boxed{\mathrm{Re}\,y = (\,0.4 \pm 2.5)\;\;10^{-3}}$$

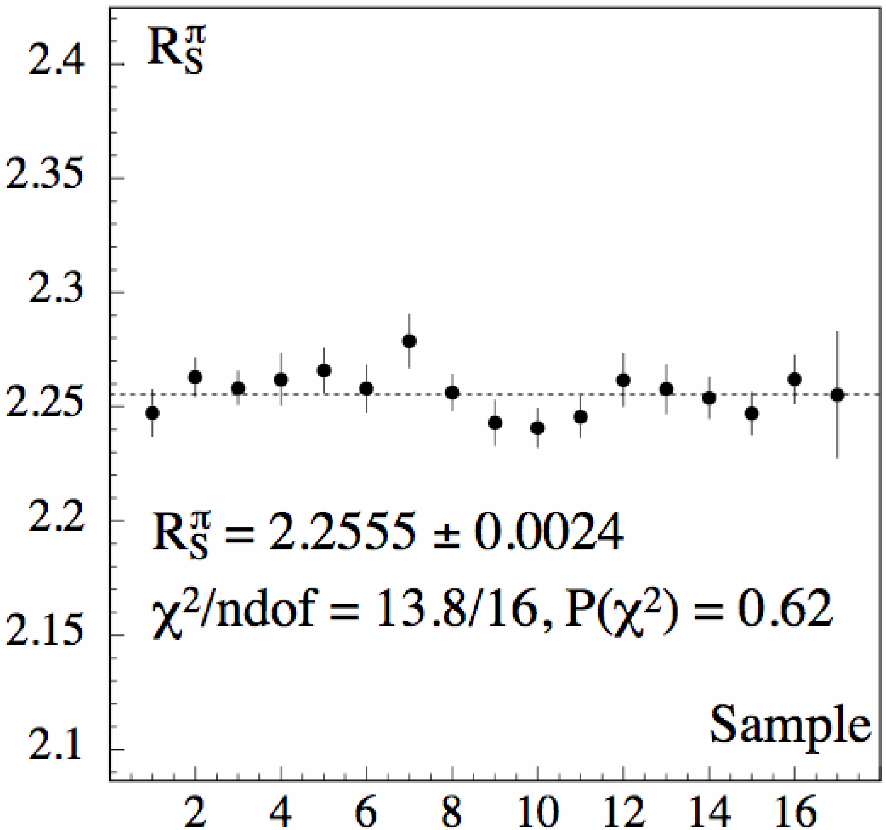
Comparable with best result (CPLEAR from unitarity, $\sigma= 3.1\times 10^{-3}$ **)**

$\Gamma(K_S \to \pi^+\pi^-(\gamma))/ \ \Gamma(K_S \to \pi^0\pi^0)$

hep-ex/0601025
Accepted by EPJC

Statistics allow 17 independent measurements, each to few per mil accuracy

$2.2555 \pm 0.0012_{stat} \pm 0.0021_{syst\text{-}stat} \pm 0.0050_{syst}$



- *2.5×10^{-3} accuracy*
- *$\times 3$ improvement on respect to KLOE 2002*
  $(2.236 \pm 0.003_{stat} \pm 0.007_{statsyst} \pm 0.013_{syst})$

KLOE average:
2.2549 ± 0.0054

$K_S \to \pi^0\pi^0\pi^0$: direct search

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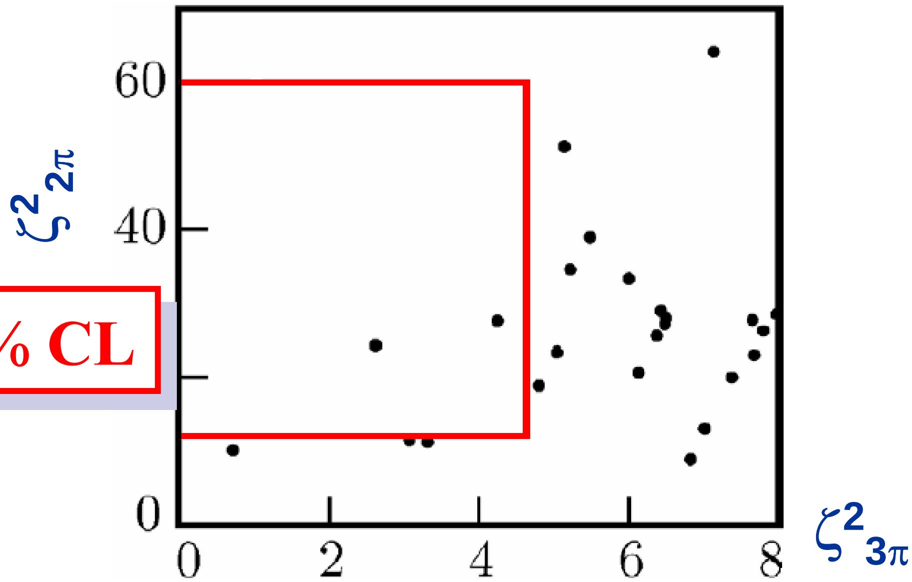
Observation of $K_S \to 3\pi^0$ signals CP violation in mixing and/or in decay:

SM prediction: $\Gamma_S = \Gamma_L\, |\varepsilon + \varepsilon'_{000}|^2$, => $BR(K_S \to 3\pi^0) \sim 2\times10^{-9}$

Previous results: $BR(K_S \to 3\pi^0) < 1.4 \times 10^{-5}$ (direct search, SND, '99)

$BR(K_S \to 3\pi^0) < 7.4 \times 10^{-7}$ (interference, NA48, '04)

- γ counting
- kinematic fit in the $2\pi^0$ and $3\pi^0$ hypothesis



$BR(K_S \to 3\pi^0) < 1.2 \times 10^{-7}$ 90% CL

$\Rightarrow |\eta_{000}| < 0.018$ at 90% CL

Latest results: BR($K_L \rightarrow \pi^+\pi^-$)

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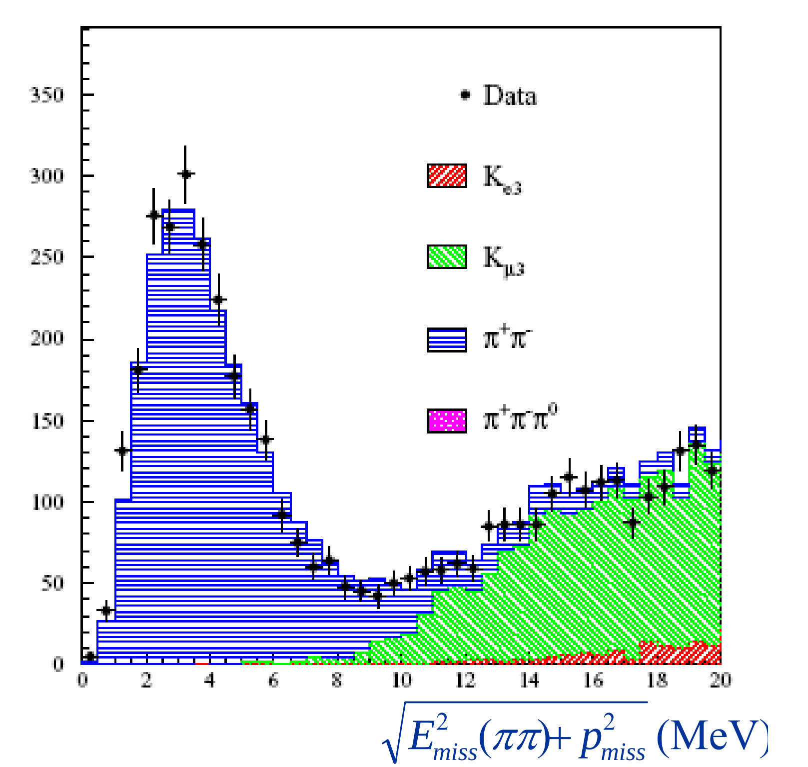
Kinematics for signal separation
$K_L \rightarrow \pi\mu\nu$ events in the same sample for K_L counting

BR = (1.963±0.012±0.017)×10^{-3}

σ_{rel}: 1.1% = 0.6%$_{stat} \oplus$ 0.9%$_{syst}$



- in agreement with KTeV 2004
  BR = (1.975 ± 0.012) ×10^{-3}
- it confirms the 4–σ discrepancy with old measurements
  (2.080 ± 0.025) ×10^{-3}
- we get:

$$|\eta_{+-}| = (2.216 \pm 0.013) \times 10^{-3}$$

[BR($K_S \rightarrow \pi\pi$) and τ_L from KLOE, τ_S from PDG04]

CPT test: the Bell-Steinberger relation

Measurements of K_S K_L observables can be used for the CPT test from unitarity :

$$(1 + i \tan \phi_{SW}) [\mathrm{Re}\, \varepsilon - i\, \mathrm{Im}\, \delta] = \frac{1}{\Gamma_S} \sum_f A^*(K_S \to f) A(K_L \to f) = \sum_f \alpha_f$$

Semileptonic decays:

$$\alpha_{kl3} = 2\tau_S/\tau_L\, B(K_L l3)\ [\mathrm{Re}\, \varepsilon - \mathrm{Re}\, y - i(\mathrm{Im}\, \delta + \mathrm{Im}\, x_+)]$$
$$= 2\tau_S/\tau_L\, B(K_L l3)\ [(A_S + A_L)/4 - i(\mathrm{Im}\, \delta + \mathrm{Im}\, x_+)]$$

ππ decays:

$$\alpha_{+-} = \eta_{+-} B(K_S \to \pi^+\pi^-)$$

$$\alpha_{00} = \eta_{00} B(K_S \to \pi^0\pi^0)$$

$$\alpha_{+-\gamma} = \eta_{+-} B(K_S \to \pi^+\pi^-\gamma)$$

πππ decays:

$$\alpha_{+-0} = \tau_S/\tau_L\, \eta_{+-0}^*\ B(K_L \to \pi^+\pi^-\pi^0)$$

$$\alpha_{000} = \tau_S/\tau_L\, \eta_{000}^*\ B(K_L \to \pi^0\pi^0\pi^0)$$

CPT test: inputs to B-S

$B(K_S \to \pi^+\pi^-)/B(K_S \to \pi^0\pi^0) = 2.2549 \pm 0.0054$

$B(K_S \to \pi^+\pi^-\gamma) < 9 \times 10^{-5}$

$B(K_S \to \pi^+\pi^-\pi^0) = (3.2 \pm 1.2) \times 10^{-7}$

$B(K_S \to \pi^0\pi^0\pi^0) < 1.2 \times 10^{-7}$

$B(K_L \to \pi l \nu) = 0.6705 \pm 0.0022$

$B(K_L \to \pi^+\pi^-\pi^0) = 0.1263 \pm 0.0012$

$B(K_L \to \pi^+\pi^-) = (1.963 \pm 0.021) \times 10^{-3}$

$B(K_L \to \pi^+\pi^-\gamma) = (29 \pm 1) \times 10^{-6}$

$B(K_L \to \pi^0\pi^0) = (8.65 \pm 0.10) \times 10^{-4}$

$\tau_S = 0.08958 \pm 0.00006$ ns

$\tau_L = 50.84 \pm 0.23$ns

$A_L = (3.32 \pm 0.06) \times 10^{-3}$

$A_S = (1.5 \pm 10.0) \times 10^{-3}$

$\phi^{SW} = (0.759 \pm 0.001)$

$\phi^{+-} = 0.757 \pm 0.012$

$\phi^{00} = 0.763 \pm 0.014$

$\phi^{000} = \phi^{+-0} = \phi^{+-\gamma} = [0, 2\pi]$

Im $x_+ = (1.2 \pm 2.2) \times 10^{-2}$ by CPLEAR

A combined fit of CPLEAR data with KLOE-KTeV ($A_S - A_L$) gives a $\times 3$ improvement:

$$\textbf{Im } x_+ = (0.8 \pm 0.7) \times 10^{-2}$$

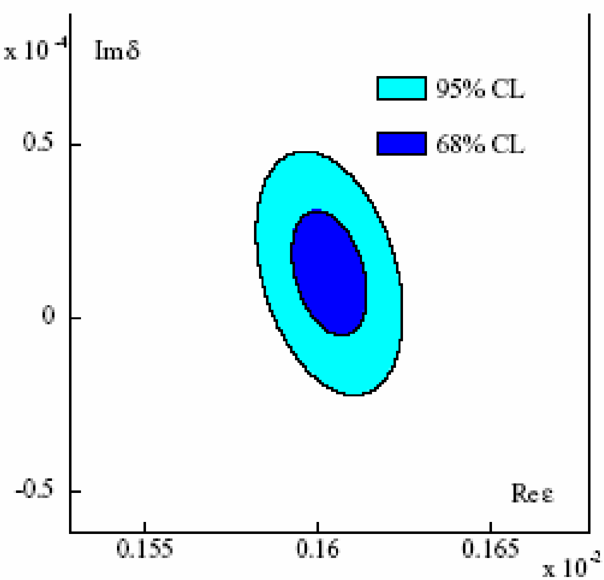
CPT test from unitarity: results

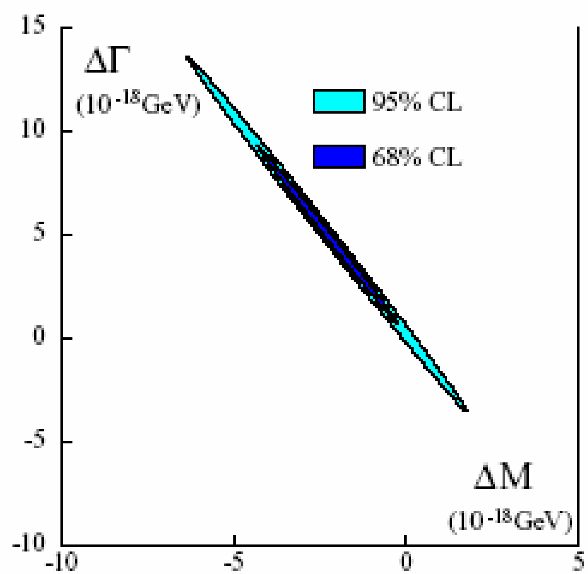
Re ε = $(160.2 \pm 1.3) \times 10^{-5}$
Im δ =$(1.2 \pm 1.9) \times 10^{-5}$

- *Uncertainty on Imδ is now dominated by ϕ_{+-} and ϕ_{00}*

Old:
Re ε = $(164.9 \pm 2.5)\ 10^{-5}$
Im δ =$(2.4 \pm 5.0)\ 10^{-5}$

From Imδ and Reδ it is possible to extract limits on
$\Delta m= (m_{K0} - m_{\overline{K0}})$ and $\Delta\Gamma = (\Gamma_{K0} - \Gamma_{\overline{K0}})$





assuming CPT violation only in the mass matrix ($\Delta\Gamma = 0$):

$|m_{K0} - m_{\overline{K0}}| < 3\times10^{-19}$ GeV

Unitarity test of CKM matrix: V_{us} , V_{us}/ V_{ud}

- **Unitarity test from 1st row:**

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 \sim |V_{ud}|^2 + |V_{us}|^2 \equiv 1 - \Delta$$

Precision test @ 10^{-3} level:

from super-allowed nuclear β-decays: $2|V_{ud}|\delta V_{ud} = 0.0005$

from semileptonic kaon decays: $2|V_{us}|\delta V_{us} = 0.0009$

- **$|V_{us}|$ extraction from K_{l3} decays**

$$\Gamma(K \to \pi l \nu(\gamma)) \propto |V_{us}\, f_+(0)|^2\, I(\lambda_t)\, S_{EW}(1 + \delta_{EM} + \delta_{SU(2)})$$

theory uncertainty: 0.8% on $f_+(0)$

- **$|V_{us}|/|V_{ud}|$ extraction from** $\Gamma(K^\pm \to \mu\nu(\gamma))/\Gamma(\pi^\pm \to \mu\nu(\gamma))$

$$\frac{\Gamma(K \to \mu\nu(\gamma))}{\Gamma(\pi \to \mu\nu(\gamma))} \propto \frac{|V_{us}|^2}{|V_{ud}|^2}\, \frac{f_K^2}{f_\pi^2}\, \frac{1 + \alpha C_K}{1 + \alpha C_\pi}$$

theory uncertainty: 1.3% on f_K/f_π

KLOE has measured all experimental inputs: BR, τ, λ

Dominant K_L BR's and τ_L

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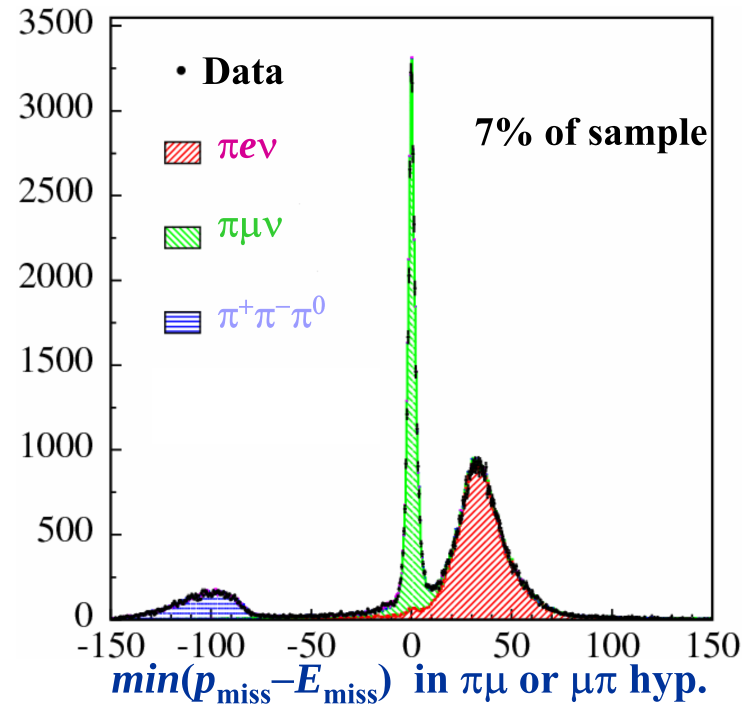
- **$K_L \to \pi e\nu, \pi\mu\nu, \pi^+\pi^-\pi^0$:**
  K_L vertex reconstructed in DC
  Fit to $p_{miss} - E_{miss}$ spectrum



- **$K_L \to \pi^0\pi^0\pi^0$:**
  Photon vertex reconstructed by TOF

- **Absolute BR: $(N_{sig}/N_{tag}) \times 1/\varepsilon_{sig}$**
  ε_{geo} dominated by error on τ_L

- **Using the constraint $\sum BR(K_L) = 1$:**

$$BR(K_L \to \pi e\nu) = 0.4007 \pm 0.0006_{stat} \pm 0.0014_{syst}$$
$$BR(K_L \to \pi\mu\nu) = 0.2698 \pm 0.0006_{stat} \pm 0.0014_{syst}$$
$$BR(K_L \to 3\pi^0) = 0.1997 \pm 0.0005_{stat} \pm 0.0019_{syst}$$
$$BR(K_L \to \pi^+\pi^-\pi^0) = 0.1263 \pm 0.0005_{stat} \pm 0.0011_{syst}$$
$$\tau_L = (50.72 \pm 0.17_{stat} \pm 0.33_{syst})\ \mathrm{ns}$$

$$\left.\begin{array}{l} 3.8\times10^{-3} \\ 5.6\times10^{-3} \\ 9.8\times10^{-3} \\ 9.6\times10^{-3} \\ 7.3\times10^{-3} \end{array}\right\} \textit{precision}$$

τ_L from $K_L \to \pi^0\pi^0\pi^0$

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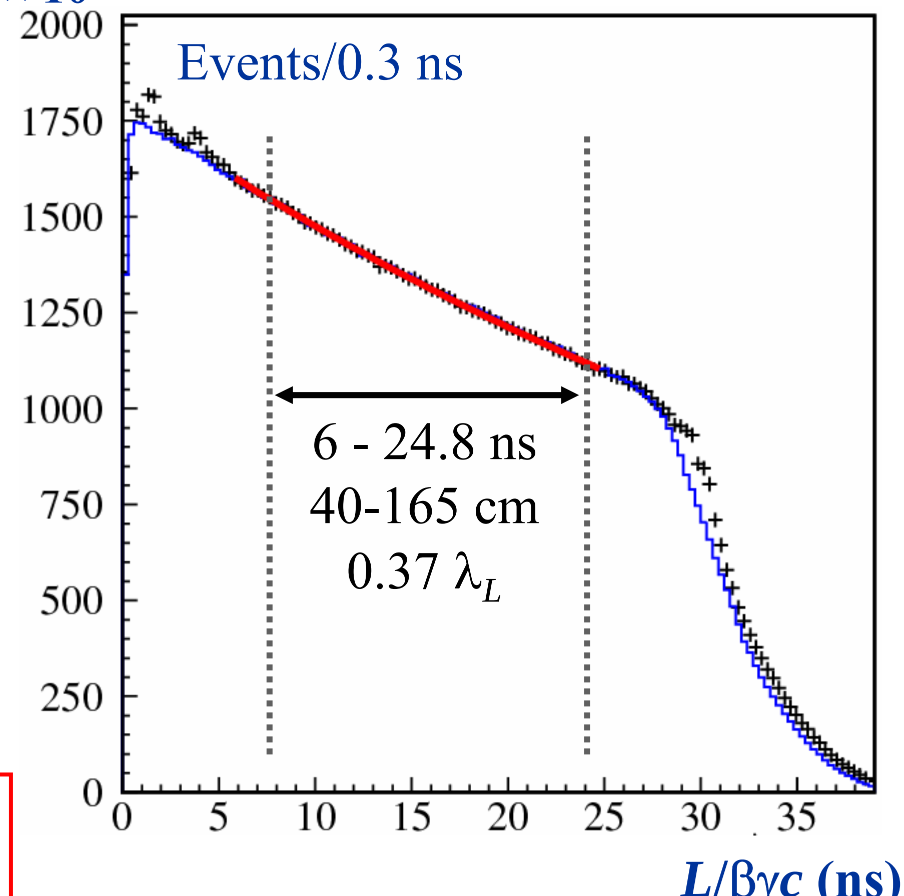
- Excellent lever arm for lifetime measurement (P_K = 110 MeV)
- K_L momentum known from tag
- Uniform reconstruction efficiency with respect to L_K



$\tau_L = 50.92 \pm 0.17_{stat} \pm 0.25_{syst}$ ns

$\sigma_{rel} \sim 5.9\times10^{-3}$

Vosburg, '72
$\tau_L = 51.54 \pm 0.44$ ns

Average with result from K_L BR's:
$\tau_L = 50.84 \pm 0.23$ ns
$\sigma_{rel} \sim 4.5\times10^{-3}$

K_{Le3} form factor slopes

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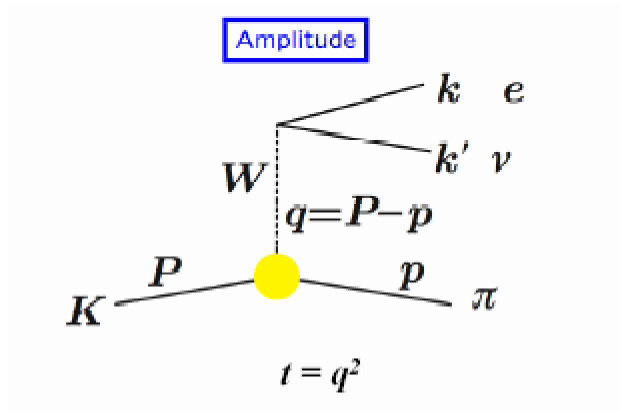
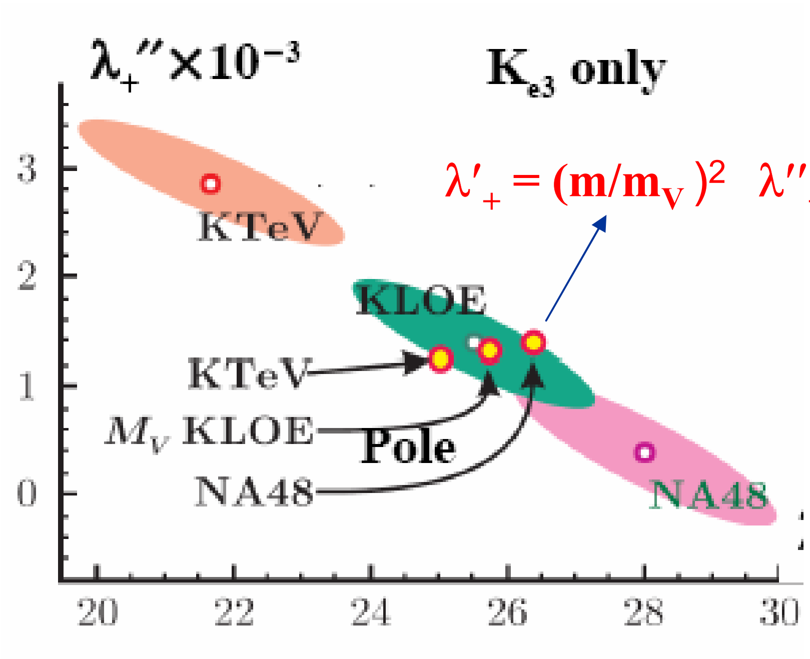
Measurement of the dependence of semileptonic *ff* from momentum transfer, t

- Fit to *t*-spectrum





$\lambda'_+ = (m/m_V)^2 \quad \lambda''_+ = 2(m/m_V)^4$

Quadratic:

$\lambda'_+ = (25.5 \pm 1.5 \pm 1.0) \times 10^{-3}$

$\lambda''_+ = (1.4 \pm 0.7 \pm 0.4) \times 10^{-3}$

$\rho(\lambda'_+, \lambda''_+) = -0.95$

Pole model:

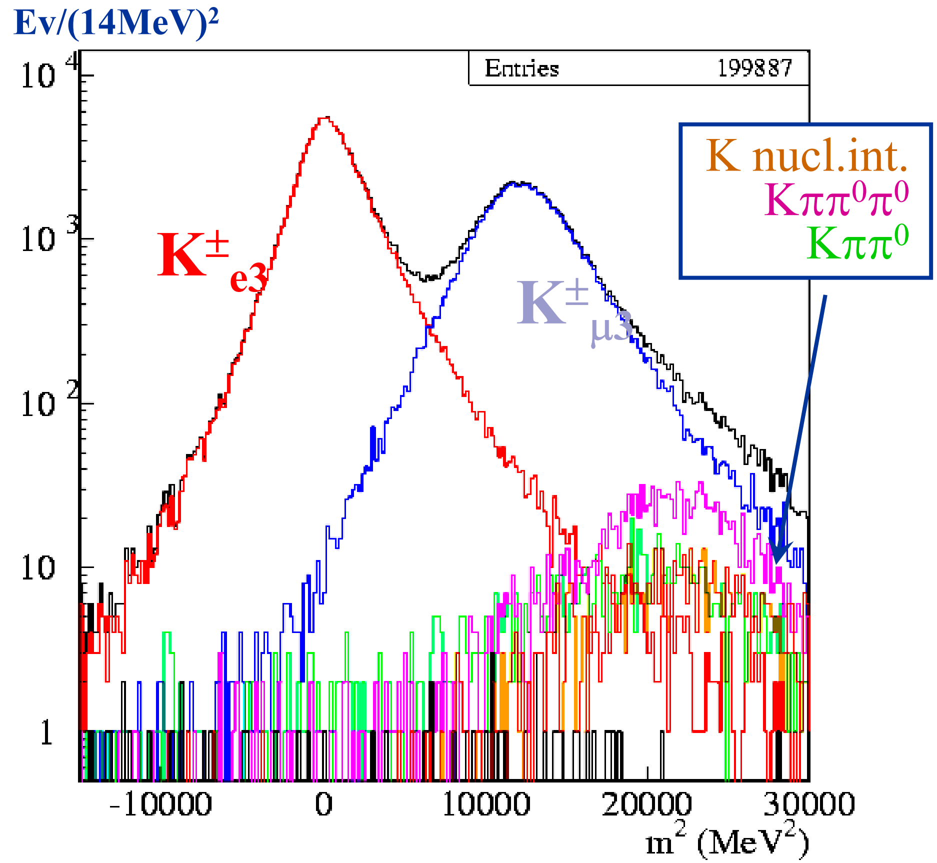
$m_V = (870 \pm 7)$ MeV

BR($K^\pm \to \pi^0 l^\pm \nu$)

• $K^+ \to \pi^0 l^+ \nu$ decays are tagged by $K^- \to \mu^- \nu$ and $K^- \to \pi^- \pi^0$

• $K^\pm \to \pi^0 e^\pm \nu$ and $K^\pm \to \pi^0 \mu^\pm \nu$ are separated by fitting the lepton mass spectrum, obtained from **TOF:**

$$t^{decay}_K = t_{lept} - L_{lept}/\beta(m_{lept})c = t_\gamma - L_\gamma/c$$



Preliminary results :

BR($K^\pm_{e3}$) = $(5.047 \pm 0.019_{stat} \pm 0.039_{syst})\times10^{-2}$

BR($K^\pm_{\mu3}$) = $(3.310 \pm 0.016_{stat} \pm 0.045_{syst})\times10^{-2}$

Current precision :

σ(Ke3) = 1.4%

σ(Kμ3) = 2.4%

$V_{us}\, f_+(0)$ from KLOE

Unitarity band:

$V_{us} = (1-V_{ud}^2)^{0.5}$

V_{ud}=0.97377(27)

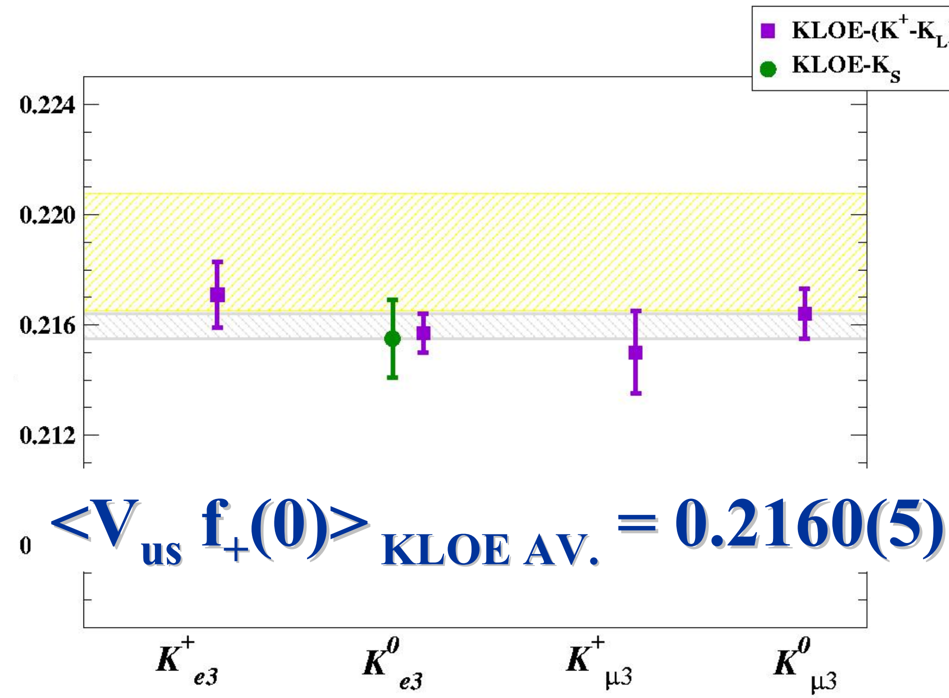
Marciano and Sirlin 2006

$f_+(0)$=0.961(8)

Leutwyler and Roos 1984

$V_{us} \times f_+(0) = 0.2187(22)$

$|V_{us}|\, f_+(0)$



$\langle V_{us}\, f_+(0)\rangle_{\text{KLOE AV.}} = 0.2160(5)$

$\langle V_{us}\, f_+(0)\rangle_{\text{KLOE+other,new}} = 0.2164(4)$

Improving the sensitivity of the CKM unitarity test :

- new results on charged kaons from KLOE
- better estimates of f_K/f_π and $f_+(0)$ from lattice
- better estimates of SU(2) and rad corrections to V_{ud} from nuclear β decay (now at 1-2%)
  (0.047% change of V_{ud} or 0.88% change of V_{us} ⇒ 1σ change of $\Delta = 1 - V_{us}^2 - V_{ud}^2$)
- KLOE 2.5 fb^{-1} data sample should definitively clarify the *ff* picture, improve BR's and lifetimes

BR($K^+ \to \mu^+ \nu(\gamma)$)

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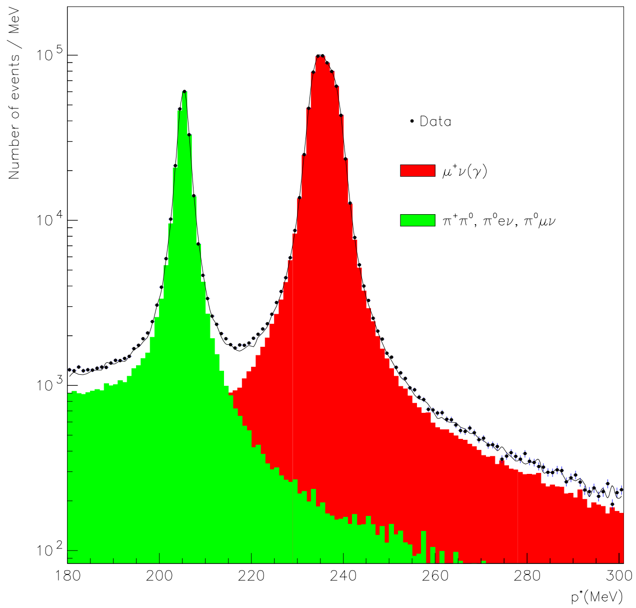
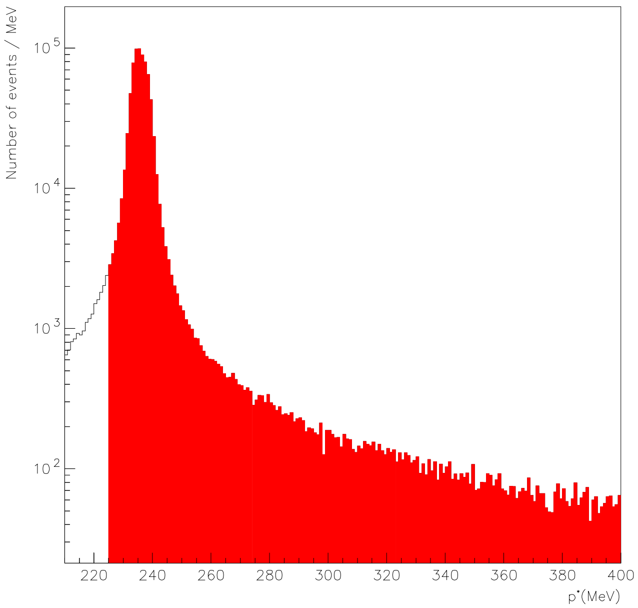
Tag from $K^- \to \mu^- \nu$
Subtraction of $\pi^+\pi^0$, $\pi^0 l^+ \nu$ background

Event counting in (225,400) MeV window of the momentum distribution in K rest frame





BR($K^+ \to \mu^+\nu(\gamma)$) = 0.6366 ± 0.0009$_{\text{stat.}}$ ± 0.0015$_{\text{syst.}}$

The V_{us} – V_{ud} plane

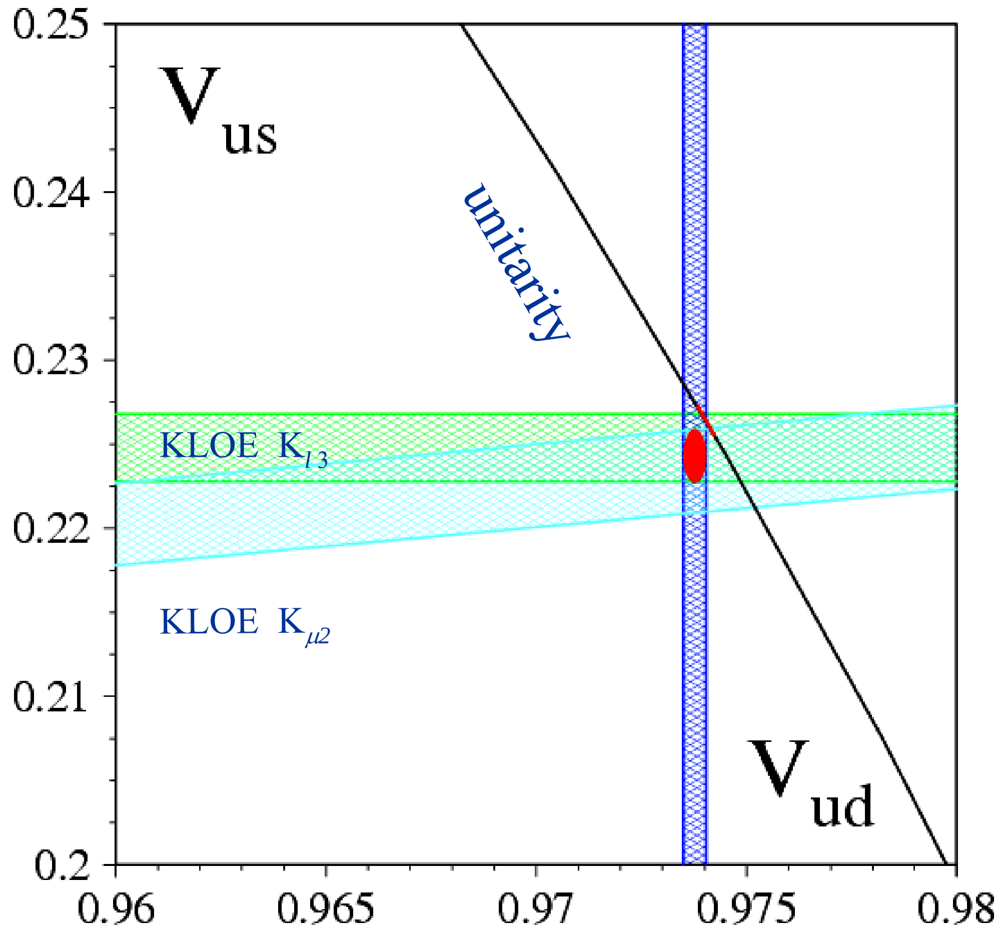
- Using f_K/f_π=1.198(3)($^{+16}_{-5}$) from MILC Coll. (2005) and KLOE BR($K^+ \to \mu^+\nu$) we get $V_{us}/V_{ud} = 0.2294 \pm 0.0026$

- $V_{us} = 0.2248 \pm 0.0020$

  K_{l3} KLOE, using $f_+(0)$=0.961(8)

- $V_{ud} = 0.97377 \pm 0.00027$

  Marciano and Sirlin
  Phys.Rev.Lett.96 032002,2006



Fit of the above results:

$V_{us} = 0.2242 \pm 0.0016$
$V_{ud} = 0.97377 \pm 0.00027$
$P(\chi^2) = 0.8$

Fit assuming unitarity:

$V_{us} = 0.2264 \pm 0.0009$
$P(\chi^2) = 0.1$

Hadron Physics

$\phi \to \pi^+\pi^-\pi^0$	Dalitz plot analysis	**PLB 561(2003) 65**
$\phi \to f_0\gamma \to \pi^+\pi^-\gamma$	f_0 coupling to ϕ, $\pi\pi$, KK	**PLB 634(2006) 148**
$\phi \to f_0\gamma \to \pi^0\pi^0\gamma$	BR($\phi \to \pi^0\pi^0\gamma$) to 5%	**PLB 537(2002) 21**
	Dalitz plot analysis, stat/syst improvements	**Submitted to EPJC**
$\phi \to \eta\, \pi^0\, \gamma$	BR($\phi \to a_0(980)\, \gamma$) to 10%	**PLB 536(2002) 209**
	stat/syst improvements	**In progress**
$\phi \to \eta'\gamma$ ($\eta\, \gamma$)	$\Gamma(\phi \to \eta'\gamma)/\Gamma(\phi \to \eta\, \gamma)$ to 12%, mixing angle to 5%	**PLB 541(2002) 45**
	stat/syst improvements	**Draft in prep.**
$\eta \to \gamma\gamma$	η mass measurement	**In progress**
$\eta \to \pi^+\pi^+\pi^0$	η mass measurement, Dalitz plot analysis	**In progress, Draft in prep.**
$\eta \to \pi^0\pi^0\pi^0$	Dalitz plot analysis	**Preliminary**
$\eta \to \pi^0\gamma\,\gamma$	BR, $m_{\gamma\gamma}$ spectrum	**In progress**
$\eta \to \pi^+\pi^- e^+e^-$	photon coupling	**In progress**
$\eta \to \pi^+\pi^-$	UL on BR to 10^{-5}	**PLB 606(2005) 276**
$\eta \to \pi^0\pi^0$	UL	**In progress**
$\eta \to \gamma\gamma\gamma$	UL on BR to 10^{-5}	**PLB 591(2004) 49**
$e^+e^- \to \pi^+\pi^-\gamma$	$a_{\mu}\,_{\|had}$ $(0.35<s_\pi<0.95\ \mathrm{GeV}^2)$ to ~ 1%	**PLB 606(2005) 12**
	$a_{\mu}\,_{\|had}$ down to threshold	**In progress**

$\pi^+\pi^-\gamma$ at large angle: looking for $f_0(980)$

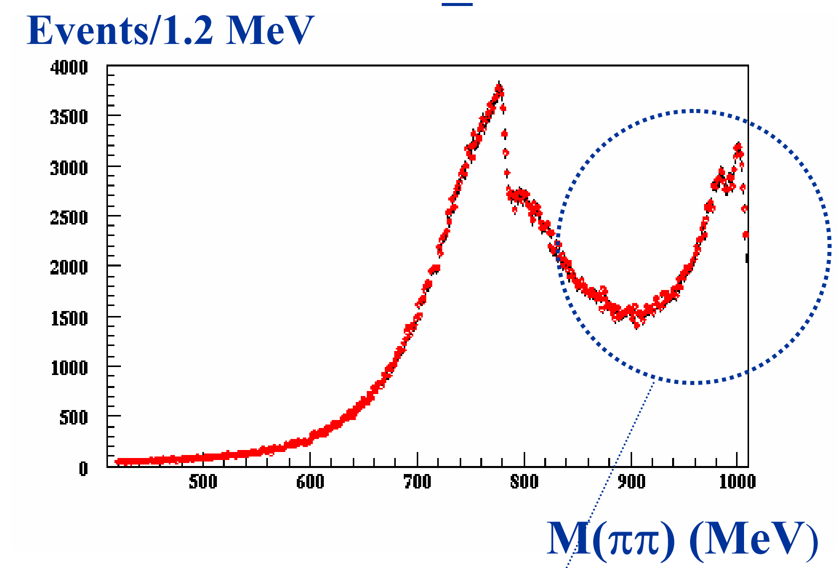
PLB 634 (2006) 148

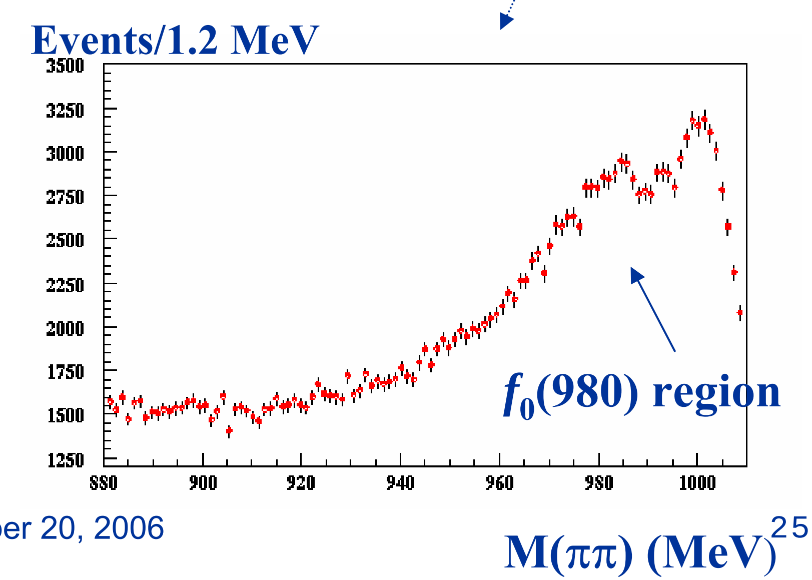
- $e^+e^- \rightarrow \pi^+\pi^-\gamma$ events with the photon at large angle ($45° < \vartheta_\gamma < 135°$)

- Main contributions:
  - ISR (radiative return to ρ, ω)
  - FSR

- Search for the f_0 signal as a deviation on $M(\pi^+\pi^-)$ spectrum from the expected ISR + FSR shape

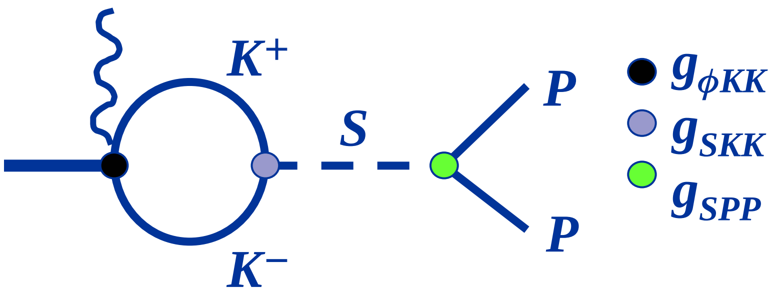
676,000 events selected (2001+2002)

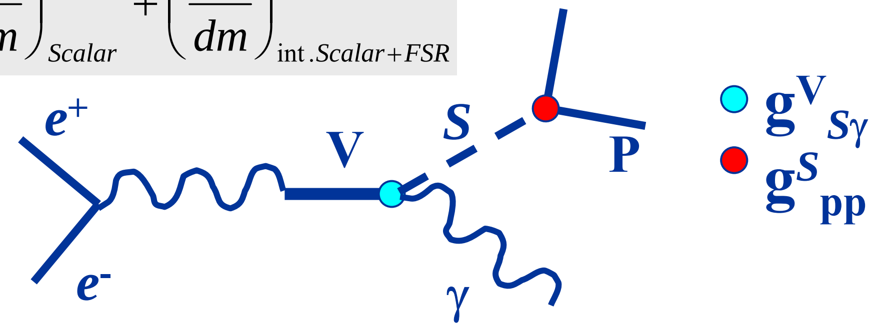




$f_0 \to \pi^+\pi^-$: fit to the $M_{\pi\pi}$ spectrum

$$\frac{d\sigma}{dm} = \left(\frac{d\sigma}{dm}\right)_{ISR+FSR+\rho\pi} + bckg(\pi^+\pi^-\pi^0 + \mu^+\mu^-\gamma) + \left(\frac{d\sigma}{dm}\right)_{Scalar} + \left(\frac{d\sigma}{dm}\right)_{int.Scalar+FSR}$$





Kaon-loop [N.N.Achasov, V.N.Ivanchenko, NPB315 (1989) 465] [N.N.Achasov, V.V.Gubin, PRD 56 (1997) 4084]

M_{f0} (MeV)	981 ÷ 985
g^2_{fK+K-} /4π (GeV²)	1.2 ÷ 3.4
$R = g^2_{fK+K-} / g^2_{f\pi+\pi-}$	2.0 ÷ 2.9

No-structure [G.Isidori et al., hep-ph/0603241]

M_{f0} (MeV)	968 ÷ 979
$g_{\phi f\gamma}$ (GeV⁻¹)	1.2 ÷ 1.8
$g_{f\pi+\pi-}$ (GeV)	0.9 ÷ 1.2
g_{fK+K-} (GeV)	1.2 ÷ 2.8
$R = g^2_{fK+K-} / g^2_{f\pi+\pi-}$	1.7 ÷ 4.8

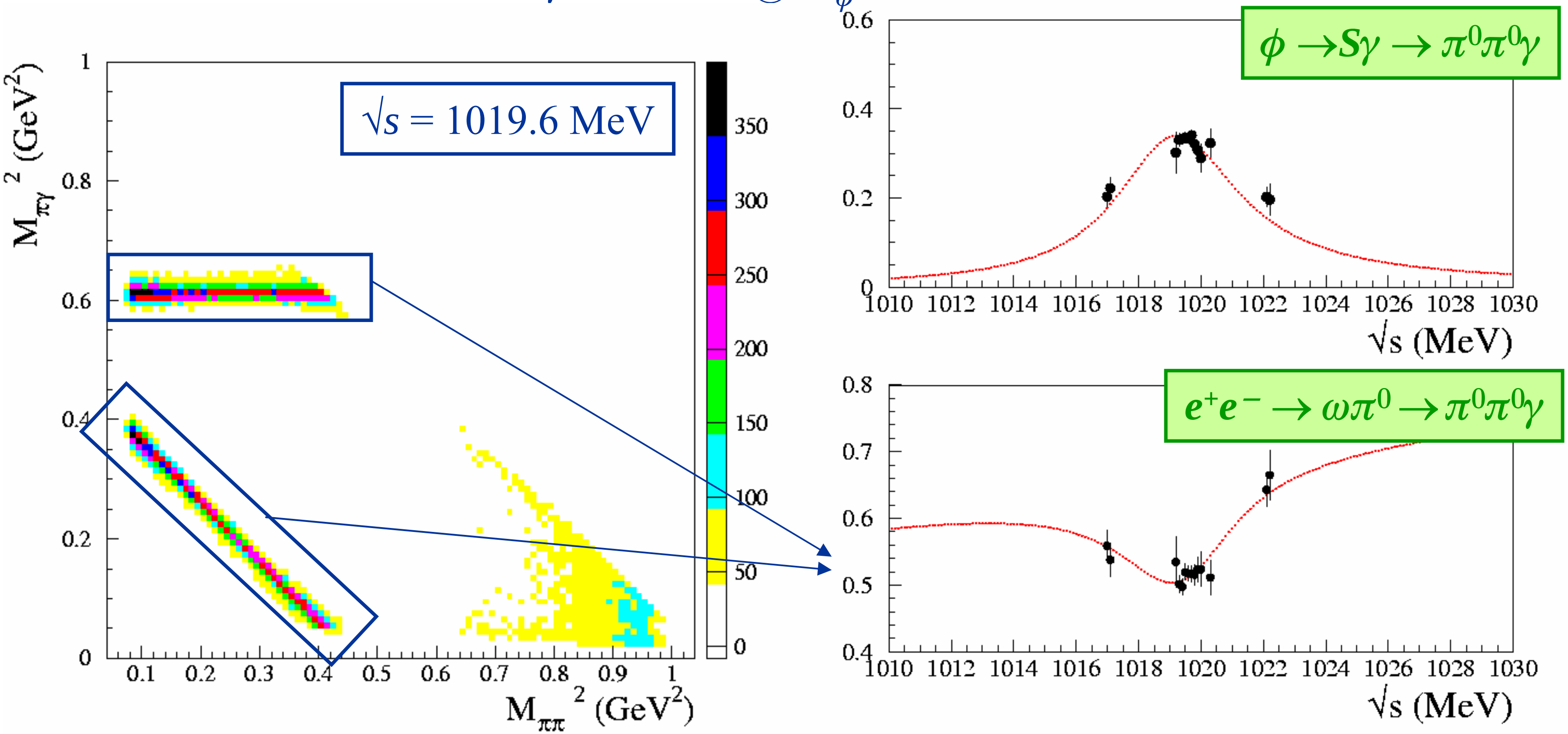
- Peak at $M_{\pi\pi}$~980 MeV due to $\phi \to f_0(980)\gamma$, with negative interf. with FSR
- In both models **the f_0(980) is strongly coupled to kaons and to the ϕ**
- **The introduction of σ(600) does not improve the fit**

The $\pi^0\pi^0\gamma$ final state

Submitted to EPJC

450 pb^{-1} from 2001 – 2002 data taking **~ 400k events**

Two main contributions to $\pi^0\pi^0\gamma$ final state @ M_ϕ:



New analysis scheme w.r.t. PLB537 (2002) 21:

✓ Allow for interference between $e^+e^- \to \omega\pi^0$ and $\phi \to S\gamma$

✓ Bi-dimensional analysis of Dalitz-plot : $M(\pi^0\pi^0)$ vs $M(\pi^0\gamma)$

Summary table and comparison

KL fit results:

$\pi^0\pi^0$: $\sigma(600)$ [but with fixed values] needed to describe data,

$\pi^+\pi^-$: $\sigma(600)$ is not needed

both channels: $f_0(980)$ strongly coupled to KK

NS fit results:

both channels: only $f_0(980)$ sufficient to describe data

$\pi^0\pi^0$wrt $\pi^+\pi^-$: weaker KK coupling

model	$f_0(980)$ param.	$\pi^+\pi^-\gamma$	$\pi^0\pi^0\gamma$
Kaon Loop	m_{f0} (MeV)	980 ÷ 987	976 ÷ 987
	g_{fKK} (GeV)	5.0 ÷ 6.3	3.3 ÷ 5.0
	$g_{f\pi+\pi-}$ (GeV)	3.0 ÷ 4.2	1.4 ÷ 2.0
	$R=g^2_{fKK}/g^2_{f\pi+\pi-}$	2.2 ÷ 2.8	3.0 ÷ 7.3
No Structure	m_{f0} (MeV)	973 ÷ 981	981 ÷ 987
	g_{fKK} (GeV)	1.6 ÷ 2.3	0.1 ÷ 1.0
	$g_{f\pi+\pi-}$ (GeV)	0.9 ÷ 1.1	1.3 ÷ 1.4
	$R=g^2_{fKK}/g^2_{f\pi+\pi-}$	2.6 ÷ 4.4	0.01 ÷ 0.5
	$g_{\phi f\gamma}$ (GeV^{-1})	1.2 ÷ 2.0	2.5 ÷ 2.7

$BR(\phi \to \eta'\gamma)/BR(\phi \to \eta\gamma)$

Draft in preparation

Two parameters needed to describe η_1-η_8 mixing in χPT

The angles are almost equal when mixing is expressed in the flavour basis

$$\boxed{\begin{aligned} \eta &= \cos\varphi_P \frac{1}{\sqrt{2}}\left|u\bar{u}+d\bar{d}\right\rangle - \sin\varphi_P\left|s\bar{s}\right\rangle \\ \eta' &= \sin\varphi_P \frac{1}{\sqrt{2}}\left|u\bar{u}+d\bar{d}\right\rangle + \cos\varphi_P\left|s\bar{s}\right\rangle \end{aligned}}$$

From the ratio we extract the mixing angle, ϕ_p (Bramon et al., Eur. Phys. J. C7 (1999) 271):

$$R = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = \mathrm{cotg}^2\varphi_P \left(1 - \frac{m_s}{\bar{m}} \frac{\mathrm{tg}\varphi_V}{\sin 2\varphi_P}\right)^2 \left(\frac{p_{\eta'}}{p_\eta}\right)^3 \quad ; \quad \left(\frac{m_s}{\bar{m}} = 1.45\right)$$

We evaluate the gluonic content of η' in the approximation of small gluonic contribution

The analysis is based on 427 pb^{-1} and

a MC sample for efficiency and background evaluation

5 times bigger, containing also details of the

machine bck extracted from data control samples.

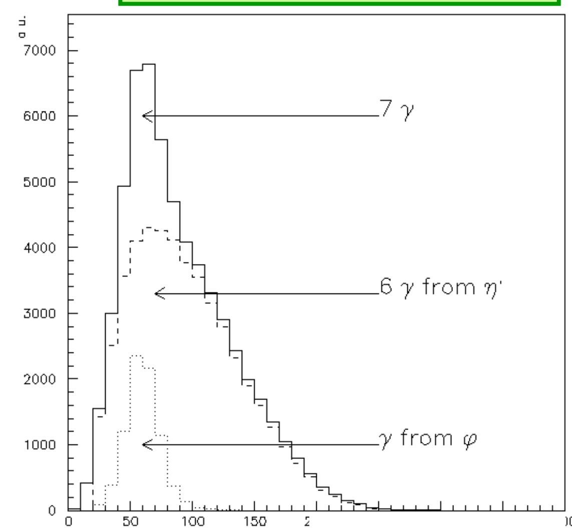
BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$) analysis

- $\phi \to \eta'\gamma$, $\eta' \to \pi^+\pi^-\eta$, $\eta \to 3\pi^0$
  $\eta' \to \pi^0\pi^0\eta$, $\eta \to \pi^+\pi^-\pi^0$ } **2 tracks + 7 photons**
- $\phi \to \eta\gamma$, $\eta \to 3\pi^0$ **7 photons**

Signal selection for $\phi \to \eta'\gamma$:

1. Two tracks vertex near I.P.
2. Seven neutral clusters with:
   - $|T_{cl} - R_{cl}/c| < 5\ \sigma_T$
   - $21° < \theta_{cl} < 159°$
3. Kinematic fit imposing global 4-momentum conservation

$\phi \to \eta'\gamma$ MC events



E_γ (MeV)

γ's from ϕ and π^0 decays overlap

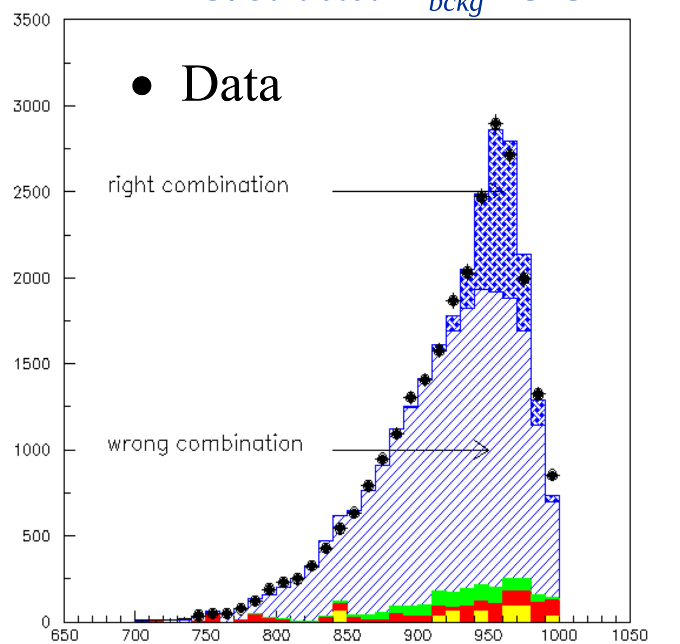
$\phi \rightarrow \eta'\gamma/\eta\gamma$ selection

Background to $\phi \rightarrow \eta'\gamma$ from $K_s \rightarrow \pi^+\pi^-(\gamma)$, $K_L \rightarrow \pi^0\pi^0\pi^0$ and $K_s \rightarrow \pi^0\pi^0$, $K_L \rightarrow \pi^+\pi^-\pi^0$

Tracking efficiency and vertex reconstruction studied on $\phi \rightarrow \pi^+\pi^-\pi^0$ control sample
Systematics on neutrals and
on background subtraction controlled changing the analysis cuts
contribution from neutral-efficiency knowledge cancels out in the ratio

$N(\eta'\gamma) = 3405 \pm 61_{stat} \pm 28_{syst}$

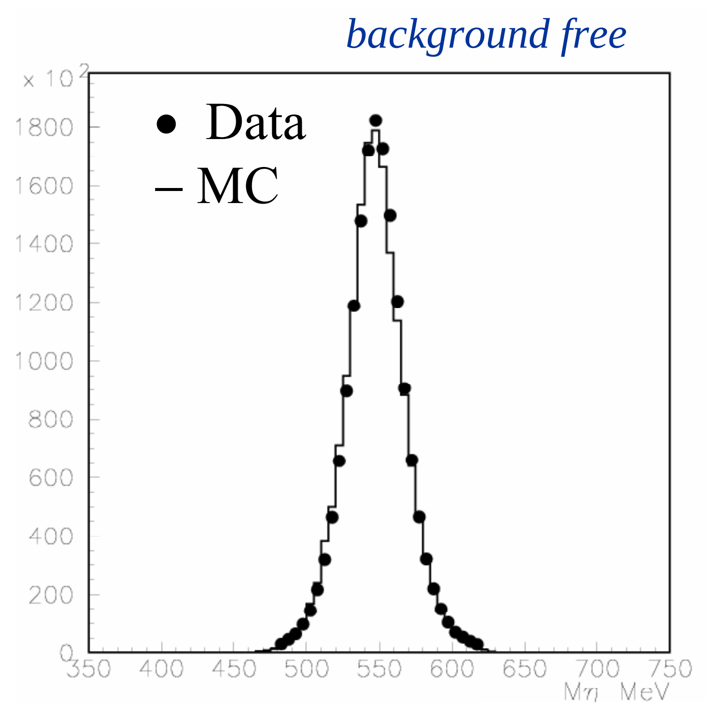
Subtracted $N_{bckg} = 345$



$M_{\eta\pi\pi}$ (MeV)

$N(\eta\gamma) = 1665000 \pm 1300$

background free



$M_{6\gamma}$ (MeV)

$BR(\phi \to \eta'\gamma)/BR(\phi \to \eta\gamma)$: results

$$R = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = \frac{N(\eta'\gamma) \quad \varepsilon_{\eta\gamma}\, BR(\eta \to \pi^0\pi^0\pi^0)}{N(\eta\gamma) \quad [BR_{crg}\varepsilon_{crg} + BR_{ntr}\varepsilon_{ntr}]} \; K_\rho$$

Interf.
$\phi \to \eta/\eta'\gamma$
$\rho \to \eta/\eta'\gamma$

$BR_{crg} = BR(\eta' \to \pi^+\pi^-\eta)\, BR(\eta \to \pi^0\pi^0\pi^0)$

$BR_{nrt} = BR(\eta' \to \pi^0\pi^0\eta)\, BR(\eta \to \pi^+\pi^-\pi^0)$

from PDG

$R = (4.74 \pm 0.09_{stat} \pm 0.20_{syst})\times 10^{-3}$
$BR(\phi \to \eta'\gamma) = (6.17 \pm 0.12 \pm 0.28)\times 10^{-5}$

Systematics dominated by the knowledge of η,η' BR's

Source	Syst. Err.
Filfo-Evcl	1%
TRK	1%
VTX	1%
Bkg	0.1%
$\varepsilon\eta / \varepsilon\eta'$	0.4%
$\chi 2$	1.5%
BR's	**3%**
K_ρ	1%
Total	**4%**

In agreement with previous KLOE result, PLB541 (2002) 45:

$$R = (4.70 \pm 0.47_{stat} \pm 0.31_{sys}) \cdot 10^{-3}$$

$$BR(\phi \to \eta'\gamma) = (6.10 \pm 0.61 \pm 0.43) \cdot 10^{-5}$$

η/η′ mixing and η′ gluon content

The η/η′ mixing angle in the quark flavour basis, φ_P , can be extracted from the ratio R using the formula [Bramon et al., Eur. Phys. J. C7 (1999) 271]

$$R = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = \cot^2 \varphi_P \left(1 - \frac{m_s}{\bar{m}} \cdot \frac{Z_{NS}}{Z_S} \cdot \frac{\tan \varphi_V}{\sin 2\varphi_P}\right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

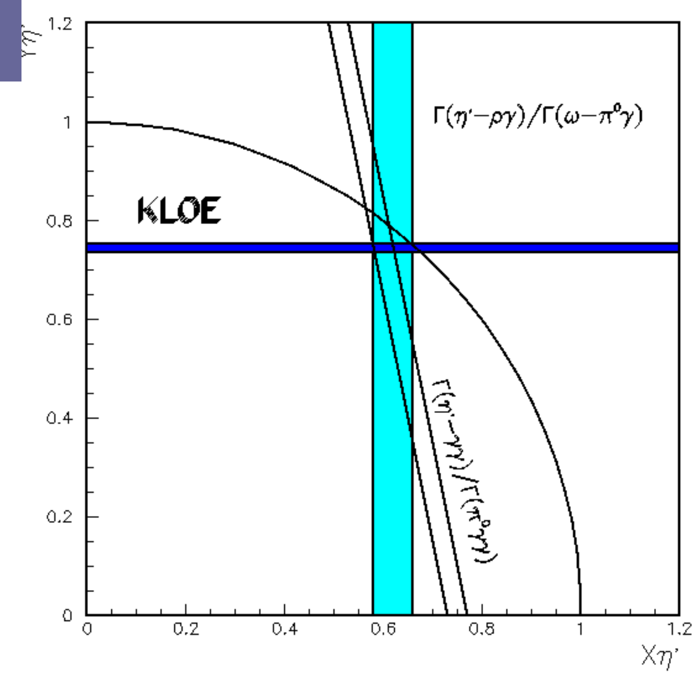
$$\varphi_P = (\,41.5 \pm 0.3_{stat} \pm 0.7_{syst} \pm 0.6_{th}\,)^\circ$$

Combined analysis to evaluate a possible gluon content of η'

$$\eta' = X \frac{1}{\sqrt{2}} |u\bar{u} + d\bar{d}> + Y\,|s\bar{s}> + Z\,|glue>$$

$$Z^2 > 0 \Leftrightarrow X^2 + Y^2 < 1$$

$$X^2+Y^2 = 0.93 \pm 0.06$$



Summary and Outlook

KLOE has obtained new results, mostly based on 20% of the data sample, including

- Measurements of the K_S-K_L and $K^{\pm}$ decay channels with precision ~ 1% or better
- Best limit on $K_S \to \pi^0\pi^0\pi^0$
- First measurement of K_S semileptonic charge asymmetry
- Evidence for $\phi \to f_0\gamma$ from $M_{\pi\pi}$ and f-b asymmetry in the channel $\pi^+\pi^-\gamma$
- η/η' mixing with $\eta' \to \pi^+\pi^- 7\gamma$
- Dalitz plot analysis of $\eta \to \pi^+\pi^- \pi^0$
- η mass

With the analyses of the 2.5 fb^{-1} data sample we can address/improve:

- QM interference studies
- $BR(K_S \to \gamma\gamma)$, $BR(K_S \to \pi^+\pi^-\pi^0)$, $BR(K_S \to \pi^+\pi^- e^+ e^-)$
- $UL(K_S \to \pi^0\pi^0\pi^0)$, $UL(K_S \to e^+ e^-)$
- Semileptonic BR's, lifetimes, *ff* slopes
- $BR(K_L \to \pi\pi)$ to few 10^{-3}
- $\Gamma(K^{\pm} \to e^{\pm}\nu)/\Gamma(K^{\pm} \to \mu^{\pm}\nu)$ to few 10^{-2}
- Combined fit of both, charged and neutral, $\pi\pi\gamma$ final states and searches for $f_0/a_0 \to KK$
- Search for $\sigma(600)$ with off-peak data using the reaction $\gamma\gamma \to \pi^0\pi^0$
- $\eta \to \pi^+\pi^- e^+ e^-$, $\eta \to \pi^0\gamma\gamma$, $\eta \to \pi^+\pi^-\gamma$, $\mu^+\mu^-\gamma$, η' decays

Spares slides

CPT test from charge asymmetry

Sensitivity to CPT violating effects through charge asymmetry

$$A_{S,L} = \frac{\Gamma(K_{S,L} \to \pi^- e^+ \nu) - \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})}{\Gamma(K_{S,L} \to \pi^- e^+ \nu) + \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})}$$

$$A_S = 2(\mathrm{Re}\,\varepsilon + \mathrm{Re}\,\delta - \mathrm{Re}\,y + \mathrm{Re}\,x_-)$$

$$A_L = 2(\mathrm{Re}\,\varepsilon - \mathrm{Re}\,\delta - \mathrm{Re}\,y - \mathrm{Re}\,x_-)$$

~~CP~~ | *~~CPT~~ in mixing* | *~~CPT~~ in decay* | *$\Delta S \neq \Delta Q$ and ~~CPT~~*

$A_S - A_L \neq 0$ implies *CPT violation*

$$\delta = \frac{1}{2}\,\frac{M_{11} - M_{22} - i(\Gamma_{11} - \Gamma_{22})/2}{m_S - m_L - i(\Gamma_S - \Gamma_L)/2}$$

$A_L = (3.322 \pm 0.058 \pm 0.047)\ 10^{-3}$, KTeV 2002

Status of η mass measurement

The two most recent and precise measurements show a 8σ's discrepancy on η mass :

GEM [COSY, Julich]

$M_\eta = (\ 547.311 \pm 0.028 \pm 0.032\ )\ \mathrm{MeV}/c^2$

[M. Abdel-Bary et al., Phys. Lett. B 619 (2005) 281]

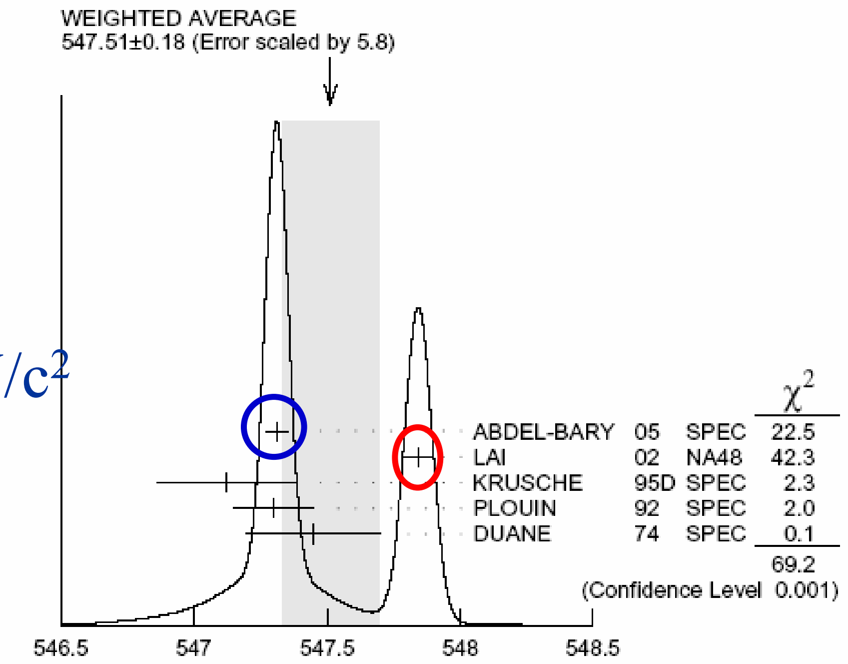
Reaction used: $p + d \rightarrow {}^3He + \eta$

NA48

$M_\eta = (\ 547.843 \pm 0.030 \pm 0.041\ )\ \mathrm{MeV}/c^2$

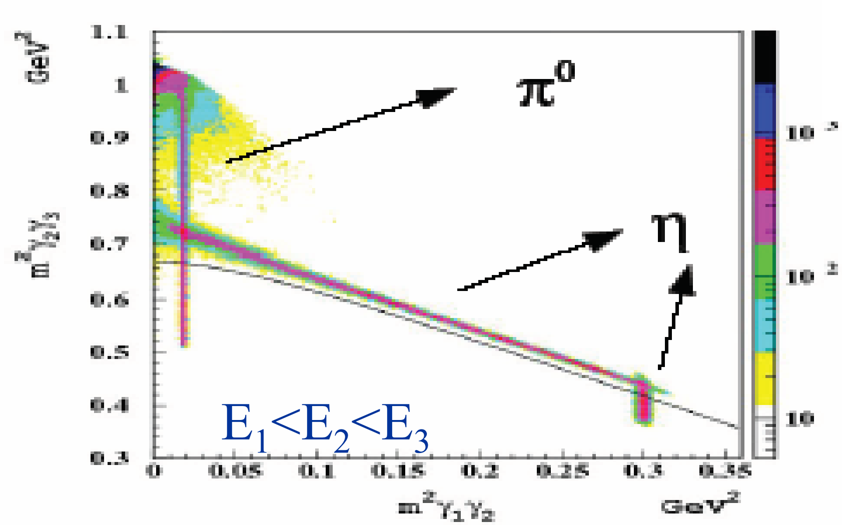
[A. Lai et al., Phys. Lett. B 533 (2002) 196]

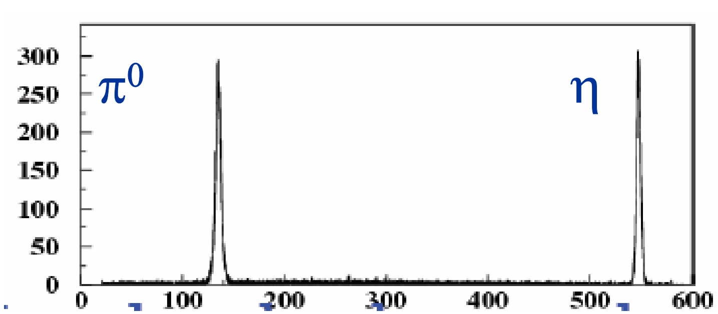
Using $\eta \rightarrow 3\pi^0$ from $\pi^- + p \rightarrow \eta + n$



$M_\eta\ (\mathrm{MeV}/c^2)$

M_η - Event Selection





$M_{\gamma\gamma}$ (MeV)

- Analysis of $\phi \to \gamma\gamma\gamma$ final state including $\phi \to \pi\gamma$ and $\phi \to \eta\gamma$ events
- Kinematic fit applied to $\phi \to \gamma\gamma\gamma$ events
- η and π^0 in different Dalitz plot regions

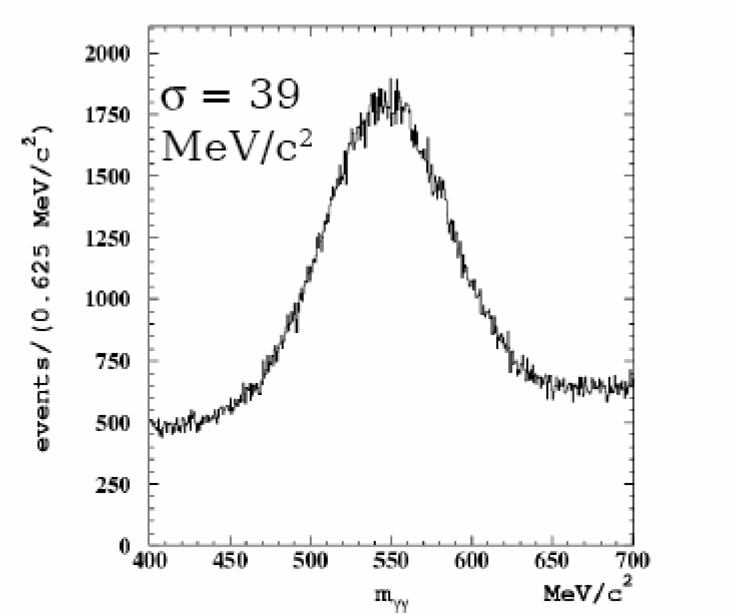
M_{η} - resolution

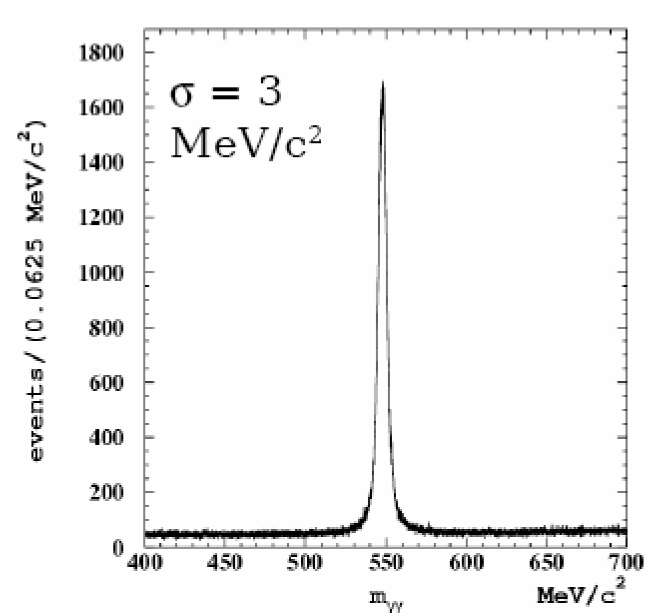
The kinematic fit with constraints from energy and momentum conservation improves $M_{\gamma\gamma}$ resolution to 3 MeV

Momentum-direction from position measurements
Photon energies from kinematic constraints
Bhabha-scattering events provide precise measurement of

$$(E_{e^+} + E_{e^-} , \mathbf{P}_{e^+} + \mathbf{P}_{e^-})$$

calibrated by a fit to the ϕ lineshape with M_{ϕ} = (1019.483 ± 0.011±0.025) MeV
from CMD-2 Phys. Lett. B575, 285





M_η - preliminary result

Evaluation of systematics from

$\sqrt{s}$,

Dalitz plot selection,

Detector geometry,

EMC linearity,

in progress

Current estimate : 69 keV/c^2

$$\mathbf{M(\pi^0) = (\,134990 \pm 6_{stat} \pm 30_{syst}\,)\ keV/c^2}$$

$$\mathbf{M(\pi^0)_{PDG} = (\,134976.6 \pm 0.6\,)\ keV/c^2}$$

$$\mathbf{M(\eta) = (\,547822 \pm 5_{stat} \pm 69_{syst}\,)\ keV/c^2}$$

In agreement with the NA48 result

In agreement with the preliminary result of the cross-check using $\eta \to \pi^+\pi^-\pi^0$:

$$\mathbf{M(\eta) = (\,547.95 \pm 0.15\,)\ MeV/c^2}$$

Analysis of the $\eta \to \pi^+ \pi^- \pi^0$ Dalitz plot

Draft in preparation

Decay sensitive to light-quark mass difference

Dynamics through Dalitz plot analysis to fix high-order contributions

$$\Gamma(\eta \to \pi^+ \pi^- \pi^0) = (Q/Q_D)^4 \ \bar{\Gamma}$$

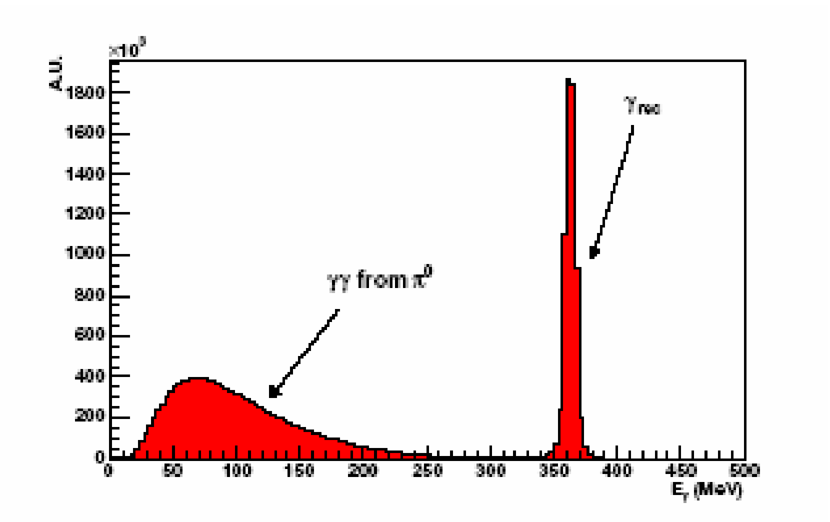
$$\mathbf{Q^2 \equiv \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}}$$

and $Q_D = 24.2$, with $\mathbf{(m^2_{\pi+} - m^2_{\pi 0})_{\mathit{em}} = (m^2_{K+} - m^2_{K0})_{\mathit{em}}}$

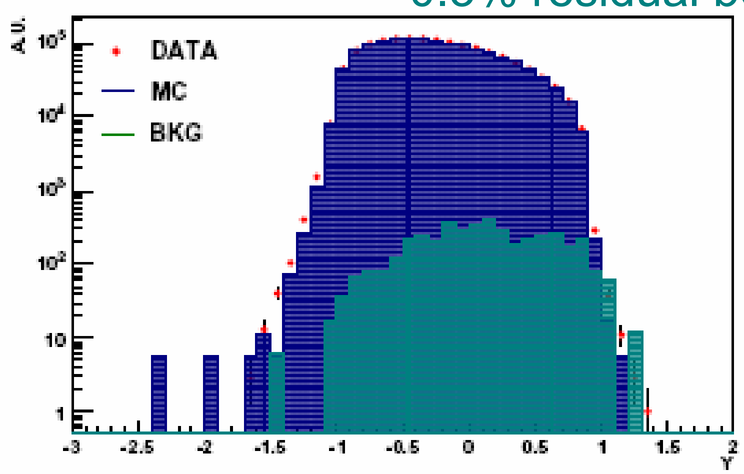
[B.Martemyanov,V.Sopov, PRD 71 (2005) 017501]

$\eta \to \pi^+ \pi^- \pi^0$ event selection

2-tracks from the interaction region
3 prompt neutral clusters E>10 MeV, θ_γ > 21°
Kinematic fit imposing 4-momentum conservation
improve photon-energy resolution
Loose cuts on fit quality, E^{ϕ}_{γ}, $E^{\eta}_{\pi+}+E^{\eta}_{\pi-}$, $M^{\eta}_{\gamma\gamma}$ to reject background from
$K_S K_L$, $\phi \to \pi^+ \pi^- \pi^0$, $\eta \to \pi^+ \pi^- \gamma$



0.3% residual bck



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

Efficiency flat in the X,Y plane, $\varepsilon \sim 36\%$

Tracking, vertex efficiency from $\phi \rightarrow \pi^+ \pi^- \pi^0$ control sample
MC correction of the efficiency for low-energy photons applied

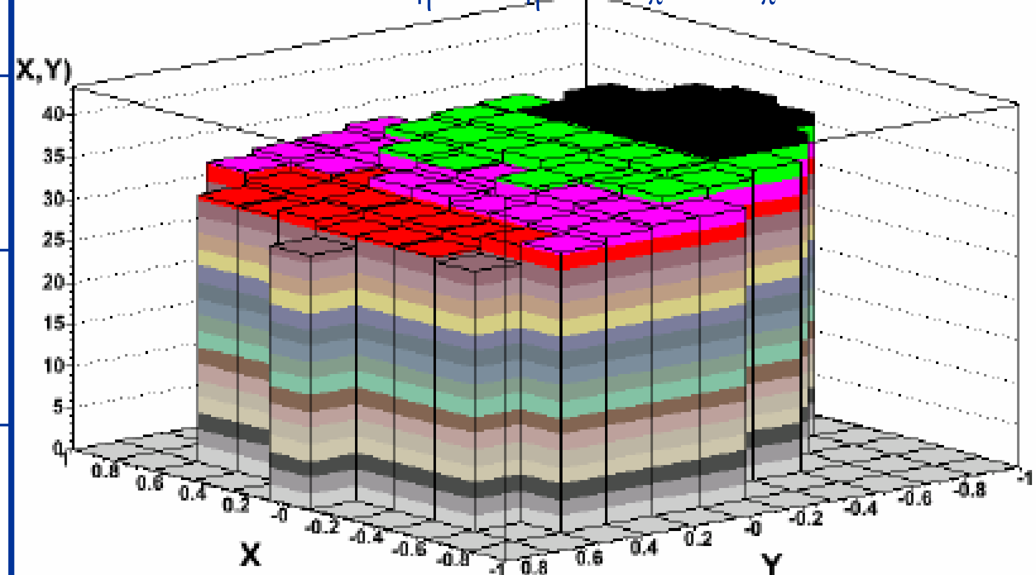
Deviations of the fit values to evaluate systematics

$|A(X,Y)|^2 = N\,(1 + aY + bY^2 + dX^2 + fY^3)$

$X = \sqrt{3}\,(T_+ - T_-)/Q_\eta$ $\qquad Y = 3T_0/Q_\eta - 1$

$Q_\eta = m_\eta - 2m_{\pi^+} - m_{\pi^0}$

	$\Delta a/a$ %	$\Delta b/b$ %	$\Delta d/d$ %	$\Delta f/f$ %
Background subtraction	**-0.09 +0.55**	**-6.4 +4.8**	**-12 +12**	**-7.1 +0.0**
Dalitz plot binning	**-0.73 +0.55**	**-4.8 +4.8**	**-12 +1.8**	**-14 +14**
Event Selection	**-1.55 +0.00**	**-0.0 +4.0**	**-21 +0.0**	**-0.0 +7.1**



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

A third-order expansion necessary to describe data distribution

$$|A(X,Y)|^2 = N (1 + aY + bY^2 + cX + dX^2 + eXY + fY^3)$$

The amplitude must be symmetric in X (C conservation) c=0, e=0

ndf	P_{χ^2}	a	b	c	d	e	f
147	73%	-1.090±0.005	0.124±0.006	0.002±0.003	0.057±0.006	-0.006±0.007	0.14±0.01
149	74%	-1.090±0.005	0.124±0.006		0.057±0.006		0.14±0.01
150	$< 10^{-6}\%$	-1.069±0.005	0.104±0.005				0.13±0.01
150	$< 10^{-8}\%$	-1.041±0.003	0.145±0.006		0.050±0.006		
151	$< 10^{-6}\%$	-1.026±0.003	0.125±0.006				

Quadratic term in X $\neq$ 0 Cubic term in Y $\neq$ 0

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

$$|A(X,Y)|^2 = N\,(1 + aY + bY^2 + dX^2 + fY^3)$$

	Nev	a	b	d	f
KLOE	**1.39 10^6**	**$-1.090 \pm 0.005 ^{+0.008}_{-0.019}$**	**$0.124 \pm 0.006 ^{+0.010}_{-0.010}$**	**$0.057 \pm 0.006 ^{+0.007}_{-0.016}$**	**$0.14 \pm 0.01 ^{+0.020}_{-0.020}$**
Layter 73	**8.09 10^4**	**-1.08 ± 0.14**	**0.034±0.027**	**0.046±0.031**	
Gormley 70	**3.00 10^4**	**-1.17 ± 0.02**	**0.21±0.03**	**0.06±0.04**	
Crystal Barrel 95	**1.08 10^3**	**-0.94 ± 0.15**	**0.11±0.27**		
Crystal Barrel 98	**3.23 10^3**	**-1.22 ± 0.07**	**0.22±0.11**	**0.06 fixed**	
tree		**-1.00**	**0.25**	**0.00**	
one-loop		**-1.33**	**0.42**	**0.08**	

BR($\eta \to \pi^0\gamma\gamma$)

Sensitive to $O(p^6)$ calculations in χPT

Challenging measurement for the background from $\eta \to \gamma\gamma$ and $\eta \to \pi^0\pi^0\pi^0$

Unsatisfactory experimental situation:

		Br($\eta \to \pi^0 \gamma\gamma$)
AGS/Crystal Ball Phys. Lett. B 589 (2004) 14	$N_\eta = 3x10^7$	$(2.7 \pm 0.9_{stat} \pm 0.5_{syst})10^{-4}$
SND – Novosibirsk Nucl. Phys. B600 (2001) 3	$N_\eta = 2.6x10^5$	$< 8.4 \times 10^{-4}$
GAMS2000 Z. Phys. C25 (1984) 225	$N_\eta = 6x10^5$	$(7.2 \pm 1.4) \times 10^{-4}$

KLOE preliminary results on the basis of $N_\eta = 1.8x10^7$
KLOE (all statistics) $N_\eta = 10^8$
MC production in progress for simulating 2004-2005 data sample
with machine bck from random triggers

$\eta \rightarrow \pi^0\gamma\gamma$ analysis

$\phi \rightarrow \eta\,\gamma$

$\downarrow$ 5 γ final state

$\pi^0\gamma\gamma$

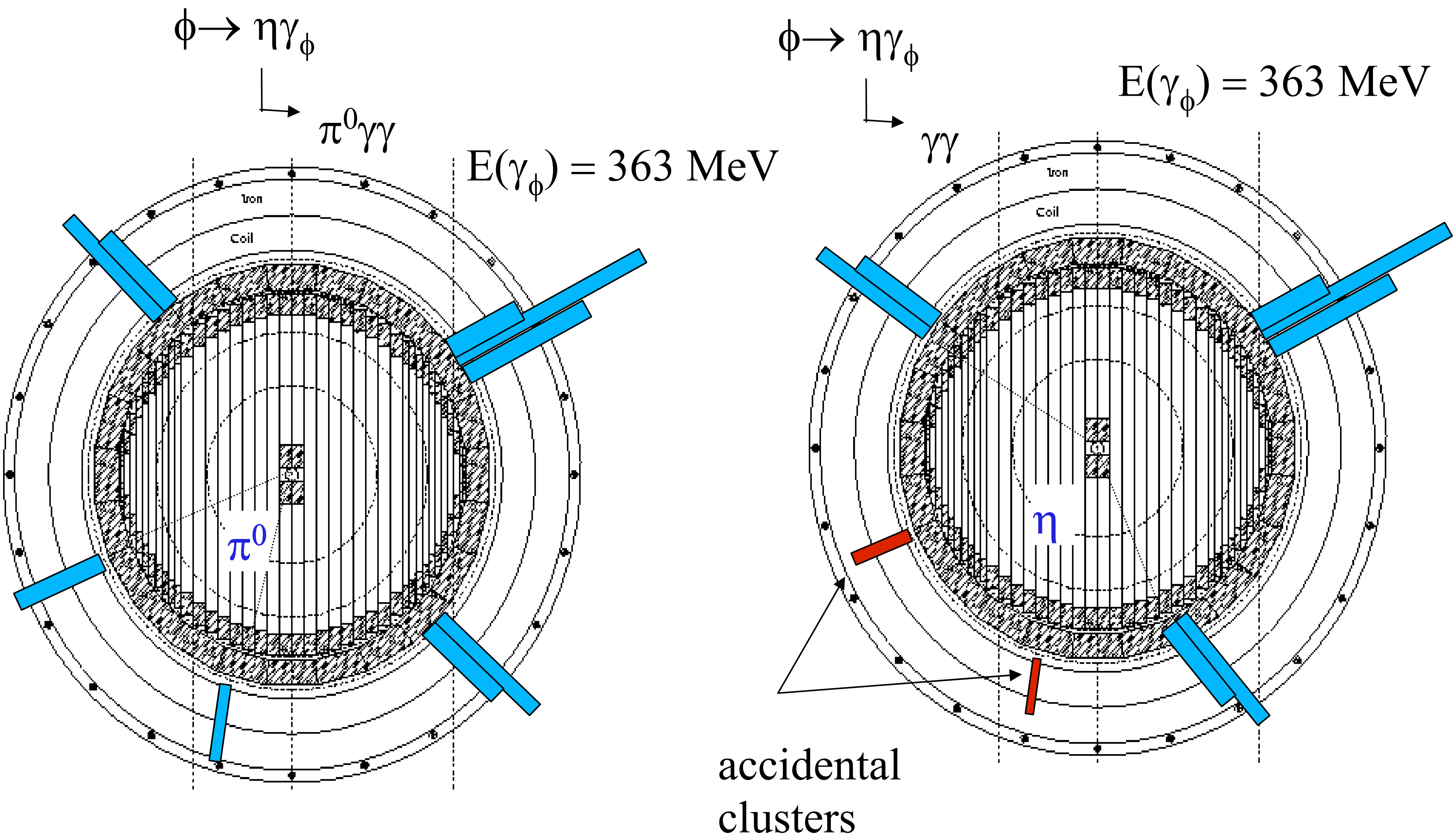
σ = 3 (8) pb
from AGS/CB (GAMS) measurement

Background from

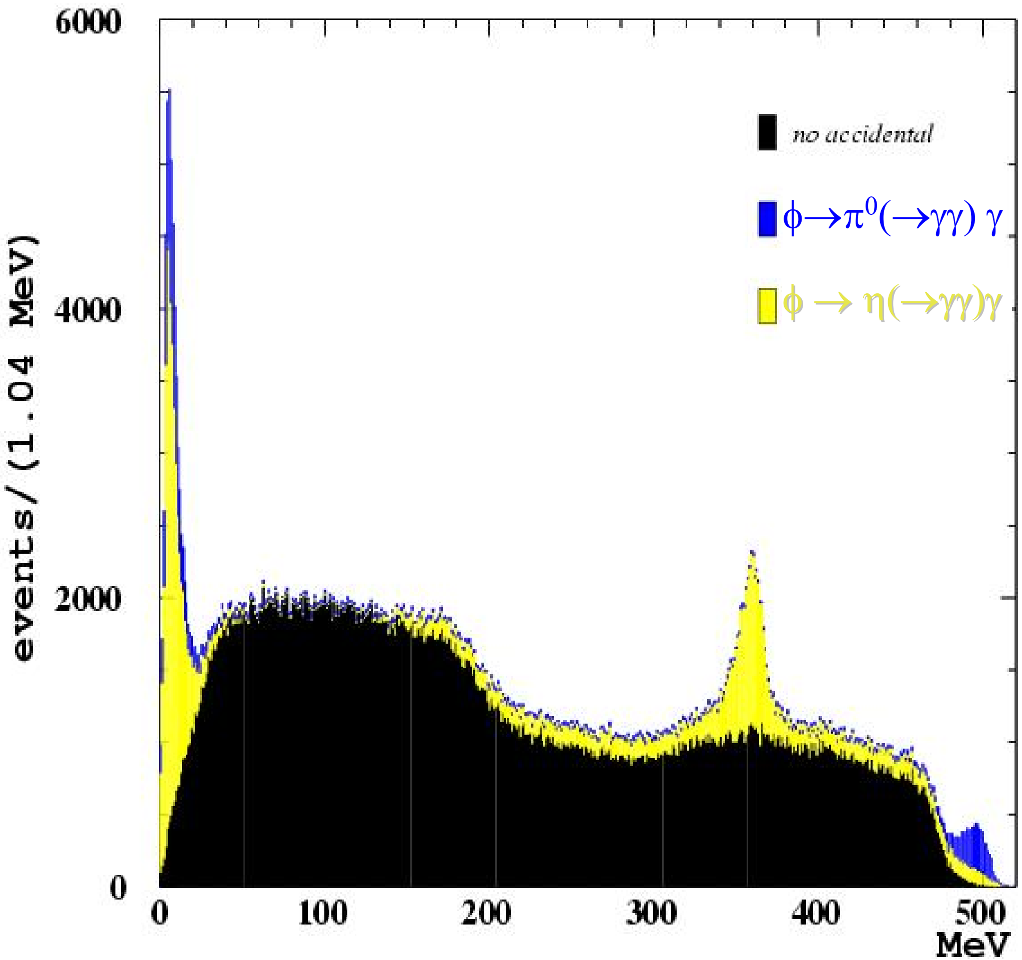
Channel	σ (pb)
$\omega\pi^0, \omega \rightarrow \pi^0\gamma,\ \pi^0 \rightarrow \gamma\gamma$	450
$f^0\gamma,\ f_0 \rightarrow \pi^0\pi^0,\ \pi^0 \rightarrow \gamma\gamma$	300
$a^0\gamma,\ a_0 \rightarrow \eta\pi^0,\ \eta \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$	260
$\eta\gamma, \eta \rightarrow \gamma\gamma$	17000
$\eta\gamma,\ \eta \rightarrow 3\pi^0$	13000

Rejected with cuts on ω, η, π^0

Drastically reduced by energy-momentum conservation and by the analysis of cluster topology to identify merged clusters to $\leq$ 10 pb

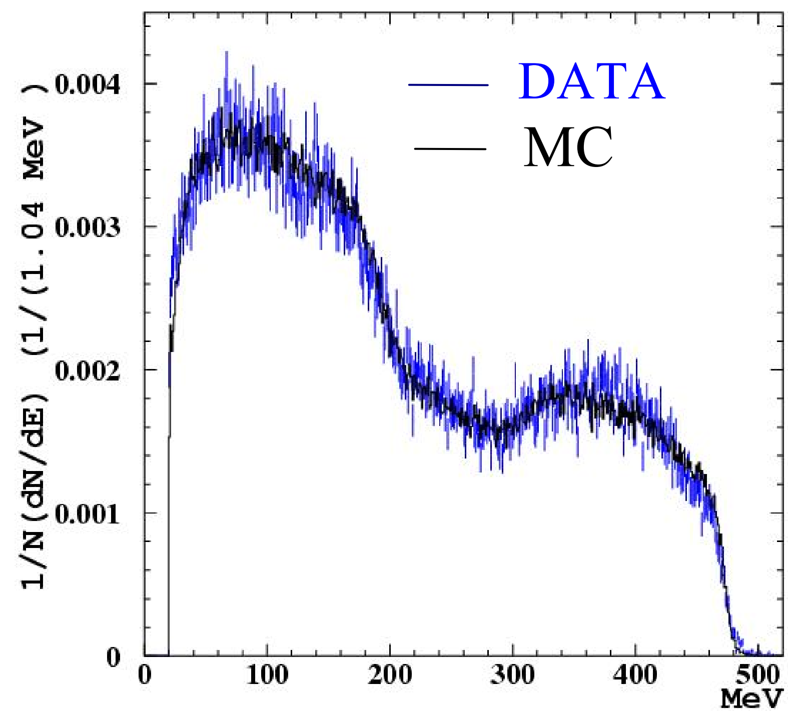


$\phi \to \eta\gamma_\phi$
$\pi^0\gamma\gamma$
$E(\gamma_\phi) = 363$ MeV
Iron
Coil
π^0
$\phi \to \eta\gamma_\phi$
$\gamma\gamma$
$E(\gamma_\phi) = 363$ MeV
Iron
Coil
η
accidental clusters



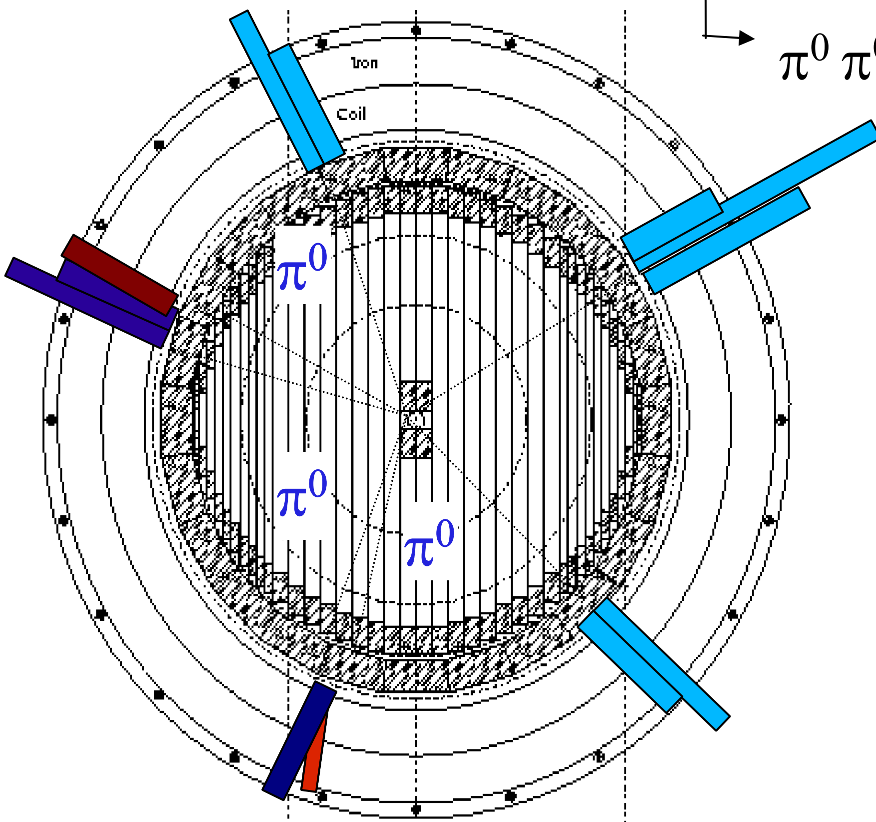
Inclusive γ energy after kinematic fit

$E_\gamma > 20$ MeV
$\theta_\gamma > 21°$

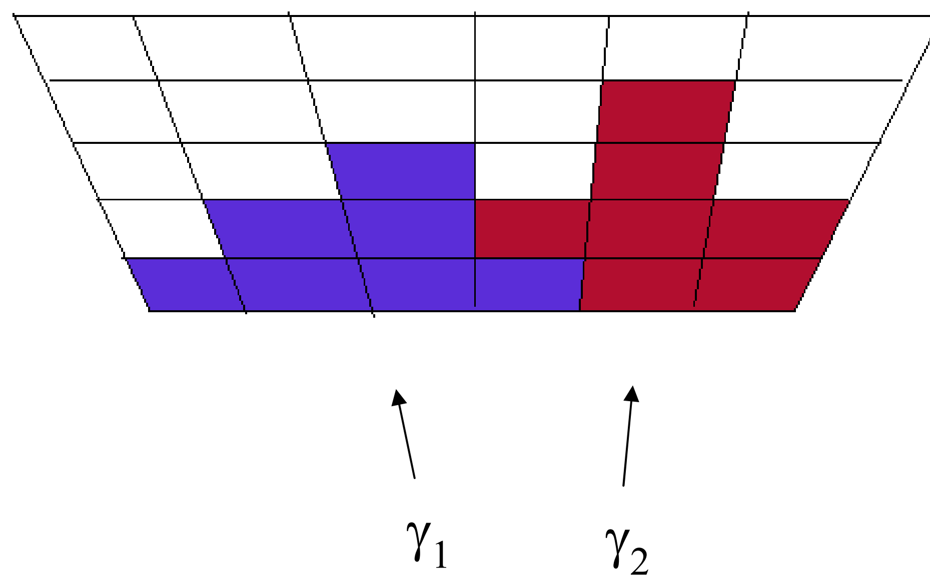


$\phi \rightarrow \eta\gamma_{\phi}$

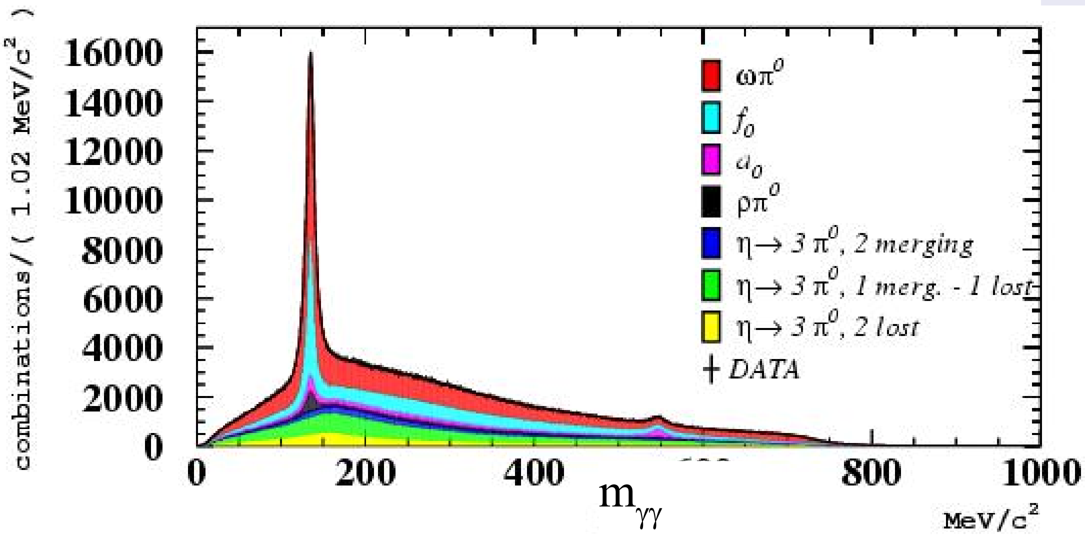
$\hookrightarrow \pi^0\,\pi^0\,\pi^0 \quad 7\gamma$



Cluster shape variables are used to identify merged clusters



$\eta \rightarrow \pi^0\gamma\gamma$ - Background evaluation

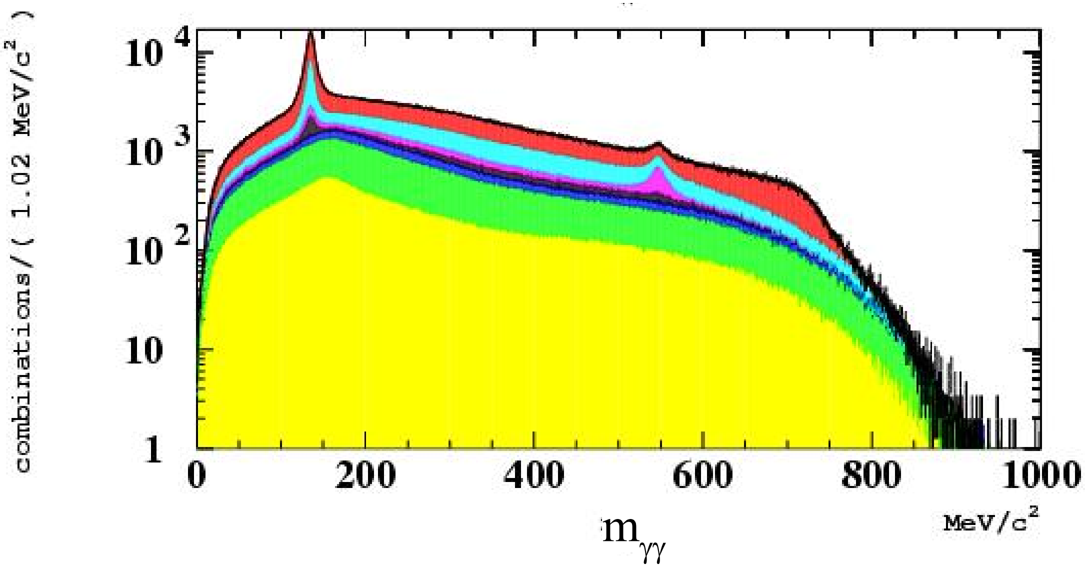


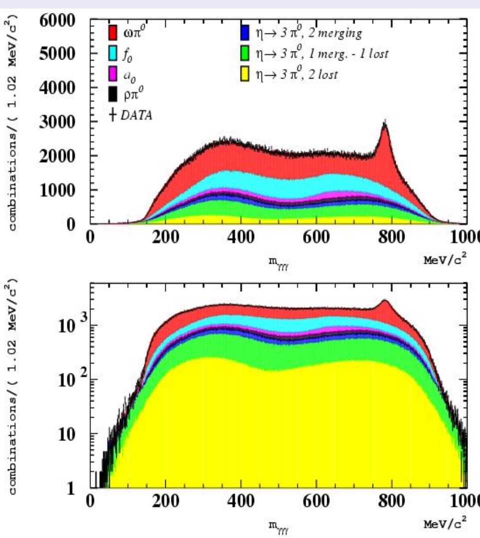
Background composition from the study of the $m_{\gamma\gamma}$ distribution

~900 bins

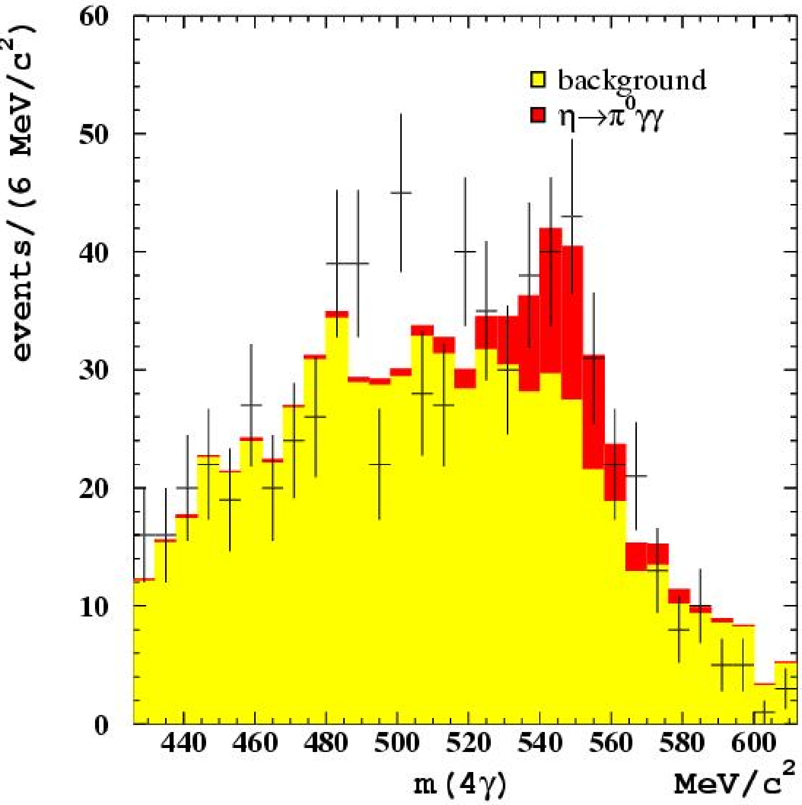
$$\chi^2 = 1.2$$

Controlled with $m_{\gamma\gamma\gamma}$ distribution





Preliminary result on BR($\eta \rightarrow \pi^0\gamma\gamma$)



$$Br(\eta \to \pi^0\gamma\gamma) = (8.0 \pm 2.7) \times 10^{-5}$$

Background + signal distribution of $M_{4\gamma}$ after fixing bckg components from the analysis of the entire 5γ sample is in agreement with DATA

$P_{bkg} = 0.907 \pm 0.049$
$P_{sig} = 0.093 \pm 0.031$
$N_{DATA} = 735$
$N_{bkg} = 667 \pm 36$ $N_{sig} = 68 \pm 23$
$\varepsilon(\eta\to\pi^0\gamma\gamma) = 4.63 \pm 0.09$ (only stat)
$N(\eta\to 3\pi^0) = 2288882$
$\varepsilon(\eta\to\pi^0\pi^0\pi^0) = 0.378 \pm 0.08_{syst} \pm 0.01_{stat}$