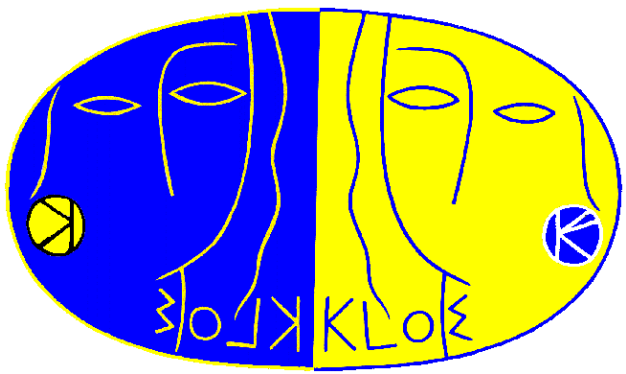
Last results from KLOE at DAΦNE



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for the KLOE Collaboration

MESON 2006
June 9th-13th 2006 – Kraków

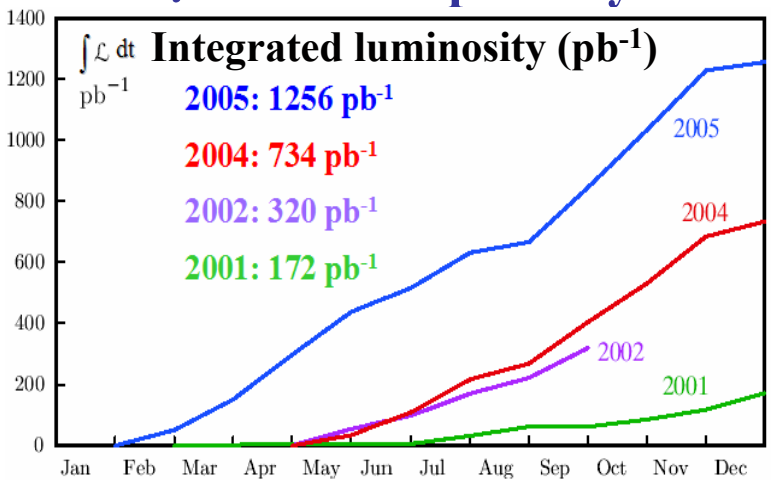
Outline

- DAΦNE and KLOE
- Kaon physics
  - $|V_{us}|$ measurement from semileptonic K decays
  - CPT and $\Delta S=\Delta Q$ tests
- "Non kaon" physics
  - Light scalar mesons
  - η mass measurement
  - η-η' mixing angle
- Future perspectives
- Conclusions

DAΦNE

- Frascati ϕ-factory: e^+e^- collider
  @ $\sqrt{s} \approx 1020$ MeV $\approx M_\phi$; $\sigma_{peak} \approx 3000$ nb

- Best performances in 2005:
  - $L_{peak} = 1.4 \times 10^{32}\ cm^{-1}s^{-1}$
  - $\int Ldt = 8.51\ pb^{-1}/day$

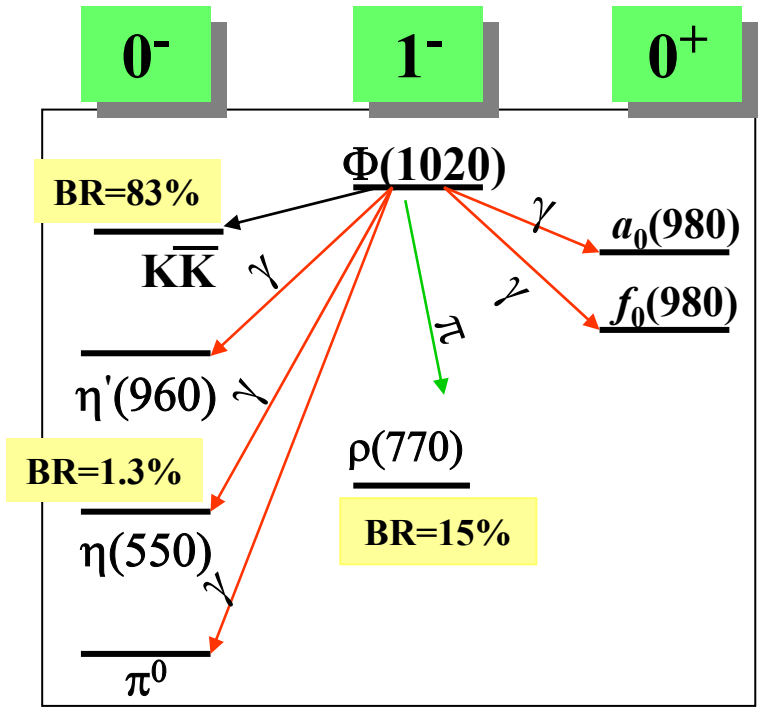


KLOE data set:

2.5 fb^{-1} on tape @ $\sqrt{s}=M_\phi$

$\Rightarrow 8\times10^9$ ϕ produced

+ 250 pb^{-1} @ $\sqrt{s}$=1000 MeV



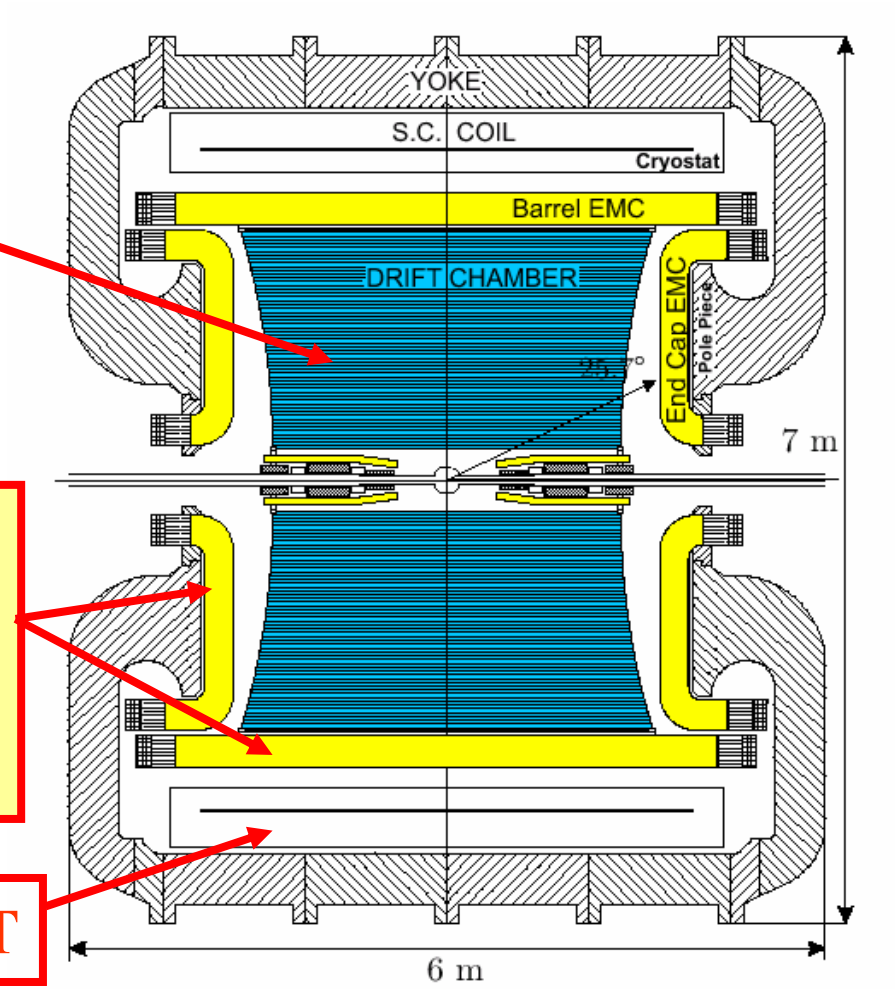
ϕ decay	Produced ev/fb^{-1}
K^+K^-	1.5×10^9
K_LK_S	1.0×10^9
ηγ	5×10^7
η′γ	2×10^5

KLOE

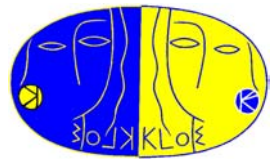
Drift chamber:
- gas: 90% He-10% iC_4H_{10}
- $\delta p_T/p_T = 0.4\%$
- $\sigma_{xy} \approx 150\ \mu m$; $\sigma_z \approx 2$ mm
- $\sigma_{vertex} \approx 1$ mm

E.m. calorimeter (Pb-Sci.Fi.):
- $\sigma_E/E = 5.4\% / \sqrt{(E(GeV))}$
- $\sigma_t = 55\ ps/\sqrt{(E(GeV))} \oplus 50\ ps$
- 98% of 4π

Magnetic field: 0.52 T



K physics at KLOE - tagging



Pure $J^{PC} = 1^{--}$ state $\Rightarrow$ $\frac{1}{\sqrt{2}}\left(|K_L,\mathbf{p}\rangle|K_S,-\mathbf{p}\rangle - |K_L,-\mathbf{p}\rangle|K_S,\mathbf{p}\rangle\right)$

$K_S, K^+ \longleftarrow \phi \longrightarrow K_L, K^-$

ϕ decay mode	BR
K^+K^-	49.1%
K_SK_L	34.1%

Tagging: observation of $K_{S,L}$ signals presence of $K_{L,S}$; K^+ signals K^-

$\Rightarrow$ Clean , normalized K^+,K^-,K_L and K_S samples (K_S unique !)

$\Rightarrow$ absolute branching ratio measurements: $BR=(N_{sig}/N_{tag})(1/\varepsilon_{sig})$

$\Rightarrow$ kaons are monochromatic

$\Rightarrow$ kaon momentum measured with $\sim$ 1 MeV resolution

K^+K^-

$\beta = 0.245$

$p^* = 127$ MeV/c

$\lambda_{\pm} = 95$ cm

K_LK_S

$\beta = 0.22$

$p^* = 110$ MeV/c

$\lambda_S = 6$ mm; $\lambda_L = 3.4$ m

$|V_{us}|$ measurement

- **Test of unitarity of CKM matrix; from first row:**

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

  - **Test if $\Delta = 0$ at 10^{-3} level:**

$$2|V_{ud}|\delta V_{ud} = 0.0005 \text{ from superallowed nuclear } \beta\text{-decays}$$

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

- **$|V_{us}|$ from semileptonic decay widths of neutral and charged kaons:**

$$\Gamma_i(K \to \pi\ell\nu(\gamma)) \propto |V_{us}\, f_+^{K\pi}(0)|^2\, S_{ew} I_i(\lambda_+, \lambda_0, 0)\ (1 + \delta^i_{em} + \delta I_i)$$

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

- **KLOE can measure almost all the experimental inputs:**

  $Br(K_{Le3})$, $Br(K_{L\mu 3})$, $Br(K_{Se3})$, $Br(K^{\pm}_{e3})$, τ_L, $\tau^{\pm}$, form factor slopes

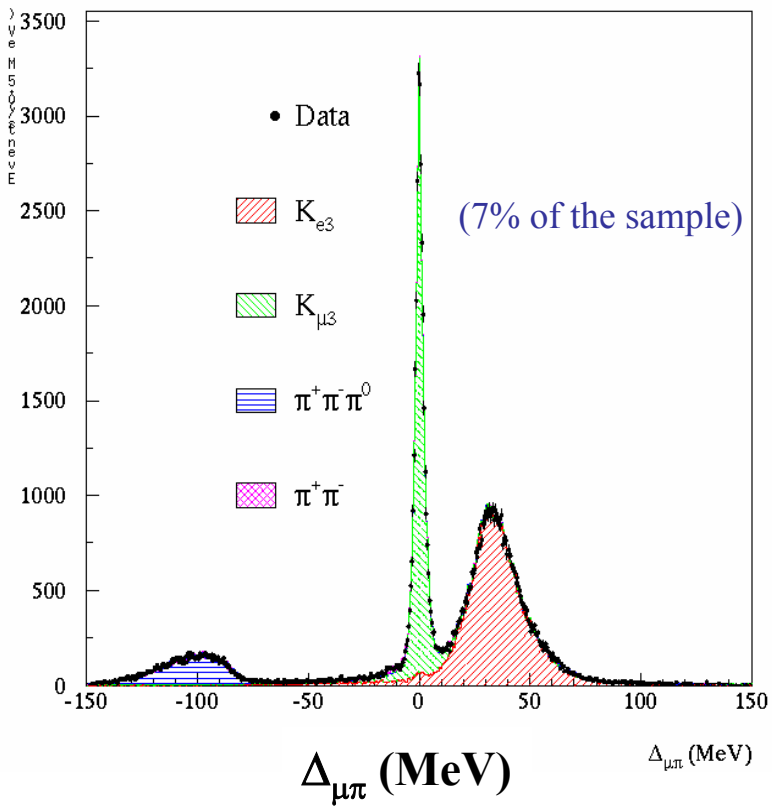
Dominant K_L decay modes

- Data sample: 328 pb^{-1} ; K_L tagged by $K_S \to \pi^+\pi^-$
- 13×10^6 evts for the measurement; 4×10^6 to evaluate efficiencies

- K_L into charged particles decays:
  - K_L vertex in the DC required
  - Best discriminant variable:

    $\Delta_{\mu\pi} = p_{miss} - E_{miss}$ in $\pi\mu$ or $\mu\pi$ hyp.
  - Fit with MC distributions

    (including radiative processes)



- $K_L \to 3\pi^0$: at least 3 γ with E > 20 MeV

  K_L vertex from TOF

  ε_{rec} = 99%, background < 1%

K_L BR's and lifetime

- **Using the constraint $\Sigma Br(K_L)=1$ (including the rare decays):**

  $BR(K_L \rightarrow \pi e \nu(\gamma)) = 0.4007 \pm 0.0006_{stat} \pm 0.0014_{syst}$

  $BR(K_L \rightarrow \pi \mu \nu(\gamma)) = 0.2698 \pm 0.0006_{stat} \pm 0.0014_{syst}$

  $BR(K_L \rightarrow 3\pi^0) = 0.1997 \pm 0.0005_{stat} \pm 0.0019_{syst}$ [PLB632(2006)]

  $BR(K_L \rightarrow \pi^+\pi^-\pi^0(\gamma)) = 0.1263 \pm 0.0005_{stat} \pm 0.0011_{syst}$

  and $\tau_L = (50.72 \pm 0.17 \pm 0.33)$ ns

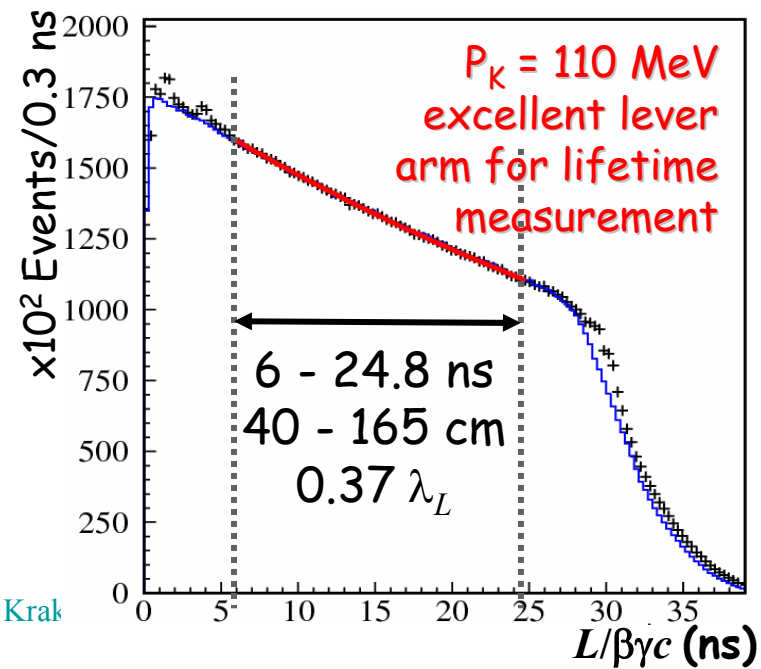
- **Direct lifetime measurement from $K_L \rightarrow 3\pi^0$**

  400 pb^{-1} data sample [PLB626(2005)]

  $\varepsilon \approx 99\%$ uniform along L

  background ~ 1.3%

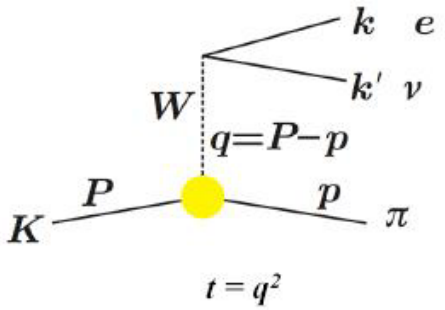
  $\tau_L = (50.92 \pm 0.17 \pm 0.25)$ ns



KLOE average $\tau_L = (50.84 \pm 0.23)$ ns

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

K_{Le3} form factor slopes



$$f_+(t) = f_+(0)\left(\frac{M_V^2}{M_V^2 - t}\right) = f_+(0)\left[1 + \lambda'_+ \frac{t}{m_\pi^2} + \frac{\lambda''_+}{2}\left(\frac{t}{m_\pi^2}\right)^2 + \ldots\right]$$

$$\lambda'_+ = \left(\frac{m_\pi}{M_V}\right)^2 \quad ; \quad \lambda''_+ = 2\lambda'_+$$

- 328 pb^{-1} data sample $\Rightarrow$ 2×10^6 K_{Le3} events
- Fit the $t = (P-p)^2$ distribution

Quadratic:

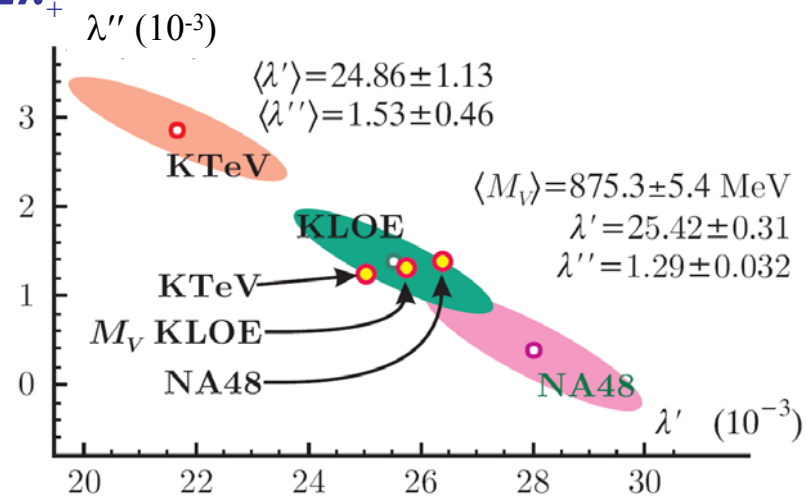
$\lambda'_+ = (25.5 \pm 1.5 \pm 1.0) \times 10^{-3}$

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

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

Pole: $M_V = (870 \pm 6 \pm 7)$ MeV

[PLB636(2006)]



Phase space integral depends on the parametrization:

$I(\lambda)_{Pole} - I(\lambda)_{quadr.}$

KLOE : 0.5×10^{-3}

KTeV : 6.0×10^{-3}

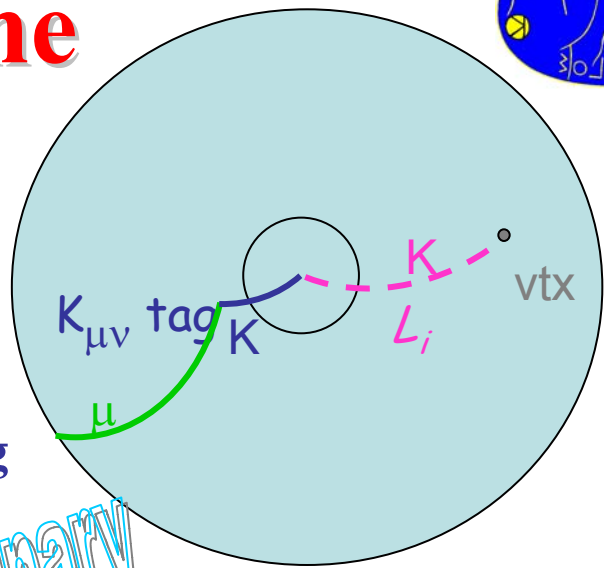
World ave.: 0.3×10^{-3}

$K^{\pm}$ lifetime

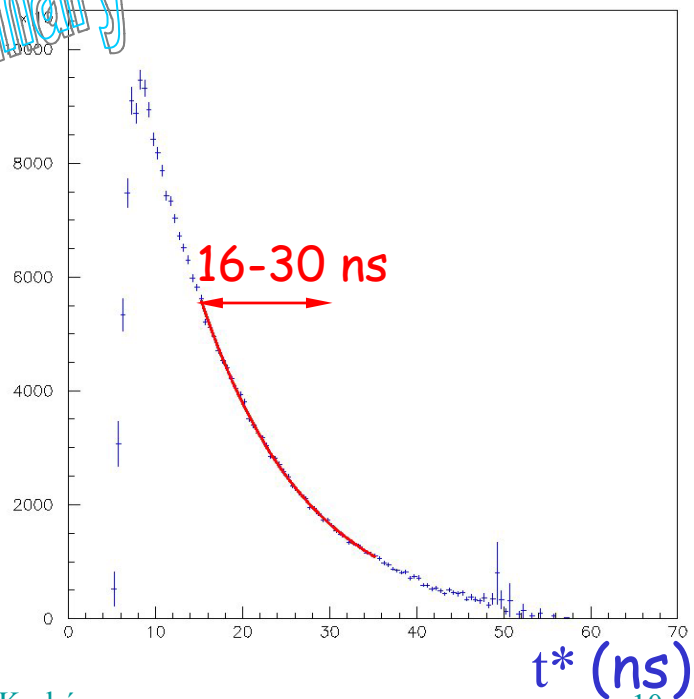
- 200 pb^{-1} data sample
- Tag with $K^{\pm} \rightarrow \mu^{\pm}\nu$
- Look for a K vertex on the opposite side
- $\tau_{\pm}$ from K decay length:

  measure the kaon decay length taking into account the energy loss

  $t^* = \sum_i L_i/(\beta_i\gamma_i c)$



$\Rightarrow \tau_{\pm} = (12.367 \pm 0.044_{Stat} \pm 0.065_{Syst})$ ns



Other method: $\tau_{\pm}$ from K decay time

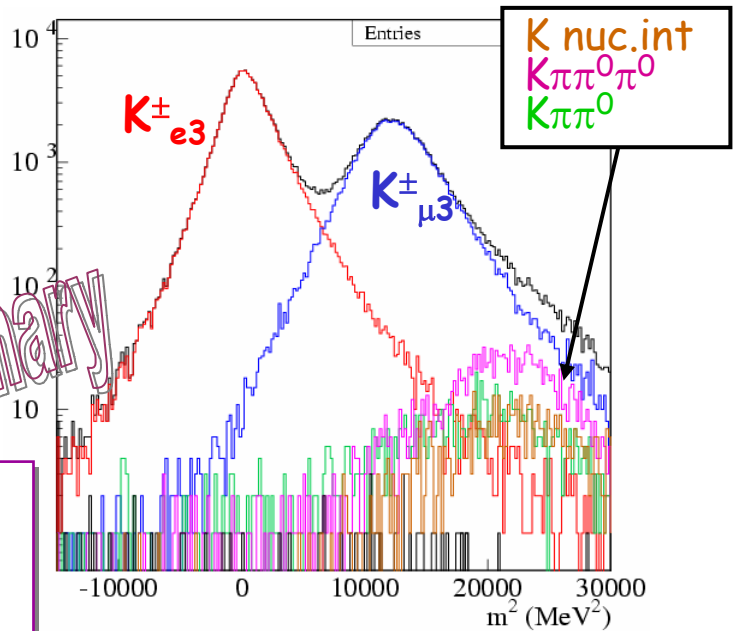
$K^{\pm} \rightarrow \pi^{\pm}\pi^0$

K decay time using the γ's from π^0

BR($K^{\pm}\to\pi^0\ell^{\pm}\nu$)

- $K^{\pm}\to\pi^0\ell^{\pm}\nu$ tagged by $K^{\mp}\to\mu^{\mp}\nu$ and by $K^{\mp}\to\pi^0\pi^{\mp}$
- $K^{\pm}\to\pi^0 e^{\pm}\nu$ and $K^{\pm}\to\pi^0\mu^{\pm}\nu$ are separated by fitting the lepton mass spectrum obtained from TOF

$t_{dec}(K) = t_\ell - L_\ell/[\beta(m)c] = t_\gamma - L_\gamma/c$

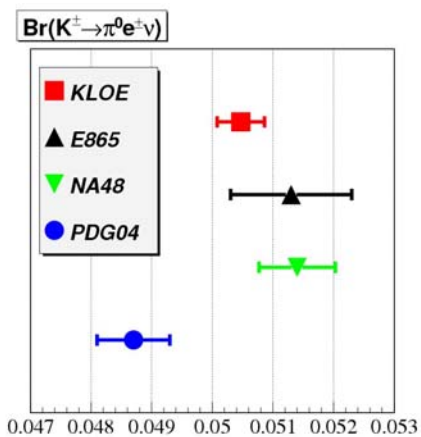


KLOE Preliminary

$BR(K^{\pm}_{e3}) = (5.047 \pm 0.019_{Stat} \pm 0.039_{Syst})\%$

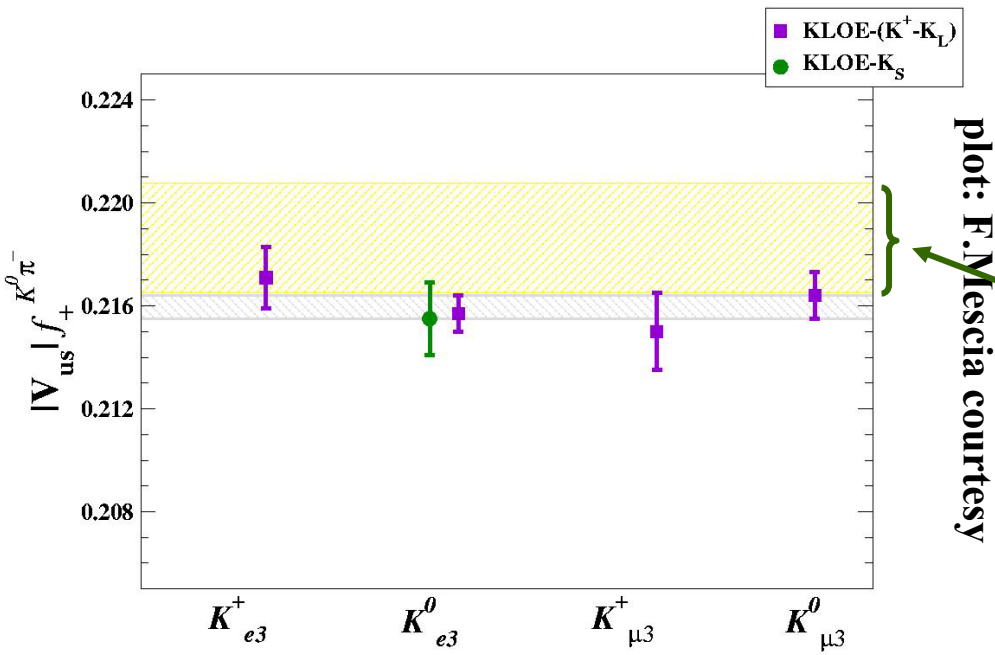
$BR(K^{\pm}_{\mu 3}) = (3.310 \pm 0.016_{Stat} \pm 0.045_{Syst})\%$

- Systematics on signal selection under evaluation



$|V_{us}|$ from KLOE

	K_{Le3}	$K_{L\mu3}$	K_{Se3}	$K^{\pm}_{e3}$	$K^{\pm}_{\mu3}$
BR	0.4007(15)	0.2698(15)	$7.046(91)\times10^{-4}$	0.05047(46)	0.03310(40)
τ	50.84(23) ns		89.58(6) ps	12.384(24) ns	



plot: F.Mescia courtesy

$\langle V_{us}\times f_+(0)\rangle_{\text{KLOE AV.}} = 0.2160(5)$ (0.25% rel.)

$\langle V_{us}\times f_+(0)\rangle_{\text{WORLD AV.}} = 0.2164(4)$

Slopes

$\lambda'_+ = 0.02542(31)$

$\lambda''_+ = 0.00129(3)$

(Pole model: KLOE, KTeV, and NA48 ave.)

$\lambda_0 = 0.01587(95)$

(KTeV and Istra+ ave.)

Unitarity band

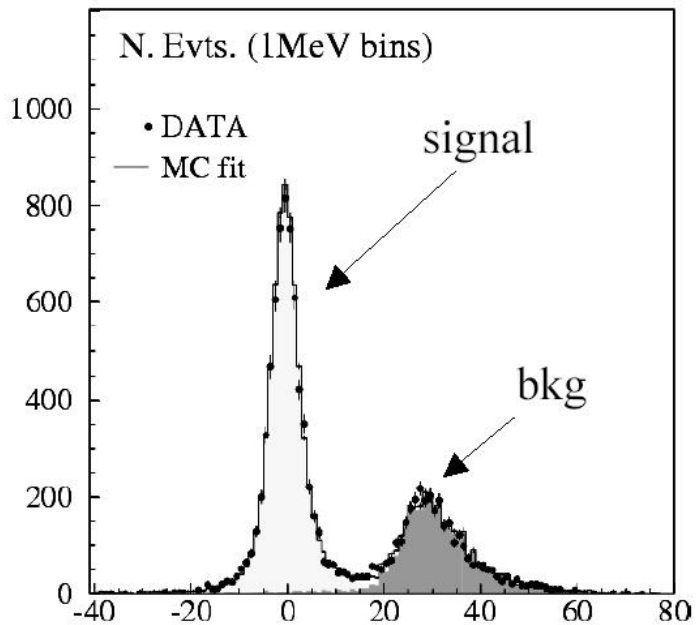
- $f_+(0)=0.961(8)$
  Leutwyler and Roos
  [ZP**C25**, 91(1984)]
- $V_{ud}=0.97377(27)$
  Marciano and Sirlin
  [PRL96 032002(2006)]

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

$K_S \to \pi e \nu$

- Data sample: 410 pb^{-1}; tag by K_L interactions in the EmC
- e/π ID from TOF
  $\Rightarrow$ charge of the lepton in the final state
- Normalization to $K_S \to \pi^+\pi^-(\gamma)$

[PLB 636(2006)]



$$BR(K_S \to \pi^- e^+ \nu) = (3.528 \pm 0.057 \pm 0.027) \times 10^{-4}$$
$$BR(K_S \to \pi^+ e^- \nu) = (3.517 \pm 0.051 \pm 0.029) \times 10^{-4}$$
$$BR(K_S \to \pi e \nu) = (7.046 \pm 0.077 \pm 0.049) \times 10^{-4}$$

[KLOE'02, PLB535, 17 pb^{-1}:$(6.91 \pm 0.34 \pm 0.15) \times 10^{-4}$]

- K_S charge asymmetry:

$$A_S = \frac{\Gamma(K_S \to \pi^- e^+ \nu) - \Gamma(K_S \to \pi^+ e^- \bar{\nu})}{\Gamma(K_S \to \pi^- e^+ \nu) + \Gamma(K_S \to \pi^+ e^- \bar{\nu})} = (1.5 \pm 9.6 \pm 2.9) \times 10^{-3}$$

[$A_L = (3.322 \pm 0.058 \pm 0.047) \times 10^{-3}$ KTeV ; $(3.317 \pm 0.070 \pm 0.072) \times 10^{-3}$ NA48]

$K_S \to \pi e \nu \Rightarrow$ CPT and $\Delta S = \Delta Q$ tests

$A_S \neq A_L \Rightarrow$ CPT violation

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

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

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

– $\Delta S \neq \Delta Q \Rightarrow$ $A_S - A_L = 4\,(\mathrm{Re}\ x_- + \mathrm{Re}\ \delta)$ ⇒ $\mathrm{Re}\ x_- = (-0.8 \pm 2.4 \pm 0.7) \times 10^{-3}$

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

Re δ from CPLEAR ($\sigma = 3.4 \times 10^{-4}$))

(CPLEAR $\sigma = 1.3 \times 10^{-2}$)

– $\Delta S = \Delta Q \Rightarrow$ $A_S + A_L = 4\,(\mathrm{Re}\ \varepsilon - \mathrm{Re}\ y)$ ⇒ $\mathrm{Re}\ y = (0.4 \pm 2.4 \pm 0.7) \times 10^{-3}$

(Re ε from PDG without assuming CPT)

(CPLEAR from unitarity $\sigma = 3.1 \times 10^{-3}$)

• Test of $\Delta S = \Delta Q$ (CPT conserv. ampl.)

(BR($K_L \to \pi e \nu$) and τ_L from KLOE and τ_S from PDG)

$$\mathrm{Re}\ x_+ = \frac{1}{4}\left(\frac{\mathrm{BR}(K_L \to \pi e \nu)\tau_S}{\mathrm{BR}(K_S \to \pi e \nu)\tau_L} - 1\right) = (-0.5 \pm 3.1 \pm 1.8) \times 10^{-3}$$

(SM expect. $O(10^{-7})$)

(CPLEAR $\sigma = 6.1 \times 10^{-3}$)

CPT test: Bell-Steinberger relation

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

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

$$\alpha_{K\ell 3} = 2\tau_S/\tau_L\, BR(K_{L\ell 3})\ [\mathrm{Re}\,\varepsilon - \mathrm{Re}\,y - i(\mathrm{Im}\,\delta + \mathrm{Im}\,x_+)]$$
$$= 2\tau_S/\tau_L\, BR(K_{L\ell 3})\ [(A_S + A_L)/4 - i(\mathrm{Im}\,\delta + \mathrm{Im}\,x_+)]$$

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

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

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

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

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

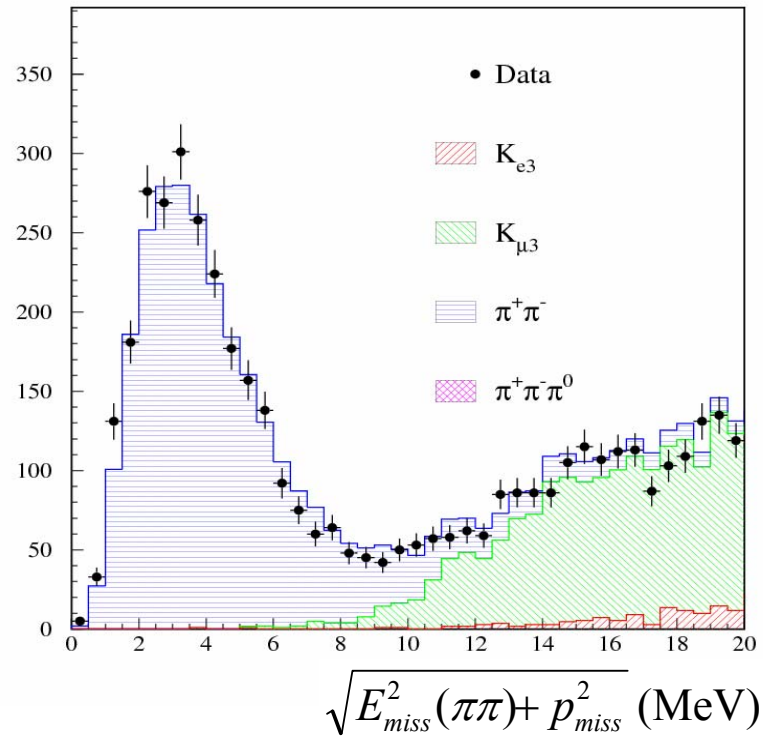
$$[\eta_f = A(K_L \to f)/A(K_S \to f)]$$

$K_L \to \pi^+\pi^-$

Accepted by PLB
hep-ex/0603041

- 328 pb^{-1}; K_L tagged by $K_S \to \pi^+\pi^-$
- K_L vertex reconstructed in DC
- PID using decay kinematics
- fit with MC spectra

normalization using $K_L \to \pi\mu\nu$ events in the same data set



$BR(K_L \to \pi^+\pi^-) = (1.963 \pm 0.012 \pm 0.017) \times 10^{-3}$

agreement with KTeV = $(1.975 \pm 0.012) \times 10^{-3}$

confirms the 4 σ discrepancy with

PDG04 $\Rightarrow (2.090 \pm 0.025) \times 10^{-3}$

using $BR(K_S \to \pi^+\pi^-)$ and τ_L from KLOE, and τ_S from PDG04

$\Rightarrow |\eta_{+-}| = (2.219 \pm 0.013) \times 10^{-3}$

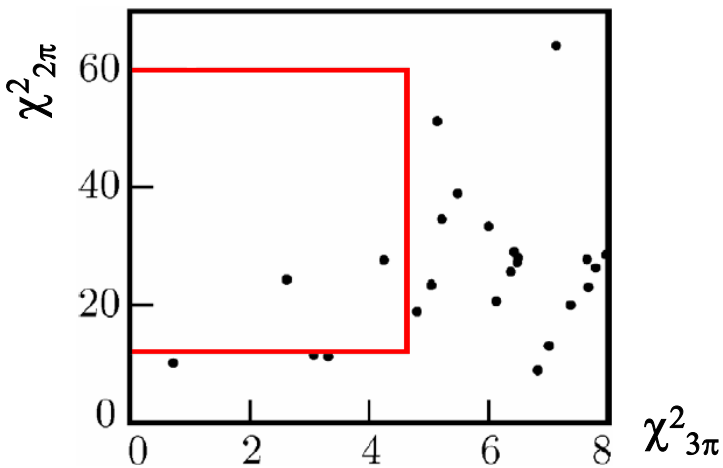
$|\varepsilon| = (2.216 \pm 0.013) \times 10^{-3}$ **PDG04 $|\varepsilon| = (2.280 \pm 0.013) \times 10^{-3}$**

1.6σ agreement with UTfit Collaboration

$K_S \to 3\pi^0$: direct search

- CP violating decay

  in the SM $\Gamma(K_S \to 3\pi^0) = \Gamma(K_L \to 3\pi^0)\,|\eta_{000}|^2 \Rightarrow BR(K_S \to 3\pi^0) \sim 2\times10^{-9}$
- 450 pb^{-1}; tag by K_L inter.in the EmC; look for events with 6 γ
- Background: $K_S \to 2\pi^0$ + 2 split/accidental clusters in the EmC



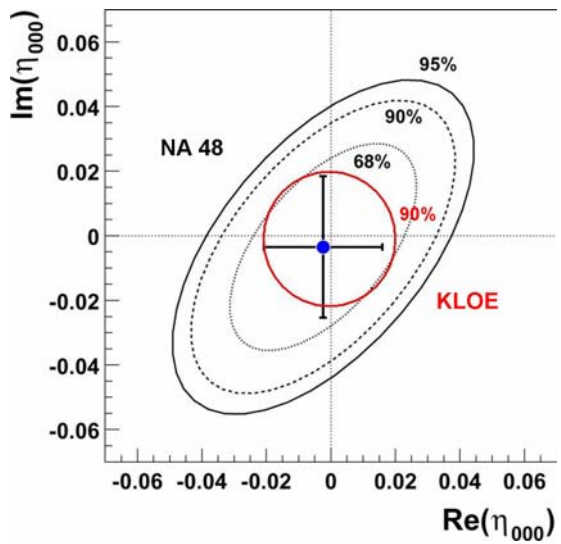
2 evts. in the signal box

$N_{bkg}(MC) = 3.13 \pm 0.90$

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

(BR < 1.4×10^{-5} @ 90% CL [SND '99]

BR< 7.4×10^{-7} [interference, NA48, '04])



- **Upper limit: $|\eta_{000}| < 0.018$ @ 90% CL**

- **Perspective for 2.5 fb^{-1} :**

  $\Rightarrow$ reduce by factor ~ 10 the upper limit

Inputs to Bell-Steinberger relation

$BR(K_S \to \pi^+\pi^-)/BR(K_S \to \pi^0\pi^0) = 2.2549 \pm 0.0059$

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

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

$BR(K_L \to \pi \ell \nu) = 0.6705 \pm 0.0022$

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

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

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

$\phi_{SW} = 0.759 \pm 0.001$

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

$\tau_S = 0.08958 \pm 0.00006$ ns

$\tau_L = 50.84 \pm 0.23$ ns

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

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

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

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

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

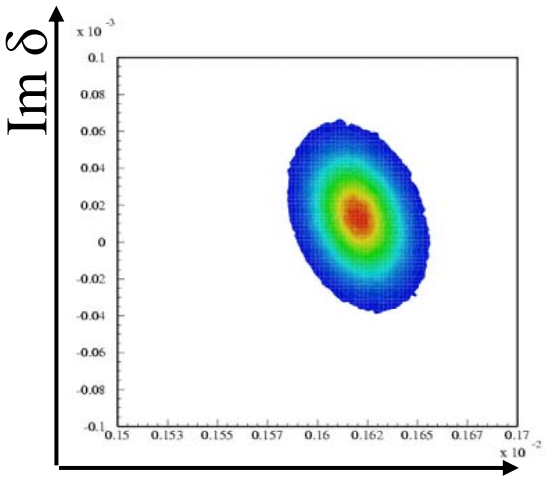
$\phi^{00} = 0.763 \pm 0.014$

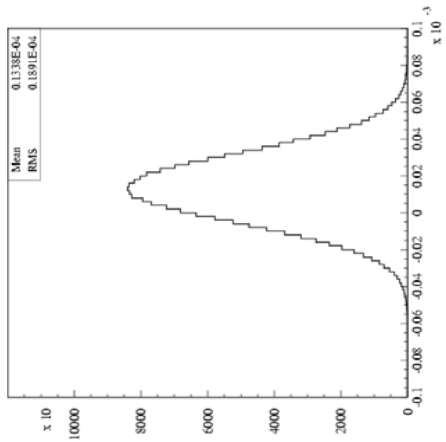
$\mathrm{Im}\, x_+ = (0.8 \pm 0.7) \times 10^{-2}$

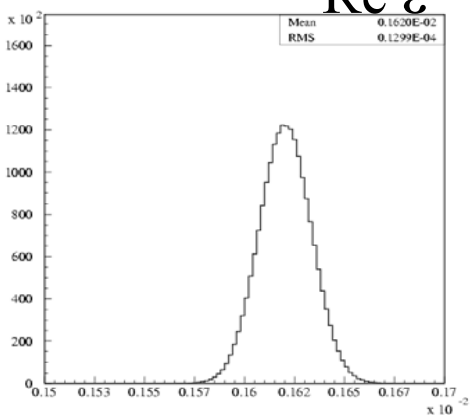
KLOE measurements

$\mathrm{Im}\, x_+$ from a combined fit of KLOE(A_S) + KTeV(A_L) + CPLEAR data

CPT test: results







$\mathrm{Re}\,\varepsilon = (160.2 \pm 1.3) \times 10^{-5}$

$\mathrm{Im}\,\delta = (1.2 \pm 1.9) \times 10^{-5}$

CPLEAR

$\mathrm{Re}\,\varepsilon = (164.9 \pm 2.5) \times 10^{-5}$

$\mathrm{Im}\,\delta = (2.4 \pm 5.0) \times 10^{-5}$

The uncertainty on Imδ is now dominated by φ_{+-} and φ_{00}

Light Scalar Mesons

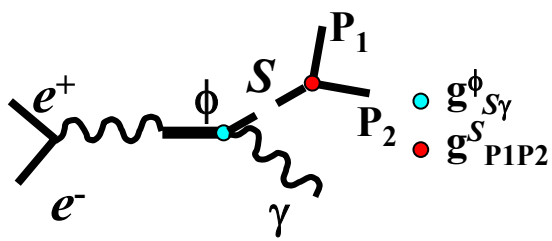
- $e^+e^- \to \phi \to f_0(980)\,\gamma$; $f_0(980)$ (I=0) $\to \pi^0\pi^0$, $\pi^+\pi^-$ $\Rightarrow$ $\pi^+\pi^-\gamma$ final state
  $\to$ 5 γ final state

  [$e^+e^- \to \phi \to a_0(980)\,\gamma$; $a_0(980)$ (I=1) $\to \eta\pi^0$]

  not easily interpreted as $q\bar{q}$ mesons ($^3P_0$ nonet)
- other interpretations: $q\bar{q}q\bar{q}$ states (Jaffe '77)
  $K\bar{K}$ molecules (Weinstein-Isgur '90)
- Fit to the mass spectrum ($\pi^+\pi^-$) or to the Dalitz plot ($\pi^0\pi^0$) to extract masses and couplings: two models exploited

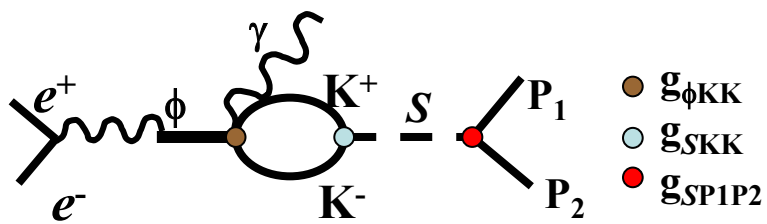
1) "No Structure" – *S* as a BW with Γ(m)

[G.Isidori, L.Maiani et al., hep-ph/0603241]



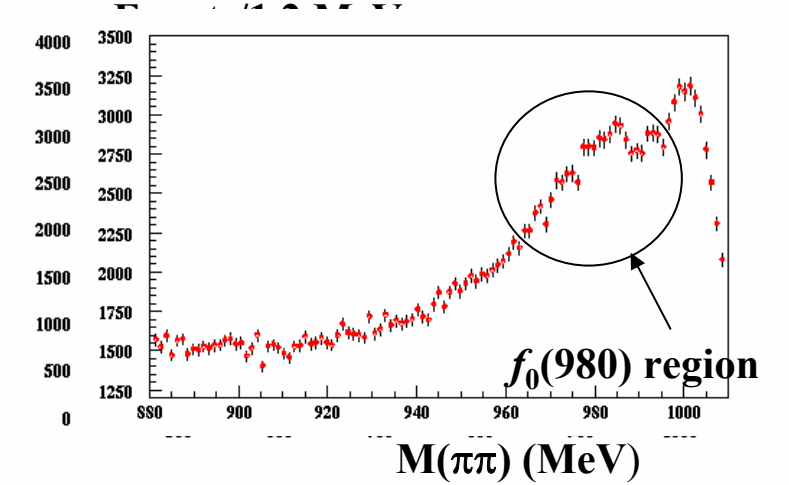
2) Kaon Loop

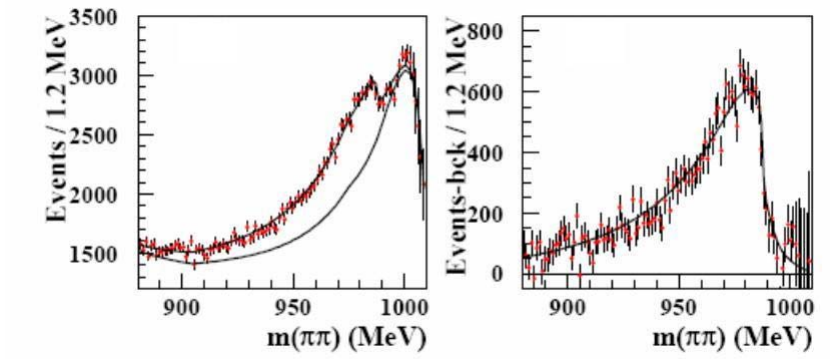
[Achasov-Ivanchenko, NPB315 (1989) 465]



$f_0(980) \rightarrow \pi^+\pi^-$

- $e^+e^- \rightarrow \pi^+\pi^-\gamma$ events with the photon at large angle ($45° < \vartheta_\gamma < 135°$)
- Main contributions: ISR (radiative return to ρ, $\omega \Rightarrow$ pion FF), FSR
- Look for deviations from the expected ISR+FSR behaviour
- Data sample: 350 pb^{-1} at ϕ peak , 676000 events selected





$f_0(980)$ param.	NS model	KL model
m_{f0} (MeV)	973 ÷ 981	980 ÷ 987
$g_{\phi f\gamma}$ (GeV^{-1})	1.2 ÷ 2.0	
$g_{f\pi+\pi-}$ (GeV)	0.9 ÷ 1.1	3.0 ÷ 4.2
g_{fKK} (GeV)	1.6 ÷ 2.3	5.0 ÷ 6.3
$R=g^2_{fKK}/g^2_{f\pi+\pi-}$	2.6 ÷ 4.4	2.2 ÷ 2.8

Fit of the spectrum:

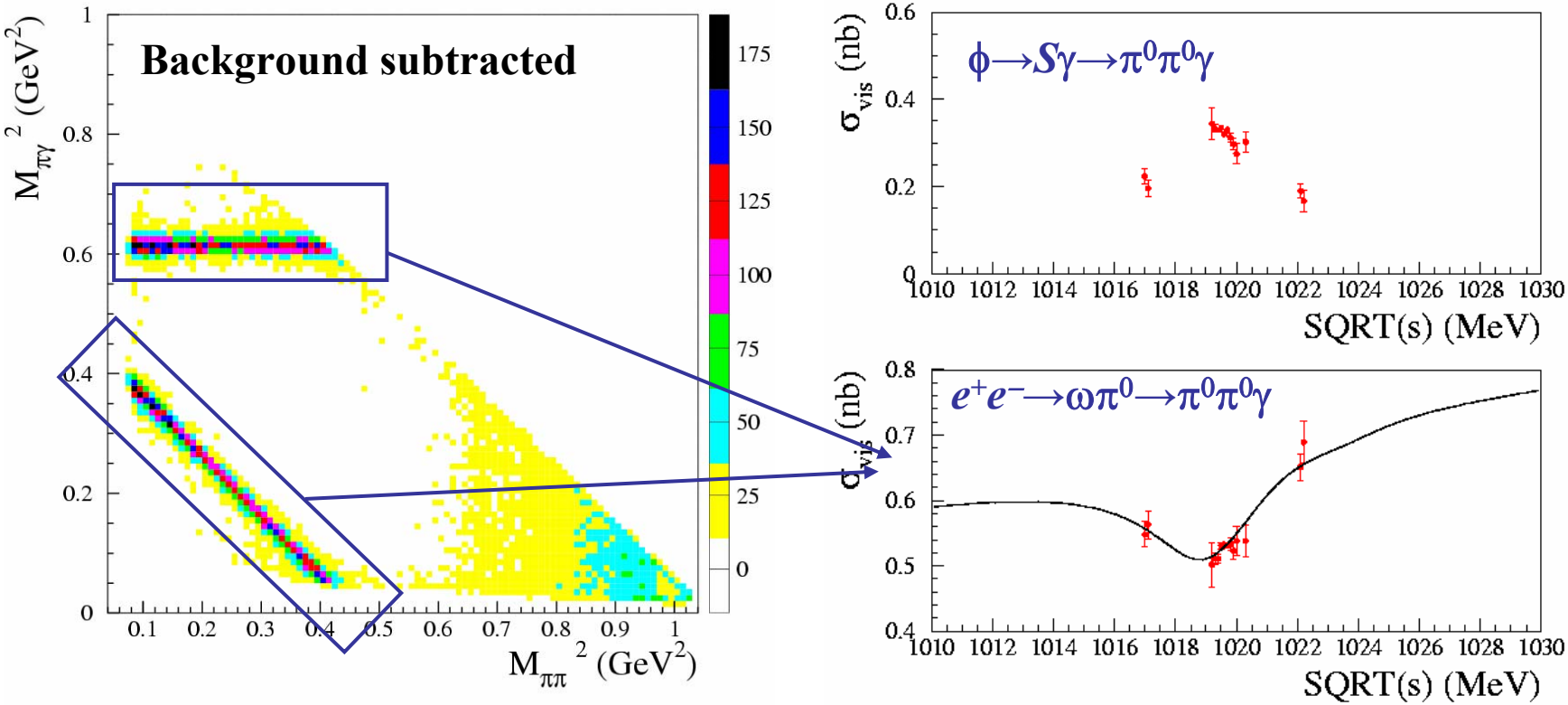
- $f_0(980)$ strongly coupled to KK and to ϕ

  $g_{fKK} > g_{f\pi\pi}$

- $\sigma(600)$ not needed in the fit

$f_0(980) \rightarrow \pi^0\pi^0$

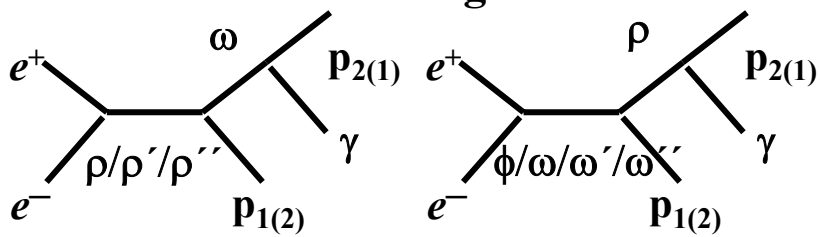
- $e^+e^- \rightarrow \pi^0\pi^0\gamma$: main contributions are $\phi \rightarrow S\gamma$ and $e^+e^- \rightarrow \omega\pi^0$ ($\omega \rightarrow \pi^0\gamma$)
- 450 pb^{-1} from 2001 – 2002 data taking $\Rightarrow$ ~ 400k events



$f_0(980) \to \pi^0\pi^0$

$$\frac{d\sigma}{dm} = \left(\frac{d\sigma}{dm}\right)_{VMD} + \left(\frac{d\sigma}{dm}\right)_{Scalar} + \left(\frac{d\sigma}{dm}\right)_{interf}$$

VMD diagrams



- **Fit to the Dalitz plot: scalars, $f_0(980)$ and $\sigma(600)$ + VDM contrib.**

Kaon loop

M_{f0} = (976.8 ± 0.3$_{fit}$ +0.9/–0.6$_{syst}$ + 10.1$_{mod}$) MeV

g_{f0K+K-} = (3.76 ± 0.04$_{fit}$ +0.15/–0.08$_{syst}$ +1.16/–0.48$_{mod}$) GeV

$g_{f0\pi+\pi-}$ = (–1.43 ± 0.01$_{fit}$ +0.05/–0.02$_{syst}$ +0.03/–0.60$_{mod}$) GeV

R_{f0} = 6.9 ± 0.1$_{fit}$ +0.2/–0.1$_{syst}$ +0.3/–3.9$_{mod}$

$g_{\phi f0\gamma}$ = (2.78 +0.02/-0.05$_{fit}$ +0.13/-0.05$_{syst}$ +1.31$_{mod}$) GeV^{-1}

"No structure"

M_{f0} = (984.7 ± 0.4$_{fit}$ +2.4/–3.7$_{syst}$) MeV

g_{f0K+K-} = (0.40 ± 0.04$_{fit}$ +0.62/–0.29$_{syst}$) GeV

$g_{f0\pi+\pi-}$ = (1.31 ± 0.01$_{fit}$ +0.09/–0.03$_{syst}$) GeV

R_{f0} = 0.09 ± 0.02$_{fit}$ +0.86/–0.42$_{syst}$

$g_{\phi f0\gamma}$ = (2.61 ± 0.02$_{fit}$ +0.05/–0.02$_{syst}$) GeV^{-1}

- $\sigma(600)$ is needed in the fit
- Some difference w.r.t. $\pi^+\pi^-$ channel
- 2.5 fb^{-1}: $f_0(980), a_0(980) \to K\bar{K}$

η mass measurement

- 8 σ discrepancy between the two most recent measurements:

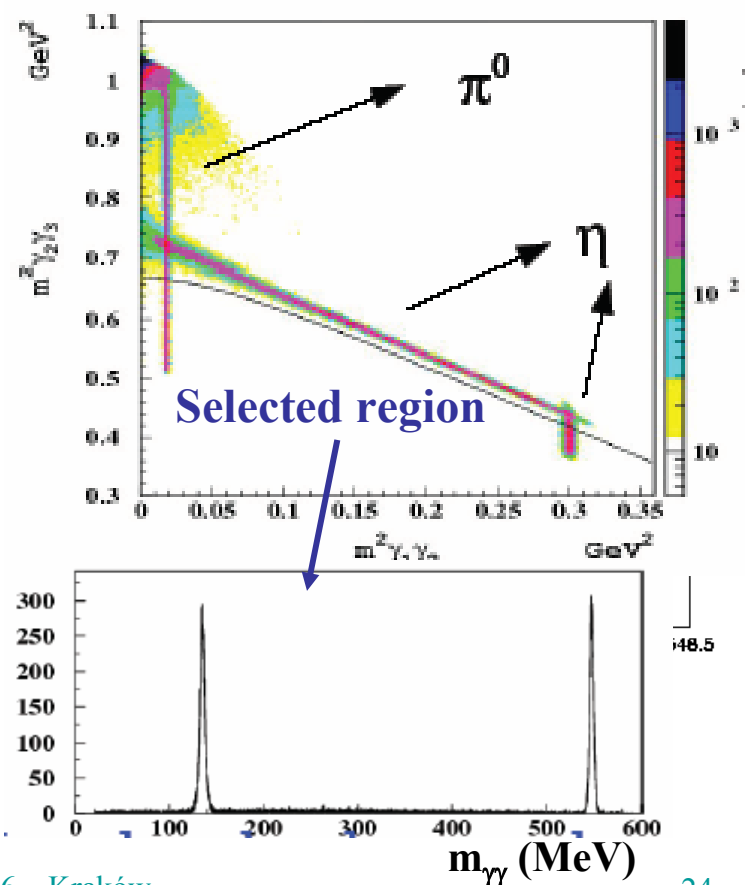
  1) GEM (COSY) $p + d \rightarrow {}^3He + \eta$

$M_\eta = (547.311 \pm 0.028 \pm 0.032)$ MeV/c² [M. Abdel-Bary et al., PLB 619 (2005) 281]

  2) NA48 $\eta \rightarrow 3\pi^0$ from $\pi^- + p \rightarrow \eta + n$

$M_\eta = (547.843 \pm 0.030 \pm 0.041)$ MeV/c²

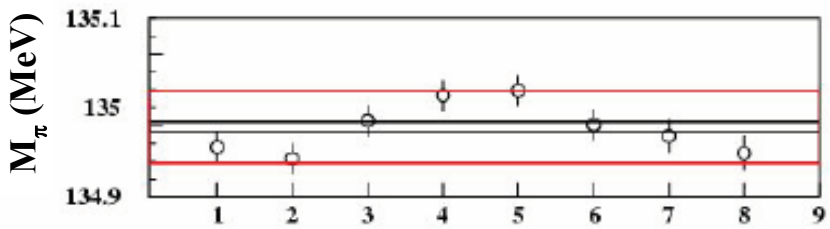
[A. Lai et al., PLB 533 (2002) 196]

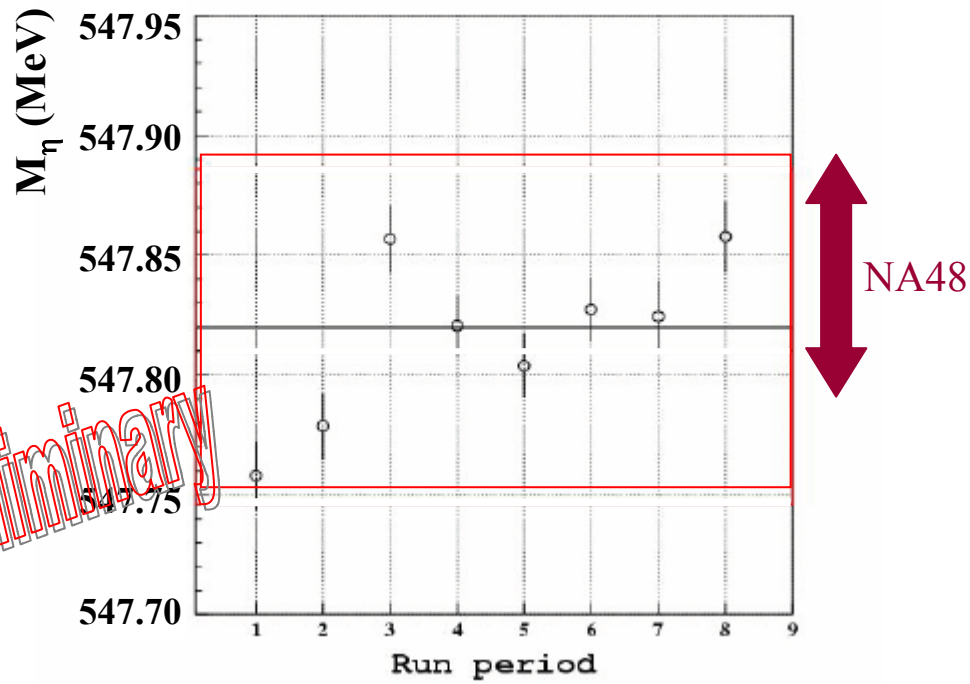


- KLOE: $\phi \rightarrow \eta\gamma$; $\eta \rightarrow \gamma\gamma$ (3 γ events)
  check with $\phi \rightarrow \pi^0\gamma$; $\pi^0 \rightarrow \gamma\gamma$
- After kinematic fit the mass is almost independent from cluster energies
  ⇒ dominated by photon positions
- φ momentum and vertex position from large angle Bhabha scattering

η mass measurement

- **Data set divided into 8 periods**





$M(\pi^0)$ $= (134990 \pm 6_{stat} \pm 30_{syst})$ keV

$M(\pi^0)_{PDG} = (134976.6 \pm 0.6)$ keV

KLOE Preliminary

$M(\eta) = (547822 \pm 5_{stat} \pm 69_{syst})$ keV

- **systematics from √s and vertex position and EmC linearity (systematics evaluation still in progress)**
- **NA48 compatibility 0.24σ**

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

- $\phi\to\eta'\gamma$; $\eta'\to\eta\,\pi^+\pi^-$; $\eta\to\pi^0\pi^0\pi^0$
  $\eta'\to\eta\pi^0\pi^0$; $\eta\to\pi^+\pi^-\pi^0$
- $\phi\to\eta\gamma$; $\eta\to\pi^0\pi^0\pi^0$

} $\pi^+\pi^-$ + 7 γ final state

$L=427\ pb^{-1}$

$N_{\eta'\gamma} = 3405 \pm 61 \pm 28$ evts.

$N_{\eta\gamma} = 16.7\times10^6$ evts.

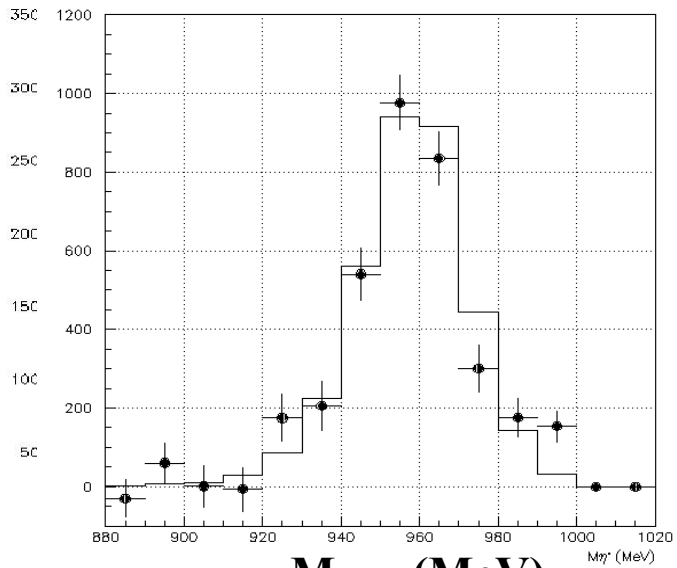
$$R=\frac{BR(\phi\to\eta'\gamma)}{BR(\phi\to\eta\gamma)}=(4.74\pm0.09\pm0.20)\times10^{-3}$$

syst. dominated by the uncertainties on $Br(\eta'\to\eta\pi\pi)$ (3%)

$R= 4.7\pm0.5\pm0.3$ **KLOE** [PLB541(2002)]
($\pi^+\pi^-+3\gamma$ final state, $17pb^{-1}$ of 2000 data)

By using the PDG value of $BR(\phi\to\eta\gamma)$
$\Rightarrow BR(\phi\to\eta'\gamma) = (6.17\pm0.12\pm0.28)\times10^{-5}$

inv.mass of $\pi^+\pi^-$+ 6 out of 7γ



$M_{\pi\pi6\gamma}$ (MeV)

η/η′ mixing and η′ gluon content

- **From the R measurement, the η-η′ mixing angle in the quark flavour basis (φ_P) can be extracted:**

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

$$\varphi_P = (41.5 \pm 0.3 \pm 0.9)^\circ \qquad \Rightarrow \quad \theta_P = (-13.1 \pm 0.3 \pm 0.6)^\circ$$

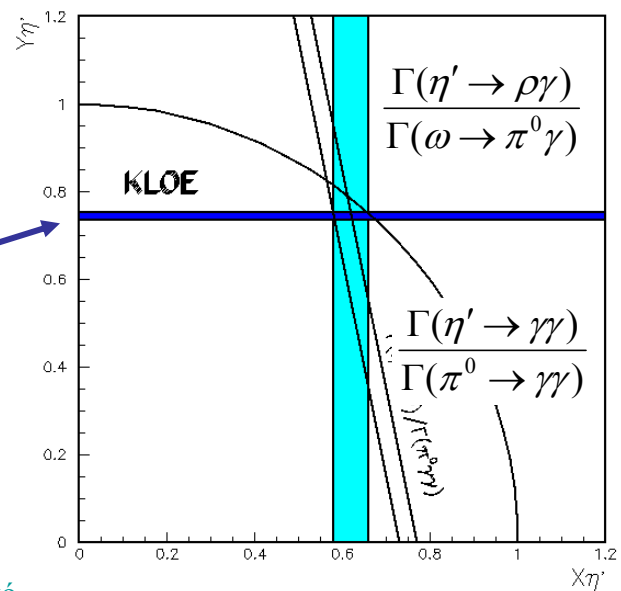
- **η′ gluon content, a consistency check:**

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

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

Assuming Z=0 $\Rightarrow$ Y=cos φ_P

$$\Rightarrow X^2+Y^2 = 0.92 \pm 0.06$$



The KLOE future

- KLOE data taking ended in Mar
- DAΦNE program scheduled up t
- Upgrade for DAΦNE has been p
  DANAE ($M_\phi < \sqrt{s} < 2.5$ GeV; $L_{peak} = 8$
  GeV))
- An Expression of Interest for the
  (KLOE2) has been presented (11
- Main physics items (based on the
  - Rare K_S decays
  - Kaon interferometry (CP, CPT
  - η, η' physics
  - Scalar mesons ($f_0(980)$,$a_0(980)\rightarrow$
  - Multi-hadron cross section from
  - Meson spectroscopy

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Conclusions

- KLOE with ~ 400 pb^{-1} improved the knowledge on kaon decays (many entries in the PDG2006)
- Major K_L BRs and τ_L measured at 0.5% -- 1% level
- $|V_{us}f_+(0)|$ at 0.25% ($|V_{us}|$ known at ~1%, dominated by theoretical error on $f_+(0)$)
- Semileptonic decays of charged and neutral K $\Rightarrow$ CKM unitarity within~1σ
- BR($K_S \to \pi e \nu$) at 1.3%, $\Rightarrow$ first measurement of A_S ($\delta A_S \sim 10^{-2}$)
- Limits on CPT violation parameters improved
- Forthcoming results: FF slopes for $K_L \to \pi\mu\nu$, BR($K_S \to \pi\mu\nu$),
- Perspectives for 2.5 fb^{-1}: uncertainties <1% for $K_S \to \pi e \nu$, $K^{\pm}_{\ell 3}$, improve FF slopes, $K_S \to \pi^+\pi^-\pi^0$

"Non kaon" physics:

- $f_0(980)$ parameters from $\pi^+\pi^-$ and $\pi^0\pi^0$ decay channels
- Preliminary η mass measurement
- η-η' mixing angle with uncertainty < 1°
- Perspectives for 2.5 fb^{-1}: search for $f_0(980)$,$a_0(980) \to KK$, rare η decays

Other results not shown: hadronic cross section via ISR, Kaon interferometry, …