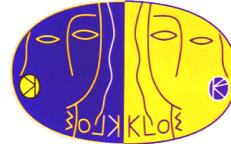


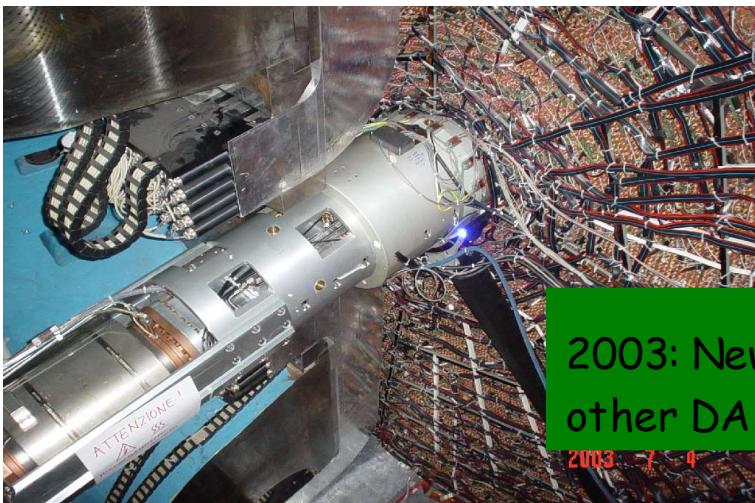
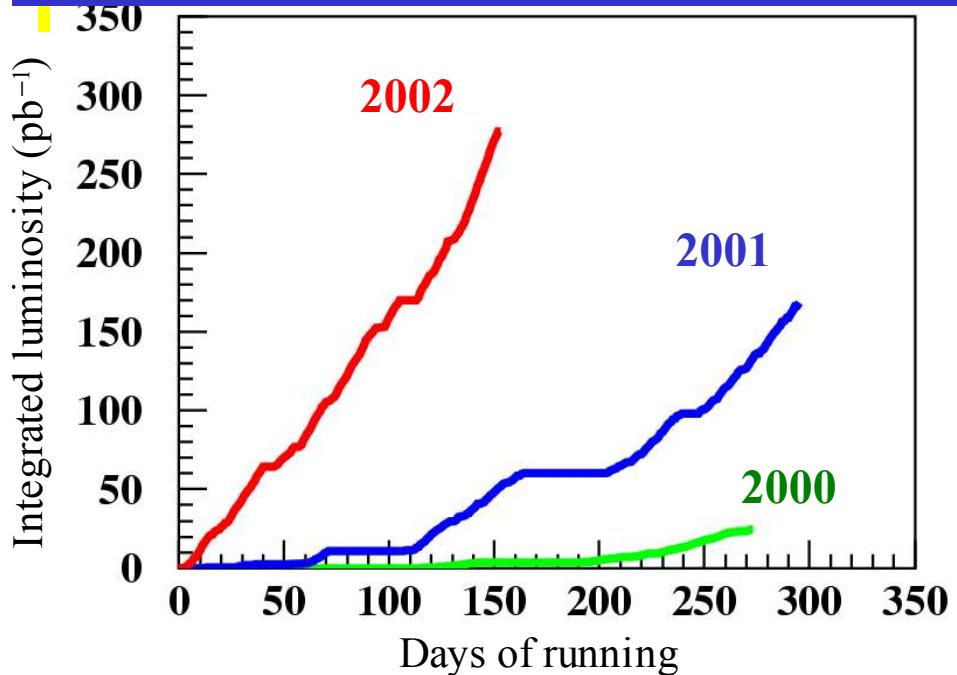
Results from KLOE



M. Antonelli (INFN-LNF)
for the KLOE Collaboration



KLOE data taking



1999 run: 2.5 pb^{-1}

$8 \times 10^6 \phi$ decays

Machine and detector studies

2000 run: 25 pb^{-1}

$80 \times 10^6 \phi$ decays

First published results

2001 run: 170 pb^{-1}

$530 \times 10^6 \phi$ decays

Published results + analysis in progress

2002 run: 280 pb^{-1}

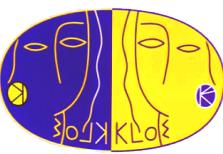
$870 \times 10^6 \phi$ decays

Goals for 2004-2005:
(start in April)

✓ $L_{\text{peak}} = 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$

✓ $L_{\text{int}} / \text{day} = 10 \text{ pb}^{-1}$

✓ $L_{\text{int}} / \text{year} = 2 \text{ fb}^{-1}$



Monte Carlo production

Samples comparable in statistics to 450 pb^{-1} of data

Each run in data set individually simulated

$\forall \sqrt{s}, \mathbf{p}_\phi, \mathbf{x}_\phi$, background, dead wires, trigger thresholds

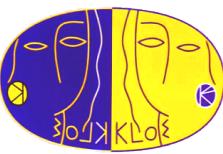
Comprehensive series of upgrades to simulation

- Suite of new generators introduced, particular emphasis on radiative processes
- Geometry carefully revised and response simulation tuned for both EmC and DC

Inclusion of accidental activity from machine background

- Extracted from $e^+e^- \rightarrow \gamma\gamma$ events in data set
- Inserted run-by-run to match temporal profile of data

NEW hadron interaction simulation (π^+, π^-, K_l)



Kaon physics @ KLOE

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

Phys. Lett. B538, 21 (2002)

$K_s \rightarrow \pi e \nu$

Phys. Lett. B535, 37 (2002)

Preliminary update with new data

$K_s \rightarrow 3\pi^0$

Preliminary results

K_s mass

KLOE Note 181 (<http://www.lnf.infn.it/kloe>)

$K_L \rightarrow \gamma \gamma$ / $K_L \rightarrow 3\pi^0$

Phys. Lett. B566, 61 (2003)

$K_L \rightarrow$ charged

Preliminary results

$K_s K_L$ interference

Preliminary results

V_{us} from K_{l3}

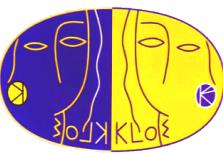
Preliminary results (hep-ex/0307016)

$K^\pm \rightarrow \pi^\pm \pi^0$ / $K^\pm \rightarrow \mu^\pm \nu$

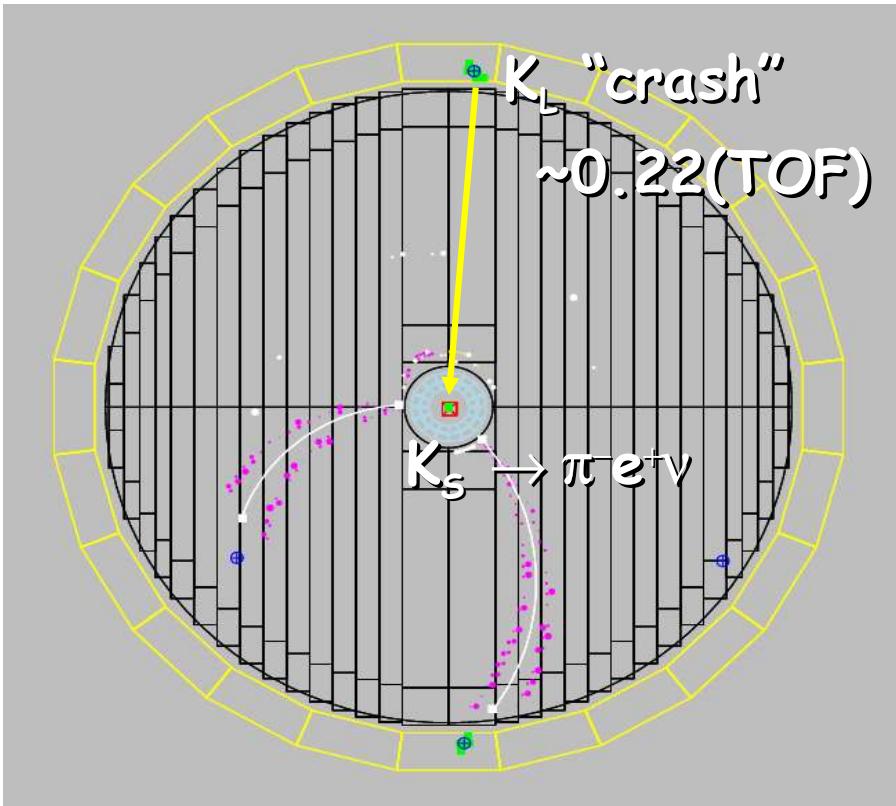
Preliminary results

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

To be submitted to PLB (hep-ex/0307054)



K_s and K_L tagging strategy

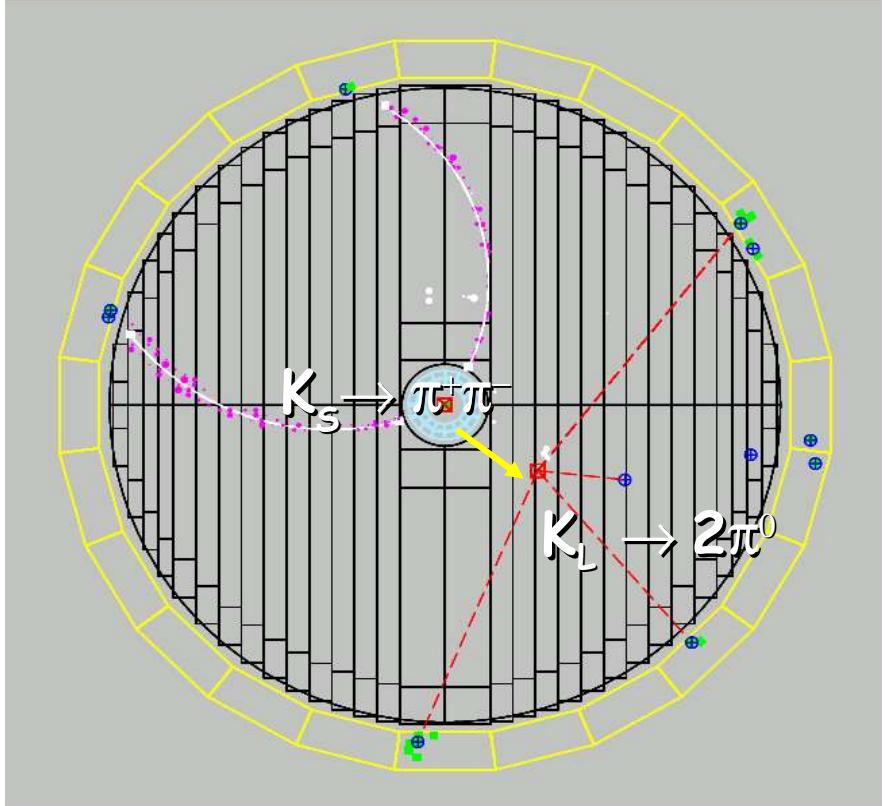


K_s tagged by K_L interaction in EmC

Efficiency $\sim 30\%$

K_s angular resolution: $\sim 1^\circ$ (0.3° in ϕ)

K_s momentum resolution: ~ 2 MeV



K_L tagged by $K_s \rightarrow \pi^+\pi^-$ vertex

Efficiency $\sim 70\% \times \text{BR}(K_s \rightarrow \pi^+\pi^-)$

K_L angular resolution: $\sim 1^\circ$

K_L momentum resolution: ~ 2 MeV



Search for $K_s \rightarrow \pi^0\pi^0\pi^0$

eP transition: SM exp. $BR \sim 2 \times 10^{-9}$

NA48 $BR < 3 \times 10^{-7}$ @ 90 CL

❖ Preselection:

$K_{\text{crash tag}} + 6$'s ($E > 7$ MeV, $|T-R/c| < 3.5\sigma_t$, $\theta > 22.5^\circ$)

Kinematic fit on K_s side

Construction of two pseudo- χ^2 to increase S/B

$\chi^2_{2\pi} : K_s \rightarrow 2\pi^0$ events (+ accidental/splitting)

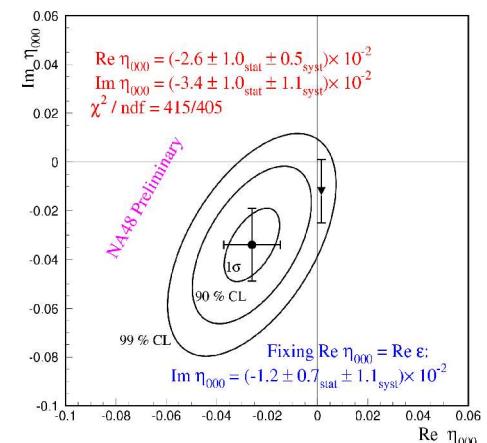
$\chi^2_{3\pi} : K_s \rightarrow 3\pi^0$ events

Preliminary results (450 pb⁻¹ '01+'02)

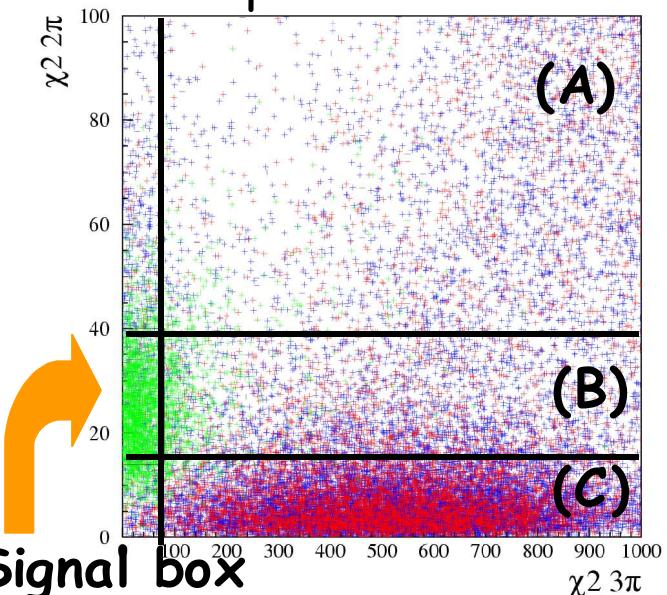
Expected background: 3.1 ± 1.9

observed: 5

$BR(K_s \rightarrow \pi^0\pi^0\pi^0) < 2.2 \times 10^{-7}$ @ 90 CL



450 pb⁻¹ '01+'02 data



$\varepsilon(K_s \rightarrow \pi^0\pi^0\pi^0) \sim 26\% \times 30\%$



Search for $K_s \rightarrow \pi^+ \pi^- \pi^0$

Branching ratio not well measured at present:

CLEAR '97 $2.5^{+1.2}_{-1.0} {}^{+0.5}_{-0.6} \times 10^{-7}$

E621 '96 $4.8^{+2.2}_{-1.6} \pm 1.1 \times 10^{-7}$

PDG Avg. $3.2^{+1.2}_{-1.0} \times 10^{-7}$

Phenomenology & χ PT $2.4 \pm 0.7 \times 10^{-7}$

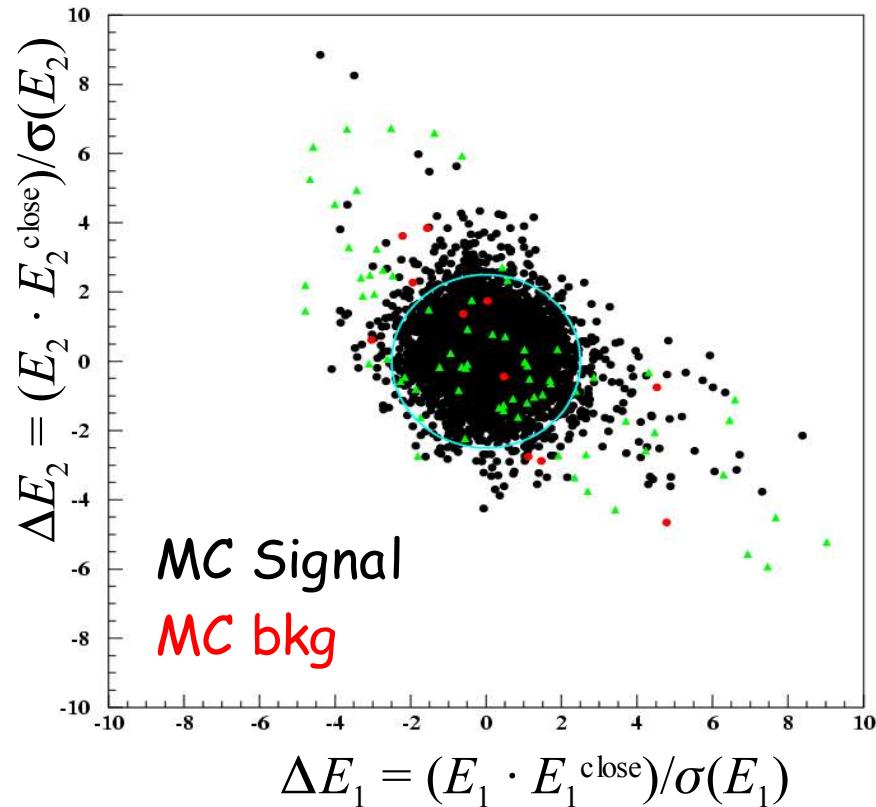
First studies: ~ 5% (reach $\sim 2 \text{ } 10^{-2} \text{ eV/pb}^{-1}$)

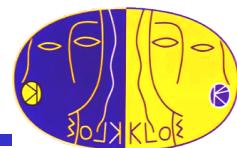
competitive with existing measurements
(improve with 2 fb^{-1})

improve BS test of unitarity with $K_s \rightarrow 3\pi$

similar performances expected for $K_s \rightarrow e^+ e^- \pi^0$

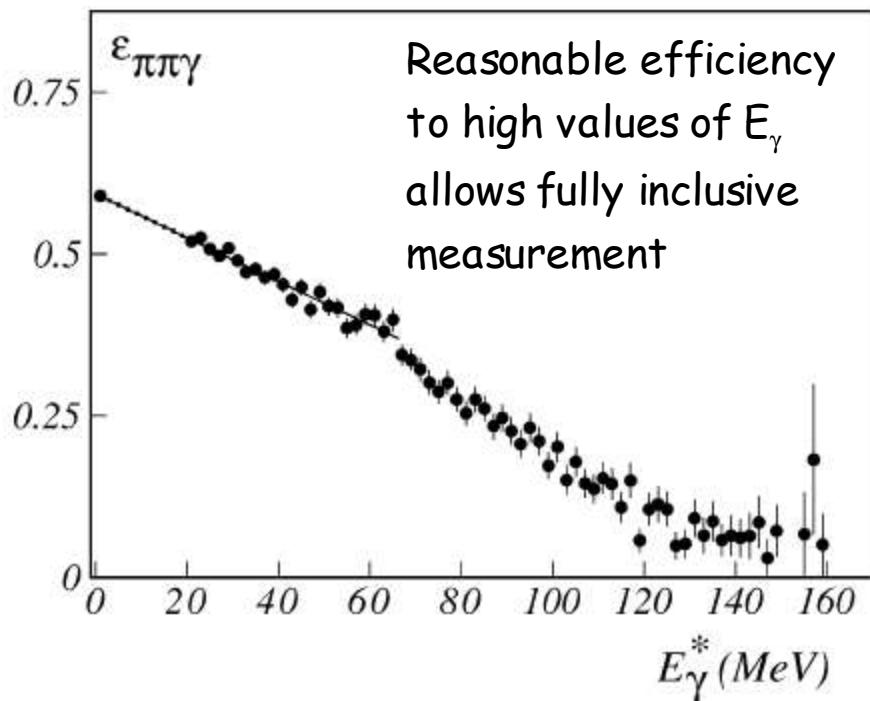
but $B(K_s \rightarrow e^+ e^- \pi^0) \sim 6 \times 10^{-9}$ (NA48 with 7 events)



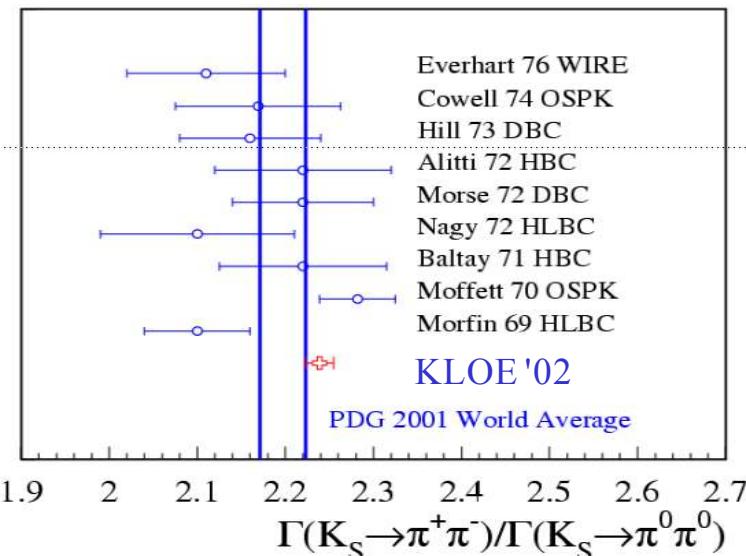


$\Gamma(K_s \rightarrow \pi^+\pi^-(\gamma)) / \Gamma(K_s \rightarrow \pi^0\pi^0)$

- ✓ First part of double ratio for $\Re(\epsilon'/\epsilon)$
- ✓ Provides information on EM isospin breaking in $K \rightarrow \pi\pi$ decays
- ✓ Can extract $\delta_0 - \delta_2$ if effective E_γ cutoff known for $\pi\pi\gamma$ channel



PDG '02	2.197 ± 0.026 (avg.)
KLOE '02	$2.236 \pm 0.003 \pm 0.015$ (17 pb ⁻¹ '00 data)



Systematic error dominates
 2000: 0.7% (tagging dominates)
 NOW: work in progress to reach O(0.1%)



Extraction of $\delta_0 - \delta_2$

Extraction of strong phase shifts from $K \rightarrow \pi\pi$

$$A_+ = (2/3)^{1/2}(A_0 + A_0)e^{i(\chi_0)} + (1/3)^{1/2}(A_2 + A_2)e^{i(\chi_2)}$$

$$A_{00} = (1/3)^{1/2}(A_0 + A_0)e^{i(\chi_0)} - (2/3)^{1/2}(A_2 + A_2)e^{i(\chi_2)}$$

$$A_{+0} = (3/4)^{1/2}(A_2 + A_2^+)e^{i(\chi_2+)}$$

$$\chi_i = \delta_i + \gamma_i; \quad \delta A_2 = \delta A_{3/2} + A_{5/2}; \quad \delta A_2^+ = \delta A_{3/2} - 2/3 A_{5/2}$$

$$\delta_0 - \delta_2$$

$$(47.7 \pm 1.5)^\circ$$

$\pi\pi$ scattering
(Colangelo et al. '01)

$$(45 \pm 6)^\circ$$

χ^{PT}
(Gasser & Meissner 91)

Analyses by
Cirigliano et al.

hep-ph/0008290

hep-ph/0310351

PDG

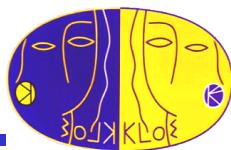
	Tree level	No Isospin breaking	Isospin breaking
$\chi_0 \chi_2$ $(57 \pm 4)^\circ$		$(57 \pm 8)^\circ$	$(60 \pm 8)^\circ$
	$\delta_0 \delta_2$	$(63 \pm 8 \pm 3)^\circ$	$(66 \pm 8 \pm 3)^\circ$
$\chi_0 \chi_2$ $(48 \pm 3)^\circ$		$(51 \pm 3)^\circ$	$(55 \pm 3)^\circ$
	$\delta_0 \delta_2$	$(57 \pm 3 \pm 3)^\circ$	$(61 \pm 3 \pm 3)^\circ$

$$) \quad \gamma_0 - \gamma_2 = 3 + 3 \pm 3$$

$$O(e^2 p^i)^0 \quad ^2$$

KLOE '02

Simulation radiative K decay



Motivations:

efficiencies evaluation @ <1% accuracy

shape of kinematic variables

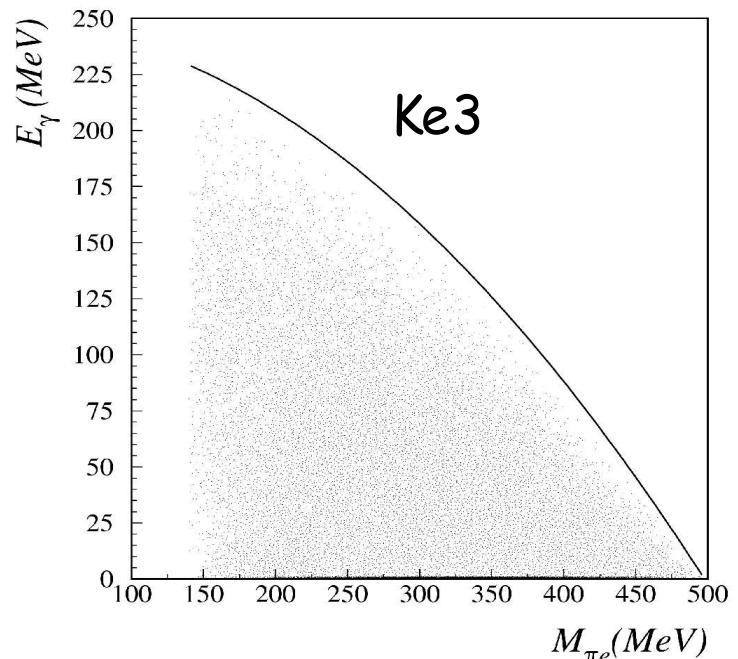
→ no threshold on photon(s) energy

Use exponentiation method:

$$\frac{d\Gamma}{dE} = \frac{a_{-1}}{(E/M)} + a_0 + a_1 \frac{E}{M} + \dots = \frac{M}{E} \left(a_{-1} + a_0 \frac{E}{M} + a_1 \left(\frac{E}{M} \right)^2 + \dots \right)$$

\downarrow

$$\frac{M}{E} \Rightarrow \left(\frac{M}{E} \right)^{1-\alpha \cdot b}$$



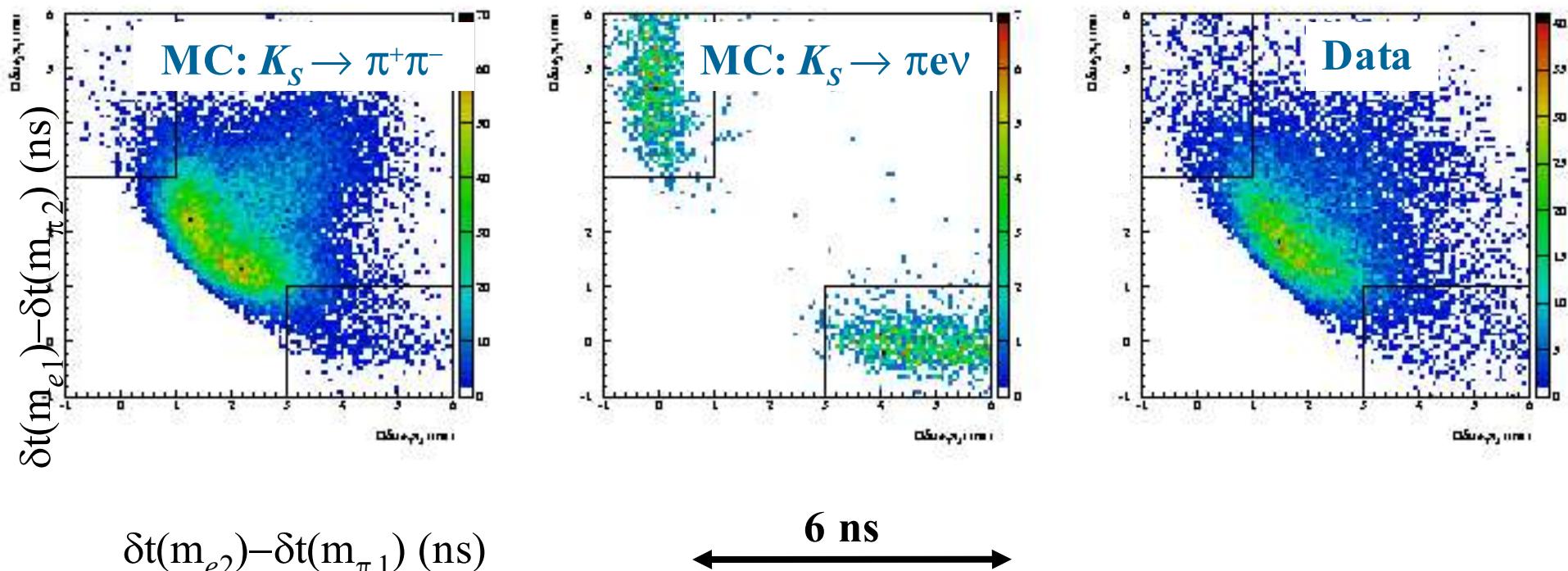
Correct behaviour for low energy photons, and small correction for higher energies (~ % since $\alpha b \sim 0.01$).

Collaboration with
G. Isidori



$K_S \rightarrow \pi e v$: selection

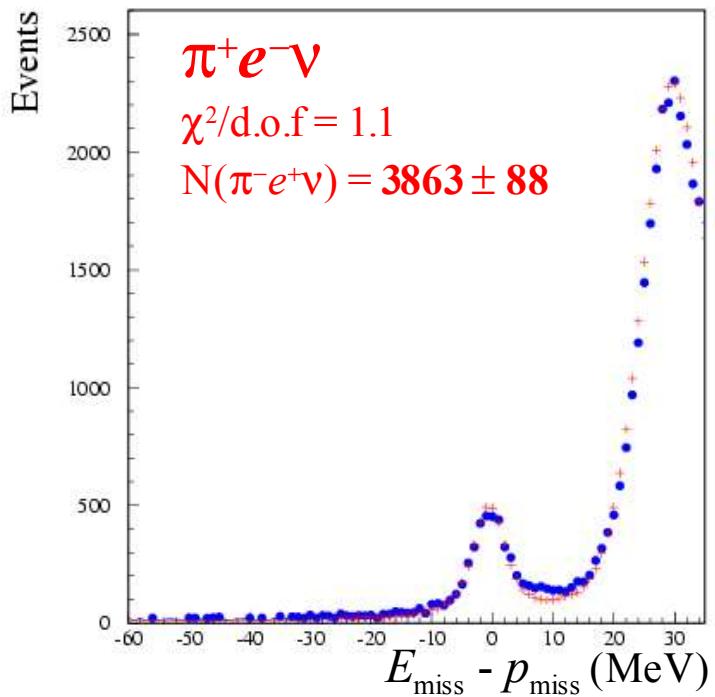
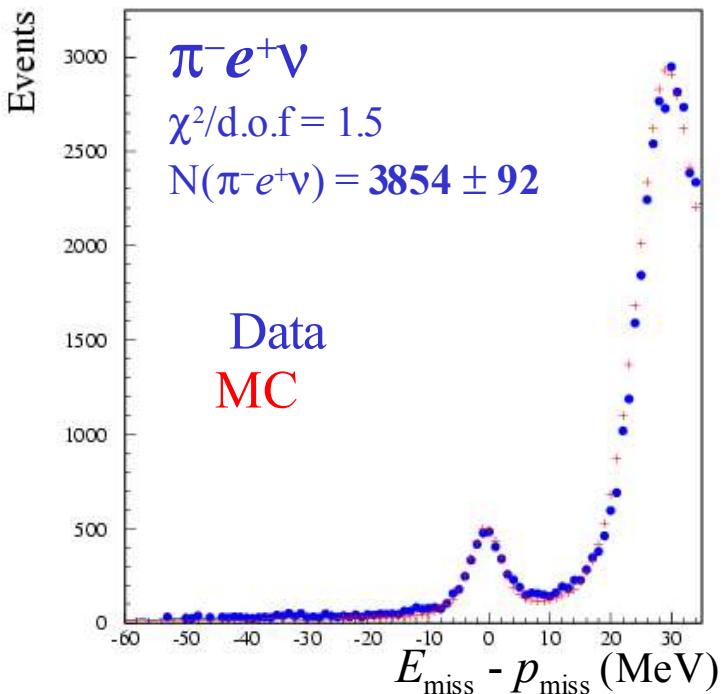
- ❖ Charged vertex at IP \rightarrow two tracks ($M_{\pi\pi} \neq M_K$)
- ❖ Both tracks associated to calorimeter clusters
- ❖ Time of flight e/π identification ($\Delta t \sim 2$ ns) : $\delta t(m) = t_{\text{cluster}} - \text{ToF}$
(ToF calculated with mass hypothesis m)





$K_s \rightarrow \pi e\nu$: BR Evaluation

Fit to the $E_{\text{miss}} - p_{\text{miss}}$ distribution with MC shape for signal and background

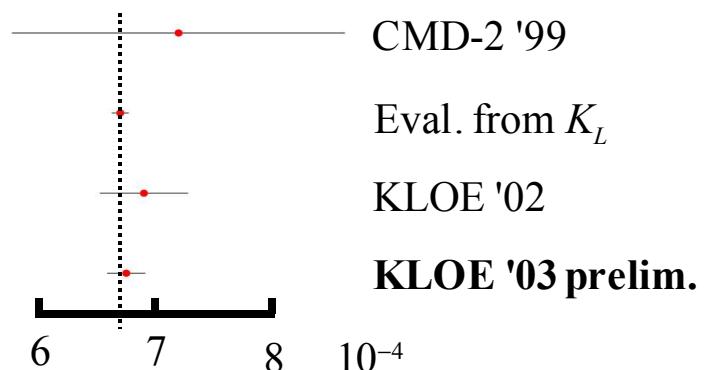


KLOE preliminary (170 pb⁻¹ '01 data)

$$\text{BR}(\pi^- e^+ \nu) = (3.46 \pm 0.09 \pm 0.06) 10^{-4}$$

$$\text{BR}(\pi^+ e^- \nu) = (3.33 \pm 0.08 \pm 0.05) 10^{-4}$$

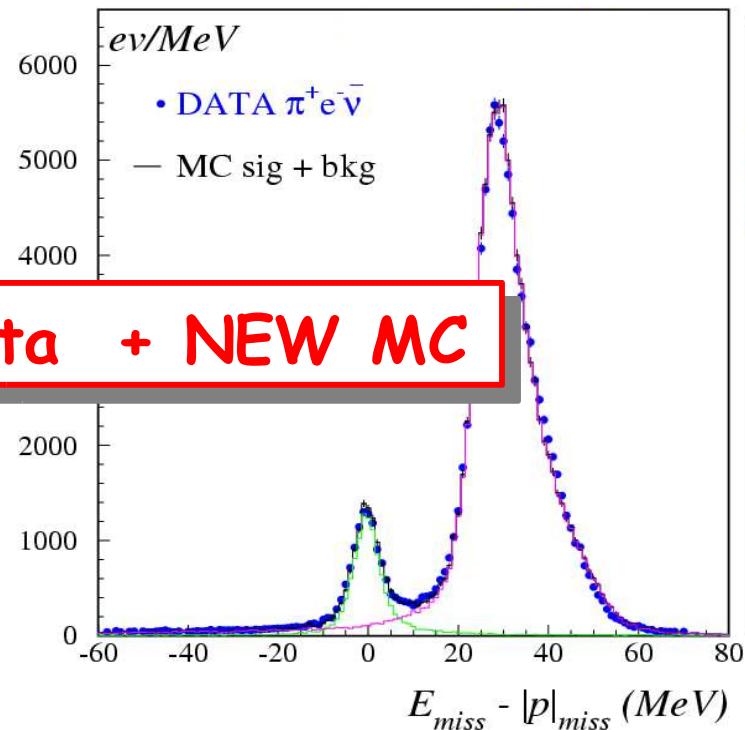
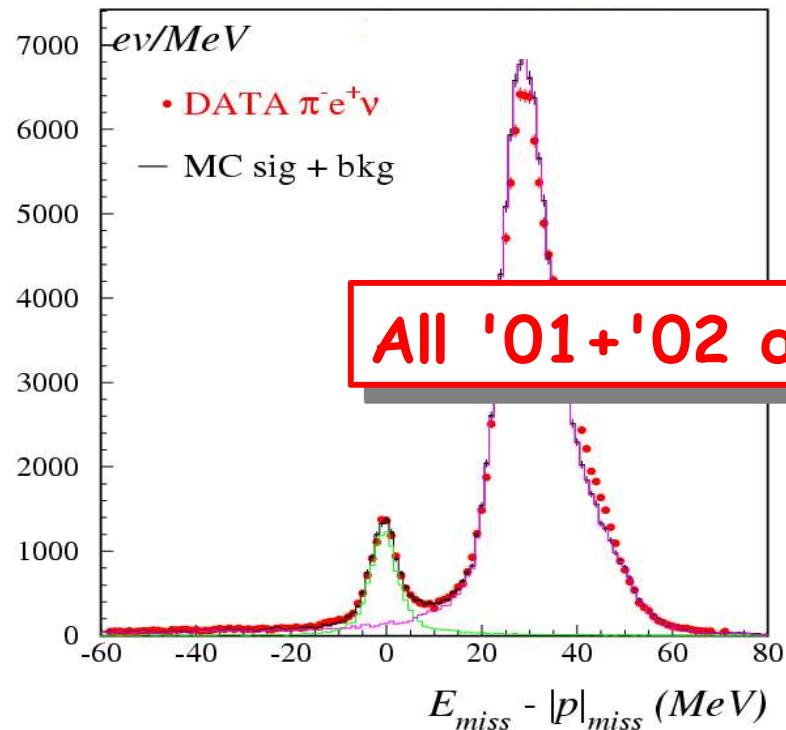
$$\text{BR}(\pi^\mp e^\pm \nu) = (6.81 \pm 0.12 \pm 0.10) 10^{-4}$$





$K_S \rightarrow \pi e\nu$: BR Evaluation

Fit to the $E_{\text{miss}} - p_{\text{miss}}$ distribution with MC shape for signal and background

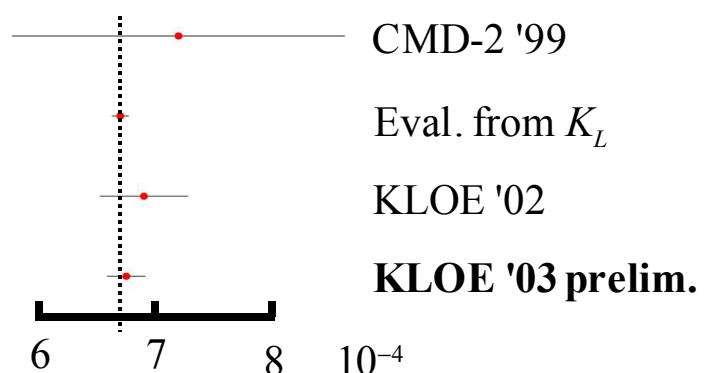


KLOE preliminary (170 pb⁻¹ '01 data)

$$\text{BR}(\pi^- e^+ \nu) = (3.46 \pm 0.09 \pm 0.06) 10^{-4}$$

$$\text{BR}(\pi^+ e^- \nu) = (3.33 \pm 0.08 \pm 0.05) 10^{-4}$$

$$\text{BR}(\pi^\mp e^\pm \nu) = (6.81 \pm 0.12 \pm 0.10) 10^{-4}$$





$K_S \rightarrow \pi e \nu$ and CPT

$$\begin{aligned} \langle \pi^- e^+ \bar{\nu} | H_W | K^0 \rangle &= a + b \\ \langle \pi^+ e^- \bar{\nu} | H_W | \bar{K}^0 \rangle &= a^* - b^* \\ \langle \pi^+ e^- \bar{\nu} | H_W | \bar{K}^0 \rangle &= c + d \\ \langle \pi^- e^+ \bar{\nu} | H_W | K^0 \rangle &= c^* - d^* \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \Delta S = \Delta Q \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \Delta S \neq \Delta Q$$

CPT

Asymmetry for K_S, K_L :

$$A_S = 2(\operatorname{Re} \varepsilon_K + \operatorname{Re} \delta_K + \operatorname{Re} b/a - \operatorname{Re} d^*/a)$$

$$A_L = 2(\operatorname{Re} \varepsilon_K - \operatorname{Re} \delta_K + \operatorname{Re} b/a + \operatorname{Re} d^*/a)$$

$A_S - A_L \neq 0$ implies ~~CPT~~

CP

CPT in mixing

CPT in decay

$\Delta S \neq \Delta Q$
and ~~CPT~~

KLOE preliminary (170 pb⁻¹ '01 data)

$$A_S = (19 \pm 17 \pm 6) \cdot 10^{-3}$$

First measurement of A_S !

Asymmetry definition:

$$A \equiv \frac{\Gamma(\pi^- e^+ \bar{\nu}) - \Gamma(\pi^+ e^- \bar{\nu})}{\Gamma(\pi^- e^+ \bar{\nu}) + \Gamma(\pi^+ e^- \bar{\nu})}$$

KTeV '02 result for A_L

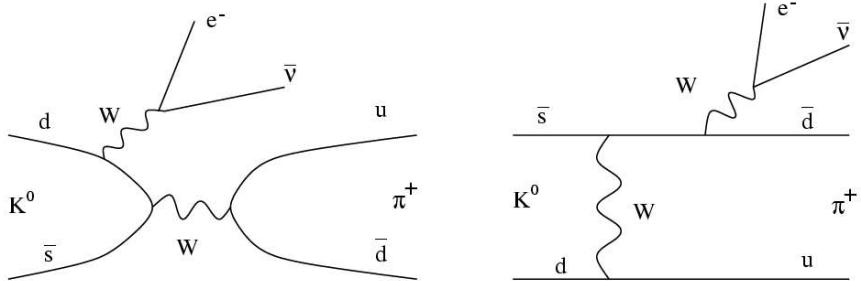
$$A_L = (3.322 \pm 0.058 \pm 0.047) \cdot 10^{-3}$$



$K_S \rightarrow \pi e\nu$ and $\Delta S = \Delta Q$

No $\Delta S \neq \Delta Q$ transitions at lowest order

$\Delta S \neq \Delta Q$ in higher order transitions



$$\text{Re } x_+ = \frac{1}{2} \frac{\text{BR}_S(\pi e\nu)/\tau_S - \text{BR}_L(\pi e\nu)/\tau_L}{\text{BR}_S(\pi e\nu)/\tau_S + \text{BR}_L(\pi e\nu)/\tau_L}$$

KLOE preliminary ($\tau_{S,L}$ and BR_L from PDG)

$$\text{Re } x_+ = (3.3 \pm 5.2 \pm 3.5) \cdot 10^{-3}$$

$$x = (c^* - d^*)/(a + b)$$

$\Delta S \neq \Delta Q$ in K^0 decay to e^+

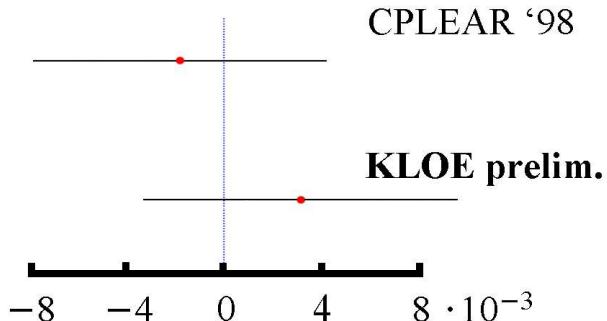
$$\bar{x} = (c + d)/(a^* - b^*)$$

$\Delta S \neq \Delta Q$ in K^0 decay to e^-

$$x_+ = (x + \bar{x})/2 = c^*/a$$

$\Delta S = \Delta Q$ if CPT conserved

SM prediction: $|x| \sim 10^{-7}$





BRs of K_L

- ✓ Preliminary results on charged modes

$$\pi^+\pi^-\pi^0 \quad 0.132 \pm 0.002$$

$$\pi\mu\nu \quad 0.271 \pm 0.002$$

$$\pi e\nu \quad 0.384 \pm 0.002$$

- ✓ Only statistical error quoted

Road to $\delta BR < 1\%:$

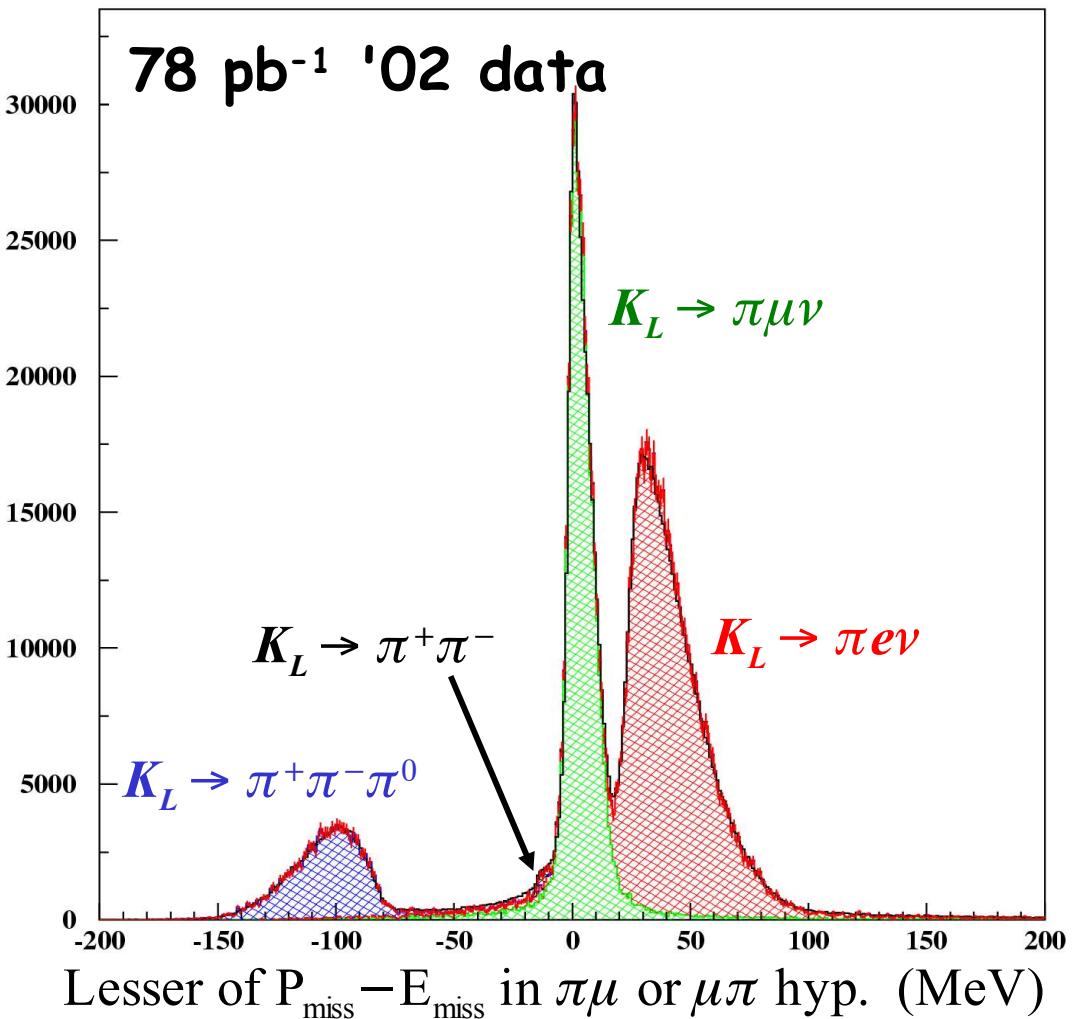
- control tracking and tag s
- include $3\pi^0$ channel
- shapes ->

high sensitivity to final state
radiation treatment in MC
generators

compare results with predictions:

$BR = 1, 3\pi^0/\pi^+\pi^- \pi^0, \pi e\nu/\pi\mu\nu$

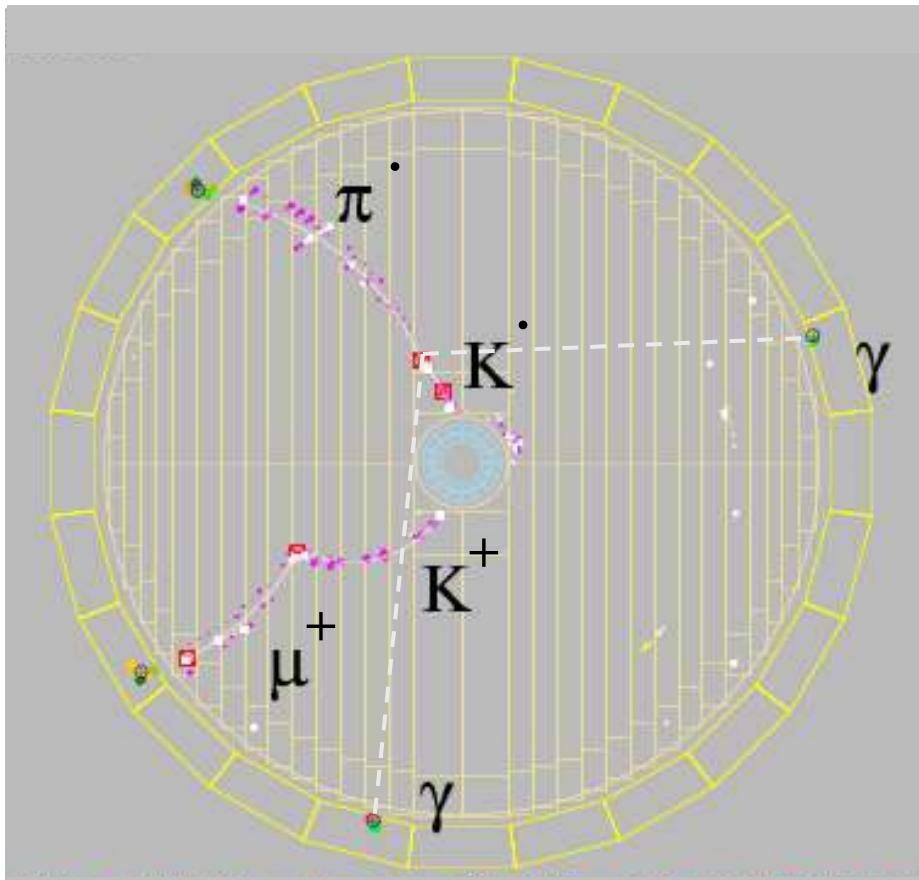
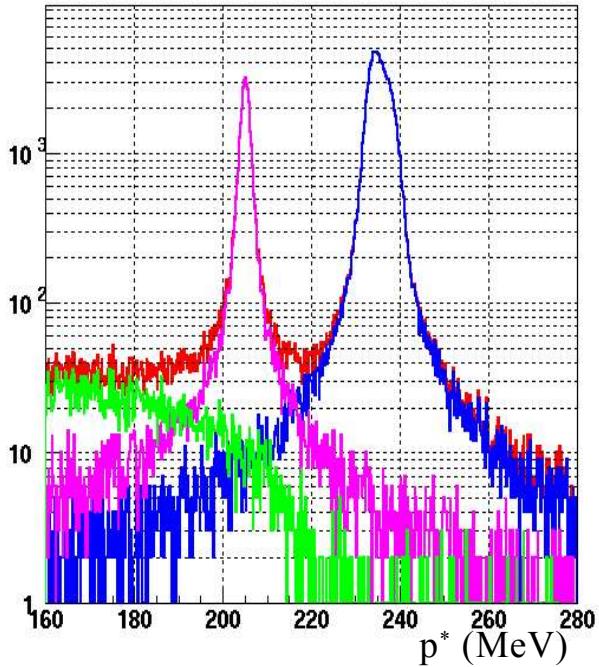
Very preliminary





Charged Kaons: tagging

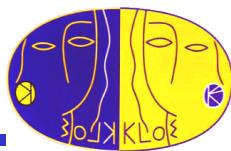
K^\pm tagging performed using $\mu^\pm\nu_\mu, \pi^\pm\pi^0$
decays: **6x10⁵ tags/pb⁻¹**



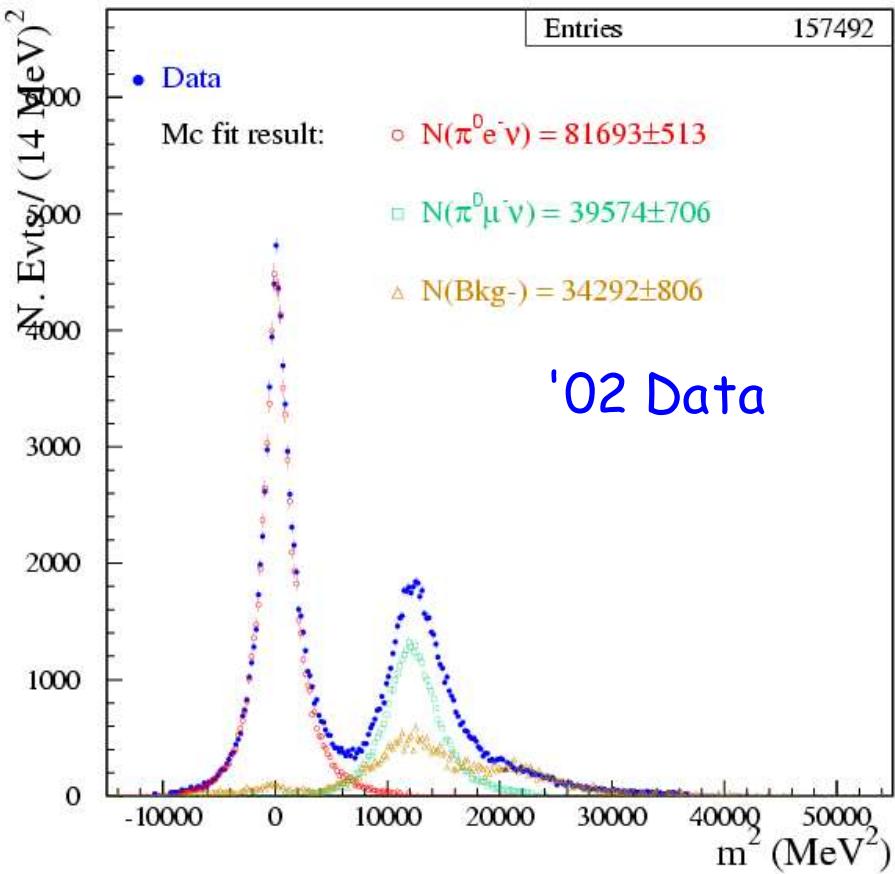
$$\phi \rightarrow K^+ K^- ; K^\pm \rightarrow \mu^\pm \nu_\mu , K^\pm \rightarrow \pi^\pm \pi^0$$

p^* peaks are used to tag K^\pm , where p^* is the charged daughter momentum in K^\pm rest frame

Charged Kaons: $K_{\ell 3}$ BR measurement



Absolute BR measurements for all channels in progress

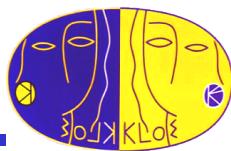


$K_{\ell 3}$ event selection:
charged daughter mass with
ToF

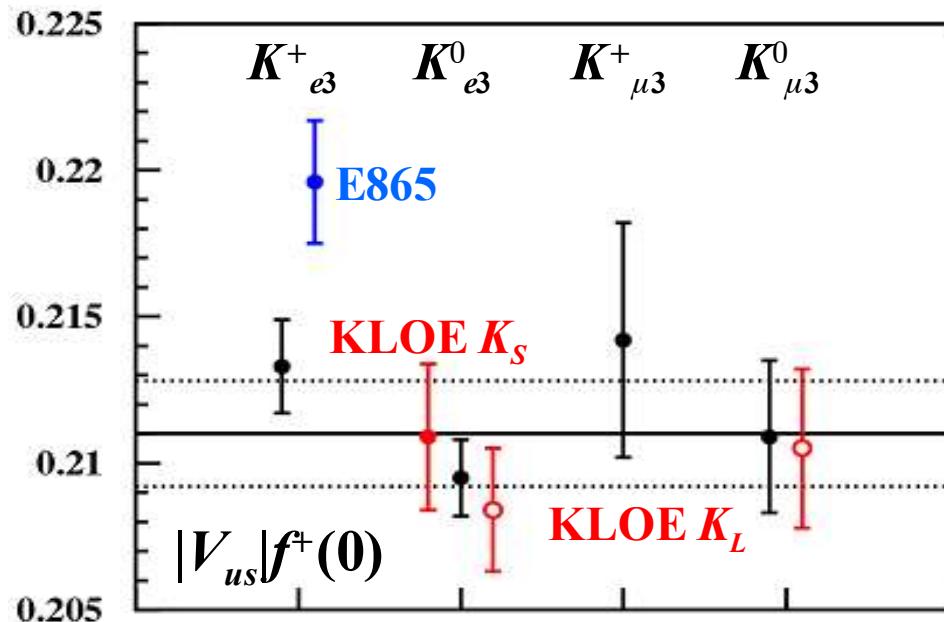
$$t_{lept}^{decay} = t_{lept} - \frac{L_{lept}}{p_{lept} c} \sqrt{p_{lept}^2 + m_{lept}^2}.$$

$$m_{lept}^2 = p_{lept}^2 \cdot \left[\frac{c^2}{L_{lept}^2} \left(t_{lept} - \frac{(t_1 - L_1/c) + (t_2 - L_2/c)}{2} \right)^2 - 1 \right]$$

V_{us} from $K_{\ell 3}$ decays



CKM WG inputs to V_{us}			
Mode	BR(%)	$10^3 \lambda_+$	$10^3 \lambda_0$
K^+_{e3}	4.87 ± 0.06	27.8 ± 1.9	
K^0_{e3}	38.79 ± 0.27	29.1 ± 1.8	
$K^+_{\mu 3}$	3.27 ± 0.06	33 ± 10	4 ± 9 ?
$K^0_{\mu 3}$	27.18 ± 0.25	33 ± 5	27 ± 6
τ_L	$(5.17 \pm 0.04) \times 10^{-8} \text{ s}$		
τ_S	$(8.9598 \pm 0.0007) \times 10^{-11} \text{ s}$		
τ_+	$(1.2384 \pm 0.0024) \times 10^{-8} \text{ s}$		



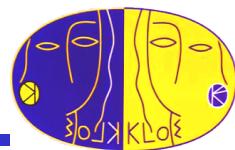
For K_{e3} modes:

$$\frac{\delta |V_{us}|}{|V_{us}|} = \underbrace{\frac{1}{2} \left(\frac{\delta \text{ BR}}{\text{BR}} \right)}_{\text{exp}} \oplus \underbrace{\frac{1}{2} \left(\frac{\delta \tau}{\tau} \right)}_{\text{th}} \oplus \frac{1}{20} \left(\frac{\delta \lambda_+}{\lambda_+} \right) \oplus \underbrace{\frac{\delta f_+(0)}{f_+(0)}}_{\text{th}}$$

$$|V_{us}| = 0.2201 \pm 0.0016_{\text{exp}} \pm 0.0018_{\text{th}}$$

? New precise measurement of $\lambda_0 = (18 \pm 1.3) \times 10^{-3}$ from charged kaons by ISTRA+ (hep-ex/0312004)

- ✓ KLOE preliminary BR's confirm previous values for K^0_{e3} , $K^0_{\mu 3}$
- ✓ KLOE will have $\text{BR}(K^+_{e3})$ soon
- ✓ KLOE will measure all BR's to < 1% and can also significantly improve λ_+ , λ_0 , τ_L



A first glance at interference

$K_S K_L$ initially in pure quantum state:

Relative time distribution for decay to two given final states shows interference

$$K_S K_L \rightarrow \pi^+ \pi^- \pi^+ \pi^- : |A(\Delta t)|^2 \propto e^{-\Gamma_L |\Delta t|} + e^{-\Gamma_S |\Delta t|} - 2e^{-(\Gamma_S + \Gamma_L)|\Delta t|/2} \cos(\Delta m \Delta t)$$

PDG '02:

$$\Delta m = (5.301 \pm 0.016) \cdot 10^{-11} \text{ s}^{-1}$$

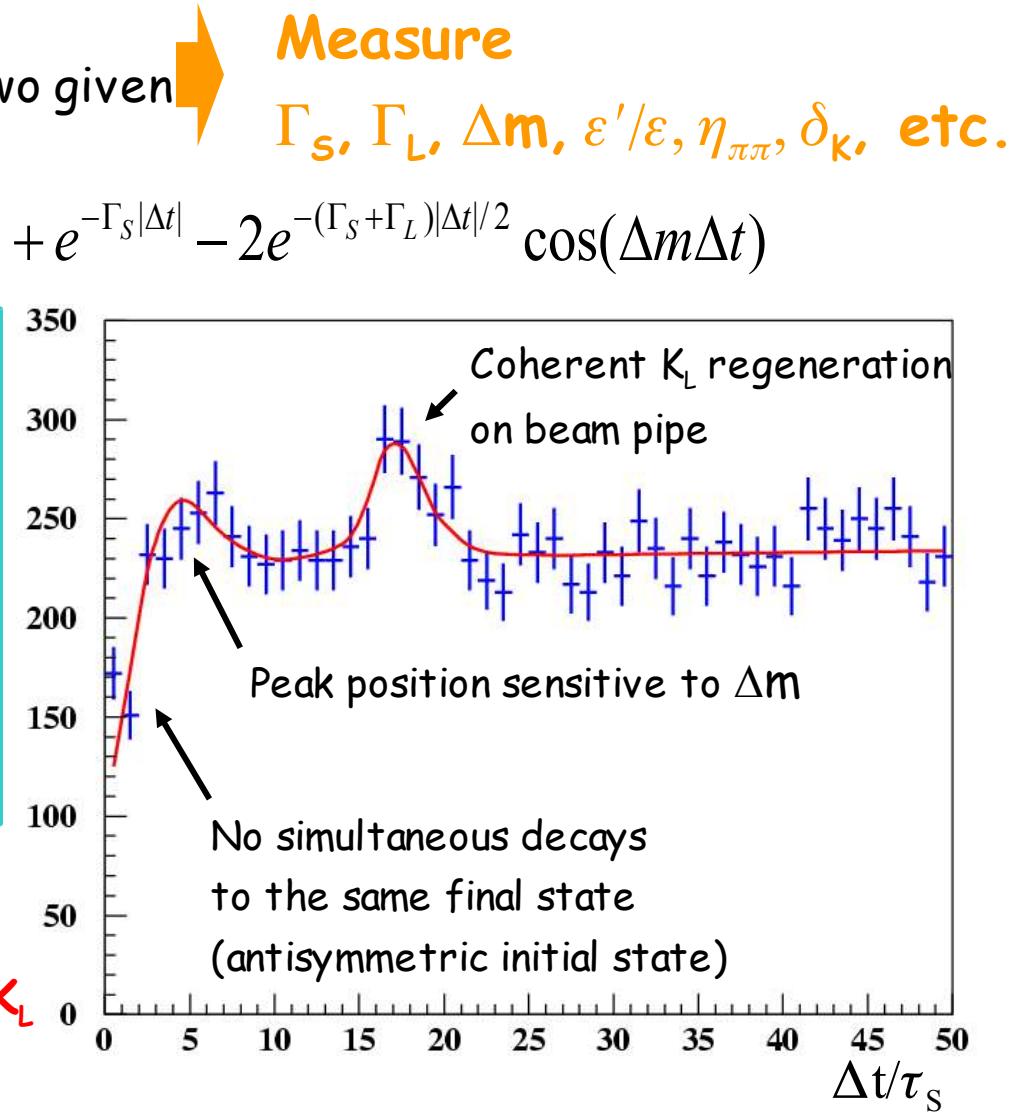
KLOE Preliminary :

$$\Delta m = (5.64 \pm 0.37) \cdot 10^{-11} \text{ s}^{-1}$$

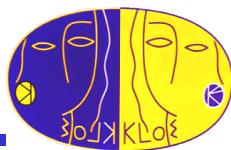
- 340 pb⁻¹ '01+'02 data
- Fit with PDG values for Γ_S, Γ_L

First observation of quantum interference in relative decay-time distribution of K_S, K_L decoherence parameters

$$\zeta_{KSKL} = 0.12 \pm 0.08; \zeta_{KOKO} = (0.8 \pm 0.5) \times 10^{-5}$$



“Non-Kaon” physics @ KLOE



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

Phys. Lett. **B561**, 55 (2003)

$\eta \not\rightarrow \gamma\gamma$ search

Submitted to Phys. Lett. B (hep-ex/0307042)

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

Preliminary results

$\phi \rightarrow \eta' \gamma$

Phys. Lett. **B541**, 45 (2002)

Preliminary update with new data

$\phi \rightarrow f_0 \gamma, a_0 \gamma$

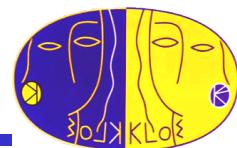
Phys. Lett. **B536**, 209 (2002)

Phys. Lett. **B537**, 21 (2002)

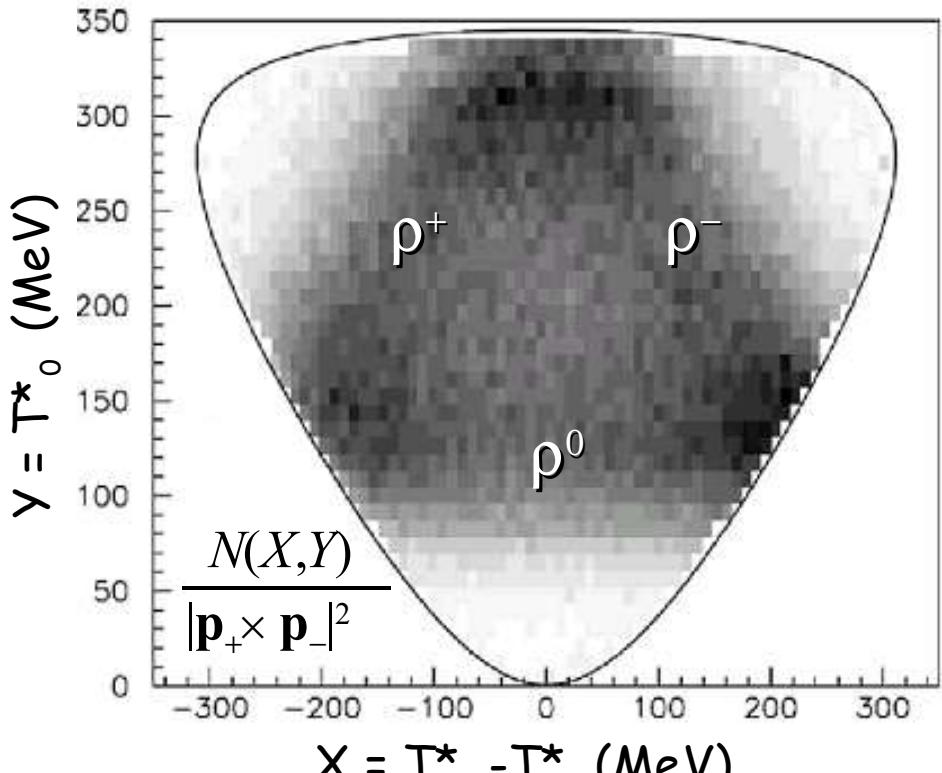
Preliminary update with new data

$\sigma(e^+ e^- \rightarrow \text{hadrons})$

next talk



Dynamics of the $\phi \rightarrow \pi^+ \pi^- \pi^0$ decay



Fit parameters:

- ❖ M_ρ, Γ_ρ For ρ^+, ρ^-, ρ^0
- ❖ $|A_{\text{dir}}|, \phi_{\text{dir}}$ Amplitudes of direct term
- ❖ $|A_{\omega\pi}|, \phi_{\omega\pi}$ and $\omega\pi$ contributions

17 pb⁻¹ '00 data, 2×10^6 events :

$$M_\rho = 775.8 \pm 0.5 \pm 0.3 \text{ MeV}$$

$$\Gamma_\rho = 143.9 \pm 1.3 \pm 1.1 \text{ MeV}$$

$$M_0 - M_\pm = 0.4 \pm 0.7 \pm 0.6 \text{ MeV}$$

$$M_+ - M_- = 1.5 \pm 0.8 \pm 0.7 \text{ MeV}$$

Relative decay intensities from integration of $|A|^2$ over Dalitz plot:

$$\left. \begin{array}{l} I_{\rho\pi} = 0.937 \\ I_{\text{dir}} = 0.0085 \\ I_{\omega\pi} = 0.0002 \end{array} \right\} \begin{array}{l} \text{Interference:} \\ I_{\rho\pi} + I_{\text{dir}} + I_{\omega\pi} \neq 1 \end{array}$$

$$\sigma(e^+ e^- \rightarrow \omega\pi^0 \rightarrow \pi^+ \pi^- \pi^0) = 92 \pm 15 \text{ pb}$$

Next: studies vs c.m. energy

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

Study of Dalitz plot sensitive to $u-d$ quark mass difference and sheds light on isospin-breaking mechanisms

Fit with a, b, d free parameters
 c, e fixed to zero

	<i>Stat. errors only</i>	
	PDG	KLOE
a	-1.08 ± 0.014	-1.05 ± 0.01
b	0.034 ± 0.027	0.20 ± 0.03
d	0.046 ± 0.031	0.05 ± 0.03

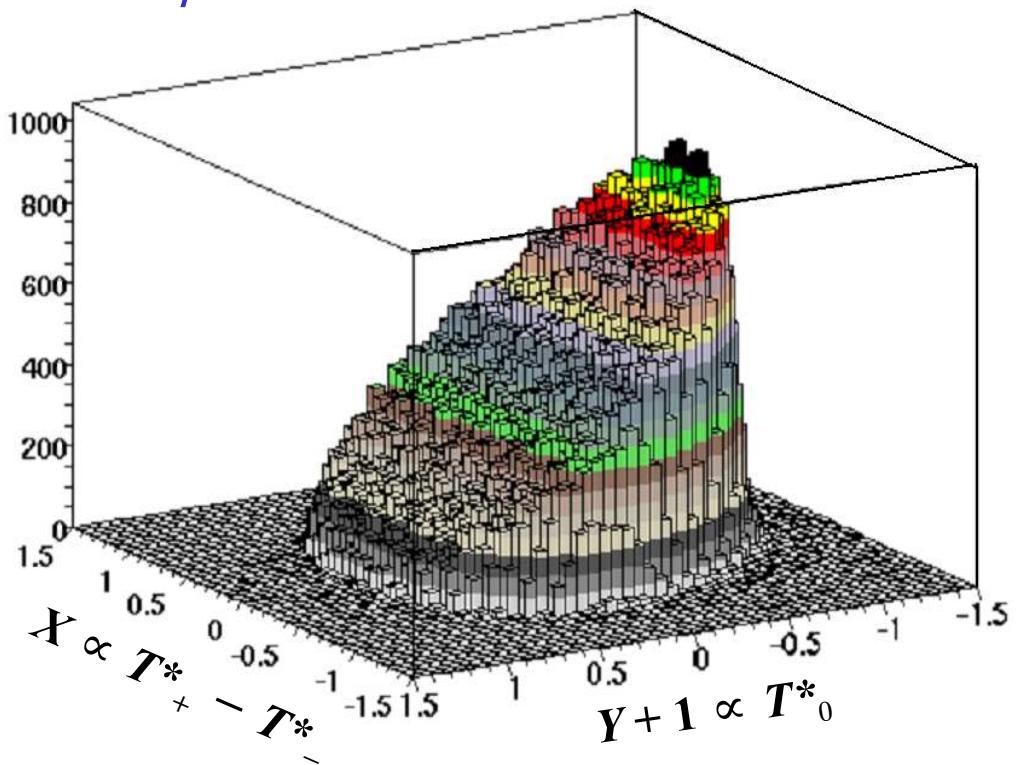
When treated as free parameters:

$$c = -0.008 \pm 0.010$$

$$e = 0.01 \pm 0.03$$

$c, e \neq 0 \rightarrow C$ violation in $\eta \rightarrow 3\pi$

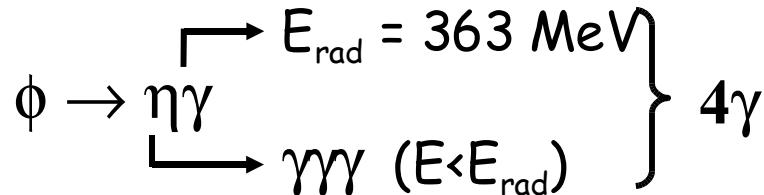
KLOE preliminary, $\sim 100 \text{ pb}^{-1}$
352K $\eta \rightarrow \pi^+ \pi^- \pi^0$ events



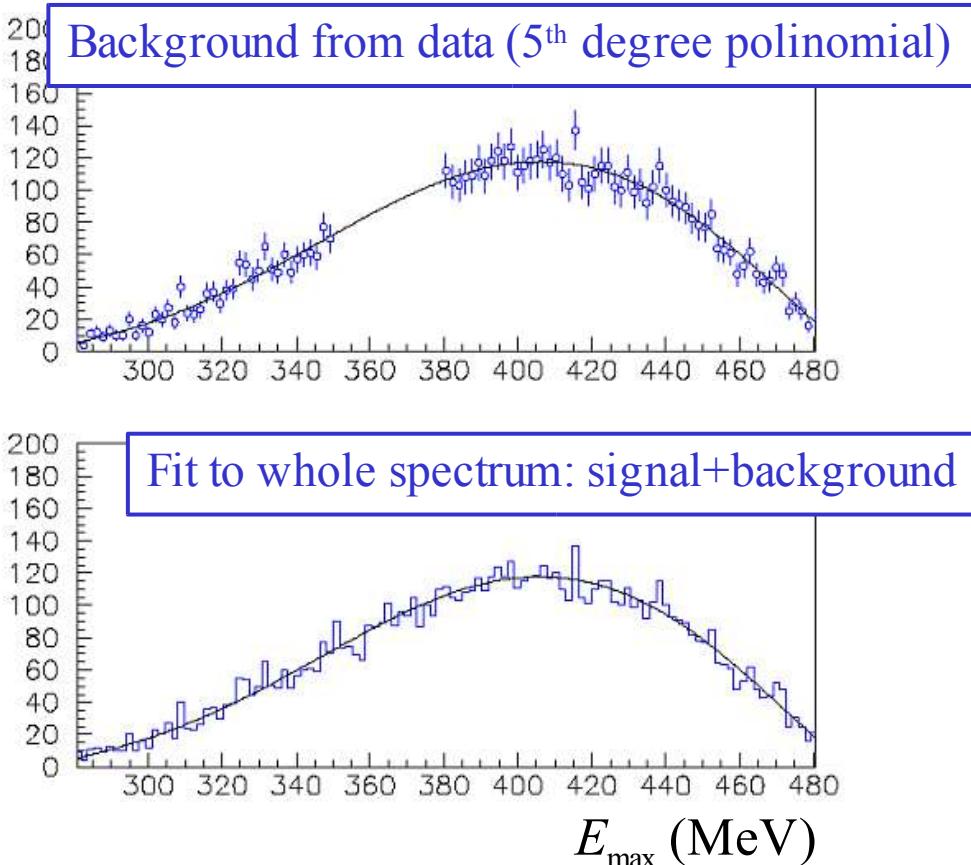
Expansion of Dalitz plot:
 $A(X, Y) \propto 1 + aY + bY^2 + cX + dX^2 + eXY$



Search for C violating events: $\eta \rightarrow \gamma\gamma\gamma$



- ❖ Reclustering to reduce 3γ background
- ❖ Preselection: 4 prompt neutral clusters with $E > 50 \text{ MeV}, |\cos\theta| < 0.91$
- ❖ $\theta_\gamma > 15^\circ$ to further reduce 3γ background
- ❖ Kinematic fit
- ❖ $M(\pi^0)$ veto eliminates $e^+e^- \rightarrow \omega\pi^0$ ($\omega \rightarrow \pi^0\gamma$) and 5γ background



KLOE '03: $\text{BR}(\eta \rightarrow \gamma\gamma\gamma) \leq 1.7 \times 10^{-5}$ @ 90% CL
 410 pb⁻¹ '01+'02 data $17 \times 10^6 \phi \rightarrow \eta\gamma$

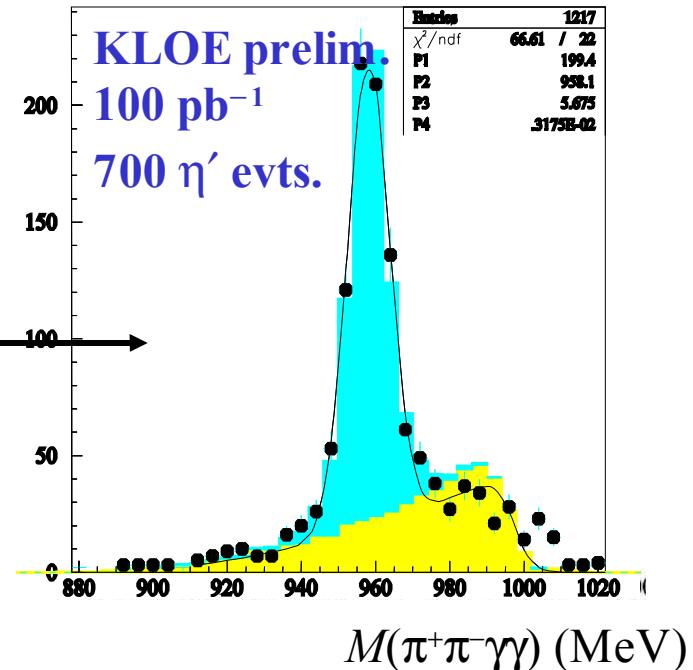
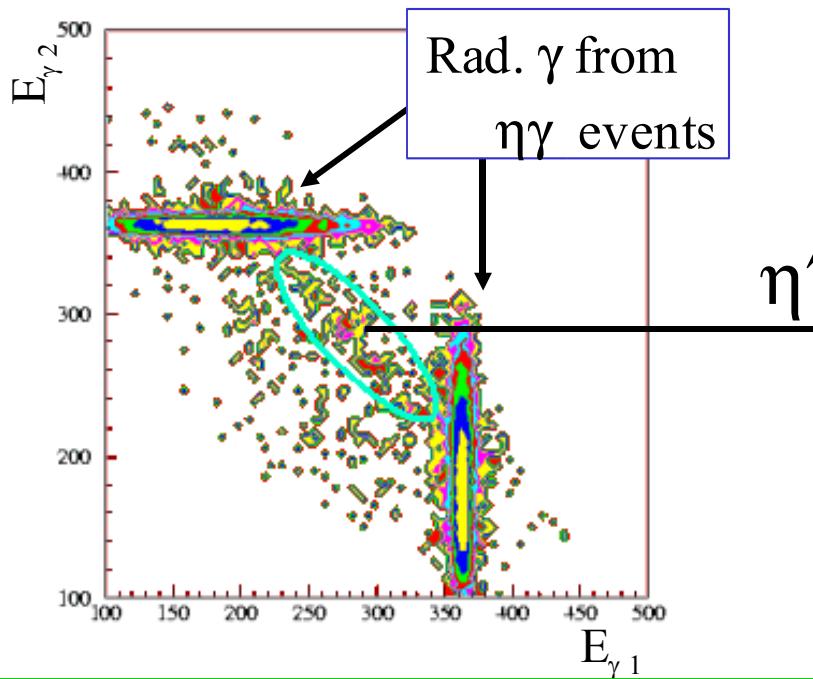
PDG '02 (GAMS2000): 5×10^{-4} 95% CL
 Crystal Ball '02 prelim: 1.8×10^{-5} 90% CL



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

$$\begin{aligned} \phi \rightarrow \eta'\gamma &\rightarrow \pi^+\pi^-\eta\gamma \\ \phi \rightarrow \eta\gamma &\rightarrow \pi^+\pi^-\pi^0\gamma \end{aligned}$$

R measured from $\pi^+\pi^-3\gamma$ final state
Same topology but different kinematics in the final state



KLOE '02: $R = (4.70 \pm 0.47_{\text{stat}} \pm 0.31_{\text{syst}}) \times 10^{-3}$
17 pb⁻¹ '00 data 124 $\phi \rightarrow \eta'\gamma$

- Using the PDG value for $\text{BR}(\phi \rightarrow \eta\gamma)$: $\text{BR}(\phi \rightarrow \eta'\gamma) = (6.10 \pm 0.61_{\text{stat}} \pm 0.43_{\text{syst}}) \times 10^{-5}$
- Pseudoscalar mixing angle: $\varphi_p = (41.8^{+1.9}_{-1.6})^\circ$ (flavor) $\vartheta_p = (-12.9^{+1.9}_{-1.6})^\circ$ (octet-singlet)
According to Bramon et al., Eur. Phys. J. C7 (1999)

Gluon content of η'

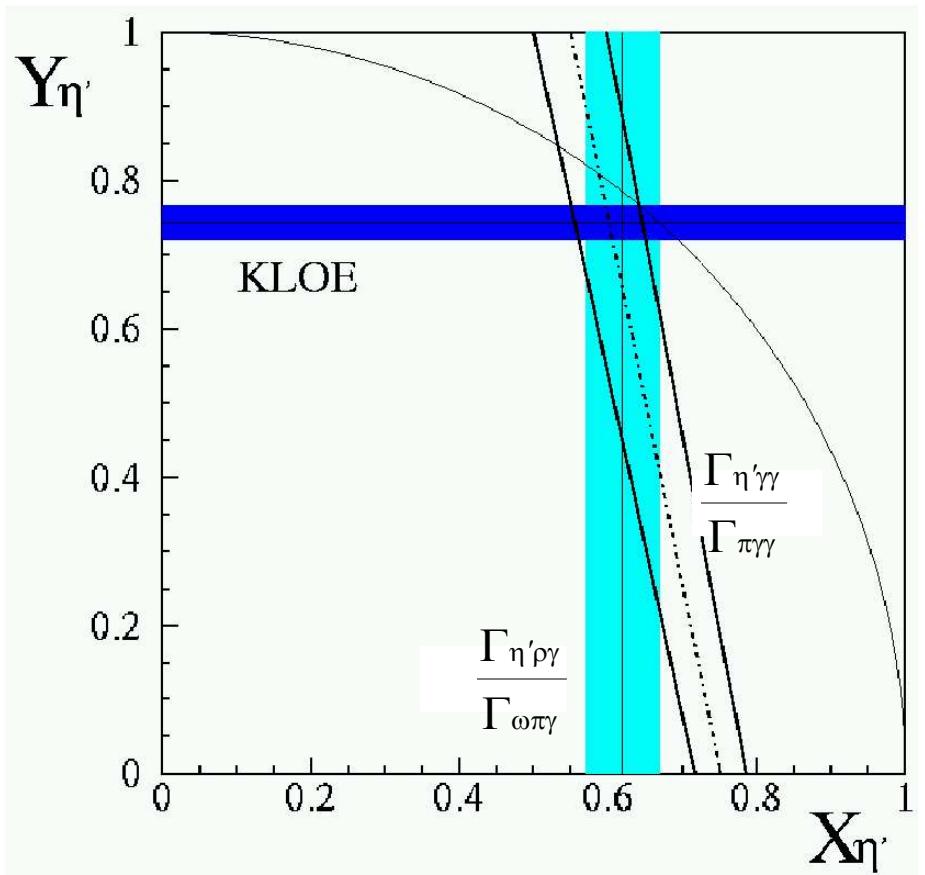
Combined analysis to evaluate the possible gluon content of η'

$$\eta' = X_{\eta'} |\bar{u}u + \bar{d}d\rangle/\sqrt{2} + Y_{\eta'} |\bar{s}s\rangle + Z_{\eta'} |\bar{g}g\rangle$$

Assuming $Z_{\eta'} = 0$:

1. Constraints on $X_{\eta'}$, $Y_{\eta'}$ from other channels
2. $Y_{\eta'} = \cos \varphi_P$ from KLOE
3. Check consistency in the $X_{\eta'} \cdot Y_{\eta'}$ plane with $X_{\eta'}^2 + Y_{\eta'}^2 = 1$

Minimizing the related χ^2 function:



$$Z_{\eta'}^2 = 0.06^{+0.09}_{-0.06}$$



Scalar mesons: $f_0(980)$ and $a_0(980)$

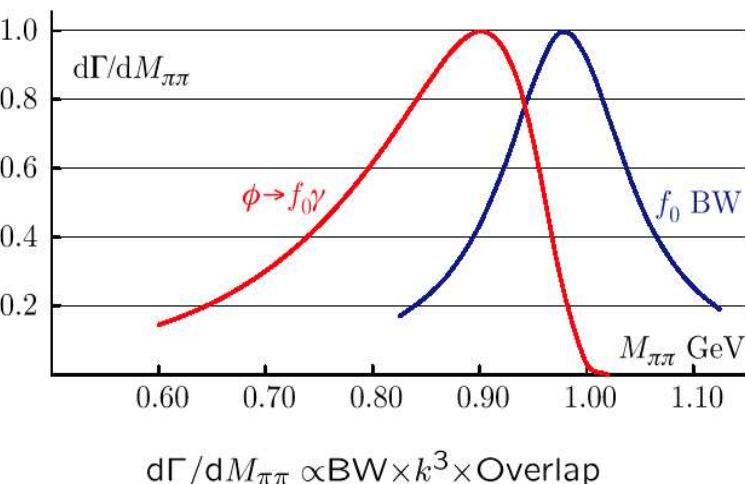
- ❖ $f_0(980)$ and $a_0(980)$ scalar mesons (S) **not easily interpreted as $2q$ states**
- ❖ Other interpretations suggested:
 - \Rightarrow **4q states** [Jaffe 1977]
 - \Rightarrow **KK molecule** [Weinstein, Isgur 1990]

Both $BR(\phi \rightarrow S\gamma)$ and **scalar mass spectra** are sensitive to their nature
 $[Achasov, Ivanchenko 1989]$

In $\phi \rightarrow S\gamma$ decays, the f_0 and a_0 mass shape is distorted by the emission of the radiative photon

$Overlap = structure\ dependent\ function$
 $k = scalar\ momentum$

	$BR(\phi \rightarrow f_0\gamma)$	$BR(\phi \rightarrow a_0\gamma)$
qq	$5 \cdot 10^{-5}$	$2 \cdot 10^{-5}$
$qqqq$	$3 \cdot 10^{-4}$	$2 \cdot 10^{-4}$
KK	10^{-5}	10^{-5}





$$\phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma$$

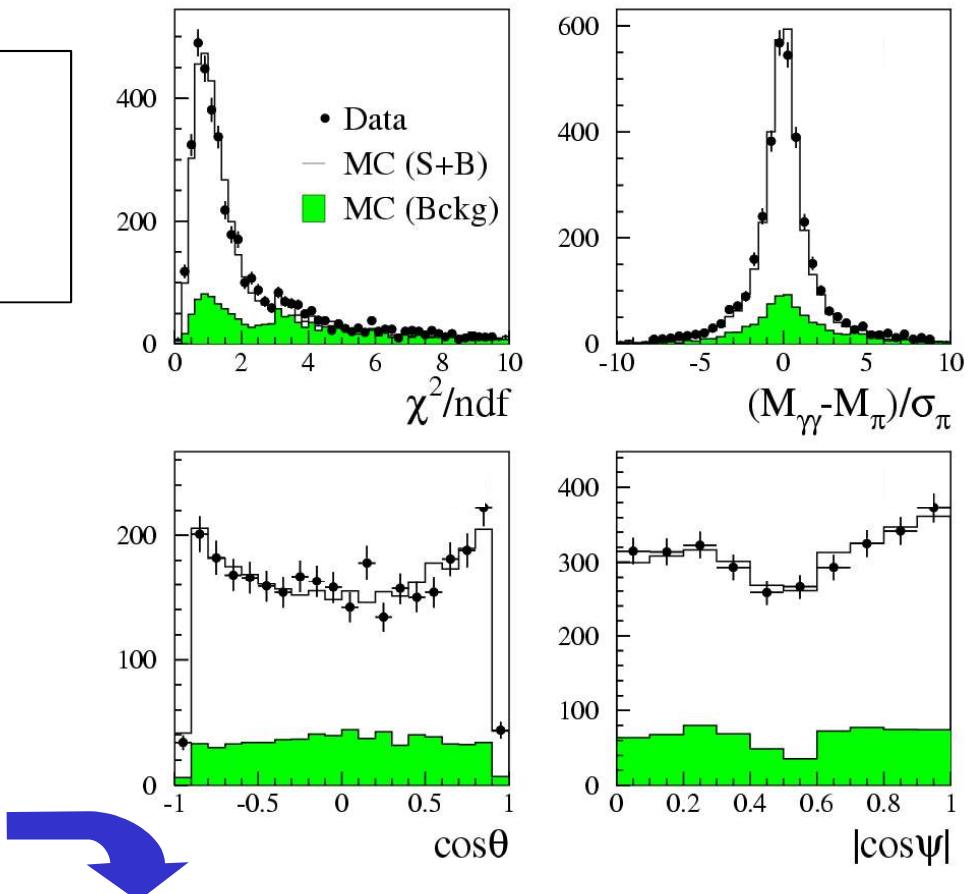
Background processes:

- ✓ $e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$ ($S/B=0.80$)
- ✓ $\phi \rightarrow \eta \pi^0 \gamma \rightarrow \gamma \gamma \pi^0 \gamma$ ($S/B=3.52$)
- ✓ $\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$ ($S/B=0.03$)

After 5 prompt neutral clusters
requirement from IP and kinematic fit:

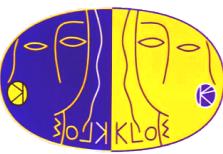
- ✓ cut on π^0 masses
- ✓ $e^+ e^- \rightarrow \omega \pi^0$ background rejection

16 pb⁻¹ '00 data: $N_{\pi\pi\gamma} = 2438 \pm 61$



PDG '02: $\text{BR}(\phi \rightarrow \pi^0 \pi^0 \gamma) = (1.08 \pm 0.17 \pm 0.09) \times 10^{-4}$

KLOE '02: $\text{BR}(\phi \rightarrow \pi^0 \pi^0 \gamma) = (1.09 \pm 0.03_{\text{stat}} \pm 0.05_{\text{syst}}) \times 10^{-4}$



$$\phi \rightarrow a_0 \gamma \rightarrow \eta \pi^0 \gamma$$

Two decay channels used: (a) $\eta \rightarrow \gamma\gamma$ (b) $\eta \rightarrow \pi^+\pi^-\pi^0$

Background processes for (a):

- $e^+e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma$ (S/B=0.23)
- $\phi \rightarrow \pi^0 \pi^0 \gamma$ (S/B=0.29)
- $\phi \rightarrow \eta \gamma \rightarrow \gamma \gamma \gamma$ (S/B=7.0×10⁻⁴)
- $\phi \rightarrow \eta \gamma \rightarrow \pi^0 \pi^0 \pi^0 \gamma$ (S/B= 8.6×10⁻⁴)

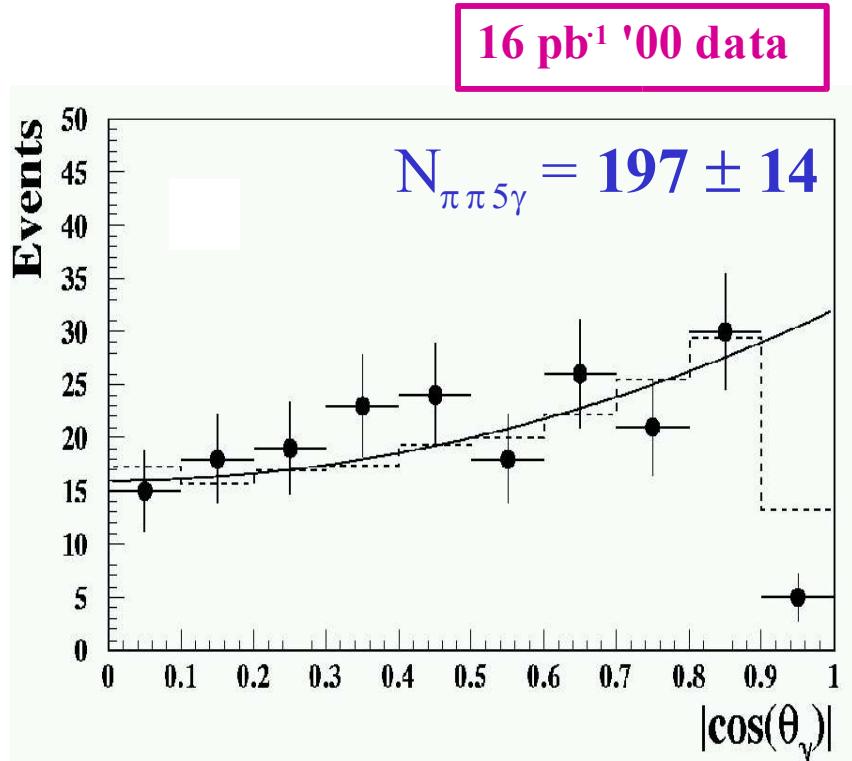
Background processes for (b):

- $e^+e^- \rightarrow \omega \pi^0 \rightarrow \pi^+ \pi^- \pi^0 \pi^0$
- $\phi \rightarrow \eta \gamma \rightarrow \pi^+ \pi^- \pi^0 \gamma$
- $\phi \rightarrow K_S K_L \rightarrow \pi^+ \pi^- \pi^0 \pi^0$

⇒ No bckg with the same final state

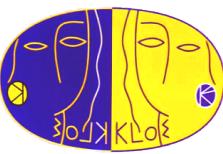
Sample selection:

- ✓ 5 prompt clusters (+2 tracks from IP)
- ✓ Kinematic fit + topological cuts



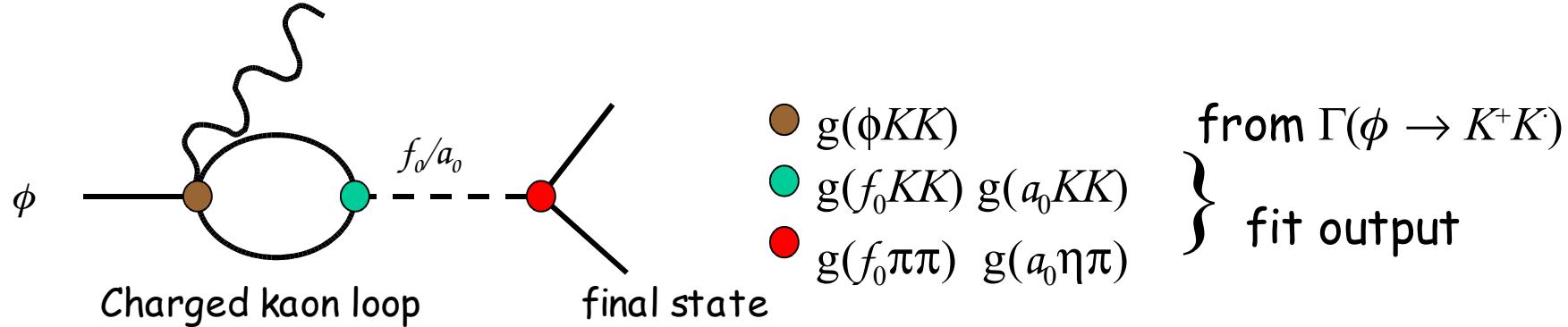
PDG '02: $\text{BR}(\phi \rightarrow \eta \pi^0 \gamma) = (8.9 \pm 1.4) \cdot 10^{-5}$

KLOE '02: $\text{BR}(\phi \rightarrow \eta \pi^0 \gamma) = (8.5 \pm 0.5_{\text{stat}} \pm 0.6_{\text{syst}}) \cdot 10^{-5}$



f_0 and a_0 couplings from K^\pm loop model

Fit to the spectra using a phenomenological approach: extraction of coupling constants



Fit to the $M_{\pi\pi}$ spectrum with:

$$1) \phi \rightarrow f_0 \gamma \rightarrow \pi^0 \pi^0 \gamma$$

$$2) \phi \rightarrow \sigma \gamma \rightarrow \pi^0 \pi^0 \gamma$$

$M_\sigma = 478 \text{ MeV}$, $\Gamma_\sigma = 324 \text{ MeV}$

[FNAL E791 · PRL 86 (2001)]

$$3) \phi \rightarrow \rho^0 \pi^0 \rightarrow \pi^0 \pi^0 \gamma$$

Fit to the $M_{\eta\pi}$ spectrum with:

$$1) \phi \rightarrow a_0 \gamma \rightarrow \eta \pi^0 \gamma$$

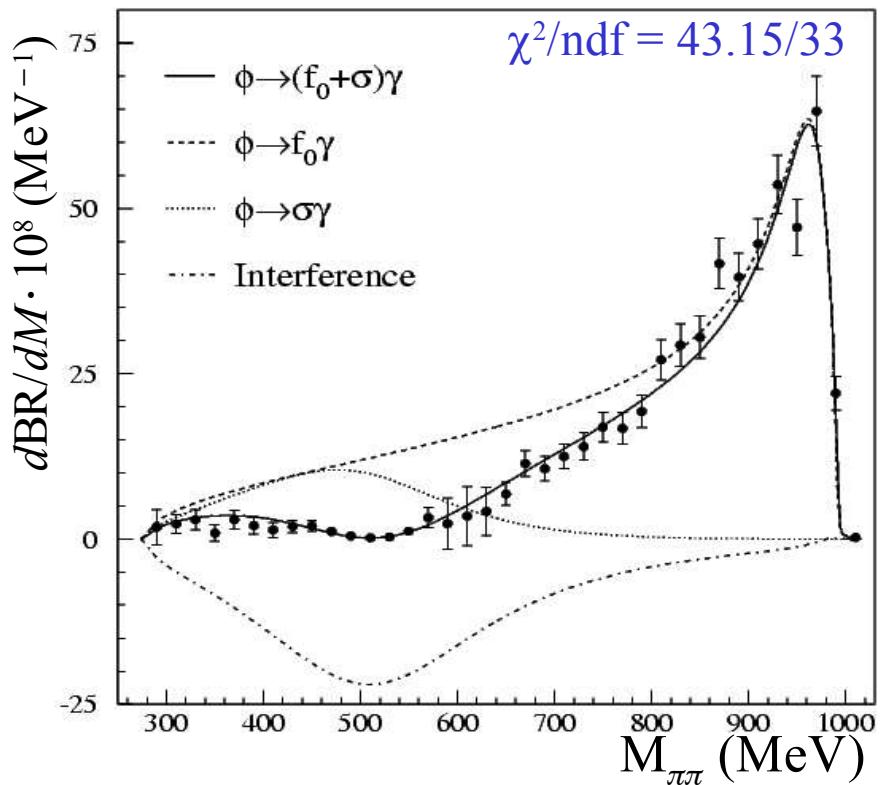
$$2) \phi \rightarrow \rho^0 \pi^0 \rightarrow \eta \pi^0 \gamma$$

◆ Combined fit to the $M_{\eta\pi}$ spectrum

◆ Relative normalization fixed to
 $\text{BR}(\eta \rightarrow \gamma\gamma) / \text{BR}(\eta \rightarrow \pi^+\pi^-\pi^0)$

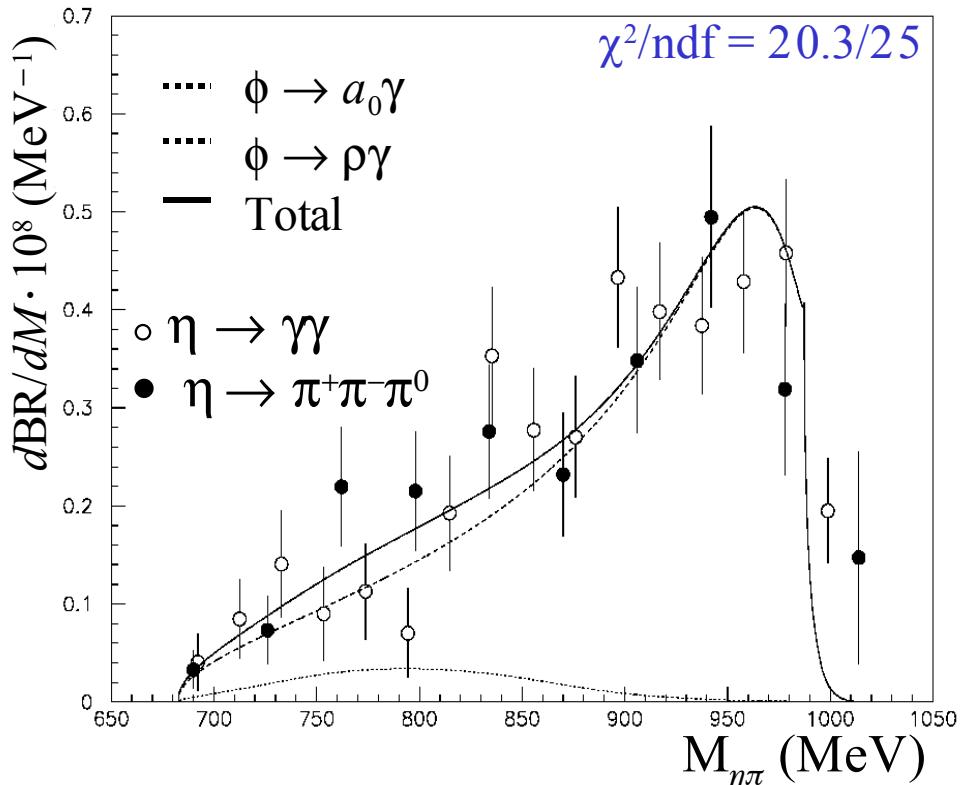
Fit results

KLOE '02: 17 pb⁻¹ '00 data



Fit results:

$$\begin{aligned} M(f_0) &= 973 \pm 1 \text{ MeV} \\ g^2(f_0 KK)/4\pi &= 2.79 \pm 0.12 \text{ GeV}^2 \\ g^2(f_0 \pi\pi)/g^2(f_0 KK) &= 0.50 \pm 0.01 \\ g(\phi\sigma\gamma) &= 0.060 \pm 0.008 \end{aligned}$$



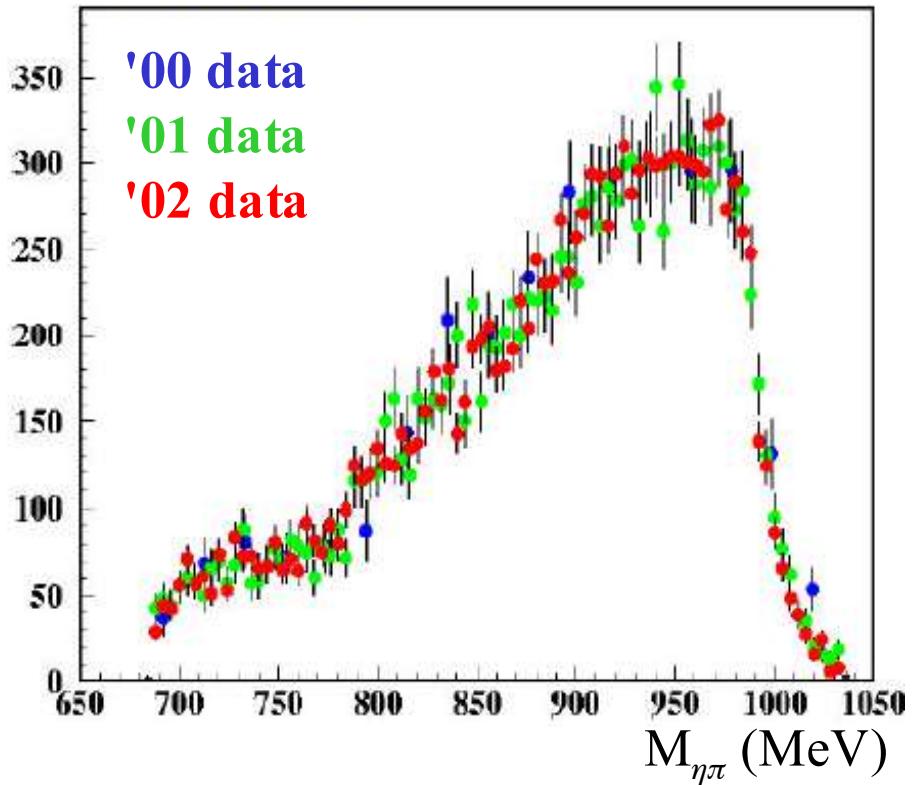
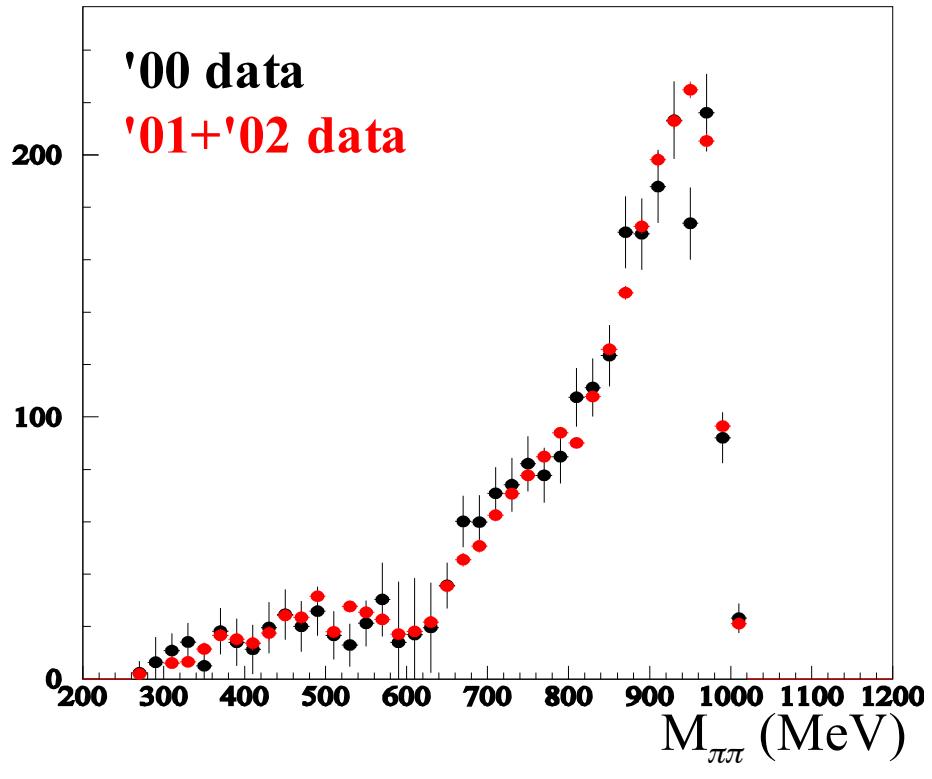
Fit results:

$$\begin{aligned} M(a_0) &= 984.8 \text{ MeV (FIXED)} \\ g^2(a_0 KK)/4\pi &= 0.40 \pm 0.04 \text{ GeV}^2 \\ g^2(a_0 \eta\pi)/g^2(a_0 KK) &= 1.35 \pm 0.09 \end{aligned}$$



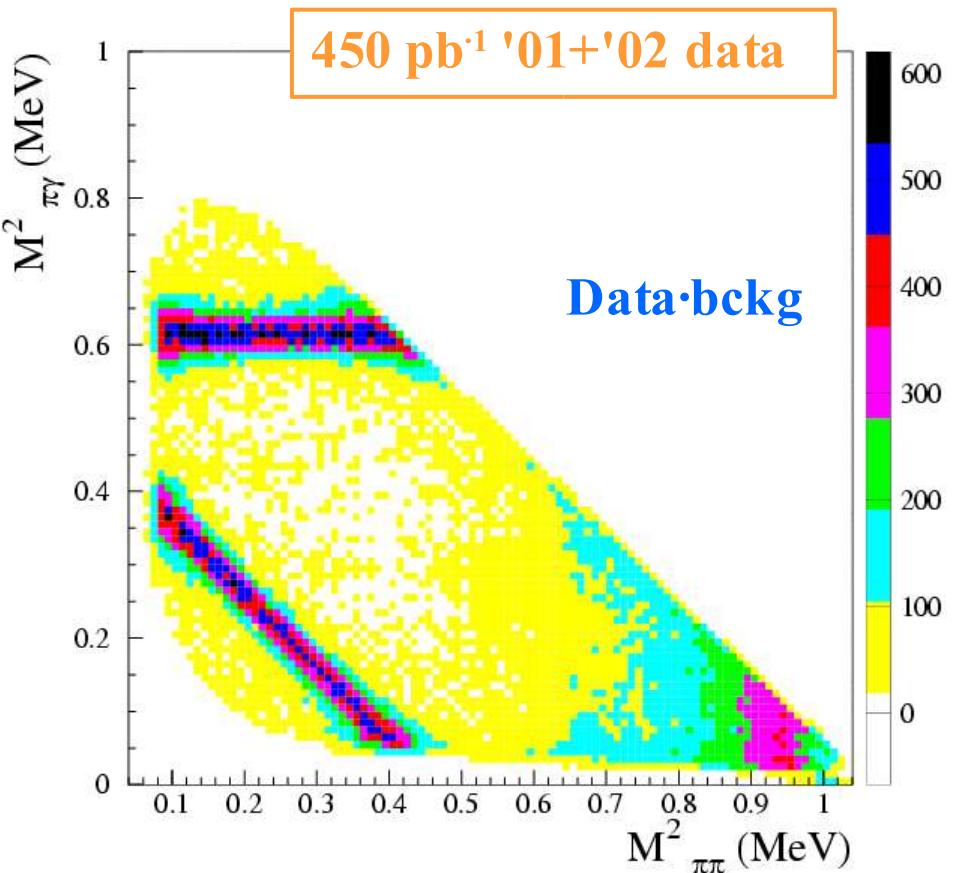
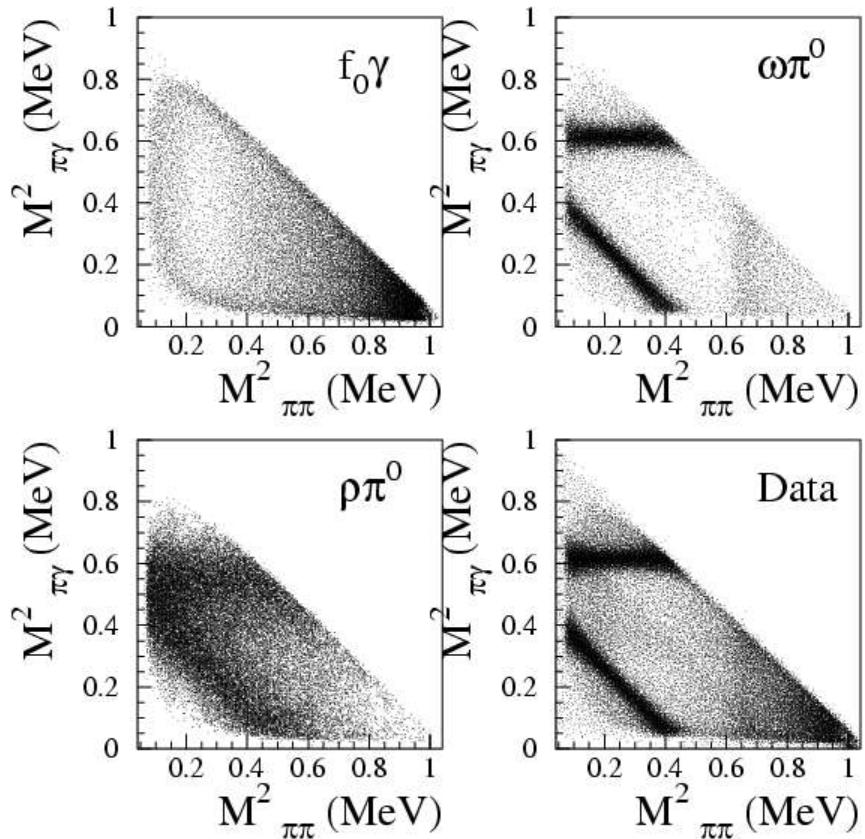
Raw mass shapes: new data

KLOE preliminary: 450 pb⁻¹ '01 + '02 data





$\phi \rightarrow \pi^0\pi^0\gamma$: Dalitz plot

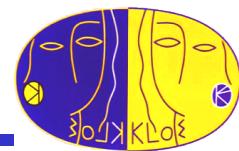


The larger statistics allows to fit to the Dalitz plot taking into account any possible interference scheme between:

$$\phi \rightarrow S\gamma \rightarrow \pi^0\pi^0\gamma, \quad \phi \rightarrow \rho\pi^0 \rightarrow \pi^0\pi^0\gamma \quad \text{and} \quad e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$$

$\phi \rightarrow \pi^0\pi^0\gamma$ analysis vs c.m. energy also in progress

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



Final state completely dominated by $e^+e^- \rightarrow \pi^+\pi^-\gamma$ with γ from ISR

Also final state radiation (FSR) contributes

Sample selection:

- 2 pion tracks from IP
- 1 photon with $\theta > 45^\circ$ (suppress ISR)

Fit to $M_{\pi\pi}$ spectrum with:

$\pi\pi\gamma$ continuum (ISR+FSR)

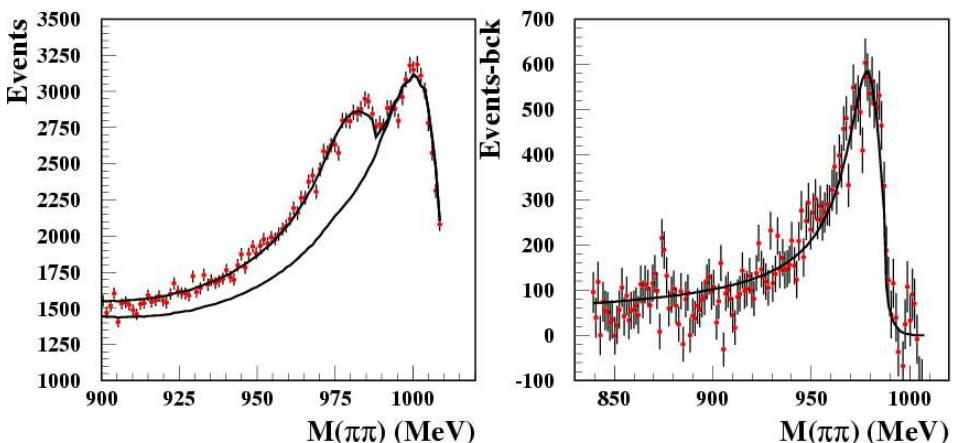
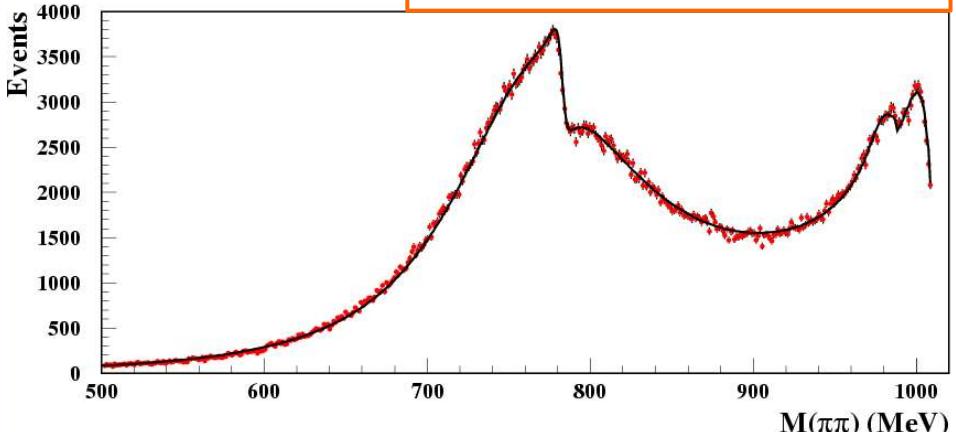
Signal (f_0)

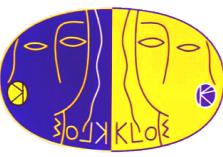
f_0 -FSR interference

Signal extraction difficult because of the huge amount of background, which depends on ρ^0 , ω and ρ' parameters.

First tentative without any f_0 -FSR interferf.

349 pb⁻¹ '01+'02 data

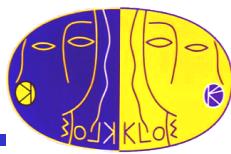




Conclusions

- ❖ KLOE is analyzing a unique data sample: $1.3 \times 10^9 \phi$ decays
- ❖ Extensions of previous KLOE analyses nearly ready:
 - ✓ $K_s \rightarrow \pi\pi$ BR's under control at per-mil level
 - ✓ K_s semileptonic asymmetry measured for first time
 - ✓ f_0, a_0 spectra with high statistics
- ❖ Many new physics results obtained or near to come:
 - ✓ Measurement of K_L, K^\pm BR's, V_{us}
 - ✓ Search for $K_s \rightarrow \pi^0 \pi^0 \pi^0$
 - ✓ Measurements of η decays
- ❖ More physics to come as we enter the fb^{-1} era

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



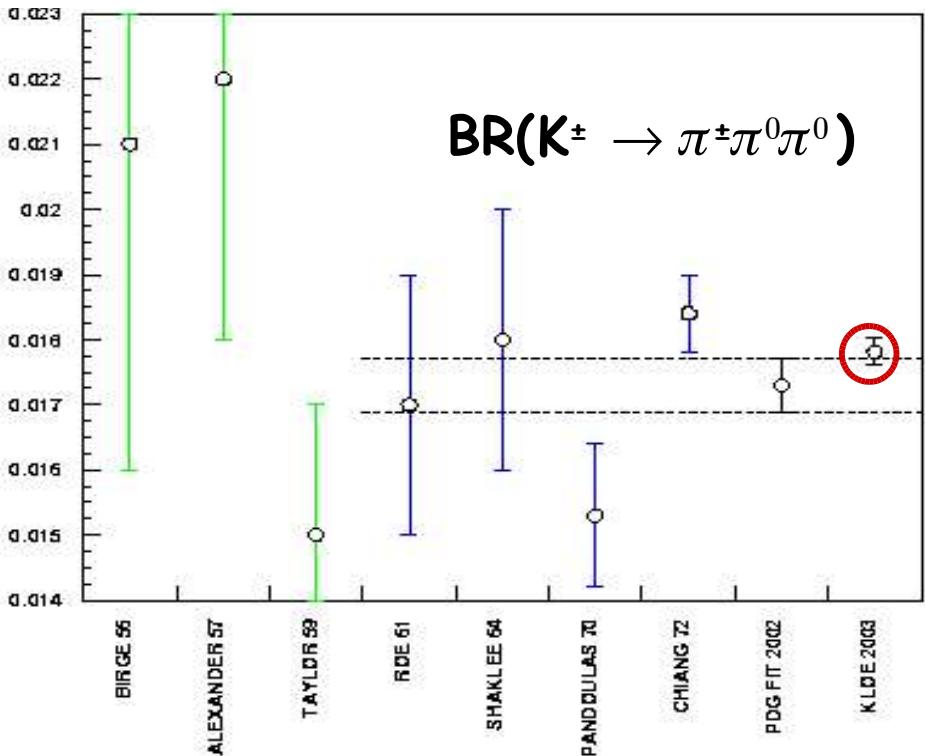
- ✓ Isospin amplitudes and phase shifts for $K \rightarrow 3\pi$ decays (input to χ PT)
- ✓ Charge asymmetries in K^\pm rates ($\sim 10^{-7}$) and Dalitz plot slopes ($\sim 10^{-6}$) signal direct CP violation

441 pb⁻¹ '01+'02 data used :

- ❖ 188 pb⁻¹ for signal search
- ❖ 253 pb⁻¹ for efficiency evaluation (divided in 3 samples)

Systematics dominated by:

- ❖ Vertex reconstruction efficiency
- ❖ K^\pm reconstruction / identification
- ❖ On-time requirements for clusters



PDG '02 fit $BR = (1.73 \pm 0.04) \%$

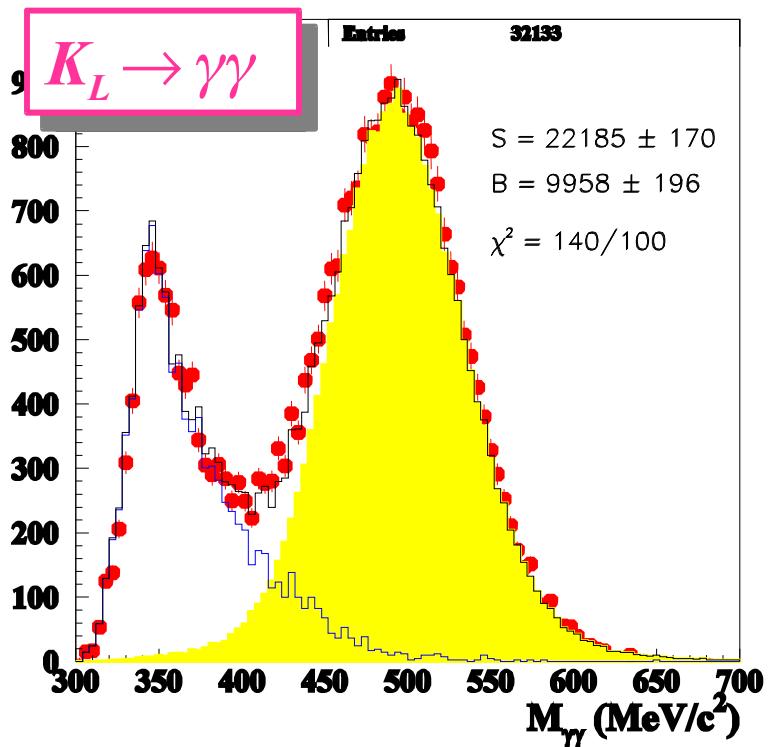
KLOE '02 $BR = (1.810 \pm 0.013 \pm 0.017) \%$

$$83 \cdot 10^3 \text{ } K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$$



$\Gamma(K_L \rightarrow \gamma\gamma) / \Gamma(K_L \rightarrow \pi^0\pi^0\pi^0)$

- ✓ Dominated by long-distance contribution (π^0, η, η')
Can be calculated in χ PT [$O(p^6)$], sensitive to θ_P
- ✓ Dominates long-distance contribution to $K_L \rightarrow \mu^+\mu^-$

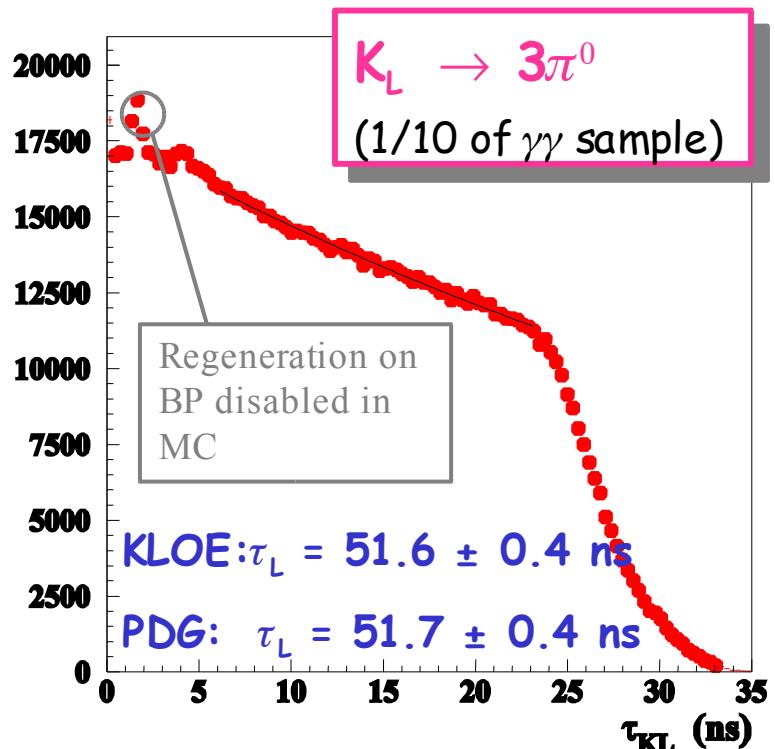


KLOE '03: $(2.793 \pm 0.022 \pm 0.024) \times 10^{-3}$

362 pb⁻¹ '01 + '02 data

$9.8 \times 10^6 K_L \rightarrow \pi^0\pi^0\pi^0$

Photon vertex reconstruction
exploiting EMC performances



NA48 '02: $(2.81 \pm 0.01 \pm 0.02) \cdot 10^{-3}$

PDG '02: $(2.82 \pm 0.08) \cdot 10^{-3}$