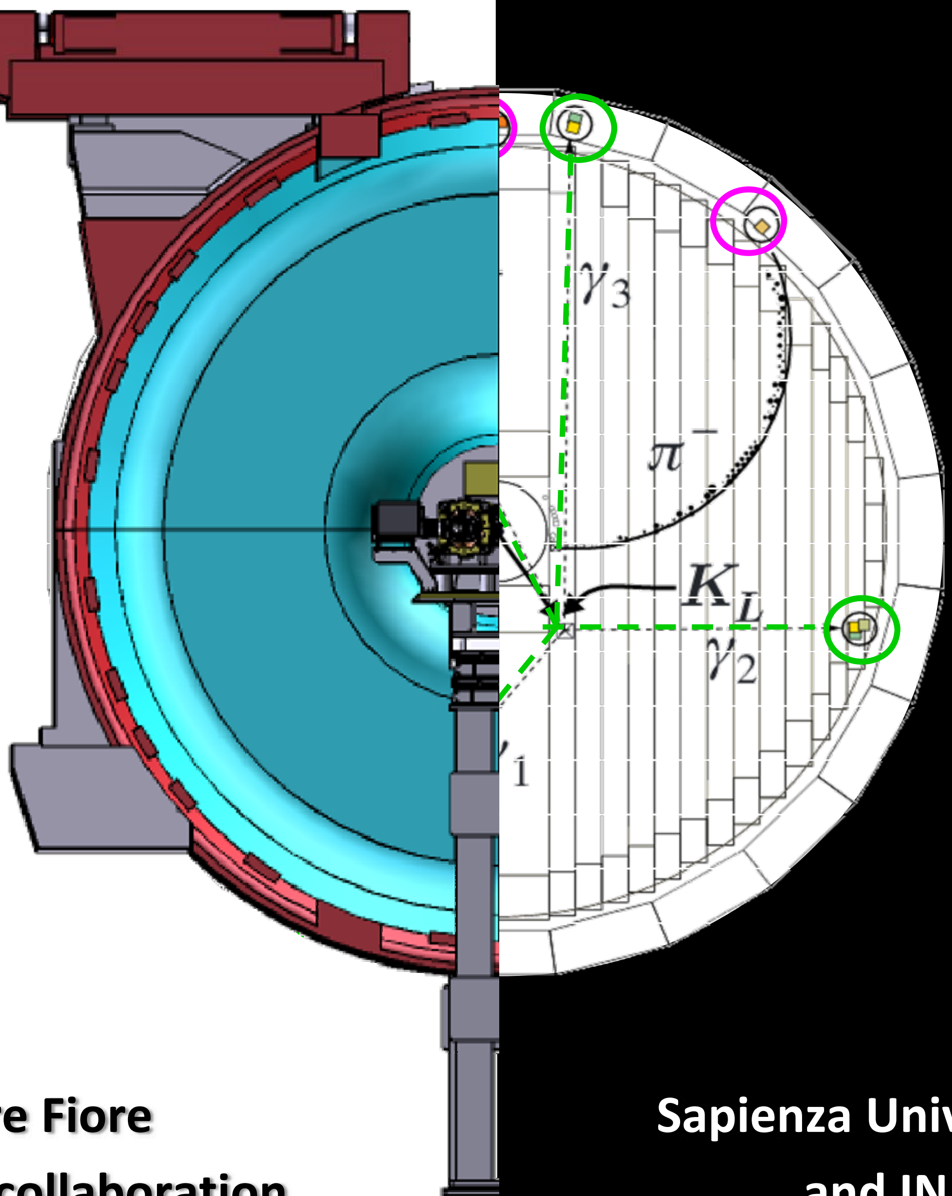
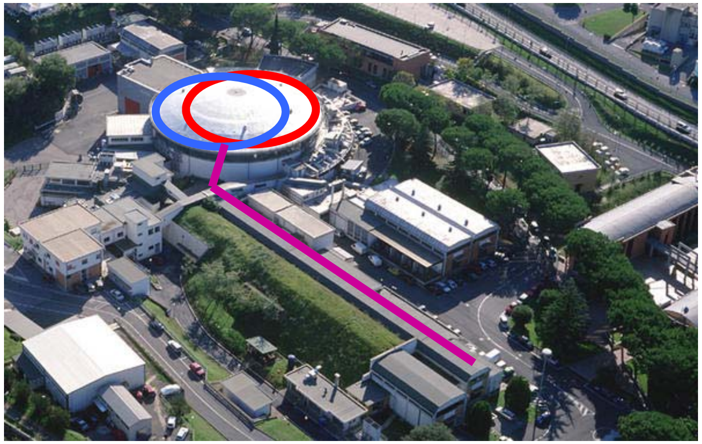
KLOE physics results and future prospects



Salvatore Fiore
for the KLOE collaboration

Sapienza Universita' di Roma
and INFN Roma

The KLOE collaboration



Frascati ϕ-factory DAϕNE:

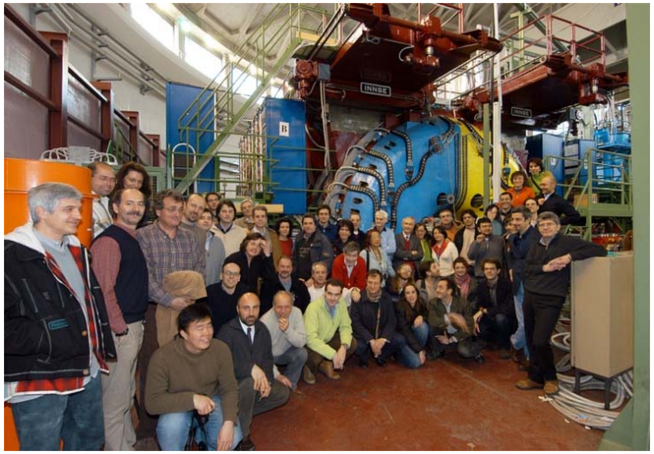
an e^+e^- collider @ $\sqrt{s}$ =1019.4 MeV = M_ϕ

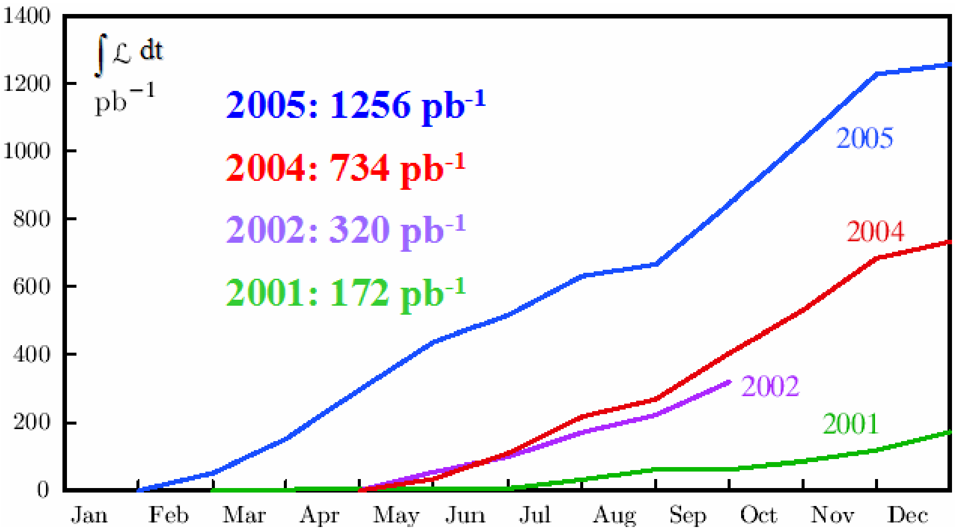
Best performances in 2005:

- ✓ L_{peak} = 1.4 × 10^{32} $cm^{-2}s^{-1}$
- ✓ ∫ Ldt = 8.5 pb^{-1}/day

KLOE has acquired 2.5 fb^{-1} @ $\sqrt{s}$=M_ϕ during years 2001-05

+ 250 pb^{-1} *off-peak* @ $\sqrt{s}$=1 GeV





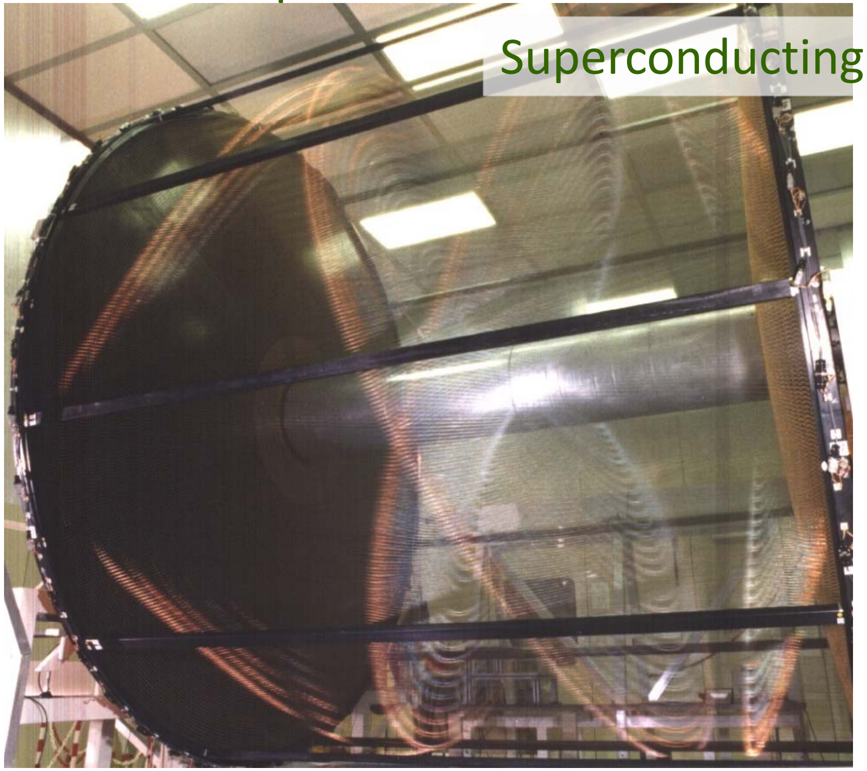
In these years tenths of articles have been published, with the contribution of more than 100 researchers

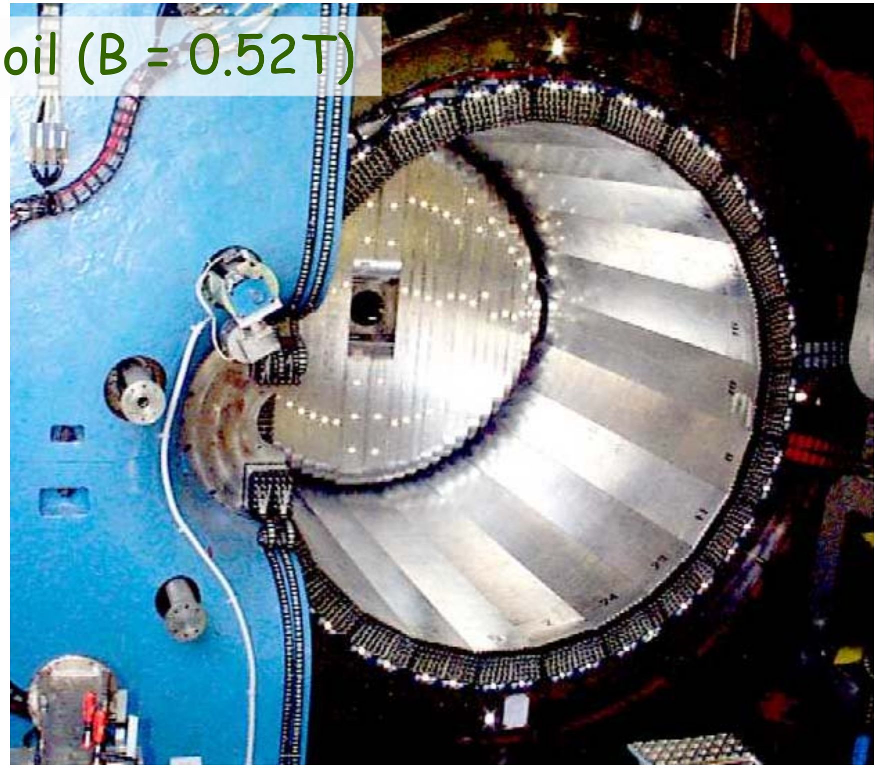
The KLOE detector

Drift chamber (4 m ∅ × 3.3 m, CF frame)
- Gas mixture: 90% He + 10% iso-C_4H_{10}
- 12582 stereo sense wires
- almost squared cells

Calorimeter
- lead/scintillating fibers (1 mm ∅), 15 X_0
- 4880 PMT's
- 98% solid angle coverage

Superconducting coil (B = 0.52T)



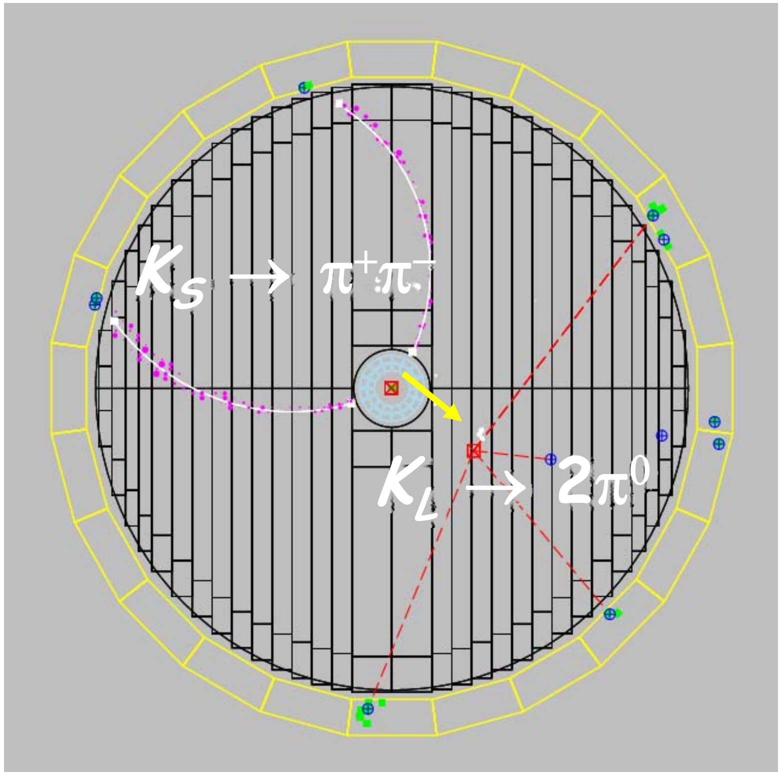


$\sigma_p/p = 0.4\ \%$ (tracks with $\theta > 45°$)
$\sigma_x^{hit} = 150\ \mu m\ (xy),\ 2\ mm\ (z)$
$\sigma_x^{vertex}\ \sim 1\ mm$
$\sigma(M_{\pi\pi})\ \sim 1\ MeV$

$\sigma_E/E = 5.7\%\ /\sqrt{E(GeV)}$
$\sigma_t = 54\ ps\ /\sqrt{E(GeV)} \oplus 140\ ps$
$\sigma_{vtx}(\gamma\gamma) \sim 1.5\ cm$ (neutral vertex resolution)

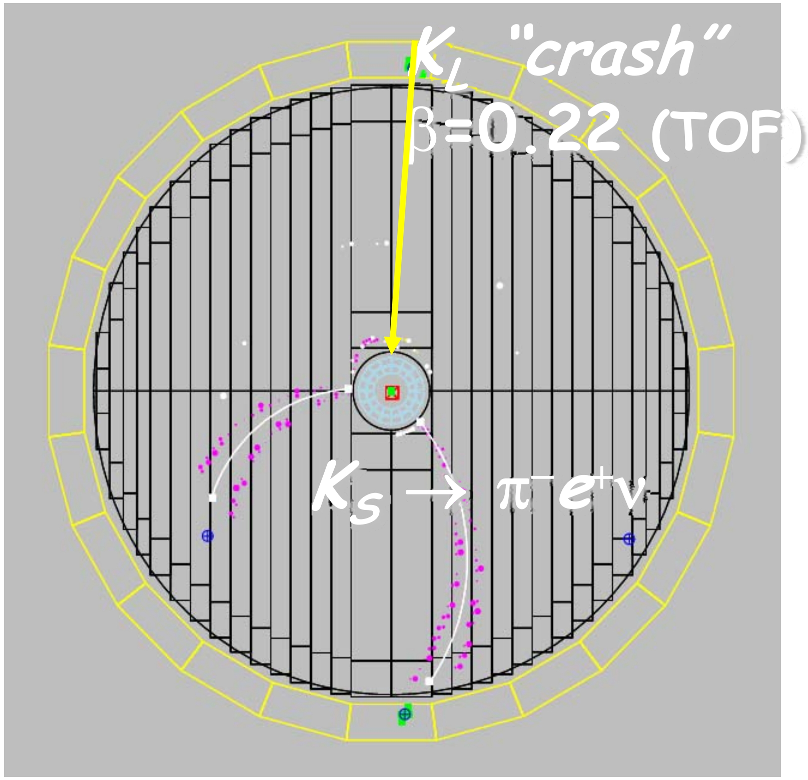
Tagging Kaon beams

K_L tagged
by $K_S \to \pi^+\pi^-$ vertex at IP



ε **~ 70%** (mainly geometrical)
K_L angular resolution: ~ 1°
K_L momentum resolution: ~ 1 MeV

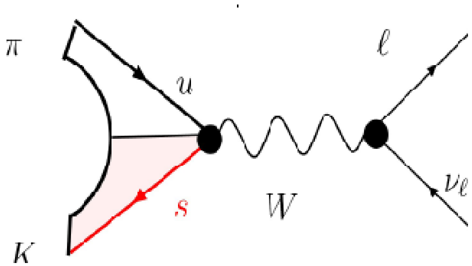
K_S tagged
by K_L interaction in EmC



ε **~ 30%** (largely geometrical)
K_S angular resolution: ~ 1° (0.3° in ϕ)
K_S momentum resolution: ~ 1 MeV

Kaon physical parameters and V_{us}

Kaon Physics for V_{us} and universality



$K_{\ell 3}$: $K \to \pi \ell \nu$

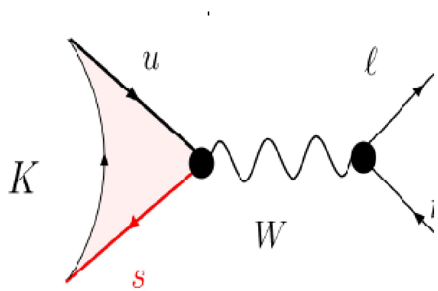
Vector transition: only 2nd order SU(3) breaking [Ademollo-Gatto]

- ❖ Precise determination of V_{us}
- ❖ Test of Lepton universality Ke3 vs Kμ3
- ❖ Most precise test of CKM unitarity

$$|V_{ud}|^2 + |V_{us}|^2 = 1 \qquad |V_{ub}|^2 \text{ negligible}$$

- ❖ Lepton-Quark universality of weak int.

$$G_F^2 \equiv G_{CKM}^2 = (|V_{ud}|^2 + |V_{us}|^2) G_F^2$$



$K_{\ell 2}$: $K \to \ell \nu$

Helicity suppressed:
Sensitivity to NP enhanced

- ❖ Precise determination of V_{us}/V_{ud}
- ❖ Test of Physics beyond the SM
  - right-handed contributions to charged weak currents
  - charged Higgs exchange (2 Higgs doublet scenarios)

$\Gamma(K_{\mu 2})/\Gamma(\pi_{\mu 2})$

- ❖ Lepton Flavor Violation test with $\Gamma(K_{e2})/\Gamma(K_{\mu 2})$

V_{us} from K_{l3} rates

$$\Gamma(K_{l3(\gamma)}) = \frac{C_K^2\, G_F^2\, M_K^5}{192\pi^3} S_{EW}\, |V_{us}|^2\, |f_+^{K^0\pi^-}(0)|^2 \times I_{Kl}(\{\lambda\}_{Kl})\,(1 + 2\Delta_K^{SU(2)} + 2\Delta_{Kl}^{EM})$$

with $K \in \{K^+, K^0\}$; $l \in \{e, \mu\}$, and:

C_K^2 1/2 for K^+, 1 for K^0

Inputs from theory:

S_{EW} Universal short distance EW correction (1.0232)

$f_+^{K^0\pi^-}(0)$ Hadronic matrix element at zero momentum transfer (t=0)

$\Delta_K^{SU(2)}$ Form factor correction for strong SU(2) breaking

Δ_{Kl}^{EM} Long distance EM effects

Inputs from experiment:

$\Gamma(K_{l3(\gamma)})$ **Branching ratios** with well determined treatment of radiative decays; **lifetimes**

$I_{Kl}(\lambda)$ Phase space integral: λs parameterize form factor dependence on t :

K_{e3} : only λ_+ (or λ_+' λ_+'')

$K_{\mu 3}$: need λ_+ and λ_0

KLOE has measured all relevant Inputs for charged and neutral kaons:

BR's, lifetimes (K_L, $K^{\pm}$), form factors (FFs)

To extract V_{us} from K_L, K_S and $K^{\pm}$

PLB 632 (2006)

$BR(K_{Le3}) = 0.4008(15)$ 0.37%

$BR(K_{L\mu3}) = 0.2699(14)$ 0.52%

PLB 626 (2005)

$\tau_L = 50.92(30)$ ns 0.58%

PLB 636 (2006)

$BR(K_S \to \pi e \nu) = 7.046(91) \times 10^{-4}$

1.3%

PLB 636 (2006)

$\lambda'_+ \times 10^3$	$\lambda''_+ \times 10^3$
25.5 ± 1.8	1.4 ± 0.8

JHEP12(2007)

$$\lambda_+' = (25.6 \pm 1.5_{stat} \pm 0.9_{syst})\times 10^{-3}$$

$$\lambda_+'' = (1.5 \pm 0.7_{stat} \pm 0.4_{syst})\times 10^{-3}$$

$$\lambda_0 = (15.4 \pm 1.8_{stat} \pm 1.3_{syst})\times 10^{-3}$$

PLB 632 (2006)

$BR(K^+ \to \mu^+\nu) = 0.6366(17)$

0.27%

JHEP 01 (2008)

$\tau^{\pm} = 12.347(30)$ 0.24%

JHEP 02 (2008)

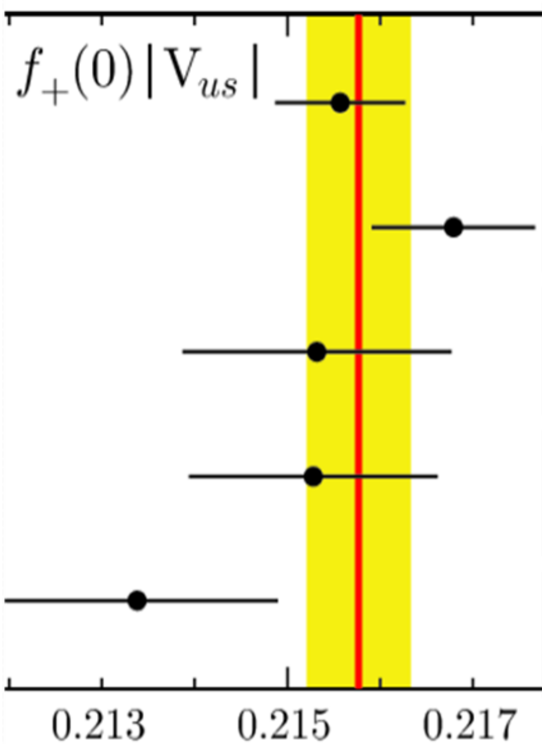
$BR(K^{\pm} \to \pi^0 e^{\pm}\nu) = 0.04965(53)$ 1%

$BR(K^{\pm} \to \pi^0 \mu^{\pm}\nu) = 0.03233(39)$ 1.2%

PLB 666 (2008)

$BR(K^+ \to \pi^+ \pi^0 (\gamma)) = 0.2065(9)$ 0.43%

$|V_{us}| f_+(0)$ at KLOE



		err %
$K_L e3$	0.2155(7)	0.3
$K_L \mu 3$	0.2167(9)	0.4
$K_S e3$	0.2152(14)	0.7
$K^{\pm} e3$	0.2152(13)	0.6
$K^{\pm} \mu 3$	0.2132(15)	0.7

All KLOE exp. inputs but K_S lifetime

PRELIMINARY K_S lifetime @ EPS09

Lepton universality

$$r_{\mu e} \equiv \frac{|f_+(0)\,V_{us}|^2_{\mu 3,\ \exp}}{|f_+(0)\,V_{us}|^2_{e3,\ \exp}} = \frac{g_\mu^2}{g_e^2}$$

$r_{\mu e}$ = 1.000(8)

τ decays: $(r_{\mu e})_\tau$ = 1.0005(41) (PDG06)

π decays: $(r_{\mu e})_\pi$ = 1.0042(33)

JHEP04(2008)059

KLOE average $|V_{us}| f_+(0)$ = 0.2157(6) $\chi 2$/ndf=7/4 (13%)

World Average 0.2163(5)

$|V_{us}|$ = 0.2237(13)

$1 - |V_{ud}|^2 - |V_{us}|^2 = 9(8)\times 10^{-4}$

$f_+(0)$=0.964(5) — PRL 100 (2008)

$|V_{ud}|$ = 0.97418(26) — PRC 77 (2008)

V_{us}, V_{ud} and V_{us}/V_{ud}

$|V_{us}/V_{ud}| = 0.2323(15)$

- $BR(K^{\pm} \to \mu^{\pm}\nu) = 0.6366(17)$
- $f_K/f_\pi = 1.189(7)$

PLB 632 (2006)

PRL 100 (2008)

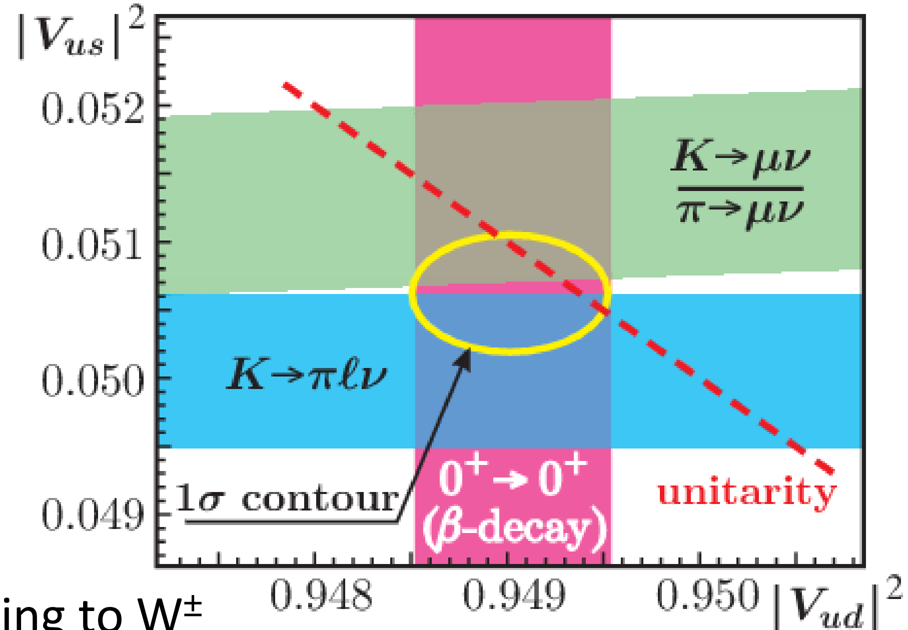
$|V_{us}| = 0.2237(13)$ from Kl3 decays

$|V_{ud}| = 0.97418(26)$

- Fit to $|V_{ud}|^2$, $|V_{us}|^2$ and $|V_{us}/V_{ud}|^2$

  JHEP 04 (2008)

  $|V_{ud}|^2 = 0.9490(5)$
  $|V_{us}|^2 = 0.0506(4)$
  $\chi^2 = 2.3/1$ (13%)



- Agreement with unitarity

  $1-V_{ud}^2-V_{us}^2 = 4(7)\times10^{-4}$ @0.6σ

- Universality of lepton and quark weak coupling to $W^{\pm}$

  $G_F = 1.166371(6)\times10^{-5}\ \mathrm{GeV}^{-2}$
  $G_{CKM} = 1.16604(40)\times10^{-5}\ \mathrm{GeV}^{-2}$
  $G_{ew} = 1.1655(12)\times10^{-5}\ \mathrm{GeV}^{-2}$ from ew precision tests

$$G_F^2 \equiv G_{CKM}^2 = (|V_{ud}|^2 + |V_{us}|^2)G_F^2$$

Other achievements in Kaon Physics

1) $K_L\mu 3$ *form factors* and preliminary update based on ½ full data set	JHEP12(2007)105
2) $K_L e3\gamma$ decay	EPJC-08-04-012
3) BR($K_S \to \gamma\gamma$) *	JHEP05(2008)051
4) Upper limit on BR($K_S \to e^+e^-$)*	PLB672(2009)203
5) Measurement of $\Gamma(K^+_{e2})/\Gamma(K^+_{\mu 2})$ *	EPJC64(2009)627
6) $K_S K_L$ interferometry *	Paper in preparation
7) K_L lifetime update with full data set	Preliminary result
8) K_S lifetime *	Preliminary result
9) BR($K_S e3$) update with full data set	In progress
10) $K_S \to \pi^0\pi^0\pi^0$ update with full data set	In progress
11) $K^\pm \to \pi^\pm\pi^-\pi^+$	In progress
12) $K^\pm$ lifetime update with full data set	In progress

** whole data sample*

Light Meson Spectroscopy

$f0/a0 \rightarrow KK\gamma$

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

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

η' gluonium content

$\phi \to K^0 \overline{K^0} \gamma$

$K^0\overline{K}^0$: $J^{PC} = 0^{++}$ symmetric quantum state, from $f_0(980)$ and $a_0(980)$ decays

Sensitive to f_0 / a_0 interference – Never been observed

Possible final states will be K_SK_S or K_LK_L : Invariant mass $\in$ [995,1020] MeV

Observed final state: $K_S \to \pi^+ \pi^- \pi^+ \pi^-$ - clean signature, 25% efficiency

Signal MC according to phase-space and radiative decay dynamics

Selection optimized on signal MC. main backgrounds: $K_SK_L \to \pi^+ \pi^- \pi^+ \pi^-$ and $e^+e^- \to \pi^+ \pi^- \pi^+ \pi^-$

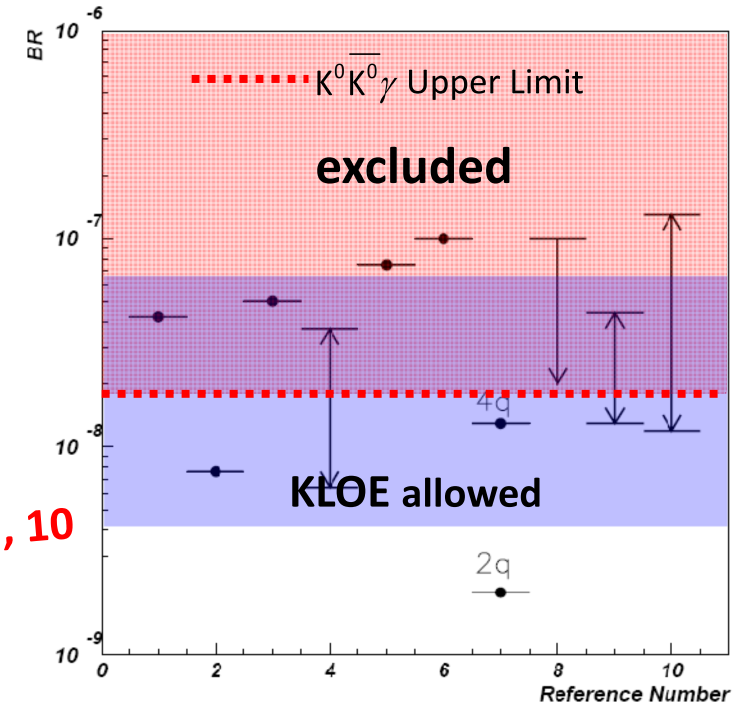
$$\int L dt = 2.18 \, fb^{-1} \, at \, \phi \, peak$$

N_{obs}=5 observed events

N_{bkg}=3.2±0.7 expected background events,

Phys.Lett.B 679 (2009), 10

$$B.R.(\phi \to K^0\overline{K}^0\gamma) < 1.9 \cdot 10^{-8} \text{ at } 90\% \text{ C.L.}$$



Consistency with KLOE measurements

Using $g_{f0\pi\pi}$, $g_{a0\eta\pi}$ couplings as measured with f_0, a_0 KLOE analyses and inserting these couplings in the Kaon-Loop model it is possible to check **consistency of different KLOE measurements done in the scalar meson sector**

The obtained range is consistent with our Upper Limit

1. Phys.Rev.D (1990)
2. A.Bramon, A.Grau, G.Pancheri (no explicit S) Phys.Lett.B289, 97 (1992)
3. (UχPT) Phys.Lett.B426, 7 (1998)
4. J.A.Oller (UχPT) Nucl.Phys.A714 (2003) 161
5. Eur.Phys.J.A31, 454 (2007)
6. S.Nussinov, T.N.Truong, Phys.Rev.Lett.63 (1989) 1349, Erratum 2003
7. Nucl.Phys.B315, 465 (1989)
8. J.Lucio, J.Pestieau (f_0 only) Phys.Rev.D42 (1990) 3253
9. N.N.Achasov, V.V.Gubin (SND data, K-Loop) Phys.Rev.D64, 094016 (2001)
10. A.Gokalp, C.S.Korkmaz, O.Yilmaz (KLOE K-Loop) Phys.Rev.D75(2007) 013001

$\eta \to \pi^+\pi^- e^+ e^-$ branching ratio

- η decay into $\pi\pi ee$ predicted with a branching ratio of $26 \div 36 \times 10^{-5}$
- At KLOE η mesons produced by radiative decay $\phi \to \eta\gamma$, monochromatic photon of 363 MeV: 1.7 fb^{-1} of ϕ-decays data → 7×10^7 η's , 0.24 fb^{-1} off the ϕ peak (background evaluation), 50 fb^{-1} of signal MC

✓FSR included by PHOTOS MC

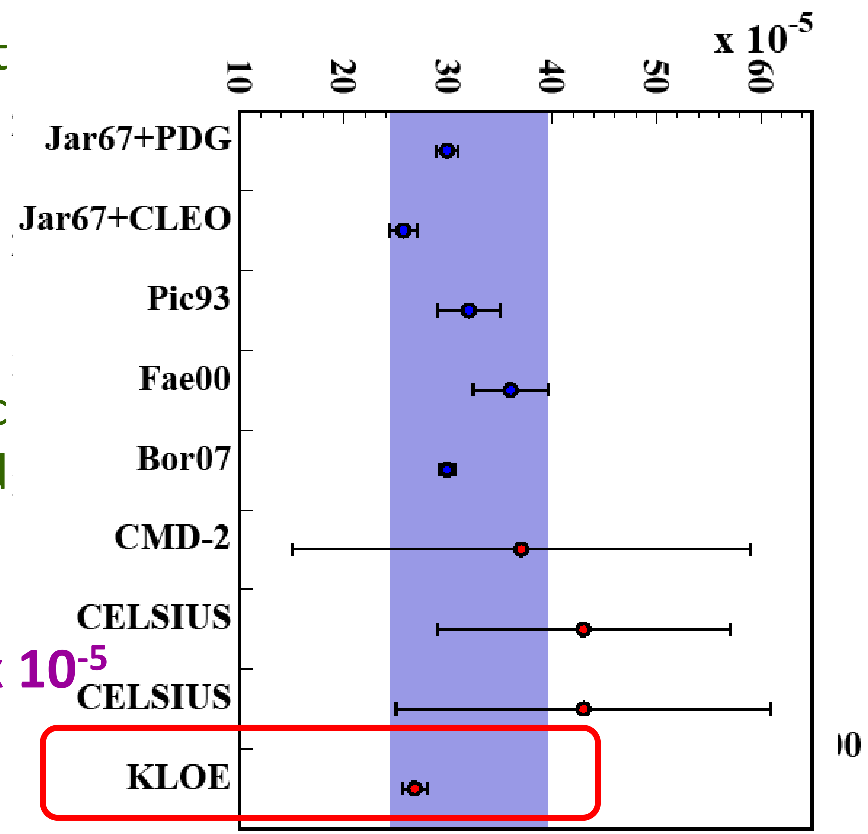
✓4-track events, only one γ, mass assignment through π decay ID or TOF, kinematic fit

✓Background:

  ✓ϕ-decays ($\pi^+\pi^-\pi^0$ or $\eta\gamma$, $\eta \to \pi^+\pi^-\pi^0$, $\pi^+\pi^-\gamma$)

  ✓continuum (radiative Bhabha + conversion)

✓Background rejection through kinematic costraints, and then fitting the background components out of the signal region

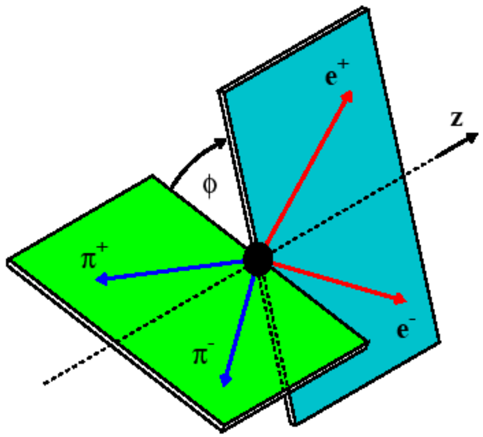


$BR(\eta \to \pi^+\pi^- e^+ e^-(\gamma)) = (26.8 \pm 0.9_{stat} \pm 0.7_{syst}) \times 10^{-5}$

Phys.Lett.B 675 (2009), 283

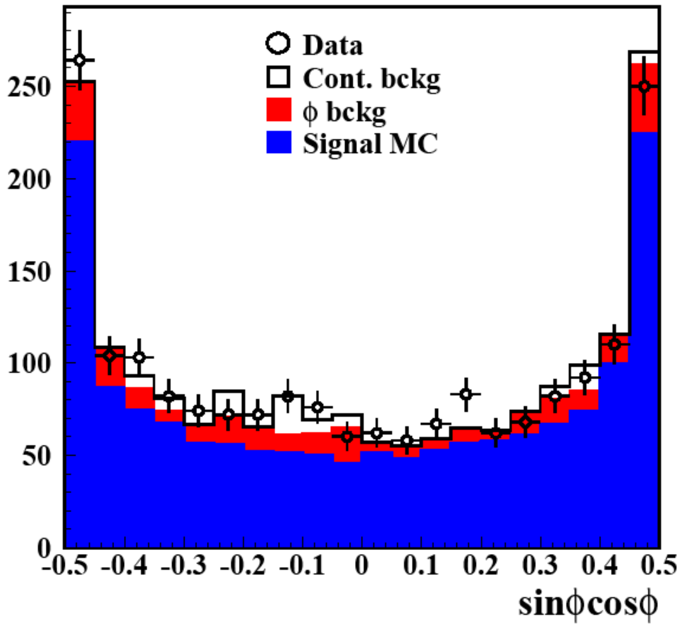
$\eta \to \pi^+\pi^- e^+ e^-$ decay plane asymmetry

A possible non-CKM CP violating mechanism* has been proposed, which could induce interference between electric and magnetic decay amplitudes



- this would result in an observable asimmetry in the angle between the planes containing the pions and the electrons, of the order of 10^{-2}

$$A_\phi = \frac{N_{\sin\phi\cos\phi>0} - N_{\sin\phi\cos\phi<0}}{N_{\sin\phi\cos\phi>0} + N_{\sin\phi\cos\phi<0}}$$



- the asymmetry has been evaluated on the final event sample to be **A_ϕ=-(0.6±2.5±1.8) x 10^{-2}**

  Phys.Lett.B 675 (2009), 283

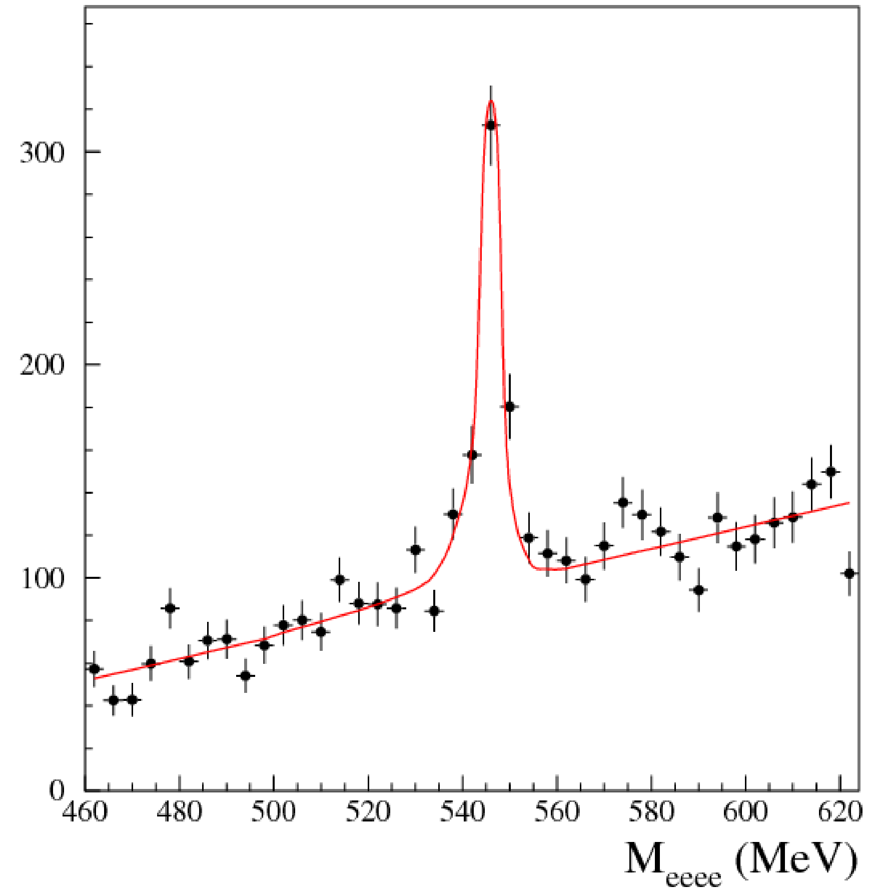
  first measurement of A_ϕ

- also checked with a control sample

*[D.Gao, Mod.Phys.Lett.A17 (2002) 1583]

$\eta \to e^+ e^- e^+ e^-$

- Data sample: **1.7 fb^{-1}**
- MC simulation according to J.Bijnens and F. Persson, arXiv:0106130 (courtesy of J.Bijnens)
- FSR included
- e^+e^- pairs from photon conversion on Beam Pipe and Drift Chamber wall rejected
- Remaining background from φ decays subtracted
- Fit to M_{eeee} distribution with MC signal + continuum background shapes yields:



$N_{eeee} = 413 \pm 31$

First observation of this decay

η' meson

- BR($\phi\to\eta'\gamma$) can probe the ss and gluonium content of η'
- The ratio R= BR($\phi\to\eta'\gamma$)/BR($\phi\to\eta\gamma$) can be related to the η-η' mixing parameters and determine the mixing angle in the flavor basis φ_P, the best parameter for a description of the mixing
- Using the approach by Bramon et al. [Eur. Phys. J. C7, 271(1999)] and introducing a possible gluonium content via $\cos^2\varphi_G$, KLOE extracts the η-η' mixing angle φ_P by measuring the quantity:

$$R_\phi = \frac{BR(\phi\to\eta'\gamma)}{BR(\phi\to\eta\gamma)} = \cot^2\varphi_P \cdot \cos^2\varphi_G \left(1-\frac{m_s}{\overline{m}}\cdot\frac{Z_q}{Z_s}\cdot\frac{\tan\psi_V}{\sin 2\varphi_P}\right)^2 \cdot \left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

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$$= (4.77 \pm 0.09_{stat} \pm 0.19_{syst}) \times 10^{-3}$$

using similar η and η' decay chains:
$\pi^+\pi^-7\gamma$ for the η', 7γ for the η

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

$$\eta'\to\pi^+\pi^-\eta,\ \eta\to\pi^0\pi^0\pi^0$$

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

$$\eta' = X_{\eta'}\frac{1}{\sqrt{2}}|u\bar{u}+d\bar{d}> + Y_{\eta'}|s\bar{s}> + Z_{\eta'}|glue>$$

$$\eta = \cos\varphi_p\frac{1}{\sqrt{2}}|u\bar{u}+d\bar{d}> - \sin\varphi_p|s\bar{s}>$$

$$X_{\eta'} = \sin\varphi_p\cos\varphi_G,\ Y_{\eta'} = \cos\varphi_p\cos\varphi_G,\ Z_{\eta'} = \sin\varphi_G$$

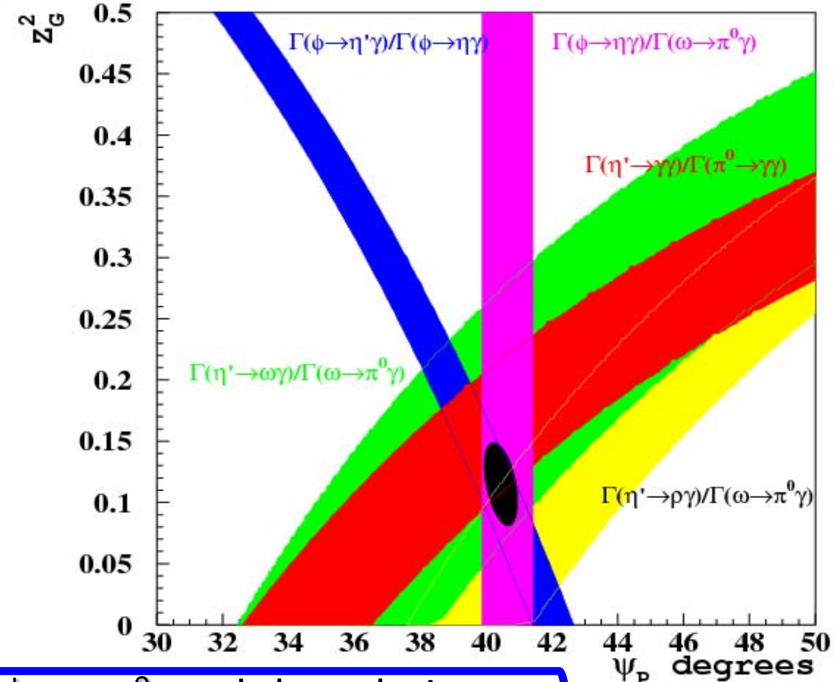
The η-η' mesons wave function can be decomposed in the quark mixing base
(J.L. Rosner, Phys.Rev.D27(1983) 1101)

η' gluonium content

New global fit with more free parameters: Z_q, Z_s, ψ_V, m_s/m , plus from PDG06:

$$\frac{\Gamma(\omega\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)} \quad \frac{\Gamma(\rho\to\pi^0\gamma)}{\Gamma(\omega\to\pi^0\gamma)} \quad \frac{\Gamma(\phi\to\eta\gamma)}{\Gamma(\omega\to\pi^0\gamma)} \quad \frac{\Gamma(\phi\to\pi^0\gamma)}{\Gamma(\omega\to\pi^0\gamma)} \quad \frac{\Gamma(K^{*+}\to K^+\gamma)}{\Gamma(K^{*0}\to K^0\gamma)}$$

Parameter	KLOE old fit	KLOE new fit	PDG08+$\omega\pi^0$
$Z_{\eta'}^2$	0.14±0.04	0.105±0.037	0.115±0.036
φ_P	(39.7±0.7)°	(40.7±0.7)°	(40.4±0.6)°
Z_q	0.91±0.05	0.866±0.025	0.936±0.025
Z_s	0.89±0.07	0.79±0.05	0.83±0.05
ψ_V	3.2°	(3.15±0.10)°	(3.32±0.09)°
m_s/m	1.24±0.07	1.24±0.07	1.24±0.07
$P(\chi^2)$	49%	17%	20%



We also fit PDG08 data, using KLOE measurement for $\phi\to\omega\pi^0$, and the relation:

$$\frac{\Gamma(\eta'\to\gamma\gamma)}{\Gamma(\pi^0\to\gamma\gamma)} = \frac{1}{9}\left(\frac{m_{\eta'}}{m_\pi}\right)^3\left(5\frac{f_\pi}{f_q}X_{\eta'} + \sqrt{2}\frac{f_\pi}{f_s}Y_{\eta'}\right)^3 \qquad f_q/f_\pi = 1,\ \ f_s/f_\pi = \sqrt{2f_K^2/f_\pi^2 - 1}$$ in the exact isospin symmetry limit

E. Kou, PRD63(2001)54027

f_K/f_π from lattice QCD (UKQCD) E. Follana et al., PRL100(2008)062002

Gluonium content confirmed at 3σ (if $Z_{\eta'}$=0, φ_P=(41.65±0.5)°, $P(\chi^2)$=1%)

Z_G can be interpreted as a mixing with a glueball with m_G = (1.41 ± 0.1) GeV (η(1405)) determined using KLOE fit results [Hai-Yang Cheng, Phys. Rev. D79 (2009) 014024]

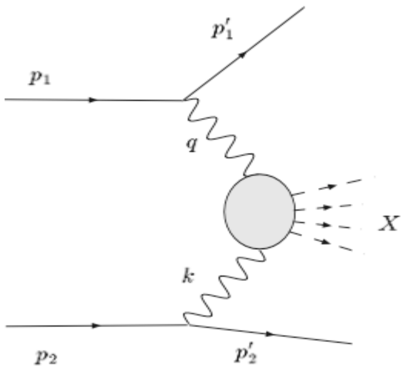
$\gamma\gamma$ physics with KLOE off-peak data

"a new challenge for KLOE"

$\gamma\gamma \rightarrow \eta$

$\gamma\gamma \rightarrow \sigma \rightarrow \pi^0\pi^0$

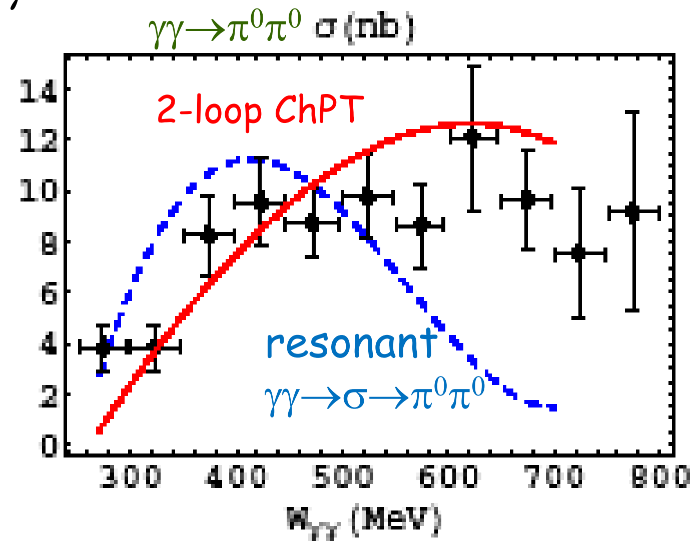
$\gamma\gamma$ physics with KLOE at DAΦNE



"$\gamma\gamma$ physics" stands for $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^- + X$

$J^{PC} = 0^{\pm+}, 2^{\pm+}$ final states through quasi-real photons: $\pi\pi(\sigma)$, η, η', f_0, a_0

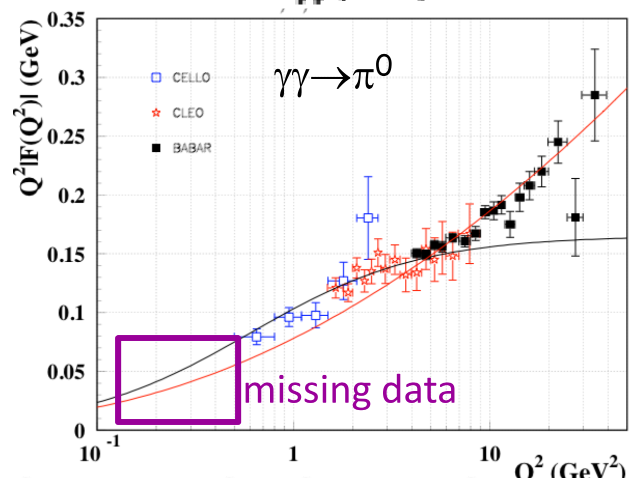
In the low-energy region, for $W_{\gamma\gamma}$<1GeV, present experimental situation is unsatisfactory:



- small data samples and large backgrounds
- small detection efficiencies and particle ID for low-mass hadronic states

✓ Study of $\gamma\gamma\rightarrow\pi^0\pi^0$ could tell about the existence and nature of σ meson

✓ meson transition form factors through $\gamma\gamma\rightarrow\pi^0$, η decays : low momentum transfer form factor crucial for light-by-light contribution to g-2 (in $\gamma\gamma\rightarrow P$ Amplitude $\propto F(P^2, Q^2, 0)$)



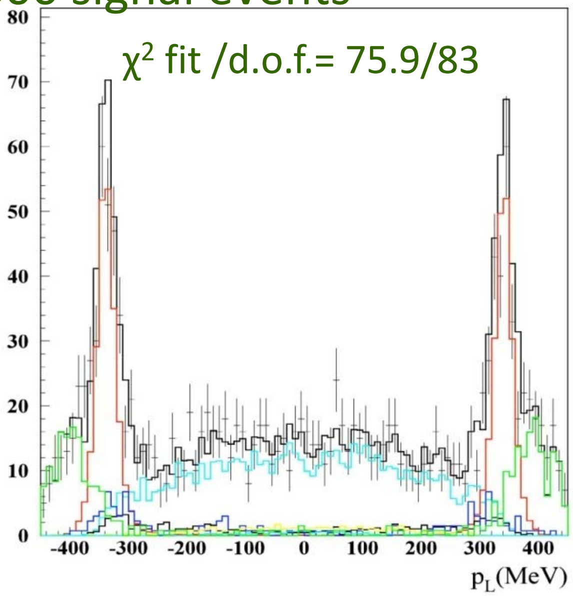
$\gamma\gamma$ events acquired at the φ peak would suffer from φ decays as background:

✓ use KLOE off-peak data @ 1GeV

✓ Tag $\gamma\gamma$ events by detecting e^+e^- (KLOE-2)

$\gamma\gamma \to \eta$ at 1 GeV

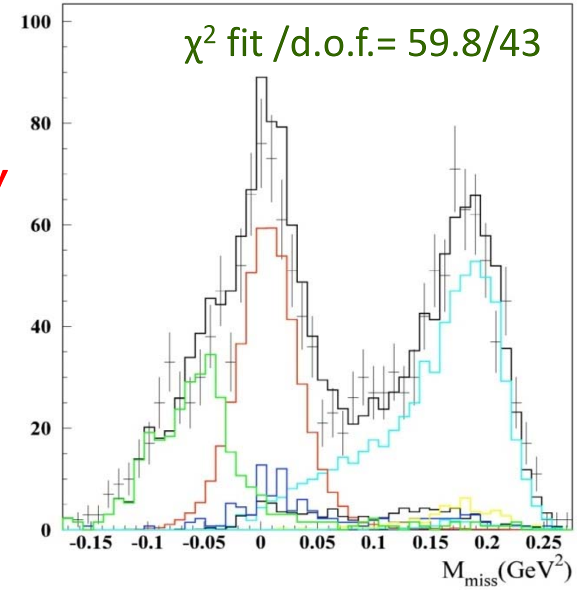
- Data sample: 240 pb-1 @ √*s = 1 GeV*
- Selected channel: $\eta \to \pi^+\pi^-\pi^0$
- Main background: $\phi \to \eta\gamma$ with undetected photon
- Fit to p_L longitudinal momentum and M_{miss}^2 in the $\phi \to \eta\gamma$ hypothesis with signal and background shapes
- ~ 600 signal events



$\phi \to \eta\gamma \to \pi^+\pi^-\pi^0\gamma$

$e^+e^- \to e^+e^-\gamma$

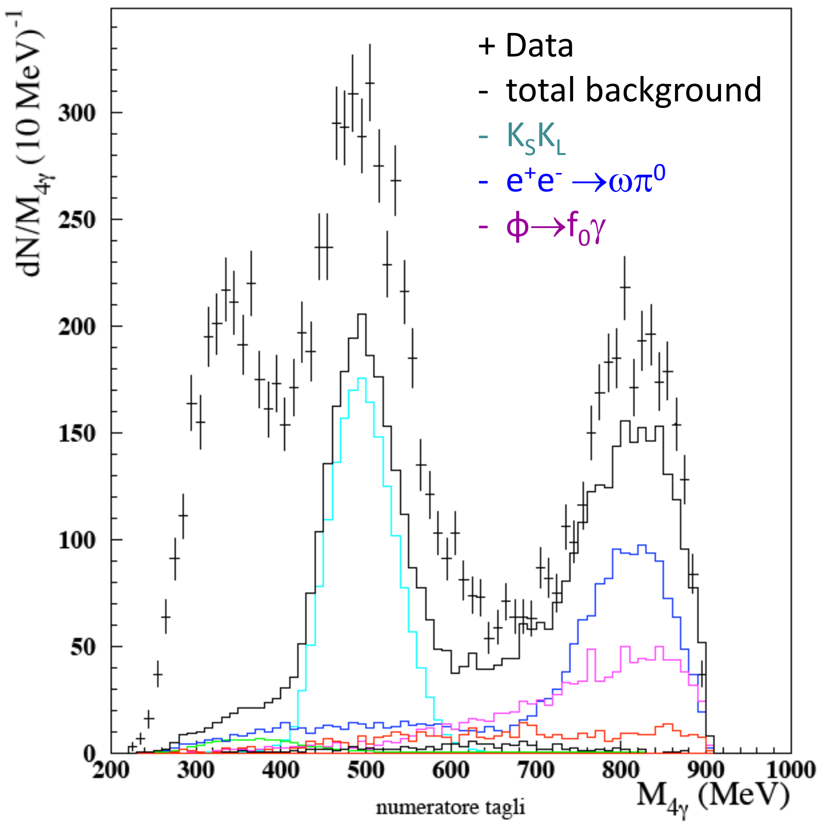
signal



- Extraction of $\sigma(e^+e^- \to e^+e^-\eta)$ and $\Gamma_{\gamma\gamma}$ in progress
- Statistical accuracy on $\Gamma_{\gamma\gamma}$ comparable with existing measurements

$\gamma\gamma \to \sigma \to \pi^0\pi^0$ at 1 GeV

- Cleanest channel to assess existence and nature of the σ meson
- $\pi^0\pi^0$ preferred w.r.t. $\pi^+\pi^-$ due to smaller background contamination
- 240 pb-1 @ √s = 1 GeV
- 10188 events after selection
- Bckg normalized using measured x-sections



Excess of ~4000 events w.r.t. known backgrounds in the $\gamma\gamma \to \sigma(600) \to \pi^0\pi^0$ region

Bckg subtraction and study of differential x-sec in progress

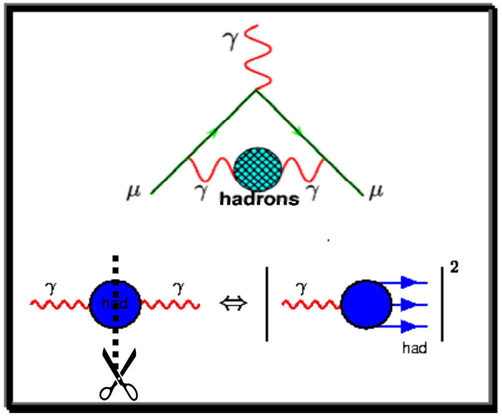
Hadronic cross section below 1 GeV

Motivation for $\sigma\ (e^+e^- \to \pi^+\pi^-)$

Hadronic contribution a_μ^{hadr} is limiting the standard model prediction for $(g-2)_\mu$!

a_μ^{had} is estimated by means of a dispersion relation (intrinsically ~$1/s^2$):

$$a_\mu^{had} = \frac{1}{4\pi^3} \int_{4m_\mu^2}^{\infty} \sigma_{had}(s)\, K(s)\, ds$$



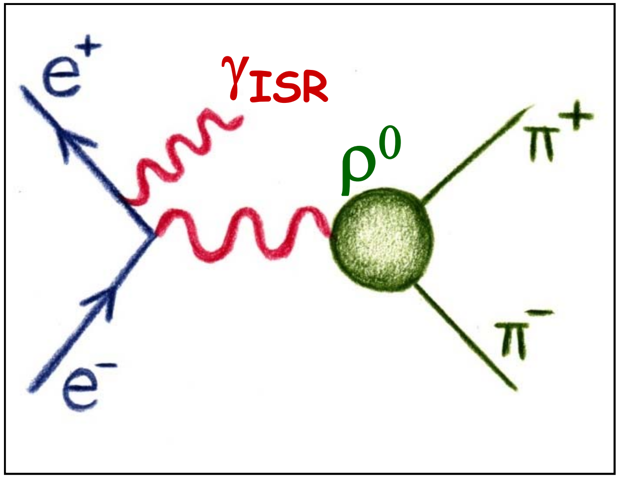
at low energies pQCD is not applicable: measurement needed

- Dominant channel below 1 GeV is $e^+e^- \to \rho \to \pi^+\pi^-$, which contributes with ~70% to the total value of a_μ^{had} :

  $\sigma(e^+e^- \to \pi^+\pi^-)$ needed with ≤ 1% precision!

DAΦNE is designed for a fixed center-of-mass energy: $\sqrt{s} = m_\phi$ Energy scan not possible!

Complementary approach: events with Initial State Radiation (ISR):



$$M^2_{hadr} \frac{d\sigma(e^+ e^- \to hadrons + \gamma_{ISR})}{dM^2_{hadr}}$$

$$= \sigma(e^+ e^- \to hadrons)\ H(M^2_{hadr})$$

- Requires precise calculations of the radiator **H**
- Requires precise understanding of effects from Final State radiation (*FSR*)

  → Phokhara MC code

Large-angle pion tracks analysis

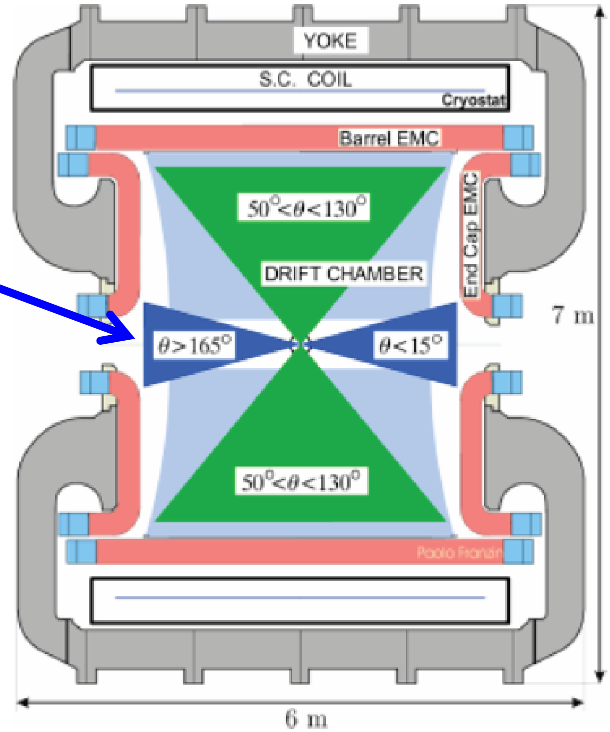
2 pion tracks at large angles
$50^o < \theta_\pi < 130^o$

Photons at large angles
$50^o < \theta_\gamma < 130^o$

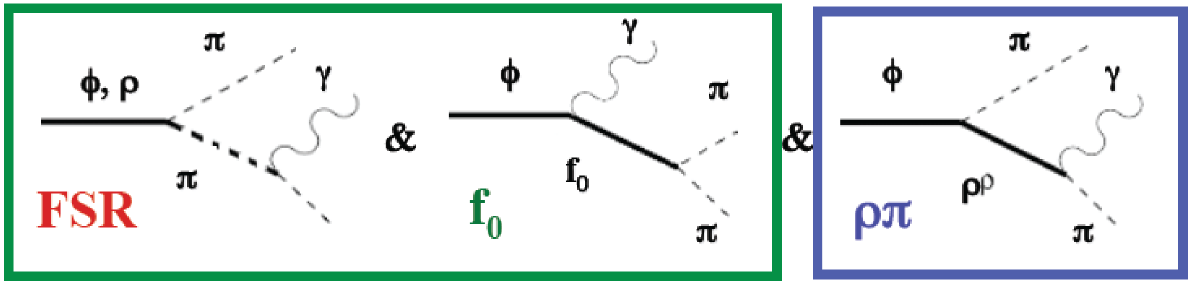
- complementary analysis w.r.t. SA
- threshold region $(2m_\pi)^2$ accessible
- γ_{ISR} photon detected (4-mom. constraints)

- lower signal statistics
- larger contribution from FSR events
- larger $\phi \to \pi^+\pi^-\pi^0$ background contamination
- irreducible background from ϕ decays

At least 1 photon with $50^o < \theta_\gamma < 130^o$ and $E_\gamma > 20$ MeV $\Rightarrow$ photon detected

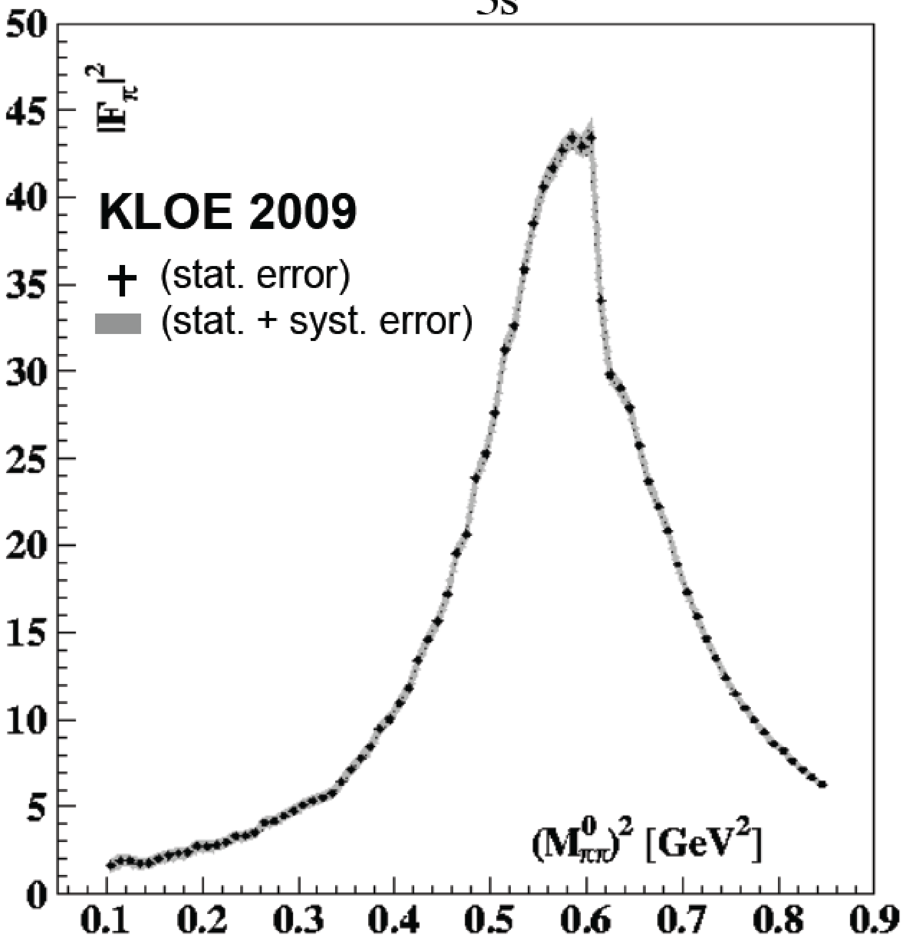


Threshold region non-trivial
due to irreducible FSR-effects, which have to be estimated from MC using phenomenological models (interference effects unknown)



New KLOE result on Large-Angle analysis

$$\sigma_{\pi\pi}(s_\pi) = \frac{\pi\alpha^2\beta_\pi^3}{3s}\left|F_\pi(s_\pi)\right|^2$$



Disp. Integral:

$$a_\mu^{had} = \frac{1}{4\pi^3}\int_{x_1}^{x_2}\sigma^{had}(s)K(s)\,ds$$

Systematic errors on $a_\mu^{\pi\pi}$(0.1-0.85 GeV^2):

Reconstruction Filter	< 0.1%
Background	0.5%
$f_0+\rho\pi$	0.4%
Omega	0.2%
Trackmass	0.5%
π/e-ID and TCA	< 0.1%
Tracking	0.3%
Trigger	0.2%
Acceptance	0.4%
Unfolding	negligible
Software Trigger	0.1%
Luminosity($0.1_{th} \oplus 0.3_{exp}$)%	0.3%

Experimental fractional error on a_μ = 1.0 %

FSR resummation	0.3%
Radiator H	0.5%
Vacuum polarization	< 0.1%

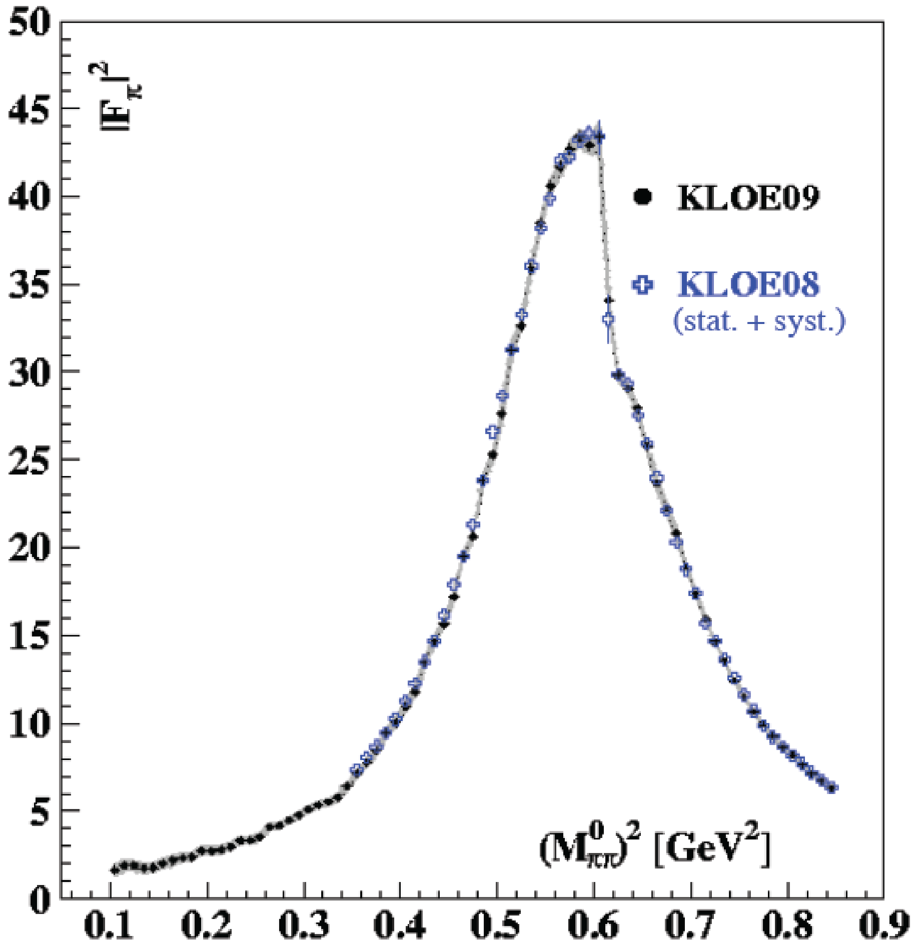
Theoretical fractional error on a_μ = 0.6 %

$a_\mu^{\pi\pi}(0.1\text{-}0.85\ \text{GeV}^2) = (478.5 \pm 2.0_{stat} \pm 4.8_{sys} \pm 2.9_{theo}) \cdot 10^{-10}$

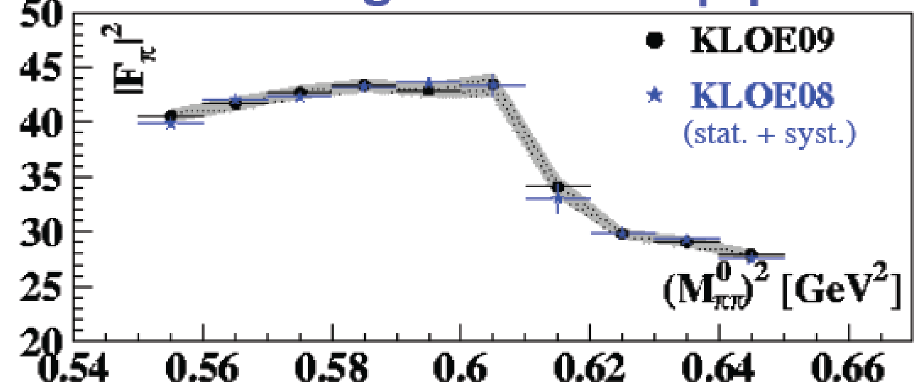
0.4% 1.0% 0.6%

Large-Angle vs. 2008 Small-Angle

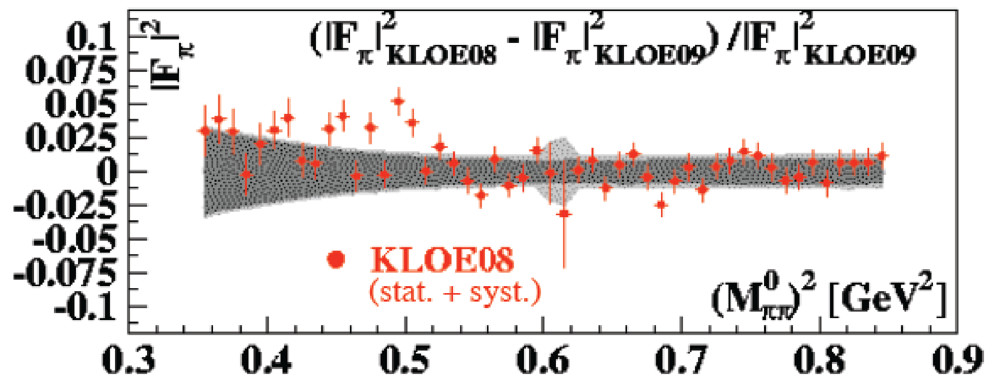
KLOE08: small angle analysis
KLOE09: large angle analysis



Zoomed region around ρ-peak:



Fractional difference:



Grey band: KLOE09 error

Future prospects: KLOE-2

New DAϕNE collider

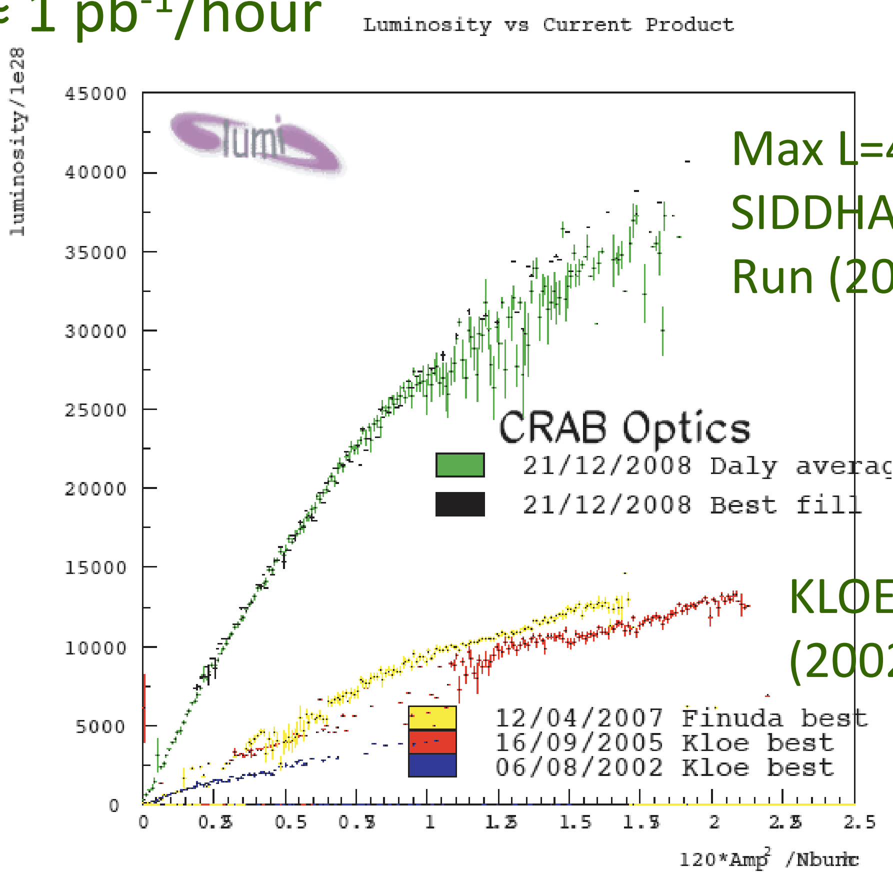
Upgrades of the KLOE detector

KLOE-2 Physics program

New DAΦNE collider

New interaction scheme implemented:

- ✓ large beam crossing angle + crabbed waist sextupoles
- ✓ Luminosity increase factor ~ 3
- ✓ $\int L dt \approx 1\ pb^{-1}$/hour



Max $L = 4.5 \times 10^{32}\ cm^{-2}s^{-1}$
SIDDHARTA
Run (2008/09)

KLOE run
(2002/05)

We already have now a deeply renewed machine capable of delivering ~5 fb^{-1}/yr

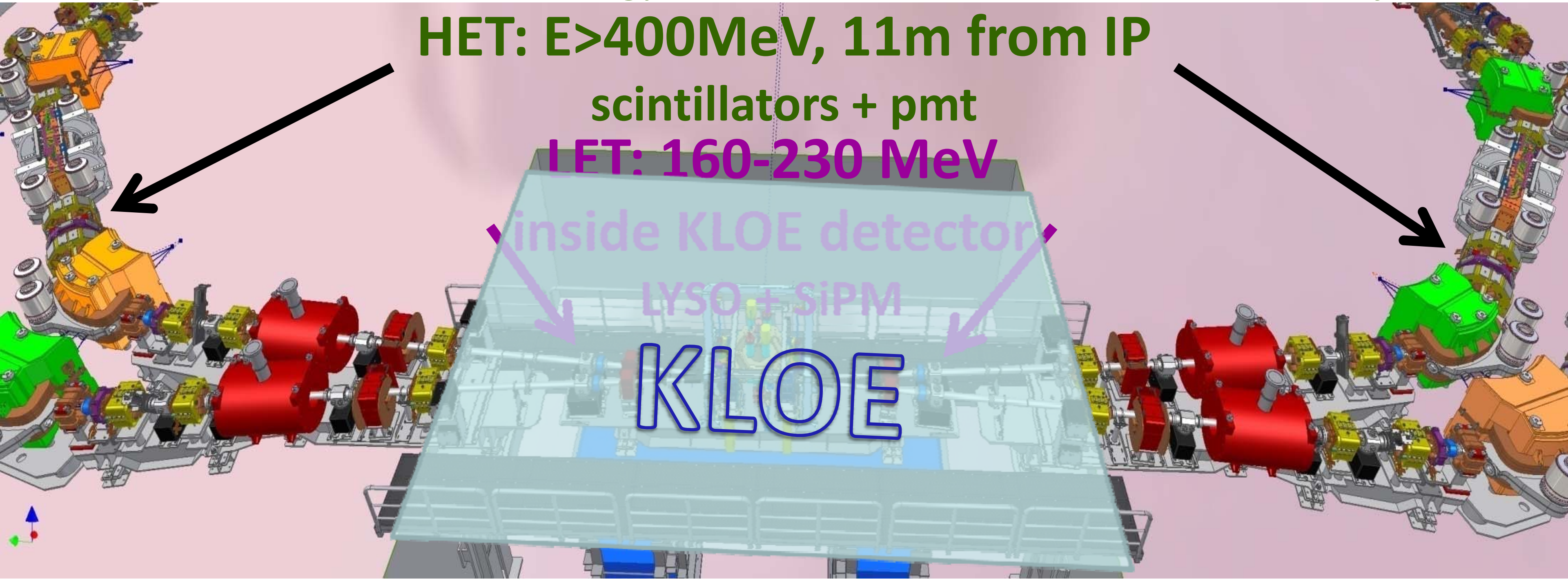
Present upgrades of the KLOE detector: $\gamma\gamma$ taggers

At $\sqrt{s}=m_\phi$, tagging $\gamma\gamma$ events by detecting e^+e^- is mandatory to reduce backgrounds, together with P_T kinematical selection on the tagged evts

Scattered electrons escape from the KLOE *detector along the DAFNE beam lines*

Magnetic elements will deflect these "off-energy" particles out of vacuum tubes.

Four tagging stations will be added: their task will be to identify $e^+e^- \to e^+e^- \gamma\gamma$ events through the detection of off-energy electrons close to the nominal beam trajectories



Combining all the information from the taggers, **we can get 500 pb^{-1} of clean $\gamma\gamma$ physics during first year of data taking**

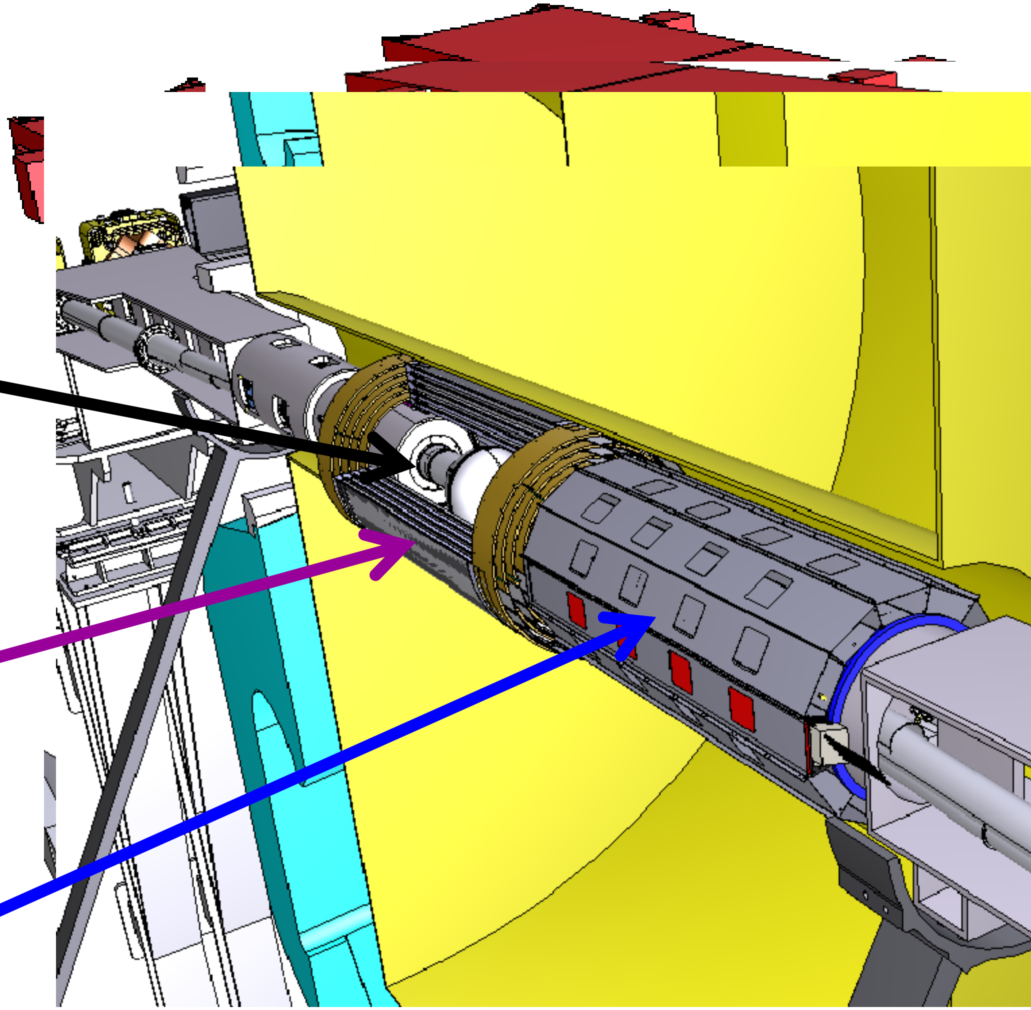
Forthcoming detector upgrades

In late 2011 new sub-detectors will be added inside KLOE in order to improve its performance:

CCAL
- ✓ LYSO + APD
- ✓ Increase acceptance for γ's from IP (21°→10°)

INNER TRACKER
- ✓ 4 layers of cylindrical triple GEM
- ✓ Better vertex reconstruction near IP
- ✓ Larger acceptance for low pt tracks

QCALT
- ✓ W + scintillator tiles + SiPM/WLS
- ✓ quadrupoles coverage for K_L decays



Physics program

KLOE collaboration achieved several precision Kaon and Hadron Physics results

The KLOE-2 collaboration is ready to start a new enthusiastic data-taking campaign, to pursue a rich physics program including:

- $\gamma\gamma$ physics
  - Study of $\Gamma(S/PS \rightarrow \gamma\gamma)$, test of χPT, existence and properties of $\sigma(600)$ meson, PS Transition Form Factor
- Kaon Physics
  - Test of CPT (and QM) in correlated kaon decays
  - Test of CPT in K_S semileptonic decays
  - Test of SM (CKM unitarity, lepton universality)
  - Test of χPT (KS decays)
- Spectroscopy of light mesons
  - η, η', f_0 , a_0, σ in ϕ radiative decays
- Dark Matter searches (light bosons at O(1 GeV))

Moreover, a proposal to increase DAFNE energy up to 2.4 GeV has been presented, to study:

- Hadronic cross section from $2m_\pi$ to 2.4 GeV
- α_{em}(MZ) and (g-2)μ

References : KLOE-2 Collaboration arXiv 1030.3868