Results in hadronic physics with the KLOE experiment in Frascati

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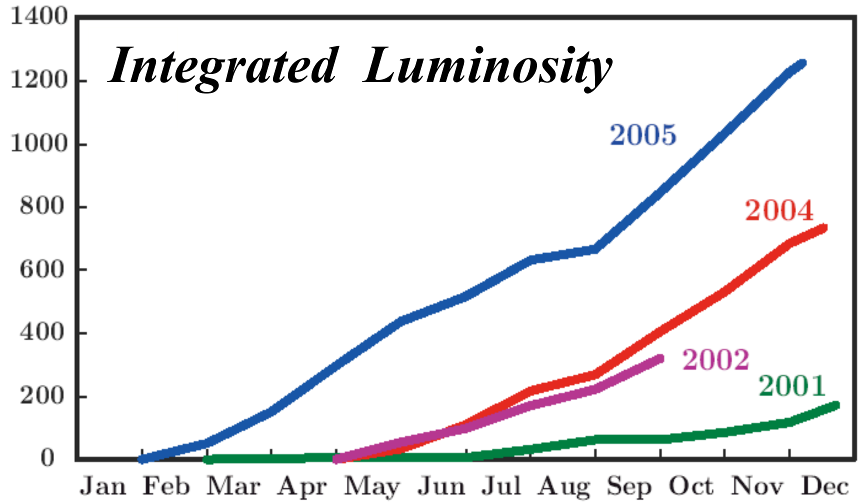
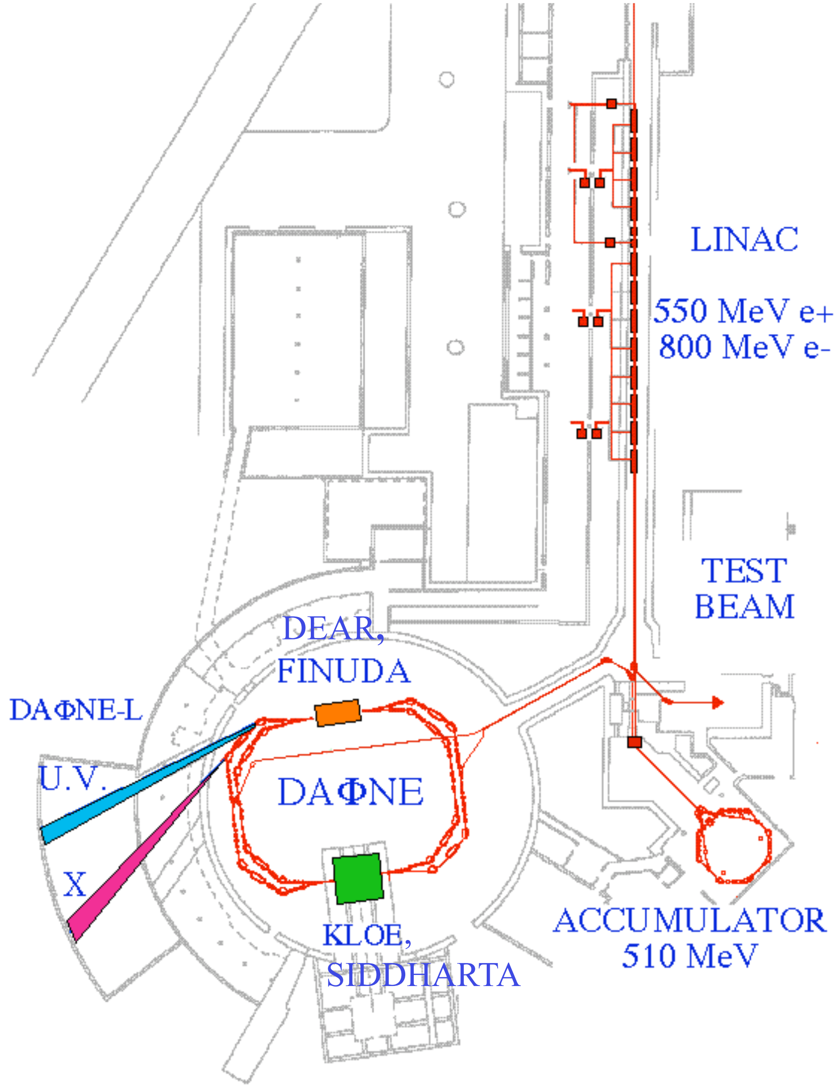
Frühjahrstagung der Deutschen Physikalischen Gesellschaft

Bochum, 16-20 March 2009

DAΦNE: A Φ-Factory

e^+e^- - collider with $\sqrt{s}$ = $m_\Phi \approx 1.0195$ GeV





Peak Luminosity L_{peak} = 1.4 • 10^{32}cm^{-2}s^{-1}

Total KLOE int. Luminosity:

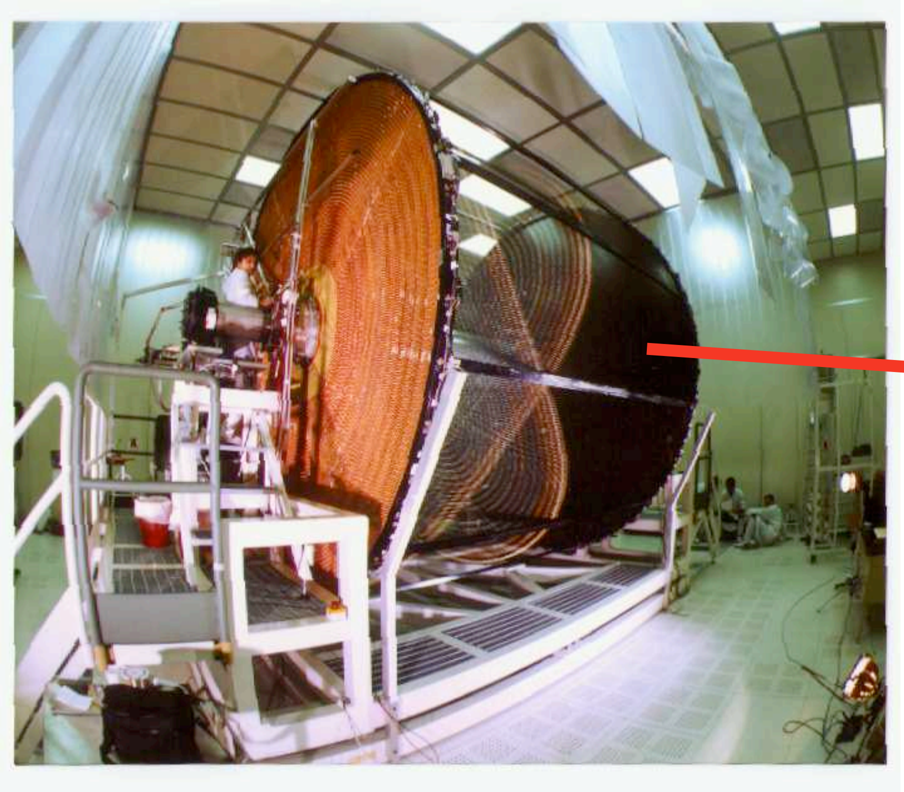
$\int \mathcal{L}\, dt$ ~ 2500 pb^{-1} (2001 - 05)

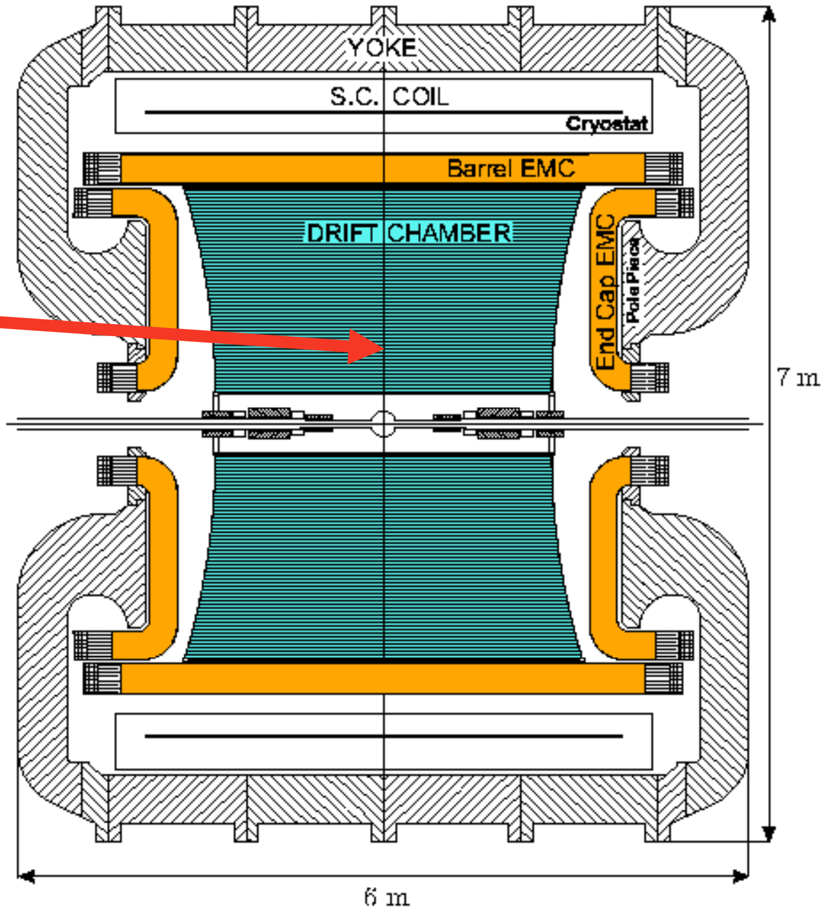
2006:

- Energy scan with 4 points around m_Φ-peak
- 250 pb^{-1} at $\sqrt{s}$ = 1 GeV

KLOE Detector

Driftchamber





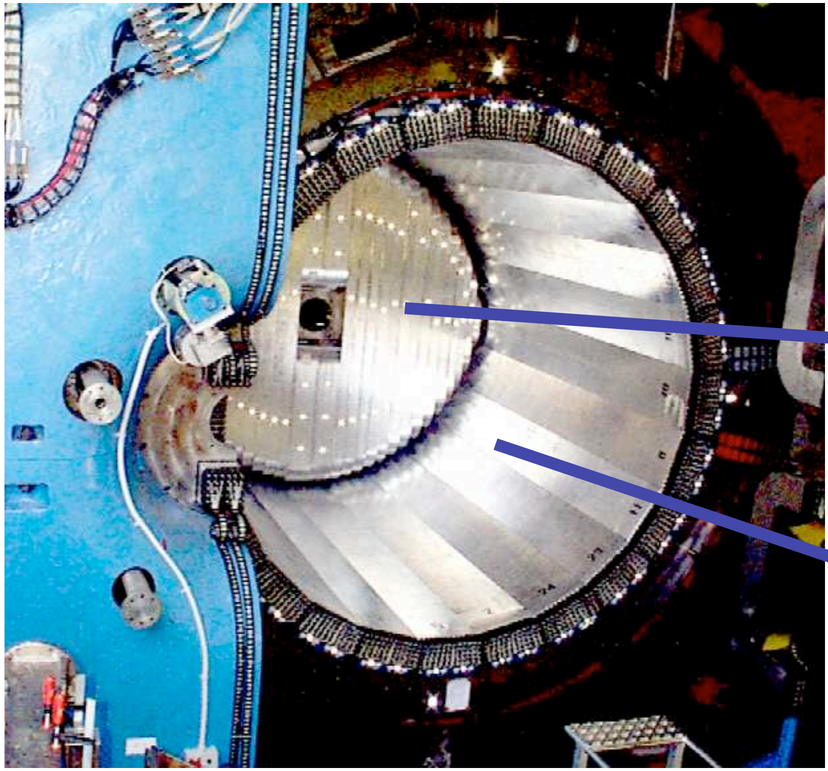
σ_p/p = 0.4% (for 90^0 tracks)

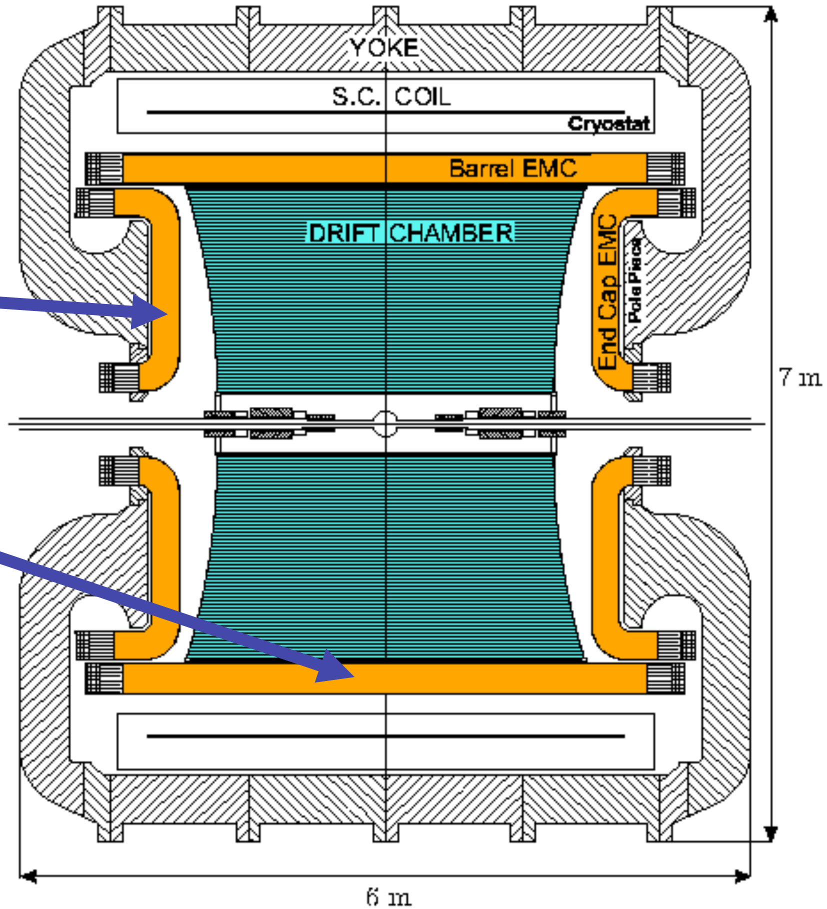
$\sigma_{xy} \approx 150\ \mu$m, $\sigma_z \approx 2$ mm

Excellent momentum resolution

KLOE Detector

Electromagnetic Calorimeter





$\sigma_E/E = 5.7\% / \sqrt{E(GeV)}$

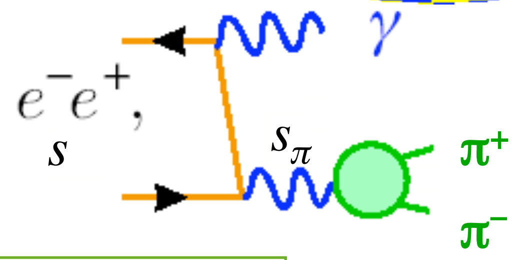
$\sigma_T = 54\ ps / \sqrt{E(GeV)} \oplus 100\ ps$

(Bunch length contribution subtracted from constant term)

Excellent timing resolution

Radiative return at KLOE

Particle factories have the opportunity to measure the cross section $\sigma(e^+ e^- \rightarrow \pi^+\pi^-)$ as a function of the pionic c.m. energy $s_\pi = M^2_{\pi\pi}$ using initial state radiation (**radiative return** to energies below the collider energy s).



$$s \cdot \frac{d\sigma(e^+ e^- \rightarrow \pi^+\pi^- + \gamma)}{ds_\pi} = \sigma(e^+ e^- \rightarrow \pi^+\pi^-)\, H(s, s_\pi)$$

Neglecting FSR

requires precise calculation of the radiator $H(s, s_\pi)$

➔ **EVA + PHOKHARA MC Generator**

(S.Binner, J.H.Kühn, K.Melnikov, PLB459,1999)

(H.Czyż, A.Grzelińska, J.H.Kühn, G.Rodrigo, EPJC27,2003)

Advantages:

- overall energy scale √s is well known and applies to all values of s_π
- syst. errors from luminosity, √s, rad. corrections enter only once, don't need to be studied for each point of s_π
- data comes together with the standard physics program of the experiment

Requirements:

- precise evaluation of radiator function
- good suppression, or understanding, of Final State Radiation (FSR)
- large integrated luminosity

1st KLOE result using 2001 data: Phys. Lett. B 606, 12 (2005)

These measurements are very important for the theoretical evaluation of the hadronic contribution to $(g_\mu - 2)$!

Measurement of $\sigma_{\pi\pi}$:

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

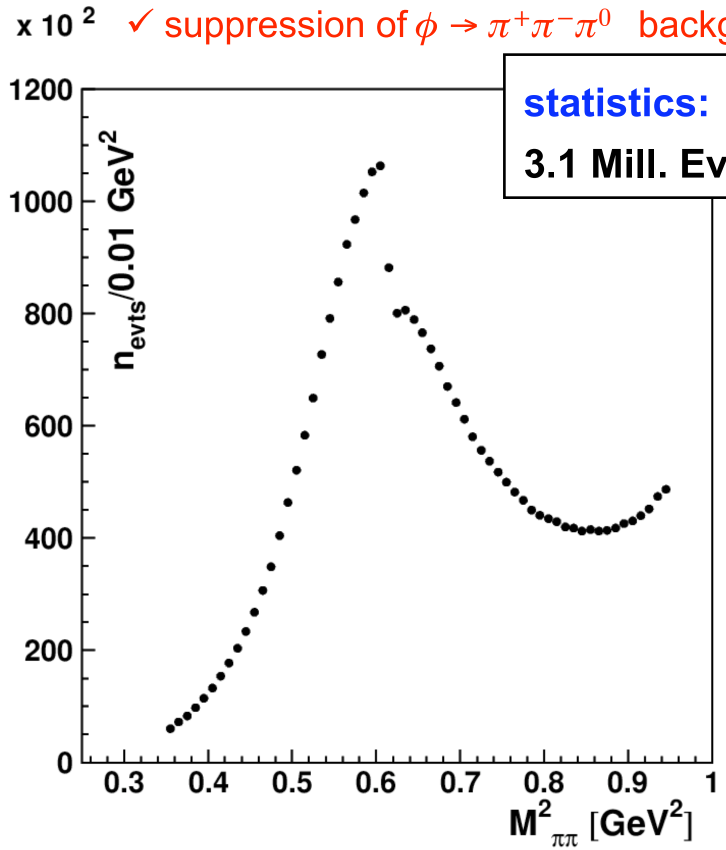
Photons at small angles
$\theta_\gamma < 15^o$ or $\theta_\gamma > 165^o$

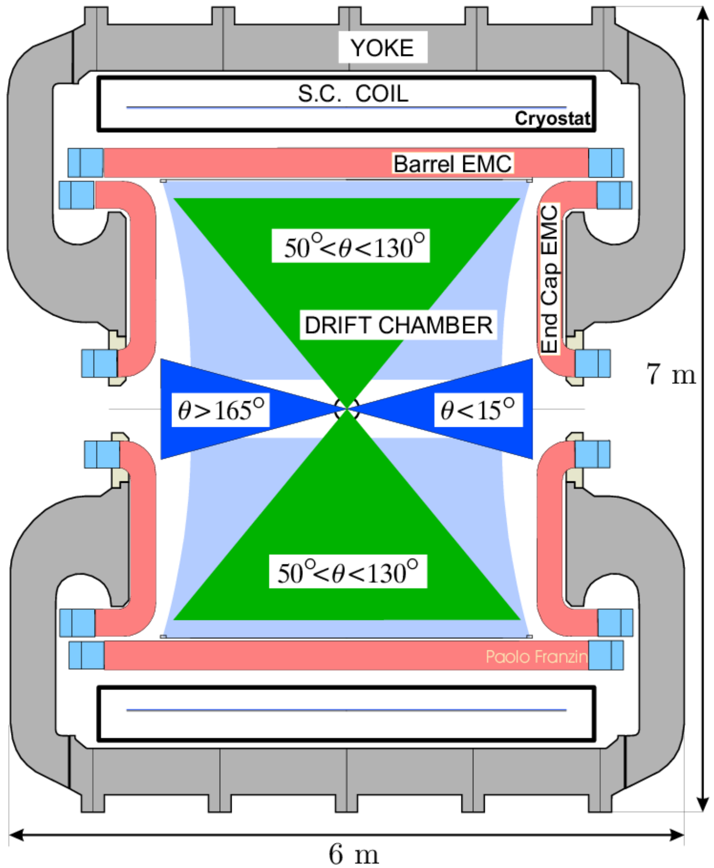
- ✓ high statistics for ISR events
- ✓ low relative FSR contribution
- ✓ suppression of $\phi \to \pi^+\pi^-\pi^0$ background

➔ **photon momentum from kinematics:**

$$\vec{p}_\gamma = \vec{p}_{miss} = -(\vec{p}_+ + \vec{p}_-)$$

statistics: 242pb^{-1}
3.1 Mill. Events



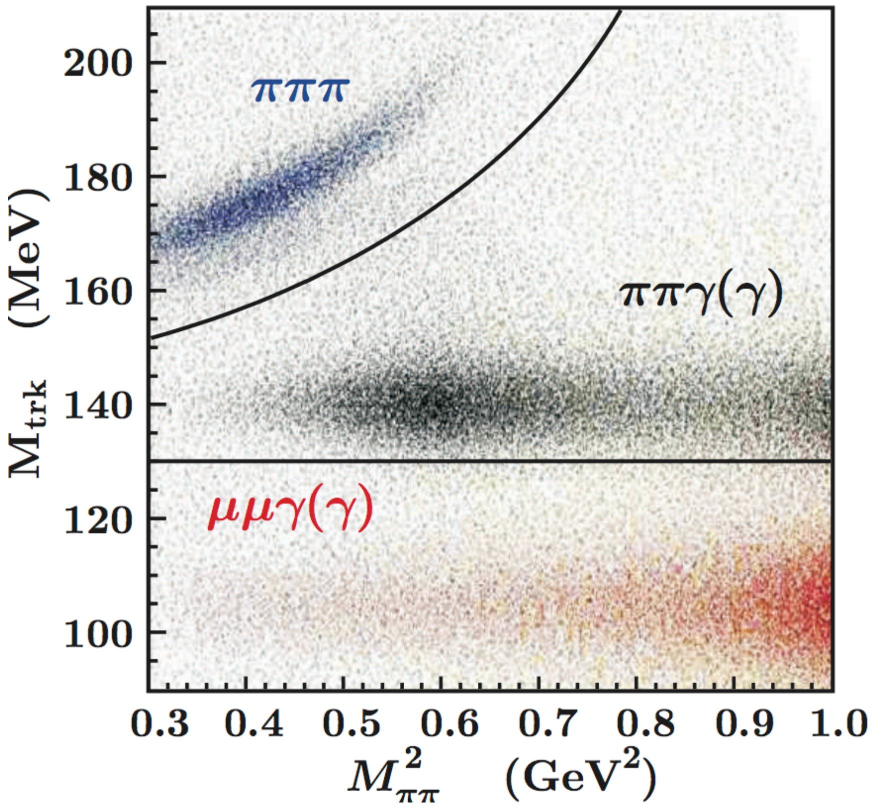


Event selection

- Experimental challenge: Fight background from
  - $\phi \to \pi^+\pi^-\pi^0$
  - $e^+e^- \to e^+e^- \gamma$
  - $e^+e^- \to \mu^+\mu^- \gamma$,

  separated by means of kinematical cuts in *trackmass* M_{Trk} (defined by 4-momentum conservation under the hypothesis of 2 tracks with equal mass and a γ)

$$\left(\sqrt{s} - \sqrt{p_1^2 + M_{trk}^2} - \sqrt{p_2^2 + M_{trk}^2}\right)^2 - (p_1 + p_2)^2 = 0$$



To further clean the samples from radiative Bhabha events, a particle ID estimator for each charged track based on Calorimeter Information and Time-of-Flight is used.

$$\frac{d\sigma_{\pi\pi\gamma}}{ds_\pi} = \frac{N^{obs} - N^{bkg}}{\Delta s_\pi} \cdot \frac{1}{\varepsilon_{sel}} \cdot \frac{1}{L}$$

Luminosity:

KLOE measures *L* with Bhabha scattering

F. Ambrosino et al. (KLOE Coll.)
Eur.Phys.J.C47:589-596,2006

55° < θ < 125°

acollinearity < 9°

p ≥ 400 MeV

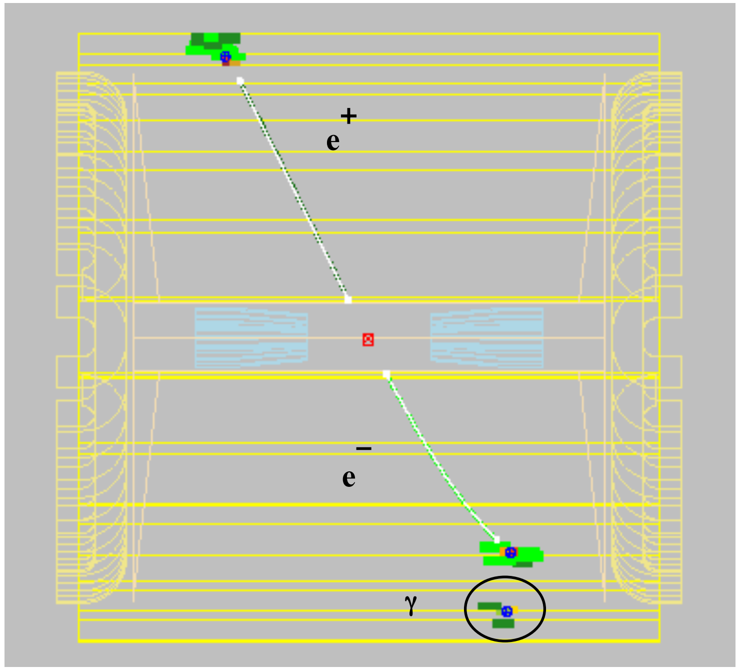
$$\int \mathcal{L}\,\mathrm{dt} = \frac{N_{obs} - N_{bkg}}{\sigma_{eff}}$$

generator used for σ_{eff}

BABAYAGA (Pavia group):

C. M.C. Calame et al., NPB584 (2000) 459

Now: *C. M.C. Calame et al., NPB758 (2006) 22*

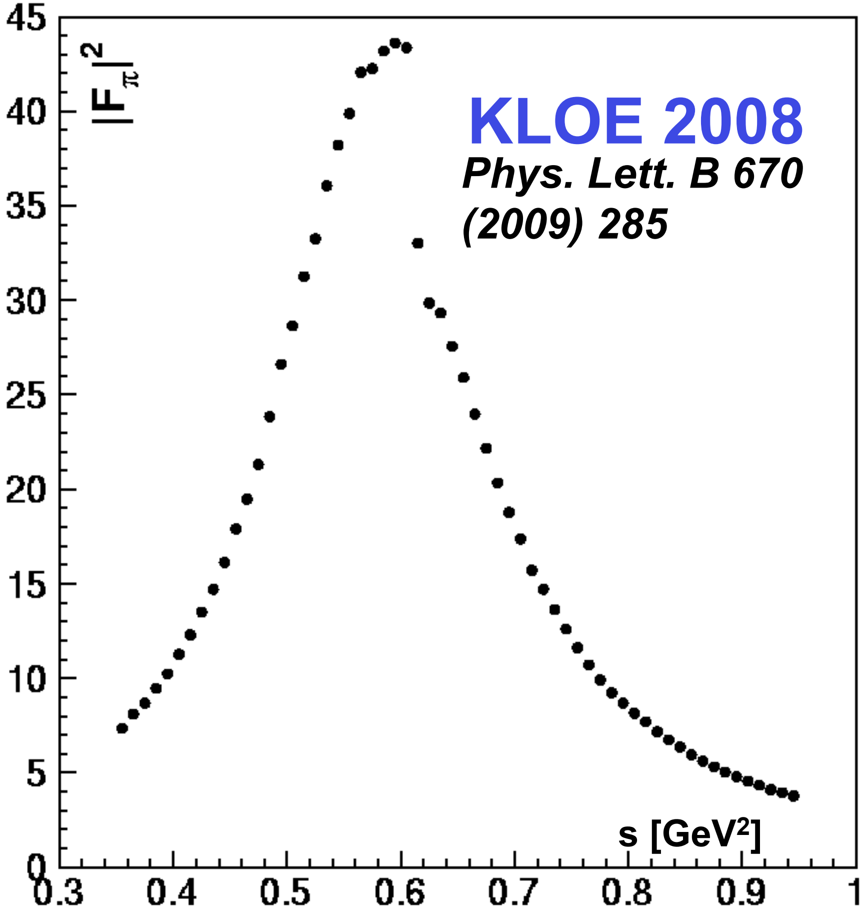


newer version (**BABAYAGA@NLO**) gives 0.7% decrease in cross section, and better accuracy: 0.1%

Systematics on Luminosity	
Theory	0.1 %
Experiment	0.3 %
TOTAL 0.1 % th ⊕ 0.3% exp = 0.3%	

New KLOE result:

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



Systematic errors on $a_\mu^{\pi\pi}$:

Reconstruction Filter	negligible
Background subtr.	0.3%
Trackmass cut	0.2%
π/e particle ID	negligible
Tracking	0.3%
Trigger	0.1%
Acceptance ($\theta_{\pi\pi}$)	0.2%
Acceptance (θ_π)	negligible
Unfolding	negligible
Software Trigger	0.1%
$\sqrt{s}$ dep. of H	0.2%
Luminosity($0.1_{th} \oplus 0.3_{exp}$)%	0.3%

experimental fractional error on a_μ = 0.6 %

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

theoretical fractional error on a_μ = 0.6 %

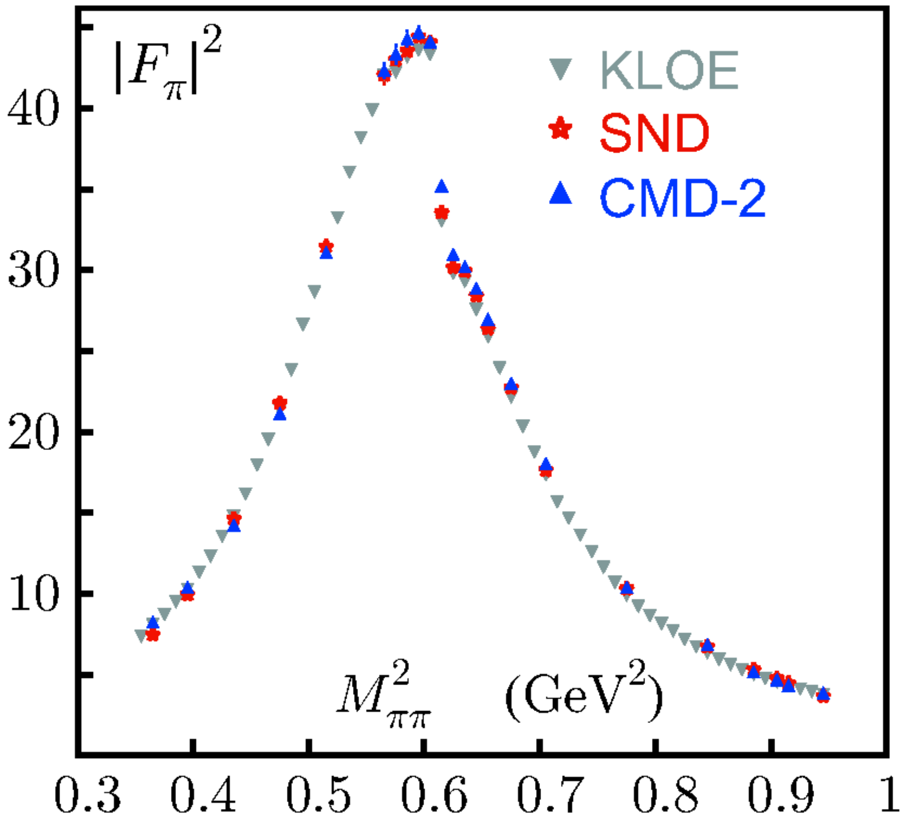
Disp. Integral:

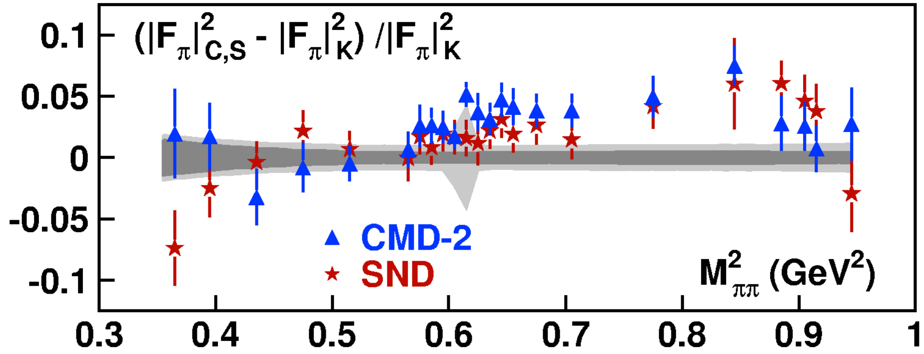
$$a_\mu^{had} = \frac{1}{4\pi^3}\int_{x_1}^{x_2}\sigma^{had}(s)K(s)\,ds$$

$a_\mu^{\pi\pi}(0.35\text{-}0.95\,\text{GeV}^2) = (387.2 \pm 0.5_{stat} \pm 2.4_{sys} \pm 2.3_{theo}) \cdot 10^{-10}$

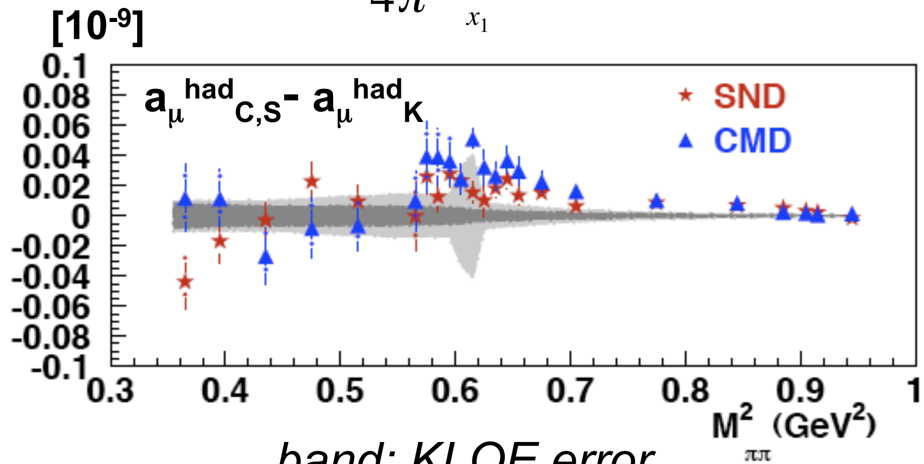
$|F_\pi|^2$ for different exp.:

Phys. Lett. B 670 (2009) 285





abs. contr. to $a_\mu^{had} = \frac{1}{4\pi^3}\int_{x_1}^{x_2} \sigma^{had}(s)\mathrm{K}(s)\,\mathrm{d}s$ per bin:

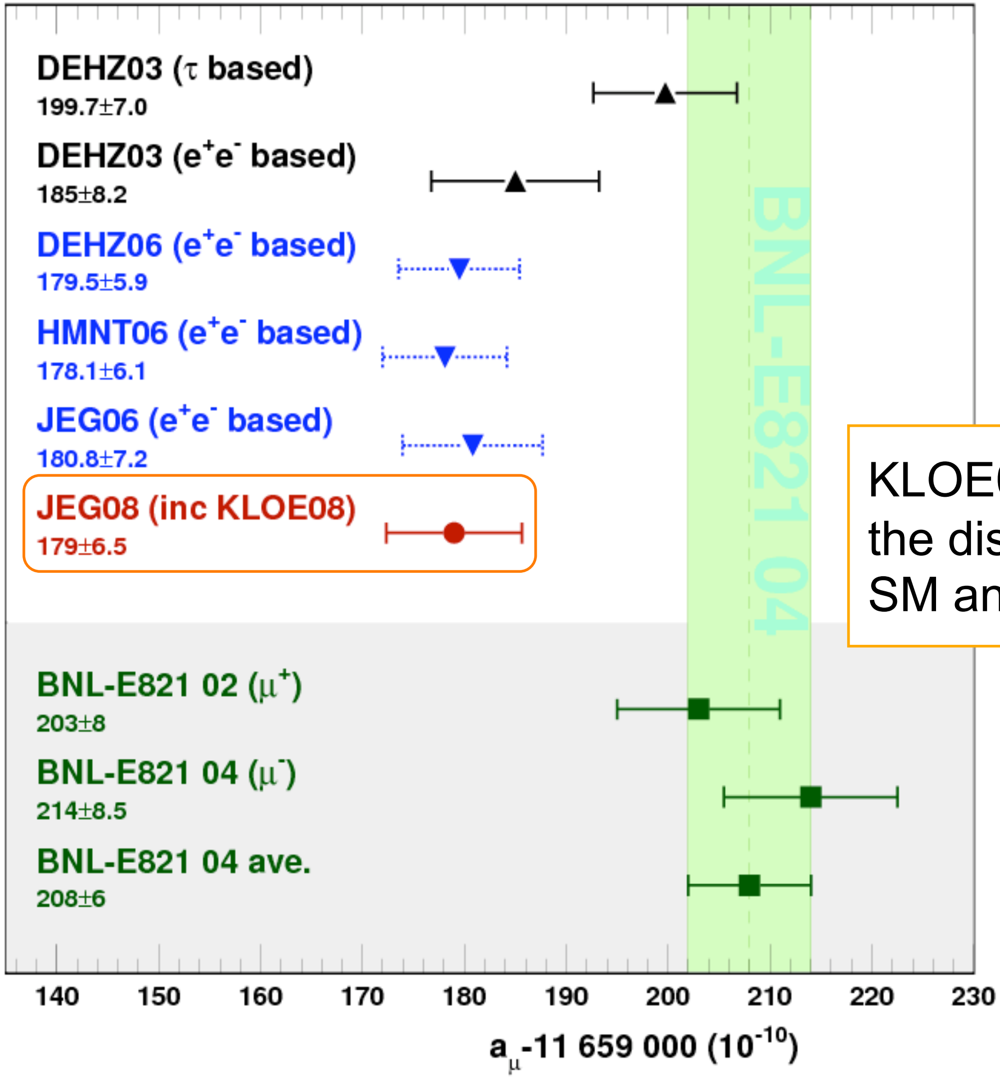


band: KLOE error
data points: CMD2/SND experiments

Improved agreement with spectra from energy scan experiments – no compensation of different regions in the dispersion integral!

$a_\mu=(g_\mu-2)/2$:

Theoretical predictions compared to the BNL result:



KLOE08 strengthens the discrepancy between SM and experiment

New analysis in progress:

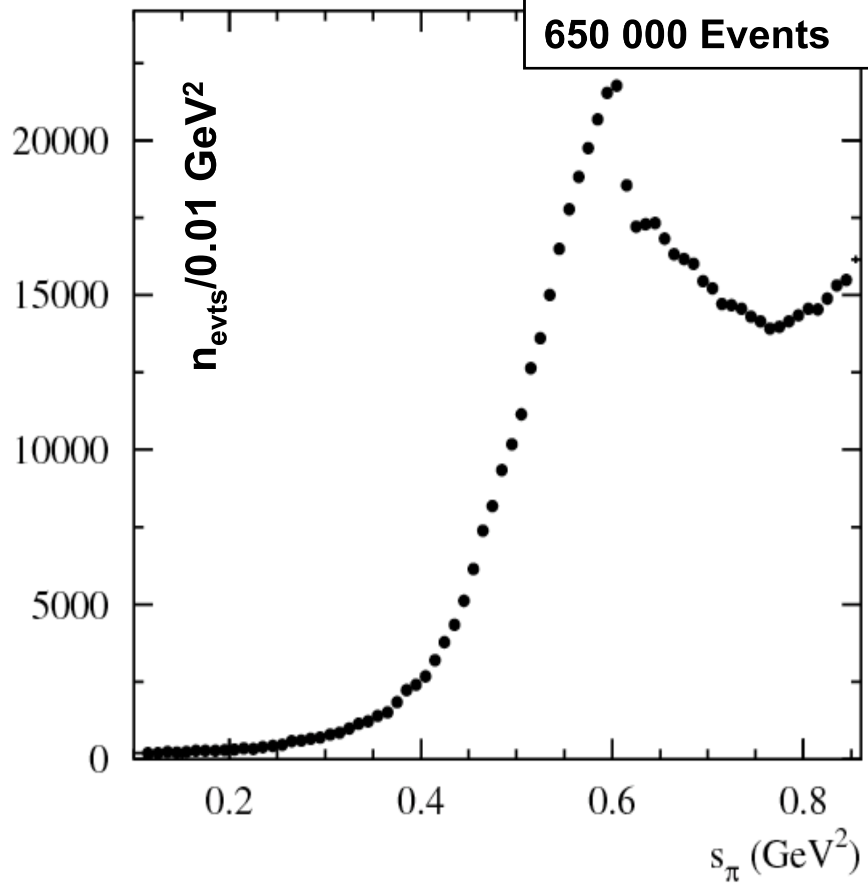
2 pion tracks at large angles
$50^o < \theta_\pi < 130^o$

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

- ✓ **independent complementary analysis**
- ✓ **threshold region $(2m_\pi)^2$ accessible**
- ✓ **γ_{ISR} photon detected (4-momentum constraints)**

- ✓ **lower signal statistics**
- ✓ **larger contribution from FSR events**
- ✓ **larger $\phi \to \pi^+\pi^-\pi^0$ background contamination**
- ✓ **irreducible background from ϕ decays ($\phi \to f_0\,\gamma \to \pi\pi\,\gamma$)**

statistics: 233pb^{-1}
650 000 Events

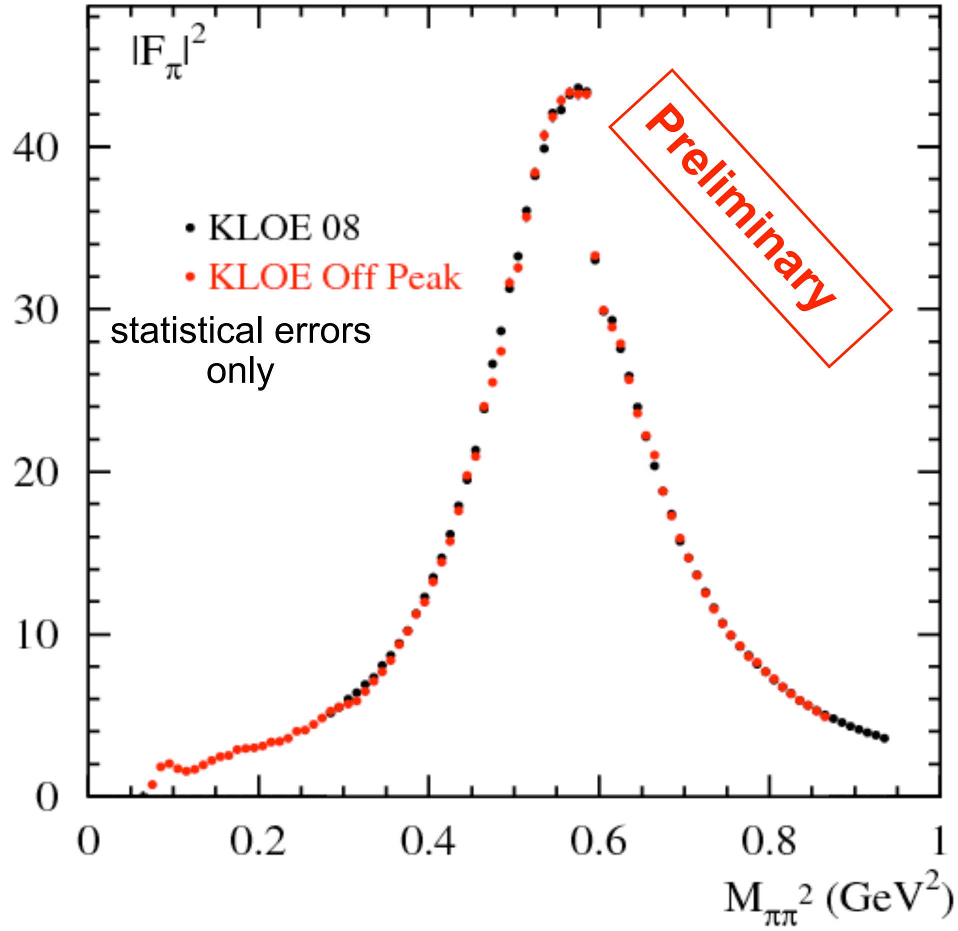


Use data sample taken at $\sqrt{s} \cong 1000$ MeV, 20 MeV below the ϕ−peak

New analysis in progress:

✓ Selection cuts established
✓ Efficiencies evaluated
✓ Few systematic uncertainties still under evaluation

Very good agreement between the spectrum of the preliminary new result and the KLOE 08 published analysis



This analysis is very close to a final result

Light scalars in ϕ decays

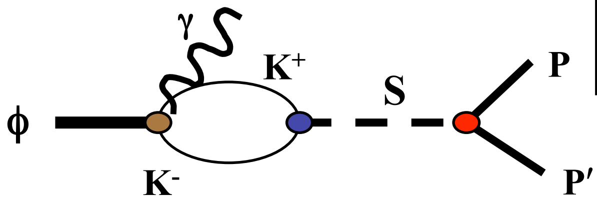
The structure of scalars below 1 GeV is still an open question:
[**qq**, **qqqq** (Jaffe '77…), **KKbar molecule** (Weinstein-Isgur '90)…]

BR and mass spectra of the radiative decays $\phi \rightarrow PP'\gamma$ **sensitive to the structure of the intermediate scalar mesons**

At KLOE: **PP′** = $\pi^0\pi^0$	$\Rightarrow$	$f_0(980)/\sigma(600)$	[EPJC49(2007)473,PLB537(2002)21]
$\pi^+\pi^-$	$\Rightarrow$	$f_0(980)/\sigma(600)$	[PLB634(2006)148]
$\eta\pi^0$	$\Rightarrow$	$a_0(980)$	[New paper in preparation, PLB536(2002)209]
K_SK_S	$\Rightarrow$	$f_0(980)/a_0(980)$	[New paper in preparation]

Phenomenological models used to describe $\phi \rightarrow S\gamma \rightarrow PP'\gamma$:

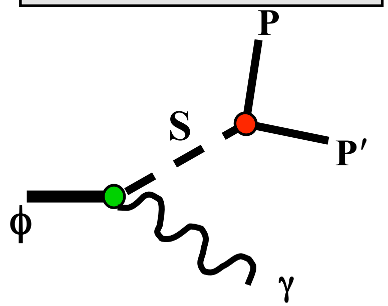
Kaon Loop



Fit params:
M_S, $g_{SPP'}$, g_{SKK}

[N.N.Achasov, V.N.Ivanchenko, NPB315 (1989) 465]
[N.N.Achasov, V.V.Gubin, PRD 56 (1997) 4084]
[N.N.Achasov, A.V.Kiselev, PRD 68 (2003) 014006]

No Structure



Fit params:
M_S, $g_{\phi S g}$, $g_{SPP'}$, g_{SKK},
continuum (polynomial)

[G.Isidori, L.Maiani, M.Nicolaci, S.Pacetti, JHEP 05 (2006) 049]

$e^+e^- \to \eta\pi^0\gamma$: search for $a_0(980)$

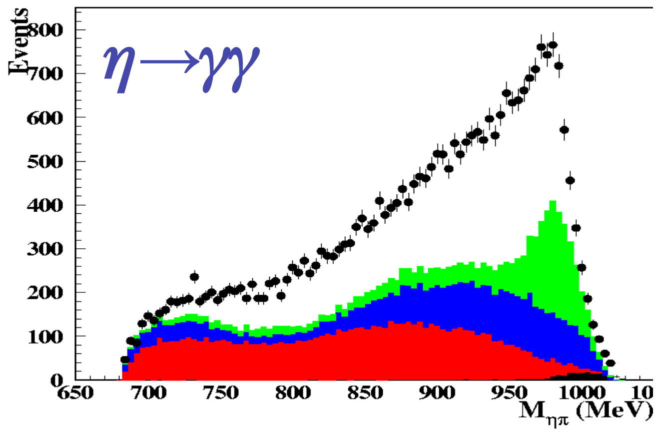
- ~400 pb^{-1} of e^+e^- collisions @ $\sqrt{s}=M_\phi$
- Dominated by $\phi \to a_0(980)\gamma$
- Decay channels: (1) $\eta\to\gamma\gamma$, (2) $\eta\to\pi^+\pi^-\pi^0$
- From event counting:

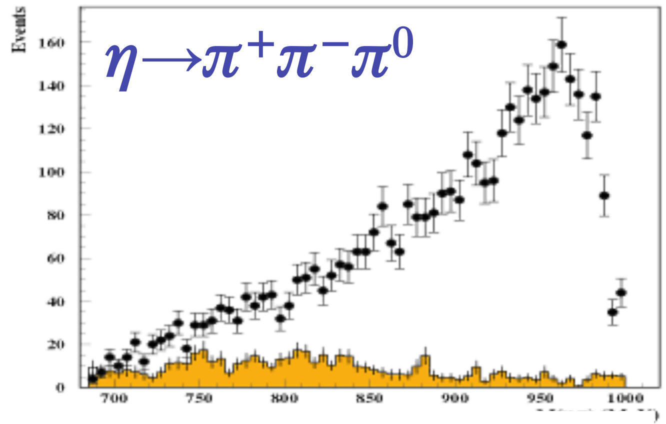
$$BR(\phi \to \eta\pi^0\gamma) = (7.01 \pm 0.10_{stat} \pm 0.20_{syst})\times 10^{-5} \quad (1)$$

$$BR(\phi \to \eta\pi^0\gamma) = (7.12 \pm 0.13_{stat} \pm 0.22_{syst})\times 10^{-5} \quad (2)$$

Combined fit to $M_{\eta\pi}$ spectra:

Parameter	Kaon Loop	No Structure
M_{a0} (MeV)	**982.5 ± 1.6 ± 1.1**	982.5 (fixed)
g_{a0KK} (GeV)	**2.15 ± 0.06 ± 0.06**	**2.01 ± 0.07 ± 0.28**
$g_{a0\eta\pi}$ (GeV)	**2.82 ± 0.03 ± 0.04**	**2.46 ± 0.08 ± 0.11**
$g_{\phi a0\gamma}$ (GeV^{-1})	1.58 ± 0.10 ± 0.16	**1.83 ± 0.03 ± 0.08**
$BR(\phi\to\rho\pi\to\eta\pi\gamma)\times 10^6$	**0.92 ± 0.40 ± 0.15**	**0.05 ± 4 ± 0.07**
$BR(\eta\to\gamma\gamma)/BR(\eta\to\pi\pi\pi)$	**1.70 ± 0.04 ± 0.03**	**1.70 ± 0.03 ± 0.01**
$P(\chi^2)$	10.4%	30.9%





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

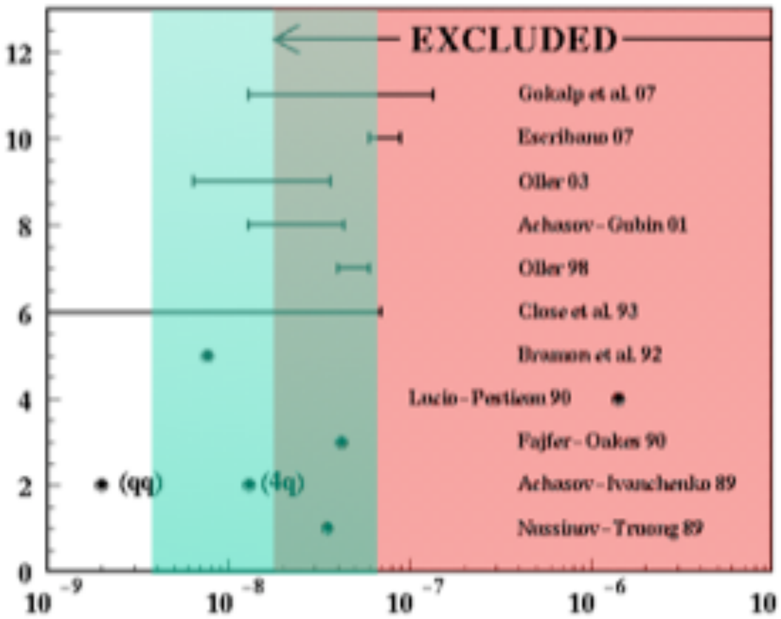
- $R = (g_{aK+K-} / g_{a\eta\pi})^2 \sim 0.6\text{-}0.7$
- R_η [PDG08] =1.73±0.04

Search for $\phi \rightarrow K^0 \overline{K}^0 \gamma$

- Expected to proceed mainly through $\phi \rightarrow [f_0(980)+a_0(980)]\gamma \rightarrow K^0\overline{K}^0\gamma$
- **Never been observed**
- Selected channel: $K_S K_S \gamma \rightarrow \pi^+\pi^-\pi^+\pi^-\gamma$ Clean topology, 24% BR reduction
- Signal MC according to phase-space and radiative decay dynamics
- Selection cuts optimized on MC (bckg: $\mathbf{K_S K_L(\gamma)}$, $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-(\gamma)$)
- 2.18 fb^{-1} data @ M_ϕ :
  - **5 EVENTS IN DATA**
  - **2.5 + 0.7 BCKG EVENTS (MC)**

$$BR(\phi \rightarrow K^0 \overline{K}^0 \gamma) < 1.9 \times 10^{-8} \; @ \; 90\% \; \text{C.L.}$$

Consistency check using KLOE couplings from $\phi \rightarrow \pi\pi\gamma$, $\phi \rightarrow \eta\pi\gamma$ in the Kaon Loop model



η/η' mixing

$$R_\phi = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = (4.77 \pm 0.09_{stat} \pm 0.19_{syst}) \times 10^{-3}$$

PLB 648 (2007) 267

Gluonium content in η' evaluated using Rosner model: [Rosner PRD27(1983) 1101] [Kou PRD63(2001)54027]

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

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

$$X_{\eta'} = \cos\phi_G \sin\varphi_P$$

$$Y_{\eta'} = \cos\phi_G \cos\varphi_P$$

$$Z_{\eta'} = \sin\phi_G$$

SU(3) relations between decay modes:

$$\frac{\Gamma(\eta' \to \rho\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = C_{M2} Z_{NS} \left| \sin(\varphi_G)\cos(\varphi_P) \right|^2$$

$$R_\phi = \cot^2(\varphi_P)\cos^2(\varphi_G)\left(1 - C_V \frac{Z_{NS}}{Z_N} \frac{1}{\sin(2\varphi_P)}\right)^2 \left(\frac{p_{\eta'}}{p_\eta}\right)^3$$

$$\frac{\Gamma(\eta' \to \gamma\gamma)}{\Gamma(\pi^0 \to \gamma\gamma)} = C_{M1} \left(5\cos(\varphi_G)\sin(\varphi_P) + \sqrt{2}\frac{f_q}{f_s}\cos(\varphi_G)\cos(\varphi_P)\right)^2$$

$$\frac{\Gamma(\eta' \to \omega\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = C_{M3} \left(Z_{NS}\sin(\varphi_G)\cos(\varphi_P) + 2C_V Z_S \sin(\varphi_G)\sin(\varphi_P)\right)^2$$

Gluonium content extracted using Z_N, Z_{NS} evaluated assuming $Z^2_{\eta'}=0$:

[Bramon et al., EPJC 7 (1999) ; PLB 503 (2001)]

$\varphi_P = (39.7 \pm 0.7)°$

$Z^2_{\eta'} = 0.14 \pm 0.04$

$P(\chi^2) = 49\%$

Escribano-Nadal, JHEP05 (2007) 006: $Z^2_{\eta'} = 0.04 \pm 0.09$

η/η' mixing

Preliminary

Global fit with more free parameters (also Z_N, Z_{NS}, ϕ_V, m_s/m)

Other SU(3) relations included :

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

Parameter	KLOE published	New fit	New fit (no P$\gamma\gamma$)
$Z^2_{\eta'}$	0.14 ± 0.04	0.105 ± 0.037	0.03 ± 0.06
ϕ_P	(39.7 ± 0.7)°	(40.7 ± 0.7)°	(41.6 ± 0.8)°
Z_{NS}	0.91 ± 0.05	0.866 ± 0.025	0.85 ± 0.03
Z_S	0.89 ± 0.07	0.79 ± 0.05	0.78 ± 0.05
ϕ_V	3.2°	(3.15 ± 0.10)°	(3.16 ± 0.10)°
m_s/m	1.24 ± 0.07	1.24 ± 0.07	1.24 ± 0.07
$P(\chi^2)$	49%	17%	40.7%

- **Gluonium content @ ~3σ level confirmed**
- **Forcing $Z_{\eta'}=0$: $\phi_P = (41.6\pm0.5)°$ with $P(\chi^2)=1\%$**
- **Discrepancy with Escribano-Nadal** ($Z_{\eta'} = 0.04 \pm 0.09$, $\phi_P = (41.4\pm1.3)°$) [JHEP05(2007)006] **due to the insertion of P$\gamma\gamma$ transitions**

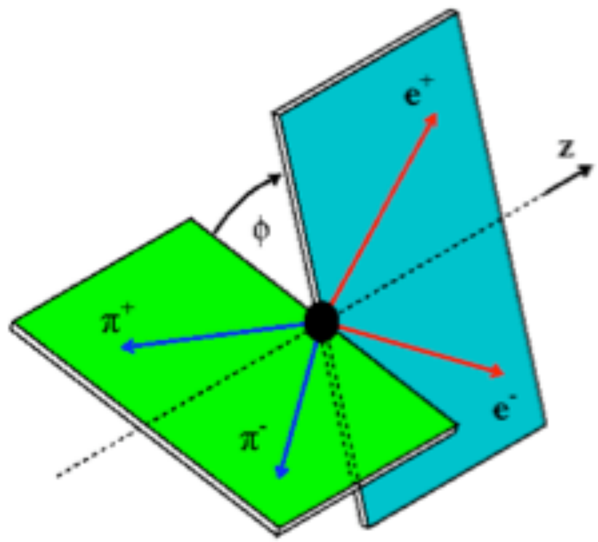
The decay $\eta \rightarrow \pi^+\pi^- e^+e^-$

- ✓ Poorly measured (4 events CMD-2, 16 events CELSIUS-WASA)
- ✓ BR predicted by ChPT and VMD models ($2.6 \div 3.6 \times 10^{-4}$)
- ✓ presence of virtual photon allows to test η structure
- ✓ Angular asymmetry between e^+e^- and $\pi^+\pi^-$ planes:
  test of non-CKM CP violation
  [D.Gao, Mod.Phys.Lett.A17 (2002) 1583]

Within SM constrained by BR($\eta \rightarrow \pi^+\pi^-$):

using experimental upper bound: $\mathbf{A_\phi < 10^{-4}}$

using theoretical predictions: $\mathbf{A_\phi \sim 10^{-15}}$

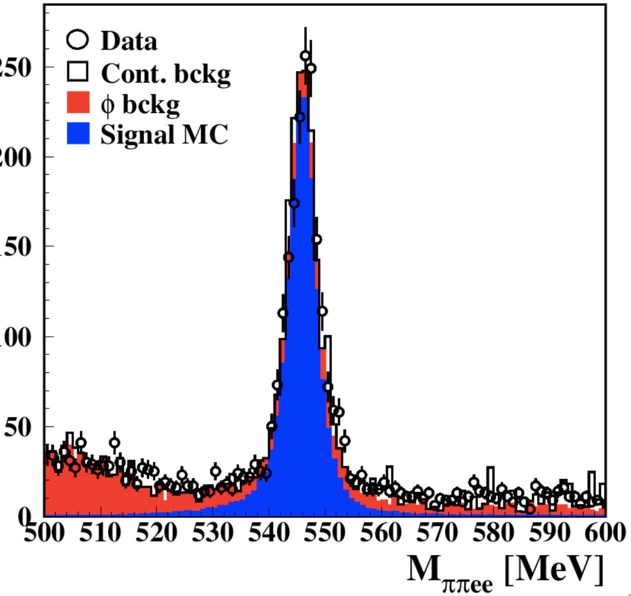


The unconventional CPV term increases A_ϕ up to 10^{-2}

The decay $\eta \to \pi^+\pi^-e^+e^-$

arXiv:0812.4830

Data sample: 1.73 fb^{-1}



PID with ToF EMC info

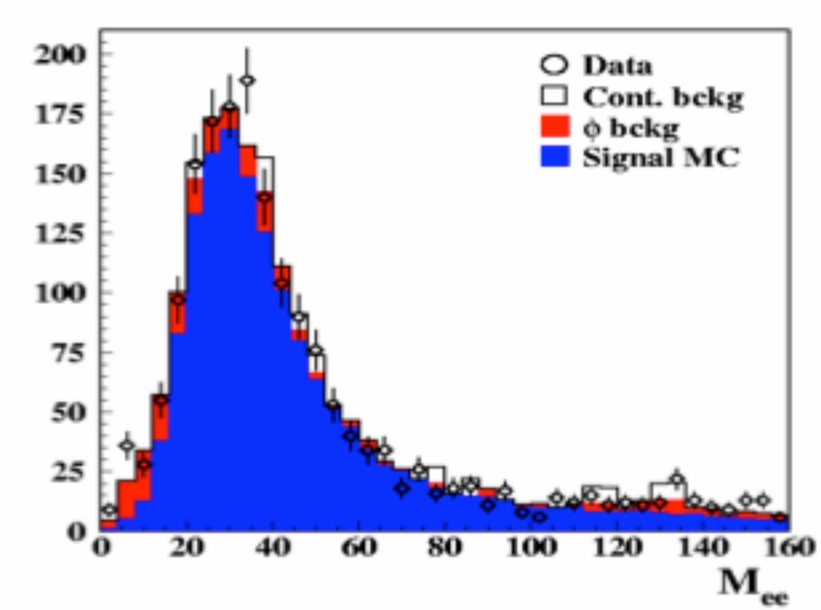
Fit on $M_{\pi\pi ee}$ side bands for background

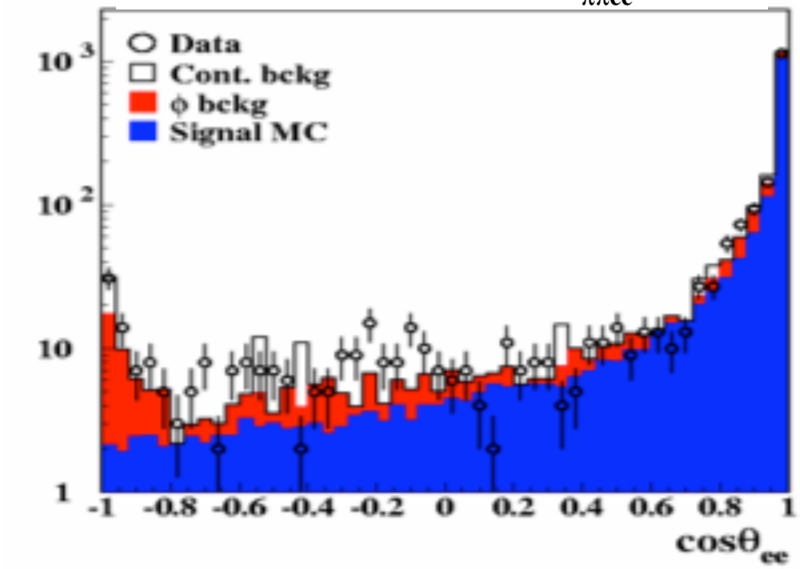
Photon conversion on Beam Pipe rejected

Counting on $M_{\pi\pi ee}$ in the signal region:

$N_{\pi\pi ee}$ = 1555 ± 52 (368 bckg evts)

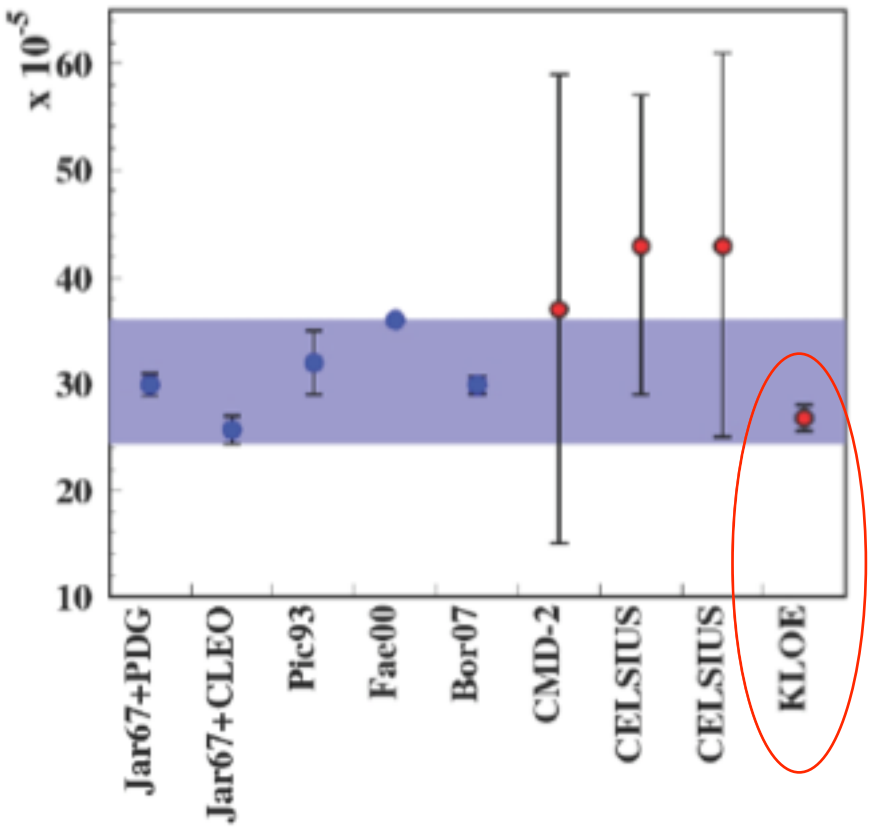
Analysis efficiency: 8%

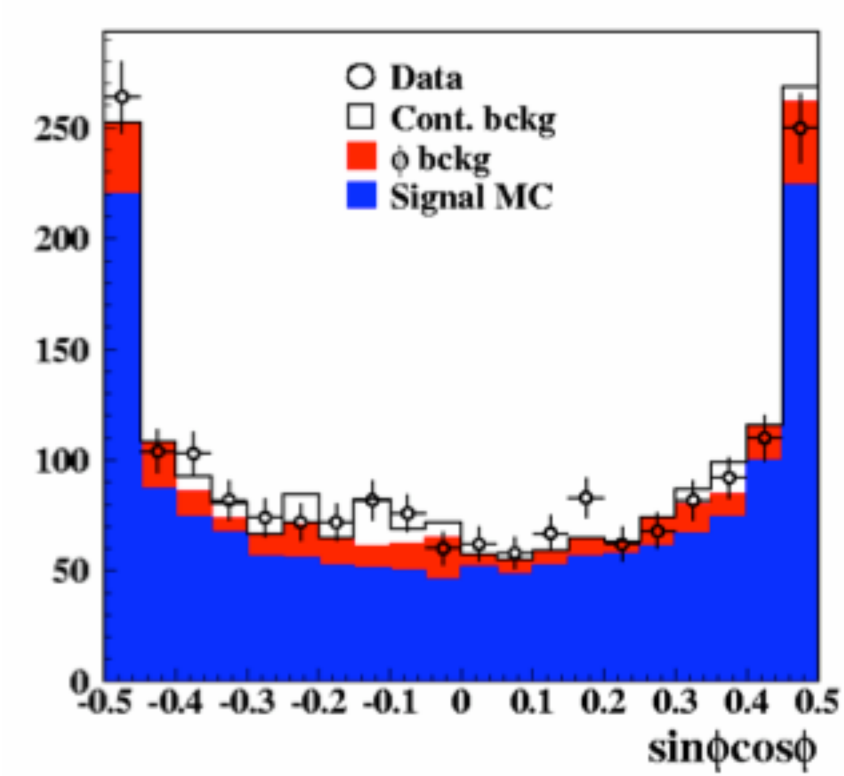




The decay $\eta \rightarrow \pi^+\pi^- e^+e^-$

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





1st measurement!

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

$$A_\phi = (-0.6 \pm 2.5_{stat} \pm 1.8_{syst}) \times 10^{-2}$$

arXiv:0812.4830

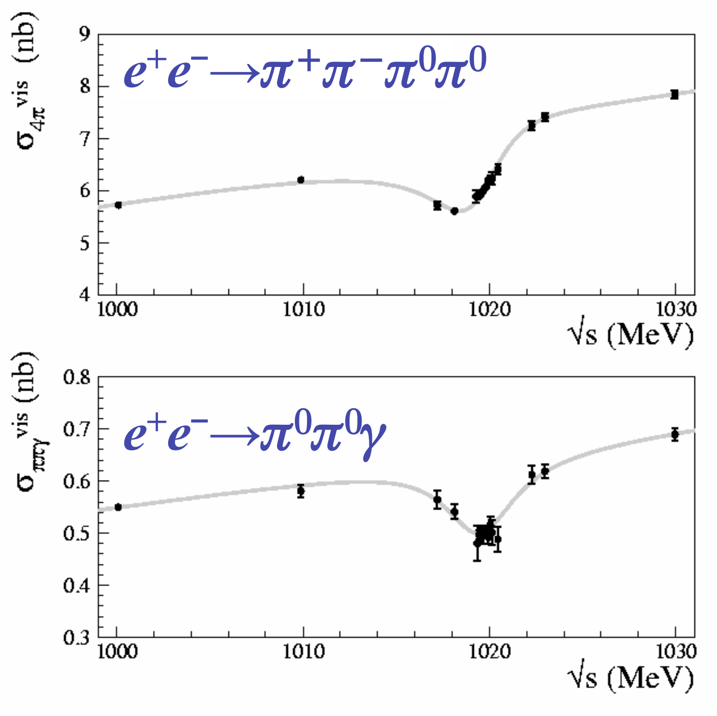
$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma, \pi^+\pi^-\pi^0\pi^0$

Interference pattern between non-resonant $e^+e^- \to \omega\pi^0$ and ϕ decays:

$$\sigma\left(\sqrt{s}\right) = \sigma_0\left(\sqrt{s}\right) \cdot \left|1 - Z\frac{M_\phi \Gamma_\phi}{D_\phi}\right|$$

Model indep. $\sigma_0(\sqrt{s})$:

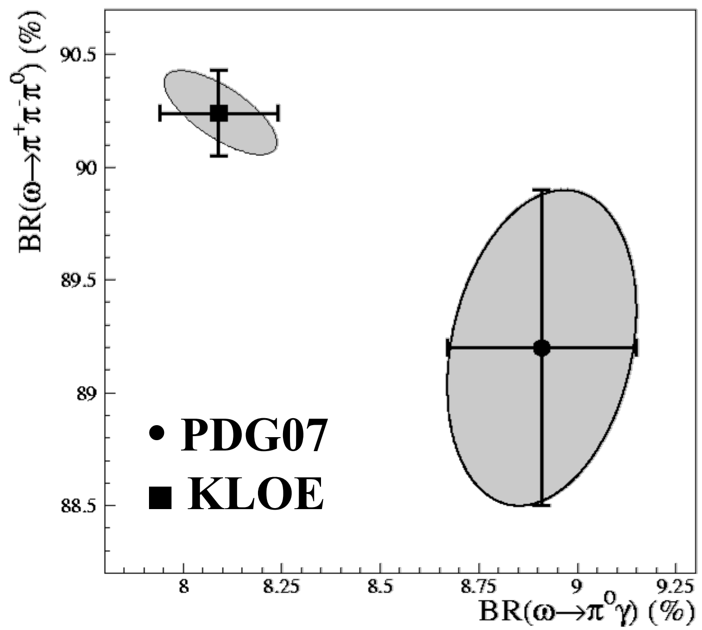
$$\sigma_0(\sqrt{s}) = \sigma_0 + \sigma'(\sqrt{s} - M_\phi)$$



From $\Gamma(\omega\to\pi^0\gamma)/\Gamma(\omega\to\pi^+\pi^-\pi^0)$ + unitarity (rare BRs (~2%)):

$BR(\omega\to\pi^+\pi^-\pi^0) = (90.24 \pm 0.19)\%$

$BR(\omega\to\pi^0\gamma) = (8.09 \pm 0.14)\%$



From fit parameters + $BR(\omega\to\pi^+\pi^-\pi^0)$:

$$BR(\phi \to \omega\pi^0) = \frac{\sigma_0^{\omega\pi}\left|Z_{4\pi}\right|^2}{\sigma_\phi} = (5.63 \pm 0.70)\times 10^{-5}$$

OZI + G-parity violating

$$\text{SND(2000)}: BR(\phi \to \omega\pi^0) = (5.2^{+1.3}_{-1.1})\times 10^{-5}$$

Conclusions

Many important results achieved by KLOE in hadronic physics:

- *a new precision measurement of the $\pi\pi$-cross section between 0.35 and 0.95 GeV^2, a complementary analysis using different acceptance cuts is close to completion*
- *BR($\phi \rightarrow a_0(980)\gamma$)*
- *Upper limit for $\phi \rightarrow KK\gamma$*
- *Gluonium content in η'*
- *BR and first measurement of the CPV plane asymmetry for $\eta \rightarrow \pi\pi ee$*
- *Precise measurement of the main ω BRs and BR($\phi \rightarrow \omega\pi^0$)*

Many more analyses ongoing

Outlook

New scheme to increase DAΦNE luminosity by a factor $O(5)$ is being implemented (large crossing angle + "crabbed waist")

Program:

1. **New KLOE data-taking will start at the end of 2009**, with the present detector + **tagger for γγ physics** ⇒ **~ 5 fb^{-1}**
2. **Detector upgrade**: inner tracker, new small angle calorimeters…
3. **KLOE-2 data taking** ⇒ **50 fb^{-1} in 3 – 4 years**

KLOE-2 physics program:

- **Kaon physics: CKM unitarity, Quantum Mechanics tests, lepton universality ($K^\pm \to e^\pm\nu$ / $K^\pm \to \mu^\pm\nu$), K_S rare decays**
- **Light hadrons: search for σ(600) in $\gamma\gamma \to \sigma \to \pi^0\pi^0$, $\phi \to (f_0/a_0)\gamma \to KK\gamma$ rare η decays, η′ physics**

SPARE SLIDES

$(g\text{-}2)_{\mu}$:

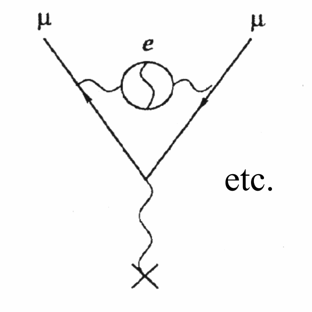
Magn. moment: $$\vec{\mu} = g\frac{e\hbar}{2mc}\vec{s} = g\mu_B\vec{s}$$

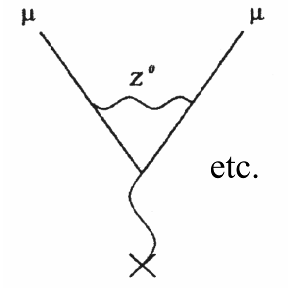
$\vec{s}$ = spin

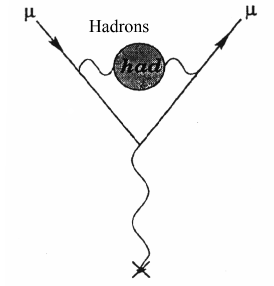
m = lepton mass

muons (s=1/2): $$\mathbf{a_\mu = (g_\mu - 2)/2 = 0 \quad (Dirac!)}$$

but…





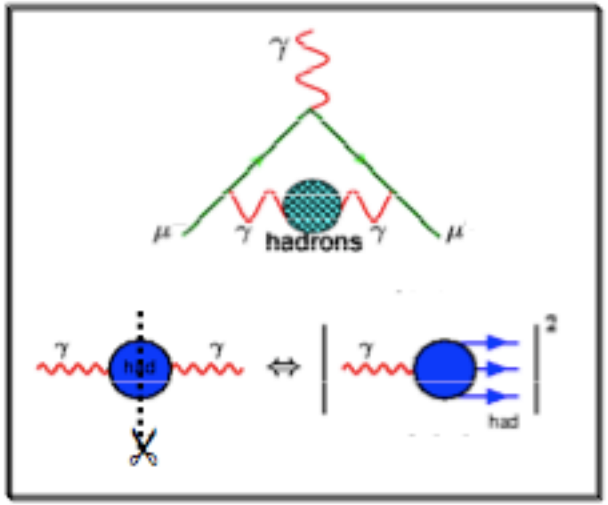


etc.

$$a_\mu^{QED} + a_\mu^{weak} + a_\mu^{had}$$

Dispersion integral for $a_\mu^{had,lo}$:

$a_\mu^{had,lo}$ can be expressed in terms of $\sigma(e^+e^- \rightarrow \text{hadrons})$ by the use of a dispersion integral:

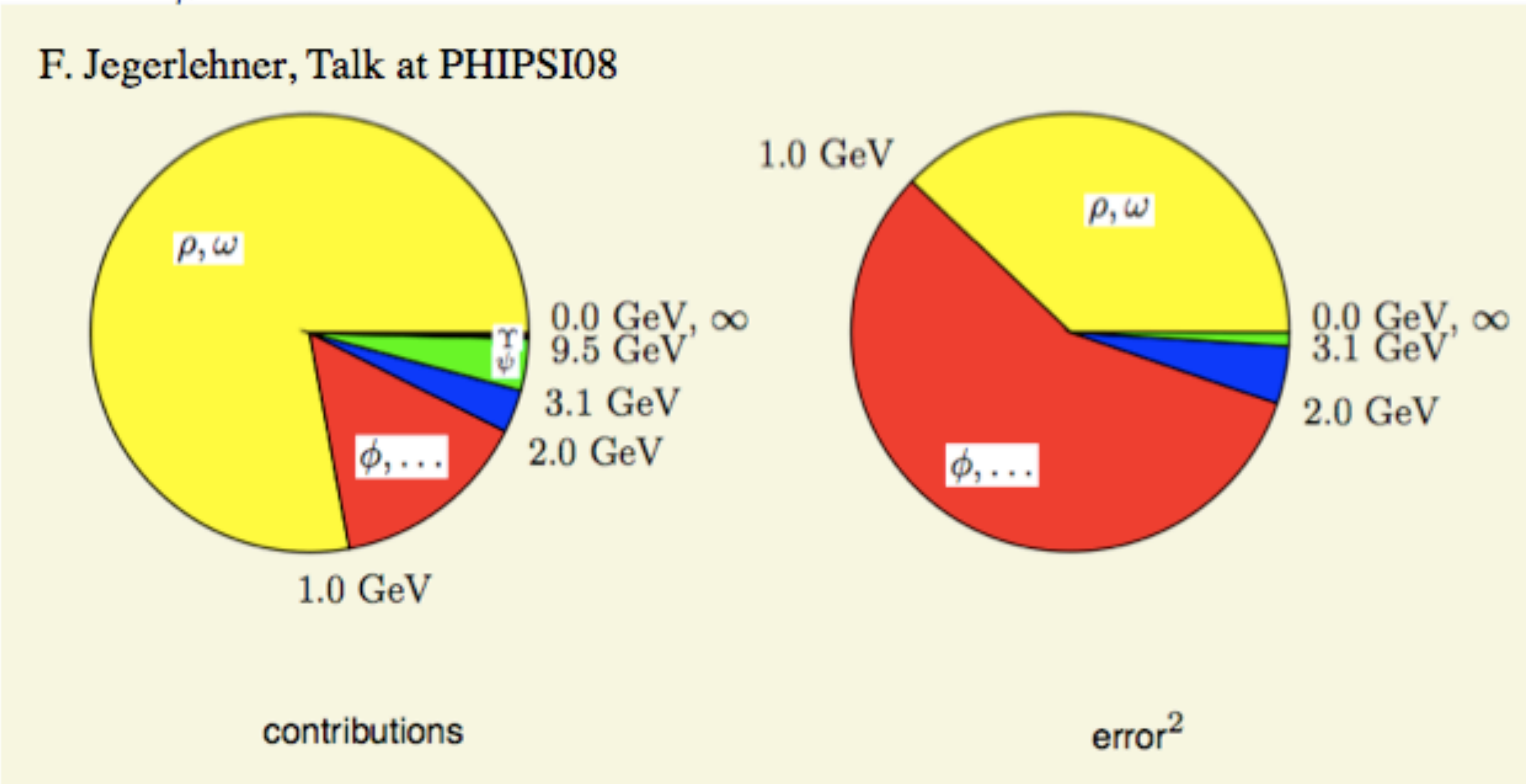


$$a_\mu^{had,lo} = \frac{1}{4\pi^3}\left(\int_{4m_\pi^2}^{E_{Cut}^2} ds\, \sigma^{had,exp}(s) K(s) + \int_{E_{Cut}^2}^{\infty} ds\, \sigma^{had,pQCD}(s) K(s) \right)$$

- E_{cut} is the threshold energy above which pQCD is applicable
- s is the c.o.m.-energy squared of the hadronic system
- K(s) is a smooth function that goes with 1/s, ***enhancing low energy contributions of $\sigma^{hadr}(s)$***

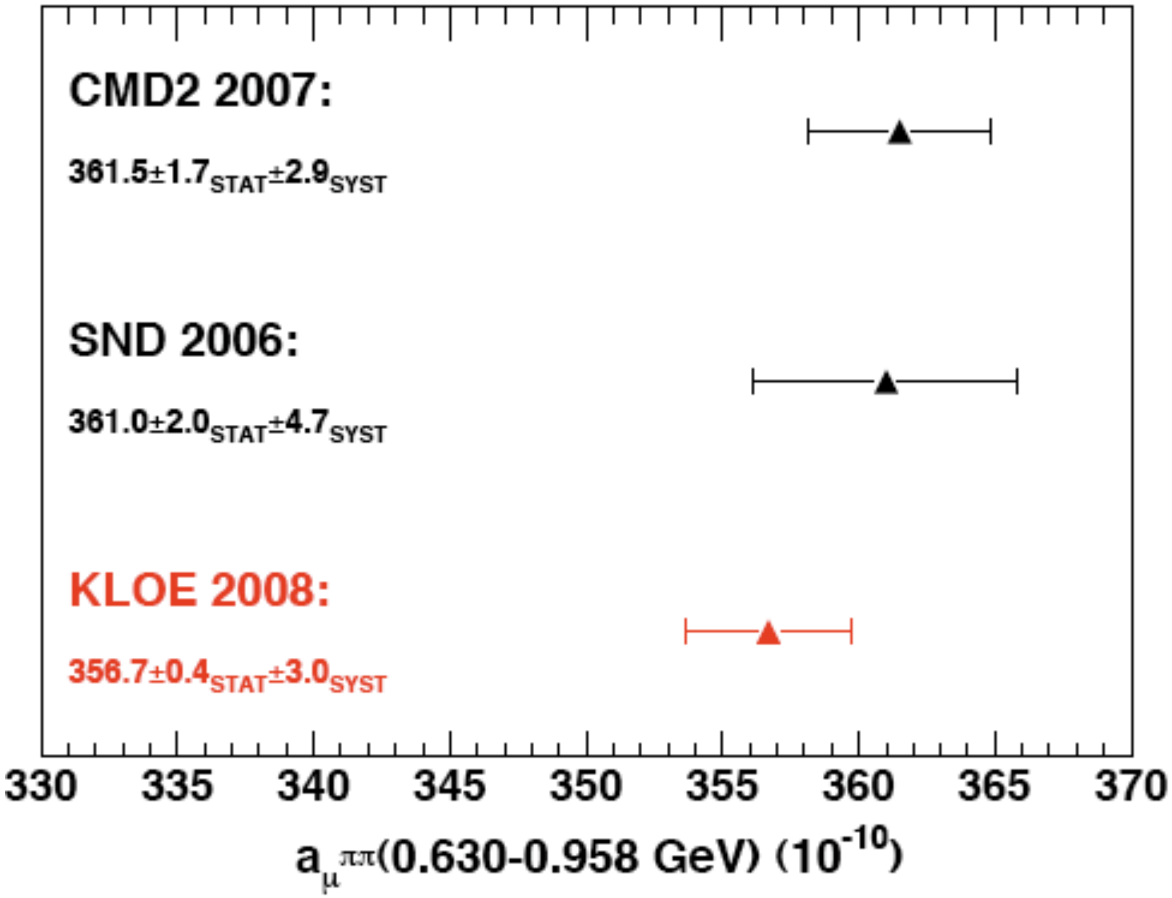
Dispersion integral:

Contributions of different energy regions to the dispersion integral and the error on a_μ^{had}



Experimental errors on σ^{had} translate into theoretical uncertainty of a_μ^{had}!
→ Needs precision measurements!

$a_\mu^{\pi\pi}$ for different exp.:

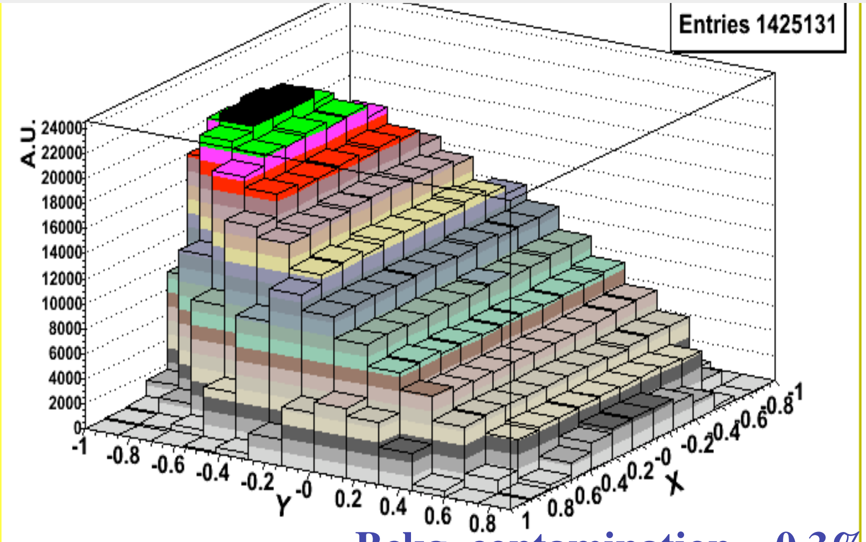


KLOE result in agreement with SND and CMD2

KLOE: $\eta \to \pi^+\pi^-\pi^0$ dynamics:

$19\times10^6\ \eta$ from $\phi \to \eta\gamma$. Tagging: recoil monochromatic photon (363 MeV)

$$|M^2| = 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3$$



Bckg. contamination ~ 0.3%

$$a = -1.090 \pm 0.005\,(\text{stat})\ ^{+0.008}_{-0.019}\,(\text{syst})$$
$$b = 0.124 \pm 0.006\,(\text{stat}) \pm 0.010\,(\text{syst})$$
$$d = 0.057 \pm 0.006\,(\text{stat})\ ^{+0.007}_{-0.016}\,(\text{syst})$$
$$f = 0.14 \pm 0.01\,(\text{stat}) \pm 0.02\,(\text{syst})$$
$$c = 0.002 \pm 0.003\,(\text{stat}) \pm 0.001\,(\text{syst})$$
$$e = -0.006 \pm 0.007\,(\text{stat})\ ^{+0.005}_{-0.003}\,(\text{syst})$$

Lowest order current algebra ($b=a^2/4$) not satisfied

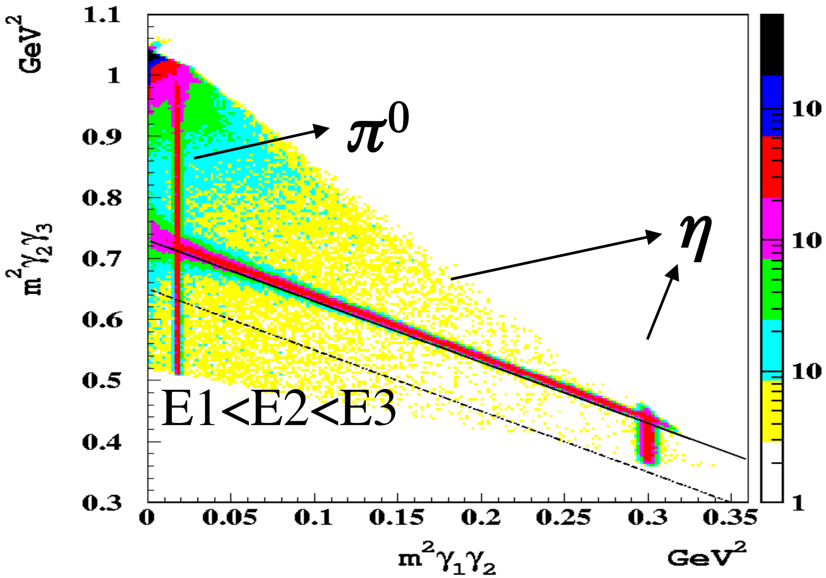
C-parity conservation

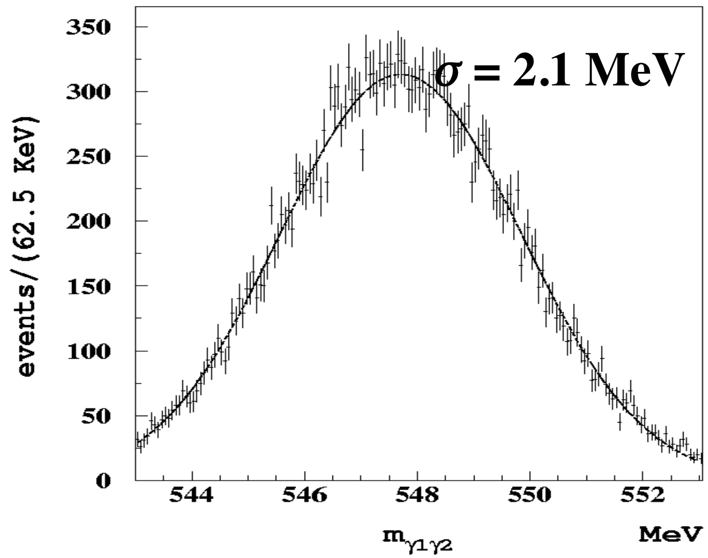
Borasoy-Nissler, Eur. Phys. J. A 26 (2005):

$a = -1.20 \pm 0.07 \quad b = 0.28 \pm 0.05 \quad c = 0.05 \pm 0.02$

Measurement of η mass:

- **$17\times10^6\,\eta$** from $\phi\rightarrow\eta\gamma$: Kinematic fit applied on $\phi\rightarrow\gamma\gamma\gamma$ events
- η and π^0 selected by looking at different Dalitz plot regions

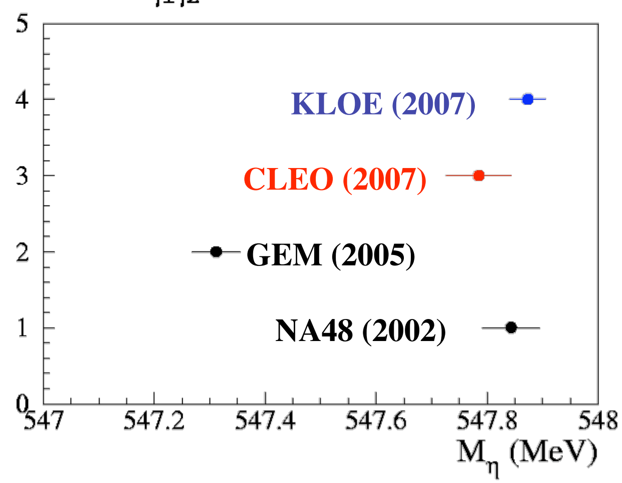




M_η = (547.874 ± 0.007 ± 0.029) MeV

Mass scale checked with $M_{\pi 0}$: 1.4 σ from PDG06

Systematics dominated by uniformity of the detector response

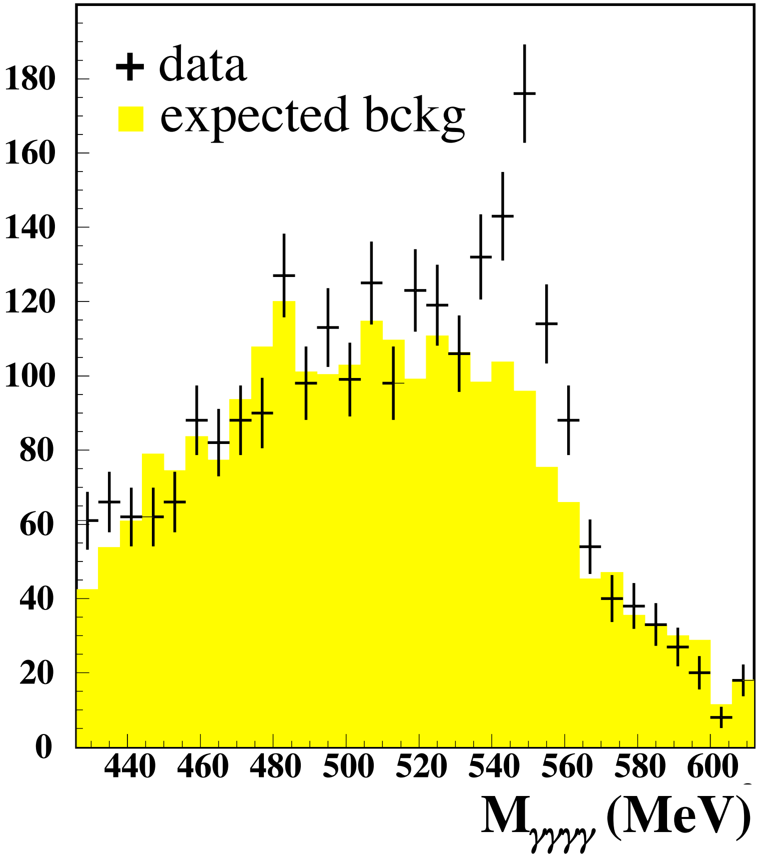


A flash on $\eta \to \pi^0\gamma\gamma$:

ChPT "golden mode": **p^2 null, p^4 suppressed, p6 dominates**

KLOE has presented a 3σ signal (only 1/5 of full statistics)

$$BR(\eta \to \pi^0\gamma\gamma) = (8.4 \pm 2.7_{stat} \pm 1.4_{syst}) \times 10^{-5}$$



CB@MAMI-B: BR = (22.5 ± 4.6 ± 1.7) × 10^{-5}
CB@AGS: BR = (22.1 ± 2.4 ± 3.8) × 10^{-5}

Analysis repeated with 1.5 fb^{-1} (2005 data):

- **the signal is confirmed**
- **BR updated result with the full sample will have ~15% error**