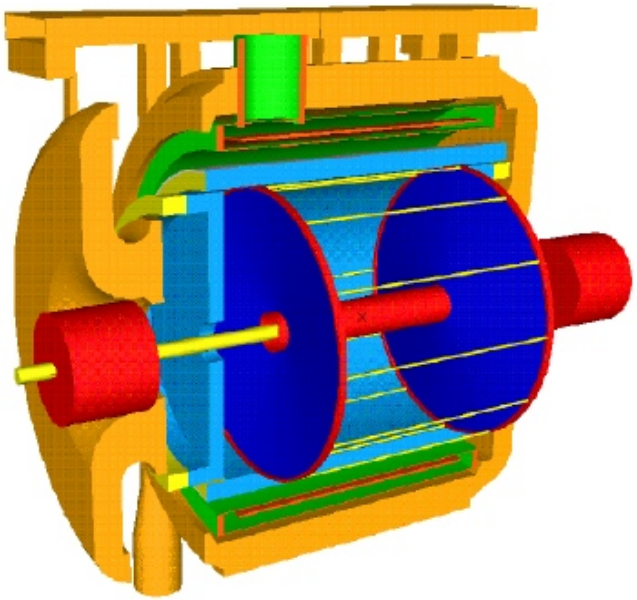
Status/results from KLOE/KLOE-2 experiment



Andrzej Kupsc
Uppsala University
for the KLOE-2 Collaboration

UPPSALA UNIVERSITET

Moscow, August 26th, 2013

Outline

KLOE-2 status

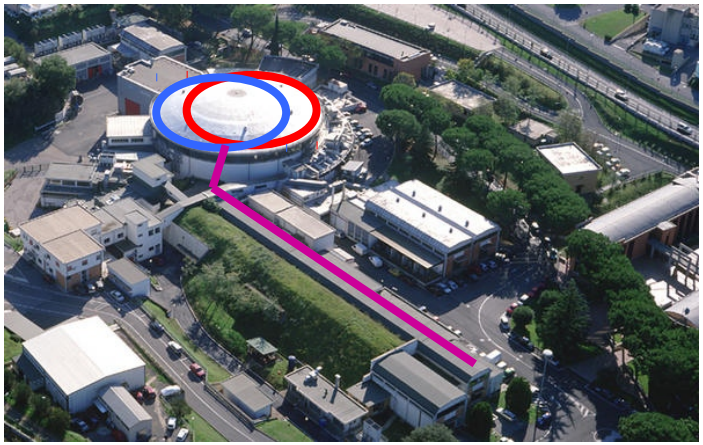
Most recent results from KLOE:

- UL: Br(Ks → $3\pi^0$) PLB723(2013)54
- $\phi \to K_L K_S \to \pi^+\pi^-\pi^+\pi^-$ (CPT and Lorentz tests) Prel.
- $e^+e^- \to \pi^+\pi^- \gamma_{ISR}$ PLB720(2013)336
- $\gamma\gamma \to \eta$ at 1 GeV ($\Gamma_{\gamma\gamma}$) JHEP 1301(2013)119
- $\phi \to \eta e^+e^-$ (U boson searches) PLB706(2012)251, PLB720(2013)111
- $e^+e^- \to \phi \to \eta/\pi^0 e^+e^-$ (TFF) Prel.
- $\eta \to \pi^+\pi^-\gamma$ Prel.
- $\eta \to \pi^+\pi^-\pi^0$ Prel.

DAΦNE luminosity upgrade

Frascati φ-factory

e^+e^- collider $\sqrt{s} = M\varphi$

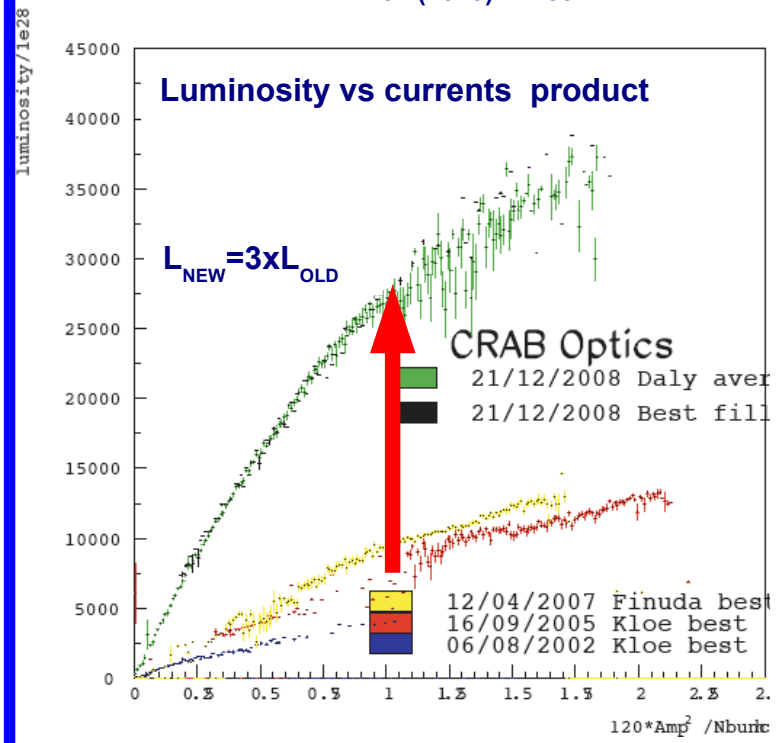


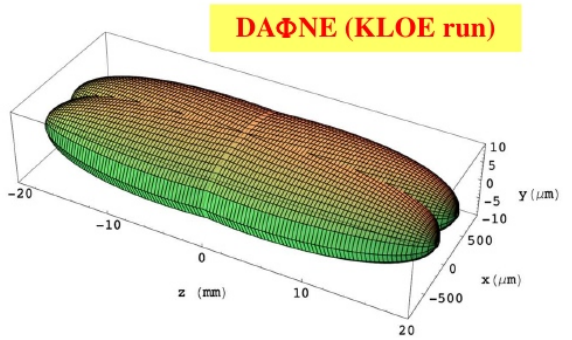
KLOE-2 IP collisions:
from 2010
Commissioning for KLOE-2
starts Sept2013
Status: $L = 1.5 \times 10^{32}\ cm^{-2}s^{-1}$
with 1.3 A + 700/800 mA,
7pb-1/day

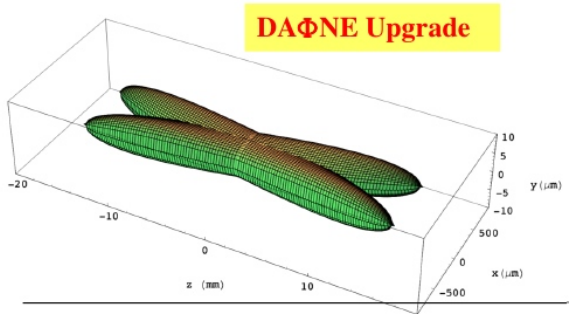
Novel interaction scheme:

large angle beam crossing
+ crabbed waist sextupoles => SuperKEK

PRL104 (2010) 174801





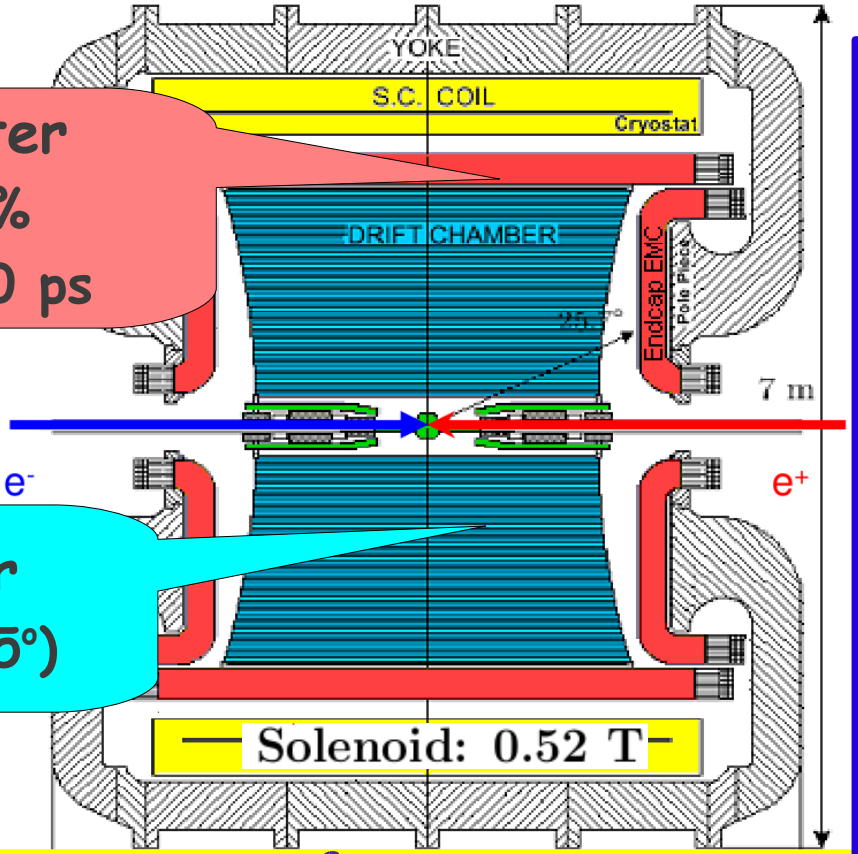


KLOE-2:
Extension of the KLOE physics program at upgraded DAΦNE

KLOE → KLOE-2

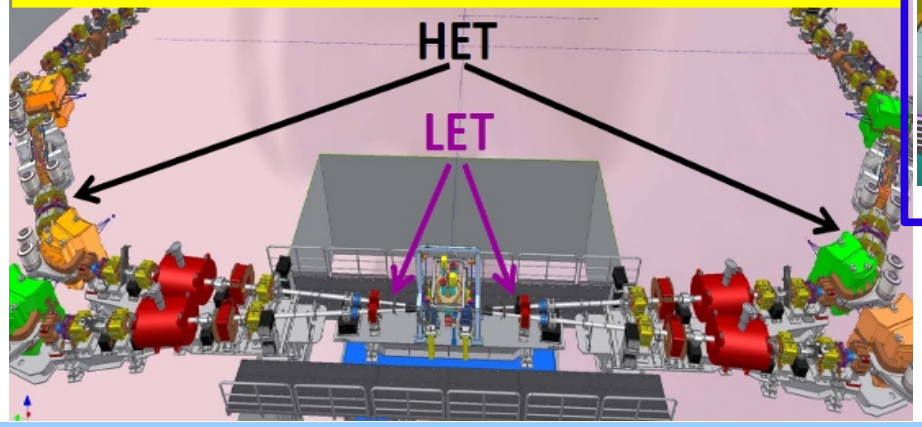
EM Calorimeter
$\delta E/E = 5.7/\sqrt{E}$ %
$\delta t = 57/\sqrt{E} \oplus 100$ ps

Drift Chamber
$\delta p_T \sim 0.4\%$ ($\theta < 45°$)



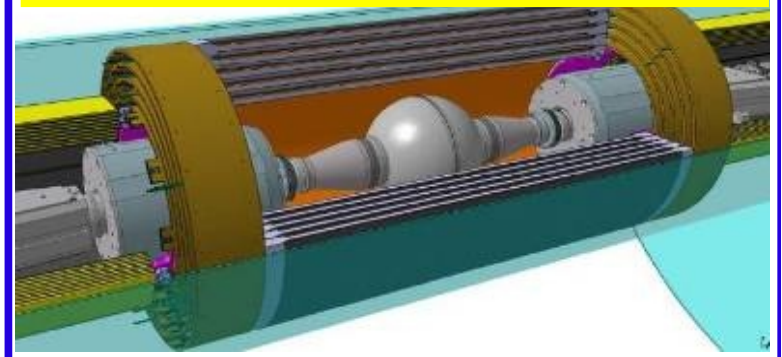
2+2 taggers for:

$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$

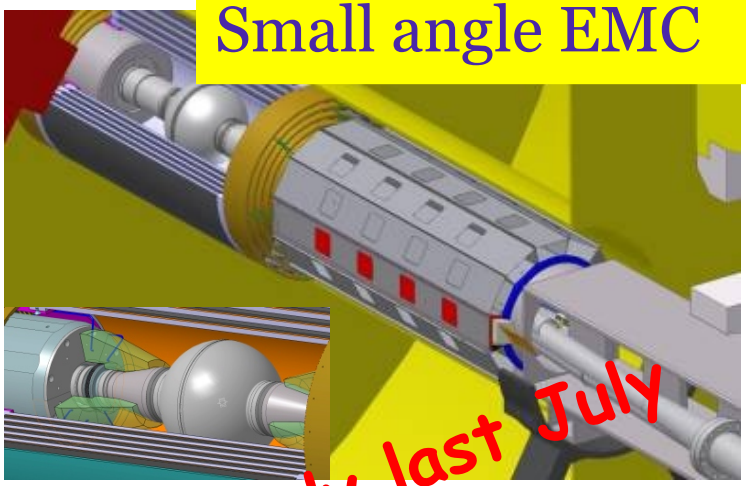


Upgrades

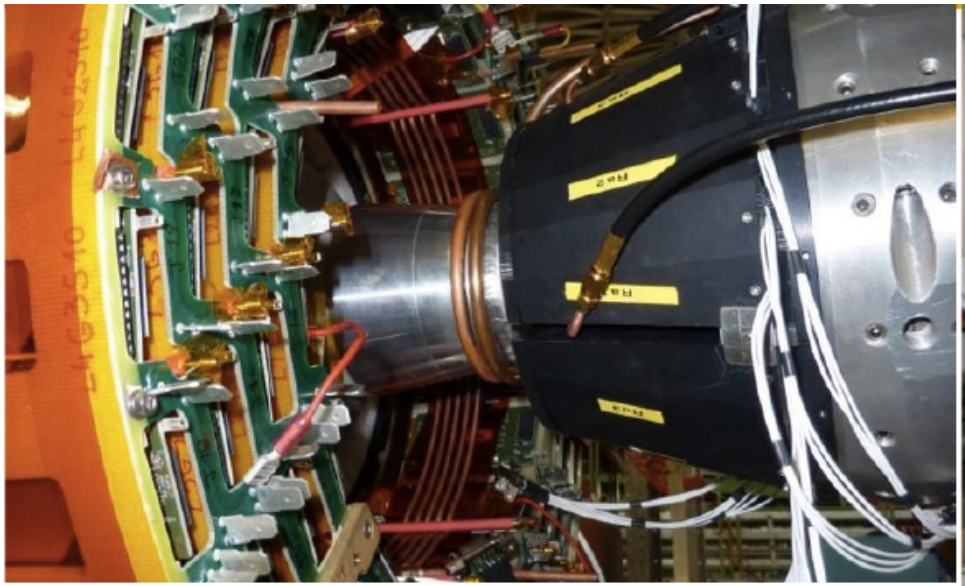
Inner Tracker: cyl. GEM



Small angle EMC

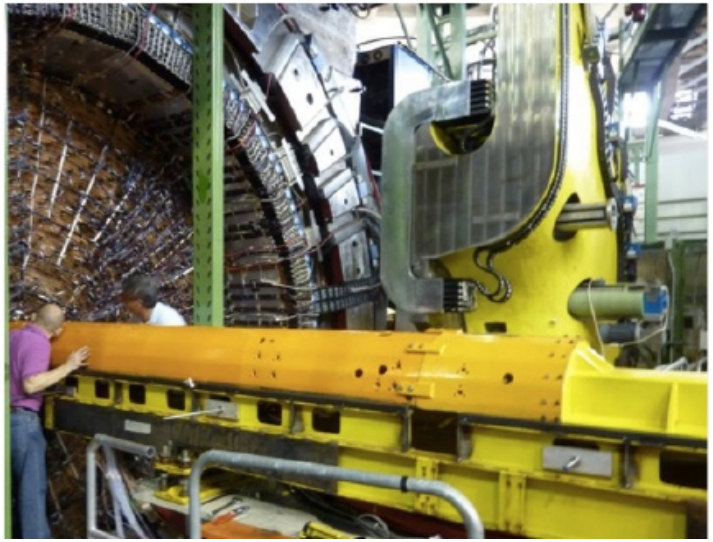


Ready last July



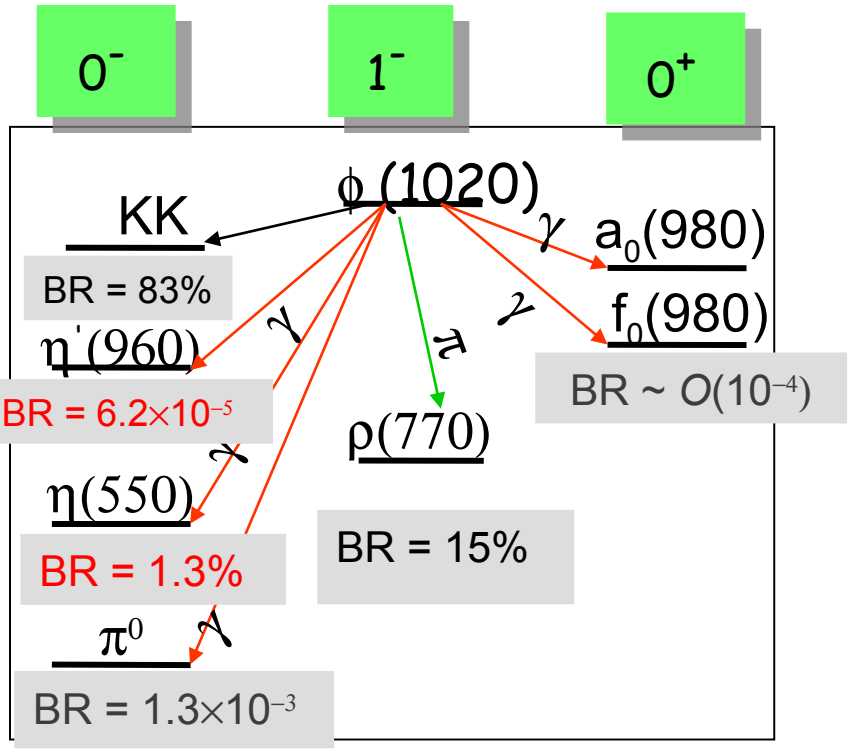
IT front-end and CCALT

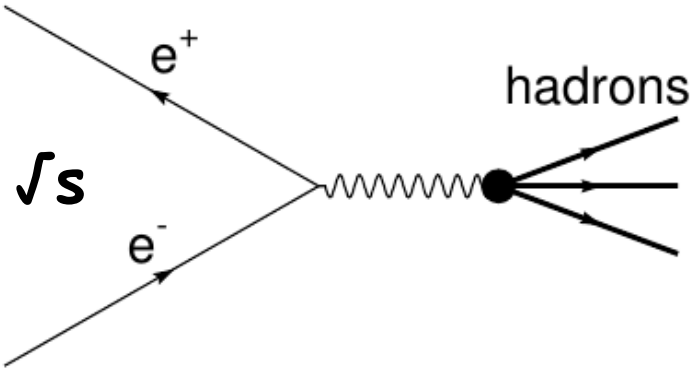
IR insertion in DAFNE



- Installation of the upgrades and the IR in DAFNE completed on July, 12th

$\gamma^* \rightarrow (\phi) \rightarrow$ Hadrons





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

$\sigma_{peak} \sim 3.1\ \mu b$

KLOE: 2.5 fb^{-1} @ $\sqrt{s} = M_\phi$ (~ 8×10^9 ϕ produced)

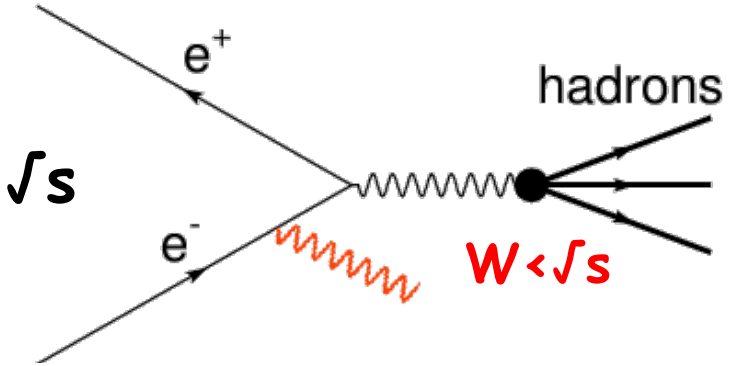
+ 250 pb^{-1} @ 1000 MeV (off-peak data)

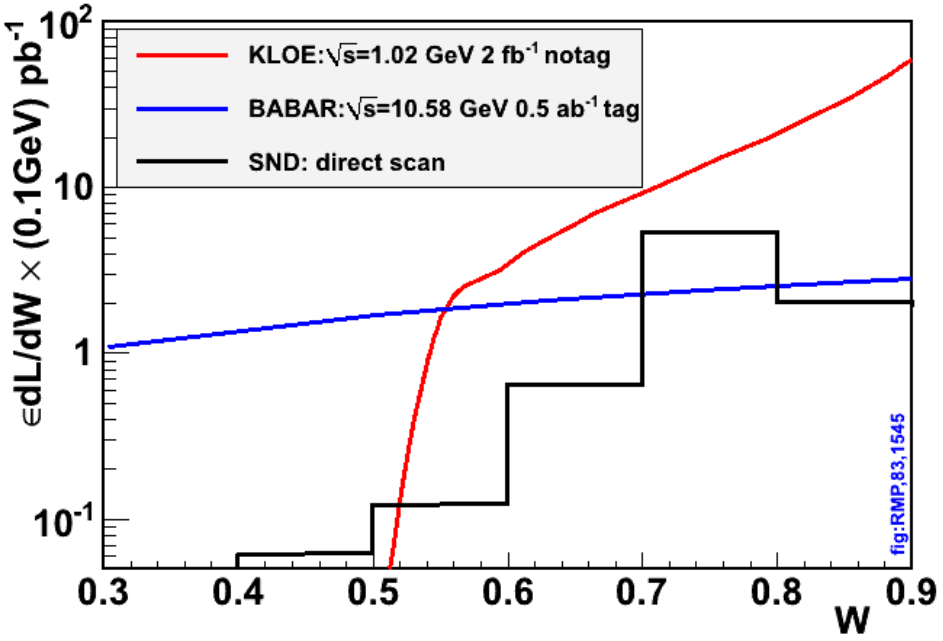
σ_T (1GeV) 80 nb

+ scan ±20 MeV ~ O(10 pb^{-1})

KLOE 2001-2005 data

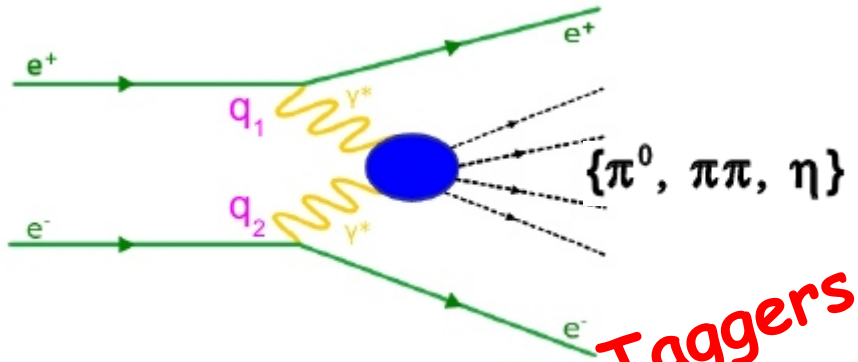
ISR | γγ



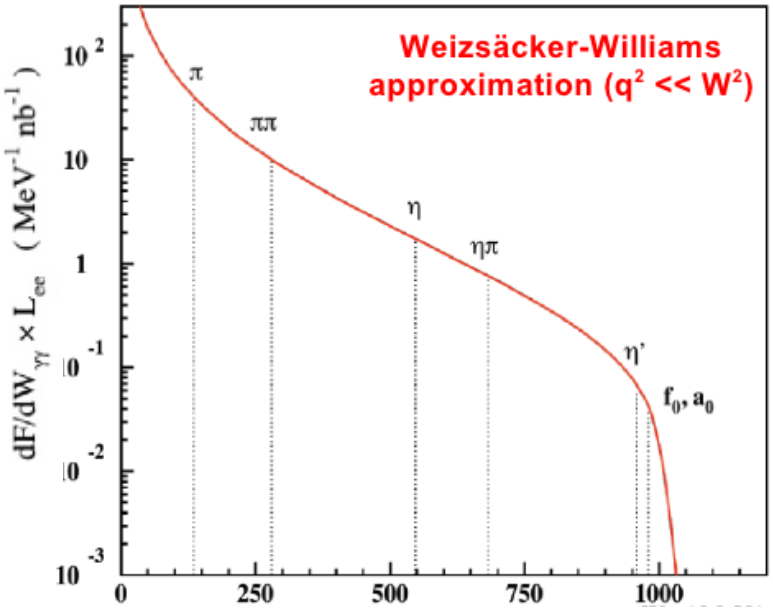


KLOE: Fv(W) in $e^+e^-\to\pi^+\pi^-(\gamma)$

Luminosity



Taggers



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

to taggers (HET or LET)

in KLOE

BR($K_S \to 3\pi^0$): UL

- $K_S \to 3\pi^0$ CP violating not yet observed

  SM (ChPT): BR($K_S \to 3\pi^0$) = $1.9 \cdot 10^{-9}$

  EXP Searches:

  KL/KS interference: NA48 $< 7.4 \cdot 10^{-7}$ 90%CL

  Direct: KLOE2005 $< 1.2 \cdot 10^{-7}$ 90%CL

  L=0.45 fb^{-1}

  K_S tagged by K_L interaction in EMC

  data 2 ev/bkg 3 ev

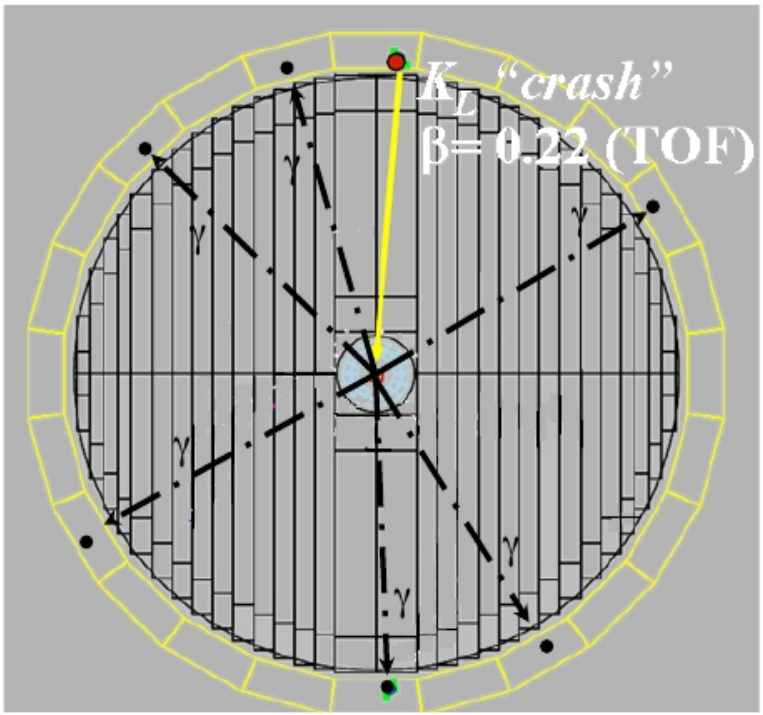
- New KLOE2013:

  PLB723(2013) 54

  L=1.7 fb^{-1} independent data

  improved selection with the same signal eff. (data 0 ev/bkg 0 ev)

  $< 2.6 \cdot 10^{-8}$ 90%CL $|\eta_{000}| < 0.088$

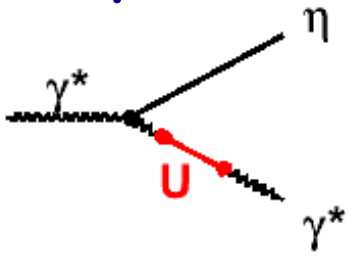


π^0,η Transition Form Factors (TFF)

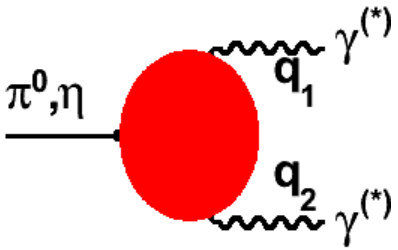
Low energy QCD

l^+l^- spectra for HI

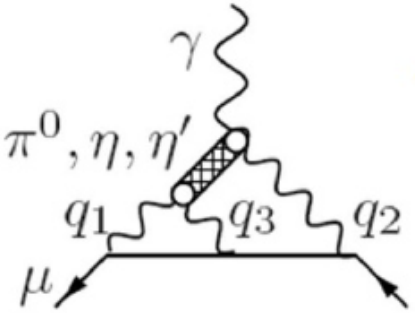
dark photon (U boson)



$$\Gamma(P \to \gamma\gamma)$$

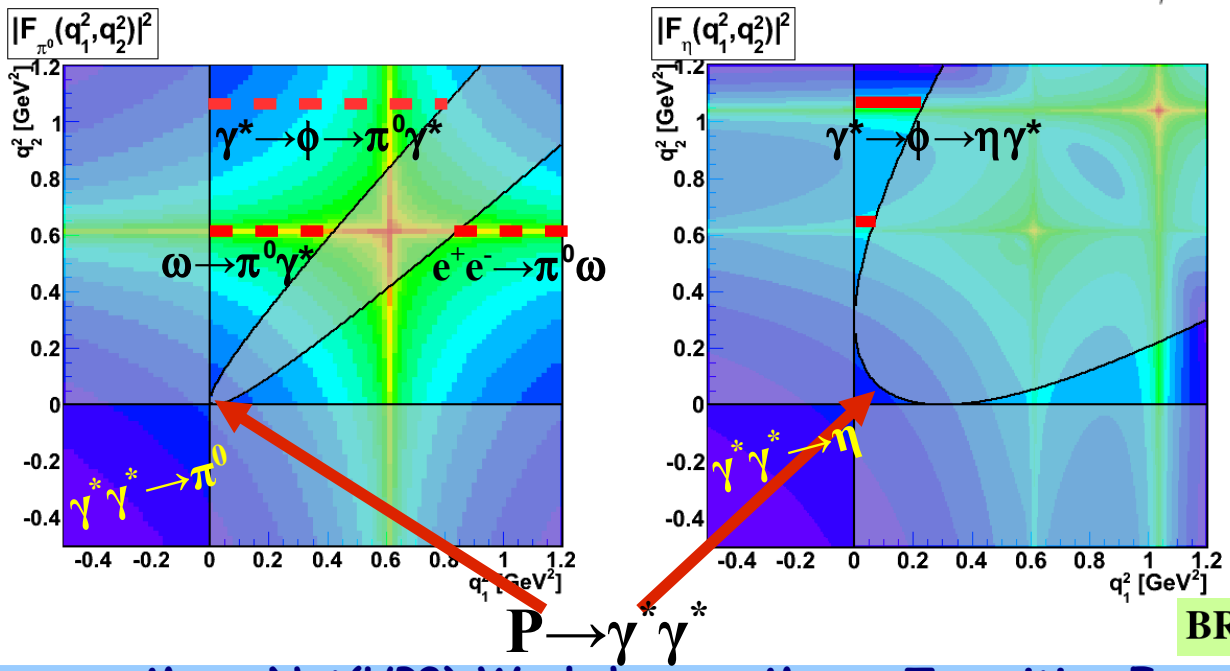


$$F_P(q_1^2, q_2^2)$$



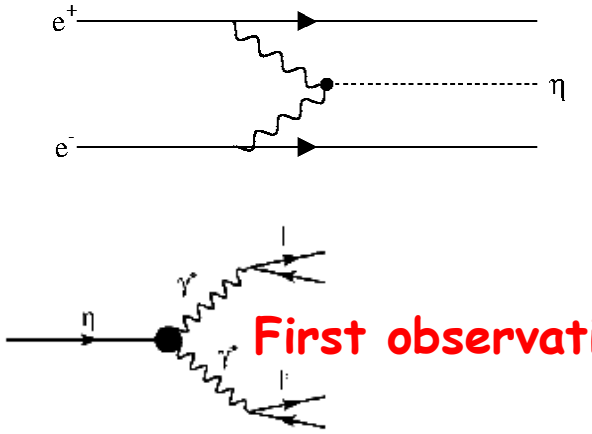
LbL for $a\mu$

$$F_P(q_1^2, m_\phi^2) \propto \frac{1}{1 - b_P(m_\phi^2) q_1^2}$$



KLOE:

Access to all 3 phys regions $|q^2|<1$ GeV^2



First observation

PLB 702 (2011) 324

$BR(\eta \to e^+e^-e^+e^-(\gamma)) = (2.4 \pm 0.2_{stat} \pm 0.1_{syst}) \times 10^{-5}$

Radiative widths η, π^0

η, π^0 : narrow and short lived

=> $\Gamma_{tot}=\Gamma_{\gamma\gamma}/BR_{\gamma\gamma}$

Two kind of measurements

$\gamma Z \rightarrow \eta, \pi^0$ Primakoff

$\delta\Gamma(\pi^0\rightarrow\gamma\gamma)$ ~2.8%

PrimEx PRL 106,162303(2011)

VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
0.510 ± 0.026	OUR FIT				
0.510 ± 0.026	OUR AVERAGE				
0.51 ± 0.12 ± 0.05	36	BARU	90	MD1	$e^+e^-\rightarrow e^+e^-\eta$
0.490 ± 0.010 ± 0.048	2287	ROE	90	ASP	$e^+e^-\rightarrow e^+e^-\eta$
0.514 ± 0.017 ± 0.035	1295	WILLIAMS	88	CBAL	$e^+e^-\rightarrow e^+e^-\eta$
0.53 ± 0.04 ± 0.04		BARTEL	85E	JADE	$e^+e^-\rightarrow e^+e^-\eta$
* * * We do not use the following data for averages, fits, limits, *etc.* * * *					
0.476 ± 0.062		[1] RODRIGUES	08	CNTR	Reanalysis
0.64 ± 0.14 ± 0.13		AIHARA	86	TPC	$e^+e^-\rightarrow e^+e^-\eta$
0.56 ± 0.16	56	WEINSTEIN	83	CBAL	$e^+e^-\rightarrow e^+e^-\eta$
0.324 ± 0.046		BROWMAN	74B	CNTR	Primakoff effect
1.00 ± 0.22		[2] BEMPORAD	67	CNTR	Primakoff effect

$\delta\Gamma(\eta\rightarrow\gamma\gamma)$ ~5%

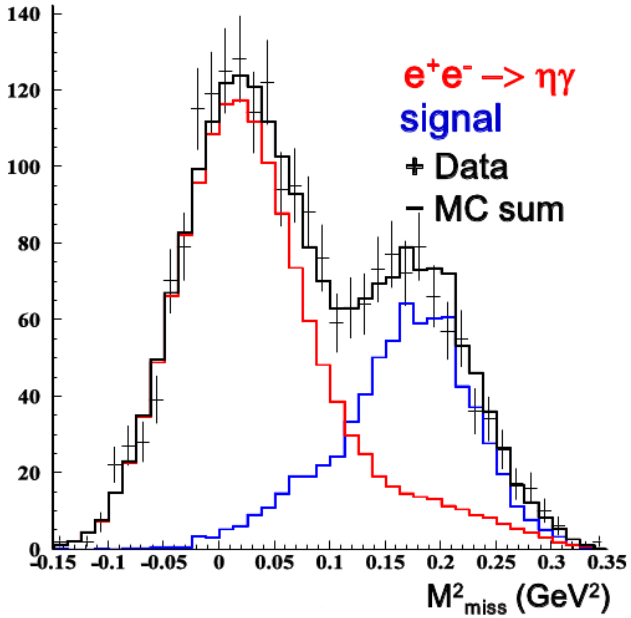
e^+e^-: $\gamma\gamma \rightarrow \eta, \pi^0$

$$\sigma(\gamma^*\gamma^* \rightarrow P) = \frac{16\pi^2}{m_P^3}\Gamma_{\gamma\gamma}|F(q_1^2, q_2^2)|^2\sqrt{(q_1\cdot q_2)^2 - q_1^2 q_2^2}\,\delta\left((q_1+q_2)^2 - m_P^2\right)$$

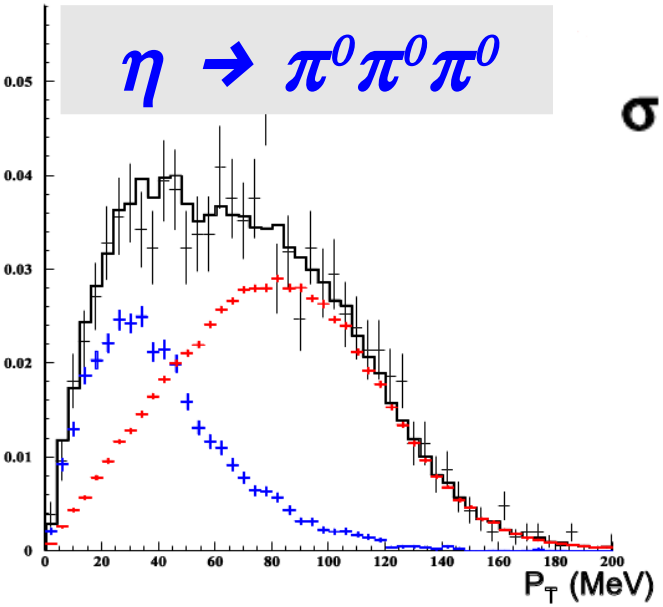
$\Gamma_{\gamma\gamma}$ fundamental parameter

=> should be know precisely (eg m_u/m_d)

η meson radiative decay width



$\eta \rightarrow \pi^0\pi^0\pi^0$



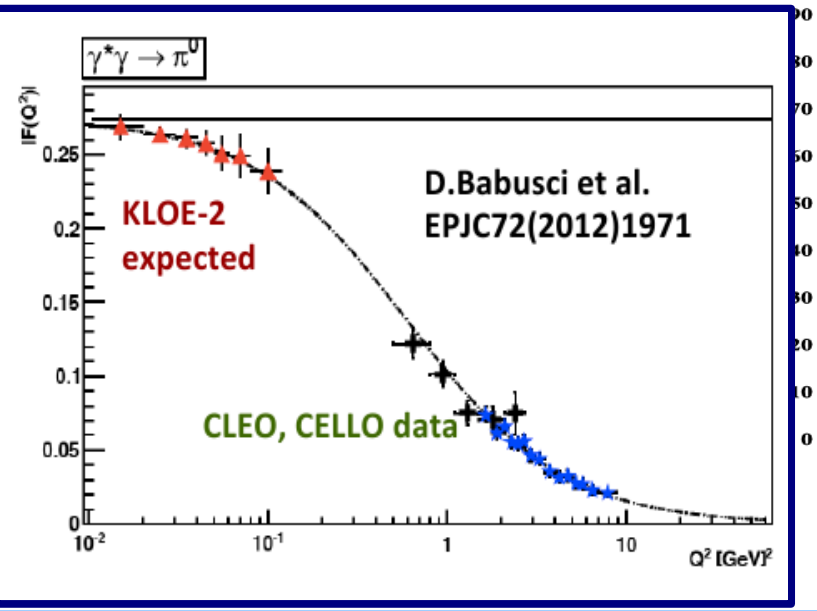
$\sigma(e^+e^- \rightarrow e^+e^-\eta, \sqrt{s}=1\text{GeV})$

$L=240\ pb^{-1}$

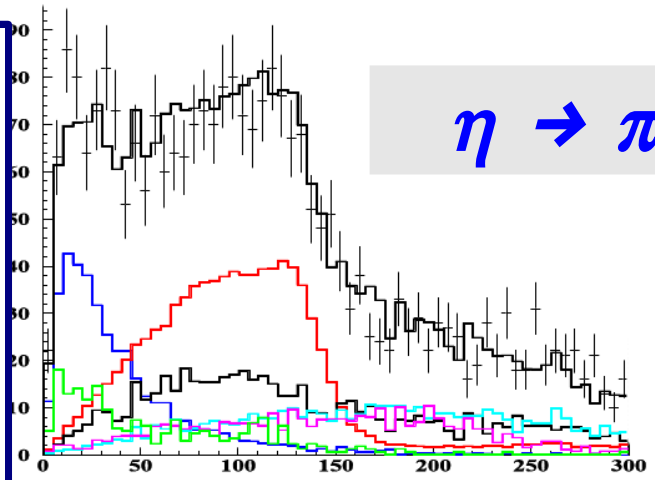
Insensitive to TFF

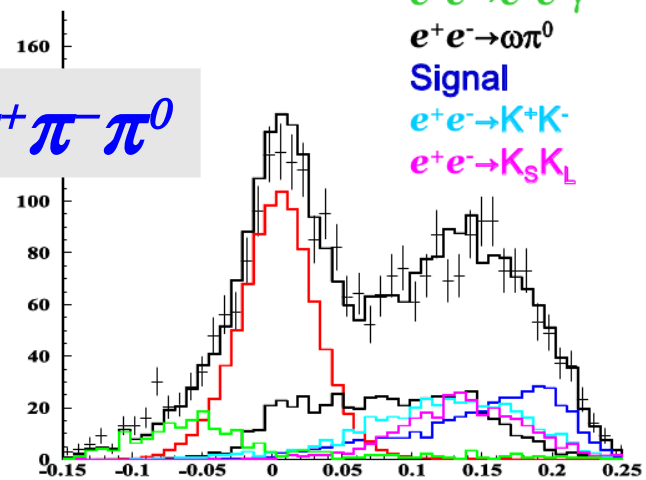
$\Gamma\gamma\gamma=520\pm20\pm13\ eV$

$32.0\pm1.5\pm0.9\ pb$



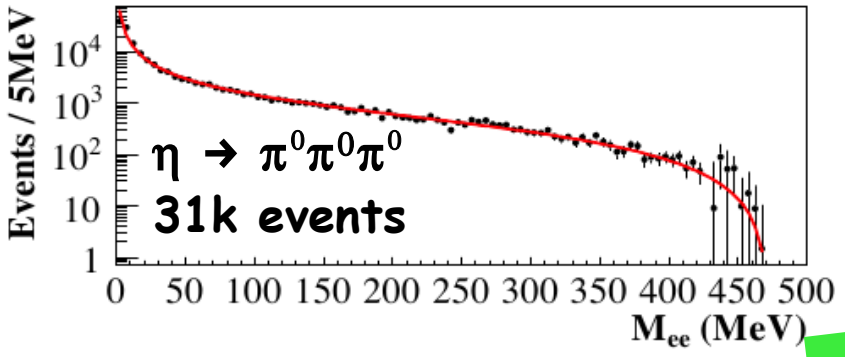
$\eta \rightarrow \pi^+\pi^-\pi^0$

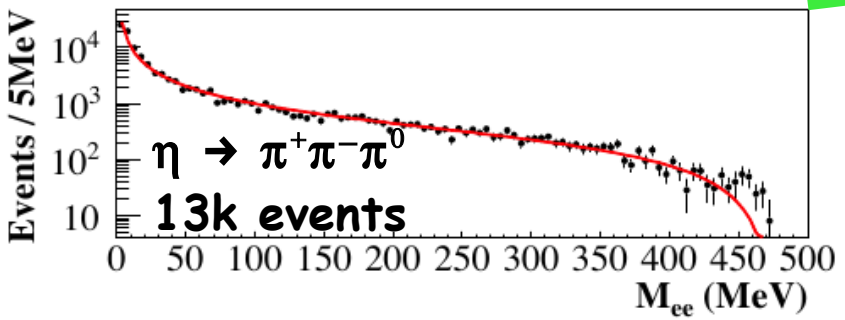


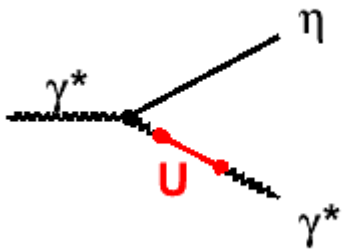


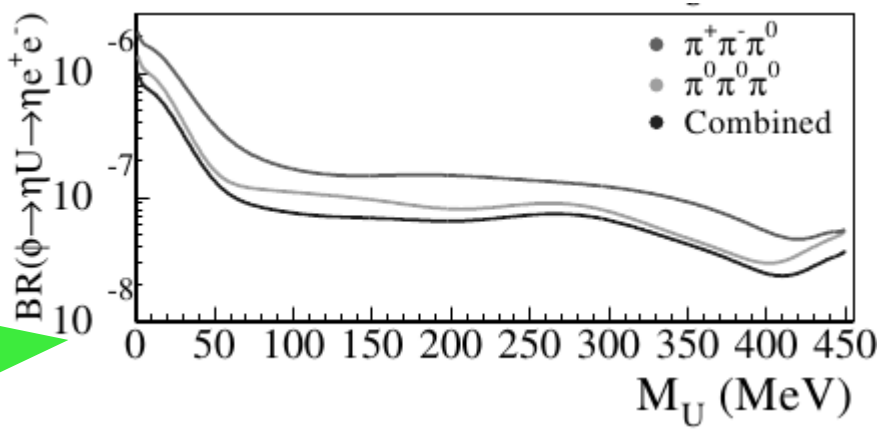
$34.5\pm2.5\pm1.0\ pb$

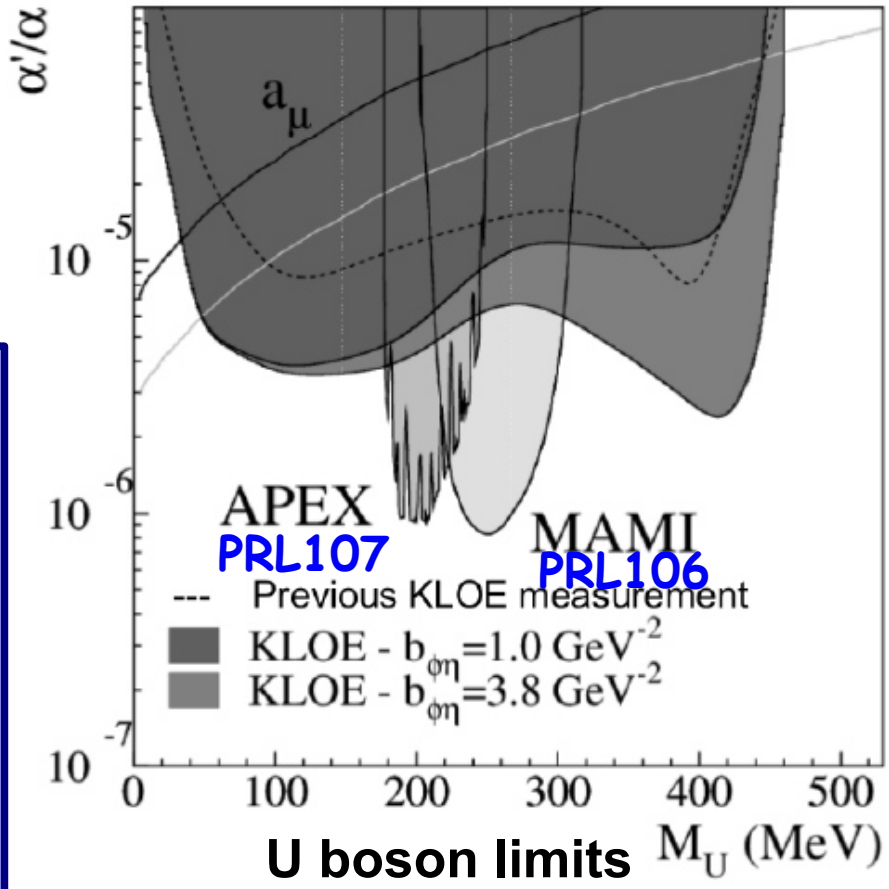
φ→e⁺e⁻η











U boson limits

Form factor/BR:

	SND/CMD-2 (2001)	KLOE – Preliminary Neutral Mode
$b_{\phi\eta}$ [GeV $^{-2}$]	3.8 ± 1.8/ --	$1.17 \pm 0.11^{+0.09}_{-0.08}$
BR (x10^4)	1.19 ± 0.31 / 1.14 ± 0.16	$1.131 \pm 0.031 \pm 0.007^{+0.011}_{-0.006}$

$$F_\eta(q^2, m_\phi^2) \propto \frac{1}{1 - b_\eta(m_\phi^2)q^2}$$

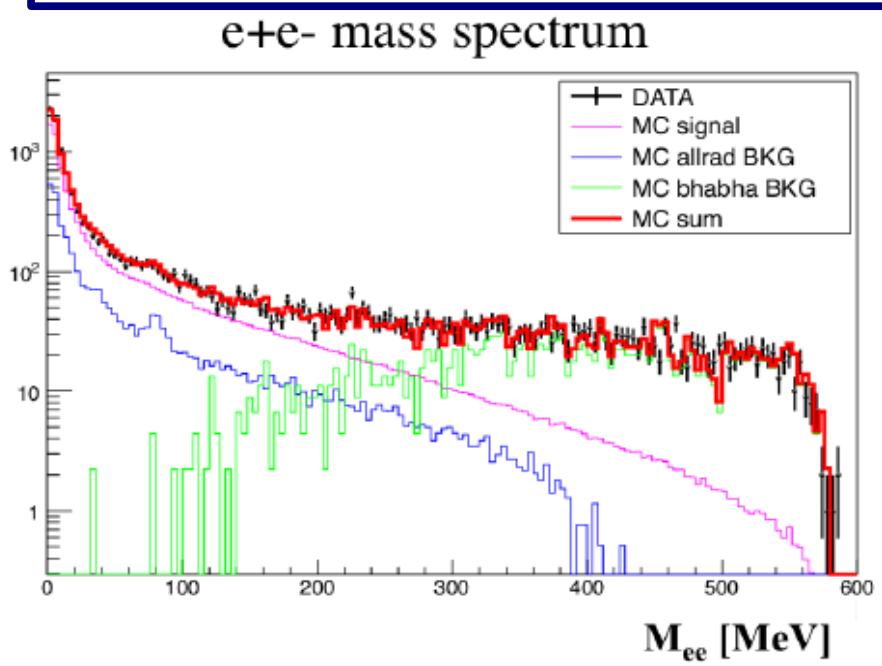
Value (10^{-5})	CL%	EVTS	Document ID		TECN
1.12 ± 0.28	OUR AVERAGE				
$1.01 \pm 0.28 \pm 0.29$		52	ACHASOV [1]	2002D	SND
$1.22 \pm 0.34 \pm 0.21$		46	AKHMETSHIN [2]	2001C	CMD2

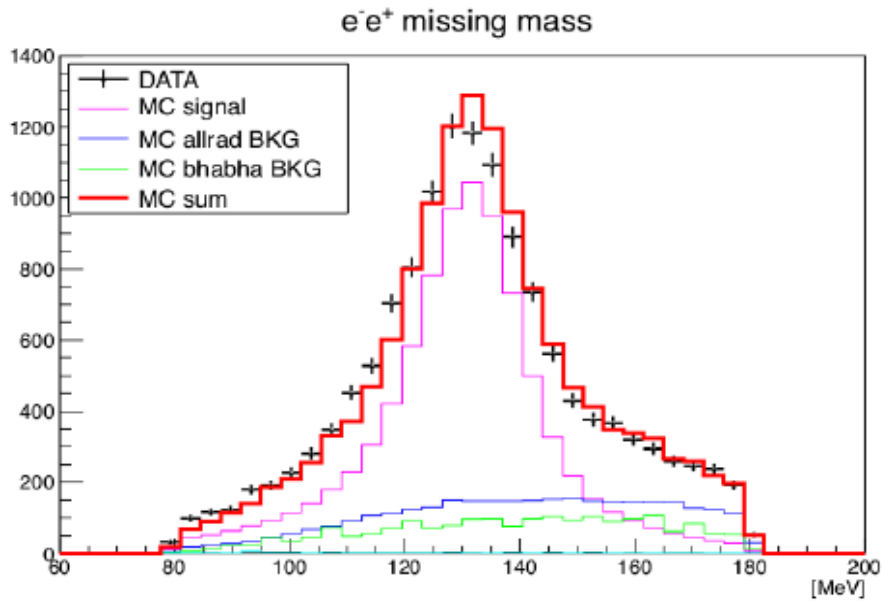
9k events

Background
radiative Bhabha
and $\varphi \to \pi^0\gamma$

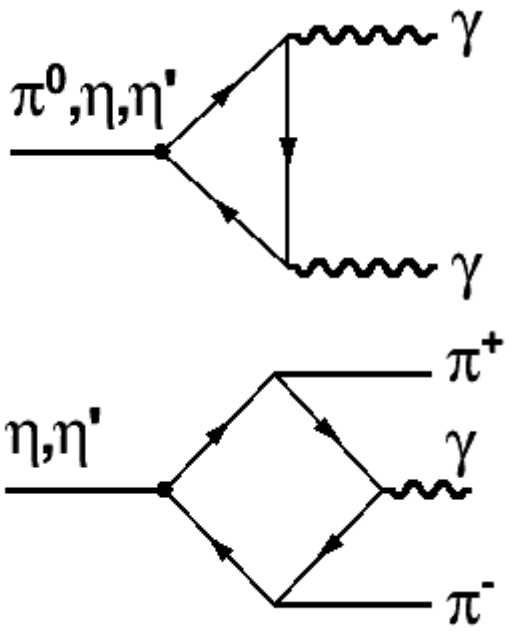
efficiency:
15% → 2%
low → high q

Analysis in progress:
background
subtraction +
global efficiency

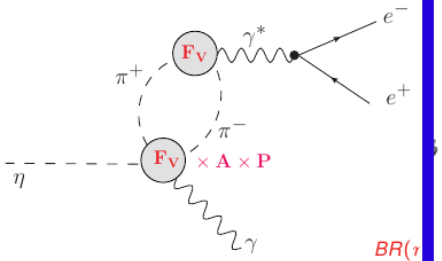


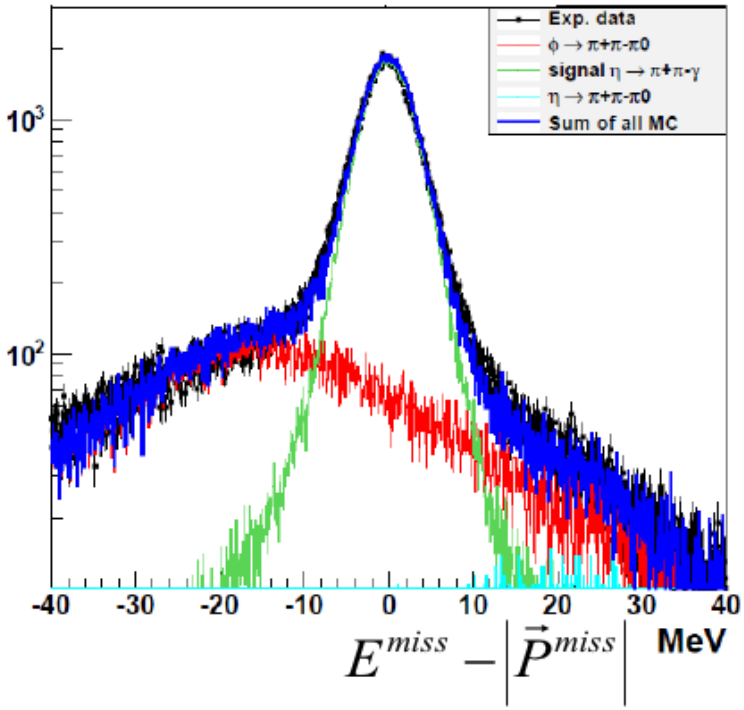


$\eta \to \pi^+\pi^-\gamma / \eta \to \pi^+\pi^-\pi^0$



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





- No kin fit:use DC resolution
- Not use EMC Energy

$\Phi \to \eta\gamma$ L = 558 pb^{-1}

205 k events

eff=21%

S/B=10

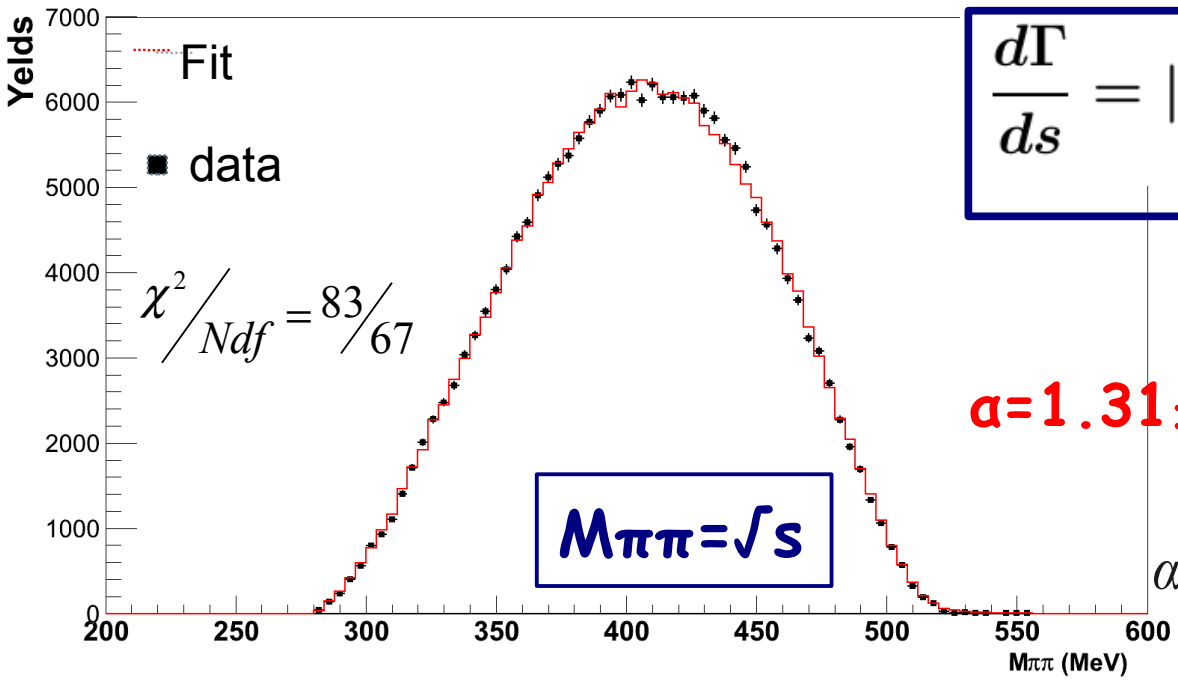
$$\frac{\Gamma(\eta \to \pi^+\pi^-\gamma)}{\Gamma(\eta \to \pi^+\pi^-\pi^0)} = 0.1856 \pm 0.0005 \pm 0.0028$$

Normalization $\eta \to \pi^+\pi^-\pi^0$

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

value	events	author	year
0.203 ± 0.008	PDG average		
0.175 ± 0.007 ± 0.006	859	Lopez	2007
0.209 ± 0.004	18 k	Thaler	1973
0.201 ± 0.006	7250	Gormley	1970

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



$$\frac{d\Gamma}{ds} = |A(1+\alpha s+\ldots)F_V(s)|^2 K_P(s)$$

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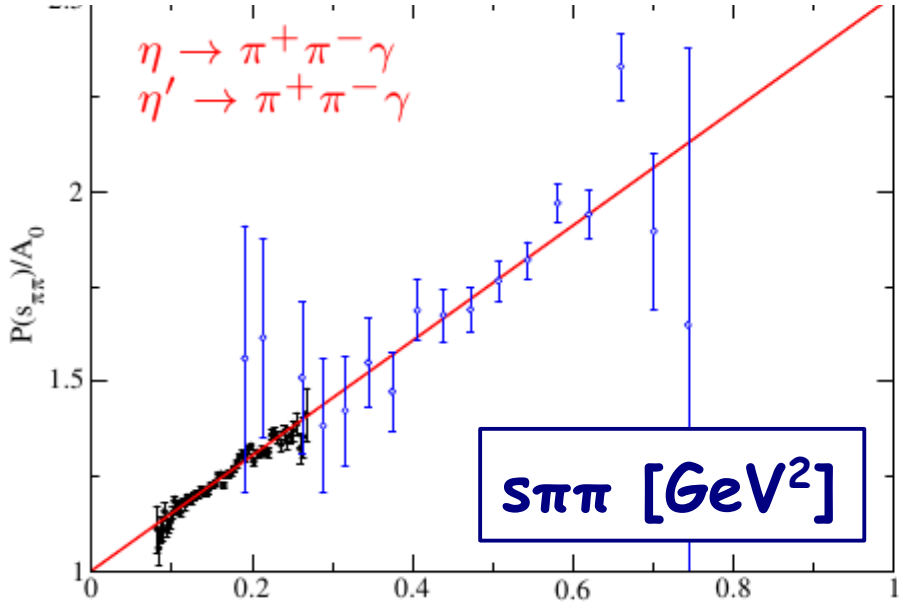
$e^+e^- \to \pi^+\pi^-$

$\alpha = 1.31 \pm 0.08_{stat} \pm 0.40_{syst} \pm 0.02_{Fv}\ GeV^{-2}$

$\alpha_{WASA} = (1.89 \pm 0.25 \pm 0.59 \pm 0.02)\ GeV^{-2}$

[WASA PLB707 (2012) 243]



$$P(s_{\pi\pi}) = A_0(1+\alpha s_{\pi\pi})$$

$\to$ α reaction specific

$\to$ $\alpha[\eta] = \alpha[\eta']$ understood
1-loop ChPT + large N_c

KLOE: A+α => $b_\eta(0) = 2.05^{+0.22}_{-0.10}\ GeV^{-2}$

arXiv:1307.5654

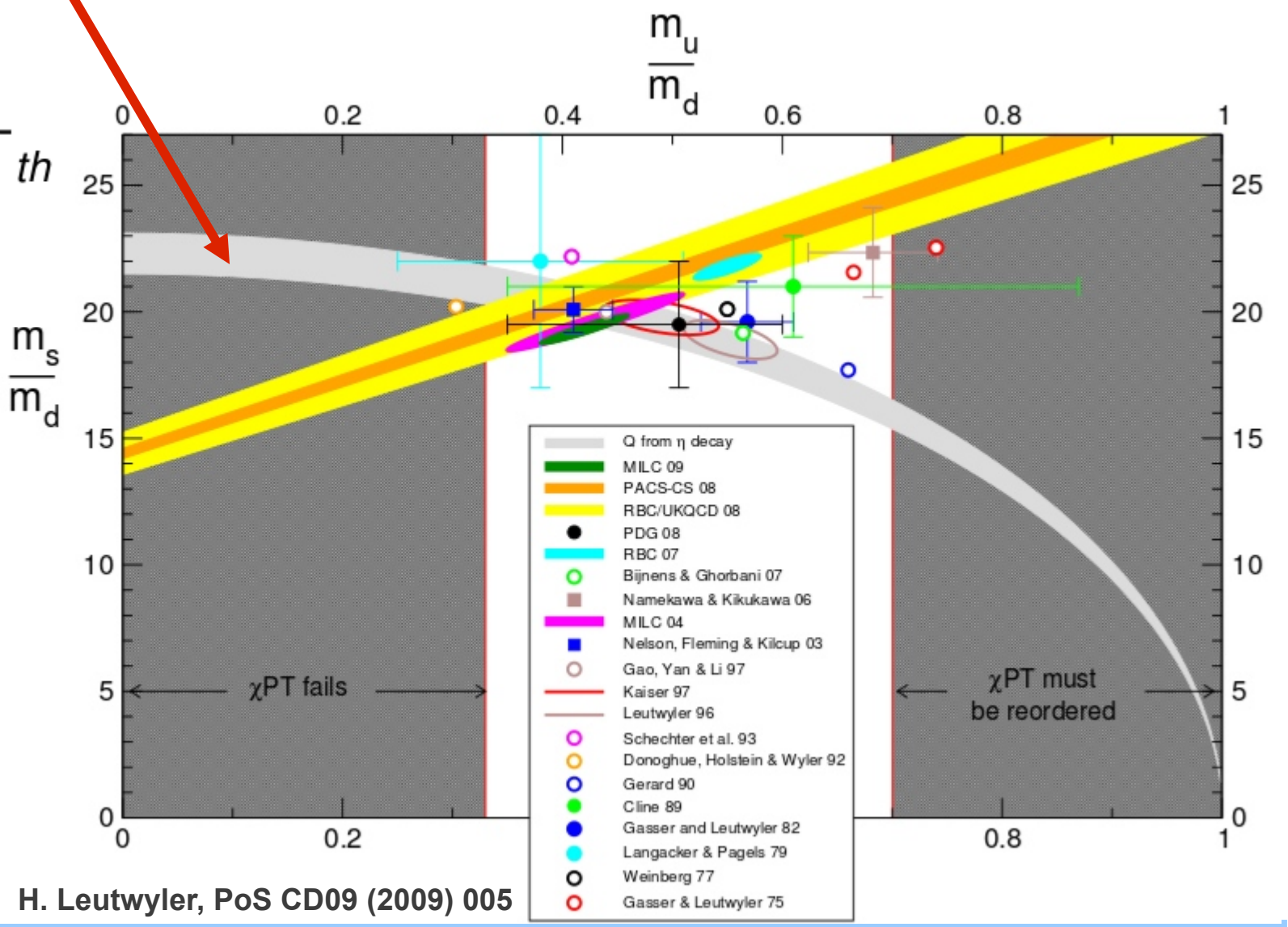
Light quark masses

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

TH: Bern-Bonn-Lund-Prague
CHPT, dispersive

$$\Gamma_{exp} = \left(\frac{Q_D}{Q}\right)^4 \Gamma_{th}$$

$$Q^{-2} \approx \frac{m_d^2 - m_u^2}{m_s^2}$$



H. Leutwyler, PoS CD09 (2009) 005

KLOE2008 analysis (JHEP 0805,006)

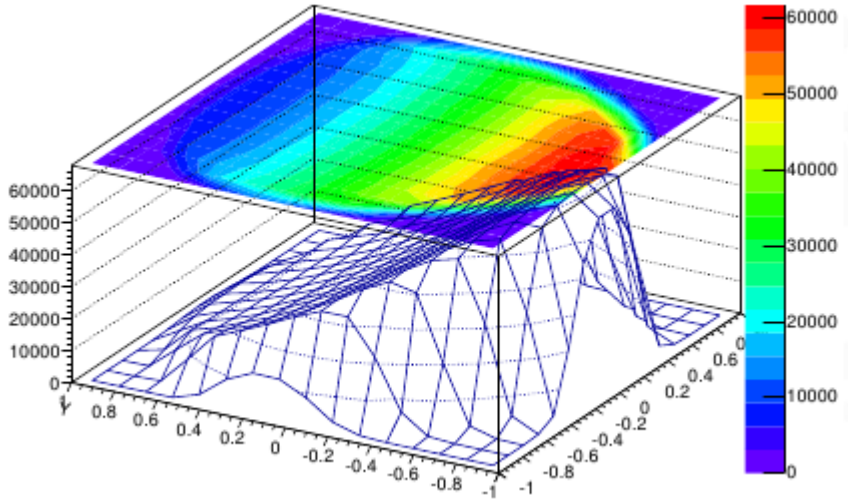
- 0.45 fb^{-1} ⇒ 1.34·10^6 events in DP
- large syst. uncertainty due to Event classification

New analysis:

- 1.7 fb-1 ⇒ 4.48·10^6 events in DP
- new analysis scheme
- improved MC
- new cross checks

$$X = \frac{T_+ - T_-}{\sqrt{3}\,\langle T\rangle}$$

$$Y = \frac{T_0}{\langle T\rangle} - 1$$



	a	b	d	f
JHEP0805,006	-1.090(5)($^{+8}_{-19}$)	0.124(6)(10)	0.057(6)($^{+7}_{-16}$)	0.140(10)(20)
preliminary, 2013	-1.104(3)(?)	0.144(3)(?)	0.073(3)(?)	0.155(6)(?)

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

New analysis PRELIMINARY (no syst.): f≠0 confirmed

fits with g...

Conclusions

Analysis of high statistics samples produced at KLOE

DAΦNE with new IP: commissioning in progress

KLOE-2 is starting a data taking campaign

- KLOE detector + taggers + IT
- Detector ready to take data

Physics program: EPJC 68 (2010),619

φ-peak run O(5 fb^{-1})

Run at 1 GeV O(1 fb^{-1})?

KLOE-2 + DAΦNE ideal tool for π^0,η TFF $-1<q^2<1$ GeV^2

- $\gamma\gamma$ with e+e- taggers in KLOE-2: π^0 $\Gamma\gamma\gamma$ 1%
- ISR measurements

KLOE-2 physics programme

γγ physics

Existence (and properties) of σ/f0(600)
Study of Γ(S/PS→γγ)
PS transition form factor

Spectroscopy

Properties of scalar/vector mesons
Rare η decays
η′ physics

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 ChPT (KS decays)

Dark matter searches

Light bosons @ O(1 GeV)

Hadronic cross section

$\alpha_{em}(M_Z)$ and (g-2)

Eur.Phys.J.C68(2010)619