Hadron Physics with KLOE and KLOE-2

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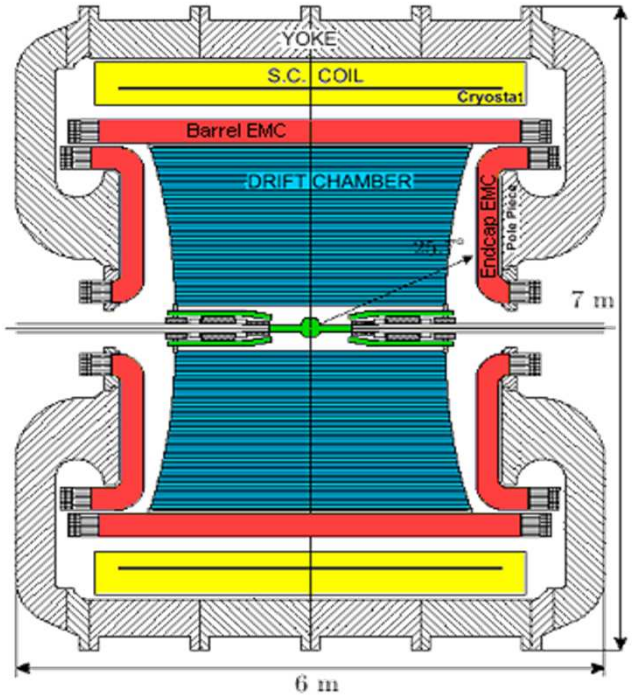
on behalf of the KLOE and KLOE-2 Collaborations

- KLOE results
- KLOE and DAΦNE upgrades
- Perspectives for KLOE-2

KLOE and DAΦNE



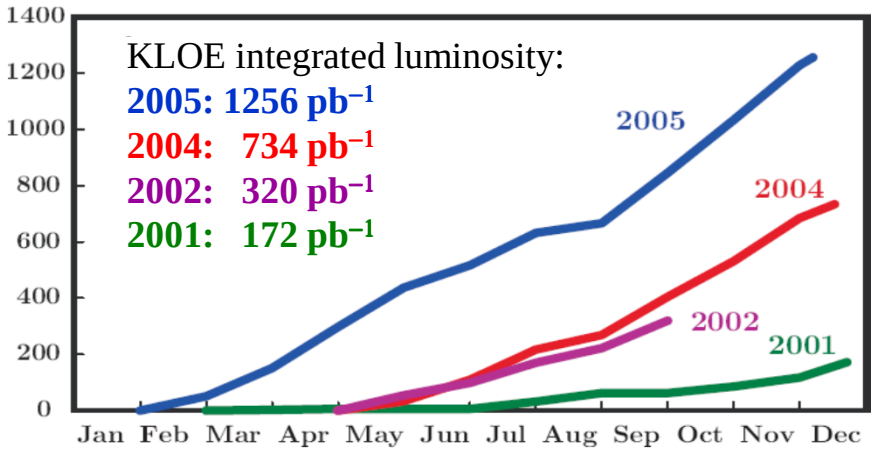
Drift chamber

- Gas mixture: **90% He + 10% C_4H_{10}**
- **$\delta p_t / p_t < 0.4\%$ ($\theta > 45^\circ$)**
- **$\sigma_{xy} \approx 150\ \mu m$; $\sigma_z \approx 2$ mm**

Electromagnetic calorimeter

- lead/scintillating fibers
- 98% solid angle coverage
- **$\sigma_E / E = 5.7\% / \sqrt{(E(GeV))}$**
- **$\sigma_t = 57$ ps $/ \sqrt{(E(GeV))} \oplus 100$ ps**
- **PID capabilities**

Magnetic field: 0.52 T



DAΦNE: e^+e^- collider @ $\sqrt{s} \sim 1020$ MeV ~ M_ϕ

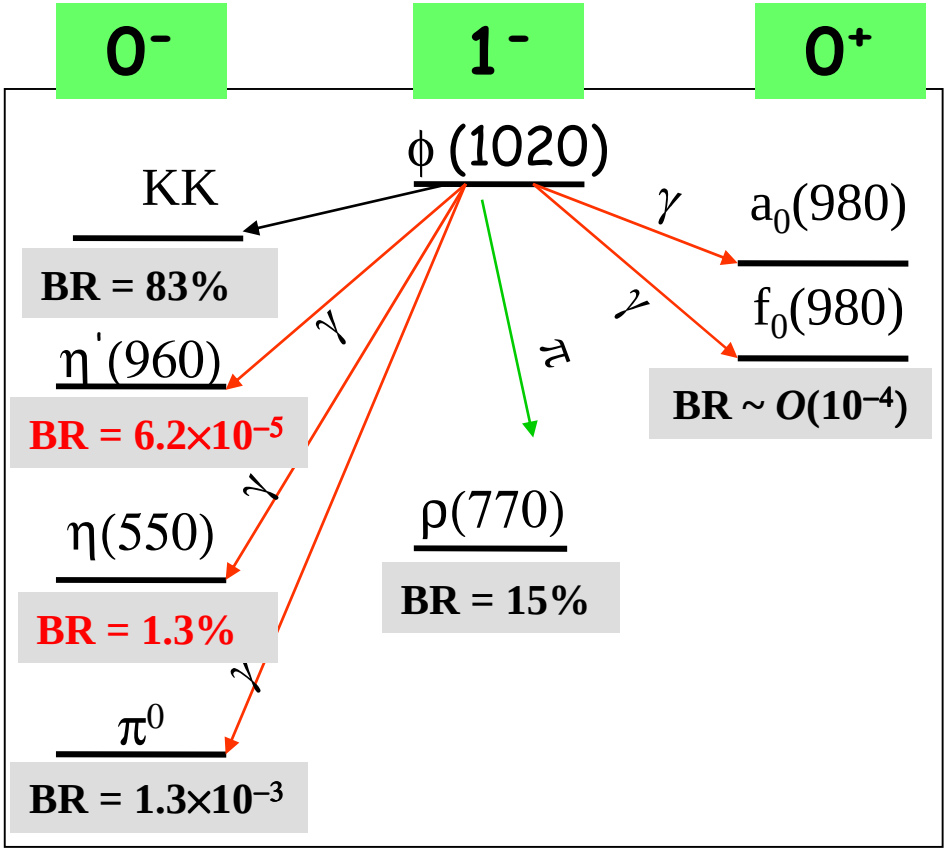
$\sigma_{peak} \sim 3.1\ \mu b$

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

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

Physics at a ϕ−factory

Decay channel	Events (2.5 fb^{-1})
K^+K^-	3.7×10^9
$K_L K_S$	2.5×10^9
$\rho\pi + \pi^+\pi^-\pi^0$	1.1×10^9
$\eta\gamma$	9.7×10^7
$\pi^0\gamma$	9.4×10^6
$\eta'\gamma$	4.6×10^5
$\pi\pi\gamma$	2.2×10^6
$\eta\pi^0\gamma$	5.2×10^5



- ✓ Kaon physics → **I. Balwierz, Thursday morning**
- ✓ Light meson spectroscopy
- ✓ Hadron production in $\gamma\gamma$ collisions
- ✓ Search for vector gauge boson → **G.Mandaglio, Thursday morning**
- ✓ Hadronic cross-section via ISR, $\pi^+\pi^-$contribution to $(g-2)_\mu$

Results on hadron physics

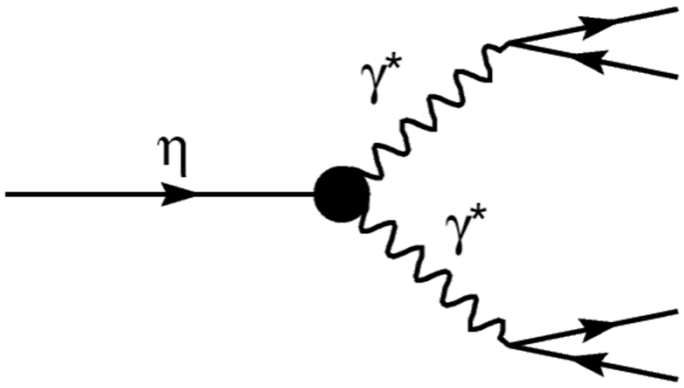
Published analyses:

- $\Gamma(\phi\to\eta'\gamma)/\Gamma(\phi\to\eta\gamma)$, PLB 541 (2002) 45
- $\phi\to\eta\pi^0\gamma$, PLB 536 (2002) 209
- $\phi\to\pi^0\pi^0\gamma$, PLB 537 (2002) 21
- $\phi\to\pi^+\pi^-\pi^0$, PLB 561 (2003) 55
- $\eta\to\gamma\gamma\gamma$, PLB 591 (2004) 49
- $\sigma(e^+e^-\to\pi^+\pi^-)$, PLB 606 (2005) 12
- $\eta\to\pi^+\pi^-$, PLB 606 (2005) 276
- $\Gamma(\phi\to l^+l^-)$, PLB 608 (2005) 199
- $\phi\to\pi^+\pi^-\gamma$, PLB 634 (2006) 148
- η mass, JHEP 12 (2007) 073
- $e^+e^-\to\pi^0\pi^0\gamma$, EPJC 49 (2007) 473
- $\Gamma(\phi\to\eta'\gamma)/\Gamma(\phi\to\eta\gamma)$, PLB 648 (2007) 267
- $\eta\to\pi^+\pi^-\pi^0$, JHEP 05 (2008) 006
- $e^+e^-\to\omega\pi^0$, PLB 669 (2008) 223
- $\sigma(e^+e^-\to\pi^+\pi^-)$, PLB 670 (2009) 285
- η/η' mixing, JHEP 07 (2009) 105
- $\eta\to\pi^+\pi^-e^+e^-$ PLB 675 (2009) 283
- $\phi\to K^0K^0\gamma$, PLB 679 (2009) 10
- $\phi\to\eta\pi^0\gamma$, PLB 681 (2009) 5
- $\eta\to\pi^0\pi^0\pi^0$, PLB 694 (2010) 16
- $\sigma(e^+e^-\to\pi^+\pi^-)$, PLB 700 (2011) 102
- $\eta\to e^+e^-e^+e^-$, PLB 702 (2011) 324
- $\phi\to\eta e^+e^-$, arXiv:1110.0411, subm. to PLB

Preliminary results:

- $\eta\to\pi^+\pi^-\gamma$, arXiv:1107.5733
- $e^+e^-\to\eta\gamma$ @ 1 GeV , arXiv:1107.3782
- $\gamma\gamma\to\eta$, arXiv:1107.3782
- $\gamma\gamma\to\pi^0\pi^0$, arXiv:1107.3782

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



- Dynamics of the triangle anomaly inside
- Useful to constrain the η electromagnetic transition form factor

Theoretical predictions: BR ~ 2.4 – 2.7 $\times 10^{-5}$

Existing measurement: BR < 6.9 $\times 10^{-5}$ @ 90% C.L. CMD-2, 2001
BR < 9.7 $\times 10^{-5}$ @ 90% C.L. WASA, 2008
(2 events, with 1.3 bckg)

At KLOE: $\phi \to \eta\gamma$, $\eta \to e^+e^-e^+e^-$

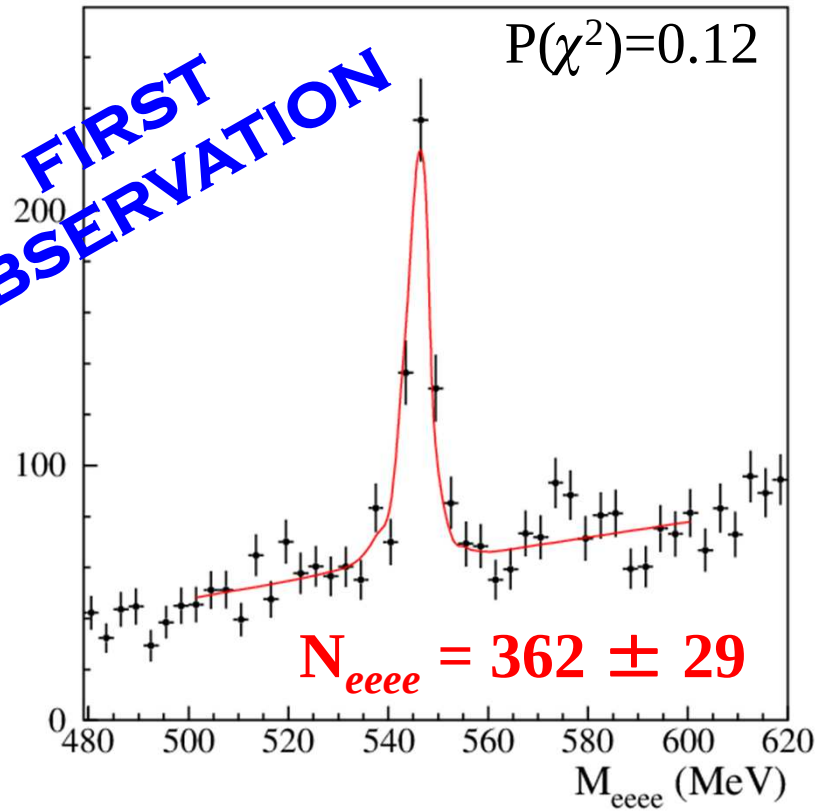
E_γ=363 MeV

at least 4 tracks from interaction point
1 photon candidate, with E>250 MeV

Measurement of BR($\eta \to e^+e^-e^+e^-(\gamma)$)

PLB 702 (2011) 324

- Data sample: **1.7 fb^{-1}**
- MC simulation according to J.Bijnens and F. Persson, arXiv:0106130
- 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 background shapes for signal + events from the continuum



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

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

$\phi \to \eta \gamma^*$ Dalitz decay allows to study the $\phi - \eta$ transition region

VMD decay parametrization [Landsberg85]:

$$\frac{d}{dq^2}\frac{\Gamma(\phi \to \eta e^+ e^-)}{\Gamma(\phi \to \eta \gamma)} = \frac{\alpha}{3\pi}\frac{|F_{\phi\eta}(q^2)|^2}{q^2}\sqrt{1-\frac{4m^2}{q^2}} \times$$

$$\times\left(1+\frac{2m^2}{q^2}\right)\times\left[\left(1+\frac{q^2}{m_\phi^2-m_\eta^2}\right)^2-\frac{4m_\phi^2 q^2}{(m_\phi^2-m_\eta^2)^2}\right]^{3/2}$$

$$F(q^2) = \frac{1}{1 - q^2/\Lambda^2}$$

FF slope:

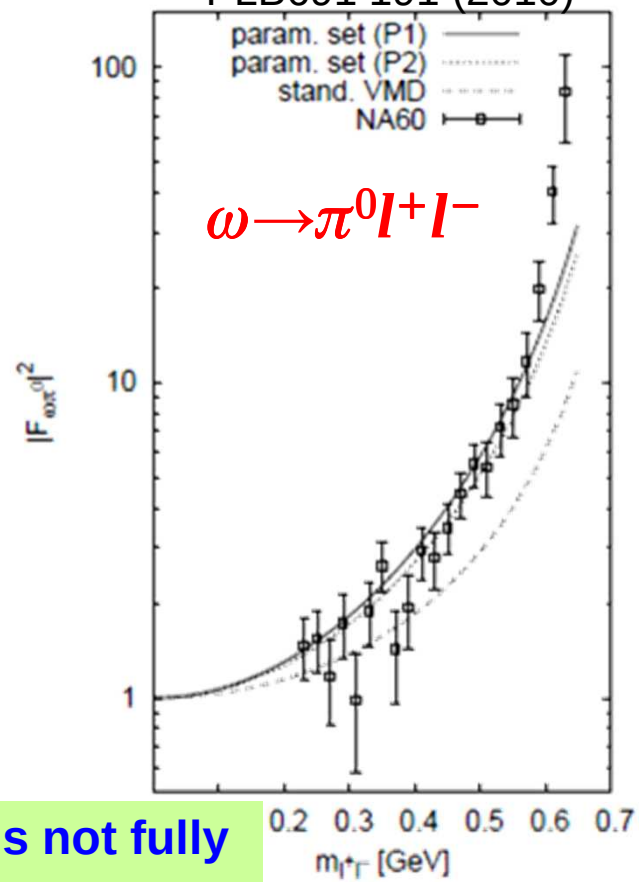
$$\begin{cases} b = dF/dq^2|_{q^2=0} \\ b_{\phi\eta} = \Lambda_{\phi\eta}^{-2} \approx 1/m_\phi^2 \approx 1\ \mathrm{GeV}^{-2} \end{cases}$$

SND, 213 events

[PLB 504 (2001) 275]:

$\mathbf{b_{\phi\eta} = (\ 3.8 \pm 1.8\ )\ GeV^{-2}}$

Terschluesen, Leupold, PLB691 191 (2010)



VPγ^* transitions not fully described by VMD

$\phi \to \eta e^+ e^-$: search for dark forces

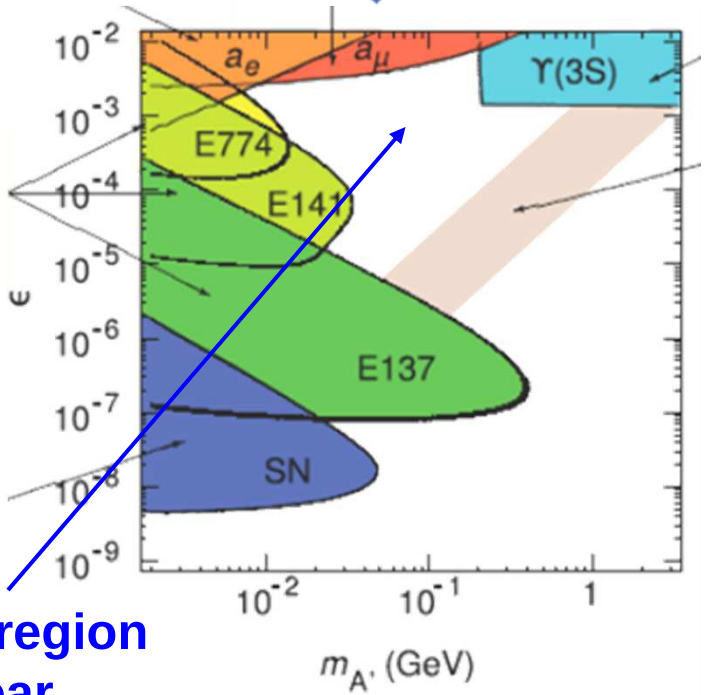
Several astrophysical observations (PAMELA, ATIC, INTEGRAL, DAMA/LIBRA) could be explained assuming the existence of a light dark sector that interacts with SM particles through a mixing of a new **gauge boson, U with O(1GeV) mass**, with the photon

[Arkani-Hamed et al. PRD79 015014 (2009), Essig et al., PRD80 015003 (2009)]

If the mixing parameter $\varepsilon \approx 10^{-4} - 10^{-3} \Rightarrow$

could be observable at KLOE through:

- $\phi \to \eta U(\to \ell^+\ell^-)$
- $e^+e^- \to U(\to \ell^+\ell^-)\gamma$
- $e^+e^- \to U^* \to U(\to \ell^+\ell^-)h'(\to$ **invisible**$)$



unconstrained region until this year

The $\phi \to \eta e^+ e^-$ decay @ KLOE

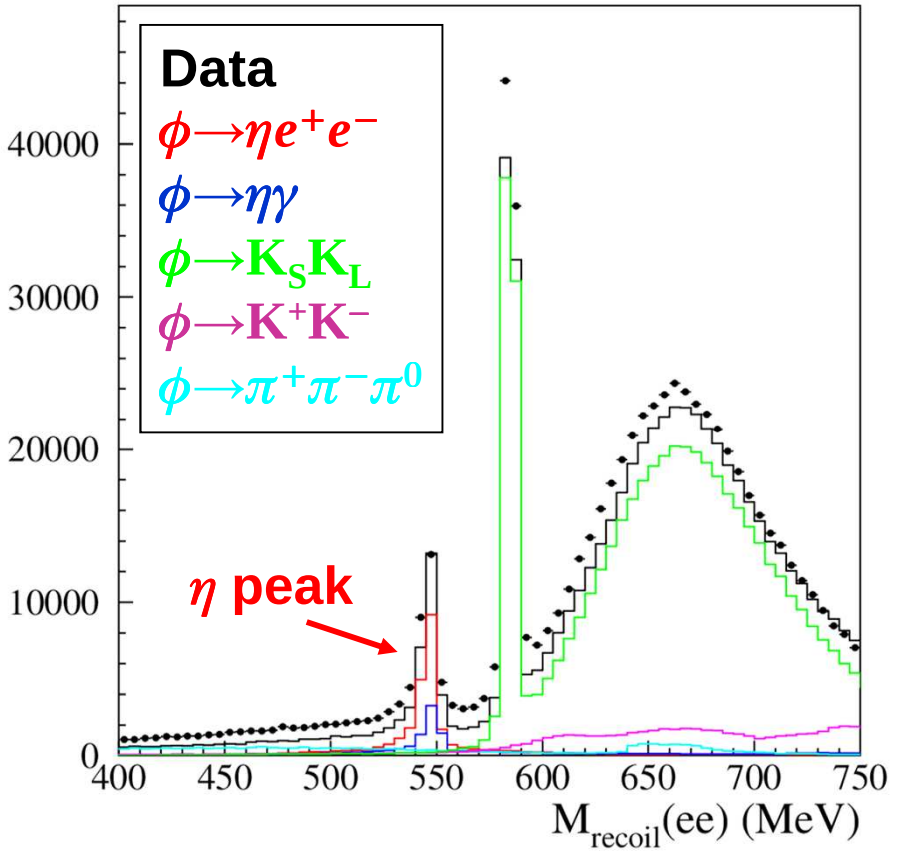
BR($\phi \to \eta e^+ e^-$) = 1.15×10^{-4} : **~10^6 $\phi \to \eta e^+ e^-$ events produced**

Selected η decay channel: $\eta \to \pi^+ \pi^- \pi^0$ (BR = 22.7%)

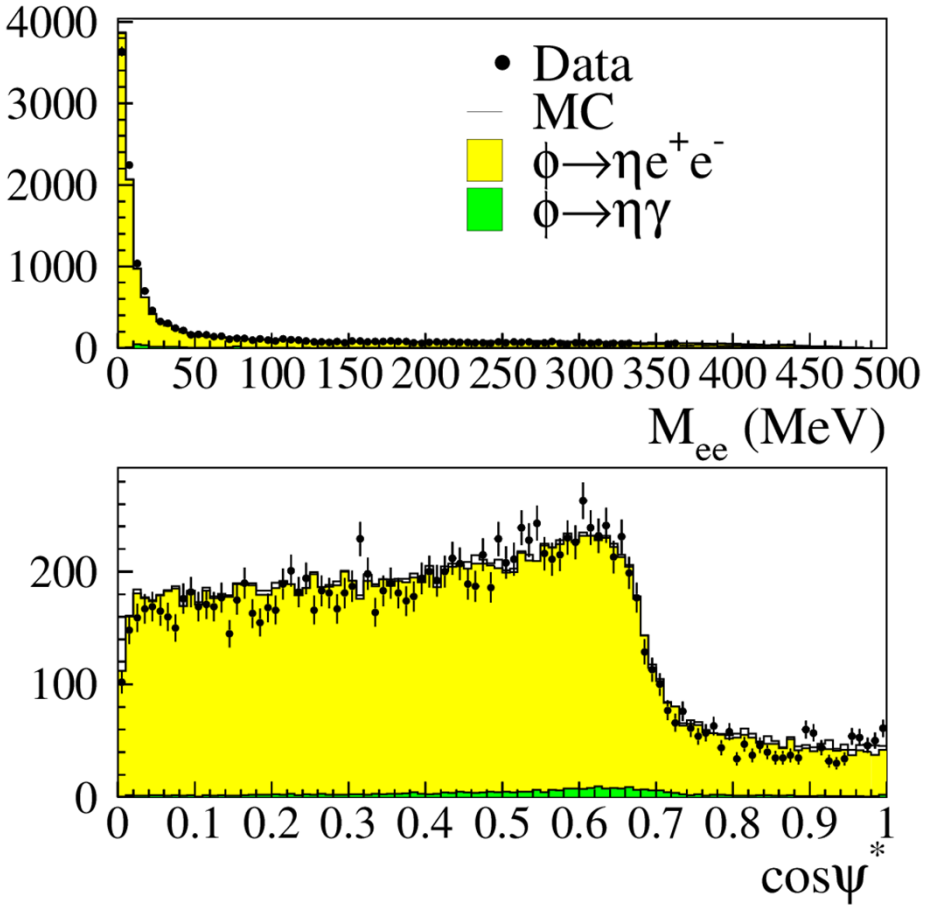
Analysis performed on **1.5 fb^{-1}**

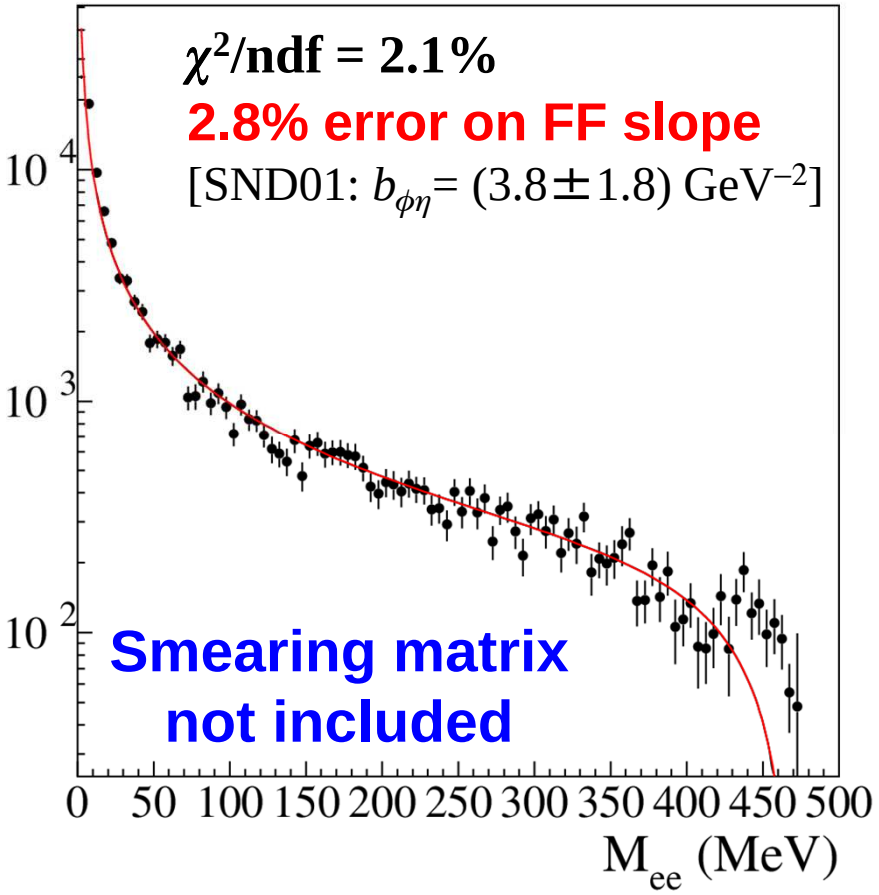
- 4 tracks in a cylinder around IP + 2 photon candidates
- Best $\pi^+\pi^-\gamma\gamma$ match to the η mass using the pion hypothesis for tracks. Other two tracks assigned to e^+/e^-
- $495 < M_{\pi\pi\gamma\gamma} < 600$ MeV
  $70 < M_{\gamma\gamma} < 200$ MeV
  $535 < M_{recoil}(ee) < 560$ MeV
- Photon conversion + ToF cuts

Recoil mass to the e^+e^- pair after $M_{\gamma\gamma}$ cut



$\phi \to \eta e^+ e^-$ @ KLOE: FF parametrization





- **~14000 $\phi \to \eta e^+ e^-$ with $\eta \to \pi^+ \pi^- \pi^0$ candidates**
- **Just very small residual background contamination from $\phi \to \eta\gamma$ events**
- **Fit parametrization from Landsberg, Phys. Rep. 128 (1985) 301**

$\phi \to \eta e^+ e^-$ @ KLOE: search for U boson

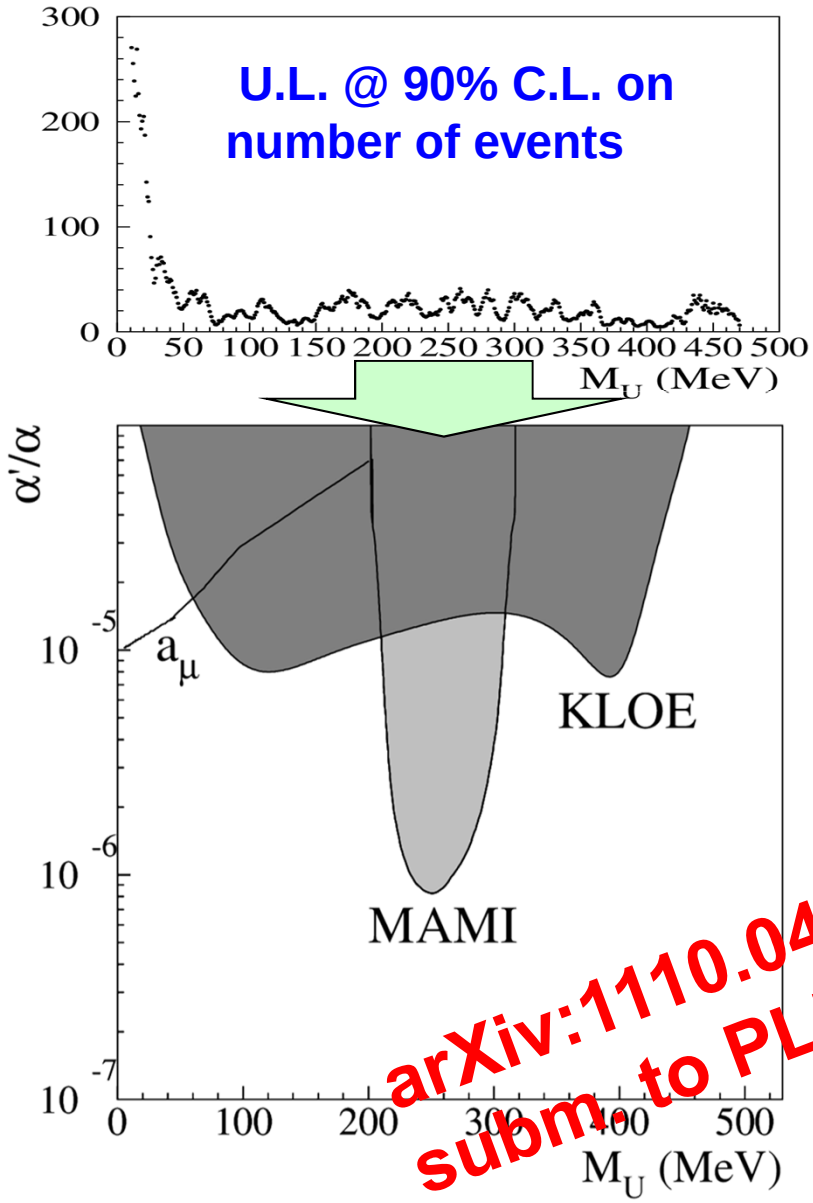
- $\phi \to \eta$U MC sample divided in subsamples of 1 MeV in M_U
- $\phi \to \eta e^+ e^-$ background from fit to M_{ee} distribution, excluding the 5 bins around the selected one
- Upper limit evaluated with the CL_S method (error on bckg included)

UL on $\alpha'/\alpha = \varepsilon^2$ takes into account the correct kinematic factors

$$\frac{\Gamma(\phi \to \eta U)}{\Gamma(\phi \to \eta \gamma)} = \varepsilon^2 \, |F_{\phi\eta\gamma}(m_U^2)|^2 \, \frac{\lambda^{3/2}(m_\phi^2, m_\eta^2, m_U^2)}{\lambda^{3/2}(m_\phi^2, m_\eta^2, 0)}$$

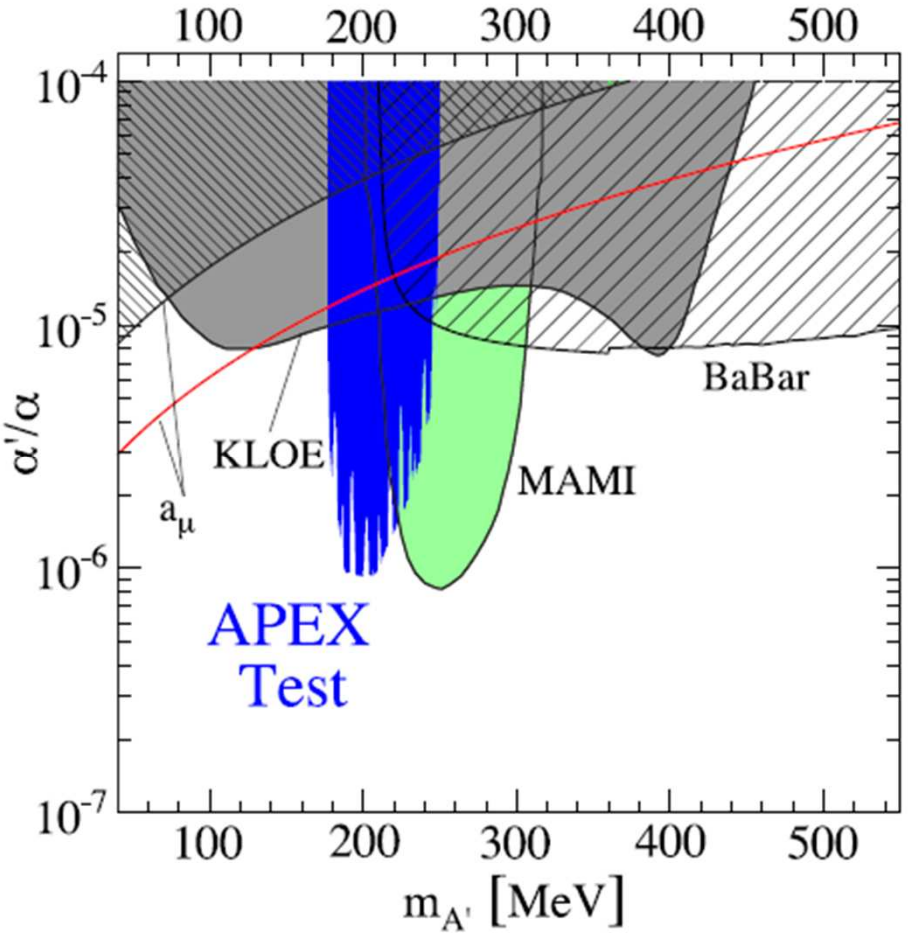
[Reece-Wang, JHEP0907:051 (2009)]

and the opening of the $U \to \mu^+ \mu^-$ threshold



U boson exclusion plot in summer 2011

From M. Drees, talk @ Lepton Photon 2011, Mumbai



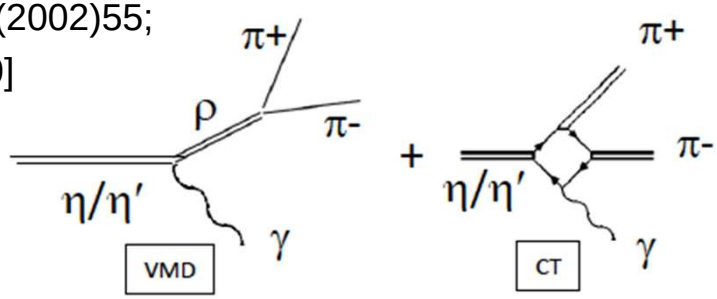
a_μ	PRD 80 095002 (2009)
MAMI	PRL 106 251802 (2011)
KLOE	arXiv:1107.2531
APEX	arXiv:1108.2750
BABAR	PRL 103 081803 (2009)

Red line: α'/α-M_U values if the muon anomaly is due to a heavy photon

$\eta/\eta' \to \pi^+\pi^-\gamma$: motivations

- **Study of the box anomaly**: test of ChPT and its unitarized extensions

  [Benayoun et al. EPJC31(2003)525; Holstein, Phys. Scripta, T99(2002)55; Borasoy, Nissler, NPA740(2004)362, Picciotto PRD45(1992)1569]



Sizeable effect of the Contact Term expected both in $\Gamma(\eta \to \pi^+\pi^-\gamma)$ and in $M_{\pi\pi}$ distribution

Decay	PDG 2010	Prediction with Box Anomaly (HLS)	Prediction without Box Anomaly
$\eta \to \pi^+\pi^-\gamma$	60±4 eV	56.3±1.7 eV	100.9±2.8 eV
$\eta' \to \pi^+\pi^-\gamma$	60±5 keV	48.9±3.9 keV	57.5±4.0 keV

HLS: Benayoun, Eur. Phys. J. C31 (2003) 525

- CLEO result (2007)

  ~ 3 σ's lower than previous measurements

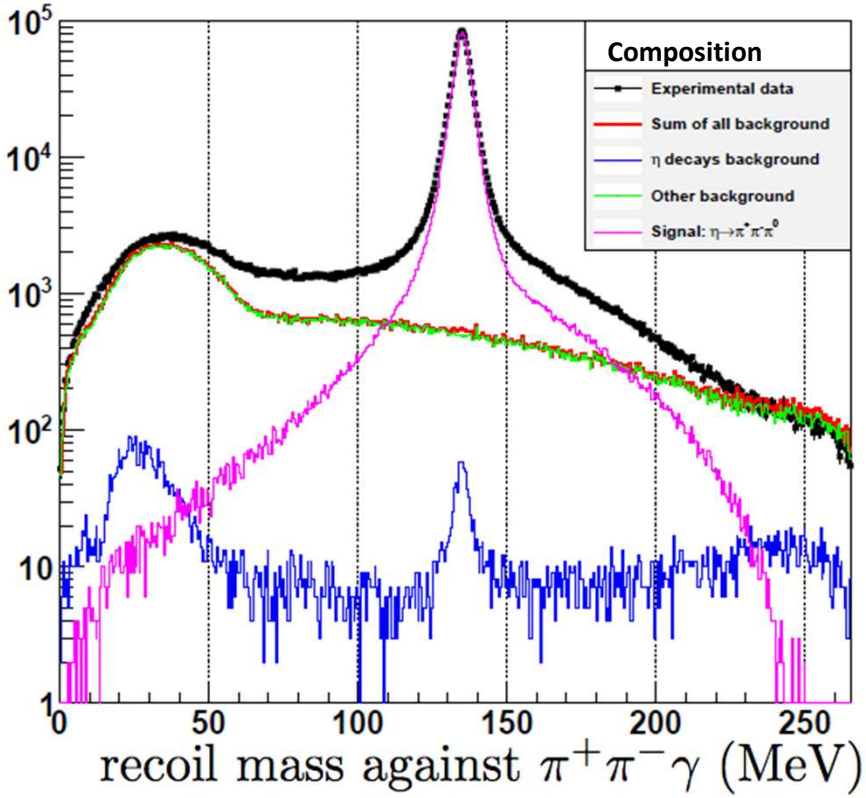
$\Gamma_{CLEO}(\eta \to \pi^+\pi^-\gamma) = (52 \pm 4)$ eV

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

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

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

- Data sample: **558 pb^{-1}**
- **N($\eta \to \pi^+\pi^-\pi^0$) = 1.19×10^6**
- ε = (22.77±0.02)%
- **B/S = 0.65%**
- Signal counting from fit to M_{recoil}
- $\sigma(e^+e^- \to \phi \to \eta\gamma)$ = (41.8 ±0.2) nb



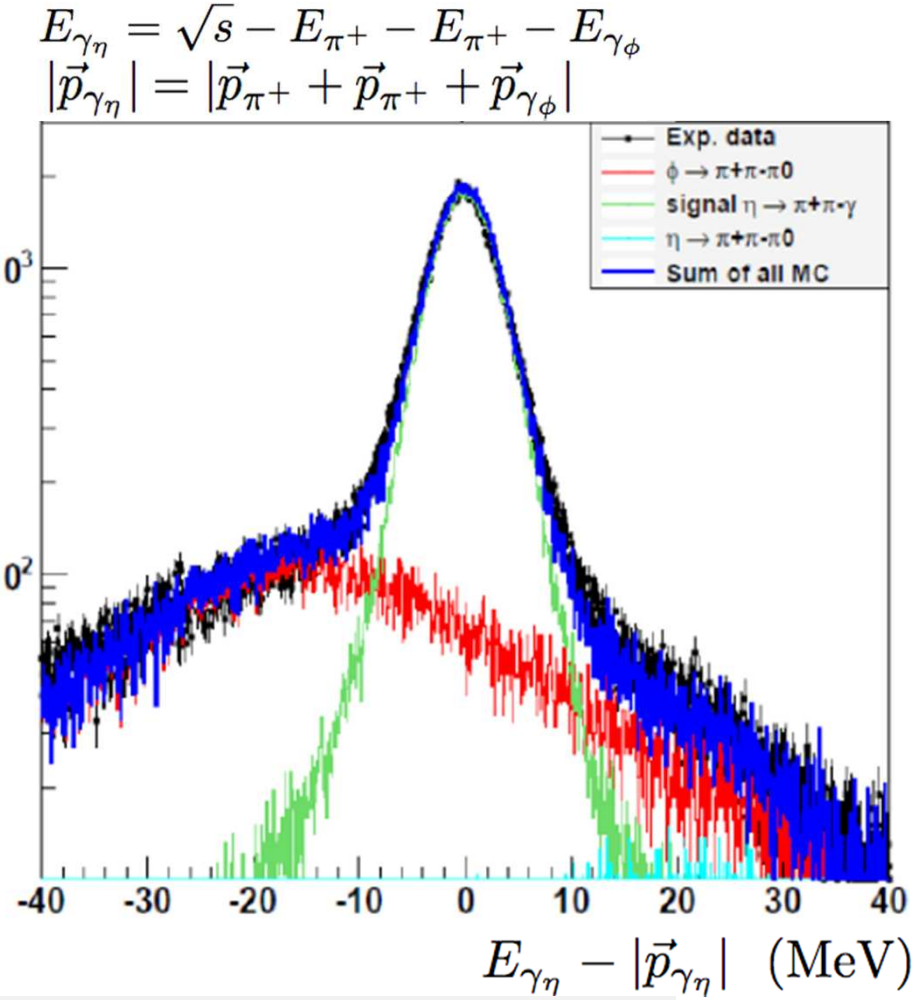
PRELIMINARY
ARXIV:1107.5733

BR($\eta \to \pi^+\pi^-\pi^0$) = (22.41 ± 0.03± 0.35)%

PDG'10: BR($\eta \to \pi^+\pi^-\pi^0$) = (22.74 ± 0.28)%

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

- Data sample: **558 pb^{-1}**
- **N($\eta\to\pi^+\pi^-\gamma$) = 204,950**
- $\varepsilon = (21.31\pm0.04)\%$
- **B/S = 10%**
- Main background: $\phi\to\pi^+\pi^-\pi^0$
- Signal counting from fit to E-p



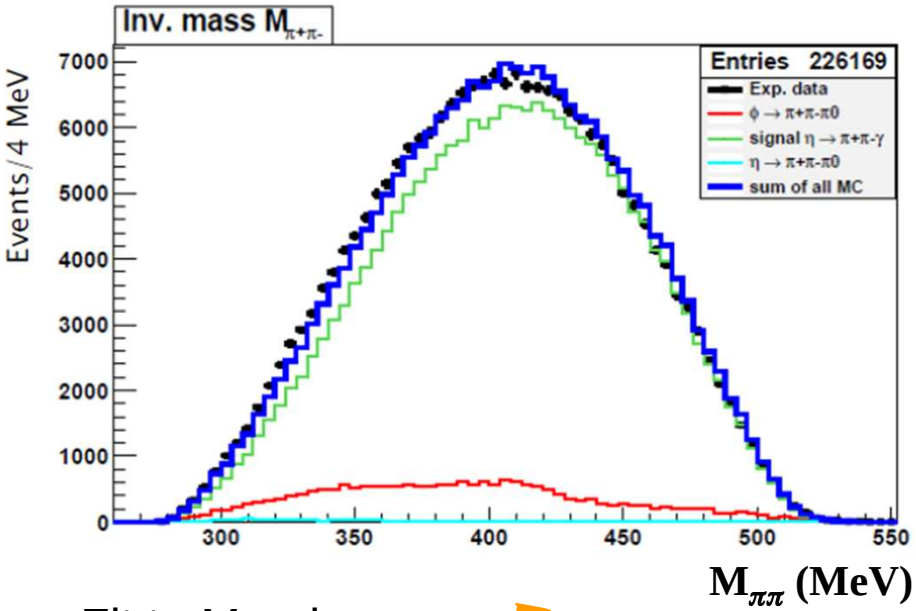
PRELIMINARY
ARXIV:1107.5733

$$\frac{\Gamma(\eta\to\pi^+\pi^-\gamma)}{\Gamma(\eta\to\pi^+\pi^-\pi^0)} = 0.1838\pm0.0005_{stat}\pm0.0030_{syst}$$

Consistent with CLEO measurement

$\eta \to \pi^+\pi^-\gamma$: fit to the $M_{\pi\pi}$ spectrum

Data-MC comparison



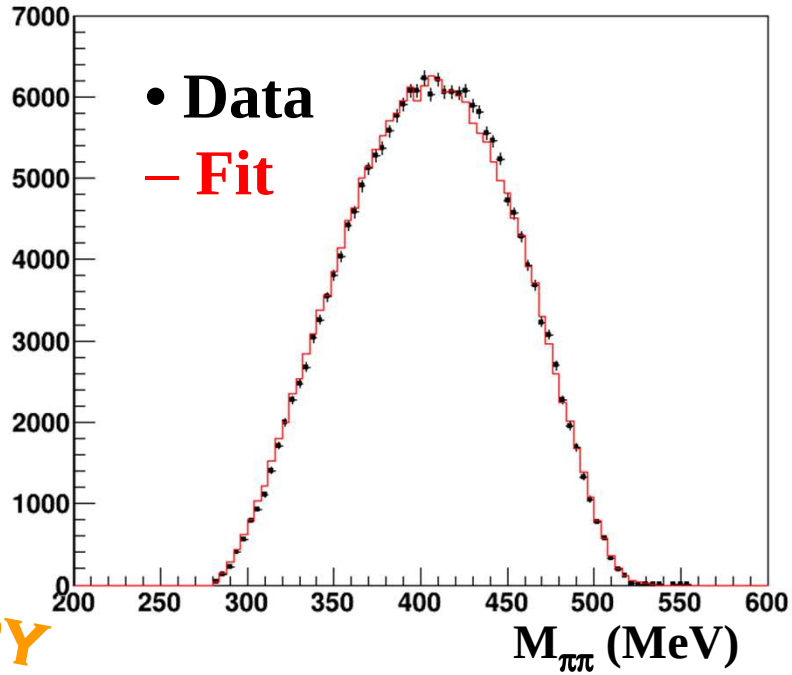
Fit to $M_{\pi\pi}$ done also by WASA arXiv:1107.5277

PRELIMINARY

ARXIV:1107.5733

Fit with CT + VMD

[Picciotto Phys. Rev. D45 (1992), 1569]



KLOE-2: box anomaly can be studied also with $\eta' \to \pi^+\pi^-\gamma$

$M_{\pi\pi}$ lineshape more sensitive to Contact Term

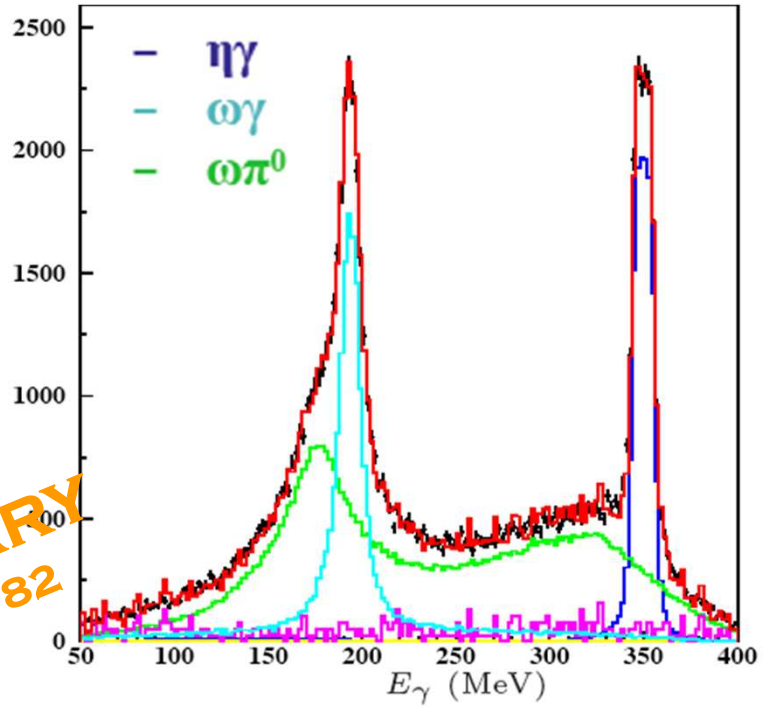
≈ 120,000 selected events expected in one year running

Measurement of $\sigma(e^+e^-\to\eta\gamma)$ @ 1 GeV

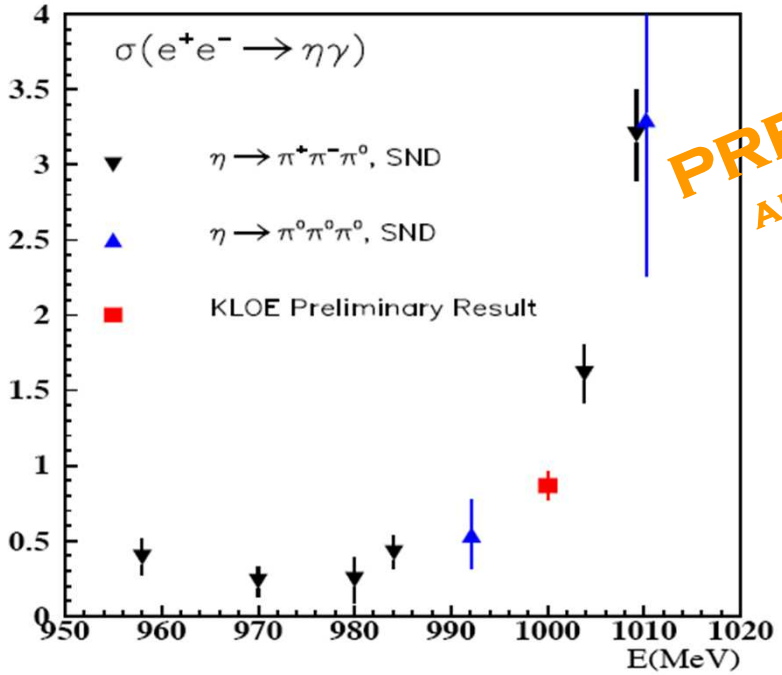
$e^+e^- \to \eta\gamma \to \pi^+\pi^-\pi^0\gamma$: 3 photons + 2 tracks

- pion ID
- kinematic cuts to suppress bckg from kaons from kaons
- kinematic fit

$\sigma(e^+e^-\to\eta\gamma,1\text{GeV}) = (0.866 \pm 0.009 \pm 0.093)$ nb



PRELIMINARY
ARXIV:1107.3782



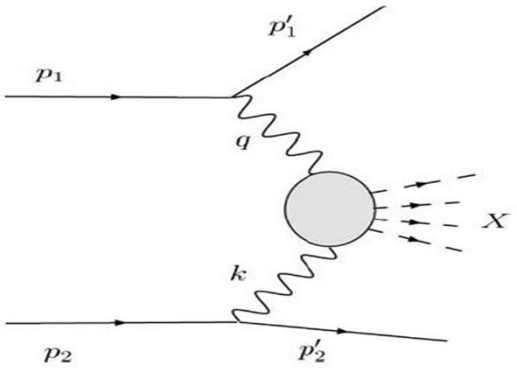
In agreement with the result from $\eta\to\pi^0\pi^0\pi^0$

(6γ's with imposed π^0, η masses + miss. E)

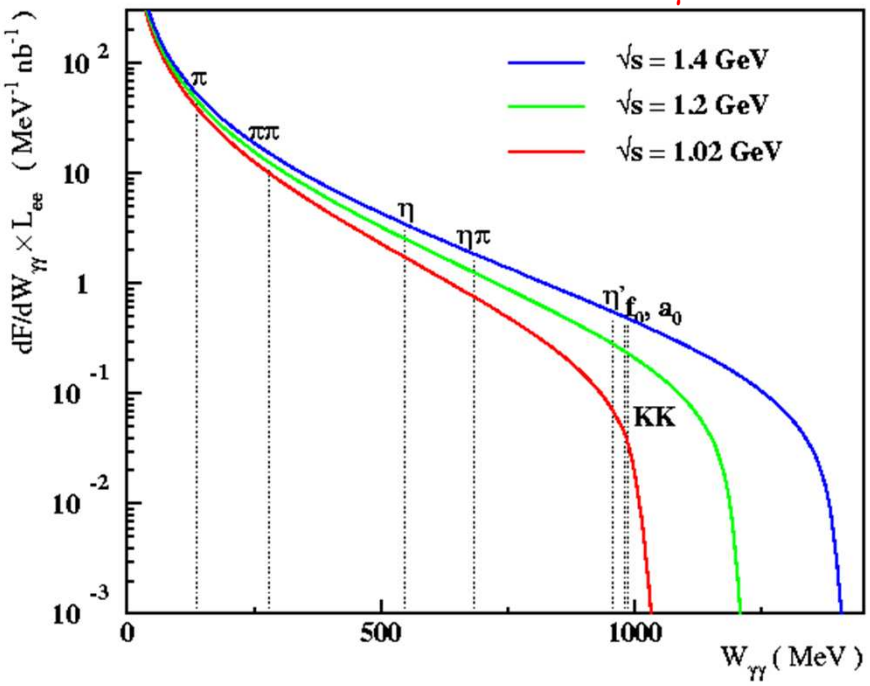
$\sigma(e^+e^-\to\eta\gamma,1\text{GeV}) = (0.875 \pm 0.018 \pm 0.035)$ nb

Background for $\gamma\gamma\to\eta$ accurately measured from the same 240 pb^{-1} sample

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



Weizsäcker-Williams approx, $|q_\gamma^2| \ll W^2$



$$\frac{dN}{dW_{\gamma\gamma}} = L_{int} \frac{dF}{dW_{\gamma\gamma}} \sigma(\gamma\gamma \rightarrow X)$$

$$\sigma_{e^+e^- \rightarrow e^+e^- X} = \frac{16\alpha^2 \Gamma_{X\gamma\gamma}}{m_X^3} \left(\ln \frac{E_b}{m_e} \right)^2 \left((y^2+2)^2 \ln \frac{1}{y} - (1-y^2)(3+y^2) \right)$$

$$y = m_X/(2E_b)$$

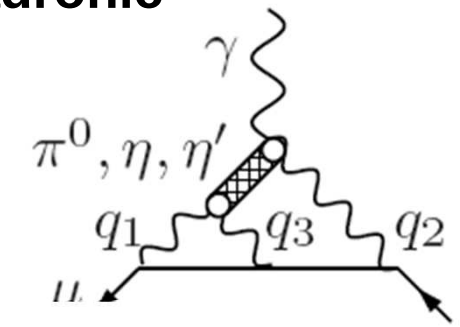
KLOE: no $e^\pm$ tagging ⇒ $\sqrt{s}$ = 1 GeV

KLOE-2: tagger to reduce background from ϕ and to close kinematics ⇒ $\sqrt{s} = M_\phi$

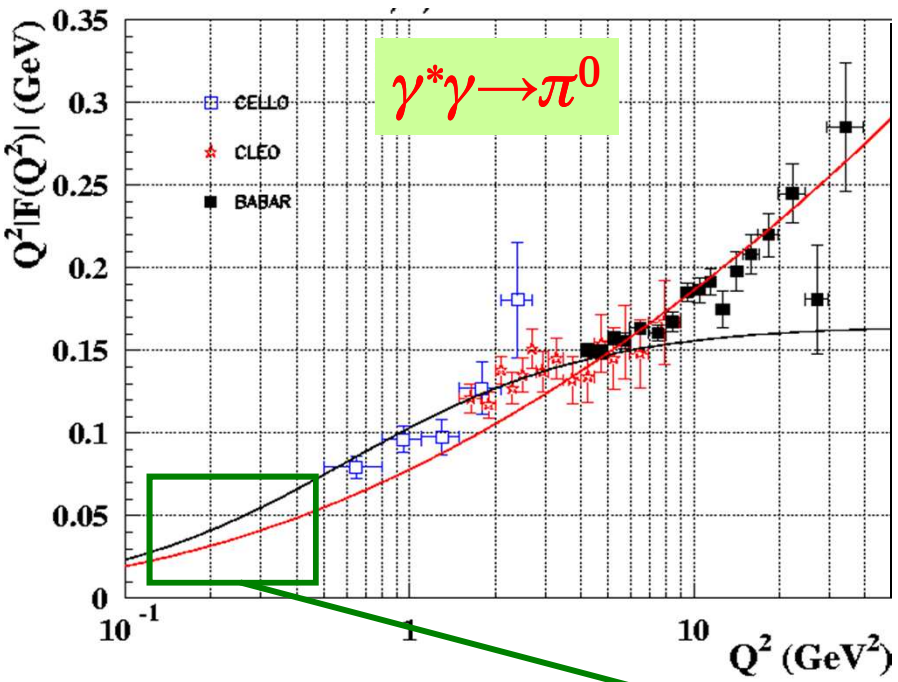
$\gamma\gamma$ physics: meson transition form factor

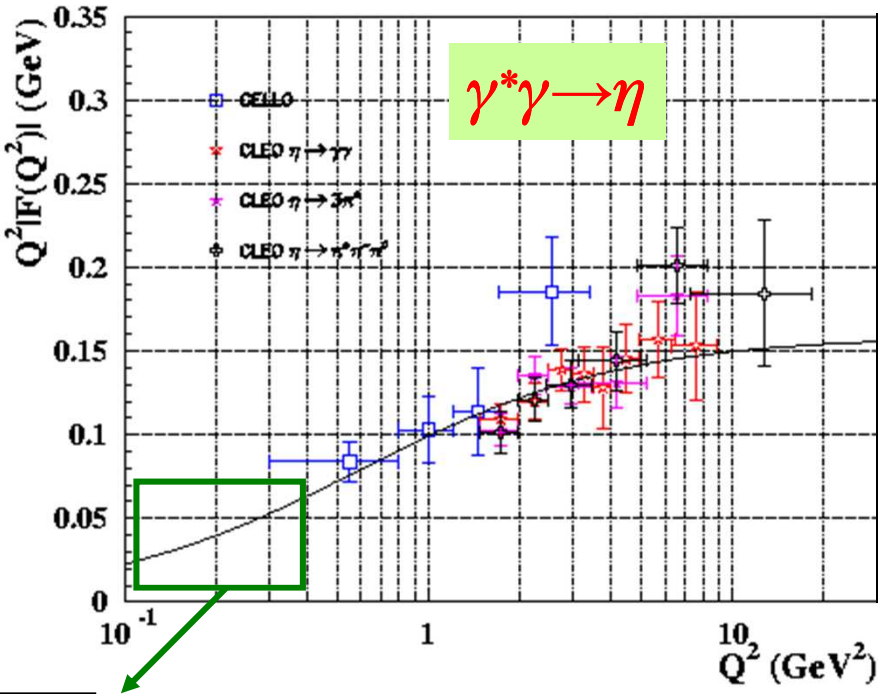
Slope of transition form factors near $q^2=0$ crucial for hadronic light-by-light contributions to g-2

$$\sigma_{\gamma\gamma\to R}(q_1,q_2) \propto \Gamma_{R\to\gamma\gamma}\frac{8\pi^2}{M_R}\delta((q_1+q_2)^2-M_R^2)\left|F(q_1^2,q_2^2)\right|^2$$



$\gamma^*\gamma\to$P ⇒ F(P^2,q^2,0)



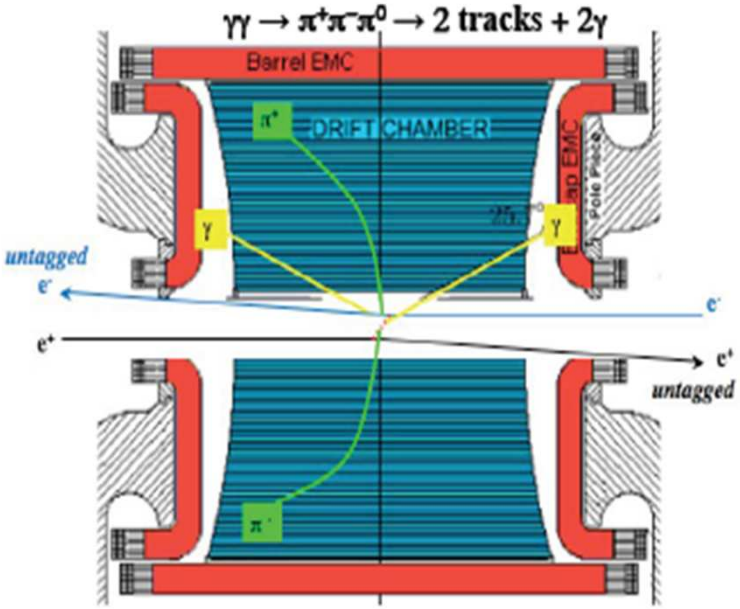


KLOE-2

$\gamma\gamma$ physics @ KLOE: $\Gamma_\eta(\gamma\gamma)$ measurement

VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT	$\sqrt{s}$ (GeV)
0.510±0.026 OUR FIT						
0.510±0.026 OUR AVERAGE						
0.51 ±0.12 ±0.05	36	BARU	90	MD1	$e^+e^- \to e^+e^-\eta$	**7.2-10.4**
0.490±0.010±0.048	2287	ROE	90	ASP	$e^+e^- \to e^+e^-\eta$	**29**
0.514±0.017±0.035	1295	WILLIAMS	88	CBAL	$e^+e^- \to e^+e^-\eta$	**9.4-10.6**
0.53 ±0.04 ±0.04		BARTEL	85E	JADE	$e^+e^- \to e^+e^-\eta$	**34.6**

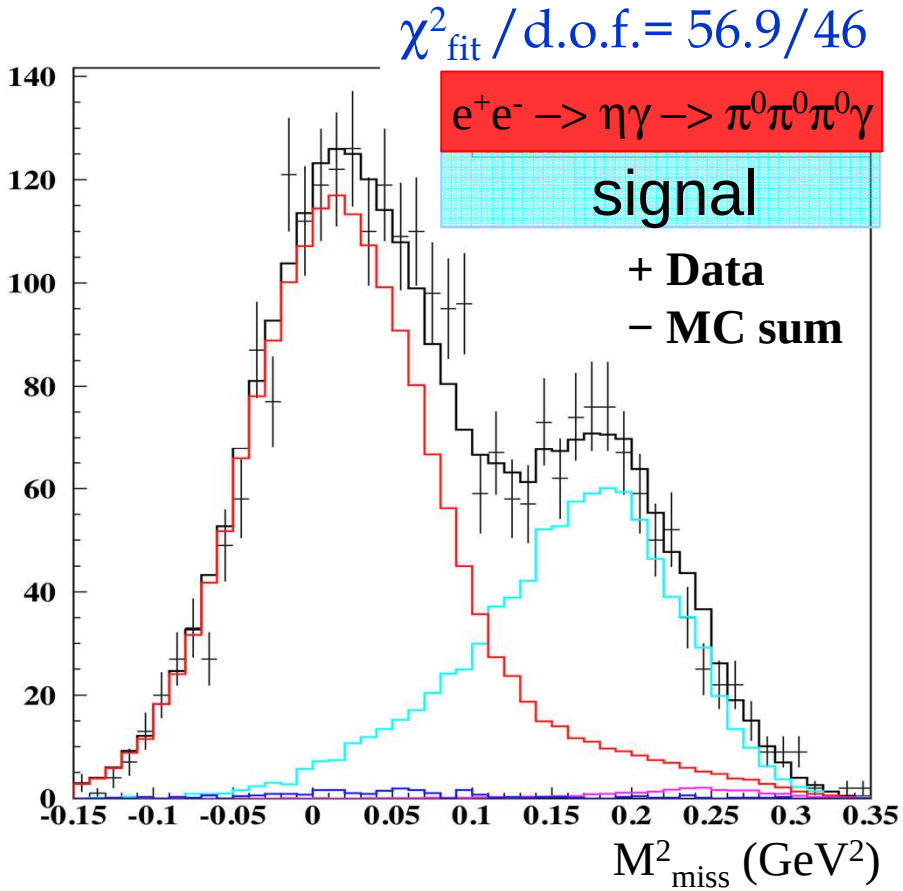
- $\gamma\gamma \to \eta$ studied at KLOE (**no tagger**)
- Data sample: **240 pb^{-1} @ $\sqrt{s}$ = 1 GeV**
  (reduced bckg contamination from ϕ)
- Selected channels: $\eta \to \pi^+\pi^-\pi^0/\pi^0\pi^0\pi^0$
- Main background: $\phi \to \eta\gamma$ with
  undetected recoil photon

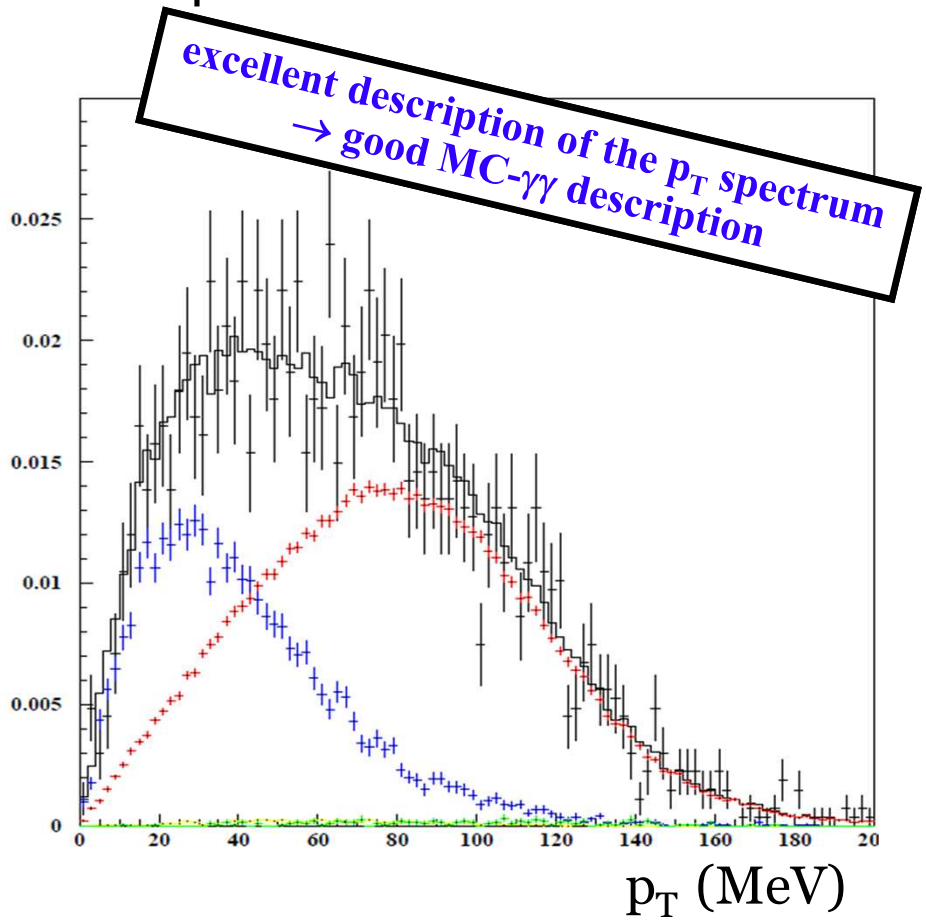


$\gamma\gamma \to \eta \to \pi^0\pi^0\pi^0$

PRELIMINARY

Fit to M_{miss}^2 with signal and background shapes



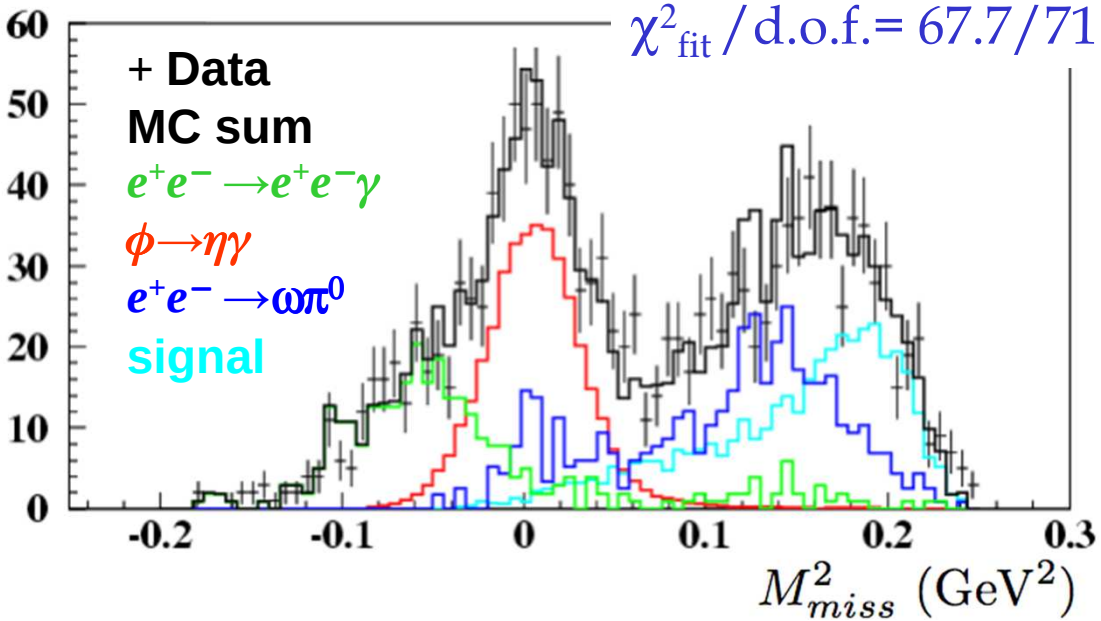


$\sigma(\gamma\gamma \to \eta) = (37.0 \pm 1.4 \pm 2.2)$ pb

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

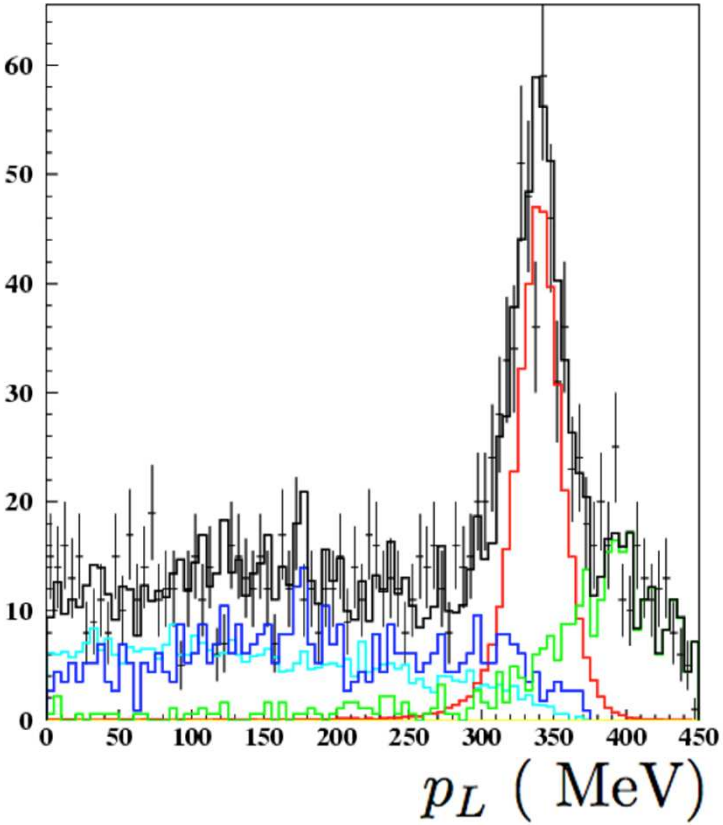
PRELIMINARY

Fit to M_{miss}^2 with signal and background shapes



1500 events,
signal fraction ~ 26%
efficiency ~ 17%

Good data-MC comparison



$$\sigma(\gamma\gamma \to \eta) = (41.7 \pm 4.0 \pm \ldots)\ \text{pb}$$

Search for $\gamma\gamma \to \sigma \to \pi^0\pi^0$

- Long debate about the experimental evidence of the $\sigma(600)$ meson
- Evidence for $\pi^+\pi^-$ bound state (E791, CLEO, BES) from Dalitz plot analyses
- Values of mass and width with large uncertainties
- **Indirect evidence in the $e^+e^- \to \pi^0\pi^0\gamma$ Dalitz plot analysis @ KLOE**

Only process to measure directly the $\sigma\gamma\gamma$ coupling → infer structure

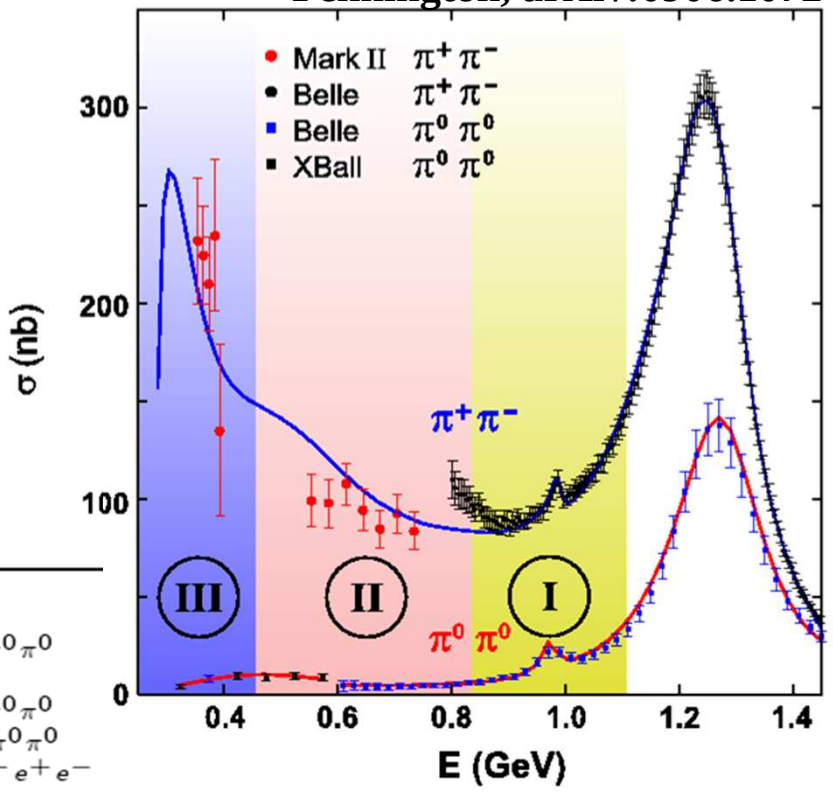
$\pi^0\pi^0$ preferred w.r.t. $\pi^+\pi^-$ due to smaller background contamination

$f_0(600)$ PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$

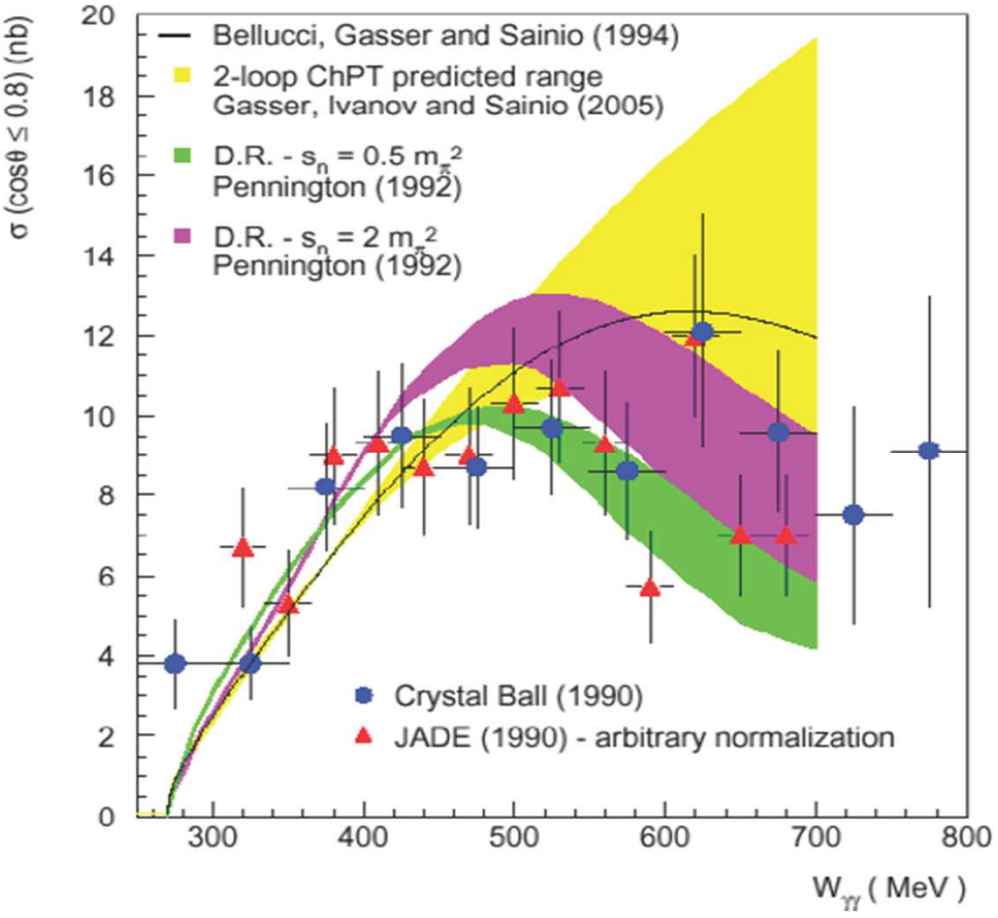
VALUE (keV)		DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.2±0.4	[48]	BERNABEU	08	RVUE	
3.9±0.6	[49]	MENNESSIER	08	RVUE	$\gamma\gamma \to \pi^+\pi^-, \pi^0\pi^0$
4.1±0.3	[50]	PENNINGTON	06	RVUE	$\gamma\gamma \to \pi^0\pi^0$
3.8±1.5	[51,52]	BOGLIONE	99	RVUE	$\gamma\gamma \to \pi^+\pi^-, \pi^0\pi^0$
5.4±2.3	[51]	MORGAN	90	RVUE	$\gamma\gamma \to \pi^+\pi^-, \pi^0\pi^0$
10 ±6		COURAU	86	DM1	$e^+e^- \to \pi^+\pi^- e^+e^-$

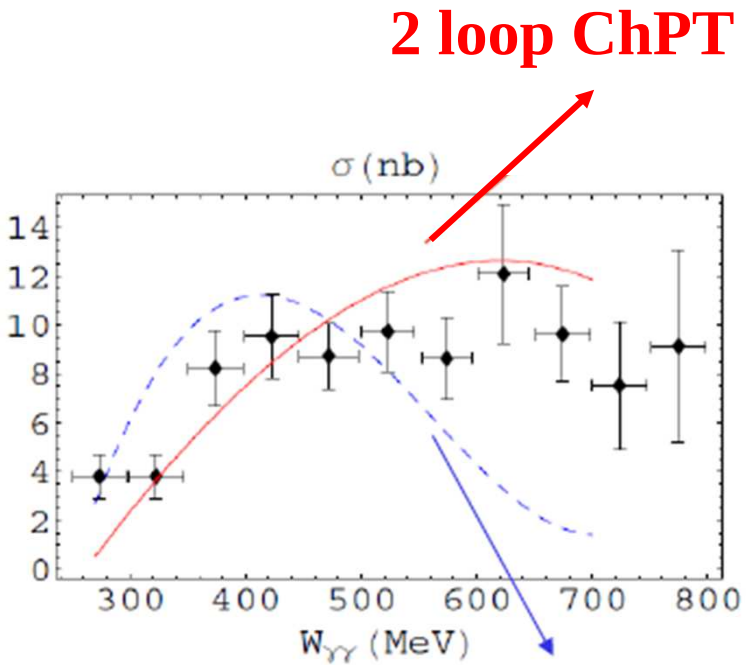
Pennington, arXiv:0906.1072



$\gamma\gamma \to \pi^0\pi^0$ at low energies

Cleanest channel to assess the nature of the σ meson



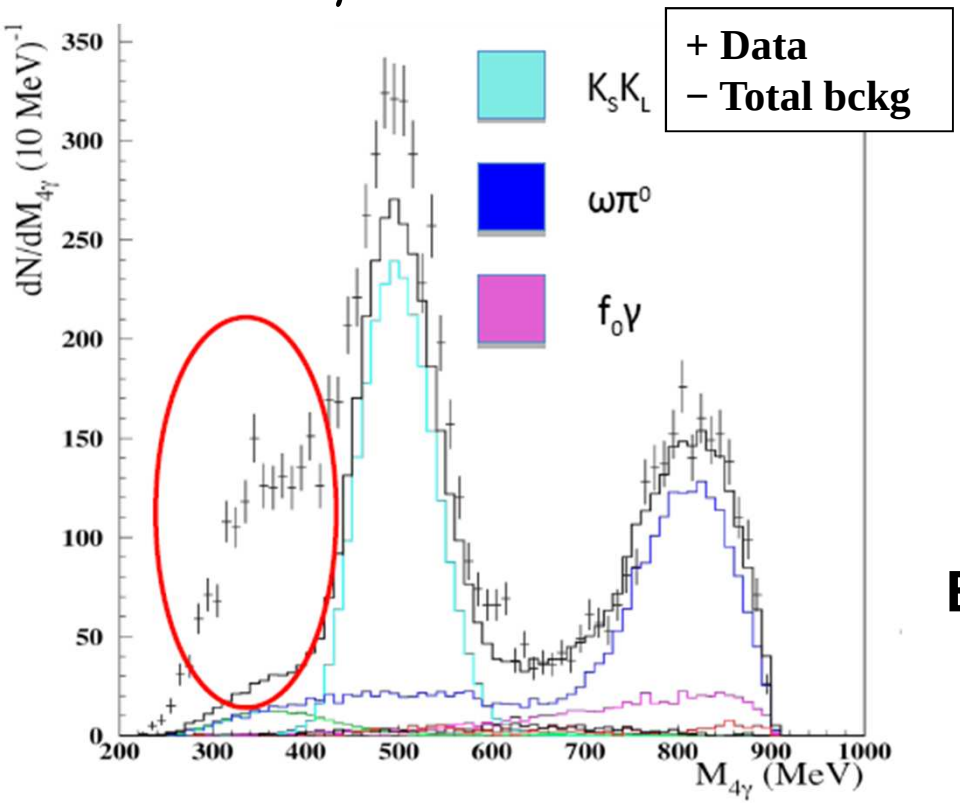


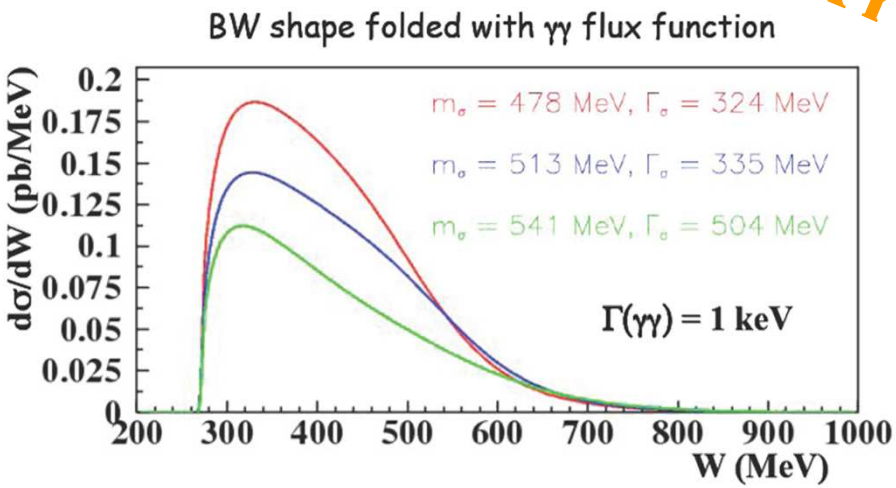
Resonant contribution
$\gamma\gamma \to \sigma$(BES values)$\to \pi^0\pi^0$
[Nguyen, Piccinini, Polosa, EPJC 47 (2006) 65]

$\gamma\gamma \to \pi^0\pi^0$

PRELIMINARY

- **240 pb^{-1} @ $\sqrt{s}$ = 1 GeV**
- **8090 events after selection**
- **Bckg contribution from fit to the $M_{4\gamma}$ spectrum**





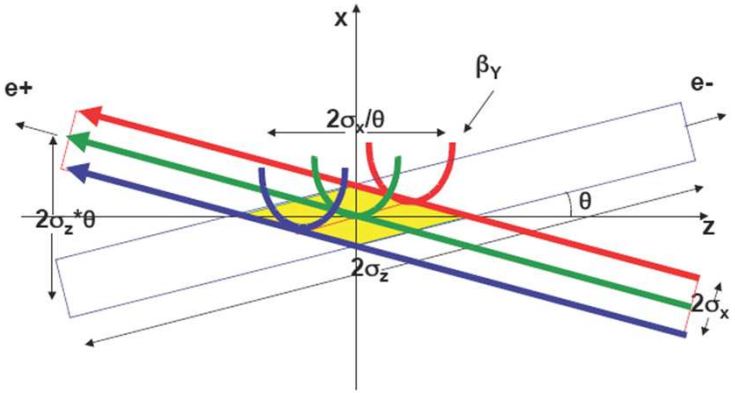
Excess of ~2000 events w.r.t. known backgrounds in the $\gamma\gamma \to \sigma(600) \to \pi^0\pi^0$ region

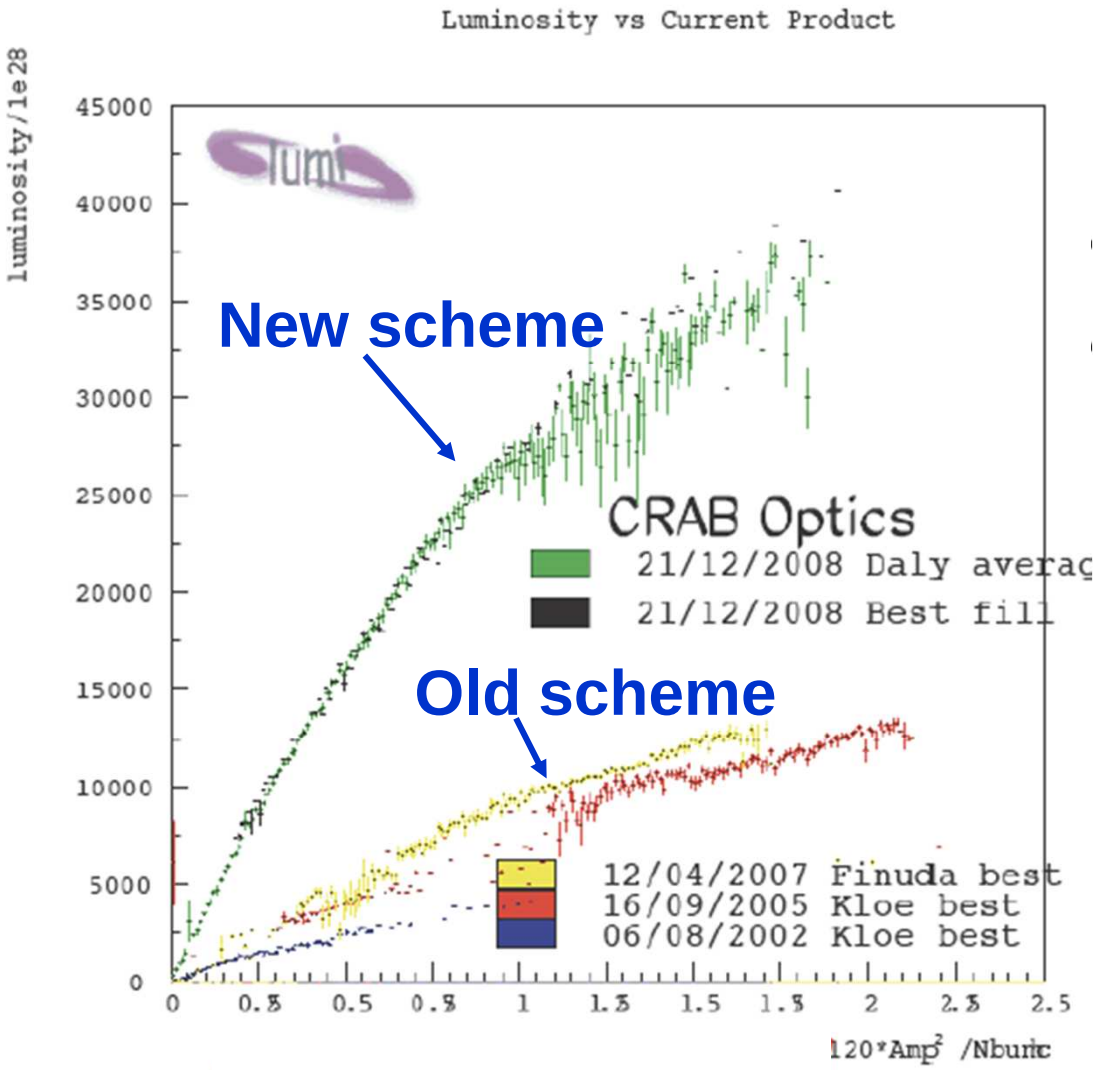
Bckg subtraction and study of differential x-sec in progress

DAΦNE upgrade

New interaction scheme implemented: large beam crossing angle + sextupoles for crabbed waist optics

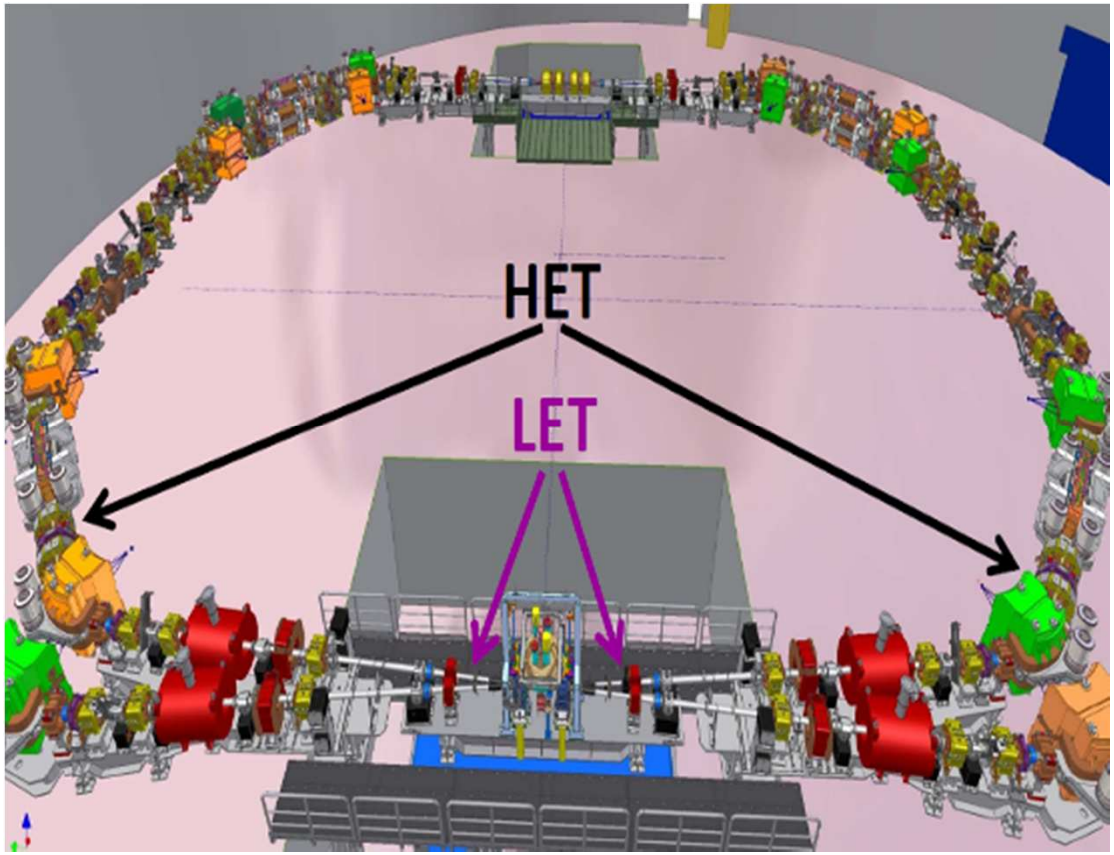
- $L_{new} \sim 3 \times L_{old}$
- $\int L dt = 1\ pb^{-1}/hour$





From KLOE to KLOE-2: $\gamma\gamma$ taggers

Detector upgrade for the first KLOE-2 run: 2+2 taggers to detect momentum of leptons in $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-X$



LET : E=160−230 MeV

- Inside KLOE detector
- LYSO+SiPM
- s_E<10% for E>150 MeV

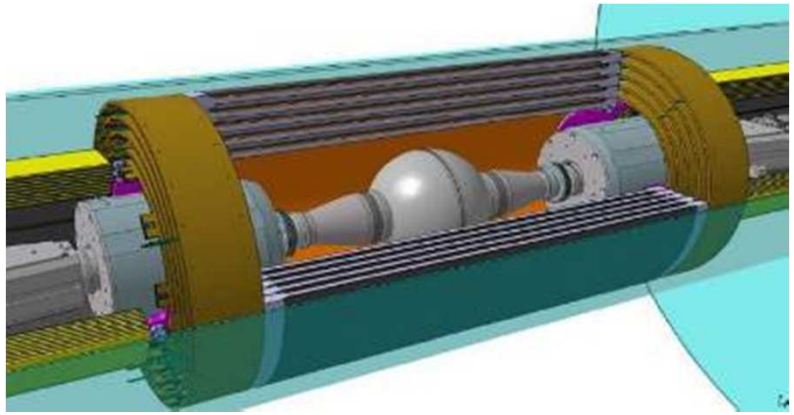
HET : E > 400 MeV

- 11 m from IP
- Scintillators + PMTs
- $\sigma_E \sim 2.5$ MeV
- $\sigma_T \sim 200$ ps

From KLOE to KLOE-2: IP detectors

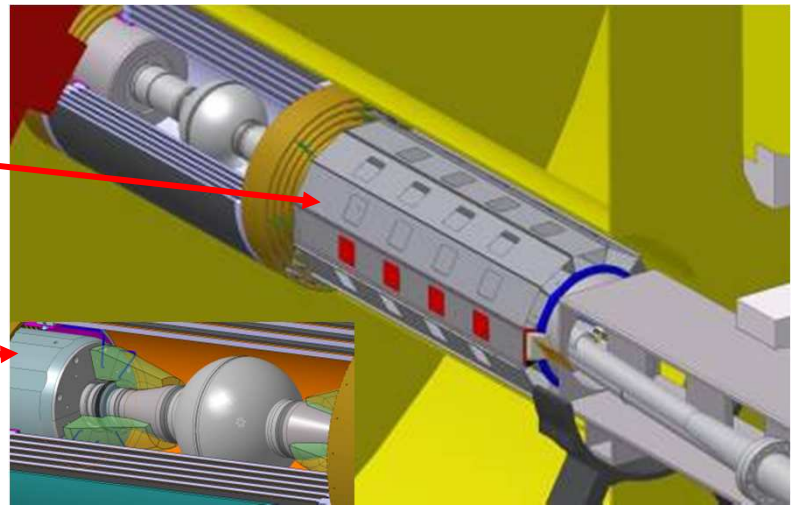
Major detector upgrades for second KLOE-2 run:

INNER TRACKER



- 4 layers of cylindrical triple GEM
- Better vertex reconstruction near IP
- Larger acceptance for low p_t tracks

QCALT



- W + scintillator tiles + SiPM/WLS
- QUADS coverage for K_L decays

CCAL

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

KLOE-2 physics program

Goal: **~20 fb^{-1} in the next 3-4 years** to extend the KLOE physics program

[G.Amelino-Camelia et al., Eur. Phys. J. C 68 (2010), 619]

❖ $\gamma\gamma$ physics	➢ Existence (and properties) of $\sigma/f_0(600)$ ➢ Study of $\Gamma(S/PS\to\gamma\gamma)$ ➢ PS transition form factor
❖ Light meson spectroscopy	➢ Properties of scalar/vector mesons ➢ Rare η decays ➢ η' physics
❖ Kaon physics	➢ Test of CPT (and QM) in correlated K decays ➢ Test of CPT in K_S semileptonic decays ➢ Test of SM (CKM unitarity,lepton universality) ➢ Test of ChPT (K_S decays)
❖ Dark forces search	➢ Vector gauge bosons @ O(1 GeV)

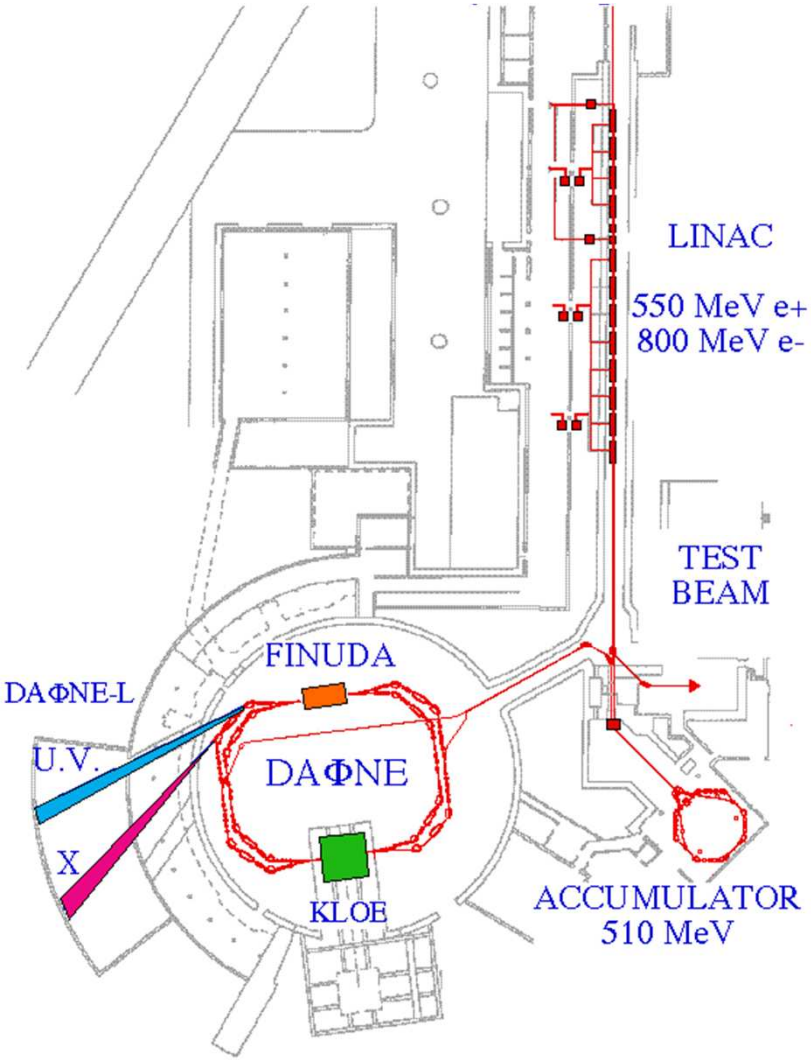
Conclusions

- **High statistics samples of light mesons produced at KLOE allowed to perform precision measurement and to look for very rare decays**

- **KLOE-2 is going to start a new data taking campaign**
  - DAΦNE expected to restart operations end of this month
  - Detector ready to take data
  - Rich physics program available [see Eur. Phys. J. C 68 (2010), 619]
  - ~ 20 fb^{-1} in the next 3-4 years @ ϕ -peak
  - Run @ 1000 MeV of $O(1\ fb^{-1})$ under discussion

- **Detector upgrades under construction: completion expected in summer 2012**

DAΦNE: the Frascati ϕ-factory



- e^+e^- collider @ $\sqrt{s} = M_\phi = 1019.4$ MeV
- 2 interaction regions
- Separate e^+ e^- rings
- 105+105 bunches, 2.7 ns bunch spacing
- $I^-_{peak} \sim 2.4$ A $I^+_{peak} \sim 1.5$ A
- Injection during data taking
- Crossing angle: 2×12.5 mrad

❖ **Running period: 1999-2007**

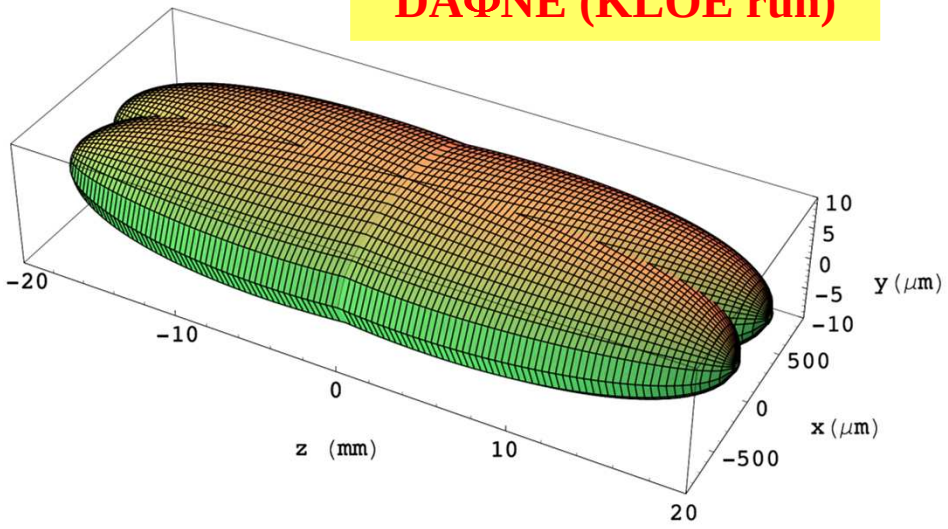
❖ **Best performances:**

➢ $L_{peak} = 1.4\times10^{32}$ cm^{-2}s^{-1}

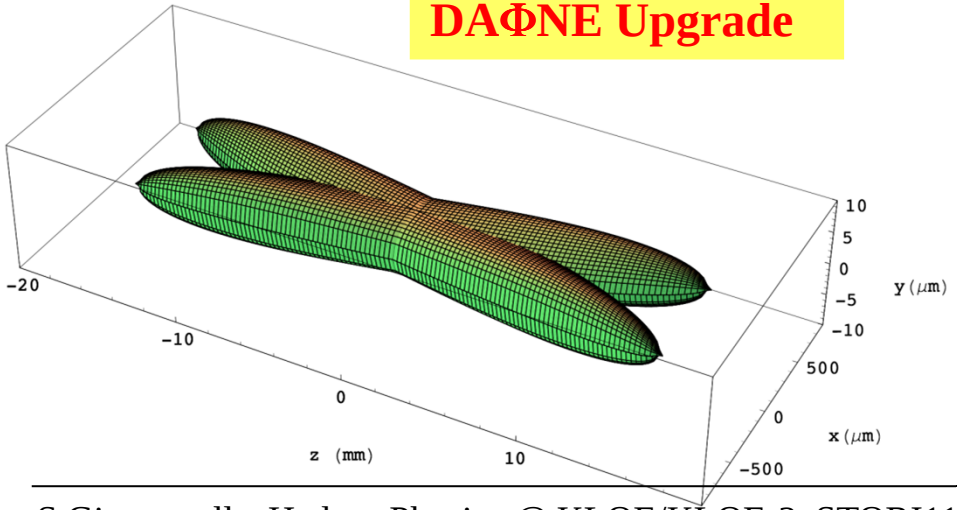
➢ $\int L dt = 8.5$ pb^{-1}/day

DAΦNE: beam profiles @ IP and parameters

DAΦNE (KLOE run)



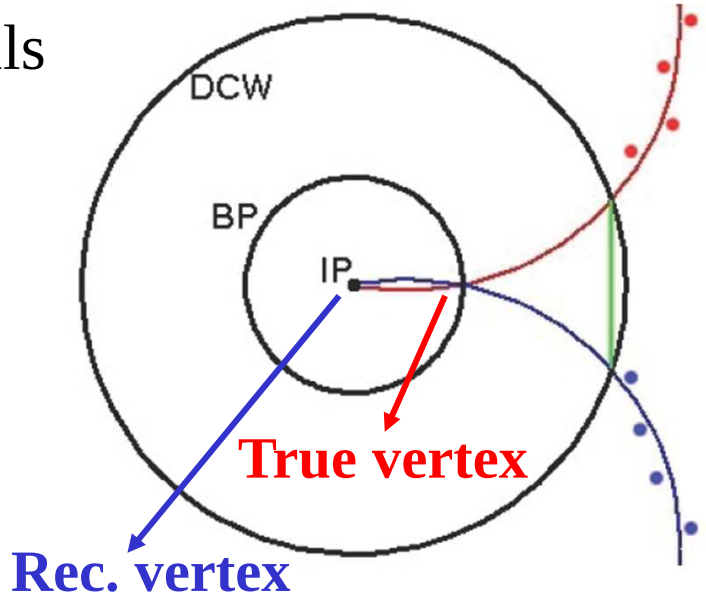
DAΦNE Upgrade

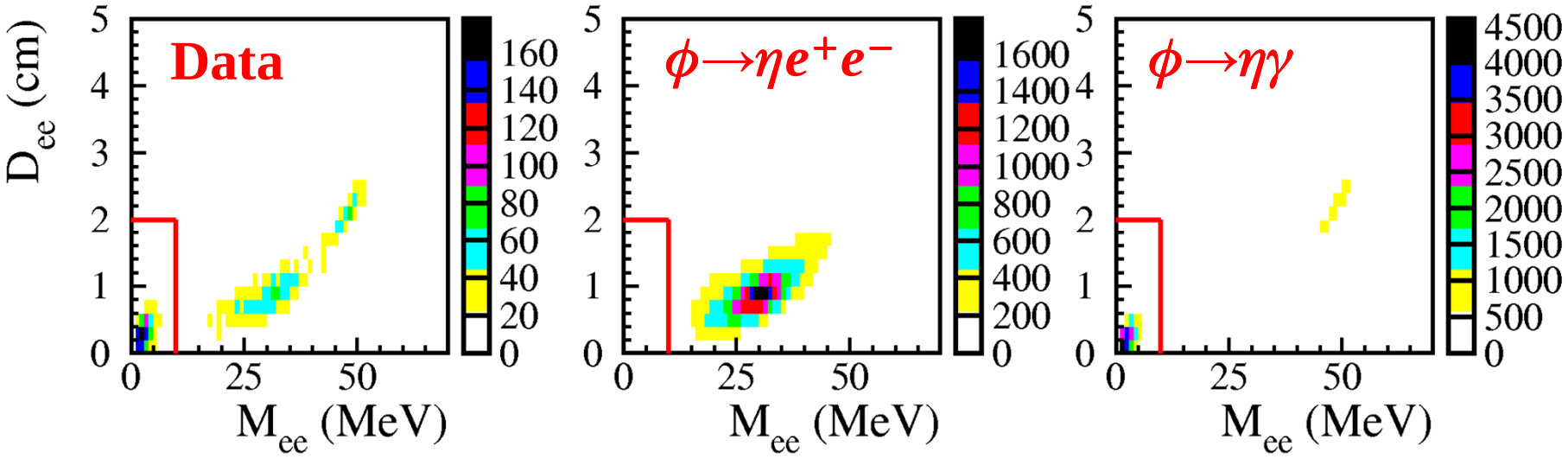


	DAΦNE (KLOE run)	DAΦNE Upgrade
I_{bunch} (mA)	13	13
N_{bunch}	110	110
β_y^* (cm)	1.7	0.65
β_x^* (cm)	170	20
σ_y^* (μm)	7	2.6
σ_x^* (μm)	700	200
σ_z (mm)	25	20
θ_{cross} (mrad) (half)	12.5	25
$\Phi_{Piwinski}$	0.45	2.5
L ($cm^{-2}s^{-1}$)	1.5×10^{32}	$>5 \times 10^{32}$

Background rejection: photon conversions

Photon conversions on Beam Pipe/DC Walls rejected by tracking back to BP/DCW surfaces the two e^+, e^- candidates and reconstructing the e^+e^- invariant mass (M_{ee}) and the distance between the two particles (D_{ee}). Both quantities are small if coming from photon conversion

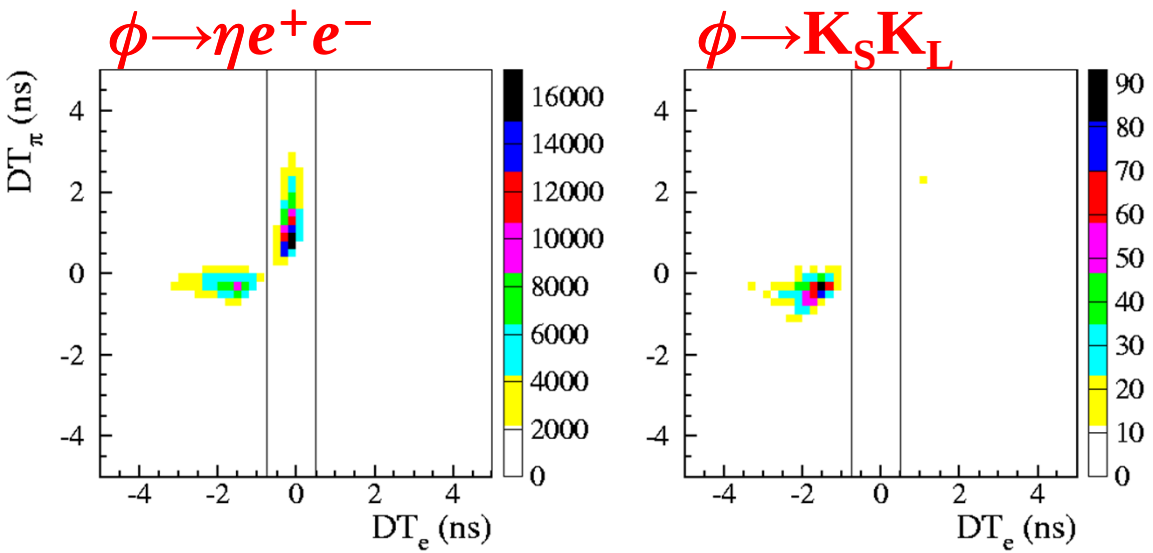


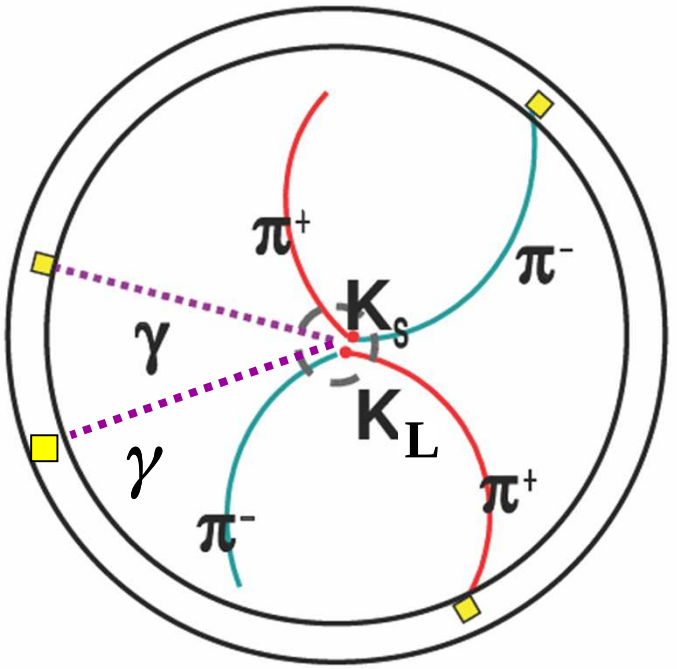


Background rejection: π-enriched events

$\phi \to$KKbar and $\phi \to \pi^+\pi^-\pi^0$ events surviving analysis cuts have more than two pions in the final state. They can be rejected using Time-of-Flight (ToF) to the calorimeter when an EMC cluster is connected to the track

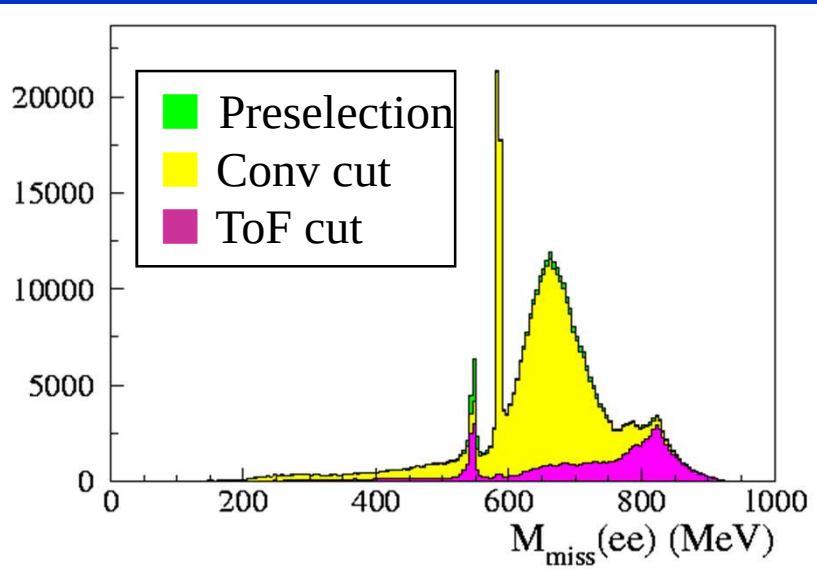
$DT = T_{track} - T_{cluster}$ variable evaluated in both electron (DT_e) and pion (DT_π) hypotheses



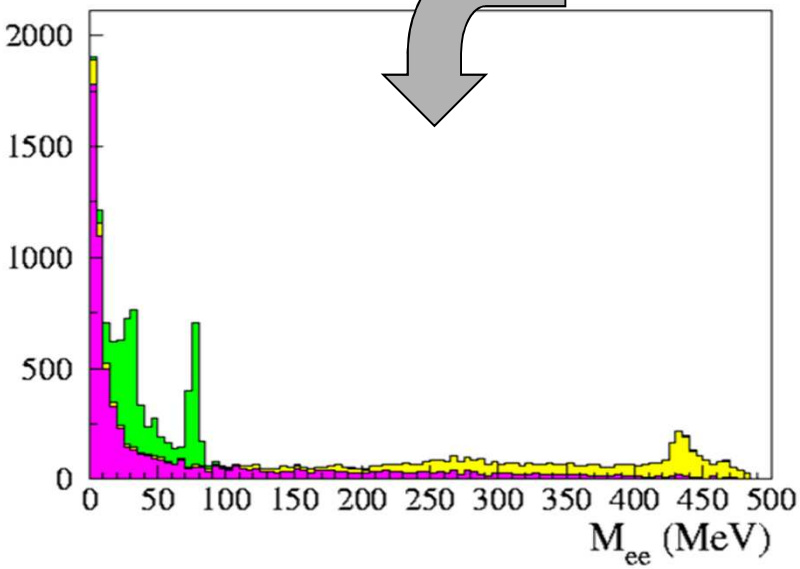


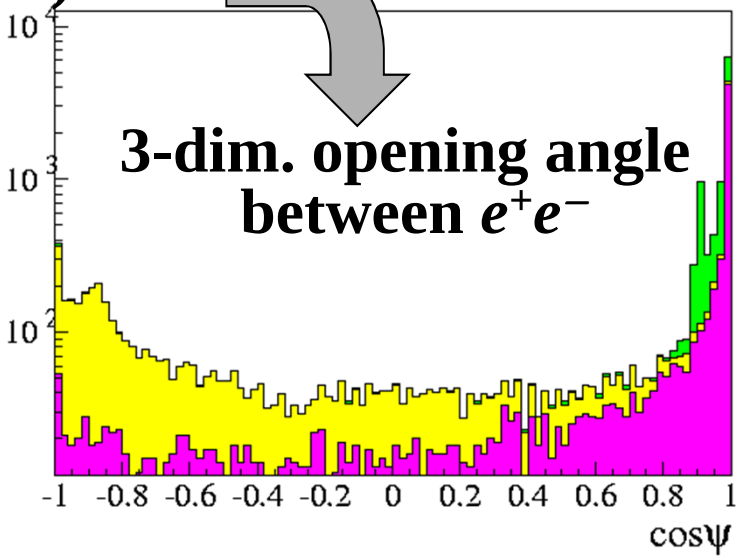
Events with e^+/e^- candidate with connected cluster outside a 3σ DT_e window removed

Background reduction on data



After $M_{miss}(ee)$ cut





3-dim. opening angle between e^+e^-

Fit to the M_{ee} shape

Decay parametrization from Landsberg85 + $F(q^2)$ approximation from Achasov, Kozhevnikov, Sov. J. Nucl. Phys. 55 (1992) 449

$$\frac{d}{dq^2}\frac{\Gamma(\phi\to\eta e^+e^-)}{\Gamma(\phi\to\eta\gamma)}=\frac{\alpha}{3\pi}\frac{|F_{\phi\eta}(q^2)|^2}{q^2}\sqrt{1-\frac{4m^2}{q^2}}\times$$

$$\times\left(1+\frac{2m^2}{q^2}\right)\times\left[\left(1+\frac{q^2}{m_\phi^2-m_\eta^2}\right)^2-\frac{4m_\phi^2q^2}{(m_\phi^2-m_\eta^2)^2}\right]^{3/2}$$

$$F(q^2)=\frac{1}{1-q^2/\Lambda^2}$$

FF slope:

$$\begin{cases} b = dF/dq^2|_{q^2=0} \\ b_{\phi\eta} = \Lambda_{\phi\eta}^{-2} \approx 1/m_\phi^2 \approx 1\ \mathrm{GeV}^{-2} \end{cases}$$