KLOE-2: physics prospects and upgrades

S. Giovannella (LNF)
on behalf of the KLOE-2 Collaboration

- Prospects for physics @ KLOE-2 with 5-10 fb^{-1}
- Status of detector upgrades
- Updates on current analyses

44th Scientific Committee – LNF, 4 June 2012

KLOE-2 with 5-10 fb^{-1}

The KLOE-2 physics program as originally proposed and published in year 2009, is based on 20 fb^{-1}, feasible starting with a data delivering of ~20 pb^{-1} per day. As this is not the case, the reach of the experiment with 5-10 fb^{-1} is being considered. Improvements are possible in several fields:

QM, CPT- and Lorentz-invariance tests with neutral Kaons, sensitive to effects at the Planck scale (10^{19} GeV)

cited by (th.): EPJ C72(2012)1956; PRD85(2012)085023; arXiv:1201.3045; arXiv:1102.3612; AIP Conf.Proc.1327(2011)118-127;...

SM test with **precision measurements of the V_{us}** element of the CKM mixing matrix

Rev. Mod. Phys.84(2012)399; arXiv:1203.6437; arXiv:1112.1984; ...

Low-energy QCD with e.g. radiative kaon, η, and η' decays and **low-mass scalars** with e.g. the study of scalar-KK coupling

EPJA47(2011)148; PRD85(2012)054018; NPB860(2012)245-266; arXiv:1112.4384; arXiv:1109.3754; NPPS207(2010)196 JHEP 1102(2011)028; arXiv:1007.4479; EPJ C71(2011)1814;...

γγ physics with e.g. the measurements of the π^0 width and $\pi^0 \rightarrow \gamma\gamma^*$ transition form factor in the space-like region

EPJ C72(2012)1917;arXiv:1202.1171; AIP Conf.Proc.1257(2010)27-36; NPPS219-220(2011)217; arXiv:0905.2017; ...

Search for the U-boson from dark sector

EPJ C71(2011)1680; JHEP 1102(2011)087; arXiv:1103.0799; arXiv:1011.3082; arXiv:1004.0691;...

V_{us}

A luminosity of 5 fb^{-1} was originally proposed for this measurement

KLOE alone, with several precision measurements of kaon decays, lifetimes, and form factors, obtained

- 0.28% fractional error on $f^+(0) \cdot V_{us}$ (w.a.: 0.23%)
- 0.30% fractional error on $\frac{V_{us}}{V_{ud}} \cdot \frac{f_\pi}{f_k}$

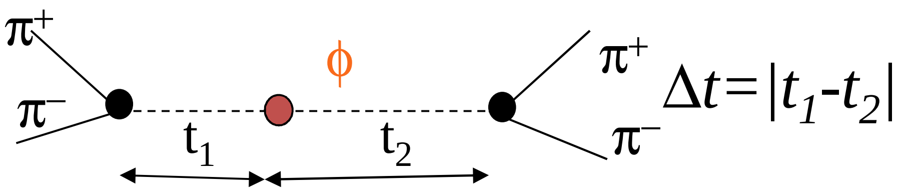
KLOE-2 can improve $f^+(0) \cdot V_{us}$ by a factor of 2

Mode	$\delta f_+(0) V_{us}$ (%): now	BR()	τ	δ	I_{Kl}	$\delta f_+(0) V_{us}$ (%): KLOE-2
$K_L e3$	0.32	0.09	0.13	0.11	0.09	0.21
$K_L \mu 3$	0.42	0.10	0.13	0.11	0.15	0.25
$K_S e3$	0.65	0.30	0.03	0.11	0.09	0.33
$K^\pm e3$	0.60	0.25	0.05	0.25	0.09	0.37
$K^\pm \mu 3$	0.70	0.27	0.05	0.25	0.15	0.40

With $f^+(0)$ at 0.2% level (Lattice-QCD calculations recently improved from 0.8% to 0.4%), the test of lepto-quark universality can be brought from 7 to 3 per mill, dominated by V_{ud} precision.

Neutral kaons interferometry: $\phi \rightarrow K_S K_L \rightarrow \pi^+\pi^-\pi^+\pi^-$

$$|i\rangle = \frac{1}{\sqrt{2}}\left[|K^0\rangle|\bar{K}^0\rangle - |\bar{K}^0\rangle|K^0\rangle\right]$$

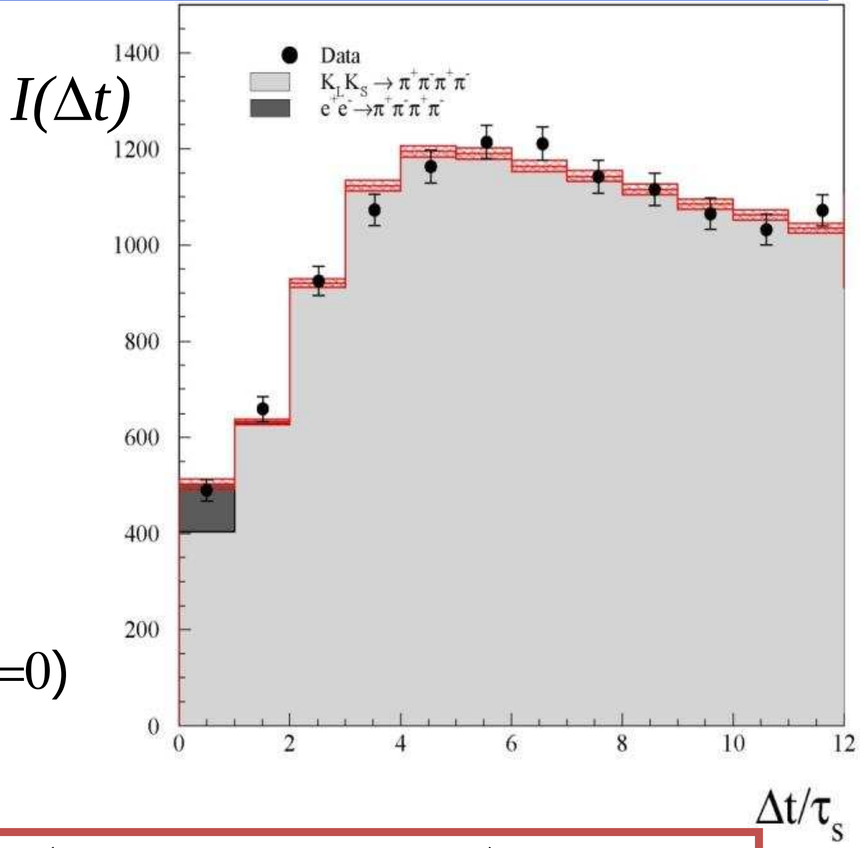


Most precise test of quantum coherence in an entangled system:

$$\zeta_{0\bar{0}} = \left(1.4 \pm 9.5_{STAT} \pm 3.8_{SYST}\right) \times 10^{-7}$$

ζ decoherence parameter (QM predicts ζ=0)

PLB 642(2006) 315 Found.Phys. 40(2010)852



Quantum gravity effects might induce:

1)decoherence and CPT violation → $\gamma = \left(0.7 \pm 1.2_{STAT} \pm 0.3_{SYST}\right) \times 10^{-21}$ GeV

(at most $\gamma = O(m_K^2/M_{Planck}) \sim 2\times10^{-20}$ GeV)

2) decoherence and CPT violation induce modification of the initial correlation of the kaon pair (at most $\omega = O(m_K^2/M_{Planck}/\Delta\Gamma)$ ~1×10^{-3}) →

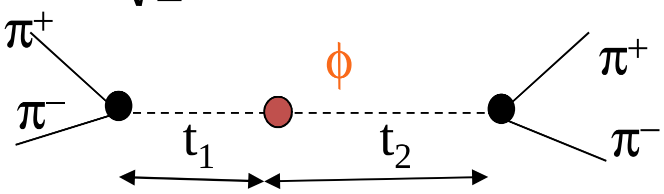
$$|i\rangle \propto \left(K^0\bar{K}^0 - \bar{K}^0 K^0\right) + \omega\left(K^0\bar{K}^0 + \bar{K}^0 K^0\right)$$

$$\Re\omega = \left(-1.6^{+3.0}_{-2.1\,STAT} \pm 0.4_{SYST}\right) \times 10^{-4}$$

$$\Im\omega = \left(-1.7^{+3.3}_{-3.0\,STAT} \pm 1.2_{SYST}\right) \times 10^{-4}$$

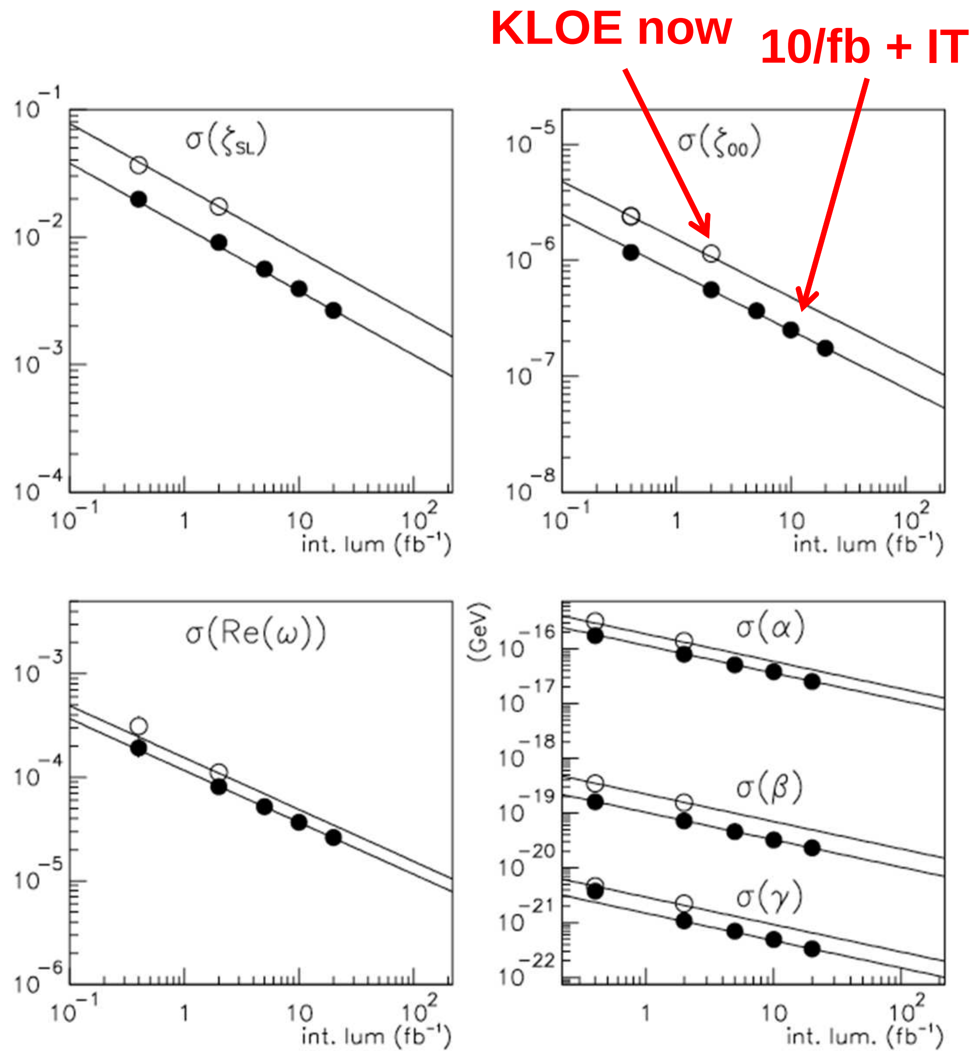
Sensitivity to QM coherence and CPT-invariance

$$|i\rangle = \frac{1}{\sqrt{2}}\left[|K^0\rangle|\overline{K}^0\rangle - |\overline{K}^0\rangle|K^0\rangle\right]$$



$$\Delta t = |t_1 - t_2|$$

The improvement in sensitivity with 5-10 fb^{-1} and the IT with respect to the present measurements is of a factor of ~4, slightly changing for different parameters

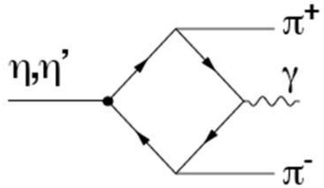


Sensitivity to QM coherence, CPT- and Lorentz-invariance

Param.	Present best published measurement	KLOE-2 (IT) L=5 fb^{-1}	KLOE-2 (IT) L=10 fb^{-1}	KLOE-2 (IT) L=20 fb^{-1}
$\zeta_{0\bar{0}}$	$(0.1 \pm 1.0) \times 10^{-6}$	$\pm 0.26 \times 10^{-6}$	$\pm 0.18 \times 10^{-6}$	$\pm 0.13 \times 10^{-6}$
ζ_{SL}	$(0.3 \pm 1.9) \times 10^{-2}$	$\pm 0.49 \times 10^{-2}$	$\pm 0.35 \times 10^{-2}$	$\pm 0.25 \times 10^{-2}$
α	$(-0.5 \pm 2.8) \times 10^{-17}$ GeV	$\pm 5.0 \times 10^{-17}$ GeV	$\pm 3.5 \times 10^{-17}$ GeV	$\pm 2.5 \times 10^{-17}$ GeV
β	$(2.5 \pm 2.3) \times 10^{-19}$ GeV	$\pm 0.50 \times 10^{-19}$ GeV	$\pm 0.35 \times 10^{-19}$ GeV	$\pm 0.25 \times 10^{-19}$ GeV
γ	$(1.1 \pm 2.5) \times 10^{-21}$ GeV compl. pos. hyp. $(0.7 \pm 1.2) \times 10^{-21}$ GeV	$\pm 0.75 \times 10^{-21}$ GeV compl. pos. hyp. $\pm 0.33 \times 10^{-21}$ GeV	$\pm 0.53 \times 10^{-21}$ GeV compl. pos. hyp. $\pm 0.23 \times 10^{-21}$ GeV	$\pm 0.38 \times 10^{-21}$ GeV compl. pos. hyp. $\pm 0.16 \times 10^{-21}$ GeV
Re(ω)	$(-1.6 \pm 2.6) \times 10^{-4}$	$\pm 0.70 \times 10^{-4}$	$\pm 0.49 \times 10^{-4}$	$\pm 0.35 \times 10^{-4}$
Im(ω)	$(-1.7 \pm 3.4) \times 10^{-4}$	$\pm 0.86 \times 10^{-4}$	$\pm 0.61 \times 10^{-4}$	$\pm 0.43 \times 10^{-4}$
Δa_0	[$(0.4 \pm 1.8) \times 10^{-17}$ GeV]	$\pm 0.52 \times 10^{-17}$ GeV	$\pm 0.36 \times 10^{-17}$ GeV	$\pm 0.26 \times 10^{-17}$ GeV
Δa_Z	[$(2.4 \pm 9.7) \times 10^{-18}$ GeV]	$\pm 2.2 \times 10^{-18}$ GeV	$\pm 1.5 \times 10^{-18}$ GeV	$\pm 1.1 \times 10^{-18}$ GeV
$\Delta a_{X,Y}$	[$\pm 6.0 \times 10^{-18}$ GeV]	$\pm 1.3 \times 10^{-18}$ GeV	$\pm 0.95 \times 10^{-18}$ GeV	$\pm 0.67 \times 10^{-18}$ GeV

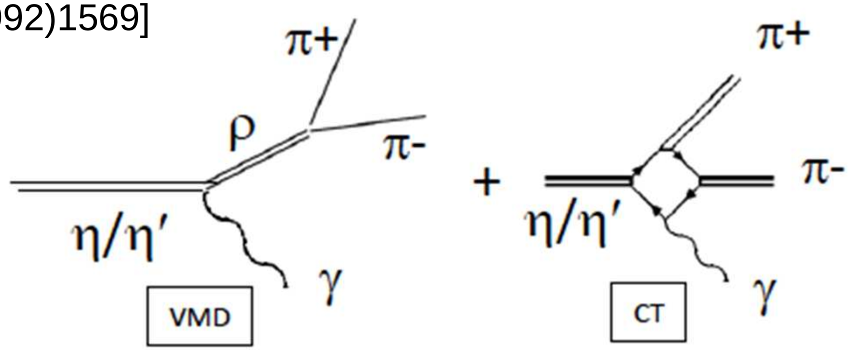
[...] KLOE preliminary

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



- **Study of the box anomaly**: test of ChPT and its 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 $\Gamma(\eta/\eta' \to \pi^+\pi^-\gamma)$ and in $M_{\pi\pi}$ distribution



Decay	PDG 2010	Prediction with Contact Term (HLS)	Prediction without Contact Term
$\eta \to \pi^+\pi^-\gamma$	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

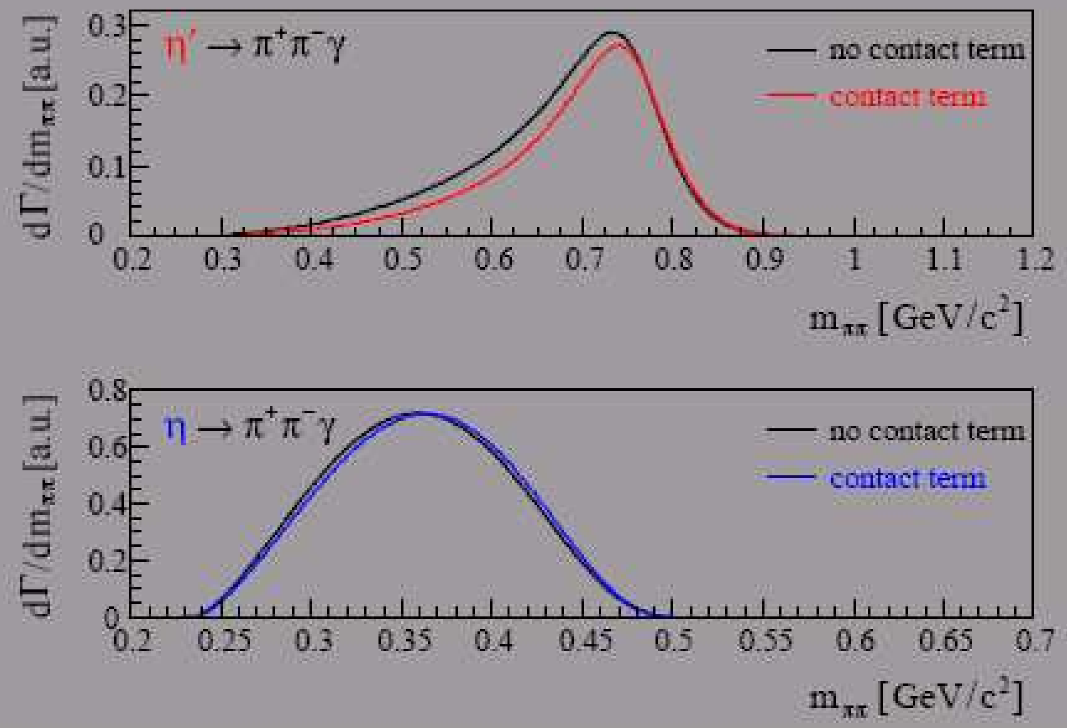
- Most precise BR measurement has ~3% error:
  CLEO 2009 (200 events) : $BR(\eta' \to \pi^+\pi^-\gamma) = 0.287 \pm 0.008$

$\eta' \to \pi^+\pi^-\gamma$: $\pi^+\pi^-$ invariant mass

EChPT, HLS model

M. Benayoun et al., Eur. Phys. J. C31 (2003) 525

$M_{\pi\pi}$ distribution from $\eta' \to \pi^+\pi^-\gamma$ decay is sensitive to the Contact Term



Existing measurements:

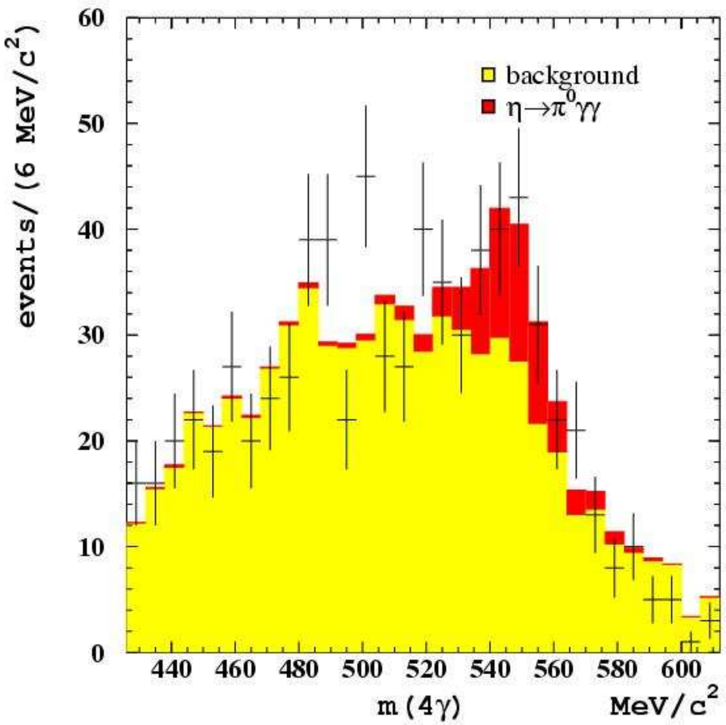
Crystal Ball (1997),	7 kevts	Evidence of CT
L3 (1998)	2 kevts	No evidence of CT

KLOE-2: 60/120 kevts with 5/10 fb^{-1} (efficiency included)

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

ChPT "golden mode": **p^2 null, p^4 suppressed, p^6 dominates**

KLOE Preliminary, 2006: 70 signal events, 3σ signal with 450 pb^{-1}, BR lower than Crystal-Ball:



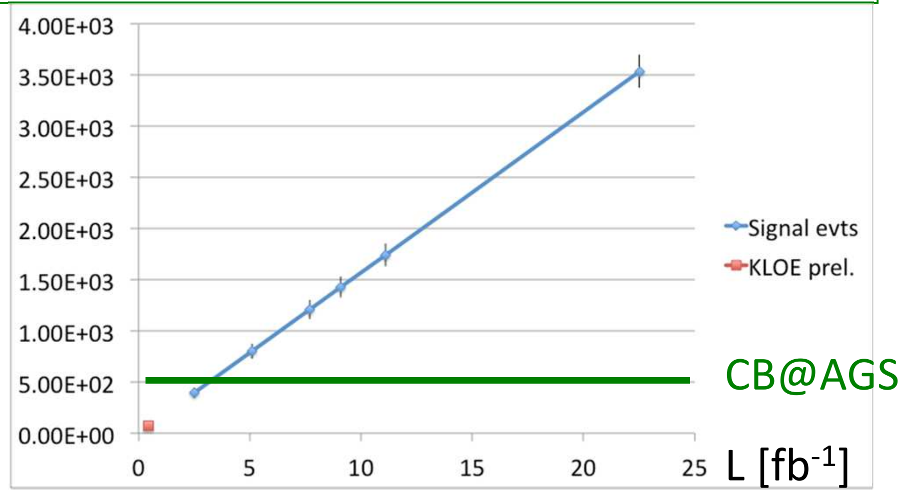
$$BR(\eta\to\pi^0\gamma\gamma) = (8.4 \pm 2.7_{stat} \pm 1.4_{syst}) \times 10^{-5}$$

CB@AGS: **BR = (22.1 ± 2.4 ± 4.7) × 10^{-5}**
PRC 78 (2008) 015206 ~ 500 signal events

CB@MAMI-B: BR = (22.5 ± 4.6 ± 1.7) × 10^{-5}
Preliminary, arXiv:0910.1331 ~ 150 signal events

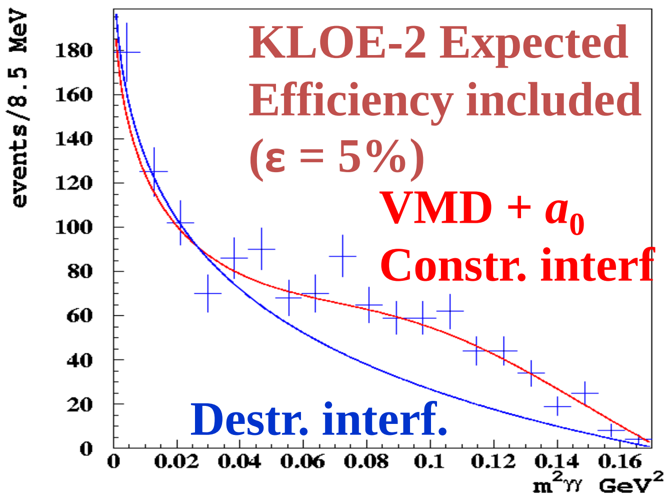
The background evaluation, from $\eta\to\pi^0\pi^0\pi^0$, is an issue: at KLOE, S/(S+B) ~ 0.13
at CB @ AGS, S/(S+B) ~ 0.17

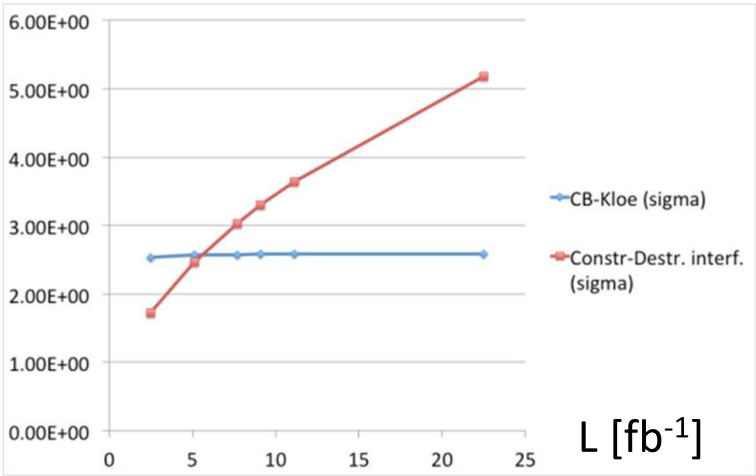
CCALT, the KLOE-2 calorimeter at low polar angle, substantially improves background suppression: **58% of the selected events with 5 photons in the central calorimeter has 1-2 photons within the CCALT acceptance, i.e. polar angle of 10° -21°**



The $\eta \to \pi^0 \gamma\gamma$ decay: $\gamma\gamma$ invariant mass

- γγ invariant mass distribution to distinguish among different models

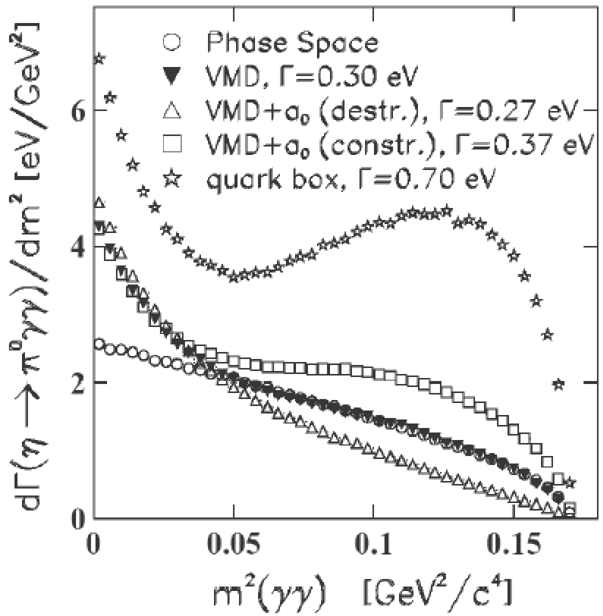




- Difference in number of σ between the two models, by assuming a bckg fraction of 87% as in the KLOE preliminary analysis

- For a 3 σ separation 7 – 8 fb^{-1} are needed

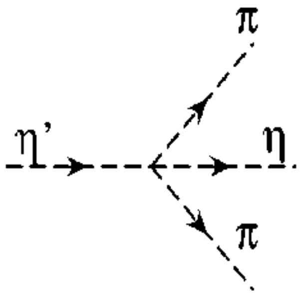
- There are also more exotic models such as the quark-box model, PR C78(2008)015206, easier to separate

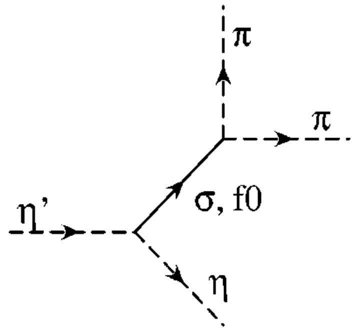


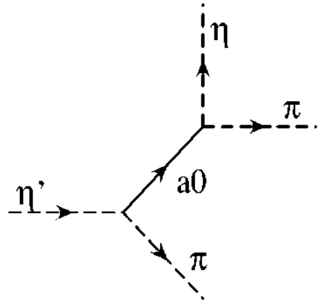
Low-mass scalar contributions to $\eta'\to\pi^+\pi^-\eta$

Sensitive to the intermediate low-mass scalars: f_0, a_0, σ

[Faribortz-Schechter,PRD60(1999)034002]



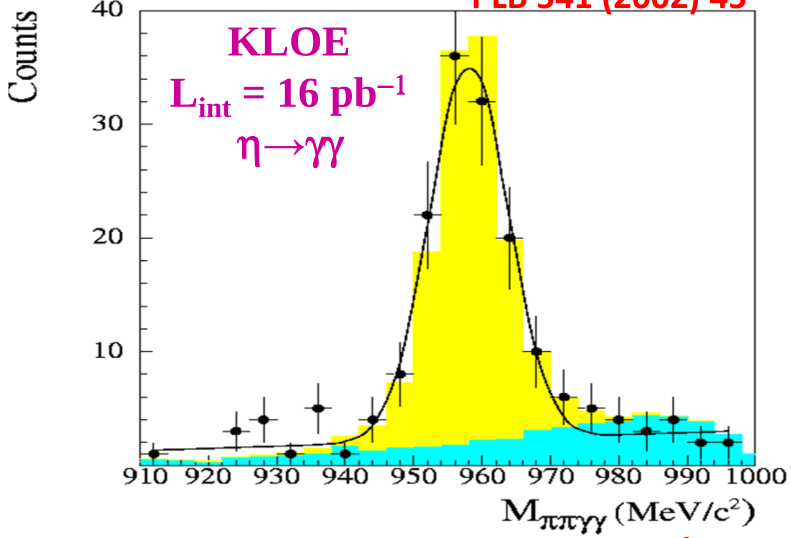


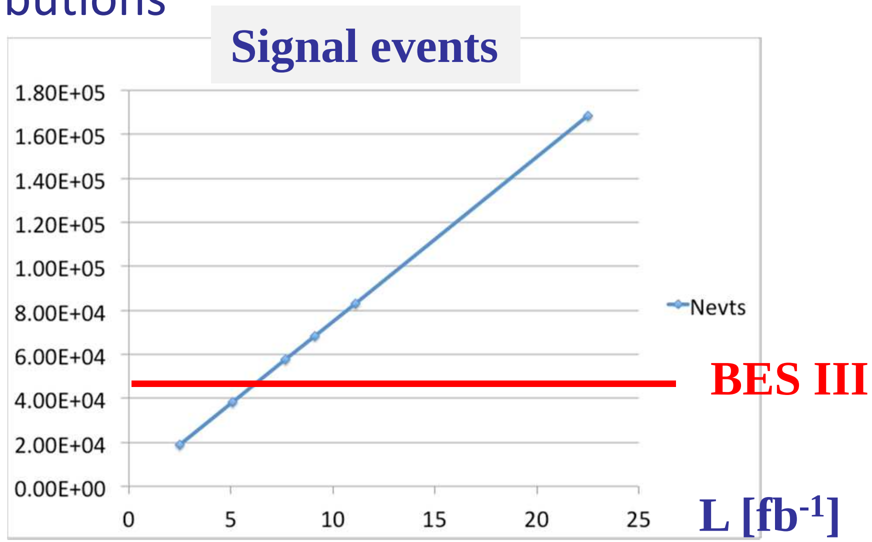


Dalitz plot (not the BR) measured by BESIII with 44000 events [PRD83(2011) 012033]

Dalitz plot fit ⇒ no evidence of scalar contributions

PLB 541 (2002) 45



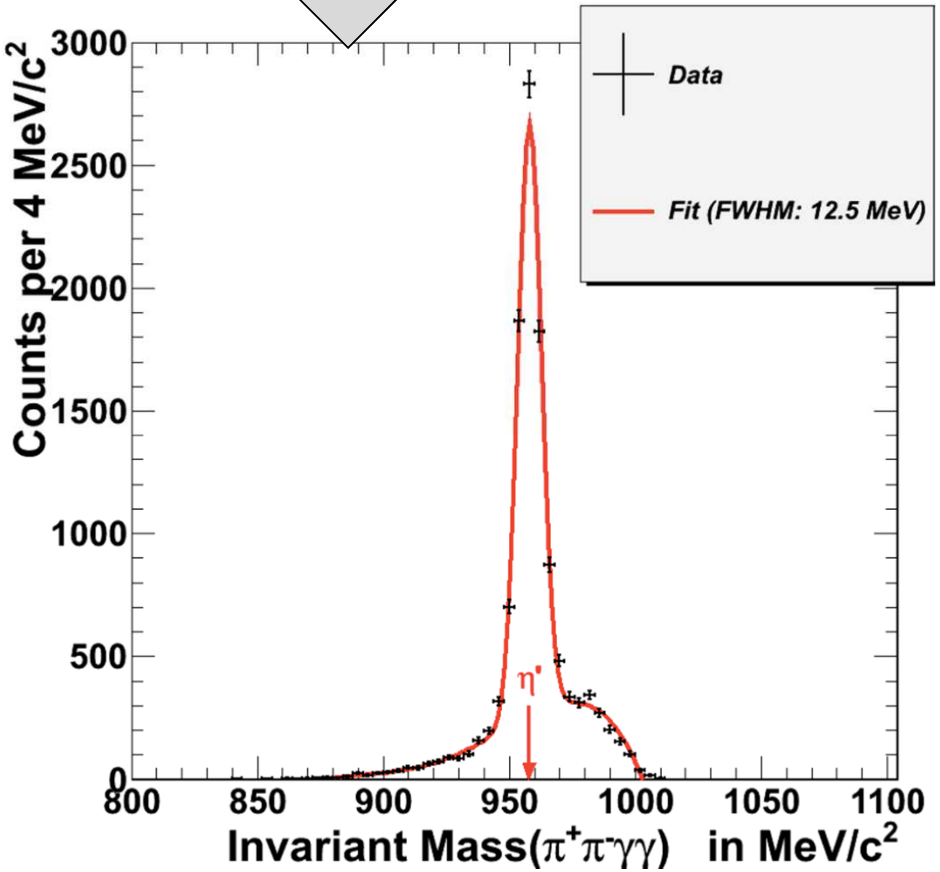


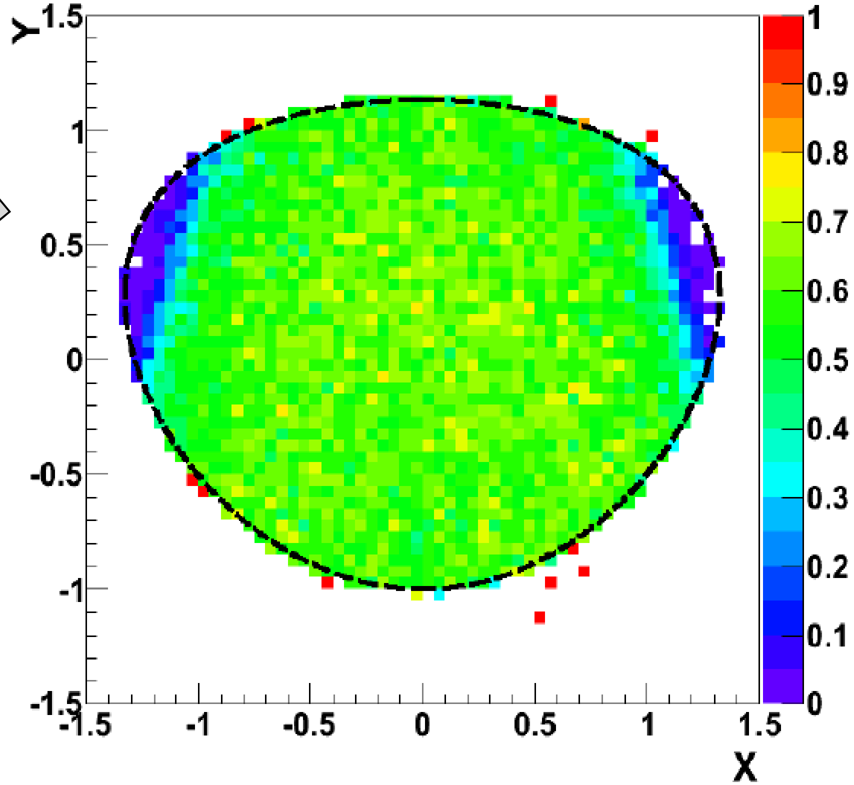
KLOE-2: 60 kevts with ~8 fb^{-1} (conservative estimate including efficiency and background subtraction), using $\eta'\to\pi^+\pi^-\eta$, $\eta\to\gamma\gamma$ decay chain

$\eta' \to \pi^+\pi^-\eta$ @ KLOE-2

Ongoing analysis on 2004/2005 data

Feasibility study of the measurement of the Dalitz-plot distribution





Drop of efficiency in the Dalitz plot corners, due to low momentum tracks (~50 MeV). Inner Tracker will increase p_T acceptance from 23 to 16 MeV

Scalar coupling to KK: $\phi \to K_S K_S \gamma$

Low-mass scalar production @ 1.02 GeV: $\phi \to (a_0/f_0)\gamma \to KK\gamma$

Never observed before

KLOE U.L. : 1.9 × 10^{-8} @ 90% C.L.

[PLB 679 (2009) 10]

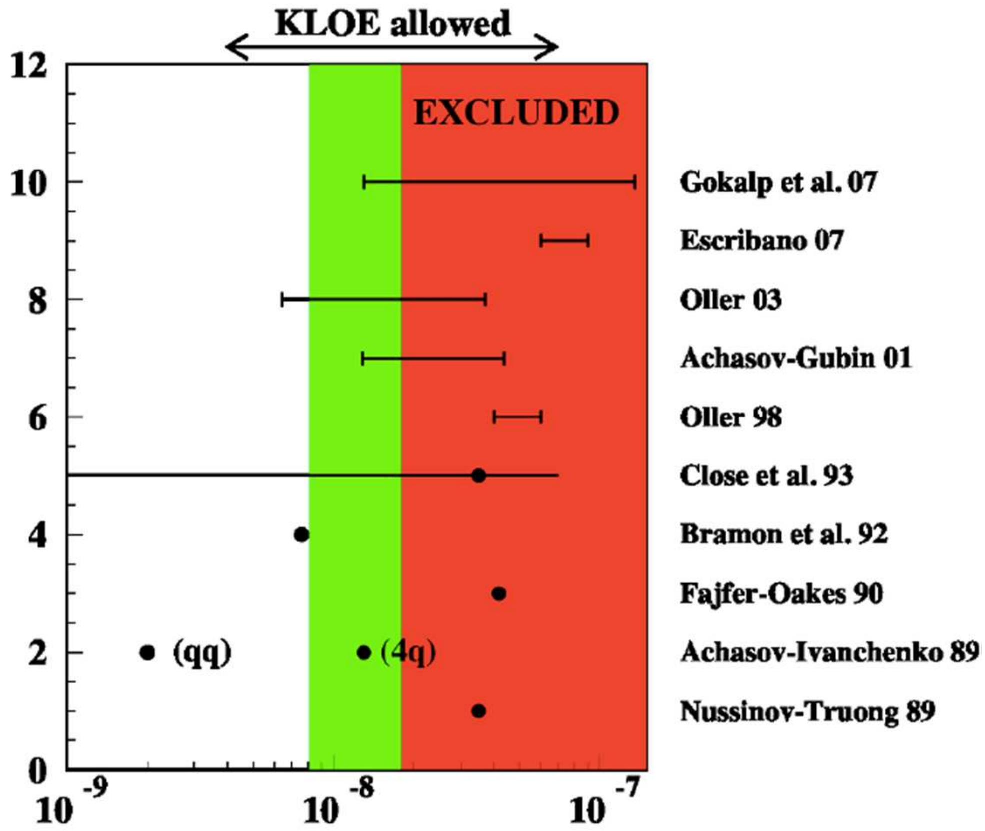
4q structure of $a_0/f_0(980)$ is the "favourite" option from our own measurement of

$$\phi \to (a_0/f_0)\gamma \to (\eta\pi/\pi\pi)\,\gamma$$

(neutral/charged pions analyzed)

A factor of ~2 improvement in the background rejection is expected from IT installation

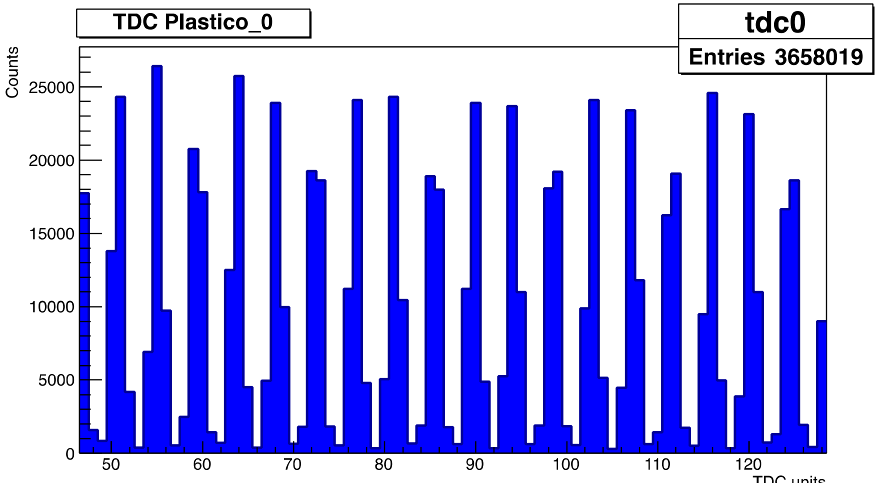
With 5 – 10 fb^{-1} we can improve the U.L. by a factor of 2 excluding other models for the scalars, including the KLOE favourite **4q** model

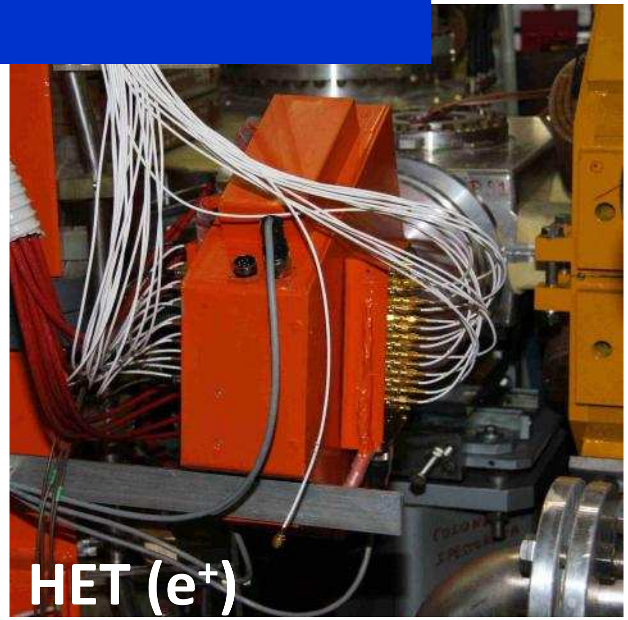


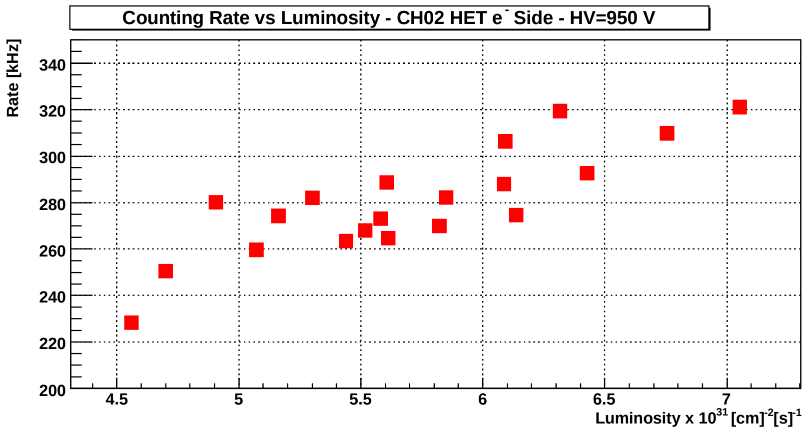
In alternative, if the KLOE results are confirmed, KLOE-2 can obtain the first evidence of the decay at ~3 σ level

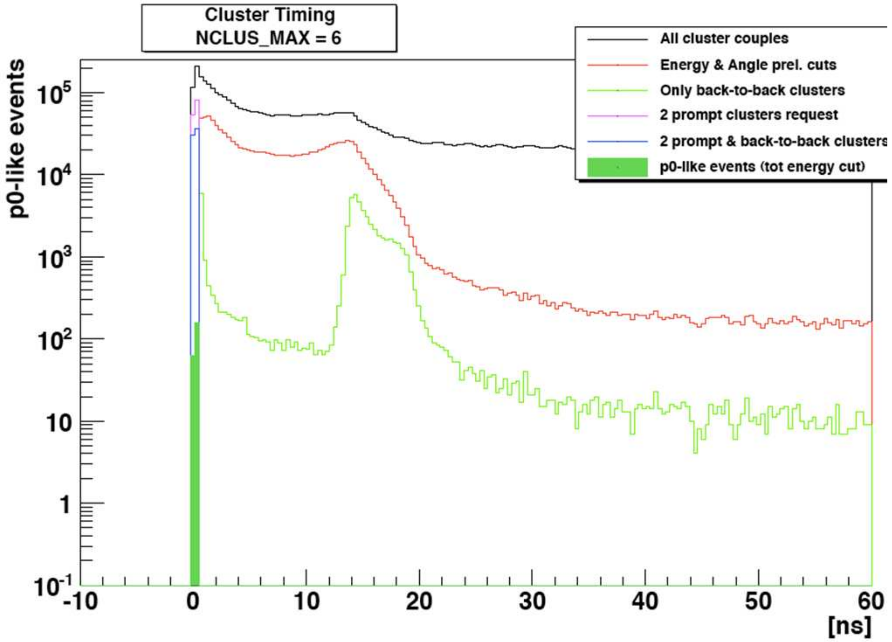
γγ physics: HET taggers

Test on DAΦNE confirms the feasibility of the measurements in coincidence with KLOE and the LET stations: bunch structure clearly visible (2.7 ns), low background levels per bunch (3-4 10^5 Hz), high rejection levels on the KLOE triggers (>10^3)





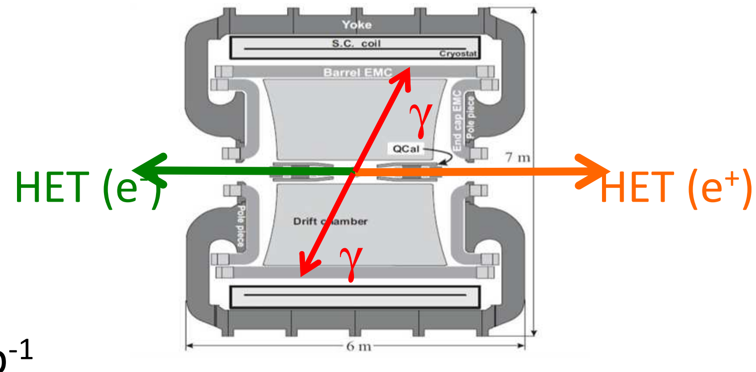




$\gamma\gamma$ physics: $e^+e^-\rightarrow e^+e^-\pi^0$

$\Gamma(\pi^0 \rightarrow \gamma\gamma)$ width

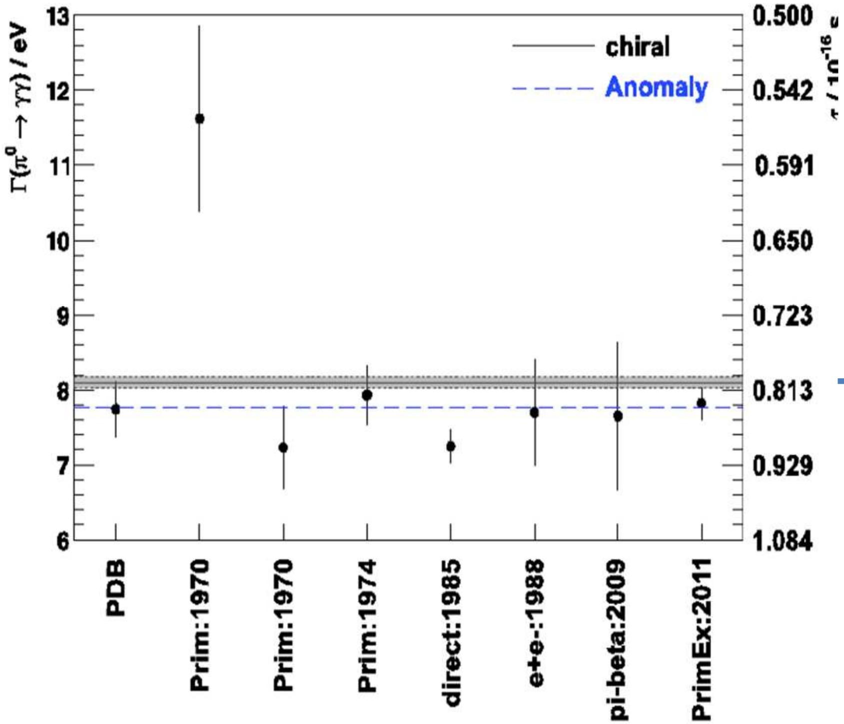
$\Gamma(\pi^0 \rightarrow \gamma\gamma)$: best measurement from Primakoff-process, PrimEX @ Jlab, at 2.8%: PRL **106**(2011)162303

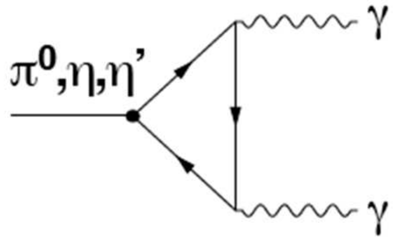


$\Gamma(\pi^0 \rightarrow \gamma\gamma)$ **at 1%** feasible at KLOE-2 with 5-6 fb^{-1}

The coincidences between KLOE central detector and HET taggers SELECT a very clean sample of ~ 1900 events per fb^{-1} (σ_{eff} = 3.4 pb)

The radiative Bhabha-scattering events fully cut out by KLOE-HET coincidence





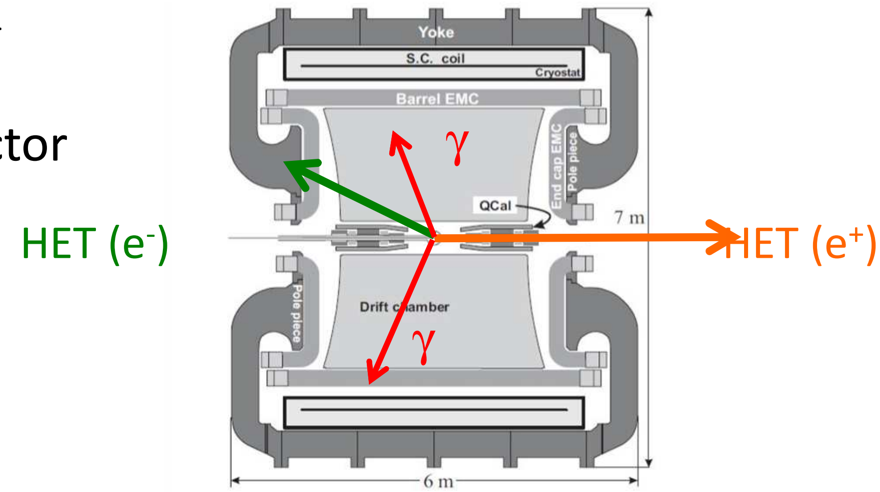
Theory and KLOE-2 precision

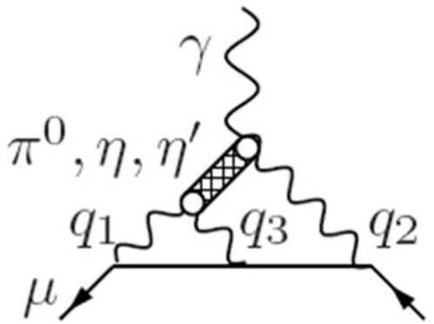
$\gamma\gamma$ physics: $e^+e^- \rightarrow e^+e^-\pi^0$

$\pi^0 \rightarrow \gamma\gamma^*$ transition form factor in the space-like region at low Q^2

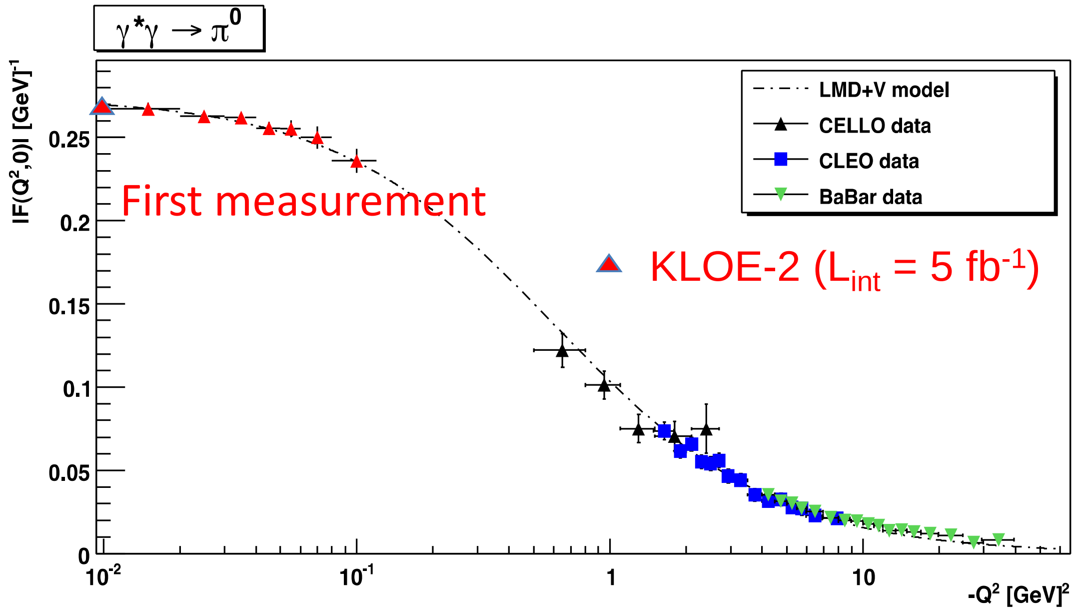
$F_{\pi^0\,\gamma\gamma^*}$ at 5-6% feasible at KLOE-2 with 5 fb^{-1}

The coincidences between KLOE central detector and one of the HET stations are used



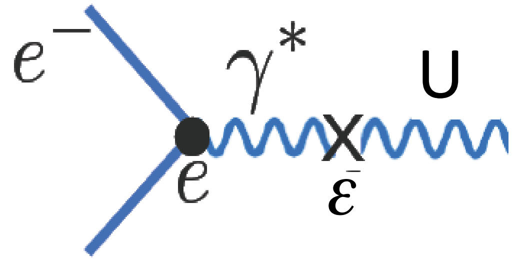


Light-by-light term to muon anomaly : both measurements, width and **$F_{\pi^0\,\gamma\gamma^*}$** contribute to a factor of ~2 reduction in the theoretical error, dominated by pseudoscalar (π^0) contribution

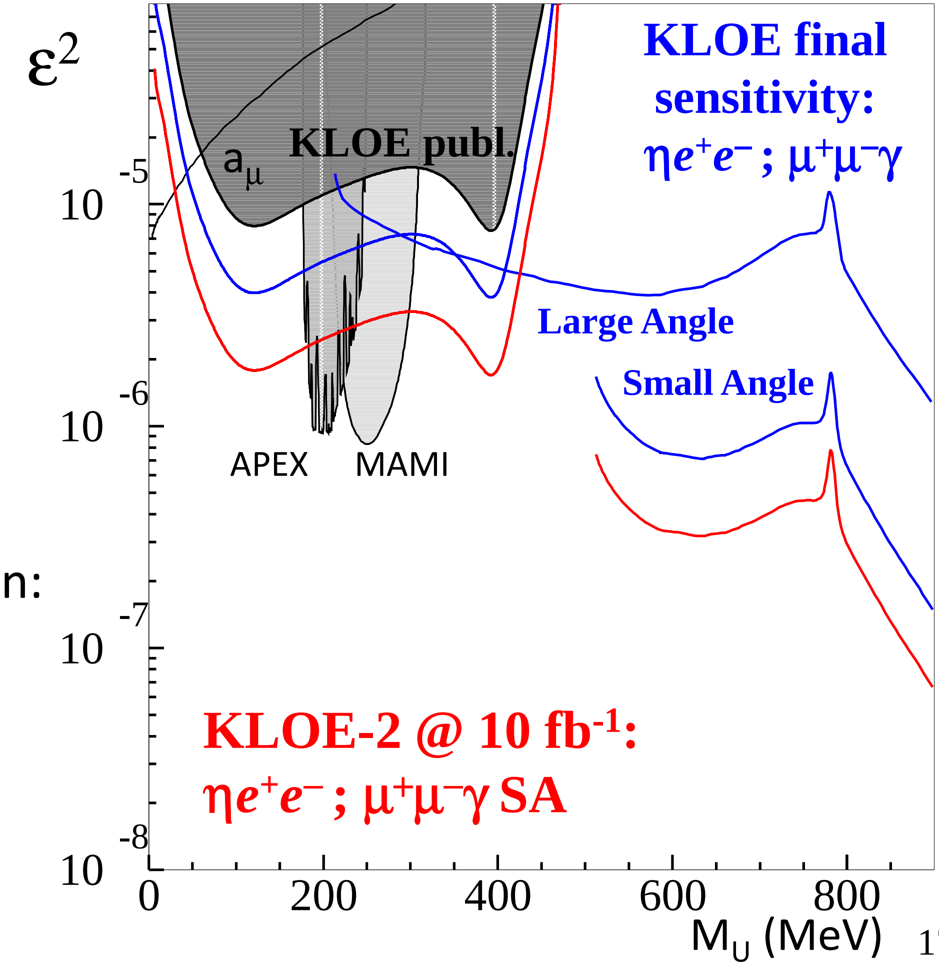


Search for dark forces

Hypothesis: existence of a hidden gauge sector, able to explain several unexpected astrophysical observations, weakly coupled with SM through a mixing mechanism of a new gauge boson, U, with the photon



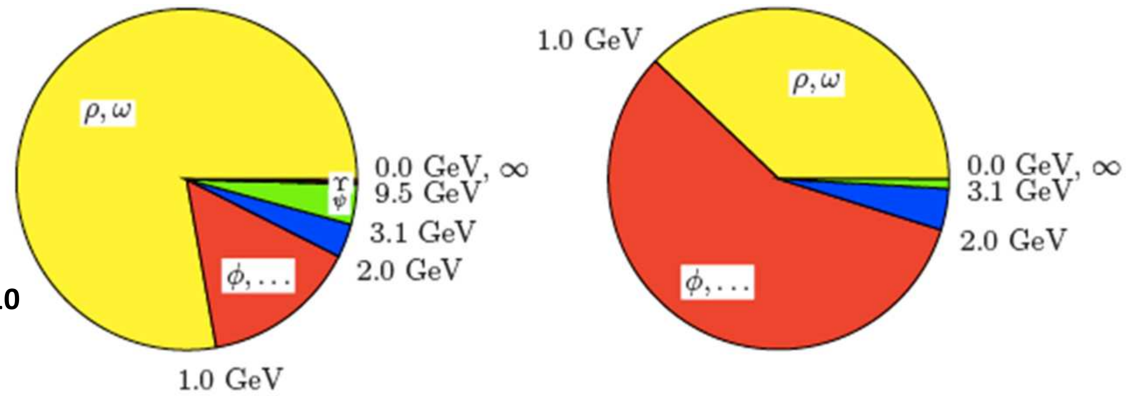
- KLOE published U.L. @ 90% C.L. on $\phi\to\eta U$, using $\eta\to\pi^+\pi^-\pi^0$, $U\to e^+e^-$
  PLB 706 (2012)
- Analysis of the $\eta\to\pi^0\pi^0\pi^0$ and $\eta\to\gamma\gamma$ channels in progess to cover 95% of the η decay channels: factor ~ 2 improvement expected
- Analysis of $e^+e^-\to U\gamma\to\mu^+\mu^-\gamma$ started on:
  i) 2 fb^{-1} sample with small-angle (undetected) photon
  ii) 200 pb^{-1} @ 1 GeV sample with large-angle (detected) ISR photons



Hadronic cross section

Dipion threshold [$2m_\pi$-0.5 GeV] contributes by a 13% fraction to a_μ^{HLO}

$a_\mu^{HLO}[2m_\pi\text{-}0.5\text{ GeV}] = (58.0 \pm 2.1)\ 10^{-10}$



KLOE measurements, using ISR method:

- 240 pb^{-1} on-peak, undetected photon @ small angle, absolute normalization:

  [PLB 670 (2009) 285]

  $a_\mu^{had,\pi\pi}[0.35<s'<0.95\text{ GeV}^2] = (387.2 \pm 0.5_{stat} \pm 2.4_{syst} \pm 2.3_{th})\ 10^{-10}$

  Detailed study of efficiencies from data (syst) — **Radiator function** (th)

- 233 pb^{-1} off-peak , detected photon @ large angle, absolute normalization:

  [PLB 700 (2011) 102]

  $a_\mu^{had,\pi\pi}[0.10<s'<0.85\text{ GeV}^2] = (478.5 \pm 2.0_{stat} \pm 5.0_{syst} \pm 4.5_{th})\ 10^{-10}$

  Needs off-peak data — **FSR modeling Radiator function** (th)

- 240 pb^{-1} on-peak , undetected photon @ small angle, $\sigma(\pi^+\pi^-\gamma)/\sigma(\mu^+\mu^-\gamma)$:

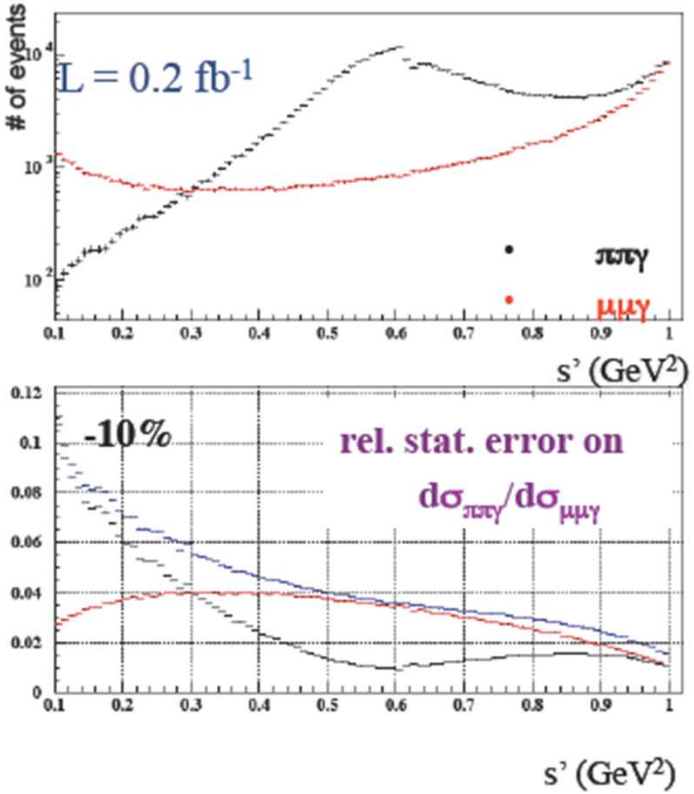
  [PRELIMINARY]

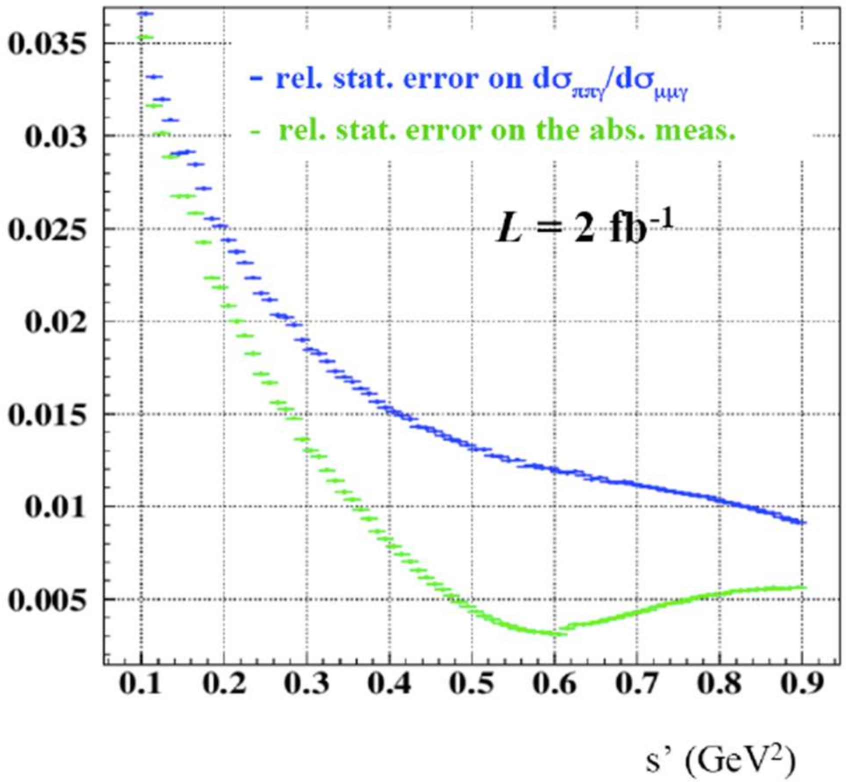
  $a_\mu^{had,\pi\pi}[0.35<s'<0.95\text{ GeV}^2] = (384.1 \pm 1.2_{stat} \pm 4.0_{syst} \pm 1.2_{th})\ 10^{-10}$

  FSR (th)

Prospects for $a_\mu^{had,\pi\pi}$

- The analysis of $\sigma(\pi^+\pi^-\gamma)/\sigma(\mu^+\mu^-\gamma)$ reduces (from 0.6 to 0.2-0.3%) the theoretical uncertainties from radiator function and vacuum polarization
- FSR corrections for LA events can be improved studying of the F-B asymmetry

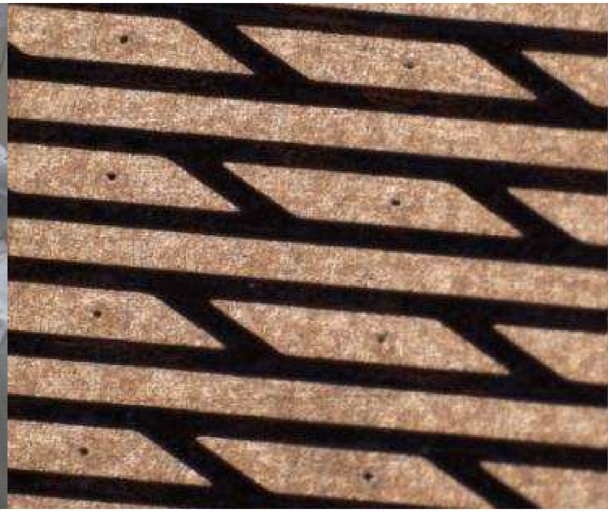




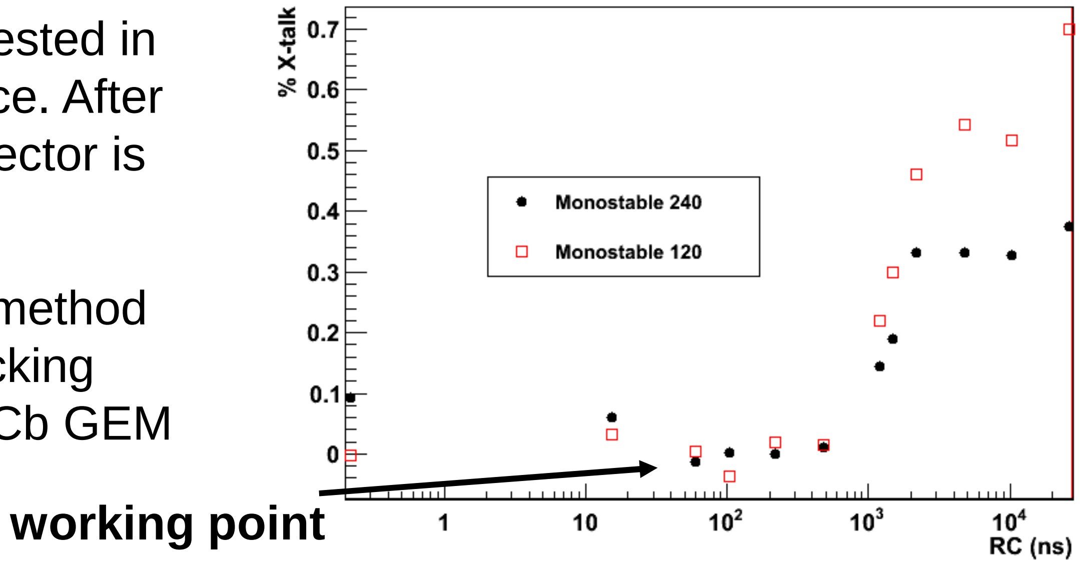
- **KLOE-2 with 1-2 fb^{-1} of off-peak data and the analysis of $\sigma(\pi^+\pi^-\gamma)/\sigma(\mu^+\mu^-\gamma)$ at large angle, can obtain 0.5% fractional precision on $a_\mu^{had,\pi\pi}$ from 1 GeV down to the 2π threshold (KLOE LA+SA: 1.2%)**

IT: tests on Layer 2

The detector is formed by 4 layers of **cylindrical triple-GEM**, with a two-dimensional readout (**X-V**) equipped with a dedicated ASIC (**GASTONE**)


- **Layer 2** built and extensively tested in temperature and with a β source. After facing many problems, the detector is now working properly.
- We implemented a very good method for the X-talk cancellation (blocking capacitor), already used in LHCb GEM detectors.



IT: construction schedule

Layer 1:

- Construction completed
- Gas tightness **> 99%**
- Construction uniformity tested with β source
- Next: cosmic rays run with L1&L2

Layer 3:

- Cathode built
- 2 CGEM electrodes are ready
- Anode just shipped
- One GEM electrode still missing
- Expected to be completed by end of July

Layer 4:

- Moulds delivered
- Construction will begin in September

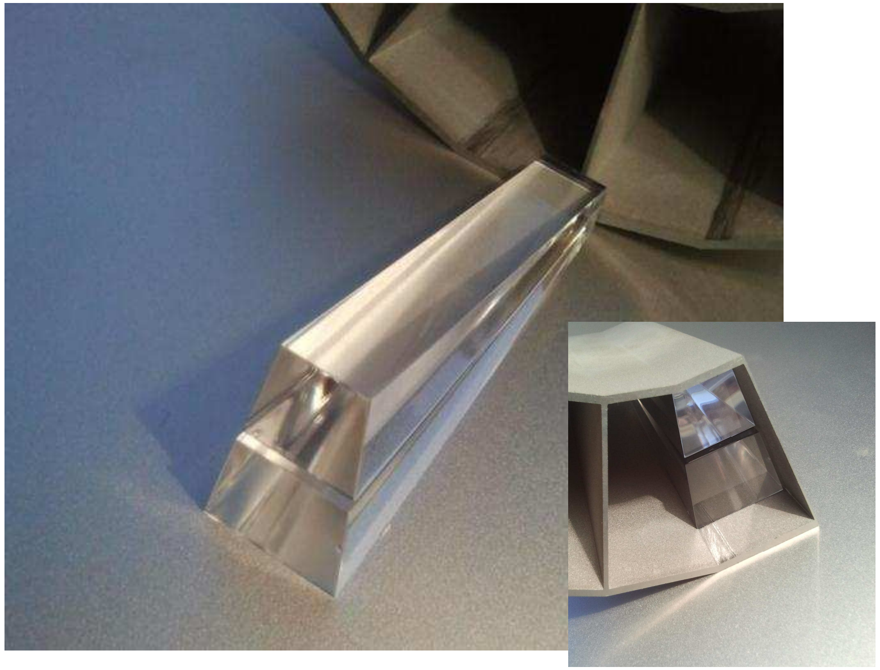
Electronics and services:

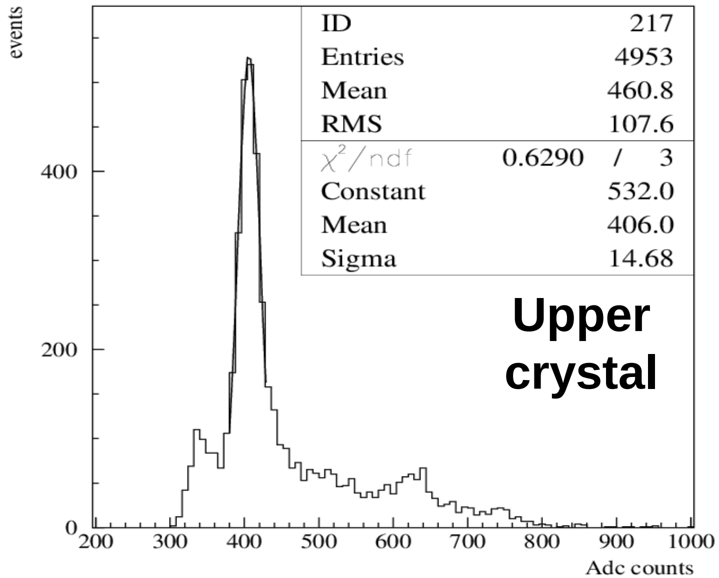
- GASTONE chip mounted and tested on L1/L2
- GIB ready and tested
- Final HV system used in CR/source tests

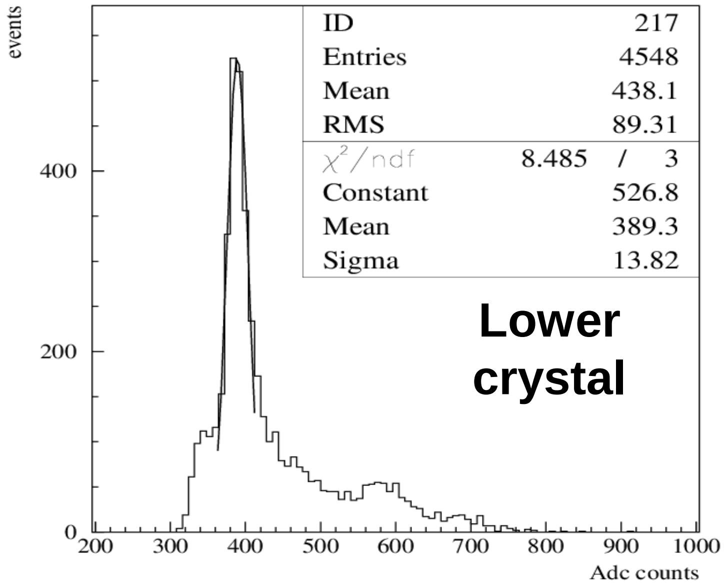
CCALT: test of delivered crystals

First two crystals delivered and under test using ^{22}Na source and PM readout:

- Pedestal = 253 ADC counts
- 10% energy resolution @ 511 keV

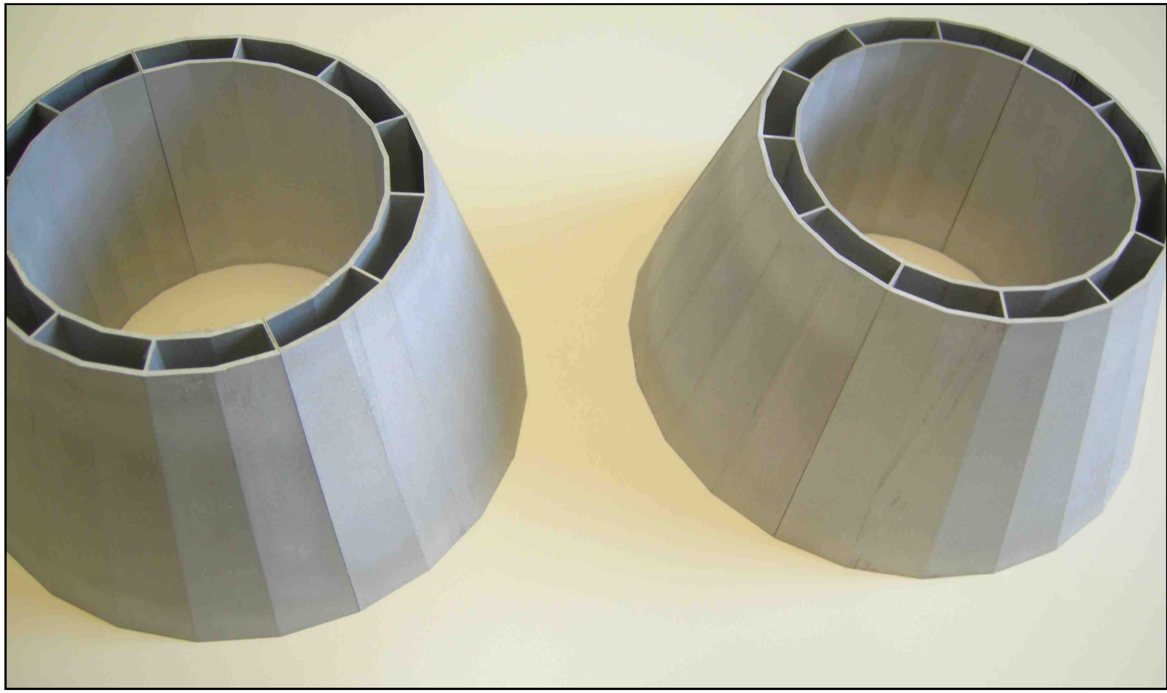






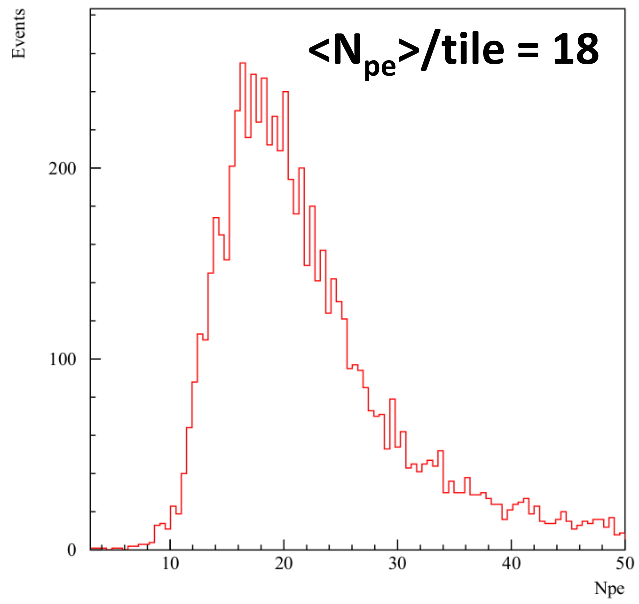
CCALT: construction schedule

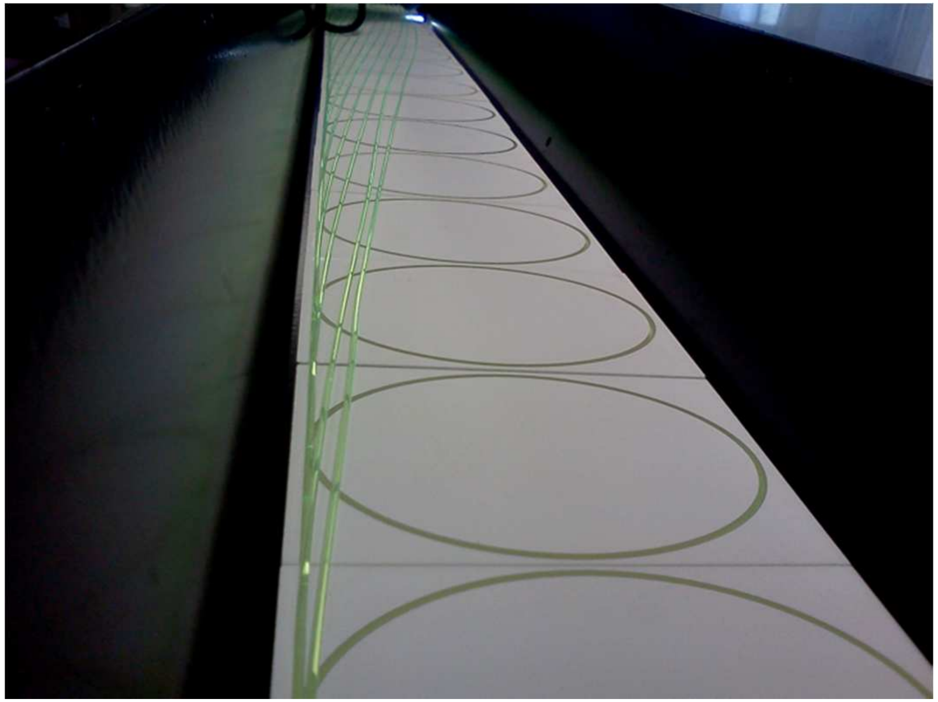
- Aluminum support shells already produced (INFN Naples)
- Final crystals under production from SICCAS. Delivery expected mid of June
- (4×4) mm^2 SiPMs from ADVANSID already produced. Expected by June
- PCB for mounting SiPM designed @ LNF. Delivery expected end of June
- Preamplifier and LED calibration driver under construction
- Standard read out with ADC and TDC boards from KLOE detectors

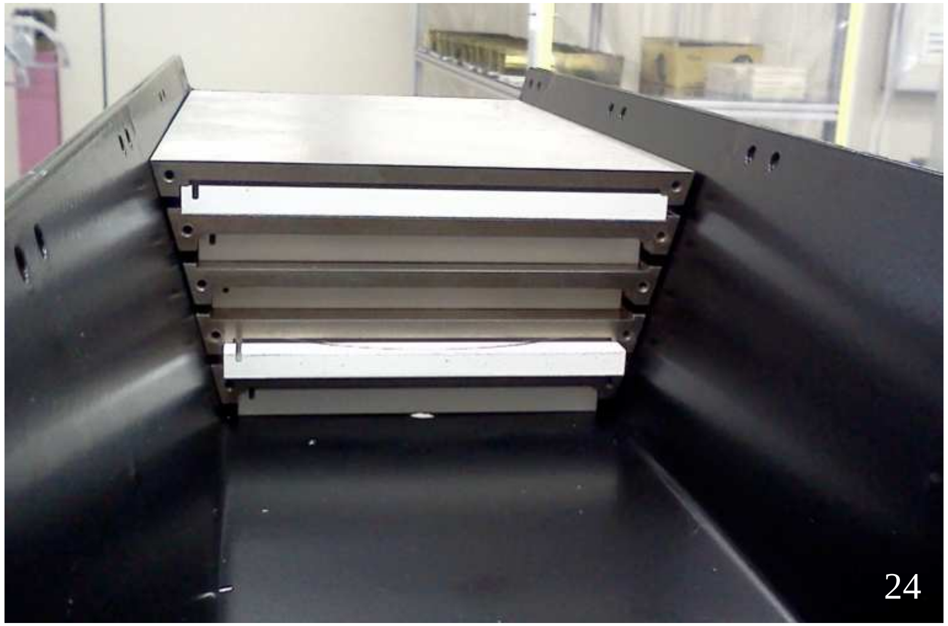


QCALT: construction status

- Two calorimeters of 12 modules (one modified to insert LET), each one divided into 2 halves
- First 6 modules completed
  - Each tile tested using Sr source to check the fiber-tile coupling
  - Cosmic ray run to check towers
  - Test beam @ BTF planned in June

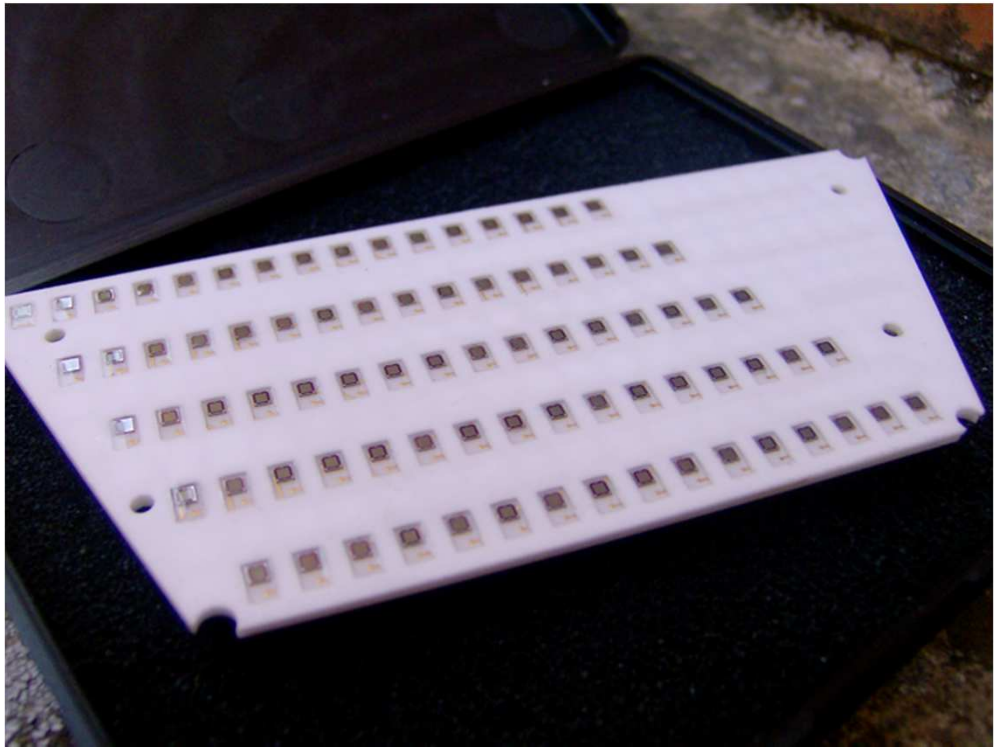






QCALT: construction status

- All the material (tiles, fibers, tungsten) needed to complete QCALT already @ LNF
- Construction of second half started: 2 weeks needed to complete the assembling
- Construction of second calorimeter will start in July (~1 month of work)
  - Mechanical structure ready
  - Tiles: first milling in progress at external company, groove milling @ LNF
- PCBs: next week @ LNF
- FEE @ LNF: final tests in progress



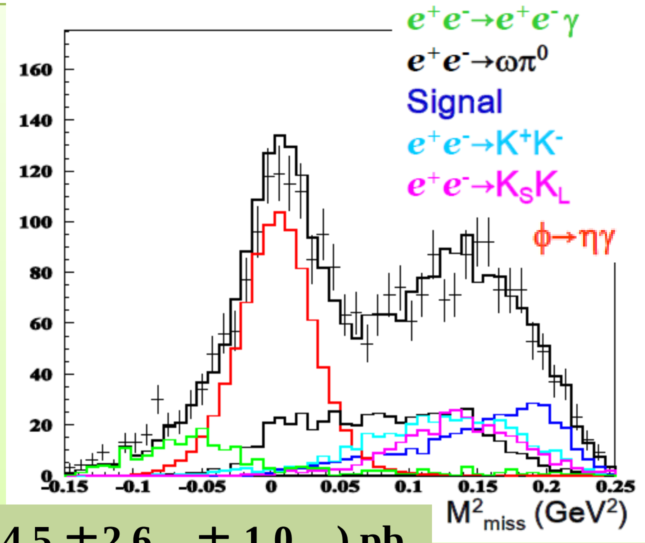
Updates on analysis

PRELIMINARY

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

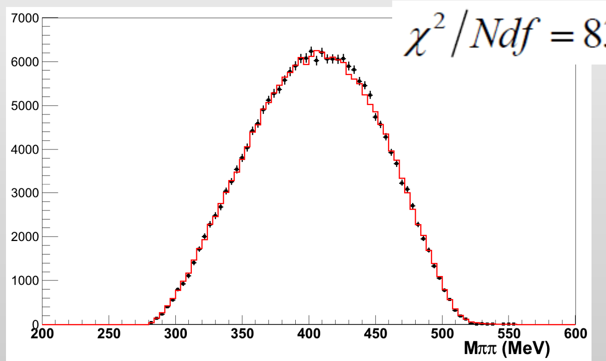
240 pb^{-1} @ $\sqrt{s}$ = 1 GeV
(to reduce bckg from ϕ)

2720 events
Signal fraction 14%



$\sigma(e^+e^- \to e^+e^-\eta)_{+-0} = (34.5 \pm 2.6_{stat} \pm 1.0_{syst})$ pb
$\sigma(e^+e^- \to e^+e^-\eta)_{000} = (32.0 \pm 1.5_{stat} \pm 0.8_{syst})$ pb

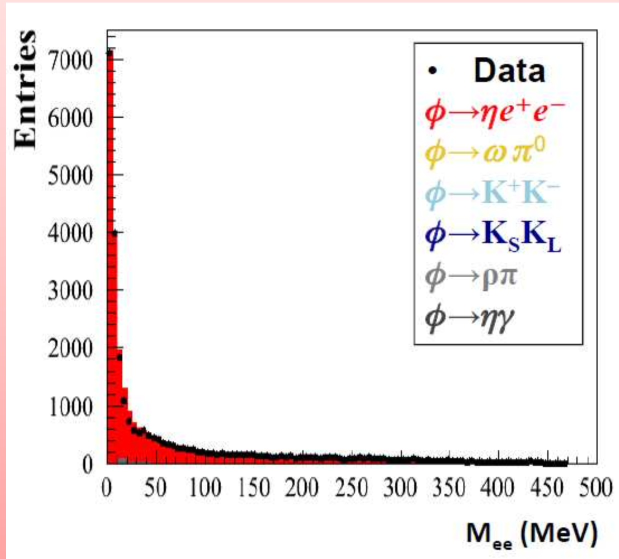
$\eta \to \pi^+\pi^-\gamma$: fit to the $M_{\pi\pi}$ spectrum



$$\frac{d\Gamma(\eta \to \pi^+\pi^-\gamma)}{d\sqrt{s_{\pi\pi}}} = \frac{1}{2\sqrt{s_{\pi\pi}}} \left| AP(s_{\pi\pi}) F_V(s_{\pi\pi}) \right|^2 \Gamma_0(s_{\pi\pi})$$

$$\alpha_{KLOE} = (1.31 \pm 0.08 \pm 0.40 \pm 0.02)\, GeV^{-2}$$

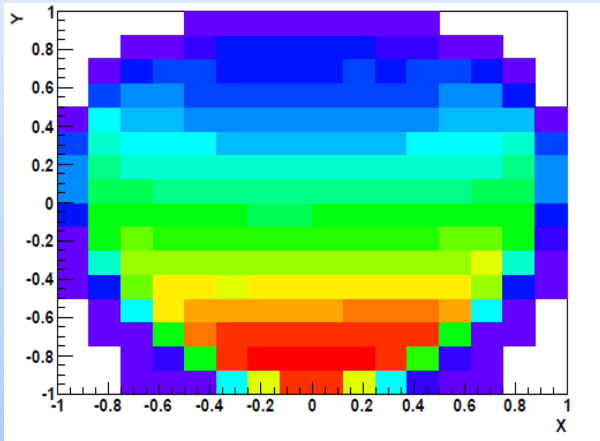
New final state for $\phi \to \eta e^+e^-$: $\eta \to \pi^0\pi^0\pi^0$



~ 26,000 evts with 1.7 fb^{-1}

Possibility to combine results with $\eta \to \pi^+\pi^-\pi^0$ to improve U boson search and extract $\phi\eta\gamma^*$ FF

New Dalitz Plot analysis of $\eta \to \pi^+\pi^-\pi^0$



~ 2×10^6 evts with 560 pb^{-1}

- ~1% residual background contamination
- Fit procedure under test with MC events

Conclusions

- Construction of upgrades and KLOE data analyses are progressing (Physics Workshop scheduled for 25-26 June, Workshop on Dark Forces at Accelerators @ LNF, 16-19 October 2012)
- Physics goals achievable with 5-10 fb^{-1} of integrated luminosity in a 2-3 years running period at DAΦNE motivate the efforts of the Collaboration to provide the accelerator experts with all the support and feedbacks needed for the machine commissioning
- They also motivate the efforts for the completion of the detector upgrades
- A machine delivering 12 pb^{-1} per day with stable operation and controlled background levels in the hot region of the endcaps, is needed for the data taking
- The feasibility of such kind of operation must be proved soon
- For this, it is mandatory to fix machine hardware criticality that have affected the operation since the beginning

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

Fit with Simple parametrization

"Model–independent approach to $\eta / \eta' \to \pi^+\pi^-\gamma$
(Stollenwerk, Hanhart, Kupsc, Meiβner and Wirzba PLB707 (2012) 184-190)

$$\frac{d\Gamma(\eta \to \pi^+\pi^-\gamma)}{ds_{\pi\pi}} = \left| A P(s_{\pi\pi}) F_V(s_{\pi\pi}) \right|^2 \Gamma_0(s_{\pi\pi})$$

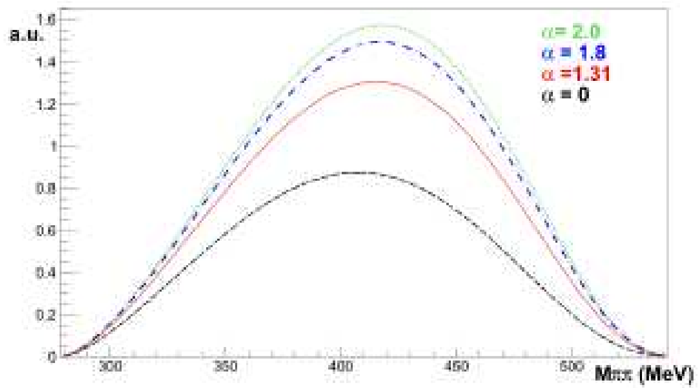
$$F_V(s_{\pi\pi}) = 1 + (2.12 \pm 0.01)s_{\pi\pi} + (2.13 \pm 0.01)s_{\pi\pi}^2 + (13.80 \pm 0.14)s_{\pi\pi}^3$$

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

$$\Gamma_0(s_{\pi\pi}) = \frac{1}{3 \cdot 2^{11} \cdot \pi^3 m_\eta^3} \left(m_\eta^2 - s_{\pi\pi}\right)^3 s_{\pi\pi} \sigma(s_{\pi\pi})^3$$

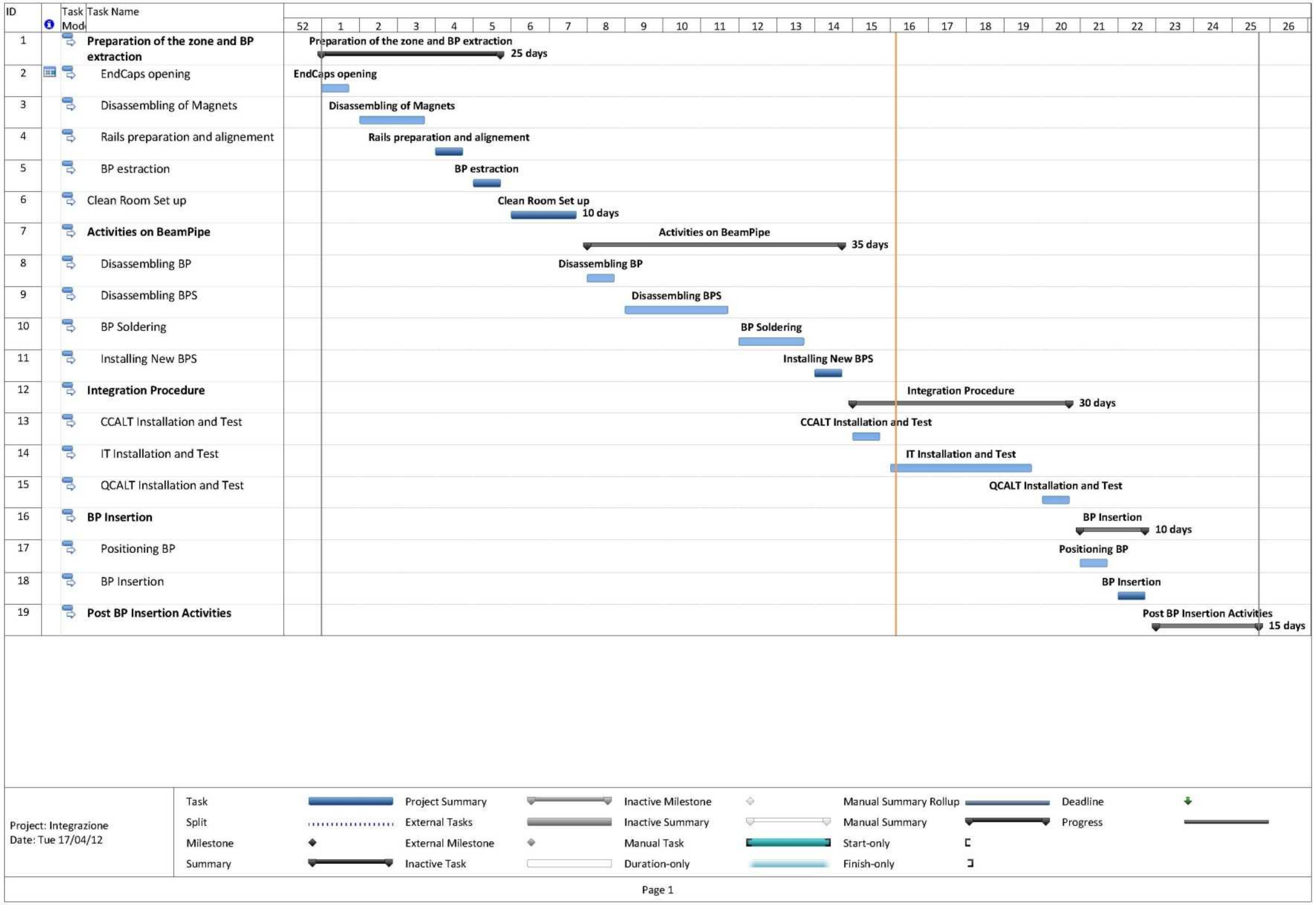
$$\sigma(s_{\pi\pi}) = \sqrt{1 - 4m_\pi^2 / s_{\pi\pi}}$$

Free parameters: $\begin{cases} A \\ \alpha \end{cases}$



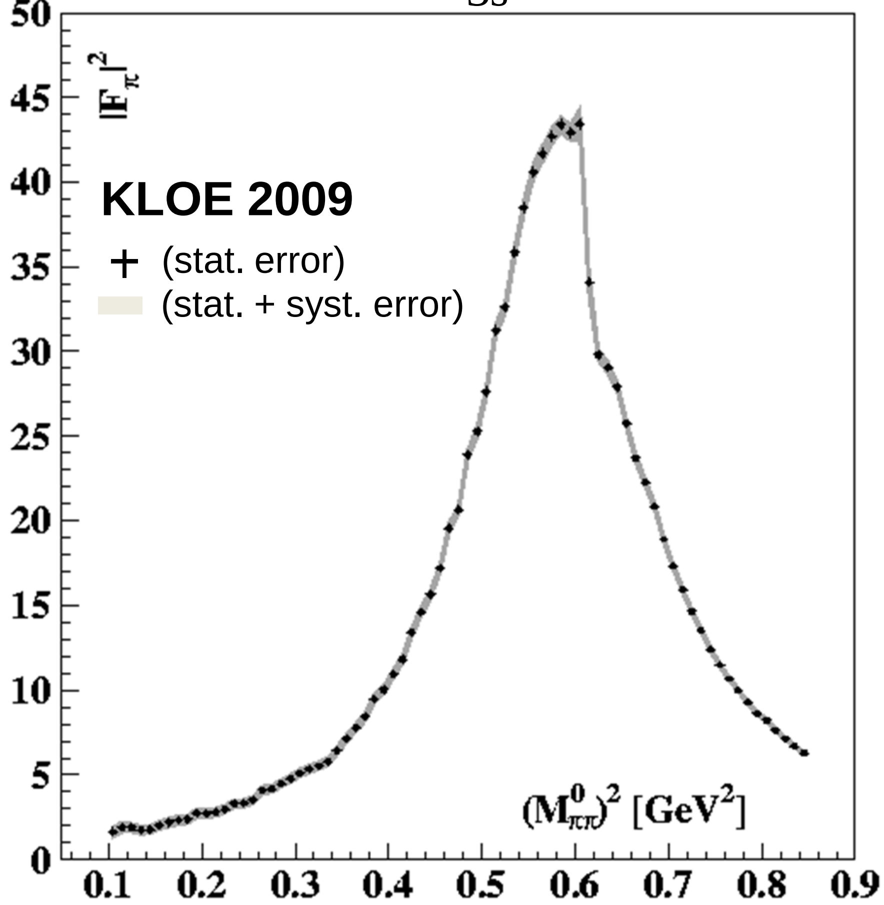
Time schedule for detector installation

A detailed plan for the installation of new detectors has been prepared, consisting of about six months of operations



KLOE results on Large Angle analysis

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



Disp. Integral:

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

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

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	0.7%
Radiator H	0.5%
Vacuum polarization	< 0.1%

Theoretical fractional error on a_μ = 0.9 %

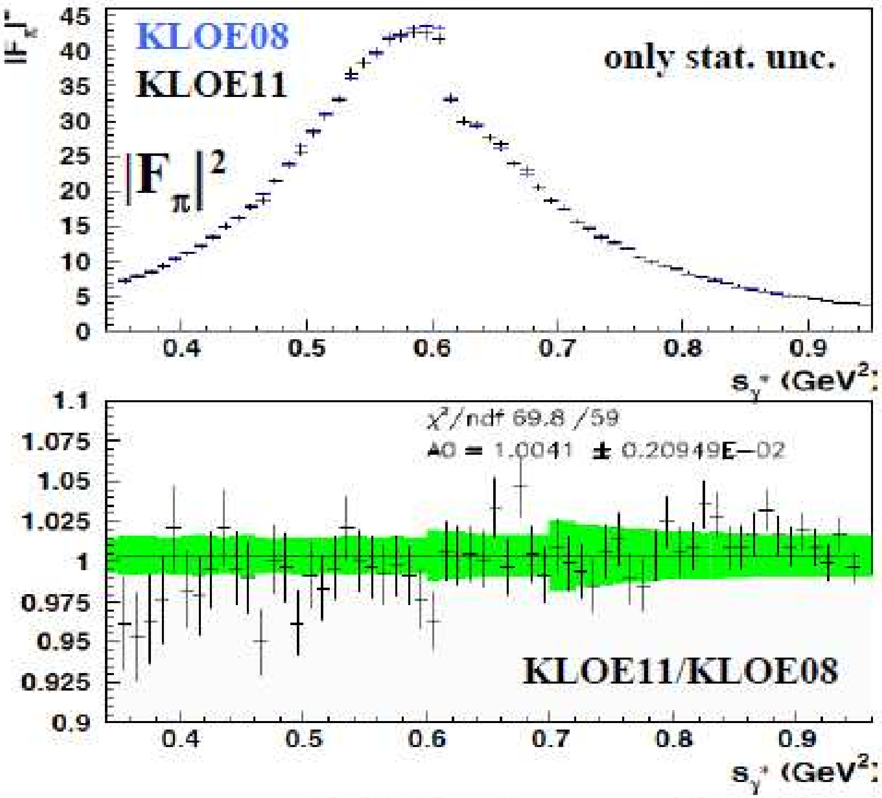
$a_\mu^{\pi\pi}(0.1\text{-}0.85\ \text{GeV}^2) = (478.5 \pm 2.0_{stat} \pm 4.8_{sys} \pm 4.5_{theo}) \cdot 10^{-10}$

0.4% 1.0% 0.9%

KLOE results on $\pi\pi\gamma/\mu\mu\gamma$ ratio

PRELIMINARY

	KLOE08	KLOE11
Syst. errors (%)	$\Delta^{\pi\pi}a_\mu$ abs	$\Delta^{\pi\pi}a_\mu$ ratio
Reconstruction Filter	negligible	negligible
Background subtraction	0.3	0.8 $(0.3_{\pi\pi\gamma} \oplus 0.7_{\mu\mu\gamma})$
Trackmass	0.2	0.4 $(0.2_{\pi\pi\gamma} \oplus 0.4_{\mu\mu\gamma})$
Particle ID	negligible	negligible
Tracking	0.3	0.6 $(0.3_{\pi\pi\gamma} \oplus 0.5_{\mu\mu\gamma})$
Trigger	0.1	0.1 $(0.1_{\pi\pi\gamma})$
Unfolding	negligible	negligible
Acceptance $(\theta_{\pi\pi})$	0.2	negligible
Acceptance (θ_π)	negligible	negligible
Software Trigger (L3)	0.1	0.1 $(0.1_{\pi\pi\gamma} \oplus 0.1_{\mu\mu\gamma})$
Luminosity	0.3 $(0.1_{th} \oplus 0.3_{exp})$	-
$\sqrt{s}$ dep. of H	0.2	-
Total exp systematics	0.6	1.0
Vacuum Polarization	0.1	-
FSR treatment	0.3	0.3
Rad. function H	0.5	-
Total theory systematics	0.6	0.3
Total systematic error	0.9	1.1



Good agreement btw the two measurements, especially in the ρ region!!!

KLOE11: $a_\mu^{\pi\pi}$,(0.35-0.95 GeV^2) = (384.1 ± 1.2stat ± 4.0sys ± 1.2theo) · 10^{-10}

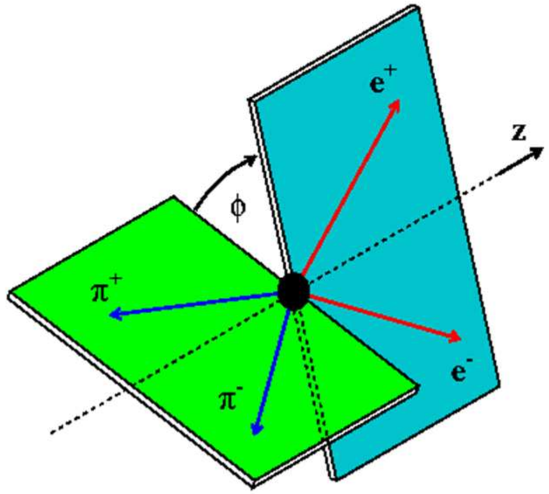
KLOE08: $a_\mu^{\pi\pi}$(0.35-0.95 GeV^2) = (387.2 ± 0.5stat ± 2.4sys ± 2.3theo) · 10^{-10}

New measurement in agreement with previous KLOE measurements

$\eta \rightarrow \pi^+\pi^- e^+ e^-$: KLOE analysis

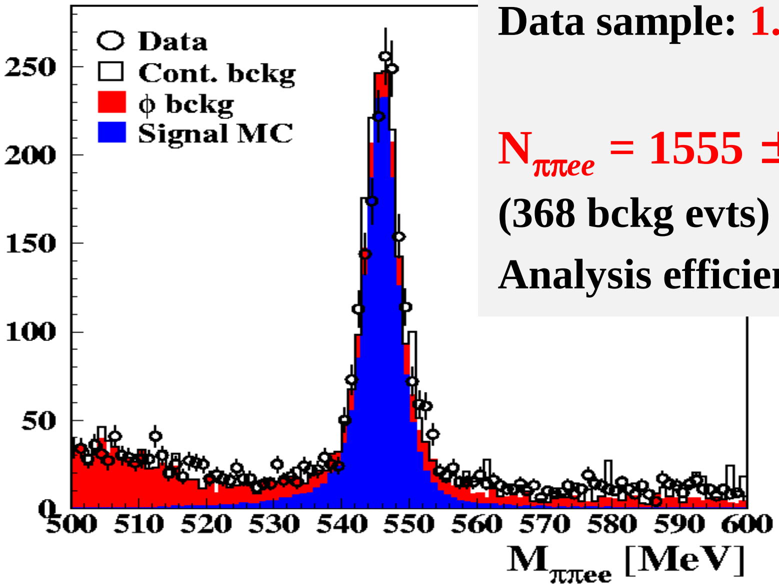
PLB 675 (2009) 283

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: $A_\phi < 10^{-4}$
- using theoretical predictions: $A_\phi \sim 10^{-15}$

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

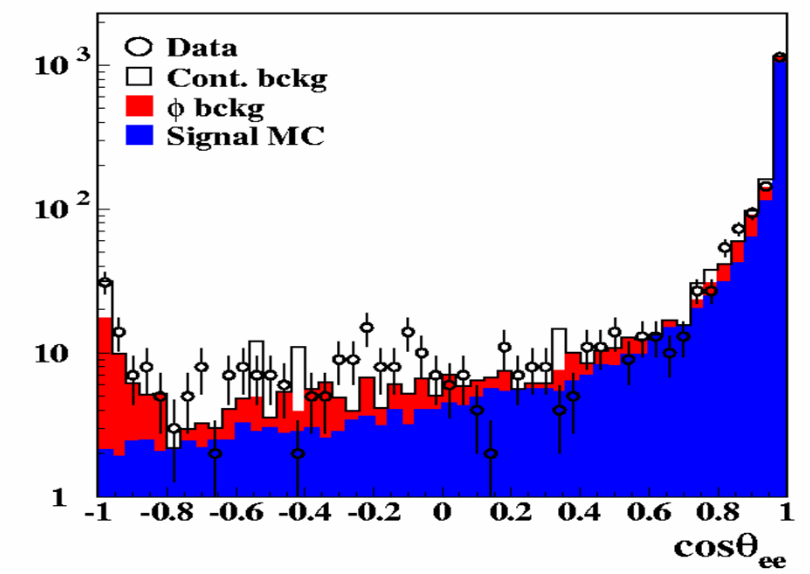


Data sample: 1.73 fb^{-1}

$N_{\pi\pi ee}$ = 1555 ± 52

(368 bckg evts)

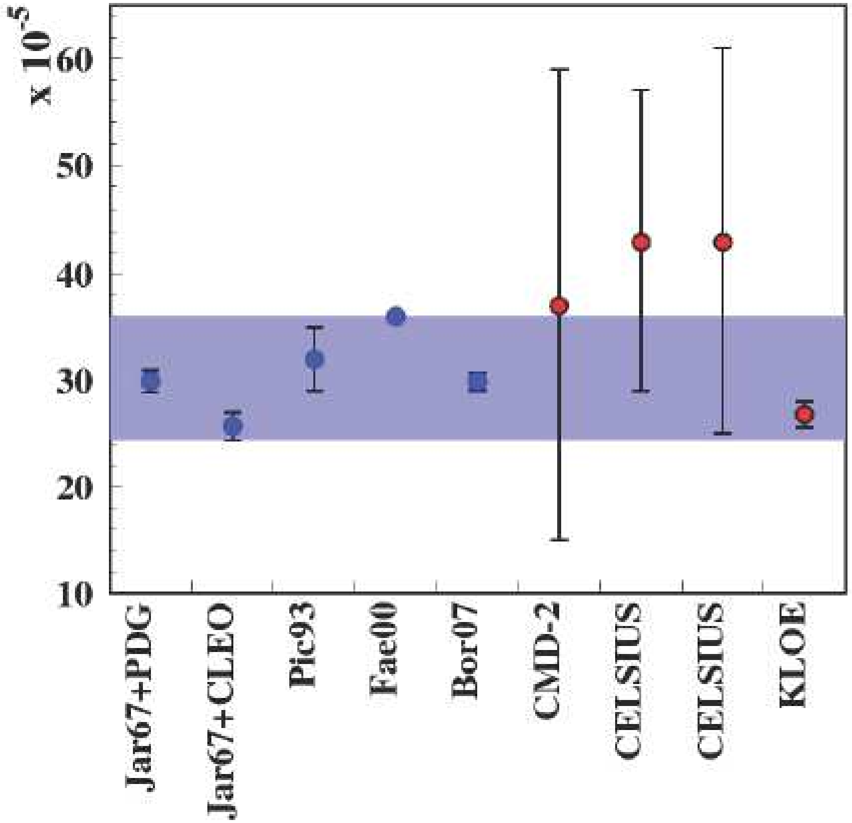
Analysis efficiency: 8%

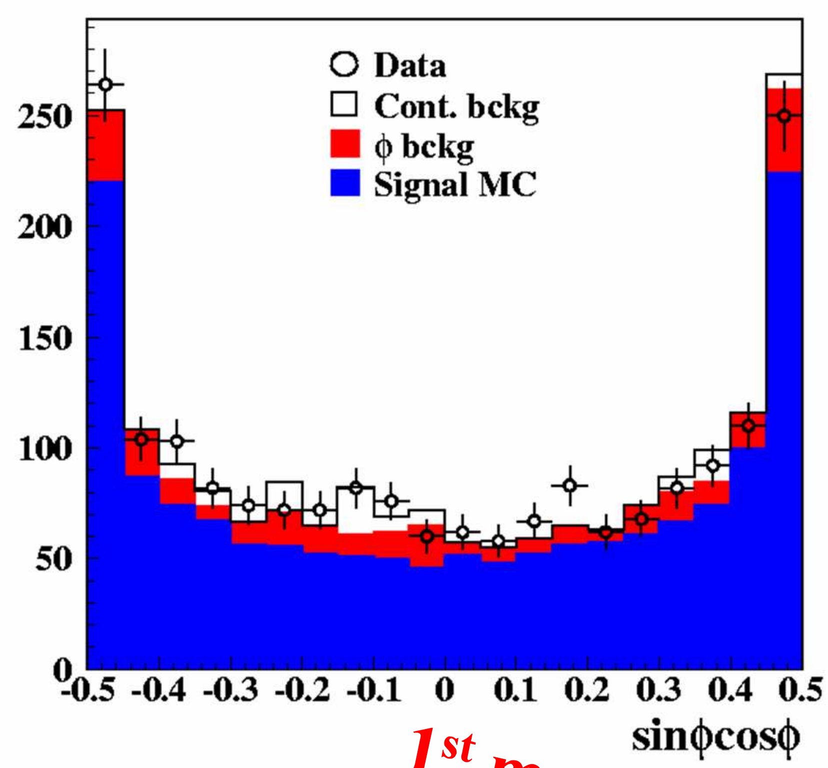


$\eta \to \pi^+\pi^- e^+ e^-$: results

PLB 675 (2009) 283

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





1st measurement!

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

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

$\eta \to \pi^+\pi^- e^+ e^-$: prospects

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

KLOE-2 with O(10 fb^{-1}):

- **BR: statistical error of 1.4%**
- **Asymmetry: statistical error from 2.5 to 1.2 $\times$ 10^{-2}**

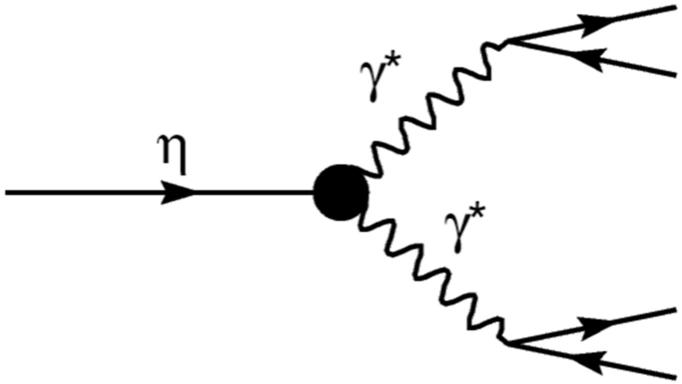
  Unconventional CP-V terms can give A_ϕ at the 10^{-2} level
- **Systematics easily reduced at the same level**
- **Inner tracker will increase acceptance for the 4 charged tracks from the IP**

$A_\phi = \frac{\ldots_{\sin\phi\cos\phi} - \ldots_{\sin\phi\cos\phi}}{N_{\sin\phi\cos\phi} + N_{\sin\phi\cos\phi}}$

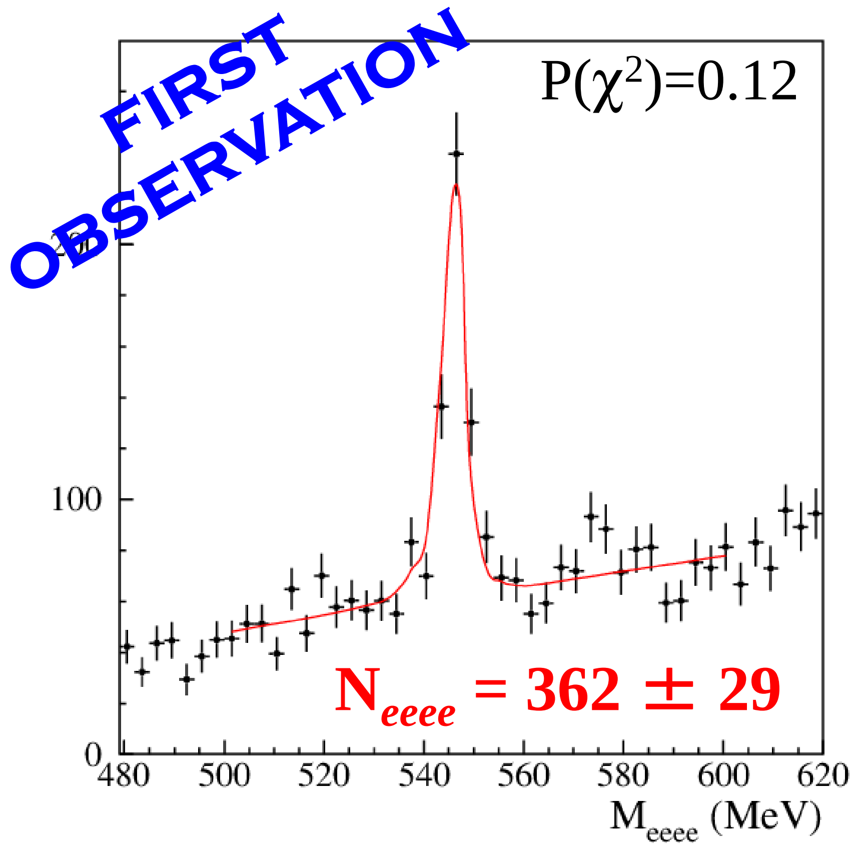
$A_\phi = (-0.6 \pm 2.5_{stat} \pm 1.8_{syst}) \times 10^{-2}$

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

PLB 702 (2011) 324



Data sample: **1.7 fb^{-1}**



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

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

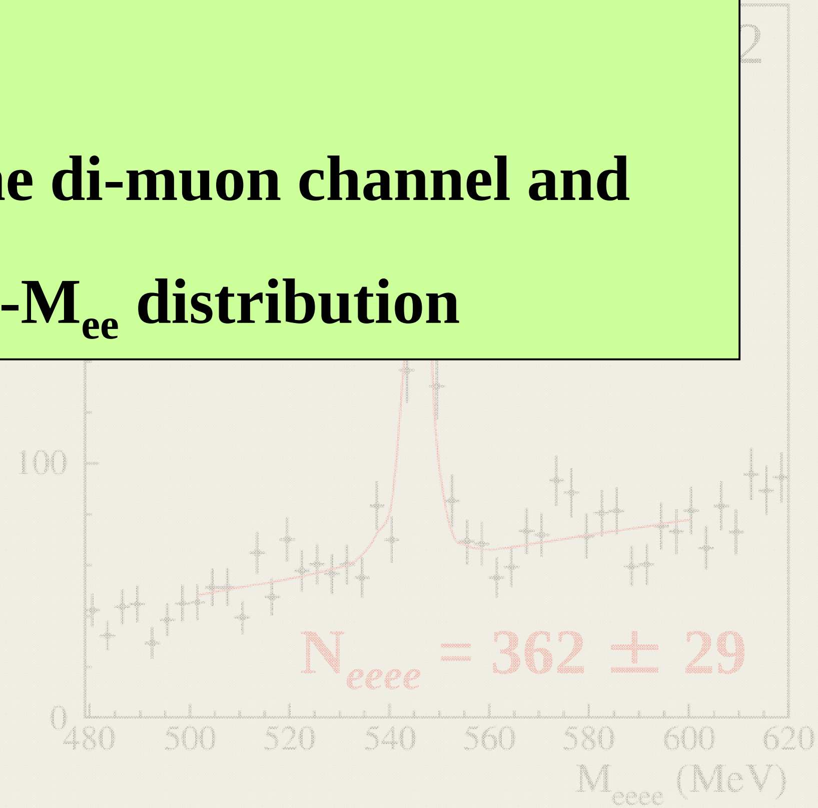
$\eta \to \mu^+ \mu^- e^+ e^-$

- Data sample: **1.7 fb^{-1}**
- MC simulation according to J.Bijnens and F. Persson, arXiv:0106130

KLOE-2 with O(10 fb^{-1})

- ❖ **can obtain first observation of the di-muon channel and**
- ❖ **can attempt the study of the $M_{\mu\mu}$-M_{ee} distribution**

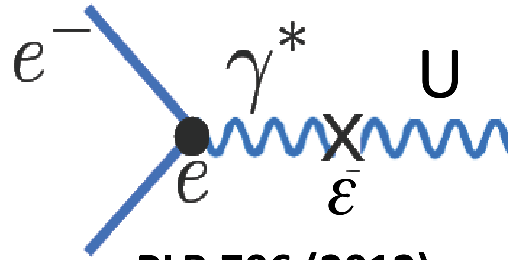
- Remaining background from φ decays subtracted
- Fit to M_{eeee} distribution with MC background shapes for signal + events from the continuum



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

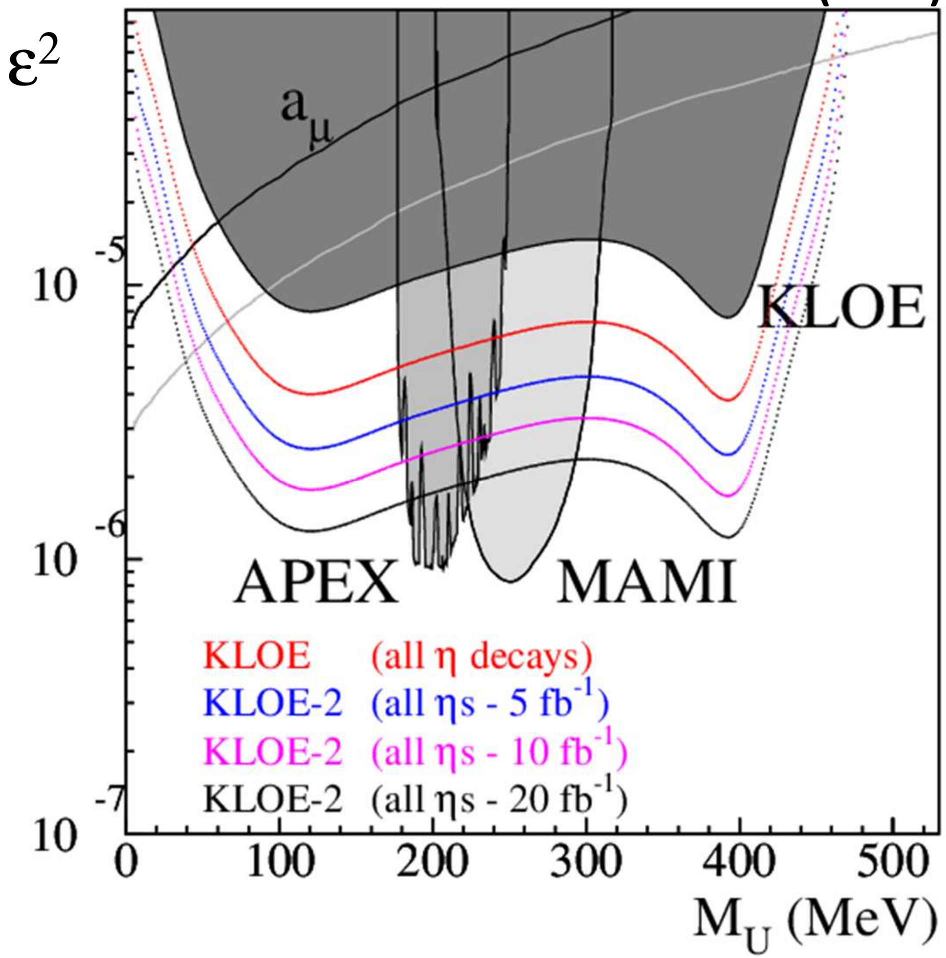
Search for dark forces: the $\phi \to \eta U$ channel

Hypothesis: existence of a hidden gauge sector, able to explain several unexpected astrophysical observations, weakly coupled with SM through a mixing mechanism of a new gauge boson, U, with the photon



PLB 706 (2012)

- KLOE published U.L. @ 90% C.L. using $\eta \to \pi^+\pi^-\pi^0$, $U \to e^+e^-$
- Analysis of the $\eta \to \pi^0\pi^0\pi^0$ and $\eta \to \gamma\gamma$ channels in progess to cover 95% of the η decay channels
- Due to larger branching ratio and analysis efficiency, an improvement of ~2 is expected
- **10 fb^{-1} will increase U.L. of a factor ~2**



Search for dark forces: the $e^+e^-\to U\gamma$ channel

- Analysis of $e^+e^-\to U\gamma\to\mu\mu\gamma$ started on:

  i) 2 fb^{-1} sample with small-angle (un-detected) photon

  ii) 200 pb^{-1} @ 1 GeV sample with large-angle (detected) ISR photons

.

→ **SA will provide the best results in the range ~500 <M_U< 1000 MeV**

- **KLOE-2 @ 10 fb^{-1} will improve of a factor of ~3:**

  → in the mass range 100<Mu<400 MeV with the $\phi\to\eta U$ channel

  → in the mass range 500-1000 MeV with the SA sample of $e^+e^-\to U\gamma\to\mu\mu\gamma$