"Measurement of $\gamma\gamma \rightarrow \pi^0$ at KLOE-2"

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Working Group on Radiative Corrections and Generators for Low Energy Hadronic Cross Section and Luminosity

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Summary

- Introduction:
  - Two-Photon Physics at DAΦNE
  - The Lepton Taggers

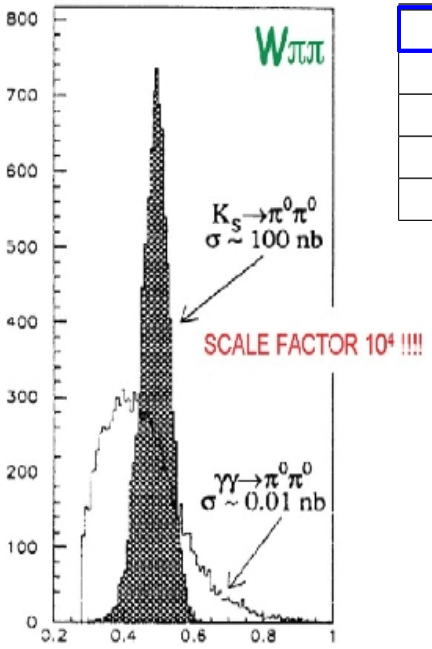
- $\gamma\gamma$ at KLOE-2
  - π^0 width measurement
  - π^0 TFF measurement

- HET detector status

- Conclusions

From KLOE to KLOE-2 : the e^+ e^- taggers

Running KLOE at Φ peak (√s = 1.02 GeV) → the importance of detecting outcoming leptons for two-photon physics purposes



Decadimento Φ in	Missing	Numero di Eventi	Background per
$K_S(\pi^0\pi^0)K_L$	K_L	~ 10^9	$\pi^0\pi^0$
$K_S(\pi^+\pi^-)K_L$	K_L	~ 2×10^9	$\pi^+\pi^-$
$\pi^+\pi^-\pi^0$	π^0	10^9	$\pi^+\pi^-$
$\eta(\gamma\gamma)\gamma$	γ	10^8	η
$\pi^0(\gamma\gamma)\gamma$	γ	~ 5×10^8	π^0

Canale γγ	Numero di Eventi
$e^+e^- \to e^+e^-\pi^0\pi^0$	2×10^4
$e^+e^- \to e^+e^-\pi^+\pi-$	2×10^6
$e^+e^- \to e^+e^-\eta$	1×10^6
$e^+e^- \to e^+e^-\pi^0$	4×10^6

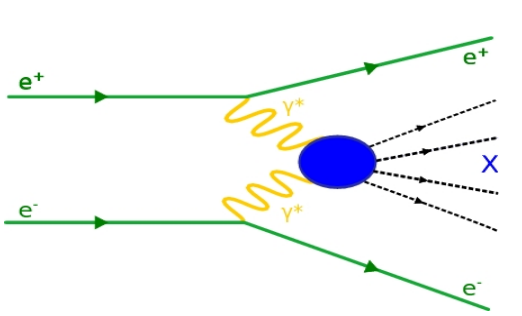
$$e^+ e^- \to K_S(\pi^0 \pi^0) K_L$$

detected missing

$$e^+ e^- \to e^+ e^- \pi^0 \pi^0$$

escaped detected

e^+ e^- TAGGING IS MANDATORY TO REDUCE Φ–DECAY BACKGROUND



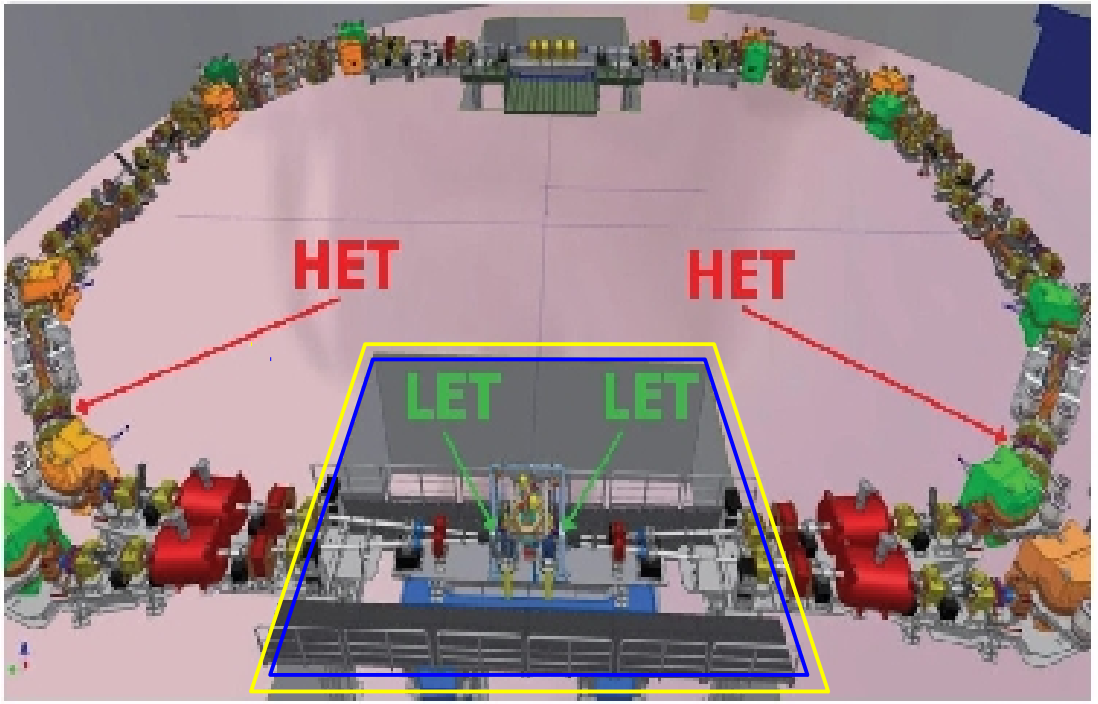
ALONG BEAM-PIPE

IN KLOE

ALONG BEAM-PIPE

The e^+ e^- taggers: LET and HET detectors

Outcoming leptons tagging allow us to close kinematics, making the measurement independent of Φ-decays background



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

to taggers (HET or LET)

in KLOE

LET (Low Energy Tagger)

→ Inside KLOE detector (1m from IP)

→ energy acceptance (160-400) MeV

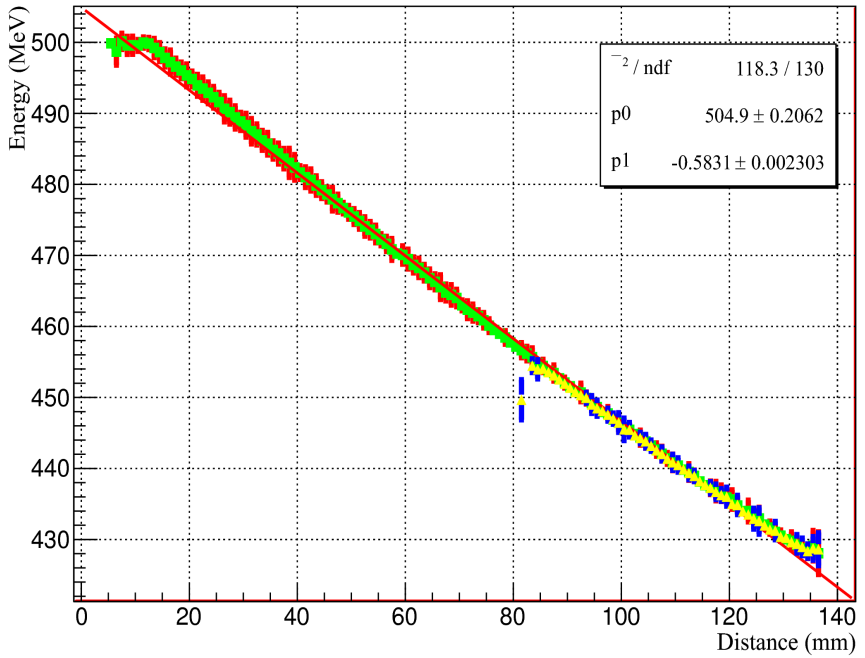
HET (High Energy Tagger)

→ After bending dipole (11m from IP)

→ energy acceptance (420-495) MeV

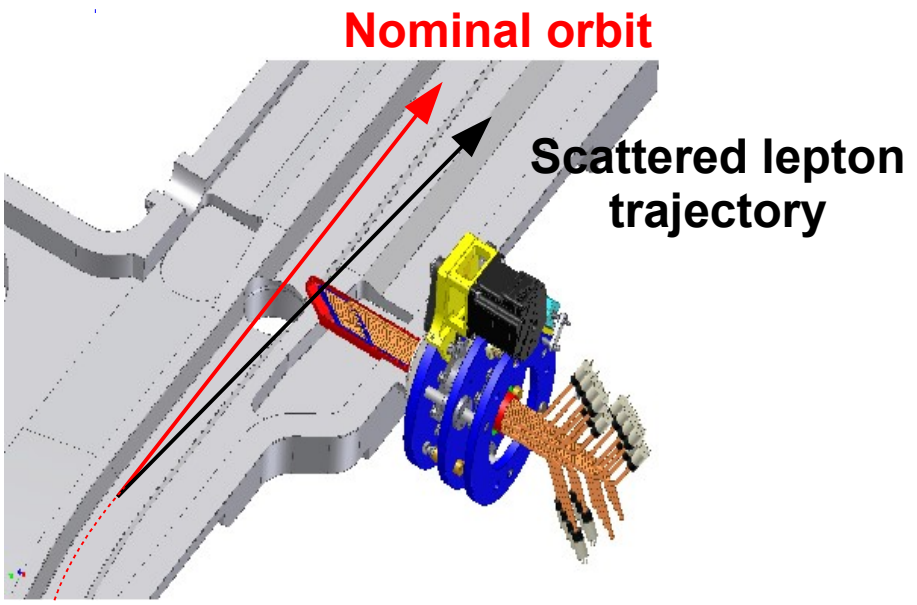
The HET detector

- HET is located 11m away from the IP (beyond DAΦNE 1st bending dipole)
- The dipole acts as a spectrometer, separating particles of different energy in the range (420 – 495 MeV) → "**E vs x**"

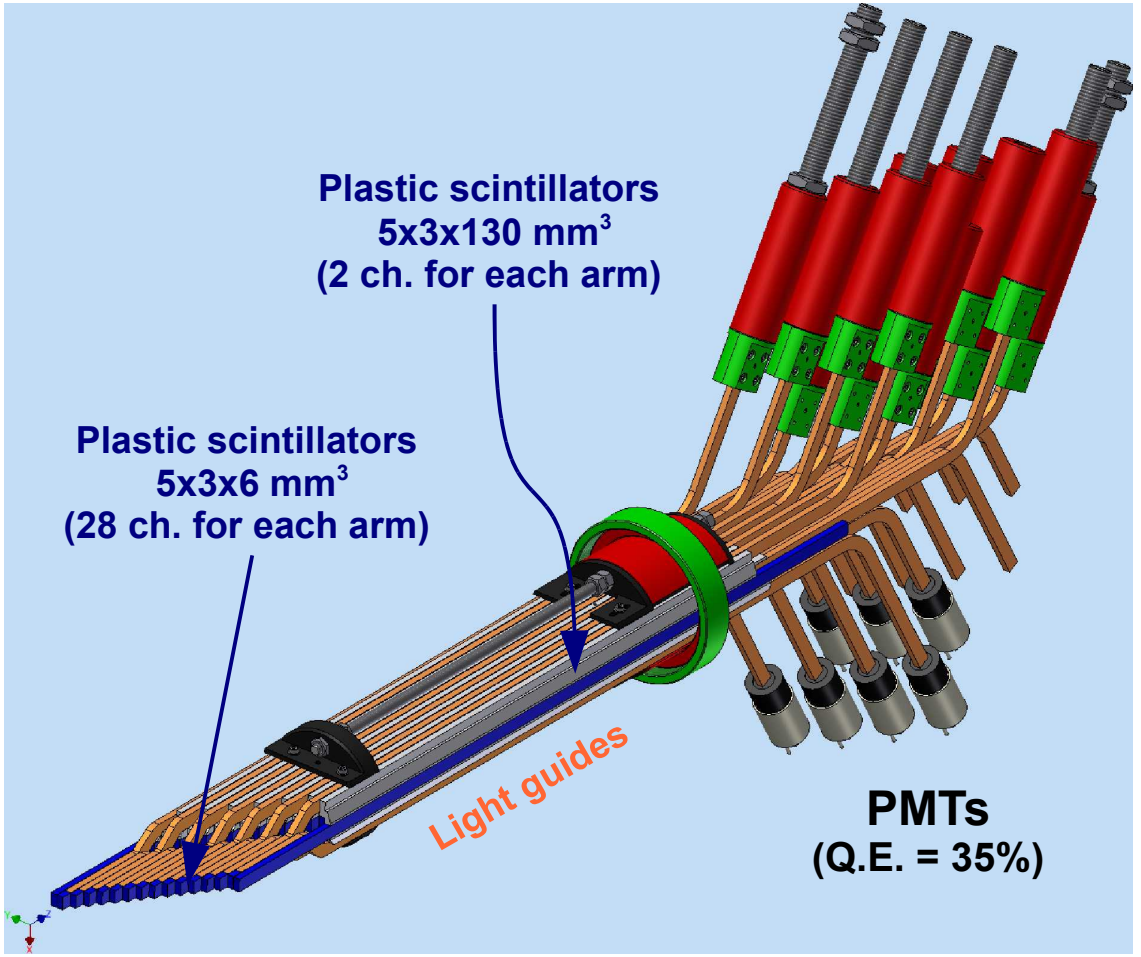


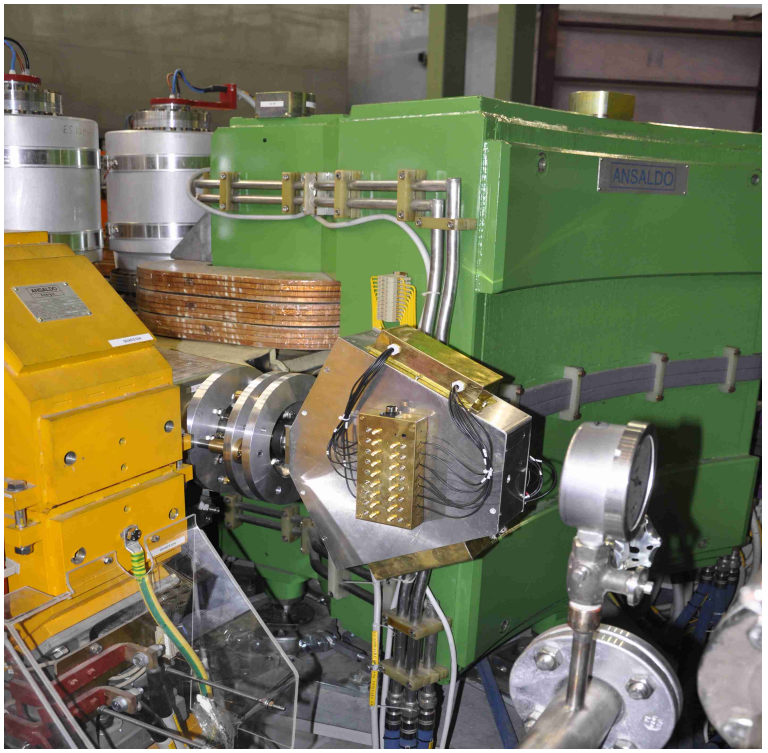
Leptons are tracked along machine optics
With BDSIM package (GEANT4 appl.)

Strong correlation between E and x
→ Position Detector



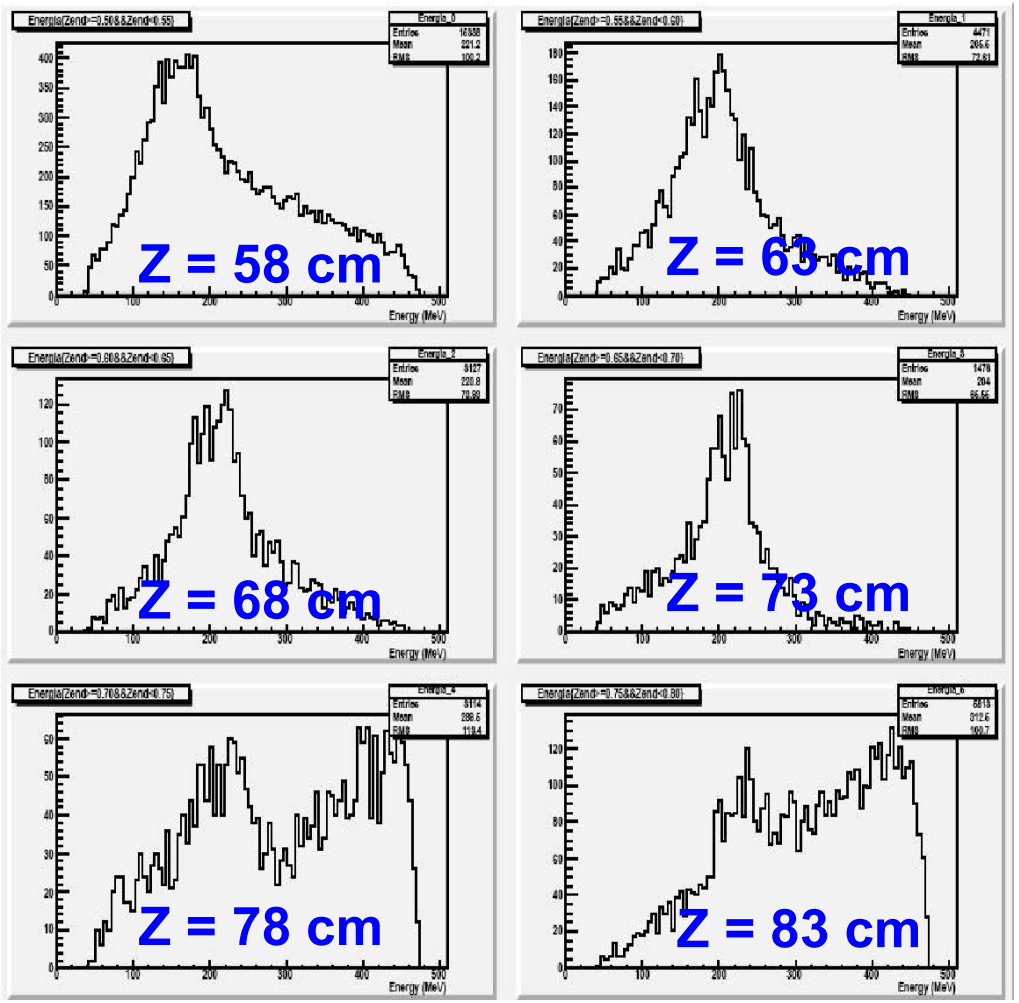
The HET detector





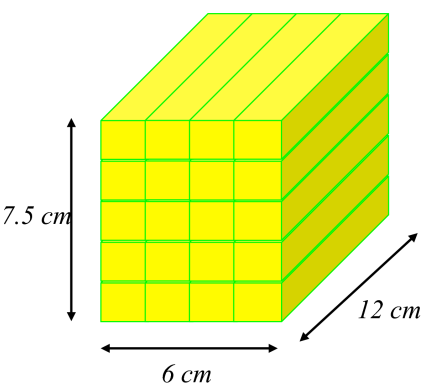
- ✔ σ_E ~ 2.5 MeV σ_t ~ 300 ps
- ✔ Electronic (from FEE to DAQ) successfully tested on beam
- ✔ Detectors in place (march 2012)

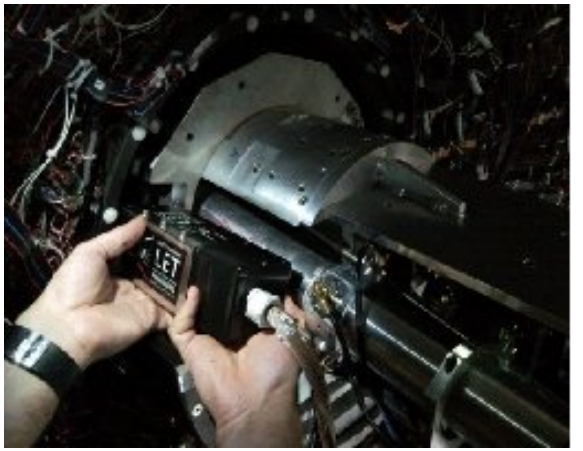
LET detector



NO correlation between E and z

→ **Calorimetric Detector**

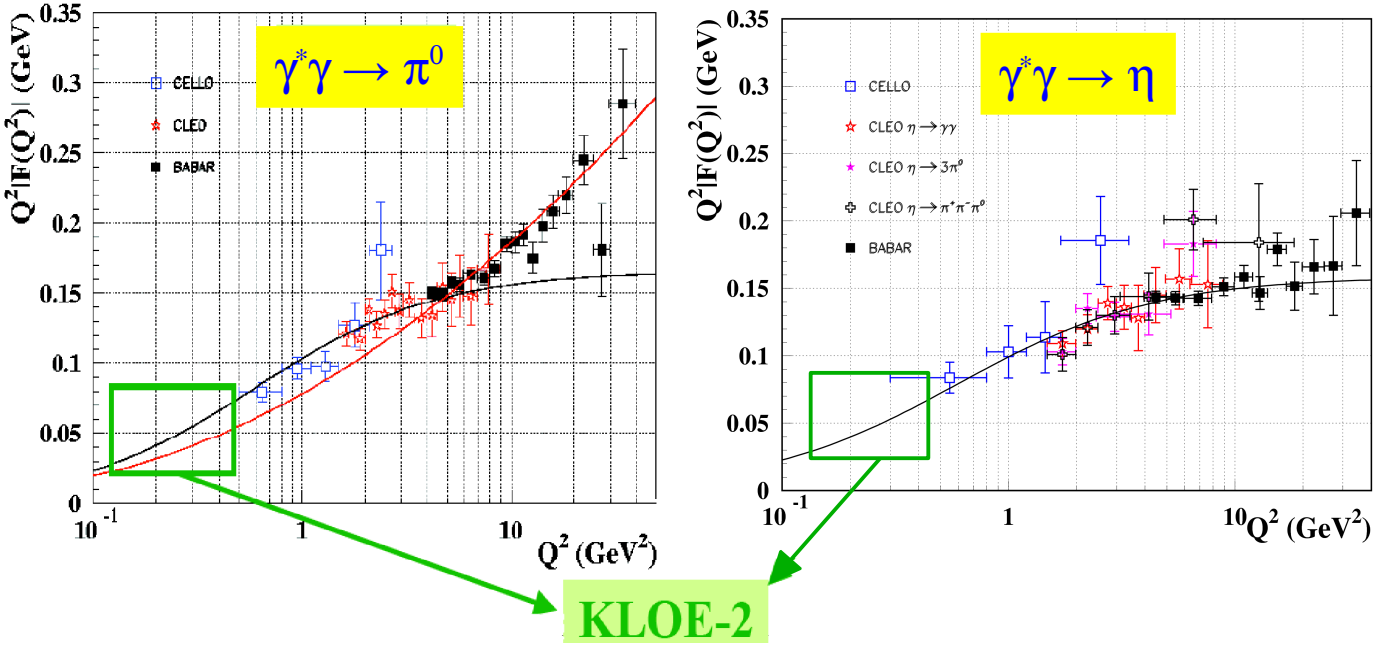


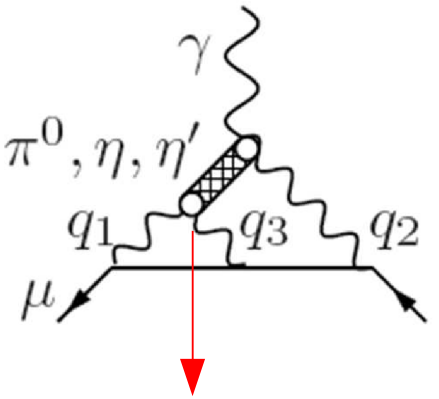


- ✔ **Inside KLOE detector (~ 1m)**
- ✔ **20 LYSO Crystals read by SiPM (not sensitive to KLOE B field)**
- ✔ **σ_E < 10% at E >150MeV**

γγ at KLOE-2: physics goal

MAIN INTEREST → PS exchange term of Hadronic Light-By-Light contribution to g-2 of μ
(MODEL DEPENDENCE of $F((q_1+q_3)^2, q^2_1, q^2_3)$)





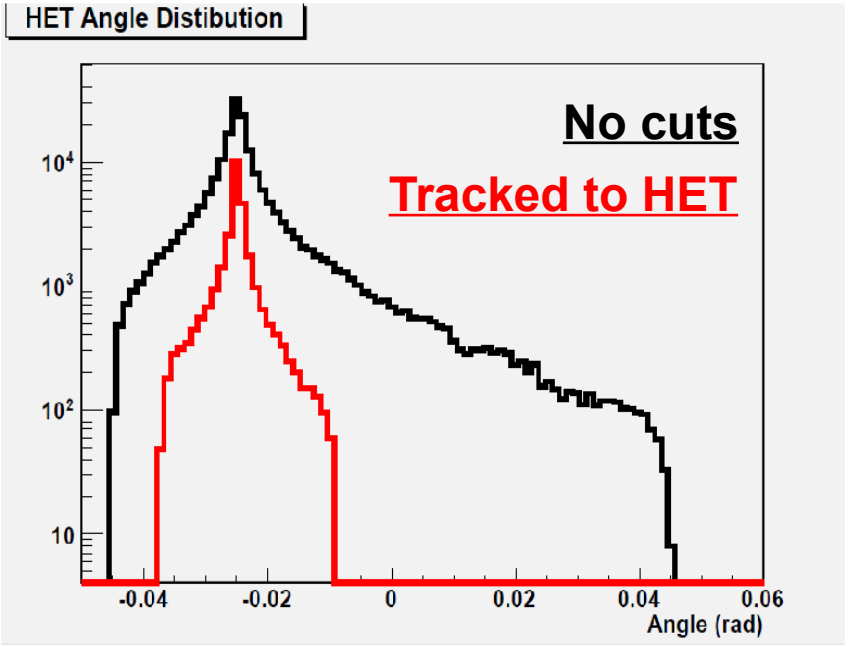
$F_{PS^*\gamma^*\gamma^*}$
Phenomenological Estimation

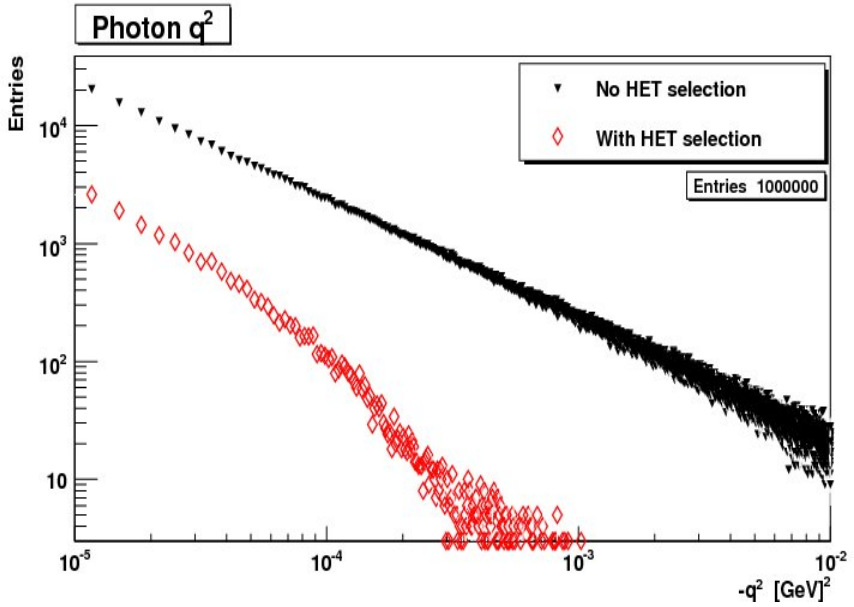
Useful experimental constraints to theoretical calculation of $a_{\mu,LbL}$ from → **Γ(PS->γγ)**
$F(M^2_{PS}, q^2, 0)$

γγ at KLOE-2: π^0 case

Simulations performed with **EKHARA** MC generator **[Comp.Phys.Comm. 182, 6 (2011) - 1338-1349]**

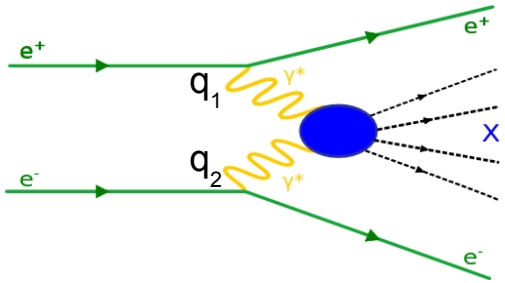
(CM frame) $e^+ e^- \to e^+ e^- \pi^0$ → **Crossing Angle + LAB boost + π^0 decay + $e^- e^+$ tracking to HET**





TAGGED LEPTONS INVOLVE QUASI-REAL γs IN PRODUCTION ($|q^2| < 10^{-3}$ GeV^2)

π^0 case: HET measurements

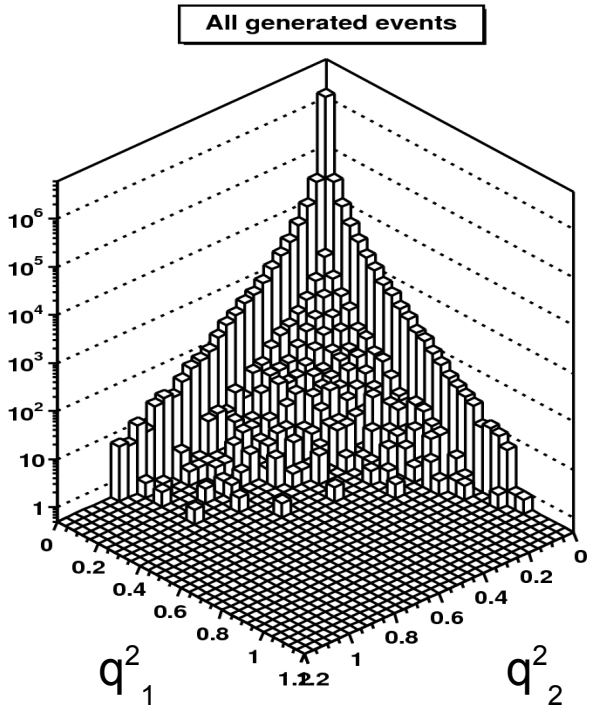


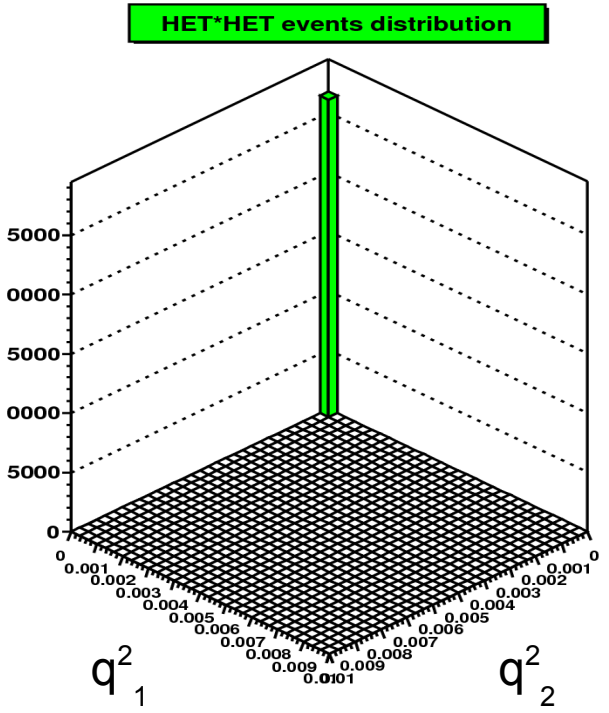
$e^+ \rightarrow$ HET
$e^- \rightarrow$ HET
$\pi^0 \rightarrow \gamma\gamma \rightarrow$ KLOE

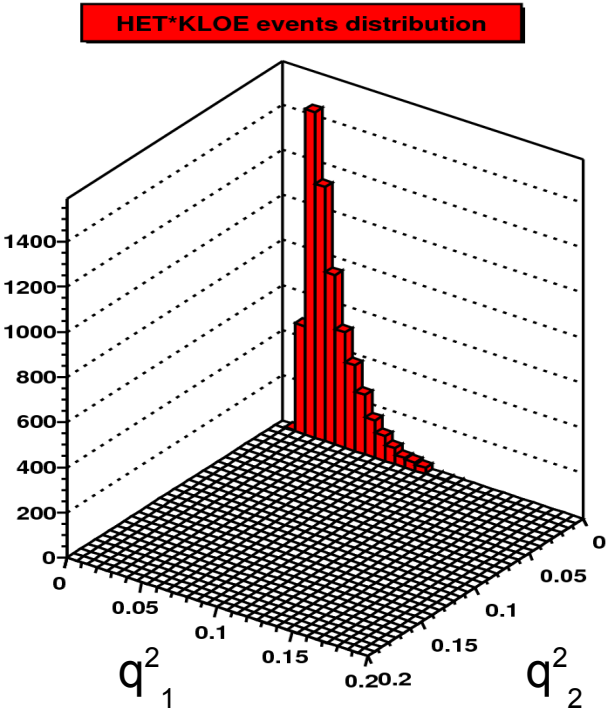
access to $\Gamma(\pi^0 \rightarrow \gamma\gamma)$

$e^+ \rightarrow$ HET
$e^- \rightarrow$ KLOE
$\pi^0 \rightarrow \gamma\gamma \rightarrow$ KLOE

access to $F(m^2_{\pi 0}, q^2, 0)$

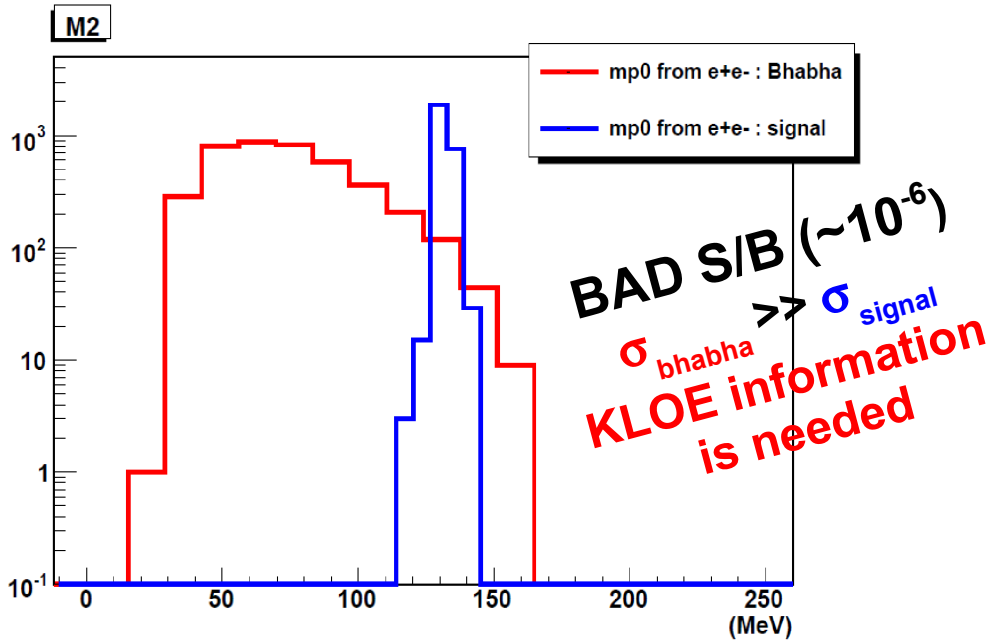






π^0 width: MC simulation results

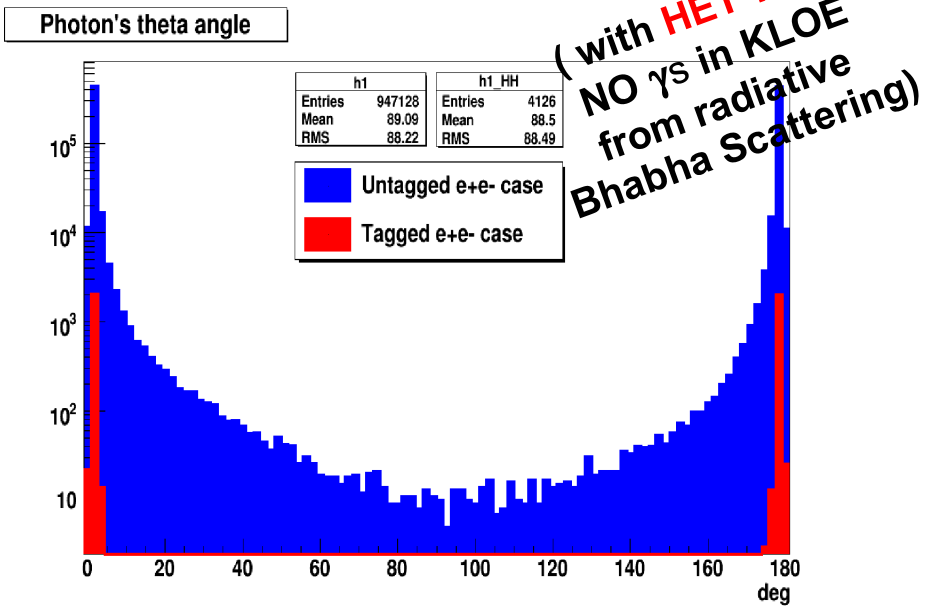
Width extraction $\Gamma_{\pi^0\to\gamma\gamma} = \frac{N_{\pi^0}}{\varepsilon L}\frac{\tilde{\Gamma}_{\pi^0\to\gamma\gamma}}{\sigma_{e^+e^-\to e^+e^-\pi^0}}$ $\Rightarrow$ $F^2_{\pi^0\gamma^*\gamma^*}(q_1^2=0, q_2^2=0) = \frac{4}{\pi\alpha^2 m_\pi^3}\Gamma_{\pi^0\to\gamma\gamma}$



BAD S/B (~10^{-6})

σ_{bhabha} >> σ_{signal}

KLOE information is needed

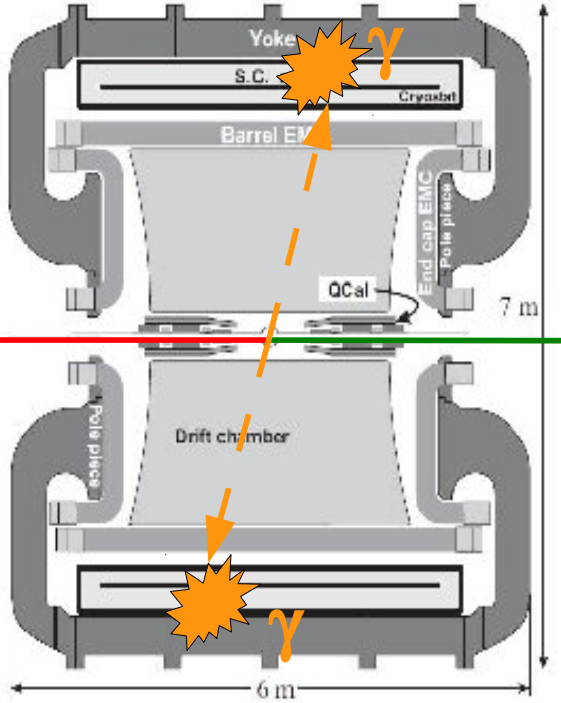


(with HET*HET: NO γs in KLOE from radiative Bhabha Scattering)

Details: EPJC 72, 1917 (2012)

Very high statistics run (~10^9 events)

π^0 case: width measurement



HET

e^-

$\gamma \rightarrow q^2 < 10^{-3}$ GeV^2

HET

e^+

$\gamma \rightarrow q^2 < 10^{-3}$ GeV^2

$\sigma_{tot}^{e^+e^-\rightarrow e^+e^-\pi^0} \simeq 0.28\ nb$ $\quad L = 5\ fb^{-1}$

$\sigma_{vis}^{x_0=30} \approx 1.90\ pb \Rightarrow N_{events} \approx 9500$

$\sigma_{vis}^{x_0=40} \approx 1.79\ pb \Rightarrow N_{events} \approx 9000$

$\sigma_{vis}^{x_0=50} \approx 1.68\ pb \Rightarrow N_{events} \approx 8500$

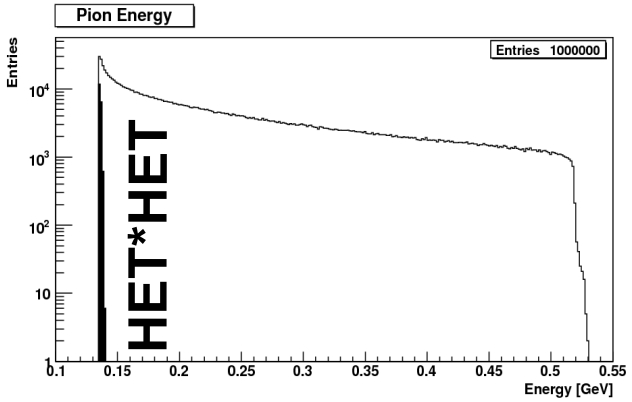
~ 1%

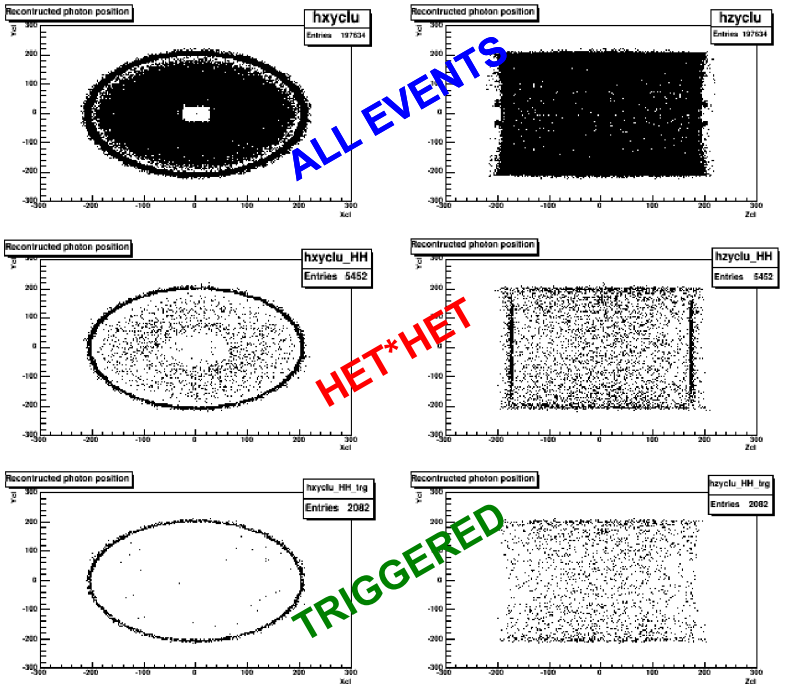
Best result from PrimEx coll.
→ 2.8%
[PRL 106, 162303 (2011)]

π^0 measurement: improved trigger possibility

Decay γs from π^0 are emitted back-to-back in width measurement case ($\pi^0(p_{max})$ ~ 30 MeV)

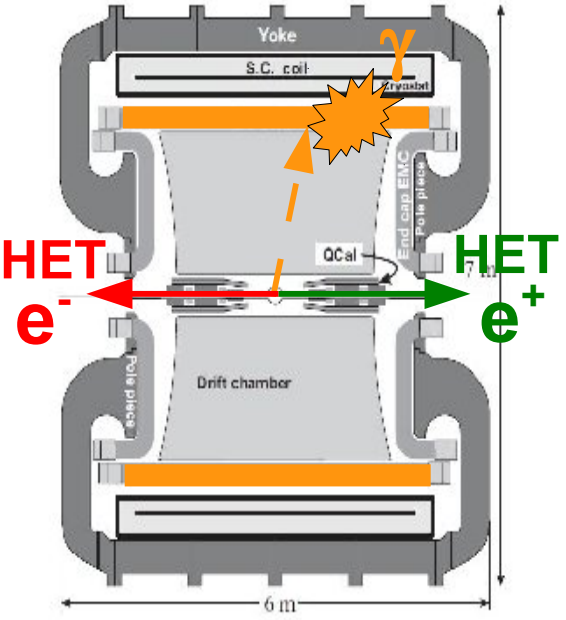
Photons energies comparable with EMC thresholds → Low TRG efficiency



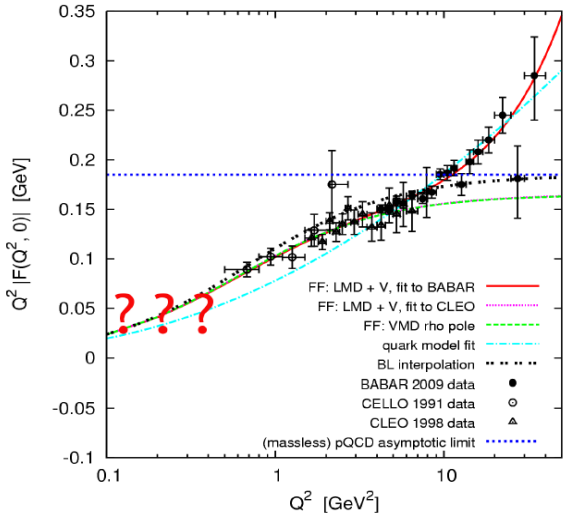


- ✔ **No Threshold changes are possible → background!!**
- ✔ **HET*HET*(Single_Barrel) ??**

To be studied...



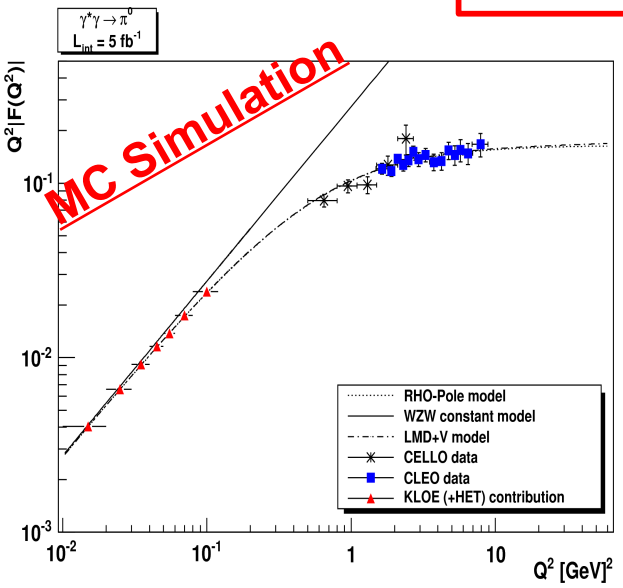
π^0 Transition Form Factor (TFF): MC simulation results



$$F^2(Q^2)_{data} = \frac{N^{data}_{\pi^0}}{L\epsilon} \frac{F^2(Q^2)_{MC}}{\sigma^{MC}_{e^-e^+\to e^-e^+\pi^0}}$$

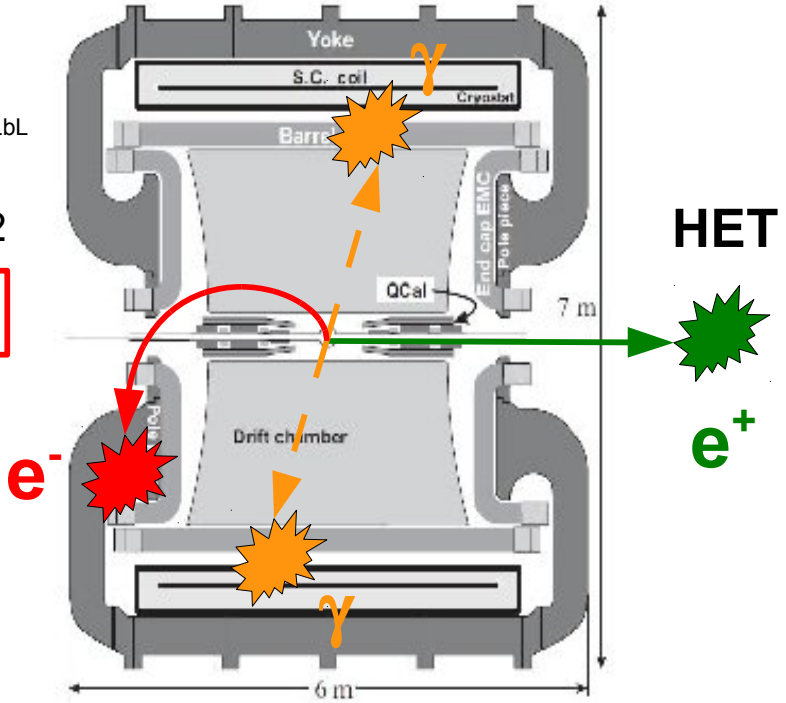
- Unexplored q^2 region
- Consistency check for FF parametrizations
- Model dependence reduction of a^{LbL}
- Factor ~2 error improvement on hadronic Light-by-Light term of g-2

Details: EPJC 72, 1917 (2012)



e⁻ → KLOE → 0.01 < q^2 < 0.1 GeV²

e⁺ → HET → q^2 < 10^{-3} GeV²

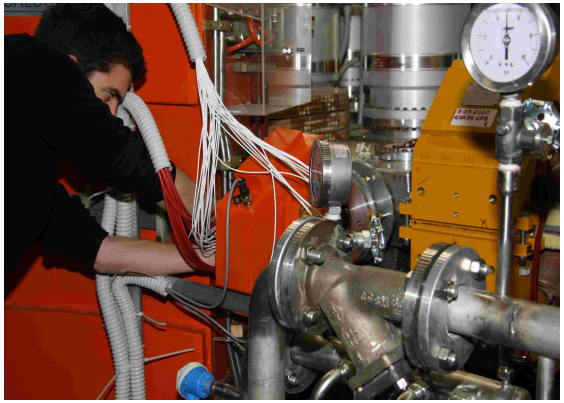


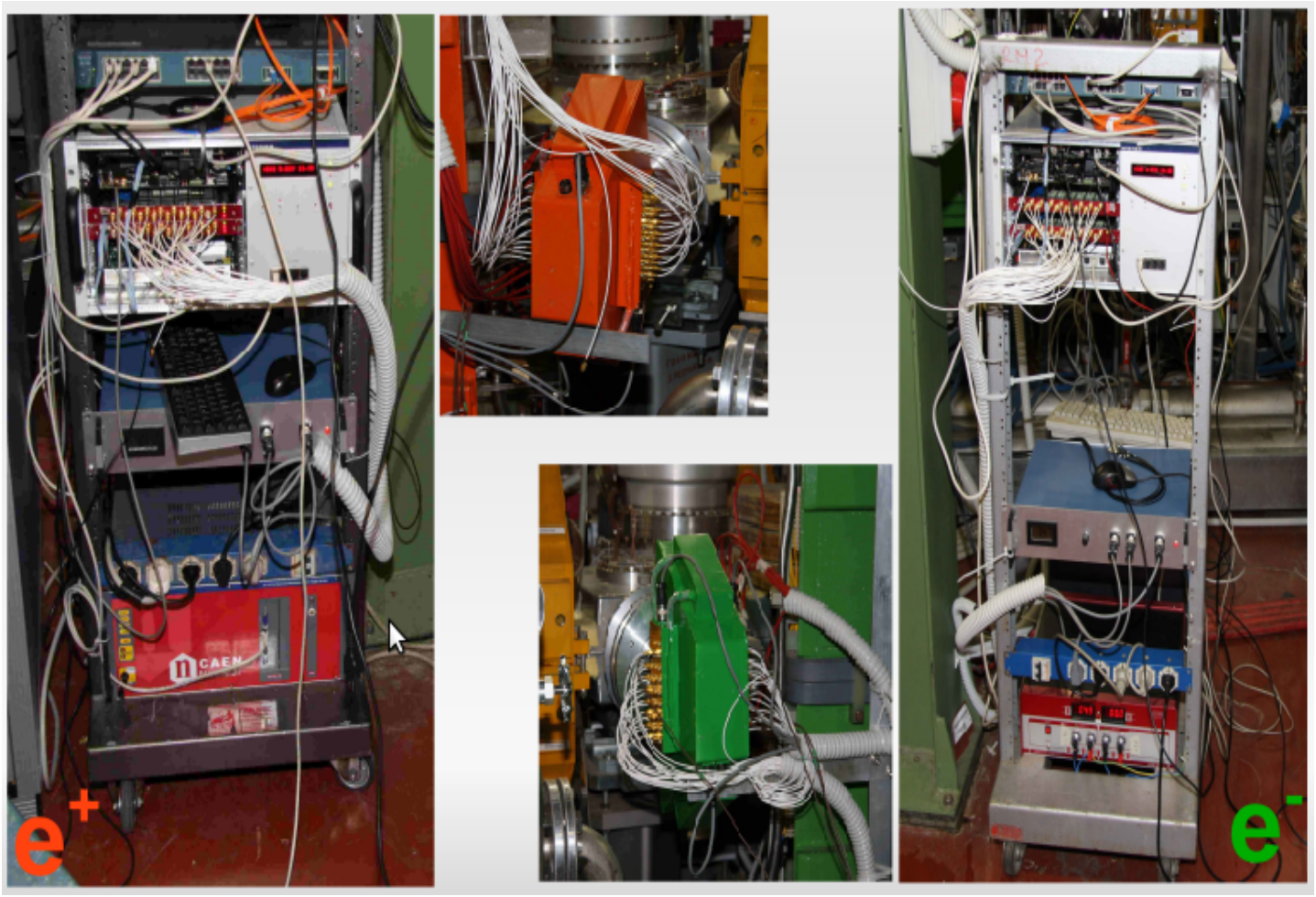
L_{int} = 5 fb^{-1} ε ≈ 20%

6% stat. error in each bin

HET detectors installation

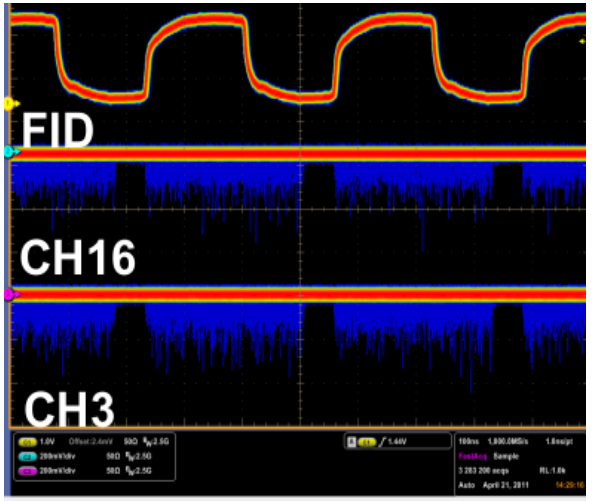
Detectors successfully installed on early March 2012

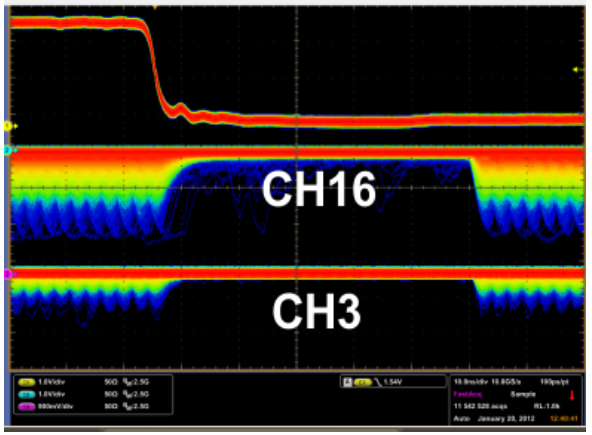




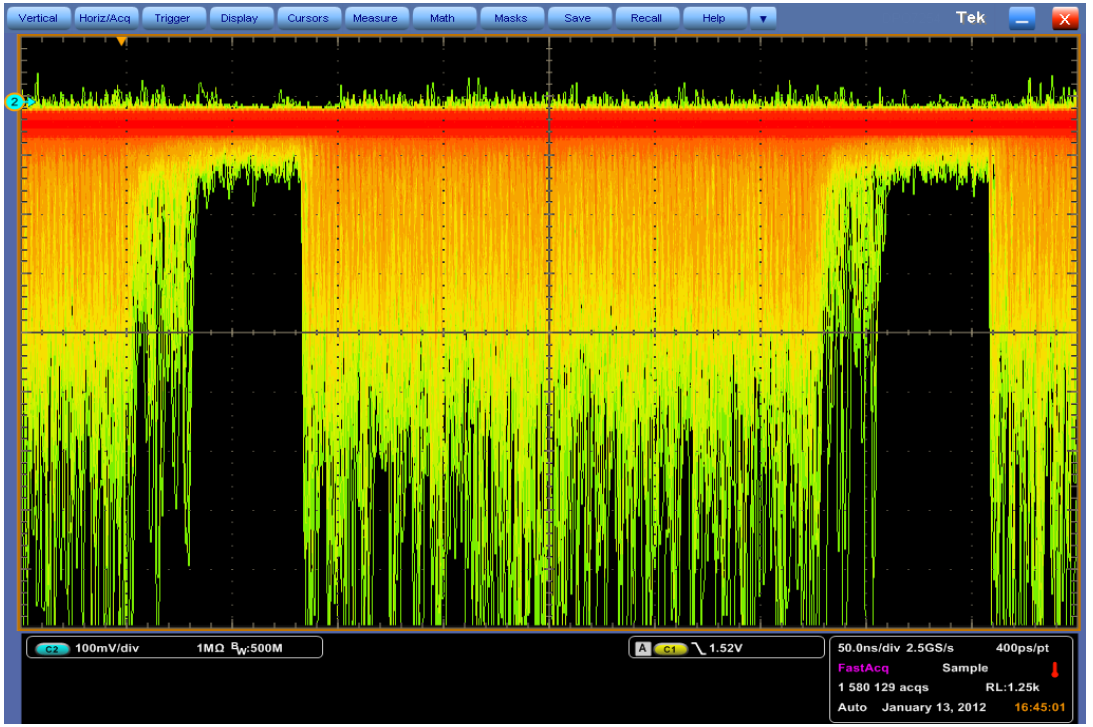
HET detectors tests on beam

Main purpose: distinguish signals coming from two consecutive bunch-crossings → **2.7 ns spacing**



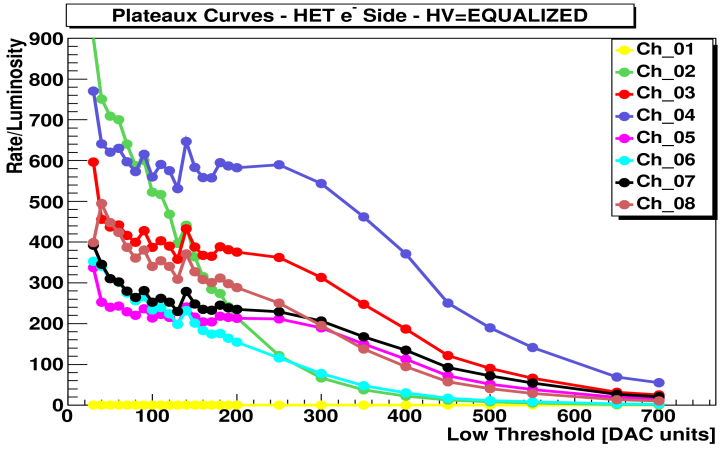


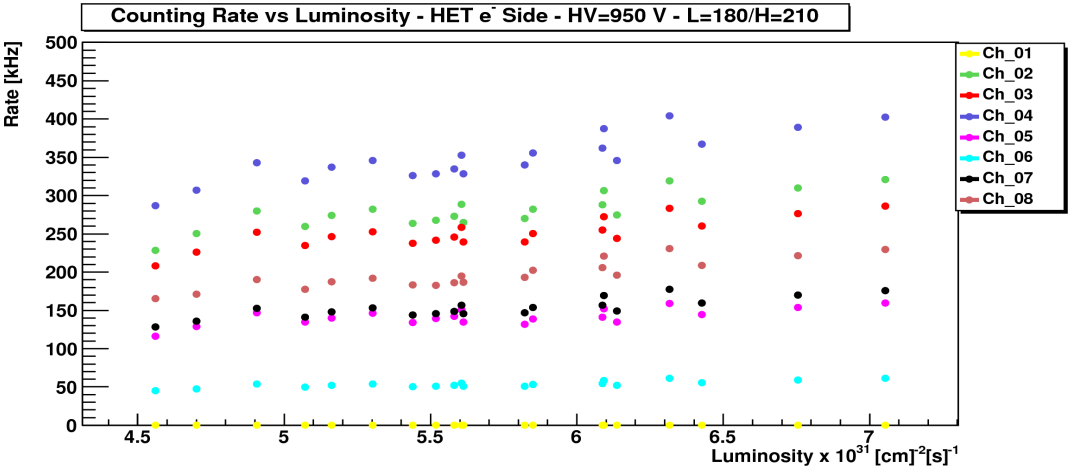
- ✔ Bunch structure of beams is clearly visible
- ✔ Bunches lack due to different injections is also observable (90/100 bunches)

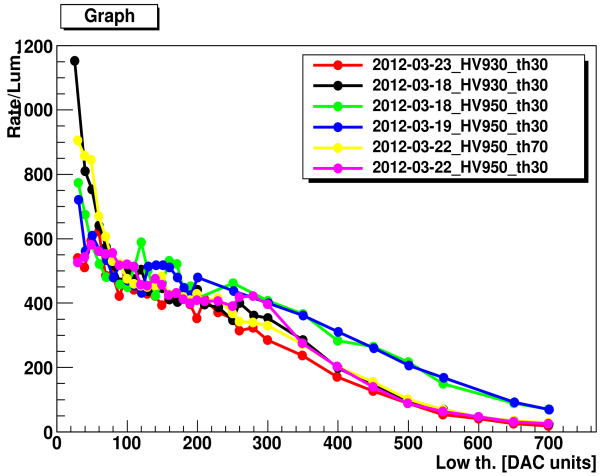


HET detectors tests on beam

Custom 16 channels fast discrimination boards and TDC system were developed



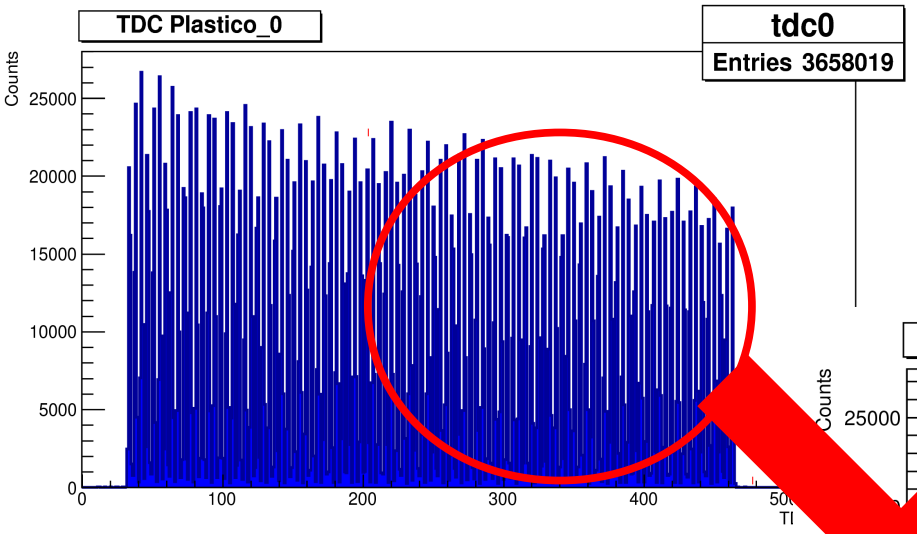




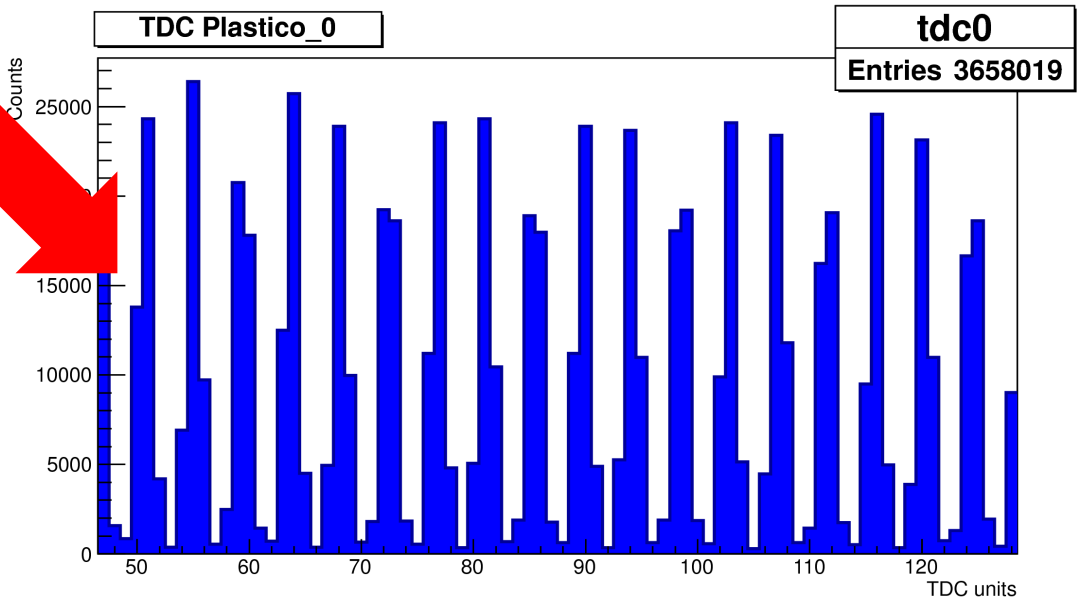
- **Discriminators plateaux curves are almost completed**
- **Discrimination rates are in agreement with expectations:**
  - 100-400 kHz on inner channels (@ 10^{32} cm^{-2} s^{-1})
  - 1 MHz on coincidence plastic

HET detectors tests on beam

TDC is able to distinguish signals from different bunches



- **1 TDC unit = 625 ps**
- **TDC resolution is ~ 300 ps (< 2.7 ns of buch crossing)**



BUNCH STRUCTURE IS VISIBLE WITH HET ELECTRONIC-CHAIN

Conclusions

- $\Gamma(\gamma\gamma \to \pi^0)$ measurement at 1% accuracy is possible at KLOE-2 with HETs installation. First 5 fb^{-1} of acquired data will be sufficient for the measurement

- The transition form factor $F_{\pi 0 \gamma \gamma *}$ will be measured for the first time at $0.01 < Q^2 < 0.1\ GeV^2$ in the space-like region → improve HLbL contribution to muon g-2

- HET detectors in place since march 2012

- Detector calibration and DACQ tests are ongoing, performances in agreement with project specifications

- New trigger system for width measurement is under study (increased statistics by a factor ~2)

Thank you for your attention