The KLOE-2 High Energy Taggers

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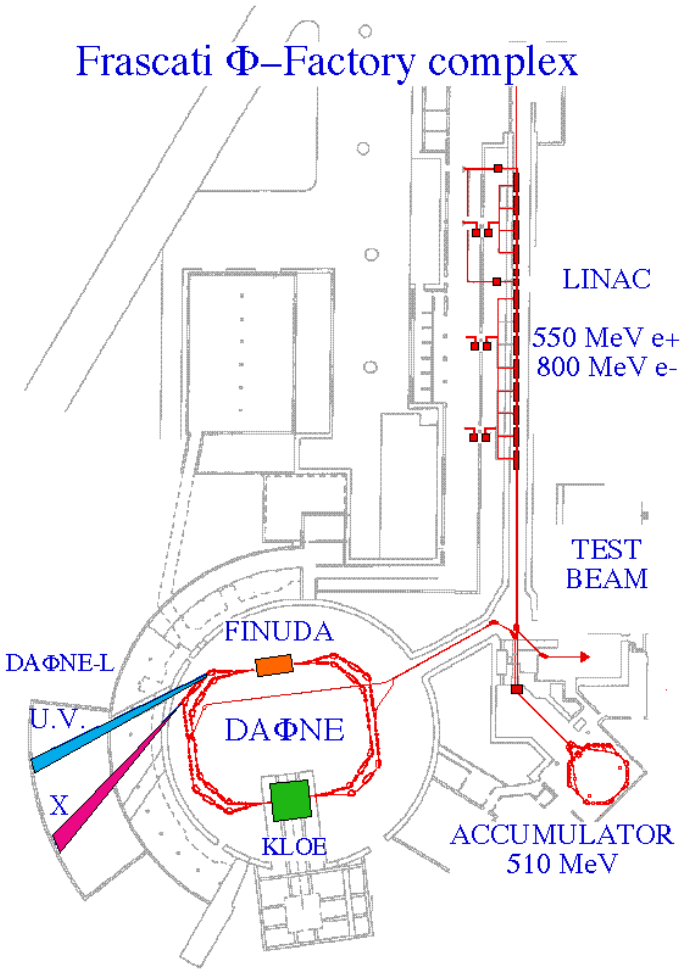
on behalf of KLOE-2 Collaboration

INFN-Laboratori Nazionali di Frascati (Italy)

INSTR-17
February 27th - March 3th 2017

DAΦNE: THE Φ-FACTORY



e^+e^- collider @ $\sqrt{s} = M_\Phi = 1.0194$ GeV

2 interaction regions

2 separate rings

105 +105 bunches, $T_{RF} = 2.7$ ns

Injection during data taking

Crossing angle: 2×12.5 mrad

Best Performance (running period 1999-2006):
$L_{\text{peak}} = 1.5 \times 10^{32}$ cm^{-2} s^{-1}

DAΦNE UPGRADES

New interaction region: large beam crossing angle + sextupoles for crabbed waist optics → Increase of peak luminosity by a factor about 2

The KLOE-2 Experiment

KLOE-2 Physics Program:

- ⋆ $\gamma\gamma$ physics

  Study of $\Gamma(\pi^0 \to \gamma\gamma)$, test of χPT, existence and properties of $\sigma(600)$ meson, PS Transition Form Factor

- ⋆ 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 χPT (KS decays)

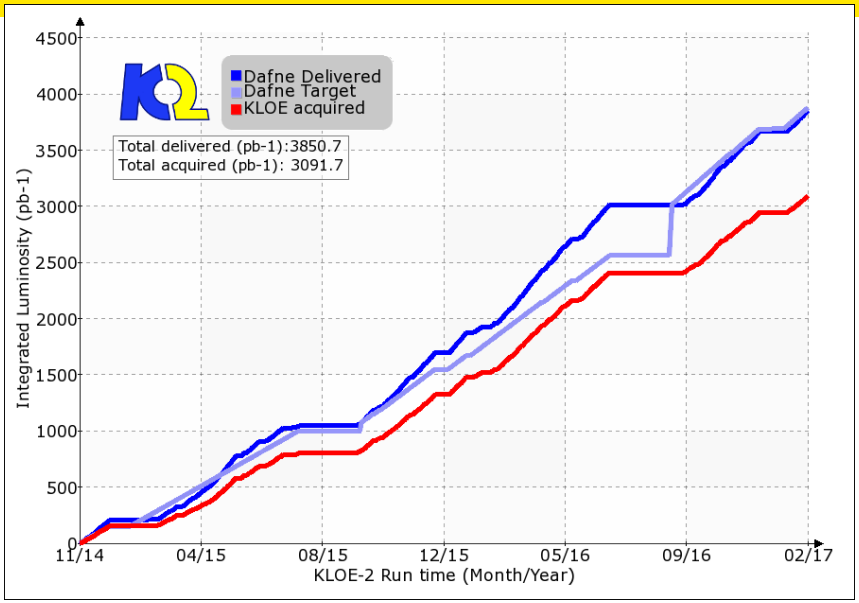
- ⋆ Spectroscopy of light mesons

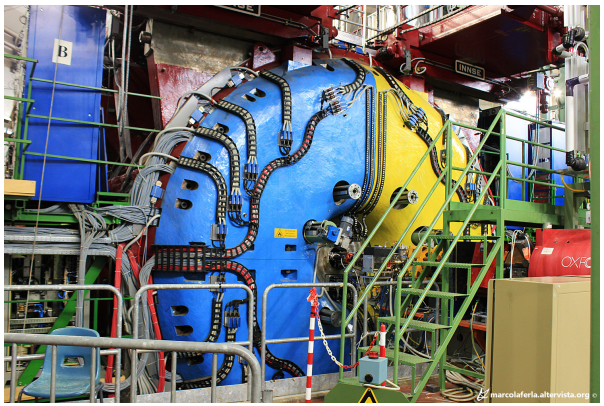
  η, η', f_0, a_0, σ in ϕ radiative decays

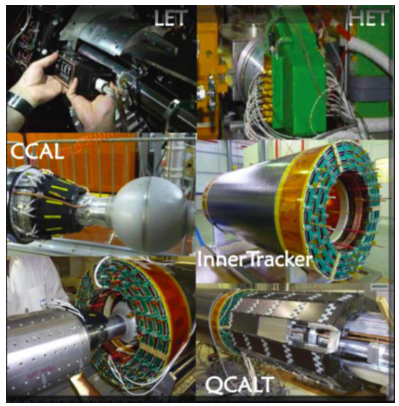
- ⋆ Dark Matter searches (light bosons at $\mathcal{O}(1$ GeV$)$

- ⋆ Hadronic cross section

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





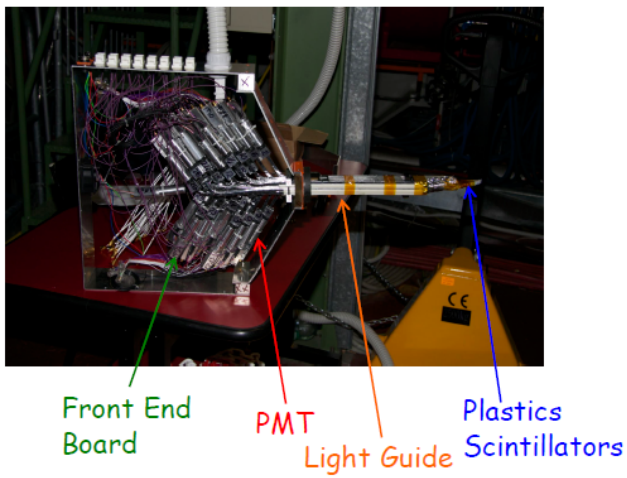


3 fb^{-1} already acquired
final goal: 5fb^{-1} by March 2018

The HET Detector

The HET stations are located 11m away the IP after the bending dipoles

The EJ-228 plastic scintillators are inserted in roman pots: 28 of 5x6x3 mm^3
1 Long Plastic for coincidence
HAMAMATSU PMT R9880U-110 SEL
Quantum efficiency $\sim 35\%$



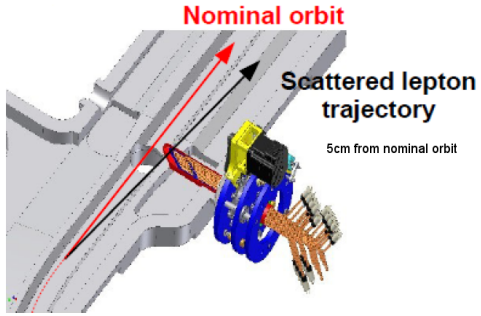
Leptons are tracked along machine optics with BDSIM package (GEANT4 appl.), MC validation in progress: Babayaga, BBBrem for Bhabha's, Ekhara for $\gamma\gamma$ events

$\sigma_\theta \sim 2,5\text{mrad}, \sigma_r \sim 5\text{mm}$

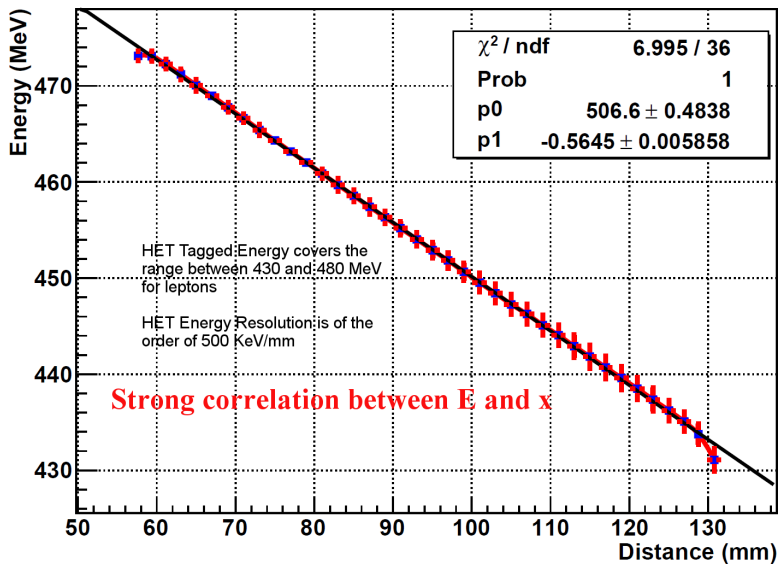
$$e^+ e^- \to e^+ e^- \gamma^* \gamma^* \to e^+ e^- X$$

to taggers

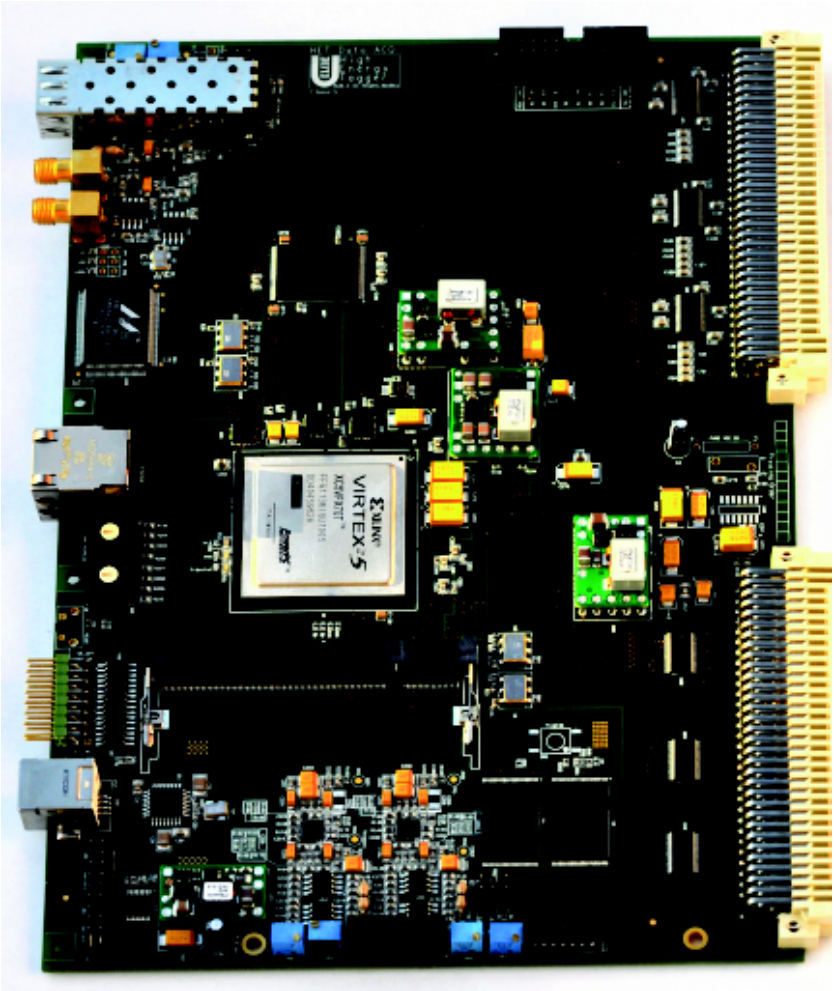
in KLOE

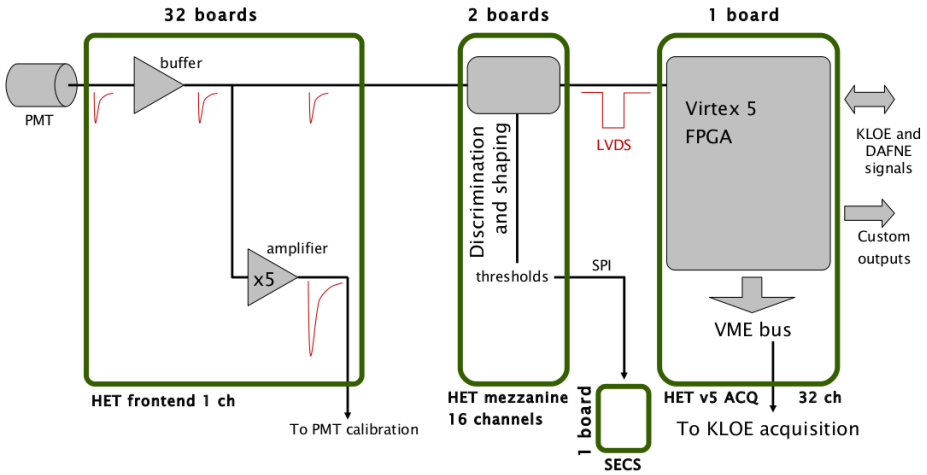


Energy of leptons vs Distance from the nominal orbit



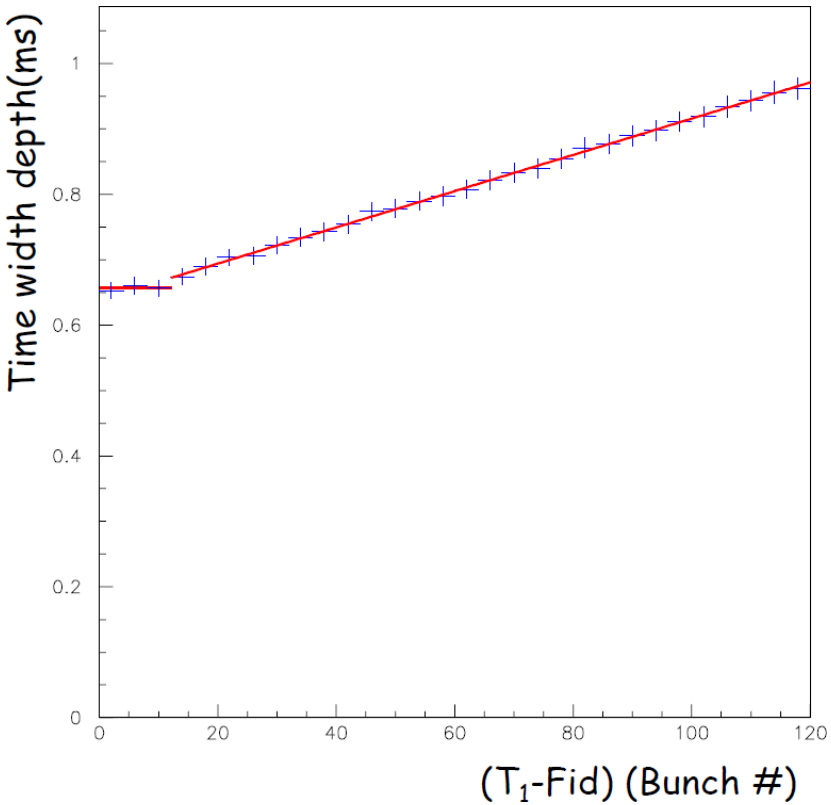
The HET DAQ



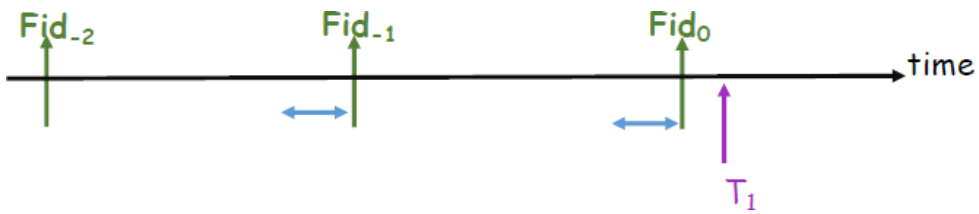


- ⋆ Discriminator provides output signal with a width of ∼2 ns → possibility to discriminate 2 consecutive bunches in DAΦNE ($\Delta T_{\text{bunch}} = 2.7$ ns)
- ⋆ TDCV5 uses custom logic in order to manage signals from HET-DAΦNE and KLOE
- ⋆ KLOE and HET acquisition systems are asynchronous: we use the Fiducial provided by DAΦNE (radio-frequency signal) which is in phase with respect to the first bunch circulating in DAΦNE
- ⋆ The HET do not provide trigger to KLOE
- ⋆ We read the history of the HET in turn of DAΦNE only when a valid KLOE trigger (T_1) is asserted

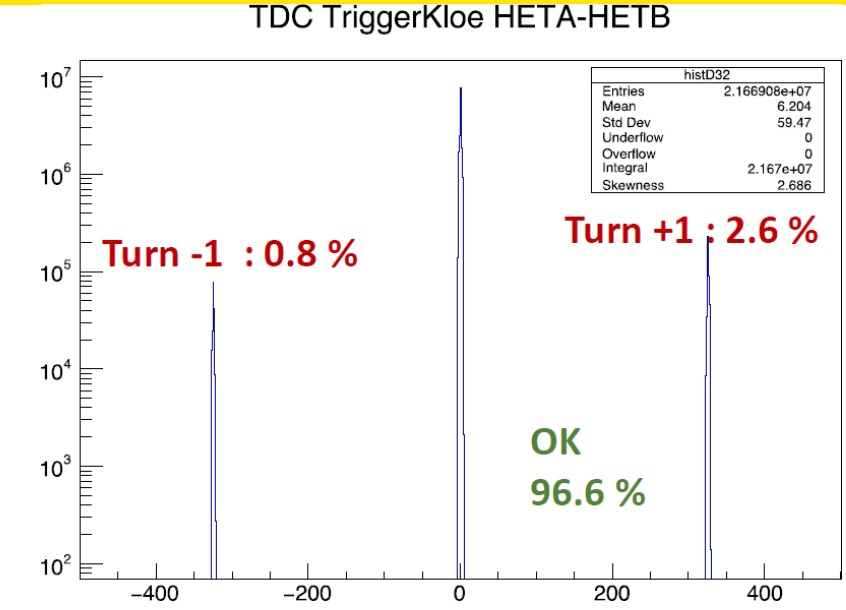
The HET DAQ

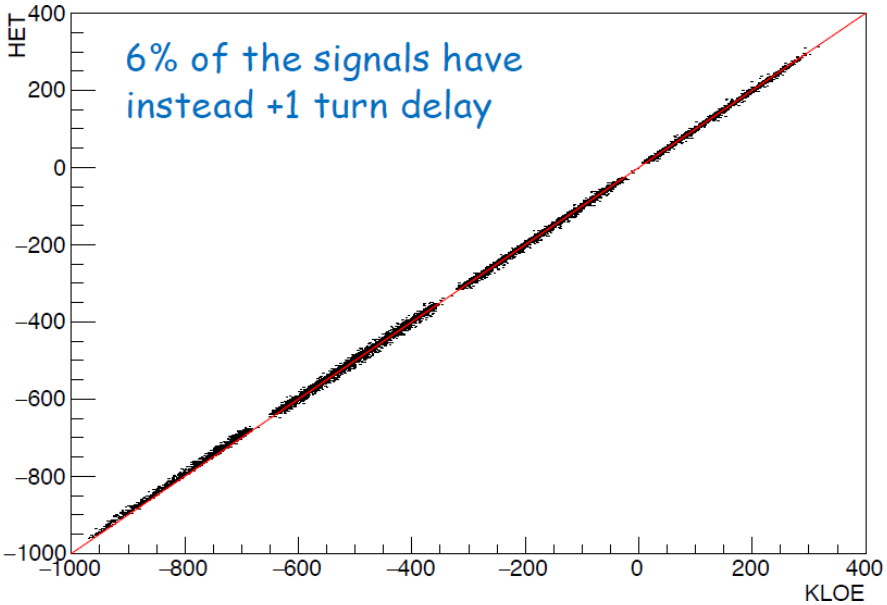


- ⋆ HET data acquisition system has been designed to register hits from two complete machine turns plus the part of a third turn preceding the trigger signal from KLOE
- ⋆ The time-depth for the HET data recording has been measured as a function of the delay between KLOE trigger and the Fiducial and ranges from 660 to 970 ns

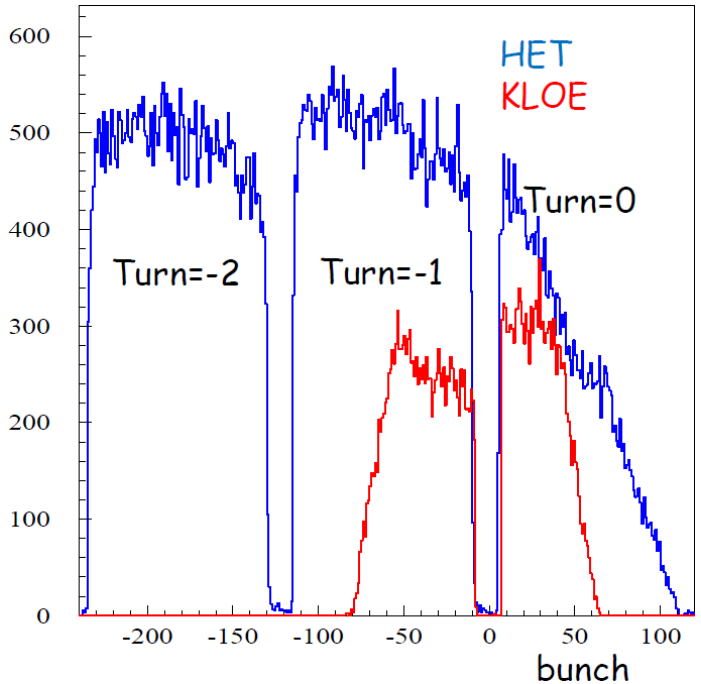


The HET Synchronization





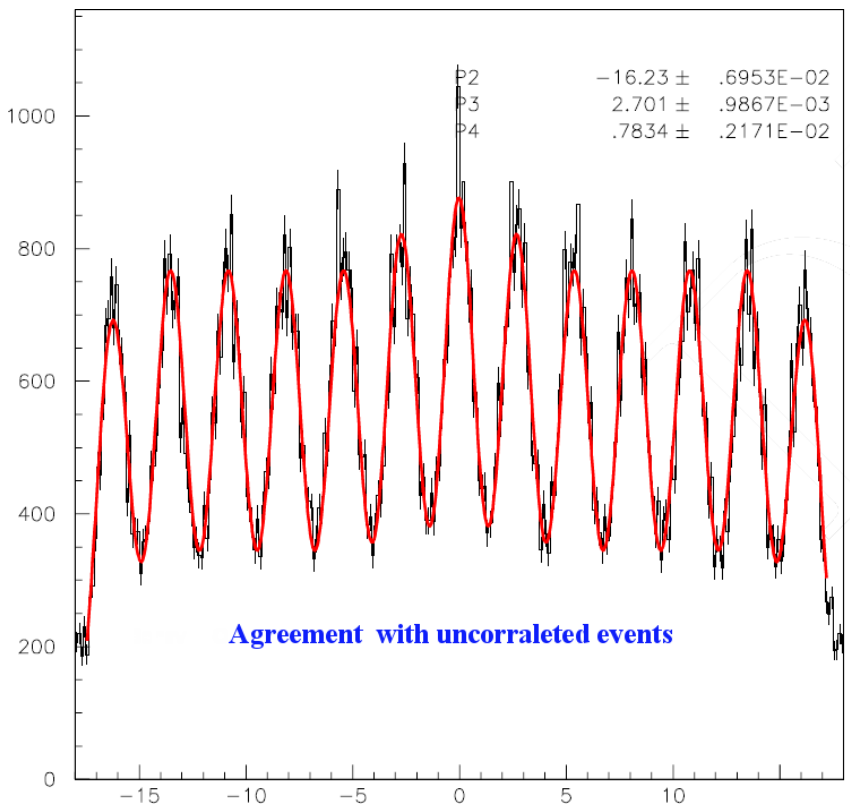
- A global delay is used for each TDCV5 in order to shift the Fiducial signal used as common start
- We acquire also the KLOE trigger T1 in both HETs
- These signals have to be found at the same TDC channel in the first DAΦNE turn for both HETs.
- The long plastic scintillator from HETs is also acquired by the TDC of KLOE trigger



Operation of the HET detector

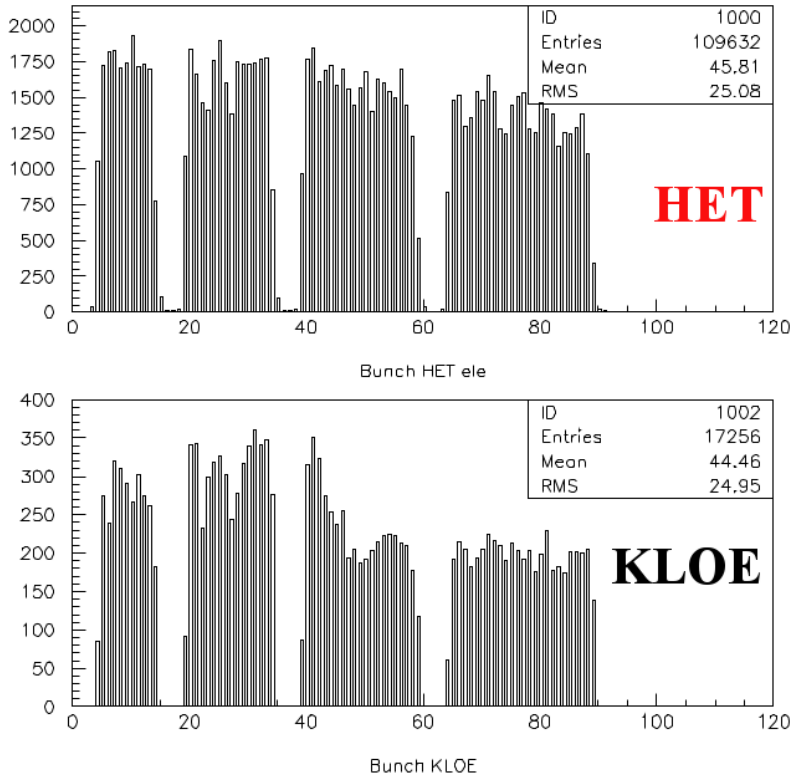
The HET has been operated since the very beginning of the KLOE-2 data-taking

Hit delay distribution between HET ele-pos
Fit performed with 13 Gaussian of same σ



Time resolution is σ_t=550(1)ps

DAΦNE Bunch structure as measured by the HET and KLOE central detector



Hardware Efficiency:

- ⋆ Scintillators + PM : eff. $\sim$ 100%
- ⋆ eff. discr. chan. : 70(60)% for e^- (e^+) side

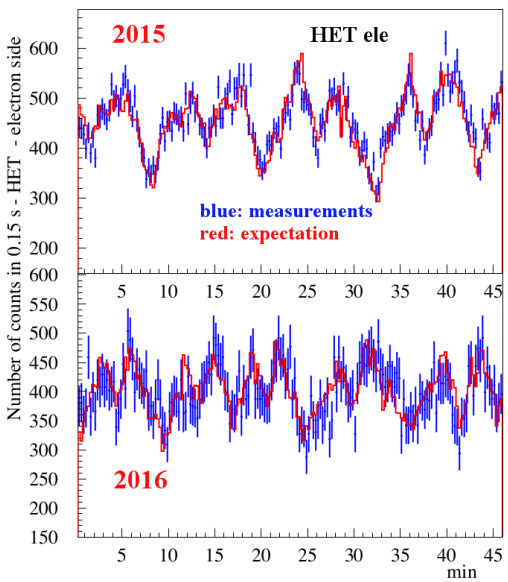
New discriminators have been installed at the beginning of 2017

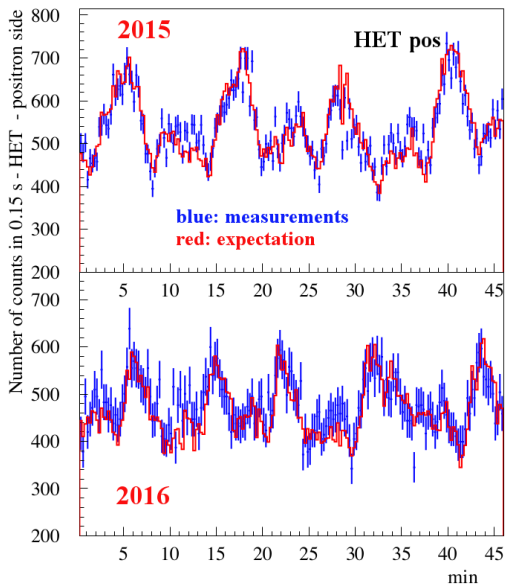
Operation of the HET detector

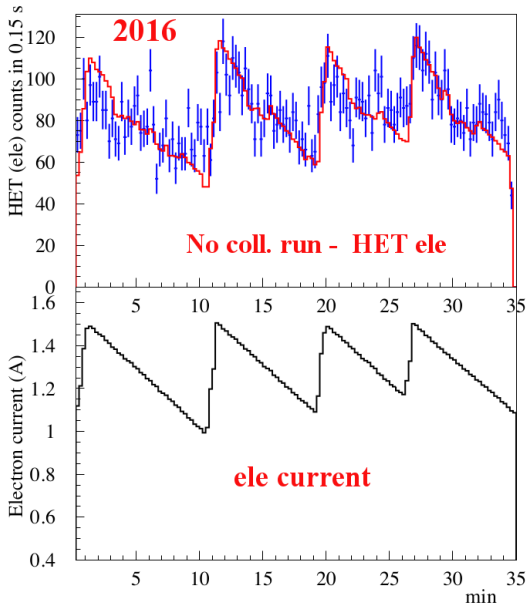
Luminometer detector: fast and reliable feedbacks on the machine operation

Rates dominated by single-arm Bhabha's (Touschek $\sim 45\%(15\%)$ for $e^-(e^+)$)

$$R_{\rm HET} = \frac{R_{\rm trig}}{\rm kHz}\left(\alpha_{\rm L_{e,p}}\frac{\rm Lumi}{0.2{\rm nb}^{-1}{\rm s}^{-1}} + \beta_{\rm e,p}\frac{I^2_{\rm e,p}}{A^2}\right)$$



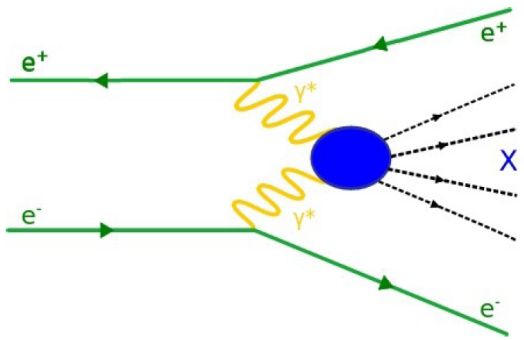


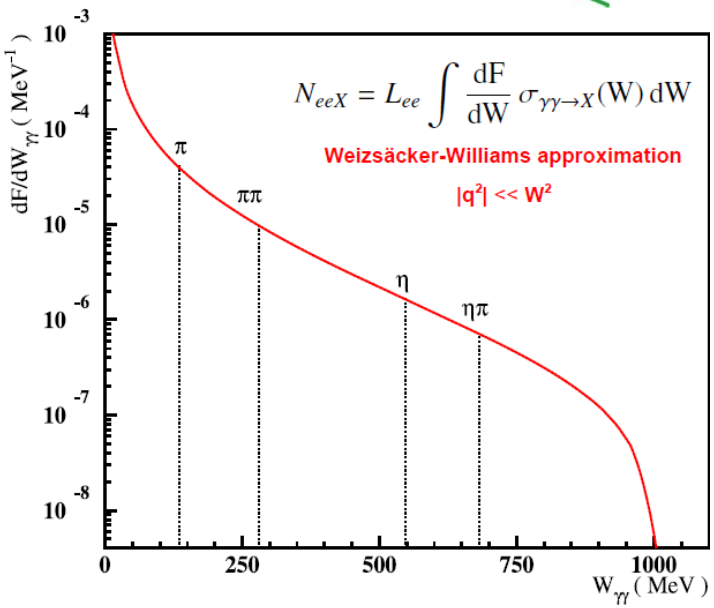


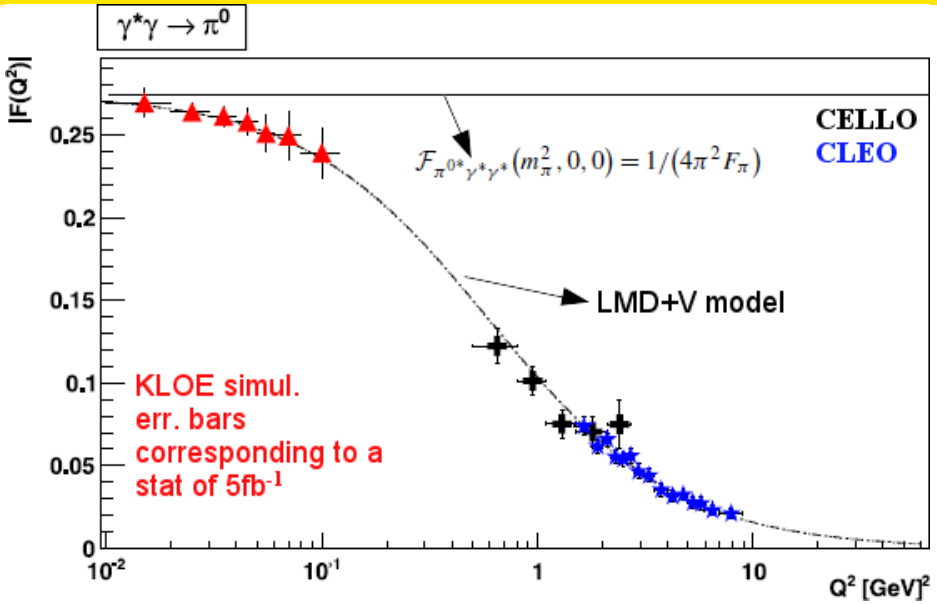
$\gamma\gamma$ Physics at KLOE-2 : Motivations

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

for quasi-real photons $J^{PC}(X) = \{0^{\pm,+}, 2^{\pm,+}\}$
$\to X = \{\pi^0, \pi\pi, \eta\}$

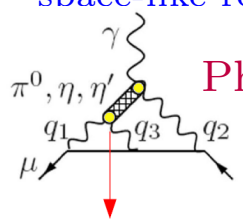






Physics goal:

- Precision measurement (1%) of the $\Gamma_{\pi^0\to\gamma\gamma}$
  $\Gamma^{\text{Th.}}_{\pi^0\to\gamma\gamma} = 8.09 \pm 0.11$eV (1.4% precision) while
  $\Gamma^{\text{PDG}}_{\pi^0\to\gamma\gamma} = 7.74 \pm 0.48$eV (6.2% precision due to meas incompatibility)
  $\mathcal{O}(10^4)$ $\gamma\gamma$ events expected for L= 5fb^{-1}
- First measurements of the $F_{\pi^0\gamma^\star\gamma}(q^2, 0)$ in the space-like region for $q^2 < 0.1\,\text{GeV}^2$



Physics motivation:
impact on the value and precision of the $a_\mu^{\text{LbyL};\pi^0}$

$\gamma\gamma$ Physics at KLOE-2: π^0 search

More than 500 pb^{-1} of integrated lumi have been processed so far and 2TB of pre-filtered data have been produced

Double-Arm events (DA) $\rightarrow$

coincidence btw HET stations ($\pm$ 1 bunch expected from resol studies, $\Delta T_{\rm bunch} \sim$ 2.7ns , <1% of KLOE triggers)

control sample of events with $2 \leq \Delta T_{ep} \leq 7$ bunches

Single-Arm events (SA) $\rightarrow$

in time with KLOE trig ($-3 \leq \Delta T_{\rm tri-clu} \leq 8$ bunches)

in time with a bunch with 2 clu in the barrel $20 < E_{clu} < 300$ MeV

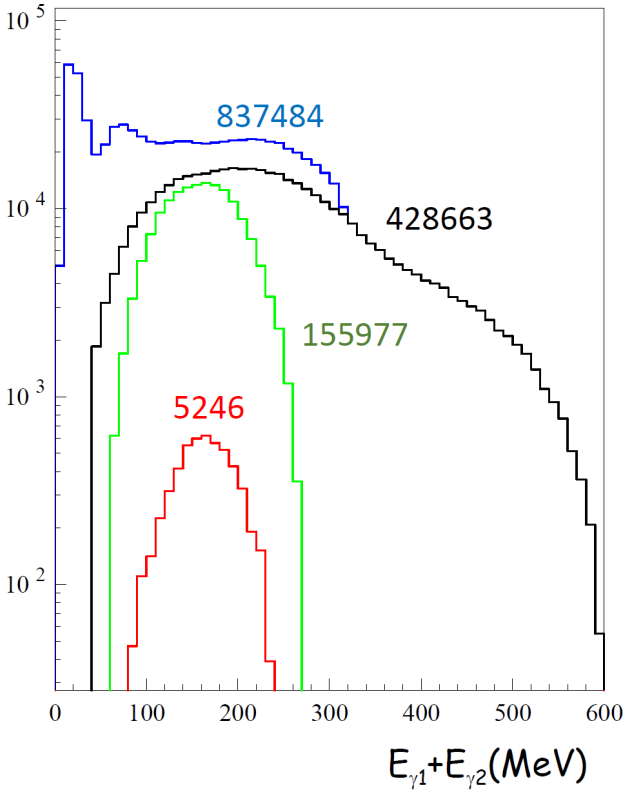
$\Delta T_{\rm KLOE_{clu}-HET} \leq 4$ bunches

Fine inter-calibration of HET and KLOE TDCs based on bunch structure seen by the KLOE EMC and HET (shift of $\pm 1 - 2$ bunches induced by the EMC time calib)

A sample of $\sim$ 550 pb^{-1} of DA events is being analyzed to search for π^0 production almost at rest

$\gamma\gamma$ Physics at KLOE-2: π^0 search

Statistics: 10^8 fully-reconstructed events
$\rightarrow$650 $\gamma\gamma$ events expected from EKHARA and BDSIM simu + trig (65%) and detector eff.



Bckg simulation based on machine bckg meas is in progress

Bckg meas is being done run-by-run using an "untagged" data sample containing events out of the coincidence window with taggers and KLOE

Analysis of the π^0 candidates requires:

(a) coincidence btw taggers hits : $|\Delta_{ep}| < 2$ bunches and in time with the KLOE trig

2 KLOE clu associated with the same bunch with $\Delta T_{\mathrm{KLOE_{clu}-HET}} \leq 4$ bunches

$E_\gamma < 300$ MeV

(b) $E_\gamma > 20$ MeV (events that can trigger the KLOE DAQ)

(c) $30 < E_\gamma < 135$ MeV

(d) $P_{\pi^0} < 90$ MeV

$\cos\alpha_{\gamma\gamma} < -0.8$

$80 < M_{\gamma\gamma} < 230$MeV

$|\Delta T - \Delta R/c| < 1.1$ ns

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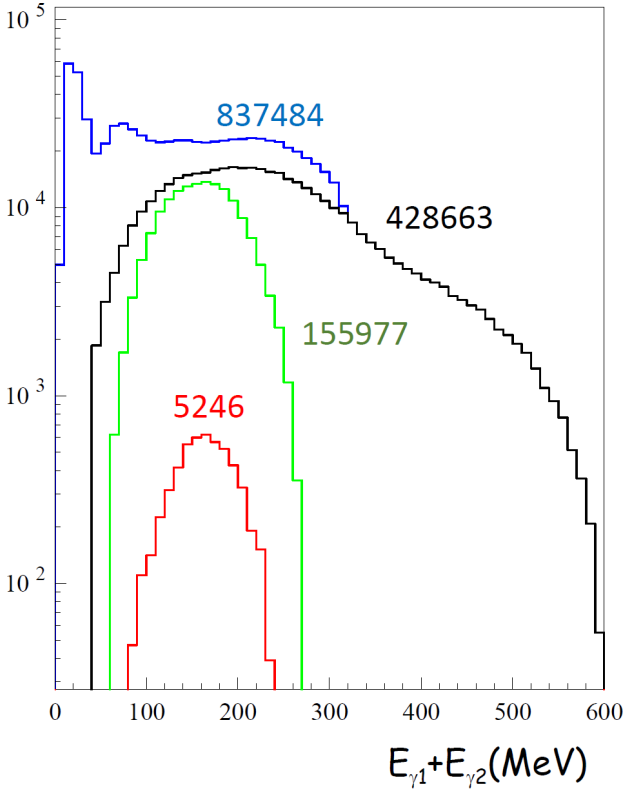

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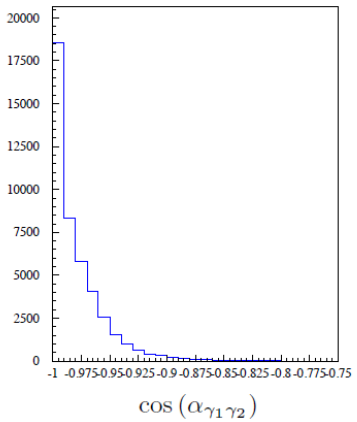
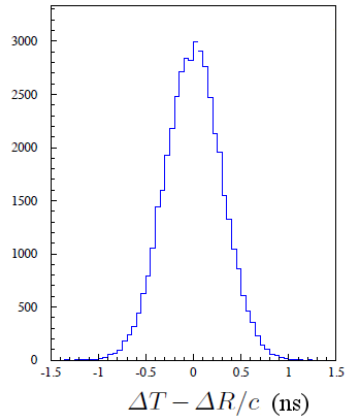
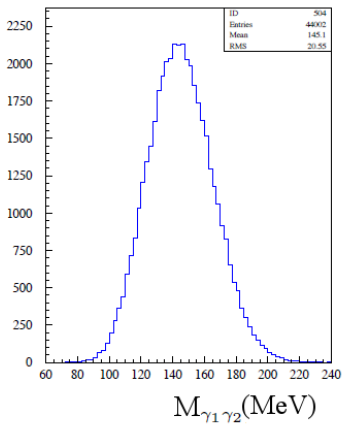
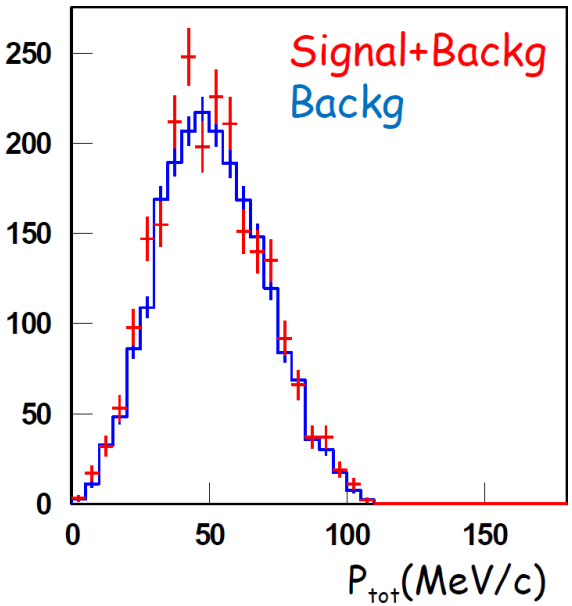
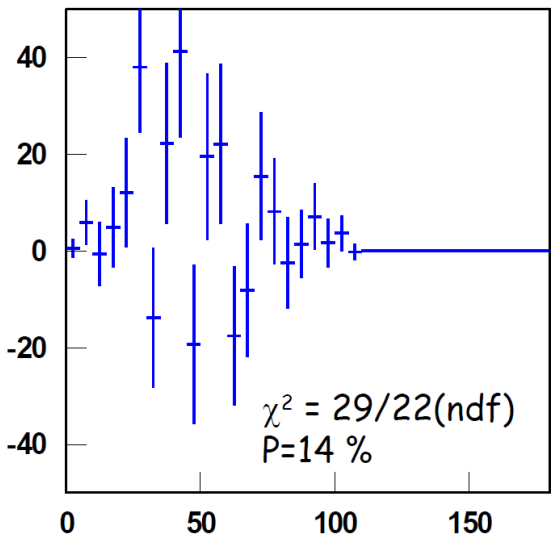






$\gamma\gamma$ Physics at KLOE-2: π^0 search





- ⋆ Bckg estimation done run by run by using an "untagged" data sample (DA events which are out of coincidence window with taggers and with KLOE DAQ)
- ⋆ Bckg normalization done using the data to bckg ratio in the supposed signal free region ($1.1 < |\Delta T - R/c| < 2.2$ ns)
- ⋆ No significant excess can be seen in the Ptot distribution
- ⋆ We are addressing some issues that can be the source of lack of signal (HET acceptance, simulation issues, KLOE magnet field)
- ⋆ In the meanwhile we are carrying out also the analysis of SA events

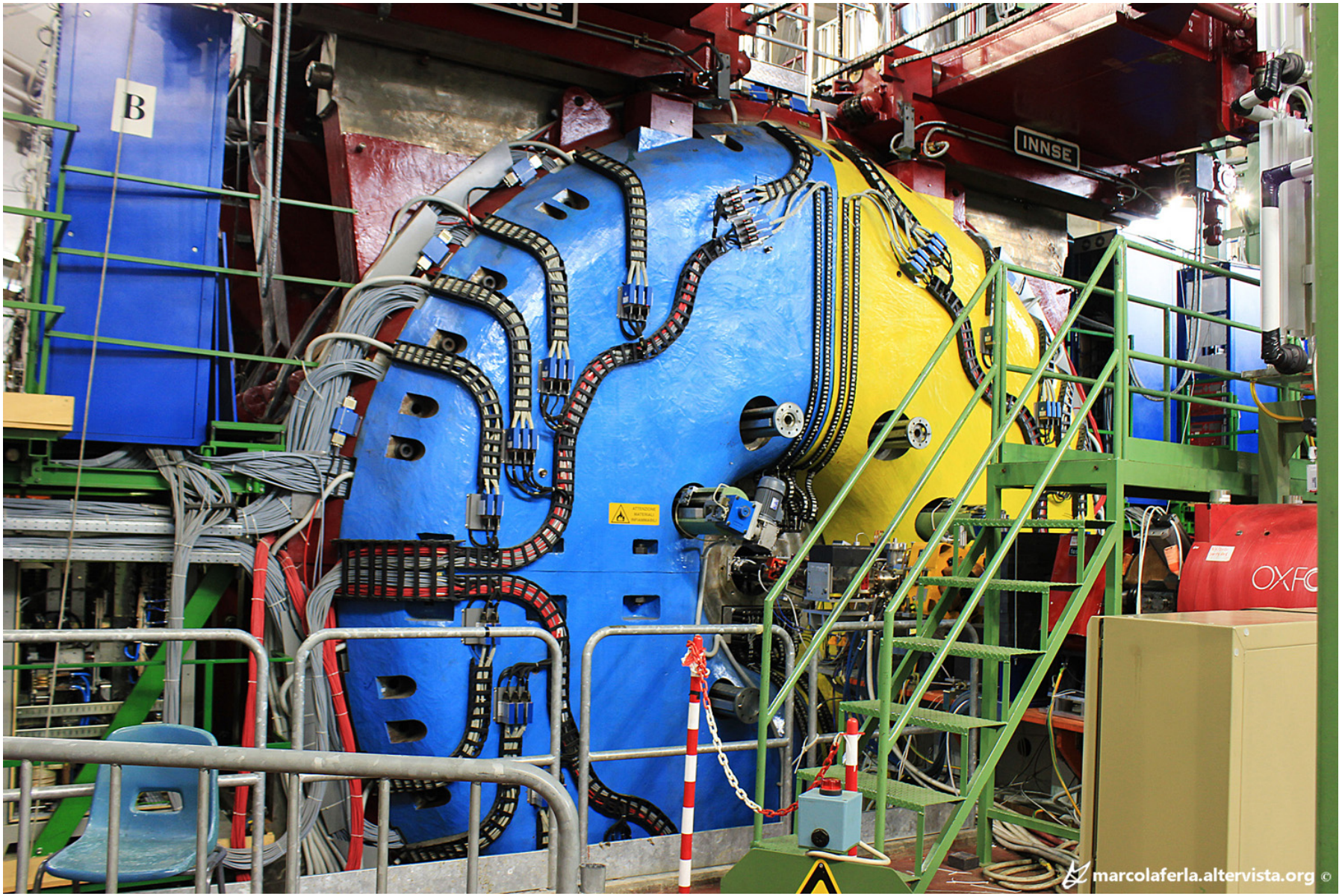
Conclusions

- ⋆ HET stations are completely noiseless
- ⋆ The timeline of the counting rate for electron and positron stations shows only 2 visible contributions : from luminosity and from Touschek particles
- ⋆ Machine background reaches a maximal relative contribution of 45% for electron and 15% for positron beams
- ⋆ The total rate dominated by Bhabha scattering is at the level of 500-600 kHz
- ⋆ We have pre-filtered candidates of single-π^0 production from $\gamma\gamma$ scattering. A total of about 500 pb^{-1} are being analyzed
- ⋆ We are addressing several issues that can be the source of lack of signal

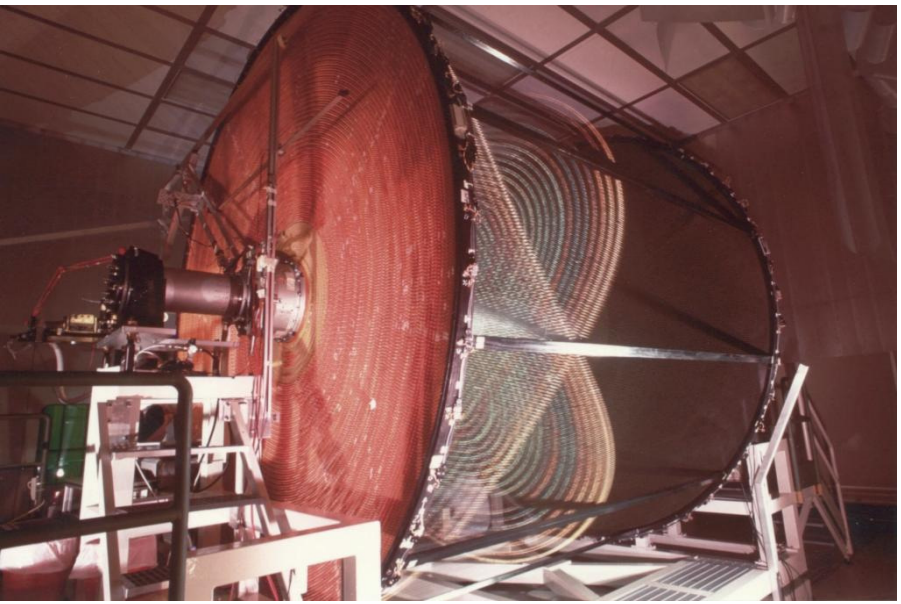
Thank You!

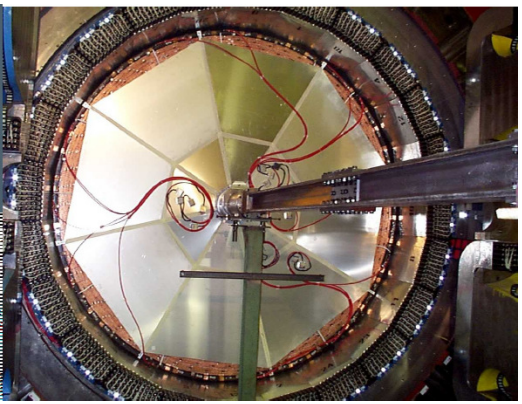
SPARES

The KLOE Detector



The KLOE DC





$\sigma_{xy} \sim 150\mu m$

$\sigma_z = 2mm$

$\sigma_{p_\perp}/p_\perp \sim 0.4\%$ (LA tracks)

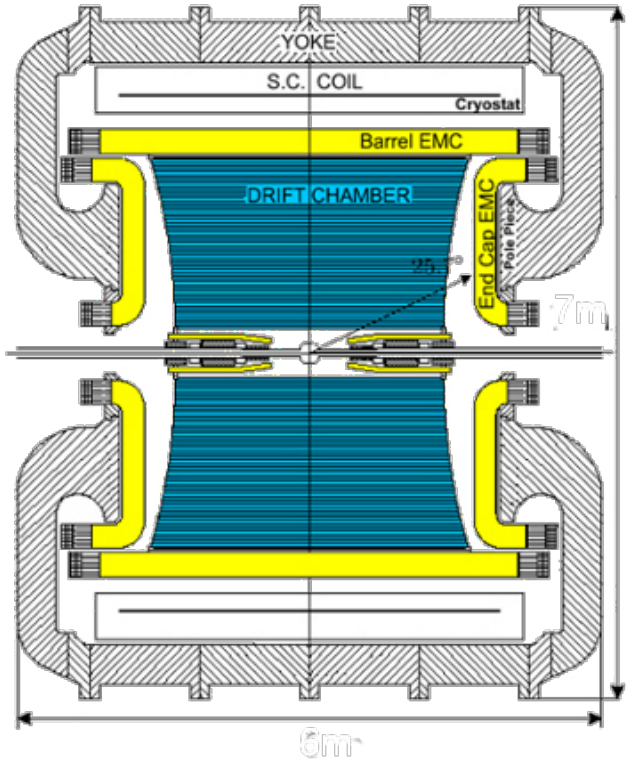
vertex resolution $\sim$3mm

12,000 sense wires

Stereo geometry

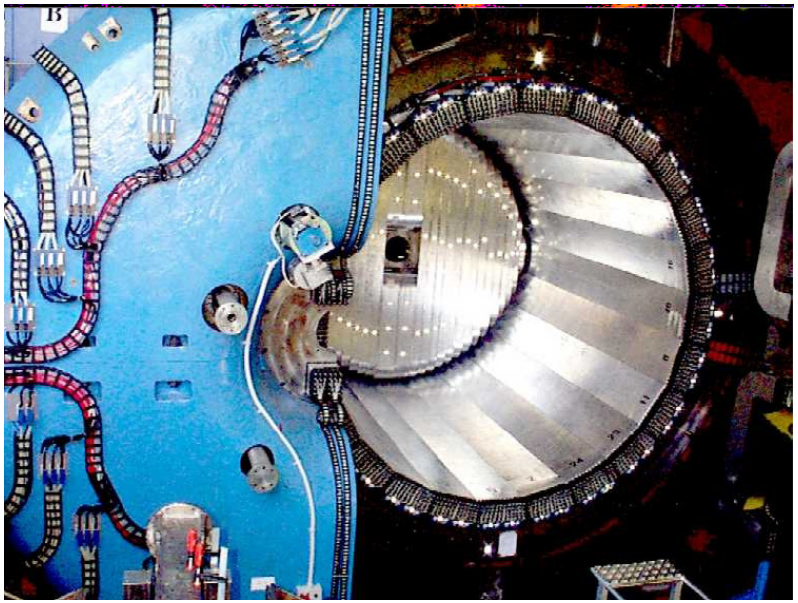
4m diameter, 3m long

gas mixture: 90% He 10% iC_4H_{10}



Excellent momentum resolution

The KLOE EMC



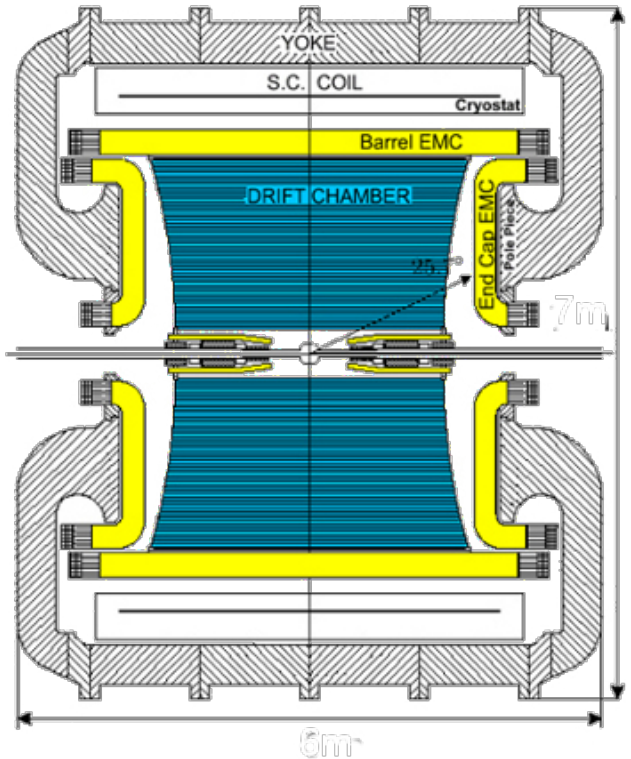
End-caps C-shaped to minimize dead zones: 98% coverage of full solid angle

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

$\sigma_T = 54ps/\sqrt{E(GeV)} \oplus 140ps$

Barrel + 2 end-caps:

Pb/scintillating fiber, 4880 PM



Excellent time resolution

The KLOE sub-detectors

INNER TRACKER:

- four layers of cylindrical triple GEM
- better vertex reconstruction near IP
- higher acceptance to low p_t tracks

CCALT:

- LYSO crystal + SiPM
- increase of angular acceptance to γ's from IP from 21° to 10°

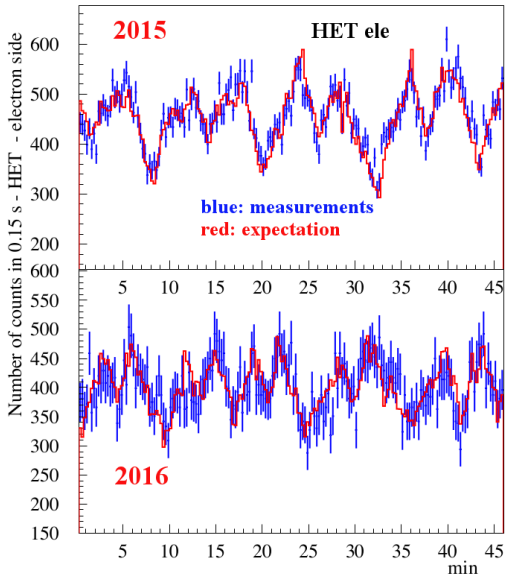
QCALT:

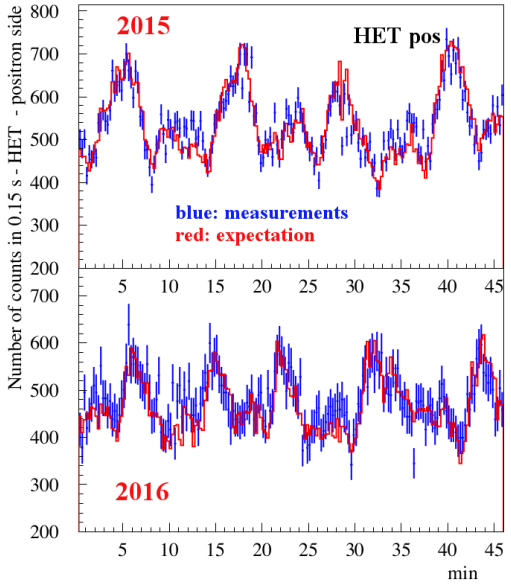
- W + Scintillator tiles+ WLS/SiPM
- QUADS coverage for K_L decays

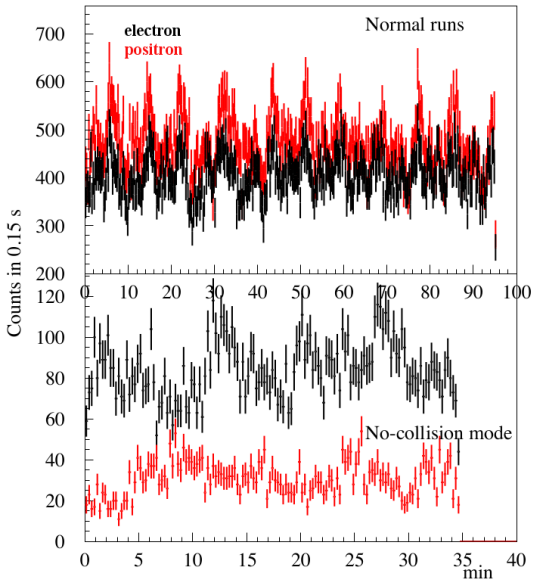
LET and HET :

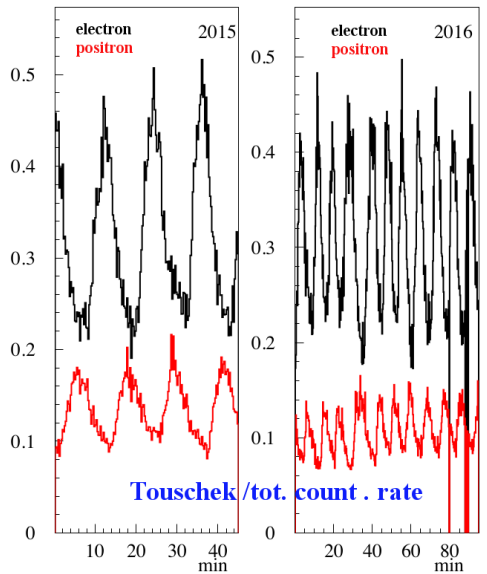
- Low and High energy tagger stations for e^+e^- coming from two-photon interaction
- LET: LYSO + SiPM
- HET: EJ228 plastic scinitllator hodoscope + Xilinx Virtex-5 FPGA

Operation of the HET detector

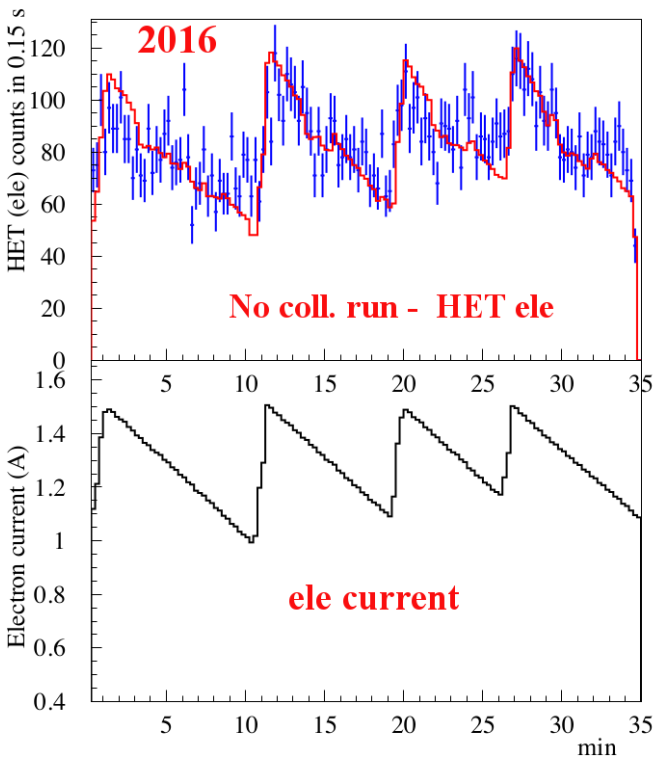


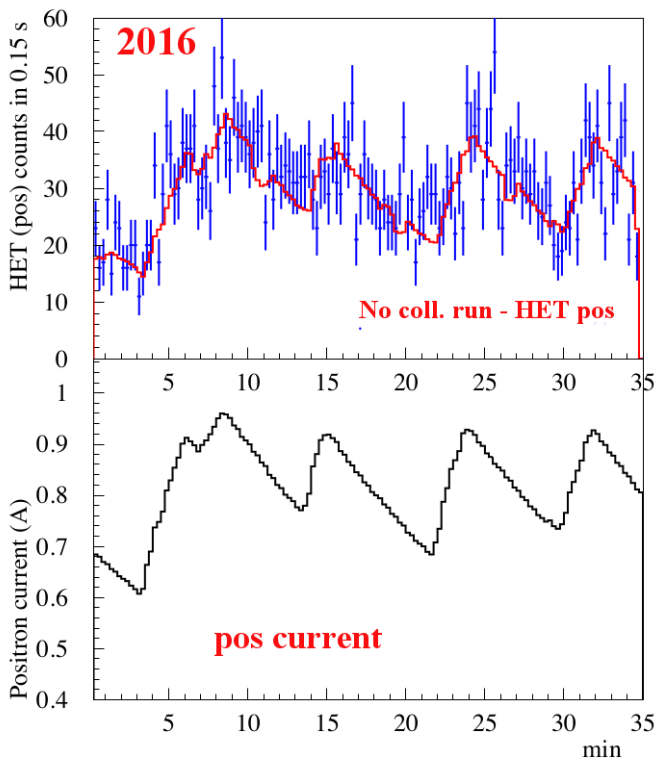






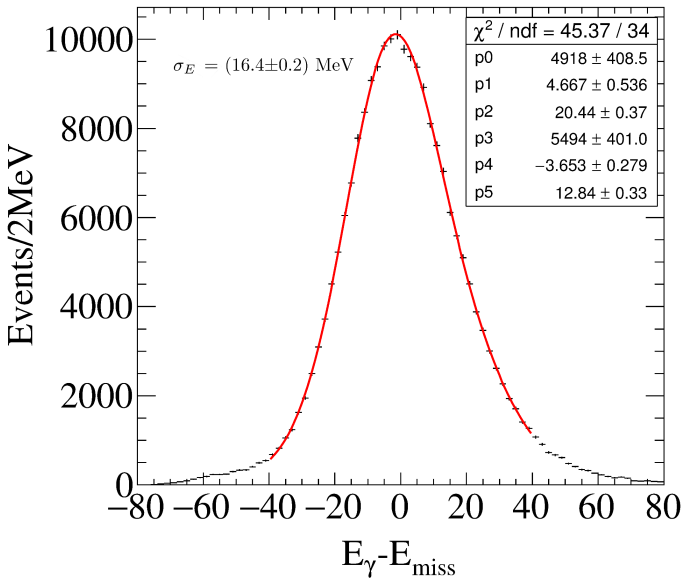
Operation of the HET detector

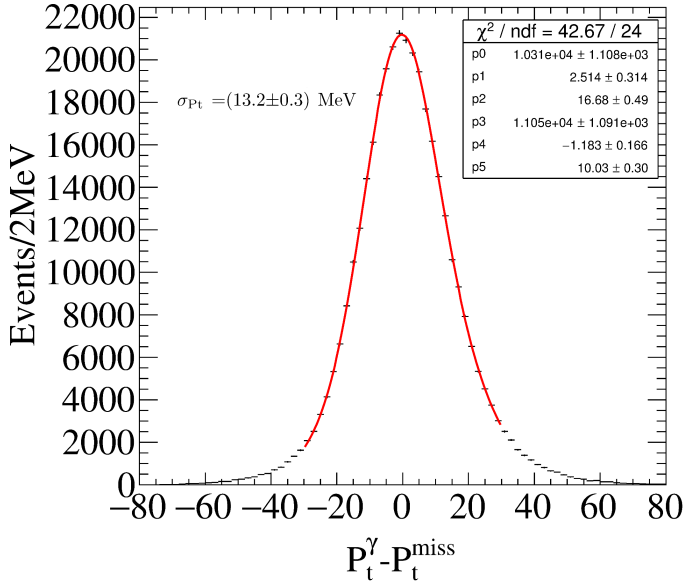


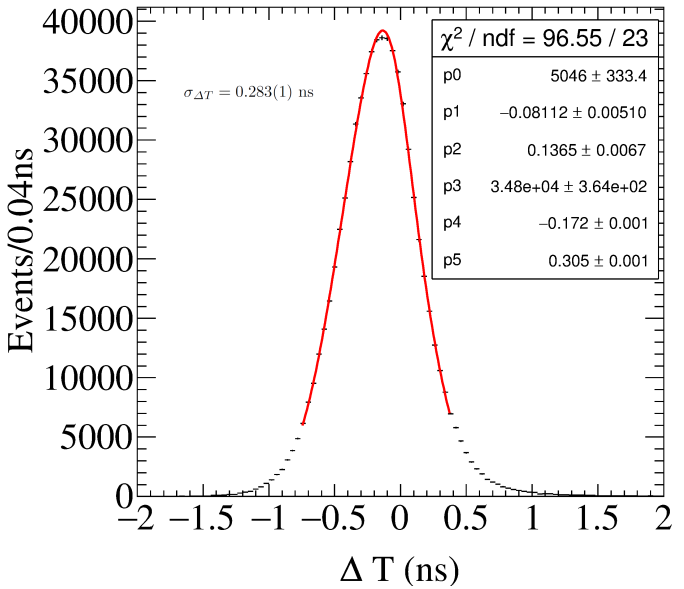


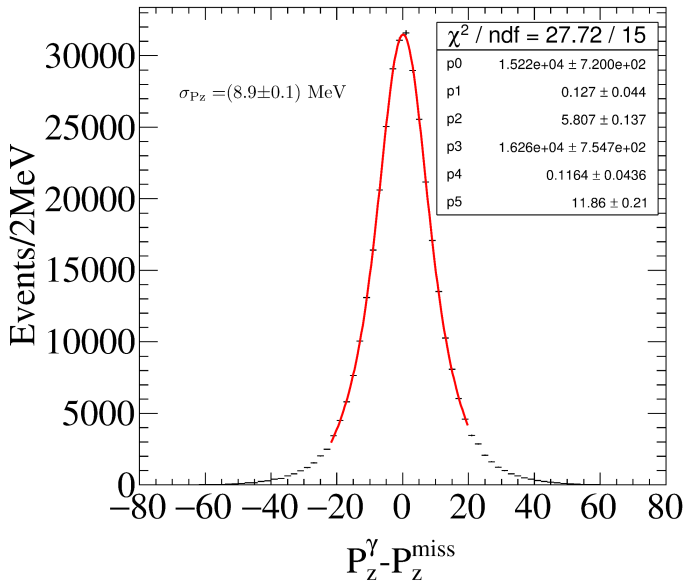
Resolution studies

Energy, momenta and time resolutions on 70 MeV energy photons. The study was performed by means of a control sample of radiative Bhabhas



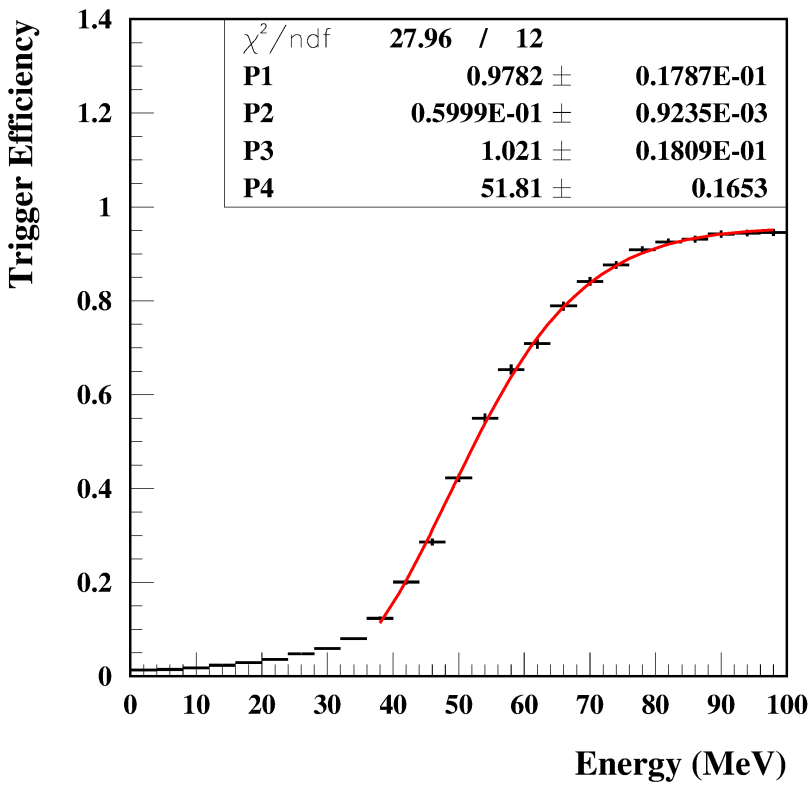


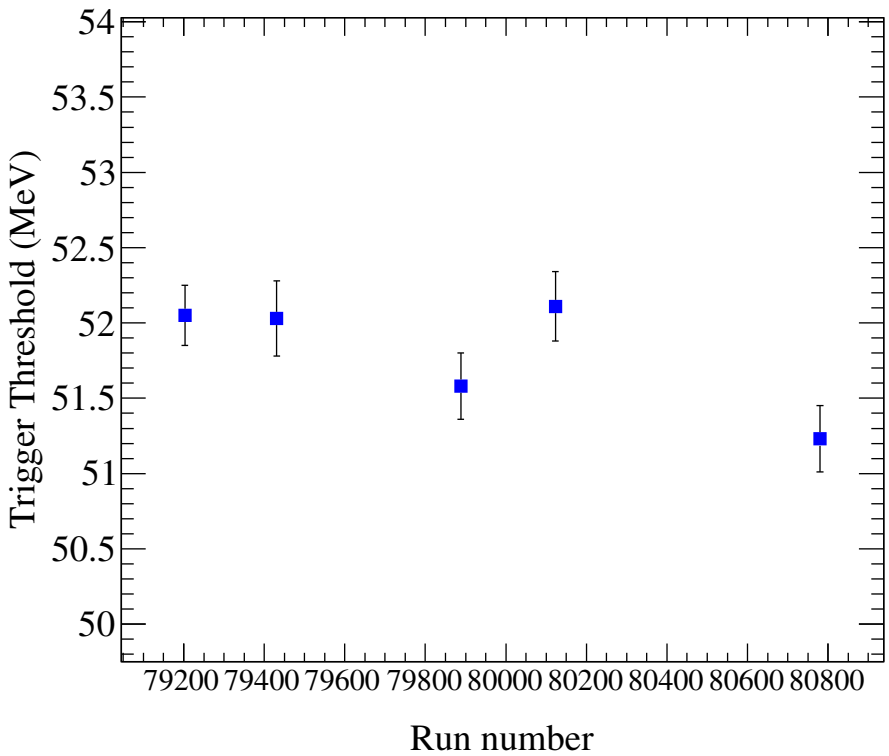




Trigger efficiency

Study based on a control sample of radiative Bhabhas

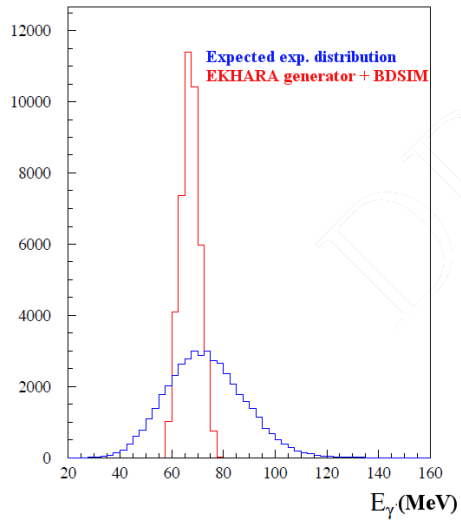


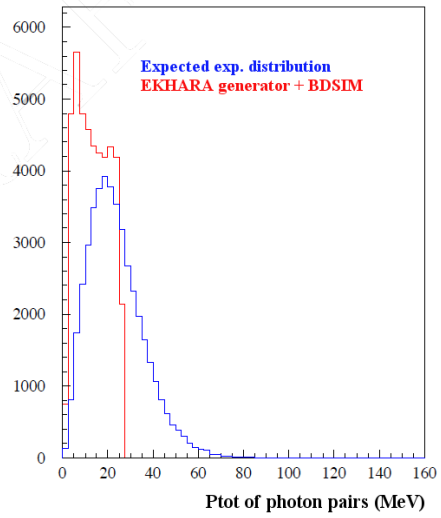


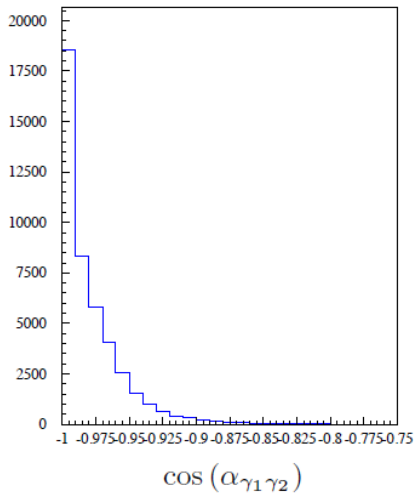
Trigger eff on 70 MeV energy photons is of about 80%

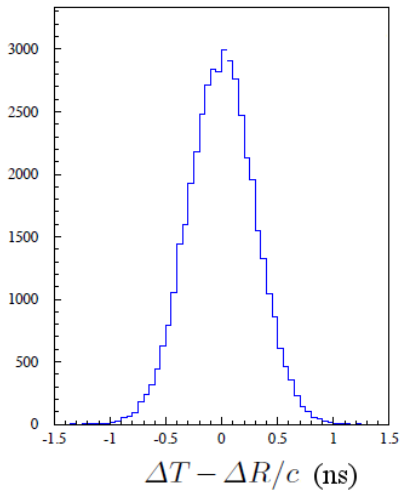
Stability of the trigger threshold over the running period November 2015–January 2016

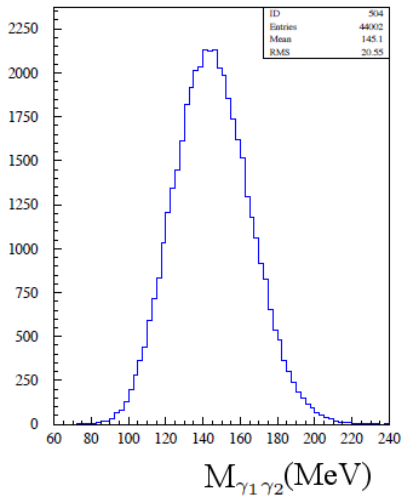
EKHARA simulation







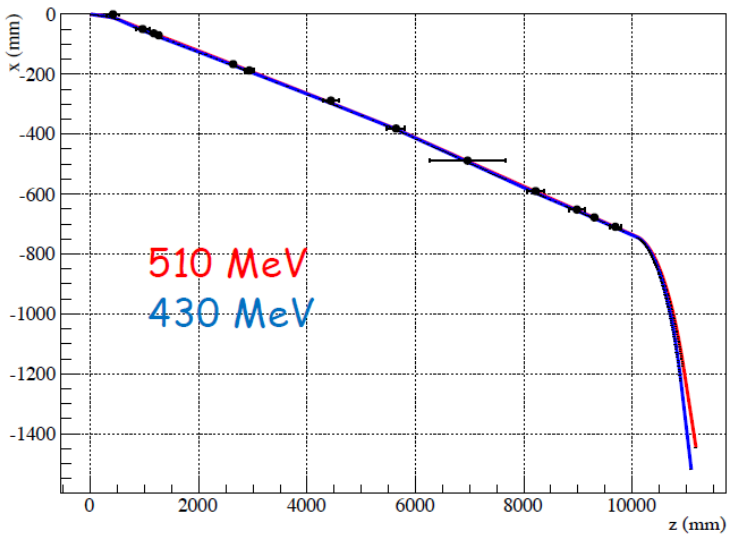


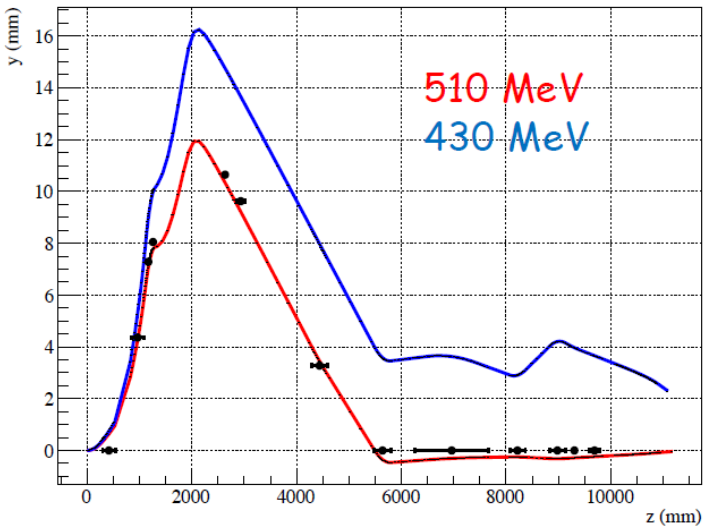


The simulated experimental distributions take into account calorimeter energy resolution and trigger threshold as measured on control samples of radiative Bhabhas.

BDSIM

Gent4 toolkit used to transport lepton through the DAΦNE magnetic lattice from IP up to HET position locate after 11 m





KLOE axial B field produce vertical shift (e^+, e^-) of off energy leptons

Cross Sections

HET Expected events with L_{int} = 5 fb^{-1}

	σ	HET Acceptance Single Arm Double Arm	σ_{eff}(pb) Single Arm Double Arm	N_{ev} Single Arm Double Arm
$e^+e^- \to e^+e^-\pi^0$	273.4 pb	7.9 % - 1.0 %	21.81 - 2.71	109050 - 13550
$e^+e^- \to e^+e^-\pi^0\pi^0$	11.7 pb	6.5 % - 0 %	0.76 - 0	3800 - 0
$e^+e^- \to e^+e^-\pi^+\pi^-$	749.7 pb	5.8 % - 0 %	43.5 - 0	217500 - 0
$e^+e^- \to e^+e^-\mu^+\mu^-$	11.5 nb	10.1 % - 0 %	1160 - 0	5827700 - 0

KLOE Trigger Efficiency should be included