The KLOE-2 Experiment

@ DAΦNE upgraded in luminosity

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On behalf of the KLOE-2 collaboration

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INFN Istituto Nazionale di Fisica Nucleare

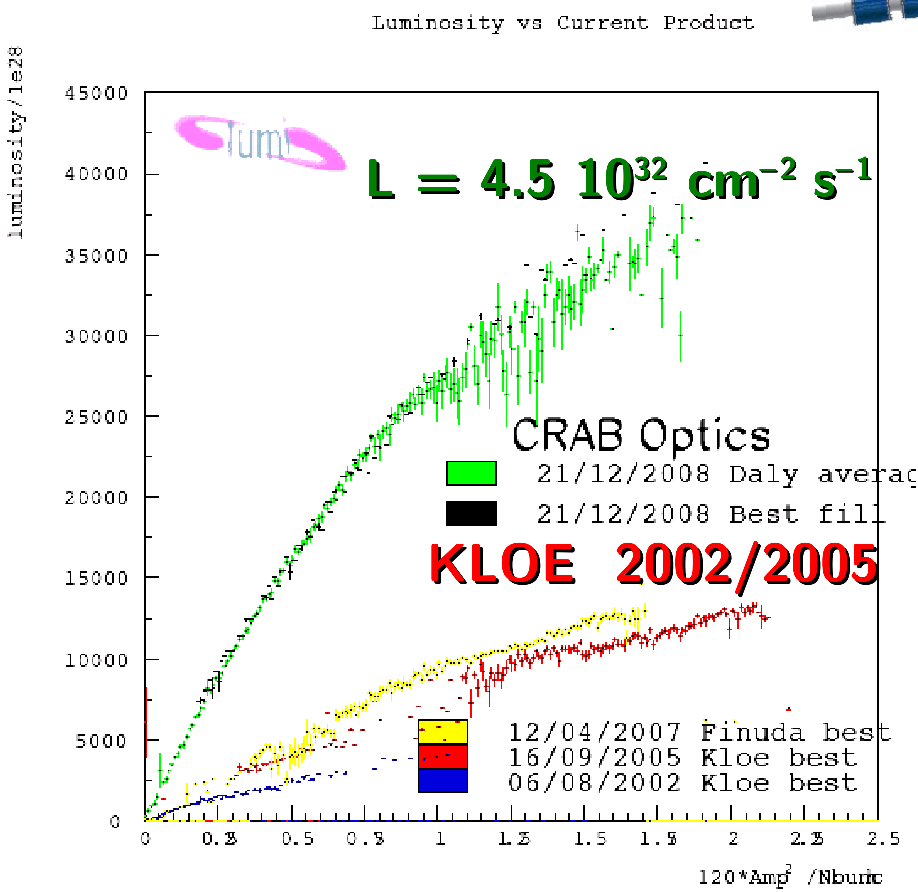
Laboratori Nazionali di Frascati

Outline

- DAΦNE upgrade
- KLOE detector and the upgrade to KLOE-2
- STEP-0: the $\gamma\gamma$ physics and taggers
- STEP-1: the Inner Tracker, tile and crystal forward calorimeters

DAΦNE upgrade

Frascati ϕ-factory: e^+e^- collider @ $\sqrt{s} \approx 1.02$ GeV $\approx M_\phi$; $\sigma_{peak} \sim 3$ μb



New interaction schema has been implemented and tested with **SIDDHARTA experiment in 2008/09**:

- Larger beam crossing angle and crab-waist sextupoles
- Luminosity increase a factor ~3
- $\int L dt \sim 1$ pb^{-1}/h

With the new configuration ~5 fb^{-1}/y can be delivered.

KLOE-2 physics program

KLOE has achieved precision results in kaon and hadron physics:

- Measurement of all BR's of K_S, K_L and $K^{\pm}$
- Study of scalar and pseudoscalar mesons
- Measurement of $e^+e^- \rightarrow \pi^+\pi^-(\gamma)$ cross section and obtained most of the dipion hadronic contribution to the muon anomaly

The KLOE-2 program includes improvements on many measurements and prospects for new items: KLOE-2 Physics paper: arXiv:1003.3868 (to be published by EPJC)

- Study of $\gamma\gamma$-physics based on sample tagged by new detectors for detecting leptons from the process $e^+e^- \rightarrow e^+e^- X$.
- Search for particles from "hidden sectors" that might explain dark matter.
- Precise measurements of the hadronic cross section near $\pi\pi$-threshold.

HIGH ENERGY PROPOSAL: upgrade in energy of the collider (from 1.02 GeV to 2.5 GeV)

Proposal for taking data with the KLOE-2 Detector at the DAΦNE collider upgraded in energy, LNF-Note 10/17(P)

The KLOE detector

Lead/scintillating-fiber calorimeter:

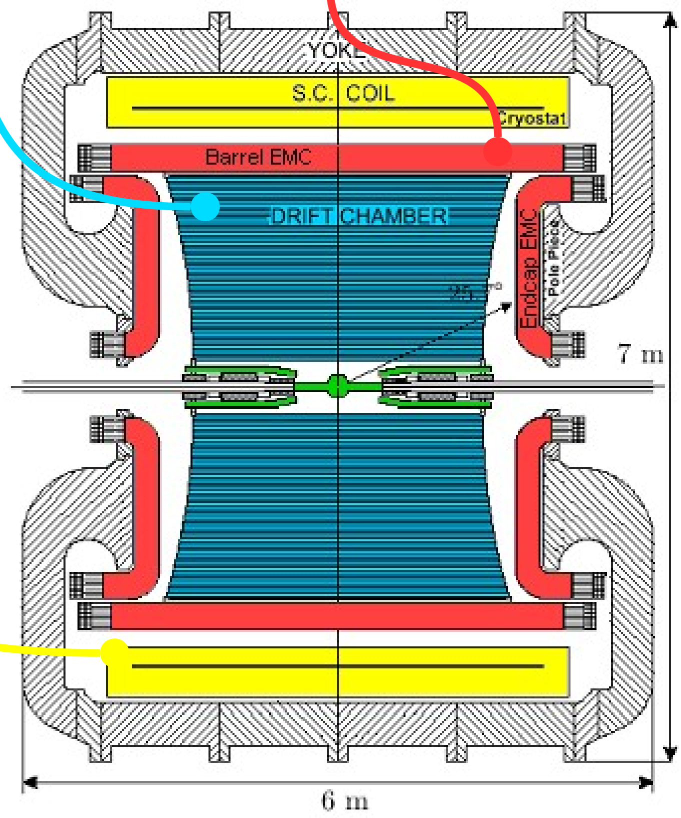
- $\sigma_E/E = 5.7\% \;/\; \sqrt{E(\text{GeV})}$
- $\sigma_t = 54 \text{ ps} \;/\; \sqrt{E(\text{GeV})} \oplus 100 \text{ ps}$
- 98% coverage of solid angle

Large cylindrical drift chamber:

- 4 m diameter – 3.7 m length
- Light structure: carbon-fiber & gas: 90% He – 10% $IsoC_4H_{10}$
- $\sigma_p/p = 0.4$ % (track with $\theta > 45°$)
- $\sigma_{vtx} \sim 3$ mm

Superconducting coil:

- $\langle B \rangle = 0.52$ T



During 2001-2006 KLOE has collected $\sim 2.5\ \text{fb}^{-1}$ of data at ϕ-peak and $250\ \text{pb}^{-1}$ off-peak ($\sqrt{s} = 1$ GeV).

KLOE roll-in

On April 2010, the KLOE detector has been moved back onto the DAΦNE beamline.

Detector maintenance on Drift Chamber, Electromagnetic Calorimeter have been now completed.

Data Acquisition System updated. Ready to take data.

B-field switched-on last week, calibration with cosmic-ray.

Status and the future...

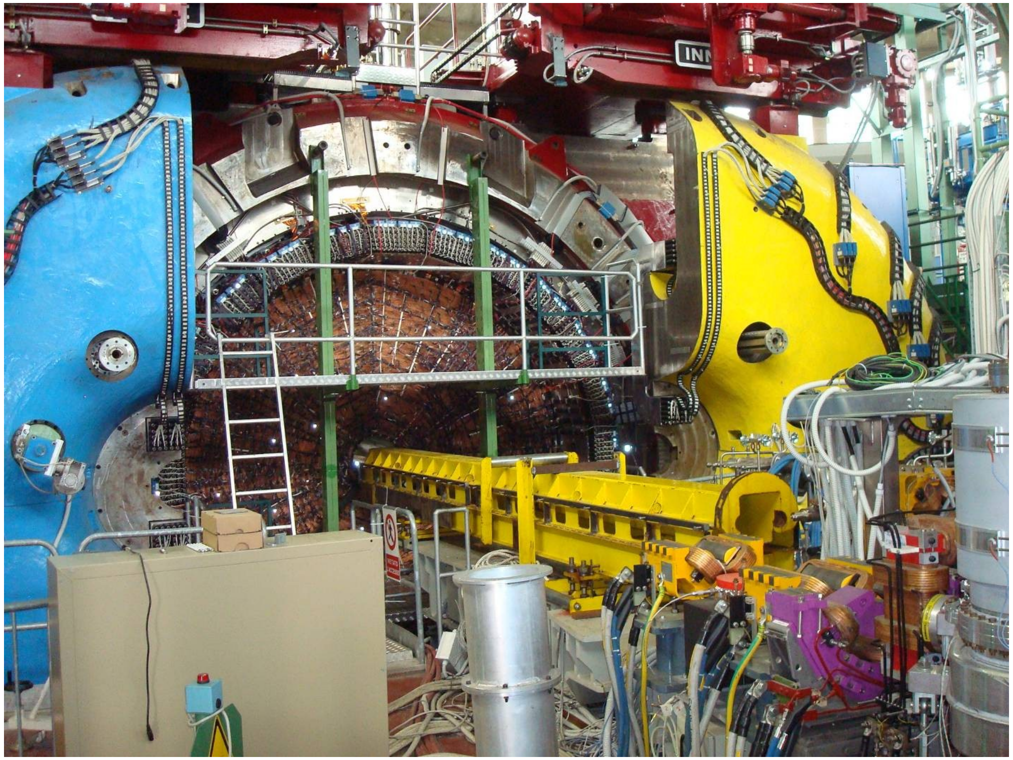
DAΦNE has begun commissioning.

First collisions are foreseen in September.

Upgrades of the KLOE detector:

STEP-0: Lepton tagging system for $\gamma\gamma$-physics LET and HET

STEP-1: 3 new detectors will be inserted, QCALT, CCALT and the IT (advanced status, insertion by fall 2011)

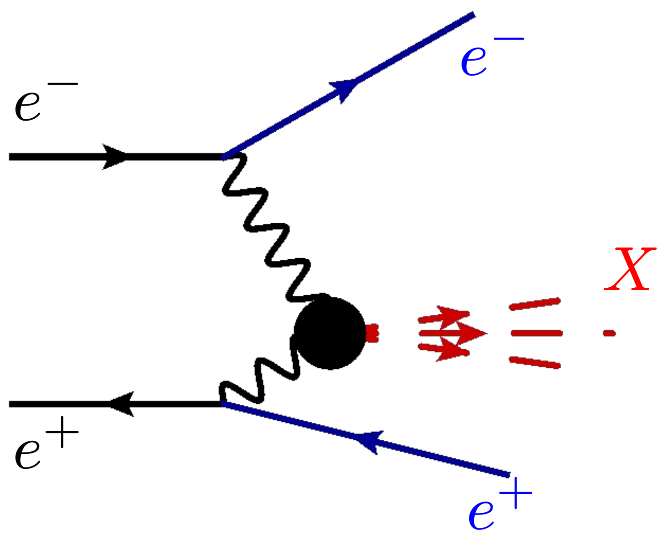


STEP-0

$\gamma\gamma$ - physics

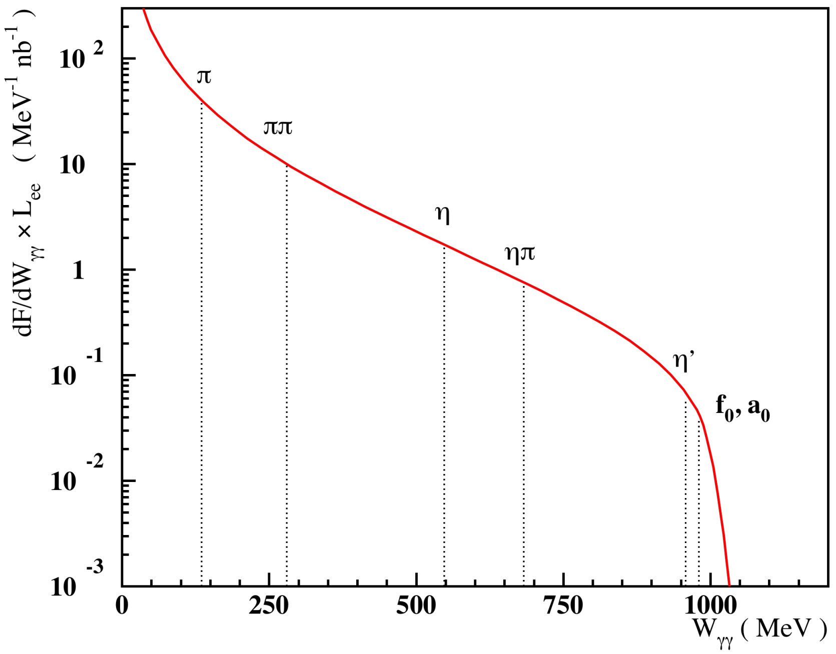
A γ-γ reaction could be depicted as follows:

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



γ-γ scattering allows the study of final states X with $J^{PC} = 0^{\pm+}$ not directly coupled to one photon ($J^{PC} = 1^{--}$), e.g. σ, η, η', a_0, f_0.

$$\frac{dN_X}{dW_{\gamma\gamma}} = L_{int}\frac{dL}{dW_{\gamma\gamma}}\sigma(\gamma\gamma \to X)$$



KLOE has used the off-peak data to search for the $\gamma\gamma$-physics events. See P. Gauzzi's talk (session 4)

Electron tagger HET LET

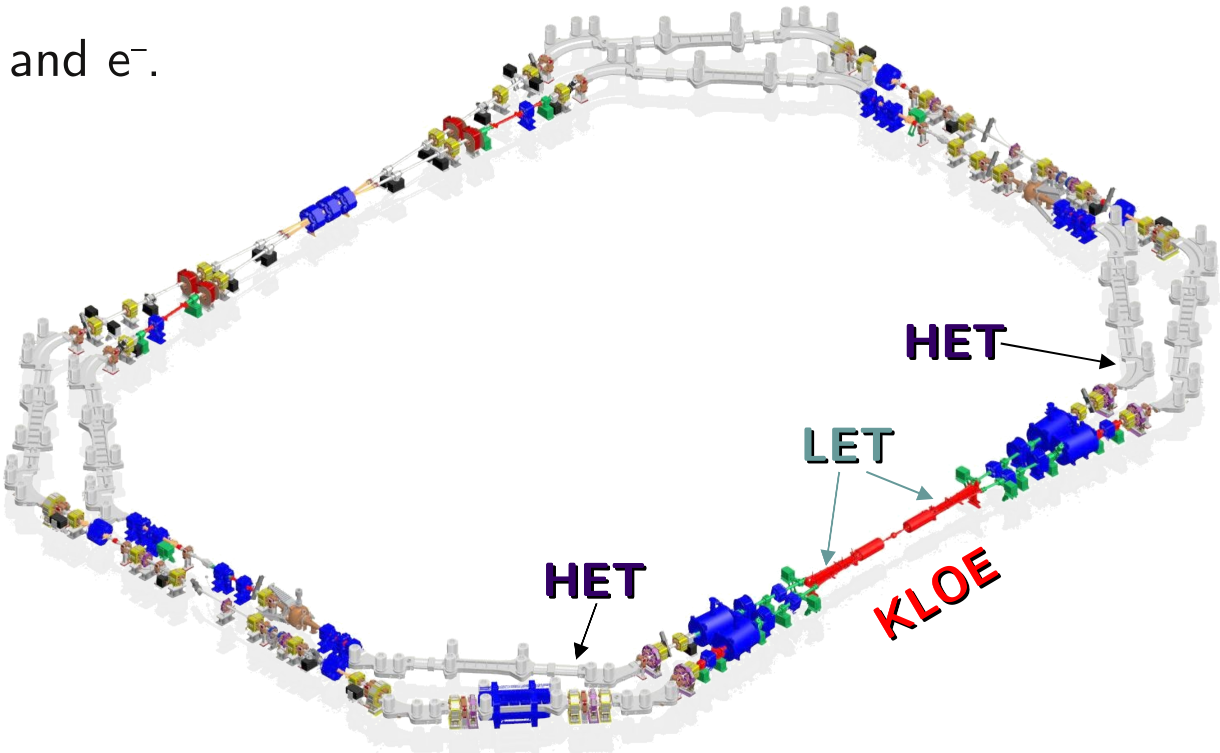
In order to identify $e^+e^- \to e^+e^-\gamma^*\gamma^*$ events 2 pairs of new detector are installed.

They will measure the off-energy e^+ and e^-.

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

Detected by taggers

Detected by KLOE



Technical design Report LNF - 10/14(P)

Electron tagger HET LET

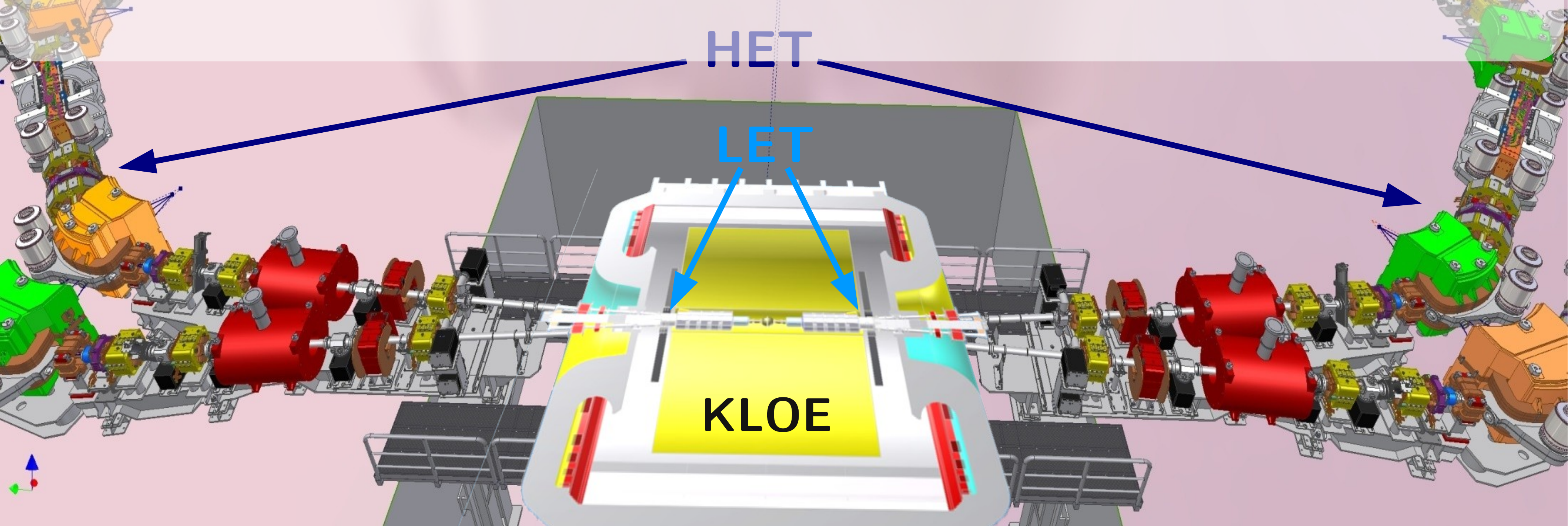
A detailed description of the beam optics is necessary to track these particles and choose where to place the taggers.

BDSIM toolkit has been used to have a detailed simulation of the off-energy particles through the machine optics.

Two positions for tagging detectors, for two e^+e^- energy ranges, have been found:

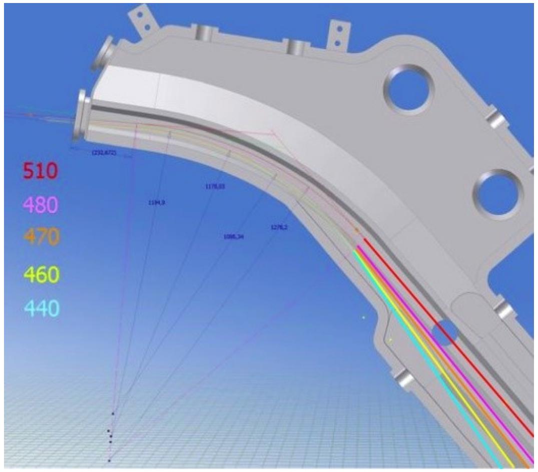
1) 160-230 MeV, ~1 m away from interaction point "Low Energy Tagger" or LET

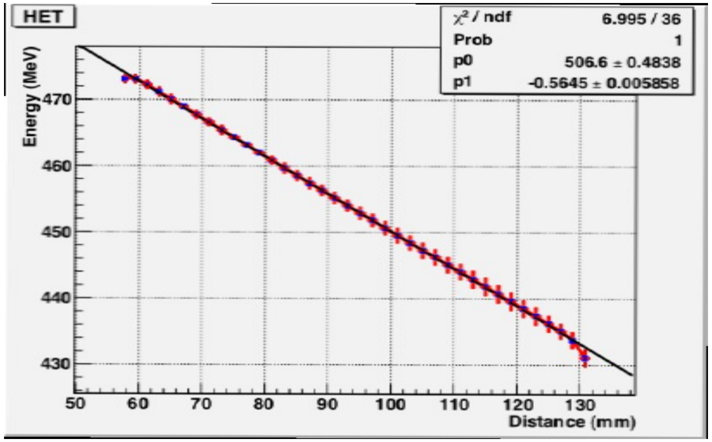
2) 425-490 MeV, ~11 m away from interaction point: "High Energy Tagger" or HET



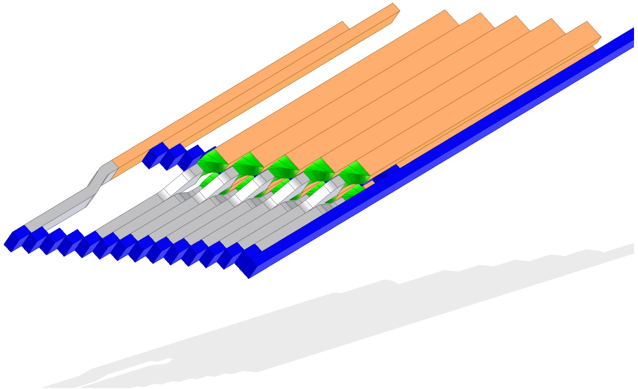
The High Energy Tagger (HET)

The first dipoles act as spectrometers spreading the trajectories in the longitudinal plane.
There is a correlation between energies and displacements in the longitudinal plane: HET is a position detector!





Hodoscope made by two rows of 15 scintillators of 3x5x6 mm^3 pitch resolution ~ 5 mm, i.e. 2.5 MeV momentum resolution.

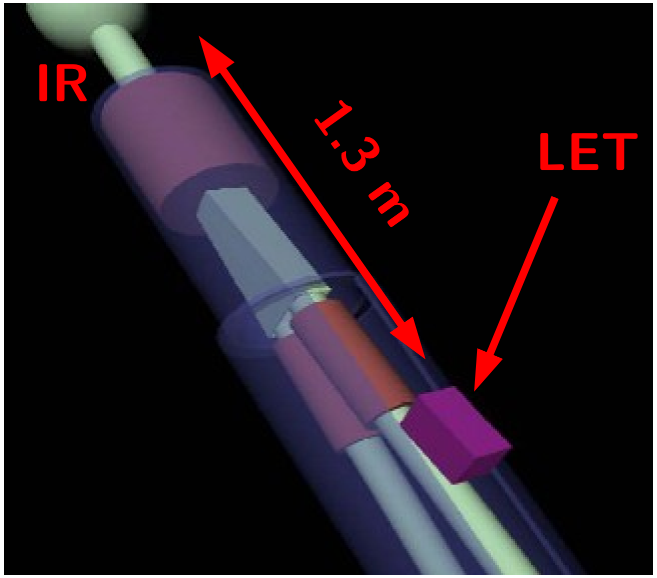


Fast scintillator EJ228 (ELJEN) coupled with light guides.
PMT Hamamatsu R9880-U110 (QE~35%).
Time resolution 200 ps (clear separation between two consecutive bunches).

The Low Energy Tagger (LET)

In the Low Energy Tagger, LET, region the off-energy leptons have no correlation between impact point and energy.

Physical constrains leads to radiation tolerant and magnetic field insensitive electronics, good energy resolution and small size.



$$\frac{\sigma_E}{E} < 10\%$$

The LET detector is composed by 20 LYSO crystals ($X_0 \sim$ 1cm) wrapped by Tyvek, each crystal is 1.5×1.5×12 cm^3. Hamamatsu MPPC were chosen as photodetectors (14400 pixels, 3×3 cm^2 active area)

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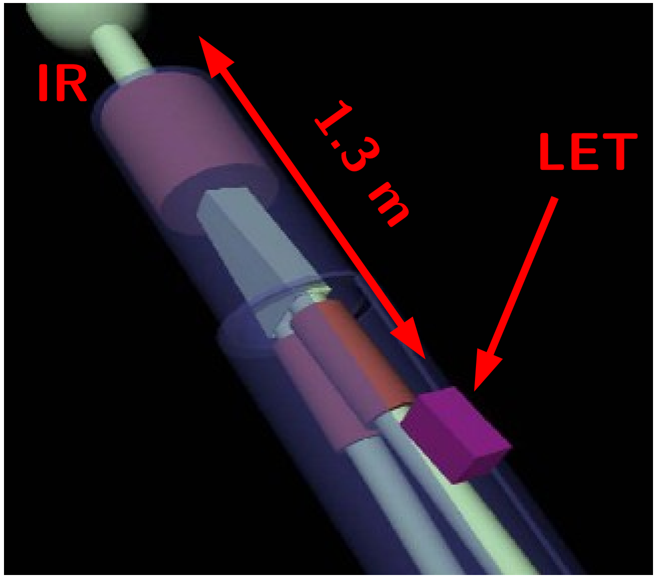

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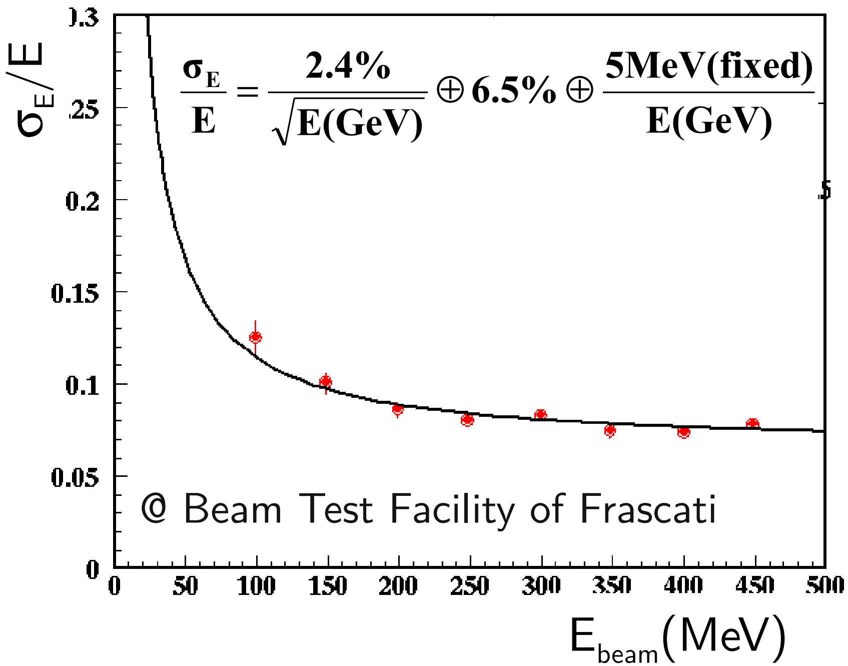

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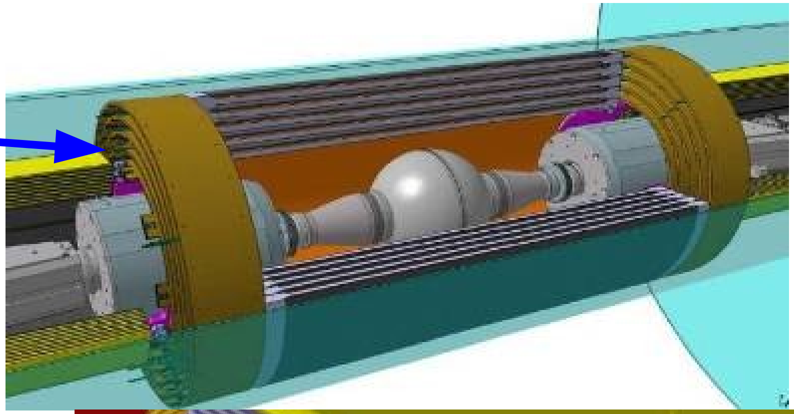
STEP-1

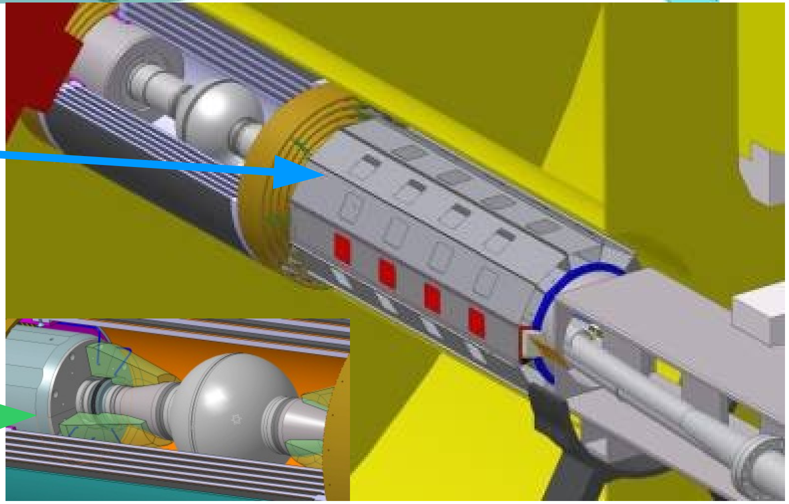
KLOE detector upgrade (STEP-1)

Major detector upgrades (~ late 2011) for second KLOE-2 run:



INNER TRACKER:

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



QCALT:

- W + scintillator tiles + SiPM/WLS;
- QUADS instrumentation for K_L decays.

CCALT:

- LYSO + APD
- Increase acceptance for γ's from IP ($21° \rightarrow 8°$)

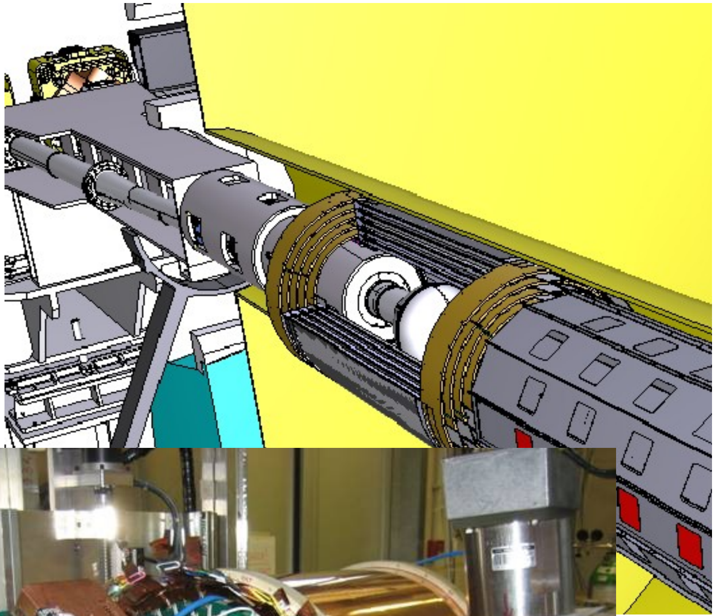
The Inner Tracker

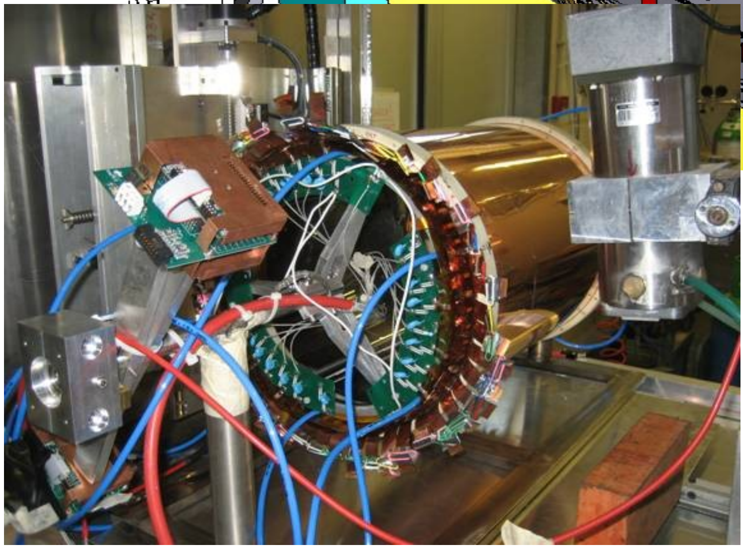
For a fine vertex reconstruction in K_S, η and η' decays and improvements in the K_S-K_L interference measurement:

- $\sigma_{r\phi} \sim 200$ μm and $\sigma_z \sim 500$ μm
- Material ~ 2% X_0
- 5kHz/cm^2 rate capability

The cylindrical GEM detector is proposed:

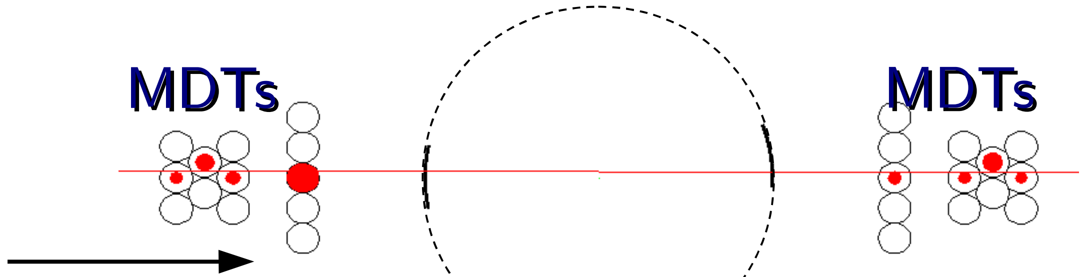
- 4 CGEM layers with radii between 13 cm and 23 cm (from the BP to inner wall of the DC)
- 70 cm active length
- XV strips-pads readout: the stereo angle is 40°
- 1.5% X_0 total radiation length in the active volume including Carbon fiber support



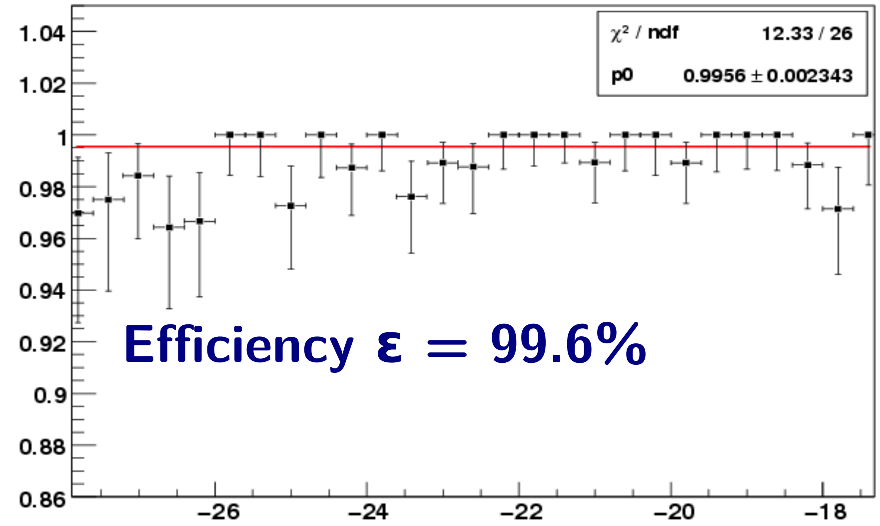


Technical Design Report of the Inner Tracker for the KLOE-2 experiment - arXiv:1002.2572

C-GEM prototype test-beam



10 GeV pion beam
CERN-PS T9 area



Gas: Ar/CO_2 = 70/30

Fields: 1.5/2.5/2.5 /4 kV/cm

$\mathbf{V_{GEM}}$: 390-380-370 =1140V, gain~2×10^4

FEE: 16-channels GASTONE [NIMA 604 (2009)]

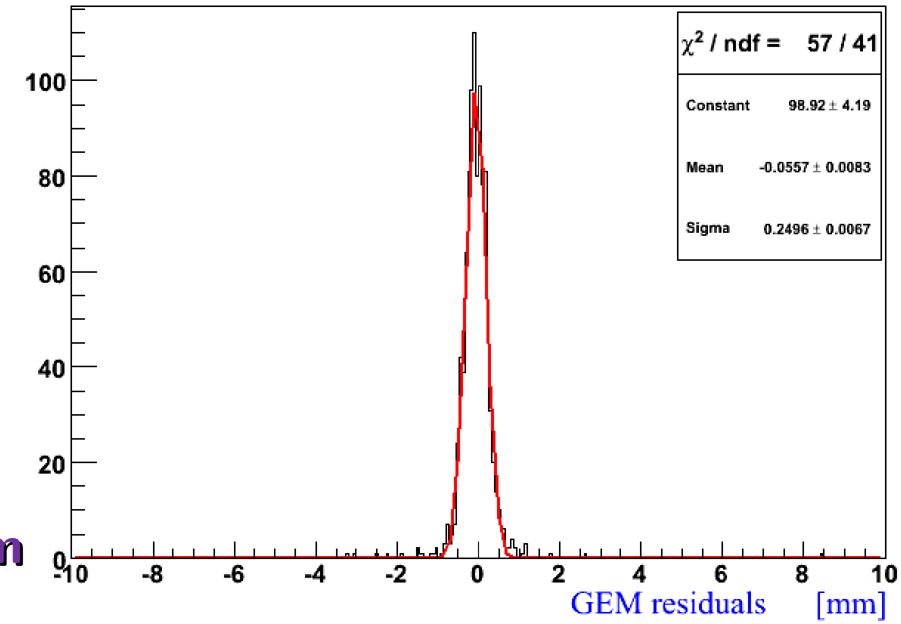
Trigger: 2x8-MDT stations -- External Tracking

Overall detector stretching load 50 kg

[NSS Conf. Rec.(2009)]

Spatial Resolution

$\sigma(\mathrm{GEM}) = \sqrt{((250\ \mu m)^2 - (140\ \mu m)^2)} \sim 200\ \mu m$



XV readout and magnetic field

A 10x10 cm² Planar GEM w/650 μm pitch **XV strips** has been realized and tested in magnetic field.

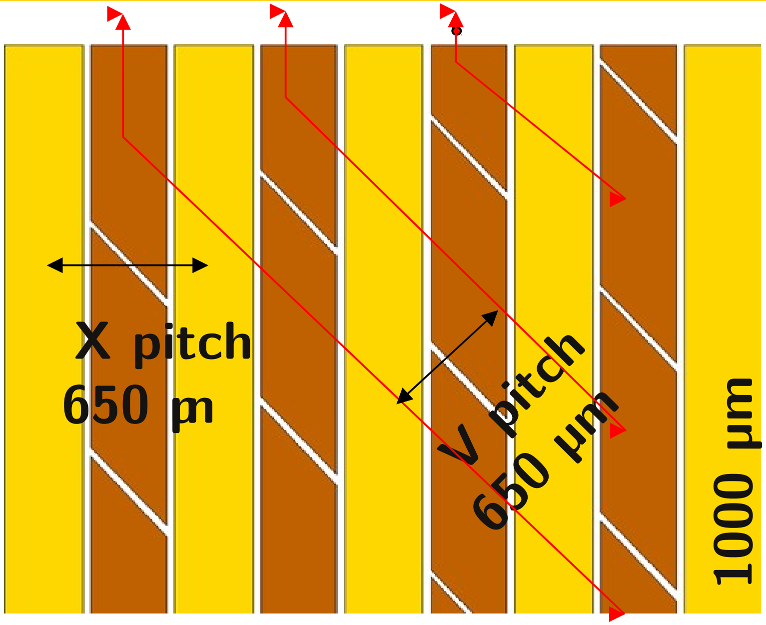
beam-line at CERN-SPS: 150 GeV pions
Goliath Magnet: dipole field up to **1.5T** in a **~3x3x1m³**

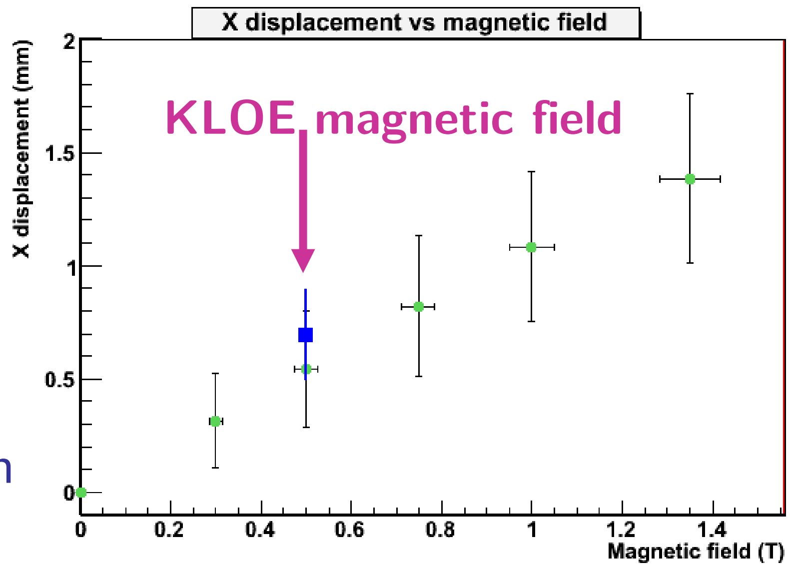
Gas: $Ar/CO_2 = 70/30$
Fields: 1.5 - 3.0 - 3.0 - 5.0 kV/cm
$\mathbf{V_{GEM}}$: 390-380-370 =1140V, gain~2×10^4

FEE: GEMs partially equipped with 22 GASTONE boards

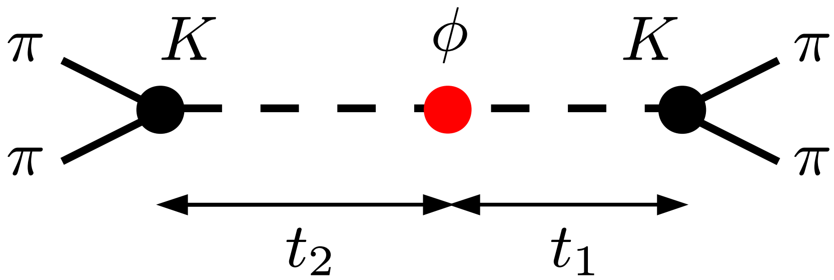
Trigger: 6 scintillators with SiPM

σ_X = 200–370 μm for a B = 0–1.3 T, σ_y = 370 μm





Impact on physics: kaon Interferometry



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

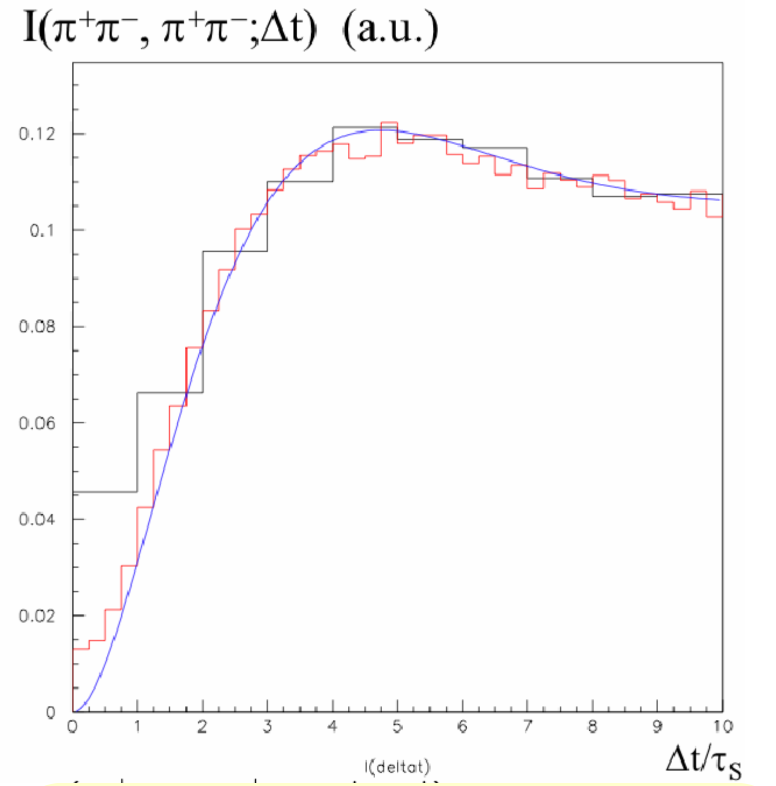
$$I(\pi^+\pi^-, \pi^+\pi^-; \Delta t) \propto$$
$$[e^{-\Gamma_L \Delta t} + e^{-\Gamma_S \Delta t}] +$$
$$-2(1 - \zeta_{SL} e^{-(\Gamma_S + \Gamma_L)\Delta t/2} \cos(\Delta m \Delta t))$$

$\zeta_{SL} = 0$ Q.M.

$\zeta_{SL} = 0.003 \pm 0.018 \pm 0.006$

Experimental sensitivity improved by a factor ~3 using the Inner Tracker.

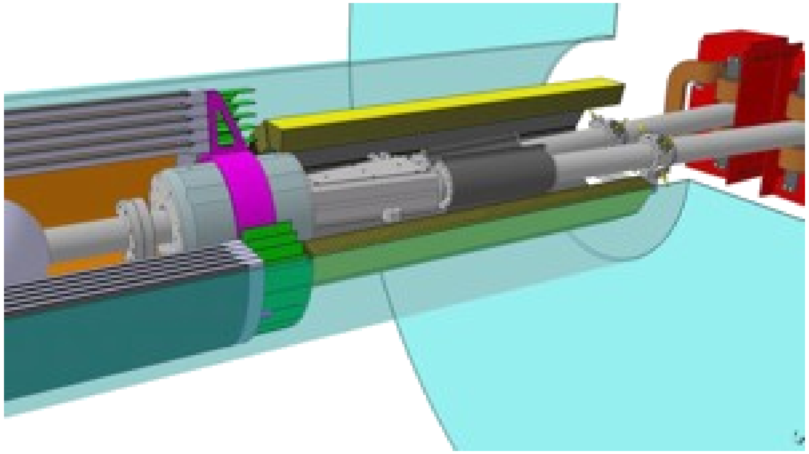
A. Di Domenico, KLOE Coll. J. Phys. Conf. Ser., 171, 012008, 2009



The $I(\pi^+\pi^-, \pi^+\pi^-; |\Delta t|)$ distribution as function of $|\Delta t|$ with the present KLOE resolution $\sigma_{|\Delta t|} \approx \tau_S$ (wide bins), with $\sigma_{|\Delta t|} \sim 0.3\ \tau_S$ (narrow bins) and the ideal case (blue line).

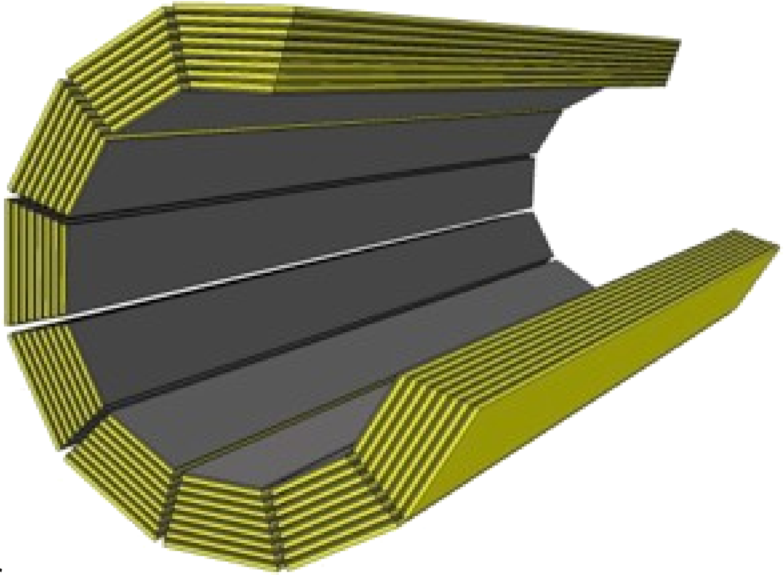
The QCALT calorimeter

Two tile calorimeters + Wavelength Shifter + SiPM readout around the new QUADs (w.r.t. old QCAL 2 times light yield, faster green fibers, 10 times improvements σ_z)



Dodecagonal structure (1 m length)

5 layers of W (**3.5mm**) + tiles (**5mm**) + air gap (**1mm**) for a total of **5.5 X_0** (**4.75cm** depth)



20 cells/layer (100 SiPM/module) for a total of 2400 readout channels;

Located along z-axis after the Inner Tracker;

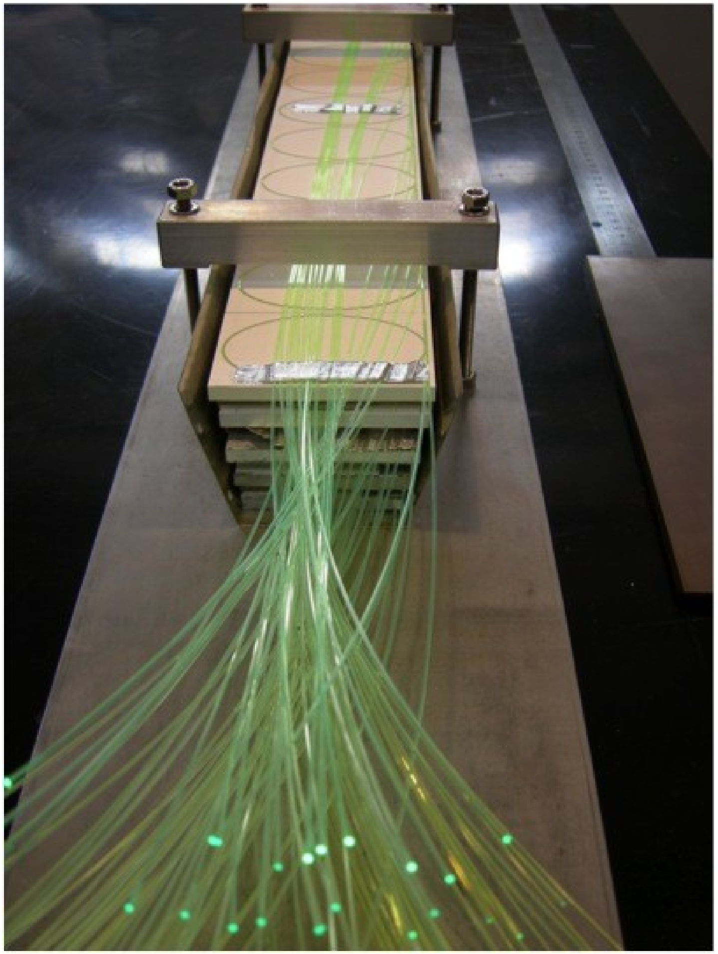
Granularity of 5×5÷5×7.7 cm^2 tiles;

Fast timing resolution (< 1 ns);

Increasing of the hermeticity of KLOE detector for photons.

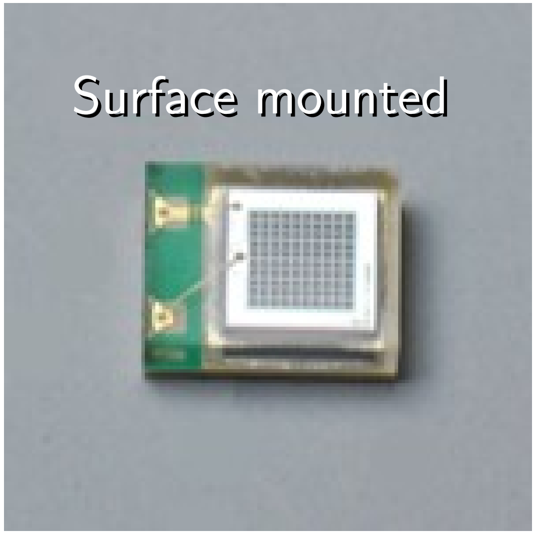
QCALT module-0

Two different solutions are tested for the wrapping of the scintillators: Tyvek and reflecting painting.

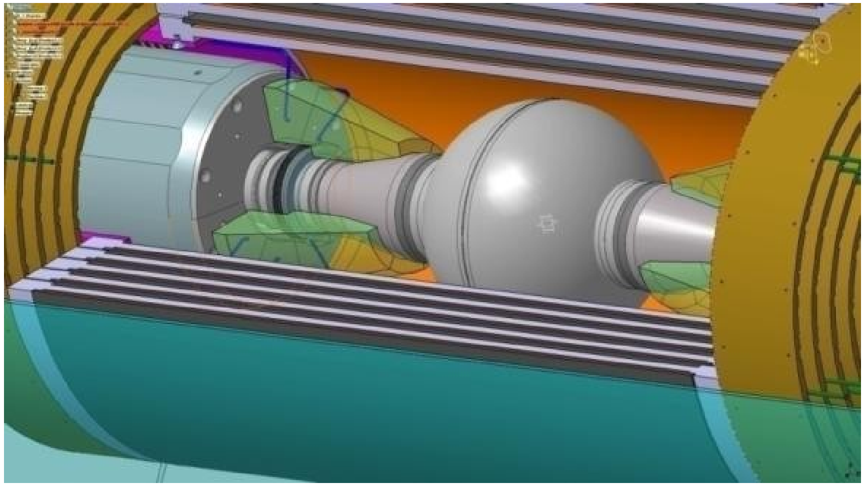


SiPM readout:

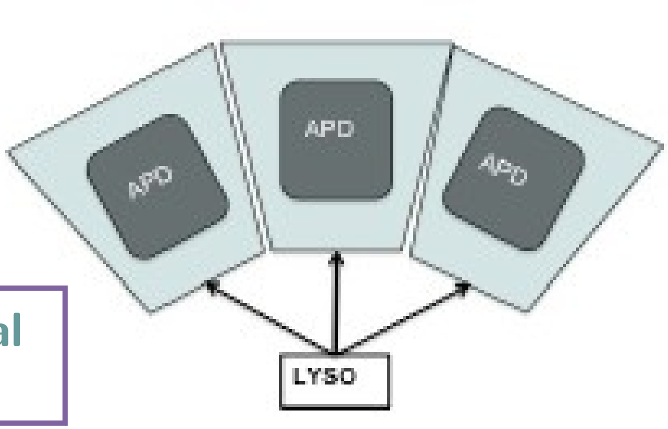
- 50 μm pixel pitch
- 400 pixels
- V_{bias} = 69 -71 V
- Gain 7.5 10^5 @V_{bias}



The CCALT Calorimeter



2 small barrels of 24 crystals each, with a length of 10-13 cm and transversal area from 1.5×1.5 cm^2 to 2×2 cm^2



Dodecagonal Barrel

First prototype has been built and tested with cosmic-ray muons and e-beam.

High Light Yield observed $\sim$ 500 pe/MeV.

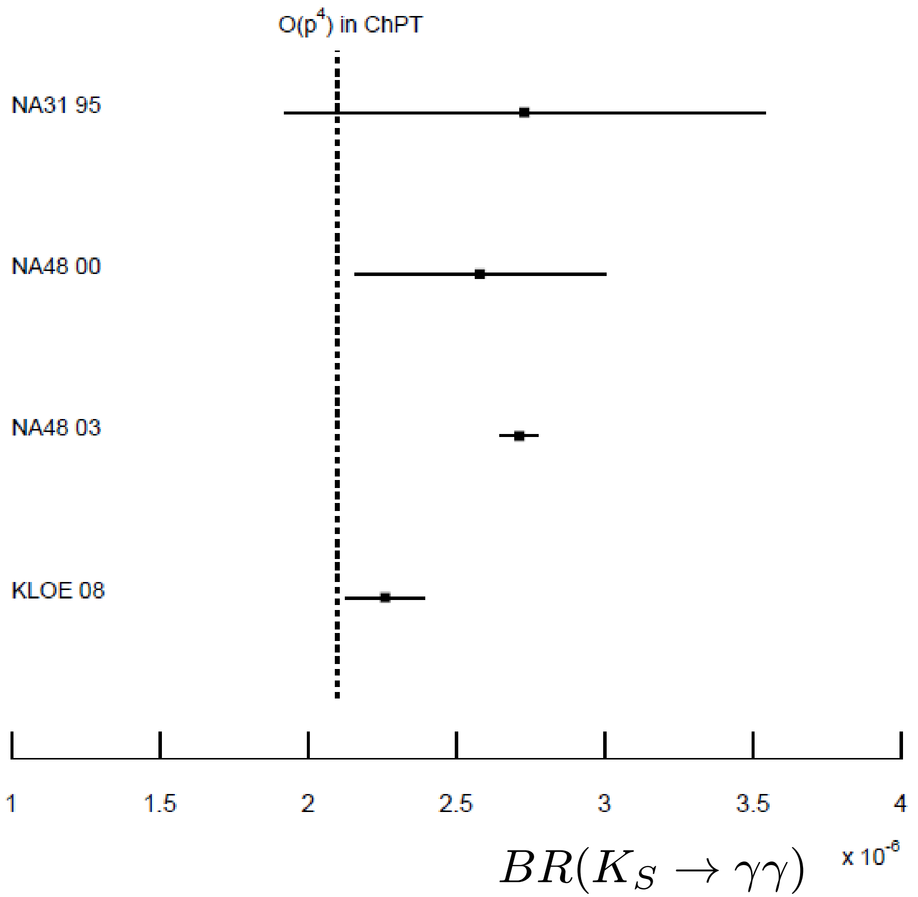
Timing resolution 250-300 ps from 100 to 500 MeV.

KLOE EMC covers down to 21°,with the CCALT extension down to 8°!

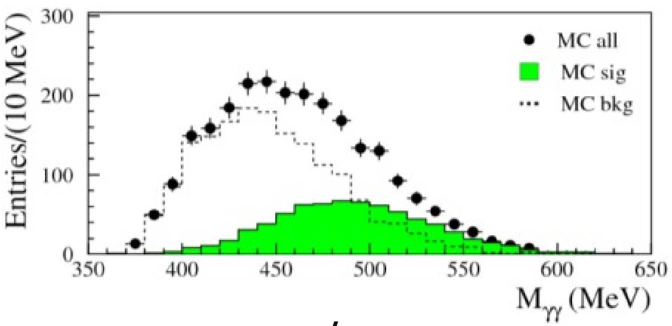
Impact on physics: $K_S \to \gamma\gamma$ decay

KLOE published measurement on BR($K_S \to \gamma\gamma$) (JHEP 0805:051,2008) differs by 3σ from NA48 result. A more precise measurement is needed!

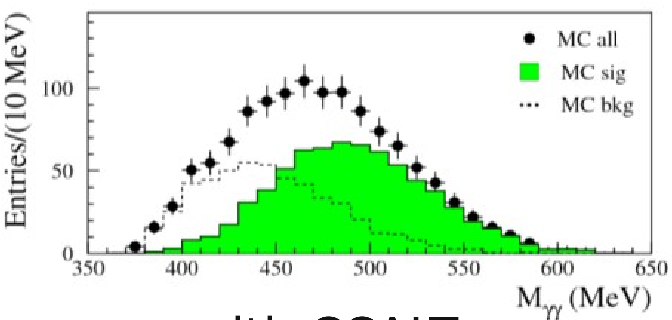
KLOE put a limits to O(p^6) prediction of χPT.



$K_S \to \gamma\gamma$ **$K_S \to \pi^0\pi^0$**



w/o CCALT

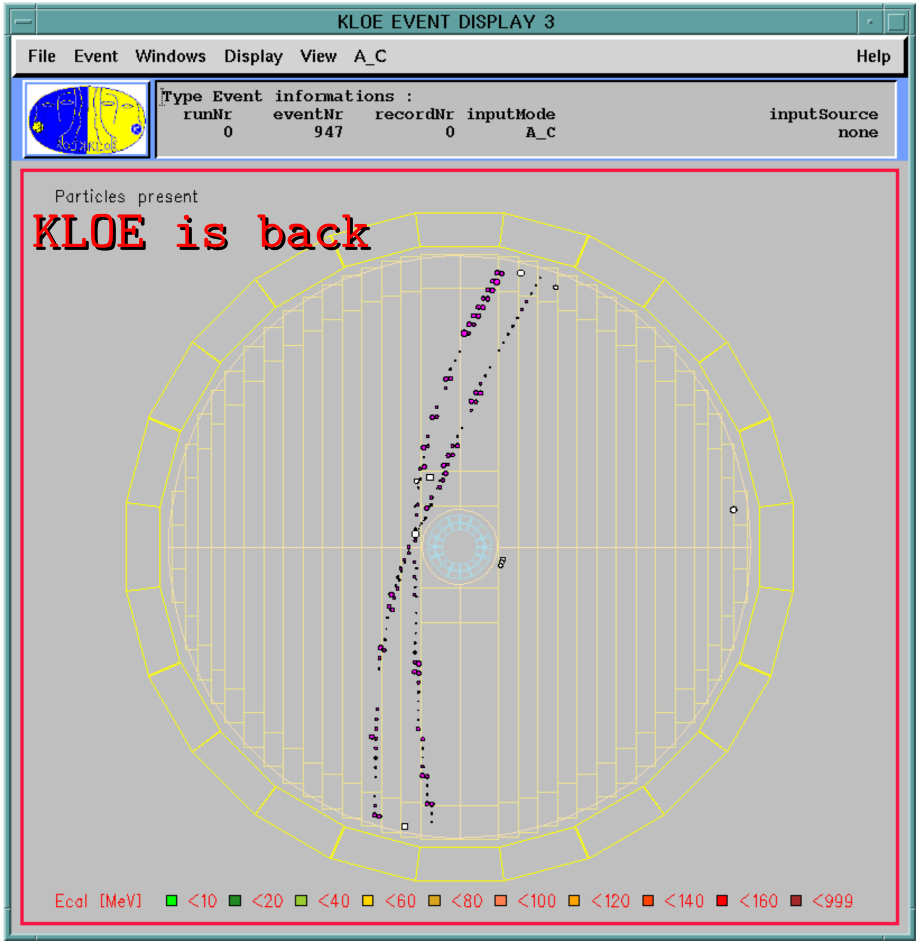


with CCALT

Major bkg: $\mathbf{K_S \to \pi^0\pi^0}$ with 2 photons lost. (beam pipe or QCAL inefficiency)

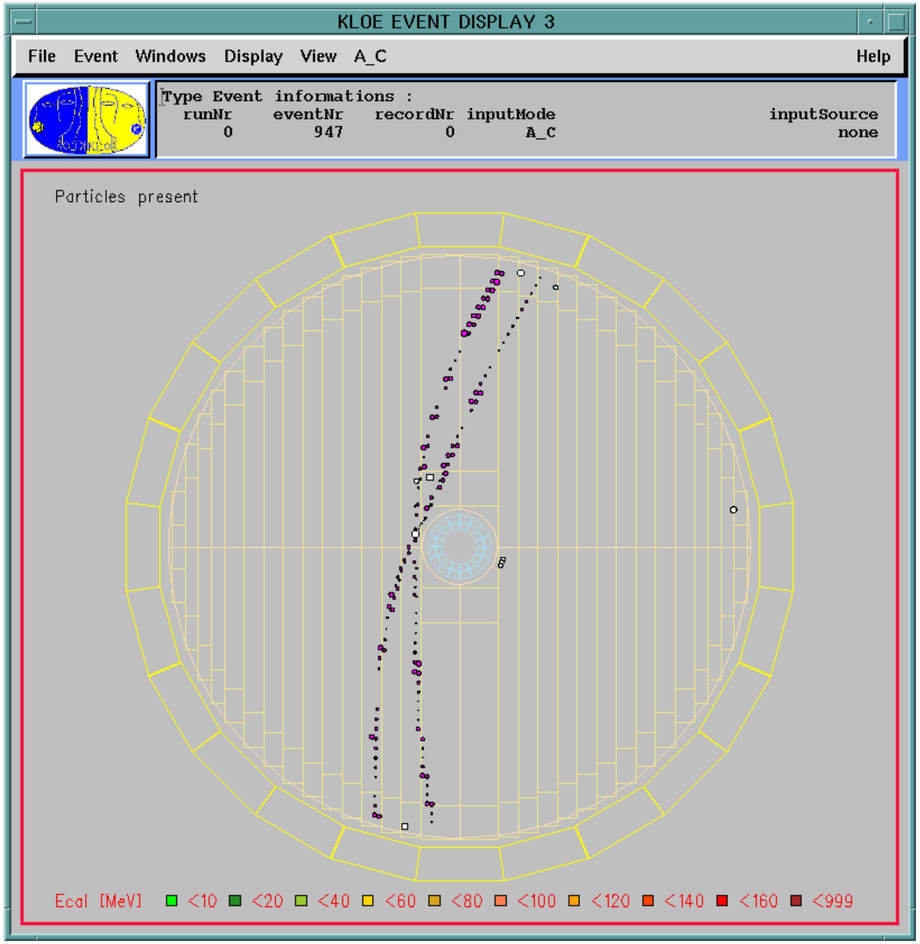
Conclusions

- New interaction region is installed;
- The KLOE detector is up and running;
- Magnet has been switched ON;
- Electron tagging system:
  - LET: tested and installed;
  - HET: mechanics installed, detector ready for operation.
- DAΦNE commissioning is starting;
- First collisions foreseen for September;
- Work is in progress for detector upgrades (IT, QCALT and CCALT), to be installed by end of 2011.



Conclusions

Thank you!



New beam pipe @ IP

Insertion of the 35μm Be cylinder inside the 10 cm sphere

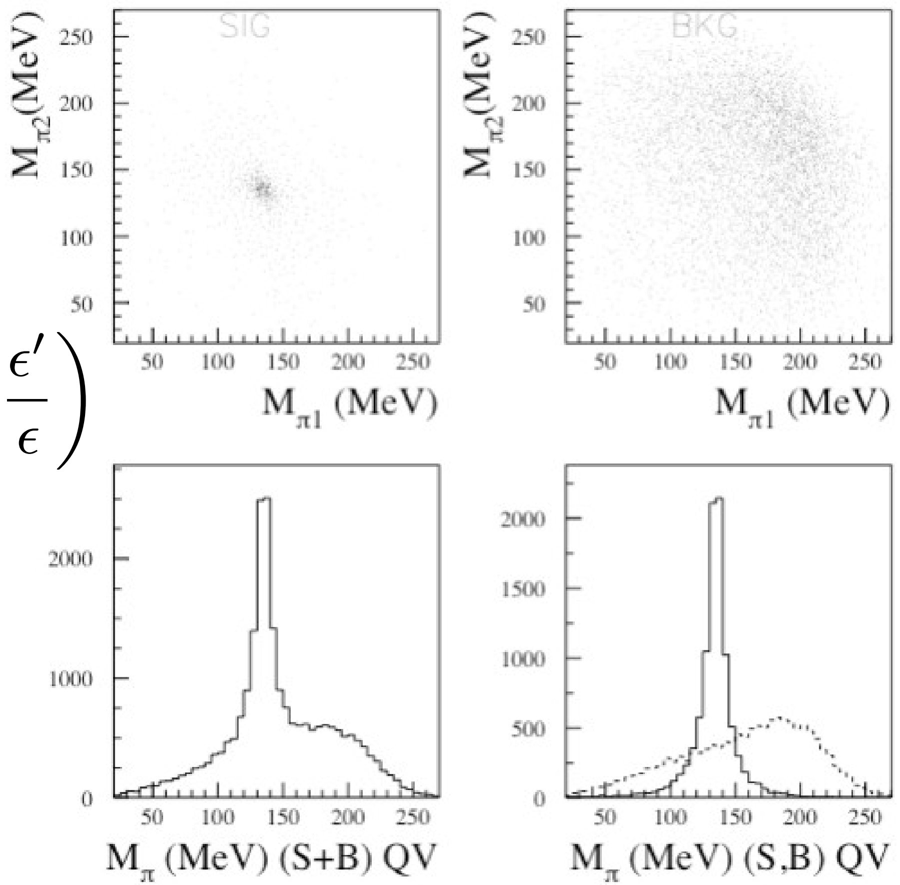
$K_L \to \pi^0\pi^0$ measurement

- KLOE was designed to study the CP violation into the $\overline{K}K$ system through $Re(\varepsilon'/\varepsilon)$ measurement.
- To reduce systematic errors we measure the double ratio:

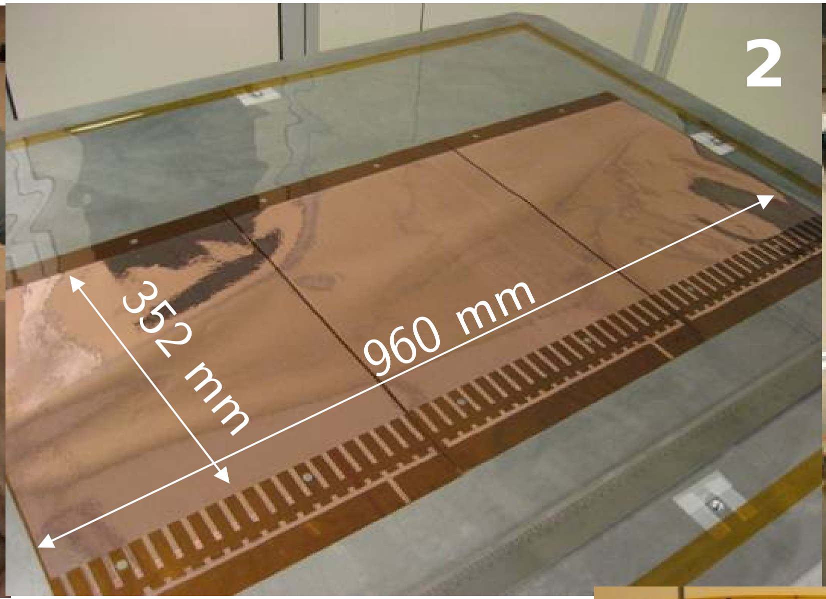
$$\frac{\Gamma(K_S \to \pi^+\pi^-)\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_L \to \pi^+\pi^-)\Gamma(K_S \to \pi^0\pi^0)} = 1 - 6\Re\left(\frac{\epsilon'}{\epsilon}\right)$$

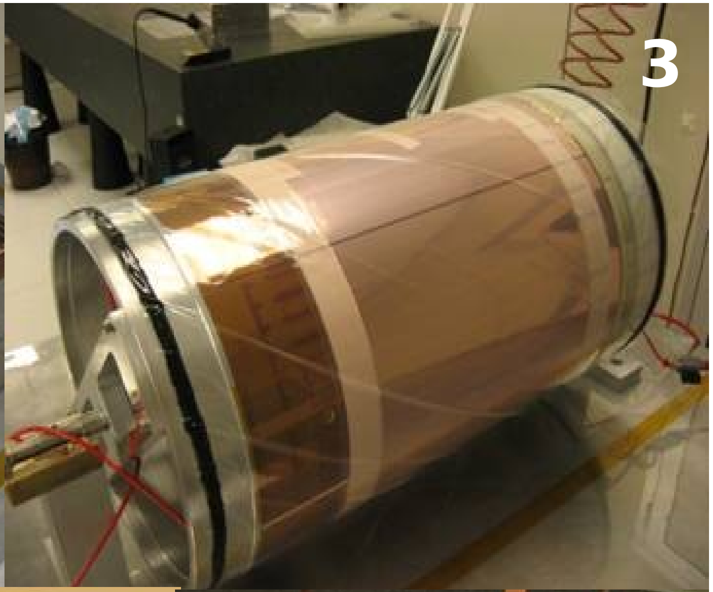
- The most important bg source in this measurement is $K_L \to 3\pi^0$;
- QCAL works well on rejecting background losing 1% of signal;
- **QCALT will increase the detection efficiency** and the high granularity will help on **reducing accidental losses**.

$K_L \to 2\pi^0$ Others with 4γ



CGEM prototype construction





1. Distribution of epoxy on foil edge
2. 3 spliced foils ~1000mm long
3. Cylindrical mould in vacuum bag
4. Cylindrical GEM foil
5. Cylindrical Cathode with annular fiberglass support flanges

Proto0.1: Ø=300mm,L=350mm;
1538 axial strips, 650 µm pitch

GEM foil production

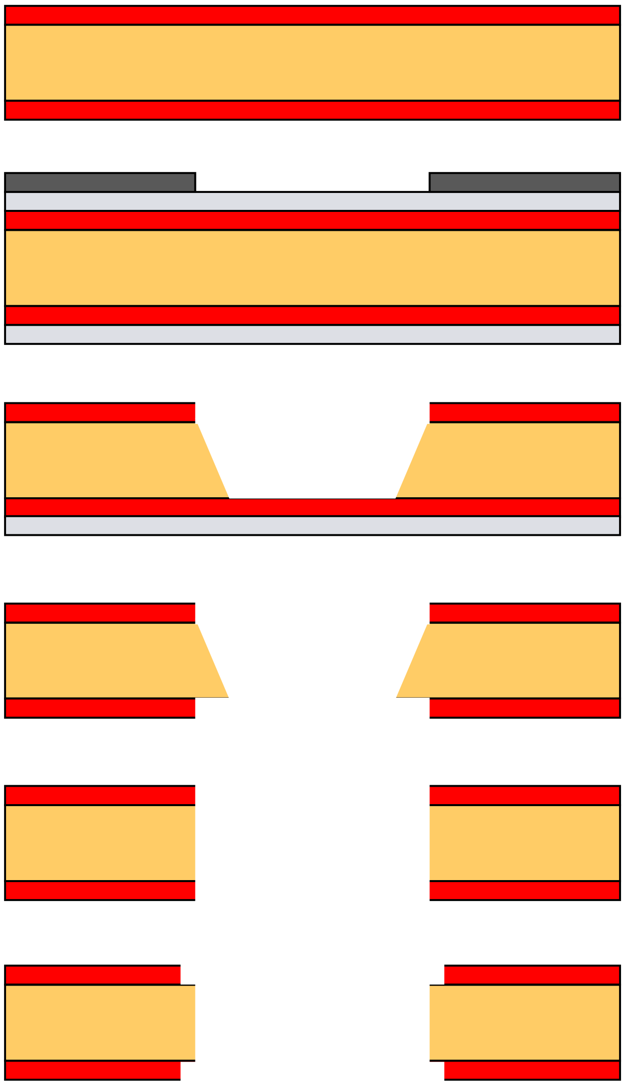
Starting raw material: 50µm Kapton foil with 5µm Copper clad

Photoresist deposition, **Single Mask**

Bottom side metal etching. Top side metal is preserved with **Cathodic Protection** technique

Back to kapton etching to get almost cylindrical shaped hole

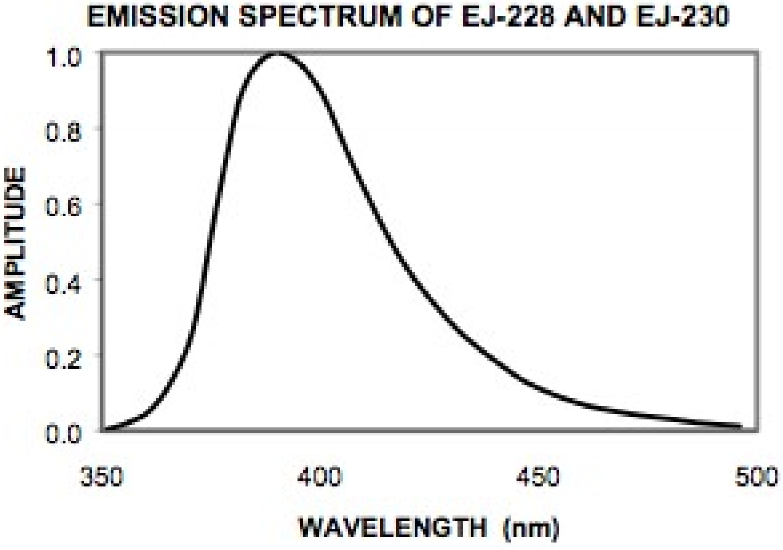
Further metal etching to form a small rim and eventually to reduce the copper thickness



Plastic scintillators characteristics (HET)

Plastic : Eljen EJ228

Physical and Scintillation Constants:	EJ-228
Light Output, % Anthracene	67
Scintillation Efficiency, photons/1 MeV e^{-1}	10,200
Wavelength of Max. Emission, nm	391
Rise Time, ns	0.5
Decay Time, ns	1.4
Pulse Width, FWHM, ns	1.2
No. of H Atoms per cm^3, x 10^{22}	5.15
No. of C Atoms per cm^3, x 10^{22}	4.69
No. of Electrons per cm^3, x 10^{23}	3.33
Density, g/cc:	1.023



Optical Sensors

PMT Hamamatsu

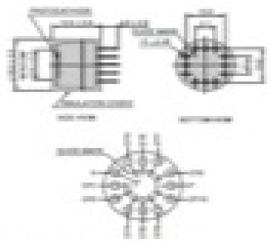
R9880U-110SEL

Super Bialkali
Quantum ϵ~40% 330 nm
Quantum ϵ~37% 400 nm

Key Specifications

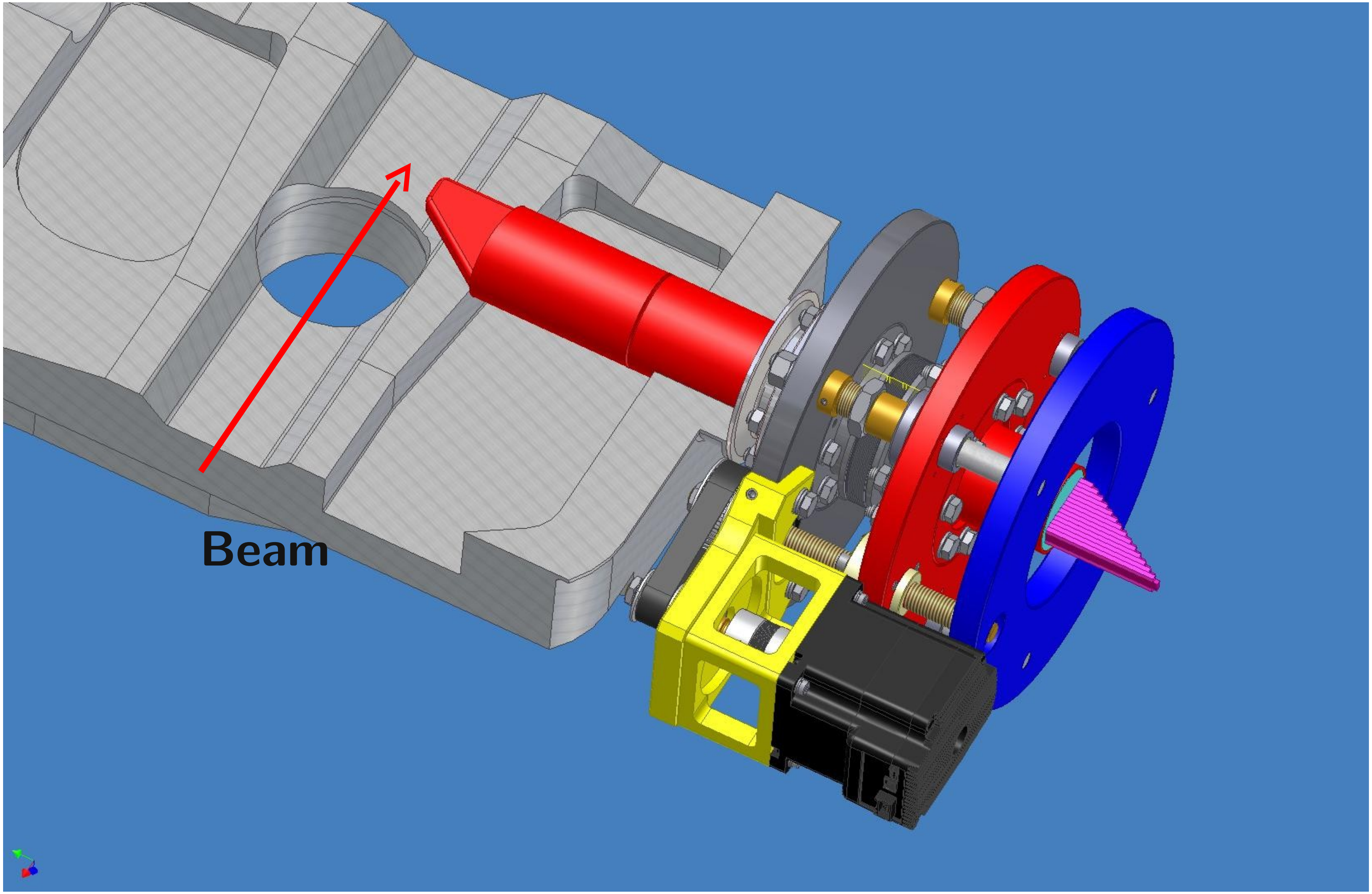
Part Number	R9880U-110
Type	Head on
Size	16 mm
Min λ	300 nm
Max λ	650 nm
Peak Sens.	330 nm
Cathode Radiant Sensitivity	120 mA/W
Window	Borosilicate
Cathode Type	Super Bialkali
Cathode Luminous Sensitivity	135 μA/lm
Cathode Blue Sensitivity Index	14
Anode Luminous Sensitivity	270A/lm
Gain	4.0E+06
Dark Current after 30 min.	1 nA
Rise Time	0.57 ns
Transit Time	3.6 ns
Number of Dynodes	10
Applied Voltage	1000 V
Multi Anode	N
Socket Bare	E678-12W
Socket + bleeder assy.	E10679

Drawing



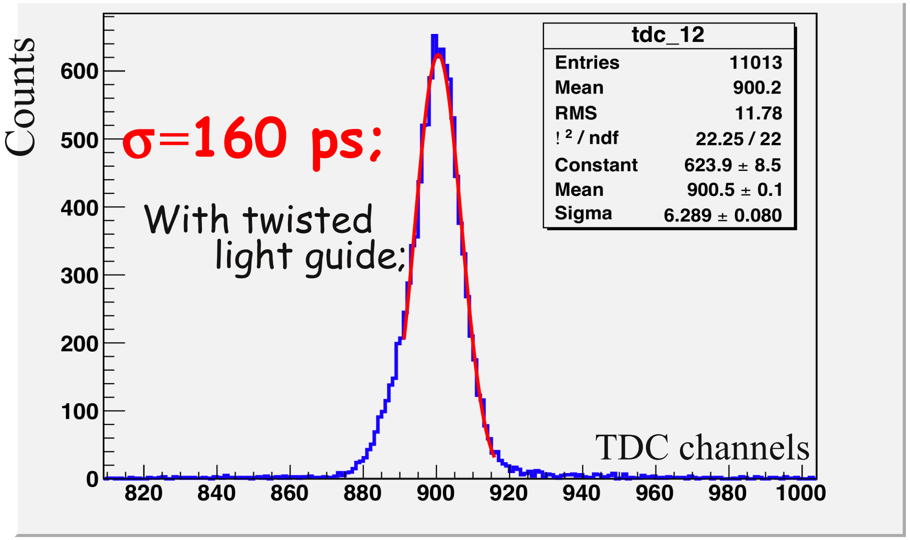
Click image to enlarge

Mechanics



Test beam: TDC results

Time difference between 2 scint. placed one next to the other



TDC channels