KLOE-2 Experiment at DAΦNE upgraded in luminosity

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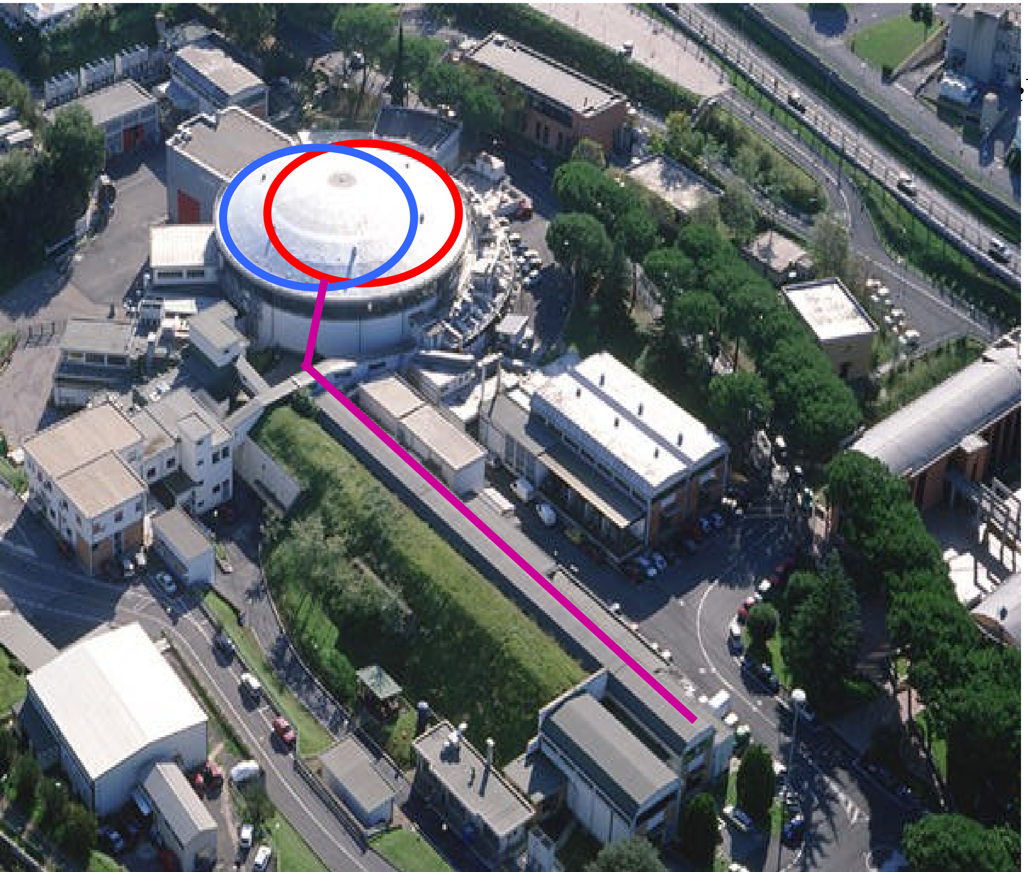
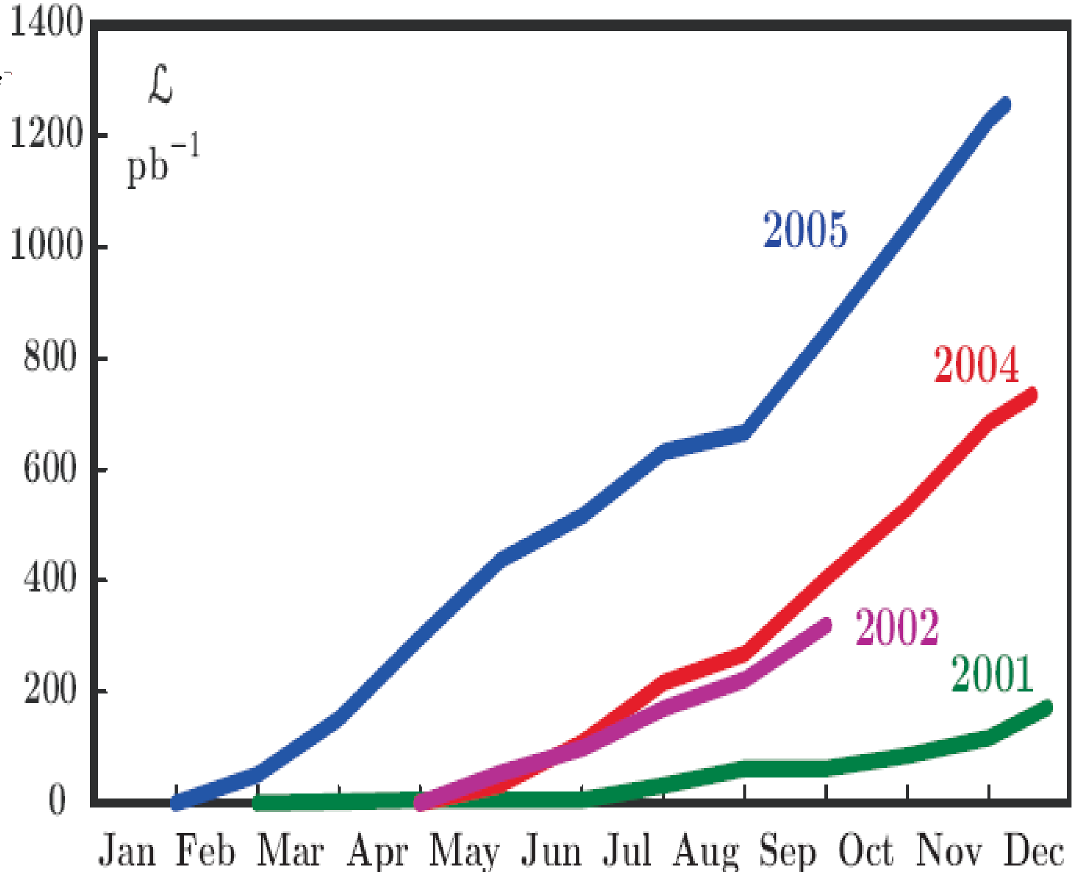
DAΦNE and KLOE

- e^+e^- now at the Φ-resonance 1019.4 MeV
- K-LOng Experiment (KLOE), using multipurpose high-rate detector, finished taking data ~ 5 years ago with 2.5 1/fb

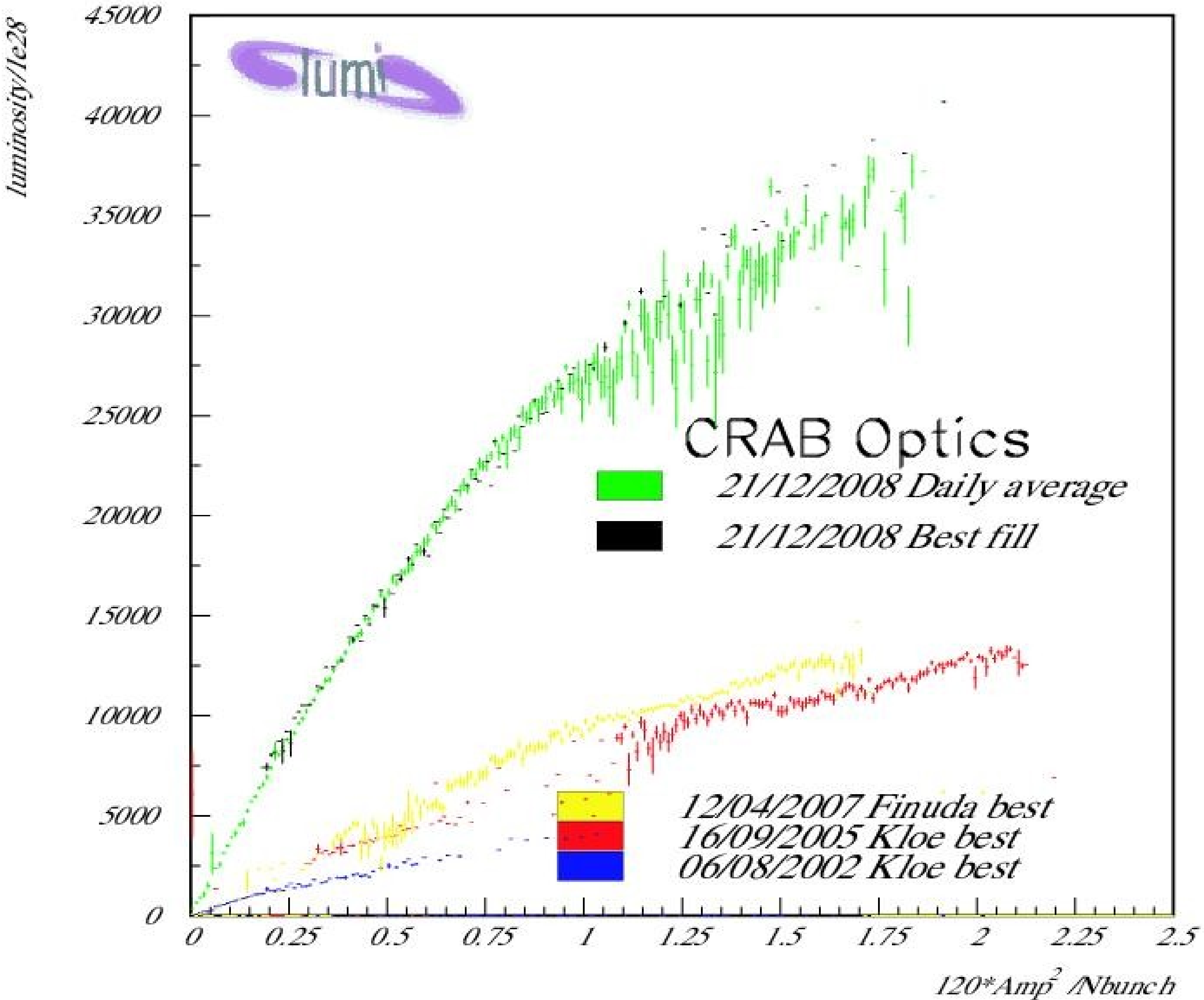




KLOE-2 and need for DAΦNE upgrade

- Ambitious physics program of KLOE-2 requires order of magnitude larger event sample than KLOE
- Going to be realized by implementing major upgrades of DAΦNE, viz.:
  - Increased Piwinski angle $\phi_{\mathbf{P}} \sim \theta/\sigma_{\mathbf{x}}$ by larger crossing angle of beams and reduced beam size at crossing point
  - „Crab waist" beam optics with suppressed betatron resonances, using two sextupoles at both sides of interaction point

Luminosity improvement with crab waist optics

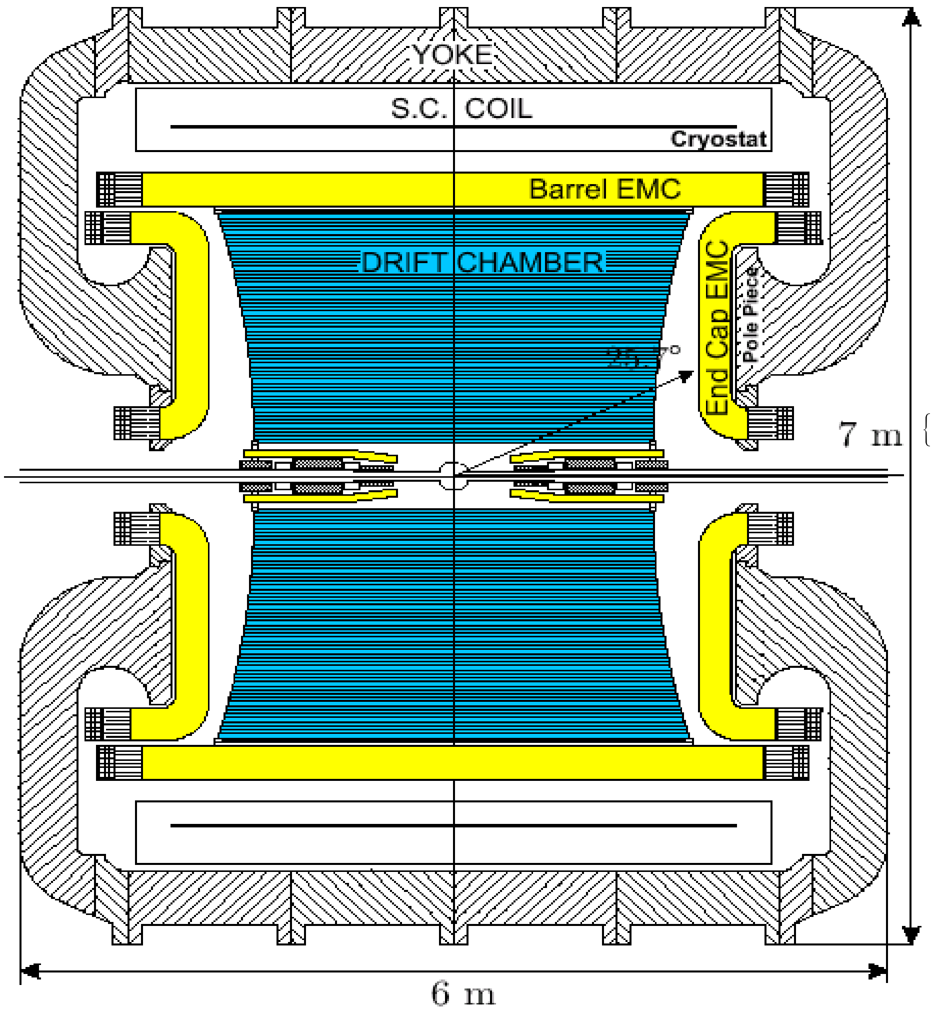


- Significant upgrade: luminosity increase 3.5-4 times w.r.t. 2005 with:
- θ increased 2 times
- σ reduced 2-3 times

KLOE-2 physics issues

- Prospects for CKM unitarity and lepton universality tests
- **The γγ physics**
- **Search for quantum decoherence and testing CPT conservation**
- Low-energy QCD: rare K decays, physics of η, η’, structure of low-mass scalars
- Contribution of vacuum polarization to $(\mathbf{g}_\mu - \mathbf{2})$
- Possible search for WIMP dark matter

Basic KLOE detector



- Drift chamber: helium+isobutane 9:1, $\sigma(\mathbf{p_T})/\mathbf{p_T} < \mathbf{0.4\%}$, $\boldsymbol{\sigma_{vtx}} \simeq \mathbf{1\ mm}$
- El-mag calorimeter: Pb+sc.fib.,

$$\sigma(\mathbf{E})/\mathbf{E} = \mathbf{5.7\%}/\sqrt{\mathbf{E}}$$

$$\sigma(\mathbf{t}) = (\mathbf{55}/\sqrt{\mathbf{E}} \oplus \mathbf{100})\ \mathrm{ps}$$

98% coverage,

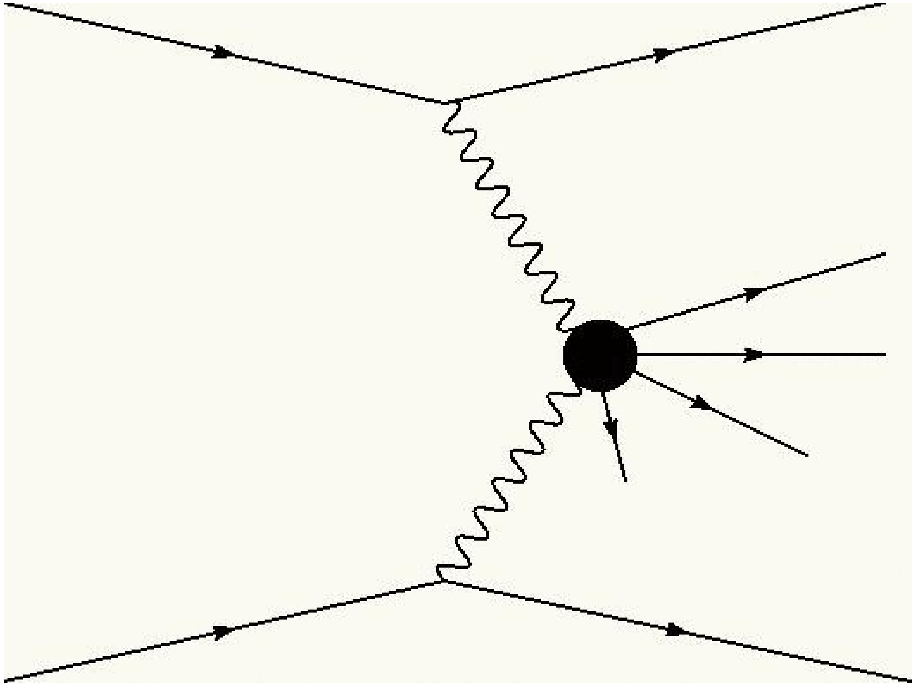
particle identification

Major KLOE-2 detector upgrades: electron taggers

Electron taggers for γγ physics;

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

Detects off-energy electrons close to the beam



Major KLOE-2 detector upgrades: electron taggers

HET: E>400 MeV, 11 m

Scintillators and PM tubes

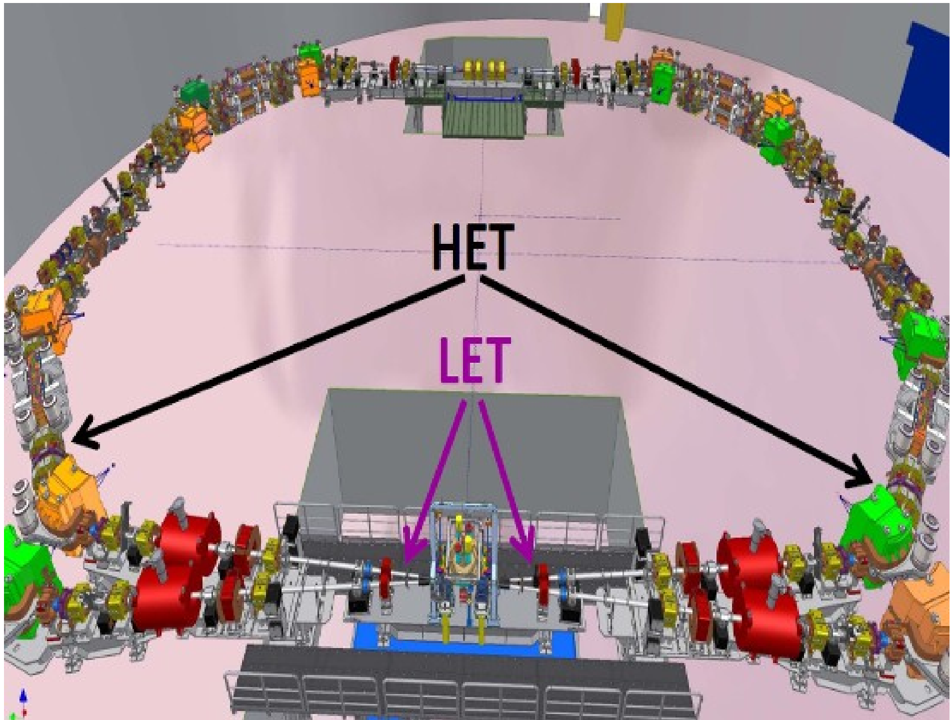
LET: 160<E<230 MeV, inner

LYSO crystals & silicon

photomultipliers

Online this year,

Suitable to 5 1/fb data/year

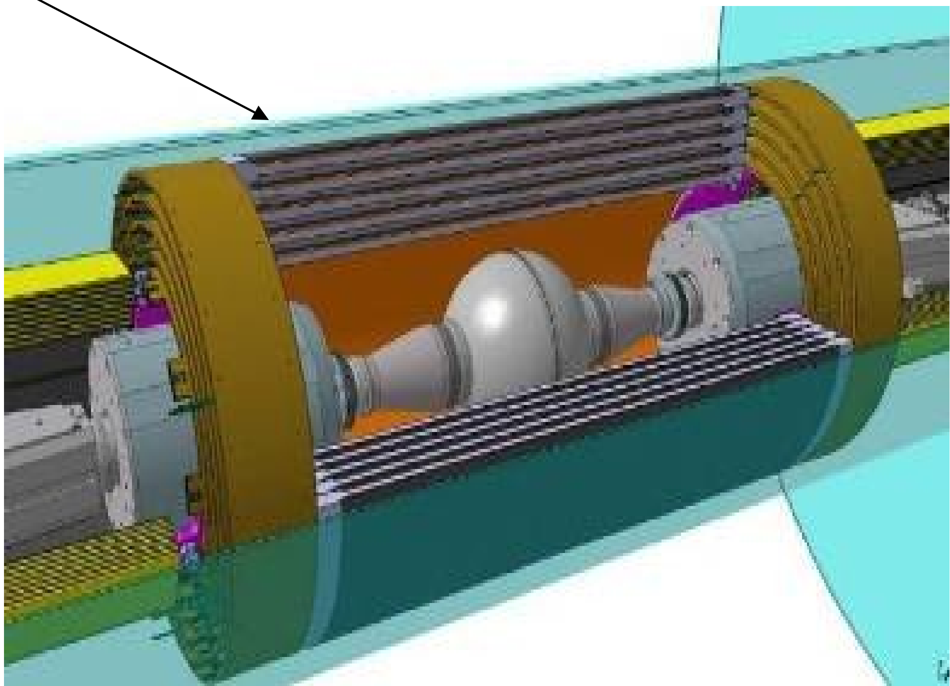


Major KLOE-2 detector upgrades: inner tracker

Inner tracking detector close to interaction point:

- improvement of vertex resolution
- better low-pT acceptance

- 4 cyllindrical GEM layers
- ~100 µm spatial resolution
- few ns time resolution



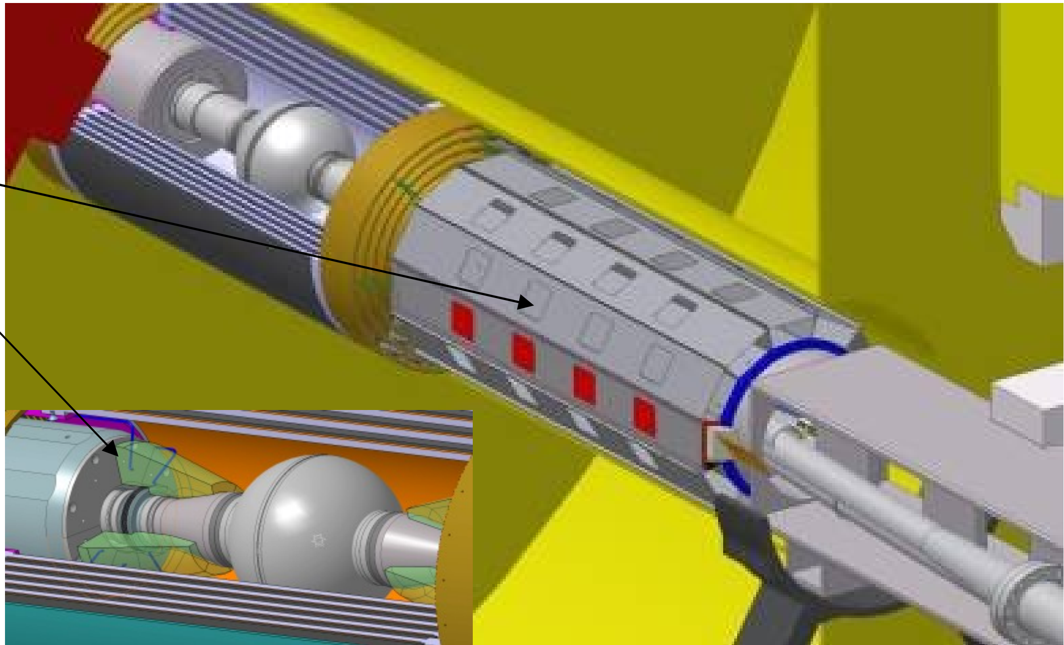
Major KLOE-2 detector upgrades: near beam detectors

CCAL:

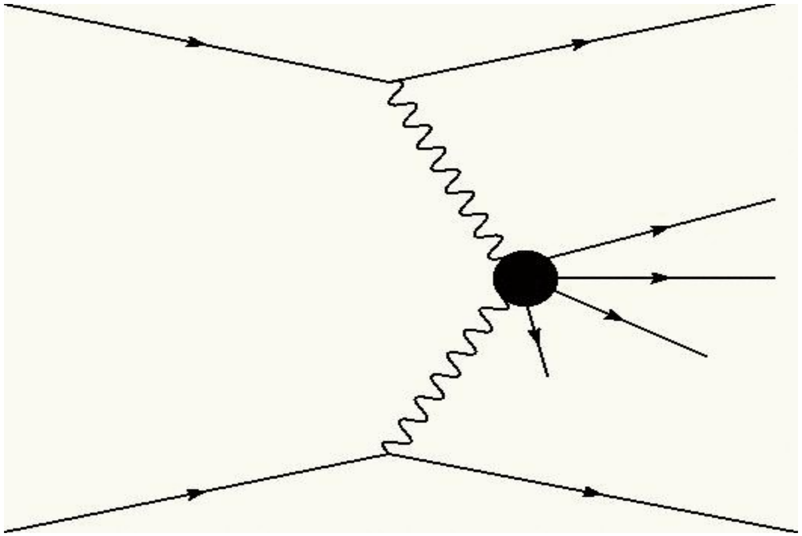
- LYSO scintillating crystals with avalanche photodiods (APD)
- 21°-->10° increased acceptance for γs

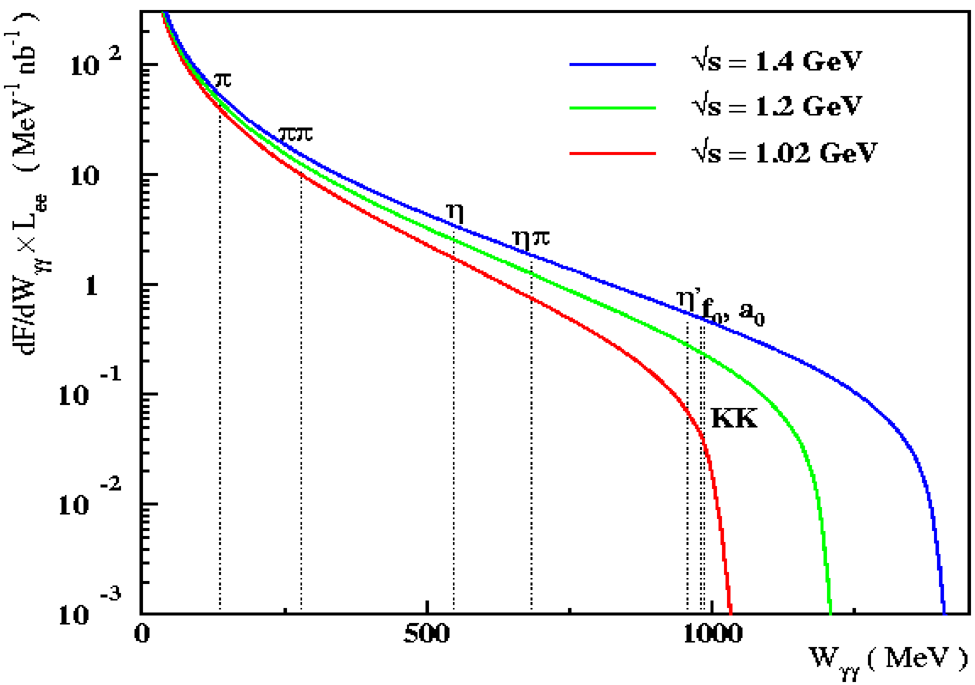
QCALT:

- Silicon photomultiplier & wavelength shifter
- Quadrupoles for KL decays



γγ physics





- For KLOE energies and kinematics both γ-s are quasi-real
- Accessible states

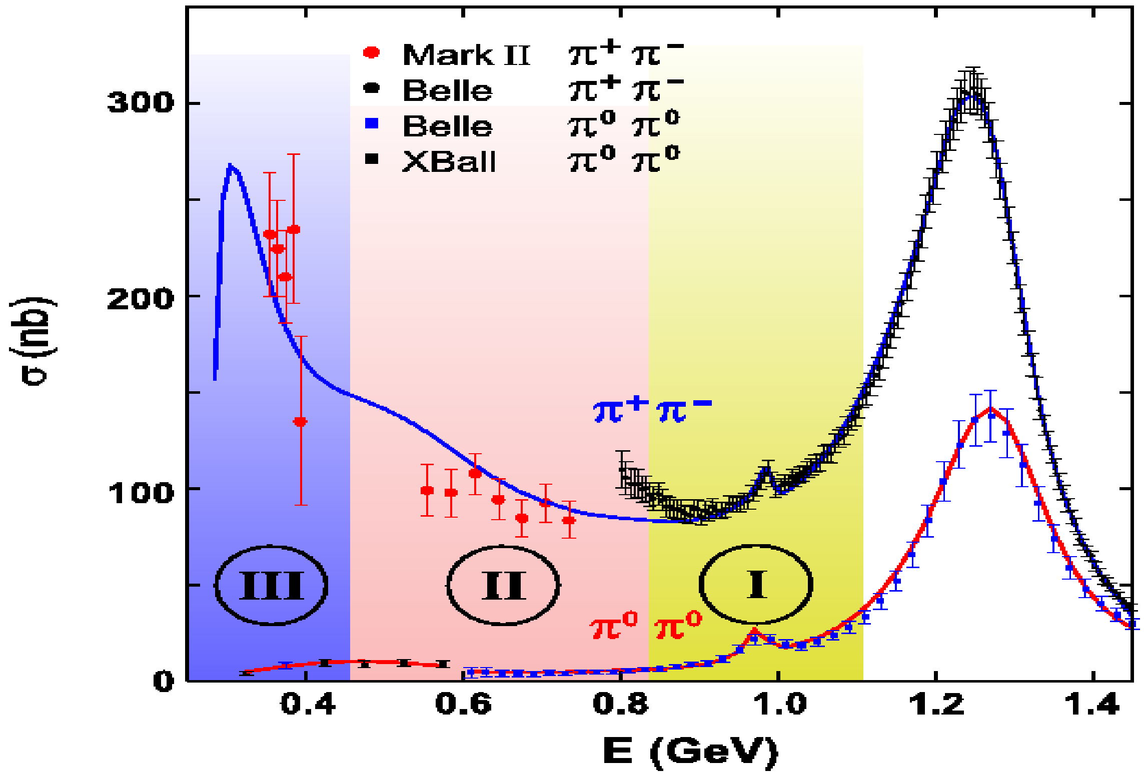
$$J_X^{PC} = 0^{\pm +},\ 2^{\pm +}$$

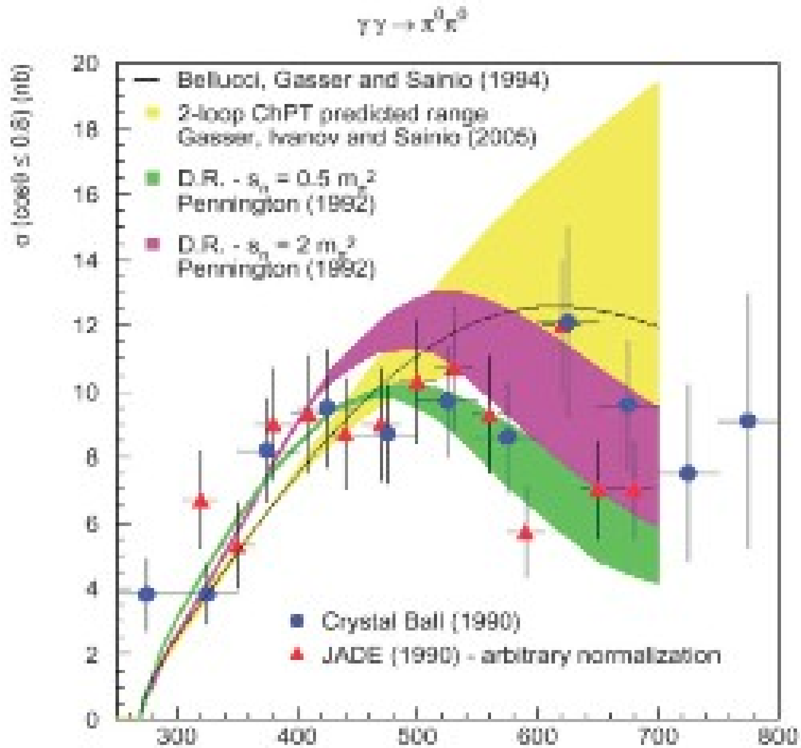
- Flux

$$\frac{dN_X}{dW_{\gamma\gamma}} = L_{ee} \frac{dF}{dW_{\gamma\gamma}} \sigma_{\gamma\gamma \to X}$$

γγ→ππ

- X is a single- or two-meson state
- σ for X=ππ; KLOE can contribute to colour-shaded areas I, II, III



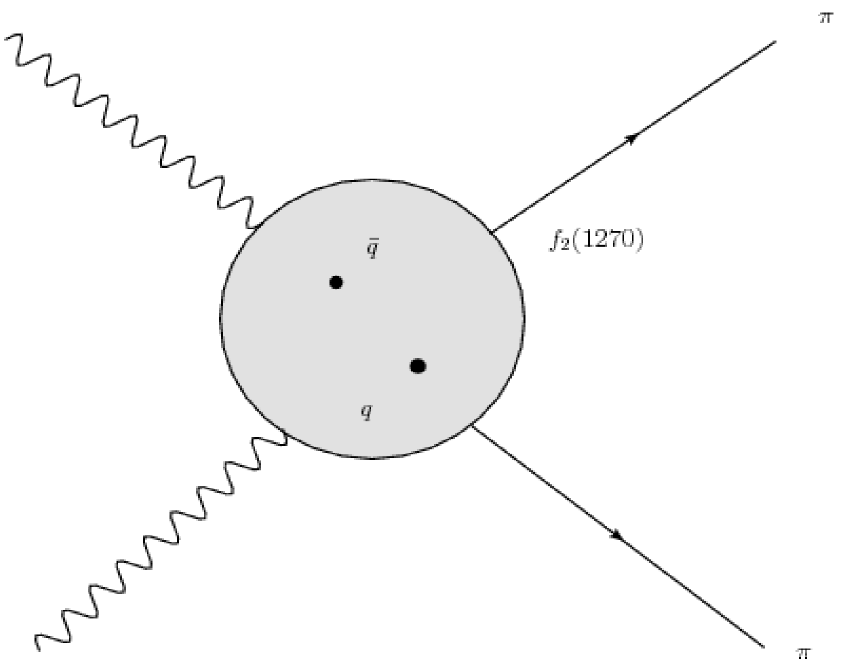


M.Pennington

γγ→ππ

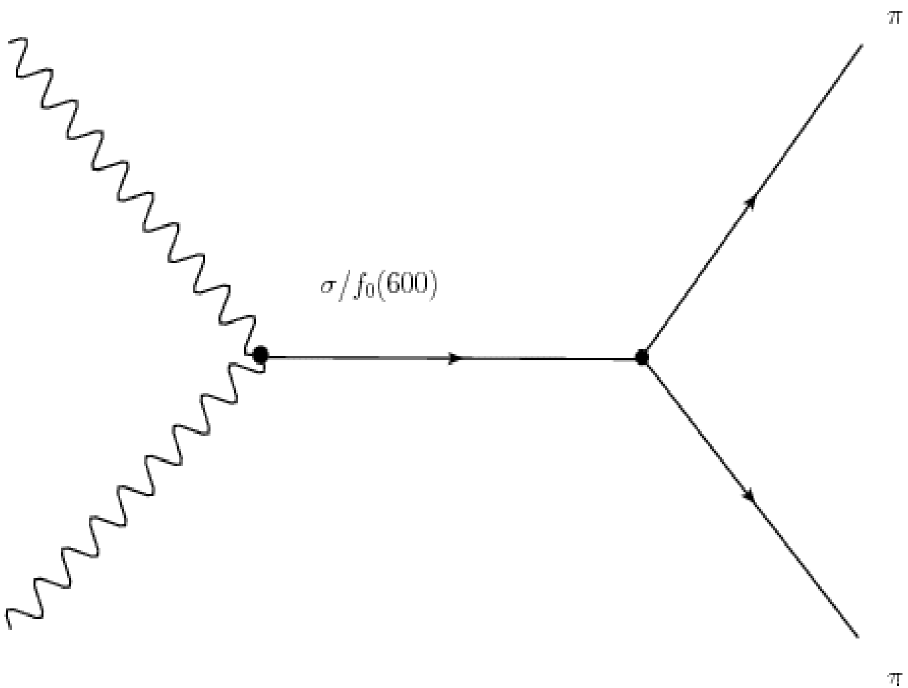
- Higher γγ energy (> 1 GeV) – photons reveal internal quark structure of f2 tensor meson
- f2(1270) decays into 2π with BR=85%

$$\sigma_{\pi^+\pi^-} \longrightarrow \sigma_{\pi^0\pi^0}$$



$\gamma\gamma \to \pi\pi$

- Lower γγ energy (< 1 GeV) – photons couple mainly to 2π final state from σ/f0 scalar decay
- σ/f0(600) dominantly decays into 2π
- $\sigma_{\pi^0\pi^0}$ becomes small



γγ→ππ

- I: 850-1100 MeV accurate measurement of 2π differential cross sections, any measurement of KK̄, πη.
- II: 450-850 MeV precision measurement of 2π in both charge modes, mainly for study of σ/f0
- III: 280-450 MeV dramatic improvement in data statistics; region crucial for PWA of resonances
- $\pi^0\pi^0$ channel cleaner than $\pi^+\pi^-$(devoid background from $\mu^+\mu^-$) .. but still Φ→KK with one escaping K (eliminated by taggers)

γγ→P

- P pseudoscalar π, η, η’
- Measurement of decay width Γ(P→γγ) from narrow-width approximation

$$\sigma_{e^+e^-\to e^+e^-P} = \frac{16\alpha^2}{m_P^3}\Gamma(P\to\gamma\gamma)(\ln E_b/m_e)^2 f(z_P)$$

$\gamma\gamma \to P$

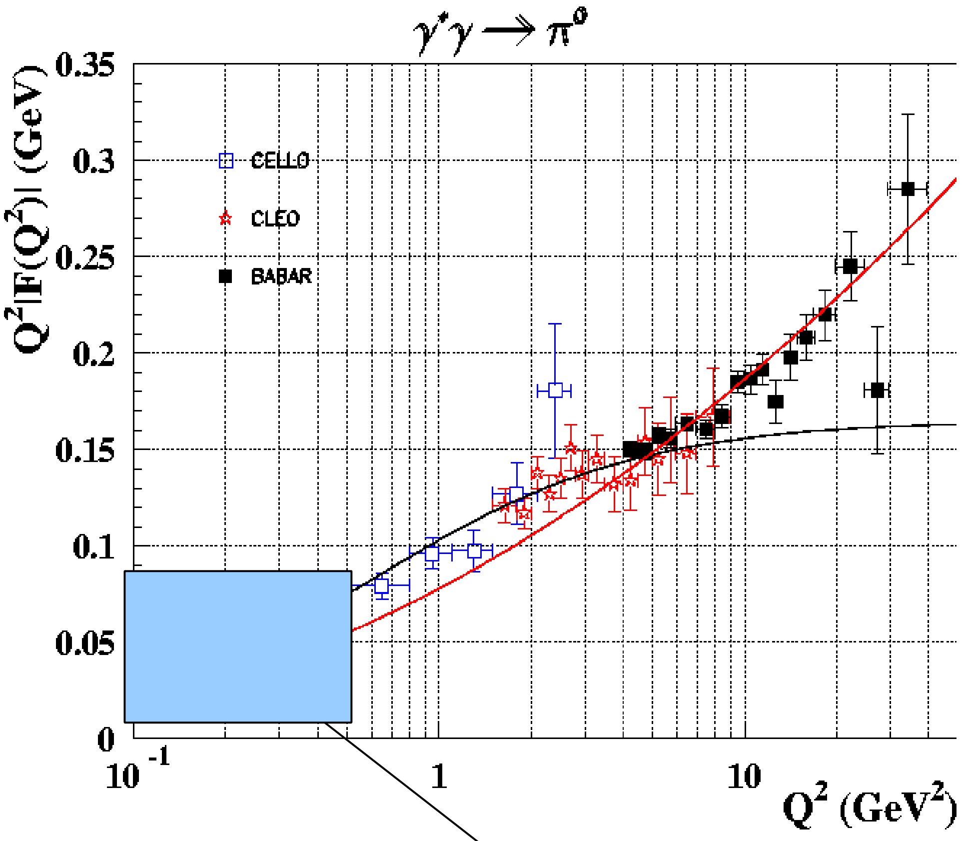
$\Gamma(P \to \gamma\gamma)$ used for determination

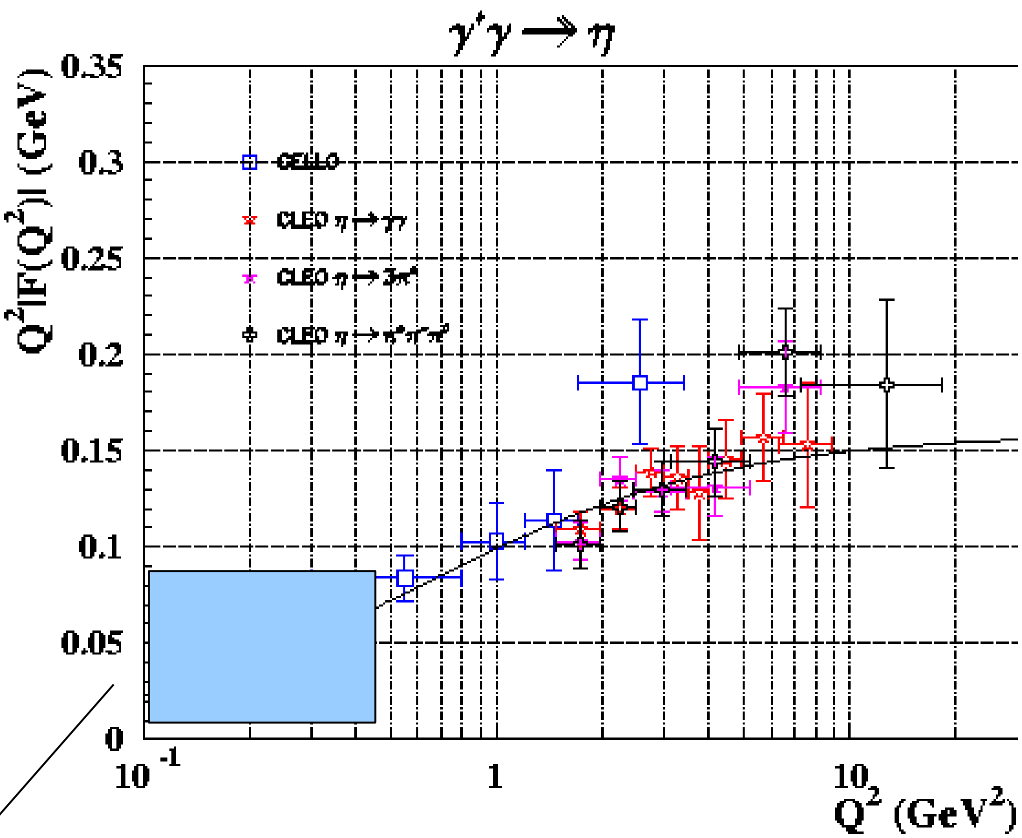
- η-η' mixing angle
- η' gluonium contents
- To determine from $\Gamma(\eta \to \gamma\gamma)$ & $\Gamma(\eta' \to \gamma\gamma)$

$$|\eta'\rangle = \cos\phi_{\mathbf{P}}\left(\sin\phi_{\mathbf{P}}|\mathbf{q\bar{q}}\rangle + \cos\phi_{\mathbf{P}}|\mathbf{s\bar{s}}\rangle\right) + \sin\phi_{\mathbf{G}}|\mathbf{G}\rangle$$

γγ→P

Transition form-factors

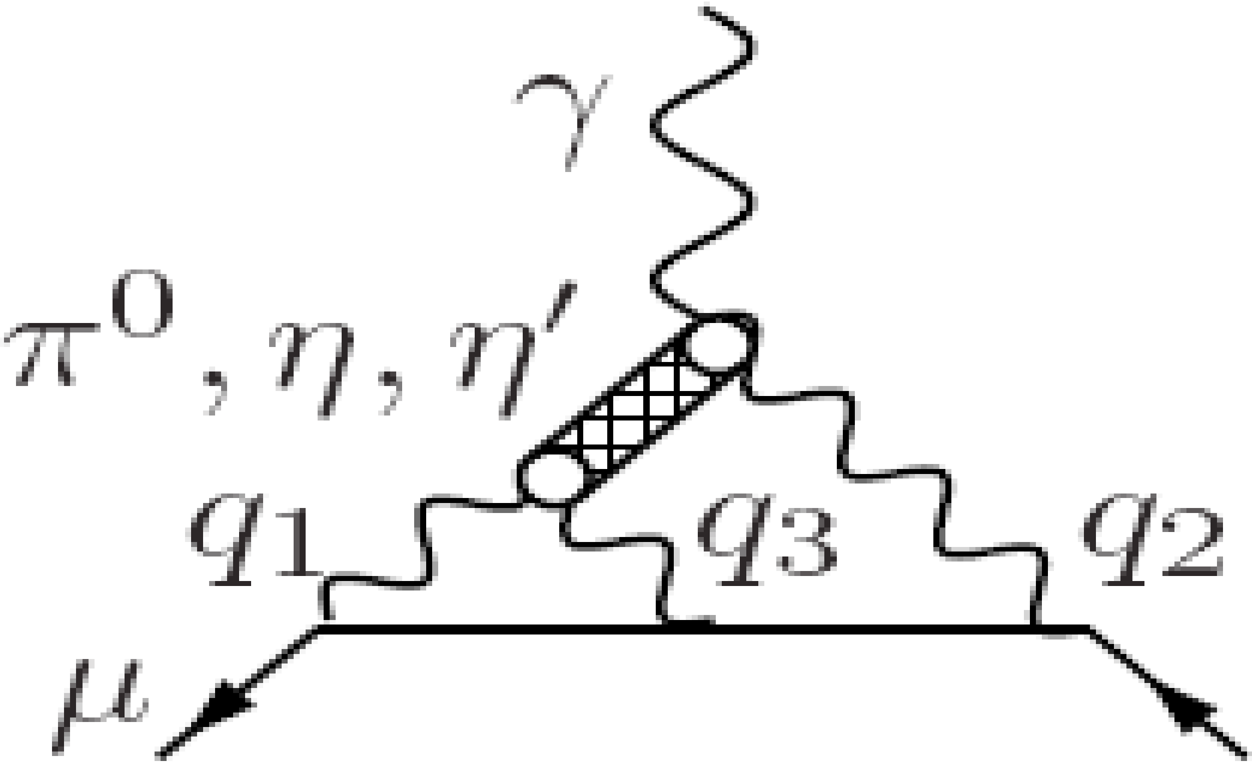




KLOE-2

$\gamma\gamma \to P$

Contribution to the light-by-light scattering in muon (g-2)



Decoherence

- Time evolution of neutral K pair from Φ decay
- Kaons are born in pure quantum entangled 1^{--} state

$$|\mathbf{i}\rangle = \frac{\mathbf{1}}{\sqrt{\mathbf{2}}}\left(|\mathbf{K_S}\rangle|\mathbf{K_L}\rangle - |\mathbf{K_L}\rangle|\mathbf{K_S}\rangle\right)$$

and evolve according to quantum mechanics

Decoherence

- Decay time difference distribution

$$\mathbf{I(f_1, f_2; \Delta t)} \sim |\eta_1|^2 \mathbf{e}^{-\Gamma_L \Delta t} + |\eta_2|^2 \mathbf{e}^{-\Gamma_S \Delta t}$$

$$-2(1-\zeta)|\eta_1||\eta_2|\mathbf{e}^{-(\Gamma_L+\Gamma_S)/2\Delta t}\cos(\Delta m \Delta t + \Delta\varphi_K)$$

- ζ – the simplest decoherence parametrization

Decoherence

Approaches with deeper physics insight

- Admixture ω of symmetric state
- $|\mathbf{i}\rangle + |\mathbf{i}'\rangle$ where

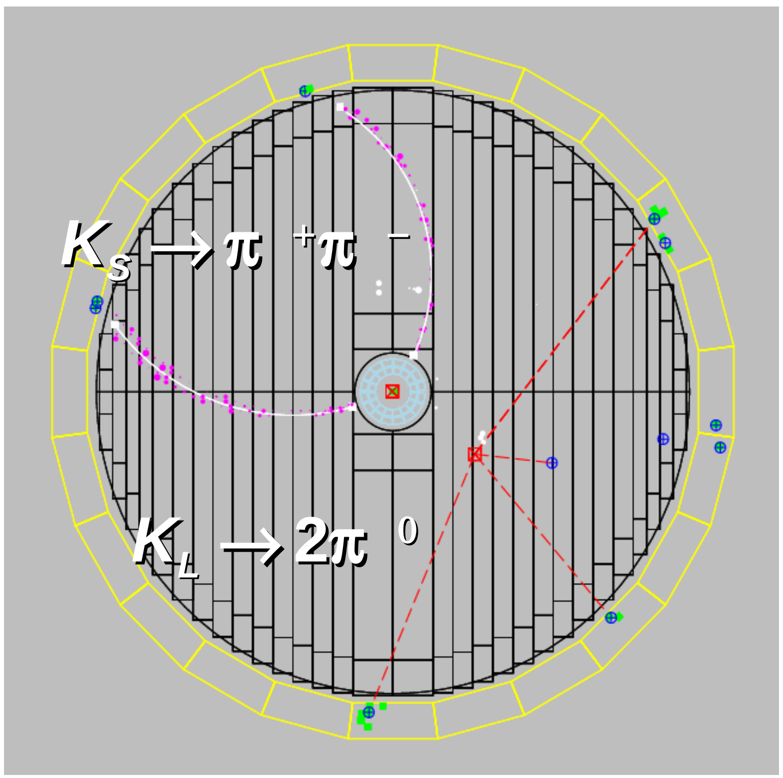
$$|\mathbf{i}'\rangle = \frac{\omega}{\sqrt{2}}(|\mathbf{K_S}\rangle|\mathbf{K_S}\rangle - |\mathbf{K_L}\rangle|\mathbf{K_L}\rangle)$$

- Dissipative term (parametrized α,β,γ) in density matrix Liouville evolution

$$\frac{\mathbf{d}\rho}{\mathbf{dt}} = \mathbf{i}[\rho, \mathbf{H}] + \delta\mathbf{H}(\alpha, \beta, \gamma) \cdot \rho$$

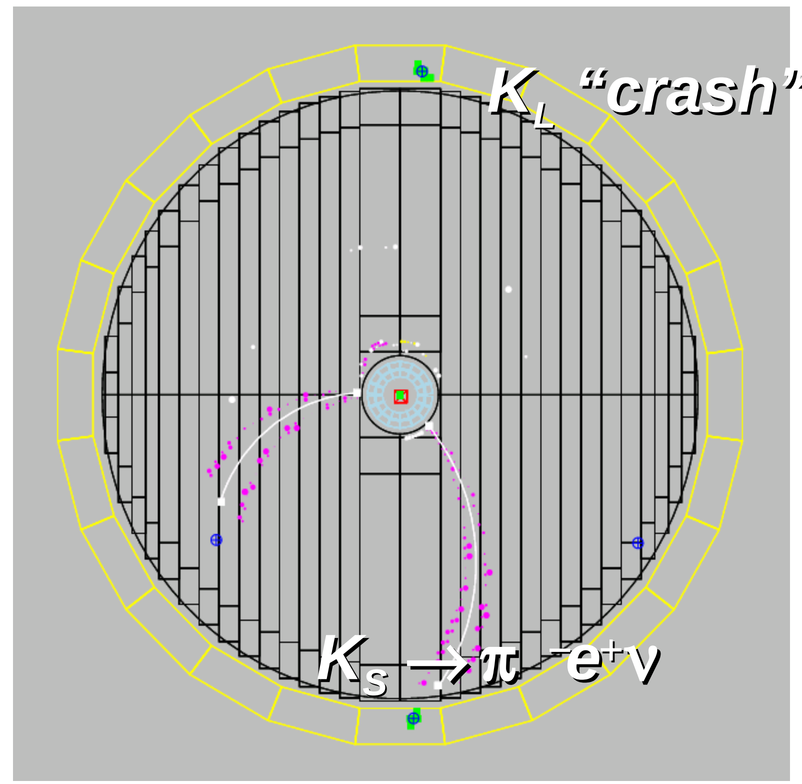
K detection in KLOE

- KL tagged by KS→ππ vertex in IP



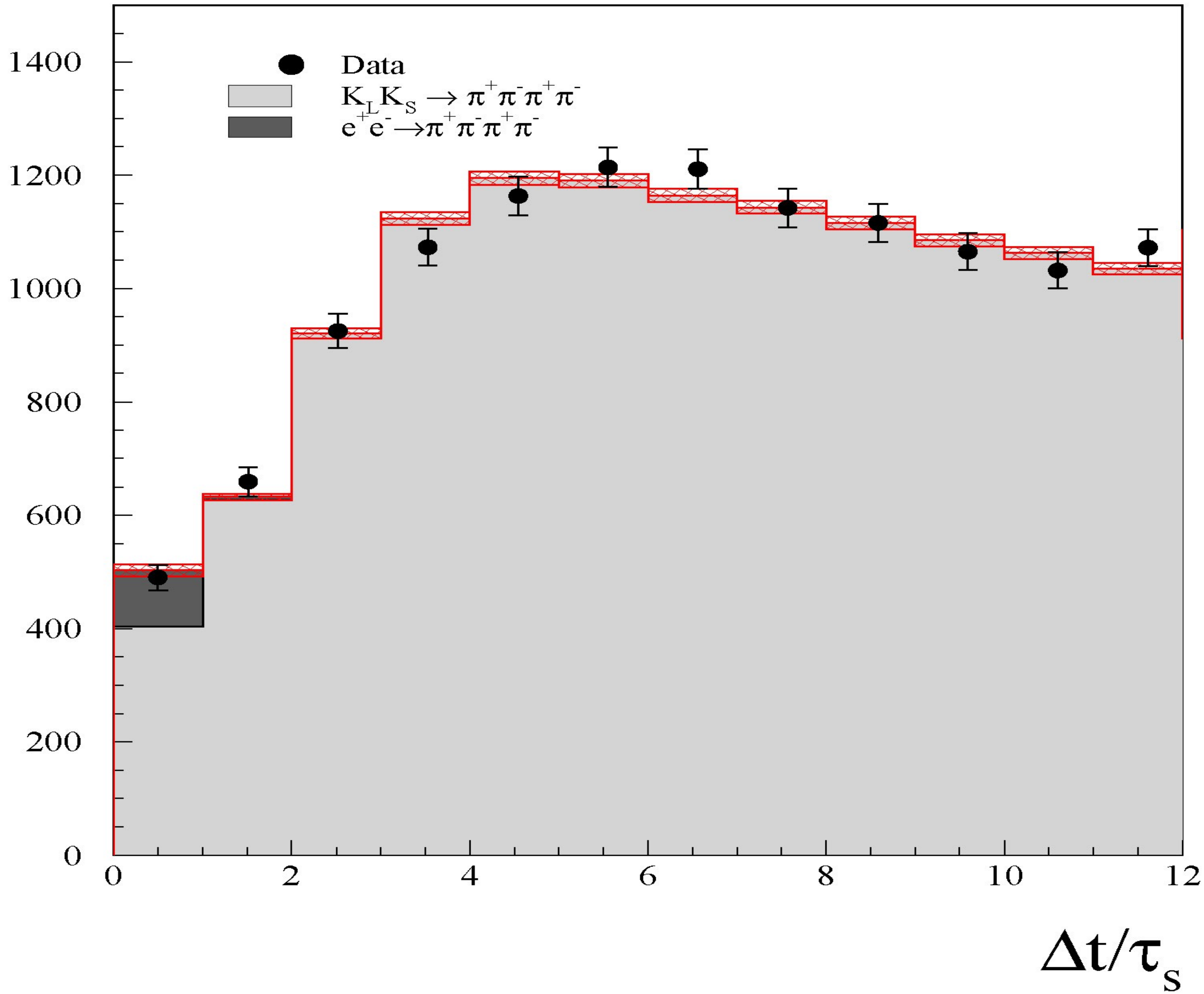
- 70% efficiency

- KS tagged by KL interaction in EMC



- 30% efficiency

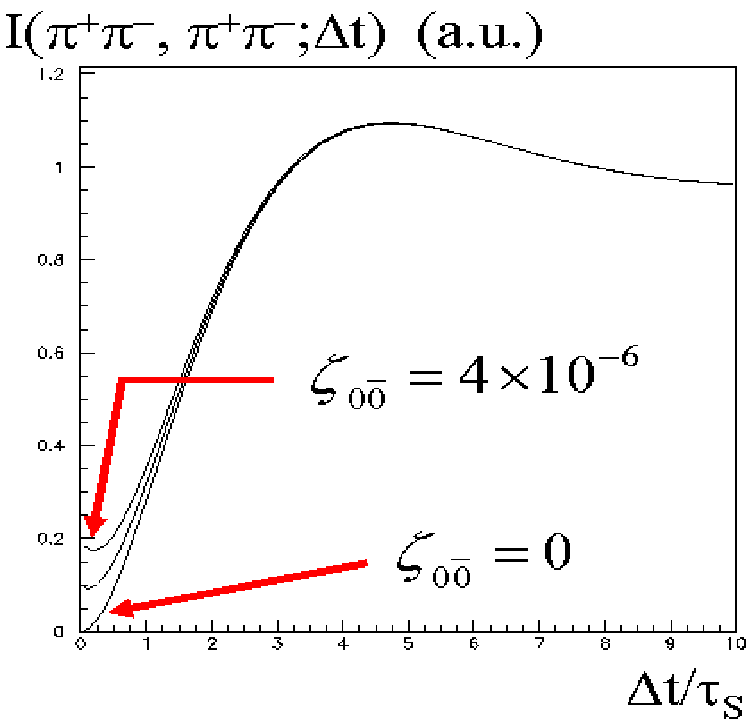
KLOE results



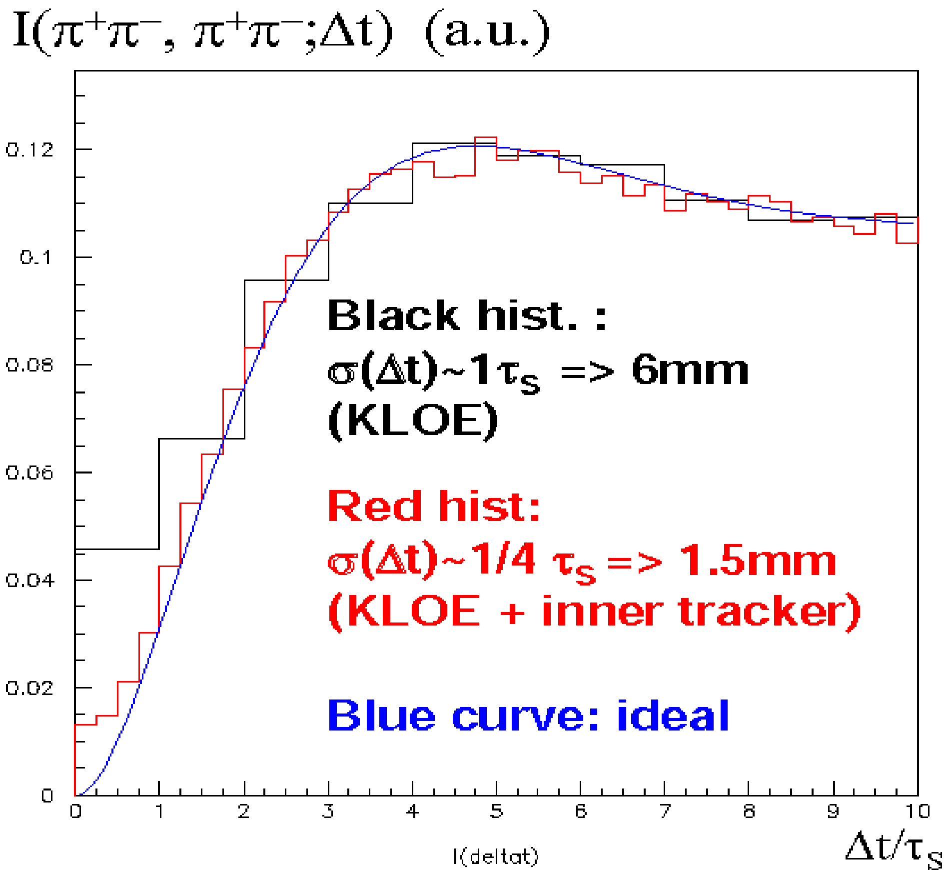
Results for the 2π identical final states; fit result in red

KLOE2: expected improvement with IT

Possible signal of decoherence concentrated at very small Δt



Theoretical distribution



Reconstructed distribution (MC)

KLOE2: expected improvement on decoherence parameters

parameter	KLOE	KLOE-2, 25 fb^{-1}
ζ_{LS}	$(0.3 \pm 1.9) \times 10^{-2}$	$\pm 0.2 \times 10^{-2}$
ζ_{00}	$(0.1 \pm 1.0) \times 10^{-6}$	$\pm 0.1 \times 10^{-6}$
$\mathrm{Re}(\omega)$	$(-1.6^{+3.0}_{-2.1} \pm 0.4) \times 10^{-4}$	$\pm 3 \times 10^{-5}$
$\mathrm{Im}(\omega)$	$(-1.7^{+3.3}_{-3.0} \pm 1.2) \times 10^{-4}$	$\pm 4 \times 10^{-5}$
α	$(-0.5 \pm 2.8) \times 10^{-17}$ GeV	$\pm 2.0 \times 10^{-17}$ GeV
β	$(2.5 \pm 2.3) \times 10^{-19}$ GeV	$\pm 0.2 \times 10^{-19}$ GeV
γ	$(1.1 \pm 2.5) \times 10^{-21}$ GeV	$\pm 0.3 \times 10^{-21}$ GeV
γ (positivity hyp.)	$(0.7 \pm 1.2) \times 10^{-21}$ GeV	$\pm 0.2 \times 10^{-21}$ GeV

Concluding remarks

- KLOE-2 continues rich physics programme of KLOE with significant improvements in data quality and statistics
- Physics running is about to start this autumn:

  KLOE2: 25 1/fb in 3 years

- Photon taggers installed
- IT, calorimeters for small angle photons and quadrupole region, later in 2011