Results From KLOE at DAFNE

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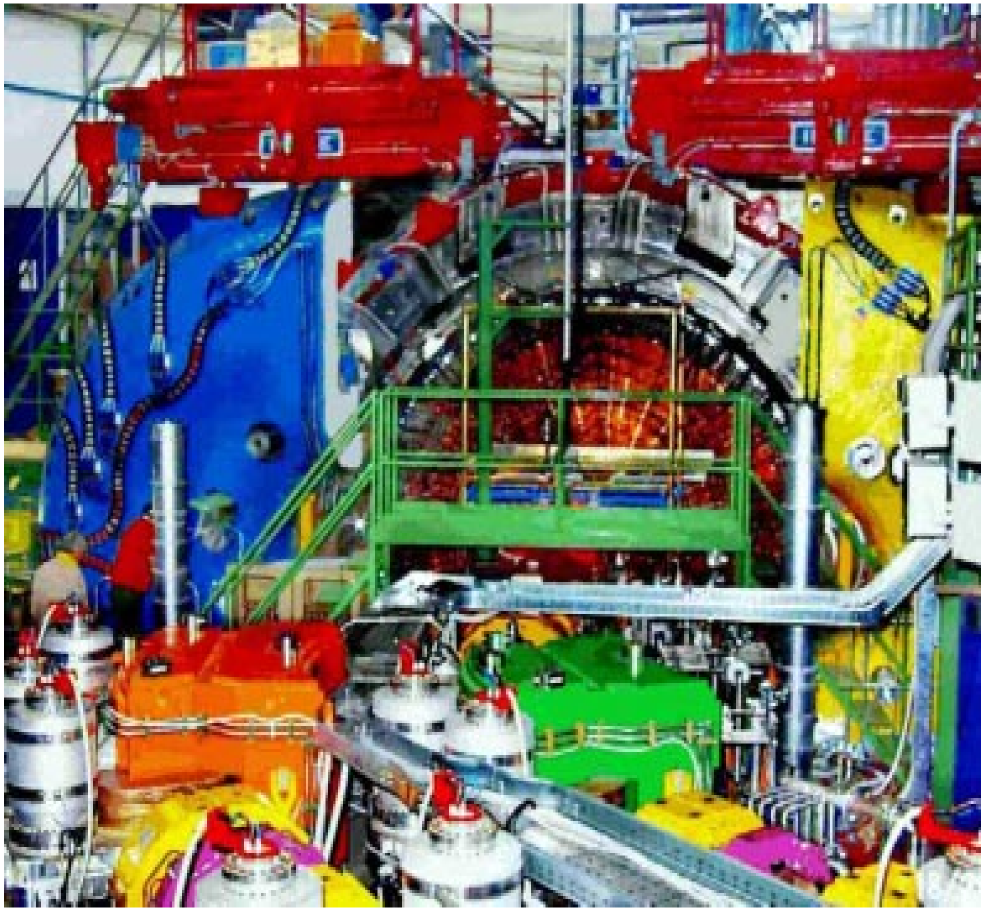
SLAC experimental seminar



The DAΦNE complex

DAΦNE is an electron-positron collider at $\sqrt{s} = 1.02$ GeV (ϕ - factory)

Design philosophy:

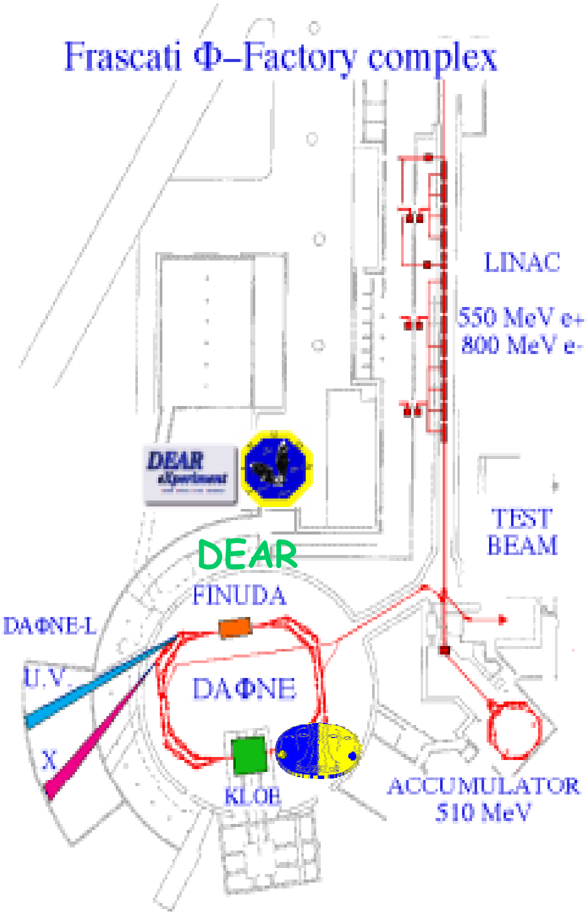
[**Moderate Single Bunch Luminosity $4 \cdot 10^{30}$ (VEPP-2M)**] * [**Large Number of Bunches (120)**]

$$\mathcal{L}_{design} = 5 \cdot 10^{32}\ cm^{-2}\ s^{-1}$$

Beam-beam @ 5A/beam => 2 indep. rings

Beam trajectory length ~ 98 m

Beam crossing frequency 368.25 MHz



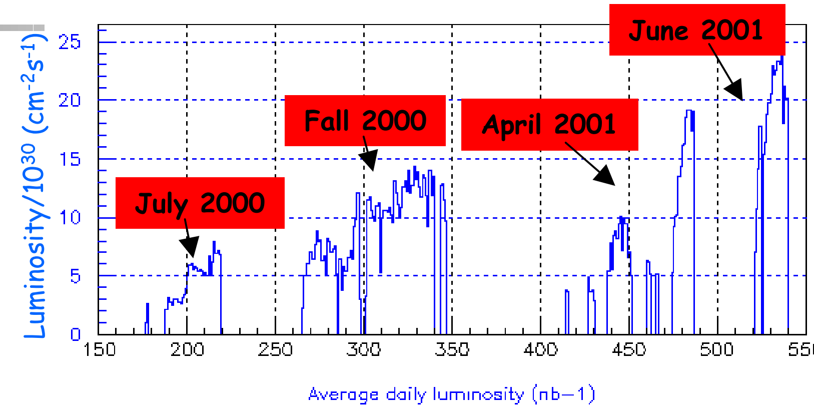
Bunch spacing : 2.7 ns

Bunch sizes @ I.P.:

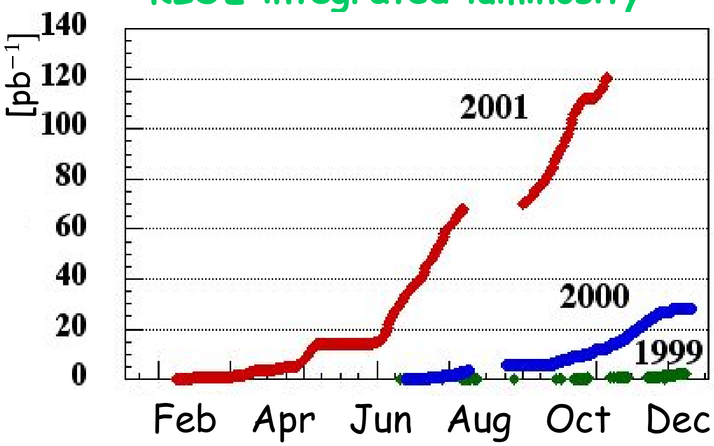
σ_x	σ_y	σ_z
2mm	20 μm	3 cm

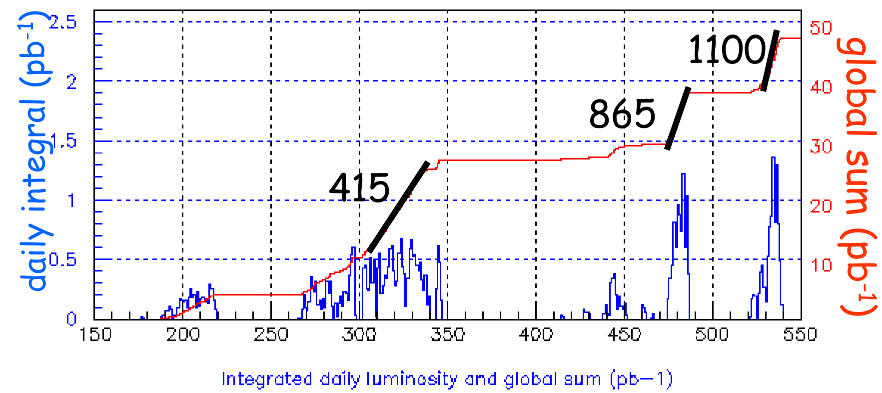
DAΦNE performance

- Discovery of wiggler problem
- New scrapers, new feedback amps
- More time dedicated to KLOE
- Achieved higher $\mathcal{L}$ (single bunch), close to 1 $\mu b^{-1} s^{-1}$
- Backgrounds...



KLOE integrated luminosity

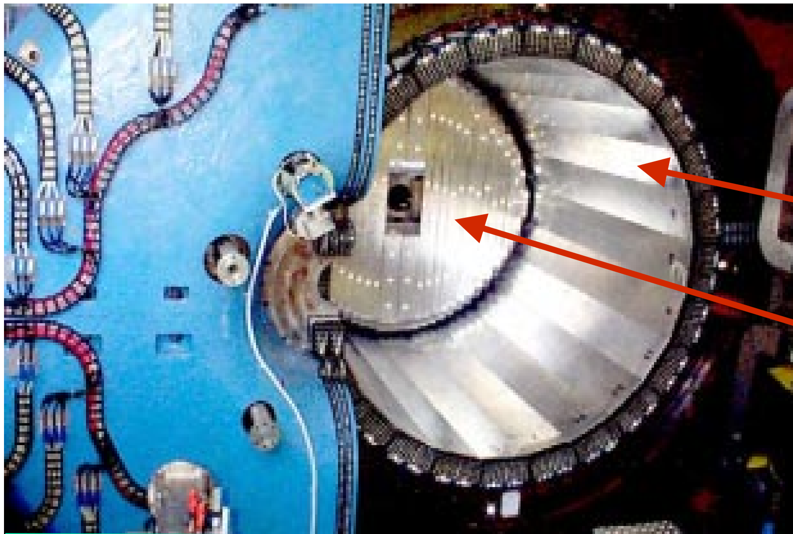


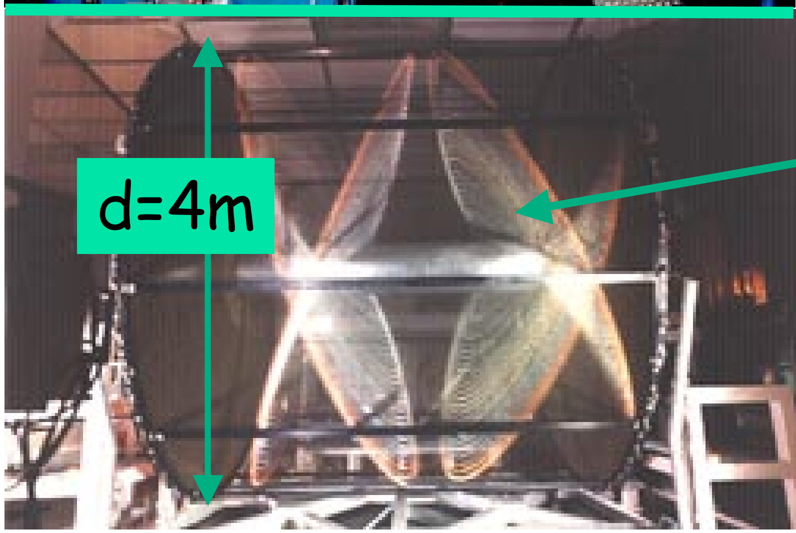


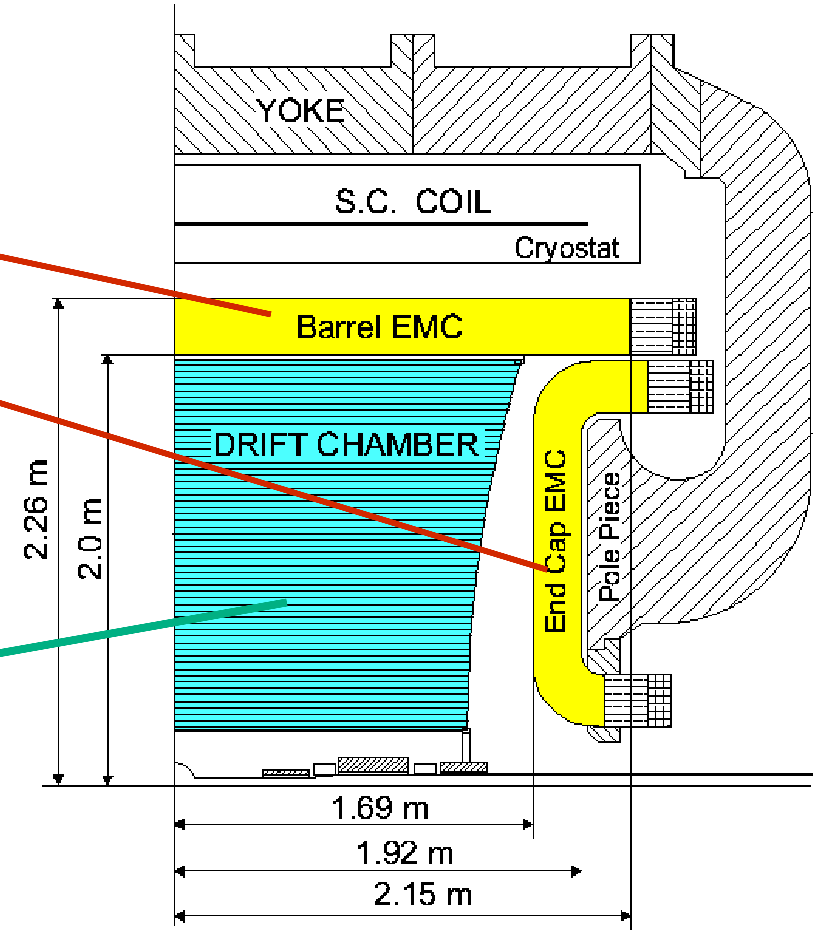
Improving continuously

	Peak	Average
$\mathcal{L}$ (cm^{-2} s^{-1})	$>4.0 \cdot 10^{31}$	$\sim 3 \cdot 10^{31}$
L_{day} (pb^{-1})	>2.0	~ 1.4

The KLOE detector







Electromagnetic Calorimeter

Efficient Detection of Photons ≥ 20 MeV

- Barrel + Endcap = 98% Hermetic Coverage
- Discriminate $K_L \to \pi^0\pi^0$ against $K_L \to \pi^0\pi^0\pi^0$
- Reconstruct $K_L \to \pi^0\pi^0$ decay vertex with a precision < 1 cm
- Serve as a 1st level Trigger

Pb - Sc.Fibres - Matrix
$\langle\rho\rangle$ = 5 g/cm^3
$\langle\lambda_0\rangle$ = 1.6 cm
sampl. frac.~15% (m.i.p.)

Design:

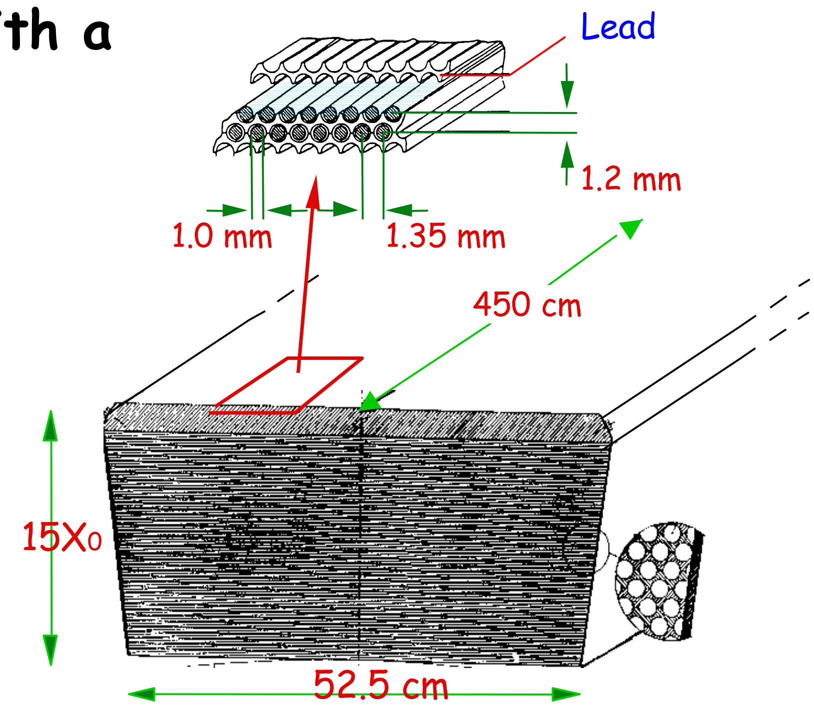
$\sigma_E/E = 5\%/\sqrt{E(\mathrm{GeV})}$

$\sigma_t = 70\ \mathrm{ps}/\sqrt{E\ (\mathrm{GeV})}$

Measured:

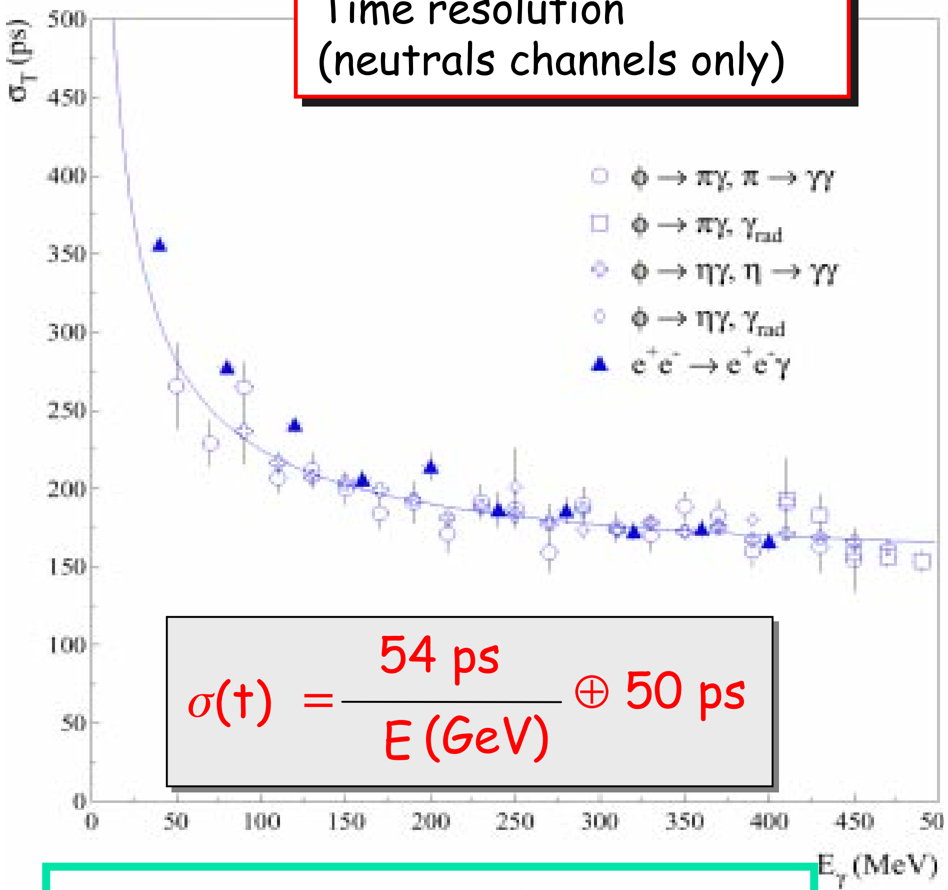
$\sigma_E/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$

$\sigma_t = 54\ \mathrm{ps}/\sqrt{E\ (\mathrm{GeV})} \oplus 50\ \mathrm{ps}$



EmC: time and energy performances

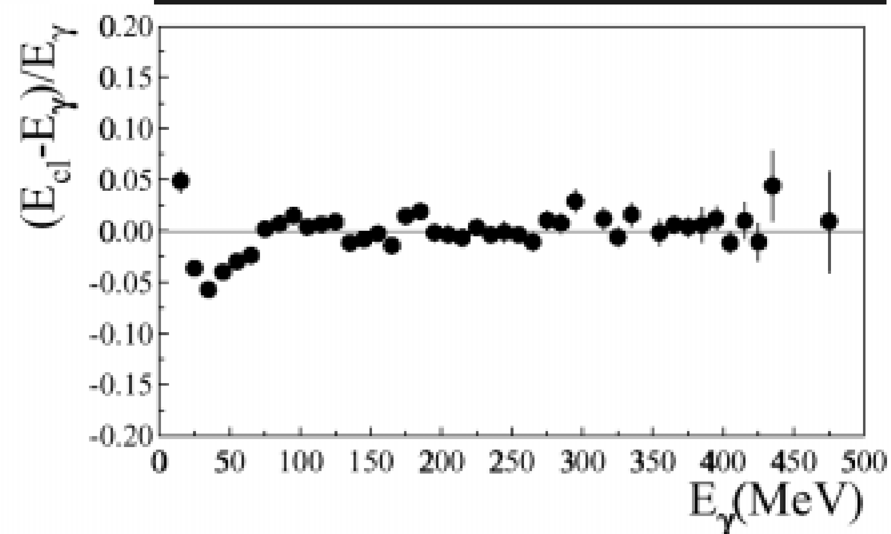
Time resolution
(neutrals channels only)

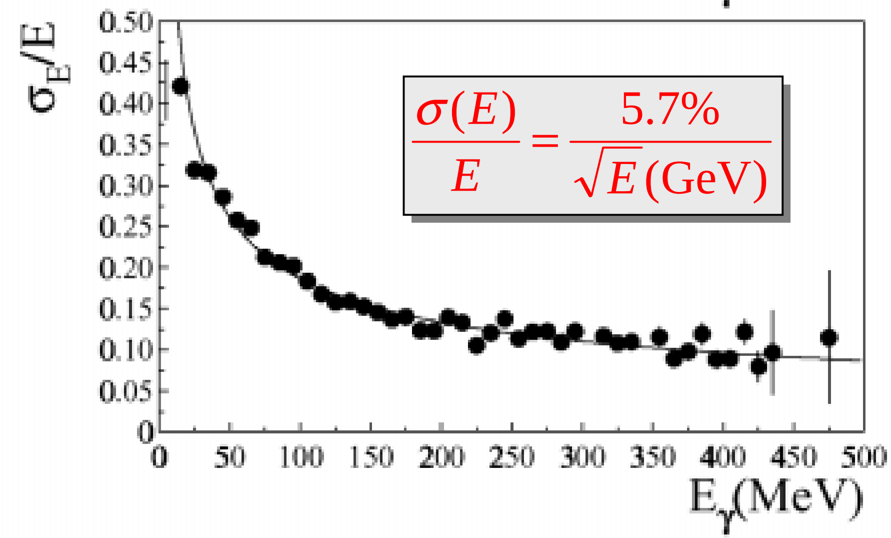


$$\sigma(t) = \frac{54\ \text{ps}}{E\ (\text{GeV})} \oplus 50\ \text{ps}$$

effects due to the beam (spread and bunch to bunch fluctuation) and to EMC cell to cell variation have been subctracted from the constant term

$e^+e^- \to e^+e^-\gamma$ E_γ from **DC**

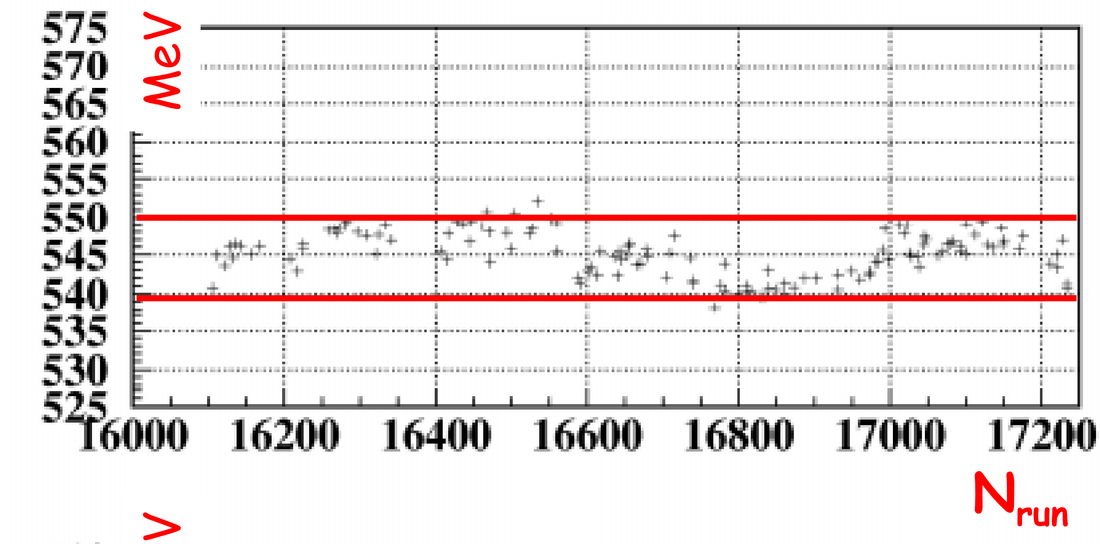




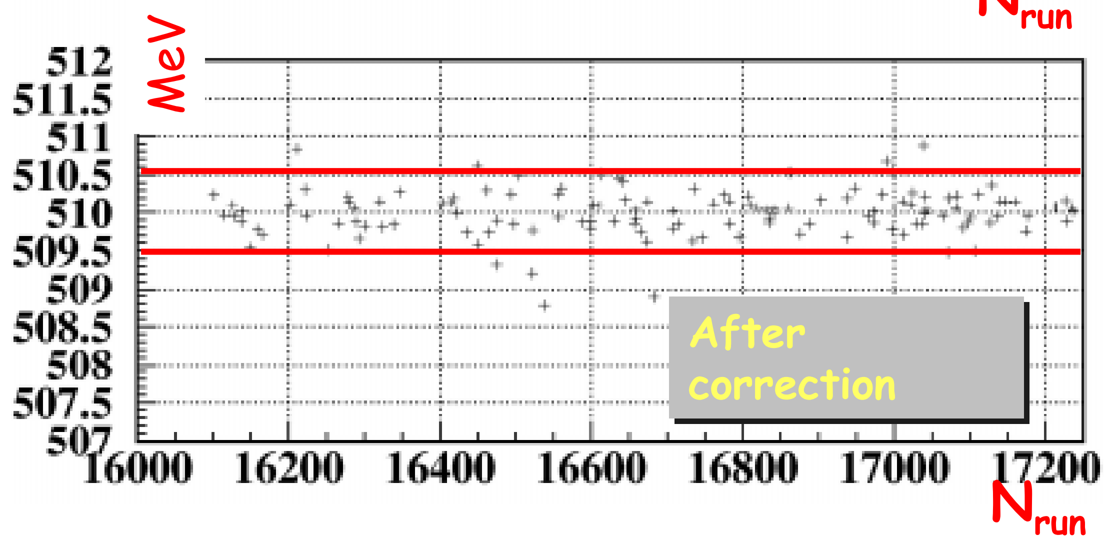
$$\frac{\sigma(E)}{E} = \frac{5.7\%}{\sqrt{E}\,(\text{GeV})}$$

EmC Calibration Monitoring & Stability

Energy variations (~2%) measured and corrected every 100 nb^{-1}

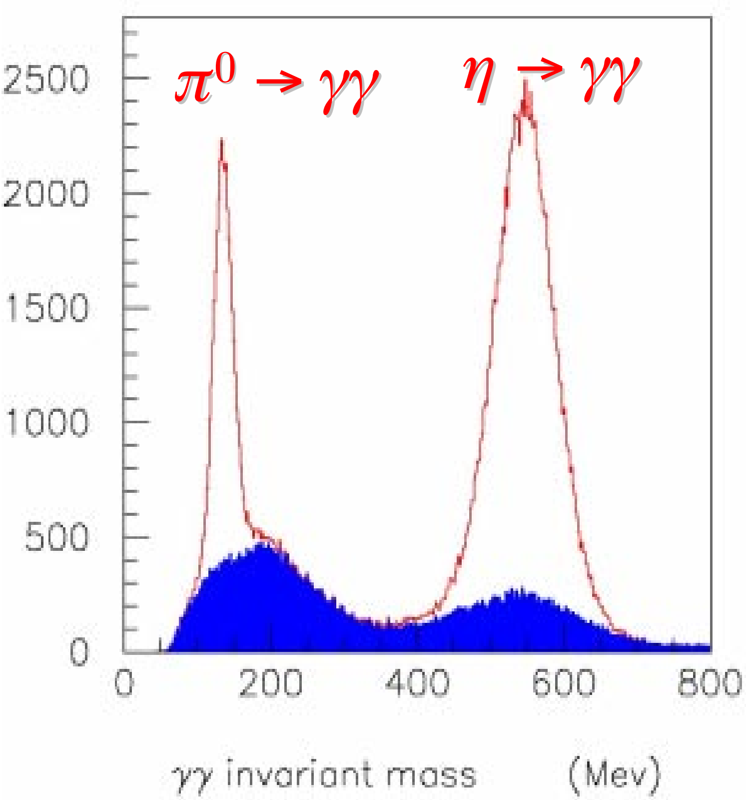


Energy absolute calibration ± 0.1%



EmC resolution on full neutral channels

$\phi \to \pi^0(\eta)\gamma \to \gamma\gamma\gamma$



m_{π^0} = 135.0 MeV
σ_m = 13.0 MeV

m_η = 546.4 MeV
σ_m = 40.3 MeV

$$\left.\frac{BR(\phi\to\eta\gamma\to\gamma\gamma\gamma)}{BR(\phi\to\pi^0\gamma\to\gamma\gamma\gamma)}\right|_{PDG} = 4.05\pm0.35$$

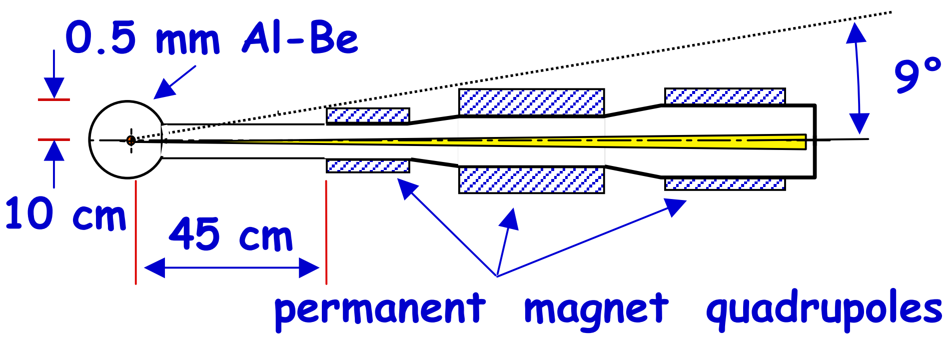
PDG '00

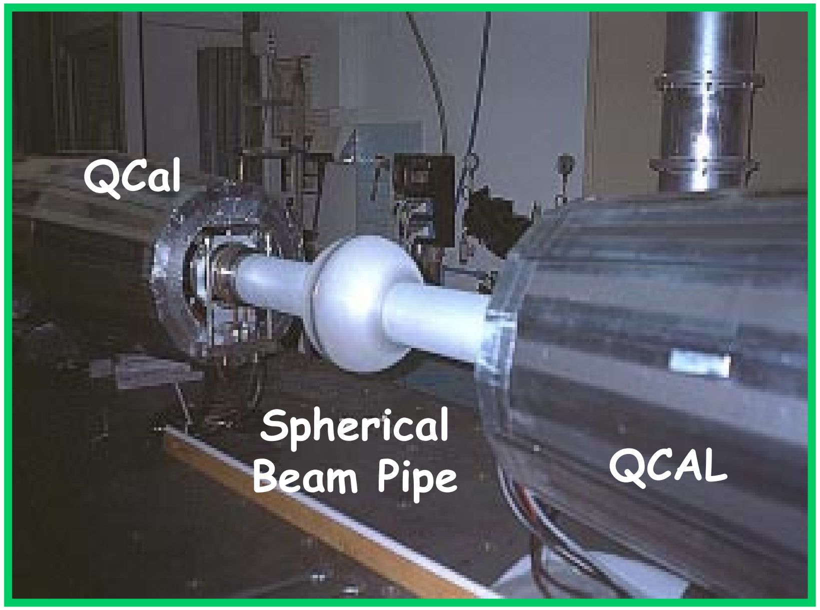
$$\left.\frac{BR(\phi\to\eta\gamma\to\gamma\gamma\gamma)}{BR(\phi\to\pi^0\gamma\to\gamma\gamma\gamma)}\right|_{KLOE} = 3.75\pm0.02\pm0.09$$

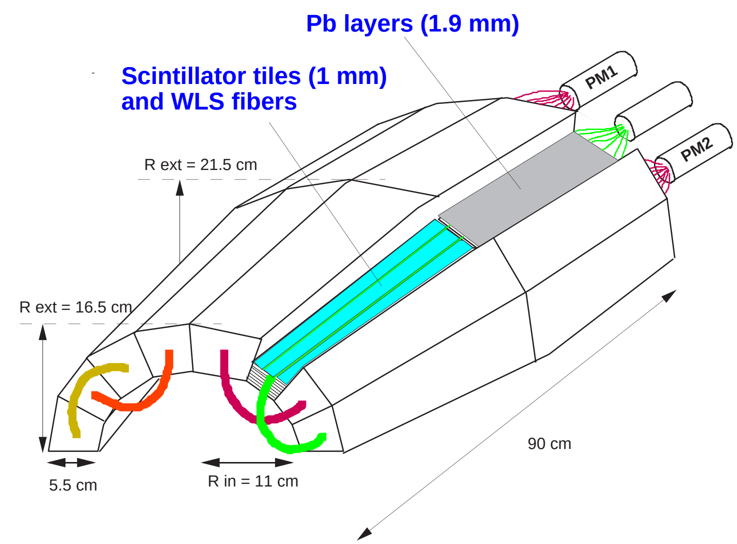
KLOE 16.6 pb^{-1}
preliminary

Quadrupole Calorimeter (QCAL)

Acceptance increased thanks to Quadrupole Instrumentation: Lead-Scintillator-Tile Sampling Calorimeter

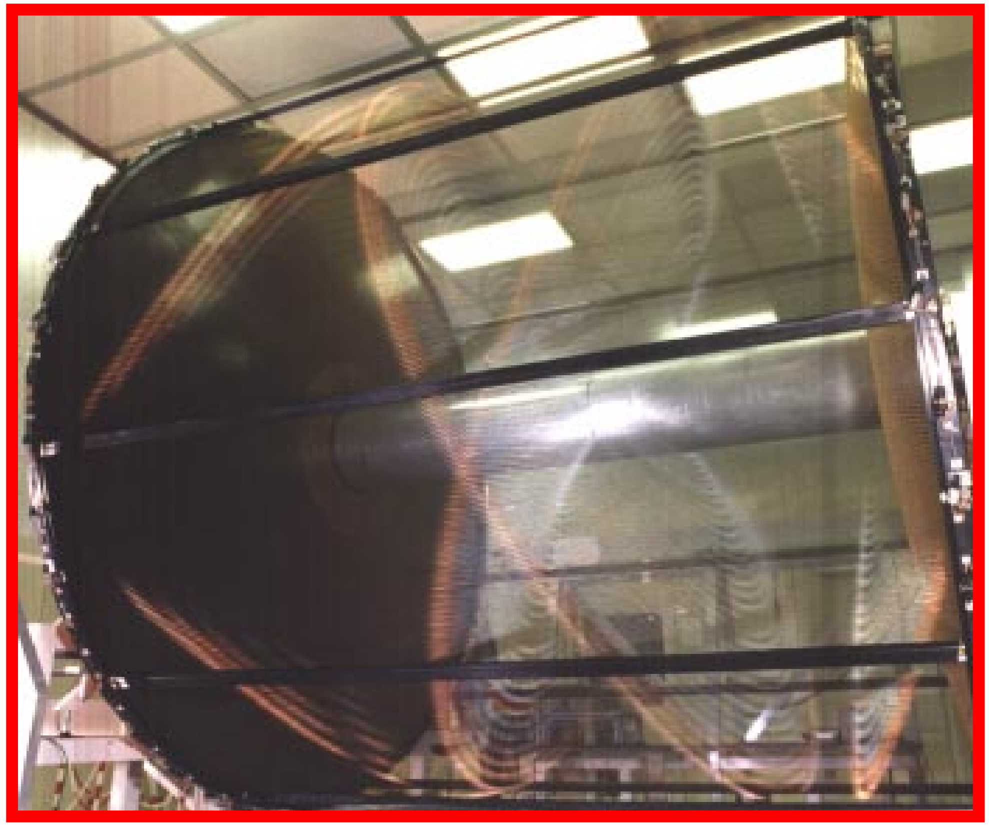






Drift Chamber

1. High and uniform track reconstruction efficiency
2. Determine the $K_{L,S}$ vertex with an accuracy ≤ 1mm
3. Good momentum resolution ($\delta p/p \sim 0.3\%$) for K_{l3} rej.
4. Transparent to low energy γ (down to 20 MeV) and $K_{L,S}$ regeneration

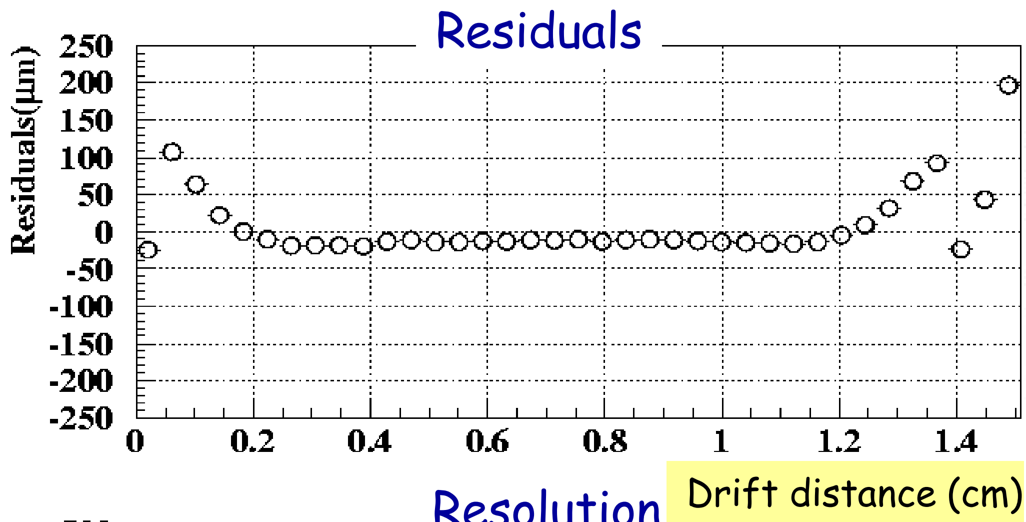


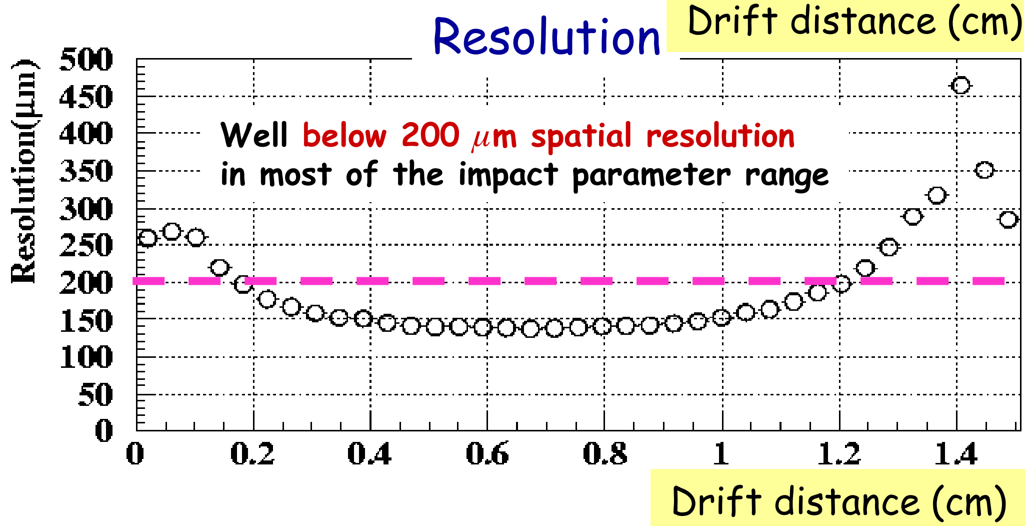
[90% He, 10% iC_4H_{10} (X_0=900m)
mechanical structure in C-Fibre
(<0.1 X_0)]

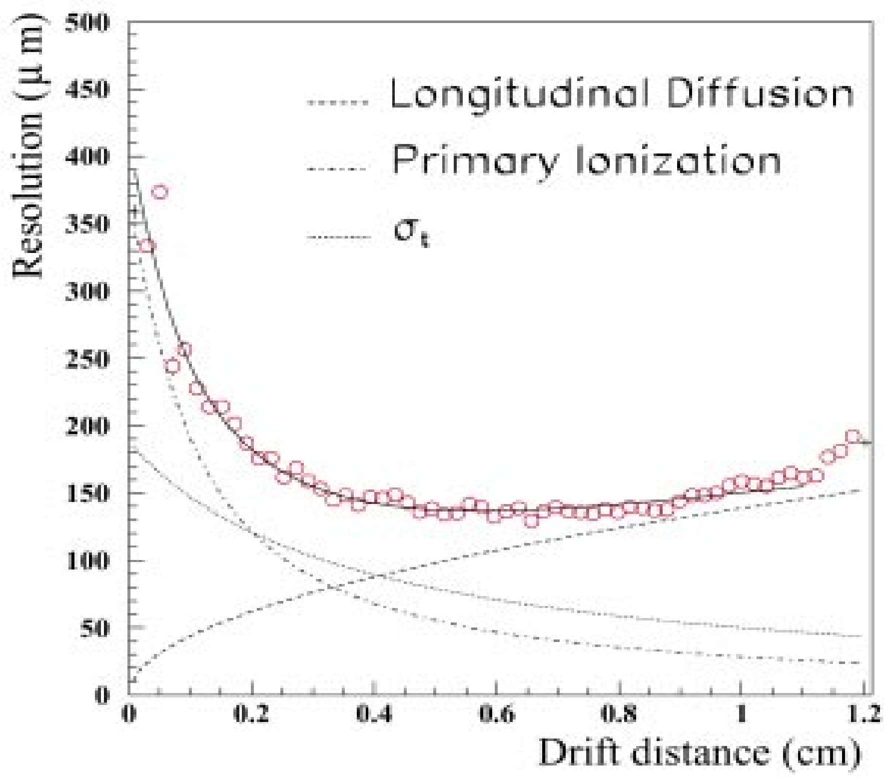
cell structure:

- 3:1 field:sense ratio
- 3 × 3 cm^2 in the 46 outer layers
- 2 × 2 cm^2 in the 12 inner layers

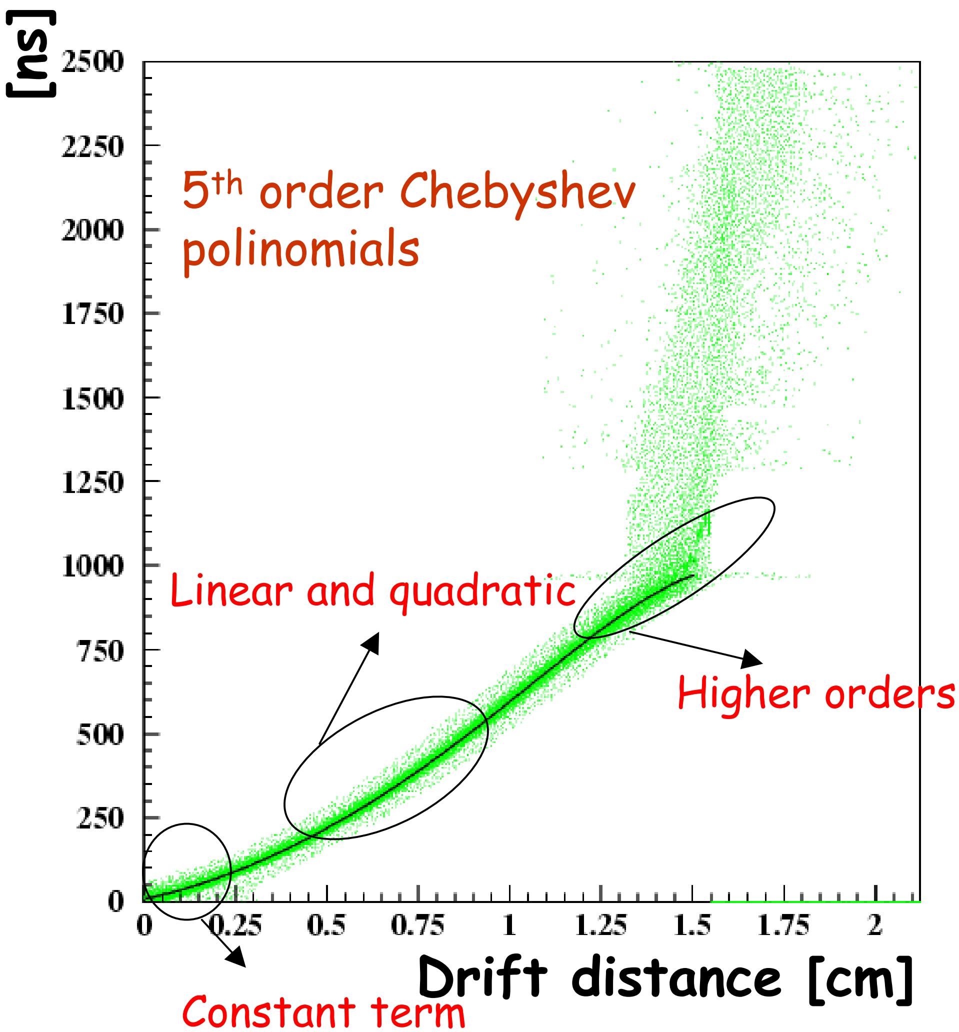
DC: point space resolution

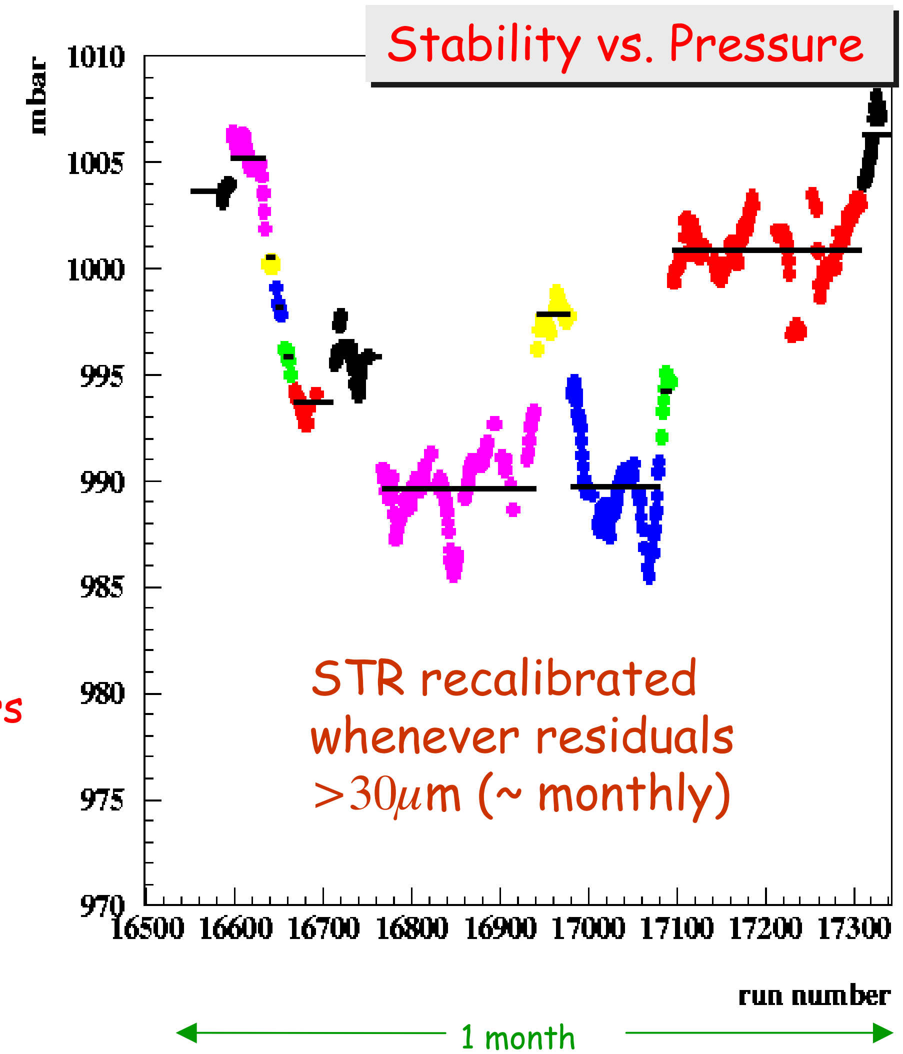




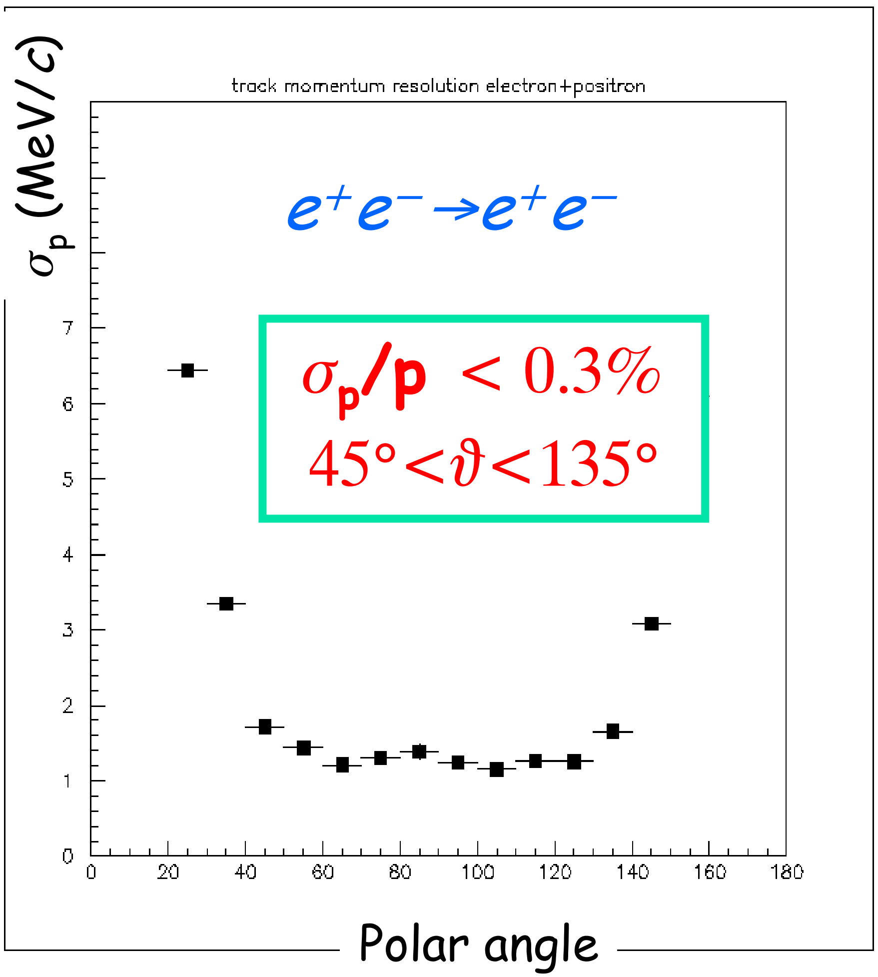


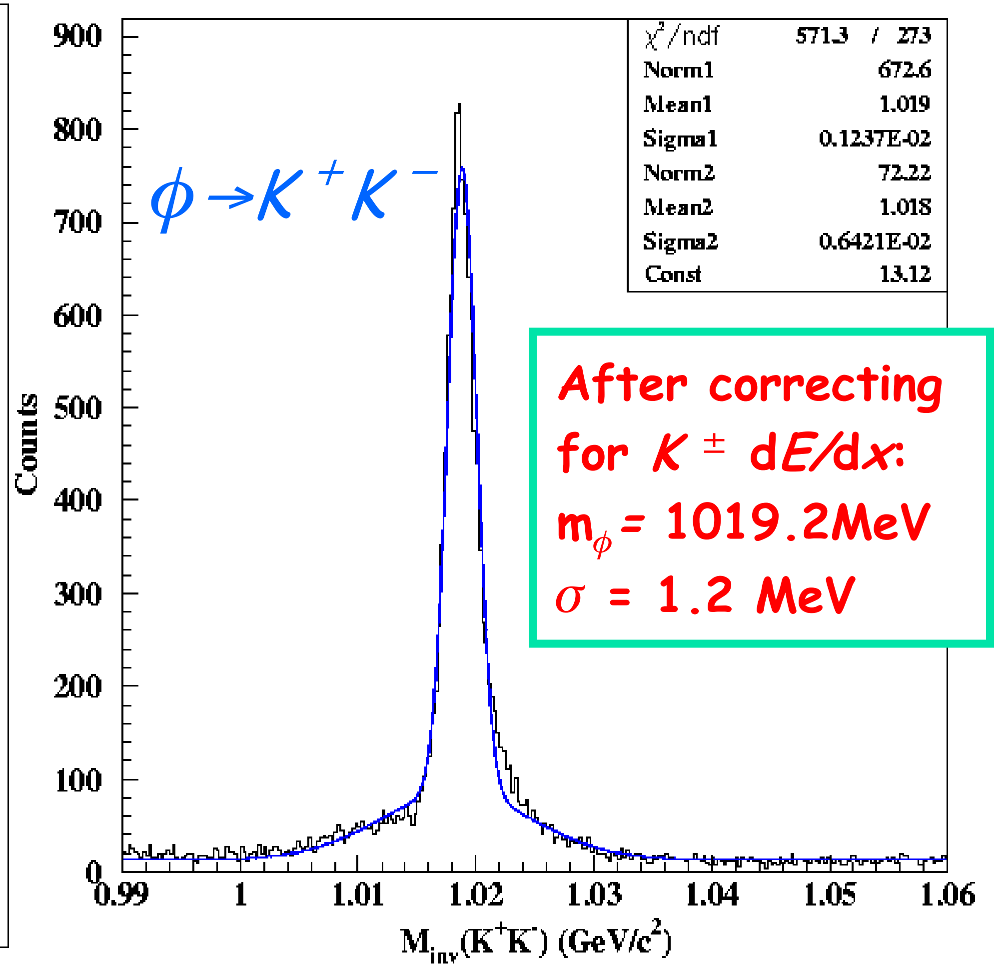
DC: s-t relations stability





DC momentum resolution I

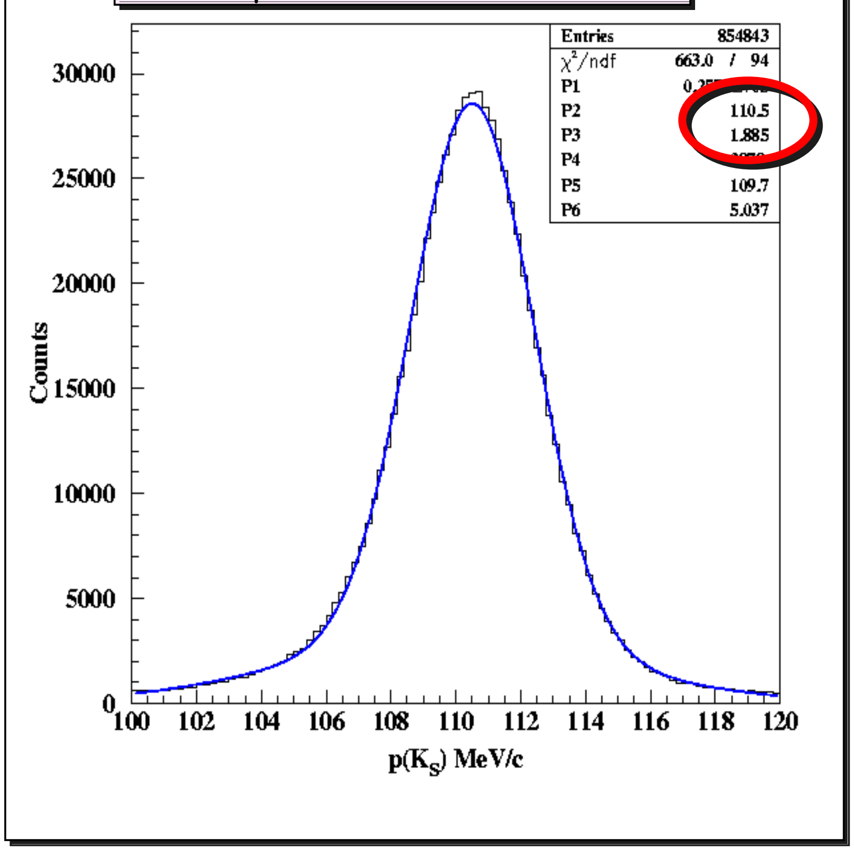




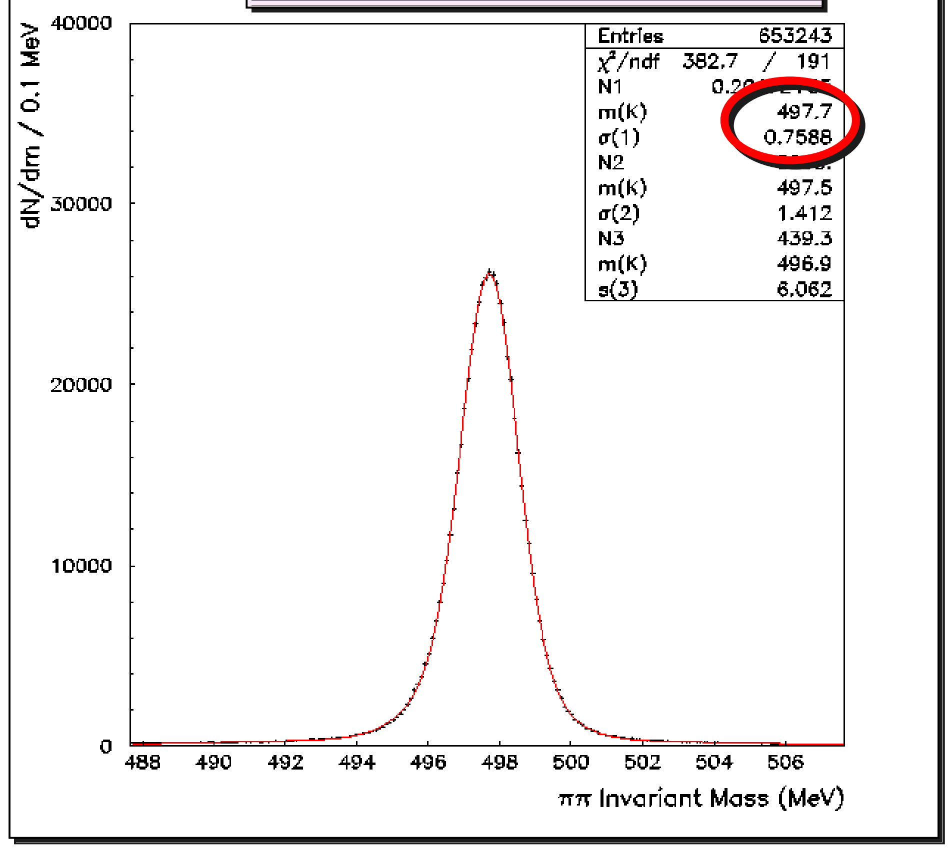
DC momentum resolution II

$K_S \rightarrow \pi^+\pi^-$

$p_{c.o.m.}$ = 110 MeV/c
σ_p = 1.8 MeV/c

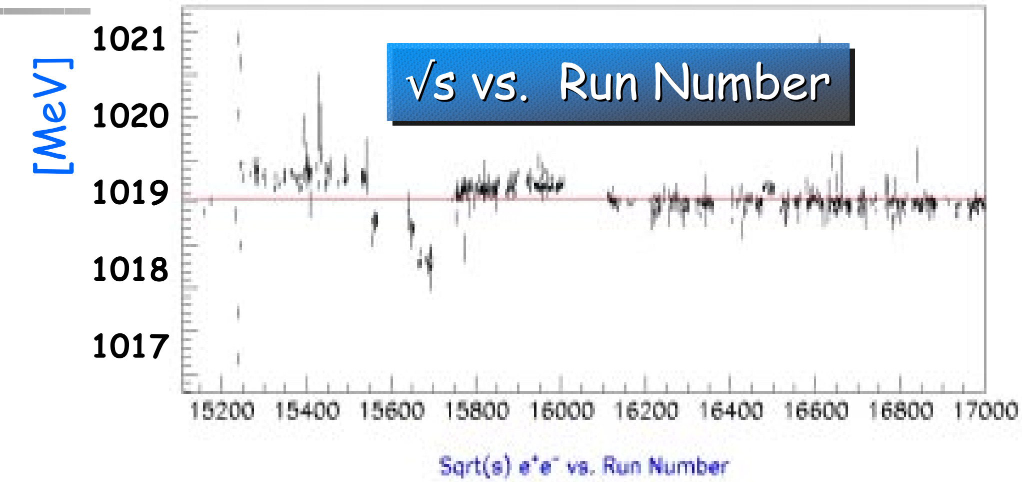


$m_{\pi\pi}$ = 497.7 MeV/c²
σ_m = 1 MeV/c²

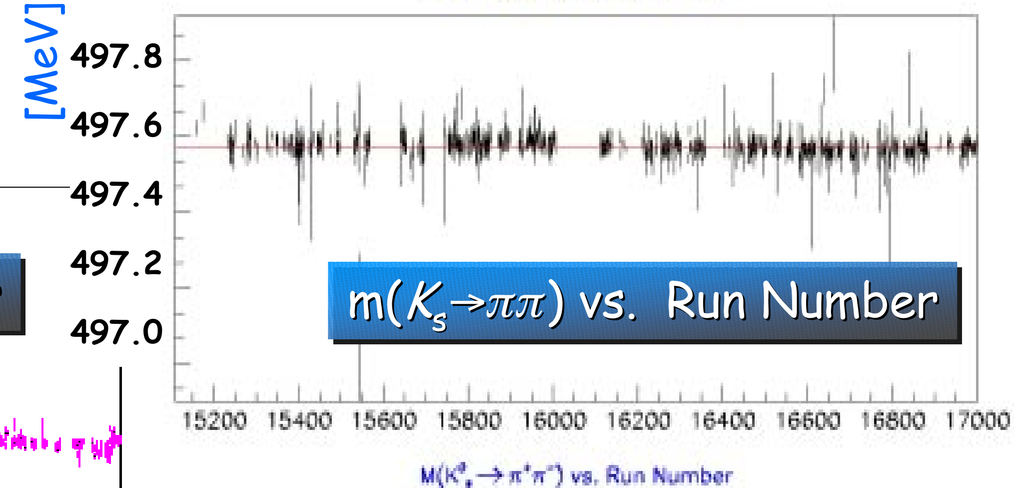


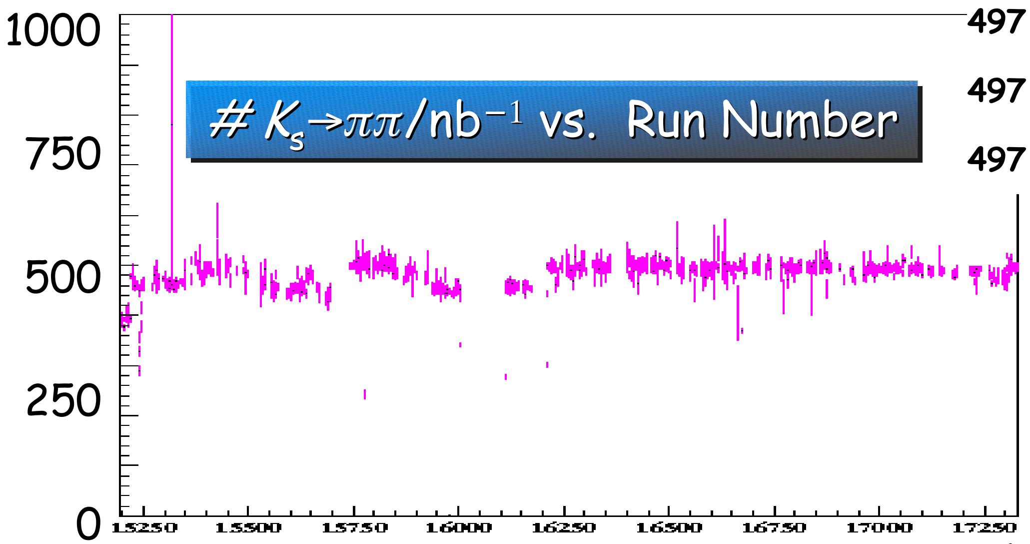
Data quality control

Center of mass energy monitored by the KLOE offline analysis: all the "jumps" are correlated with machine energy changes and ϕ scan.



K_s mass reconstruction stable during the physics runs



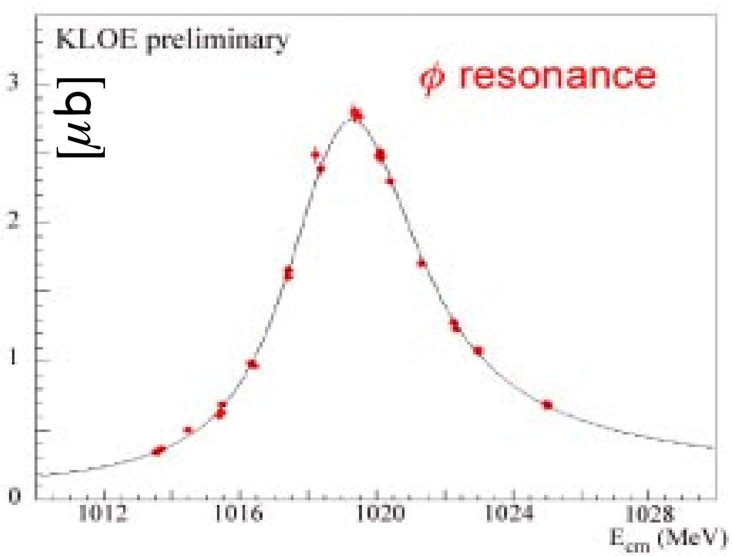


September/December 2000

Physics at a ϕ factory

Decay	BR(%)
$\phi \to K^+ K^-$	49.1
$\phi \to K_S K_L$	33.8
$\phi \to \rho\,\pi \,/\, \pi^+\pi^-\pi^0$	15.6
$\phi \to \eta\,\gamma$	1.26

p_K = 110 MeV/c
λ_S, λ_L = 6 mm, 3.5 m



- $\phi \to K_S K_L$ provides monochromatic K_S, K_L beams in pure $J^{PC} = 1^{--}$ state
- $K_S (K_L)$ tagged by observation of $K_L (K_S)$
- KLOE can measure K_S and K_L: *separately* BR's for all 4 modes in the double ratio

$$1 - 6\Re(\varepsilon'/\varepsilon) = \frac{BR(K_L \to \pi^0\pi^0)/BR(K_L \to \pi^+\pi^-)}{BR(K_S \to \pi^0\pi^0)/BR(K_S \to \pi^+\pi^-)}$$

- *CP* and *CPT* studies via quantum interferometry
- Tagged K_S beam allows study of rare K_S decays

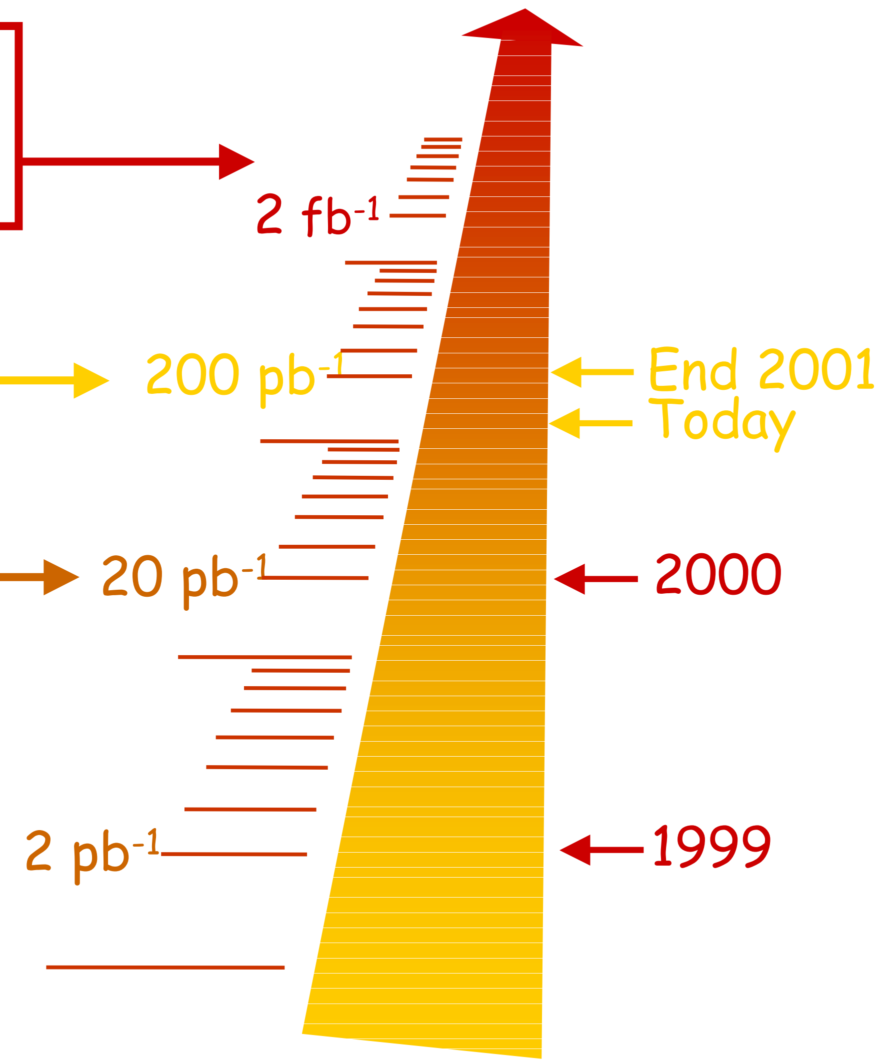
The KLOE physics program

ε'/ε to $O(10^{-4})$ via double ratio
Semileptonic asymmetry (*CPT* test)
Interferometry

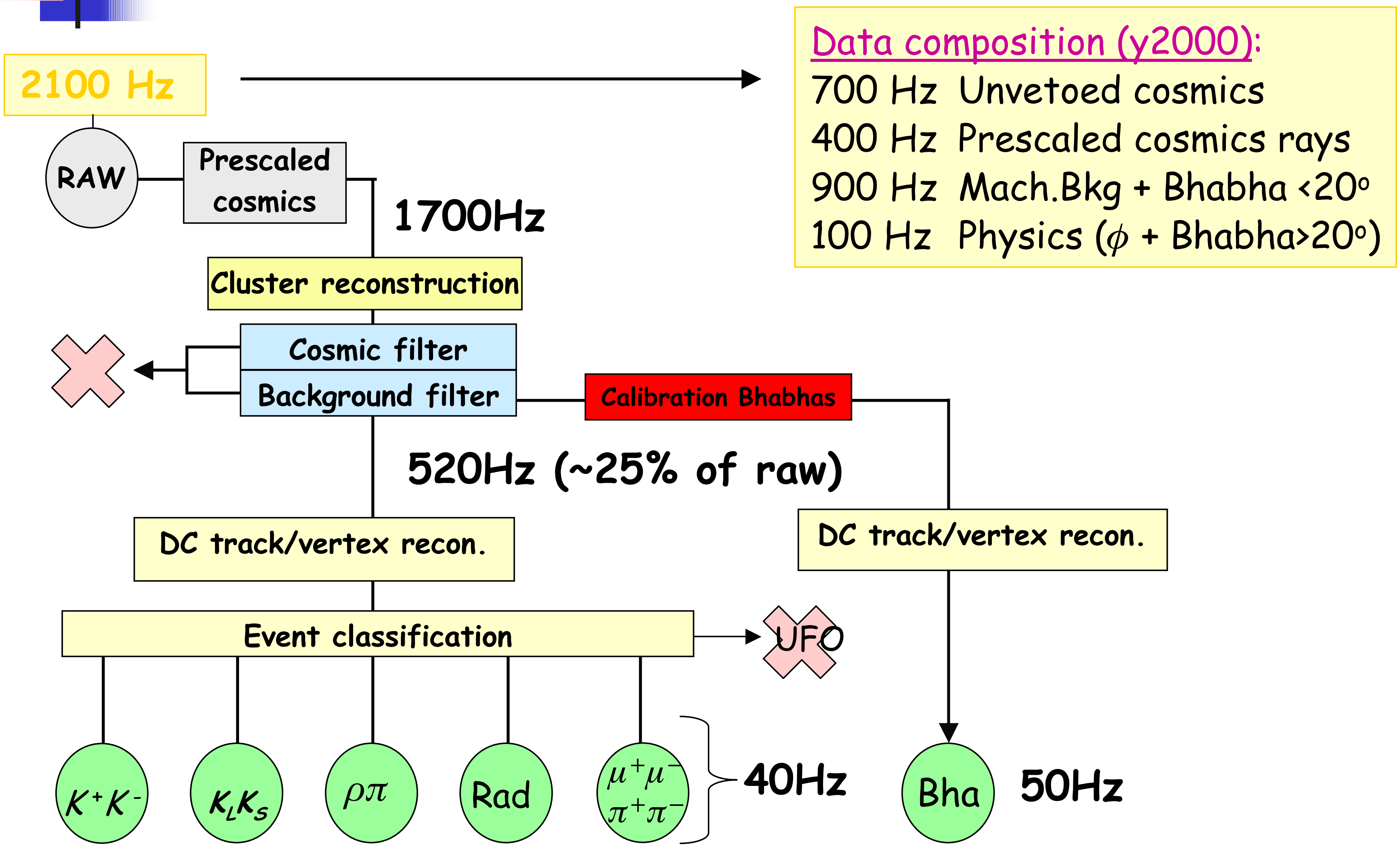
Definitive K_S and ϕ physics
$K_S \to 3\pi^0$, other rare K_S decays
$K_L \to 2\pi$, $K_L \to \gamma\gamma$, form factors
$\sigma(e^+e^- \to \text{hadrons})$ to 1% (stat)

K_S physics
- $BR(K_S \to \pi^+\pi^-)/BR(K_S \to \pi^0\pi^0)$
- $BR(K_S \to \pi e \nu)$

ϕ radiative decays
- $\phi \to f_0\gamma$, $a_0\gamma$
- $\phi \to \eta'\gamma$, $\eta\gamma$



Event streaming: datarec flow diagram



Event yields in Y2000

23 pb^{-1} (~17 with stable trigger)

Stream	Events (M)
K^+K^-	19
$K_S K_L$	64
$\rho\,\pi$	6
radiative	23
Bhabha	127

10.9 M K_L tagged by $K_S \to \pi^+\pi^-$
7.2 M K_S tagged by K_L interactions in EmC

ϕ radiative decays (non Kaon physics)

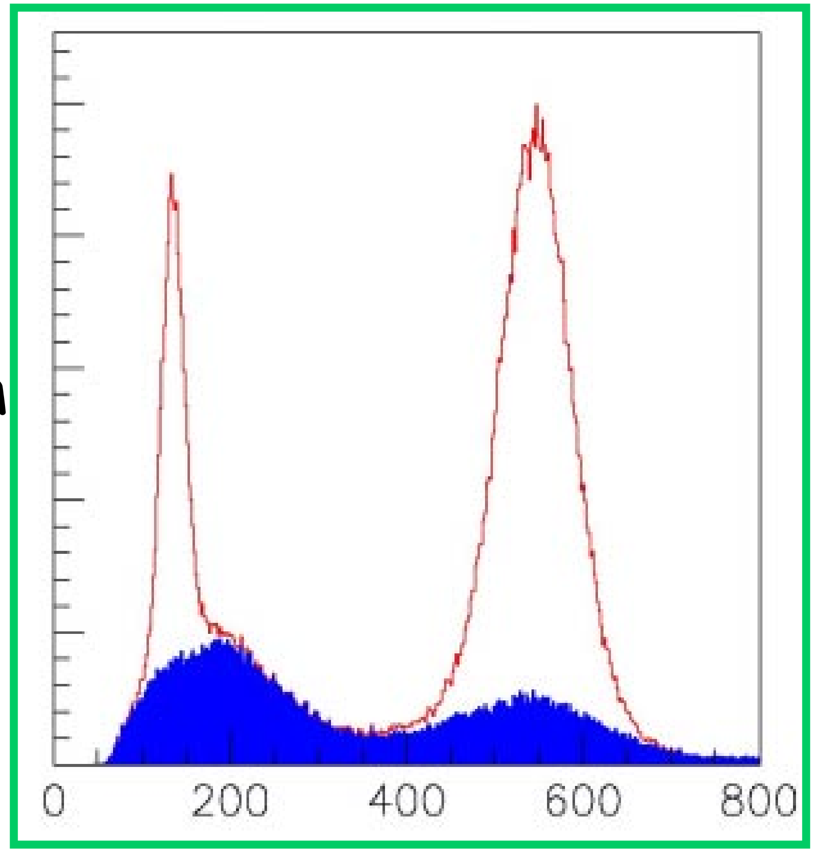
- $\phi \rightarrow 3\gamma$
- $\phi \rightarrow 5\gamma$
- $\phi \rightarrow \pi^+\pi^- + 3\gamma$
- $\phi \rightarrow \pi^+\pi^-\pi^0$
- Hadronic cross section

$\phi \to \eta\gamma, \phi \to \pi^0\gamma$

Event selection:

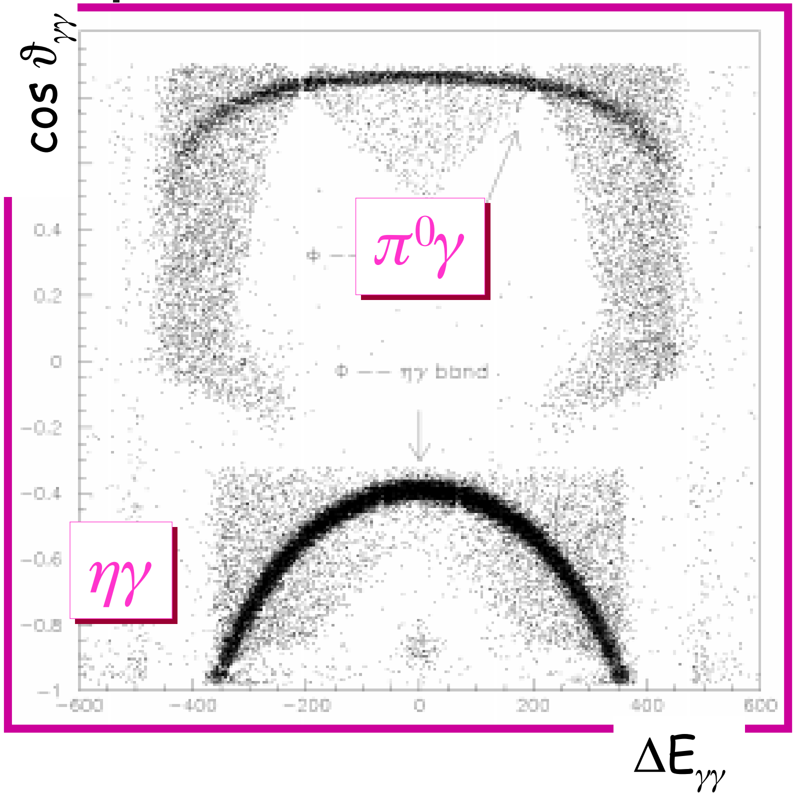
- 3 prompt γs, $E_{tot} > 800MeV$
- Kinematic fit with 4-momentum conservation
- Photon assignment: minimization of $\chi^2(\pi^0\gamma)$, $\chi^2(\eta\gamma)$

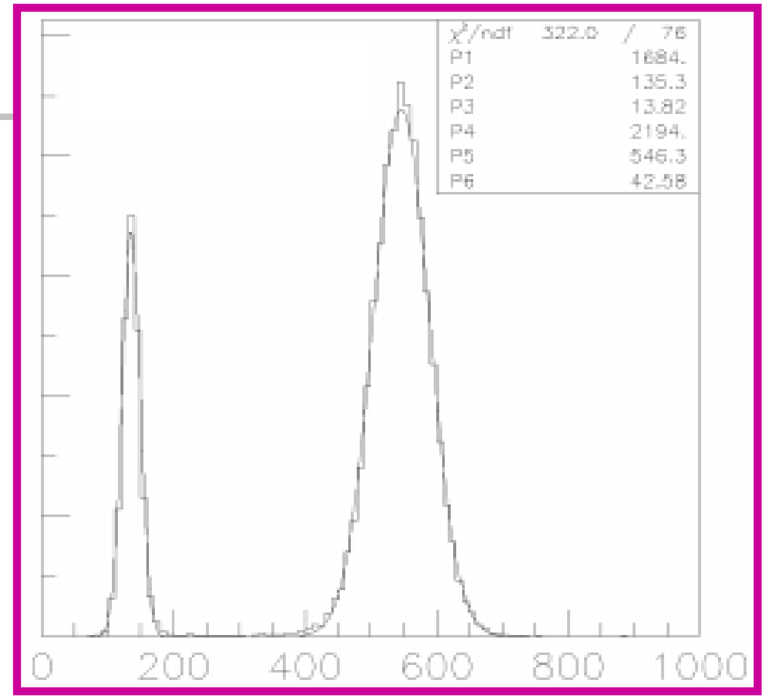
Final efficiency : ε = 63%



Main background comes from
$e^+e^- \to \gamma\gamma(\gamma)$ ( ) see next slide

$\phi \to \eta\gamma, \phi \to \pi^0\gamma$





Background uniform in the sidebands

$$\frac{\Gamma(\phi\to\eta\,\gamma\to\gamma\gamma\gamma)}{\Gamma(\phi\to\pi^0\gamma\to\gamma\gamma\gamma)} = 3.75 \pm 0.02 \pm 0.09$$ KLOE 2000 preliminary ($16.6\ pb^{-1}$)

KLOE* : $BR(\phi \to \pi^0\gamma) = (1.377 \pm 0.01 \pm 0.07)\cdot 10^{-3}$

: $BR(\phi \to \eta\gamma) = (1.264 \pm 0.008 \pm 0.056)\cdot 10^{-3}$

Scalars: $\phi\to\pi^0\pi^0\gamma$ ($f_0\gamma$) and $\phi\to\eta\pi^0\gamma$ ($a_0\gamma$)

Composition of f_0 and a_0 mesons uncertain

Precise measurements of BR($\phi\to f_0\gamma$) and BR($\phi\to a_0\gamma$) may distinguish between various models: $q\bar{q}q\bar{q}$ state, $K\bar{K}$ molecule, ordinary $q\bar{q}$ meson

Detect 5γ final states

$$\begin{cases} \phi \to f_0\gamma \to \pi^0\pi^0\gamma \to 5\gamma \\ \phi \to a_0\gamma \to \eta\pi^0\gamma \to 5\gamma \end{cases}$$

<u>Summary of backgrounds:</u>

Resonant:

$$\phi \to \rho^0\pi^0 \to \pi^0\pi^0\gamma$$
$$\phi \to \rho^0\pi^0 \to \eta\pi^0\gamma$$

Continuum:

$$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$$
$$e^+e^- \to \omega\pi^0 \to \eta\pi^0\gamma$$

Misreconstructed, 3γ

$$\phi \to \pi^0\gamma$$
$$\phi \to \eta\gamma \to \gamma\gamma\gamma$$
$$e^+e^- \to \gamma\gamma(\gamma)$$

Misreconstructed, 7γ

$$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$$

$\phi \to \pi^0\pi^0\gamma$ ($f_0\gamma$) and $\phi \to \eta\pi^0\gamma$ ($a_0\gamma$)

Preselection common to the two analyses:

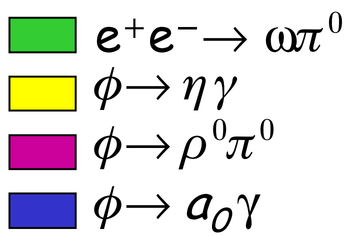
- 5 photons in EmC with energy > 7 MeV coming from the I.R. ($|T - R/c| \leq 5 \cdot \sigma_t$)
- Acceptance cut: $21^0 < \vartheta_{EmC} < 159^0$

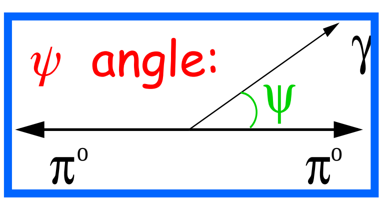
Further analysis steps:

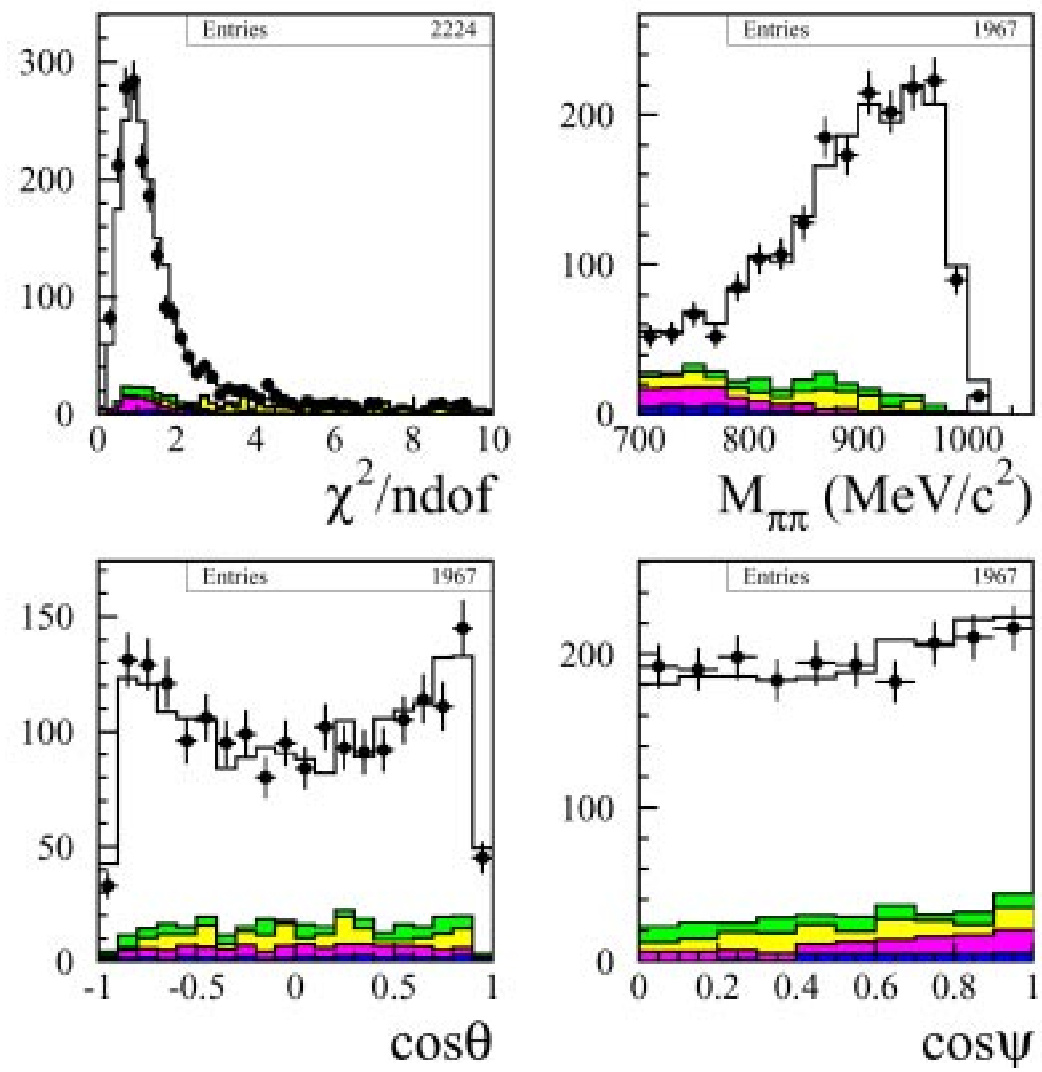
- First kinematic fit (4-momentum conservation, *no* mass constraints on intermediate resonances)
- Photon pairing (best χ^2 for $\pi^0\pi^0\gamma, \eta\pi^0\gamma, \omega\pi^0, \eta\gamma, \pi^0\gamma$ hypothesis)
- Second kinematic fit *with* mass constraints on intermediate resonances

Scalar states: $\phi \rightarrow f_0\gamma \rightarrow \pi^o\pi^o\gamma$

Background to $\phi \rightarrow f_0\gamma$	S/B
$e^+e^- \rightarrow \omega\pi^0 \rightarrow \pi^0\pi^0\gamma$	0.6
$\phi \rightarrow \rho^0\pi^0 \rightarrow \pi^0\pi^0\gamma$	3.7
$\phi \rightarrow a_0\gamma \rightarrow \eta\,\pi^0\gamma \rightarrow \gamma\gamma\pi^0\gamma$	3.5
$\phi \rightarrow \pi^0\gamma$	0.10
$\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$	0.02







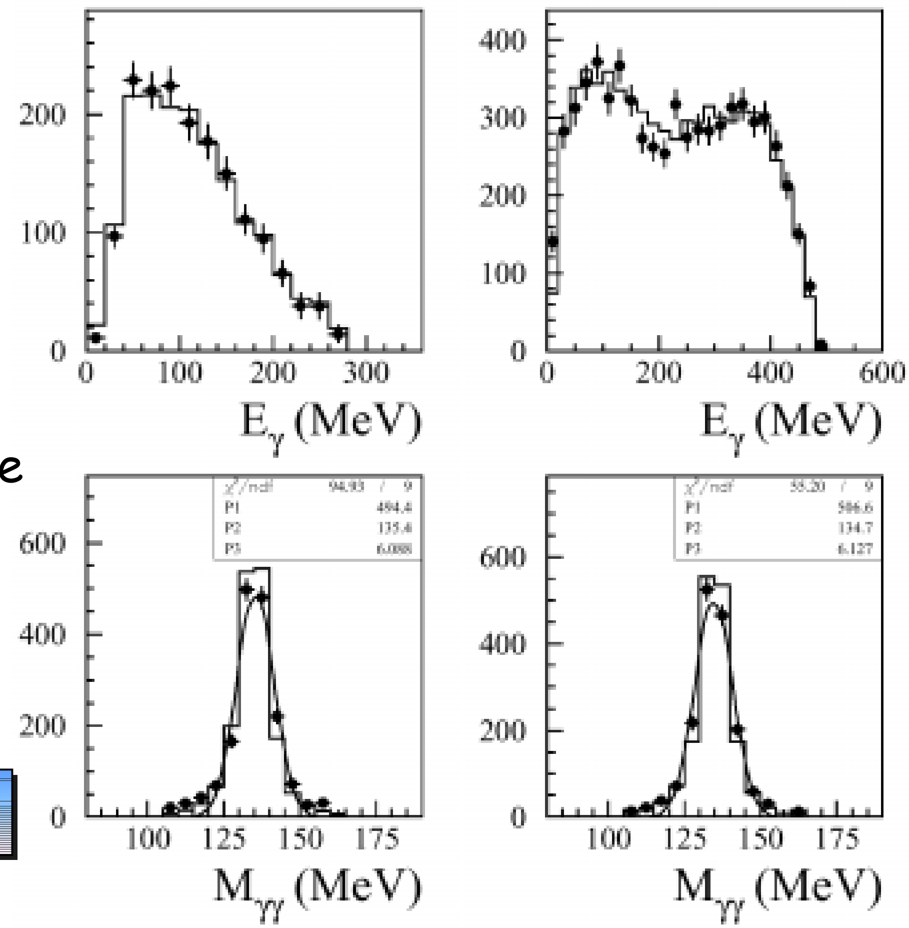
$\phi \to f_0\gamma \to \pi^0\pi^0\gamma$: BR evaluation

After background subtraction:

$N_{fo} = 1662 \pm 43_{stat}$ ($N_{bkg} = 305 \pm 13_{stat}$)

in 17pb^{-1}

(Final efficiency : ε= 39.7%)



Each $M_{\pi\pi}$ bin population is corrected by the MC analysis efficiency.
The BR is evaluated normalizing to $\phi \to \eta\gamma \to \gamma\gamma\gamma$, and neglecting interference with $\phi \to \rho^0\pi^0 \to \pi^0\pi^0\gamma$:

$$BR(\phi \to f_0\gamma \to \pi^0\pi^0\gamma) = (7.9 \pm 0.2_{stat}) \cdot 10^{-5}$$

Preliminary

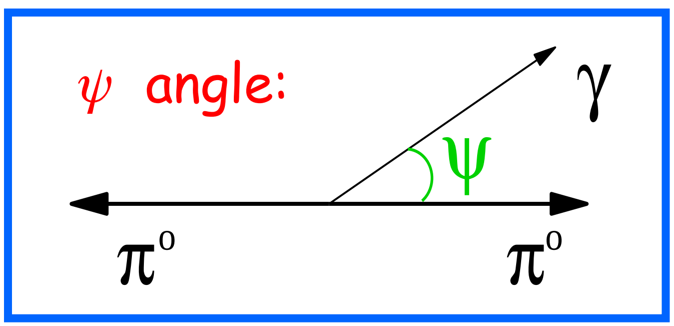
[for $M_{\pi\pi}$ > 700 MeV] hep-ex/0107024, KLOE collab.

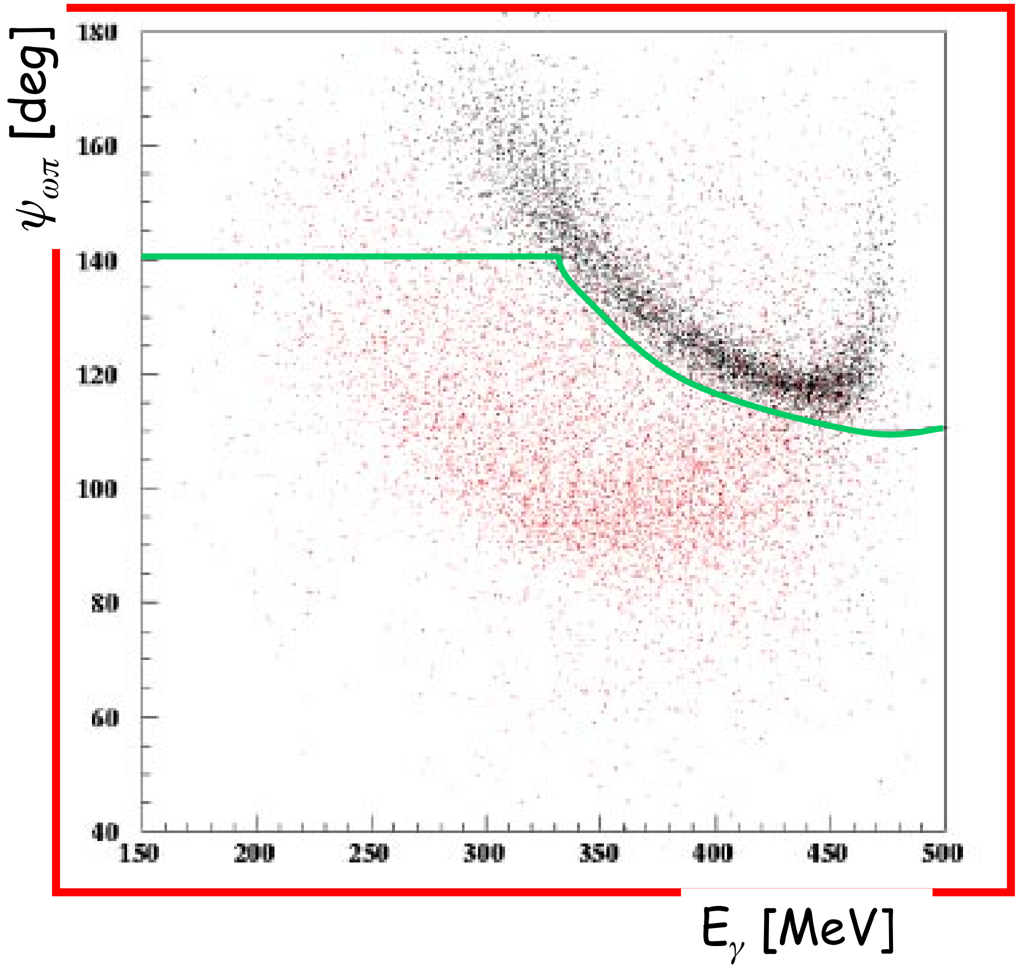
Systematic error under study: it should not exceed 10%

$a_0\gamma \to \eta\pi^0\gamma \to 5\gamma$: background rejection

Background to $\phi \to a_0\gamma$	S/B
$e^+e^- \to \omega\pi^0 \to \eta\pi^0\gamma$	70
$\phi \to \rho^0\pi^0 \to \eta\pi^0\gamma$	5.3
$\phi \to \rho^0\pi^0 \to \pi^0\pi^0\gamma$	1.0
$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$	0.14
$\phi \to f_0\gamma \to \pi^0\pi^0\gamma$	0.27
$\phi \to \pi^0\gamma$	0.10
$\phi \to \eta\gamma \to \gamma\gamma\gamma$	$6.1 \cdot 10^{-3}$
$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$	$7.5 \cdot 10^{-3}$

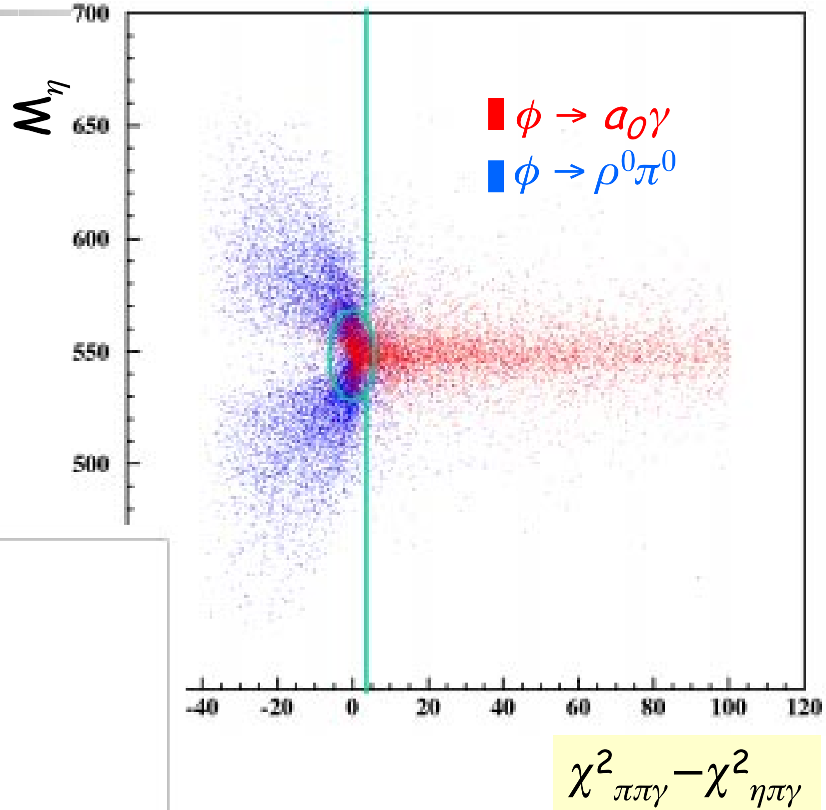
1. $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$
cut on (E_γ, ψ) plane





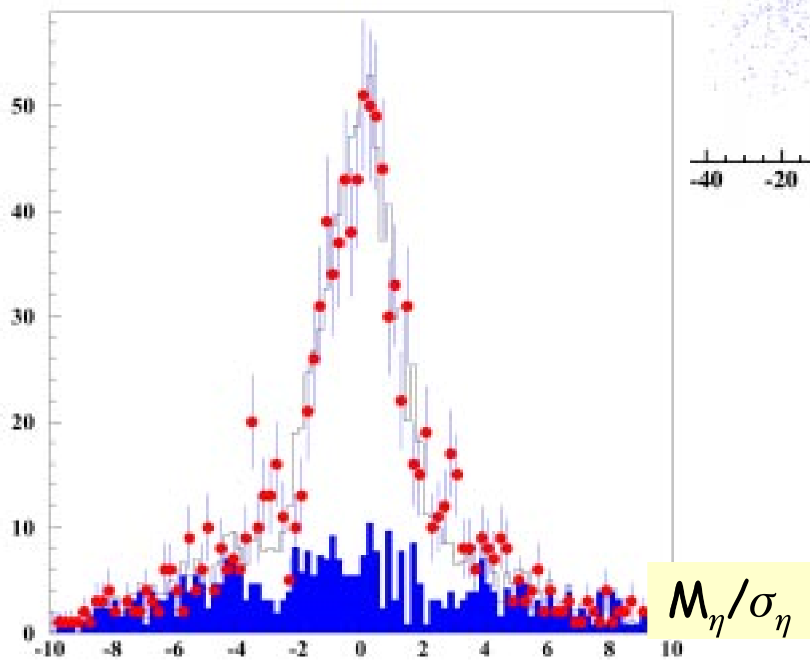
$a_0\,\gamma \to \eta\pi^0\gamma \to 5\gamma$: background rejection

2. $\phi \to \rho\pi^0 \to \pi^0\pi^0\gamma$
cut on ($\chi^2_{\pi\pi\gamma} - \chi^2_{\eta\pi\gamma}$, **M**$_\eta$) plane



3. $\phi \to \eta\gamma \to \gamma\,\gamma\,\gamma$
rejects events with **M**$_{\gamma\gamma}$ = **M**$_\eta$
and E_{rad} = 363 MeV

4. $\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$
2σ cut on **M**$_\eta$



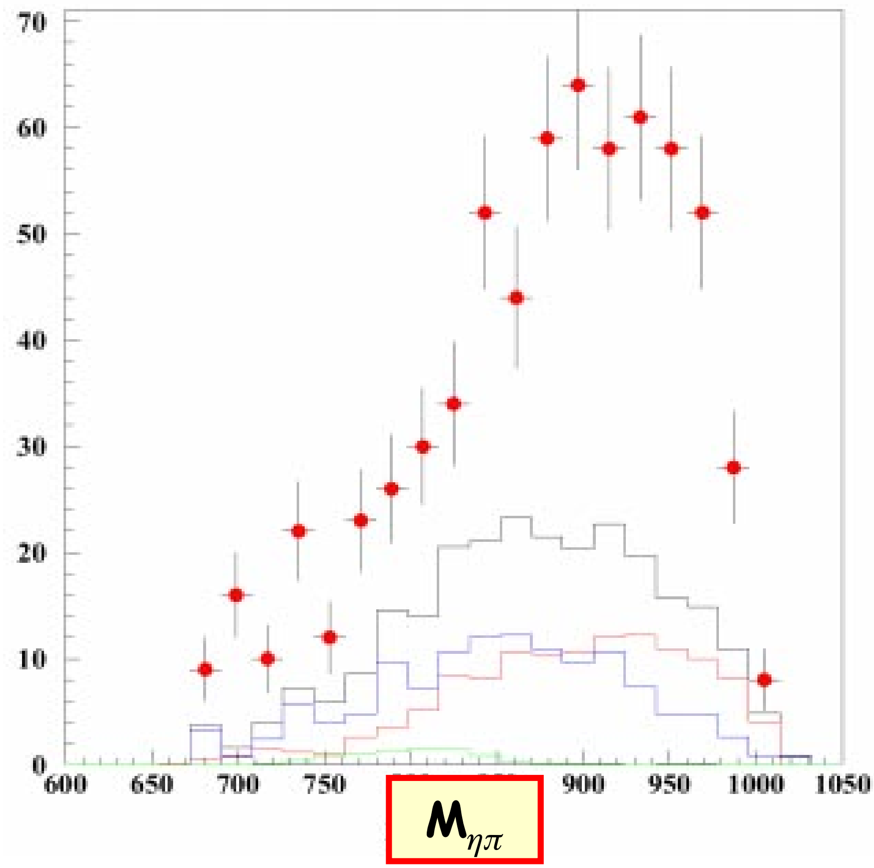
$a_0\,\gamma \rightarrow \eta\pi^0\gamma \rightarrow 5\gamma$: final distributions

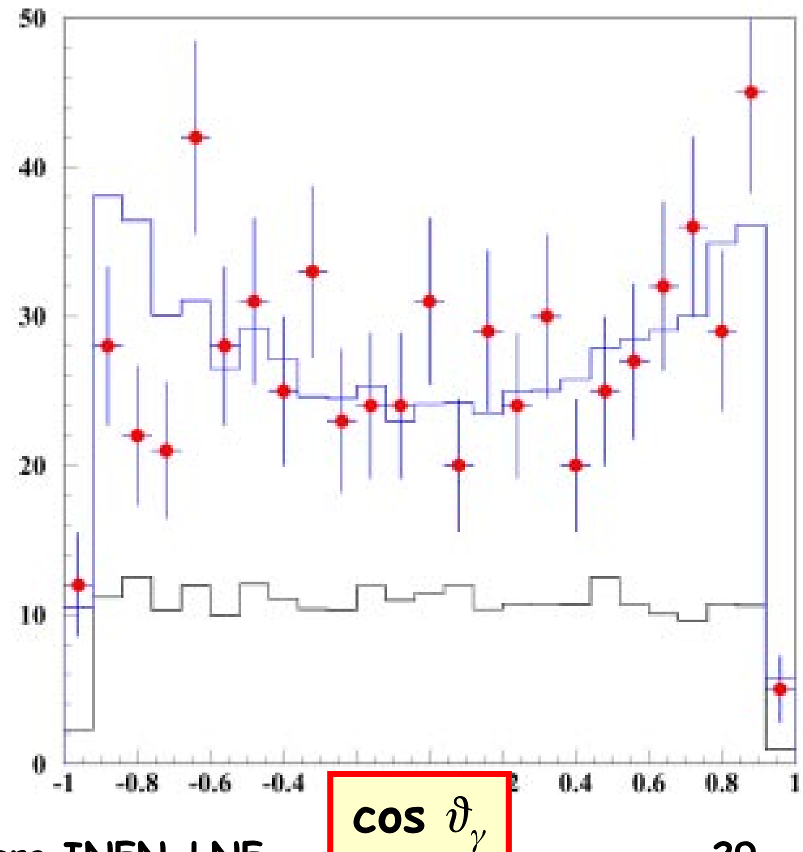
$e^+e^- \rightarrow \omega\pi^0 \rightarrow \eta\pi^0\gamma$

$\pi^0\pi^0\gamma$

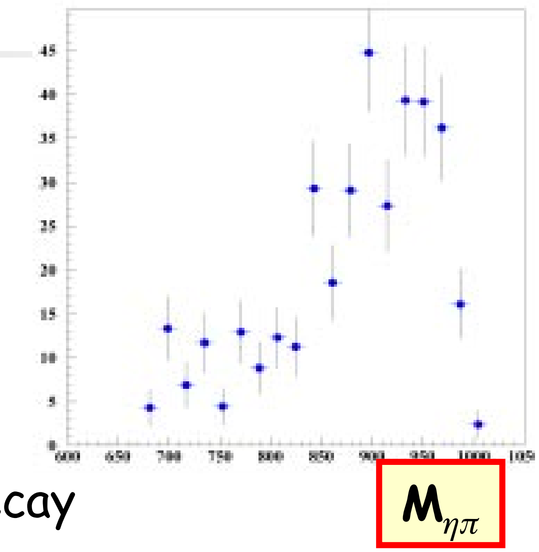
$\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$

total background





$a_0\gamma \to \eta\pi^0\gamma \to 5\gamma$: BR evaluation



After background subtraction:

$N_{\eta\pi\gamma} = 413 \pm 28_{stat}$ ($N_{bckg} = 253 \pm 11_{stat}$) in $17 pb^{-1}$

(Final efficiency : ε= 27.2%)

$BR(\phi \to \eta\pi^0\gamma) = (7.4 \pm 0.5_{stat}) \times 10^{-5}$

Subtracting the contribution from the $\phi \to \rho^0\pi^0 \to \eta\pi^0\gamma$ decay (neglecting the interference) we find:

$BR(\phi \to a_0\gamma \to \eta\pi^0\gamma) = (5.8 \pm 0.5_{stat}) \times 10^{-5}$

KLOE Preliminary

Systematic error under study: it should not exceed 10%

Ratio of the two BR's:

$$\frac{BR(\phi \to f_0\gamma)}{BR(\phi \to a_0\gamma)} = \frac{3\times(7.9 \pm 0.2_{stat})}{5.8 \pm 0.5_{stat}} = 4.1 \pm 0.4_{stat}$$

Well in agreement with the value predicted by F. Close et al. (hep-ph/0106108) based on the picture that these systems have a compact core $q\bar{q}q\bar{q}$ surrounded by a $K\bar{K}$ cloud.

Pseudoscalar states: $\phi \to \eta\gamma, \eta'\gamma$

- With the decay $\phi \to \eta'\gamma$ decay we can probe the gluonic content of the η': theoretical predictions for BR($\phi \to \eta'\gamma$) range from 2x10^{-4} down to ~10^{-6} in case of significant gluonic content.

- The mass eigenstates η(547), η'(958) can be related to the SU(3) octet singlet states η_8, η_1 through the mixing angle ϑ_p:

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} \cos\vartheta_p & -\sin\vartheta_p \\ \sin\vartheta_p & \cos\vartheta_p \end{pmatrix} \begin{pmatrix} \eta_8 \\ \eta_1 \end{pmatrix}$$

- The value of the mixing angle has been discussed many times in the last 30 years: both from theoretical predictions and from phenomenological analyses it varies from $-23°$ to $-10°$.

Extract mixing angle from:

$$R_\phi = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)}$$

$\phi \rightarrow \eta\,\gamma, \eta'\,\gamma$

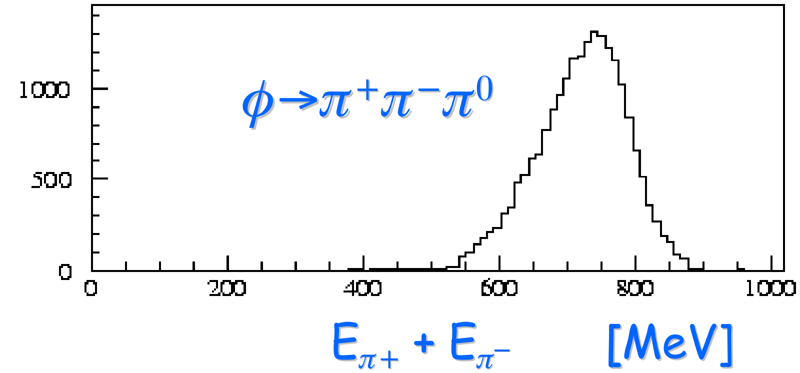
$\phi \rightarrow \eta\,\gamma \rightarrow \pi^+\pi^-\pi^0\gamma \rightarrow \pi^+\pi^- 3\,\gamma$ (BR~$3 \cdot 10^{-3}$)

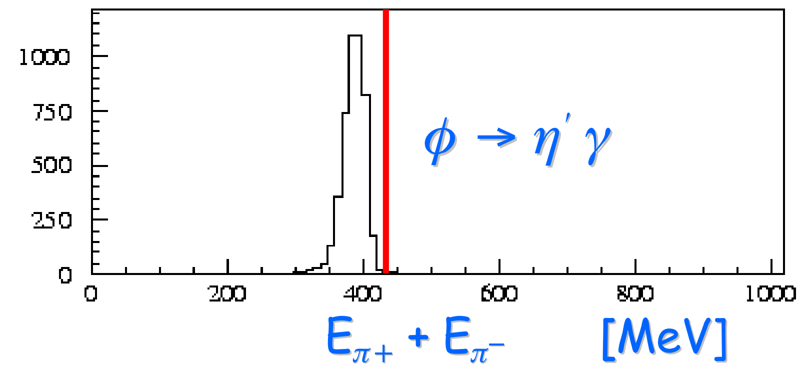
$\phi \rightarrow \eta'\gamma \rightarrow \pi^+\pi^-\eta\,\gamma \rightarrow \pi^+\pi^- 3\,\gamma$ (BR~$2 \cdot 10^{-5}$)

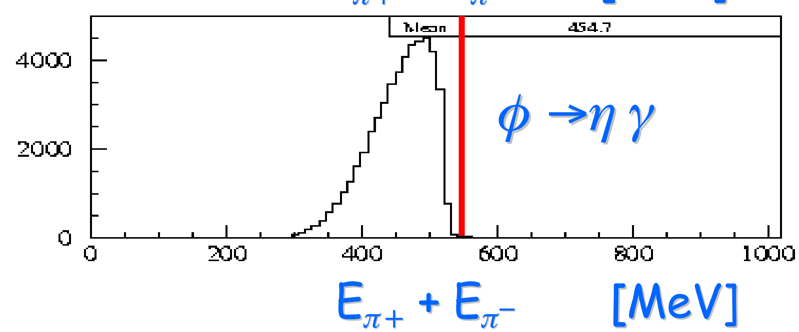
Main backgrounds: $\phi \rightarrow K_S\,K_L$, $\phi \rightarrow \pi^+\pi^-\pi^0$

Event selection:

- 1 prompt vertex, 3 prompt γs ($\vartheta_{\gamma-\gamma} > 18°$)
- $E_{\pi+}$+E_{π^-} < 430 MeV for $\phi \rightarrow \eta'\gamma$
- $E_{\pi+}$+E_{π^-} < 550 MeV for $\phi \rightarrow \eta\gamma$
- Kinematic fit

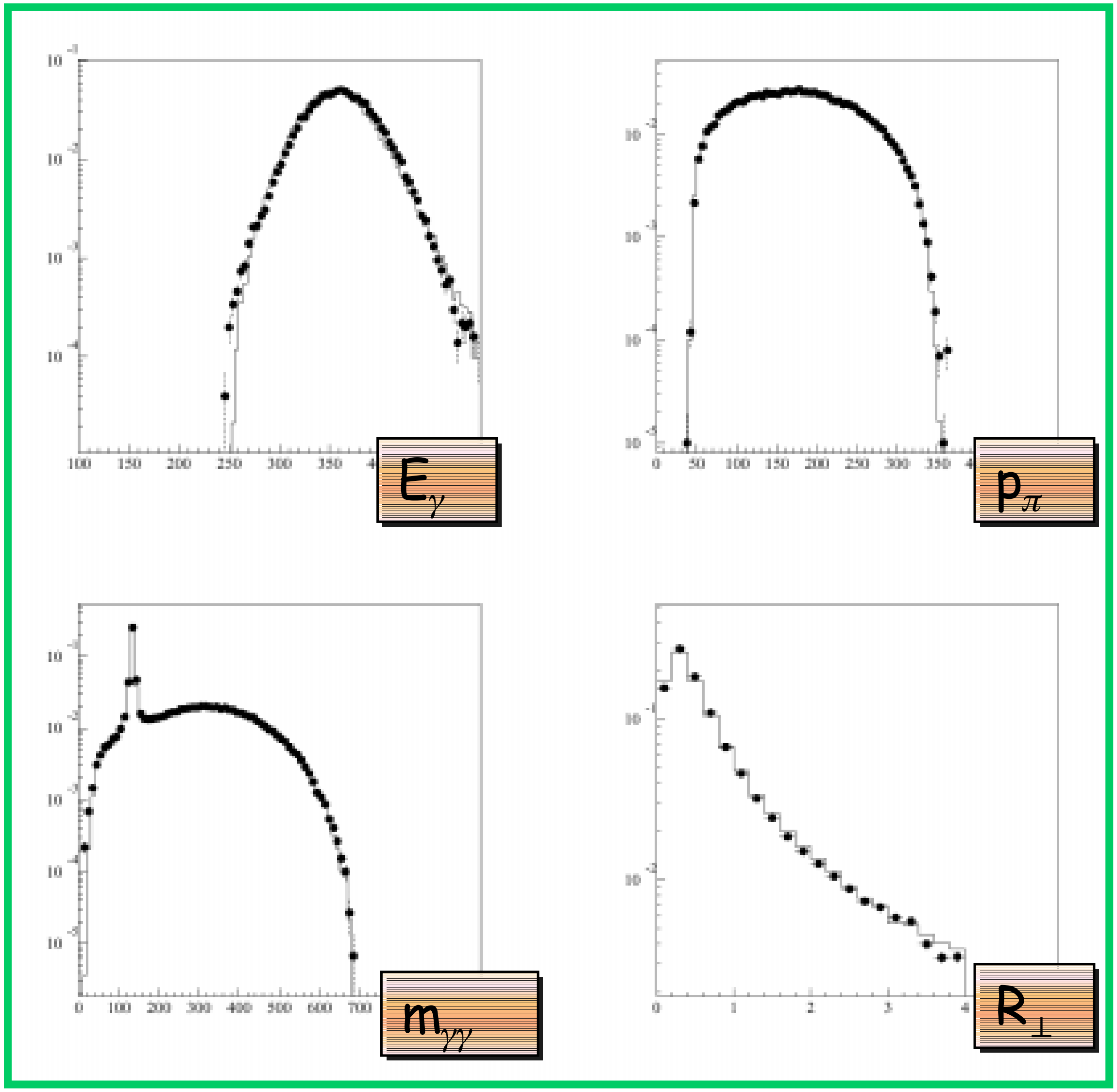






$\phi \to \eta\gamma, \eta'\gamma$

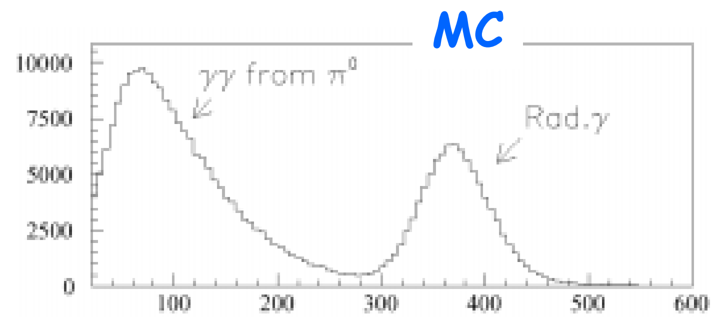
$\phi \to \eta\gamma$ is the main background to $\eta'\gamma$ but also a good control sample



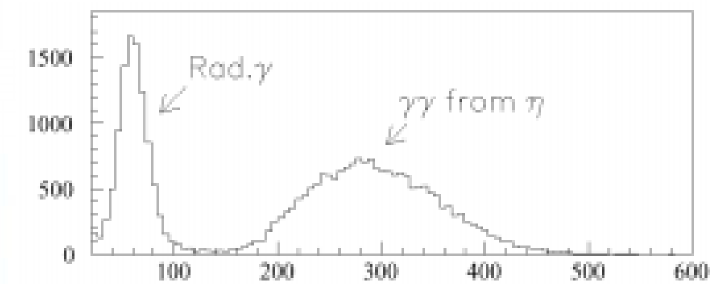
$\phi \to \eta\,\gamma, \eta'\,\gamma$

- The photon energy spectrum of $\phi \to \eta\gamma$ and $\phi \to \eta'\gamma$ events allows a very clear identification of the photons in the two cases.

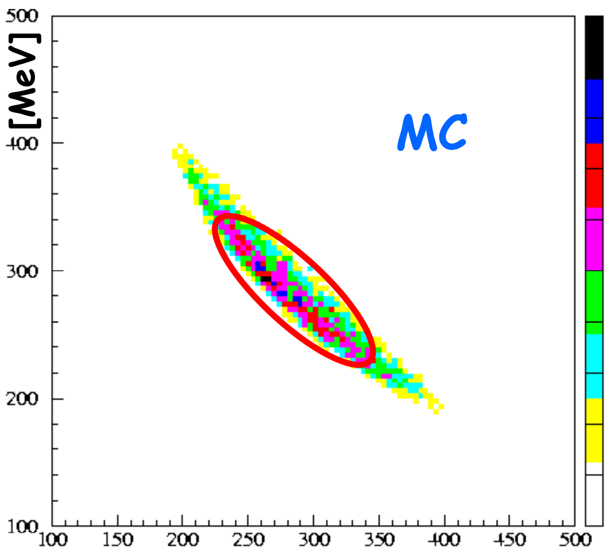
- This can be used to exploit correlations between the energies of two hardest photons in the $\phi \to \eta'\gamma$ events.



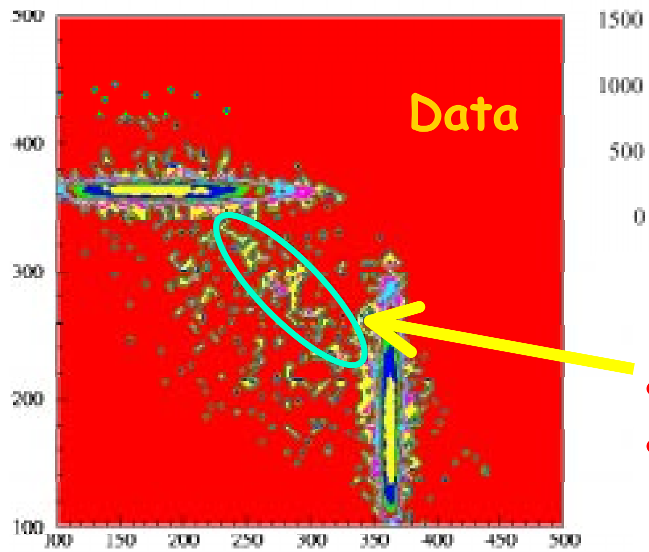
$\phi \to \eta\,\gamma$ E_γ [MeV]



$\phi \to \eta'\gamma$ E_γ [MeV]



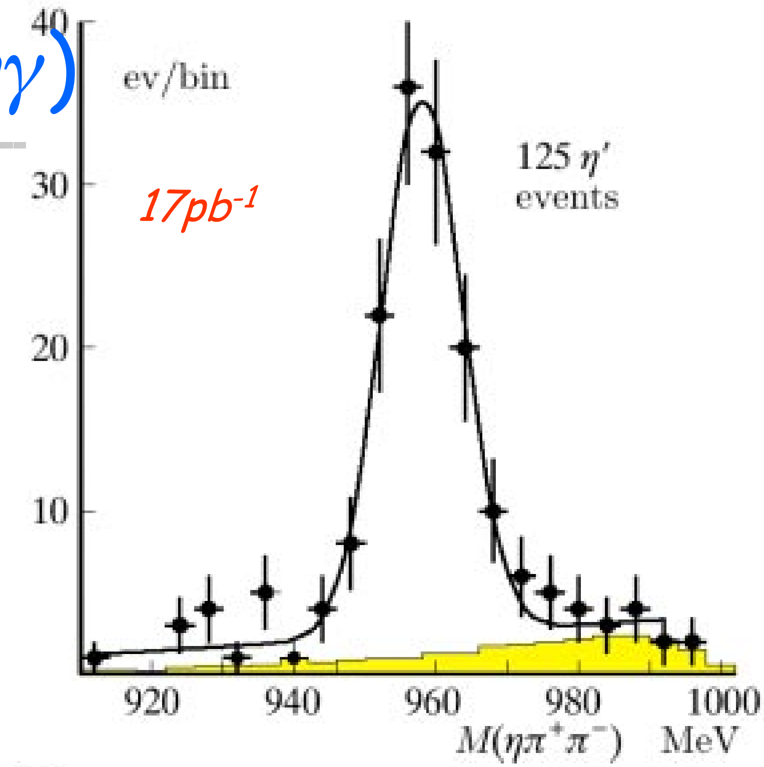
E_1 vs E_2 (after kin. fit) [MeV]



E_1 vs E_2 (after kin. fit) [MeV]

- $\phi \to \eta'\gamma$ inside the ellipse
- $\phi \to \eta\gamma$ in the two bands at E~363 MeV

BR($\phi \to \eta'\gamma$), BR($\phi \to \eta\gamma$)



After background subtraction:

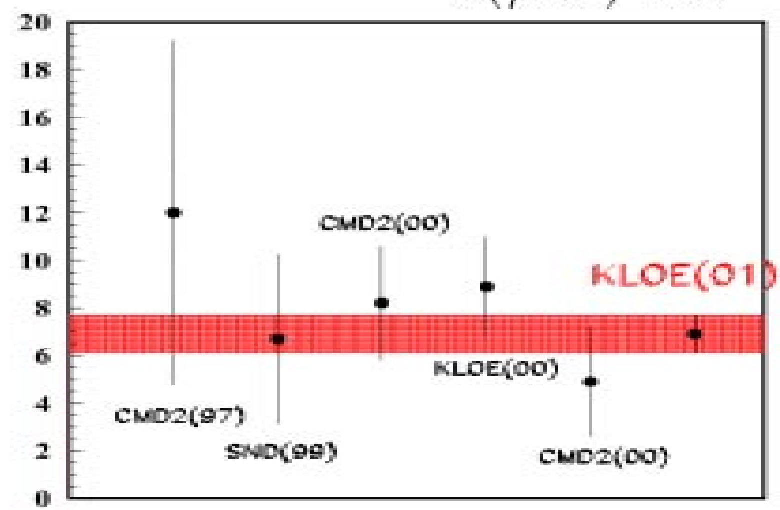
$N_{\eta'\gamma} = 125 \pm 12_{stat} \pm 5_{syst}$

$N_{\eta\gamma} = (502.1 \pm 2.2_{stat}) \cdot 10^2$

(Final efficiency : $\varepsilon_{\eta'\gamma} = 23\%$, $\varepsilon_{\eta\gamma} = 37.6\%$)

Ratio of the two BFs:

$$R = \frac{BR(\phi \to \eta'\gamma)}{BR(\phi \to \eta\gamma)} = (N_{\eta'}\varepsilon_{\eta'}/N_{\eta}\varepsilon_{\eta}) \cdot R_{BR}$$
$$= (5.3 \pm 0.5_{stat} \pm 0.3_{syst}) \cdot 10^{-3}$$



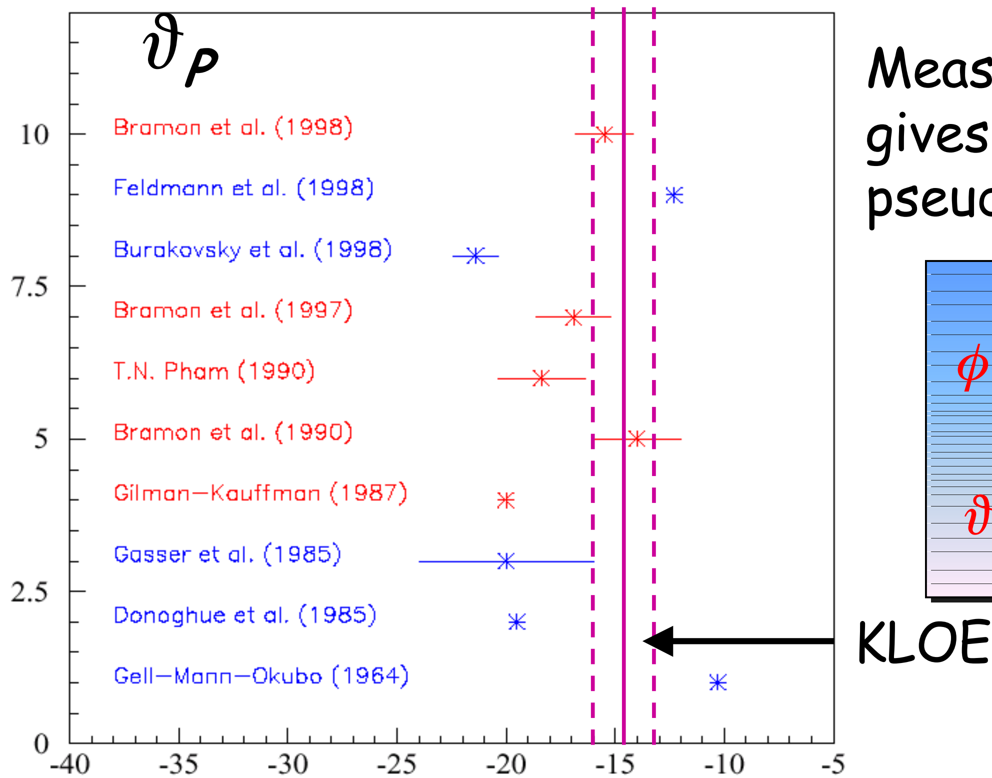
From the ratio R we extract the BR:

$$BR(\phi \to \eta'\gamma) = (6.8 \pm 0.6_{stat} \pm 0.5_{syst}) \cdot 10^{-5}$$

...and the mixing angle:

$\eta-\eta'$ Mixing angle

KLOE 2000 preliminary (17 pb^{-1})



- Theoretical predictions
- Phenomenological analyses

Measurement of $BR(\phi \to \eta'\gamma)/BR(\phi \to \eta\gamma)$ gives most accurate determination of pseudoscalar mixing angle to date:

$$\phi_p = 40.0^{\circ}\,{}^{+1.7^{\circ}}_{-1.5^{\circ}} \quad \text{(flavor basis)}$$

$$\vartheta_p = 14.7^{\circ}\,{}^{+1.7^{\circ}}_{-1.5^{\circ}} \quad \text{(octet-singlet basis)}$$

… which disfavor a large gluonic content of the η'

$\phi \rightarrow \pi^+\pi^-\pi^0$

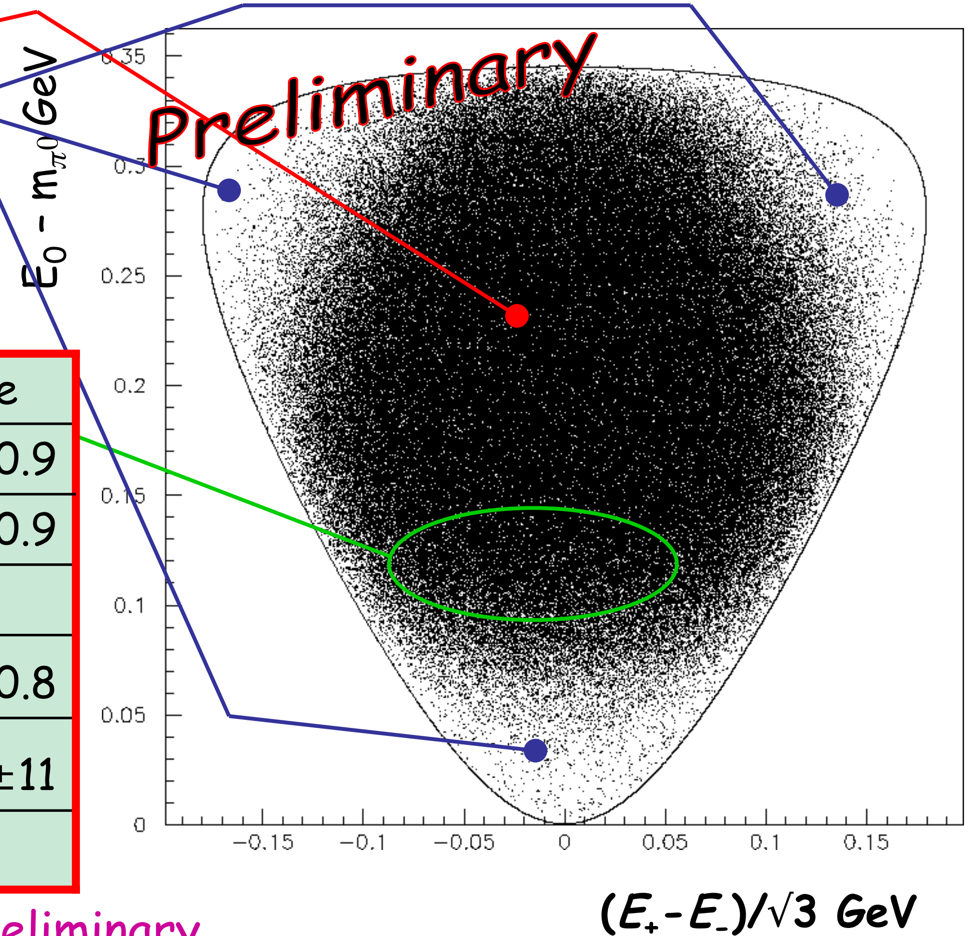
3 contributions to the binned Dalitz plot

~3M events

$\phi \rightarrow \rho^{\pm,0}\pi^{0,\pm}$

$\phi \rightarrow \pi^+\pi^-\pi^0$ (direct)

$e^+e^- \rightarrow \omega\pi^0$



Parameter	Fit Result	PDG value
$m(\rho^0)$ MeV/c^2	773.0±0.6	776.0±0.9
$m(\rho^+)$ MeV/c^2	775.3±0.4	776.0±0.9
$\Delta m(+/-)$ MeV/c^2	0.4±0.3*	
$\Gamma(\rho^0)$ (MeV)	145.6±2.2	150.2±0.8
A(direct)/A($\rho\pi$)%	8.5±0.5	−15±11
ϕ(direct)-$\phi(\rho\pi)$	$(88\pm9)^o$	

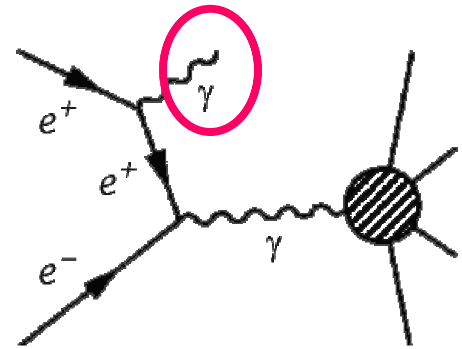
KLOE preliminary

* CPT test, at $5 \cdot 10^{-4}$

Efficiency from MC. Work in progress to reduce systematics.

$\sigma(e^+e^- \to \text{hadrons})$

KLOE can measure $d\sigma/dM_{\pi\pi}^2(e^+e^- \to hadr.)$ for $2m_\pi < M_{\pi\pi} < m_\phi$ using $e^+e^- \to \pi^+\pi^-\gamma$ with γ radiated in initial state (ISR)



~65% of a_μ^{hadr} $(5000 \cdot 10^{-11})$ comes from this interval in $M_{\pi\pi}$

Precise knowledge of ISR and FSR required, including *all* radiative corrections

- FSR suppressed with acceptance cuts (as opposed to included in fit to $dN/dM_{\pi\pi}^2$)
- Exclusive measurement of $\pi^+\pi^-\gamma$ final state (multi-photon final state excluded)

Measurement is delicate, but KLOE can make unique contributions:

- Confirm and complement results from $e^+e^- \to \pi^+\pi^-$ and τ data, with different systematics
- Measure $d\sigma/dM_{\pi\pi}^2$ for low $M_{\pi\pi}$ (< 0.6 GeV)

The Montecarlo: EVA

- EVA generates the process $e^+e^- \to \pi\pi\gamma(\gamma)$, with a hard photon (E_γ>10MeV) emitted by ISR or by FSR, and possibly a soft photon (collinear radiation)
- The current version supplies only the Born level, therefore we must apply a lower limit to the polar angle to avoid divergences; because of this the current definition of small angle is:

$$5° < \vartheta_{\pi\pi} < 21° \cup 159° < \vartheta_{\pi\pi} < 175°$$

- This implies a loss of a factor ~6 in statistics and a problem with the detector angular resolution at small angles (smearing)
- Kuehn et al. have published (hep-ph/0106132 , 13 Jun 2001) the NLO corrections to the process; the new version of EVA will be soon available

The measurement of σ_{hadr}

$$\frac{d\sigma}{dM^2_{\pi\pi}} = \frac{N^{obs} - N^{bkg}}{\Delta M^2_{\pi\pi}} \times \frac{1}{\varepsilon\ L}$$

$$\varepsilon = \varepsilon_{acc}\,\varepsilon_{sel}\,\varepsilon_{trig}$$

- ✓ acceptance ε_{acc} evaluated from MC (large angle; small angle)
- ✓ global selection efficiency ε_{sel} evaluated from DATA+MC
- ✓ trigger efficiency ε_{trig} evaluated from DATA

- Experimental **Backgrounds:**

$e^+e^- \to \pi^+\pi^-\gamma$ (Final State Radiation)

$e^+e^- \to e^+e^-\gamma$ (radiative Bhabha)

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

$e^+e^- \to \phi \to \pi^+\pi^-\pi^0$ (BR = 15.5 %)

- **Luminosity** measured using large angle Bhabha scattering (→1%)

FSR reduction

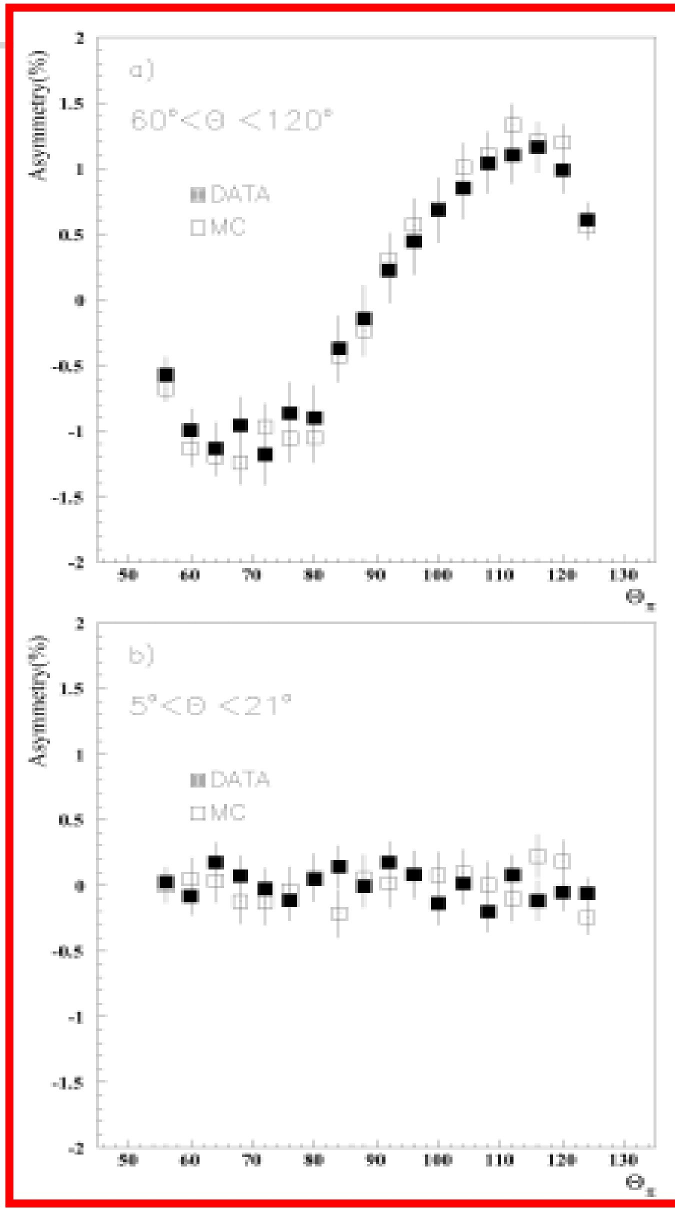
FSR γs ~ collinear with pions $\propto(\sin\vartheta^2)$

- `small angle' γ
- $E_\gamma > 10$ MeV
- $p_T > 200$ MeV/c

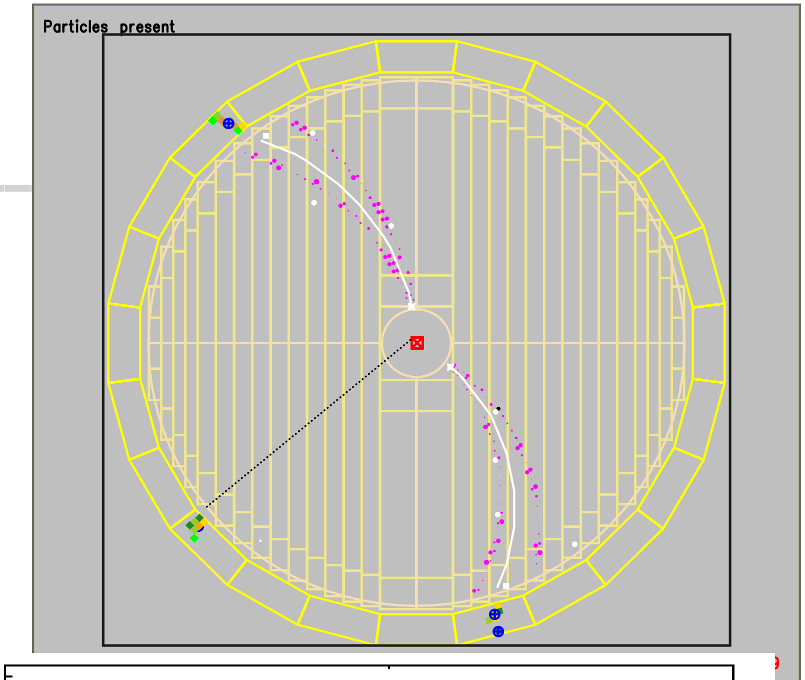
FSR through a point like pion in EVA

$$A(\theta_\pi) = \frac{N^{\pi^+}(\theta_\pi) - N^{\pi^-}(\theta_\pi)}{N^{\pi^+}(\theta_\pi) + N^{\pi^-}(\theta_\pi)}$$

As expected, FB (ISR-FSR) asymmetry reduced at small photon angles



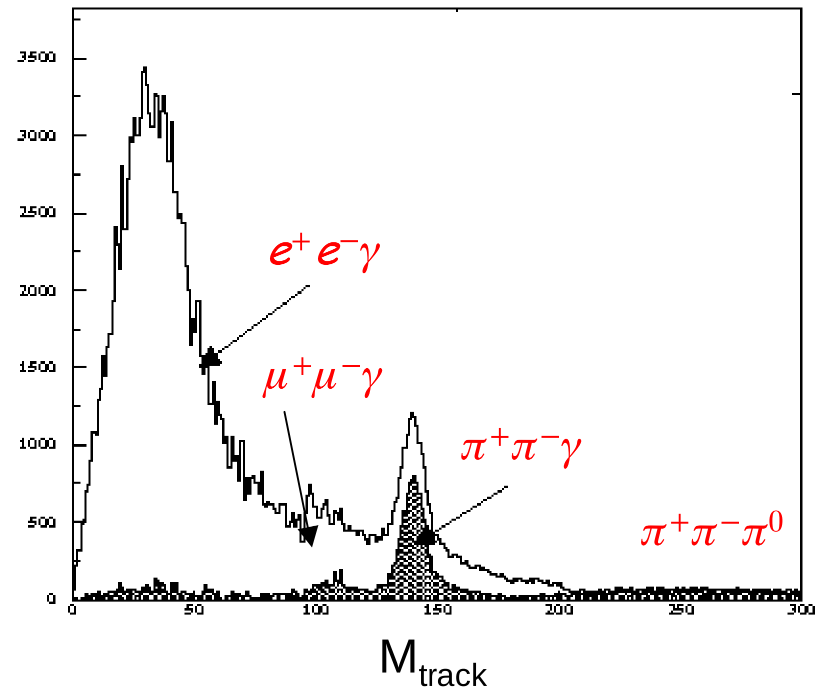
$\pi^+\pi^-\gamma$ identification



- Look for missing momentum in $\pi\pi$ tracks
  - Use drift chamber, $55° < \vartheta_\pi < 125°$,
  - Estimate E_γ and ϑ_γ from $\pi\pi$ vertex and ϕ boost
- 2 fiducial volumes:
  small angle: $5° < \vartheta_\gamma < 21°;\ 169° < \vartheta_\gamma < 175°$
  large angle: $60° < \vartheta_\gamma < 120°$
- Use calorimeter for π identification:
  likelihood function using:
  time-of-flight, shower profile
- 2σ cut on M_{track}

$$q_\gamma^2 = \left(M_\phi - \sqrt{\vec{p}_1^{\,2} + M_{track}^2} - \sqrt{\vec{p}_2^{\,2} + M_{track}^2} \right)^2 = 0$$

- No need of γ information from EmC

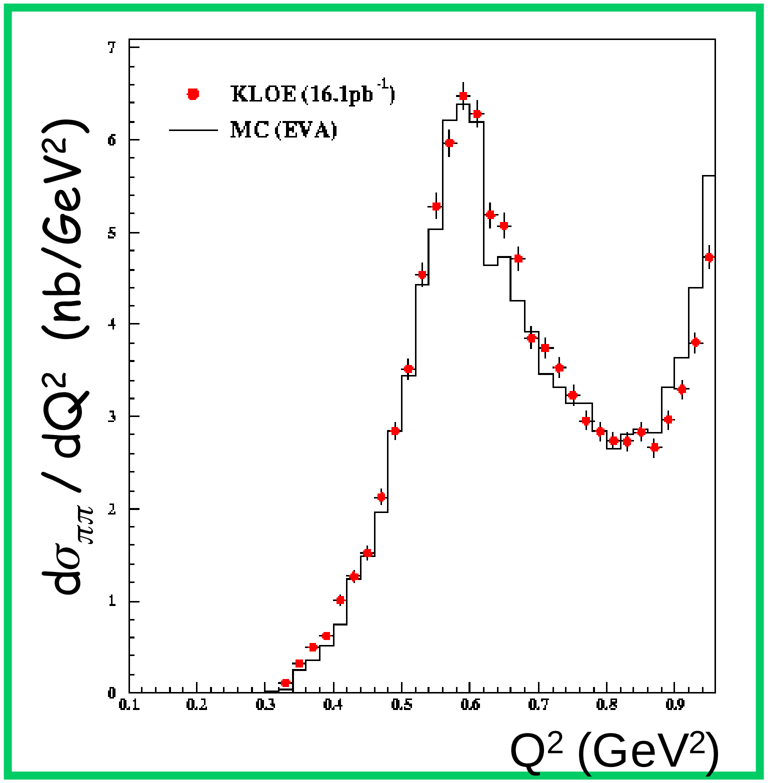


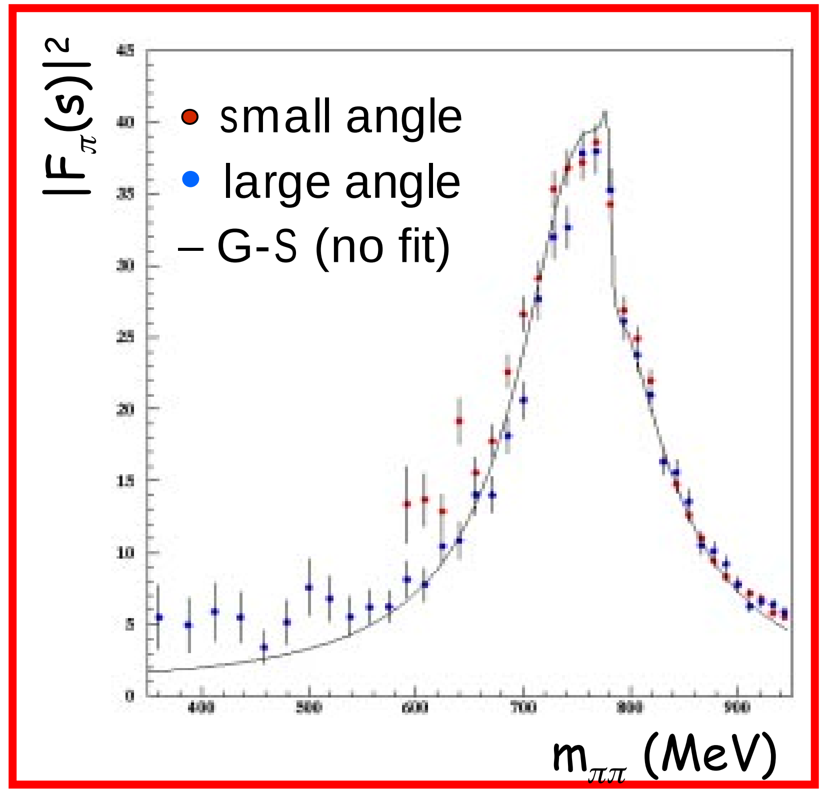
$d\sigma_{\pi\pi}/dQ^2$

KLOE 2000 preliminary (16.1 pb^{-1})

Statistical errors
Experimental systematics
Theoretical systematics

} few %



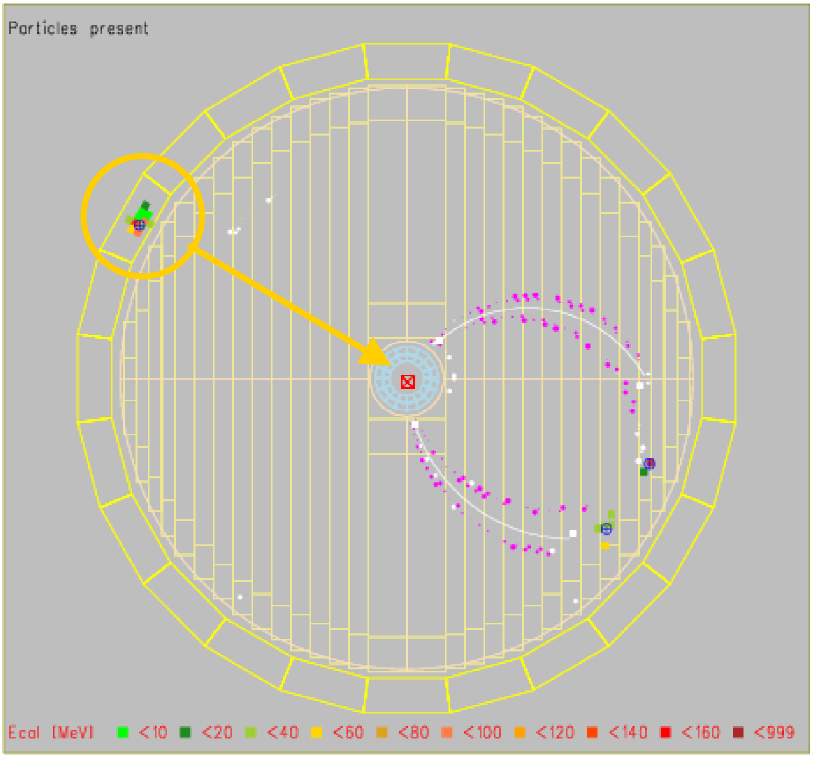


$\phi \to K_S K_L$

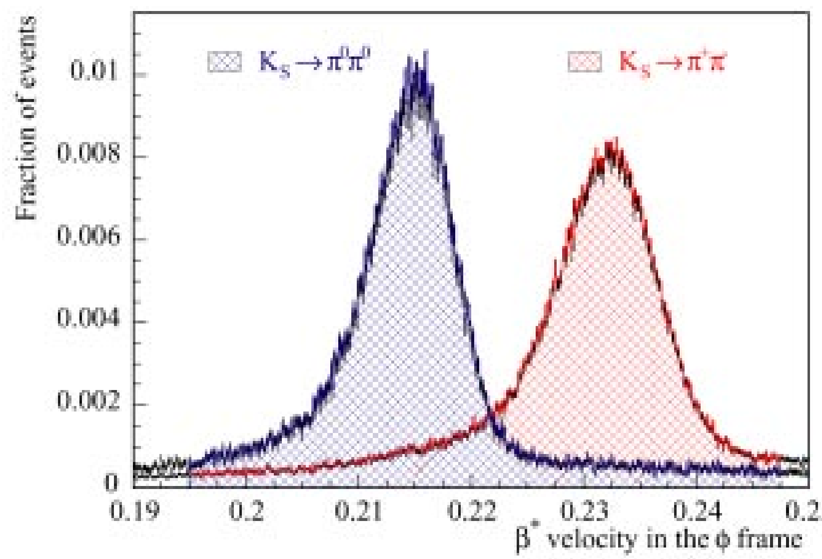
- $K_S \to \pi^+\pi^- / K_S \to \pi^0\pi^0$
  (a first step to the double ratio!)
- $K_S \to \pi e \nu$

Tagging of K_S decays

TOF-identified K_L interaction in EmC "K_L crash" ($E_{KL} > 100$ MeV, $\cos\vartheta_{KL} > 0.7$) provides a clean K_S tag



In 17 pb^{-1} ~ 5.4M K_L crash candidates



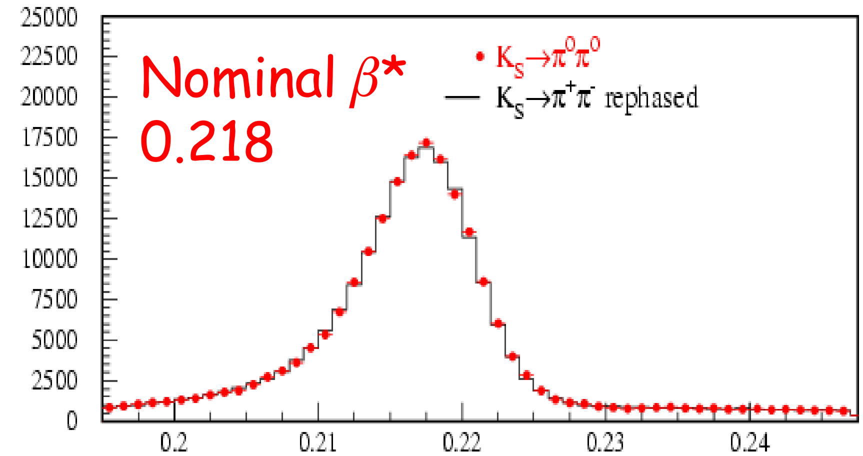
β^* = velocity of K_L in the ϕ rest frame

K_L crash tag

- Absolute time-zero of the event is fixed *a posteriori* using the fastest cluster in the event
- Global time is synchronized to (an integer multiple of) the bunch crossing frequency
- γ hypothesis is used at the first stage of the reconstruction

Tag efficiency is slightly dependent on the K_S decay due to the different global t_0 estimations, given by:

- prompt γ's in $K_S \to \pi^0\pi^0$
- pion clusters in $K_S \to \pi^+\pi^-$
- pion or electron clusters in $K_S \to \pi e \nu$



After correction for different pion velocities and trigger latency

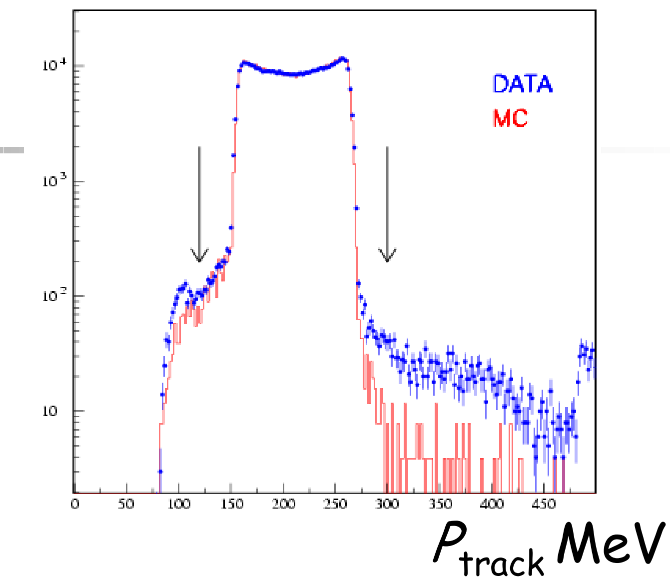
40% of time, K_L crash triggers by itself.
Facilitates determination of trigger efficiency

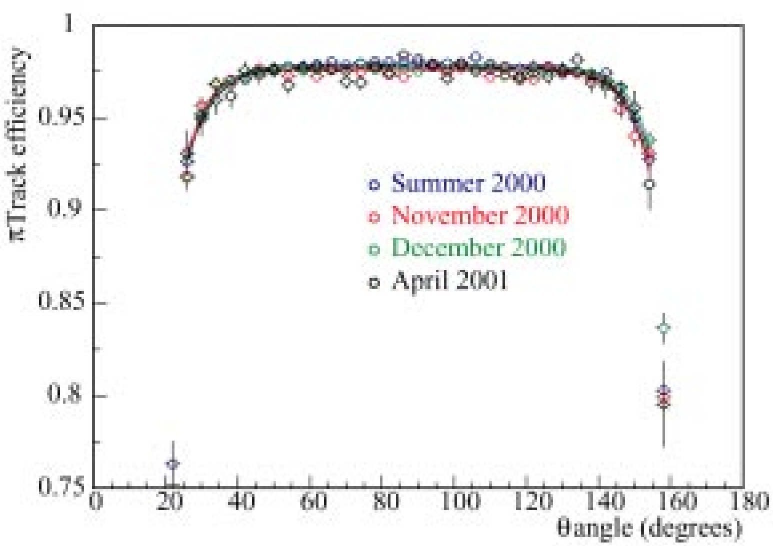
$K_S \to \pi^+\pi^-$

K_L crash + 2 tracks from IP

Acceptance and very loose p cuts

Conditional single-track reconstruction efficiency from $K_S \to \pi^+\pi^-$ data





ε(sel·rec) = (58.5 ± 0.1) %

Single-particle t_0 and trigger efficiencies from data:

$K_S \to \pi^+\pi^-$

also $K_L \to \pi e \nu$, $\phi \to \pi^+\pi^-\pi^0$

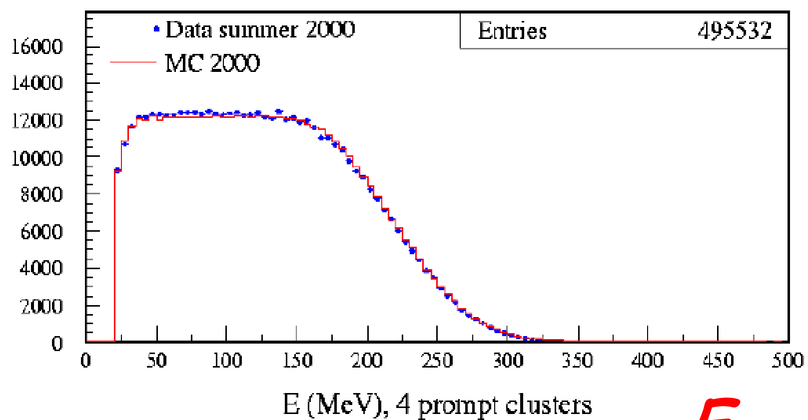
plugged into MC

$\varepsilon(t_0 \cdot \text{trig})$ = (96.5 ± 0.5) %

$K_S \to \pi^0\pi^0$

K_L crash + 4 prompt clusters

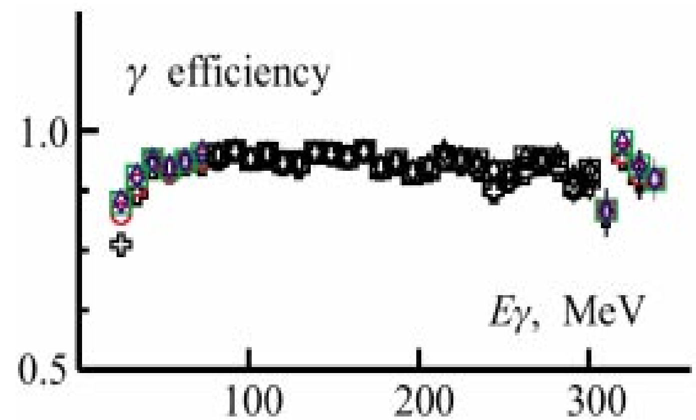
Acceptance (ϑ) and *E* cuts—correction from MC



E_γ

Photon detection efficiency from data using $\phi \to \pi^+\pi^-\pi^0$ events

ε(sel·rec) = (56.7 ± 0.1)%



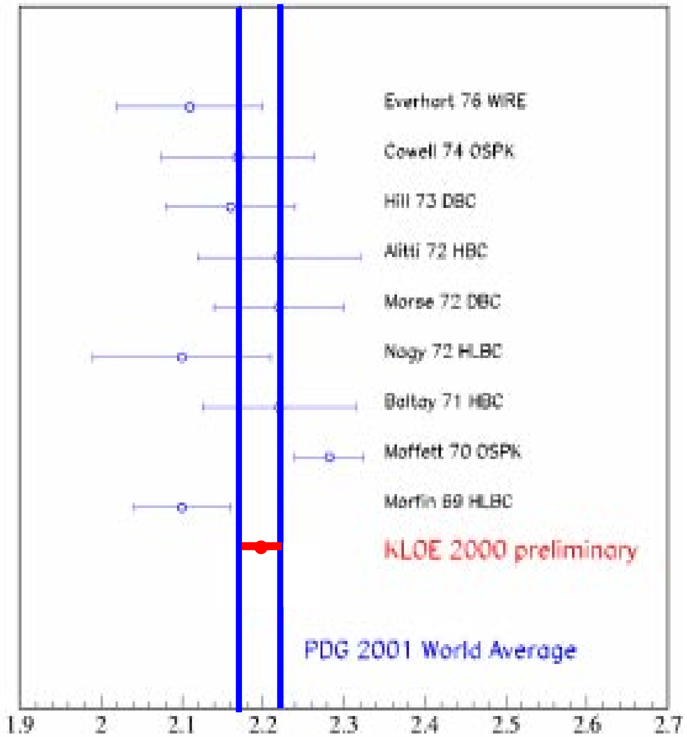
Trigger efficiency estimated by measuring probability of having 0,1 triggering clusters from data

$\varepsilon(t_0 \cdot \text{trig})$ = (99.69 ± 0.03)%

$BR(K_S \rightarrow \pi^+\pi^-)/BR(K_S \rightarrow \pi^0\pi^0)$

KLOE 2000 preliminary (17 pb^{-1}) $2.211 \pm 0.002_{stat} \pm 0.027_{syst}$

PDG 2000 $2.197 \pm 0.026_{stat} \pm 0.013_{syst}$



Contribution to systematic error	%
$K_S \rightarrow \pi^0\pi^0$ selection*	1.0
Tag bias	0.5
$K_S \rightarrow \pi^+\pi^-$ trigger and t_0	0.5
$K_S \rightarrow \pi^+\pi^-$ selection	0.1
$K_S \rightarrow \pi^0\pi^0$ trigger	0.02
Overall systematic error	1.2

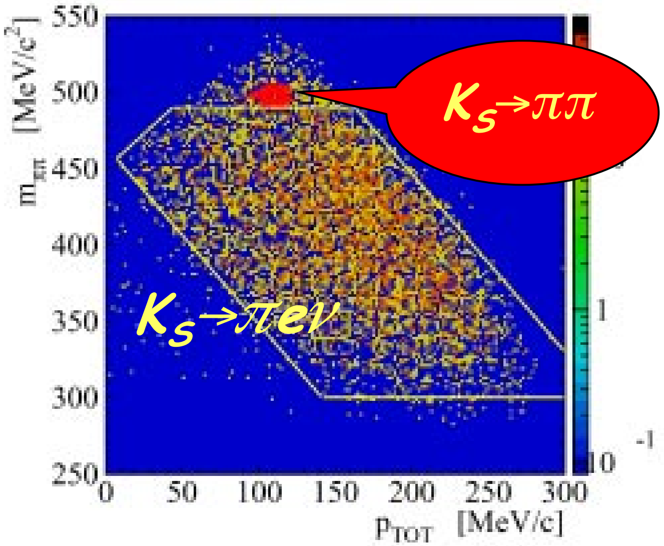
Work on $d\Gamma(K_S \rightarrow \pi^+\pi^-\gamma)/dE_\gamma$ in progress

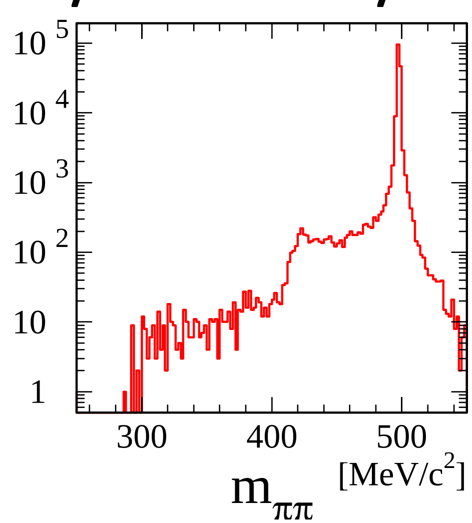
K_s semileptonic decays

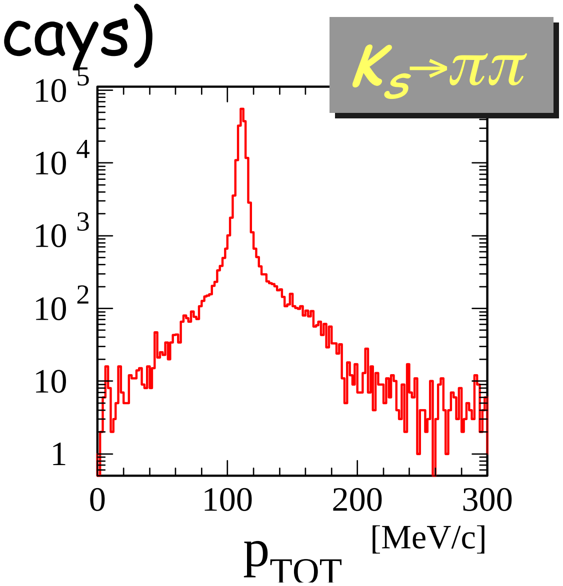
- $BR^{th}(K_S \to \pi e \nu)$ = BR $(K_L \to \pi e \nu)$ $\Gamma_L/\Gamma_S \approx 6.7 \cdot 10^{-4}$ if $\Delta S = \Delta Q$
- Only measurement: $(7.2 \pm 1.4) \cdot 10^{-4}$ from CMD-2 (based on 75 candidates)
- Background from $K_S \to \pi\pi$ (Signal/bckgd $\approx 10^{-3}$)
  $K_S \to \pi\pi\gamma$ (Signal/bckgd $\approx 1/3$)

Strategy:

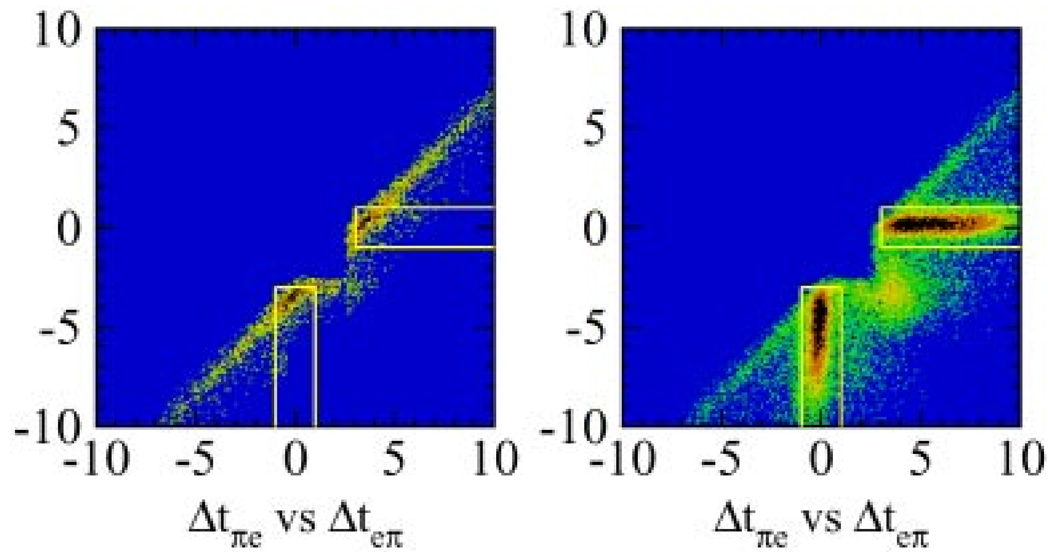
- Kinematic cuts (2-body vs.3-body decays)







K_s semileptonic decays

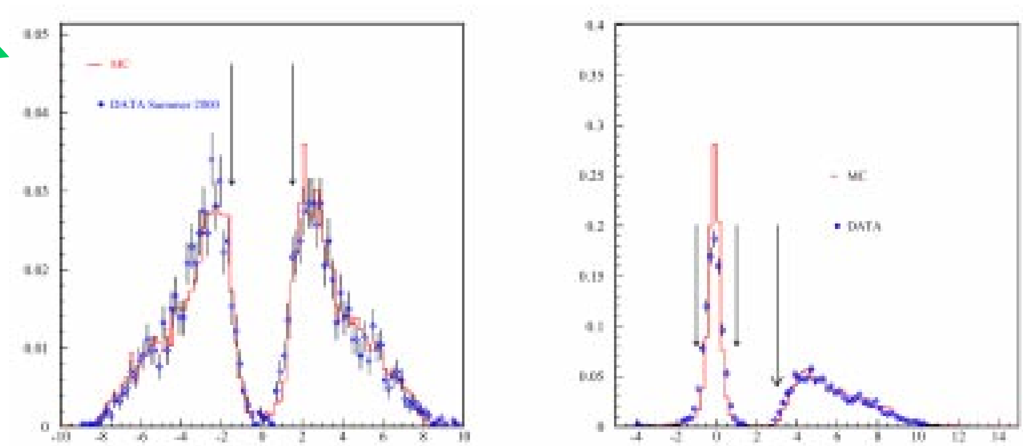


Strategy (cont):

- time-of-flight to reduce $K_S \to \pi\pi$ and $K_S \to \pi\pi\gamma$
- ...and identify $K_S \to \pi e \nu$

$$\Delta t_{\pi e} = (t - L/\beta c)_\pi - (t - L/\beta c)_e$$

- Efficiency from $K_L \to \pi e \nu$ decays near the origin
- High-purity sample ($> 99.7\ \%$), isolable by kinematical cuts



K_s semileptonic decays

Strategy (cont):

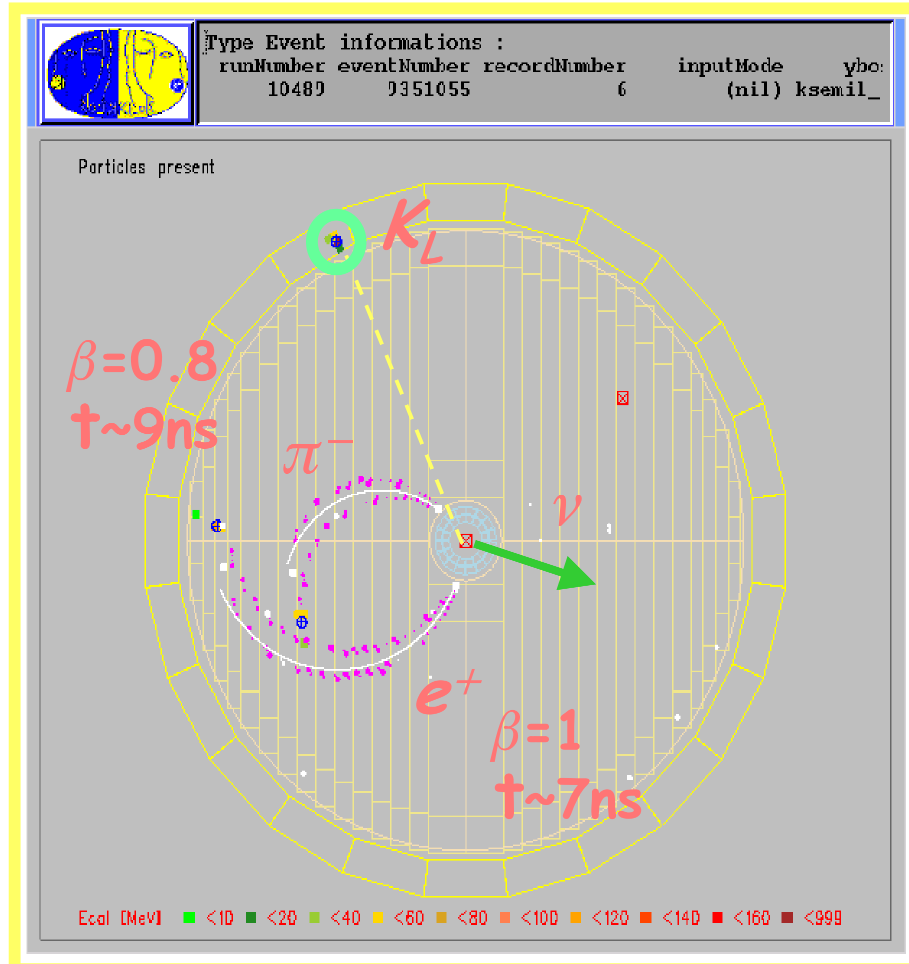
- Reconstruct p_ν from K_L direction

Single-particle t_0, track-cluster, and trigger efficiencies from data using:

$K_L \to \pi e \nu$ near origin

$\phi \to \pi^+\pi^-\pi^0, K_S \to \pi^+\pi^-$

MC-weighted to get overall correction

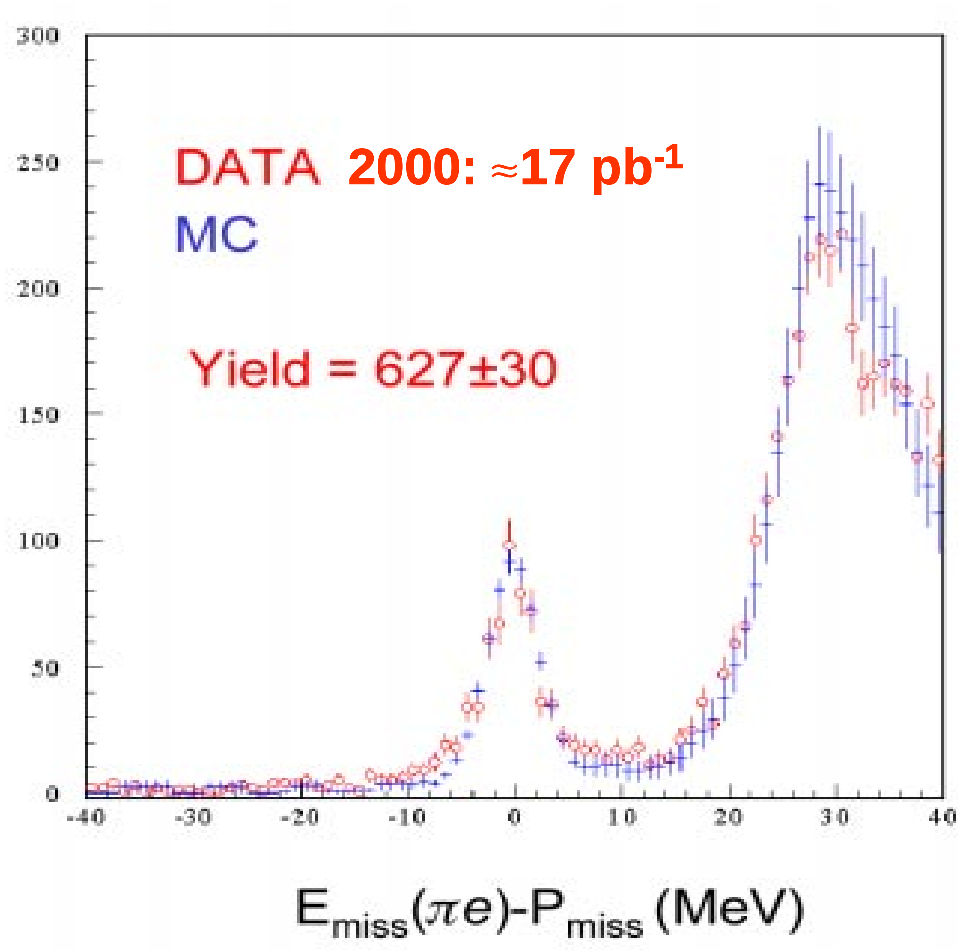


K_S semileptonic decays

Overall selection efficiency:
$(21.4 \pm 0.2_{stat} \pm 0.7_{syst})\%$

Fit to E_{miss}-p_{miss} spectrum using MC spectra for signal and $\pi^+\pi^-$ background

Normalization to $K_S \rightarrow \pi^+\pi^-$ decays



K_s semileptonic decays

KLOE 2000 preliminary (17 pb^{-1})	**$(6.69 \pm 0.40) \cdot 10^{-4}$**
CMD-2 1999, 75 ± 13 evts.	$(7.2 \pm 1.4) \cdot 10^{-4}$
$\Gamma(K_S \to \pi e \nu) = \Gamma(K_L \to \pi e \nu)$	$(6.70 \pm 0.07) \cdot 10^{-4}$

Correction	%
Preselection	$62.4 \pm 0.3_{stat} \pm 2.0_{syst}$
Acceptance	$51.1 \pm 0.2_{stat}$
Track topology cuts	$95.8 \pm 0.1_{stat} \pm 0.3_{syst}$
Cluster·t_0·trigger	$85.3 \pm 0.4_{stat} \pm 0.5_{syst}$
TOF selection	$82.0 \pm 0.7_{stat}$
Tag bias	$97.7 \pm 0.4_{stat} \pm 0.5_{syst}$

Conclusions

- DAFNE performance has improved considerably during the first two years of KLOE data taking
- The KLOE detector is performing well
- First ~20 pb^{-1} of KLOE data have yielded results on:
  $BR(K_S \to \pi^+\pi^-)/BR(K_S \to \pi^0\pi^0)$, $BR(K_S \to \pi e \nu)$
  $\phi \to f_0\gamma \to \pi^0\pi^0\gamma$, $\phi \to a_0\gamma \to \eta\pi^0\gamma$, $\phi \to \eta\gamma$, $\phi \to \eta'\gamma$
- 200 pb^{-1} expected by end of 2001 will permit:
  - Complete and definitive results for the above items
  - $K_S \to 3\pi^0$, $K_S \to \gamma\gamma$, $K_S \to \pi^+\pi^-\gamma$ decays
  - $K_L \to 2\pi$, $K_L \to \gamma\gamma$ decays
  - Charged kaon decays
  - $\sigma(e^+e^-$ hadrons) to 1% statistical error