KLOE: Status of Data Taking and Analysis

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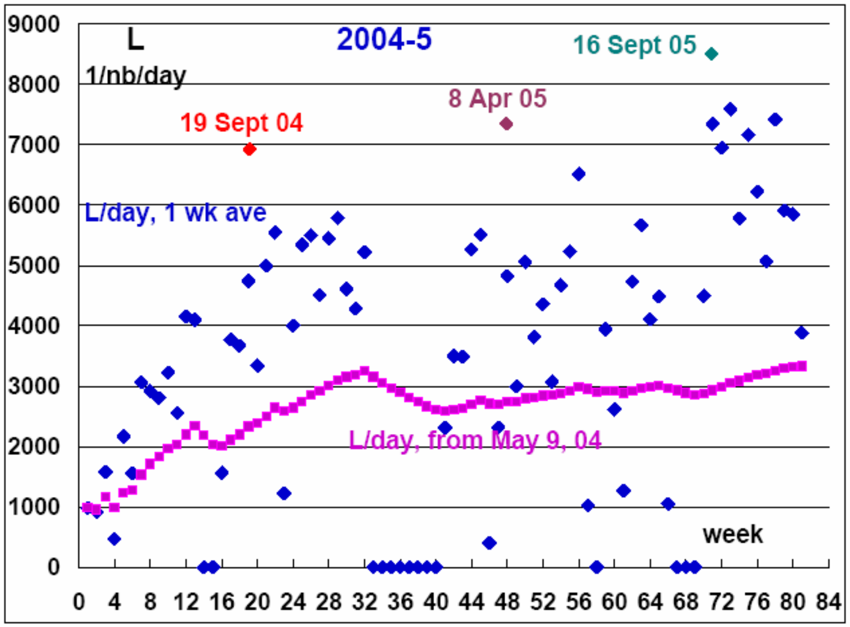
on behalf of the KLOE Collaboration

- **Current data taking**
- **2 fb^{-1} MC production / Offline status**
- **Selected items from analysis in progress**

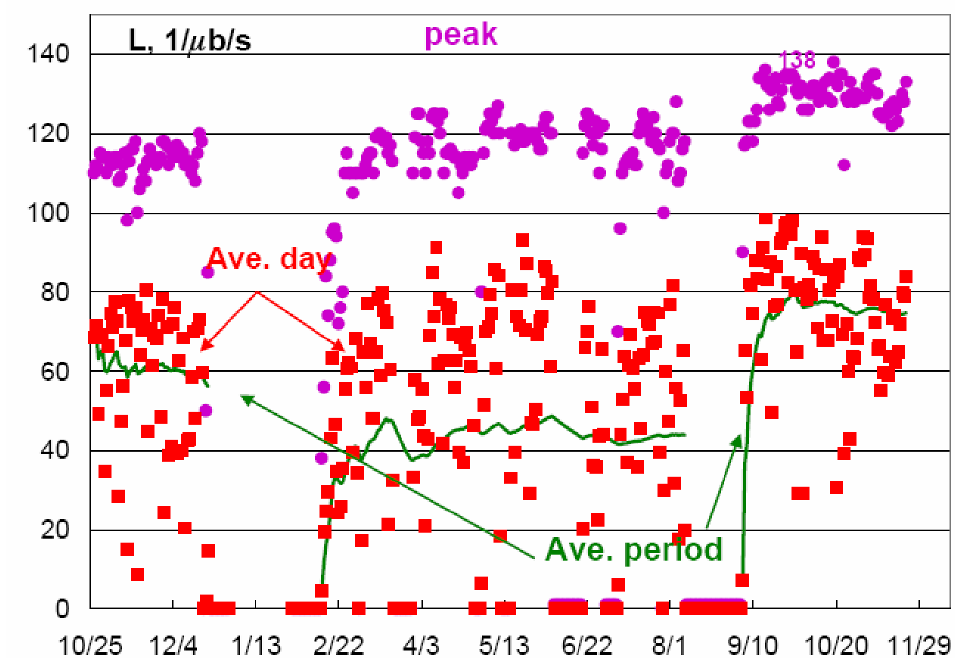
XXXI LNF Scientific Commettee – LNF, 28–30 November 2005

2004-2005 data taking

Integrated luminosity (nb^{-1}/day)



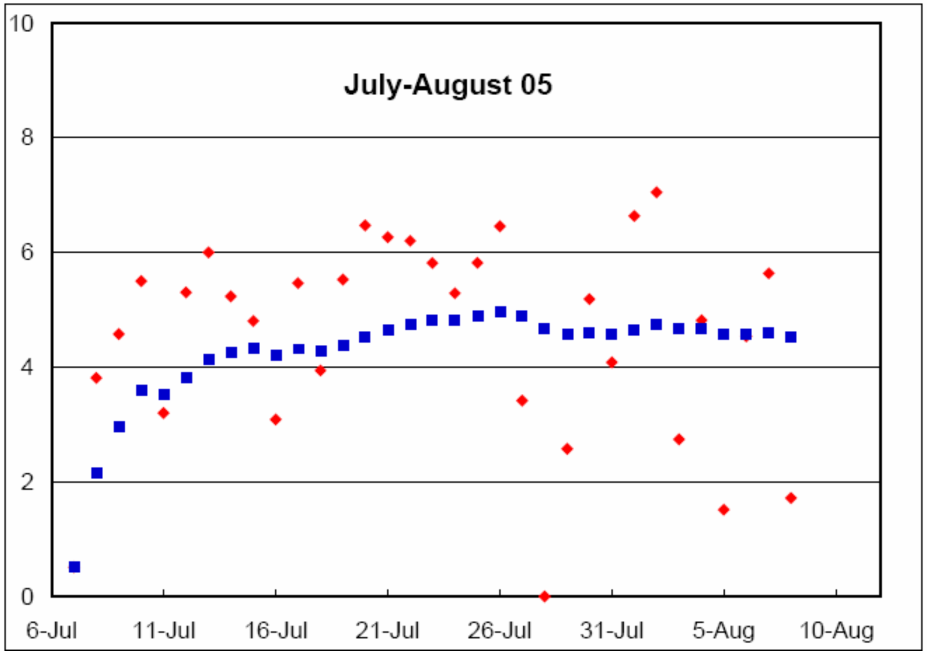
Instantaneous luminosity (μb^{-1}/s)

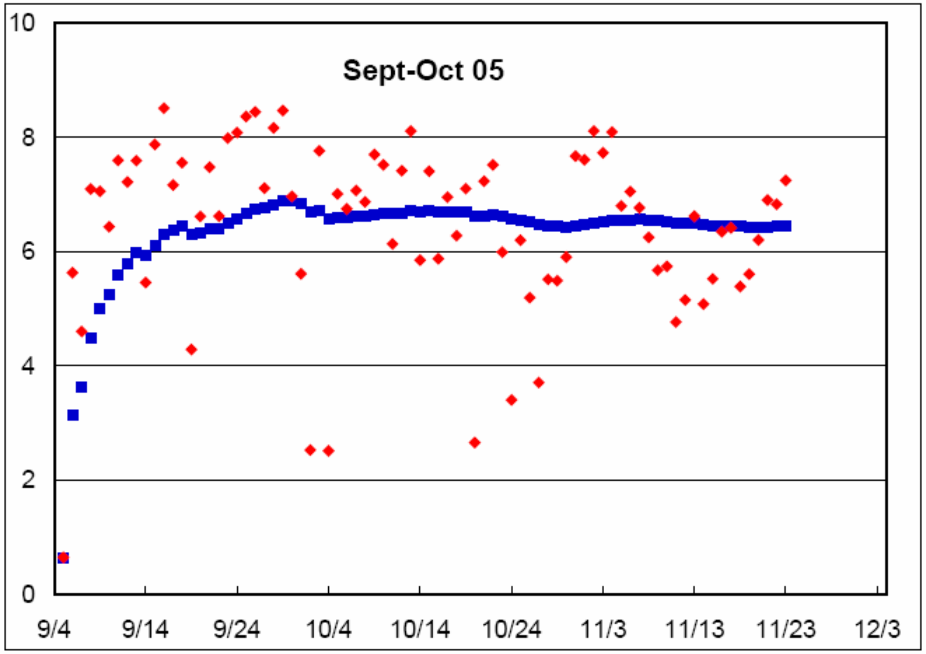


- Maximum L/day reached: **8.51 pb^{-1}**
- **Best running conditions from September 05**

2005 data taking

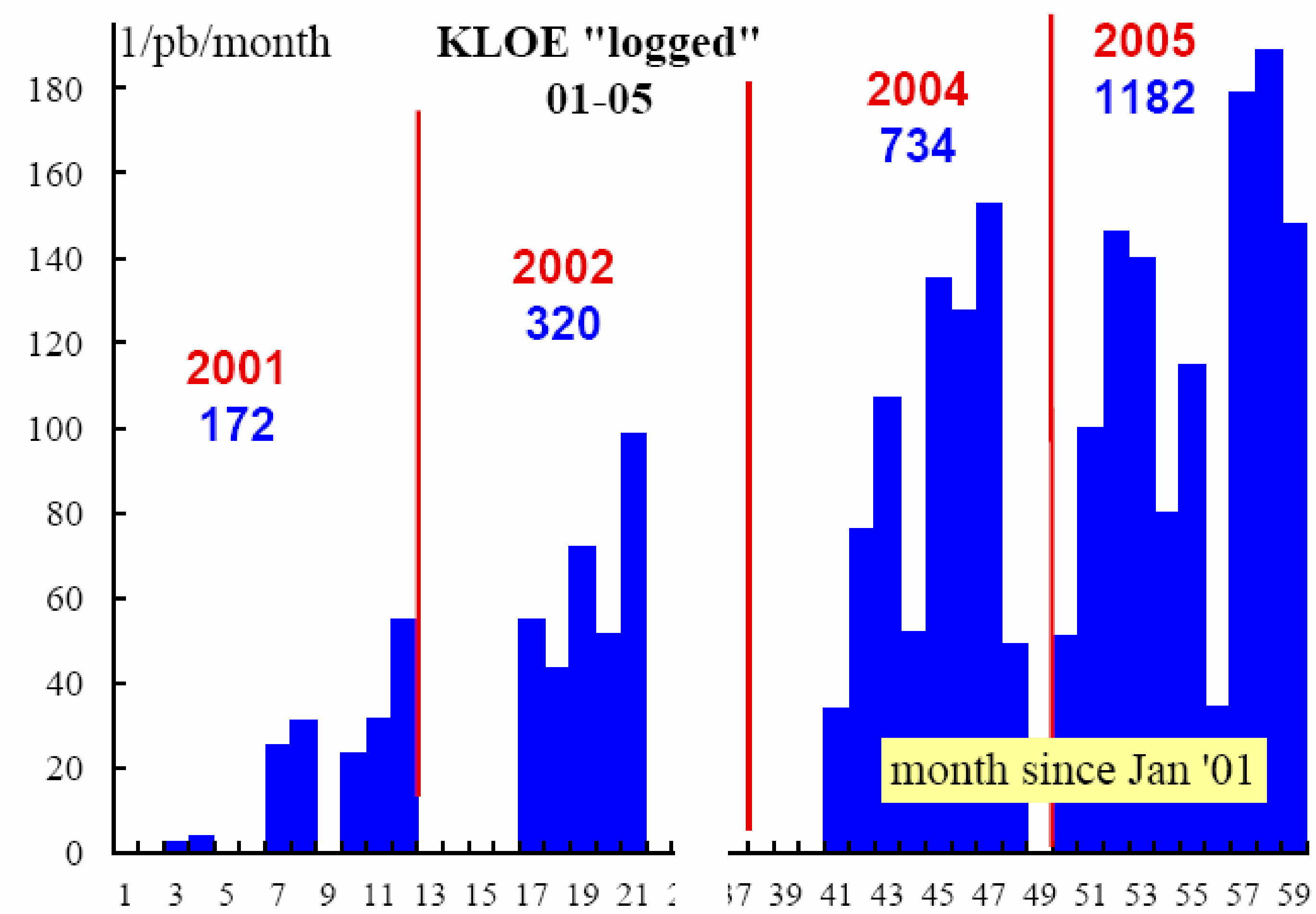
Integrated luminosity (nb^{-1}/day)





- ♦ L/day (pb^{-1})
- ■ Mean starting from 1st bin

KLOE integrated luminosity



L_{int}(2004-2005) ~ 1.9 fb^{-1} … The 2 fb^{-1} goal is approaching!

[97% GOOD , 96% Fully calibrated , 89% Already reconstructed]

MC production for 2 fb^{-1} analysis

Main improvements for simulation of 2004-2005 data

- Map of 2004 machine and trigger conditions
  2005 in progress
- New IR geometry in simulation
- Better parameterizations of EmC response
  Time, energy resolution; cluster efficiencies
- Improved simulation of nuclear interactions/regeneration in DC wall and beam pipe
- New secondary decay generators
  $K_S \to \pi^+\pi^- e^+e^-; \pi \to e\nu, \pi \to e^+e^-$
- Inserted background from events acquired with random trigger
- Simulation of *dE*/*dx* measurement in DC

MC production plans

Averaged over entire MC sample: 0.21M evts/B80 day = 2.4 Hz
0.41 s/evt (simulation + reconstruction + DST)

2001-2002 MC production

$\phi \to$ all, scale = 0.2
$K_S K_L$, scale = 1
$K^+ K^-$, scale = 1
ϕ radiative, scale = 5
Other (1M evts/pb^{-1})

Total: 3.1M evts/pb^{-1}
(about same as number of ϕ decays in data)

Estimated time for 2004-2005 MC

2001-2002 450 pb^{-1}	**2004-2005 2000 pb^{-1}**
1.85G evts 8800 B80 days	**8.25G evts 39000 B80 days**

2004-2005 MC production ($\phi \to$ all, scale = 0.2) starting now

Offline resources: CPU

2006 offline projects	Time needed (B80 days)
Online reconstruction of 2006 data	3000
Reprocessing of 2004 data	16000
MC production for 2004-2005 data	39000
Other tasks	5000
Total	**63000**

Current offline farm:

200 B80 CPUs (60 typically reserved for analysis)

Offline work completed in 450 days (15 months) on 140 B80s

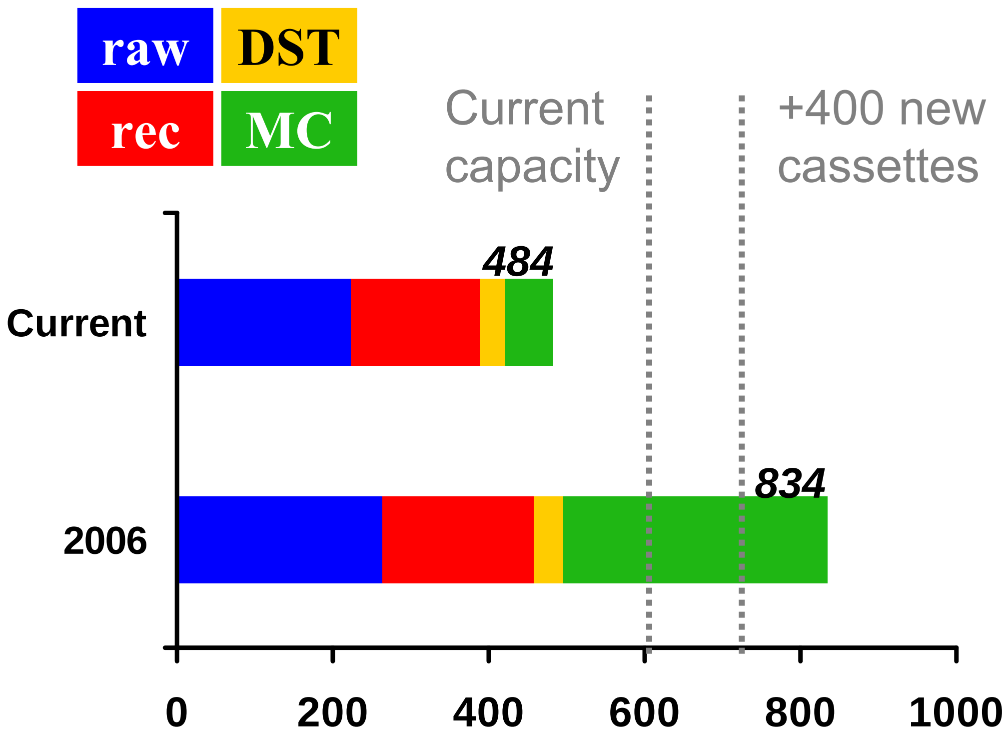
Expansion plans:

Ordering 3 16-way 1.5 GHz Power5 servers

Will add 200 B80 to offline farm → **work completed in 6 months**

Offline resources: tape library

Tape library usage (TB)



2006 estimate includes:

- Closing of holes in datarec/DST coverage
- Off-peak running in 2006
- MC for '04-'05 data

Library capacity:

- Currently **600 TB**
- Expandable to **1400 TB**
  (1000/3600 slots in use in new library)

Order ready for 400 new cassettes (120 TB)

Offline resources: disk space

DSTs cached on nfs-mounted disks for fast analysis access

DST volume

Current	2006
33 TB data 10 TB MC **43 TB total**	40 TB data 41 TB MC **81 TB total**

Current DST cache capacity: **13 TB**

Purchase of 21 TB + new controller approved

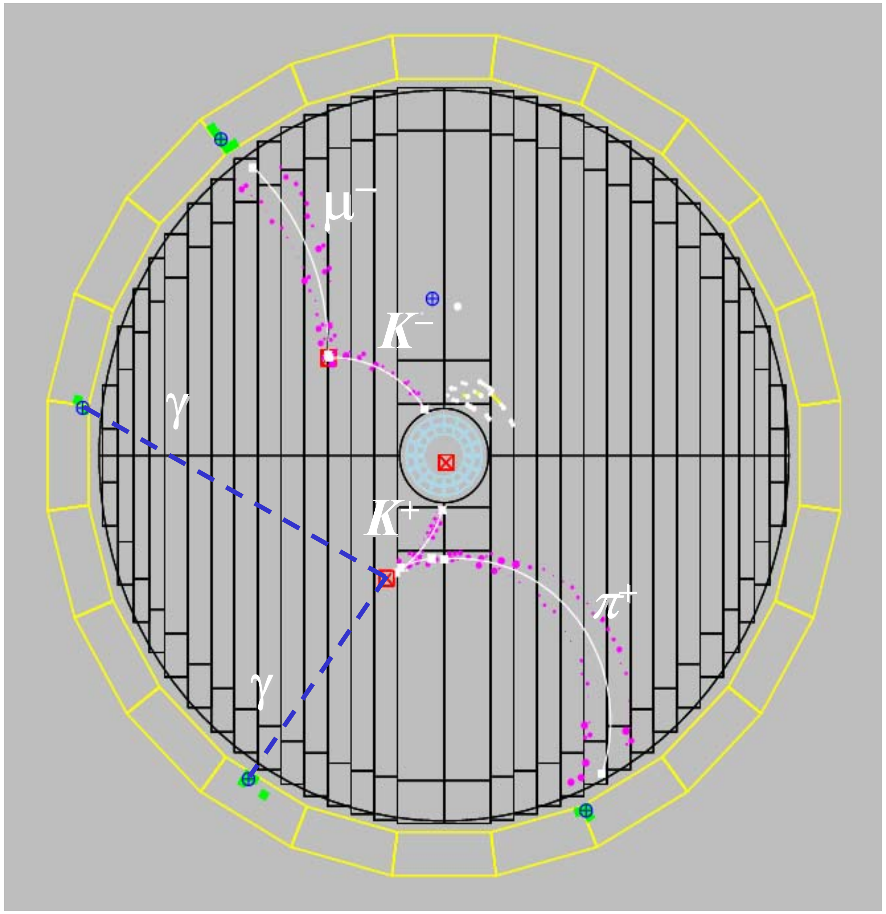
Will request additional disk space (~30 TB) next year

Status of 2005 papers on kaons

	Last SC	Today
BR of major K_L decays	Preliminary measurements	Accepted by PLB
K_L lifetime	Preliminary measurement	PLB 626 (2005) 15-23
K_L form factors		Draft in writing
$K_L \to \pi^+\pi^-$		In progress
$K_S \to \pi^0\pi^0\pi^0$	Submitted to Phys. Lett.	PLB 619 (2005) 61-70
$K_S \to \pi^+\pi^-(\gamma)$ / $K_S \to \pi^0\pi^0$	Update with '01-'02 data	PLB draft in writing
$K_S \to \pi e \nu$	Update with '01-'02 data	PLB draft ready
$K_S \to \pi^+\pi^-\pi^0$	In progress (also 2004 data)	
Q.M. interference	Preliminary results	
$K^\pm \to \mu\nu$	Preliminary measurement	Accepted by PLB
$K^\pm \to \pi \mu \nu$, $K^\pm \to \pi e \nu$	In progress	Preliminary measurement
$K^\pm$ lifetime	In progress	

$K^{\pm}_{\ell 3}$: tag selection

- ✓ Track from IP, momentum cut:
  70 MeV $\leq p_K \leq$ 130 MeV
- ✓ Decay vertex in fiducial volume:
  40cm $\leq \rho_{VTX} \leq$ 150 cm
- ✓ Secondary track extrapolated to EMC
- ✓ 2-body decays identified by 3σ cut in p*
- ✓ For $K_{\pi 2}$ tags, require also π^0 identification
- ✓ To reduce the dependency of "tagging" on the decay mode of the other kaon, the tag has to satisfy the trigger



350 pb^{-1}
from 2001-2002 data

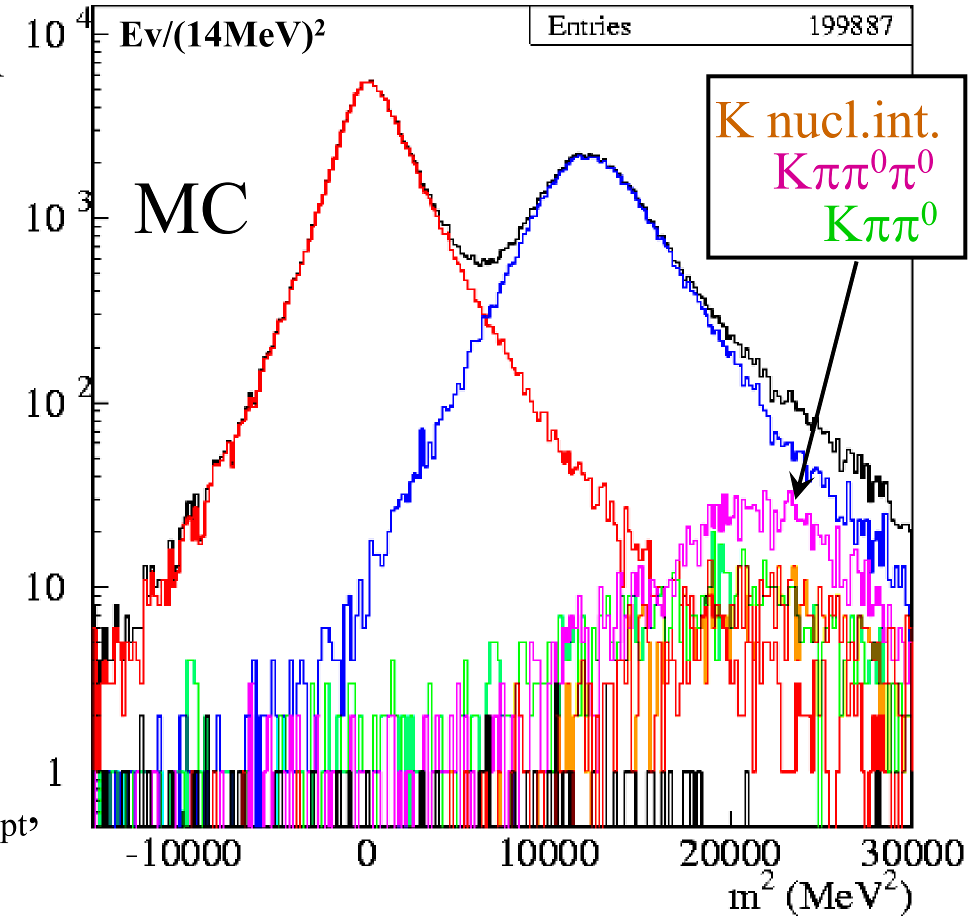
Tag	$K^+_{\mu 2}$	$K^+_{\pi 2}$	$K^-_{\mu 2}$	$K^-_{\pi 2}$
N_{TAG}	**21 699 562**	**8 466 737**	**22 655 426**	**8 233 472**

$K^{\pm}_{\ell3}$: signal selection

- ✓ 1-prong kaon decay vertex in the fiducial volume: 40cm $\leq \rho_{VTX} \leq$ 150 cm
- ✓ Secondary track extrapolated to EMC
- ✓ Rejection of two-body decays:
  $p^*(m_\pi) \leq 195$ MeV
- ✓ π^0 search: 2 neutral clusters in EMC, with ToF matching the K decay vertex ($\delta(\delta t)<3\sigma_t$)
- ✓ Spectrum of charged daughter mass, m^2_{lept}, from TOF measurement imposing

$$t^{decay}_K = t_{lept} - L_{lept}/(\beta_{lept}c) = \langle t_\gamma - L_\gamma/c \rangle$$

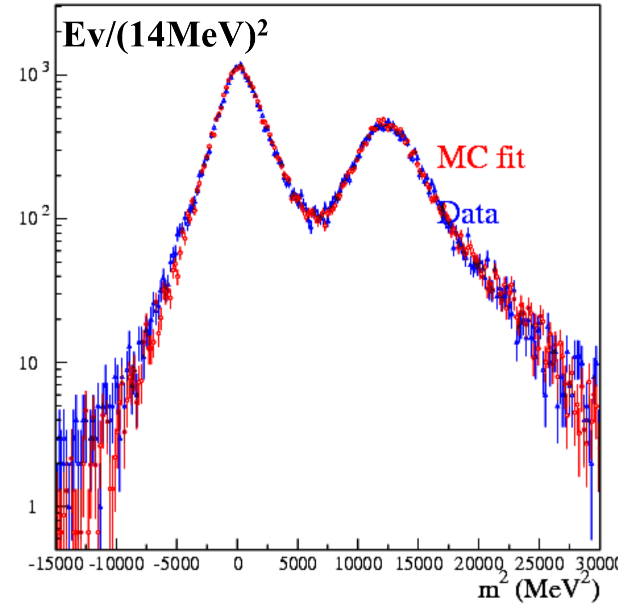
- ✓ Kinematical cuts to reject non-semileptonic decays



The residual background is about ~ 1.5% of the selected $K^{\pm}_{l3}$ sample

$K^{\pm}_{\ell 3}$: event counting

✓ Fit m^2_{lept} spectrum with a linear combination of K_{e3} and $K_{\mu 3}$ shapes + background contribution



✓ Selected signal events in 2001/2002 data set

Tag	$K^+_{\mu 2}$	$K^+_{\pi 2}$	$K^-_{\mu 2}$	$K^-_{\pi 2}$
N_{Ke3}	**62 781(321)**	**24 914(208)**	**66 657(334)**	**24 225(204)**
$N_{K\mu 3}$	**37 461(264)**	**14 827(170)**	**39 988(277)**	**14 608(168)**

$BR(K_{e3})$	**(5.047 ± 0.046 ± 0.080)%**
$BR(K_{\mu 3})$	**(3.310 ± 0.040 ± 0.070)%**

KLOE preliminary

❖ **Systematic error still preliminary**

❖ Error currently dominated by the **knowledge of selection efficiency**

❖ **Fractional accuracy** (first error only) **of 0.9% for K_{e3}, 1.2% for $K_{\mu 3}$**

$\tau_{K^{\pm}}$: present situation

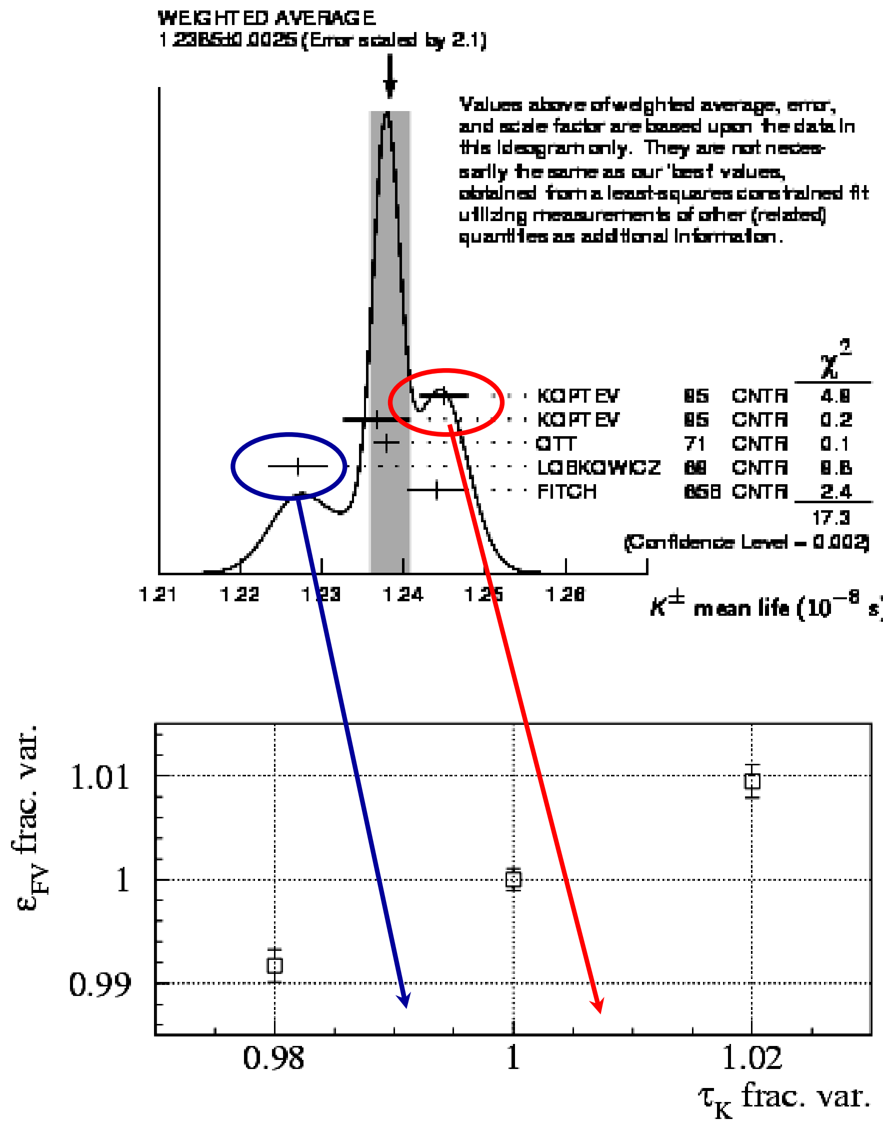
- V_{us} experimental input
  0.2% fractional accuracy; 0.1% for V_{us}

- Affects BR measurements due to geometrical acceptance

- $\tau_{\pm}$ PDG entries: discrepancies between in-flight and at-rest measurements and between different stoppers

- **New high statistics $\tau_{\pm}$ measurement almost complete at KLOE, now under the review of the collaboration**

- Two different methods to measure $\tau_{\pm}$:
  - ✓ **K decay length**
  - ✓ **K decay time**
  - $\Rightarrow$ **cross checks on systematics**



$\tau_{K^\pm}$ measurement @ KLOE

- Self-triggering $K_{\mu\nu}$ tag
- K track on the signal side
- Decay vertex in FV

Method 1

- Signal K extrapolated to the IP: dE/dx correction applied along the path

$$t_K = \sum \frac{L_i}{\beta_i}\sqrt{1-\beta_i^2}$$

L_i = step length

- Tracking efficiency and resolution measured on data by means of neutral vertex identification
- Fit to the t_K distribution
- **0.2% fractional error**

Method 2

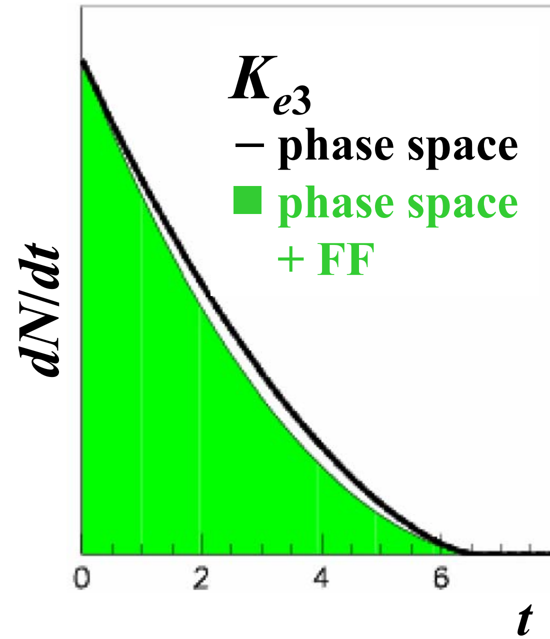
- Use only $K_{\pi 2}$ decays
- Use tag information to estimate the t_0 of the $\phi \to K^+K^-$ decay
- Identify the clusters belonging to π^0
- Measure the kaon decay time through the photon arrival time

$$t_K = \left(t_\gamma - \frac{r_\gamma}{c} - t_0 \right)\gamma_K$$

- **0.5% fractional error**

K_{Le3} form-factor slopes

Form-factor slopes for $K \to \pi l \nu$ decays needed for extraction of V_{us} (evaluation of phase-space integrals)



Ed Blucher

Parametrization:

$$t = (p_K - p_\pi)^2/m^2_{\pi^+}$$

For K_{e3}: $f_+(t) = f_+(0)\,[1 + \lambda_+ t]$ ***or***

$$f_+(0)\,[1 + \lambda'_+ t + \tfrac{1}{2}\lambda''_+ t^2]$$

KLOE results for $K_L \to \pi e \nu$ decays:

- 328 pb^{-1} of ’01 + ’02 data
- K_L decays tagged by $K_S \to \pi^+\pi^-$ satisfying trigger ($\varepsilon \sim 30\%$)
- Two tracks in fiducial volume forming vertex
- Kinematic cuts + TOF PID to reduce background (~ 0.7% final contamination)
- Separate measurement for each charge state ($e^+\pi^-$, π^+e^-) to check systematics

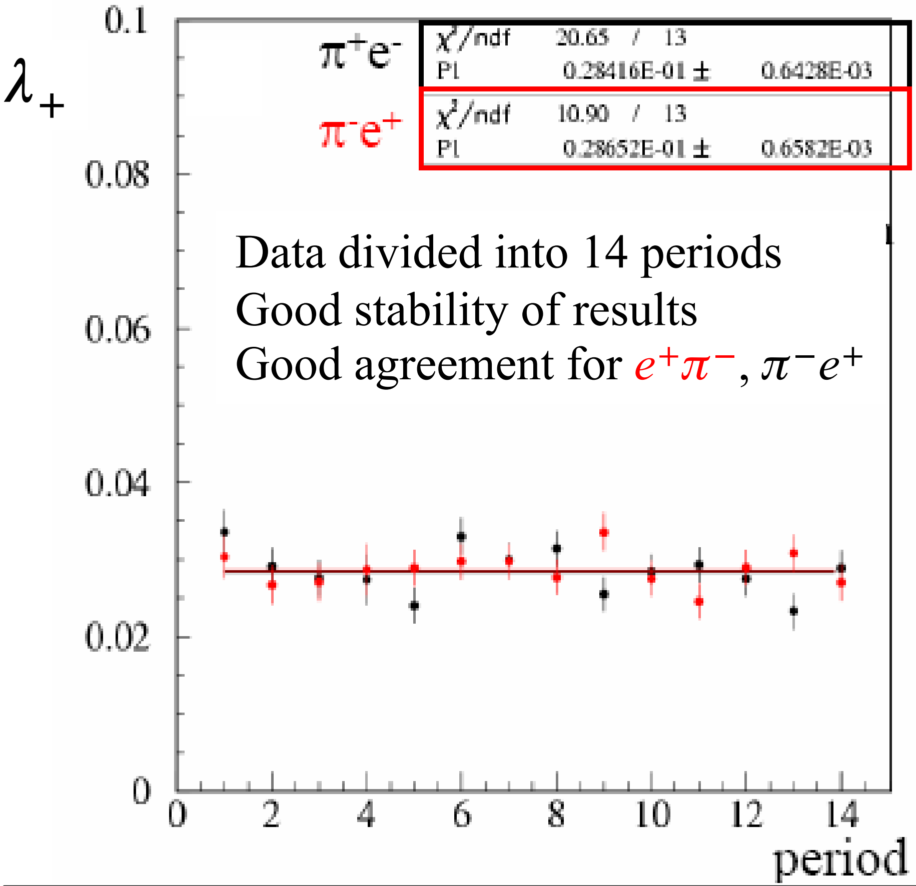
Fits for K_{Le3} form-factor slopes

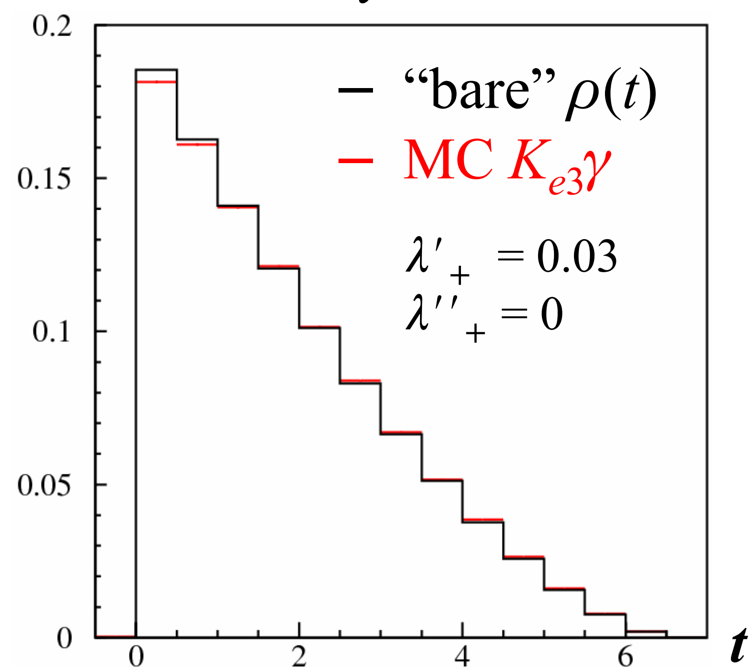
Divide data into 20 bins ($-3 < t < +7$)

$$N_i = N_0 \sum_{j=1}^{20} A_{ij}\, \varepsilon_j\, \rho_j(\lambda'_+, \lambda''_+)\, F_j^{FSR}$$

- A_{ij} Smearing matrix (MC)
- ε_j Reconstruction efficiency
- ρ_j "Bare" K_{e3} decay density
- F_j^{FSR} FSR correction

Obtained from MC generator, effect mainly at low t





K_{Le3} form-factor slopes

328 pb^{-1} '01 + '02 data , 2 × 10^6 K_{e3} decays

Linear fit:

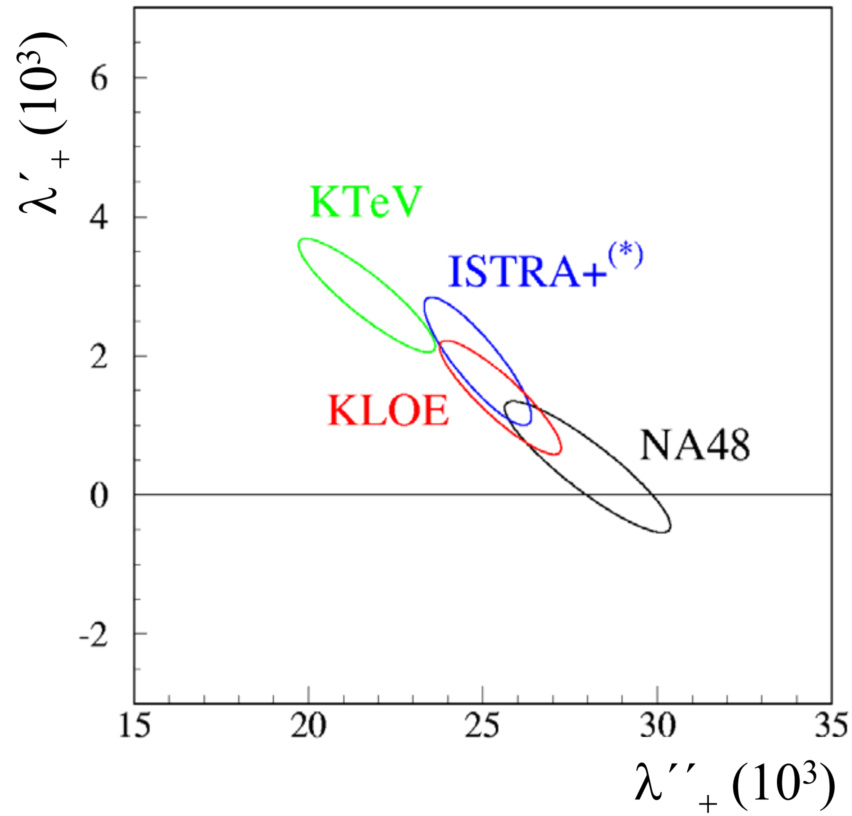
	$\lambda_+ \times 10^{-3}$	χ^2/dof
$e^+\pi^-$	28.7 ± 0.7	156/181
π^+e^-	28.5 ± 0.6	174/181
All	28.6 ± 0.5	330/363

$$\lambda_+ = (28.6 \pm 0.5 \pm 0.4) \times 10^{-3}$$

Quadratic fit:

	$\lambda'_+ \times 10^{-3}$	$\lambda''_+ \times 10^{-3}$	χ^2/dof
$e^+\pi^-$	24.6 ± 2.1	1.9 ± 1.0	152/180
π^+e^-	26.4 ± 2.1	1.0 ± 1.0	173/180
All	25.5 ± 1.5	1.4 ± 0.7	325/362

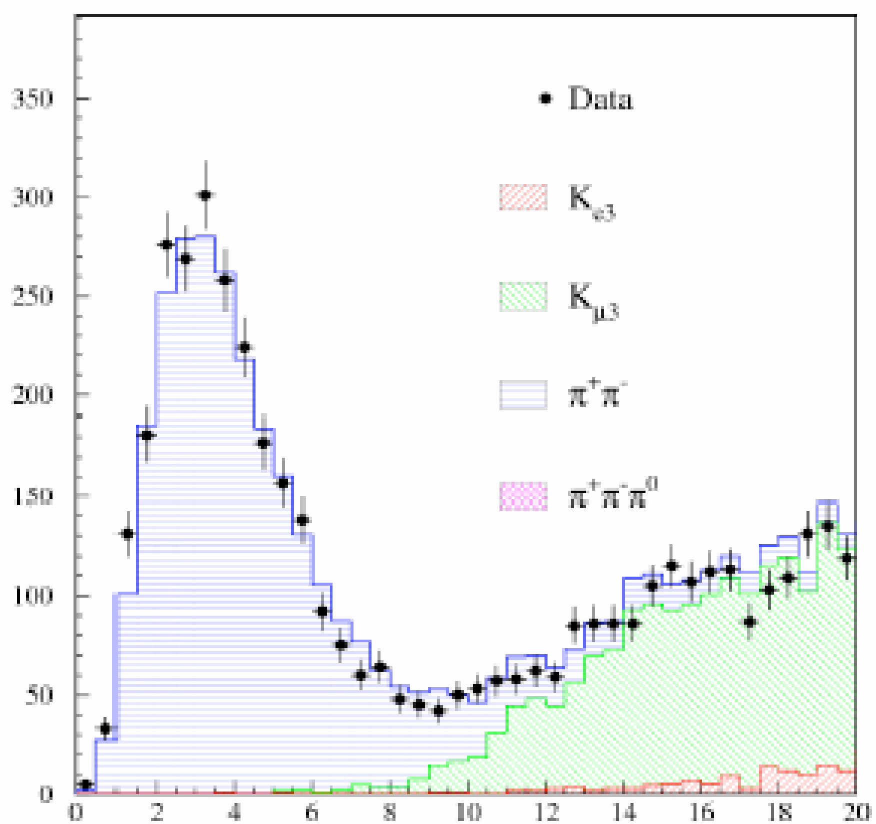
$$\lambda'_+ = (25.5 \pm 1.5 \pm 1.0) \times 10^{-3}$$
$$\lambda''_+ = (1.4 \pm 0.7 \pm 0.3) \times 10^{-3}$$
$$\rho(\lambda'_+, \lambda''_+) = -0.95$$

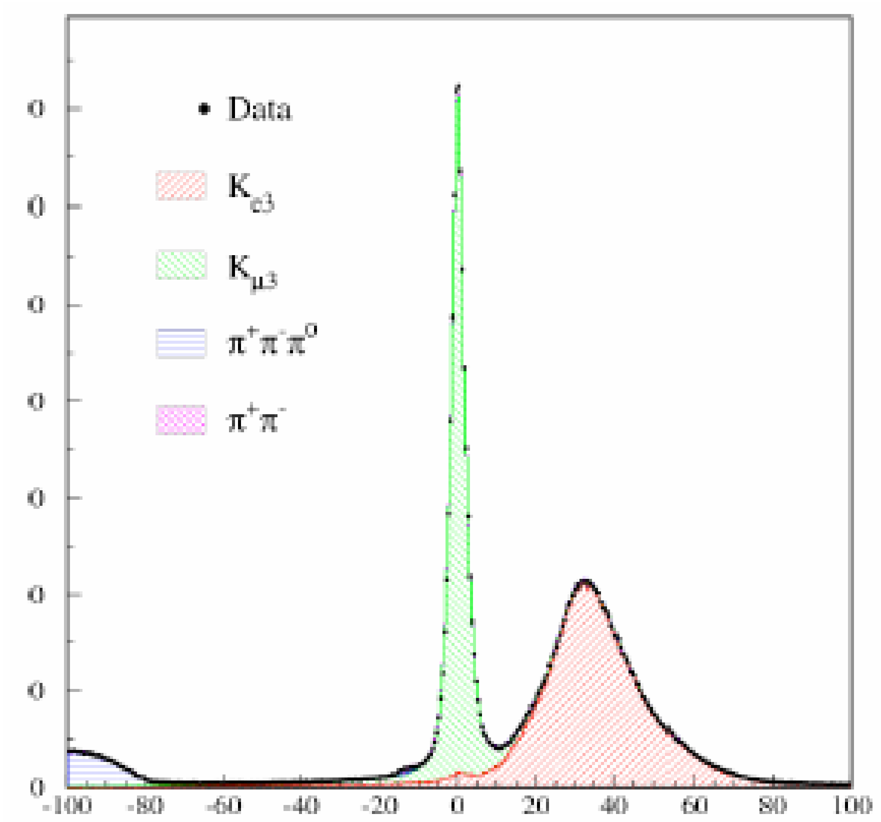


(*) ISTRA+ corrected

BR($K_L \to \pi^+\pi^-$)

Signal and $K_{\mu 3}$ background counting from fit to different distributions





BR measurement + extraction of ε , δ from Bell-Steinberger relation completed…
Now under the review of the collaboration

$\Gamma(K_S \to \pi^+\pi^-(\gamma))/\Gamma(K_S \to \pi^0\pi^0)$

Interest in $K_S \to \pi\pi$ branching ratios:

- $R_{\pi\pi}$ fixes BR($K_S \to \pi^+\pi^-(\gamma)$), used to normalize BR($K_S \to \pi e \nu$)
- Opportunity to push systematics for high-precision KLOE measurements
- First part of double ratio for Re ε'/ε
- Provides information on EM isospin breaking in $K \to \pi\pi$ decays
- Can extract $\delta_0 - \delta_2$ if effective E_γ cutoff known for $\pi\pi\gamma$ channel

KLOE '02 (17 pb^{-1} '00 data) **2.236 ± 0.015**

Repeat analysis with various improvements:

- **New simulation of machine background in MC**
  Reproduces effects *e.g.* on selection efficiency on a run-by-run basis
- **Improved K_L-crash simulation**
  Leads to optimized choice of K_L-crash energy cut: 100 → 300 MeV
- **Higher statistics allow stability of result to be studied**

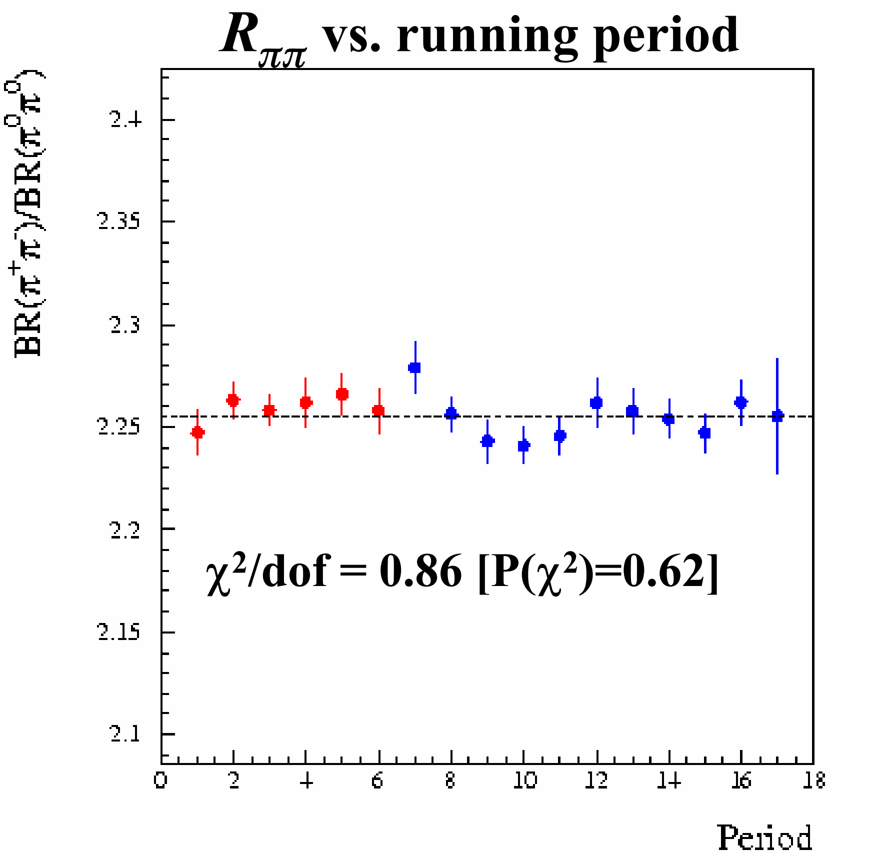
$\Gamma(K_S \to \pi^+\pi^-(\gamma))/\Gamma(K_S \to \pi^0\pi^0)$

KLOE '02 **$2.236 \pm 0.006_{stat} \pm 0.007_{statsyst} \pm 0.013_{syst}$**

(17 pb^{-1} '00 data)

KLOE '05 **$2.2555 \pm 0.0014_{stat} \pm 0.0020_{statsyst} \pm 0.0052_{syst}$**

(410 pb^{-1} '01 +'02 data)



Fractional error on $R_{\pi\pi}$	
Source	**Error (%)**
Event counting	0.060
Stat corrections	0.089
$\pi^+\pi^-$ acceptance	0.169
$\pi^0\pi^0$ acceptance	0.080
Trigger	0.067
Tag	0.051
Background	0.010
FILFO	0.074
Total error	**0.250**

Semileptonic K_S decays

Sensitivity to *CPT* violation through the charge asymmetry:

$$A^l_{S,L} = \frac{\Gamma(K_{S,L} \to \pi^- l^+ \nu) - \Gamma(K_{S,L} \to \pi^+ l^- \bar{\nu})}{\Gamma(K_{S,L} \to \pi^- l^+ \nu) + \Gamma(K_{S,L} \to \pi^+ l^- \bar{\nu})}$$

$A_S \neq A_L$ signals *CPT* violation in mixing and/or in $\Delta S \neq \Delta Q$ decay amplitudes

Sensitivity to *CP* violation in K^0-$\bar{K}^0$ mixing:

$A_S = 2\ \mathrm{Re}\ \varepsilon$, assuming *CPT* symmetry

A_S has never been measured!

$\Gamma(K_S \to \pi l \nu)$ provides test of $\Delta S = \Delta Q$ rule:

$\Gamma_S(\pi l \nu)/\Gamma_L(\pi l \nu) = 1 + 4\ \mathrm{Re}\ x$

Can obtain $|V_{us}|$ from measurements of $\Gamma(K_S \to \pi l \nu)$

Analysis of $K_S \to \pi e \nu$ decays

Event selection:

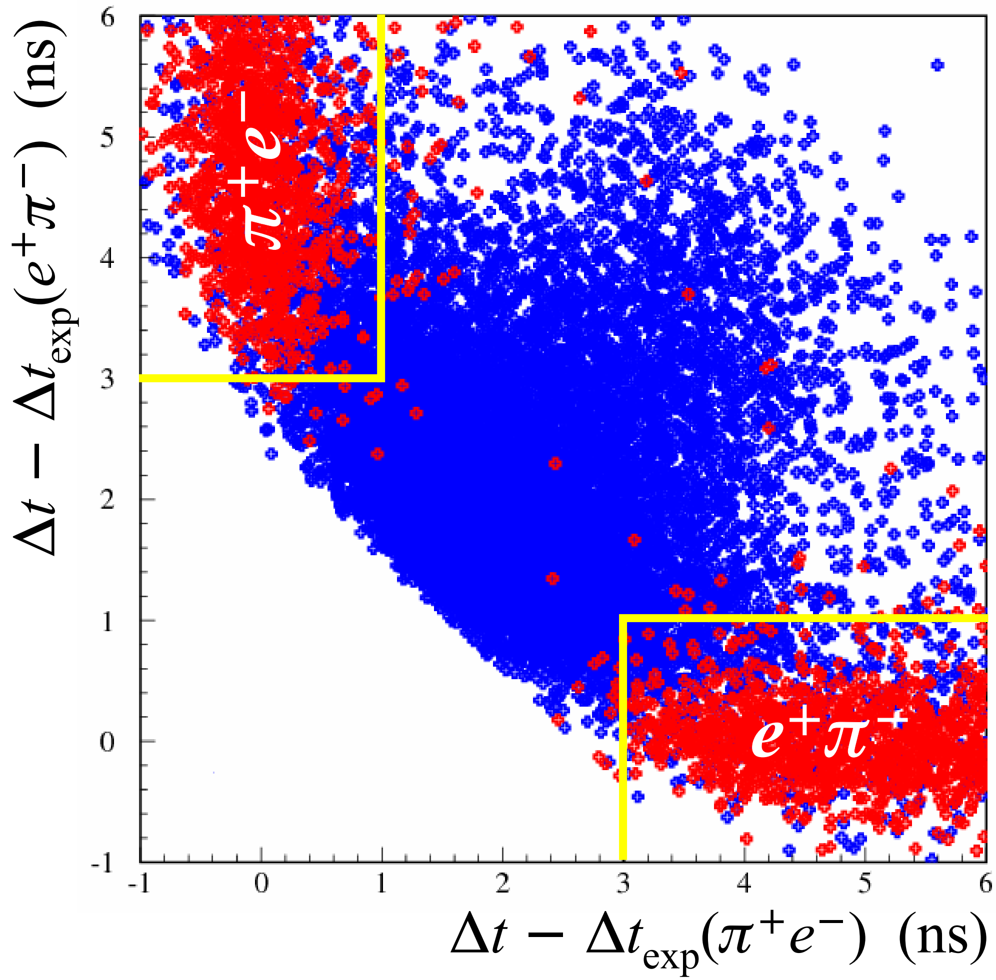
- K_S tagged by K_L crash
- Two tracks from IP to EmC
- Kinematic cuts to reject background from $K_S \to \pi\pi$
- Track-cluster association required

***e*/π ID from TOF**

Identifies charge of final state

Obtain number of signal events from a constrained likelihood fit of multiple data distributions

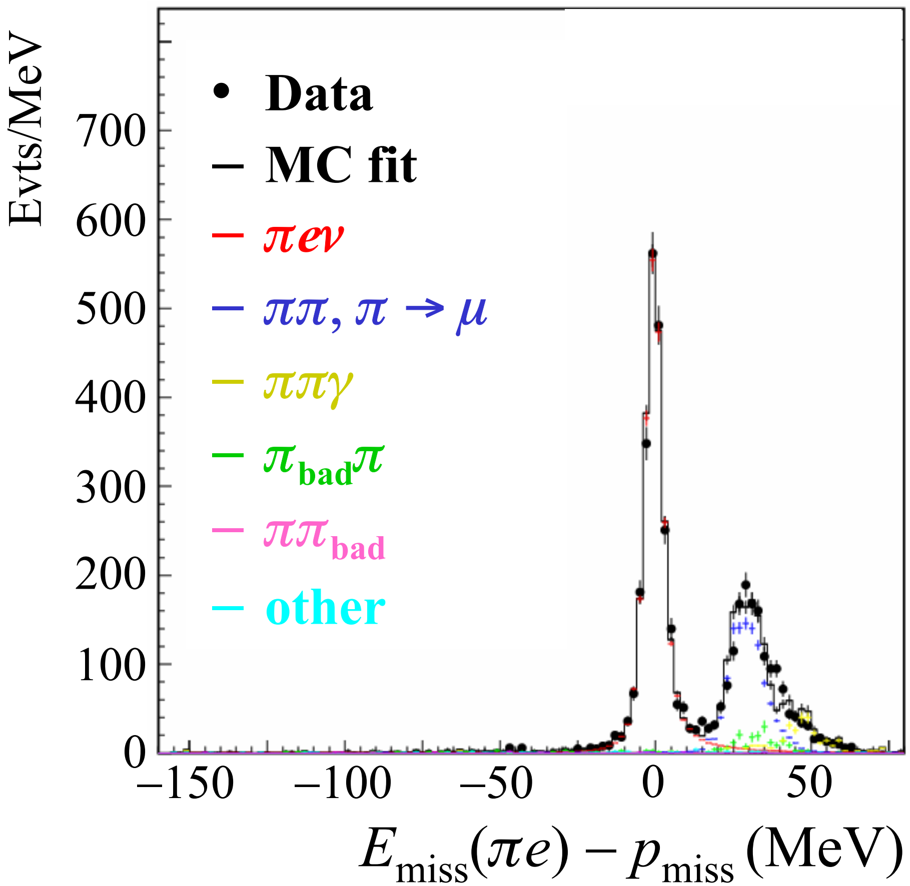
Normalize using $K_S \to \pi^+\pi^-(\gamma)$ events in same data set



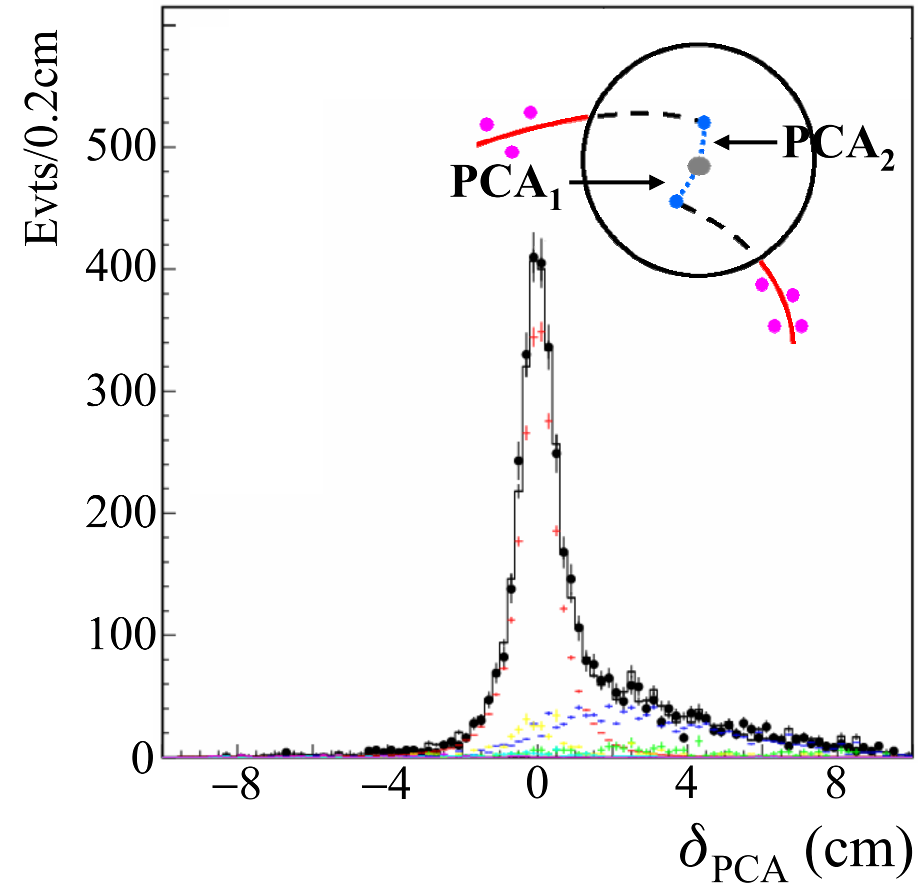
$K_S \to \pi e \nu$: signal extraction

Fit distributions of 5 variables in data with various MC sources

Close kinematics: $E_{miss}(\pi e) - p_{miss} = 0$
MC includes $\pi e \nu \gamma$ and $\pi \pi \gamma$ processes



δ_{PCA} = PCA$_1$ – PCA$_2$ eliminates $\pi \to \mu$ kinks and badly reconstructed tracks



$K_S \to \pi e \nu$: results

Branching ratios:
410 pb^{-1} '01 + '02 data

$$\mathrm{BR}(\pi^- e^+ \nu) = (3.529 \pm 0.057 \pm 0.027) \times 10^{-4}$$
$$\mathrm{BR}(\pi^+ e^- \bar{\nu}) = (3.518 \pm 0.051 \pm 0.029) \times 10^{-4}$$
$$\mathrm{BR}(\pi e \nu) = (7.048 \pm 0.076 \pm 0.050) \times 10^{-4}$$

BR($\pi e \nu$) [KLOE '02, 17 pb^{-1}]: $(6.91 \pm 0.34 \pm 0.15) \times 10^{-4}$

Charge asymmetry:

$$A_S = (1.5 \pm 9.6 \pm 2.9) \times 10^{-3}$$

With 2.5 fb^{-1}: $\delta A_S \sim 3 \times 10^{-3} \sim 2\,\mathrm{Re}\,\varepsilon$

Linear FF slope:

$$\lambda_+ = (33.8 \pm 4.1) \times 10^{-3}$$

In good agreement with linear fit from K_L semileptonic form factor
[$(28.6 \pm 0.6) \times 10^{-3}$]

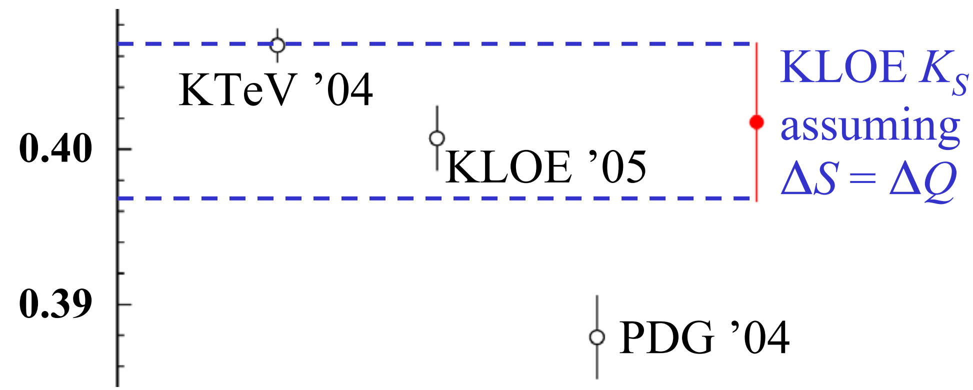
$K_S \to \pi e \nu$: results

Test of $\Delta S = \Delta Q$ rule:

$\tau(K_S)$ = 89.58 ± 0.06 ps
PDG

$\tau(K_L)$ = 51.01 ± 0.20 ns
PDG + KLOE '05 (avg.)

BR(K_{Le3})



Test of $\Delta S = \Delta Q$ rule:

$$\Re(x_+) = (\, 0.4 \pm 3.1 \pm 1.8) \times 10^{-3}$$

Factor 2 improvement w.r.t. current most precise measurement

$\tau(K_S)$	PDG
$\tau(K_L)$	PDG + KLOE '05 (avg.)
BR($K_L \to \pi e \nu$)	KLOE

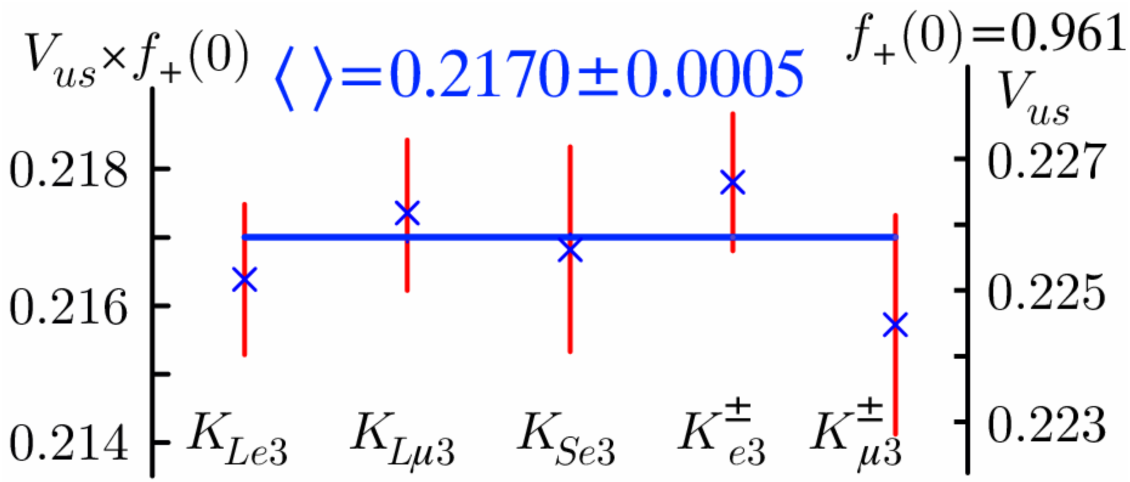
Test of ~~CPT~~:

$$\Re(x_-) = (\, -0.2 \pm 2.4 \pm 0.7) \times 10^{-3}$$

Factor 5 improvement w.r.t. current most precise measurement

A_L	KTeV
$\Re(\delta)$	CPLEAR

KLOE and V_{us}



Expect from unitarity

$V_{us} f_+(0) = 0.2181 \pm 0.0022$

$V_{ud} = 0.9739 \pm 0.0003$

Marciano, CKM '05

Hardy & Towner '04 (SFT)

$f_+(0) = 0.961 \pm 0.008$

Leutwyler & Roos

BRs from KLOE

	K_Le3	$K_L\mu3$	K_Se3	$K^{\pm}e3$	$K^{\pm}\mu3$
BR	0.4007	0.2698	0.00709	0.0505	0.0331
δBR	0.0015	0.0015	0.00009	0.0004	0.0005

K_L lifetime from KLOE

$\tau_L = (50.84 \pm 0.23)$ ns

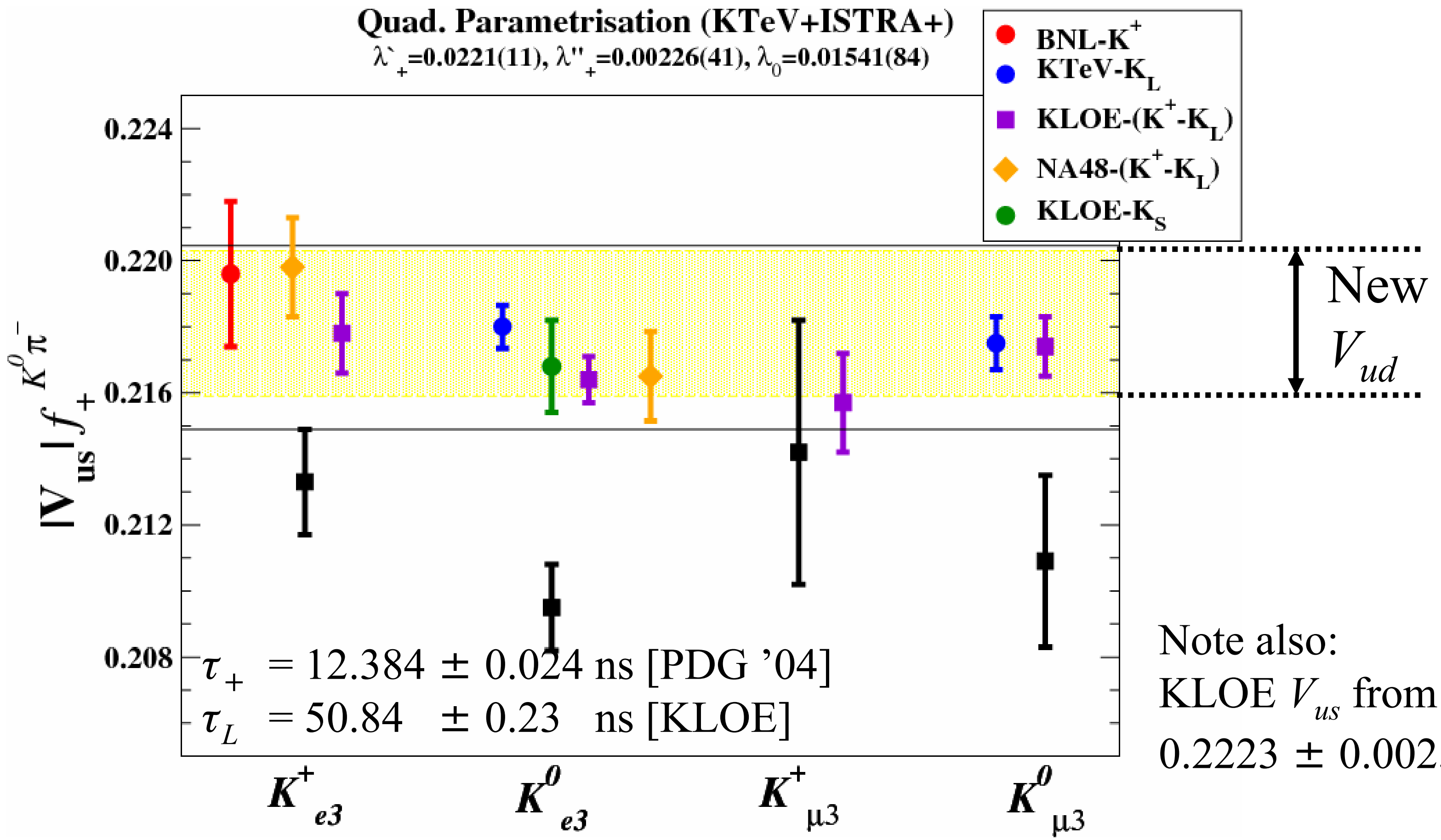
Avg. of direct, Σ BR = 1 determinations

Quadratic form-factor parameterizations:

$$\left.\begin{array}{l} \lambda'_+ = 0.0221 \pm 0.0011 \\ \lambda''_+ = 0.0023 \pm 0.0004 \\ \lambda_0 = 0.0154 \pm 0.0008 \end{array}\right\} \langle \text{KTeV ISTRA+} \rangle$$

V_{us}: summary of recent measurements

Thanks to F. Mescia
(see hep-ph/0411097)



Note also:
KLOE V_{us} from $K_{\mu 2}$
0.2223 ± 0.0025

The V_{us}–V_{ud} plane

Inputs:

V_{us} = 0.2258 ± 0.0020 (K_{l3} KLOE)
V_{ud} = 0.97390 ± 0.00027 (Marciano)
V_{us}/V_{ud} = 0.2294 ± 0.0026 ($K_{\mu 2}$ KLOE)

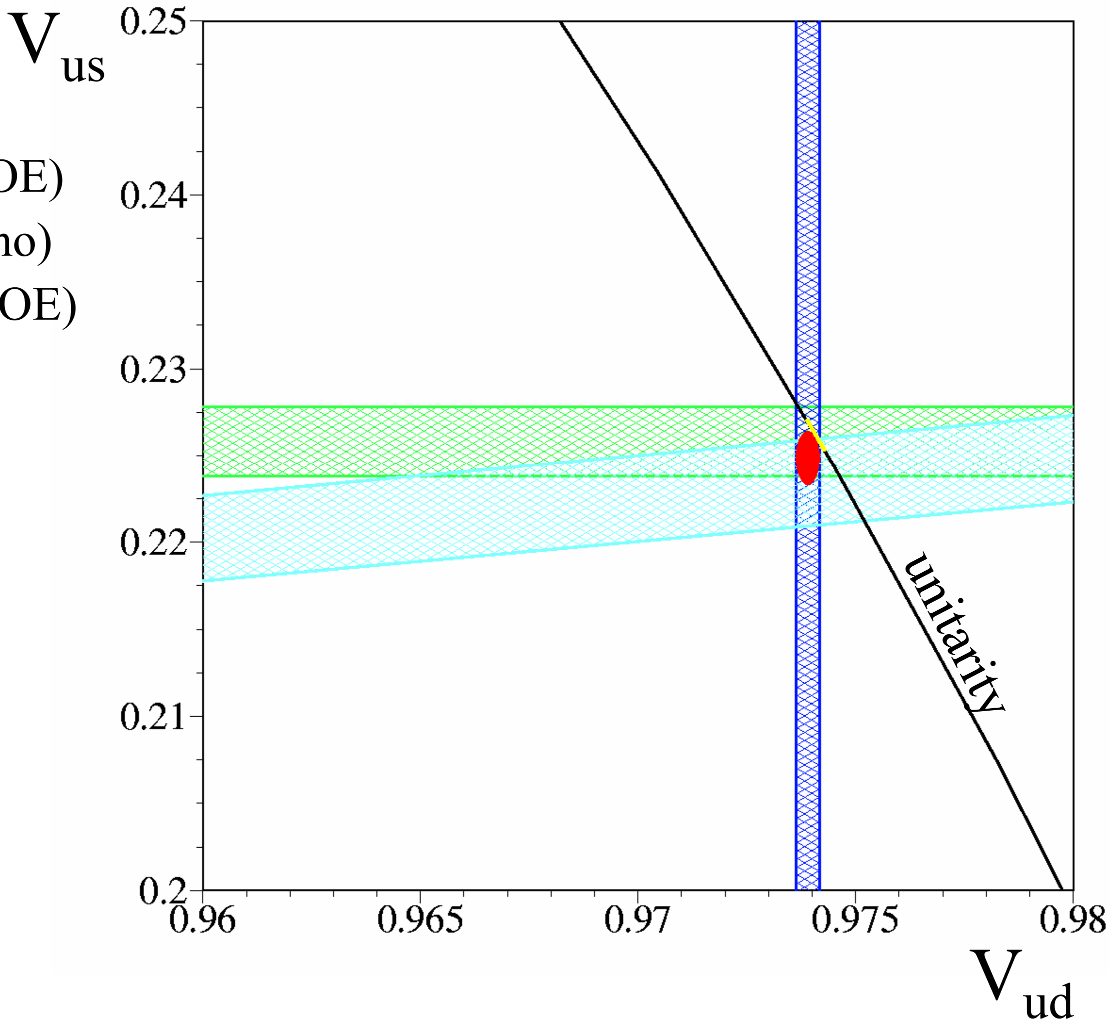
Fit results:

V_{us} = 0.2249 ± 0.0016
V_{ud} = 0.97390 ± 0.00027

Fit results assuming unitarity:

V_{us} = 0.2262 ± 0.0009

$P(\chi^2) = 0.43$



Status of 2005 papers on ϕ decays

	Last SC	Today
$\phi \rightarrow a_0(980)\gamma \rightarrow \eta\pi^0\gamma$	Update in progress	
$\phi \rightarrow f_0(980)\gamma \rightarrow \pi^0\pi^0\gamma$	Update in progress	Int. documentation in writing
$\phi \rightarrow f_0(980)\gamma \rightarrow \pi^+\pi^-\gamma$	Update in progress	Submitted to PLB
$\phi \rightarrow \eta'\gamma$ / $\phi \rightarrow \eta\gamma$	Preliminary measurement	
$\eta \rightarrow \pi^0\gamma\gamma$	Preliminary measurement	
Dalitz plot $\eta \rightarrow \pi^+\pi^-\pi^0$	Preliminary measurement	Int. documentation ready
Dalitz plot $\eta \rightarrow \pi^0\pi^0\pi^0$	Preliminary measurement	Int. documentation in writing
Upper limit BR($\eta \rightarrow \pi^+\pi^-$)	PLB 606 (2005) 276	
η mass measurement		Preliminary measurement
$\phi \rightarrow \omega\pi^0 \rightarrow \pi^+\pi^-\pi^0\pi^0$	In progress	Waiting for scan data…
ϕ leptonic widths	PLB 608 (2005) 199-205	
Hadronic cross section	PLB 606 (2005) 12-24	Update in progress + LA analysis

Status of η mass measurement

4 May 2005:
The GEM Collaboration, hep-ex/0505006 [COSY, Julich]

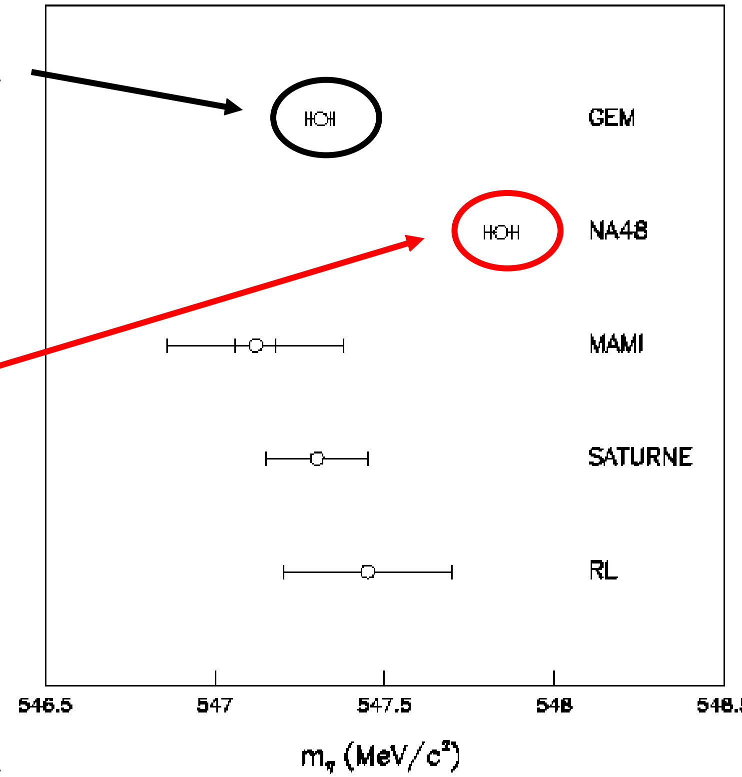
$M_\eta = (\ 547.311 \pm 0.028 \pm 0.032\ )\ \mathrm{MeV}/c^2$

Reaction used: $p + d \rightarrow {}^3He + \eta$

High discrepancy with NA48!

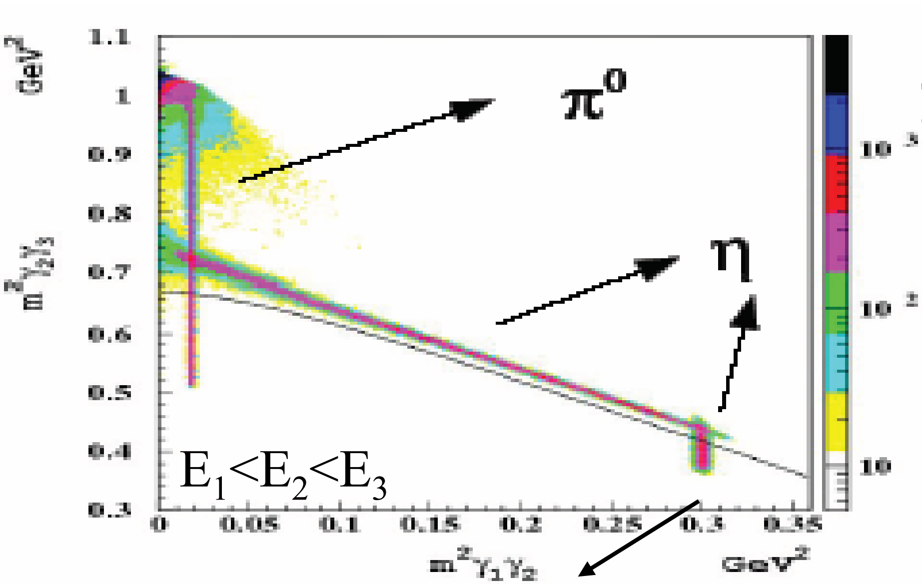
Using $\eta \rightarrow 3\pi^0$ from $\pi^- + p \rightarrow \eta + n$:

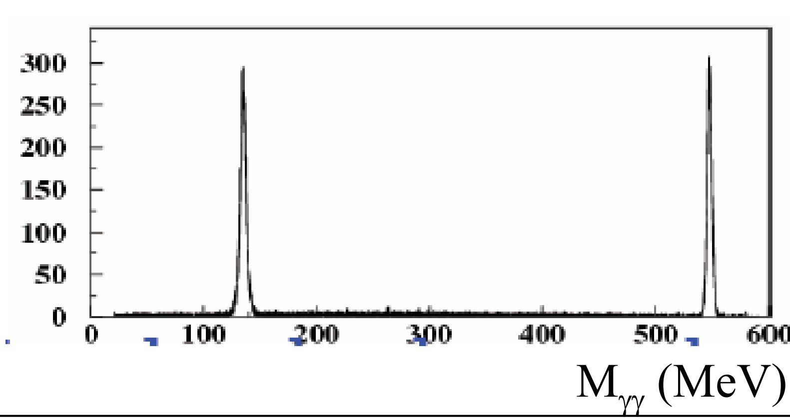
$M_\eta = (\ 547.843 \pm 0.030 \pm 0.041\ )\ \mathrm{MeV}/c^2$
[A. Lai et al., Phys. Lett. B 533 (2002) 196]

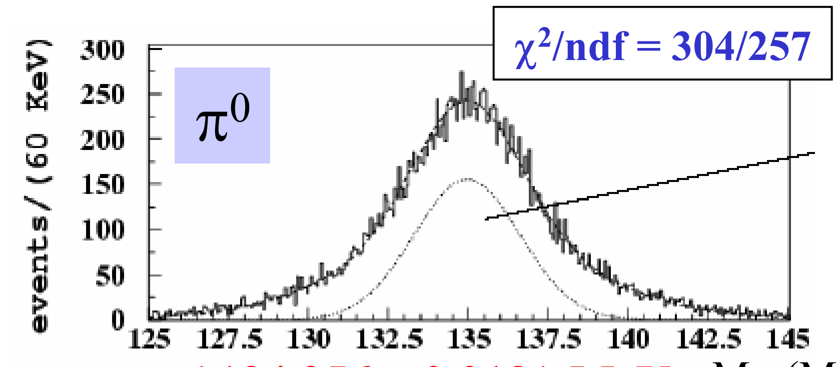


M_η measurement @ KLOE

- Kinematic fit applied on $\phi \to \gamma\gamma\gamma$ events
- η and π^0 selected by looking at different Dalitz plot regions



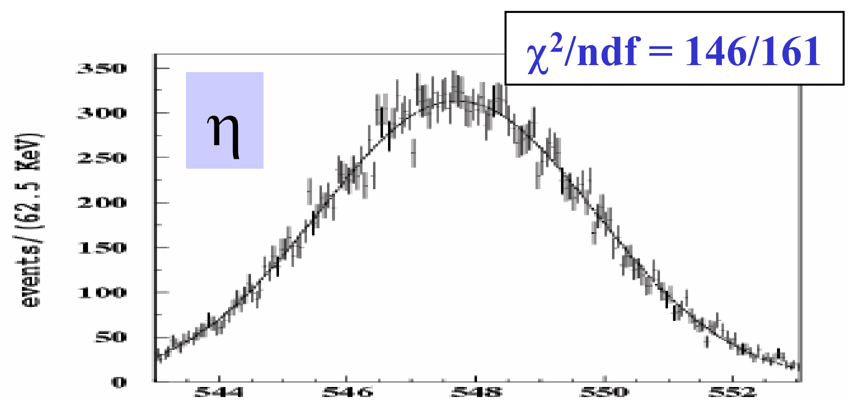




μ = (134.956 ± 0.018) MeV

σ = (1.66 ± 0.005) MeV

$M_{\gamma\gamma}$ (MeV)



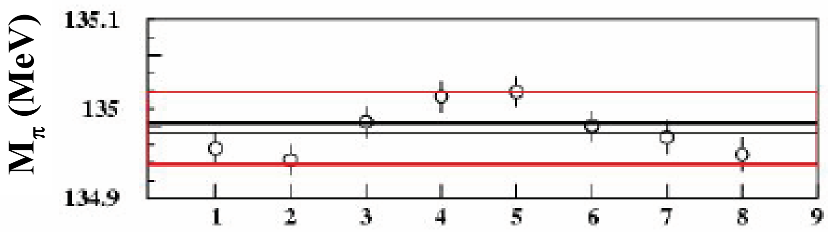
μ = (547.708 ± 0.014) MeV

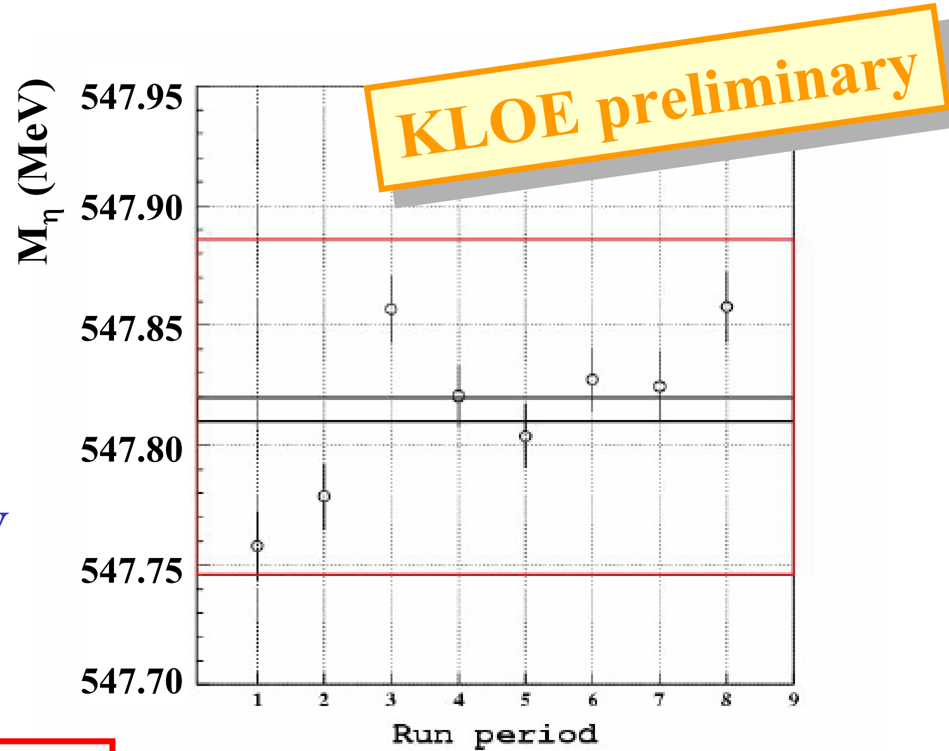
σ = (2.143 ± 0.012) MeV

$M_{\gamma\gamma}$ (MeV)

M_η measurement @ KLOE

Data set divided in 8 periods





$M(\pi^0) = (134990 \pm 6_{stat} \pm 30_{syst})$ keV

$M(\pi^0)_{PDG} = (134976.6 \pm 0.6)$ keV

$M(\eta) = (547822 \pm 5_{stat} \pm 69_{syst})$ keV

- Syst just from $\sqrt{s}$ and vertex position – EMC linearity in progress
- NA48 compatibility: 0.24 σ
- New measurement in progress using $\eta \rightarrow \pi^+\pi^-\pi^0$ decay

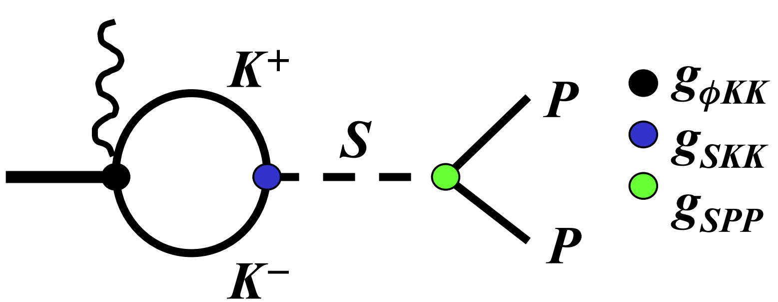
Light scalar mesons @ KLOE

- $f_0(980)$ and $a_0(980)$ produced @ KLOE through $\phi \to S\gamma$
- $f_0(980)$ and $a_0(980)$ scalar mesons not easily interpreted as $q\bar{q}$ states
- Other interpretations suggested:
  - ⇒ **$qq\bar{q}\bar{q}$ states** [*Jaffe 1977*]
  - ⇒ **$K\bar{K}$ molecule** [*Weinstein, Isgur 1990*]

Both BR($\phi \to S\gamma$) and scalar mass spectra are sensitive to their nature
[*Achasov, Ivanchenko 1989*] We use two models:

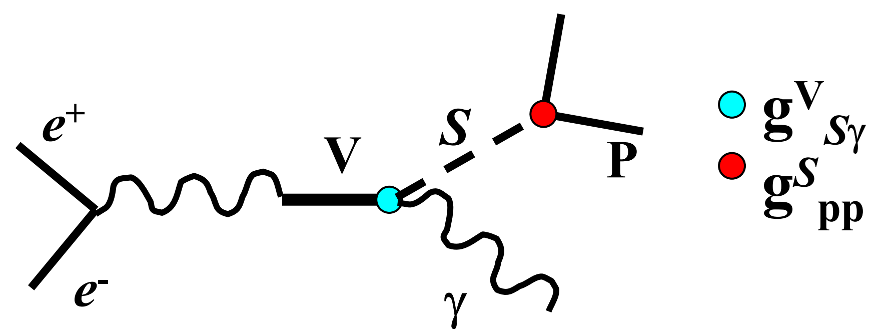
1) Kaon Loop

[Achasov-Ivanchenko, NPB315 (1989) 465]



2) "No Structure"

[Isidori-Maiani, private comunication]

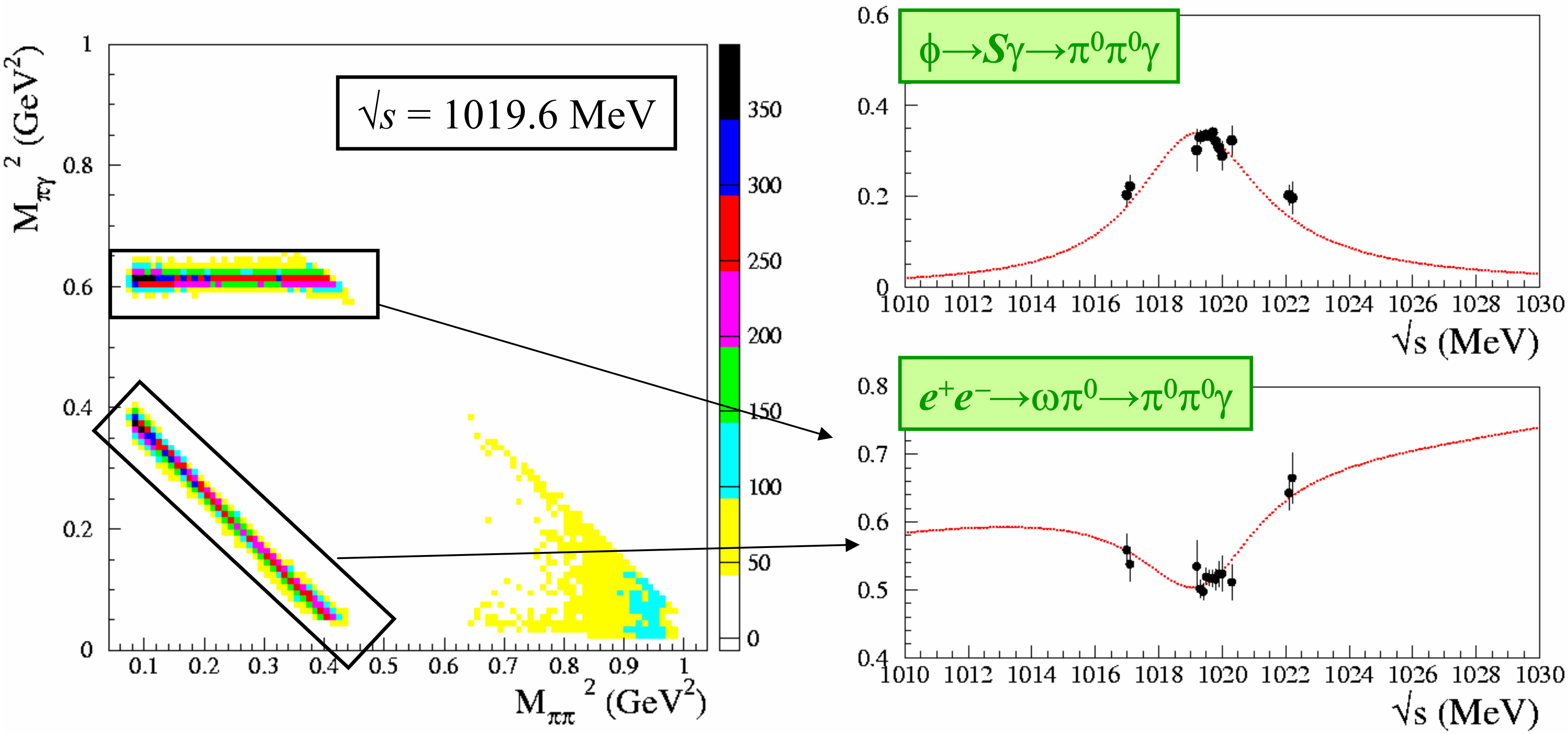


S described as a BW with $\Gamma_S(m)$
+ higher order corrections

$\pi^0\pi^0\gamma$ final state: VMD *vs* scalar

450 pb^{-1} from 2001 – 2002 data taking ⇒ **~ 400k events**

Two main contributions to $\pi^0\pi^0\gamma$ final state @ M_ϕ:

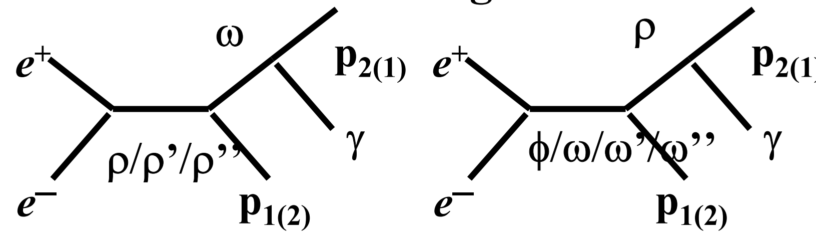


Differently from the past, we will not subtract the VMD contribution… **WE FIT IT**

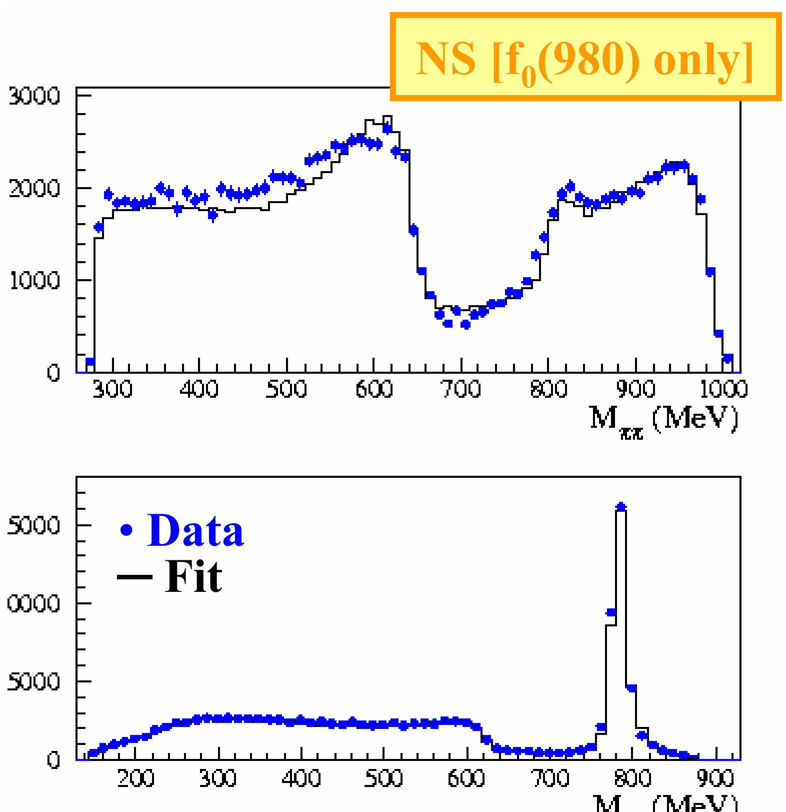
$\pi^0\pi^0\gamma$ final state: Dalitz fit results

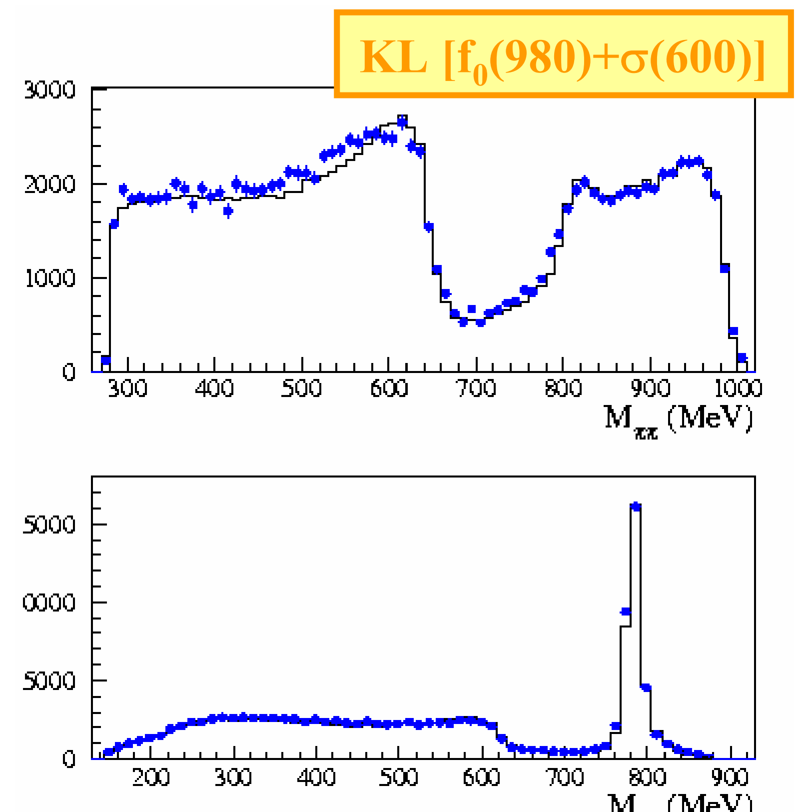
$$\frac{d\sigma}{dm} = \left(\frac{d\sigma}{dm}\right)_{VMD} + \left(\frac{d\sigma}{dm}\right)_{Scalar} + \left(\frac{d\sigma}{dm}\right)_{\text{interf}}$$

VMD diagrams



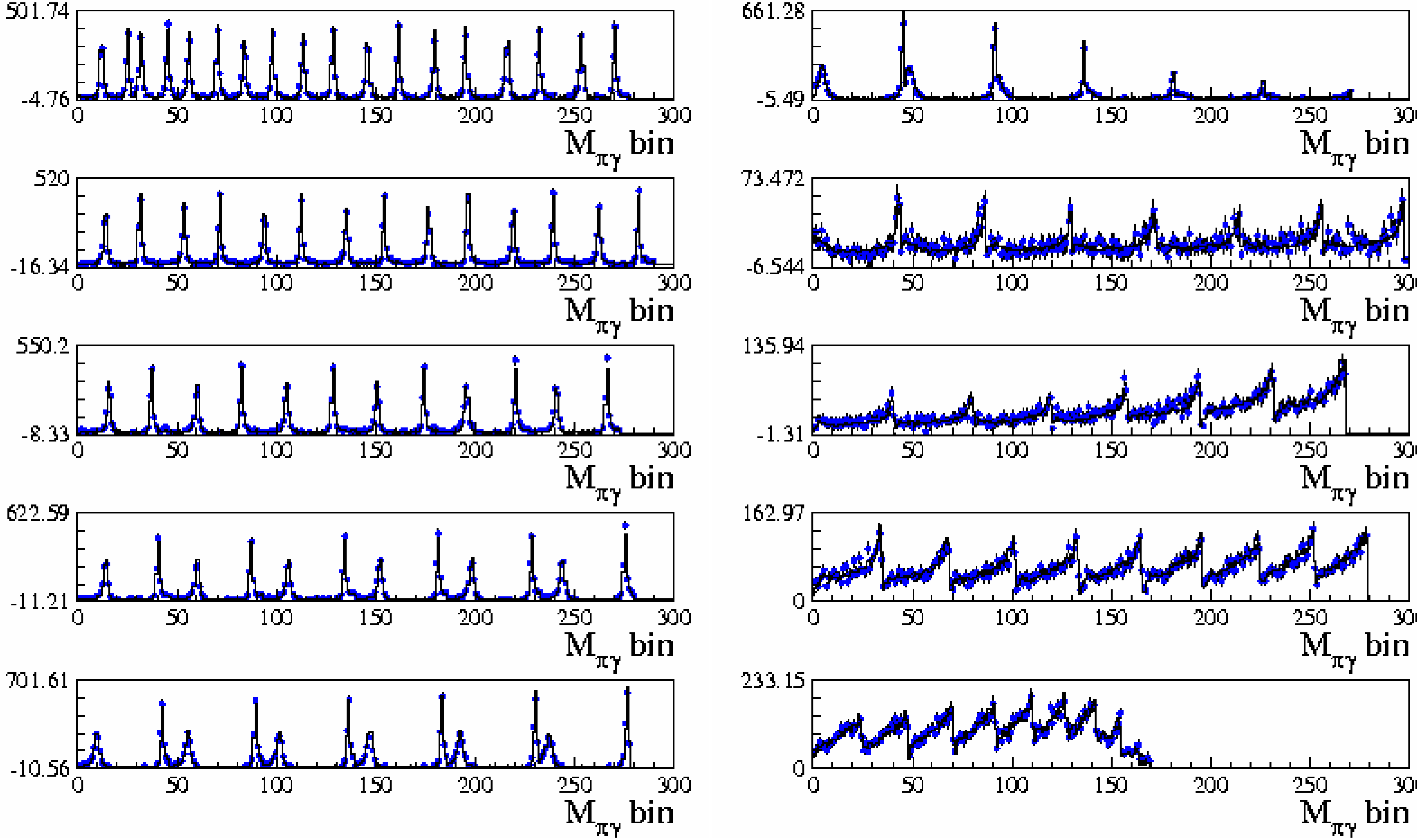
Dalitz plot projections:





K loop fit results: $f_0(980) + \sigma(600)$

Data-MC comparison in Dalitz slices



$\pi^+\pi^-\gamma$ @ large angle: looking for f_0

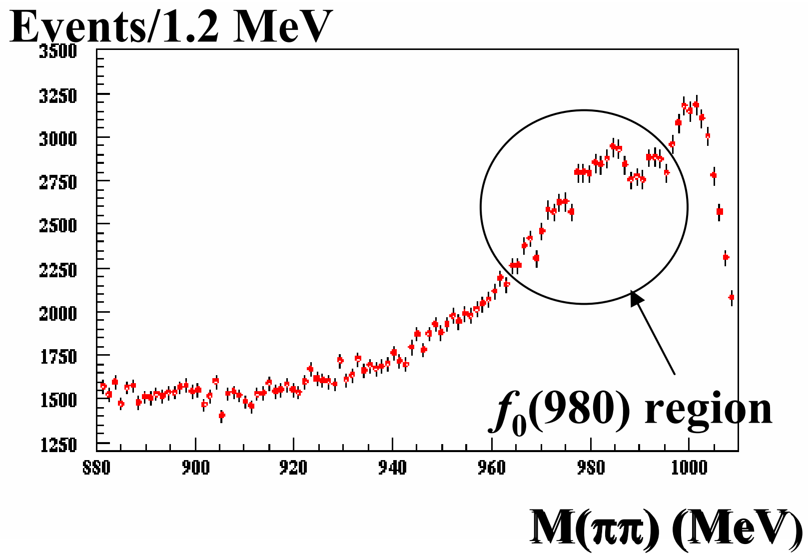
- $e^+e^- \to \pi^+\pi^-\gamma$ events with the photon at large angle ($45° < \vartheta_\gamma < 135°$)

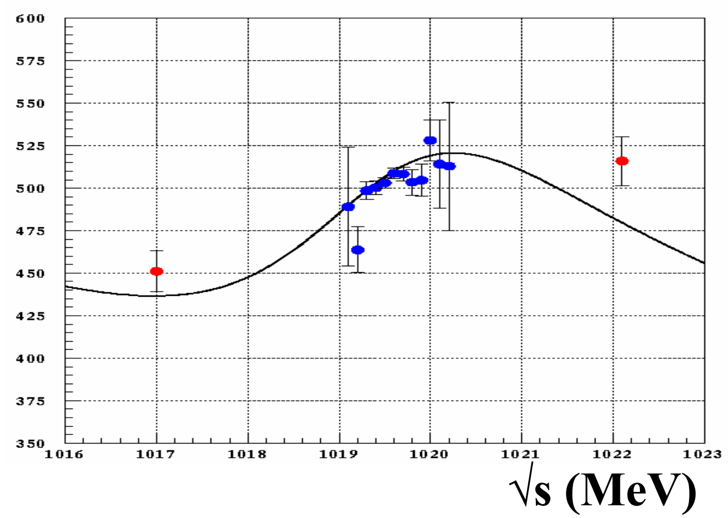
- Main contributions:
  - ISR (radiative return to ρ, ω)
  - FSR

- Search for the f_0 signal as a deviation on M ($\pi^+\pi^-$) spectrum from the expected ISR + FSR shape

- **676,000 events selected** (2001+2002)

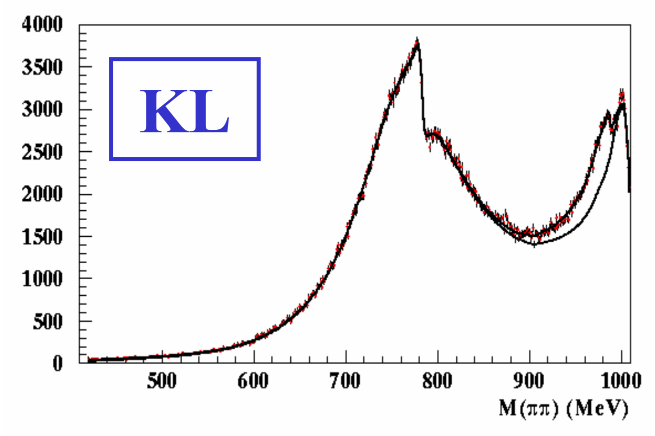
- **Expected interference pattern of σ_{vis} *vs* $\sqrt{s}$ in the signal region $M_{\pi\pi} \in [900 \div 1000$ MeV]**

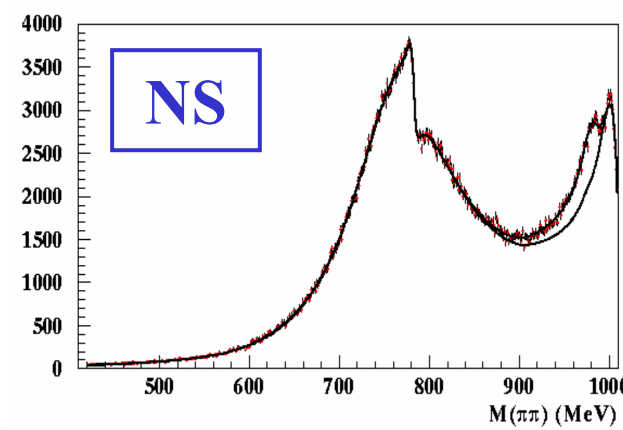




$f_0 \to \pi^+\pi^-$: fit to the $M_{\pi\pi}$ spectrum

$$\frac{d\sigma}{dm} = \left(\frac{d\sigma}{dm}\right)_{ISR+FSR+\rho\pi} + bckg(\pi^+\pi^-\pi^0 + \mu^+\mu^-\gamma) + \left(\frac{d\sigma}{dm}\right)_{Scalar} + \left(\frac{d\sigma}{dm}\right)_{\mathrm{int}.Scalar+FSR}$$





M_{f0} (MeV)	981 ÷ 985
g^2_{fK+K-} /4π (GeV²)	1.2 ÷ 3.4
$R = g^2_{fK+K-} / g^2_{f\pi+\pi-}$	2.0 ÷ 2.9

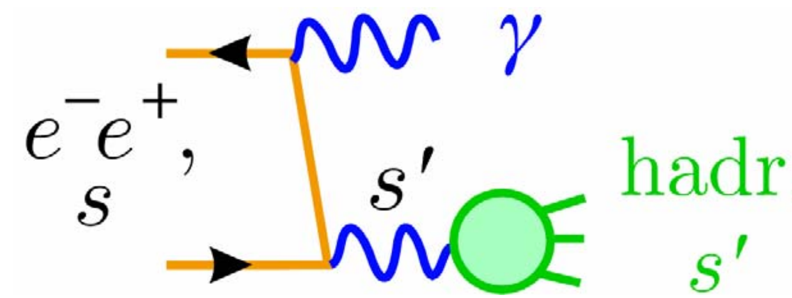
M_{f0} (MeV)	968 ÷ 979
$g_{\phi f\gamma}$ (GeV^{-1})	1.2 ÷ 1.8
$g_{f\pi+\pi-}$ (GeV)	0.9 ÷ 1.2
g_{fK+K-} (GeV)	1.2 ÷ 2.8
$R = g^2_{fK+K-} / g^2_{f\pi+\pi-}$	1.7 ÷ 4.8

- **In both models R>1**
- **The introduction of σ(600) does not improve the fit**

$\sigma(e^+e^-\to\pi^+\pi^-)$ from $\pi^+\pi^-\gamma$ events

KLOE has shown, for the first time, that is possible to measure $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$ at fixed $\sqrt{s}$ with high accuracy:

$(s' = s - 2 E_\gamma \sqrt{s})$



Exploit ISR to extract $\sigma(e^+e^- \to \pi^+\pi^-)$ for $\sqrt{s'}$ from $2m_\pi \to \sqrt{s}$

- Luminosity from $e^+e^-(\gamma)$ counts, $55° < \theta_e < 125°$, σ at 0.5% (th) 0.3%(exp)
- Radiator function $\mathbf{H(M_{\pi\pi}{}^2)}$, defined as:

$$M_{\pi\pi}{}^2 \frac{d\sigma(\pi\pi\gamma, M_{\pi\pi}{}^2)}{dM_{\pi\pi}{}^2} = H(M_{\pi\pi}{}^2)\, \sigma(\pi\pi, M_{\pi\pi}{}^2),$$

with inclusion of radiative effects, from QED MC calculation (PHOKHARA, Karlsuhe Theory Group, Kühn et al.)

Two data samples for $\pi^+\pi^-\gamma$ events

Photons at small angles
($\theta_\gamma < 15^o$ or $\theta_\gamma > 165^\circ$)

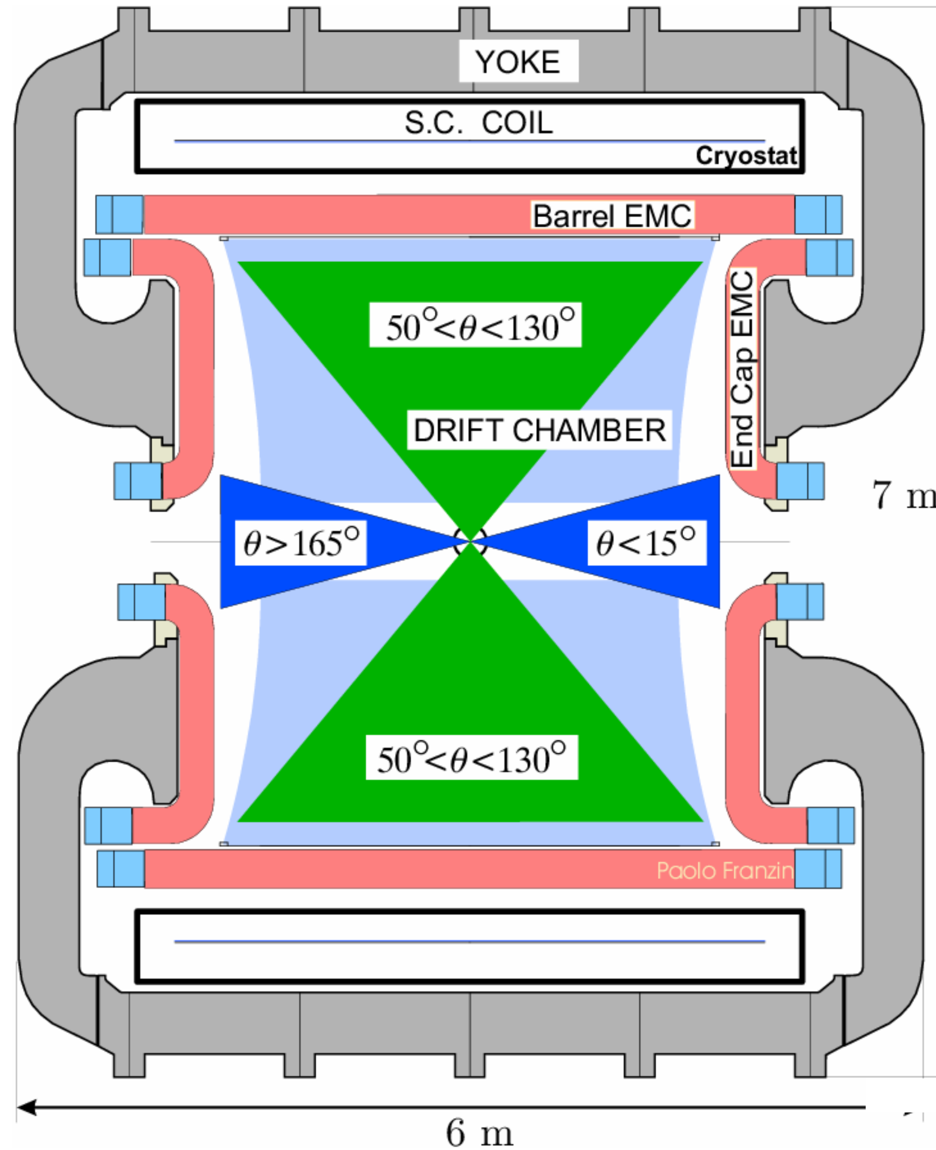
→ Photon NOT DETECTED

- ✓ High Statistics for **ISR** Photons
- ✓ Low relative contribution of **FSR** <0.5% in entire $M_{\pi\pi}$ – range
- ✓ Small amount of other background

Photons at large angle
($50^o < \theta_\gamma < 130^\circ$)

→ Photon detection required

- ✓ High amount of **FSR** and background
- ✓ Allows measurement at threshold
- ✓ Allows measurement of charge asymmetry → Test of FSR



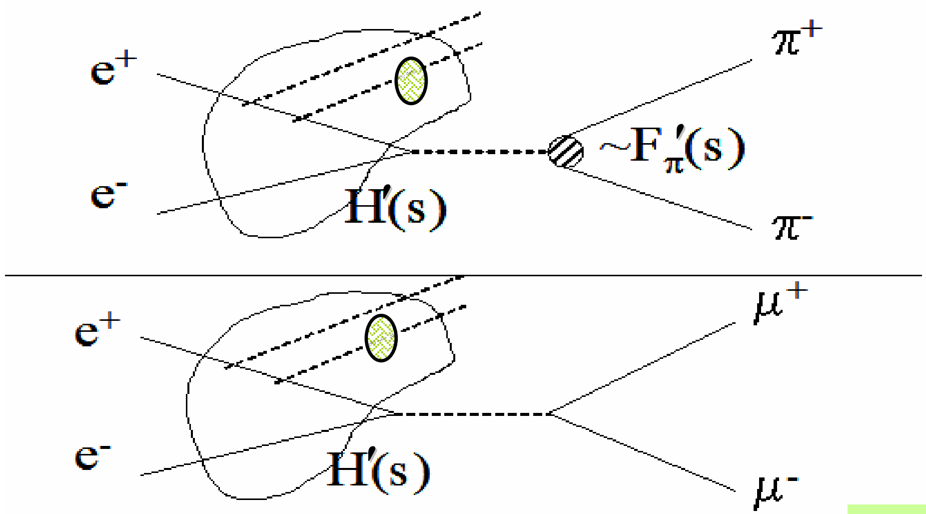
Prospects for small angle analysis

Analysis of the new data (2 fb^{-1}): **take advantage of larger statistics!**

Change strategy ➡ **normalizing to $\mu^+\mu^-\gamma$**

$$\sigma_{\pi\pi}^{Born}(s') \approx \frac{d\sigma_{\pi\pi\gamma}^{obs}/ds'}{d\sigma_{\mu\mu\gamma}^{obs}/ds'}\,\sigma_{\mu\mu}^{Born}(s')$$

Differently from the old analsyis statistics is an issue, due to the small $\mu\mu\gamma$ cross section in some S bins



Many systematics cancel out on the theory side:

Luminosity, VP , radiator

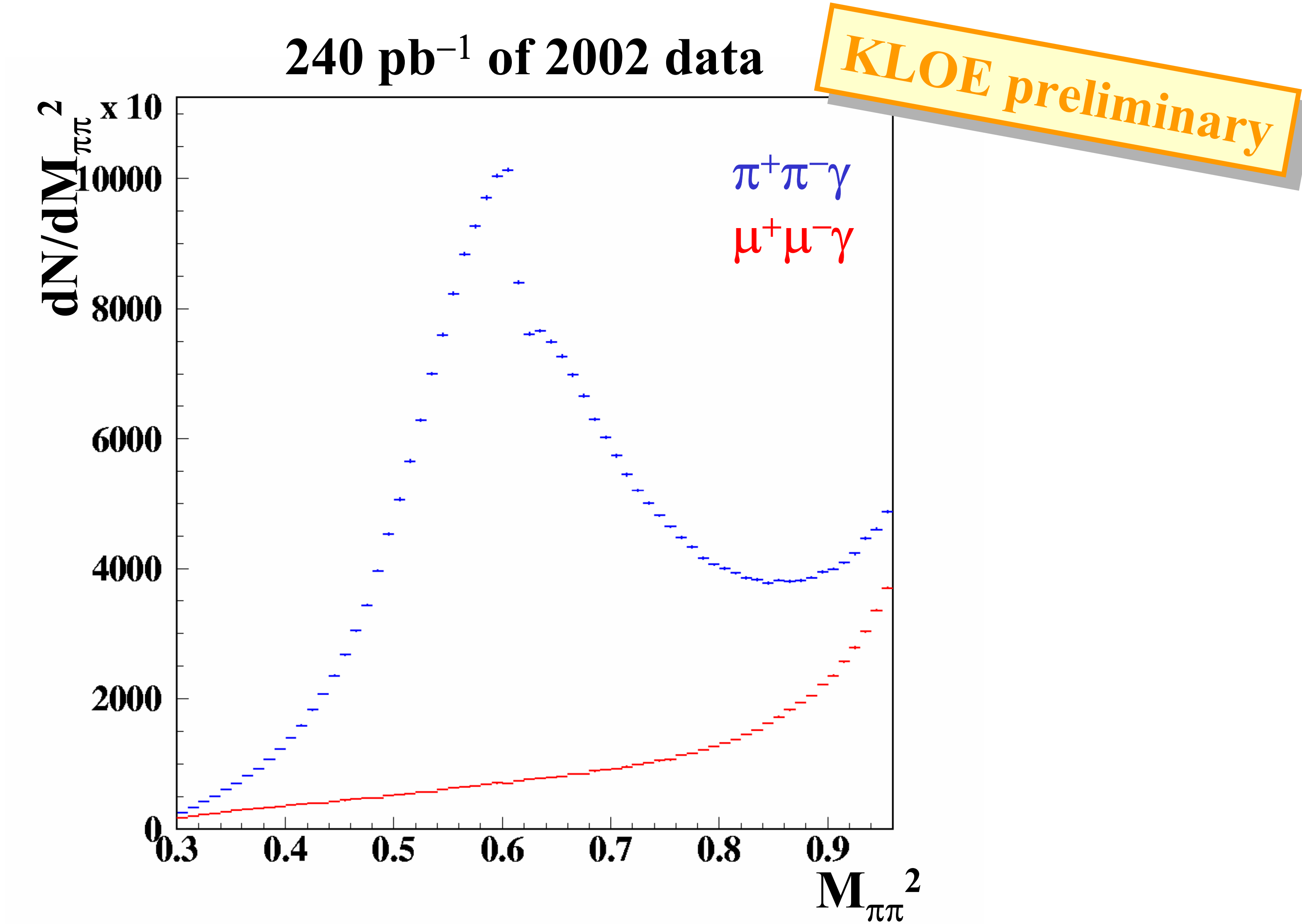
or reduce to small corrections on the experimental side

tracking , vtx efficiencies

and trigger veto

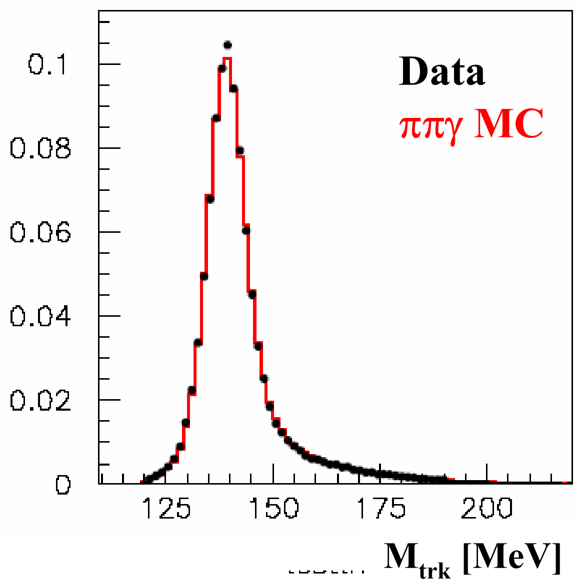
Improvements also on Filter/ECL strategies

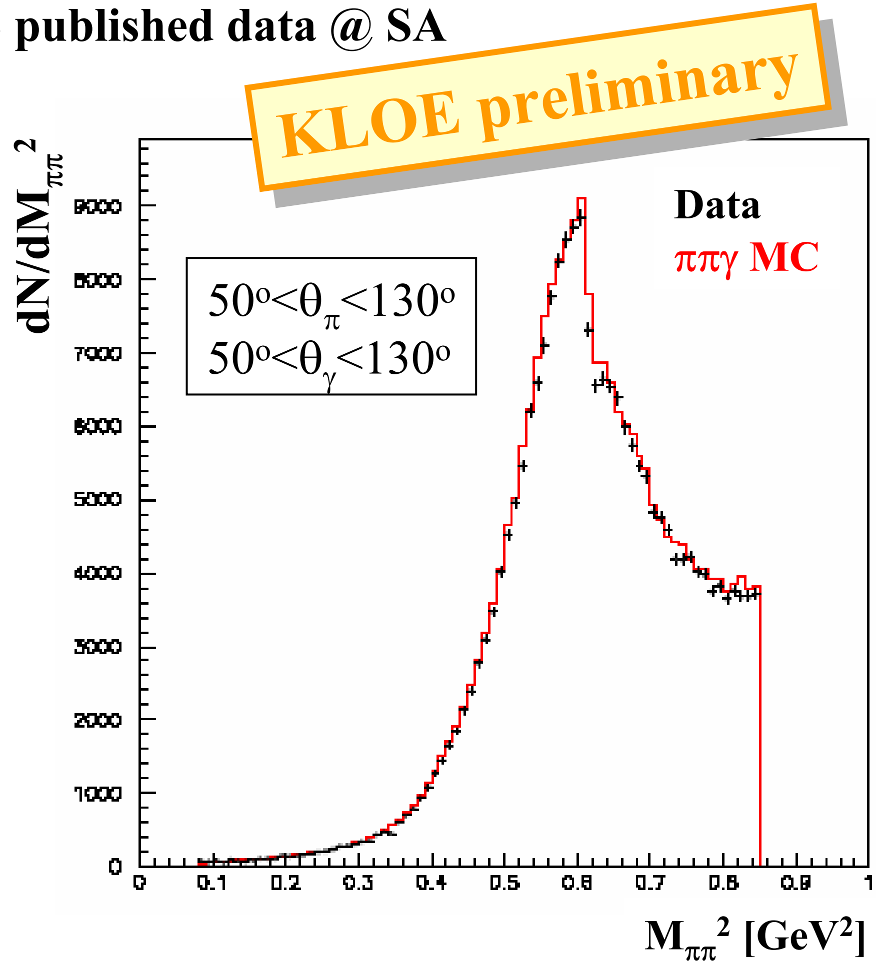
Small angle analysis: $\pi^+\pi^-\gamma$ *vs* $\mu^+\mu^-\gamma$

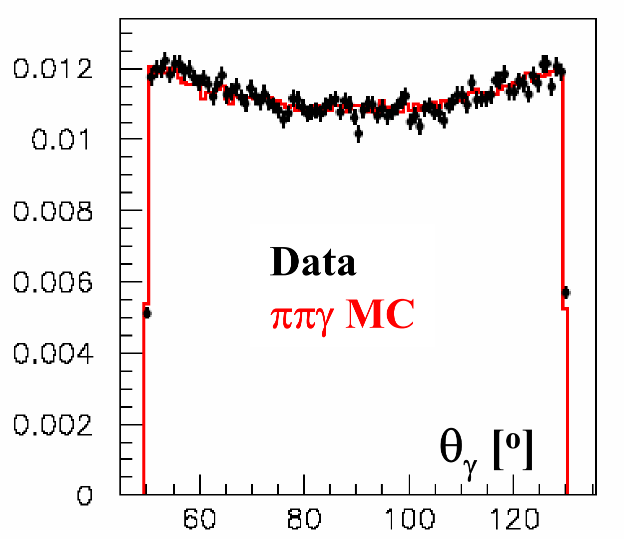


$\pi^+\pi^-\gamma$ @ large angle

Same KLOE published data @ SA







- ❖ The spectrum extends down to the 2-pions threshold
- ❖ **10 times more statistics on tape!**

Program for off-peak runs

✓ **ϕ scan**

4 points of 10 pb^{-1} in the 1010-1030 MeV region

- Calibration of KLOE energy scale, line shape
- Studying the model dependence of the f_0
- BR($\phi \to \omega\pi^0$), ϕ leptonic widths, …

✓ **Off-peak data**

200 pb^{-1} at 1000 MeV c.m. energy

- **Measurement of the $\sigma(\pi^+\pi^-\gamma)$ down to threshold**
- Two-photon physics with KLOE: $e^+e^- \to e^+e^-(\gamma\gamma \to \eta,\sigma)$

Conclusions

- **The analyses of 2001-2002 data are at a mature stage**
  8 PLBs published/submitted + 4 in pipeline… hope to break the wall of 10 PLB/year!

- **We have (almost) reached the goal of 2 fb^{-1} for 2004-2005 data taking at M_ϕ**

- **Off-peak data taking and energy scan will follow**

- **These two new data sets will allow to extend our physics program**

- **We are preparing our MC/OFFLINE tools for the analysis of new data**