PHIPSI08

Laboratori Nazionali di Frascati (Roma),
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International Workshop on e+e- collisions from Phi to Psi

A precise new KLOE measurement of $|F_\pi|^2$ with ISR and extraction of $a_\mu^{\pi\pi}$ for [0.35,0.95] GeV^2

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Outline

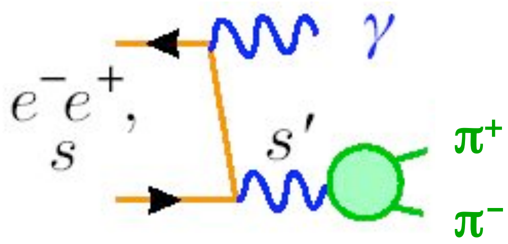
- Introduction: ISR method
- Selection criteria: improvements on

  new data (242 pb^{-1}) with respect to

  the published (140 pb^{-1}) analysis
- Results and comparisons
- Conclusions and outlook

The cross section $\sigma_{e+e- \to \pi+\pi-}$ from ISR events

at a fixed $\sqrt{s}$, studying *Initial State Radiation* events, $\sigma_{e+ e- \to \pi+ \pi-}(s)$ is extracted



ISR only: $$M^2_{\pi\pi} \frac{d\sigma_{e^+e^- \to \pi^+\pi^-\gamma}}{dM^2_{\pi\pi}} = \sigma_{e^+e^- \to \pi^+\pi^-}(M^2_{\pi\pi}) \cdot H(M^2_{\pi\pi}, \theta_{min})$$

➔ **EVA + PHOKHARA MC Generator**

(S. Binner, J.H. Kühn, K. Melnikov, PLB459,1999)

(H.Czyż, A.Grzelińska, J.H Kühn, G.Rodrigo, EPJC27,2003)

main advantage:

no point-to-point errors on beam energy and luminosity

main requirement:

precise knowledge of ISR radiative corrections

1st KLOE publication (based on 140 pb^{-1})

A. Aloisio et al., PLB606(2005)12

Selection of $\pi\pi\gamma$ events at small angle

a) 2 tracks with $50^o < \theta_{track} < 130^o$

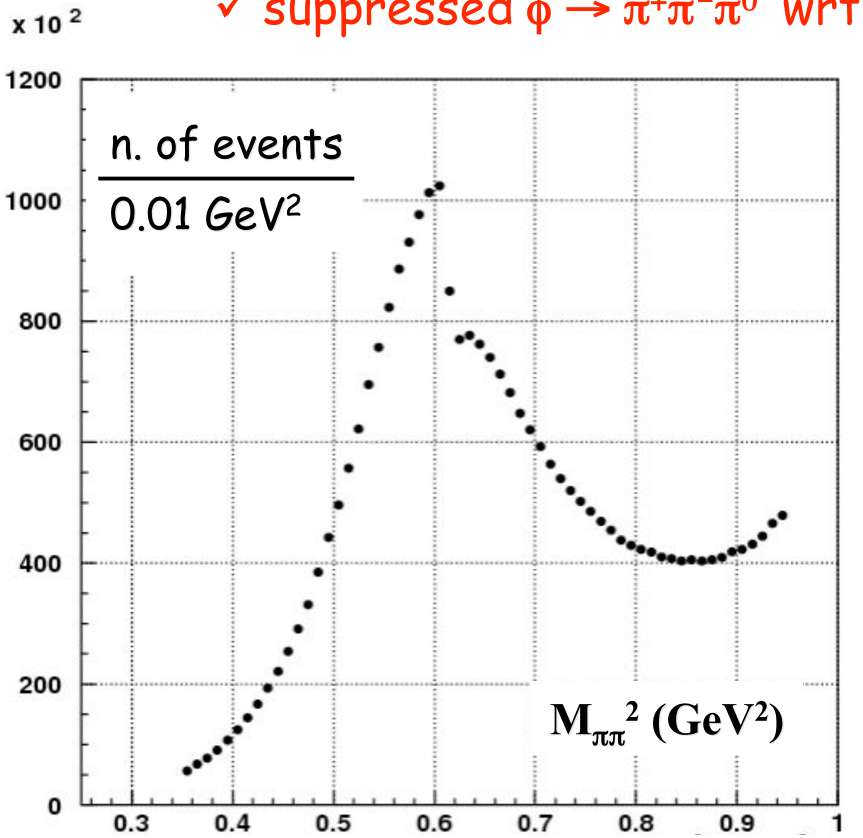
b) small angle γ ($\theta_{\pi\pi} < 15^o$)

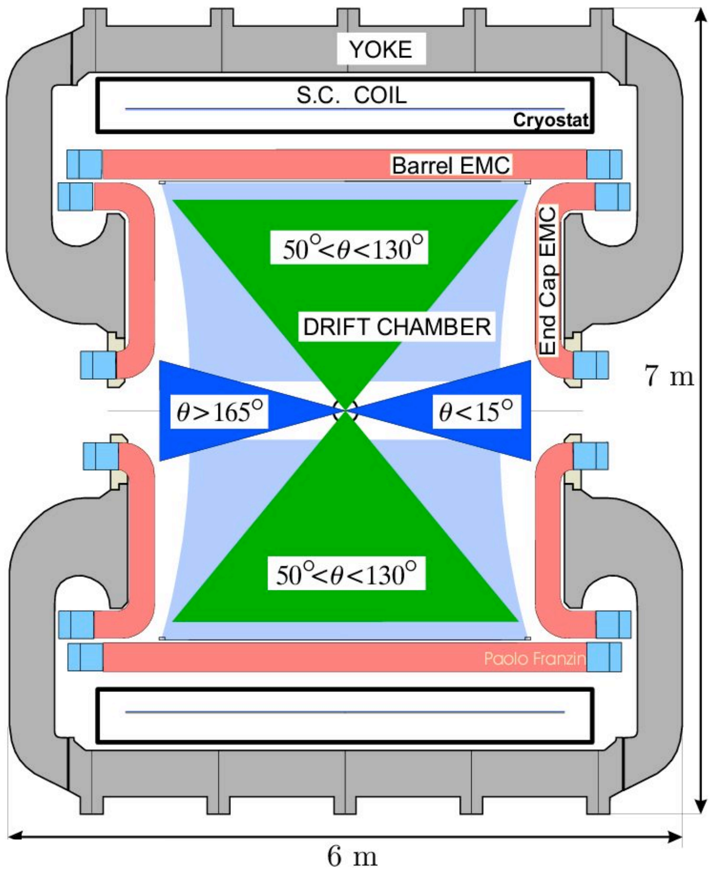
kinematics: $\vec{p}_\gamma = \vec{p}_{miss} = -(\vec{p}_+ + \vec{p}_-)$

✓ high statistics for ISR (~ θ^{-2})

✓ low relative FSR contribution

✓ suppressed $\phi \to \pi^+\pi^-\pi^0$ wrt the signal





statistics: 242pb-1

3.4 Million Events

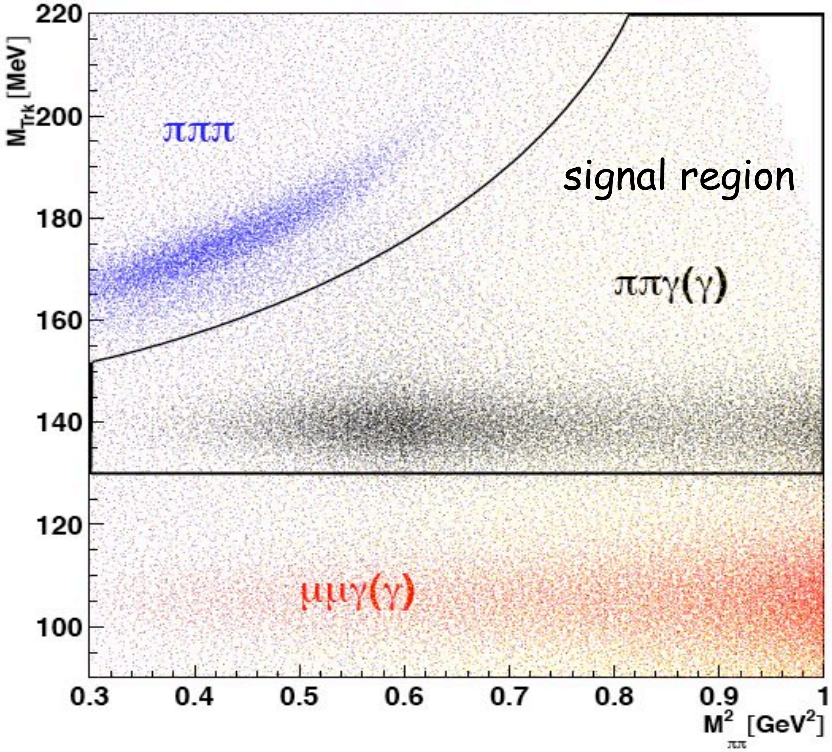
Selection of $\pi\pi\gamma$ events: suppress background

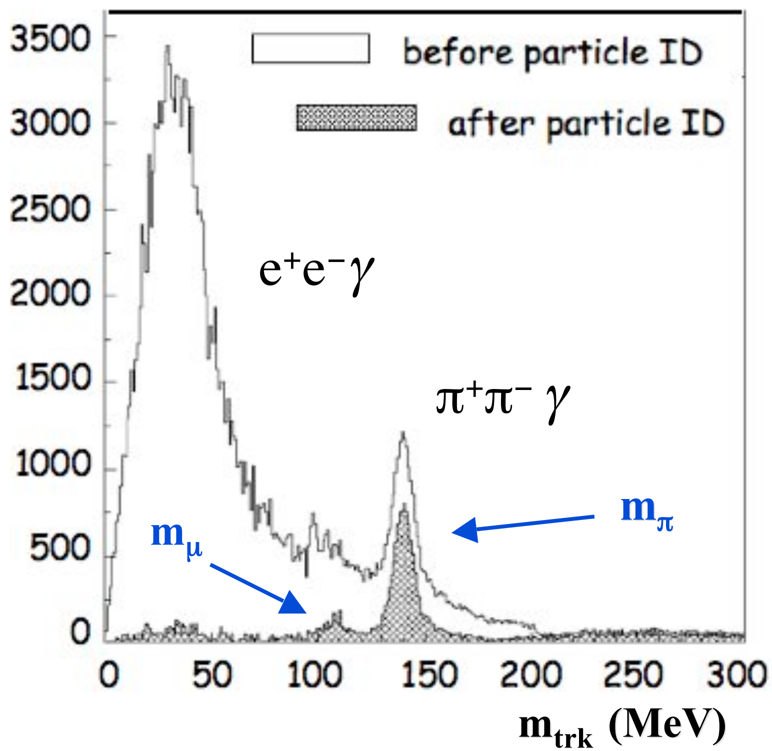
suppress
$e^+e^- \to e^+e^-\gamma$

π/e separation performed with particle ID based on the calorimeter

remnant
$e^+e^- \to \mu^+\mu^-\gamma$ & $\phi \to \pi^+\pi^-\pi^0$

cut and estimated as a function of $M_{\pi\pi}^2$



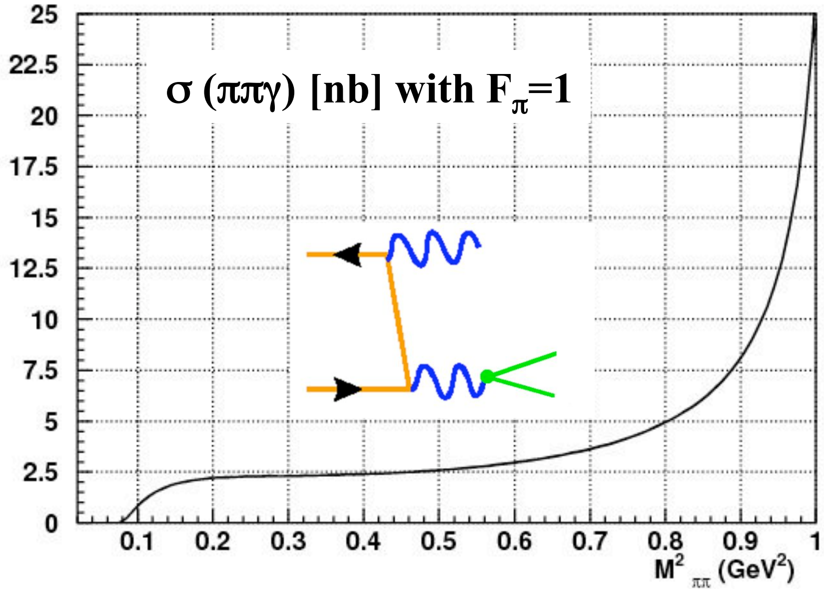


m_{trk}, defined under the hypothesis of 2 equal mass particles and 1 γ in the final state

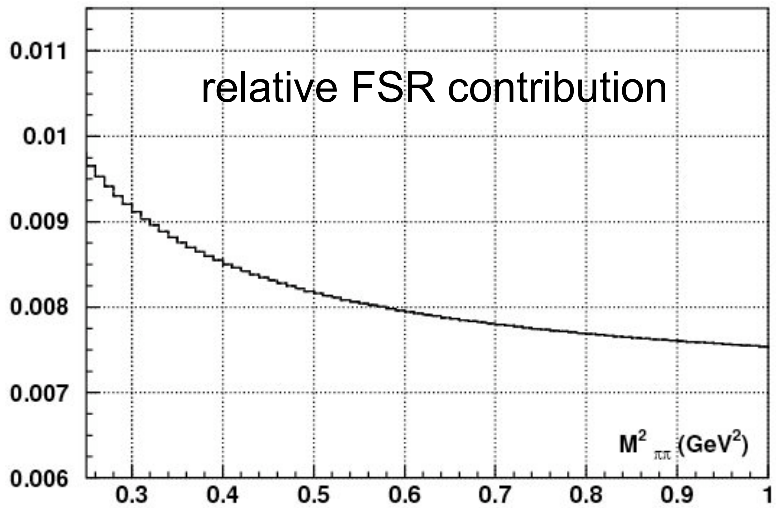
Radiative corrections

- **ISR-Process calculated at NLO-level**
  PHOKHARA generator (Czyż, Kühn et.al)
  Precision: 0.5%

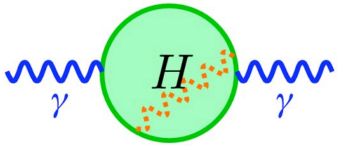
$$M^2_{\pi\pi} \frac{d\sigma_{\pi\pi\gamma}}{dM^2_{\pi\pi}} = \sigma_{\pi\pi}(s) \times \mathbf{H(s)}$$

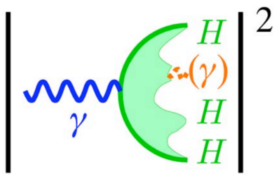


i) Bare Cross Section
divide by Vacuum Polarisation
➔ from F. Jegerlehner

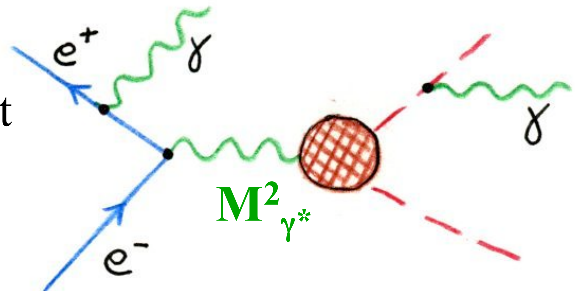


ii) FSR - Corrections
cross section $\sigma_{\pi\pi}$ must be inclusive for FSR





FSR corrections taken into account in the efficiency evaluation and in $\mathbf{M^2_{\pi\pi} \rightarrow M^2_{\gamma^*}}$



Improvements compared to the published analysis

$$\frac{d\sigma_{\pi\pi\gamma}}{dM^2_{\pi\pi}} = \frac{N^{obs} - N^{bkg}}{\Delta M^2_{\pi\pi}} \cdot \frac{1}{\varepsilon_{sel}} \cdot \frac{1}{L}$$

error table in the published work PLB606(2005)12

Reconstruction filter	0.6%
Background	0.3%
M_{trk} cuts	0.2%
Particle ID	0.1%
Tracking	0.3%
Vertex	0.3%
Trigger	0.3%
Acceptance	0.3%
Unfolding	0.2%
Luminosity $(0.5_{th} \oplus 0.3_{exp})$%	0.6%

improved machine conditions (luminosity and background) in the new data set

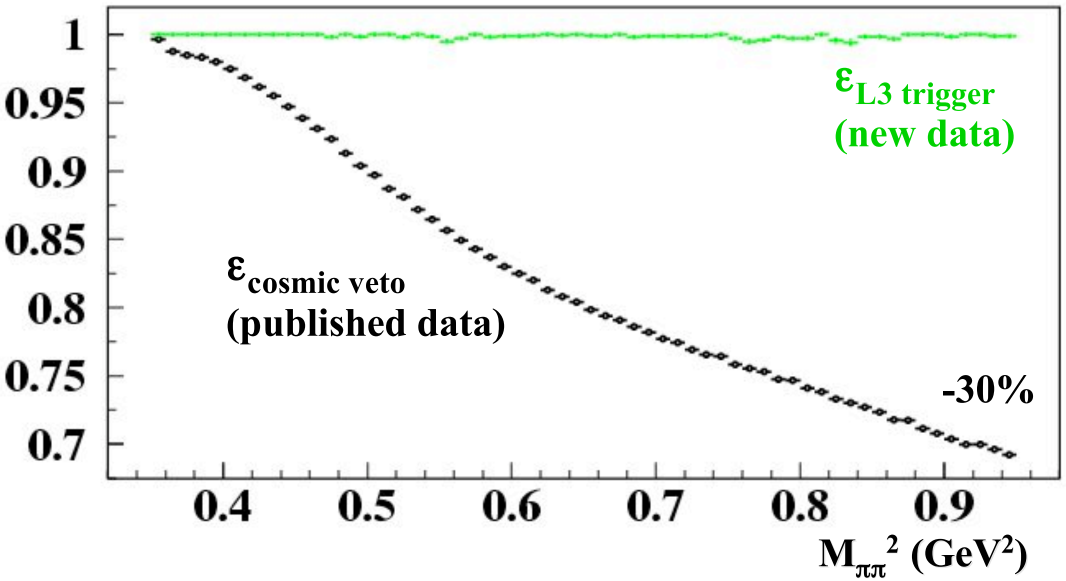
improved offline-event filter reduces systematic uncertainty to < 0.1% (→ Reconstruction filter)

improvements (e.g. no vertex requirement) on the selection (→ Vertex)

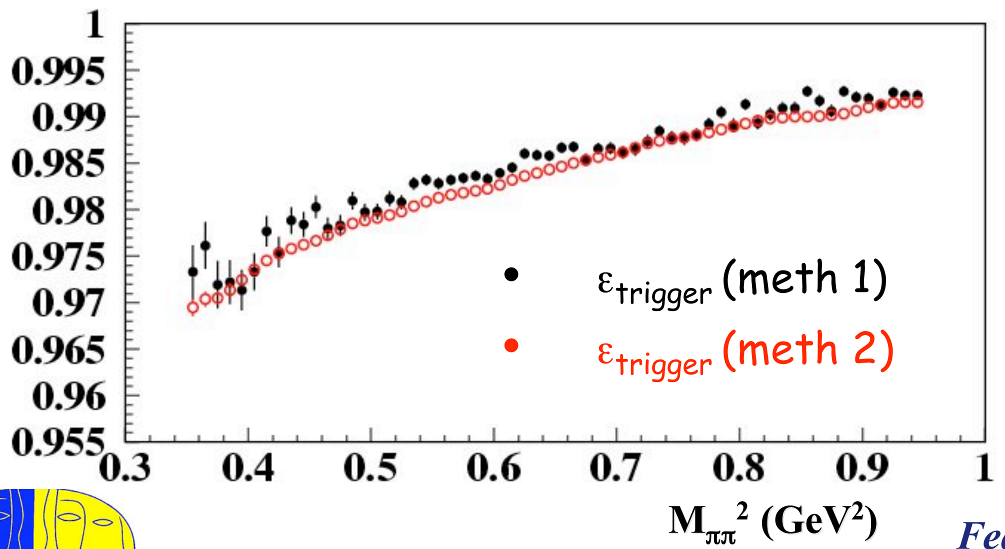
30% inefficiency (veto of cosmic rays) recovered by introducing 3rd level trigger (→ Trigger)

new generator **BABAYAGA@NLO**, error on σ_{Bhabha} from 0.5% to 0.1% (→ Luminosity)

Trigger improvements



the main source (hardware veto of cosmic rays) of inefficiency in the published result has been removed



trigger efficiency: fractional error given by relative difference of 2 independent methods *from data* → *0.1%*

Federico Nguyen
08-04-2008

Update in the Bhabha cross section: luminosity

KLOE measures $\mathcal{L}$ with Bhabha scattering

F. Ambrosino et al. (KLOE Coll.)
Eur.Phys.J.C47:589-596,2006

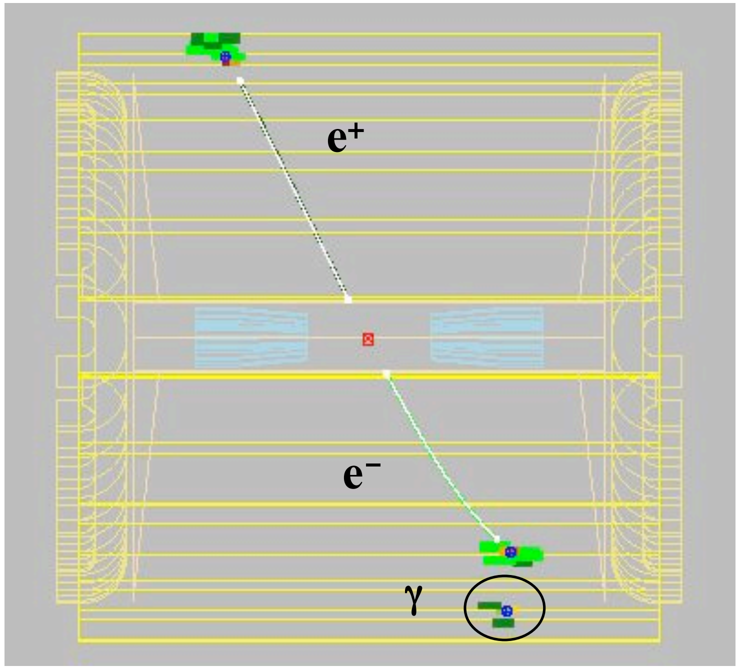
$55° < \theta < 125°$

acollinearity $< 9°$

$p \geq 400$ MeV

$$\int \mathcal{L}\, dt = \frac{N_{obs} - N_{bkg}}{\sigma_{eff}}$$

generator used for σ_{eff}
BABAYAGA (Pavia group):
C. M.C. Calame et al., NPB758 (2006) 22
see C.M.C. Calame's talk



new version (**BABAYAGA@NLO**) gives
0.7% decrease in cross section,
and better accuracy: 0.1%

Systematics on Luminosity	
Theory	0.1 %
Experiment	0.3 %
TOTAL 0.1 % th $\oplus$ 0.3% exp = 0.3%	

Error table and results

Background	M^2 dep (0.1-0.4%)
M_{trk} cuts	0.2%
Particle ID	0.3%
Tracking	0.3%
Trigger	0.1%
Acceptance	M^2 dep (0.1%)
Unfolding	0.2%
L3 Trigger	0.1%
Luminosity $(0.1_{th} \oplus 0.3_{exp})$%	0.3%

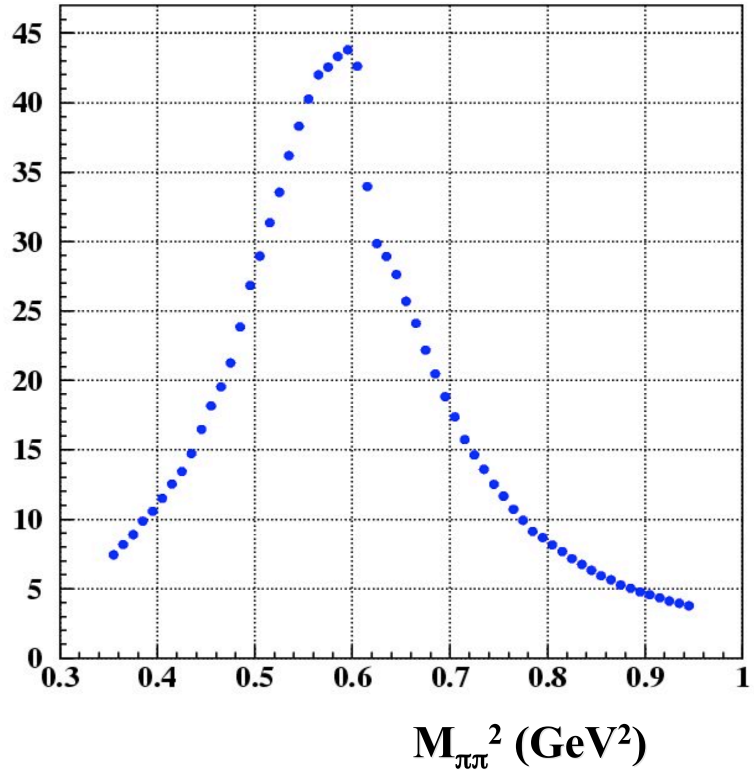
experimental fractional error on a_μ = 0.7%

Radiator H	0.5%

total fractional error on a_μ = 0.9%

$$\sigma_{\pi\pi} = \frac{\pi\alpha^2\beta_\pi^3}{3s}|F_\pi|^2$$

F_π resolution effects unfolded



Federico Nguyen
08-04-2008

KLOE results on a_μ (1)

Dispersion integral for 2π channel in the mass range $0.35\ \mathrm{GeV}^2 < M_{\pi\pi}^2 < 0.95\ \mathrm{GeV}^2$

$$a_\mu^{\pi\pi} = \frac{1}{4\pi^3} \int_{0.35\mathrm{GeV}^2}^{0.95\mathrm{GeV}^2} ds\, \sigma(e^+e^- \to \pi^+\pi^-)\, K(s)$$

published result (Phys. Lett. B606 (2005) 12):

$a_\mu^{\pi\pi}([0.35\text{-}0.95]\ \mathrm{GeV}^2) = (388.7 \pm 0.8_{stat} \pm 3.5_{sys} \pm 3.5_{th}) \cdot 10^{-10}$

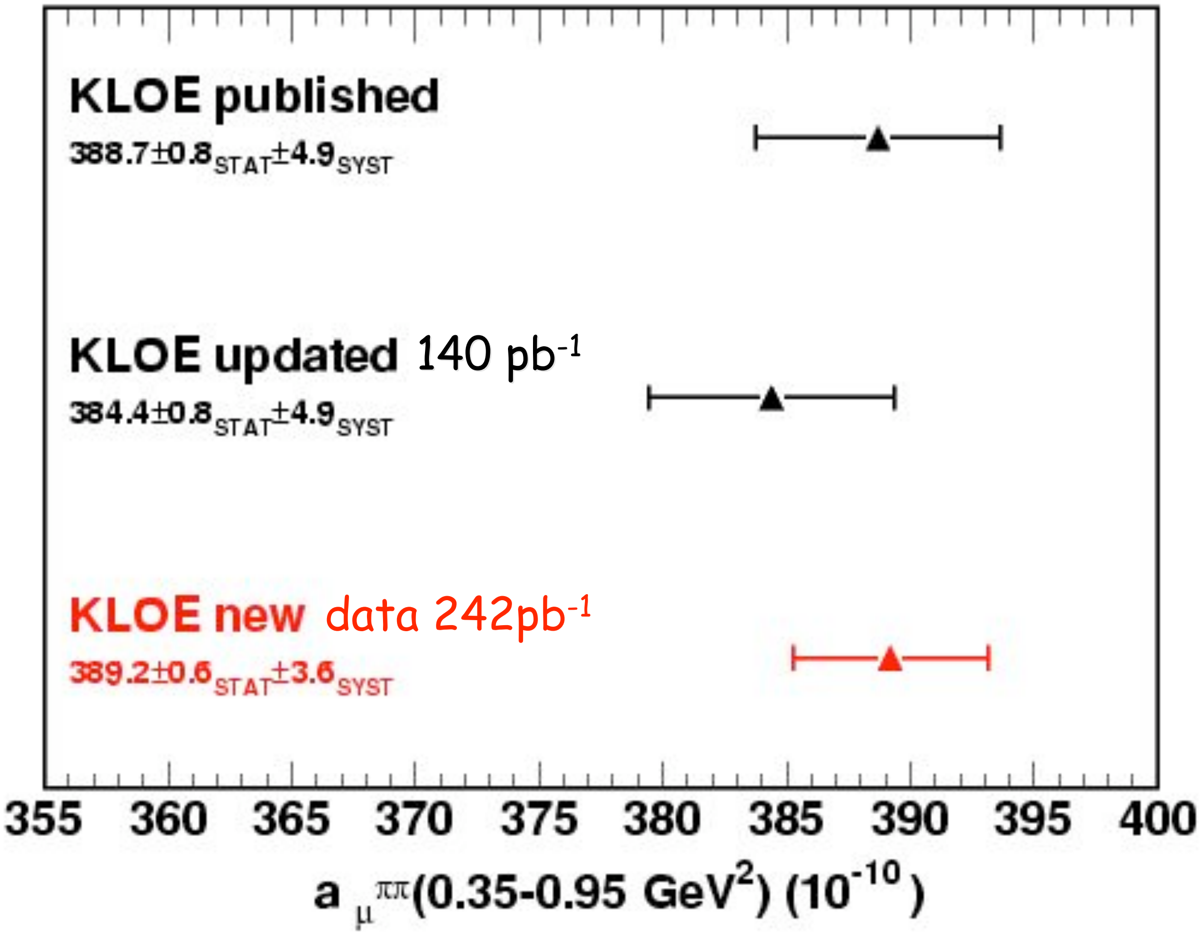
applying update for trigger efficiency and change in theoretical σ_{Bhabha}:

$a_\mu^{\pi\pi}([0.35\text{-}0.95]\ \mathrm{GeV}^2) = (384.4 \pm 0.8_{stat} \pm 3.5_{sys} \pm 3.5_{th}) \cdot 10^{-10}$

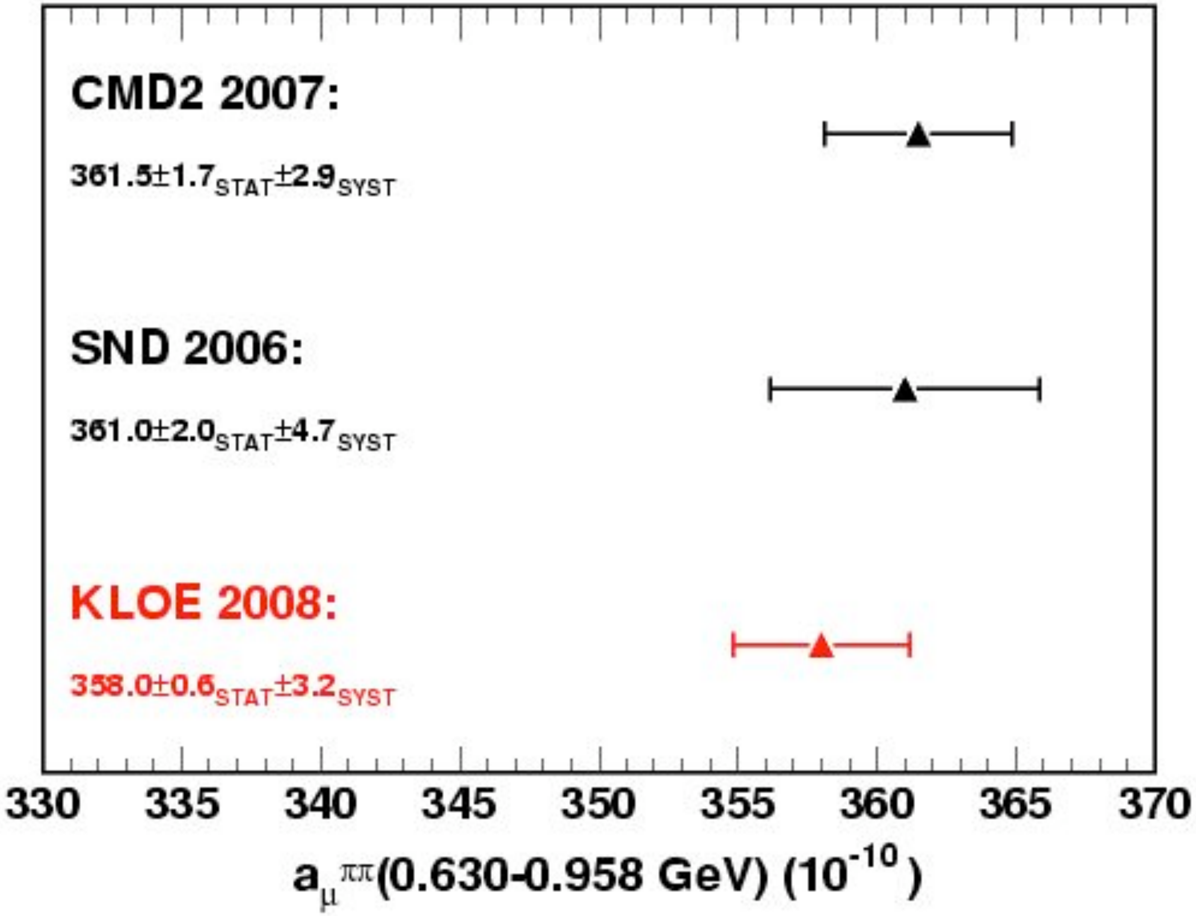
new:

$a_\mu^{\pi\pi}([0.35\text{-}0.95]\ \mathrm{GeV}^2) = (389.2 \pm 0.6_{stat} \pm 3.0_{sys} \pm 2.0_{th}) \cdot 10^{-10}$

KLOE results on a_μ (2)

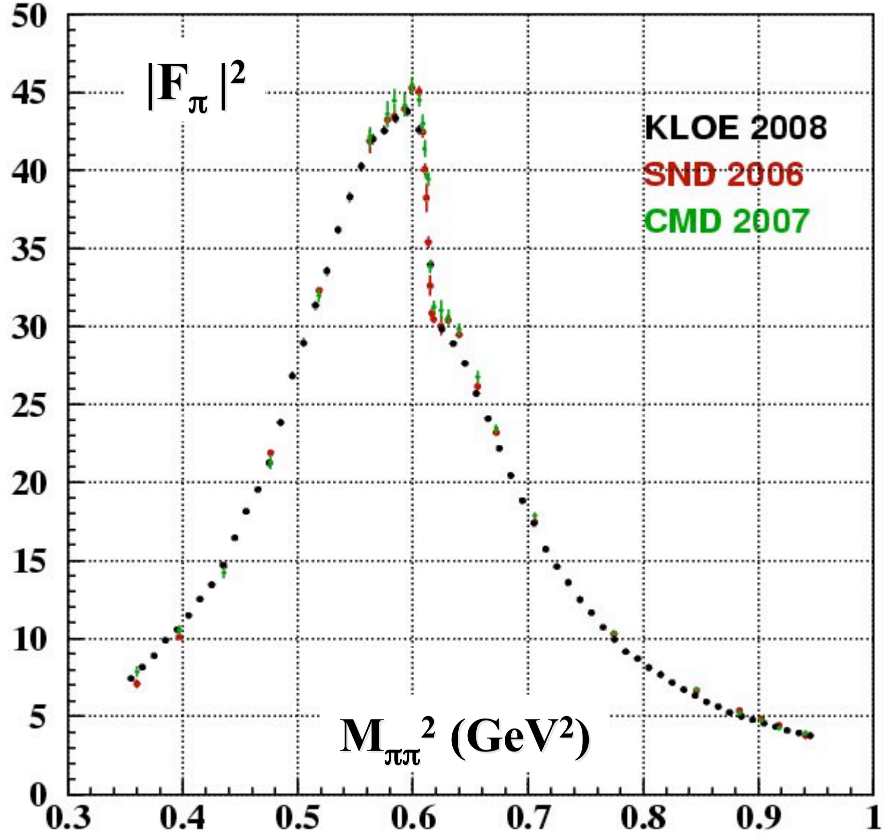


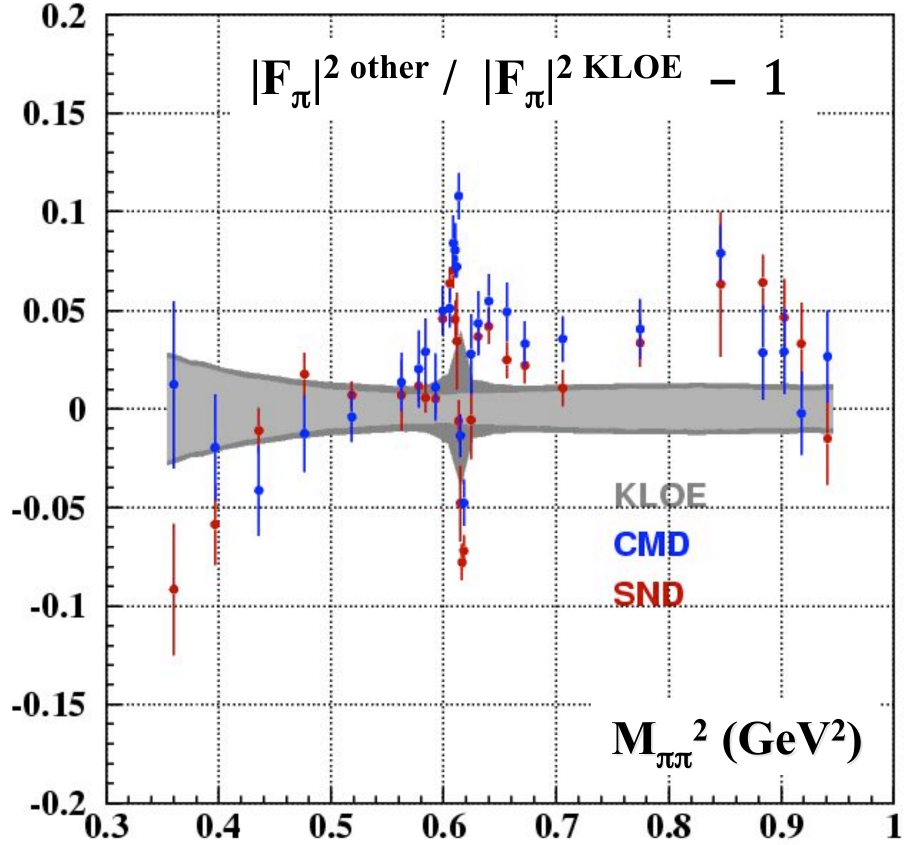
Results on a_μ in the same range: a comparison



KLOE result in agreement with CMD2 and SND

F_π comparison with other results



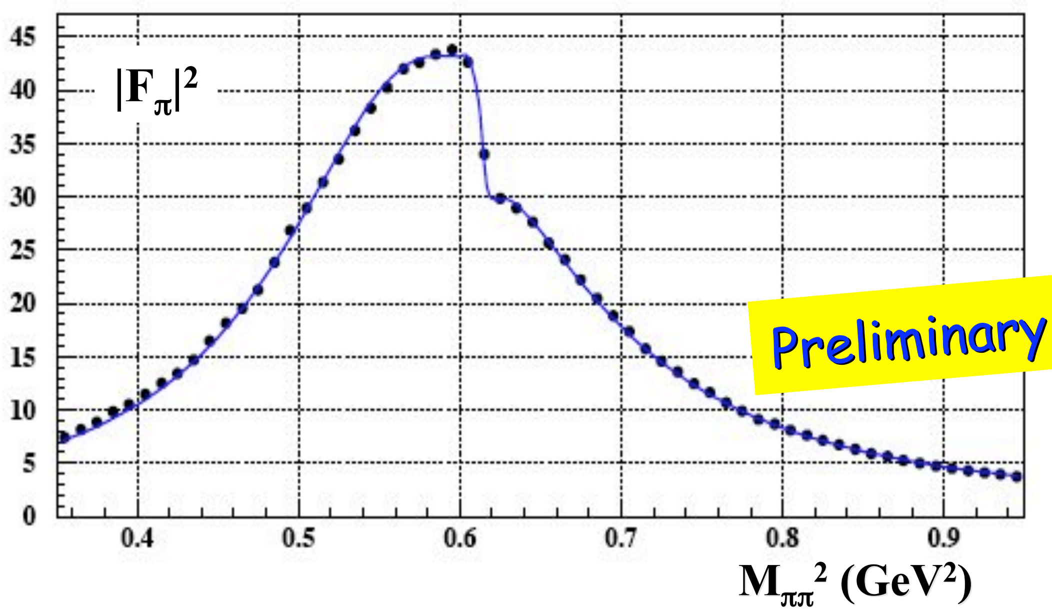


only statistical errors are shown
better agreement on the ρ peak

band: KLOE error, and
data points: other experiments

Fit to the pion form factor

$$F_\pi(s) = \frac{BW_\rho^{GS}(s)\left(1+\delta\frac{s}{M_\omega^2}BW_\omega(s)\right)+\beta BW_{\rho'}^{GS}(s)}{1+\beta}$$



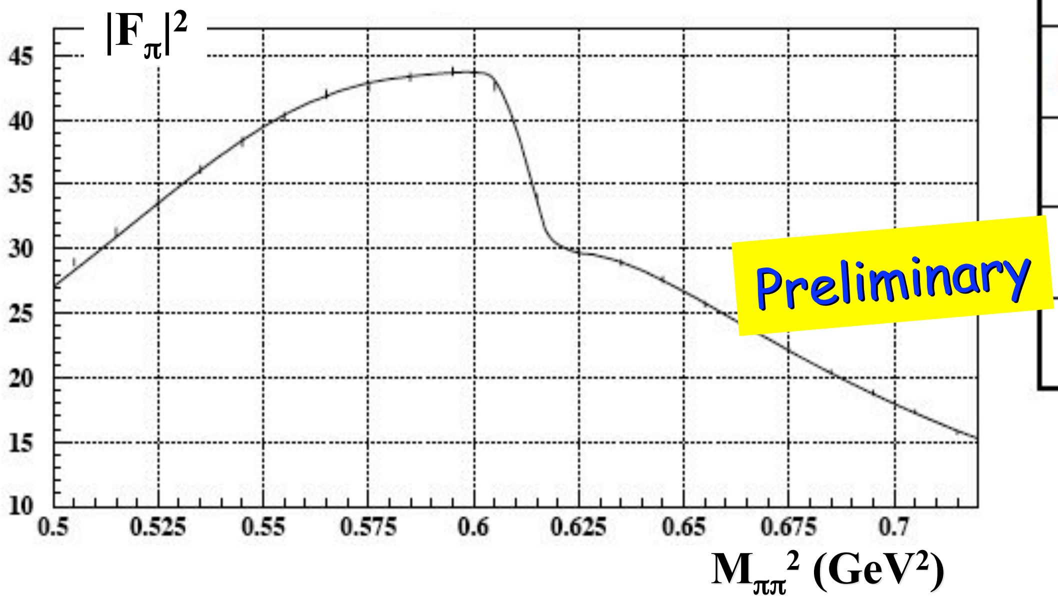
statistical error only

	this fit	PDG
M_ρ (MeV)	773.7 ± 0.2	775.5 ± 0.4
Γ_ρ (MeV)	146.5 ± 0.4	149.4 ± 1.0
$M_{\rho'}$ (MeV)	1460	
$\Gamma_{\rho'}$ (MeV)	310	
M_ω (MeV)	783.2 ± 0.4	782.65 ± 0.12
Γ_ω (MeV)	8.2 ± 1.0	8.49 ± 0.08
a (10^{-3})	1.48 ± 0.11	-
b (10^{-3})	−84.1 ± 1.2	-
δ (deg)	12.3° ± 4.1°	

χ^2/dof = 79.3/54

Fit in the ρ-ω region: momentum scale check

$$F_\pi(s) = \frac{BW_\rho^{GS}(s)\left(1+\delta\frac{s}{M_\omega^2}BW_\omega(s)\right)+\beta BW_{\rho'}^{GS}(s)}{1+\beta}$$



statistical error only

	this fit	PDG
M_ρ (MeV)	775.0 ± 0.4	775.5 ± 0.4
Γ_ρ (MeV)	148.3 ± 1.2	149.4 ± 1.0
$M_{\rho'}$ (MeV)	1460	
$\Gamma_{\rho'}$ (MeV)	310	
M_ω (MeV)	782.6 ± 0.6	782.65 ± 0.12
Γ_ω (MeV)	10.0 ± 1.0	8.49 ± 0.08

ω mass where expected:
momentum scale is OK

Conclusions

We have obtained the contribution to $a_\mu^{\pi\pi}$ in the range between 0.35 - 0.95 GeV^2 using cross section data obtained via the ISR events with photon emission at small angles.

- *The result from new data agrees with the updated result from the published KLOE analysis, we are working to combine results*

- KLOE results also agree with recent results on $a_\mu^{\pi\pi}$ from the CMD2 and SND experiments at VEPP-2M in Novosibirsk

- The new F_π shows better agreement with Novosibirsk spectra

Outlook

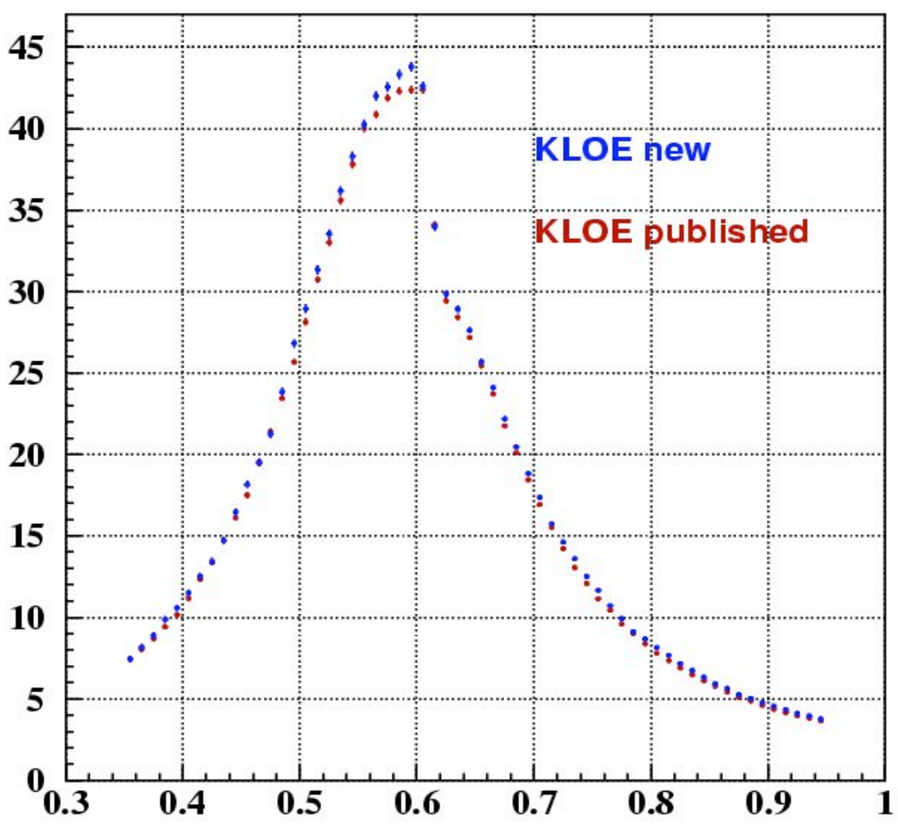
- Independent analysis is in progress using detected photons emitted at large angle (progress in scalar meson modelling)

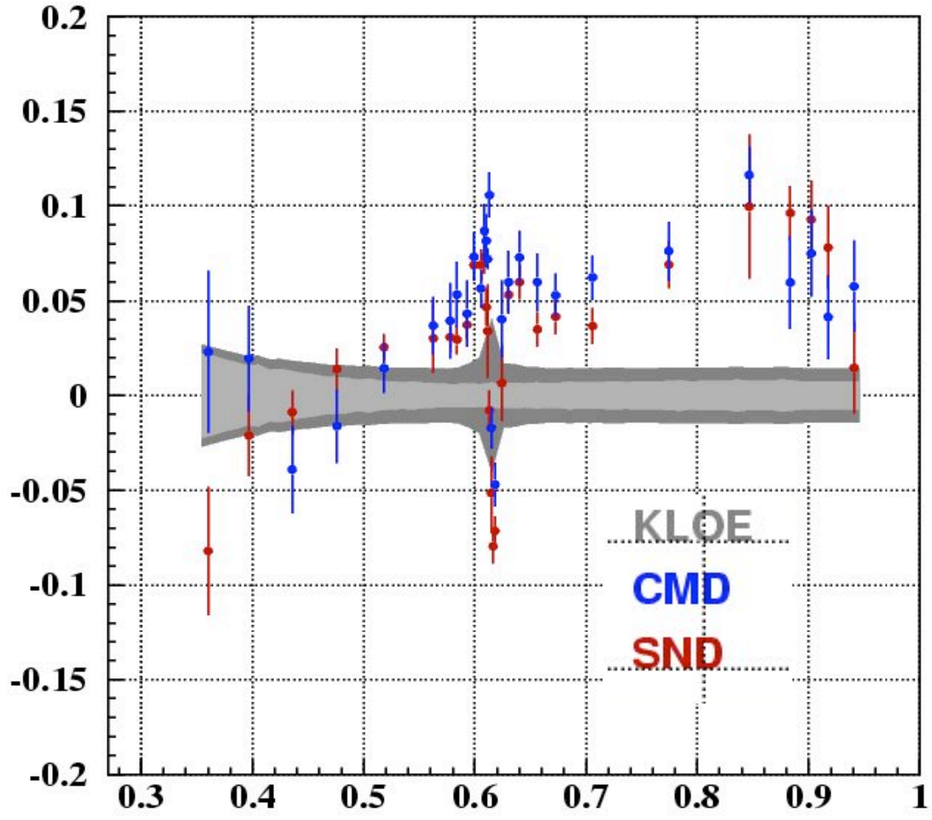
- We are also measuring the pion form factor using the ratio of $\pi\pi\gamma$ over $\mu\mu\gamma$ yields (instead of absolute normalization)

- Finally we are measuring pion form factor from data taken at $\sqrt{s}= M_{\phi}$ - 20 MeV (1 GeV)

SPARES

Comparison 2001-2002 data





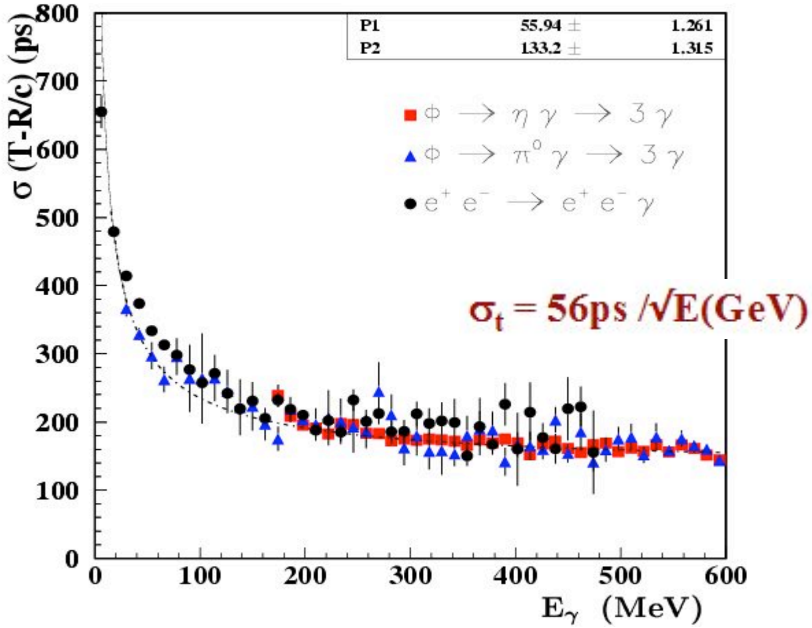
KLOE: performances for the $\pi\pi\gamma$ analysis

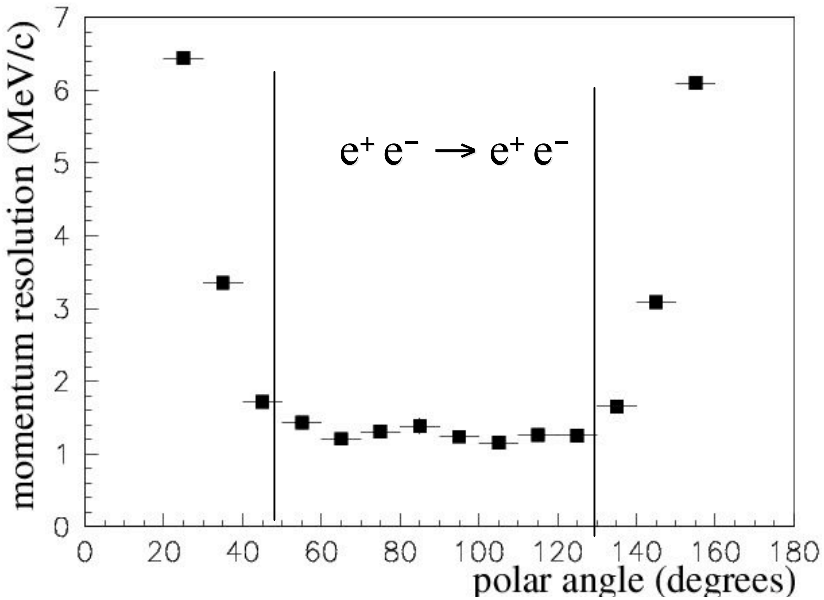
see talk of A. Passeri

Electromagnetic Calorimeter
Pb / Scintillating Fibres
Endcap + Barrel = 98% (4π)

Drift Chamber
4 m ∅, *3.3 m* length
90% He, *10%* i-C_4H_{10}

$\sigma_E/E = 5.4\%/\sqrt{E(\mathrm{GeV})}$





$\sigma_p/p = 0.4\%$ *($\theta > 45°$)*

$\sigma_{M\pi\pi} \sim 1$ MeV

both detectors provide the trigger