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DPG Tagung
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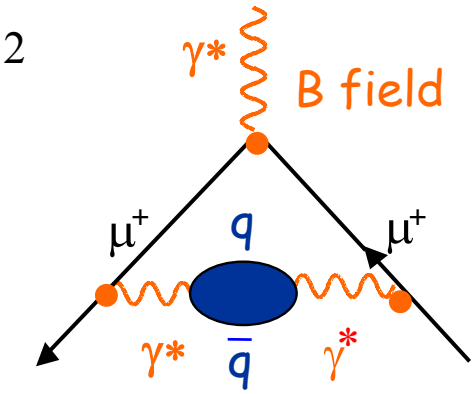
Measurement of the hadronic cross section at KLOE

- Introduction
- Small photon angle analysis (Phys. Lett. B606, 12 (2005))
- Large photon angle analysis (in progress)
- Conclusion

Hadronic contribution to $(g-2)_\mu$

Magnetic momentum: $\vec{\mu} = g_\mu \frac{e\hbar}{2m_\mu c}\vec{s}$ with $a_\mu = (g_\mu - 2)/2$



Due to quantum corrections: $a_\mu^{SM} = a_\mu^{QED} + a_\mu^{had} + a_\mu^{EW}$

a_μ^{had} includes contributions not evaluable in pQCD, but it can be provided by $\sigma(e^+ e^- \to \text{hadrons})$ by means of dispersion relation:

$$a_\mu^{hadr} = \frac{1}{4\pi^3} \int_{4m_\pi^2}^{\infty} ds\ \sigma^{hadr,\exp}(s)\ K(s)$$

K(s) is a steady function that goes with 1/s, ***enhancing low energy contributions of*** $\sigma^{hadr}(s)$

In energy range <1 GeV, $e^+e^- \to \pi^+\pi^-$ contributes to more than 60% to a_μ^{had}

$\sigma(e^+e^- \to \pi^+\pi^-)$ with Radiative Return

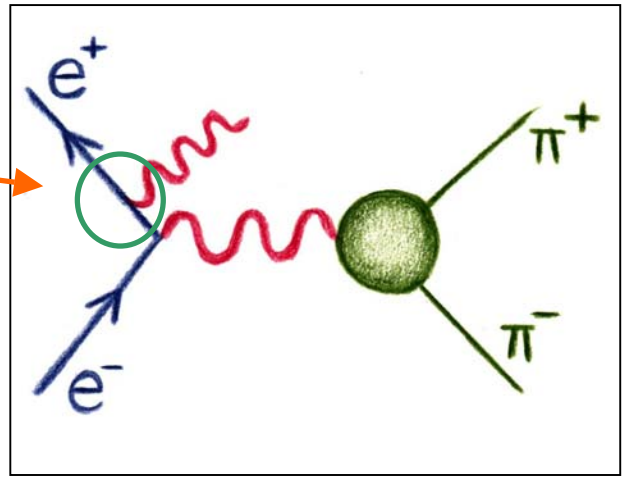
Particle factories (fixed c.m. energy) have the opportunity to measure the cross section $\sigma(e^+ e^- \to \text{hadrons})$ as a function of the hadronic c.m. energy $M^2_{hadrons}$ by using the **radiative return**.

(S.Binner, J.H. Kühn, K. Melnikov, Phys.Lett. B459,1999)

Precise knowledge of ISR – process:
Radiator function $H(Q^2, \theta_\gamma, M^2_\varphi)$

MC generator: Phokhara

(H. Czyz, A. Grzelinska, J.H. Kühn, G. Rodrigo, hep-ph/0308312)



"**Radiative Return**" to $\rho(\omega)$ resonance $e^+e^- \to \rho(\omega)\,\gamma \to \pi^+\pi^-\gamma$

$$M^2_{hadr} \frac{d\sigma(e^+ e^- \to hadrons + \gamma)}{dM^2_{hadrons}} = \sigma(e^+ e^- \to hadrons)\, H(M^2_{hadr})$$

This method is a complementary approach to the energy scan.

Small angles analysis

- Acceptance

$50^o < \theta_\pi < 130^o$, $\theta_{miss} < 15^o$ and $\theta_{miss} > 165^o$

No photon tagging

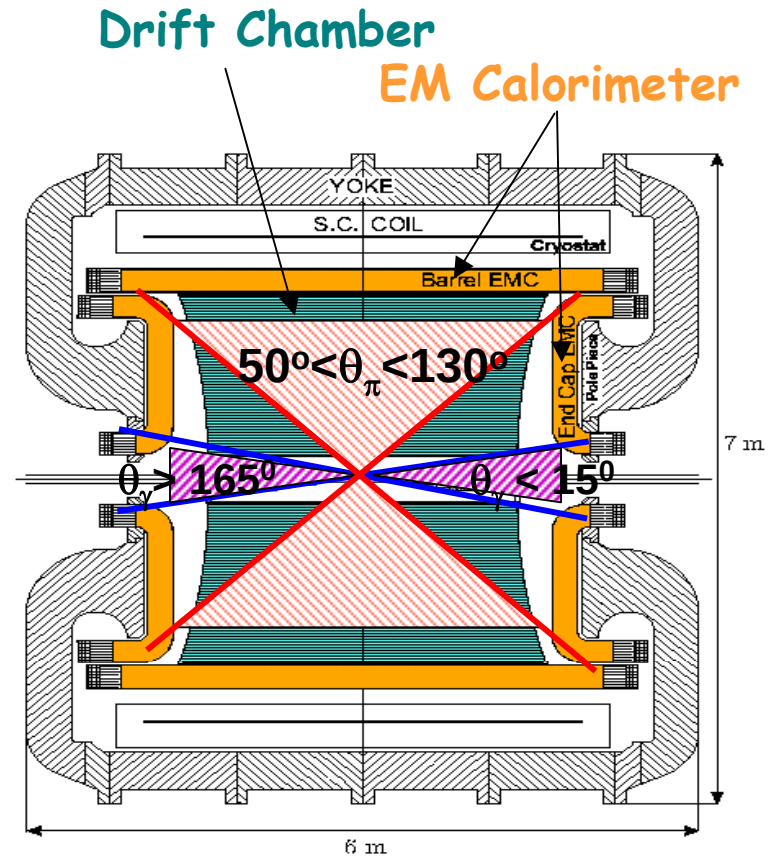
Low relative **FSR contribution** and background contamination

- Event analysis and background evaluation:

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

- Division by the radiator function, and correction for the vacuum polarization and FSR contribution

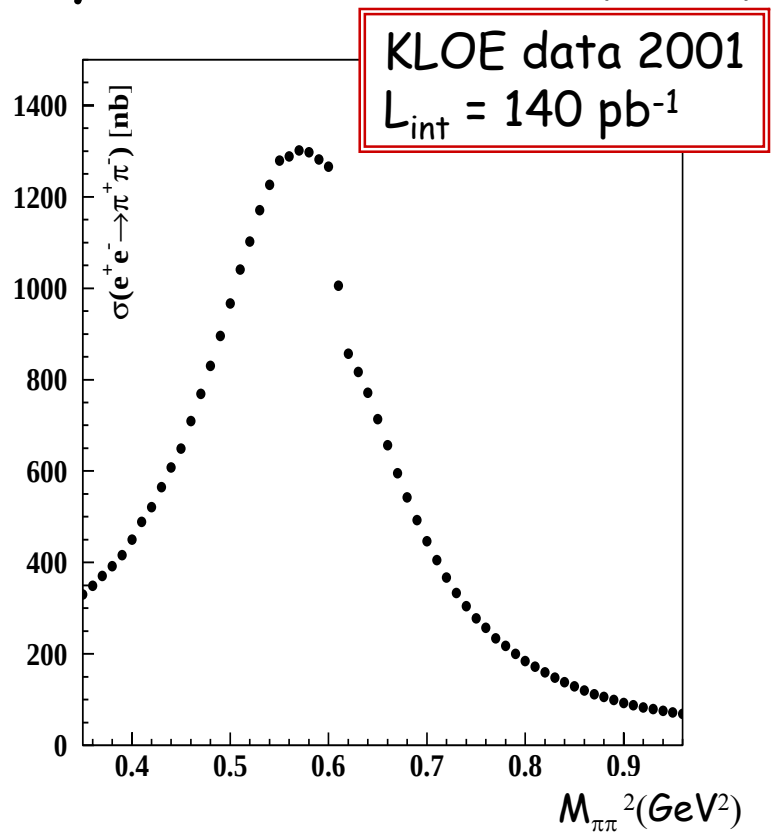
cross section
$\sigma(e^+e^- \to \pi^+\pi^-)$



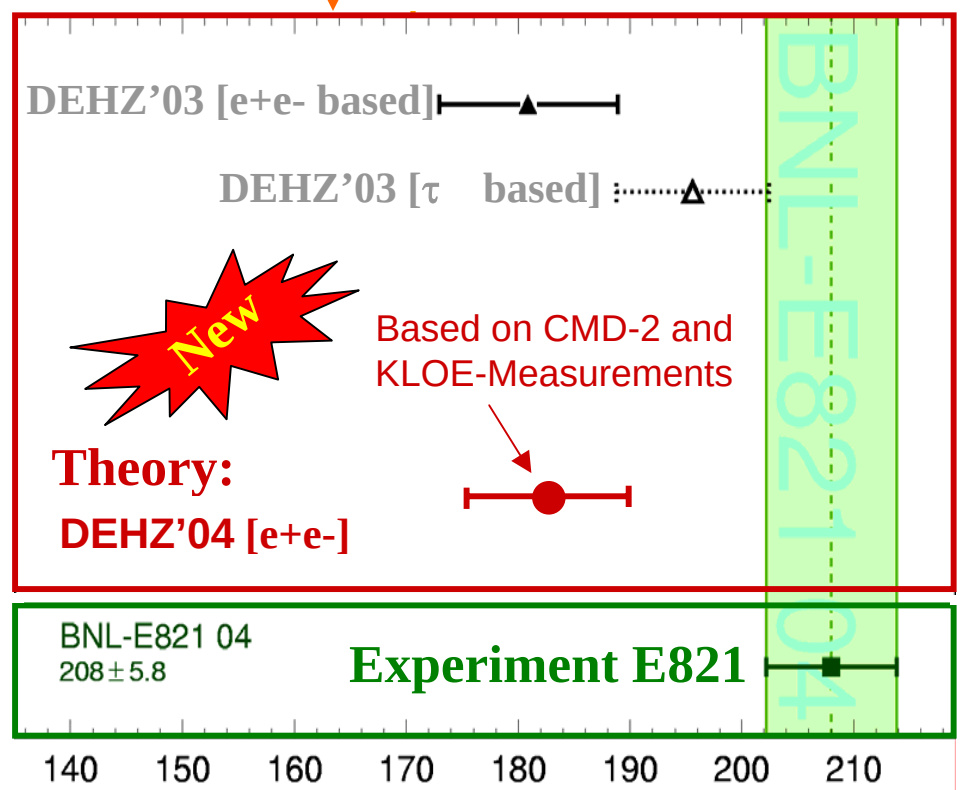
... see talk of A. Denig
(T 112 Eingeladene Vorträge II
tomorrow 15:30)

Result of small angles analysis

Phys. Lett. B606, 12 (2005)



its impact on a_μ



a_μ – 11 659 000 · 10^{-10}

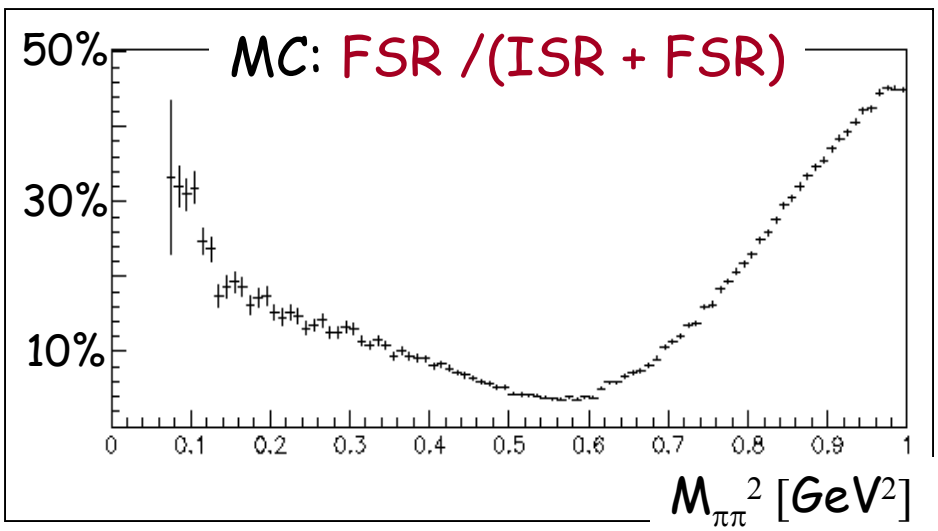
KLOE and CMD-2 in fair agreement in ρ peak region.

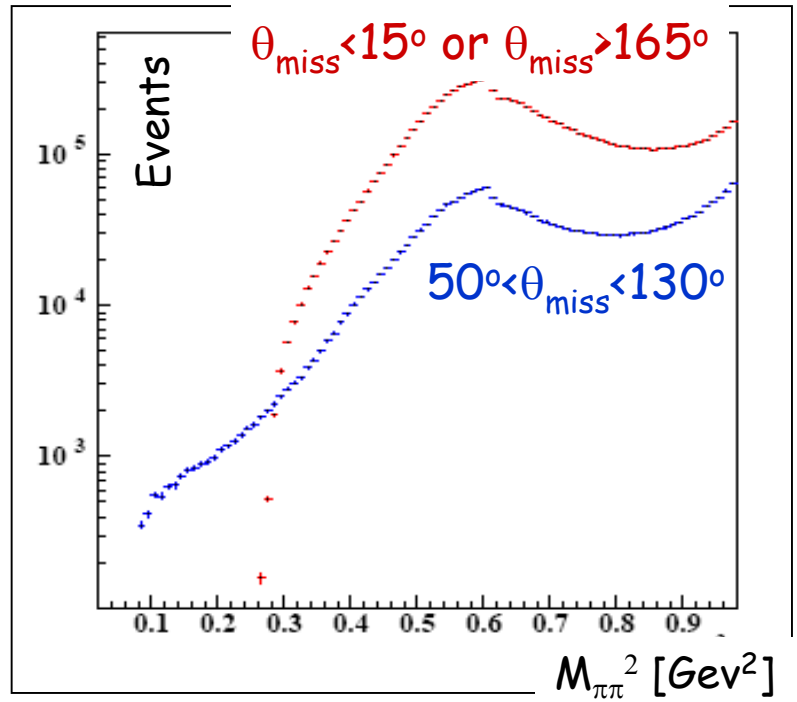
A. Höcker @ ICHEP04: hep-ph/0410081

Large photon angles analysis

Motivations

- At large photon angles it is possible to investigate the low $M_{\pi\pi}$ region (20% contribution to a_μ)
- The relative amount of FSR is very big ⇒ possibility to test the model used in MC to simulate it





.....but

- statistic becomes an issue at threshold
- huge amount of background from $\pi^+\pi^-\pi^0$

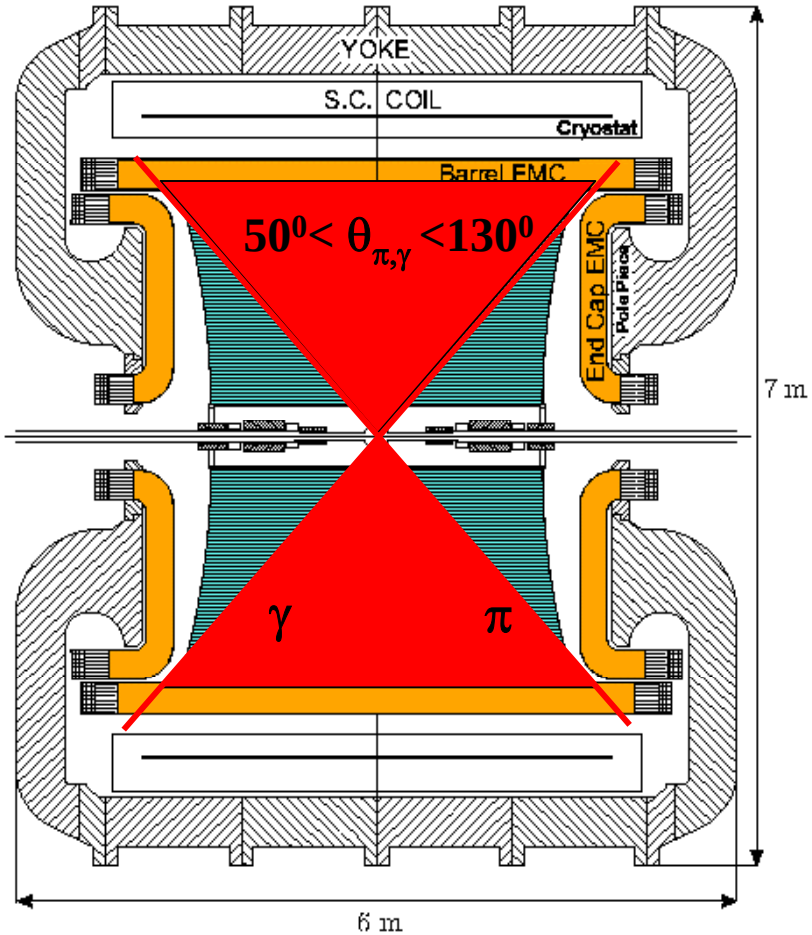
Signal selection

Tracks: $50^o < \theta_\pi < 130^o$

In this region we detect photons
⇒ **tagged** measurement

Event is selected if at least one photon has

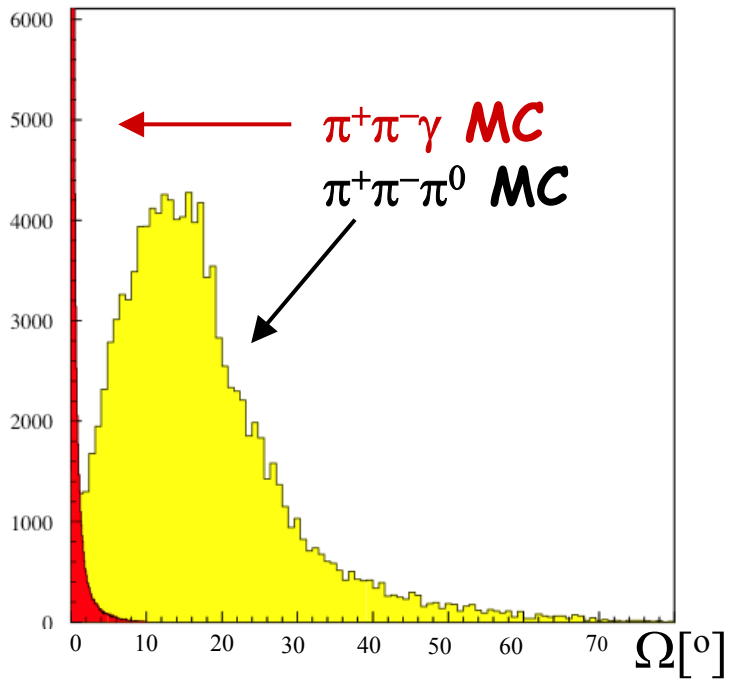
$50^o < \theta_\gamma < 130^o$
$E_\gamma > 50$ MeV



Background rejection 1/2

The detection of photons is crucial in the rejection of $\pi^+\pi^-\pi^0$

By cutting on the angle between the missing momentum $\vec{p}_\gamma = -\vec{p}_{miss} = -(\vec{p}_+ + \vec{p}_-)$ and the **tagged** photon $\Omega = a\cos\left(\frac{\vec{p}_\gamma \cdot \vec{p}_{miss}}{|\vec{p}_\gamma||\vec{p}_{miss}|}\right)$ we have a powerful separation between $\pi^+\pi^-\gamma$ and $\pi^+\pi^-\pi^0$

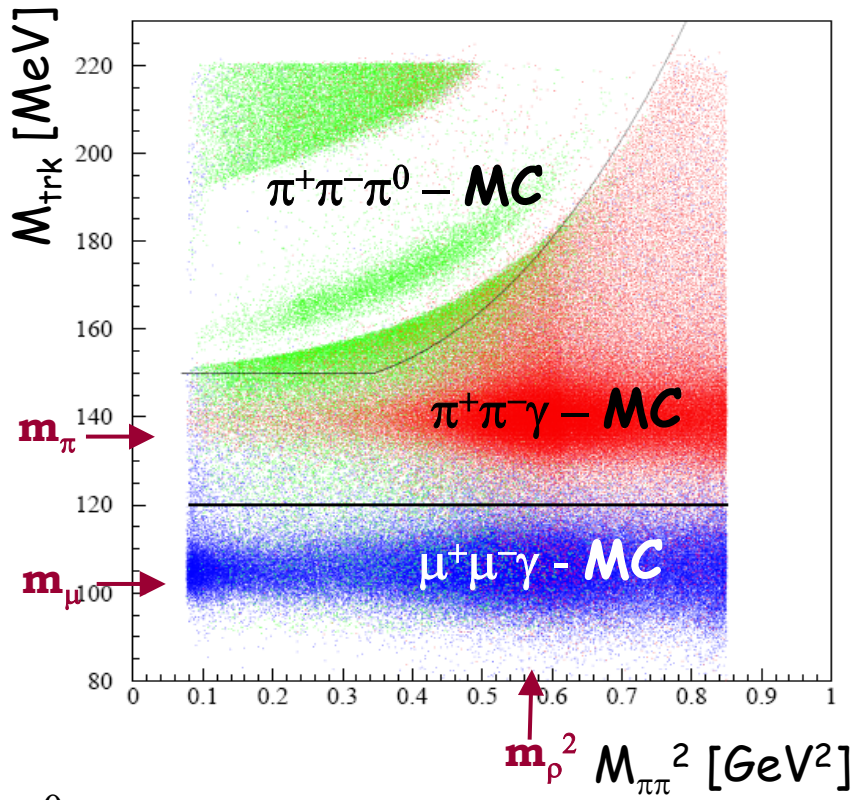


Background rejection 2/2

Further cuts for background rejection

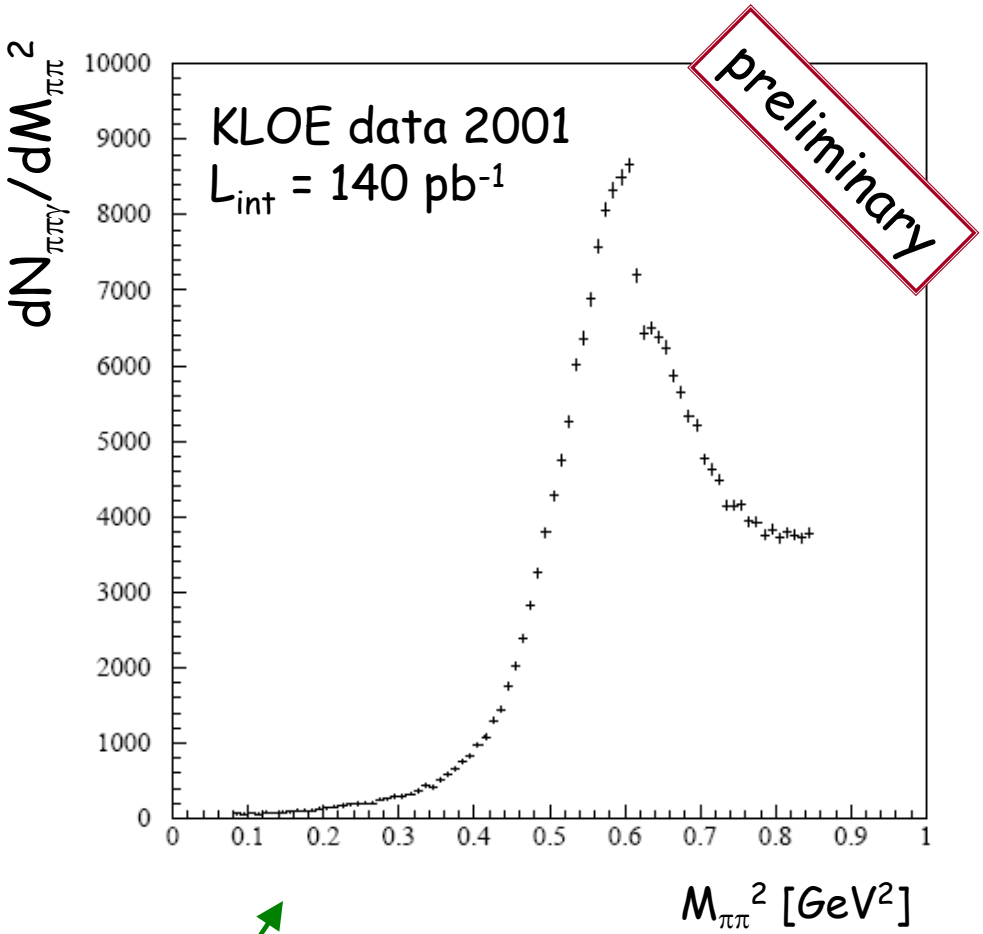
- Radiative Bhabhas $e^+e^- \rightarrow e^+e^-\gamma$ are separated by means of a Likelihood-Method (signature of EmC-Clusters and time of flight of particle tracks)

- To reject $\mu^+\mu^-\gamma$ and $\pi^+\pi^-\pi^0$ background a cut in the plane M_{trk} vs. $M_{\pi\pi}^2$ is applied. M_{trk} is a kinematical variable obtained by solving



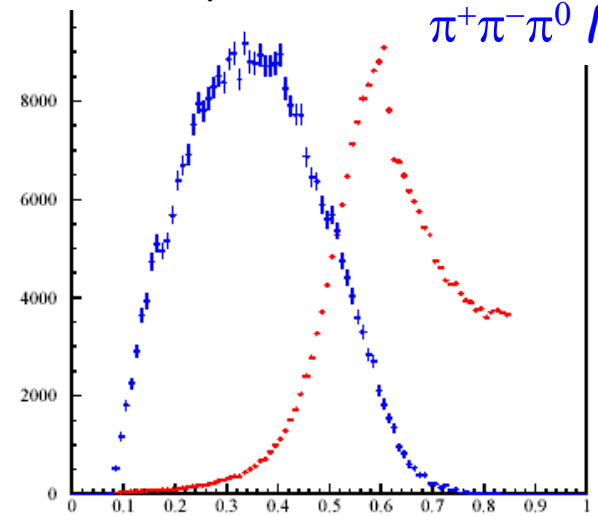
$$\left(M_\phi - \sqrt{|\vec{p}_1|^2 + M_{trk}^2} - \sqrt{|\vec{p}_2|^2 + M_{trk}^2}\right)^2 - |\vec{p}_1 + \vec{p}_2|^2 = 0$$

Preliminary spectrum

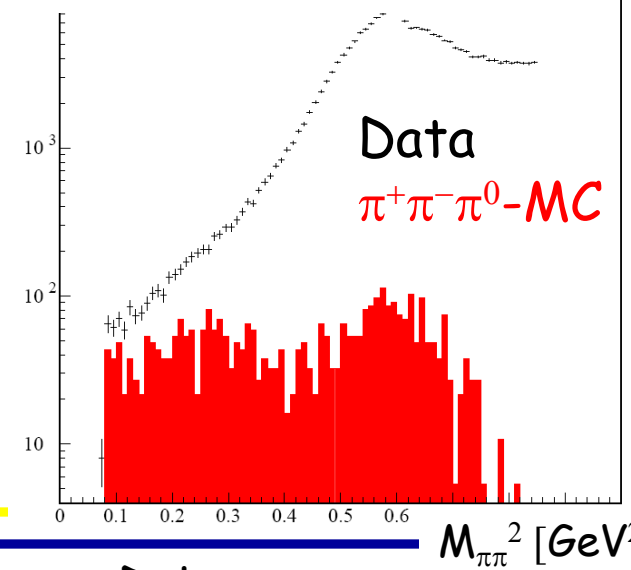


The spectrum extends down to the 2-pions threshold
(10 times more statistics on tape!)

After acceptance — $\pi^+\pi^-\gamma$ MC
$\pi^+\pi^-\pi^0$ MC



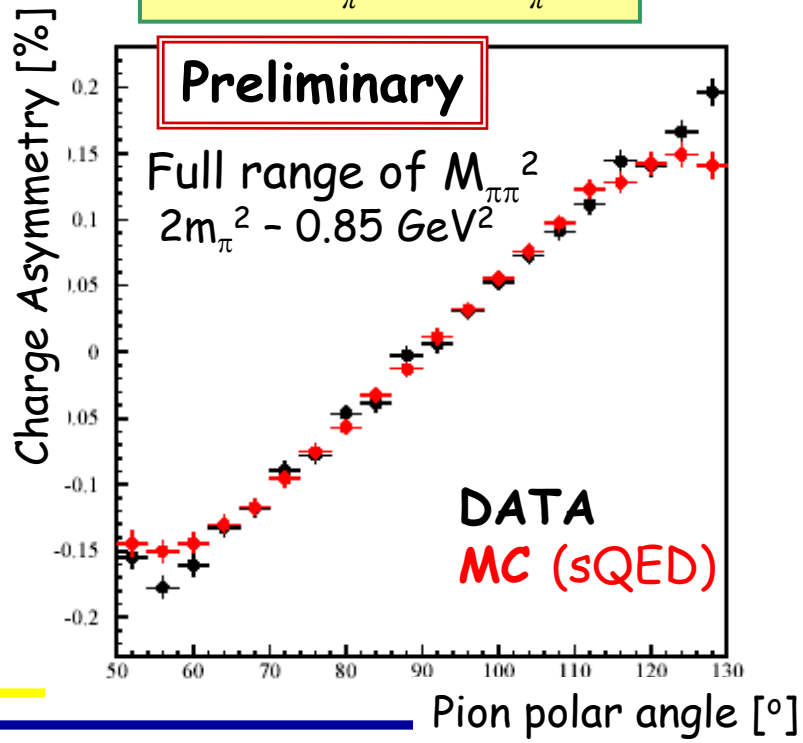
After the whole selection

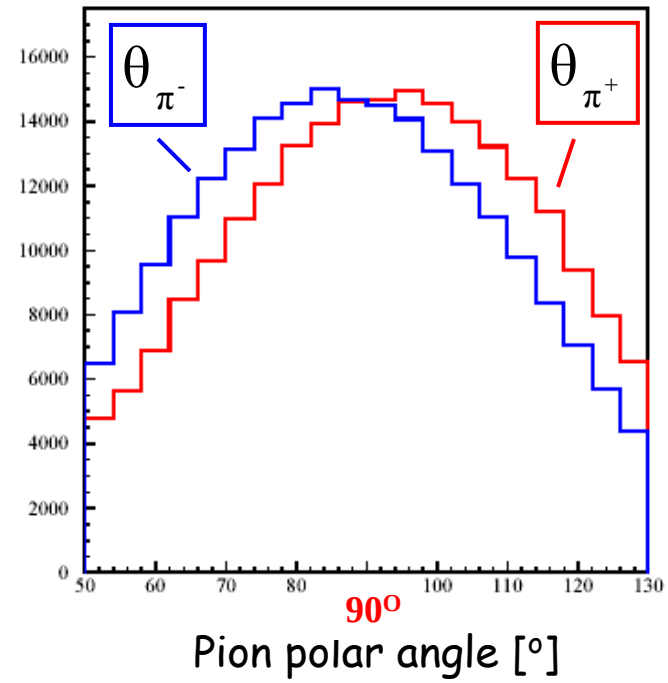


Charge asymmetry

The final state in case of ISR or FSR is in an odd or even charge conjugation state respectively. At large photon angles, the amount of FSR is large and the interference between the two terms gives a sizeable effect in the charge asymmetry A

$$A(\theta) = \frac{N_{\pi^+}(\theta) - N_{\pi^-}(\theta)}{N_{\pi^+}(\theta) + N_{\pi^-}(\theta)}$$





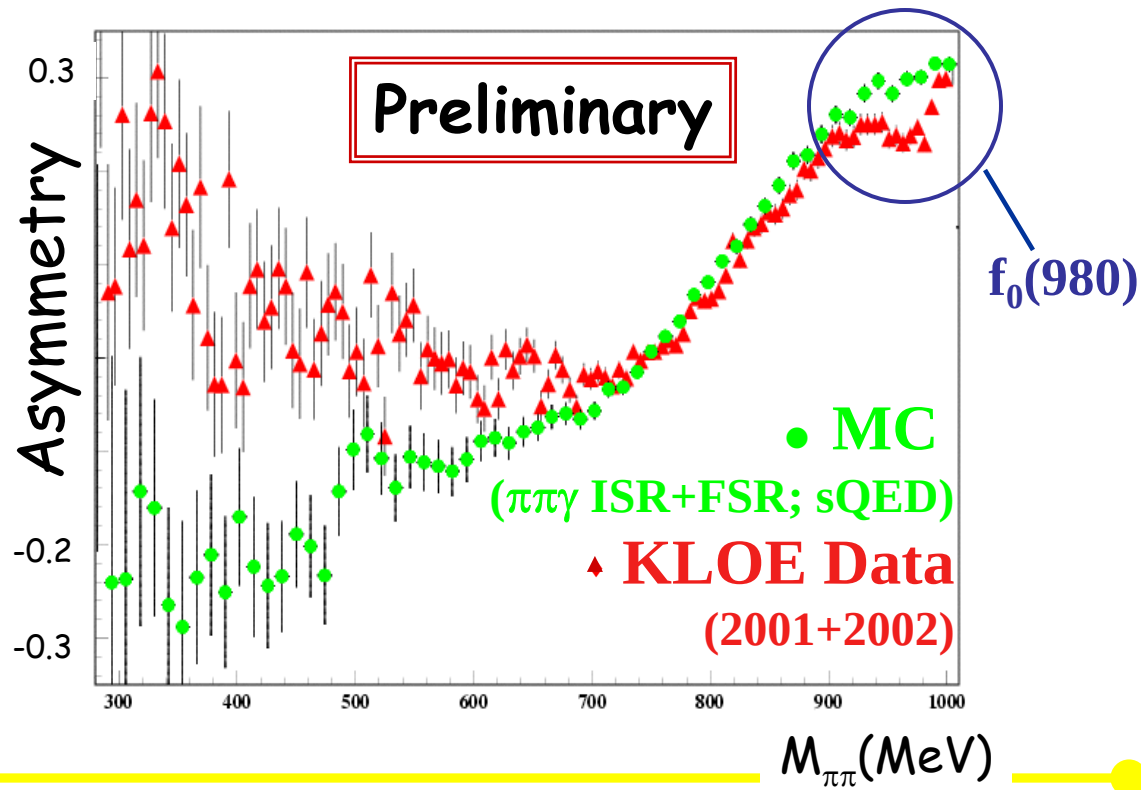
➔ test the model of FSR (sQED) used in Montecarlo, by comparing data vs Montecarlo

Charge asymmetry 2/2

The charge asymmetry is also a very sensitive parameter for studying the presence and nature of the scalar particles $f_0(980)$ and $f_0(600)$ from ϕ radiative decays.

Czyz, Grzelinska, Kühn, hep-ph/0412239

Look at the charge asymmetry as a function of $M_{\pi\pi}$ we find large deviations from the prediction of sQED at the very high and low $M_{\pi\pi}$ region



Conclusion & Outlook

- ✓ KLOE has published the first measurement of the $e^+e^- \to \pi^+\pi^-$ cross section with the radiative return, proving the feasibility and high precision of this new method

- ✓ A complementary analysis is in progress:
  measure the $e^+e^- \to \pi^+\pi^-$ cross section down to the 2-pions threshold region
  study the issue of FSR

- In addition, an upgrade of the small photon angle analysis is in progress using 2002 data
- Measurement of $\sigma(e^+ e^- \to \pi^+\pi^-\gamma)/\sigma(e^+e^- \to \mu^+\mu^-\gamma)$
  (normalization to muons) $\Rightarrow$ direct measurement of R

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