MEASUREMENT of e^+e^- HADRONIC CROSS SECTION with RADIATIVE RETURN at KLOE

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On behalf of the KLOE Collaboration

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Summary

- Motivation of σ_{hadr}
- σ_{hadr} with radiative return
- Results on $\sigma(e^+e^-\rightarrow\pi^+\pi^-)$ at small angle
- Conclusions and outlook

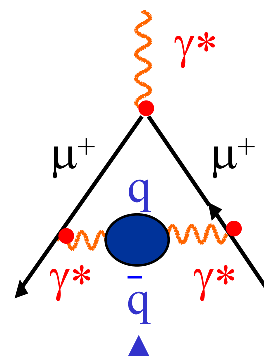
Why the measurement of the cross section is important?

THE ANOMALOUS MAGNETIC MOMENT OF THE MUON

Magnetic moment for pointlike fermion → $\vec{\mu} = g_\mu \frac{e}{2m_\mu}\vec{s}$ $\underbrace{g_\mu = 2}_{\text{Dirac}}(1 + a_\mu)$

$g \neq 2$ (Dirac prediction) because there are quantum correction

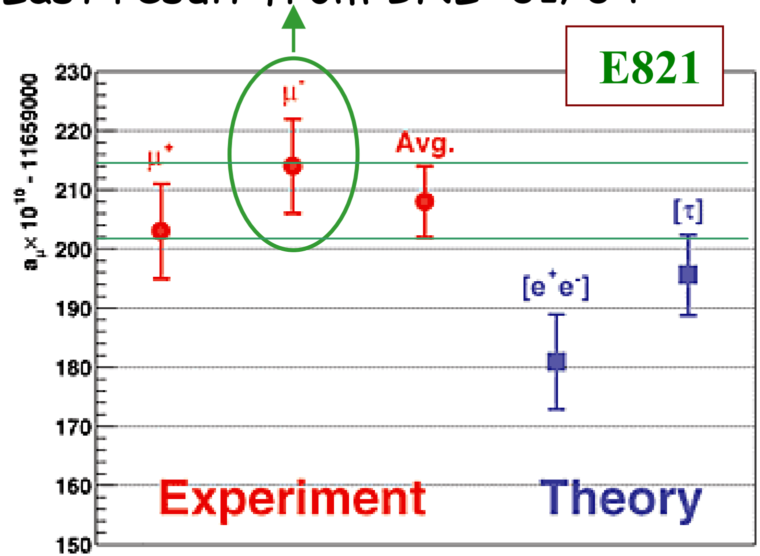
$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{had} + a_\mu^{EW}$$



Hadronic vacuum polarizatio

Status of a_μ: Theorical vs Experimental value

Last result from BNL: 01/04



τ-data from ALEPH, OPAL, CLEO
e+e- dominated by CMD-2

$|a_\mu(e^+ e^-) - a_\mu(\text{data})|$: 2.7 σ -Deviation

$|a_\mu(\tau) - a_\mu(\text{data})|$: 1.4 σ - Deviation

⇩

A NEW MEASUREMENT IS VERY IMPORTANT!

Hadronic contribution to a_μ

- The error on a_μ(theo) is dominated by the error on a_μ^{had}
  - This quantity is not evaluable in pQCD, but it can be calculated by **DISPERSION INTEGRAL:**

$$a_\mu^{had} = \frac{\alpha}{3\pi^2} \int_{4m_\pi^2}^{\infty} ds \ \frac{K(s)}{s} R(s)$$

$$R(s) = \frac{\sigma(e^+e^- \rightarrow hadrons)}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$$

$$K(s) = KernelFunction \propto {}^1\!/_s$$

<u>Input:</u>

a) Hadronic electron-positron cross section data

b) Hadronic τ- decays, which can be used with the help of the CVC-theorem and an isospin rotation (plus isospin breaking corrections)

The factors **1/s** in *the dispersion relation* makes the low energy region particularly relevant.

The $e^+e^- \rightarrow \pi^+\pi^-$ channel accounts for ~70% of the contribution both to a_μ^{had}

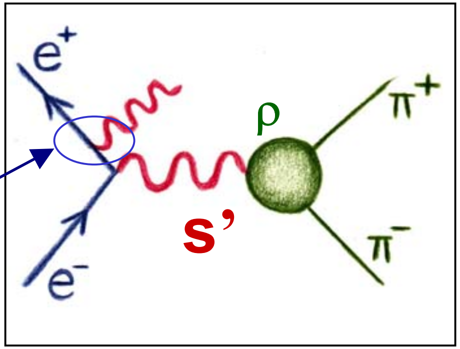
How to perform this measurement?

traditional way : measuring cross section by varying $e^{\pm}$ beams energy → energy scan

BUT

DAΦNE is a ϕ - factory and therefore runs at fixed c.m.s.-energy: $\sqrt{s} = m_{\phi} = 1.019$ MeV

Complementary approach:
Take events with
Initial State Radiation (ISR)



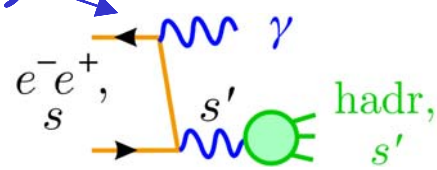
"Radiative Return" to ρ-resonance:

$e^+ e^- \rightarrow \rho + \gamma \rightarrow \pi^+\pi^- + \gamma$

σ(had) through radiative return

The $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$ is a function of the 2-Pion invariant mass **$s' = M_{\pi\pi}$**. To extract $\sigma(e^+e^- \to \pi^+\pi^-)$ with the ISR we

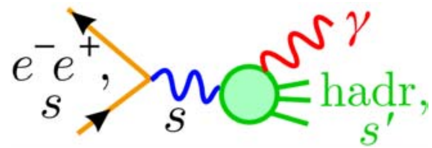
- Need to know the ***RADIATOR FUNCTION H(s)***



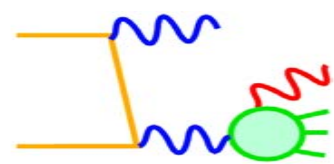
H(s) is evaluable From MC Phokhara

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

- Have to get rid of "pure" FSR: which causes events with $M_{g*} = \sqrt{s}$ to be assigned to lower $\sqrt{s'}$ values

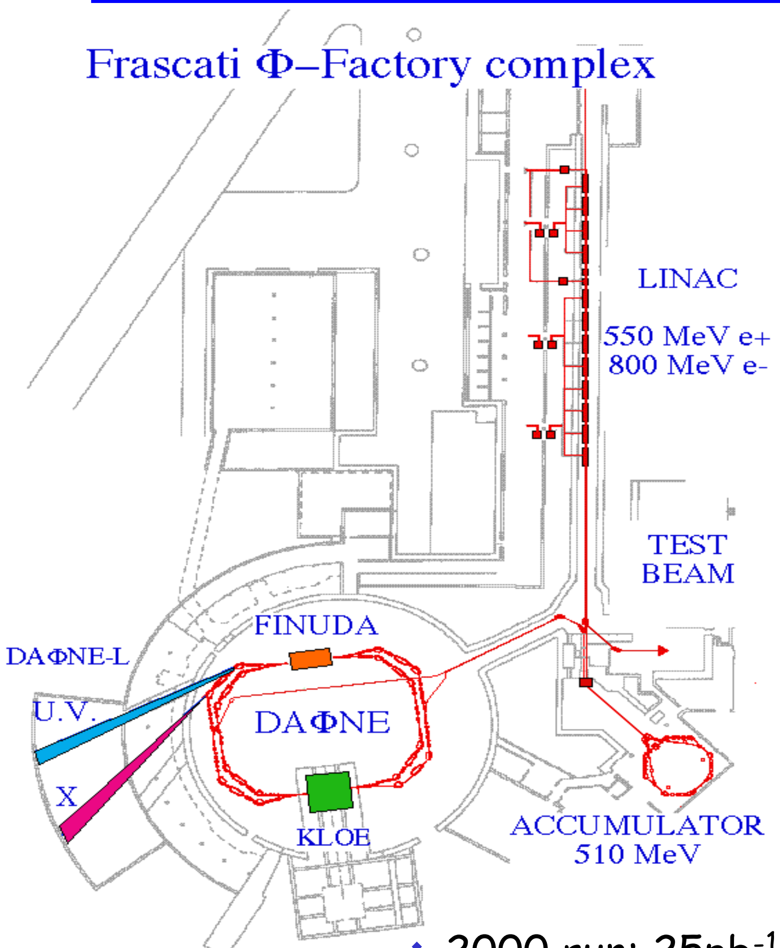


- Have to properly include radiative corrections (including simultaneously emission of ISR and FSR)



DAΦNE: the Double Annular Φ-factory for Nice Experiments

Frascati Φ–Factory complex



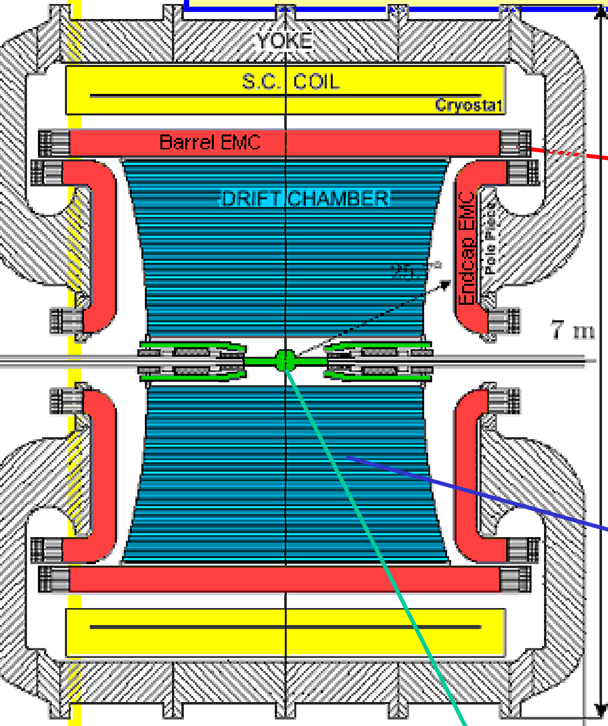
- $E_{beams} \approx 510$ MeV
- 2 separate rings for e^+e^- to minimize beam-beam interaction
- two interaction region: KLOE-DEAR/FINUDA
- crossing angle: 12.5 mrad ($p_x(\phi)$ $\approx$13 MeV)

DAΦNE Parameters	*Design*
N of bunches	*120+120*
Lifetime (mins)	*120*
Bunch current (mA)	*40*
L_{bunch} $(cm^{-2}s^{-1})$	4.4×10^{30}
L_{peak} $(cm^{-2}s^{-1})$	5.3×10^{32}

DAΦNE performance:

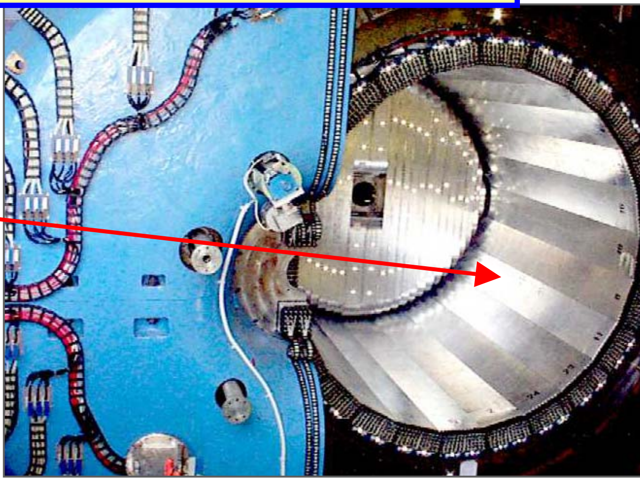
- 2000 run: 25pb^{-1}, 7.5 x10^{7} ϕ decay → first published results
- 2001 run: 190pb^{-1}, 5.7 x10^{8} ϕ decay } Anlysis in progress
- 2002 run: 300pb^{-1}, 9.0 x10^{8} ϕ decay

The KLOE detector: K LOng Experiment



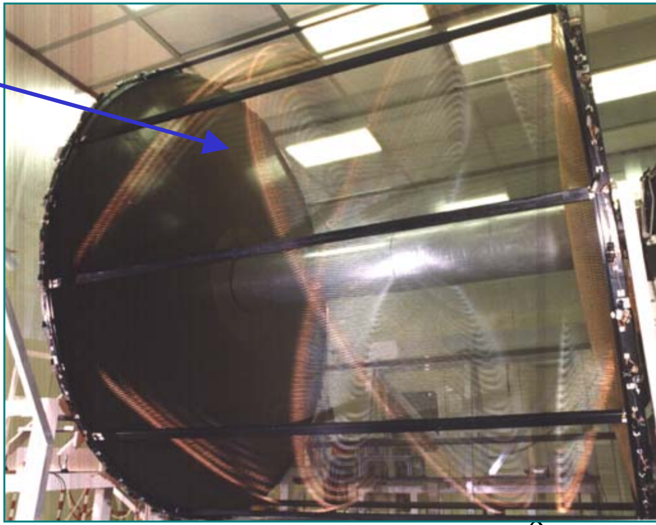
Electromagnetic calorimeter

- *lead/scintillating fibers (1 mm ∅), 15 X_0*
- *4880 PMT's*
- *98% solid angle coverage*

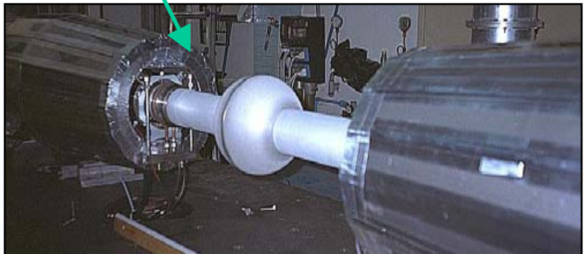


***Drift chamber** (4 m ∅ × 3.75 m, CF frame)*

- *Gas mixture: 90% He + 10% C_4H_{10}*
- *12582 stereo-stereo sense wires*
- *almost squared cells*



- ***Beam pipe :*** *(spherical, 10 cm ∅, 0.5 mm thick)*
- ***Instrumented permanent magnet quadrupoles*** *(32 PMT's)*



Measurement of $\sigma_{\pi\pi\gamma}$ - Analysis scheme

Pion tracks at large angles
from a vertex close to IP

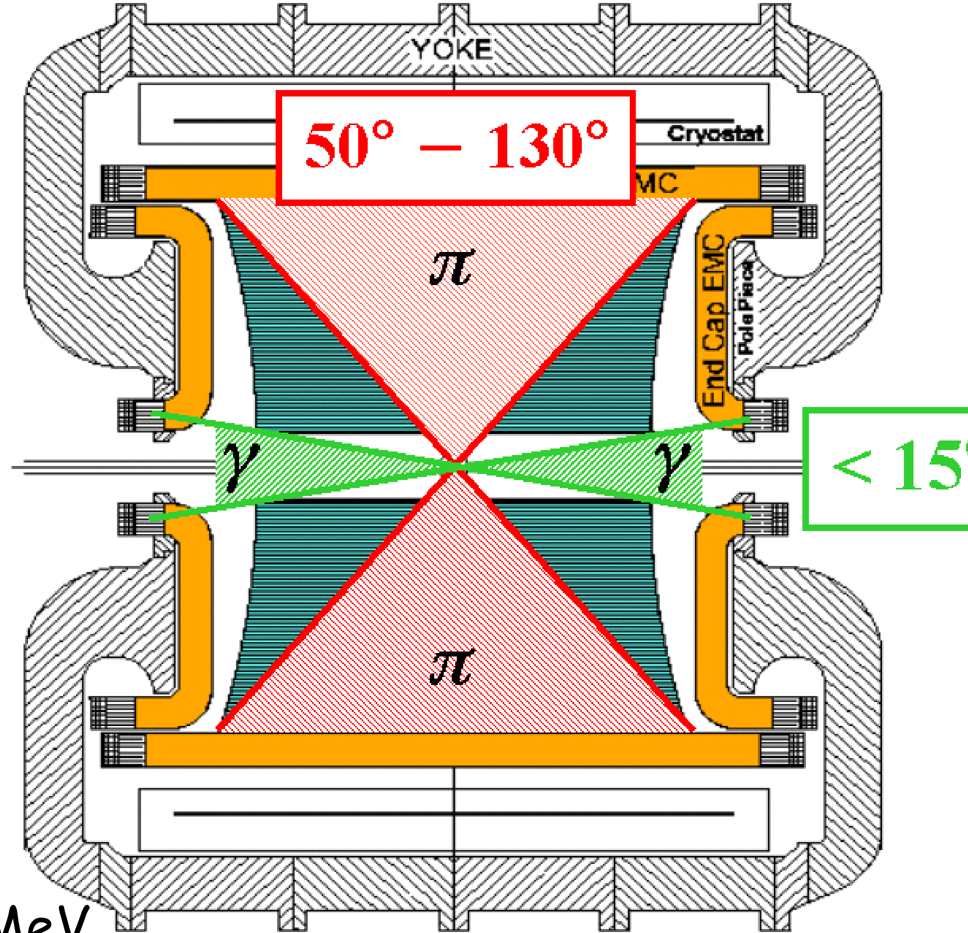
Photons at small angles
to enhance ISR:
$d\sigma_{ISR}/d\Omega \sim 1/\sin^2\theta$

$\Downarrow$

☺ relative contribution of "pure" FSR below the % level over entire $M_{\pi\pi}$ spectrum

☺ reduce background

☹ Lose events with $M_{\pi\pi}$< 600 MeV



→ LARGE ANGLE ANALYSIS
(see after...)

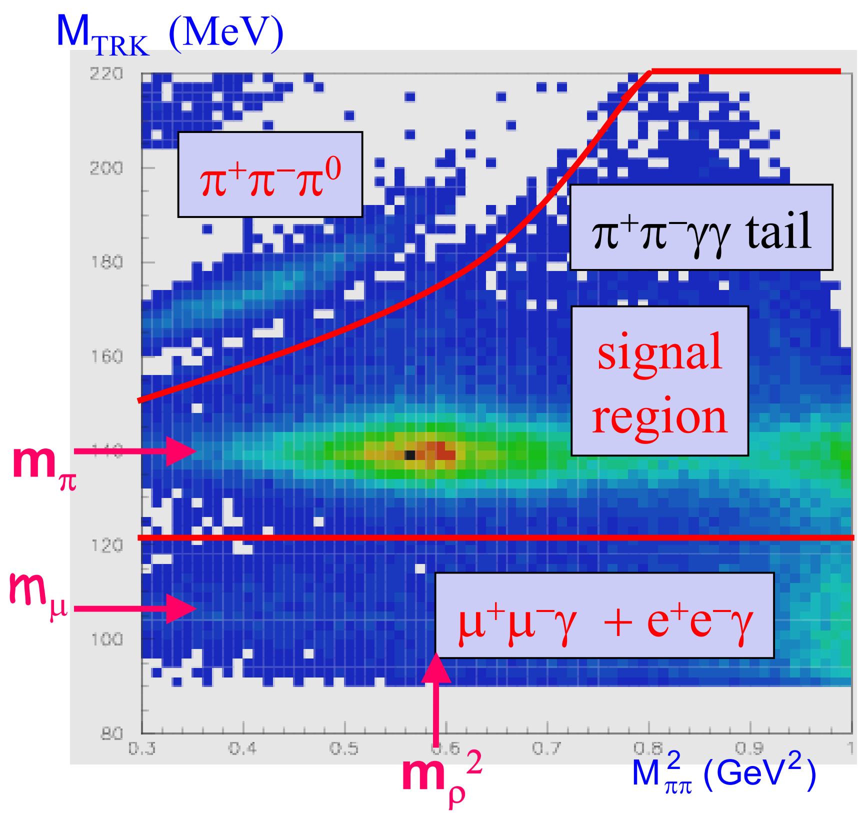
Summary of syst. errors and background

Acceptance	0.3%
Trigger	0.3%
FILFO	0.6%
Tracking	0.3%
Vertex	0.3%
Likelihood	0.1%
Track mass	0.2%
Backg. Subsraction	0.5%
Unfolding	0.3%
Total exp	**1.0%**
Luminosity	0.6%
Vacuum Polarization	0.2%
FSR	0.3%
Radiator function	0.5%
Total theory	**0.9%**

1. Rad. Bhabhas: Pion-Electron-Separation by means of a Particle-ID algorithm

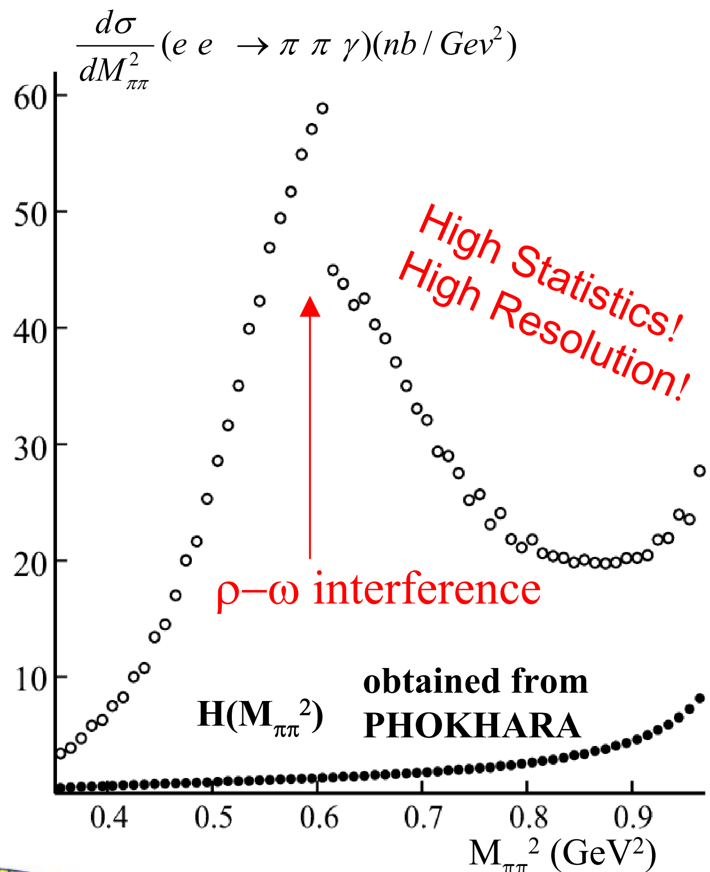
2. $\phi \to \pi^+\pi^-\pi^0$, $e^+e^- \to \mu^+\mu^-\gamma$: Kinematic Separation: "Trackmass"

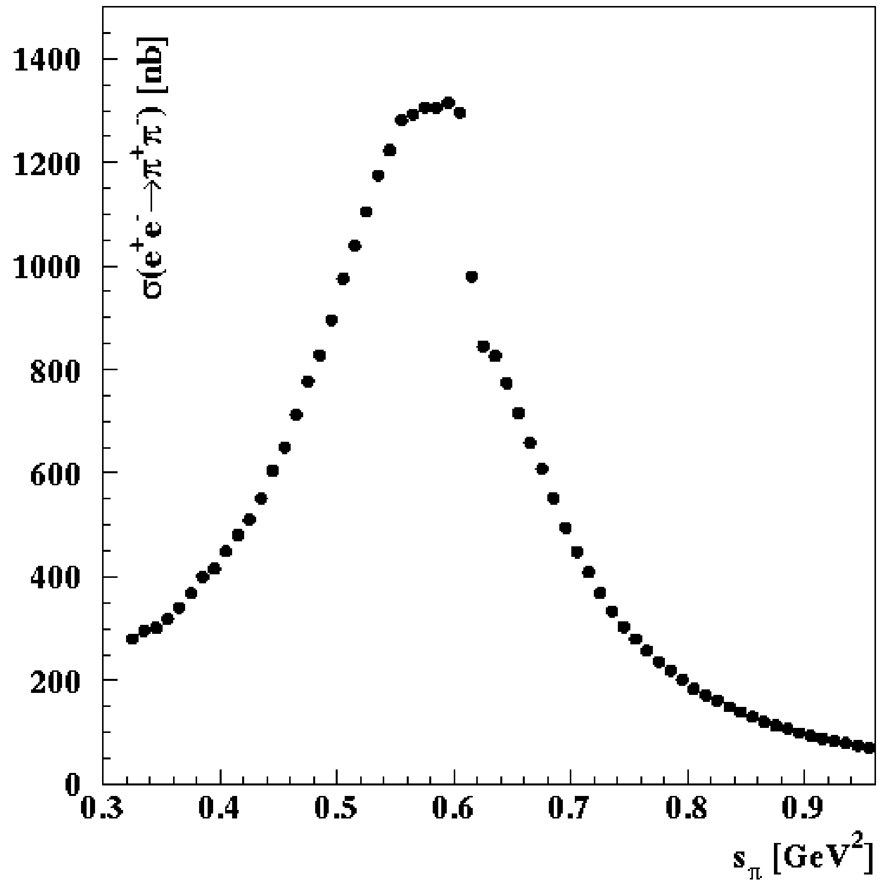
$$\left(M_\phi - \sqrt{\vec{p}_1^{\,2} + M_{trk}^2} - \sqrt{\vec{p}_2^{\,2} + M_{trk}^2}\right)^2 - (\vec{p}_1 + \vec{p}_2)^2 = q_\gamma^2 = 0$$



Analysis: $\sigma(e^+e^- \rightarrow \pi^+\pi^-\gamma)$

Statistics: **141pb^{-1} of 2001-Data 1.5 Million Events**





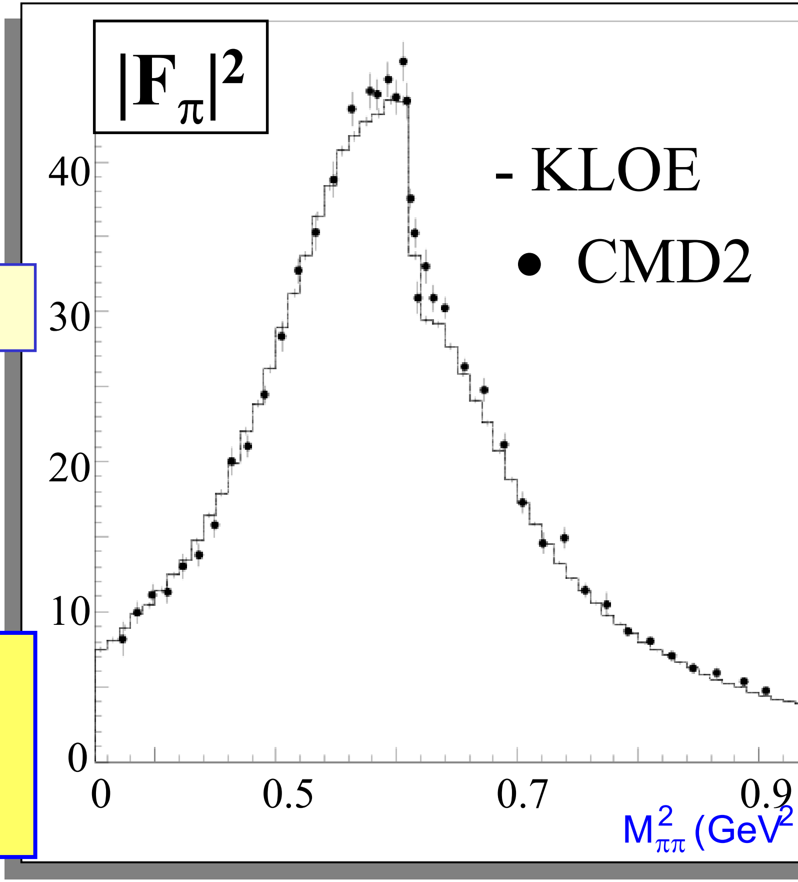
Analysis: Pion Form Factor and a_μ^{had}

- We have evaluated the **dispersions integrals for the 2-Pion-Channel** in the energy range $0.35 < M^2_{\pi\pi} < 0.95$ GeV^2

$$a_\mu^{\pi\pi} = (389.2 \pm 0.8_{stat} \pm 3.9_{syst} \pm 3.5_{theo})\ 10^{-10}$$

- **Comparison with CMD-2** in energy range $0.37 < M^2_{\pi\pi} < 0.93$ GeV^2

KLOE	$(376.5 \pm 0.8_{stat} \pm 5.1_{syst+theo})\ 10^{-10}$
CMD2	$(378.6 \pm 2.7_{stat} \pm 2.3_{syst+theo})\ 10^{-10}$

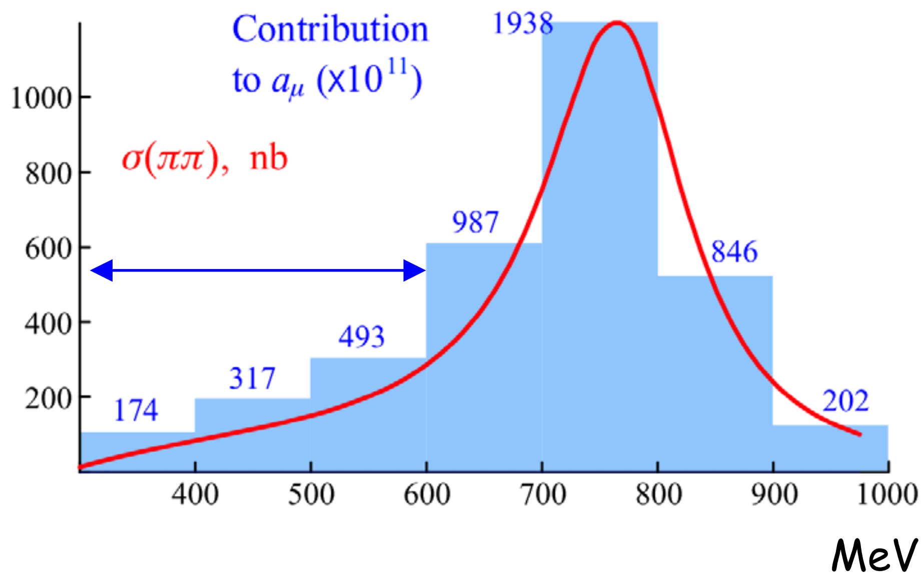


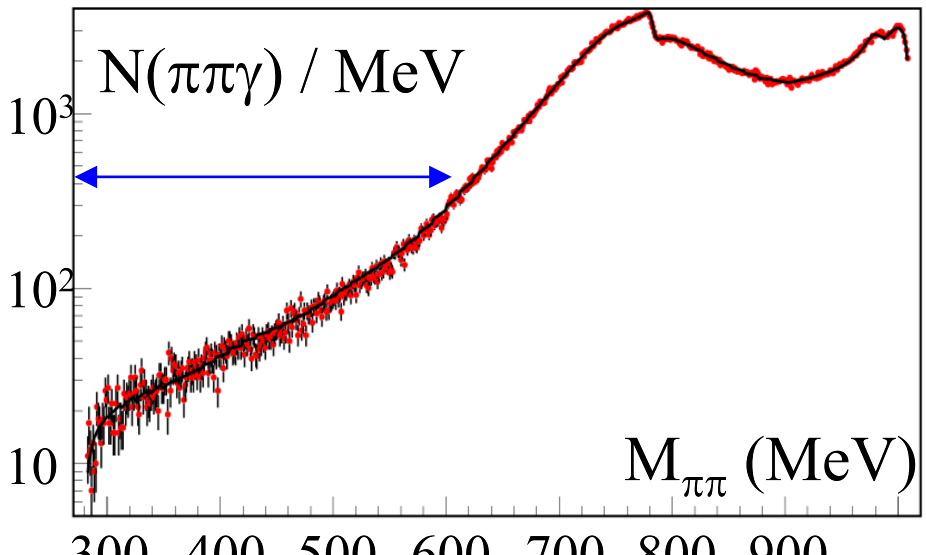
The results are in good agreement!

$$\sigma(e^+e^- \to \pi^+\pi^-) = \frac{\pi\alpha^2}{3M^2_{\pi\pi}}\beta^3 \,|\, F_\pi(M^2_{\pi\pi}) \,|$$

(1) a_μ^{had} prospect: Large Angle analysis

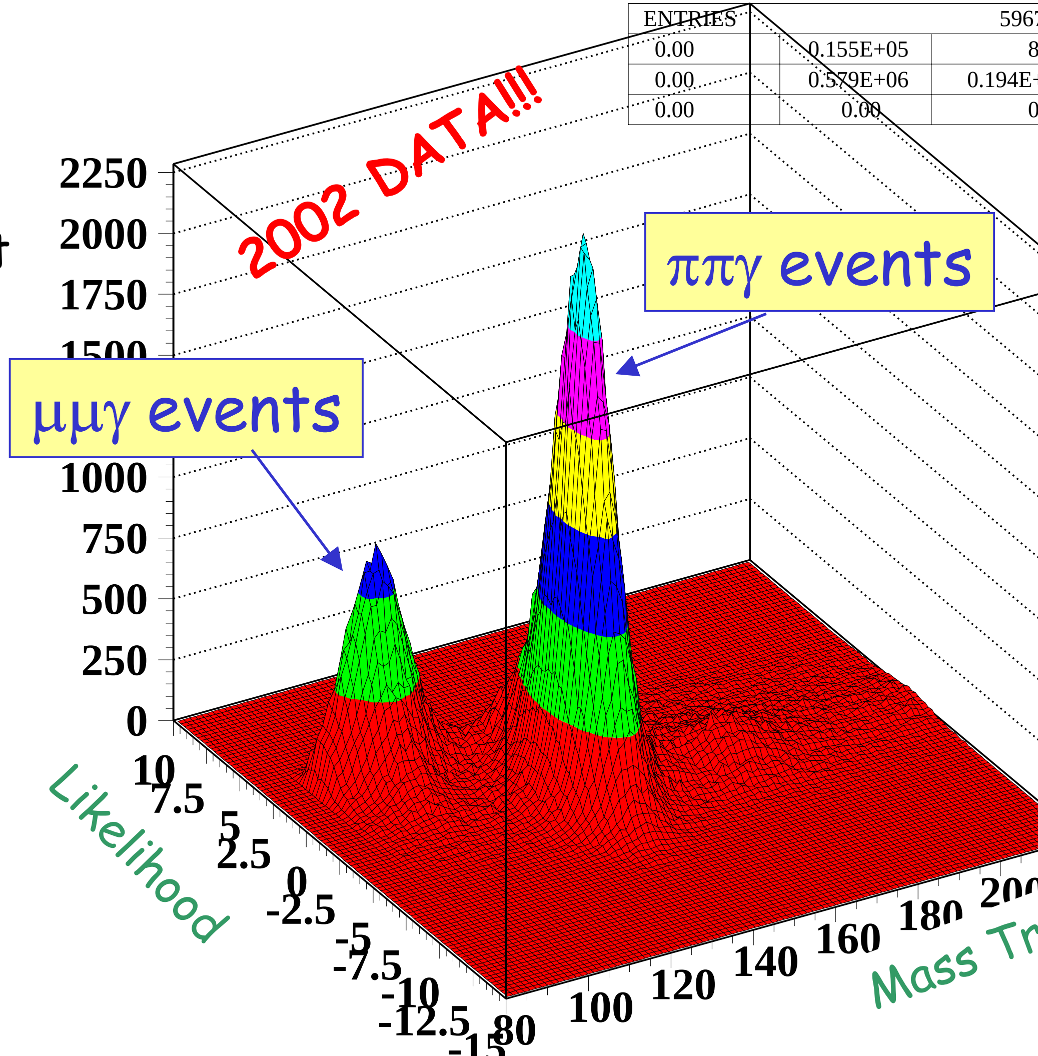
- ✓The energy region close to threshold, **$M_{\pi\pi}$ < 600 MeV**, is excluded by our selection cuts
- ✓ This region contributes **~20%** to a_μ^{had}
- ✓We use events at large photon angles to access lower $M_{\pi\pi}^2$ region. (Photon tagging will be possible in this case)
- ✓Check FSR parametrization (by looking to charge asymmetry)
- ✓ *This analysis is going on…*





(2) a_μ^{had} prospect: the direct measurement of $R_\gamma = \dfrac{e^+e^- \to \pi^+\pi^-\gamma}{e^+e^- \to \mu^+\mu^-\gamma}$

- ✓ We are also studying a direct measurement of R
- ✓ This method is independent from the luminosity estimate
- ✓ We are working on obtaining particle ID combining calorimetric and kinematically variables



Conclusion:

Summary:

- We have presented the first precise measurement of hadronic cross section using radiative return at KLOE

- Our result is in agreement with CMD2, therefore confirming the existing discrepancy bewteen SM and BNL result on $(g-2)_\mu$

Ongoing activities

- Large angle photon analysis: to study the low $M_{\pi\pi}^2$ region and measure the asymmetry to check the FSR results

- The direct measurement of $R = \sigma(e^+e^- \to \pi^+\pi^-\gamma)/\sigma(e^+e^- \to \mu^+\mu^-\gamma)$