Report on $\sigma(e^+e^-\rightarrow\text{hadrons})$

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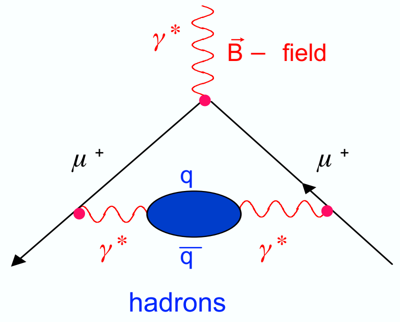
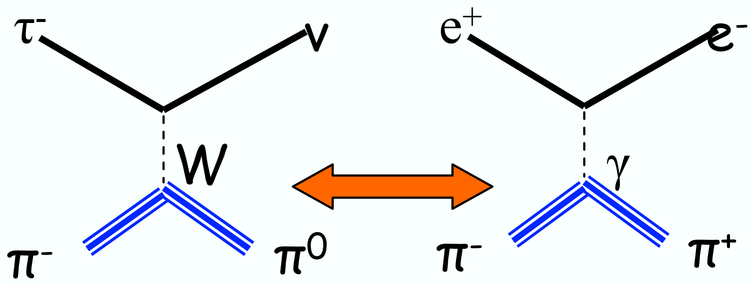
1. The significance of σ(hadrons) on a_μ, E. De Rafael
2. Obtaining $\sigma_{\text{had}}(s')$ at fixed s, H. Czyz
3. Update from CMD-2. A. Sibidanov
4. Results from Babar, E. Solodov
5. First results from KLOE, S. Mueller
6. What KLOE can do at DAFNE2, A. Denig

EW Test : a_μ measurement

- Anomalous Muon Magnetic Moment a_μ receives contributions from
  - QED 11658470.35 ± 0.28 10^{-10}
  - HAD,LO 685-709 ± 6 10^{-10}
  - LxL 8 ± 4 10^{-10}
  - WEAK 15.4 ± 0.2 10^{-10}

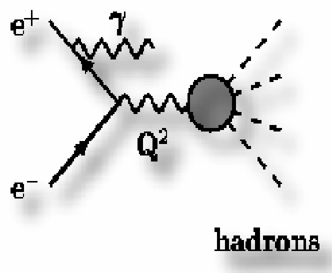


- HAD,LO obtained from data
  - $a_\mu^{had,LO} = \int_{4m_\pi^2} \sigma_{had}(s)\, K(s) ds$ main contribution (60%) from the ρ region
  - Assuming CVC and Isospin Symmetry, $\sigma_{had}(s)$ can be derived also from τ

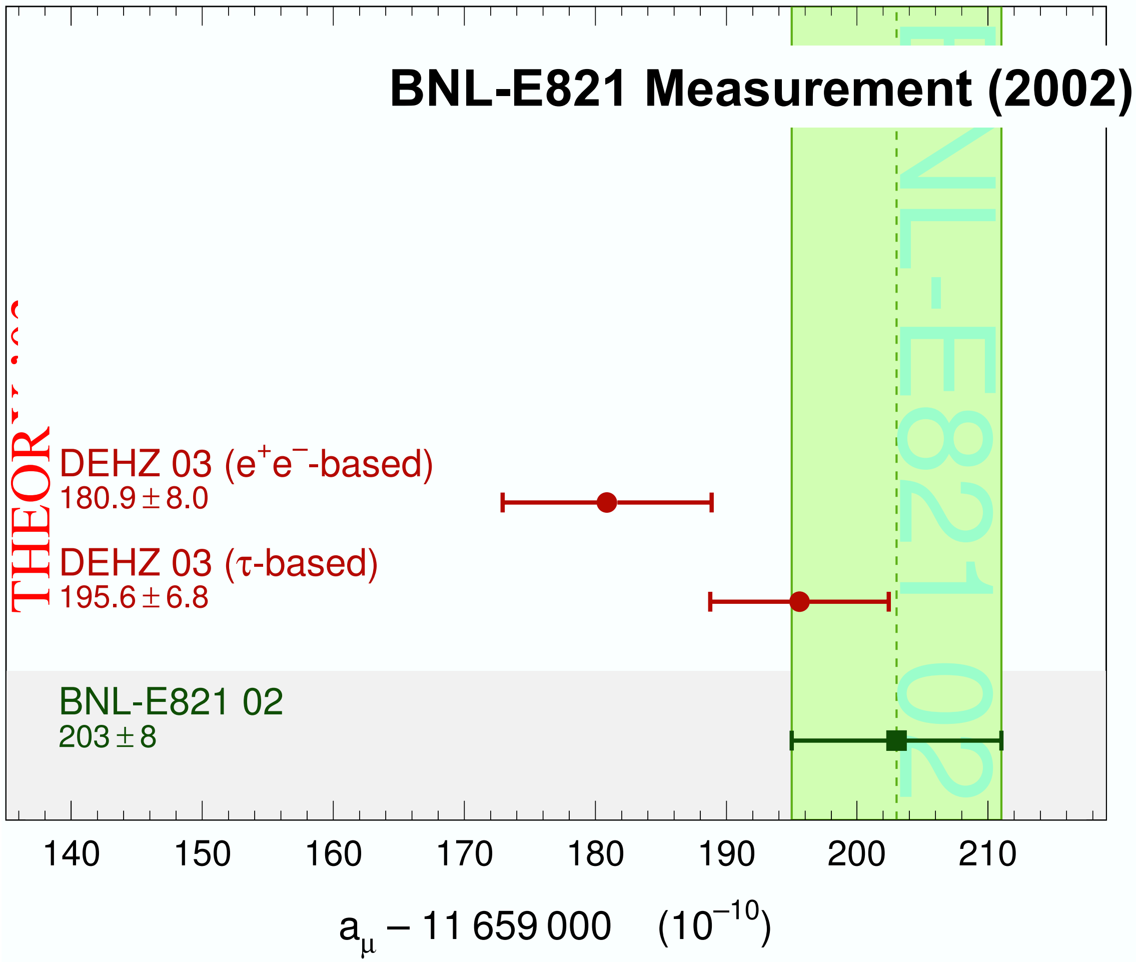


- KLOE can measure $\sigma_{had}(s)$ via radiative return.

  At fixed beam energy, the ISR reduces the effective energy



Status : a_μ measurement

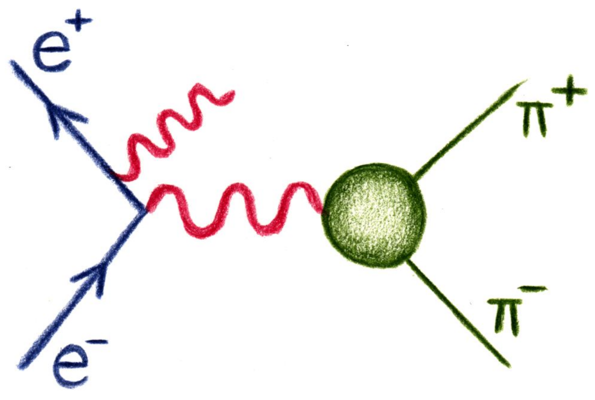


Evaluation using only e^+e^- - Data has changed 08-03 after reanalysis of CMD-2 data: 2 σ - Deviation

Evaluation using only τ – Data: Agreement with Exp.

$\sigma(e^+e^- \to \pi^+\pi^-)$ with ISR:

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



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

This method is a **complementary approach** to the standard energy scan.

It requires precise calculations of the radiator ***H***.

➔ **EVA + Phokhara MC Generator**

(S. Binner, J.H. Kühn, K. Melnikov, Phys. Lett. B 459, 1999)

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

$M_{\pi\pi}^2$- Spectrum:

140 pb^{-1} of 2001 data were analyzed according to the items discussed.

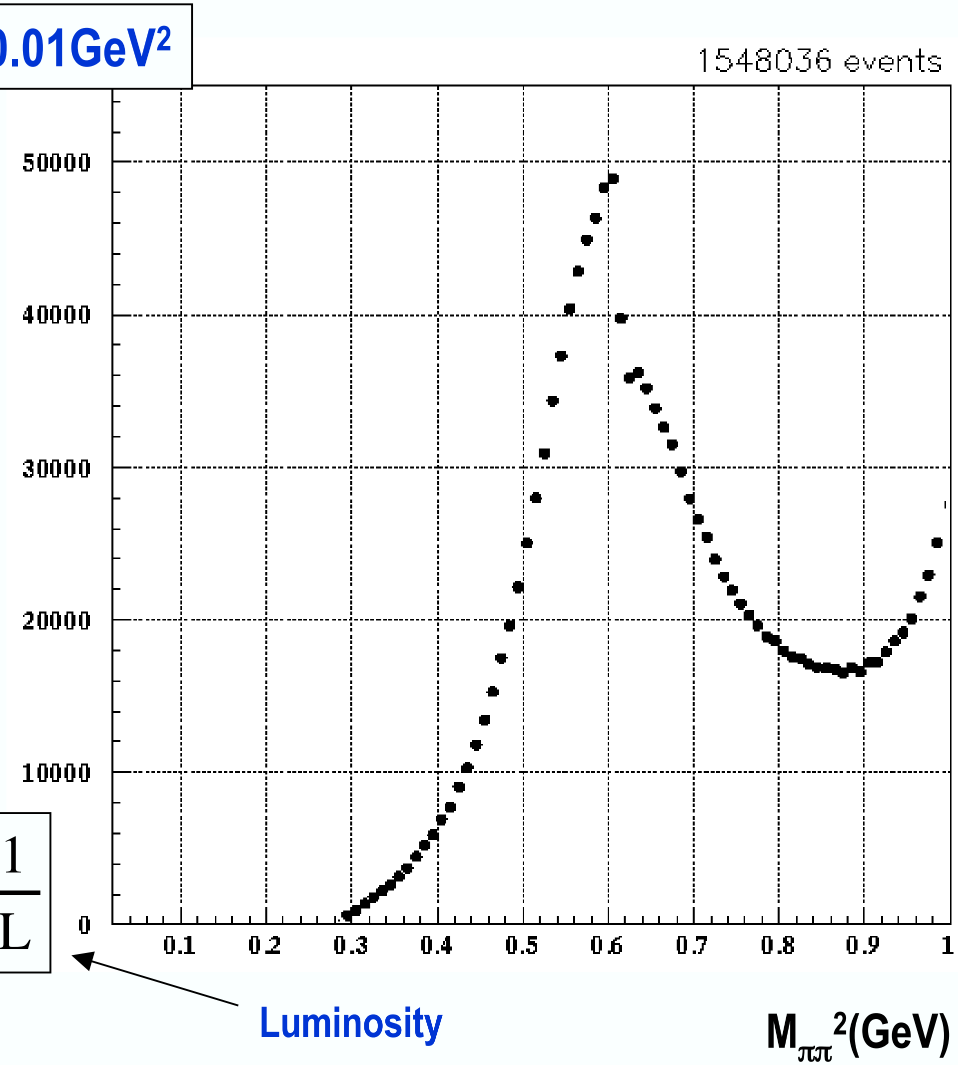
After selection: **1 500 000 events**
(11000 evts/pb^{-1})

statistical error/bin $< 1\%$
for $M_{\pi\pi}^2 > 0.45$ GeV^2

Signal, Background

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

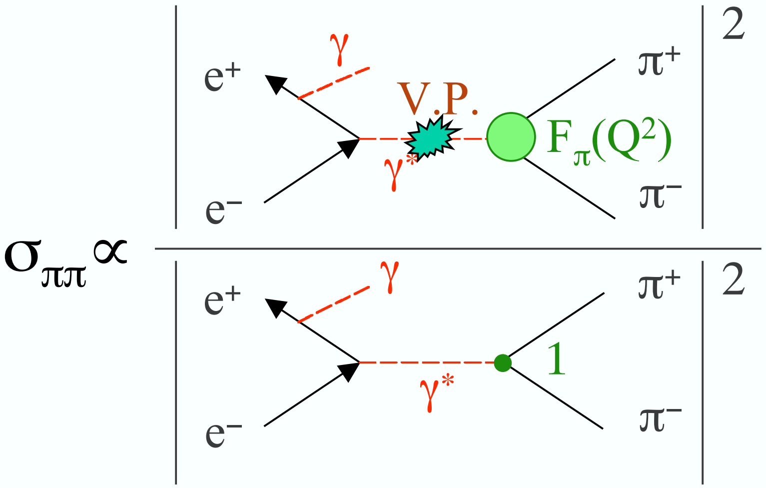
Selection efficiency, Luminosity

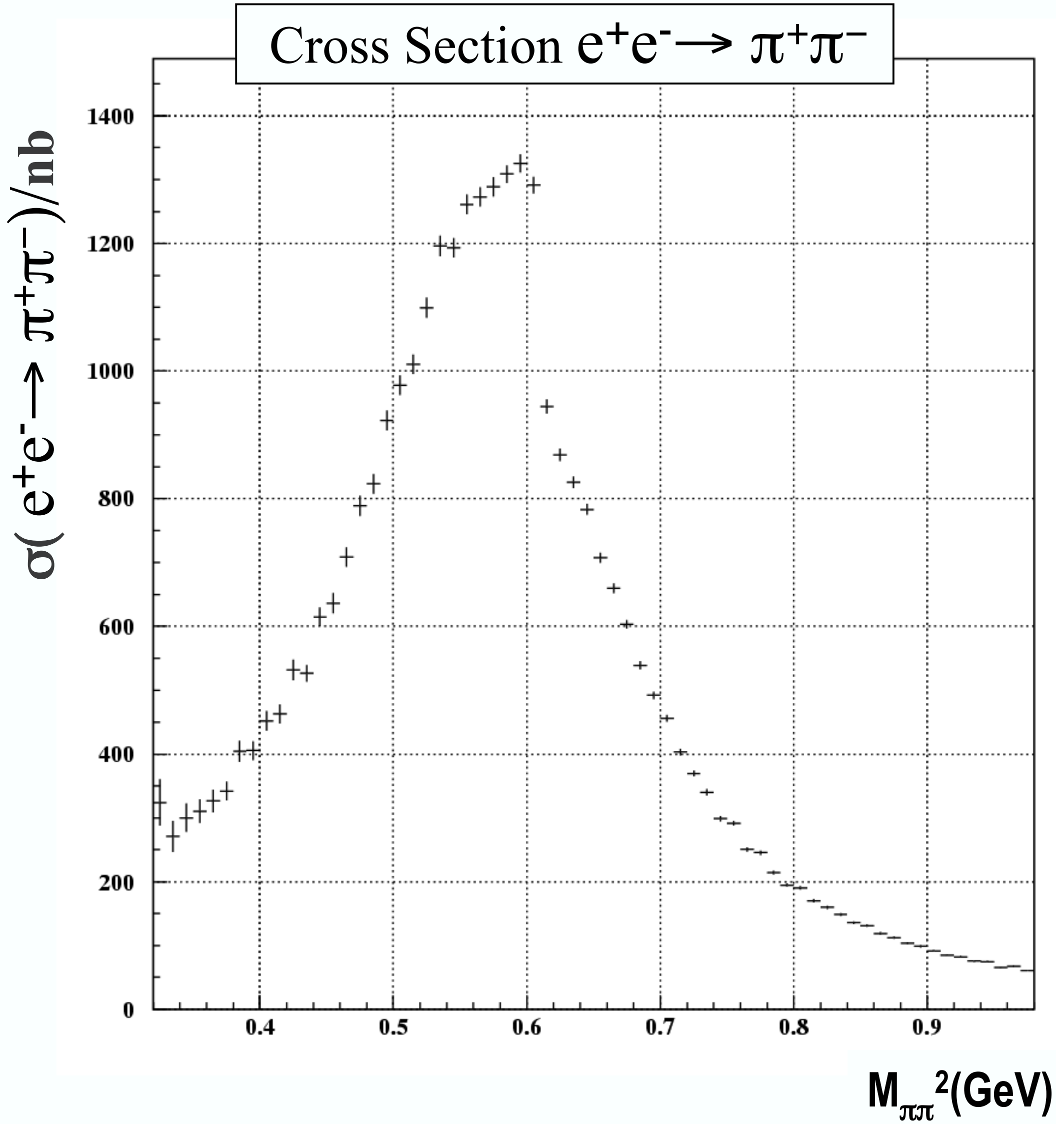


Acceptance: $\theta_{\pi\pi}<15^o$ ($\theta_{\pi\pi}>165^o$), $50^o<\theta_\pi<130^o$, $E_\Sigma>10$ MeV

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

After dividing by the radiation function $H(M_{\pi\pi}^2)$, one gets the cross section **$\sigma(e^+e^- \rightarrow \pi^+\pi^-)$** in bins of **$M_{\pi\pi}^2$**

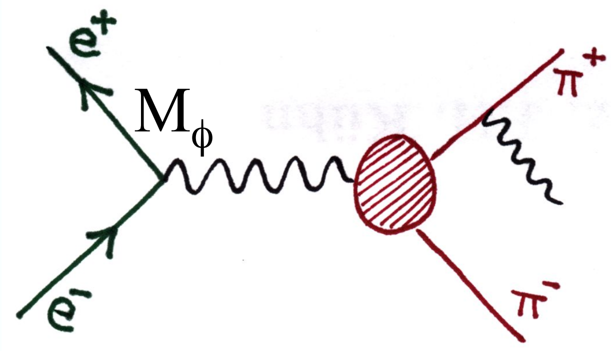




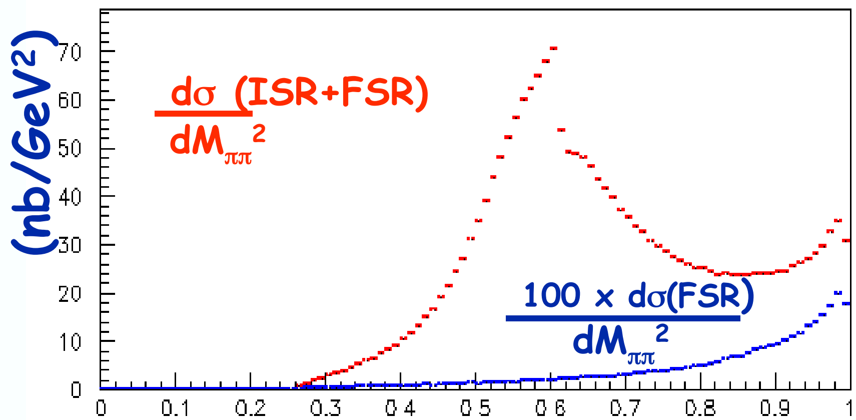
Rad. corrections: FSR (LO)

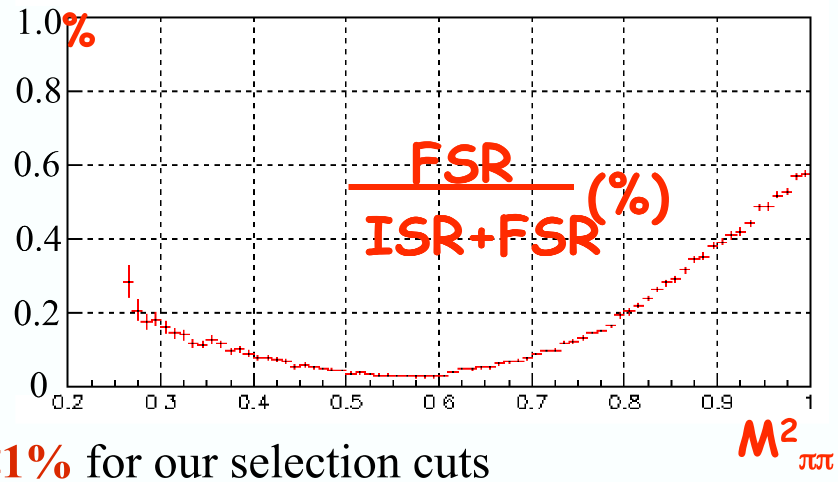
The cross section has to be corrected with respect to Final State Radiation (FSR).

At LO final state radiation, there is no initial state radiation and the e^+ and the e^- collide at the energy M_ϕ:



This process has been studied with the **EVA** MC program:

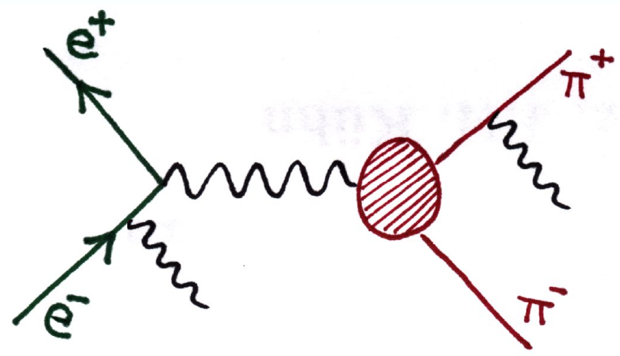


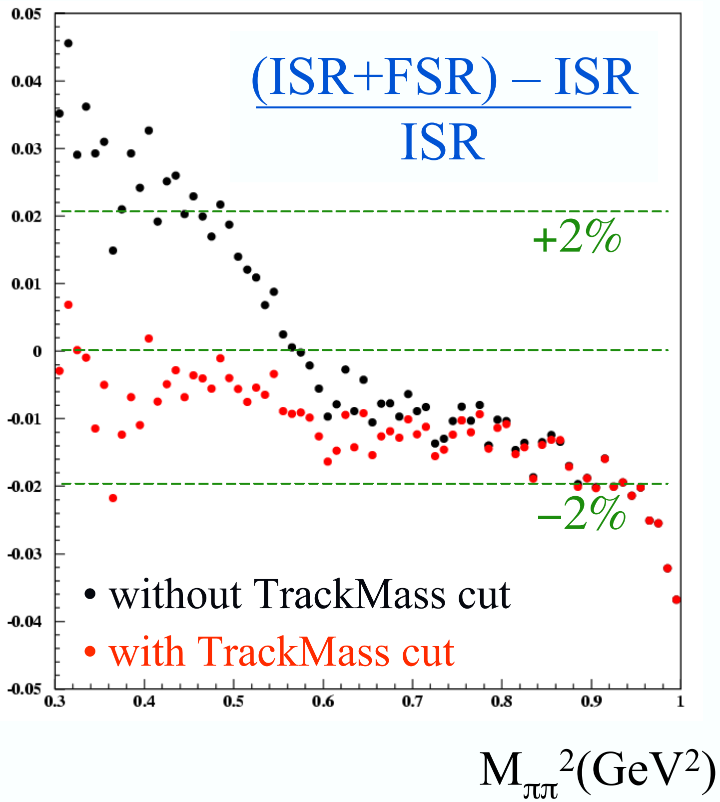


Contribution of **FSR(lo) <1%** for our selection cuts

Rad. corr.: FSR (LO+NLO)

Just recently we got a new version of Phokhara which also simulates events with the presence of
1 ISR- and 1 FSR-photon:





A preliminary check shows that
the FSR contribution is at most 1-2%.
As of now, we *do not* apply any correction for FSR and add a contribution of 2% to the systematic error

Preliminary value for a_μ^{had}

- We have integrated the bare cross section in the same region covered by CMD2 ($0.37<Q^2<0.95$):

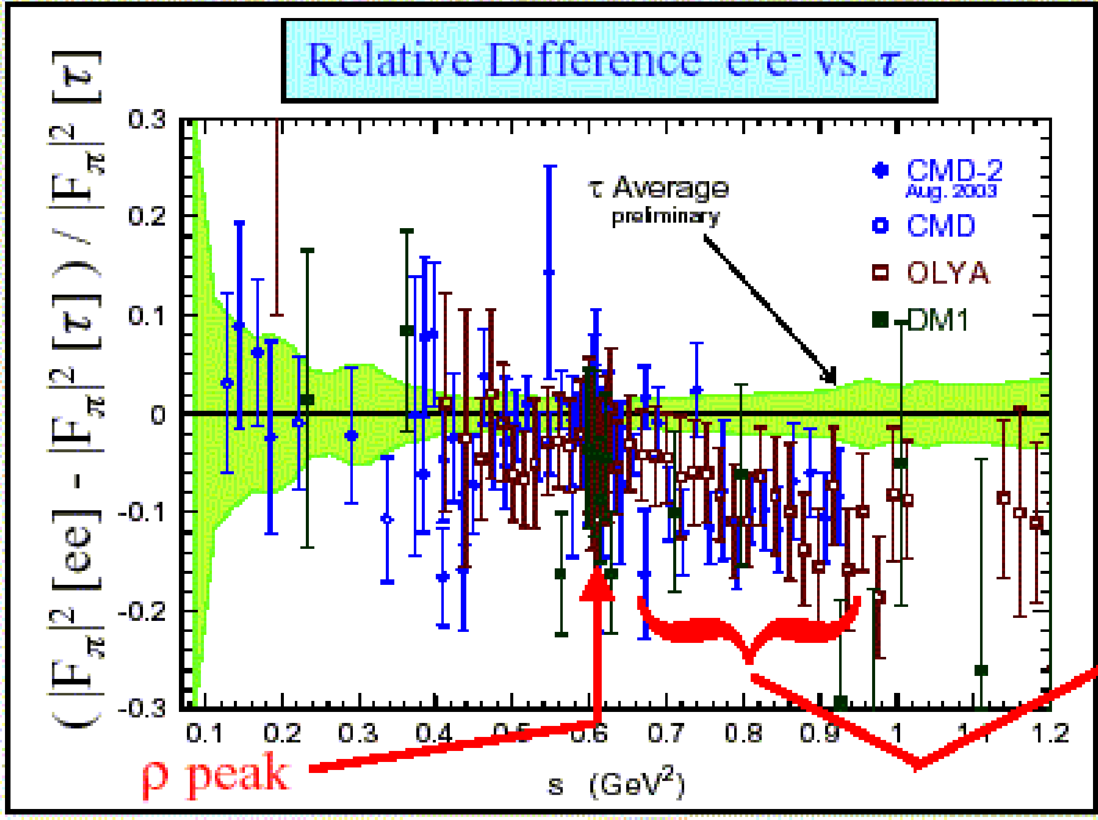
  $a_\mu^{had,LO} \times 10^{10}(0.37:0.95) = 374.1 \pm 1.1_{stat} \pm 5.2_{syst} \pm 3.0_{theo}\ (^{+7.5}_{-0.}\ \mathrm{FSR})$

- CMD-2 result (20-Aug-2003) is :

  $a_\mu^{had,LO} \times 10^{10}(0.37:0.95) = 378.6 \pm 2.7_{stat} \pm 2.3_{syst+theo}$

- The two numbers are compatible, given the systematic error. We are studying the *FSR corrections*

e^+e^- - versus τ - Data



In a large energy range above the ρ-peak τ-data is systematically higher ≈ 10% … 15% !

Q^2/GeV^2	KLOE a_μ^{had}	CMD2* a_μ^{had}
0.37:0.6	$256.2 \pm 4.1\ (^{+5.1}_{-0})_{FSR}$	256.4 ± 2.5
0.6:0.92	$117.9 \pm 2.1\ (^{+2.3}_{-0})_{FSR}$	123.3 ± 1.8

KLOE data confirm the discrepancy between e^+e^- and τ data in the region above the ρ peak

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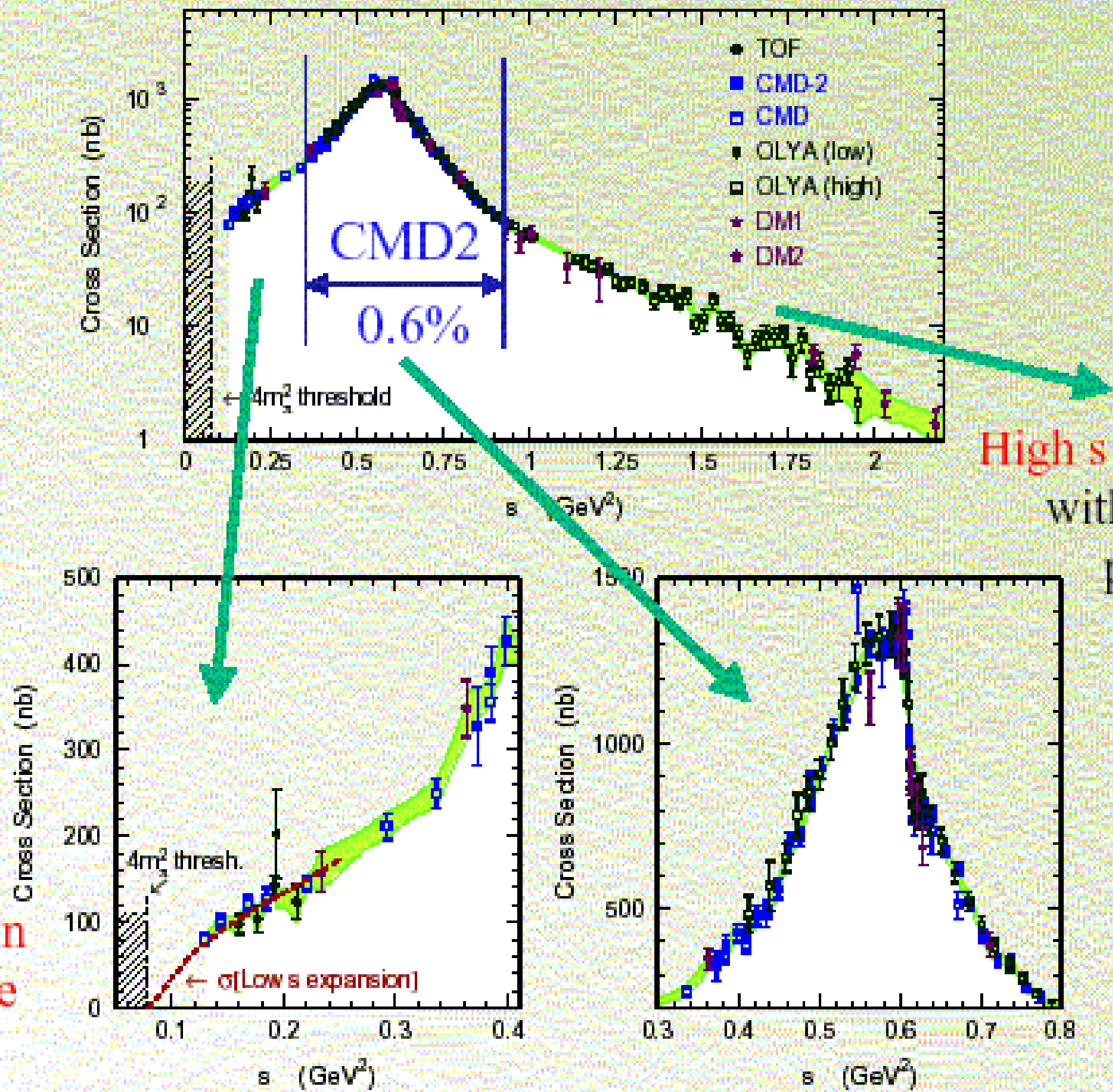
Exp. Situation: 2 Pions



High s region measured with relatively poor precision (~5%)

Measure low s region in large photon angle analysis with KLOE

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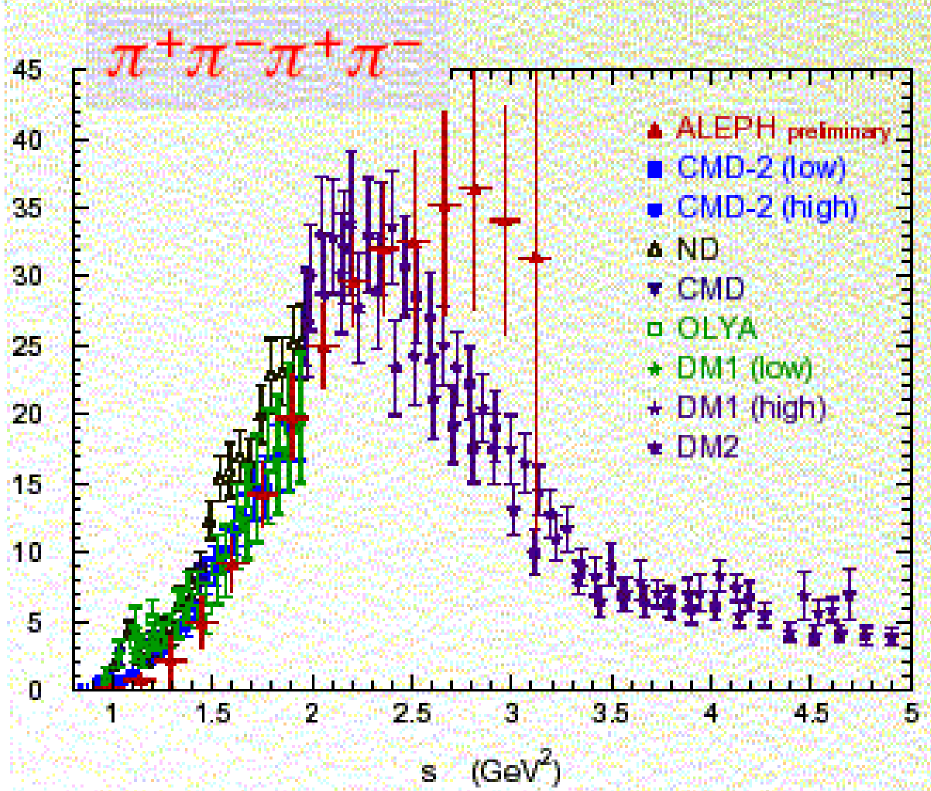
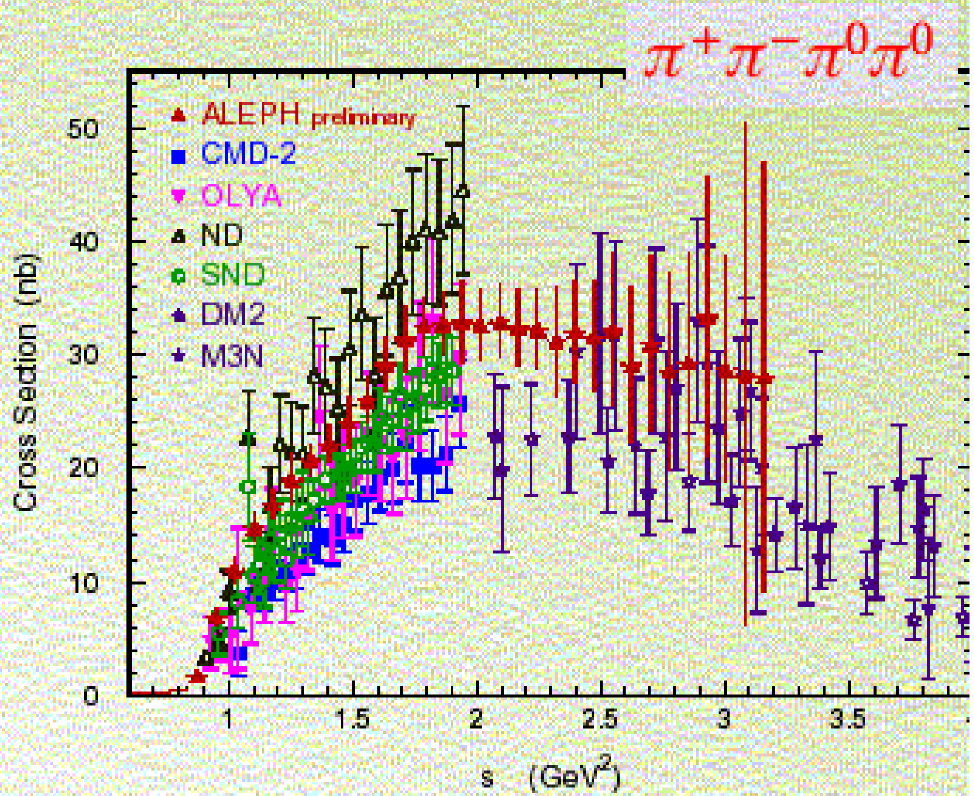
Exp. Situation: 4 Pions

ISR - Analysis at BABAR, Result to be published soon, see E. Solodov's talk





Very large errors of > 10%, in the case of $\pi^+\pi^-\pi^0\pi^0$ up to 50%

Overall normalization errors visible between different experiments

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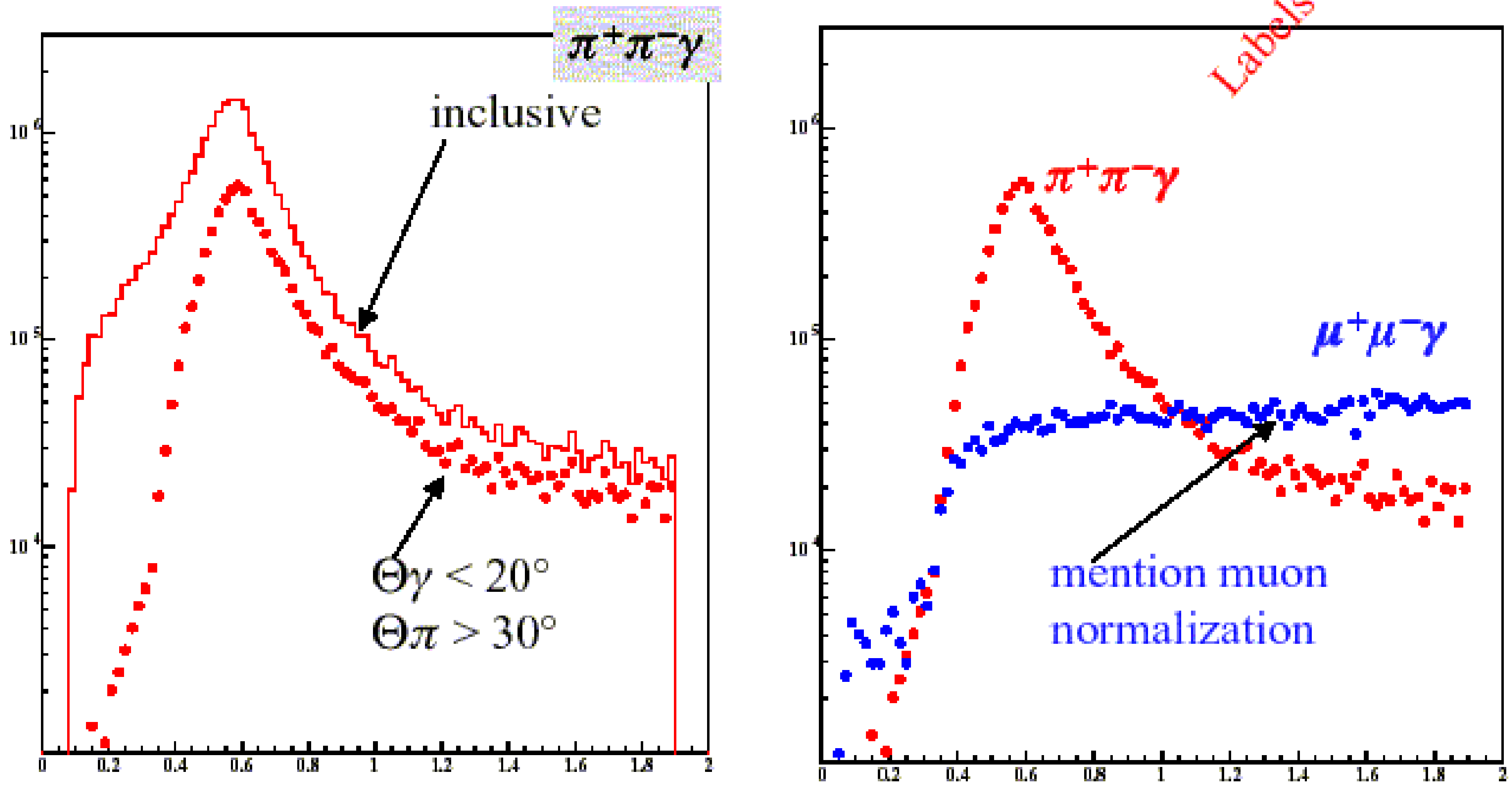
Energy Range 1 – 2 GeV

- The energy range 1 - 2 GeV is crucial for an improvement on the theoretical knowledge of a_μ
- 2 - Pion - Channel > 1GeV is now giving the largest contribution to the error of a_μ^{hadr}
- 3 - Pion - and 4 - Pion - Channels are very poorly known and contribute each to about 7% to total error
- Future Measurements from:
  - BABAR: Rad. Return all channels
  - VEPP-2000: Energy Scan all channels
  - DAΦNE - 2 ??? ???

… unclear what are the plans at BELLE/CLEO-c corresp. the Rad. Return

Radiative Return @ $\sqrt{s} = 2$ GeV

Number of events for 100pb-1



Conclusion & What Next ?

- KLOE has shown the feasability of the Radiative Return Method to perform a high precision measurements of the hadronic cross section $\sigma(e^+e^- \to \pi^+\pi^-)$
- Preliminary KLOE data are consistent with data from CMD-2
- New experimental value for a_μ from E821 expected soon (factor √2 improvement ?)
- What can be done on the theoretical side in order to improve?

Cross Section Measurements at
higher energies and higher multiplicites

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Conclusion

- The anomalous magnetic moment a_μ shows a 2σ deviation between theory and experiment if e^+e^- data are used for the hadronic contribution

- For a future improved evaluation of a_μ, the measurement of the hadronic cross section in the energy range 1 - 2 GeV with a percision $O(1\%)$ is of great importance $(\delta a_\mu^{hadr} \approx 3x10^{-10})$

- The feasibitity of the Radiative Return has been shown by the actual new KLOE data for the 2-Pion-channel for $\sqrt{s}=m_\phi$

- At DAΦNE -2 the radiative return is an option if the c.m.s. - energy of the machine cannot be tuned; $Ldt \approx O(1\text{fb}^{-1})$ are required for higher multiplicity hadronic channels.