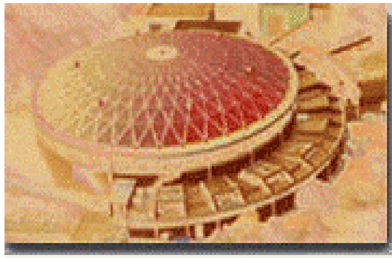

KLOE-Measurement of the Hadronic Cross Section and Perspectives at DAΦNE-2

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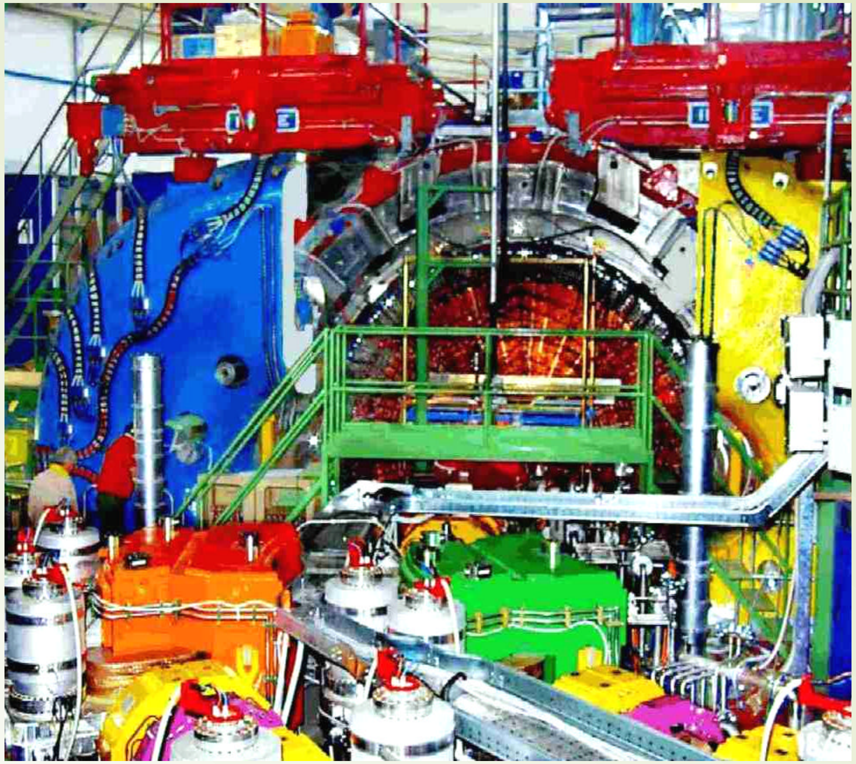
Universität Karlsruhe

KLOE in DAΦNE *Hall*



Outline:

- ❑ Motivation & Status of a_μ
  Interpretation of KLOE - Results
- ❑ Future Perspectives for DAΦNE 2

Muon - Anomaly

Motivation: Determination of Hadronic Vacuum Polarization
= High Precision Test of the Standard Model:

- Anomalous magnetic moment of the muon $a_\mu = (g-2)_\mu$
- Running Fine Structure Constant at Z^0-mass $\alpha_{QED}(M_Z)$

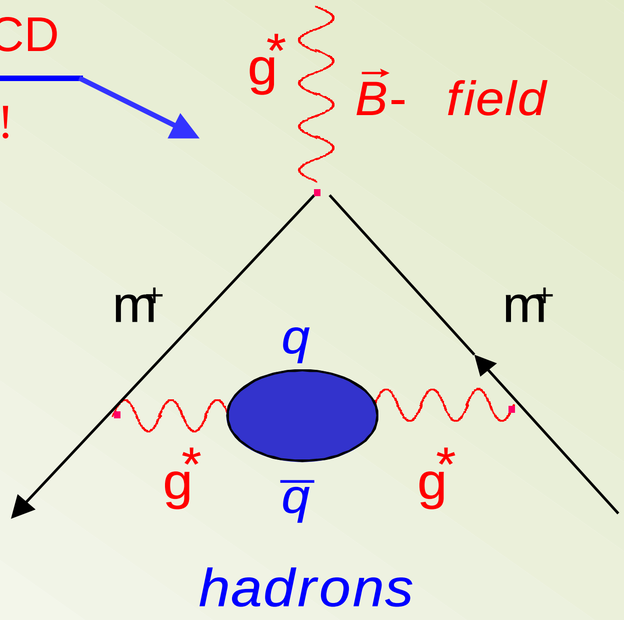
2nd largest contrib., cannot be calculated in pQCD

Error is dominating total Error of a_μ !

$$a_\mu^{theor} = a_\mu^{QED} + a_\mu^{had} + a_\mu^{weak} + a_\mu^{new}$$

$$a_\mu^{had} \quad \int_{4m_\pi^2}^{\infty} ds\, \sigma_{hadr}(s)\, K(s)$$

$$\sigma_{hadr}(e^+e^- \to \gamma^* \to q\,\bar{q} \to hadrons)$$



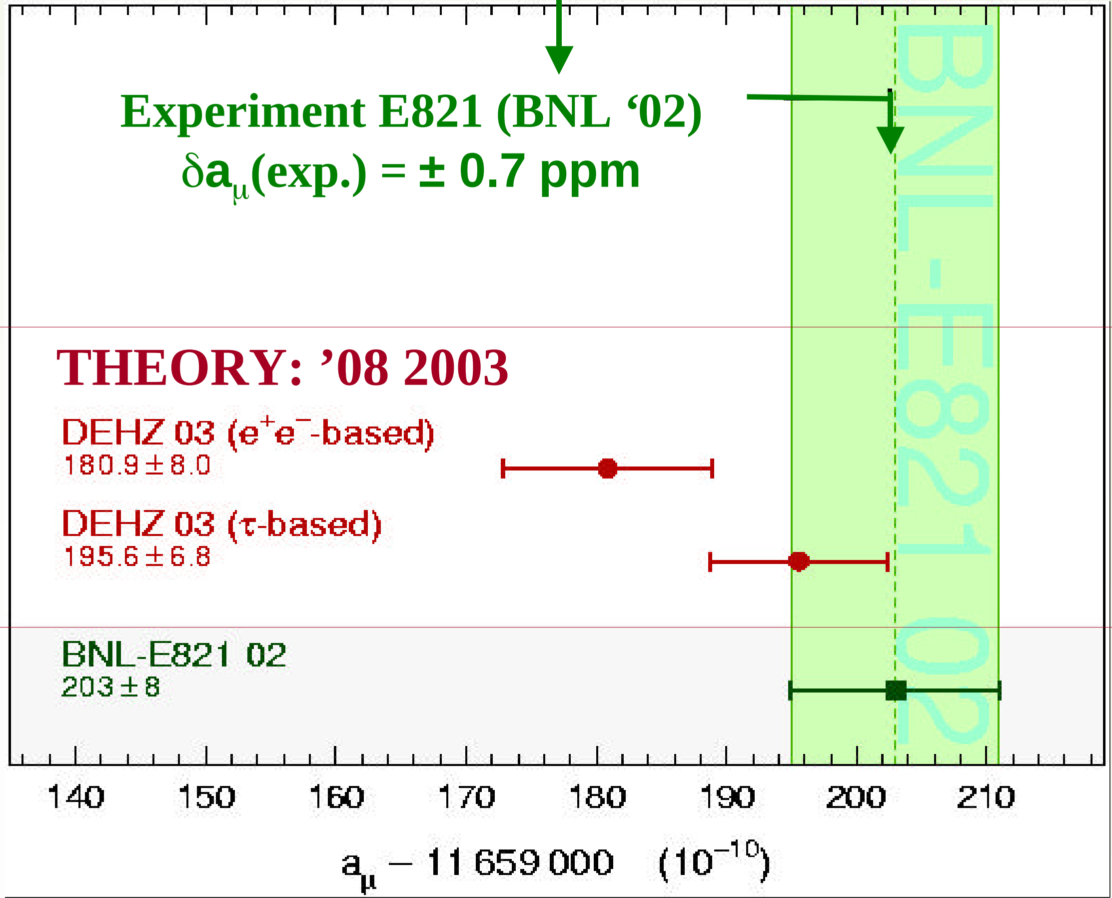
INPUT

a) hadronic Electron-Positron-Cross Section Data

b) hadronic τ- Decays, via CVC-Theorem & Isospin Rotation (Isospin Breaking Correct.)

Status: Muon - Anomaly

Compare Experimental Value with Theory - Prediction for Muon-Anomaly



New Data Input from:

a) CMD-2 (Novosibirsk) in $\pi^+\pi^-$ Channel: 0.6% Precision < 1 GeV reanalysis of their data publ. '08/03

b) τ-Data from ALEPH, OPAL, CLEO

} Theory Evaluation using only e^+e^- - Data 2 σ - Deviation

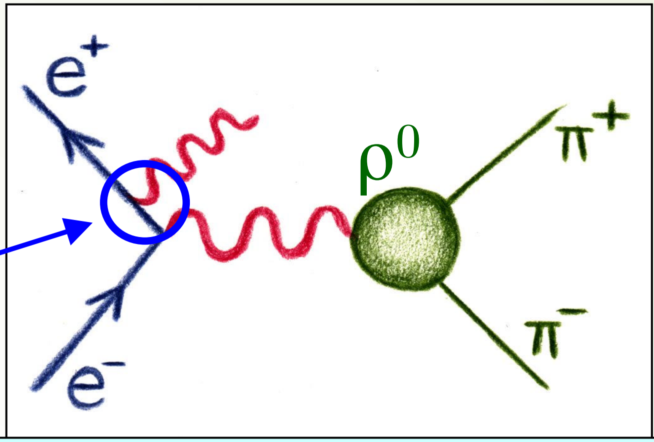
} Theory Evaluation using only τ – Data: Agreement with Exp.

Radiative Return

- Standard Method for Cross Section Measurement is the Energy Scan, i.e. the systematic variation of the c.m.s.-energy of the accelerator
- DAΦNE is a φ- factory and therefore designed for a fixed c.m.s.-energy: $\sqrt{s} = m_\varphi = 1.019$ MeV; a variation of the energy is not foreseen in near future

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

ISR



"Radiative Return" to ρ-Resonance:

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

Cross Section as a Function of the 2-Pion invariant Mass $M_{\pi\pi}$

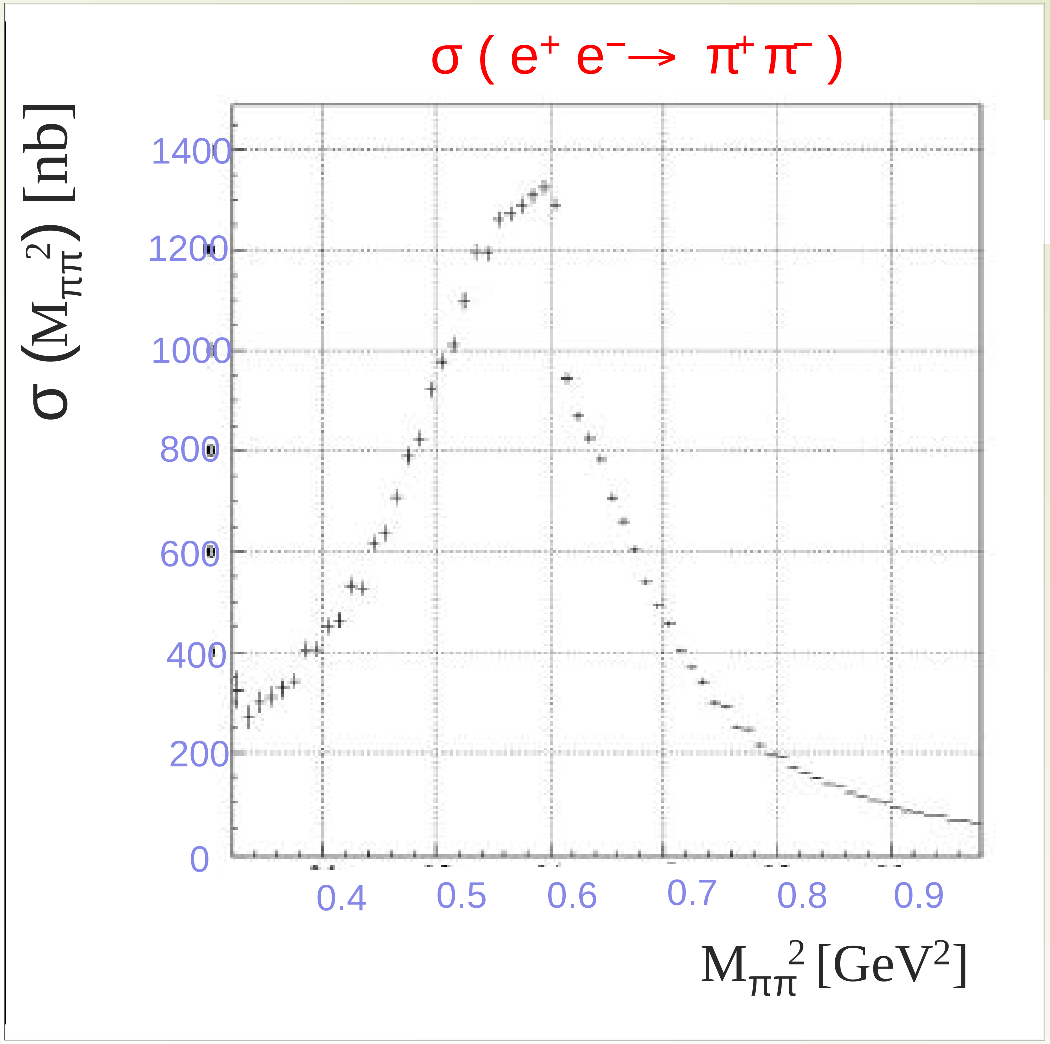
$$\frac{d\sigma(e^+ e^- \to \pi^+ \pi^- \gamma)}{dM_{\pi\pi}}$$

MC-Generator PHOKHARA = NLO
J. Kühn, H. Czyz, G. Rodrigo
Radiator-Function H(s)

$$M_{\pi\pi} \frac{d\sigma_{\pi\pi\gamma}}{dM_{\pi\pi}} = \sigma_{\pi\pi}(s) \times H(s)$$

KLOE Result $\sigma(e^+e^- \rightarrow \pi^+\pi^-)$

see Talk Stefan Müller



Systematic Errors:

- 1.4% Experiment
- 0.8% Rad. Corrections
- 2% error on FSR

$a_\mu \times 10^{10}$

$$a_\mu^{\pi\pi} \int_{0.37}^{0.93} ds\, \sigma(e^+e^- \to \pi^+\pi^-)\; K(s)$$

In order to see how KLOE data compares with existing e^+e^- data from CMD-2 we have integrated the bare cross section according to the dispersion integral in the energy range $0.37 < M_{\pi\pi}^2 < 0.93\ \mathrm{GeV}^2$

PRELIMINARY

KLOE:

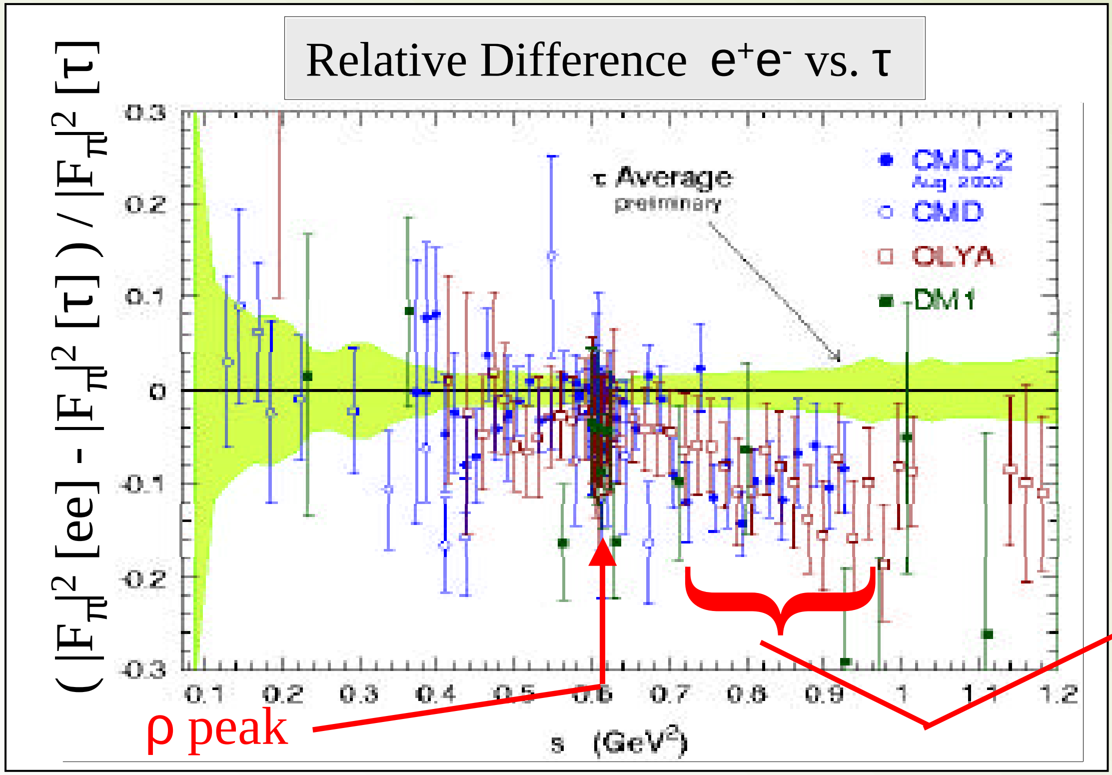
$a_\mu^{\pi\pi} = 374.1 \pm 1.1_{stat} \pm 5.2_{syst} \pm 3.0_{theo} \left({}^{+7.5}_{-0.}\right)_{FSR}$

CMD-2:

$a_\mu^{\pi\pi} = 378.6 \pm 2.7_{stat} \pm 2.3_{syst}$

The two numbers are compatible given the systematic error,
but FSR corrections must be refined with the new version of Phokhara

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

Conclusion & What Next ?

- KLOE has shown the feasability of the Radiative Return to perform a high precision measurements of the hadronic cross section $\sigma(e^+e^- \rightarrow \pi^+\pi^-)$

- Preliminary KLOE data are consistent with CMD-2; τ-data do not agree with e^+e^- - data at large values of $M_{\pi\pi}$?!

- New experimental value for a_μ from E821 expected soon What can be done on the theoretical side in order to improve?

1) Understand Difference between e^+e^- and τ -data
2) Cross Section Measurements at Higher Energies and Higher Multiplicites

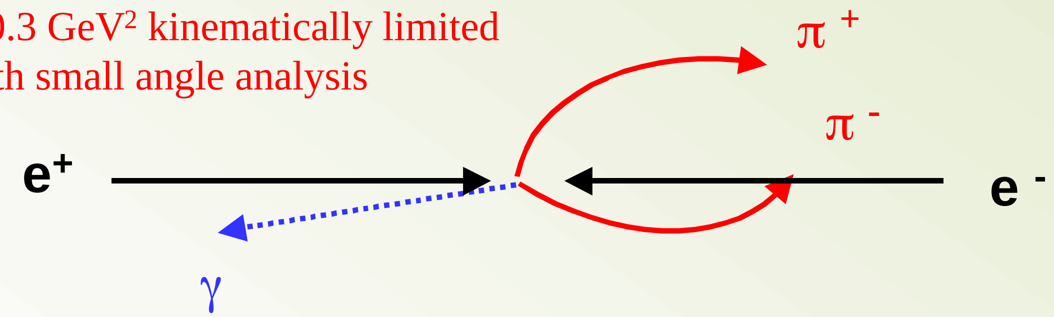
KLOE - Perspectives at DAΦNE-2

DAΦNE-2

Option 1: $\sqrt{s} = m_\varphi$, high luminosity

- Use high statistics for an improved Radiative Return Measurement $\pi^+\pi^-$
- Perform Large Angle Analysis in order to measure the 2-Pion-cross section down to the $(2m_\pi)$ - threshold (Photon - Tagging!)

< 0.3 GeV² kinematically limited with small angle analysis

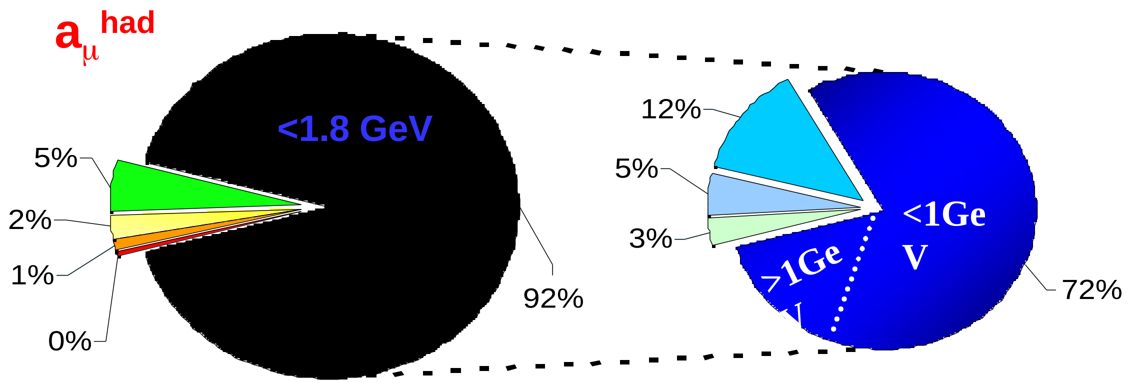


- Run partly off-resonance to study φ background

Option 2: $\sqrt{s} \neq m_\varphi$
$1 \leq \sqrt{s} \leq 2$ GeV

… the rest of this talk …

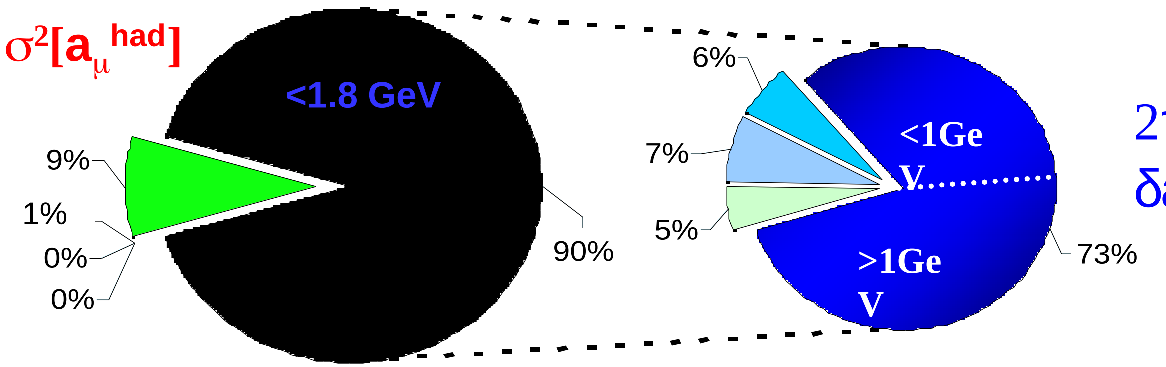
Hadronic Contributions a_μ^{hadr}



2π contribution a_μ^{had} :

62% $\sqrt{s}$ < 1GeV

10% $\sqrt{s}$ > 1 GeV



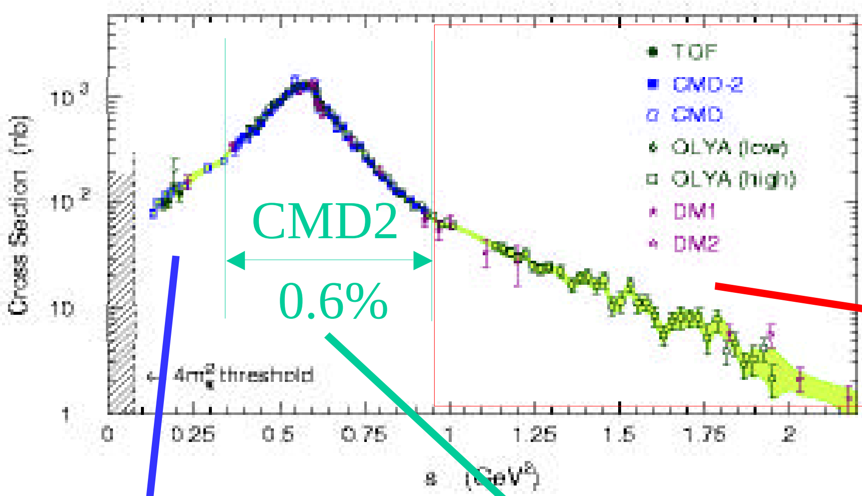
2π contribution δa_μ^{had} :

28% $\sqrt{s}$ < 1GeV

45% $\sqrt{s}$ > 1 GeV

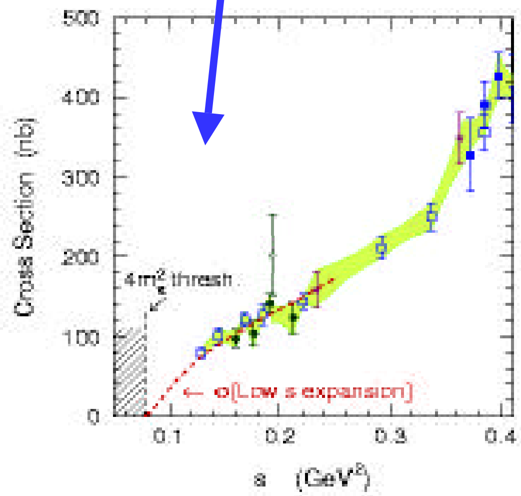
Calculations based on hep-ph/0308213

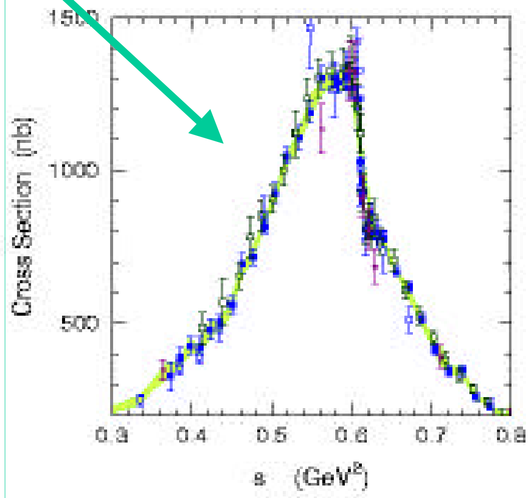
Exp. Situation: 2 Pions



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

Measure low s region in large photon angle analysis with KLOE





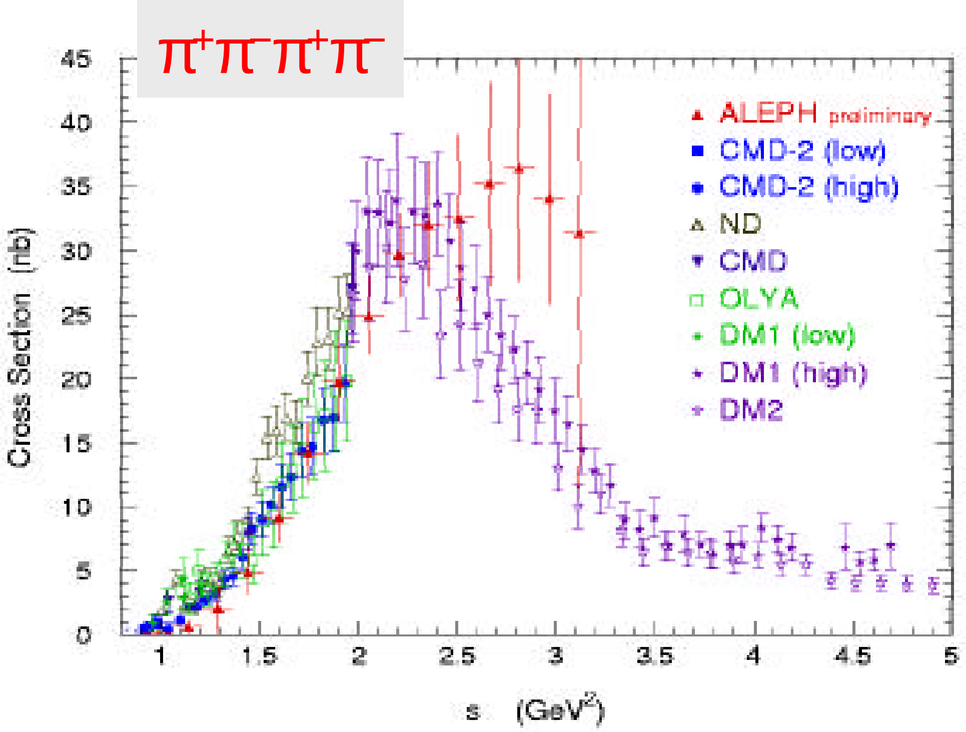
ρ peak region covered by:

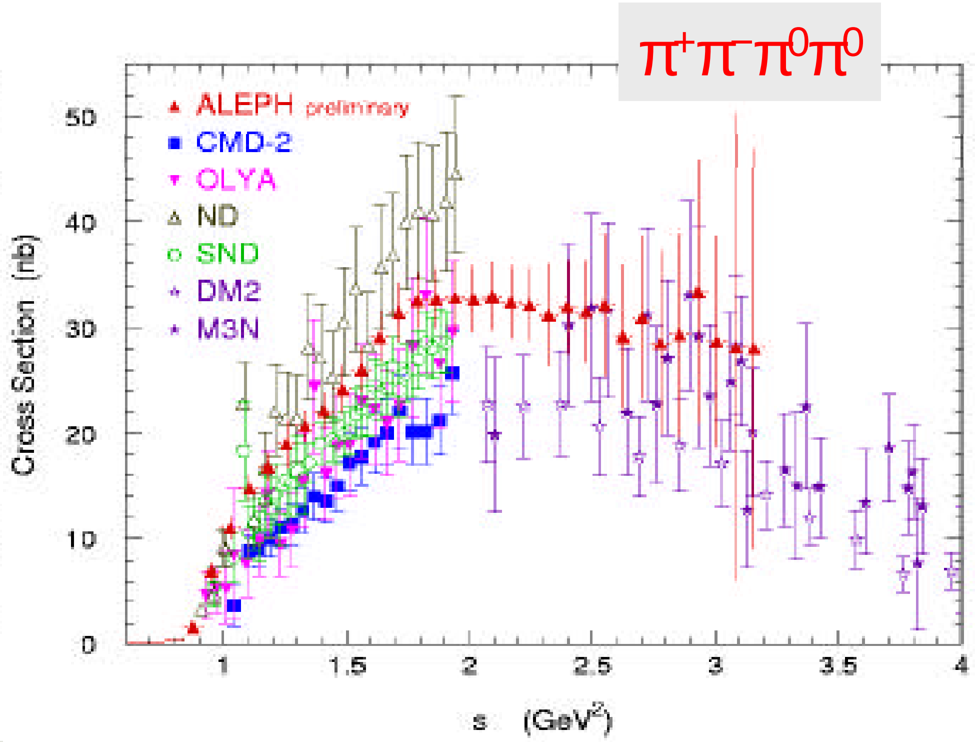
- CMD-2
- τ-data
- KLOE

very high precision 0.6% CMD-2

Exp. Situation: 4 Pions

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





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

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 - Channel and even much more 4 - Pion - Channel are poorly known and need to be measured > 1 GeV
- Actual / Future Measurements from:
  - BABAR: Rad. Return all channels
  - VEPP-2000: Energy Scan all channels
  - DAΦNE-2 *Energy Scan or Rad. Return ???*

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

Radiative Return vs. Energy Scan

Energy Scan seems the natural way of measuring hadronic cross sections, experience at DAΦNE has shown that the Radiative Return has to be considered as a complementary approach

Advantages:

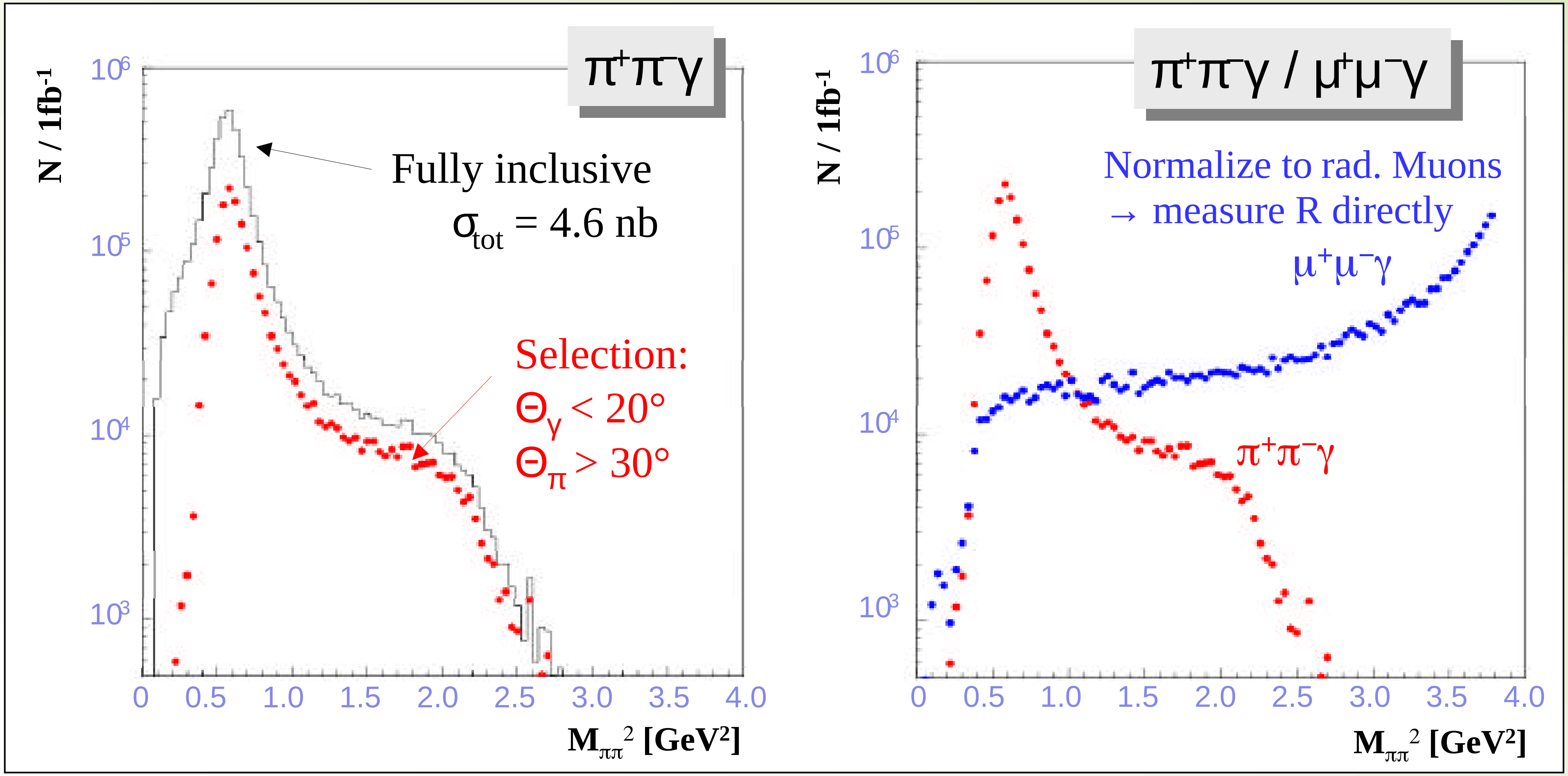
- Data comes as a by-product of the standard program of the machine
- Systematic errors from Luminosity, $\sqrt{s}$, rad. corrections... enter only once and do not have to be studied for each point of s

Disadvantages:

- Requires a precise theoretical calculation of the Radiator Function
- Requires good suppression (or under= standing) of Final State Radiation (FSR); the model of scalar QED used so far can be tested however by measuring the charge asymmetry
- Needs high integrated Luminosity; for 2-Pion-channel at DAΦNE-1 no problem, but might become critical for low hadr. cross-sections

Radiative Return 2πγ @ √ s = 2 GeV

- Preliminary MC Study with Event-Generator Phokhara vs 3.0
- Plotted are the Number of $\pi^+\pi^-\gamma$ events / 1 fb^{-1} (Bin width = 0.04GeV^2)



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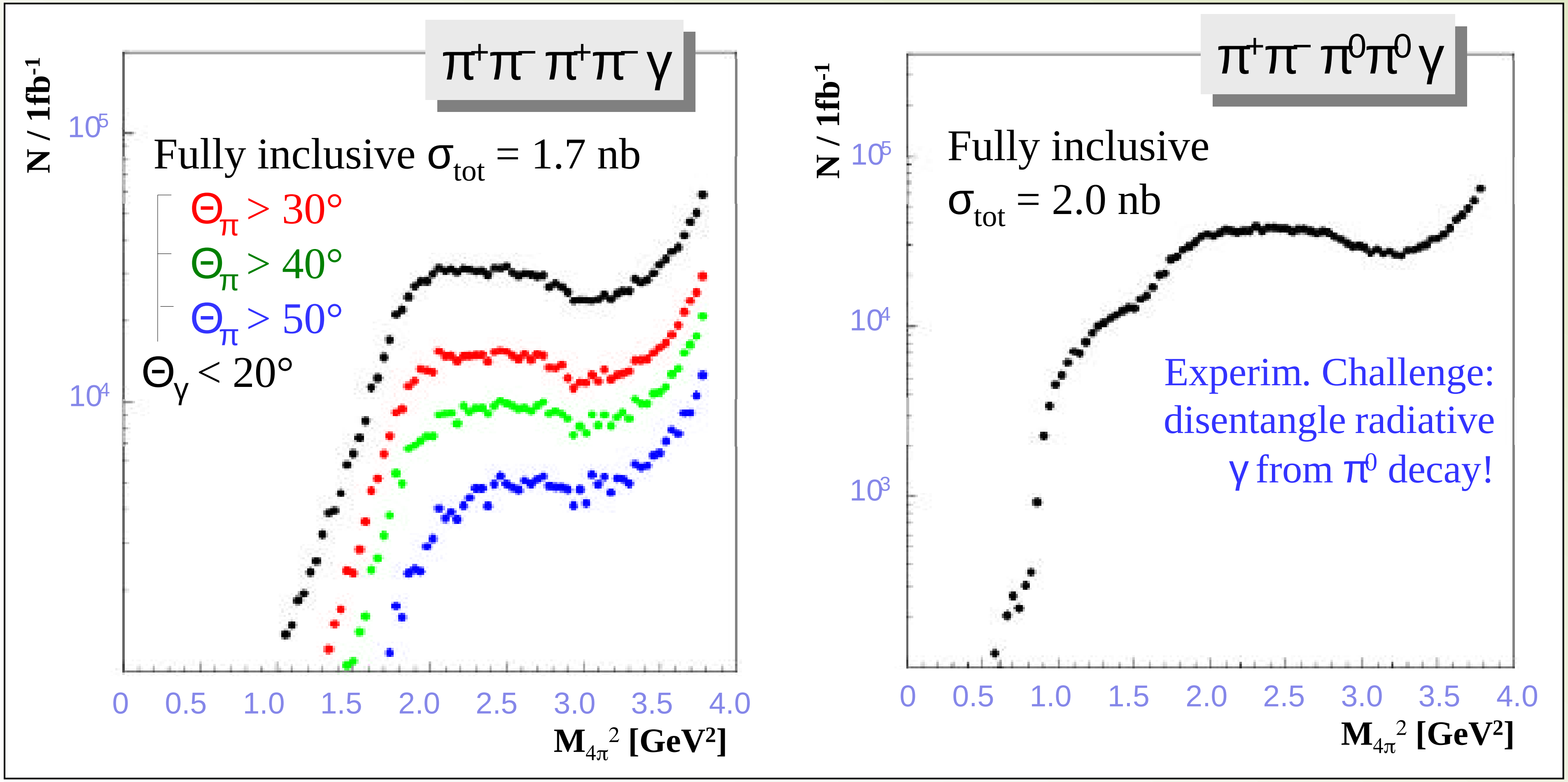

Radiative Return @ $\sqrt{s}$ = 2 GeV

- No background from resonant φ- decays like in DAΦNE-1
- FSR @ 2GeV much reduced with respect to DAΦNE-1

Background

- Integrated Luminosities > O(1 fb^{-1}) are mandatory
- Normalization to Muons with advantages from experimental and theoretical point of view

Normalization

Analysis-Items:

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

Invariant Mass

High resolution KLOE-DC (δp/p)≈0.4% ideal for M_{hadr} measurement of charged tracks; for neutral pions due to limited Energy Resolution of the EmC (δE/E=5.7%/√E(GeV) smeared

Selections-Efficiency + Acceptance

To understand Selection Efficiencies and Acceptances a detailed MC study is necessary ; no a-priori problems visible. Use experience obtained so far!

Items to be studied for instance:

- understand π^0 reconstruction in $\pi^+\pi^-\pi^0\pi^0\gamma$
- understand selection of 4 charged pions for $\pi^+\pi^-\pi^+\pi^-\gamma$

Conclusion

- Right now 2.0 σ deviation between theory and experiment for the anomalous magnetic moment of the muon → needs clarification !

- For a future improved evaluation of a_μ the measurement of the hadronic cross section in the energy range 1 - 2 GeV with a precision O (1%) is of great importance:
  Goal to reach $\delta a_\mu^{hadr} \approx 2...3 \times 10^{-10}$

- 2 - Pion - Channel < 1 GeV still very interesting in order to understand the e^+e^- - τ - puzzle (energy scan as cross check?)

- At DAΦNE - 2 the radiative return seems a feasable option if the energy of the machine cannot be tuned for an energy scan

Work supported by:

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Emmy – Noether - Programm

Perspectives for α(m_Z^2)

2π	3π (+ω,φ)	4π	> 4π (+KK)	1.8 - 3.7	3.7 - 5 (+J/ψ, ψ)	5 - 12 (+ϒ)	12 - ∞

< 1.8 GeV