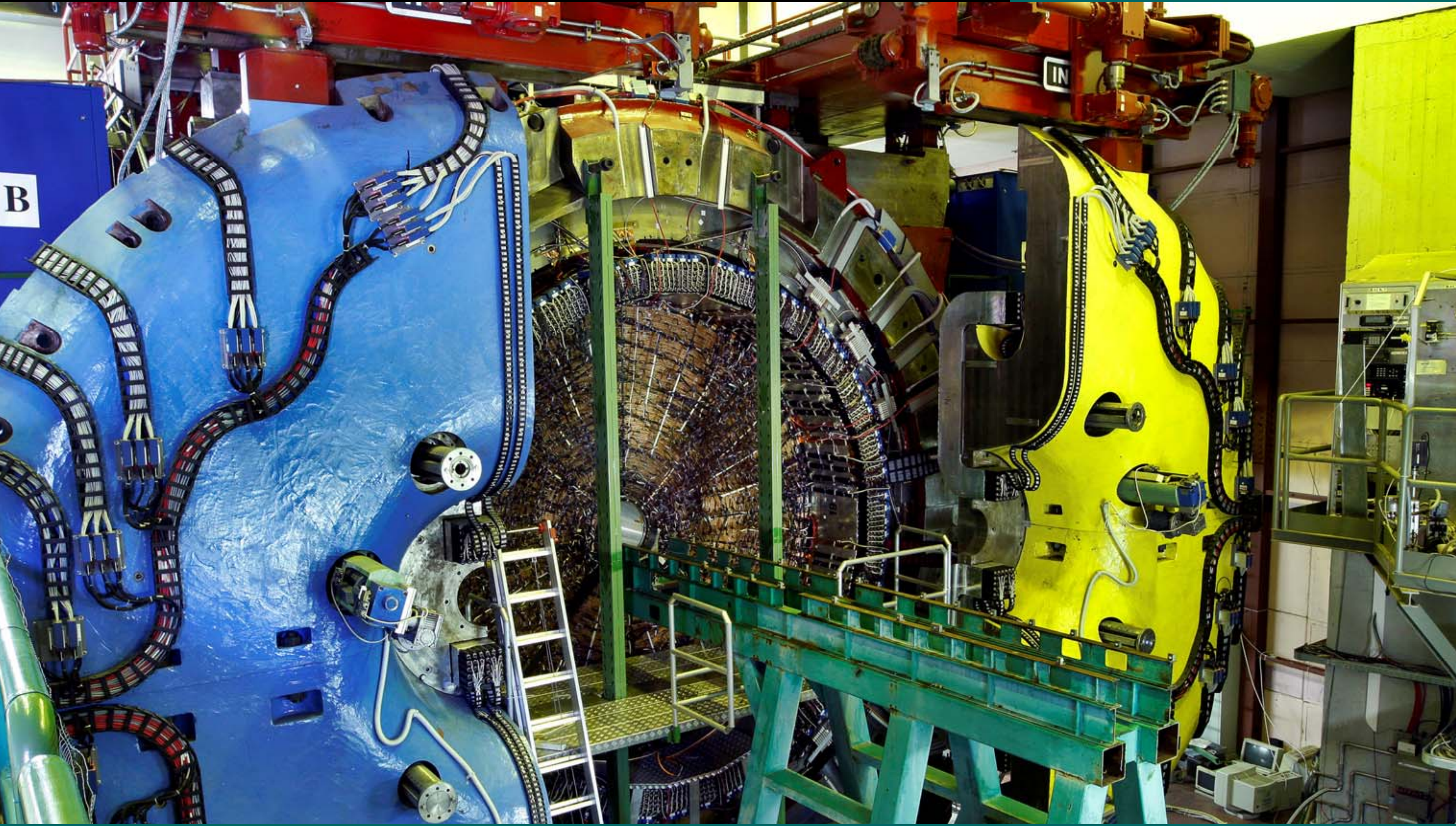


Laboratori Nazionali di Frascati dell'INFN

Report from KLOE2 Physics Workshop

LNF-SC May 11, 2009

The Workshop

- Plans for KLOE2 data taking in year 2009-2010 have been approved and funded in June, 2008.
- Main physics topics discussed to point out those of major interest for focusing the efforts and further requests for data taking
- The contributions to the workshop will appear in a paper on the “Physics Program of the KLOE2 experiment at the phi factory” to submit for publication
- All people contacted accepted to contribute – 22 invited participants, mainly theoreticians, plus people in the KLOE2 Collaboration : total 60
- We are collecting contributions and writing the draft

Outline

- CKM Unitarity and Lepton Flavour Universality
- Kaon Interferometry
- Dark matter quest
- Low-Energy QCD
- Physics in the Continuum: hadronic cross section
- Physics in the Continuum: γ-γ processes

CKM Unitarity and Lepton Flavor Universality

Workshop Program

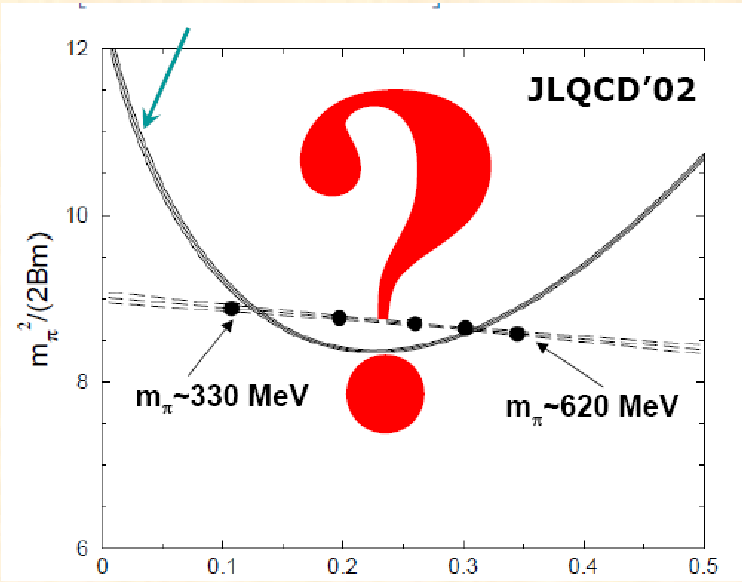
	Test of the Standard Model	
Chair:	D'Ambrosio	**ke2/ksemil**
9.15	Mescia	Standard Model probes: Lepton Universality, Vus
9.45	De Lucia	Highlights on Vus and Lepton Universality with Kaons
10.10	Sciascia	Highlights on Kaon form factors
10.35	Escribano	Dispersive representation of the Kpi vector ff and fits to tau to K pi nu_tau and Ke3 data
10.55	Passeri	Improving on Kaon lifetimes

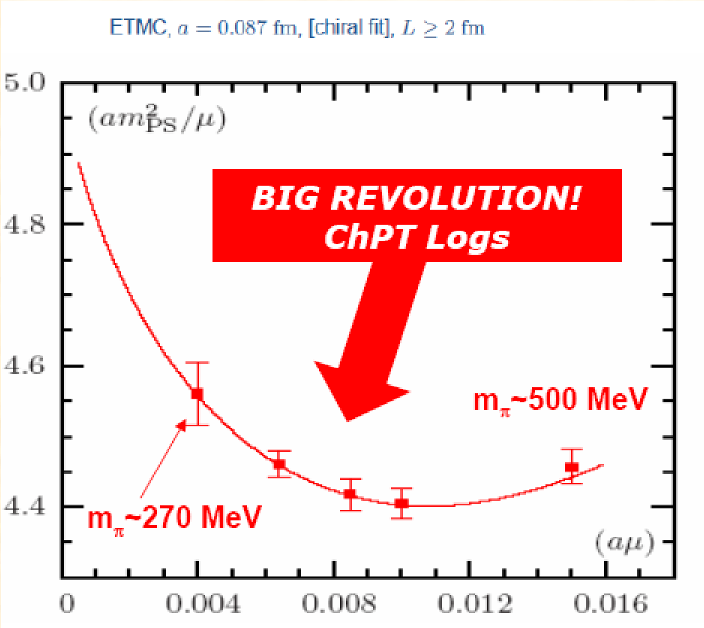
- Very promising recent results from Lattice presented by F. Mescia
- Short-term prospects for improving accuracy on f_K/f_π and $f^+_K(0)$
- The new theoretical precision calls for new data to improve sensitivity
  - on CKM unitarity
  - on lepton universality

Lattice-QCD results

F.Mescia

• Wilson: *CERN-TOV.-'05,*	m_π~280 MeV	(N_F=2)
• Twisted-mass: *ETMC '07,*	m_π~280->250 MeV	(N_F=2 -> N_F=2+1+1)
• Clover: *BMW '08,*	m_π~190 MEV	(N_F=2+1)
• Clover: *PACS-CS-'08,*	m_π~156 MEV	(N_F=2+1)
• DomainWall: *RBC-'06,*	m_π~330 MEV	(N_F=2+1)
• "Staggered: *MILC-2002,*	m_π~240 MeV	(N_F=2+1) "





LQCD improvement on the form factors

- *Vector* **Weak Universality** $\Rightarrow$

$$V_{us} f_+(0) = 0.2166(5) \Rightarrow V_{us}^{Kl3} = 0.2246(12)$$

exp:0.21% th:0.5%!!

$$|V_{ud}|^2 + |V_{us}|^2 = 0.9995(7)$$

- *Axial* **Weak Universality** $\Rightarrow$

$$V_{us} / V_{ud} f_K / f_\pi = 0.2760(6) \Rightarrow V_{us} / V_{ud} = 0.2321(15)$$

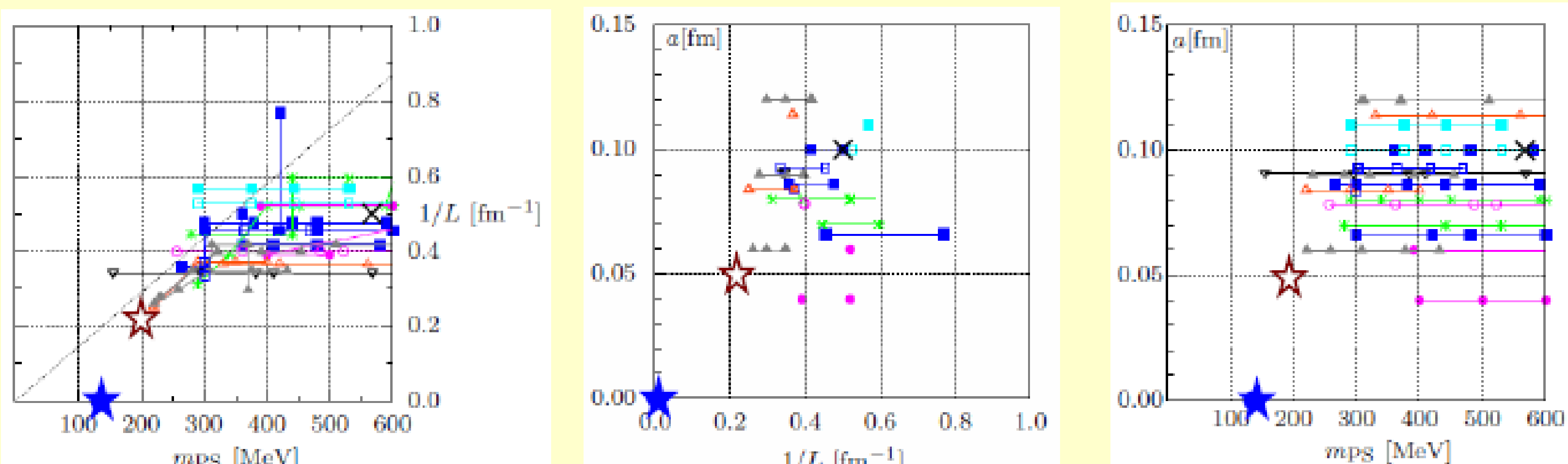
exp:0.21% th:0.6%!!

Thanks recent unquenched development, setup for Kaon precision phys.

***a*~0.05 *fm*, *L* ≥ 4.5 *fm* and 200 ≤ m_π ≤ 300 MeV is not far away**

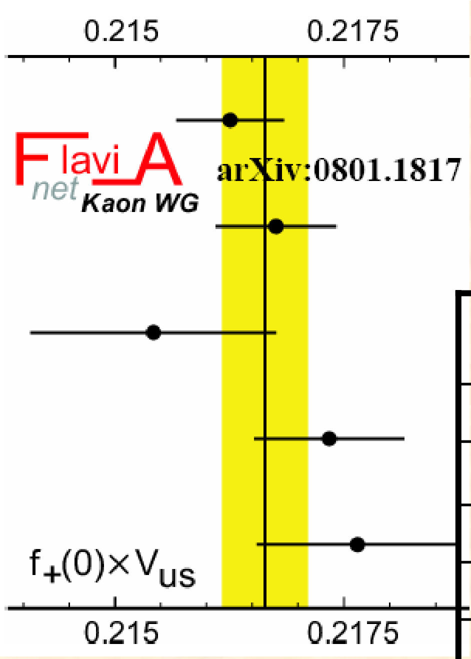
$\sigma_{f+(0)}$~0.1%, $\sigma_{fK/f\pi}$~0.1%

F.Mescia



$f_+(0)$ Vus

$$\Gamma(K_{l3(\gamma)}) = \frac{C_K^2 G_F^2 M_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 I_{K\ell}(\lambda_{+,0}) (1+\delta^K_{SU(2)}+\delta^{K\ell}_{em})^2$$



The World-Average can be improved by KLOE2 with the measurements of

- the K_S semileptonic branching ratio
- the K_L and $K^\pm$ lifetime

E.DeLucia, A. Passeri

	%err	BR	τ	δ	I_{Kl}	%err	BR	τ	δ	I_{Kl}
K_Le3 0.2163(6)	0.28	0.09	0.19	0.15	0.09	0.24	0.09	0.13	0.15	0.09
$K_L\mu3$ 0.2168(7)	0.30	0.10	0.18	0.15	0.15	0.27	0.10	0.13	0.15	0.15
K_Se3 0.2154(13)	0.67	0.65	0.03	0.15	0.09	0.35	0.30	0.03	0.15	0.09
$K^\pm e3$ 0.2173(8)	0.39	0.26	0.09	0.26	0.09	0.38	0.25	0.05	0.26	0.09
$K^\pm\mu3$ 0.2176(11)	0.51	0.40	0.09	0.26	0.15	0.41	0.27	0.05	0.26	0.15
Aver 0.2166(5)	0.23					0.14				

Unitarity test

- Fit to $|V_{ud}|^2$, $|V_{us}|^2$ and $|V_{us}/V_{ud}|^2$

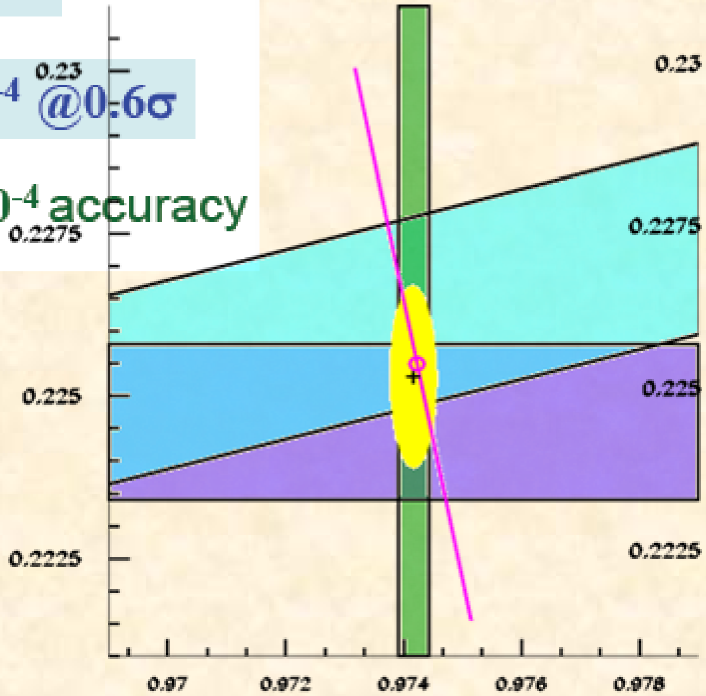
JHEP 04 (2008)

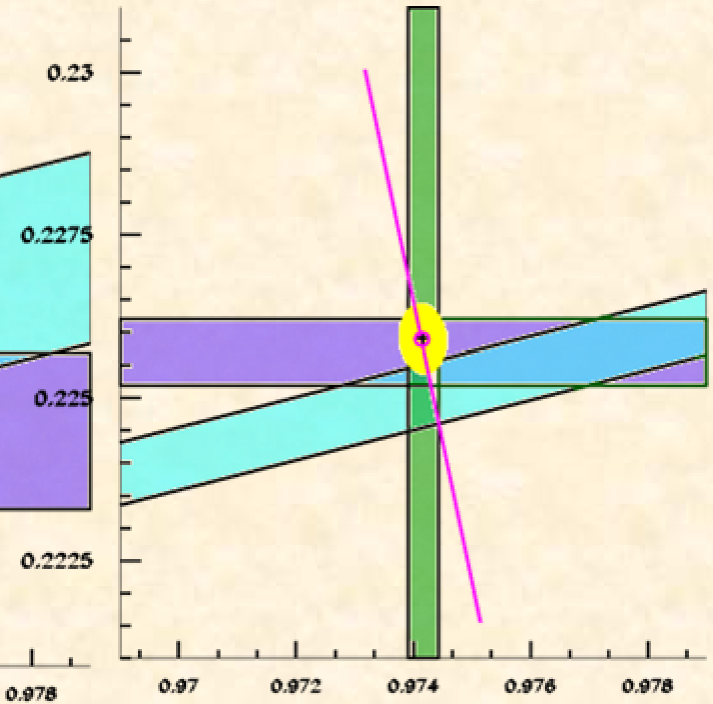
$|V_{ud}|^2 = 0.9490(5)$
$|V_{us}|^2 = 0.0506(4)$
$\chi^2 = 2.3/1\ (13\%)$

- $1 - V_{ud}^2 - V_{us}^2 = 4(7) \times 10^{-4}$ @0.6σ

World Average: 6×10^{-4} accuracy

$\sigma(1 - V_{ud}^2 - V_{us}^2) = (3 \div 4) \times 10^{-4}$





Elicity-suppressed modes

E.DeLucia

- In the SM $R_K=\Gamma(Ke2)/\Gamma(K\mu2)$ precisely calculated 0.04% (cancellation of hadronic uncertainties)

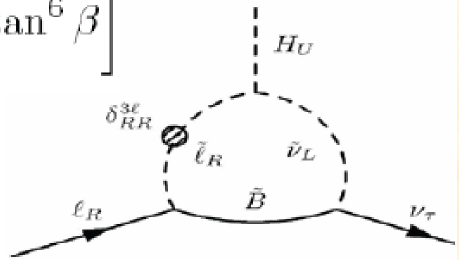
$R_K^{SM}=2.477(1)\times10^{-5}$ [Cirigliano, Rossell JHEP10(2007)005]

- Ke2 amplitude helicity-suppressed ⇒ ideal candidate for NP search

- Lepton Flavor Violation in the MSSM would enhance R_K up to 1%

LFV appears at 1-loop level via an effective $H^+\ell\nu_\tau$ Yukawa interaction dominated by $e\nu_\tau$ [Masiero-Paradisi-Petronzio PRD74 (2006) 011701]

$$R_K^{\rm LFV} \approx R_K^{\rm SM}\left[1+\left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)|\Delta_{13}|^2\tan^6\beta\right]$$



Δ_{13} lepton flavor violating coupling

Ke2

E.DeLucia

Using the complete KLOE data set (2.2 fb^{-1}) we obtain:

$$R_K = (2.493 \pm 0.025_{stat} \pm 0.019_{syst}) \times 10^{-5}$$
$$= (2.493 \pm 0.032) \times 10^{-5}$$

$R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

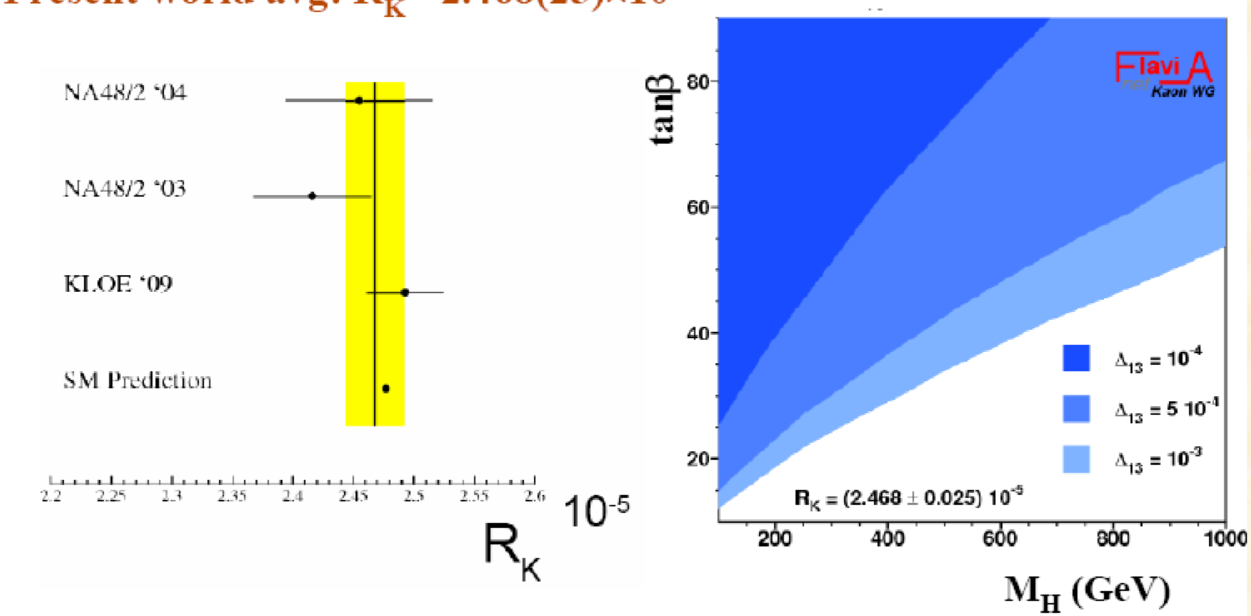
Results separated by charge (uncorrelated errors only):

$R_K(K^+) = (2.496 \pm 0.037) \times 10^{-5}$ and $R_K(K^-) = (2.490 \pm 0.038) \times 10^{-5}$

R_K at 1.3% from 1.4 10^4 Ke2 decays→0.7% with additional 5 fb^{-1}

25 fb^{-1} to reach 0.4%

Present world avg: $R_K = 2.468(25) \times 10^{-5}$



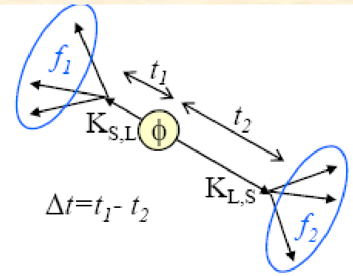
Neutral Kaon Interferometry

Chair:	Wisliki	CPT,QM and QG
16.20	Hiesmayr	Fundamental tests of quantum mechanics with neutral kaons: theory overview
16.50	Amelino-Camelia	Quantum Gravity Phenomenology
17.20	Di Domenico	CPT and QM tests with neutral kaons: perspectives at KLOE2

Neutral kaon interferometry

A. Di Domenico

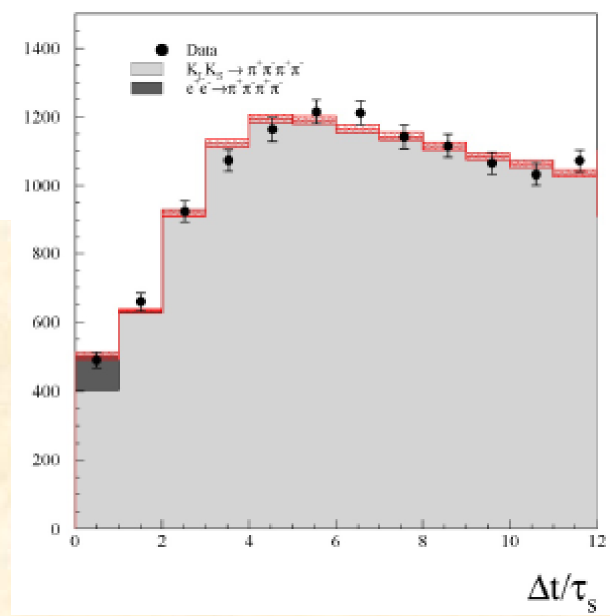
$$|i\rangle = \frac{N}{\sqrt{2}}\left[|K_S(\vec{p})\rangle|K_L(-\vec{p})\rangle - |K_L(\vec{p})\rangle|K_S(-\vec{p})\rangle\right]$$



Double differential time distribution:

$$I(f_1,t_1;f_2,t_2) = C_{12}\left\{|\eta_1|^2 e^{-\Gamma_L t_1 - \Gamma_S t_2} + |\eta_2|^2 e^{-\Gamma_S t_1 - \Gamma_L t_2} - 2|\eta_1||\eta_2| e^{-(\Gamma_S+\Gamma_L)(t_1+t_2)/2}\cos[\Delta m(t_2 - t_1) + \phi_1 - \phi_2]\right\}$$

Interference term



Time evolution of the kaons from φ decay good probe for QM coherence, but also CPT and Lorentz invariance

Quantum Mechanics : decoherence

B. Hiesmayr

$$|\psi^-\rangle \cong |K^0\rangle_l \otimes |\overline{K}^0\rangle_r - |\overline{K}^0\rangle_l \otimes |K^0\rangle_r$$

50% → $|K^0\rangle_l \otimes |\overline{K}^0\rangle_r$

50% → $|\overline{K}^0\rangle_l \otimes |K^0\rangle_r$

$$P^{\zeta}(f_1,t_l;f_2,t_r) = |A_1|^2 + |A_2|^2 - 2(1-\zeta)\,\mathrm{Re}\{A_1^* A_2\}$$

	decoherence in K_S/K_L:	decoherence in $K^0/\overline{K}^0$:
Bertlmann, Grimus, Hiesmayr, Phys.Rev. D (1999)	$\zeta^{K_S K_L} = 0.13\left\{\begin{matrix}+0.16\\-0.15\end{matrix}\right.$	$\zeta^{K^0\overline{K}^0} = 0.4 \pm 0.7$
KLOE Coll., Phys. Lett. B (2006)	$\zeta^{K_S K_L} = 0.018 \pm 0.040_{stat} \pm 0.07_{syst}$	$\zeta^{K^0\overline{K}^0} = (0.10 \pm 0.21_{stat} \pm 0.04_{syst}) \cdot 10^{-5}$
March 2009	$\zeta^{K_S K_L} = 0.003 \pm 0.018_{stat} \pm 0.006_{syst}$	$\zeta^{K^0\overline{K}^0} = (1.4 \pm 9.5_{stat} \pm 3.8_{syst}) \cdot 10^{-7}$

B-mesons:

Bertlmann, Grimus PRD (2001) $\zeta^{B_H B_L} = -0.06 \pm 0.1$

A.Go, BELLE, quant-ph/0702267 $\zeta^{B_H B_L} = 0.029 \pm 0.057$

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Decoherence

A. Di Domenico

[1] Hawking, Comm.Math.Phys.87 (1982) 395; [2] Wald, PR D21 (1980) 2742;[3] Ellis et. al, NP B241 (1984) 381; PRD53 (1996)3846 [4] Huet, Peskin, NP B434 (1995) 3; [5] Benatti, Floreanini, NPB511 (1998) 550 [6] Bernabeu, Ellis, Mavromatos, Nanopoulos, Papavassiliou: Handbook on kaon interferometry [hep-ph/0607322]

Modified Liouville – von Neumann equation for the density matrix of the kaon system:

$$\dot{\rho}(t) = \underbrace{-iH\rho + i\rho H^{+}}_{\text{QM}} + L(\rho)$$

extra term inducing decoherence: pure state => mixed state

J. Ellis et al.[3-6] => model of decoherence for neutral kaons => 3 new CPTV param. α,β,γ:

$$L(\rho) = L(\rho; \alpha, \beta, \gamma)$$

$$\alpha, \gamma > 0 \quad , \quad \alpha\gamma > \beta^2$$

At most: $\alpha, \beta, \gamma = O\left(\frac{M_K^{\ 2}}{M_{PLANCK}}\right) \approx 2\times 10^{-20}$ GeV

Quantum Gravity and CPT symmetry

G. Amelino-Camelia

quantum-gravity scenarios with violations of CPT symmetry might also require some corresponding modifications of the recipe for obtaining multiparticle states from singleparticle states for identical particles. This may in particular apply to the neutral-kaon $K_0 - \bar{K}_0$ system, since standard CPT transformations take K_0 into $\bar{K}_0$ but violations of CPT symmetry are likely to also induce a modification of the link between K_0 and $\bar{K}_0$, at the level of the description of multiparticle states

Some authors (Mavromatos, Bernabeu,....) recently proposed a phenomenology inspired by this argument and based on the following parametrization of the state $|i>$ initially produced by a ϕ-meson decay:

$$|i> \propto ((|K_S(p), K_L(-p)> - |K_L(p), K_S(-p)>) + \omega(|K_S(p), K_S(-p)> - |K_L(p), K_L(-p)>)$$

where the complex parameter ω essentially characterizes the level of contamination of the state $|i>$ by the (otherwise unexpected) C-even component $|K_S(p), K_S(-p)> - |K_L(p), K_L(-p)>$.

KLOE FINAL :

$$\Re\omega = \left(-1.6^{+3.0}_{-2.1\,STAT} \pm 0.4_{SYST}\right)\times 10^{-4}$$

$$\Im\omega = \left(-1.7^{+3.3}_{-3.0\,STAT} \pm 1.2_{SYST}\right)\times 10^{-4}$$

$$|\omega| < 1.0\times 10^{-3} \quad \text{at } 95\%\ \text{C.L.}$$

Neutral Kaon Interferometry

KLOE FINAL 2004-05

$$\zeta_{SL} = (0.3 \pm 1.8_{STAT} \pm 0.6_{SYST}) \times 10^{-2}$$

$$\zeta_{0\bar{0}} = (1.4 \pm 9.5_{STAT} \pm 3.8_{SYST}) \times 10^{-7}$$

$$\gamma = (0.7 \pm 1.2_{STAT} \pm 0.3_{SYST}) \times 10^{-21}\ \text{GeV}$$

$$\Re\omega = (-1.6^{+3.0}_{-2.1\,STAT} \pm 0.4_{SYST}) \times 10^{-4}$$

$$\Im\omega = (-1.7^{+3.3}_{-3.0\,STAT} \pm 1.2_{SYST}) \times 10^{-4}$$

KLOE step-0 5 fb^{-1}

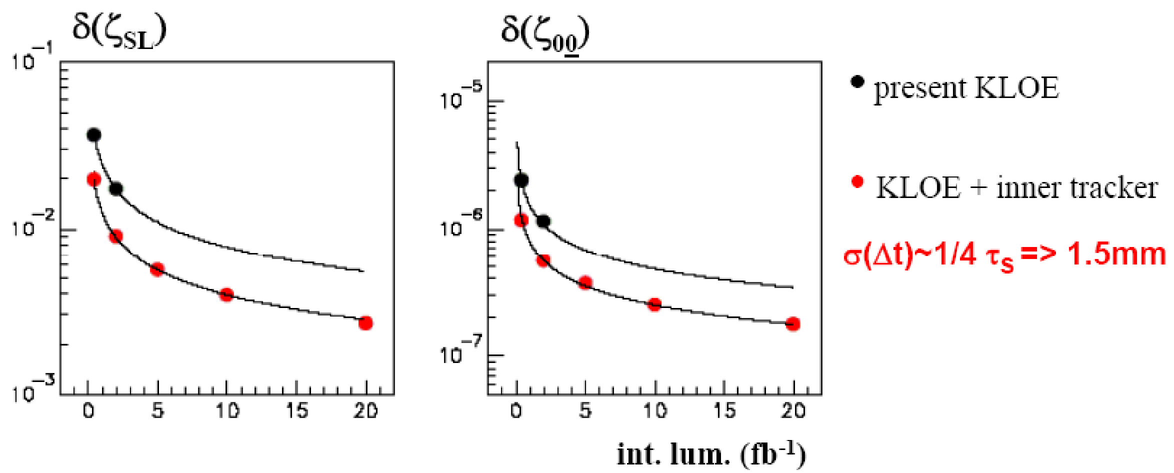
$$\zeta_{SL} = (\pm 1.0_{STAT} \pm 0.6_{SYST}) \times 10^{-2}$$

$$\zeta_{0\bar{0}} = (\pm 5.2_{STAT} \pm 3.8_{SYST}) \times 10^{-7}$$

$$\gamma = (\pm 0.6_{STAT} \pm 0.3_{SYST}) \times 10^{-21}\ \text{GeV}$$

$$\Re\omega = (^{+1.7}_{-1.2\,STAT} \pm 0.4_{SYST}) \times 10^{-4}$$

$$\Im\omega = (^{+1.8}_{-1.7\,STAT} \pm 1.2_{SYST}) \times 10^{-4}$$



Results very sensitive to vertex reconstruction
IT realization equivalent to x3 data sample

Search for WIMP secluded sector

Chair:	Patera	**The search for exotics**
11.40	Boehm	Can low energy experiments play part to the dark matter quest?
12.10	Bossi	Searches for non standard physics signals with KLOE2

Celine Boehm, Annecy LAPTH

- Scalar Dark Matter Candidates $O(10^{-3} \div 1)$ GeV are simultaneously compatible with
  - relic density
  - γ ray fluxes
  - experimental limits from particle physics

key issue

- Constraints:
  - weak coupling with the ordinary sector through light gauge (higgs) boson
    - Mostly from the electron/muon anomalous moment

F.Bossi

Several recent puzzling astrophysical observations (PAMELA, ATIC, INTEGRAL, DAMA) can be interpreted by postulating the existence of some secluded gauge sector with a rich phenomenology at low ($\mathcal{O}$(1 GeV)) energies.

The coupling with standard particles gives rise to a number of possible signatures observable at low energy colliders such as the B-factories and DAFNE

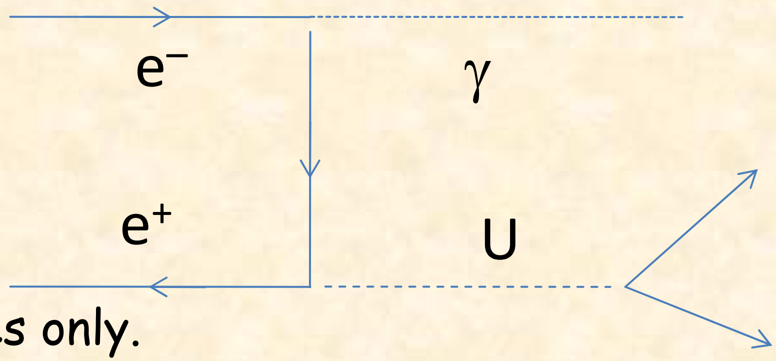
The cross sections for the processes of interest scale typically with 1/s, so the event rates at DAFNE are comparable to those at the present day B-factories

I will concentrate on the possible signatures of 2 of the new particles: a neutral vector boson "U" mediating the new interaction, and the related higgs-like particle "h' "

F.Bossi

The U boson can be observed through the radiative process:

$e^+e^- \to U\gamma \to \to l^+l^-$ ($l=e,\mu$)



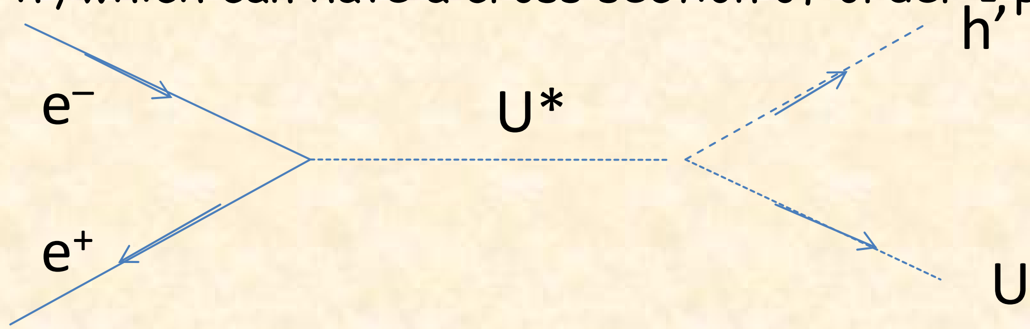
The cross section for this process is suppressed wrt the QED continuum by a factor k^2, so it can be at most ≈ 1 pb

We consider U boson decays to SM particles only.
If it can decay also to DM particles it can result in a single photon + missing energy signature.

An analysis for such a signature would require a dedicated trigger not presently in the KLOE trigger table. BaBar has explicitely taken a few weeks of data with such a kind of trigger, with null results
However such an experiment would require a calorimeter with exceptional energy resolution, which is not the case of KLOE

All in all, the γ + 2 leptons channel might be worth studying in some detail for masses of the U boson exceeding 500 MeV.
The γ + missing energy is at present hopeless

Another mechanism for secluded particles production is the higgs'-strahlung: $e^+e^- \rightarrow U\,h'$, which can have a cross section of order 1 pb at DAFNE energies



If $m_{h'} < m_u$ then the higgs' is relatively long-lived, $\mathcal{O}(10^{-9}$ s) thus escaping detection inside KLOE

The resulting signal (again assuming that the U decays only to SM particles) would then be a pair of leptons + missing energy

In this case:

- The QED background due to radiative processess is suppressed by the high detection efficency for γ's of the KLOE calorimeter
- The missing energy must be equal to the missing momentum for photons but sizeably different for massive particles. The resolution is dominated by the DC
- The angular distribution for the higgsstrahlung is proportional to $\sin^3(\theta)$, which enhances the geometrical acceptance and further suppresses the QED backgrounds

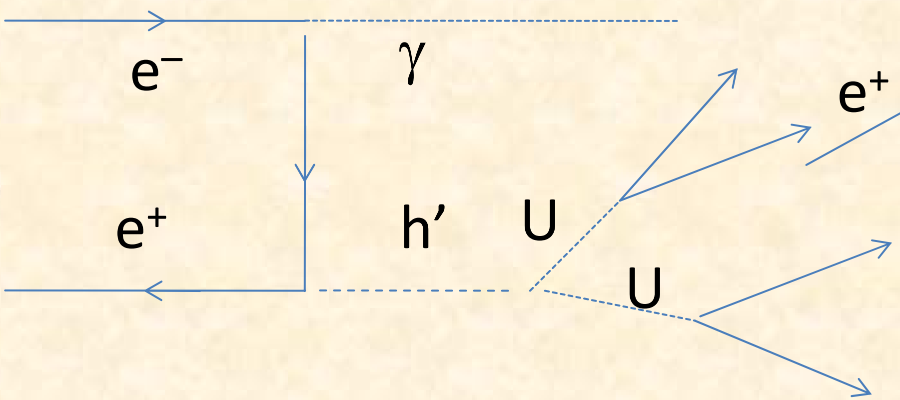
The two produced leptons have energies high enough to trigger the events with efficiencies > 90% for almost all possible combinations of m_U and $m_{h'}$, at least for the electron channel

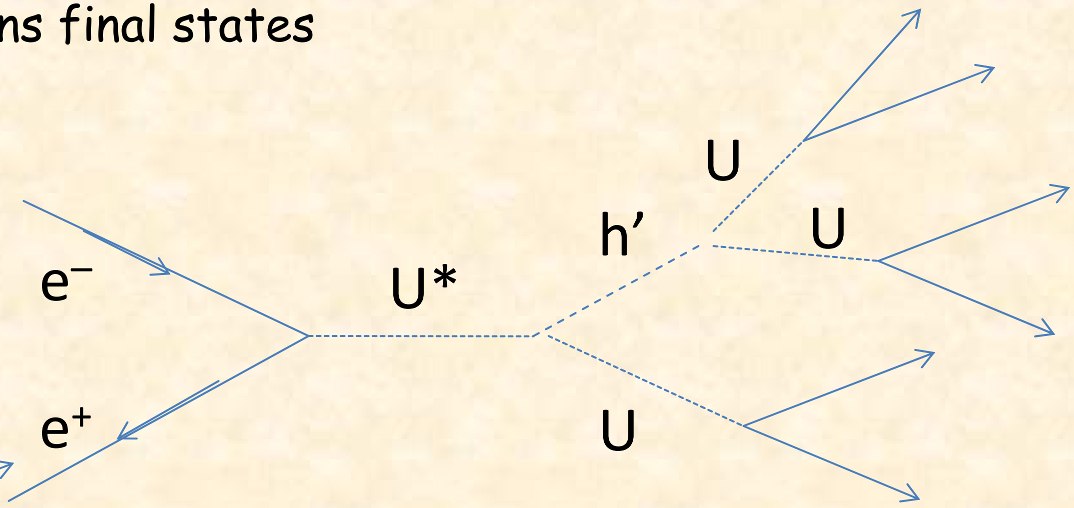
A possible background specific to DAFNE is $K_S \to \pi^+\pi^-$, with the parent K_L flying through the apparatus

This should be a problem only for the muon channel and for masses of the U boson close to m_K. It can however be well calibrated by using K crash events

If it turns out to be still a problem one can always think to run at $\sqrt{s} < 2m_K$

If $m_{h'} > 2\, m_U$ then the higgs' decays mainly into two U bosons giving rise to spectacular 4 leptons+γ or 6 leptons final states





Assuming resonable detection efficiencies k=10^{-2} is in the reach of KLOE already with the data sample presently on tape.

KLOE-2 can improve on this in a two-fold way:

1. More luminosity, which is trivial
2. Better detector: the use of the IT and of the forward calorimeters can improve acceptance for Ug and help rejecting the conversions

At full statistics we could reach k=10^{-3}

The phenomenology which mostly motivates these models disfavour much lower values for k

Low Energy QCD

Low-energy QCD and Light Meson Spectroscopy

Chair:	Palutan	**Kaon decays**
9.45	D'Ambrosio	Theoretical issues on radiative (and non-leptonic) Kaon decays
10.15	Archilli	Highlights on semi-rare Kaon decays at KLOE2: radiative channels
10.40	Martini	Highlights on semi-rare Kaon decays at KLOE2: non-leptonic channels
11.05		Break
Chair:	Hoistad	**eta/eta' decays and light meson spectroscopy**
11.30	Kupsc	Interest and Prospects for experiments on eta/eta' decays
12.00	Giacosa	Scalar Mesons in radiative processes
12.25	Eidelman	Experimental Review on Light Vector Meson Spectroscopy
12.50	Di Micco	Highlights on phi radiative decays at KLOE2
13.20		Lunch
14.45	Di Donato	eta/eta' decays: the pipigamma channel
15.05	Versaci	eta decays into four charged particles at KLOE2

- Prospects for improvements on radiative and non leptonic kaon decays discussed (G.D'Ambrosio, F.Archilli, M.Martini)
- Short-term results for $Ks \to 3\pi^0$ and $Ks \to \pi^+ \pi^- \pi^0$

B.Di Micco

Interest on radiative η decays: $\eta \to \pi\pi ee, eeee, ee\mu\mu$

The first % measurement of the η' branching ratios will be possible allowing to precisely determine the η' gluonium content;

. $\sigma \to \pi^+\pi^-$ can be observed both in the $\phi \to \pi^+\pi^-\gamma$ and in the $\eta' \to \pi^+\pi^-\eta$, its couplings can be measured and compared against 4q and 2q models;

. The decay $\phi \to (f_0 + a_0)\gamma \to K^0 K^0 \gamma \to K_S K_S \gamma$ could be observed for the first time;

The study of the process $\eta \to \pi^0\gamma\gamma$ will allow to strongly test ChPT p^6 with resonance saturation.

Physics in the continuum: σ_{had}

Chair:	Eidelman	**g-2, alpha_em**
12.40	Isidori	Overview on off-peak physics
13.05	Hertzog	New experiment on g-2
13.30		Lunch
14.30	Passera	The muon g-2 discrepancy: Errors or new physics?
14.55	Fedotovich	Improving on hadronic contribution to alpha_em and g-2 at VEP2000
15.20	Venanzoni	Improving on hadronic contribution to alpha_em and g-2 at KLOE2
15.45	Babusci	Precision measurement of beam energy

- Precision tests of the Standard Model with the potentiality for the discovery of signals of New Physics are limited by the measurement of the hadronic cross section at low energy.

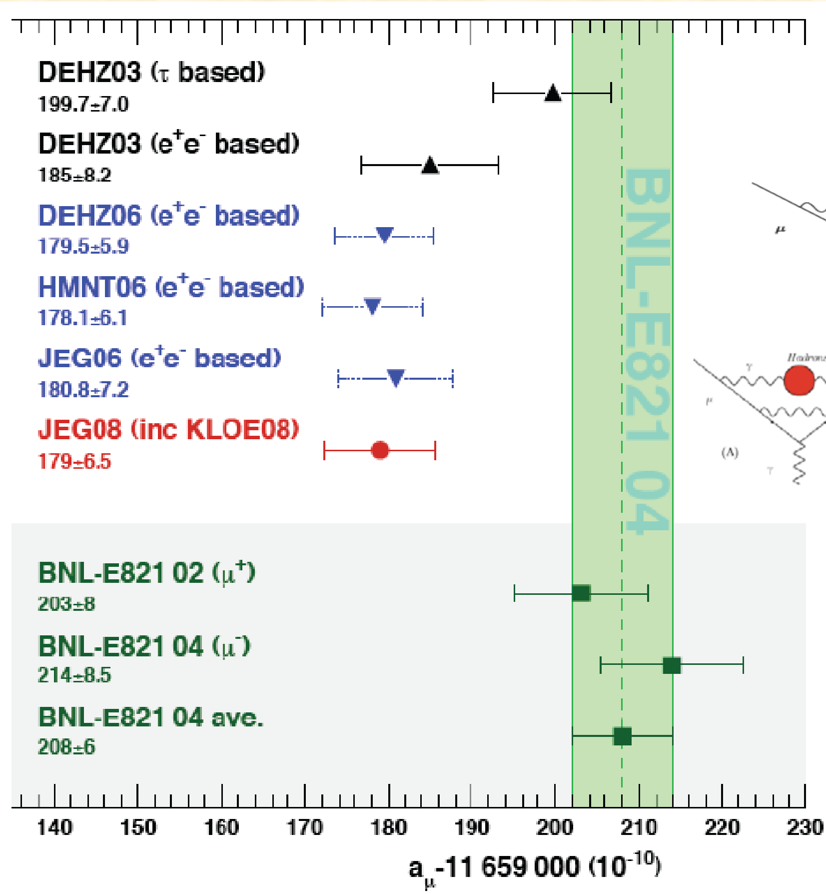
- We have to improve on the hadronic contributions to $(g-2)_\mu/2$ and α_{em}
  - to solve the 3σ discrepancy on a_μ
  - for precision physics at the O(TeV) scale

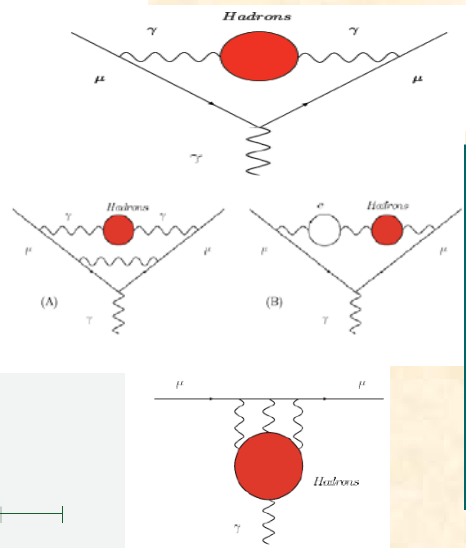
Hadronic contribution to $(g\text{-}2)_\mu$

$$\delta a_\mu^{EXP} = 6.3\ 10^{-10}$$
$$\delta a_\mu^{SM} = 6.5\ 10^{-10}$$

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

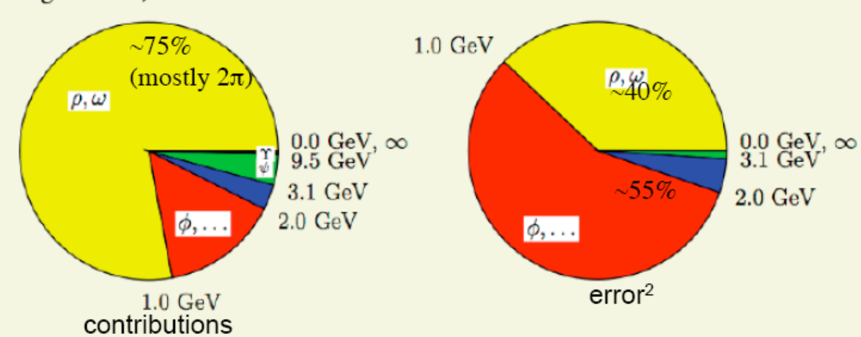
$$\delta a_\mu^{QED} = 0.02\ 10^{-10}$$
$$\delta a_\mu^{EW} = 0.22\ 10^{-10}$$



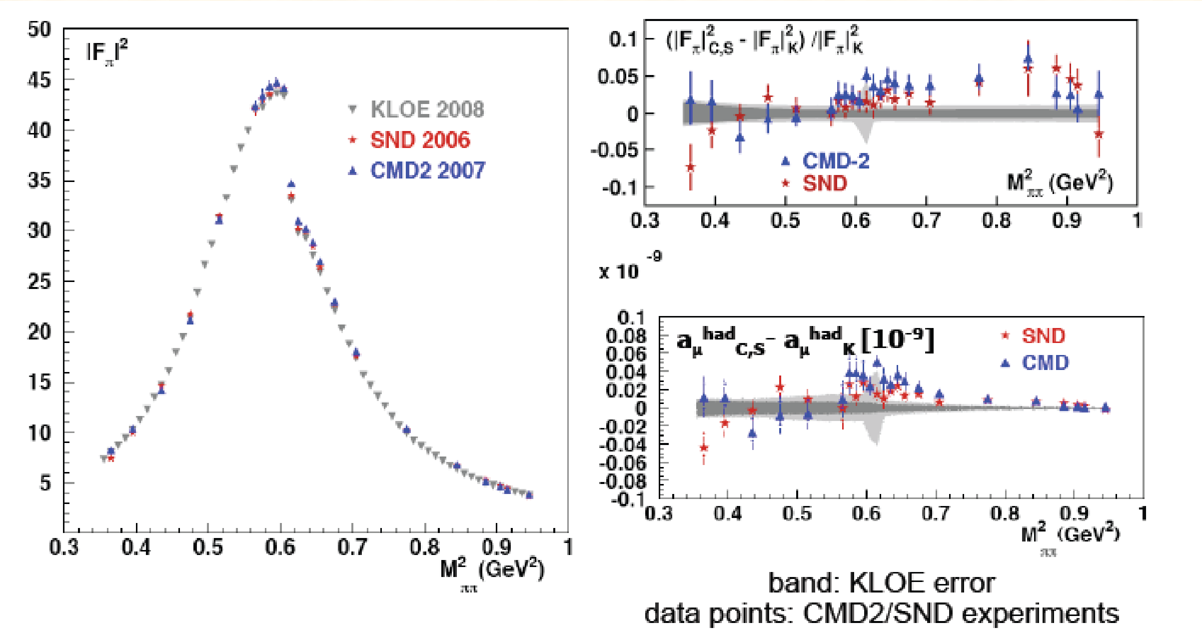


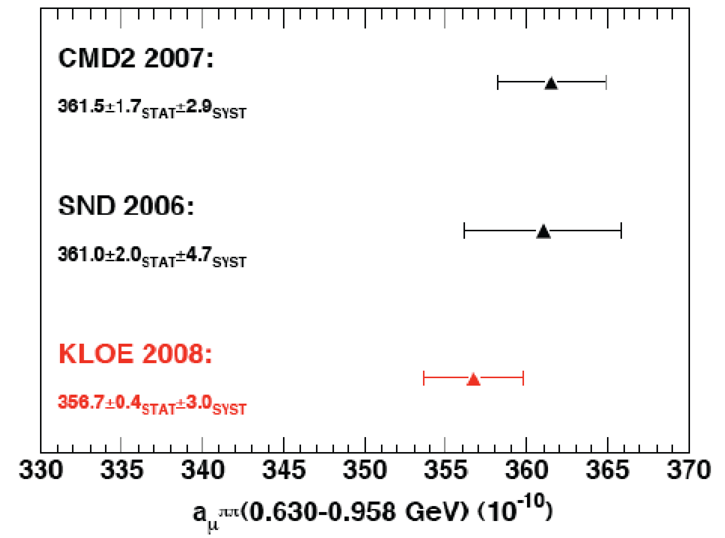
$$a_\mu^{had} = a_\mu^{had,LO} + a_\mu^{had,HO} + a_\mu^{had,LBL}$$
$$a_\mu^{had,LO} = (692.3 \pm 6.0)\ 10^{-10}$$
$$a_\mu^{had,HO} = (-9.8 \pm 0.1)\ 10^{-10}$$
$$a_\mu^{had,LBL} = (10.5 \pm 2.6)\ 10^{-10}$$

F. Jegerlehner, Talk at PHIPSI08



e+e- measurements





Error in σ_{had}?

PHYSICAL REVIEW D **78**, 013009 (2008)

The muon $g-2$ and the bounds on the Higgs boson mass

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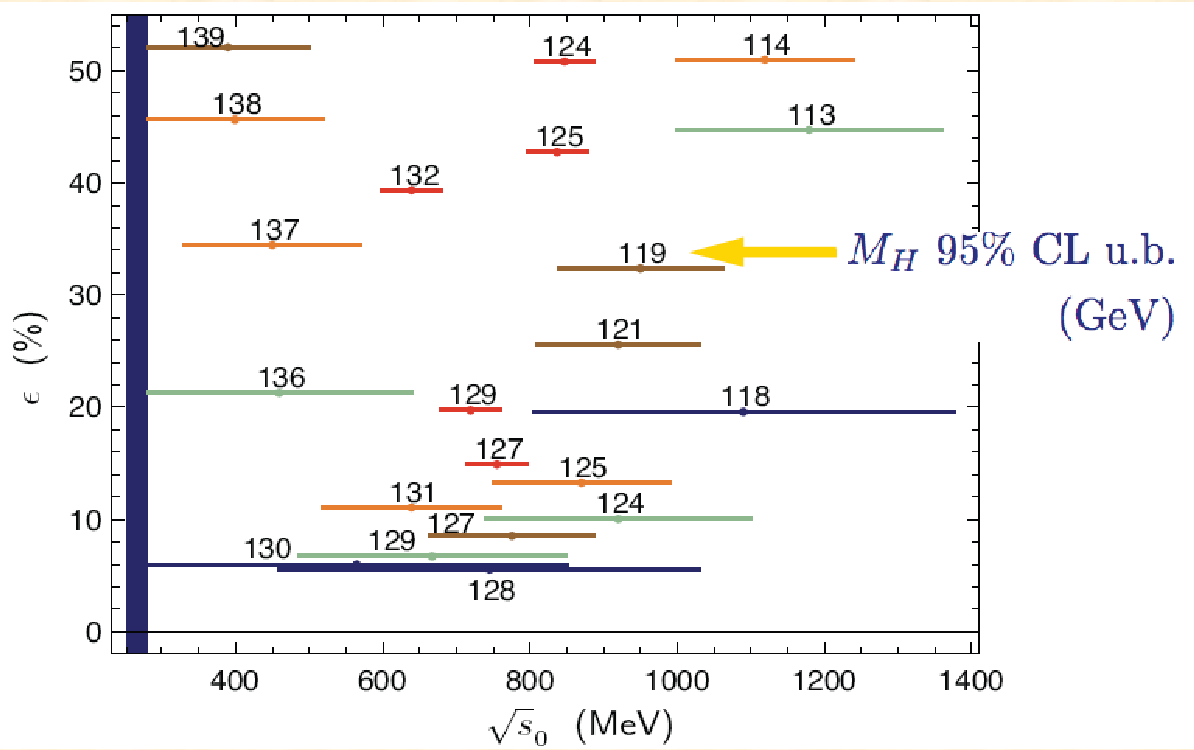
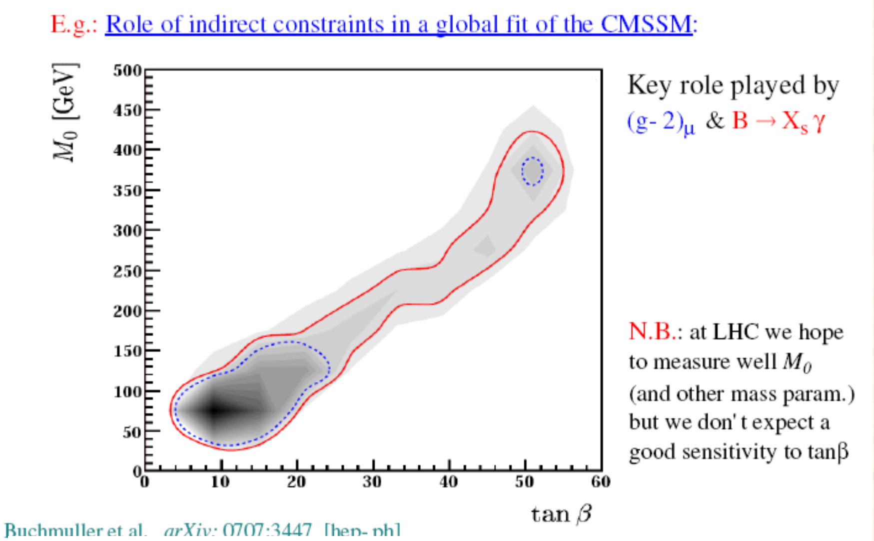
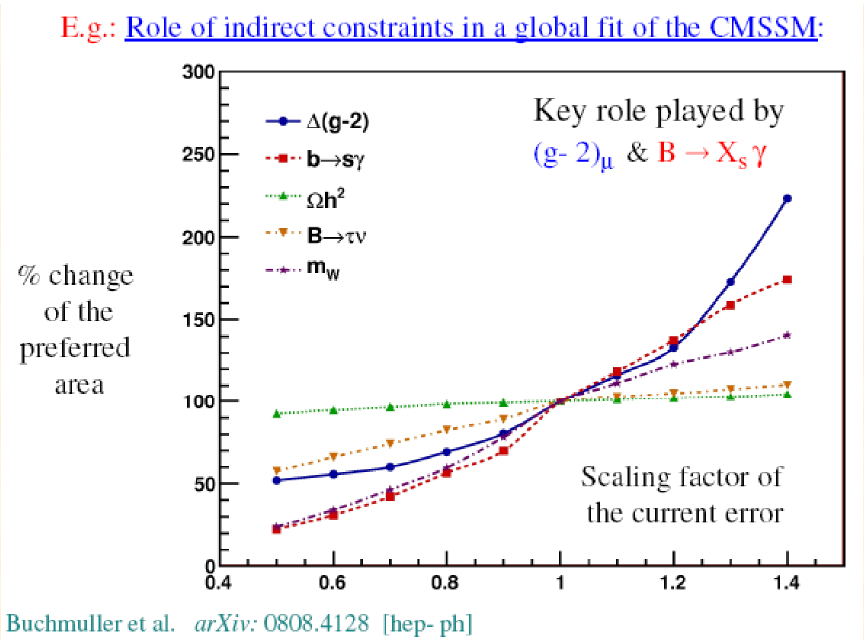


MSSM sensitivity to a_μ

G.Isidori





P-989 proposal at Fermilab

D.Hertzog

- Proposol to improve by a factor of 4 the $(g-2)_\mu/2$ measurement presented in March
- Fermilab Director and PAC, on April

This is an opportune and excellent proposal which is well motivated and represents a technically sound incremental advance over previous work. Realizing the goal would result in an important step forward for fundamental physics measurements, which fits well with Fermilab's other future efforts in precision muon physics at the Intensity Frontier.

The Committee recommends that the opportunity presented by this relatively low-cost and high-quality project be pursued.

- Next step is an independent cost / impact review

Now: Δa_μ(Expt – Thy) = $295 \pm 81 \times 10^{-11}$ 3.6 σ

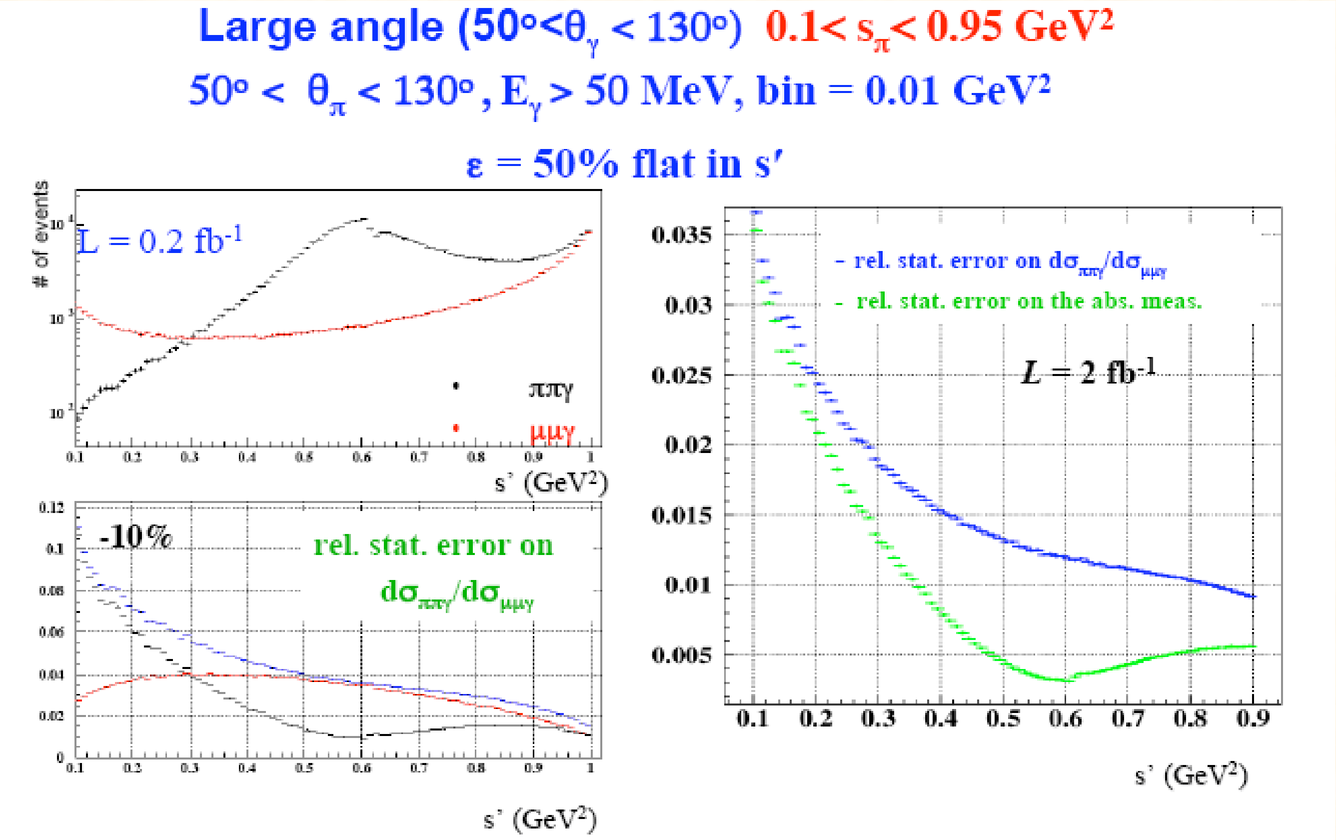
- Expected situation after experiment:
  - Experimental uncertainty: 63 → 16×10^{-11}
    - 0.1 ppm statistical → 21x the E821 events
    - 0.1 ppm systematic overall
      - 0.07 ppm field → 0.17 → 0.07
      - 0.07 ppm w_α → 0.21 → 0.07
  - Theory uncertainty: 51 → 30×10^{-11}

Future: Δa_μ(Expt – Thy) = xx $\pm 34 \times 10^{-11}$

deviation close to 9σ

σ_{had} down to $\pi\pi$ threshold

G.Venanzoni



- The 0.7% uncertainty in σ_{had} at $\sqrt{s}<1$ GeV can be reduced to 0.4% with O(fb^{-1}) off-peak integrated luminosity at DAFNE.

- In addition, a reduction of the uncertainty on σ_{had} @ $(1 < \sqrt{s} < 2)$ GeV from 5% to 2% is needed to have $\delta a_\mu^{had,LO} \simeq \delta a_\mu^{had,LBL}$ and $\delta a_\mu^{SM} \simeq 4.2\ 10^{-10}$

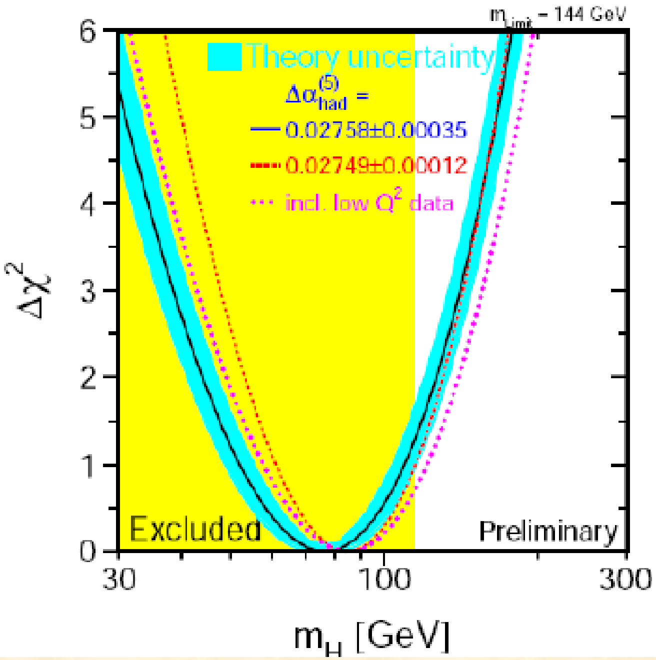
Hadronic contribution to α_{em}

G.Isidori

While $\alpha_{em}(m_e)$ is known with an incredible precision [$\sim 3\times10^{-9}$!], the error on $\alpha_{em}(M_Z)$ - the effective coupling relevant at the electroweak scale- is much larger because of hadronic uncertainties:

$$\frac{\Delta\alpha_{em}(M_Z)}{\alpha_{em}(M_Z)} \sim (1-4)\times10^{-4}$$

Significant source of uncertainty (*given the precision reached on other e.w. fundamental couplings*) →



$$\frac{\delta G_\mu}{G_\mu} \sim 8.6\times10^{-6}$$

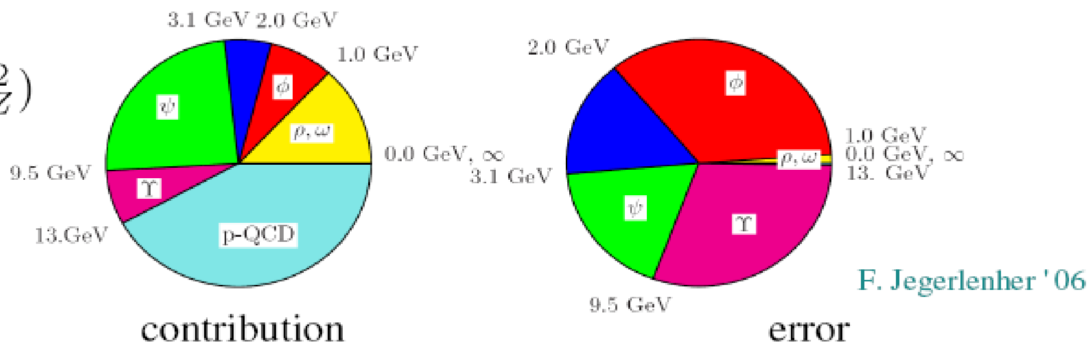
$$\frac{\delta M_Z}{M_Z} \sim 2.4\times10^{-5}$$

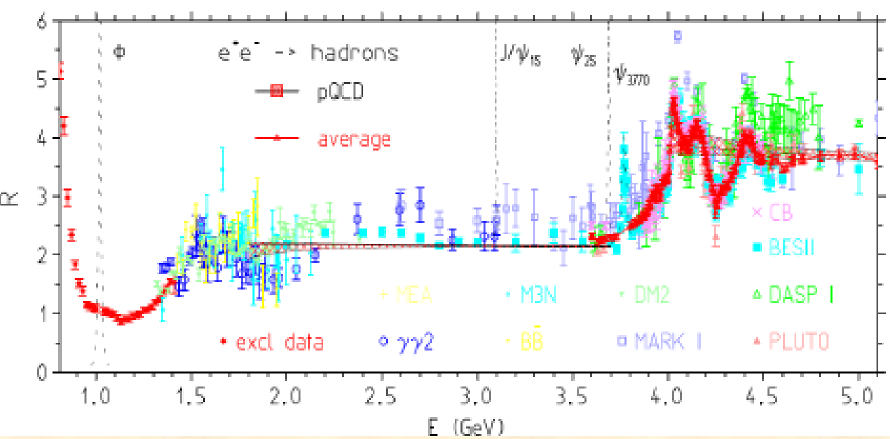
Hadronic contribution to α_{em}

$$\alpha(M_Z) = \frac{\alpha}{1-\Delta\alpha(M_Z)} \quad \text{with} \quad \Delta\alpha = \Delta\alpha_{lep} + \Delta\alpha^{(5)}_{had} + \Delta\alpha_{top}$$

$$\Delta\alpha^{(5)}_{had}(M_Z) = \frac{M_Z^2}{4\alpha\pi^2}\, P\int_{4m_\pi^2}^{\infty} ds\, \frac{\sigma(s)}{M_Z^2 - s}$$

$\Delta\alpha_{had}^{(5)}(M_z^2) = 0.02768\ (22)$ *Hagiwara et al. 06*





G.Isidori

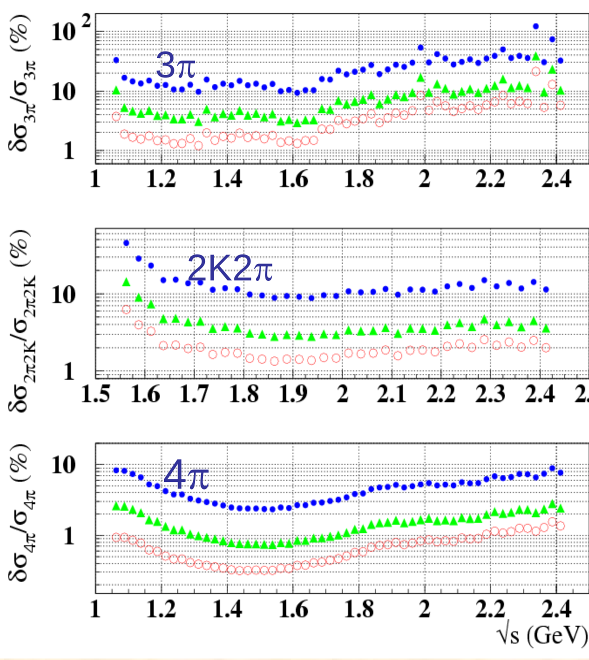
The high- energy range is not an issue: we can reduce the error using theory

The key problem is the E < 2.5 GeV region

- A reduction of the uncertainty on σ_{had} @ $(1 < \sqrt{s} < 2)$ GeV from 5% to 1% needed to have

$\delta\alpha_{em}/\alpha_{em} \cong \delta G_\mu/G_\mu \cong \delta M_Z/M_Z \cong O(10^{-5})$

Improving on σ_{had} in the [1 ÷2] GeV region

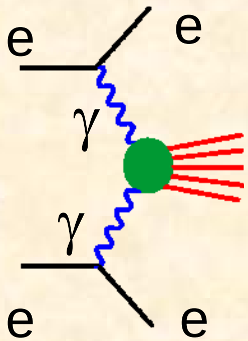


- Energy scan @10 pb-1 per point is **statistically** better than $O(1\ ab^{-1})$ B-factories

CMD-3 precision goal :

Source of error	2pi √s < 1 GeV	3pi √s < 2.0 GeV	4pi 2>√s>1.1 Ge
Event separation	0.2%	0.2%-0.5%	1%
Fiducial volume	0.2%(LXe,0.1%)	0.3%	2%
Energy calibration	< 0.1% 1%	< 0.1% 1%	< 0.1% (0.5%)
Efficiency correction	0.1%	0.3%	1%
Pion losses (decay,NI)	0.1%	0.4%	1%
Other	0.2%	(0.3 - 0.7)%	1%
Radiative corrections	0.1%	< 0.3%	< 0.3%
Total	0.35%	0.8%	2.9%
Total (no depolariz.)	1.1%	(1.3 – 1.5)%	3%

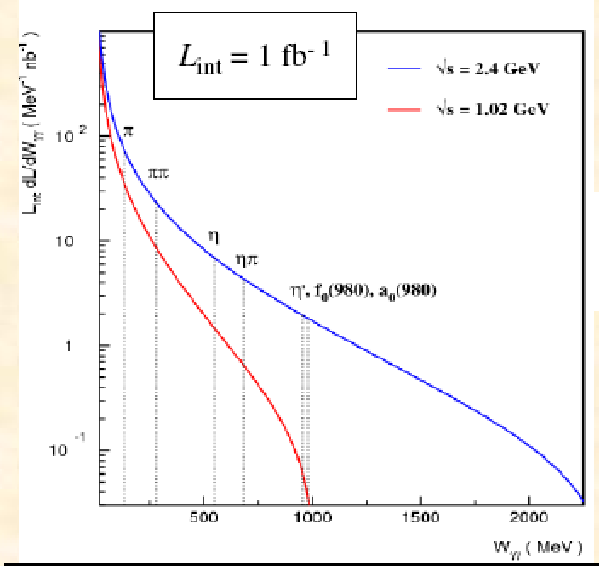
Physics in the continuum: γγ processes



	g-g Physics	
Chair:	Ceradini	
15.25	Pennington	How precision data from KLOE2 on two-photon production of hadrons will determine the underlying Physics
15.55	Nguyen	gg physics at KLOE2
16.30		Break
17.00	Raimondi	Running below and above the phi peak at DAFNE
17.25	Gonnella	Considerations on the tagger for gg physics at KLOE2

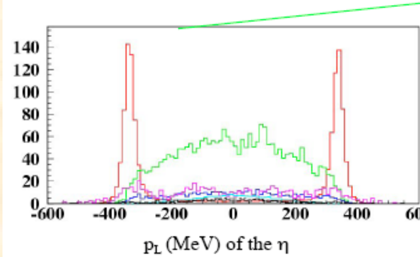
- Pseudoscalar widths
  - π^0, η : off-peak data with the tagging system
  - η', $f_0(980)/a_0(980)$: only at $\sqrt{s}$> 1.5 GeV

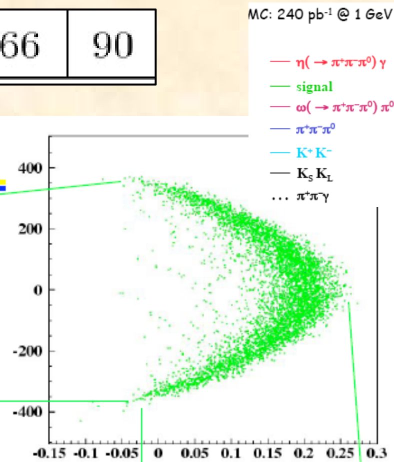
$\sqrt{s}$ (GeV)	1	1.2	1.4
$\sigma_{e^+e^-\to e^+e^-\pi^0}$ [pb]	266	317	364
$\sigma_{e^+e^-\to e^+e^-\eta}$ [pb]	43	66	90



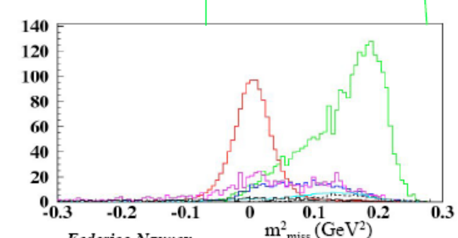
$$\frac{dN_X}{dW_{\gamma\gamma}} = L_{int}\frac{dL}{dW_{\gamma\gamma}}\sigma(\gamma\gamma\to X)$$

$e^+e^- \to e^+e^-\eta$: p_L vs. M_{miss}^2



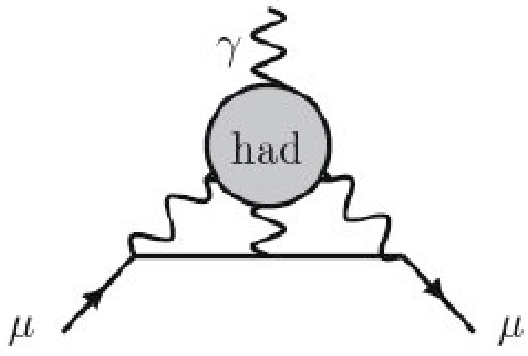


$$M^2_{miss} = s + m_\eta^2 - 2\sqrt{s}\sqrt{p_T^2 + m_\eta^2 + p_L^2}$$
$$= s + m_\eta^2 - 2\sqrt{s}E_T\left(1 - \frac{p_L^2}{E_T^2}\right)^{1/2}$$
$$\simeq s + m_\eta^2 - 2\sqrt{s}E_T - \sqrt{s}\frac{p_L^2}{E_T}$$
$$E_T = \sqrt{p_T^2 + m_\eta^2} \sim m_\eta$$

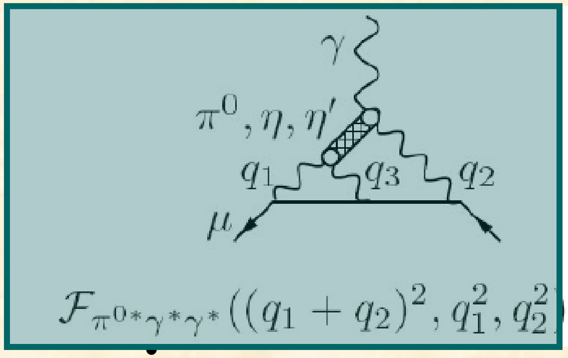


Federico Nguyen 09-04-2009

Hadronic-LBL contribution to a_μ



F.Nguyen



Contribution	N/JN
π^0, η, η'	99 ± 16
π, K loops	-19 ± 13
π, K loops + other subleading in N_c	–
axial vectors	22 ± 5
scalars	-7 ± 2
quark loops	21 ± 3
total	116 ± 39

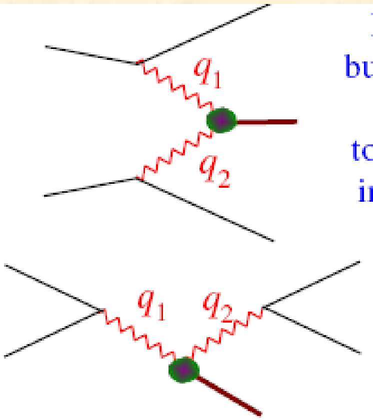
$a_\mu^{\mathrm{LbL;had}} \times 10^{11}$

G.Isidori

Some infos on these f.f. are obtained from
- radiative Dalitz decays [$dF(0, q^2)/dq^2$]
- leptonic decays [weighted integral of the f.f.]

What we really miss is $d^2 F(q_1^2, q_2^2)/dq_1^2\, dq_2^2$ which could possibly extracted from

$\gamma^*\gamma^* \to$ P at large angle and/or $\gamma^* \to$ P γ^*, both at large energy [Bijnens, Persson, '01]

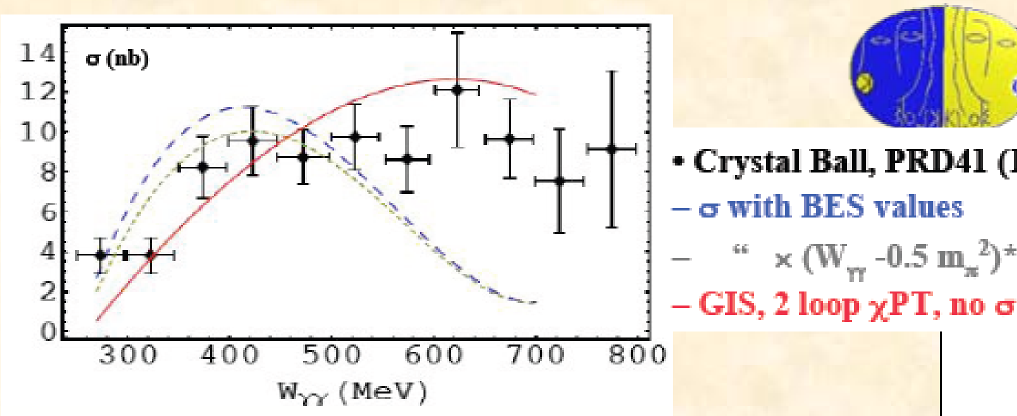


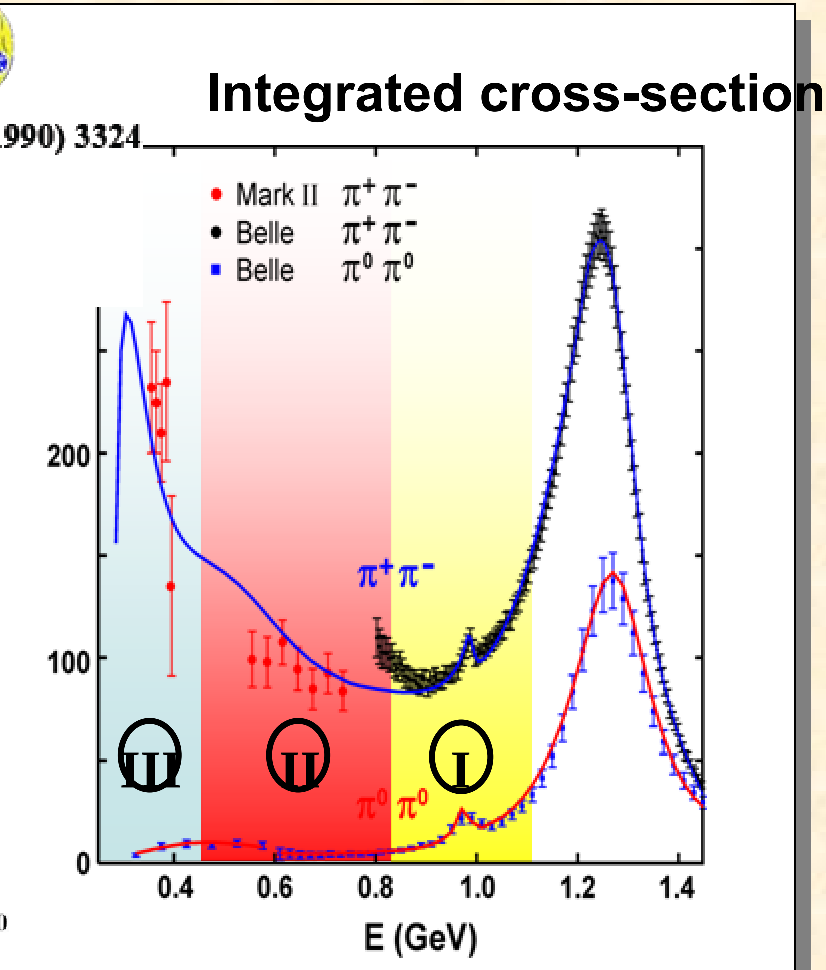
Not easy, but definitely worth to be further investigated

Scalar spectroscopy: $\gamma\gamma$ production

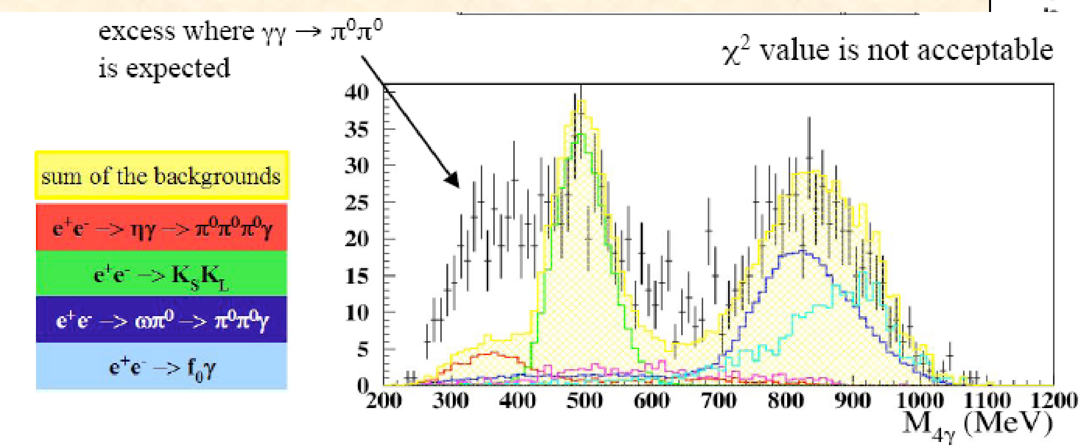
- There are open issues in low-energy spectroscopy (4q states, …) that benefit from $\gamma-\gamma$ measurements at KLOE-2

M.Pennington





$\gamma-\gamma$ tagger system at KLOE-2 for backg. rejection

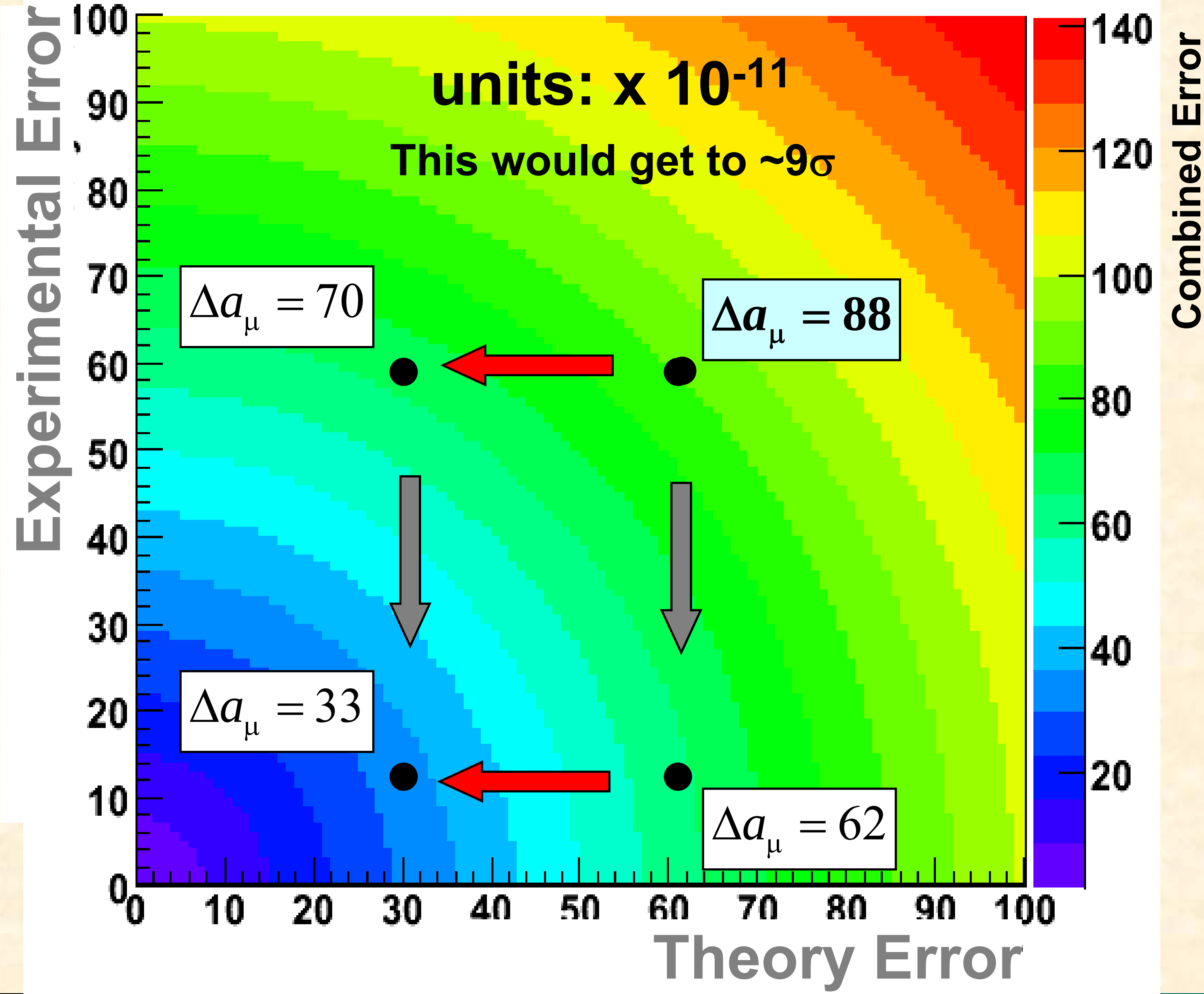


Conclusions

- There are several open questions in particle physics that require experimentation at low energy
- Lattice QCD results on form factors will call soon for new data on semileptonic kaon decays
- Kaon Interferometry is unique for CPT and QM tests at the Planck scale
- The DM problem, combined with other puzzling results suggested exotic extensions of the SM with new light states. At KLOE-2 a large part of the parameter space can be explored.
- Deeper studies of pseudoscalars and scalars are needed to understand several aspects of non-perturbative QCD
- A major improvement in the precision of the hadronic cross section is requested for
  - solving the 3-σ discrepancy on $(g-2)_\mu$ / to further constrain MSSM
  - obtaining the fundamental parameter α_{em} at the level of precision needed for the TeV scale

Spares

Solving the 3σ discrepancy



F. Mescia

$$\frac{B(K\to\mu\nu)}{B(\pi\to\mu\nu)}\times\frac{B(n\to pl\nu)}{B(K\to\pi l\nu)}=\left(\frac{f_K}{f_\pi}\frac{1}{f_+(0)}\right)^2\times\left(1+g^H\frac{m_K^2}{m_{H^+}^2}\right)^2(\text{known f.s})$$

$$R_{l23}=\left|\frac{V_{us}(K_{\ell 2})}{V_{us}(K_{\ell 3})}\times\frac{V_{ud}(0^+\to 0^+)}{V_{ud}(\pi_{\ell 2})}\right|$$

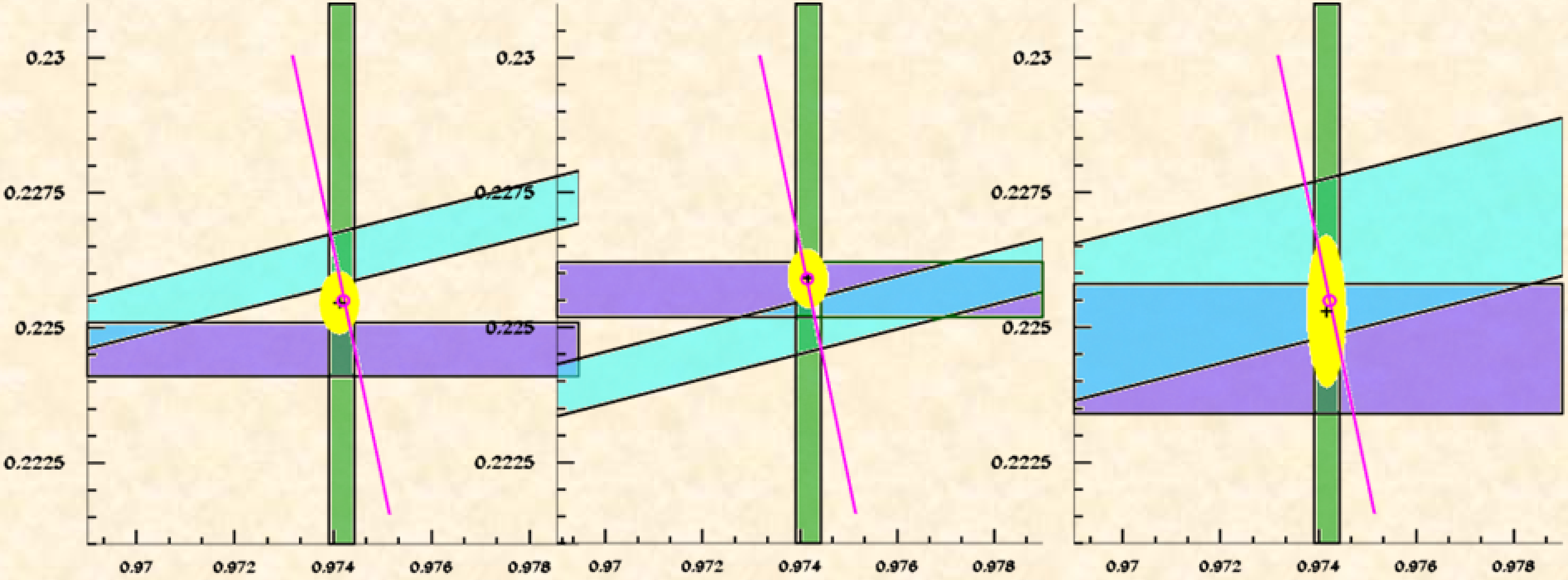
$$R_{l23}=\left|1-\frac{m_{K^+}^2}{M_{H^+}^2}\left(1-\frac{m_d}{m_s}\right)\frac{\tan^2\beta}{1+\epsilon_0\tan\beta}\right|$$

$|V_{ud}| = 0.97418(26)$ (superallowed $0^+ \to 0^+$)

$|V_{ud}| = 0.9746(19)$ (neutron decay).

$|V_{ud}| = 0.9728(30)$ (pion decay)

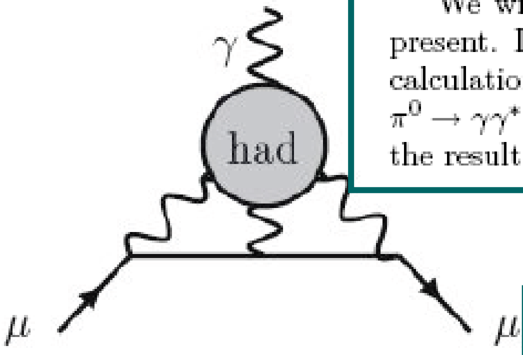
$|V_{ud}| = 0.9719(17)$ (nuclear mirror transitions)

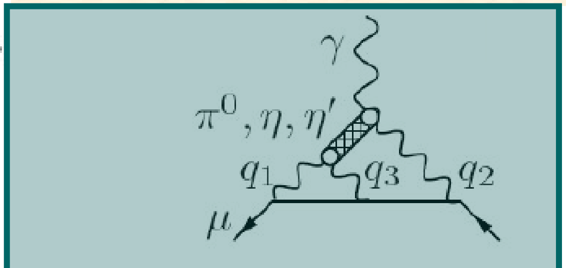


F.Nguyen

$a_\mu^{had,LBL}$ = (10.5 ± 2.6) 10^{-10} J.Prades et at., arXiv:0901.0306

We wish to emphasize, however, that this is only what we consider to be our best estimate at present. In view of the proposed new $g_\mu - 2$ experiment, it would be nice to have more independent calculations in order to make this estimate more robust. More experimental information on the decays $\pi^0 \to \gamma\gamma^*$, $\pi^0 \to \gamma^*\gamma^*$ and $\pi^0 \to e^+e^-$ (with radiative corrections included) could also help to confirm the result of the main contribution in Eq. (12).





$\mathcal{F}_{\pi^{0*}\gamma^*\gamma^*}((q_1+q_2)^2, q_1^2, q_2^2)$

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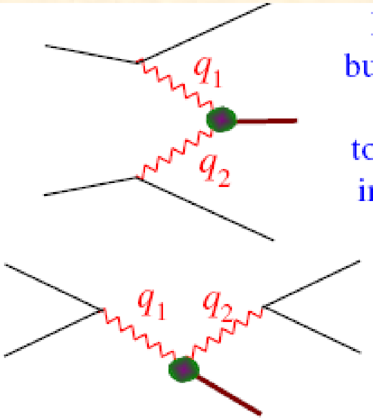
G.Isidori

Not easy, but definitely worth to be further investigated



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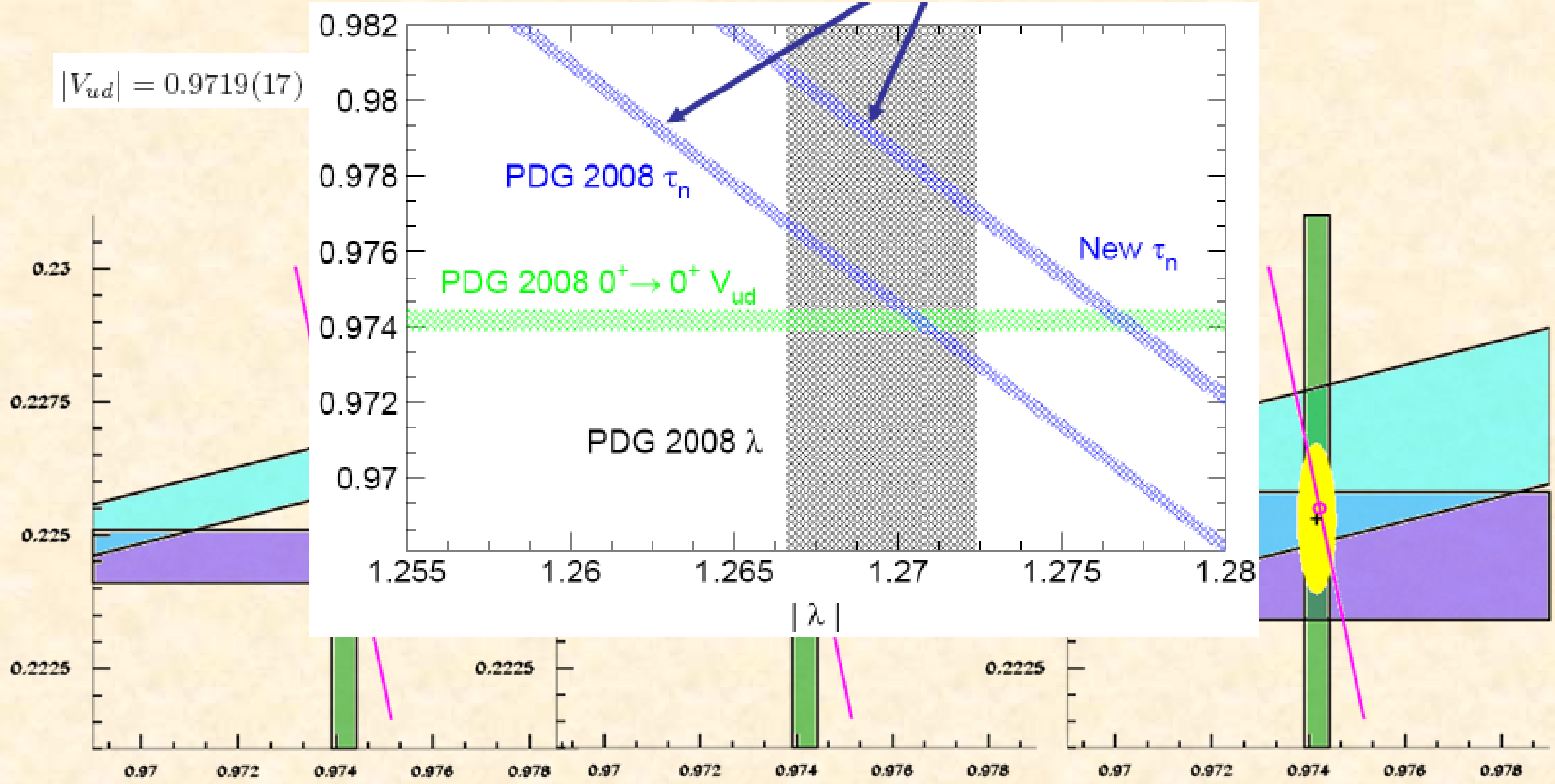
$|V_{ud}| = 0.9746(19)$ (neutron decay).

$|V_{ud}| = 0.9719(17)$



$$\frac{\Gamma(K_{\mu 2(\gamma)})}{\Gamma(\pi_{\mu 2(\gamma)})} = \frac{|V_{us}|^2}{|V_{ud}|^2} \times \frac{f_K^2}{f_\pi^2} \times \frac{M_K(1-m_\mu^2/M_K^2)^2}{m_\pi(1-m_\mu^2/m_\pi^2)^2} \times 1+\alpha(C_K - C_\pi)$$