PHYSICS ISSUES AT DAΦNE 2

Fabio Bossi, LNF

Frascati 6 Novembre 2003

PHYSICS ISSUES AT DAΦNE 2

- NUCLEON FORM FACTORS (HE)
- KAON PHYSICS (HL)
- HYPERNUCLEAR SPECTROSCOPY (HL)
- HADRONIC CROSS SECTION (HL,HE)

HL = *HIGH LUMINOSITY*

HE = *HIGH ENERGY*

BARYONS FORM FACTORS

NUCLEON FORM FACTORS IN THE TIME LIKE REGION

Differential x-section:

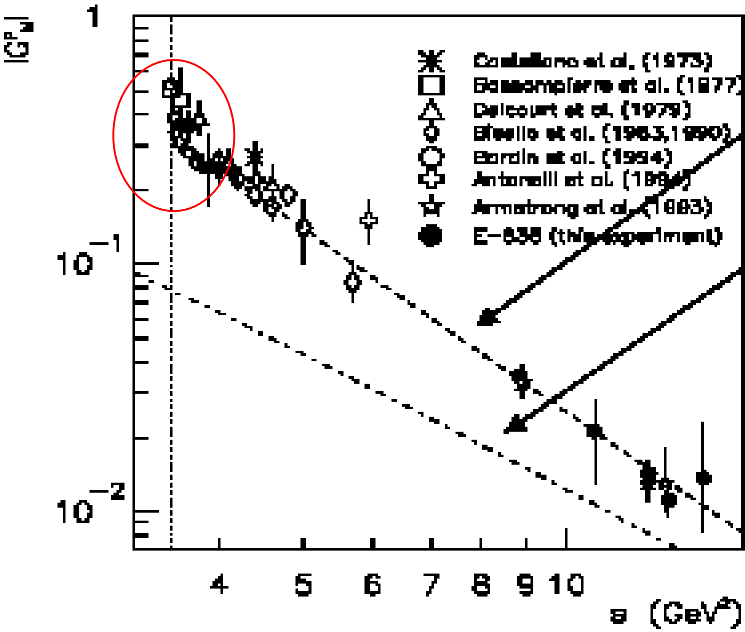
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta C}{4Q^2}\left[\left|G_M(Q^2)\right|^2(1+\cos^2\theta^*) + \frac{4m_p^2}{Q^2}\left|G_E(Q^2)\right|^2 \sin^2\theta^*\right]$$

G_E, G_M complex numbers, ***need polarization of final state*** to measure the relative phase

At large Q^2, ***$G(Q^2) = G(-Q^2)$***

If only valence quarks ***$G_M(n) = G_M(p) / 2$***

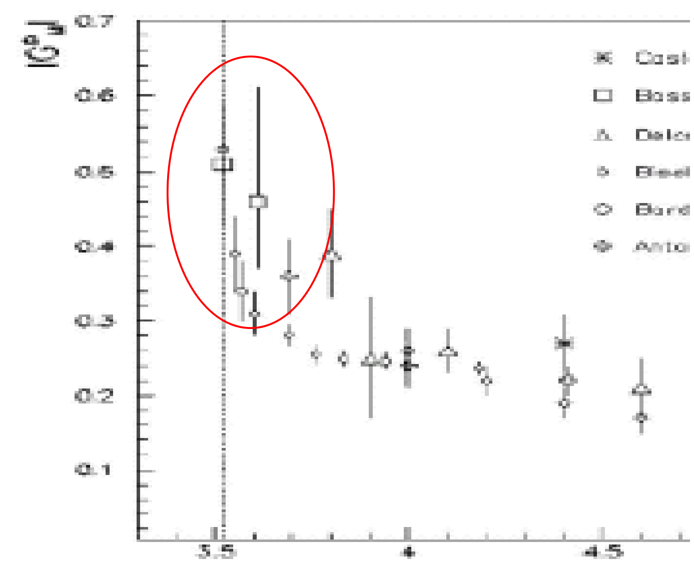
PROTON FORM FACTOR



pQCD fit

$G(Q^2) = G(-Q^2)$

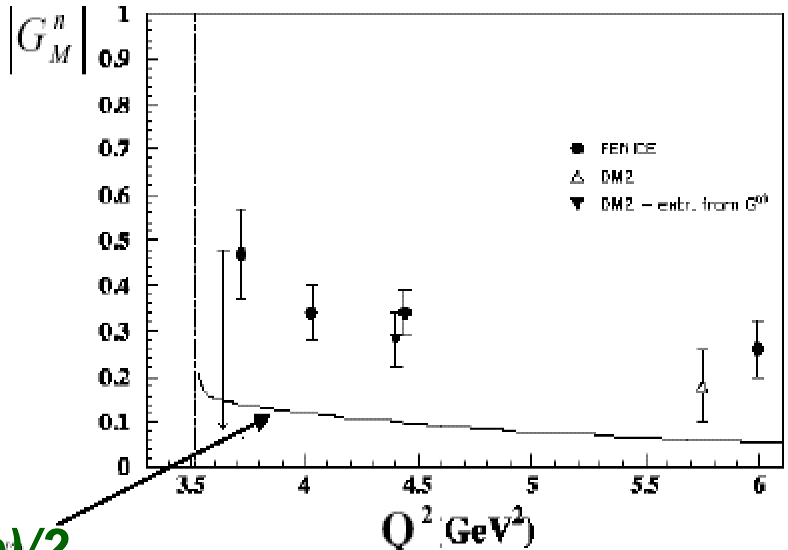
factor 2 from naive prediction!



rapid fall just above threshold

A. De Falco

NEUTRON FORM FACTOR



$G_M(p)/2$

***Data from FENICE only*,**

74 events, ∫Ldt = 0.4 pb^{-1}

$G_M(n) > G_M(p)$!

A. De Falco

Λ FORM FACTOR

Only one existing measurement (DM2) based on 4 events @ 2.4 GeV

EVENT YIELDS

$\sigma(e^+e^- \rightarrow NN) \sim 0.1 \div 1$ nb

400 ÷ 4000 events/day @ present luminosity

$\sigma(e^+e^- \rightarrow \Lambda\Lambda) \sim 0.1$ nb

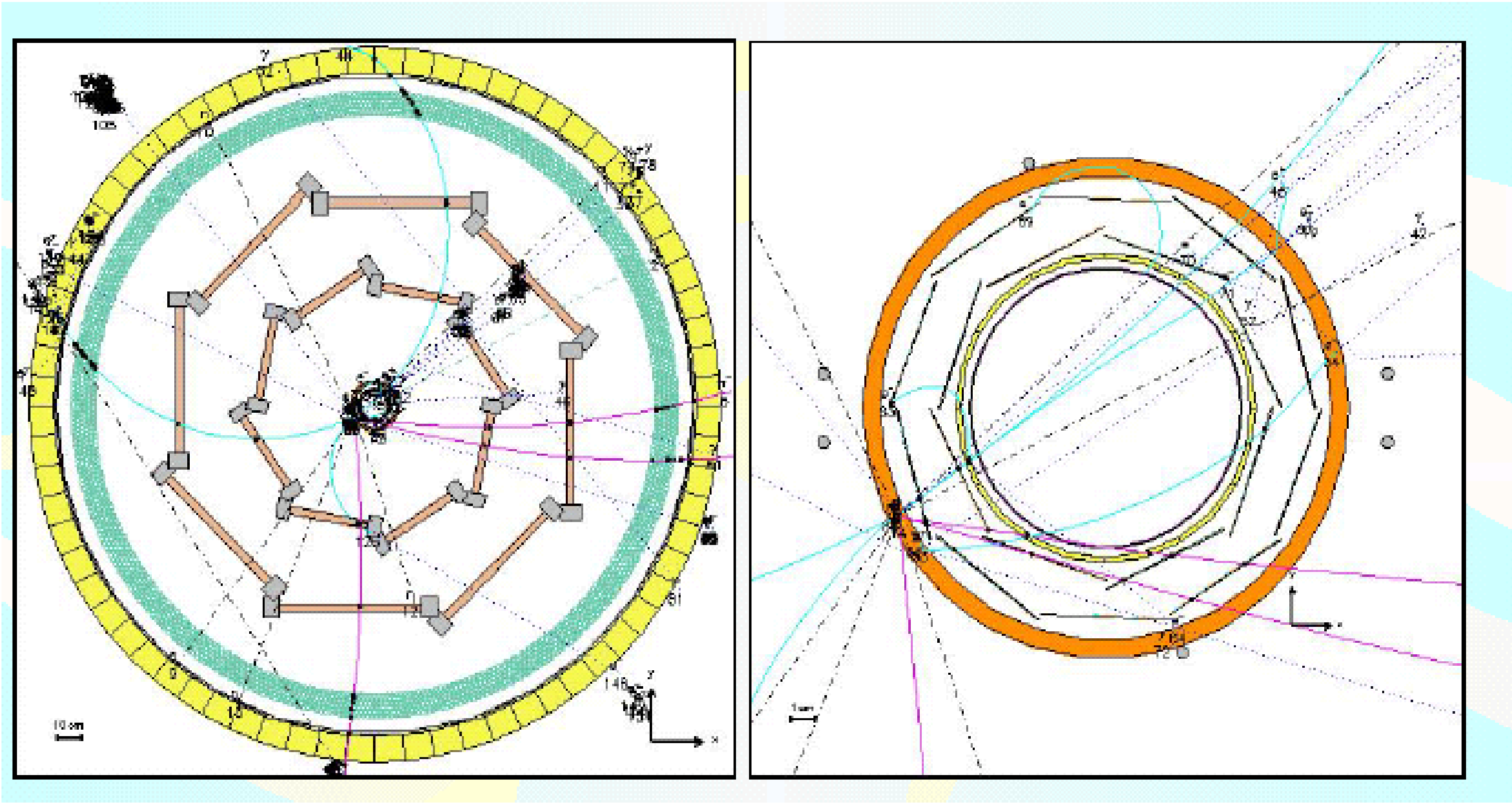
400 events/day @ present luminosity

FINUDA estimates efficiencies ranging between (5 ÷ 40)% for nucleons (no idea for Λ's) (A. Filippi)

Major limitation of FINUDA present setup is limited angular acceptance (KLOE has full solid angle coverage)

FINUDA might measure p polarization! (A. Filippi)

FINUDA TYPICAL EVENT



$e^+e^- \rightarrow n\bar{n}$ $\sqrt{s}$ = 1890 MeV

A. Filippi

MY CONCLUSIONS ON BARYON F.F.

***NUCLEON F.F. CAN BE MEASURED WITH UNPRECEDENTED PRECISION AT D2 AS LONG AS L > few* 10^{31}**

DISCRIMINATION BETWEEN NN AND $\gamma\gamma$ ***EVENTS (B/S ~ 4) BASED ON TIMING MIGHT RESULT VERY DIFFICULT DUE TO HIGH BUNCH X-ING RATE IN DAΦNE***

LAMBDA F.F. MEASUREMENT SHOULD BE PURSUED $\rightarrow$ ***S > 2.4 GeV***

KAON PHYSICS

G. Isidori

Rare K decays & Flavor Physics

The SM can be considered as the *renormalizable part* of an effective field theory, valid up to a (still undetermined) cut–off scale Λ:

$$\mathscr{L} = \mathscr{L}_{\text{gauge}}(A_i, \psi_i) + \mathscr{L}_{\text{Higgs}}(\phi, \psi_i, v) + \Sigma_i \frac{c_i}{\Lambda^2} O_i^{(6)} + \ldots$$

? (v ↔ Λ)

Only 3 couplings
- simple
- tested with high precision

More than 15 coupl.
- complicated
- not very well known yet

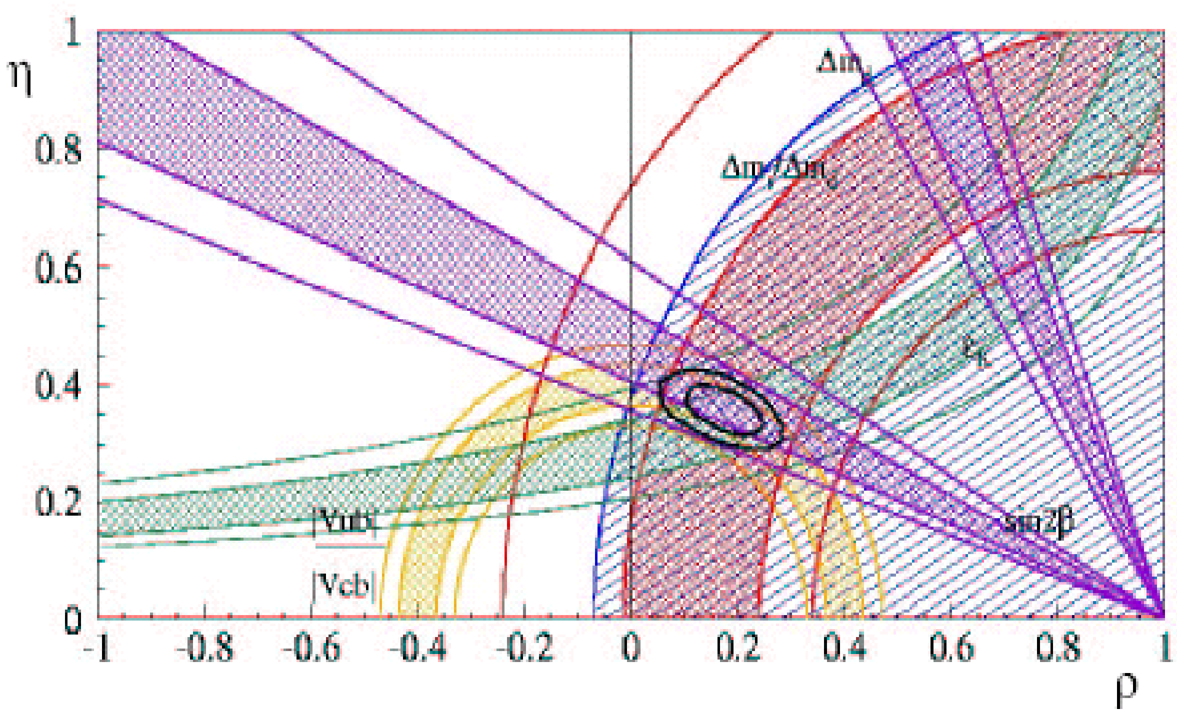
2 +...	Higgs Potential
3 +...	Lepton's Yukawa coupl.
10	Quark's Yukawa coupl.

[FLAVOR PHYSICS]

Quark–flavor mixing is a key ingredient to understand the symmetry–breaking sector of the SM and, possibly, to provide an indirect indication about the value of Λ → Rare decays

The Flavor Problem:

Available data on $\Delta F=2$ FCNC amplitudes (meson–antimeson mixing) already provides serious constraints on the scale of New Physics...



e.g.:

$K^0-\bar{K}^0$ mixing

⇓

$\Lambda \gtrsim 100$ TeV

for $O^{(6)} \sim (\bar{s}d)^2$

much more severe than bounds on the scale of flavor–conserving operators from e.w. precision data

...while a natural stabilization of the Higgs potential ⇒ $\Lambda \sim 1$ TeV

After the recent precise data from *B* factories, it is more difficult [although not impossible...] to believe that this is an accident

G. Isidori

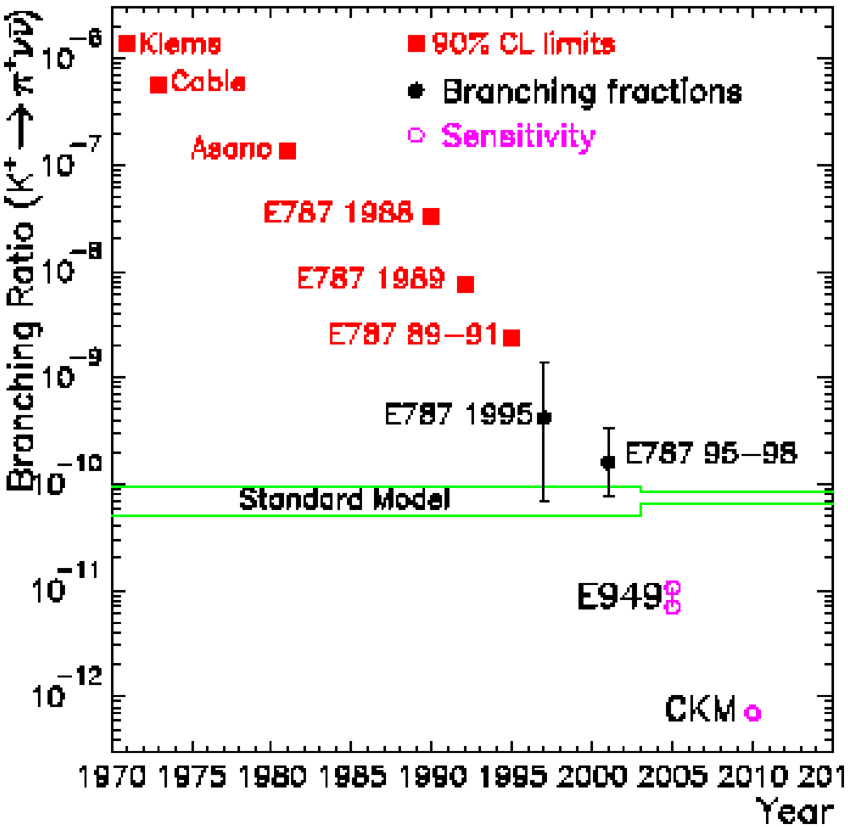
G. Isidori

decreasing SM contrib. →

decreasing SM contrib. ↓ (rows)

	$b \to s$ ($\sim\lambda^2$)	$b \to d$ ($\sim\lambda^3$)	$s \to d$ ($\sim\lambda^5$)
$\Delta F=2$ box	ΔM_{Bs} $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd} $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4−quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s \gamma$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d \gamma$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu\mu$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu\mu$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

(circled) = *Theoretical error < 10%*

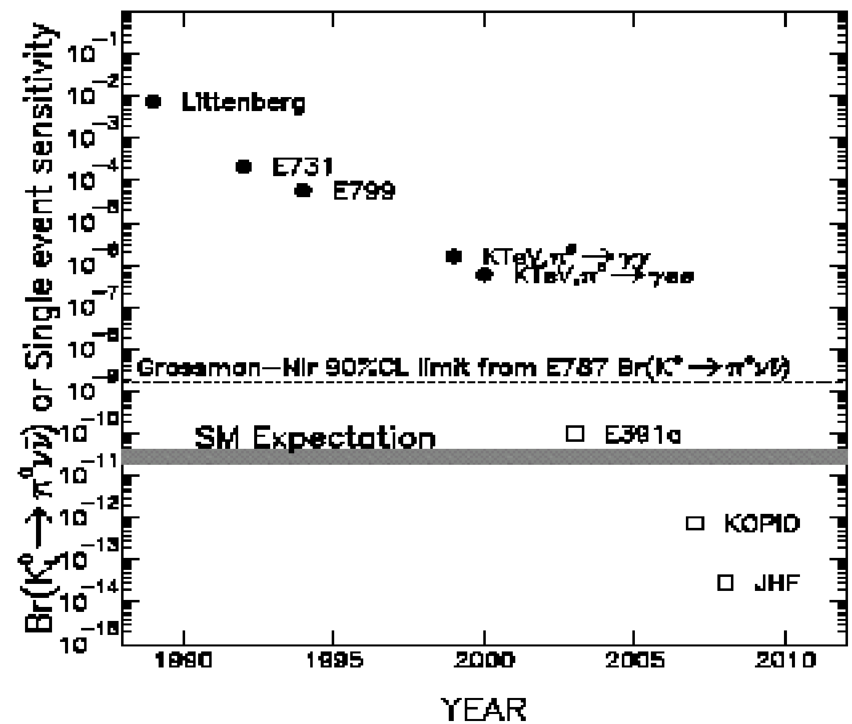


$K^+ \to \pi^+ \nu \bar{\nu}$ history

E787: completed.

E949: 12 week run in 2002, can reach sensitivity goal of $\leq 10^{-11}$ when remaining 48 weeks of approved running is funded.

History of $K_L^0 \to \pi^0 \nu \bar{\nu}$



D. Jaffe

Outlook for $K \to \pi\nu\bar{\nu}$ measurements

E787: completed

E949: Approved by DOE(1999), DOE halts HEP at AGS(2002), awaiting funding to continue

CKM: Stage I approval(2001), data taking in 2009(?)

KOPIO: Approved by NSF(2003), construction start in 2005

Stopped by DOE !

D. Jaffe

$K_L \Rightarrow \pi^0 \nu\nu$ at a Φ factory?

A Φ-factory is naturally suited for this search since:

- **Kaons are tagged**
- **Kaons 4-momentum is known (reconstruction of decay kinematics allowed)**
- **Beam free of neutral baryons backg.**

Production rate: 10^6 K_S-K_L pairs / pb^{-1}

1 year @ 10^{35} $cm^{-2}s^{-1}$: 10^{12} K_L produced

observed decays: 30 * ε_{tot} / year (SM)

must be $\varepsilon_{tot} \geq\sim 10\%$

F. Bossi

F. Bossi

Conclusions

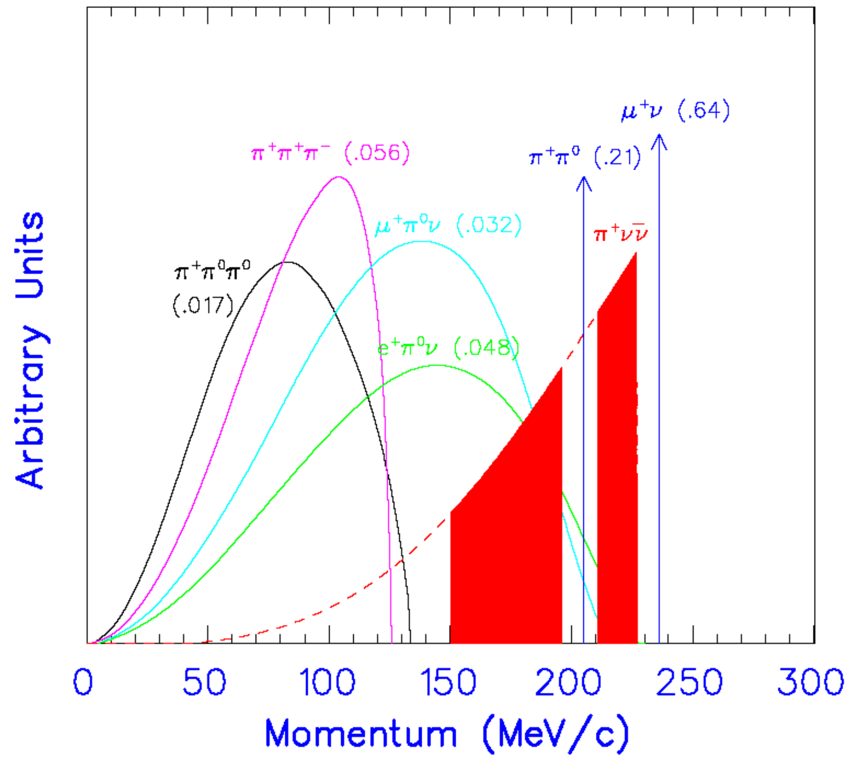
Physics & Machine

- The search for $K_L \to \pi^0 \nu\nu$ requires luminosities of order 10^{35} $cm^{-2}s^{-1}$
- The large x-ing angle option, although fascinating, seems to present some major disadvantage in terms of tagging wrt to the conventional one
- Beam related backgounds have to be kept under control

Detector

- Supplementary investigations needed on photon detection efficiency
- Tagging, trigger, and t_0 determination are an issue

CONCLUSIONS ON $K^\pm \to \pi^\pm \nu\nu$ WITH KLOE



L. Passalacqua

A KLOE-like detector can probably reach a sound rejection factor to address $K^\pm \to \pi^\pm \nu\nu$.

Minimum luminosity should be 10^{35}.

Should add a micro-vertex.

Should add a non-γ-distructive πμ separation system

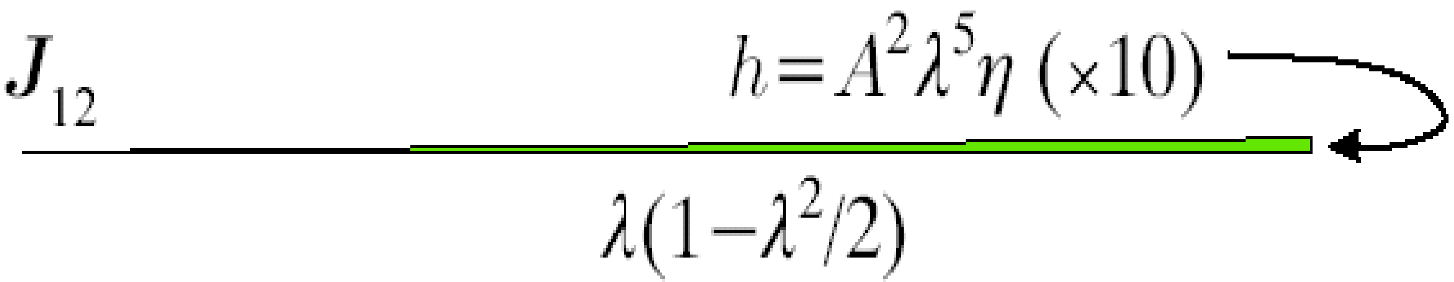
P. Franzini

$K^{\pm 0} \to \pi^{\pm 0} \nu\bar{\nu}$ cannot be measured

1. Cannot compete with hadron machines. KAMI: $4-7\times10^{13}$ K_L decays/y in detector. ϕ–factory @ $\mathcal{L}$=10^{35} cm^{-2} s^{-1} ; $2-3\times10^{11}$ K_L dec/y.
2. E787 (2 ev) has collected 6×10^{12} K^+ decays. E949 should improve by a factor 5, but no AGS. CKM improve by another factor 10, but recently put on hold.
3. $K^{\pm}$ experiments need strong pion ID or muon rejection. Efficiencies of few % are conceivable at higher p_μ. Still need $\mathcal{L}$>10^{36}.
4. A new limit has little value. Must measure BR.

P. Franzini

5. 8 years ago, I did believe $K \to \pi\nu\nu$ was fundamental. Today I do not think so.
6. Too bad



To get η need λ and A!

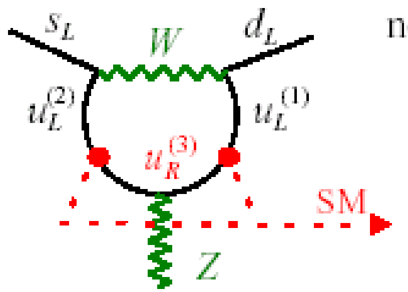
$\delta(A^2\lambda^5)/(A^2\lambda^5) \sim 5.6\%$, K. Schubert, LP03.
Optimistic?

…but still remember

B) Models with new sources of flavor mix. ➡ large effects posssible [no λ^5 suppression] in several specific frameworks.

[the optimistic perspective]

e.g.: MSSM with non−universal A terms



$(V_{ts}^* m_t) \times (V_{td} m_t)$

Nir & Worah, '97
Buras, Silvestrini & Romanino, '97
Colangelo & G.I, '98

Model−independent bound: $\Gamma(K_L \to \pi^0 \nu\nu) < \Gamma(K^+ \to \pi^+ \nu\nu)$

[Grossman & Nir, '97]

➡ $B(K_L \to \pi^0 \nu\nu) < 1.8 \times 10^{-9}$ [90% C.L.]

Two orders of magnitudes above the SM: a wide unexplored region of possible exciting new phenomena...

G. Isidori

P. Franzini

KLOE at DAΦNE2

- $\Delta S = \Delta Q$, use charge exchange, $K^+ \Rightarrow K^0$, $K^- \Rightarrow \overline{K}^0$ to tag strangeness.
- Use interference to measure $\Re\eta_{+-} \ldots \Im\eta_{00}$, $\Im\delta$
- K_S, and K_L, leptonic asymmetry$\rightarrow\Re\delta$. This would be the first look at the Plank scale in particle physics.
- Push all modes to the limit, $\sim 10^{-(10-11)}$

Kaon interferometry: what can be measured

A . Di Domenico

Double differential time distribution:

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

where $t_1(t_2)$ is the time of one (the other) kaon decay into f_1 (f_2) final state and:

$$\eta_i = |\eta_i| e^{i\phi_i} = \langle f_i | K_L \rangle / \langle f_i | K_S \rangle \qquad C_{12} = \frac{N^2}{2} \left| \langle f_1 | K_S \rangle \langle f_2 | K_S \rangle \right|^2$$

$f_i = \pi^+\pi^-, \pi^0\pi^0, \pi l\nu, \pi^+\pi^-\pi^0, 3\pi^0, \pi^+\pi^-\gamma$ ..etc

characteristic interference term at a ϕ-factory => interferometry

Integrating in (t_1+t_2) we get the time difference ($\Delta t = t_1 - t_2$) distribution (1-dim plot):

$$I(f_1, f_2; \Delta t \geq 0) = \frac{C_{12}}{\Gamma_S + \Gamma_L}\left[|\eta_1|^2 e^{-\Gamma_L \Delta t} + |\eta_2|^2 e^{-\Gamma_S \Delta t} - 2|\eta_1||\eta_2| e^{-(\Gamma_S+\Gamma_L)\Delta t/2} \cos(\Delta m \Delta t + \phi_2 - \phi_1)\right]$$

for $\Delta t < 0$ $\quad \Delta t \to |\Delta t|$ and $1 \leftrightarrow 2$

From these distributions for various final states f_i we can measure the following quantities:

$$\Gamma_S \,,\ \Gamma_L \,,\ \Delta m \,,\ |\eta_i| \,,\ \arg(\eta_i) = \phi_i$$

Kaon interferometry: main observables

A . Di Domenico

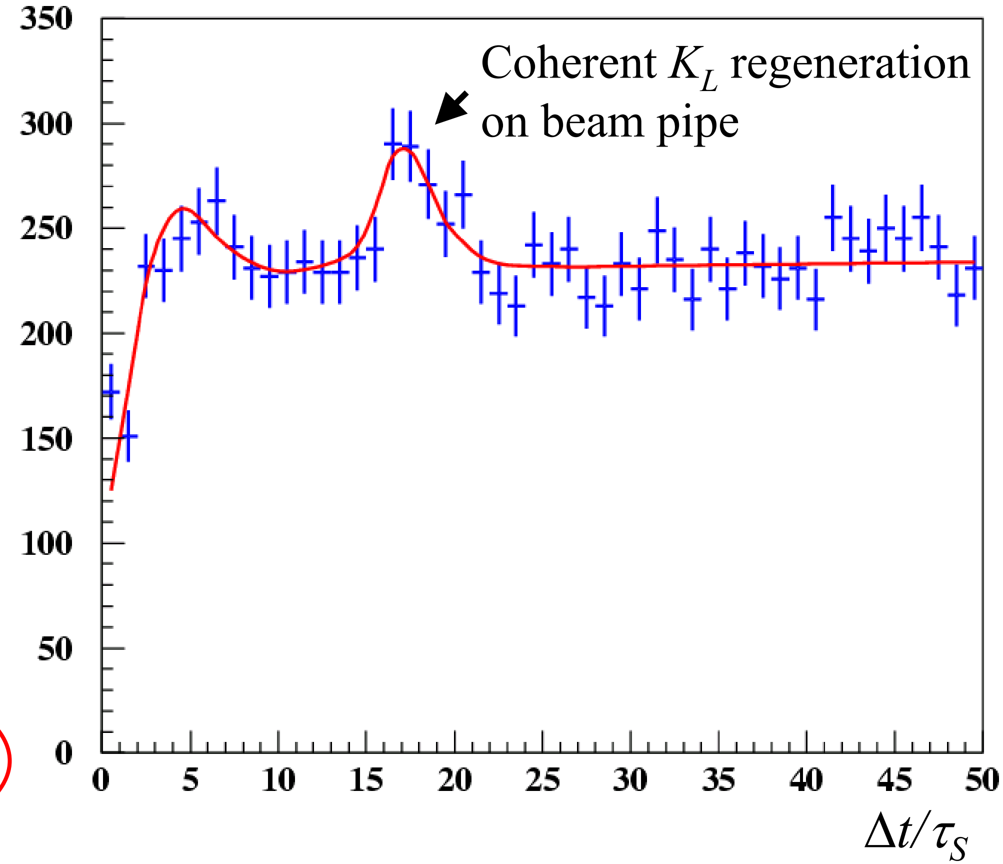
mode	measured quantity	parameters
$\phi \to K_S K_L \to \pi^+\pi^- \ \pi^+\pi^-$	$I(\pi^+\pi^-, \pi^+\pi^-; \Delta t)$	$\Delta m \quad (\Gamma_S \quad \Gamma_L)$
$\phi \to K_S K_L \to \pi^+\pi^- \ \pi^0\pi^0$	$A(\Delta t) = \frac{I(\pi^+\pi^-, \pi^0\pi^0; \Delta t > 0) - I(\pi^+\pi^-, \pi^0\pi^0; \Delta t < 0)}{I(\pi^+\pi^-, \pi^0\pi^0; \Delta t > 0) + I(\pi^+\pi^-, \pi^0\pi^0; \Delta t < 0)}$	$\Re\left(\frac{\varepsilon'}{\varepsilon}\right) \quad \Im\left(\frac{\varepsilon'}{\varepsilon}\right)$
$\phi \to K_S K_L \to \pi\ell\nu \ \ \pi\ell\nu$	$A_{CPT}(\Delta t) = \frac{I(\pi^- e^+ \nu, \pi^+ e^- \bar{\nu}; \Delta t > 0) - I(\pi^- e^+ \nu, \pi^+ e^- \bar{\nu}; \Delta t < 0)}{I(\pi^- e^+ \nu, \pi^+ e^- \bar{\nu}; \Delta t > 0) + I(\pi^- e^+ \nu, \pi^+ e^- \bar{\nu}; \Delta t < 0)}$	$\Re\delta_K - \Re\left(\frac{d^*}{a}\right)$ $\Im\delta_K + \Im\left(\frac{c^*}{a}\right)$
$\phi \to K_S K_L \to \pi\pi \ \ \pi\ell\nu$	$A(\Delta t) = \frac{I(\pi^- e^+ \nu, \pi^+\pi^-; \Delta t) - I(\pi^+ e^- \bar{\nu}, \pi^+\pi^-; \Delta t)}{I(\pi^- e^+ \nu, \pi^+\pi^-; \Delta t) + I(\pi^+ e^- \bar{\nu}, \pi^+\pi^-; \Delta t)}$	$\phi_{\pi\pi}$

$$A_L = 2\left(\Re\varepsilon_K - \Re\delta_K + \Re b/a + \Re d^*/a\right)$$

$\phi \rightarrow K_S K_L \rightarrow \pi^+\pi^- \pi^+\pi^-$

A . Di Domenico

Fit including Δt resolution and efficiency effects + regeneration:
Γ_S, Γ_L fixed from PDG



KLOE preliminary
340 pb^{-1} (2001 + 2002 data)

$\Delta m = (5.64 \pm 0.37) \times 10^{11}\ \hbar\ s^{-1}$

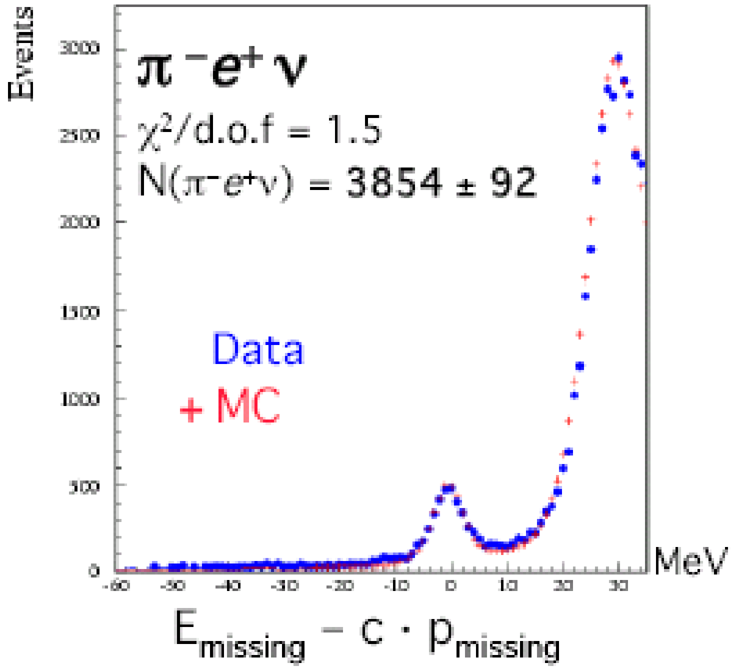
PDG '02: $(5.301 \pm 0.016) \times 10^{11}\ \hbar\ s^{-1}$

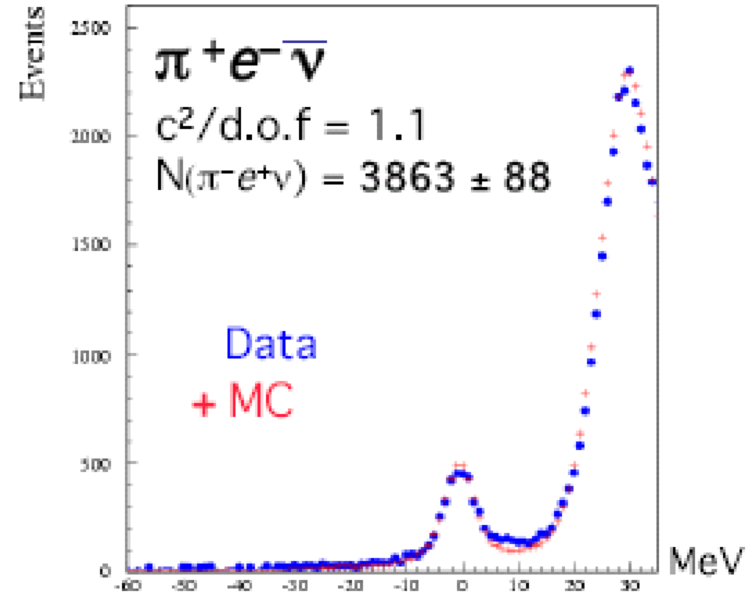
At a new ϕ-factory with 500 fb^{-1} :
$\delta\Delta m \sim 0.009 \times 10^{11}\ \hbar\ s^{-1}$

S. Dell'Agnello

$BR(K_S \to \pi e \nu)$

KLOE '03 preliminary result w/170 pb^{-1} 2001 data

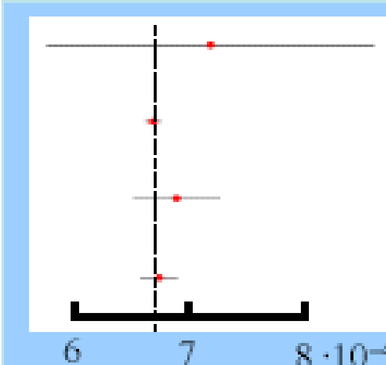




$BR(\pi^- e^+ \nu) = (3.46 \pm 0.09 \pm 0.06) \cdot 10^{-4}$

$BR(\pi^+ e^- \bar{\nu}) = (3.33 \pm 0.08 \pm 0.05) \cdot 10^{-4}$

$BR(\pi^\mp e^\pm \nu) = (6.81 \pm 0.12 \pm 0.10) \cdot 10^{-4}$



CMD-2 '99

PDG eval. from K_L

KLOE '02 PLB 535 2002

KLOE '03 prelim.

BR($K_S \to \pi e \nu$): charge asymmetry

Matrix elements of semil. decays

$$\langle \pi^- e^+ \nu | H_W | K^0 \rangle = a + b$$
$$\langle \pi^+ e^- \bar{\nu} | H_W | \bar{K}^0 \rangle = a^* - b^*$$

$$\langle \pi^+ e^- \bar{\nu} | H_W | K^0 \rangle = c + d$$
$$\langle \pi^- e^+ \nu | H_W | \bar{K}^0 \rangle = c^* - d^*$$

Symmetry	Constraints
T	*Im a = Im b = Im c = Im d = 0*
CP	*Im a = Re b = Im c = Re d = 0*
CPT	*b = d = 0*
$\Delta S = \Delta Q$	*c = d = 0*

Charge asymmetry

$$A \equiv \frac{\Gamma(\pi^- e^+ \nu) - \Gamma(\pi^+ e^- \bar{\nu})}{\Gamma(\pi^- e^+ \nu) + \Gamma(\pi^+ e^- \bar{\nu})}$$

$$\begin{cases} A_S = 2(\mathrm{Re}\,\varepsilon_K + \mathrm{Re}\,\delta_K + \mathrm{Re}\,b/a - \mathrm{Re}\,d^*/a) \\ A_L = 2(\mathrm{Re}\,\varepsilon_K - \mathrm{Re}\,\delta_K + \mathrm{Re}\,b/a + \mathrm{Re}\,d^*/a) \end{cases}$$

$A_S - A_L = 4\mathrm{Re}\,\delta_K - 4\mathrm{Re}\,d^*/a \quad 0$
implies CPT violation

~~CP~~ | *~~CPT~~ in mixing* | *~~CPT~~ in decay* | *ΔS ΔQ and ~~CPT~~*

KLOE preliminary
$A_S = (19 \pm 17 \pm 6) \cdot 10^{-3}$
First measurement of A_S!

Compare to A_L w.a.
$A_L = (3.322 \pm 0.055) \cdot 10^{-3}$
$A_L = A_S = 2\,\mathrm{Re}\,\varepsilon_K$ if CPT conserved

CPLEAR PL B444 1998 Re $\delta_K = (2.9 \pm 2.7)\ 10^{-4}$ 3

S. Dell'Agnello

The KAON system already provides the strongest upper bound on CPT conjugates states

$$\Delta M_K / M_K < 10^{-18}$$

To improve on this one should aim at measuring δ with a precision of ~ 10^{-5} or better which implies ~10^9 K_S semileptonic decays

@ 5 10^{34} one gets ~ 3 10^8 $K_S \to \pi e \nu$ decays/year

(and b.t.w. ~ 1000 $K_S \to 3\pi^0$ decays/year)

Efficiencies have to be applied but note that precision scales with $\sqrt{N_{ev}}$

Conclusions: detector upgrades @D2

- Just an exercise for future discussion/work
- If IR-D2 smaller, we can consider a compact inner vertex detector inside the Drift Chamber (r=10-25cm)
  - add z measurement !!! Helps pattern recognition
  - improves vertexing at IP and interferometry for all-track events like $K_L K_S \rightarrow \pi^+\pi^- \pi^+\pi^-$ and $K_L K_S \rightarrow \pi e \nu \pi^+\pi^-$
  - helps ID Kaon interactions (esp. Q-exch.) in the inner DC wall
  - if beam pipe were pure Be: big bonus for reconstruction
  - if pure Be sphere difficult ⇒ make a cylinder w/same radius
  - QCAL experience will be useful; can make new QCAL smaller
- Calorimeter: increasing readout granularity would improve clustering and enhance PID
- Current drift chamber upgrade w/new ADCs (enhances e/π but also) helps π/μ separation in K^0 decays

S. Dell'Agnello

HYPERNUCLEAR SPECTROSCOPY

OPEN QUESTIONS

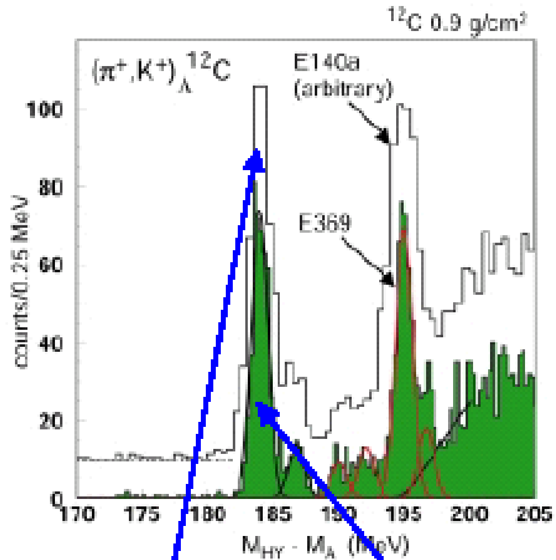
A. Feliciello

- (low-energy) YN (YY) interaction
  - detailed knowledge of the hypernuclear fine structure
    - → evaluation of the spin dependent terms of the ΛN interaction
  - measurement of angular distribution and polarization of γ-rays
    - → determination of spin and parity of each observed level
- Impurity nuclear physics
  - measurement of transition probability B(E2)
    - → information on the size and deformation of hypernuclei
    - → measurement of nucleus core shrinking → glue role of Λ
- Properties of hyperons in nuclear matter (medium effect)
  - measurement of transition probability B(M1)
    - → g-factor value for Λ in nuclear matter

FINUDA IS COMING!

A. Feliciello

KEK data

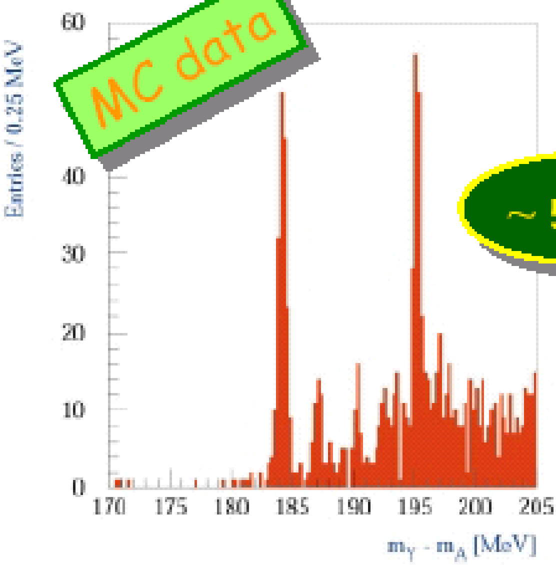


ΔE = 1.9 MeV FWHM

ΔE ~ 1.5 MeV FWHM

ΔE ~ 0.75 MeV FWHM

MC data

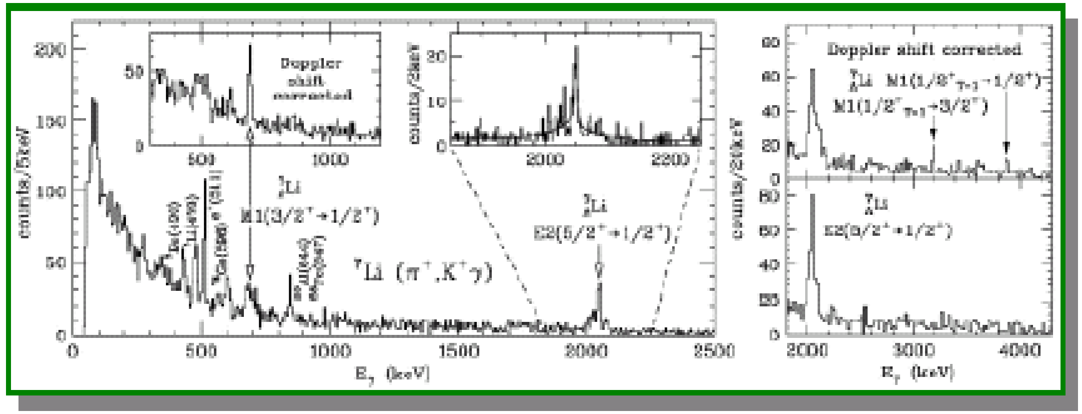


~ 5 pb^{-1}

$^{12}C(K^-_{stop}, \pi^-)^{12}_{\Lambda}C$

ONE STEP BEYOND: γ SPECTROSCOPY

KEK E419



Precise hypernuclear γ-spectroscopy has been established as new frontier in strangeness nuclear physics

NEED HIGH LUMINOSITY DUE TO LOW EVENT RATES (AND LOW DETECTOR EFFICIENCIES)

A. Feliciello

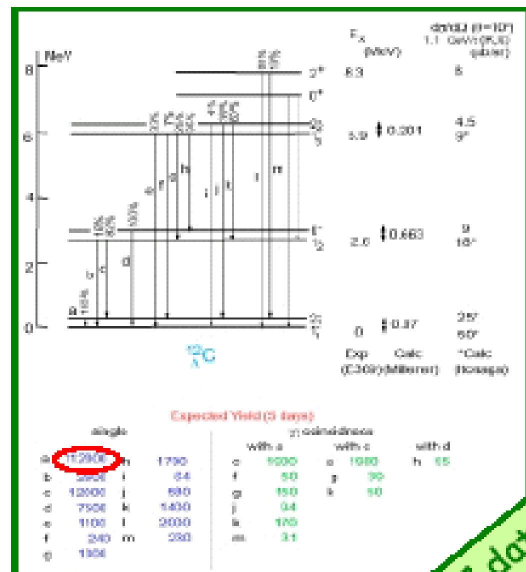
FINUDA WITH GERMANIUM DETECTOR

SLIGHTLY REDUCED DETECTOR ACCEPTANCE

@ $\mathcal{L} = 10^{34}\ cm^{-2}\ s^{-1}$ FINUDA can observe ~ 1.6×10^4 ev/h from YN g.s.

- machine duty cycle: 75%
- spectrometer acceptance: 72%
- Ge acceptance: ~ 30%
- ε_{Ge}: ~ 30%

~ 1.87×10^4 ev/d



MC data

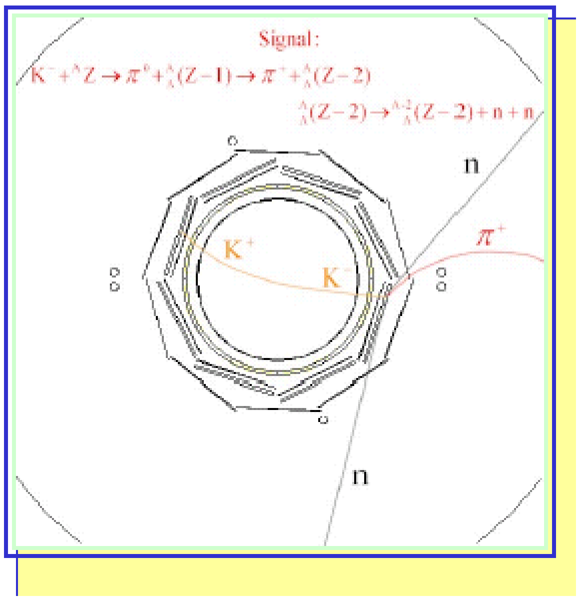
5 day data taking

~ 9.33×10^4 ev

A. Feliciello

PRODUCTION OF NEUTRON RICH HYPERNUCLEI

V. Paticchio



- Search for the existence of neutron-rich hypernuclei
- Exotic nuclear matter, with extreme N/Z ratio (${}^7_\Lambda H$, ${}^6_\Lambda H$, ${}^{12}_\Lambda Be$)
- Study of mass distributions more extended than ordinary nucleus
- Study of the effect of Λ hyperon on neutron-halo
- Interest of astrophysics to explain various phenomena of high density matter in neutron-star

Typical counting rate with FINUDA @ 10^{34} : 130 ev/h

HADRONIC CROSS SECTION

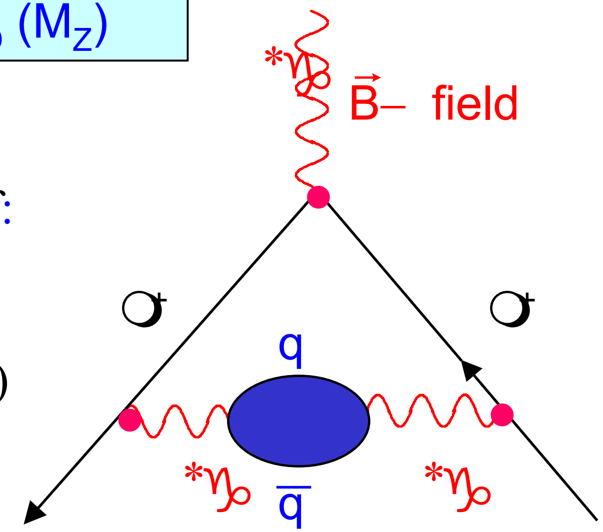
Muon - Anomaly

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 $\alpha_{QED}(M_Z)$

Dirac-Theory: $(g-2) = 0$

Quantum Corrections: $(g-2) \neq 0$ due to corrections of:
- electromagnetic Interaction
- weak Interaction
- strong Interaction (and maybe NEW PHYSICS ???)



hadrons

Hadronic Vacuum Polarization

$$a_\mu = (g_\mu - 2)/2 = \alpha/2\pi + \ldots$$

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

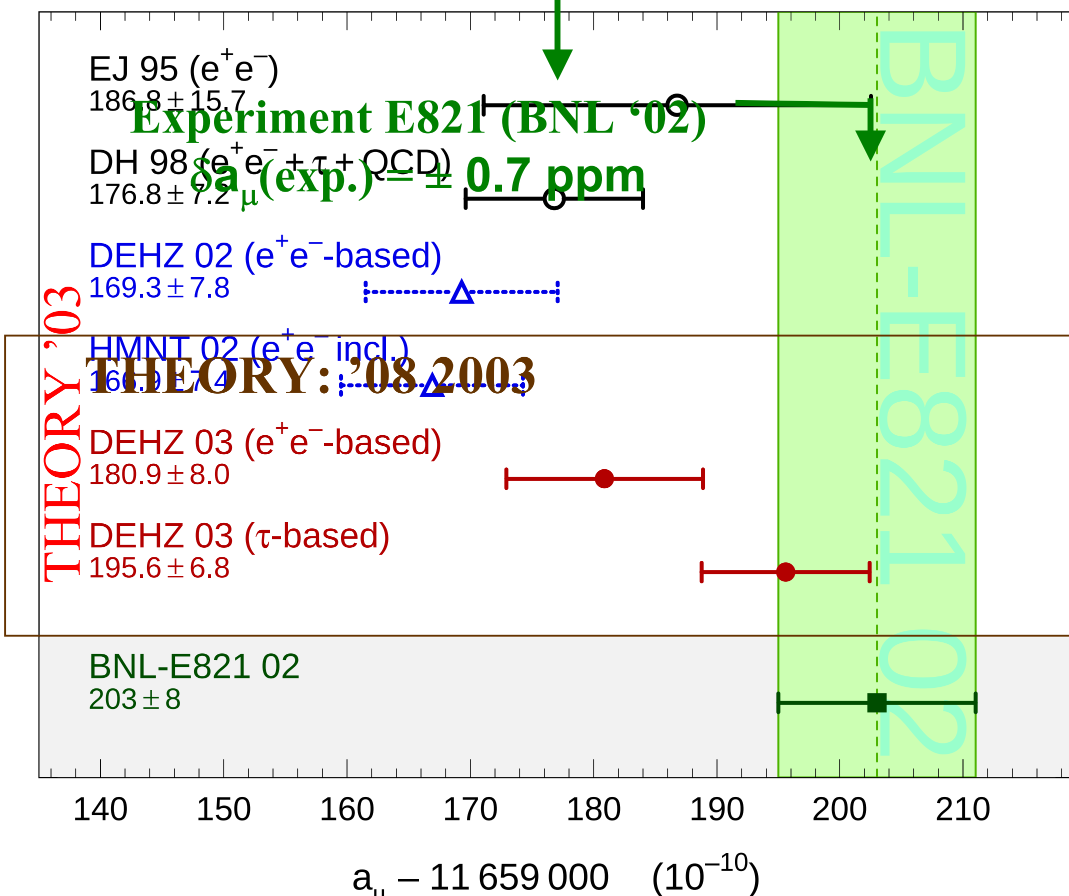
2nd largest contrib., cannot be calculated in pQCD

Error of hadronic contribution is dominating total Error !

Status: Muon - Anomaly

How to test the Standard Model?

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

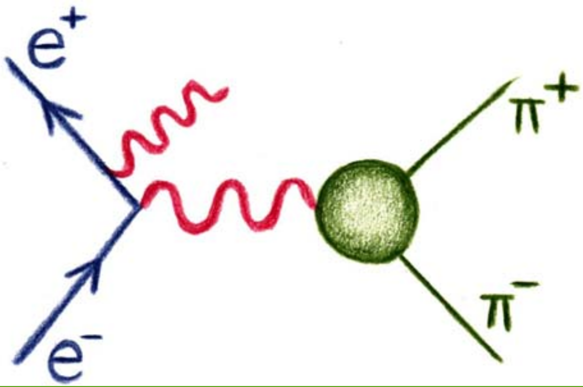
} Theory Evaluation using only e^+e^- - Data 2 σ - Deviation

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

RADIATIVE RETURN @ KLOE & BABAR

S. Müller

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



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

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)

Preliminary KLOE value for $a_\mu \times 10^{10}$

$$a_{\mu}^{\pi\pi} \propto \int_{0.37}^{0.95} ds\,\sigma(e^+e^- \to \pi^+\pi^-)\cdot K(s)$$

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 $0.37 < M_{\pi\pi}^2 < 0.93\ \text{GeV}^2$

***KLOE*:**

$$a_\mu^{\pi\pi} = 378.4 \pm 0.8_{stat} \pm 4.9_{syst} \pm 4.5_{theo}$$

***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

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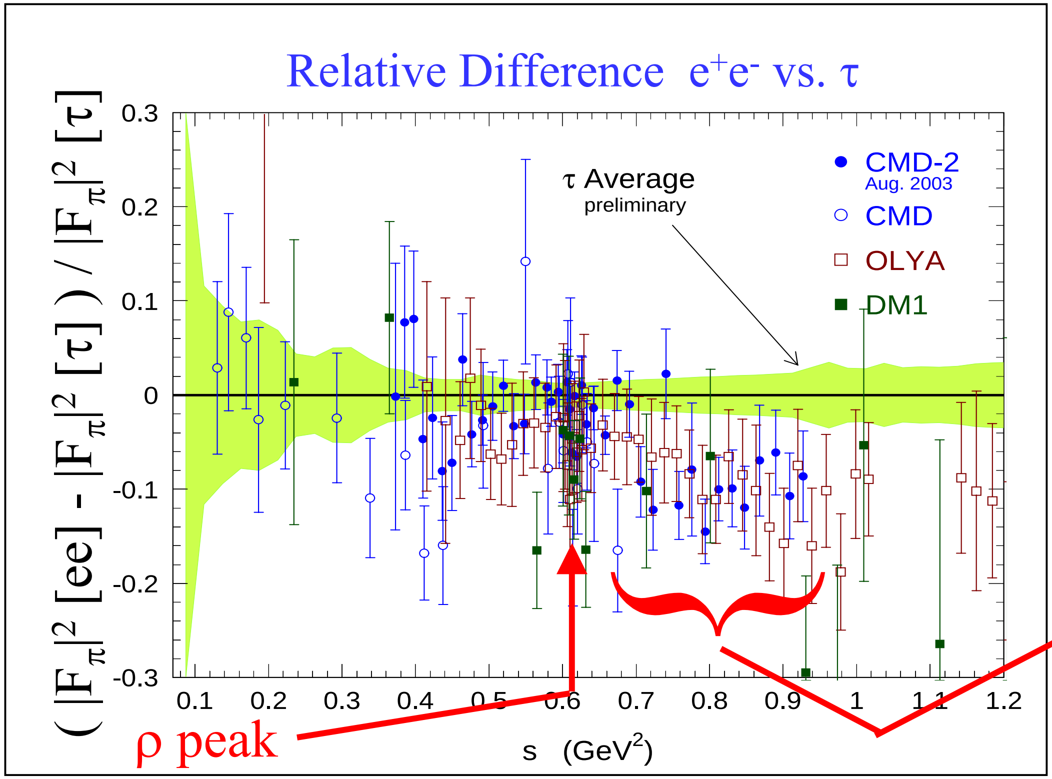
e^+e^- - versus τ - Data

Q^2 /GeV^2	KLOE a_μ^{had}	CMD2 a_μ^{had}
0.37:0.65	309.4 ± 5.0	308.5 ± 2.8
0.65:0.93	68.8 ± 1.0	72.2 ± 0.7

← ***our interpolation***



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

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

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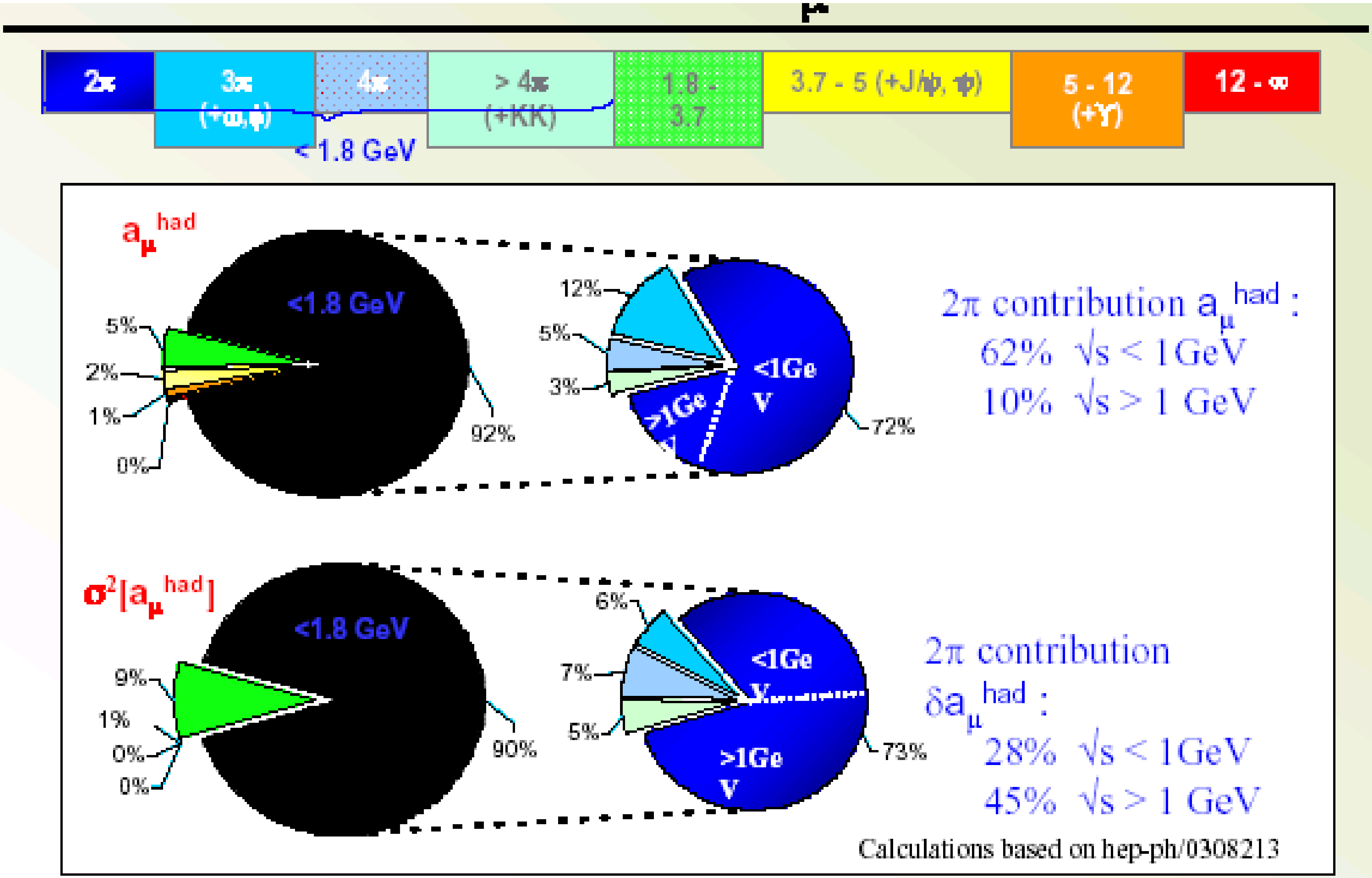

2π
3π (+ω,φ)
4π
> 4π (+KK)
1.8 - 3.7
3.7 - 5 (+J/ψ, ψ)
5 - 12 (+Υ)
12 - ∞
< 1.8 GeV
a_μ^{had}
<1.8 GeV
5%
2%
1%
0%
92%
12%
5%
3%
<1GeV
>1GeV
72%
2π contribution a_μ^{had} :
62% √s < 1GeV
10% √s > 1 GeV
$\sigma^2[a_\mu^{had}]$
<1.8 GeV
9%
1%
0%
0%
90%
6%
7%
5%
<1GeV
>1GeV
73%
2π contribution
δa_μ^{had} :
28% √s < 1GeV
45% √s > 1 GeV
Calculations based on hep-ph/0308213

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- 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 ***(E. Solodov)***
  - VEPP-2000: Energy Scan all channels ***(A. Sibidanov)***
  - DAΦNE-2 *Energy Scan or Rad. Return ???*

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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

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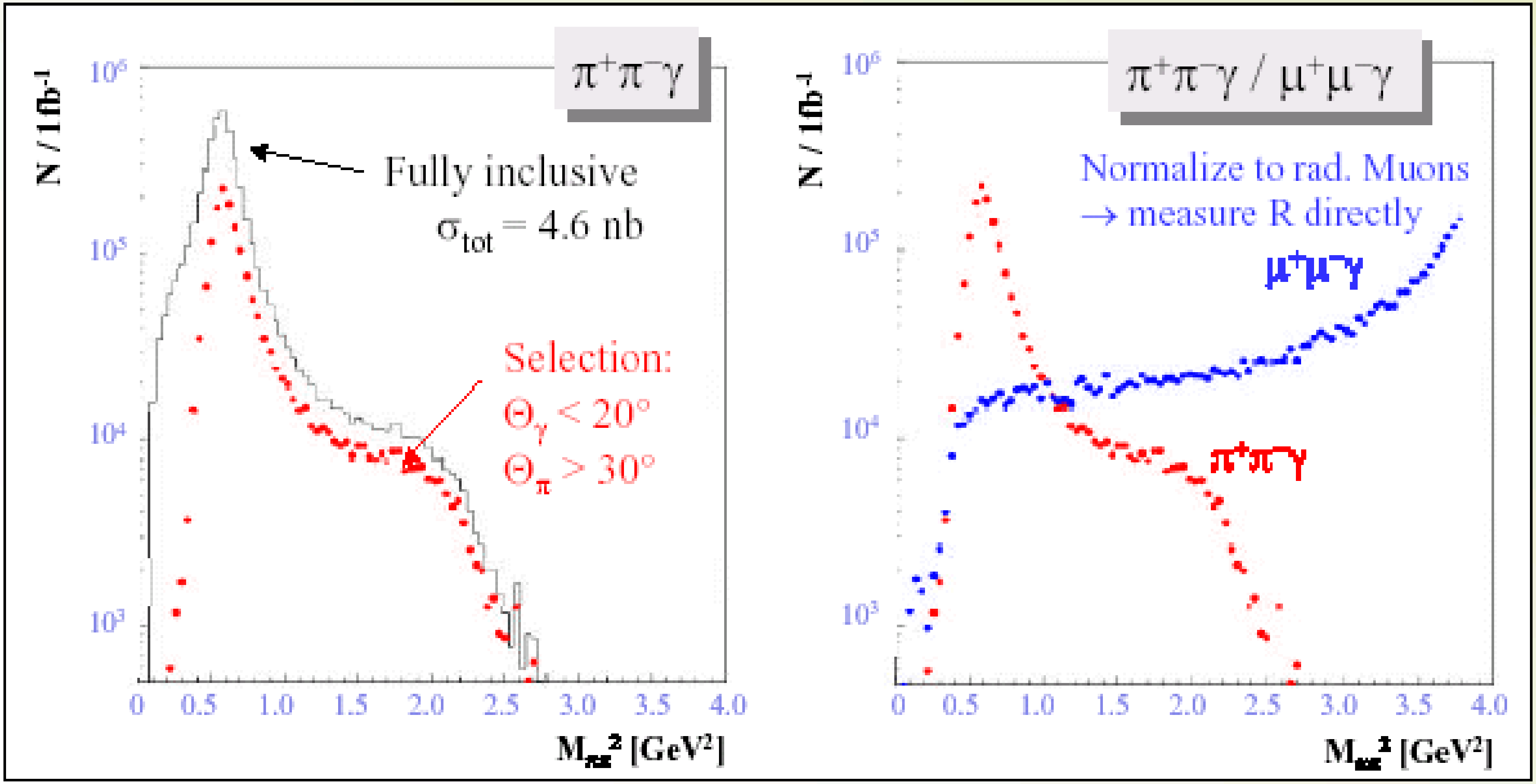
Radiative Return $2\pi\gamma$ @ $\sqrt{s} = 2$ GeV

- 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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CONCLUSIONS ON σ_{HAD}

- Right now 2.0 σ deviation between theory and experiment for the anomalous magnetic moment of the muon $\rightarrow$ 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?)

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

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