Gino Isidori (LNF)

1st Euridice Collaboration Meeting

[Frascati, 18−20 October 2002]

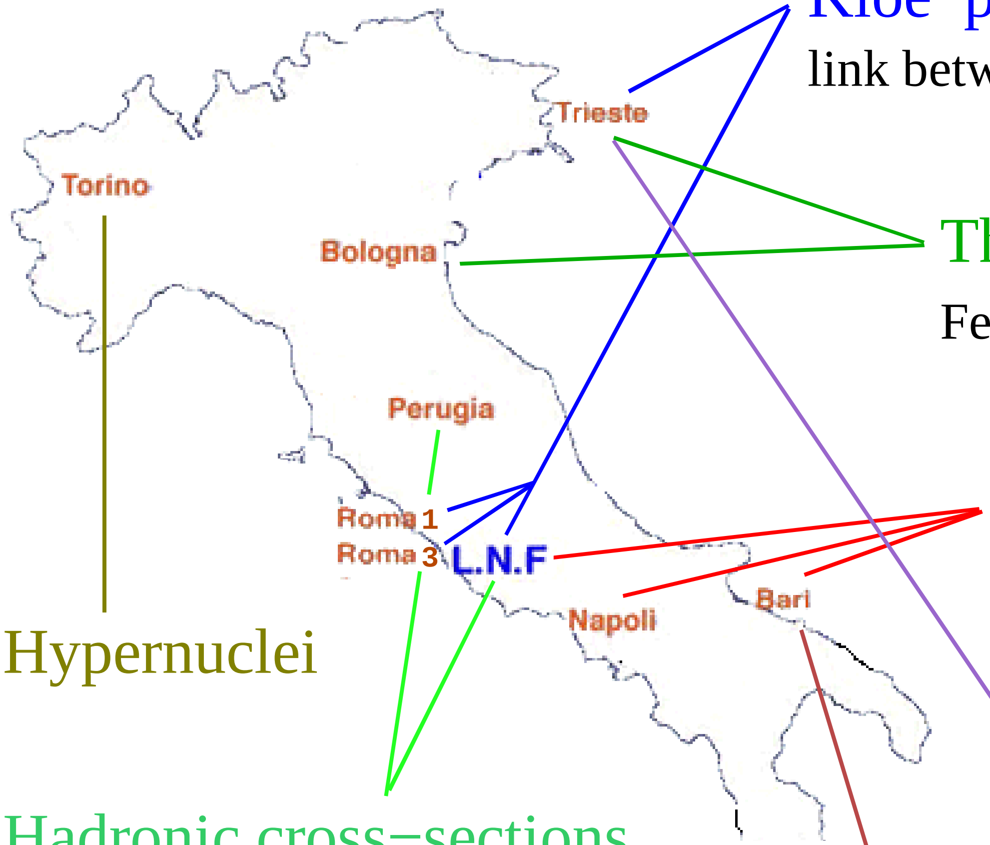
The EURIDICE −INFN node

9 Institutions

27 Researchers [15 full−time equiv.]

1 Φ Factory !

The EURIDICE –INFN physics program



Kloe physics [$K^{\pm}$ & $K_{L,S}$ decays, $e^+e^- \to$ had. (+ γ)]
link between th. (CHPT, rad. corr.) & exp.
⇒ Round Table, Scuri

Th. of $(g-2)_\mu$ analytic evaluation of multi–loop
Feynman diagrams; hadr. contr. to light–by–light
⇒ Czyz

Th. of CP–violation & flavour mixing
precise estimates of rare B & K decays
within & beyond the SM ⇒ D'Ambrosio

Hypernuclei

Non–standard time–evolution
dissipative effects in M-$\bar{M}$ systems ⇒ Benatti

Hadronic cross–sections
high–energy total cross–section
(soft gluon resummation);
space– and time–like f. factors
⇒ Ginzburg, Stern

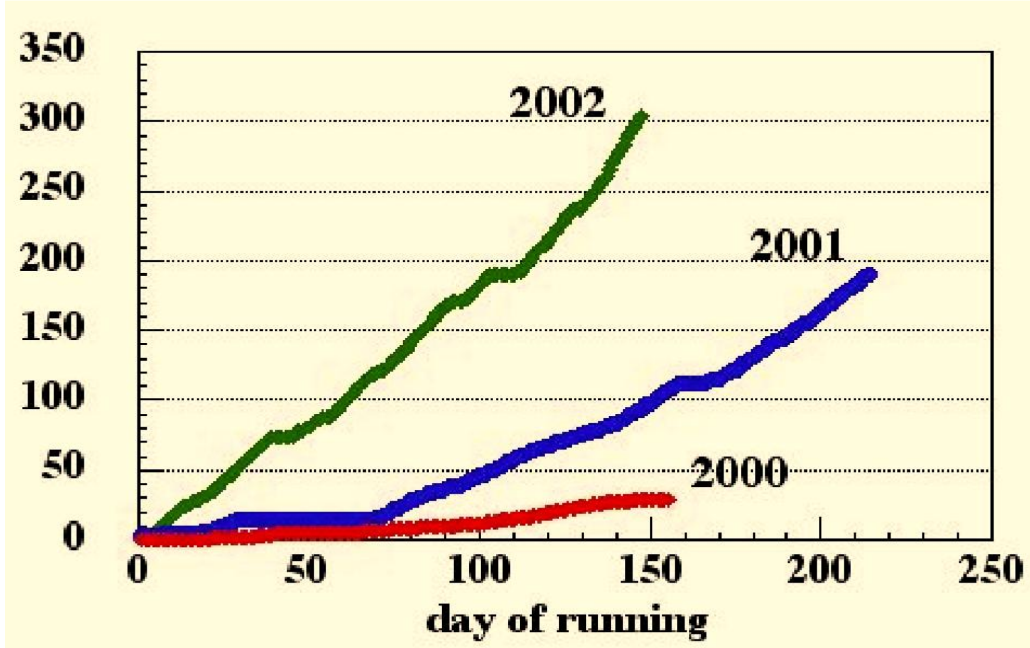
Heavy–meson dynamics
QCD sum–rules, HQET ⇒ Colangelo, De Fazio

KLOE physics

Very efficient DAΦNE ⊕ KLOE
run in 2002: $\int \mathscr{L}$ ('01+'02)= 500 pb^{-1}

⇓

~ 5×10^8 K_L K_S (untagged) pairs



Wide list of on−going activities [Φ, η and K decays]

Three outstanting research lines with 500 pb^{-1} :
(personal point of view)

several non−INFN links:

- $\sigma[e^+e^- \to$ had. $(+\gamma)]$ @ 10^{-2} level (or better) ⇔ $\Pi_\gamma(q^2)$ [DESY, Karlsruhe, Warsav]
- $\Gamma(K^{\pm}_{l3})$ & $\Gamma(K^{0}_{l3})$ @ 10^{-3} level (+ γ spectrum) ⇔ V_{us} , CHPT [Bern, Marseille, Valencia, Wien]
- Rare K_S decays [$K_S \to \pi l\nu$, 3π, πll down to 10^{-8} SES] ⇔ CPT, CP, CHPT [Valencia, Wien]

KLOE physics program

Discrete symmetries

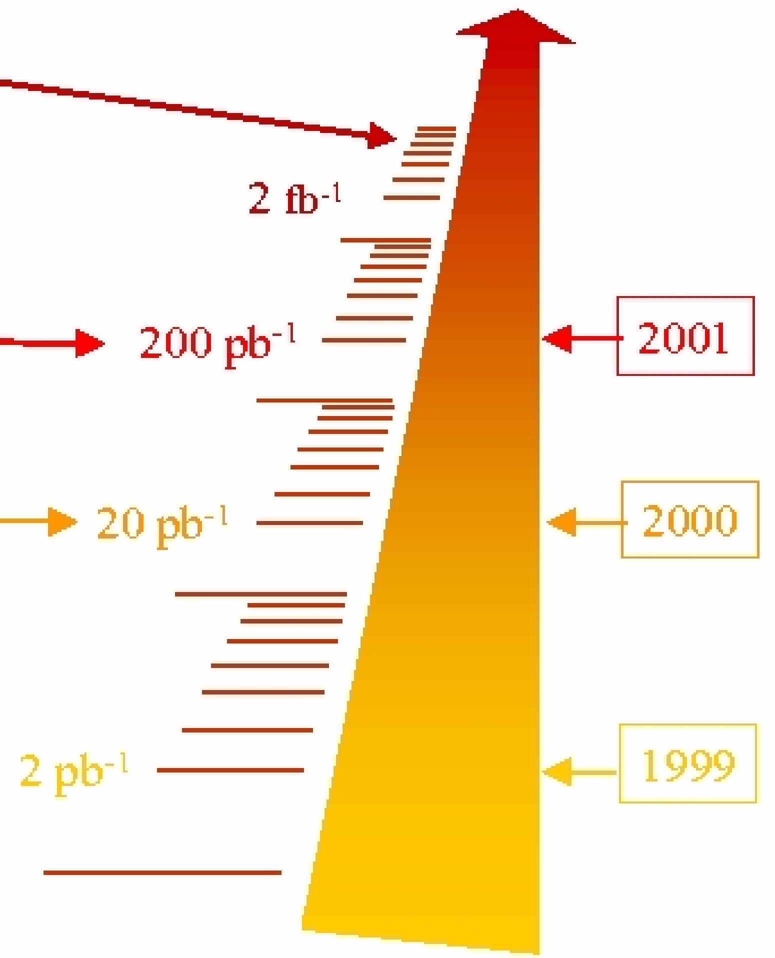
- ε'/ε to via double ratio (CP direct)
- Semileptonic asymmetry (CPT)
- $K_L K_S$ Interferometry

- $K_S \to \gamma\gamma$, $K_S \to 3\pi$, $K_S \to \pi\pi\gamma$
- $K_L \to 2\pi$, $K_L \to \gamma\gamma$
- V_{us} from $K^{\pm}$ and K_L decays
- $\sigma(e^+e^- \to \pi^+\pi^-)$ to < 1 % (stat)

on tape

- K_S decays
  - $BR(K_S \to \pi^+\pi^-)/BR(K_S \to \pi^0\pi^0)$
  - $BR(K_S \to \pi e \nu)$
- ϕ radiative decays
  - $\phi \to f_0\gamma$, $a_0\gamma$ scalar
  - $\phi \to \eta'\gamma$, $\eta\gamma$ pseudoscalar

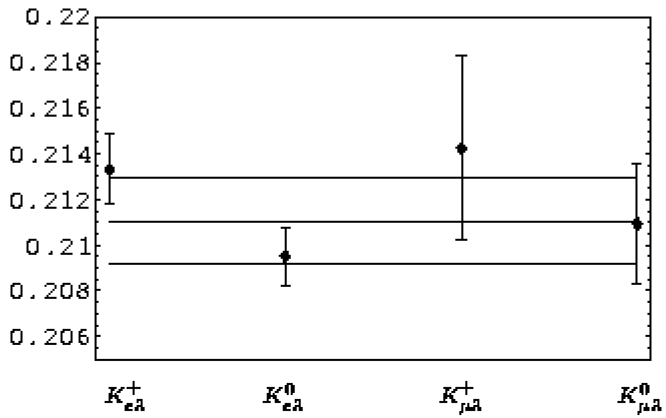
first published results



S. Miscetti, Aug. 2002

Present status of V_{us}

$f(0)\times V_{us}$



data after inclusion of SU(2) breaking corrections

large spread after SU(2) corr.
[γ–inclusive measurements?]

Cirigliano *et al.* '02
⇒ talk by Neufeld

Measuring V_{us} at KLOE

KLOE can improve the accuracy in the knowledge of Γ(e3) measuring:

- both charged and neutral kaons absolute BR's with the same detector
- directly the kaon partial decay width

$(\delta V_{us})^{exp} = 0.019$

$(\delta V_{us})^{th.} = 0.018$

Traditional method:

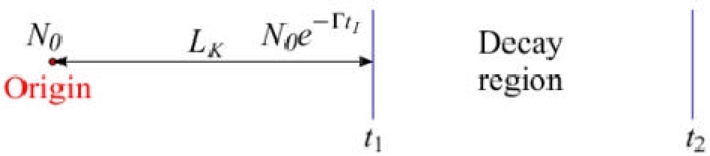
- measurement of $\Gamma = 1/\tau$
- measurement of BR(e3)

$\Gamma(e3) = BR(e3) \times \Gamma$

$$\frac{\delta\,\Gamma(e3)}{\Gamma(e3)} = \sqrt{\left(\frac{\delta\tau}{\tau}\right)^2 + \left(\frac{\delta(BR(e3))}{BR(e3)}\right)^2}$$

KLOE :

- by the tag count the number of K produced , N_{KL}
- count the number N_{e3} of semileptonic decays in the decay region



$\Gamma(e3) = (\Delta N_{e3} / \Delta t)/N_{KL}$

Γ is a correction & δτ/τ dependence reduced by a factor ≈5

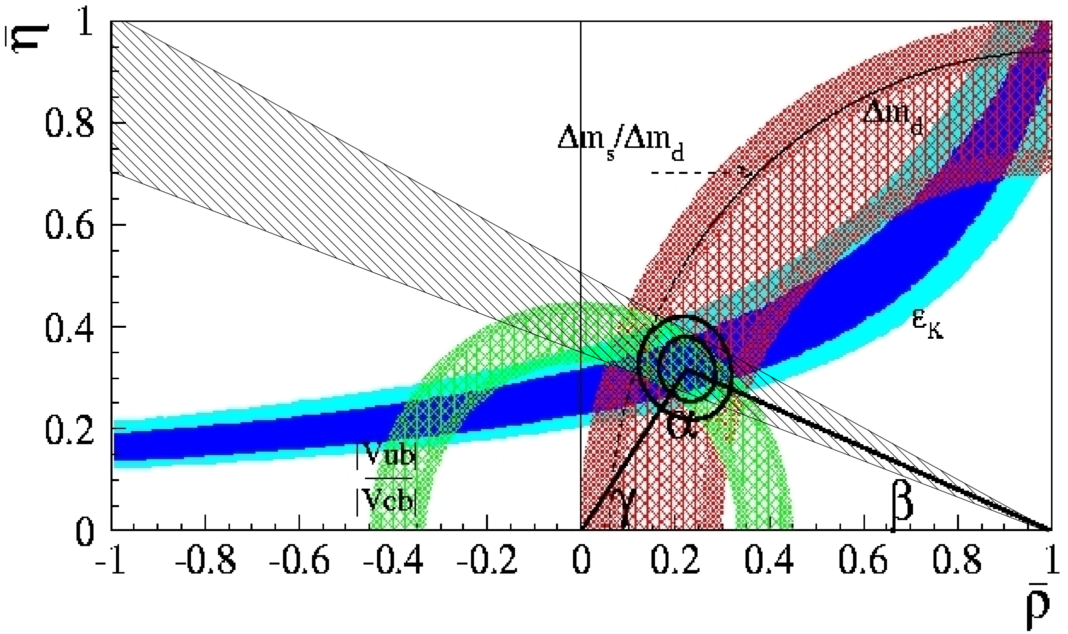
E. De Lucia,
Sept. 2002

- Theory of CP−violation and flavour mixing

My main activity in ’01−’02

The Flavour Problem

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



E.g.: $\bar{K}^0 - K^0$ mixing

$\Downarrow$

$\Lambda \gtrsim 100$ TeV for $O^{(6)} \sim (\bar{s}d)^2$

much more stringent that the bounds on the scale of flavour−conserving op. from ew precision data (~ few TeV)

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

After the recent precise data from *B* factories, it is very difficult to believe this is an accident...

Two possible solutions:

- *pessimistic* [very unnatural]: $\Lambda > 100$ TeV

  $\Rightarrow$ almost nothing to learn from other FCNC processes

- *natural*: $\Lambda \sim 1$ TeV + flavour–mixing protected by additional symmetries

  $\Rightarrow$ still a lot to learn from FCNCs [especially from $\Delta F=1$ processes]

$\Downarrow$

Minimal Flavour Violation (MFV) hypothesis:

The breaking of the flavour symmetry occurs at very high scales and is mediated at low energies only by terms proportional to SM Yukawa coupl.

- natural implementation in many consistent scenarios [SUSY, technicolour, extra dimensions,...] [wide literature]

- possible to build a predictive low−energy EFT including only SM fields $\Rightarrow$ model−independent approach [D'Ambrosio, Giudice, G.I., Strumia, '02]

Minimal Flavour Violation

The maximal group of unitary field transf. allowed by $\mathscr{L}^{\rm SM}_{\rm gauge}$ is:

$$G_F = U(3)^5 = \underbrace{SU(3)^2_l \times SU(3)^3_q \times U(1)_{PQ} \times U(1)_{E_R}}_{\text{subgroup broken by } \mathscr{L}^{\rm SM}_{\rm Yukawa}} \times U(1)_B \times U(1)_L \times U(1)_Y$$

$$SU(3)^2_l = SU(3)_{L_L} \times SU(3)_{E_R}$$

$$SU(3)^3_q = SU(3)_{Q_L} \times SU(3)_{U_R} \times SU(3)_{D_R}$$

subgroup responsible for quark mixing
[Yukawa structure, CKM matrix]

$U(1)_{PQ}$: glob. phase of D_R & E_R

$U(1)_{E_R}$: glob. phase of E_R

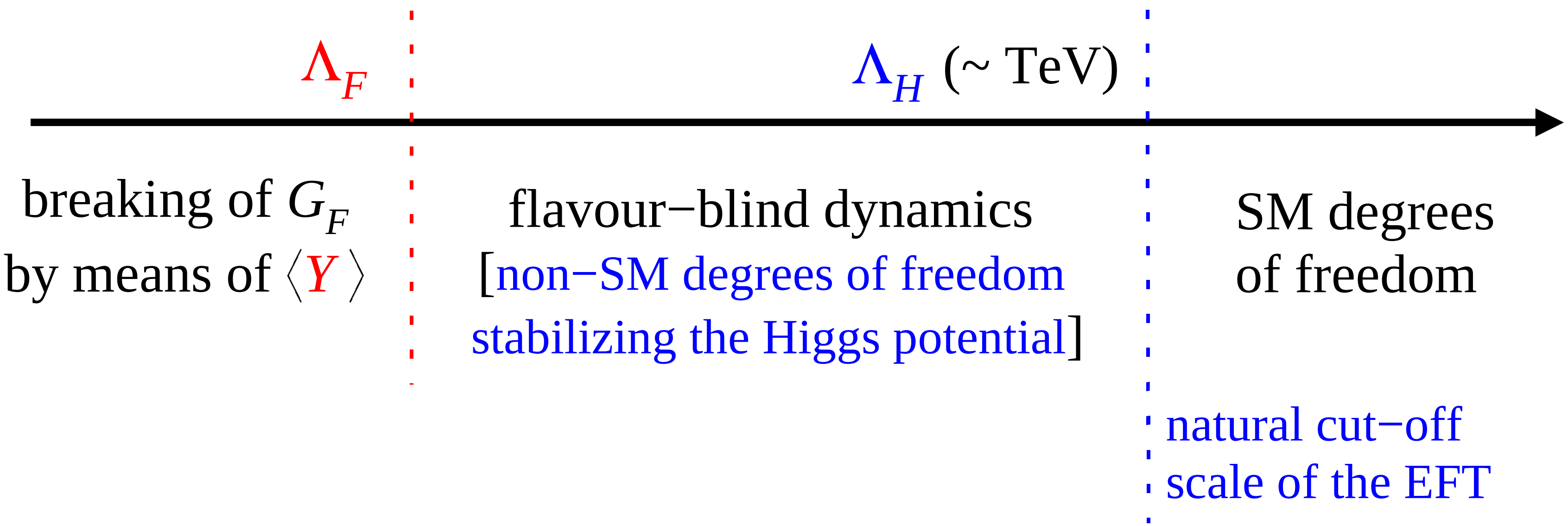
groups relevant in multi−Higgs models [overall Yukawa norm.]

$$\mathscr{L}_{\rm Yukawa} = \bar{Q}_L Y_D D_R H + \bar{Q}_L Y_U U_R (H)_c + \bar{L}_L Y_L E_R H + \text{h.c.}$$

Since G_F is already broken within the SM, it is not consistent to impose it as an exact symmetry beyond the SM.

However, we can (formally) promote G_F to be an exact symmetry, assuming the Yukawa matrices are the vacuum expectation values of appropriate auxiliary fields:

e.g.: $Y_D \sim (3,\bar{3},1)$ & $Y_U \sim (3,1,\bar{3})$ under $SU(3)_{Q_L} \times SU(3)_{U_R} \times SU(3)_{D_R}$



A low–energy EFT (including only SM fields) satisfies the criterion of MFV if all higher–dimensional operators, constructed from SM and Y fields, are (formally) invariant under G_F

Chivukula & Georgi, '89
DGIS, '02

$$Y_D = \mathrm{diag}(y_d, y_s, y_b) \qquad Y_U = V^+ \times \mathrm{diag}(y_u, y_c, y_t)$$

→ the CKM matrix is the only source of quark mix.

$$(\lambda_{FC})_{ij} = (Y_U Y_U^+)_{ij} \approx y_t^2 V^*_{3i} V_{3j}$$

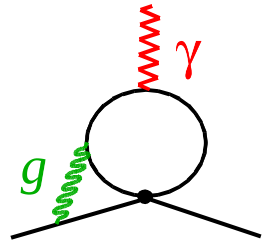
λ_{FC} is the effective coupl. ruling all FCNCs with external d quarks
(as within the SM for s.d. dominated amplitudes)

- all FCNC amplitudes have the same CKM structure as in the SM
  [e.g.: $A(b \to s\gamma) \propto V_{bt} V_{ts}$, $A(s \to d\gamma) \propto V_{st} V_{td}$, ...]
- only the flavour–independent magnitude of FCNC amplitudes can be modified by (non–standard) dimension–six operators → Rare decays
- "*phase measurement*" [e.g.: $a(B \to \psi K_S)$, $\Delta M_{B_d} / \Delta M_{B_s}$] are completely unaffected by (non–standard) dimension–six operators

$B \to X_s\, l^+ l^-$ @ NNLO

Different LL counting than in $B \to X_s \gamma$

[$Q_9 \leftrightarrow Q_{1-6}$ starts @ 1 loop ⇒ NNLO simpler]

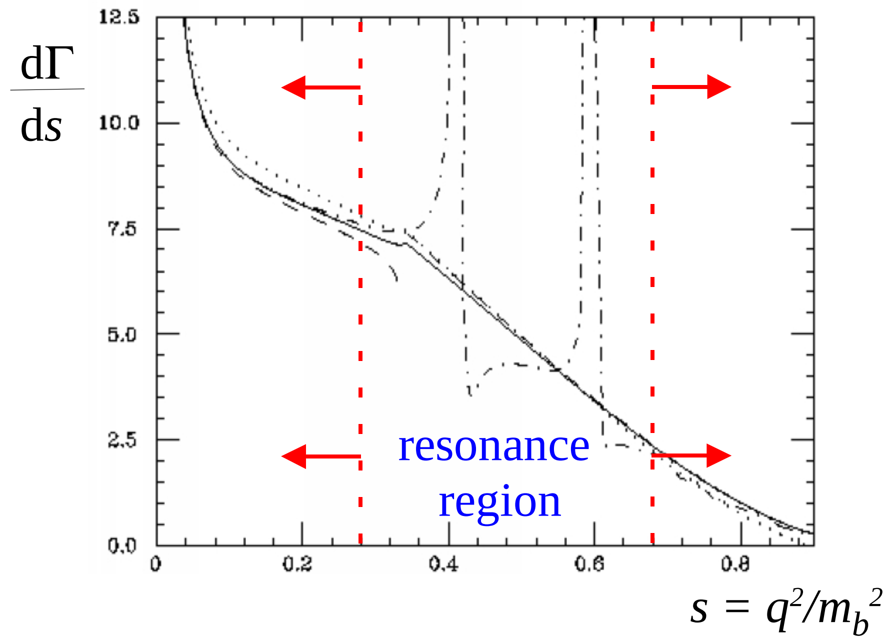


- partial NNLO available
  for the dilepton spectrum

  [Bobeth *et al.* '01, Asatrian *et al.* '01]

- full NNLO available for the
  lepton FB asymmetry

  [Ghinchulov *et al.* '02, Asatrian *et al.* '02]



$$\int \frac{d^2\Gamma(B\to X_s \mu^+ \mu^-)}{ds\, d\cos\vartheta} sgn(\cos\vartheta) \;\propto\; \Re\left[C_{10}^*\left(s C_9^{eff}(s) + r(s) C_7\right)\right]$$

th. error $\lesssim 5$ %

θ = angle between
μ^+ & B momenta

- direct access to the relative phases of the C_i
- axial current (C_{10}) ⇒ no $4q$−mixing
  ⇒ short−distance not *diluted* ⇒ excellent sensitivity to Λ_{NP}

Possible extensions/generalizations of the MFV approach:

I) Inclusion of extra Higgs doublets $\Leftrightarrow$ breaking of the U(1)'s

The breaking of the SU(3) groups is not necessarily related to the breaking of the U(1)'s

The CKM matrix remains the only source of quark mixing, but we are free to modify the overall normalization of the Y $\Leftrightarrow$ large $\tan\beta$

$\Downarrow$

Model−indep. approach to large $\tan\beta$ effects (SUSY and non−SUSY) in rare decays (all orders resummationof non−decoupl. terms)

G.I. & A. Retico, '01, '02;
DGIS '02

II) Inclusion of SUSY degrees of freedoms $\Rightarrow$ EFT valid to higher scales

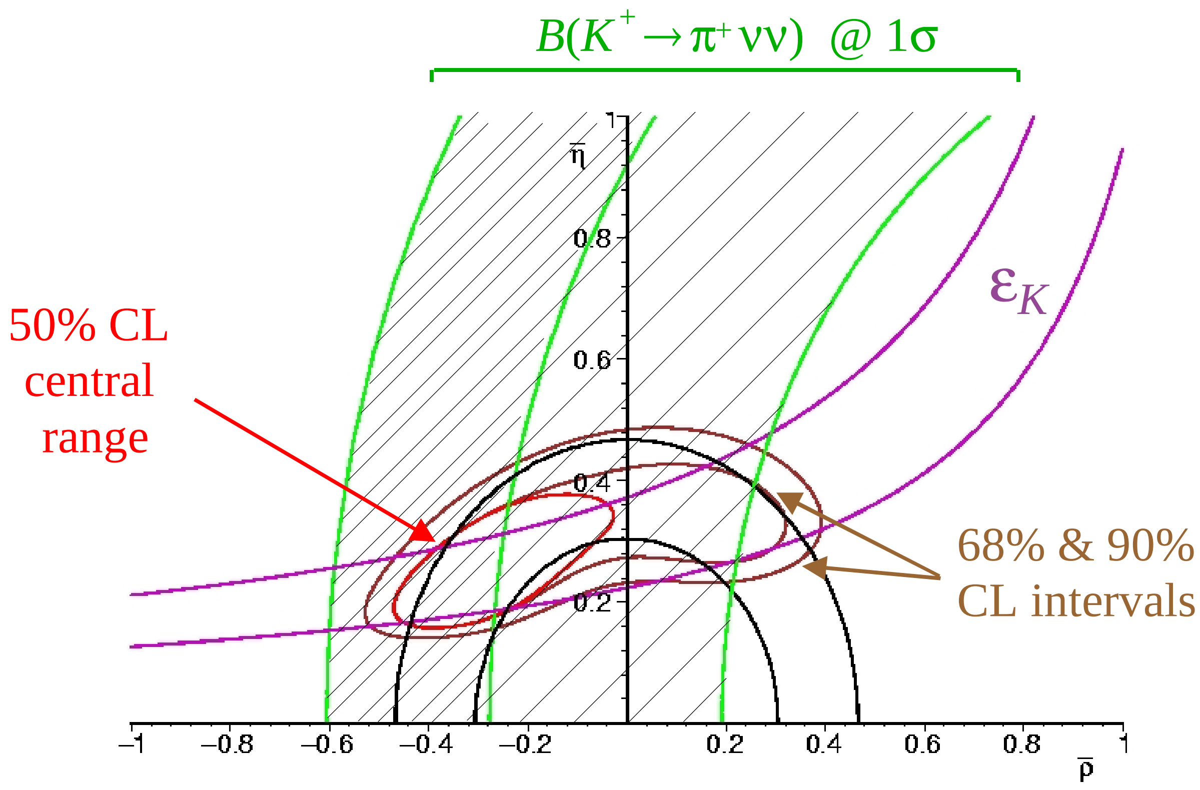
⋮

Interesting developments still to be investigated

Is there still room for non−MFV models ?

The key prediction of MFV is the link between $b \to s$, $b \to d$, & $s \to d$ and this is certainly not well tested yet

E.g.: UT fit ignoring ΔB=2 data [i.e. allowing a non−MFV contr. to $(\bar{b}d)^2$]:



[D'Ambrosio & G.I. '01]

There is still room for non−MFV operators, even in the ΔF=2 sector, but these can at most induce O(1) effects with respect to the SM amplitude

⇓

important to perform new precision tests of the $b\to s$, $b\to d$, $s\to d$ link

Conclusions

The INFN node has

- several well–established links
  inherited from EURODAPHNE

- several on–going projects on the wider
  physics program of EURIDICE ...

[many activities have not been presented in this short overview
$\Rightarrow$ see individual talks today & tomorrow]

...which could naturally lead to new productive collaborations