FCNC Processes Waiting for Great Discoveries (Daniel Wyler’s 60th)

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(Technical University Munich, TUM-IAS)

Zurich, Jan 8th, 2010

Overture

Frontiers of Elementary Particle Physics → **Search for Physics Laws at very short distance scales**

Heisenberg Principle : **To test 10^{-18} m we need $E \cong 200$ GeV**

Frontiers of Elementary Particle Physics → **Search for Physics Laws at very short distance scales**

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LHC $E \approx 4$ TeV → **Tests at $5 \cdot 10^{-20}$ m possible**

Frontiers of Elementary Particle Physics → **Search for Physics Laws at very short distance scales**

Heisenberg Principle : **To test 10^{-18} m we need $E \cong 200$ GeV**

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Unlikely that we can do better before 2050 through high energy collider experiments.

Frontiers of Elementary Particle Physics → **Search for Physics Laws at very short distance scales**

Heisenberg Principle : **To test 10^{-18} m we need E ≅ 200 GeV**

LHC E ≈ 4 TeV → **Tests at $5 \cdot 10^{-20}$ m possible**

Unlikely that we can do better before 2050 through high energy collider experiments.

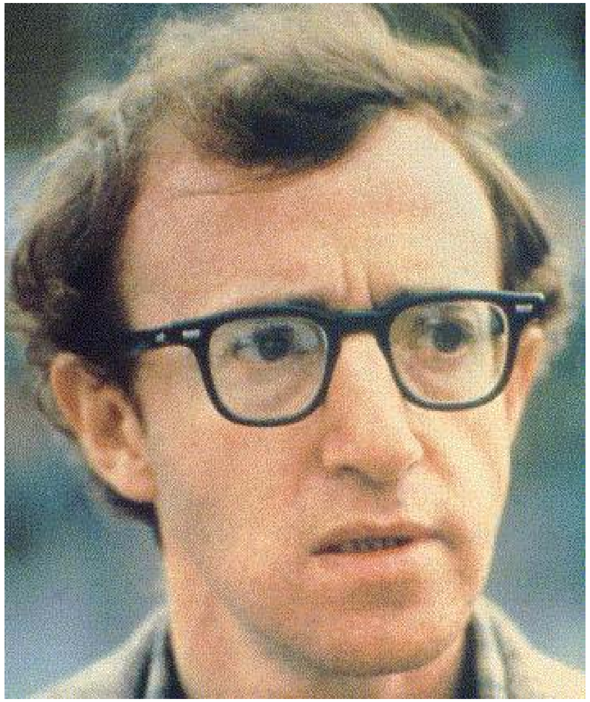
Flavour Physics governed by Quantum Fluctuations is sensitive to E ≈ 200 TeV and even higher energy scales → **Tests at 10^{-21} m and shorter scales possible** → **Frontiers in testing very very short distance scales belong to Flavour Physics**

but **Very high precision required !!**

Main Message of this Talk

Daniel Wyler contributed in an important manner to Flavour Physics

Second Main Message of this Talk

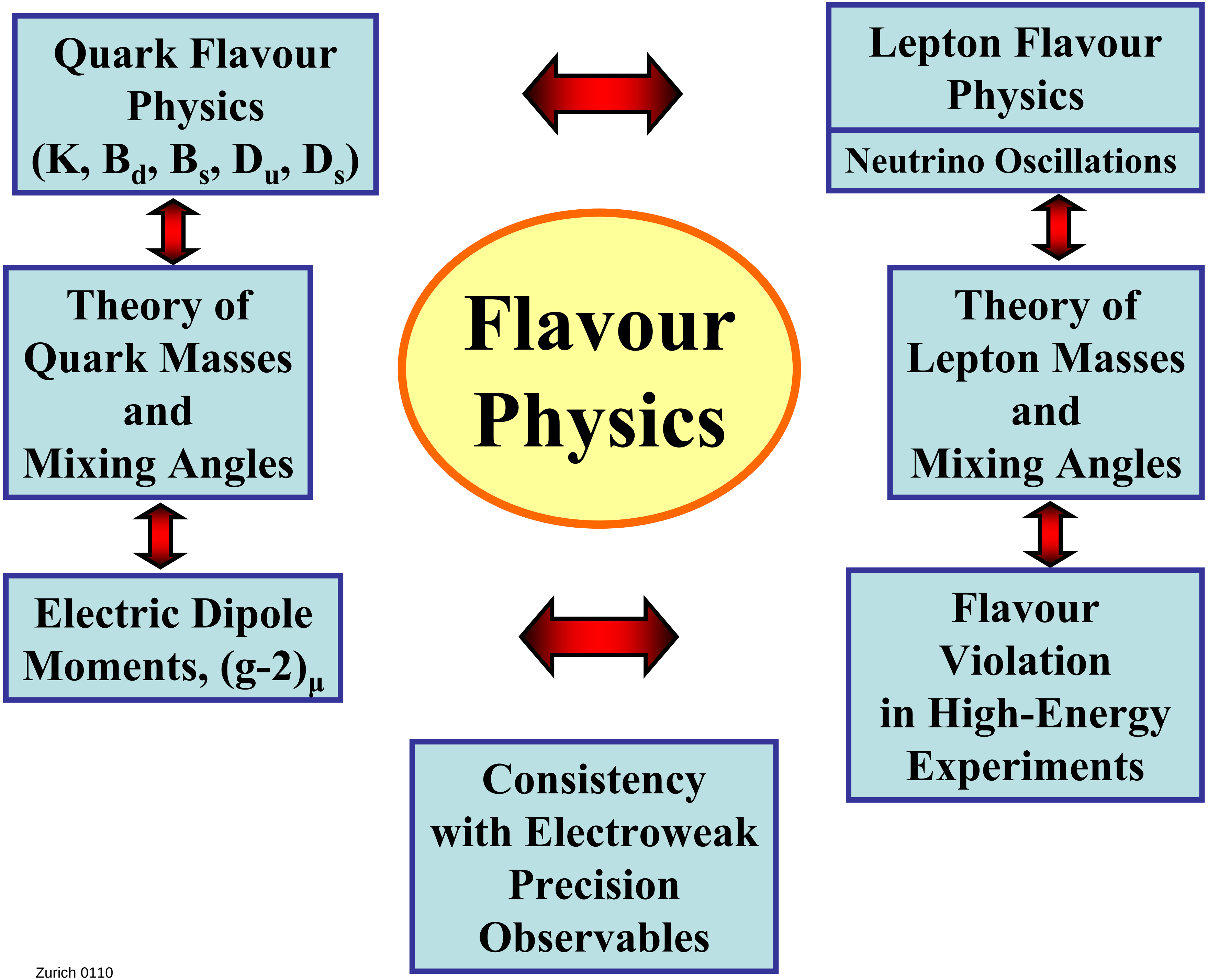


Woody Allan hopefully also contributed in an important manner to Flavour Physics

Another Important Message of this Talk

In our search for a more fundamental theory we need to improve our understanding of Flavour Physics

Graham Ross: collected works


Quark Flavour Physics
(K, B_d, B_s, D_u, D_s)
Lepton Flavour Physics
Neutrino Oscillations
Theory of Quark Masses and Mixing Angles
Flavour Physics
Theory of Lepton Masses and Mixing Angles
Electric Dipole Moments, $(g-2)_\mu$
Flavour Violation in High-Energy Experiments
Consistency with Electroweak Precision Observables

Yet

Impressive Success of the CKM Picture of Flavour Changing Interactions

(GIM)

1. Several tensions between the flavour data and the SM exist.

2. Hierarchies in Fermion Masses and Mixing Angles have to be understood with the help of some New Physics (NP).

3. There is still a lot of room for NP contributions, in particular in rare decays of mesons and leptons, in ~~CP~~ flavour violating transitions and EDM´s.

Are 1. - 3. somehow related ?
Will we see any footprints of this NP in the 2010´s ?

Strategy for the Next 23 Min

1. Theoretical Framework (~ 4 min)

2. Waiting for Signals of New Physics in FCNC Processes (~ 18 min)

3. Final Messages (~ 1 min)

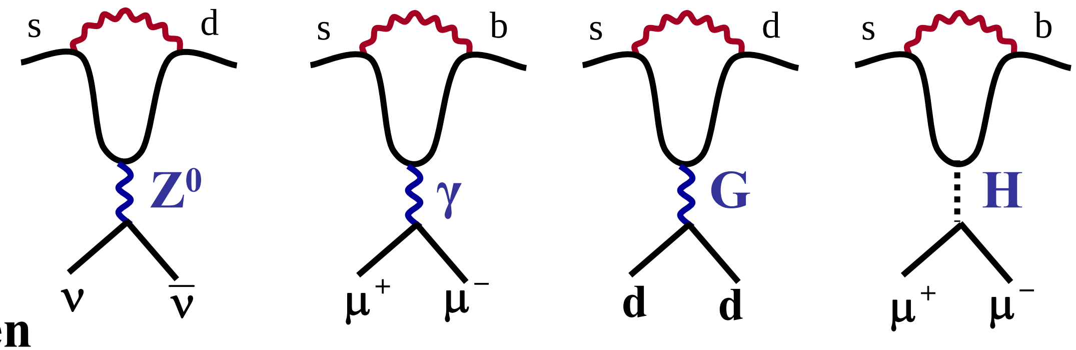
(hep-ph/0910.1032): "Flavour Theory : 2009"

1.

Theoretical Framework

Basic Diagrams in FCNC Processes

Penguin Family :

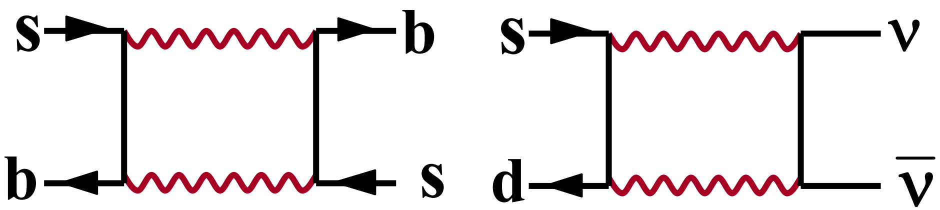


← **New Physics enters here**

Similar diagrams in LFV and EDM´s

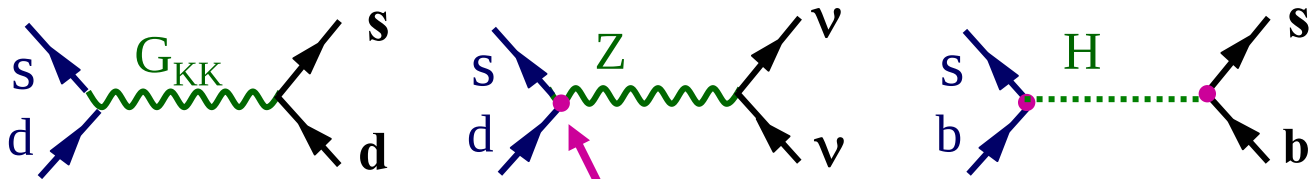
(GIM broken at one loop)

Box Diagrams

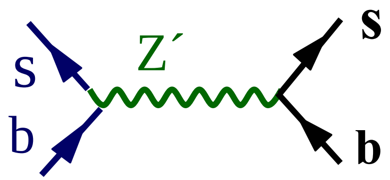


+ **other box diagrams**

Tree Diagrams



(GIM broken at tree level)



RS

Generated through mixing with New Gauge Bosons

Double Higgs Penguin in SUSY

Master Formula for FCNC Amplitudes

Long Distance
(Non-perturbative
Lattice)

Flavour and CPV
in SM and MFV
enters only here

Short Distance
Functions
(Perturbation TH)

(real for MFV)

$$A(FCNC) = \sum_i B_i \eta_i^{QCD} V_i^{CKM} F_i(m_t, NP)$$

Renormalization
Group (QCD)
LD $\leftrightarrow$ SD

Only Loops
if GIM works

NP can add
new B_i´s absent
in SM

(New Operators
with new
Dirac Structures)

Q_{LR}
(right-handed
currents, S, P)

NP can add
new loops and
trees with new
flavour parameters
and CPV phases

non-MFV

Most popular BSM Directions

CMFV
(constrained MFV)

MFV (NMFV) (GMFV)

LHT
(Littlest Higgs with T-parity)

SUSY
(flavour models)

Z′
(Langacker…)

RS
(Randall-Sundrum)
(Warped Extra Dimensions)

4th G
(Hou.., Soni.., Lenz.., Melic)

Vector-Like Quarks
(Branco…, del Aguila)

Non-Decoupling

↓

New gauge bosons, fermions, scalars in loops and even trees with often non-CKM interactions.

Little Hierarchy Problem

Electroweak Precision Tests

+

Agreement of the CKM Picture of Flavour and CP Violation with existing Data (FCNC)

$\Lambda_{NP} \approx 1000$ **TeV** (generic)

(generic)

$\Lambda_{NP} \approx 5$ **TeV**

Very strong Constraints on Physics beyond SM with scales O (1 TeV)

Necessary to solve the hierarchy problem

$(M_{PLANCK} >> \Lambda_{EW})$

Message 1 : **New Physics at TeV-Scale must have a non-Generic Flavour Structure**

Message 2 : **Protection Mechanisms to suppress FCNCs generated by TeV-Scale New Physics required**

Ciuchini et al
Isidori et al
Agashe et al
+50

★

MFV | **GIM** | **RS-GIM** | **T-Parity** | **R-Parity**

Alignment | **Degeneracy** | **Flavour Symmetries** (abelian, non-abelian)

Custodial Symmetries (continuous, discrete)

Daniel at Large

(129 papers)

Gronau-Wyler Method for γ	571
Effective Lagrangians for New Interactions (Buchmüller-Wyler)	566
Weak Interaction Breakdown Induced by Supergravity (Nilles, Srednicki, Wyler)	454
Leptoquarks (Buchmüller, Rückl, Wyler)	397

500 + 2 250 + 5 100 + 14

8234

h = 51

2.

Waiting for Signals of New Physics in FCNC Processes

Models investigated by TUM-Teams

(This decade)

SM	MFV	MSSM+MFV	Z´-Models
General MSSM	Universal Extra Dimensions	RS with custodial protection	
Littlest Higgs	Littlest Higgs with T-Parity	SUSY+Flavour Abelian Symmetry (Agashe+Carone)	
SUSY with SU(3) Flavour (Ross et al) (RVV2)	SUSY with SU(2) Flavour (LH-currents)	Flavour Blind MSSM	4G

My Collaborators

SUSY


W. Altmannshofer


S. Gori


P. Paradisi


D. Straub

LHT


M. Blanke


B. Duling


S. Recksiegel


C. Tarantino

RS


M. Albrecht


M. Blanke


B. Duling


K. Gemmler

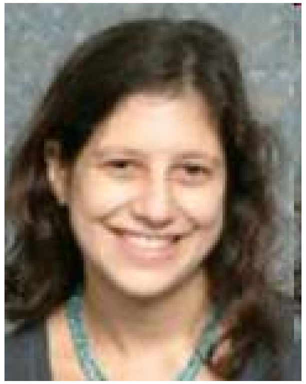

S. Gori


A. Weiler

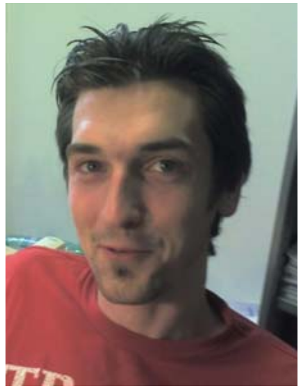
$B \rightarrow K^{*} l^{+} l^{-}$


W. Altmannshofer


P. Ball


A. Bharucha


D. Straub


M. Wick

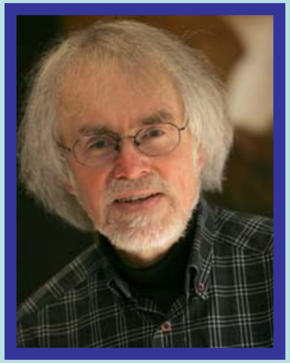
Charm Physics


I.Bigi


M. Blanke

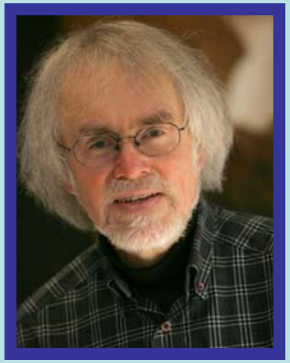

S. Recksiegel

4 Generations

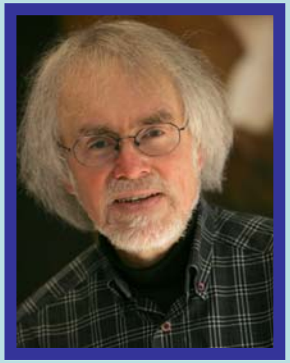


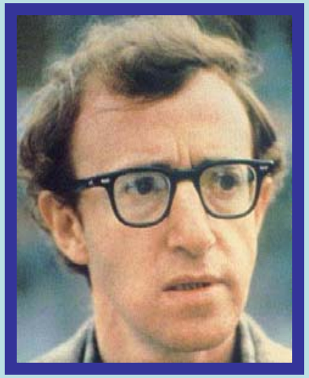
Hopefully new Collaborators

Hopefully new Collaborators



Hopefully new Collaborators





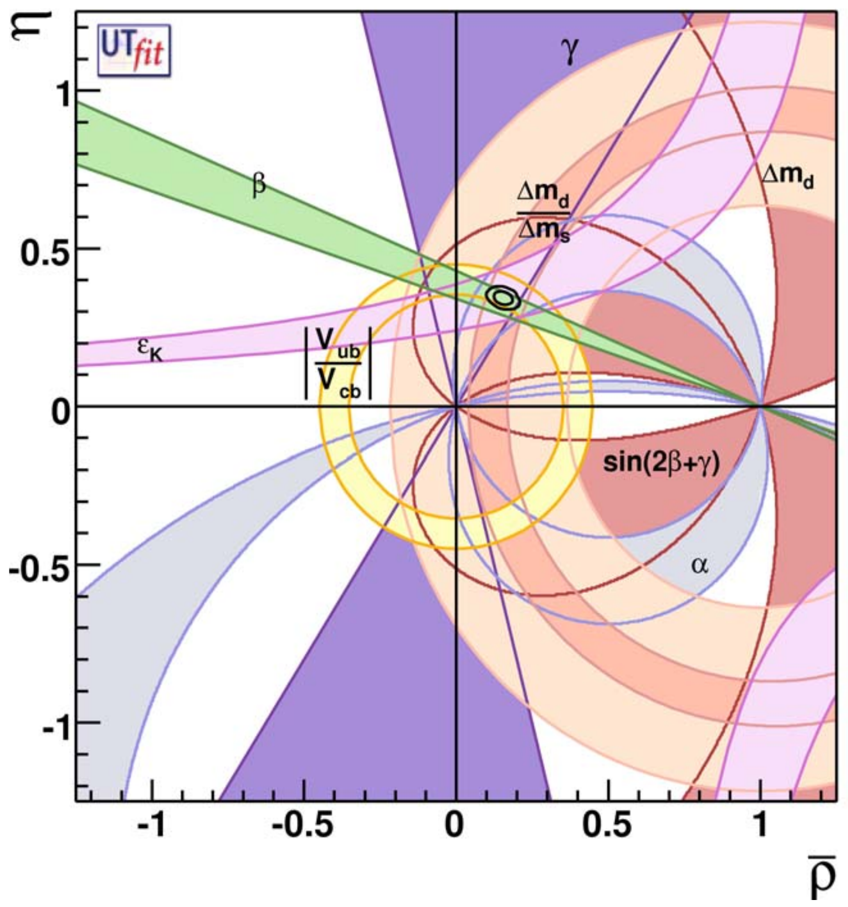
BWA Collaboration

Pleasing Guido M.

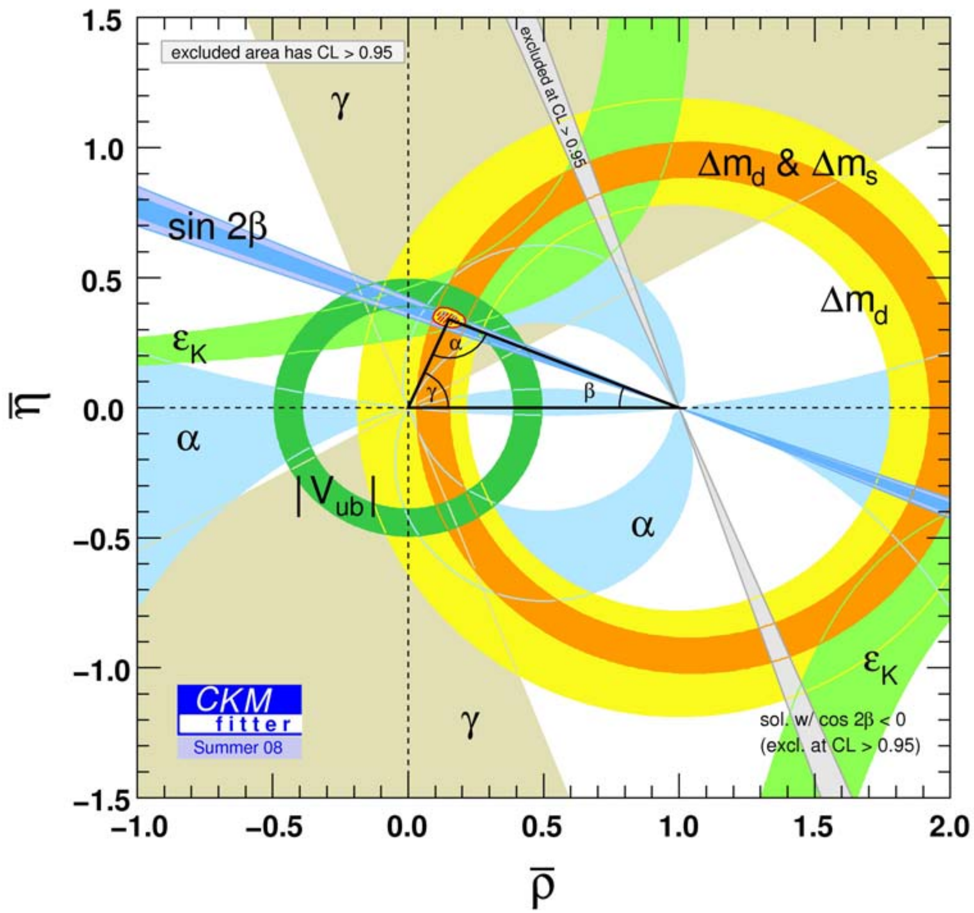
Unitarity Triangle Fits

(Icons of Flavour Physics)

UT fit



CKM fitter



Unitarity Triangle

(R_b, γ) Reference UT (Goto et al)

(coming decade)

$$\alpha \overset{?}{=} 90^\circ$$

(this decade)

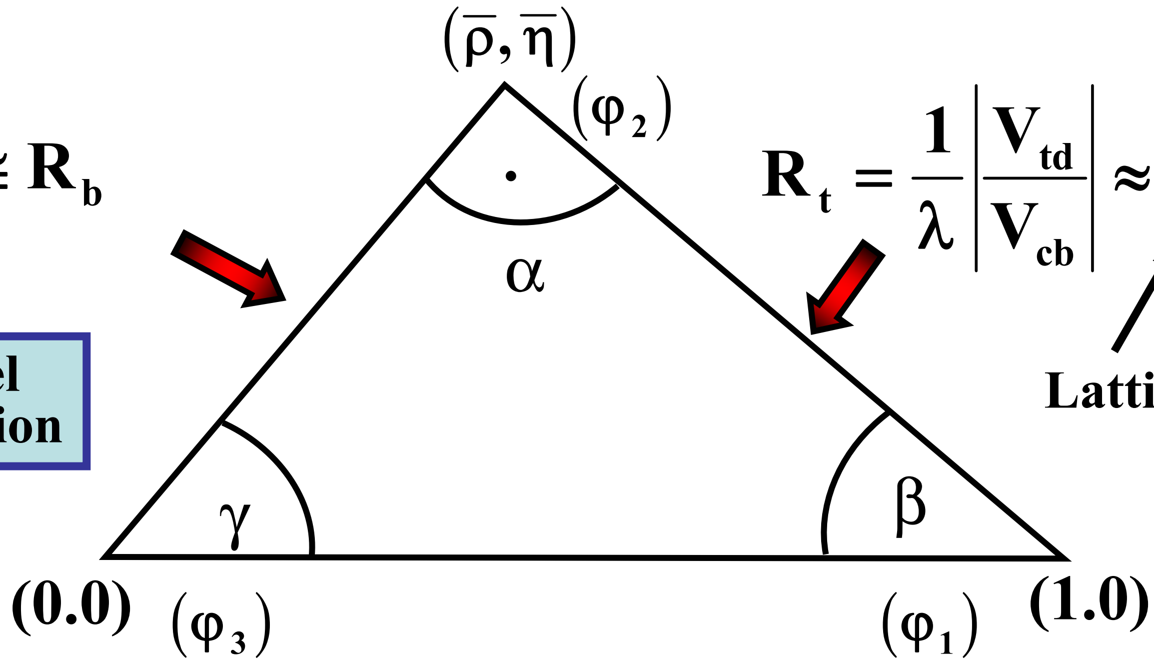
R_t, β Universal UT of CMFV (BGGJS, BBGT)

$(\varphi_{NP}=0,\ r_{NP}=1)$

$$\frac{1}{\lambda}\left|\frac{V_{ub}}{V_{cb}}\right| \cong R_b$$

Tree Level Determination

(NP free)



$$R_t = \frac{1}{\lambda}\left|\frac{V_{td}}{V_{cb}}\right| \approx \xi \sqrt{\frac{\Delta M_d}{\Delta M_s}}\, r_{NP}$$

Lattice

$$\xi = 1.21 \pm 0.04$$

Loop Determination

(Not NP free)

Flavour Matrix

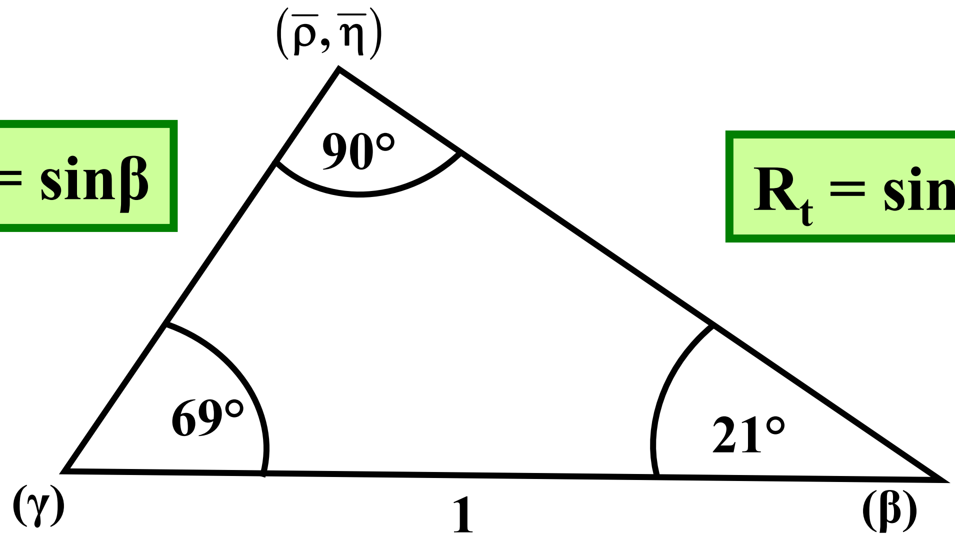
$\varphi_{NP} = 0$, $r_{NP} = 1$	$\varphi_{NP} = 0$, $r_{NP} \neq 1$
$\varphi_{NP} \neq 0$, $r_{NP} \neq 1$	$\varphi_{NP} \neq 0$, $r_{NP} \neq 1$

$$S_{\psi K_s} = \sin(2\beta + 2\varphi_{NP})$$

Unitarity Triangle in LO Approximation

$\alpha = 90°$ $\sin 2\beta = 2/3$

$R_b = \sin\beta$



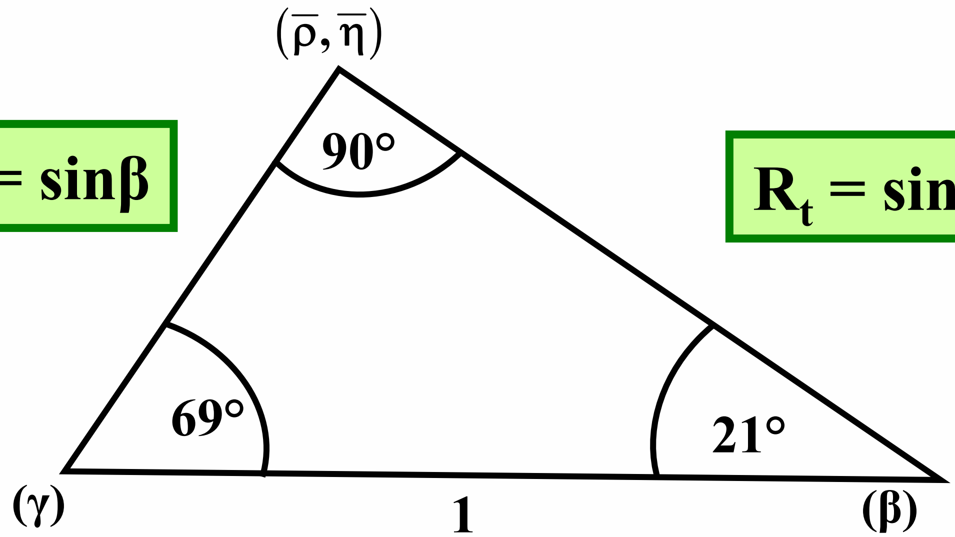
$R_t = \sin(\alpha+\beta)$

$\bar{\rho} = \sin\beta\cos\gamma$ $\bar{\eta} = \sin\beta\sin\gamma$

Unitarity Triangle in LO Approximation

$\alpha = 90°$ $\sin 2\beta = 2/3$

$R_b = \sin\beta$



$R_t = \sin(\alpha+\beta)$

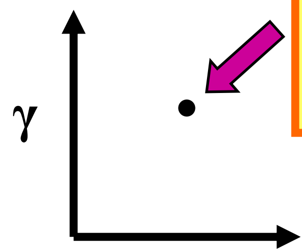
$\bar\rho = \sin\beta\cos\gamma$ $\bar\eta = \sin\beta\sin\gamma$

Search for New Physics in 2010´s

★ **To study transparently possible tensions between ε_K, $\sin 2\beta$, V_{ub}, γ, $\Delta M_d / \Delta M_s$**

Leave $(\bar{\rho}, \bar{\eta})$ plane

Go to



Tree level (NP free) Determination possible

$$R_b \sim \left|\frac{V_{ub}}{V_{cb}}\right|$$

★ **To search for NP in rare K, B_d, B_s, D decays, $\not{CP}$ in B_s, D decays, Lepton Flavour Violations**

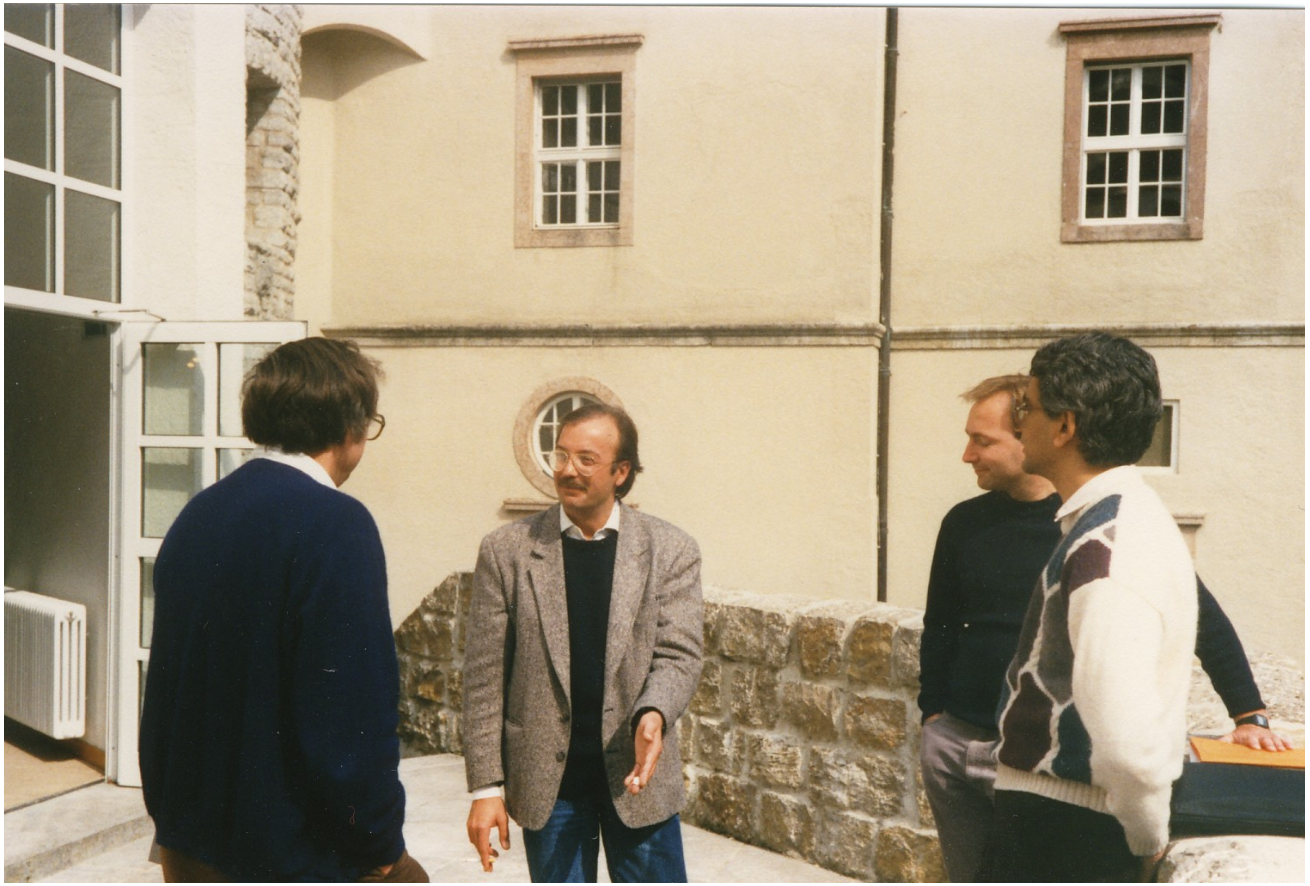
Go to

Specific Plots (Correlations)

$$\mathrm{Br}(K_L \to \pi^0 \nu\bar{\nu}) \text{ vs } \mathrm{Br}(K^+ \to \pi^+ \nu\bar{\nu})$$
$$\mathrm{Br}(B_s \to \mu^+\mu^-) \text{ vs } S_{\psi\varphi}$$
$$\mathrm{Br}(B_s \to \mu^+\mu^-) \text{ vs } \mathrm{Br}(B_d \to \mu^+\mu^-)$$
$$\mathrm{Br}(K^+ \to \pi^+ \nu\bar{\nu}) \text{ vs } S_{\psi\varphi}$$
$$d_n \text{ vs } S_{\varphi K_s}$$
$$A_{CP}(B \to X_S\gamma) \text{ vs } S_{\varphi K_s}$$
$$\mathrm{Br}(\tau \to \mu\gamma) \text{ vs } \Delta(g-2)_\mu$$
$$\mathrm{Br}(\tau \to \mu\mu\mu) \text{ vs } \mathrm{Br}(\tau \to \mu\gamma)$$
$$\mathrm{Br}(\mu \to 3e) \text{ vs } \mathrm{Br}(\mu \to e\gamma)$$

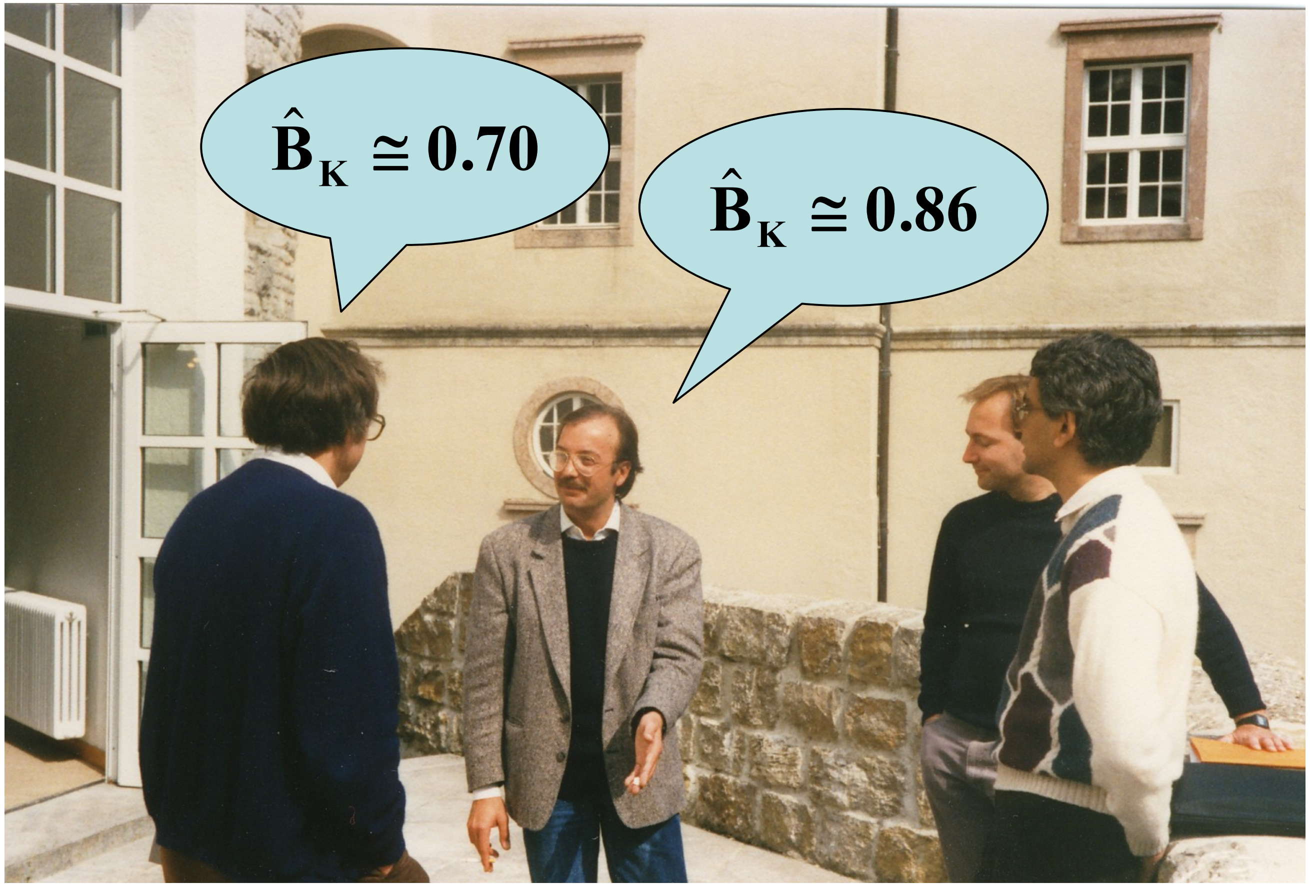
★ **Correlations will be crucial to distinguish various NP scenarios**

Hadronic Matrix Elements (1988)



Ringberg Workshop

Hadronic Matrix Elements (1988)



Ringberg Workshop

Can SM describe simultaneously $\not{CP}$ in K and B_d Systems?

(NLO) (NLO)

$$|\varepsilon_K|^{SM} \sim \kappa_\varepsilon \hat{B}_K |V_{cb}|^2 \left(\frac{1}{2} |V_{cb}|^2 R_t^2 \sin 2\beta \underbrace{\eta_{tt}^{QCD}} S_0(x_t) + F(\underbrace{\eta_{ct}^{QCD}, \eta_{cc}^{QCD}}, m_c, ..) \right)$$

BJW (90) HN (94)

2009 News

★ $\hat{B}_K \cong 0.72 \pm 0.03$ (precise and lower by ~ 10% vs 2007)

RBC-UKQCD
Aubin et al.
ETMC

★ $\kappa_\varepsilon \cong 0.92 \pm 0.02$ (correction neglected in the past)

AJB + Guadagnoli (08)
(Nierste; Vysotsky)

Large N
$\hat{B}_K = 0.75$
BBG (87)

★ NNLO QCD calculation of η_{cc}, η_{ct} Brod + Gorbahn (09)

(BG) $|\varepsilon_K^{SM}| = (1.80 \pm 0.22) \cdot 10^{-3}$ $|\varepsilon_{exp}| = (2.223 \pm 0.012) \cdot 10^{-3}$

(BaBar Belle) using $(\sin 2\beta)_{\psi K_s} = 0.672 \pm 0.023$ (NA48, KLOE, KTeV)

Diego Guadagnoli

Possible Solutions to ε_K - Anomaly

$$|\varepsilon_K|^{SM} \sim \kappa_\varepsilon \hat{B}_K |V_{cb}|^2 \left(\frac{1}{2} |V_{cb}|^2 R_t^2 \sin 2\beta \eta_{tt}^{QCD} S_0(x_t) + F\left(\eta_{ct}^{QCD}, \eta_{cc}^{QCD}, m_c, ..\right) \right)$$

1. Add New Physics to ε_K

CMFV $S_0(x_t) \to S_0(x_t) + \Delta S_0^{NP}$ or simply $\Delta\varepsilon_k$ (Non-MFV)

AJB Guadagnoli

2. Increase $\sin 2\beta \cong 0.67 \Rightarrow 0.85$

$\varphi_{NP} \cong -8.1^o$ ⇓ Large $|V_{ub}|$ ⟷ Super-B

Lunghi Soni

$$S_{\psi K_s} = \sin(2\beta + 2\varphi_{NP})$$

(Utfit; BBGT; Ball, Fleischer; Branco et al)

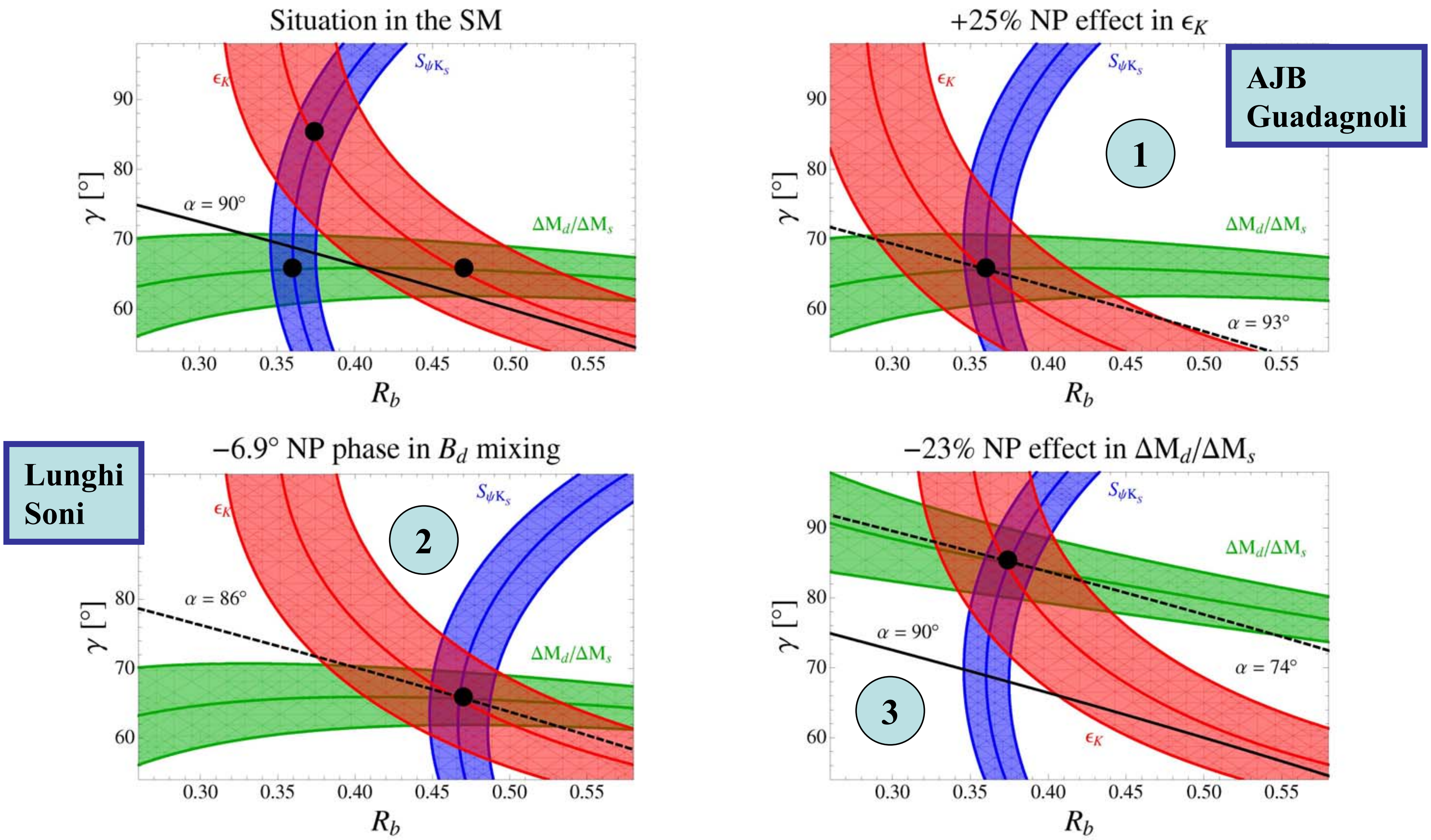
3. Increase R_t ⇒ $\gamma = \delta_{CKM} \approx 67^o \Rightarrow 82^o$ ⟷ LHC

4. Increase $|V_{cb}| \approx (41.2 \cdot 10^{-3}) \Rightarrow (43.5 \cdot 10^{-3})$ ⟷ Super-B

AJB, Parodi, Stocchi (2002)
Altmannshofer, AJB, Guadagnoli (2007)

The R_b-γ Plane

Altmannshofer, AJB, Gori, Paradisi, Straub (2009)



$K^+ \to \pi^+\nu\bar{\nu}$ and $K_L \to \pi^0\nu\bar{\nu}$ (Z°-penguins)

(TH cleanest FCNC decays in Quark Sector)

Extensive TH efforts over 20 years :

Buchalla, AJB; Misiak, Urban (NLO QCD)
AJB, Gorbahn, Haisch, Nierste (NNLO QCD)
Brod, Gorbahn (QED, EW two loop)
Isidori, Mescia, Smith (several LD analyses)
Buchalla, Isidori (LD in $K_L \to \pi^0\nu\bar{\nu}$)

$$\frac{Br(K^+ \to \pi^+\nu\bar{\nu})}{Br(K_L \to \pi^0\nu\bar{\nu})} = 3.2 \pm 0.2$$

SM : $Br(K^+ \to \pi^+\nu\bar{\nu}) = (8.4 \pm 0.7)\cdot 10^{-11}$ $Br(K_L \to \pi^0\nu\bar{\nu}) = (2.6 \pm 0.4)\cdot 10^{-11}$

Exp : $Br(K^+ \to \pi^+\nu\bar{\nu}) = \left(17 \begin{array}{c} +11 \\ -10 \end{array}\right)\cdot 10^{-11}$ $Br(K_L \to \pi^0\nu\bar{\nu}) \le 6.8 \cdot 10^{-8}$

(E787, E949 Brookhaven) (E391a, KEK)

Future :

NA62
Project X (FNAL)

J-PARC KOTO

Both very sensitive to New Physics

CP-conserving
TH uncertainty 2-3%

CP-Violation in Decay
TH uncertainty 1-2%

Maximal Enhancements of $K_L \to \pi^0 \nu\bar{\nu}$ and $K^+ \to \pi^+ \nu\bar{\nu}$

Model independent bound

$$Br(K_L \to \pi^0 \nu\bar{\nu}) \le 4.4\, Br(K^+ \to \pi^+ \nu\bar{\nu})$$

Grossman Nir

Model	$Br(K^+ \to \pi^+ \nu\bar{\nu})$	$Br(K_L \to \pi^0 \nu\bar{\nu})$
CMFV	20%	20%
MFV	30%	30%
LHT	150%	200%
RS	60%	150%
GMSSM	300%	500%
AC	2%	2%
RVV	10%	10%

(Bobeth et al Haisch, Weiler Isidori et al)

(Blanke et al)

(Duling et al)

(ABGPS)

SUSY with flavour symmetries

(abelian)

(non-abelian)

Large RH Currents

RS = RS with custodial protections

AC = Agashe, Carone

RVV = Ross, Velaso-Sevilla, Vives (04)

$U(1)_F$

$SU(3)_F$

★

$B_s \to \mu^+\mu^-$ and $B_d \to \mu^+\mu^-$

Z-Penguin + Boxes (SM CMV)

SM

$$Br(B_s \to \mu^+\mu^-) = (3.6 \pm 0.4)\cdot 10^{-9}$$

$$Br(B_d \to \mu^+\mu^-) = (1.1 \pm 0.1)\cdot 10^{-10}$$

Error dominated by $\hat{B}_{d,s}$

AJB (03)

CMFV "Golden Relation"

$$\frac{Br(B_s \to \mu^+\mu^-)}{Br(B_d \to \mu^+\mu^-)} = \frac{\hat{B}_d}{\hat{B}_s}\frac{\tau(B_s)}{\tau(B_d)}\frac{\Delta M_s}{\Delta M_d}$$

$(\Delta B = 1)$ $(\Delta B = 2)$

(1.00±0.03) Lattice

Valid in all CMFV models

Can be strongly violated in SUSY, LHT, RS

95% CL

$$Br(B_s \to \mu^+\mu^-) \le \begin{cases} 3.3\cdot 10^{-8} & (CDF) \\ 5.3\cdot 10^{-8} & (D0) \end{cases}$$

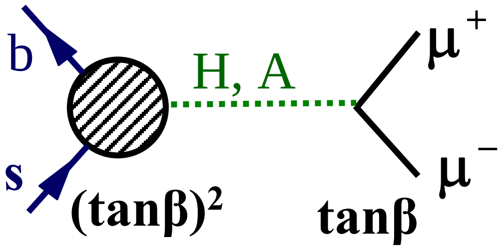
$$Br(B_d \to \mu^+\mu^-) \le 1\cdot 10^{-8} \quad (CDF)$$

LHC should be able to discover $B_s \to \mu^+\mu^-$ even at the SM level

$B_{s,d} \to \mu^+\mu^-$ in SUSY and Higgs Penguins

(Helicity suppression lifted)

Babu, Kolda (99),…+100



$$Br\left(B_{s,d} \to \mu^+\mu^-\right) \sim \frac{(\tan\beta)^6}{M_A^4}$$

Can reach CDF and DØ bounds

Very important for the distinction of SUSY from LHT and RS !!!

$$\frac{Br\left(B_{s,d} \to \mu^+\mu^-\right)_{LHT}}{Br\left(B_{s,d} \to \mu^+\mu^-\right)_{SM}} \leq 1.3$$

(Z-penguin)
(Blanke et al) (09)

$$\frac{Br\left(B_{s,d} \to \mu^+\mu^-\right)_{RS}}{Br\left(B_{s,d} \to \mu^+\mu^-\right)_{SM}} \leq 1.1$$

(Z-penguin + Z-tree with r.h. couplings)
(Custodial protection at work)
(Gori et al) (08)

Mixing Induced CP Asymmetry in $B_s \to \psi\varphi \;\left(S_{\psi\varphi}\right)$

(TH very clean;*) Analog of $S_{\psi K_s}$)

$$S_{\psi\varphi} = \sin\left(2|\beta_s| - 2\varphi_s^{new}\right) \overset{SM}{\cong} 0.035$$

$$V_{ts} = -|V_{ts}| e^{-\beta_s}$$

$$\left(\beta_s = -1°\right)$$

New Phase in $B_s^0 - \overline{B}_s^0$ mixing

$0.81^{+0.12}_{-0.32}$

★ CDF D0

$$0.20 \le \left(S_{\psi\varphi}\right)_{exp} \le 0.98$$

90% C.L. (HFAG)

If confirmed, clear signal of NP with non-MFV interactions and new sources of ~~CP~~

Model Expectations

$$S_{\psi\varphi} \le \begin{cases} 0.75 \;\; \text{(AC)} \;\; \text{(abelian flavour, SUSY) (Higgs penguin)} \\ 0.50 \;\; \text{(RVV)} \;\; \text{(non-abelian flavour, SUSY) (Higgs penguin)} \\ 0.75 \;\; \text{(RS)} \;\; \text{(Heavy KK Gauge Bosons)} \;\; \text{(Duling et al (08))} \\ 0.30 \;\; \text{(LHT)} \;\; \text{(Mirror Fermions at work)} \;\; \text{(Tarantino et al (09))} \end{cases}$$

ABGPS

*) See however Faller, Fleischer, Mannel (08)

Maximal Enhancements of $S_{\psi\varphi}$, $Br(B_s \to \mu^+\mu^-)$ and $K^+ \to \pi^+\nu\bar{\nu}$

(without taking correlation between them)

Model	Upper Bound on ($S_{\psi\varphi}$)	Enhancement of $Br(B_s \to \mu^+\mu^-)$	Enhancement of $Br(K^+ \to \pi^+\nu\bar{\nu})$
CMFV	0.04	20%	20%
MFV	0.04	1000%	30%
LHT	0.30	30%	150%
RS	0.75	10%	60%
GMSSM	0.75	1000%	300%
AC	0.75	1000%	2%
RVV	0.50	1000%	10%

Correlations between $K^+ \to \pi^+ \nu\bar{\nu}$, $K_L \to \pi^0 \nu\bar{\nu}$, $S_{\psi\varphi}$, $B_s \to \mu^+\mu^-$

★ **Impact of a future $S_{\psi\varphi} \approx 0.3$**

LHT
RS

Sizable Enhancements in $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ excluded in RS and unlikely in LHT

$B_{s,d} \to \mu^+\mu^-$ SM-like

(Blanke et al)

(abelian)
AC
RVV
(non-abelian)

$Br(B_s \to \mu^+\mu^-)$ forced to be $3 \cdot Br(B_s \to \mu^+\mu^-)_{SM} \sim 10^{-8}$

SUSY Flavour Models

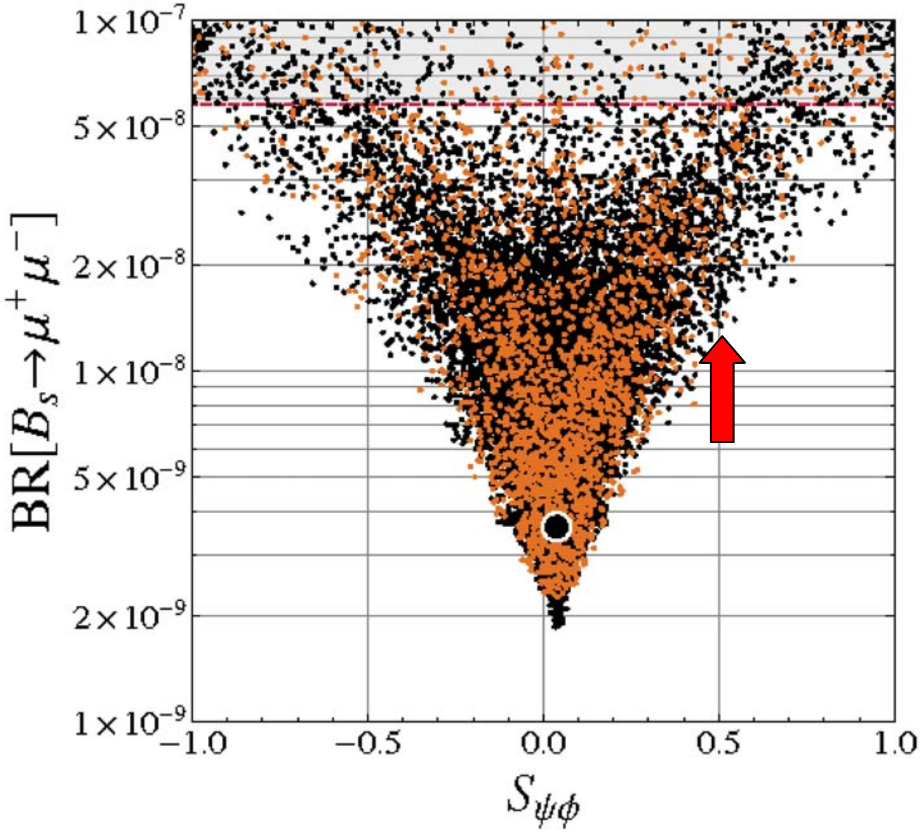
Altmannshofer, AJB, Gori, Paradisi, Straub (09) **ABGPS**

CDF, D0
LHCb

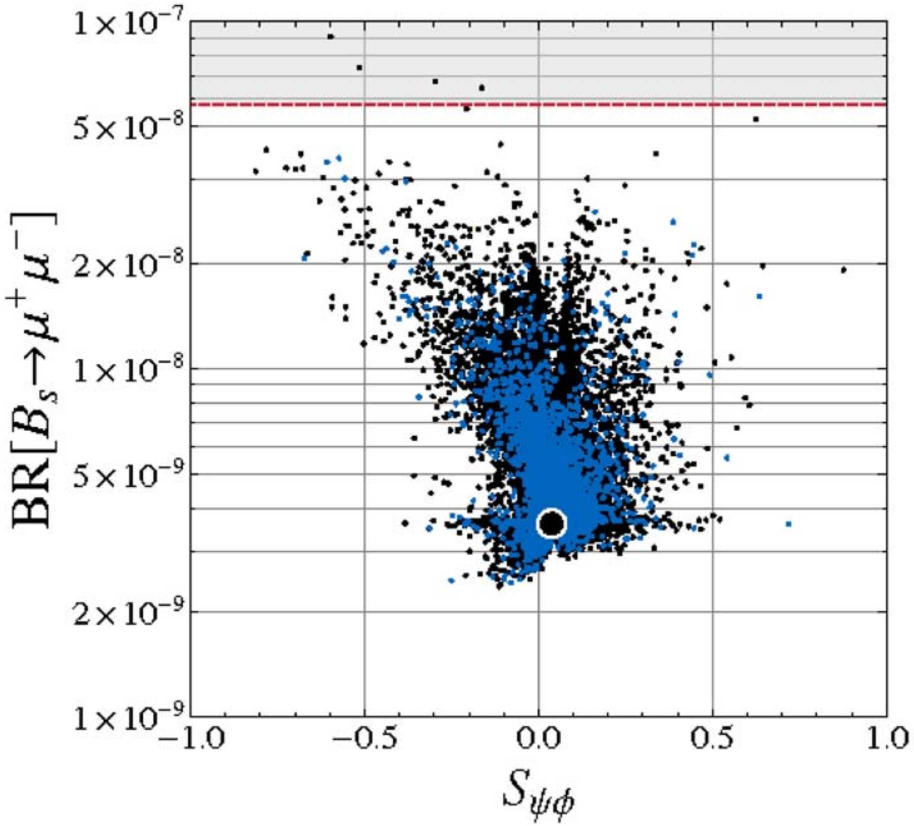
$Br\left(B_s \to \mu^+\mu^-\right)$ vs $S_{\psi\varphi}$

ABGPS

Solution 3 to ε_K-Anomaly
Abelian (AC)



Solution 1 to ε_K-Anomaly
Non-Abelian (RVV)



(Large Effects in D^0-$\bar{D}^0$)

(Small Effects in D^0-$\bar{D}^0$)

Lepton Flavour Violation, $\Delta(g-2)_\mu$ and EDM's

$S_{\varphi K_s} = 0.44 \pm 0.17$ $\qquad (S_{\varphi K_s})_{SM} \approx (S_{\psi K_s})_{SM} + 0.02 \approx 0.70$

(Beneke)

(MEGA) $\quad Br(\mu \to e\gamma) < 1.2 \cdot 10^{-11}$ ➡ 10^{-13}(MEG) $\quad$ SM:10^{-54}

$(a_\mu)_{SM} < (a_\mu)_{exp} \quad (3.1\sigma)$

$a_\mu = \frac{1}{2}(g-2)_\mu$

(Regan et al) $\quad d_e < 1.6 \cdot 10^{-27}$ ➡ 10^{-31} $\quad (d_e)_{SM} \approx 10^{-38}$

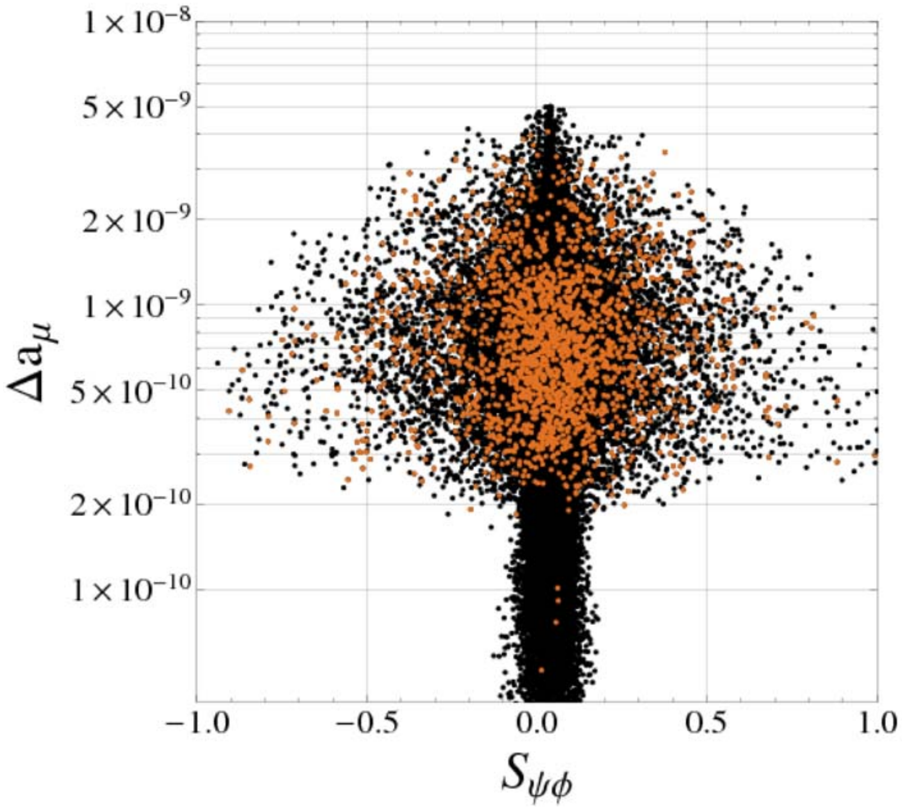
(Baker et al) $\quad d_n < 2.9 \cdot 10^{-26}$ ➡ 10^{-28} $\quad (d_n)_{SM} \approx 10^{-32}$

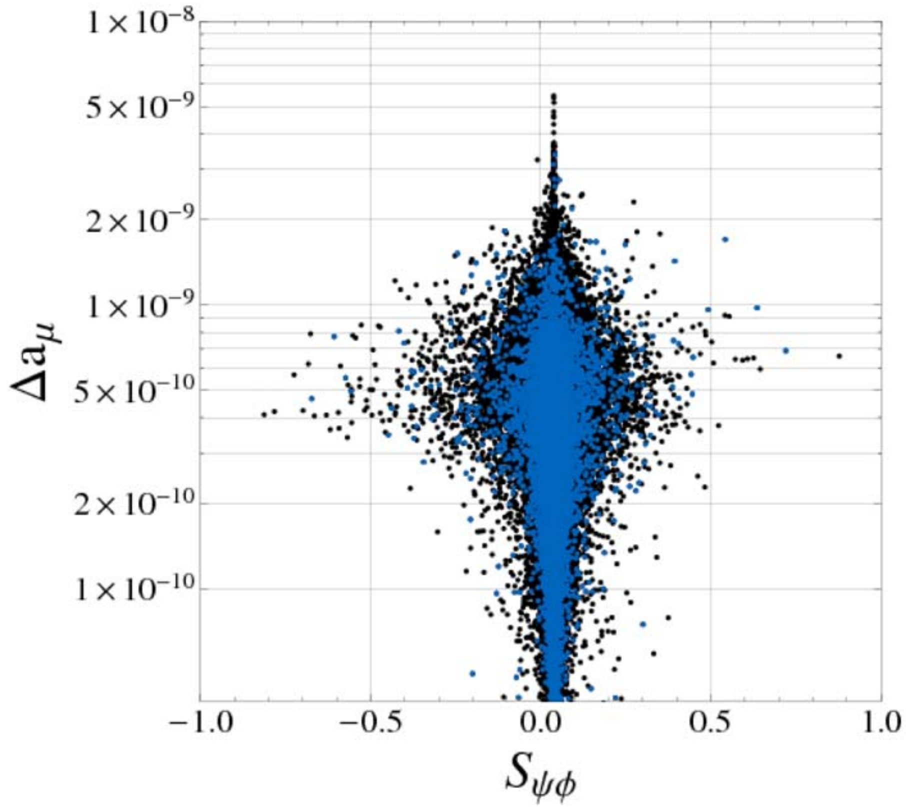
[e cm]

Simultaneous Solution to Δa_μ and $S_{\psi\varphi}$ Anomalies

Solution 3 to ε_K-Anomaly
Abelian (AC)

Solution 1 to ε_K-Anomaly
Non-Abelian (RVV)



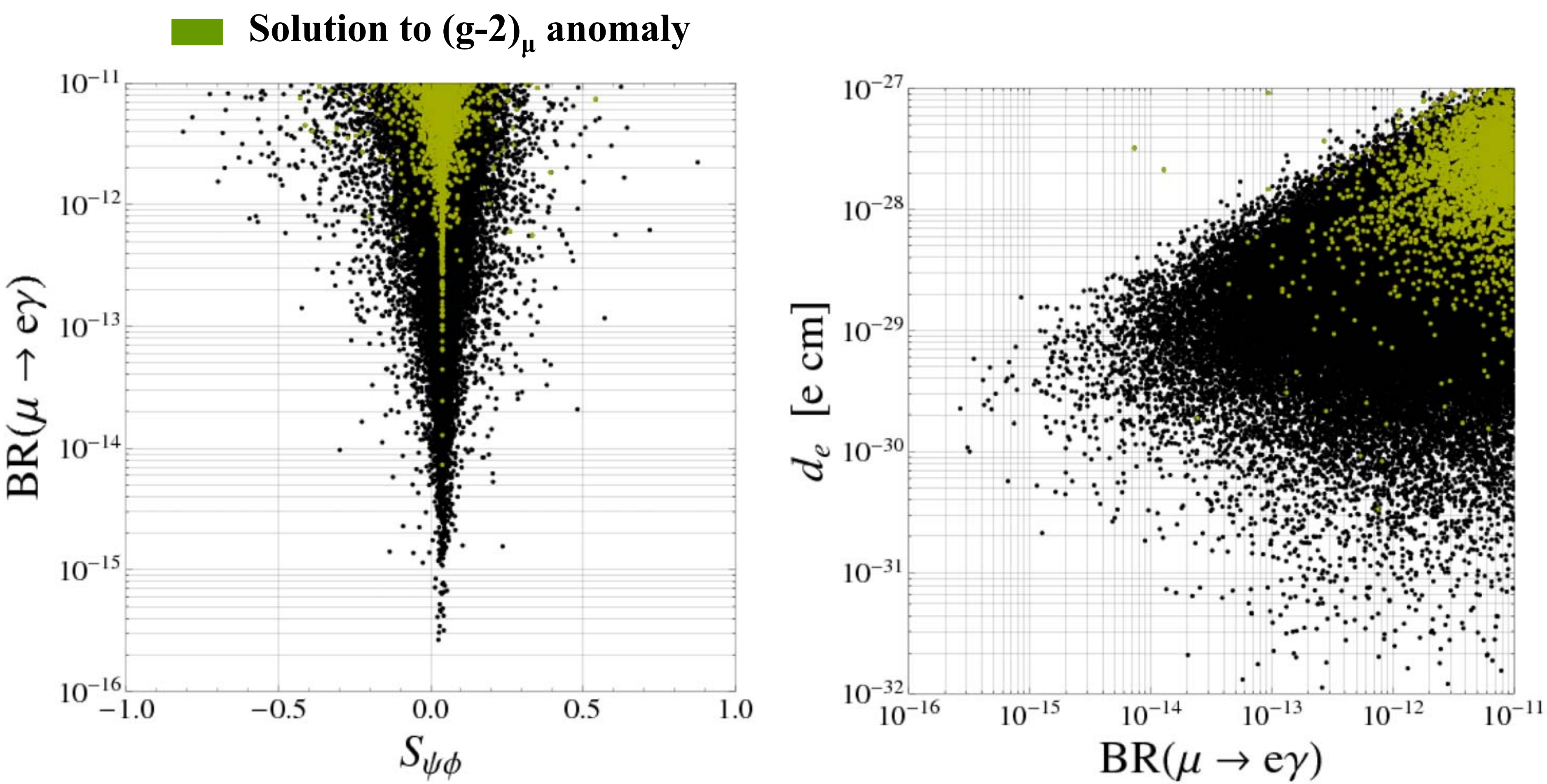


(Large Effects in D^0-$\bar{D}^0$)

(Small Effects in D^0-$\bar{D}^0$)

Correlations in the SU(3) Flavour Model (RVV2)

ABGPS



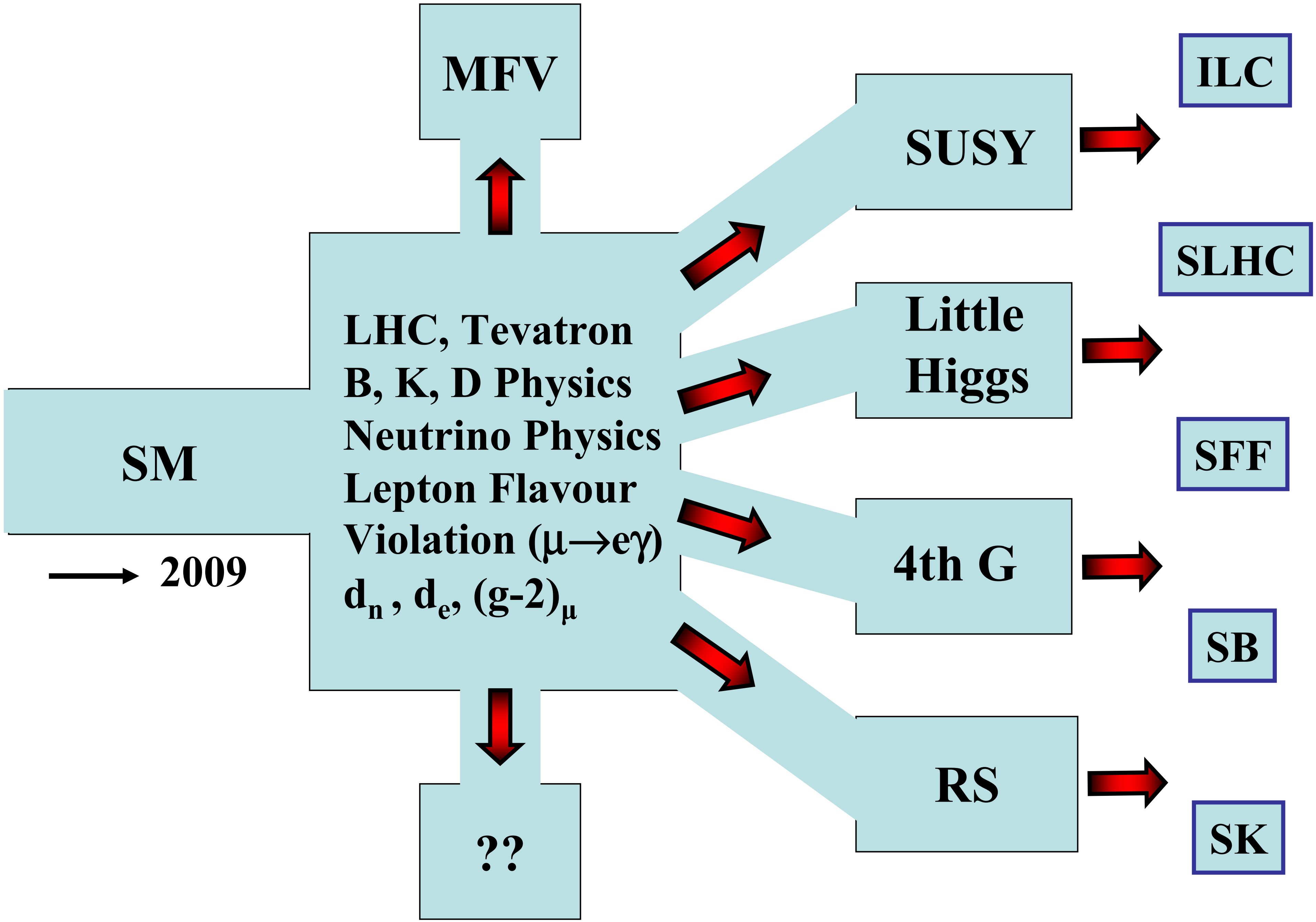
ABGPS

DNA Tests of Flavour Models

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}\,(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	★★

4.

Final Messages


MFV
SUSY
ILC
SLHC
Little Higgs
SFF
SM
LHC, Tevatron
B, K, D Physics
Neutrino Physics
Lepton Flavour Violation (μ→eγ)
d_n , d_e, $(g-2)_\mu$
2009
4th G
SB
RS
SK
??

Final Messages of this Talk

Flavour Physics (Quarks and Leptons) :

Many observables (decays) not measured yet or measured poorly. Flavour Physics only now enters the precision era.

↓

Spectacular deviations from SM still possible ⟷ **Interplay** ⟷ **Direct searches at Tevatron, LHC, ILC**

Final Messages of this Talk

Flavour Physics (Quarks and Leptons) :

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↓

Spectacular deviations from SM still possible ⟷ Interplay ⟷ **Direct searches at Tevatron, LHC, ILC**

DNA Flavour Test of NP models

Correlations between various observables can distinguish NP scenarios easier than LHC ! ★

Great discoveries and goals are just ahead of us !

Most Important Goals for the Coming Decades

Most Important Goals for the Coming Decades

2020
Daniel's
70th

Most Important Goals for the Coming Decades

2020
Daniel's
70th

2030
Daniel's
80th

Most Important Goals for the Coming Decades

2020 Daniel's 70th	2030 Daniel's 80th	2040 Daniel's 90th

Most Important Goals for the Coming Decades

2020
Daniel's
70th

2030
Daniel's
80th

2040
Daniel's
90th

2050
Daniel's
100th

Daniel, Happy Birthday to You !!

Daniel, Happy Birthday to You !!