Hunting New Animalcula with Flavour

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(Technical University Munich, TUM-IAS)

Planck 2011
Lisbon, June 3rd, 2011

Overture

1676

A very important year for the humanity !

1676 : The Discovery of the Microuniverse (Animalcula) (The Empire of Bacteria)

Antoni van Leeuwenhoek
***24.10.1632 ✞27.08.1723**

10^{-6}m

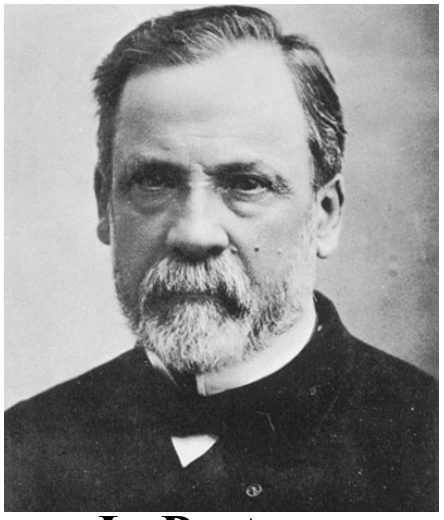
~500 Microscopes

(Magnification by ~300)

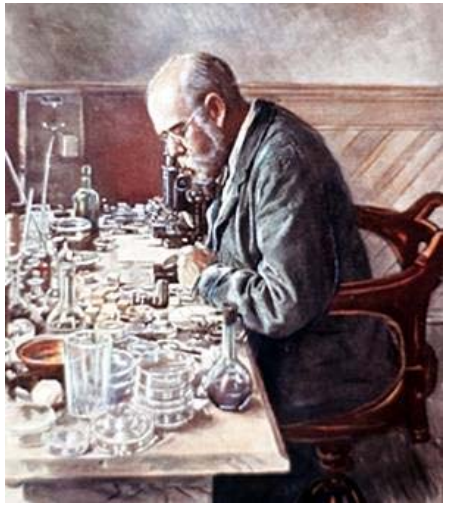
Animalcula Hunters

Antoni van Leeuwenhoek
***24.10.1632 ✞27.08.1723**

Lazzaro Spallanzani
***12.01.1729 ✞12.02.1799**



L. Pasteur
***27.12.1822 ✞28.09.1895**



Robert Koch
***11.12.1843 ✞27.05.1910**

An Excursion towards the Very Short Distance Scales:

1676 - 2020

Microuniverse	10^{-6}m	Bacteriology Microbiology
Nanouniverse	10^{-9}m	Nanoscience
Femtouniverse	10^{-15}m	Nuclear Physics Low Energy Elementary Particle Physics
Attouniverse	10^{-18}m	High Energy Particle Physics (present)
High Energy Proton-Proton Collisions at the LHC	$5 \cdot 10^{-20}$m	Frontiers of Elementary Particle Physics in 2010´s
High Precision Measurements of Rare Processes (Europe, Japan, USA)	10^{-21}m	Zeptouniverse

Most important Message from this Talk

Antoni van Leeuwenhook discovered in 1676

Animalcula

Most important Message from this Talk

Antoni van Leeuwenhook discovered in 1676

Animalcula

We all expect to discover New Animalcula

in the coming years with the help

of LHC and High Precision Experiments

But how will these New Animalcula look like ?

But how will these New Animalcula look like ?

Overture Completed!

Lisbon Symphony No. 4

Lisbon Symphony No. 4

1st Movement : **Basic Strategy (7 min)**

Lisbon Symphony No. 4

1st Movement	:	Basic Strategy (7 min)
2nd Movement	:	Expectations and first Messages from New Animalcula (12 min)

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4th Movement	:	Finale: Vivace ! (2 min)

(hep-ph/0910.1032): "Flavour Theory : 2009"
(hep-ph/1012.1447): "MFV and Beyond"

Lisbon Symphony No. 4

1st Movement	:	Basic Strategy (7 min)
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ENCORE !

(hep-ph/0910.1032): "Flavour Theory : 2009"
(hep-ph/1012.1447): "MFV and Beyond"

1st Movement

Basic Strategy

Crucial Question

What is the Origin of Particle Masses and the Reason for their Hierarchy and Hierarchy of their Flavour-Changing Interactions ?

Which Dynamics could be responsible for the observed structure of Electroweak Symmetry Breaking and of Patterns seen in Flavour Physics ?

1. **Could it be an elementary SM Higgs system with all problems of instability under radiative corrections (hierachy problems) ?**

Crucial questions in Particle Physics

2. **Could it be a new strong dynamics with a composite Higgs or without Higgs at all ?**

3. **Could this dynamics help us understanding matter-antimatter asymmetry and the amount of dark matter in the universe ?**

4. **Would these dynamics explain anomalies in flavour physics ?**

CKM **(Nobel Prize 2008)**

Dirac Medal (2010)

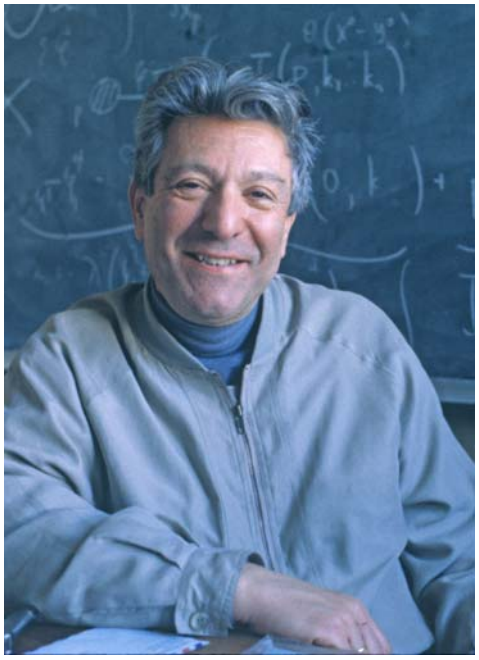
N. Cabibbo (1935-2010)

M. Kobayashi

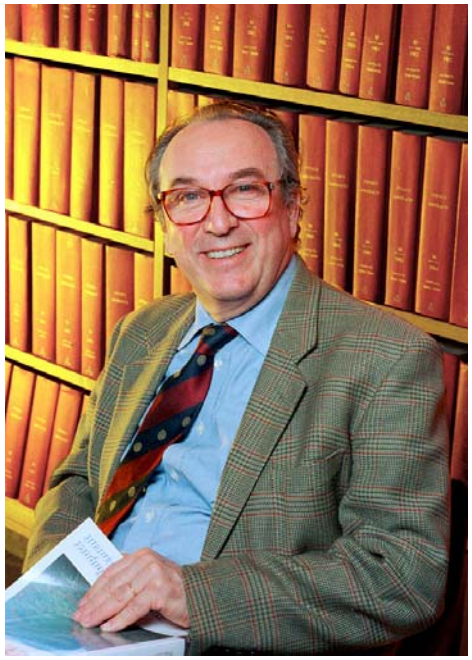
T. Maskawa

EPS (High Energy Price 2011)

Sheldon Glashow



John Iliopoulos

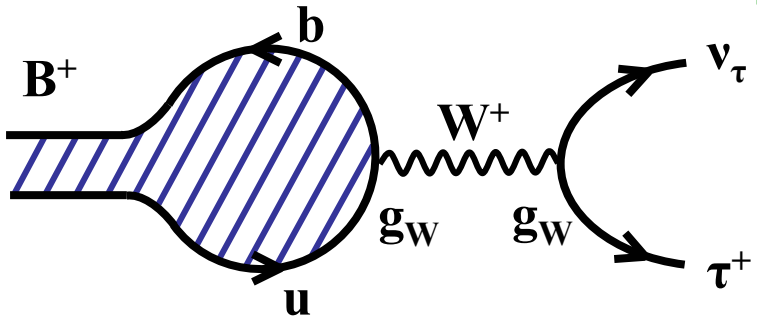


Luciano Maiani

GIM

Indirect Search: Precision Measurements of Decays of Mesons and Leptons

$B^+ \to \tau^+ \nu_\tau$

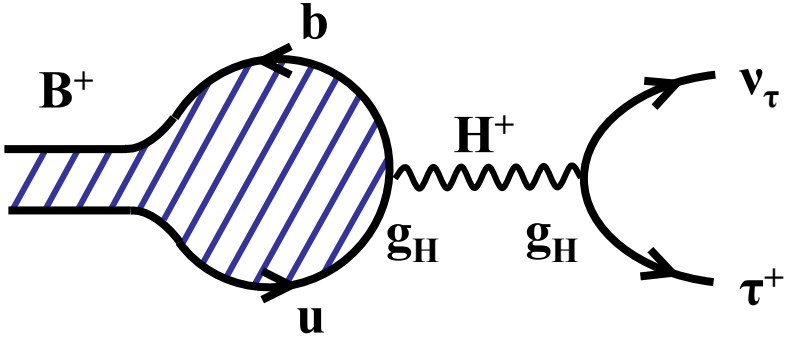


Standard Model

$$Br\left(B^+ \to \tau^+ \nu_\tau\right)_{SM} = \left| A \frac{g_W^2}{M_W^2} \right|^2$$

$m_B \approx 5$ GeV

A, B – parameters of a given theory



Contribution of a new charged Heavy Particle

$$Br\left(B^+ \to \tau^+ \nu_\tau\right) = \left| A \frac{g_W^2}{M_W^2} + B \frac{g_H^2}{M_H^2} \right|^2$$

$$\Delta = Br\left(B^+ \to \tau^+ \nu_\tau\right) - Br\left(B^+ \to \tau^+ \nu_\tau\right)_{SM} \neq 0$$

Signal of a new particle

In Order to identify New Animalcula through Flavour Physics

We need

1. **Many precision measurements of many observables and precise theory.**

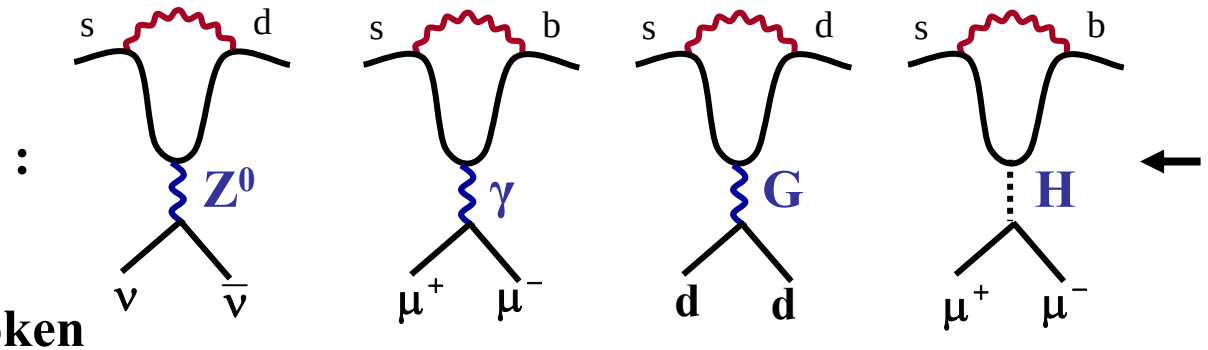
2. **Study Patterns on Flavour Violation in various New Physics models (correlations between many flavour observables).**

...and

3. **Correlations between low energy flavour observables and Collider Physics (LHC, Tevatron)**

Basic Diagrams in FCNC Processes

Penguin Family

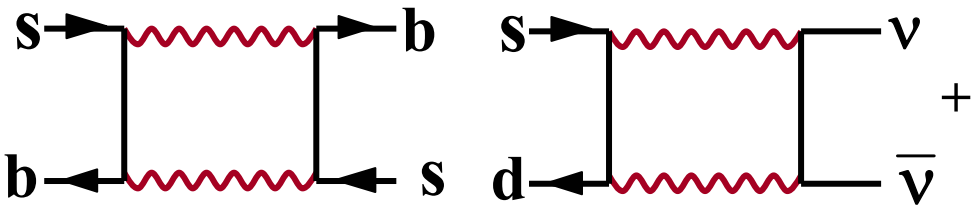


New Physics enters here

(GIM broken at one loop)

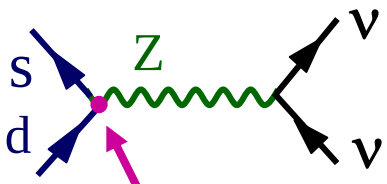
Similar diagrams in LFV and EDM´s

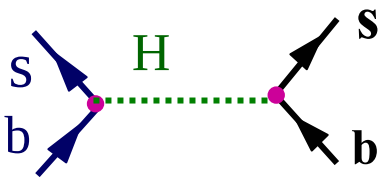
Box Diagrams



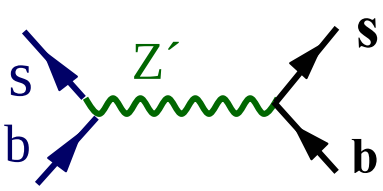
other box diagrams

Tree Diagrams





(GIM broken at tree level)



RS

Generated through mixing with New Gauge Bosons

Double Higgs Penguin in SUSY

Basic Questions for Flavour Physics

New Flavour violating CPV phases?

Flavour Conserving CPV phases?

Non-MFV Interactions?

(Non-CKM)

Right-Handed Charged Currents?

Scalars H^0, $H^\pm$ and related FCNC´s?

New Fermions? New Gauge Bosons?

How to explain dynamically 22 free Parameters in the Flavour Sector ?

Most popular BSM Directions

CMFV

(constrained MFV)

NEW **MFV**

(NMFV)
(GMFV)

NEW **2HDM**

LHT

(Littlest Higgs with T-parity)

SUSY

(flavour models)

Z′

(Langacker…)

NEW **RHMFV**

RS

(Randall-Sundrum)
(Warped Extra Dimensions)

NEW **4th G**

(Hou.., Soni.., Lenz.., Melic)
Munich

Vector-Like Quarks

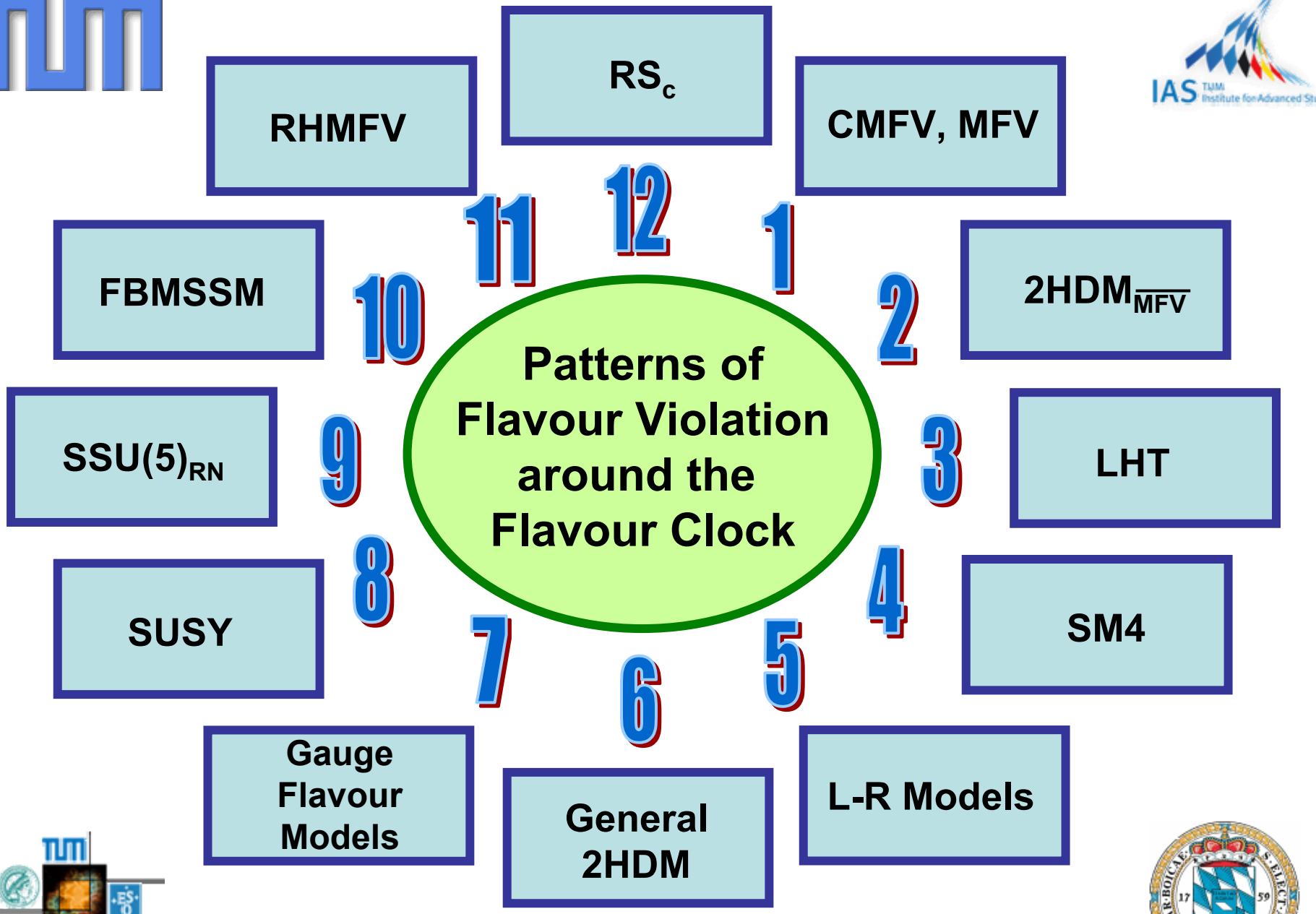
(Branco…, del Aguila)

Gauge Flavour Models NEW

L-R Models NEW

Non-Decoupling

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



hep-ph/1012.1447

Superstars of 2011 – 2015 (Flavour Physics)

$S_{\psi\varphi}$

$\not{CP}$ in $B_s^0 - \overline{B}_s^0$

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

$\left(B_d \to \mu^+\mu^-\right)$

$K^+ \to \pi^+ \nu\overline{\nu}$

$\left(K_L \to \pi^0 \nu\overline{\nu}\right)$

$\left(B_s \to \varphi\varphi\right)$

$\left(B^+ \to \tau^+ \nu_\tau\right)$

$\left(B_d \to K^* \mu^+\mu^-\right)$

ε'/ε *)

(Lattice)

γ from Tree Level Decays

$\mu \to e\gamma$

$\tau \to \mu\gamma$

$\tau \to e\gamma$

$\mu \to 3e$

$\tau \to 3$ leptons

EDM´s

$(g-2)_\mu$

*) Direct $\not{CP}$ in $K_L \to \pi\pi$

Big Superstars for 2011-2013

$S_{\psi\varphi}$

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

$\mu \to e\gamma$

Mixing induced CP Violation

$(B_s^0 - \overline{B}_s^0)$

$\left(S_{\psi\varphi}\right)_{SM} \cong 0.04$

$\left(S_{\psi K_S}\right)_{SM} \cong 0.80$

Mixing induced CP Violation

$(B_d^0 - \overline{B}_d^0)$

$Br\left(B_{s,d} \to \mu^+\mu^-\right)_{SM} \cong 3.2 \cdot 10^{-9}\left(1 \cdot 10^{-10}\right)$

CP-conserving Quark-Flavour Violating

$Br\left(\mu \to e\gamma\right)_{SM} \cong 0\left(10^{-54}\right)$

Lepton Flavour Violation

Precise prediction for ε_K (~~CP~~ in $K_L \to \pi\pi$)

and

Precise measurement of CKM phase = γ

Big Superstar 2011

Big Superstar 2011

Happy Birthday to You !

2nd Movement

Expectations and First Messages from New Animalcula

Departures from Standard Model Expectations

~~CP~~

$K^0 - \overline{K}^0 \quad (\varepsilon_K) \quad \frac{|\varepsilon_K|_{SM}}{|\varepsilon_K|_{exp}} \approx 0.83 \pm 0.10$ (AJB, Guadagnoli) (Brod, Gorbahn)

$B_d^0 - \overline{B}_d^0 \quad (S_{\psi K_s}) \quad (S_{\psi K_s}) \cong \begin{matrix} 0.80 \pm 0.04 \quad (SM) \quad (UTfit) \\ 0.672 \pm 0.022 \quad (exp) \end{matrix}$

$B_s^0 - \overline{B}_s^0 \quad (S_{\psi\varphi}) \quad \frac{(S_{\psi\varphi})_{exp}}{(S_{\psi\varphi})_{SM}} \approx 10 - 20$ (CDF, DØ, Lenz+Nierste)

LHCb ?

0.04

$$(S_{\psi\varphi})_{exp} \approx 0.8 \,^{+0.1}_{-0.2}$$

$$\frac{Br(B^+ \to \tau^+ \nu)_{exp}}{Br(B^+ \to \tau^+ \nu)_{SM}} \cong 2.2 \pm 0.5$$

$$|V_{ub}| = \begin{cases} 4.5 \cdot 10^{-3} & \text{Inclusive Decays } (B \to X_u l \nu) \\ 3.5 \cdot 10^{-3} & \text{Exclusive Decays } (B \to \rho l \nu) \\ & \text{and SM - CKM fit} \end{cases}$$

(Right-handed currents? Crivellin; Mannel et al. AJB, Gemmler, Isidori)

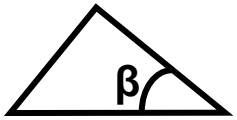
Possible Simplest Solutions

Soni, Lunghi

AJB, Guadagnoli
UTfitters
Lenz, Nierste +
CKMfitters
Laiho, Lunghi,
van der Water
Fleischer et al
Blanke et al
Branco et al
....

A New <u>negative</u> ~~CP~~ phase φ_{new} in $B_d^0 - \overline{B}_d^0$ Mixing

$\Rightarrow$ $|V_{ub}|$ from inclusive decays is correct



$$\left(S_{\psi K_s}\right)_{SM} = \sin 2\beta \rightarrow S_{\psi K_s} = \sin\left(2\beta - \varphi_{new}\right)$$

0.80 0.68 for $\varphi_{new} = 10°$

$\Rightarrow$ ε_K and $Br\left(B^+ \rightarrow \tau^+ \nu\right)$ much closer to experiment

B <u>Dynamical Model</u> : Non-Supersymmetric Two-Higgs Doublet Model with <u>Flavour Blind Phases</u> (AJB, Carlucci, Gori, Isidori AJB, Isidori, Paradisi)

$2HDM_{\overline{MFV}}$

Correlated Implications:

★ Large $S_{\psi\varphi}$, $Br\left(B_s \rightarrow \mu^+\mu^-\right)$, $Br\left(B_d \rightarrow \mu^+\mu^-\right)$, EDM's

Very strong activity in 2HDM over last 30 years:

In particular:

Lisbon Masters

Gustavo Branco Army

See many papers: Pich, Tuzon, Jung, ...

(non-SUSY)

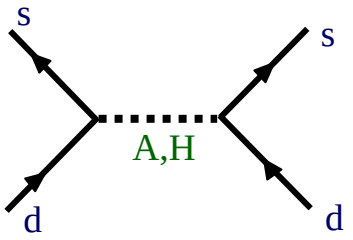
General 2HDM with MFV and Flavour Blind CPV Phases (in Yukawa Couplings)

(1005.5310)

(AJB, Carlucci, Gori, Isidori)

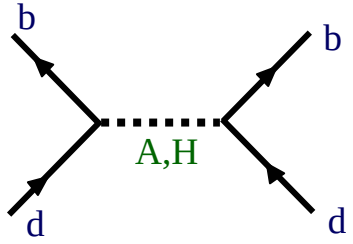
Provides correct pattern

ε_K :



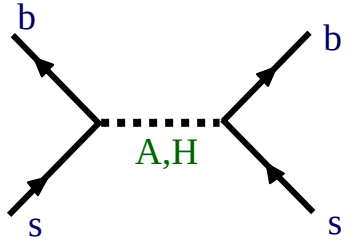
$$\approx \left[\frac{m_d m_s}{M_H^2}\right] m_t^4 \left(\tan\beta\right)^2 \left(V_{ts}^* V_{td}\right)^2$$ (tiny)

$S_{\psi K_s}$:



$$\approx \left[\frac{m_b m_d}{M_H^2}\right] m_t^4 \left(\tan\beta\right)^2 \left(V_{tb}^* V_{td}\right)^2 e^{i\varphi_{new}}$$

$S_{\psi\varphi}$:



$$\approx \left[\frac{m_b m_s}{M_H^2}\right] m_t^4 \left(\tan\beta\right)^2 \left(V_{tb}^* V_{ts}\right)^2 e^{i\varphi_{new}}$$

$$S_{\psi K_s} = \sin\left(2\beta - \theta_d^H\right) \qquad S_{\psi\varphi} \cong \sin\left(\theta_s^H\right)$$

$$\frac{\theta_d^H}{\theta_s^H} \approx \frac{m_d}{m_s} \approx \frac{1}{17}$$

Large RG QCD effects Q_{LR}

$$\sin 2\beta > S_{\psi K_s}$$

$\left(|\varepsilon_K|\right.$ enhanced$\left.\right)$

$$\frac{\tan\beta \approx 10 - 20}{M_H \approx 250\,\text{GeV}}$$

$|\varepsilon_K|$ vs $S_{\psi\varphi}$ and $S_{\psi K_s}$ vs $S_{\psi\varphi}$ in a General 2HDM with MFV and Flavour Blind CPV

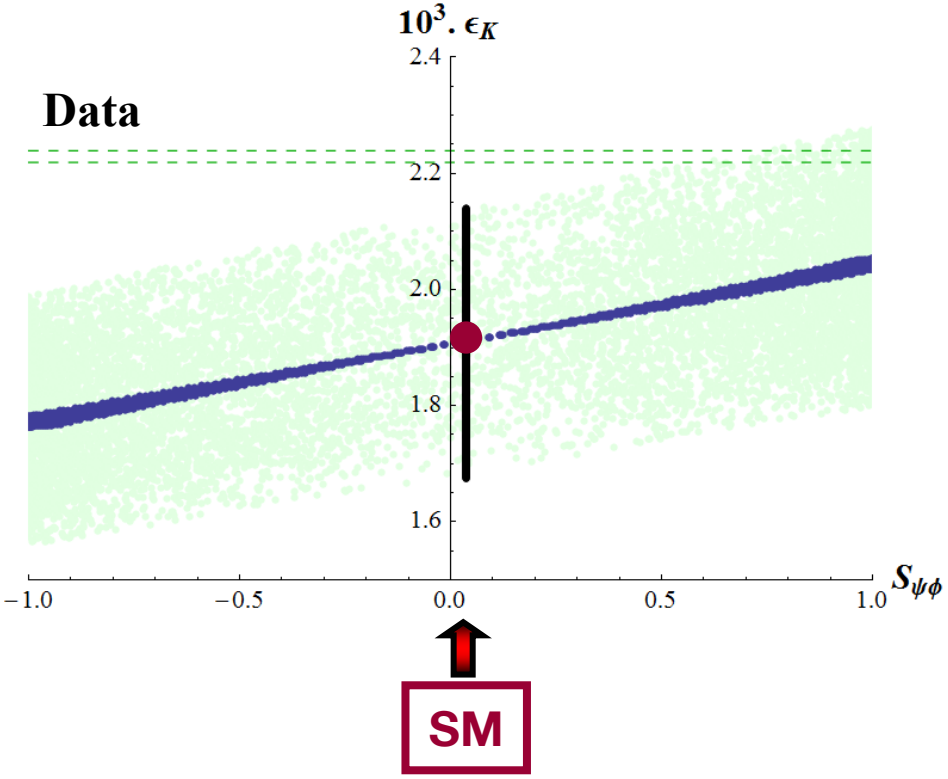
(AJB, Carlucci, Gori, Isidori)

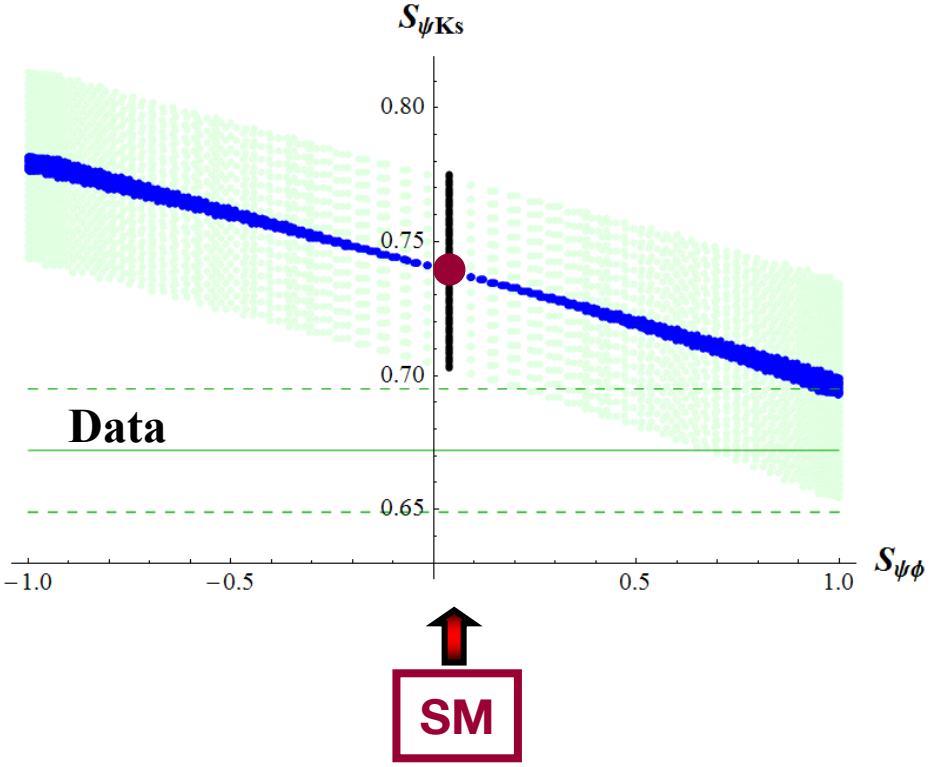
Correct pattern of NP effecs

Correlation between various ~~CP~~ Effects

(But the effects appear a bit too weak)

$2HDM_{\overline{MFV}}$





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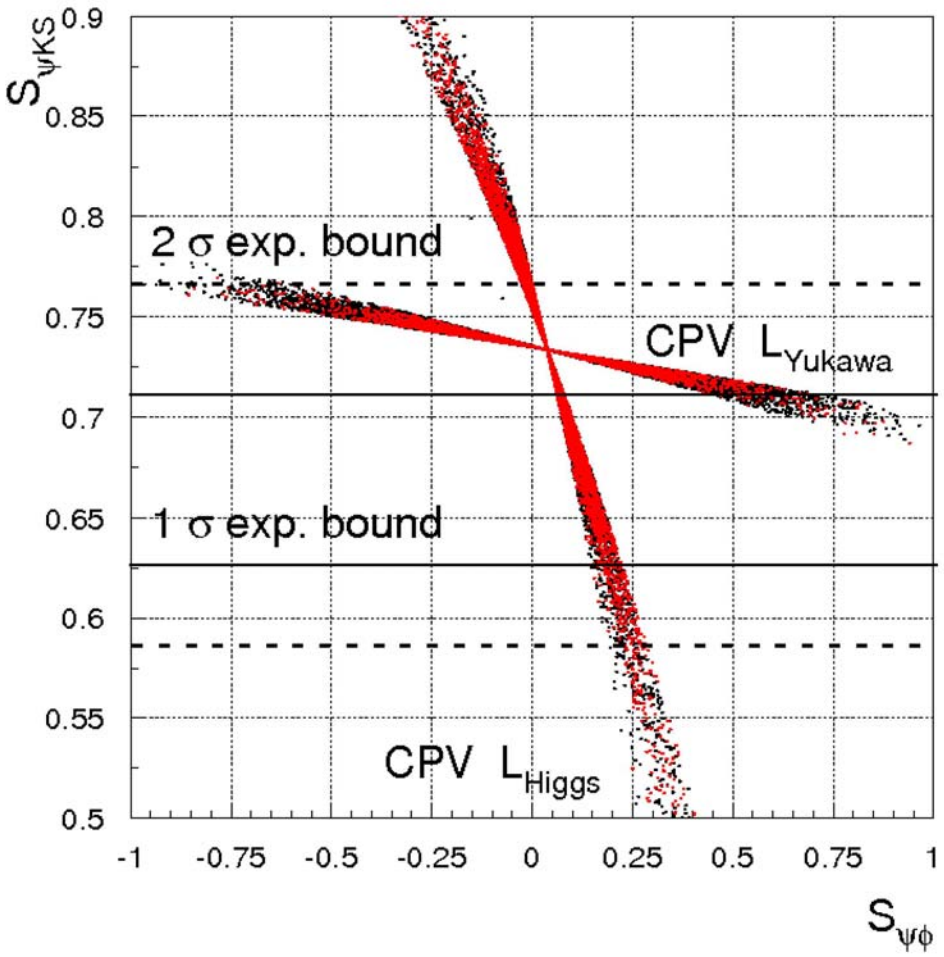
More on 2HDM with MFV and Flavour Blind Phases

Correlation between ~~CP~~ Effects



AJB, Isidori, Paradisi 1007.5291

$$S_{\psi K_s} = \sin\left(2\beta - \theta_d^H\right) \qquad S_{\psi\varphi} \cong \sin\left(\theta_s^H\right)$$

L_{Yukawa} :

$$\frac{\theta_d^H}{\theta_s^H} \approx \frac{m_d}{m_s} \approx \frac{1}{17}$$

BCGI

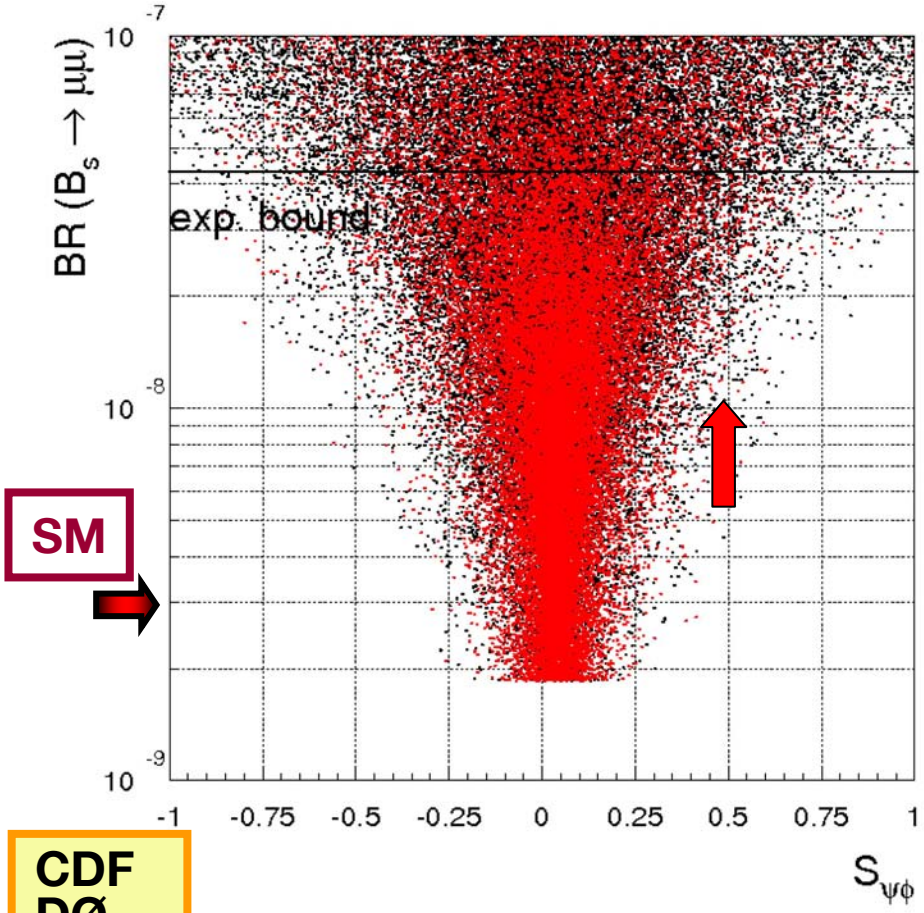
L_{Higgs} : (potential)

$$\frac{\theta_d^H}{\theta_s^H} = 1$$

Kagan, Perez, Volansky, Zupan
Paradisi, Straub
Dobrescu, Fox, Martin
Blum, Hochberg, Nir
Ligeti, Papucci, Perez, Zupan

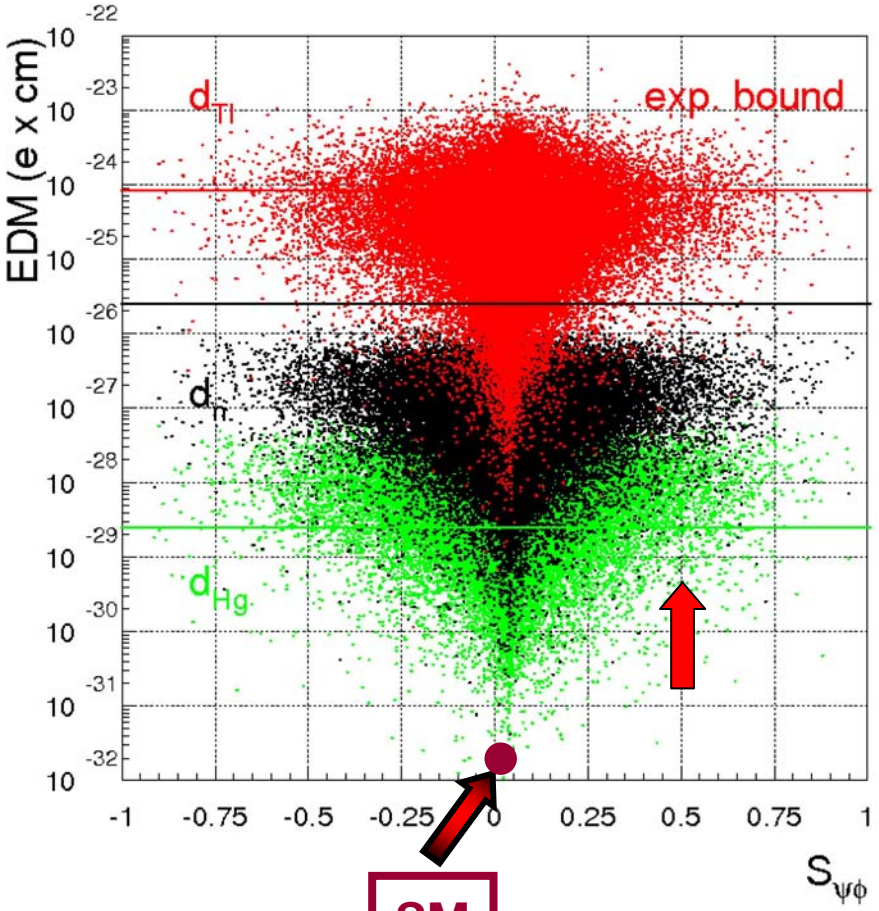
More on 2HDM with MFV and Flavour Blind Phases

$\mathbf{2HDM}_{\overline{\mathbf{MFV}}}$



SM

CDF
DØ
LHCb



SM

AJB, Isidori, Paradisi 1007.5291

Models with non-MFV Interactions facing Large $S_{\psi\varphi}$

Model Expectations

$$S_{\psi\varphi} \leq \begin{cases} 0.80 \ \text{(4G) (Fourth Generation) (t') (Soni, Hou, Munich, Lenz)} \\ 0.75 \ \text{(AC) (abelian flavour, SUSY) (Higgs penguin)} \quad \text{ABGPS} \\ 0.50 \ \text{(RVV) (non-abelian flavour, SUSY) (Higgs penguin)} \\ 0.75 \ \text{(RS) (Heavy KK Gauge Bosons) (Duling et al (08))} \\ 0.30 \ \text{(LHT) (Mirror Fermions at work) (Tarantino et al (09))} \end{cases}$$

$$(S_{\psi\varphi})_{SM} \approx 0.04$$

ABGPS = Altmannshofer, AJB, Gori, Paradisi, Straub 0909.1333

Implications of an Enhanced $S_{\psi\varphi}$

1. Enhanced $\mathrm{Br}\left(B_s \to \mu^+\mu^-\right)$
   (SUSY flavour models, $2\mathrm{HDM}_{\overline{\mathrm{MFV}}}$, 4G)
2. Enhanced $\mathrm{Br}\left(B_d \to \mu^+\mu^-\right)$
   ($2\mathrm{HDM}_{\overline{\mathrm{MFV}}}$, also in some SUSY flavour models)
3. $\mathrm{Br}\left(B_d \to \mu^+\mu^-\right)$ forced to be SM-like in 4G
4. $K^+ \to \pi^+\nu\bar{\nu}$ and $K_L \to \pi^0\nu\bar{\nu}$ forced to be SM-like
   (LHT, Randall-Sundrum)
5. Automatic enhancements in SUSY-GUT models:
   $\mathrm{Br}\left(\mu \to e\gamma\right)$, $\mathrm{Br}\left(\tau \to \mu\gamma\right)$, $\left(g-2\right)_\mu$, d_e, d_n

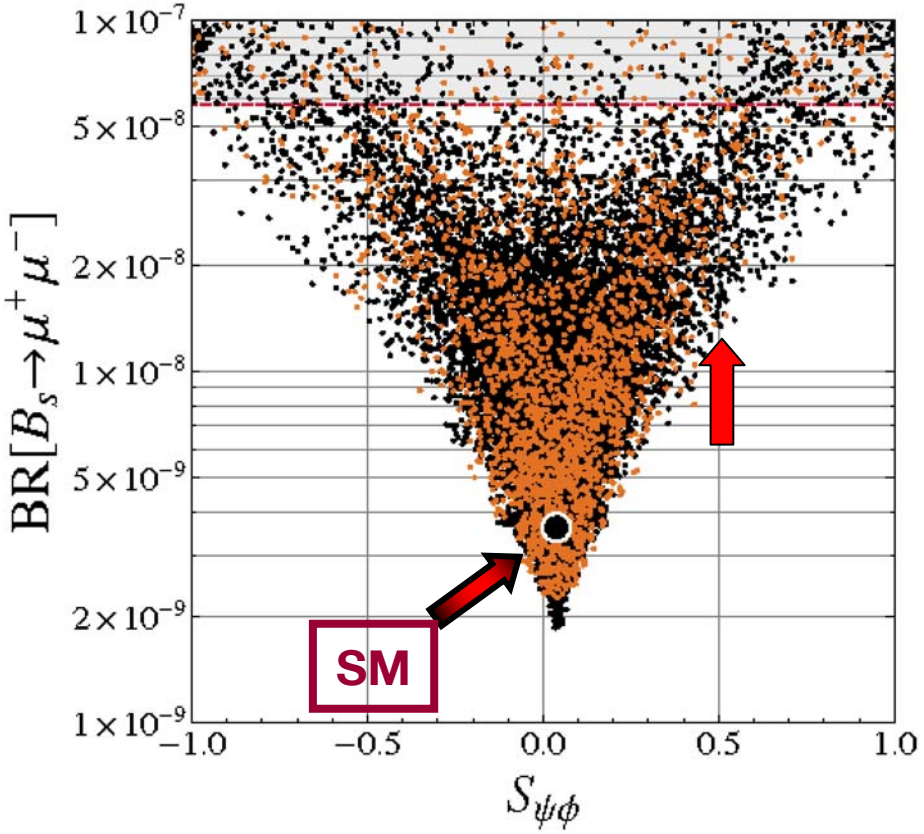
CDF, D0
LHCb

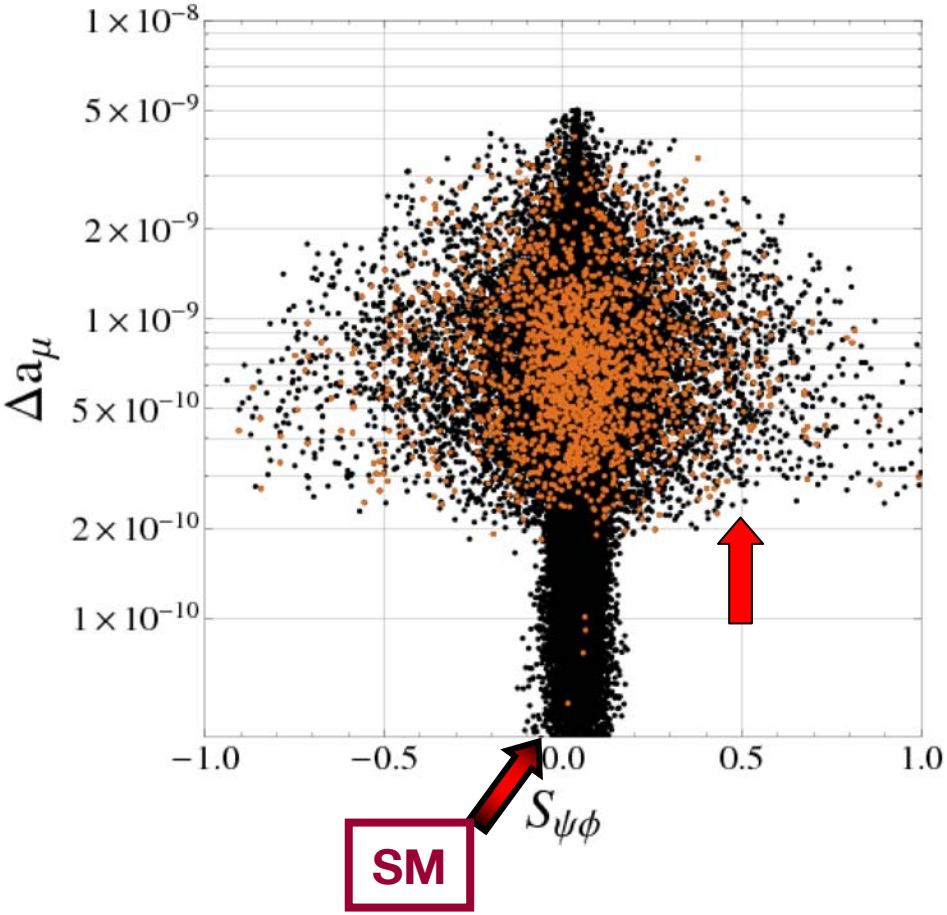
$\mathbf{Br(B_s \to \mu^+\mu^-)}$ **vs** $\mathbf{S_{\psi\varphi}}$

SUSY

ABGPS
(0909.1333)

$\mathbf{\Delta a_\mu}$ **vs** $\mathbf{S_{\psi\varphi}}$





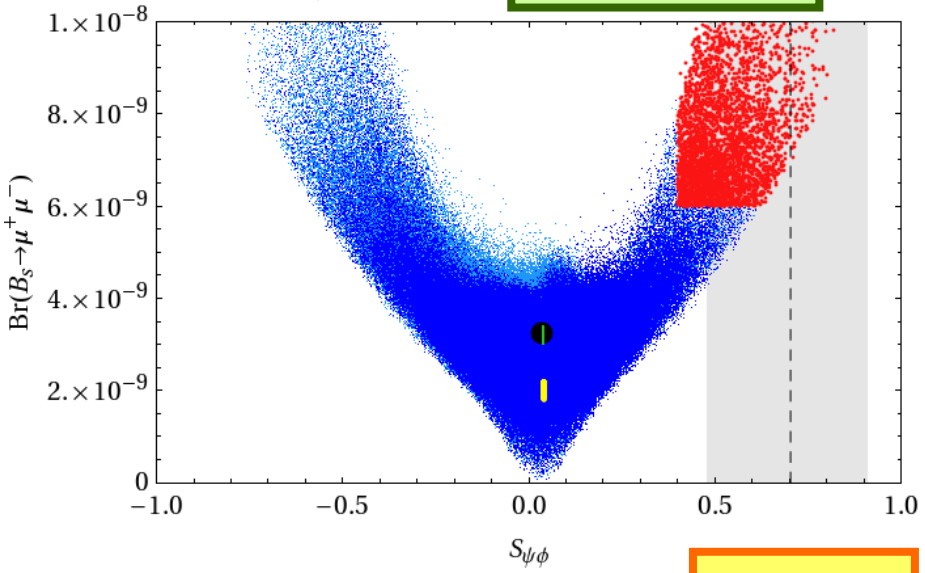
$Br(B_s \to \mu^+\mu^-)$ vs $S_{\psi\varphi}$

4G

BDFHPR (1002.2126)

Similar Result by Soni et al.

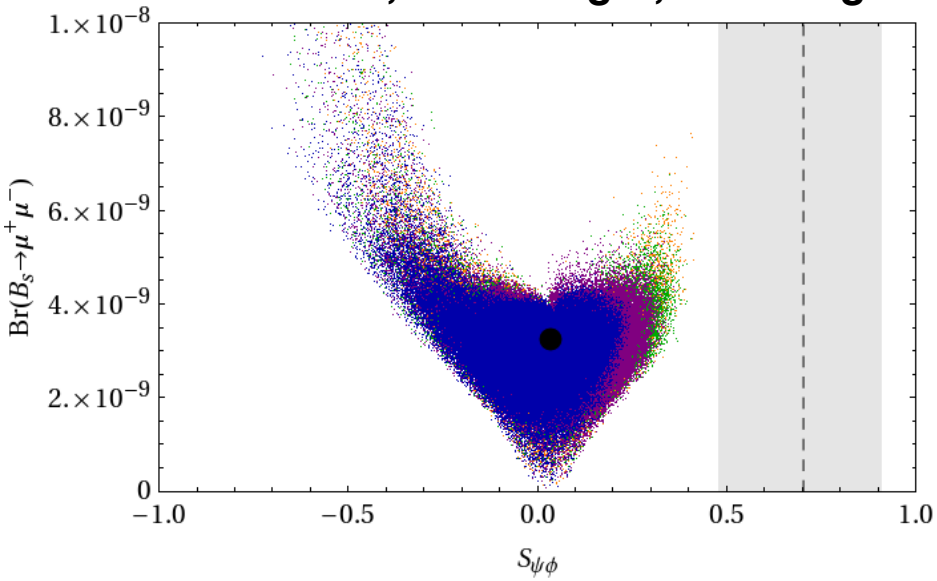
See also Hou et al. and Lenz et al.



CDF D0

No Impact on Δa_μ

AJB, Duling, Feldmann, Heidsieck, Promberger, Recksiegel



Adding ε'/ε Constraint

4G has hard time to describe simultaneously ε'/ε and $S_{\psi\varphi} > 0.2$ if $B_{6,8}$ within 20% from large N values

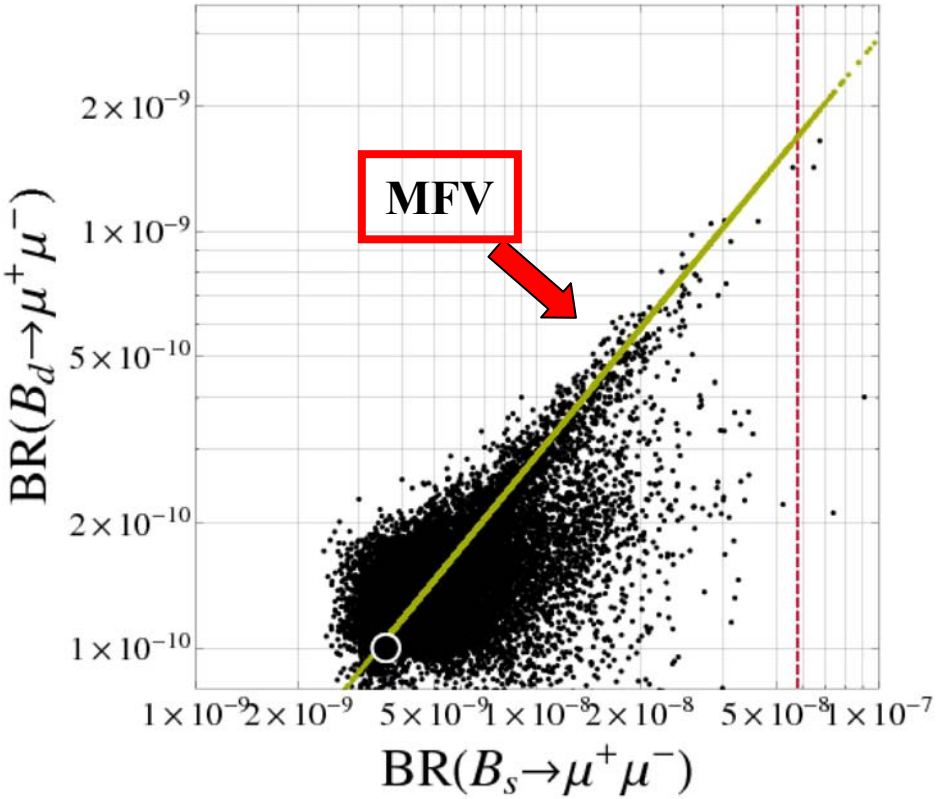
ABGPS

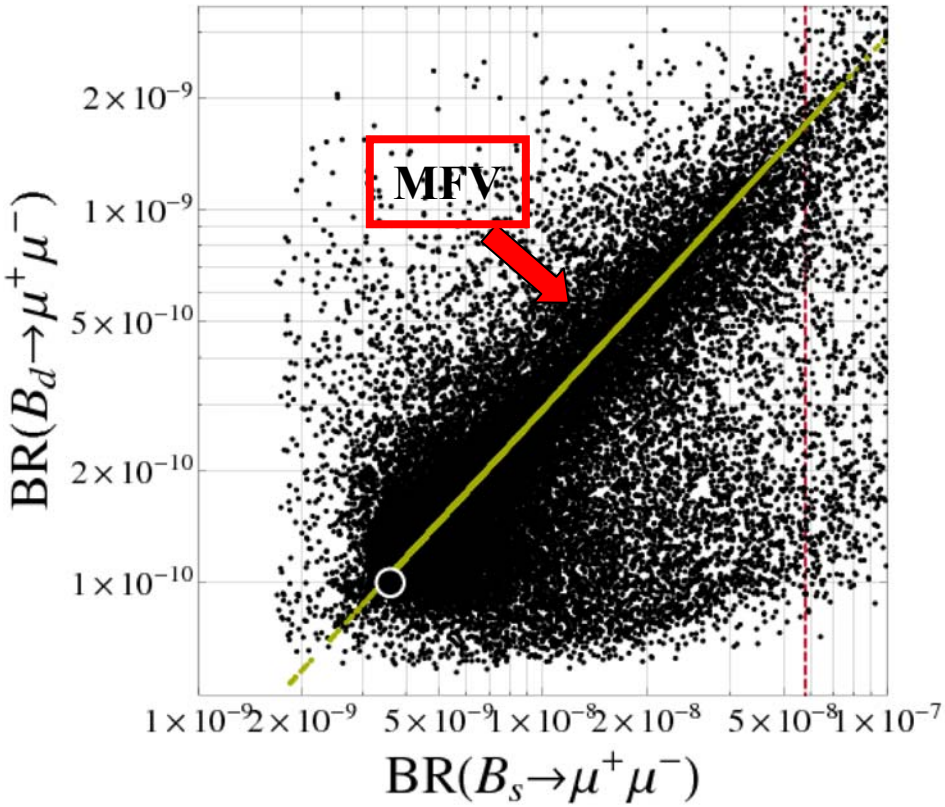
(0909.1333)

$$Br\left(B_d \to \mu^+\mu^-\right) \text{ vs } Br\left(B_s \to \mu^+\mu^-\right)$$

SUSY

MFV AJB; Hurth, Isidori, Kamenik, Mescia





RVV2 (RH currents)

LH currents

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

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

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

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

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

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

[e cm]

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

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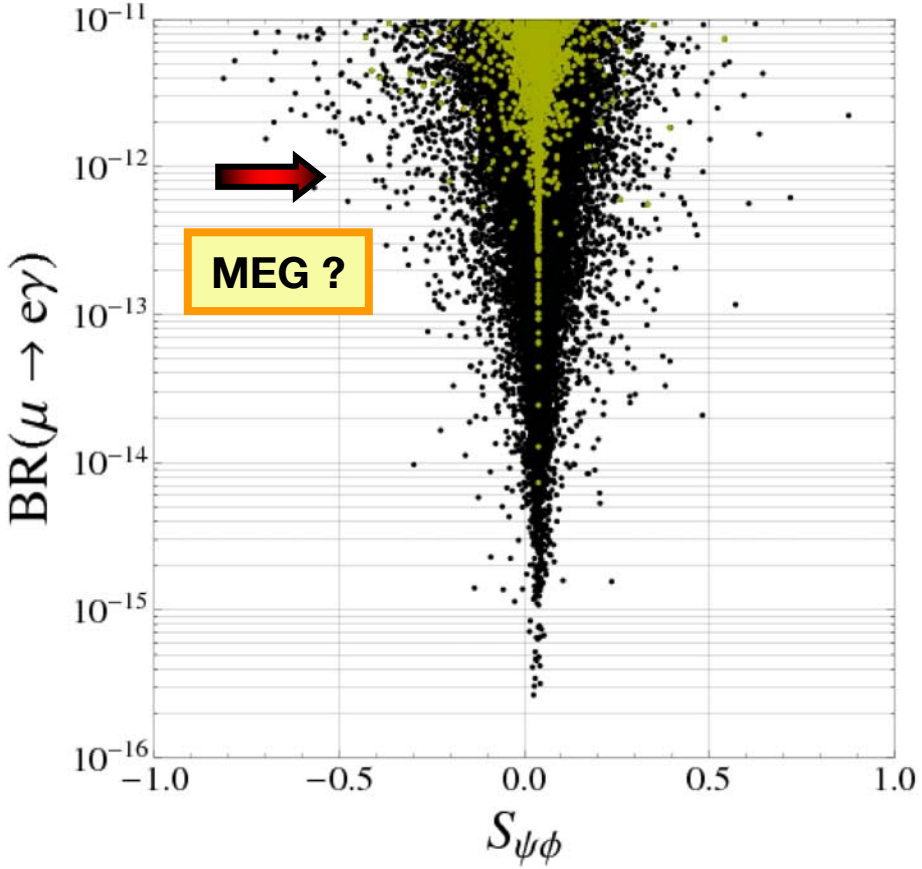
[e cm]

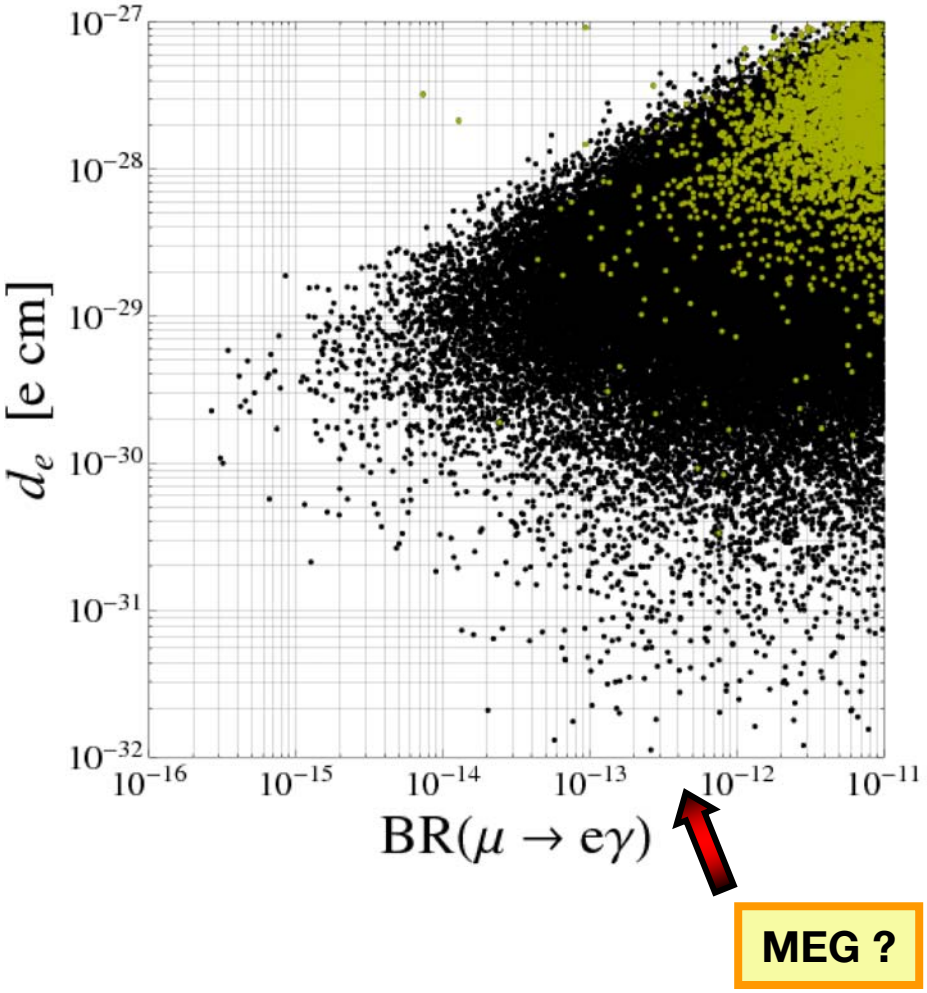
★ **MEG:** $Br(\mu \to e\gamma) = O(10^{-12})$ Rumours

ABGPS

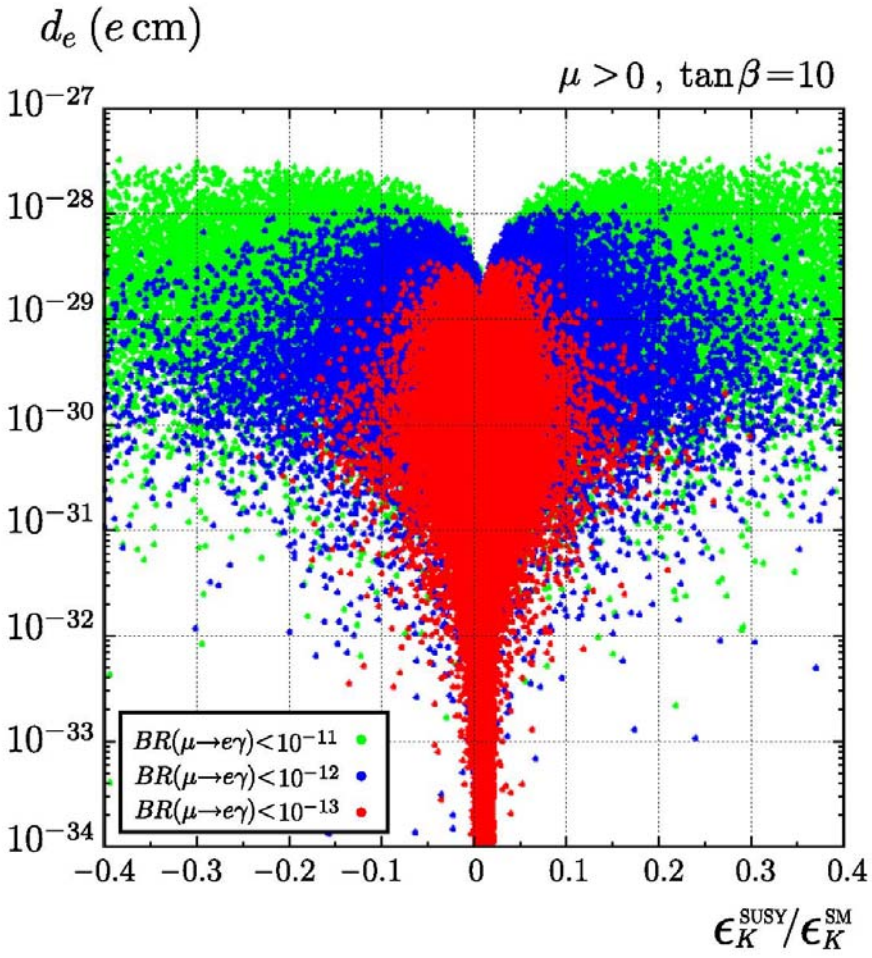
Correlations in the SU(3) Flavour SUSY Model (RVV)

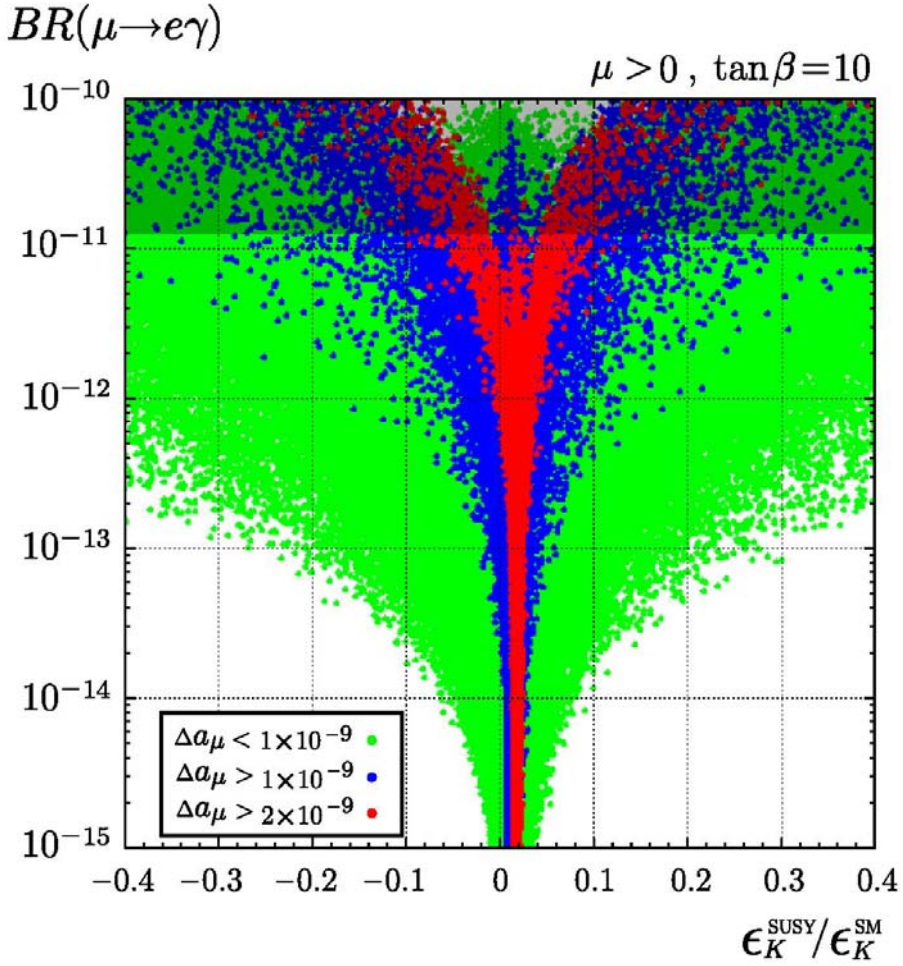
Solution to $(g-2)_\mu$ anomaly





Correlations within SUSY-SU(5)-GUT with RH Neutrinos





AJB, Nagai, Paradisi, 1011.1993

DNA Tests of Flavour Models

O_i : Observables ***M_i : Models beyond SM***

	M_1	M_2	M_3	M_4	M_5
O_1	★★★	★	★	★	★★
O_2	★	★★	★★★	★★	★
O_3	★★	★★★	★★	★	★
O_4	★★★	★★	★	★★★	★★
O_5	★	★★★	★	★★	★★★

★★★ **Very large New Physics effect**

★★ **Moderate New Physics effect**

★ **Very small New Physics effect**

DNA Tests of Flavour Models

ABGPS

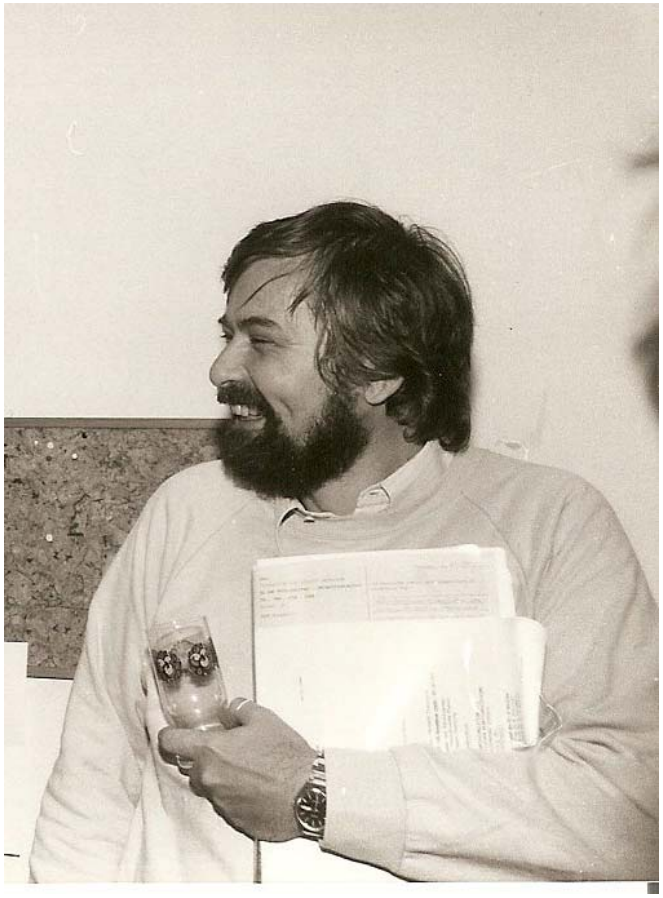
0909.1333

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS	4G
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?	★★
ϵ_K	★	★★★	★★★	★	★	★★	★★★	★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?	★★
$A_{\rm CP}\,(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?	★
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?	★★
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?	★★
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★	★★★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★	★
d_e	★★★	★★★	★★	★	★★★	★	★★★	★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?	★

2020 Vision

	NEW SM
$D^0 - \bar{D}^0$	★★
ϵ_K	★★
$S_{\psi\phi}$	★★★
$S_{\phi K_S}$	★★
$A_{\rm CP}\,(B \to X_s\gamma)$	★
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★★
$A_9(B \to K^*\mu^+\mu^-)$	★
$B \to K^{(*)}\nu\bar{\nu}$	★★★
$B_s \to \mu^+\mu^-$	★★★
$K^+ \to \pi^+\nu\bar{\nu}$	★★
$K_L \to \pi^0\nu\bar{\nu}$	★★★
$\mu \to e\gamma$	★★★
$\tau \to \mu\gamma$	★★★
$\mu + N \to e + N$	★★★
d_n	★★★
d_e	★★★
$(g-2)_\mu$	★★

Hans-Peter Visions



3rd Movement

Neutral Heavy Gauge Bosons and $B \rightarrow X_s \gamma$

The Impact of Flavour Changing Neutral Gauge Bosons on $B \to X_s \gamma$

AJB, Luca Merlo, Emmanuel Stamou: (BMS)

Z´-Models + Non-Abelian Gauge Symmetry

f_i= SM quarks
F_i= heavy quarks

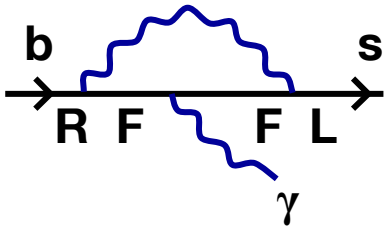
Most Analyses : charged Gauge Bosons and + 2/3 Quarks in $B \to X_s \gamma$

But Heavy Neutral A_H with FC Couplings:

$A_H \bar{f}_i f_j$ $A_H \bar{F}_i f_j$

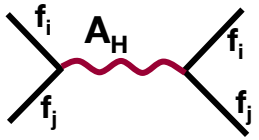
Could also contribute !

Directly :



Similar effects in $\mu \to e\gamma$, $t \to c\gamma$, EDM´s $(g-2)_\mu$

Indirectly :



+ QCD mixing with Dipole Operators

Neutral Current-Current Operators

Direct : $\Delta A(b \to s\gamma) \approx \frac{m_F}{m_b} C_L^{sF*} C_R^{bF}$

Couplings between SM and heavy quarks

Huge enhancement for $m_F \sim 0$ (1 TeV)

unless $C_L^{sF*} C_R^{bF}$ sufficiently small

Good News for Flavour Models with see-saw mechanism

: $C_L^{sF*} \approx \sqrt{\frac{m_s}{m_F}}\, \tilde{C}_L^{sF*}$, $C_R^{bF} \approx \sqrt{\frac{m_b}{m_F}}\, \tilde{C}_R^{bF}$

$$\Delta A(b \to s\gamma) \approx \sqrt{\frac{m_s}{m_b}}\, \tilde{C}_L^{sF*},\ \tilde{C}_R^{bF}$$

Generally small direct effect

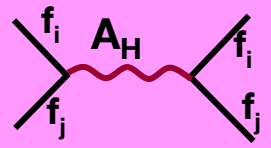
But in the case of different NP scenarios the impact could be large

Indirect : **It is known that charged current-current operators enhance Br($B \to X_s\gamma$) by a factor of 2-3 through QCD mixing with dipole operator.**

Bertolini et al (87)
Deshpande et al (87)
Misiak et al (2006)

Similarly, independently of F :

Neutral current-current operators originating in



have similar impact.

(LO QCD analysis in BMS)

Dominant new effect in $B \to X_s\gamma$ in Flavour Gauge Models

{ **54 neutral current-current operators !** }

$$\frac{1}{m_A^2} C_L^{sf*} C_R^{bf} \xrightarrow{QCD} Br(B \to X_s\gamma)$$

Detailed analysis including constraints on $C_L^{sf} C_R^{bf}$ in progress

FCNC Effects in a Minimal Theory of Fermion Masses

AJB, Grojean, Pokorski, Ziegler (1105.3725)
(describes heavy fermion effects in several models: FN, RS, …)

1. **No direct coupling of SM quarks to Higgs.**

2. **SM Yukawa couplings generated through mixing of heavy vectorial fermions with SM quarks:**

$$Y^{SM} = \frac{m_Q m_U}{M_Q M_U}\,\lambda$$

mixings

flavour-anarchial Yukawa in vectorial fermion sector

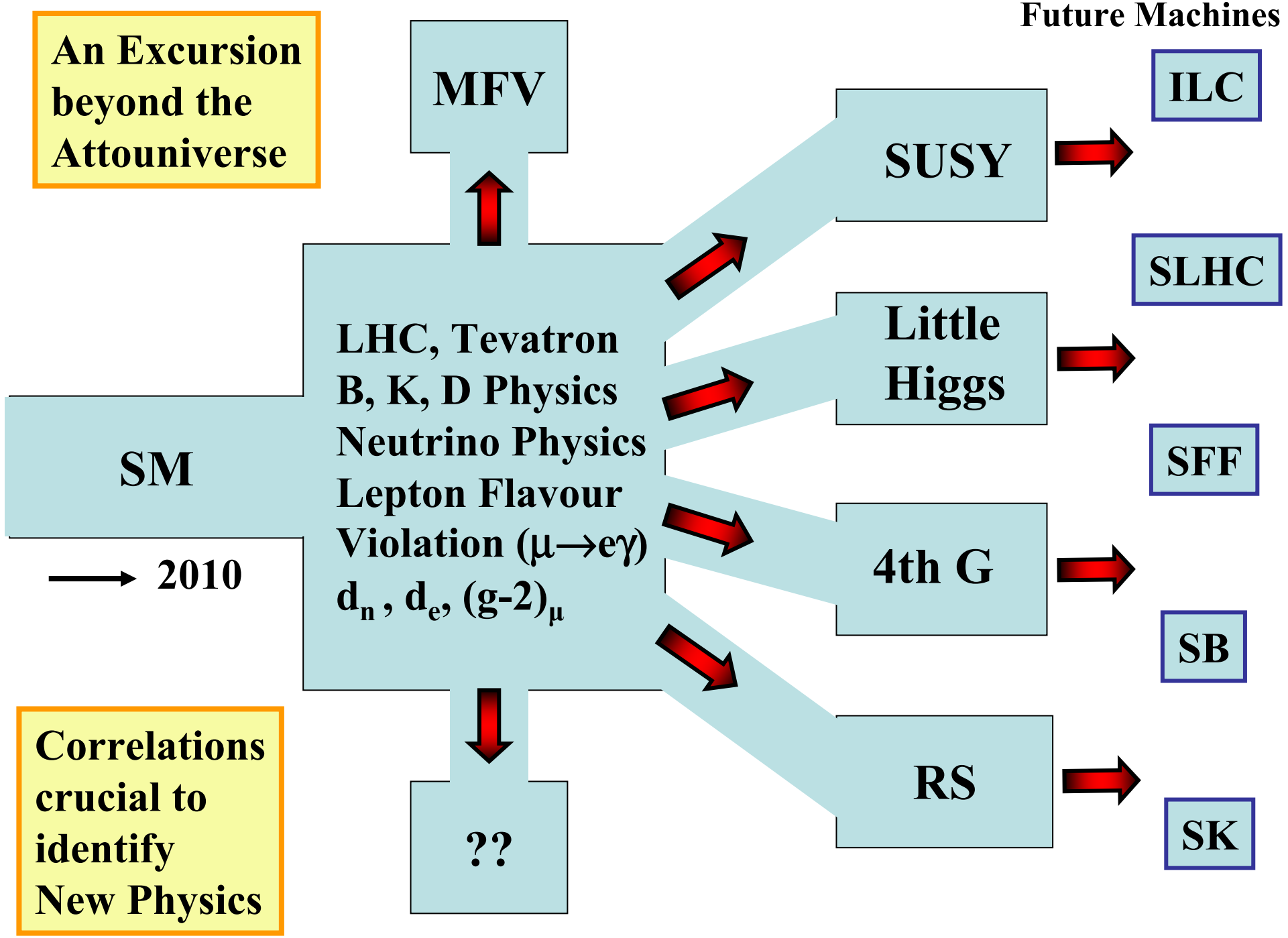
masses of vectorlike fermions

3. **Modification of $W^{\pm}$, Z, H couplings (FCNC´s) but M_Q, M_U ~ 0 (few TeV) allowed while satisfying all constraints and fitting quark masses + CKM matrix.**

Detailed analysis soon !

4th Movement

Finale: Vivace !


An Excursion beyond the Attouniverse
Future Machines
MFV
ILC
SUSY
SLHC
Little Higgs
SFF
SM
LHC, Tevatron
B, K, D Physics
Neutrino Physics
Lepton Flavour Violation (μ→eγ)
d_n , d_e, $(g-2)_\mu$
2010
4th G
SB
RS
SK
??
Correlations crucial to identify New Physics

Superstars of 2011 – 2015 (Flavour Physics)

$S_{\psi\varphi}$

$\not{CP}$ in $B_s^0 - \overline{B}_s^0$

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

$\left(B_d \to \mu^+\mu^-\right)$

$K^+ \to \pi^+ \nu\overline{\nu}$

$\left(K_L \to \pi^0 \nu\overline{\nu}\right)$

$\left(B_s \to \varphi\varphi\right)$

$\left(B^+ \to \tau^+ \nu_\tau\right)$

$\left(B_d \to K^* \mu^+\mu^-\right)$

ε'/ε *)

(Lattice)

γ from Tree Level Decays

$\mu \to e\gamma$

$\tau \to \mu\gamma$

$\tau \to e\gamma$

$\mu \to 3e$

$\tau \to 3$ leptons

EDM´s

$(g-2)_\mu$

*) Direct $\not{CP}$ in $K_L \to \pi\pi$

Many Thanks to my Collaborators

SUSY


W. Altmannshofer

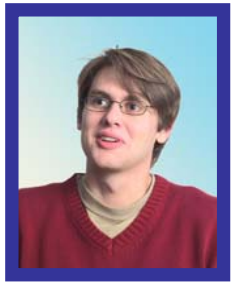

S. Gori


P. Paradisi


D. Straub

LHT


M. Blanke


B. Duling


A. Poschen-rieder


S. Recksiegel


C. Tarantino

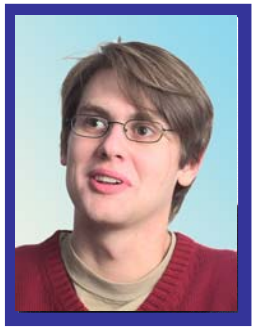

S. Uhlig


A. Weiler

RS


M. Albrecht


M. Blanke


B. Duling


K. Gemmler


S. Gori


A. Weiler

4 G

B. Duling

T. Heidsieck

C. Promberger

T. Feldmann

S. Recksiegel

2 HDM

M.V.Carlucci

S. Gori

G. Isidori

ε_K

D. Guadagnoli

RH Currents

K. Gemmler

G. Isidori

More Collaborators

I.Bigi

P. Ball

A. Bharucha

M. Wick

L. Calibbi

M. Nagai

More Collaborators


I.Bigi


P. Ball


A. Bharucha


M. Wick


L. Calibbi

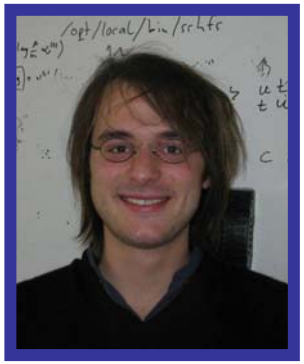

M. Nagai


L. Merlo


C. Grojean


A. Lenz

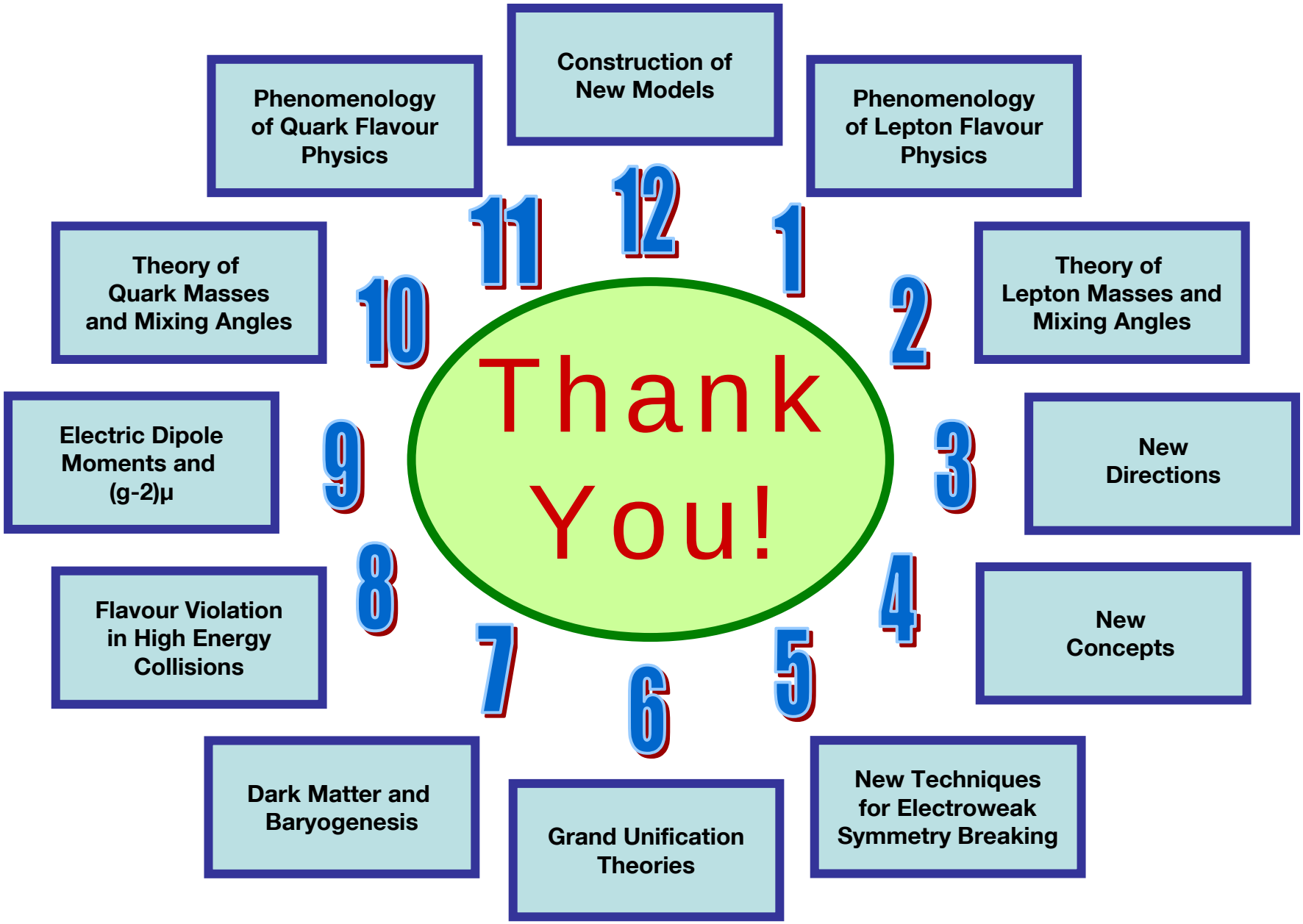

S. Pokorski


E. Stamou


R. Ziegler


J. Girrbach

New Animalcula in Sight !


Construction of New Models
Phenomenology of Lepton Flavour Physics
Theory of Lepton Masses and Mixing Angles
New Directions
New Concepts
New Techniques for Electroweak Symmetry Breaking
Grand Unification Theories
Dark Matter and Baryogenesis
Flavour Violation in High Energy Collisions
Electric Dipole Moments and (g-2)μ
Theory of Quark Masses and Mixing Angles
Phenomenology of Quark Flavour Physics
Thank You!
1
2
3
4
5
6
7
8
9
10
11
12

ENCORE

ENCORE

$SU(7)_M \otimes U(1)_F$

ENCORE

$SU(7)_M \otimes U(1)_F$ Local Organizing Principle


THE
MAGNIFICENT
SEVEN
They fought like seven hundred

The Magnificent Seven

Jorge C. Romao

Gustavo C. Branco

Filipe Joaquim

Ricardo Gonzales-Felipe

David Emmanuel Costa

Sergio Palomarez Ruiz

Luca Silva-Marcos

Queen Gui

Thank You !!!

Jorge C. Romao

Gustavo C. Branco

Filipe Joaquim

Ricardo Gonzales-Felipe

Queen Gui

David Emmanuel Costa

Sergio Palomarez Ruiz

Luca Silva-Marcos