MAIANI *70*, La Sapienza, Rome, Sept. 21-22, 2011

SUPER – GIM

facing the

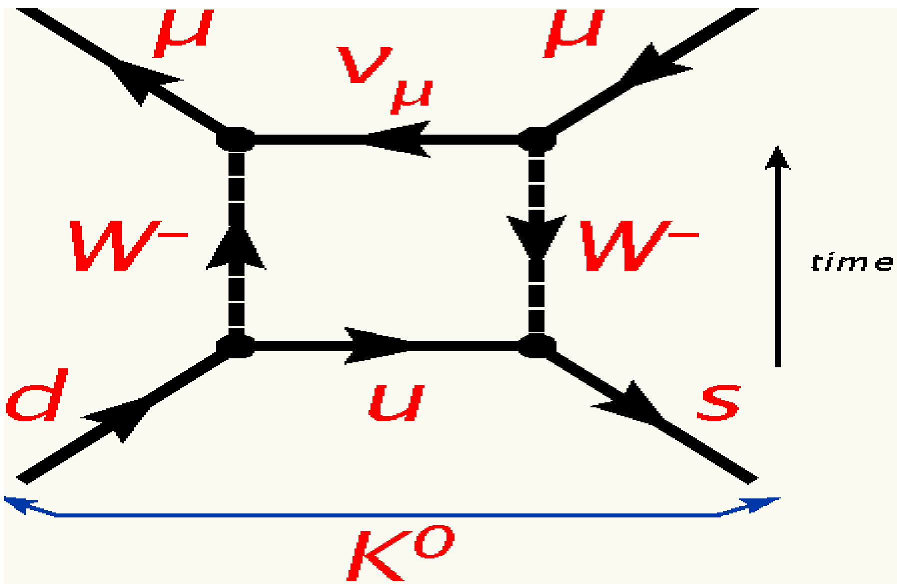
7 TeV LHC RESULTS

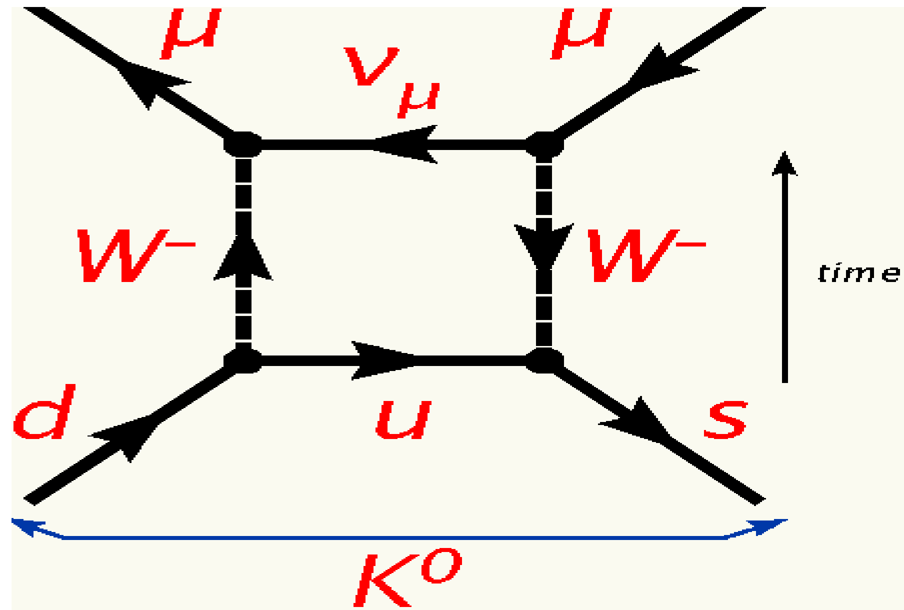
Antonio Masiero

Univ. Padova and INFN, Padova

COPING WITH INFINITIES

- 1972: **GIM** Mechanism



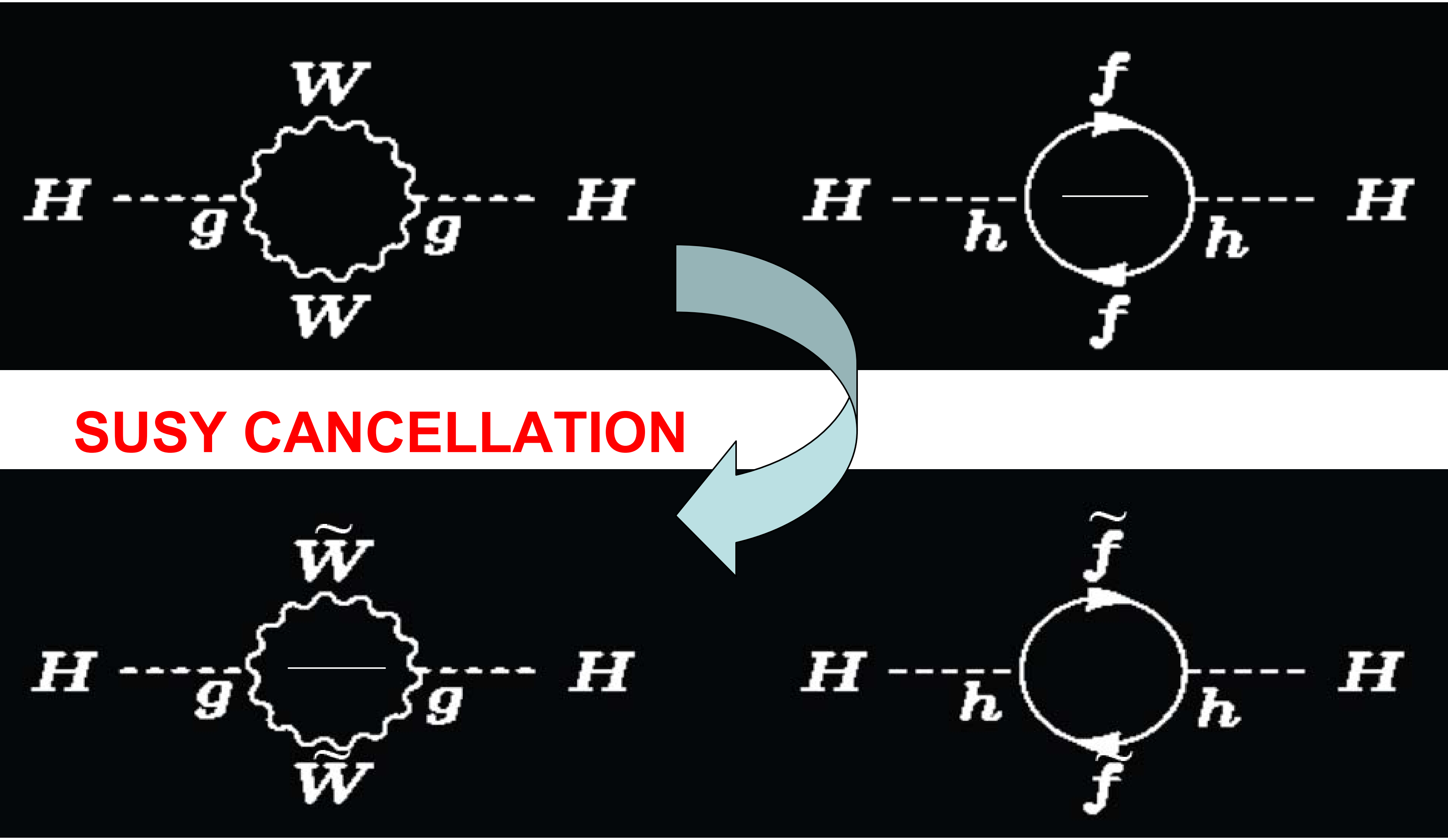


$$\mathcal{M}_1 \propto \sin\theta_c \cos\theta_c \ , \ \mathcal{M}_2 \propto -\sin\theta_c \cos\theta_c$$

CANCELLATION

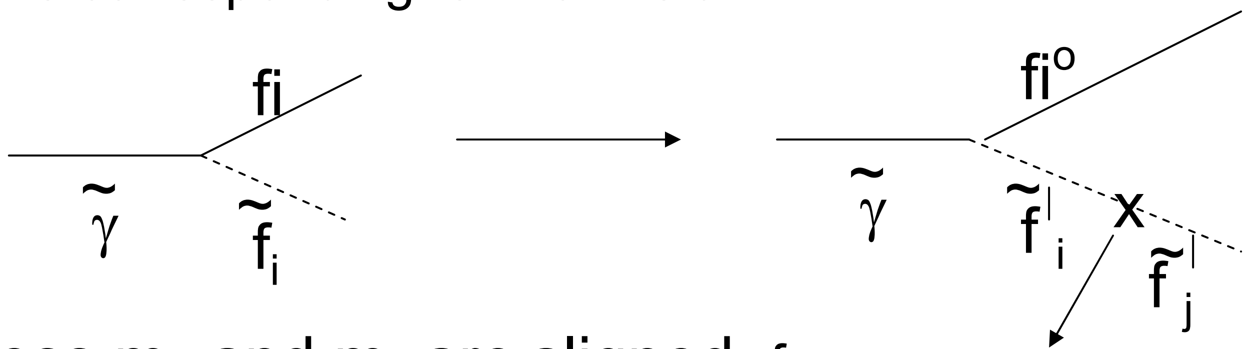
LUCIANO FACING THE GAUGE HIERARCHY

1979: Gif-sur-Yvette Summer School



SCKM basis

SUPER CKM: basis in the LOW - ENERGY phenomenology where through a rotation of the whole superfield (fermion + sfermion) one obtains DIAGONAL Yukawa COUPL. for the corresponding fermion field



Unless m_f and $m_{\tilde f}$ are aligned, $\tilde f$ is not a mass eigenstate

$\Delta_{ij}^f \longrightarrow \delta_{ij}^f \equiv \Delta_{ij}^f / m_{\tilde f}^{ave}$

Hall, Kostelecki, Raby

Bertolini, Borzumati, A.M., Ridolfi 1991
Gabbiani, Gabrielli, A.M. Silvestrini 1996

BOUNDS ON THE HADRONIC FCNC: 1 - 3 DOWN GENERATION

	$\lvert\Re(\delta^d_{13})_{LL}\rvert$		$\lvert\Re(\delta^d_{13})_{LL=RR}\rvert$	
x	TREE	NLO	TREE	NLO
0.25	4.9×10^{-2}	6.2×10^{-2}	3.1×10^{-2}	1.9×10^{-2}
1.0	1.1×10^{-1}	1.4×10^{-1}	3.4×10^{-2}	2.1×10^{-2}
4.0	6.0×10^{-1}	7.0×10^{-1}	4.7×10^{-2}	2.8×10^{-2}
	$\lvert\Im(\delta^d_{13})_{LL}\rvert$		$\lvert\Im(\delta^d_{13})_{LL=RR}\rvert$	
x	TREE	NLO	TREE	NLO
0.25	1.1×10^{-1}	1.3×10^{-1}	1.3×10^{-2}	8.0×10^{-3}
1.0	2.6×10^{-1}	3.0×10^{-1}	1.5×10^{-2}	9.0×10^{-3}
4.0	2.6×10^{-1}	3.4×10^{-1}	2.0×10^{-2}	1.2×10^{-2}
	$\lvert\Re(\delta^d_{13})_{LR}\rvert$		$\lvert\Re(\delta^d_{13})_{LR=RL}\rvert$	
x	TREE	NLO	TREE	NLO
0.25	3.4×10^{-2}	3.0×10^{-2}	3.8×10^{-2}	2.6×10^{-2}
1.0	3.9×10^{-2}	3.3×10^{-2}	8.3×10^{-2}	5.2×10^{-2}
4.0	5.3×10^{-2}	4.5×10^{-2}	1.2×10^{-1}	—
	$\lvert\Im(\delta^d_{13})_{LR}\rvert$		$\lvert\Im(\delta^d_{13})_{LR=RL}\rvert$	
x	TREE	NLO	TREE	NLO
0.25	7.6×10^{-2}	6.6×10^{-2}	1.5×10^{-2}	9.0×10^{-3}
1.0	8.7×10^{-2}	7.4×10^{-2}	3.6×10^{-2}	2.3×10^{-2}
4.0	1.2×10^{-1}	1.0×10^{-1}	2.7×10^{-1}	—

ELW. SYMM. BREAKING STABILIZATION VS. FLAVOR PROTECTION: THE SCALE TENSION

$$M(B_d\text{-}\bar{B}_d) \sim c_{SM} \frac{(y_t V_{tb}{}^* V_{td})^2}{16\,\pi^2 M_W{}^2} + c_{new} \frac{1}{\Lambda^2}$$

If $c_{new} \sim c_{SM} \sim 1$

Isidori

$\Lambda > 10^4$ TeV for $O^{(6)} \sim (\bar{s}\, d)^2$

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

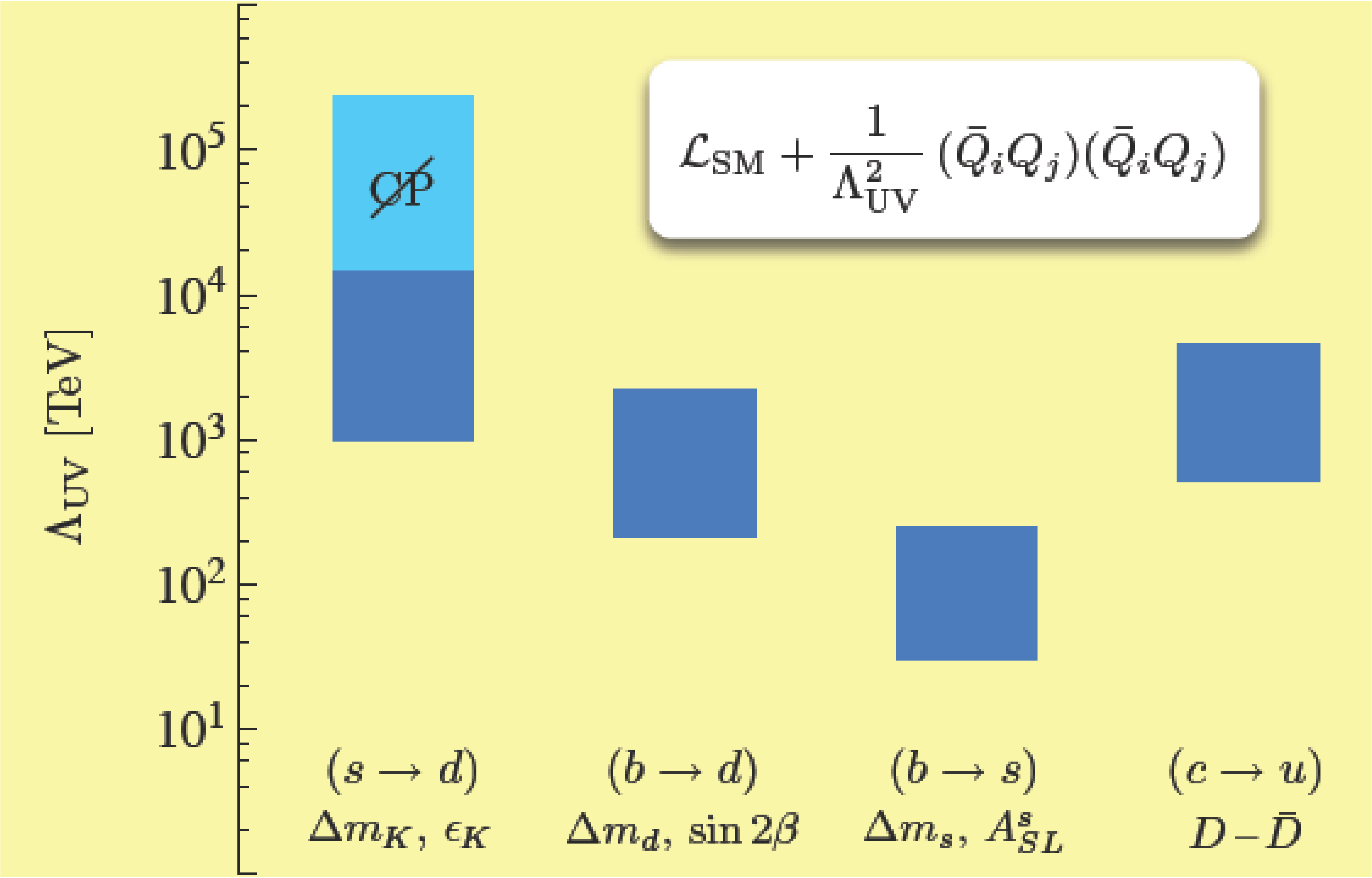
$\Lambda > 10^3$ TeV for $O^{(6)} \sim (\bar{b}\, d)^2$

[B^0-$\bar{B}^0$ mixing]

UV SM COMPLETION TO STABILIZE THE ELW. SYMM. BREAKING: $\Lambda_{UV} \sim O(1\text{ TeV})$

Flavor Structure in the SM and Beyond

NEUBERT EPS-HEP 2011



Generic bounds without a flavor symmetry

$K-\overline{K}$	8×10^{-7}	6×10^{-9}
$D-\overline{D}$	5×10^{-7}	1×10^{-7}
$B-\overline{B}$	5×10^{-6}	1×10^{-6}
$B_s-\overline{B_s}$	2×10^{-4}	2×10^{-4}

→ **SMALLNESS OF THE NP COUPLINGS IF THE NP SCALE IS 1 TEV**

$$Y_t\sim1,\quad Y_c\sim10^{-2},\quad Y_u\sim10^{-5}$$

$$Y_b\sim10^{-2},\quad Y_s\sim10^{-3},\quad Y_d\sim10^{-4}$$

$$Y_\tau\sim10^{-2},\quad Y_\mu\sim10^{-3},\quad Y_e\sim10^{-6}$$

$$|V_{us}|\sim0.2,\quad |V_{cb}|\sim0.04,\quad |V_{ub}|\sim0.004,\quad \delta_{KM}\sim1$$

→ **SMALLNESS OF THE SM COUPLINGS**

NIR

THE FLAVOUR PROBLEMS

FERMION MASSES

What is the rationale hiding behind the spectrum of fermion masses and mixing angles (our "**Balmer lines**" problem)

→ **LACK OF A FLAVOUR "THEORY"**

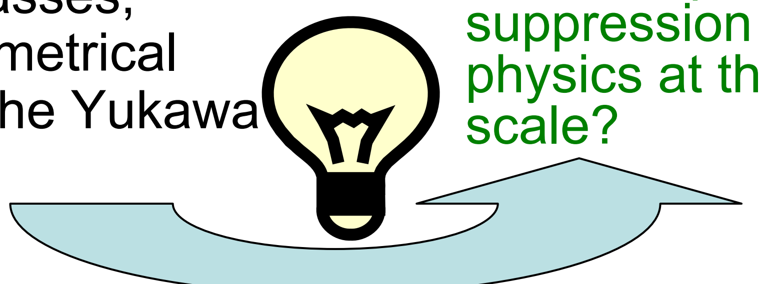
(new flavour – horizontal symmetry, radiatively induced lighter fermion masses, dynamical or geometrical determination of the Yukawa couplings, …?)

FCNC

Flavour changing neutral current (FCNC) processes are suppressed.

In the SM two nice mechanisms are at work: the **GIM mechanism** and the structure of the **CKM mixing matrix.**

How to cope with such delicate suppression if the there is new physics at the electroweak scale?



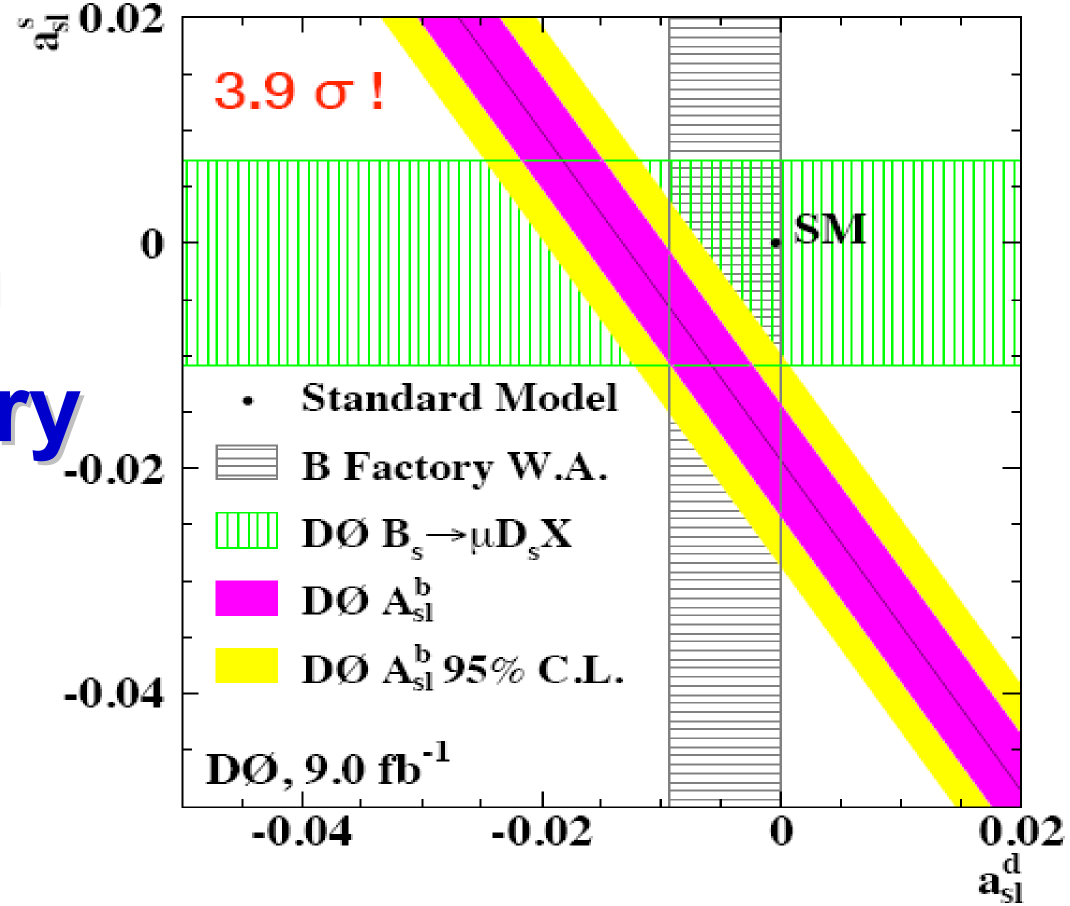
FLAVOR BLINDNESS OF THE NP AT THE ELW. SCALE?

- **THREE DECADES OF FLAVOR TESTS** (Redundant determination of the UT triangle → verification of the SM, theoretically and experimentally "high precision" FCNC tests, ex. b → s + γ, CP violating flavor conserving and flavor changing tests, lepton flavor violating (LFV) processes, …) clearly state that:
- A) in the **HADRONIC SECTOR** the **CKM flavor pattern of the SM represents the main bulk of the flavor structure and of (flavor violating) CP violation;**
- B) in the **LEPTONIC SECTOR**: although neutrino flavors exhibit large admixtures, LFV, i.e. non – conservation of individual lepton flavor numbers in FCNC transitions among charged leptons, is extremely small: once again the SM is right (to first approximation) predicting negligibly small LFV

EVIDENCE OF NP ALONG THE HIGH INTENSITY ROAD?

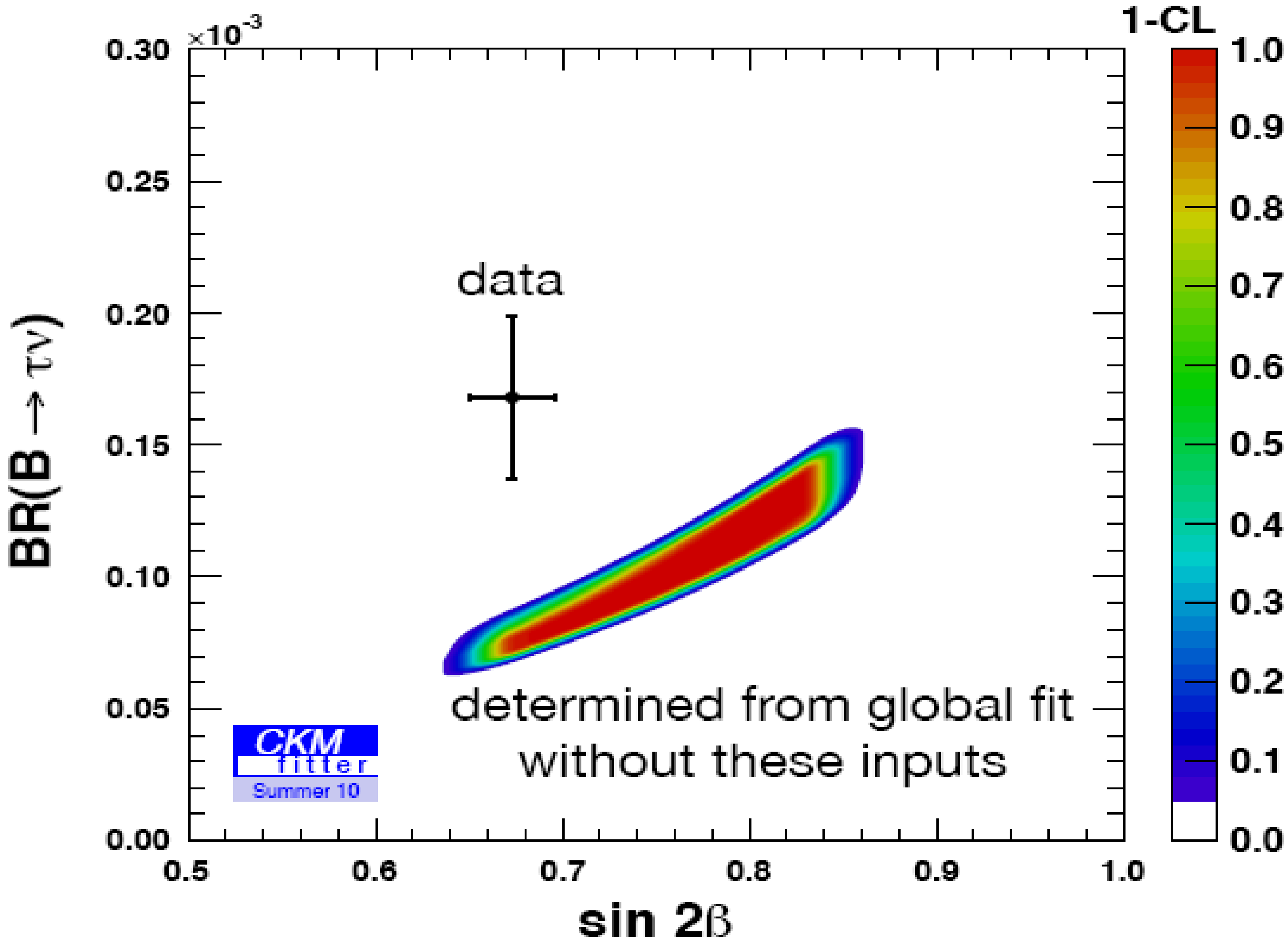
- "FLAVOR COLDS for the SM:

Like-sign dimuon charge asymmetry



But ***tension*** in the UT fit even neglecting CPV in the B_s mixing

Lenz, Nierste + CKMfitter (2010)



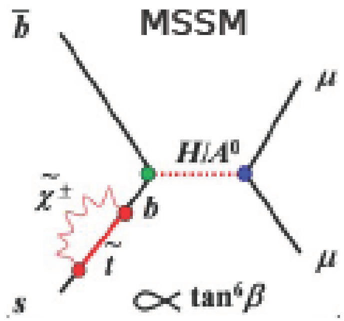
V_{ub} CRISIS

- discrepancies in the determinations of V_{ub} from inclusive semileptonic decays $B \to X_u l\nu$, exclusive semileptonic decays $B \to \pi l\nu$, and leptonic decay $B \to \tau\nu$ ("V_{ub} crisis")
- large difference of (14.4±2.9)% in the direct CP asymmetries measured in $B^0 \to K^+\pi^-$ vs. $B^+ \to K^+\pi^0$ decays, which is in conflict with the prediction of (2.2±2.4)% from QCD factorization ("$B \to K\pi$ puzzle")
- enhanced $B_s \to \mu^+\mu^-$ branching ratio observed by CDF (but not by LHCb and CMS ☹)

NEUBERT, EPS11

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

- interesting rare decays, which can be much enhanced in models with a warped extra dimension or SUSY models with large tanβ



Excess in B_s mode reported by CDF:

$$\mathcal{B}(B_s \to \mu^+\mu^-) = (1.8^{+1.1}_{-0.9}) \cdot 10^{-8} \qquad \text{SM:} \quad (3.2 \pm 0.2) \cdot 10^{-9}$$

$$\mathcal{B}(B_d \to \mu^+\mu^-) < 6.0 \cdot 10^{-9} \qquad \text{SM:} \quad (1.0 \pm 0.1) \cdot 10^{-10}$$

Unfortunately no excess seen at LHCb (CMS):

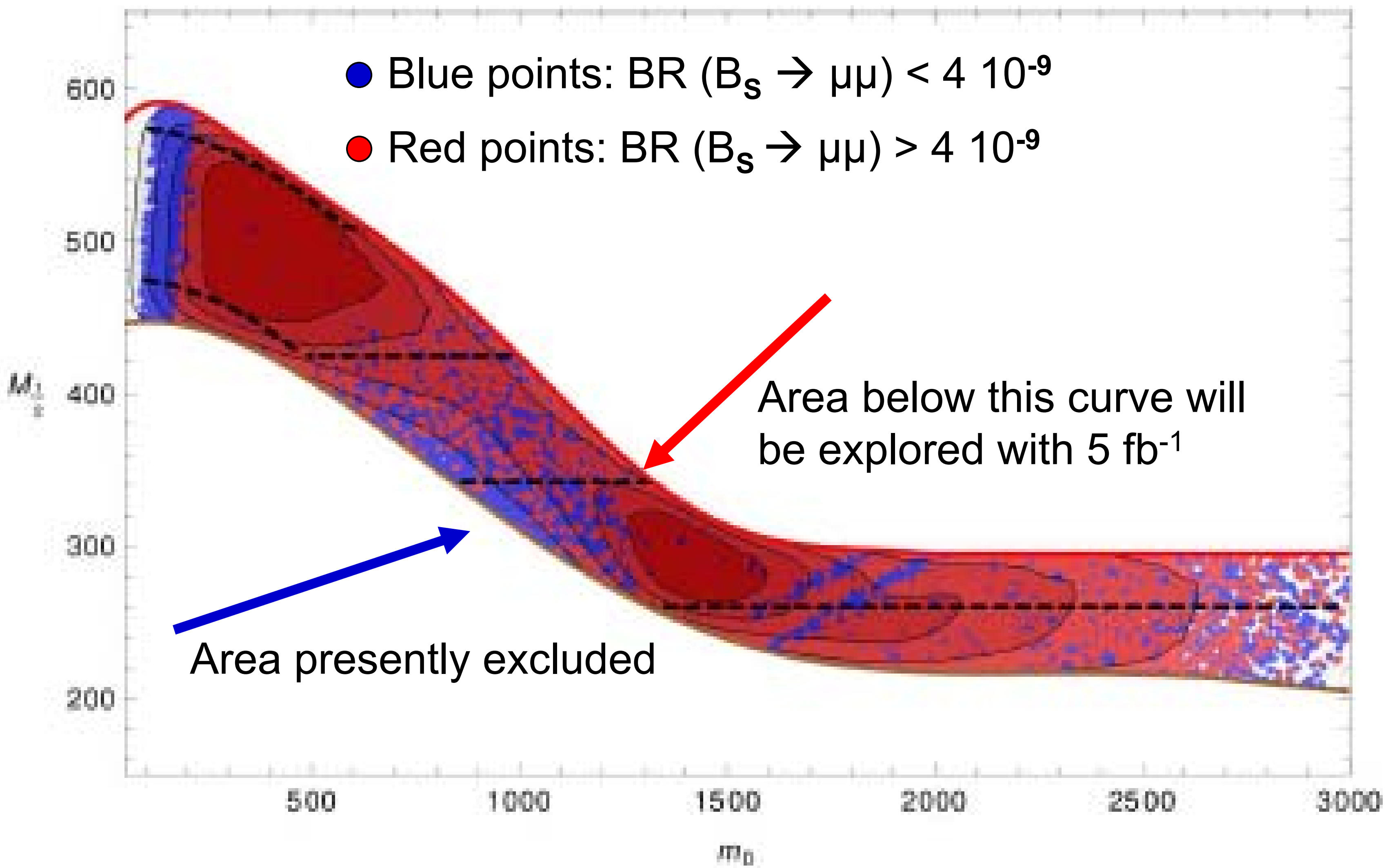
$$\mathcal{B}(B_s \to \mu^+\mu^-) < 1.5\ (1.9) \cdot 10^{-8}$$
$$\mathcal{B}(B_d \to \mu^+\mu^-) < 5.2\ (4.6) \cdot 10^{-9}$$

(at 95% CL)

NEUBERT EPS11

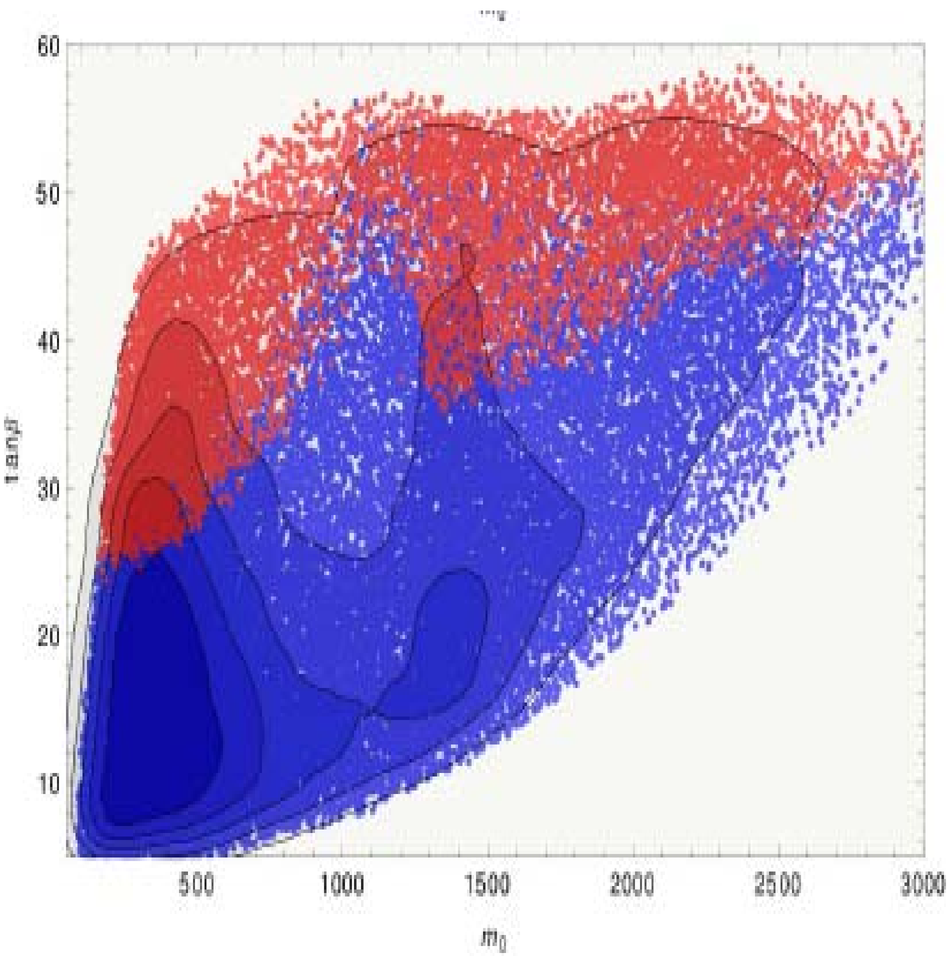
These bounds to not rule out the CDF result, but without refined LHC measurements the situation is inconclusive!

Calibbi, Hodgkinson, Jones, A.M. and Vives work in progress

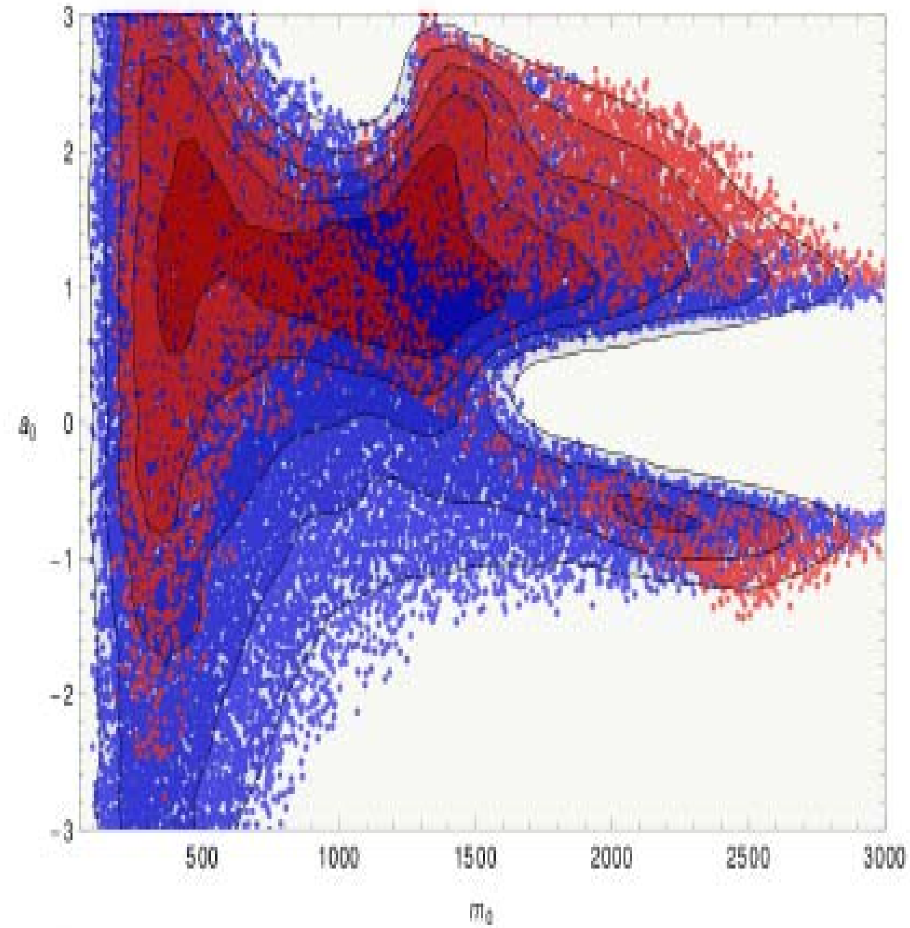


Calibbi, Hodgkinson, Jones, A.M. and Vives work in progress

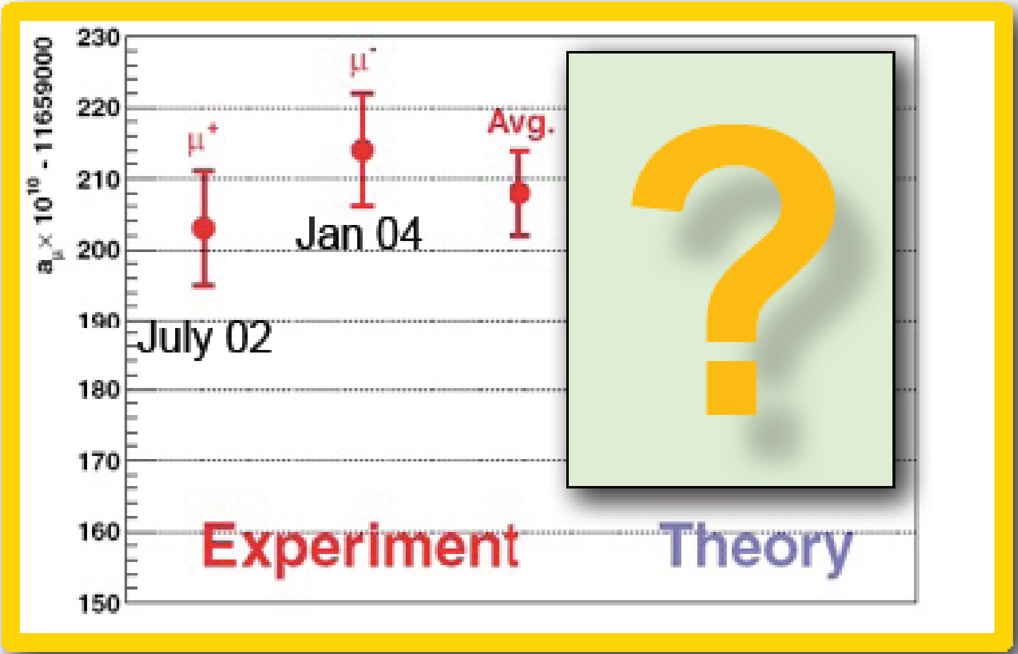
Relevance for **tanβ** exploration



Relevance for the scalar trilinear parameter **A** exploration



The muon g-2: the experimental result



- **Today:** $a_\mu^{EXP} = (116592089 \pm 54_{stat} \pm 33_{sys}) \times 10^{-11}$ [0.5ppm].
- **Future:** new muon g-2 experiments proposed at:
  - Fermilab (P989), aiming at 0.14ppm → Has now Stage 1 Approval!
  - J-PARC aiming at 0.1 ppm

  [D. Hetzog & N. Saito, U.Paris, Feb 2010; B. Lee Roberts & T. Mibe, Tau2010]
- **Are theorists ready for this (amazing) precision?** Not (yet)

The muon g-2: Standard Model vs. Experiment

Adding up all contributions, we get the following SM predictions and comparisons with the measured value:

$a_\mu^{EXP} = 116592089\ (63) \times 10^{-11}$

E821 – Final Report: PRD73 (2006) 072 with latest value of $\lambda = \mu_\mu/\mu_p$ (CODATA'06)

	$a_\mu^{SM} \times 10^{11}$	$(\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM}) \times 10^{11}$	σ
[1]	116 591 782 (59)	307 (86)	3.6
[2]	116 591 802 (49)	287 (80)	3.6
[3]	116 591 828 (50)	261 (80)	3.2
[4]	116 591 894 (54)	195 (83)	2.4

with $a_\mu^{HHO}(lbl) = 105\ (26) \times 10^{-11}$

[1] F. Jegerlehner, A. Nyffeler, Phys. Rept. 477 (2009) 1

[2] Davier et al, EPJ C71 (2011) 1515 (includes BaBar and KLOE10 2π)

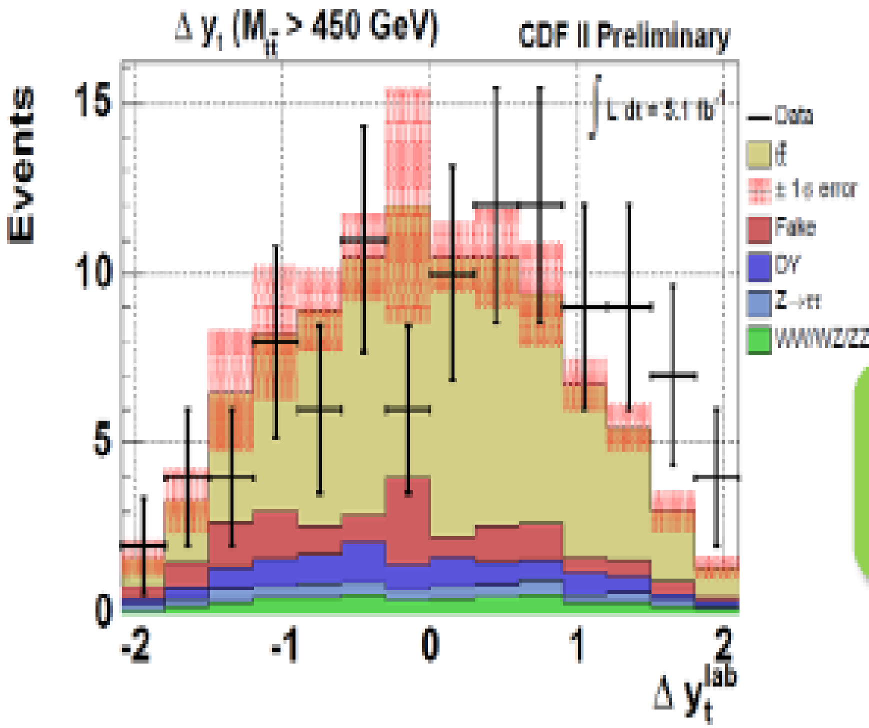
[3] HLMNT11: Hagiwara et al, arXiv:1105.3149 (incl BaBar and KLOE10 2π)

[4] Davier et al, Eur.PJ C71 (2011) 1515, τ data.

Note that the th. error is now about the same as the exp. one

Top anti-Top asymmetry

5.1 fb^{-1}



CDF public note 10436

$$A_{fb} = 0.42 \pm (0.15)^{stat} \pm (0.05)^{syst}$$

(dilepton final state)

✓ 2.3σ from the SM prediction.
✓ 3.4σ in the l+jets topology.

DUPERRIN EPS-HEP 2011

✓ axigluons, diquarks, new weak bosons, EDs etc..

W_R ? Feruglio, Maiani, A.M. 1989

✓ Or gluon radiations modeling at NLO?

What to make of this triumph of the CKM pattern in hadronic **flavor tests**?

New Physics at the Elw. Scale is Flavor Blind
CKM exhausts the flavor changing pattern at the elw. Scale →

MINIMAL FLAVOR VIOLATION

MFV : Flavor originates only from the SM Yukawa coupl.

New Physics introduces

NEW FLAVOR SOURCES in addition to the CKM pattern. They give rise to contributions which are <10% in the "flavor observables" which have already been observed!

MSSM ⊗ FAMILY SYMM.

- **AMBITION**: **simultaneously** accounting for the "correct" SM fermion masses and mixings (***SM Flavor Puzzle***) **and** a structure of the SUSY soft breaking masses allowing for adequate FCNC suppression + possible "explanation" of the alleged SM FCNC difficulties (***SUSY Flavor Puzzle***)

- Mechanism a la Frogatt – Nielsen with **abelian or non-abelian family symmetry**

$SU(3)$ Flavour model

ROBERTS, ROMANINO, ROSS, VELASCO-SEVILLA;
ROSS, VELASCO-SEVILLA, VIVES

- $Q, L \sim \mathbf{3}$ and $d^c, u^c, e^c \sim \mathbf{3}$; flavon fields: $\theta_3, \theta_{23} \sim \overline{\mathbf{3}}$, $\overline{\theta}_3, \overline{\theta}_{23} \sim \mathbf{3}$

- Family Symmetry breaking: $SU(3) \xrightarrow{\langle\theta_3\rangle} SU(2) \xrightarrow{\langle\theta_{23}\rangle} \emptyset$

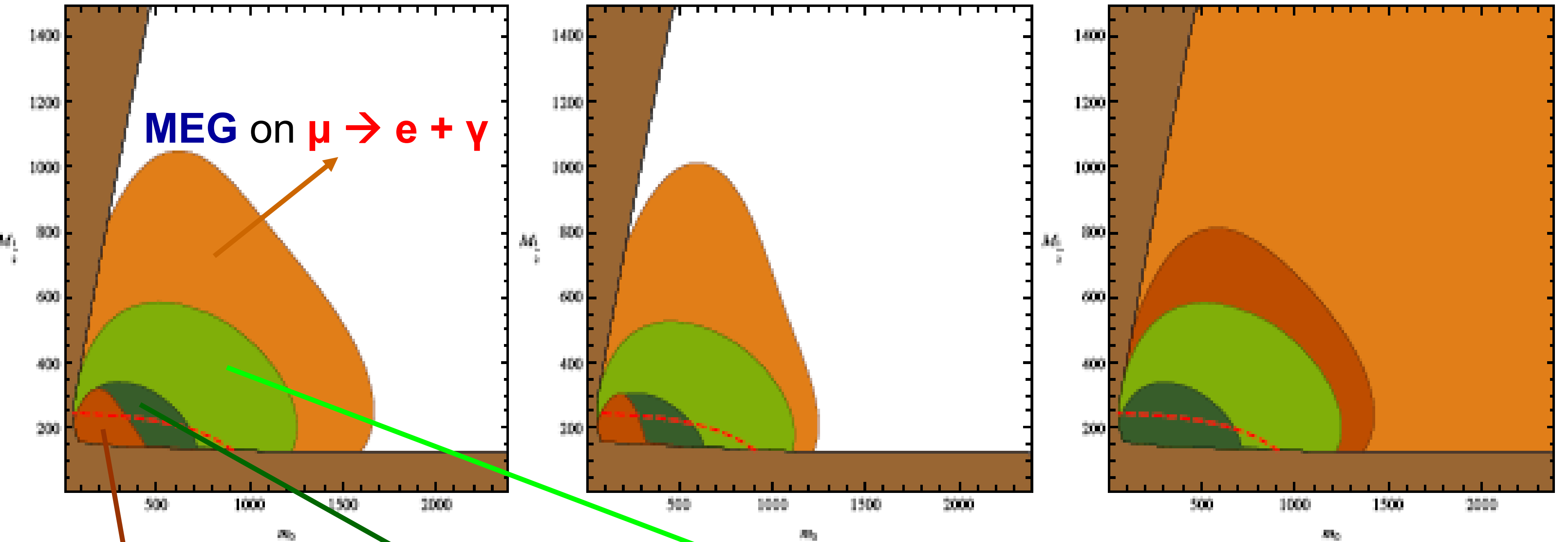
$$\theta_3, \overline{\theta}_3 = \begin{pmatrix} 0 \\ 0 \\ a_3 \end{pmatrix}, \quad \theta_{23}, \overline{\theta}_{23} = \begin{pmatrix} 0 \\ b \\ b \end{pmatrix} \text{ with } \left(\frac{a_3}{M}\right) \sim \mathcal{O}(1), \left(\frac{b}{M_u}\right) \simeq \left(\frac{b}{M_d}\right)^2 = \varepsilon \sim 0.05.$$

- Yukawa superpotential: $W_Y = H\psi_i\psi_j^c \left[\theta_3^i\theta_3^j + \theta_{23}^i\theta_{23}^j\left(\theta_3\overline{\theta_3}\right) + \epsilon^{ikl}\overline{\theta}_{23,k}\overline{\theta}_{3,l}\theta_{23}^j\left(\theta_{23}\overline{\theta_3}\right)\right]$

$$Y^f = \begin{pmatrix} 0 & a\,\varepsilon^3 & b\,\varepsilon^3 \\ a\,\varepsilon^3 & \varepsilon^2 & c\,\varepsilon^2 \\ b\,\varepsilon^3 & c\,\varepsilon^2 & 1 \end{pmatrix} \frac{|a_3|^2}{M^2},$$

O. VIVES

LFV CONSTRAINTS IN THE $M_0 - M_{1/2}$ SUSY PLANE



PRESENT BOUND ON
τ → μ + γ

FUTURE BOUND ON τ → μ + γ
at SUPER B

PRESENT BOUND ON
μ → e + γ

CALIBBI, JONES, A.M., J-H. PARK, POROD and VIVES

SuperFlavor vs. LHC Sensitivity Reach in testing Λ_{SUSY}

	superB	general MSSM	high-scale MFV
$\left\|\left(\delta^d_{13}\right)_{LL}\right\| \; (LL \gg RR)$	$1.8 \cdot 10^{-2} \frac{m_{\tilde{q}}}{(350\,\mathrm{GeV})}$	1	$\sim 10^{-3} \frac{(350\,\mathrm{GeV})^2}{m^2_{\tilde{q}}}$
$\left\|\left(\delta^d_{13}\right)_{LL}\right\| \; (LL \sim RR)$	$1.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\,\mathrm{GeV})}$	1	$-$
$\left\|\left(\delta^d_{13}\right)_{LR}\right\|$	$3.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\,\mathrm{GeV})}$	$\sim 10^{-1} \tan\beta \frac{(350\,\mathrm{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-4} \tan\beta \frac{(350\,\mathrm{GeV})^3}{m^3_{\tilde{q}}}$
$\left\|\left(\delta^d_{23}\right)_{LR}\right\|$	$1.0 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\,\mathrm{GeV})}$	$\sim 10^{-1} \tan\beta \frac{(350\,\mathrm{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-3} \tan\beta \frac{(350\,\mathrm{GeV})^3}{m^3_{\tilde{q}}}$

SuperB can probe MFV (with small-moderate tanβ) for TeV squarks; for a generic non-MFV MSSM → sensitivity to squark masses > 100 TeV !

SLOW-DECOUPLING OF NP IN FCNC

Ciuchini, Isidori, Silvestrini

SUSY SEE-SAW

- **UV COMPLETION OF THE SM TO STABILIZE THE ELW. SCALE:**

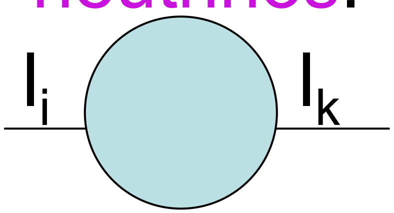
LOW-ENERGY SUSY

- **COMPLETION OF THE SM FERMIONIC SPECTRUM TO ALLOW FOR NEUTRINO MASSES**: NATURALLY SMALL PHYSICAL NEUTRINO MASSES WITH RIGHT-HANDED NEUTRINO WITH A LARGE MAJORANA MASS

SEE-SAW

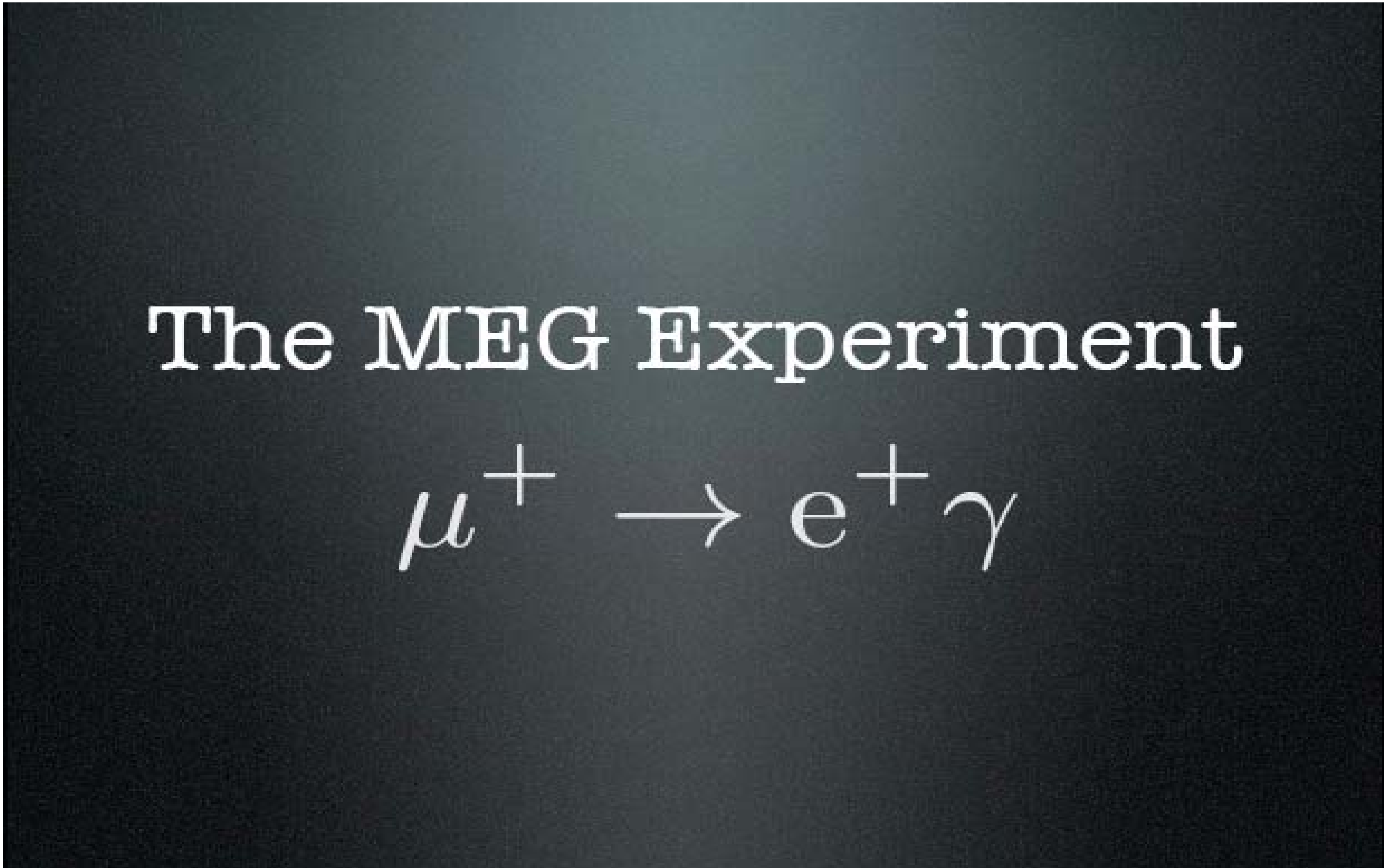
LFV and NEW PHYSICS

- Flavor in the HADRONIC SECTOR:
  CKM paradigm
- Flavor in the LEPTONIC SECTOR:
  - Neutrino masses and (large) mixings
  - Extreme smallness of LFV in the charged lepton sector of the SM with massive neutrinos:



suppressed by $(m_{\nu_i}^2 - m_{\nu_k}^2) / M_W^2$

NEW BOUND OF MEG AT THE EPS 2011



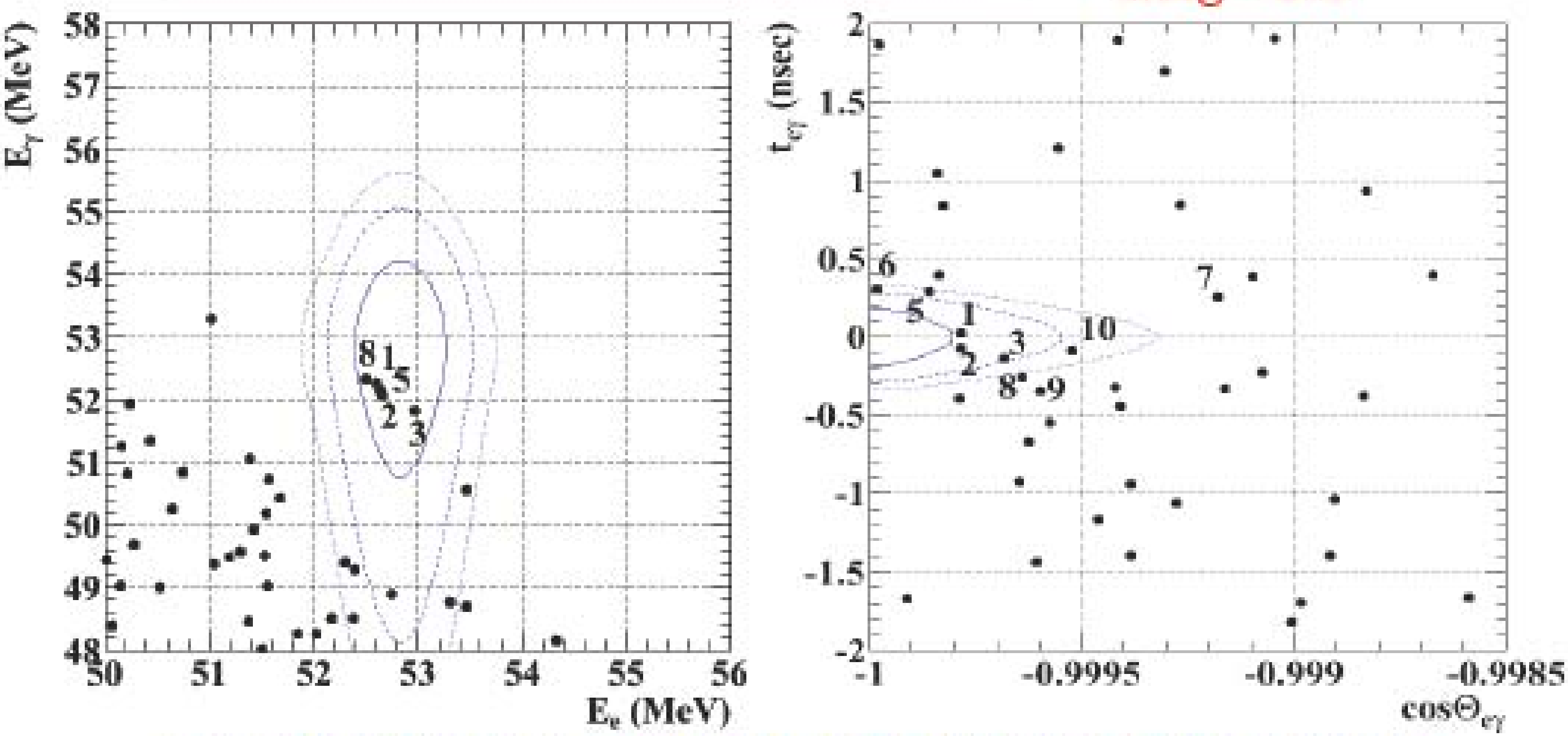
SHOWN AT ICHEP 2010

Event distribution after unblinding

BR < 1.5×10^{-11} @90%CL

6.1×10^{-12} expected

Nsig = 3.0

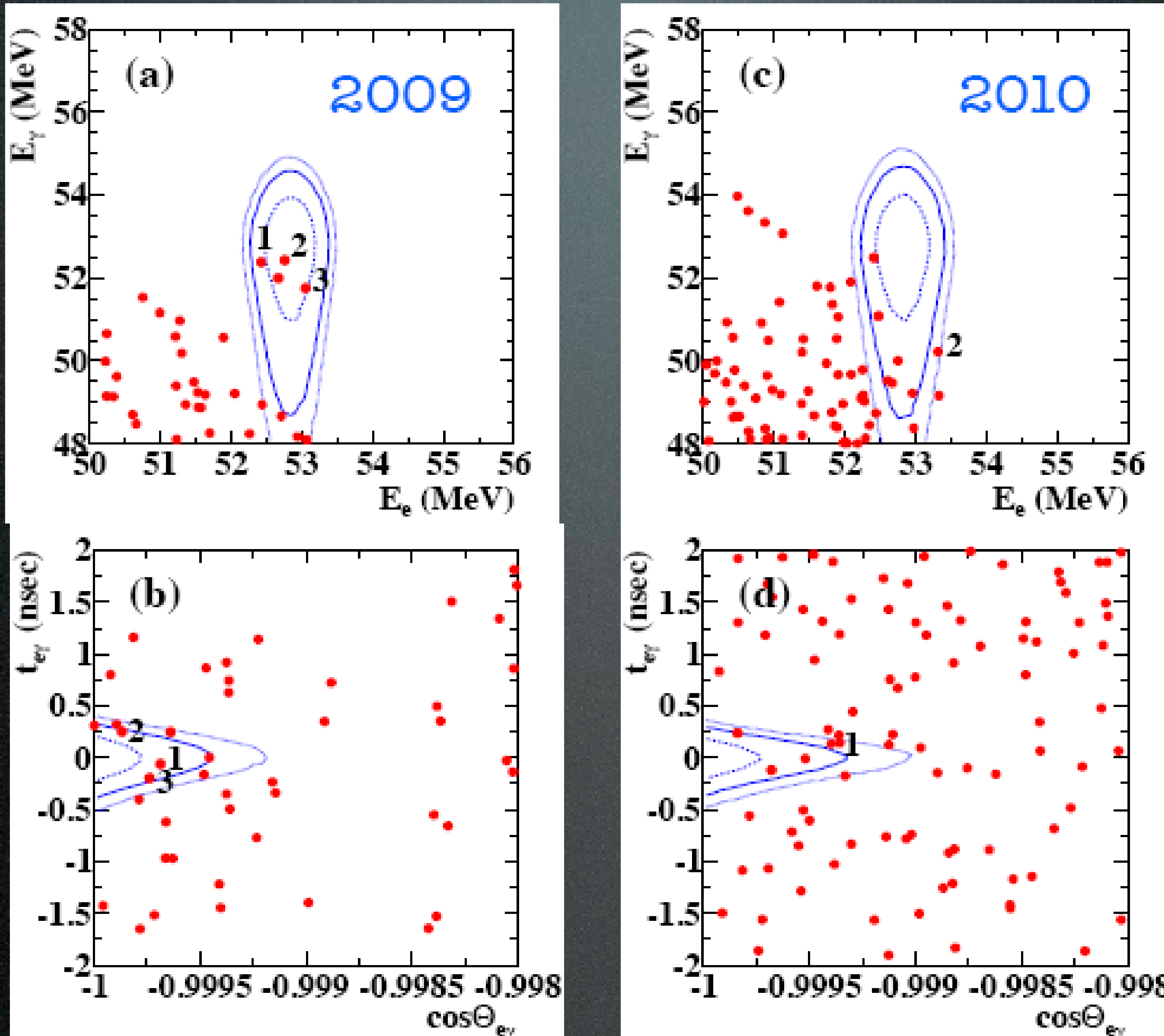


preliminary result of MEG 2009 data

Blue lines are 1(39.3 % included inside the region w.r.t. analysis window), 1.64(74.2%) and 2(86.5%) sigma regions.

For each plot, cut on other variables for roughly 90% window is applied.

Numbers in figures are ranking by $L_{sig}/(L_{RMD}+L_{BG})$. Same numbered dots in the right and the left figure are an identical event.


(a)
2009
(c)
2010
E_γ (MeV)
E_e (MeV)
(b)
(d)
$t_{e\gamma}$ (nsec)
$\cos\Theta_{e\gamma}$

MEG summary

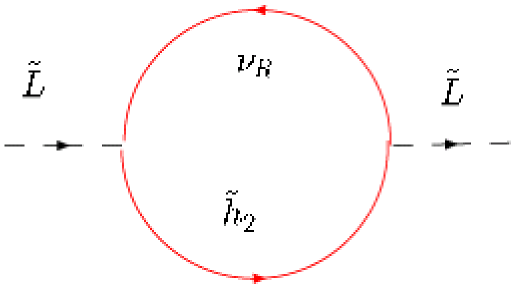
- 2009+2010 data consistent w/ no signal
- New physics is now constrained by 5× tighter upper limit:
  $BR < 2.4\times10^{-12}$ @90% C.L.
  (Preprint will be posted at arXiv today)
- MEG is accumulating more data this and next year to reach $O(10^{-13})$ sensitivity;
  So stay tuned!
- Detector improvements/upgrades

T. MORI AT THE EPS-HEP 2011

<u>SUSY SEESAW</u>: *Flavor universal SUSY breaking and yet* ***large lepton flavor violation***

Borzumati, A. M. 1986 (after discussions with W. Marciano and A. Sanda)

$$L = f_l \, \bar{e}_R L h_1 + f_\nu \, \bar{\nu}_R L h_2 + M \, \nu_R \nu_R$$



$$\left(m^2_{\tilde{L}}\right)_{ij} \sim \frac{1}{8\pi^2}\left(3m_0^2 + A_0^2\right)\left(f_\nu^\dagger f_\nu\right)_{ij} \log\frac{M}{M_G}$$

Non-diagonality of the slepton mass matrix in the basis of diagonal lepton mass matrix depends on the **unitary matrix U which diagonalizes ($f_\nu^+ f_\nu$)**

The hadron-lepton mixing angles puzzle

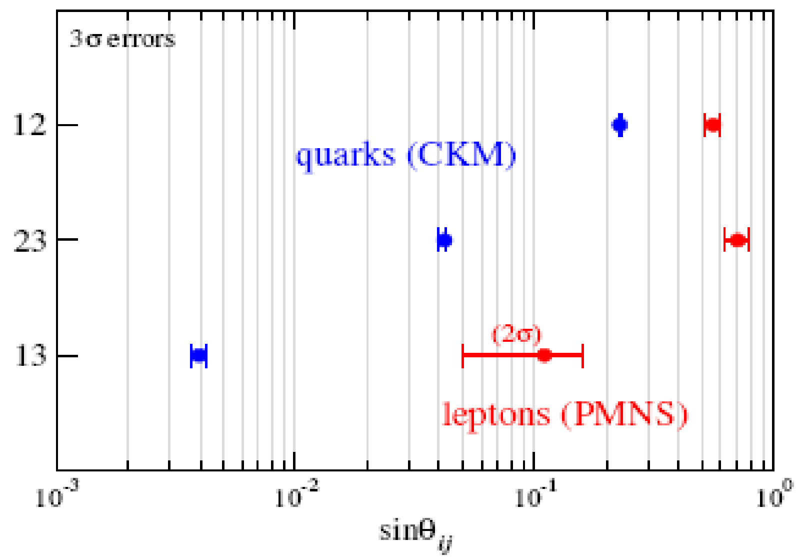
CKM versus PMNS

Quark mixing:

$$U_{CKM} = \begin{pmatrix} 1 & \epsilon & \epsilon \\ \epsilon & 1 & \epsilon \\ \epsilon & \epsilon & 1 \end{pmatrix}$$

Lepton mixing:

$$U_{PMNS} = \frac{1}{\sqrt{3}} \begin{pmatrix} \mathcal{O}(1) & \mathcal{O}(1) & \epsilon \\ \mathcal{O}(1) & \mathcal{O}(1) & \mathcal{O}(1) \\ \mathcal{O}(1) & \mathcal{O}(1) & \mathcal{O}(1) \end{pmatrix}$$



How Large LFV in SUSY SEESAW?

- 1) Size of the **Dirac neutrino couplings f_ν**

- 2) Size of the **diagonalizing matrix U**

In **MSSM seesaw** or in **SUSY SU(5)** (Moroi): not possible to correlate the neutrino Yukawa couplings to know Yukawas;

In **SUSY SO(10)** (A.M., Vempati, Vives) at least one neutrino Dirac Yukawa coupling has to be of the **order of the top Yukawa coupling** → one large of O(1) f_ν

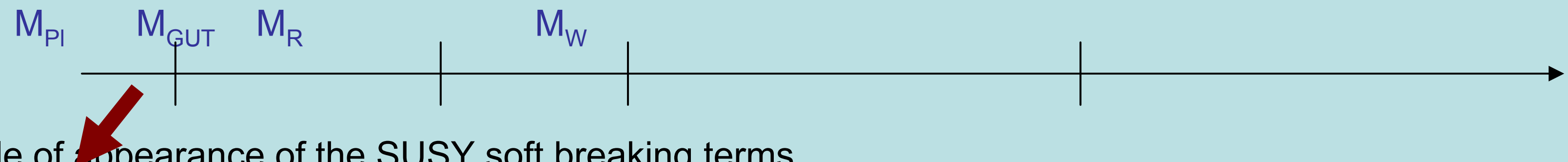
U → two "extreme" cases:

a) **U with "small" entries** → ***U = CKM***;
b) **U with "large" entries** with the exception of the 13 entry
→ ***U = PMNS*** matrix responsible for the diagonalization of the neutrino mass matrix

THE STRONG ENHANCEMENT OF LFV IN SUSY SEESAW MODELS CAN OCCUR

EVEN IF THE MECHANISM RESPONSIBLE FOR SUSY BREAKING IS ABSOLUTELY FLAVOR BLIND

LFV in SUSYGUTs with SEESAW



Scale of appearance of the SUSY soft breaking terms
resulting from the spontaneous breaking of supergravity

Low-energy SUSY has "memory" of all the multi-step RG occurring from such superlarge scale down to M_W

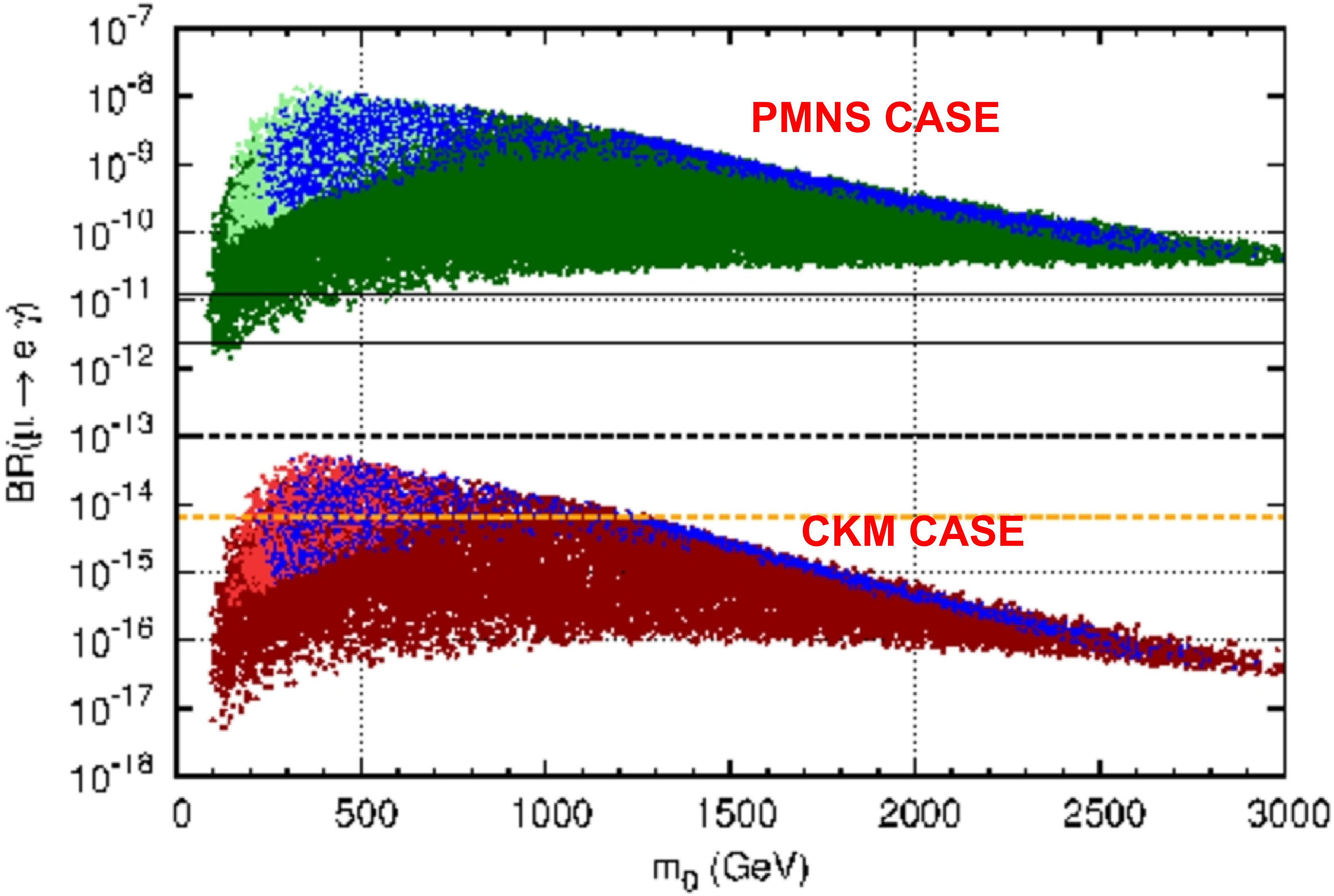
potentially large LFV

Barbieri, Hall; Barbieri, Hall, Strumia; Hisano, Nomura, Yanagida; Hisano, Moroi, Tobe Yamaguchi; Moroi;A.M.,, Vempati, Vives; Carvalho, Ellis, Gomez, Lola; Calibbi, Faccia, A.M, Vempati

LFV in MSSMseesaw: μ $e\gamma$ Borzumati, A.M.

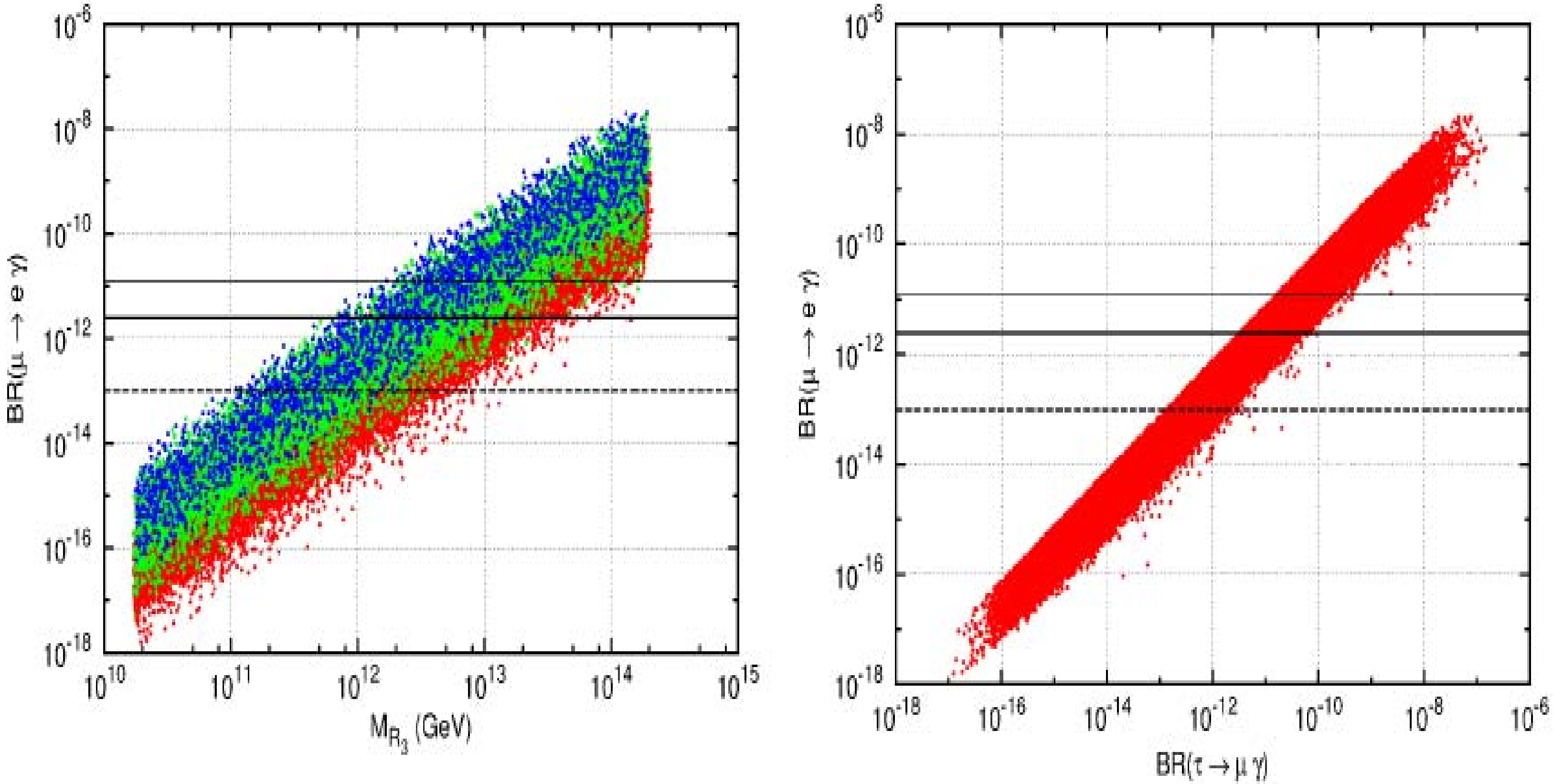
τ $\mu\gamma$ Blazek, King;

General analysis: Casas Ibarra; Lavignac, Masina,Savoy; Hisano, Moroi, Tobe, Yamaguchi; Ellis, Hisano, Raidal, Shimizu; Fukuyama, Kikuchi, Okada; Petcov, Rodejohann, Shindou, Takanishi; Arganda, Herrero; Deppish, Pas, Redelbach, Rueckl; Petcov, Shindou



Calibbi, Hodgkinson, Jones, A.M. and Vives work in progress

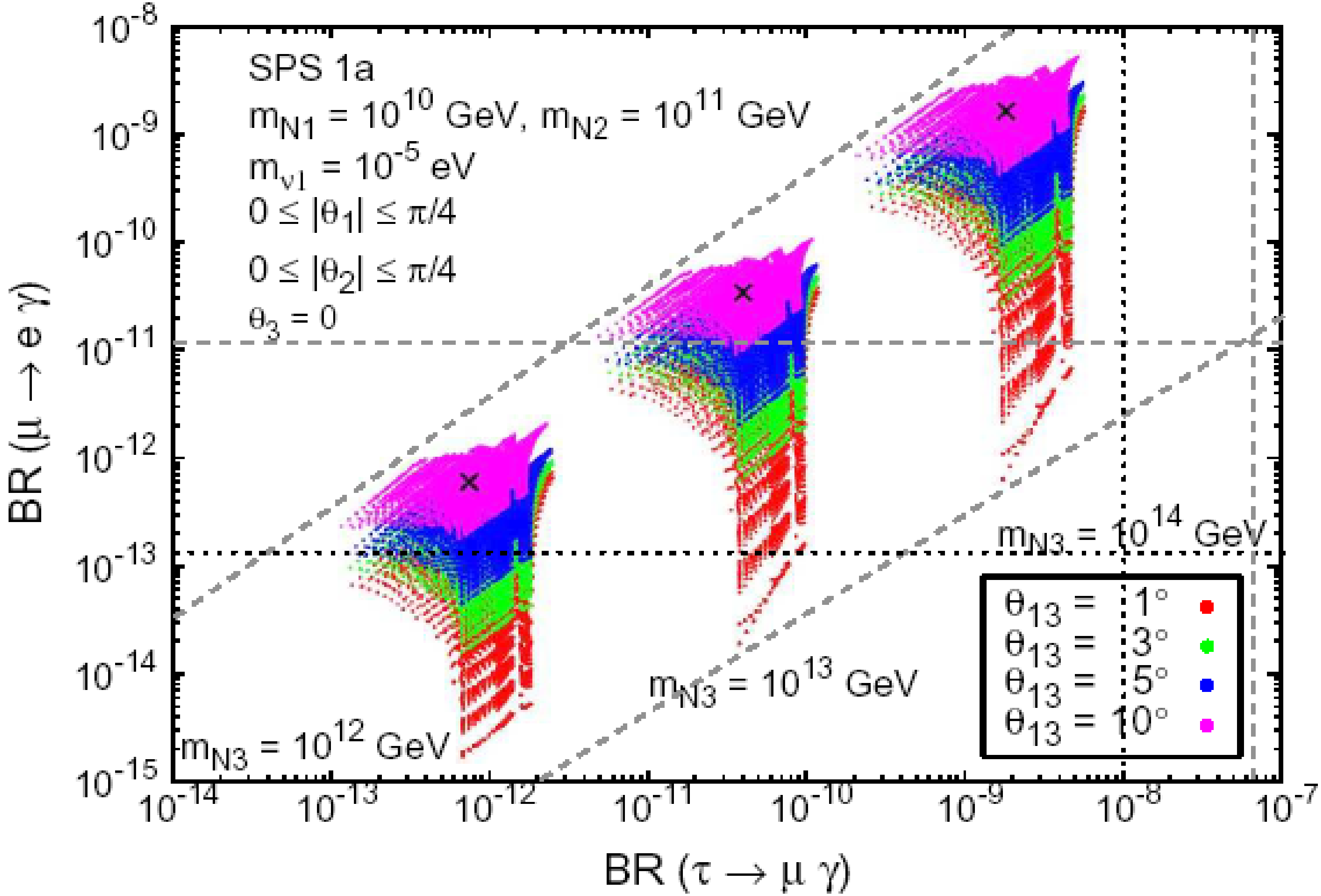
Bounds on the RH neutrino mass scale from LFV in SUSY See-Saw



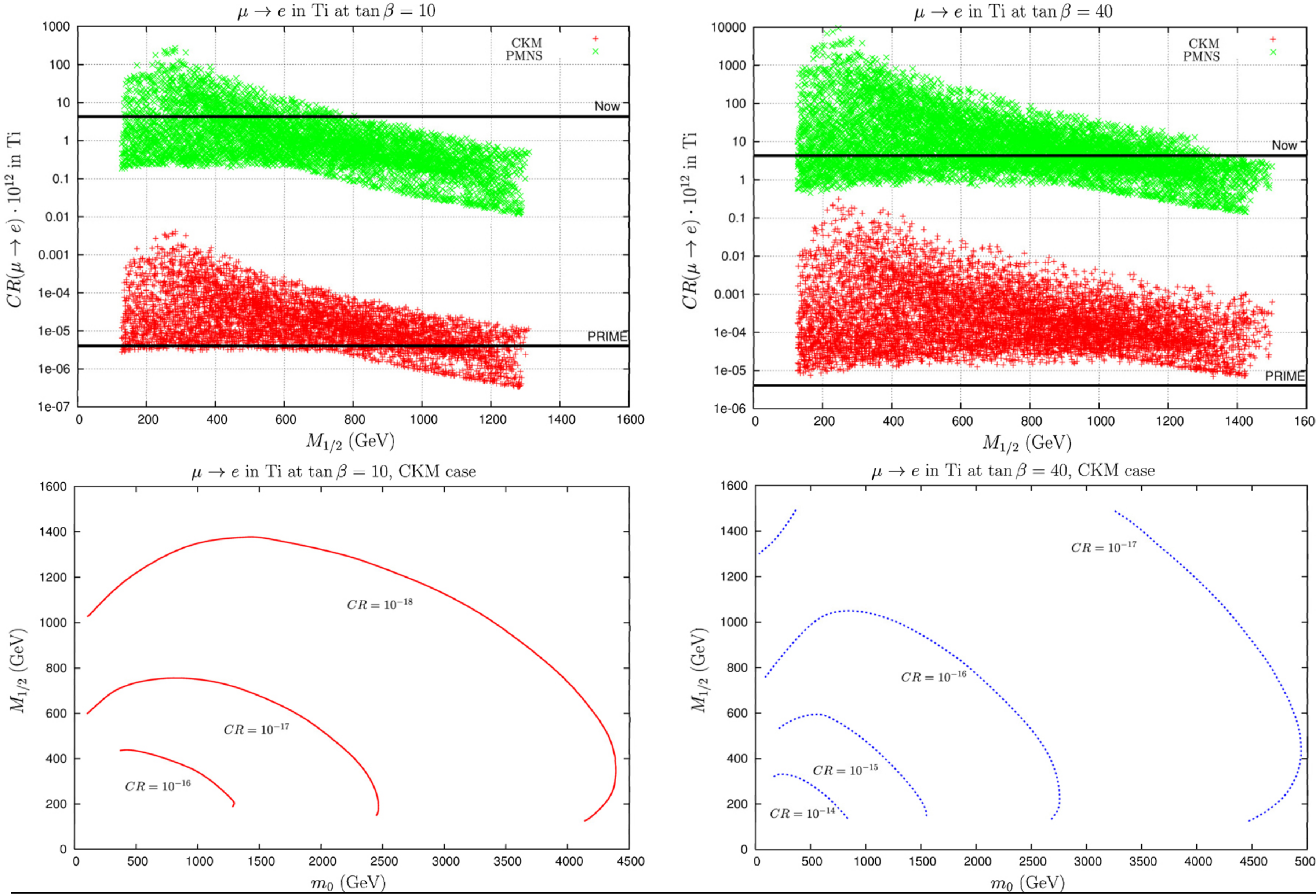
Calibbi, Hodgkinson, Jones, A.M. and Vives work in progress

FIG. 8: $R = 1$ scenario with hierarchical M_R. Left panel: BR($\mu \to e\gamma$) vs. M_{R_3} (green points give $\delta a_\mu > 10^{-9}$, blue points $\delta a_\mu > 2 \times 10^{-9}$); right panel: BR($\mu \to e\gamma$) vs. BR($\tau \to \mu\gamma$).

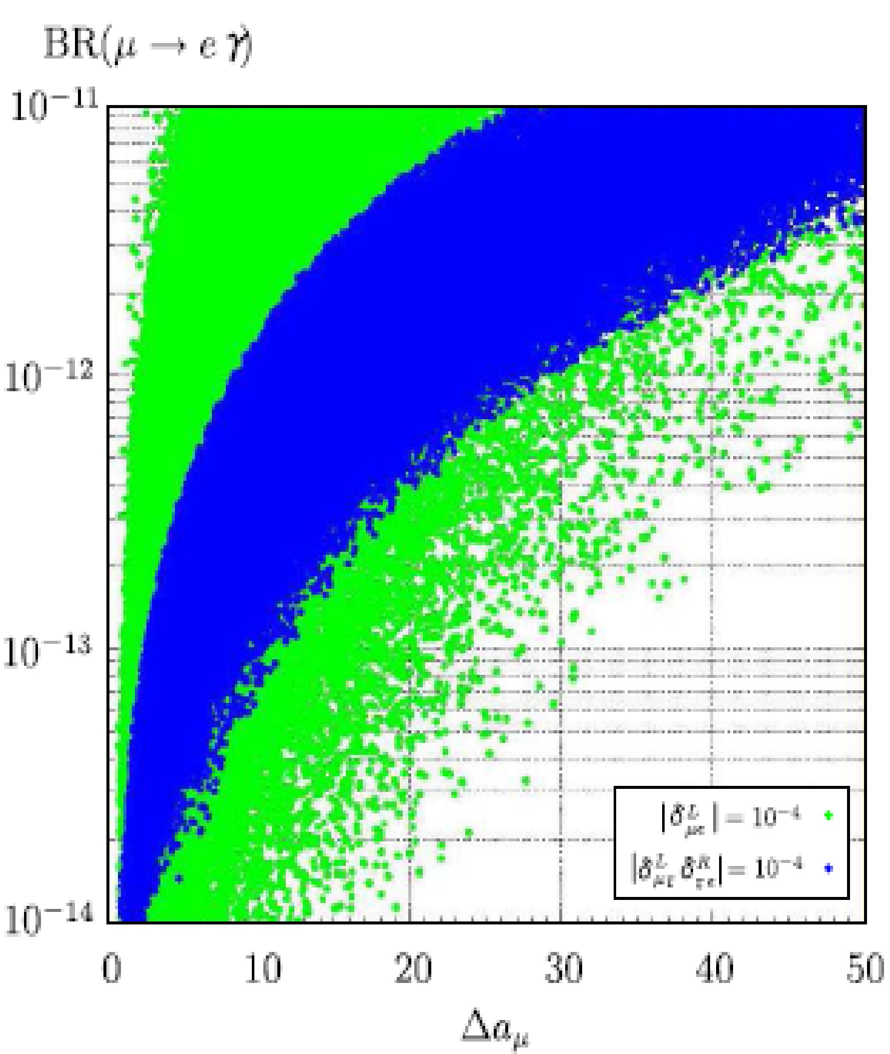
Antusch, Arganda, Herrero, Teixeira



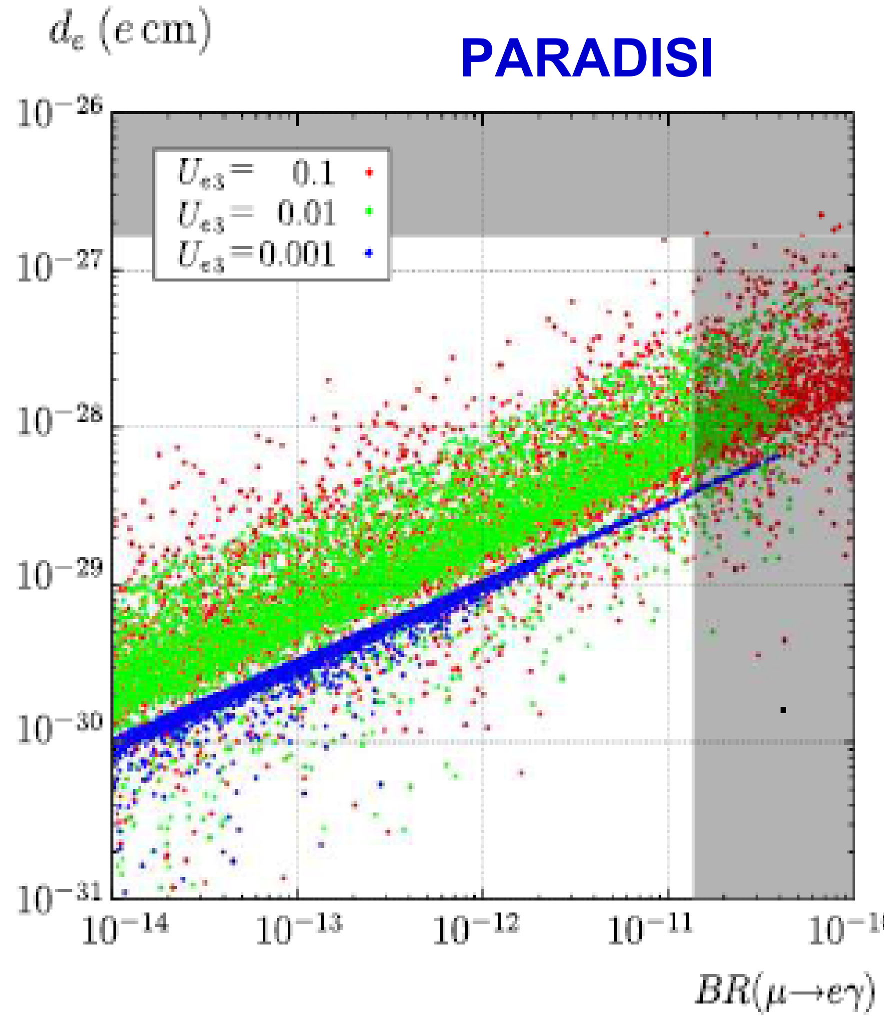
$\mu \to e$ in Ti and **PRISM/PRIME** conversion experiment



LFV, g – 2, EDM: a promising correlation in SUSY SEESAW



PARADISI



DEVIATION from μ - e UNIVERSALITY

A.M., Paradisi, Petronzio

- Denoting by $\Delta r_{NP}^{e-\mu}$ the deviation from $\mu - e$ universality in $R_{K,\pi}$ due to new physics, i.e.:

$$R_{K,\pi} = R_{K,\pi}^{SM}\left(1 + \Delta r_{K,\pi\,NP}^{e-\mu}\right),$$

- we get at the 2σ level:

$$-0.063 \leq \Delta r_{K\,NP}^{e-\mu} \leq 0.017 \quad \text{NA48/2}$$

$$-0.0107 \leq \Delta r_{\pi\,NP}^{e-\mu} \leq 0.0022 \quad \text{PDG}$$

Presently: error on R_K down to the **1% level** (KLOE (09) and NA48 (07 data);using 40% of the data collected in 08, NA62 is now decreasing the uncertainty at the **0.7% level**
Prospects: Summer conf. we'll have the result concerning the 40% data analysis by NA62 and when the analysis of the whole sample of data is accomplished **the stat. uncertainty will be < 0.3%**

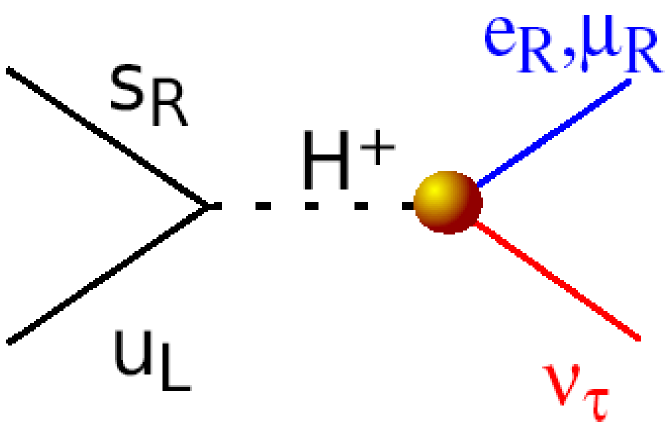
HIGGS-MEDIATED LFV COUPLINGS

- When non-holomorphic terms are generated by loop effects (HRS corrections)
- And a source of LFV among the sleptons is present
- → Higgs-mediated (radiatively induced) H-lepton-lepton LFV couplings arise

Babu, Kolda; Sher; Kitano,Koike,Komine, Okada; Dedes, Ellis, Raidal; Brignole,Rossi; Arganda,Curiel,Herrero,Temes; Paradisi; Brignole,Rossi

H mediated LFV SUSY contributions to R_K

$$R_K^{LFV} = \frac{\sum_i K \to e\nu_i}{\sum_i K \to \mu\nu_i} \simeq \frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)} \ , \quad i = e, \mu, \tau$$



$$eH^\pm \nu_\tau \to \frac{g_2}{\sqrt{2}} \frac{m_\tau}{M_W} \Delta_R^{31} \tan^2\beta$$

$$\Delta_R^{31} \sim \frac{\alpha_2}{4\pi} \delta_{RR}^{31}$$

$$\Delta_R^{31} \sim 5 \cdot 10^{-4} \quad t_\beta = 40 \quad M_{H^\pm} = 500\mathrm{GeV}$$

$$\Downarrow$$

$$\Delta r_{K\,SUSY}^{e-\mu} \simeq \left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right) |\Delta_R^{31}|^2 \tan^6\beta \approx 10^{-2}$$

Extension to B $\longrightarrow$ $l\nu$ deviation from universality
Isidori, Paradisi

SUSY GUTs

- UV COMPLETION OF THE SM TO STABILIZE THE ELW. SCALE:

LOW-ENERGY SUSY

TREND OF UNIFICATION OF THE SM GAUGE COUPLINGS AT HIGH SCALE:

GUTs

Large ν mixing $\leftrightarrow$ large b-s transitions in SUSY GUTs

In SU(5) $d_R \longleftrightarrow l_L$ connection in the 5-plet

Large $(\Delta^l_{23})_{LL}$ induced by large f_ν of $O(f_{top})$

is accompanied by large $(\Delta^d_{23})_{RR}$

Exercise 10

In SU(5) assume large f_ν (Moroi)

In SO(10) f_ν large because of an underlying Pati-Salam symmetry

(**Darwin Chang**, A.M., Murayama)

See also: Akama, Kiyo, Komine, Moroi; Hisano, Moroi, Tobe, Yamaguchi, Yanagida; Hisano, Nomura; Kitano,Koike, Komine, Okada

FCNC HADRON-LEPTON CONNECTION IN SUSYGUT

If

soft **SUSY breaking terms** arise
at a scale > M_{GUT}, they have to **respect the underlying quark-lepton GU symmetry**

constraints on δ^{quark} **from LFV** and
constraints on δ^{lepton} **from hadronic FCNC**

Ciuchini, A.M., Silvestrini, Vempati, Vives PRL 2004
general analysis **Ciuchini, A.M., Paradisi, Silvestrini, Vempati, Vives** NPB 2007
For previous works: Baek, Goto, Okada, Okumura PRD 2001;
Hisano, Shimizu, PLB 2003;
Cheung, Kang, Kim, Lee PLB 2007
Borzumati, Mishima, Yamashita hep-ph 0705:2664
For recent works: Goto, Okada, Shindou, Tanaka PRD 2008;
Ko, J-h. Park, Yamaguchi arXiv:0809:2784

GUT -RELATED SUSY SOFT BREAKING TERMS

$$m_Q^2 = m_{\tilde{e}^c}^2 = m_{\tilde{u}^c}^2 = m_{\mathbf{10}}^2$$

$$m_{\tilde{d}^c}^2 = m_L^2 = m_{\bar{\mathbf{5}}}^2$$

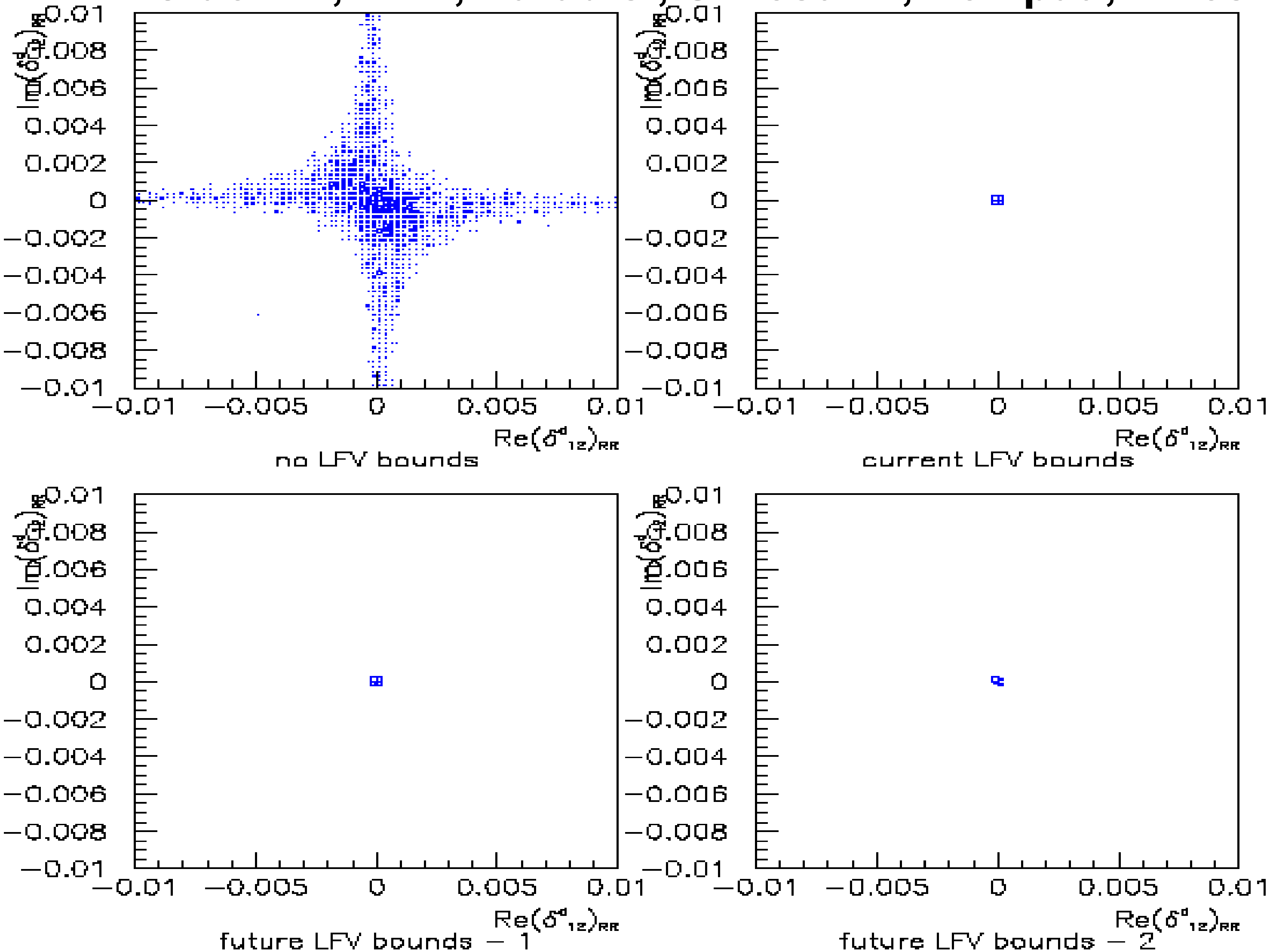
$$A_{ij}^e = A_{ji}^d \, .$$

SU(5) RELATIONS

	Relations at weak-scale	Relationss at $M_{\rm GUT}$
(1)	$(\delta^u_{ij})_{\rm RR} \approx (m^2_{e^c}/m^2_{u^c})\ (\delta^l_{ij})_{\rm RR}$	$m^2_{{u^c}_0} = m^2_{{e^c}_0}$
(2)	$(\delta^q_{ij})_{\rm LL} \approx (m^2_{e^c}/m^2_{Q})\ (\delta^l_{ij})_{\rm RR}$	$m^2_{Q_0} = m^2_{{e^c}_0}$
(3)	$(\delta^d_{ij})_{\rm RR} \approx (m^2_{L}/m^2_{d^c})\ (\delta^l_{ij})_{\rm LL}$	$m^2_{{d^c}_0} = m^2_{L_0}$
(4)	$(\delta^d_{ij})_{\rm LR} \approx (m^2_{L_{avg}}/m^2_{Q_{avg}})\ (m_b/m_\tau)\ (\delta^l_{ij})^\star_{\rm LR}$	$A^e_{{ij}_0} = A^d_{{ji}_0}$

Bounds on the hadronic $(\delta_{12})_{RR}$ as modified by the inclusion of the LFV correlated bound

Ciuchini, A.M., Paradisi, Silvestrini, Vempati, Vives



A FUTURE FOR THE HIGH INTENSITY AND ASTROPARTICLE ROADS IN OUR SEARCH BEYOND THE SM?

- The traditional **competition** between direct and indirect (FCNC, CPV) searches to establish who is going **to see the new physics first** is no longer the priority, rather

- **COMPLEMENTARITY** between direct and indirect searches for New Physics is the key-word

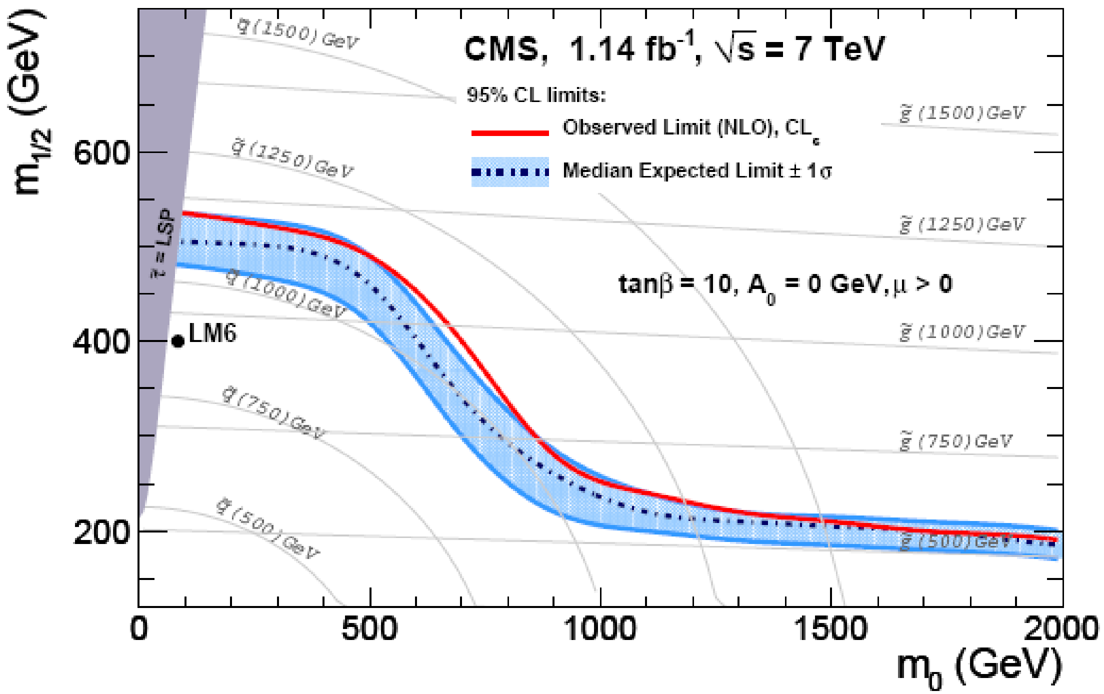
- Twofold meaning of such complementarity:

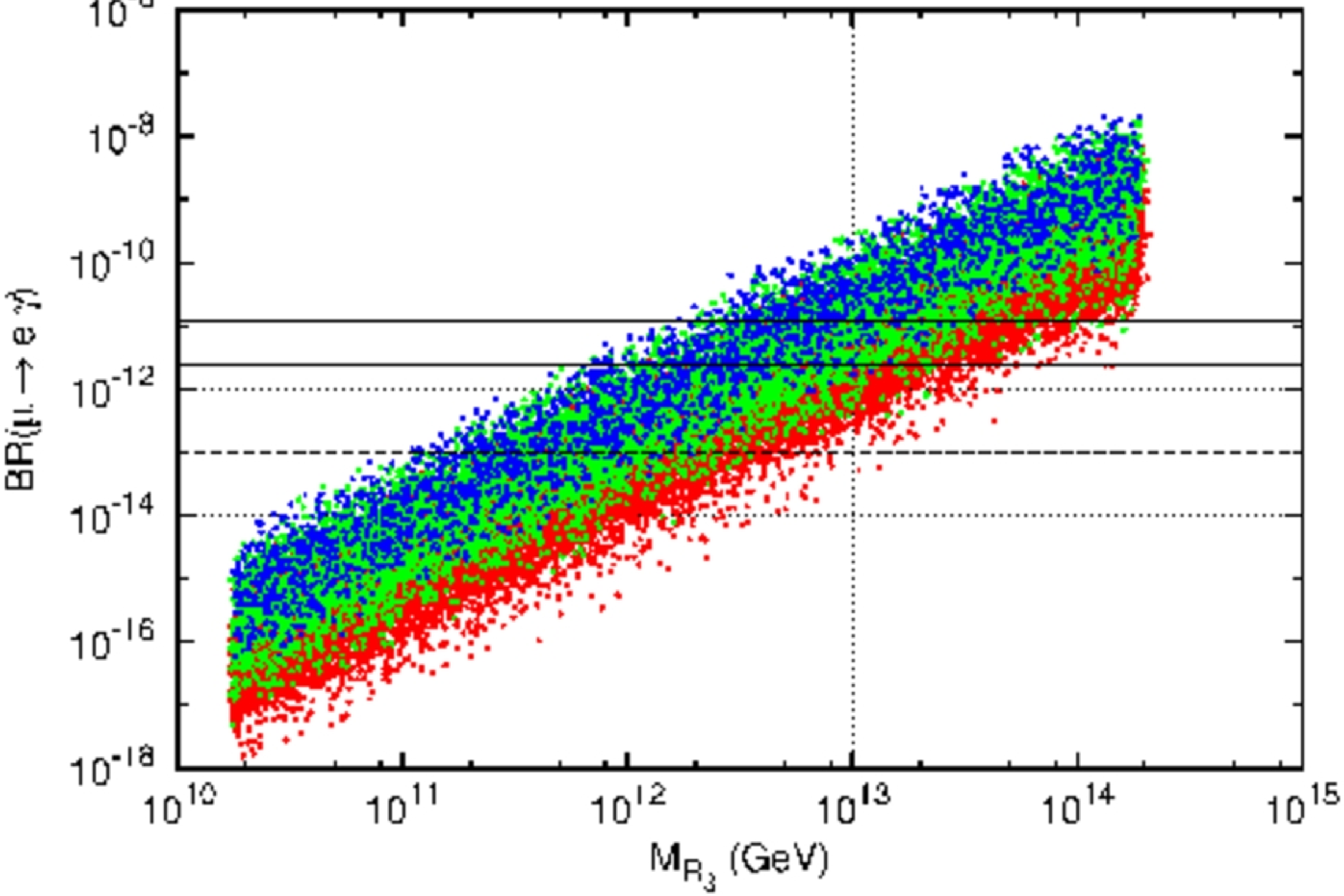
i) **synergy in "reconstructing" the "fundamental theory"** staying behind the signatures of NP;

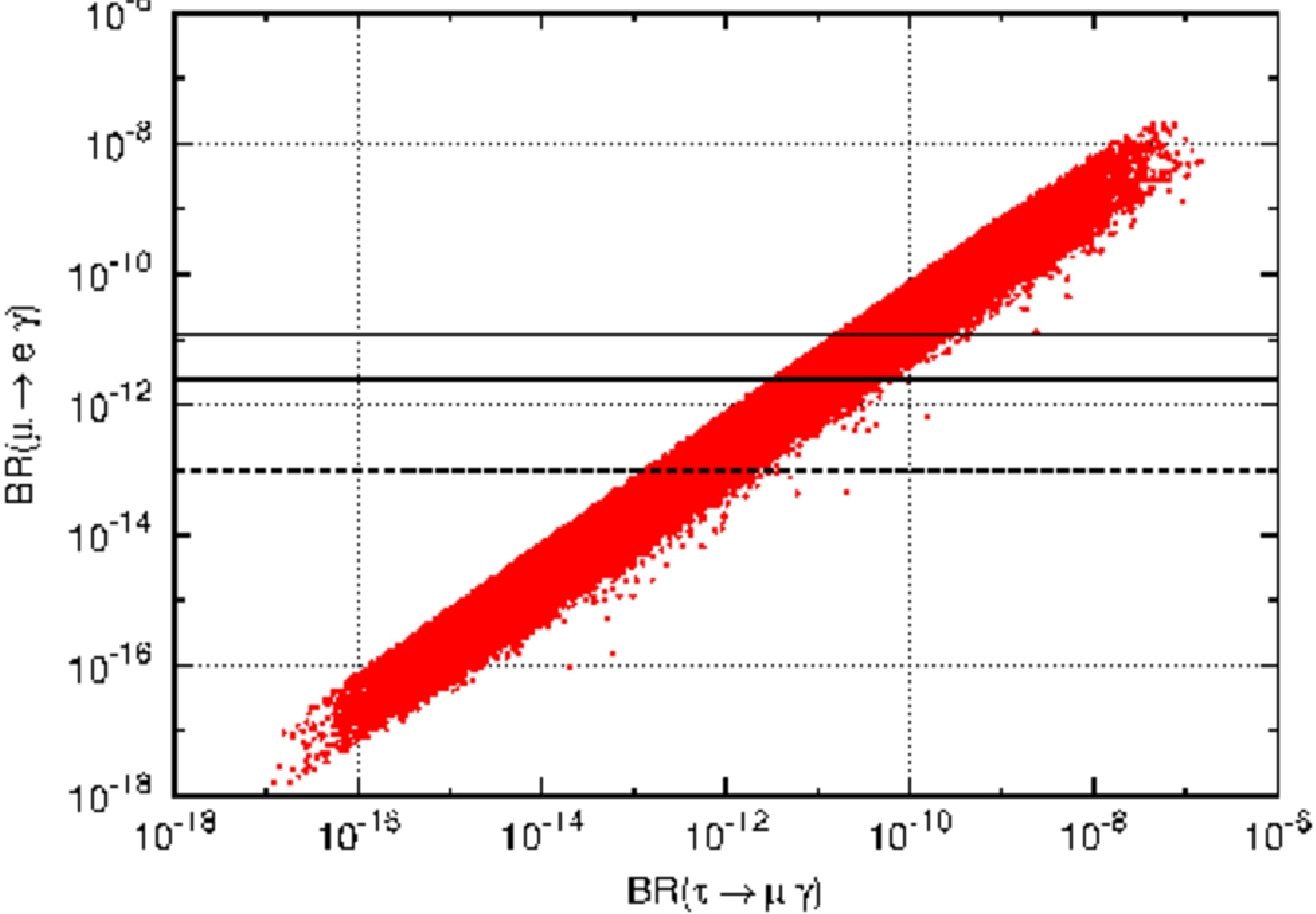
ii) **coverage of complementary areas of the NP parameter space** (ex.: multi-TeV SUSY physics)

Drawing by G. Martinelli

BACK-UP SLIDES


CMS, 1.14 fb^{-1}, $\sqrt{s}$ = 7 TeV
95% CL limits:
Observed Limit (NLO), CL_s
Median Expected Limit ± 1σ
tanβ = 10, A_0 = 0 GeV, μ > 0
LM6
$\tilde{\tau}$ = LSP
$\tilde{q}$ (1500) GeV
$\tilde{q}$ (1250) GeV
$\tilde{q}$ (1000) GeV
$\tilde{q}$ (750) GeV
$\tilde{q}$ (500) GeV
$\tilde{g}$ (1500) GeV
$\tilde{g}$ (1250) GeV
$\tilde{g}$ (1000) GeV
$\tilde{g}$ (750) GeV
$\tilde{g}$ (500) GeV
$m_{1/2}$ (GeV)
m_0 (GeV)
0
500
1000
1500
2000
200
400
600

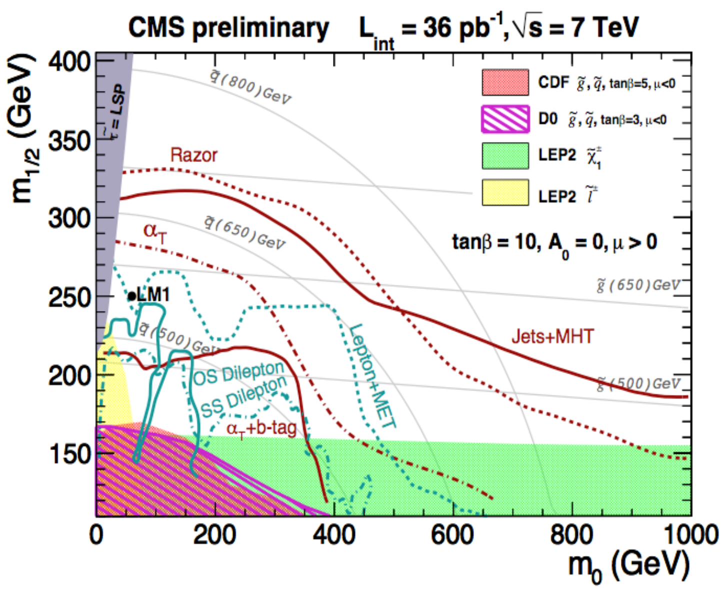

BR(μ → e γ)
10-6
10-8
10-10
10-12
10-14
10-16
10-18
10^10
10^11
10^12
10^13
10^14
10^15
M_R3 (GeV)

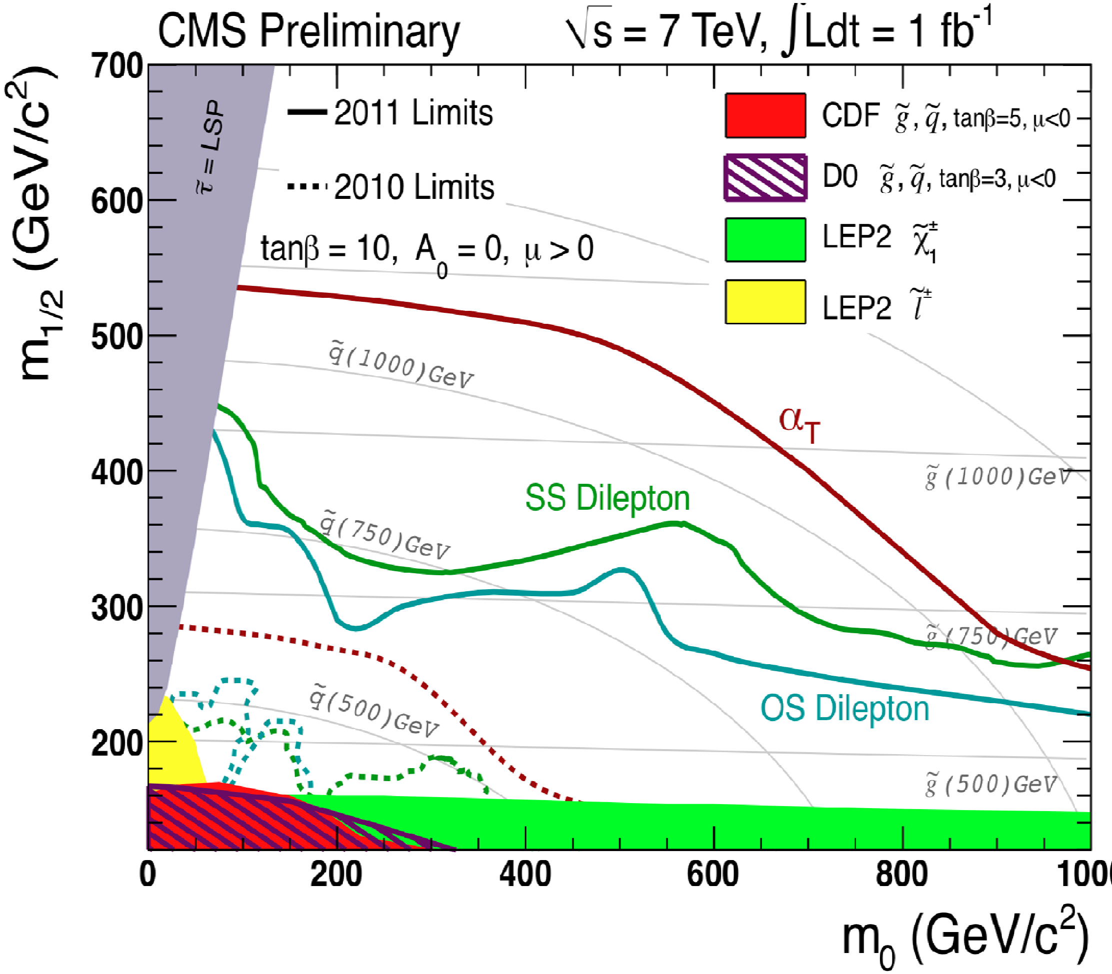


10^-6
10^-8
10^-10
10^-12
10^-14
10^-16
10^-18
BR(μ → e γ)
10^-18
10^-16
10^-14
10^-12
10^-10
10^-8
10^-6
BR(τ → μ γ)

Progress on SUSY

Results of the first three SUSY analyses completed on 2011 data (α_T , Same Sign and Opposite Sign dileptons).



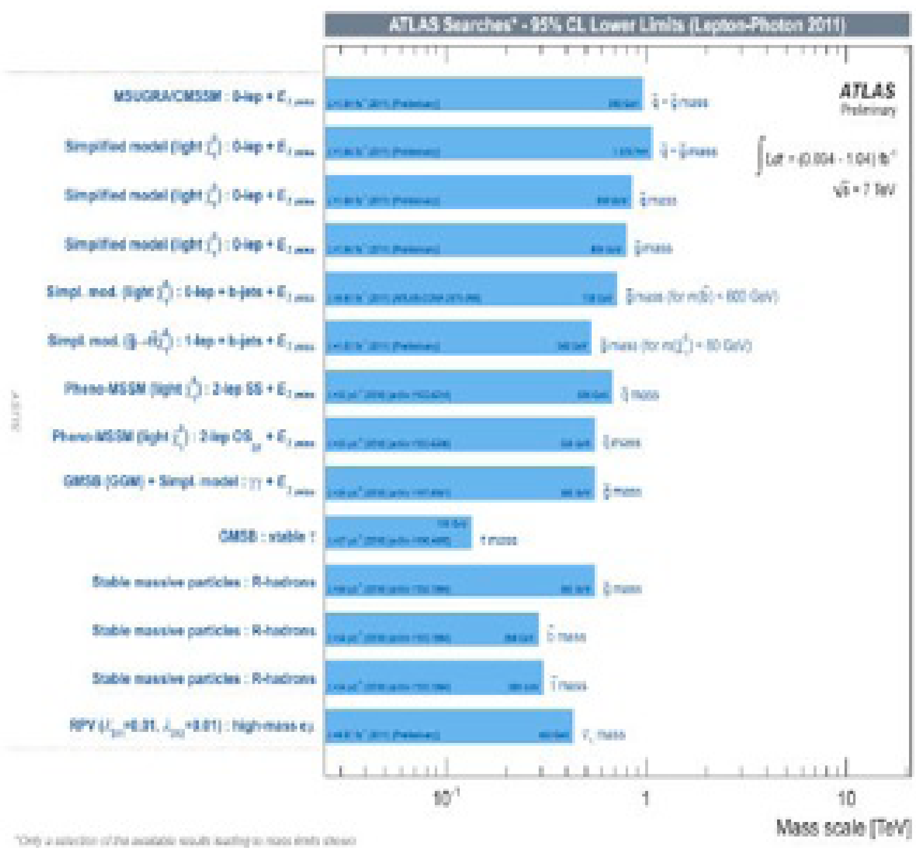


Within the constrained SSM models we are crossing the border of excluding gluinos and squarks up to 1TeV and beyond. The air is getting thin for constrained SUSY. More conclusive results after summer.

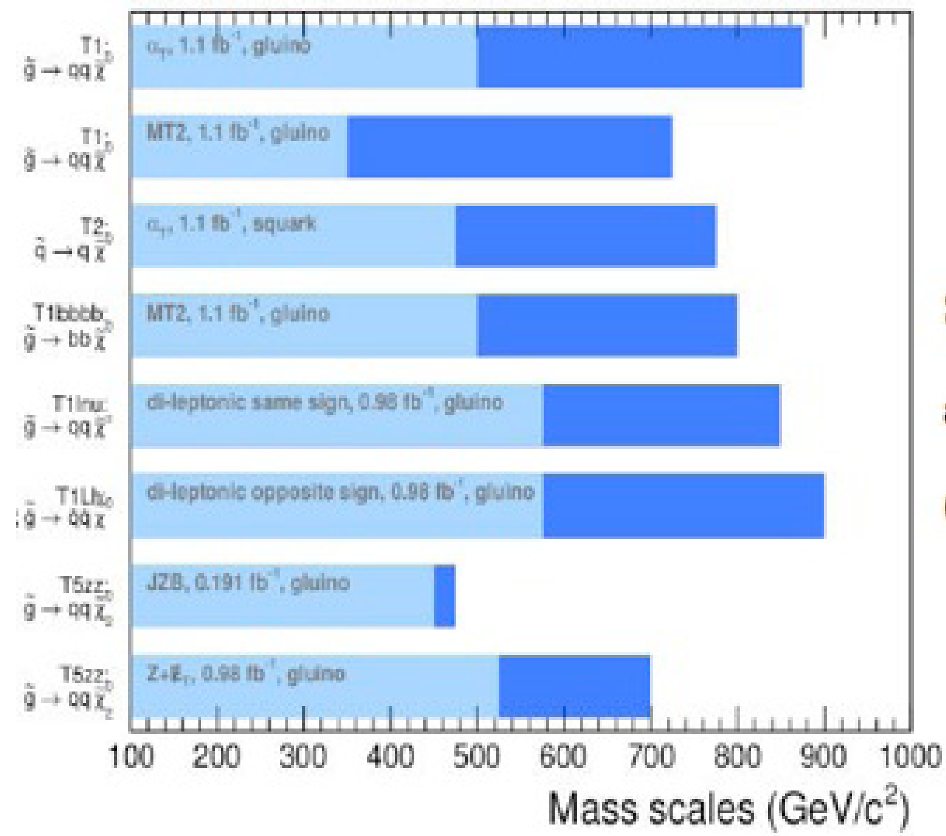
No Obvious Signs of New Physics YET

Cavanaugh, Hewett, Kraml, Polesello, WGII on MET Signatures, Implications of LHC Physics for TeV NP, Cern, 2/9/11

ATLAS Search Summary



CMS Search Summary



- 1^{st} 6 months of a 20 year program!
- NP could be at ~2 TeV or more complicated than the simplest scenarios