

**Opera Coll. Meeting, Miniworkshop on Neutrino Physics,
Bologna, September 8, 2011**

**NEW PHYSICS
from
NEUTRINO PHYSICS**

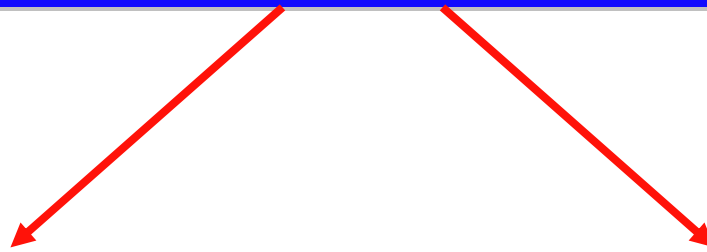
**Antonio Masiero
Univ. of Padova and INFN, Padova**

PROLOGUE

... no firm indication that some NEW PHYSICS sets in at the electroweak scale (i.e., with new particles and phenomena at the TeV mass scale) and

... yet, we are strongly convinced that TeV New Physics is present

WHY TO GO BEYOND THE SM



“OBSERVATIONAL” REASONS

•HIGH ENERGY PHYSICS

NO (but $A_{FB}^{Z \rightarrow bb}$

•FCNC, $CP \neq$

NO (but CPV in B_s , $\sin 2\beta$ tension...)

•HIGH PRECISION LOW-EN.

NO (but $(g-2)_\mu$...)

•NEUTRINO PHYSICS

YES $\nu \neq 0$, $\theta_\nu \neq 0$

•COSMO - PARTICLE PHYSICS

YES DM, ΔB_{cosm} , INFLAT., DE)

THEORETICAL REASONS

•INTRINSIC INCONSISTENCY OF SM AS QFT

NO (spont. broken gauge theory without anomalies)

•NO ANSWER TO QUESTIONS THAT “WE” CONSIDER “FUNDAMENTAL” QUESTIONS TO BE ANSWERED BY “FUNDAMENTAL” THEORY

YES (hierarchy, unification, flavor)

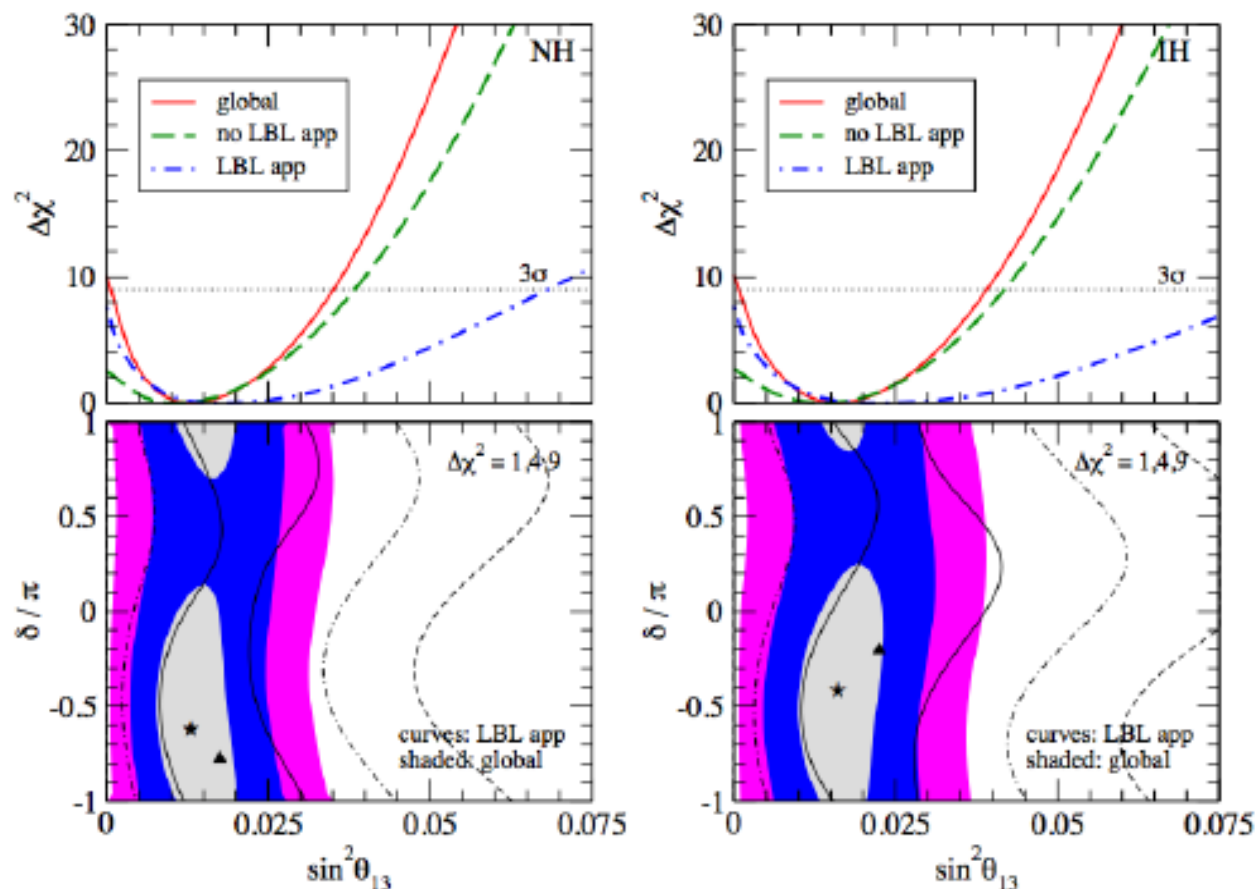
3-flavour oscillation parameters TS, Tortola, Valle, 1108.1376

From T. Schwetz's plenary talk at LP2011

	best fit $\pm 1\sigma$	3σ range	prec@ 3σ	
$\frac{\Delta m_{21}^2}{10^{-5}\text{eV}^2}$	$7.59^{+0.20}_{-0.18}$	7.09–8.19	7%	KamLAND
$\frac{\Delta m_{31}^2}{10^{-3}\text{eV}^2}$	$2.50^{+0.09}_{-0.16}$ $-(2.40^{+0.08}_{-0.09})$	2.14 – 2.76 $-(2.13 - 2.67)$	12%	MINOS
$\sin^2 \theta_{12}$	$0.312^{+0.017}_{-0.015}$	0.27–0.36	14%	SNO
$\sin^2 \theta_{23}$	$0.52^{+0.06}_{-0.07}$ 0.52 ± 0.06	0.39–0.64	24%	SuperK
$\sin^2 \theta_{13}$	$0.013^{+0.007}_{-0.005}$ $0.016^{+0.008}_{-0.006}$	0.001–0.035 0.001–0.039	120%	T2K + global data
δ	$(-0.61^{+0.75}_{-0.65}) \pi$ $(-0.41^{+0.65}_{-0.70}) \pi$	$0 - 2\pi$	—	

upper: normal hierarchy, lower: inverted hierarchy

Global data on θ_{13} TS, Tortola, Valle, 1108.1376



$$\sin^2 \theta_{13} = 0.013^{+0.007}_{-0.005}$$

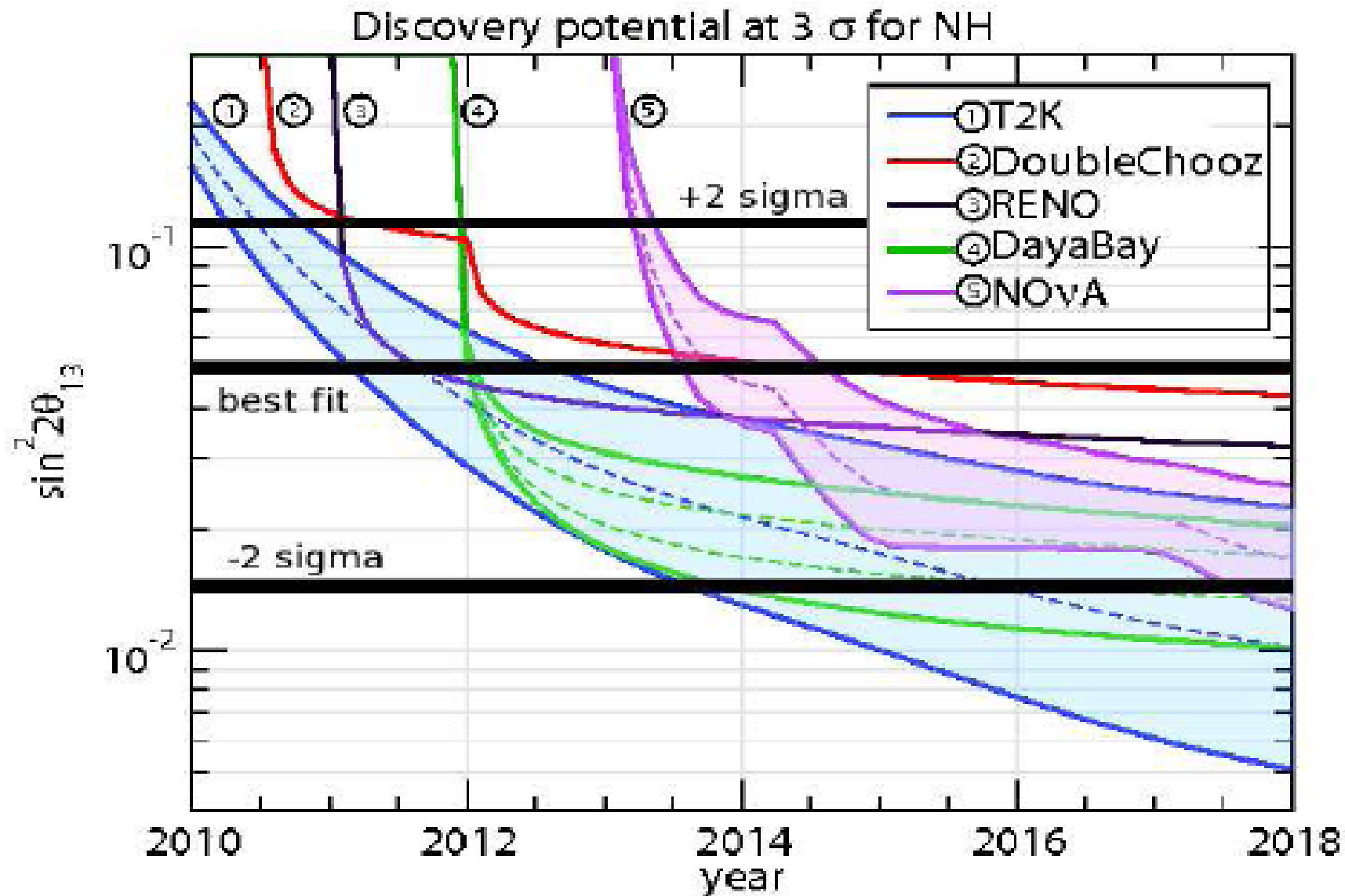
$$\sin^2 \theta_{13} = 0.016^{+0.008}_{-0.006}$$

$$\theta_{13} = 0 : \Delta\chi^2 = 10.1 (3.2\sigma)$$

similar results by Fogli et al, 1106.6028; Maltoni @ EPS11

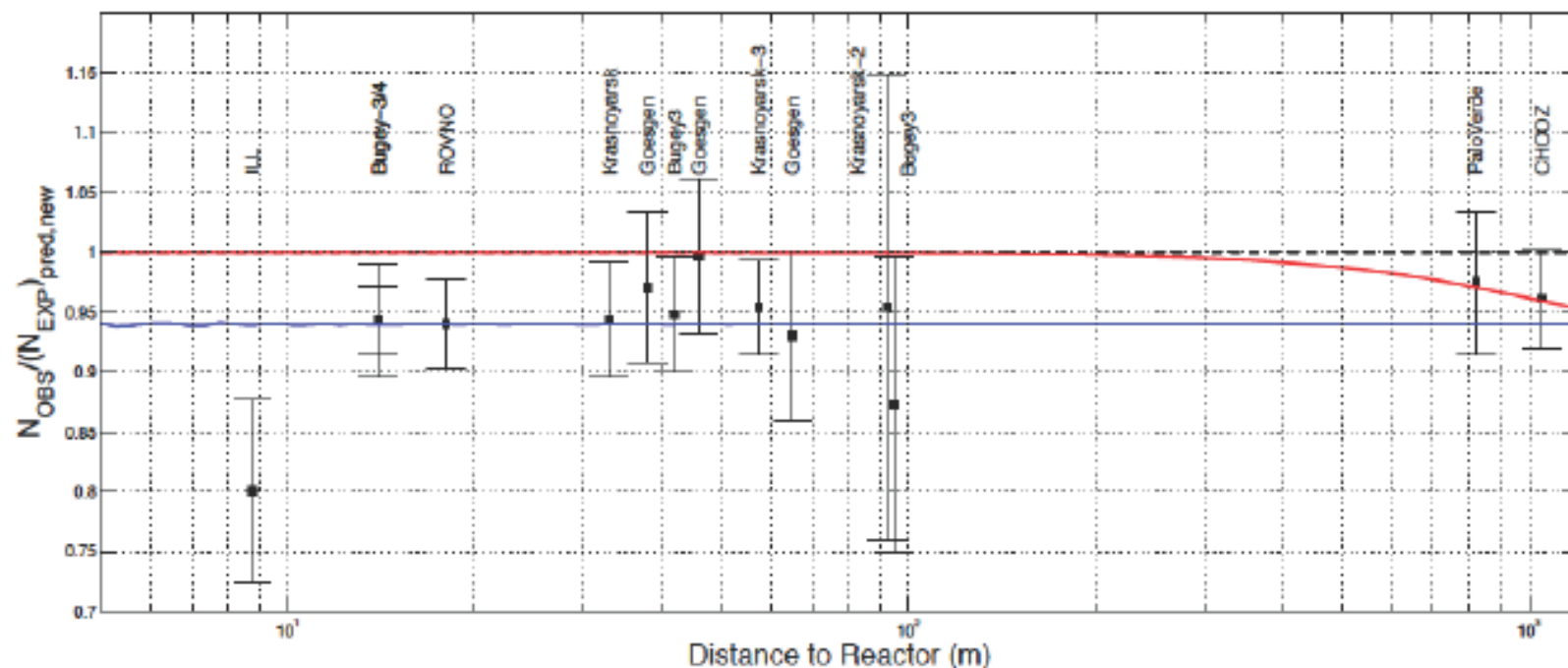
prospects for θ_{13}

MEZZETTO, SCHWETZ, 2010



New reactor fluxes and reactor data

Mention et al., 1101.2755



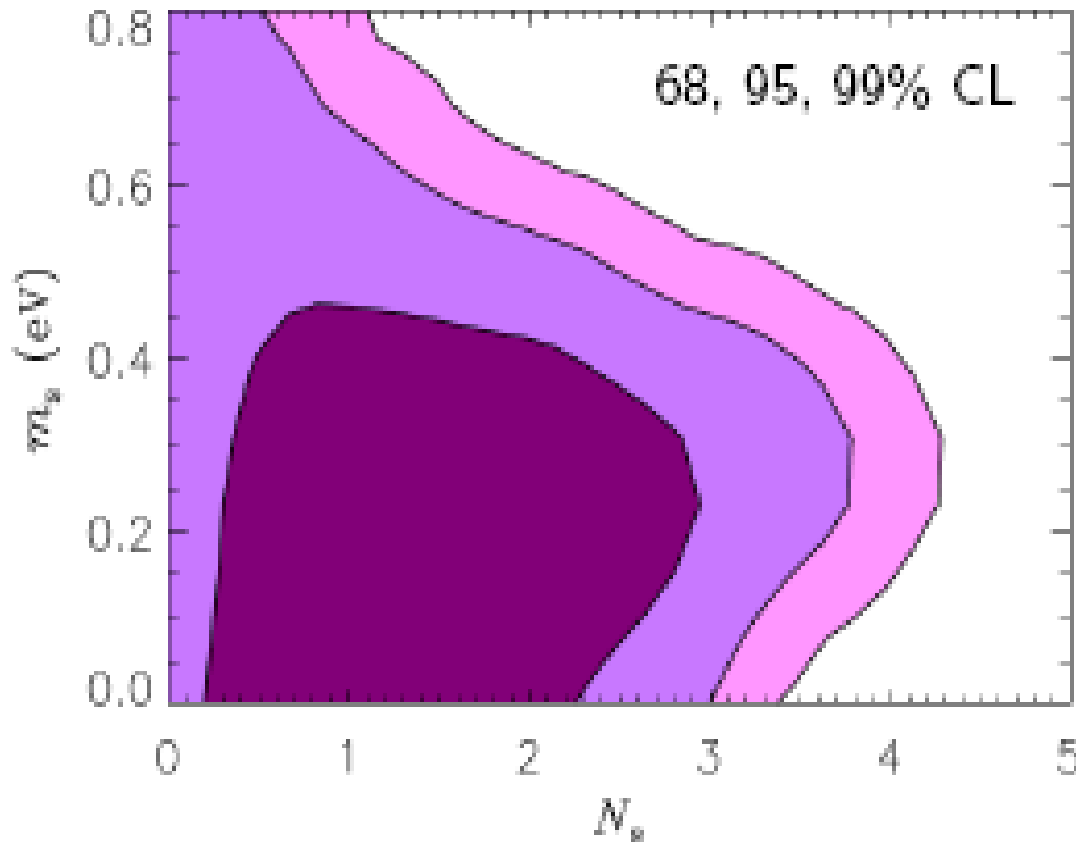
- ▶ non-zero θ_{13} can reduce flux at $L \gtrsim 1$ km but not shorter baselines
- ▶ sterile neutrino with $\Delta m^2 \sim 1 \text{ eV}^2$ can account for rate reduction at $L \gtrsim 10 - 100$ m
- ▶ systematic error or problem with new calculations?

More hints for eV neutrinos from $\nu_\mu \rightarrow \nu_e$ searches

- ▶ **LSND** $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$, $87.9 \pm 22.4 \pm 6.0$ excess events
 $P = (0.264 \pm 0.067 \pm 0.045)\% \sim 3.8\sigma$ away from zero
- ▶ **KARMEN** $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$, tight constraint on LSND region
 (slightly smaller L/E than LSND)
- ▶ **MiniBooNE** $\nu_\mu \rightarrow \nu_e$
 $E > 475$ MeV: no excess, $E < 475$ MeV: $\sim 3\sigma$ excess
- ▶ **MiniBooNE** $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$, excess consistent with LSND in 2ν framework
UPDATE: Z. Djurcic @ NuFact11 results for 8.58×10^{20} p.o.t. still
 consistent with LSND, but significance lower: no-osc disfavoured at
 91.1% CL, compared to 99.4% CL for previous 5.66×10^{20} p.o.t.

Limits on the number of sterile neutrinos from COSMOLOGY

Hamann et al., 1006.5276



CMB and info on large scale structures **favor some extra neutrinos**, but **they exclude two new sterile neutrinos in the eV range**

Also Big Bang

NUCLEOSYNTHESIS

$N_s < 1.2$ (95% CL)

Mangano and Serpico

1103.1261

The **hadron-lepton** mixing angles puzzle

3-flavour summary

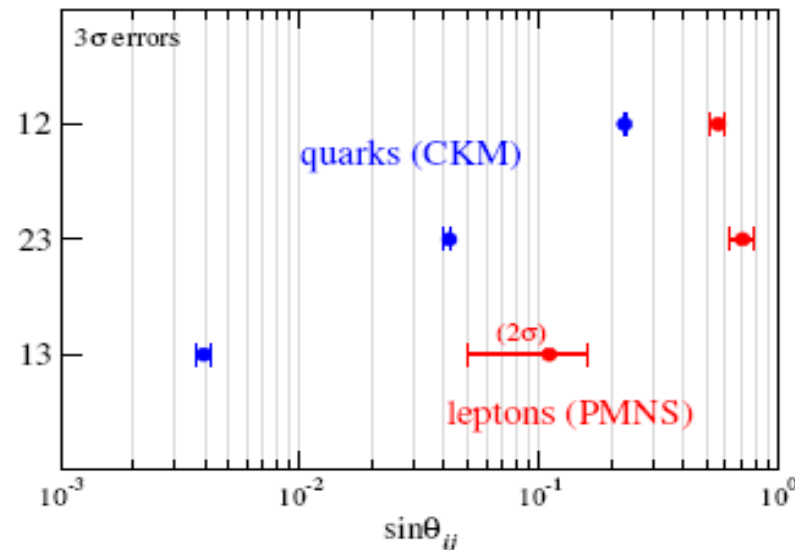
CKM versus PMNS

Quark mixing:

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

Lepton mixing:

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





Scenario Envisaged

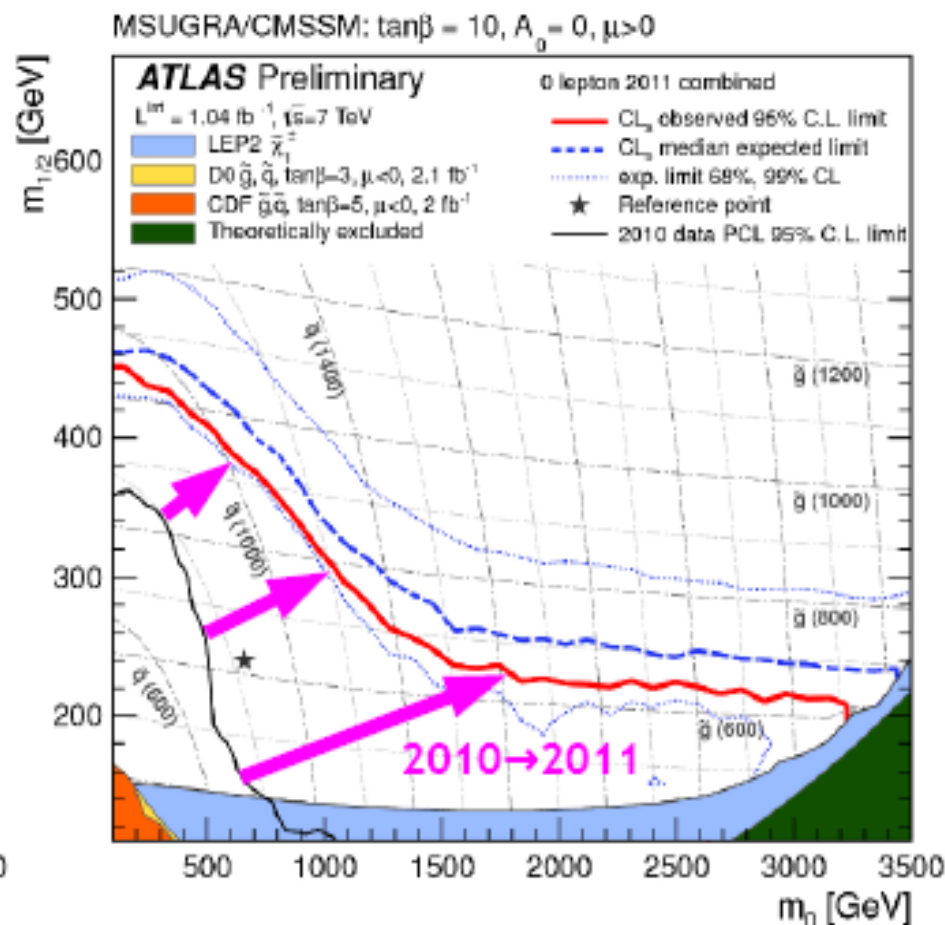
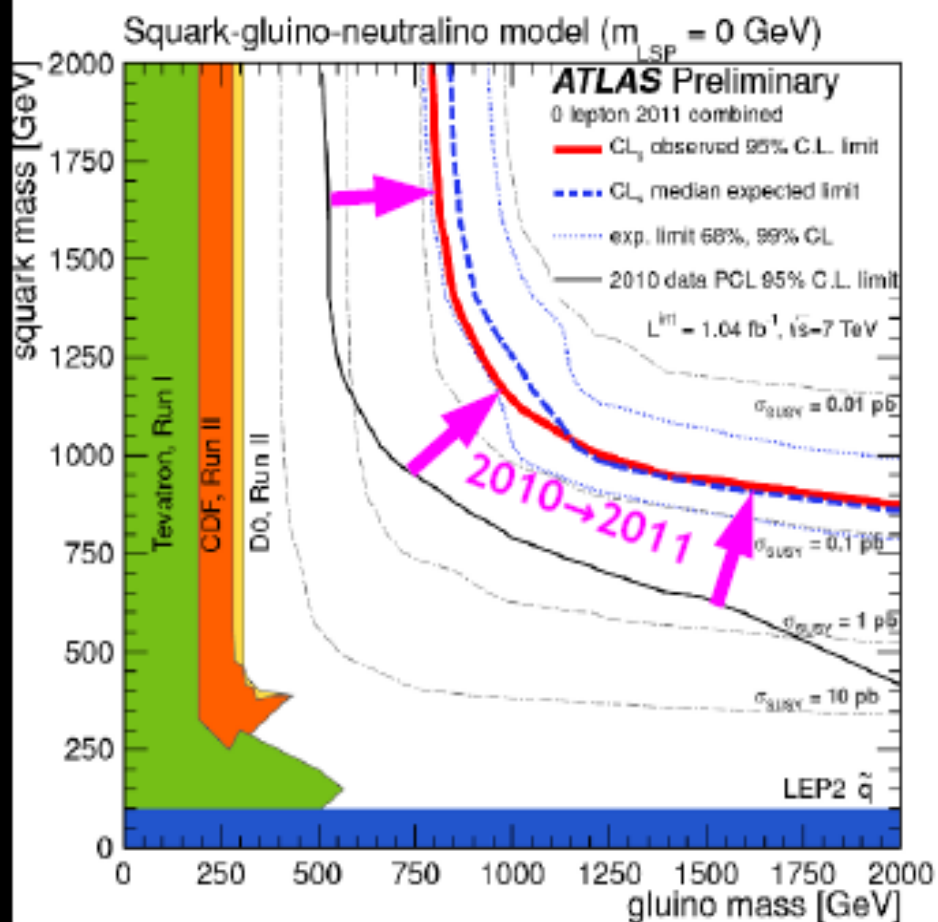
- The planning model of the years ahead:

Year	Luminosity	Total	Beam energy
2011	4-5	4-5	3.5
2012	10	15	3.5/4
2013	0	15	-
2013	0	15	-
2014	10	25	6.5

- MD suggests $5 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$ possible this month

W. MURRAY, Implications of LHC Results for TeV-scale Physics, CERN, 29/8 -2/9

SUSY in 0-lepton channel



Simplified model with two \tilde{q} generations, $m(\tilde{\chi}_1^0) \sim 0$

$m_{\tilde{g}} > 800 \text{ GeV}$ $m_{\tilde{q}} > 850 \text{ GeV}$

Equal mass case: $m_{\tilde{g}} = m_{\tilde{q}} > 1.075 \text{ TeV}$

MSUGRA/CMSSM: $\tan\beta=10$, $A_0=0$, $\mu>0$

Equal mass case: $m_{\tilde{q}} = m_{\tilde{g}} > 980 \text{ GeV}$

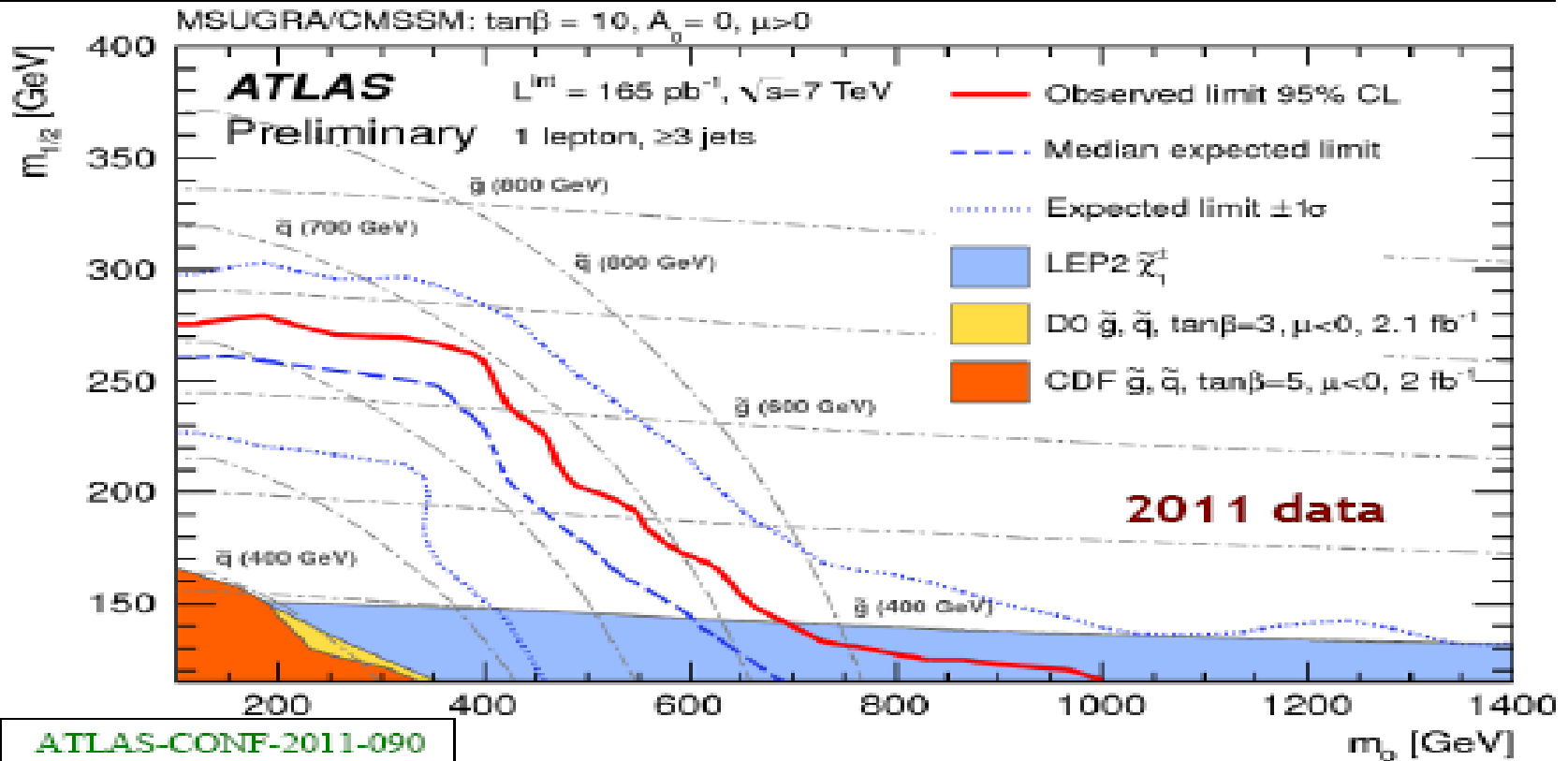
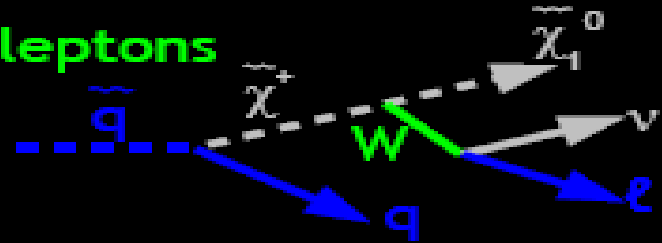
D. CHARLTON EPS-HEP 2011

SUSY in 1-lepton channel

D. CHARLTON EPS-HEP 2011

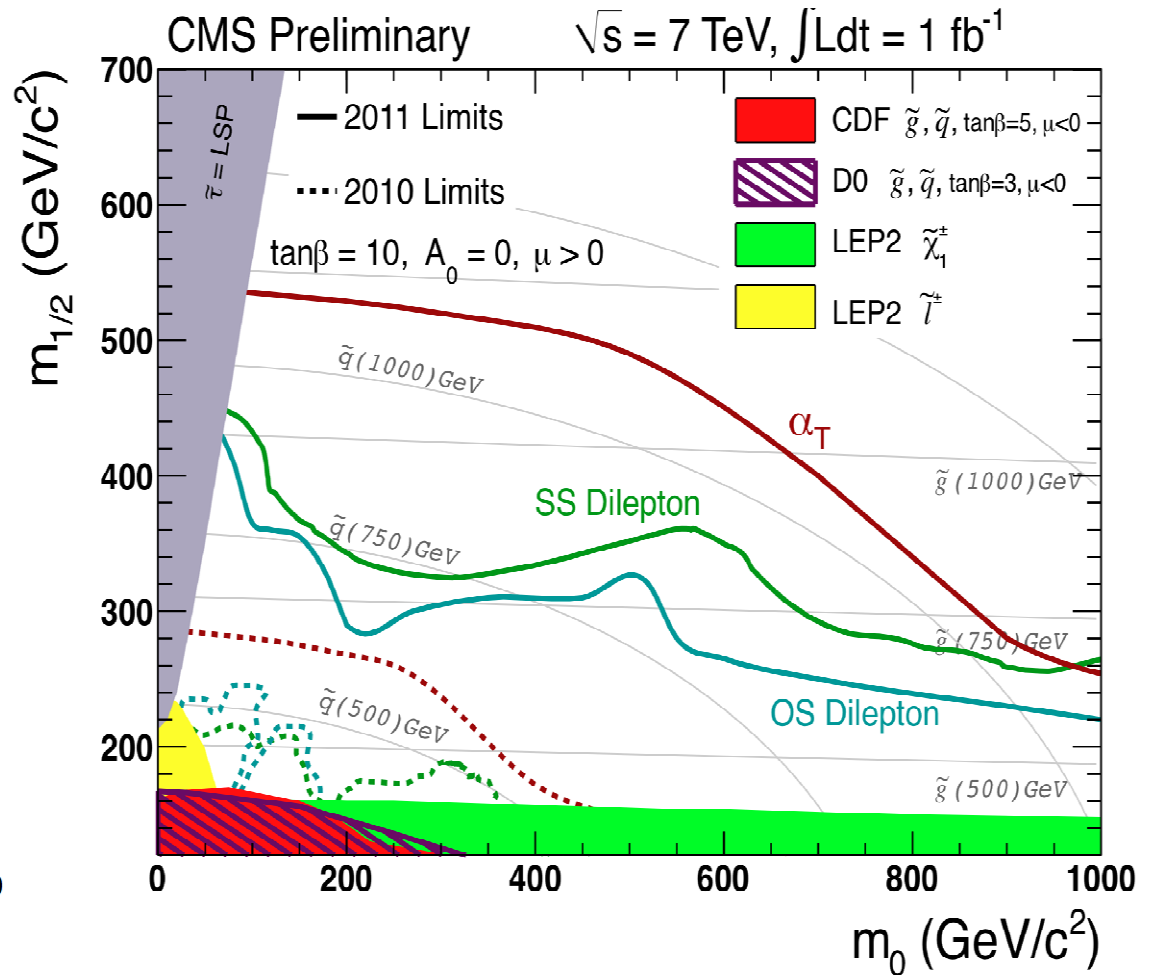
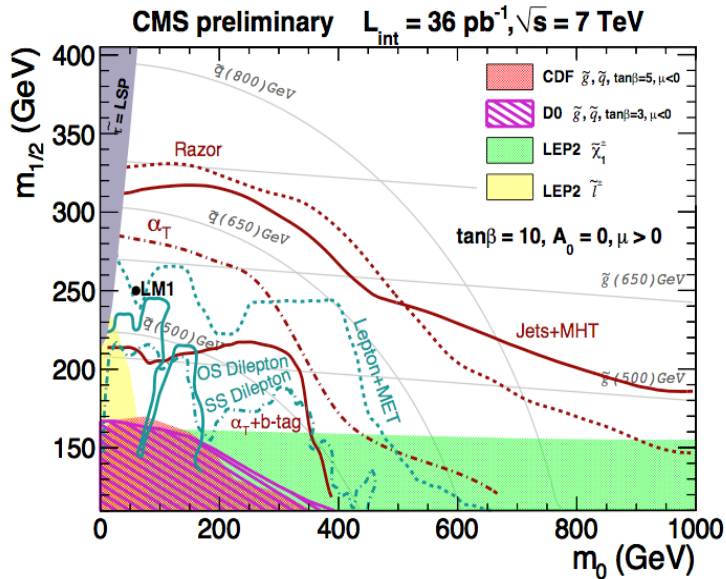
gg, gq, qq may give isolated leptons

Single e/μ , jets, E_T^{miss}



Progress on SUSY

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

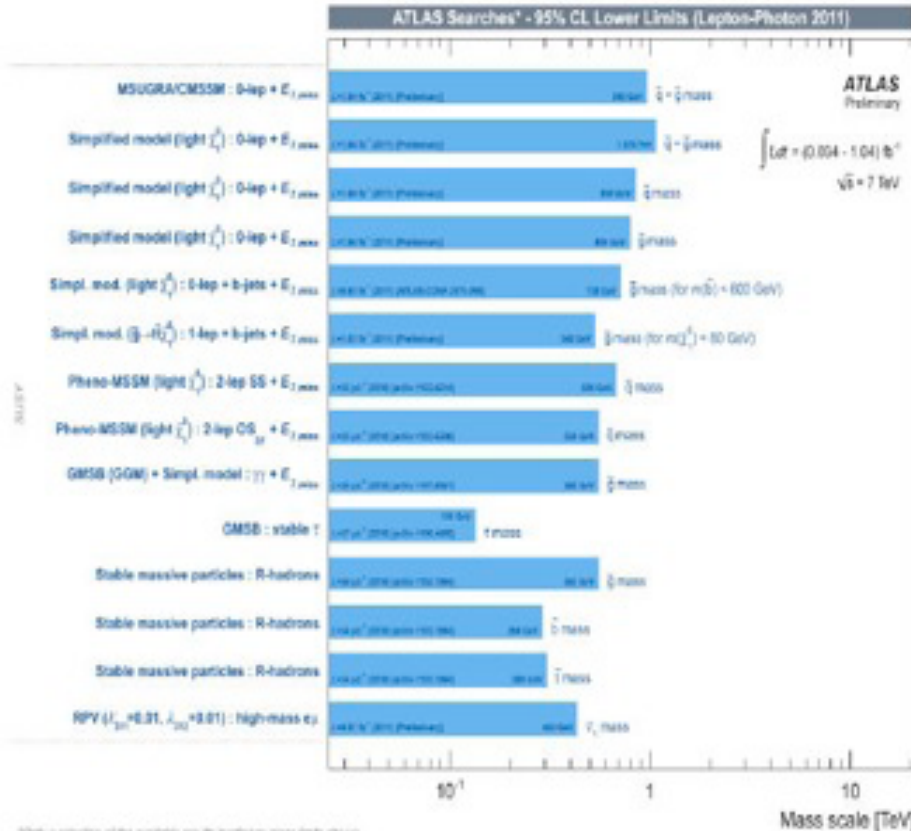


Within the constrained SSM models we are crossing the border of excluding gluinos and squarks up to 1TeV and beyond. The air is getting thin for constrained SUSY. More conclusive results after summer.

No Obvious Signs of New Physics YET

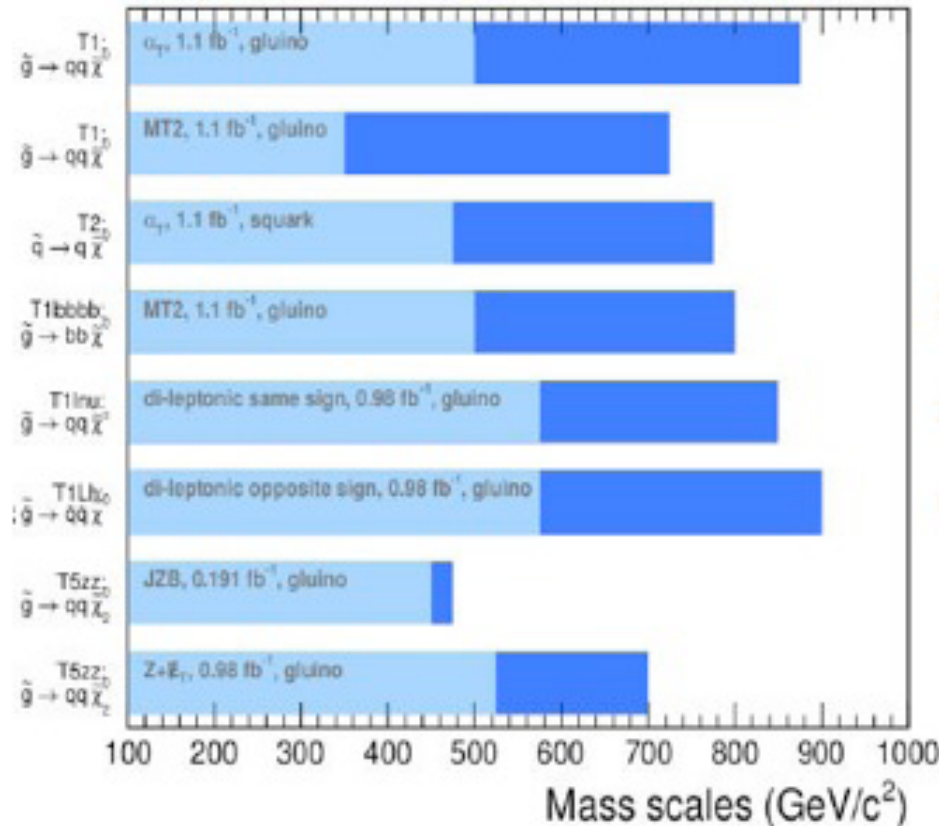
Cavanaugh, Hewett, Kraml, Polesello, WGII on MET Signatures, Implications of LHC Physics for TeV NP, Cern, 2/9/11

ATLAS Search Summary



*Only a selection of the available results leading to mass limits shown

CMS Search Summary

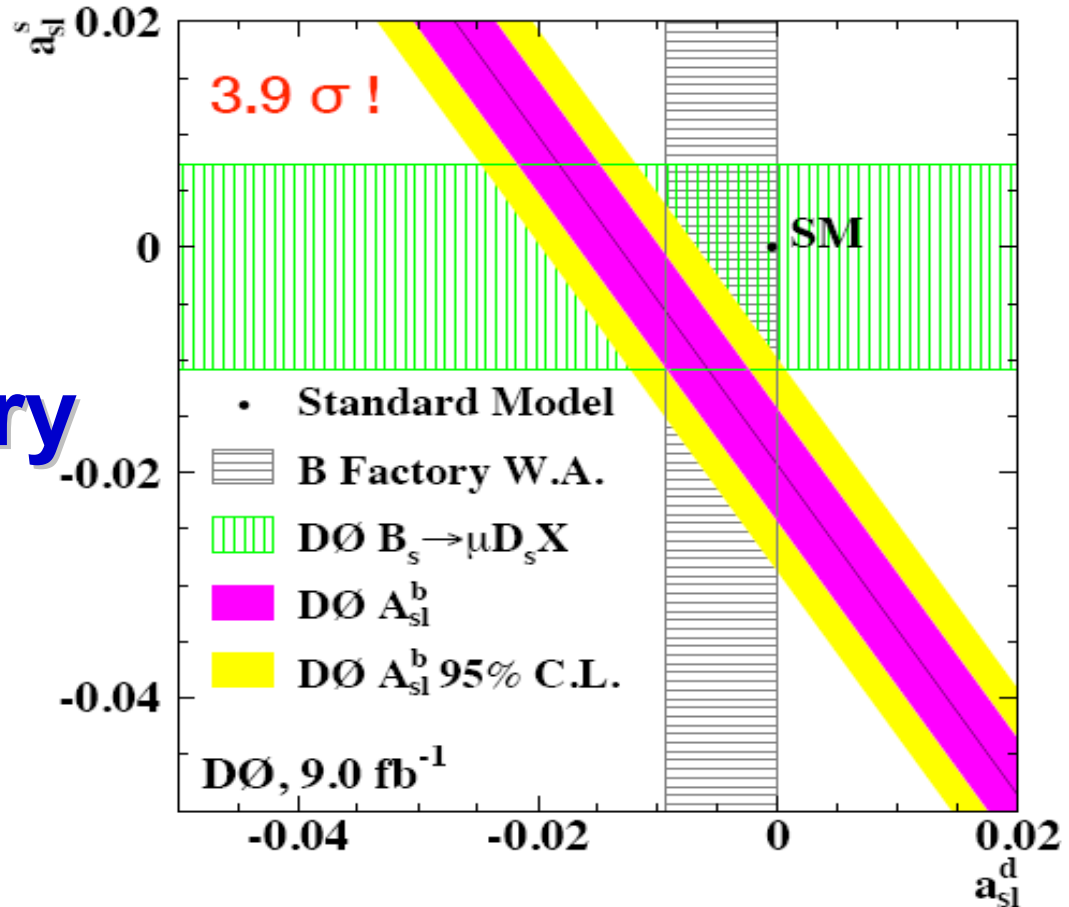


- 1st 6 months of a 20 year program!
- NP could be at ~2 TeV or more complicated than the simplest scenarios

EVIDENCE OF NP ALONG THE HIGH INTENSITY ROAD?

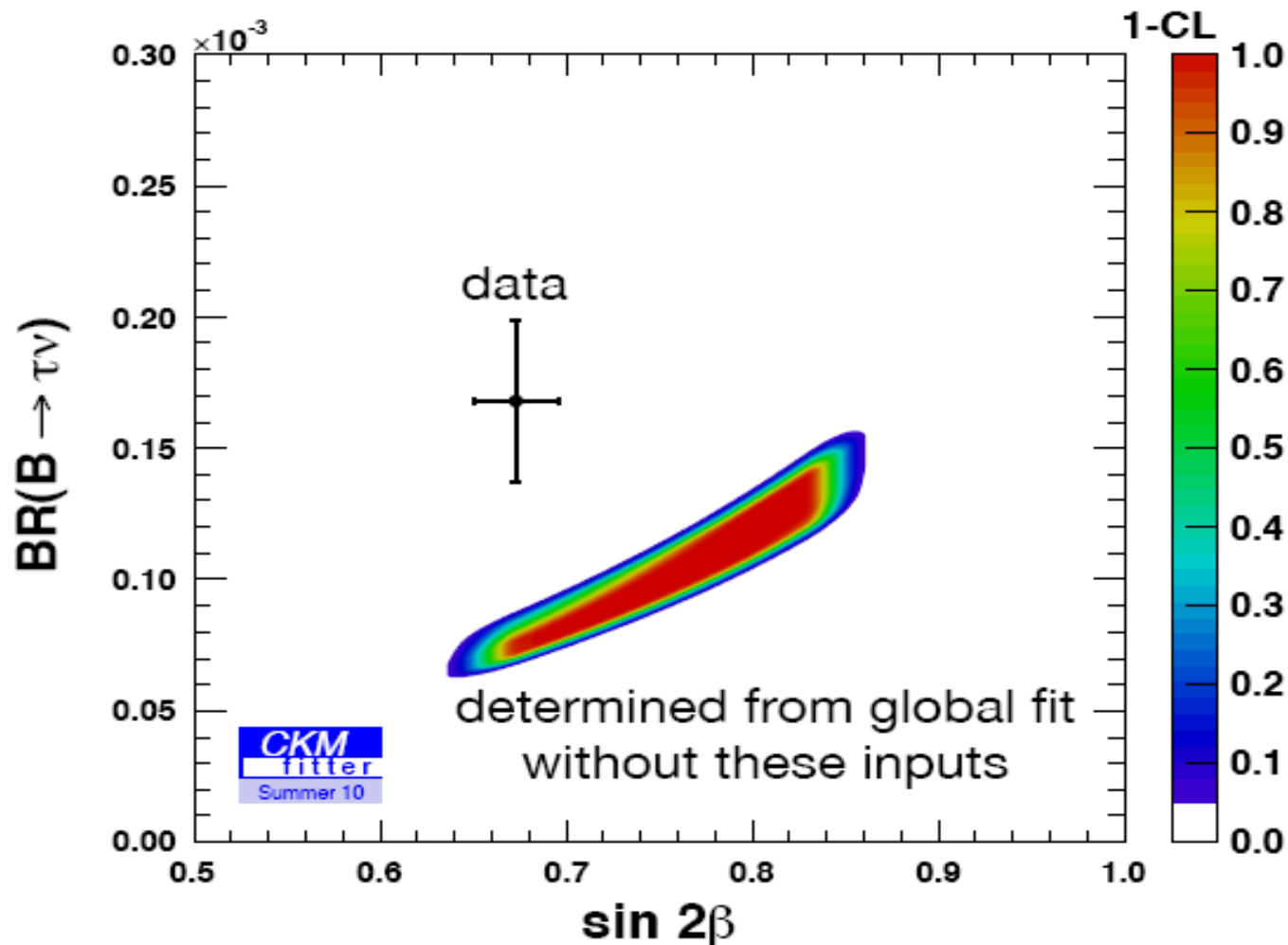
- “FLAVOR COLDS for the SM:

Like-sign dimuon charge asymmetry



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

Lenz, Nierste + CKMfitter (2010)

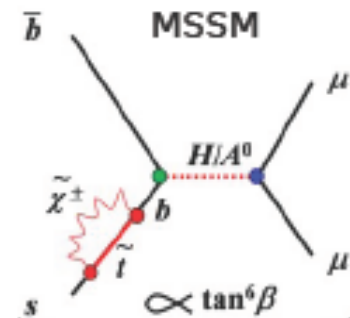


V_{ub} CRISIS

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

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

- * interesting rare decays, which can be much enhanced in models with a warped extra dimension or SUSY models with large $\tan\beta$



Excess in B_s mode reported by CDF:

$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^-) = (1.8_{-0.9}^{+1.1}) \cdot 10^{-8}$$

$$\text{SM: } (3.2 \pm 0.2) \cdot 10^{-9}$$

$$\mathcal{B}(B_d \rightarrow \mu^+ \mu^-) < 6.0 \cdot 10^{-9}$$

$$\text{SM: } (1.0 \pm 0.1) \cdot 10^{-10}$$

Unfortunately no excess seen at LHCb (CMS):

$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^-) < 1.5 (1.9) \cdot 10^{-8}$$

(at 95% CL)

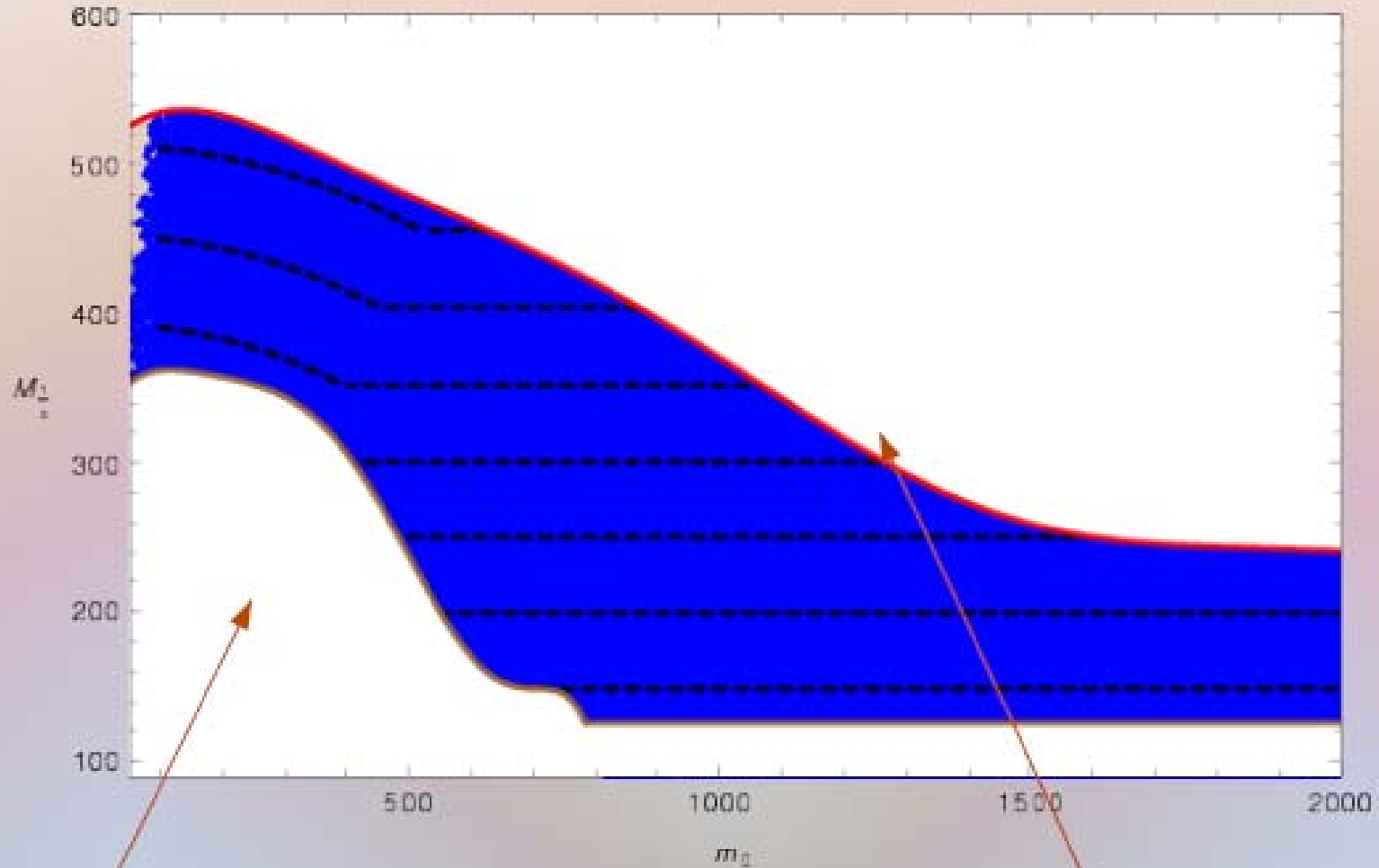
$$\mathcal{B}(B_d \rightarrow \mu^+ \mu^-) < 5.2 (4.6) \cdot 10^{-9}$$

NEUBERT EPS11

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

Relevant Parameter Space for 2 fb^{-1}

Jones at the EPS-HEP 2011 on the work in progress by Calibbi, Hodgkinson, Jones, A.M. and Vives



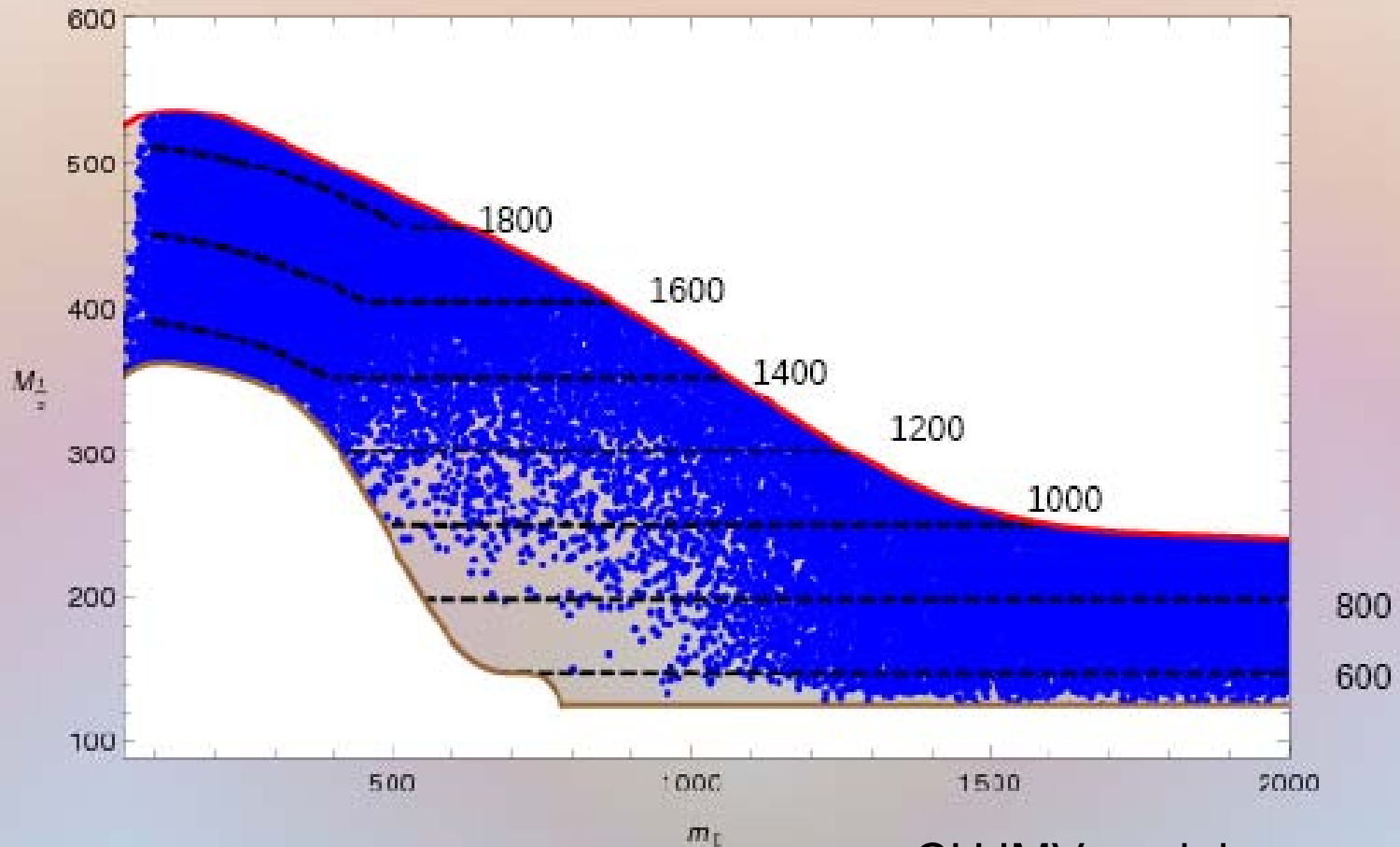
ATLAS Collaboration (1102.5290 [hep-ex])

Baer, Barger, Lessa, Tata (1004.3594 [hep-ph])

Flavour 3σ Constraints

$$b \rightarrow s\gamma$$

$$(g - 2)_\mu$$



CHJMV work in progress

The Role of $B_s \rightarrow \mu \mu$

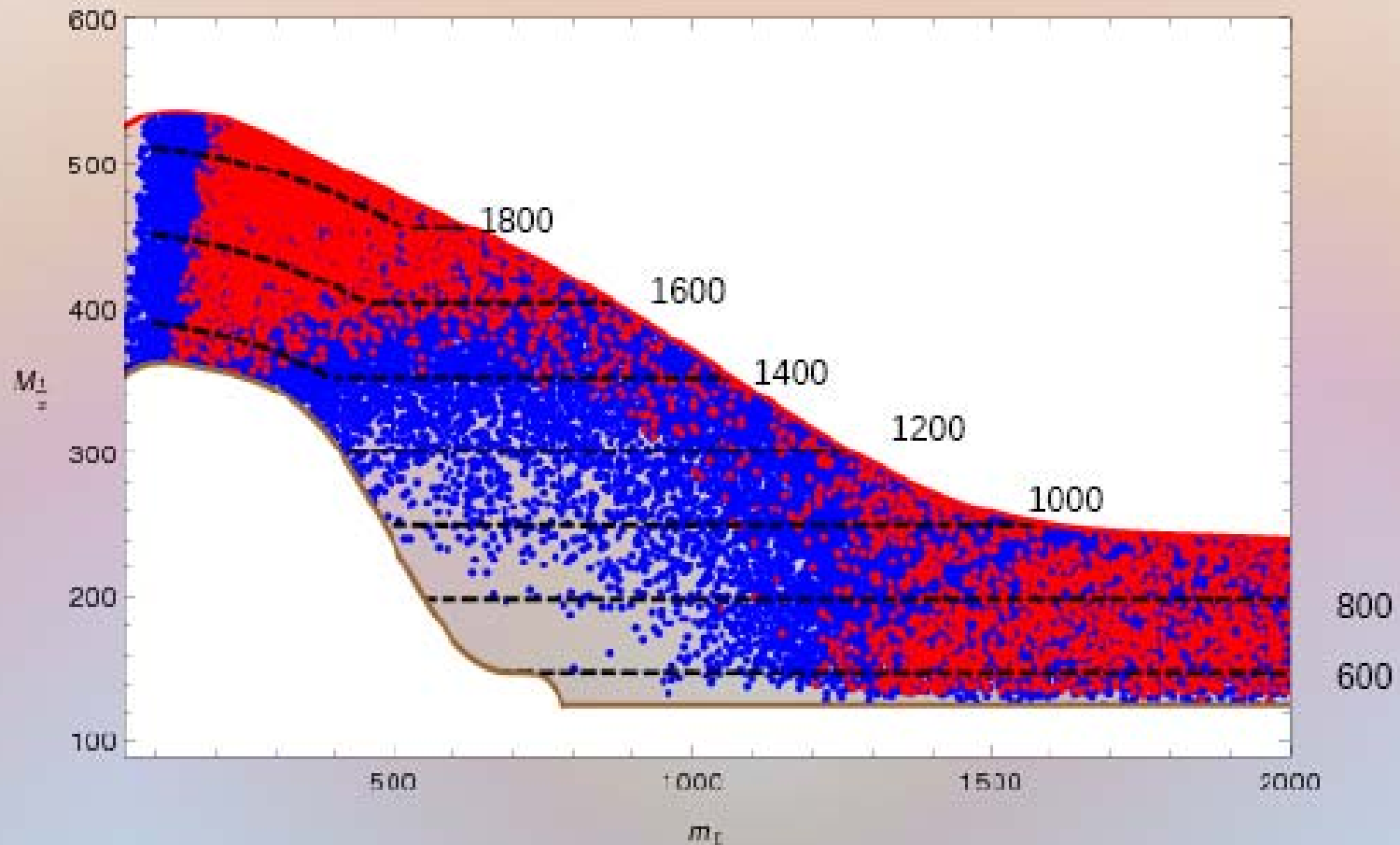
- LHCb with 2 fb^{-1}
 - Exclusion of $\text{BR}(B_s \rightarrow \mu \mu)$ down to 4×10^{-9} , 95% C.L.
 - 3σ evidence of $\text{BR}(B_s \rightarrow \mu \mu)$ down to 5×10^{-9} .
 - 5σ discovery of $\text{BR}(B_s \rightarrow \mu \mu)$ down to 9×10^{-9} .

R. Lambert @ Moriond

- CDF with 7 fb^{-1}
 - $\text{BR}(B_s \rightarrow \mu \mu) = (1.8 \pm 1) \times 10^{-8}$

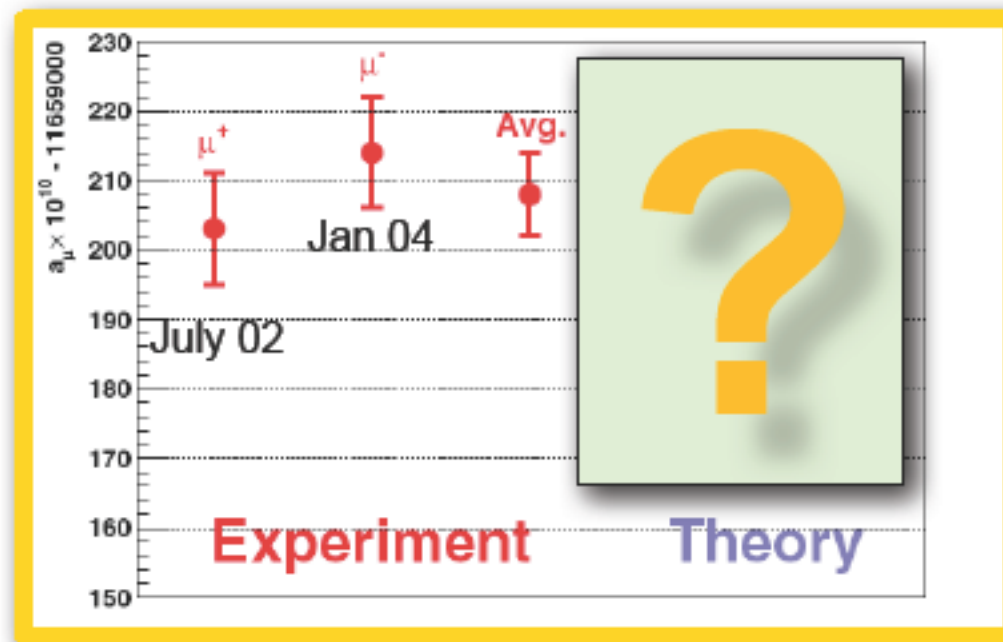
Exclusion due to $B_s \rightarrow \mu\mu$

$$\text{BR}(B_s \rightarrow \mu\mu) < 4 \times 10^{-9}$$



CHJMV work in progress

The muon g-2: the experimental result



- Today: $a_\mu^{\text{EXP}} = (116592089 \pm 54_{\text{stat}} \pm 33_{\text{sys}}) \times 10^{-11}$ [0.5ppm].
- Future: new muon g-2 experiments proposed at:
 - Fermilab (P989), aiming at 0.14ppm **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:

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

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

	$a_{\mu}^{\text{SM}} \times 10^{11}$	$(\Delta a_{\mu} = a_{\mu}^{\text{EXP}} - a_{\mu}^{\text{SM}}) \times 10^{11}$	σ
[1]	116 591 782 (59)	307 (86)	3.6
[2]	116 591 802 (49)	287 (80)	3.6
[3]	116 591 830 (52)	259 (82)	3.2
[4]	116 591 894 (54)	195 (83)	2.4

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

- [1] F. Jegerlehner, A. Nyffeler, Phys. Rept. 477 (2009) 1
- [2] Davier et al, arXiv:1010.4180, Oct 2010 (includes BaBar and KLOE10 2π)
- [3] HLMNT10: Hagiwara et al, Tau 2010, Sep. 2010 (incl BaBar and KLOE10 2π)
- [4] Davier et al, arXiv:1010.4180, Oct 2010, 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

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

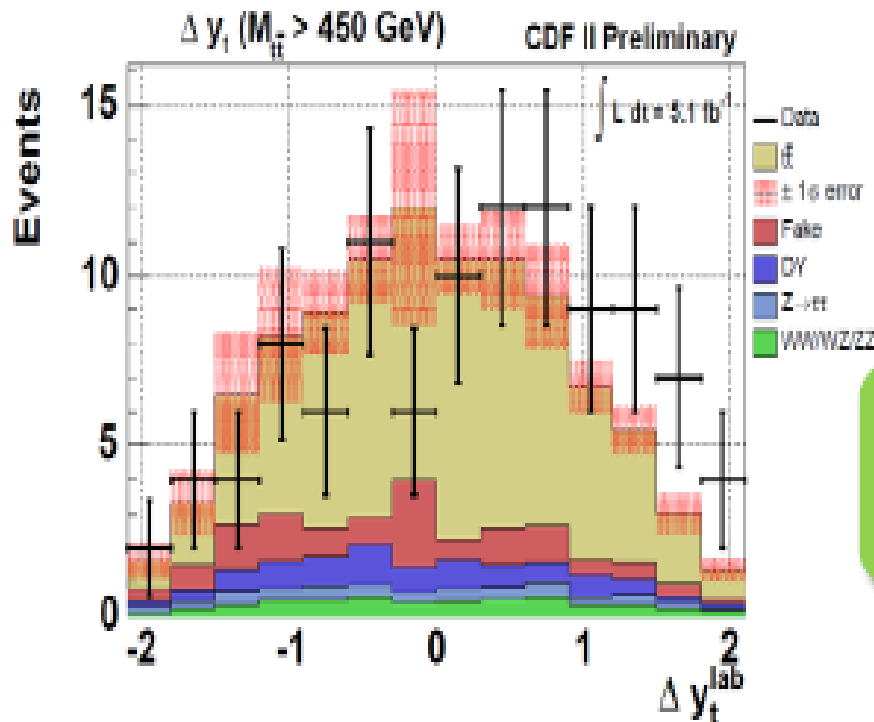
(dilepton final state)

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

DUPERRIN EPS-HEP 2011

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

✓ Or gluon radiations modeling at NLO?



SOMETHING is needed at
the TeV scale to enforce
the unitarity of the
electroweak theory

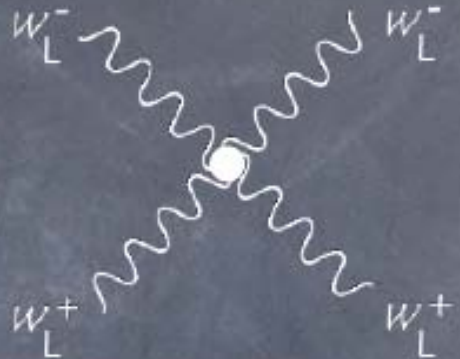
What is the mechanism of EWSB?

susy, LH... models assume that we already know the answer to

What is unitarizing the WW scattering amplitudes?

W_L & Z_L part of EWSB sector \Rightarrow W scattering is a probe of Higgs sector interactions

$$\epsilon_l = \begin{pmatrix} |\vec{k}| & E & \vec{k} \\ M & M & |\vec{k}| \end{pmatrix}$$



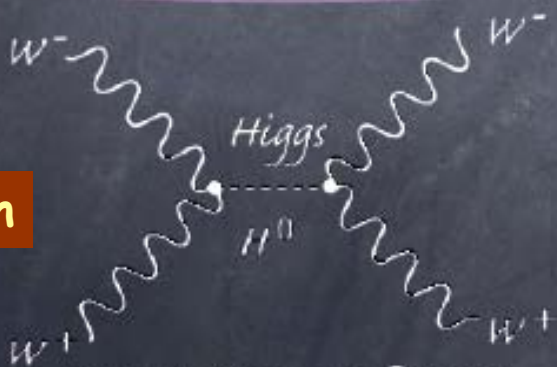
$$\mathcal{A} = g^2 \left(\frac{E}{M_W} \right)^2$$

loss of perturbative unitarity around 1.2 TeV

Weakly coupled models

Strongly coupled models

Grojean



prototype: Susy
susy partners \sim 100 GeV

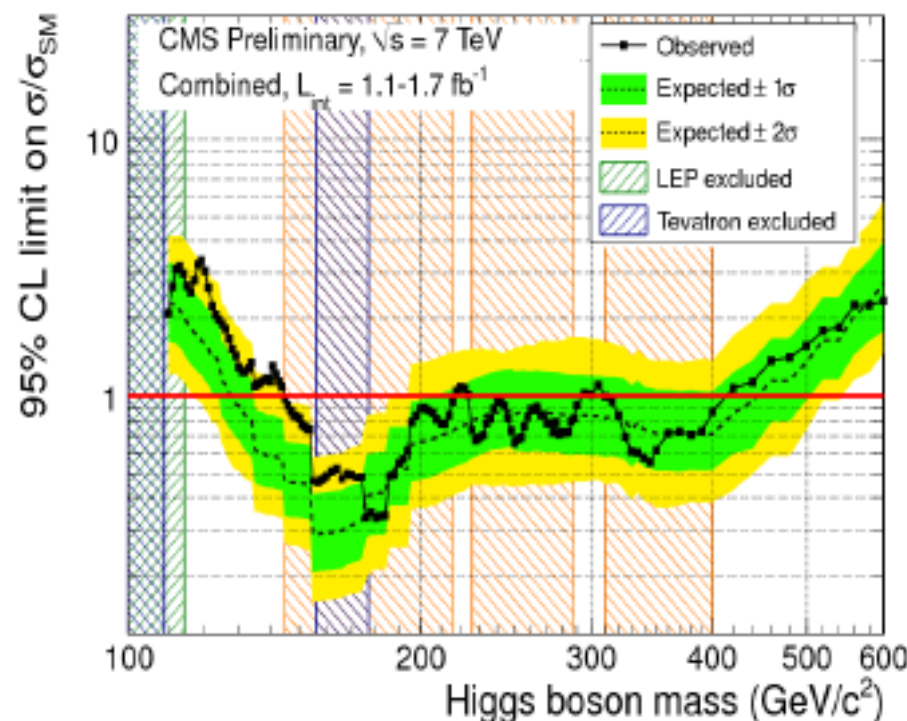
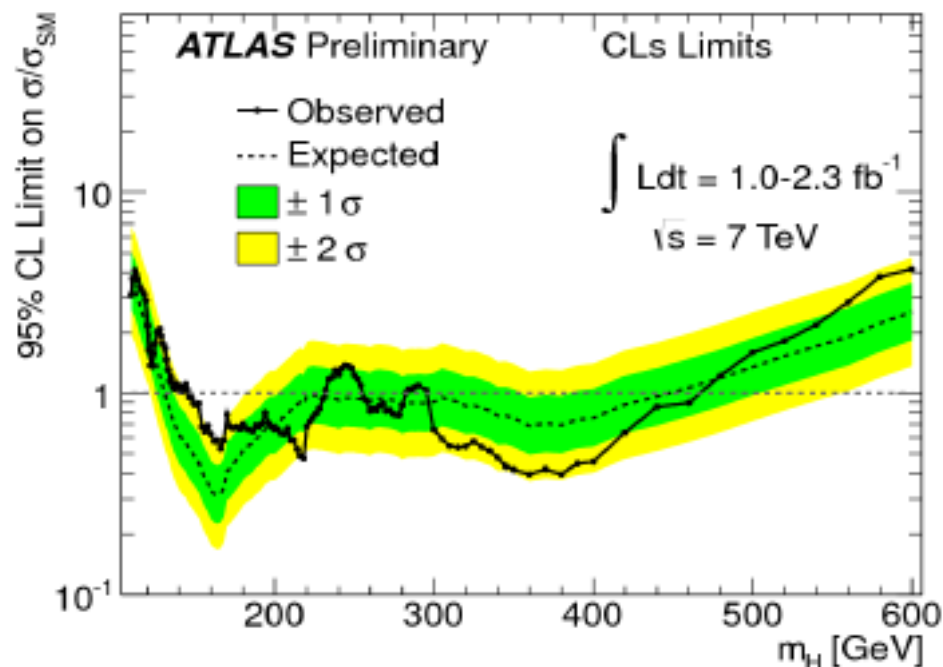
Different signatures at the LHC!



prototype: Technicolor
rho meson \sim 1 TeV



The Standard Model

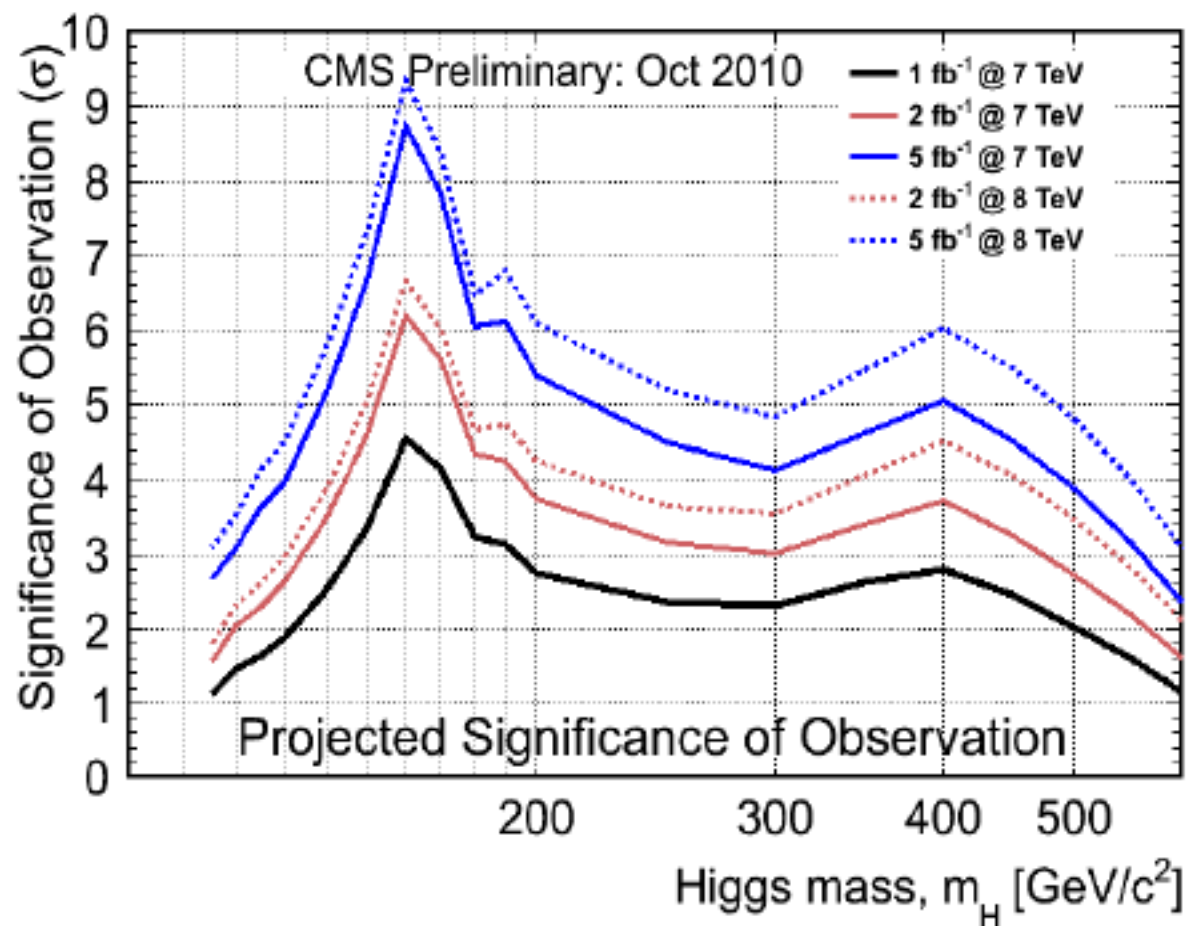


- ATLAS and CMS exclude 145 to 460GeV together
 - Islands (e.g. 300) not formally excluded, but are close
- Focus on 114-145GeV



Signal significance

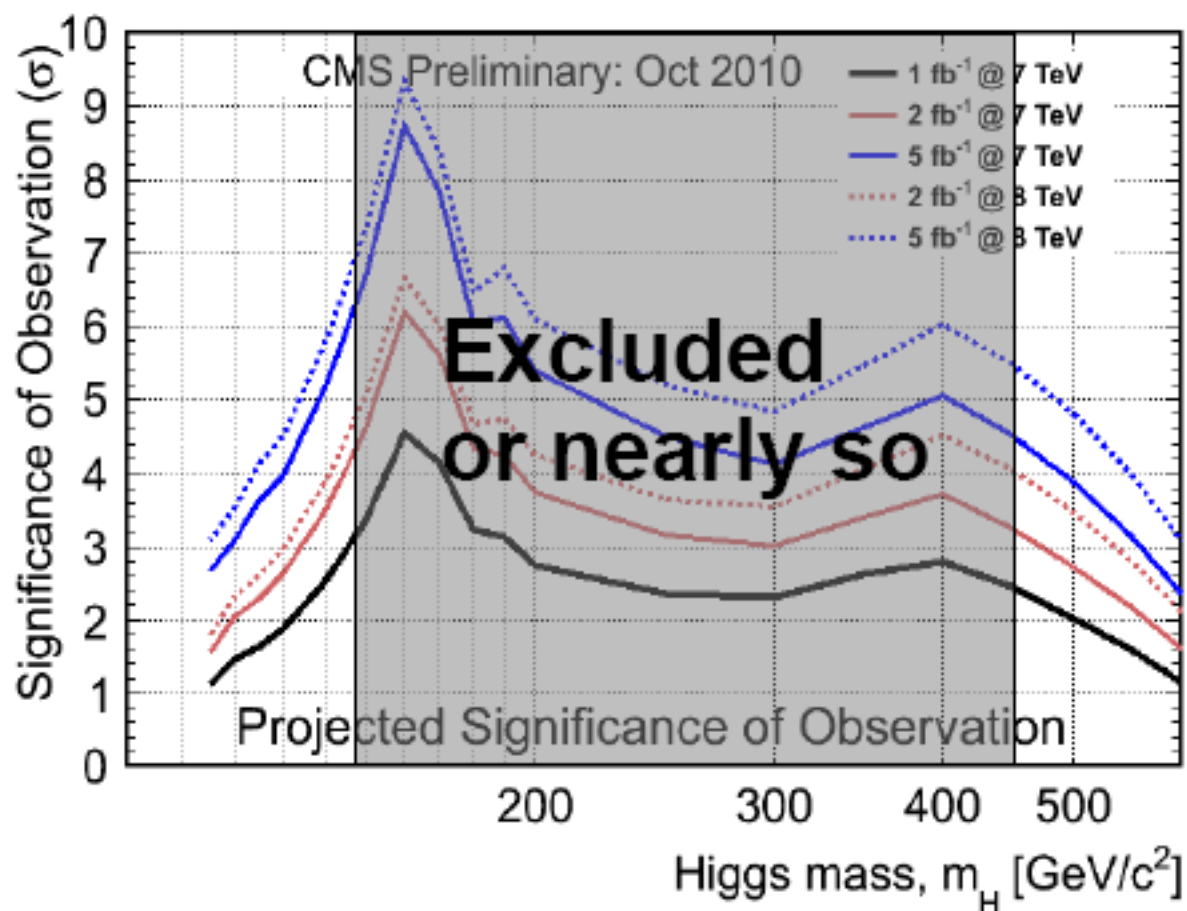
- 5fb^{-1} gives either experiment large sensitivity
- Projections slightly optimistic at 115
 - Need $\gamma\gamma$ resolution!
 - Or SM cover needs combination





Signal significance

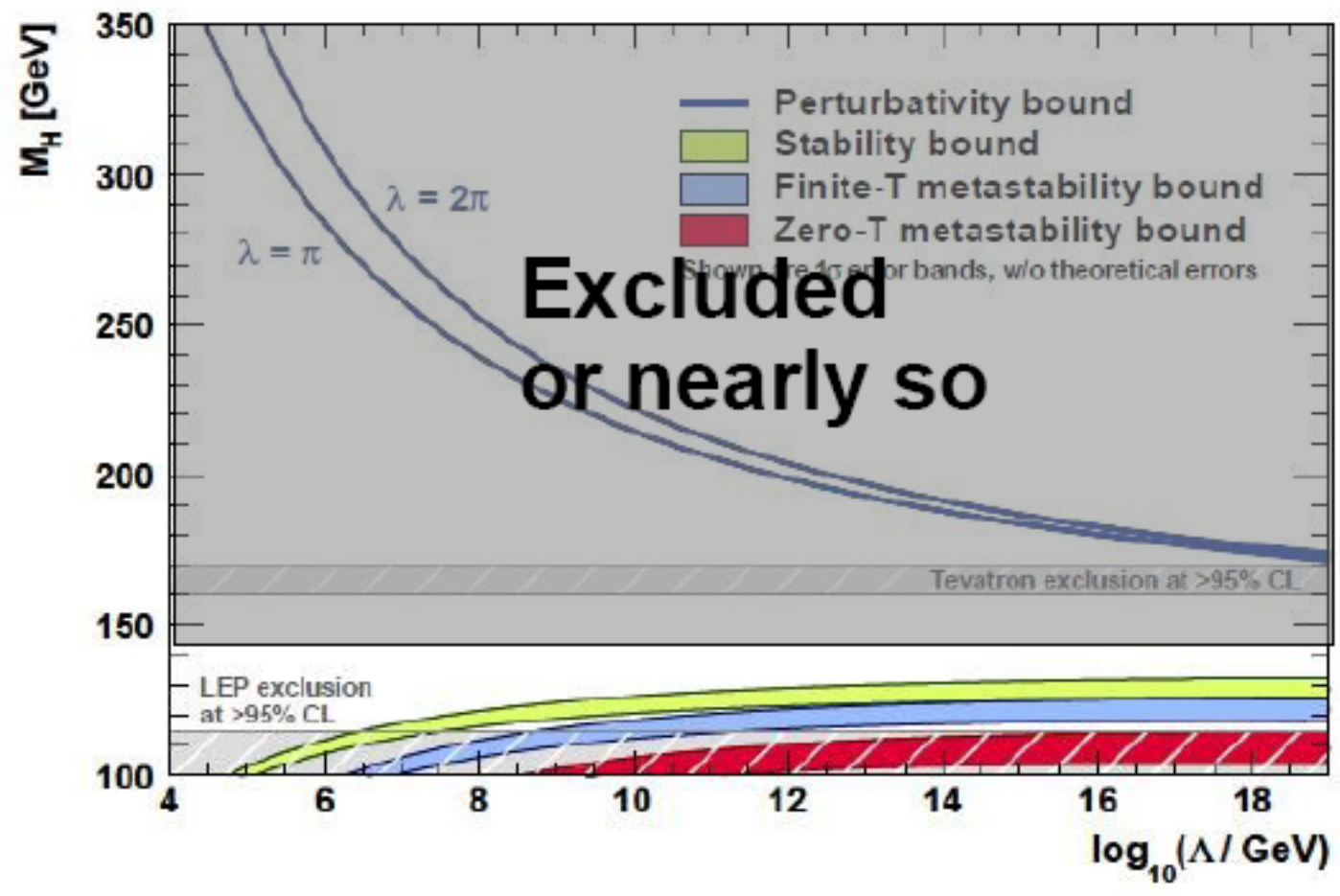
- 5fb^{-1} gives either experiment large sensitivity
- Projections slightly optimistic at 115
 - Need $\gamma\gamma$ resolution!
 - Or SM cover needs combination



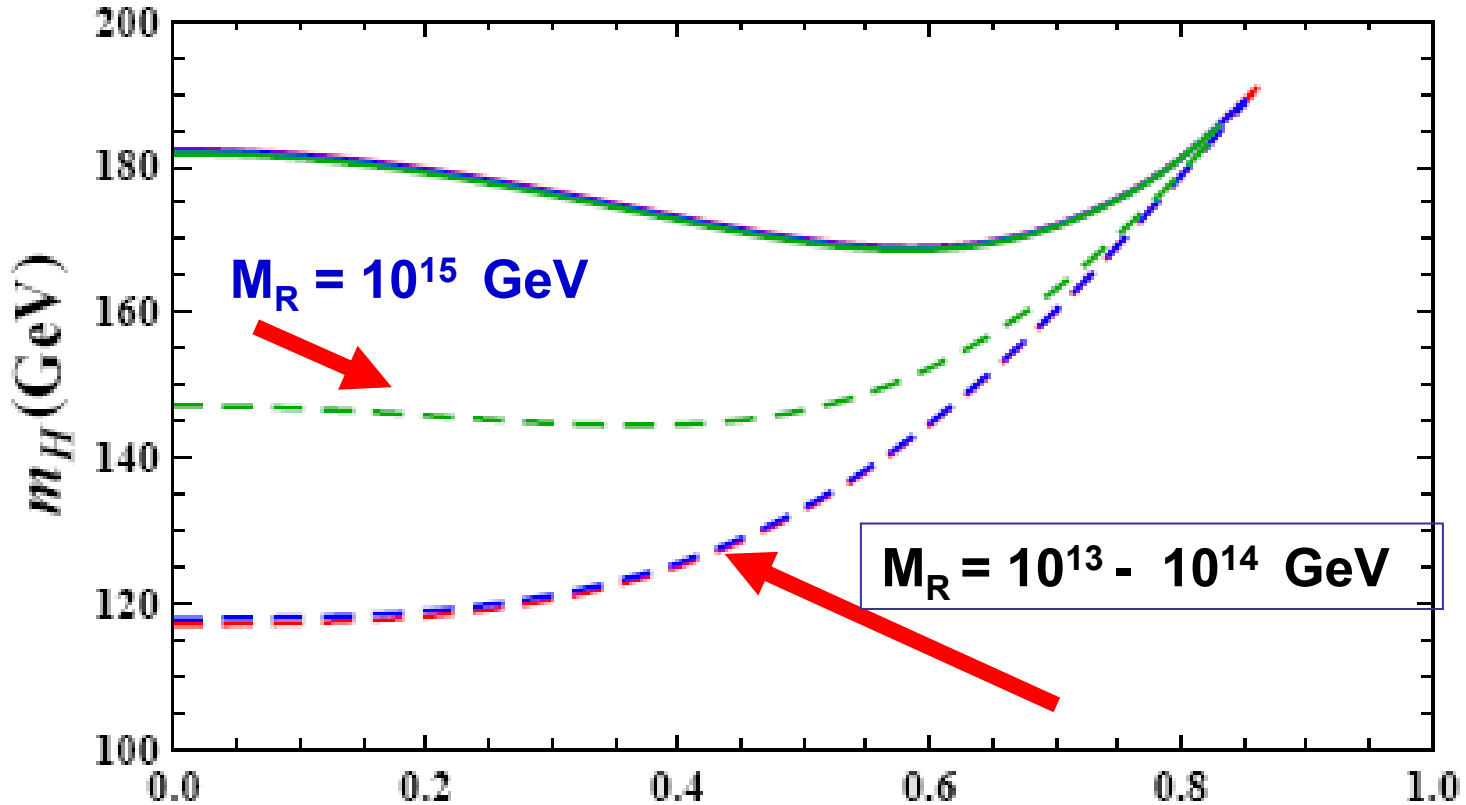


Higgs Stability

- Only small stable region left
- Are we heading into region where Higgs demands new physics?
- Know very soon!



Modification of the vacuum stability and perturbativity bounds on the Higgs boson mass in the presence of new heavy vector-like fermions and type I see-saw mechanism for neutrino masses



Coupling of vectorlike fermions of κ
500 GeV to ordinary fermions

Gogoladze, He and Shafi
1004.4217



Summary 2012

- Running in 2012...
 - Assumed order of 12fb^{-1}
- LHC combination will offer 5σ sensitivity to many SM Higgs
 - Unless $m_H=115$; then $3.5\sigma+$
- The luminosity from the 2 year run will
 - Allow exploration of TeV scale ASAP
 - Give a clear picture of the way ahead
- The 2012 run will consolidate the 2011 picture into incontrovertible fact.

Is it possible that there is “only” a light higgs boson and no NP?

- This is acceptable if one argues that no ultraviolet completion of the SM is needed at the TeV scale simply because there is no actual fine-tuning related to the higgs mass stabilization (**the correct value of the higgs mass is “environmentally” selected**). This explanation is similar to the one adopted for the cosmological constant
- Barring such wayout, **one is lead to have TeV NP to ensure the unitarity of the elw. theory at the TeV scale**

% FINE-TUNING FOR THE NEW PHYSICS AT THE ELW. SCALE

- **Elementary Higgs** → In the **MSSM** % fine-tuning among the SUSY param. to avoid light SUSY particles which would have been already seen at LEP and Tevatron **and now also at LHC**
- **Elementary Higgs** → **PSEUDO-GOLDSTONE boson in the LITTLE HIGGS model** → Λ^2 div. cancelled by new colored fermions, new W,Z, γ , 2Higgs doublets... → % fine-tuning to avoid too large elw. Corrections
- **COMPOSITE HIGGS** in a **5-dim.** holographic theory (Higgs is a **PSEUDO-GOLDSTONE** boson and the elw. symmetry breaking is triggered by bulk effects (in 5 dim. the theory is **WEAKLY** coupled, but in 4 dim. the bulk looks like a **STRONGLY** coupled sector) → also here % fine-tuning needed to survive the elw. precision tests

1. Present “Observational” Evidence for New Physics

- **NEUTRINO MASSES** 
- **DARK MATTER** 
- **MATTER-ANTIMATTER ASYMMETRY** 
- **INFLATION** 

**COULD (AT LEAST SOME OF)
THE “OBSERVATIONAL” NEW
PHYSICS BE LINKED TO THE
ULTRAVIOLET COMPLETION OF
THE SM AT THE ELW. SCALE ?**

The Energy Scale from the “Observational” New Physics

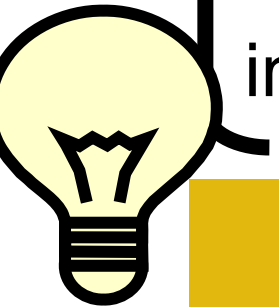
neutrino masses

dark matter

baryogenesis

inflation

NO NEED FOR THE
NP SCALE TO BE
CLOSE TO THE
ELW. SCALE



The Energy Scale from the “Theoretical” New Physics

★ ★ ★ Stabilization of the electroweak symmetry breaking
at M_W calls for an **ULTRAVIOLET COMPLETION** of the SM
already at the TeV scale +

★ **CORRECT GRAND UNIFICATION “CALLS” FOR NEW PARTICLES
AT THE ELW. SCALE**

***THE DM ROAD TO NEW
PHYSICS BEYOND THE SM:
IS DM A PARTICLE OF
THE NEW PHYSICS AT
THE ELECTROWEAK
ENERGY SCALE ?***

CONNECTION DM – ELW. SCALE

THE WIMP MIRACLE: STABLE ELW. SCALE WIMPs

1) ENLARGEMENT OF THE SM

SUSY
(x^μ, θ)

EXTRA DIM.
(x^μ, j^i)

LITTLE HIGGS.
SM part + new part

Anticomm.
Coord.

New bosonic
Coord.

to cancel Λ^2
at 1-Loop

2) SELECTION RULE

R-PARITY LSP

KK-PARITY LKP

T-PARITY LTP

→ DISCRETE SYMM.

Neutralino spin 1/2

spin1

spin0

→ STABLE NEW PART.

3) FIND REGION (S) PARAM. SPACE WHERE THE “L” NEW PART. IS NEUTRAL + $\Omega_L h^2$ OK

m_{LSP}

~100 - 200
GeV *

m_{LKP}

~600 - 800
GeV

m_{LTP}

~400 - 800
GeV

* But abandoning gaugino-masss unif. → Possible to have m_{LSP} down to 7 GeV

Bottino, Donato, Fornengo, Scopel

IS THE “*WIMP MIRACLE*” AN ACTUAL MIRACLE?

USUAL STATEMENT

Many possibilities for DM candidates, but WIMPs are really special: peculiar coincidence between particle physics and cosmology parameters to provide a VIABLE DM CANDIDATE AT THE ELW. SCALE

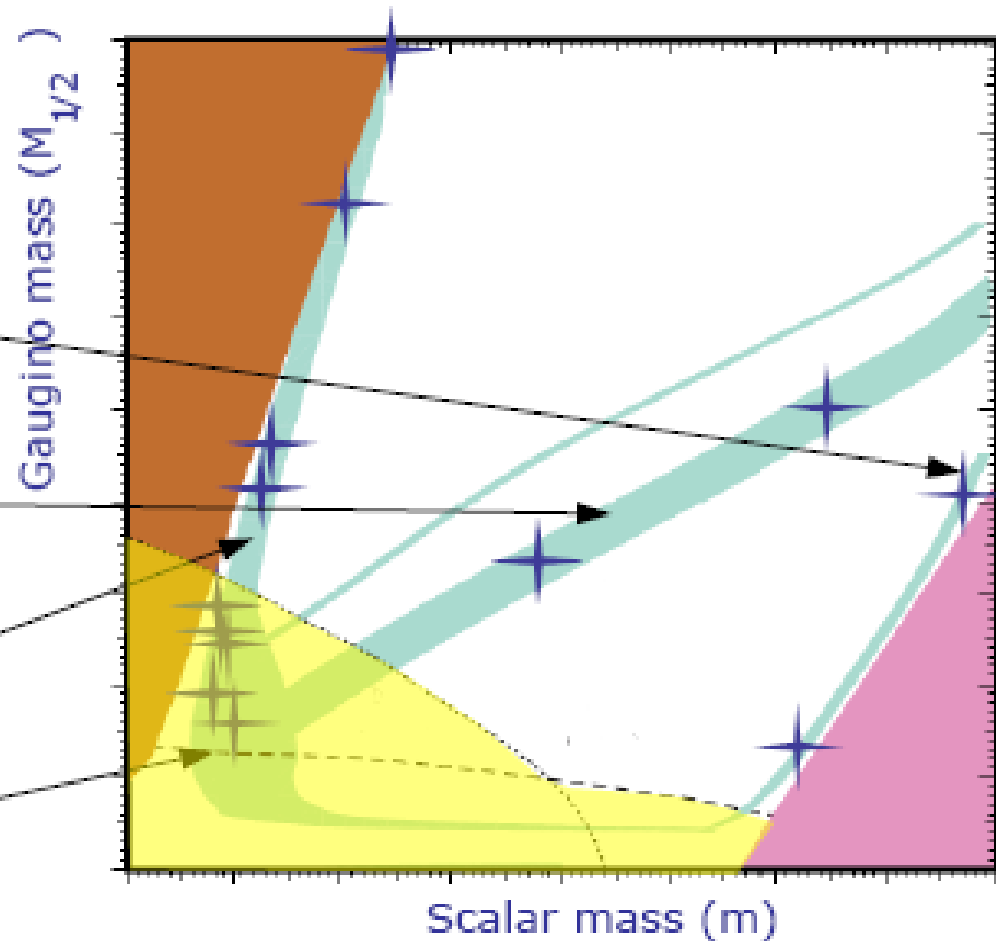
HOWEVER

when it comes to quantitatively reproduce the precisely determined DM density → once again the fine-tuning threat...

LHC reach in the SUSY parameter space (example CMSSM - $A, M, m, \tan\beta, \mu$)

Regions compatible with Neutralino DM (having correct relic density)

- Focus-Point region (Higgsino-Bino neutralino)
- Resonant annihilation (with pseudoscalar Higgs)
- Coannihilation region (small LSP-NLSP mass difference)
- Bulk (small SUSY masses)
Mostly excluded by LEP constraints (still available in non-minimal models)



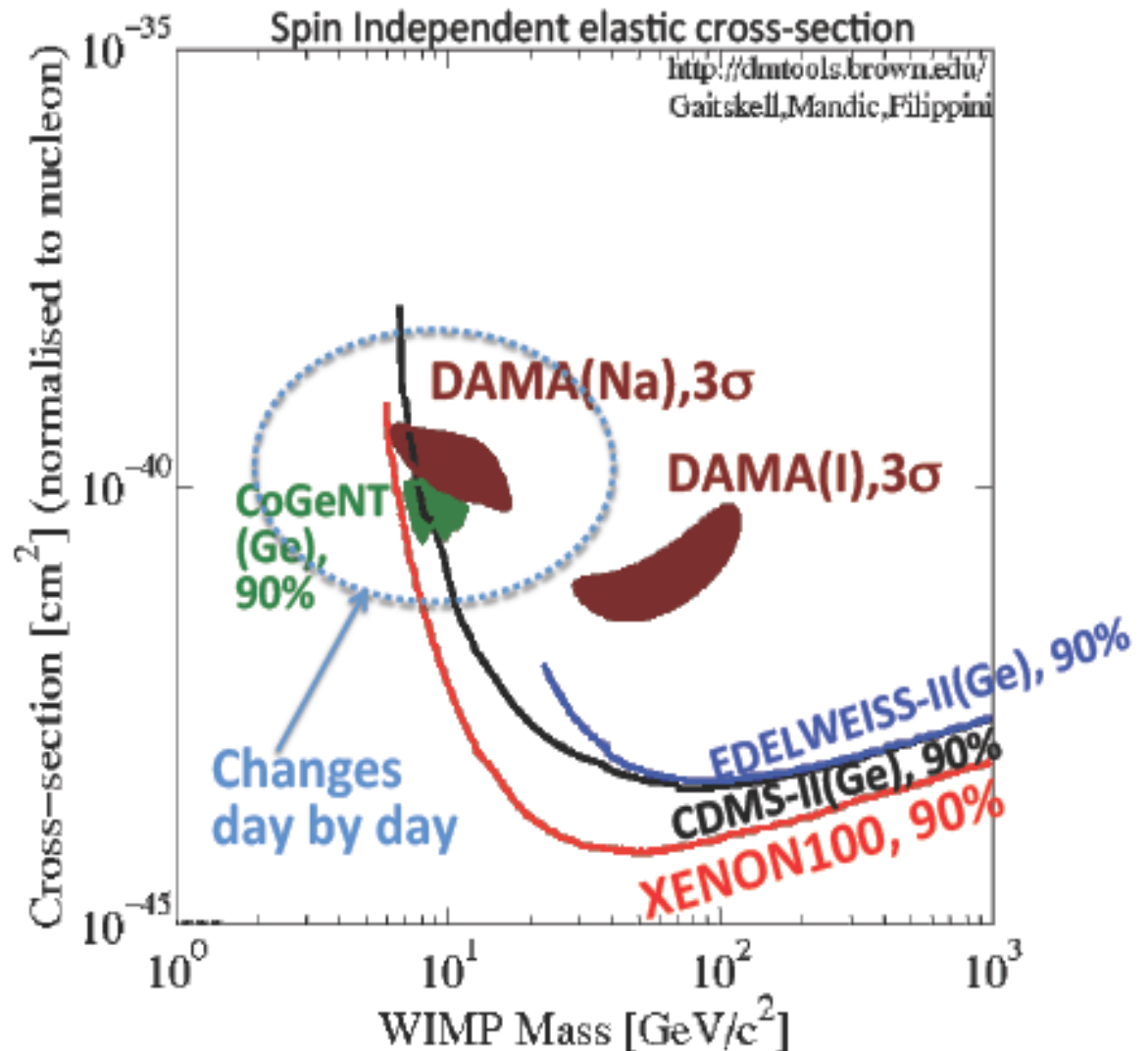
(see e.g., Ellis, Ferstl, Olive)

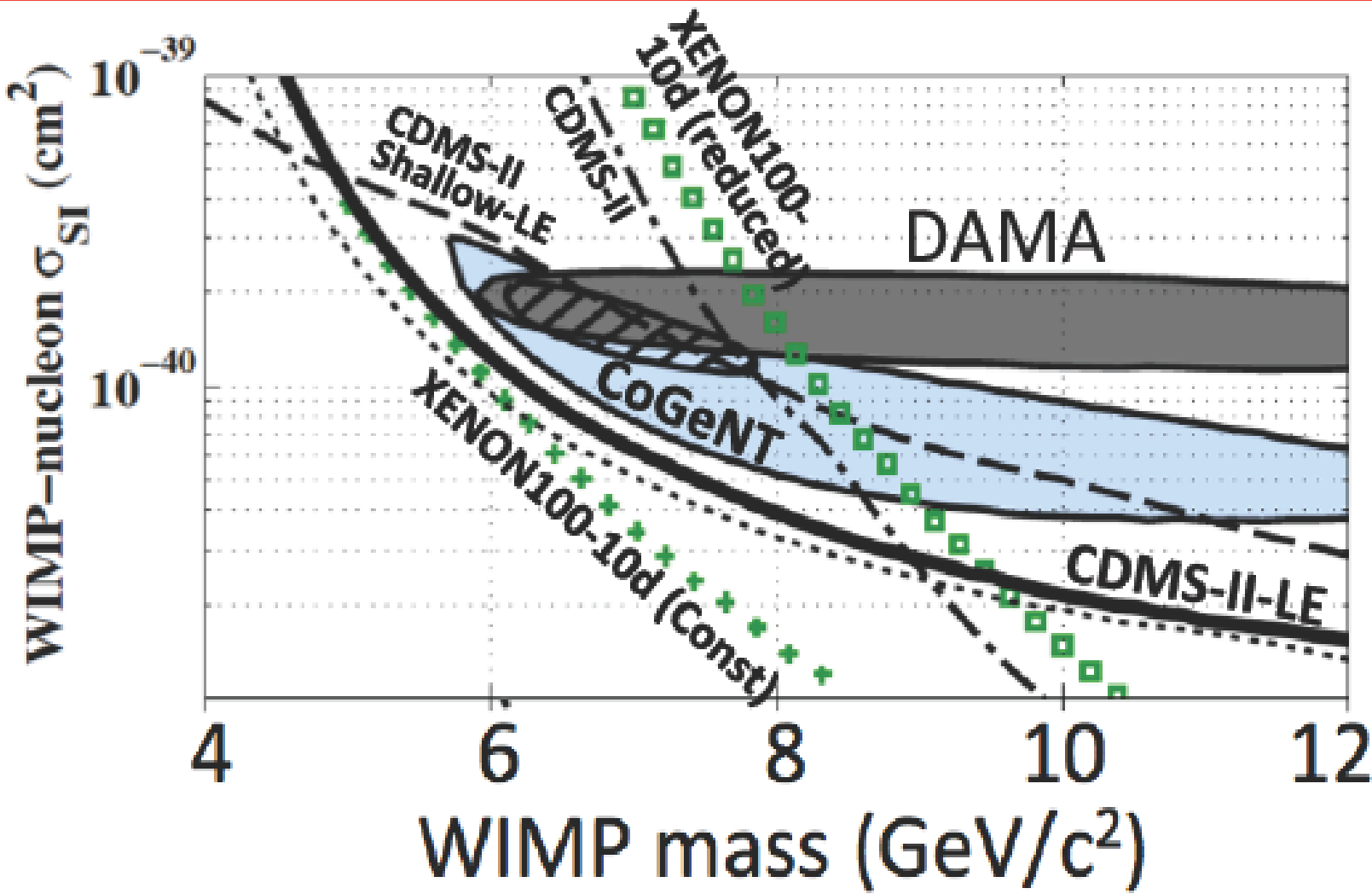
Recent Status

Sorry,
We did not plot all the
results

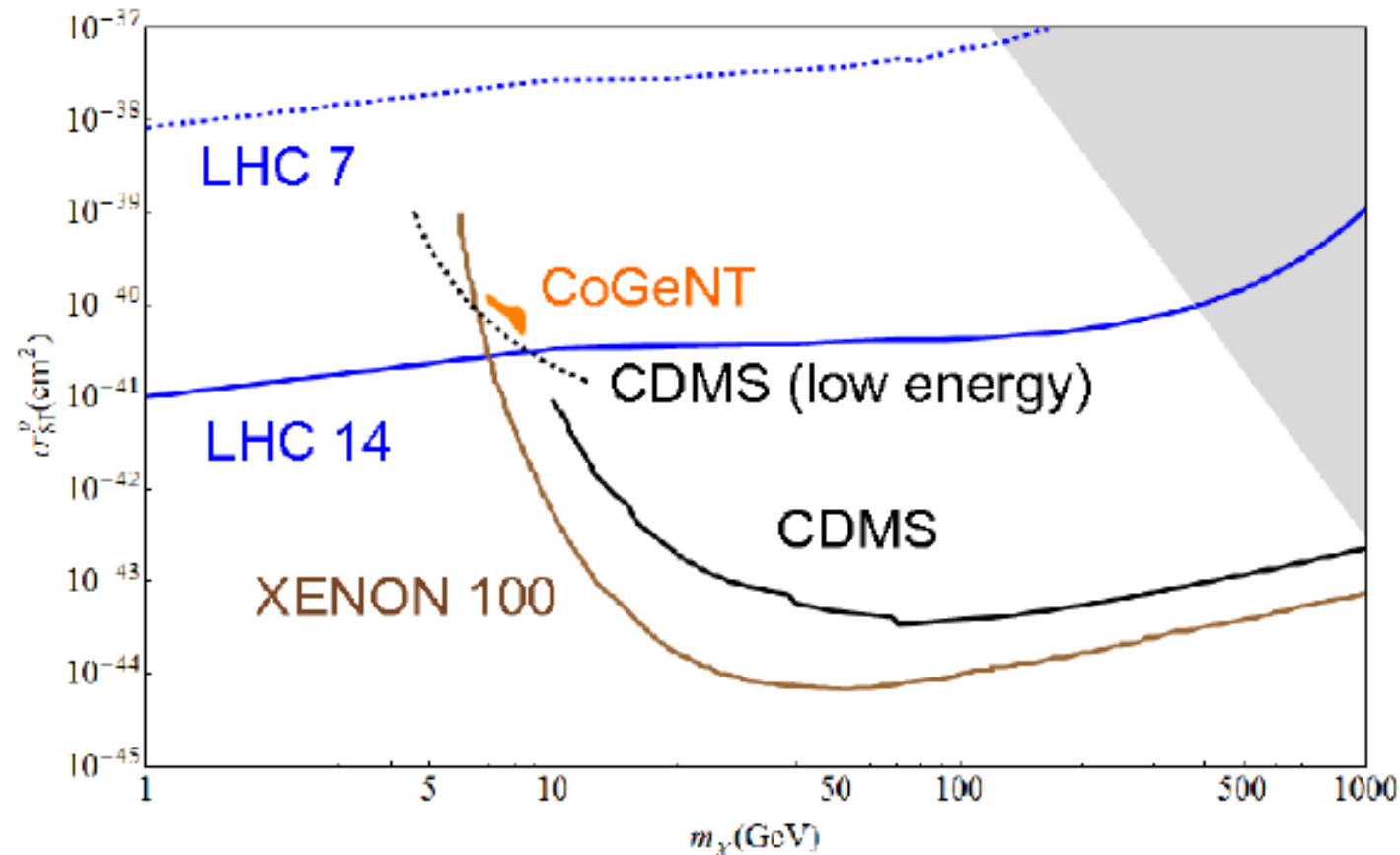
CRESST-II:
Wait until their FINAL
results

Low threshold Analysis by
CDMS-II (LE) and
XENON-10 (LE)





Bounds on the reachable DM cross section with quarks at the LHC in comparison with the sensitivity reached by DM direct searches



Bai, Fox, Harnik, arXiv:1005.3797; Wang, Li, Shao, Zhang, arXiv:1107.2048; Fox, Harnek, Kopp, Tsai, arXiv:1103.0240

DM and **NON-STANDARD COSMOLOGIES** **BEFORE NUCLEOSYNTHESIS**

- **NEUTRALINO RELIC DENSITY MAY DIFFER FROM ITS STANDARD VALUE**, i.e. the value it gets when the expansion rate of the Universe is what is expected in Standard Cosmology (EX.: **SCALAR-TENSOR THEORIES OF GRAVITY, KINATION, EXTRA-DIM. RANDALL-SUNDRUM TYPE II MODEL, ETC.**)
- **WIMPS MAY BE “COLDER”**, i.e. they may have smaller typical velocities and, hence, they may lead to smaller masses for the first structures which form **GELMINI, GONDOLO**

WHY $H \neq H_{\text{GR}}$

$$H_{\text{GR}}^2 = \frac{1}{3M_p^2} \rho_{\text{tot}} \simeq 2.76 g_* \frac{T^4}{M_p^2}$$

1 Change the number of relativistic d.o.f.'s, g_* ;

R. Catena

2 Consider a ρ_{tot} not dominated by relativistic d.o.f.'s;

- Kination

P. Salati, Phys. Lett. B 571 (2003) 121

3 Consider theories where the effective Planck mass is different from the constant M_p :

- Scalar-Tensor theories

R. C., N. Fornengo, A. Masiero, M. Pletroni and F. Rosati, Phys. Rev. D 70 (2004) 063519

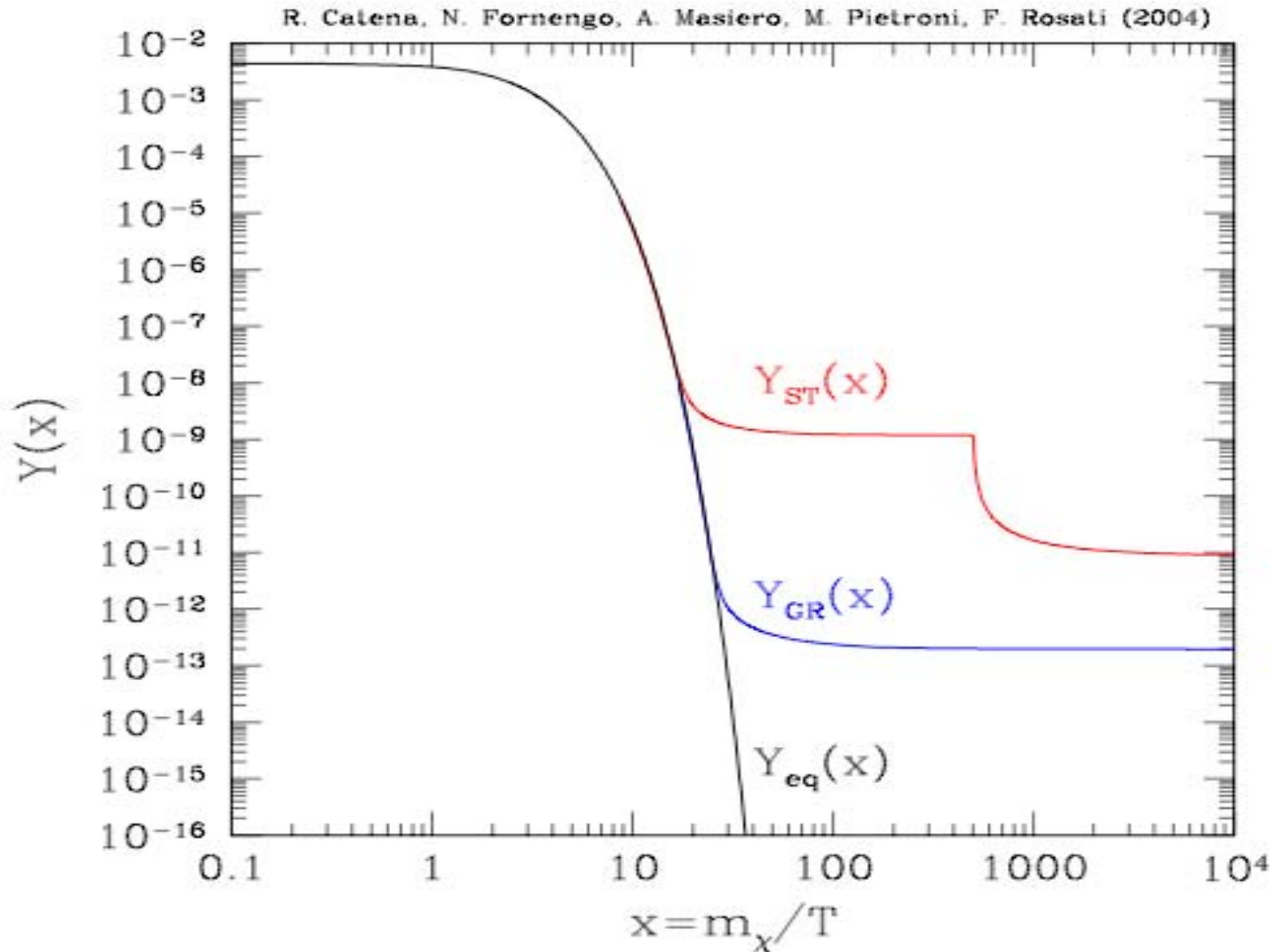
- Extradimensions

L. Randall and R. Sundrum, Phys. Rev. Lett. 83 (1999) 4690

LARGER WIMP ANNIHILATION CROSS-SECTION IN NON-STANDARD COSMOLOGIES

- Having a Universe expansion rate at the WIMP freeze-out larger than in Standard Cosmology → possible to provide a DM adequate WIMP population even in the presence of a larger annihilation cross-section (Catena, Fornengo, A.M., Pietroni)
- Possible application to increase the present DM annihilation rate to account for the PAMELA results in the DM interpretation (instead of other mechanisms like the Sommerfeld effect or a nearby resonance)

NEUTRALINO RELIC ABUNDANCE IN GR AND S-T THEORIES OF GRAVITY



$$H = A(T)H_{\text{std}} \quad \text{at early times}$$

$$H = H_{\text{std}} \quad \text{at later times}$$

$$A(T) = 1 + \eta \left(\frac{T}{T_f} \right)^\nu \tanh \left(\frac{T - T_{\text{re}}}{T_{\text{re}}} \right)$$

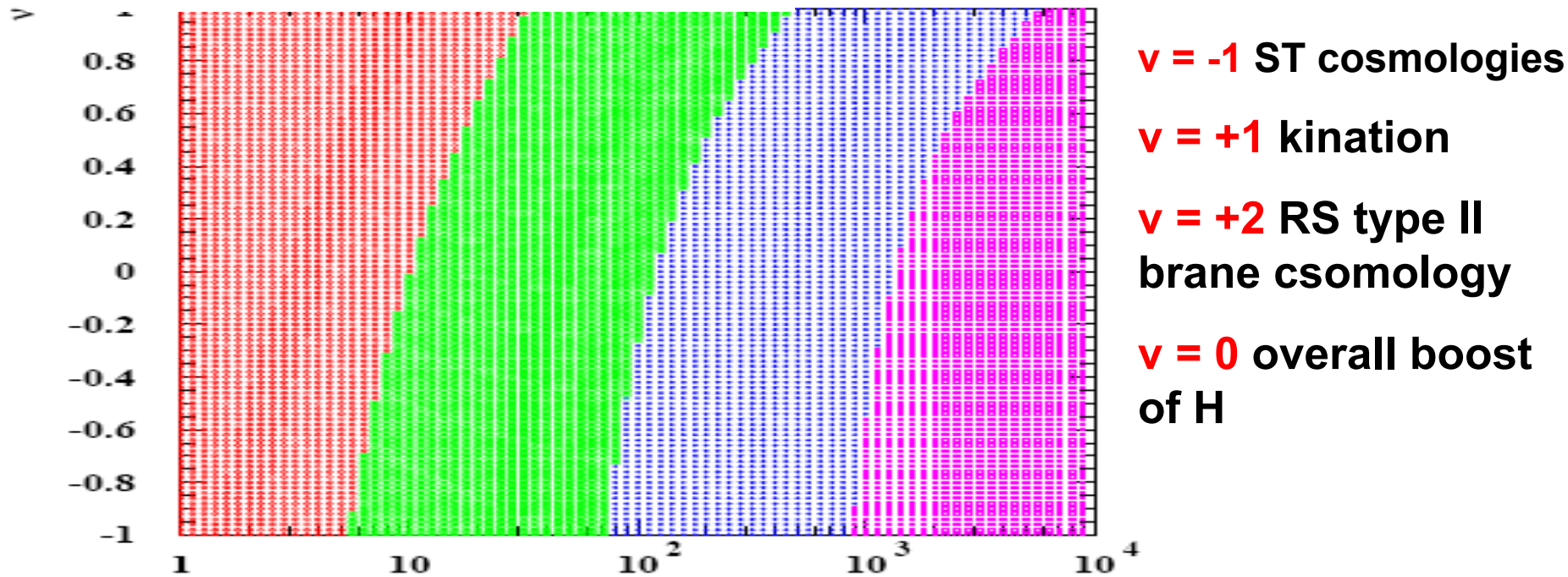
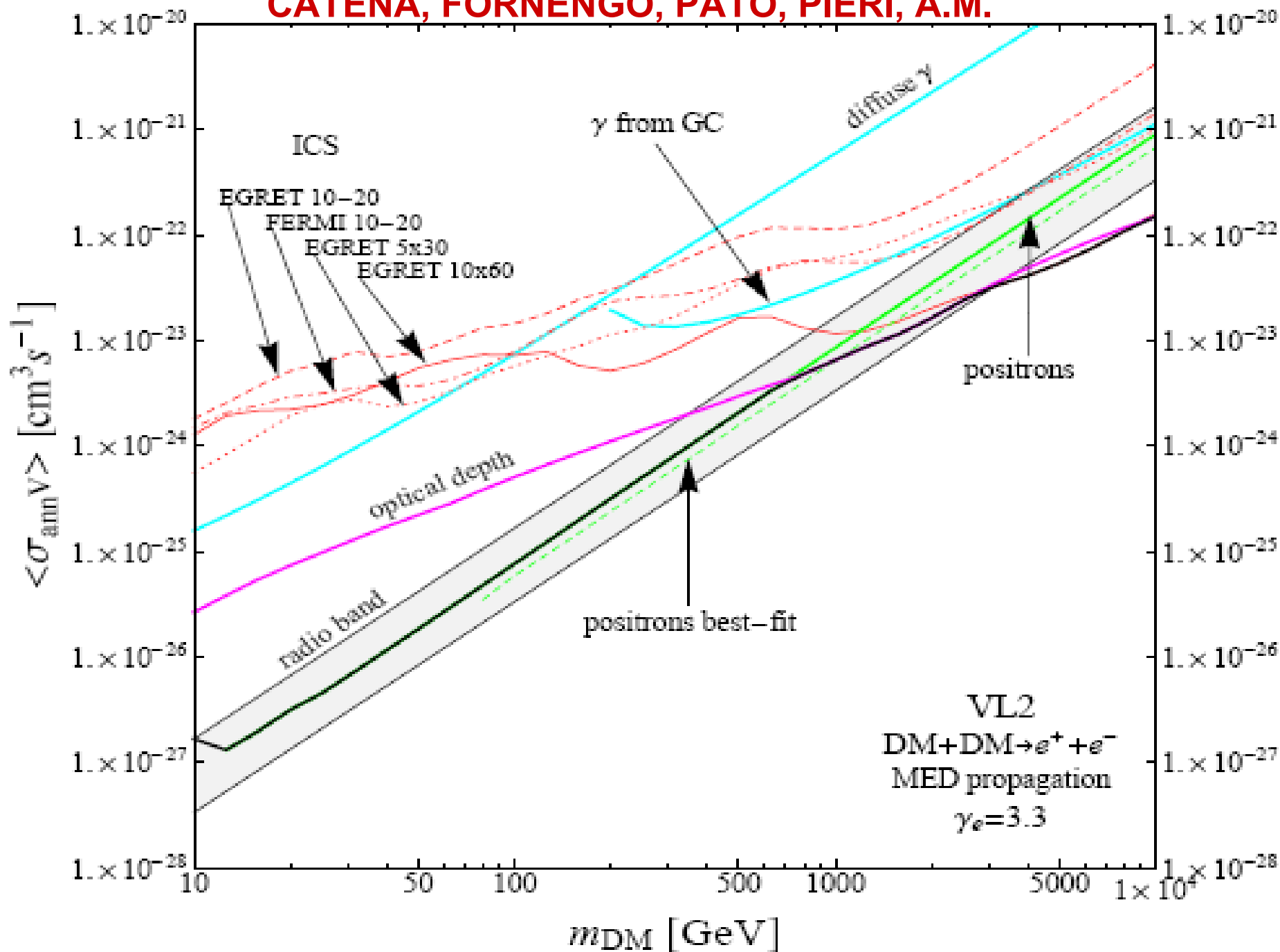


FIG. 12: Contour plot of the enhancement $R = (\Omega h^2)/(\Omega h^2)_{\text{GR}}$ of the WIMP relic abundance in a scenario with enhanced Hubble rate compared to the standard GR cosmology. The different bands refer to (from left to right): $1 \leq R \leq 10$, $10 < R \leq 100$, $100 < R \leq 1000$, $1000 < R$. The highest value of R is around $7.5 \cdot 10^3$. We have fixed $m_\chi = 500$ GeV and $T_{\text{re}} = 10^{-3}$ GeV. For all points, the WIMP relic-density, as calculated in the modified cosmology, satisfies the dark matter density constraint.

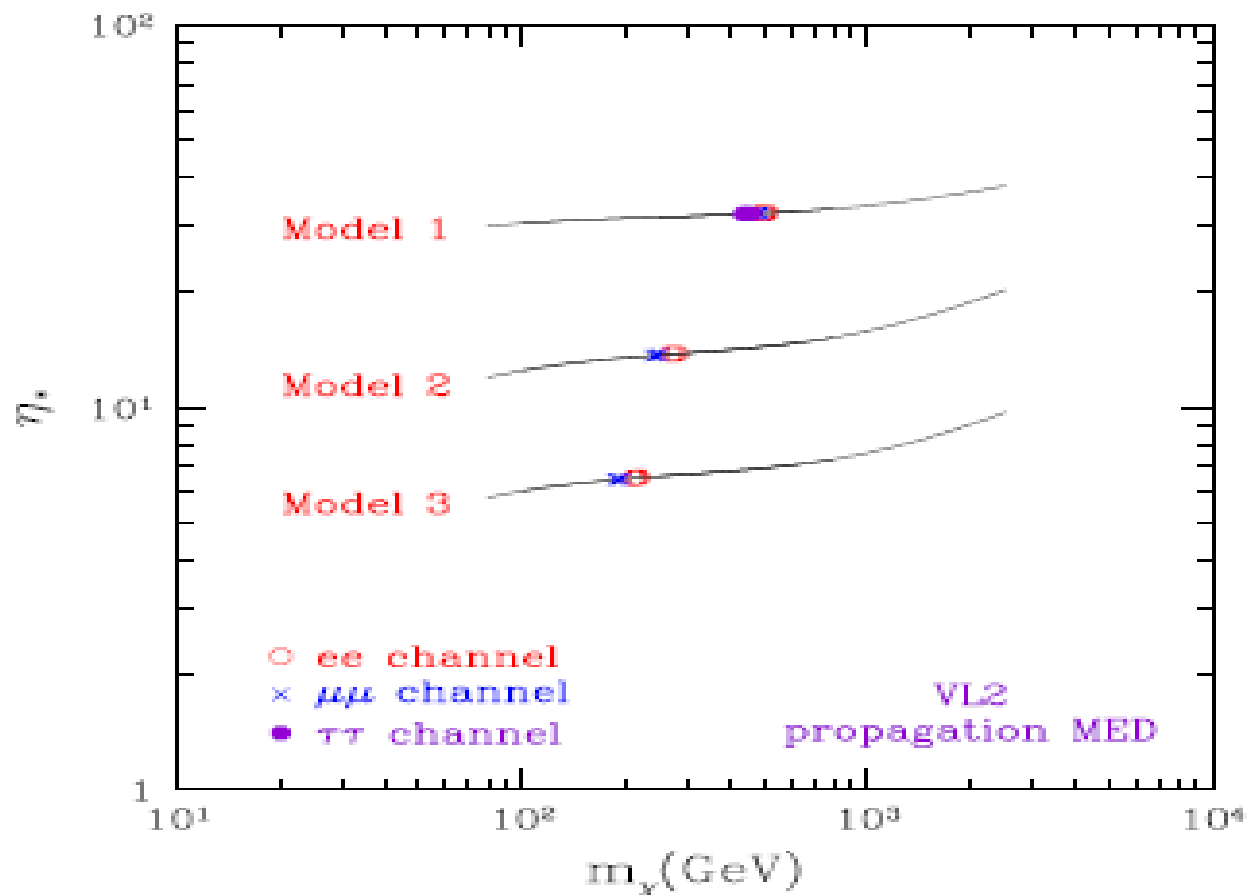
**SCHELKE,
CATENA,
FORNENGO,
A.M., PIETRONI**

CATENA, FORNENGO, PATO, PIERI, A.M.

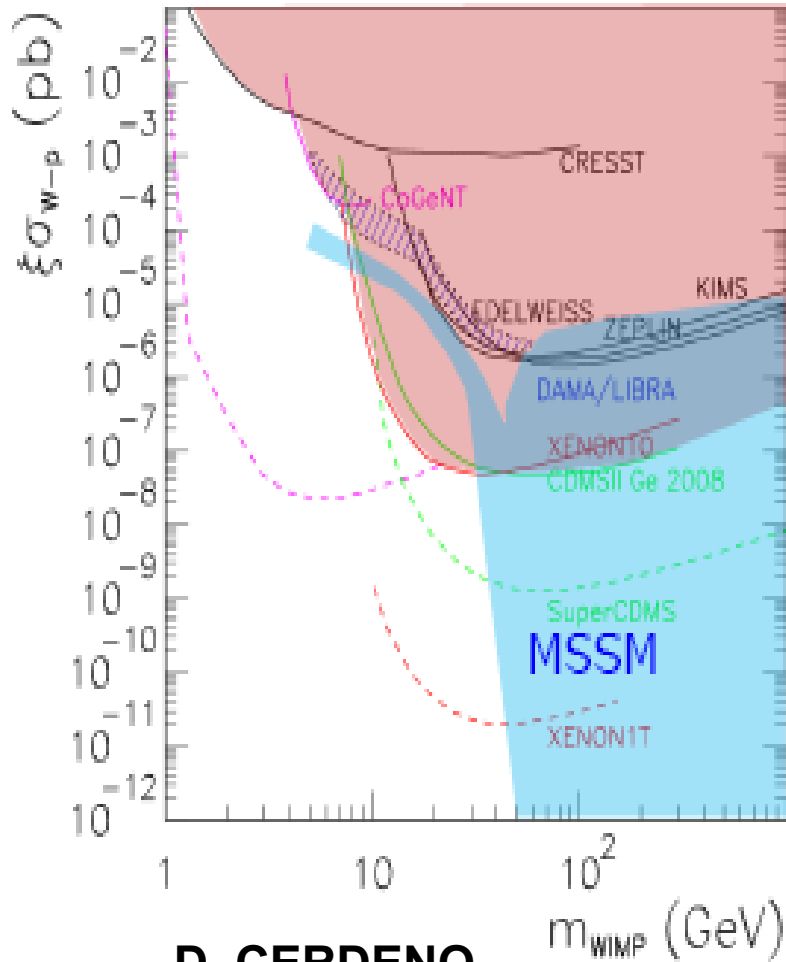


For a ~ 100 GeV WIMP, large departures from GR ($H/H_{\text{GR}} > 100$) are unlikely

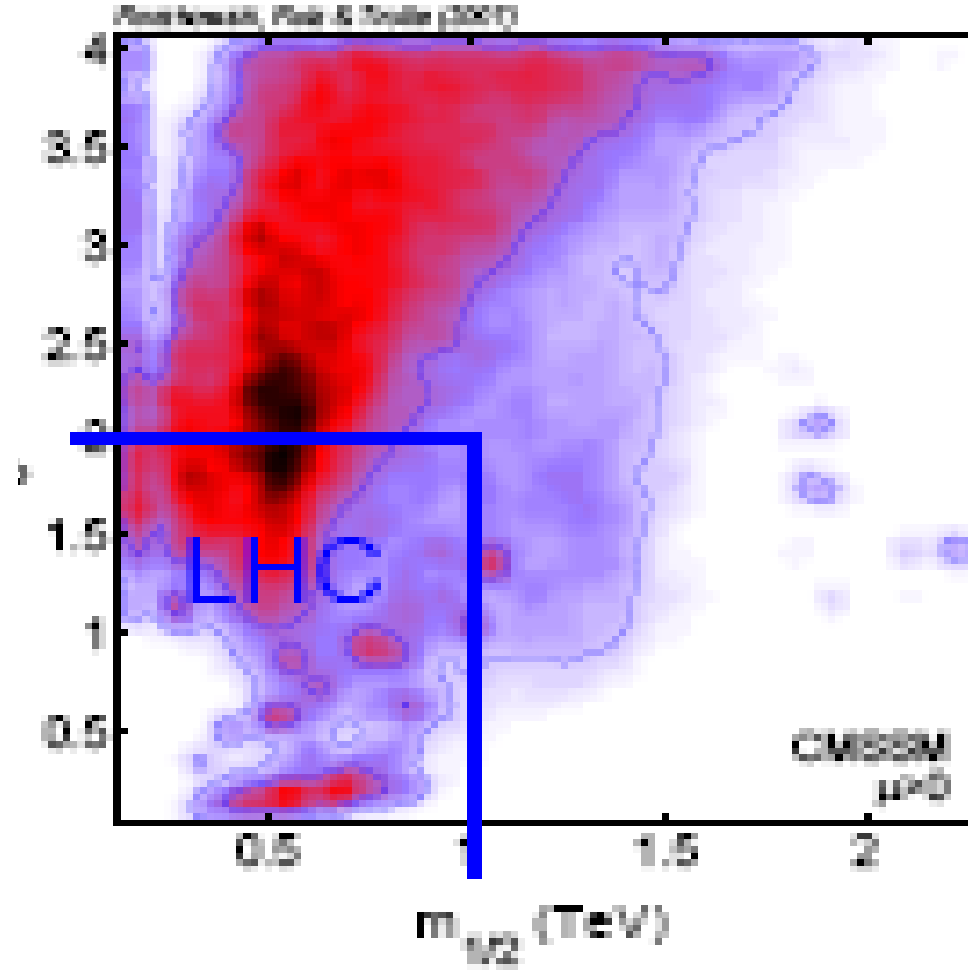
CFPPM '10



On the LHC – Direct DM searches coverage of the MSSM parameter space

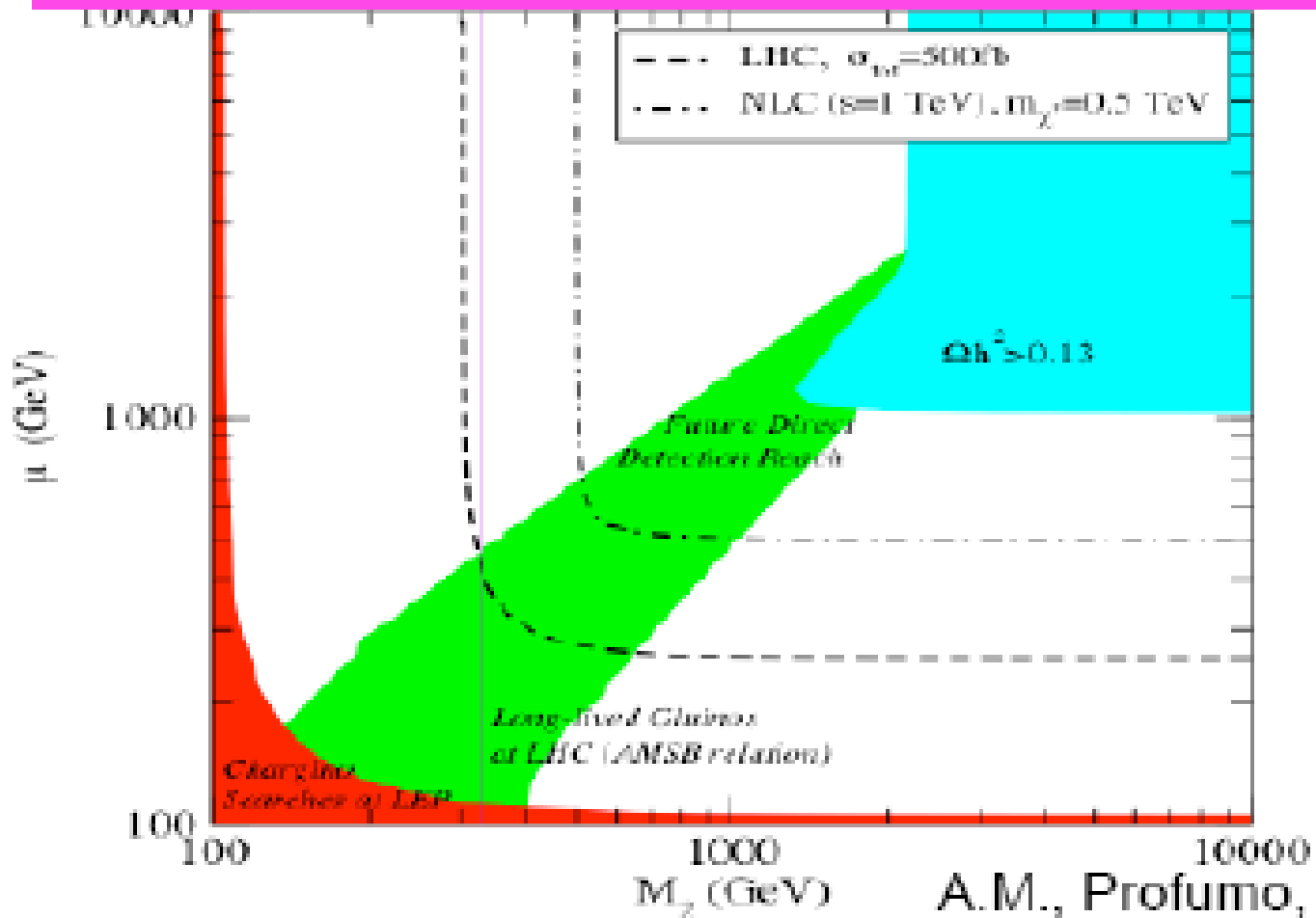


**D. CERDENO
WONDER10**



L. Roszkowski et al.

LHC, ILC, DM SEARCHES SENSITIVITIES



DIRECT AND INDIRECT SEARCHES FOR WIMPs

- **PROBING NEW PHYSICS AT THE ELW. SCALE**
- **INFORMATION ON THE EVOLUTION OF THE EARLY UNIVERSE BEFORE THE NUCLEOSYNTHESIS TIME, i.e. at times < 1 sec.**


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

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

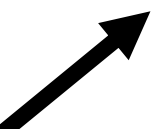
If $c_{\text{new}} \sim c_{\text{SM}} \sim 1$

Isidori

$\Lambda > 10^4 \text{ TeV}$ for $O^{(6)} \sim (\bar{s} d)^2$
[$K^0 - \bar{K}^0$ mixing]



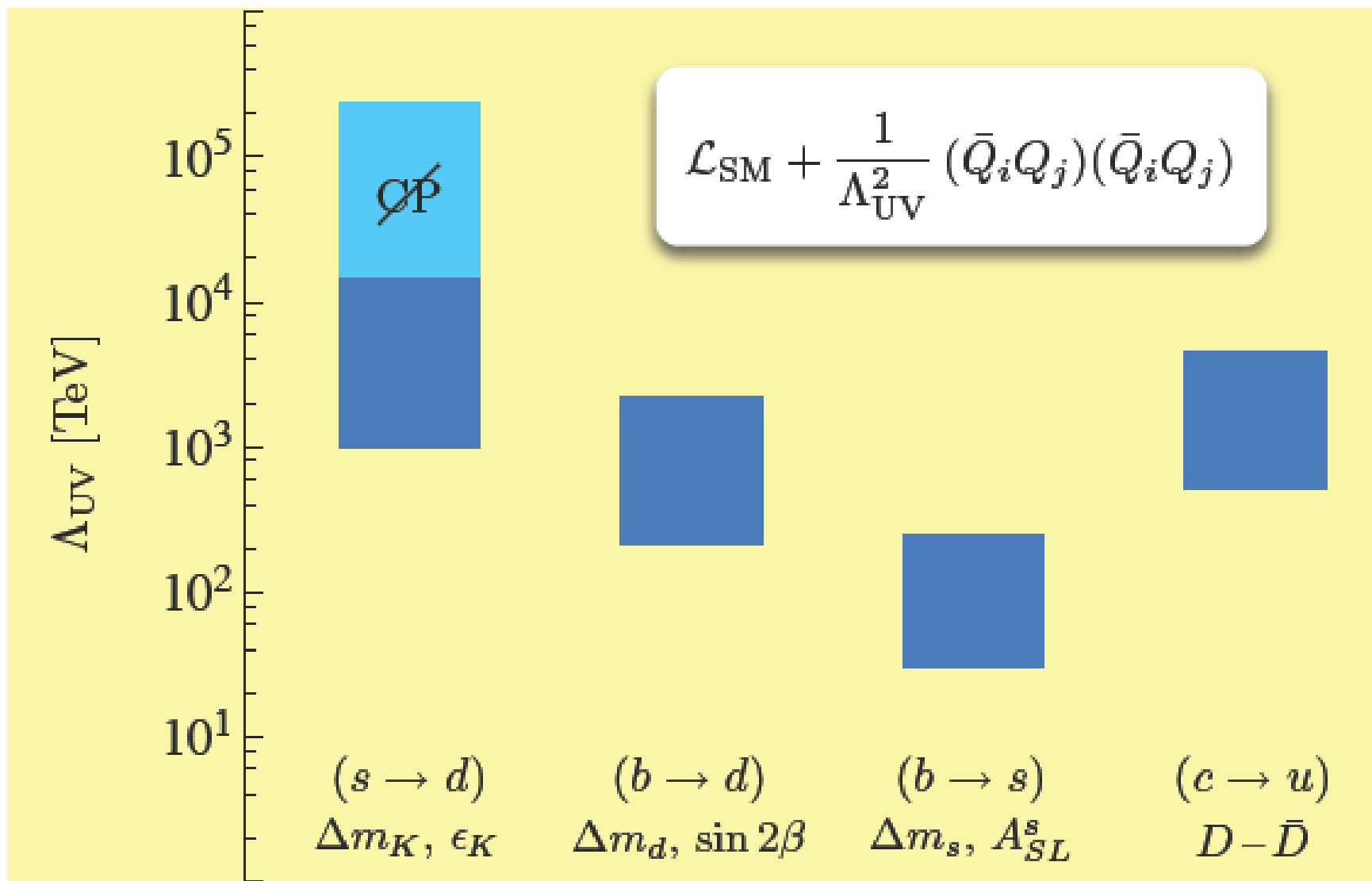
$\Lambda > 10^3 \text{ TeV}$ for $O^{(6)} \sim (\bar{b} d)^2$
[$B^0 - \bar{B}^0$ mixing]



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

Flavor Structure in the SM and Beyond

NEUBERT EPS-HEP 2011



Generic bounds without a flavor symmetry

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

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

$$Y_t \sim 1, \quad Y_c \sim 10^{-2}, \quad Y_u \sim 10^{-5}$$

$$Y_b \sim 10^{-2}, \quad Y_s \sim 10^{-3}, \quad Y_d \sim 10^{-4}$$

$$Y_\tau \sim 10^{-2}, \quad Y_\mu \sim 10^{-3}, \quad Y_e \sim 10^{-6}$$

$$|V_{us}| \sim 0.2, \quad |V_{cb}| \sim 0.04, \quad |V_{ub}| \sim 0.004, \quad \delta_{KM} \sim 1$$

**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”**

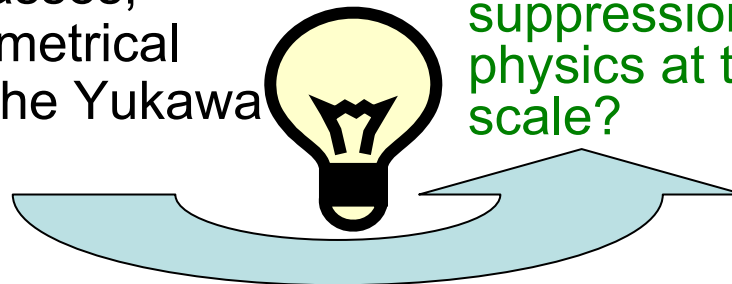
(new flavour – horizontal symmetry, radiatively induced lighter fermion masses, dynamical or geometrical determination of the Yukawa couplings, ...?)

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**.

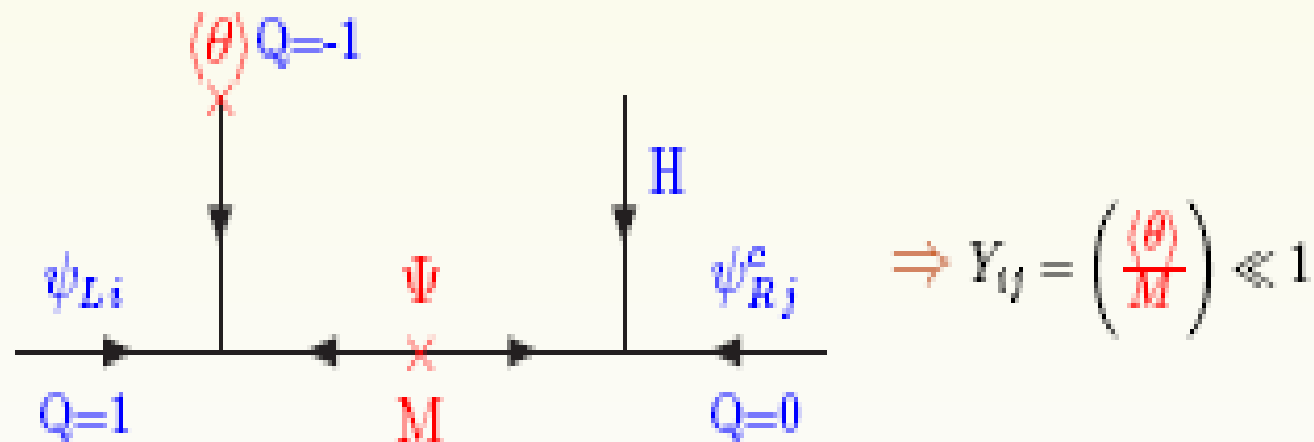
How to cope with such delicate suppression if there is new physics at the electroweak scale?



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**

- Froggatt-Nielsen mechanism and flavour symmetry to understand small Yukawa elements. Example: $U(1)_F$



Yukawa Textures

What we want:

$$Y_u \propto \begin{pmatrix} 0 & \varepsilon^3 & \varepsilon^3 \\ \varepsilon^3 & \varepsilon^2 & \varepsilon^2 \\ \varepsilon^3 & \varepsilon^2 & 1 \end{pmatrix} \quad Y_d \propto \begin{pmatrix} 0 & \bar{\varepsilon}^3 & \bar{\varepsilon}^3 \\ \bar{\varepsilon}^3 & \bar{\varepsilon}^2 & \bar{\varepsilon}^2 \\ \bar{\varepsilon}^3 & \bar{\varepsilon}^2 & 1 \end{pmatrix}$$

$$\varepsilon = 0.05 \quad \bar{\varepsilon} = 0.15$$

$SU(3)$ Flavour model

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

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

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

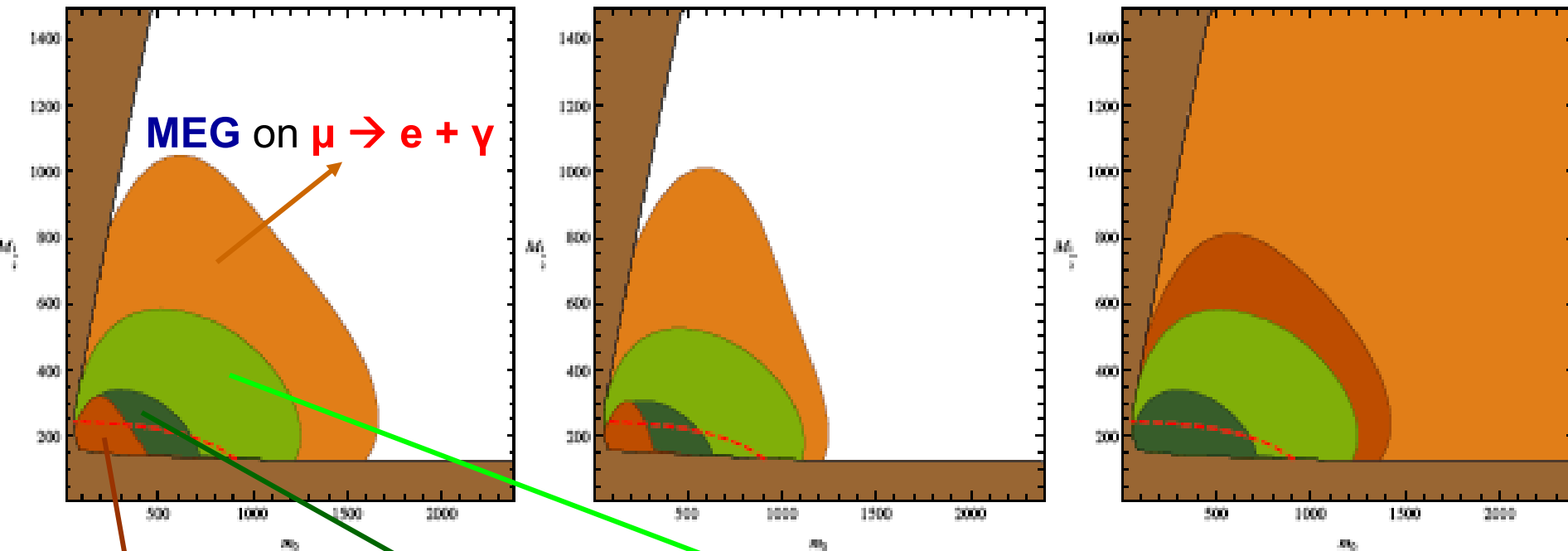
$\theta_3, \bar{\theta}_3 = \begin{pmatrix} 0 \\ 0 \\ a_3 \end{pmatrix}, \theta_{23}, \bar{\theta}_{23} = \begin{pmatrix} 0 \\ b \\ b \end{pmatrix}$ with $\left(\frac{a_3}{M}\right) \sim \mathcal{O}(1), \left(\frac{b}{M_u}\right) \simeq \left(\frac{b}{M_d}\right)^2 = \epsilon \sim 0.05.$

• Yukawa superpotential: $W_Y = H \psi_i \psi_j^c \left[\theta_3^i \theta_3^j + \theta_{23}^i \theta_{23}^j (\theta_3 \bar{\theta}_3) + \epsilon^{ikh} \bar{\theta}_{23,k} \bar{\theta}_{3,l} \theta_{23}^j (\theta_{23} \bar{\theta}_3) \right]$

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

O. VIVES

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



MEG on $\mu \rightarrow e + \gamma$

PRESENT BOUND ON
 $\tau \rightarrow \mu + \gamma$

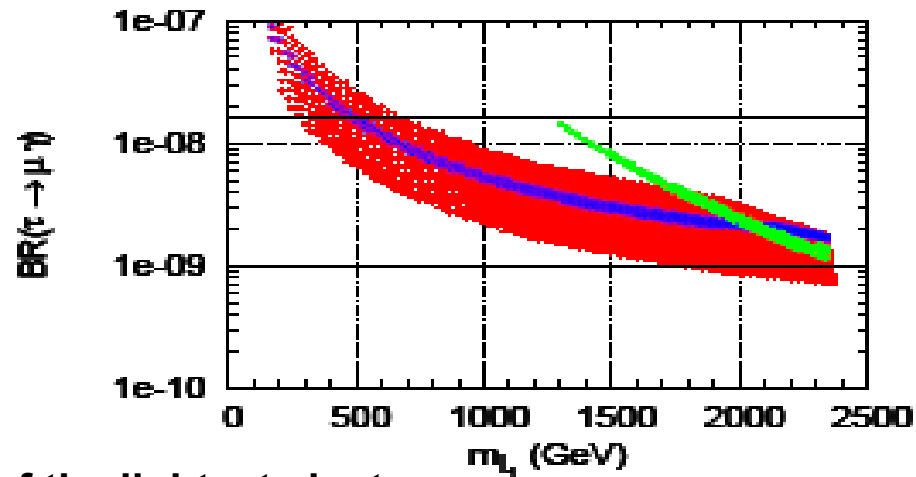
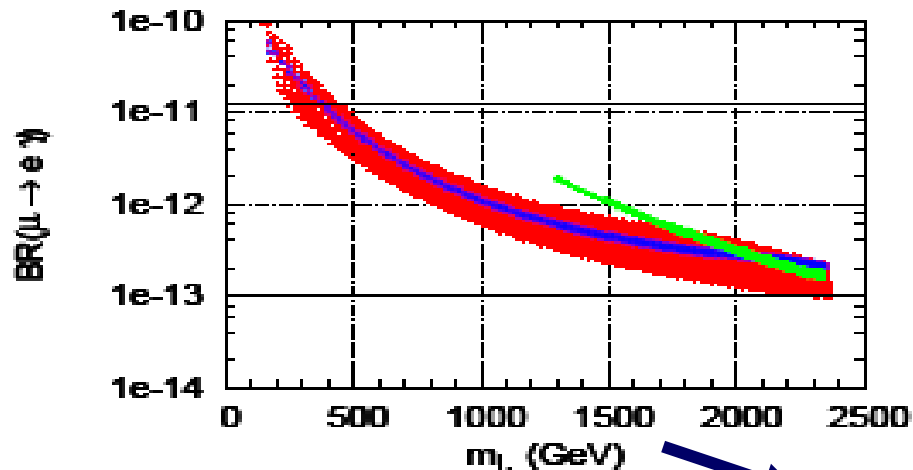
FUTURE BOUND ON $\tau \rightarrow \mu + \gamma$
at SUPER B

PRESENT BOUND ON
 $\mu \rightarrow e + \gamma$

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

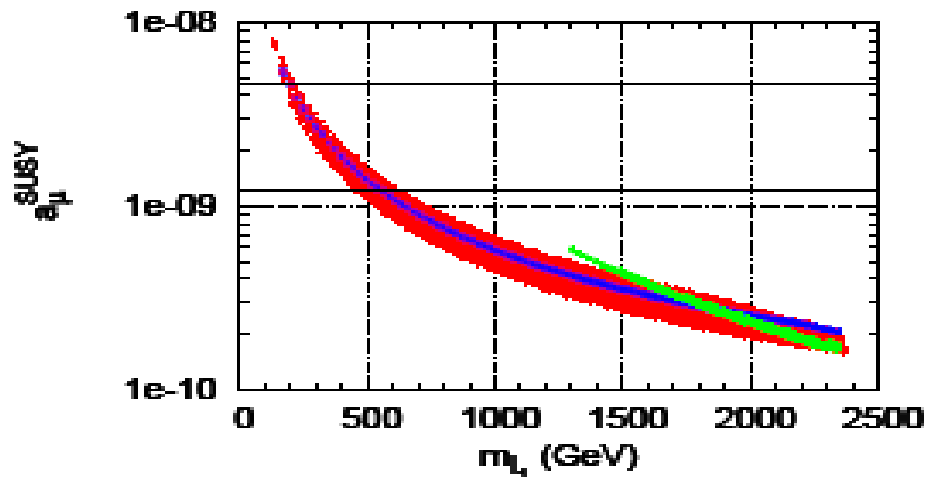
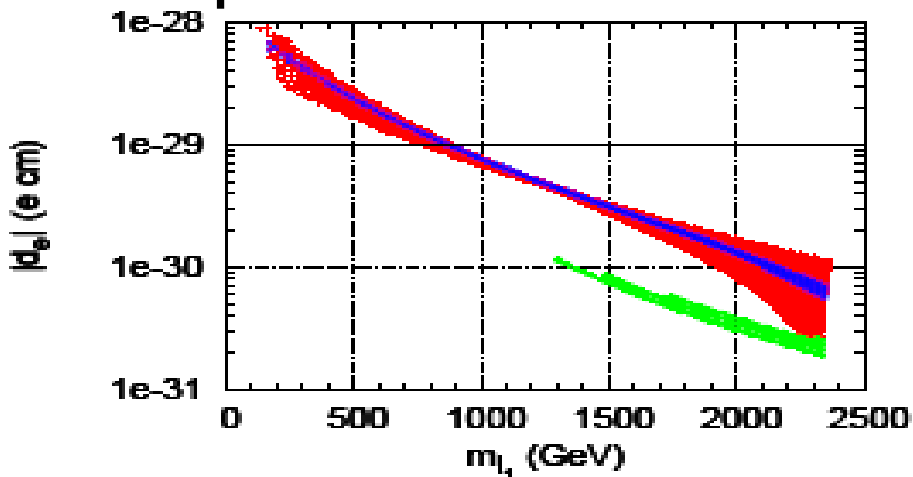
LEPTONIC OBSERVABLES IN *SU(3) – FLAVORED SUSY with LARGE SUSY CP CONTRIBUTIONS*

IN THE POINTS OF THE COLORED REGIONS THE “ ϵ_K DISCREPANCY”
 IS ACCOUNTED FOR BY SUSY CONTRIBUTIONS CJMPPV ‘09



$\tan \beta = 30$ and $A = 0$

Mass of the lightest slepton



FLAVOR BLINDNESS OF THE NP AT THE ELW. SCALE?

- **THREE DECADES OF FLAVOR TESTS** (Redundant determination of the UT triangle \longrightarrow verification of the SM, theoretically and experimentally “high precision” FCNC tests, ex. $b \longrightarrow s + \gamma$, 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

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 \longrightarrow

**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!

SuperB vs. LHC Sensitivity

Reach in testing Λ_{SUSY}

	superB	general MSSM	high-scale MFV
$ \left(\delta_{13}^d\right)_{LL} (LL \gg RR)$	$1.8 \cdot 10^{-2} \frac{m_{\tilde{q}}}{(350\text{GeV})}$	1	$\sim 10^{-3} \frac{(350\text{GeV})^2}{m_{\tilde{q}}^2}$
$ \left(\delta_{13}^d\right)_{LL} (LL \sim RR)$	$1.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\text{GeV})}$	1	—
$ \left(\delta_{13}^d\right)_{LR} $	$3.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\text{GeV})}$	$\sim 10^{-1} \tan \beta \frac{(350\text{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-4} \tan \beta \frac{(350\text{GeV})^3}{m_{\tilde{q}}^3}$
$ \left(\delta_{23}^d\right)_{LR} $	$1.0 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\text{GeV})}$	$\sim 10^{-1} \tan \beta \frac{(350\text{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-3} \tan \beta \frac{(350\text{GeV})^3}{m_{\tilde{q}}^3}$

SuperB can probe MFV (with small-moderate $\tan\beta$) for TeV squarks; for a generic non-MFV MSSM \longrightarrow sensitivity to squark masses > 100 TeV !

Ciuchini, Isidori, Silvestrini ***SLOW-DECOUPLING OF NP IN FCNC***

Estimates of error for 2015



Hadronic matrix element	Current lattice error	6 TFlop Year	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9% (22% on $1-f_+$)	0.7% (17% on $1-f_+$)	0.4% (10% on $1-f_+$)	< 0.1% (2.4% on $1-f_+$)
\hat{B}_K	11%	5%	3%	1%
f_B	14%	3.5 - 4.5%	2.5 - 4.0%	1 - 1.5%
$f_{B_s} B_{B_s}^{1/2}$	13%	4 - 5%	3 - 4%	1 - 1.5%
ξ	5% (26% on $\xi-1$)	3% (18% on $\xi-1$)	1.5 - 2 % (9-12% on $\xi-1$)	0.5 - 0.8 % (3-4% on $\xi-1$)
$\mathcal{F}_{B \rightarrow D/D^*lv}$	4% (40% on $1-\mathcal{F}$)	2% (21% on $1-\mathcal{F}$)	1.2% (13% on $1-\mathcal{F}$)	0.5% (5% on $1-\mathcal{F}$)
$f_+^{B\pi}, \dots$	11%	5.5 - 6.5%	4 - 5%	2 - 3%
$T_1^{B \rightarrow K^*/\rho}$	13%	----	----	3 - 4%

SUSY SEE-SAW

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

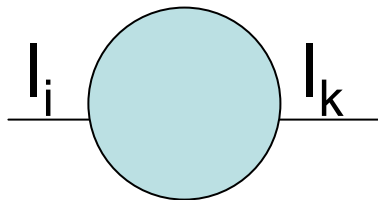
**LOW-ENERGY
SUSY**

- 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:

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

NEW BOUND OF MEG AT THE EPS 2011

The MEG Experiment

$$\mu^+ \rightarrow e^+ \gamma$$

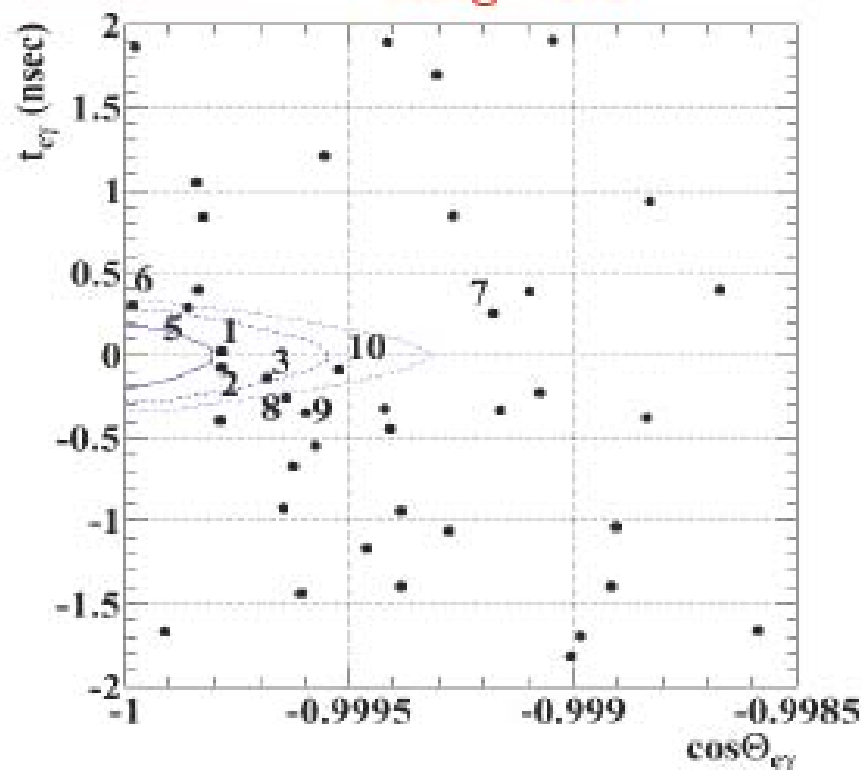
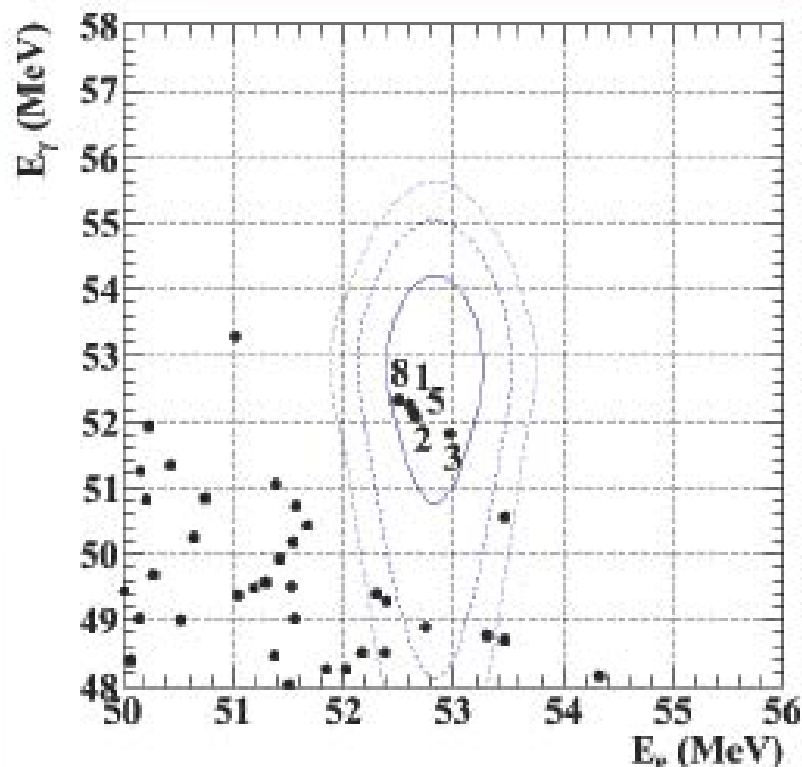
Event distribution after unblinding



$BR < 1.5 \times 10^{-11}$ @90%CL

6.1×10^{-12} expected

$N_{sig} = 3.0$

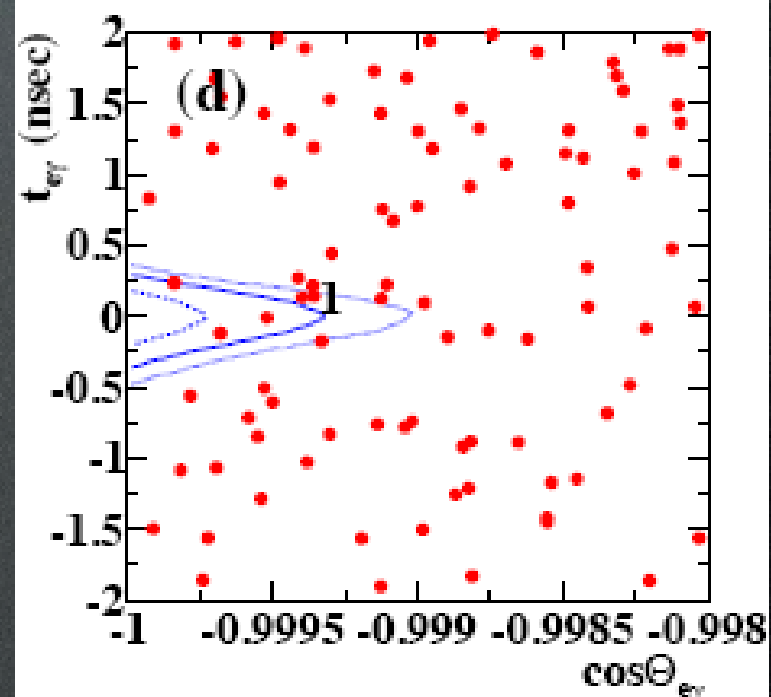
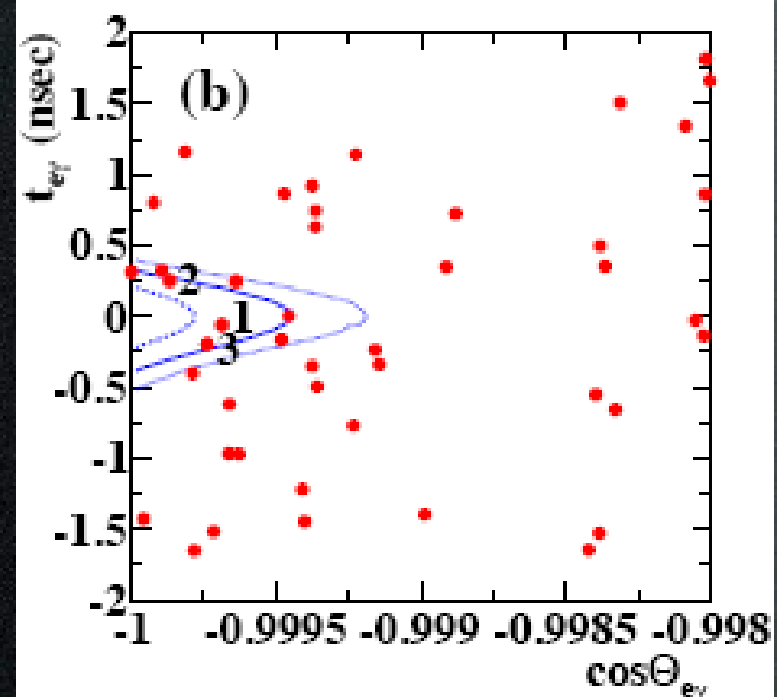
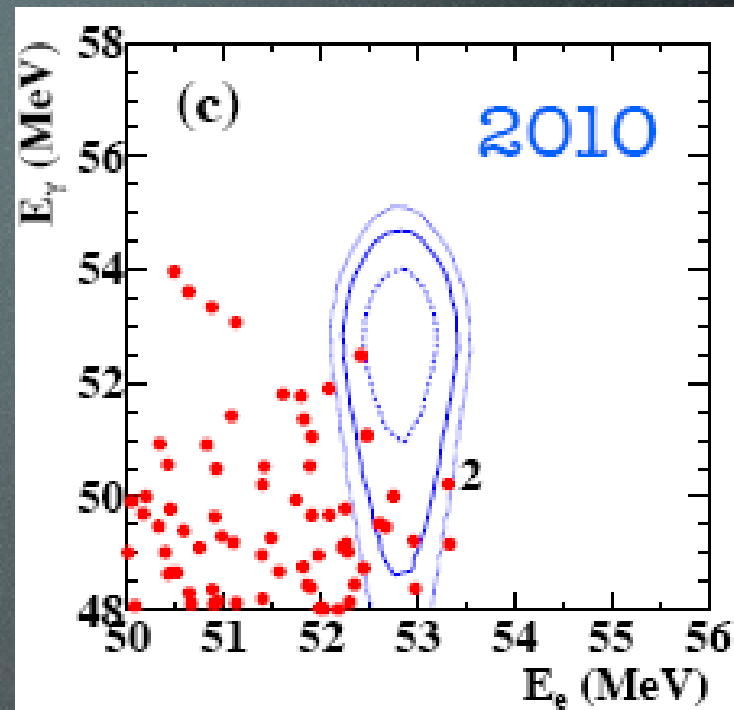
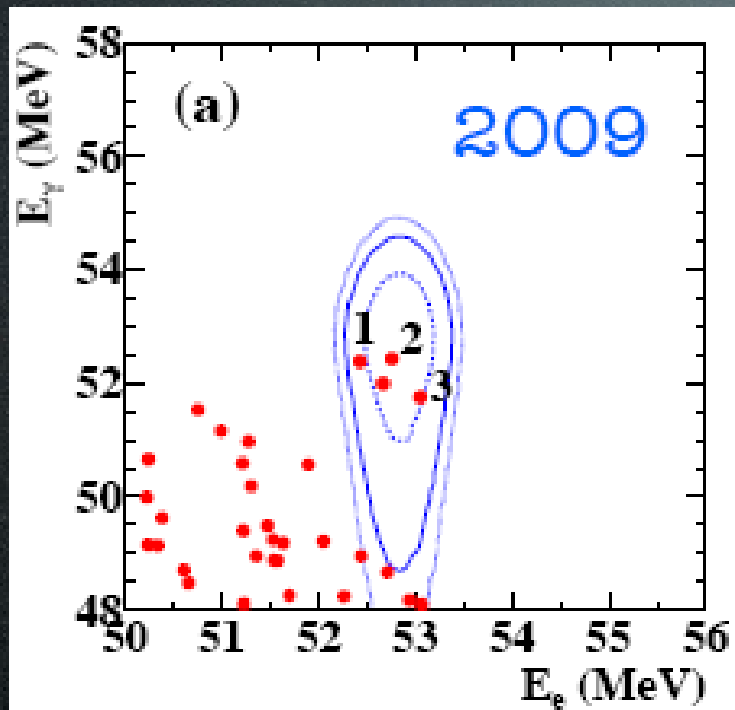


preliminary result of MEG 2009 data

Blue lines are 1(58.3% included inside the region w.r.t. analysis window), 1.64(74.2%) and 2(88.5%) sigma regions.

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

Numbers in figures are ranking by $L_{sig}/(L_{sig}+L_{B0})$. Same numbered dots in the right and the left figure are an identical event.



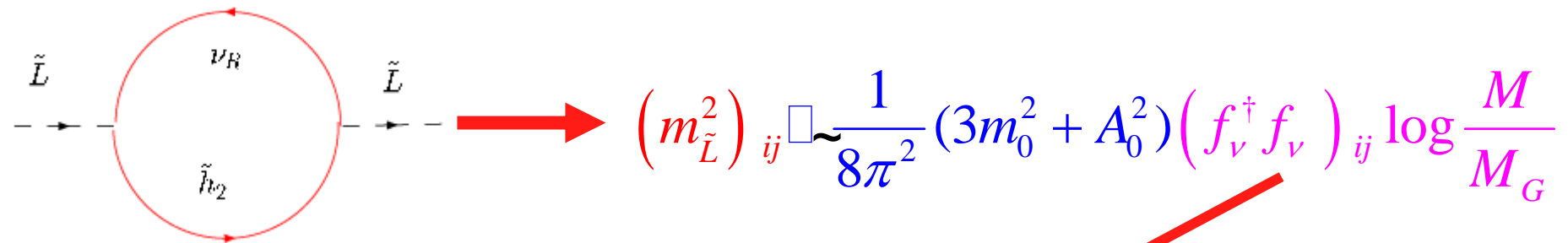
MEG summary

- 2009+2010 data consistent w/ no signal
- New physics is now constrained by
5× tighter upper limit:
 $BR < 2.4 \times 10^{-12}$ @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

SUSY SEESAW: Flavor universal SUSY breaking and yet large lepton flavor violation

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

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



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

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** \longrightarrow one large of $O(1) f_\nu$

U \longrightarrow two “extreme” cases:

- a) U with “small” entries \longrightarrow $U = CKM$;
- b) U with “large” entries with the exception of the 13 entry \longrightarrow $U = PMNS$ 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

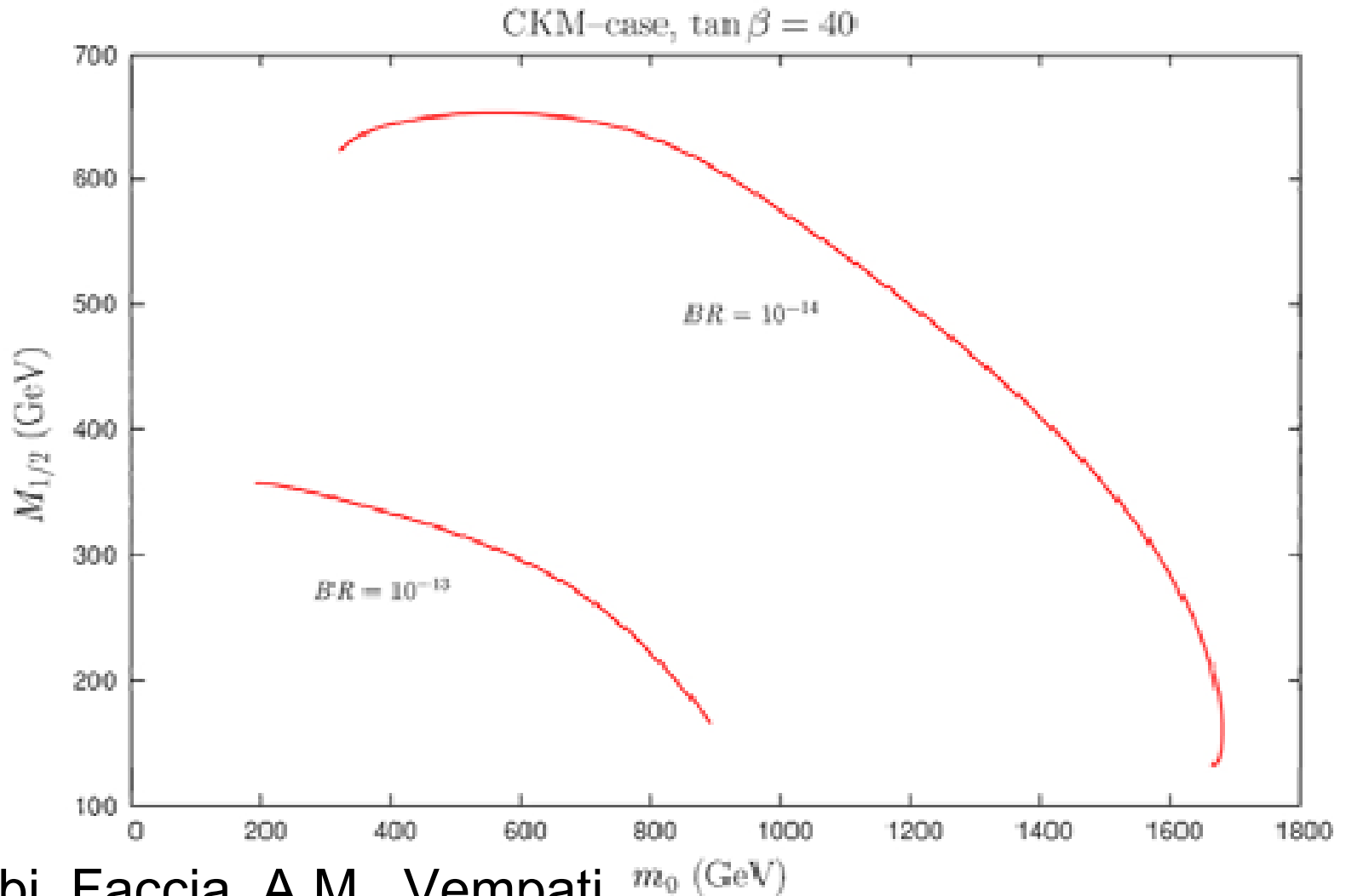
potentially large LFV

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;

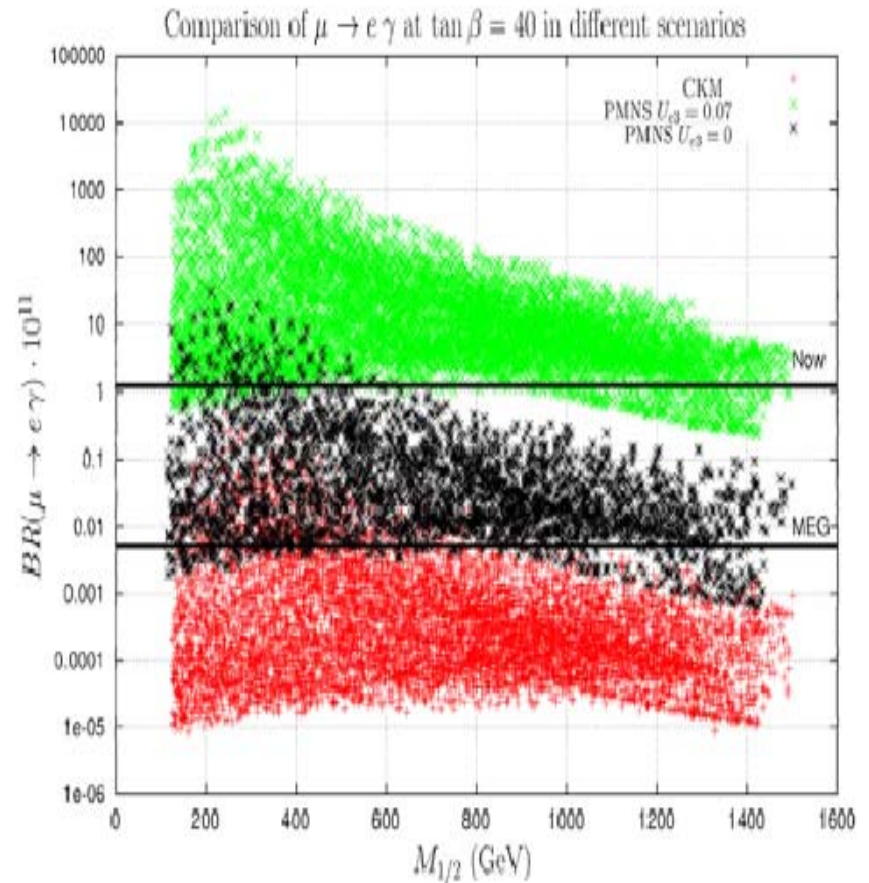
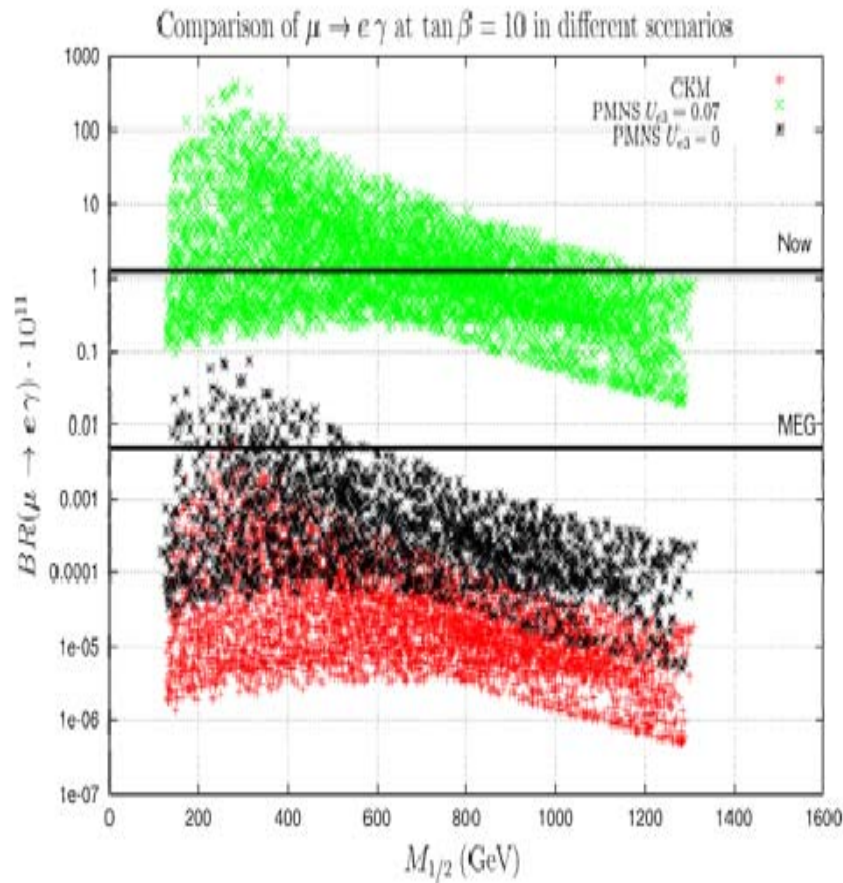
General analysis: Casas Ibarra; Lavignac, Masina, Savoy; Hisano, Moroi, Tobe, Yamaguchi; Ellis, Hisano, Raidal, Shimizu; Fukuyama, Kikuchi, Okada; Petcov, Rodejohann, Shindou, Takanishi; Arganda, Herrero; Deppish, Pas, Redelbach, Rueckl; Petcov, Shindou

MEG POTENTIALITIES TO EXPLORE THE SUSY SEESAW PARAM. SPACE

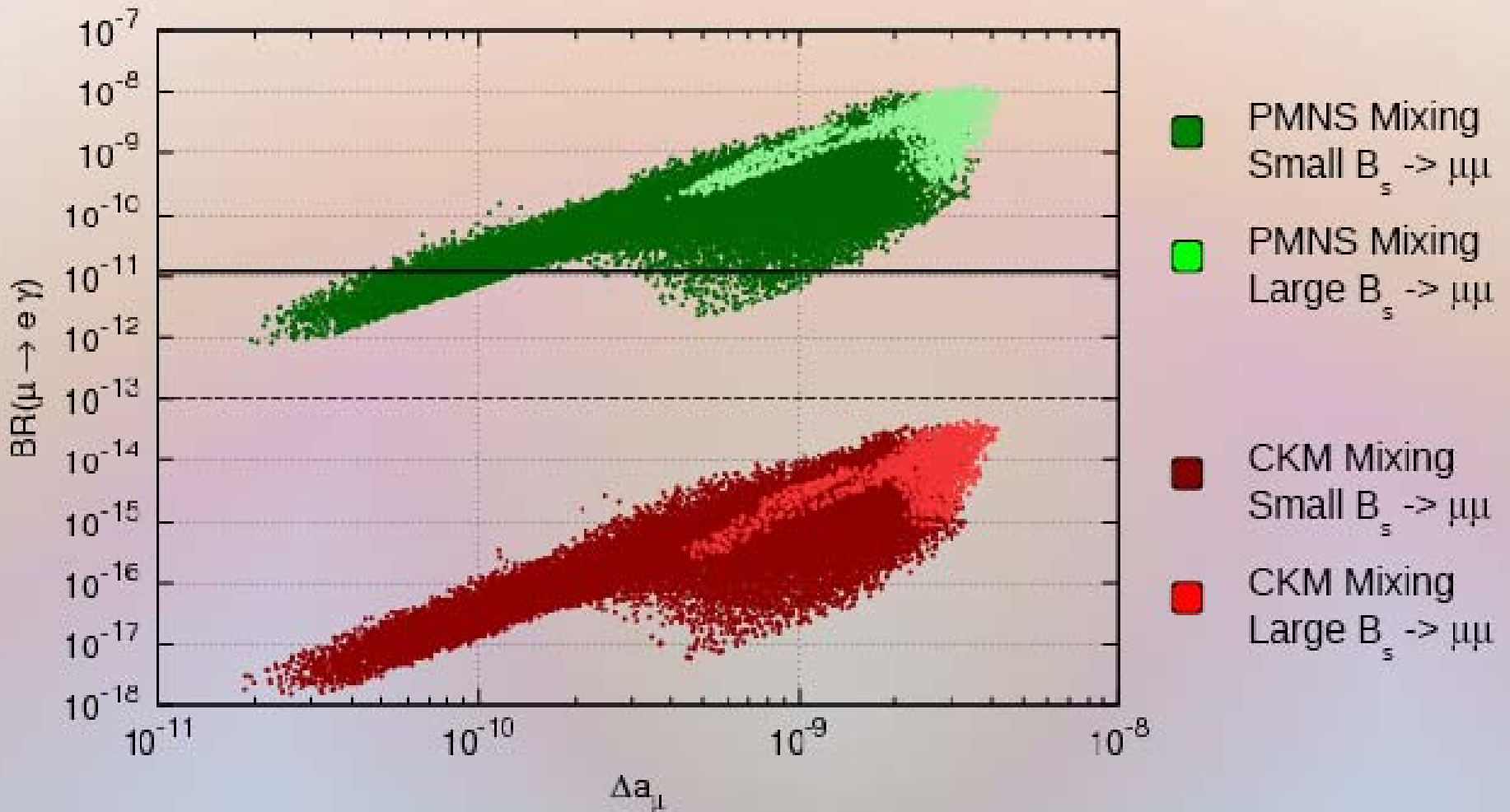


$\mu \rightarrow e\gamma$ in SUSYGUT: past and future

$\mu \rightarrow e\gamma$ in the $U_{e3} = 0$ PMNS case



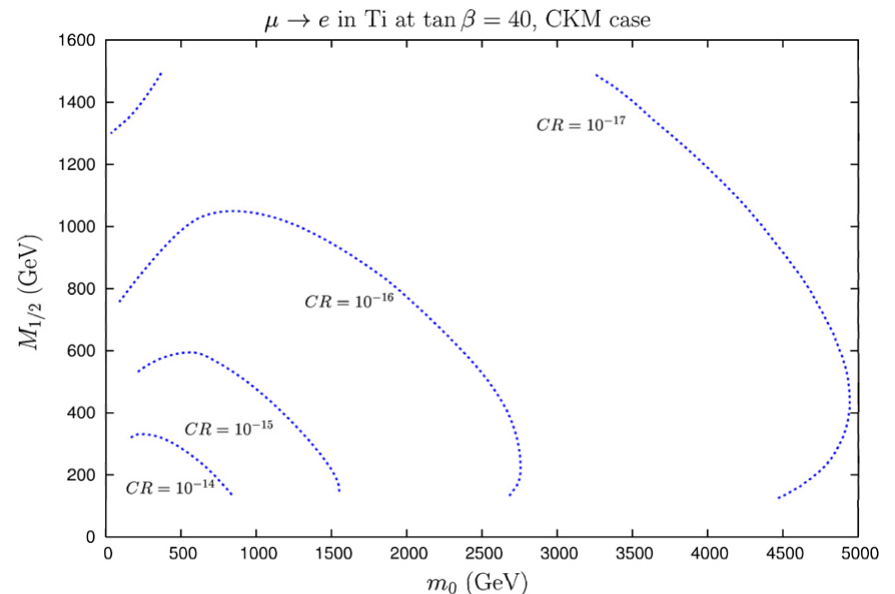
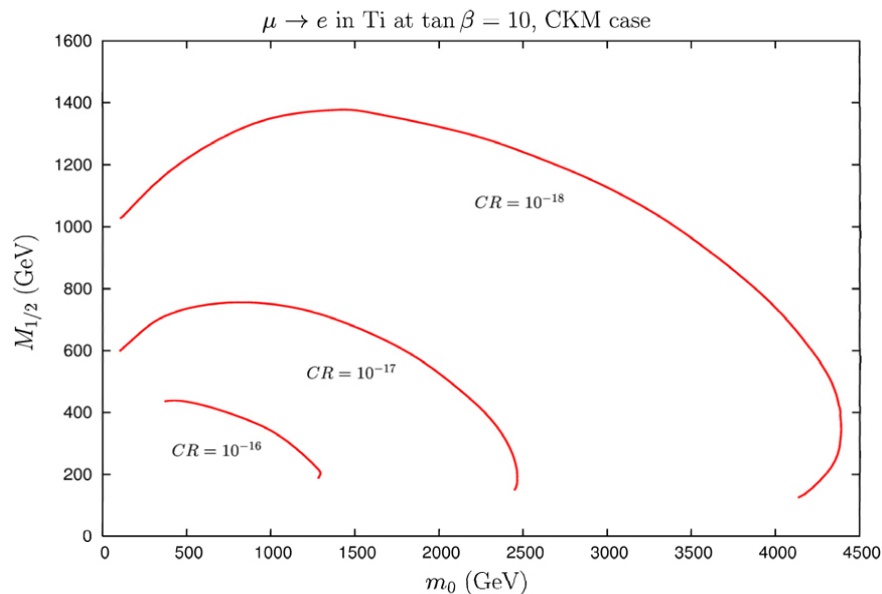
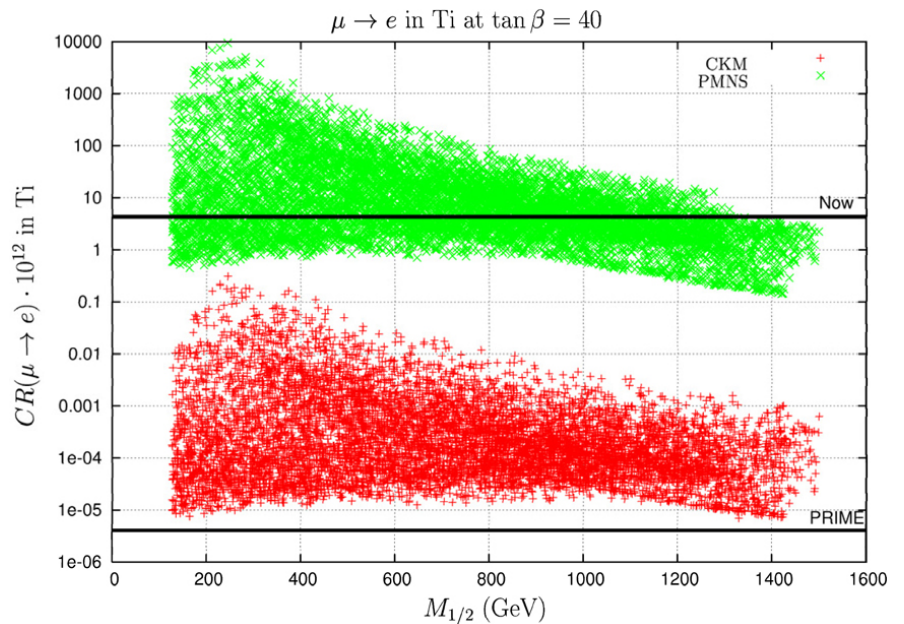
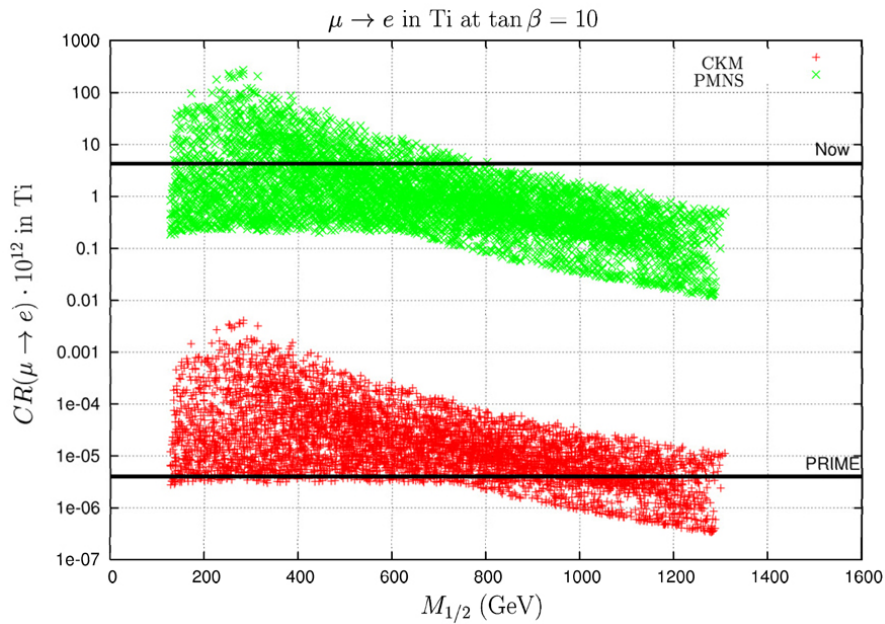
Comparing CKM and PMNS

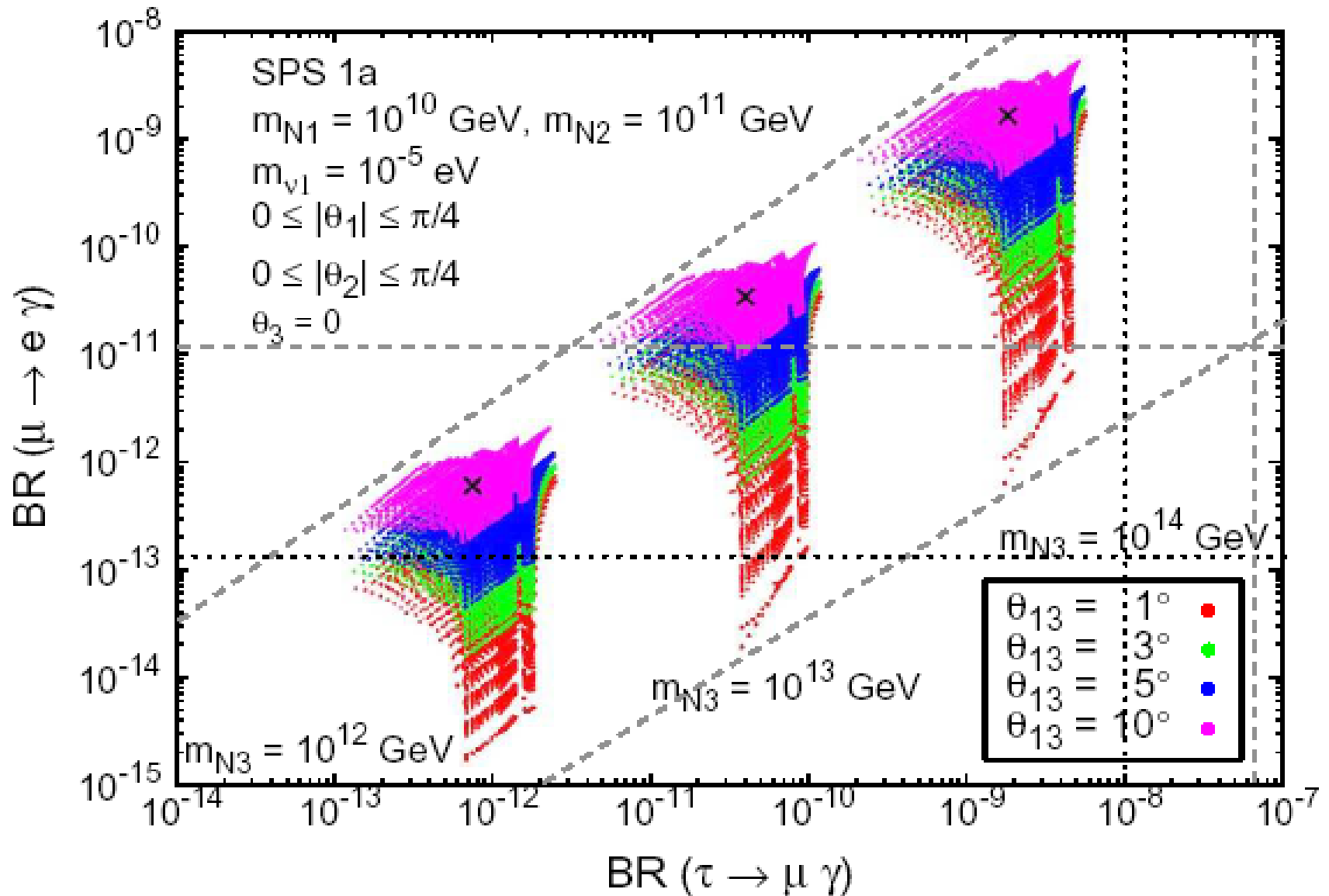


$$m_{\nu_1} = 0.001 \text{ eV}$$

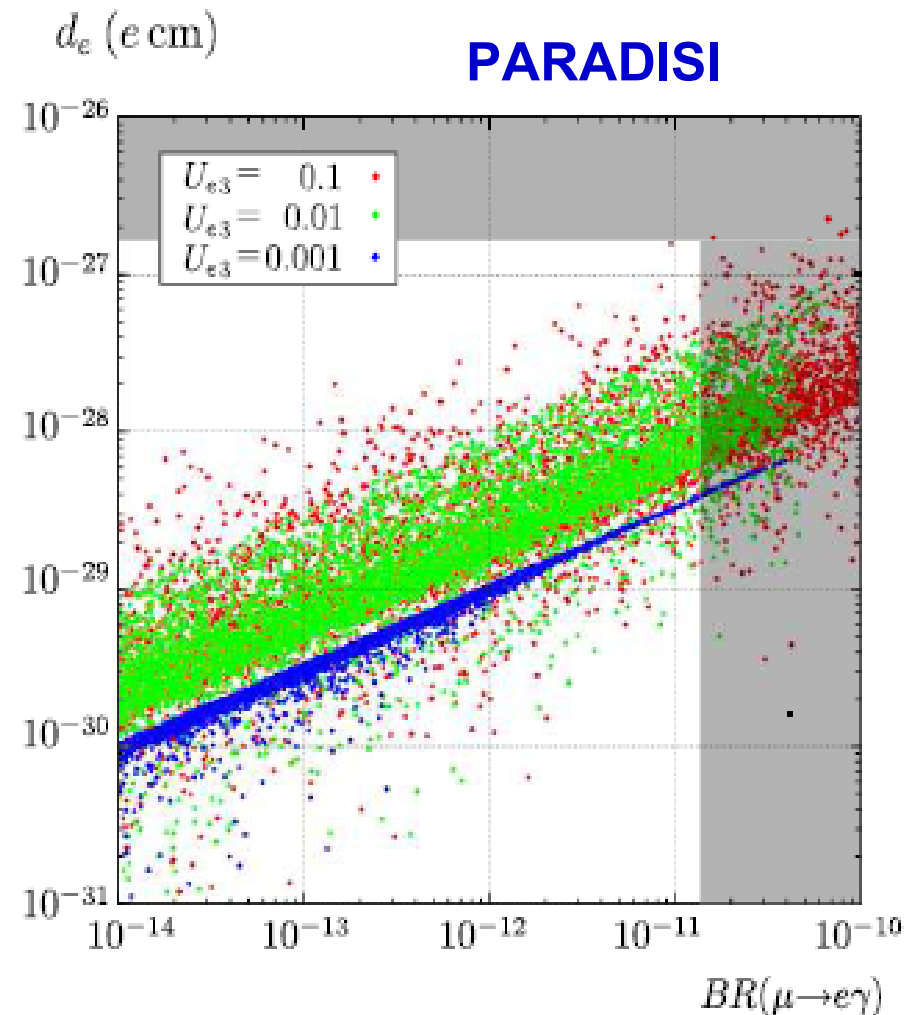
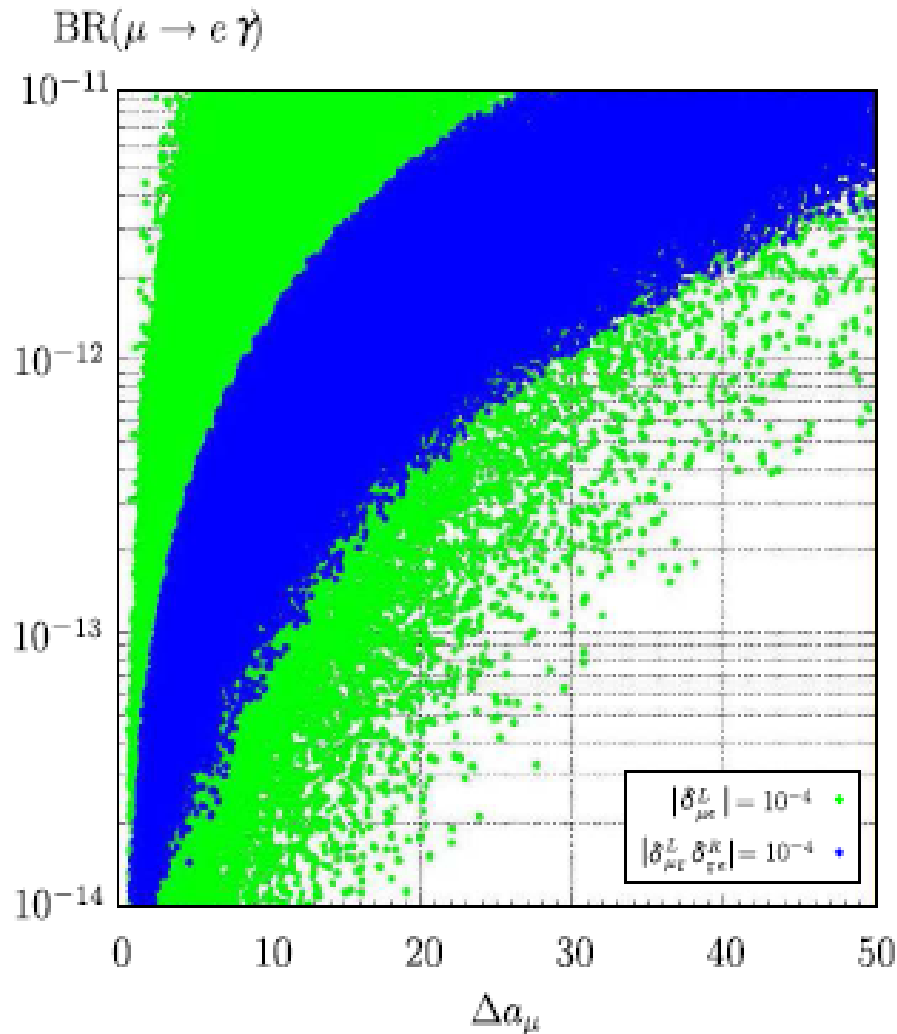
$$\sin^2 2\theta_{13} = 0.04$$

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





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



DEVIATION from $\mu - e$ 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**

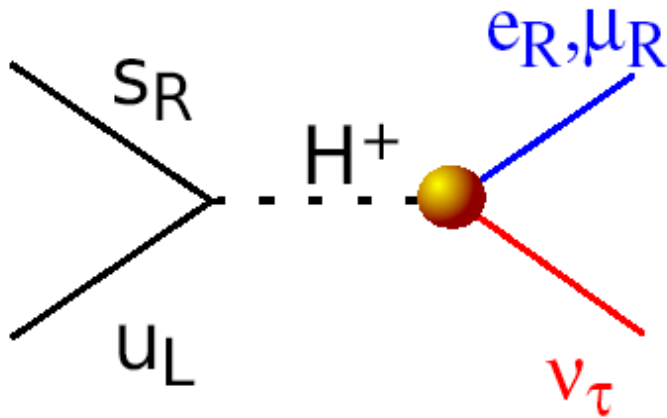
Prospects: Summer conf. we'll have the result concerning the 40% data analysis by NA62 and when the analysis of the whole sample of data is accomplished **the stat. uncertainty will be < 0.3%**

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

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



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

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

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

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

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

LFU breaking occurs with LFV

LFU breaking occurs in a **LF conserving** case because of the splitting in slepton masses

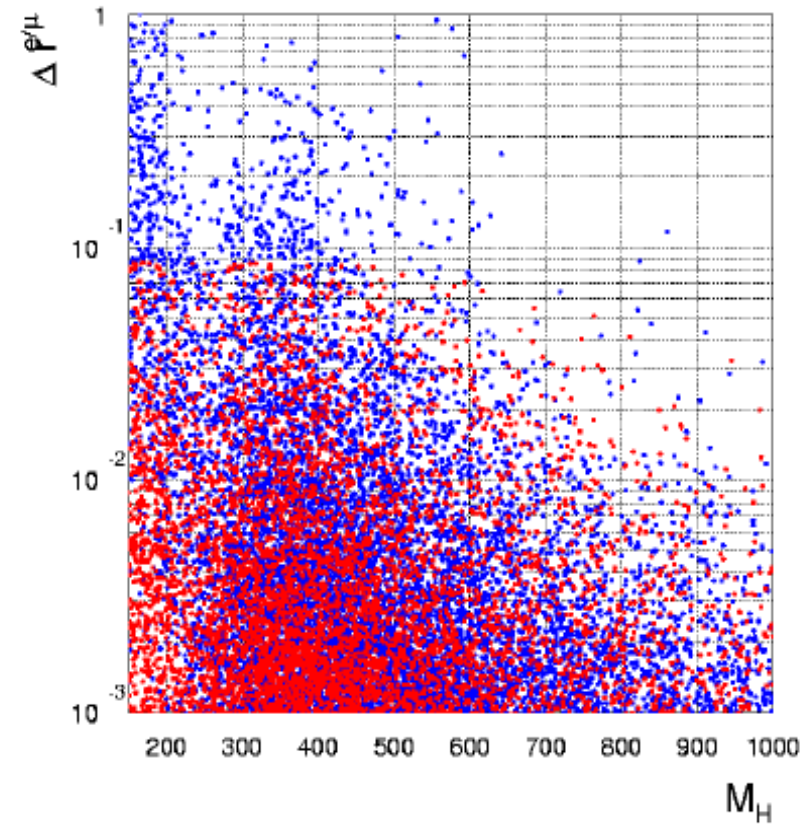
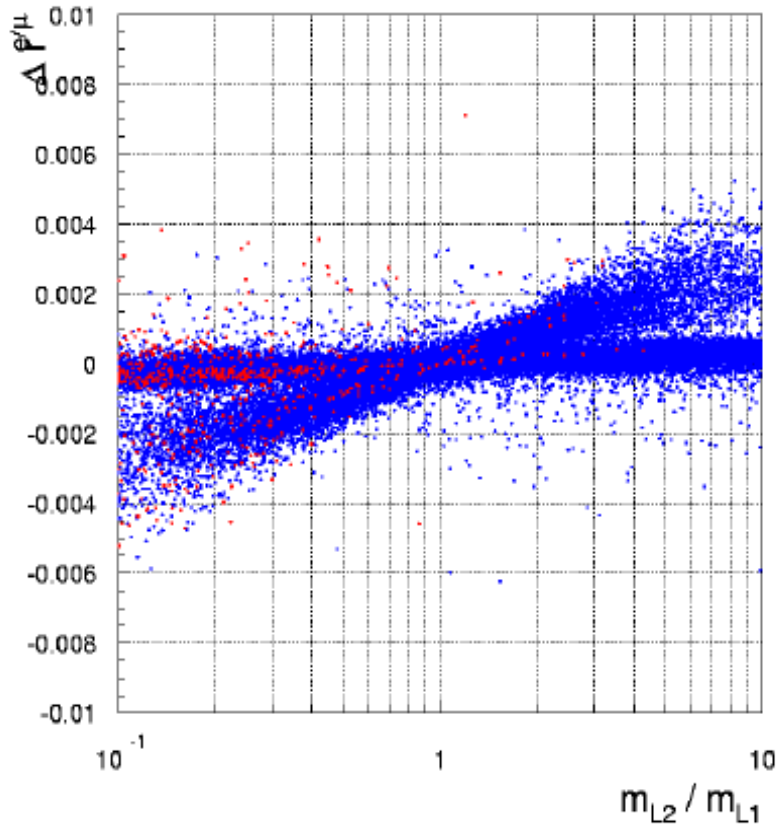


Figure 2: Left: $\Delta r_K^{e/\mu}$ as a function of the mass splitting between the second and the first (left-handed) slepton generations. Red dots can saturate the $(g - 2)_\mu$ discrepancy at the 95% C.L., i.e. $1 \times 10^{-9} < (g - 2)_\mu < 5 \times 10^{-9}$. Right: $\Delta r_K^{e/\mu}$ as a function of M_{H+} .

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

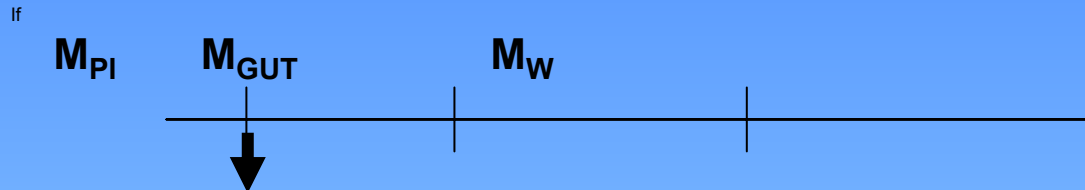
In **SU(5)** assume large f_ν (Moroi)

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



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

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

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

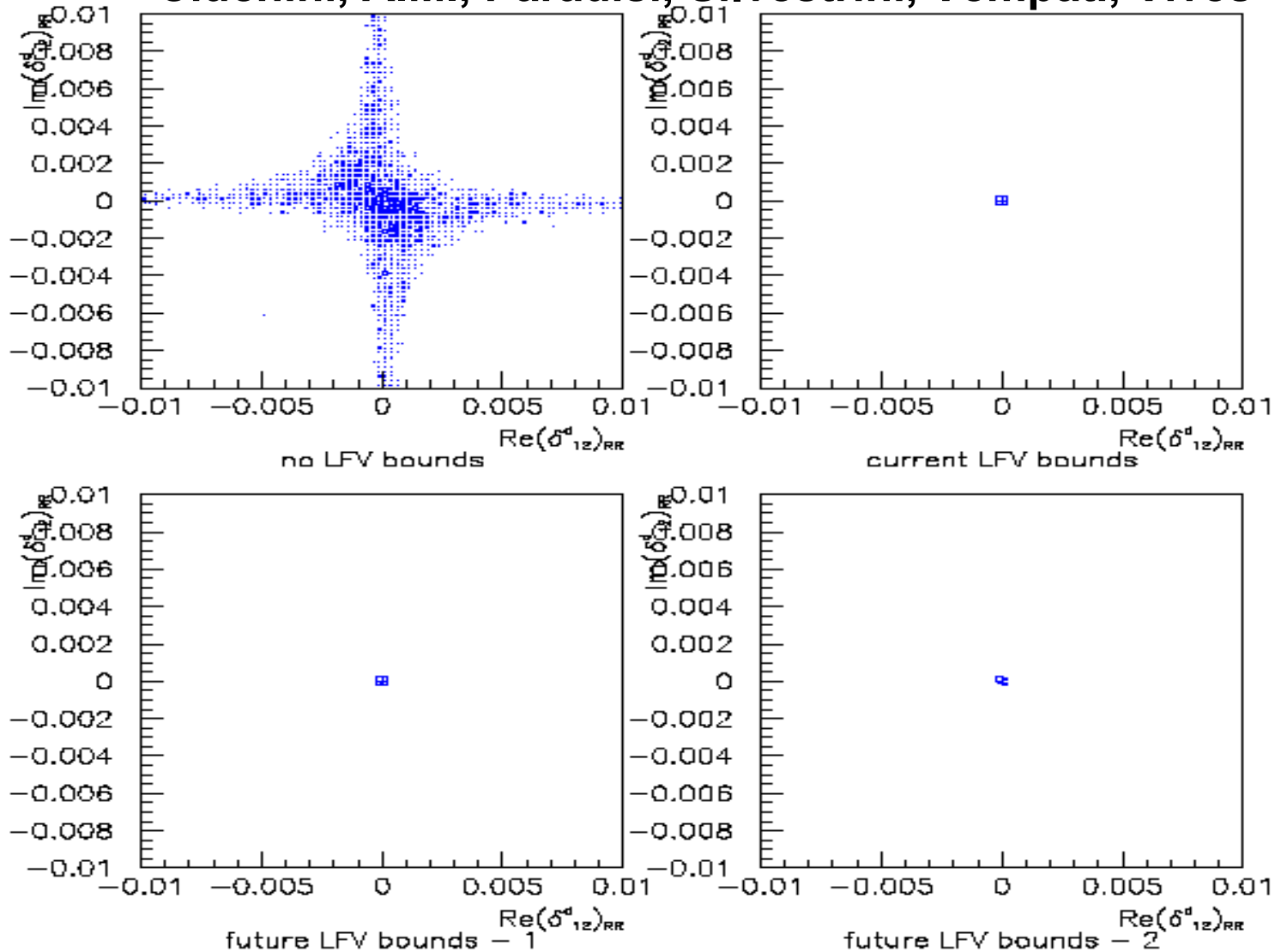
$$A_{ij}^e = A_{ji}^d.$$

SU(5) RELATIONS

	Relations at weak-scale	Relations at M_{GUT}
(1)	$(\delta_{ij}^u)_{\text{RR}} \approx (m_{e^c}^2/m_{u^c}^2) (\delta_{ij}^l)_{\text{RR}}$	$m_{u^c_0}^2 = m_{e^c_0}^2$
(2)	$(\delta_{ij}^q)_{\text{LL}} \approx (m_{e^c}^2/m_Q^2) (\delta_{ij}^l)_{\text{RR}}$	$m_{Q_0}^2 = m_{e^c_0}^2$
(3)	$(\delta_{ij}^d)_{\text{RR}} \approx (m_L^2/m_{d^c}^2) (\delta_{ij}^l)_{\text{LL}}$	$m_{d^c_0}^2 = m_{L_0}^2$
(4)	$(\delta_{ij}^d)_{\text{LR}} \approx (m_{L_{\text{avg}}}^2/m_{Q_{\text{avg}}}^2) (m_b/m_\tau) (\delta_{ij}^l)_{\text{LR}}^*$	$A_{ij_0}^e = A_{ji_0}^d$

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

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

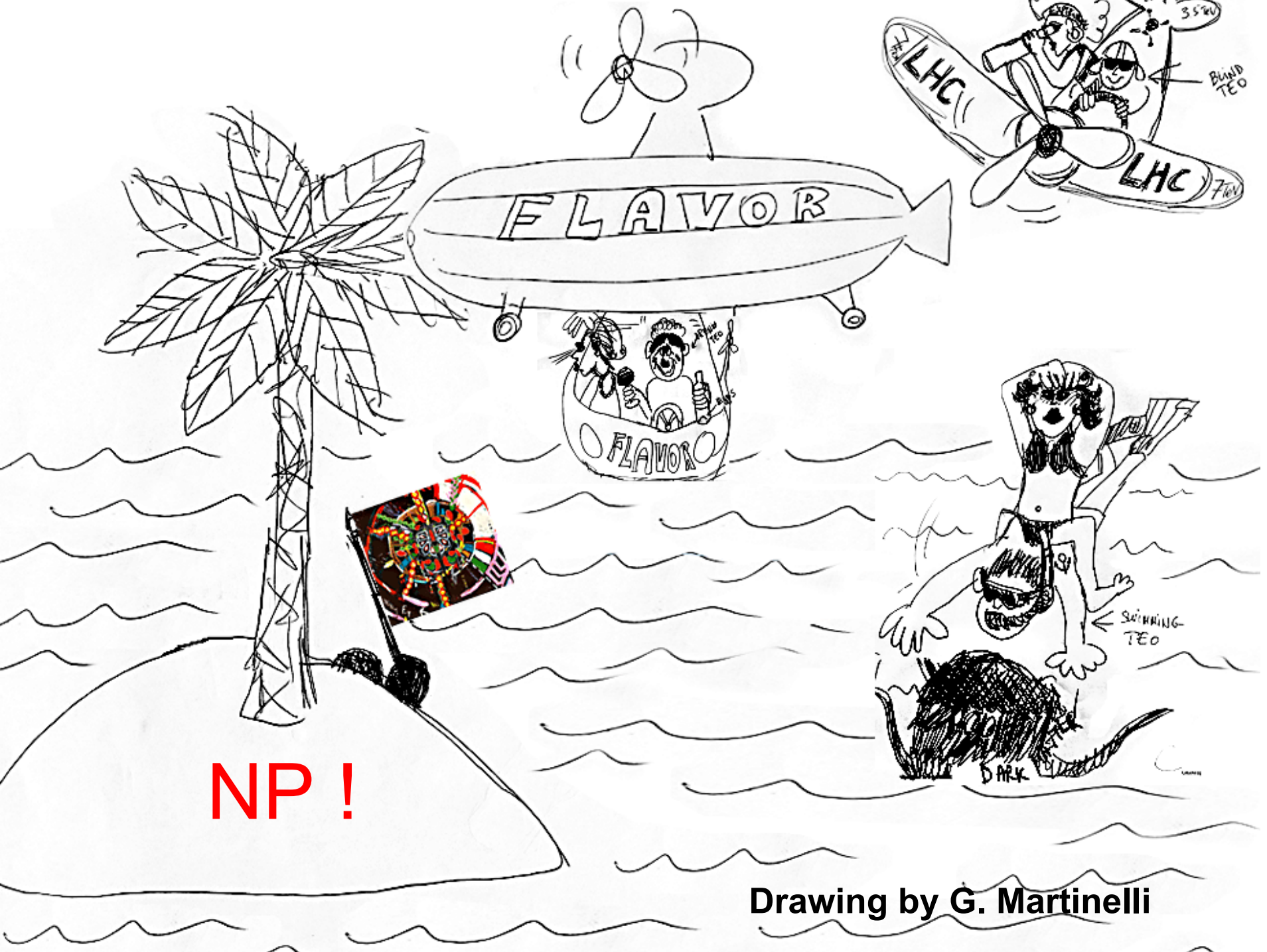


3 QUESTIONS

- Are we sure that there is new physics (NP) at the TeV scale? **YES** (barring an anthropic approach)
- If yes, are we sure that LHC will see something “new”, i.e. beyond the SM with its “standard higgs boson”? **YES**
- If there is new physics at the TeV scale, what can flavor and DM physics tell to LHC and viceversa? (or, putting it in a less politically correct fashion: if LHC starts seeing some new physics signals, are flavor and DM physics still a valuable road to NP, or are they definitely missing that train? **NO**, actually to catch the “right train” it is highly desirable, though maybe strictly not necessary, to make use of **all the three roads at the same time**

A FUTURE FOR FLAVOR PHYSICS 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)



NP!

Drawing by G. Martinelli