Planck 2012, Warsaw, 1 June ’12

Particle physics after the first LHC results

Guido Altarelli
Univ. Roma Tre/CERN

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This is not a summary!!
What is it? You will see!

I will not cover astro-cosmology: see the previous speaker

I will not cover the more formal aspects
(for my incompetence)

Apologies to
Ovrut, Buican, Zwirner,
Abel, Ludeling, Grinstein,
Komargodski, Rattazzi,
Taylor, von Gersdorff

I only would like to say that the talk by Dvali on a radically new approach to black hole physics is the one that mostly impressed me

My scope is the phenomenology of particle physics
in this exciting LHC time

Before the LHC start many people were ready to bet that:

- strongly interacting new physics particles (gluinos, s-quarks...) would make the first discoveries
- the Higgs was considered more difficult, in particular if light
- the H ---> $\gamma\gamma$ mode was thought to be very difficult and that it would take a long time to get it

Now we know that no new particles were found so far, that there are indications for a light Higgs and that the best evidence is from $\gamma\gamma$

The main LHC results so far

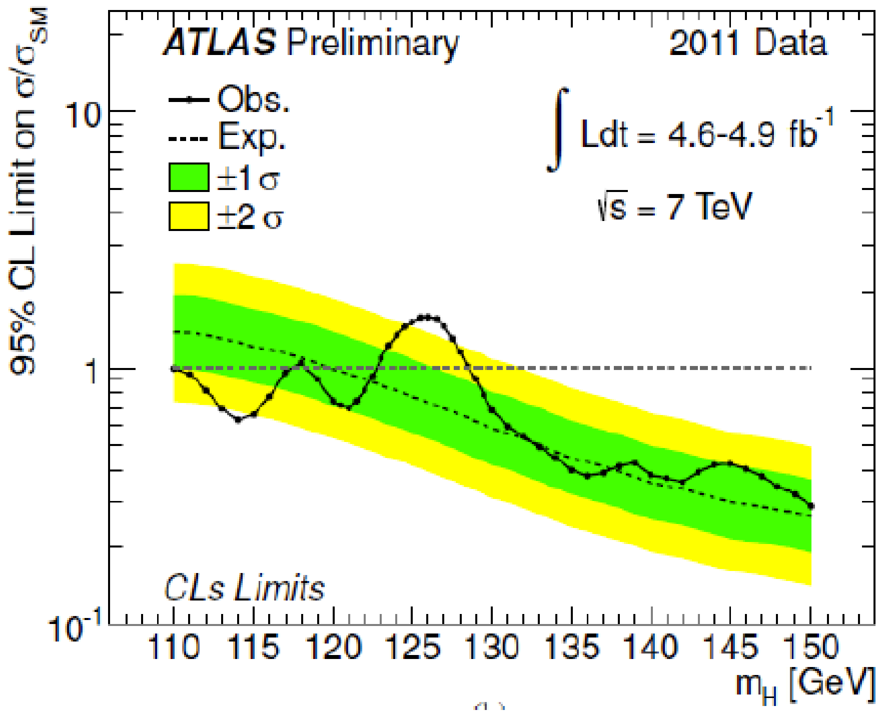
- A robust exclusion interval for the SM Higgs. Essentially only a narrow window below 600 GeV: 115-128 GeV.
- Some indication for $m_H \sim 125$ GeV

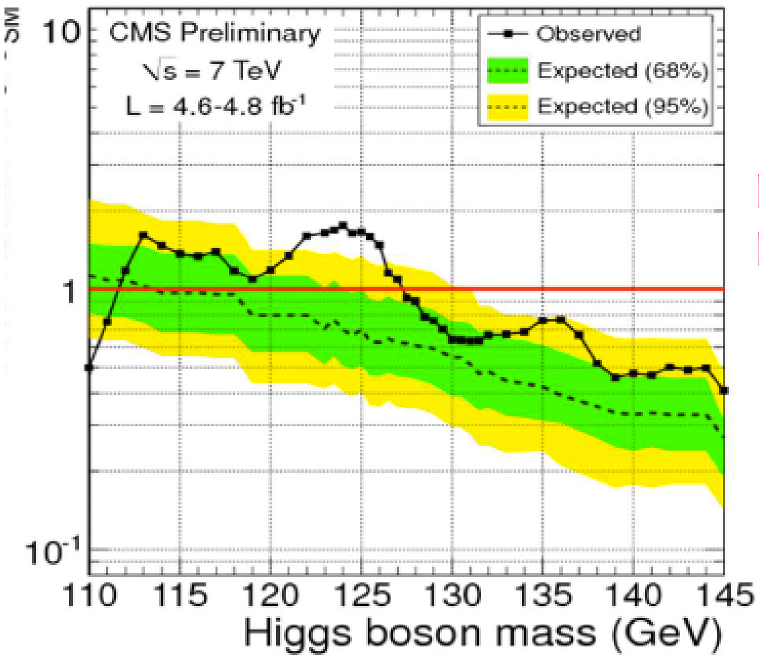
The SM Higgs is close to be observed or excluded!

Either the SM Higgs is very light (~ 125 GeV)
or rather heavy (i.e. > 600 GeV)

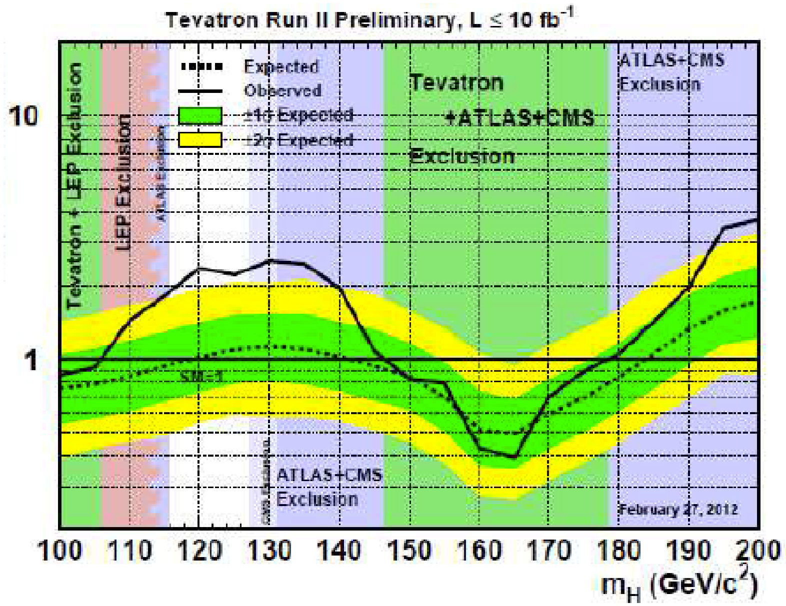
- No evidence of new physics, although a big chunk of new territory has been explored

- Important results on B and D decays from LHCb (also CMS) [e.g. $B_s \to J/\Psi\phi$, $B_s \to \mu\mu$, ... CP viol in D decay]





Kobel
Kovalskyi

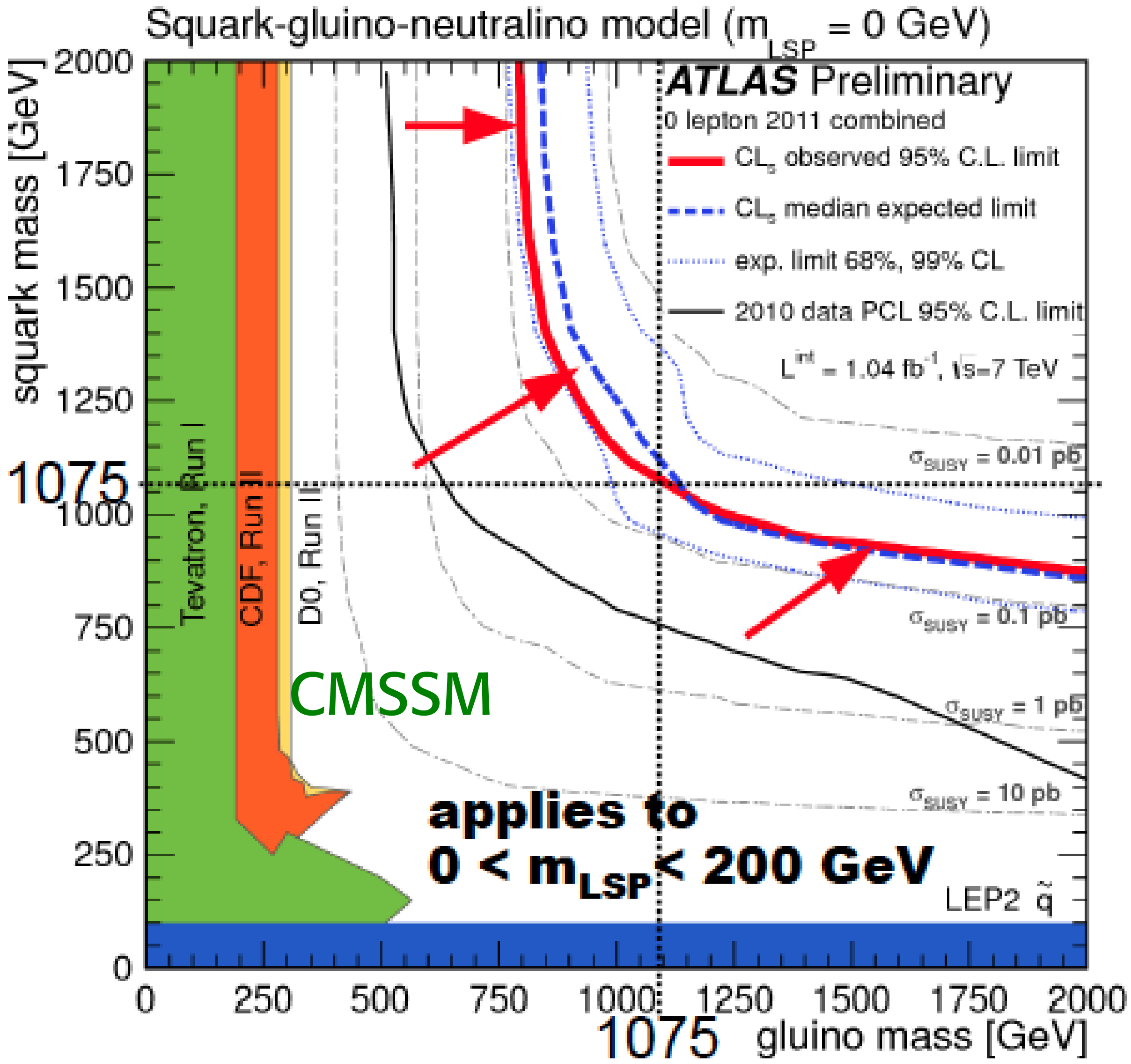


m_H = 125 GeV would be
a great discovery.
By itself an adequate return
for the LHC investment

A large new territory has been explored and no new physics

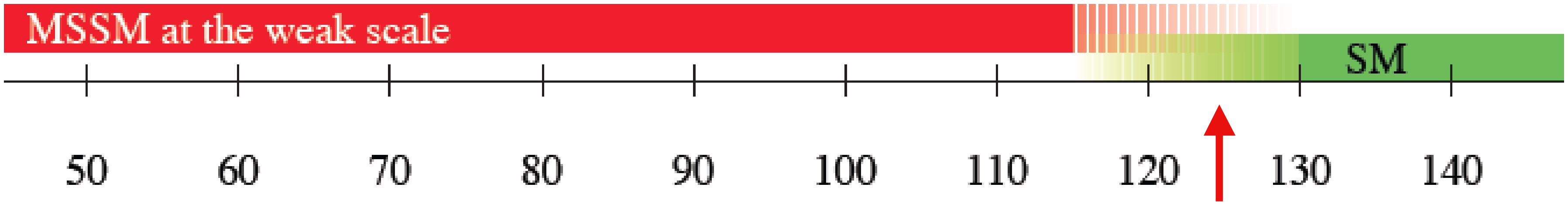
This negative result
is perhaps depressing
but certainly brings
a very important input
to our field

Jets + missing E_T



The range m_H = 122 - 128 GeV is in agreement with precision tests, compatible with the SM and also with the SUSY extensions of the SM

Strumia



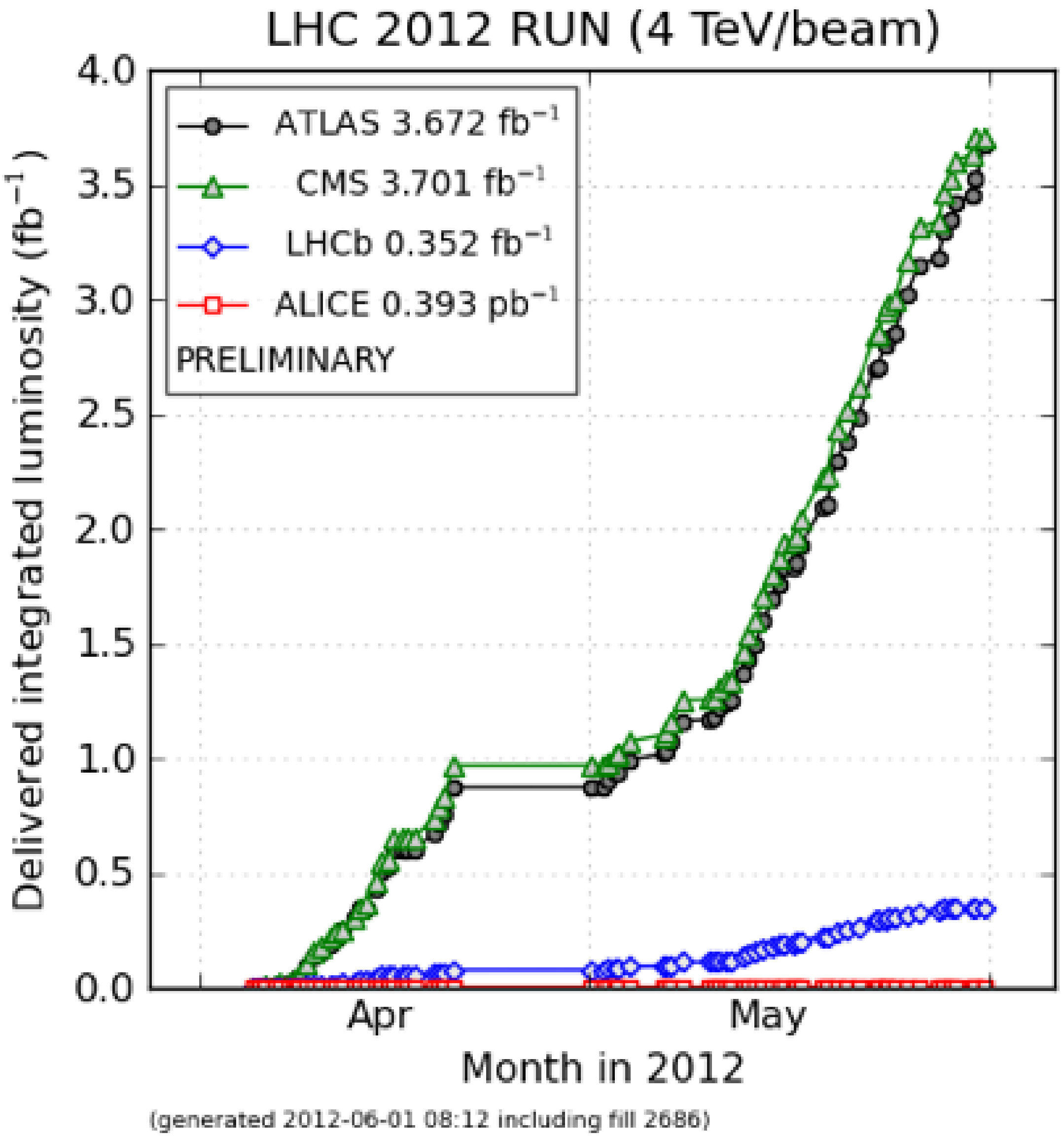
m_H ~125 GeV is what you expect from a direct interpretation of EW precision tests: no fancy conspiracy with new physics to fake a light Higgs while the real one is heavy
(in fact no "conspirators" have been spotted: no new physics)

m_H > 600 GeV would point to the conspiracy alternative

Certainly the evidence could still evaporate

We need to wait for the 2012 run

The 8 TeV run is going rather well (~ 5 fb^{-1} for ICHEP?)



What if the evidence evaporates in '12?

Can we do without the Higgs?

The most immediate disease that needs a solution is
the occurrence of unitarity violations in some amplitudes

To avoid this either there is one or more Higgs particles
or some new states (e.g. new vector bosons)

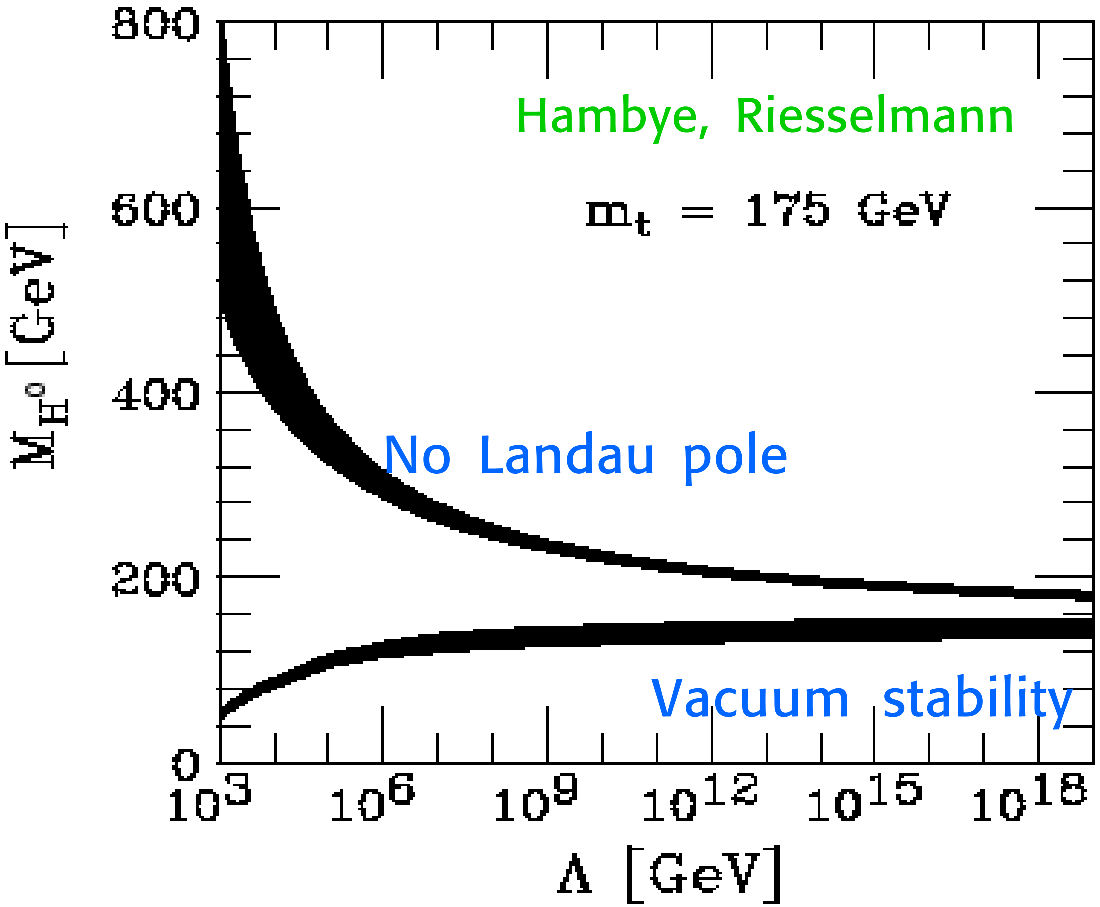
Thus something must happen at the few TeV scale!!

While this is a theorem, once there is the Higgs,
the necessity of new physics on the basis of naturalness
is not a theorem

Nilles said yesterday: "no fine tuning is not a dogma"

Theoretical bounds on the SM Higgs mass

Λ: scale of new physics beyond the SM



Upper limit: No Landau pole up to Λ

Lower limit: Vacuum (meta)stability

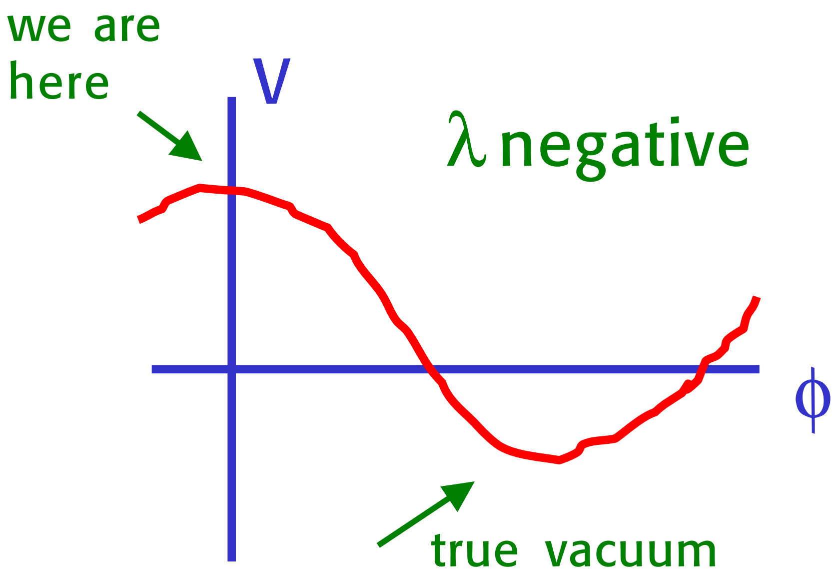
If the SM would be valid up to M_{GUT}, M_{Pl} with a stable vacuum then m_H would be limited in a small range

depends on m_t and α_s ⟶ 130 GeV $< m_H <$ 180 GeV

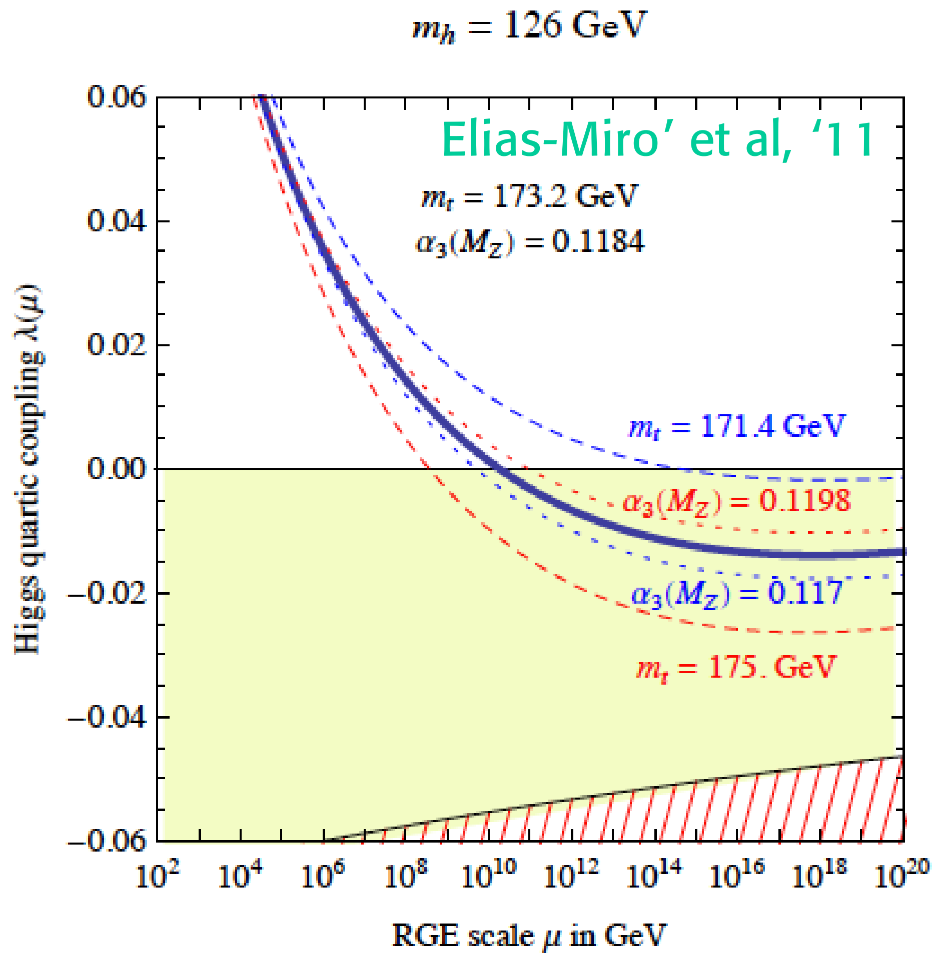
Isn't m_H = 125 GeV a bit too light?

But metastability (with sufficiently long lifetime) is enough!

$$V[\phi] = -\mu^2\phi^2 + \lambda\phi^4$$



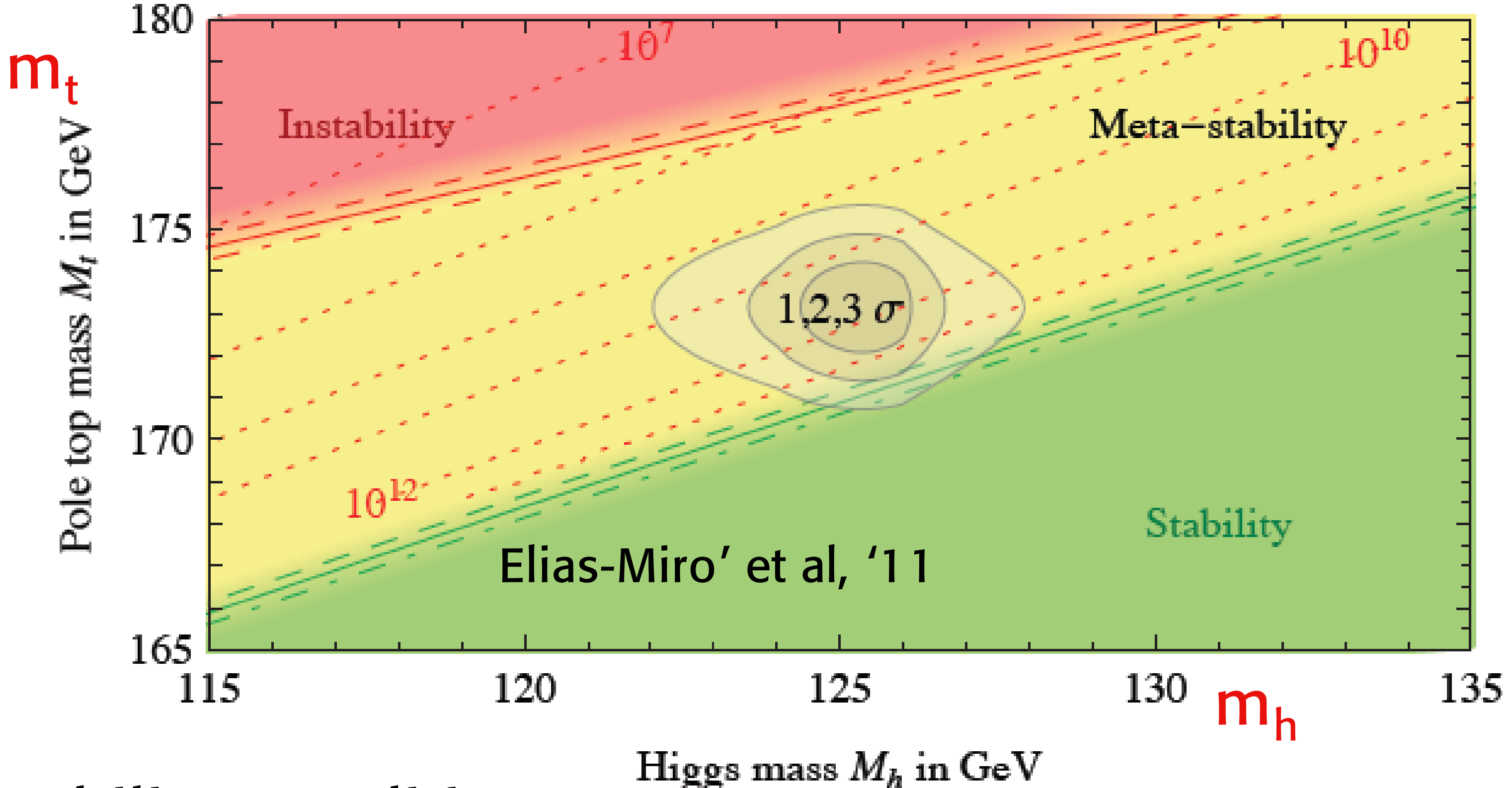
(something is assumed to stabilize V at ~ M_{Pl})



In the absence of new physics, for m_H ~ 125 GeV,
the Universe becomes metastable at a scale Λ ~ 10^{10} GeV

But the SM remains viable up to M_{Pl} (Early universe implications)

For m_H ~ 125 GeV the SM vacuum is metastable



Strumia

Stability condition

$$M_h\ [\mathrm{GeV}] > 129.4 + 1.4\left(\frac{M_t\ [\mathrm{GeV}] - 173.1}{0.7}\right) - 0.5\left(\frac{\alpha_s(M_Z) - 0.1184}{0.0007}\right) \pm 1.0_{\mathrm{th}}$$

Shaposhnikov

For the measured values both λ and $\beta(\lambda)$ vanish near M_{Pl}

If the Higgs is confirmed then the couplings are crucial in order to determine if it is SM or not

Contino

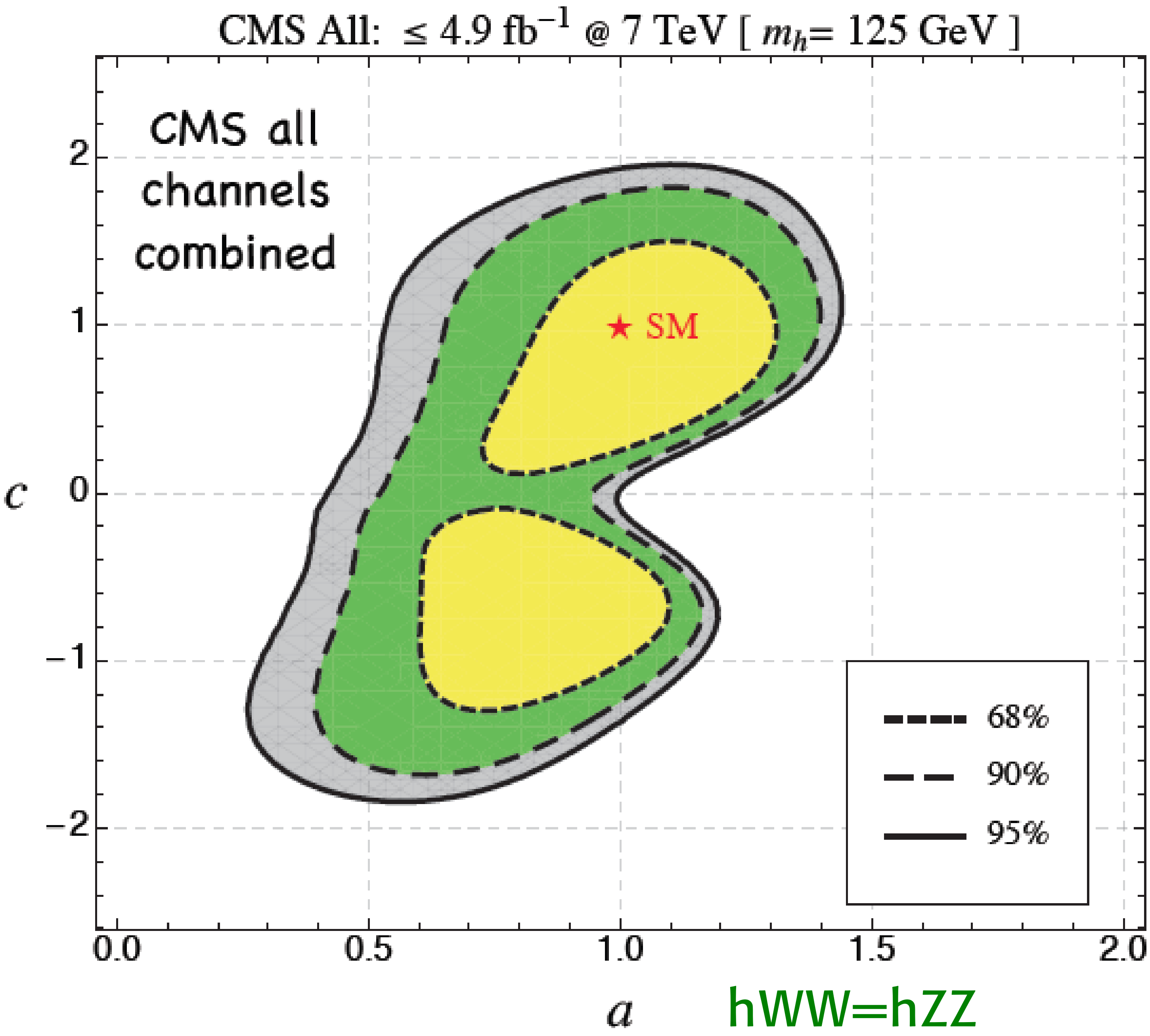
$$\mathcal{L} = \frac{1}{2}(\partial_\mu h)^2 - \frac{1}{2}m_h^2 h^2 - \frac{d_3}{6}\left(\frac{3m_h^2}{v}\right)h^3 - \frac{d_4}{24}\left(\frac{3m_h^2}{v^2}\right)h^4 \ldots$$

$$- \left(m_W^2 W_\mu W_\mu + \frac{1}{2}m_Z^2 Z_\mu Z_\mu\right)\left(1 + 2a\frac{h}{v} + b\frac{h^2}{v^2} + \ldots\right)$$

$$- \sum_{\psi=u,d,l} m_{\psi^{(i)}} \bar{\psi}^{(i)}\psi^{(i)}\left(1 + c_\psi\frac{h}{v} + c_{2\psi}\frac{h^2}{v^2} + \ldots\right) + \ldots$$

Falkowski
Azatov
Grojean
Strumia
Carena
Wagner
Haisch

It would really be astonishing if no deviation from the SM is seen hψψ



CMS All: ≤ 4.9 fb^{-1} @ 7 TeV [m_h= 125 GeV]
CMS all channels combined
★ SM
68%
90%
95%
c
2
1
0
−1
−2
0.0
0.5
1.0
1.5
2.0
a

hWW=hZZ

The Standard Model works very well

So, why not find the Higgs and declare particle physics solved?

Because of both:

Conceptual problems

- Quantum gravity
- The hierarchy problem
- The flavour puzzle

.....

and experimental clues:

- Neutrino masses
- Coupling unification
- Dark matter
- Baryogenesis
- Vacuum energy
- some experimental anomalies: $(g\text{-}2)_\mu$, ...

insert here your preferred hints

Some of these problems point at new physics at the weak scale: eg
Hierarchy
Dark matter (perhaps)

A crucial question for the LHC

Is Dark Matter a WIMP?

LHC can probably tell yes or no to WIMPS

LHC has good chances because it can reach any kind of WIMP:

WIMP: Weakly Interacting Massive Particle
with m ~ 10^1-10^3 GeV

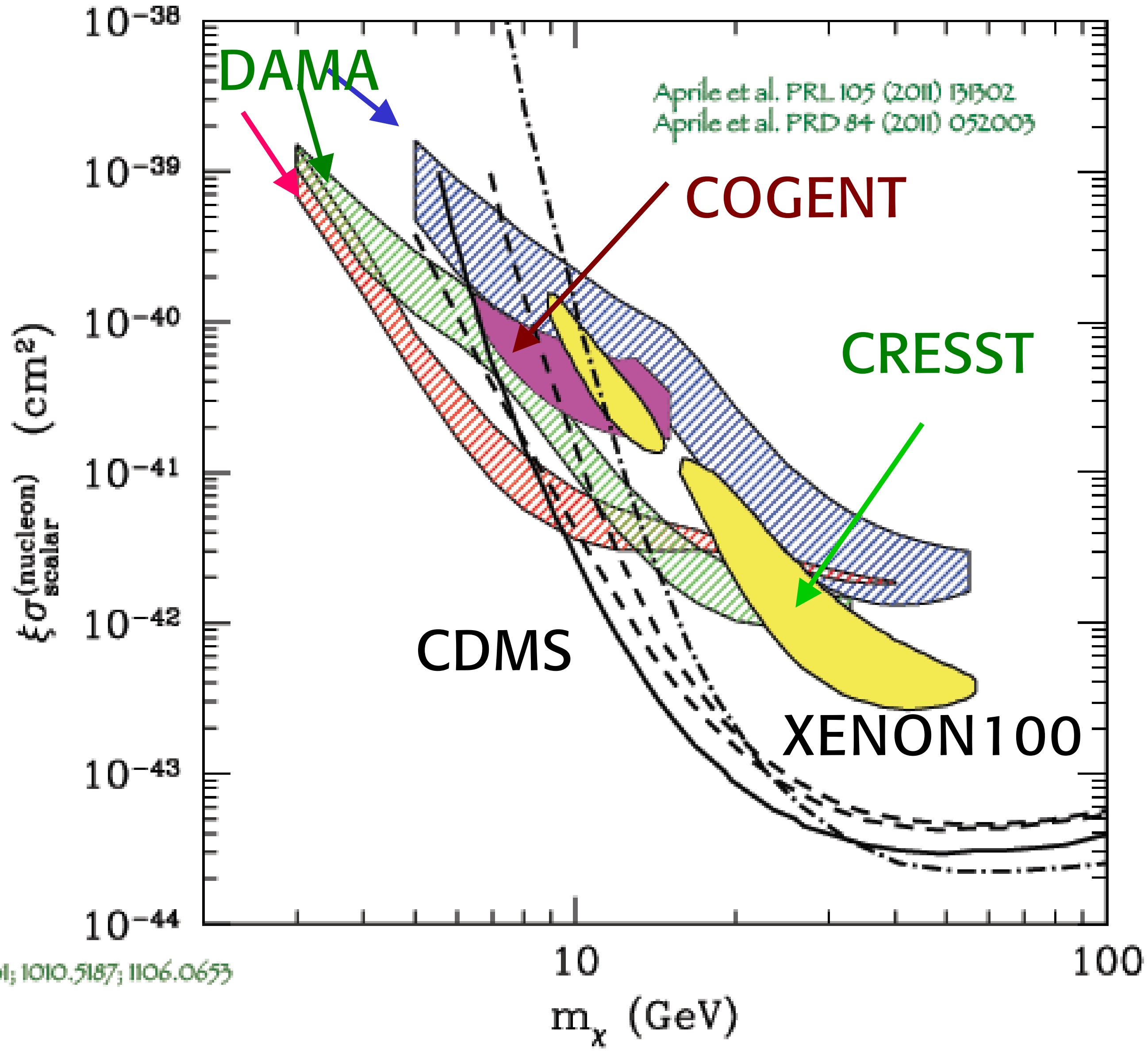
For WIMP's in thermal equilibrium after inflation the density is:

$$\boxed{\Omega_\chi h^2 \simeq const. \cdot \frac{T_0^3}{M_{\mathrm{Pl}}^3 \langle \sigma_A v \rangle} \simeq \frac{0.1\ \mathrm{pb} \cdot c}{\langle \sigma_A v \rangle}}$$

can work for typical weak cross-sections!!!

This "coincidence" is a good indication in favour of a WIMP explanation of Dark Matter

Strong competition on WIMPS search from underground labs



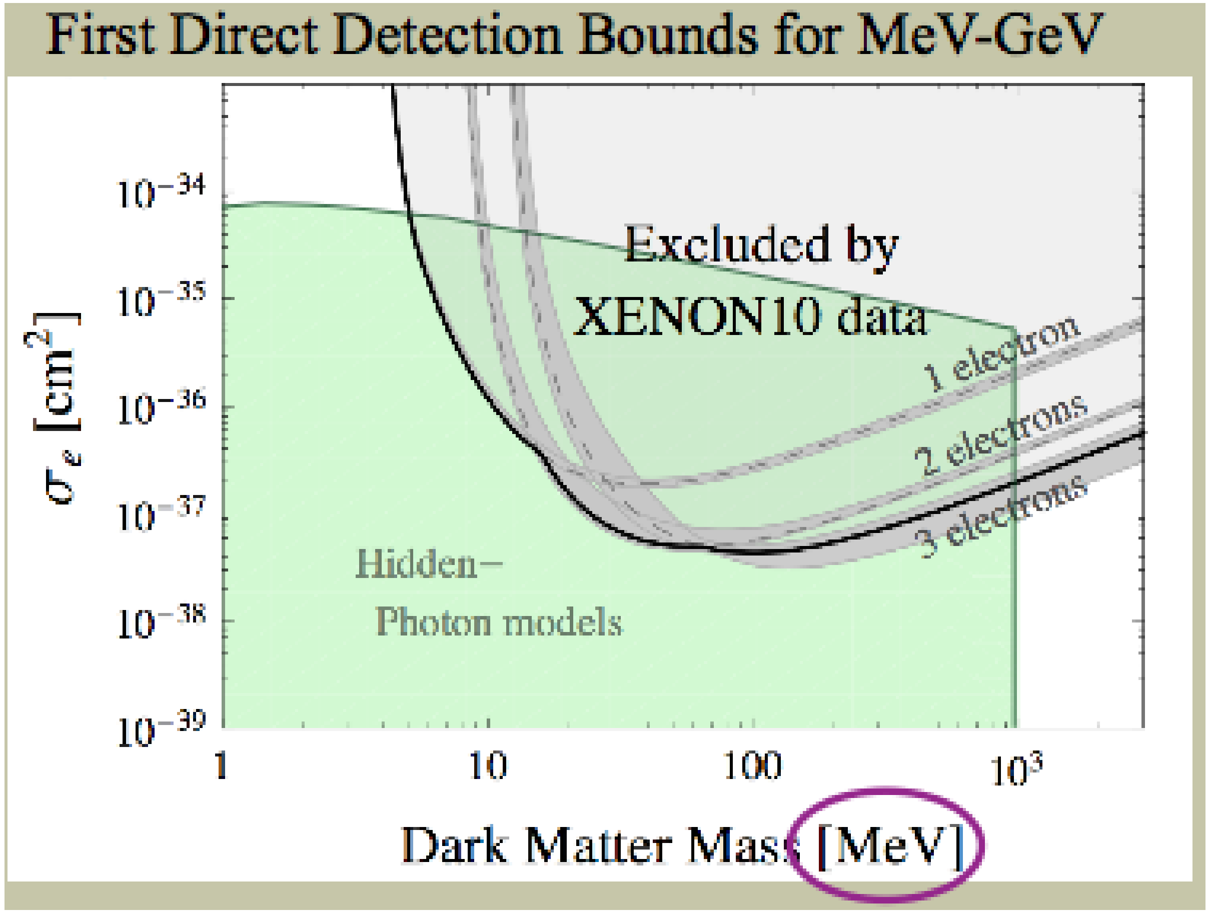
Fornengo

06.2031; 1010.5187; 1106.0653

But What If It's Not a WIMP??

First Direct Detection Limits on Sub-GeV Dark Matter from XENON10

Volansky



The hierarchy problem: the naturalness principle

Has been and is the main motivation for new physics at the weak scale

But at present our confidence on naturalness as a guiding principle is being more and more challenged

No indirect evidence of new physics

No direct evidence of new physics at the LHC7

Barbieri, Strumia

The LEP Paradox: m_h light, new physics must be close but its effects were not visible at LEP2, Tevatron and now at the LHC (so far)

⊕ The B-factory Paradox: and not visible in flavor physics

Solutions to the hierarchy problem

- Supersymmetry: boson-fermion symm.

  The most ambitious and widely accepted
  Simplest versions now marginal
  Plenty of viable alternatives

- Strong EWSB: Technicolor

  Strongly disfavoured by LEP. Coming back in new forms

  Composite Higgs

  Higgs as PG Boson, Little Higgs models……

- Extra spacetime dim's that somehow "bring" M_{Pl} down to o(1TeV) [large ED, warped ED, ……]. Holographic composite H

  Exciting. Many facets. Rich potentiality. No baseline model emerged so far

  Antoniadis, Neubert, Gunion

- Ignore the problem: invoke the anthropic principle

  Extreme, but not excluded by the data

Apparently some amount of fine tuning is imposed on us by the data. More now after LHC7.

Unnatural models start being common

with very large fine tuning

Arkani-Hamed, Dimopoulos
Giudice Romanino

Split SUSY

Hall, Nomura

High Scale SUSY

Shaposhnikov theory

....

with large fine tuning

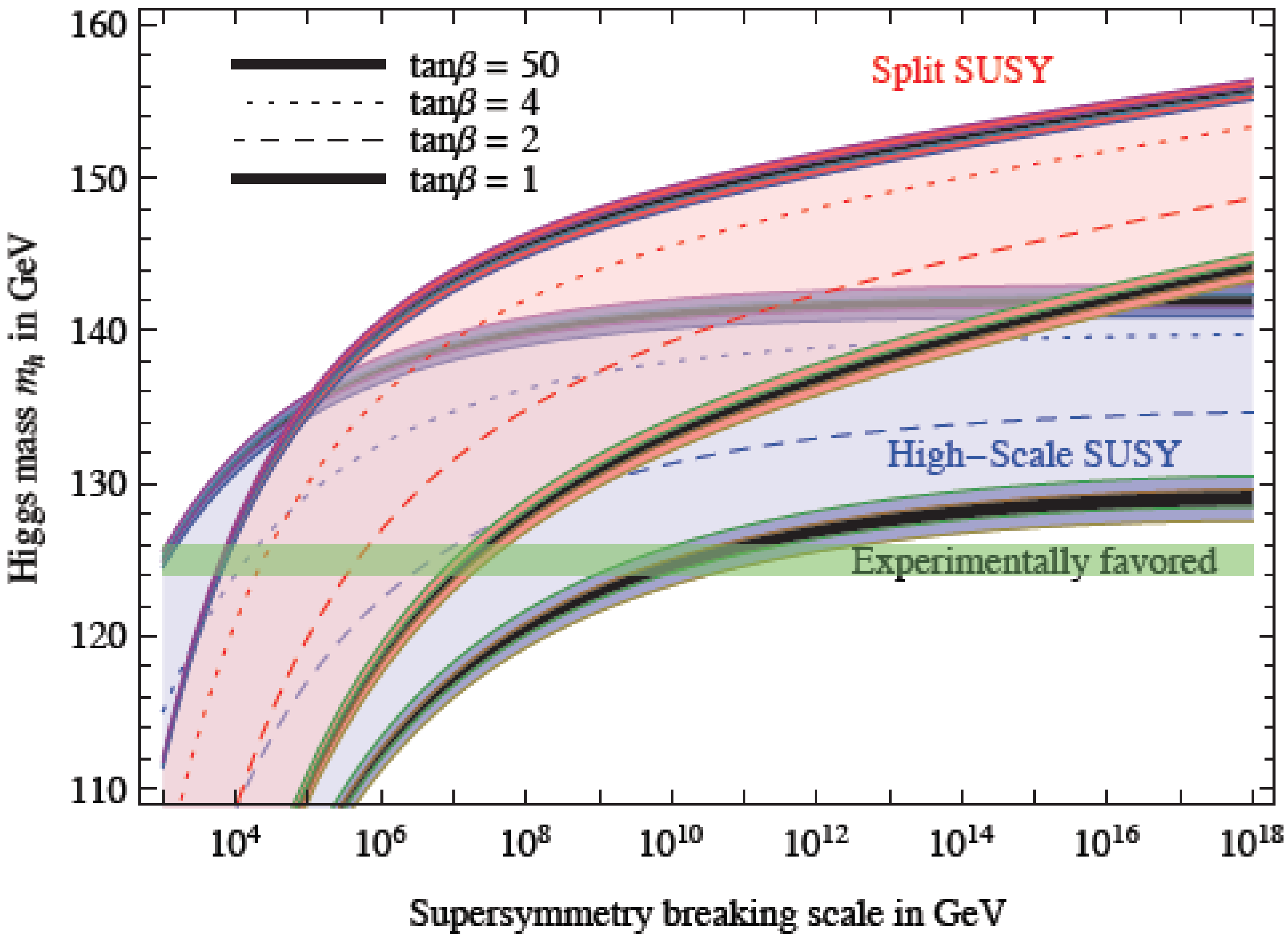
5-10 TeV gluinos....

Khoze
Shih

Nilles theory

......

m_H ~ 125 GeV imposes strong constraints on Split SUSY and High Scale SUSY



Strumia

A minimal anthropic model

An enlarged SM (to include RH ν's, coupling unification in GUT) valid up to a large scale is an (enormously fine tuned) option

following the anthropic philosophy, the Multiverse, the Landscape

A light Higgs

SO(10) non SUSY GUT

SO(10) breaking down to e.g. $SU(4)xSU(2)_L xSU(2)_R$ at an intermediate scale ($10^{11\text{-}12}$)
[coupling unification, p-decay OK]

Majorana neutrinos and see-saw (-> $0\nu\beta\beta$)

Axions as dark matter

Baryogenesis thru leptogenesis

recall that μ -> e γ, edm of neutron.... are not seen!

No new physics at the LHC (how sad!) except perhaps a $Z'_{B\text{-}L}$ [$(g\text{-}2)_\mu$ and other present deviations from SM in colliders should be disposed of]

Zurek

Craig

So...supersymmetry?

On one hand, thus far there is no evidence for SUSY at the LHC.

On the other hand, a Higgs at ~125 GeV really wants to be supersymmetric (within 30% of the Z mass!)

So let's not give up just yet...

Years ago, after LEP2, in a talk I said

"the SUSY train is late"

Today I should say

"perhaps the SUSY train will never arrive at the LHC"

Once the no fine tuning taboo has been infringed
it is not clear where to stop

The general MSSM has > 100 parameters

Simplified versions with a drastic reduction of parameters are used for practical reasons, e.g.

CMSSM, mSUGRA : universal gaugino and scalar soft terms at GUT scale $m_{1/2}$, m_0, A_0, $tg\beta$, $\mathrm{sign}(\mu)$

NUHM1,2: different than m_0 masses for H_u, H_d (1 or 2 masses)

It is only these oversimplified models that are now cornered

Impact of m_H ~ 125 GeV on SUSY models

Minimal models with gauge mediation are disfavoured (predict m_H too light)

Arbey et al'11; Draper et al, '11

more elaborated versions could work

Endo et al '11

Khoze
Shih
Romanino

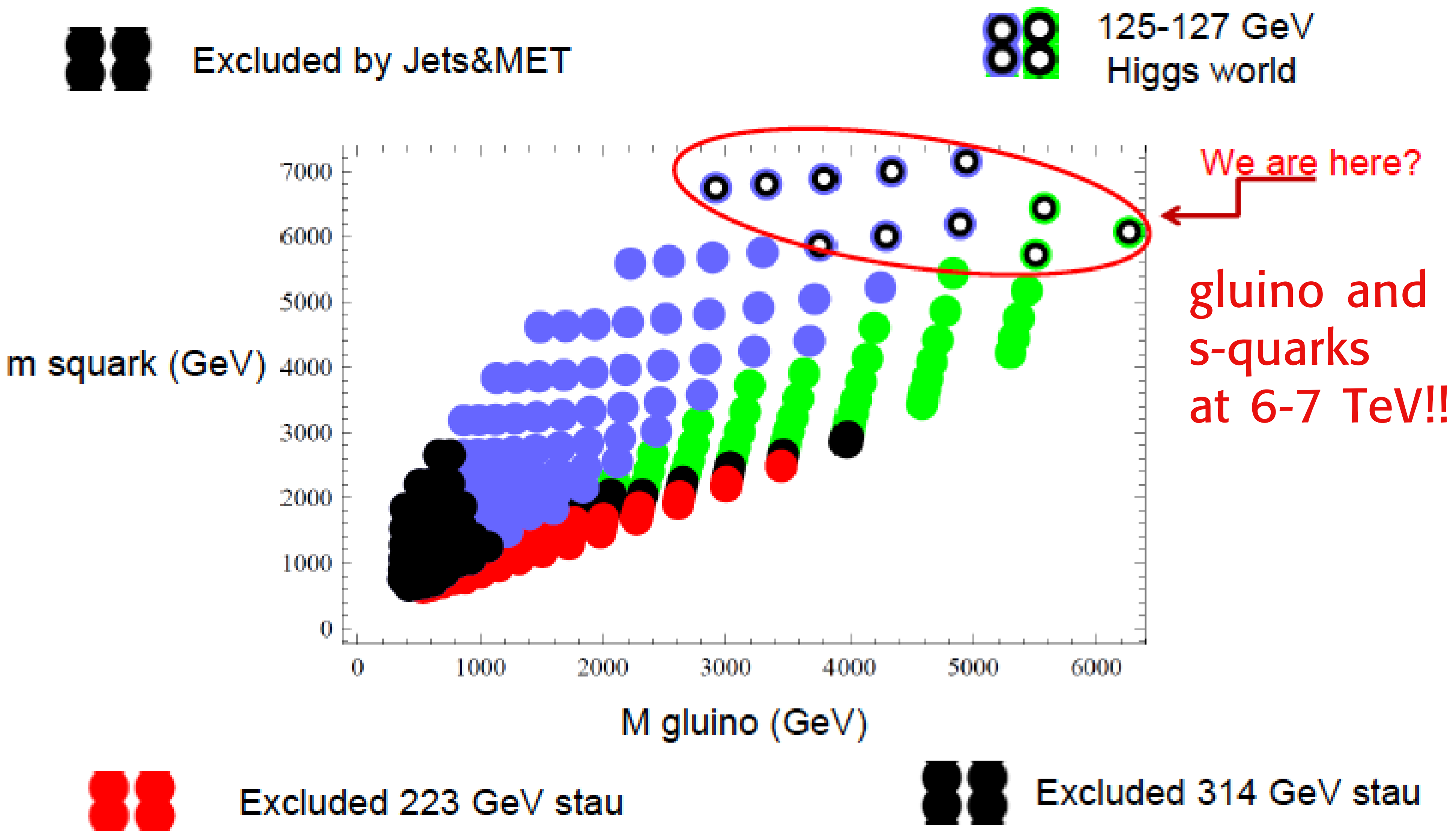
Anomaly mediation is also generically in trouble

Gravity mediation is better but CMSSM, mSUGRA, NUHM1,2 need squarks heavy, A_t large and lead to tension with g-2 (that wants light SUSY) and b->sγ

Arbey et al'11 ,Akura et al; Baer et al; Battaglia et al; Buchmuller et al, Kadastik et al; Strege et al; '11

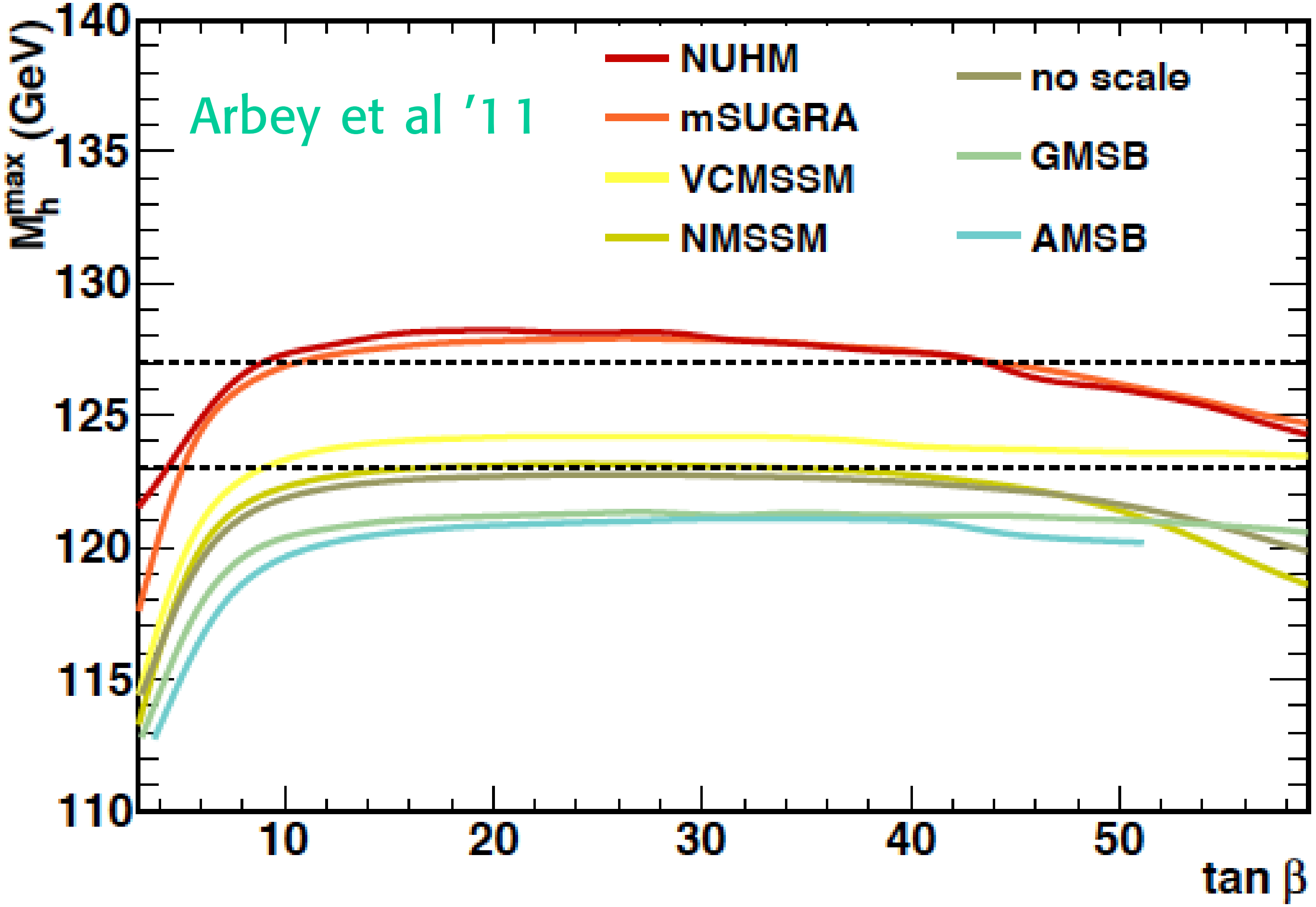
Khoze

Pure GGM @ M=10^8 GeV what's left of…



$m_H = 125$ GeV plus new bounds from negative searches disfavour simplest versions of SUSY

Mahmoudi



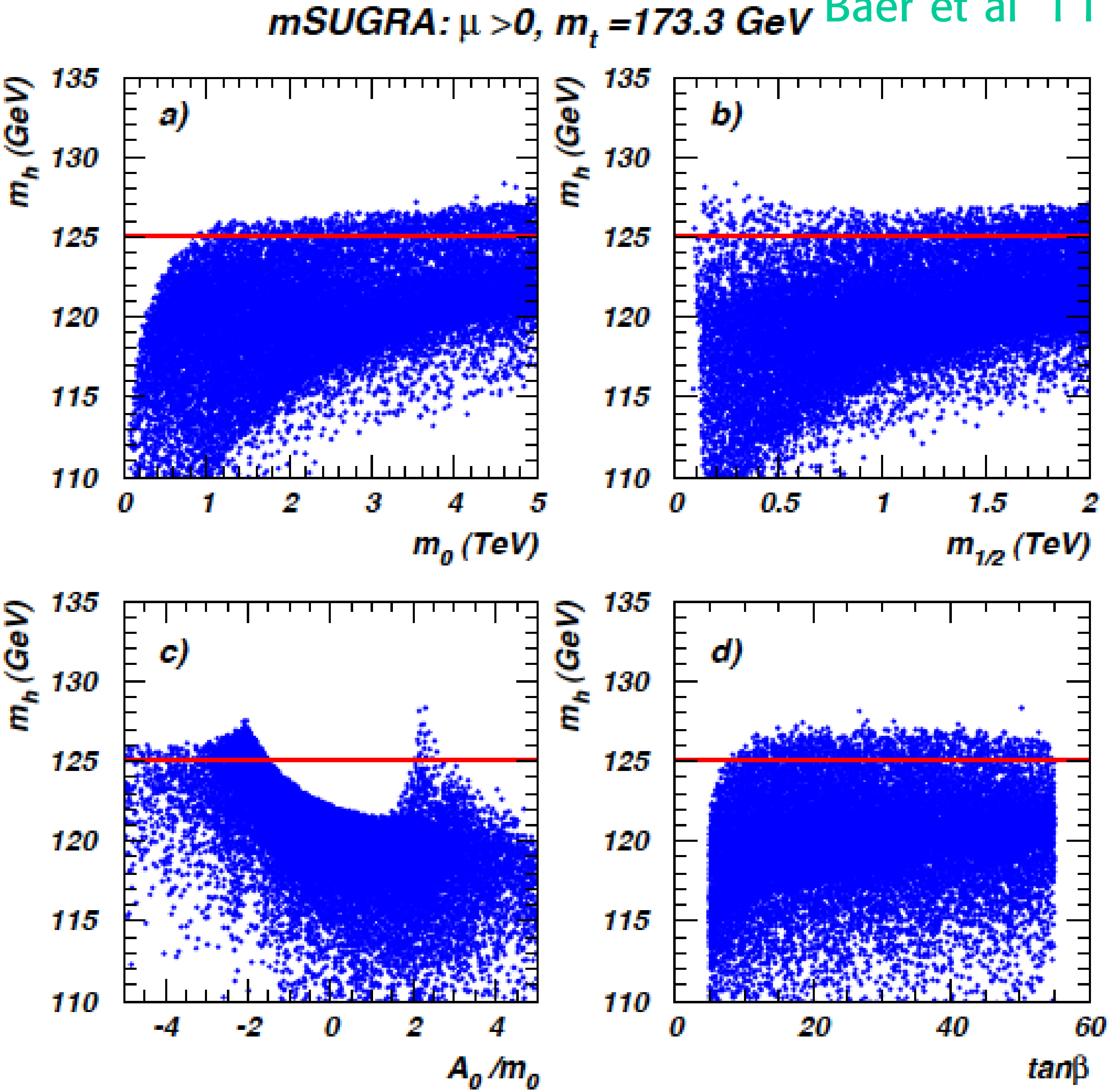
model	AMSB	GMSB	mSUGRA	no-scale	cNMSSM	VCMSSM	NUHM
$M_h^{\max}$	121.0	121.5	128.0	123.0	123.5	124.5	128.5

M_H ~125 GeV makes CMSSM/mSUGRA marginal

Terrible fine tuning

Ghilencea

Baer et al '11



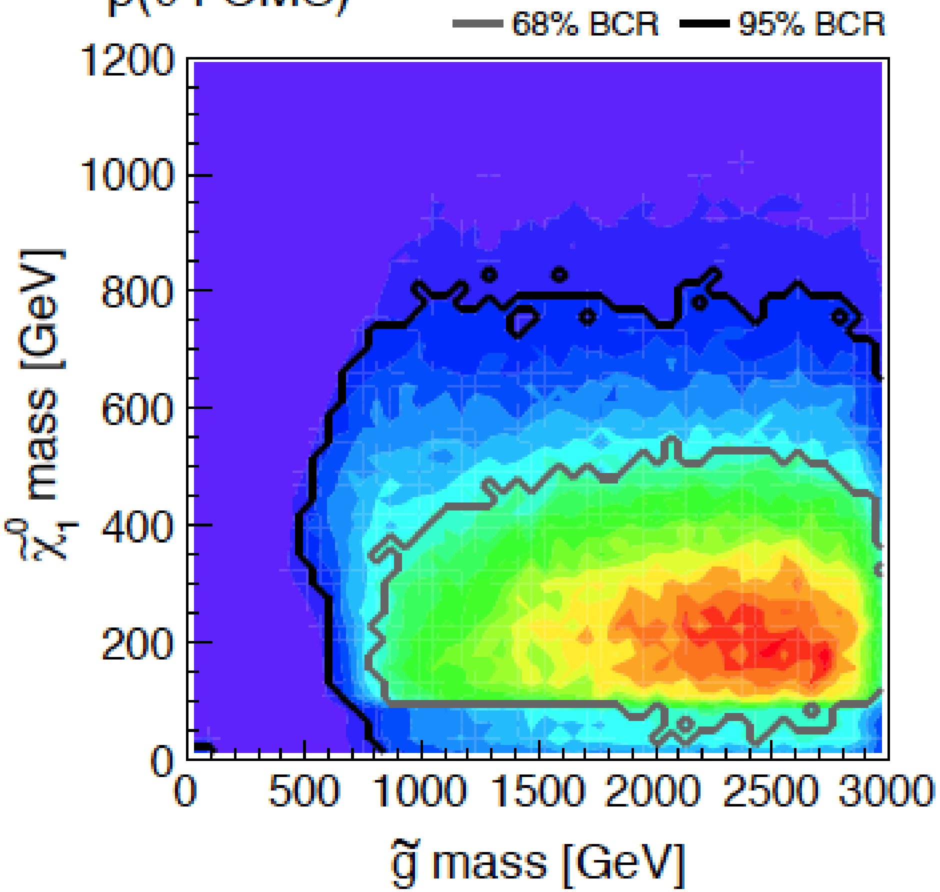
A more flexible setup is the MSSM with CP and R conservation and 19 parameters (pMSSM)

recently studied in several works

Arbey et al '11, '12

Mahmoudi

$p(\theta \mid \text{CMS})$



Parameter
$\tan\beta$
M_A
M_1
M_2
M_3
$A_d = A_s = A_b$
$A_u = A_c = A_t$
$A_e = A_\mu = A_\tau$
μ
$M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$
$M_{\tilde{e}_R} = M_{\tilde{\mu}_R}$
$M_{\tilde{\tau}_L}$
$M_{\tilde{\tau}_R}$
$M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$
$M_{\tilde{q}_{3L}}$
$M_{\tilde{u}_R} = M_{\tilde{c}_R}$
$M_{\tilde{t}_R}$
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$
$M_{\tilde{b}_R}$

As a comparison, the upper limit on m_h is larger in the pMSSM

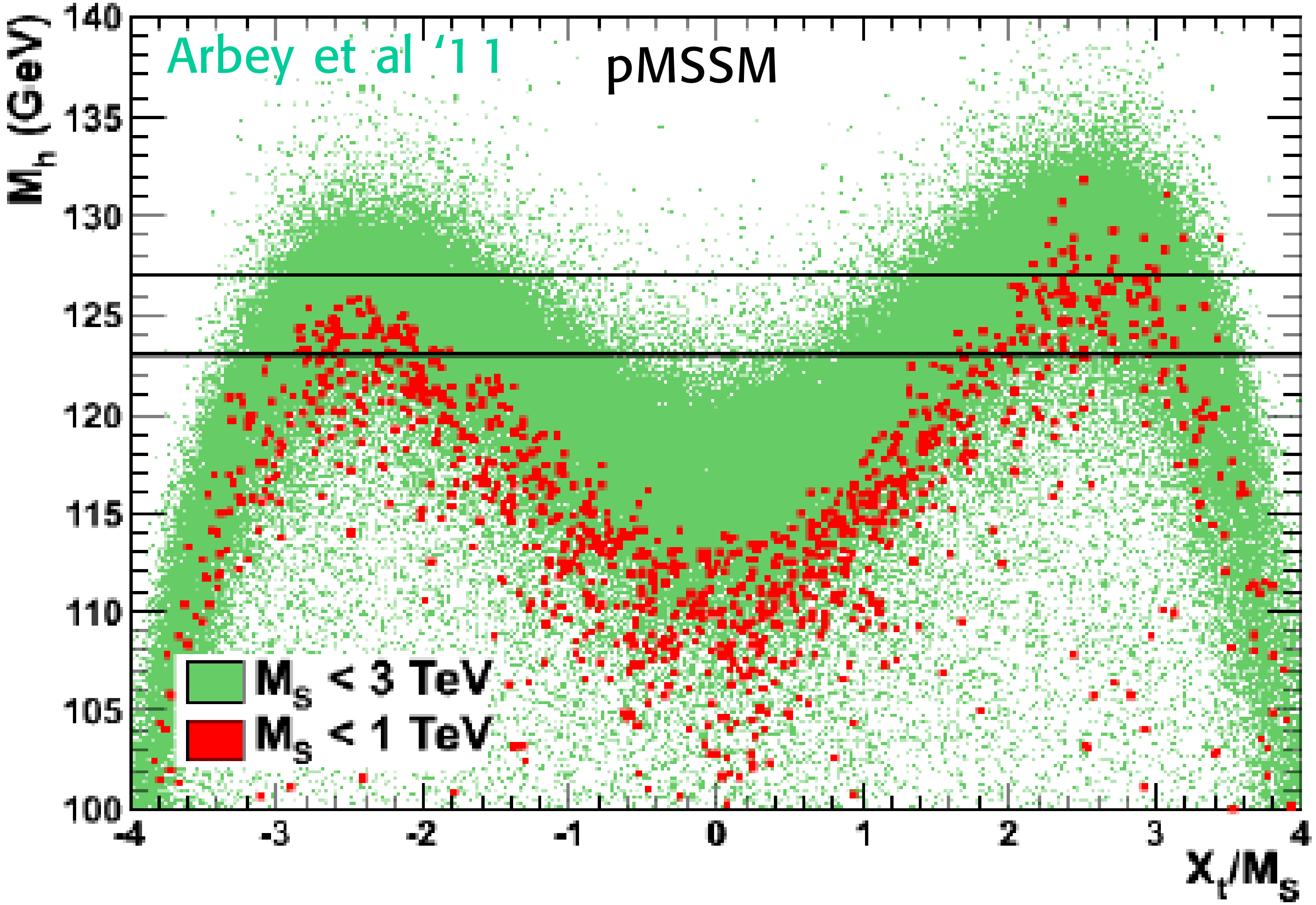
$m_h^2 = m_Z^2 |\cos 2\beta|^2 + \delta m_h^2$

$$\delta m_h^2 = \frac{3G_F}{\sqrt{2}\pi^2} m_t^4 \left(\log\left(\frac{\overline{m}_{\tilde{t}}^2}{m_t^2}\right) + \frac{X_t^2}{\overline{m}_{\tilde{t}}^2}\left(1 - \frac{X_t^2}{12\overline{m}_{\tilde{t}}^2}\right)\right)$$

$125^2 = 91^2 + 86^2$

Mahmoudi

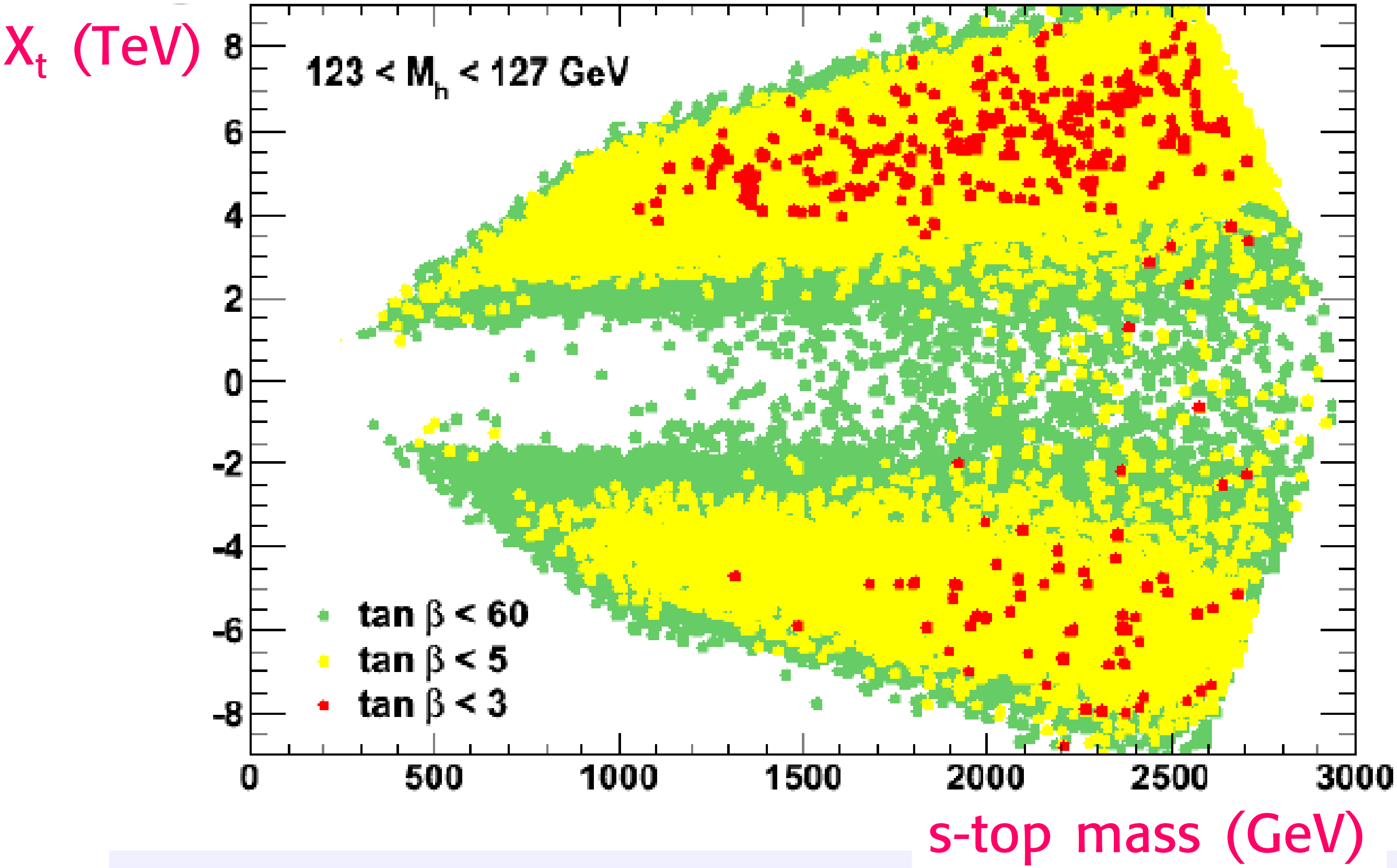
$X_t = A_t - \mu \cot\beta$



large M_S
large X_t
needed

Arbey et al '11

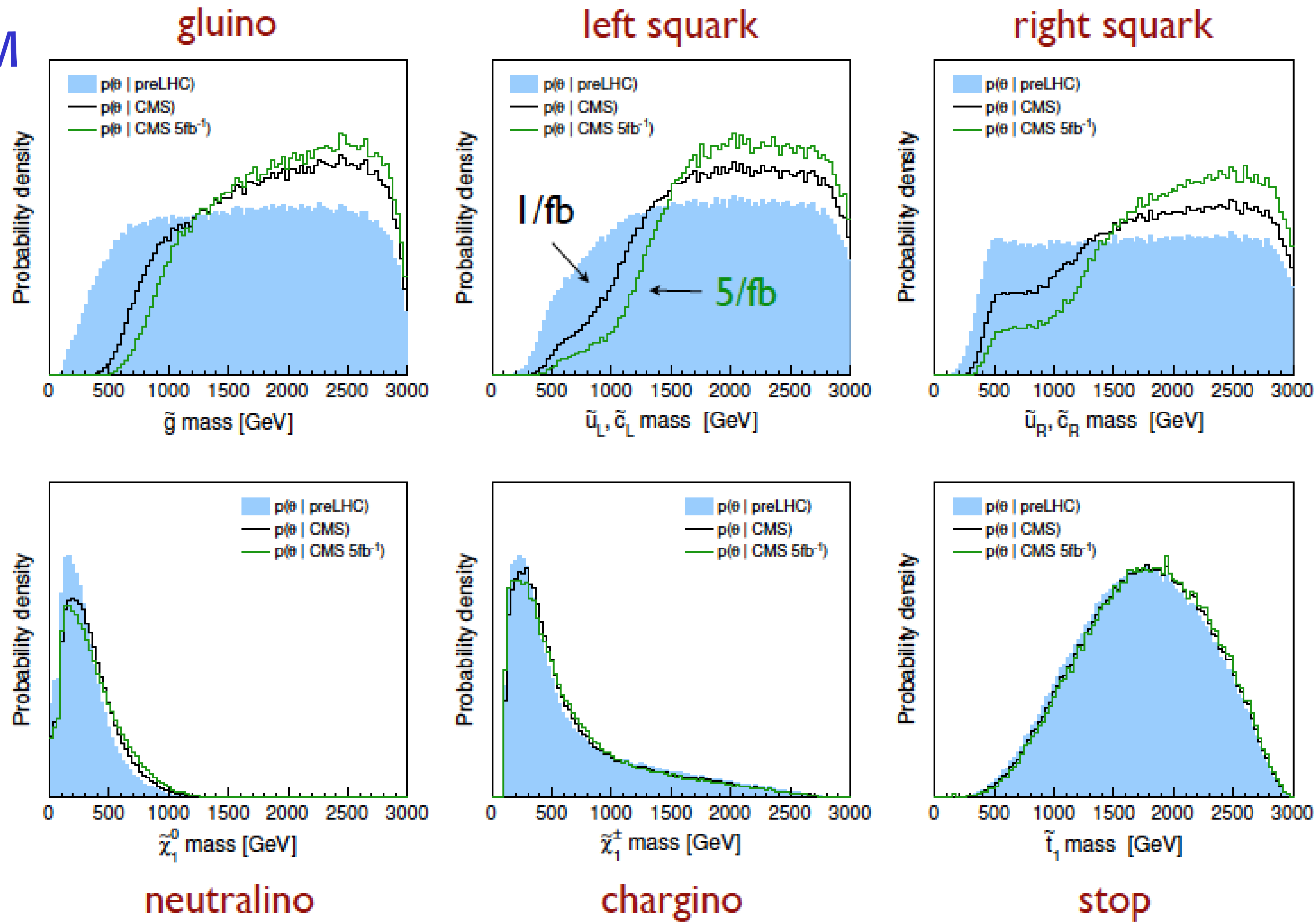
Mahmoudi



gluinos and 1-2 gen s-quarks are mostly affected by LHC
not EW-inos and stops

Sekmen et al ‘11

pMSSM



One must go beyond the CMSSM, mSUGRA, NUHM1,2

There is plenty of room for more sophisticated versions of SUSY as a solution to the hierarchy problem

The pMSSM shows that SUSY is alive

For an orderly retreat

Simplest new ingredients

- Heavy first 2 generations
- NMSSM
- λ SUSY

$\left.\begin{array}{l}\text{NMSSM}\\ \lambda\ \text{SUSY}\end{array}\right\}$ an extra Higgs singlet

The last trench of natural SUSY!

For MSSM to be natural $m_{\tilde{g}}, m_{\tilde{t}}, m_{\tilde{b}}, m_{\tilde{h}}$ < ~1 TeV

Sanz, Badziak

Tree level

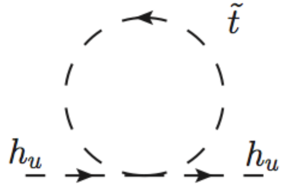
Papucci

$\sin^2 2\beta << 1$

(no extra singlet in MSSM)

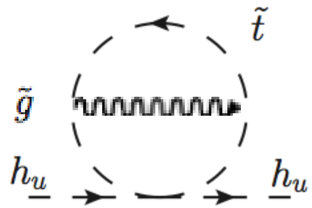
$$-\frac{m_Z^2}{2} = |\mu|^2 + m_{H_u}^2$$

μ related to lightest Higgsino mass



$$\delta m_{H_u}^2|_{stop} = -\frac{3}{8\pi^2} y_t^2 \left(m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2 + |A_t|^2\right) \log\left(\frac{\Lambda}{\mathrm{TeV}}\right)$$

largest radiative corrections involve s-top and gluinos

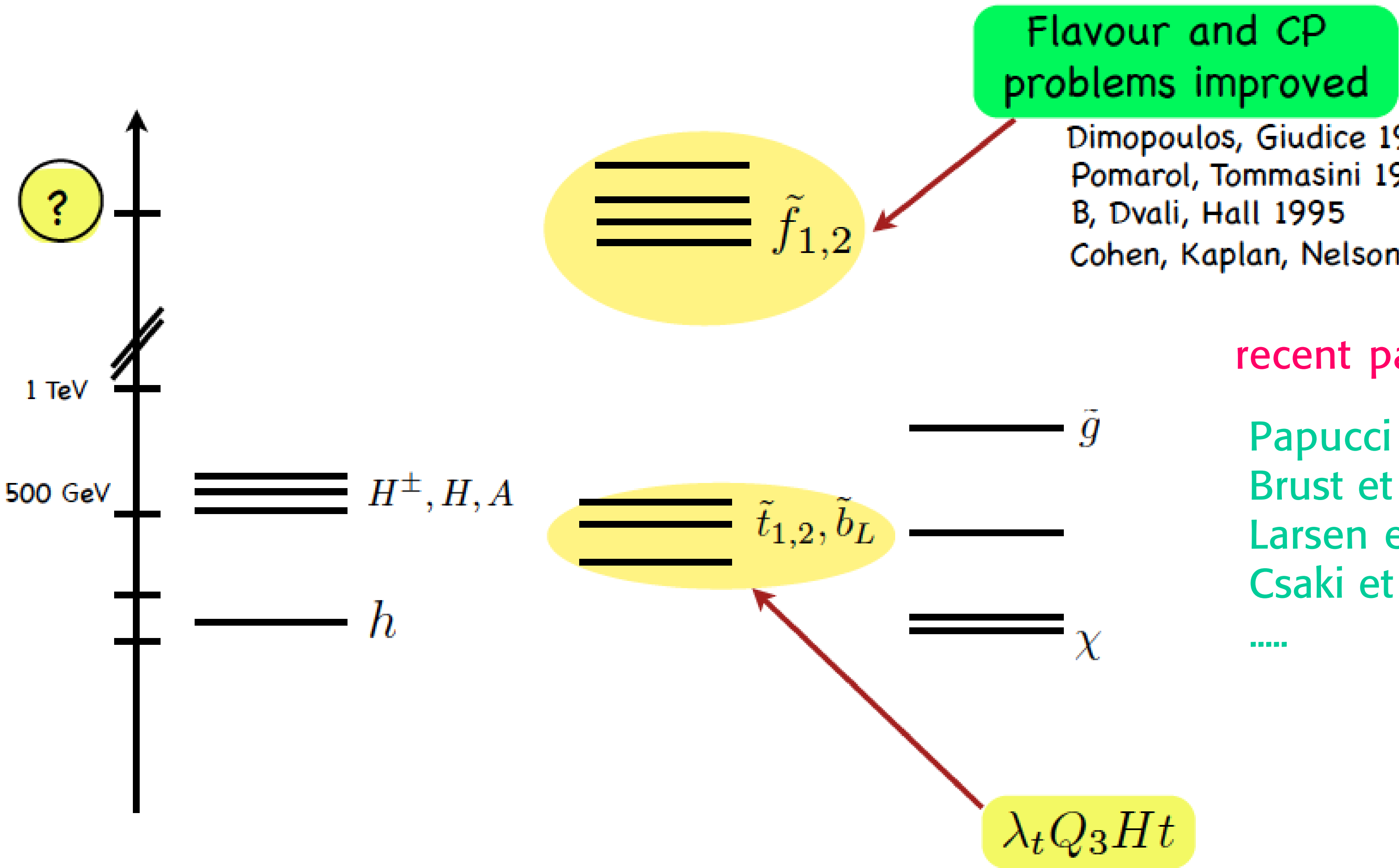


$$\delta m_{H_u}^2|_{gluino} = -\frac{2}{\pi^2} y_t^2 \left(\frac{\alpha_s}{\pi}\right) |M_3|^2 \log^2\left(\frac{\Lambda}{\mathrm{TeV}}\right)$$

Beyond the CMSSM, mSugra, NUHM1,2

Heavy 1st, 2nd generations

Barbieri



Dimopoulos, Giudice 1995
Pomarol, Tommasini 1995
B, Dvali, Hall 1995
Cohen, Kaplan, Nelson 1996

pioneer papers

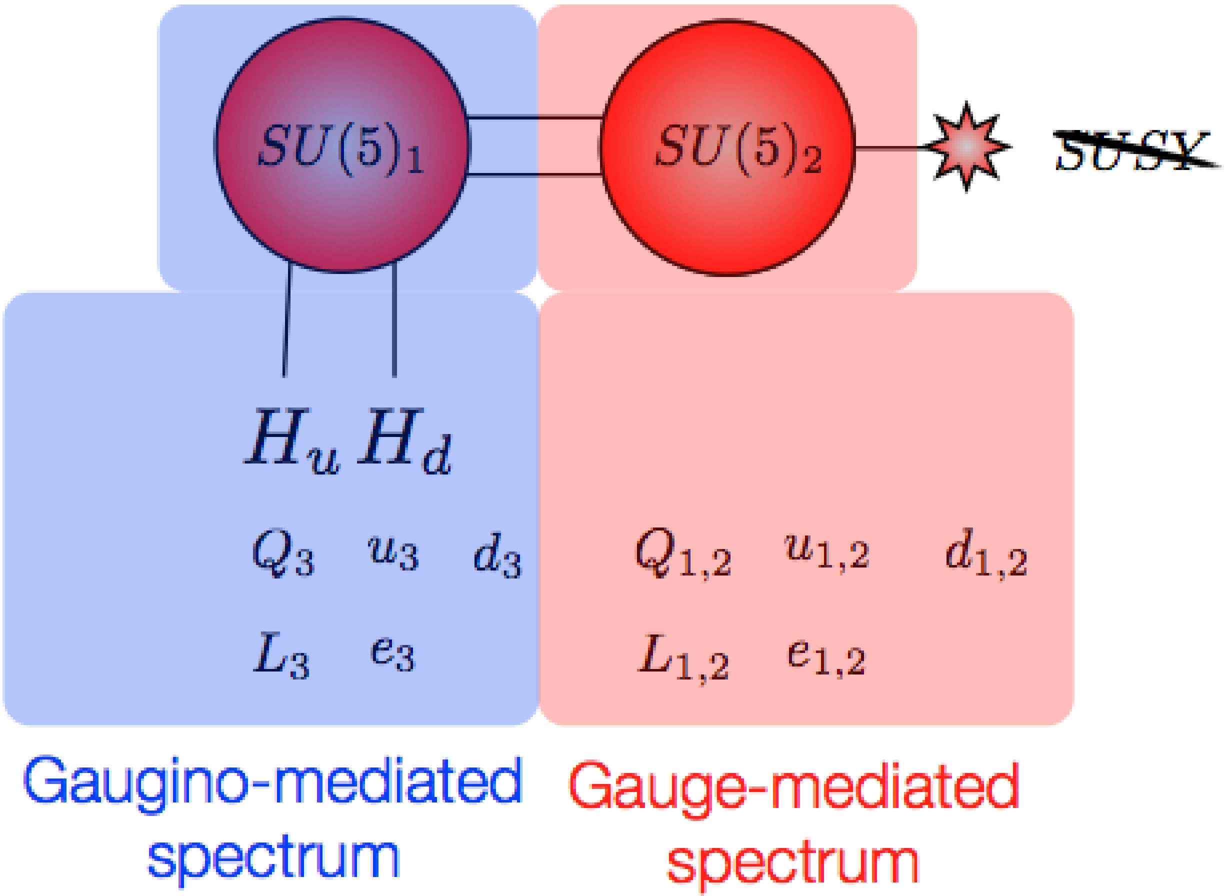
recent papers, e.g.

Papucci et al '11
Brust et al '11
Larsen et al '12
Csaki et al '12
.....

[NC, Green, Katz 1103.3708; NC, Dimopoulos, Gherghetta 1203.0572]

Splitting the families

Craig



Going beyond the MSSM: an extra singlet Higgs

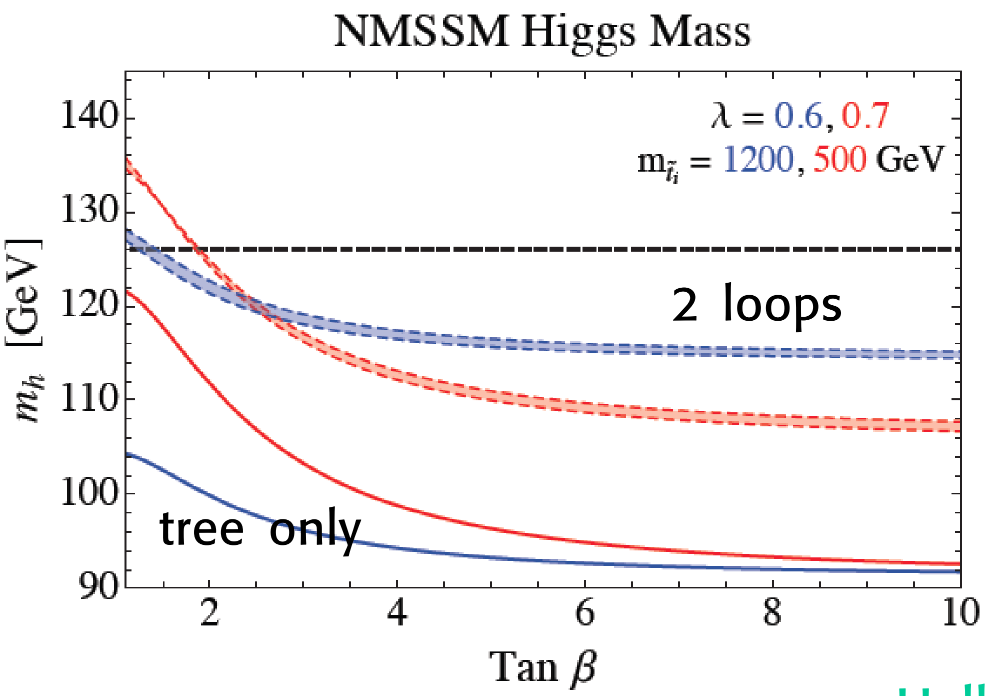
In a promising class of models a singlet Higgs S is added and the μ term arises from the S VEV (the μ problem is solved)

$$\lambda \, S H_u H_d$$

Mixing with S can modify the Higgs mass and couplings at tree level

NMSSM: $\lambda < \sim 0.7$ the theory remains perturbative up to M_{GUT}
(no need of large stop mixing, less fine tuning)

λ SUSY: $\lambda \sim 1 - 2$ for $\lambda > 2$ theory non pert. at ~ 10 TeV

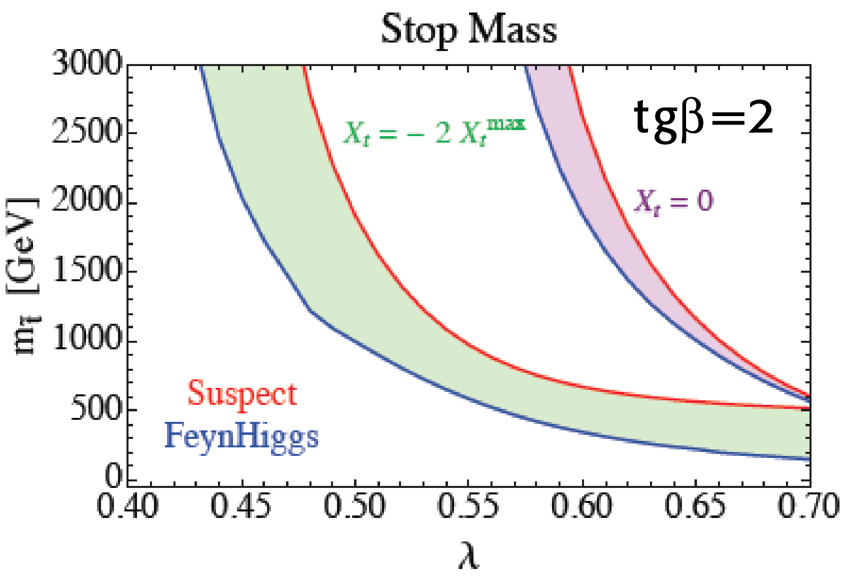


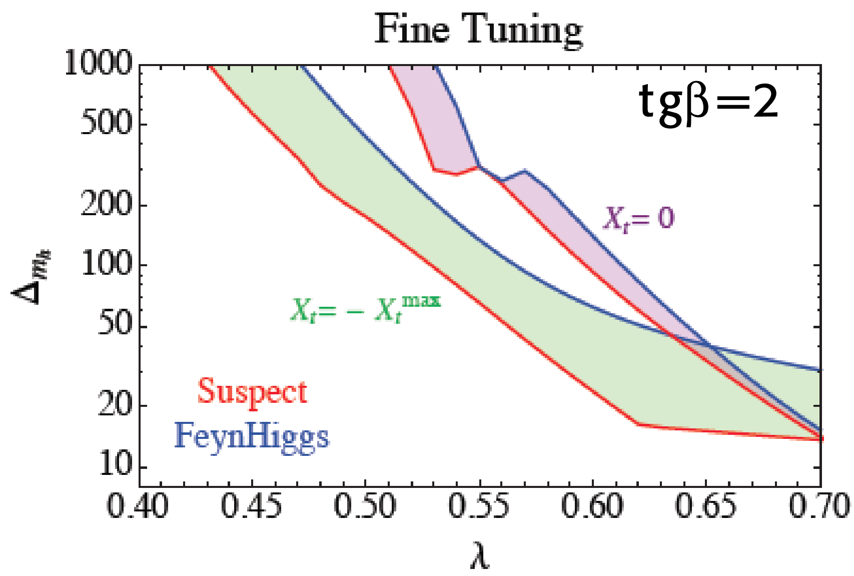
additional term

$$m_h^2 = M_Z^2 \cos^2 2\beta + \lambda^2 v^2 \sin^2 2\beta + \delta_t^2$$

less need of loop terms
-> lighter s-top, less FT

Hall et al '11



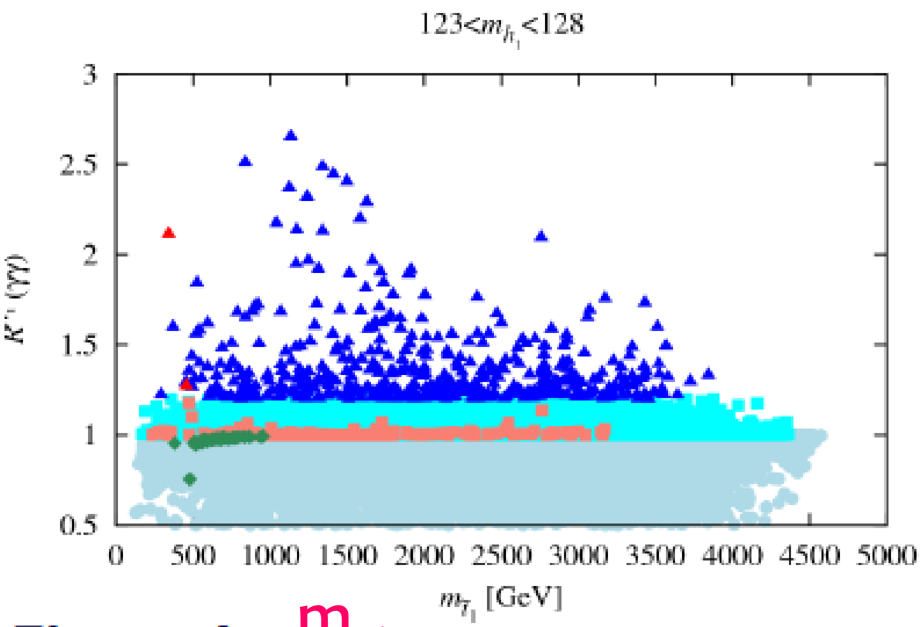


$m_H \sim 125$ GeV

Gunion

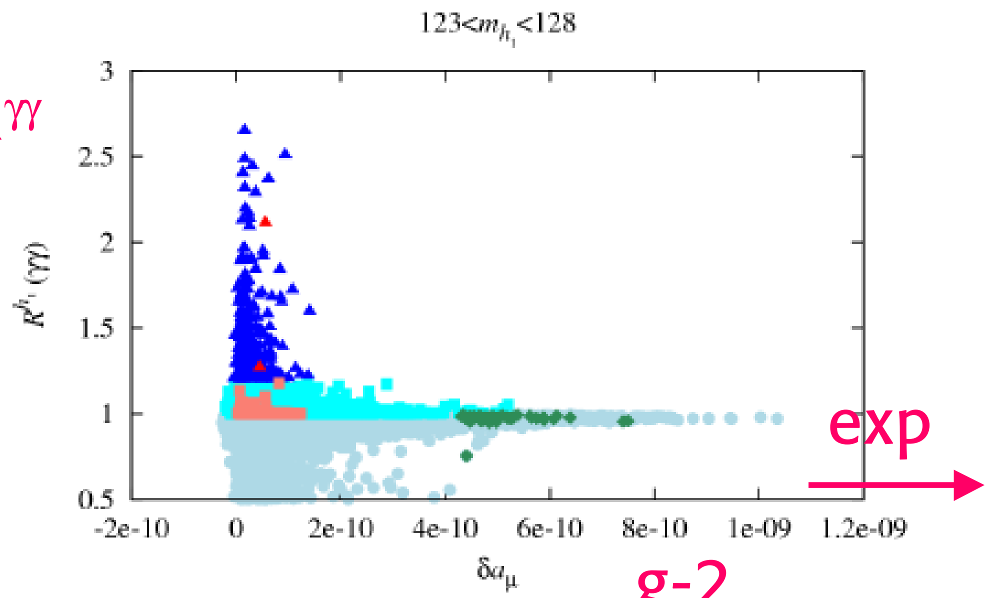
Figure Legend

	LEP/Teva	B-physics	$\Omega h^2 > 0$	$\delta a_\mu(\times 10^{10})$	XENON100	$R^{h_1/h_2}(\gamma\gamma)$
●	√	√	$0 - 0.136$	×	√	$[0.5, 1]$
■	√	√	$0 - 0.094$	×	√	$(1, 1.2]$
▲	√	√	$0 - 0.094$	×	√	> 1.2
■	√	√	0.094-0.136	×	√	$(1, 1.2]$
▲	√	√	0.094-0.136	×	√	> 1.2
◆	√	√	$0.094 - 0.136$	4.27-49.1	√	~ 1



$R^{\gamma\gamma}$

m_{stop}



exp

g-2

Muon g-2

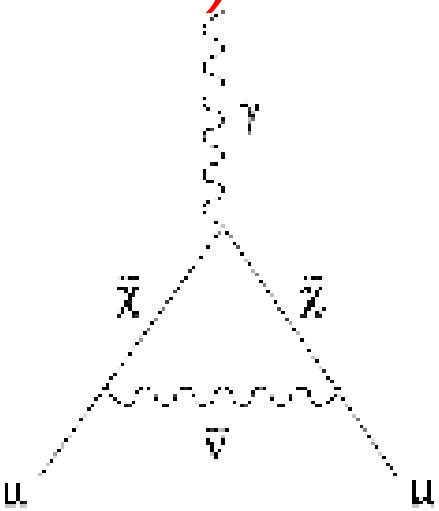
$a_\mu^{exp} - a_\mu^{SM} = (28.7 \pm 8.0) \times 10^{-10}$

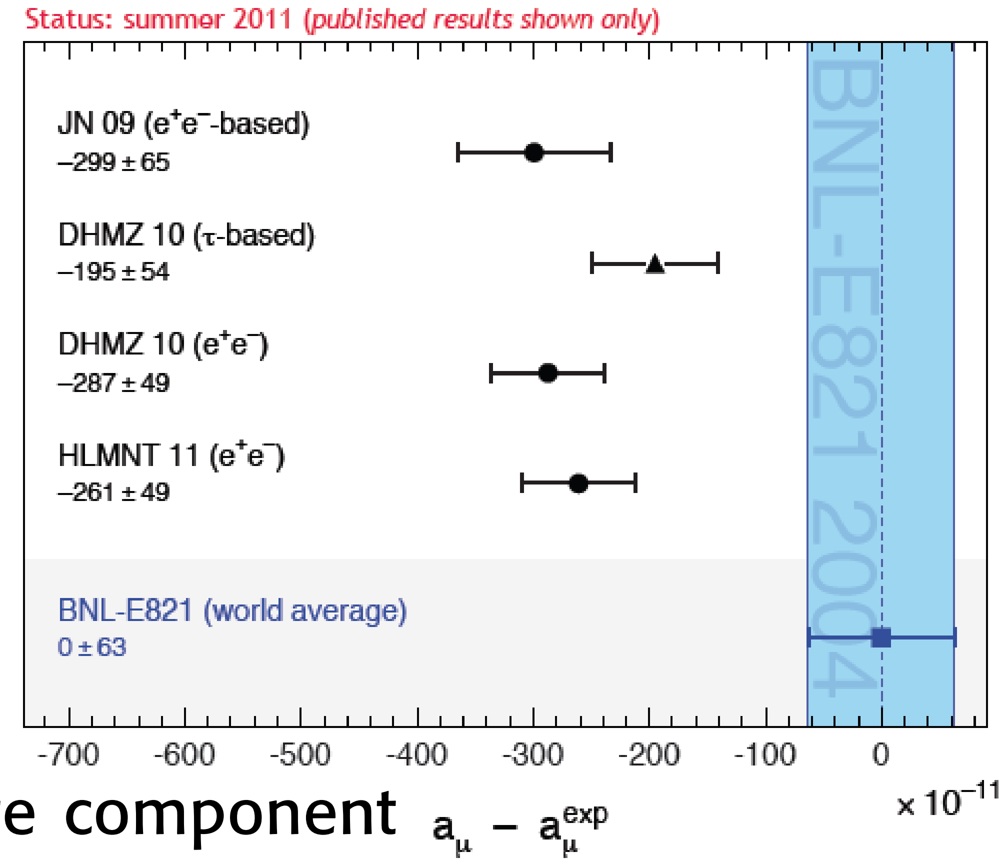
- 3.6 "standard deviations" (e^+e^-)
- 2.4 "standard deviations" (τ)

a_μ is a plausible location for a new physics signal!!

$$\delta a_\mu = 13 \cdot 10^{-10} \left(\frac{100 GeV}{M_{SUSY}} \right)^2 tg\beta$$

eg could be light SUSY (now essentially excluded by mH ~ 125 GeV and LHC7 limits)





Th error from γ–γ is a large component

The flavour problem

Buras
Perez
Haisch

No clear and firm deviation from the SM

Still there is space for new physics
of very non generic type

$U(2)^3$ — Barbieri, Sala, Butazzo

Flavour and extra dimensions — Neubert

SUSY and Flavour — Raby, Calibbi

Charm CP violation — Kamenik, Lodone

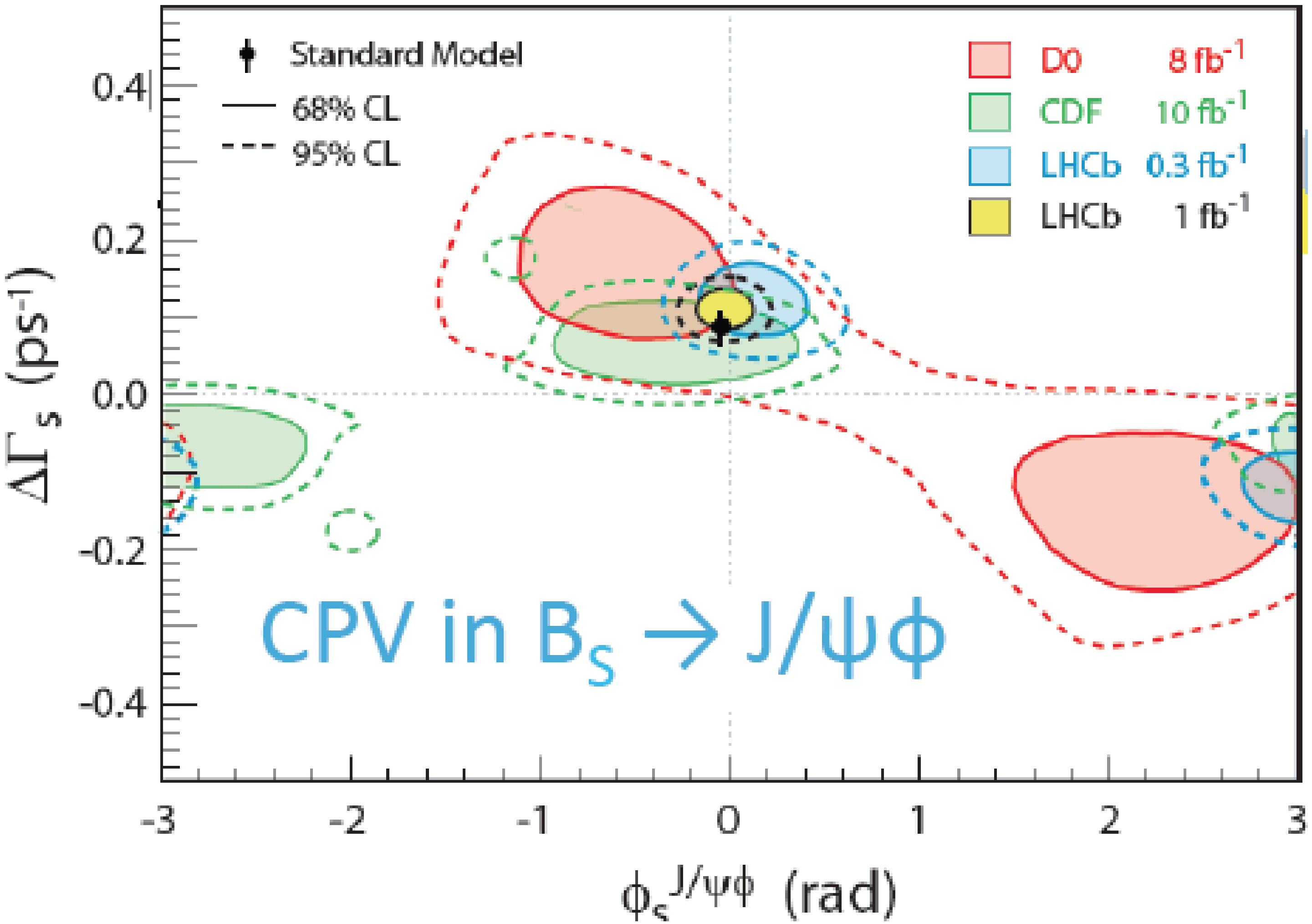
.....

LHC and flavor physics

Important results from LHCb

Marconi

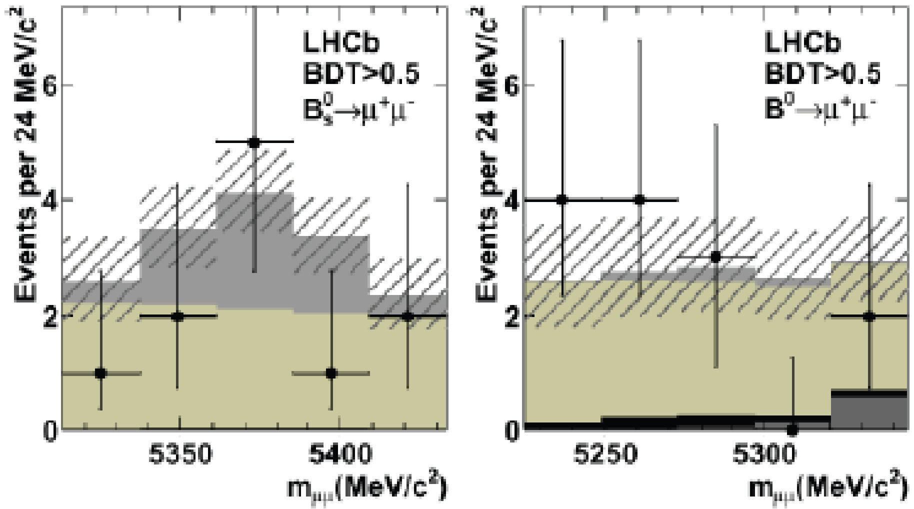
Back into agreement with SM



LHCb: Br(B_s -> $\mu\mu$) < 4.5 10^{-9} (95% c.l.)

$B_{(s)} \rightarrow \mu^+\mu^-$

LHCb-PAPER-2012-007
arXiv:1203.4493

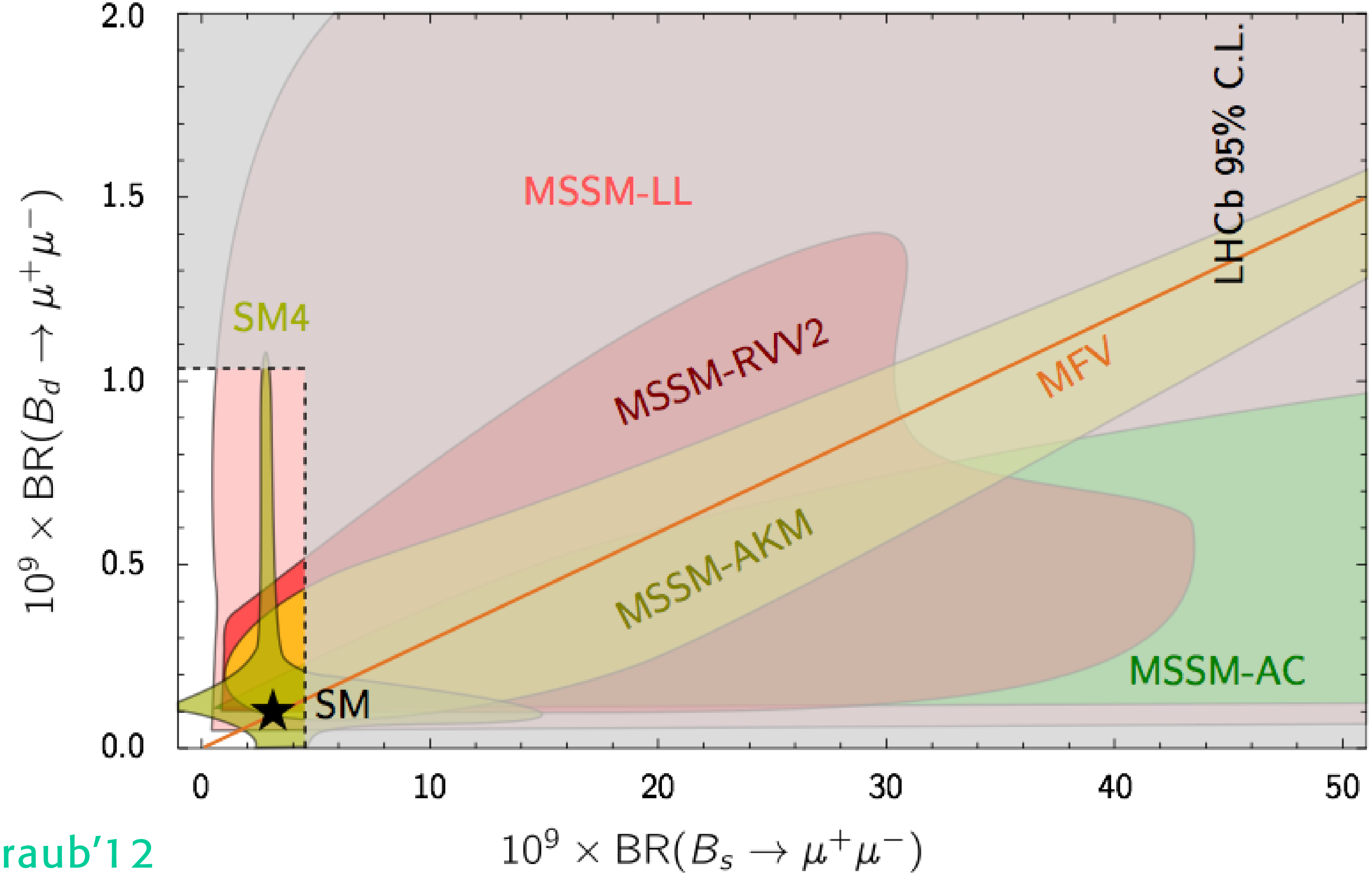


Mode	Limit	at 90 % CL	at 95 % CL
$B_s^0 \rightarrow \mu^+\mu^-$	Exp. bkg+SM	6.3×10^{-9}	7.2×10^{-9}
	Exp. bkg	2.8×10^{-9}	3.4×10^{-9}
	Observed	3.8×10^{-9}	$\boxed{4.5 \times 10^{-9}}$
$B^0 \rightarrow \mu^+\mu^-$	Exp. bkg	0.91×10^{-9}	1.1×10^{-9}
	Observed	0.81×10^{-9}	$\boxed{1.0 \times 10^{-9}}$

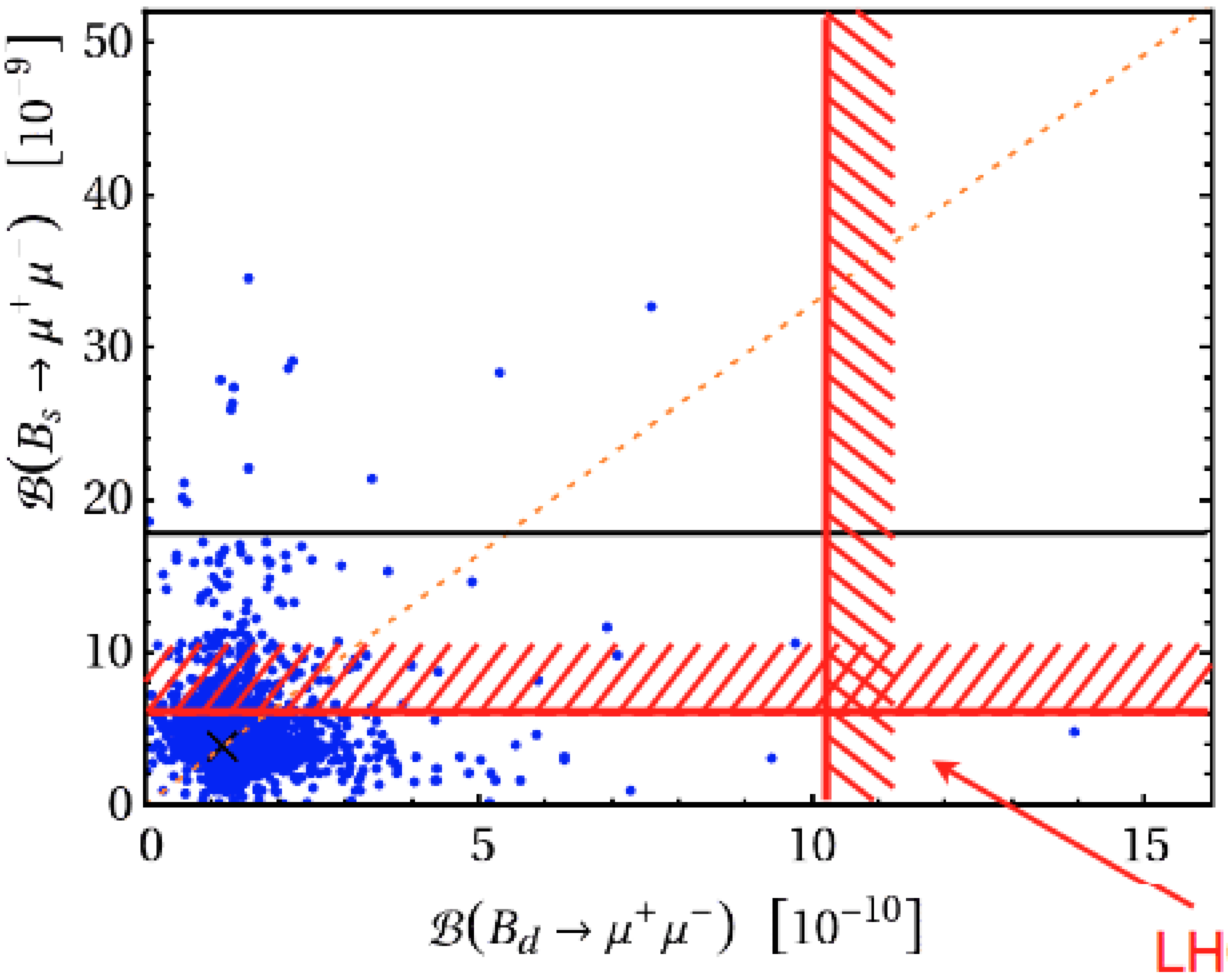
$\boxed{B(B_s \rightarrow \mu^+\mu^-) = (0.8^{+1.8}_{-1.3}) \times 10^{-9}}$

LHCb: Br(B_s -> $\mu\mu$) < 4.5 10^{-9} (95% c.l.)

Buras



Straub'12



Neubert

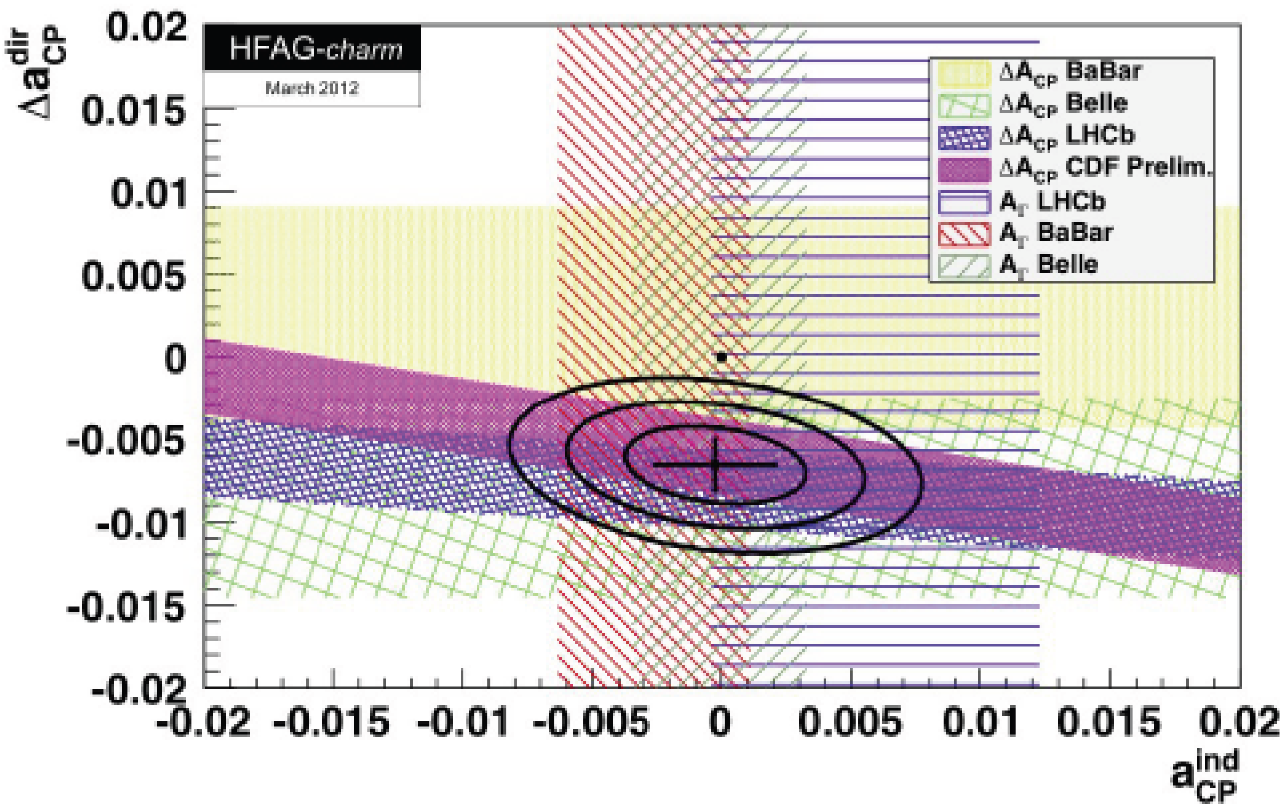
RS model of flavour

Hierarchies from warping factors

LHCb upper bounds (95% CL) @ Moriond EW 2012

Bauer, Casagrande, Haisch, MN (2009)
see also: Blanke et al. (2008)

Evidence of CPV in charm



Not clear whether New Physics or SM

Result, based on 0.62/fb of 2011 data

$\Delta A_{CP} = [-0.82 \pm 0.21(\text{stat.}) \pm 0.11(\text{syst.})]\%$

Kamenik, Perez

New flavour phenomena and the Fermi scale

$U(2)^3$ Summary and conclusions

Barbieri

⇒ If $U(2)^3$ with Minimal breaking

$$\Delta\mathcal{L} = \Sigma_i \frac{c_i}{(4\pi v)^2}\xi_i \mathcal{O}_i \quad \text{and} \quad |c_i| = 0.2 \div 1$$

consistent with current data ⇒ Hence the title of the talk

⇒ Several observables to watch:

Sala

$$S_{\Psi\phi},\ b \to s(d)\gamma,\ b \to s(d)l\bar{l}, \nu\bar{\nu},\ K \to \pi\nu\bar{\nu}$$

⇒ If $U(2)^3$ with Generic breaking

$\Delta a_{CP}^{exp}(D) = -(0.67 \pm 0.16)\%$ from cromo-electric up⇔charm dipole

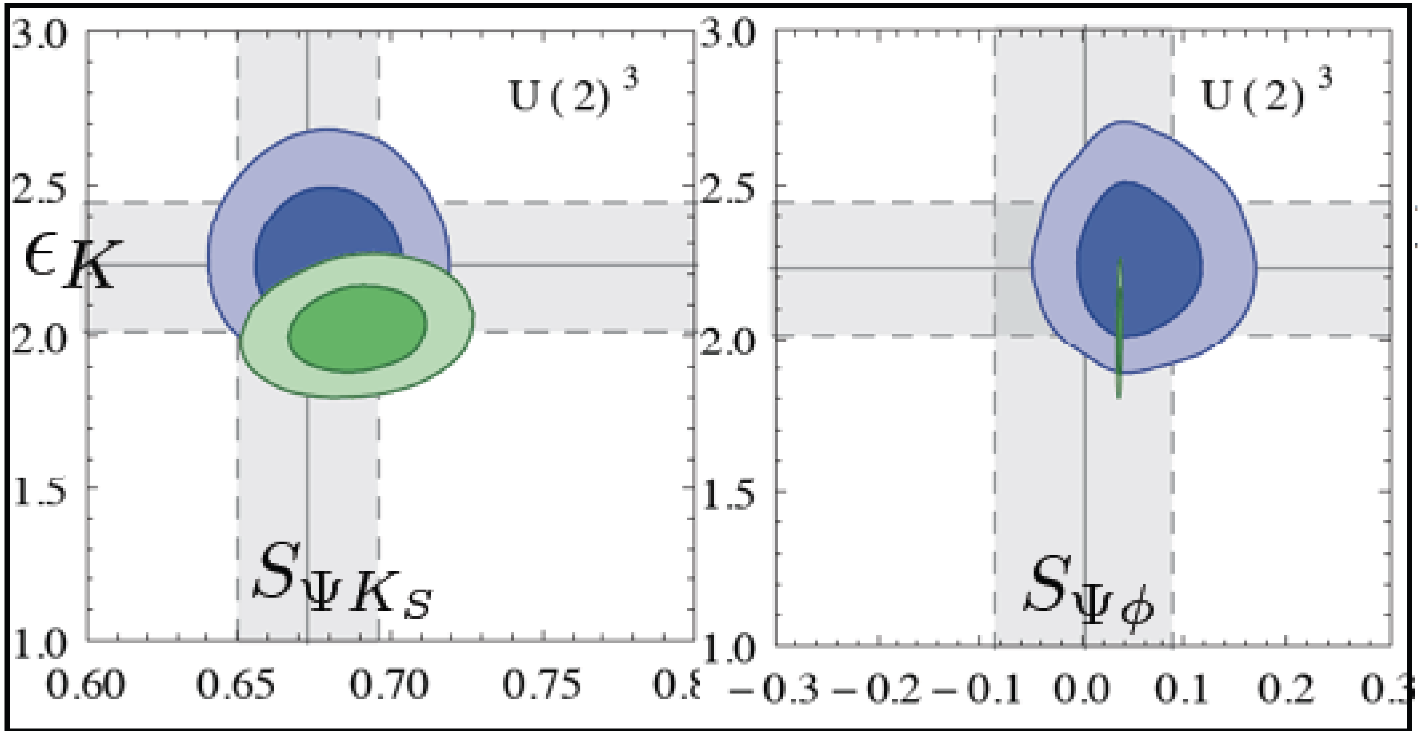
if needed, consistently with d_n - bound

⇒ If new signals observed, best signature of $U(2)^3$

is s⇔d correlation in b-decays as in the SM

(as in MFV, yes, but...)

Barbieri



Consistent with $$\Delta\mathcal{L} = \Sigma_i \frac{c_i}{(4\pi v)^2}\xi_i \mathcal{O}_i$$

and $$|c_i| = 0.2 \div 1$$

Important developments in neutrino physics

G. Ross
Feruglio

We now know θ_{13} with fair precision

	$\sin^2 2\theta_{13}$	$\sin^2 \theta_{13}$
T2K [1106.2822]	$0.11^{+0.11}_{-0.05}$ $(0.14^{+0.12}_{-0.06})$	$0.028^{+0.019}_{-0.024}$ $(0.036^{+0.022}_{-0.030})$
MINOS [1108.0015]	$0.041^{+0.047}_{-0.031}$ $(0.079^{+0.071}_{-0.053})$	$0.010^{+0.012}_{-0.008}$ $(0.020^{+0.019}_{-0.014})$
DC [1112.6353]	$0.086 \pm 0.041 \pm 0.030$	$0.022^{+0.019}_{-0.018}$
DYB [1203.1669]	$0.092 \pm 0.016 \pm 0.005$	0.024 ± 0.005
RENO [1204.0626]	$0.113 \pm 0.013 \pm 0.019$	0.029 ± 0.006

$\sin^2\theta_{13} = 0.025 \pm 0.003$

$\theta_{13} \sim 9^\circ$ (cfr $\theta_C \sim 13^\circ$)

Fogli *et al.* 1205.5254 (see also [Forero, Tortola and Valle 1205.4018])

(Normal Hierarchy)

Merlo
Palazzo
Blankenburg
Meroni
Luhn
Spinrath

$$\Delta m^2_{\rm sol} = (7.54^{+0.26}_{-0.22}) \times 10^{-5}\,{\rm eV}^2$$

$$\Delta m^2_{\rm atm} = (2.43^{+0.07}_{-0.09}) \times 10^{-3}\,{\rm eV}^2$$

$$\sin^2\theta_{12} = 0.307^{+0.018}_{-0.016}$$

$$\sin^2\theta_{23} = 0.398^{+0.030}_{-0.026}$$

← Indication of θ_{23} non maximal

$$\sin^2\theta_{13} = 0.0245^{+0.0034}_{-0.0031}$$

$$\delta = \pi(0.89^{+0.29}_{-0.44})$$

← Indication of $\cos\delta < 0$

Here 3 neutrinos assumed

Are there small admixtures of sterile neutrinos? To be clarified

θ_{13} near the previous bound, θ_{23} non maximal go in the direction of Anarchy

No order for leptons -> Anarchy

$\theta_{12}, \theta_{13}, \theta_{23}$ are just 3 random angles

In the lepton sector no symmetry, no dynamics is needed; only chance

Hall, Murayama, Weiner '00
de Gouvea, Murayama '12

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θ_{13} near the previous bound, θ_{23} non maximal move away from Tri-Bimaximal mixing $\theta_{13} = 0$, $\theta_{23} = 45^o$, $\sin^2\theta_{12} = 1/3$

$$U_{TB} = \begin{pmatrix} \sqrt{\frac{2}{3}} & \sqrt{\frac{1}{3}} & 0 \\ -\sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & -\sqrt{\frac{1}{2}} \\ -\sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & \sqrt{\frac{1}{2}} \end{pmatrix} \longrightarrow$$

Discrete flavour groups
A maximum of order

Anarchy is a different manifestation of “no New Physics”

Anarchy is also in line with the anthropic philosophy: neutrino mixing angles values are not crucial for our existence: they can be random

In this case also the game is not over:
one can reproduce the data well in terms of symmetry + corrections (now guided by the extra information)

Ross, Feruglio, Merlo, Luhn, Meroni, Spinrath.....

Individual models make predictions on the neutrino spectrum, CP violation phase, $0\nu\beta\beta$, lepton flavour violating processes and the relation with CKM parameters that can pick up the right model

Conclusion

The Higgs comes closer

2012 will be the year of the Higgs:
yes or no to the SM Higgs

New Physics is pushed further away

But the LHC experiments are just at the start and
larger masses can be reached in 2012
and even more in the 14 TeV phase

Supersymmetry? Compositeness? Extra dimensions?
Anthropic? We shall see!

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Stay (Fine-)Tuned!!

As the last speaker, on behalf of all participants,
I thank the Organizers who have done really
a great job!
Planck 2012 allowed a complete overview
of our field in a most confortable setting with the
pleasant Warsaw spring background