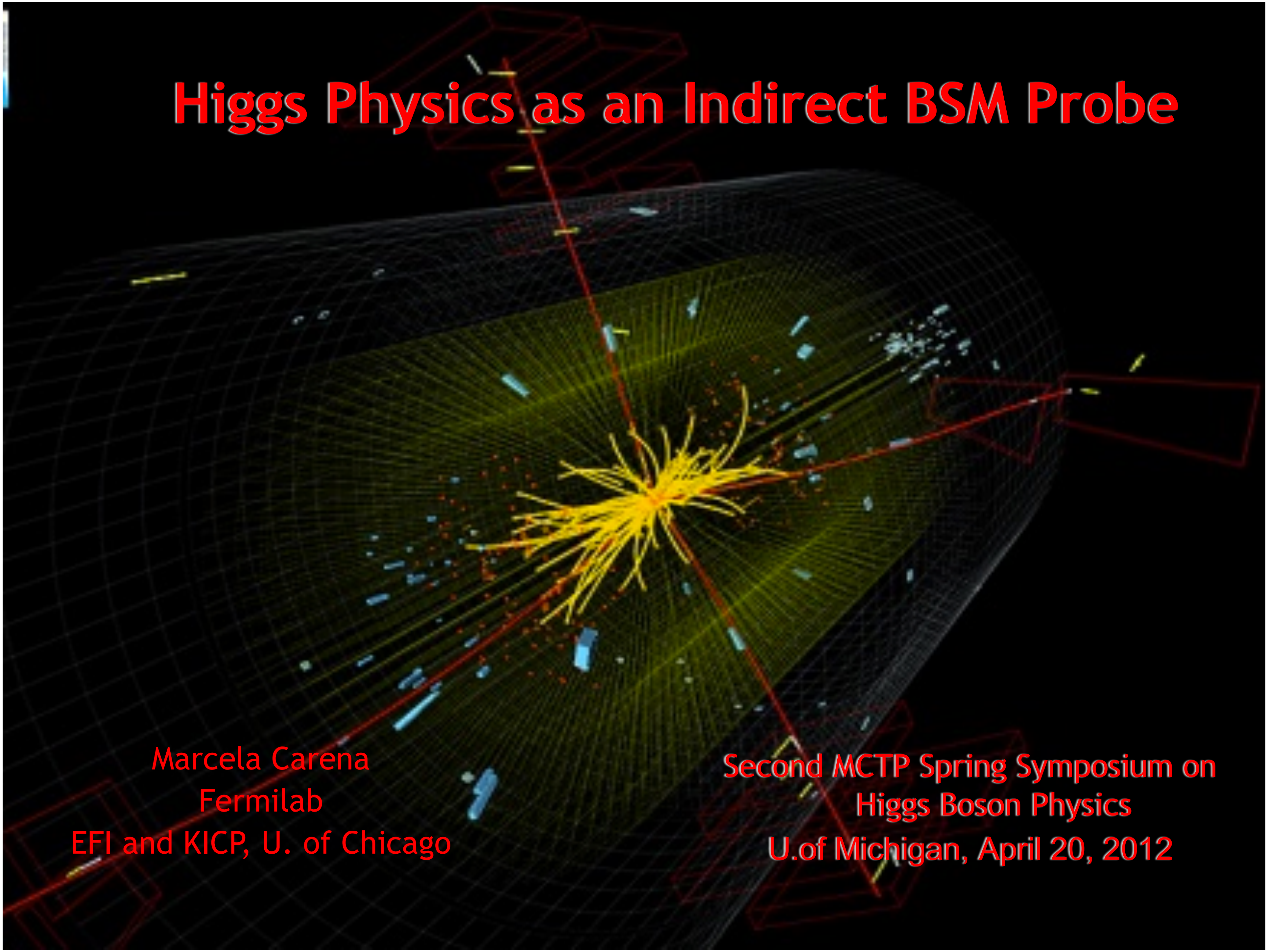
Higgs Physics as an Indirect BSM Probe



Marcela Carena
Fermilab
EFI and KICP, U. of Chicago

Second MCTP Spring Symposium on
Higgs Boson Physics
U.of Michigan, April 20, 2012

The Standard Model

works beautifully, explaining all experimental phenomena to date with great precision ➔ no compelling hints for deviations

But many questions remain unanswered:

Origin of electroweak symmetry breaking

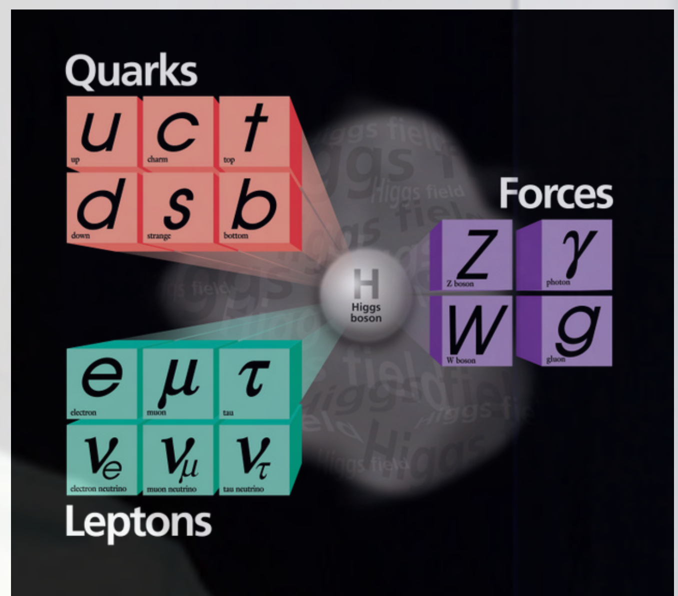
Origin of generations and structure of Yukawa interactions

Matter-antimatter asymmetry

Unification of forces

Neutrino masses

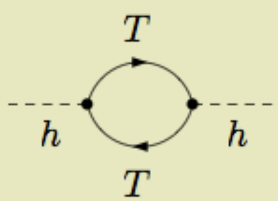
Dark matter and dark energy



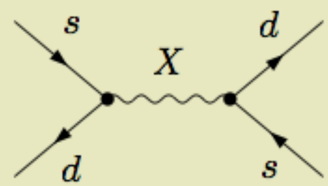
Hence, the "prejudice" that there must be "New Physics"

Standard Model and Beyond

$$\mathcal{L}_{\rm EFT} = \underbrace{\boxed{\Lambda_{\rm UV}^2 \Phi^\dagger\Phi - \lambda(\Phi^\dagger\Phi)^2}}_{\text{electroweak symmetry breaking} \Downarrow \text{Higgs mass}} + \mathcal{L}_{\rm SM}^{\rm gauge} + \mathcal{L}_{\rm SM}^{\rm Yukawa} + \underbrace{\boxed{\frac{\mathcal{L}^{(5)}}{\Lambda_{\rm UV}}} + \boxed{\frac{\mathcal{L}^{(6)}}{\Lambda_{\rm UV}^2}}}_{\Downarrow} + \ldots$$



$$\sim \frac{g_T^2}{16\pi^2}\Lambda_{\rm UV}^2$$



$$\sim \frac{g_X^2}{\Lambda_{\rm UV}^2}$$

no fine-tuning $\Downarrow$

bounds on flavor mixing $\Downarrow$ assuming *generic* flavor structure

$\Lambda_{\rm Higgs} < 1$ TeV $\quad$ $\Lambda_{\rm flavor} > 10^3$ TeV

Possible solutions to flavor problem explaining $\Lambda_{\rm Higgs} << \Lambda_{\rm flavor}$:

$\Lambda_{\rm UV}$ >> 1 TeV: Higgs fine tuned, new particles too heavy for LHC

$\Lambda_{\rm UV} \approx$ 1 TeV: quark flavor-mixing protected by a flavor symmetry

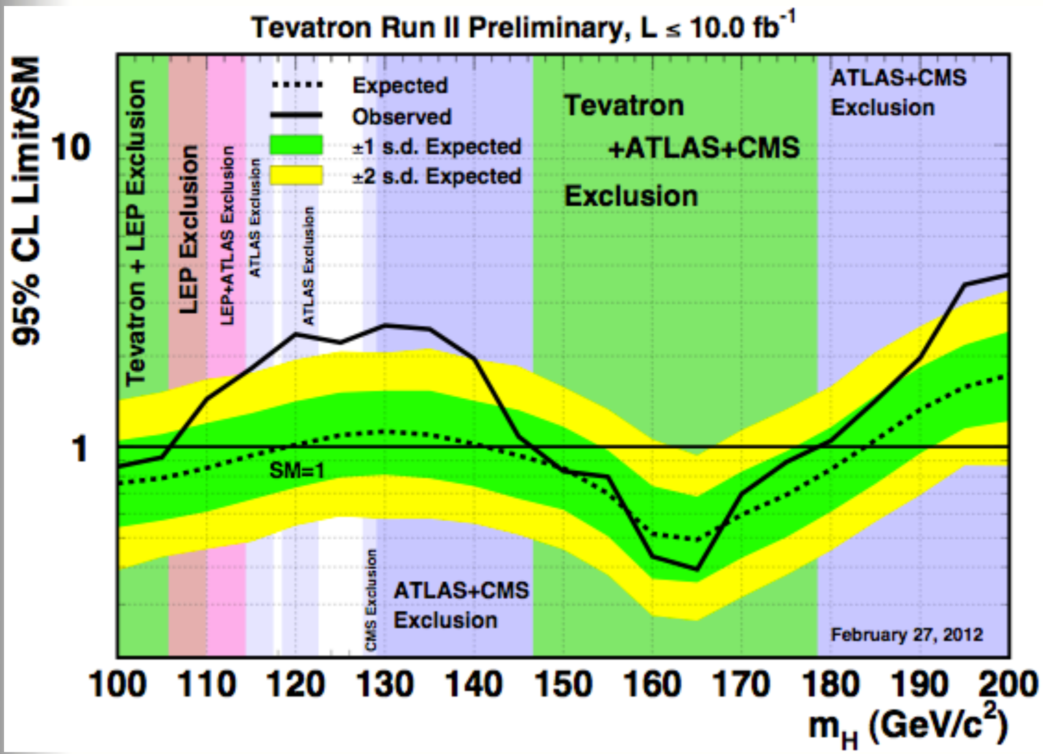
Very Exciting Times !

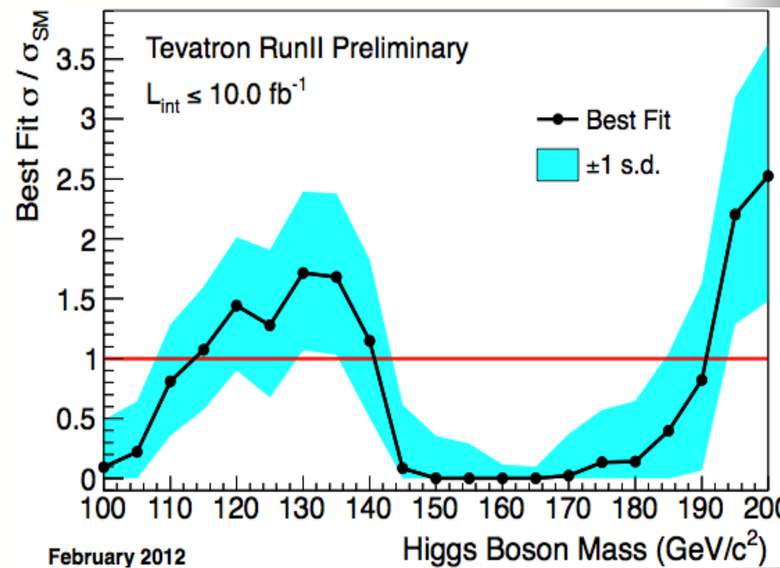
The Tevatron and LHC experiments

are extensively testing the SM-like Higgs

above the LEP limit

Tevatron results at a glance





- Exclusion sensitivity close to/below SM prediction in the whole mass range from 100 to 190 GeV
- Clear exclusion around region of max. sensitivity
- Broad data excess (> 2s) consistent with a signal from 115 to 135 GeV , with a maximum at 120 GeV (2.7s and LEE 2.2s)
- Quantifying the excess: main effect comes from H→bb (2.8s or 2.6s with LEE)

LHC results at a glance

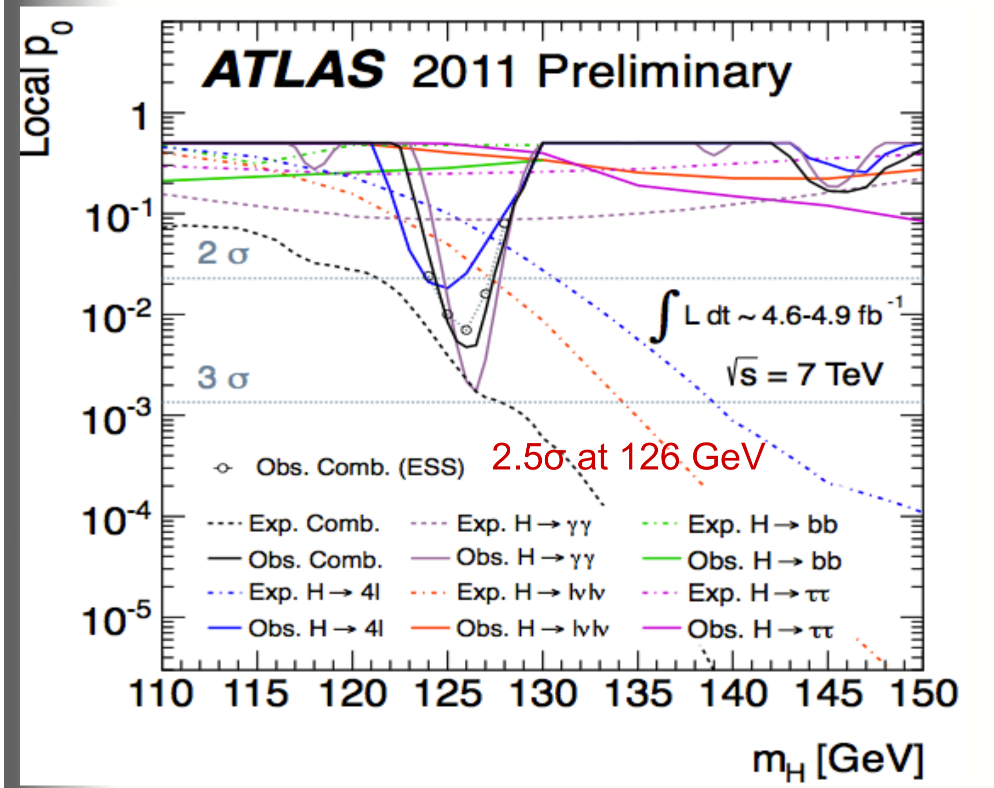
ATLAS: Expected exclusion at 95% CL: 120-555 GeV

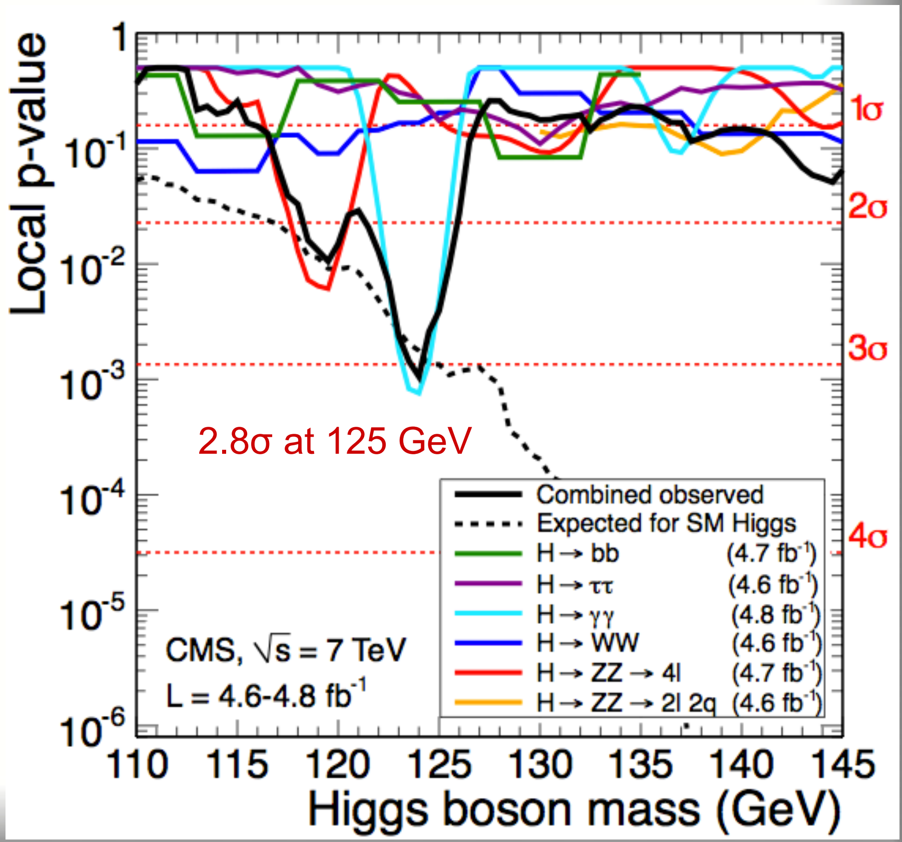
Observed exclusion at 95% CL: 110-117.5, 118.5-122.5, 129-539 GeV

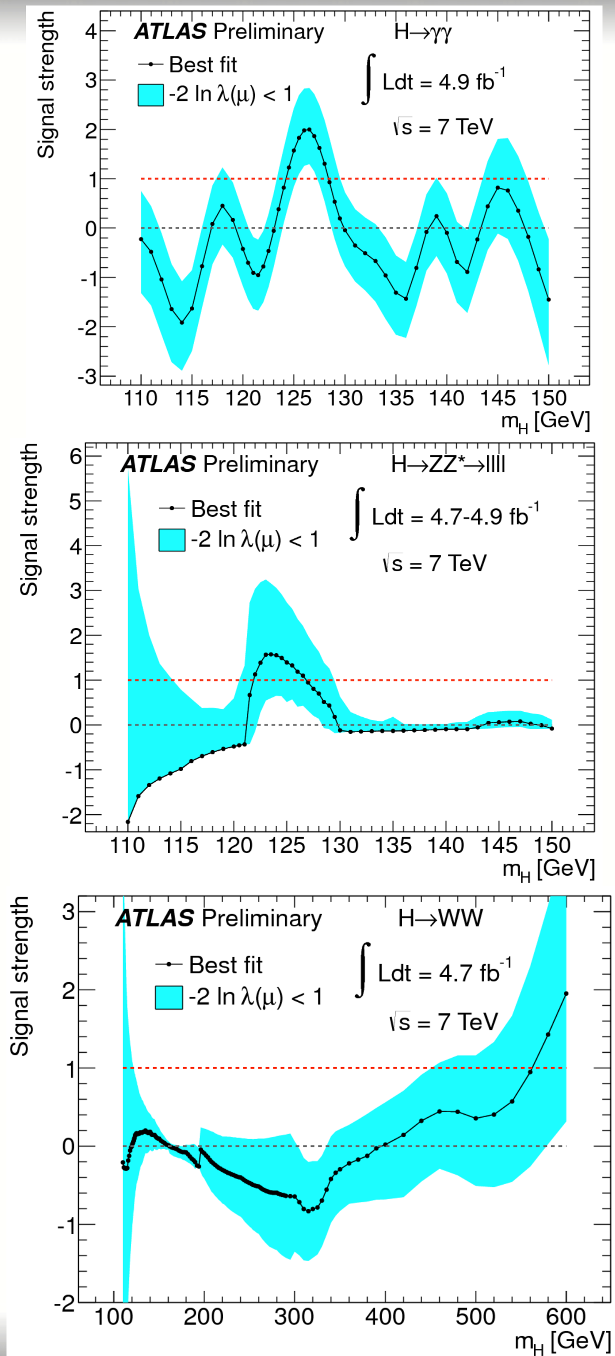
CMS: Expected 95% CL: 114.5 - 525 GeV

Observed exclusion at 95% CL: 127.5 - 600 GeV

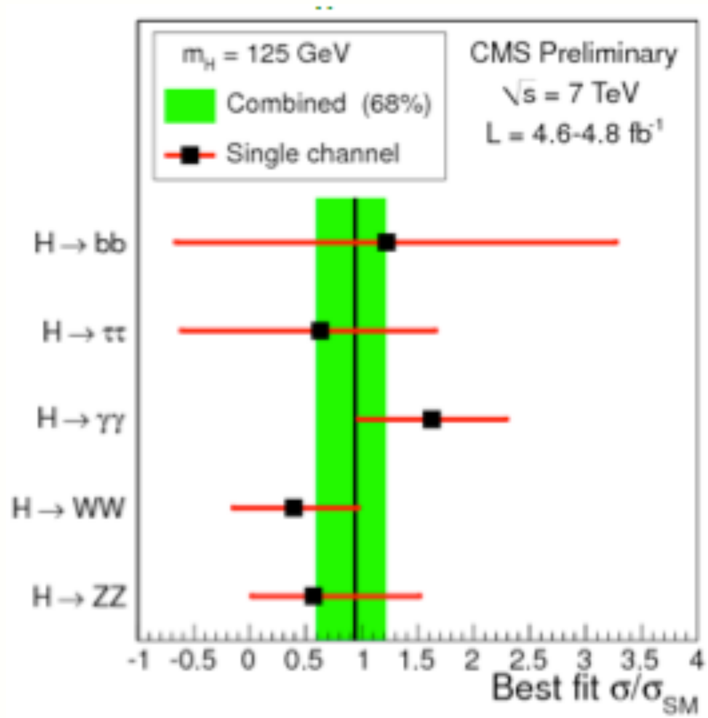
Is there a Hint of a signal?







Data shows: a 125 GeV Higgs is the most consistent with a SM-like Higgs hypothesis.



except H→WW at ATLAS (but not wildly)
H→WW also 1σ low at CMS

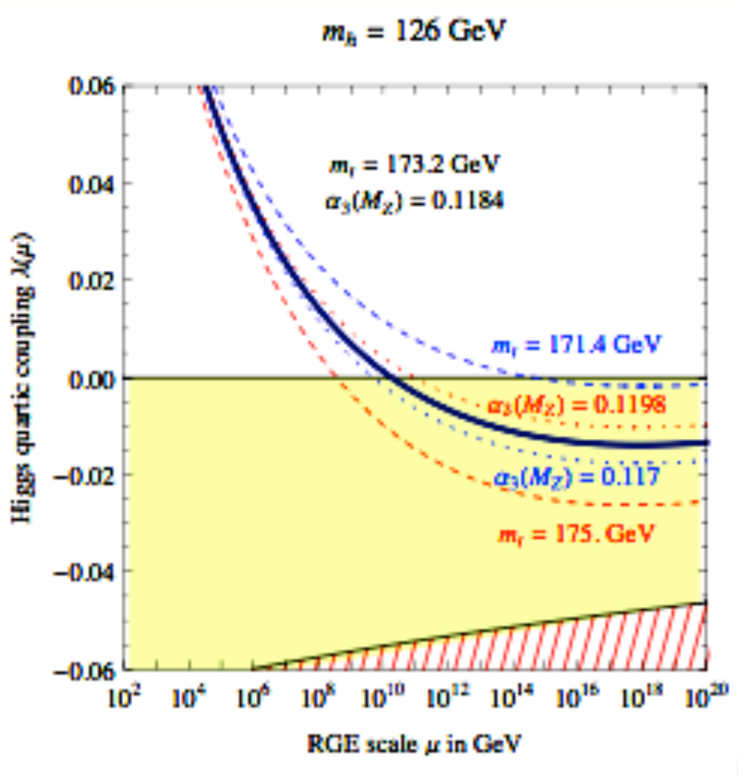
The photon rate about 1 sigma larger than SM expected in both experiments

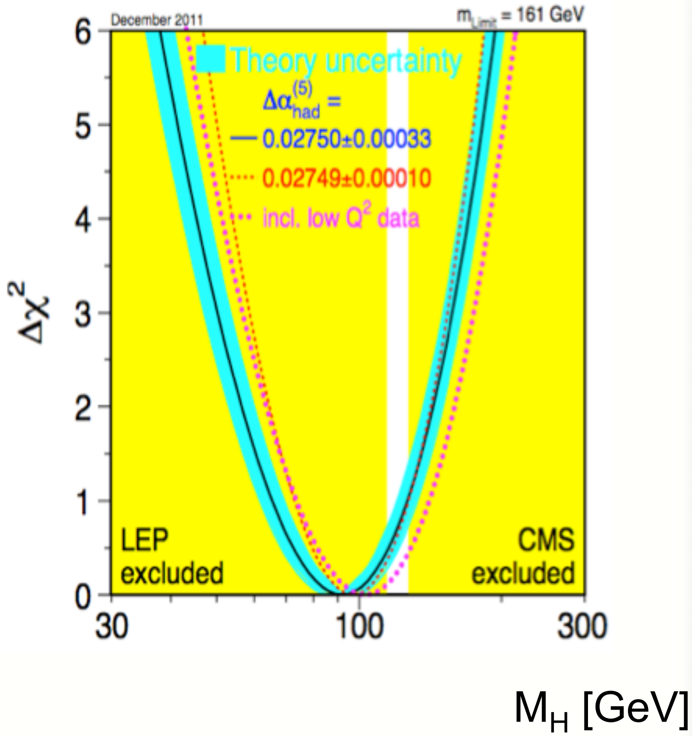
A Higgs mass in the range 115-129 GeV

Overlaps with the region preferred by indirect Precision Electroweak Observables within the SM

Preferred value: $M_H = 92^{+34}_{-26}$ GeV

Upper bound $M_H < 161\,\mathrm{GeV}$





but the stability of our universe tends to prefer

new physics at a lower scale

By the end of 2012 (most probably) we will either rule out a SM Higgs or confirm the existence of a new light resonance (~ 125 GeV ?)

If observed excess of events is confirmed

Higgs discovery will mark the birth of the hierarchy problem:

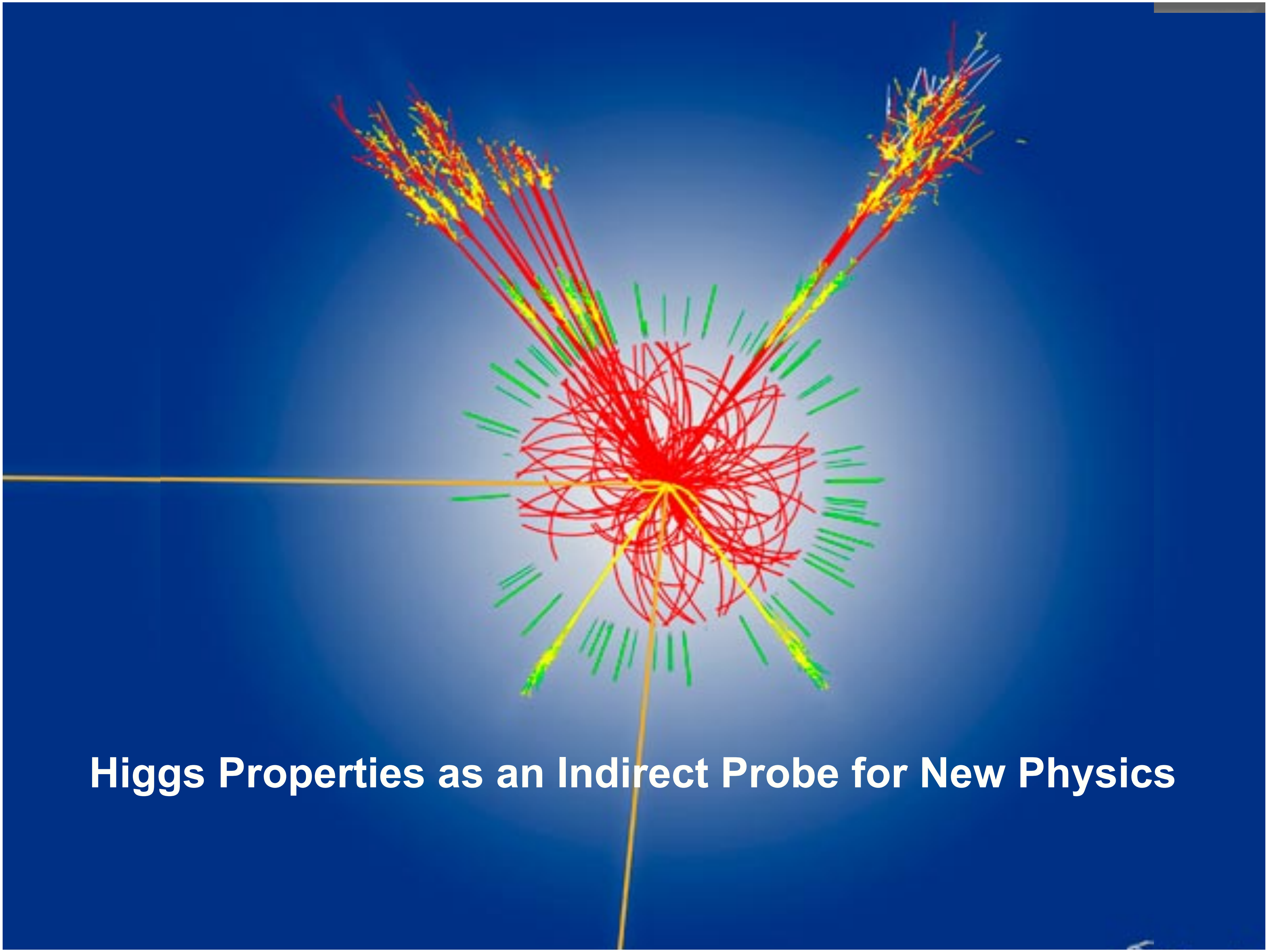
one of the main motivations for physics beyond the SM

detailed study of Higgs properties

Is it spin 0, it is CP even, is it elementary, is it part of a weak doublet?
Which are all its production mechanisms and decay rates? …

will help to probe whether the Higgs sector is as simple as predicted by the SM

Higgs couplings to photons and gluons are loop-suppressed in the SM and hence are particularly sensitive to the presence of new particles



Higgs Properties as an Indirect Probe for New Physics

What does a 125 GeV SM-like Higgs imply for SUSY?

Many Talks: Wagner, Shah, Low, Hall

Summarizing features:

•**Low energy MSSM** (no constraints on high energy parameters of the theory)

- Large mixing in the stop sector A_t > 1.5 TeV
- No hard lower bound on the lightest stop

  If one stop light: less than a few hundred GeV ➔ the heavy stop should be about or above a few TeV

  In the case of similar stop soft masses the lightest stop must be heavier (above 500 GeV)
- Intermediate values of tan beta lead to the largest values of m_h for the same values of soft stop mass parameters

  [at large tan beta, light staus/sbottoms can decrease mh by several GeVs via Higgs mixing effects]

Can departures in the production rates at the LHC disentangle among different SUSY spectra?

The event rate depends on three quantities

$$B\sigma(p\bar{p} \to h \to X_{\rm SM}) \equiv \sigma(p\bar{p} \to h)\frac{\Gamma(h \to X_{\rm SM})}{\Gamma_{\rm total}}$$

- The three of them may be affected by new physics.
- If one SM rate is modified, of course, the total width is modified as well, producing modifications of all other BR's as well

Main production channel: Gluon Fusion

Main/first search modes: decay into diphotons/WW/ZZ

How much can we perturbe the gluon production mode?

Is it possible to change WW and ZZ decay rates independently?

Can we vary the Higgs rate into di-photons independently from the rate into WW/ZZ?

What about the decay rate into b-pairs at the Tevatron?

Departures in the production rates at the LHC:

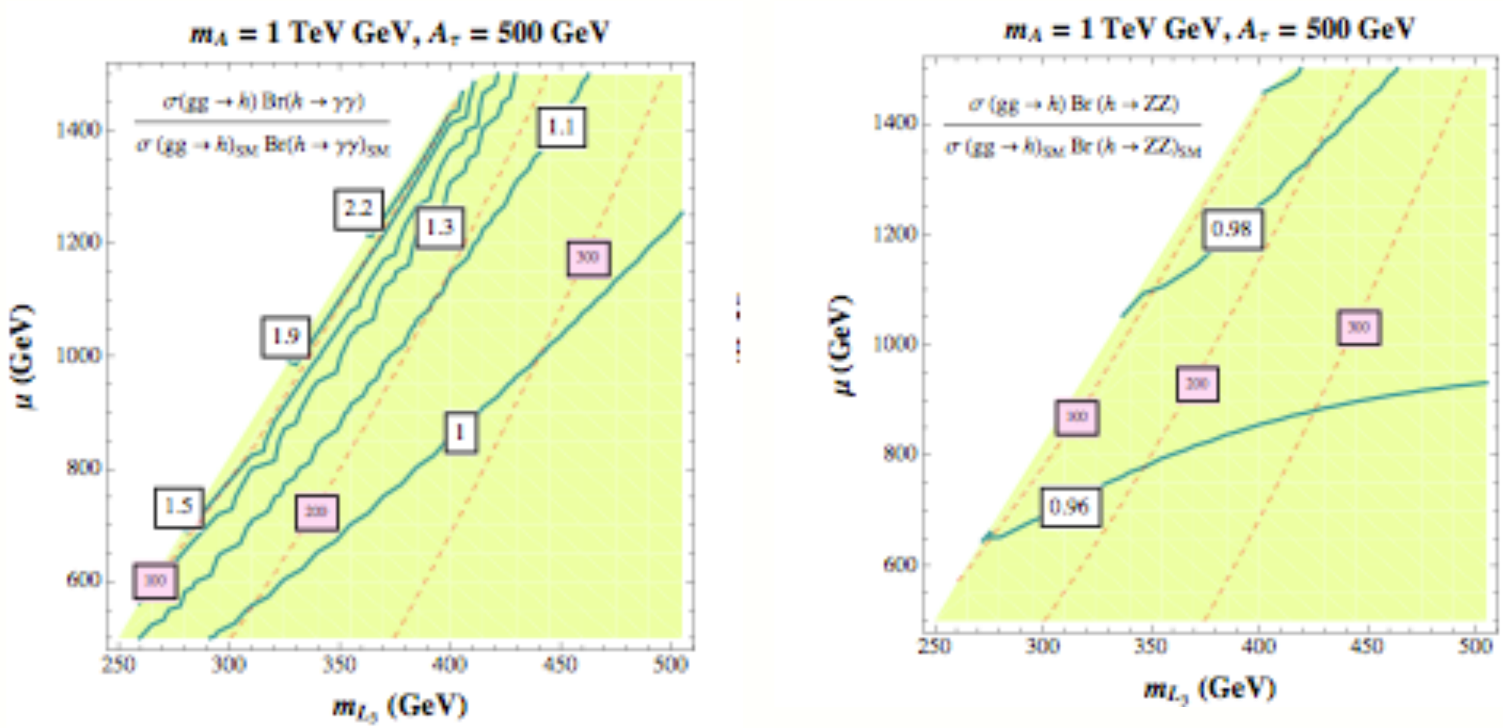
1) Through SUSY particle effects in loop induced production processes
2) Through enhancement/suppression of the Higgs-bb and Higgs-di-tau coupling strength via mixing in the Higgs sector

- Light 3rd gen. stops can increase the gluon fusion rate, but for A_t as required by m_h ~125 GeV, it is always SM-like or slightly suppressed
- Light staus (~100 GeV) with large mixing ➔ large mu and tan beta can enhance the Higgs into di-photon rate without changing the Higgs into WW/ZZ rates **(Figure)**
- Possible moderate suppression of WW and ZZ via gluon fusion suppression or via enhancement of bb and di-taus decay rates through Higgs mixing (triggered by At and for large tan beta by Ab, Atau)
- Possible slight enhancement of bb decay rates (Tevatron) via Higgs mixing effects. (via At is problematic since requires stops too light for Mh)

It is possible to enhance the Higgs into di-photon rate without changing the Higgs into WW/ZZ rates?

YES: for light Staus with large mixing ➔ large mu and large tan beta

$$\mathcal{M}_{\tilde{\tau}}^2 \simeq \begin{bmatrix} m_{L_3}^2 + m_\tau^2 + D_L & h_\tau v(A_\tau \cos\beta - \mu \sin\beta) \\ h_\tau v(A_\tau \cos\beta - \mu \sin\beta) & m_{E_3}^2 + m_\tau^2 + D_R \end{bmatrix}$$



M_h ~ 125 GeV . [M.C, Gori, Shah, Wagner]

Radiative corrections to Higgs couplings

and light particles in loop mediated processes

can change Higgs searches in a very crucial manner

[significant dependence on 3^{rd} generation light SUSY Spectrum
not yet constrained by LHC searches]

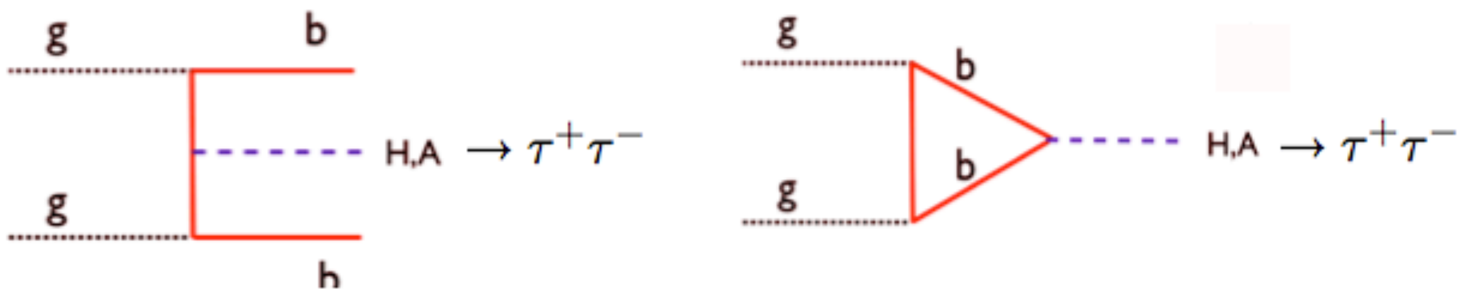
Enhancement/suppression

of main production mode/s as well as main decay channels:

very important consequences for the interpretation of

Higgs signals/bounds at the Tevatron and the LHC

Non-Standard MSSM Higgs searches in inclusive $\tau^+\tau^-$ decays



$$\sigma\left(b\bar{b},gg \to A\right) \times BR(A \to \tau\tau) \cong \sigma\left(b\bar{b},gg \to A\right)_{SM} \times \frac{\tan\beta^2}{\left(1+\Delta_b\right)^2+9}$$

M. C., Heinemeyer, Wagner,Weiglein '05

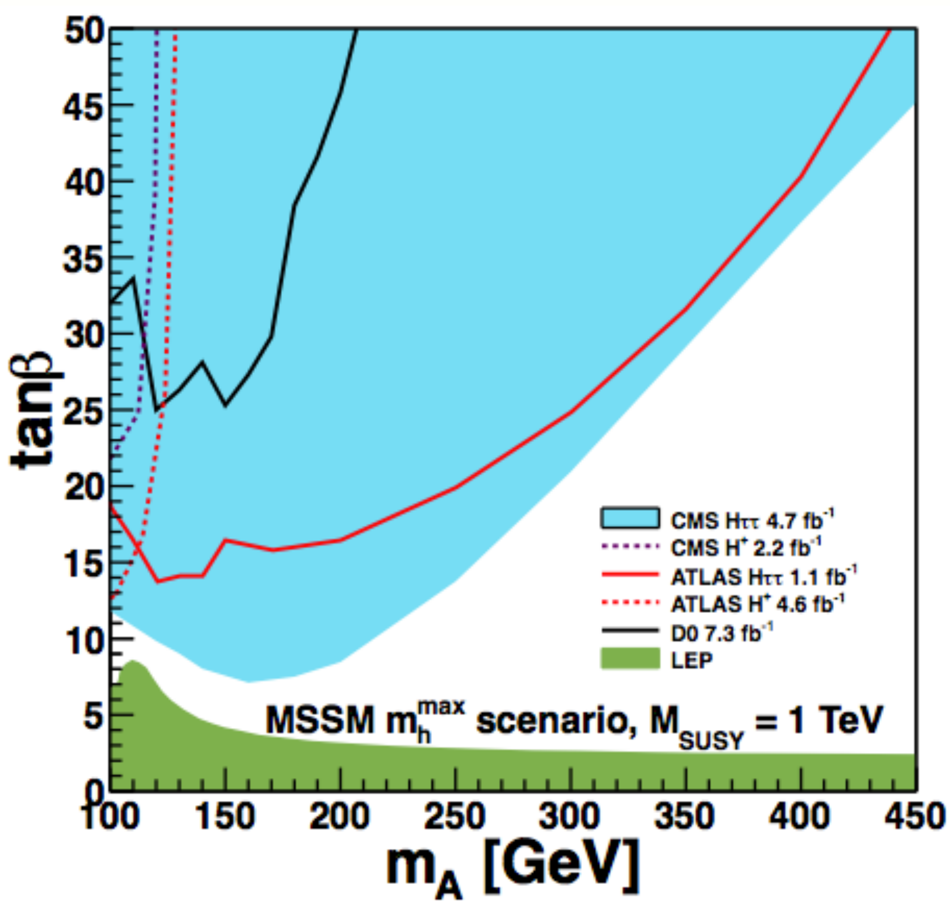
tan beta enhanced vertex corrections to A/Hbb coupling from SUSY loops

- Important reach for large tanb, small m_A
- Weaker dependence on SUSY parameters via radiative corrections

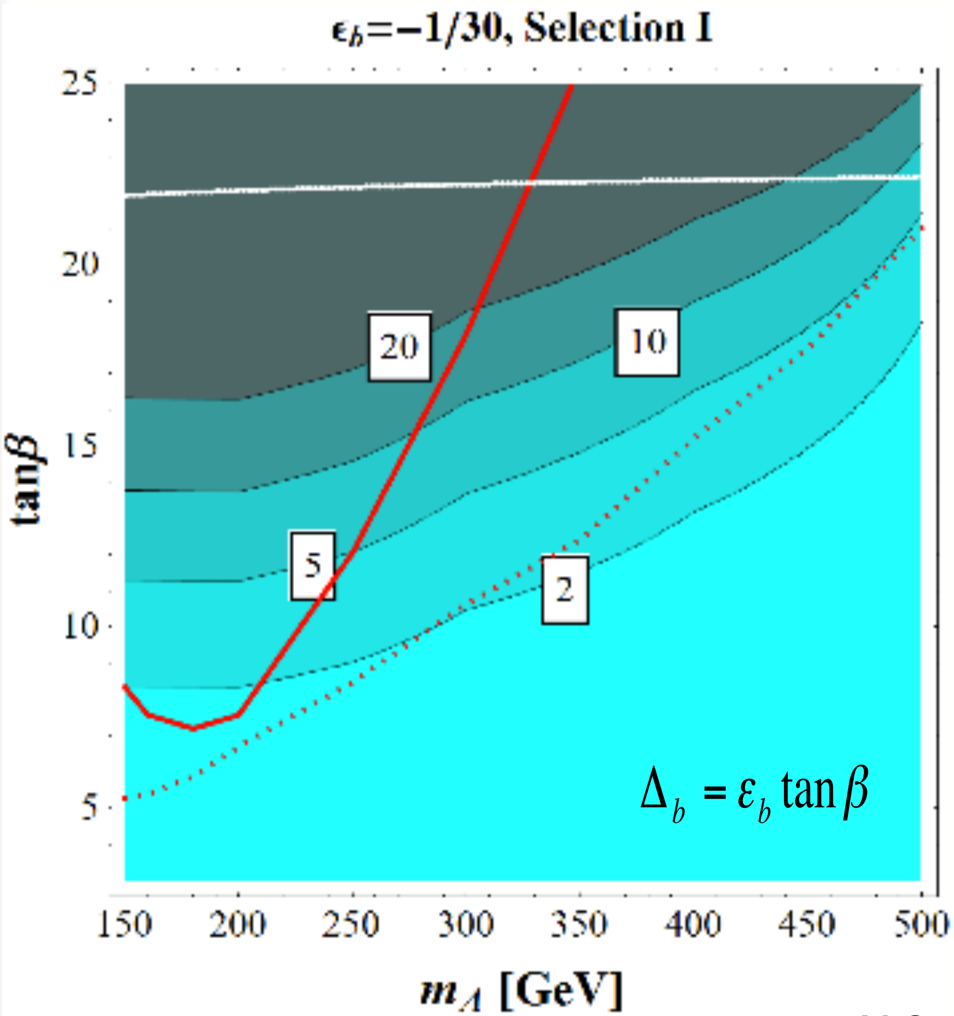
- Also possible to look for bbA/H with A/H decays to bb ==> 3 b's final state BUT, strong dependence on SUSY spectrum via radiative corrections

$$\sigma\left(b\bar{b}A\right) \times BR\left(A \to b\bar{b}\right) \cong \sigma\left(b\bar{b}A\right)_{SM} \times \frac{\tan\beta^2}{\left(1+\Delta_b\right)^2} \times \frac{9}{\left(1+\Delta_b\right)^2+9}$$

MSSM non-standard Higgs searches
The state of the art



MSSM non-standard Higgs searches in 3b's decays



Statistical significance at the 7 TeV LHC for an integrated luminosity of 30 fb-1

The red solid (dashed) : present (projected at 30 fb-1) bound on inclusive A/H → di-taus.

M.C, Gori,Juste,Menon,Wagner,Wang

Back to the Higgs-Flavor connection

The flavor problem in SUSY Theories

SUSY breaking mechanisms ==> can give rise to large FCNC effects

- Novel sfermion-gaugino-fermion interactions, e.g. for the down sector

$$\bar{d}^{i}_{L,R}\,\tilde{\lambda}\,\tilde{d}^{j}_{L,R} \rightarrow \bar{d}_{L,R} D^{+}_{L,R} \tilde{D}_{L,R} \tilde{\lambda}\,\tilde{d}_{L,R}$$

$\boxed{\text{recall } V_{CKM} = U_L^{+} D_L}$

where $\tilde{D}_{L,R}$ come from the block diagonalization of the squark mass matrix

$$\begin{pmatrix} \tilde{d}_L^{i\,*} \tilde{d}_R^{i\,*} \end{pmatrix} \begin{pmatrix} M_Q^2 + \mathrm{v}_1^2 \hat{h}_d^{+} \hat{h}_d + D_{\tilde{d}_L} & \mathrm{v}_1 \left(A_d^{*} - \mu \tan\beta \right) \hat{h}_d^{+} \\ \mathrm{v}_1 \hat{h}_d \left(A_d - \mu^{*} \tan\beta \right) & M_D^2 + \mathrm{v}_1^2 \hat{h}_d \hat{h}_d^{+} + D_{\tilde{d}_R} \end{pmatrix} \begin{pmatrix} \tilde{d}_L^{i} \\ \tilde{d}_R^{i} \end{pmatrix}$$

- Diagonal entries are 3x3 matrices with M_Q^2, M_D^2 the soft SUSY breaking mass matrices and the rest proportional to the Yukawa or I
- Off-diagonal matrices are proportional to the Yukawa and to the soft SUSY breaking matrices A_d coming from the Higgs-sfermions trilinear interactions:

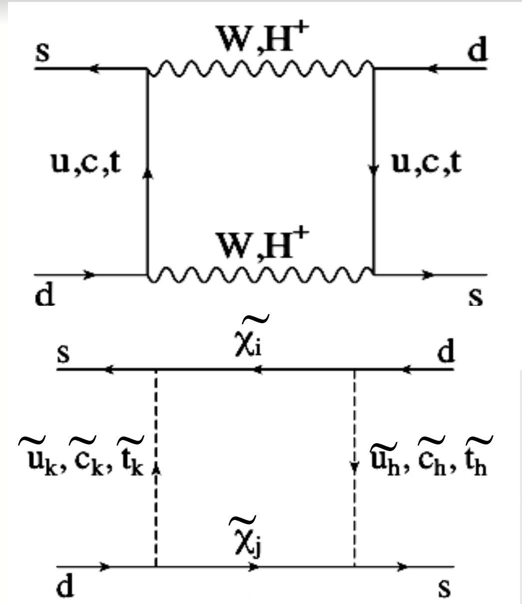
$$\tilde{u}_L^{i*} \left(A_u^{*} \phi_2^{*} - \mu \phi_1^{*} \right) \hat{h}_u^{+} \tilde{u}_R^{j} + \tilde{d}_L^{i*} \left(A_d^{*} \phi_1 - \mu \phi_2 \right) \hat{h}_d^{+} \tilde{d}_R^{j} + h.c.$$

e.g. for the down sector $\longrightarrow$ $\tilde{d}_L^{*} \tilde{D}_L^{+} (A_d^{*} \phi_1 - \mu \phi_2) \underbrace{D_L h_d^{+} D_R^{+}}_{\hat{h}_d^{+}} \tilde{D}_R \tilde{d}_R + h.c.$

Minimal Flavor Violation

- At tree level: the quarks and squarks diagonalized by the same matrices $\tilde{D}_{L,R} = D_{L,R}; \quad \tilde{U}_{L,R} = U_{L,R}$

Hence, in the quark mass eigenbasis the only FC effects arise from charged currents via V_{CKM} as in SM.

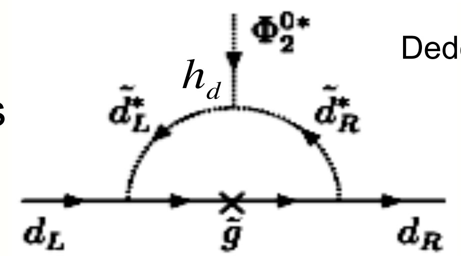


Isidori, Retico: Buras et al.

- At loop level: FCNC generated by two main effects:

1) Both Higgs doublets couple to up and down sectors

==> important effects in the B system at large tan beta



Dedes, Pilaftsis

2) Soft ~~SUSY~~ parameters obey RG equations:

given their values at the ~~SUSY~~ scale, they change significantly at low energies

==> RG evolution adds terms prop. to $h_d h_d^+$ and $h_u h_u^+$, and h.c.

In both cases the effective coupling governing FCNC processes

$$(X_{FC})_{ij} = (h_u^+ h_u)_{ij} \propto m_t^2 \, V_{3i}^{CKM*} V_{3j}^{CKM} \qquad \text{for } i \neq j$$

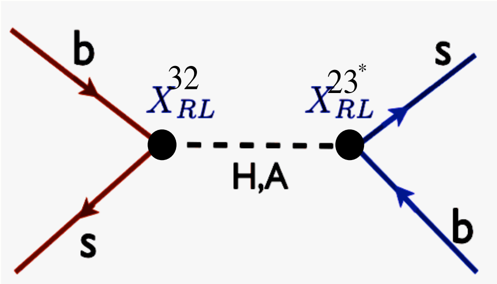
D'Ambrosio, Giudice, Isidori, Strumia

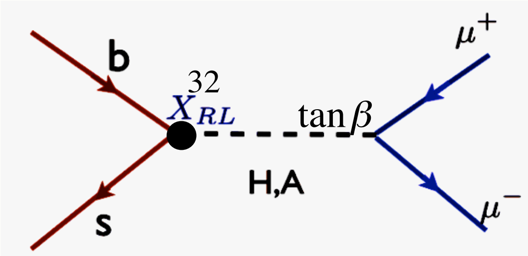
✦ Loop-induced A/H mediated FCNC's:

$$-L_{FCNC} = \bar{b}_R (X_{RL}^S)^{bs} s_L \phi_S + h.c. \qquad \text{with} \quad \left(X_{RL}^{H/A}\right)^{bs} \approx -\frac{m_b}{v} \frac{h_t^2 \; \varepsilon_Y \; \tan\beta^2}{\left(1+\varepsilon_0^3 \tan\beta\right)\left(1+\Delta_b\right)} V_{CKM}^{tb^*} V_{CKM}^{ts}$$

Loop factors intimately connected to the structure of the squark mass matrices.

$$\varepsilon_0^i \approx \frac{2\alpha_s}{3\pi} \frac{\mu^* M_{\tilde{g}}^*}{\max\left[m_{\tilde{d}_1^i}^2, m_{\tilde{d}_2^i}^2, M_{\tilde{g}}^2\right]} \qquad \varepsilon_Y \approx \frac{\mu^* A_t^*}{16\pi^2 \max\left[m_{\tilde{t}_1}^2, m_{\tilde{t}_2}^2, \mu^2\right]}$$





$$\left(\Delta M_{B_S}\right)^{SUSY} \propto - \frac{X_{RL}^{32} X_{LR}^{32}}{m_A^2}$$

Negative sign with respect to SM

$$BR(B_S \to \mu^+\mu^-)^{SUSY} \propto \frac{\left|X_{RL}^{32}\right|^2 \tan\beta^2}{m_A^4} \propto \frac{\left|\mu A_t\right|^2 \tan\beta^6}{m_A^4}$$

MFV: correlation between SUSY contributions

$$\frac{\Delta M_{B_S}}{BR(B_S \to \mu^+\mu^-)} \propto \frac{m_A^2}{\tan\beta^2}$$

A/H at collider reach:

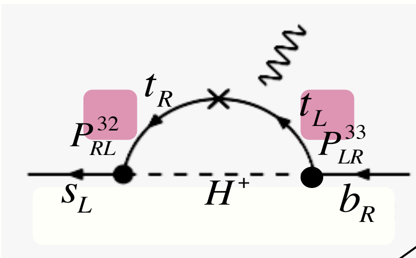
strong constraints on $\left|\Delta M_S\right|_{DP}^{SUSY}$

good agreement with data

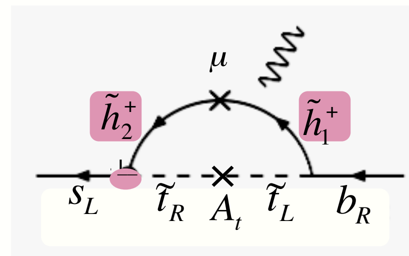
✦ Charged Higgs mediated flavor changing effects:

Similar to neutral Higgs case: tanb enhanced charged Higgs - squark loop corrections

- **Charged Higgs and chargino-stop contributions to** $BR(B \to X_S \gamma)$



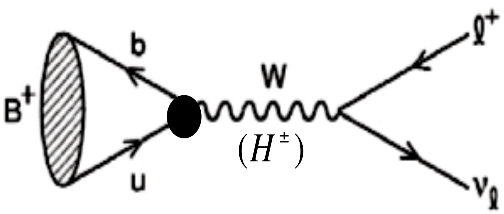
$$\delta h_t \propto h_t \frac{2\alpha_S}{3\pi} \mu^* M_{\tilde{g}}$$



$$A_{H^+} \propto \frac{(h_t - \delta h_t \tan\beta)\, m_b}{(1+\Delta_b)} g[m_t, m_{H^+}]\, V_{ts}$$

$$A_{\chi^+} \propto \frac{\mu A_t \tan\beta\, m_b}{(1+\Delta_b)} \mathrm{h}_t^2 f[m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu]\, V_{ts}$$

- $B_u \to \tau\nu$ **transition** MSSM charged Higgs & SM contributions interfere destructively



$$R_{B_u \to \tau\nu} = \frac{\mathrm{BR}(B_u \to \tau\nu)^{MSSM}}{\mathrm{BR}(B_u \to \tau\nu)^{SM}} = \left[1 - \left(\frac{m_B^2}{m_{H^\pm}^2}\right) \frac{\tan\beta^2}{(1+\varepsilon_0^3 \tan\beta)}\right]^2$$

In vast regions of SUSY space, indirect searches in B observables may be more powerful than direct Higgs searches

FCNC and the scale of SUSY Breaking

- FCNC's induced by Higgs-squark loops depend on the flavor structure of the squark soft SUSY breaking parameters

- **If ~~SUSY~~ is transmitted to the observable sector at high energies M~M_{GUT}**

even starting with universal masses (MFV) in the supersymmetric theory:

Ellis, Heinemeyer, Olive, Weiglein
M.C, Menon, Wagner

Due to RG effects:

1) The effective FC strange-bottom-neutral Higgs is modified: $B_s \to \mu^+\mu^-$

$$\left(X_{RL}^{H/A}\right)^{bs} \approx -\frac{m_b}{v}\frac{(\,\varepsilon_0^3-\varepsilon_0^{1,2}+h_t^2\varepsilon_Y\,)\;\tan\beta^2}{\left(1+\varepsilon_0^3\tan\beta\right)\left(1+\Delta_b\right)}V_{CKM}^{tb^*}V_{CKM}^{ts}$$

$\varepsilon_0^3-\varepsilon_0^{1,2}>0$ and proportional to $\mu M_{\tilde{g}}$

If $\mu A_t<0$ and $\mu M_{\tilde{g}}>0$

possible cancellation of effects

2) Flavor violation in the gluino sector induces relevant contributions to $b \to s\gamma$

$$A_{\tilde{g}} \propto \alpha_S(m_0^2-m_{Q_3}^2)M_{\tilde{g}}\mu\;\tan\beta\;F(m_0,m_R,m_{\tilde{b}_i},m_{\tilde{d}_i},M_{\tilde{g}})$$

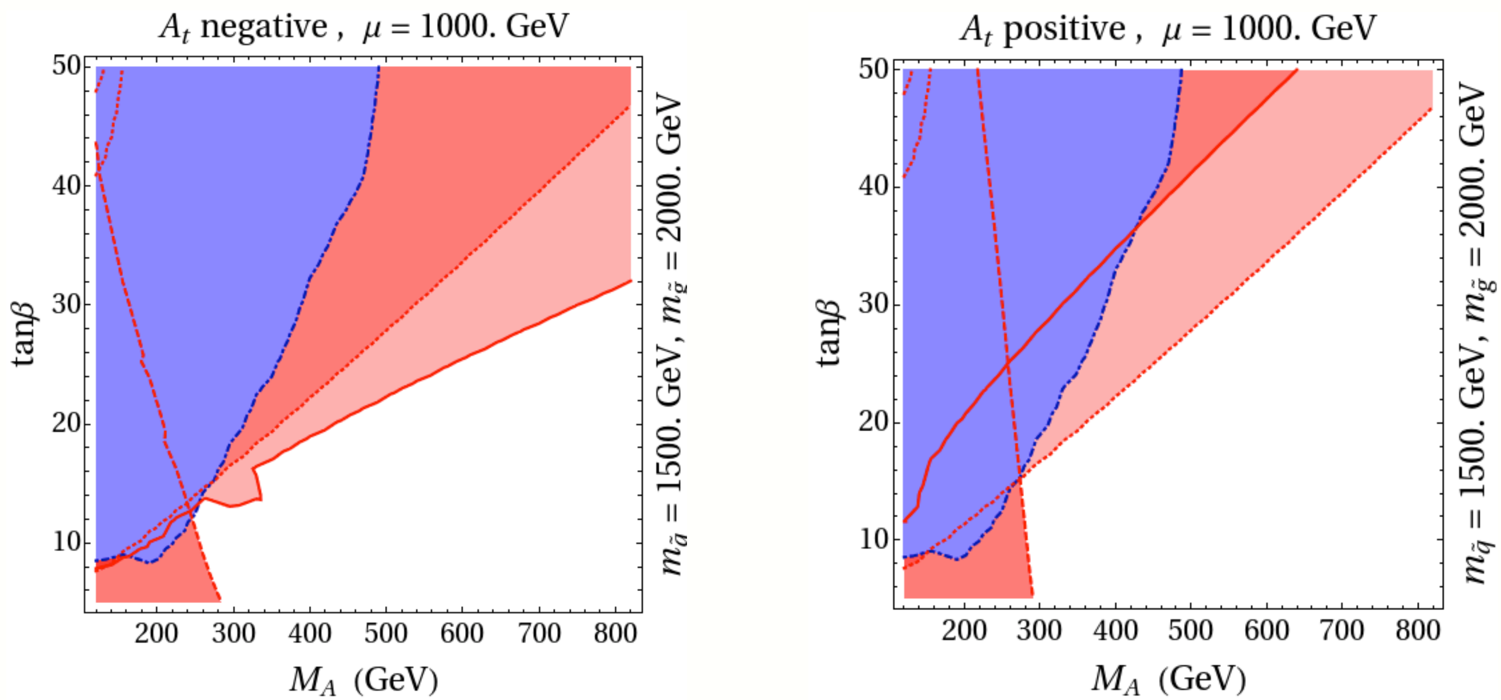
Borzumati, Bertolini, Masiero,Ridolfi

- **If ~~SUSY~~ is transmitted at low energies: M~ M_{SUSY}**

Squark mass matrices approx. block diag, only FC effects in the chargino-stop& H^+ loops

M_h ~ 125 GeV and flavor in the MSSM

MFV ➔ low energy SUSY breaking



- **Red dotted line from B → tau nu** ➔ Independent on stop mixing, most robust

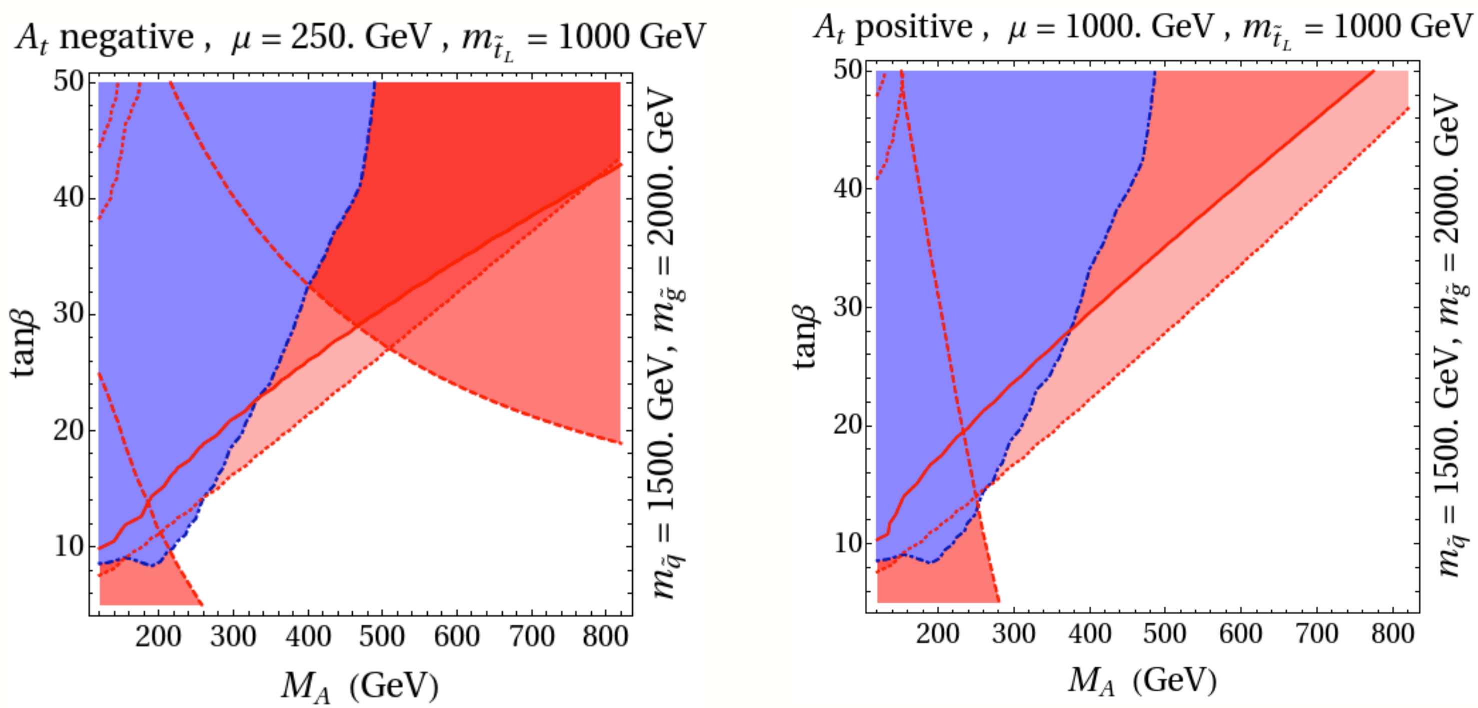
- Blue line: combined CMS/Atlas bounds on A/H →taus
- Red solid line: B_s → mu^+mu^-

Altmannshofer, MC, Shah, Yu

- Red dashed line from B →X_s gamma

M_h ~ 125 GeV and flavor in the MSSM

MFV ➔ high energy SUSY breaking



- **Red dotted line from B → tau nu ➔ almost independent of RG evolution**
- Blue line: combined CMS/Atlas bounds on A/H →taus

Altmannshofer, MC, Shah,Yu

- Red solid line: $\mathbf{B_s} \rightarrow$ **mu⁺mu⁻**
- Red dashed line from B →X_s gamma

Positive values of A_t less constraining for large m_A and large tan beta

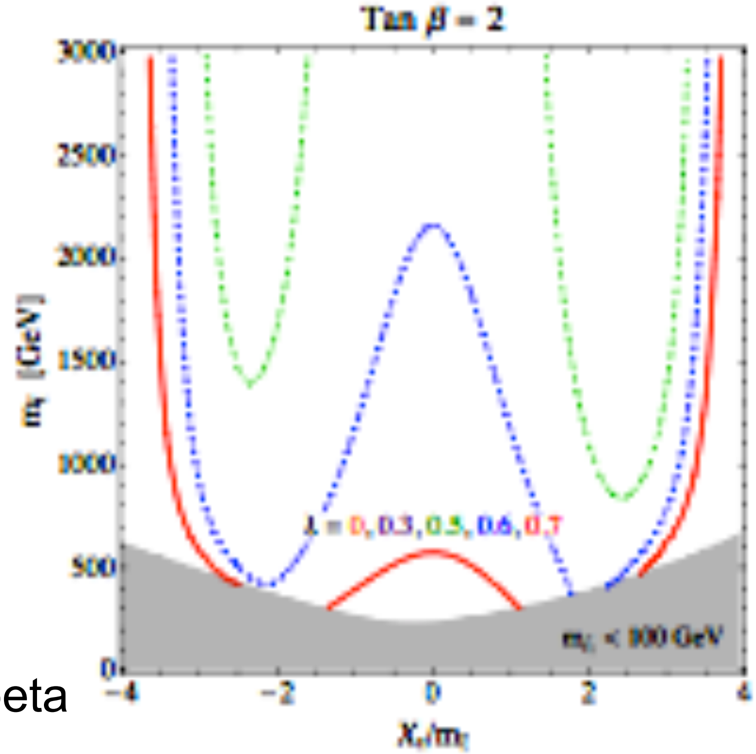
If a SM-like Higgs particle exists, the LHC will measure its mass and production rates

Many minimal SUSY models can produce m_h=125 GEV

NMSSM: extra singlet S
with extra parameter

$$W \supset \lambda S H_u H_d + \hat{\mu} H_u H_d + \frac{M}{2} S^2$$

See talk by L. Hall



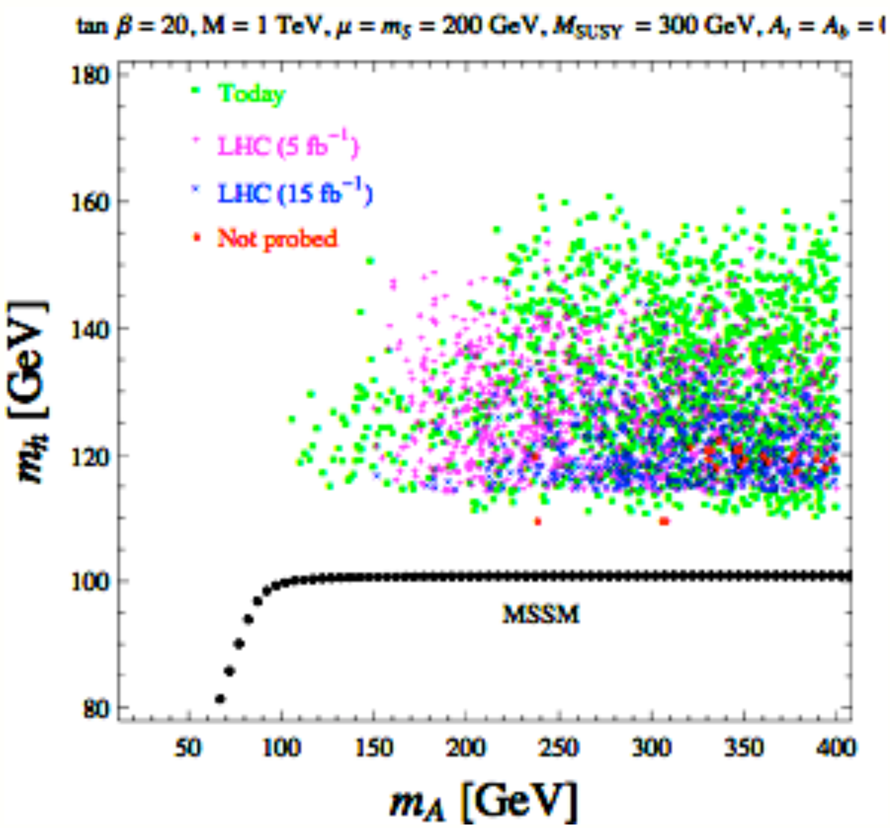
Hall, Pinner, Ruderman

- Large effect on the mass only for low tan beta
- More freedom in gluon fusion production
- Higgs mixing effects can be also triggered by extra new parameter
- Light staus would not enhance di-photon rate since at low tan beta there is negligible mixing in the stau sector.

More general MSSM Higgs extensions: EFT approach

$$W = \mu H_u H_d + \frac{\omega_1}{2M}(H_u H_d)^2 \quad W_X \supset \frac{\omega_1}{2M} X (H_u H_d)^2$$

Dine, Seiberg, Thomas;
Antoniadis, Dudas, Ghilencea, Tziveloglou
M.C, Kong, Ponton, Zurita



Scan over parameters including all possible dimension 5 and 6, SUSY Higgs operators

Higgs mass = 125 GeV easy to achieve for light stops, small mixing

Enhancement of h→di-photons due to bb suppression or light staus

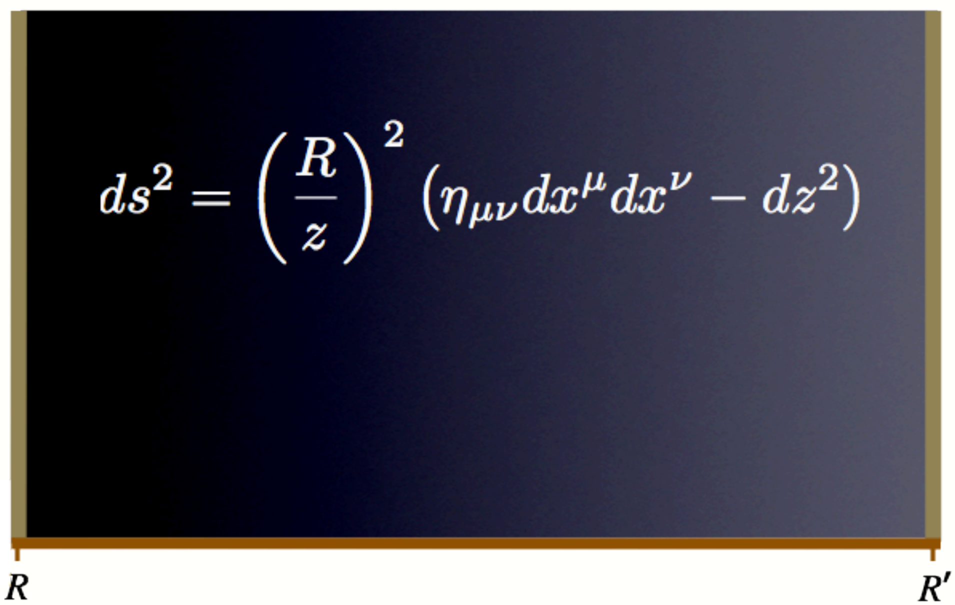
Higgs cascade decays → from large splitting in masses : h/H→ AA

If the new physics is seen only indirectly it will be hard to disentangle among new singlets, triplets, extra Z', W', a given mixture of the above

Higgs Physics in a Warped Extra Dimension

Embedding the SM in a warped extra dimension   Randall, Sundrum

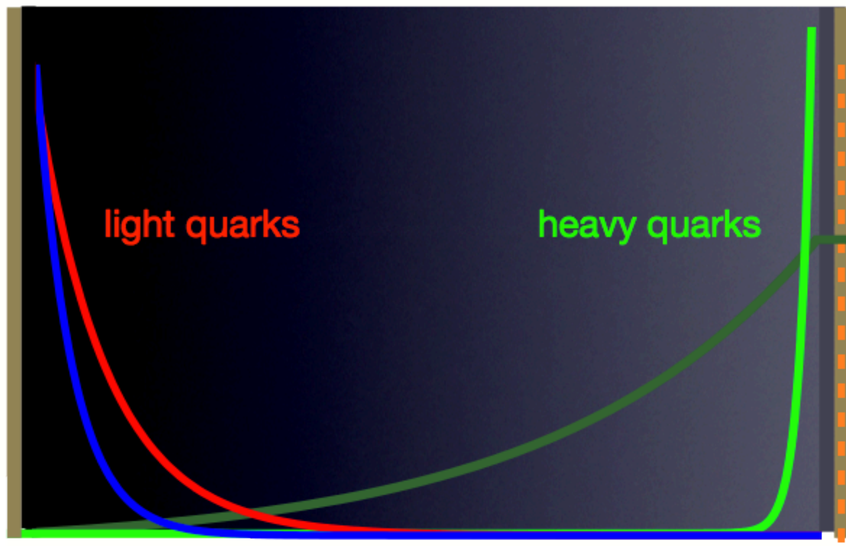
ultraviolet
(UV) brane



Infrared
(IR) brane

Warped extra dimension models address, at the same time,
the **gauge hierarchy problem and the flavor problem**
(hierarchies in the spectrum of quark masses and mixing angles)

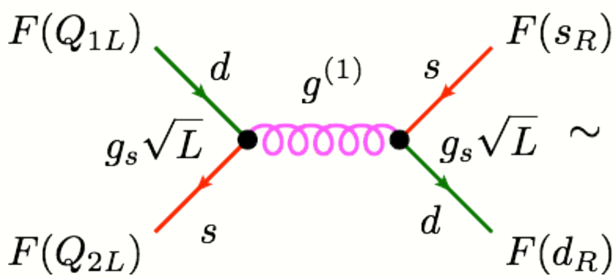
Flavor Structure in a Warped Extra Dimension



Grossman, Neubert;
Ghergetta, Pomarol

Fermion localization depends exponentially on O(1) parameters related to 5D **bulk masses. Overlap integrals with IR-localized Higgs give fermion mass hierarchies**

RS-GIM protection of FCNCs



$$\sim \frac{g_s^2}{M_{\mathrm{KK}}^2} L \, F(Q_{1L})F(d_R)\, F(Q_{2L})F(s_R)$$

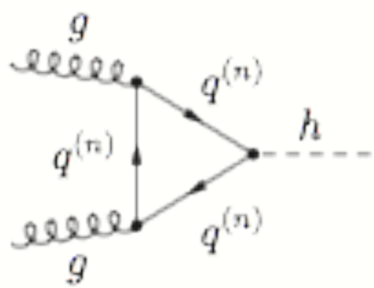
Still new symmetries needed to suppress dangerous FCNC's and to fit EWPT with KK modes in the few TeV mass range

Higgs phenomenology in RS

- **Large number of bulk fermionic fields in the 5D theory induce large loop effects, changing the effective hγγ & hgg couplings significantly**
- **KK towers of light quarks contribute as much as heavy quark ones****
- **Effect even more pronounced in models with custodial protection**

Much like flavor physics, precision Higgs physics probes quantum effects of new particles!

RS Higgs puzzle



Two independent calculations of Higgs production and decay in the RS model (with custodial symmetry) predict **opposite effects**

Casagrande, Goertz, Haisch, Neubert, Pfoh

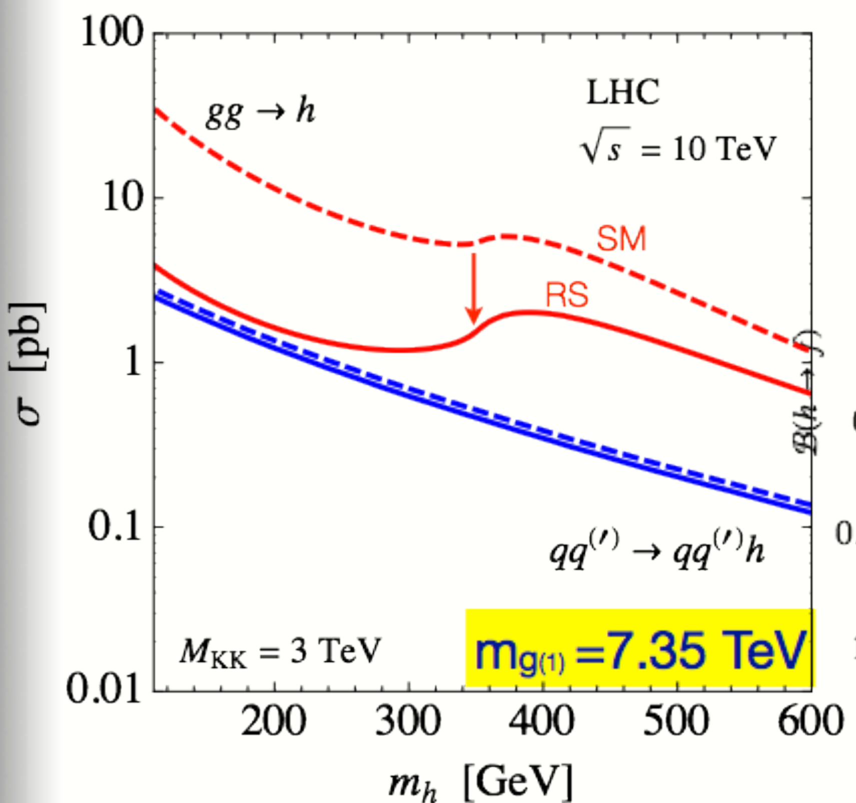
Find **suppression of gg→h & h→gg, but enhancement of h→γγ**

Azatov, Toharia, Zhu

Find **enhancement of gg→h & h→gg, but suppression of h→γγ**

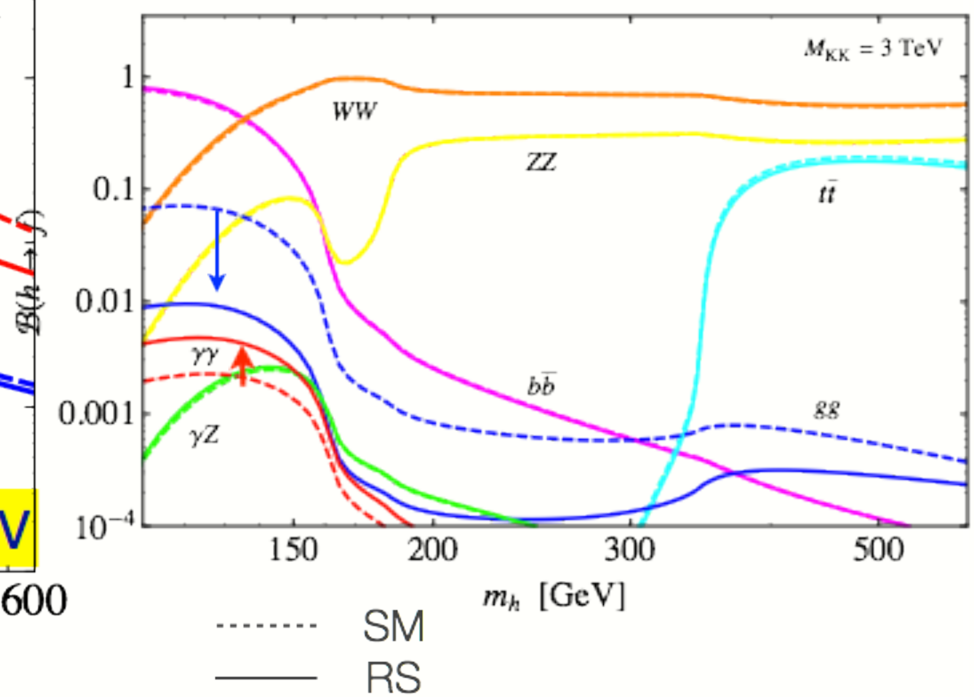
Higgs production cross sections and BR's

spectacular effects on Higgs production via gluon fusion, even for KK masses out of production reach at LHC



Casagrande, Goertz, Haisch, Neubert, Pfoh

Correspondingly, find **significant enhancement (suppression) of the h→γγ *(h→gg)* branching ratios:**



Solving the RS puzzle

•Both calculations are correct!

M.C, Casagrande, Goertz, Haisch, Neubert

In both calculations, the hqq couplings are derived by **regularizing the Higgs profile by smearing it out over an interval of width η, e.g.:**

Difference from **non-commutativity of limits $N_{max}\to\infty$ and $\eta\to 0$**

RS models with a physical UV cutoff (warped Planck scale), required to solve the hierarchy problem, single out a way in which the limits should be taken

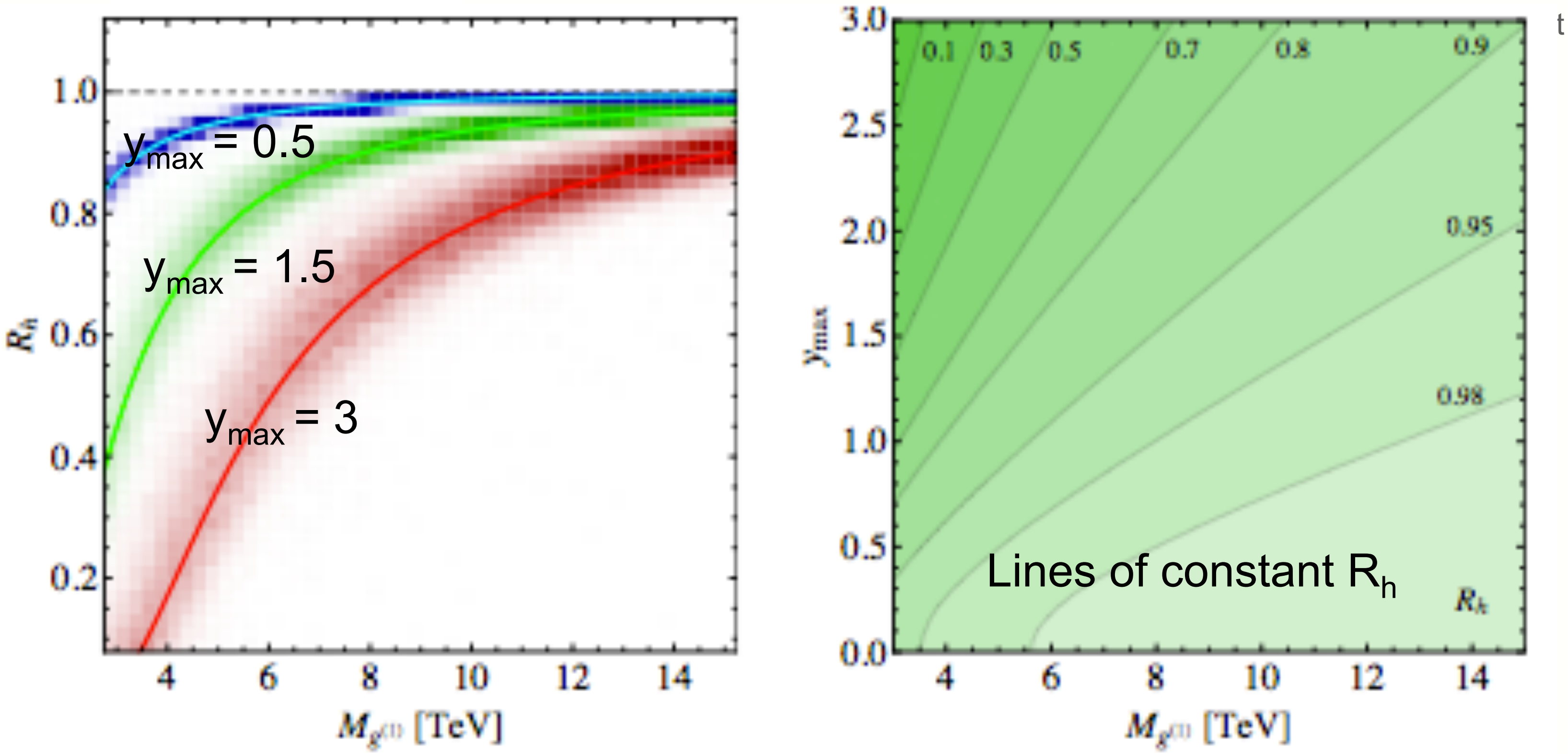
For loop graphs including a Higgs boson as an external particle, the warped Planck scale is the **several TeV scale (brane Higgs)**

KK modes with masses M_{KK}/η (with $\eta \ll 1$) lie far above cutoff and must be omitted from the effective theory for consistency:

Their contribution would correspond to a logarithmic evolution of the effective hgg coupling arising at **trans-Planckian energies**

Higgs Phenomenology in Minimal RS model: Production

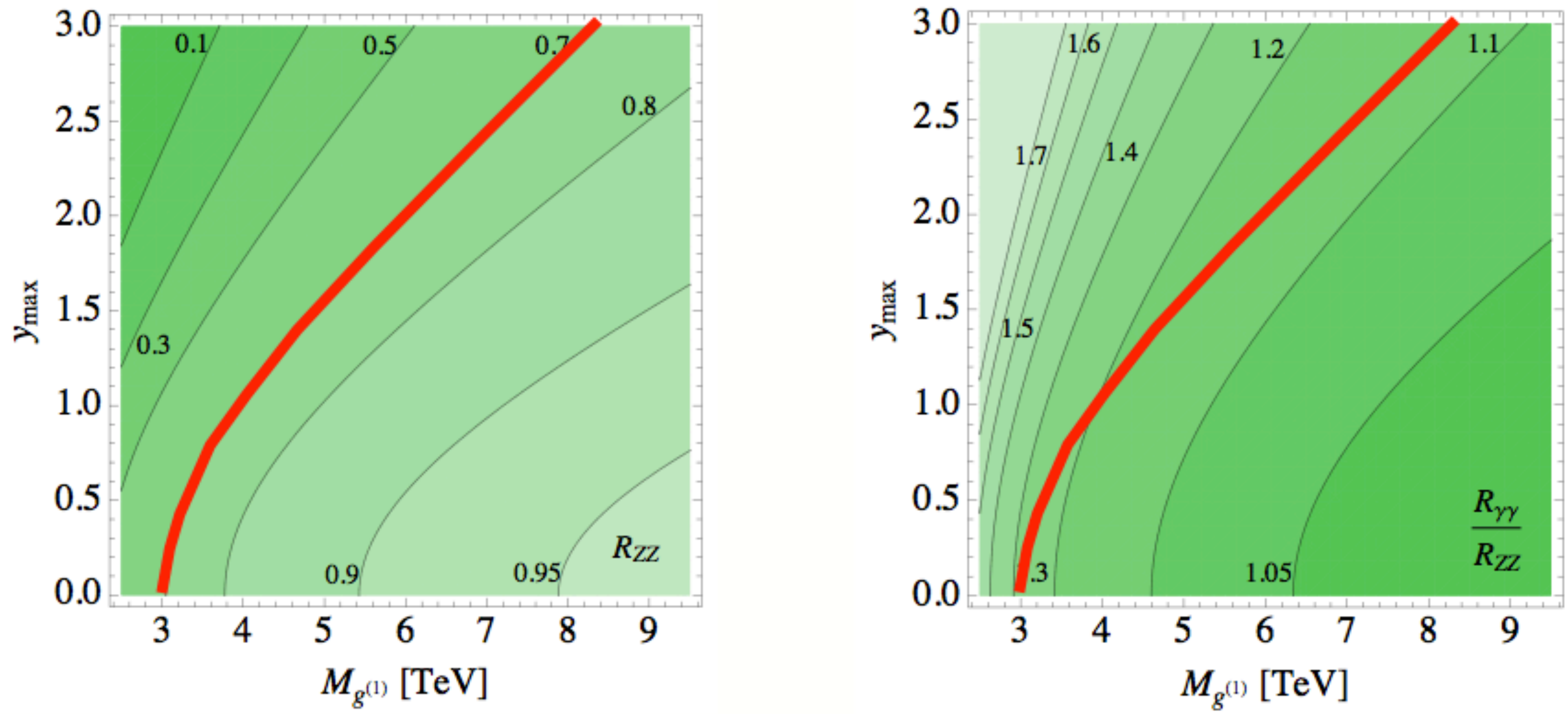
$$R_h = \frac{\sigma(gg \to h)_{\mathrm{RS}}}{\sigma(gg \to h)_{\mathrm{SM}}}$$ ➔ Suppression



◆ Strong suppression could be interpreted as a **hint for existence of WEDs and translated into parameter space of such models**

◆**σ(gg→h) close to SM prediction would imply tight bounds on model parameters, perhaps moving KK masses out LHC reach for direct production**

Higgs Phenomenology in Minimal RS model: Decay



Higgs to diphotons can be larger than H→ZZ but below SM value

A measurement **R_{ZZ} ≈ 0.7 along with a slight enhancement of the di-photon over the ZZ channel would then imply (for y_{max} =3) KK masses ≈ 8 TeV, far outside reach for direct production at the LHC (a lower bound R_{ZZ} > 0.7 would imply very strong bounds)**

Conclusions

The SM Higgs mechanism solves the Mystery of Mass of all the fundamental particles

➔**The LHC will soon have the final word on the SM Higgs**

If A Higgs-like particle is observed,
it will be crucial to measure all its production/decay rates and
any other new particles that may change the Higgs properties-

- *including missing energy signals of dark matter –*

Much like rare FCNC processes,
Higgs production in gluon-gluon fusion and Higgs decays
into the di-photon final state are loop-suppressed processes,
which are sensitive to new heavy particle

Higgs phenomenology provides a superb laboratory for probing new physics in the EWSB sector at the quantum level