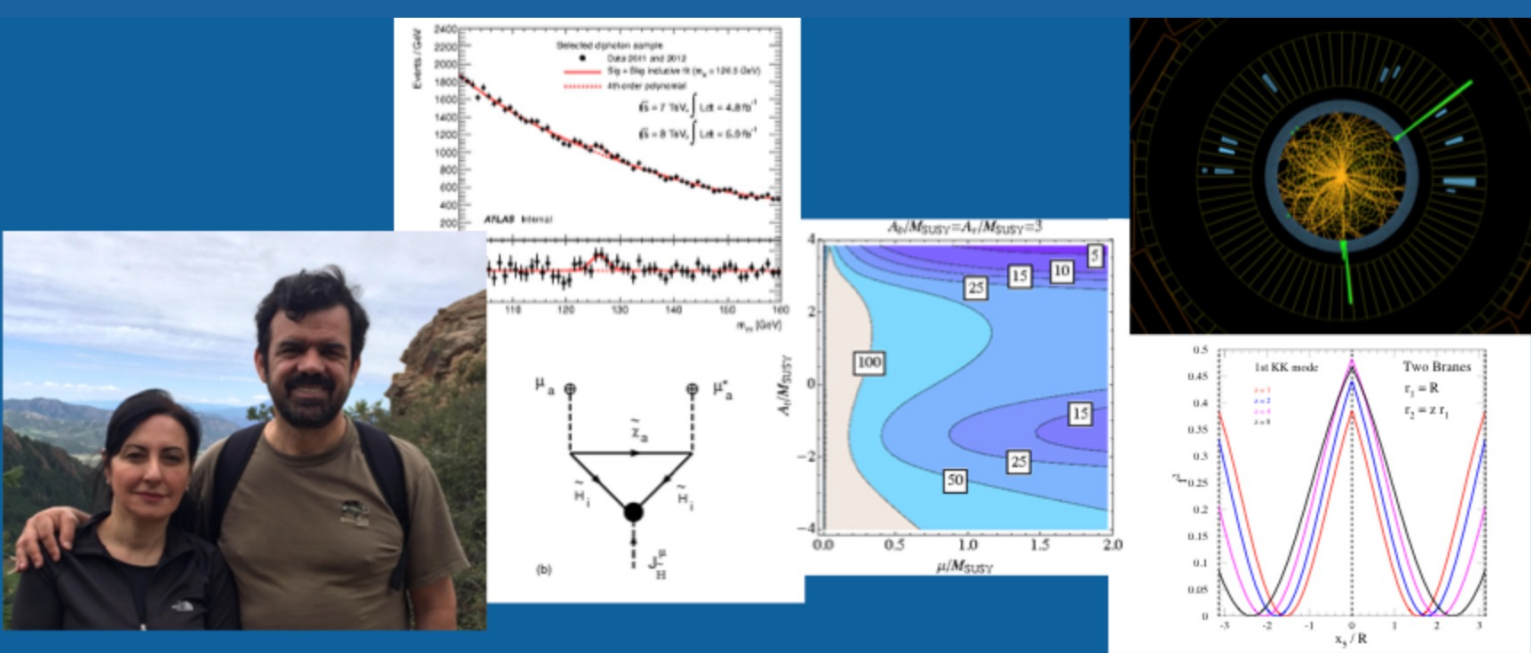


# My Journey through Physics with Marcela and Carlos

Howard E. Haber  
May 28, 2023



Beyond the SM from Colliders to the Early Universe



# In the beginning

## ➤ July—August, 1991

Roberto Peccei and I co-organized the “Workshop on CP Violation and Heavy Flavor Physics” at the Aspen Center for Physics. Marcela and Carlos attended the workshop. I noticed them from afar but we did not interact.

## ➤ Later that year...



## The Higgs sector in the minimal supersymmetric model: Radiative corrections and their implications

#40

[Howard E. Haber](#) ([UC, Santa Cruz](#)) (Apr, 1992)

Contribution to: [International Workshop on Electroweak Symmetry Breaking](#), 225-249

 [links](#)

 [cite](#)

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 [reference search](#)

 [1 citation](#)

## Renormalization group analysis of the Higgs sector in the minimal supersymmetric standard model

#41

[K. Sasaki](#) ([Yokohama Natl. U.](#)), [Marcela Carena](#) ([Munich, Max Planck Inst.](#)), [C.E.M. Wagner](#) ([Munich, Max Planck Inst.](#)) (Dec, 1991)

Published in: *Nucl.Phys.B* 381 (1992) 66-86

 [DOI](#)

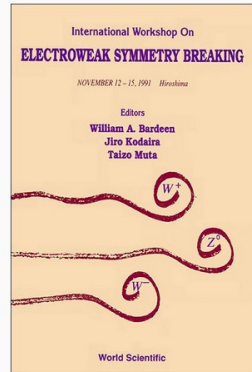
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 [111 citations](#)

➤ November,  
1991



## Electroweak Symmetry Breaking

### Proceedings of the International Workshop

International Workshop on Electroweak Symmetry  
Breaking, Hiroshima, Japan, 12 – 15 November 1991

<https://doi.org/10.1142/1738> | August 1992

Pages: 464

Edited By: William A Bardeen (*Fermilab*), Jiro Kodaira  
(*Hiroshima University, Japan*), and Taizo Muta (*Hiroshima  
University, Japan*)

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- I give a talk at the International Workshop on Electroweak Symmetry Breaking, Hiroshima, Japan entitled “The Higgs Sector in the Minimal Supersymmetric Model: Radiative Corrections and Their Implications”.
- K. Sasaki gives a talk in Hiroshima on work in collaboration with Marcela and Carlos. I take particular notice.

## ➤ July, 1992

- Marcela, Carlos and I attend another workshop at the Aspen Center for Physics (ACP). This time, Marcela walks up to me in the ACP library and introduces herself. Apparently, I responded “I am aware of your work. I see that you are one of my competitors”. In hindsight, not the optimal response.
- Nevertheless, shortly thereafter, we somehow end up on the same hike to Buckskin Pass.





My first picture with Marcela and Carlos at Crater Lake











- By the end of the ACP workshop of 1992, we had become quite friendly. We had a chance to deepen our friendship on a trip to Erice (in Sicily, Italy).

## ➤ October, 1992

- Marcela, Carlos and I attended the 23rd Workshop of the INFN Eloisatron Project in Erice (Trapani), Italy. We had a chance to tour some of the ancient Roman cites in the vicinity.











## ➤ January—September, 1995

- After two more years with a number of shared conferences, I was excited at the opportunity to spend nine months as a Scientific Associate at CERN in 1995, where Marcela and Carlos were both located.
- We were still (friendly) competitors. But we also had fun concocting a crazy model to explain a 3.5 sigma discrepancy in the LEP measurement of the  $Z \rightarrow b\bar{b}$  decay (the  $R_b$  anomaly).

# Effective potential methods and the Higgs mass spectrum in the MSSM <sup>★</sup>

M. Carena, M. Quirós<sup>1</sup>, C.E.M. Wagner

*CERN, TH Division, CH-1211 Geneva 23, Switzerland*

Received 28 August 1995; revised 27 November 1995; accepted 11 December 1995

Z. Phys. C 75, 539–554 (1997)

**ZEITSCHRIFT  
FÜR PHYSIK C**  
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## Approximating the radiatively corrected Higgs mass in the minimal supersymmetric model

Howard E. Haber<sup>1,2</sup>, Ralf Hempfling<sup>3</sup>, André H. Hoang<sup>4</sup>

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<sup>4</sup> Institut für Theoretische Teilchenphysik, Universität Karlsruhe, Kaiserstrasse 12, D-76128 Karlsruhe, Germany

Received: 17 September 1996



Nuclear Physics B 472 (1996) 55–78

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# Four-generation low energy supersymmetry with a light top quark

M. Carena, H.E. Haber<sup>1</sup> C.E.M. Wagner

*CERN, TH Division, CH-1211 Geneva 23, Switzerland*

Received 18 January 1996; revised 3 May 1996; accepted 7 May 1996



Table 1

Example of model spectrum and parameters ( $\tan \beta = 1.6$ )

Particle	Mass (GeV)	Particle	Mass (GeV)
$t$	80	$\tilde{\chi}_1^0$	25
$b'$	105	$\tilde{\chi}_1^+$	65
$t'$	175	$\tilde{\chi}_2^0$	66
$\tau'$	50	$\tilde{g}$	190
$N_{\tau'}$	80	$\tilde{b}$	264
$h^0$	67	$\tilde{t}$	50
$A^0$	300	$\tilde{b}'$	116
$H^\pm$	310	$\tilde{t}'$	263
Parameter	Value (GeV)	Parameter	Value (GeV)
$\mu$	−460	$M_{\tilde{Q},\tilde{U},\tilde{D}}$	275
$M_1$	23	$M_{\tilde{Q}',\tilde{U}',\tilde{D}'}$	250
$M_2$	54	$A_{t,b}$	695
$M_3$	70	$A_{t',b'}$	−155



In September, 1995, we celebrated Carlos' birthday in Ferney-Voltaire





➤ December 31, 1999

- Our greatest failure: we did not succeed in posting the last paper of the second millennium to the arXiv.

KA-TP-10-1999

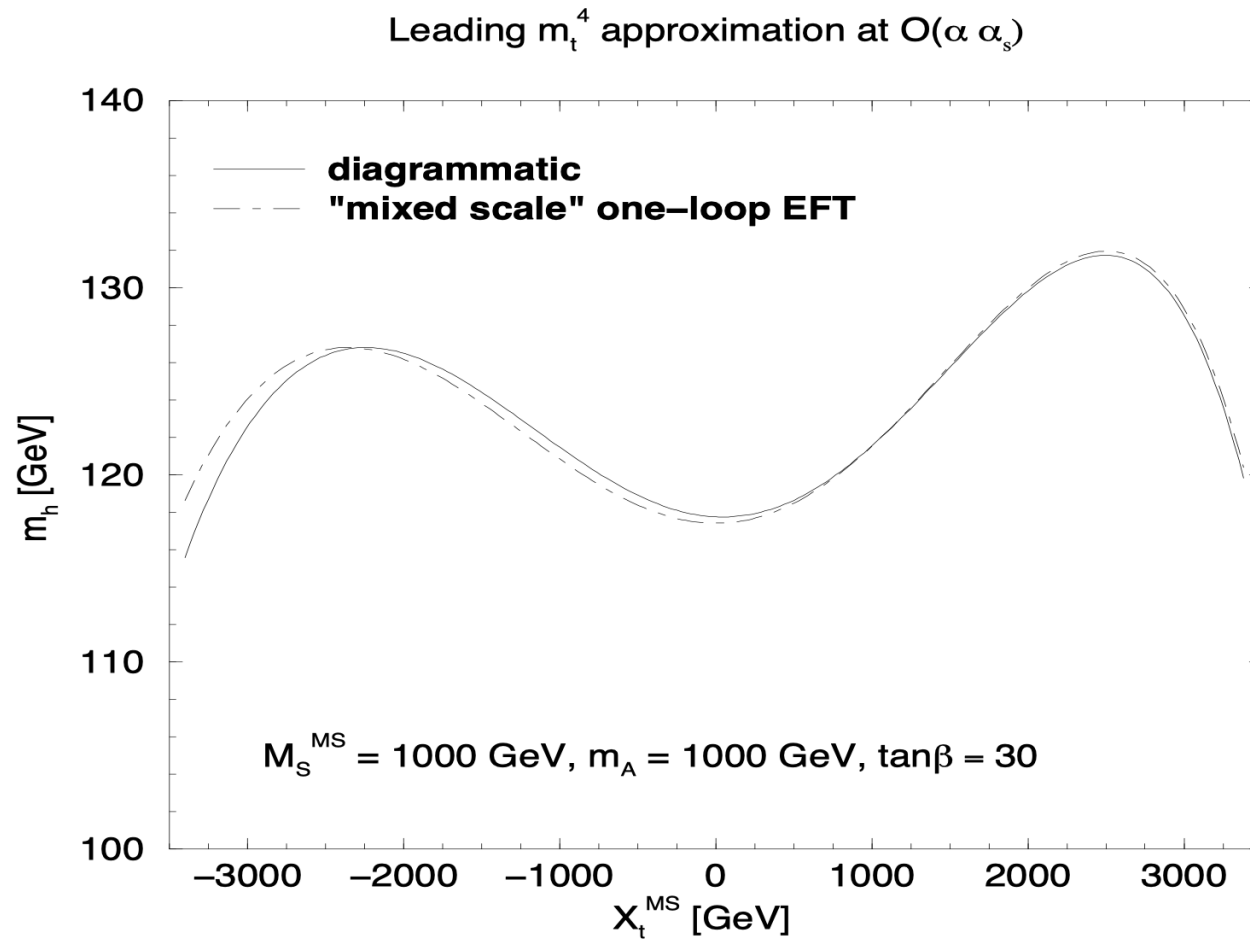
SCIPP-99/46

[hep-ph/0001002](#)

# Reconciling the Two-Loop Diagrammatic and Effective Field Theory Computations of the Mass of the Lightest $\mathcal{CP}$ -even Higgs Boson in the MSSM

M. Carena <sup>§,†</sup>, H.E. Haber <sup>‡</sup>, S. Heinemeyer <sup>‡</sup>,

W. Hollik <sup>¶</sup>, C.E.M. Wagner <sup>†,\*,‡</sup> and G. Weiglein <sup>†</sup>

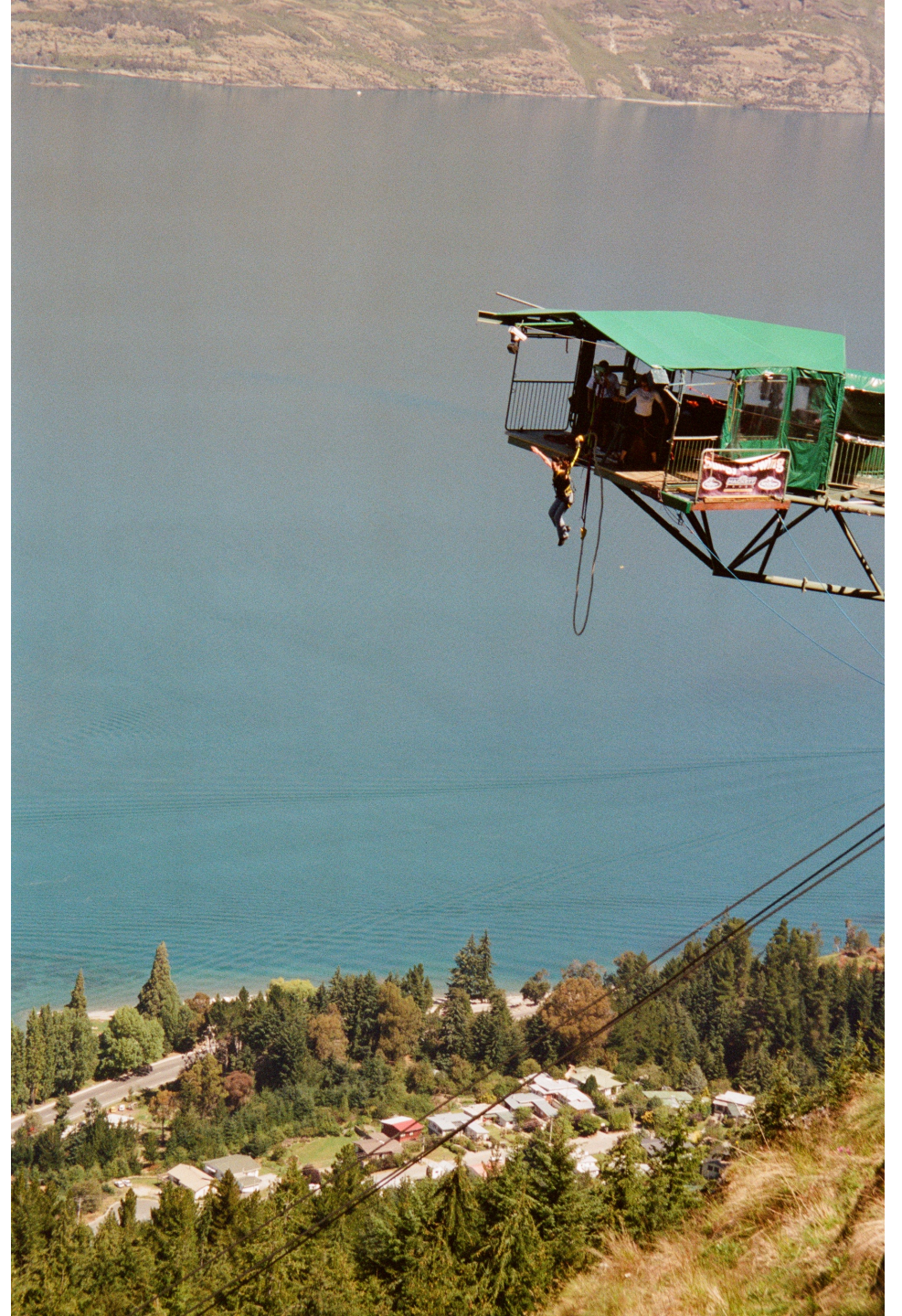


**Figure 2.** Comparison of the diagrammatic two-loop  $\mathcal{O}(m_t^2 h_t^2 \alpha_s)$  result for  $m_h$ , to leading order in  $\bar{m}_t/\bar{M}_S$  [eqs. (46) and (47)] with the “mixed-scale” one-loop EFT result [eq. (49)]. Note that the latter now includes the threshold corrections due to stop mixing in the evaluation of  $\bar{m}_t(M_S)$  in contrast to the EFT results depicted in fig. 1. “Mixed-scale” indicates that in the no-mixing and mixing contributions to the one-loop Higgs mass, the running top quark mass is evaluated at different scales according to eq. (48). See text for further details. The two graphs above are plotted for  $\bar{M}_S = m_A = (m_{\tilde{q}}^2 + \bar{m}_t^2)^{1/2} = 1 \text{ TeV}$  for the cases of  $\tan\beta = 1.6$  and  $\tan\beta = 30$ , respectively.



## ➤ January, 2002

Marcela, Carlos, and I attend the 18th International Workshop on Weak Interactions and Neutrinos (WIN-02) in Christchurch, New Zealand. Following the meeting, I joined Marcela and Carlos in Queenstown and a car trip to Milford Sound. Became an honorary member of the Carena-Wagner family while serving as a witness to some death-defying feats.













➤ February—August, 2002

Marcela visits Santa Cruz in February for an intensive period of writing and coffee consumption.





**PERGAMON**

Progress in Particle and Nuclear Physics 50 (2003) 63–152

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**Progress in  
Particle and  
Nuclear Physics**

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<http://www.elsevier.com/locate/npe>

## **Higgs Boson Theory and Phenomenology**

M. CARENA<sup>1</sup> and H.E. HABER<sup>2</sup>

*<sup>1</sup>Fermi National Accelerator Laboratory,  
P.O. Box 500, Batavia, IL 60510, USA*

*<sup>2</sup>Santa Cruz Institute for Particle Physics,  
University of California, Santa Cruz, CA 95064, USA*

576 citations and counting





SUSY-2009 in Boston

## ➤ A collaboration from 2014--2016

PHYSICAL REVIEW D **91**, 035003 (2015)

### **Complementarity between nonstandard Higgs boson searches and precision Higgs boson measurements in the MSSM**

Marcela Carena,<sup>1,2,3</sup> Howard E. Haber,<sup>4,5</sup> Ian Low,<sup>6,7</sup> Nausheen R. Shah,<sup>8</sup> and Carlos E. M. Wagner<sup>2,3,6</sup>

PHYSICAL REVIEW D **93**, 035013 (2016)

### **Alignment limit of the NMSSM Higgs sector**

Marcela Carena,<sup>1,2,3</sup> Howard E. Haber,<sup>4</sup> Ian Low,<sup>5,6</sup> Nausheen R. Shah,<sup>7,8</sup> and Carlos E. M. Wagner<sup>2,3,5</sup>



## Higgs field alignment in supersymmetric models

In the NMSSM, the superpotential contains a term  $\lambda H_U H_D N$ , where  $N$  is a singlet superfield. The parameter  $\lambda$  plays a significant role in determining the Higgs mass. Remarkably, approximate Higgs field alignment is achieved for  $\lambda = \lambda^{\text{alt}}$ .

This scenario provides a much richer phenomenology for future LHC searches.

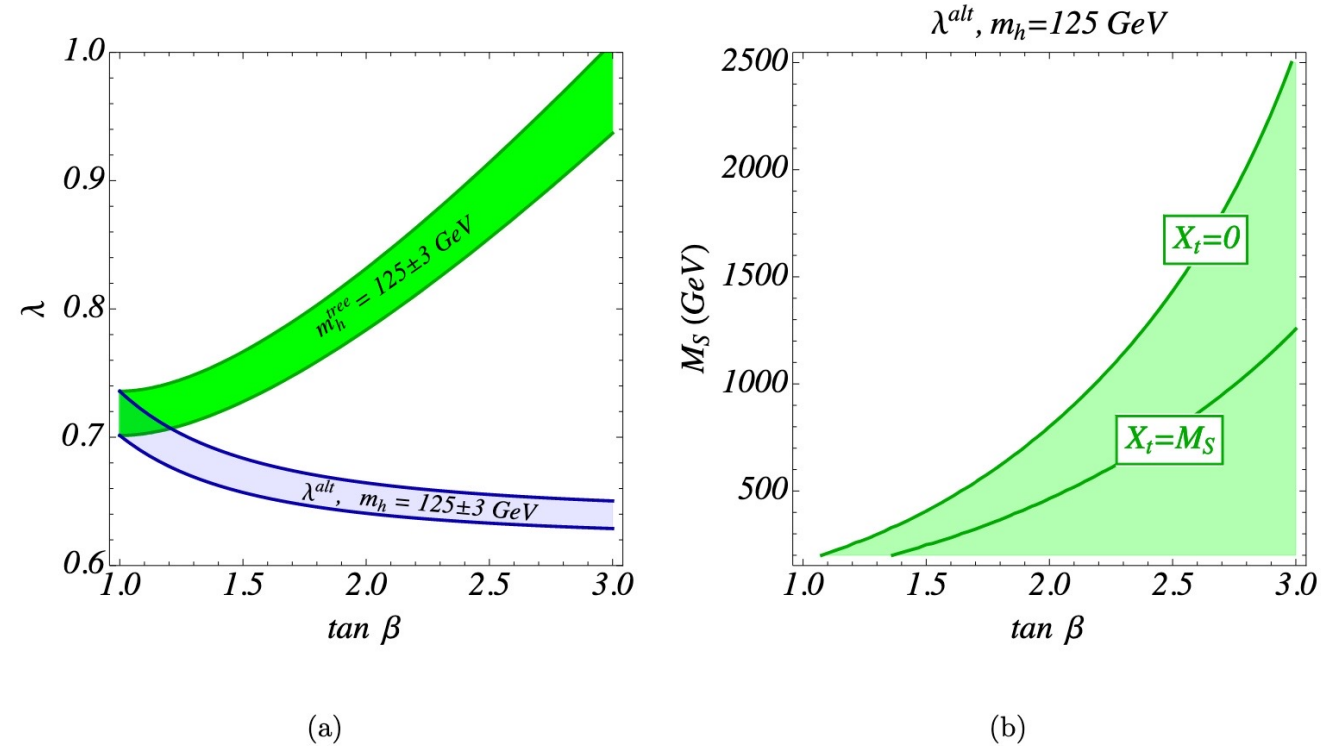


FIG. 2: Left panel : The blue shaded band displays the values of  $\lambda$  as a function of  $\tan \beta$ , necessary for alignment for  $m_h = 125 \pm 3$  GeV. Also shown in the figure as a green band are values of  $\lambda$  that lead to a tree-level Higgs mass of  $125 \pm 3$  GeV. Right panel : Values of  $M_S$  necessary to obtain a 125 GeV mass for values of  $\lambda$  fixed by the alignment condition and stop mixing parameter  $X_t = 0$  and  $X_t = M_S$ . The dominant two-loop corrections are included.

Taken from M. Carena, H.E. Haber, I. Low, N. Shah and C.E.M. Wagner, [arXiv:1510.09137](https://arxiv.org/abs/1510.09137)





September, 2022 in Paris celebrating Carlos' 60<sup>th</sup> birthday



In this meeting, we celebrate the milestone birthdays of Marcela and Carlos (a little after the fact). We also celebrate their many achievements in the pursuit of some of Nature's most treasured secrets. But most of all, I will celebrate the incredible friendship we have shared that has so enriched my life.

We wish you many more years of success and look forward to many new adventures to come.



