



# Taller Más allá del Modelo Estándar y Astropartículas

## SPACEMATH

Breve introducción de uso para SpaceMath v.2.0

16 de marzo de 2023

Tomás Antonio Valencia Pérez

**IFUNAM - 15 y 16 marzo 2023**

- 1 ¿QUÉ ES SPACEMATH?
- 2 SPACEMATH v.2.0: DETALLES TÉCNICOS, REQUISITOS PARA INSTALACIÓN
- 3 INSTALACIÓN DE SPACEMATH v.2.0
- 4 USO BÁSICO DE SPACEMATH v.2.0
- 5 CONCLUSIONES

¿QUÉ ES SPACEMATH?

## La idea

- Una paquetería de Mathematica para la búsqueda del espacio de parámetros más allá del Modelo Estándar.

## SpaceMath v.1.0

SpaceMath v1.0 es capaz de encontrar regiones permitidas para parámetros libres de modelos de extensión usando los datos de bosón de Higgs dentro de una interfaz amigable y en un entorno intuitivo en el que los usuarios ingresan los acoplamientos, establecen parámetros y ejecutan Mathematica de la manera tradicional. Como resultado, son generadas tablas y gráficos con valores y áreas en concordancia con los datos experimentales.

## SpaceMath v.2.0

El propósito de esta guía es describir cómo instalar y usar SpaceMath v.2.0 utilizando las observables físicas: the Higgs boson data (HBD) & Lepton Flavor-Violating Processes (LFV) con 2 formas de manejo para el usuario: Modo Experto y Modo Amigable.

SPACEMATH v.2.0:  
DETALLES TÉCNICOS,  
REQUISITOS PARA  
INSTALACIÓN

## Información

- Nombre de la paquetería de Mathematica: SpaceMath (más precisamente, en esta guía usaremos SpaceMath v.2.0).
- Desarrolladores: The SpaceMath team, compuesto por Marco A. Arroyo-Ureña y Tomás A. Valencia Pérez.
- Colaboradores: Myriam Mondragón Ceballos.
- Repositorio: <https://github.com/spacemathapp>
- Sitio web:  
<https://spacemath-project.gitbook.io/api-docs/>
- Manual: DOI: 10.31349/RevMexFisE.19.020206.

## Requisitos

- Para usar esta guía, necesitará una computadora con un sistema operativo que ejecute Wolfram Mathematica (la versión de SpaceMath que vamos a usar necesita Mathematica v.12.0 o superior).
- Además de este requisito, es muy recomendable que la computadora tenga 4 Gb de RAM o más.
- También necesitará una buena conexión a Internet para descargar la paquetería.
- Es útil conocer el manejo básico del lenguaje Wolfram, pero no es obligatorio. Los comandos necesarios se darán y explicarán en esta guía.



# INSTALACIÓN DE SPACEMATH v.2.0

## Verificación del sistema

- Verifique que Mathematica v.12.0++ este instalado en su computadora.
- Abra un notebook de Mathematica y corra la siguiente instrucción:

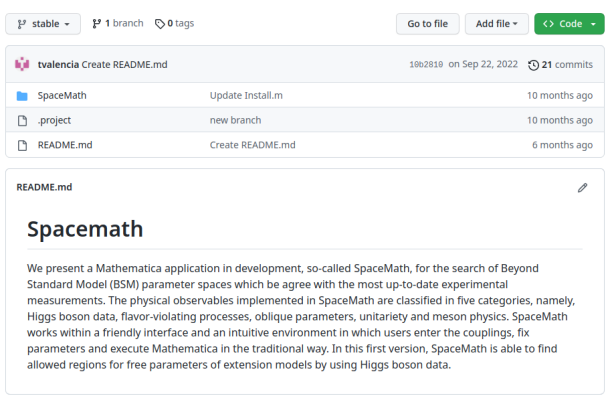
```
In[1]:= $Version
```

```
Out[1]= 13.1.0 for Microsoft Windows (64-bit) (June 16, 2022)
```

- Si su computadora tiene una versión anterior, es posible que algunas características de SpaceMath v.2.0 no estén disponibles.

# Instalación de SpaceMath v.2.0

- Vaya al sitio del repositorio de SpaceMath y descargue el archivo *SpaceMath-2.0.paclet*.



The screenshot shows a GitHub repository page for 'SpaceMath' by user 'tvalencia'. At the top, there are navigation buttons: 'stable' (selected), '1 branch', and '0 tags'. To the right are buttons for 'Go to file', 'Add file', and 'Code'. Below this is a commit history table:

File	Commit Message	Time
SpaceMath	Update Install.m	10 months ago
.project	new branch	10 months ago
README.md	Create README.md	6 months ago

Below the table is the content of the selected file, 'README.md'. The title is 'Spacemath'. The text reads: 'We present a Mathematica application in development, so-called SpaceMath, for the search of Beyond Standard Model (BSM) parameter spaces which agree with the most up-to-date experimental measurements. The physical observables implemented in SpaceMath are classified in five categories, namely, Higgs boson data, flavor-violating processes, oblique parameters, unitarity and meson physics. SpaceMath works within a friendly interface and an intuitive environment in which users enter the couplings, fix parameters and execute Mathematica in the traditional way. In this first version, SpaceMath is able to find allowed regions for free parameters of extension models by using Higgs boson data.'

## Instalación de SpaceMath v.2.0

- Si descargó el archivo en su directorio *Documents* entonces ejecute las instrucciones siguientes:

```
In[2]:= LocalPath = $UserDocumentsDirectory
Out[2]:= /home/valencia/Documents

In[3]:= PacletInstall[FileNameJoin[{LocalPath, "SpaceMath-2.0.paclet"}]]

Out[3]:= PacletObject[ Name: SpaceMath
Version: 2.0 ]
```


- Ahora, simplemente ejecute el siguiente comando y SpaceMath será cargado en su entorno de trabajo en Mathematica.

The screenshot shows a Mathematica notebook cell with the command `In[4]:= << SpaceMath``. The output is a web-style interface for SpaceMath v.1.0. At the top, there is a logo with 'SM' in a box and 'SPACEMATH V.1.0' to its right. Below the logo is a row of five blue buttons: 'Documentation Center', 'Examples', 'Github site', 'Ask a question', and 'Cite'. In the center is a white button with the text 'Observables'. Below that is a red box containing the authors' information: 'Authors: M. A. Arroyo—Ureña' and 'T. A. Valencia—Pérez', with their respective affiliations: 'Centro Interdisciplinario de Investigación y Enseñanza de la Ciencia Benemérita Universidad Autónoma de Puebla' and 'Instituto de Física Universidad Nacional Autónoma de México'. At the bottom is a pink button that says 'Contact us: spacemathapp@gmail.com'.

# USO BÁSICO DE SPACEMATH v.2.0

## Formas de trabajo

- SpaceMath v.2.0 ofrece al usuario 2 formas de trabajar: **Expert Mode** y **Friendly Mode**.
- Tomemos como ejemplo a la observable **LHC Higgs boson data**:



The screenshot displays the SpaceMath v.1.0 interface. At the top, the logo 'SM SPACEMATH V.1.0' is visible. Below the logo are five navigation buttons: 'Documentation Center', 'Examples', 'GitHub site', 'Ask a question', and 'Cite'. The main content area is titled 'Observables' and features a dropdown menu with 'LHC Higgs boson data' selected. Below this, the authors are listed: M. A. Arroyo—Ureña (Centro Interdisciplinario de Investigación y Enseñanza de la Ciencia, Benemérita Universidad Autónoma de Puebla) and T. A. Valencia—Pérez (Instituto de Física, Universidad Nacional Autónoma de México). A 'Contact us' button with the email 'spacemathapp@gmail.com' is located at the bottom.

**SM** SPACEMATH  
V.1.0**LHC Higgs boson data****Signal strength modifiers  $R_x$** **Expert Mode**

RZ	▼
RW	▼
RGamma	▼
Rb	▼
Rtau	▼
RXALL	▼
Intersection	▼

**Friendly Mode**

RZ	▼
RW	▼
RGamma	▼
Rb	▼
Rtau	▼
RXALL	▼
Intersection	▼

**Higgs boson coupling modifiers  $K_i$** **Expert Mode**

KZ	▼
KW	▼
KGamma	▼
Kb	▼
Ktau	▼
Kglu	▼
KXALL	▼
Intersection	▼

**Friendly Mode**

KZ	▼
KW	▼
KGamma	▼
Kb	▼
Ktau	▼
Kglu	▼
Intersection	▼
KXALL	▼

Close



# Expert Mode

- Disponible para fijar desde 1 hasta 4 parámetros.

**SM SPACEMATH V.1.0**

## LHC Higgs boson data

### Signal strength modifiers Rx

Expert Mode	Friendly Mode
RZ	RZ
RW	RW
RGamma	RGamma
Rb	Rb
Rtau	Rtau
One parameter	Intersection
Four parameters	
Random 4—parameters	

### Higgs boson coupling modifiers Ki

Expert Mode	Friendly Mode
KZ	KZ
KW	KW
KGamma	KGamma
Kb	Kb
Ktau	Ktau
Kglu	Kglu
KXALL	Intersection
Intersection	KXALL

Close

# LHC Higgs boson data

Signal strength modifiers  $R_\tau$

## Rtau

### Expert Mode

Load SpaceMath package:

```
<<SpaceMath
```

Input couplings:

- THDM - III couplings taken from arXiv : hep - ph / 0509 353 v2

```
ghTT[a_,Att_,Cab_,tb_]:= (g/2) (mt/mW) ((Cos[a]/(tb*Cos[ArcTan[tb]]))-Sqrt[2] Cab/(g*tb*Cos[ArcTan[tb]])) (mW/mt)*(mt/vev*Att))
ghbb[a_,Abb_,Cab_,tb_]:= (g/2) (mb/mW) (((-Sin[a]*tb)/Sin[ArcTan[tb]])+Sqrt[2] (Cab*tb)/(g*Sin[ArcTan[tb]])) (mW/mb)*(mb/vev*Abb))
ghTautau[a_,Atata_,Cab_,tb_]:= (g/2) (mtau/mW) (((-Sin[a]*tb)/Sin[ArcTan[tb]])+Sqrt[2] (Cab*tb)/(g*Sin[ArcTan[tb]])) (mW/mtau)*(mtau/vev*Atata))
ghW[sab_]:=gw*mi*sab
ghZZ[sab_]:=gz*mZ*sab
```

The Yukawa Lagrangian in term of physical states is given as follows:

$$\begin{aligned}
\mathcal{L}_Y = & \frac{g}{2} \left( \frac{m_d}{m_W} \right) \bar{d}_i \left[ \frac{\cos \alpha}{\cos \beta} \delta_{ij} + \frac{\sqrt{2} \sin(\alpha - \beta)}{g \cos \beta} \left( \frac{m_W}{m_d} \right) (\hat{Y}_2^d)_{ij} \right] d_j H \\
& + \frac{g}{2} \left( \frac{m_d}{m_W} \right) \bar{d}_i \left[ -\frac{\sin \alpha}{\cos \beta} \delta_{ij} + \frac{\sqrt{2} \cos(\alpha - \beta)}{g \cos \beta} \left( \frac{m_W}{m_d} \right) (\hat{Y}_2^d)_{ij} \right] d_j h \\
& + i \frac{g}{2} \left( \frac{m_d}{m_W} \right) \bar{d}_i \left[ -\tan \beta \delta_{ij} + \frac{\sqrt{2}}{g \cos \beta} \left( \frac{m_W}{m_d} \right) (\hat{Y}_2^d)_{ij} \right] \gamma^5 d_j A \\
& + \frac{g}{2} \left( \frac{m_u}{m_W} \right) \bar{u}_i \left[ \frac{\sin \alpha}{\sin \beta} \delta_{ij} - \frac{\sqrt{2} \sin(\alpha - \beta)}{g \sin \beta} \left( \frac{m_W}{m_u} \right) (\hat{Y}_2^u)_{ij} \right] u_j H \\
& + \frac{g}{2} \left( \frac{m_u}{m_W} \right) \bar{u}_i \left[ \frac{\cos \alpha}{\sin \beta} \delta_{ij} - \frac{\sqrt{2} \cos(\alpha - \beta)}{g \sin \beta} \left( \frac{m_W}{m_u} \right) (\hat{Y}_2^u)_{ij} \right] u_j h \\
& + i \frac{g}{2} \left( \frac{m_u}{m_W} \right) \bar{u}_i \left[ -\cot \beta \delta_{ij} + \frac{\sqrt{2}}{g \sin \beta} \left( \frac{m_W}{m_u} \right) (\hat{Y}_2^u)_{ij} \right] \gamma^5 u_j A,
\end{aligned}$$

where  $i$  and  $j$  stand for the fermion flavors, with  $i \neq j$ , in general. As far as the lepton interactions, it is similar to type-down quarks part with the exchange  $d \rightarrow \ell$  and  $m_d \rightarrow m_\ell$ .

Execute the command:

```
Rtau[
gh tt[ArcCos[ cab]+ArcTan[ tb],Att, cab, tb],
gh bb[ArcCos[ cab]+ArcTan[ tb],Abb, cab, tb],
gh tau[ArcCos[ cab]+ArcTan[ tb],1, cab, tb],
cab, tb,-1,1,1,15,
"cos(α-β)", "tanβ", Att, Abb,
0.9,1,0.05,0.9,1,0.05,"Att","Abb",
30
][[2]]
```

If you need to get a data list:

```
TableRtau[
gh tt[ArcCos[ cab]+ArcTan[ tb],1, cab, tb],
gh bb[ArcCos[ cab]+ArcTan[ tb],1, cab, tb],
gh tau[ArcCos[ cab]+ArcTan[ tb],1, cab, tb],
cab,-1,1,0.1,
tb,1,15,1
]
```

For more details:

?Rtau

?TableRtau

Table 1: Left: THDM-III ghXX couplings. Right: Intries for SpaceMath v1.0

Coupling from Yukawa Lagrangian in eq. (4)	Input to SpaceMath v1.0
$gh_{tt} = \frac{g}{2} \frac{m_t}{m_W} \left[ \frac{\cos \alpha}{\sin \beta} \delta_{Lj} - \frac{\sqrt{2} \cos(\alpha - \beta)}{g \sin \beta} \left( \frac{m_W}{m_t} \right) \left( \tilde{Y}_2^F \right)_{tt} \right]$	$gh_{tt}[a.,Att.,Cab.,tb.] := (g/2) (m_t/m_W) ((\cos[a]/tb * \cos[ArcTan[tb]]) - (\sqrt{2} * Cab / (g * tb * \cos[ArcTan[tb]]) * (m_W/m_t) * (mt/vev * Att))$
$gh_{bb} = \frac{g}{2} \frac{m_b}{m_W} \left[ \frac{\sin \alpha}{\cos \beta} \delta_{Lj} - \frac{\sqrt{2} \cos(\alpha - \beta)}{g \cos \beta} \left( \frac{m_W}{m_b} \right) \left( \tilde{Y}_2^F \right)_{bb} \right]$	$gh_{bb}[a.,Abb.,Cab.,tb.] := (g/2) (mb/m_W) ((-\sin[a] * tb / \sin[ArcTan[tb]]) + (\sqrt{2} * (Cab * tb) / (g * \sin[ArcTan[tb]]) * (m_W/m_b) * (mb/vev * Abb))$
$gh_{\tau\tau} = \frac{g}{2} \frac{m_\tau}{m_W} \left[ \frac{\sin \alpha}{\cos \beta} \delta_{Lj} - \frac{\sqrt{2} \cos(\alpha - \beta)}{g \cos \beta} \left( \frac{m_W}{m_\tau} \right) \left( \tilde{Y}_2^F \right)_{\tau\tau} \right]$	$gh_{\tau\tau}[a.,Atata.,Cab.,tb.] := (g/2) (m_tau/m_W) ((-\sin[a] * tb / \sin[ArcTan[tb]]) + (\sqrt{2} * (Cab * tb) / (g * \sin[ArcTan[tb]]) * (m_W/m_tau) * (m_tau/vev * Atata))$
Description	
<ul style="list-style-type: none"> <li>We define <math>a = \alpha</math>, <math>Cab = \cos(\alpha - \beta)</math>, <math>sab = \sin(\alpha - \beta)</math>, <math>tb = \tan \beta</math>, <math>(\tilde{Y}_2^F)_{ij} = \sqrt{m_i m_j} A_{ij} / v</math> and <math>\sin \beta = \tan \beta \cos(\tan^{-1}(\tan \beta))</math>.</li> <li>The terms <math>mf</math> (<math>f = \text{fermions}</math>), <math>mV</math> (<math>V = Z, W</math>), <math>g</math> and <math>vev</math> are the fermion masses, gauge boson masses, <math>SU(2)</math> coupling constant and the vacuum expectation value, respectively. These quantities are loaded once SpaceMath v1.0 is executed.</li> </ul>	

For more details:

In[60]: ?Rtau

Symbol

Rtau(gh tt\_gh bb\_gh tau a\_x y\_x min\_x max\_y min\_y max\_x label\_y label\_x for\_y for\_x formax\_x forstep\_y formin\_y formax\_y forstep\_x forlabel\_PP\_III)→

This command evaluates  $R_{\tau}$  when there is dependence on two or more parameters. The arguments gh tt, gh bb and gh tau are the h tt, h bb and h tau couplings. Here, h represents to

5M-like Higgs boson while t, b and tau are the top and bottom quarks and the tau-lepton. Labels x and y indicate the parameters to constrain, while xmin (ymin) and

xmax (ymax) are the initial and final values defined by users. Argument x label (y label) is used for indicates the X axis label (Y axis label). The arguments for (yfor), xformin (yformin),

xforstep (yforstep) represent an additional parameter to constrain, namely: initial value, final value and the steps from xformin (yformin) to xformax (yformax),

respectively. Label [III] stands for confidence level, i=1 (2) indicates 1σ (2σ). Finally, PP is an option for plotting functions that specifies how many initial sample points to use.

**ghtt**

Coupling of the Higgs boson to a top quark pair.

**ghbb**

Coupling of the Higgs boson to a bottom quark pair.

**ghtautau**Coupling of the Higgs boson to a  $\tau$  lepton pair.**ghVV**Coupling of the Higgs boson to a  $V = W, Z$  gauge boson pair.**gCH**

Coupling of the Higgs boson to a charged scalar boson pair.

**x, y, xfor, yfor**

Parameters to be constrained.

**xmin, xmax**Interval from xmin to xmax for parameter x:  $xmin \leq x \leq xmax$ .**ymin, ymax**Interval from ymin to ymax for parameter y:  $ymin \leq y \leq ymax$ .**xformin, xformax**Interval from xformin to xformax for parameter xfor:  $xformin \leq xfor \leq xformax$ .**Commands to generate  $\mathcal{R}_X$  graphs.**

SpaceMath v1.0

- 5 RV[ghtt., ghbb., ghVV., x., y., xmin., xmax., ymin., ymax., xlabel., ylabel., xfor., yfor., xformin., xformax., xforstep., yformin., yformax., yforstep., PP.][[i]]  
This command graphs  $\mathcal{R}_V$  ( $V = W, Z$ ) as a function of the parameters to be constrained: x, y, xfor, yfor.
- 6 RGam[ghtt., ghbb., ghWW., gCH., mCH., x., y., xmin., xmax., ymin., ymax., xlabel., ylabel., xfor., yfor., xformin., xformax., xforstep., yformin., yformax., yforstep., PP.][[i]]  
This command graphs  $\mathcal{R}_\gamma$  as a function of the parameters to be constrained: x, y, xfor, yfor.
- 7 Rtau[ghtt., ghbb., ghtautau., x., y., xmin., xmax., ymin., ymax., xlabel., ylabel., xfor., yfor., xformin., xformax., xforstep., yformin., yformax., yforstep., PP.][[i]]  
This command graphs  $\mathcal{R}_\tau$  as a function of the parameters to be constrained: x, y, xfor, yfor.
- 8 Rb[ghtt., ghbb., x., y., xmin., xmax., ymin., ymax., xlabel., ylabel., xfor., yfor., xformin., xformax., xforstep., yformin., yformax., yforstep., PP.][[i]]  
This command graphs  $\mathcal{R}_b$  as a function of the parameters to be constrained: x, y, xfor, yfor.

**yformin, yformax**Interval from yformin to yformax for parameter yfor:  $yformin \leq yfor \leq yformax$ .**xforstep**

Steps from xformin to xformax.

**yforstep**

Steps from yformin to yformax.

**xlabel (ylabel)**

Label for x axis (y axis).

**PP**

Sample points to use for plotting functions.

**NN**

Number of random values to generate.

**[i]**Stands for confidence level  $i=1$  (2), indicates  $1\sigma$  ( $2\sigma$ ).**mCH**

Charged scalar mass.

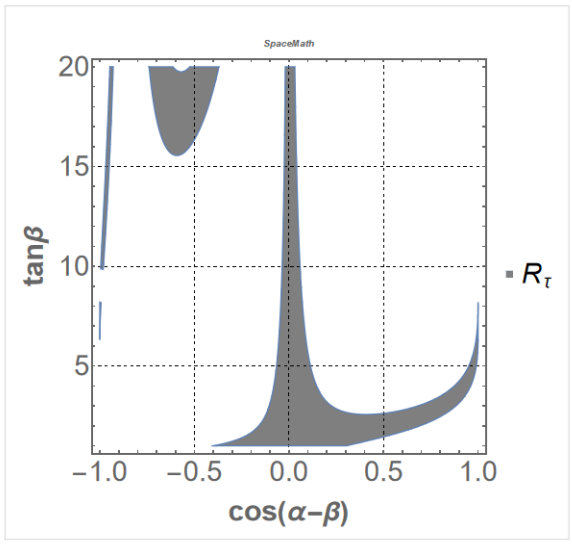
**xi**

Random values parameters to be generated.

Att

Abb

Out[62]=



# LHC Higgs boson data

Signal strength modifiers  $R_\tau$

## RtauRandom

### Expert Mode

Load SpaceMath package:

```
<<SpaceMath`
```

Input couplings:

- THDM - III couplings taken from arXiv : hep - ph / 0509 353 v2

```
ghTT[a_,Att_,Cab_,tb_] := (g/2) (mt/mW) ((Cos[a] / (tb*Cos[ArcTan[tb]])) - Sqrt[2] Cab / (g*tb*Cos[ArcTan[tb]])) (mW/mt) * (mt/vev*Att))
ghbb[a_,Abb_,Cab_,tb_] := (g/2) (mb/mW) (((-Sin[a]*tb)/Sin[ArcTan[tb]]) + Sqrt[2] (Cab*tb) / (g*Sin[ArcTan[tb]])) (mW/mb) * (mb/vev*Abb))
ghTautau[a_,Atata_,Cab_,tb_] := (g/2) (mtau/mW) (((-Sin[a]*tb)/Sin[ArcTan[tb]]) + Sqrt[2] (Cab*tb) / (g*Sin[ArcTan[tb]])) (mW/mtau) * (mtau/vev*Atata))
ghMW[sab_] := gw*mW*sab
ghZZ[sab_] := gz*mZ*sab
```

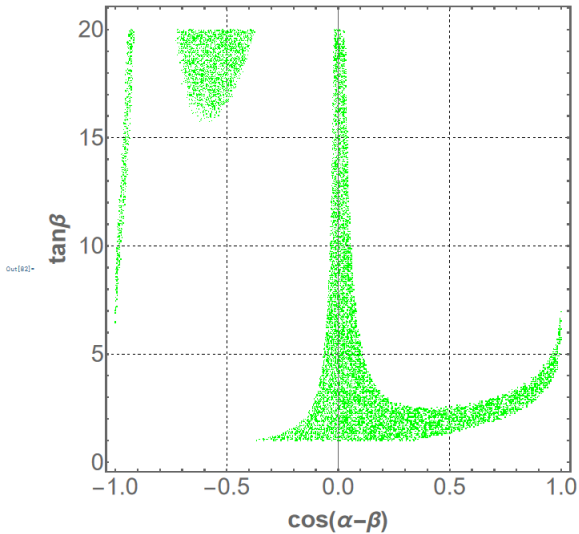
Execute the command:

```
RtauRandom[
  ghTT[ArcCos[cab]+ArcTan[tb],Att,cab,tb],
  ghbb[ArcCos[cab]+ArcTan[tb],Abb,cab,tb],
  ghTautau[ArcCos[cab]+ArcTan[tb],1,cab,tb],
  cab,-1,1,
  tb,1,15,
  Att,0.9,1,
  Abb,0.9,1,
  5000
];
```

```
PlotRtauRandom[1,2,"cos(a-β)", "tanβ"] [2]
```

For more details:

```
?RtauRandom
?PlotRtauRandom
```



# Friendly Mode

- Disponible para fijar desde 1 hasta 4 parámetros.

**SM SPACE MATH v.1.0**

### LHC Higgs boson data

**Signal strength modifiers Rx**

Expert Mode	Friendly Mode
RZ	RZ
RW	RW
RGamma	RGamma
Rb	Rb
Rtau	Rtau
IKALL	One parameter Four parameters
Intersection	Intersection

**Higgs boson coupling modifiers Ki**

Expert Mode	Friendly Mode
KZ	KZ
KW	KW
KGamma	KGamma
Kb	Kb
Ktau	Ktau
Kglu	Kglu
IKALL	Intersection
Intersection	IKALL

Close



# SpaceMath 2.0

## LHC Higgs boson data – Signal strength modifiers $R_W$

Example

Clear

Couplings

Couplings

ghHt:

TIP

ghbb:

TIP

ghWW:

TIP

Setting parameters

ghHt

ghHt[R1,...] Enter R1 value

ghHt[\_R2,...] Enter R2 value

ghHt[\_R3,...] Enter R3 value

ghHt[\_R4,...] Enter R4 value

ghWW

ghWW[T1,...] Enter T1 value

ghWW[\_T2,...] Enter T2 value

ghWW[\_T3,...] Enter T3 value

ghWW[\_T4,...] Enter T4 value

ghbb

ghbb[S1,...] Enter S1 value

ghbb[\_S2,...] Enter S2 value

ghbb[\_S3,...] Enter S3 value

ghbb[\_S4,...] Enter S4 value

Parameter values

Values for x

x:  xlabel:

xmin:  xmax:

Values for y

y:  ylabel:

ymin:  ymax:

Values for xfor

xfor:  xforlabel:

xformin:  xformax:

xforstep:

Values for yfor

yfor:  yforlabel:

yformin:  yformax:

yforstep:

Adjustment

pp:   $\sigma$ :

xstep:  ystep:

Plot Figure

Table

Close

# LHC H

D. C.

Example

Parameters

Parameters

ghtt: {a,At2,Ca2,tb}

ghbb: {a,At2,Ca2,tb}

ghWW: {sa2}

Couplings

Couplings

ghtt:  $(g/2) (mt/mW) ((\text{Cos}[a]/(tb \cdot \text{Cos}[\text{ArcTan}[tb]]) - \text{Sqrt}[2] \cdot \text{Ca2}/(g \cdot tb \cdot \text{Cos}[\text{ArcTan}[tb]]))$   
 $(mZ/mt) - (mt/v_{ev} \cdot \text{At2}))$

⚠ TIP

ghbb:  $(g/2) (mb/mW) (((-\text{Sin}[a] \cdot tb) / \text{Sin}[\text{ArcTan}[tb]]) + \text{Sqrt}[2] \cdot (\text{Ca2} \cdot tb) / (g \cdot \text{Sin}[\text{ArcTan}[tb]]))$   
 $(mZ/mb) - (mb/v_{ev} \cdot \text{Ab2}))$

⚠ TIP

ghWW:  $gz \cdot mW \cdot sa2$

⚠ TIP

## SpaceMath 2.

Higgs boson data – Signal s

Setting parameters

ghtt		ghbb	
ghtt[R1, ...]	$\text{ArcCos}[\text{Ca}2] + \text{ArcTan}[\text{tb}]$	ghbb[S1, ...]	$\text{ArcCos}[\text{Ca}2] + \text{ArcTan}[\text{tb}]$
ghtt[, R2, ...]	At2	ghbb[, S2, ...]	Ab2
ghtt[, , R3, ...]	Ca2	ghbb[, , S3, ...]	Ca2
ghtt[, , , R4]	tb	ghbb[, , , S4]	tb

ghWW	
ghWW[T1, ...]	$\sqrt{1 - \text{Ca}2^2}$
ghWW[, T2, ...]	0
ghWW[, , T3, ...]	0
ghWW[, , , T4]	0

0

Strength modifiers  $R_W$

Clear

Parameter values

Values for x

x: Ca2      xlabel:  $c_{a\beta}$   
xmin: -1      xmax: 1

Values for y

y: tb      ylabel:  $t_\beta$   
ymin: 1      ymax: 40

Values for xfor

xfor: At2      xforlabel: Att  
xformin: 0      xformax: 1  
xforstep: 0.1

Values for yfor

yfor: Ab2      yforlabel: Abb  
yformin: 0      yformax: 1  
yforstep: 0.1

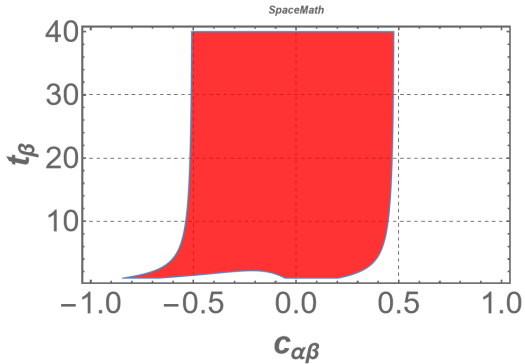
Adjustment

PP: 100       $\sigma$ : 2  
xstep: 0.1      ystep: 0.1

Plot Figure

Att

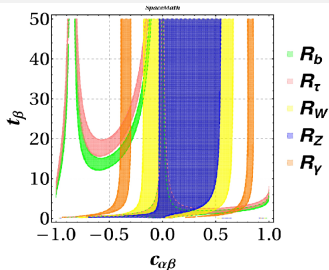
Abb



▪  $R_v$

## All Signal strength

```
RXALL[ghtt[ArcCos[Cab] + ArcTan[tb], Att, Cab, tb],  
ghbb[ArcCos[Cab] + ArcTan[tb], Abb, Cab, tb],  
ghZZ[Sqrt[1 - Cab^2]], ghWW[Sqrt[1 - Cab^2]]  
ghtau[ArcCos[Cab] + ArcTan[tb], 1, Cab, tb],  
0, mCH, Cab, tb, -1, 1, 0.1, 50, "cos( $\alpha - \beta$ )",  
"tan  $\beta$ ", Att, Abb, 0.9, 1, 0.1, 0.9, 1, 0.1, 80][[2]]
```




# CONCLUSIONES

## Conclusiones y perspectivas

- Ha sido publicada la primera versión de SpaceMath habilitada con datos del bosón de Higgs.
- Por concluir la construcción de la segunda versión de SpaceMath habilitada con datos del bosón de Higgs, procesos con violación de sabor leptónico y con 2 forma de trabajo para el usuario.
- Estudiar el espacio de parámetros de diversos modelos.
- Que sea usado por los estudiantes e investigadores



8 results |  cite allCitation Summary 


Most Recent ▾

**Lepton flavor violation in the Littlest Higgs model with T-parity realizing an inverse seesaw** #1

Iván Pacheco (CINVESTAV, IPN) (Sep 19, 2022)

 links cite claim reference search 0 citations**Lepton flavour violation in hadron decays of the tau lepton within the littlest Higgs model with T-parity** #2

Iván Pacheco (CINVESTAV, IPN), Pablo Roig (CINVESTAV, IPN) (Jul 8, 2022)

Published in: *JHEP* 09 (2022) 144 • e-Print: 2207.04085 [hep-ph] pdf DOI cite claim reference search 6 citations**Higgs Pair Production at the LHC through the Flavon** #3Marco A. Arroyo-Ureña (Unlisted, MX and Mexico U.), Amit Chakraborty (SRM U., Amaravati), J. Lorenzo Díaz-Cruz (Unlisted, MX and Puebla U., Mexico), Dilip Kumar Ghosh (IACS, Kolkata), Najimuddin Khan (Harish-Chandra Res. Inst.) et al. (May 25, 2022)  
e-Print: 2205.12641 [hep-ph] pdf cite claim reference search 3 citations**Single top production via FCNC couplings at an  $e^-e^+$  collider with center-of-mass energy  $\sqrt{s} = 240$  GeV** #4

M.A. Arroyo-Ureña (Mexico U., Cuautitlan), J. Lorenzo Díaz-Cruz (Puebla U., Mexico), R. Gaitán (Mexico U., Cuautitlan), J.H. Montes de Oca (Mexico U., Cuautitlan), T.A. Valencia-Pérez (Mexico U.) (Feb 9, 2022)

**GRACIAS  
POR SU ATENCIÓN**