1-loop

Diego Restrepo

Instituto de Física
Universidad de Antioquia
Phenomenology Group
http://gfif.udea.edu.co

Systematic study of the d=5 Weinberg operator at one-loop order #1
Florian Bonnet (Wurzburg U.), Martin Hirsch (Valencia U., IFIC), Toshihiko Ota (Munich, Max Planck Inst.), Walter Winter (Wurzburg U.) (Apr, 2012)
Published in: JHEP 07 (2012) 153 • e-Print: 1204.5862 [hep-ph]
pdf DOI cite claim reference search 192 citations

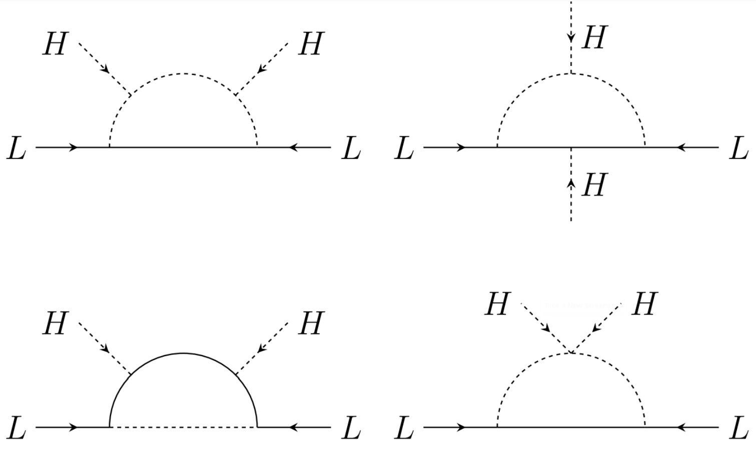


Figure 1. The four different 1-loop diagrams that can lead to genuine neutrino mass models [15]. Top line: T-I-1 (left) and T-I-2 (right), bottom T-I-3 (left) and T-3 (right).

Up to electro-weak triplets
(Color singlets)

Systematic study of the d=5 Weinberg operator at one-loop order #1

Florian Bonnet (Wurzburg U.), Martin Hirsch (Valencia U., IFIC), Toshihiko Ota (Munich, Max Planck Inst.), Walter Winter (Wurzburg U.) (Apr, 2012)

Published in: *JHEP* 07 (2012) 153 • e-Print: 1204.5862 [hep-ph]

pdf DOI cite claim reference search 192 citations

$$-i\Sigma^{\nu}_{ij}(p) = \int \frac{d4k}{(2\pi)^4} \left(y_{in\alpha}\right) iS_F(k) \left(y_{jn\alpha}\right) i\Delta_F(p+k)$$

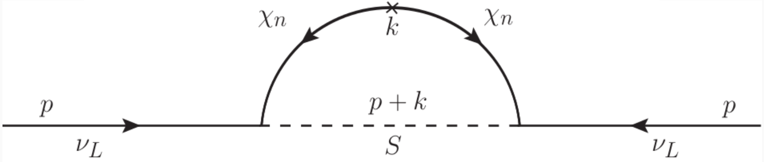


Figure 9.1: Generic one-loop neutrino mass contribution

$$M^{\nu}_{ij} = -\frac{y_{in\alpha}y_{jn\alpha}}{16\pi^2} m_{\chi_n} \left[\mathrm{cte}(\infty) + f\left(m_{\chi_n}, m^2_{S_\alpha}\right)\right]$$

where

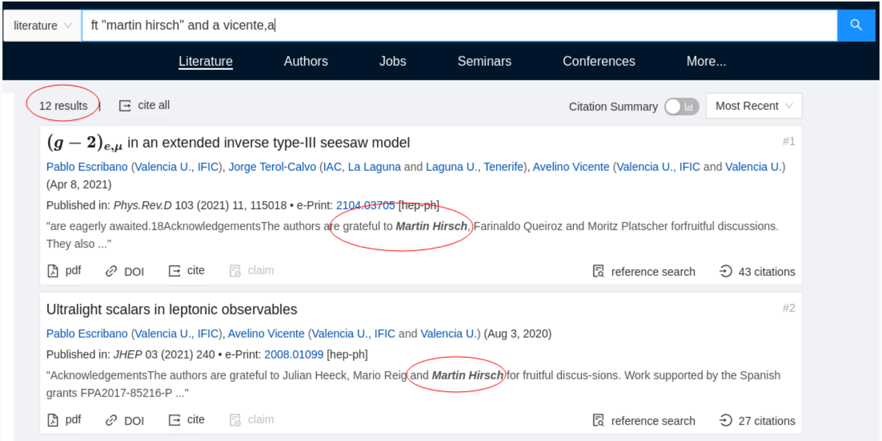
$$f\left(m^2_{\chi_n}, m^2_{S_\alpha}\right) = \frac{m^2_{S_\alpha} \ln\left(m^2_{S_\alpha}\right) - m^2_{\chi_n} \ln\left(m^2_{\chi_n}\right)}{m^2_{\chi_n} - m^2_{S_\alpha}}$$

Up to electro-weak triplets

(Color singlets)

Hirsch-subindex → In the Acknowledgements section

```
ft "martin hirsch" and a AUTHOR
```



José W.F. Valle $\boxed{16}$ Avelino Vicente $\boxed{12}$ Diego Aristizabal $\boxed{7}$ Diego Restrepo $\boxed{7}$

#9

Models with radiative neutrino masses and viable dark matter candidates

Diego Restrepo (Antioquia U.), Oscar Zapata (Antioquia U.), Carlos E. Yaguna (Munster U., ITP) (Aug 16, 2013)

Published in: *JHEP* 11 (2013) 011 • e-Print: 1308.3655 [hep-ph]

"Diego Aristizabal for helpful discussions.O.Z. is also very grateful to ***Martin Hirsch*** for his enlightening discussions.References[1] Planck Collaboration Collaboration ..."

pdf DOI cite claim reference search 118 citations

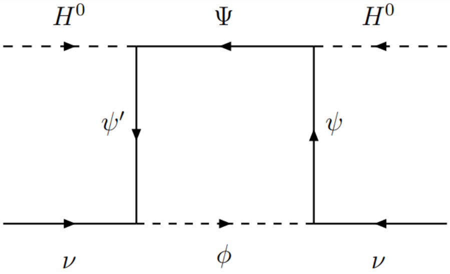


Figure 3. One-loop contribution to neutrino mass in the T1-3 models.

Ψ	ψ'	ϕ	ψ
1^F_α	$2^F_{1+\alpha}$	1^S_α	$2^F_{\alpha-1}$

Table 19. Model T1-3-A.

Up to electro-weak triplets

(Color singlets)

Result: 35 models

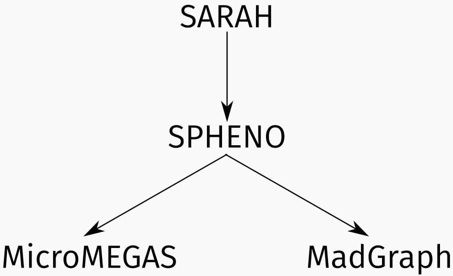
SARAH / Models / SSDM / SSDM.m

restrepo 4.6.0

Code Blame Executable File · 109 lines (68 loc) · 2.68 KB

```
Off[General::spell]

Model`Name = "SSDM";
Model`NameLaTeX ="Singlet scalar Dark Matter";
Model`Authors = "Diego Restrepo (based on SM model by F.Staub)";
Model`Date = "2015-11-16";
```



Radiative neutrino masses in the singlet-doublet fermion dark matter model with scalar singlets

Diego Restrepo(Antioquia U.), Andrés Rivera(Antioquia U.), Marta Sánchez-Peláez(Antioquia U.), Oscar Zapata(Antioquia U.), Walter Tangarife(Tel Aviv U.)

PHYSICAL REVIEW D **92**, 013005 (2015)

TABLE I. α set of scalars and Weyl fermions of the model.

Symbol	$(\mathrm{SU}(2)_L, \mathrm{U}(1)_Y)$	Z_2	Spin
S_α	(1,0)	−	0
N	(1,0)	−	1/2
$\tilde{R}_u$,	$(2, +1/2)$	−	1/2
R_d	$(2, -1/2)$	−	1/2

Like the MSSM bino-Higgsino sector (arbitrary couplings)

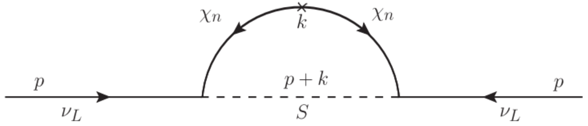


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S.

Radiative neutrino masses in the singlet-doublet fermion dark matter model with scalar singlets

Diego Restrepo(Antioquia U.), Andrés Rivera(Antioquia U.), Marta Sánchez-Peláez(Antioquia U.), Oscar Zapata(Antioquia U.), Walter Tangarife(Tel Aviv U.)

PHYSICAL REVIEW D **92**, 013005 (2015)

TABLE I. α set of scalars and Weyl fermions of the model.

Symbol	$(\mathrm{SU}(2)_L, \mathrm{U}(1)_Y)$	Z_2	Spin
S_α	(1,0)	−	0
N	(1,0)	−	1/2
$\tilde{R}_u$,	(2, +1/2)	−	1/2
R_d	(2, −1/2)	−	1/2

Like the MSSM bino-Higgsino sector (arbitrary couplings)

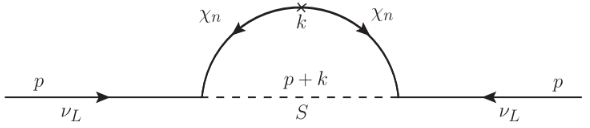


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions $(n = 1, 2, 3)$ and a singlet scalar S.

$$M^\nu_{ij} = -\sum_\alpha \frac{h_{i\alpha} h_{j\alpha}}{16\pi^2} \sum_{n=1}^{3} (N_{3n})^2 m_{\chi_n} B_0(0; m^2_{\chi_n}, m^2_{S_\alpha}), \tag{6}$$

where $B_0(0; m^2_{\chi_n}, m^2_{S_\alpha})$ is the B_0 Passarino-Veltman function [25] and (N_{mn}) are matrix elements of the rotation matrix $\mathbf{N}$. By using the identity

$$\sum_{n=1}^{3} (N_{3n})^2 m^\chi_n = (\mathbf{M}^\chi)_{33} = 0, \tag{7}$$

we obtain the expected cancellation of divergent terms coming from the mass-independent term in B_0, leading to the finite neutrino mass matrix

$$M^\nu_{ij} = \sum_\alpha \frac{h_{i\alpha} h_{j\alpha}}{16\pi^2} \sum_{n=1}^{3} (N_{3n})^2 m_{\chi_n} f(m_{S_\alpha}, m_{\chi_n}) \tag{8}$$

Radiative neutrino masses in the singlet-doublet fermion dark matter model with scalar singlets

Diego Restrepo(Antioquia U.), Andrés Rivera(Antioquia U.), Marta Sánchez-Peláez(Antioquia U.), Oscar Zapata(Antioquia U.), Walter Tangarife(Tel Aviv U.)

PHYSICAL REVIEW D **92**, 013005 (2015)

TABLE I. α set of scalars and Weyl fermions of the model.

Symbol	$(SU(2)_L, U(1)_Y)$	Z_2	Spin
S_α	(1,0)	–	0
N	(1,0)	–	1/2
$\tilde{R}_u$,	(2, +1/2)	–	1/2
R_d	(2, −1/2)	–	1/2

Like the MSSM bino-Higgsino sector (arbitrary couplings)

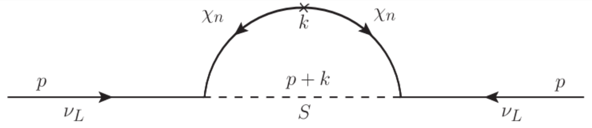
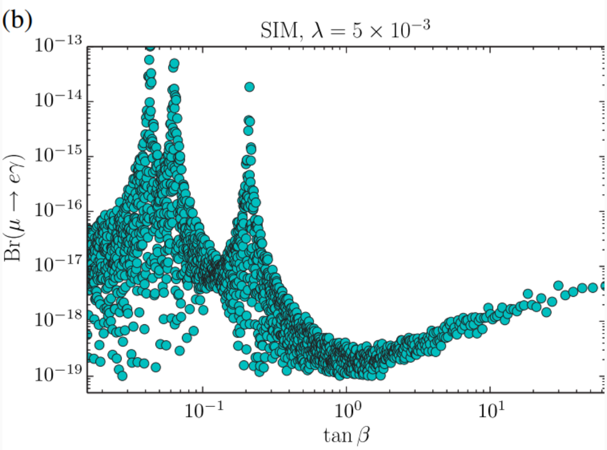


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S.

SPHENO



Radiative neutrino masses in the singlet-doublet fermion dark matter model with scalar singlets

Diego Restrepo(Antioquia U.), Andrés Rivera(Antioquia U.), Marta Sánchez-Peláez(Antioquia U.), Oscar Zapata(Antioquia U.), Walter Tangarife(Tel Aviv U.)

PHYSICAL REVIEW D **92**, 013005 (2015)

TABLE I. α set of scalars and Weyl fermions of the model.

Symbol	$(SU(2)_L, U(1)_Y)$	Z_2	Spin
S_α	(1,0)	–	0
N	(1,0)	–	1/2
$\tilde{R}_u$,	$(2, +1/2)$	–	1/2
R_d	$(2, -1/2)$	–	1/2

Like the MSSM bino-Higgsino sector (arbitrary couplings)

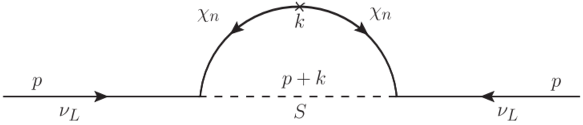
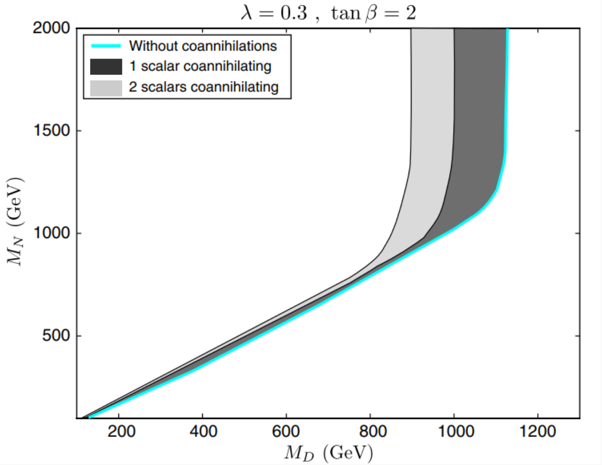


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions $(n = 1, 2, 3)$ and a singlet scalar S.

MicroMEGAS



Diego Restrepo(Antioquia U.), Andrés Rivera(Antioquia U.), Marta Sánchez-Peláez(Antioquia U.), Oscar Zapata(Antioquia U.), Walter Tangarife(Tel Aviv U.)

PHYSICAL REVIEW D **92**, 013005 (2015)

TABLE I. α set of scalars and Weyl fermions of the model.

Symbol	$(\mathrm{SU}(2)_L,\ \mathrm{U}(1)_Y)$	Z_2	Spin
S_α	(1,0)	−	0
N	(1,0)	−	1/2
$\tilde{R}_u$,	(2, +1/2)	−	1/2
R_d	(2, −1/2)	−	1/2

Like the MSSM bino-Higgsino sector (arbitrary couplings)

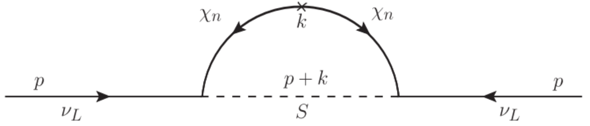
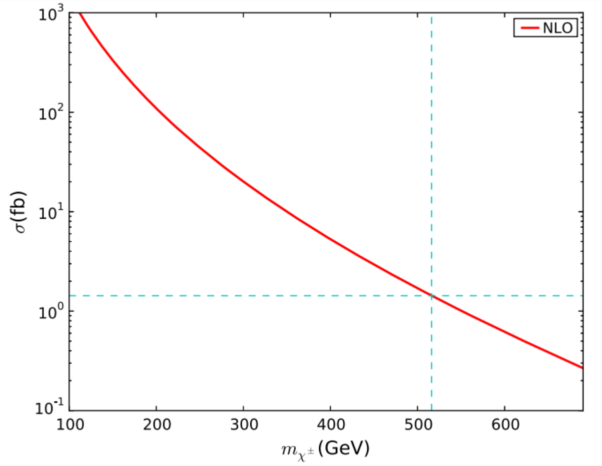


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions $(n = 1, 2, 3)$ and a singlet scalar S.

MadGraph



minimal-lagrangians: Generating and studying dark matter model Lagrangians with just the particle content #1

Simon May (Garching, Max Planck Inst.) (Mar 18, 2020)

Published in: *Comput.Phys.Commun.* 261 (2021) 107773 • e-Print: 2003.08037 [hep-ph]

pdf DOI cite claim reference search 0 citations

minimal-lagrangians 1.1.2

```
pip install minimal-lagrangians
```

Latest version

Released: Apr 13, 2020

```
restrepo@tuxillo:~$ minimal-lagrangians T1-3-A 0
 - ½ M_φ² φ²
 - λ₁ (H^† H) φ² - λ₂ φ⁴
 - (M_ψψ' ψ ψ' + H.c.) - (½ M_Ψ Ψ Ψ + H.c.)
 - (y₁ (H^† ψ') Ψ + H.c.) - (y₂ (H ψ) Ψ + H.c.) - (y₃ (L ψ') φ + H.c.)
restrepo@tuxillo:~$ minimal-lagrangians --format SARAH T1-3-A 0
LagBSMNoHC = - 1/2 Mphi2 phi.phi \
         - lambda1 conj[H].H.phi.phi - lambda2 phi.phi.phi.phi;
LagBSMHC = - Mpsipsiq psi.psiq - 1/2 MCPsi CPsi.CPsi \
         - y1 conj[H].psiq.CPsi - y2 H.psi.CPsi - y3 l.psiq.phi;

The SARAH model files (T1_3_A_alpha_0.m, particles.m, parameters.m, SPheno.m)
have been written to the directory ./SARAH_model_T1_3_A_alpha_0/
```

All 35 models implemented

How many 1-loop neutrino mass models are there? #4

Carolina Arbeláez (CCTVal, Valparaiso and Santa Maria U., Valparaiso), Ricardo Cepedello (Wurzburg U.), Juan Carlos Helo (La Serena U. and Unlisted, CL), Martin Hirsch (Unlisted, CL), Sergey Kovalenko (Andres Bello Natl. U.) (May 25, 2022)

Published in: *JHEP* 08 (2022) 023 • e-Print: 2205.13063 [hep-ph]

pdf DOI cite claim reference search 7 citations

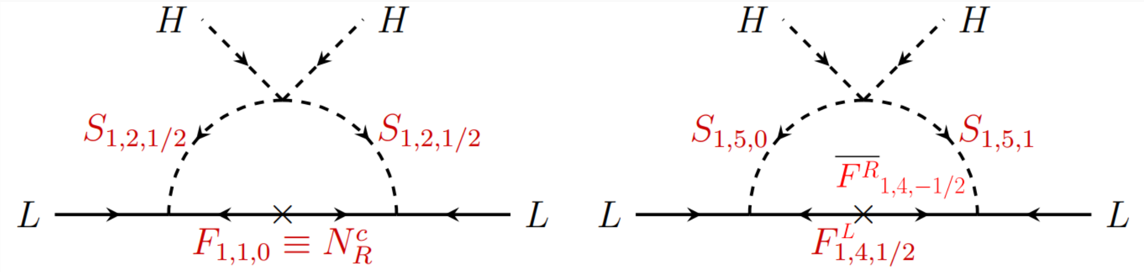


Figure 2. Two examples of dark matter models. To the left the original scotogenic model [47]; to the right an accidentally stable DM model, see text.

How many 1-loop neutrino mass models are there? #4

Carolina Arbeláez (CCTVal, Valparaiso and Santa Maria U., Valparaiso), Ricardo Cepedello (Wurzburg U.), Juan Carlos Helo (La Serena U. and Unlisted, CL), Martin Hirsch (Unlisted, CL), Sergey Kovalenko (Andres Bello Natl. U.) (May 25, 2022)

Published in: *JHEP* 08 (2022) 023 • e-Print: 2205.13063 [hep-ph]

pdf DOI cite claim reference search 7 citations

Exit models		Dark matter models	
SM field in the loop	Only fields beyond the SM	Stabilizing symmetry	Accidentally stable
38	368	115	203
406		318	
724			

Table 1: (i) use only scalars and fermions as BSM fields; and (ii) avoid stable charged relics. "Exits" as particles that can decay into standard model fields

1-loop Dirac neutrinos case

Bound-state dark matter and Dirac neutrino masses #5

M. Reig (Valencia U., IFIC), D. Restrepo (Antioquia U.), J.W.F. Valle (Valencia U., IFIC), O. Zapata (Antioquia U.) (Mar 22, 2018)

Published in: *Phys.Rev.D* 97 (2018) 11, 115032 • e-Print: 1803.08528 [hep-ph]

"[27], instead of QCD, as suggestedin Ref. [2].ACKNOWLEDGMENTSWe thank ***Martin Hirsch*** for very useful discussions. Work supported by the Spanish grants FPA2017-85216-P ..."

pdf DOI cite claim reference search 39 citations

Minimal radiative Dirac neutrino mass models #4

Julian Calle (Antioquia U.), Diego Restrepo (Antioquia U.), Carlos E. Yaguna (UPTC, Tunja), Óscar Zapata (Antioquia U.) (Dec 13, 2018)

Published in: *Phys.Rev.D* 99 (2019) 7, 075008 • e-Print: 1812.05523 [hep-ph]

"COLCIENCIAS through the Grants 111565842691 and111577657253. D.R thanks ***Martin Hirsch*** for illuminating discussions. O.Z. acknowledges the ICTP Simonsassociates ..."

pdf DOI cite claim reference search 44 citations

Effective Dirac Neutrino Mass Operator in the Standard Model With a Local Abelian Extension #5

Diego Restrepo (Antioquia U.), David Suarez (Antioquia U.) (Dec 17, 2021)

Published in: *Front.in Phys.* 10 (2022) 838531 • e-Print: 2112.09524 [hep-ph]