



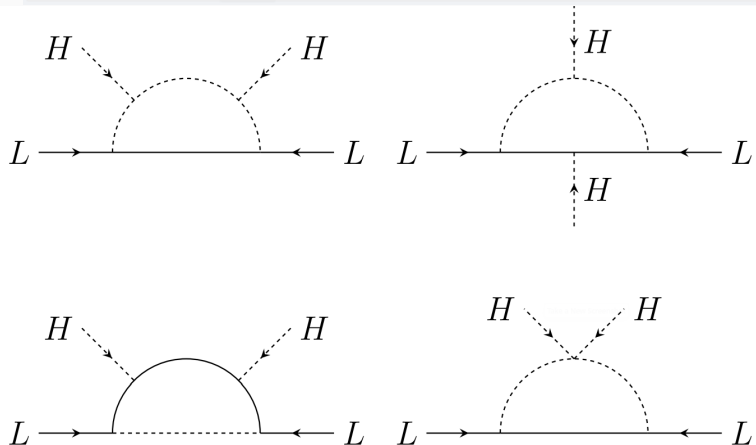
UNIVERSIDAD DE ANTIOQUIA
1803

1-loop

Diego Restrepo

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





Up to electro-weak triplets
(Color singlets)

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).

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](#)

$$-i\Sigma_{ij}^{\nu}(p) = \int \frac{d^4k}{(2\pi)^4} (y_{in\alpha}) iS_F(k) (y_{jn\alpha}) i\Delta_F(p+k)$$

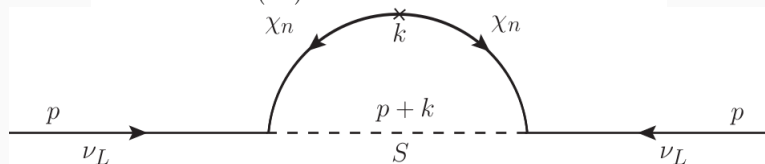


Figure 9.1: Generic one-loop neutrino mass contribution

$$M_{ij}^{\nu} = -\frac{y_{in\alpha}y_{jn\alpha}}{16\pi^2}m_{\chi_n} [\text{cte}(\infty) + f(m_{\chi_n}, m_{S_\alpha}^2)]$$

where

$$f(m_{\chi_n}^2, m_{S_\alpha}^2) = \frac{m_{S_\alpha}^2 \ln(m_{S_\alpha}^2) - m_{\chi_n}^2 \ln(m_{\chi_n}^2)}{m_{\chi_n}^2 - m_{S_\alpha}^2}$$

Up to electro-weak triplets
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Hirsch-subindex → In the Acknowledgements section

ft "martin hirsch" and a AUTHOR

literature ▾ ft "martin hirsch" and a vicente,a

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$(g - 2)_{e,\mu}$ in an extended inverse type-III seesaw model #1
Pablo Escribano (Valencia U., IFIC), Jorge Terol-Calvo (IAC, La Laguna and Laguna U., Tenerife), Avelino Vicente (Valencia U., IFIC and Valencia U.) (Apr 8, 2021)
Published in: *Phys.Rev.D* 103 (2021) 11, 115018 • e-Print: [2104.03705 \[hep-ph\]](#)
"are eagerly awaited.18AcknowledgementsThe authors are grateful to **Martin Hirsch**, Farinaldo Queiroz and Moritz Platscher for fruitful discussions. They also ..."

pdf DOI cite claim reference search 43 citations

Ultralight scalars in leptonic observables #2
Pablo Escribano (Valencia U., IFIC), Avelino Vicente (Valencia U., IFIC and Valencia U.) (Aug 3, 2020)
Published in: *JHEP* 03 (2021) 240 • e-Print: [2008.01099 \[hep-ph\]](#)
"AcknowledgementsThe authors are grateful to Julian Heeck, Mario Reig and **Martin Hirsch** for fruitful discussions. Work supported by the Spanish grants FPA2017-85216-P ..."

pdf DOI cite claim reference search 27 citations

José W.F. Valle 16

Avelino Vicente 12

Diego Aristizabal 7

Diego Restrepo 7

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

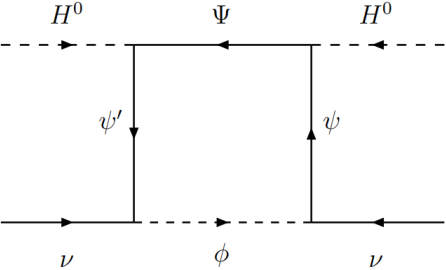


Figure 3. One-loop contribution to neutrino mass in the T1-3 models.

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 

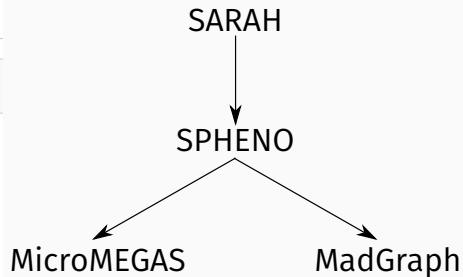
 restrepo 4.6.0

Code

Blame

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

```
1  Off[General::spell]
2
3  Model`Name = "SSDM";
4  Model`NameLaTeX ="Singlet scalar Dark Matter";
5  Model`Authors = "Diego Restrepo (based on SM model by F.Staub)";
6  Model`Date = "2015-11-16";
7
```



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	$(\text{SU}(2)_L, \text{U}(1)_Y)$	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)

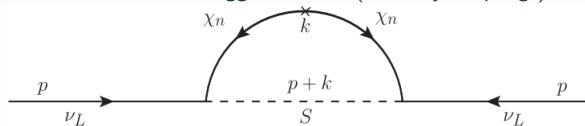


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S .

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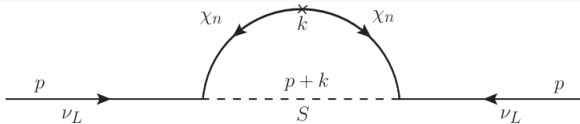


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S .

$$M_{ij}^\nu = -\sum_\alpha \frac{h_{i\alpha} h_{j\alpha}}{16\pi^2} \sum_{n=1}^3 (N_{3n})^2 m_{\chi_n} B_0(0; m_{\chi_n}^2, m_{S_\alpha}^2), \quad (6)$$

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

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

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

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

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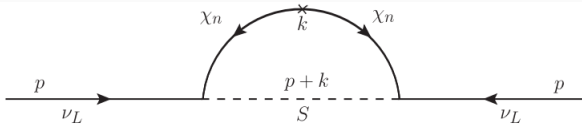
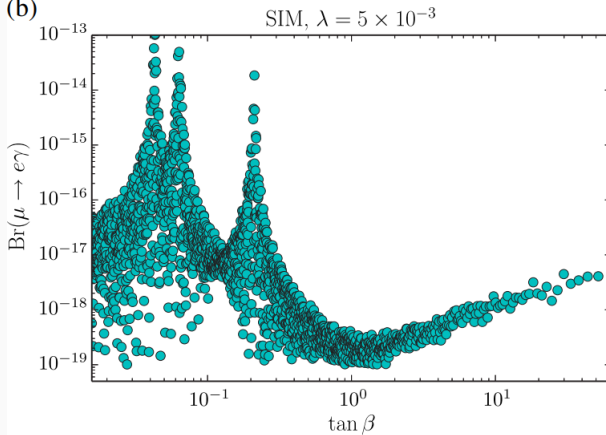


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SPHENO

(b)



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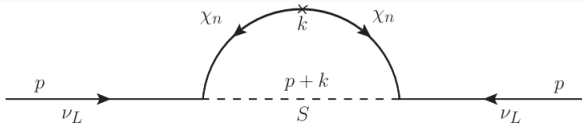
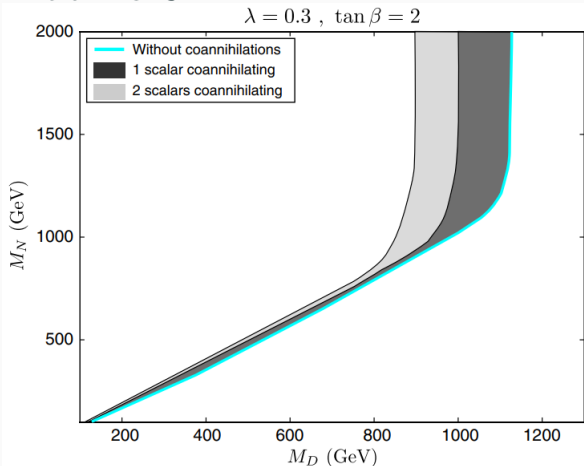


FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S .

MicroMEGAS



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

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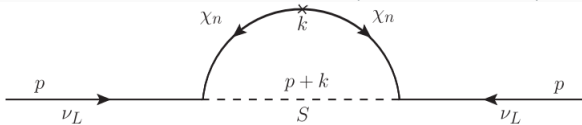
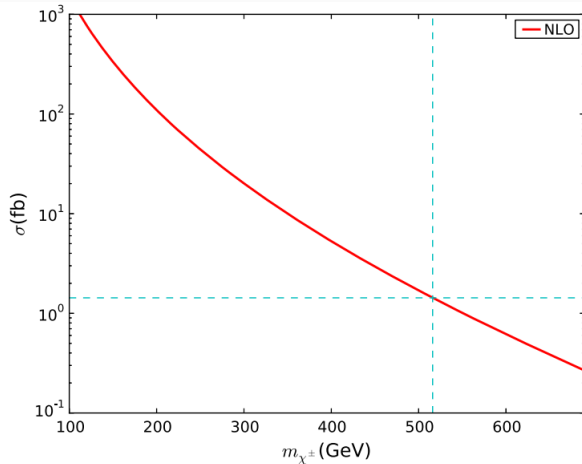



FIG. 1. One-loop Weyl-spinor Feynman rules [29] for the contributions to the neutrino mass, with three Majorana fermions ($n = 1, 2, 3$) and a singlet scalar S .

MadGraph



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

Published in: *Comput.Phys.Commun.* 261 (2021) 107773 • e-Print: [2003.08037](https://arxiv.org/abs/2003.08037) [hep-ph] pdf  DOI  cite  claim reference search 0 citations

minimal-lagrangians 1.1.2

[Latest version](#)`pip install minimal-lagrangians` 

Released: Apr 13, 2020

```
restrepo@tuxillo:~$ minimal-lagrangians T1-3-A 0
```

```

- 1/2 M_φ^2 φ^2
- λ_1 (H^† H) φ^2 - λ_2 φ^4
- (M_ψ ψ' ψ + H.c.) - (1/2 M_Ψ Ψ Ψ + H.c.)
- (y_1 (H^† ψ') Ψ + H.c.) - (y_2 (H ψ) Ψ + H.c.) - (y_3 (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/

Carolina Arbeláez (CCTVal, Valparaíso and Santa María U., Valparaíso), Ricardo Cepedello (Würzburg U.), Juan Carlos Helo (La Serena U. and Unlisted, CL), Martin Hirsch (Unlisted, CL), Sergey Kovalenko (Andrés Bello Natl. U.) (May 25, 2022)

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

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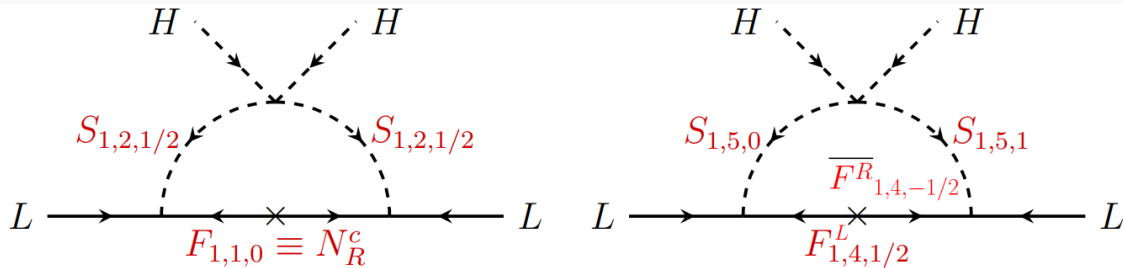


Figure 2. Two examples of dark matter models. To the left the original scotogenic model [47]; to the right an accidentally stable DM model, see text.



See ./scotodecay.nb and Tensor products

How many 1-loop neutrino mass models are there?

#4

Carolina Arbeláez (CCTVal, Valparaíso and Santa María U., Valparaíso), Ricardo Cepedello (Würzburg U.), Juan Carlos Helo (La Serena U. and Unlisted, CL), Martin Hirsch (Unlisted, CL), Sergey Kovalenko (Andrés Bello Natl. U.) (May 25, 2022)

Published in: *JHEP* 08 (2022) 023 • e-Print: [2205.13063](https://arxiv.org/abs/2205.13063) [hep-ph]

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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 suggested in Ref. [2]. ACKNOWLEDGMENTS We 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]

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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]

