the neutrino dark matter connection

JOSÉ W F VALLE

8th IBS Conference UAM, 13-17 Nov 2023

ASTROPARTICLES
Astroparticles and High Energy Physics Group

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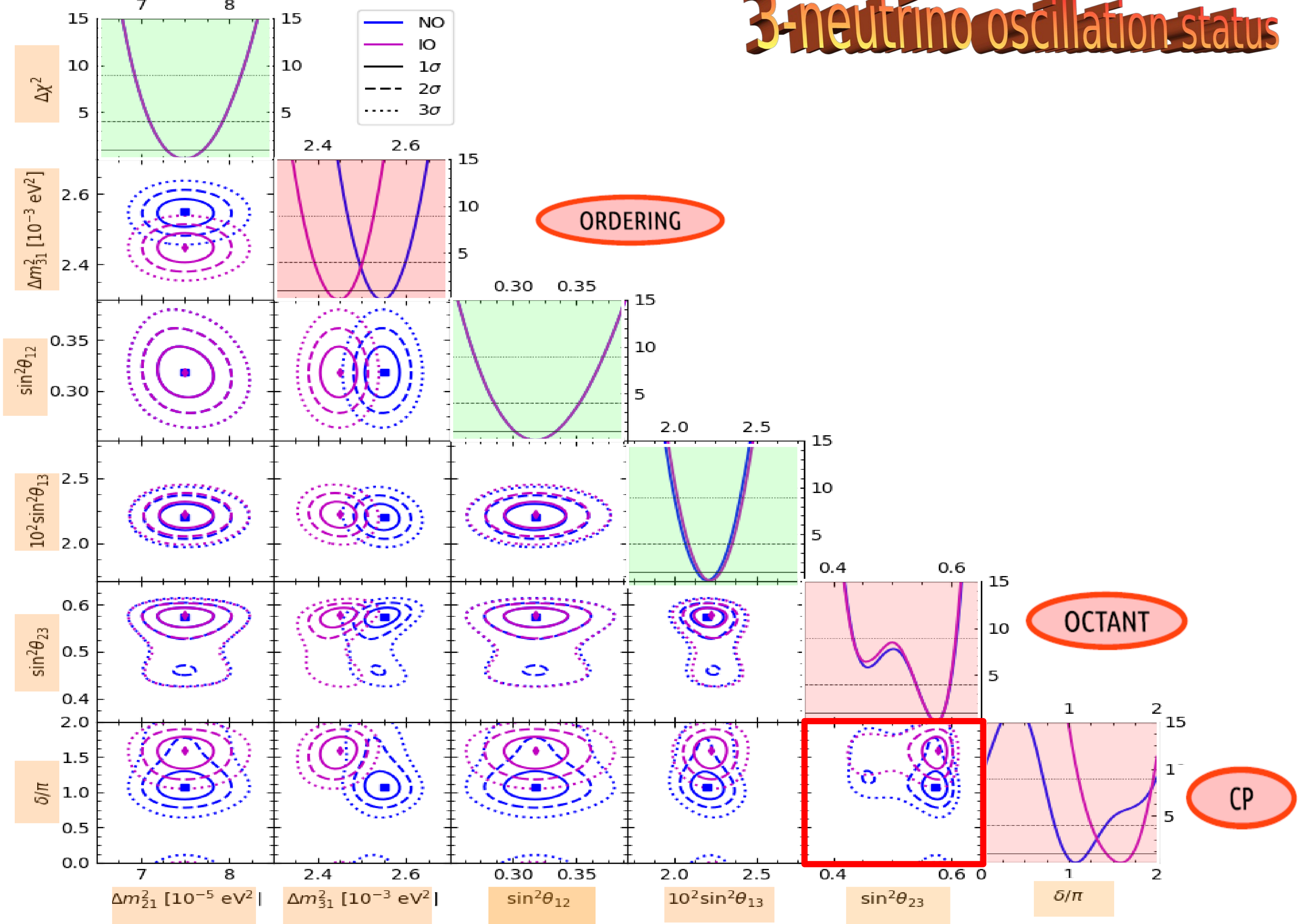
Universitat de València
CSIC Consejo Superior de Investigaciones Científicas
Gobierno de España
Ministerio de Ciencia e Innovación
Generalitat Valenciana
Conselleria de Educación, Universidades y Empleo

3-neutrino oscillation status

PF de Salas et al JHEP02(2021)071

https://globalfit.astroparticles.es/

https://zenodo.org/record 4593330#.YFoBVWNKjIo



$$\sin^2 2\theta_{13} = 0.0853^{+0.0024}_{-0.0024} \quad \text{(2.8\% precision)}$$

Agreement with NuFit and Bari

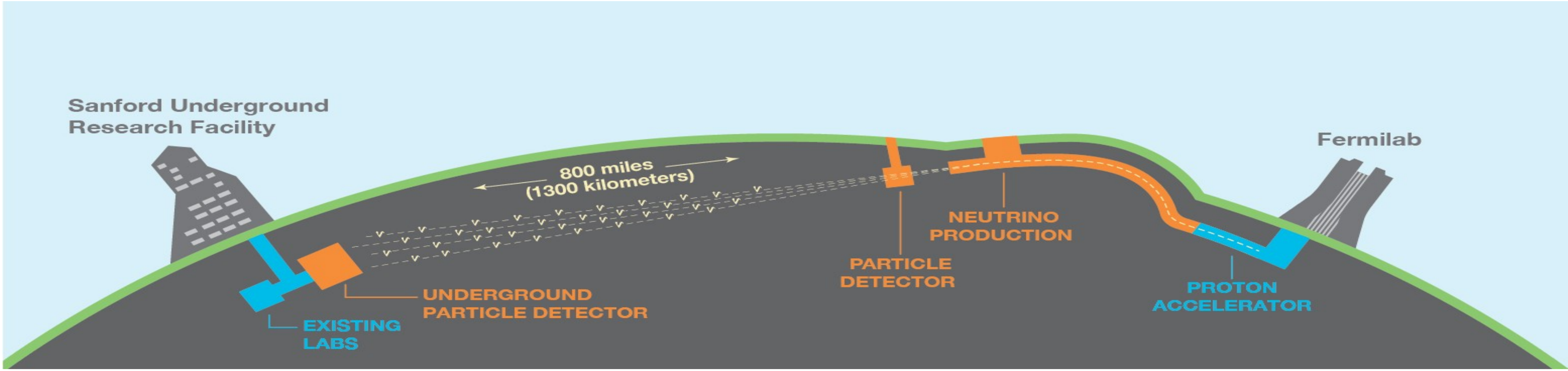
@jwvalle2

CPV

DUNE 2008.12769

Hyper-K

ESSnuSB



CPV

PhysRevLett117(2016)061804

New J.Phys. 19 (2017) 9, 093005

PhysRevD97 (2018) 095026

DUNE 2008.12769

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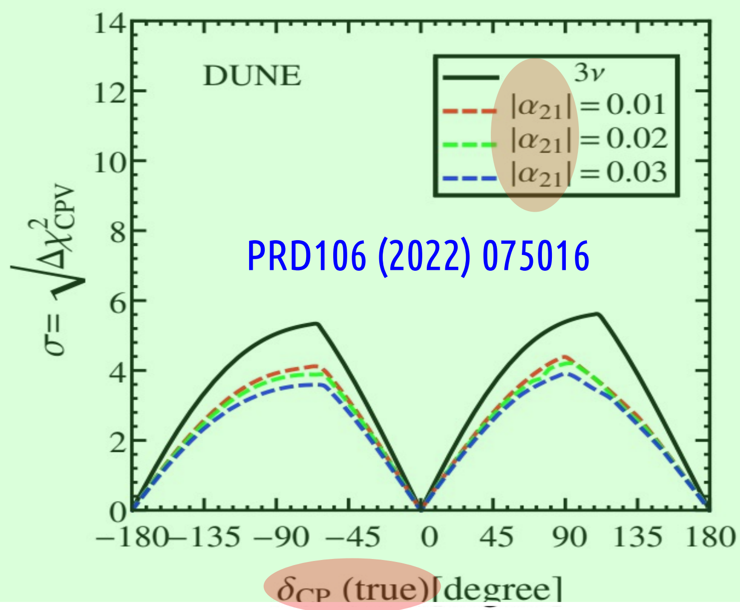
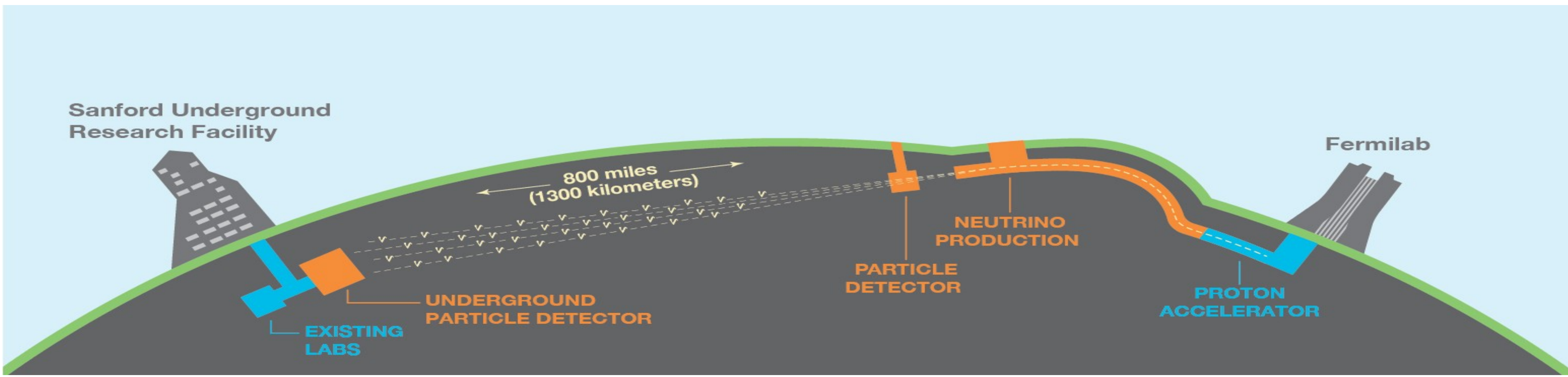


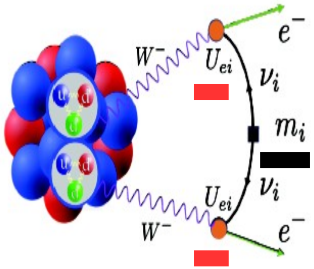
Expected CP discovery Sensitivity: standard 3-nu vs Unitarity violation



@jwvalle3

neutrinoless doublebeta decay

$$\left|\sum_j U_{ej}^2 m_j\right| = \left|c_{12}^2 c_{13}^2 m_1 + s_{12}^2 c_{13}^2 m_2 e^{2i\phi_{12}} + s_{13}^2 m_3 e^{2i\phi_{13}}\right|$$



Original

Schechter & JV PRD22 (1980) 2227

Rodejohann, JV Phys.Rev. D84 (2011) 073011

Versus PDG phase convention

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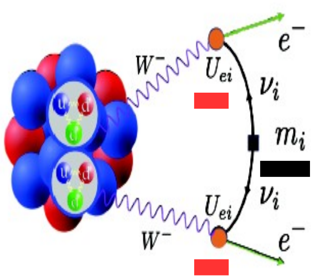

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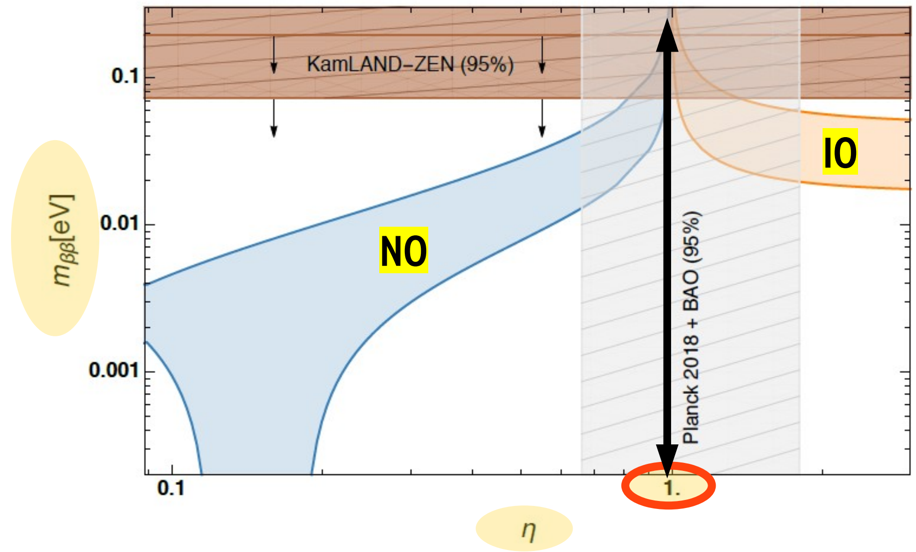

Nearly degenerate

Lattanzi et al JHEP 10 (2020) 213

degeneracy parameter

KamLAND-Zen 2203.02139

GERDA 2009.06079

neutrinoless doublebeta decay

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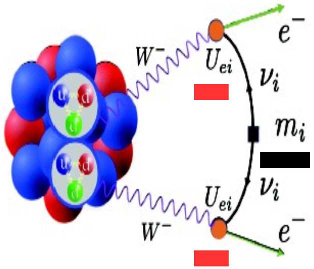

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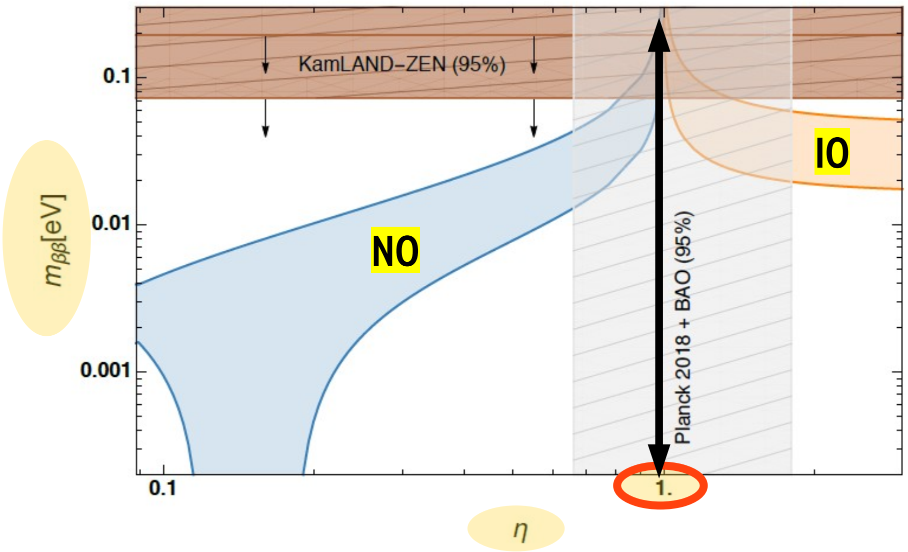


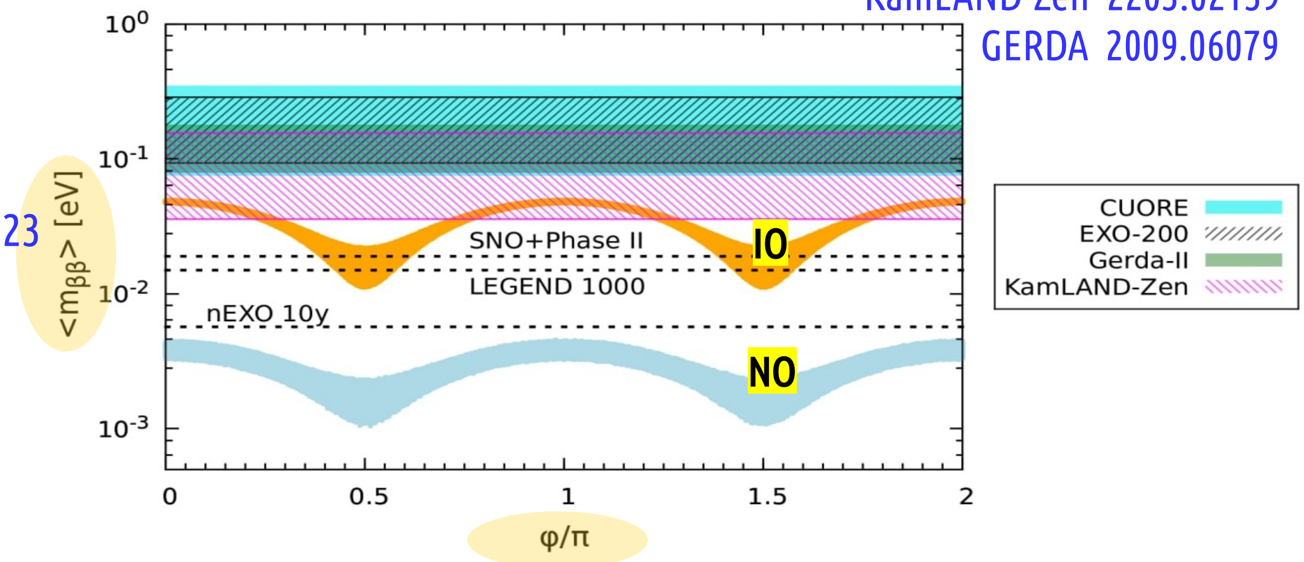
Nearly degenerate Lattanzi et al JHEP 10 (2020) 213

degeneracy parameter

KamLAND-Zen 2203.02139
GERDA 2009.06079

➢ **One-massless neutrino**

Reig et al Phys.Lett. B790 (2019)303
Barreiros, Felipe & Joaquim JHEP (2019) 223
Mandal et al PLB789 (2019) 132
Avila et al Eur.Phys.J.C 80 (2020) 10, 908



REVIEWS
C Adams et al 2212.11099
Agostini et al. Science 365 (2019) 1445

majorana phase

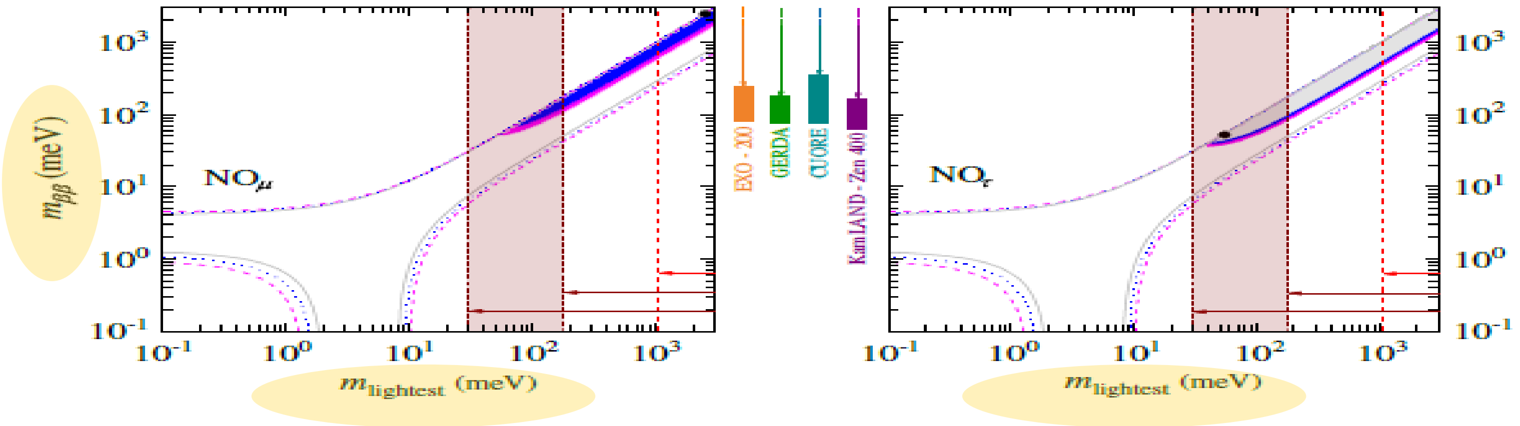
@jwvalle4

- **3-massive case**

Lower bounds from oscil. legacy + family symmetries

Dorame et al PhysRevD86(2012)056001
Dorame et al Nucl.Phys.B861 (2012) 259-270
King et al Phys.Lett. B724 (2013) 68-72 etc

From Barreiros et al JHEP04(2021)249



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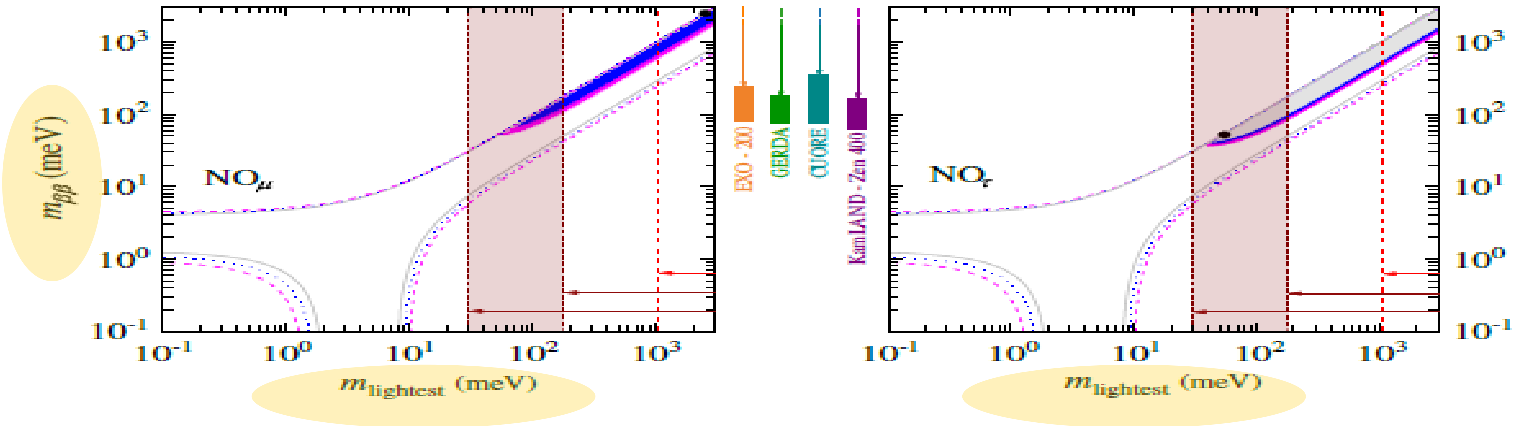
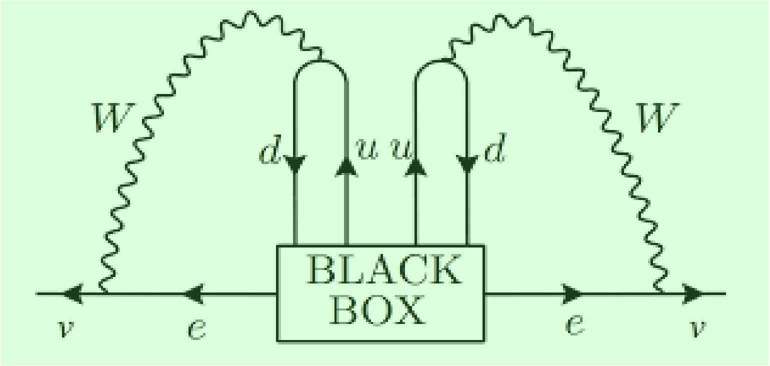


Significance

Schechter, Valle 1982

Duerr, Lindner, Merle JHEP06(2011)091

B.J.P. Jones 2108.09364 (TASI 2020)



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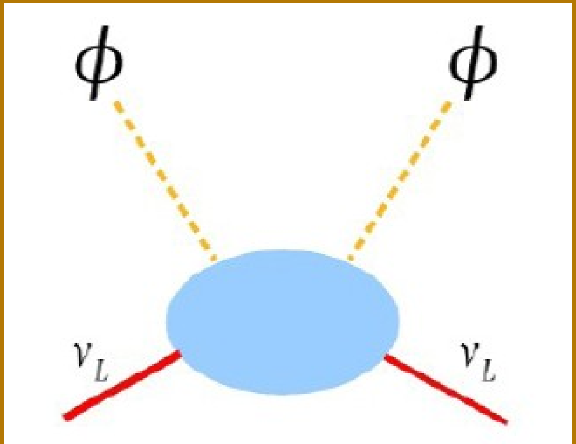
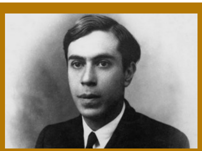
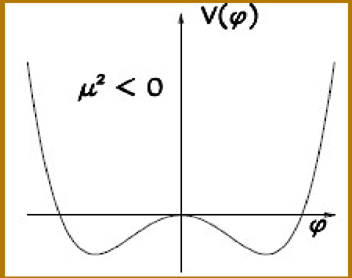
Origin of neutrino mass





Origin of neutrino mass

stability

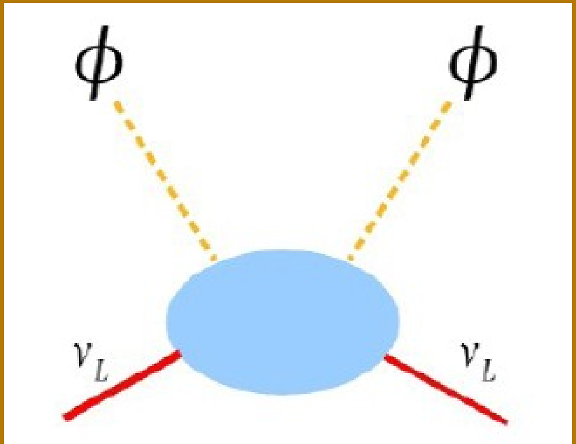


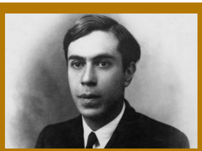
SEESAW dynamics

$$v_3 v_1 \sim {v_2}^2$$

Mandal et al PRD101 (2020) 115030

JHEP03(2021)212 & JHEP07(2021) 029





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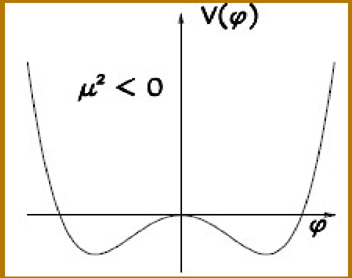

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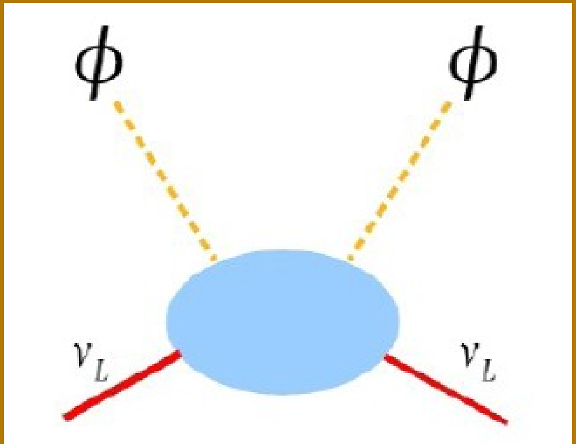
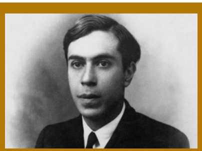
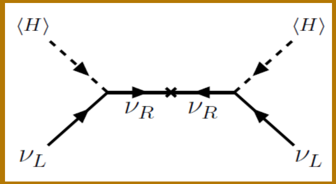
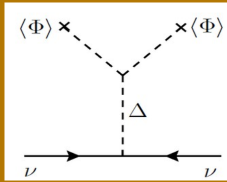






TYPE I

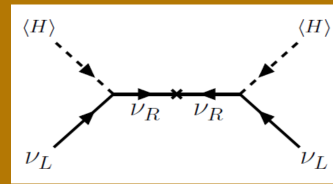
Minkowski 77
Gellman Ramond Slansky 80
Glashow, Yanagida 79
Mohapatra Senjanovic 80
Lazarides Shafi Weterrich 81
Schechter-Valle 80 & 82



TYPE II

Schechter-Valle 80 & 82
Miranda et al
PLB829 (2022) 137110
PRD105 (2022) 095020

Origin of neutrino mass



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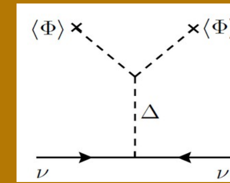

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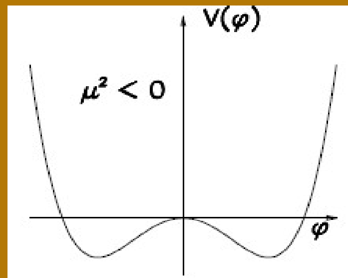

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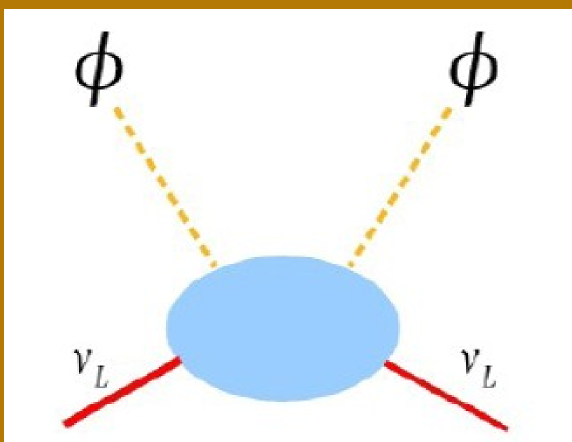
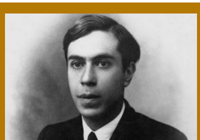
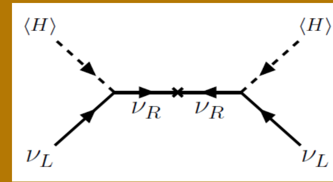




L-R seesaw # of Rs = # Ls (3,3)

SM seesaw any # of singlets (3,m)

Origin of neutrino mass



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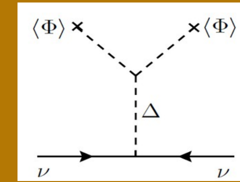

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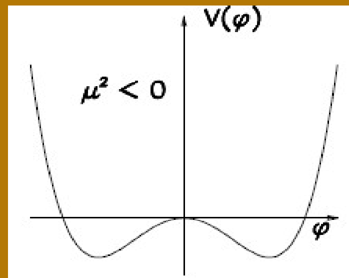

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Mandal et al PRD101 (2020) 115030
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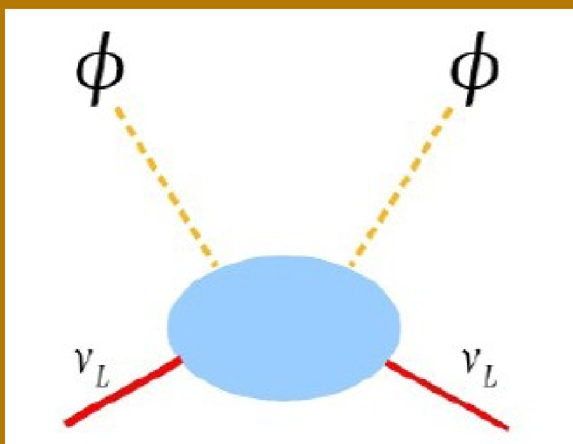
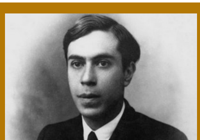


- **MISSING PARTNER**

(3,2) min viable type1 seesaw
(3,1) **scoto-seesaw** template

$m_{\beta\beta}$



Origin of neutrino mass

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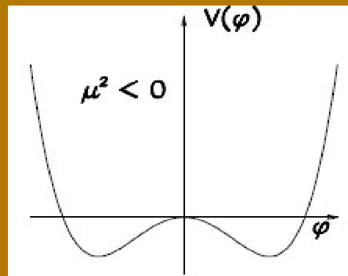

Mandal et al PRD101 (2020) 115030

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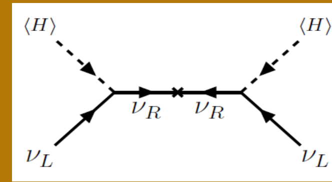

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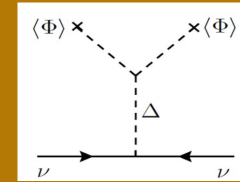

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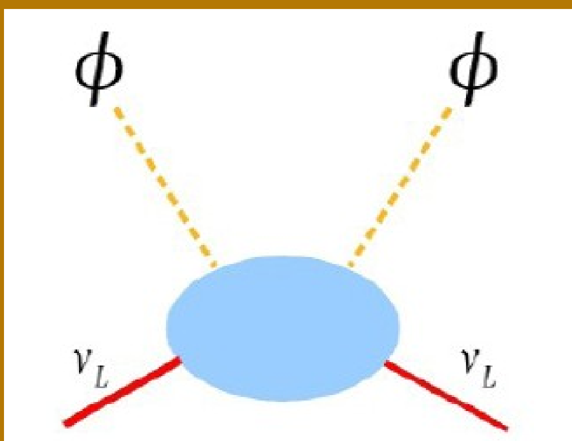

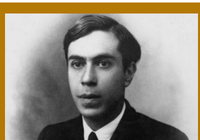

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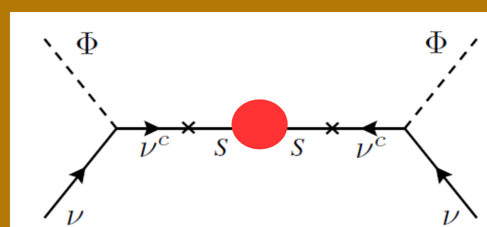
  (3,1) scoto-seesaw template

$m_{\beta\beta}$

- **LOW-SCALE Type1 SEESAW (3,6) ISS & LSS**



Mohapatra,Valle 86

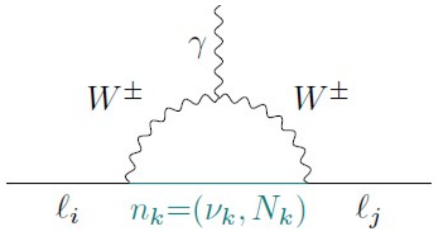
Akhmedov et al Phys.Rev.D53 (1996) 2752
PhysLettB368 (1996) 270

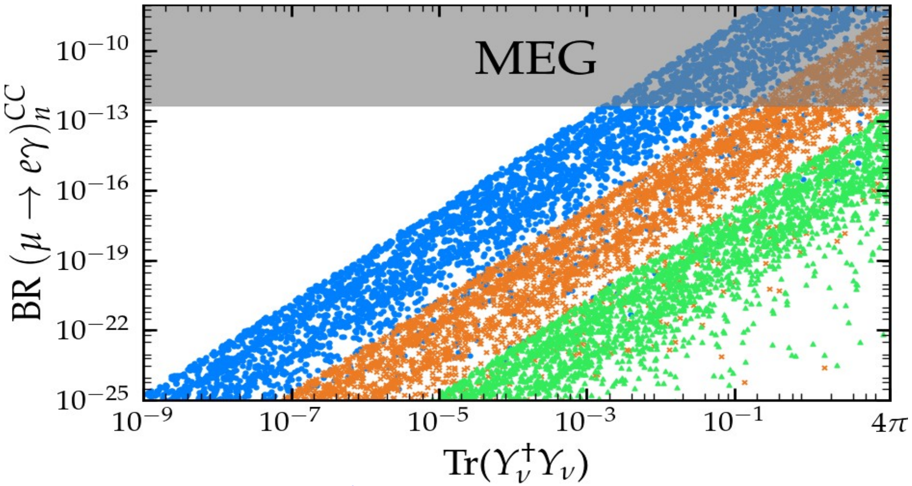
Malinsky et al PhysRevLett95(2005)161801

@jwvalle6

CC Lepton Flavor Violation In low-scale seesaw

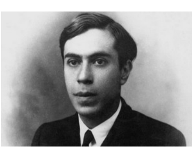
(3,6)





From Batra et al 2305.00994

● $M_N = 1\ TeV$ × $M_N = 10\ TeV$ ▲ $M_N = 100\ TeV$



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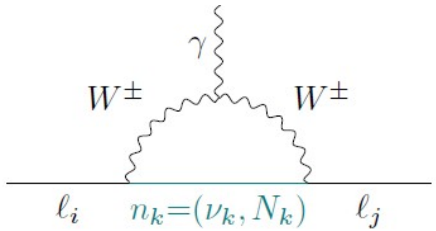
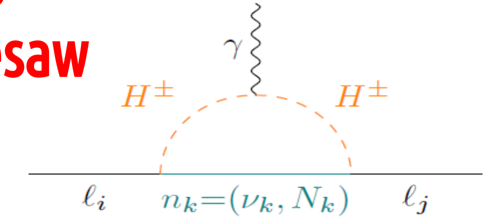
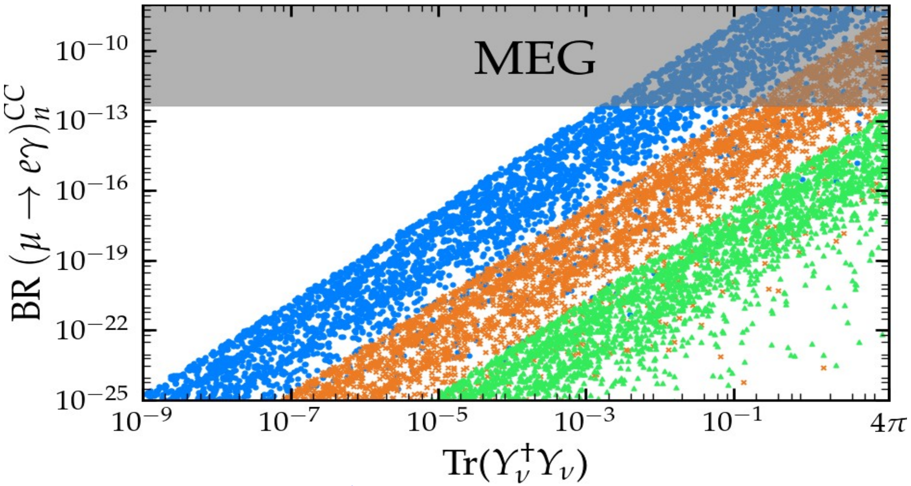
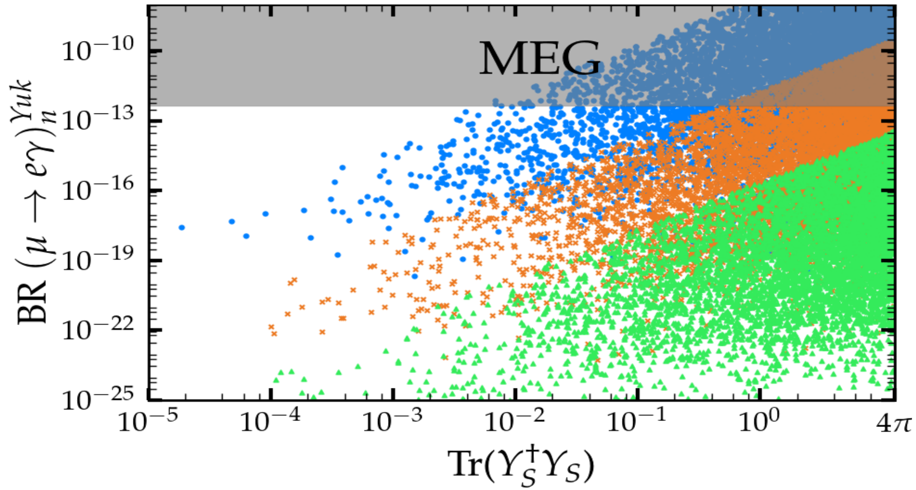


(3,6)

Leptophilic Higgs cLFV in linear seesaw





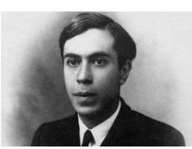


From Batra et al 2305.00994

● $M_N = 1\ TeV$ × $M_N = 10\ TeV$ ▲ $M_N = 100\ TeV$

cLFV persists in the massless neutrino limit

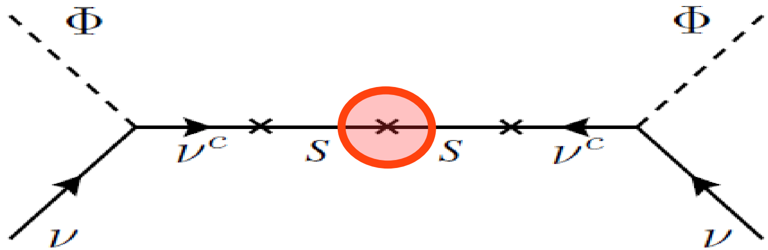
Bernabeu et al B187 (1987) 303-308



@jwvalle7

double protection in low scale seesaw

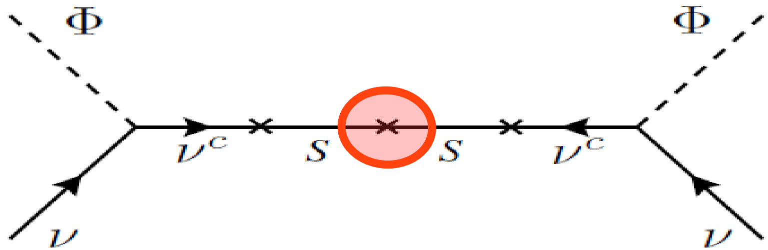
(3,6)



radiative

double protection in low scale seesaw

(3,6)



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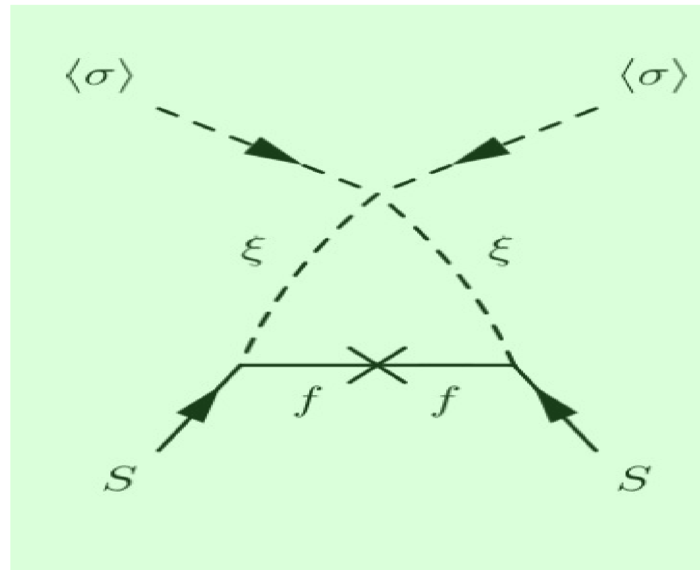
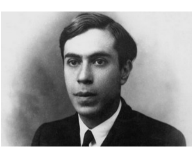


is dark matter the seed of neutrino mass?

Mandal et al Phys.Lett.B821 (2021) 136609

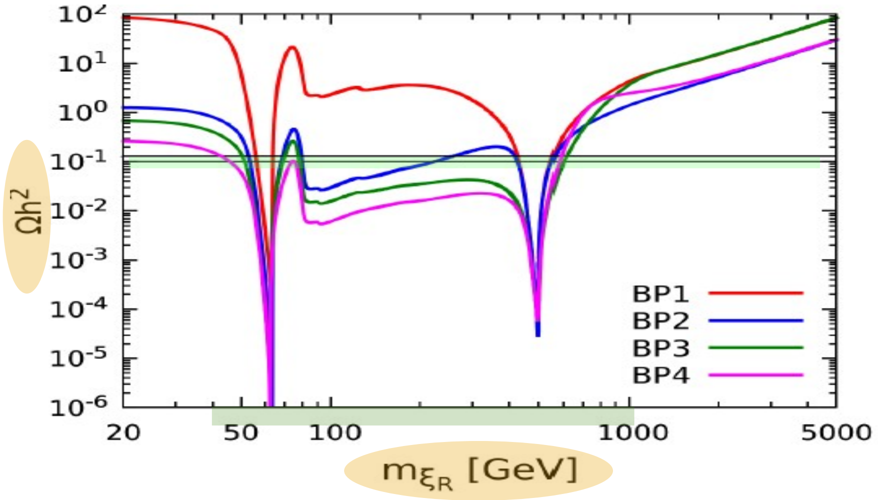


@jwvalle8

low-scale type-1

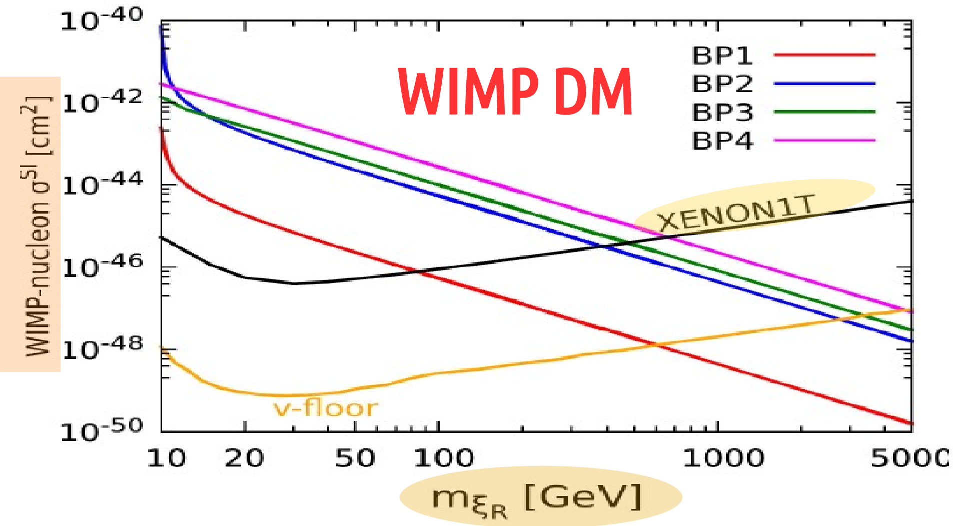
dark inverse seesaw (3,6)

LambdaCDM



Mandal et al
Phys.Lett.B821 (2021) 136609

Xenon1T PhysRevLett.121.111302
PandaX Lux-Zepellin



With large cLFV effects

@jwvalle9

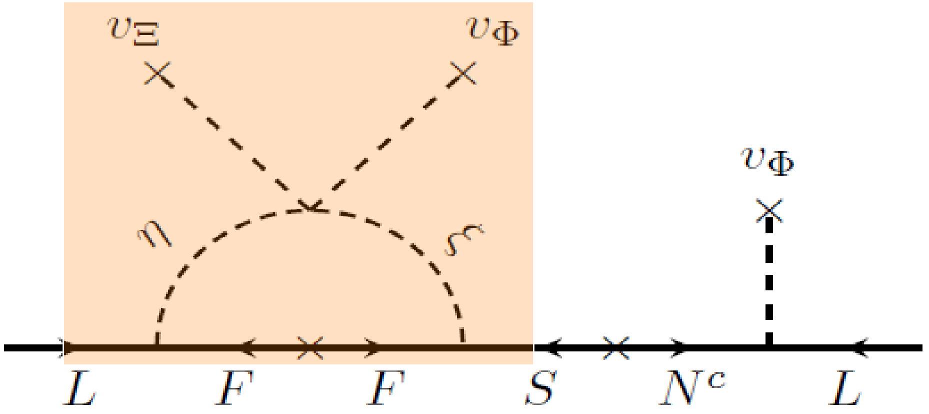
low-scale type-1 dark linear seesaw (3,6)

$$M_\nu = \begin{pmatrix} 0_{3\times3} & m_D & \varepsilon \\ m_D^T & 0_{3\times3} & M \\ \varepsilon^T & M & 0_{3\times3} \end{pmatrix}$$

Carcamo, Vishnudath, J.V. JHEP 09 (2023) 046

$$m_{\text{light}} = -\left[m_D M^{-1}\varepsilon^T + \varepsilon M^{-1} m_D^T\right]$$

(Also Batra, Camara, Joaquim, 2305.01687)



low-scale type-1 **dark linear seesaw** (3,6)

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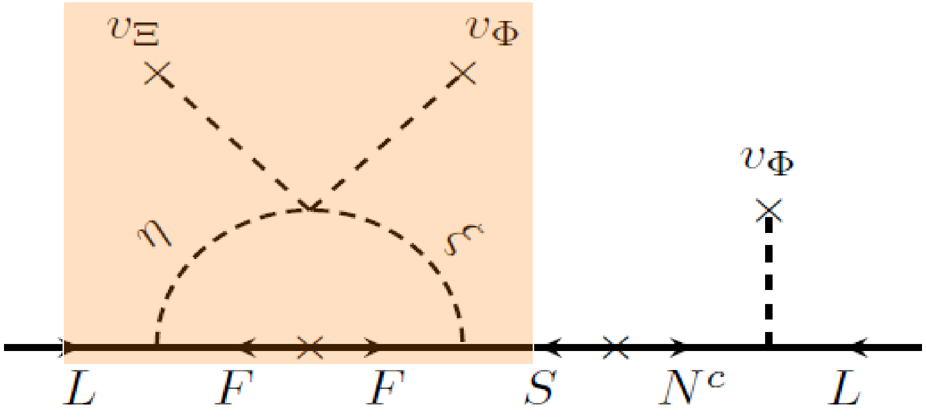

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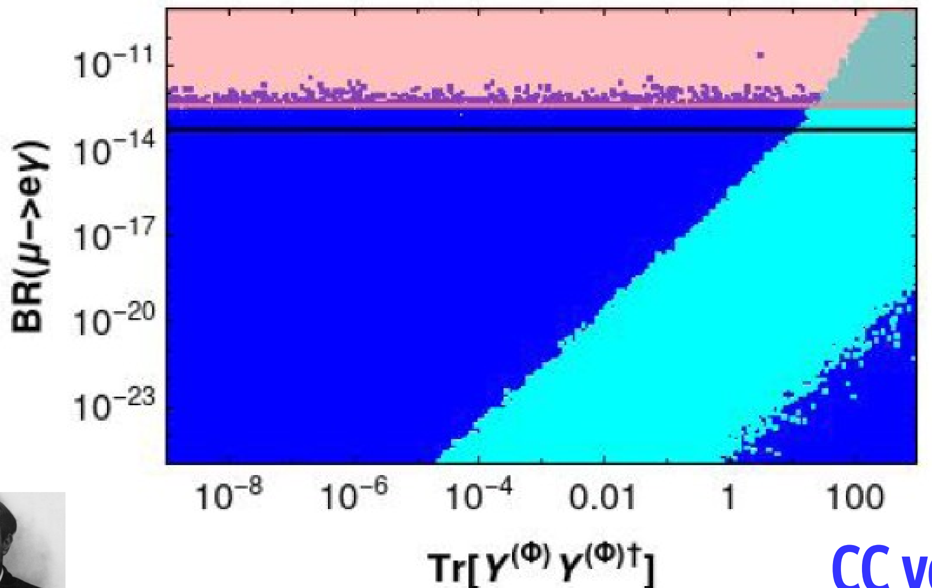
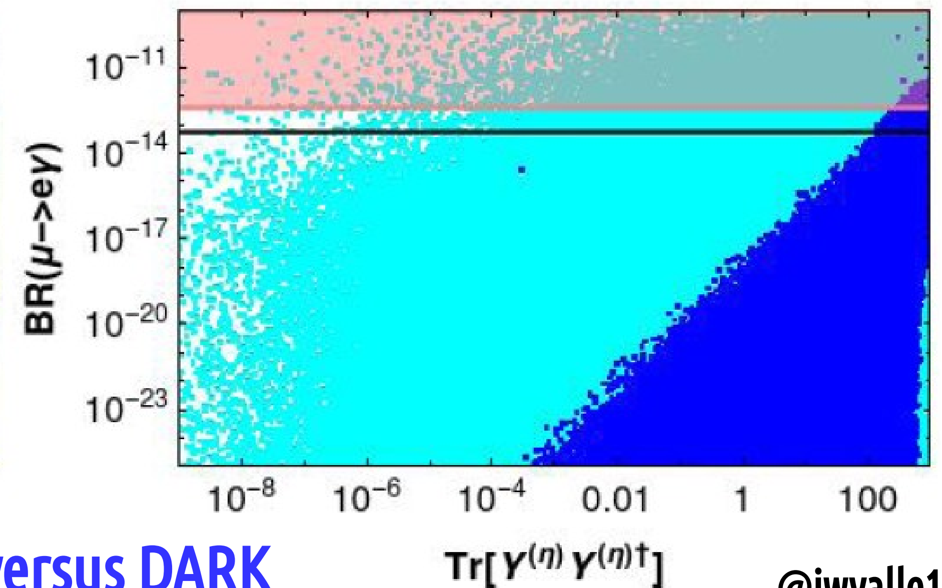




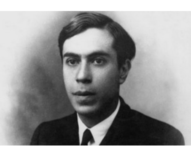
CC versus DARK

@jwvalle10

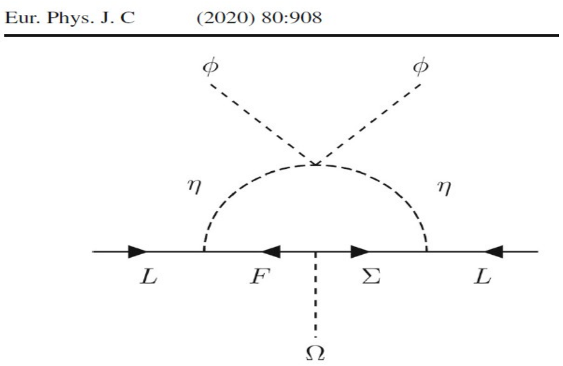
LOOP

scoto

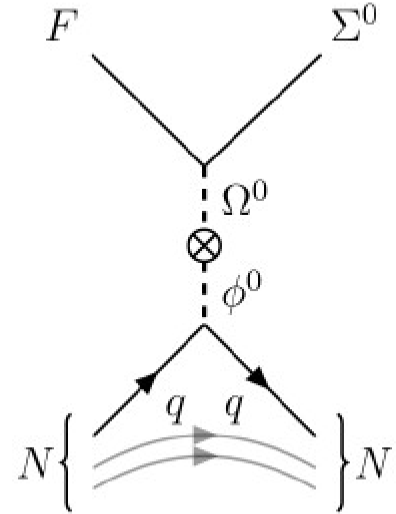
Ma hep-ph/0601225
Tao hep-ph/9603309
Dark-mediated nu-mass loop



generalized scoto DM

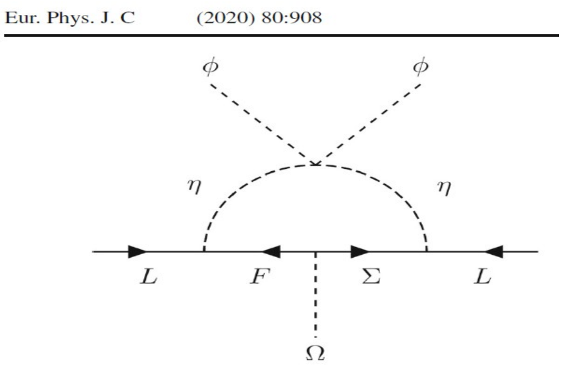


M. Hirsch et al JHEP 10 (2013) 149
A. Merle et al JHEP 07 (2016) 013
Rocha-Moran, Vicente JHEP 07 (2016) 078
Restrepo, Rivera JHEP 04 (2020) 134
Avila et al Eur.Phys.J.C 80 (2020) 10, 908



Karan, Sadhukhan, Valle 2308.09135

generalized scoto DM



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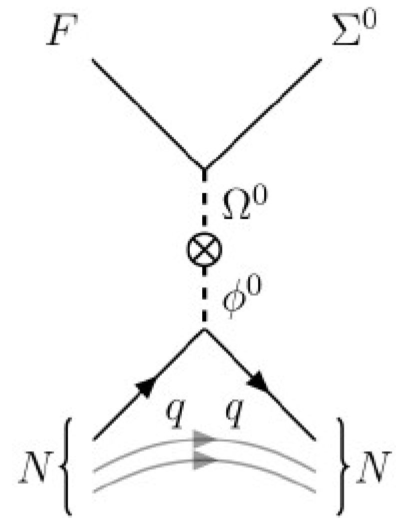

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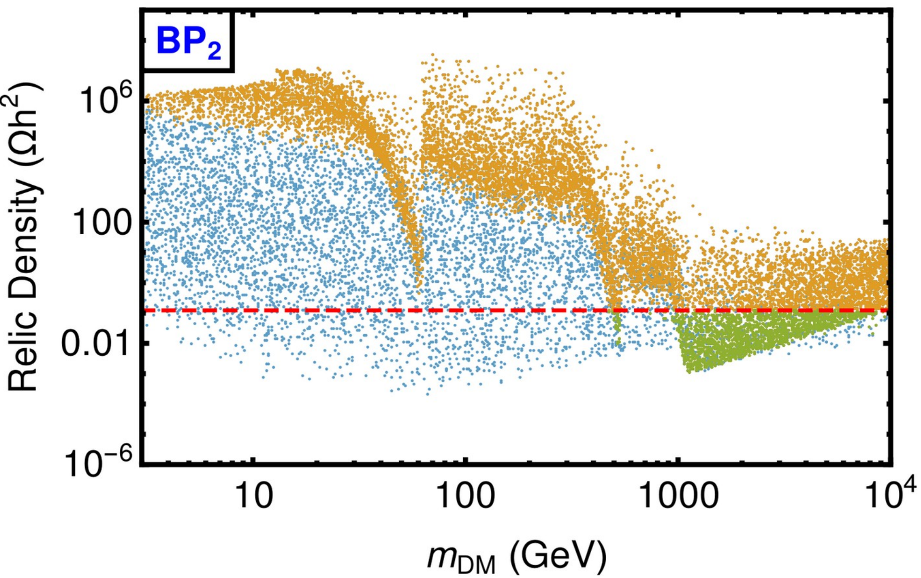
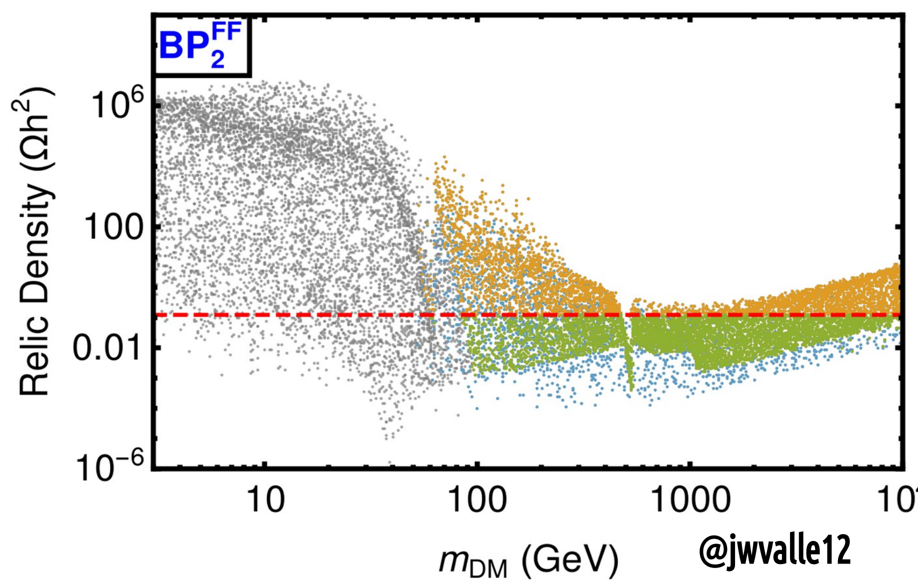
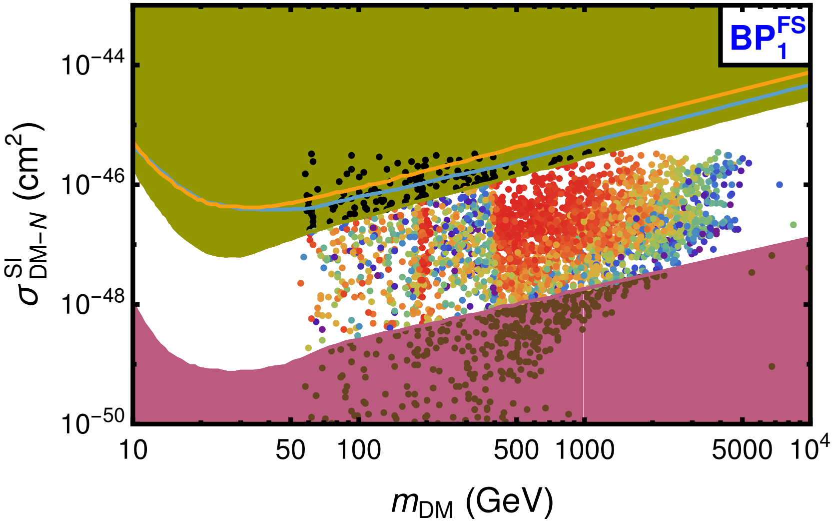
No DM coannihilation:



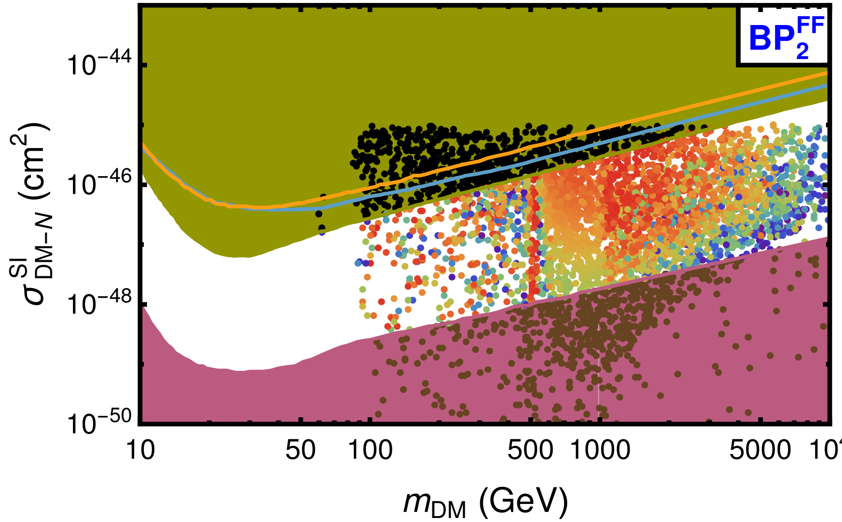
With DM coannihilations



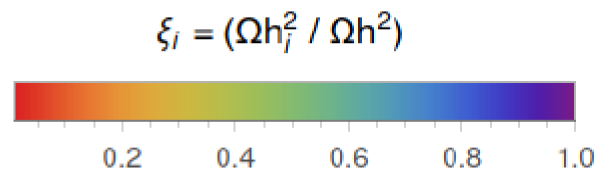
@jwvalle12



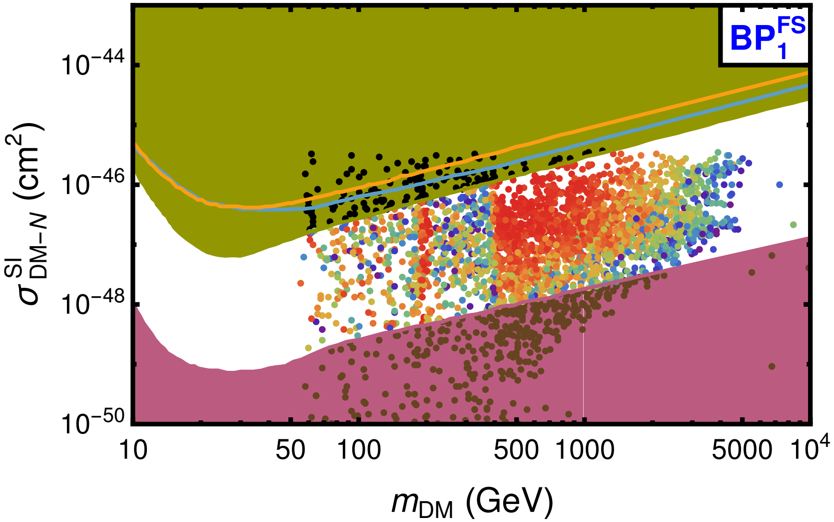
Higher v_Ω (4 GeV): Fermion-Scalar Coannihilation

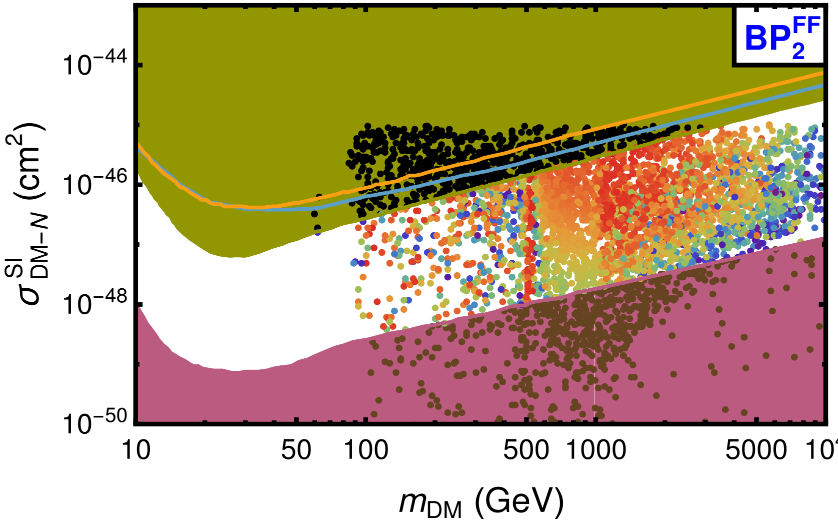


Lower v_Ω (1.5 GeV): Fermion-Fermion Coannihilation



Karan, Sadhukhan, Valle 2308.09135

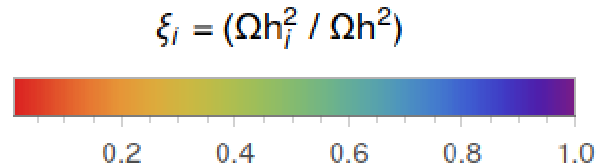




Higher v_Ω (4 GeV): Fermion-Scalar Coannihilation

Lower v_Ω (1.5 GeV): Fermion-Fermion Coannihilation

LFV Process	Current Bound	Future Sensitivity
$\mathcal{B}(\mu \to e\gamma)$	4.2×10^{-13} [44]	6.0×10^{-14} [45]
$\mathcal{B}(\mu \to 3e)$	1.0×10^{-12} [46]	$\sim 10^{-16}$ [47, 48]
$\mathcal{C}(\mu, Au \to e, Au)$	7.0×10^{-13} [49]	–
$\mathcal{C}(\mu, Ti \to e, Ti)$	4.3×10^{-12} [49]	$\sim 10^{-18}$ [50]
$\mathcal{C}(\mu, Pb \to e, Pb)$	4.6×10^{-11} [49]	–
$\mathcal{C}(\mu, Al \to e, Al)$	–	$\sim 10^{-17}$ [51, 52]



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DBD lower bound

probing scoto DM at colliders

LEP

indirect detection

@jwvalle13

scoto seesaw

LOOP

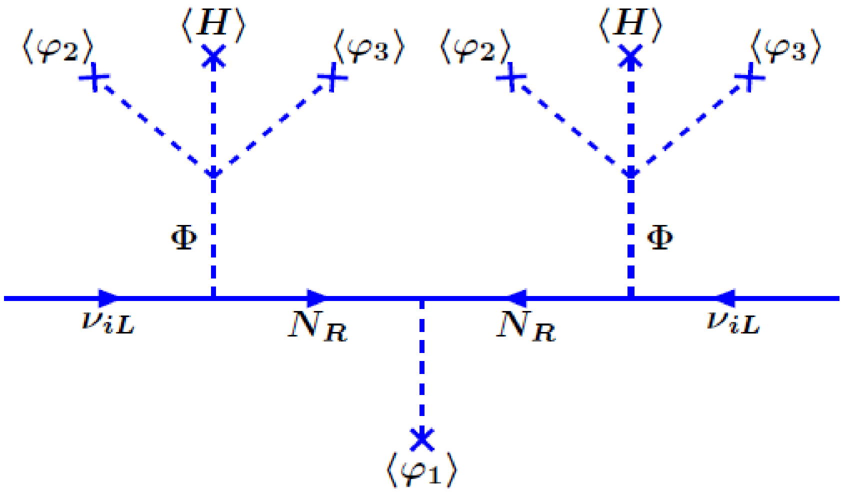
TREE

$$\frac{\Delta m^2_{\rm SOL}}{\Delta m^2_{\rm ATM}} = 0.0302^{+0.0012}_{-0.0010}$$

Simplest version in Phys.Lett.B 789 (2019) 132-136 and Phys.Lett.B 819 (2021) 136458

Atm neutrinoseesaw scale

Leite, Sadhukhan, Valle 2307.04840



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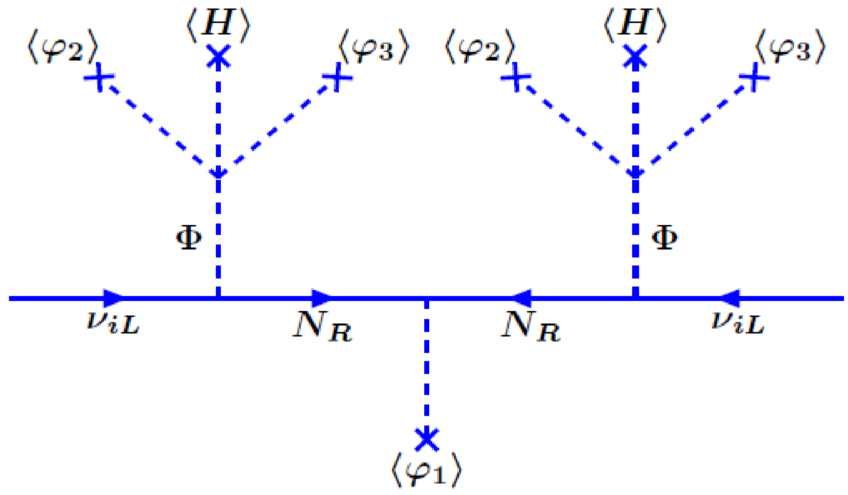
Leite, Sadhukhan, Valle 2307.04840



scoto seesaw

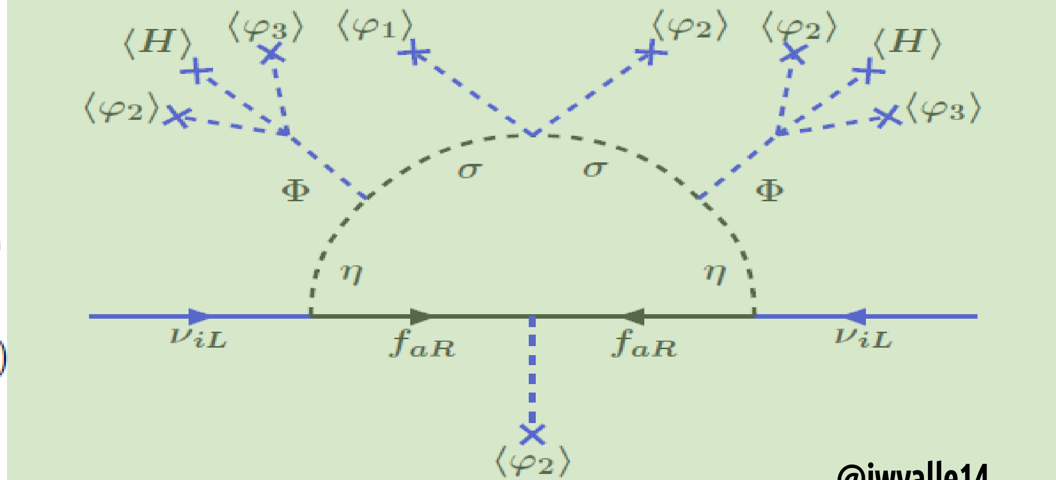
LOOP

TREE

$$\frac{\Delta m^2_{\rm SOL}}{\Delta m^2_{\rm ATM}} = 0.0302^{+0.0012}_{-0.0010}$$

dynamical solar scoto scale

$B-L$ charges $(f_{1R}, f_{2R}, N_R) \sim (-4,-4,5)$



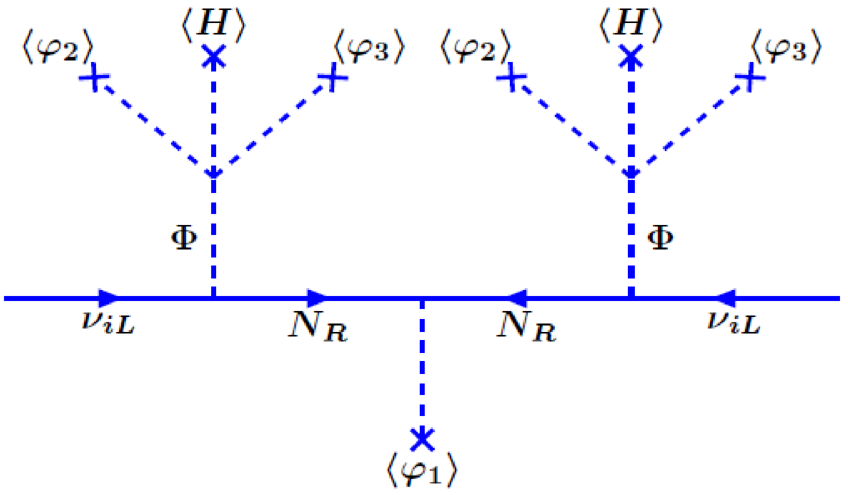
Drell-Yan N_R pair production

@jwvalle14

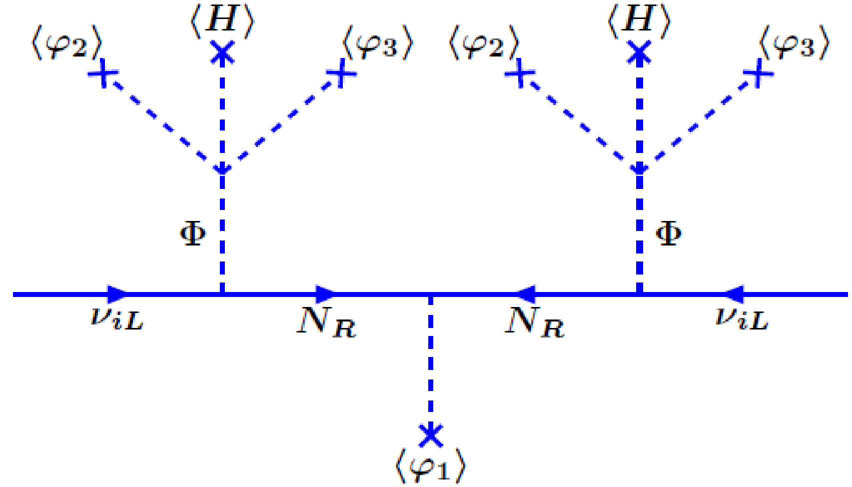
lowering the seesaw scale (3,3)

Leite, Sadhukhan, Valle 2307.04840

Tiny induced leptophilic higgs vev



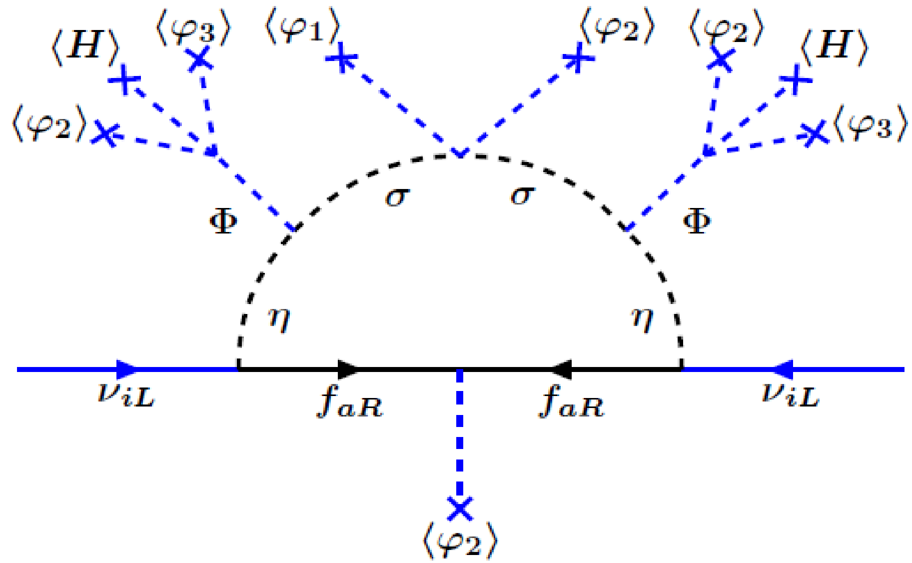
lowering the seesaw scale (3,3)



Leite, Sadhukhan, Valle 2307.04840

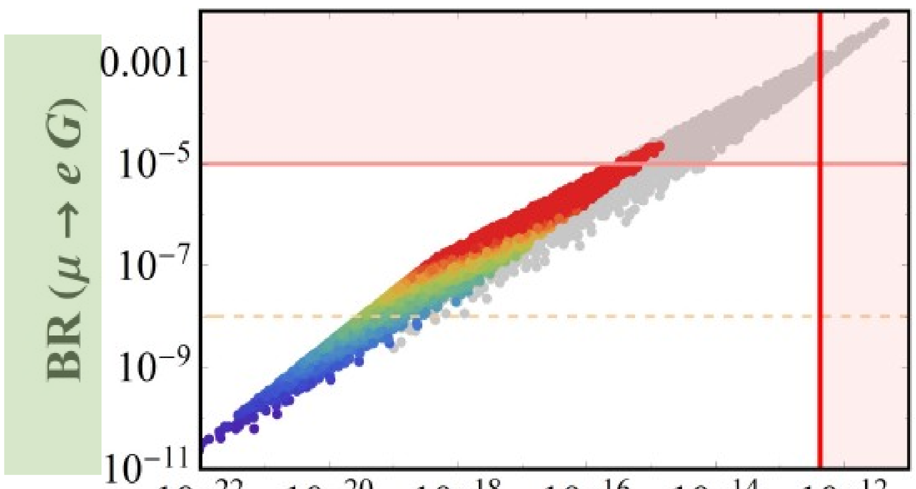
Tiny induced leptophilic higgs vev

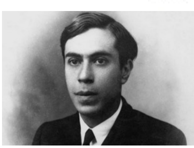
scoto seesaw



$B-L$ charges $(f_{1R}, f_{2R}, N_R) \sim (-4,-4,5)$

CLFV





@jwvalle15

HIGGS DISCOVERY NOT THE LAST BRICK TO THE SM

Oscillation discovery brought in

precision oscillation program,
CP, octant, ordering, NSI,unitarity,
0nuDBD, **CEvNS** ...

HIGGS DISCOVERY NOT THE LAST BRICK TO THE SM

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DM may seed or mediate Neutrino mass generation

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DM may seed or mediate Neutrino mass generation

Besides direct and indirect detection Can have cLFV and Collider imprints

@jwvalle16