Westfälische Wilhelms-Universität Münster

Neutrino masses and dark matter

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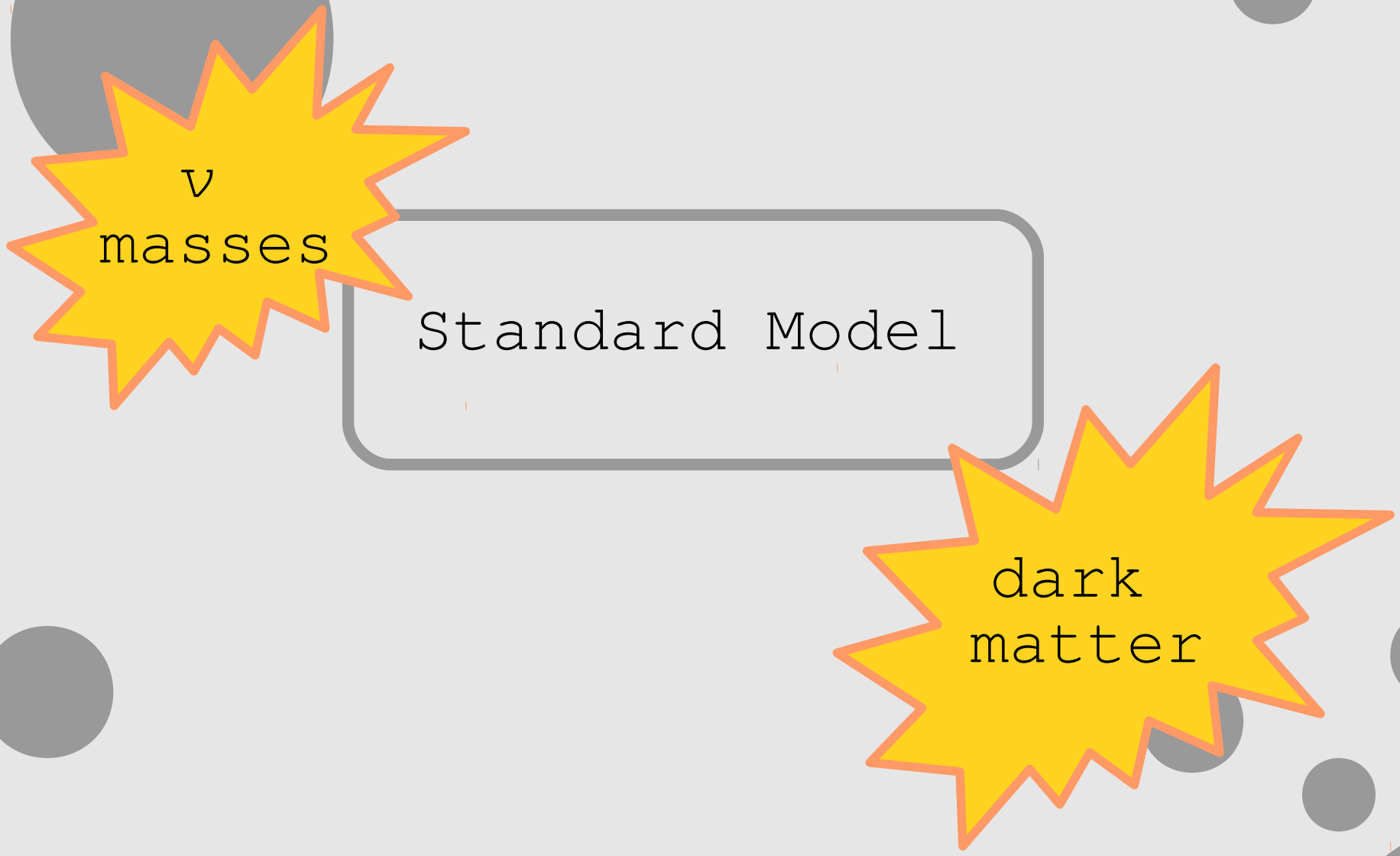
Warsaw Workshop on Non-Standard Dark Matter 2nd – 5th June 2016

Standard Model


ν
masses
Standard Model
dark
matter

Neutrino mass evidence

Observation of neutrino oscillation implies $m_\nu \neq 0$

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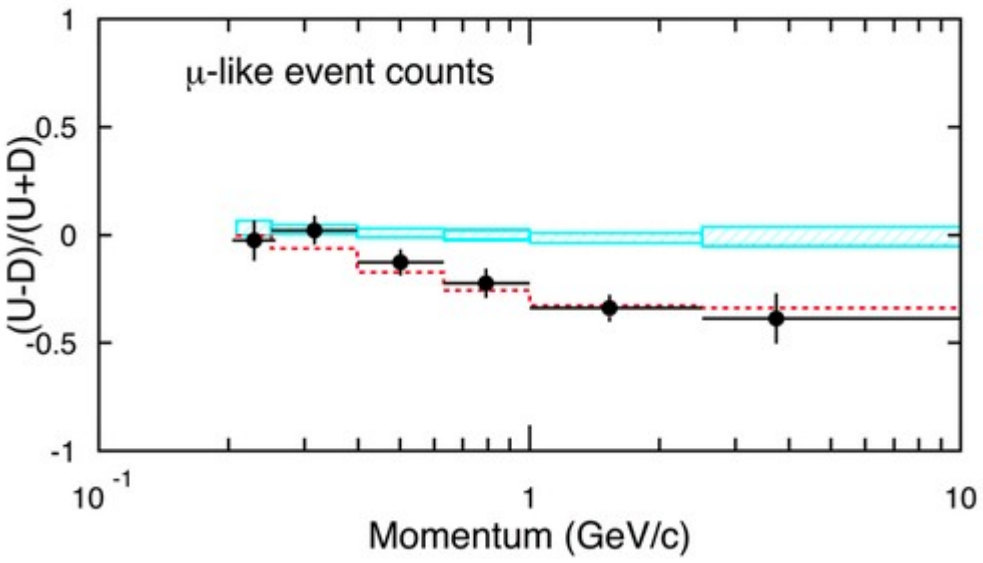

Neutrino conversion [4]
@ SuperKamiokande

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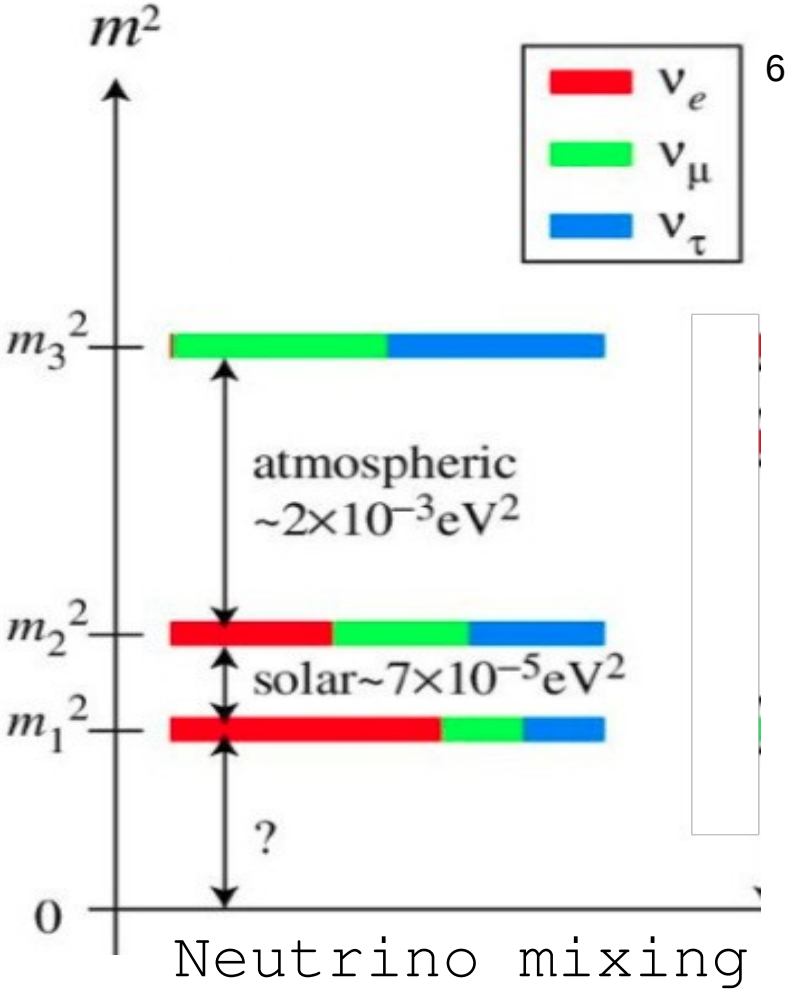

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T12A - Neutrino masses and dark matter

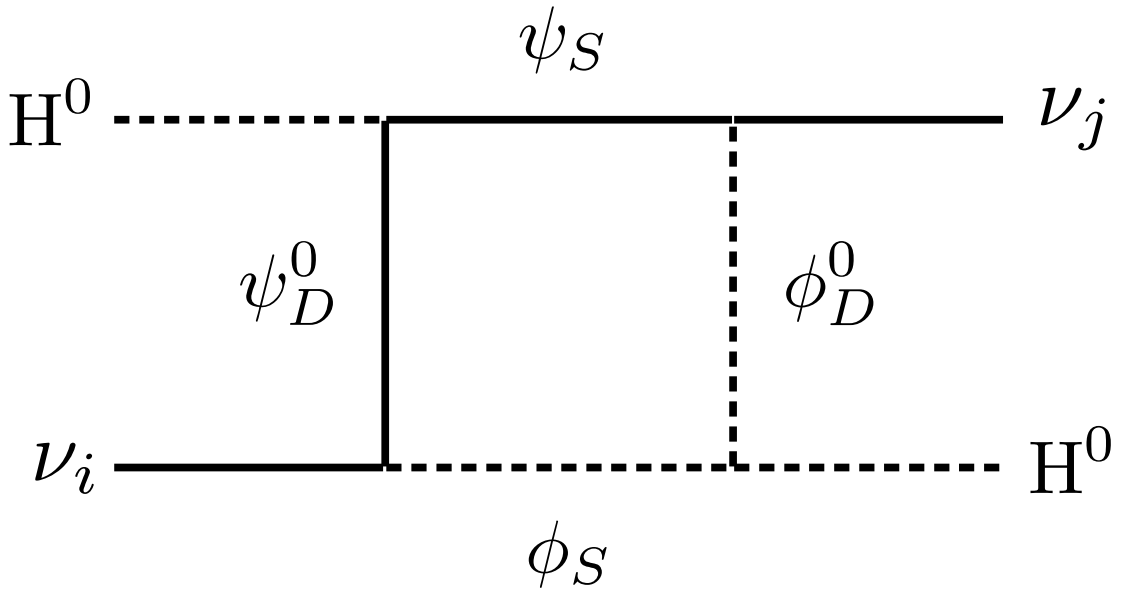
D.Restrepo, O.Zapata, C.Yaguna - JHEP11(2013)

Additional particles

Fermions:
singlet ψ_S
doublet ψ_D

Scalars:
singlet ϕ_S
doublet ϕ_D

Additional Z_2 symmetry



- Majorana neutrino masses
- Neutrino mixing

Scalar singlet doublet dark matter

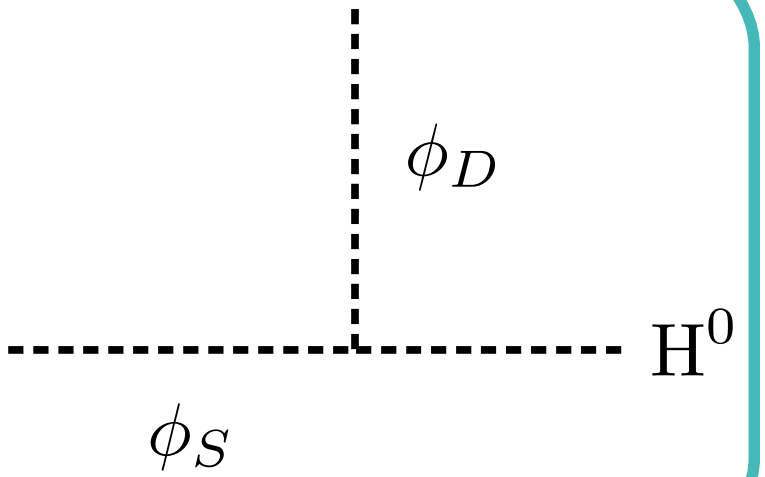
C.Cheung, D.Sanford - JCAP 02(2014)

Scalar doublet

$$\phi_D = \begin{pmatrix} \phi^- \\ \phi_{\mathrm{D,R}} + i\phi_{\mathrm{D,I}} \end{pmatrix}$$

Mixing term

$$\mathrm{A}(\phi_{\mathrm{S}}\mathrm{H}\bar{\phi}_{\mathrm{D}} + \mathrm{h.c.})$$



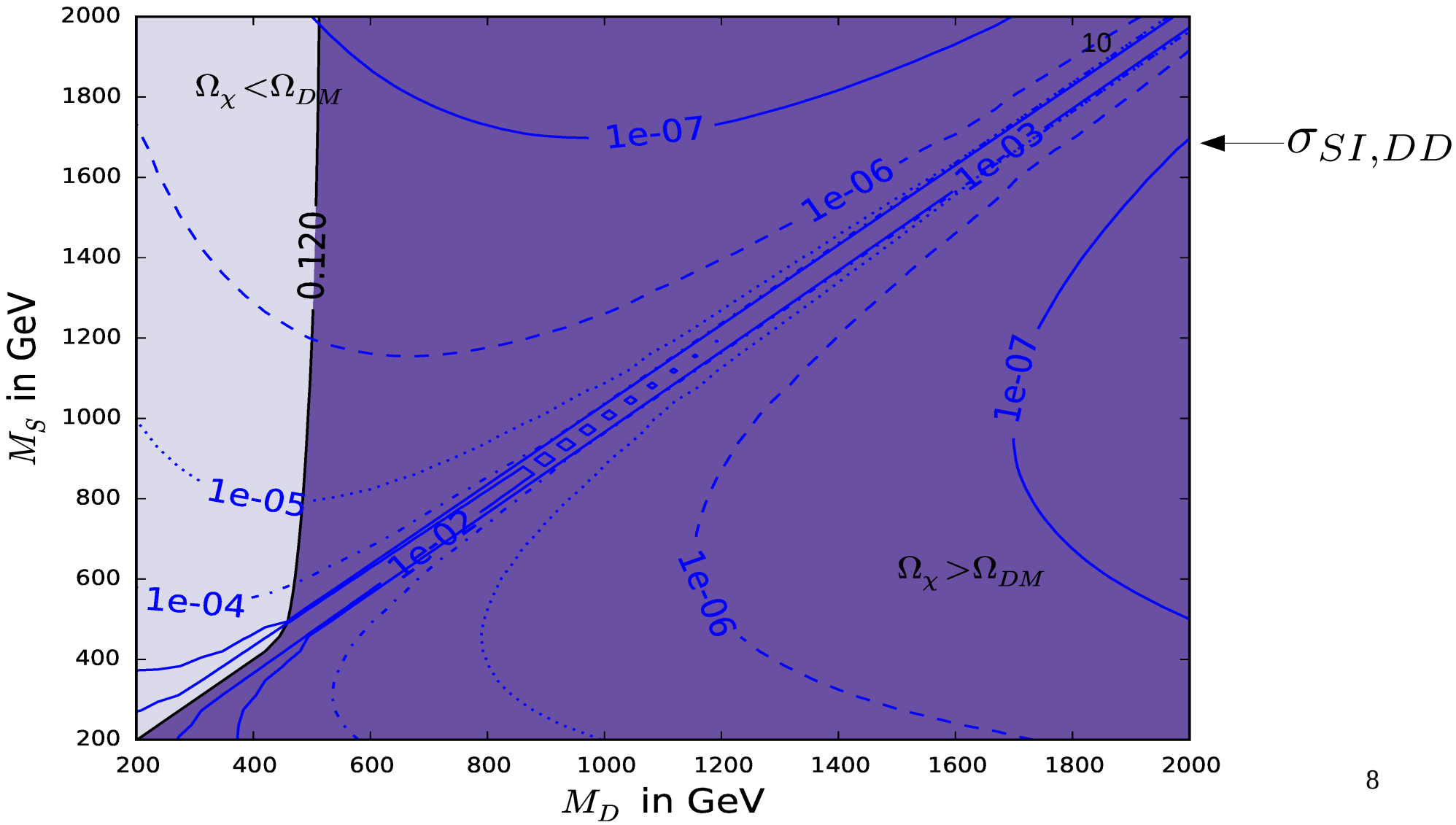
EWSB

Mixing between Singlet ϕ_S and neutral doublet components $\phi_{\mathrm{D,R}}$ $\phi_{\mathrm{D,I}}$

Mass basis X

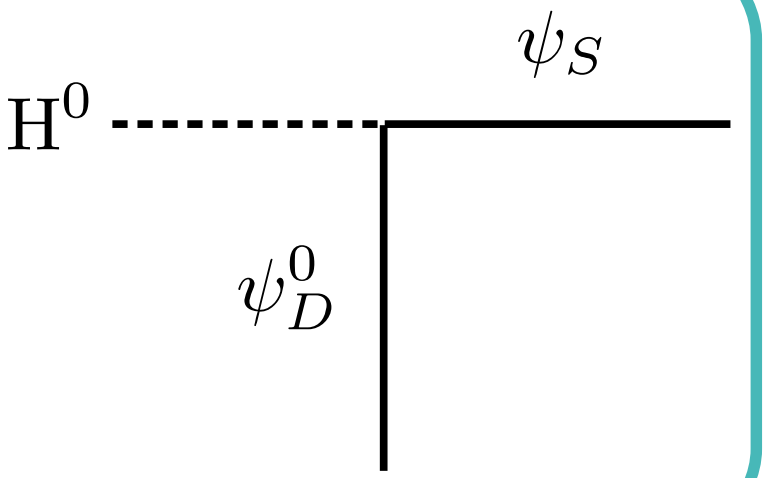
Singlet doublet scalar dark matter

Lightest mass eigenstate X_{i} : dark matter



Fermion singlet doublet dark matter

C.Cheung, D.Sanford - JCAP 02(2014)



EWSB

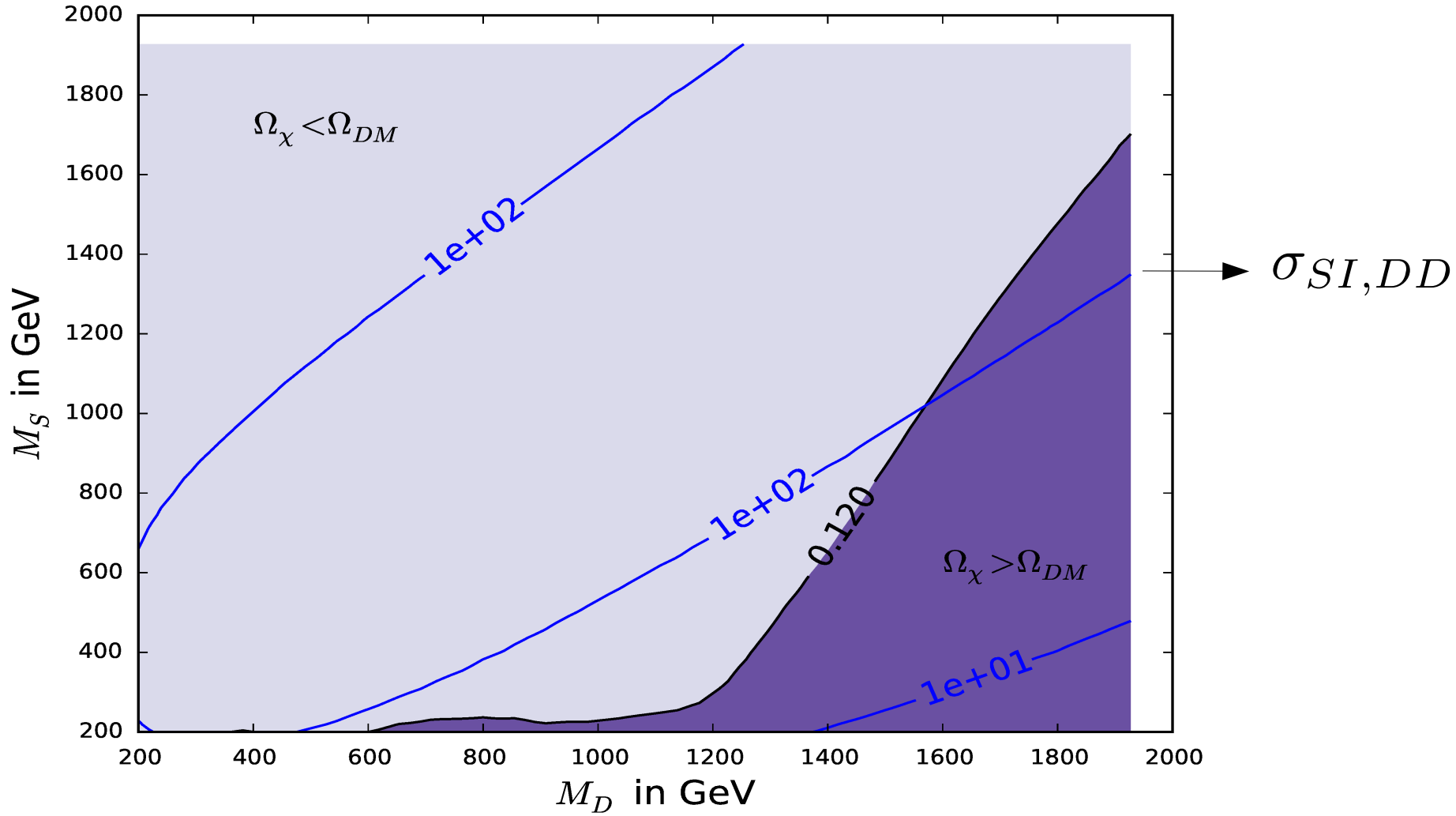
Mixing between **Majorana** singlet ψ_S and neutral left- and right handed **Dirac** doublet components $\psi^0_{\mathrm{D,L}}$ and $\psi^0_{\mathrm{D,R}}$

Fermion doublet

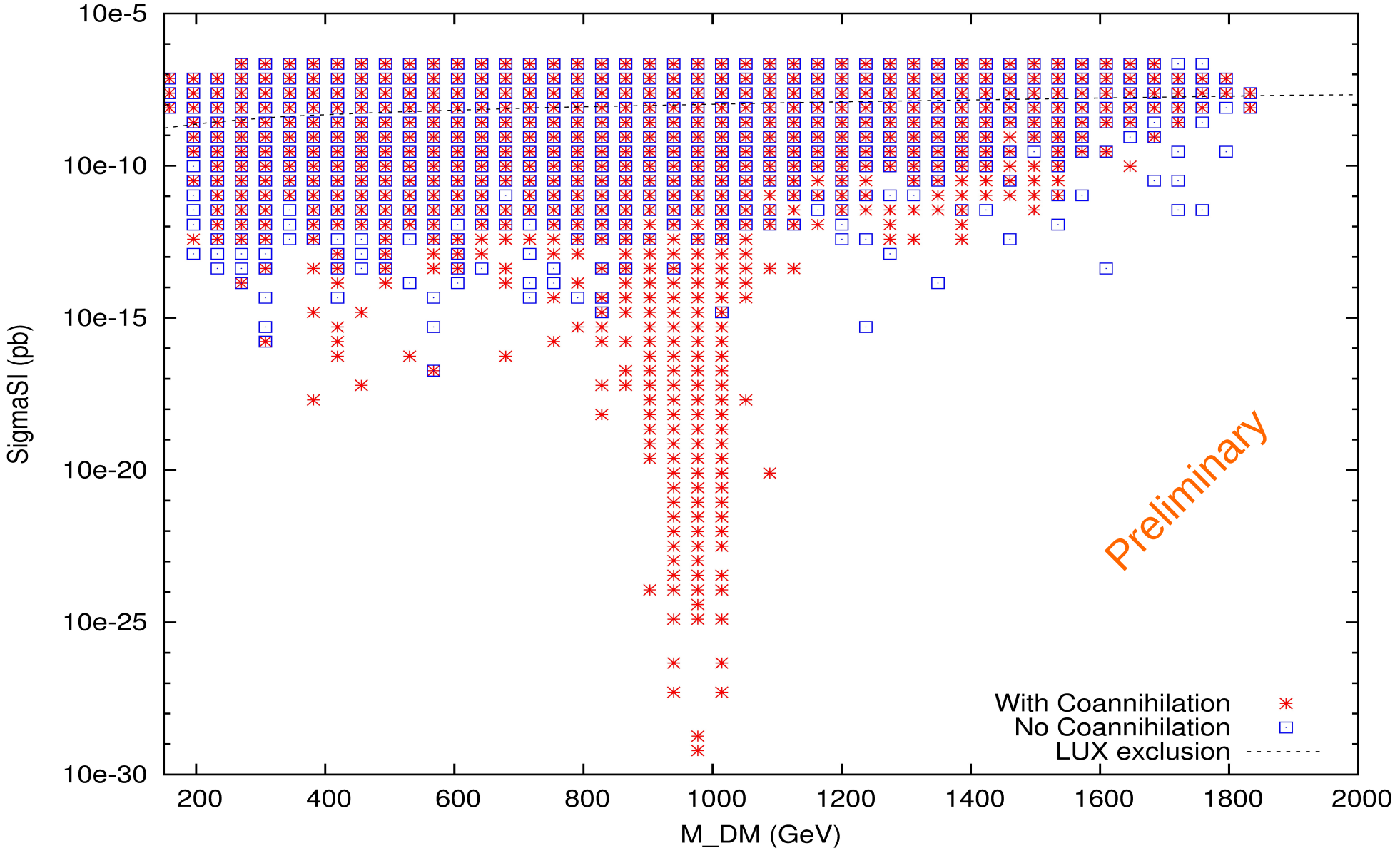
$$\psi_D = \begin{pmatrix} \psi^-_{\mathrm{D}} \\ \psi^0_{\mathrm{D}} \end{pmatrix}$$

Three **Majorana** mass eigenstates χ_{i}

Singlet doublet fermion dark matter



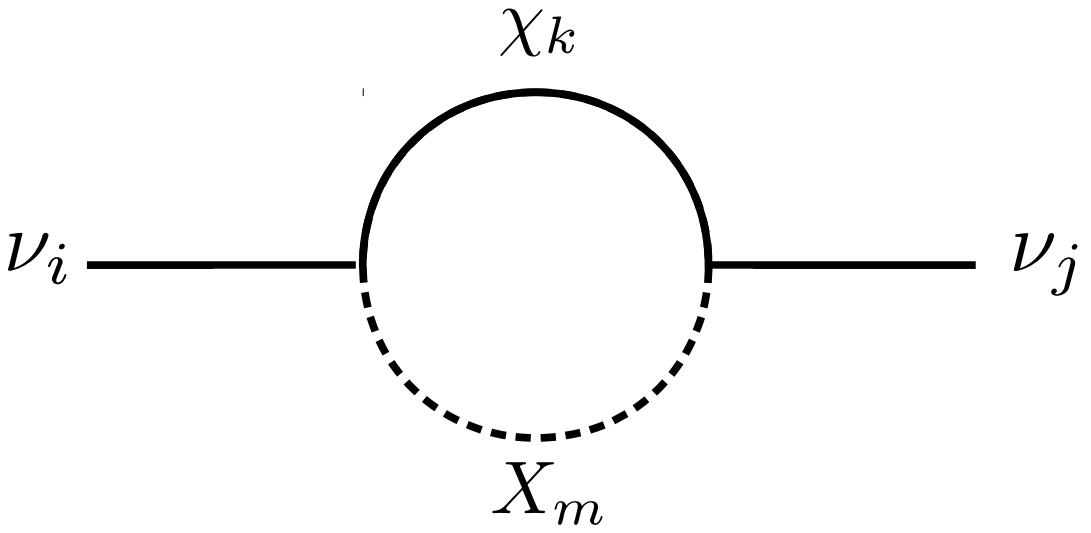
Singlet doublet fermion dark matter



Neutrino masses within T12A

After EWSB:

$$\mathcal{L}_{\rm lep} = G_{ijk}\chi_i\nu_j X_k$$



- Fermion χ_k
- Scalar X_m
- Loop diagram: expression for neutrino mass matrix element m_{ij}
- neutrino mixing

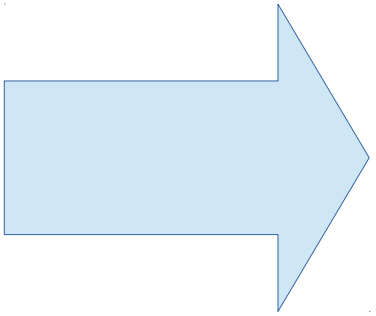
Neutrino masses within T12A

Mass Eigenvalues

$m_1 = 0$
$m_2 = (\Delta m_{12}\hat{}2)\hat{}1/2$
$m_3 = (\Delta m_{13}\hat{}2)\hat{}1/1$

Mixing Angles

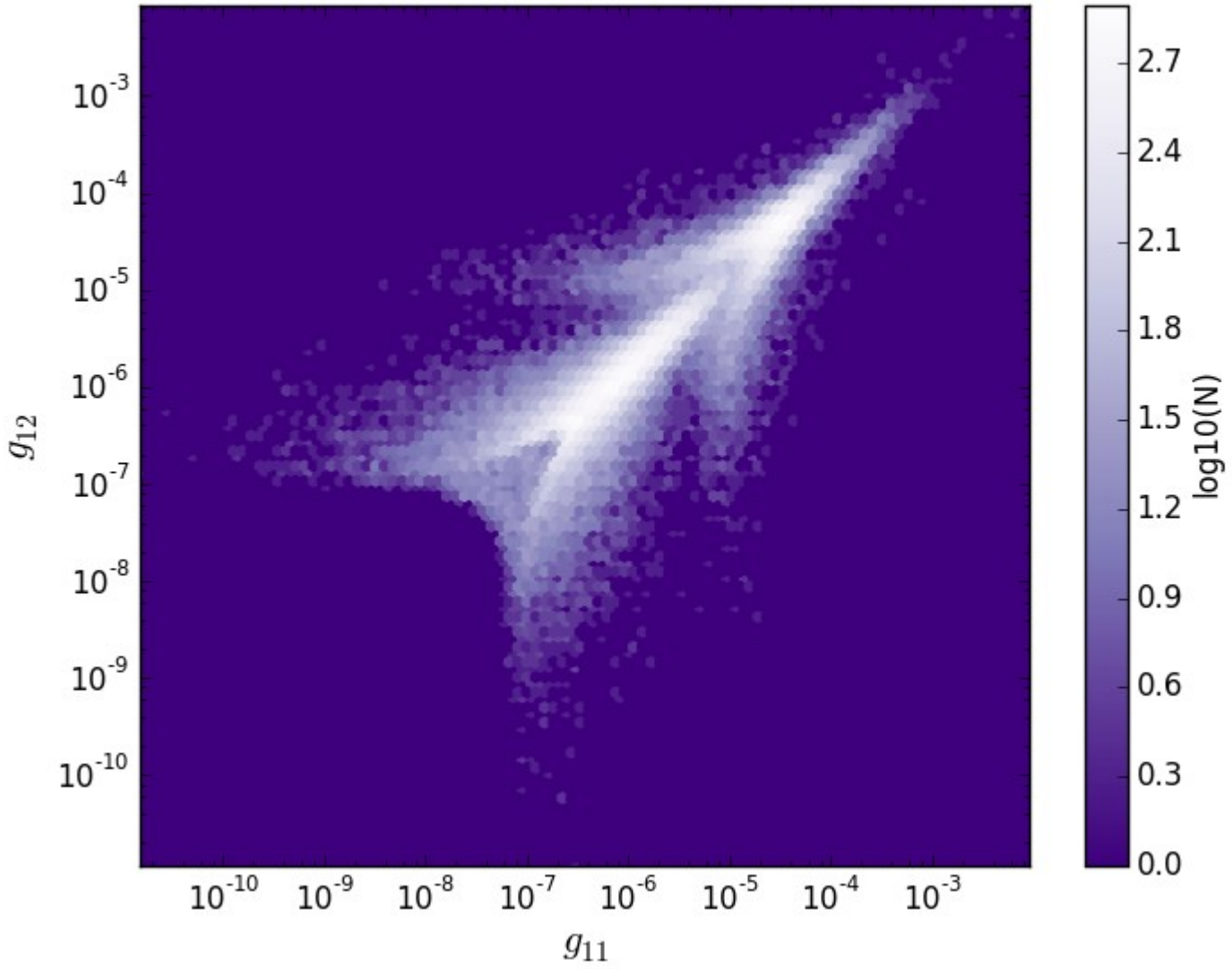
Θ_{12}
Θ_{13}
Θ_{23}



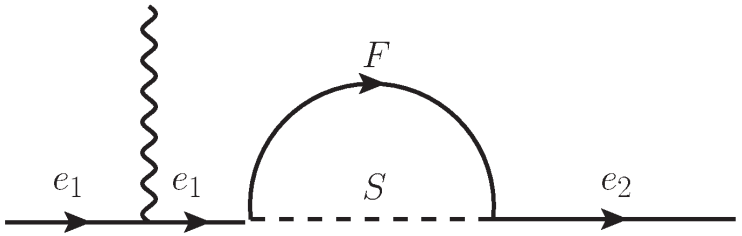
Neutrino Couplings

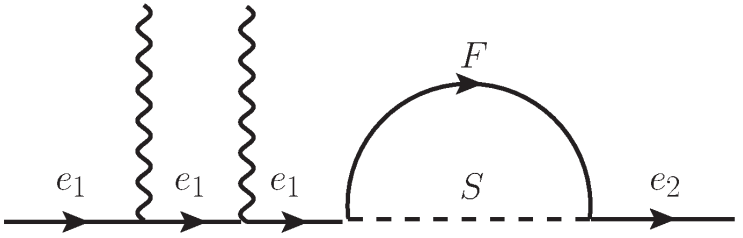
g_{11} g_{21}
g_{12} g_{22}
g_{13} g_{23}

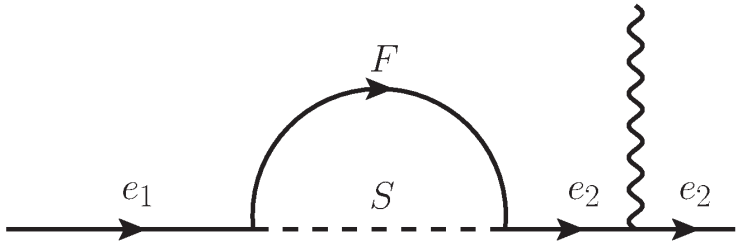
Neutrino masses within T12A

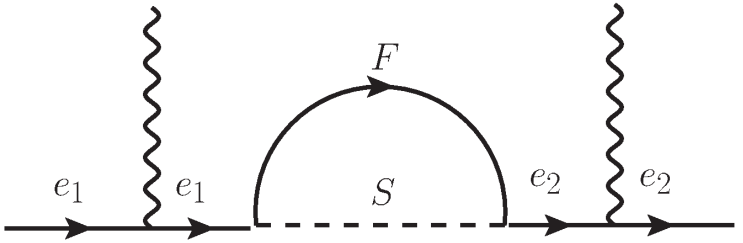


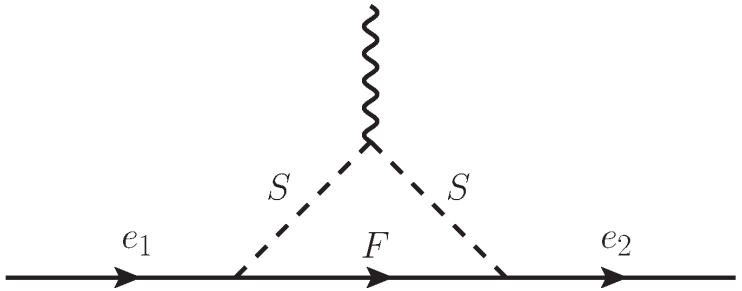
Lepton Flavour Violation

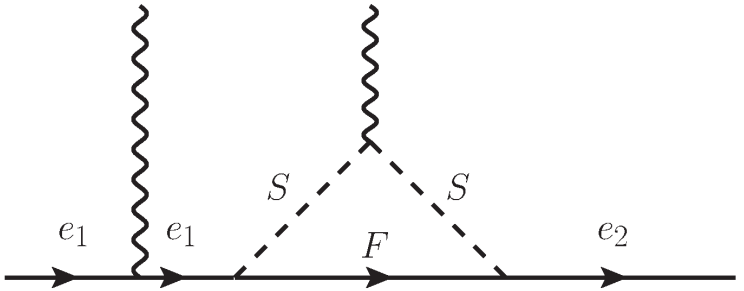


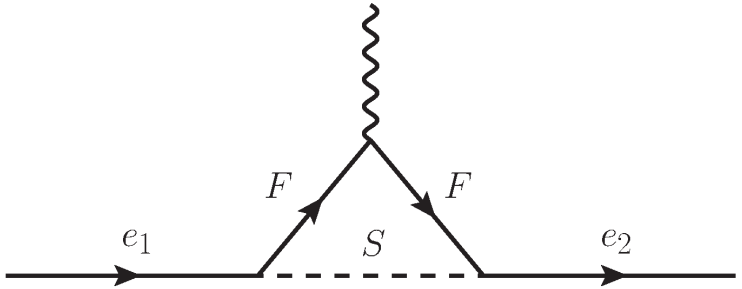


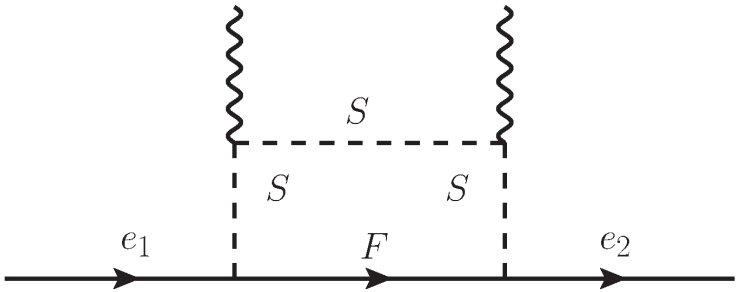












Summary and outlook

- Model T12A
  - new Z_2 symmetry
  - fermionic and scalar singlets and doublets
- Loop contributions generate neutrino mass
- lightest odd particle: dark matter

- Dark matter observables:
  - relic density
  - direct detection cross section
  - indirect detection signals

  - neutrino physics
  - Higgs physics
  - lepton flavor violating processes
  - ...

References

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