A Minimal Model for Dark Matter and Radiative Neutrino Masses

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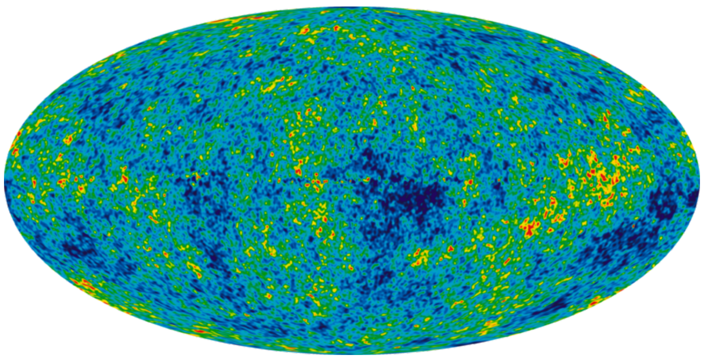
With Prof. Dr. M. Klasen and Dr. C. Yaguna

Annual GrK Retreat 25th – 28th September 2017

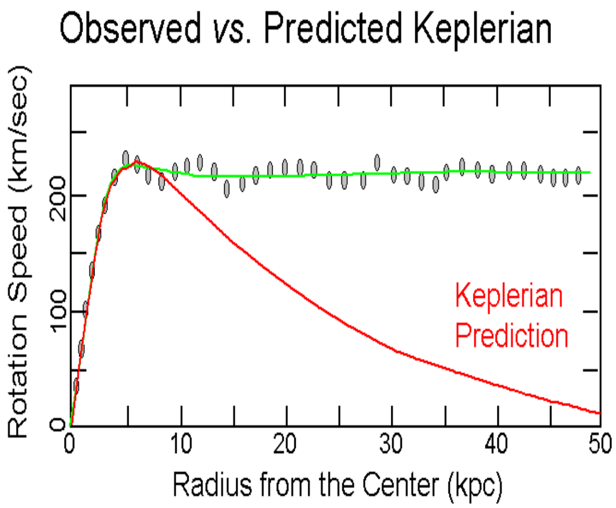
Evidence for dark matter

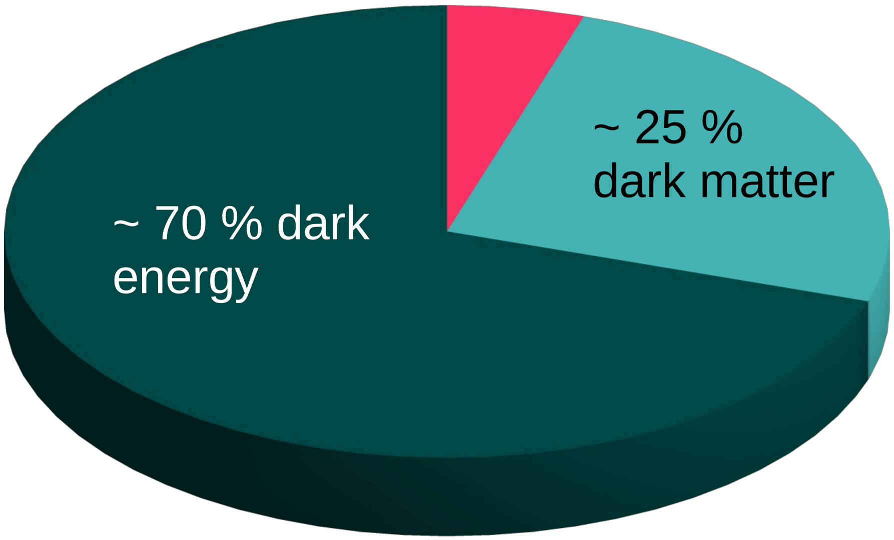
CMB anisotropy[1]



Gravitational lensing[3]

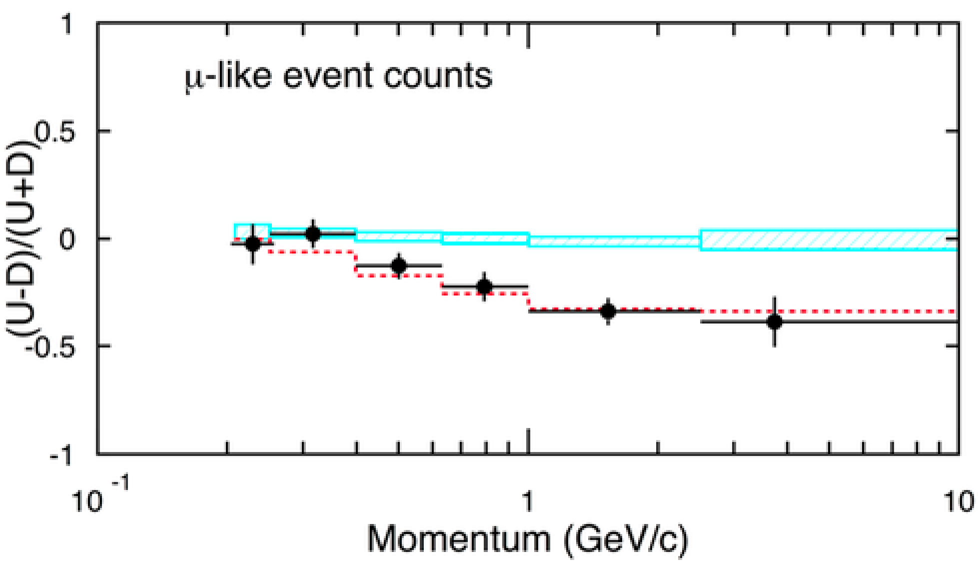
Rotation[2]





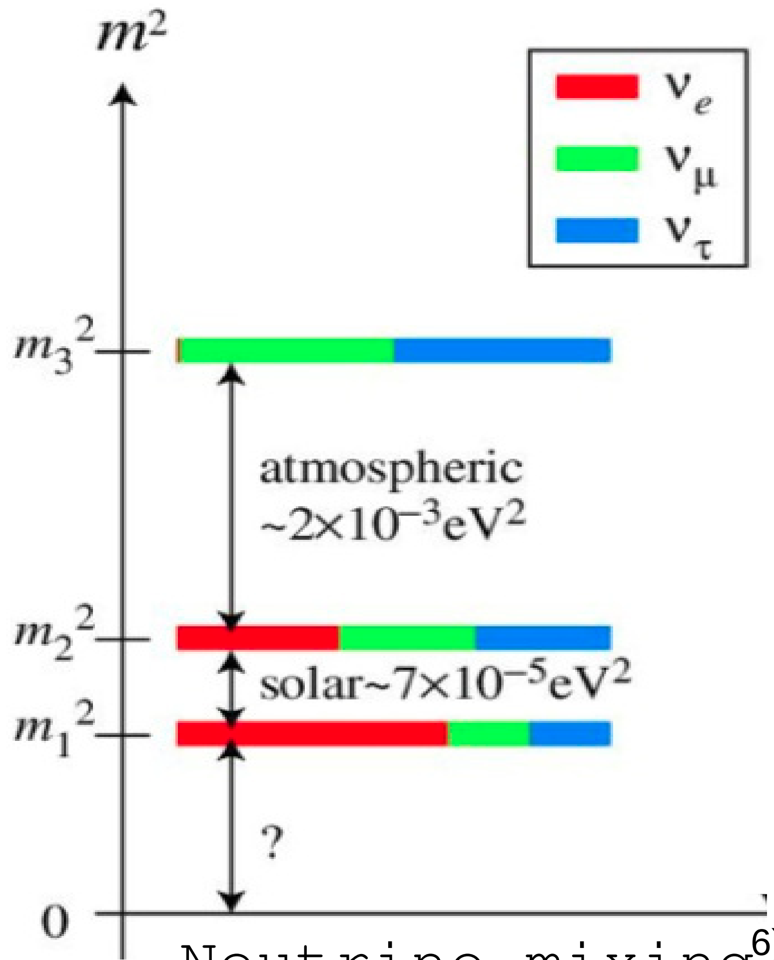
Evidence for neutrino masses

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



Neutrino conversion [4)]
@ SuperKamiokande

5)



Neutrino mixing [6)]

Model T12A

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

Standard Model

+

Fermion Doublet ψ_D
Fermion Singlet ψ_S

+

Scalar Doublet ϕ_D
Scalar Singlet ϕ_S

+

Extra Z_2 symmetry

Dark Matter

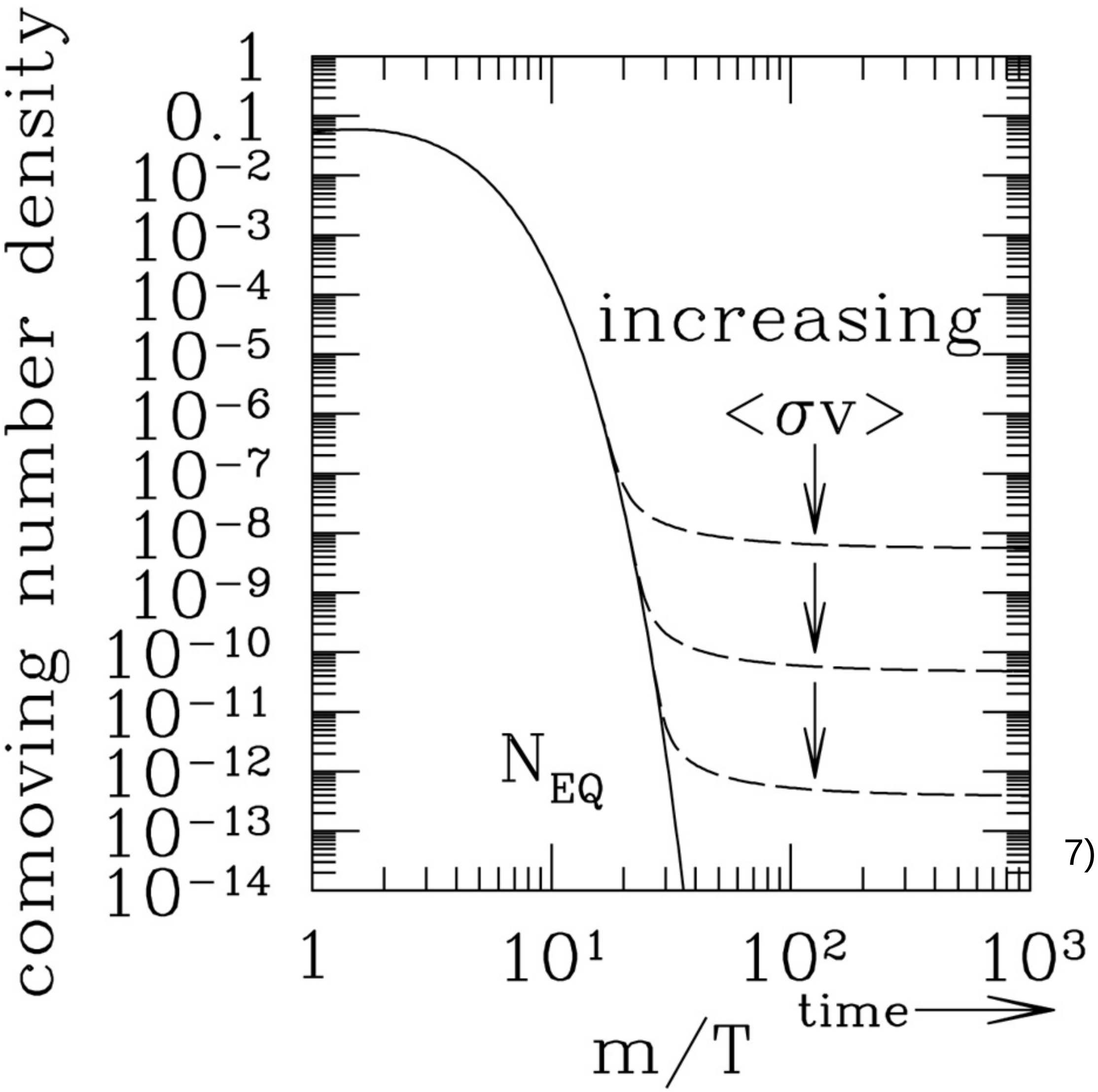
+

Neutrino Masses

+

Lepton flavor violation

I. Dark matter relic density



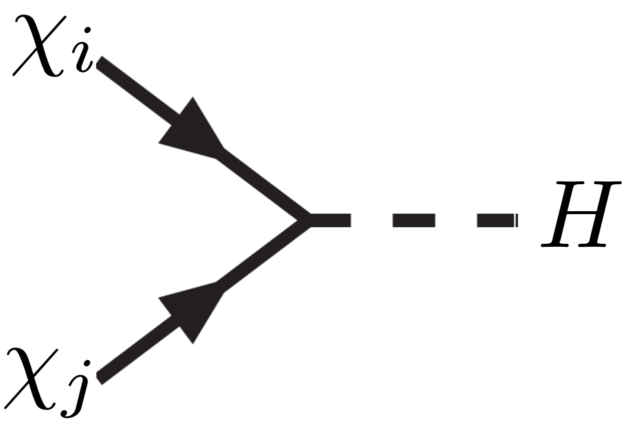
7)

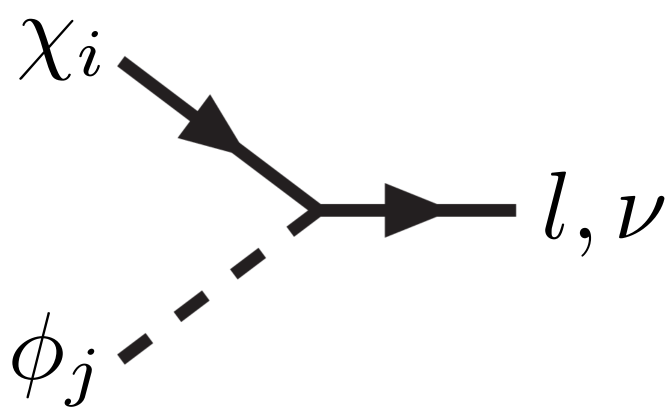
$\chi\chi \rightarrow SMSM$

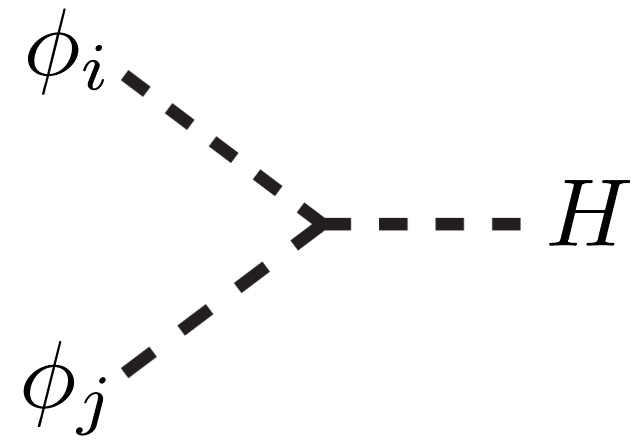
$\chi\phi \rightarrow SMSM$

$\phi\phi \rightarrow SMSM$

Relic density: Annihilation channel







annihilation

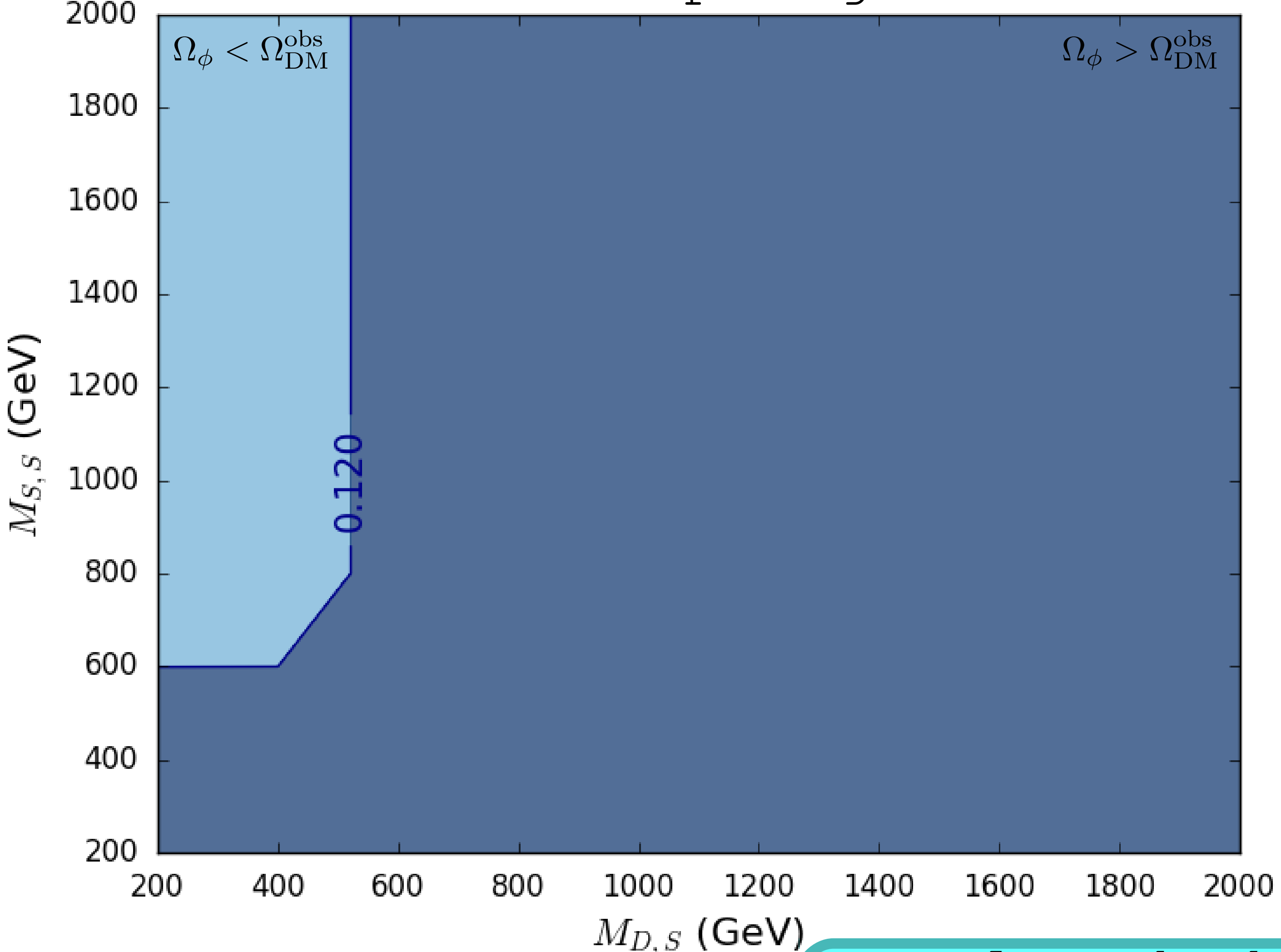
co-annihilation

annihilation

Scalar dark matter

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

Fixed couplings

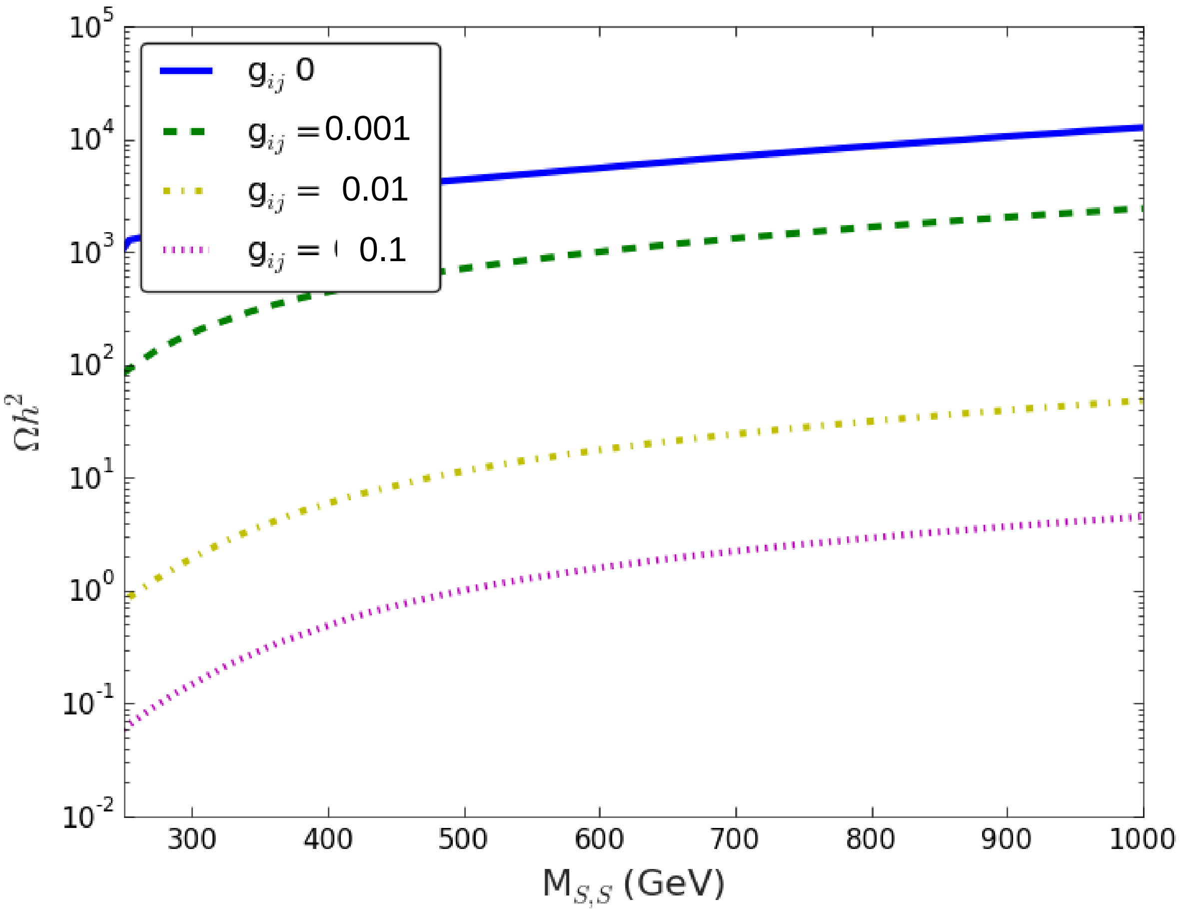


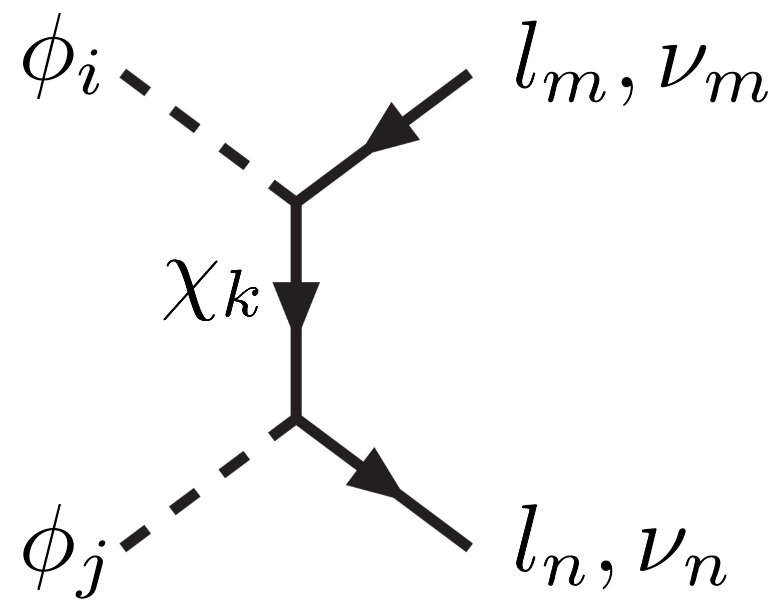
Planck : $\Omega h^2 \approx 0.12$

Scalar dark matter
Singlet mass $M_{S,S}$
Doublet mass $M_{D,S}$

Scalar *leptophilic* dark matter

Fixed: $M_{D,S}/M_{S,S}, M_{S,F}/M_{S,S}, M_{D,F}/M_{S,S}$

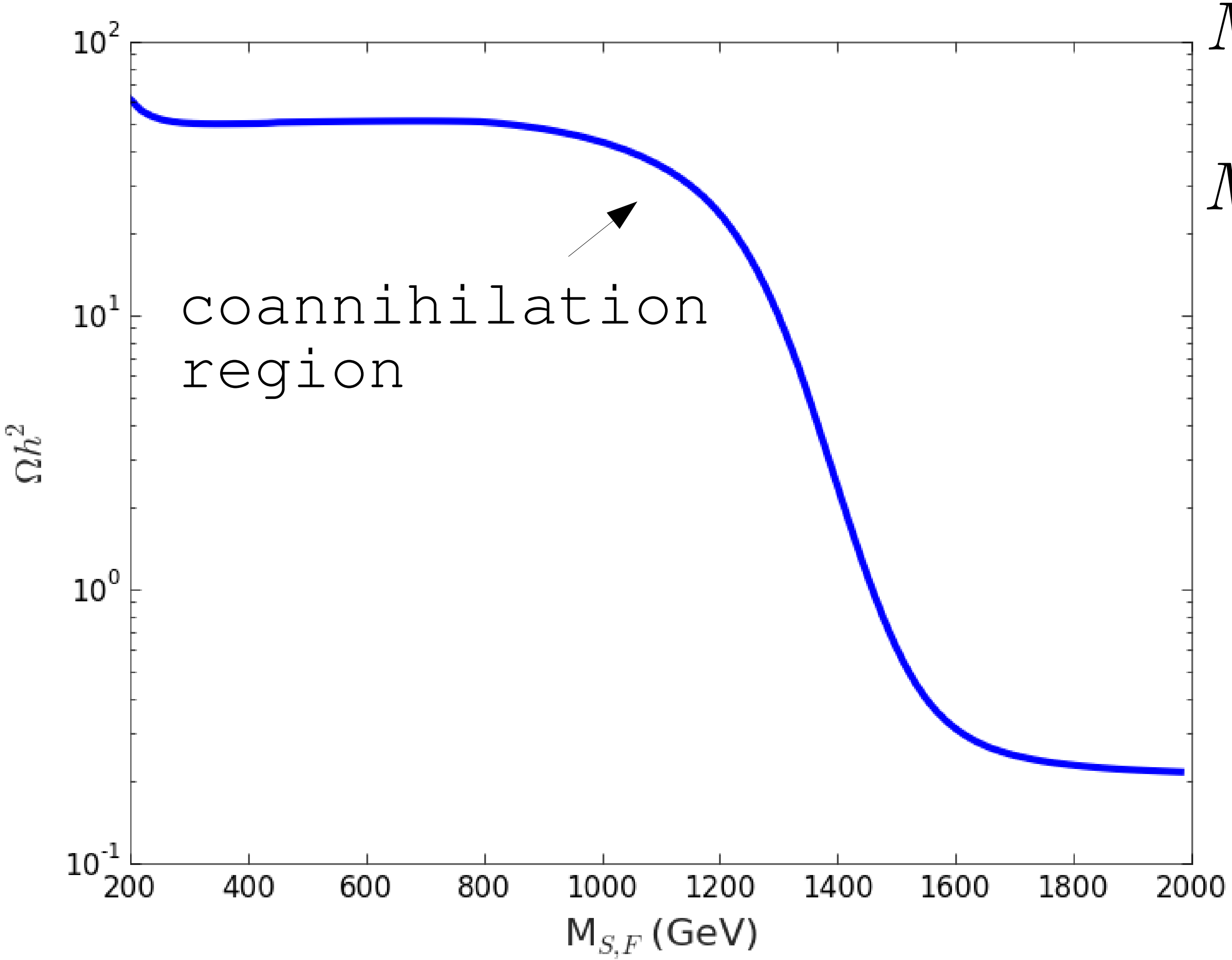




No influence on direct detection

Fermion dark matter

Fixed: $M_{D,F} = 1500$ GeV



Scalar decoupled:

$M_{S,S} = 2500$ GeV

$M_{D,S} = 3500$ GeV

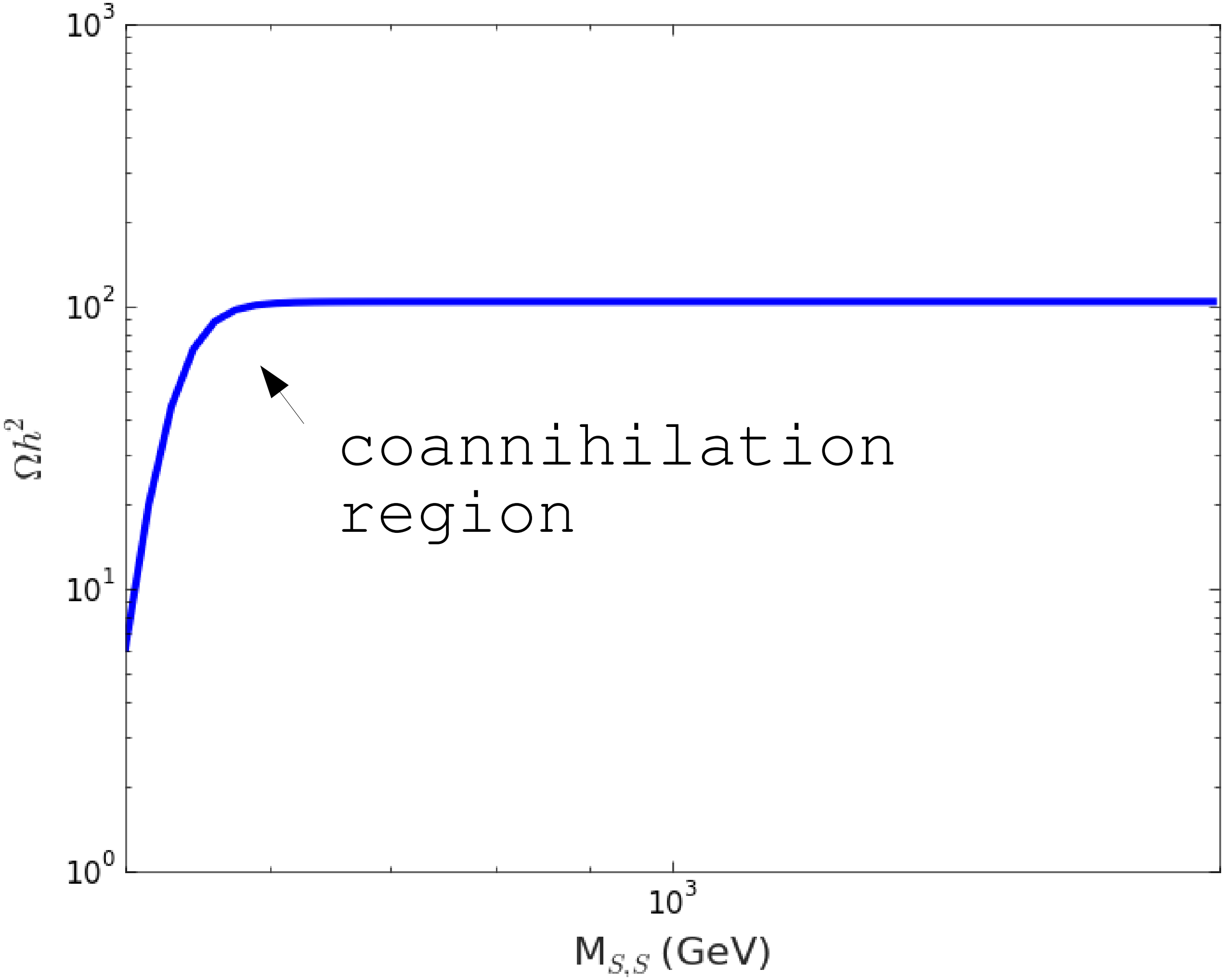
Scalar fermion coannihilation

Fixed: $M_{D,F} = 500$ GeV

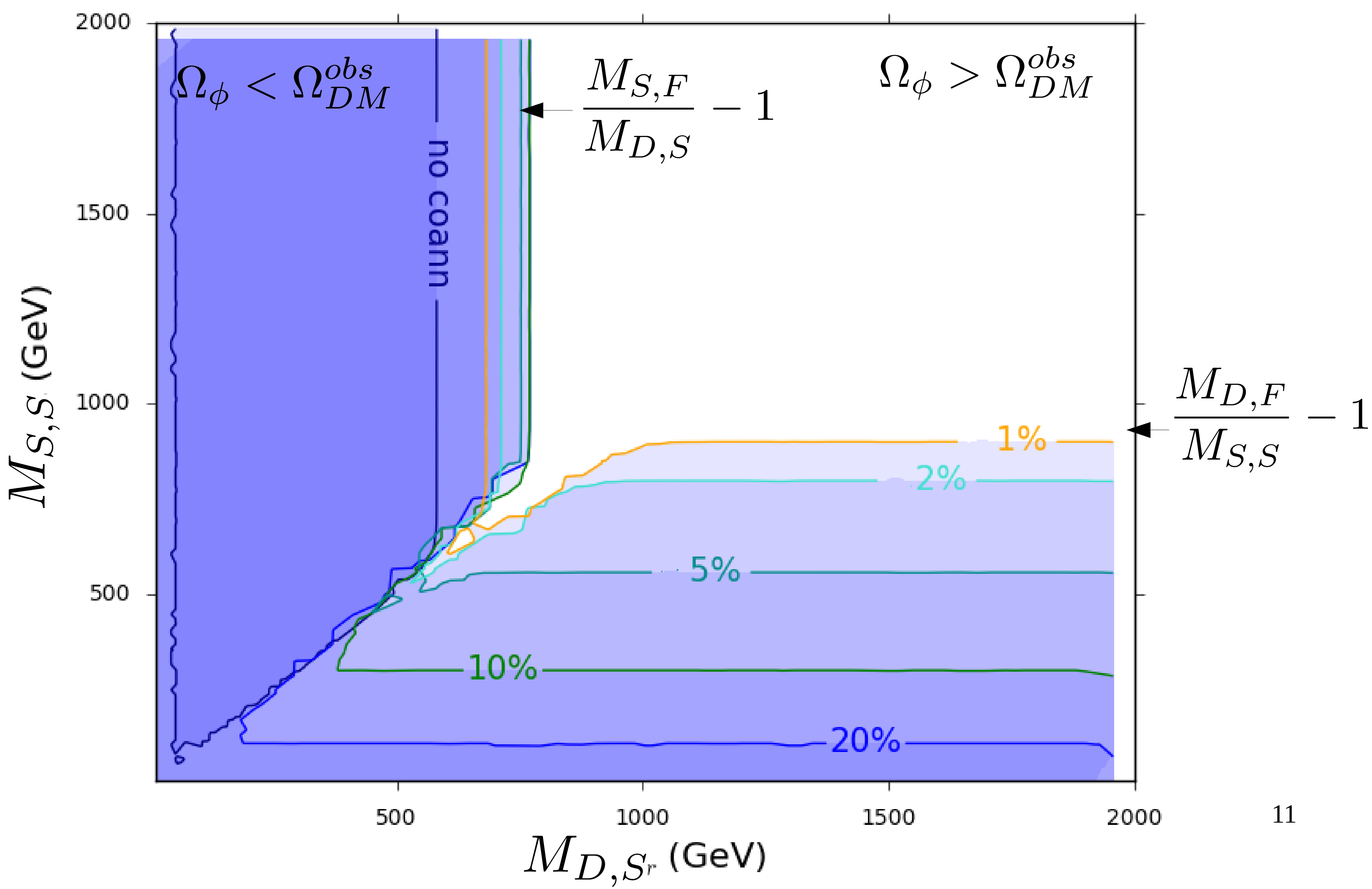
Others decoupled:

$M_{S,F} = 3500$ GeV

$M_{D,S} = 1500$ GeV



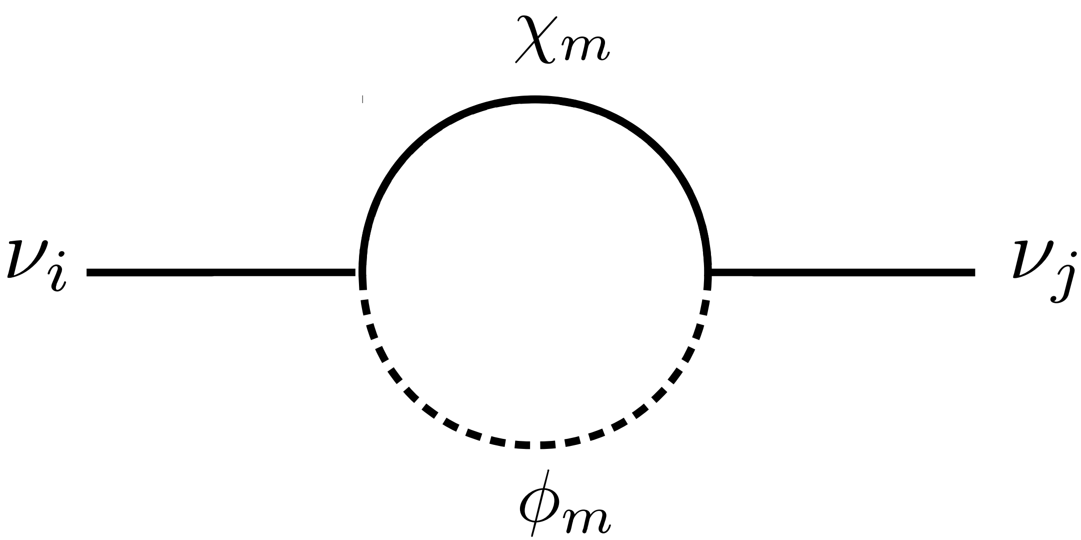
Coannihilation influcene on Ω



II. Neutrino masses

Before EWSB: $\mathcal{L}_{\text{lep}} = g_{1j}\Psi_D L_j \phi_S + g_{2j}\Psi_S L_j \phi_D$

After EWSB: $\mathcal{L}_{\text{lep}} = G_{ijk}\chi_i \nu_j \phi_k$



G_{ijk} contain also

- scalar Higgs couplings
- fermion Higgs couplings y_1, y_2
- masses $M_{S,S}, M_{D,S}, M_{S,F}, M_{D,F}$

Obtain **two** non-zero neutrino masses
→ experimental constraints determine bounds on G_{ijk}

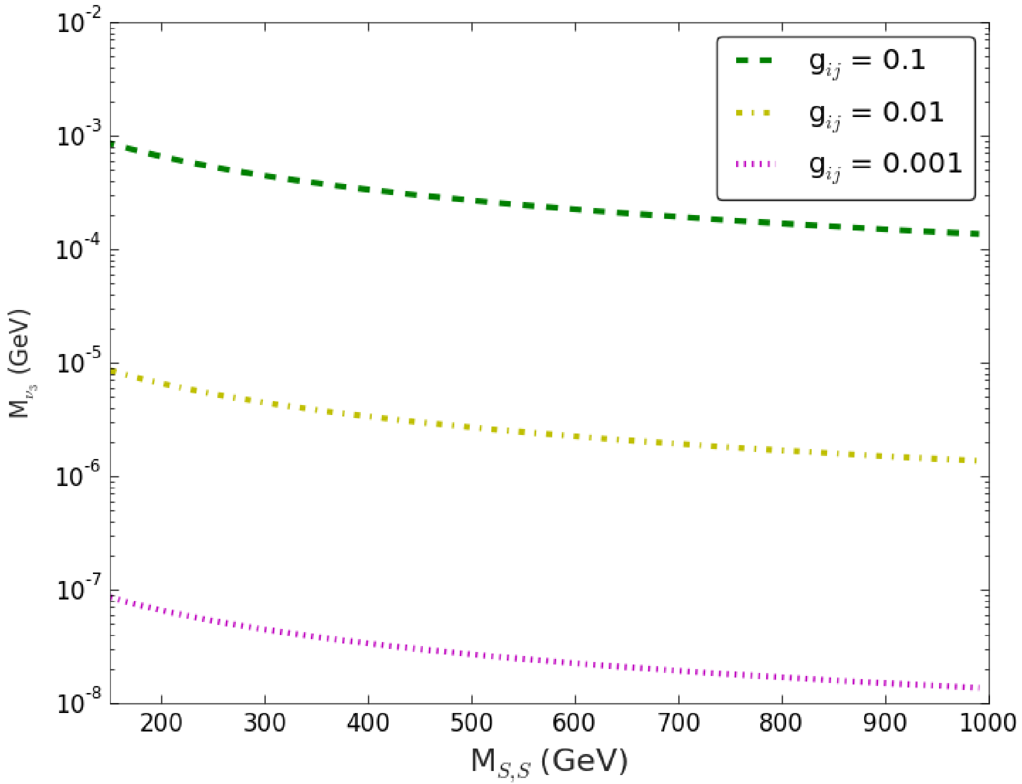
Neutrino masses vs scalar/fermion DM

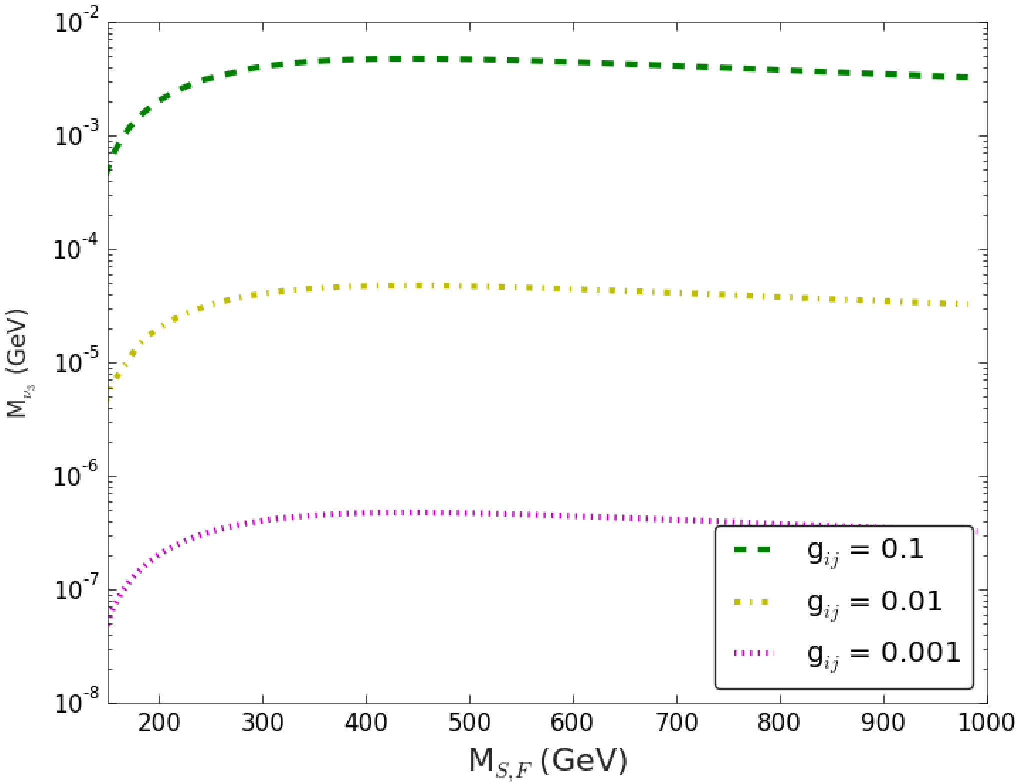
Fixed:

$M_{D,S}/M_{S,S}, M_{S,F}/M_{S,S}, M_{S,F}/M_{S,S},$

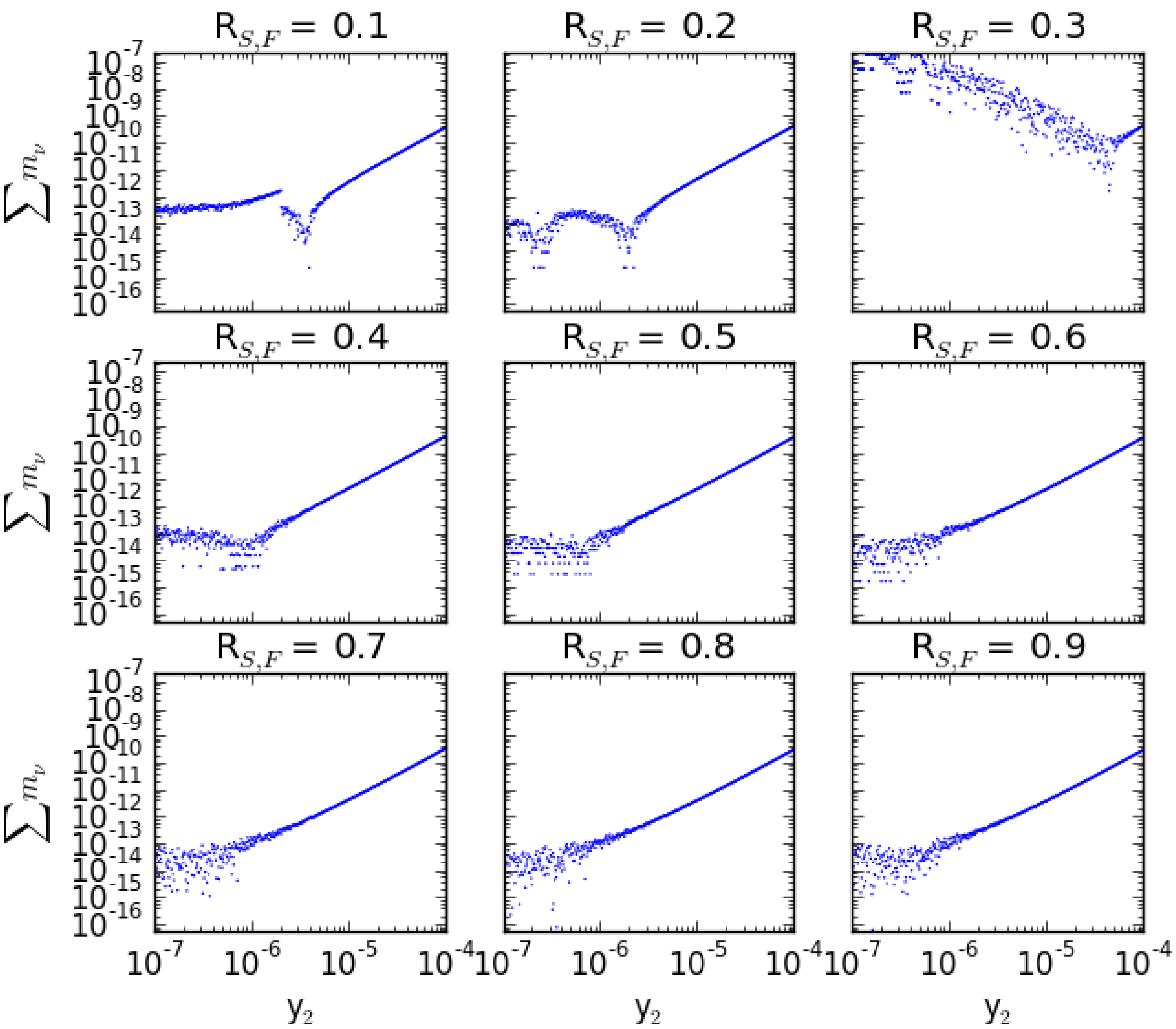
Fixed:

$M_{S,S}/M_{S,F}, M_{D,S}/M_{S,F}, M_{D,F}/M_{S,F}$





Neutrino masses vs fermion Higgs coupling

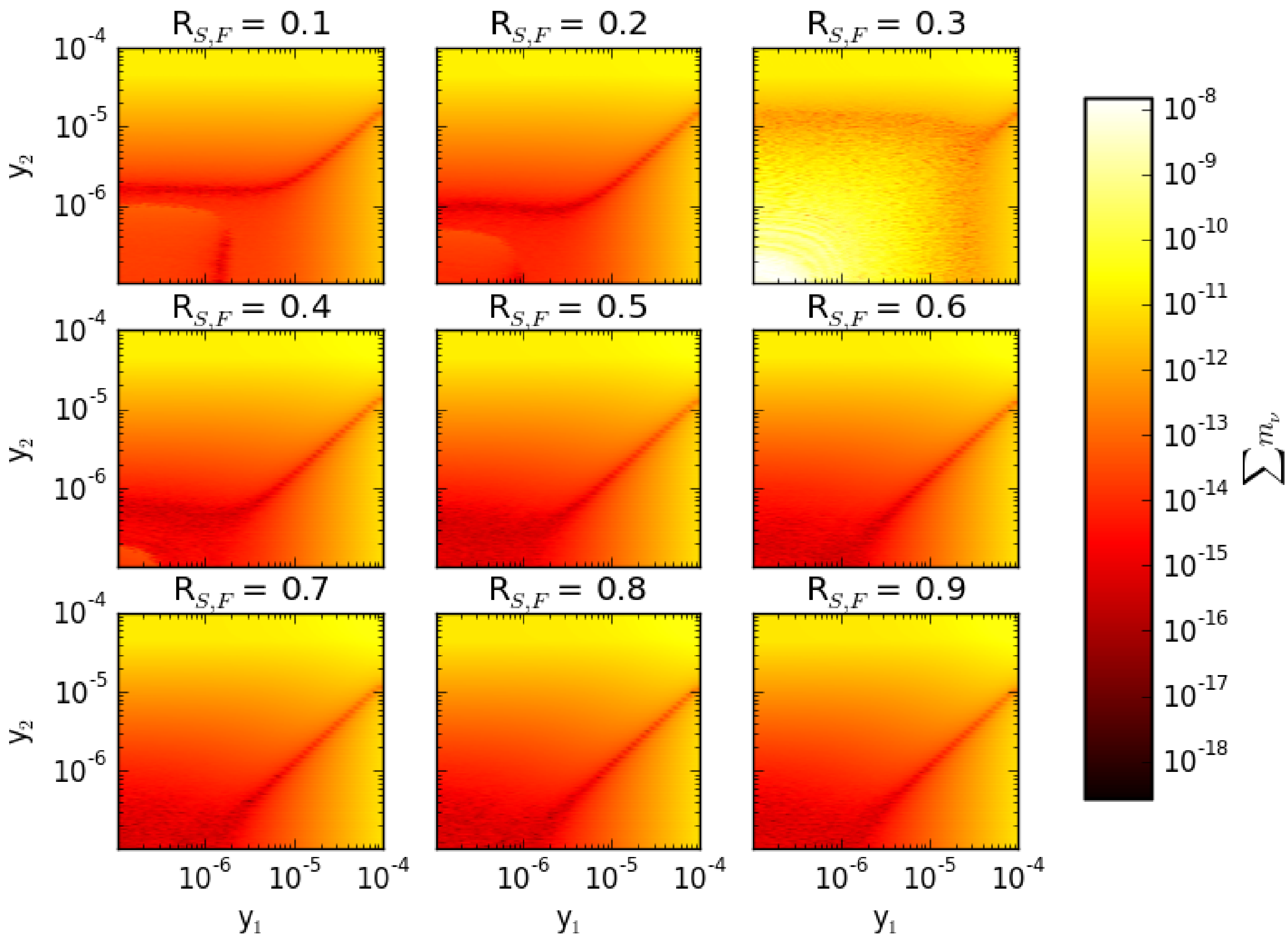


$$M_{S,S}/M_{S,F} = R_{S,F}$$

$$M_{S,S}/M_{D,F} = 0.6$$

$$M_{S,S}/M_{D,S} = 0.3$$

Neutrino masses vs fermion Higgs couplings y_1, y_2



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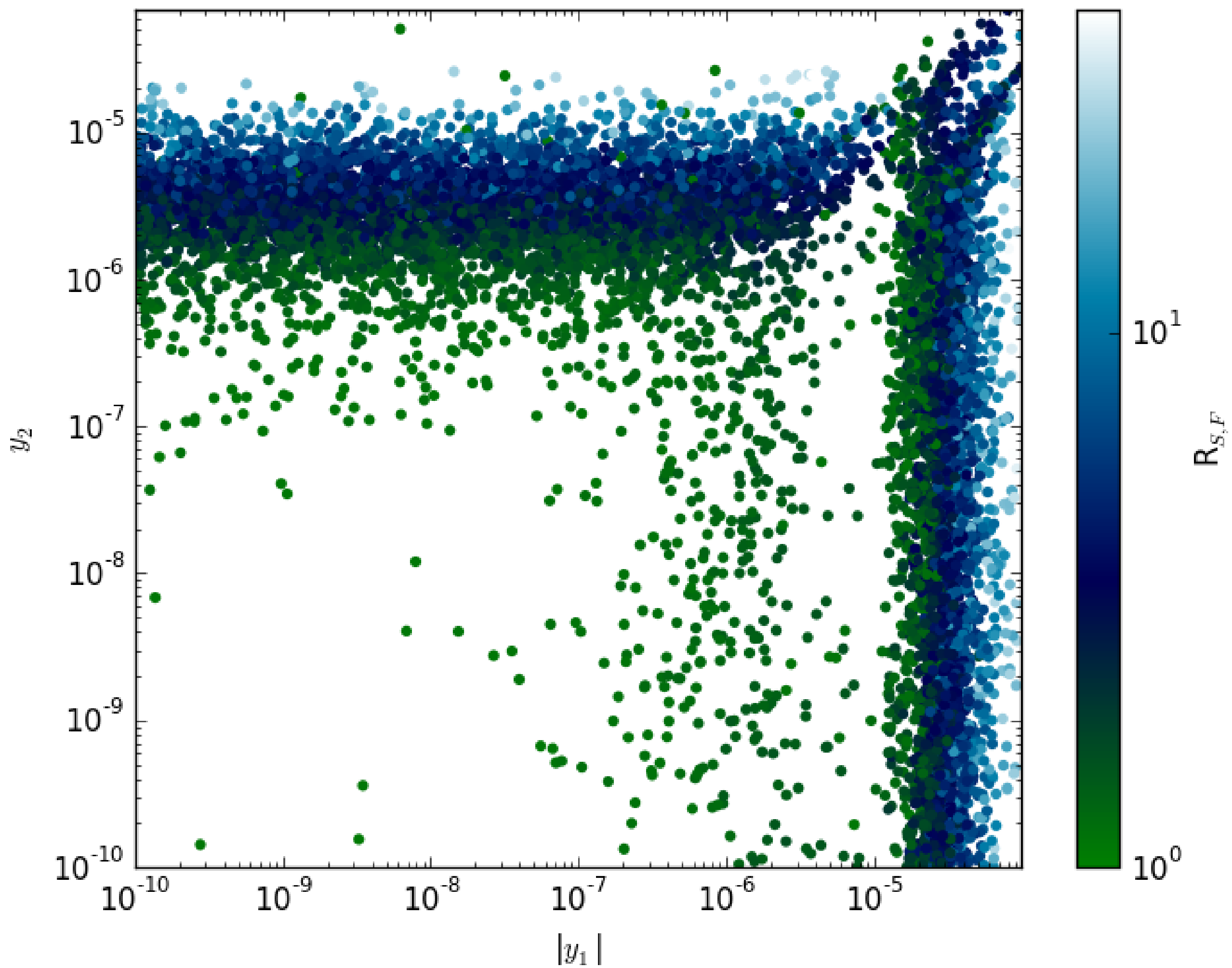
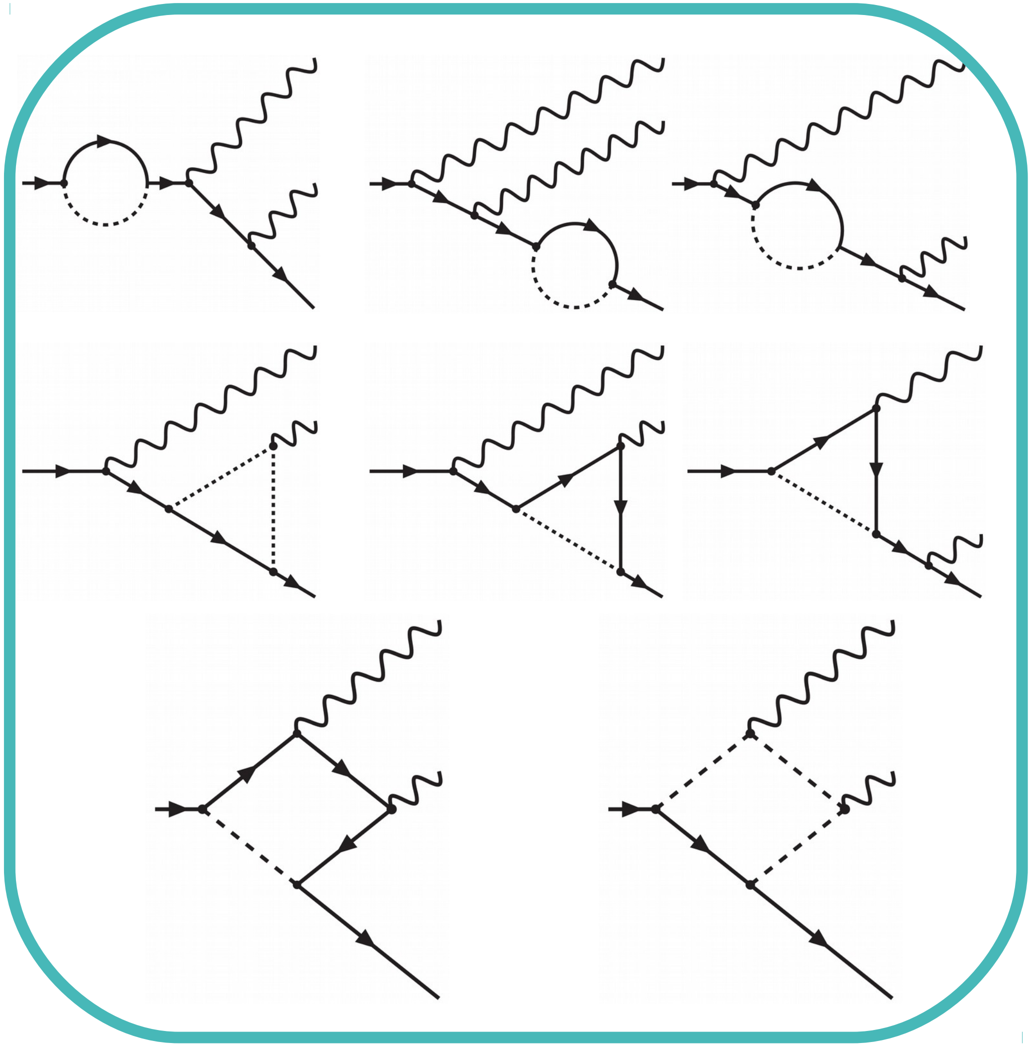
$$M_{S,S}/M_{D,S} = 0.3$$

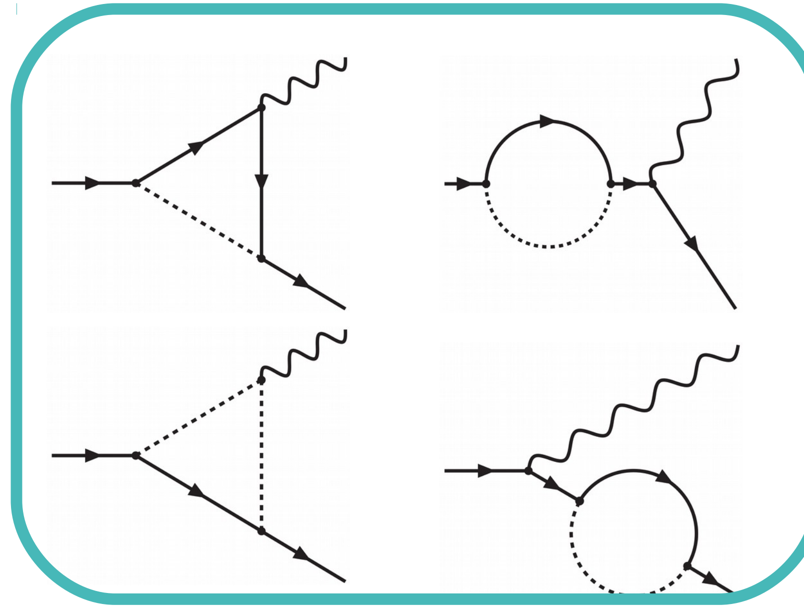
Mass ratio vs fermion Higgs couplings y_1, y_2

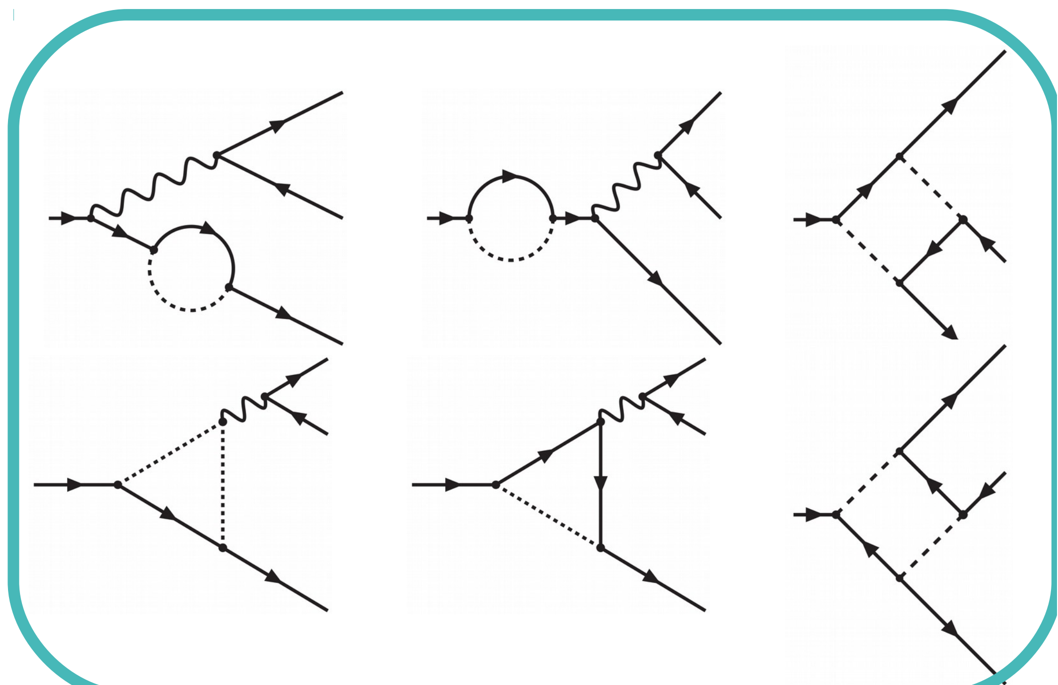


Choose: Scalar dark matter with coannihilation
Impose: Relic density Ω, neutrino masses Δm_ν
LFV constraints

III. Lepton flavour violation

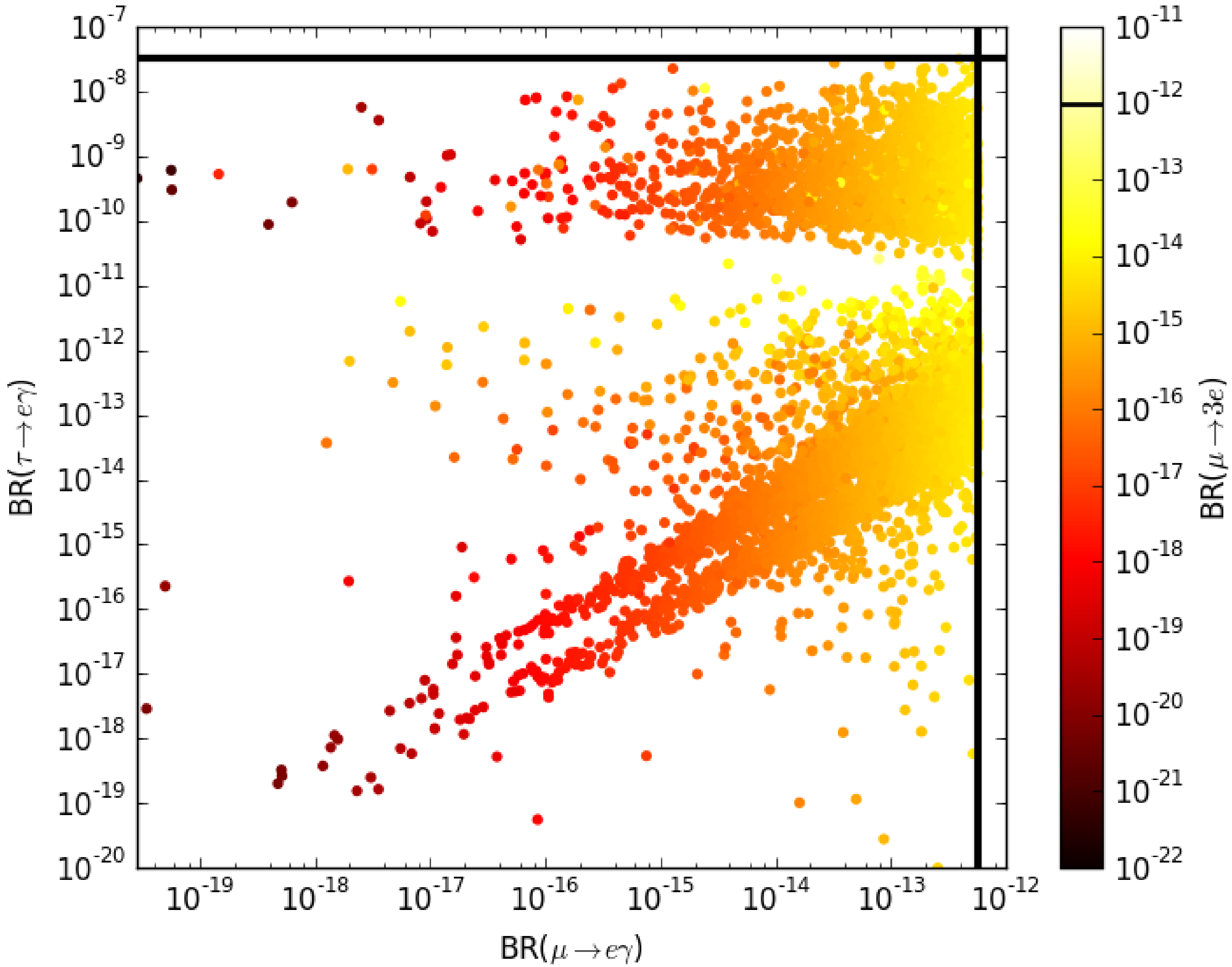






In collaboration with
B. Herrmann at LAPTH

Experimental constraints on lepton flavour violation

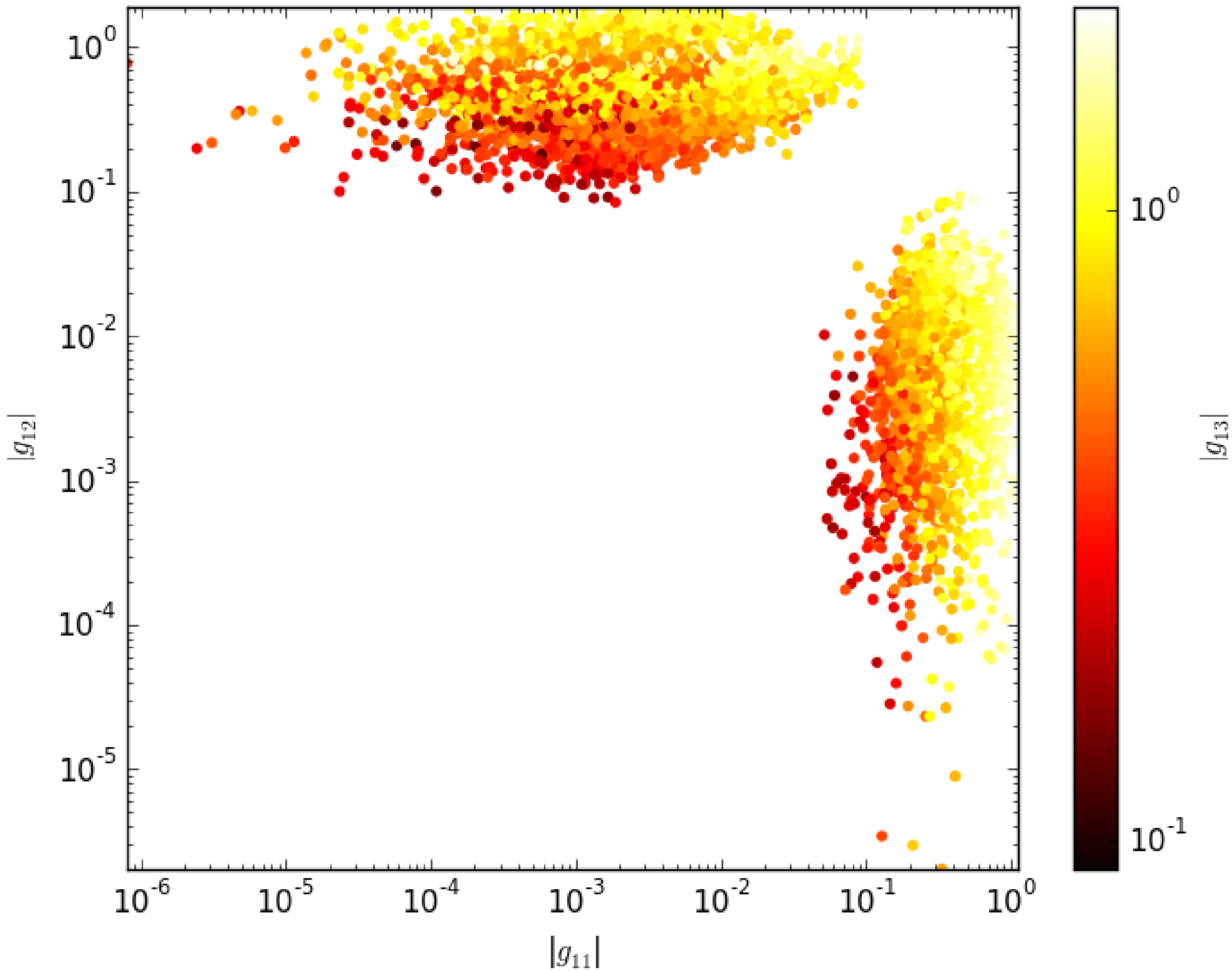


Choose: Scalar dark matter with coannihilation

Impose: Relic density Ω, neutrino masses Δm_ν

LFV constraints

Impact on scalar-fermion-lepton couplings g_{ij}



Choose: Scalar dark matter with coannihilation

Impose: Relic density Ω, neutrino masses Δm_ν, LFV constraints

Summary and outlook

- Model T12A
  - New Z_2 symmetry
  - Fermionic and scalar singlets and doublets

- Physical degrees of freedom
  - Loop contributions generate neutrino mass
  - Lightest odd particle: dark matter

- Dark matter observables:
  - Relic density
  - Direct detection cross section
  - Indirect detection signals

- Other observables:
  - Neutrino physics
  - Higgs physics
  - Lepton flavor violating processes
  - ...

Questions?

Thank you for your attention.
Do you have any questions?

References

1) D.~J. Fixsen.The Astrophysical Journal, 707:916--920, 2009
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3) http://chandra.harvard.edu/photo/2006/1e0657/more.html
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10) C.Cheung, D.Sanford - JCAP 02(2014)