Neutrino masses and a generic model of R-parity violation

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The minimal supersymmetric SM

- One superpartner for every SM particle
- One additional Higgs Superfield
- R-parity conservation $R_P = (-1)^{3(B-L)+2S}$
- Lightest supersymmetric particle is stable
- No lepton or baryon number violation
- No neutrino masses

R-parity violation (RPV)

- The LSP is no longer stable and can decay into SM particles
- Lepton and baryon number violating operators in the superpotential are now allowed
- Viable neutrino masses can be generated

$$W_{RPV} = \mu_i L_i H_u + \frac{1}{2}\lambda_{ijk} L_i L_j E_k^C + \lambda'_{ijk} L_i Q_j D_k^C + \frac{1}{2}\lambda''_{ijk} U_i^C D_j^C D_k^C$$

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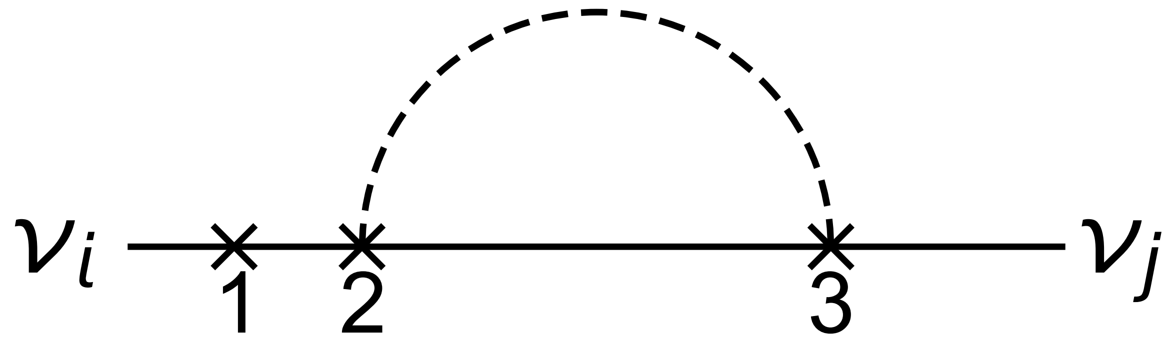
Neutrino masses

- Neutrino/neutralino mixing via the bilinear Operator
- Only one massive neutrino at tree-level
- Loop contributions via several combinations of bi- and trilinear couplings
- Three masseigenvalues at 1-loop-level



Neutrino masses

$$m_{ij} = M_S \delta^i_\mu \delta^j_\mu + \kappa_1 \left[\sum_{k,n} m_{e_k} m_{e_n} \delta^{ink}_\lambda \delta^{jkn}_\lambda + 3 \sum_{k,n} m_{d_n} m_{d_k} \delta^{ink}_{\lambda'} \delta^{jkn}_{\lambda'} \right]$$
$$+ \kappa_2 \left[\sum_k m_{e_k} \left(\delta^i_\mu \delta^{jkk}_\lambda + \delta^j_\mu \delta^{ikk}_\lambda \right) + 3 \sum_k m_{d_k} \left(\delta^i_\mu \delta^{jkk}_{\lambda'} + \delta^j_\mu \delta^{ikk}_{\lambda'} \right) \right]$$

$$\kappa_1 = \frac{1}{8\pi^9 M_S} \qquad \kappa_2 = \frac{g}{16\pi^2 \sqrt{2}}$$

$$\delta^i_\mu = \mu_i/\mu \quad \delta^{ijk}_\lambda = \lambda_{ijk} \quad \delta^{ijk}_{\lambda'} = \lambda'_{ijk}$$

A. Abada, G. Bhattacharyya and M. Losada, Phys. Rev. D 66 (2002) 071701

Two generic flavor symmetries

- Goal: reduce the number of 48 (complex) couplings
- Symmetry A fixes the Yukawa sector and the quark and charged lepton sector
- Symmetry A protects baryon number (no rapid proton decay)
- Number of couplings reduced from 48 to 39

Two generic flavor symmetries

- Symmetry B corresponds to lepton number
- Breaking of symmetry B introduces lepton number and flavor violation
- The LNV bi- and trilinear couplings now depend on the charge of the operator under symmetry B
- Make two assumptions for the charges to reduce the number of remaining independent couplings

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Symmetry B assumptions

- Only leptons are charged under symmetry B
- The charges obey the relation $Q_B(L_i) = -Q_B(E_i^C)$
- Reduction of independent LNV couplings to six

$$Q_B(L_i Q_j D_k^C) = Q_B(L_i H_u) = Q_B(L_i) \Rightarrow \lambda'_{ijk} \rightarrow \lambda'_i \rightarrow \mu_i$$

$$Q_B(L_i L_j E_j^C) = Q_B(L_i) \Rightarrow \lambda_{ijj} \rightarrow \lambda'_i \quad (i \neq j)$$

Couplings

- New relations between various LFV processes
- Tightest bound for any of the dependent couplings now translates to all others
- Very small λ' couplings, due to neutrino mass constraints and Kaon-experiments
- Loose bounds for the remaining λ couplings

Ind. Couplings	Dependencies
μ_1	λ'_{1jk}, λ_{1jj}
μ_2	λ'_{2jk}, λ_{2jj}
μ_3	λ'_{3jk}, λ_{3jj}
λ_{123}	-
λ_{132}	-
λ_{231}	-

Experimental access to neutrino masses

- PMNS matrix parametrized by 3 angles (accessible), and 3 phases (unconstrained)
- Two mass squared differences
- Undetermined hierarchy of the three masseigenvalues (inverted/normal hierarchy)
- Upper bounds for the absolute neutrino mass (three different sources)

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Bounds

M. C. Gonzalez-Garcia, M. Maltoni and J. Salvado, JHEP 1004 (2010) 056

parameter	LB	BF	UB
θ_{12}	31,5	34,4	37,6
θ_{23}	39,5	42,3	47,6
θ_{13}	0,0	6,8	13,2
$\Delta m^2_{21}/(10^{-5}\,\mathrm{eV}^2)$	6,90	7,59	8,20
$\Delta m^2_{31}/(10^{-3}\,\mathrm{eV}^2)$	2,03 (IH)	2,40 (IH)	2,79 (IH)
	2,15 (NH)	2,51 (NH)	2,90 (NH)

$m_e < 2.1\,\mathrm{eV}$ $\qquad m_{ee} < [0.32,\ 1.00]\,\mathrm{eV}$

$$\sum_i |m_i| < 0.67\,\mathrm{eV}$$

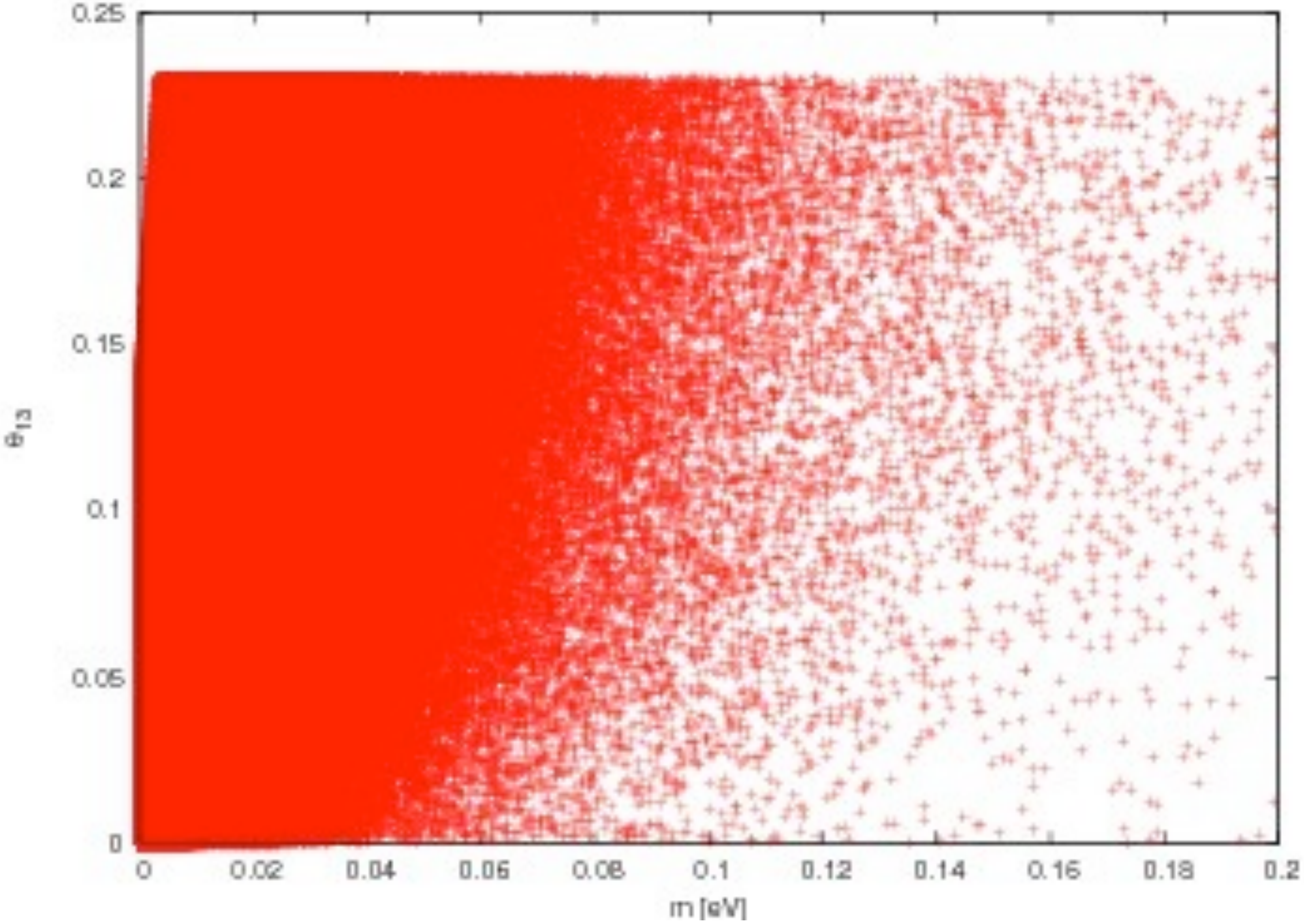
V. M. Lobashev, Nucl. Phys. A 719, 153 (2003)

H. V. Klapdor-Kleingrothaus et al., Eur. Phys. J. A 12, 147 (2001)

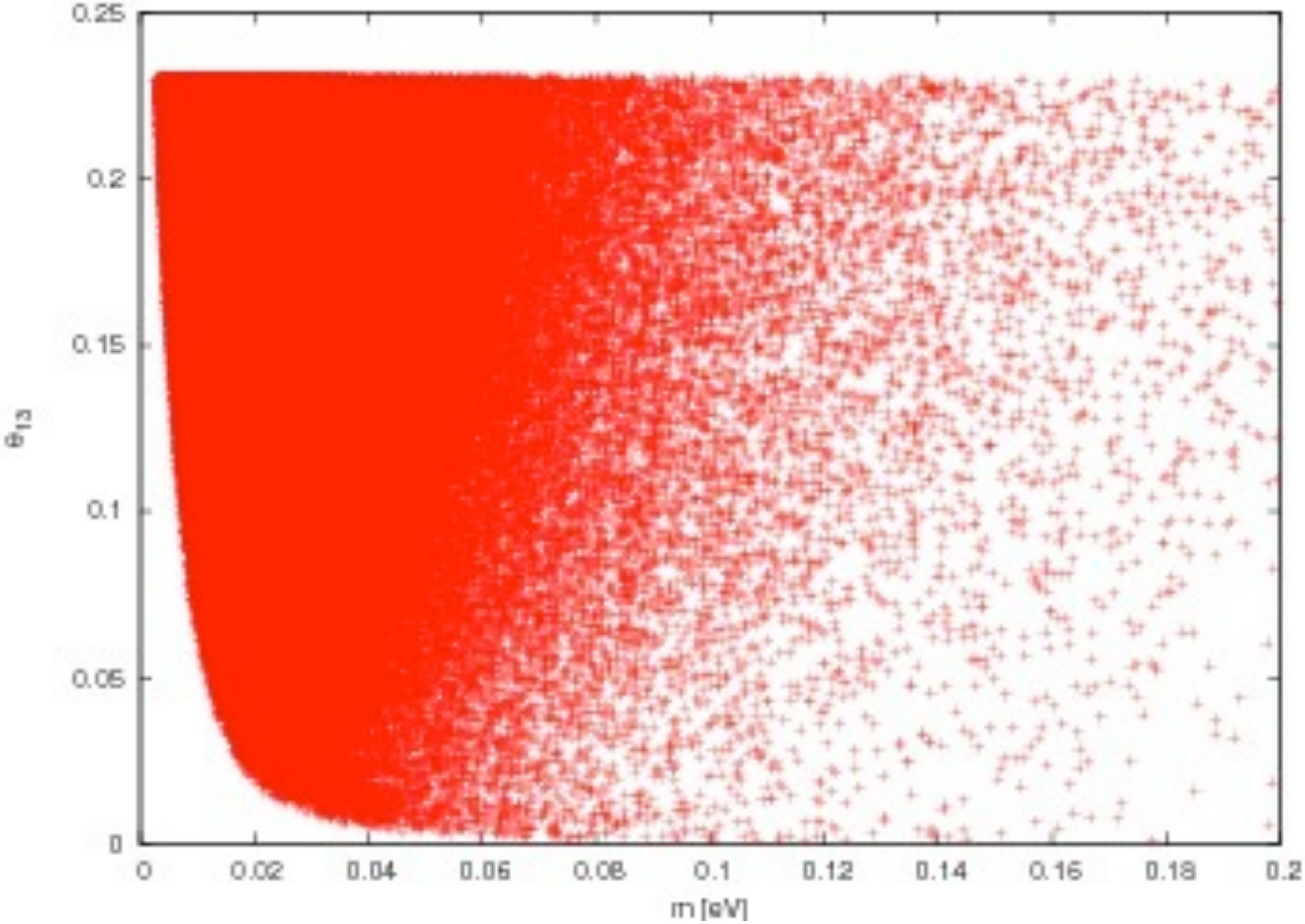
E. Komatsu et al. [WMAP Collaboration], Astrophys. J. Suppl. 180, 330 (2009)

Parameterscan

- 5 parameters
- m < 0.2 eV, θ_{13} within 3σ bounds, phases unconstrained (remaining oscillation parameters at best fit values)
- Check if couplings are within the bounds
- 3.24×10^8 randomly generated points scanned
- IH: ~7 000 000 valid points
- NH: ~300 000 valid points



Scatterplot of the results (IH)



Scatterplot of the results (NH)

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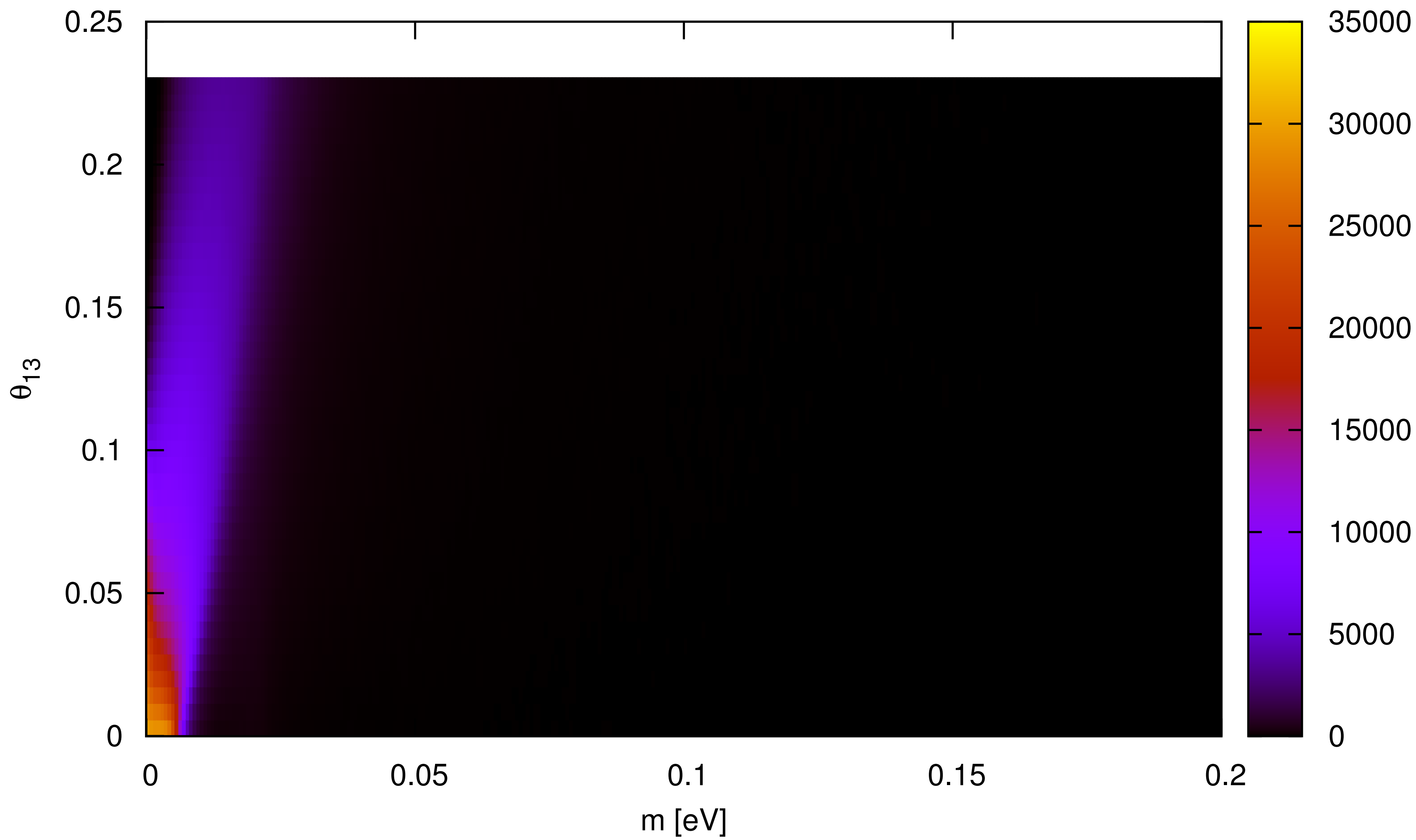

Distribution of valid points (IH)

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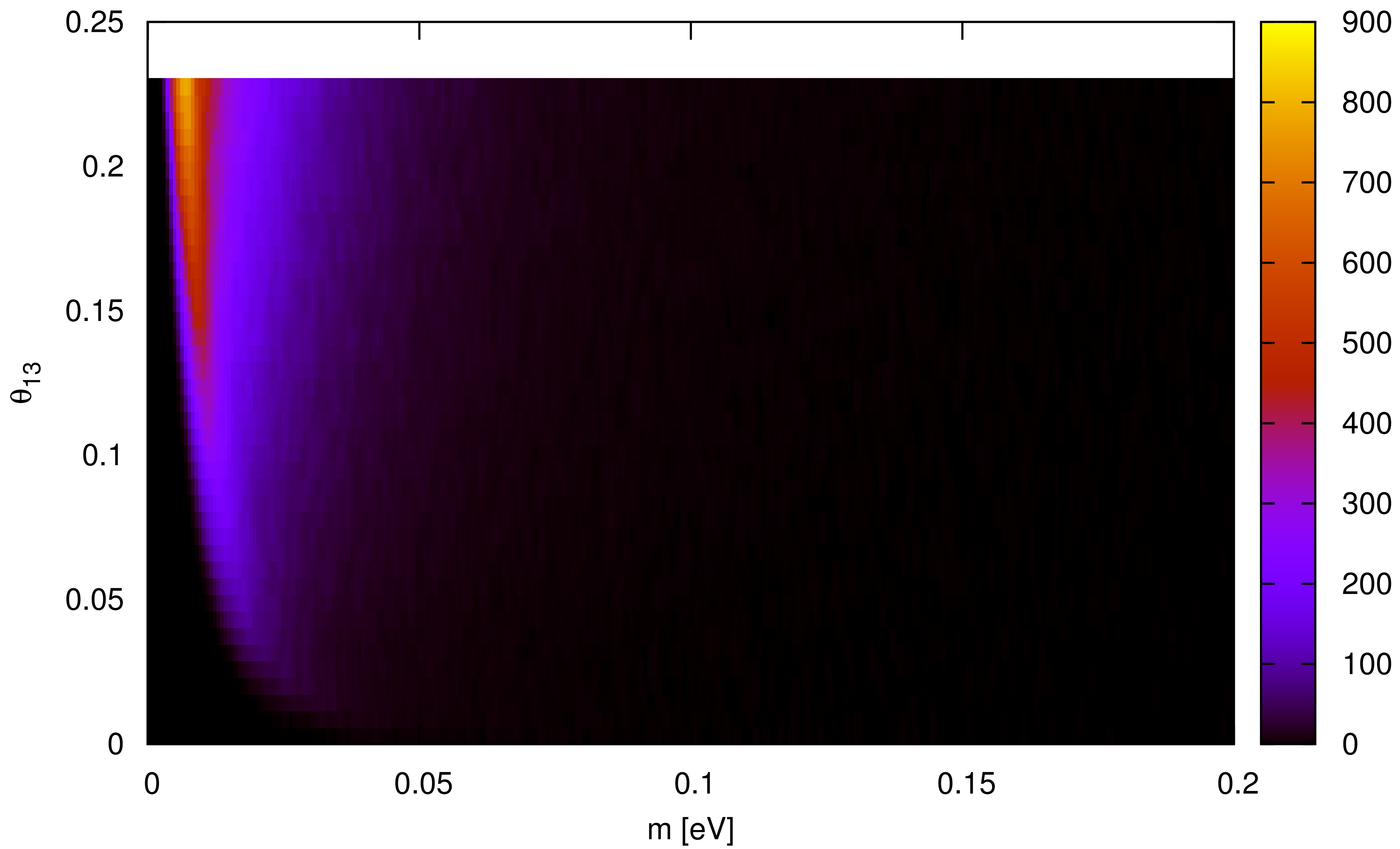


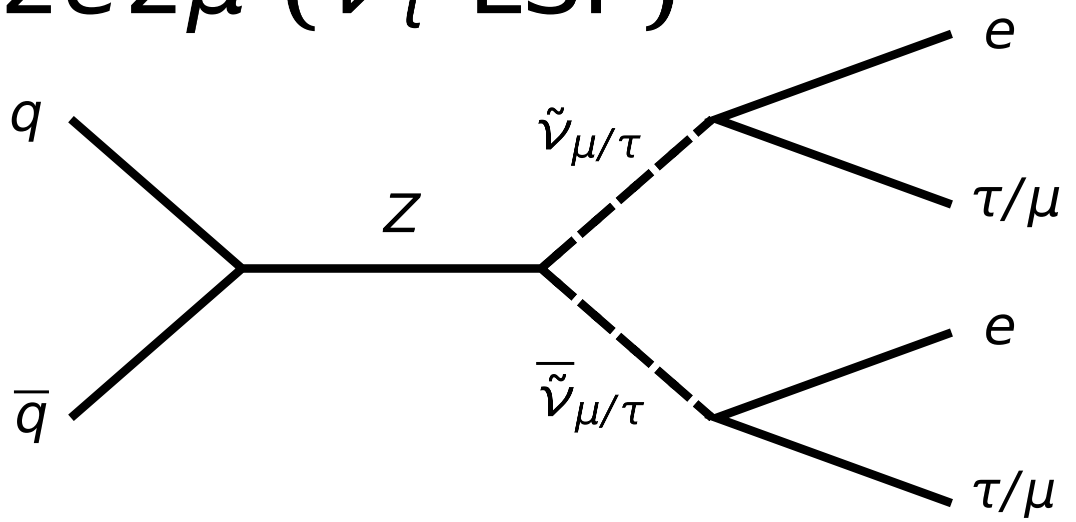
Distribution of valid points (NH)

Collider phenomenology

- Only lambda-couplings relevant
- Biggest coupling $\lambda_{231} \approx 0.1$
- Possible LHC signatures (very preliminary)

$$2p \rightarrow 2\tilde{\nu}_\mu \rightarrow 2e2\tau \; (\tilde{\nu}_\mu \text{ LSP})$$

$$2p \rightarrow 2\tilde{\nu}_\tau \rightarrow 2e2\mu \; (\tilde{\nu}_\tau \text{ LSP})$$



Summary

- We presented an economic way, based on two generic flavor symmetries, to introduce RPV with 6 couplings instead of 48
- The resulting coupling pattern prefers IH over NH
- IH and NH can be distinguished by their preference for θ_{13}
- The large λ_{231} probably yields interesting collider signatures