

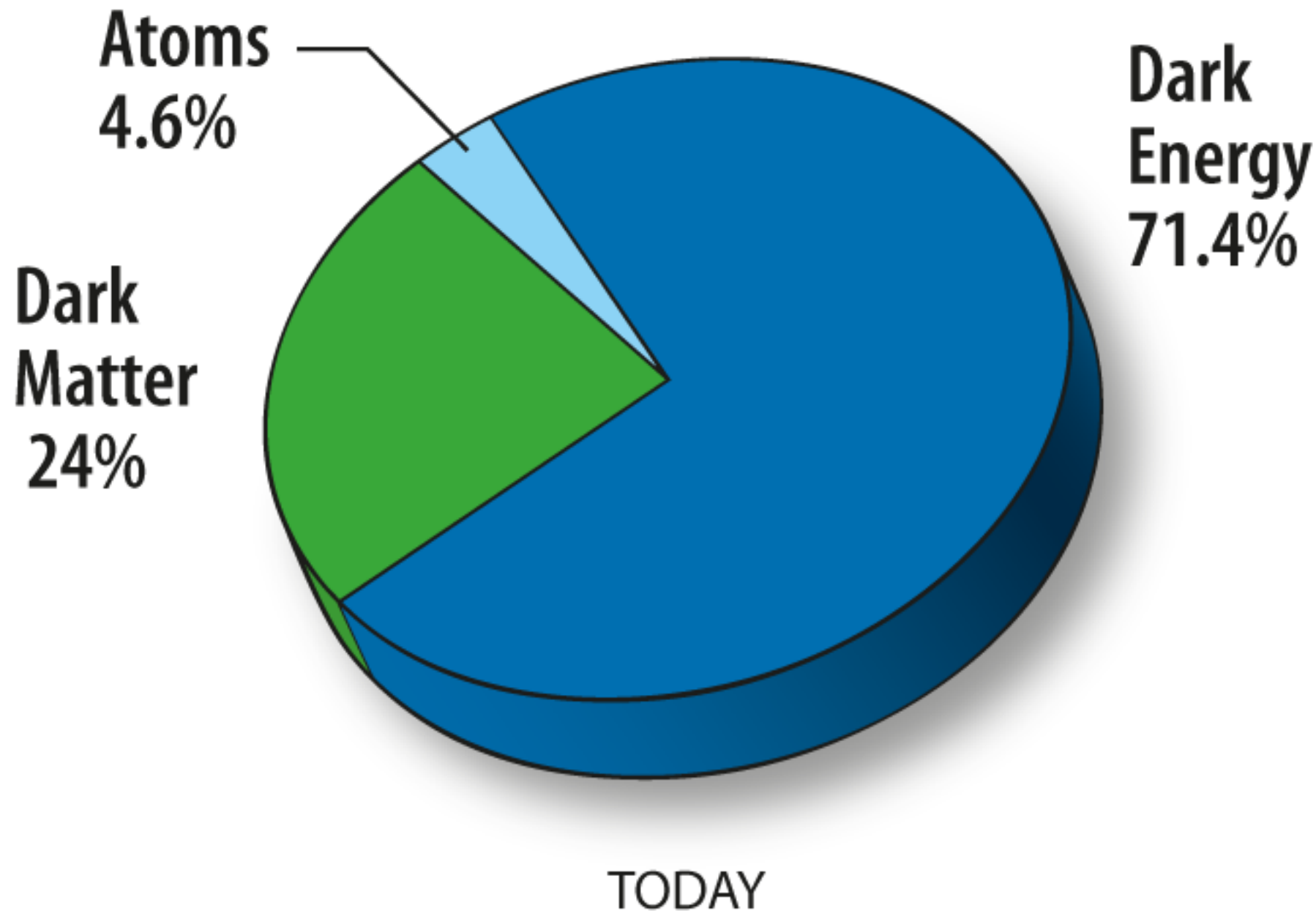
Quo Vadis, DM?

Antonio Delgado
University of Notre Dame

- Introduction: Problems with “standard” DM
- Solutions:
 - Pure Higgsino
 - Blind spots
 - Gravitino
- Conclusion

Collaborators: M.E. Cabrera, A. Casas, A. Martin, M. Quirós and S. Robles

Introduction

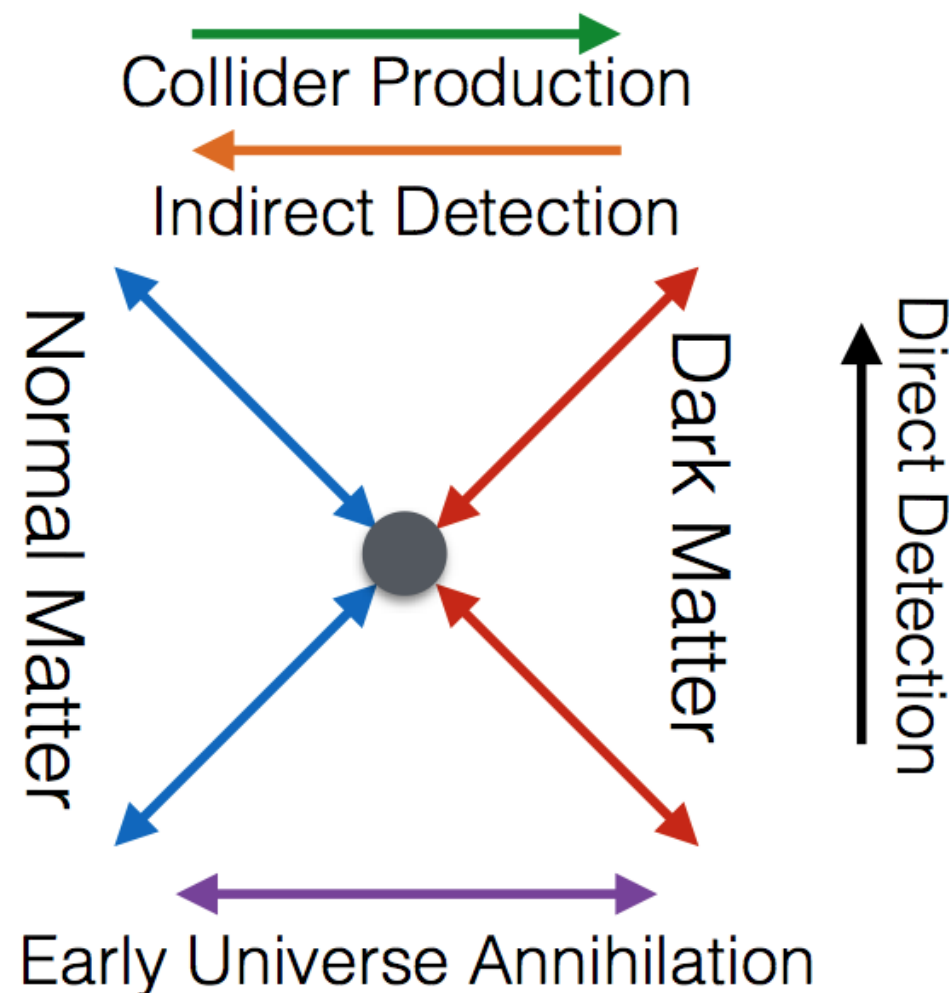


- DM may be the most established reason for physics BSM

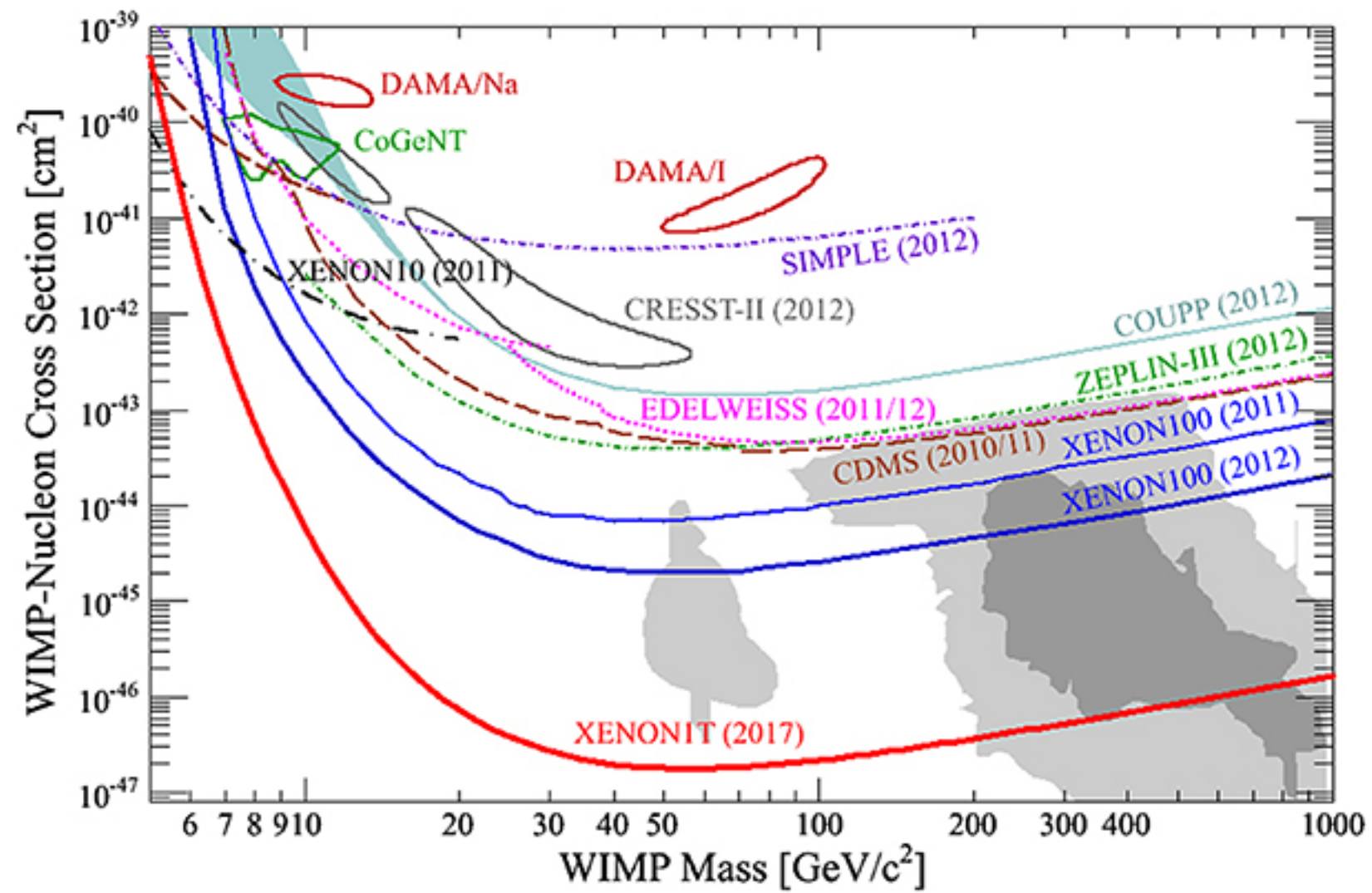
- It turns out that a **WIMP**: a stable massive object with weak interactions and a mass around the EW scale reproduces the observed relic abundance.

$$\Omega h^2 \simeq 0.118$$

- It has interesting experimental consequences.



- But:

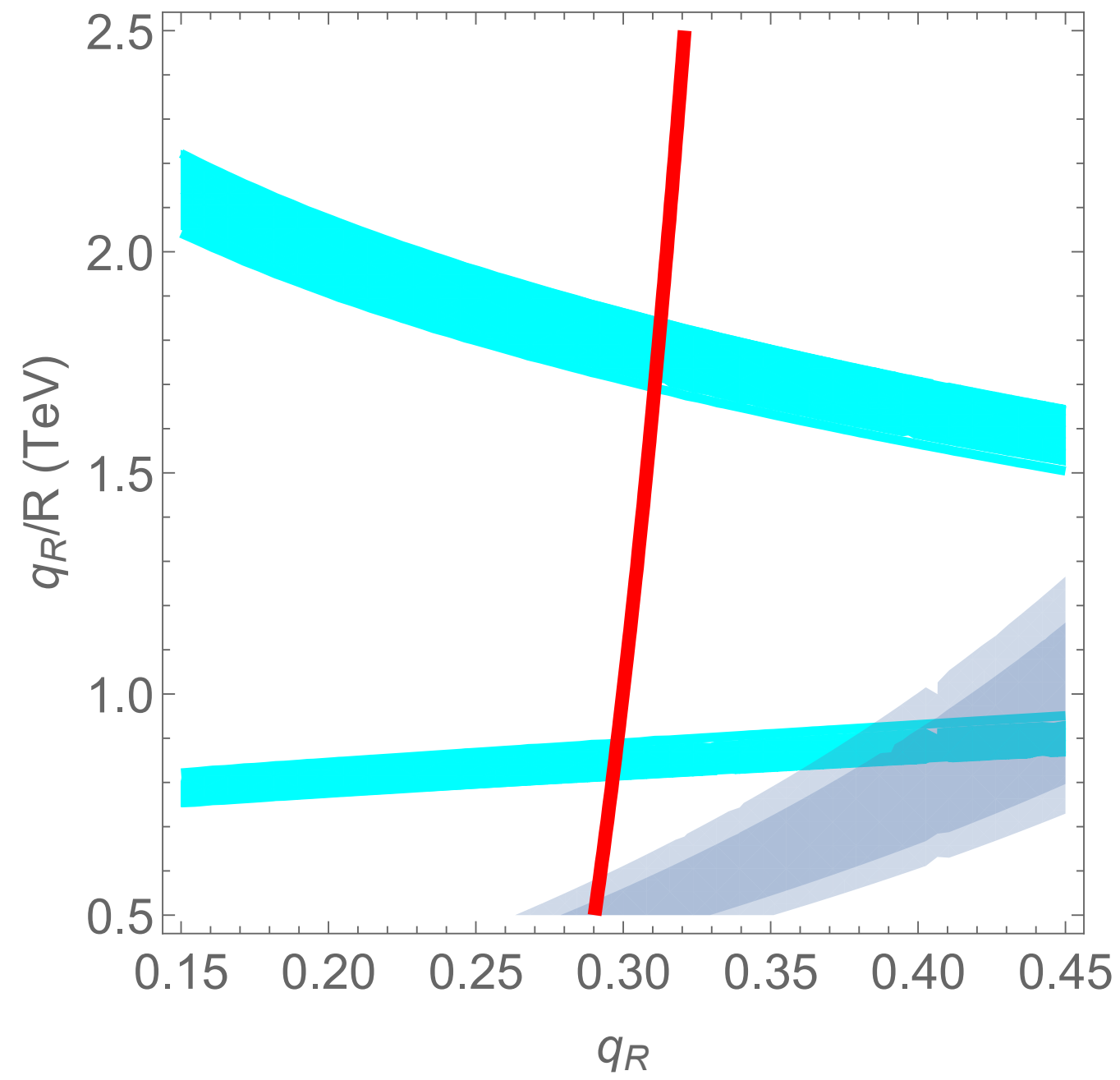


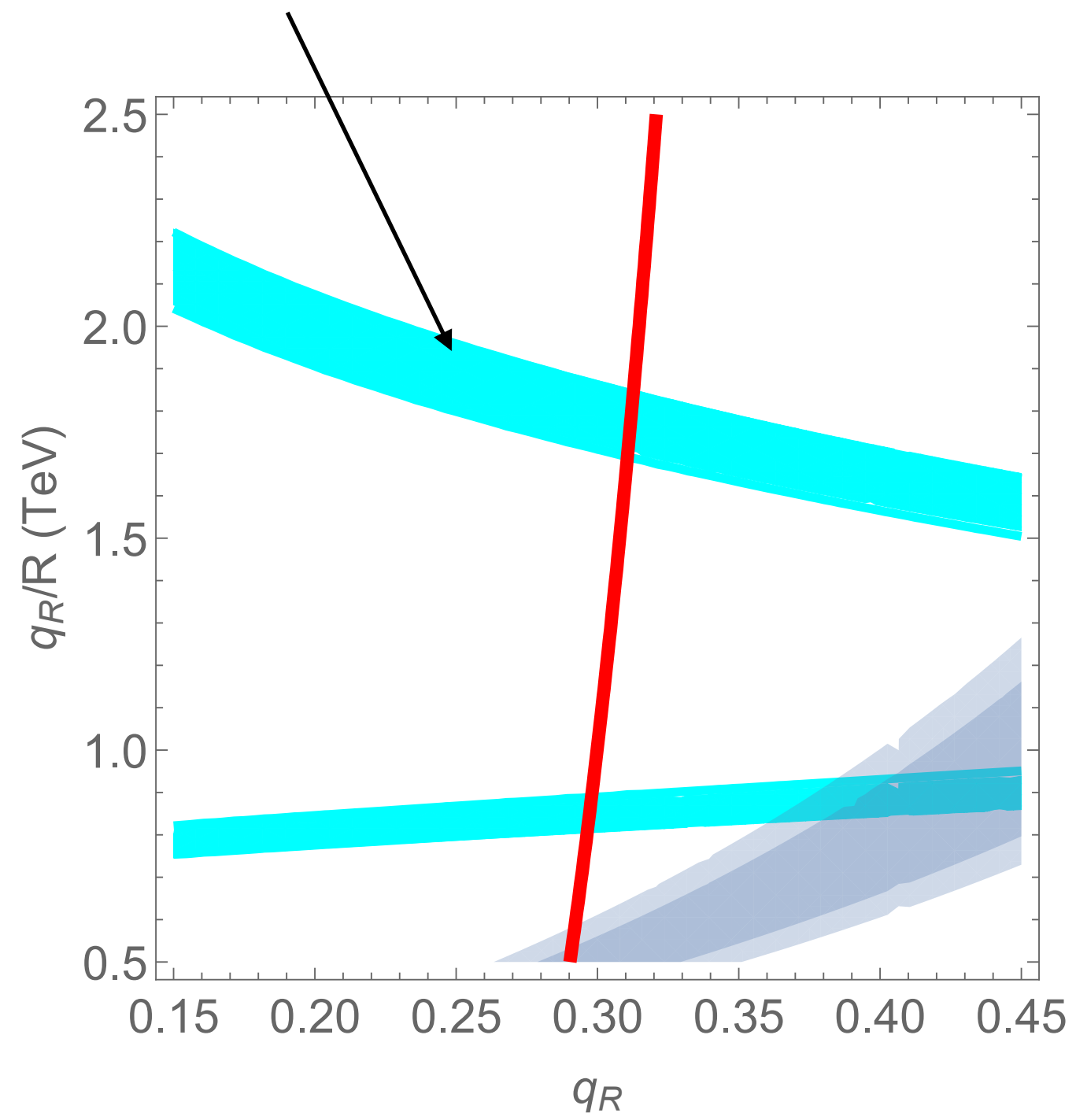
- Most models (well-tempered, higgs portals,...) are excluded by **DD bounds**.
- Among the usual candidates for DM in the **MSSM** (**neutralinos**) the ones with less constraints (specially from direct detections):
 - Pure **Higgsino** with mass $\sim 1.1-1.2$ TeV.
 - Blind spot in a Higgsino-Bino
 - Gravitino

Pure Higgsino

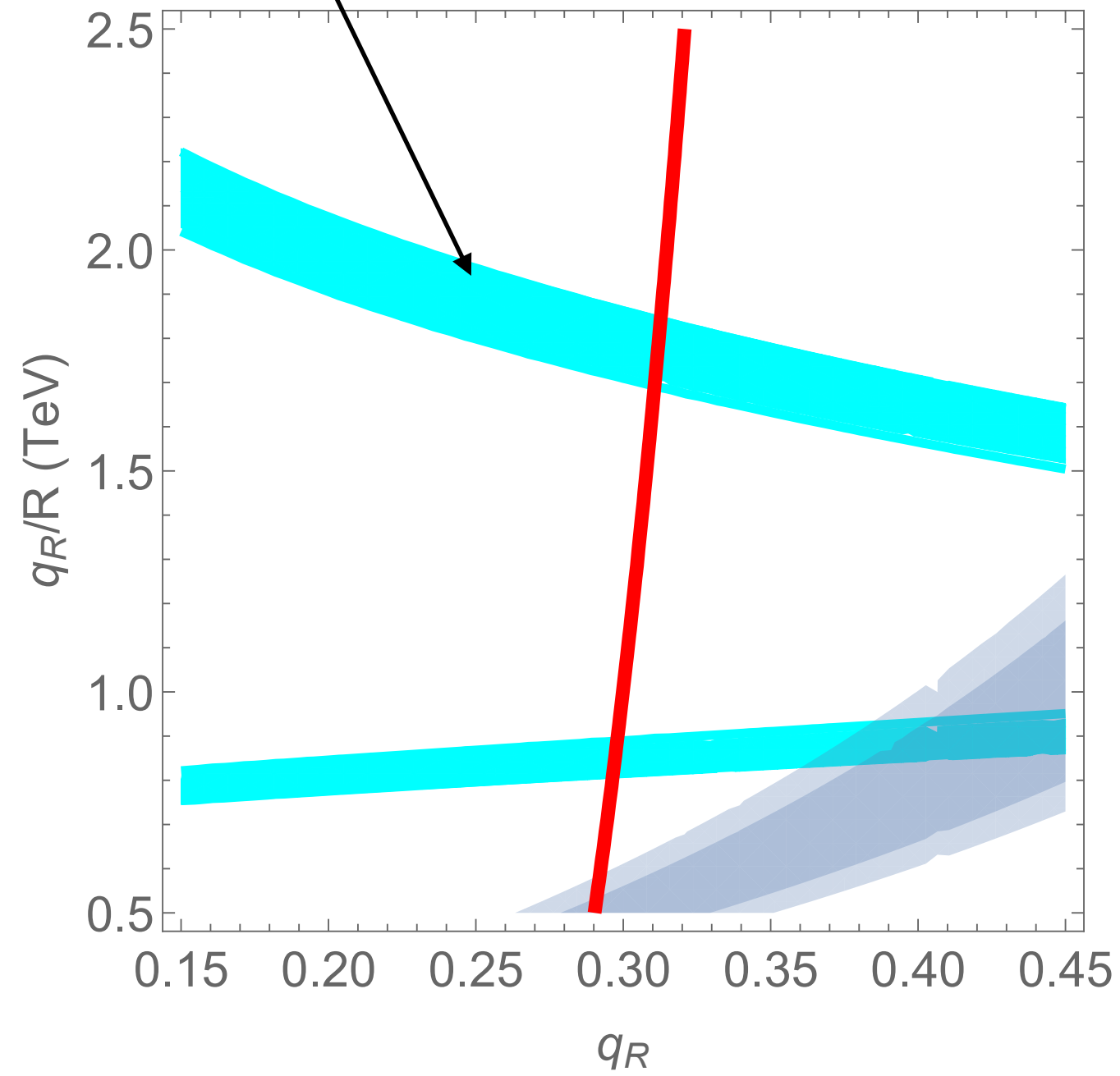
arXiv:1812.08019

- The model is 5D extension of the MSSM.
- The extra dimension of size πR is compactified on an orbifold S^1/Z_2
- The discrete symmetry Z_2 breaks half of the super symmetries making all fields either even/odd
- The model has three free parameters (q_R, q_H, R)

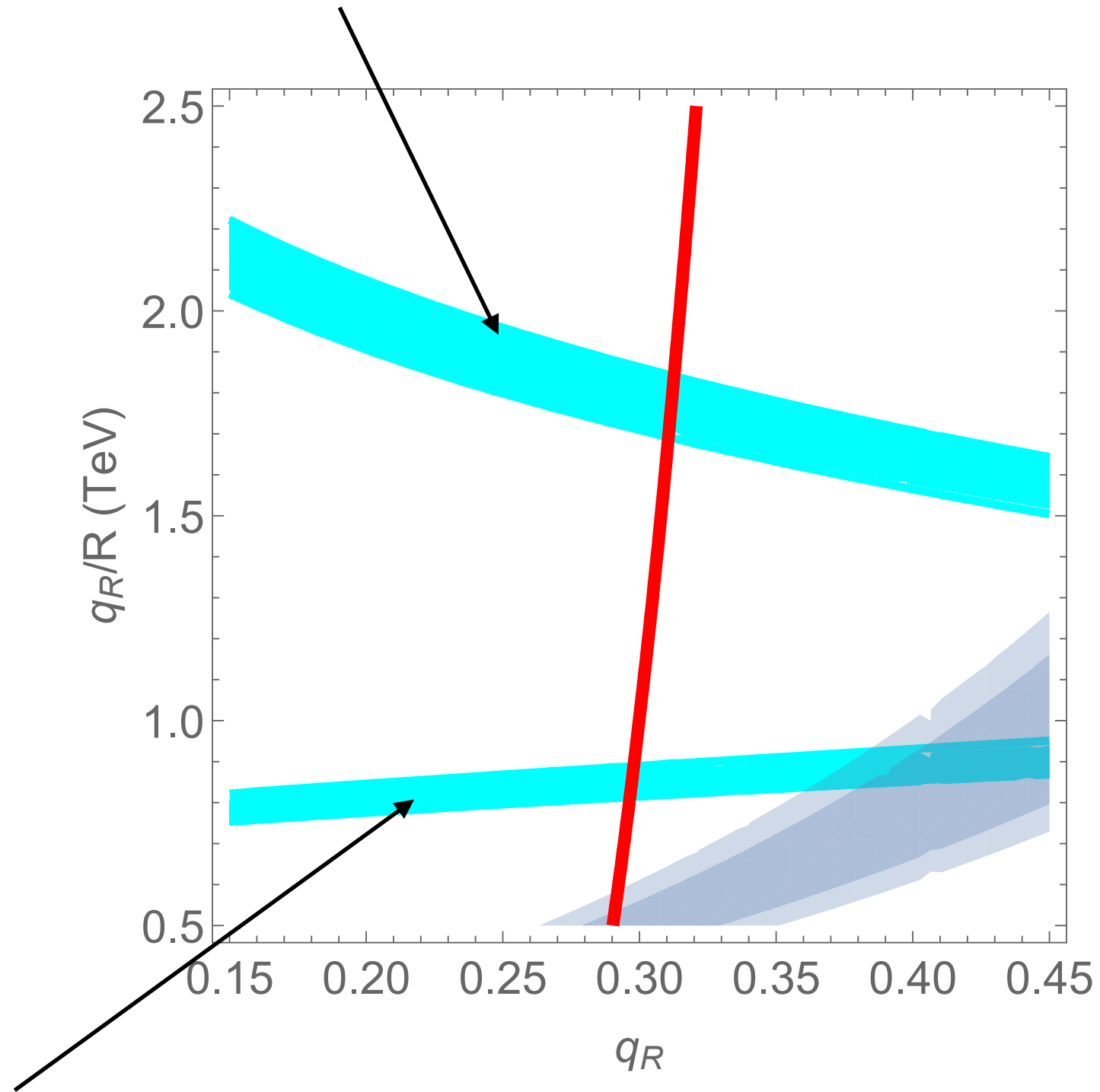




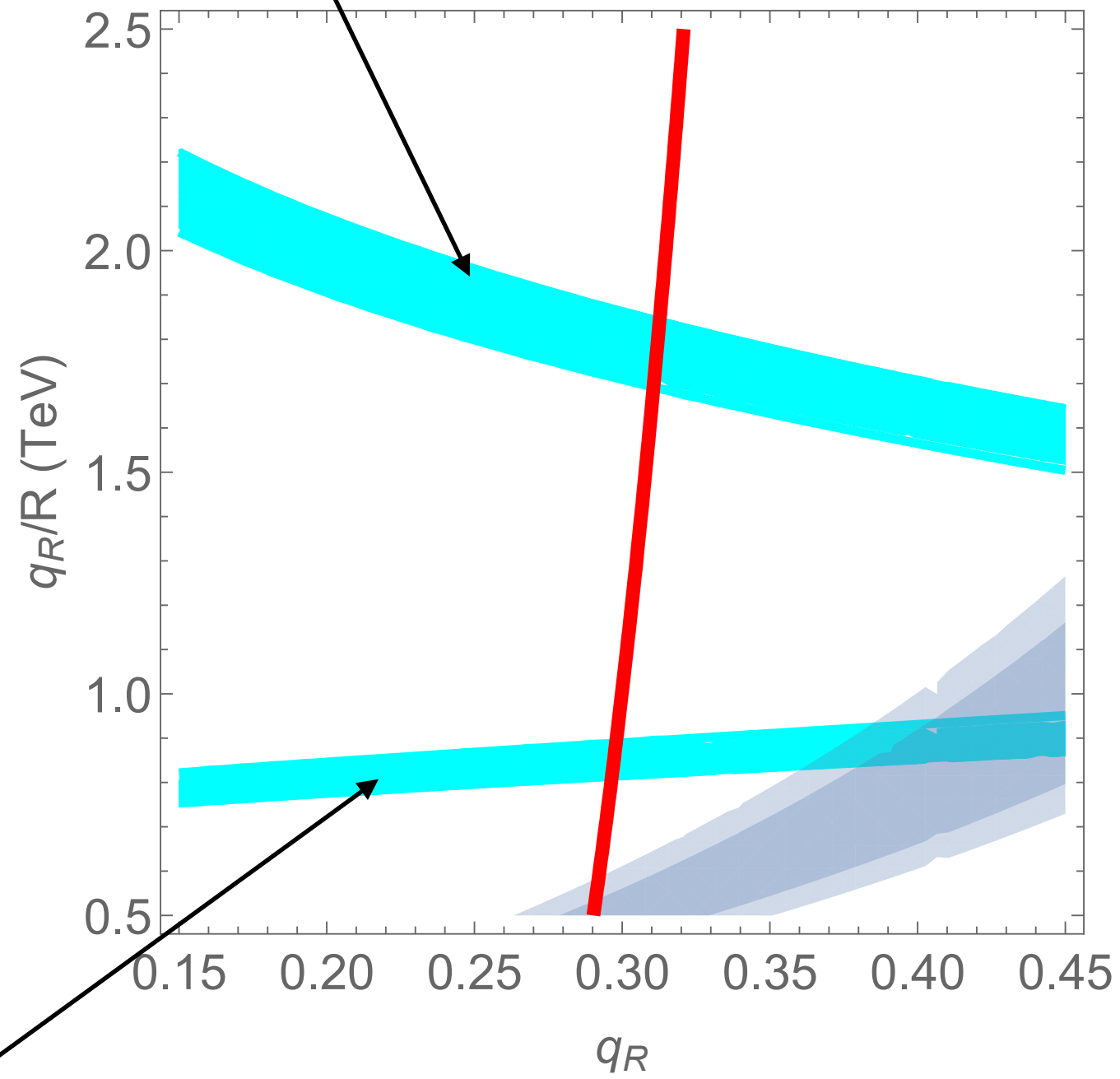
EWSB for 1.1-1.2 TeV Higgsino



EWSB for 1.1-1.2 TeV Higgsino

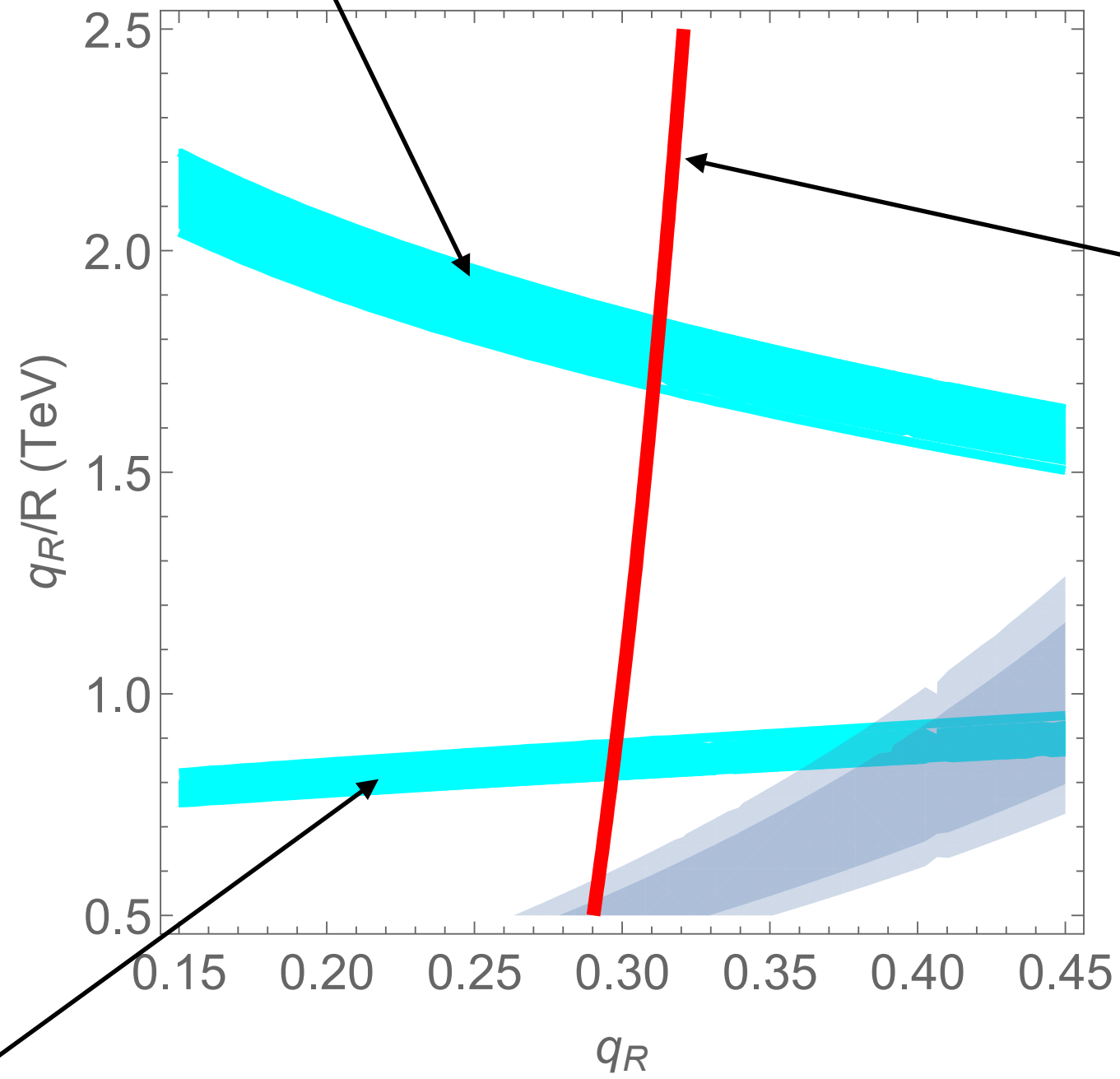


EWSB for 1.1-1.2 TeV Higgsino



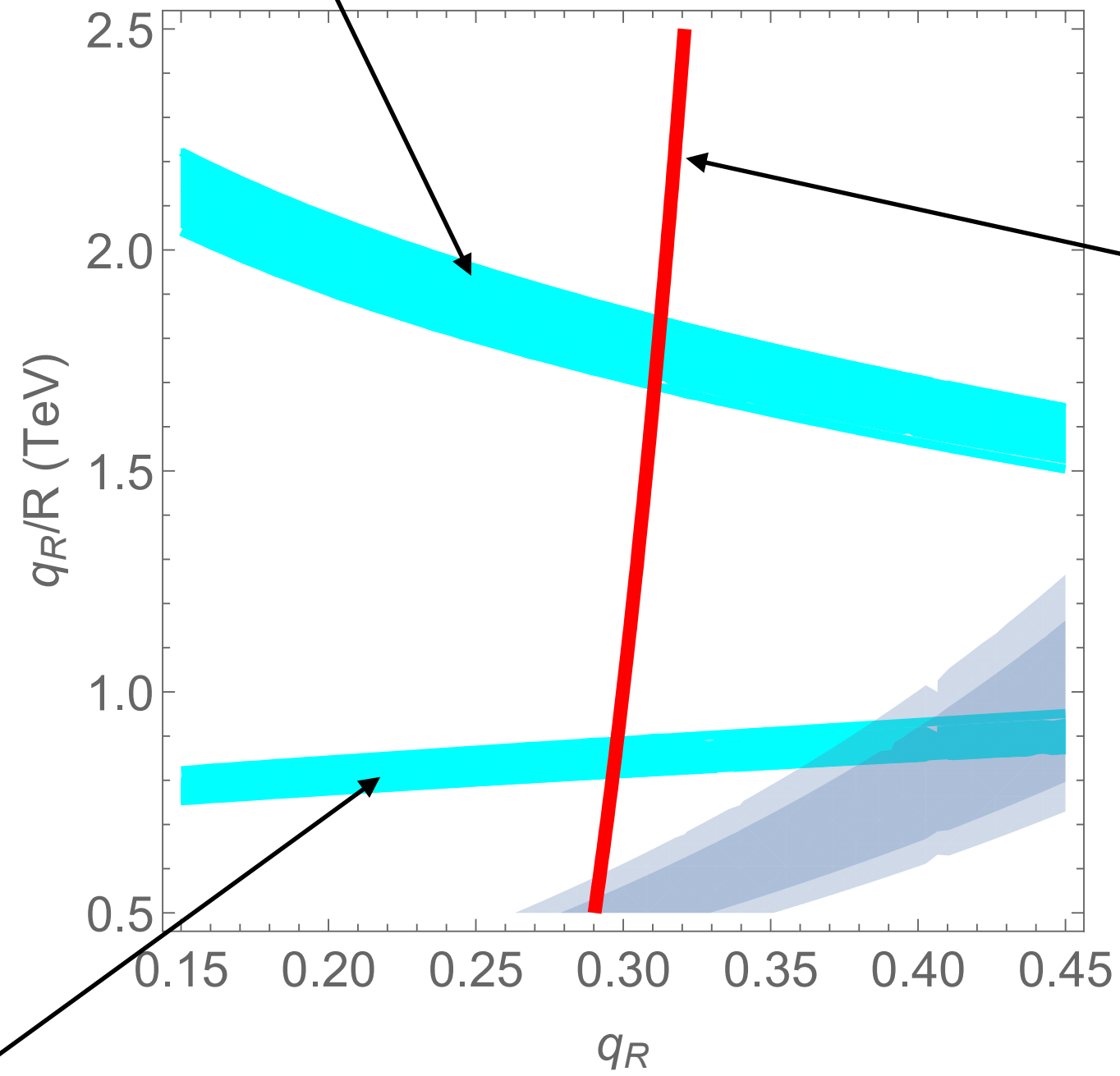
Higgsino not the LSP

EWSB for 1.1-1.2 TeV Higgsino



Higgsino not the LSP

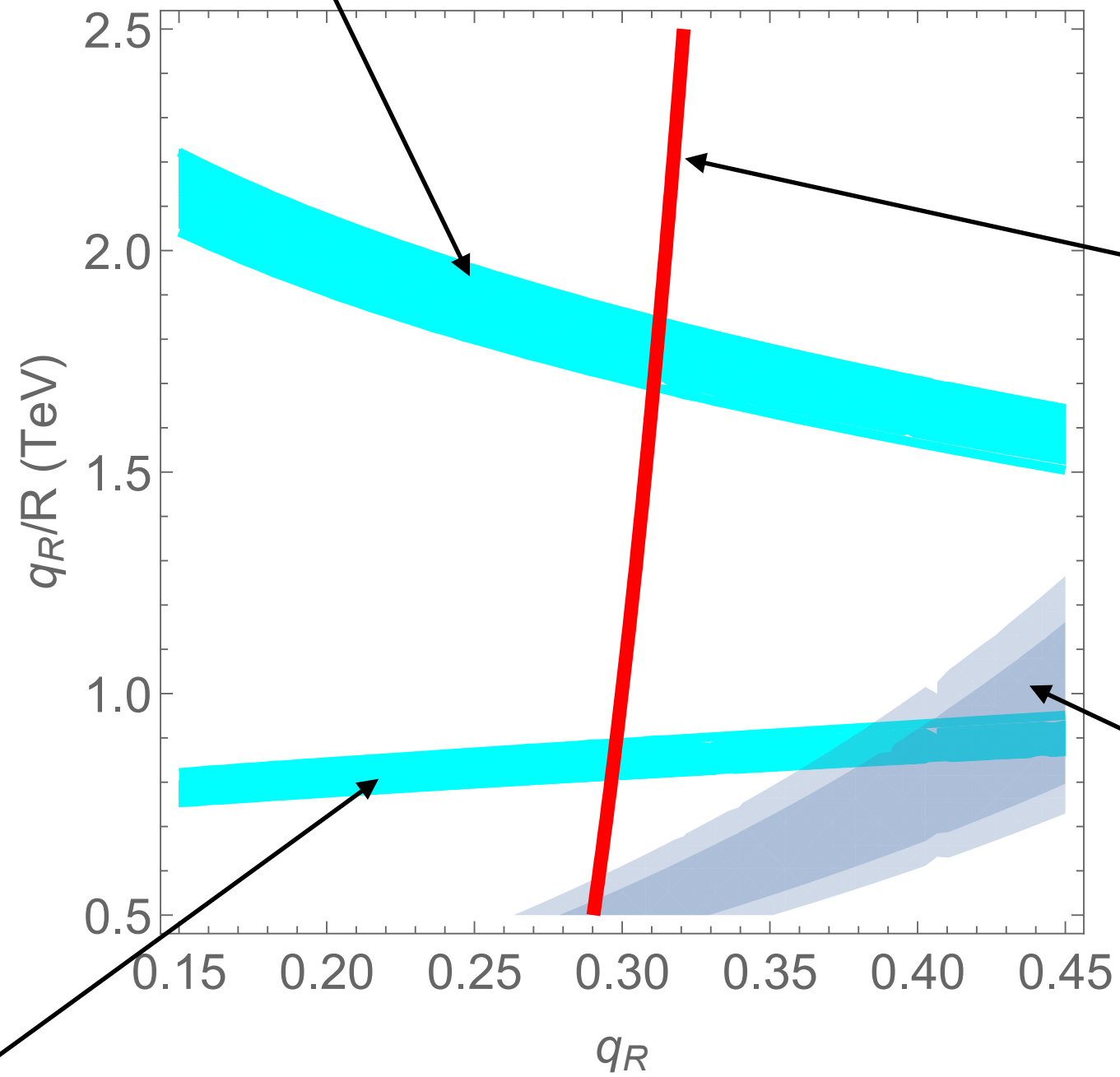
EWSB for 1.1-1.2 TeV Higgsino



$m_h = 125$ GeV

Higgsino not the LSP

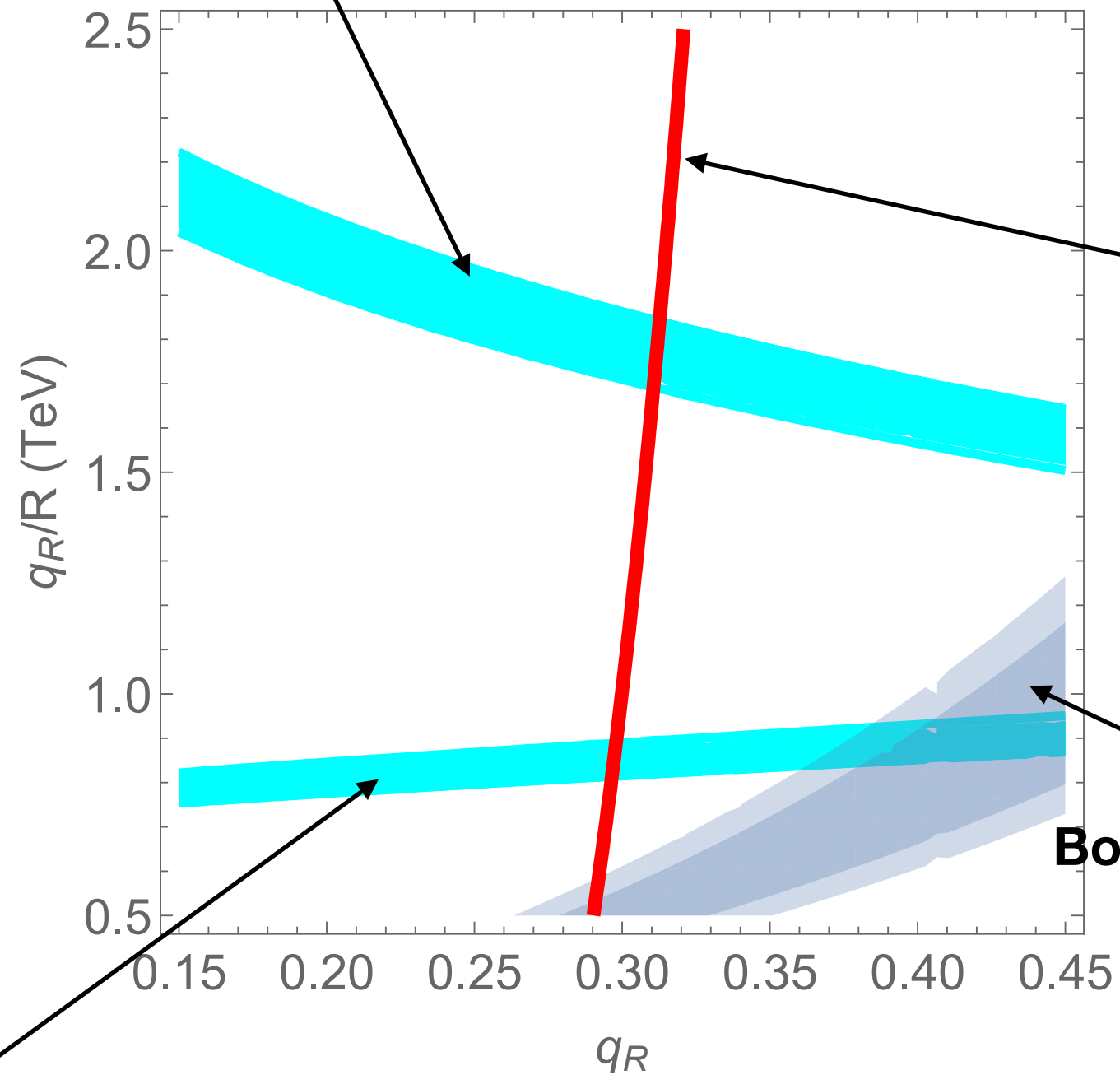
EWSB for 1.1-1.2 TeV Higgsino



$m_h=125$ GeV

Higgsino not the LSP

EWSB for 1.1-1.2 TeV Higgsino



$m_h=125$ GeV

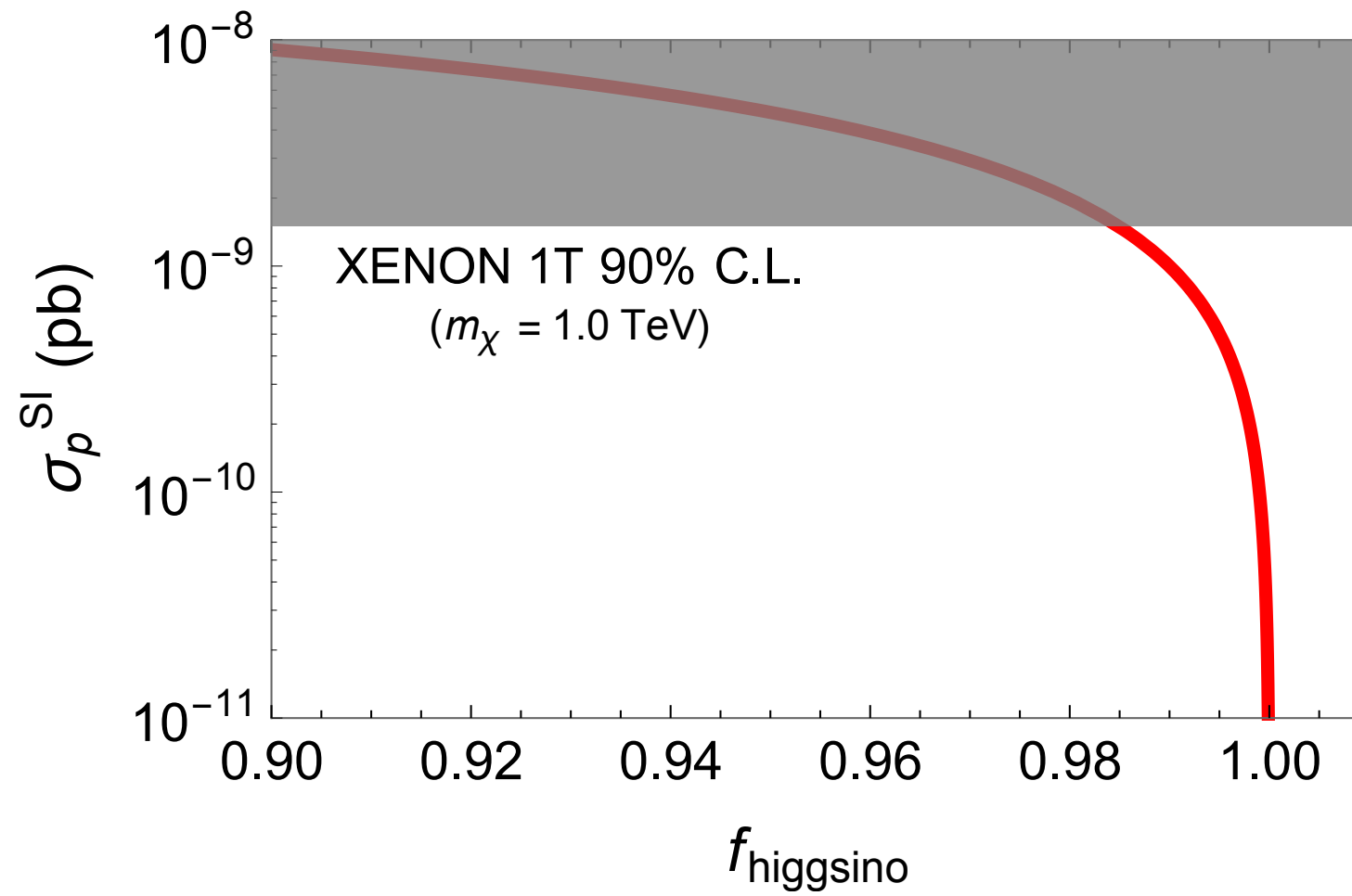
Both higgses get a vev

Higgsino not the LSP

Point	q_R	q_H	$1/R$ (TeV)	q_R/R (TeV)	q_H/R (TeV)	$M_{\tilde{g}}$ (TeV)	$m_{\mathcal{H}'}$ (TeV)
A	0.31	0.2	5.5	1.7	1.1	2.0	2.7
B	0.31	0.2	5.9	1.9	1.2	2.1	2.9

- Range of values for masses of the LSP between 1.1-1.2 TeV

1802.04097



- The LSP is 99% Higgsino and has a cross section of 10^{-10} pb

- A 2 TeV gluino may need HL ($\sim 1 \text{ ab}^{-1}$) LHC
- The best chance to discover the Higgsino is in direct detection experiments like XENON-nT or LZ
- Fine tuning in this model is smaller than normal due to:
 - Low supersymmetry breaking scale
 - The electroweak scale depends linearly and not quadratically on the parameters

Blind Spots

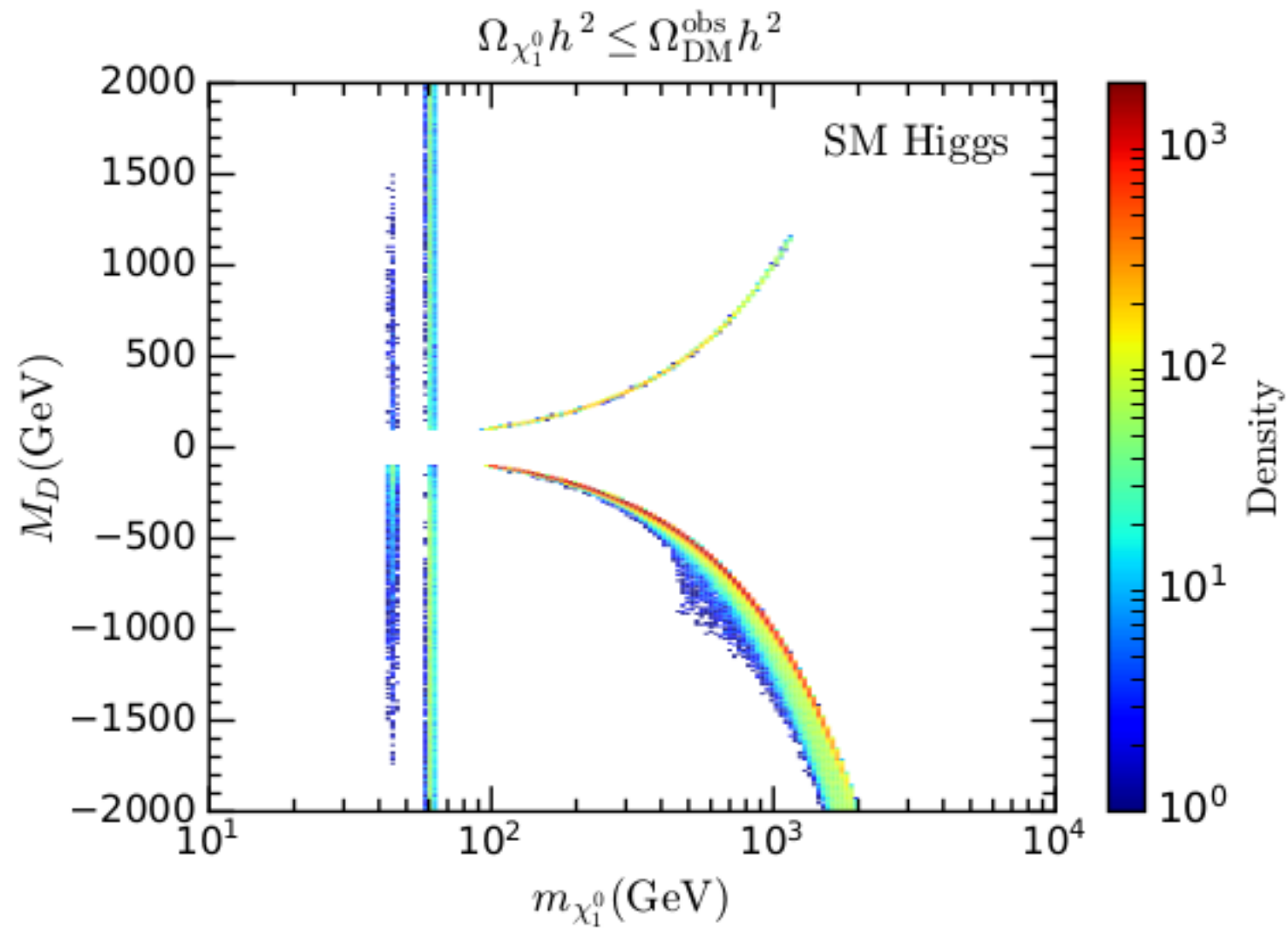
arXiv:1912.01578

- Blind spots corresponds to points in parameter space where the coupling of the DM to nuclei is suppressed.
- We are going to analyze those in a generic model where DM is an admixture of a singlet and doublet fermion (bino-higgsino) in a 2HDM

$$- \mathcal{L} \supset \frac{1}{2} M_S S S + M_D D_1 D_2 + y_1^1 S D_1 \bar{\Phi}_1 + y_2^1 S D_2 \Phi_1 + y_1^2 S D_1 \bar{\Phi}_2 + y_2^2 S D_2 \Phi_2 + h.c.$$

- Higgs measurements force us to be in the alignment limit

Decoupling limit



$$y_{h\chi_1\chi_1} \propto \pm M_D \sin 2\theta + |m_{\chi_1^0}|$$

Alignment without decoupling

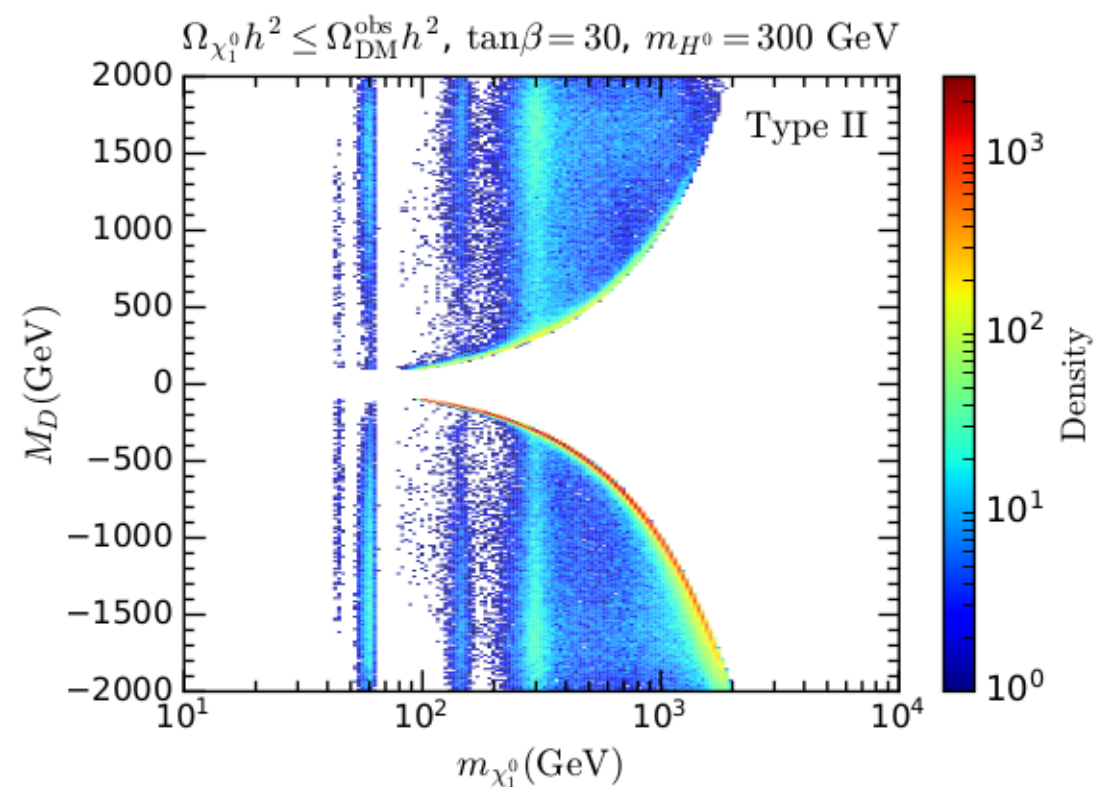
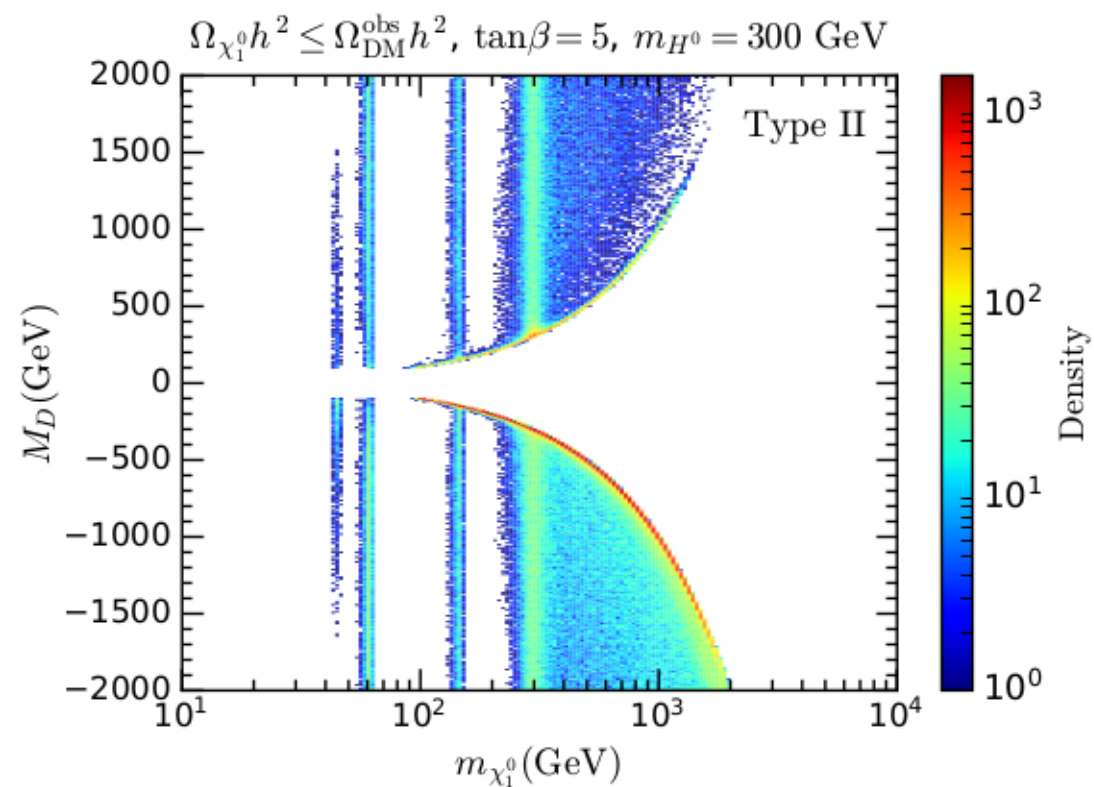
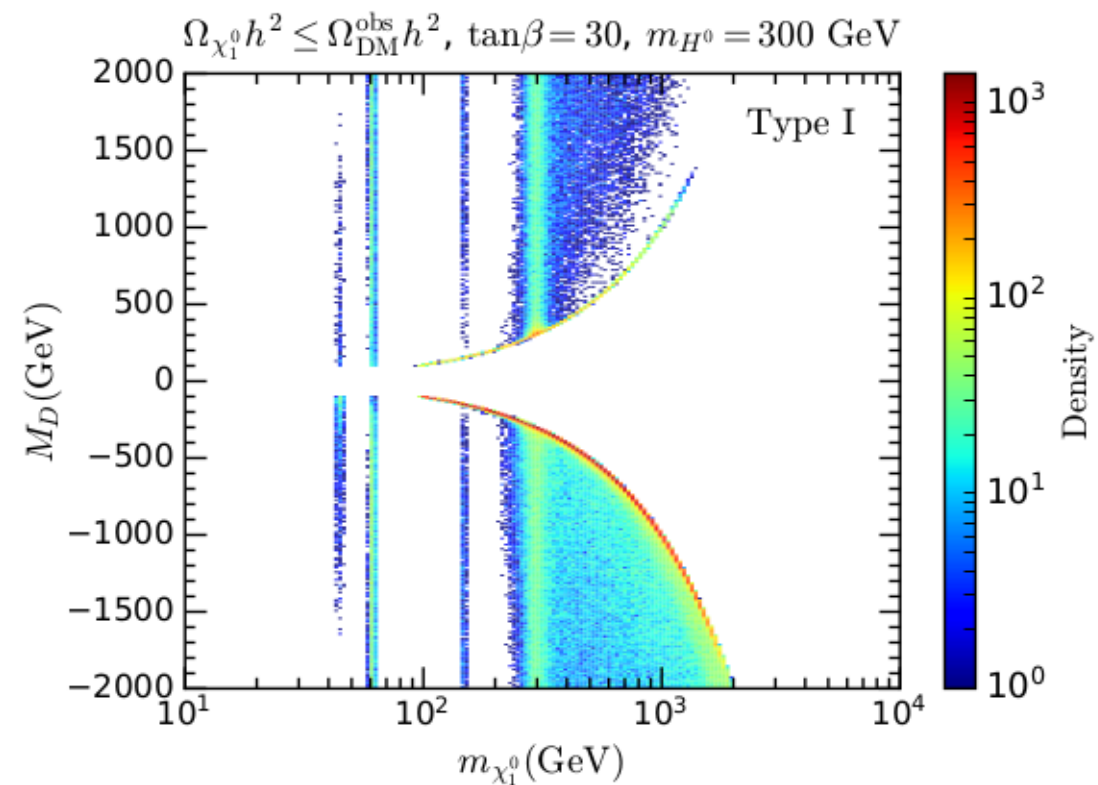
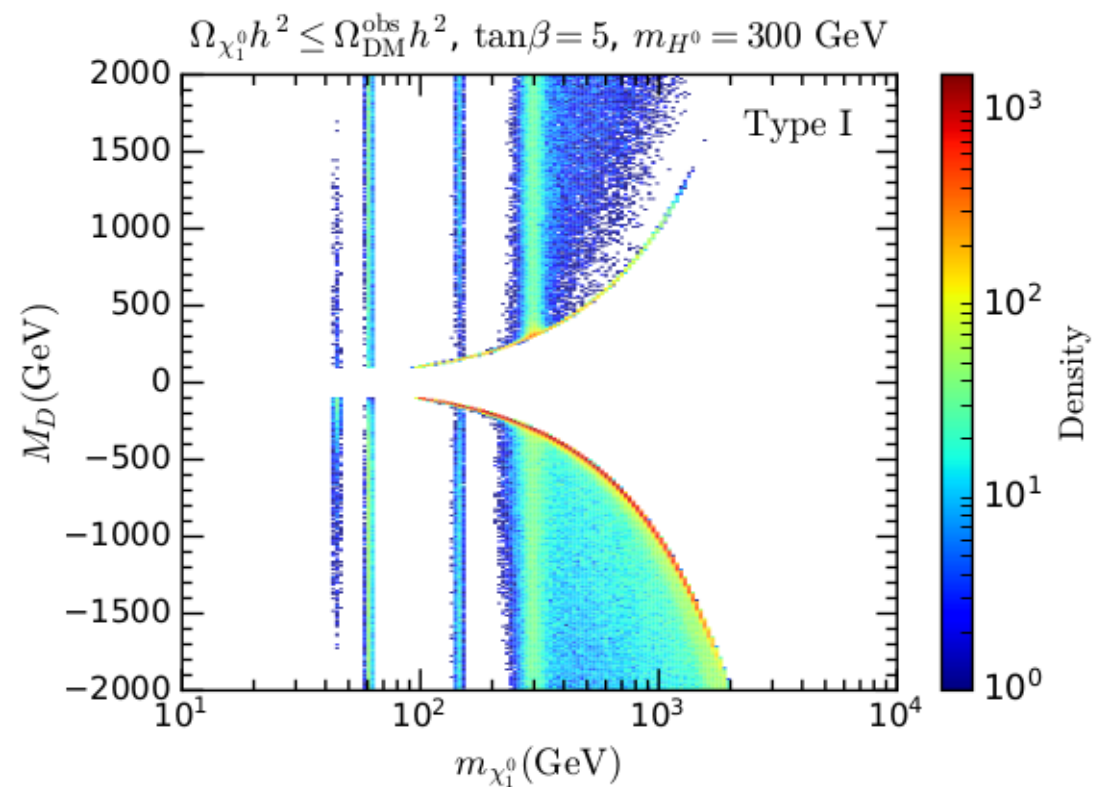
Z6=0

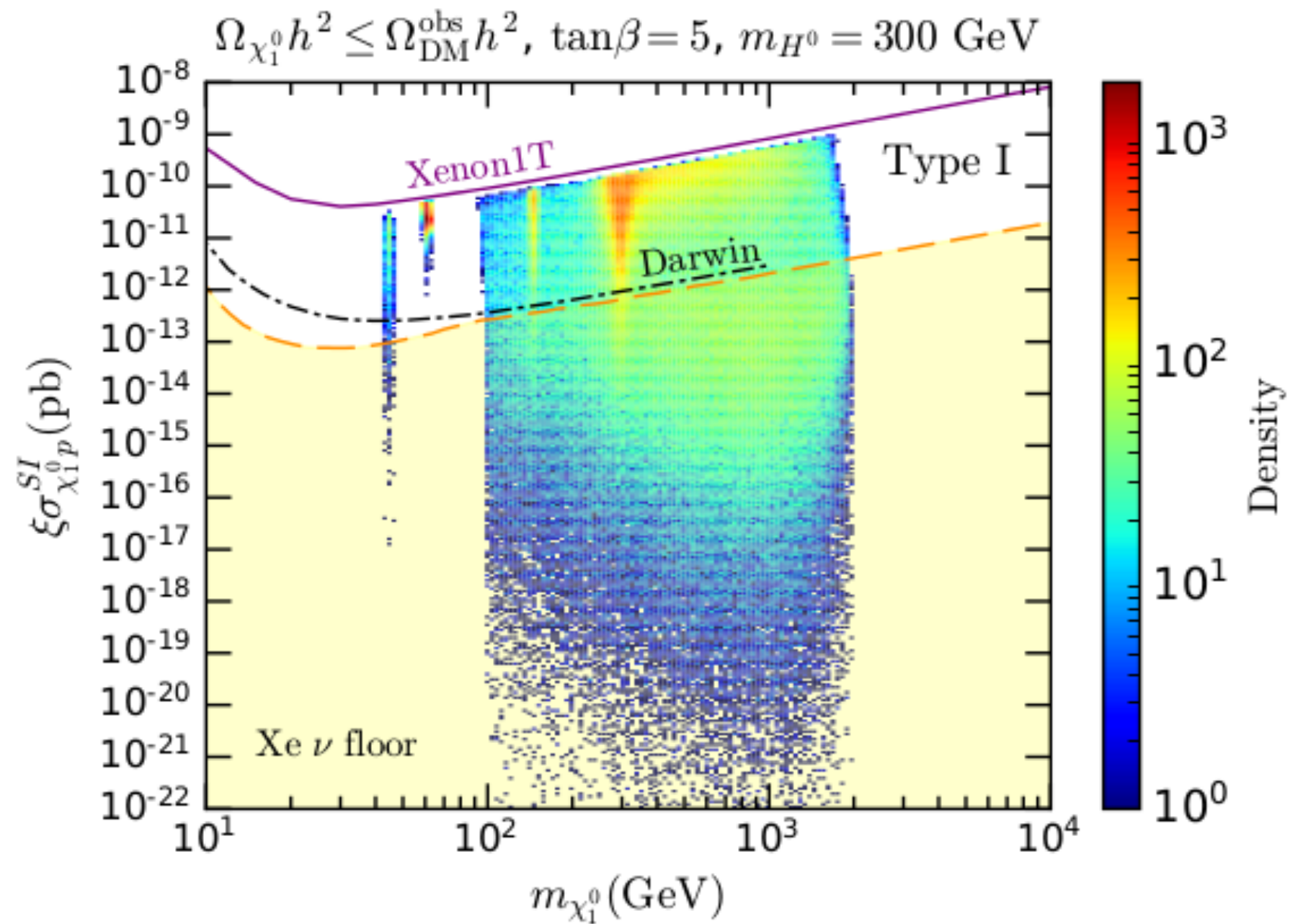
$$y_{\text{DD}}^{\text{eff}} \equiv \sum_q \left[y_{h\chi_1\chi_1} + \frac{m_h^2}{m_H^2} C_q y_{H\chi_1\chi_1} \right] f_q^N$$

$$y_{h\chi_i\chi_i} = -\frac{1}{2\mathcal{D}} y^2 v (\pm M_D \sin 2\theta + |m_{\chi_i^0}|) ,$$

$$y_{H\chi_i\chi_i} = -\frac{1}{2\mathcal{D}} y \tilde{y} v (\pm M_D \sin(\theta + \tilde{\theta}) + |m_{\chi_i^0}| \cos(\theta - \tilde{\theta}))$$

$$\mathcal{D} = \pm 2|m_{\chi_i^0}|M_S - 3m_{\chi_i^0}^2 + \frac{1}{2}y^2v^2 + M_D^2$$



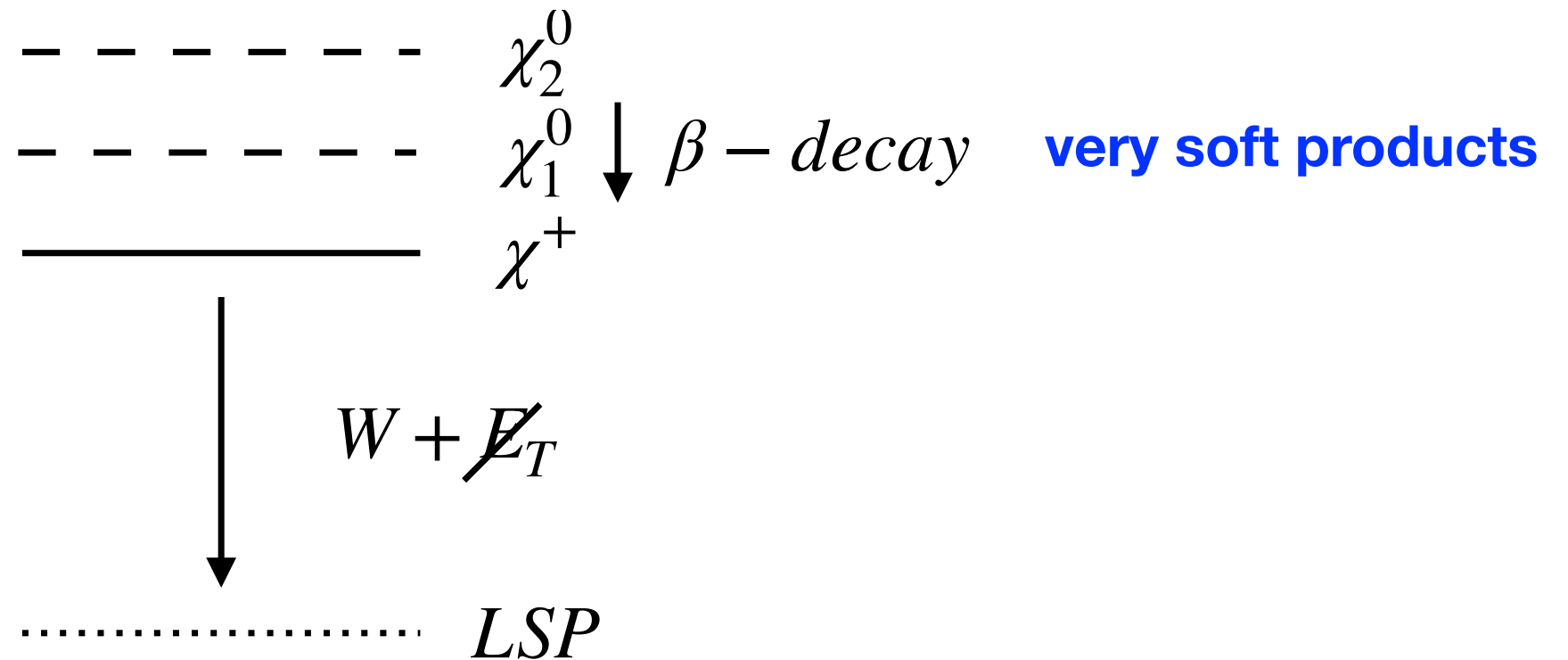


SI DD cross section for a 2HDM

Gravitino

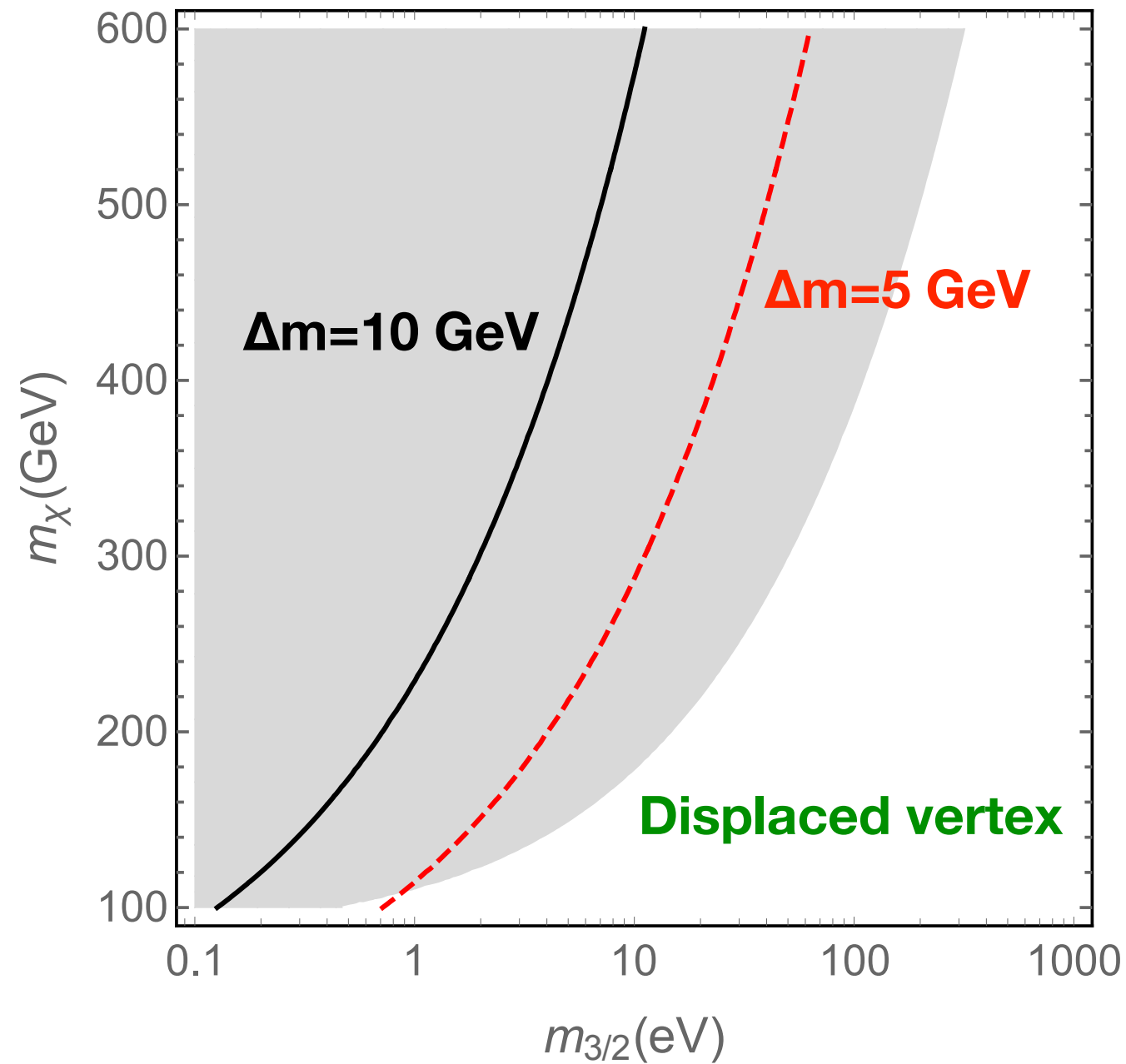
arXiv:1912.03215

- One candidate for DM which is insensitive to DD measurements is the Gravitino
- It is the LSP in models of GMSB.
- It allows to a spectrum where the NLSP may be a chargino leading to a very interesting signal.



Sample spectrum with the chargino as NLSP

- This spectrum is insensitive to tri-leptons if the neutralinos do not decay to the LSP directly and the whole doublet contributes to the same signal **WW+MET**



Region of the parameter space where the neutralino do not decay to the LSP

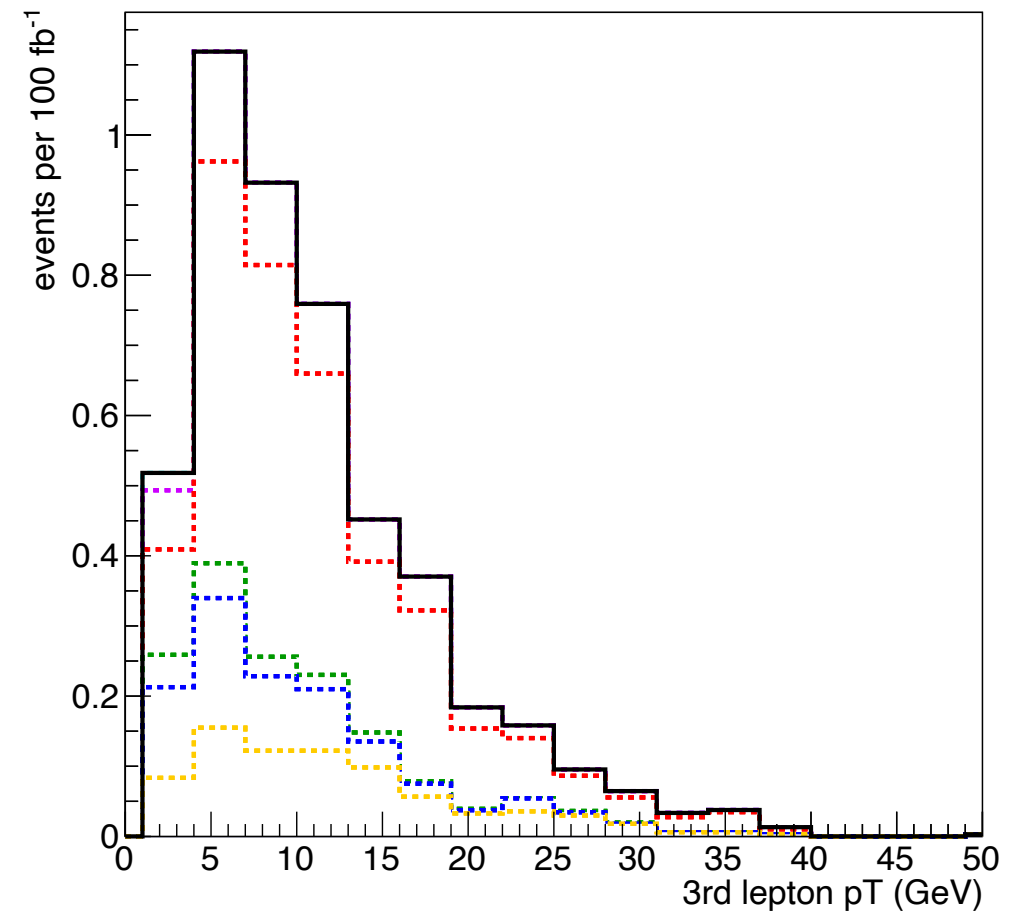
- There is a search ([arXiv:1908.08215](#)) for WW+MET, with the full run II date

- There is a search ([arXiv:1908.08215](#)) for WW+MET, with the full run II date

**We have reinterpreted
the bound and we obtained
 $m > 460$ GeV
(ATLAS quotes a bound of 410 GeV
For an isolated chargino)**

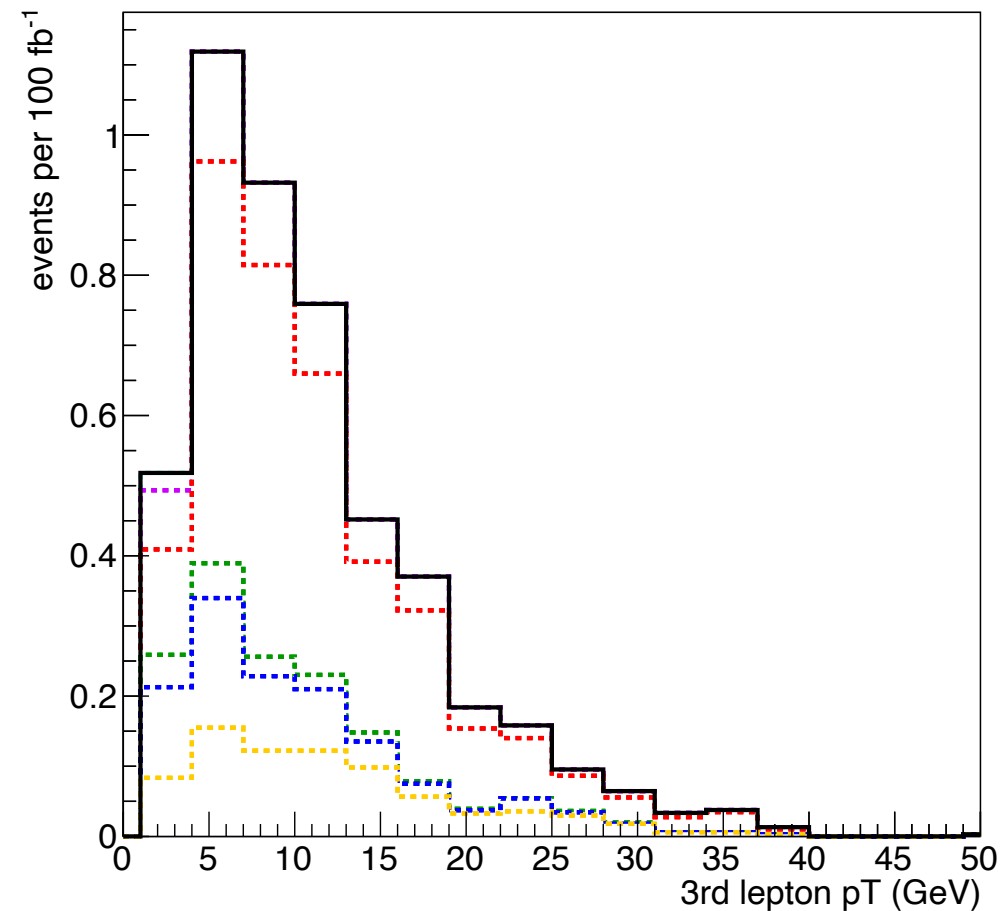
- There is a search ([arXiv:1908.08215](https://arxiv.org/abs/1908.08215)) for WW+MET, with the full run II date

**We have reinterpreted
the bound and we obtained
 $m > 460$ GeV
(ATLAS quotes a bound of 410 GeV
For an isolated chargino)**



- There is a search ([arXiv:1908.08215](https://arxiv.org/abs/1908.08215)) for WW+MET, with the full run II date

**We have reinterpreted
the bound and we obtained
 $m > 460$ GeV
(ATLAS quotes a bound of 410 GeV
For an isolated chargino)**



**The figure indicates the spectrum of the
Third lepton that could be use
To discriminate between models**

Conclusions

- In this talk I have shown three different scenarios of DM that escape DD detection:
 - Pure Higgsino (~ 1.1 TeV) in an extra dimensional model
 - Blind spots in a 2HDM in the alignment without decoupling limit
 - Chargino NLSP in GMSB
- There are still a lot of parameter space in WIMP scenarios that can lead to very interesting signatures. Specially in new colliders (FCC-hh, muon collider) ‘work in progress’