Quo Vadis, DM?

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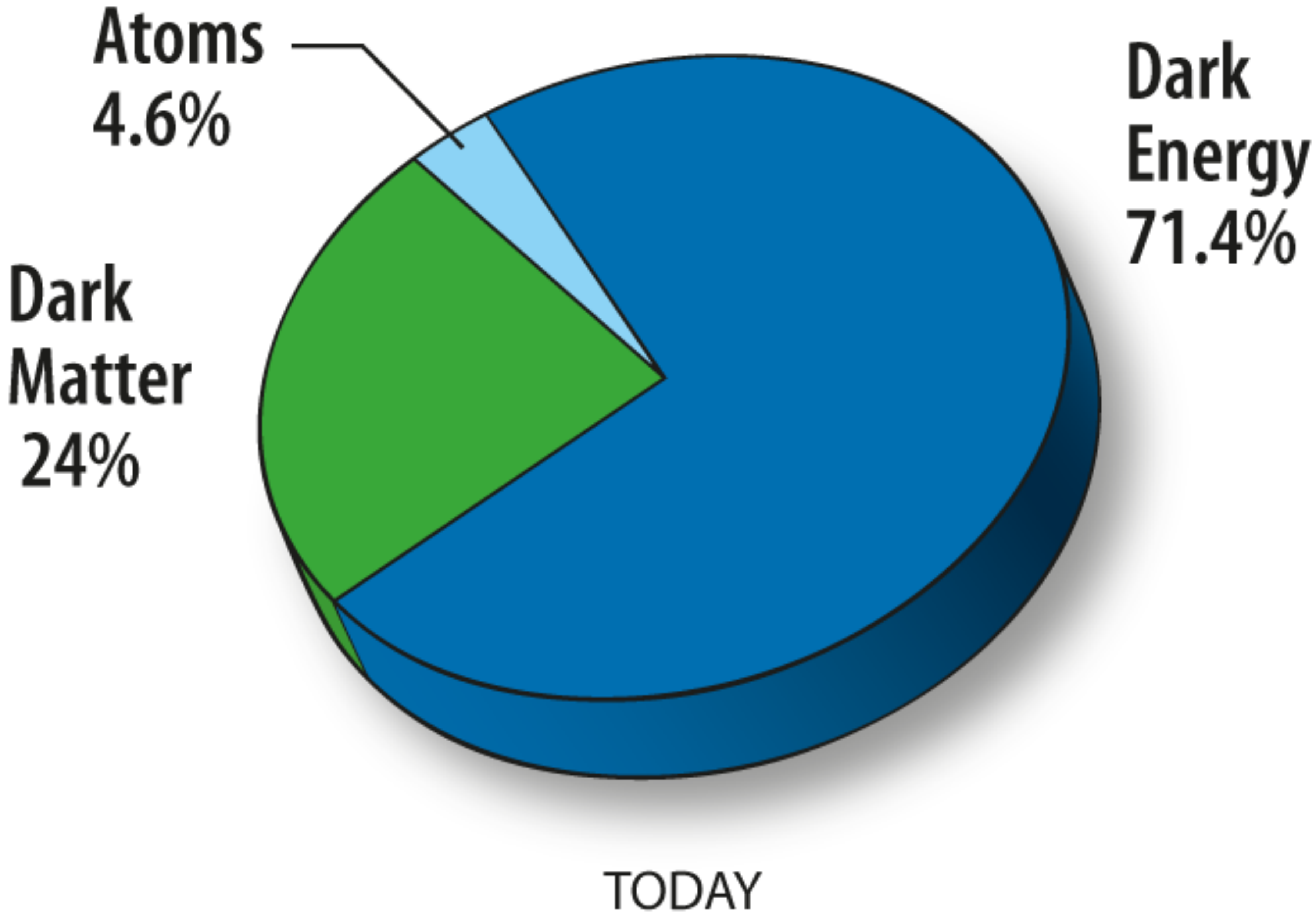
- Introduction: Problems with “standard" DM
- Solutions:
  - Pure Higgisino
  - Blind spots
  - Gravitino
- Conclusion

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

Introduction

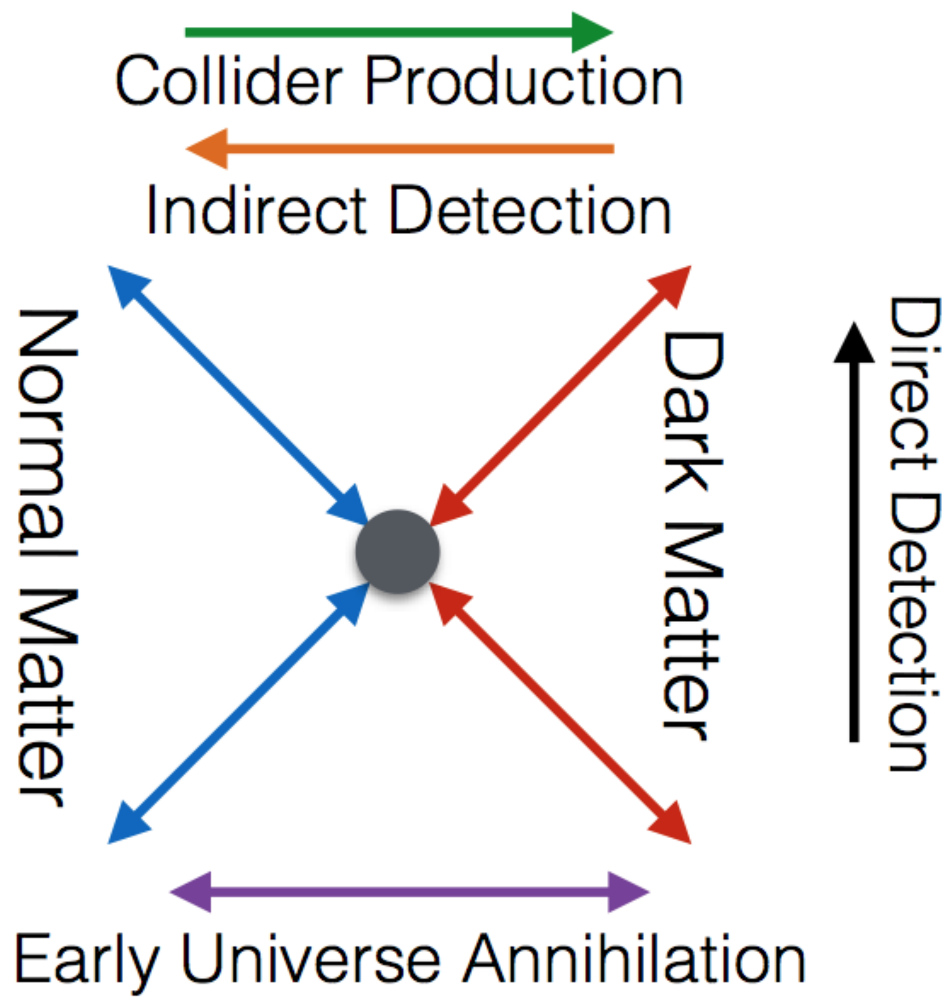


- DM may be the most stablished reason for physics BSM

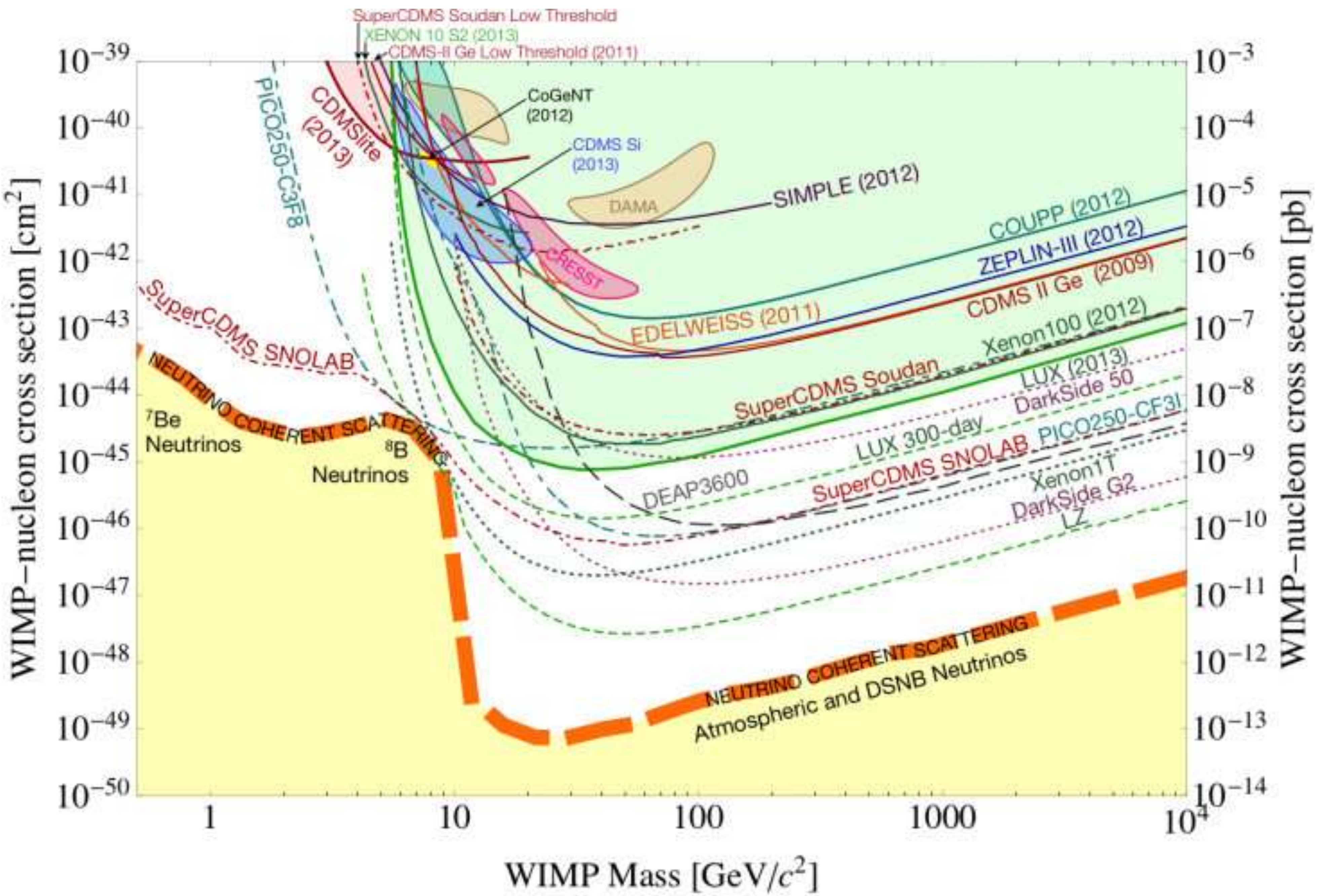
- It turns out that a WIMP: a stable massive object with weak interactions and a mass around the EW scale reproduces the observed relic abundance.

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

- It has interesting experimental consequences.



- But:



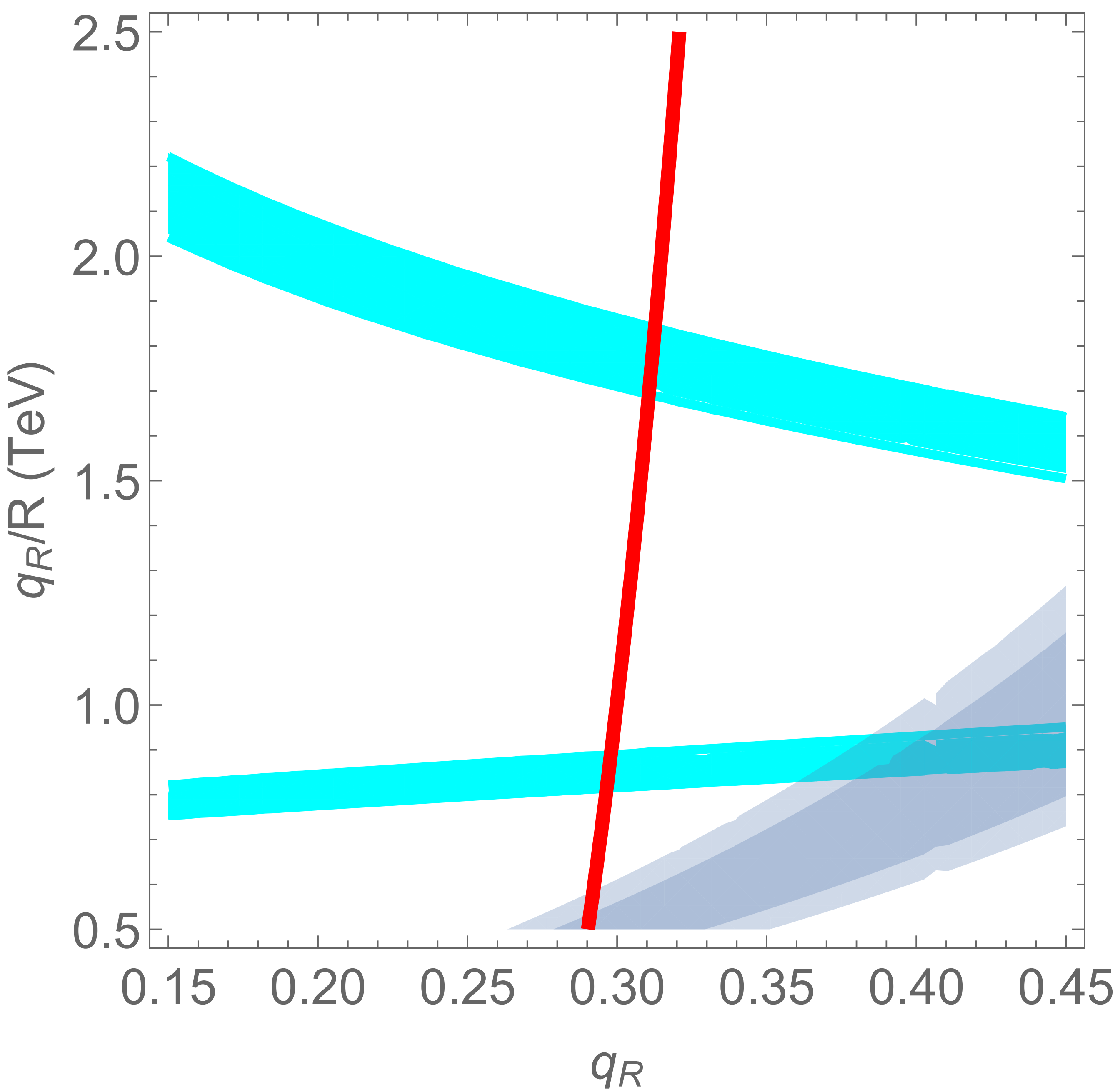
SuperCDMS Soudan Low Threshold
XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
CRESST
CDMSlite (2013)
PICO250-C3F8
SuperCDMS SNOLAB
NEUTRINO COHERENT SCATTERING
7Be Neutrinos
8B Neutrinos
Xenon100 (2012)
SuperCDMS Soudan
LUX (2013)
DarkSide 50
PICO250-CF3I
LUX 300-day
SuperCDMS SNOLAB
DEAP3600
Xenon1T
DarkSide G2
LZ
Atmospheric and DSNB Neutrinos
WIMP–nucleon cross section [cm2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c2]

- 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 constrains (specially from direct detections):
  - Pure Higgsino with mass ~1.1-1.2 TeV.
  - Blind spot in a Higgsino-Bino
  - Gravitino

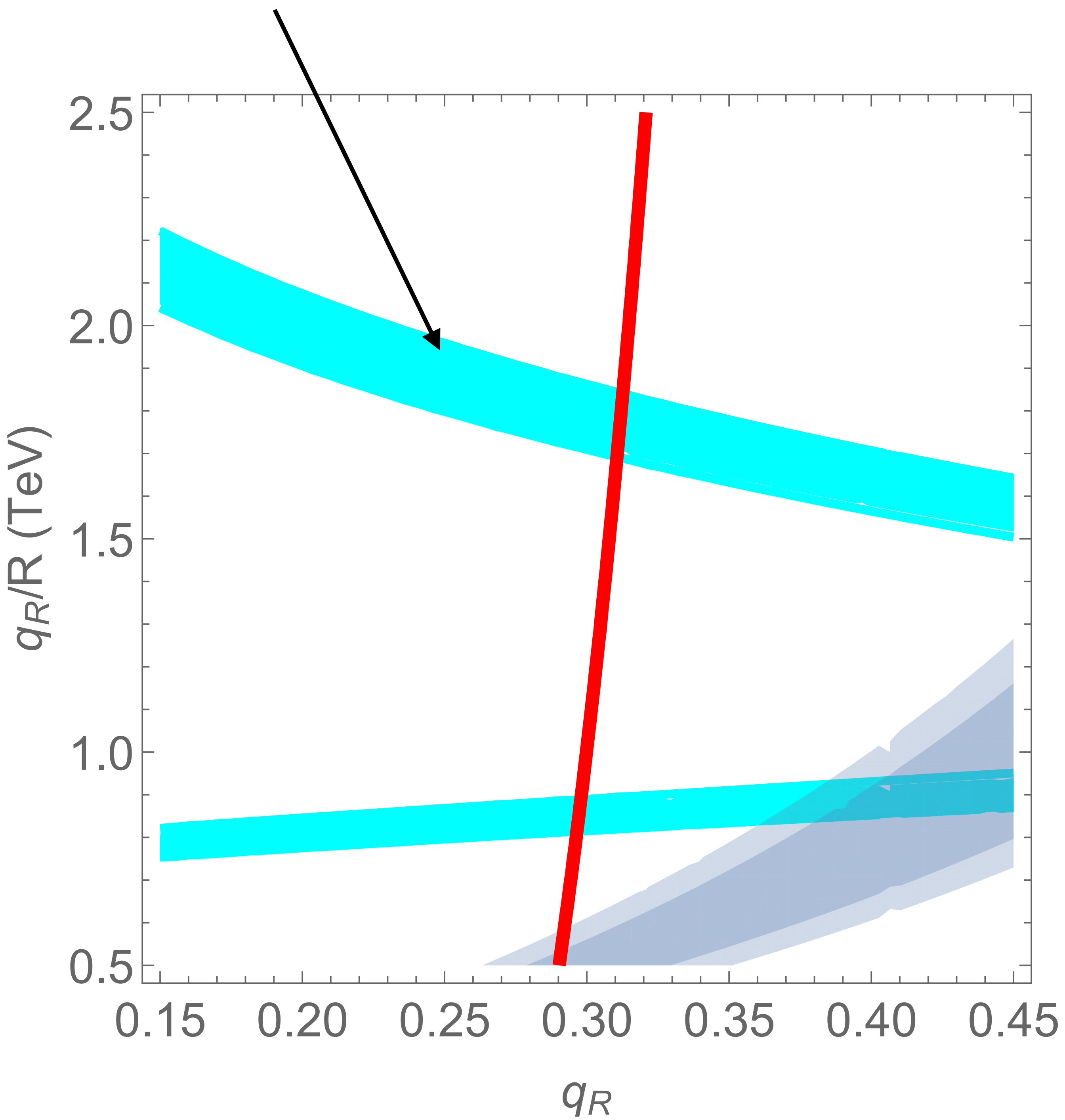
Pure Higgsino

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)



2.5
2.0
1.5
1.0
0.5
q_R/R (TeV)
0.15
0.20
0.25
0.30
0.35
0.40
0.45
q_R


2.5
2.0
1.5
1.0
0.5
q_R/R (TeV)
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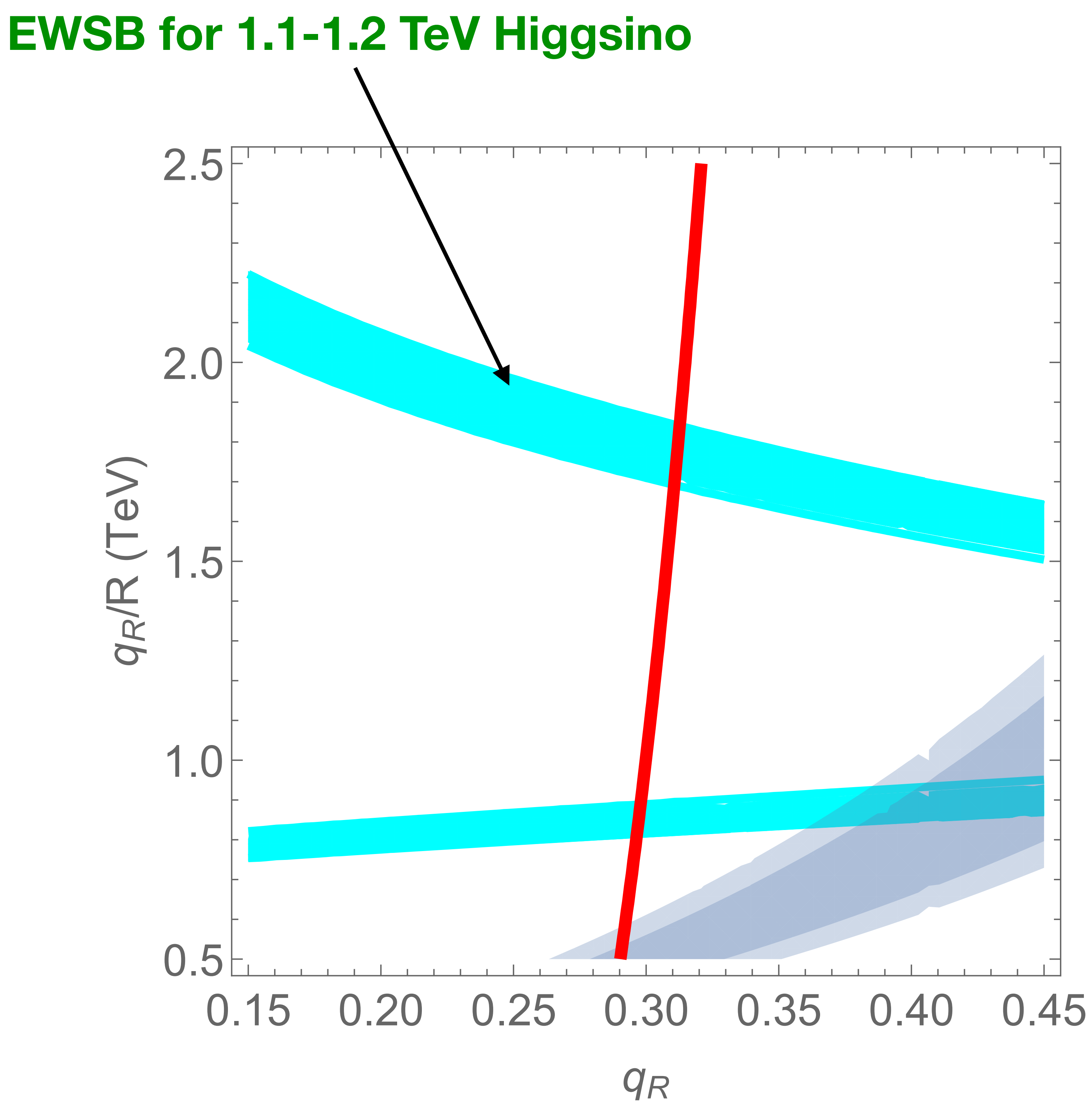
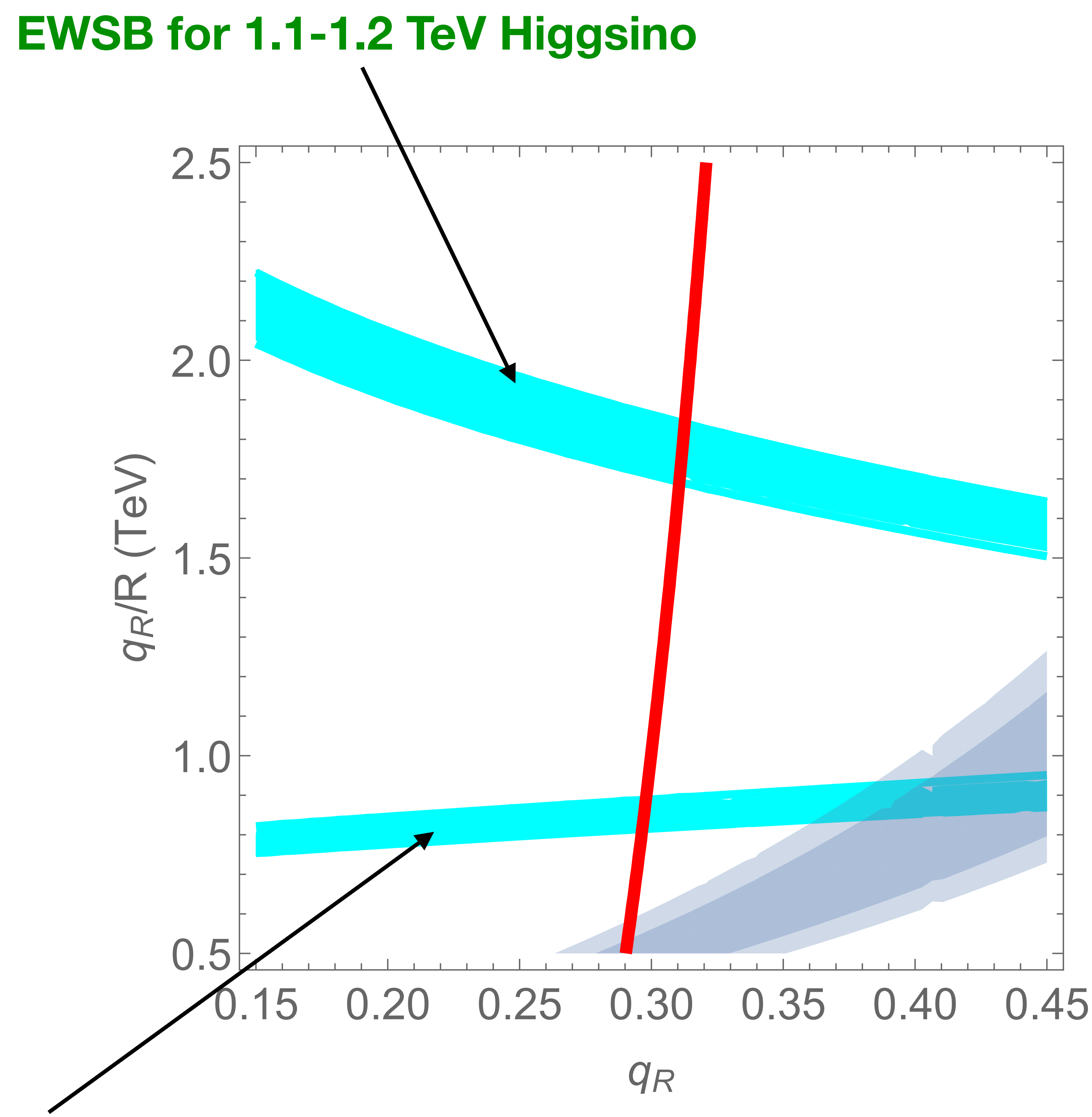
q_R



EWSB for 1.1-1.2 TeV Higgsino
q_R/R (TeV)
2.5
2.0
1.5
1.0
0.5
0.15
0.20
0.25
0.30
0.35
0.40
0.45
q_R



EWSB for 1.1-1.2 TeV Higgsino
2.5
2.0
1.5
1.0
0.5
q_R/R (TeV)
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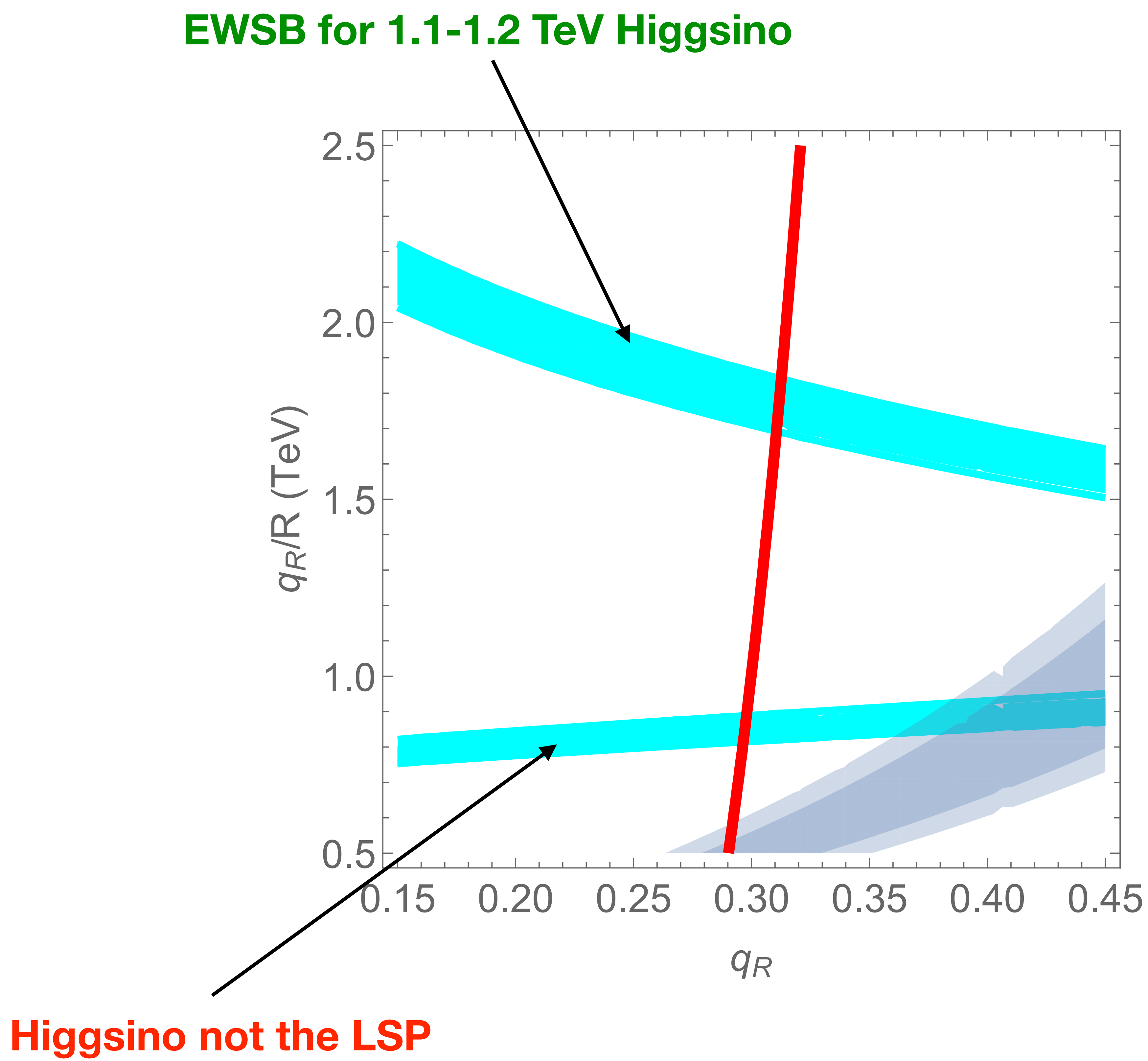
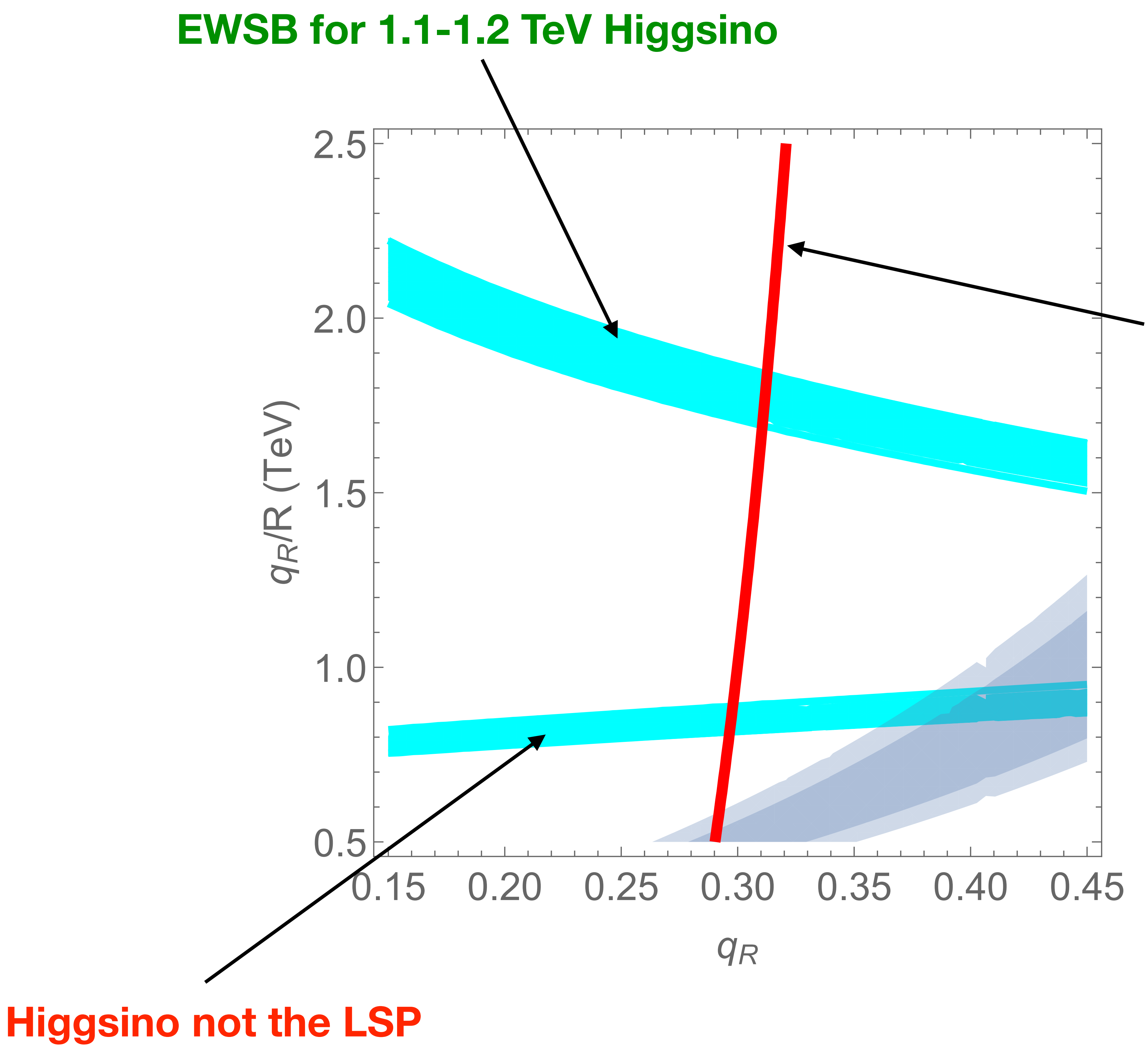
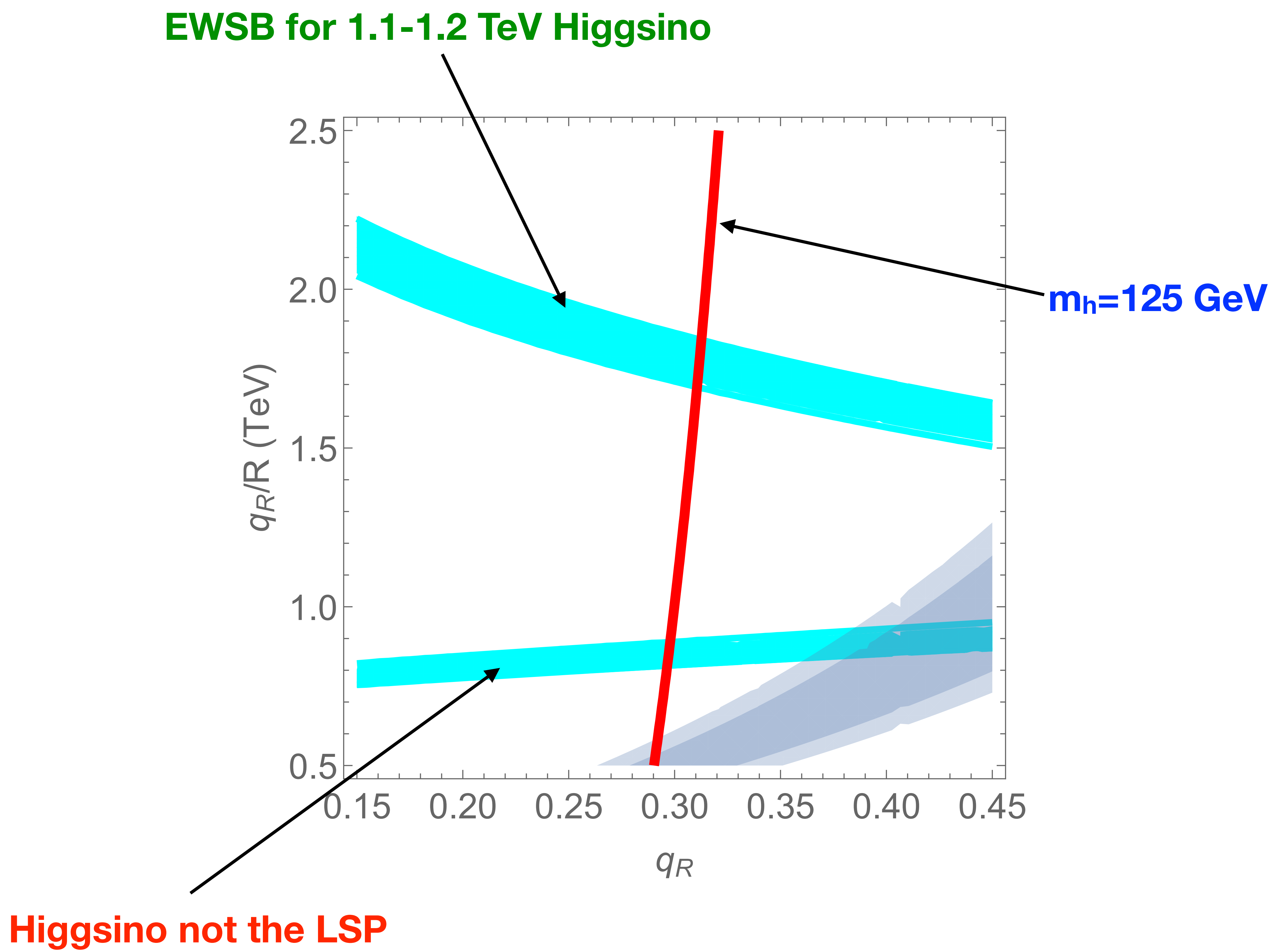
0.20
0.25
0.30
0.35
0.40
0.45
q_R

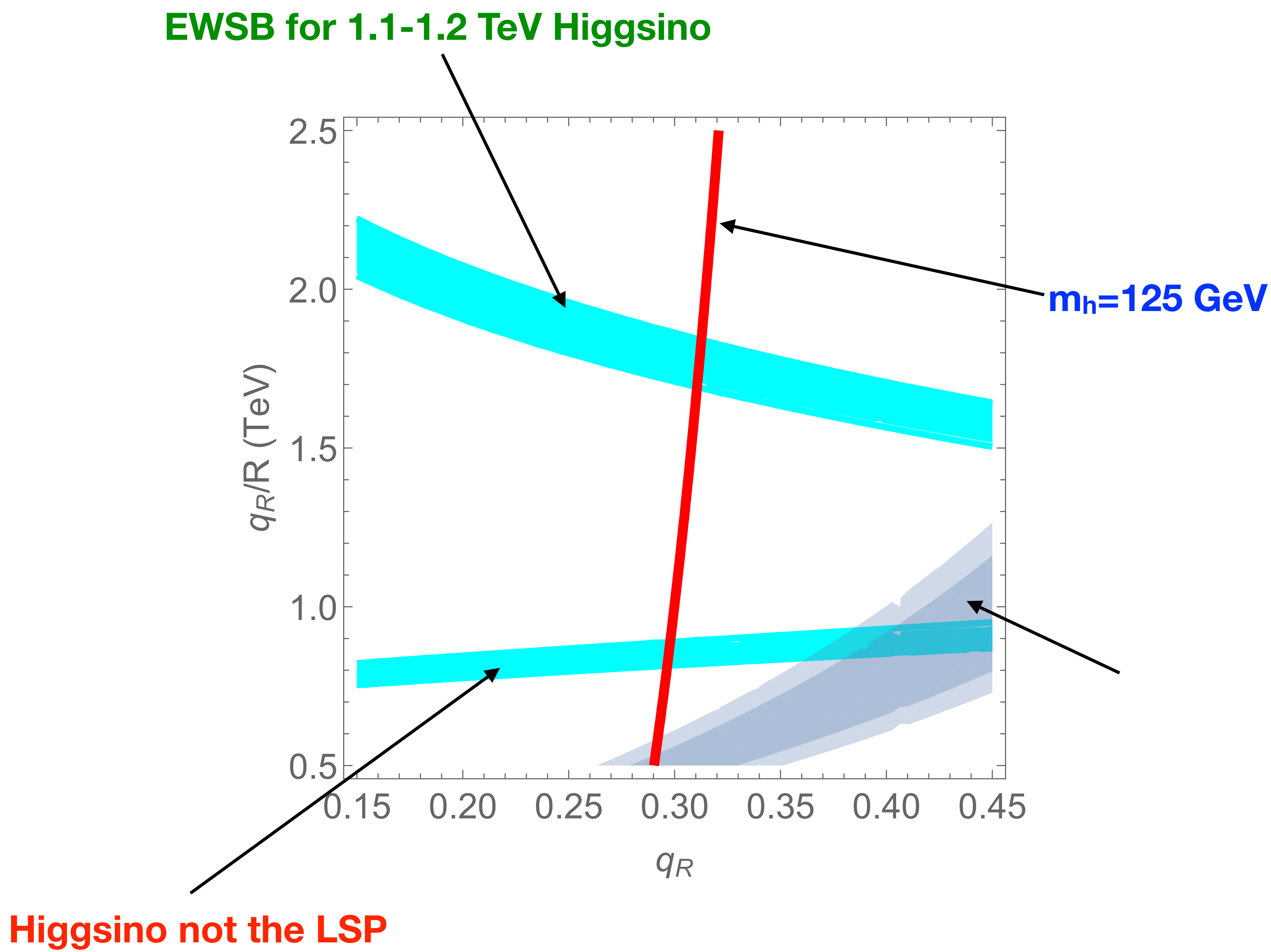


EWSB for 1.1-1.2 TeV Higgsino
Higgsino not the LSP
2.5
2.0
1.5
1.0
0.5
q_R/R (TeV)
0.15
0.20
0.25
0.30
0.35
0.40
0.45
q_R

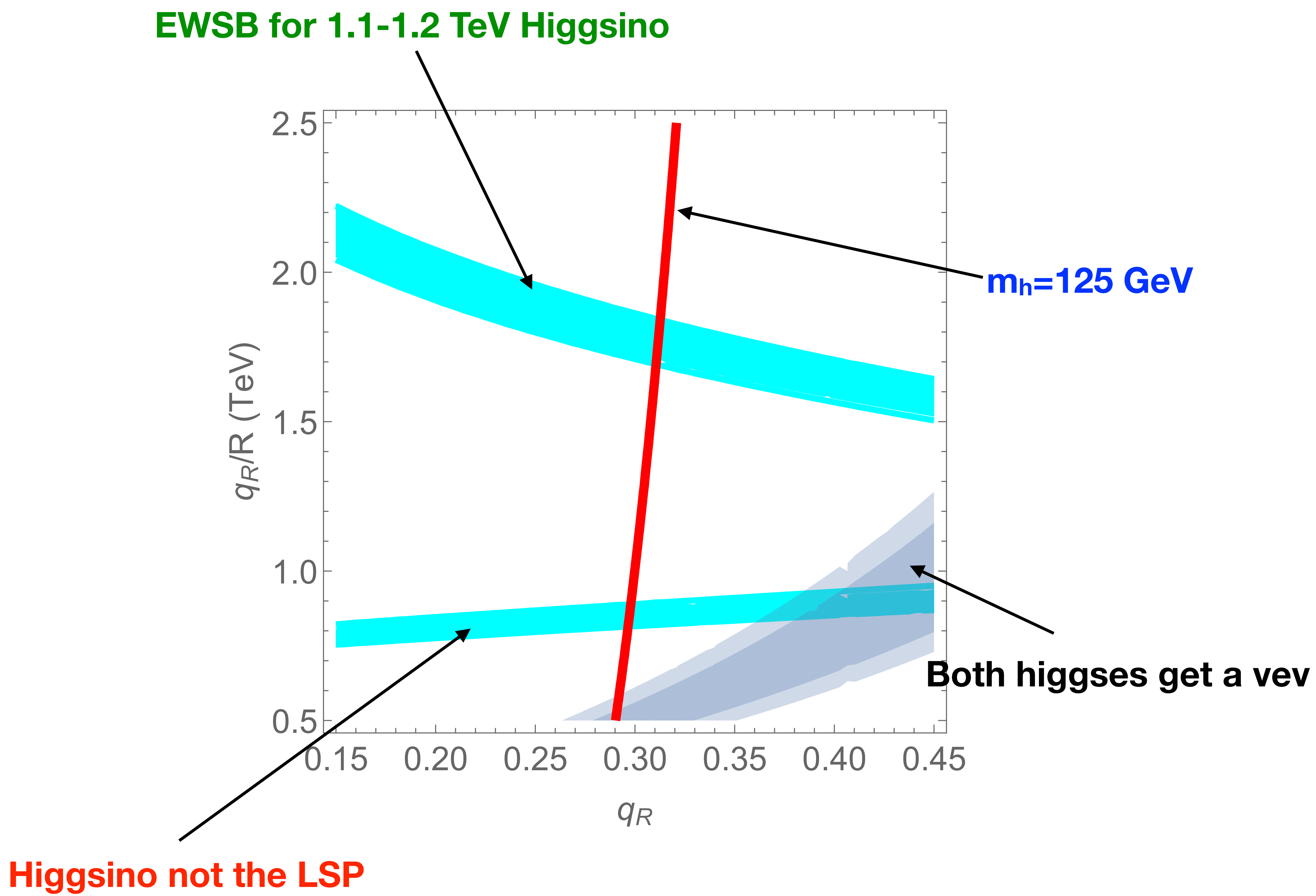


EWSB for 1.1-1.2 TeV Higgsino
Higgsino not the LSP
2.5
2.0
1.5
1.0
0.5
0.15
0.20
0.25
0.30
0.35
0.40
0.45
q_R/R (TeV)
q_R


EWSB for 1.1-1.2 TeV Higgsino
m_h=125 GeV
Higgsino not the LSP
2.5
2.0
1.5
1.0
0.5
q_R/R (TeV)
0.15
0.20
0.25
0.30
0.35
0.40
0.45
q_R

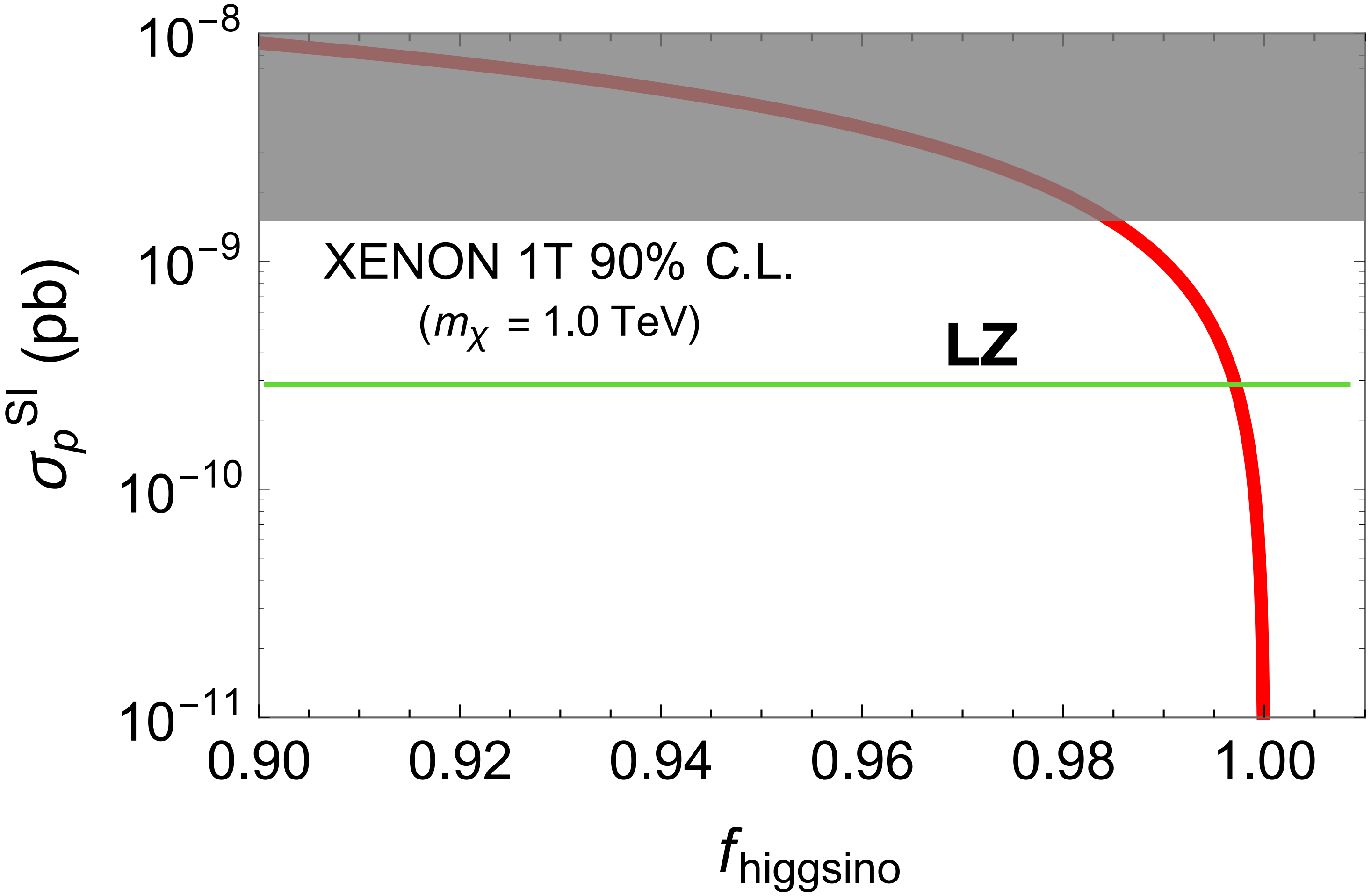


EWSB for 1.1-1.2 TeV Higgsino
m_h=125 GeV
Higgsino not the LSP
q_R/R (TeV)
q_R
2.5
2.0
1.5
1.0
0.5
0.15
0.20
0.25
0.30
0.35
0.40
0.45


EWSB for 1.1-1.2 TeV Higgsino
m_h=125 GeV
Both higgses get a vev
Higgsino not the LSP
q_R/R (TeV)
q_R
2.5
2.0
1.5
1.0
0.5
0.15
0.20
0.25
0.30
0.35
0.40
0.45

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
Kowalska & Sessolo

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

- A 2 TeV gluino may need HL (~1 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

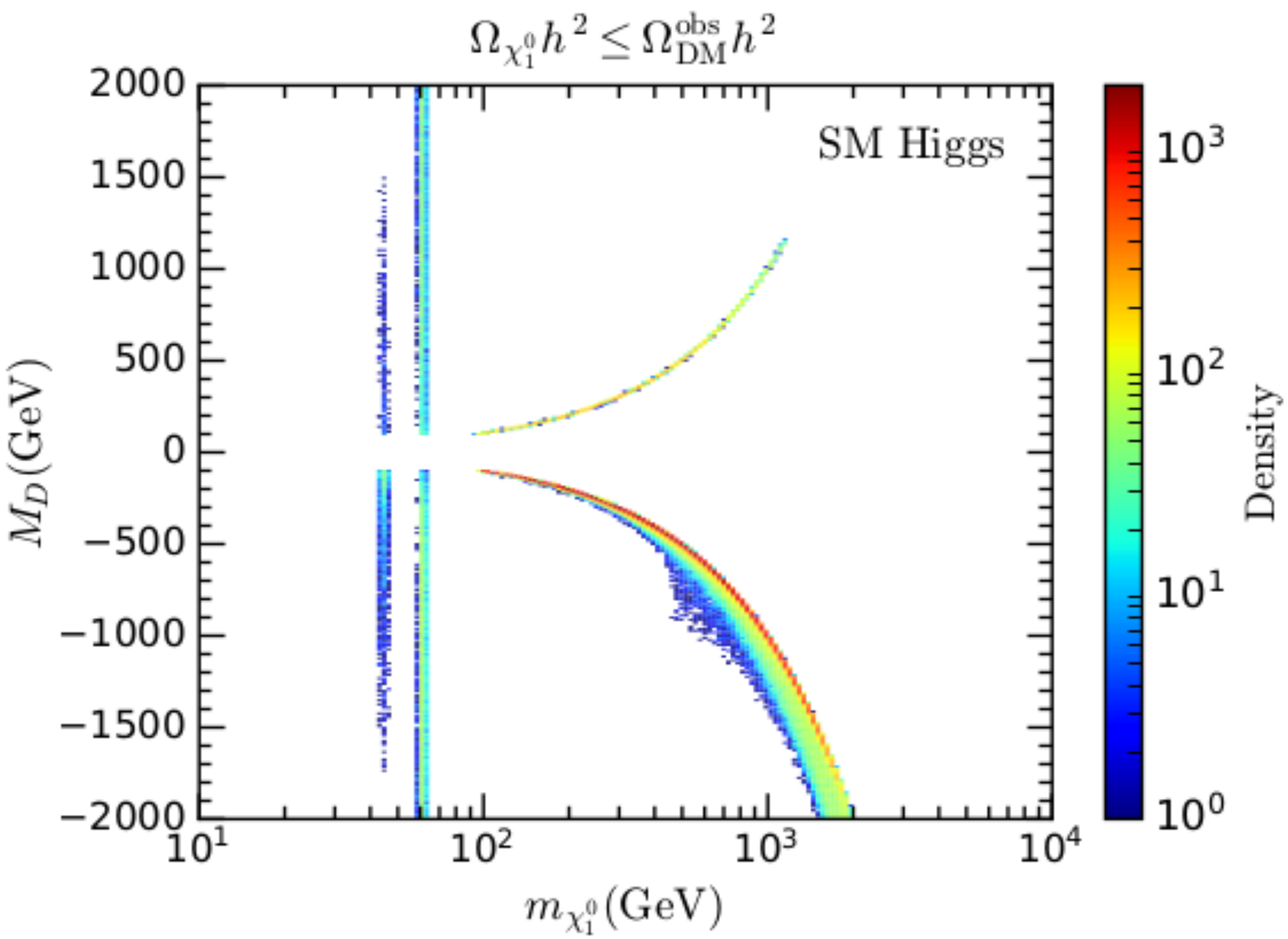
- Blind spots corresponds to points in parameter space where the coupling of the DM to nuclei is suppressed.

- 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



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

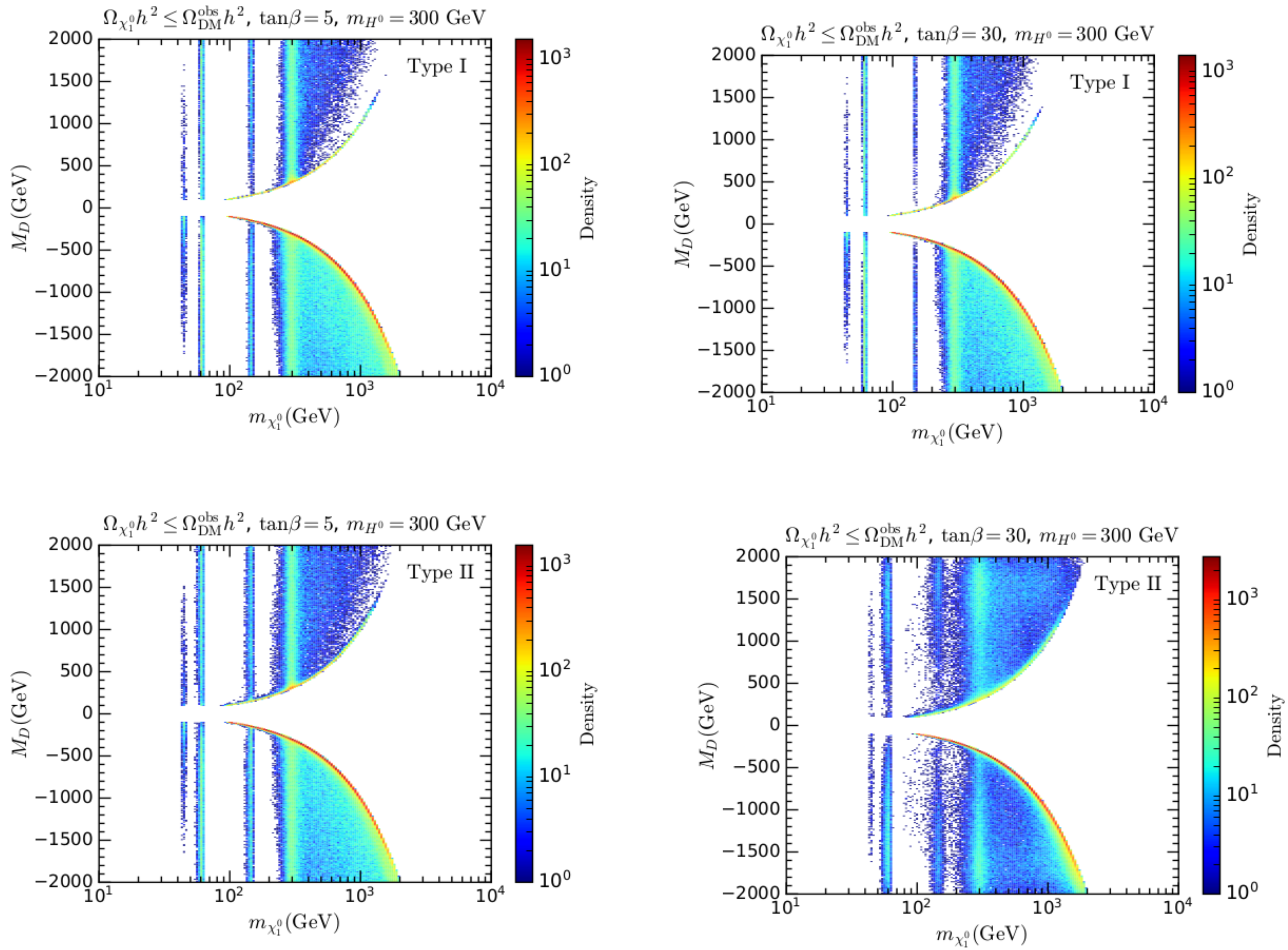
Alignment without decoupling

Z6=0

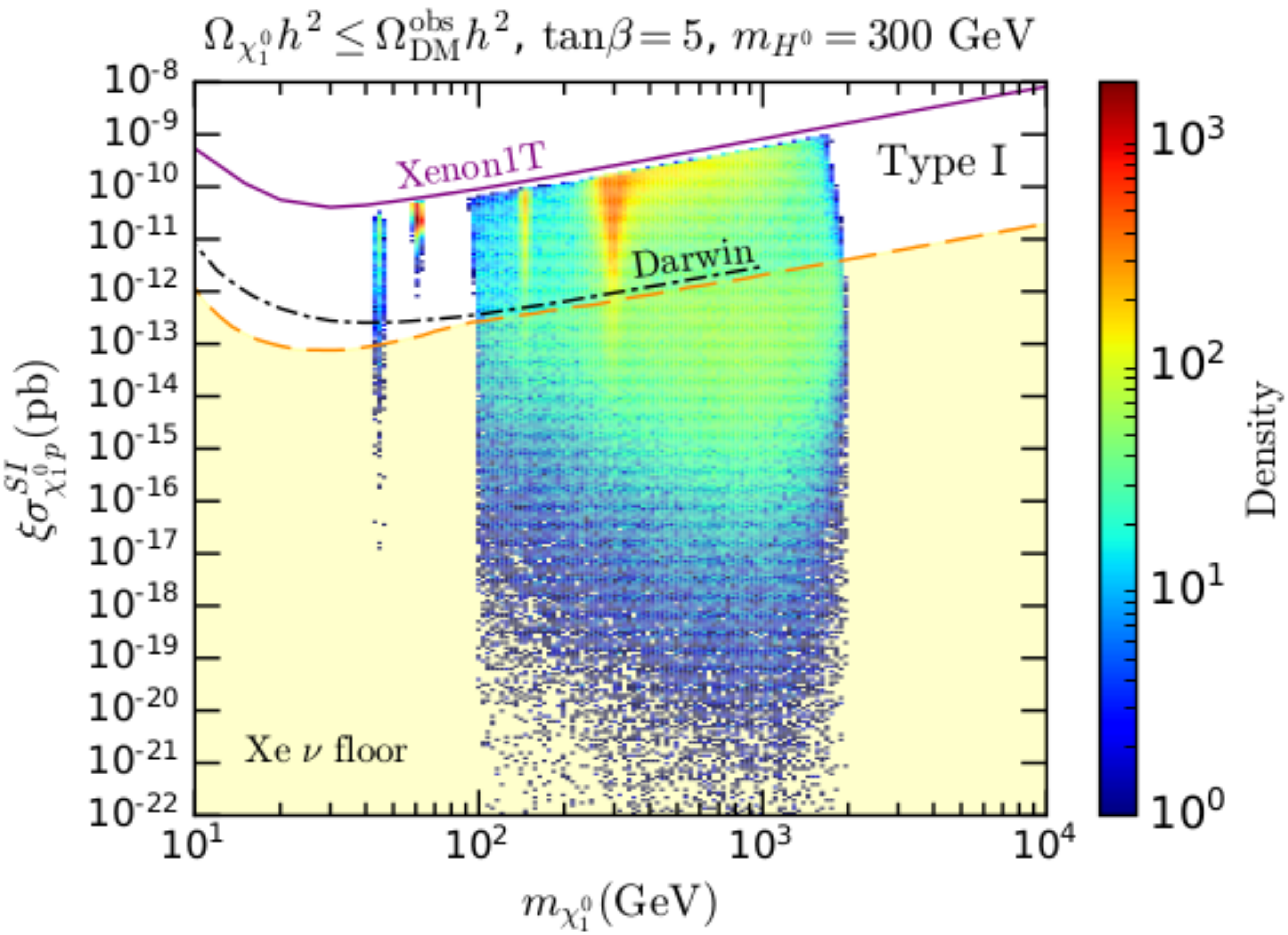
$$y_{\rm DD}^{\rm eff} \equiv \sum_q \left[y_{h\chi_1\chi_1} + \frac{m_h^2}{m_H^2} C_q \; y_{H\chi_1\chi_1} \right] f_q^N$$

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

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



$\Omega_{\chi_1^0} h^2 \leq \Omega_{\rm DM}^{\rm obs} h^2$, $\tan\beta = 5$, $m_{H^0} = 300$ GeV
Type I
$\Omega_{\chi_1^0} h^2 \leq \Omega_{\rm DM}^{\rm obs} h^2$, $\tan\beta = 30$, $m_{H^0} = 300$ GeV
Type I
$\Omega_{\chi_1^0} h^2 \leq \Omega_{\rm DM}^{\rm obs} h^2$, $\tan\beta = 5$, $m_{H^0} = 300$ GeV
Type II
$\Omega_{\chi_1^0} h^2 \leq \Omega_{\rm DM}^{\rm obs} h^2$, $\tan\beta = 30$, $m_{H^0} = 300$ GeV
Type II
M_D(GeV)
$m_{\chi_1^0}$(GeV)
Density
2000
1500
1000
500
0
−500
−1000
−1500
−2000
10^1
10^2
10^3
10^4
10^0



SI DD cross section for a 2HDM

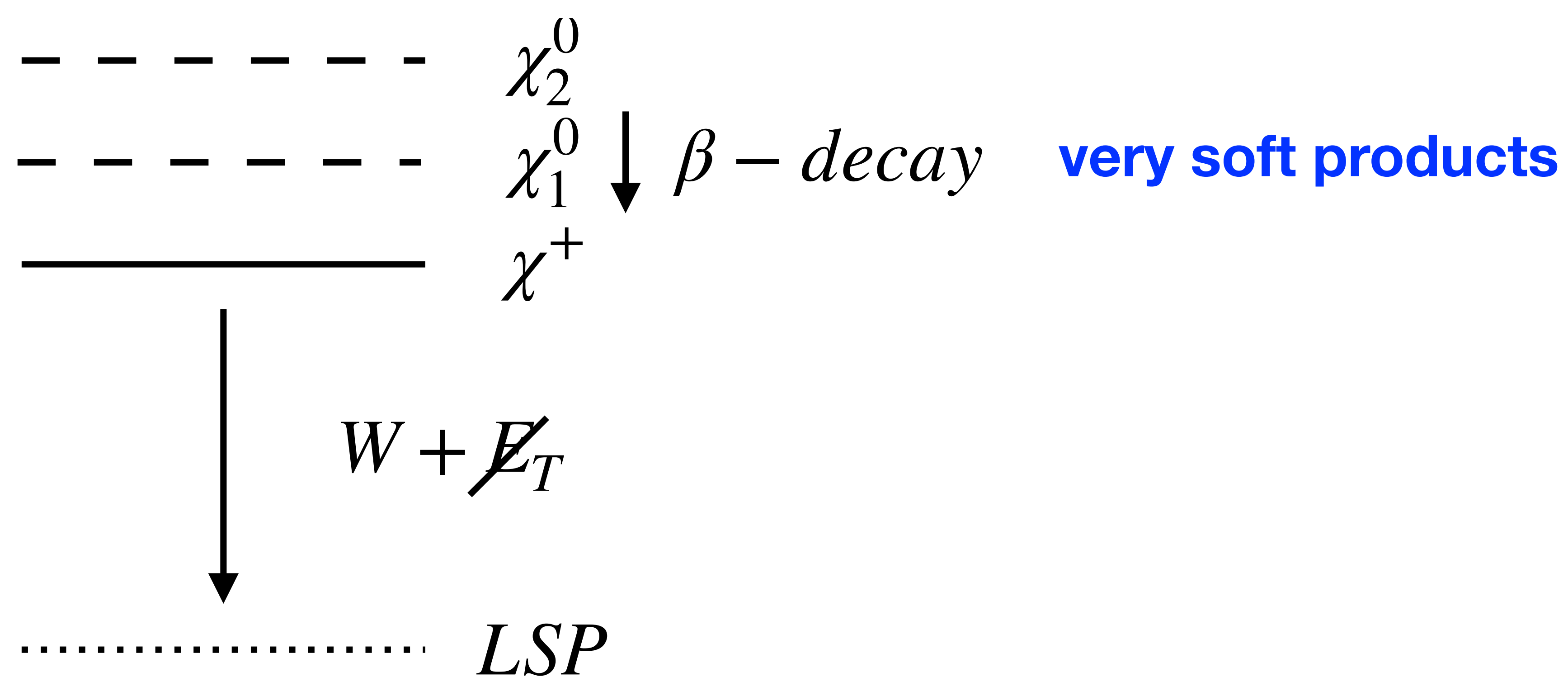
Gravitino

arXiv:1912.03215

- One candidate for DM which is insensitive to DD measurements is the Gravitino

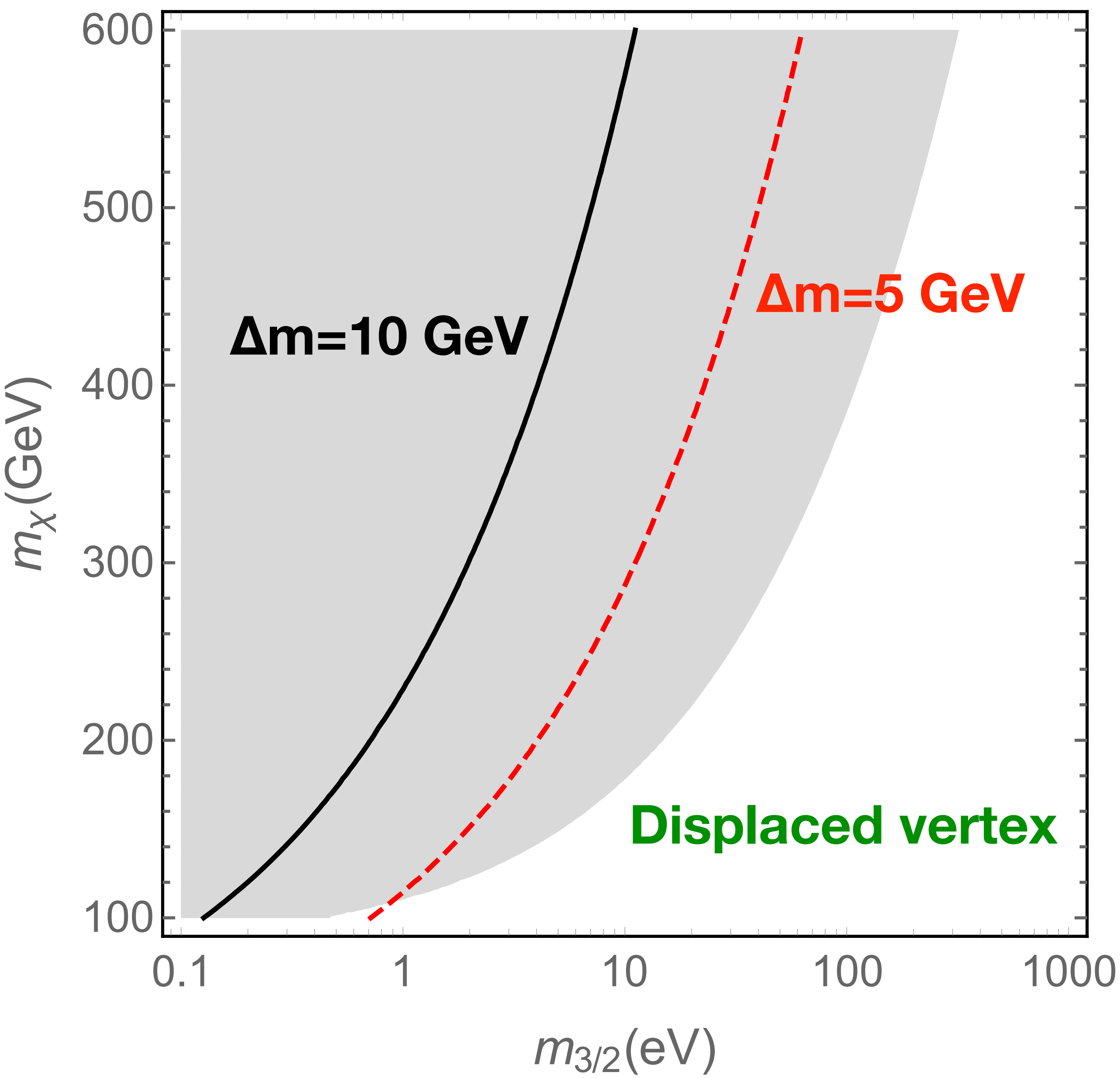
- It is the LSP in models of GMSB.

- 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

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

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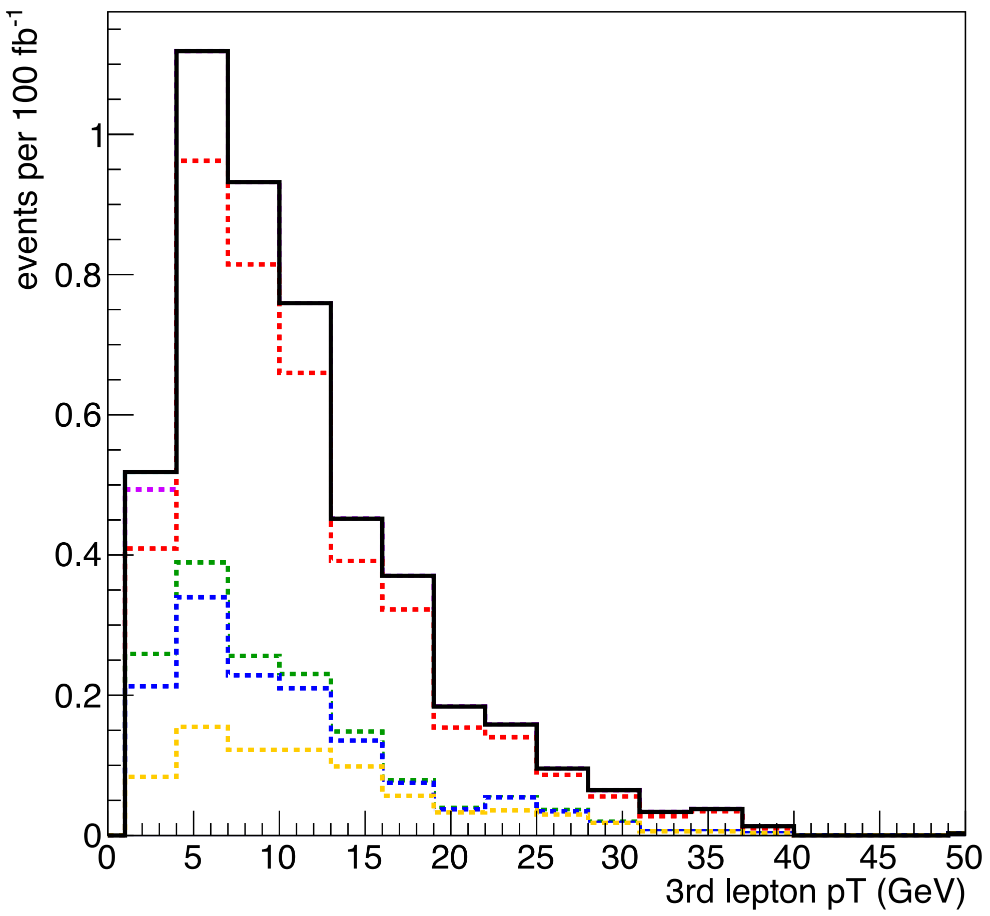

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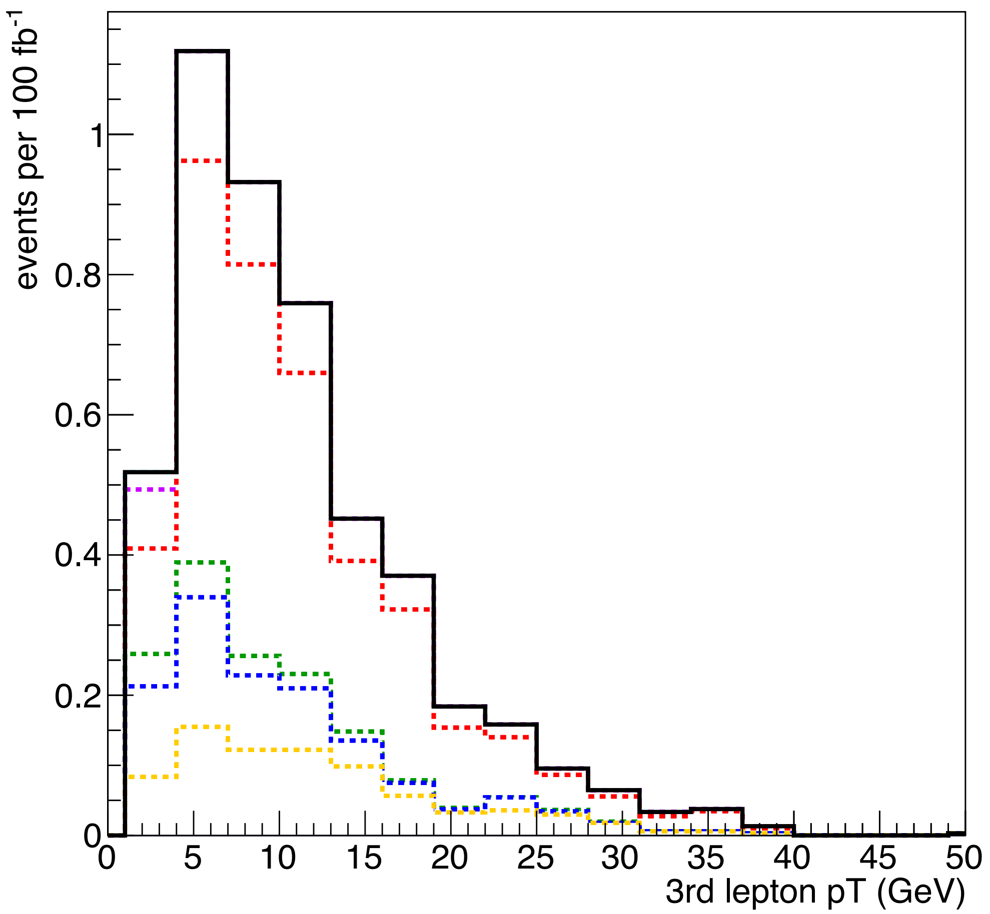

The figure indicates the spectrum of the Third lepton that could be use To discriminate between models

Conclusions

- In this talk I have shown three different scenarios of DM that scape DD detection:
  - Pure Higgisino (~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’