Prospects for electroweakinos at the HL-LHC

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Based on collaboration with Jiu Liu, Carlos Wagner, and Xiaoping Wang

arXiv:2008.11847 **[hep-ph]**
arXiv:2006.07389 **[hep-ph]**

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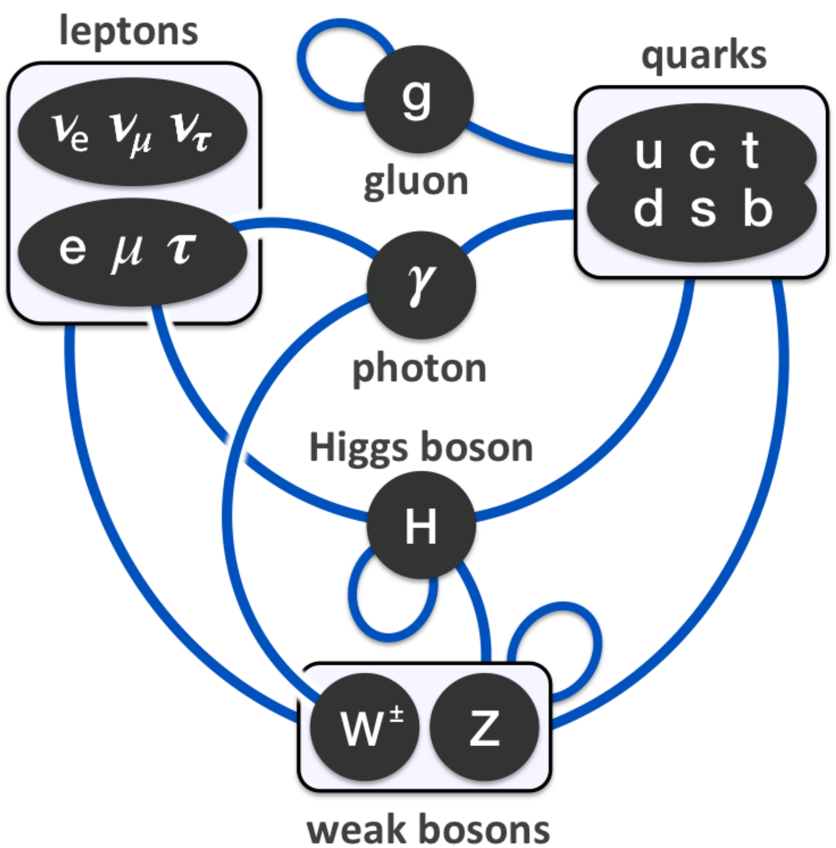
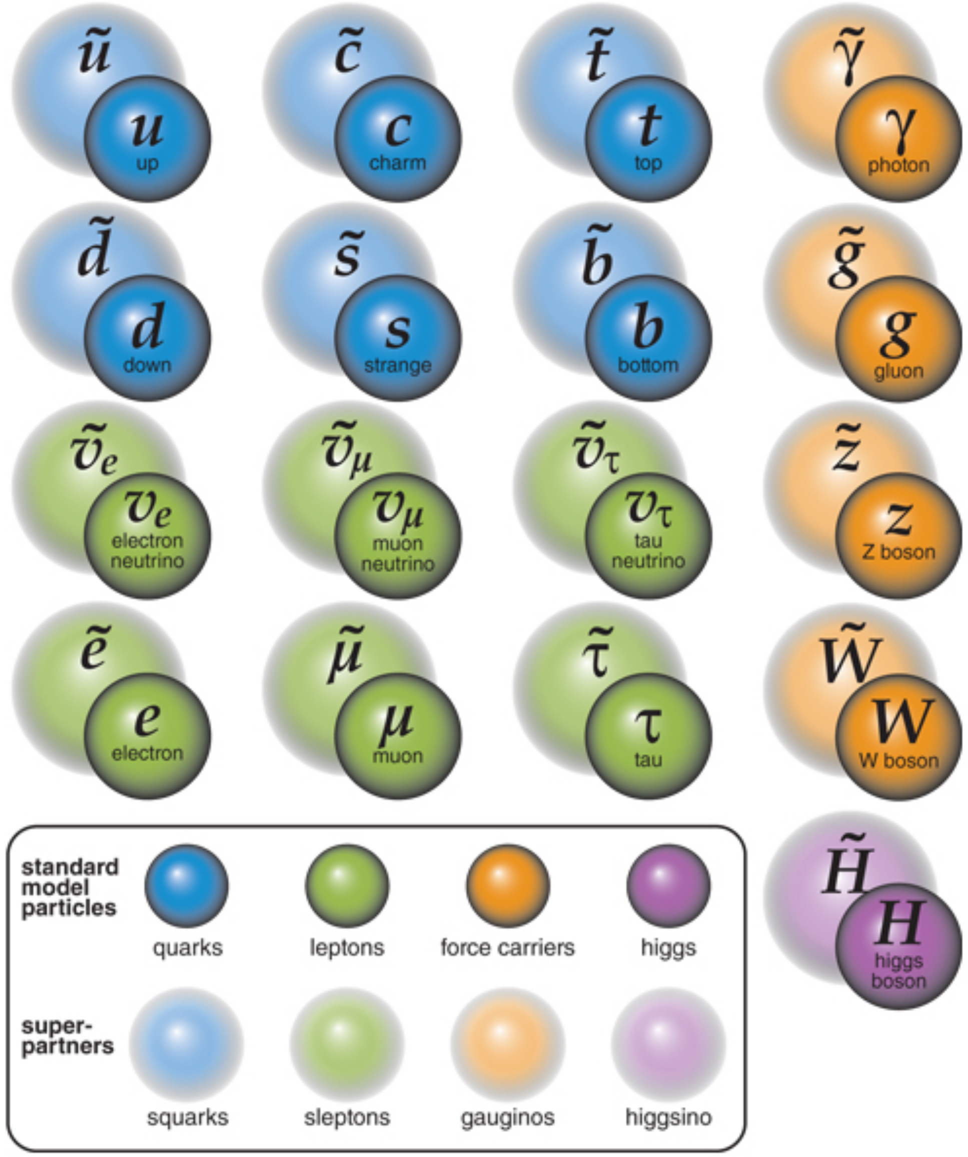
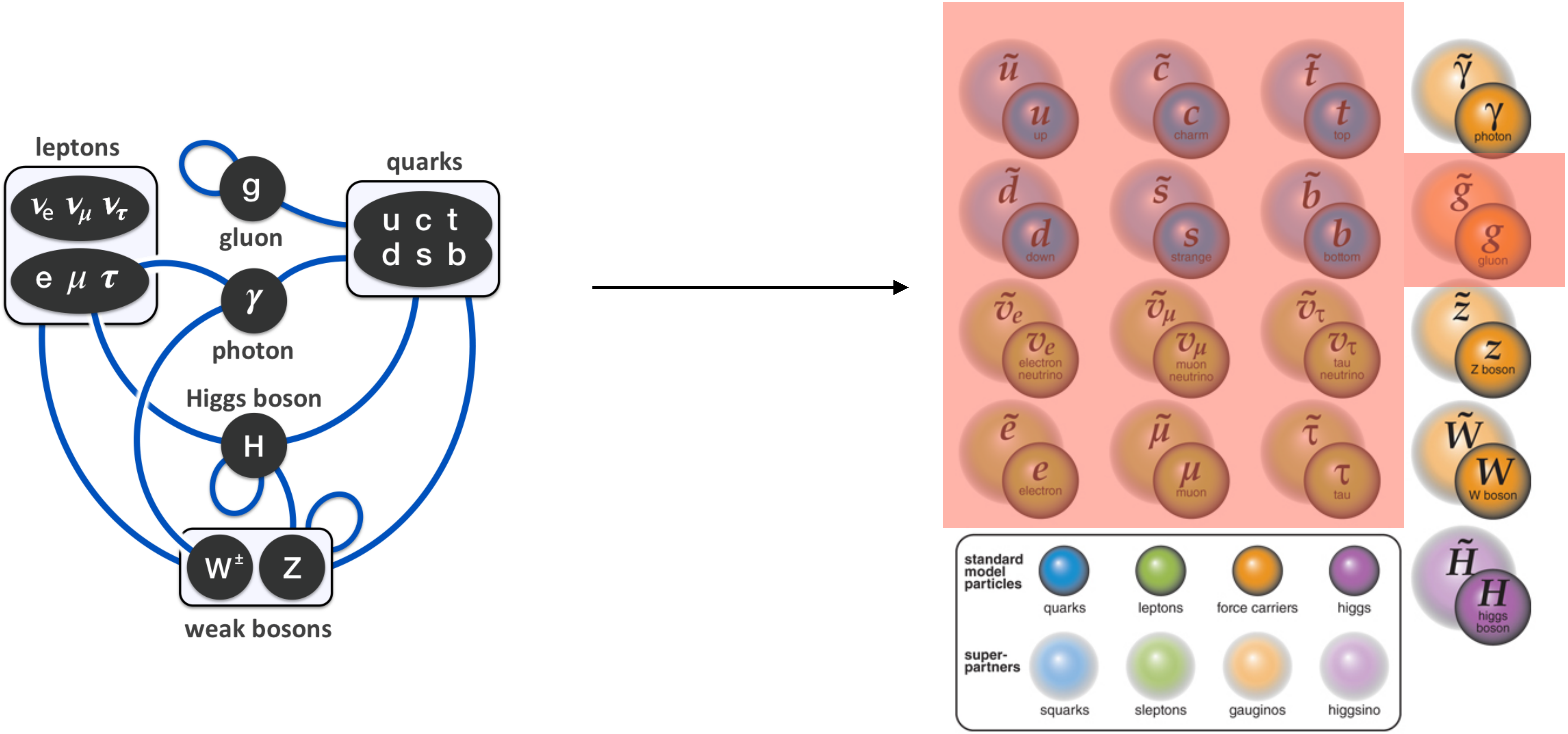
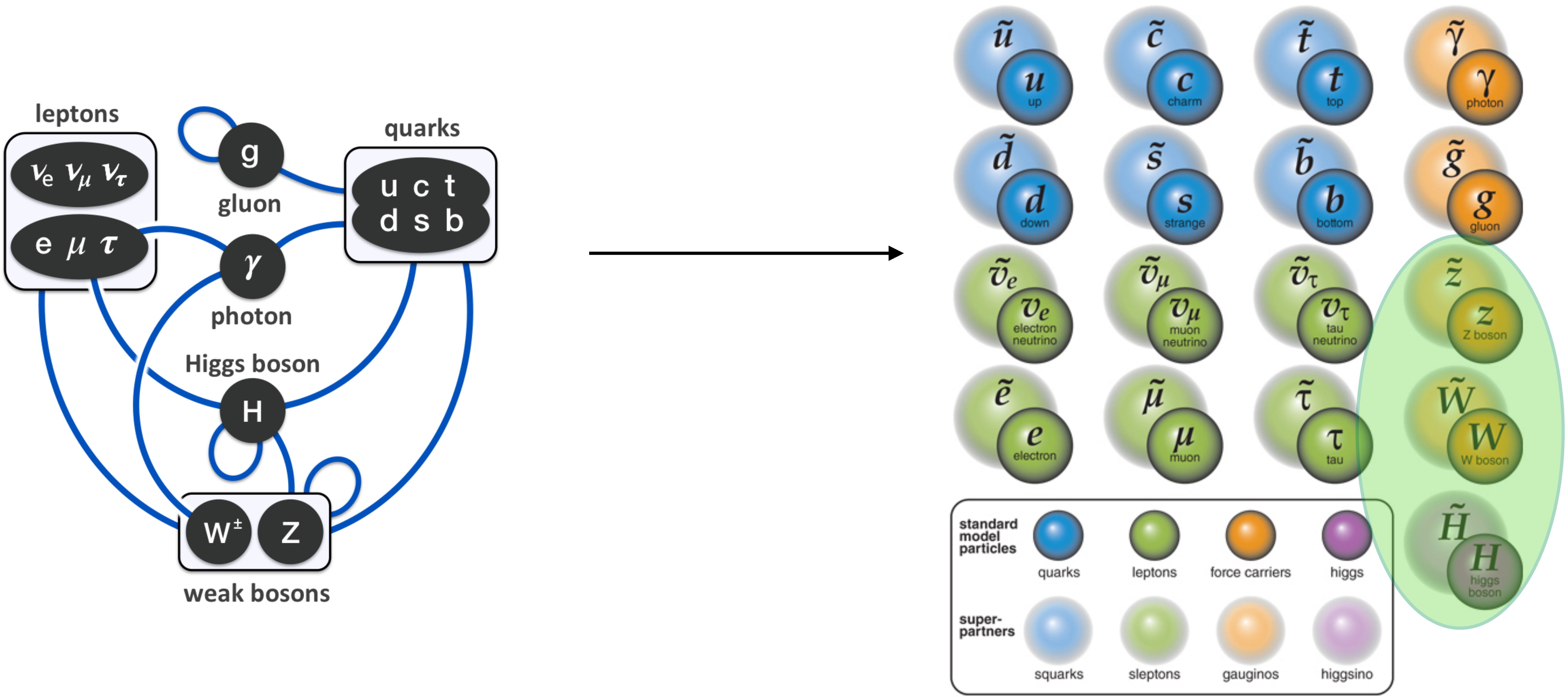
Motivation


leptons
ν_e ν_μ ν_τ
e μ τ
g
gluon
quarks
u c t
d s b
γ
photon
Higgs boson
H
$W^\pm$ Z
weak bosons


$\tilde{u}$ u up
$\tilde{c}$ c charm
$\tilde{t}$ t top
$\tilde{\gamma}$ γ photon
$\tilde{d}$ d down
$\tilde{s}$ s strange
$\tilde{b}$ b bottom
$\tilde{g}$ g gluon
$\tilde{\nu}_e$ ν_e electron neutrino
$\tilde{\nu}_\mu$ ν_μ muon neutrino
$\tilde{\nu}_\tau$ ν_τ tau neutrino
$\tilde{z}$ z Z boson
$\tilde{e}$ e electron
$\tilde{\mu}$ μ muon
$\tilde{\tau}$ τ tau
$\tilde{W}$ W W boson
$\tilde{H}$ H higgs boson
standard model particles
quarks
leptons
force carriers
higgs
super-partners
squarks
sleptons
gauginos
higgsino



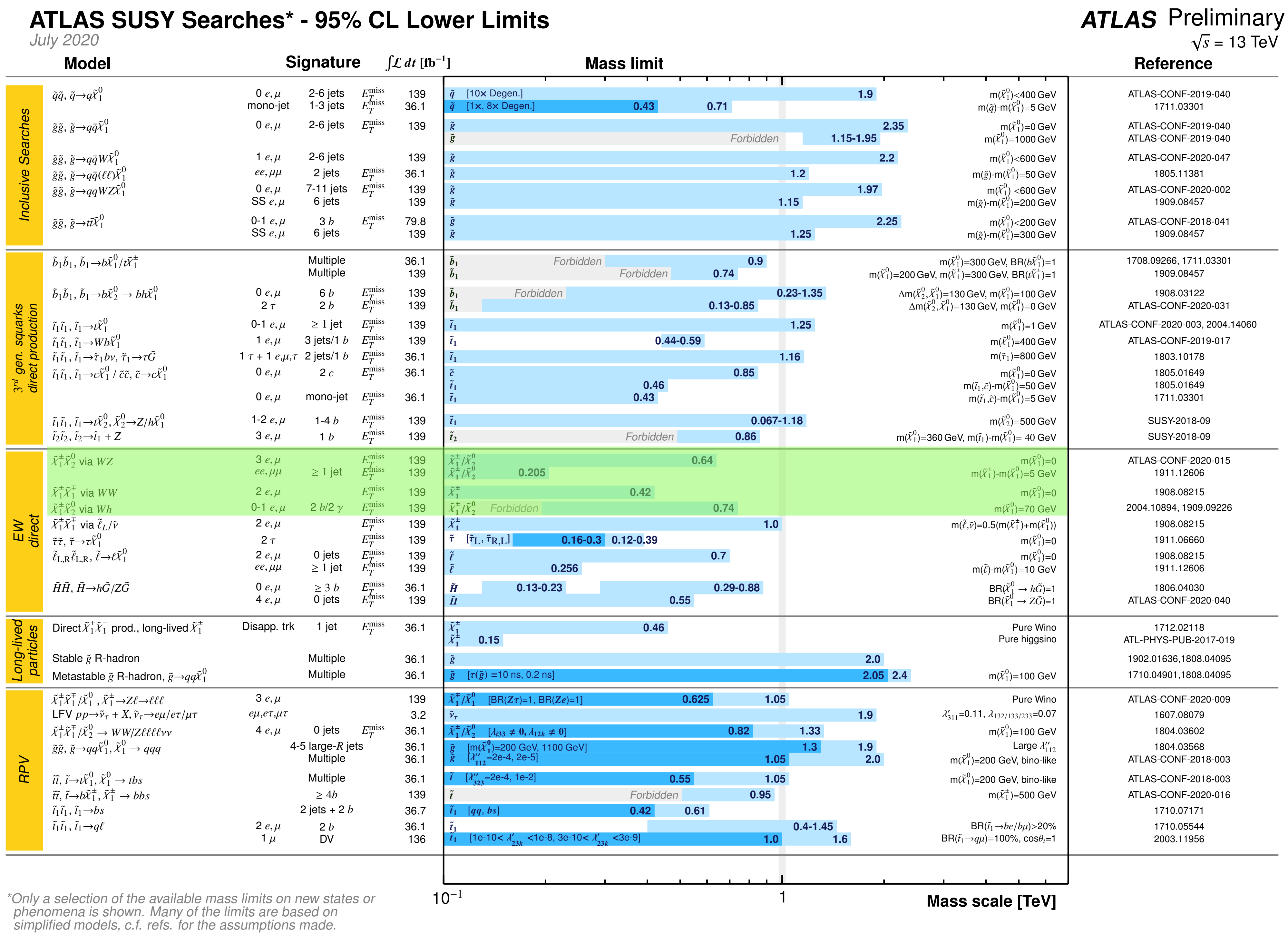
Scalars & in particular strongly interacting superpartners studied in great detail so far, stringent limits



Plenty of room to explore weakly interacting sfermions

Current status

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults



For my talk: EWino direct channels *without* sleptons. Looking at final states resulting from W +Z/h decays: bounds ranging ~200-700 GeV

Current status

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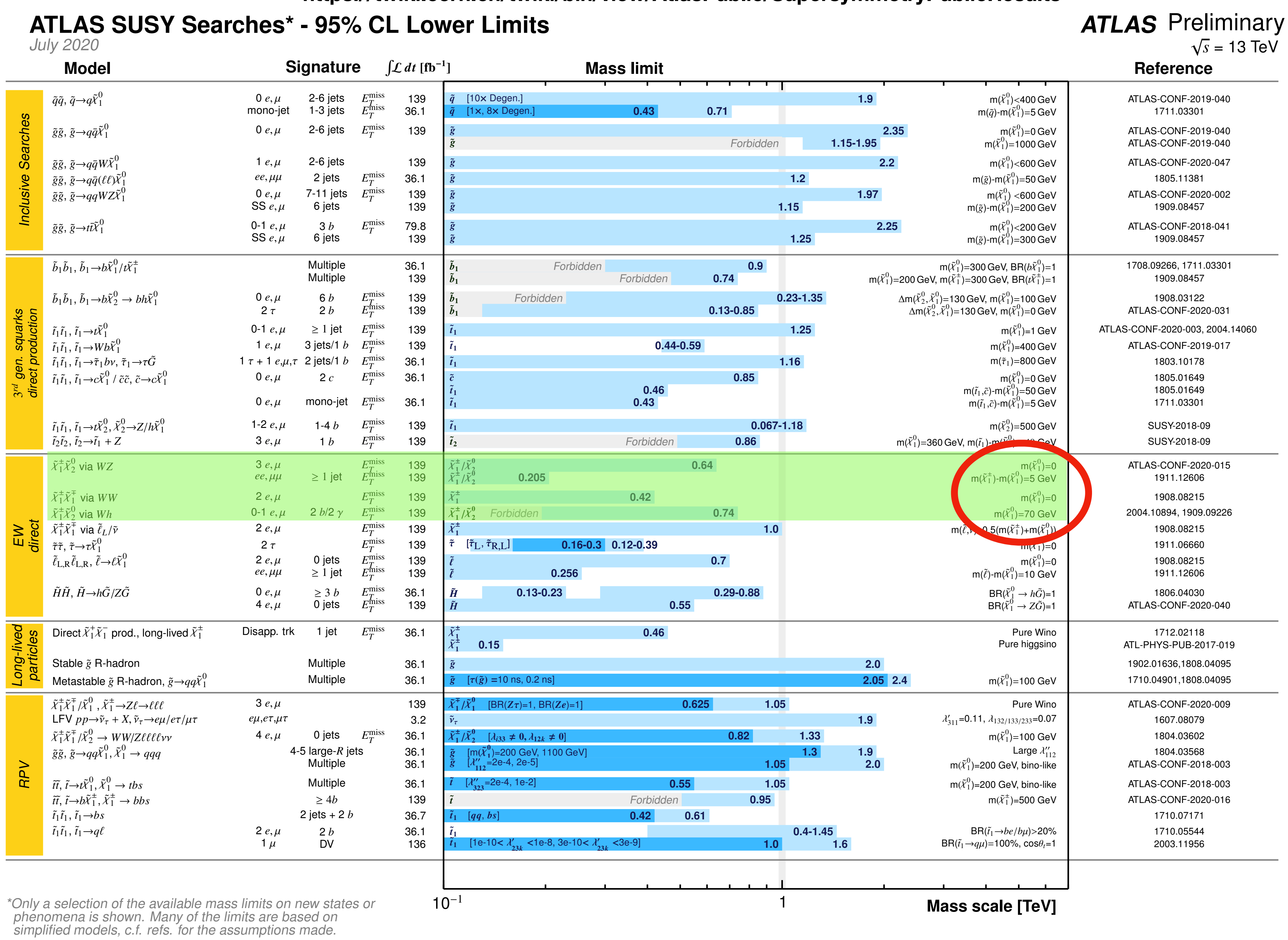


Fine print: simplified models with specific spectrum and/or BRs=100%

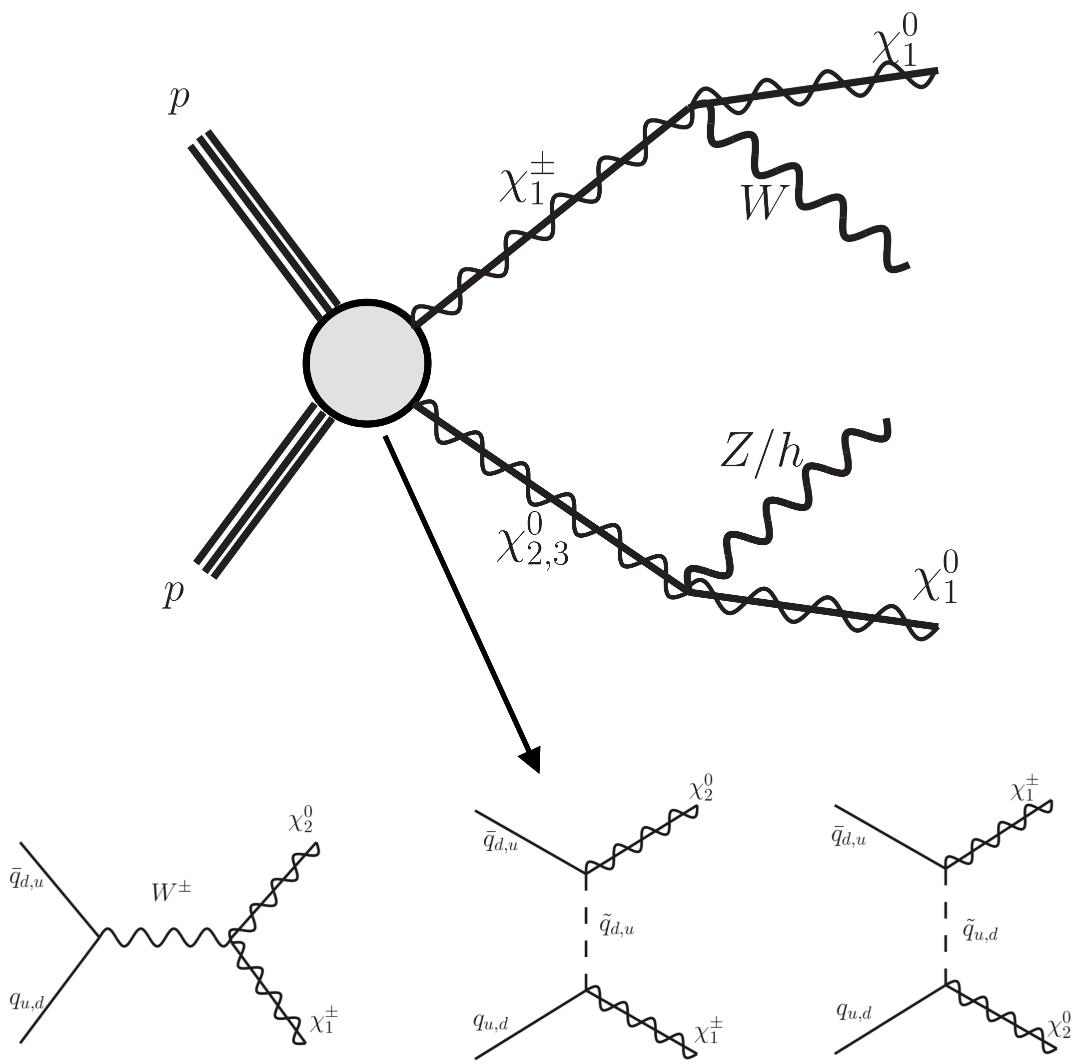
MSSM dynamics: spectrum *and* BRs determined by same parameters. Different channels give complementary information

Search channels

Looking at EW direct production without sleptons, decaying through W + Z/h

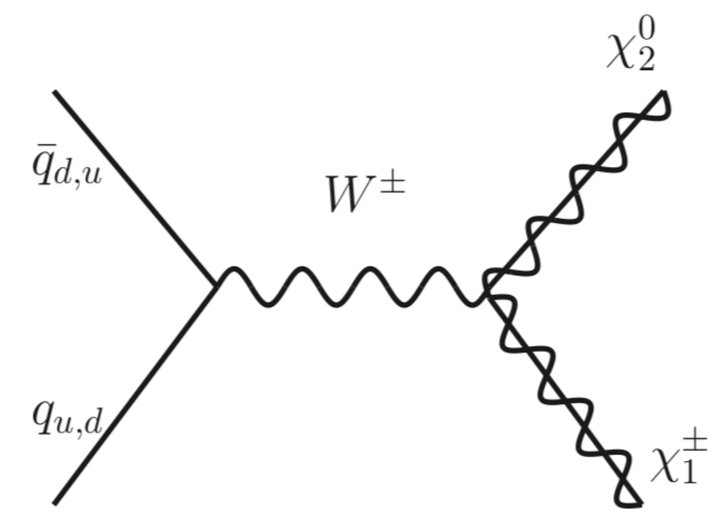
Wino scenario

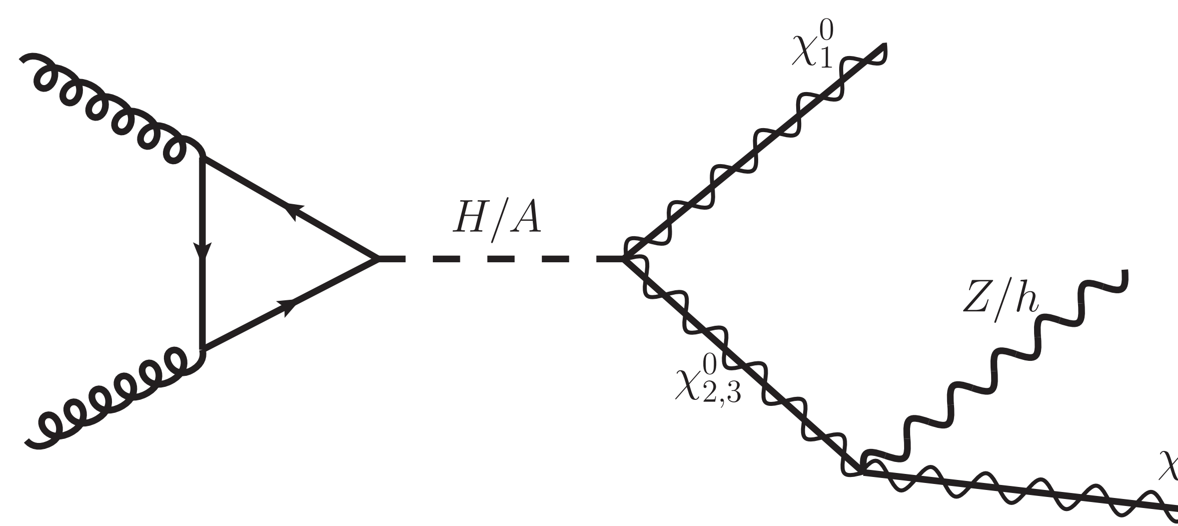
$$M_1 \lesssim M_2 \ll |\mu|$$



Higgsino-Bino scenario

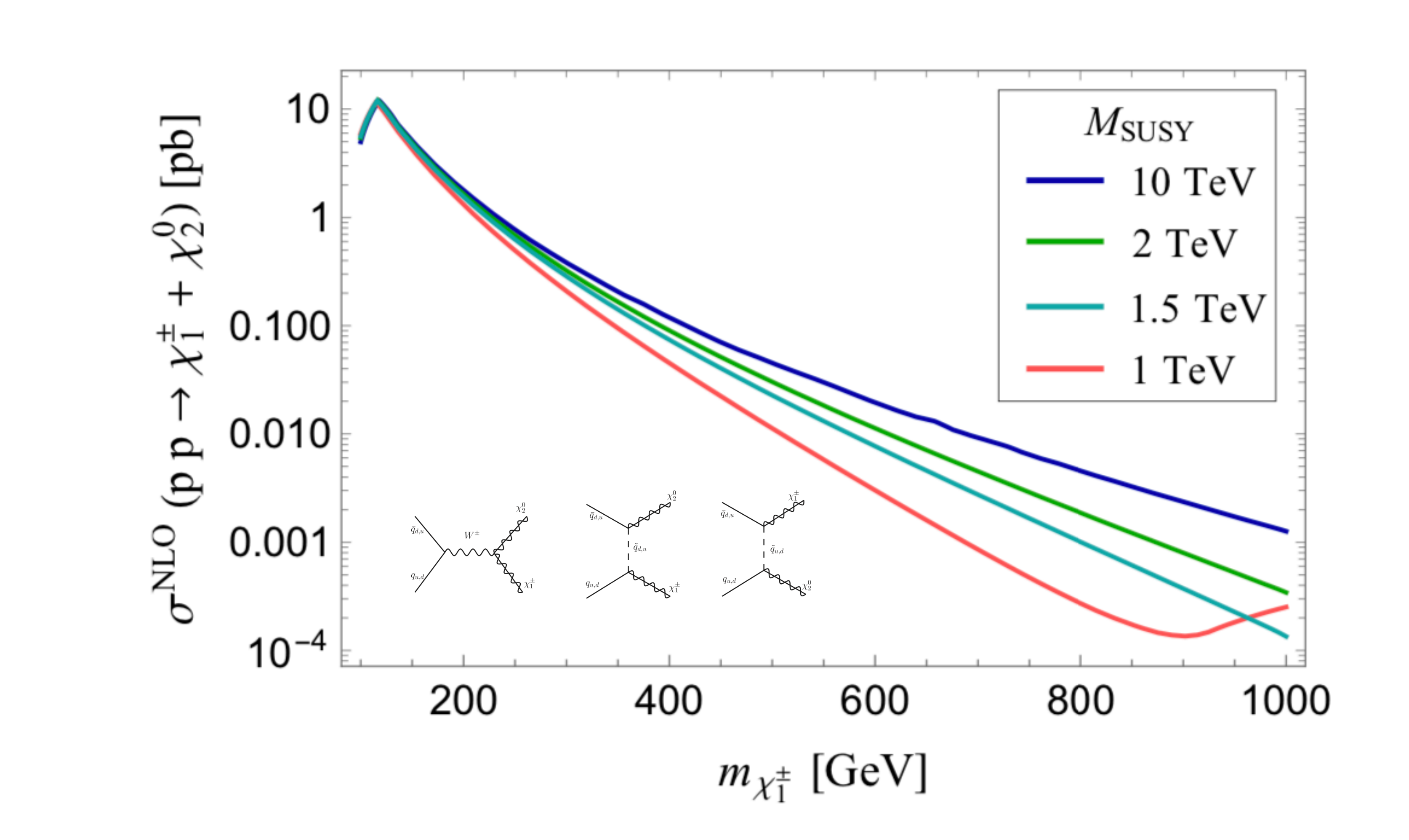
$$M_1 \lesssim |\mu| \ll M_2$$





Wino scenario

- Wino scenario (large components of $\tilde{W}$):
  - Traditional search channel considered by ATLAS and CMS collaborations
  - Cross sections actually connected to SUSY strong sector - major implications for EWino bounds!



M_{SUSY} = overall scale of scalar super partners. 1 - 10 TeV suggested by measured value of Higgs mass

arXiv:2008.11847 **[hep-ph]**

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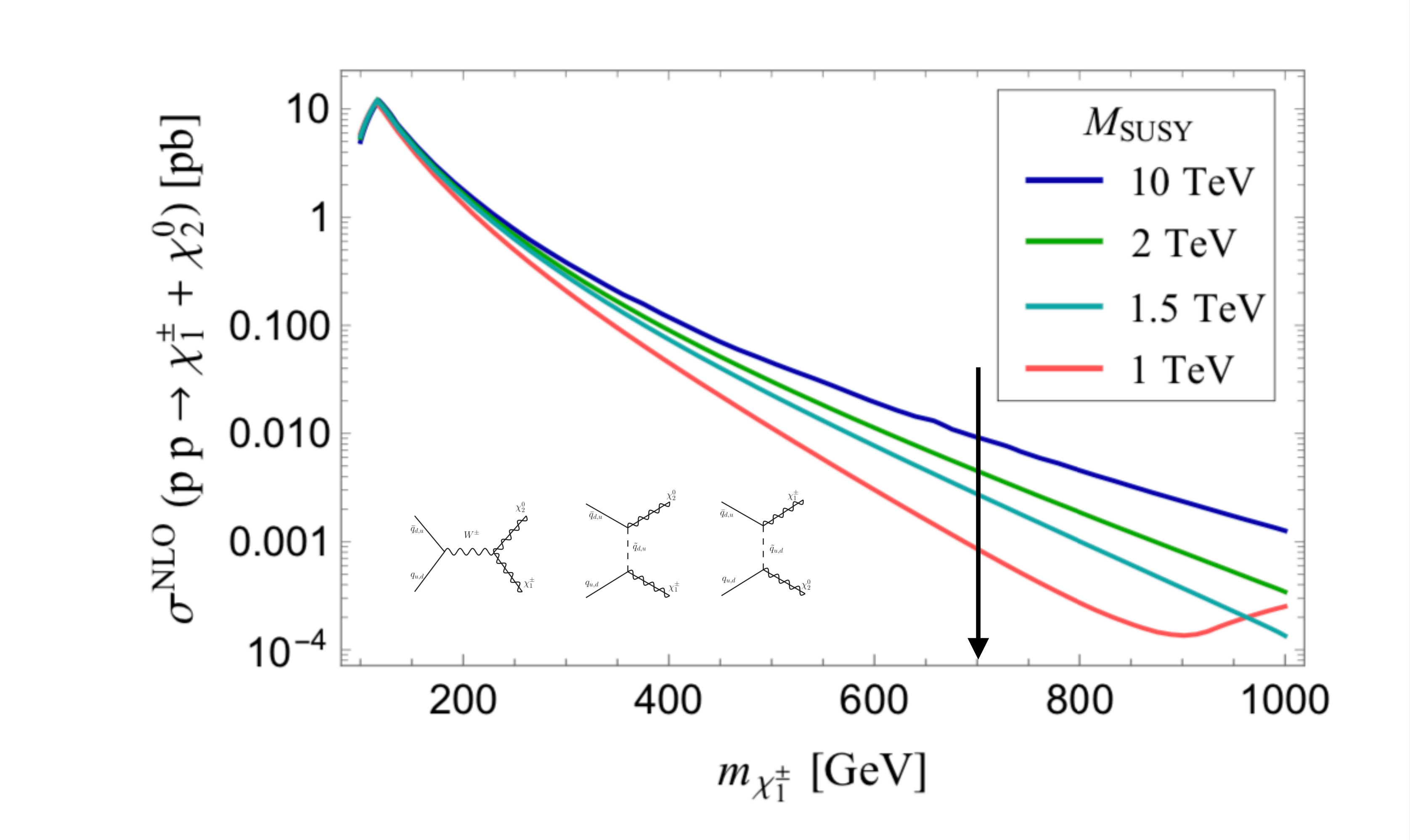

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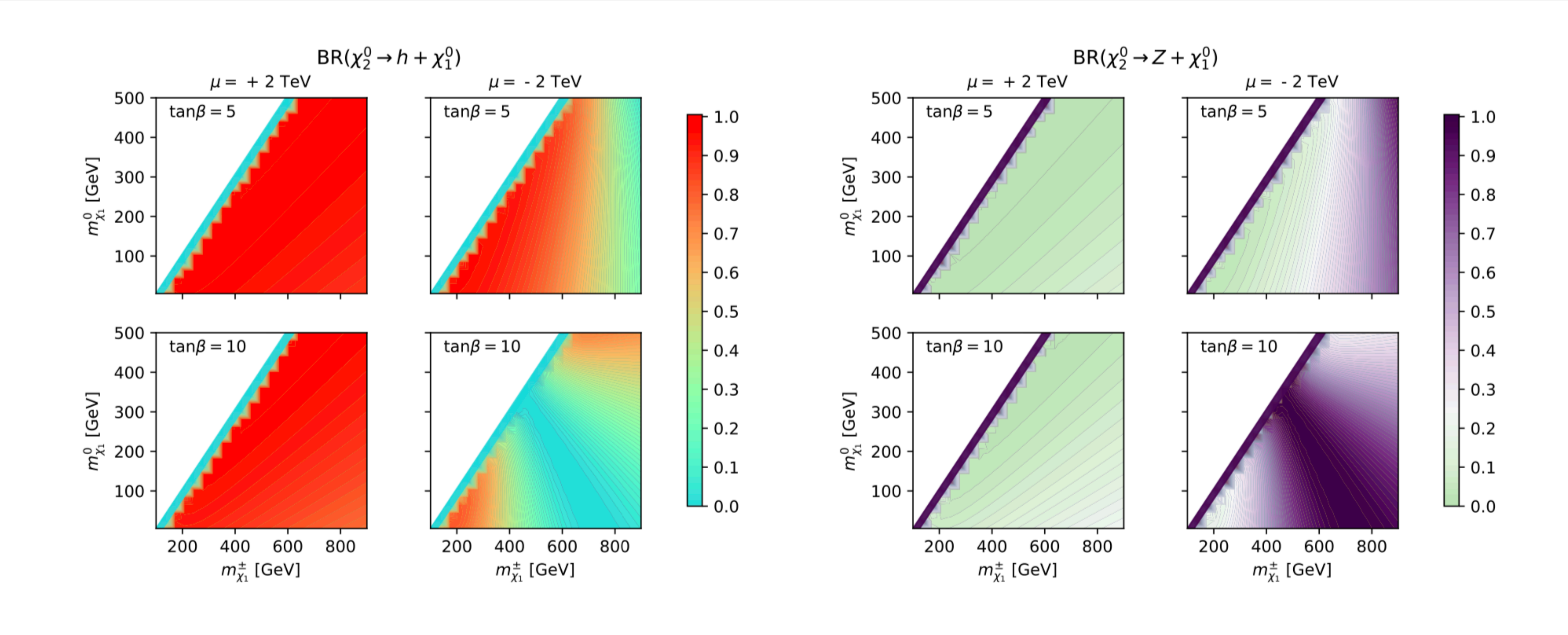
Wino scenario

- Wino scenario (large components of $\tilde{W}$):
  - Sign of μ matters



Take away: trilepton searches good for compressed region or special region of parameters. Fairly robust ultimate reach for $m_1^\pm$ from W+h channels

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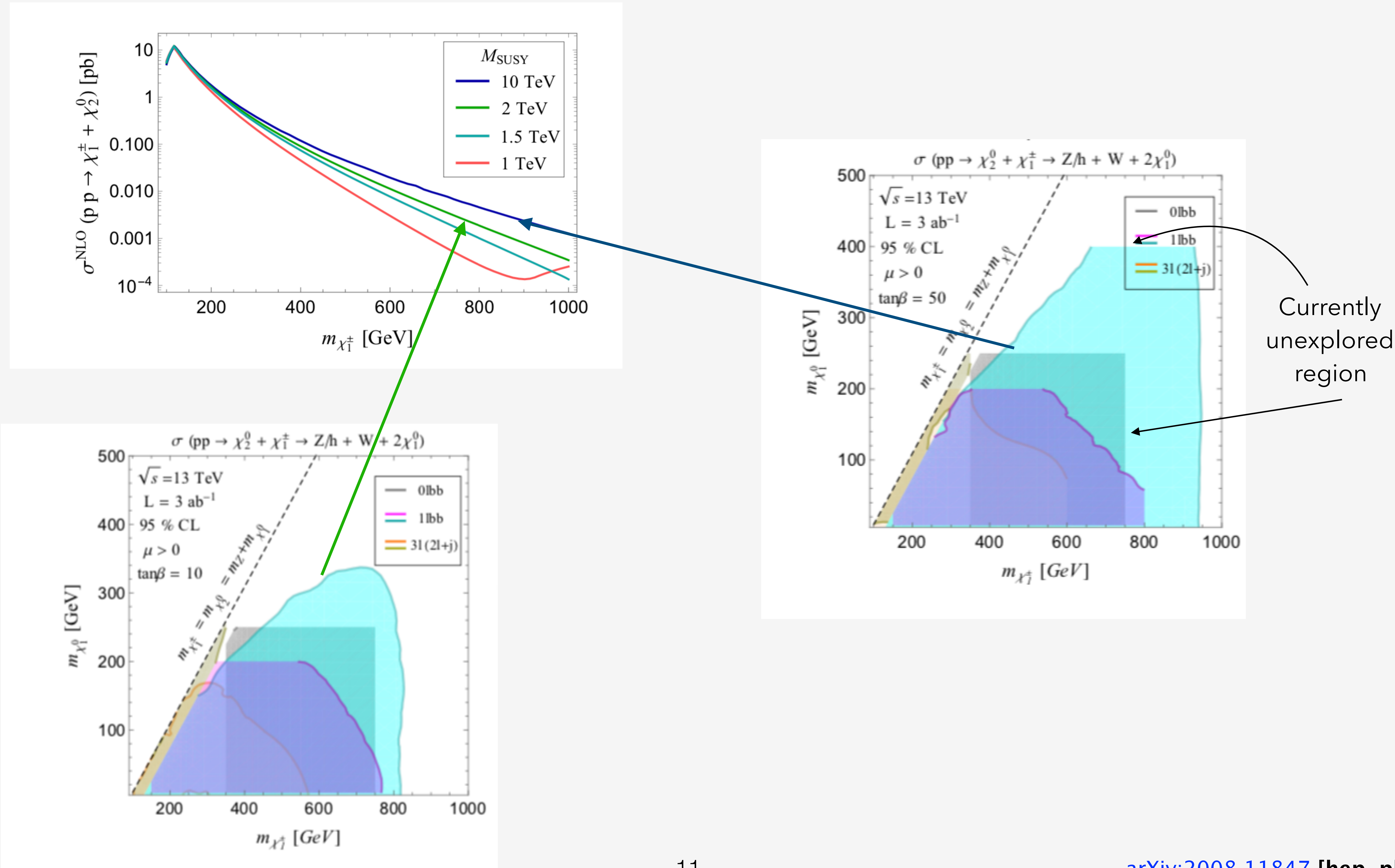
Wino scenario



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Wino summary

$M_1 \lesssim M_2 \ll |\mu|$

- Direct EW searches gives indirect info on squark sector through prod x-section
- Sign of μ can have drastic consequences in branching ratios

Assuming the optimal case for the HL-LHC, when $M_{SUSY} \to 10$ TeV, projection of current analyses gives reach of $m_{\chi_1^\pm} \simeq 1$ TeV, $m_{\chi_1^0} \simeq 400$GeV

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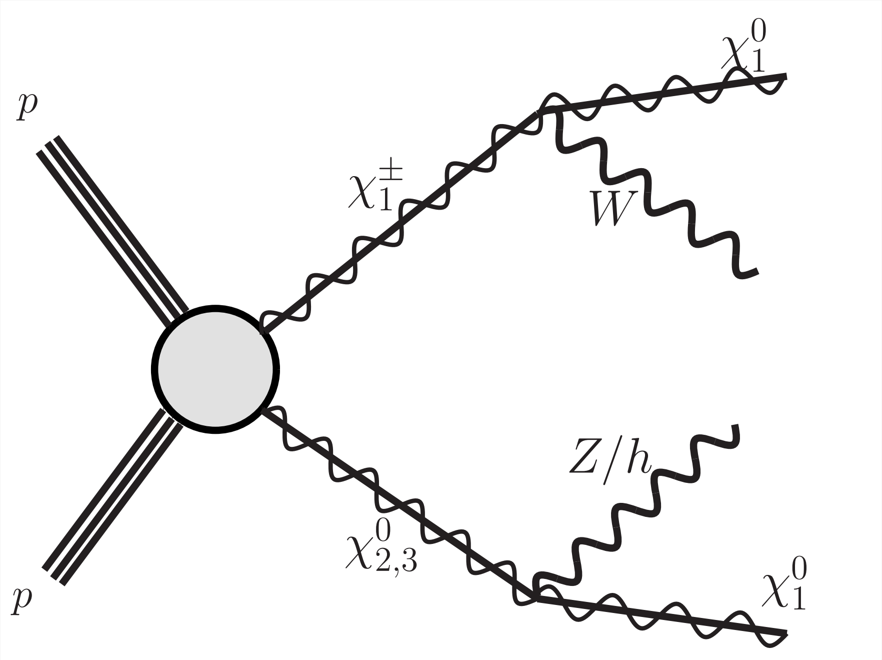
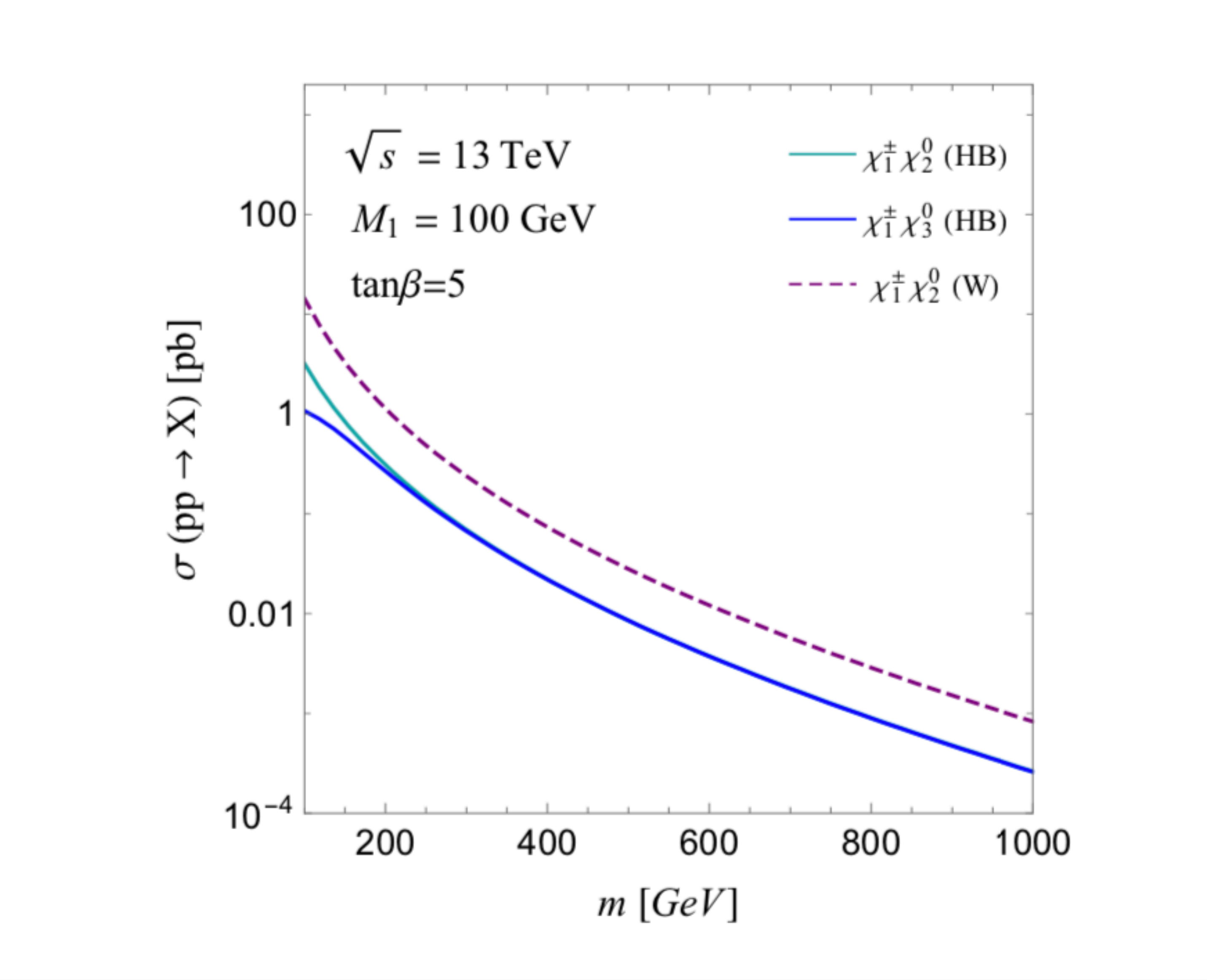
Higgsino-Bino scenario

$$M_1 \lesssim |\mu| \ll M_2$$





χ_2^0 & χ_3^0 give comparable contributions now, $m_{\chi_1^\pm} \simeq m_{\chi_2^0} \simeq m_{\chi_3^0}$

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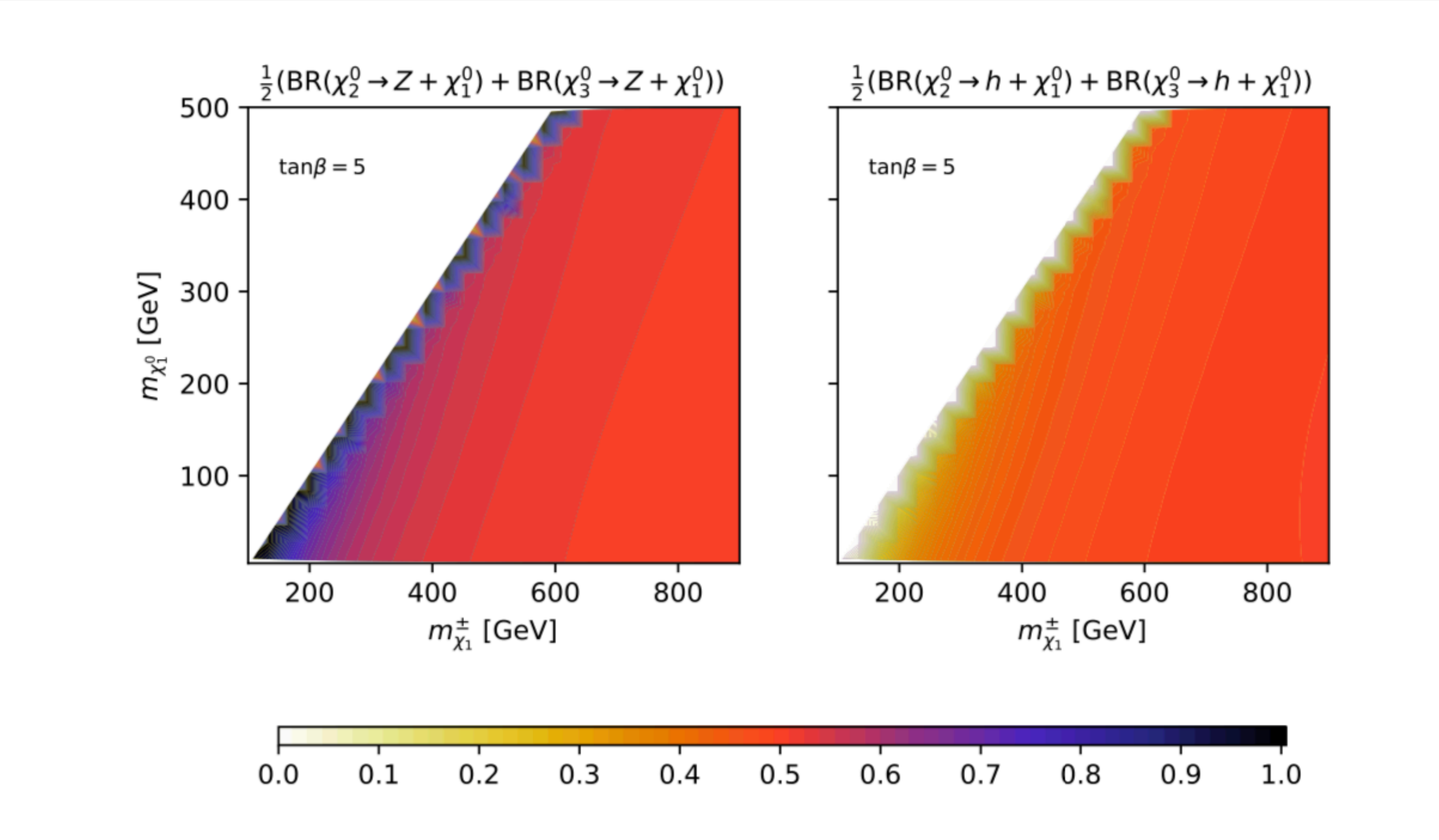
Higgsino-Bino scenario



Simple pattern of overall branching ratio to Z or h

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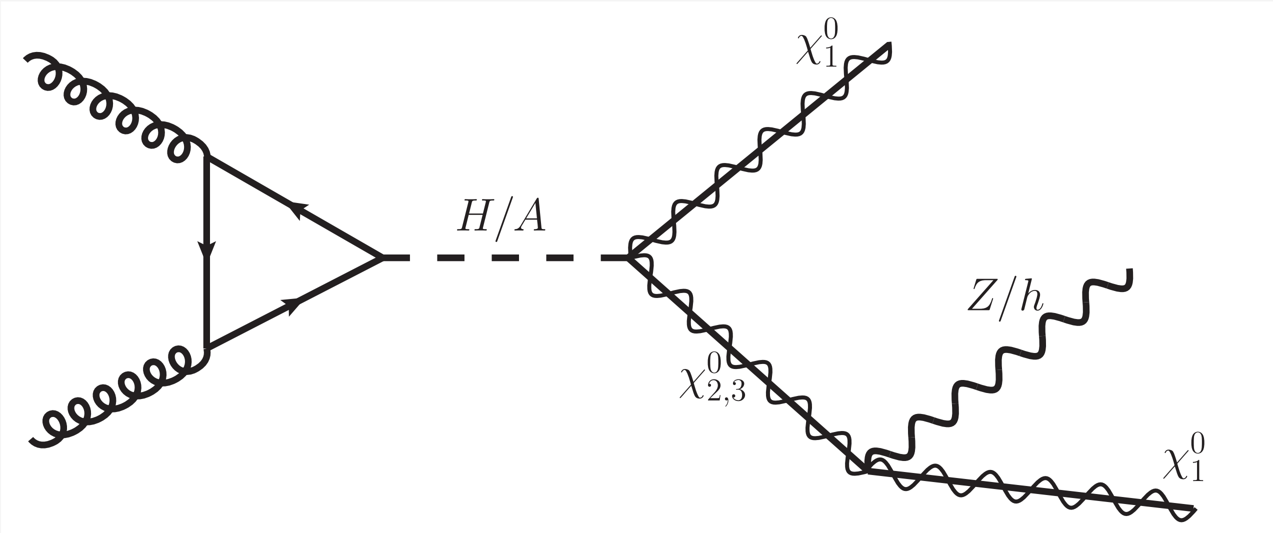
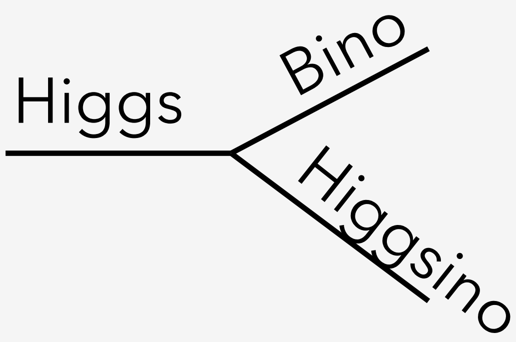
Higgsino-Bino scenario

Complementary channel





~ coupling not suppressed by mixing

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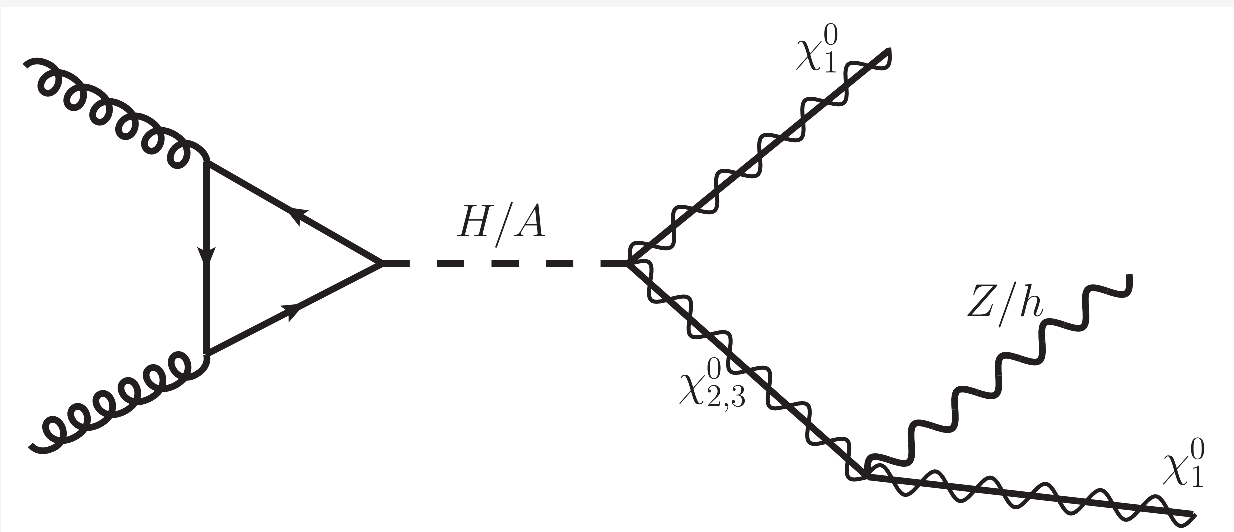
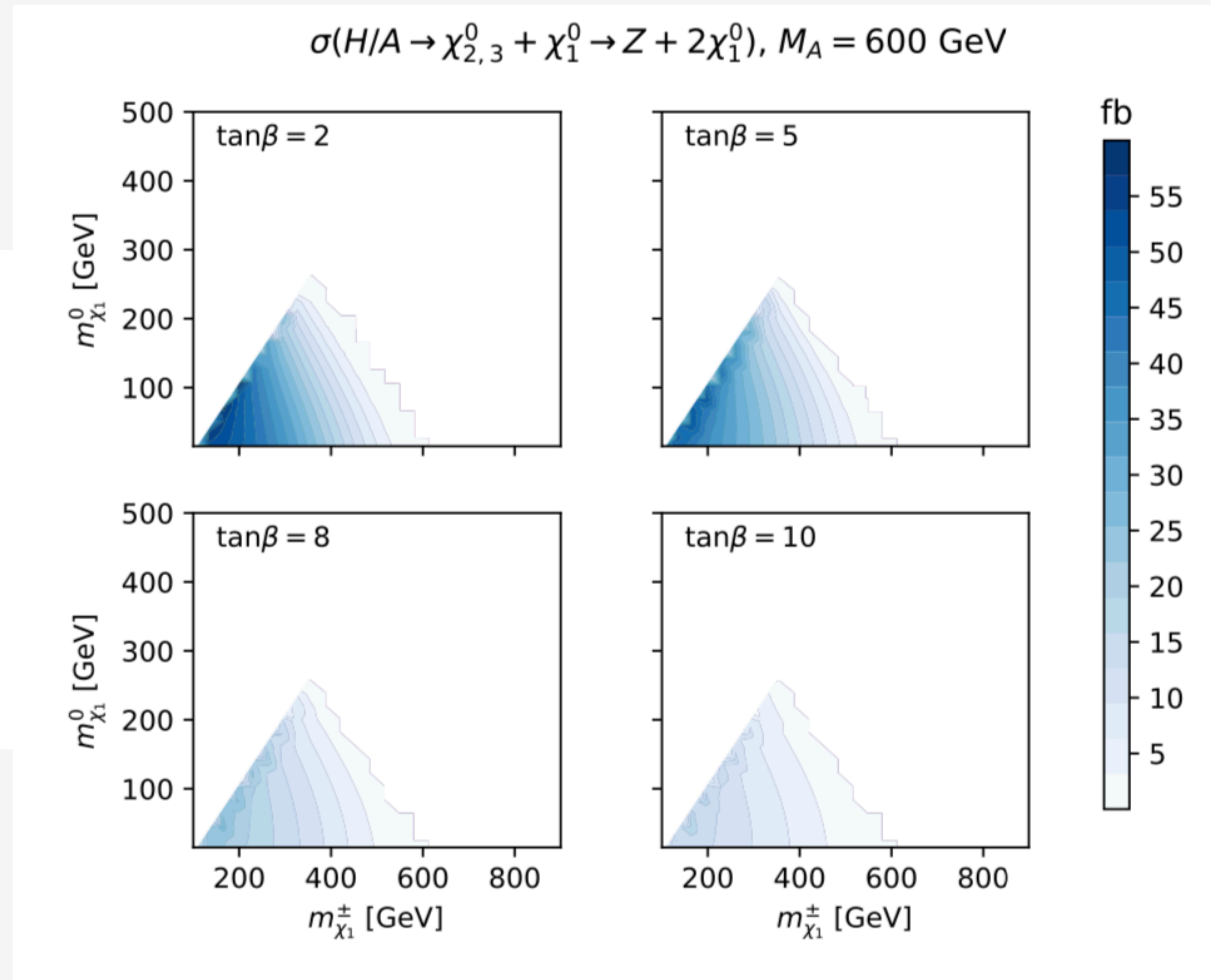
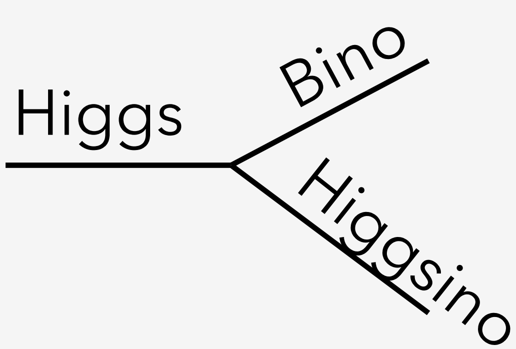
Higgsino-Bino scenario

Complementary channel







$\mathcal{O}(1-10)$fb size x-section

Very different kinematics due to heavy resonance

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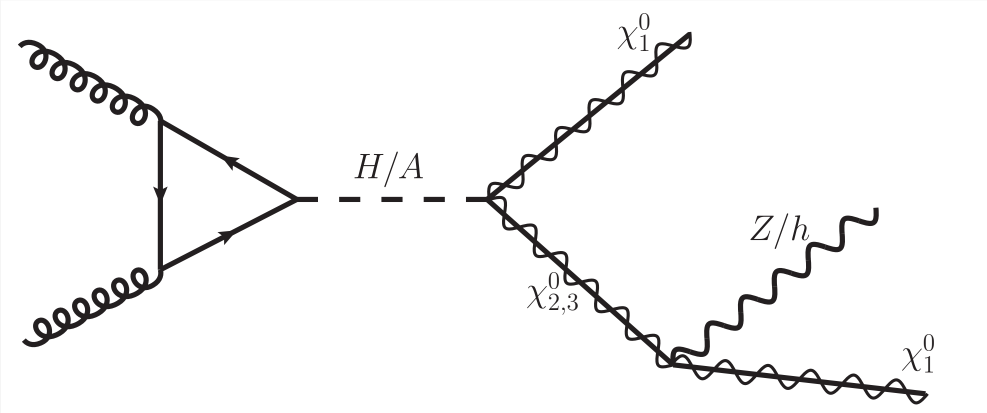
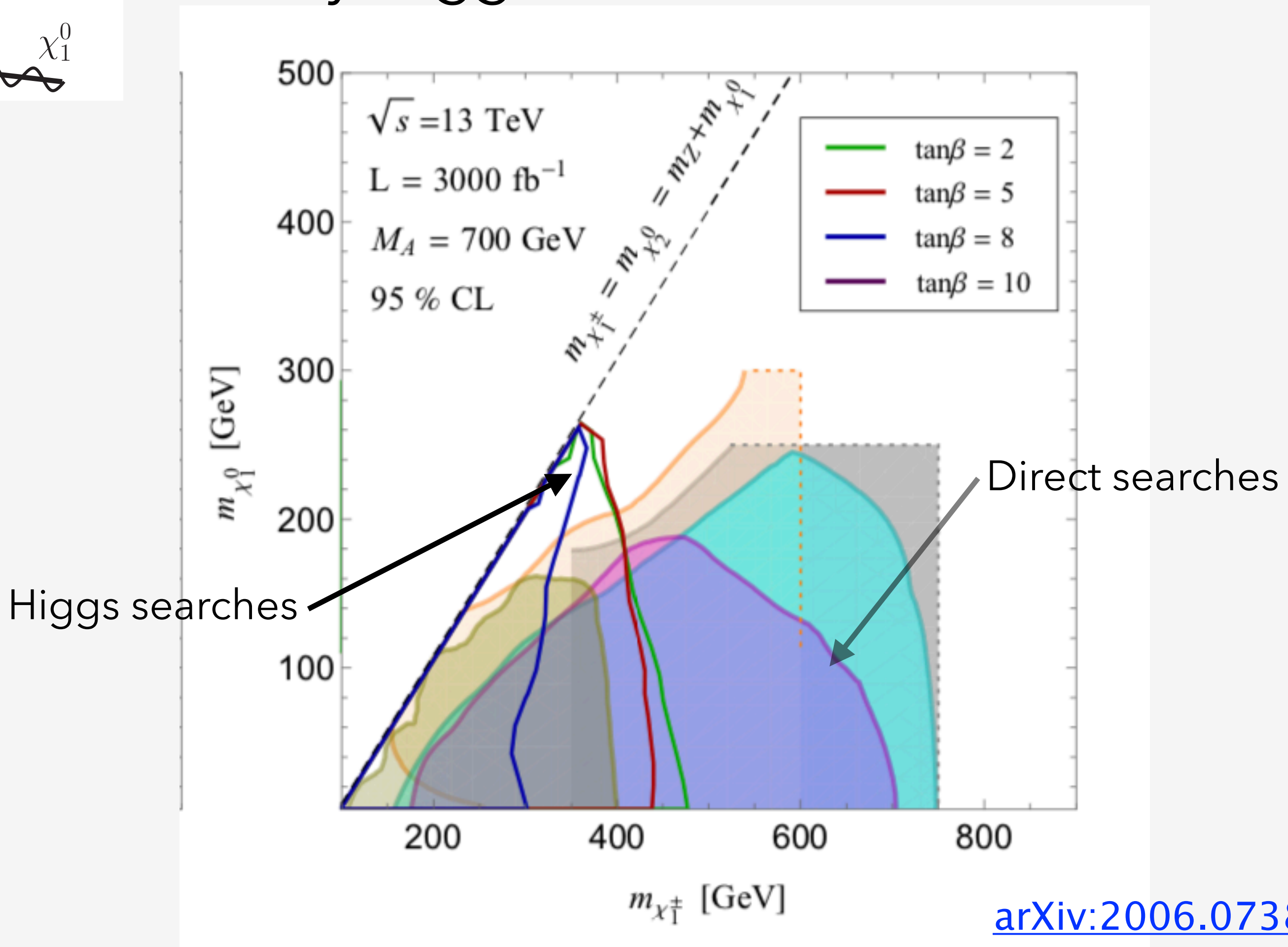
Higgsino-Bino scenario

- Higgsino-Bino scenario (large components of $\tilde{H}$):
  - Alternative search channel NOT yet explored (in detail) by ATLAS and CMS



Not only relevant for EWinos, but gives additional handle on the heavy Higgs sector in the MSSM



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Higgsino-Bino summary

$M_1 \lesssim |\mu| \ll M_2$

- Weaker direct production (no squark channel) than in Wino case
- Pattern of mixing allows alternative search channel with complementary region to explore decays. Additionally probes Higgs sector

Optimal case of $m_A = 700$ GeV, gives significant reach in compressed region $m_{\chi_1^\pm} \simeq 400$ GeV, $m_{\chi_1^0} \simeq 300$GeV

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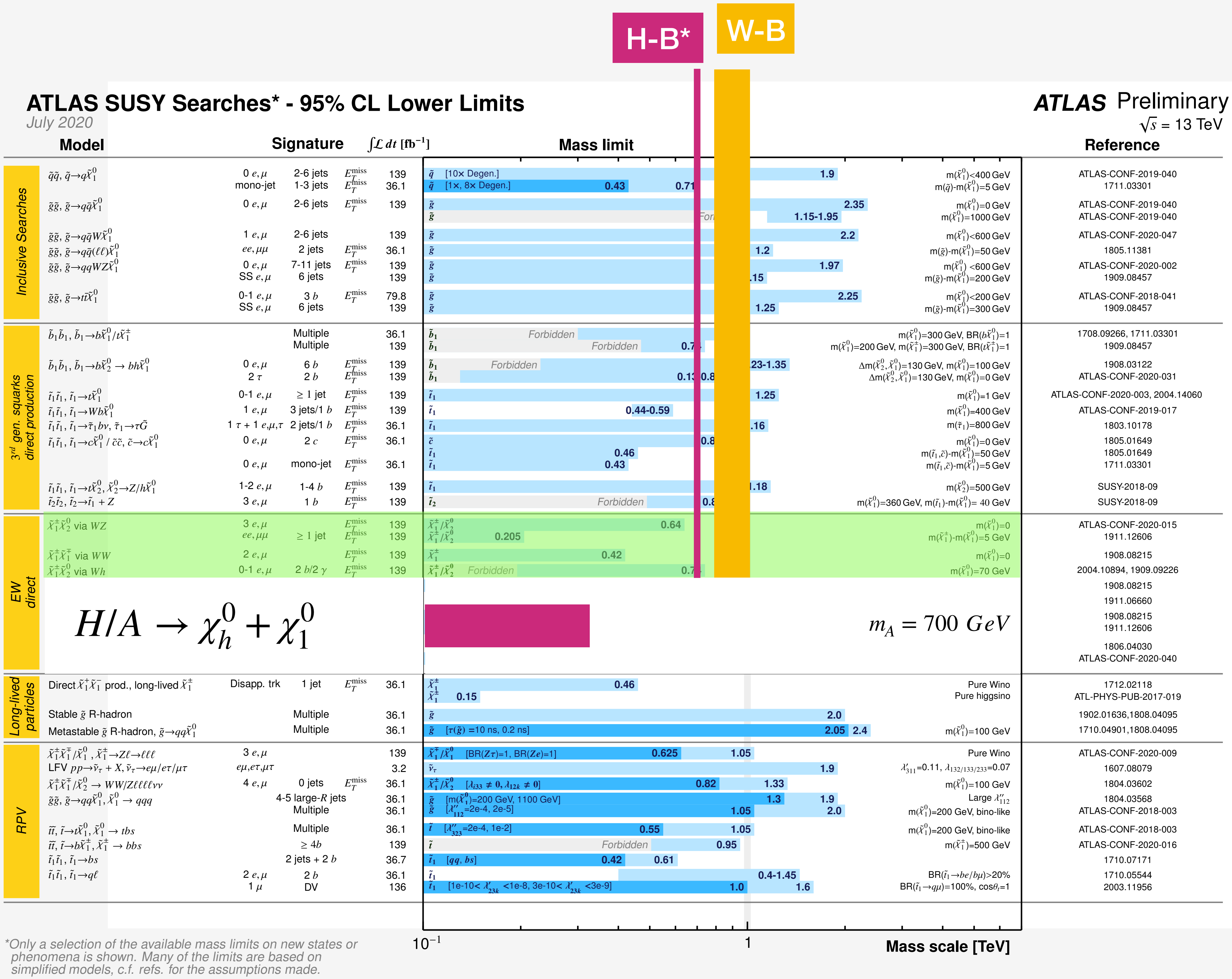

*Current bounds highly relaxed in H-B scenario

Summary

- Traditional EW search channels can probe different mixing scenarios btw a Wino/bino-like spectrum and Higgsino/Bino-like spectrum
- Each case requires different kind of search strategy (branching ratios, production channels, kinematics)
- HL-LHC has strong potential to explore all of these regions, probing multiple aspects of SUSY models: Higgs sector, EWino mixings, squarks (indirectly)

We will learn a lot about EWinos at the HL-LHC :)

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