Current LHC sensitivity to heavy Higgs decays into electroweakinos in the MSSM

Thea Engler

University of Freiburg

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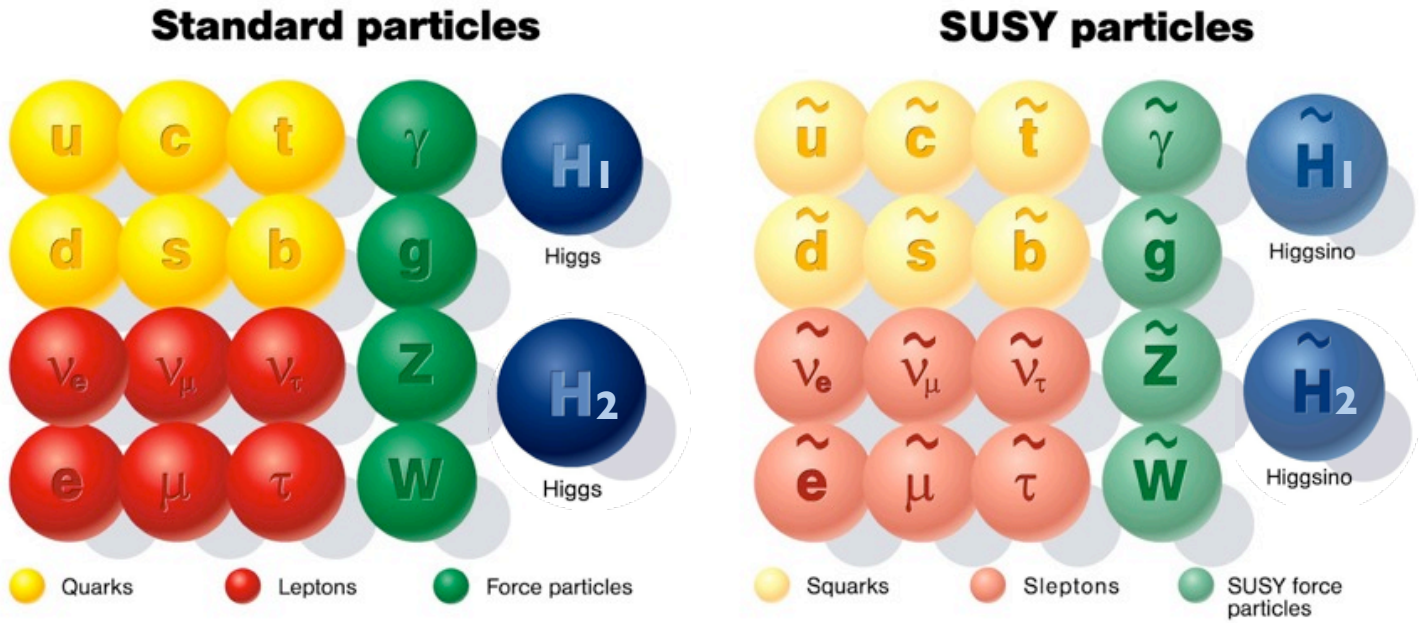
DESY Theory Group
supervised by Georg Weiglein, Tim Stefaniak, Emanuele Bagnaschi

Outline

Minimal Supersymmetric Standard Model (MSSM)

Supersymmetry: bosons $\leftrightarrow$ fermions



Neutralinos $\widetilde{\chi}_i^0$ (i=1,2,3,4): mixtures of $\widetilde{\gamma}, \widetilde{Z}, \widetilde{h}_1^0, \widetilde{h}_2^0$

Charginos $\widetilde{\chi}_j^{\pm}$ (j=1,2): mixtures of $\widetilde{W}^{\pm}, \widetilde{h}^{\pm}$

$\widetilde{\chi}_1^0$ is the lightest supersymmetric particle (LSP) and stable.

MSSM Higgs sector

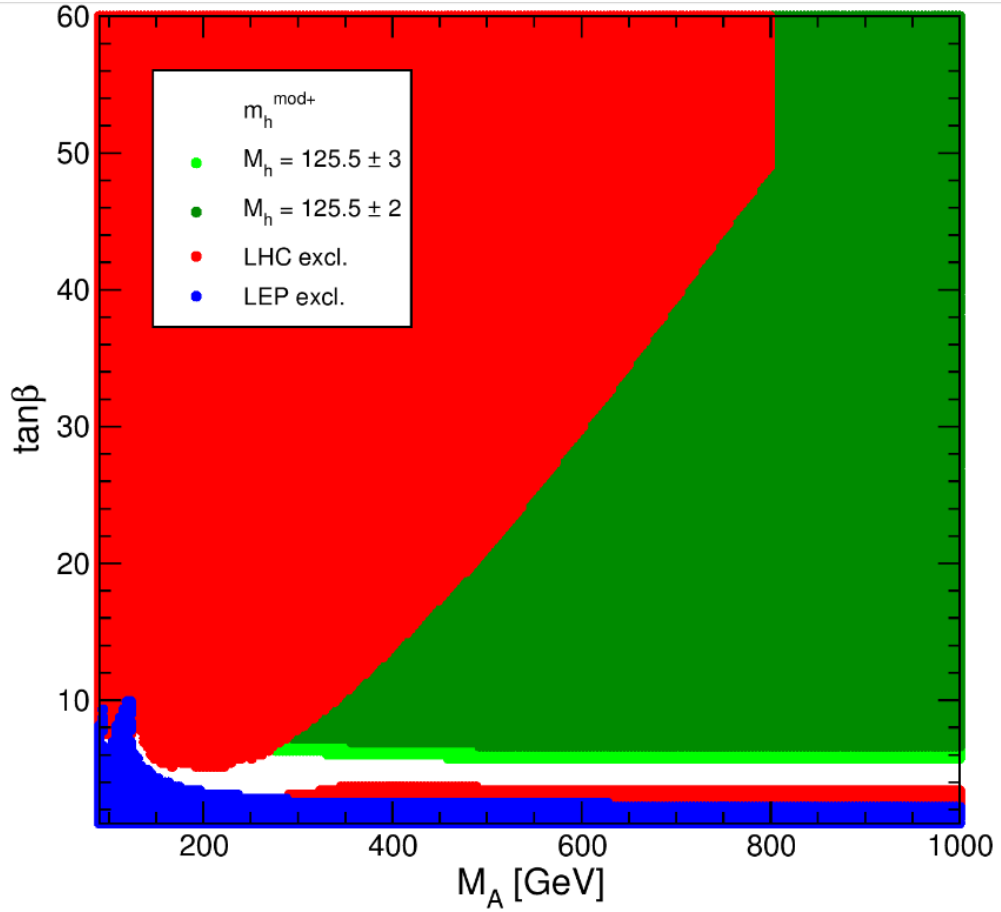
Two Higgs doublets $\rightarrow$ 5 physical Higgs states

- h, H: CP-even Higgs boson
- A: CP-odd Higgs boson
- $H^{\pm}$: charged Higgs boson pair

light Higgs boson $h \approx$ SM-like Higgs boson ($m_h \approx 125$ GeV)

important parameters for our analysis: M_A, $\tan\beta = \frac{v_2}{v_1}$

MSSM Higgs benchmark scenario (m_h^{mod+})



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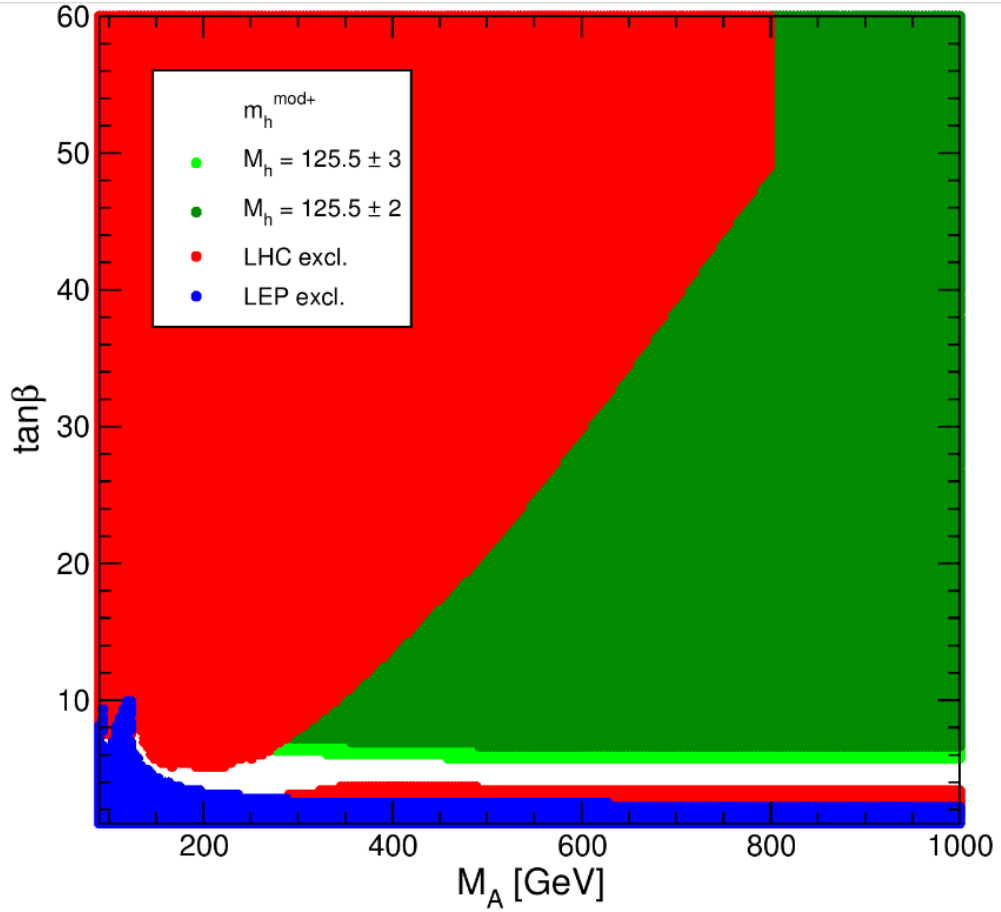
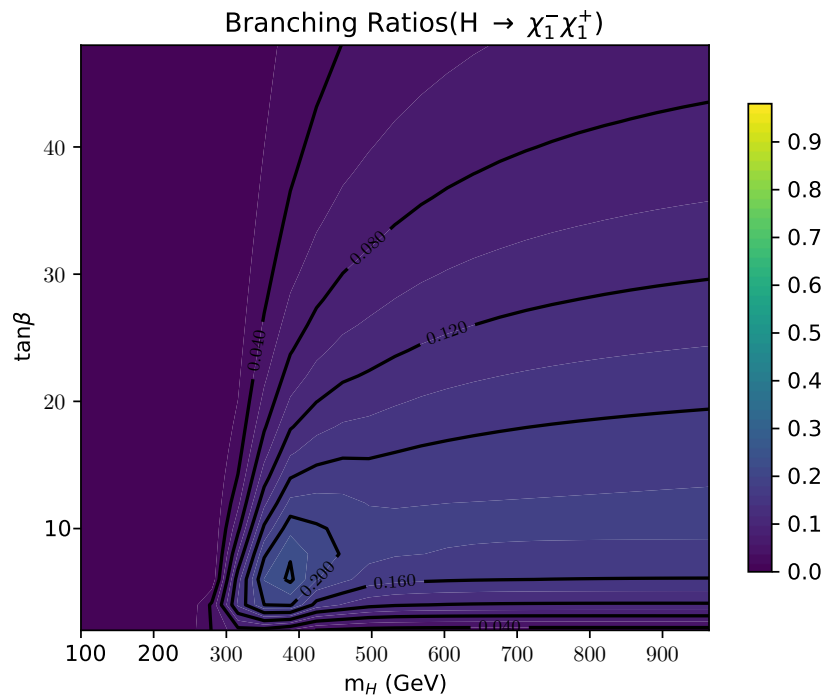


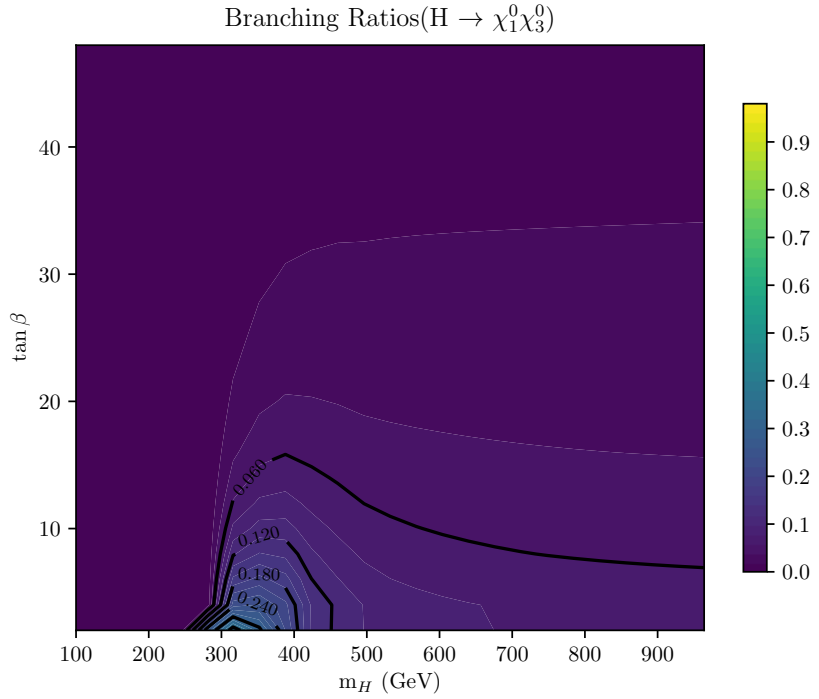
- $M_2 = \mu = 200$ GeV $\rightarrow$ light neutralinos and charginos ($M_{\tilde{\chi}_1^0} \approx 88$ GeV, $M_{\tilde{\chi}_2^0} \approx M_{\tilde{\chi}_1^\pm} \approx 160$ GeV),
- high number of H/A decays to electroweakinos.

Branching Ratio of the heavy Higgs decaying into gauginos

$$H \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$$



$$H \to \tilde{\chi}_1^0 \tilde{\chi}_3^0$$



Successive decays:

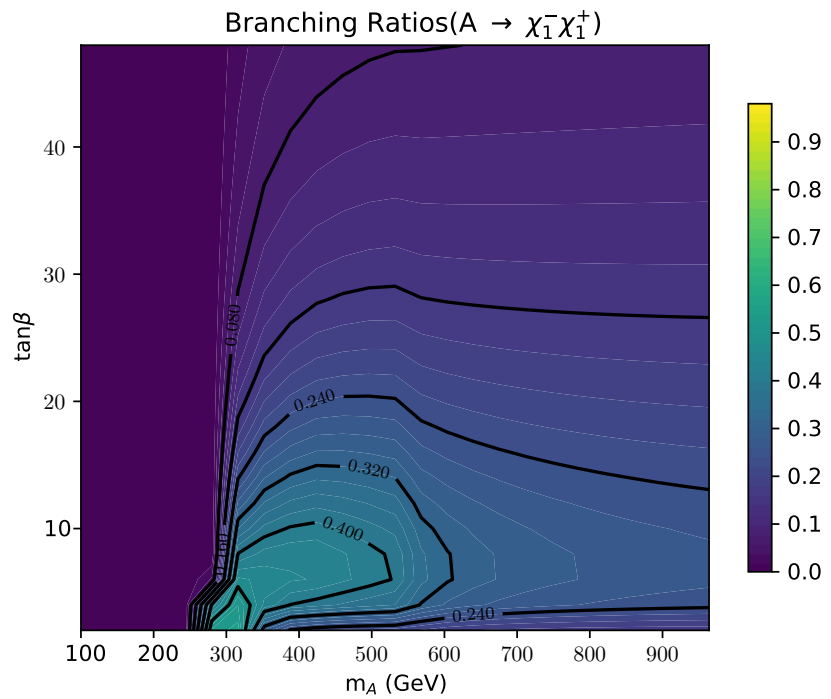
$\tilde{\chi}_1^\pm \to W^\pm \tilde{\chi}_1^0$ (100%), $\tilde{\chi}_3^0 \to Z \tilde{\chi}_1^0$ (100%), $\tilde{\chi}_1^0$ stable.

promising collider signature:

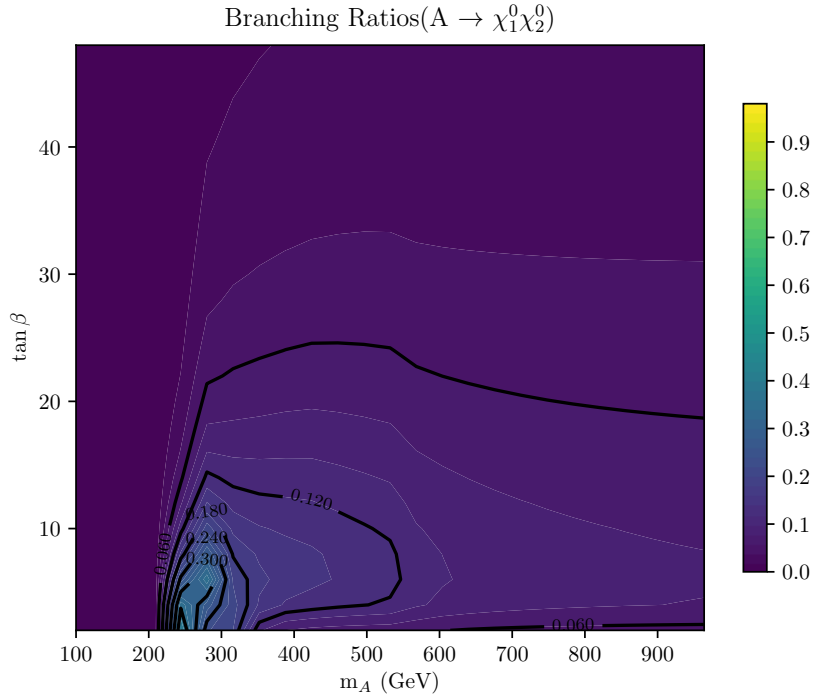
2 leptons + missing transverse energy ($\not{E}_T$)

Branching Ratio of the heavy Higgs decaying into gauginos

$$A \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$$



$$A \to \tilde{\chi}_1^0 \tilde{\chi}_2^0$$



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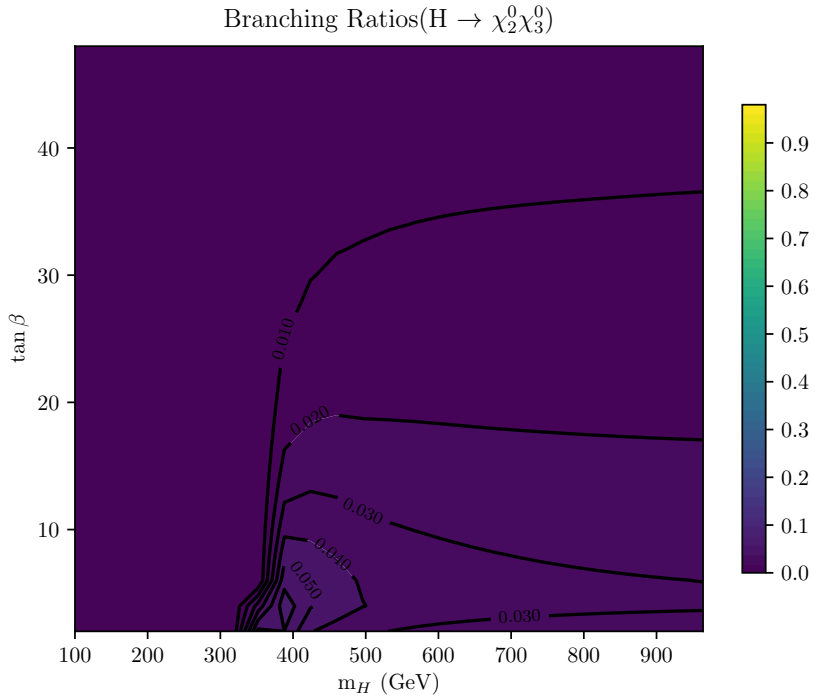

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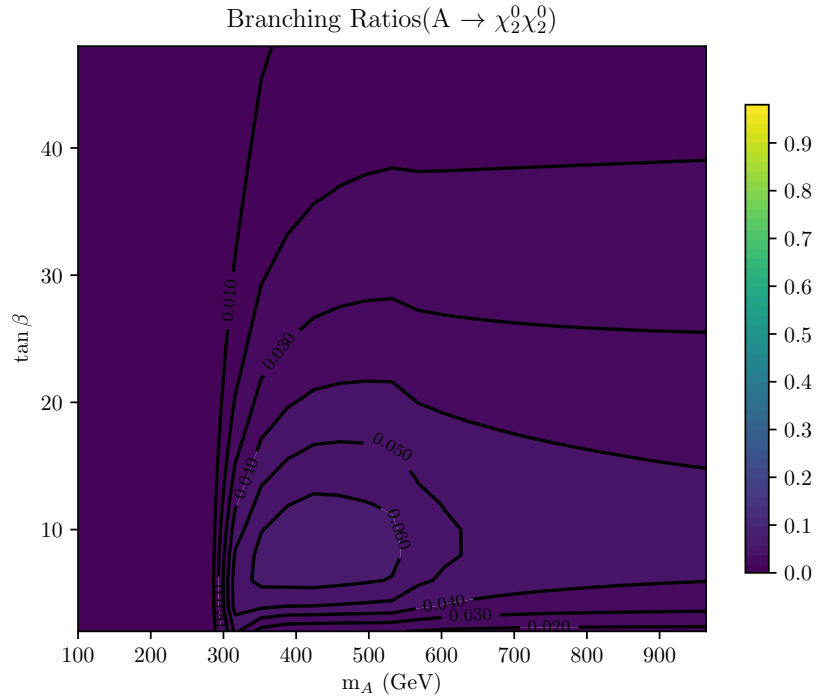


Successive decays:

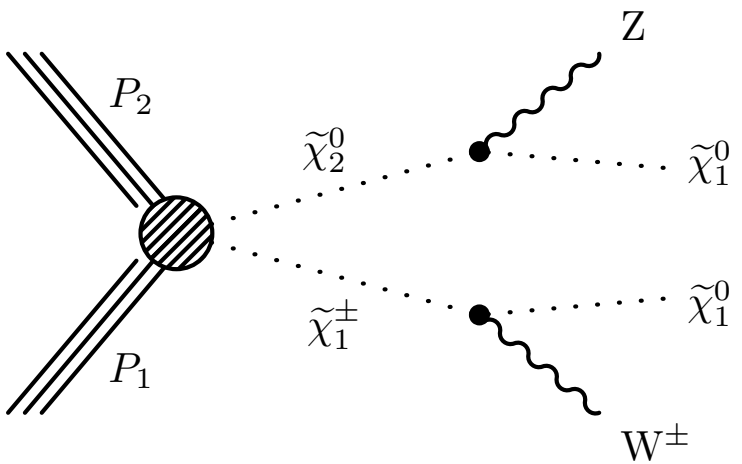
$\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$ (100%), $\tilde{\chi}_3^0 \to Z\tilde{\chi}_1^0$ (100%), $\tilde{\chi}_1^0$ stable.

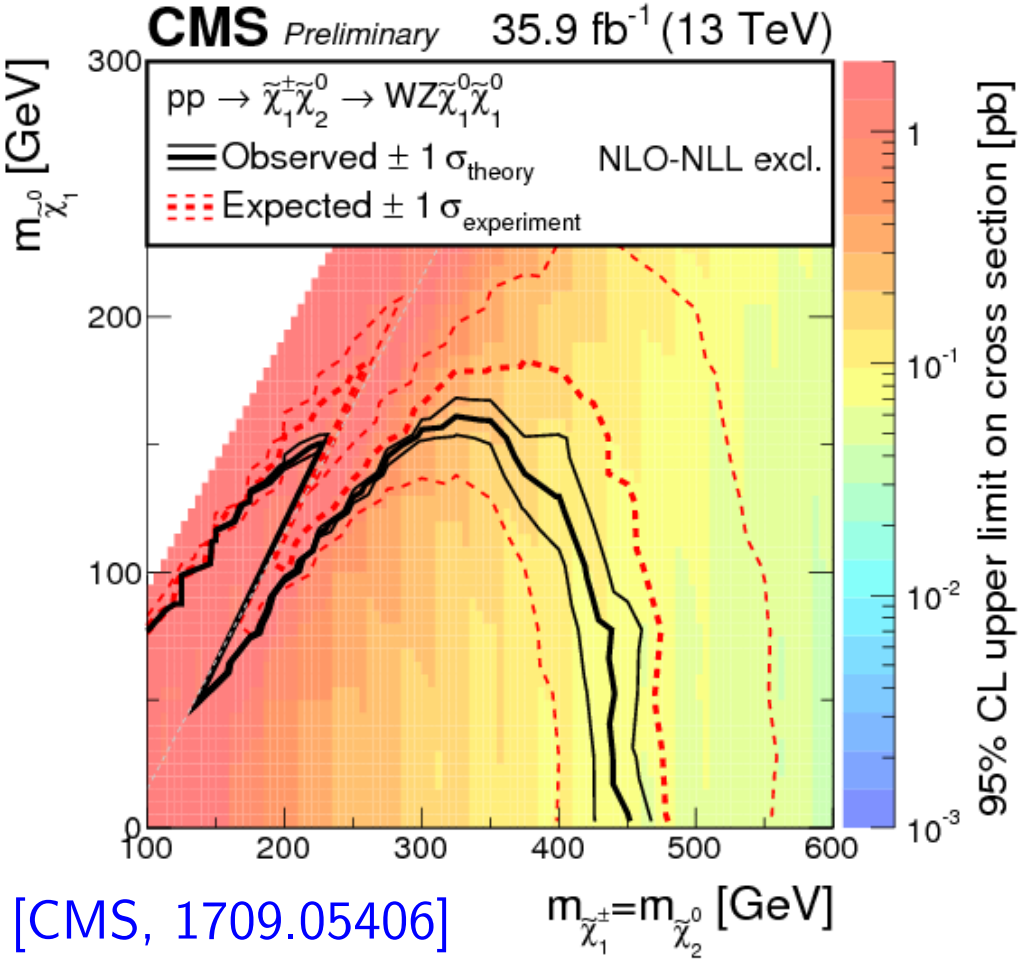
promising collider signature:

4 leptons + missing transverse energy ($\not{E}_T$)

LHC searches for neutralinos and charginos ("EW-inos")

Production modes: $pp \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$, $pp \to \tilde{\chi}_2^0 \tilde{\chi}_2^0$, $pp \to \tilde{\chi}_1^\pm \tilde{\chi}_2^0$





$M_{\tilde{\chi}_1^0} \approx 88$ GeV

$M_{\tilde{\chi}_2^0} \approx M_{\tilde{\chi}_1^\pm} \approx 160$ GeV

[CMS, 1709.05406]

promising signature: multiple leptons (2,3,4..) + $\not{E}_T$

Aim of this project

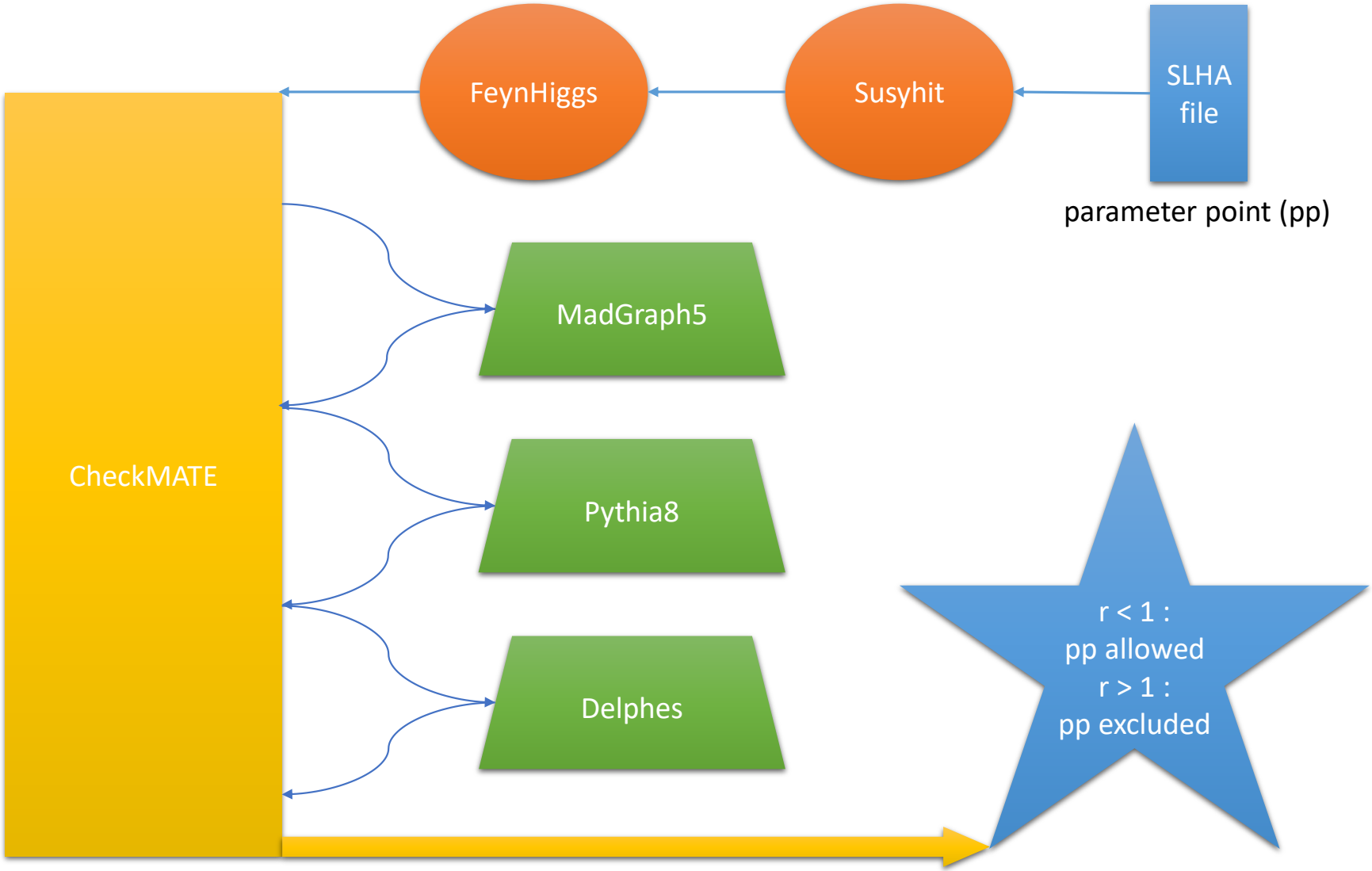
1. Do LHC EW-ino searches exclude the m_h^{mod+} scenario?
2. What happens if the additional contribution from heavy Higgs decays to EW-inos is taken into account?

Procedure [for 1 and 2]:

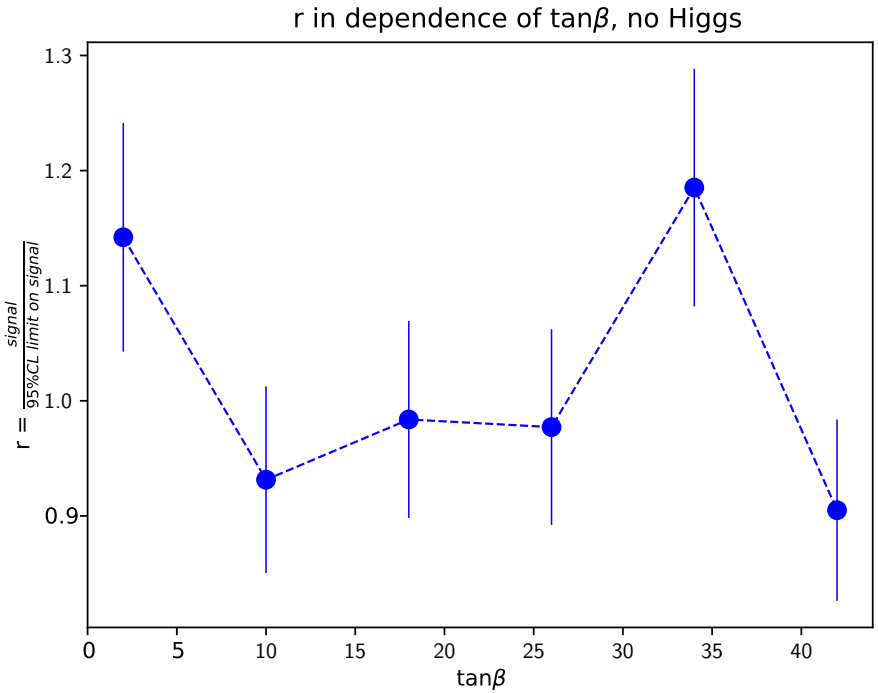
- estimate **number of signal events (s)** for m_h^{mod+} parameter points (with Monte-Carlo simulation),
- compare with experimental **upper limit on number of signal events (s_{limit})**:

$$r \equiv \frac{s}{s_{\text{limit}}}, \qquad \begin{aligned} r \leq 1 &\Rightarrow \text{allowed}, \\ r > 1 &\Rightarrow \text{excluded}. \end{aligned}$$

Computer tools



Results



- Most sensitive analysis: $4\ell + \not{E}_T$ signal region, [CMS,1709.05406]

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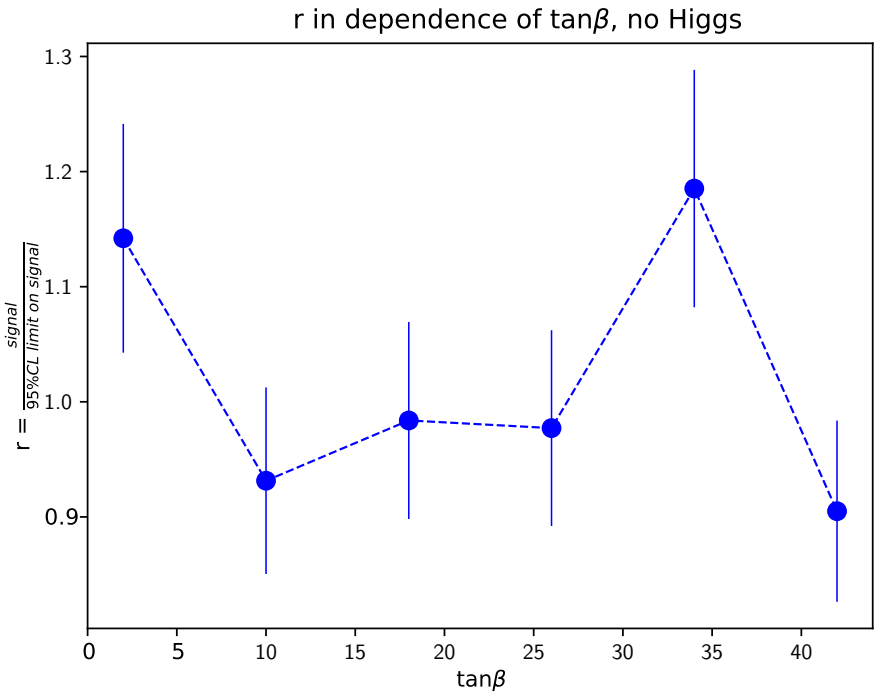

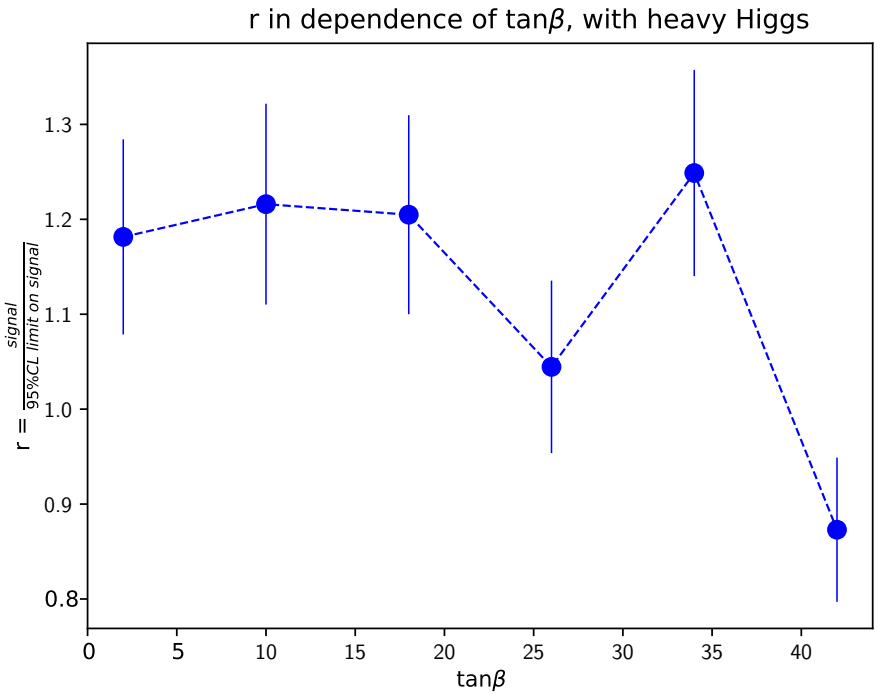

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- Exclusion at $\tan\beta \sim$ 10-15 influenced by Higgs contribution: H/A decays to $\widetilde{\chi}_2^0\widetilde{\chi}_2^0$ and $\widetilde{\chi}_2^0\widetilde{\chi}_3^0$ important (4ℓ final state!)

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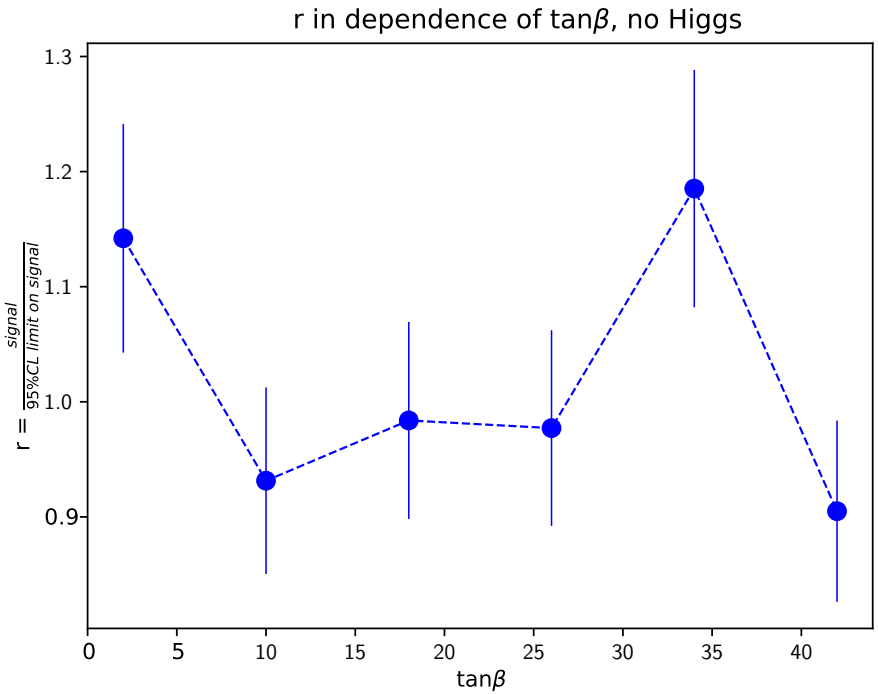

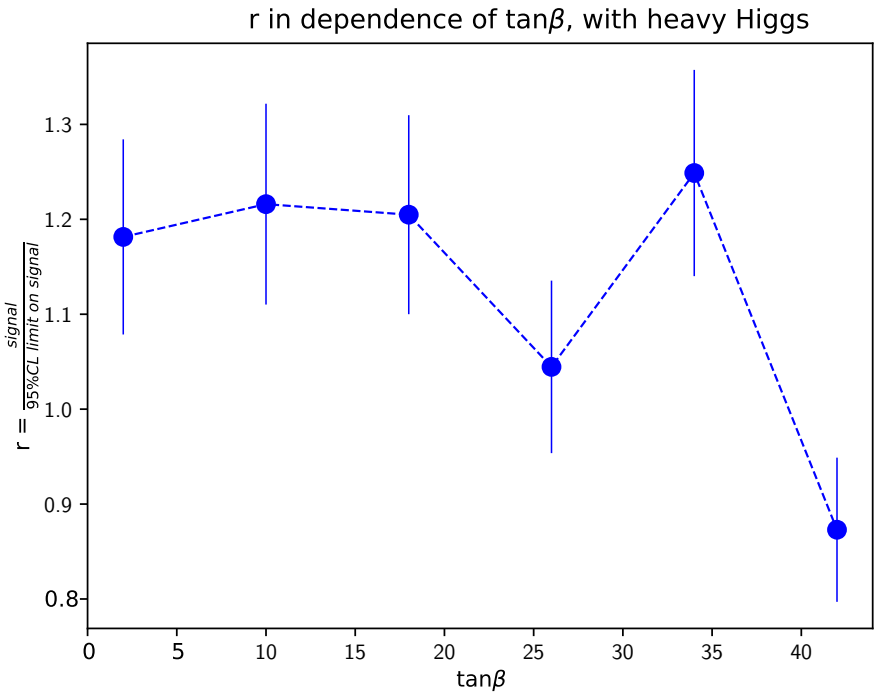

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- Still large statistical uncertainty despite 1.5M events per parameter point.

Conclusions & Outlook

- LHC is sensitive to m_h^{mod+} for the direct electroweakino production and nearly excluded by the direct EW-ino searches.
- When heavy Higgs decay into EW-ino, are additionally taken into account: tendency of increased r-value for $M_A = 352$ GeV and $\tan\beta \sim 10 - 15$.

Next steps

Consider full $(M_A, \tan\beta)$ plane,
Consider recently updated MSSM Higgs benchmark scenarios, [1808.07542]
NLO corrections on production (expected increase $\sim 20\%$).