Search for Supersymmetry at the LHC
Charged Higgs to SUSY with Three Leptonic Final State Particles

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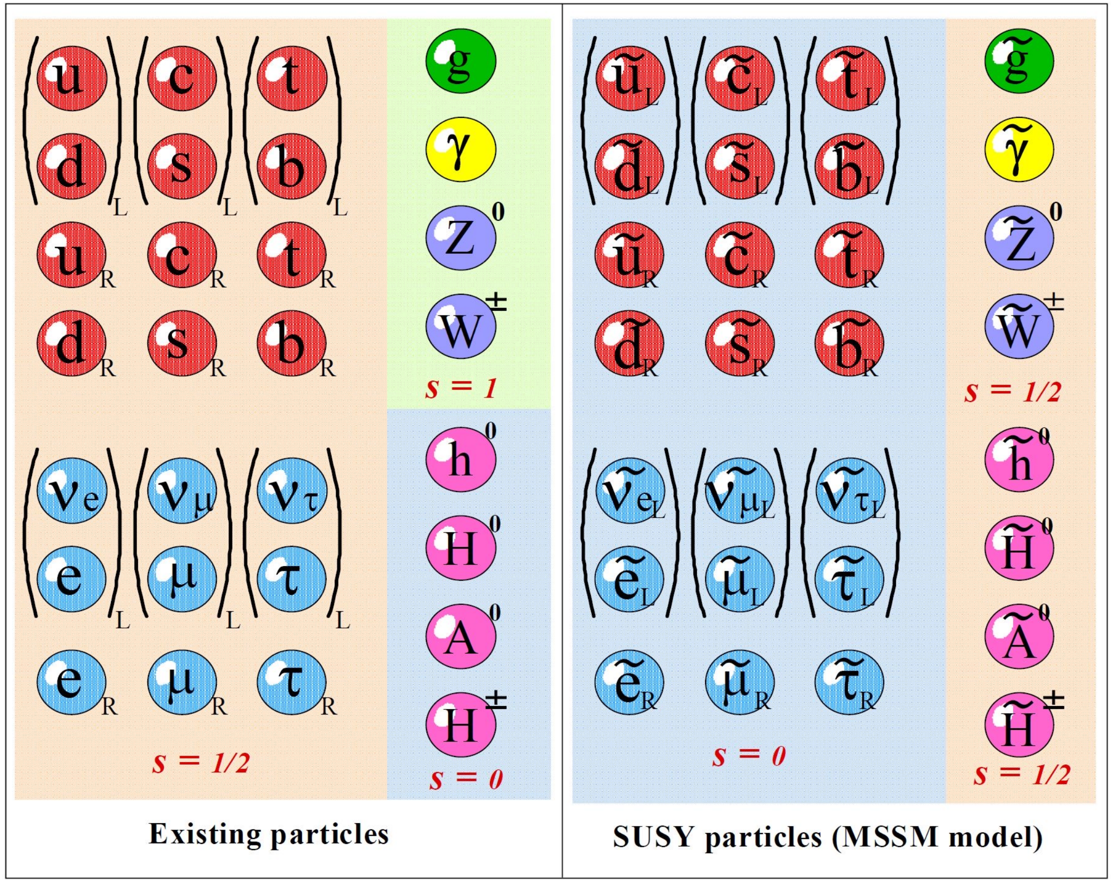
Abstract

Search for Supersymmetry at the LHC - Charged Higgs to SUSY with Three Leptonic Final State Particles AMY REWOLDT, None, UTA-ATLAS COLLABORATION — In the attempt to answer some questions about our universe, the LHC (Large Hadron Collider) at CERN is superior at collecting data at very high energy particle collisions. As of now, physicists have obtained precise measurements describing particle interactions which agree remarkably well with the standard model (SM). However, the SM theory does not satisfy the concerns contemporary theoretical physics presents, like the abundance of dark matter in the universe and the hierarchy problem. Supersymmetry (SUSY) addresses most issues with unnatural theoretical divergence known as the hierarchy problem and it introduces a dark matter candidate. In the minimal supersymmetric standard model (MSSM), a set of SUSY particles or super-partners are introduced, composing the simplest SUSY model. These SUSY particles couple through the Higgs field and their angular momentum spin term, differing by $|1/2|$of their corresponding SM partner. Particles can be simulated in Monte-Carlo collision data to study their kinematics and interactions. By analyzing charged Higgs decays into SUSY particles, experimentalists determine the feasibility of SUSY appearing in this channel which has not yet been analyzed at the LHC. Charged Higgs to SUSY probes the theoretical parameter space which is not accessible by other benchmark charged Higgs decays. Additionally, the case in which three leptons appears in the final state is promising due to the enhanced production when coupling to a heavy Higgs particle.

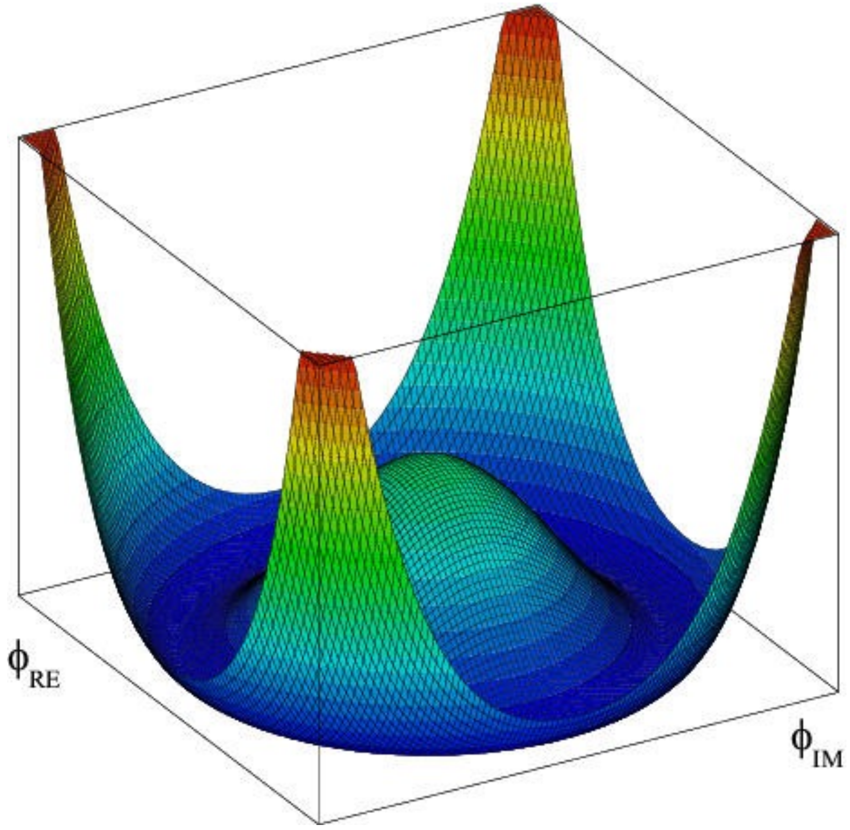
Supersymmetric Standard Model

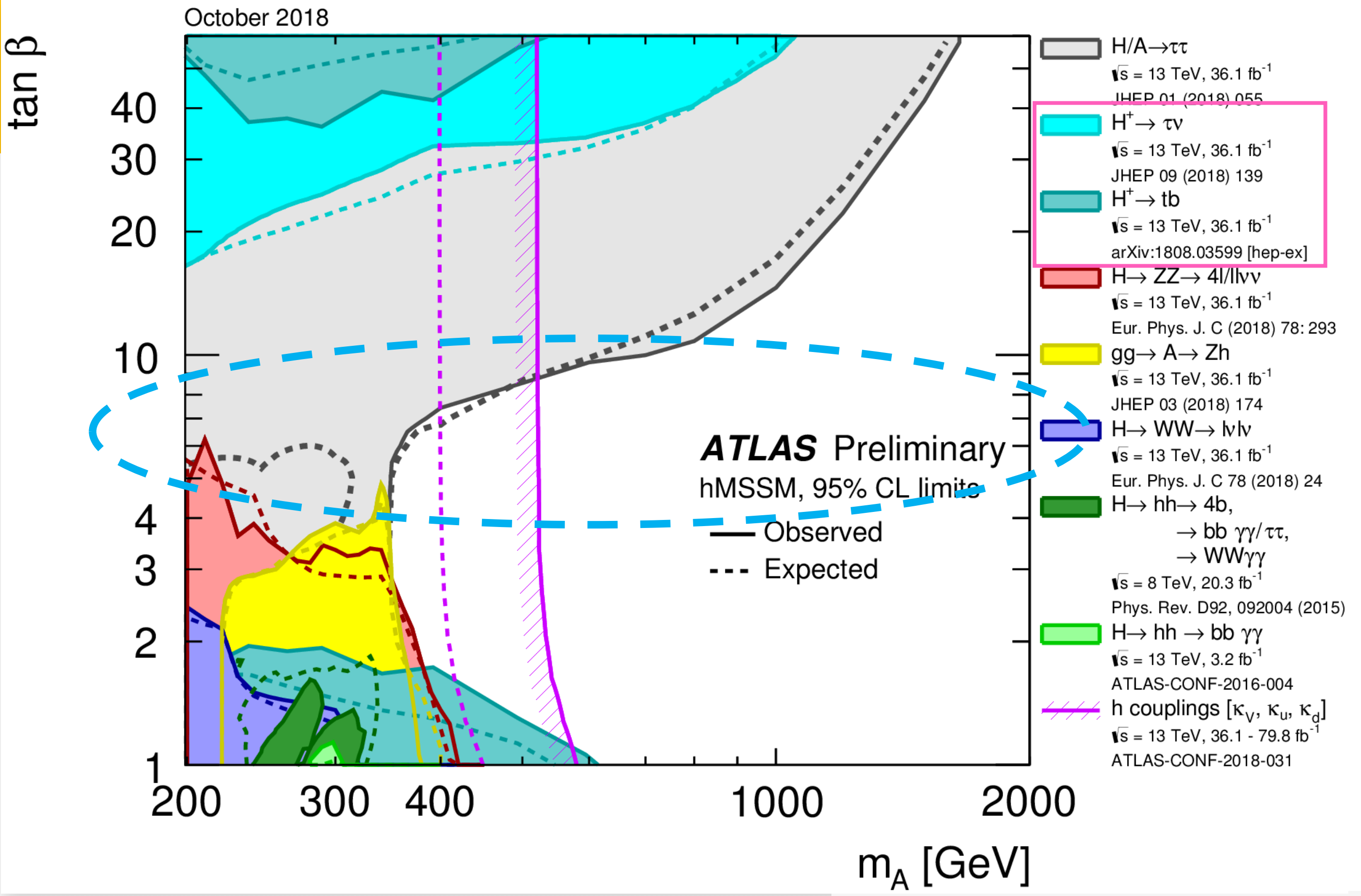
- Minimal Supersymmetric Standard Model (MSSM) is a SUSY model with the minimal number of new particle states and interactions while remaining consistent.
- MSSM gives existing particles in SM a superpartner with spin differing by a half-integer. This implies each fermion has a bosonic partner & vice versa.
- The partners of the SM Higgs & gauge bosons (higgsinos, winos, and bino) are collectively referred to as electroweakinos ($\chi_i^+\chi_j^0$).
- MSSM is an extended 2HDM (2 Higgs doublet Model), where up-type and down-type couple to separate doublets.

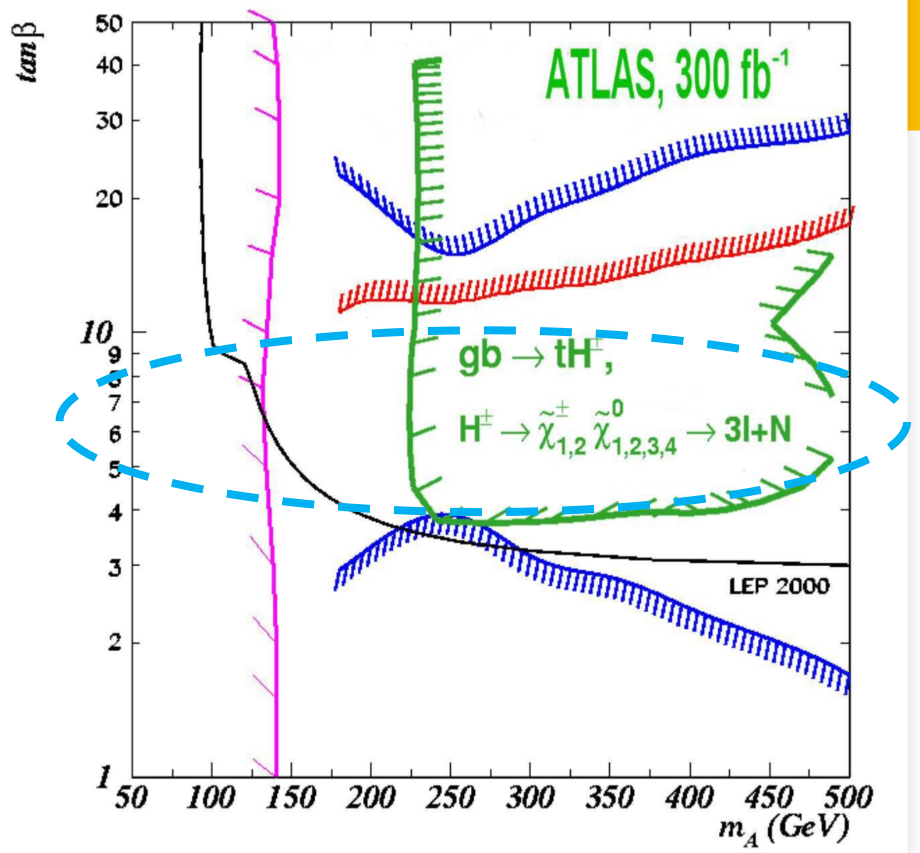


Additional Higgs Doublet and Parameter Space ($\tan\beta$ v. m_A)

- In the MSSM theory, an additional Higgs doublet is needed, thereby adding an additional Higgs field. Both have their own non-zero vacuum expectation value.
- $\tan\beta$ is the ratio of the two vacuum expectation values.
- This allows for the definition of parameter space, $\tan\beta$ v. m_A, where m_A is the mass of A (pseudoscalar Higgs boson).

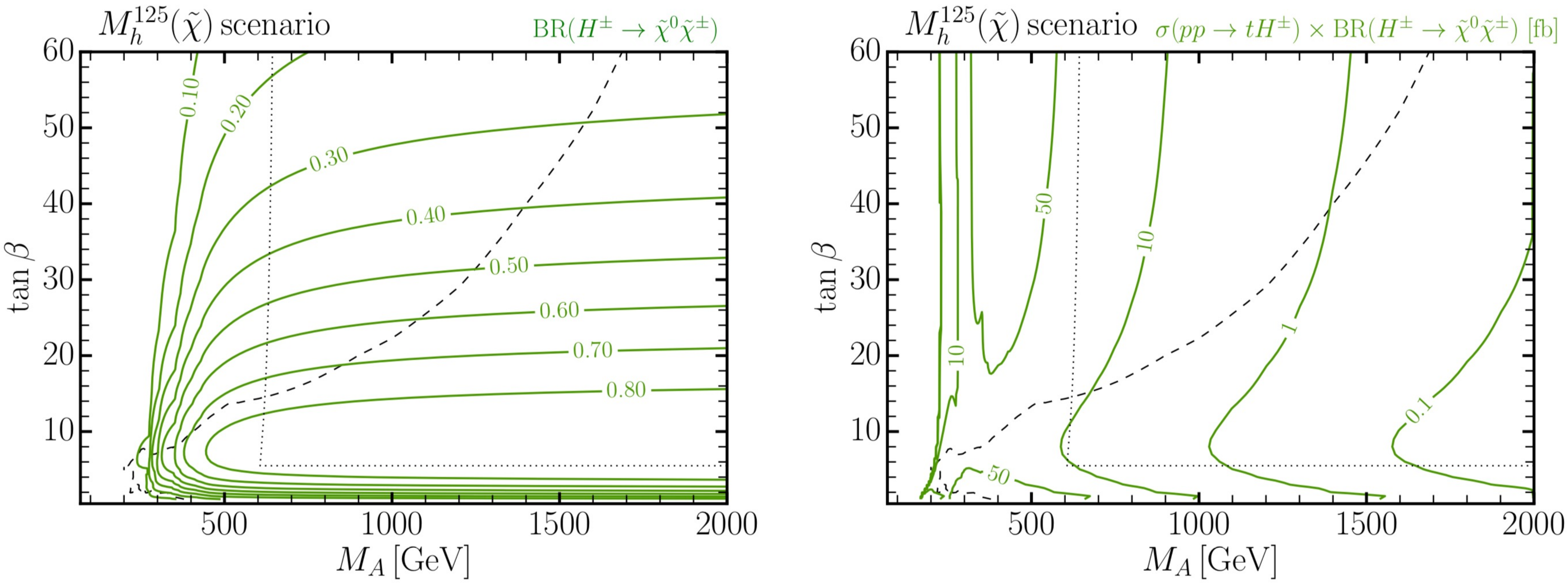






H+ ➞ SUSY and Unexplored "Wedge Region"

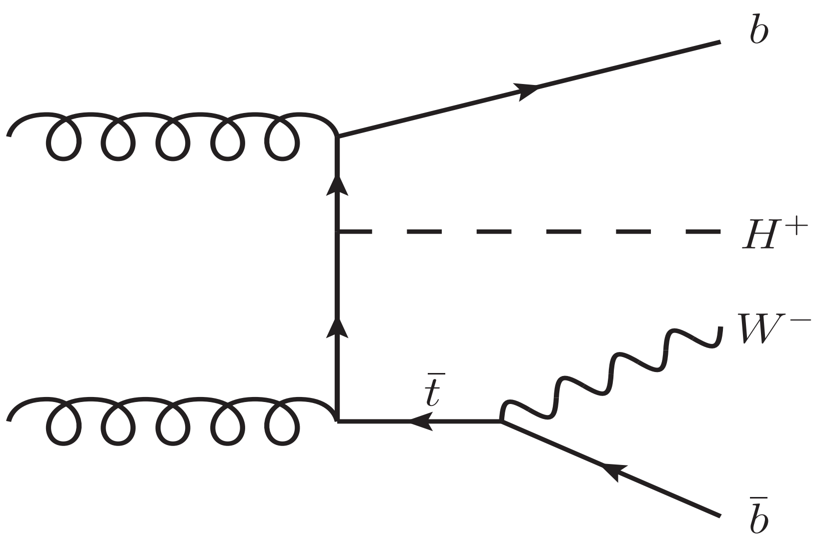
- H/A, H+ bounds are well defined for strongly interacting particles, but they fail to cover electroweak sector. The intermediate tanβ "wedge" region ($4<\tan\beta<10$) lies where $H^+\rightarrow$SM processes are suppressed.
- The H^+tb Yukawa coupling, given by ($m_b\tan\beta+m_t\cot\beta$) goes through a minimum around $\tan\beta\sim\mathrm{sqrt}(m_t/m_b)$. While rates suffer for $H^+\rightarrow$SM because of this, $H^+\rightarrow$SUSY does not have this coupling in the decay and would have better sensitivity to this region with same production rates.

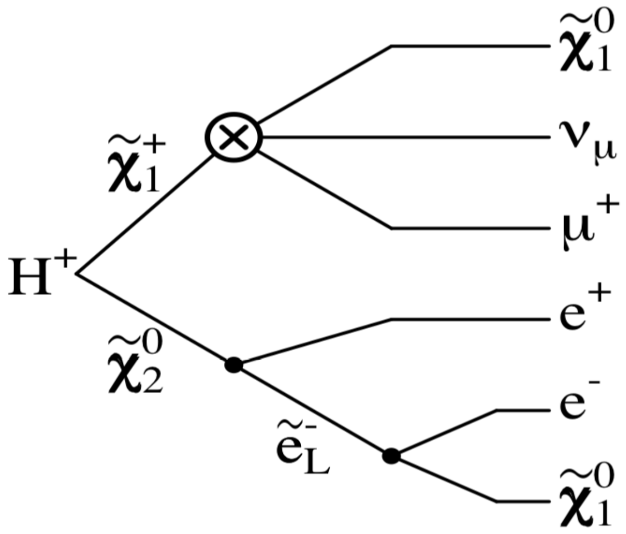


Benchmark Scenario

- Electroweak sector consists of sleptons, charginos, neutralinos, and heavy Higgs bosons, but the low rate of direct production for EWinos require new production modes with higher cross sections, cleaner final states, or improved search strategies.
- Latest benchmark scenario shows charged Higgs to chargino-neutralino pair can be dominant for intermediate values of tanβ and Higgs mass > 500GeV.
- The total rate of production for tH^+ followed by H^+ decaying to an electroweakino pair motivates further study (arXiv:1808.07542).

$H^+ \to$ SUSY (3ℓ + MET)





$$pp \to H^\pm + X, \quad H^\pm \to \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to 3\ell + E_T^{miss}$$

- $H^+ \to$ SUSY (3ℓ + MET) has not yet been explored by the LHC collaborations, as it is a new approach to the possible discovery of SUSY! (arXiv1811.11918).
- The purpose of this study is to motivate the feasibility of detecting SUSY within this decay mode when analyzing actual ATLAS detector data.
- A few features of final state
  - The transverse mass of 3ℓ + MET is directly related to the mass of H^+.
  - The invariant mass of the opposite sign same flavor (OSSF) dilepton pair is kinematically constrained by χ_2^0 and slepton ($\tilde{l}$), where χ_1^0 is the only non-visible particle in final decay product.

$$M_{\ell\ell_{max}} = \sqrt{\left(m^2_{\tilde{\chi}^0_j} - m^2_{\tilde{\ell}}\right)\left(m^2_{\tilde{\ell}} - m^2_{\tilde{\chi}^0_1}\right)/m^2_{\tilde{\ell}}}$$

Mass Points Chosen Based on Benchmark				
H+ mass (GeV)	X_1^+ mass	X_2^0 mass	e~l (GeV) mass	X_1^+ mass
500	120	165	110	105
600	120	165	110	105
700	120	165	110	105
800	120	165	110	105
1000	120	165	110	105