



pMSSM Scan: First Pass at EWK Cross-Sections

EF08: Snowmass pMSSM scans – November 11, 2020

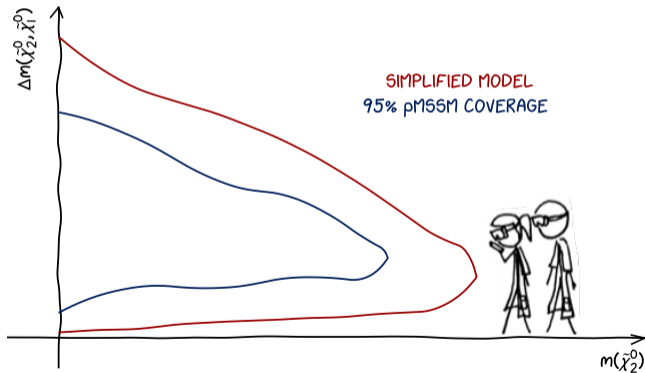
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“Non-Simplified” Exclusion Contours

What will we really be able to say about SUSY at future colliders?

Mostly interested in compressed EWK scenarios (e.g. higgsinos) at hadron colliders



- Optimize searches for simplified models but extrapolate sensitivity to realistic ones
- Scan pMSSM, calculate cross-sections and BRs, renormalize signal yields accordingly
- Redraw exclusion contours that cover some fraction of scanned pMSSM points
- Will need to generate some events for validation
 - ▶ Important changes in kinematics?
 - ▶ Contributions from cascade decays?



Model Generation:

- Small higgsino-like scan over EWK parameters to get started
- Using SoftSUSY (external to pMSSMFactory) for now, move to SPheno in the future?
- Output s1ha files are input to pMSSMFactory for cross-sections, BRs, event generation, etc.

Scan Details:

- $M_1 \in [100 \text{ GeV}, 2 \text{ TeV}]$ in steps of 100 GeV
- $M_2 \in [100 \text{ GeV}, 2 \text{ TeV}]$ in steps of 100 GeV
- $\mu \in [100 \text{ GeV}, 300 \text{ GeV}]$ in steps of 20 GeV
- $\tan \beta = [10, 20, 30]$

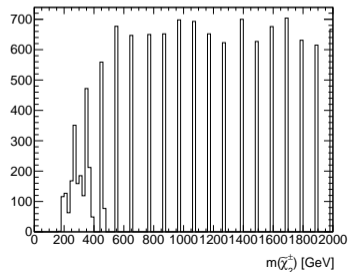
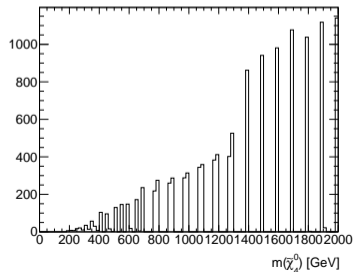
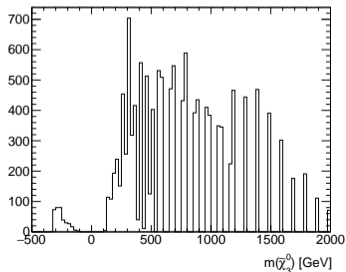
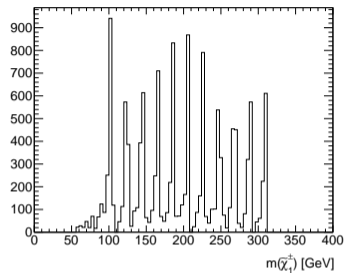
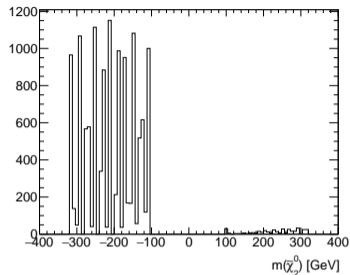
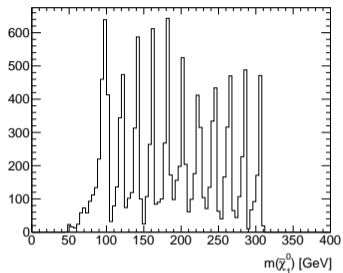
} **13.2k Models**

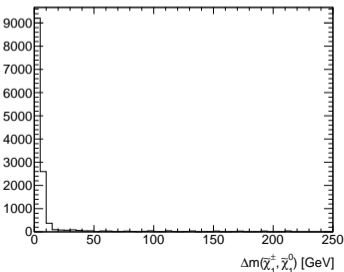
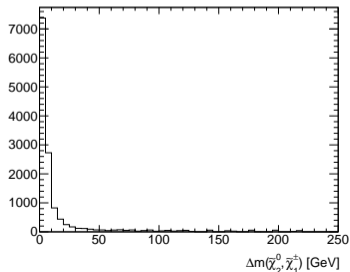
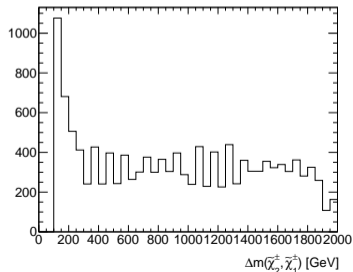
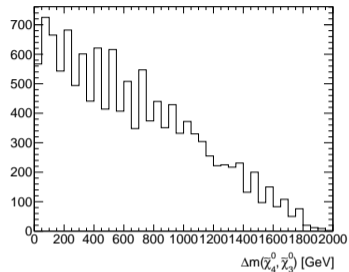
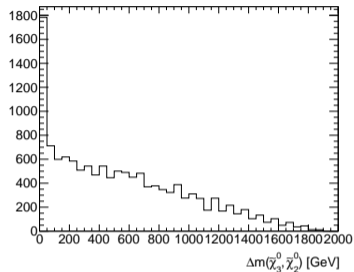
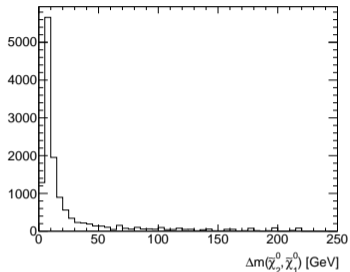


Workflow Details:

- Implemented newest Prospino to set arbitrary collider energies
 - ▶ Still needs to be merged into official pMSSMFactory
 - ▶ Track down suboptimal artifacts from Run 1 scan
- LO Cross-sections here calculated assuming 100 TeV pp collider
- Run as Condor jobs, results stored in MySQL database
- Final output: TTree with one entry per model
 - ▶ SUSY masses, parameters, cross-sections, BFs

Cross_section_nn11	BF_chi_10_other
Cross_section_nn12	BF_chi_10_to_e_L
Cross_section_nn13	BF_chi_10_to_gravitino_Z
Cross_section_nn14	BF_chi_10_to_gravitino_gam
Cross_section_nn15	BF_chi_10_to_gravitino_h
Cross_section_nn16	BF_chi_10_to_mu_L
Cross_section_nn17	BF_chi_10_to_nu_e_L
Cross_section_nn18	BF_chi_10_to_nu_mu_L
Cross_section_nn22	BF_chi_10_to_nu_tau_1
Cross_section_nn23	BF_chi_10_to_tau_1
Cross_section_nn24	BF_chi_1p_other
Cross_section_nn25	BF_chi_1p_to_chi_10
Cross_section_nn26	BF_chi_1p_to_chi_20
Cross_section_nn27	BF_chi_1p_to_chi_30
Cross_section_nn28	BF_chi_20_other
Cross_section_nn33	BF_chi_20_to_chi_10
Cross_section_nn34	BF_chi_20_to_chi_10_Z
Cross_section_nn35	BF_chi_20_to_chi_10_h
Cross_section_nn36	BF_chi_20_to_chi_1p
Cross_section_nn37	BF_chi_20_to_chi_1p_W
Cross_section_nn38	BF_chi_20_to_chi_2p
Cross_section_nn44	BF_chi_20_to_chi_2p_W
Cross_section_nn45	BF_chi_2p_other
Cross_section_nn46	BF_chi_2p_to_chi_10

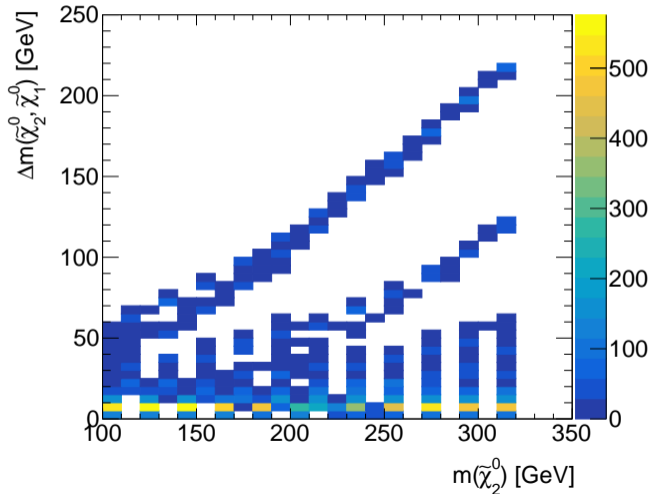






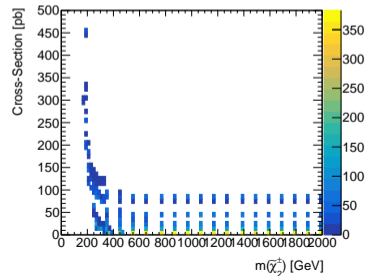
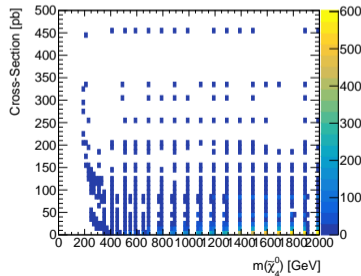
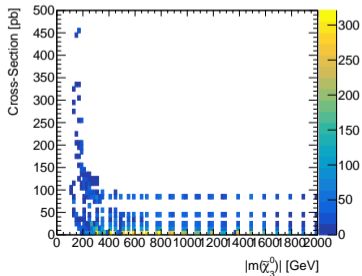
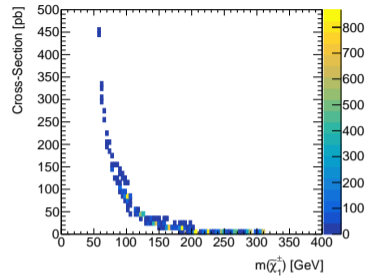
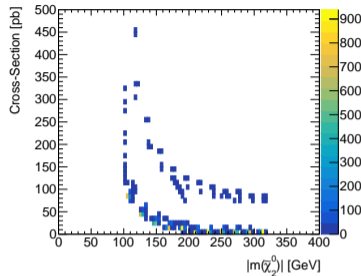
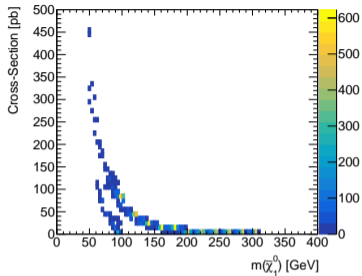
“Standard” Δm vs. m Plot

Scan prefers compressed models with $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) \approx 10$ GeV, but can be correlated with $m(\tilde{\chi}_2^0)$



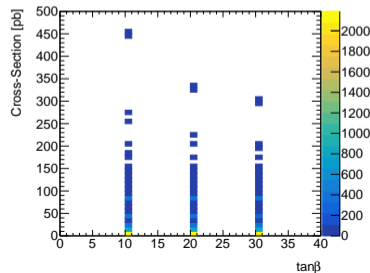
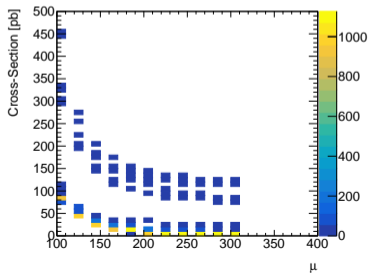
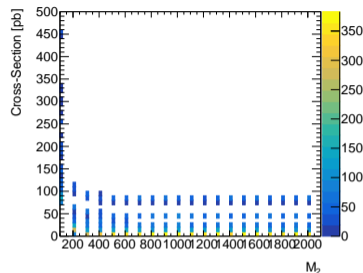
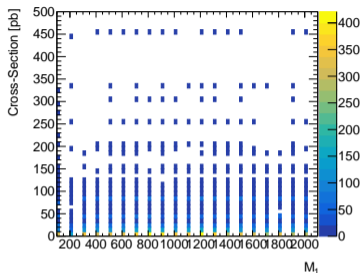


Cross-Sections ($\tilde{\chi}_2^0 \tilde{\chi}_1^0 + \tilde{\chi}_2^0 \tilde{\chi}_1^\pm + \tilde{\chi}_1^+ \tilde{\chi}_1^-$) vs. Mass

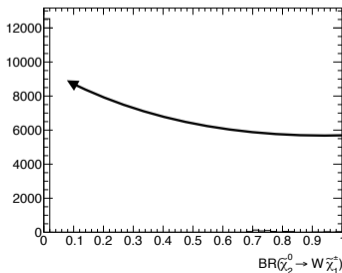
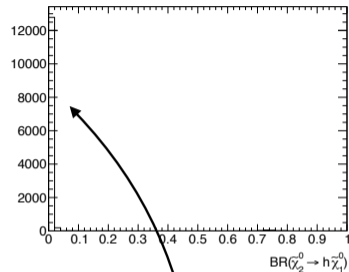
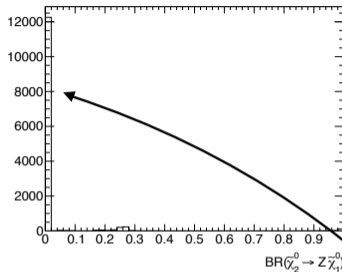
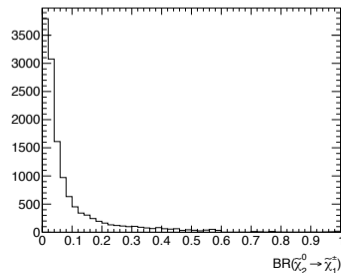
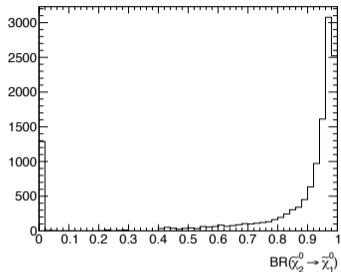




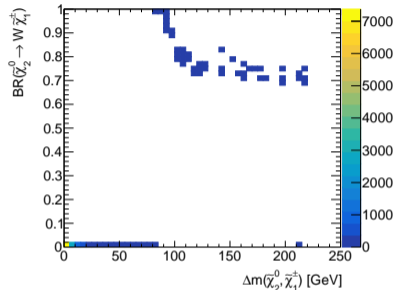
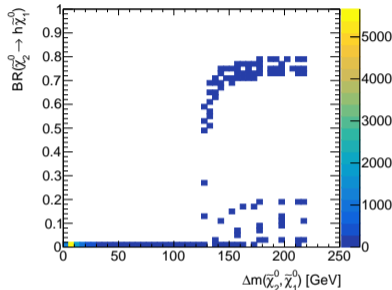
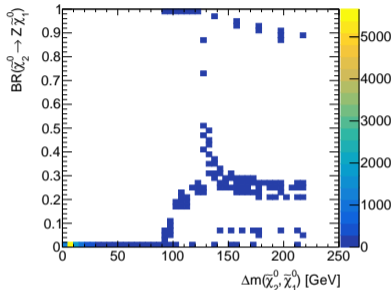
Cross-Sections ($\tilde{\chi}_2^0 \tilde{\chi}_1^0 + \tilde{\chi}_2^0 \tilde{\chi}_1^\pm + \tilde{\chi}_1^+ \tilde{\chi}_1^-$) vs. SUSY Parameters



Branching Ratios: $\tilde{\chi}_2^0$



Not handling decays via off-shell bosons properly?



Hunch Confirmed:

- BRs only turn on when mass-splitting is above boson mass poles
- Out-of-the-box pMSSMFactory is not extracting off-shell decays properly from slha files
- Crucial for signal normalization in e.g. compressed multi-lepton searches



Summary:

- Coming up to speed on ATLAS pMSSM framework
- First pass at LO cross-sections for EWK pMSSM scan at 100 TeV pp collider
- Machinery for SUSY params \rightarrow models \rightarrow cross-sections
 - ▶ SoftSUSY + pMSSMFactory
 - ▶ Setup is easy, minimal barrier to results like these
- One undergrad thesis at Penn focusing on this

Open Topics:

- Decide scan parameters/range/methodology
- SoftSUSY or SPheno for model generation?
- LO \rightarrow NLO? How to account for hard ISR jet for compressed searches?
- Fix BRs involving off-shell bosons



Backup



- Cross-sections for individual processes in ntuples are named according to Prospino scheme
- In Prospino, “nn” refers to neutralino/chargino pair production (30 unique processes)
- Individual electroweakinos are given numbers:
 - ▶ 1, 2, 3, 4 = $\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$
 - ▶ 5, 6 = $\tilde{\chi}_1^+, \tilde{\chi}_2^+$
 - ▶ 7, 8 = $\tilde{\chi}_1^-, \tilde{\chi}_2^-$
- Branches in ntuples refer to these processes via “nnXY”, where X and Y specify the pair-produced ewkinos
 - ▶ Example: “LO_nn25” is LO cross-section for $\tilde{\chi}_2^0\tilde{\chi}_1^+$ production
 - ▶ Example: “Cross_section_nn12” is NLO cross-section for $\tilde{\chi}_1^0\tilde{\chi}_2^0$ production if available, otherwise LO