UC SANTA CRUZ

CERN

ATLAS pMSSM Efforts

Dr. Giordon Stark

for ATLAS pMSSM efforts

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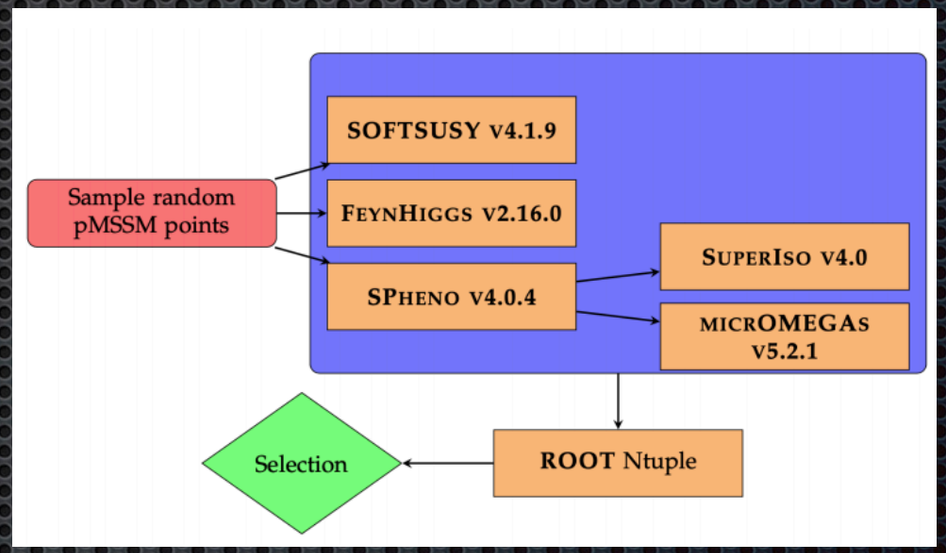
indico.fnal.gov/e/46307/

ATLAS Run II pMSSM

- Build up on our existing knowledge from the Run 1 efforts
  - user-interface via pMSSMFactory framework
  - sampling via flat prior
- Some lessons learned:
  - analysis preservation
  - likelihood preservation
  - truth-level validation and evaluation



- Incorporate the 160+ published ATLAS SUSY searches and identify coverage and see what's left 🔍
- Questions or Comments? Email the subgroup conveners:
  - ✉ atlas-phys-susy-summaries-conveners

Organization

Grand Scan

Brian Petersen

Leonora Vesterbacka

- General 19-parameter scan and overall summary
- Maintain/develop common software infrastructure and tooling

ElectroWeaK

Sarah Williams

Jeanette Lorenz

- Focus on electroweakinos with and without light sleptons

Third Generation

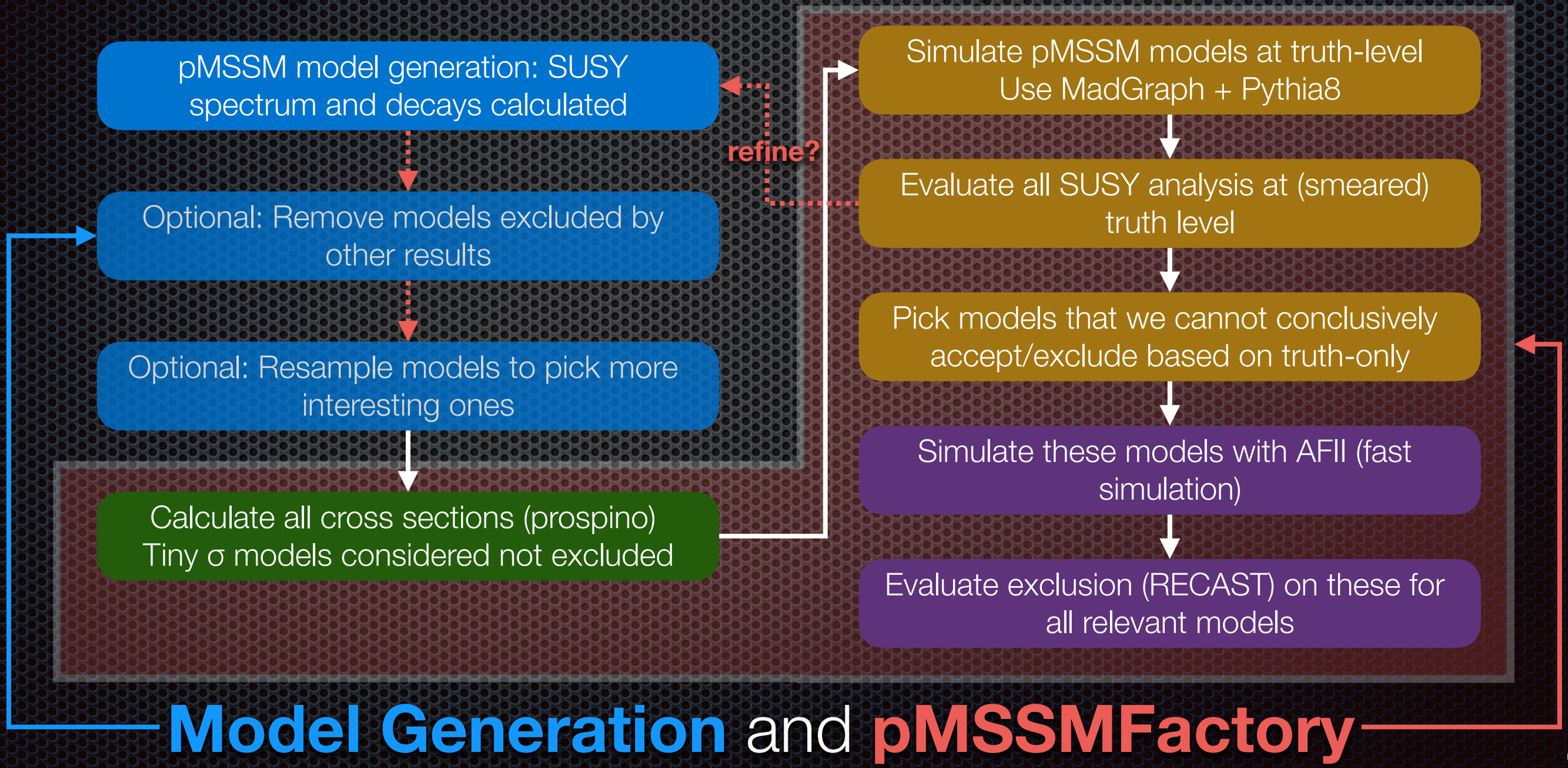
Antonia Strübig

Frederik Rühr

- Focus on light stops/sbottoms

Evaluation Chain

- Goal: be robust and CPU-efficient by avoiding unnecessary event generation/full simulation where possible



Model Generation and **pMSSMFactory**

Toolings Involved

pMSSM Model Generation

- internal code for generating ~1e9 models
- relies on theory tools: (see next slide)

pMSSMFactory

- internal code for reinterpreting existing ATLAS SUSY searches on a large (~1e6) set of (pMSSM) SUSY models
- relies on: truth evaluation, fast simulation, RECAST, pMSSM model generator

SimpleAnalysis

- internal code for performing truth-level analysis (think RIVET but with Truth AODs)
- ATLAS has plans to make this software public for theorists in the near future! Allows theorists to check our published analysis codes on their samples at truth-level. [We publish snippets in HEPData at the moment].

RECAST

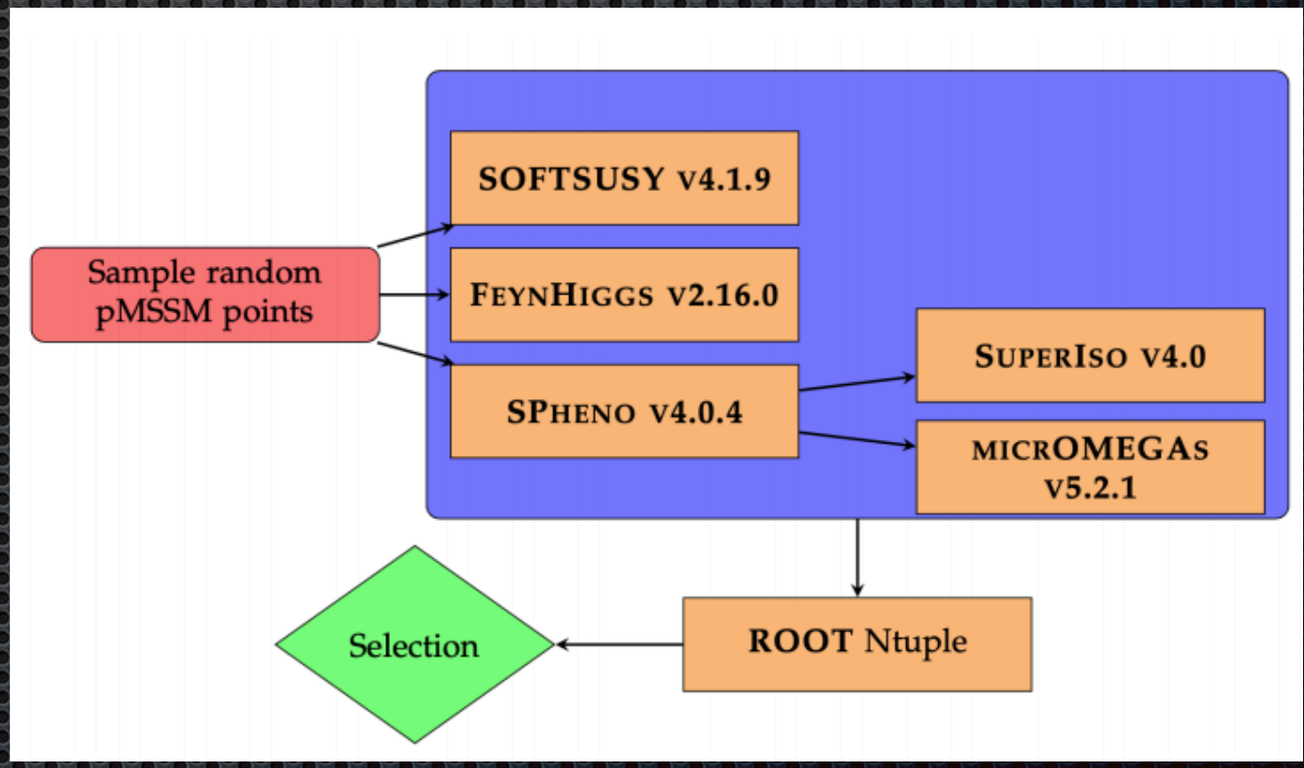
- framework for analysis preservation and reinterpretation used widely in ATLAS
- See slides: https://cds.cern.ch/record/2280505/files/ATL-SOFT-SLIDE-2017-674.pdf

pyhf and Simplified Likelihoods

- Likelihood preservation for HistFactory format in JSON (“HiFa JSON”): https://scikit-hep.org/pyhf/
- Simplified likelihoods can greatly speed up statistical fits (on-going effort in ATLAS to publicize internal tools for producing simplified likelihoods from HiFa JSON likelihoods)

Theory Toolings

- SoftSUSY 4.1.9
  - spectrum generator
- FeynHiggs 2.16.0
  - Higgs mass calculation
- SPheno 4.0.4
  - (main) spectrum generator
- SuperIso 4.0
  - flavour physics
- micrOMEGAs 5.2.1
  - DM relic density + flavor physics



❓ Which spectrum generator to use? Leaning towards SPheno

Incorporation of Higgs mass

- Currently working on incorporating FeynHiggs and SPheno/SoftSUSY for event generation input
- Two step process
  1. FeynHiggs on top of SPheno/SoftSUSY for calculating on right set of parameters
  2. Re-iterate SPheno/SoftSUSY for tuning BF(SUSY)
- Almost working!
  - SPheno-4.0.4 has a bug that will be fixed
  - SoftSUSY-2.1.10 has it working (our internal version)

⭐ Can generate models with most accurate predictions!

EWK Scan Ranges

Parameter	Min value	Max value	Note
$m_{\tilde{L}_1}(=m_{\tilde{L}_2})$	10 TeV	10 TeV	Left-handed slepton (first two gens.) mass
$m_{\tilde{e}_1}(=m_{\tilde{e}_2})$	10 TeV	10 TeV	Right-handed slepton (first two gens.) mass
$m_{\tilde{L}_3}$	10 TeV	10 TeV	Left-handed stau doublet mass
$m_{\tilde{e}_3}$	10 TeV	10 TeV	Right-handed stau mass
$m_{\tilde{Q}_1}(=m_{\tilde{Q}_2})$	10 TeV	10 TeV	Left-handed squark (first two gens.) mass
$m_{\tilde{u}_1}(=m_{\tilde{u}_2})$	10 TeV	10 TeV	Right-handed up-type squark (first two gens.) mass
$m_{\tilde{d}_1}(=m_{\tilde{d}_2})$	10 TeV	10 TeV	Right-handed down-type squark (first two gens.) mass
$m_{\tilde{Q}_3}$	2 TeV	5 TeV	Left-handed squark (third gen.) mass
$m_{\tilde{u}_3}$	2 TeV	5 TeV	Right-handed top-squark mass
$m_{\tilde{d}_3}$	2 TeV	5 TeV	Right-handed bottom-squark mass
$\lvert M_1\rvert$	0 TeV	2 TeV	Bino mass parameter
$\lvert M_2\rvert$	0 TeV	2 TeV	Wino mass parameter
$\lvert\mu\rvert$	0 TeV	2 TeV	Bilinear Higgs mass parameter
M_3	1 TeV	5 TeV	Gluino mass parameter
$\lvert A_t\rvert$	0 TeV	8 TeV	Trilinear top coupling
$\lvert A_b\rvert$	0 TeV	2 TeV	Trilinear bottom coupling
$\lvert A_\tau\rvert$	0 TeV	2 TeV	Trilinear τ coupling
M_A	0 TeV	5 TeV	Pseudoscalar Higgs boson mass
$\tan\beta$	1	60	Ratio of Higgs vacuum expectation values

- Anything not affecting EWK sector is integrated out (high mass)
- Sleptons will be both decoupled and coupled
- Keep LSP type (Higgsino/Wino/Bino) ~uniformly distributed
- Require light LSP and light C1 (both < 1.5 TeV)

❗ Higgs constraints do not impact EWK scans much

3G Scan Ranges

Parameter	Min value	Max value	Note
$m_{\tilde{L}_1}(=m_{\tilde{L}_2})$	0 TeV	2 TeV	Left-handed slepton (first two gens.) mass
$m_{\tilde{e}_1}(=m_{\tilde{e}_2})$	0 TeV	2 TeV	Right-handed slepton (first two gens.) mass
$m_{\tilde{L}_3}$	0 TeV	2 TeV	Left-handed stau doublet mass
$m_{\tilde{e}_3}$	0 TeV	2 TeV	Right-handed stau mass
$m_{\tilde{Q}_1}(=m_{\tilde{Q}_2})$	0 TeV	5 TeV	Left-handed squark (first two gens.) mass
$m_{\tilde{u}_1}(=m_{\tilde{u}_2})$	0 TeV	5 TeV	Right-handed up-type squark (first two gens.) mass
$m_{\tilde{d}_1}(=m_{\tilde{d}_2})$	0 TeV	5 TeV	Right-handed down-type squark (first two gens.) mass
$m_{\tilde{Q}_3}$	0 TeV	5 TeV	Left-handed squark (third gen.) mass
$m_{\tilde{u}_3}$	0 TeV	5 TeV	Right-handed top squark mass
$m_{\tilde{d}_3}$	0 TeV	5 TeV	Right-handed bottom squark mass
$\lvert M_1\rvert$	0 TeV	2 TeV	Bino mass parameter
$\lvert M_2\rvert$	0 TeV	2 TeV	Wino mass parameter
$\lvert\mu\rvert$	0 TeV	2 TeV	Bilinear Higgs mass parameter
M_3	0 TeV	5 TeV	Gluino mass parameter
$\lvert A_t\rvert$	0 TeV	8 TeV	Trilinear top coupling
$\lvert A_b\rvert$	0 TeV	2 TeV	Trilinear bottom coupling
$\lvert A_\tau\rvert$	0 TeV	2 TeV	Trilinear τ lepton coupling
M_A	0 TeV	5 TeV	Pseudoscalar Higgs boson mass
$\tan\beta$	1	60	Ratio of the Higgs vacuum expectation values

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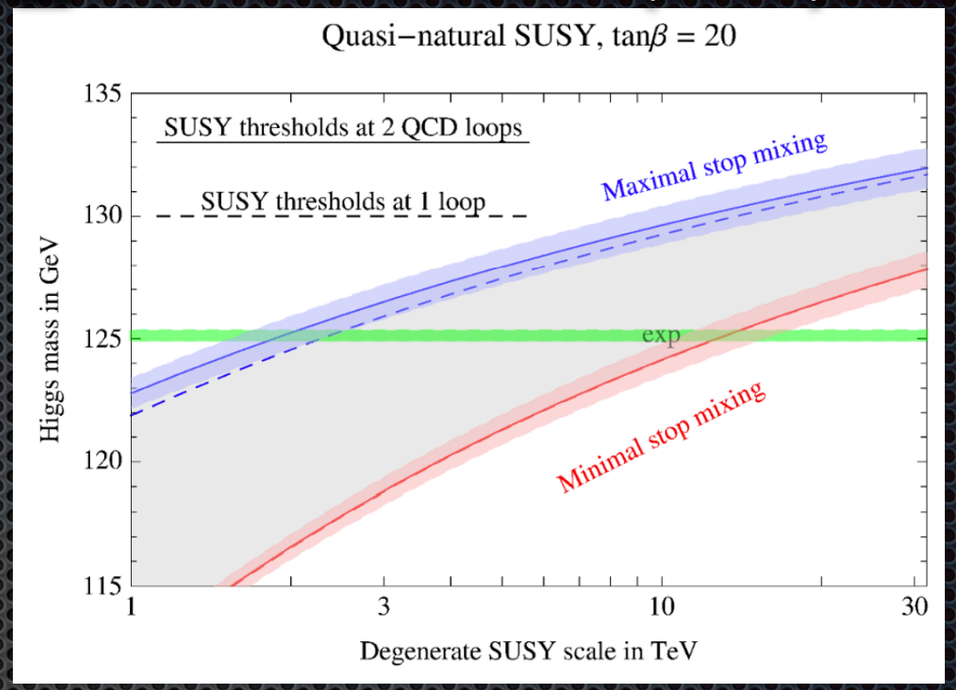
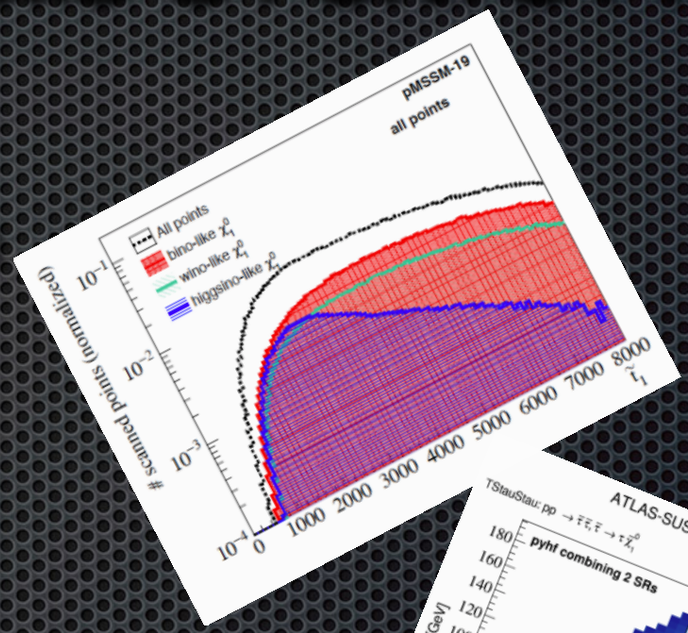


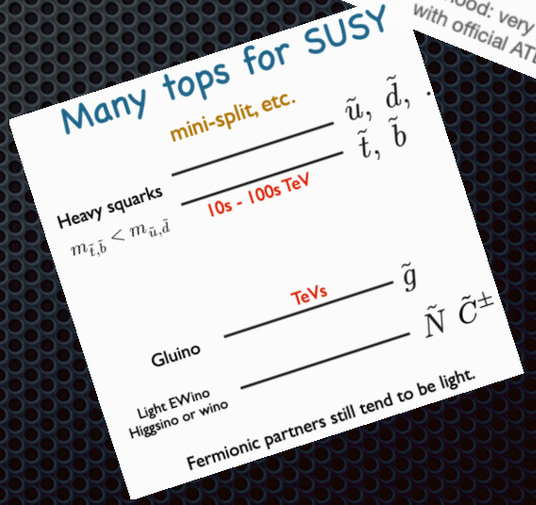
- Similar to general scan but focus on models with light third generation squarks
- Require: 3rd generation squark lighter than 1st/ 2nd generation squarks/ gluinos
- Try to keep phase-space uniformly sampled

❓ Higgs constraints impact scans! How do we get light stops?

Outreach and Collaboration

- In addition to all these efforts, we've also been reaching out to theorists to gather feedback during this process
- Sabine Kraml's feedback on public likelihood HiFa JSONs: https://indico.cern.ch/event/957797/contributions/4026032/
- LianTao Wang on pMSSM Scans and DM: https://indico.cern.ch/event/953522/
- Sven Heinemeyer on FeynHiggs: https://indico.cern.ch/event/933618/
- SModelS (Wolfgang Waltenberger) on simplified likelihoods, and incorporating public search results: https://indico.cern.ch/event/906946/





Always looking for more talks. Drop a line!

Conclusion

- ATLAS pMSSM effort is underway, with some new ideas being explored
  - perhaps use an ML-guided approach for sampling?
  - support long-lived particle searches (disappearing tracks, Stable Massive particles, R-hadrons, etc…)
- Identify best pheno calculators for non-SUSY constraints
  - DM, B-physics, Higgs, etc…
- Please get in touch with us (atlas-phys-susy-summaries-conveners) if you have particular feedback!