pMSSM scan

General idea

MCMC scan for prior density
O(10^6 - 10^7) points

- Prior density should only contain non-controversial low energy results
  - no DM (except upper boundary?)
  - no g-2
  - (no b->s gamma?)
- Parameters are restricted by rectangular box
  - masses < X TeV?
  - |couplings| < 7 TeV?

→

Pick points to simulate according to pick probability function
Use pick probability to simulate points in interesting regions of the parameter space (reweight to no bias prior)

- Low - finetuning
- Compatible with DM relic density & direct/indirect detection
- Low stop mass?
- Low stau mass?
- Low electroweak masses?

→

Evaluate simulated points using CMS analyses, produce posterior density

- Need to get CMS analysis groups to run their analyses over the simulated point
- Target are all CMS analyses published by Spring 2019
- Need to be able to provide them the points early next year

Open Questions

Where to implement Higgs bounds?

- Against prior: Continuous improvement on higgs bounds, prior too inflexible (Sabine Kraml)
- Against posterior: higgs bounds are ATLAS & CMS. Include both in prior? Disentangle results to only use CMS?

-> Show two versions of posterior density: with/without higgs bounds?

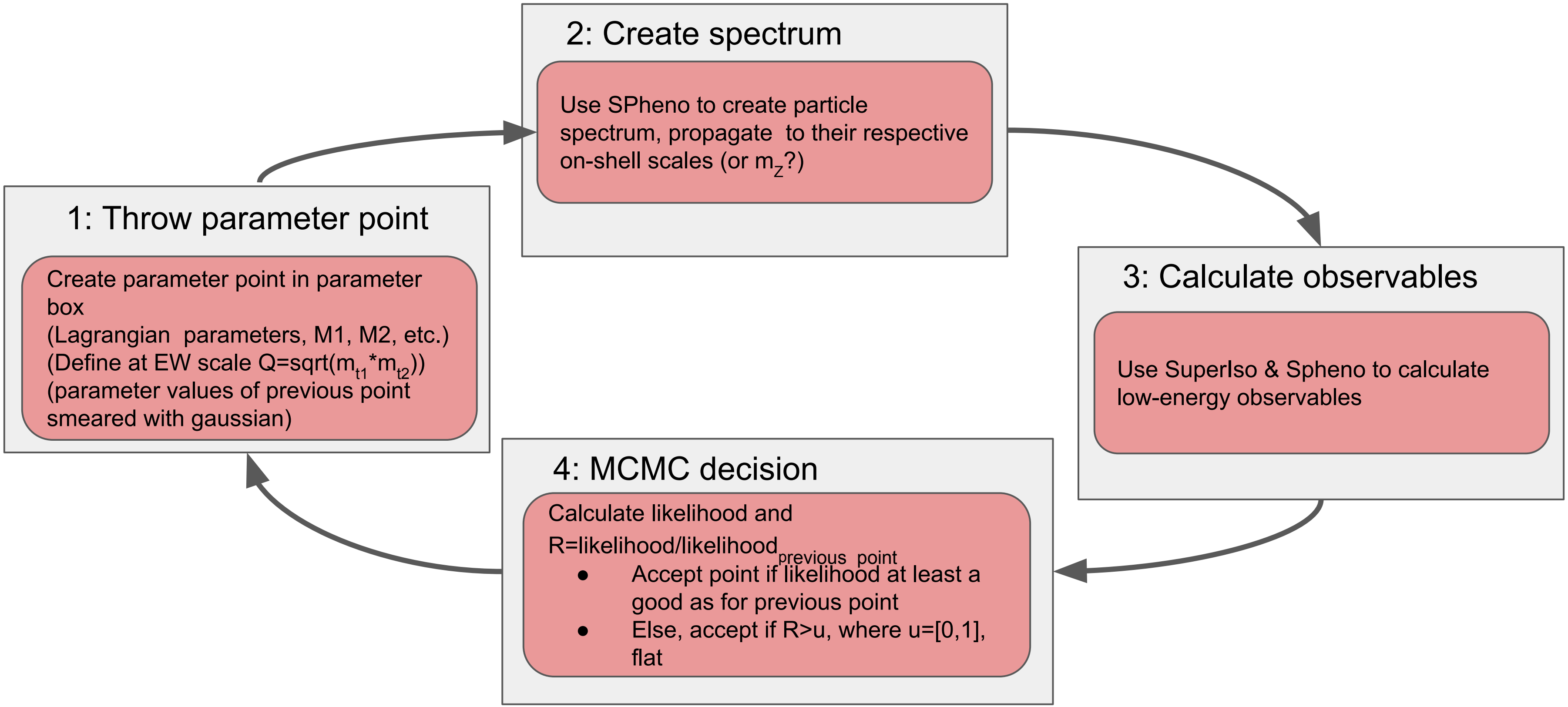
How big a parameter box?

- 10 TeV for strong particles?, 4 TeV for electroweak?
- |couplings| < 7 TeV? (as in run-I)

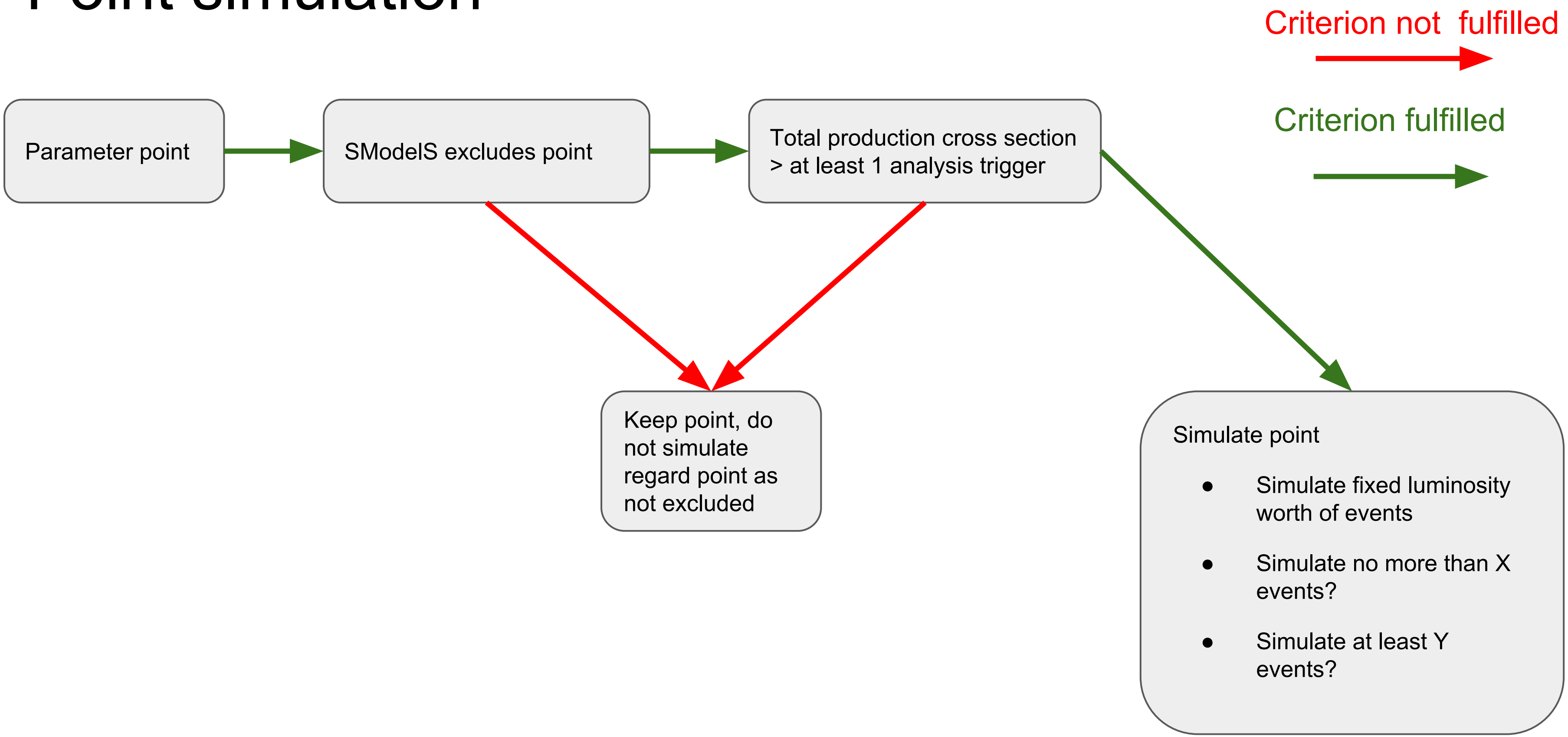
to consider:

- Set upper EW boundary above s-channel production mass limit of all strong particles (include strong->EW decay signatures)

MCMC scan workflow



Point simulation



Pick probability

Choices for pick probability increase

- Flat increase if one criterion fulfilled
- Smooth functional increase if criterion fulfilled
- multiply/add pick probability increase if >1 criterion fulfilled

Choices for pick probability criteria

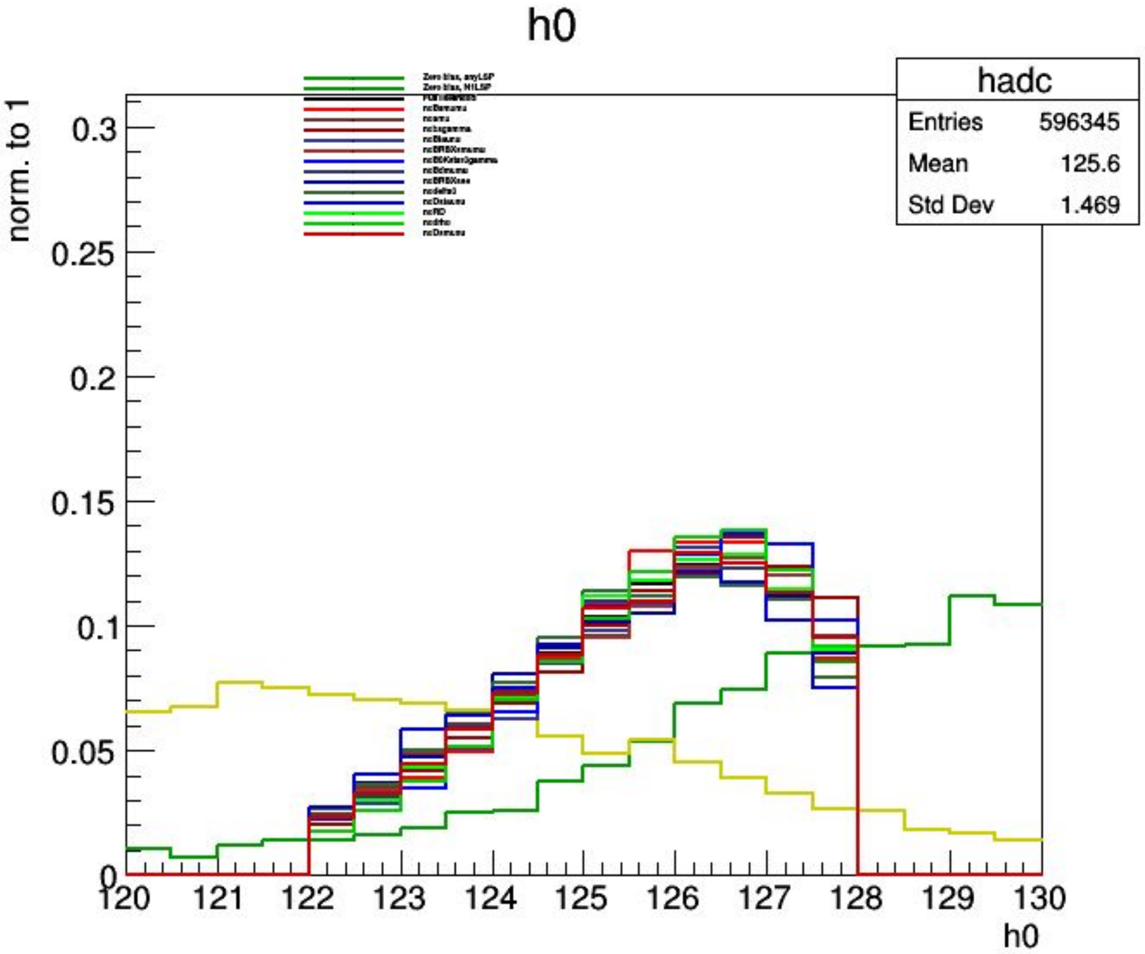
- Low fine-tuning
  - DeltaEW?
  - Another measure?
- Low stop mass (solves big hierarchy problem)
- Low EW mass?
  - Target regions that CMS 2018 is sensitive to
- Compatibility with DM constraints?
  - How much should point explain relic density? 90%? 70%?
  - Use smooth function for this criterion only?

News & Summary 22.11.18

- 1 runs (only 1 contribution to likelihood) still not looked at
  - Have not yet been looked at
  - Might have been produced with wrong superiso likelihood
- Started looking at n-1 plots: Need to decide which observables to keep
- First plots for convergence done
- Currently producing one scan with SPheno and one with softsusy
- Reinitiate discussion with
  - Sabine & Sezen on spectrum generator issue
  - Basil, Sezen on parameter ranges, differently sized ranges for EW, strong
  - Harrison on MCMC convergence

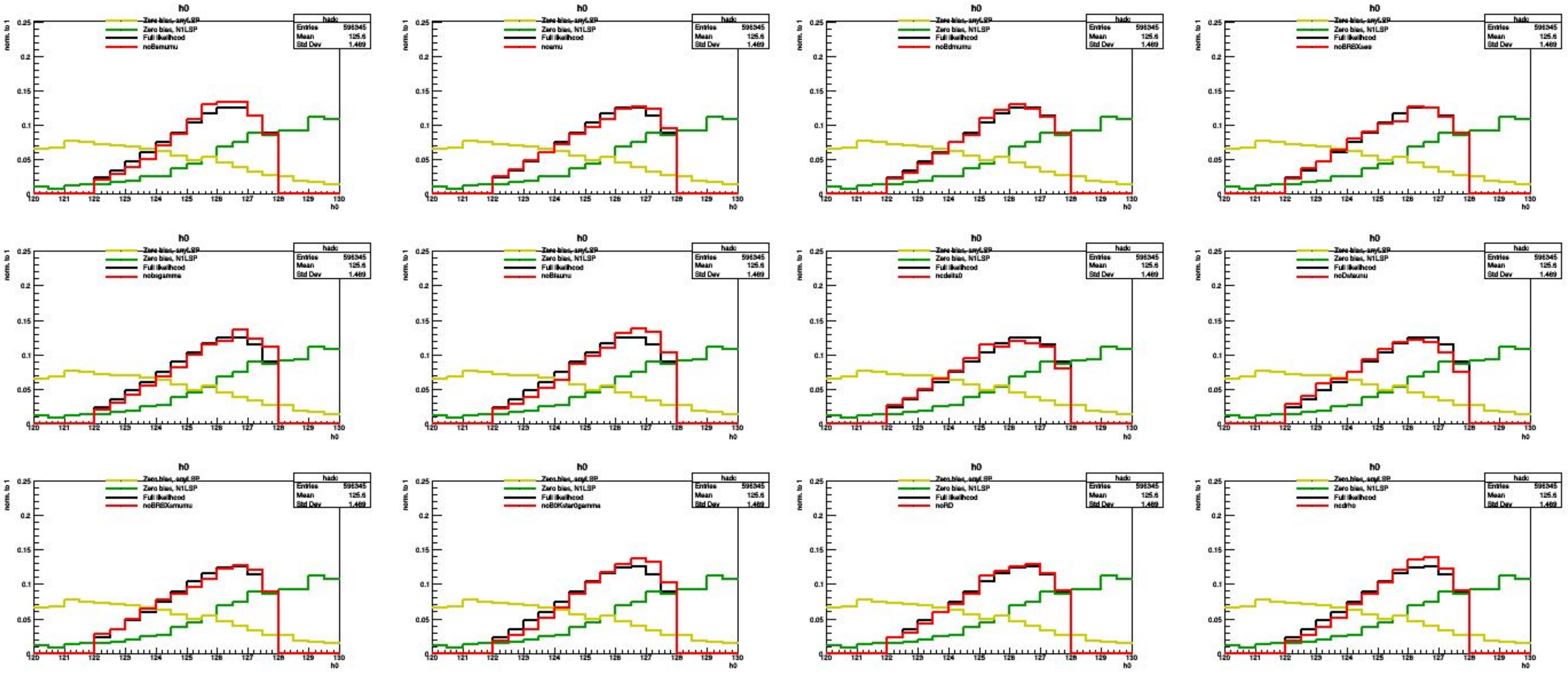
N-1 study

Beware: N-1 slepton range up to 3 TeV, Full likelihood scan up to 4 TeV



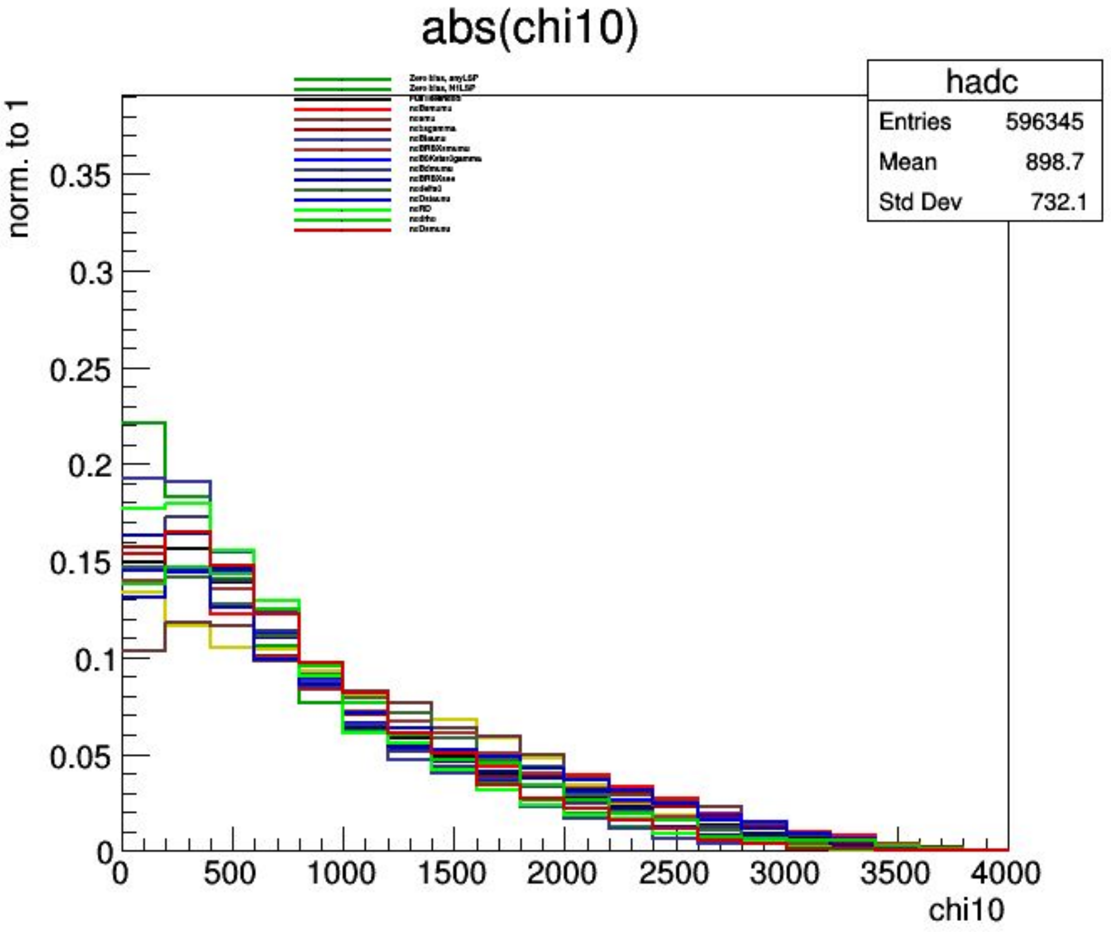
N-1 study: h0

Beware: N-1 slepton range up to 3 TeV, Full likelihood scan up to 4 TeV



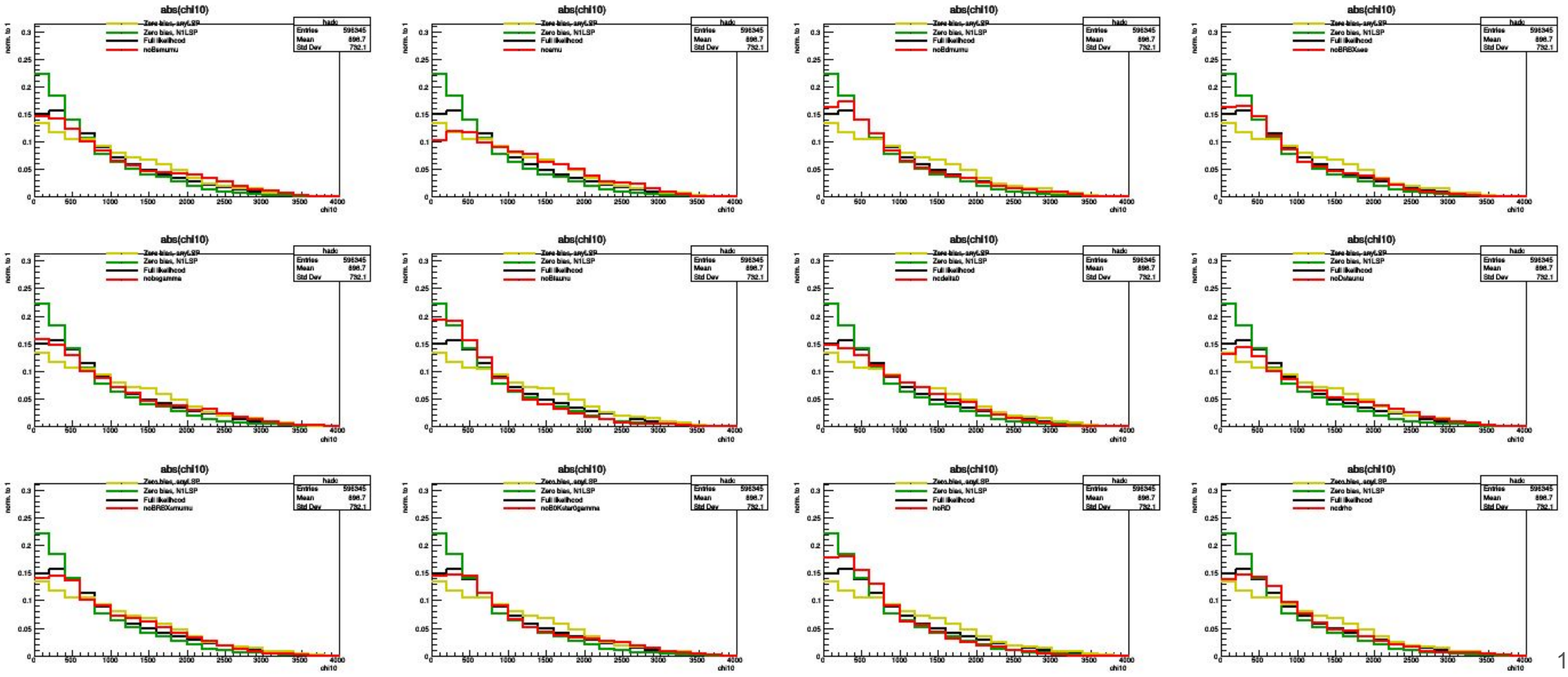
N-1 study

Beware: N-1 slepton range up to 3 TeV, Full likelihood scan up to 4 TeV



N-1 study: chi10

Beware: N-1 slepton range up to 3 TeV, Full likelihood scan up to 4 TeV



Current parameter borders

- mu,M_1,M_2 ∈ [-4000,4000]
- m_A ∈ [0,4000]
- M_3 ∈ [0,10000]
- Slepton mass parameters ∈ [0,4000]
- Squark mass parameters ∈ [0,10000]
- Trilinear couplings ∈ [-7000,7000]
- tanβ ∈ [2,60]

- Why 4 TeV for electroweak parameters?
  - Threshold must be above any strong particle mass that is accessible for the LHC
  - Pythia LO cross section for pair production of squarks (gluinos?) with m_{squark}(m_{gluino}?) = 2 TeV is O(10^-5 fb) -> no expected event at 10^2 fb^{-1}
  - Interesting phenomenology expected for M1,M2 ≳ 3 TeV

(current) list of low energy observables

- a_{mu} (pdg value)
- BR(b->s nu nu) ←Not discovered, not used
- BR(b u -> tau nu) (HFLAV value)
- BR(c s -> tau nu) (pdg value)
- BR(c s -> mu nu) (pdg value) correlated with above?
- delta(rho) (pdg value)Is this the deviation in m_W, m_Z, Weinberg angle relation?
- R(D) (HFLAV value)
- mb(Q=mb) (pdg value) ← SPheno does not seem to use these as input, instead it uses a default value
- mt (pdgvalue)
- alphas (pdg value)

Superiso chi2

- Δ_0 (B->K gamma)
- BR(b->s gamma)
- BR(b s -> mu mu)
- BR(b d -> mu mu)
- BR(b->s mu mu)
- BR(b->s e e)
- BR(B0->K*0 gamma)

MCMC Convergence

- Sezen sent 1 presentation & 1 paper detailing different convergence heuristics
- Sezen suggested Gelman and Rubin method:
  - Compares variances of different parallel chains with in-chain variances for each degree of freedom
  - Parallel chains need very dispersed starting points
- Gelman & Rubin method seems to converge instantly. Difficult to find overdispersed starting points?
- Try out Kolmogorov Smirnov test for consecutive sets of N points for each observable and each chain

Convergence plots

Slide stolen from
Eric B. Ford (Penn State) Bayesian Computing for Astronomical Data Analysis June 5, 2015

Estimate Potential Scale Reduction Factor

Gelman-Rubin diagnostic ($\hat{R}$)

- Compute *m* independent Markov chains
- Compares variance of each chain to pooled variance
- If initial states (θ_{1j}) are overdispersed, then $\hat{R}$ approaches unity from above
- Provides estimate of how much variance could be reduced by running chains longer
- It is an *estimate!*

$$W = \frac{1}{m}\sum_{j=1}^{m} s_j^2 \qquad \bar{\bar{\theta}} = \frac{1}{m}\sum_{j=1}^{m}\bar{\theta}_j$$

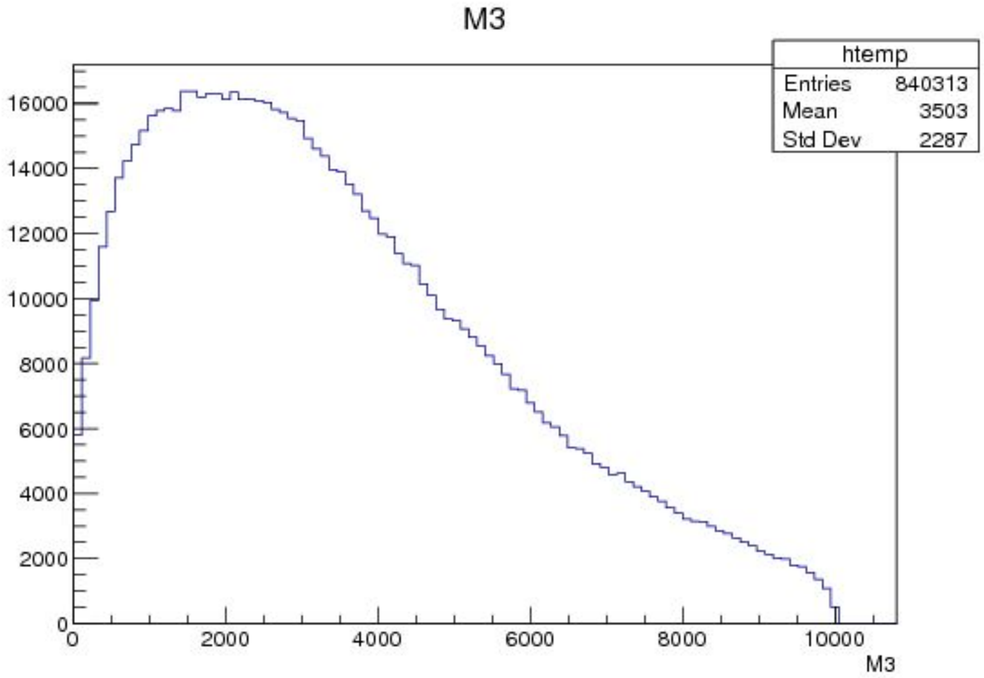
$$B = \frac{n}{m-1}\sum_{j=1}^{m}(\bar{\theta}_j - \bar{\bar{\theta}})^2 \qquad s_j^2 = \frac{1}{n-1}\sum_{i=1}^{n}(\theta_{ij} - \bar{\theta}_j)^2$$

$$\hat{\mathrm{Var}}(\theta) = (1 - \frac{1}{n})W + \frac{1}{n}B \qquad \hat{R} = \sqrt{\frac{\hat{\mathrm{Var}}(\theta)}{W}}$$

Archive

M3 spectrum in trial run

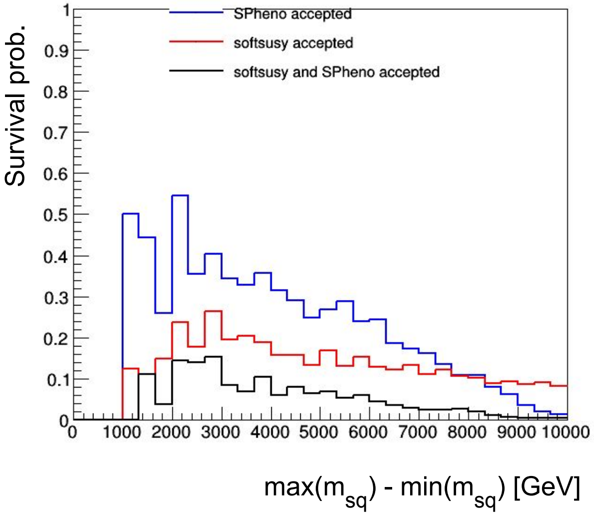
- Unexpected decrease of spectrum towards higher values of M3
- Not expected from likelihood
- Feature also seen in zero-bias run with likelihood = 1
- Feature starts to appear right around 3 TeV, possibly contributed to “edge effect” in Run-1 scan.



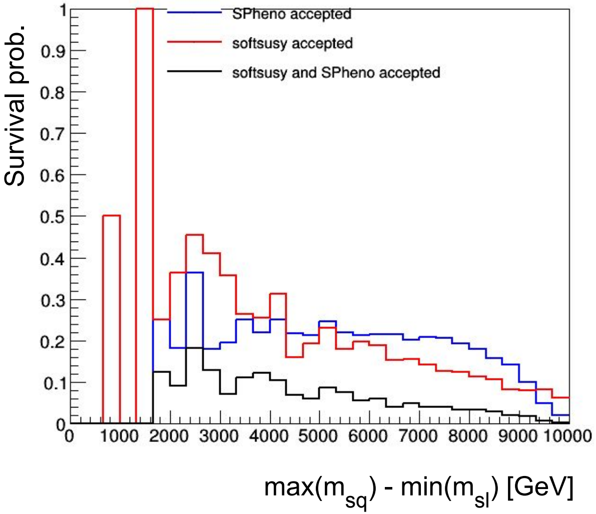
Survival probabilities for SPheno & softsusy

- Calculation of sfermion masses is sensitive to large mass splittings -> Tachyons appear for high mass differences
- SPheno seems more sensitive to mass differences in squark sector,
- Softsusy seems more sensitive to mass differences between squark & slepton sector

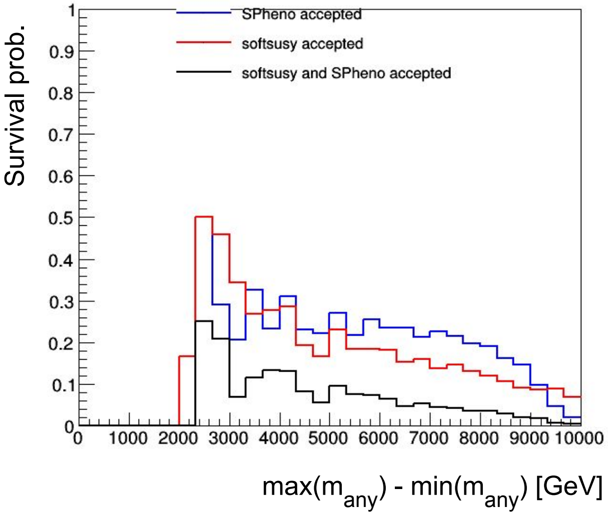
Mass differences in squark sector



Mass differences between squark and slepton sector

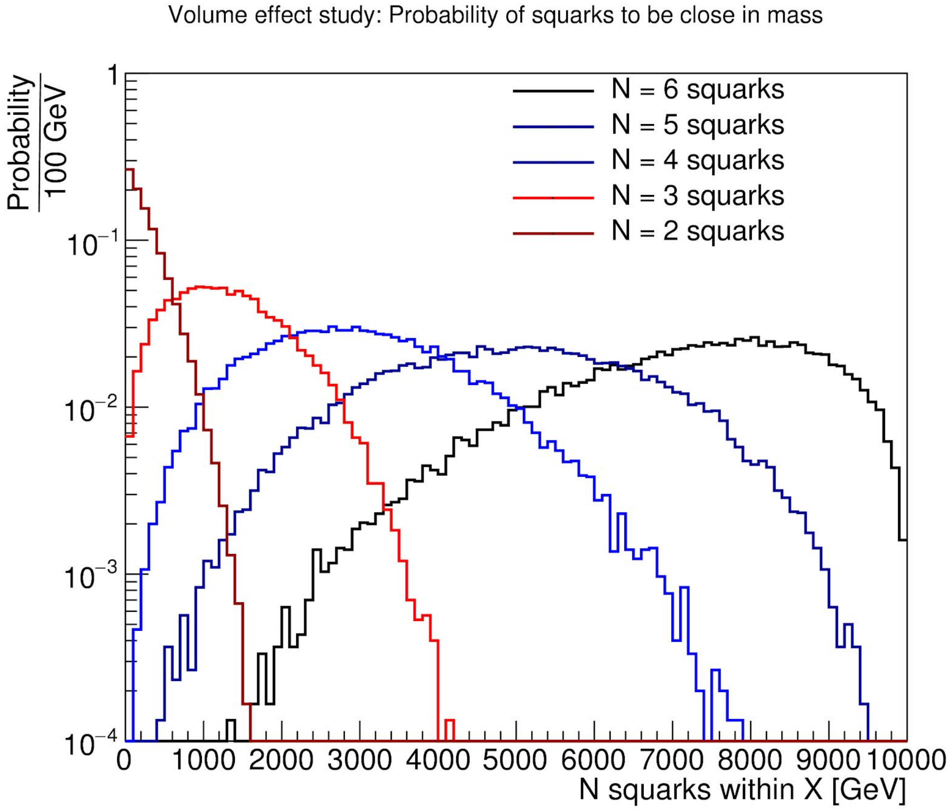


Mass differences in sfermion sector



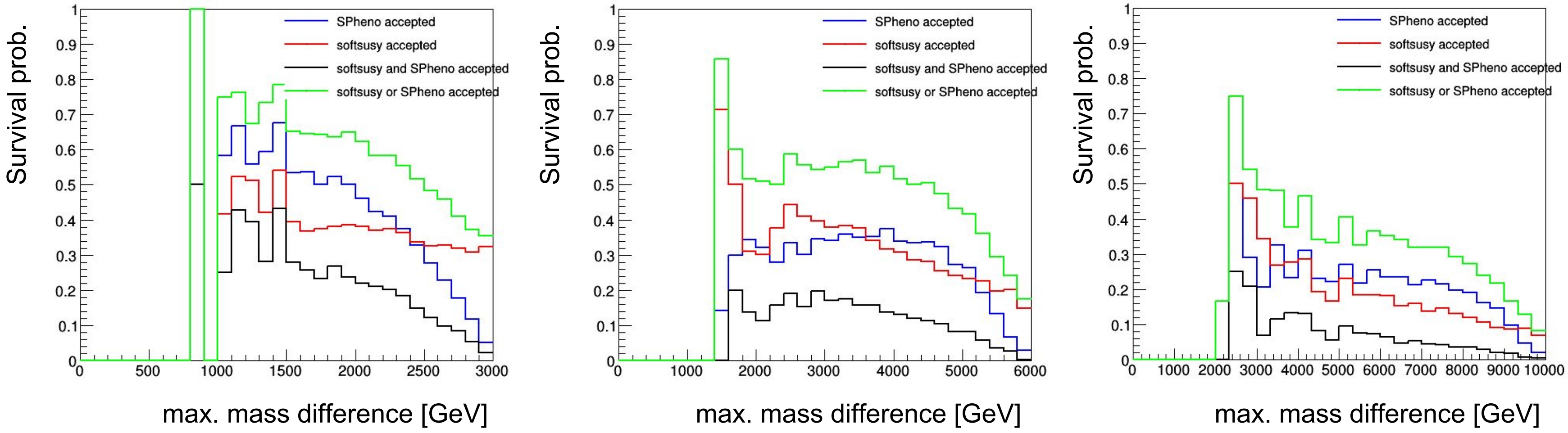
Volume effect study: Squark masses

- Probability to find N squarks within X GeV of each other
- Points with 3 degenerate squarks probable
- Points with more than 3 degenerate squarks highly unlikely



Spectrum generator issue with different box sizes

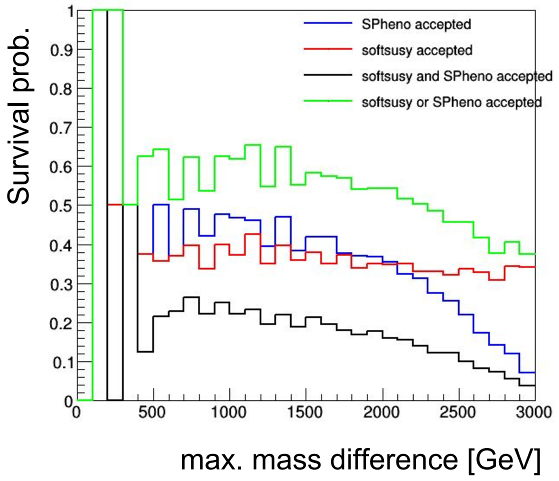
Survival probability for maximum mass different between any sparticles

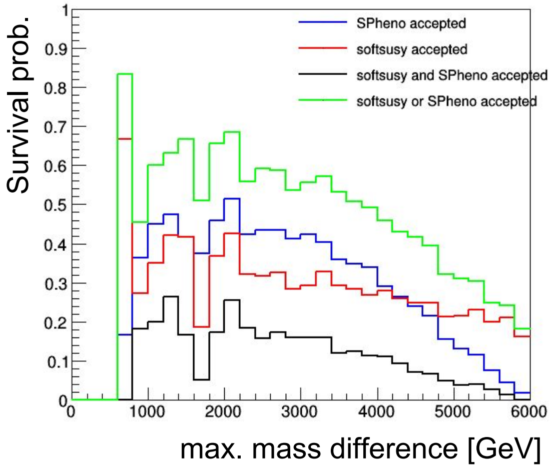


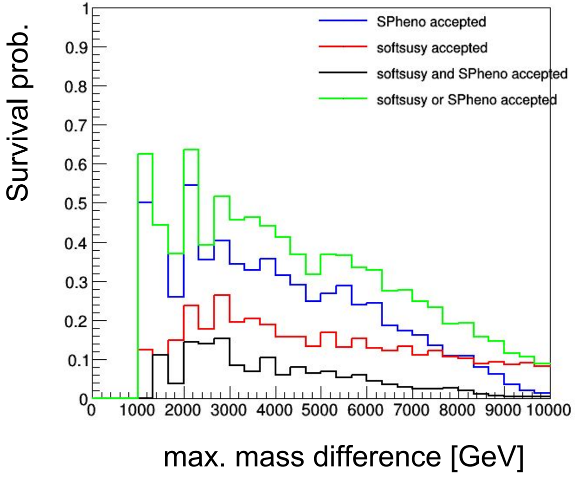
Spectrum generator issue with different box sizes

Survival probability for maximum mass different between squarks

- Spheno problematic, softsusy mostly flat



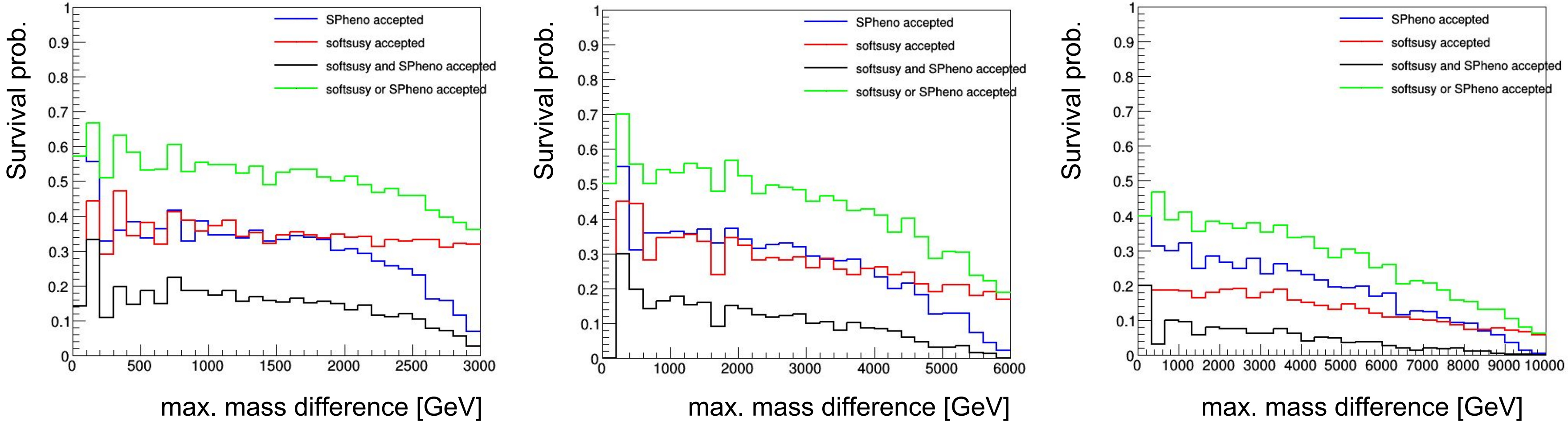




Spectrum generator issue with different box sizes

Survival probability for maximum mass different between squarks except stop

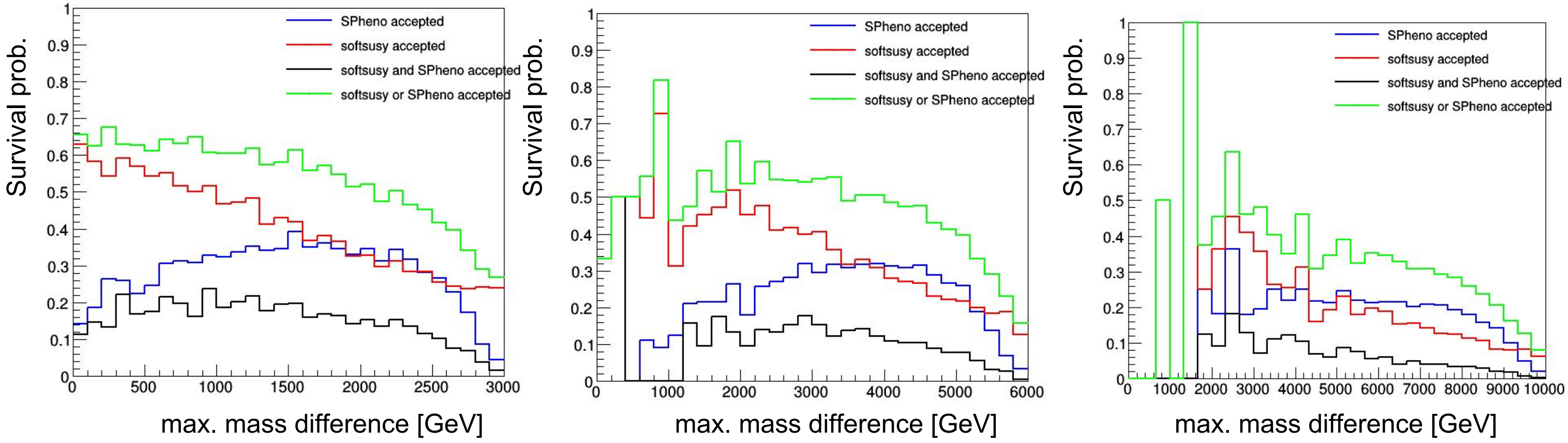
- Spheno problematic, softsusy mostly flat



Spectrum generator issue with different box sizes

Survival probability for maximum mass different between squarks and sleptons

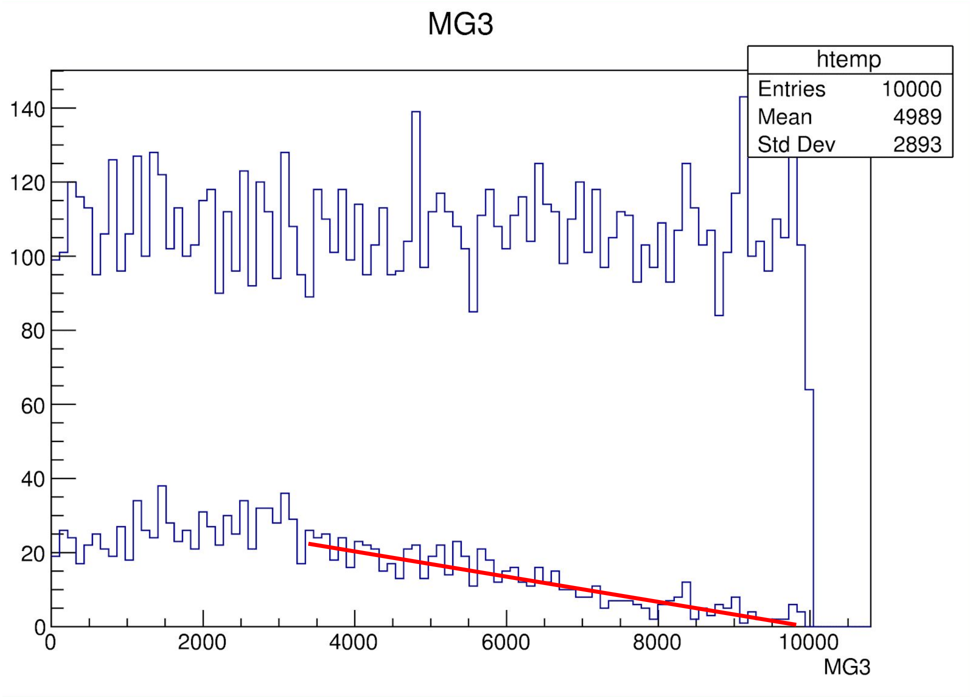
- Both problematic



M3 spectrum for SPheno accepted & rejected points

- SPheno can “reject” an input point on the basis of an unphysical spectrum
- Upper histogram (inclusive accepted+rejected) is flat
- Lower histogram (accepted points only) show **decreasing** spectrum

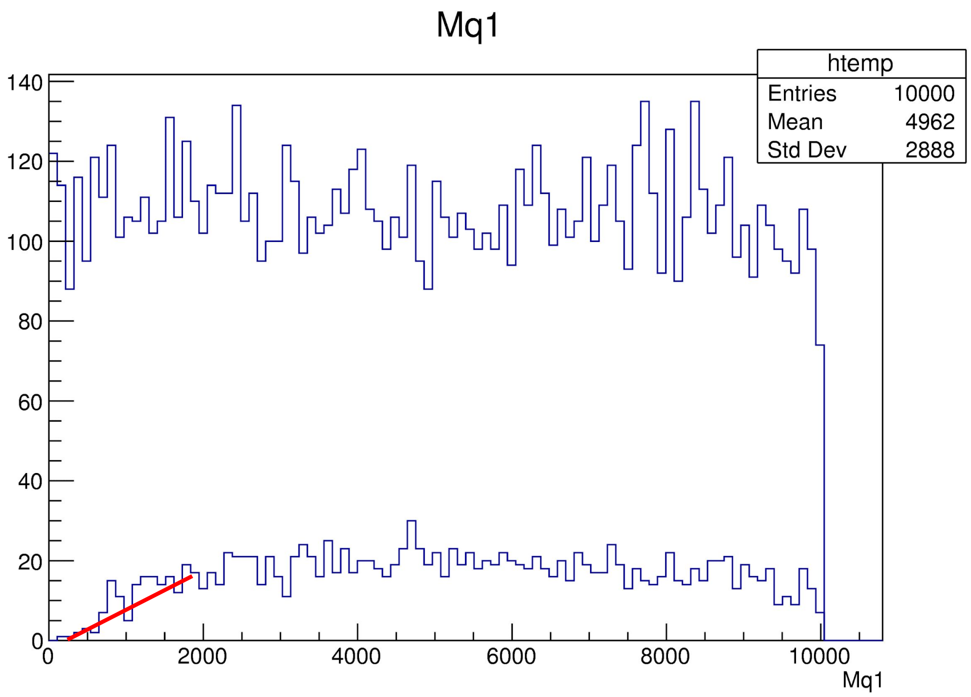
-> SPheno rejection of unphysical points introduces bias



Mq1 spectrum for SPheno accepted & rejected points

- SPheno can “reject” an input point on the basis of an unphysical spectrum
- Upper histogram (inclusive accepted+rejected) is flat
- Lower histogram (accepted points only) show **increasing** spectrum

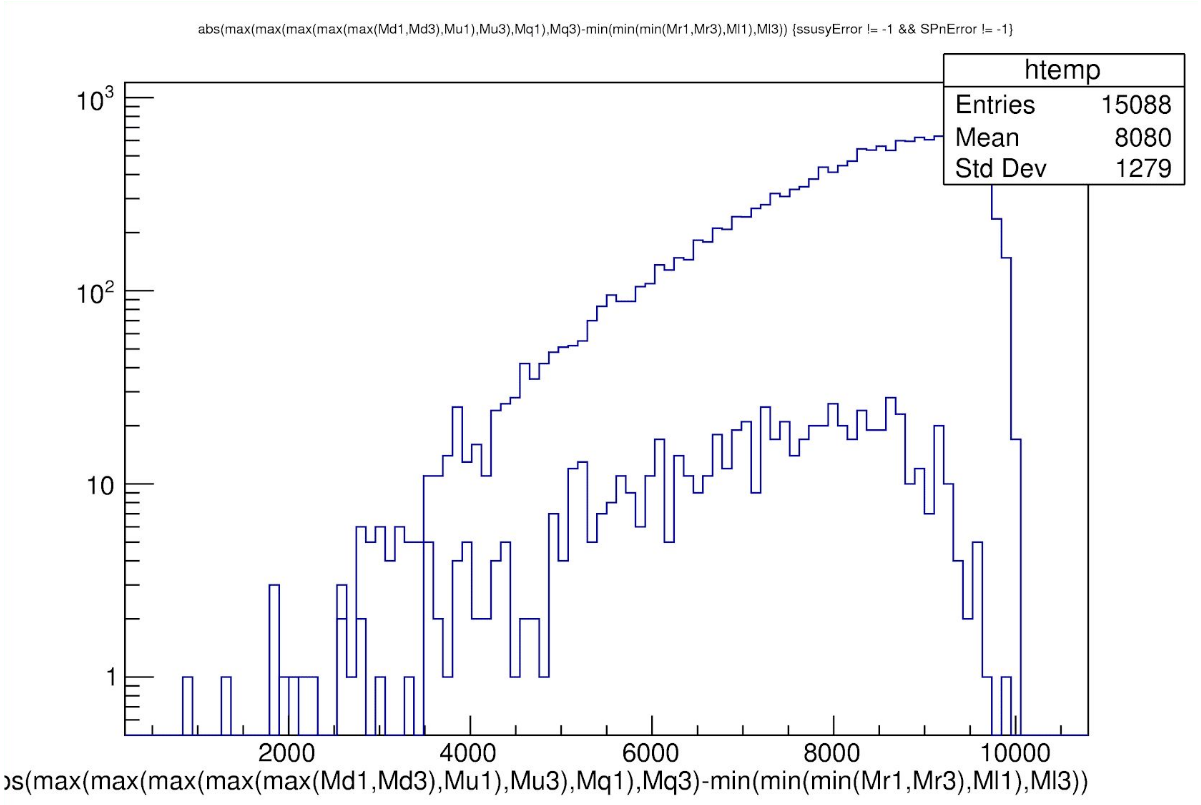
-> SPheno rejection of unphysical points introduces bias



Max difference between slepton & squark mass

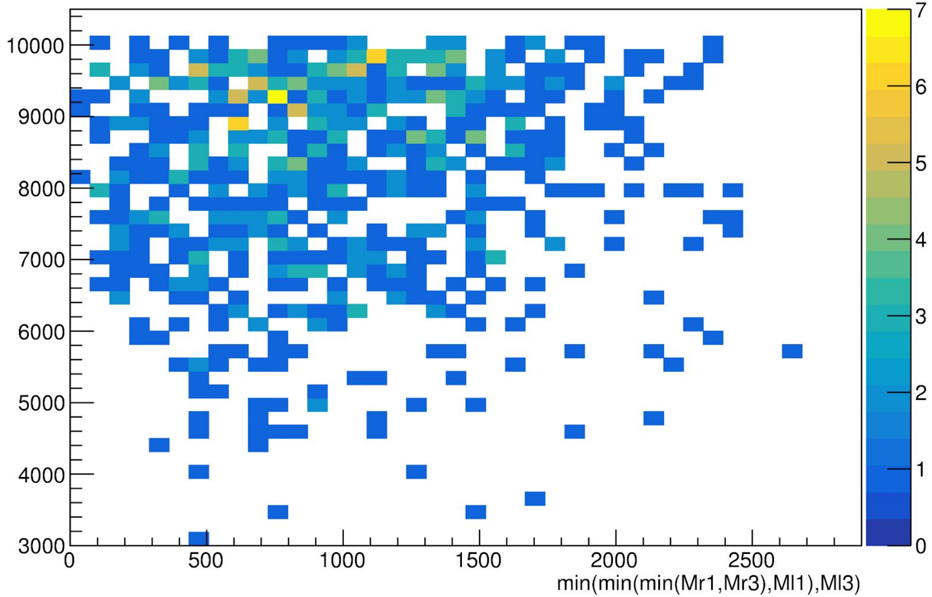
Upper curve: Failed both SPheno and softsusy

Lower curve: accepted by both

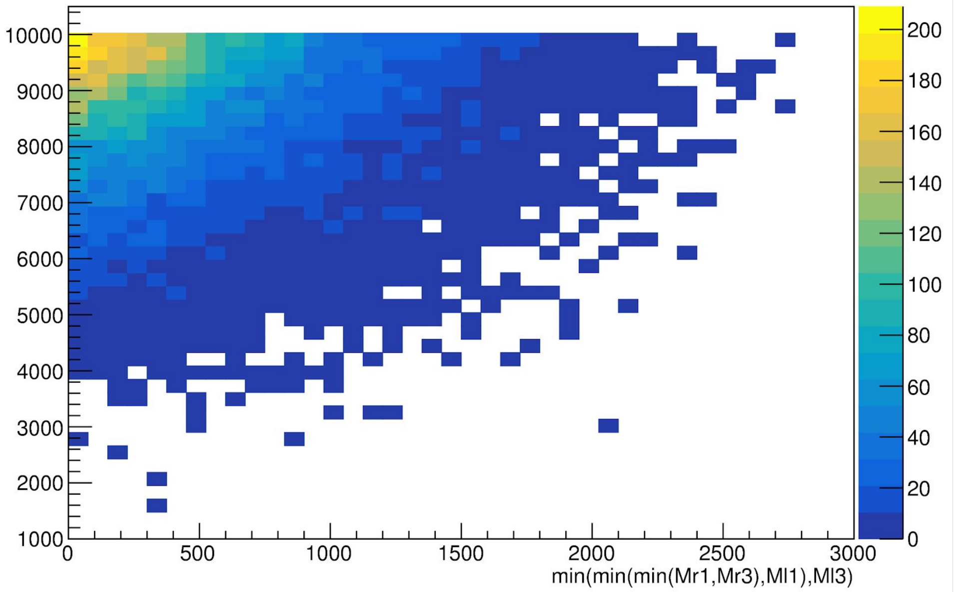


max squark mass (y-axis) vs min slepton mass (x-axis)

Accepted by both

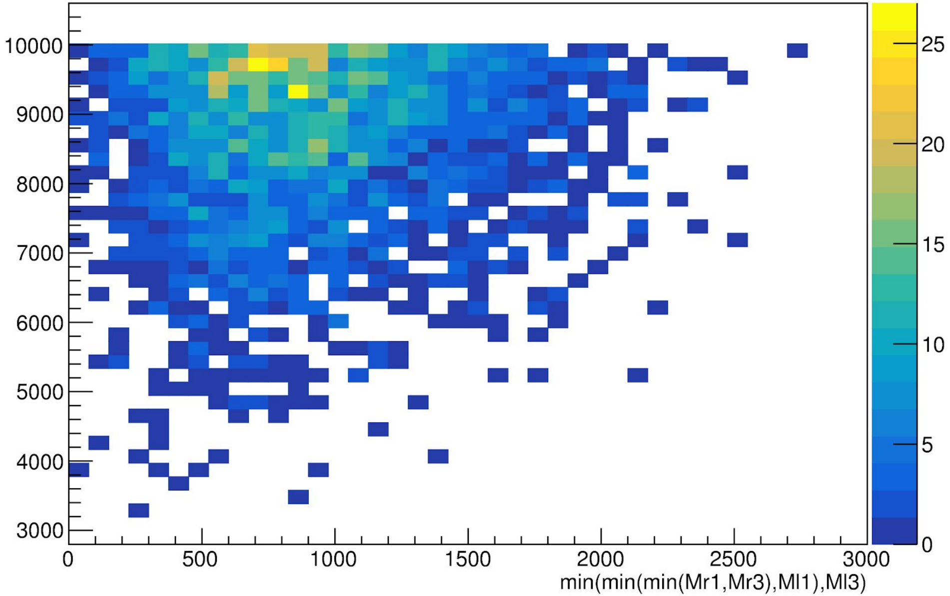


Rejected by both

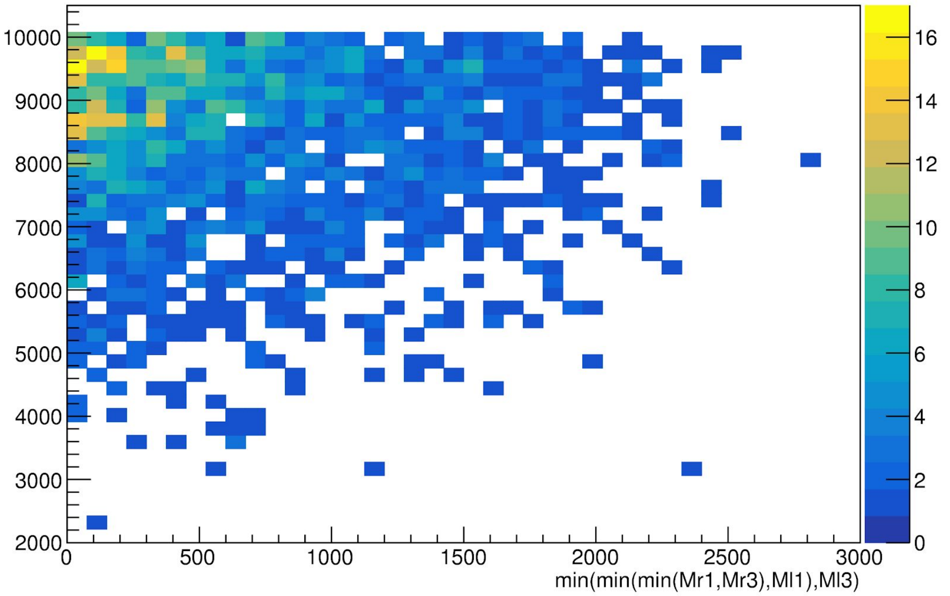


max squark mass (y-axis) vs min slepton mass (x-axis)

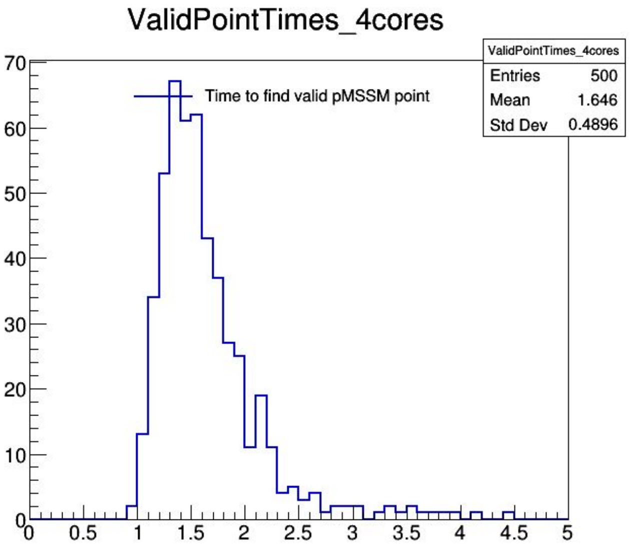
Rejected by softsusy,
accepted by SPheno

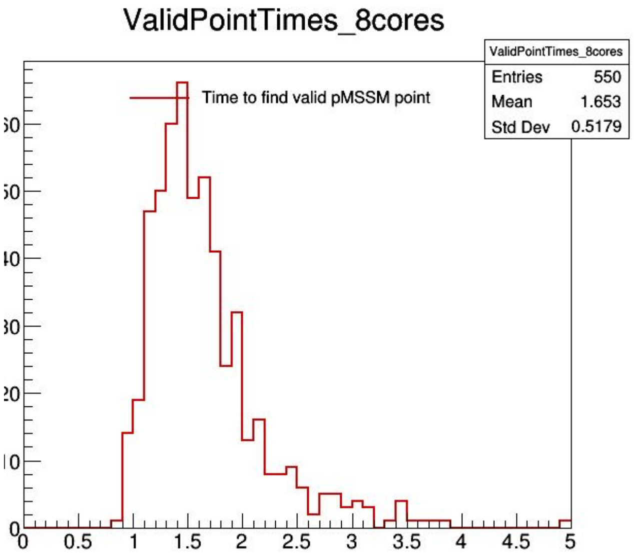


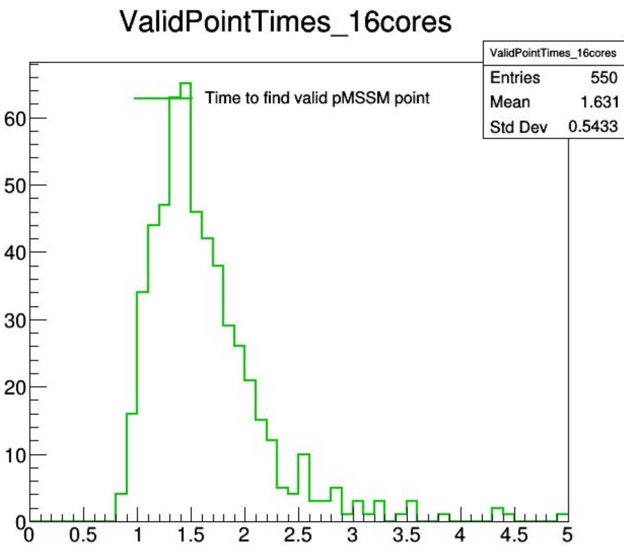
Rejected by SPheno,
accepted by softsusy



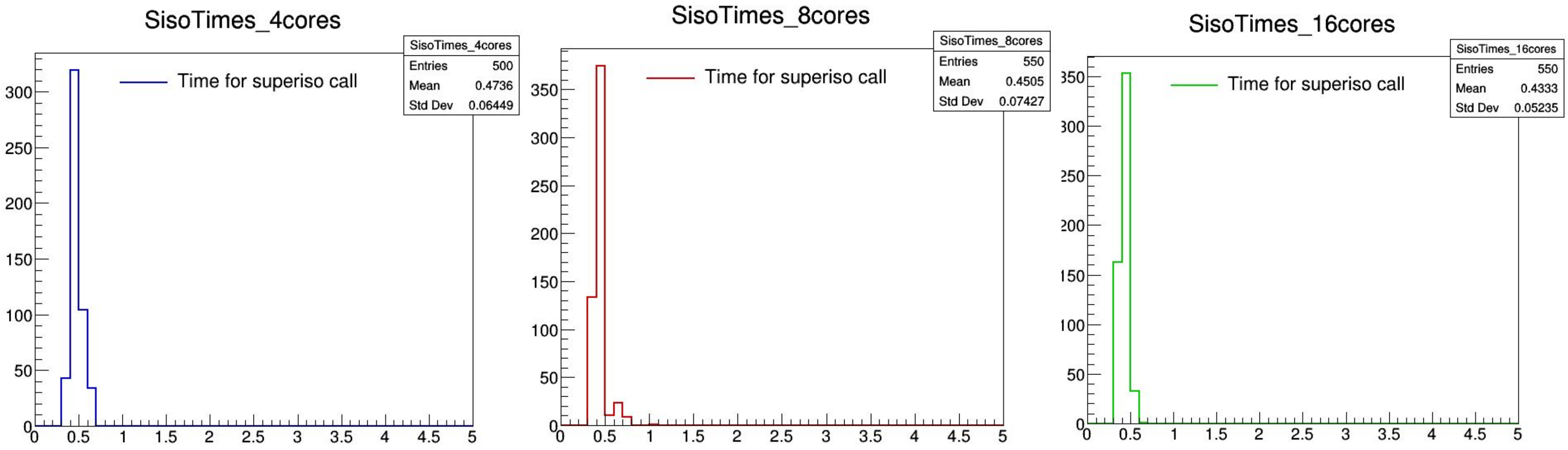
Time cost on bird machines: SPheno + N1 LSP



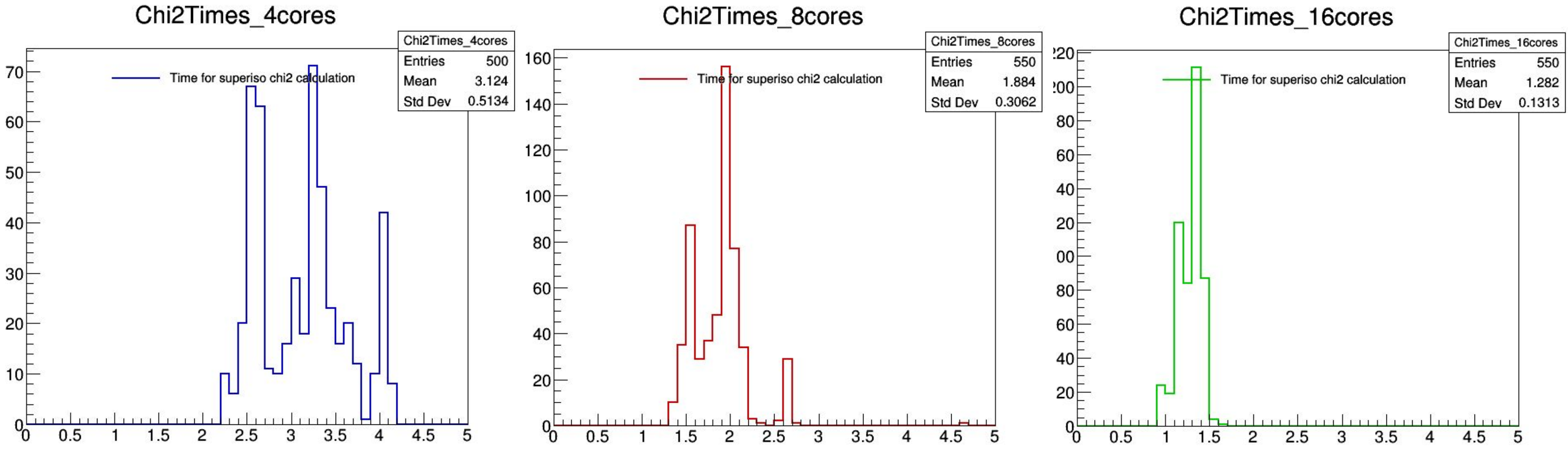




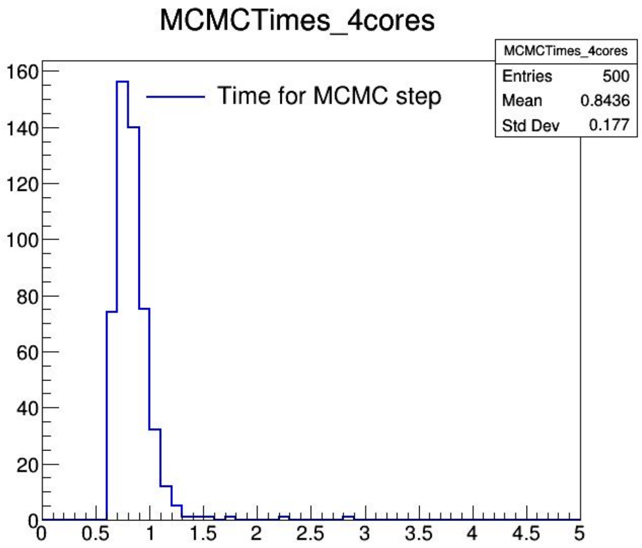
Time cost on bird machines: Superiso call

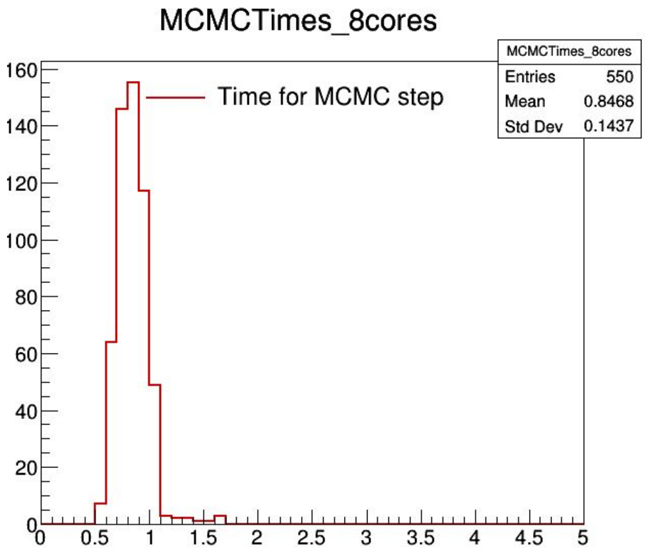


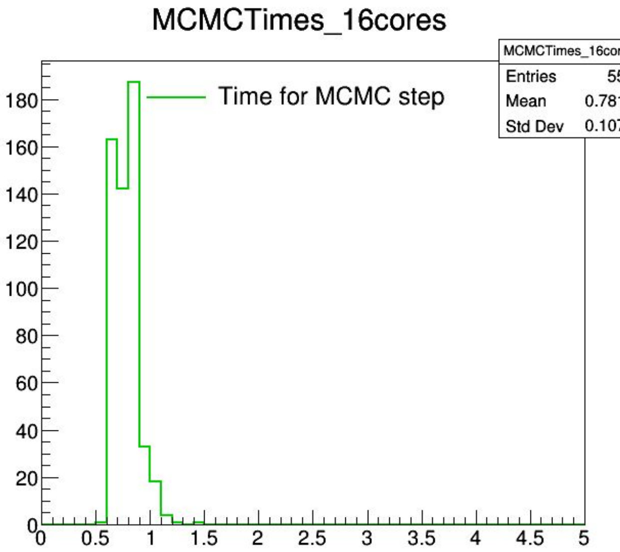
Time cost on bird machines: Superiso Chi2 calc



Time cost on bird machines: MCMC step







MCMC Questions for our favorite theorist:

- Which low-energy observables?
  a. Sabine: Selection seems fine, nothing missing
  b. Sabine suggested not using BR(B->K*ll), don’t know exactly why.
- Why do we include top&bottom mass and alpha_s?
  a. Which top mass do we use?
  b. Sabine: Definitely include. Also: Higgs box at 125 +-3 GeV
- Are any of the low energy observables we use highly correlated?
  a. Nazila: Different observables of same decay channel highly correlated, otherwise very little correlation between decay channels

MCMC optimization

- Find out how many iterations of point randomization it takes to produce a valid point
  - O(1) usually
- Find out how many valid points contain a non- neutralino LSP
  - Can the LSP be inferred by the lagrangian parameters?
  - Can we define regions of lagrangian parameter configurations that always produce a non-neutralino lsp?
  - O(0) usually
- How long is the loop for a point allowed to take?
  - Currently takes 2-4 seconds to find point, less than 1s to make MCMC decision
- Currently: The first 5-10 iterations are super fast (O(0.5s)), then it slows down to O(3s) per iteration <- solved! using micromegas to determine LSP was slow, now using self-written code

MCMC optimization 2

- Since we now want to use superiso likelihood, the following comes up:
  - Likelihood calculation is decoupled from SLHA writing -> To get both the likelihood value and write the low-energy observables to SLHA, two calls of superiso are required. Is this ok?
    - yes?
  - Do we save the superiso chi2 (and n_obs) value to the SLHA file?
    - yes

News 04.09.18

- Now implementing a binary Higgs constraint of 125 +- 3 GeV
- Revisiting superiso in-built likelihood according to Nazilas suggestions.
    - Using the OpenMP library seems to have drastically reduced time cost to O(1s) per point
    - Using a reduced set of observables is also possible now, to further reduce computation time
    - Sabine suggested not using BR(B->K*ll). I think because its not essential and is split into over 100 different contributions to the superiso likelihood
- Sezen suggested introducing a simple (linear?) prior that favors low squark masses
- Some discussion happened on the check for MCMC convergence. Sezen provided two papers on MCMC convergence, but I have not looked into them yet. She also suggested using the so-called “Gelman and Rubin method”
- Scan should be documented on twiki page. Will start on that soon.

News 11.09.18

- Now running with higgs box at 125+-3 GeV
- Increased mu,M1,M2,mA box sizes to 4 TeV, as interesting phenomenology occurs for small mu, decoupled M1,M2 (displaced tracks)
- Now using superiso in-built likelihood
  - not using BR(B->K*ll)
  - observables not used in superiso likelihood included as before
- Sezen suggested introducing a simple (linear?) prior that favors low squark masses
  - not used for now
- have not yet looked into MCMC convergence
- have not started on twiki/gitlab documentation
- started mass producing points, target = 10^6

News 18.09.18

- have not yet looked into MCMC convergence
- have not started on twiki/gitlab documentation
- started mass producing points, target = 10^6
  - stopped for now, superiso chi2 takes O(10s) on naf machines, I suspect the OpenMP library is missing there

News 25.09.18

- have not yet looked into MCMC convergence
- have not started on twiki/gitlab documentation
- started mass producing points, target = 10^6
  - stopped for now, superiso chi2 takes O(10s) on naf machines, I suspect the OpenMP library is missing there <- FIXED: Issue was that bird machines need to be told to use more than one core
- Next:
  - Do N-1 plots for likelihood contributors
  - Learn about MCMC convergence

News 09.10.18

- Have started looking into MCMC convergence
- Have started on twiki/gitlab documentation
- 8*10^5 Points available for study
- N-1 runs done with O(20k) points each

Next:

  - implement MCMC convergence criteria, take a first look and find burn in value

News & Summary 16.10.18

- Have started looking into MCMC convergence
  - Rubin & Gelman method shows instant convergence?
- Started looking into trial scan, O(10^6) points
  - observed odd behaviour in gluino spectrum at high values
  - observed odd behaviour at low end of mass spectra of **all** sparticles except gluino
- N-1 runs done with O(20k) points each
  - Had to redo them, as superiso likelihood was not correctly implemented (same applies for trial run shown in next slides)
- 1 runs (only 1 contribution to likelihood) done with O(20k) points each
  - Have not yet been looked at
- Next:
  - prepare update for rest of the group soon
  - find another convergence measure?
  - Study implications of bullet 2

News & Summary 30.10.18

- 1 runs (only 1 contribution to likelihood) done with O(20k) points each
    - Have not yet been looked at
- Study of spectrum generator point rejection bias ongoing
    - Werner Porod (Author of SPheno) suggested high mass splittings between sleptons and squarks are problematic for the theory side

News & Summary 15.11.18

- 1 runs (only 1 contribution to likelihood) still not looked at
  - Have not yet been looked at
  - Might have been produced with wrong superiso likelihood
- Study of spectrum generator point rejection more or less done
  - High mass splittings in squark sector problematic for SPheno, leads to tachyons
  - High mass splitting between squarks and sleptons problematic for softsusy
  - Smaller box size tested, does not seem to help in relevant range
- Performed a volume effect study: How many points where the squarks have similar mass can we expect?
- New idea for convergence measure: Use Kolmogorov Smirnov test for consecutive sets of N points for each observable and each chain
- Currently producing a new scan with SPheno as spectrum generator
  - Increased slepton parameter range to 4 TeV

Todo 15.11.18

- Figure out how to separate low-energy calculation from spectrum generation in SPheno in order to try MCMC chains with softsusy
- Reinitiate discussion with
  - Sabine & Sezen on spectrum generator issue
  - Basil, Sezen on parameter ranges, differently sized ranges for EW, strong
  - Harrison on MCMC convergence

(current) list of low energy observables

- a_{mu} (pdg value)
- BR(b->s gamma) (pdg value)
- BR(b->s mu mu) (HFLAV value)
- BR(b->s nu nu) ←Not discovered, not used
- BR(b d -> mu mu) (HFLAV value)
- BR(b s -> mu mu) (pdg value) is this correlated with above? Is it sensitive to CKM?
- BR(b u -> tau nu) (HFLAV value)
- Δ_0 (B->K gamma) (HFLAV value) ← Isospin/CP

Superiso chi2

- Δ_0 (B->K gamma)