SUSY-AI: fast exclusion determination using full ATLAS results with machine learning

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Talk based on [1605.02797]

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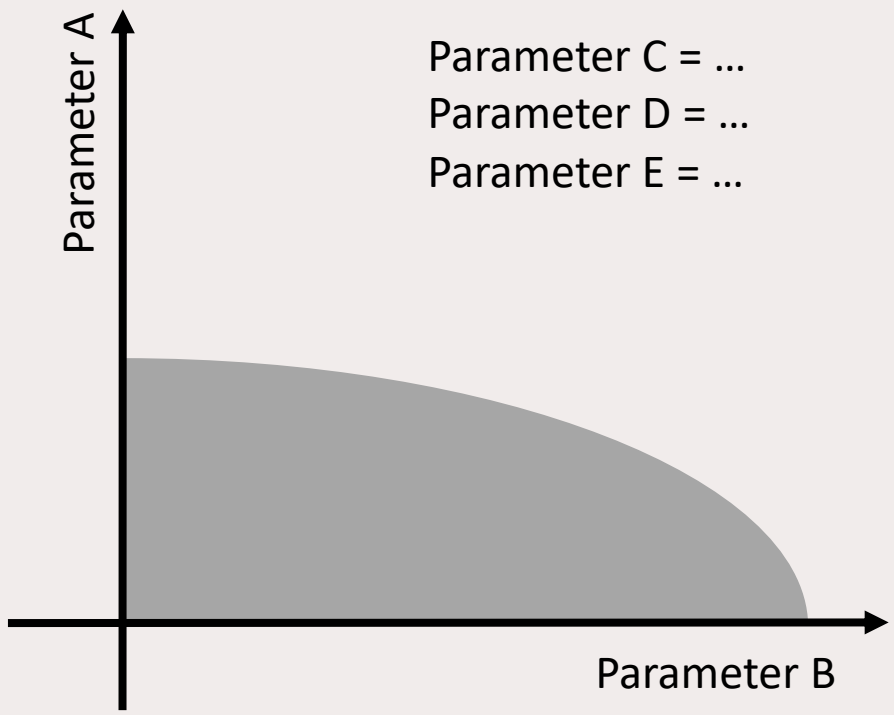
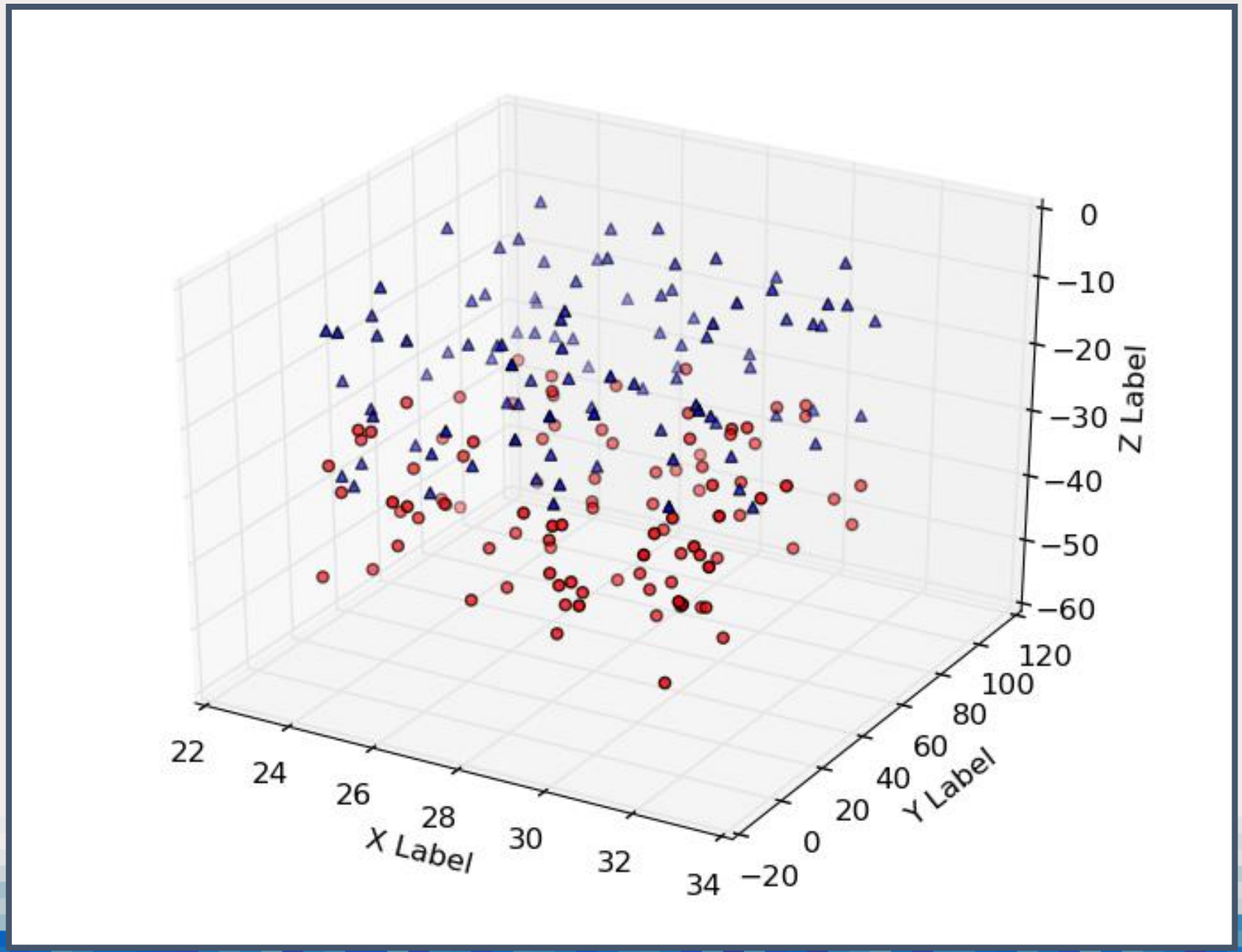
Model exclusion in Particle Physics

- Model of new physics needed to solve mystery of gravity, dark matter, hierarchy problem
- Supersymmetry is a serious candidate for this position, but not observed (yet?)

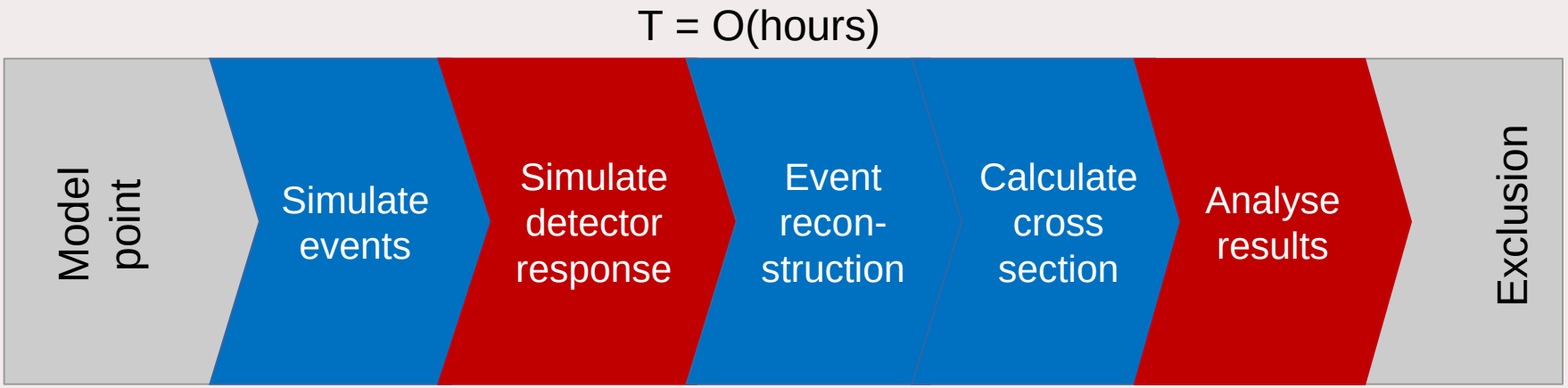
Goal set limits on models and its parameters

- Published limits suffer from their projections




0
−10
−20
−30
−40
−50
−60
Z Label
120
100
80
60
40
20
0
−20
Y Label
22
24
26
28
30
32
34
X Label

Exclusion analysis



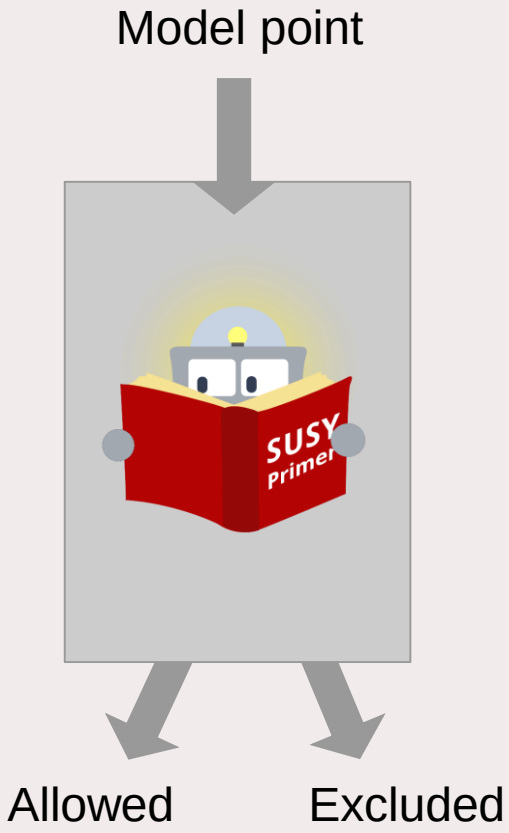
Machine Learning

Data property prediction based on example (training) data

- Learn possibly hard data pattern
- Wide range of algorithms...
  - Boosted decision trees
  - Neural networks
  - Decision trees
  - Random Forest
- … and applications
  - Spam detection
  - Health care
  - Advertising
  - Auto pilot in cars

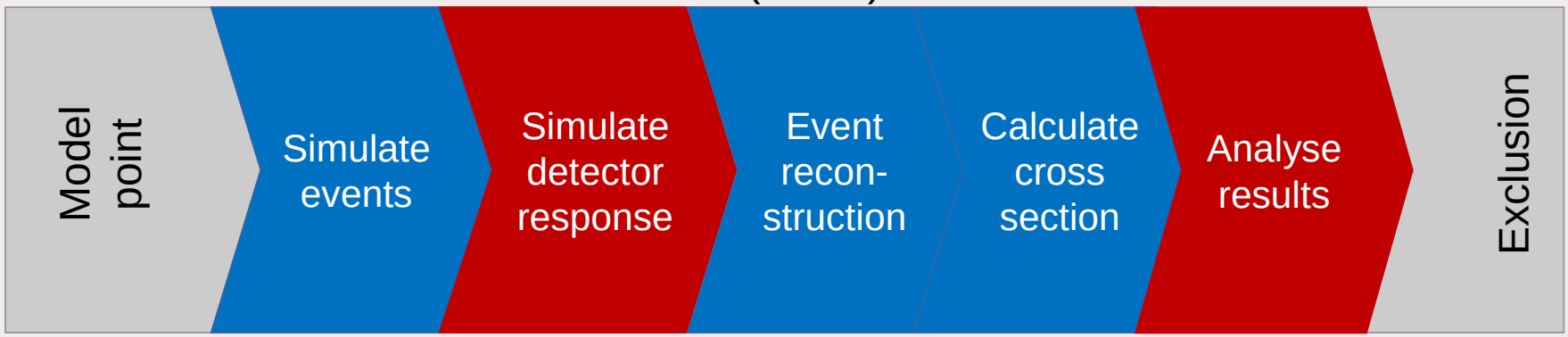
Machine Learning Applied

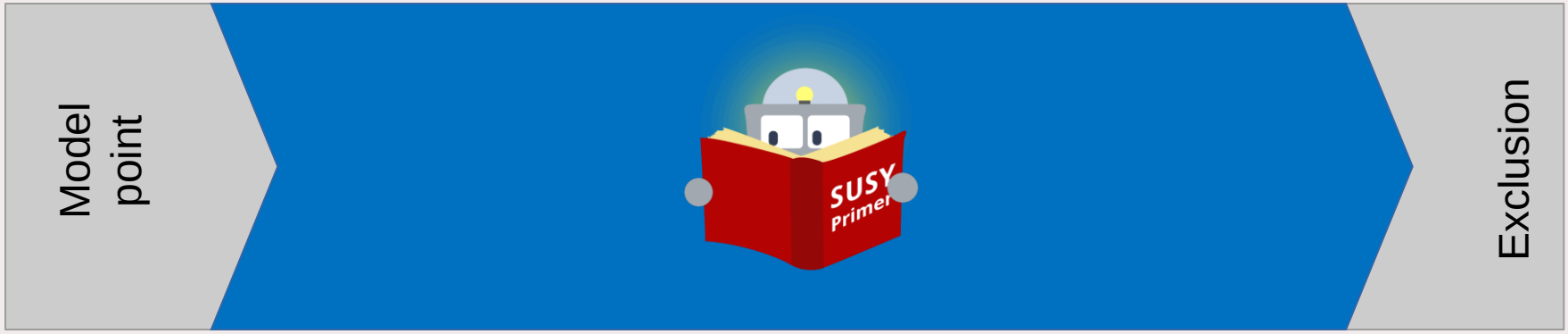
- Training data: model points in supersymmetric model with only phenomenologically relevant parameters (pMSSM)
  source: ATLAS [1508.06608]
- Testing data: independent (unseen) data



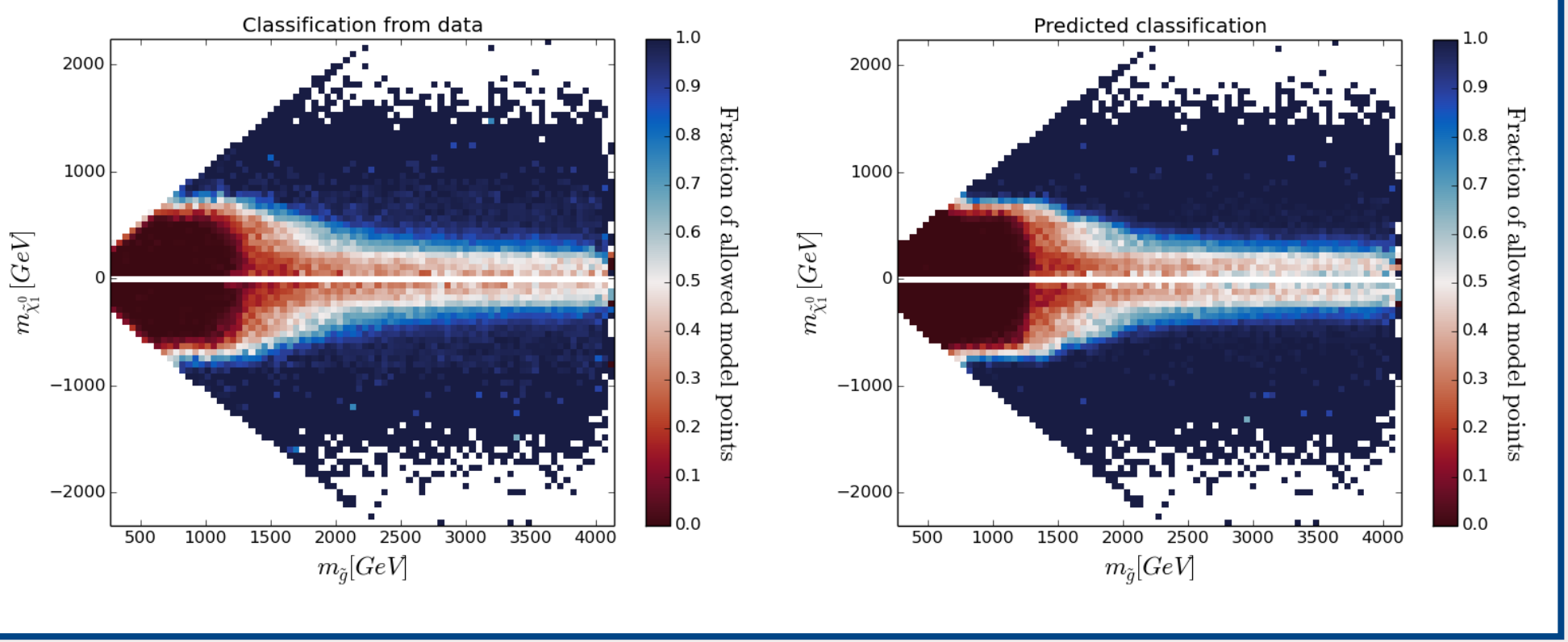
Exclusion analysis

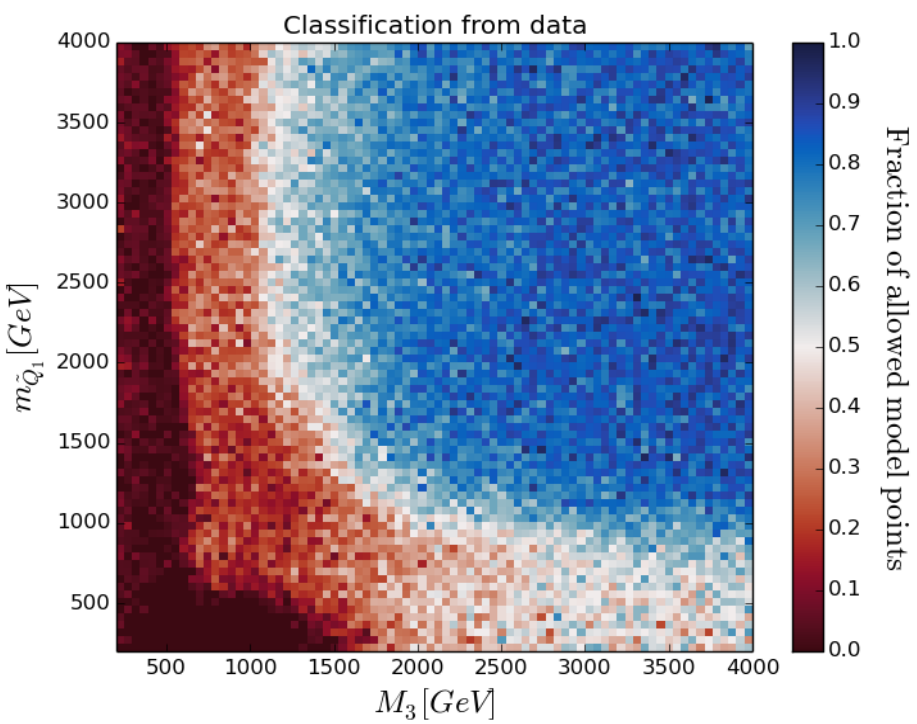
T = O(hours)

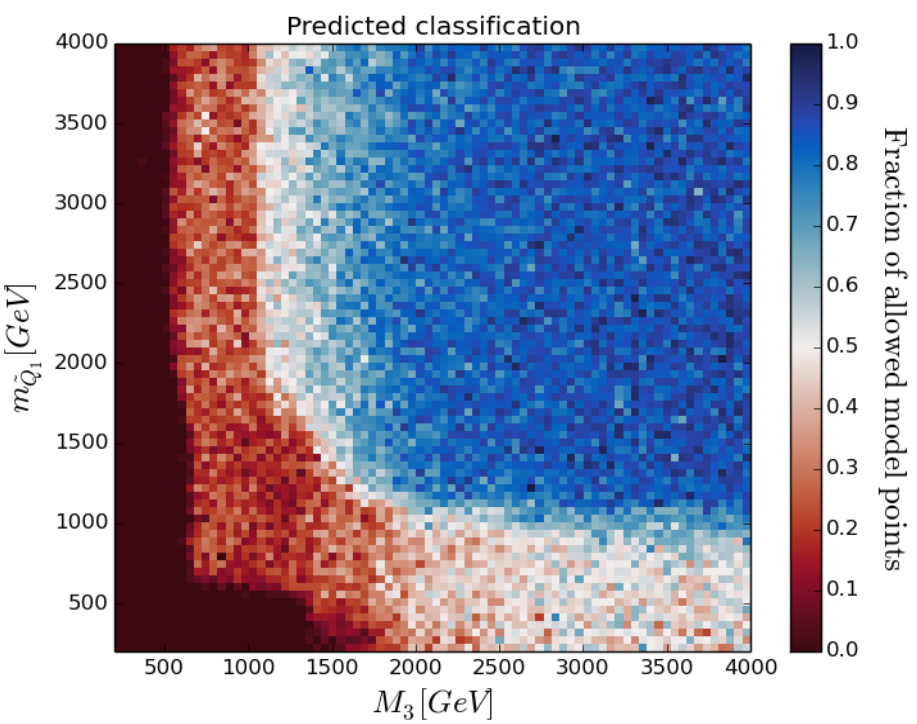


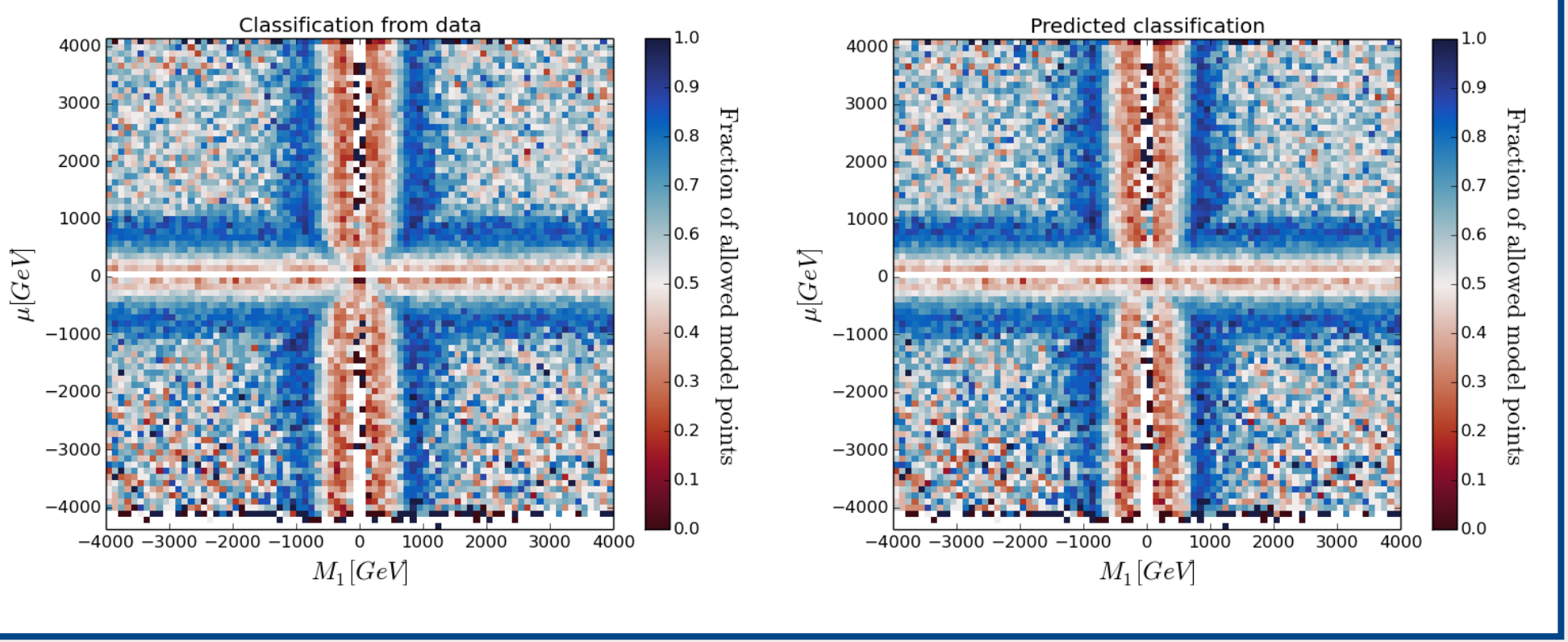


T = < O(1 ms)


Classification from data
Predicted classification
$m_{\tilde{\chi}_1^0}[GeV]$
$m_{\tilde{g}}[GeV]$
Fraction of allowed model points
2000
1000
0
−1000
−2000
500
1000
1500
2000
2500
3000
3500
4000
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


Classification from data
$m_{\tilde{Q}_1}\,[GeV]$
$M_3\,[GeV]$
Fraction of allowed model points


Predicted classification
$m_{\tilde{Q}_1}\,[GeV]$
$M_3\,[GeV]$
Fraction of allowed model points


Classification from data
Predicted classification
$\mu\,[GeV]$
$M_1\,[GeV]$
Fraction of allowed model points
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

Why use SUSY-AI / Machine Learning

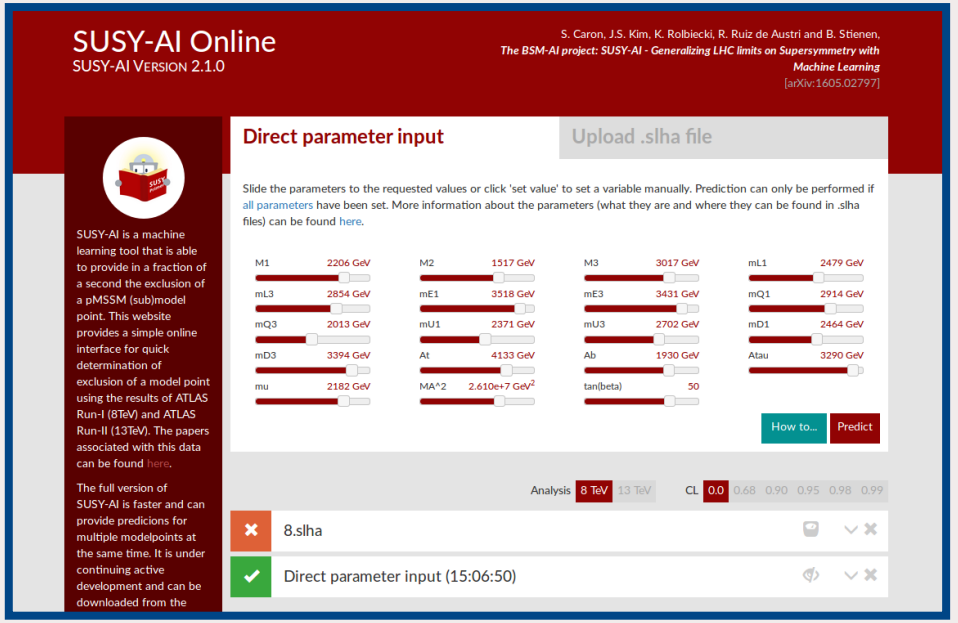
- Fast statistical results based on earlier analyses
- High accuracy (93.2%) by learning hard-to-see relations in data
- Works also in submodels of the learned model
- Providing confidence levels on prediction

- Publishing multivariate data
- Creating plots not present in paper
- Re-usability and persistence of analysis and results

SUSY-AI (Online)

- Tool has been published
  https://susyai.hepforge.org
  - Python interface to classifier
  - Scikit-learn package for ML implementation

- Online interface
  http://susy-ai.org/
  - All functionalities except batch predictions
  - Predictions in < 2 seconds



Summary and Conclusions

- High-speed + high accuracy prediction of ATLAS exclusion
- Applicable to phenomenological supersymmetry and its submodels
- Programmatic and online interface (http://www.susy-ai.org)

- First time use of Machine Learning for publishing and extrapolating multivariate results
- More models will be done
  - Dark Matter models
  - Higgs couplings
  - Effective Field Theories
  - …

- Development can be accelerated with more public data