Learning (from) High-dimensional Models
with PhenoAI and iDarkSurvey

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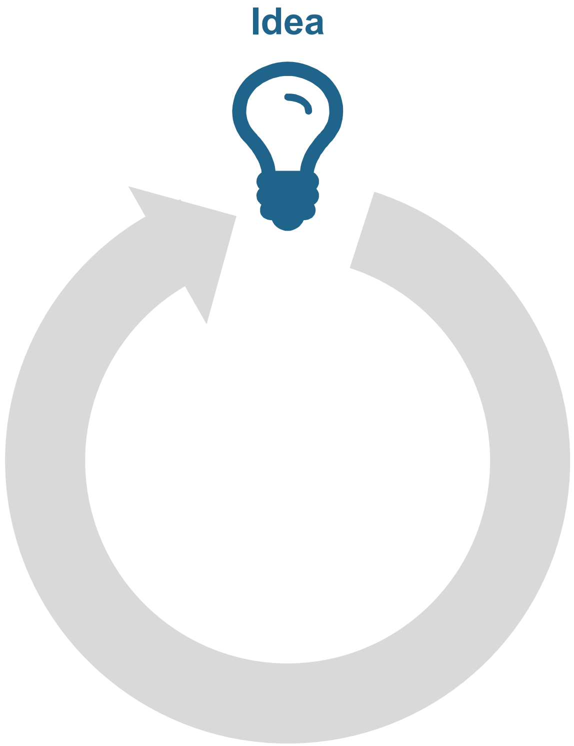
How do we do (particle) physics?

The Circle of Physics



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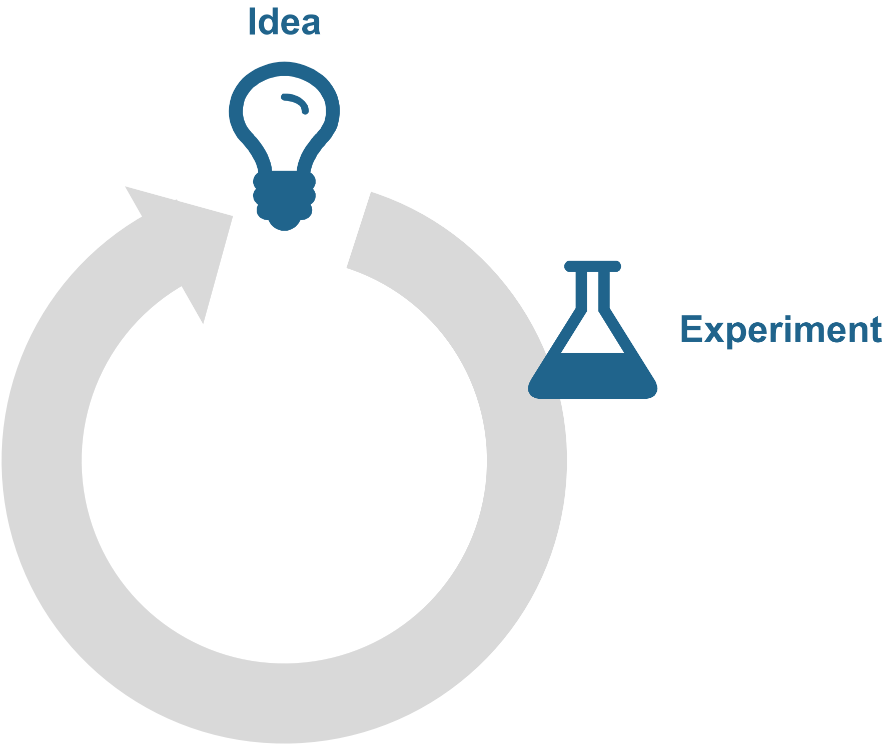

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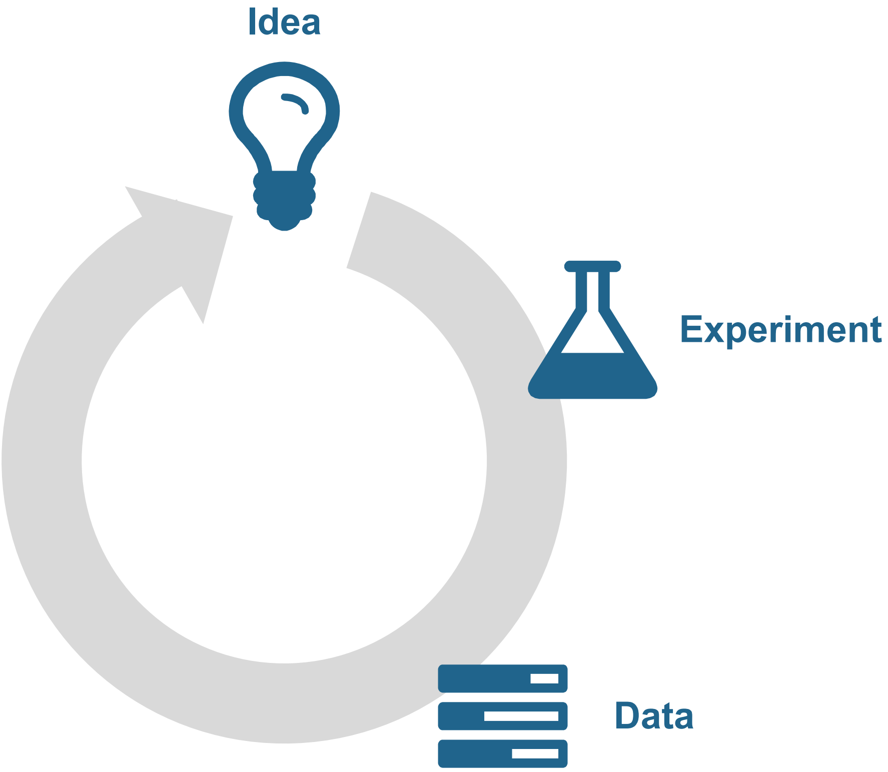

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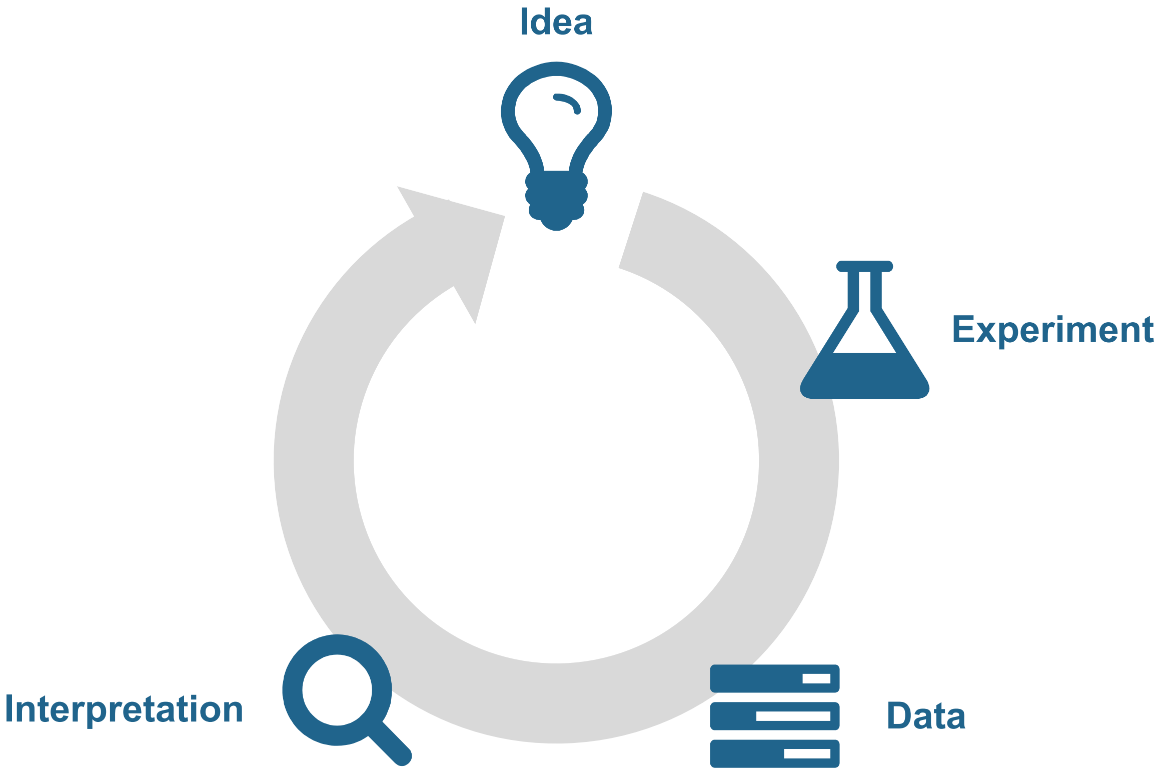

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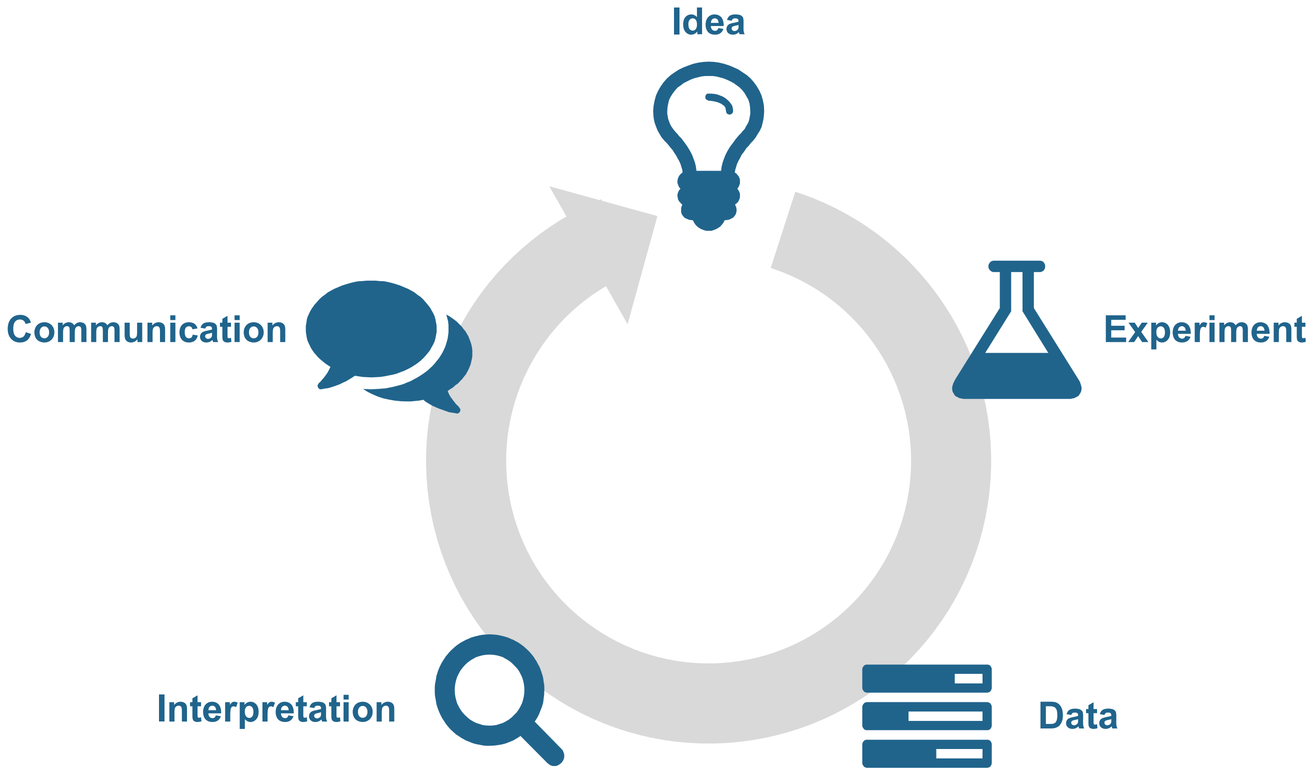

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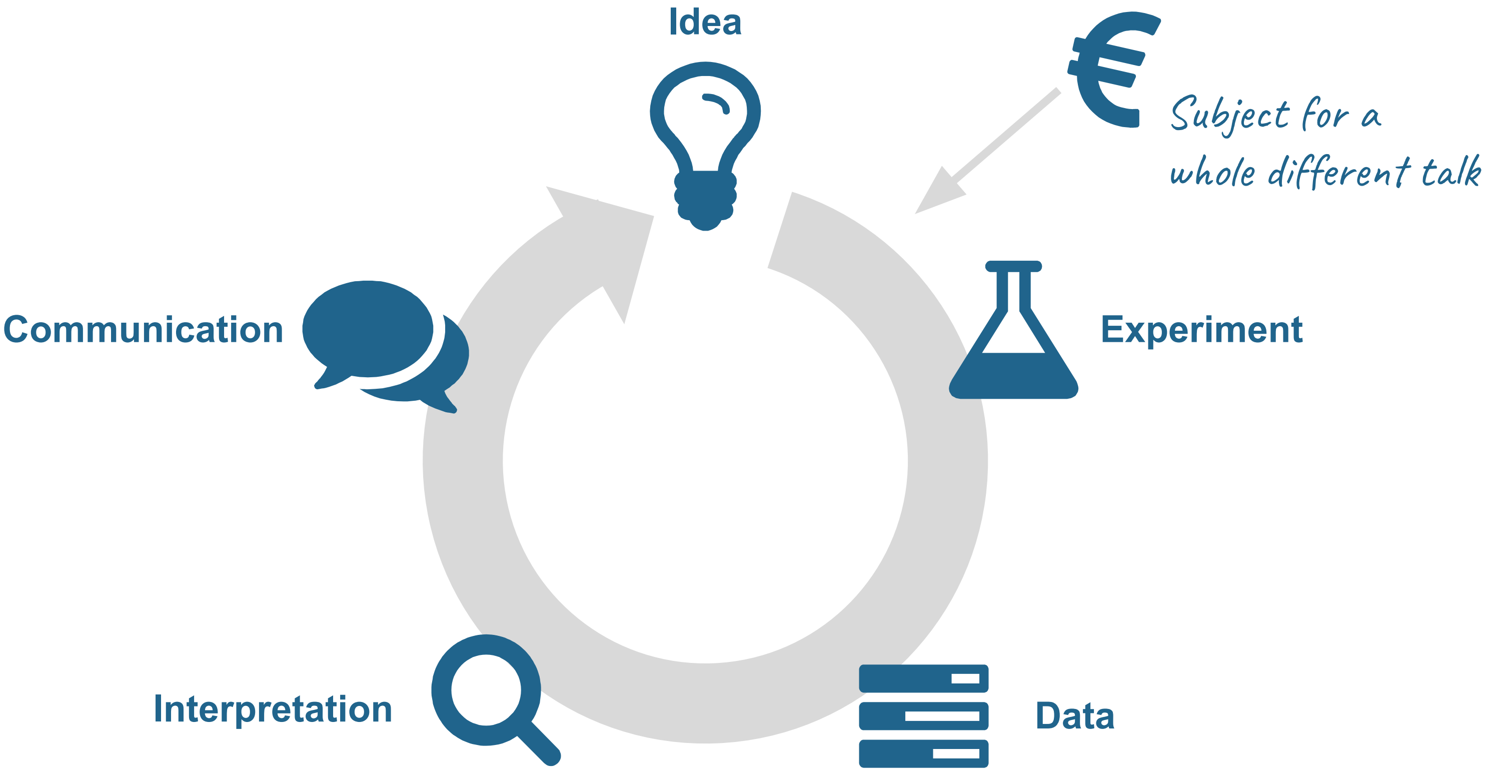

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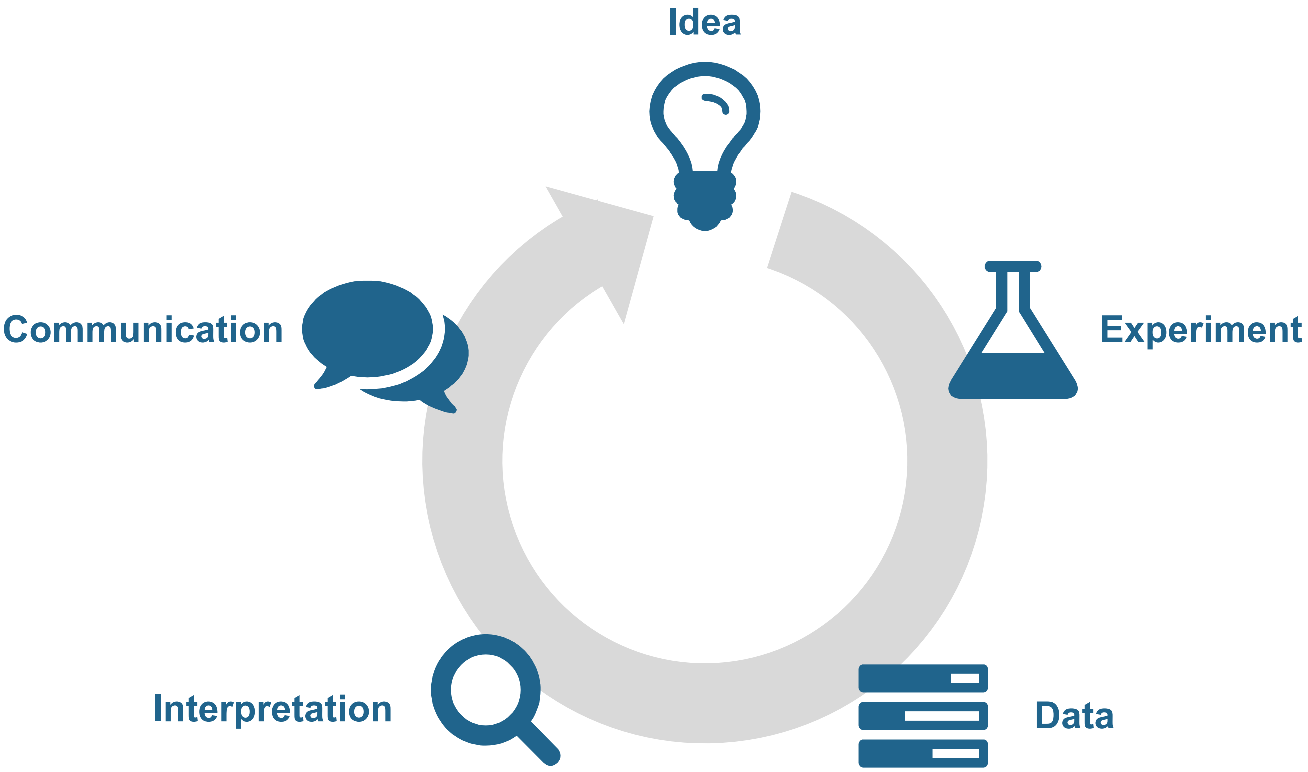

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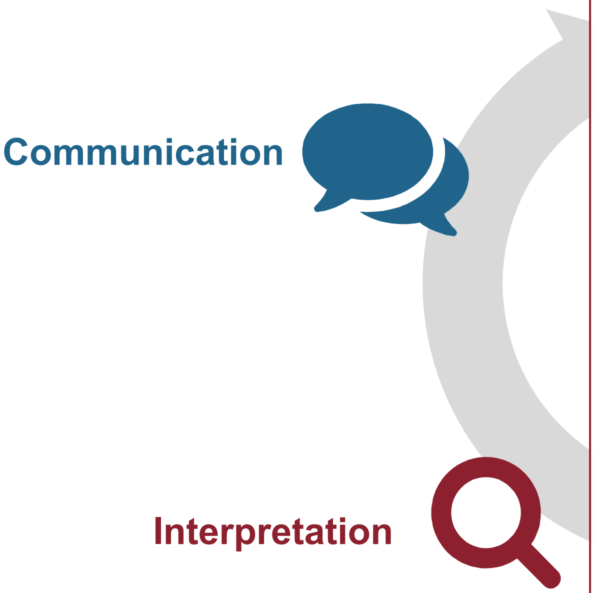
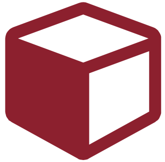


- Inherently model dependent
  - ⟶ different model = different interpretation

- Interpretation of the results in the context of a single model point is computationally very expensive
  - ⟶ Simplified models are often used, but

 $\neq N *$ 

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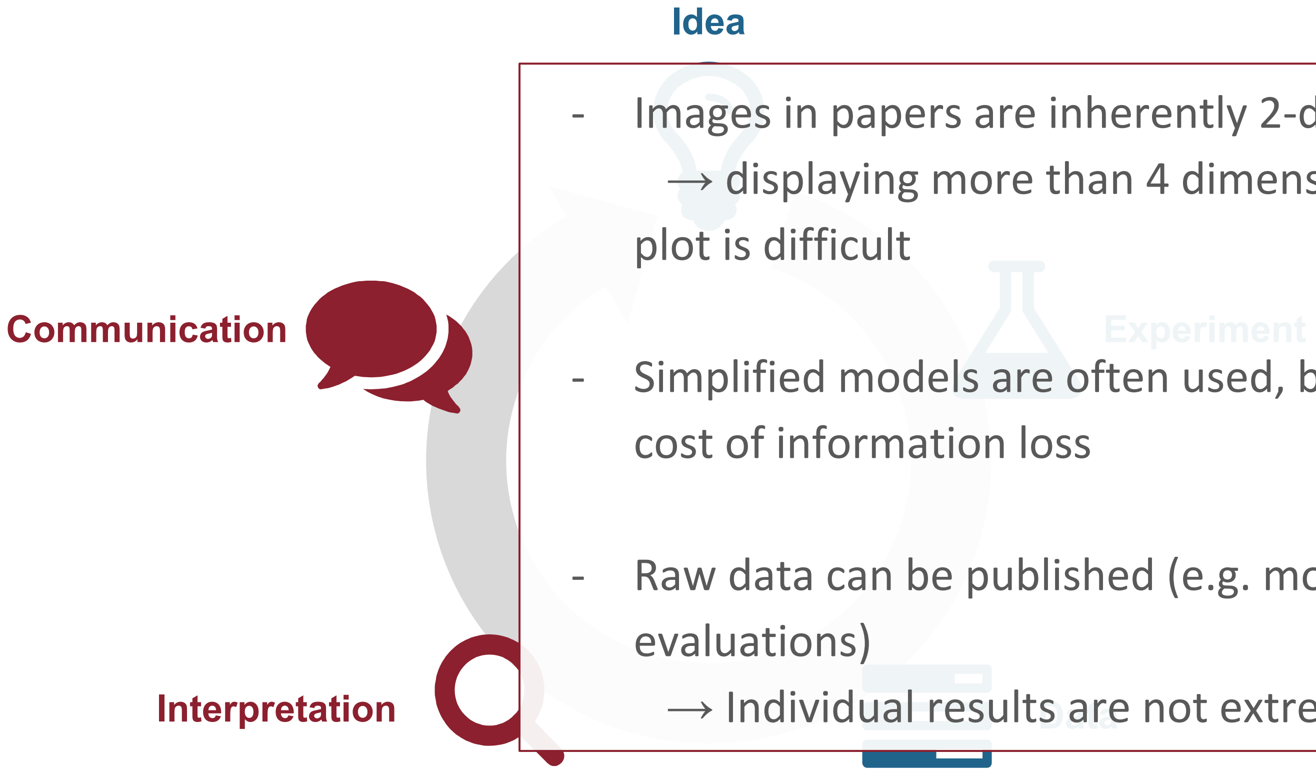
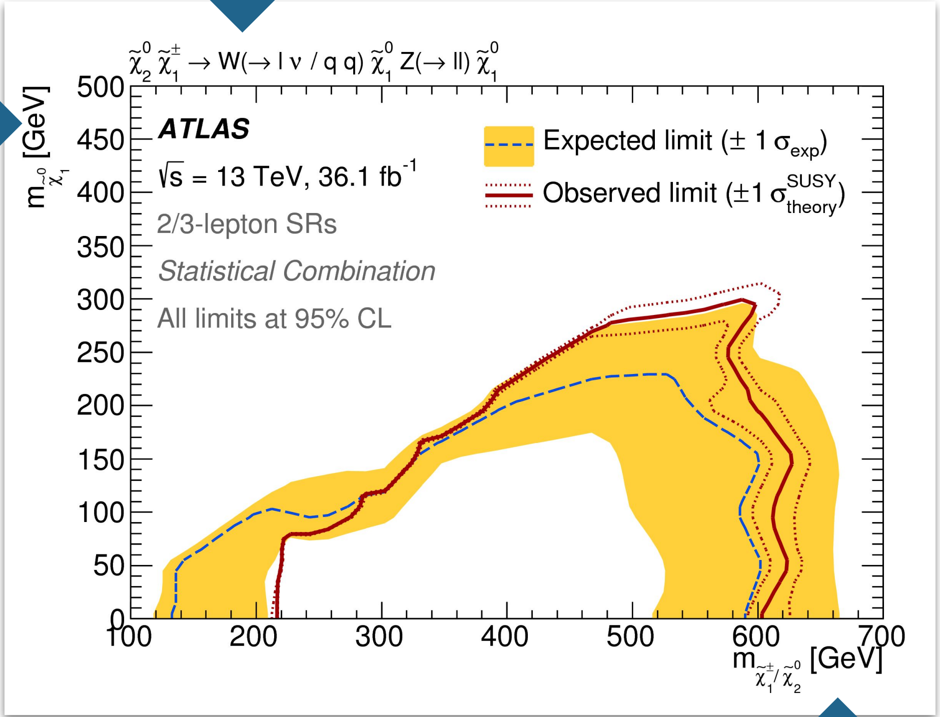


- Images in papers are inherently 2-dimensional
  → displaying more than 4 dimensions in a plot is difficult

- Simplified models are often used, but at the cost of information loss

- Raw data can be published (e.g. model points + evaluations)
  → Individual results are not extremely useful

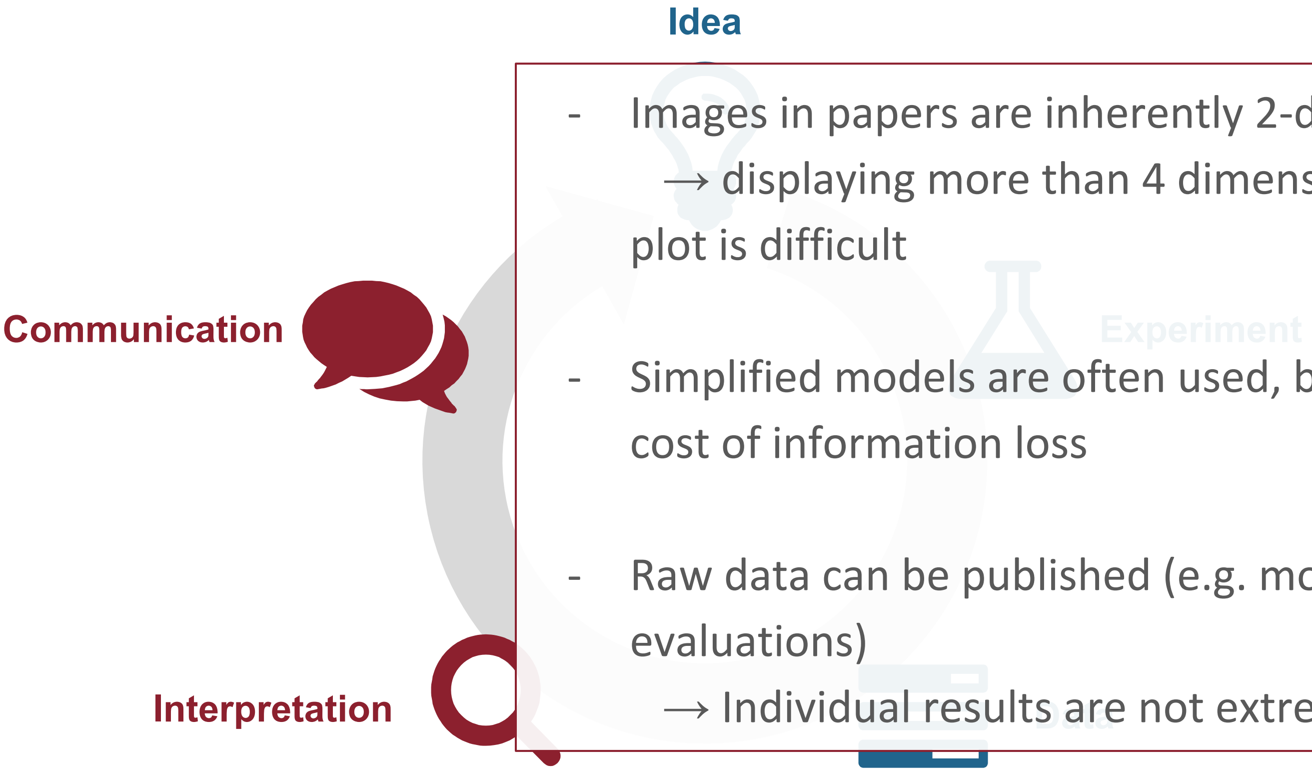


What if...

- i don't have a 100% BR to the specified final state?
- i want to know the exclusion in another projection?
- i have the other free parameters set differently?

Core of the problem:
Plotting N>2 dimensions is hard

The Circle of Physics



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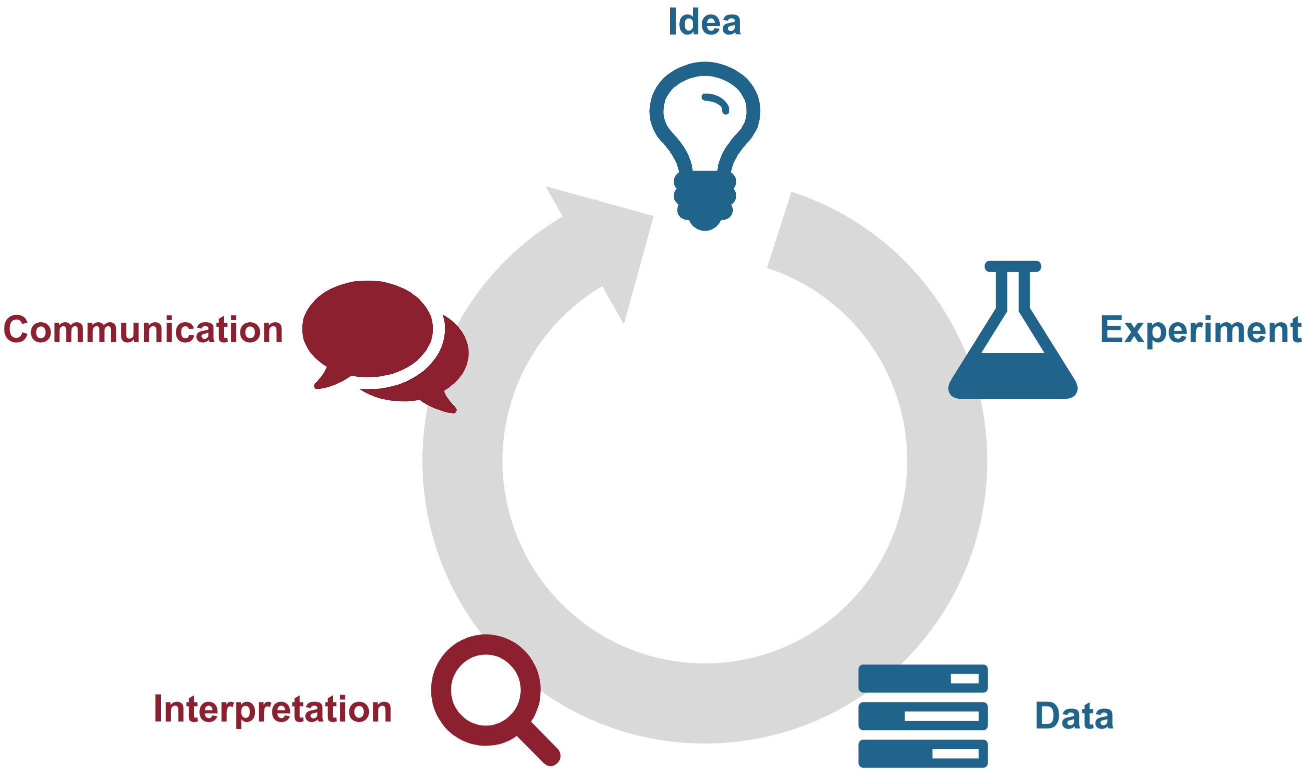
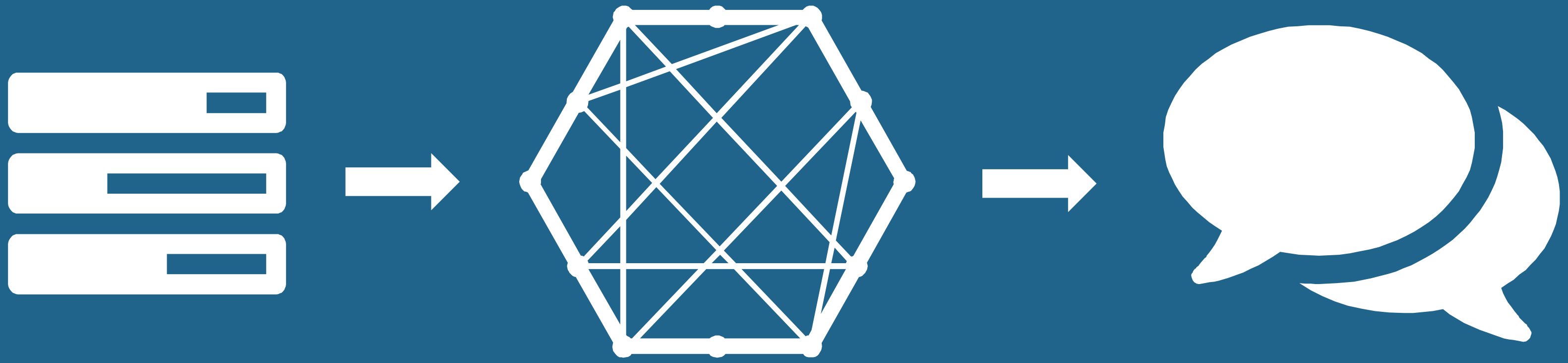
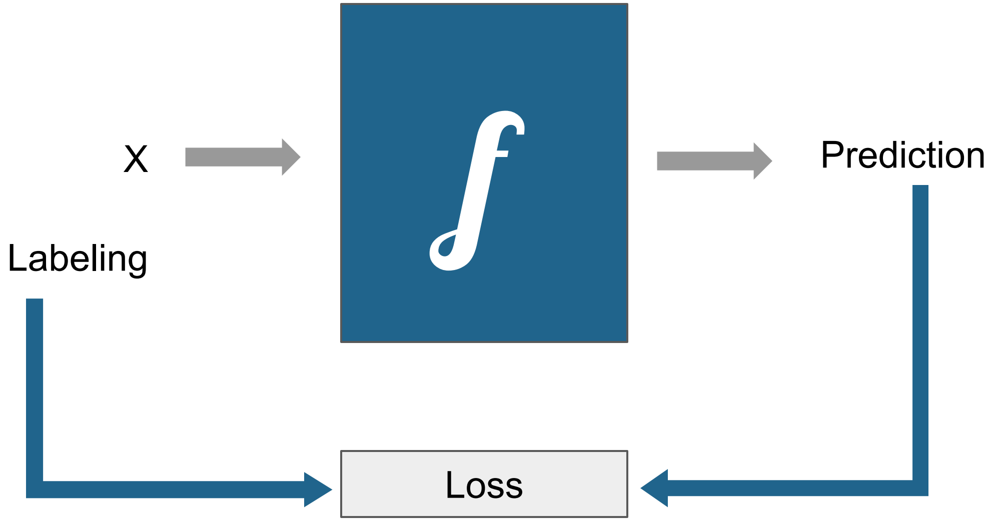


How to manage our information to retain most of it?

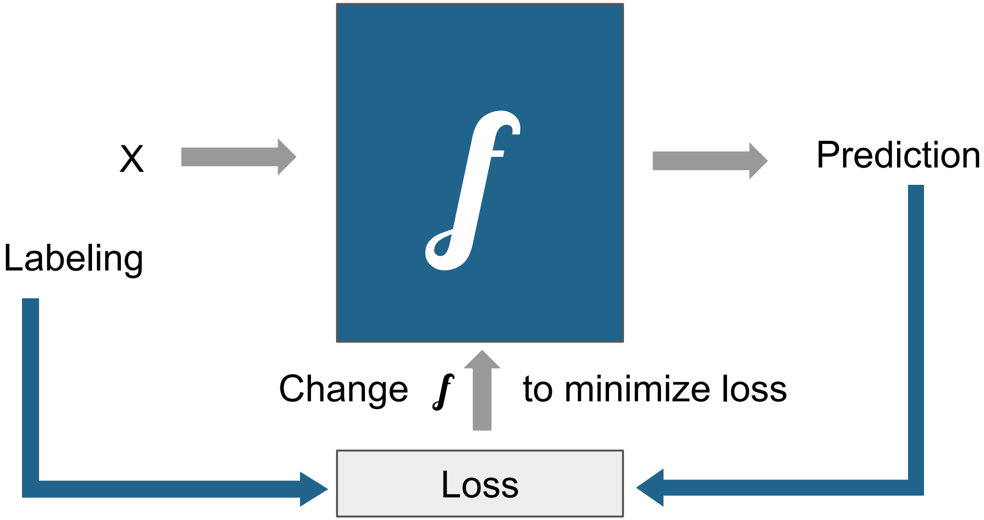


Machine Learning as a solution

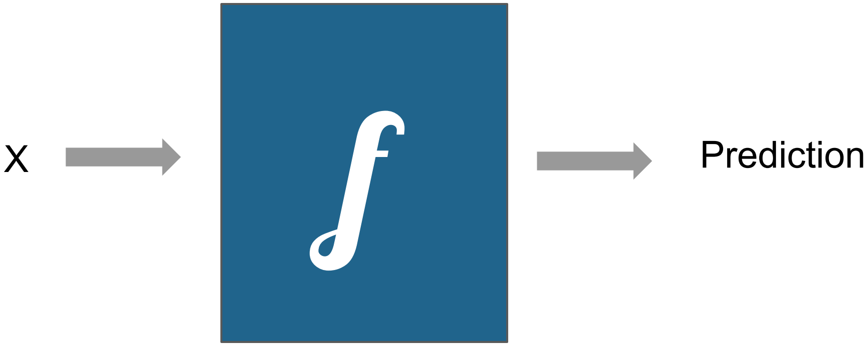
Machine Learning as a solution



Machine Learning as a solution



Machine Learning as a solution

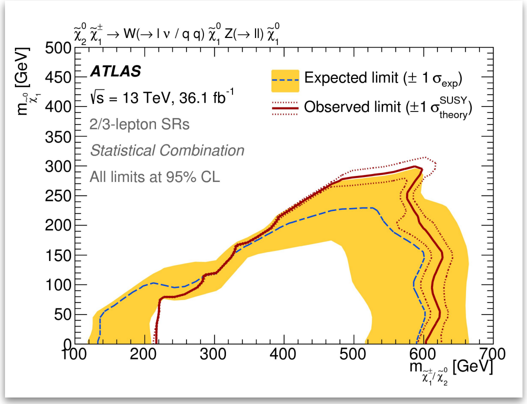


Encodes our model and entire analysis workflow

Machine Learning as a solution

Example

m_chargino
m_neutralino

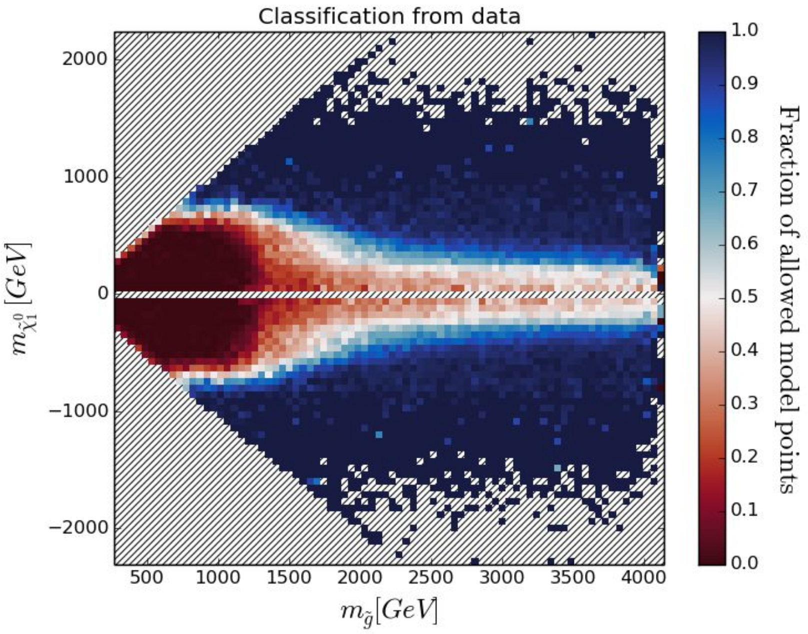


Encodes our model and entire analysis workflow

But... can be N>2...

SUSY-AI as proof-of-principle

DOI: 10.1140/epjc/s10052-017-4814-9



- pMSSM19
- 300,000 training points
  10.1007/JHEP10(2015)134
- Exclusion determined by 22 different analyses
- RandomForest (for the *connaisseurs*)

SUSY-AI as proof-of-principle

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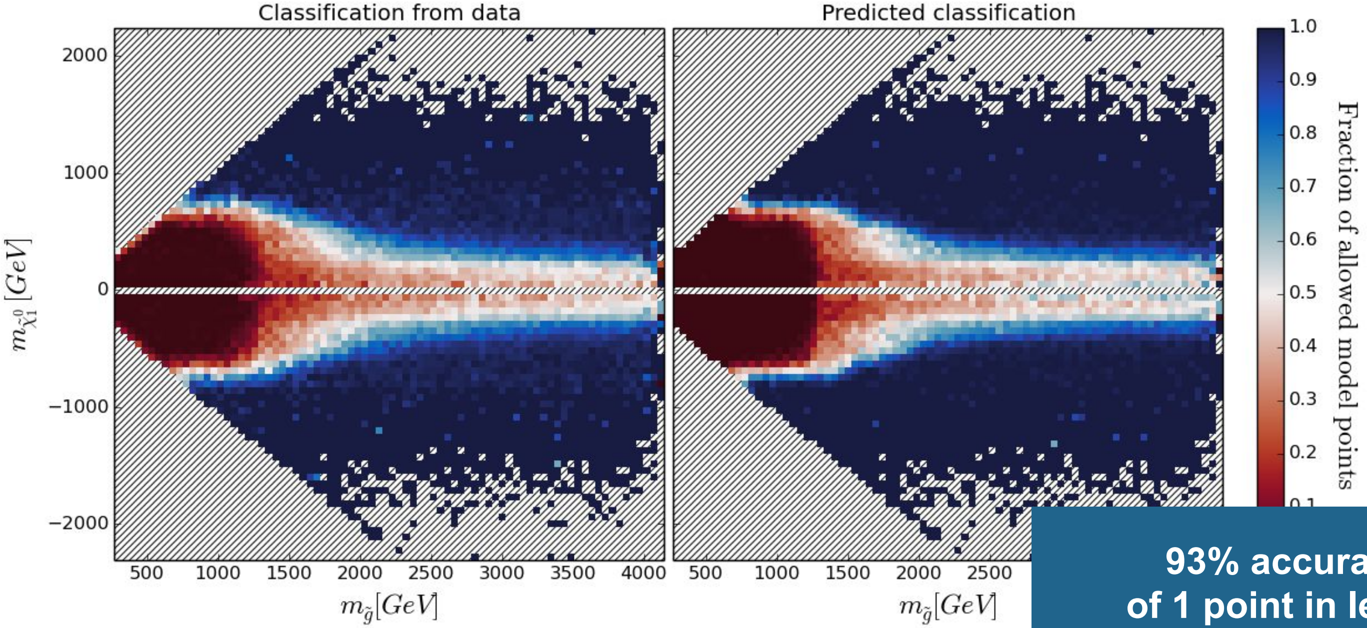
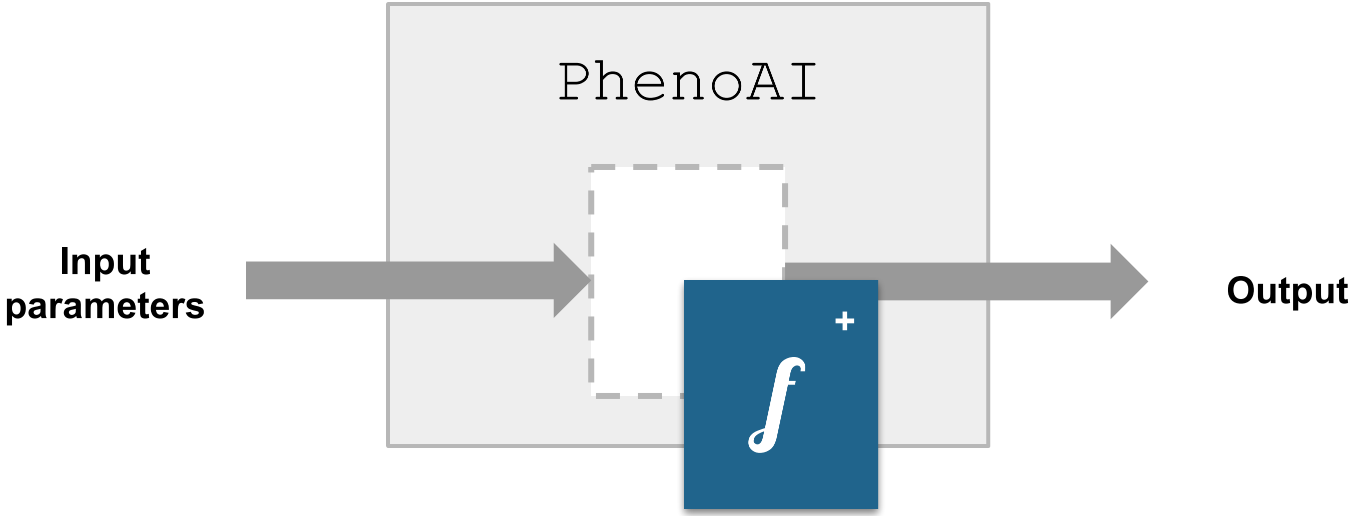


93% accuracy at a rate of 1 point in less than a ms in a full 19-dimensional model

PhenoAI as natural evolution



Machine Learning is abstracted away:
anyone with Python knowledge can use the trained models

Communication of high-dimensional results becomes possible:
publish a trained algorithm

PhenoAInalyses

- Trained algorithms (**AInalyses**) still need to be made. You can do this yourself, or …
- … download one from the AInalysis library on the PhenoAI website
- Currently working on AInalyses for:
  - Cross Sections << *See S. Otten's talk tomorrow*
  - Electroweakino
  - Likelihoods from Gambit

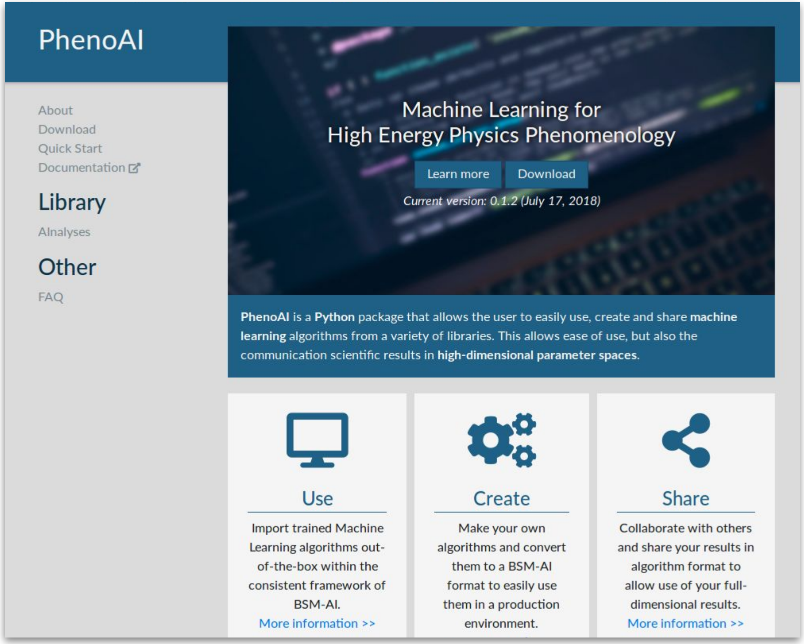
PhenoAI *"Pheno for the masses"*

- PhenoAI is available via pip3 (`phenoai`) and via the website http://hef.ru.nl/~bstienen/phenoai

- Extensive documentation available

- Feedback is more than welcome!

- Paper will be out soon



But what about data?

Data publishing

- Individual data points (e.g. model points) are not really informative on their own

- Data can be published on HEPData, but...
  - … lacks an easy interface to navigate and explore the data
  - … data sets can not be easily compared

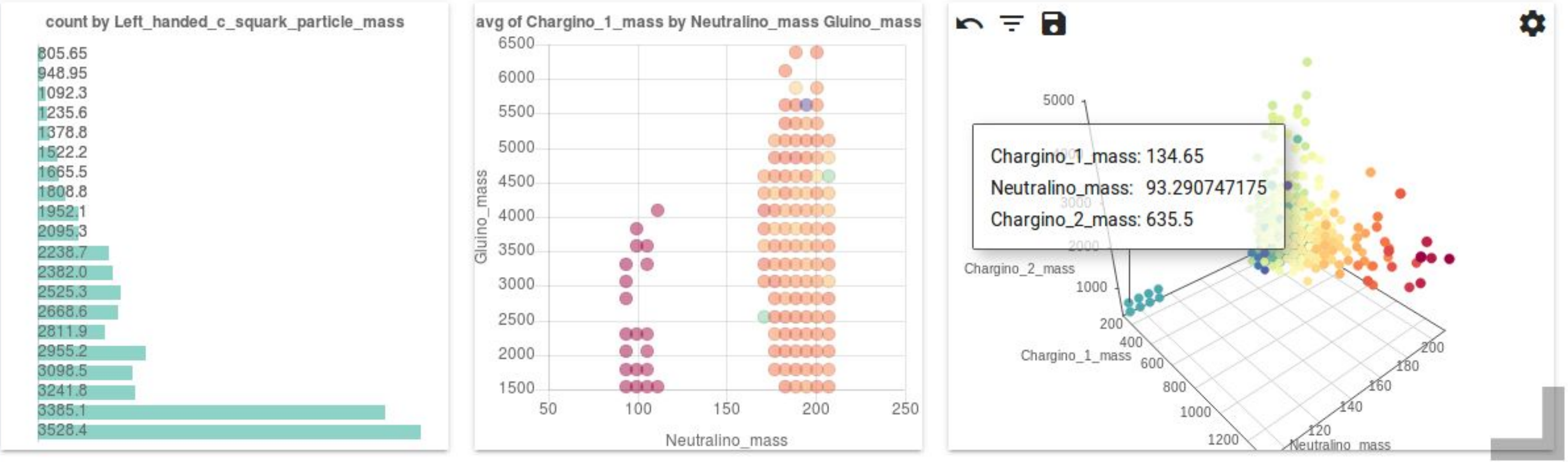
Result: Publishing information like model point evaluations is still not extremely common in our field.

iDarkSurvey for Data Publishing

netherlands eScience center

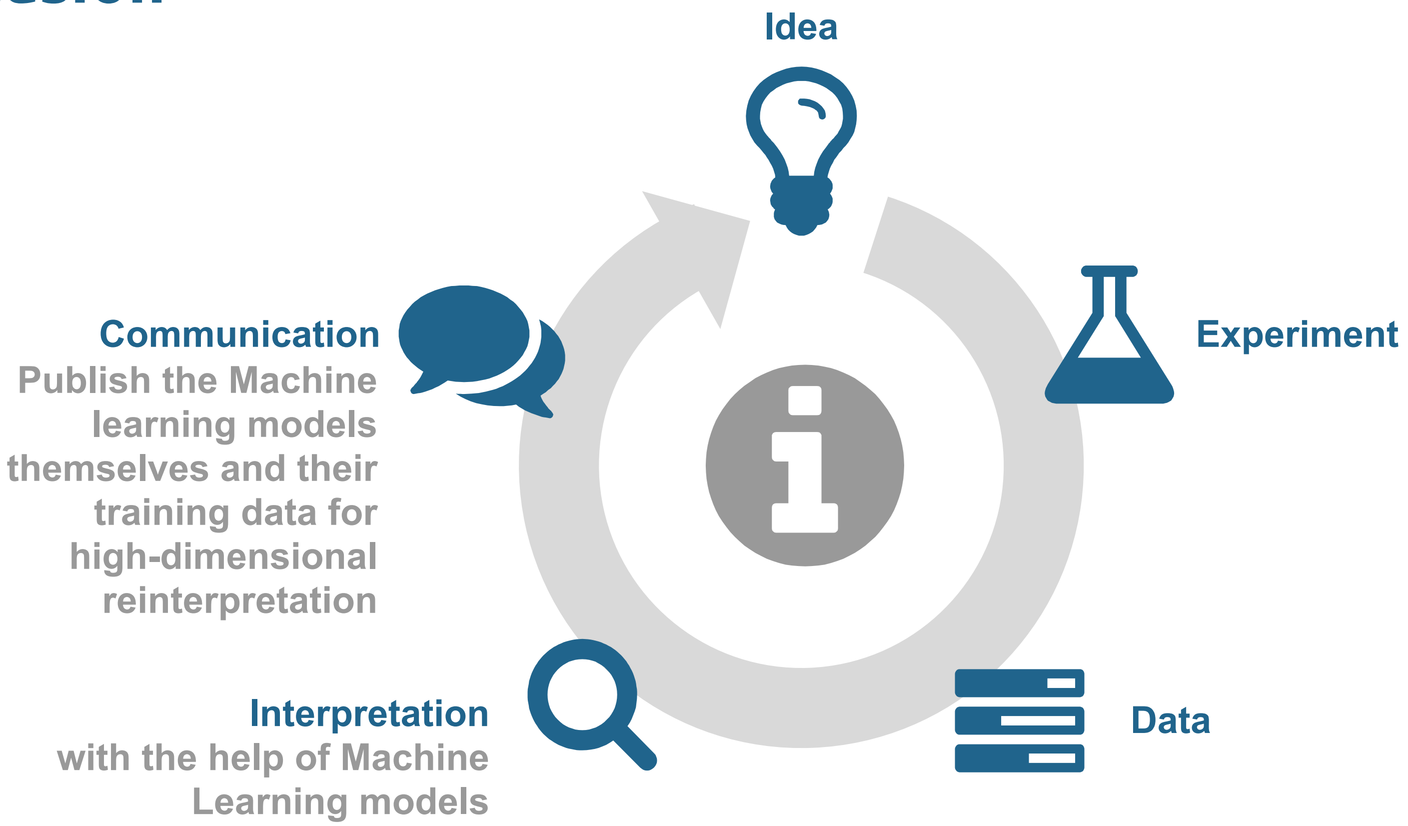
- Online data storage for high energy physics data
- Has online plotting interface to explore data
- Multiple data sets can easily be compared within the same plots
- Own data can be viewed alongside the data in the database
- Online demo at http://www.idarksurvey.org/

iDarkSurvey for Data Publishing



http://www.idarksurvey.org/

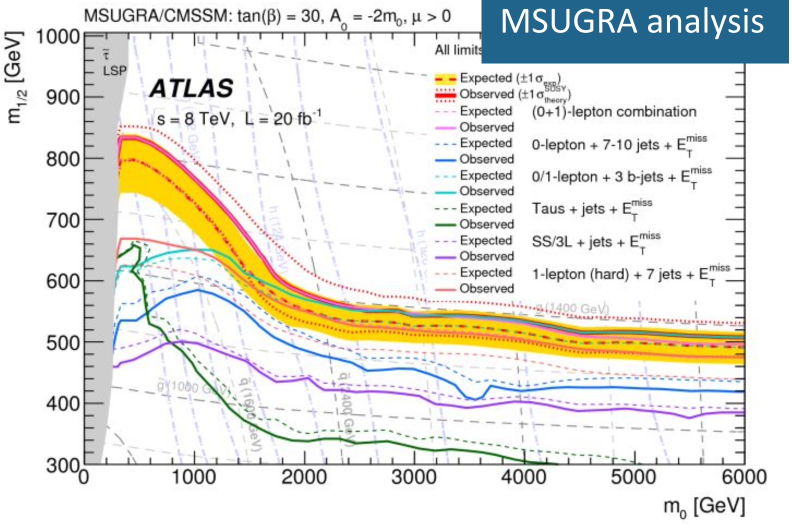
Conclusion


Idea
Experiment
Data
Interpretation
with the help of Machine
Learning models
Communication
Publish the Machine
learning models
themselves and their
training data for
high-dimensional
reinterpretation

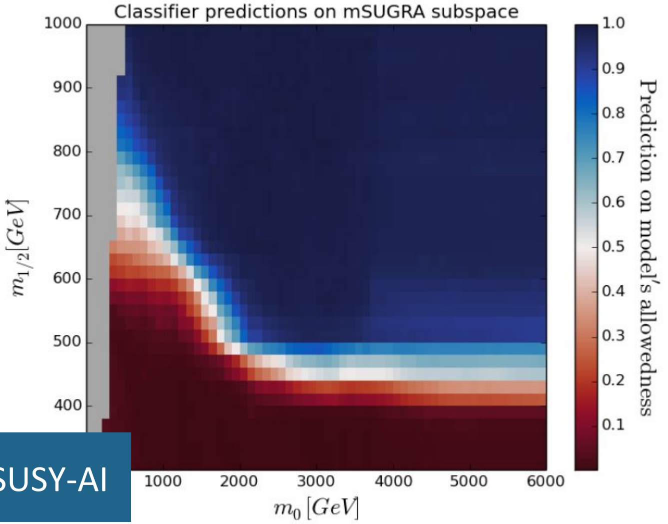
Extra slides

What about my simplified model?

Training on a full model still allows access to submodels. SUSY-AI was trained on the pMSSM19, of which MSUGRA/CMSSM is a submodel.



MSUGRA analysis

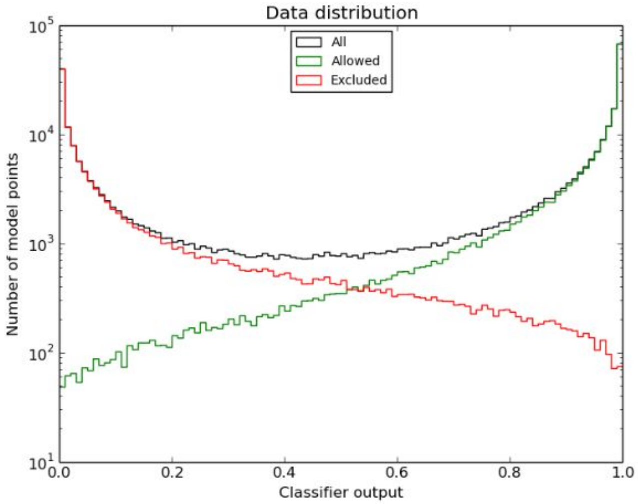


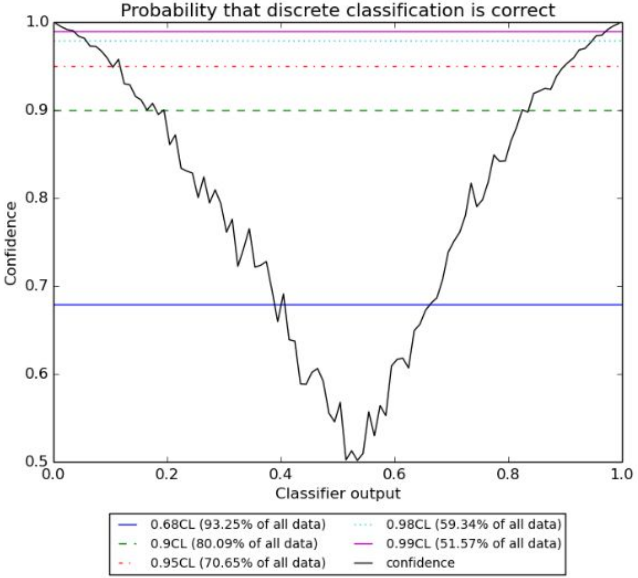
SUSY-AI

Comparison not entirely fair: the dedicated MSUGRA/CMSSM scan combined signal regions in a smart way, whereas the exclusion of the SUSY-AI dataset uses the simple: “if excluded by any analysis -> excluded”

Confidence construction from SUSY-AI

SUSY-AI is a classifier, but outputs a continuous value between 0 (excluded) and 1 (allowed). It can *not* be interpreted as a probability, but can be transformed into one.





Is PhenoAI really that simple?

```
from phenoai.phenoai import PhenoAI

master = PhenoAI()
master.add("./example_ainalysis", "example")
result = master.run(X)
```

Yes

Learning to use PhenoAI

PhenoAI aims to be as easy to use as possible. To this end we have created:

- online documentation
- in-code documentation
- example scripts
- a quick start manual

We are busy optimizing the learning experience of PhenoAI even further, making material as a tutorial and a cheat sheet.

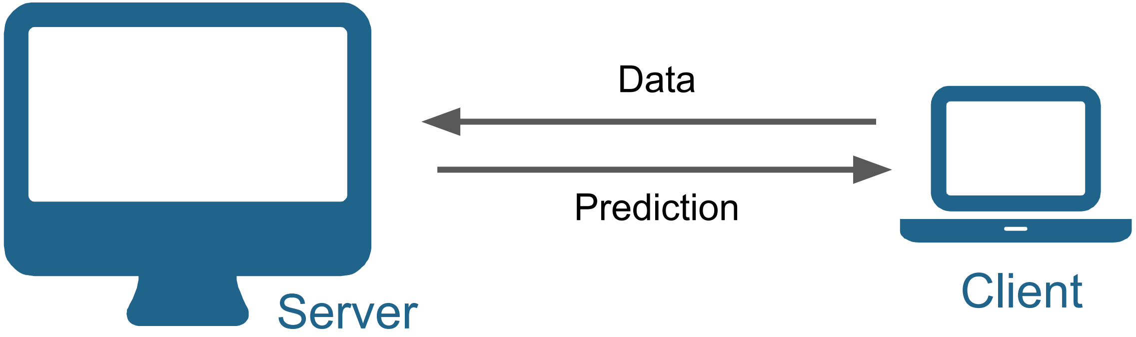
Supported ML libraries

All estimators and models created with Keras/tensorflow and scikit-learn are supported within PhenoAI. We are in the process of adding support for ROOT TMVA models as well.

Server-client structure

PhenoAI has a built-in ability to create a server-client structure. The server has the AInalyses loaded, the client can be added to any script and will query the server for prediction on a specific data set. In this way, the loading and configuration overhead are needed only once.

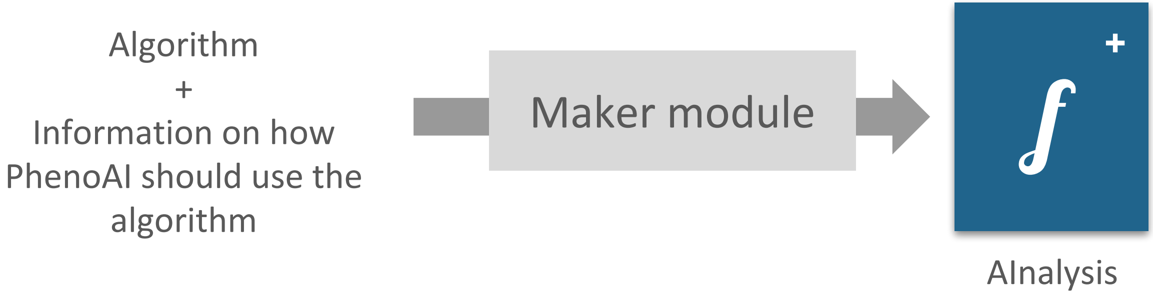
Server and client can of course just be the same machine



Maker module

In order to use a trained algorithm within PhenoAI, it needs to be stored within a folder with a PhenoAI configuration file. This collective as files is called an AInalysis and can, in principle, be made by hand. It is however more convenient to use the `phenoai.maker` module. Which will indicate if errors are made.

Example scripts on how to use the maker module are availble.



DarkMachines

PhenoAI is connected to the DarkMachines initiative as well, a research collective aiming to unravel the mystery that is dark matter with the help of machine learning. See darkmachines.org for more information.