Machine learning in Higgs physics

Giles Strong – LIP-Lisbon

Lisbon mini-school on Particle and Astro-particle Physics

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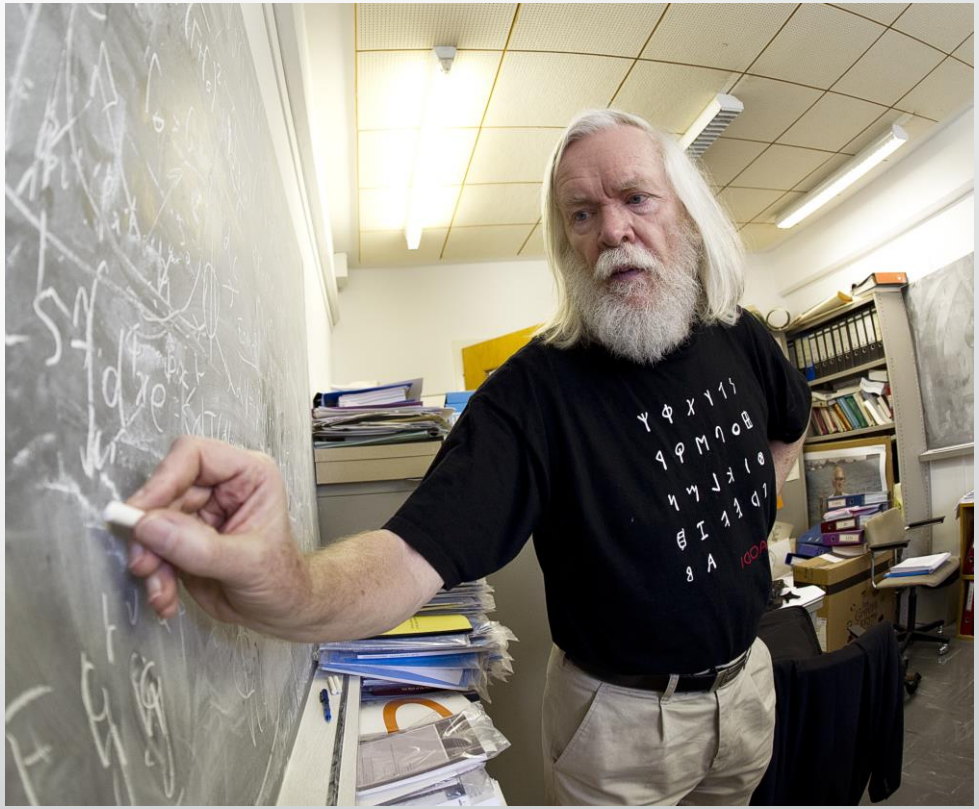
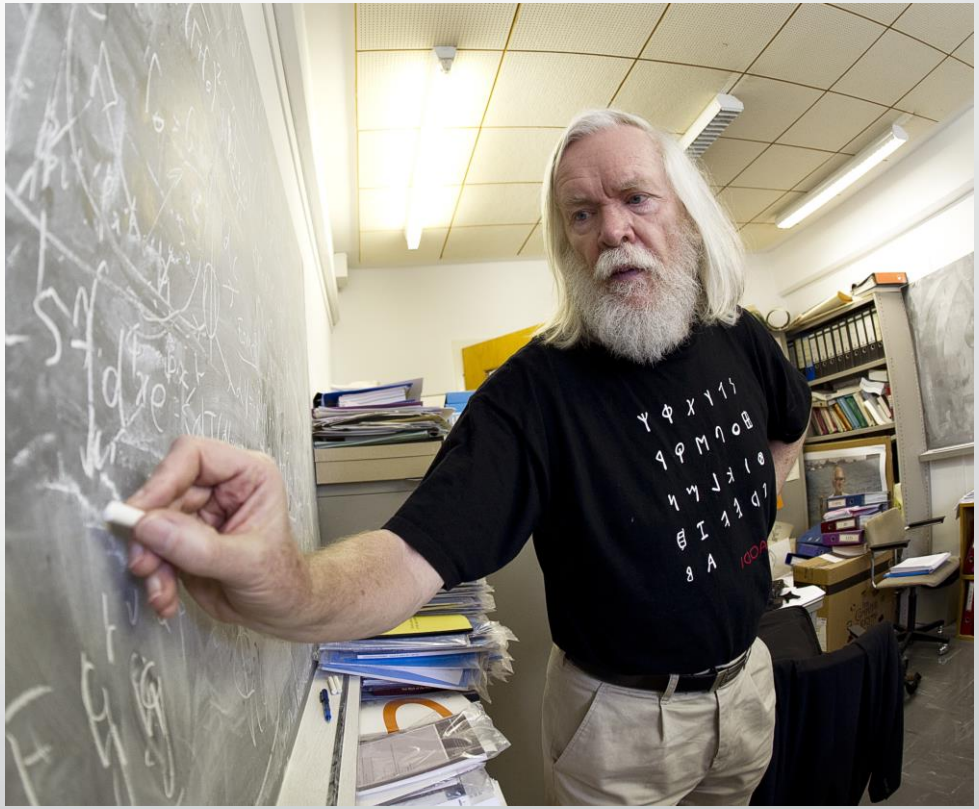




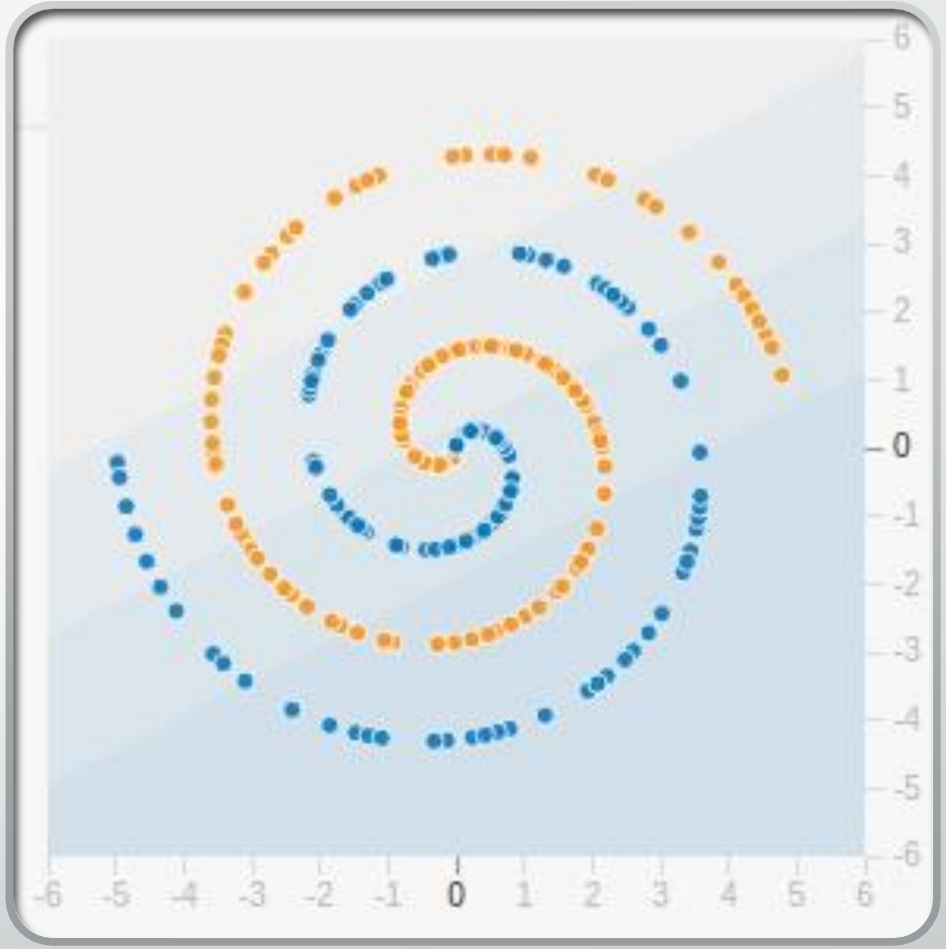
Machine Learning

What is machine learning?

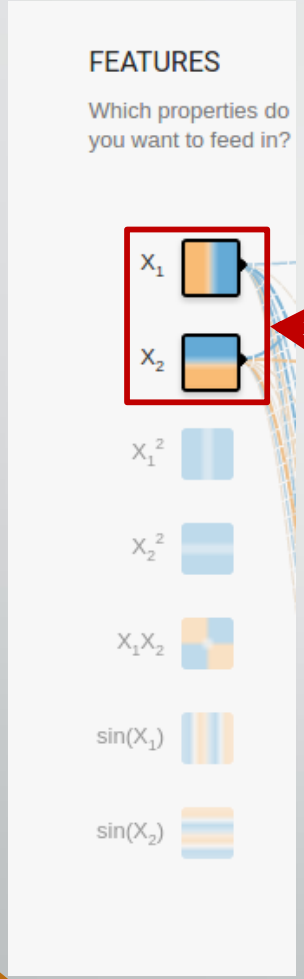
- In essence, it is the automation of model building
- By exposing a machine to a large amount of data, it can build up an understanding of the patterns within the data, and form predictive models
- Several methods exist, but let's examine artificial neural-networks

Artificial neural-networks

Say we want to predict the class (orange or blue) of points according to their position

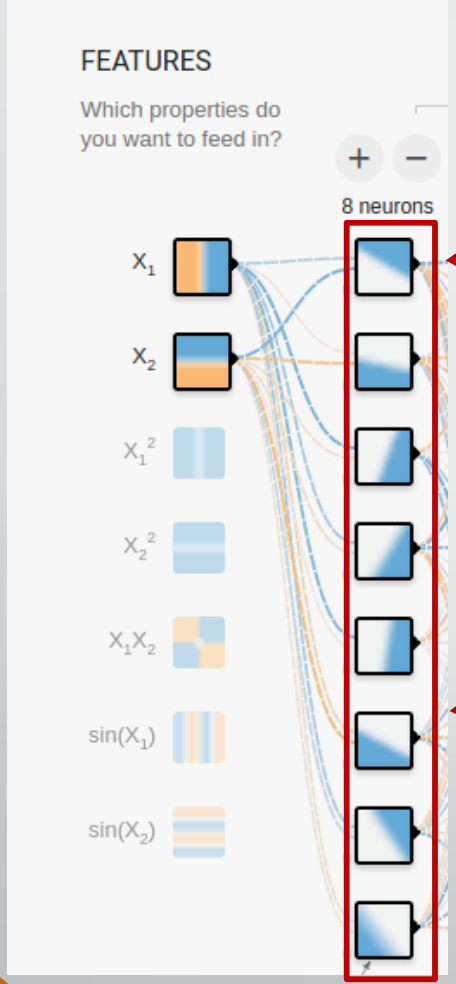


Artificial neural-networks



2 input features:
X and Y coordinates

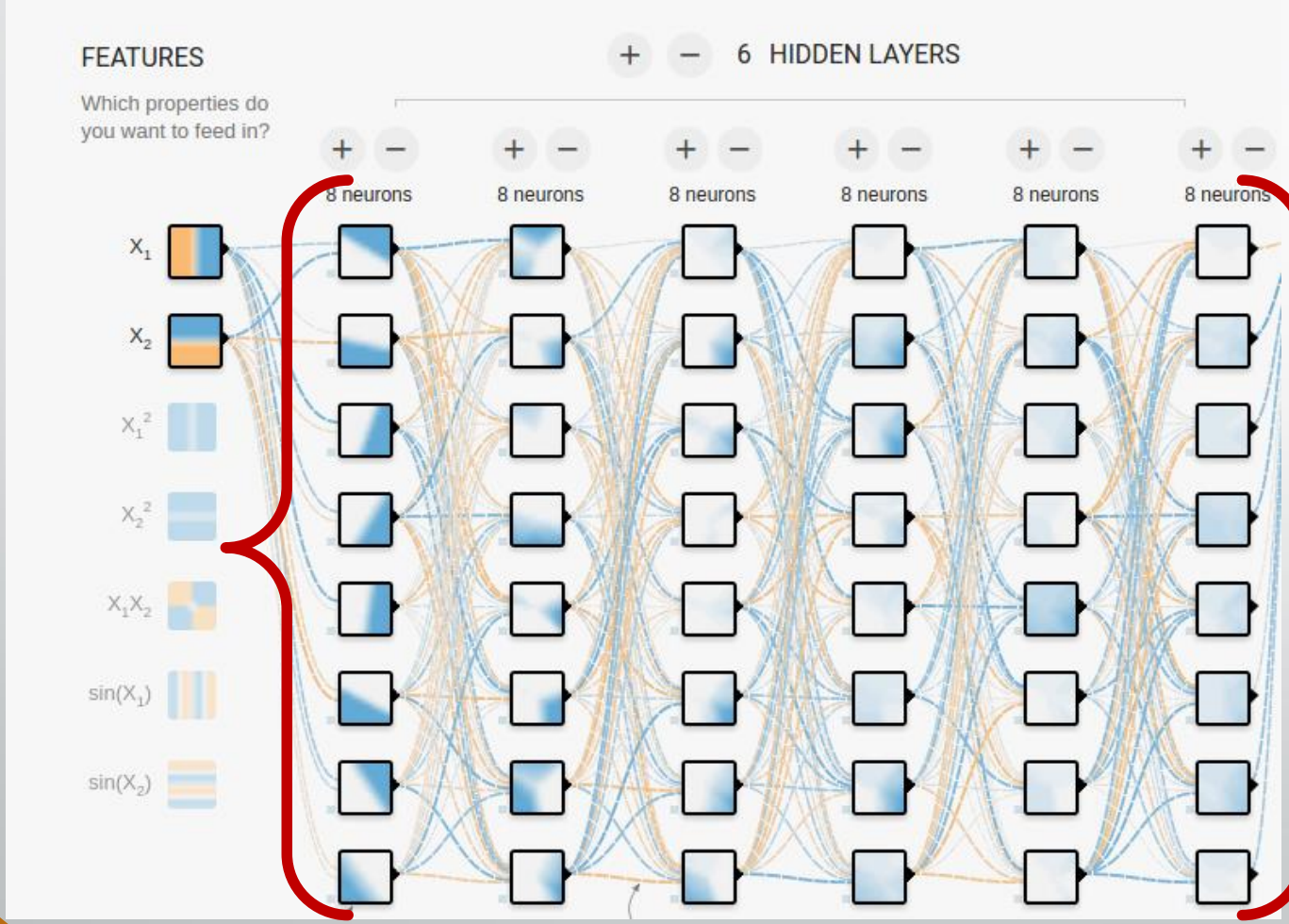
Artificial neural-networks



Neuron – applies mathematical transformation

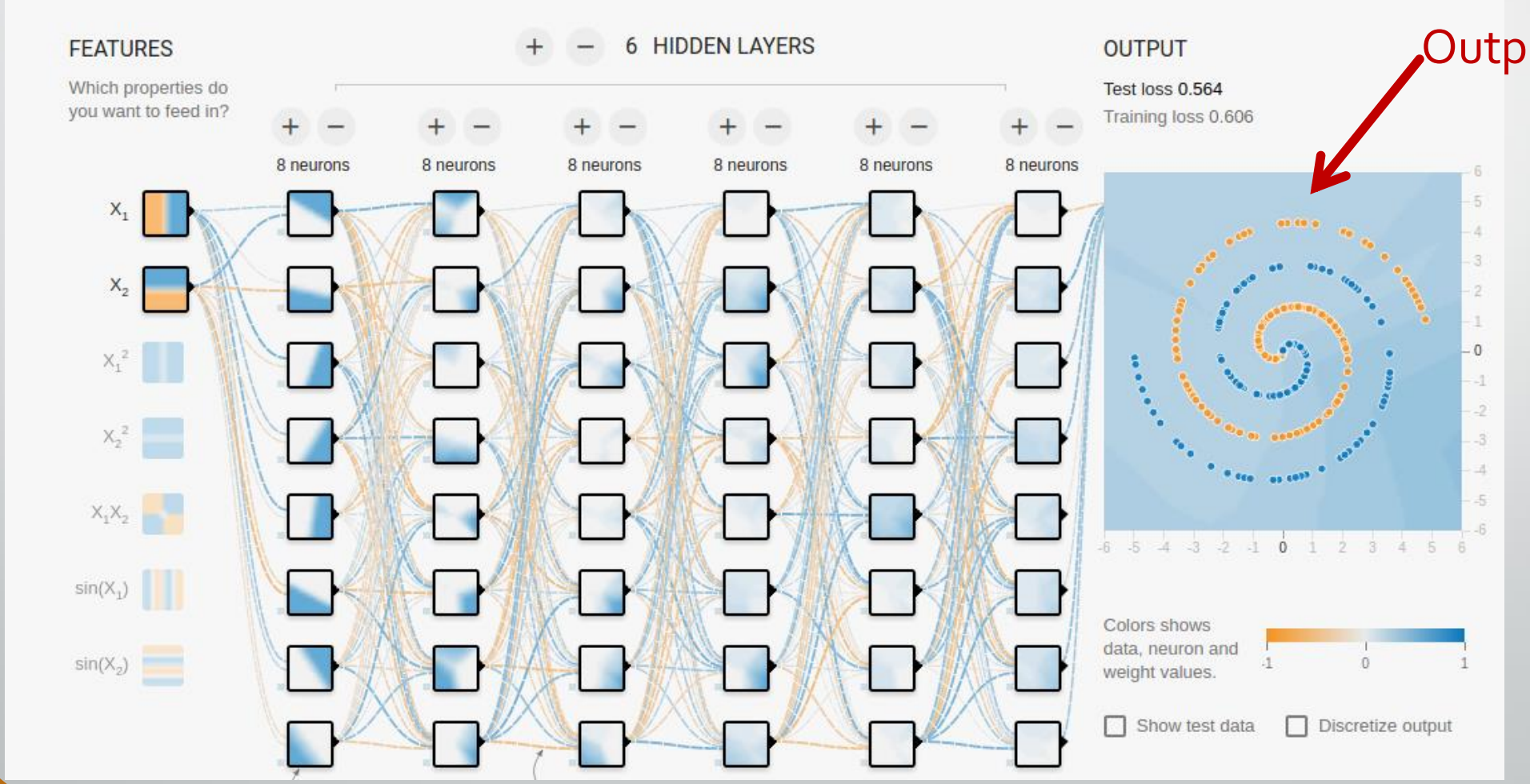
Layer of neurons

Artificial neural-networks



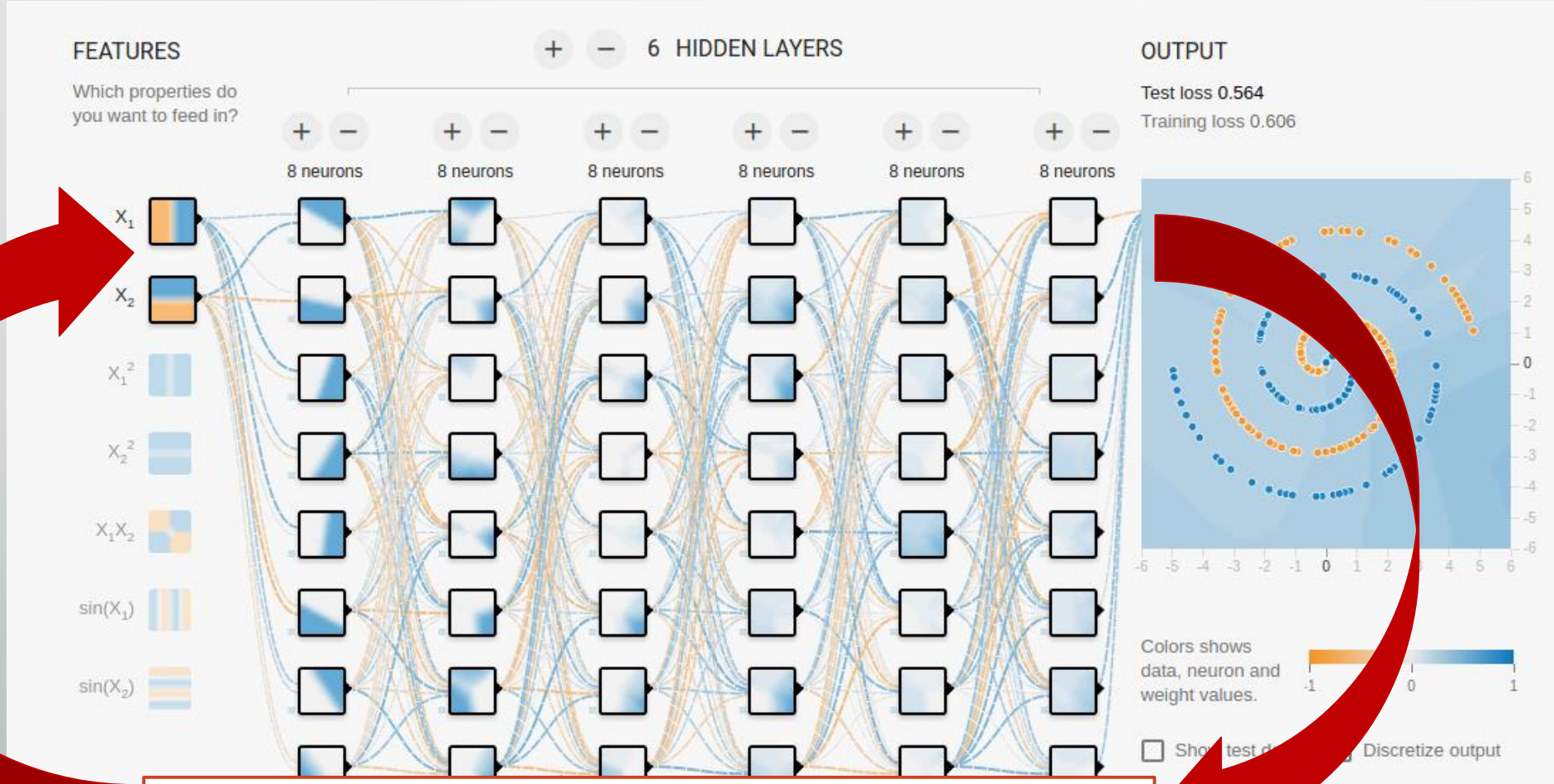
Add additional layers

Artificial neural-networks



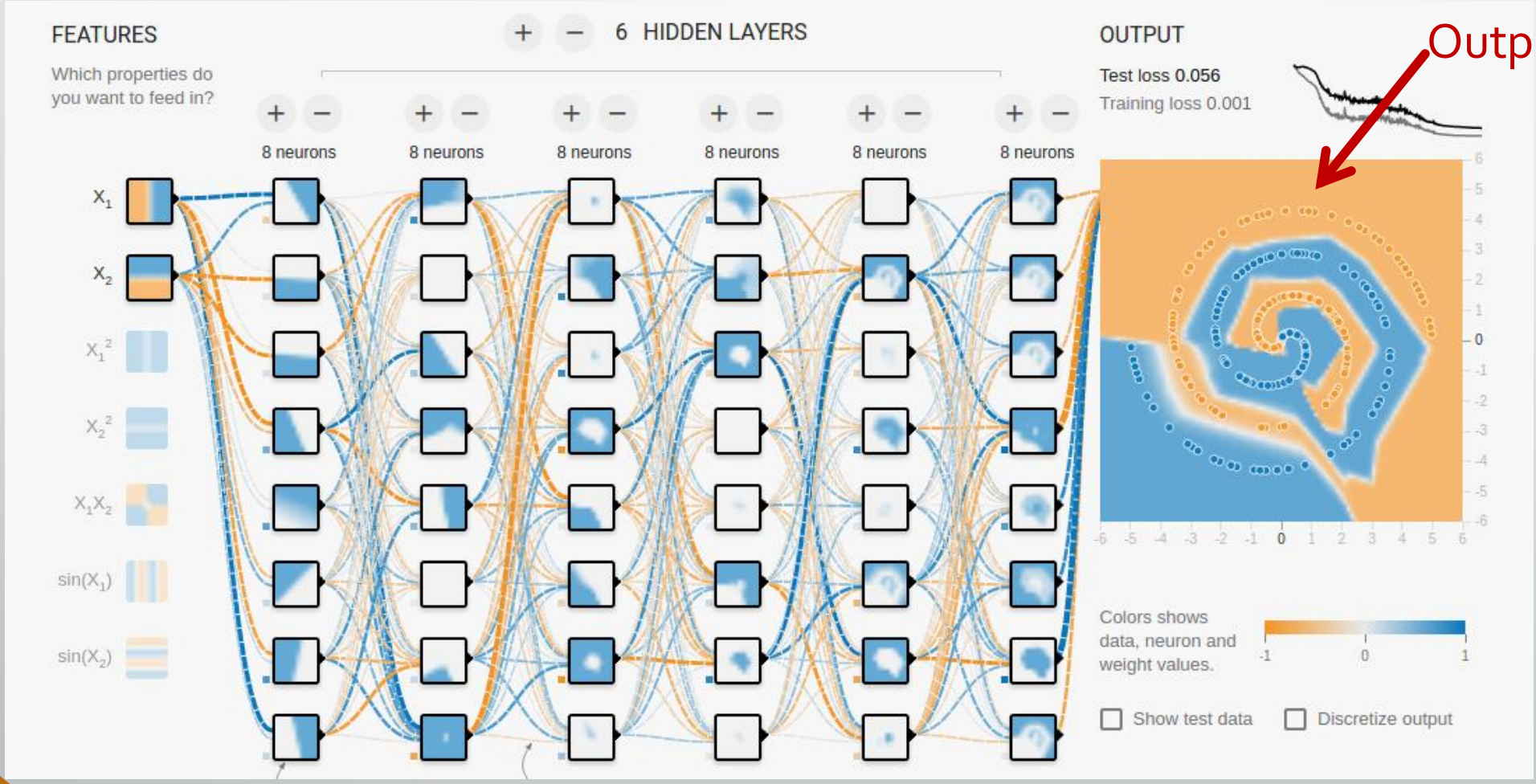
Output

Artificial neural-networks



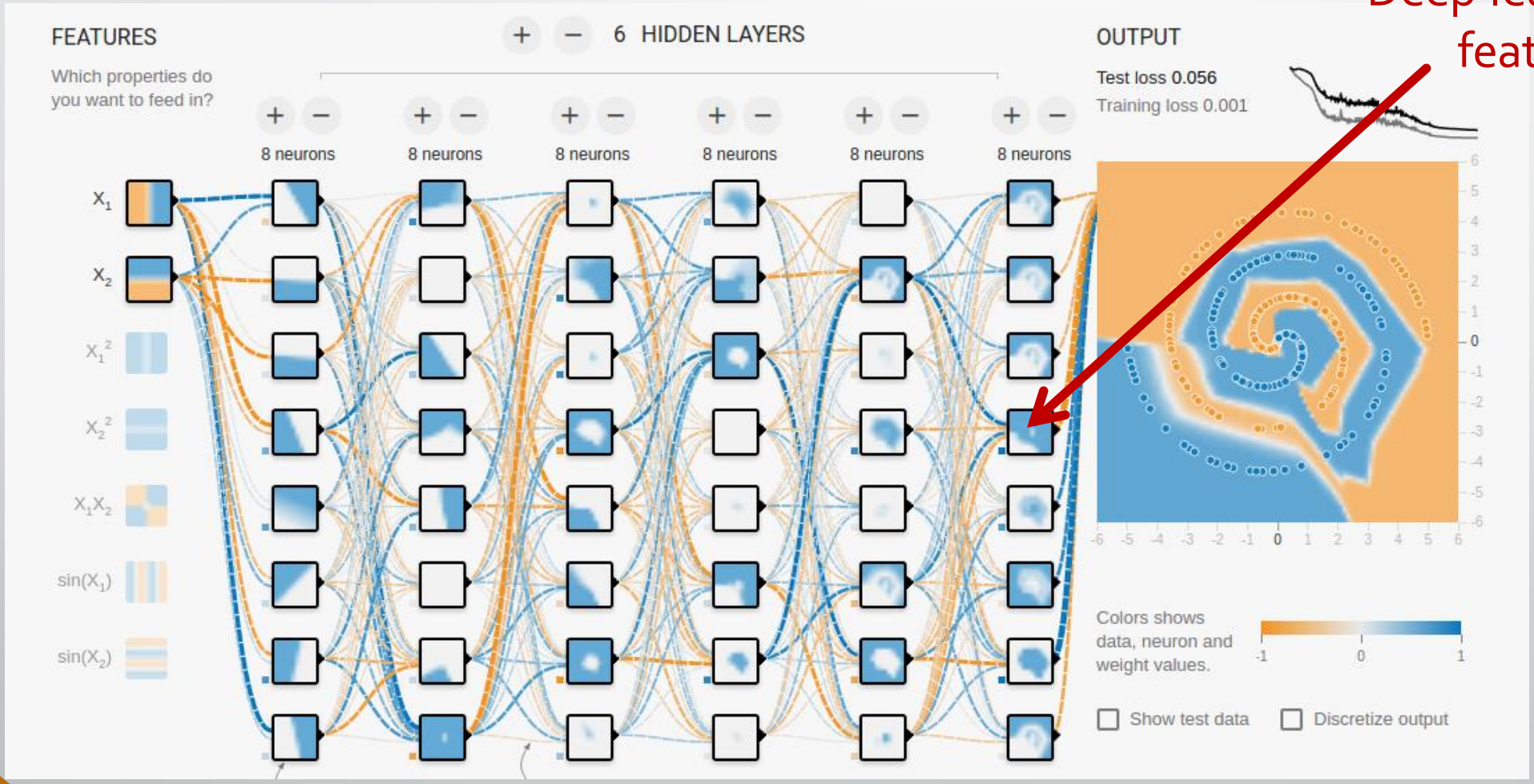
Iterative training process

Artificial neural-networks



Artificial neural-networks

Deep learning of features



Machine learning in particle physics

- We just classified points by their positions
- Imagine if instead the inputs were observables you could measure in a particle detector like CMS

Machine learning in particle physics

- We just classified points by their positions
- Imagine if instead the inputs were observables you could measure in a particle detector like CMS
- Now you could classify collisions according to the particle process which occurred
- Neural-networks can also be used for regression; estimating numbers like particle masses from data

Machine Learning in particle physics

Jet tagging

Regression

Event triggering

Many applications exist

Classification

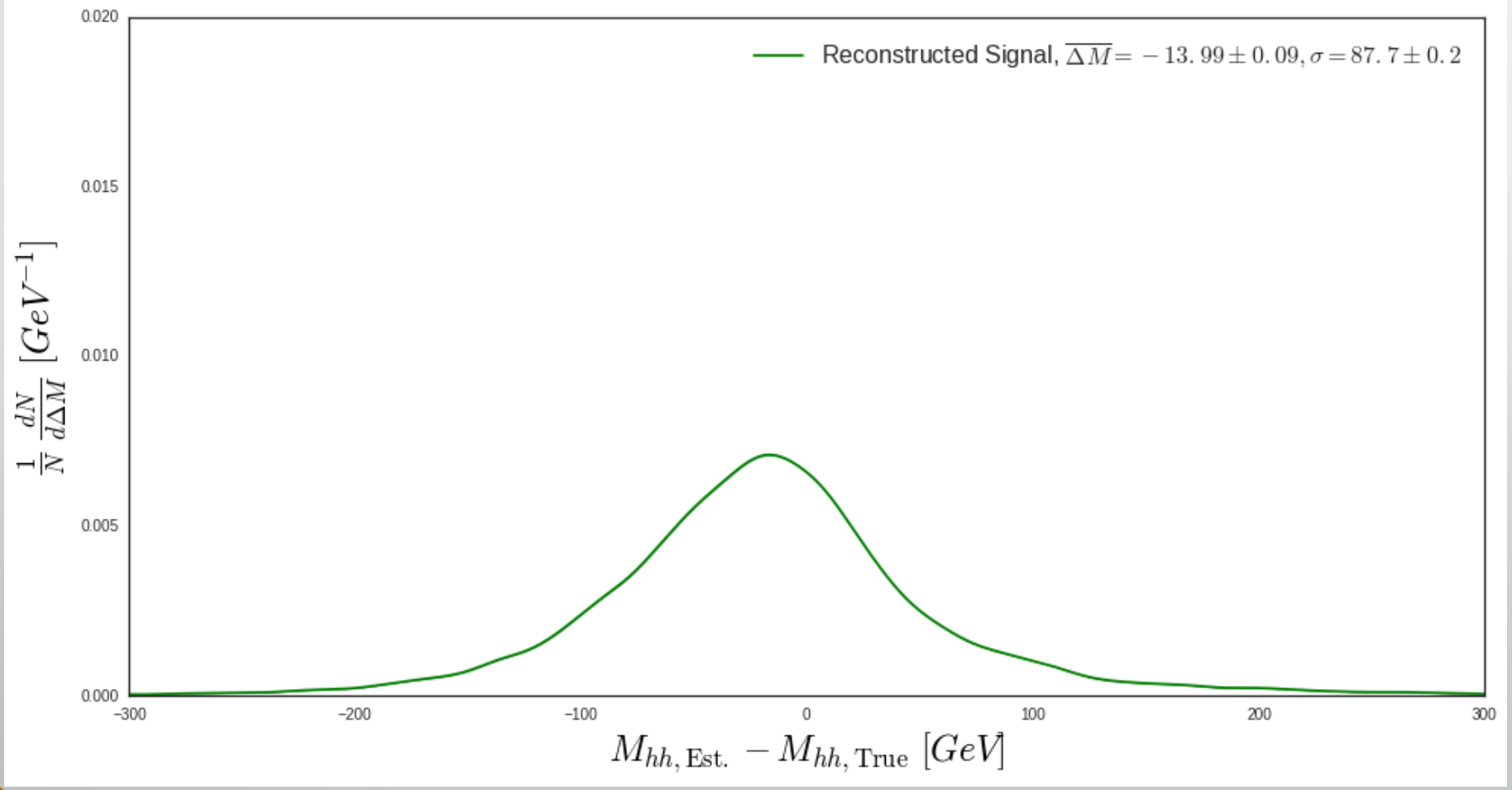
Simulation

Model evaluation

ML in di-Higgs physics - an example

- Reconstructing the di-Higgs mass can be imprecise due to missing energy (neutrinos)
- By training a machine to understand the relationships between observable features and the true values of variables, the precision can be improved

Di-Higgs mass: reconstruction estimate



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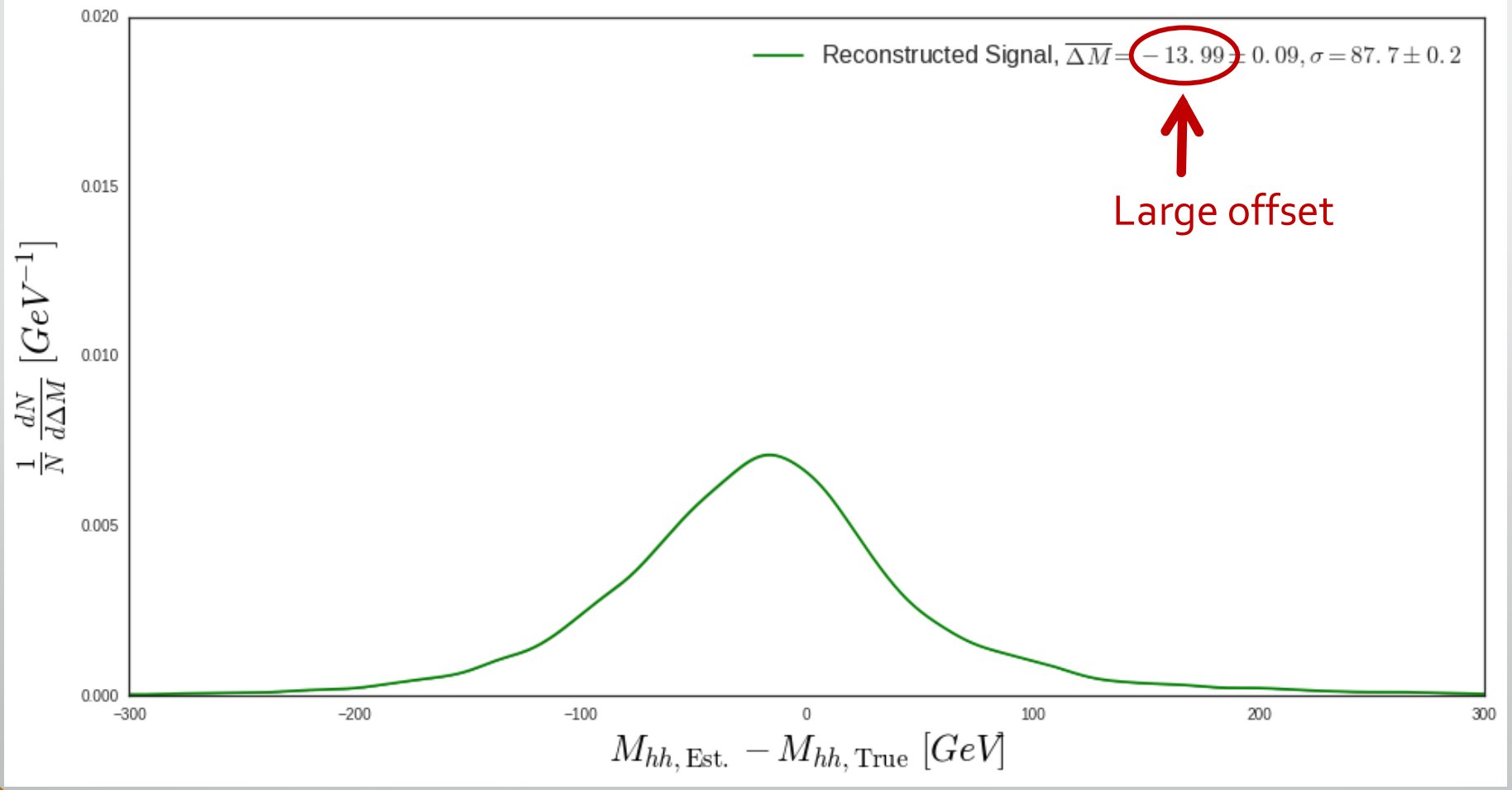

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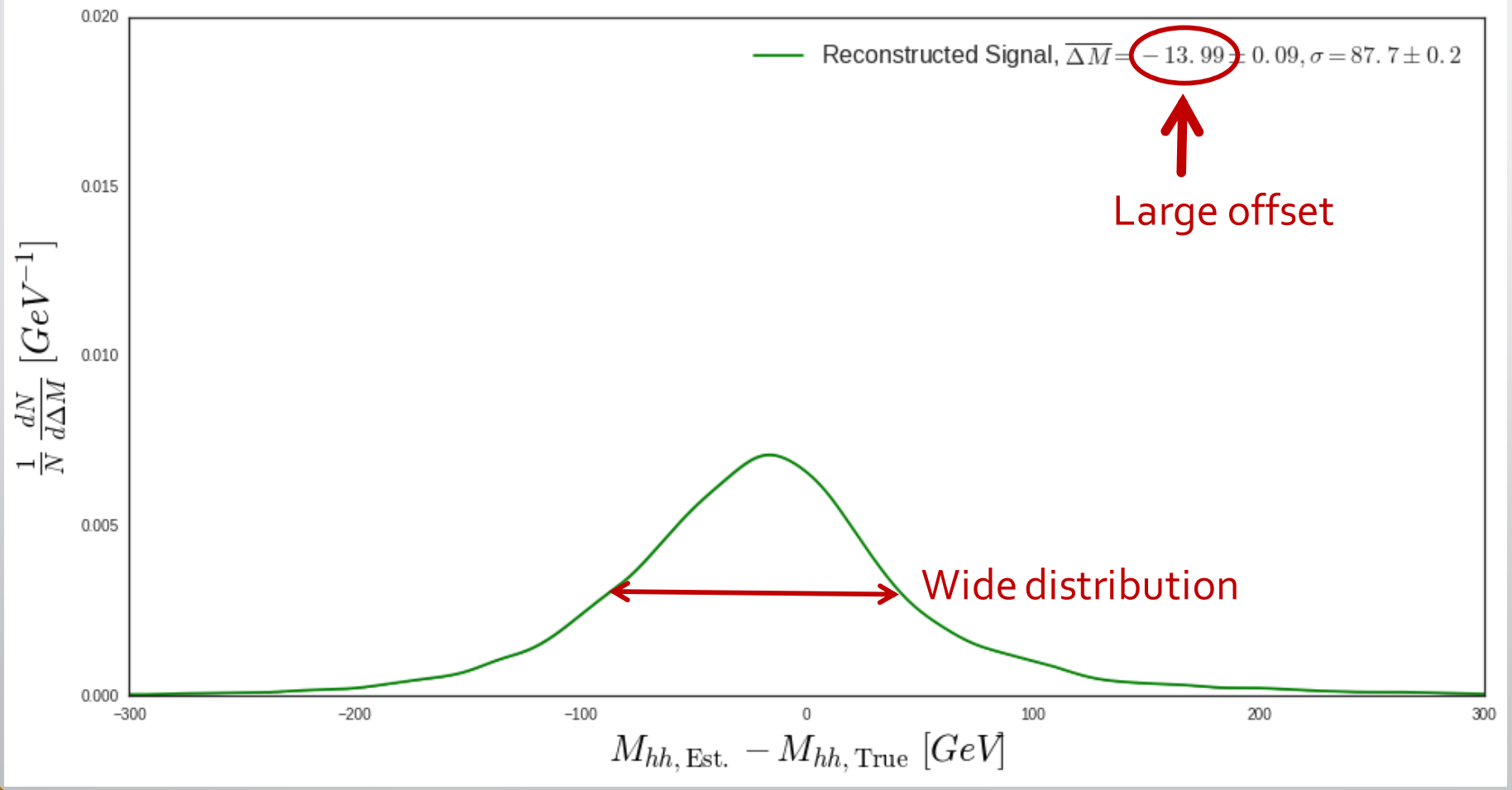

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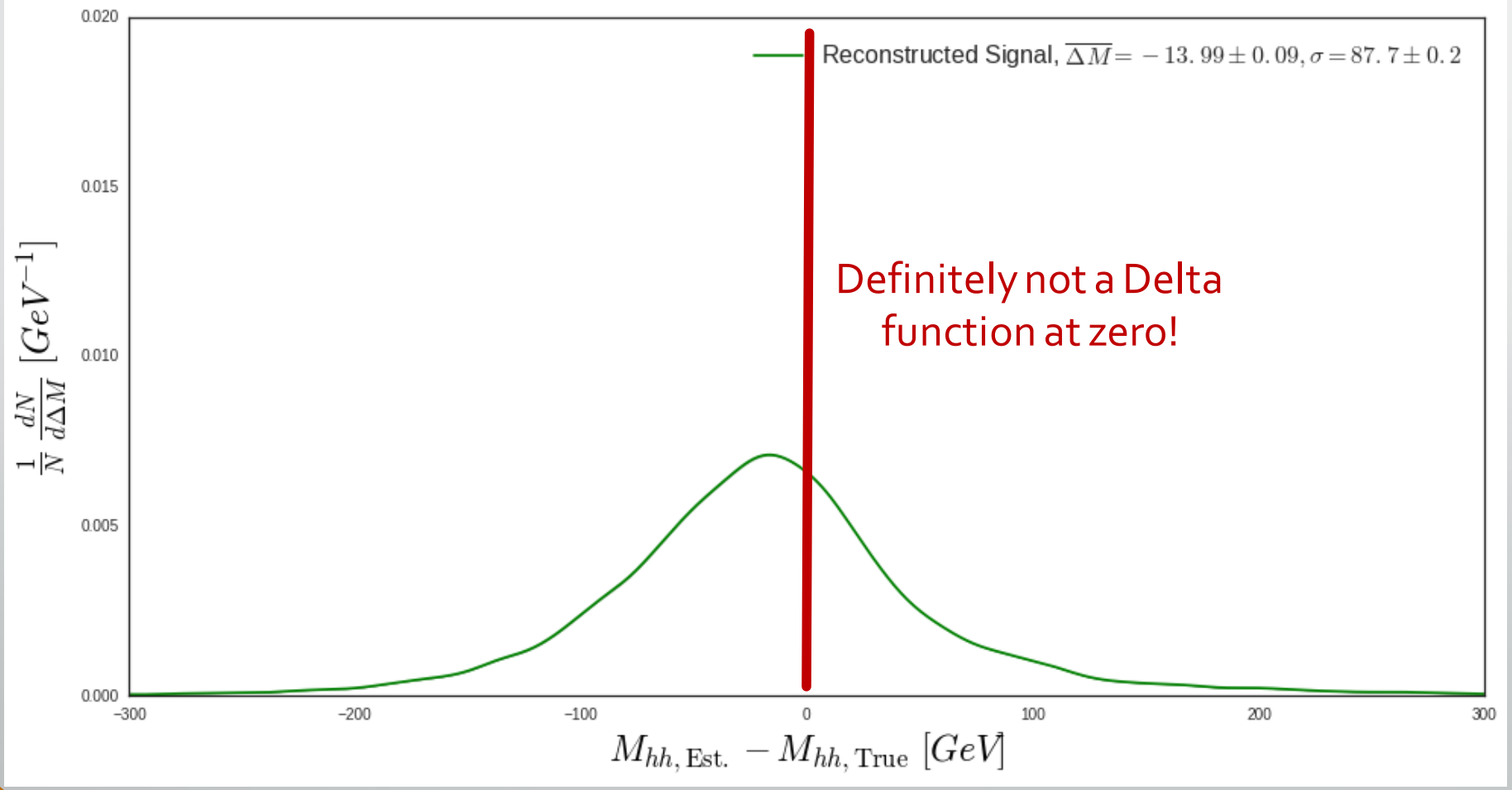
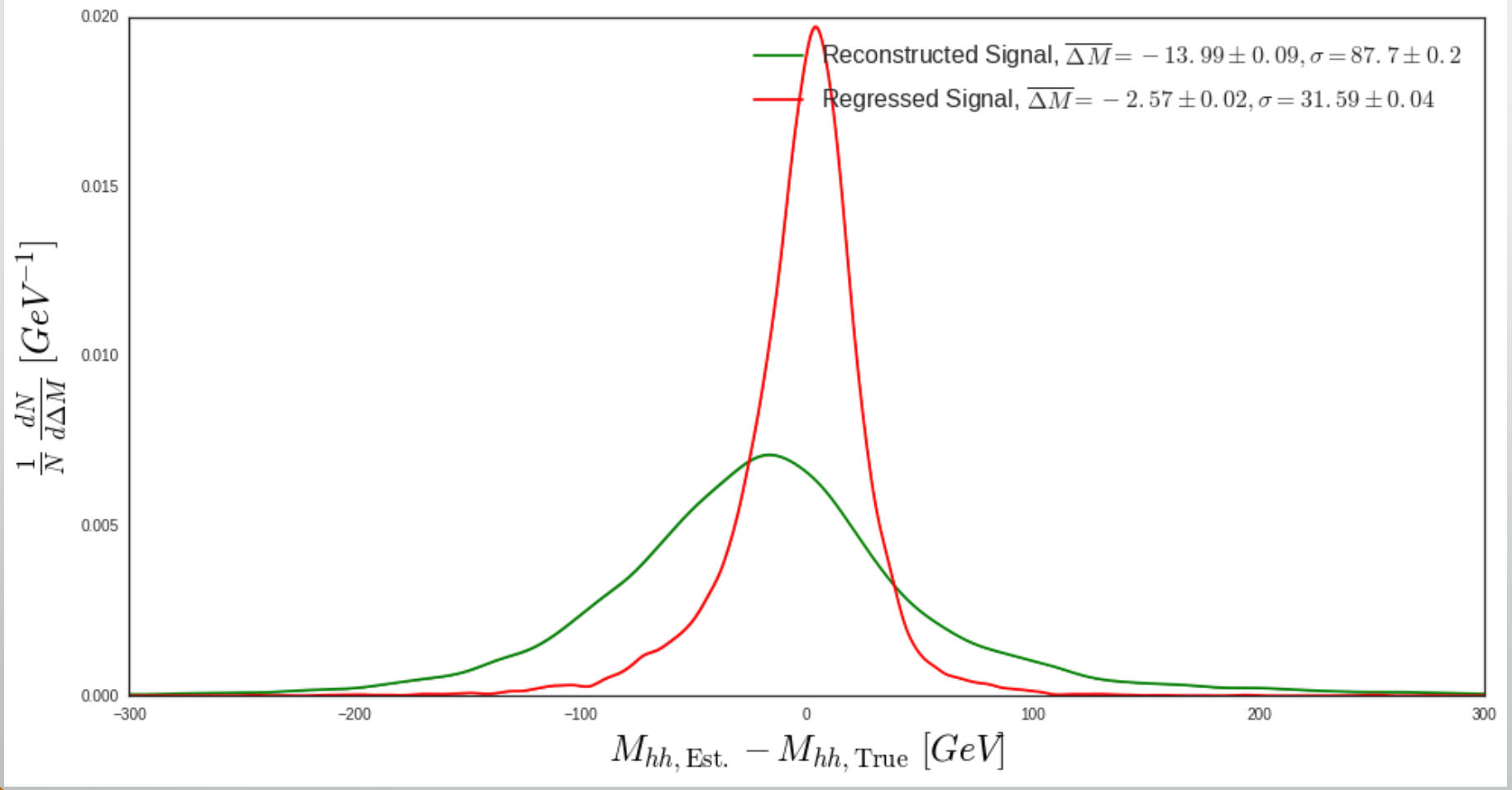


Di-Higgs mass: regressed estimate



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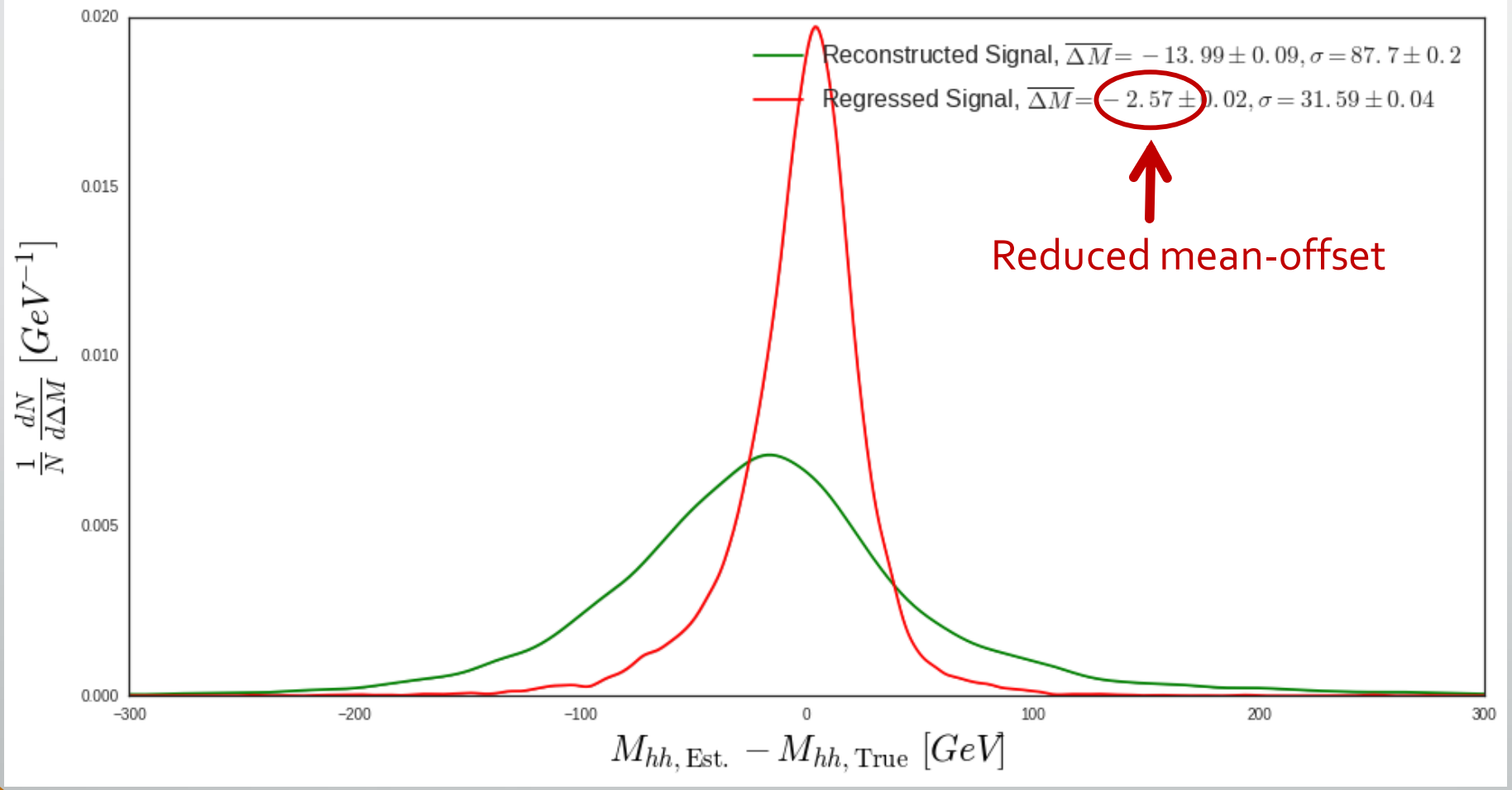

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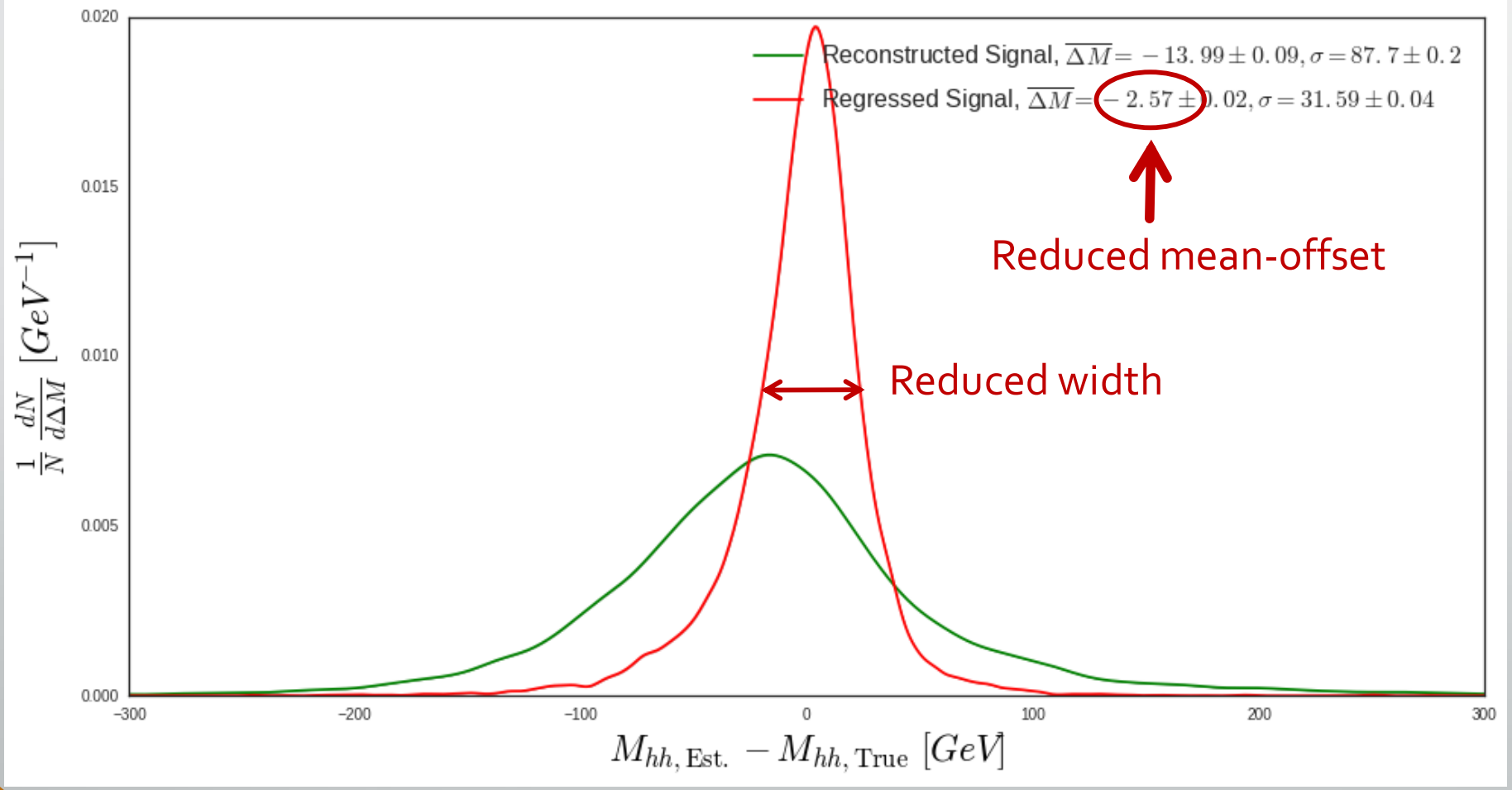

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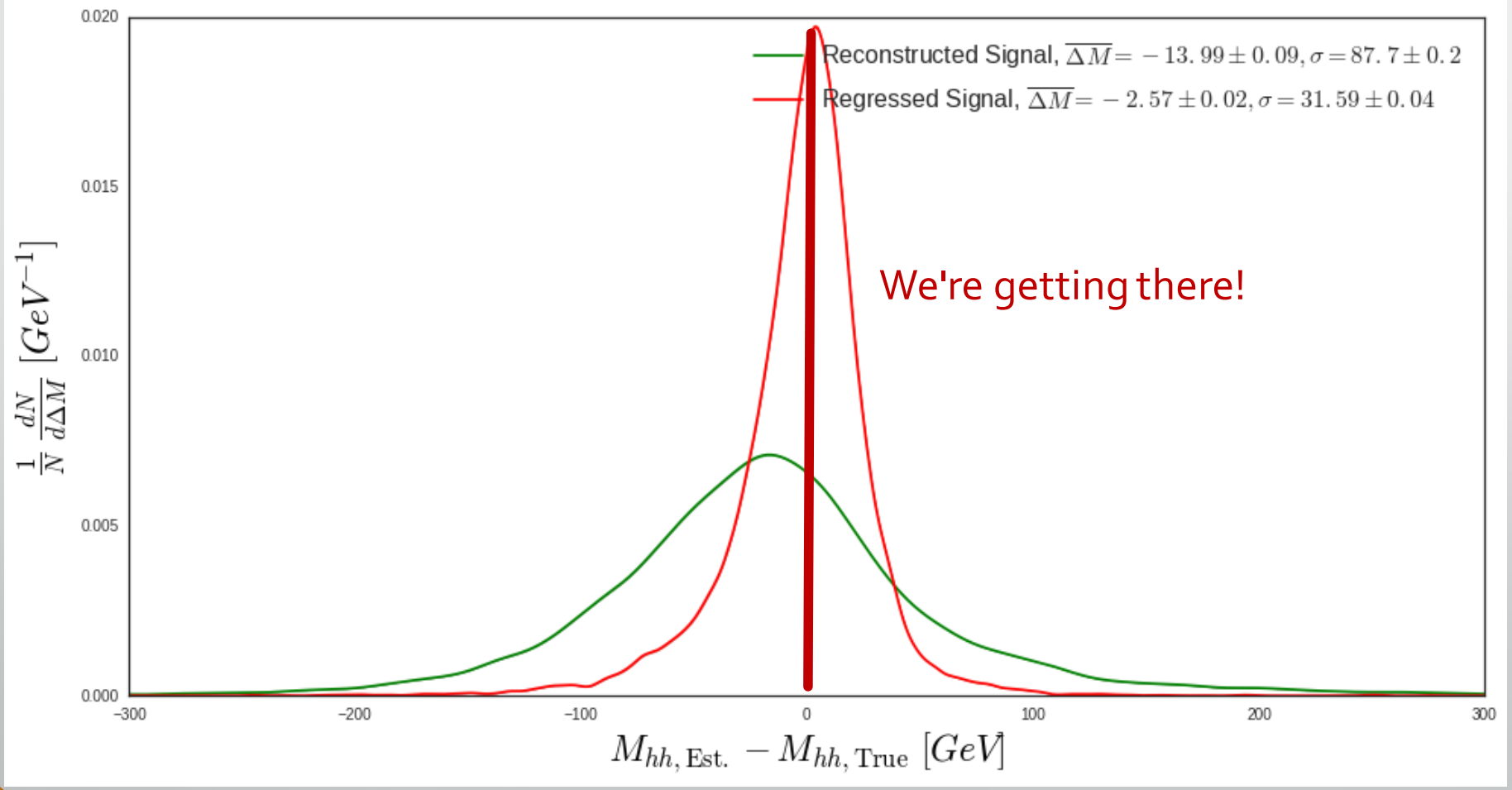

Opportunities for you at LIP

- Master's theses
- Summer internships
- Lecture series

Conclusion

- Several opportunities for you to get involved!
- ML is increasingly becoming the standard approach in particle physics
- It is also heavily used in industry and other areas of research
- Under heavy research itself

Further reading – Searches terms

- Browser-based ML playgrounds:
  - Tensorflow playground
  - Gradient boosting playground
- Introductory course on ML: mlhep2016 github
- Network focussing on ML in physics: amva4np

Further reading - Links

- Browser-based ML playgrounds:
  - http://playground.tensorflow.org/
  - https://arogozhnikov.github.io/2016/07/05/gradient_boosting_playground.html
- Introductory course on ML: https://github.com/yandexdataschool/mlhep2016
- Parameterised classifiers: https://arxiv.org/abs/1601.07913 https://arxiv.org/abs/1506.02169
- Example investigation: https://cds.cern.ch/record/2204934/files/HIG-16-028-pas.pdf
- Network focussing on ML in physics: https://amva4newphysics.wordpress.com/