Dealing with negative weights in neural networks

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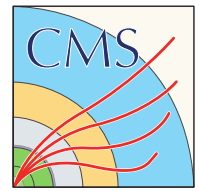
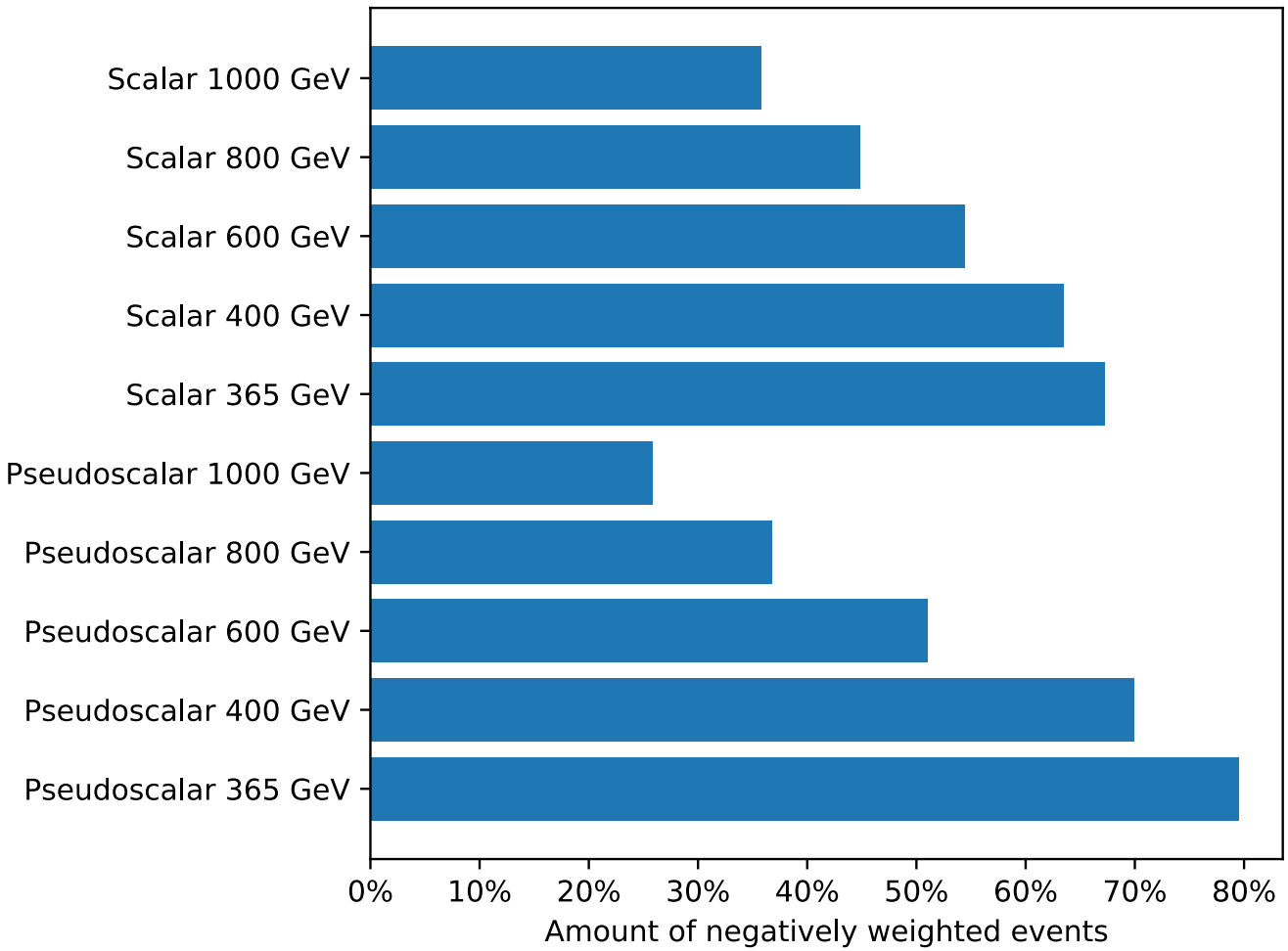
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES



Negative weights in heavy Higgs

Many events with negative generator weights in heavy Higgs datasets. Shown here is interference only of 2018 datasets.



In neural networks

One problem out of several

Training a neural network f with loss function F and weight w means minimizing the function

$$\sum_i w_i \cdot L\left(y_i, f(x_i)\right)$$

Splitting up: let N and P be so that $w_i < 0 \; \forall i \in N$ and $w_i \geq 0 \; \forall i \in P$

$$\sum_{i \in P} w_i \cdot L\left(y_i, f(x_i)\right) - \underbrace{\sum_{i \in N} |w_i| \cdot L\left(y_i, f(x_i)\right)}_{r}$$

The function can become arbitrarily small by increasing the loss in r. The neural network can do that if x (the input) allows differentiating between N and P.

How particle physicists work around it

In case one has only few negative weights, during training one might

- Ignore weights
- Take the absolute
- Throw out negative events

My solution: Transform weights

Find positive weights without changing the distributions. Done by another neural network.
Example:

	$i = 0$	$i = 1$	$i = 2$	$i = 3$	$i = 4$
x_i	15	23	15	15	90
w_i	1	1	1	-1	1
transformed w_i	$1/3$	1	$1/3$	$1/3$	1

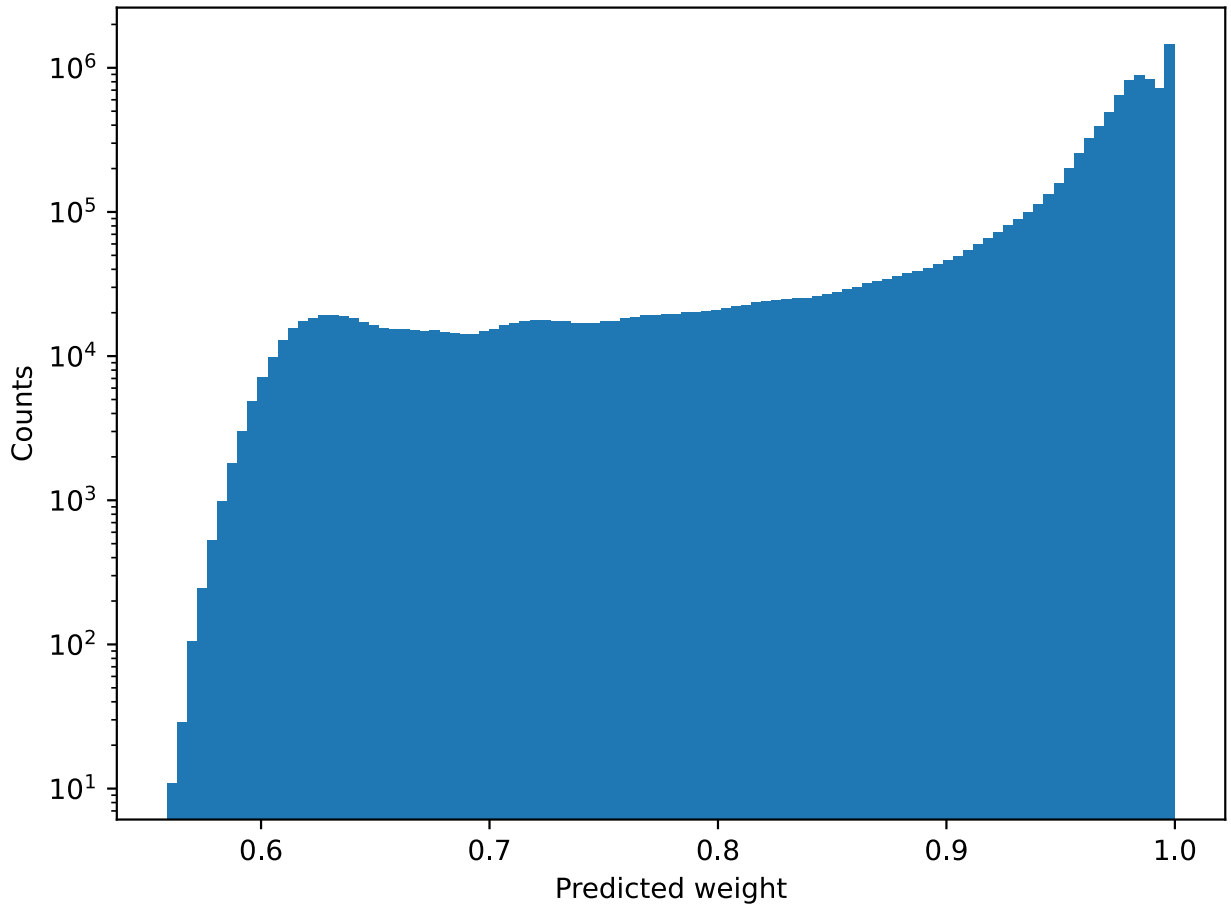
Histogram of x stays unchanged when switching between w_i and transformed w_i.

Neural network architecture

- Dense network
- ReLU activation, sigmoid as final activation
- 5 layers, $O(100)$ nodes each
- Binary cross entropy loss
- Inputs: generator top momenta, m_{tt}, c_{hel} (from last copy)

Neural network output

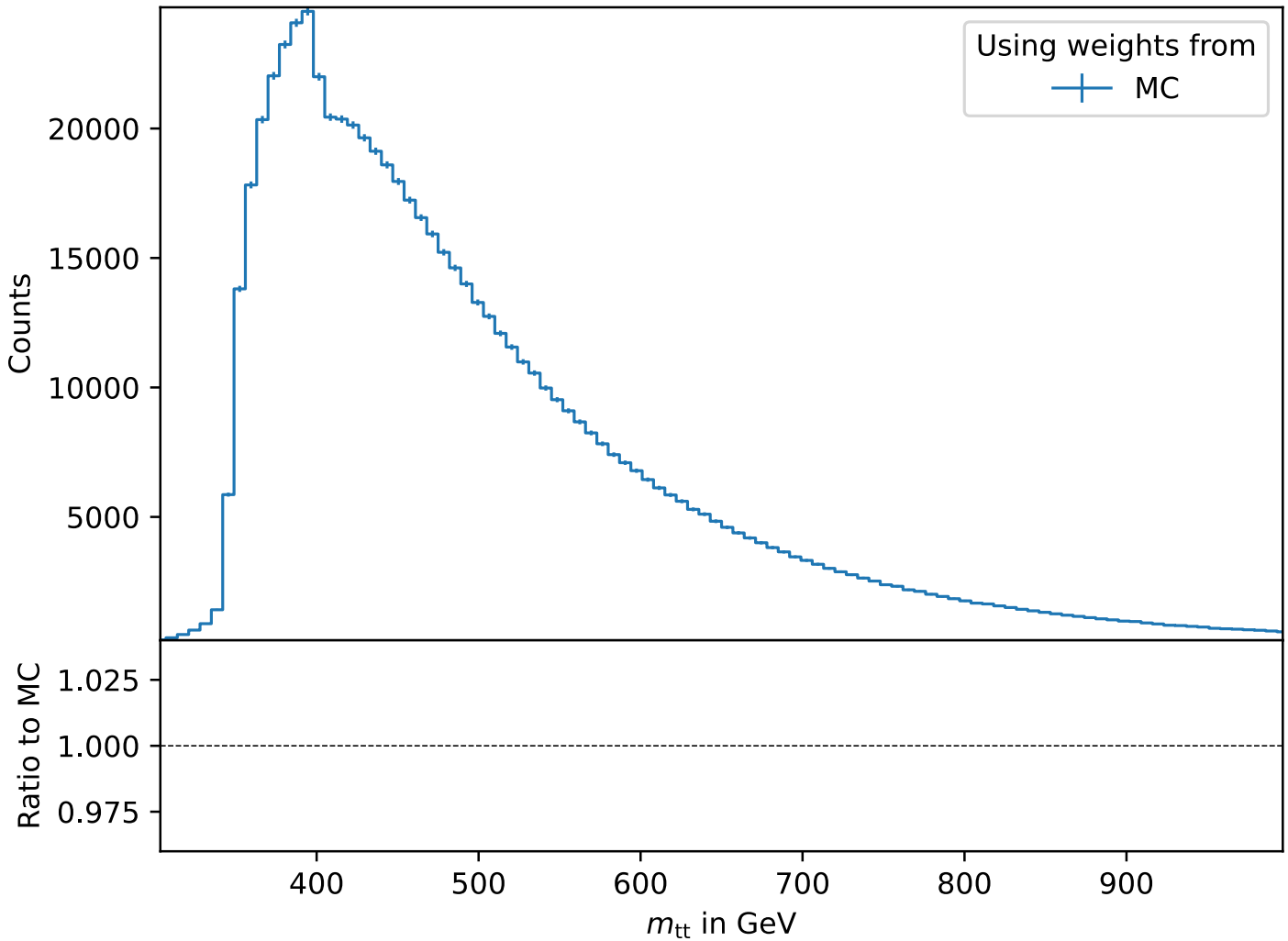
Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \to ll\nu\nu$



None of the output weights are negative anymore!

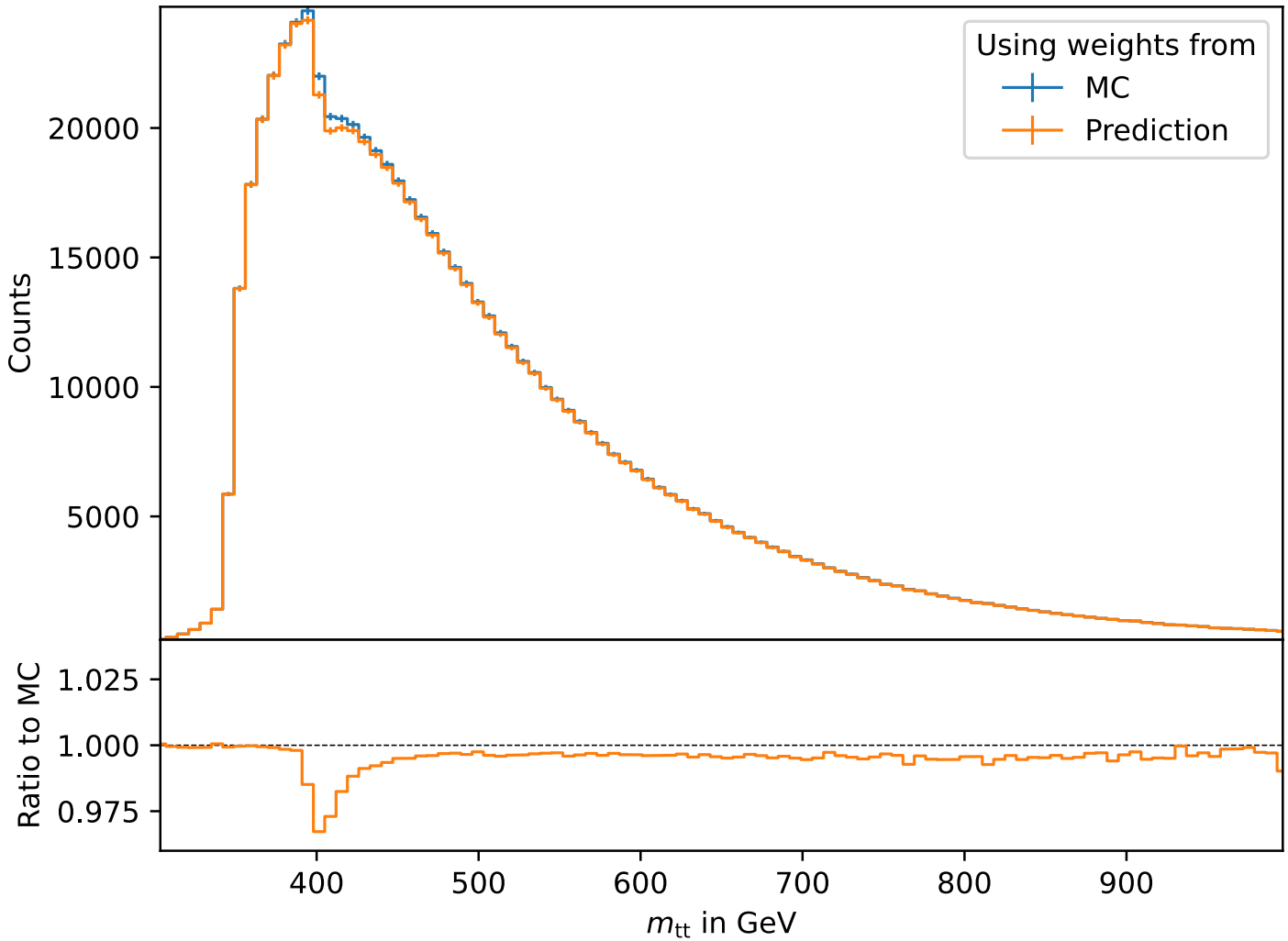
Looking at MC

Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \rightarrow ll\nu\nu$



Results from the neural network

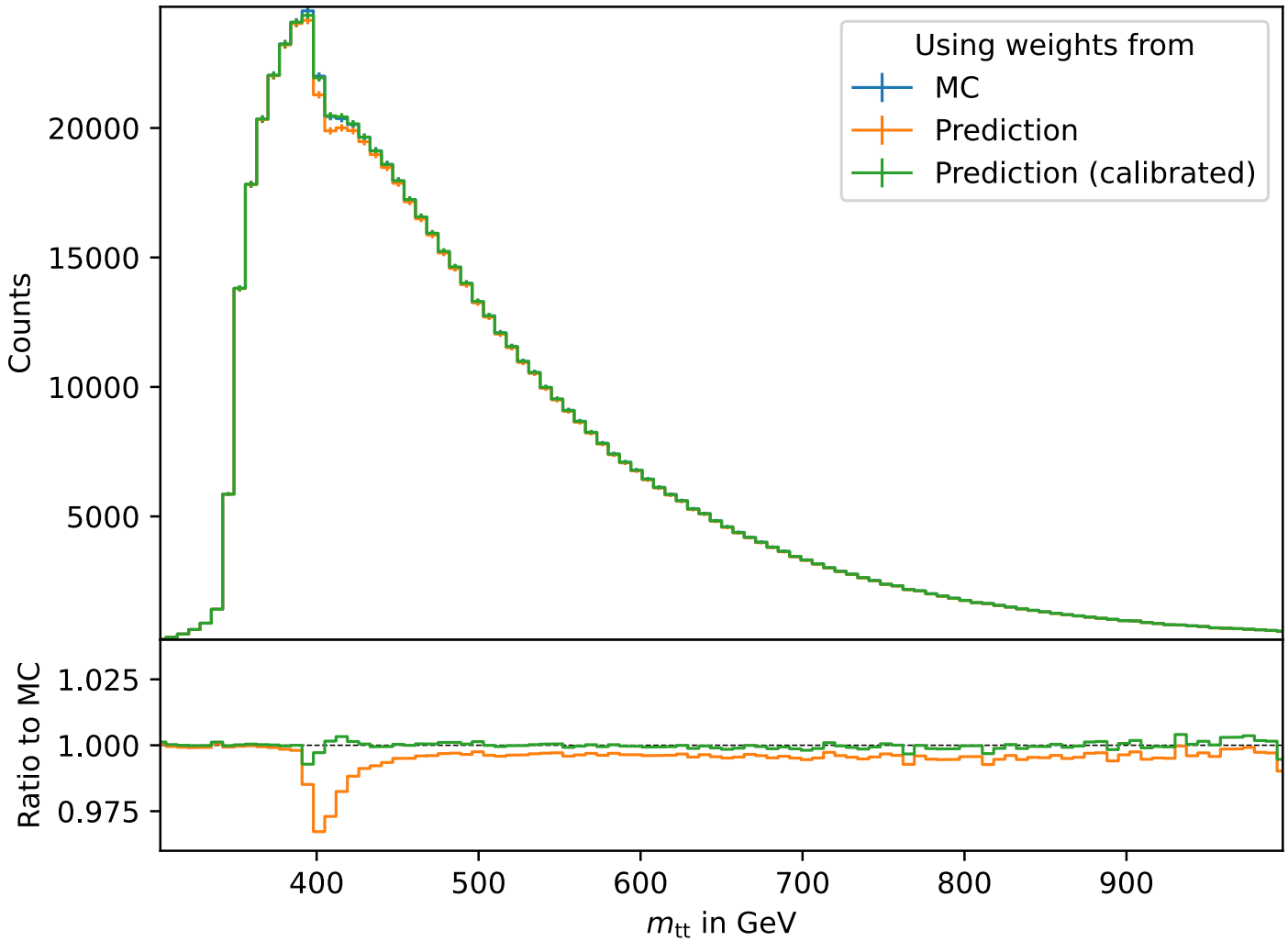
Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \to ll\nu\nu$



Small offset by a constant factor and bump at Higgs mass.

Results from the neural network

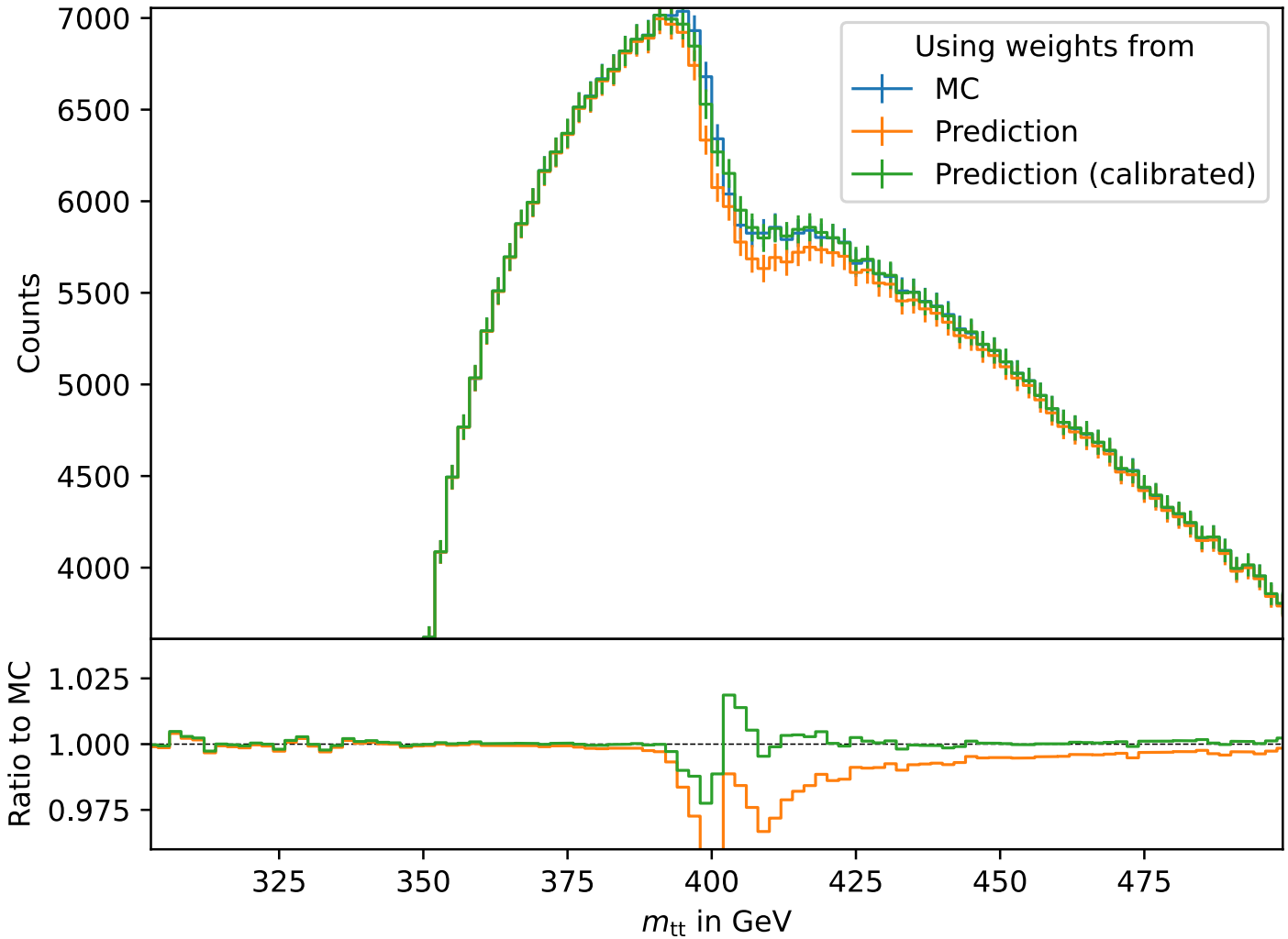
Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \rightarrow ll\nu\nu$



Calibration with isotonic regression improves the results a lot.

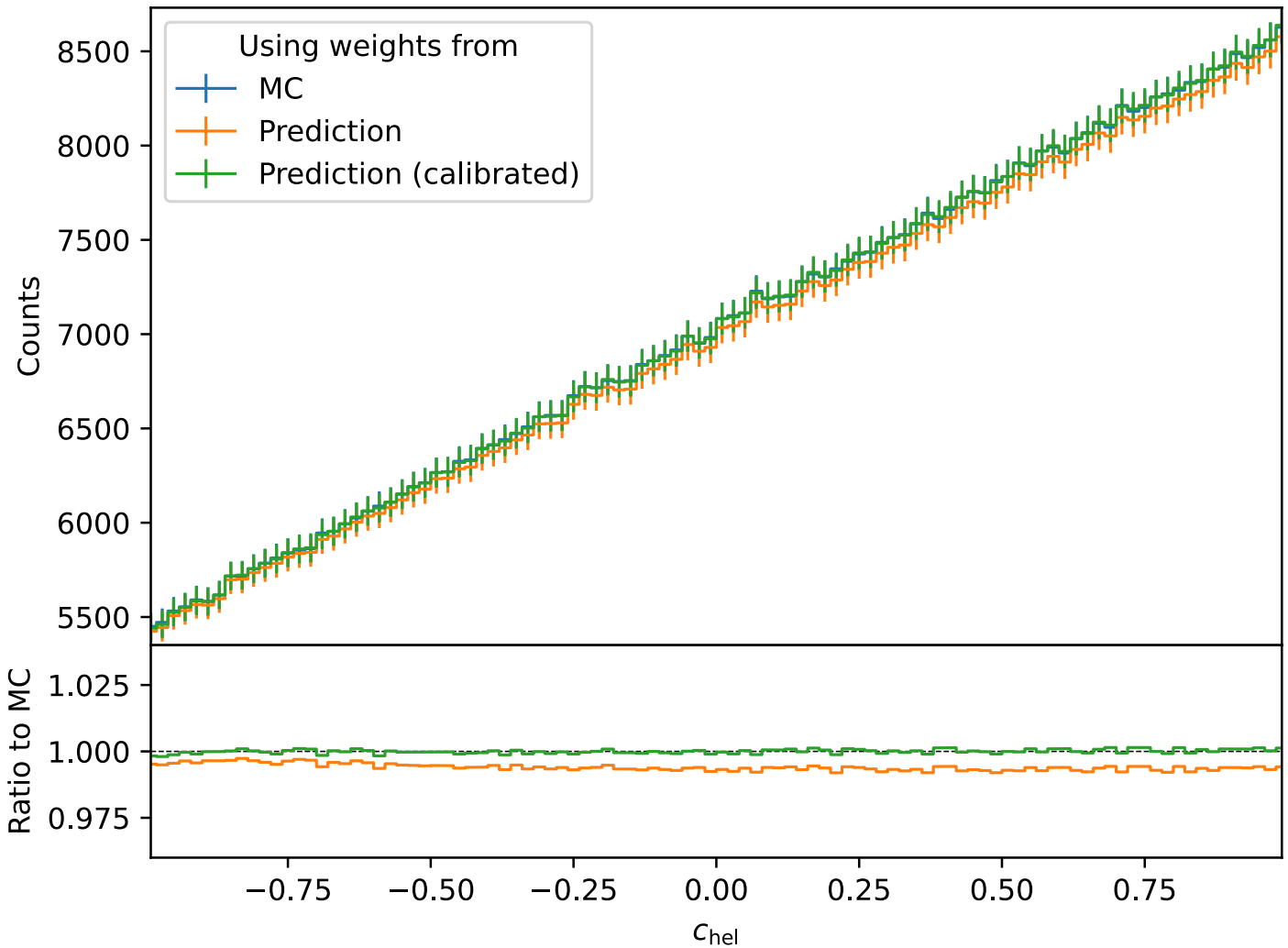
Results from the neural network

Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \to ll\nu\nu$



Results from the neural network

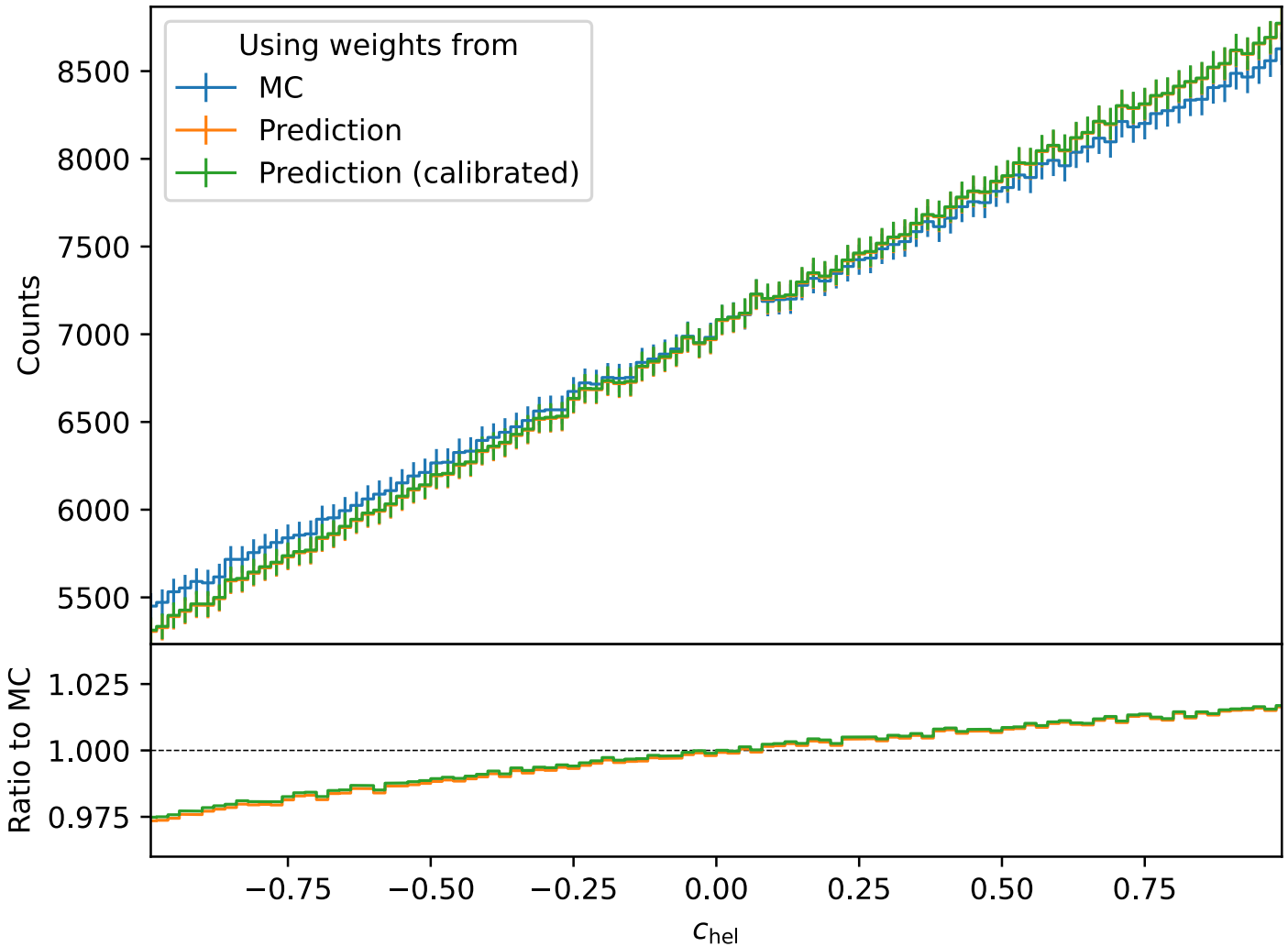
Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \to ll\nu\nu$



Similar results as m_{tt}.

Results from the neural network

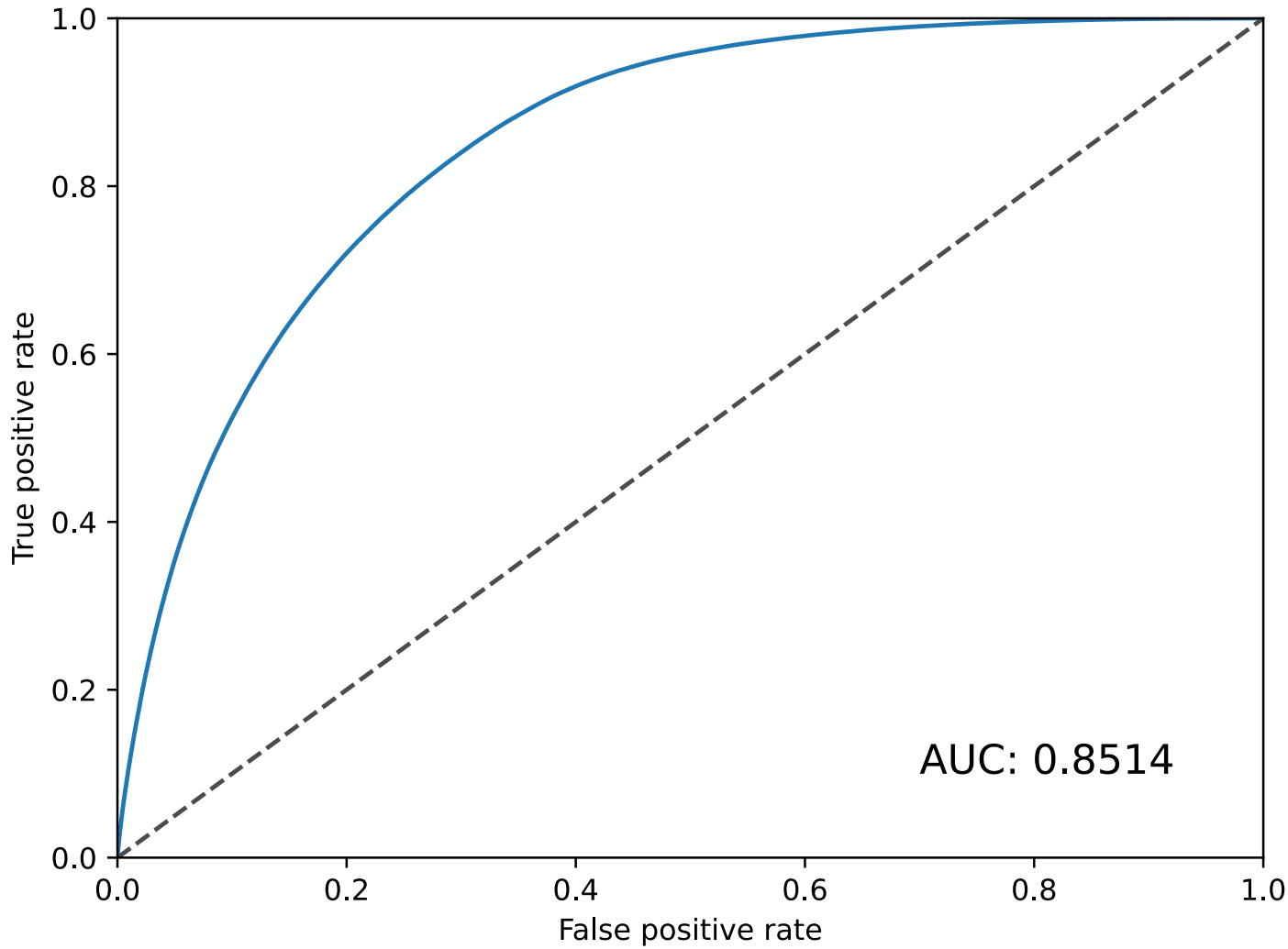
Pseudoscalar, 400 GeV, 3 % width, with SM $t\bar{t} \to ll\nu\nu$, c_{hel} is not an input



Disagreement in this distribution: A change in slope

Results from an actual classifier

Classifying between SM $t\bar{t} \rightarrow ll\nu\nu$ and heavy Higgs using transformed weights



Well working classifier possible now!

Next up

- Which inputs to use?
- Train final neural network simultaneously with weight-transforming network?

Thank you