technische universität dortmund

IceCube SOUTH POLE NEUTRINO OBSERVATORY

SFB 876 Providing Information by Resource-Constrained Data Analysis

lehrstuhl physik e5

Exploring Antarctic Ice Properties Using Generative Neural Networks

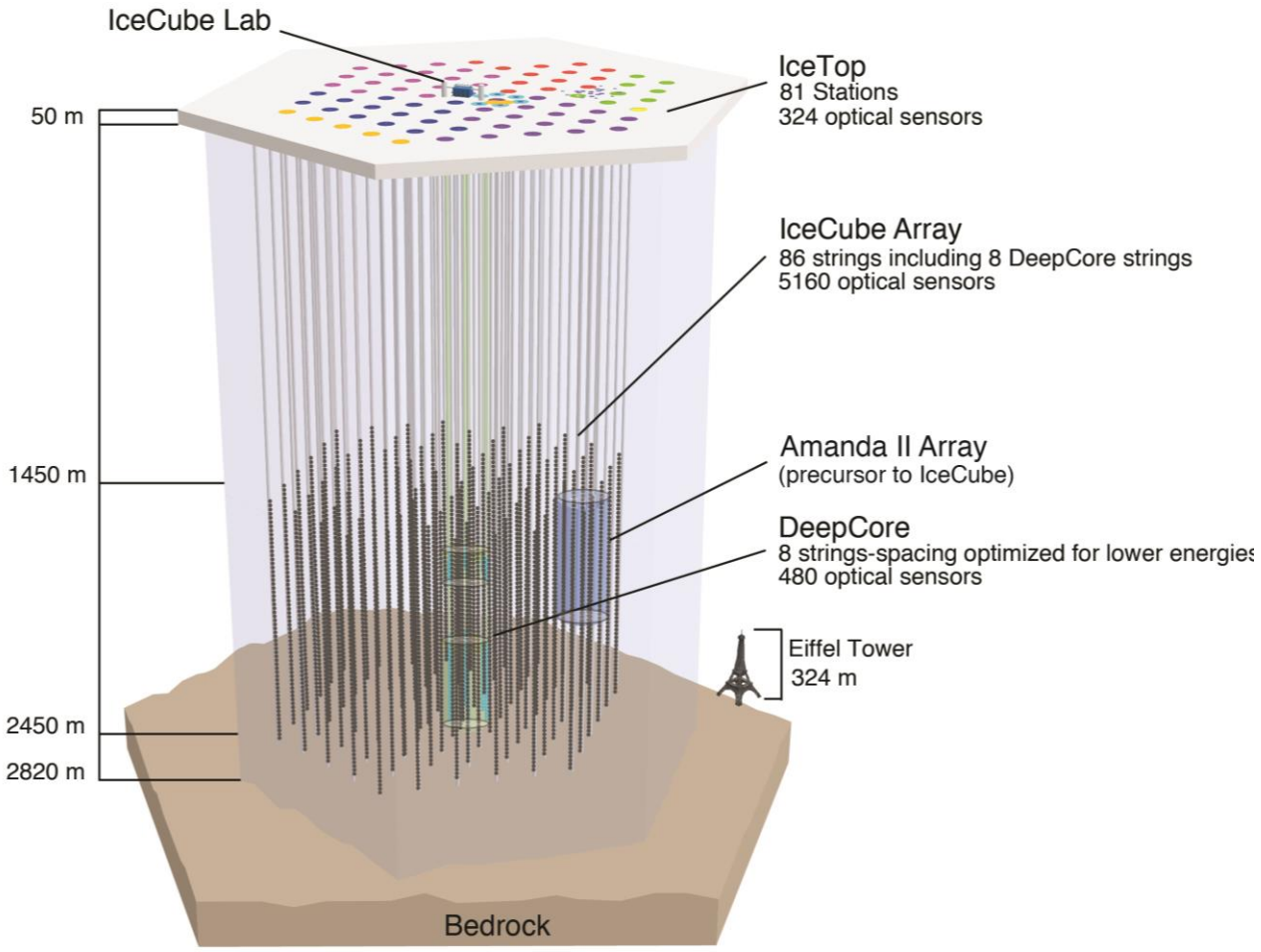
Sebastian Bange, Mirco Hünnefeld, Alexander Harnisch

19.02.2019

sebastian.bange@tu-dortmund.de

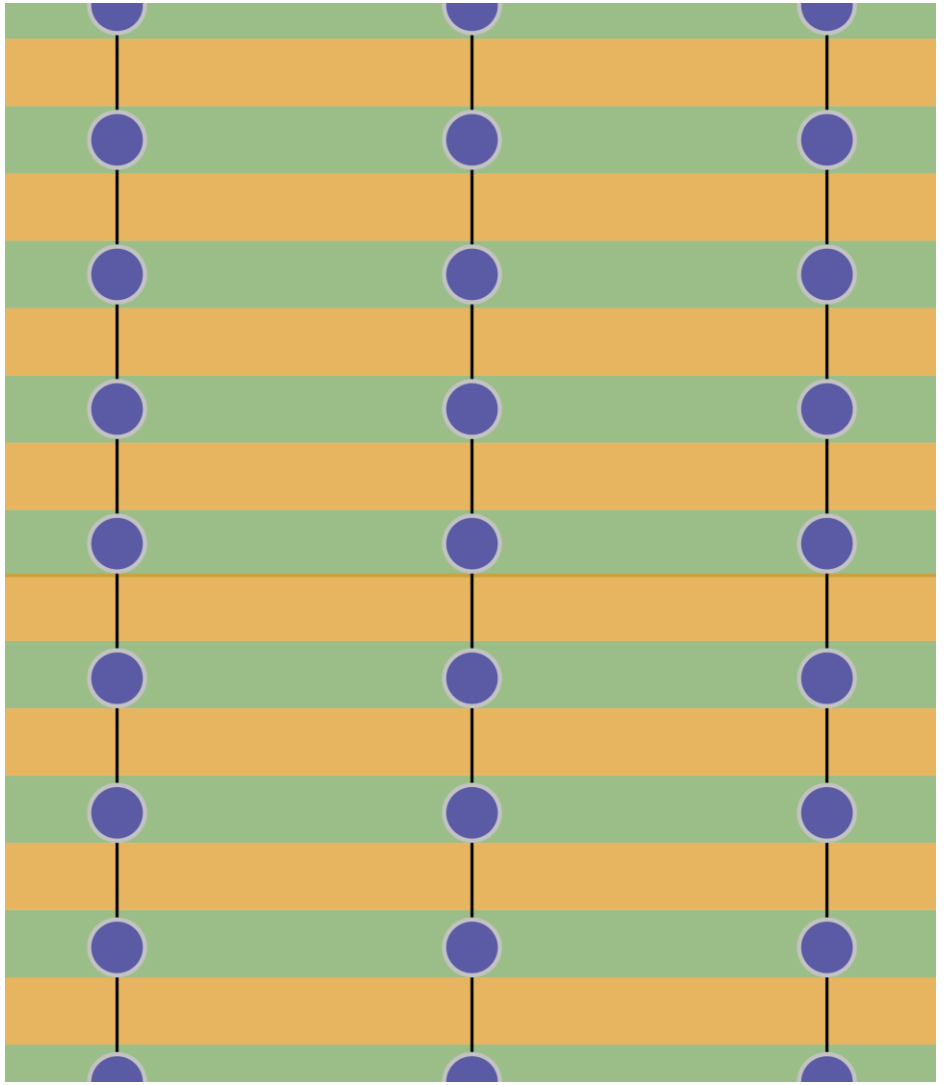
Detector

- Located inside the Antarctic ice
- 86 strings with 60 photomultiplier (DOM) each
- 1km³ in size
- Detects Cherenkov radiation



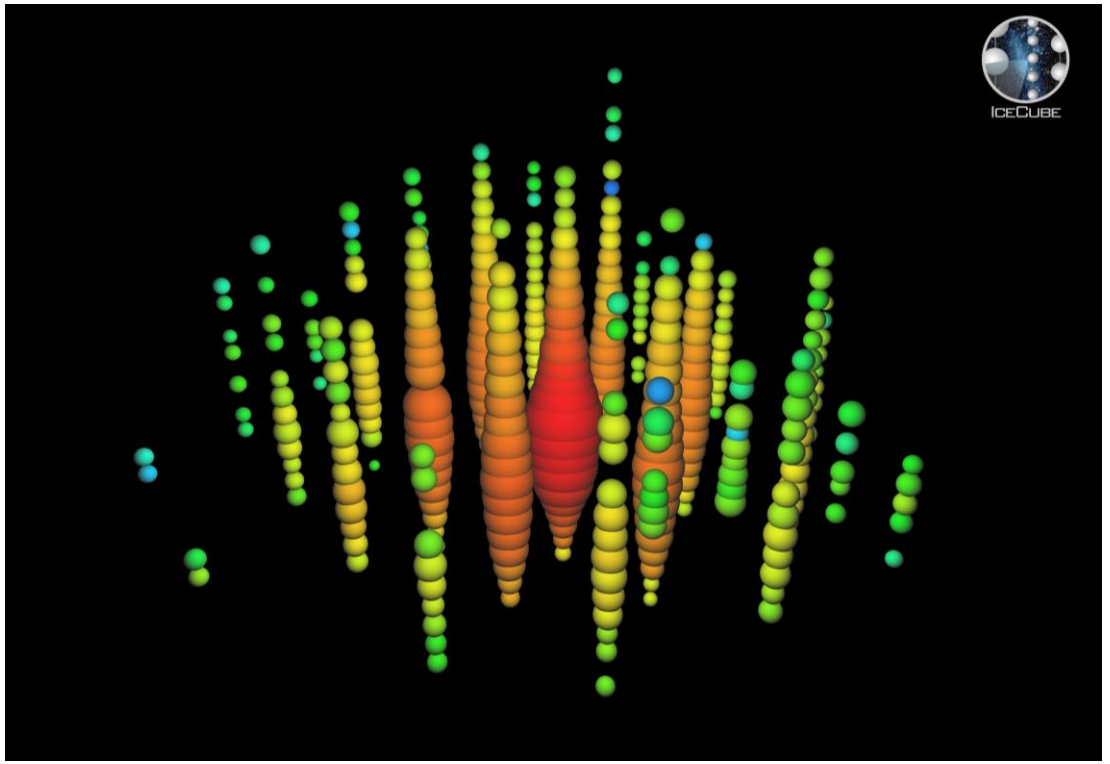
Ice Model

- Light gets absorbed:
  - Mean free path = $[a]^{-1}$
  - Absorption coefficient a
- Light scatters:
  - Mean free path = $[b(1 - \langle \cos\theta \rangle)]^{-1}$
  - Scattering coefficient b
- Depth dependent coefficients
  - Describe the ice in layer
  - 10m per layer
  - 170 layer in total

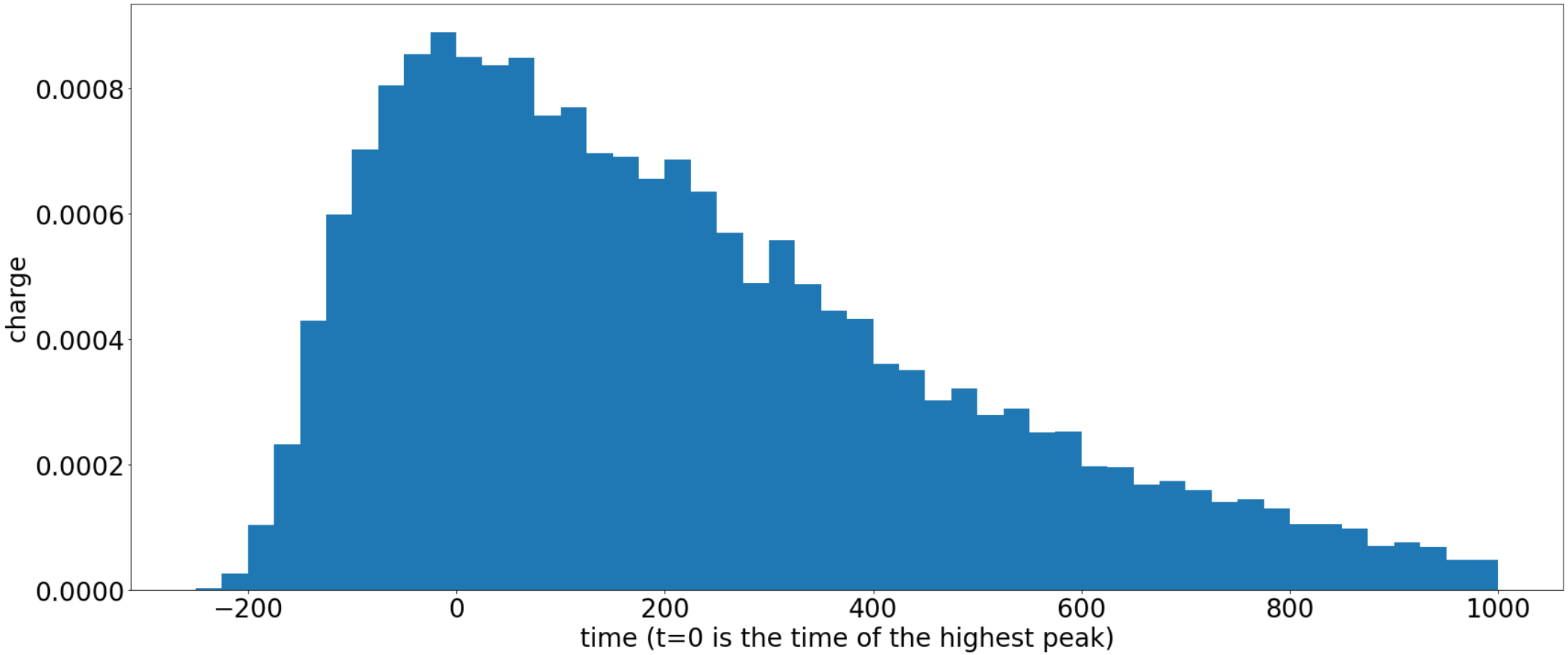


Flasher Runs

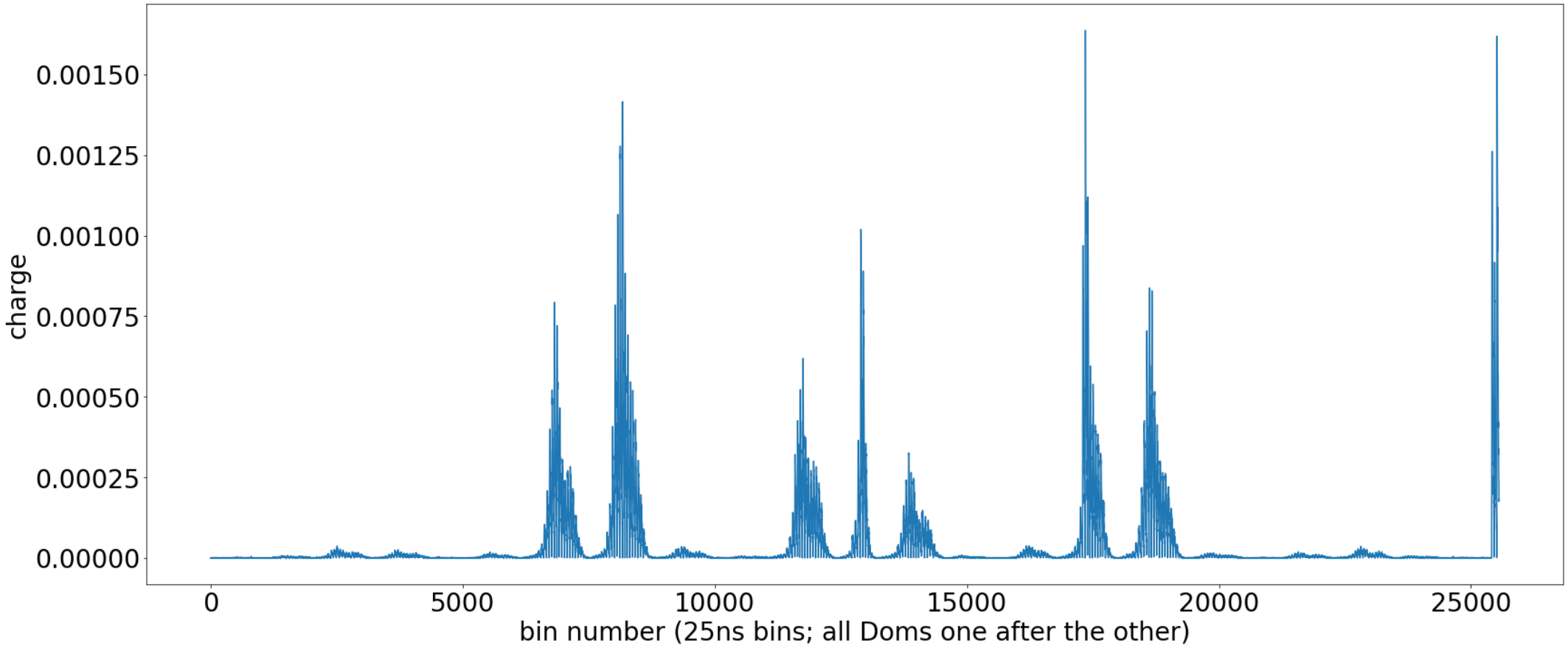
- Each DOM has 12 LEDs
- Flash one LED per “flasher event”
- Nearby DOMs measure the waveform



Flasher runs

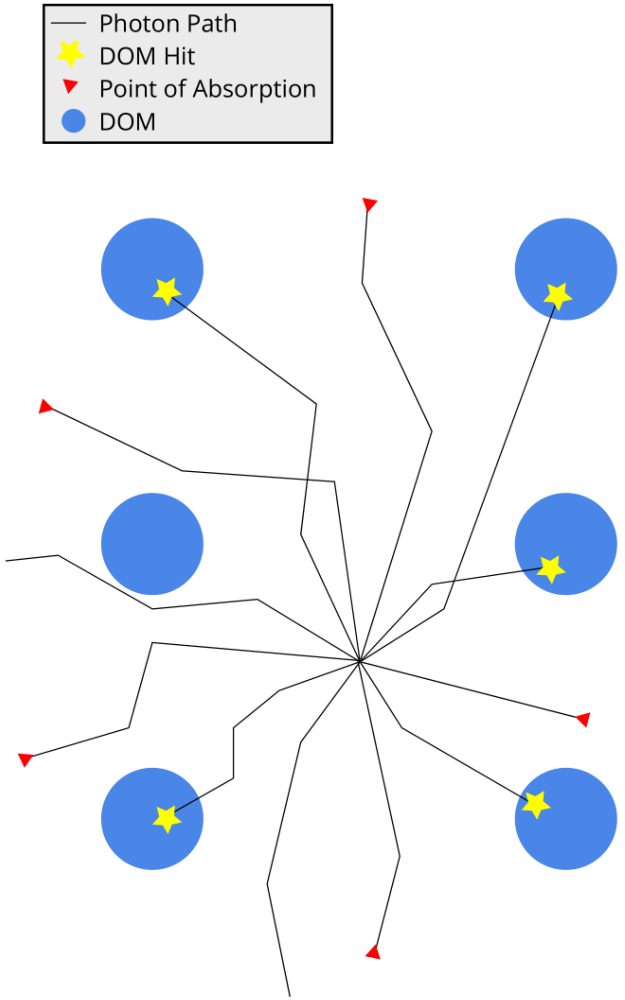


Flasher runs



Photon Propagation Code

- Initialize photon at source
- While photon is not absorbed:
  - Calculate straight path distance
  - Does it hit a DOM?
  - No → continue
  - Yes → log which DOM and travel time
- Use only one flasher as source for now

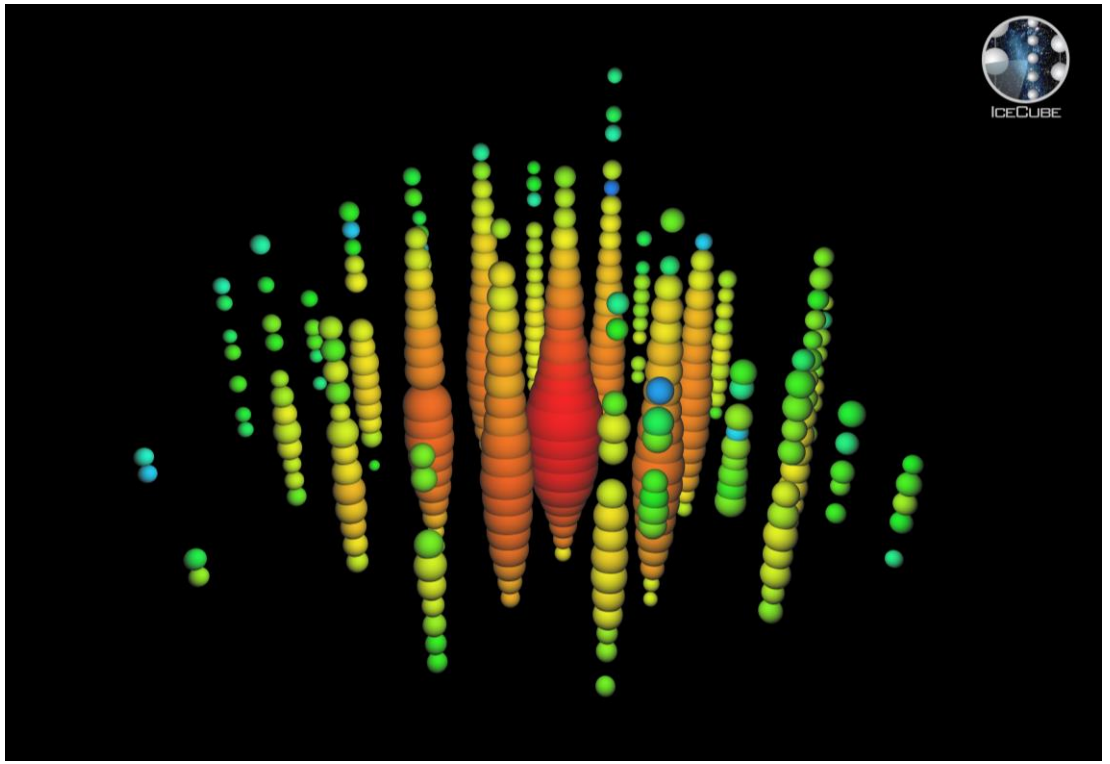


Flasher Runs

- Each DOM has 12 LEDs
- Flash one LED per “flasher event”
- Nearby DOMs measure the waveform

Idea:

- Simulate the events to estimate the waveform
- Use a network of fully connected layers
- Reverse the network to predict the coefficients

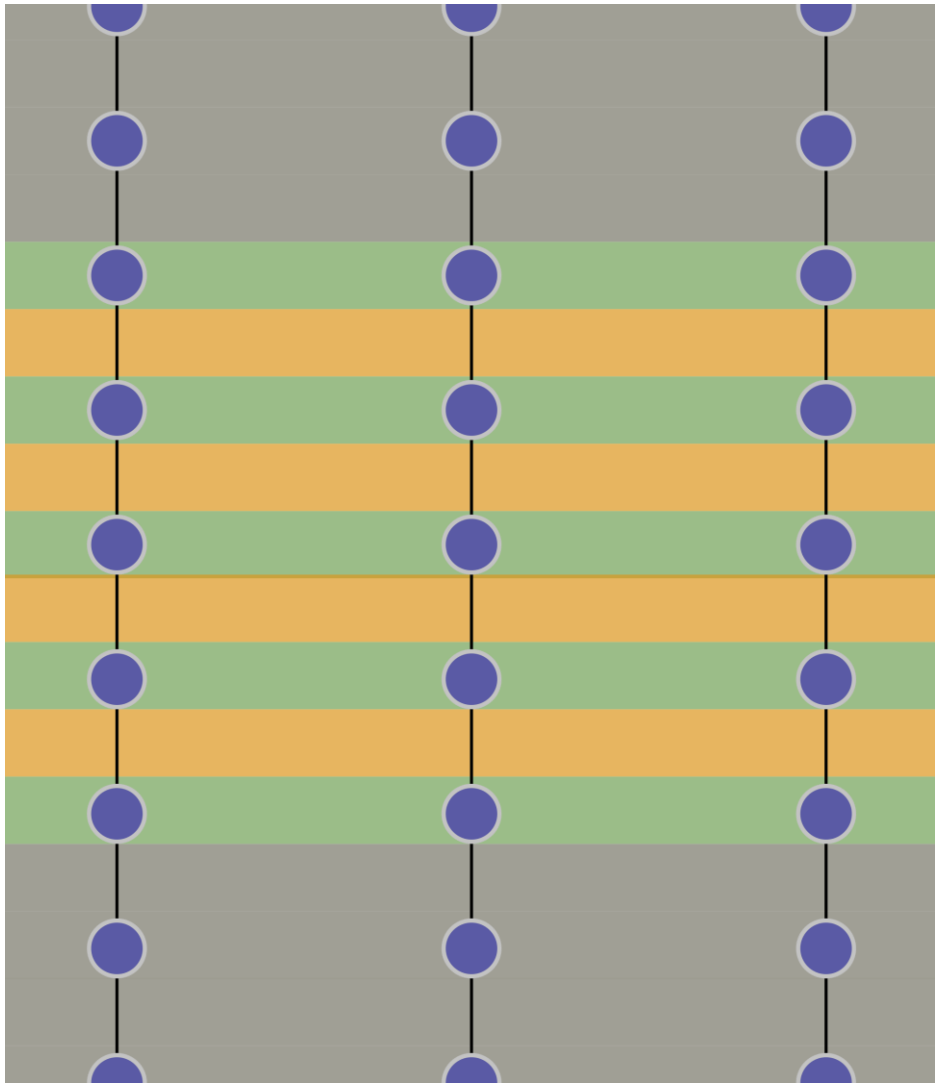


Neural Network

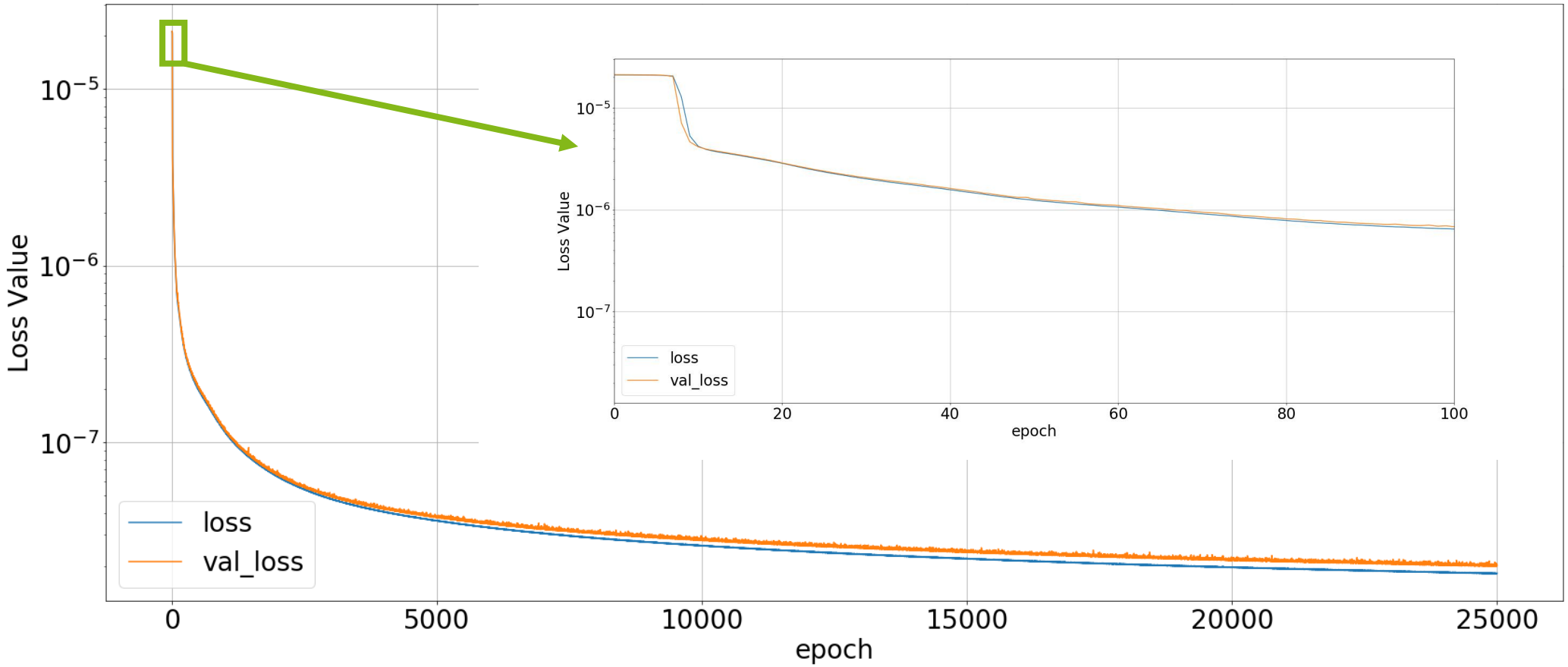
- All 340 coefficients drawn uniformly:
  - $a \in [0{,}002; 0{,}05]$
  - $b \in [0{,}007; 0{,}2]$
- Input: 9 layer around flasher

  $\leftrightarrow$ 18 parameters
- Two hidden layer with 256 parameters each
- Output: 73 DOMs, 20 bins each

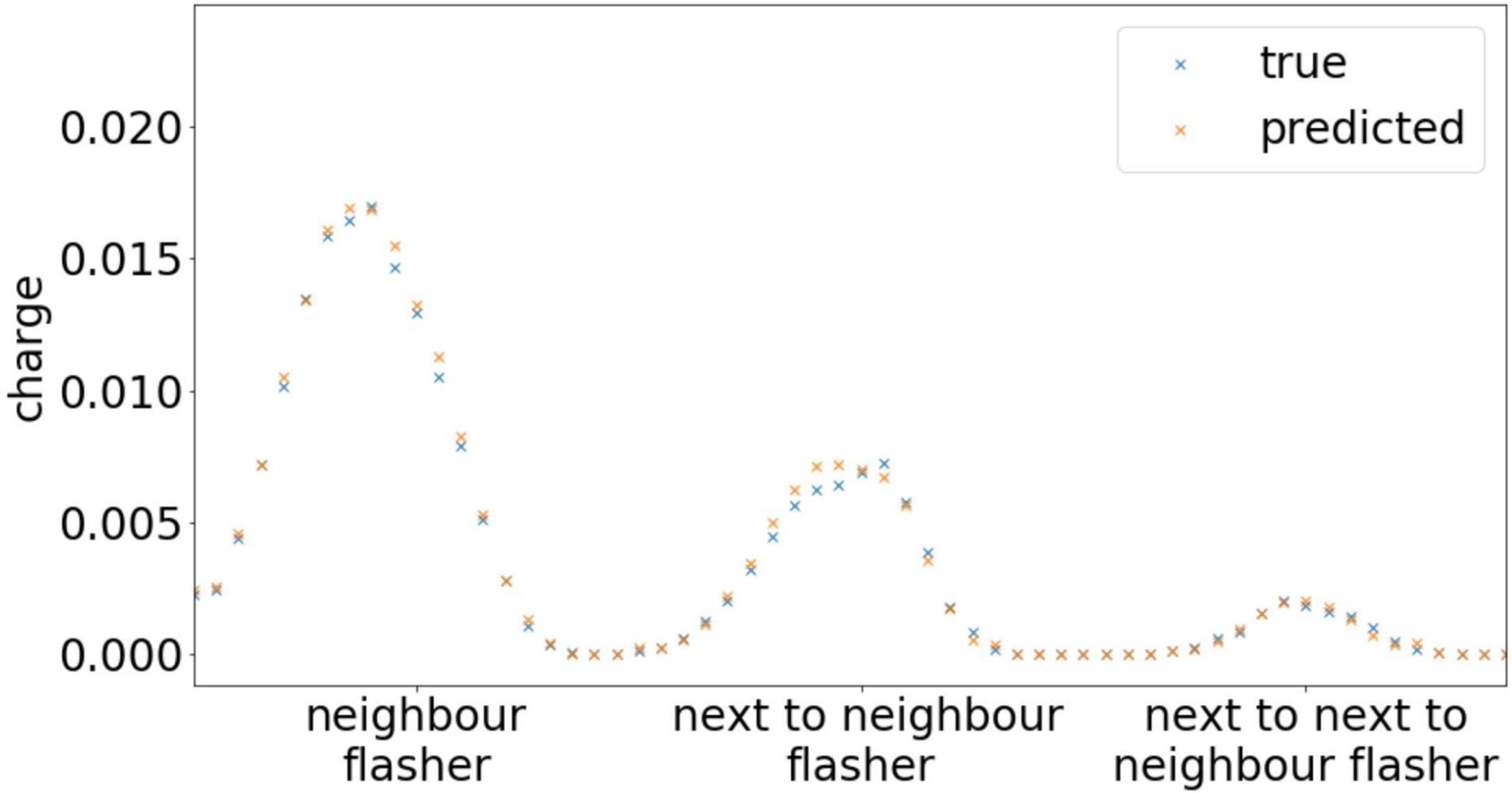
  $\leftrightarrow$ 1460 parameters
- Loss: MSE, optimizer: adam
- Train events: 8778
- Validation events: 976



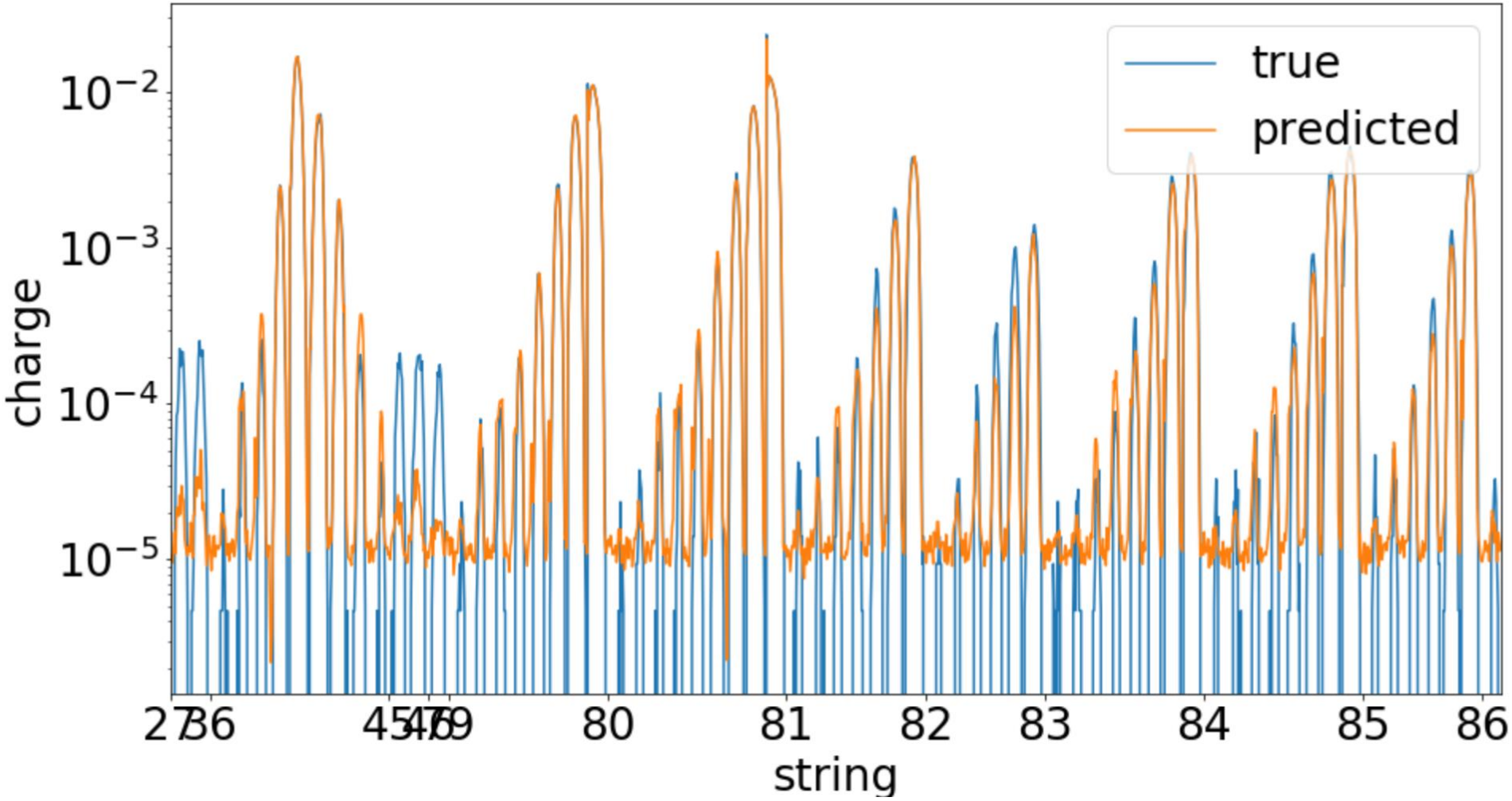
Neural Network – Loss



Neural Network – Prediction



Neural Network – Prediction



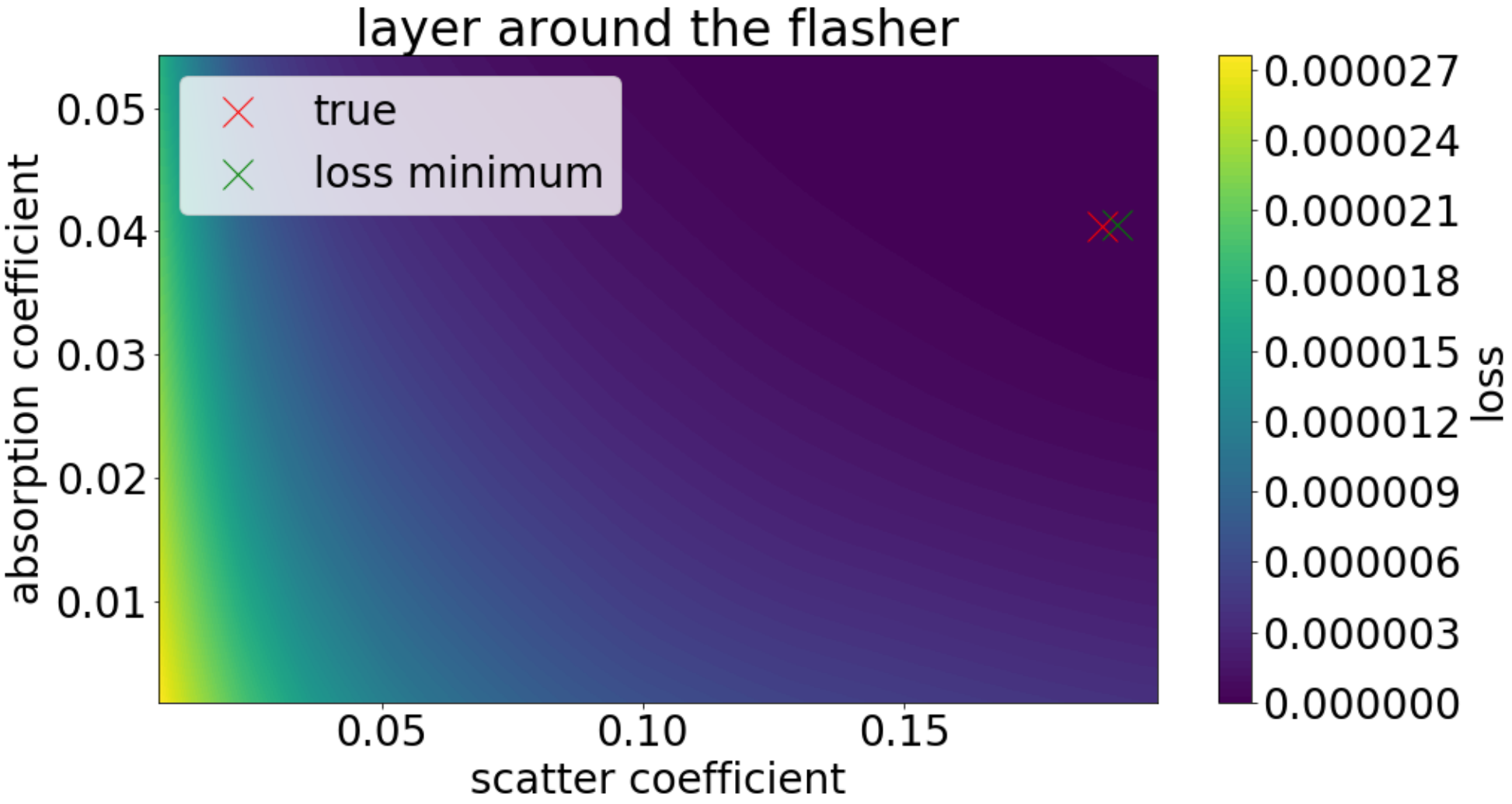
Neural Network – Conclusion

- Converges quickly
- Shows promising results with low number of training events
- No signs of overfitting yet
- Smoothens the waveform
  → Reduced dependence on statistical fluctuations

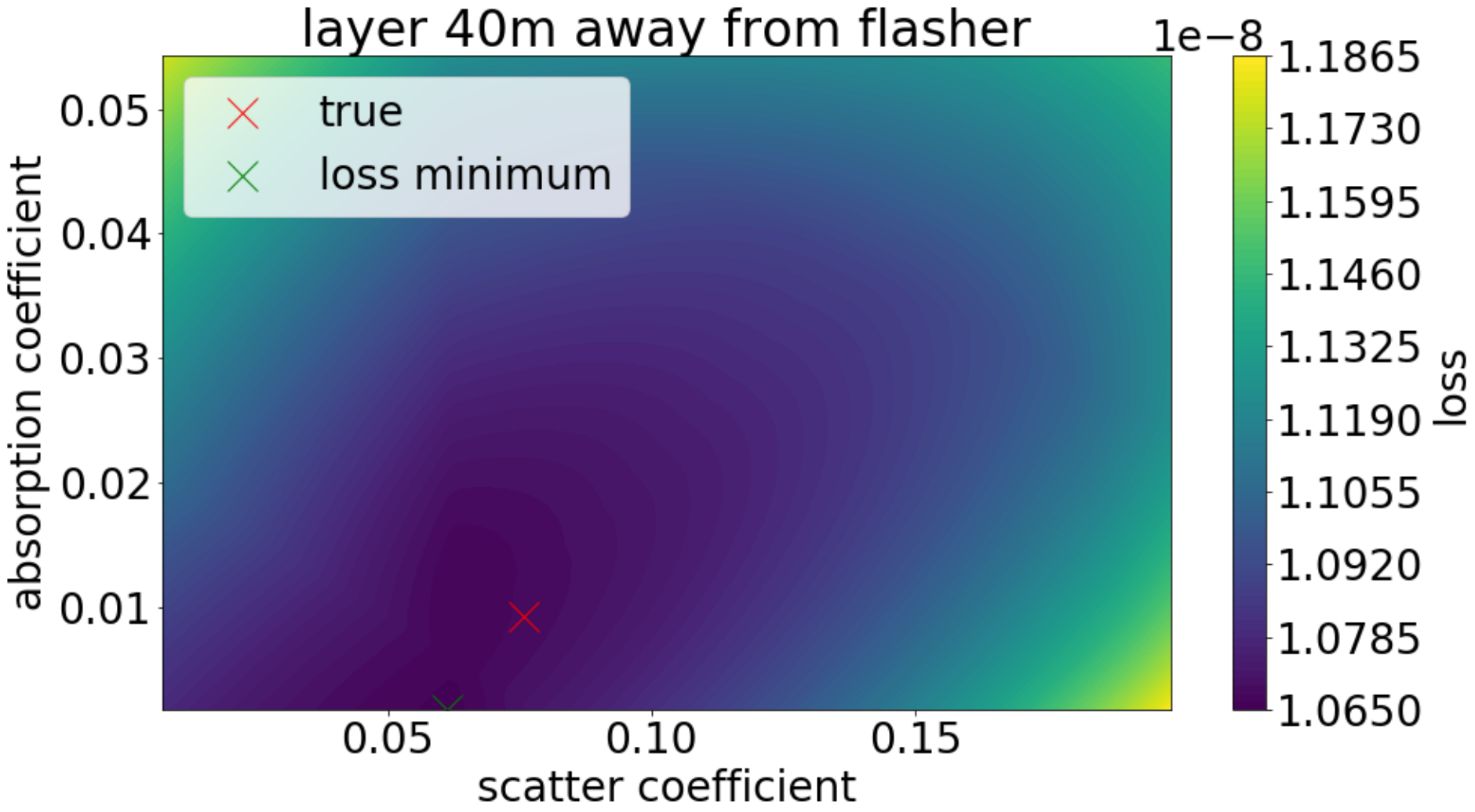
Next step:

- Test if network is reversible by scanning the loss

Neural Network Manual Loss Scan

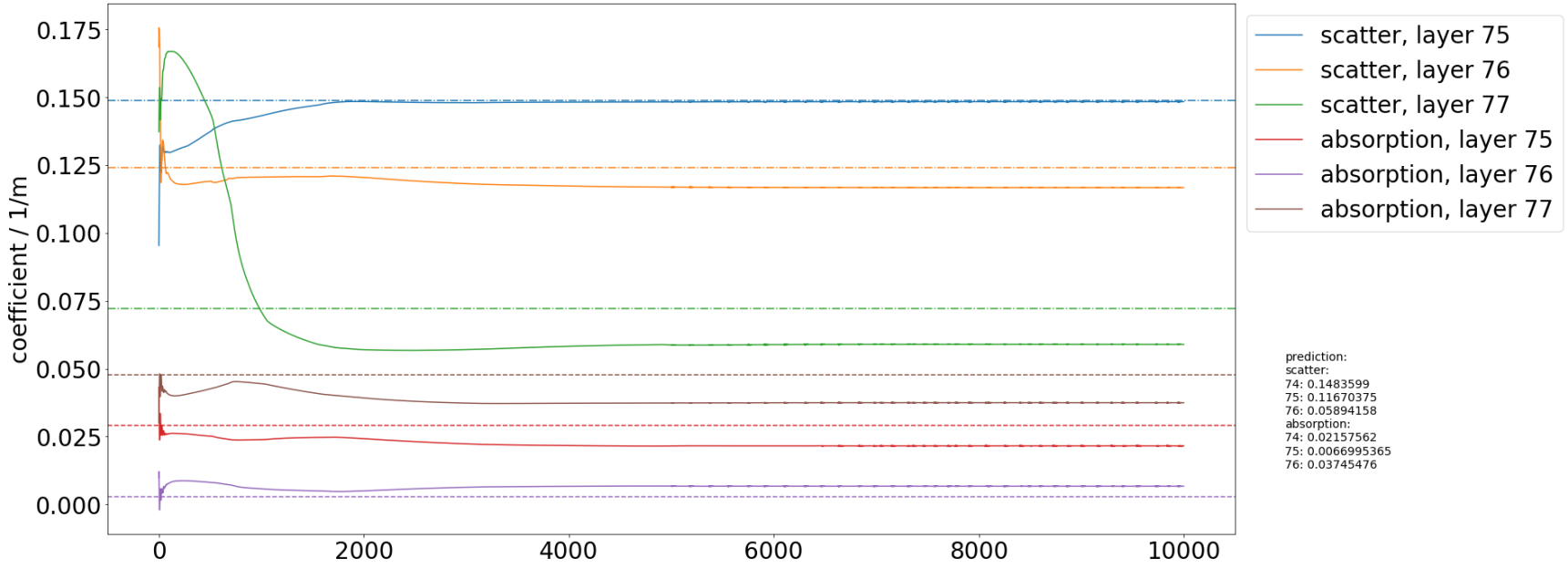


Neural Network Manual Loss Scan



Neural Network – Reversed

- Smooth loss function
- True minimum should be easily found
- Rough estimate: Predictions are within 5% of validation data



Conclusion and Outlook

- Waveform can be predicted accurately
- The network can easily be reversed due to the smooth loss function

Next steps:

- Extend the network to flash one full string
- Predict all 340 coefficients at one time
- Get much more statistics in the relevant interval
- Predict with real data

Neural Network – Loss Difference