Deep Neural Network searching for an air shower radio signal

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Motivation

Future of ultra high energy (UHE) astroparticle physics

HELMHOLTZ ASSOCIATION

Alliance for Astroparticle Physics

UHE neutrinos and photons, e.g. GZK ones
- Sources
- Particle physics
- Neutrinos

Motivation

Future of ultra-high energy (UHE) astroparticle physics

UHE neutrinos and photons, e.g. GZK ones
- Sources
- Particle physics
- Neutrinos

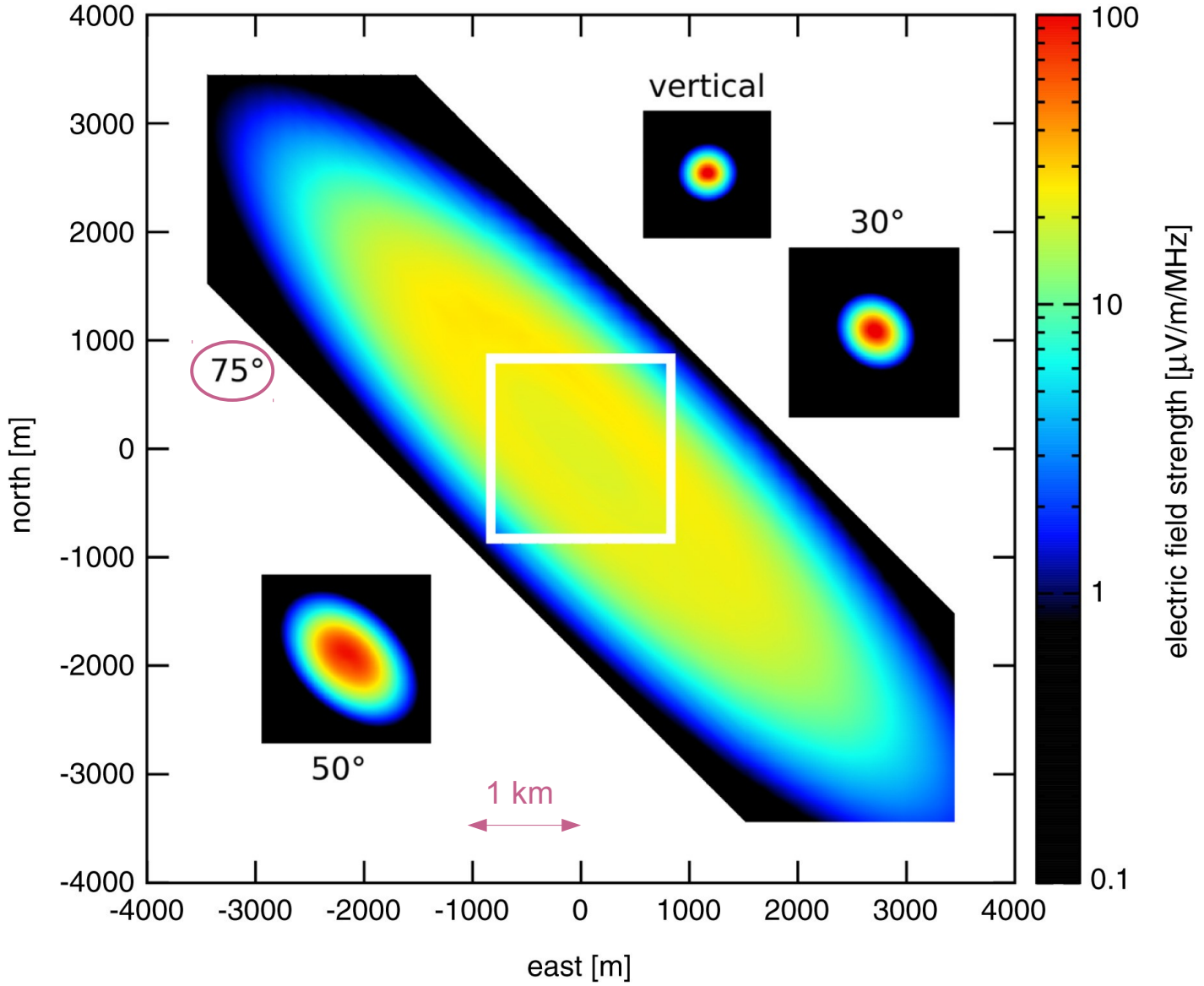
Experiment: 10 x exposure of the Pierre Auger Observatory

Energy and composition

A sparse array of self-triggering antennas

Online identification of air shower signals?

Electric field strength



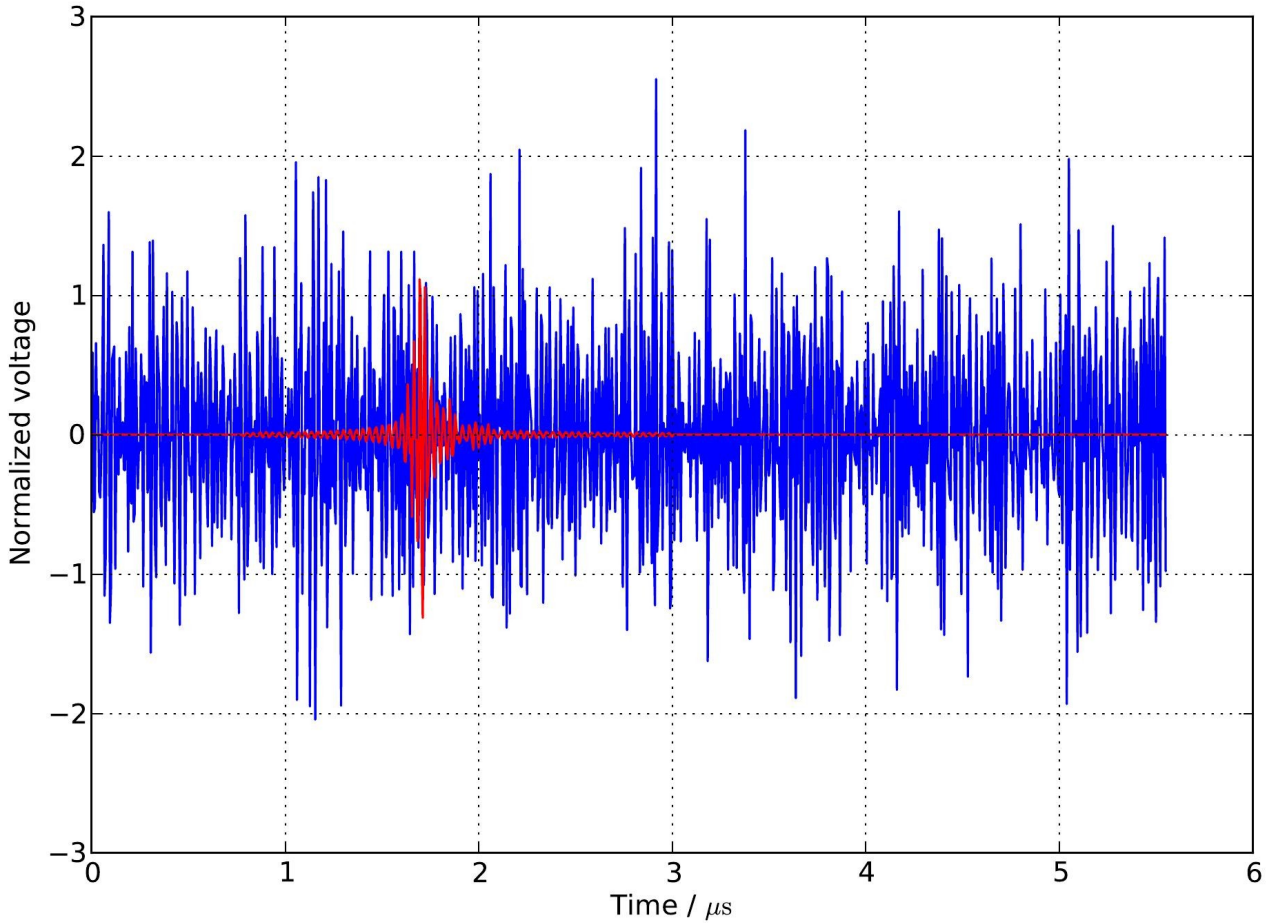
5 EeV

30 – 80 MHz

Large footprint → low signal

T. Huege, arXiv:1601.07426

Data



Noise

- Normal distribution
- Different components
- Bandpass filter

Air shower

- Simulated for AERA (thanks to C. Glaser)
- Scaling the amplitude

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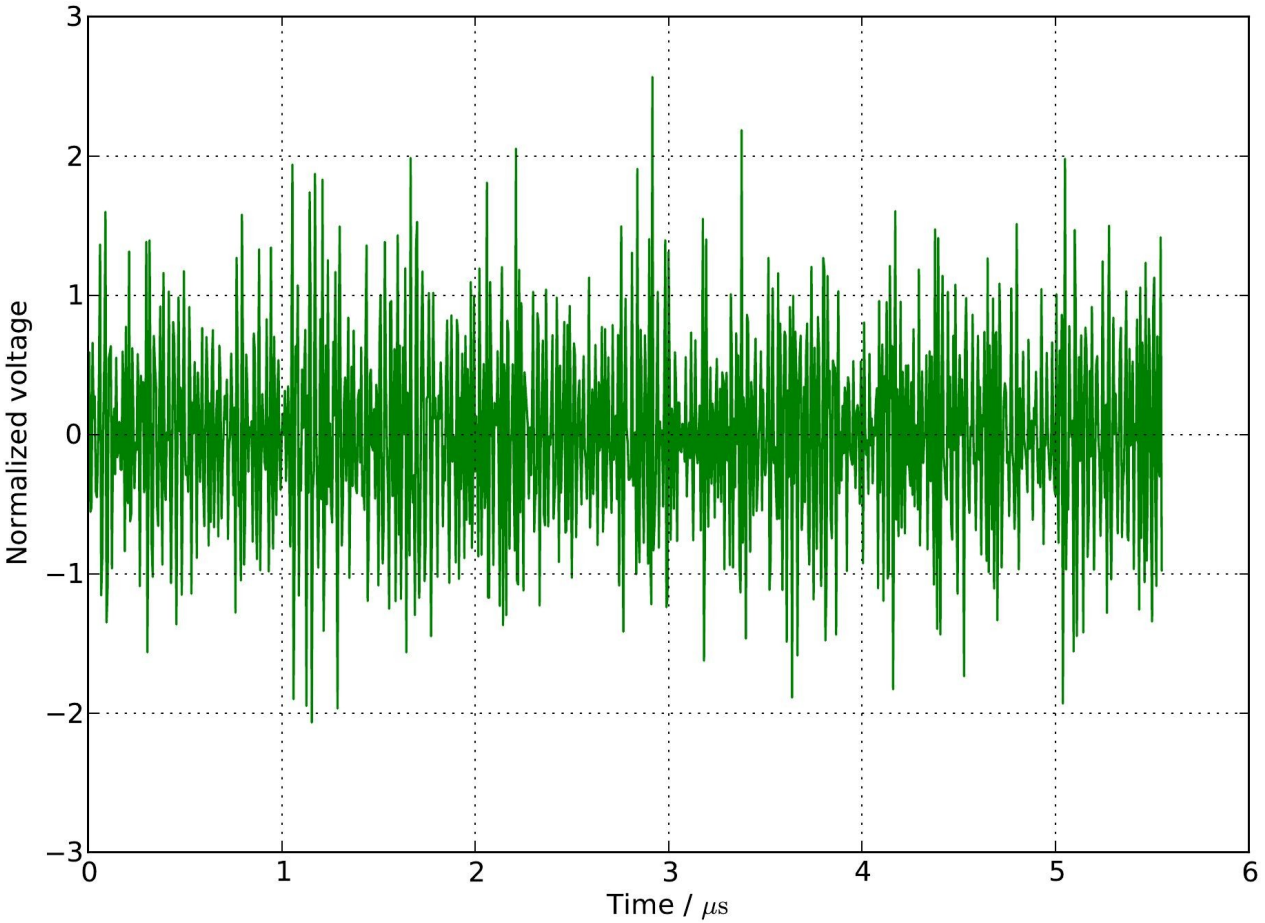
Signal-to-noise ratio (SNR)

Data



Deep neural network
is data hungry

↓

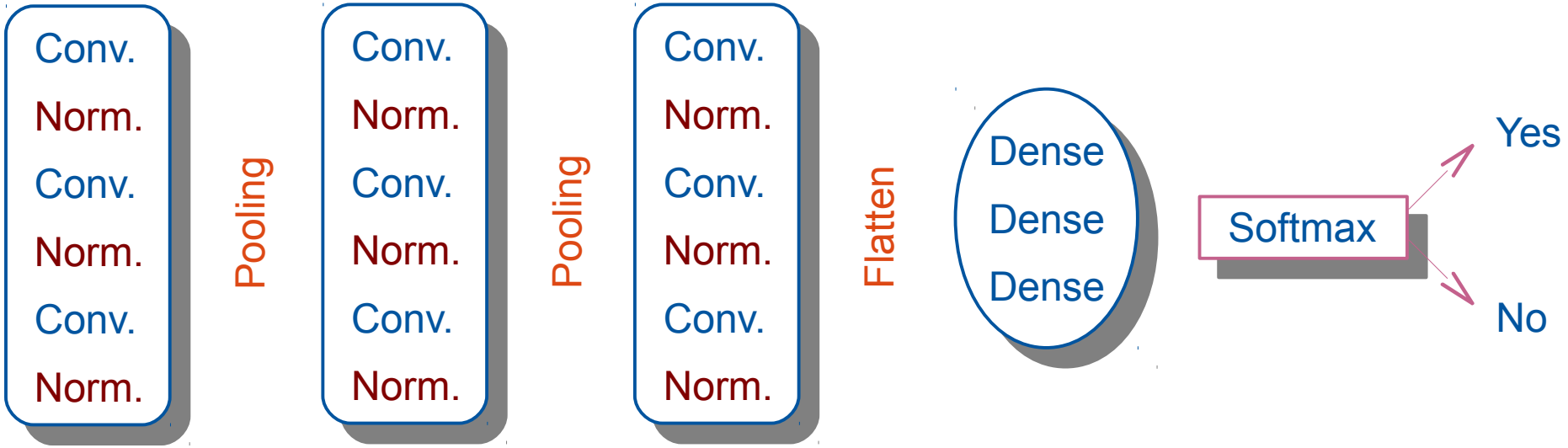
Data augmentation

Training:
- 100k traces
- 50% w/ signal

Testing:
- 20k traces
- Only 1% w/ signal

Supervised learning → Binary classification

Deep Neural Network (DNN) model

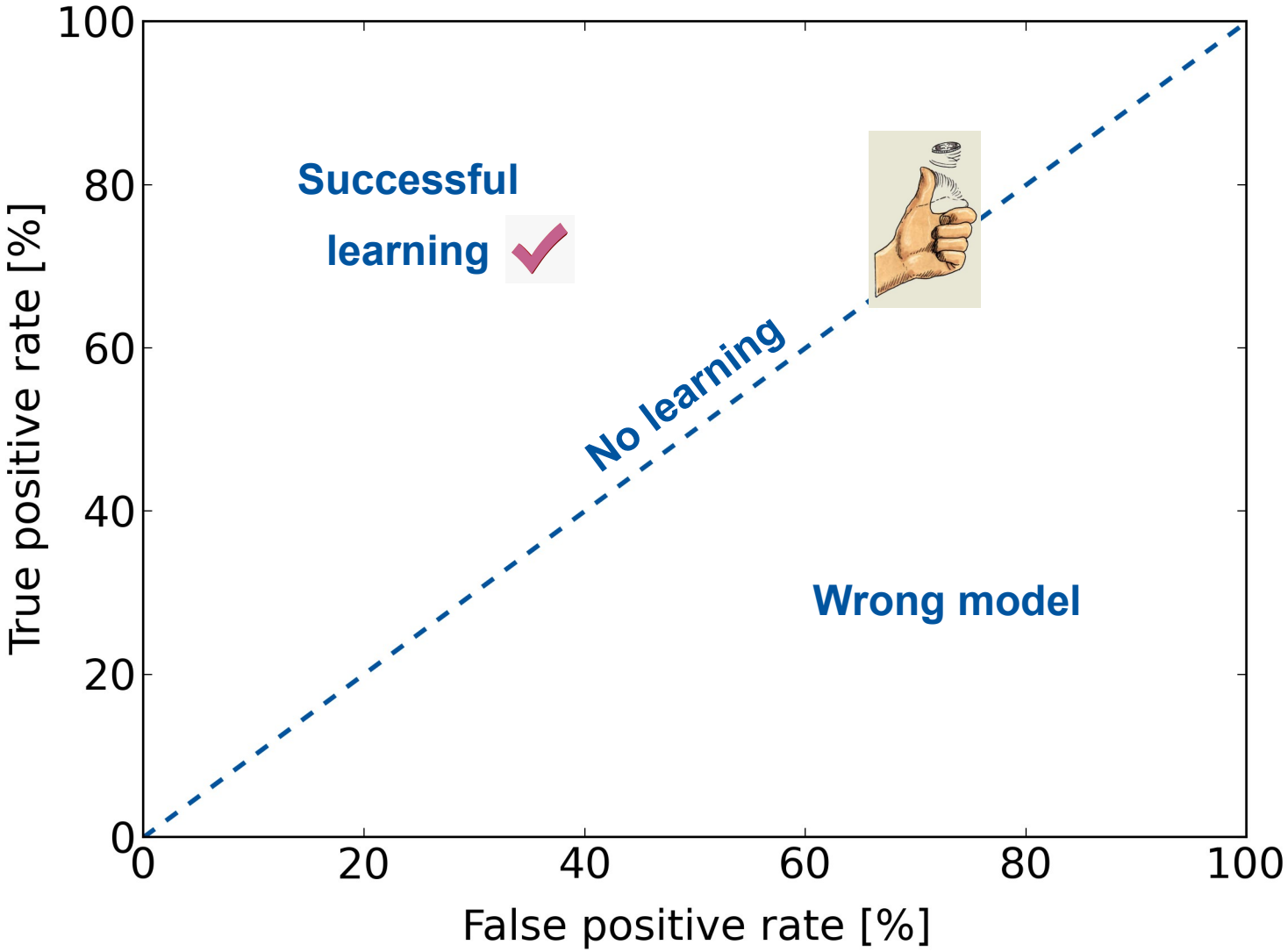


Feedforward network

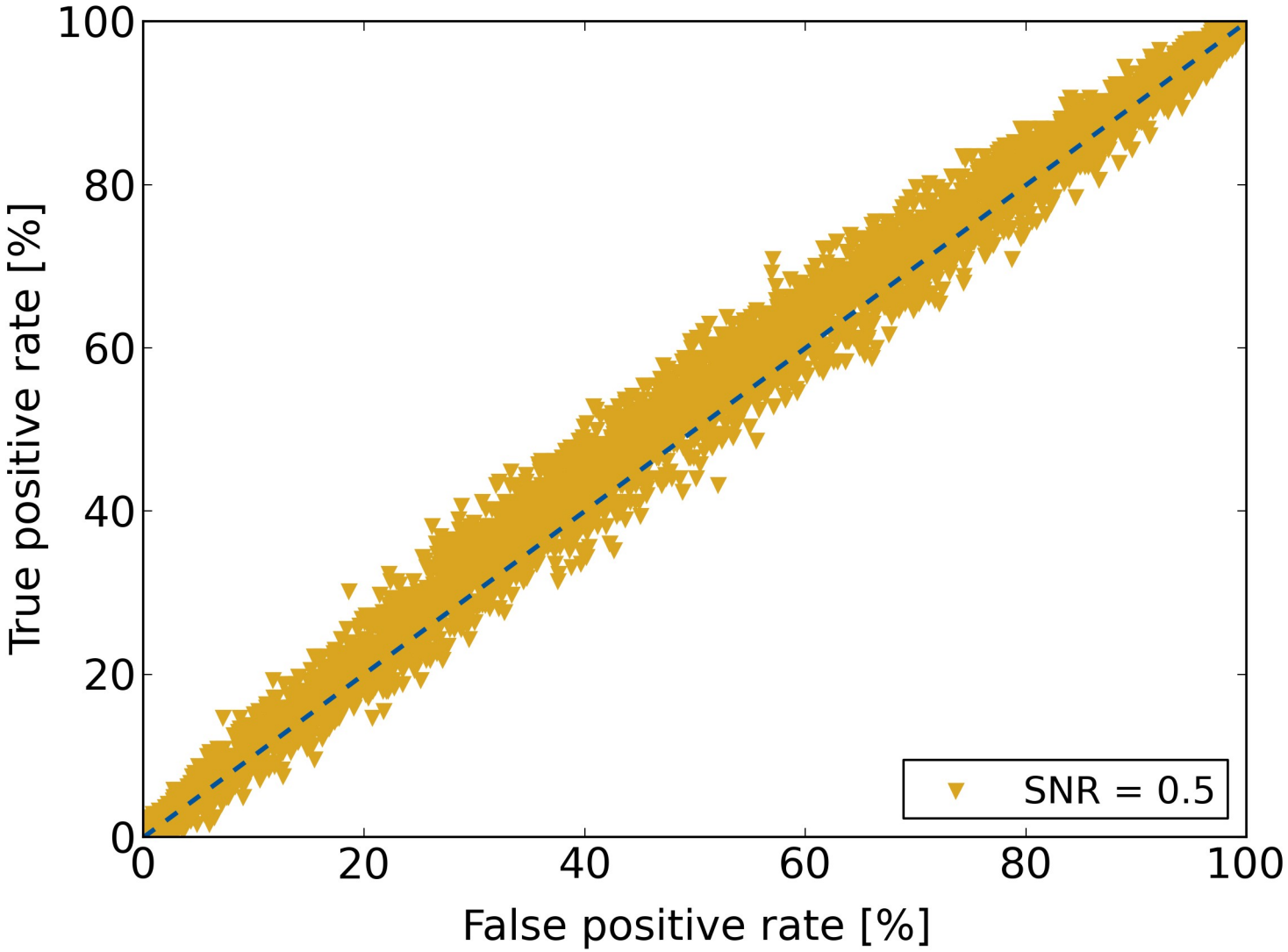
- Data and batch normalization
- Weights initialization: a truncated normal distribution centered on zero (he_normal)
- Activation: the rectified linear unit (ReLU) function
- Cost function: the logarithmic loss function (binary_crossentropy)
- Training optimization: the Adam algorithm

Hyperparameters → random search → VISPA

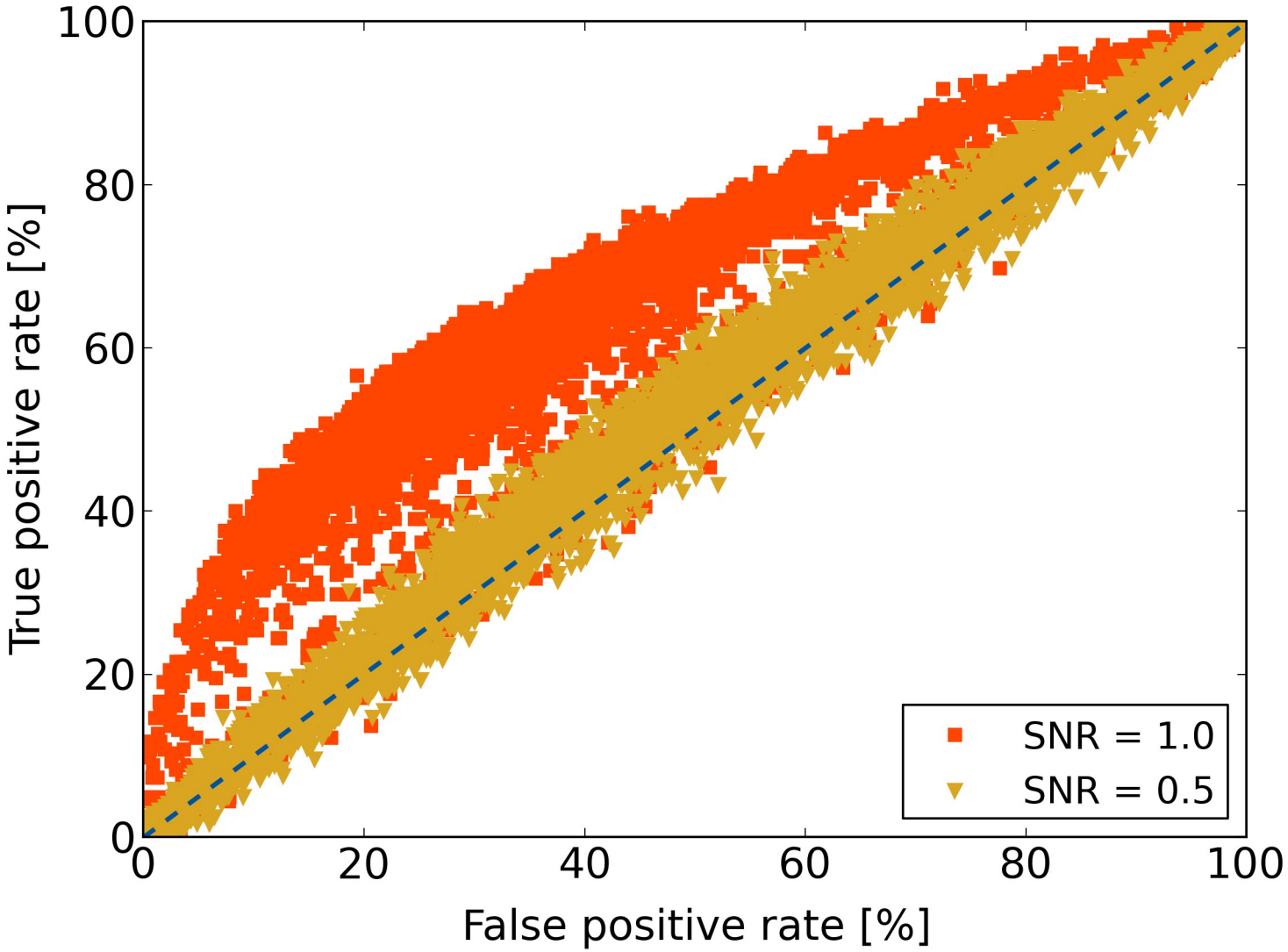
Receiver operating characteristic (ROC) curve



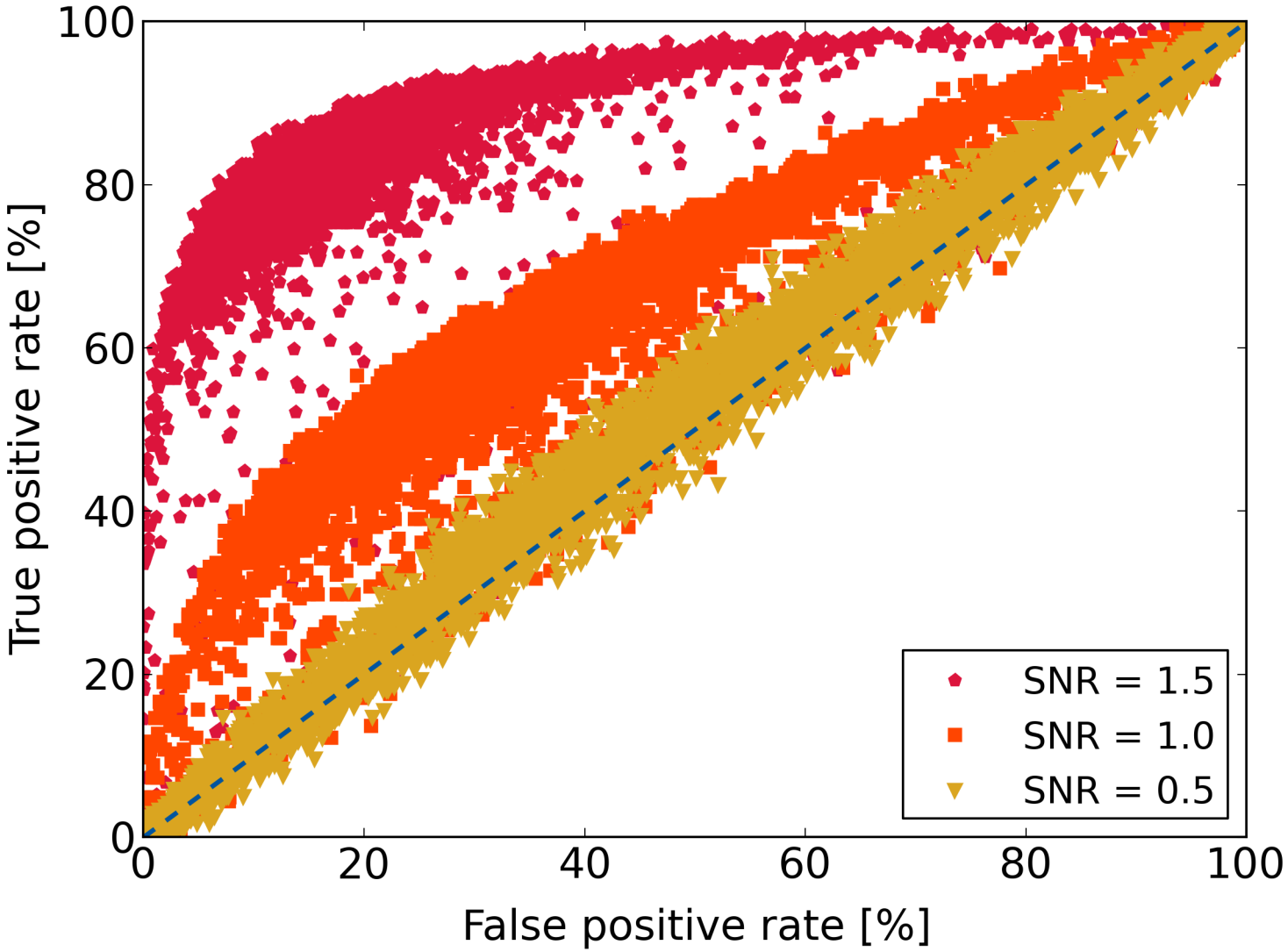
Evaluation


True positive rate [%]
False positive rate [%]
0
20
40
60
80
100
SNR = 0.5

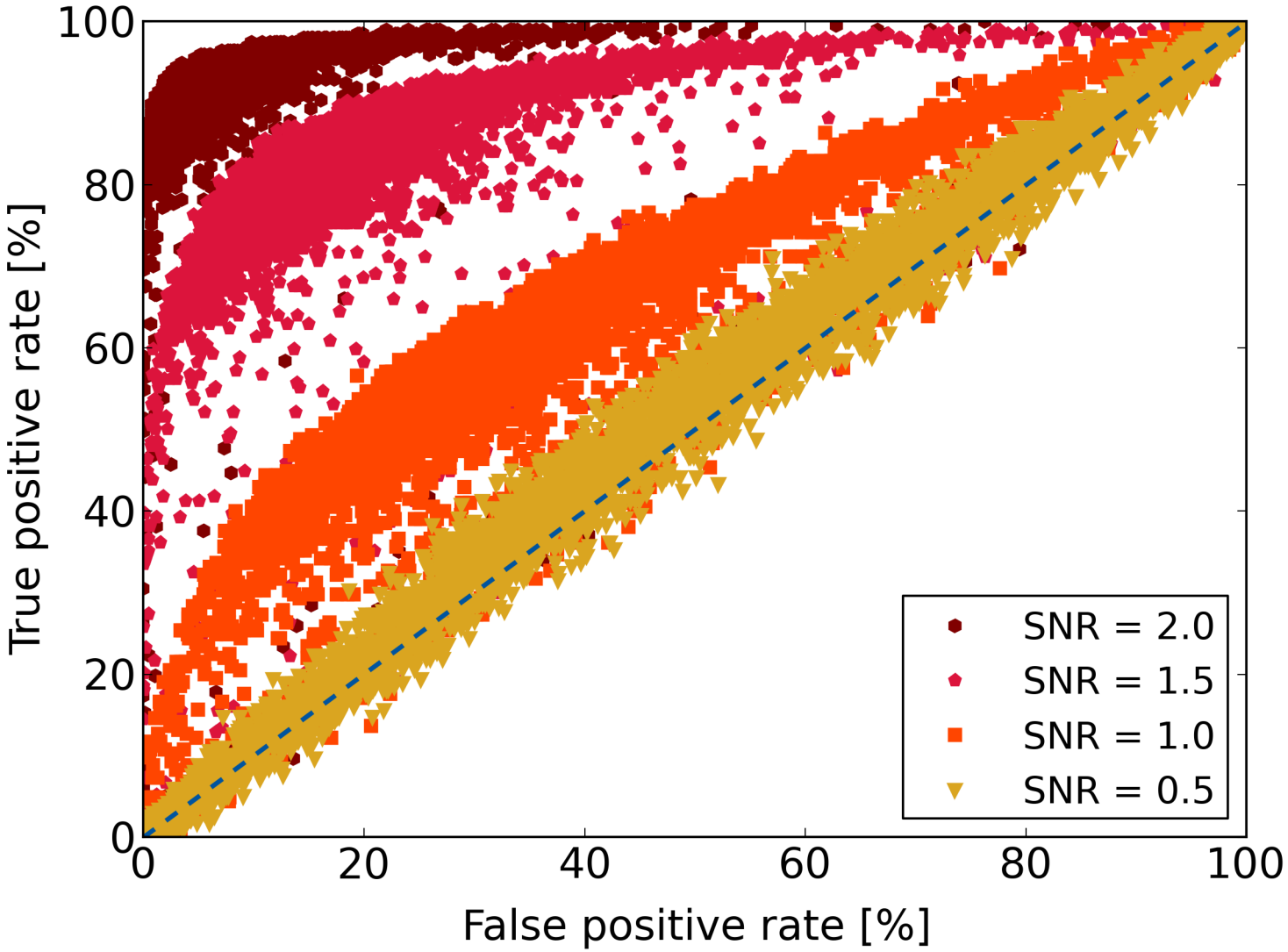
Evaluation


True positive rate [%]
False positive rate [%]
0
20
40
60
80
100
SNR = 1.0
SNR = 0.5

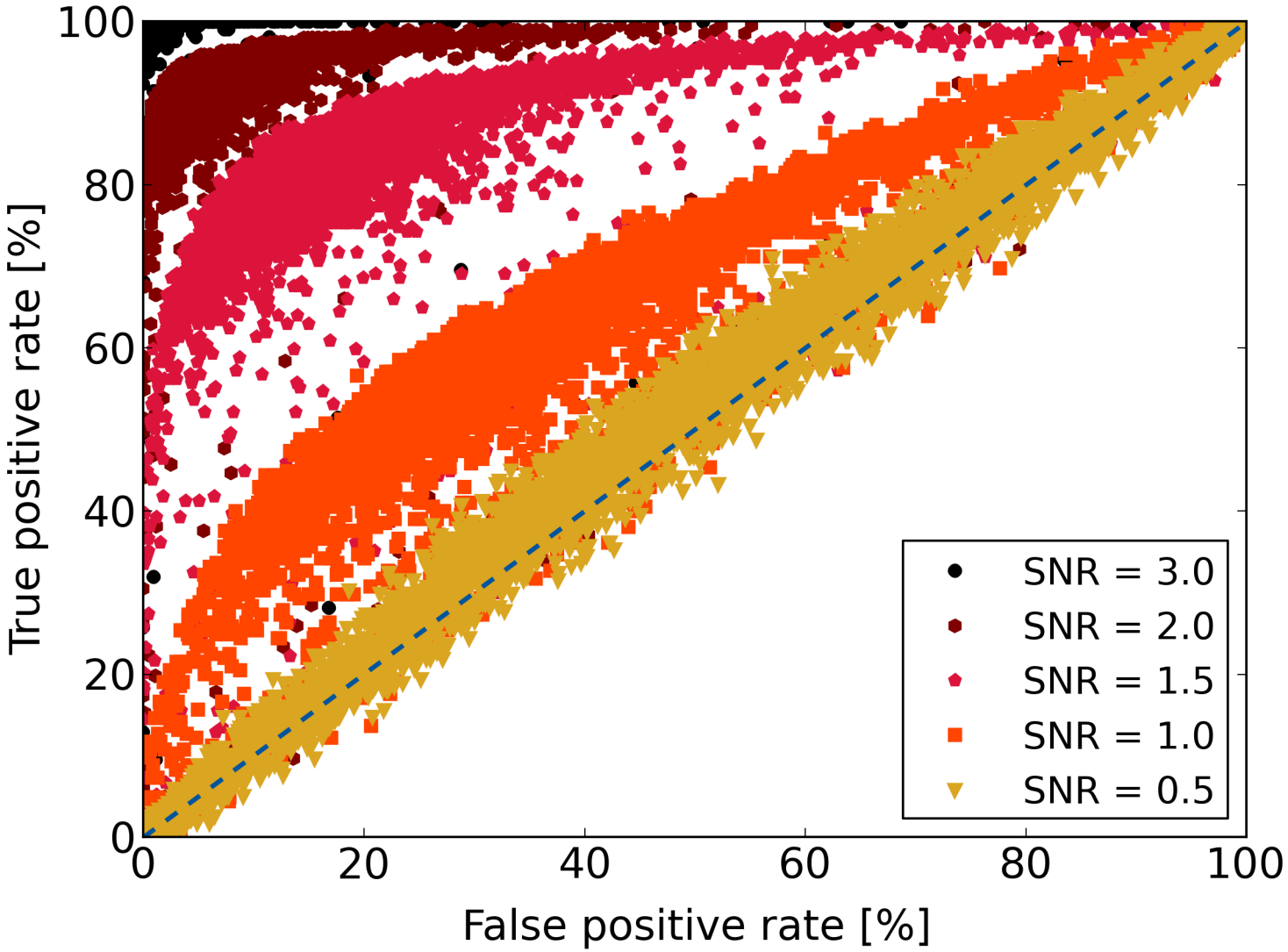
Evaluation


True positive rate [%]
False positive rate [%]
0
20
40
60
80
100
SNR = 1.5
SNR = 1.0
SNR = 0.5

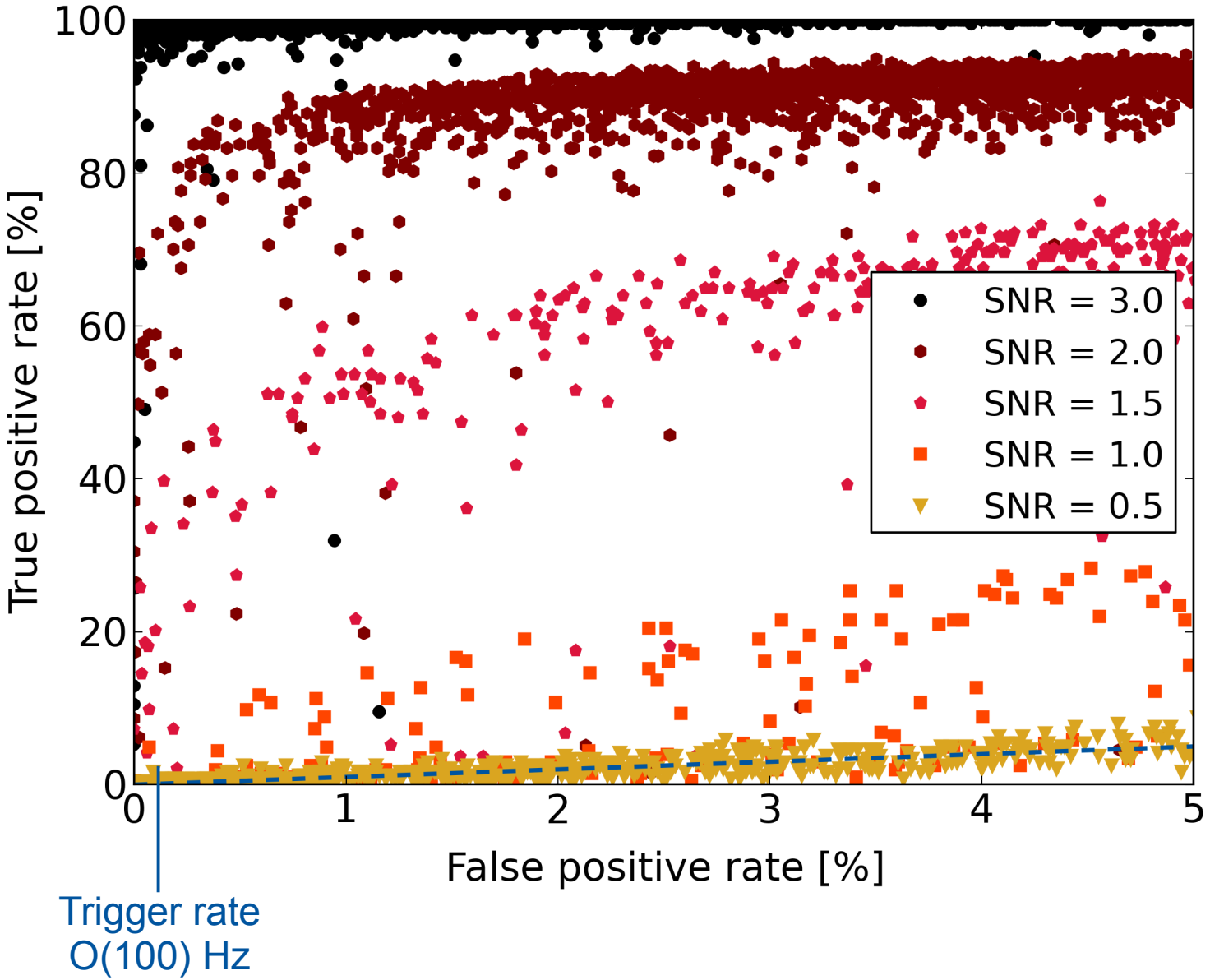
Evaluation


True positive rate [%]
False positive rate [%]
0
20
40
60
80
100
SNR = 2.0
SNR = 1.5
SNR = 1.0
SNR = 0.5

Evaluation


True positive rate [%]
False positive rate [%]
0
20
40
60
80
100
SNR = 3.0
SNR = 2.0
SNR = 1.5
SNR = 1.0
SNR = 0.5

Low FPR


100
80
60
40
20
0
True positive rate [%]
0
1
2
3
4
5
False positive rate [%]
SNR = 3.0
SNR = 2.0
SNR = 1.5
SNR = 1.0
SNR = 0.5
Trigger rate
O(100) Hz

Conclusion

Trained deep neural network model

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Radio signal from extensive air showers

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Self-triggering antennas in a future UHECR experiment