KU LEUVEN

Identification of strongly lensed gravitational-wave pairs with deep learning

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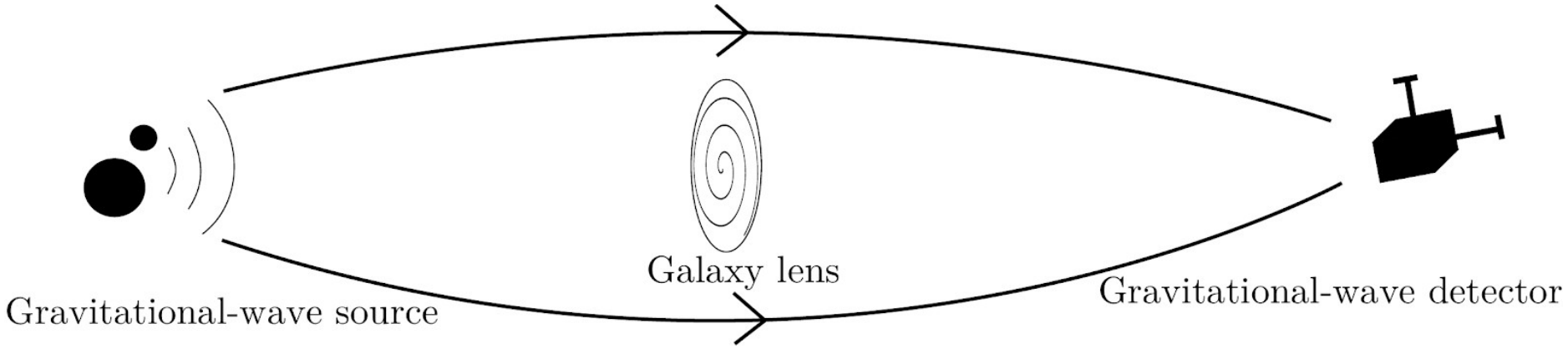
Strong gravitational lensing



[1]

Multiple images with different

- Times of arrival
- Amplitudes
- Phases

[1] LIGO

Problem

Current identification methods: ~O(hour)/pair (without PE)

Estimated detection rate for Einstein Telescope: ~O(10^5 – 10^6) events/year [2]

~O(10^{10} – 10^{12}) pairs!

Even larger increase for triplets, quadruplets...

Need for faster methods

[2] Maggiore et *al*., 2020

Deep learning solutions

Considered for different tasks in GW data analysis

Existing work (Goyal et *al.* 2021):

Analysis of pairs of events, time-frequency representation

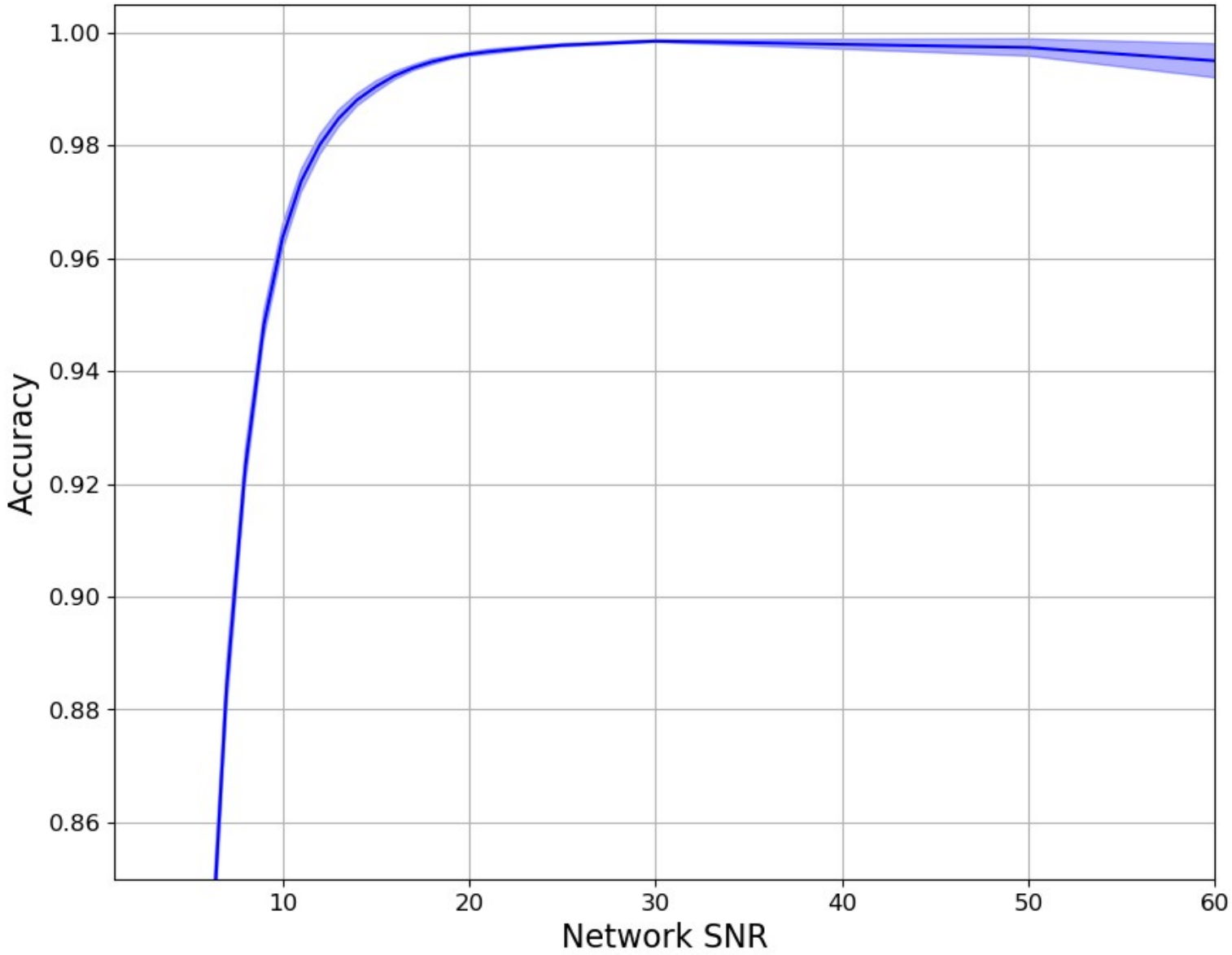
In this work:

Analysis of pairs of events, time series representation

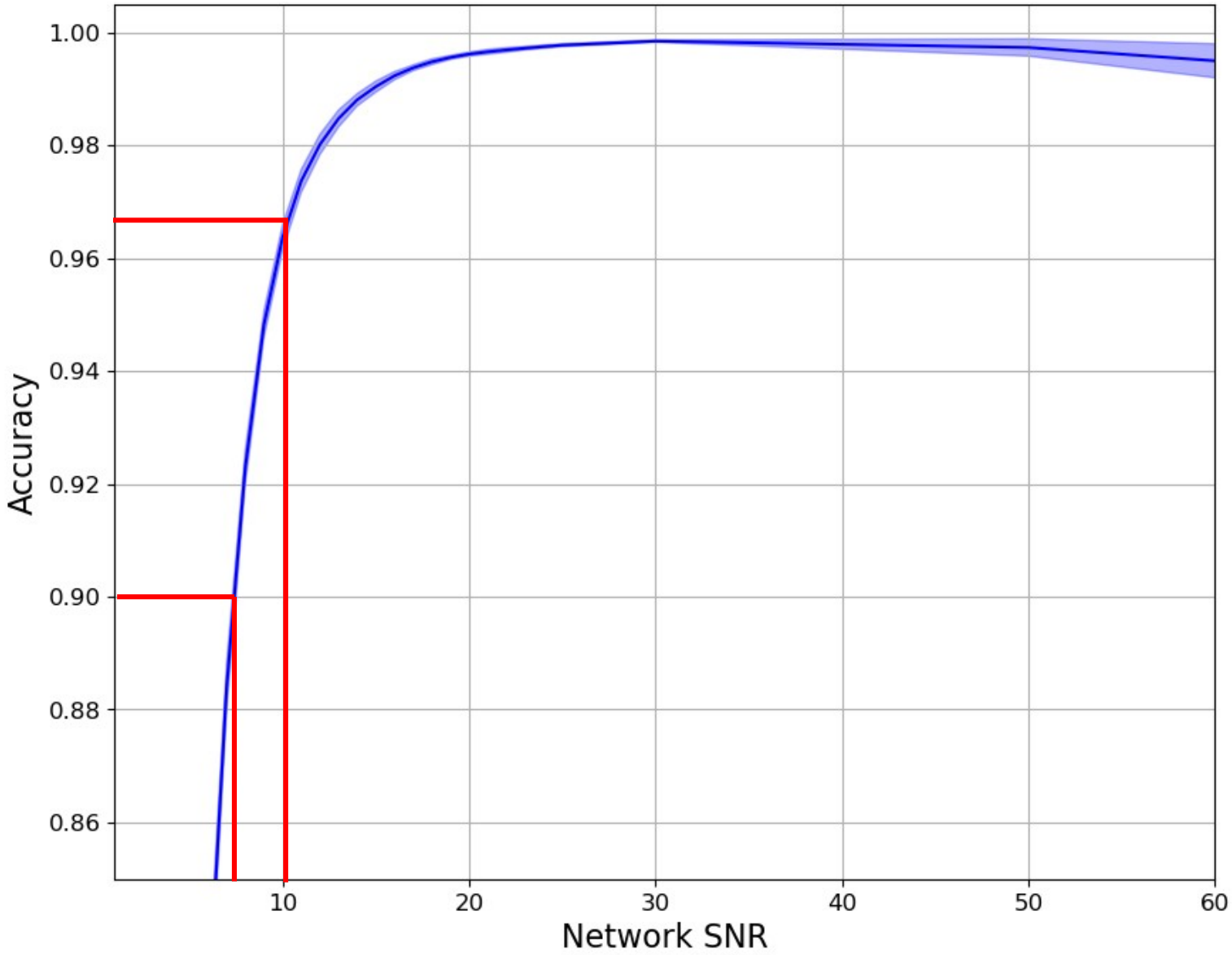
Simplified case (fixed position of the source, limited amplitude changes)

Computation time: ~5ms for a batch of 250 pairs (~O(1s) with data loading)

Performance



Performance



Conclusion

Problem:

Large increase in detection rates ⟶ current methods unable to keep up with the drastically increasing number of combinations

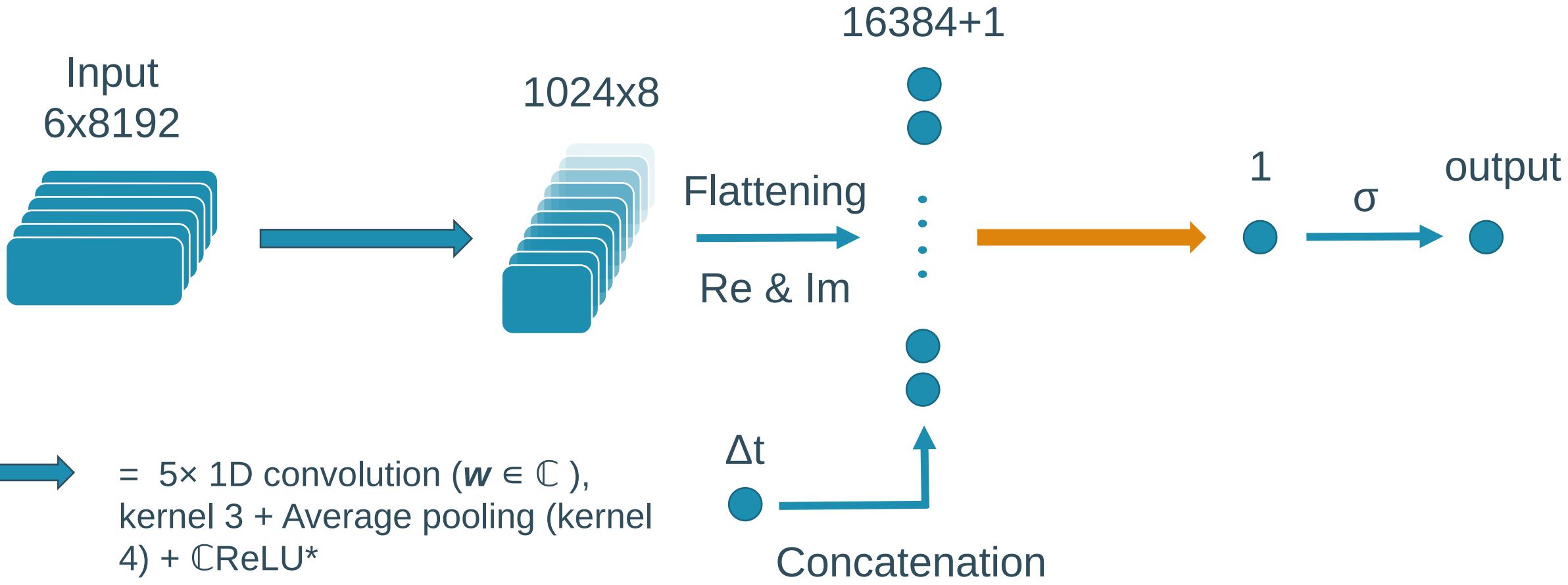
Solution:

Fast identification of lensed pairs using deep learning

Performance:

Still needs improvements (training strategy, different source positions), but promising results

Neural network

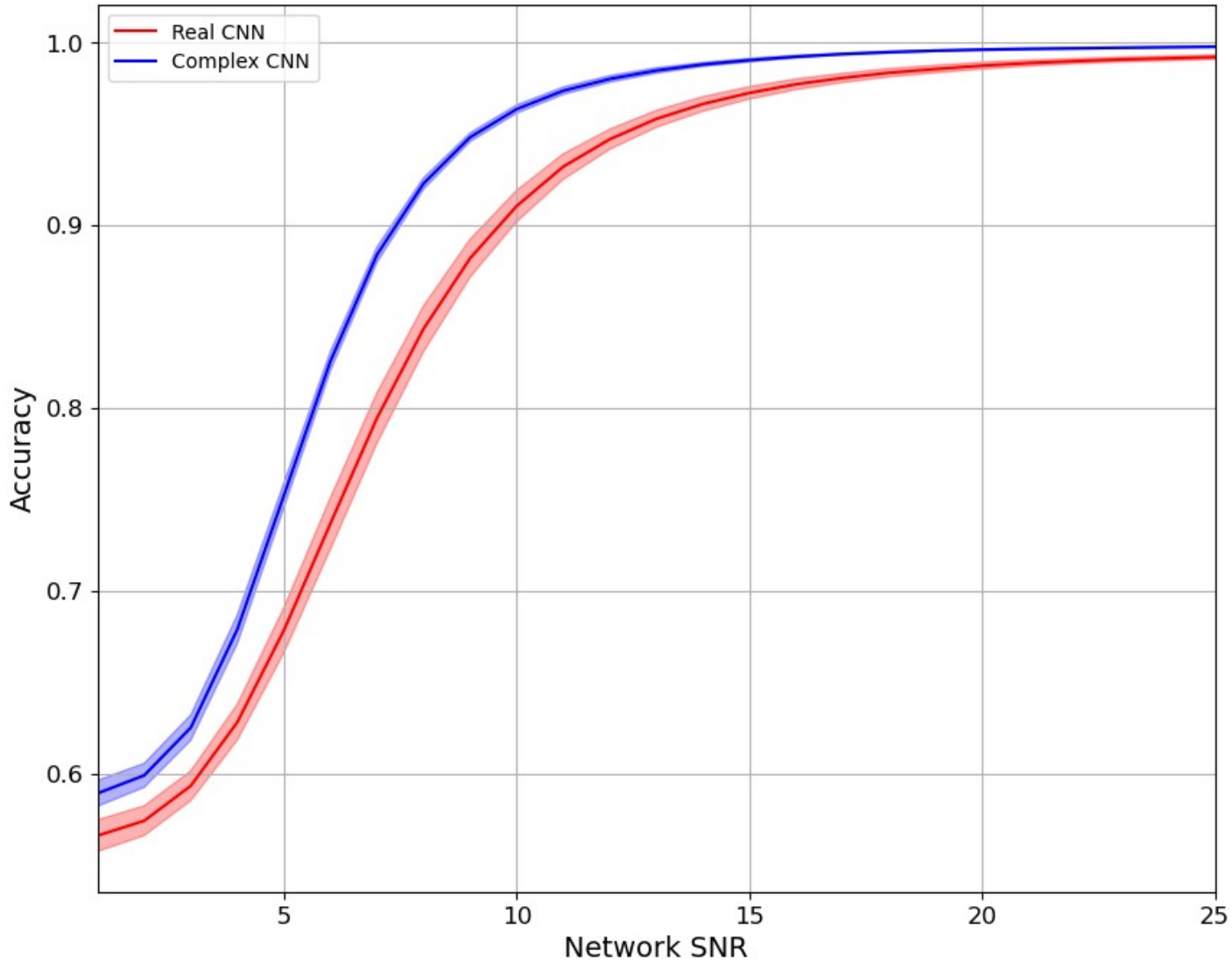


= 5× 1D convolution ($\boldsymbol{w} \in \mathbb{C}$), kernel 3 + Average pooling (kernel 4) + ℂReLU*

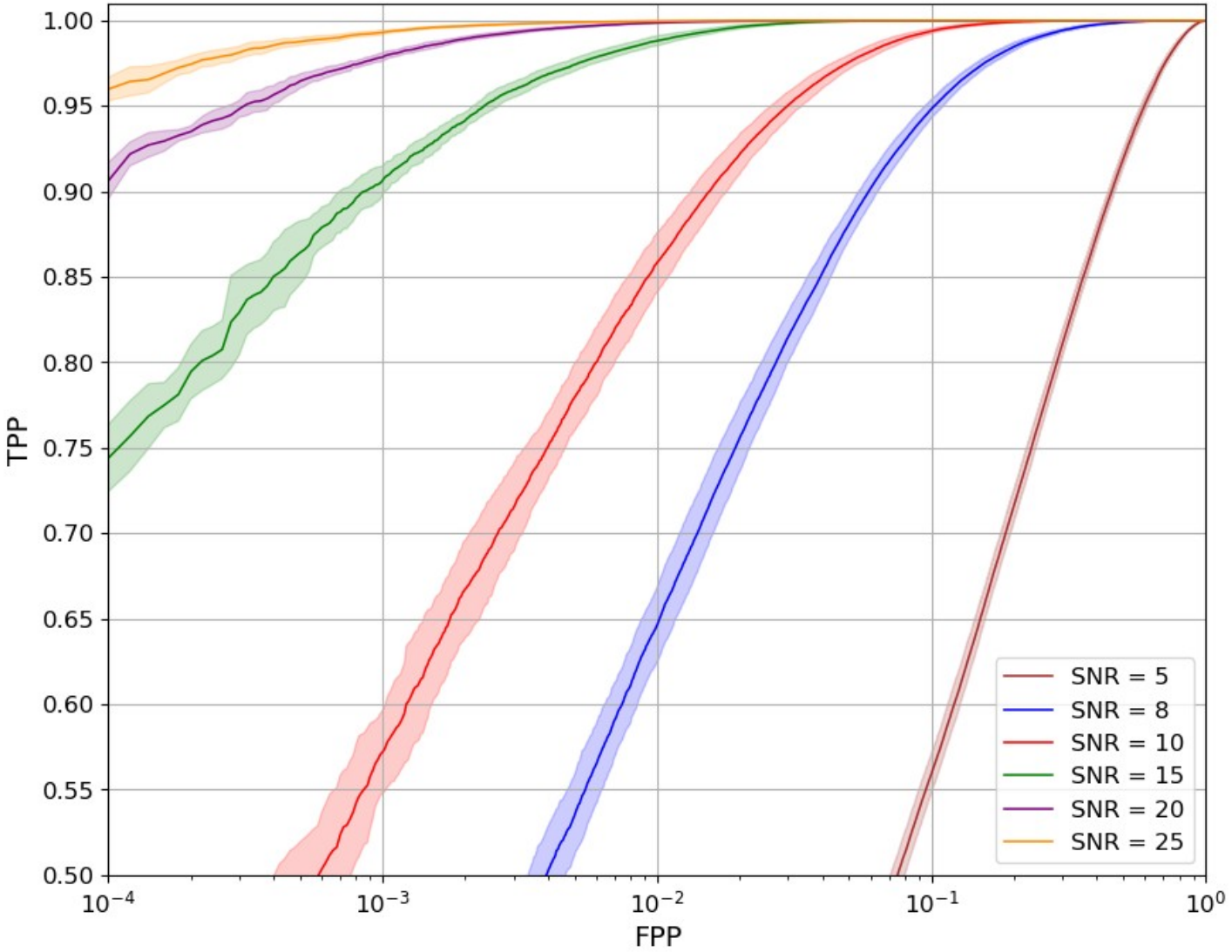
= MLP (16385 – 50 – 25) + ReLU

*e.g. Cole et al. 2021

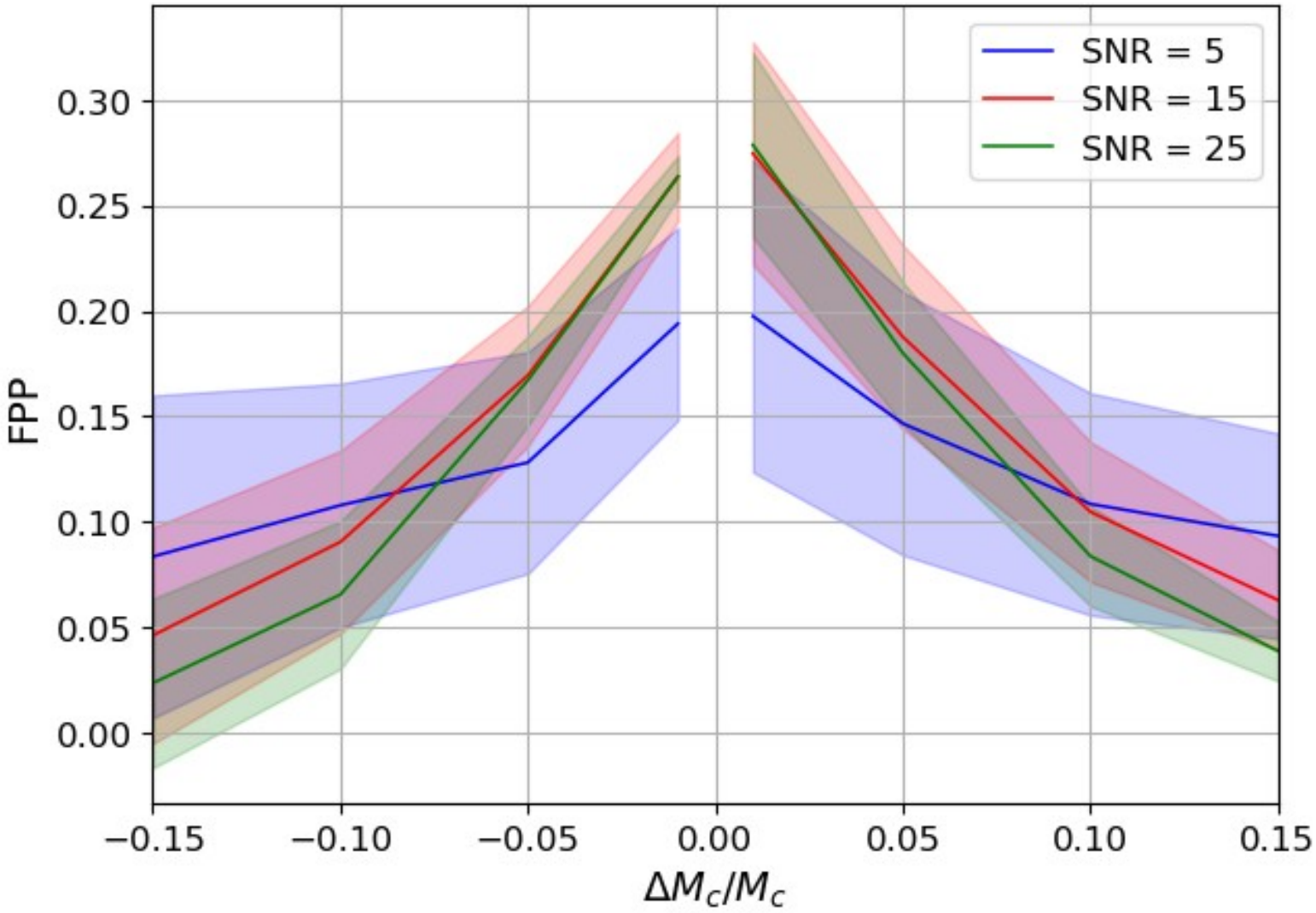
Real- vs Complex-valued CNN



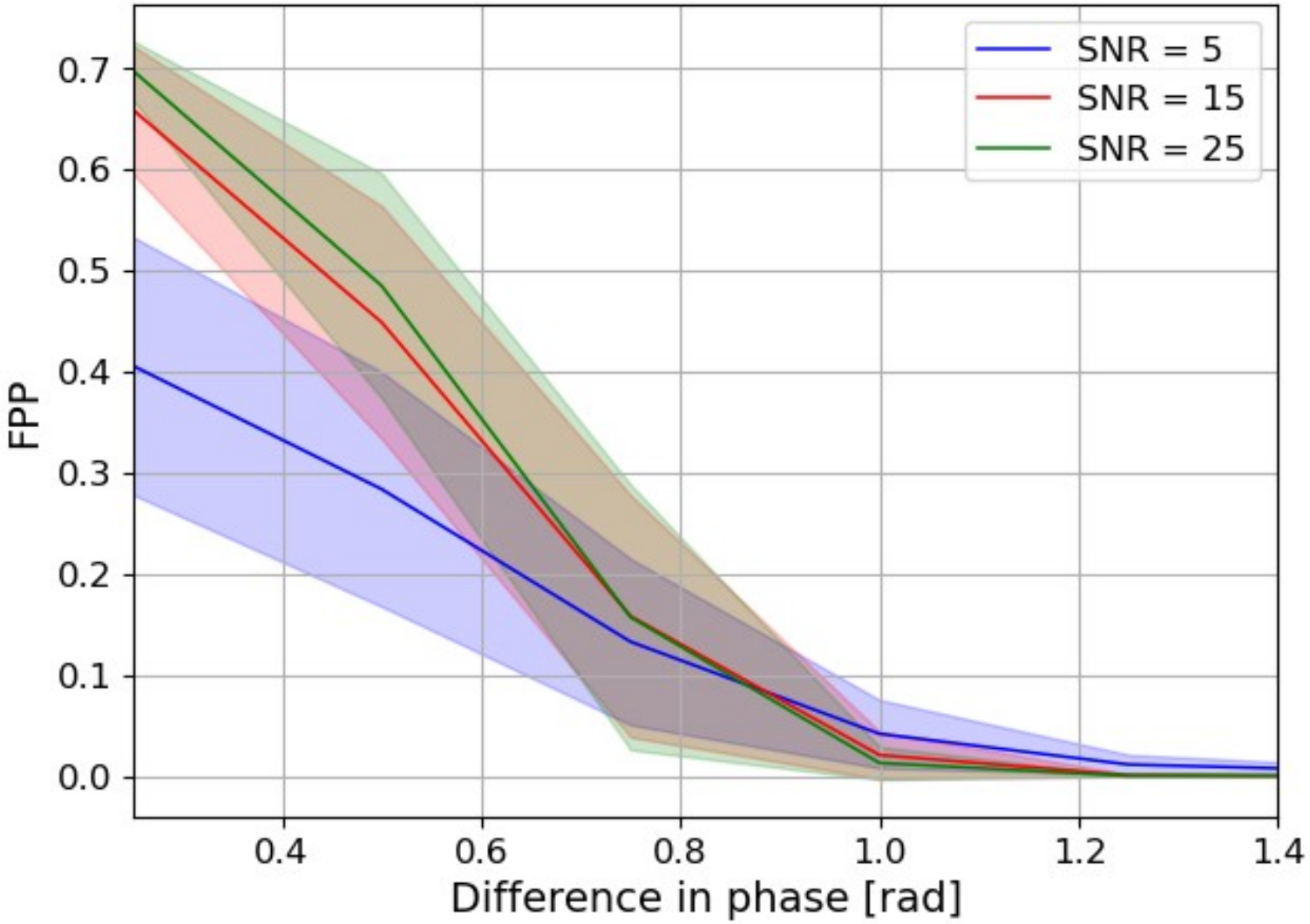
ROC curves/ TPP vs FPP



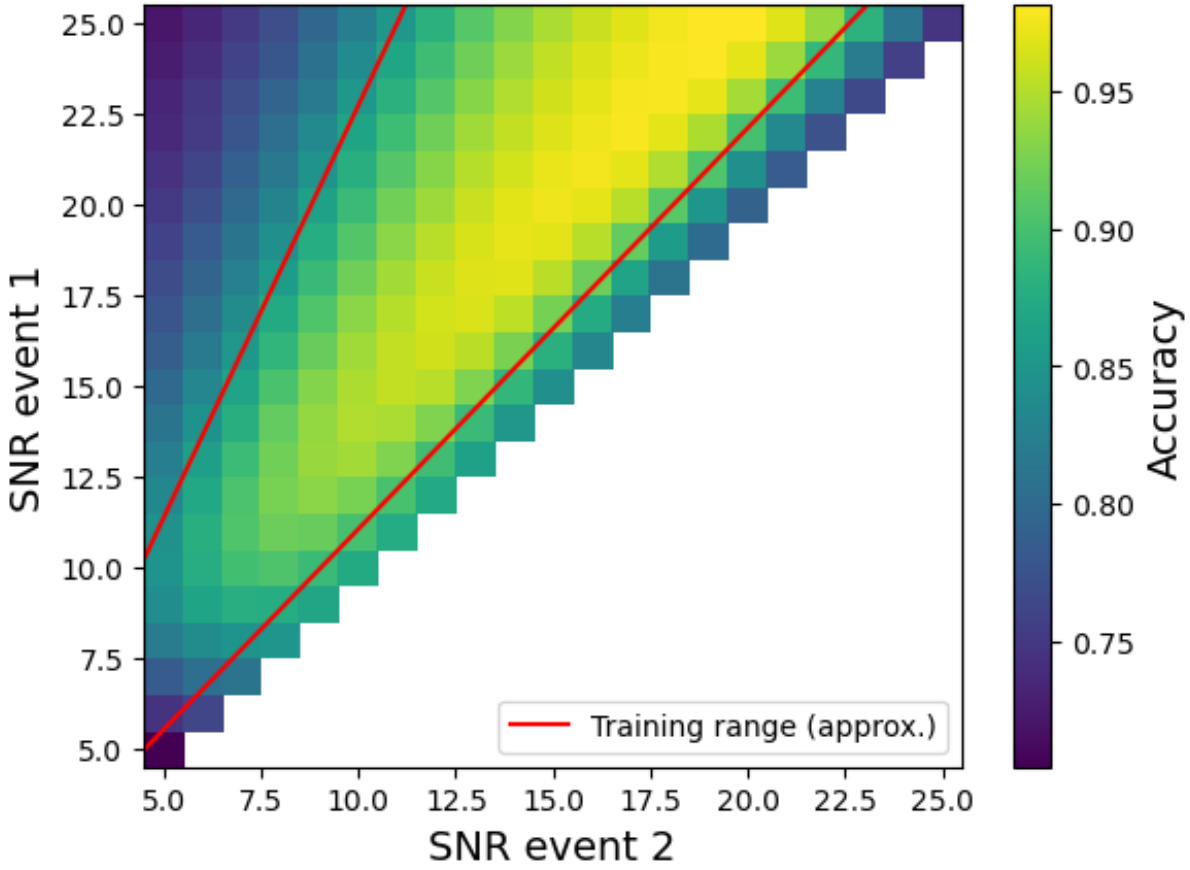
Sensitivity to a change in chirp mass

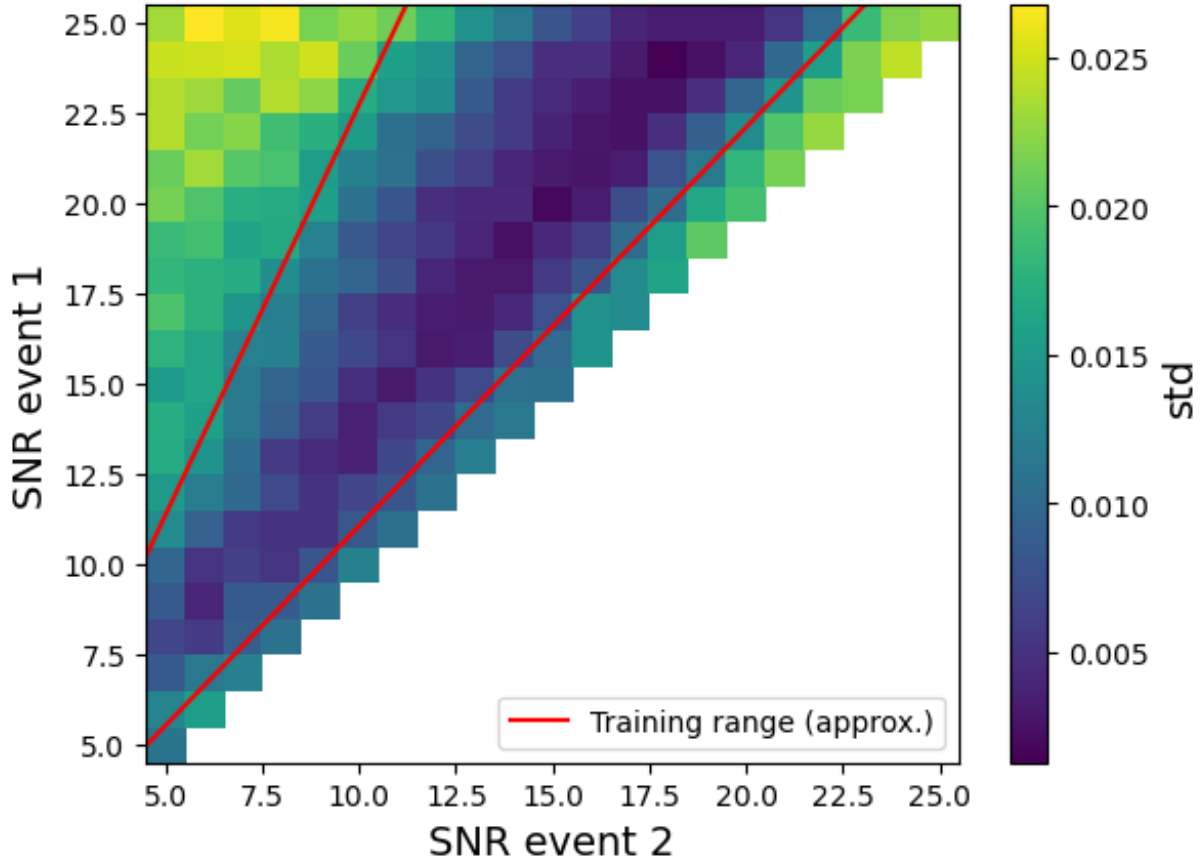


Sensitivity to a difference in initial phase

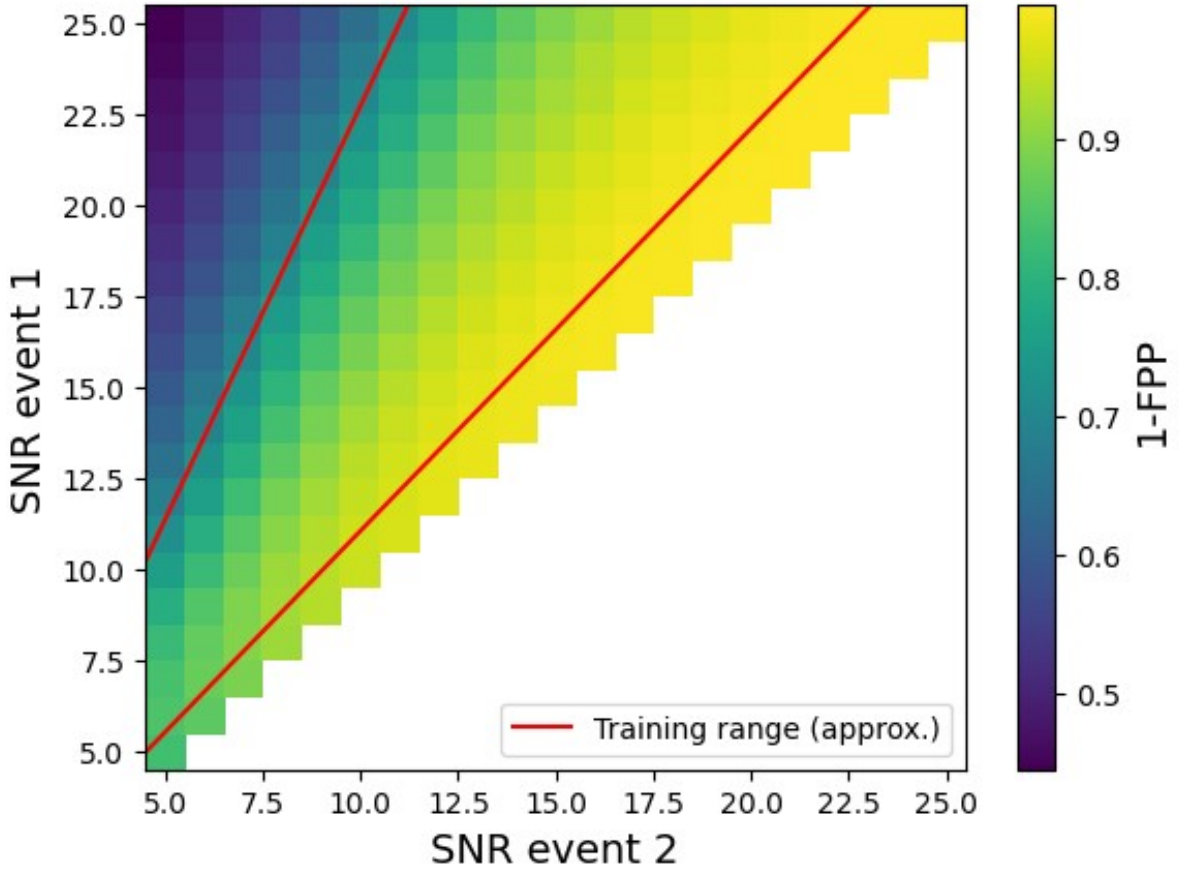


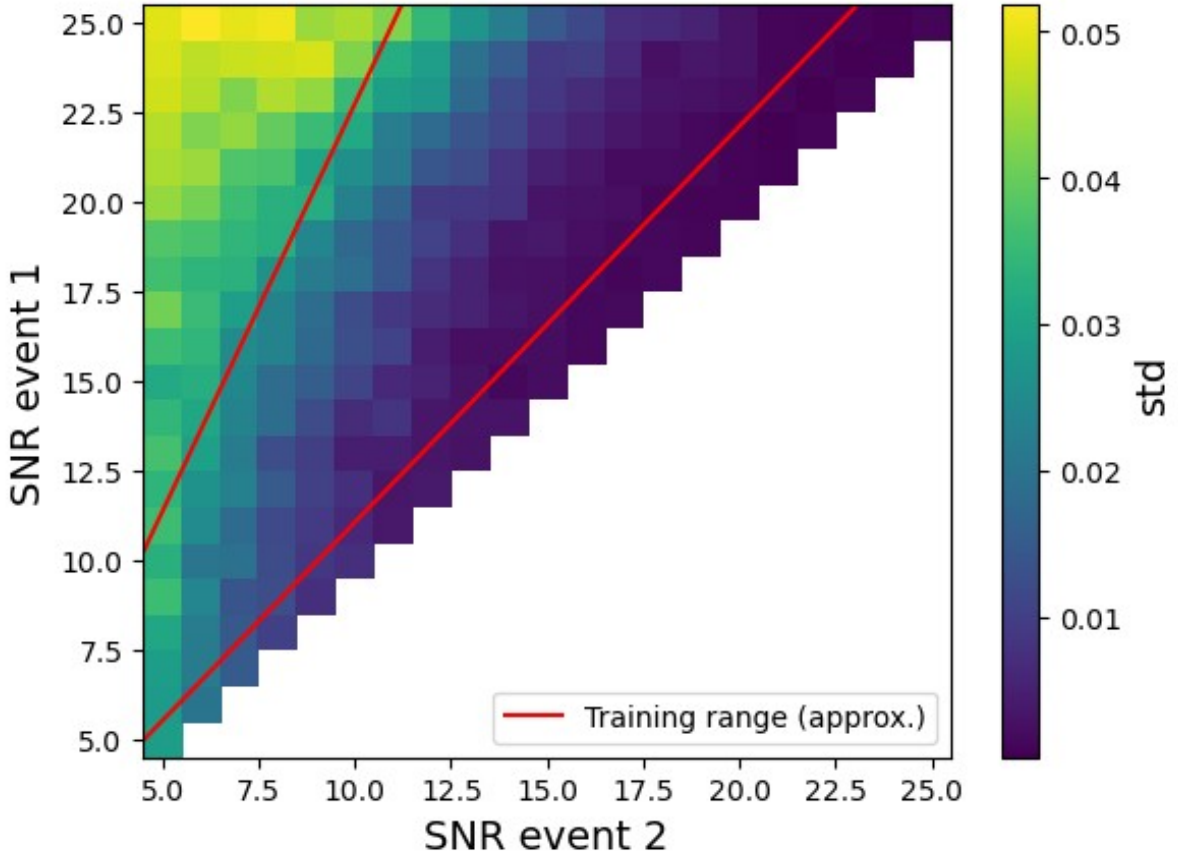
Per-SNR performance (1)





Per-SNR performance (2)





Per-SNR performance (3)