Searches for anomalies in the gravitational waves data

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Aim

Create a machine learning pipeline allowing detection of GW (of glitches) regardless of knowledge about assumed signal template (as in the case of matched filtering).

Anomalies

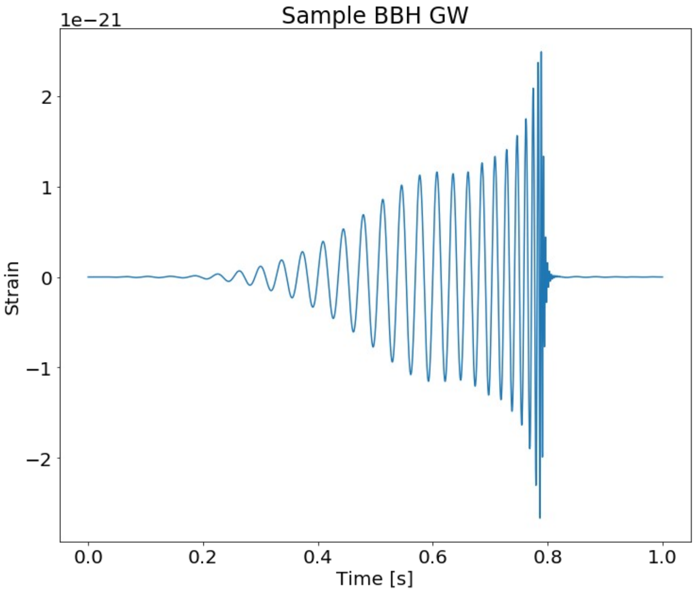
Everything that is not **usual** non-stationary noise found in the interferometer, like gravitational wave signals and glitches.

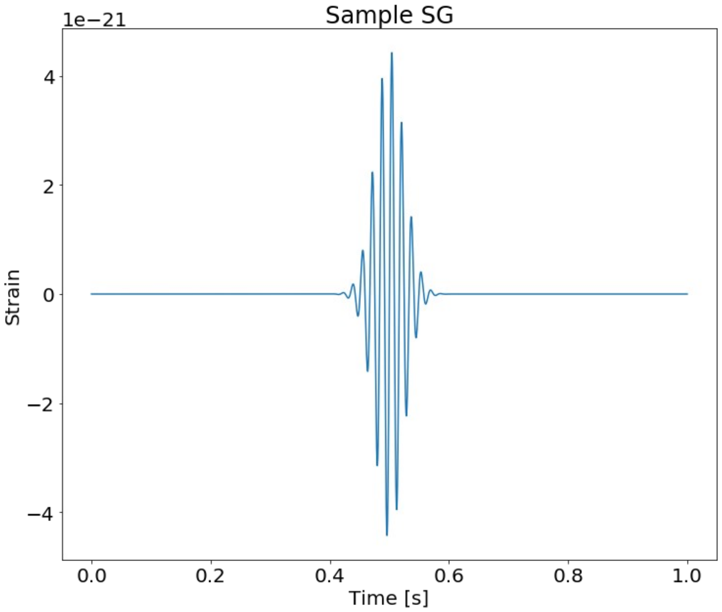
Concept

- Train the machine learning on the data consisting of real strain with injected anomalies as the input and pure noise as the output – train the model to reconstruct only noise
- By subtracting input from the output we should obtain either original anomaly signal (GW or glitch) or nothing in case of pure noise

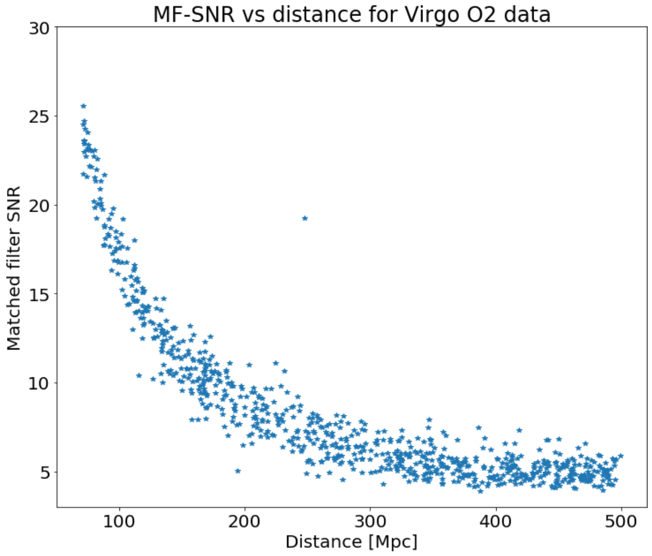
Data

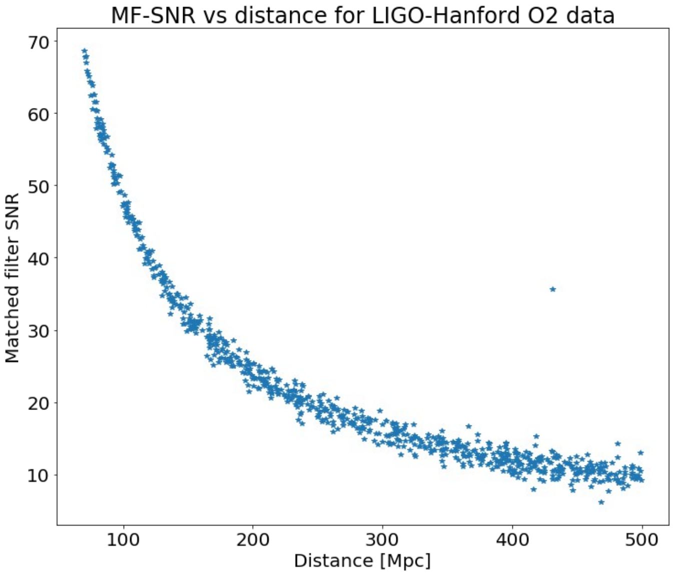
- 4 hours of whitened real O2 data with injected anomalies (binary black holes - BBH and sine-gaussian - SG glitches) every 10 second

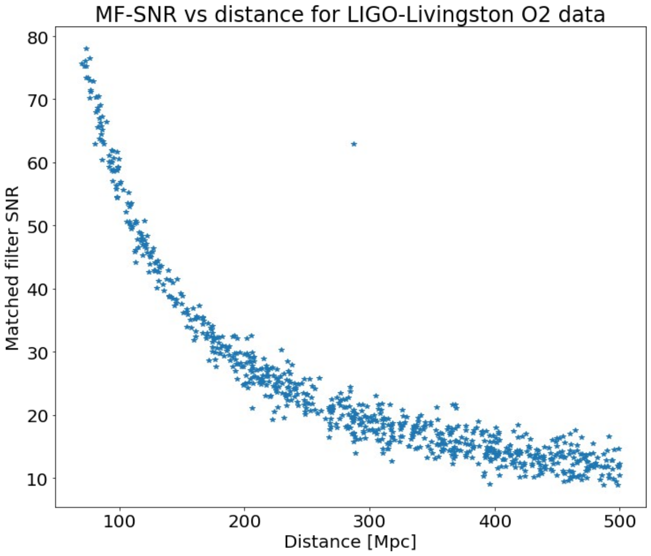




SNR vs distance





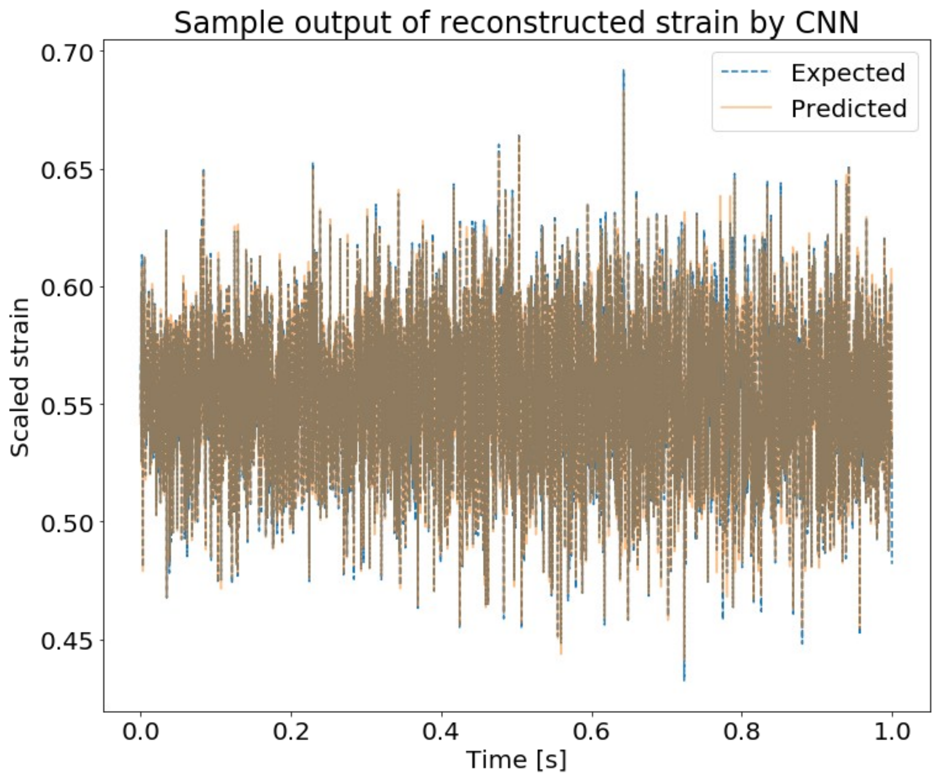


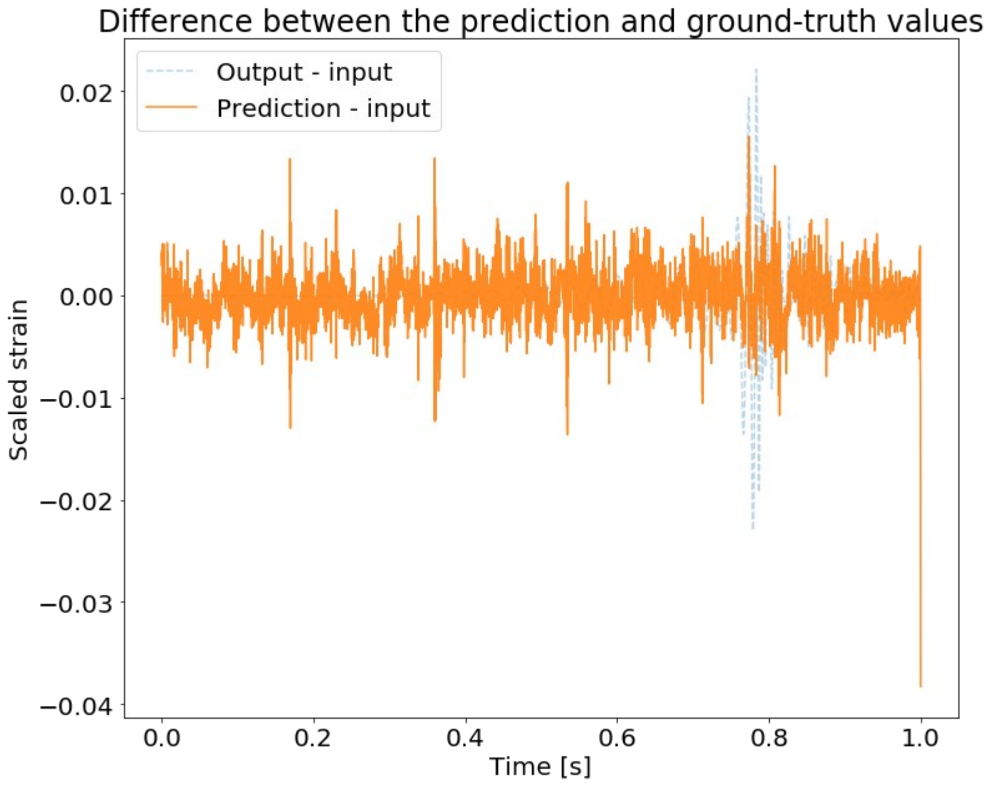
Architecture

- AE CNN with three hidden layers: (256, 128, 256) and kernel of size 3
- Activation functions: *relu* for hidden layers and *sigmoid* for the output
- Adam optimizer with learning rate of 0.0005
- Mean Squared Error loss function

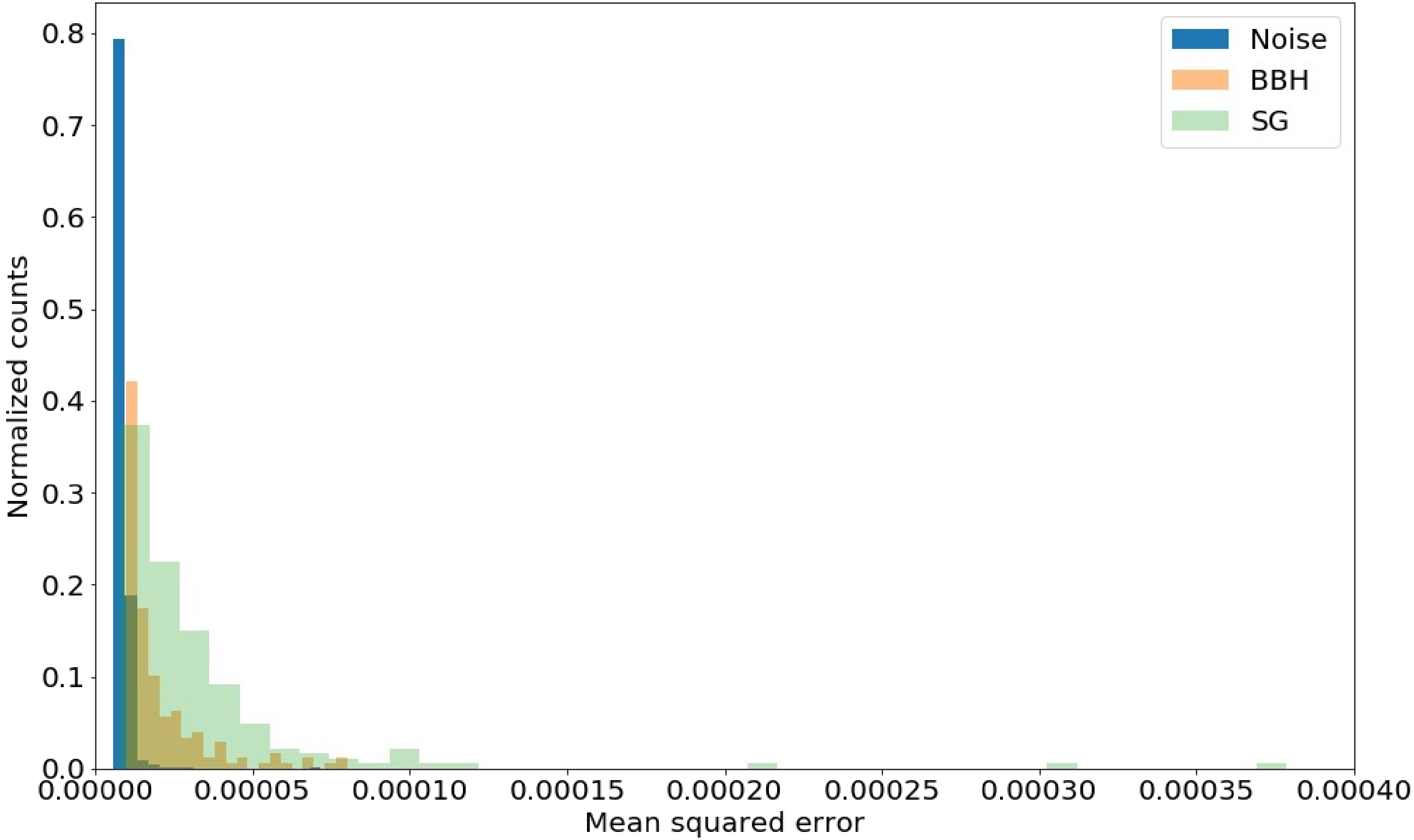
Virgo results

Virgo: sample output

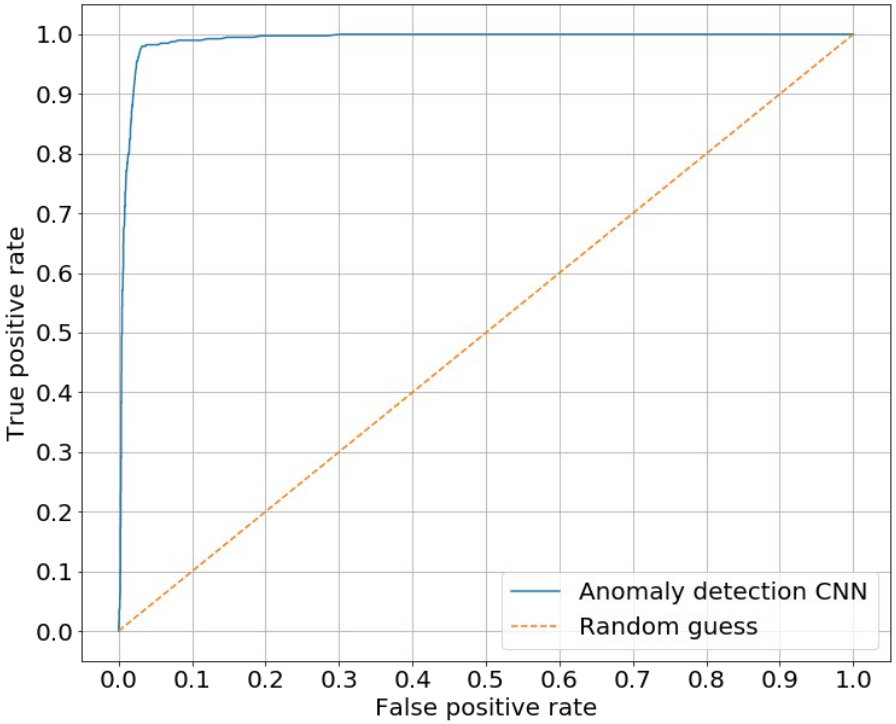




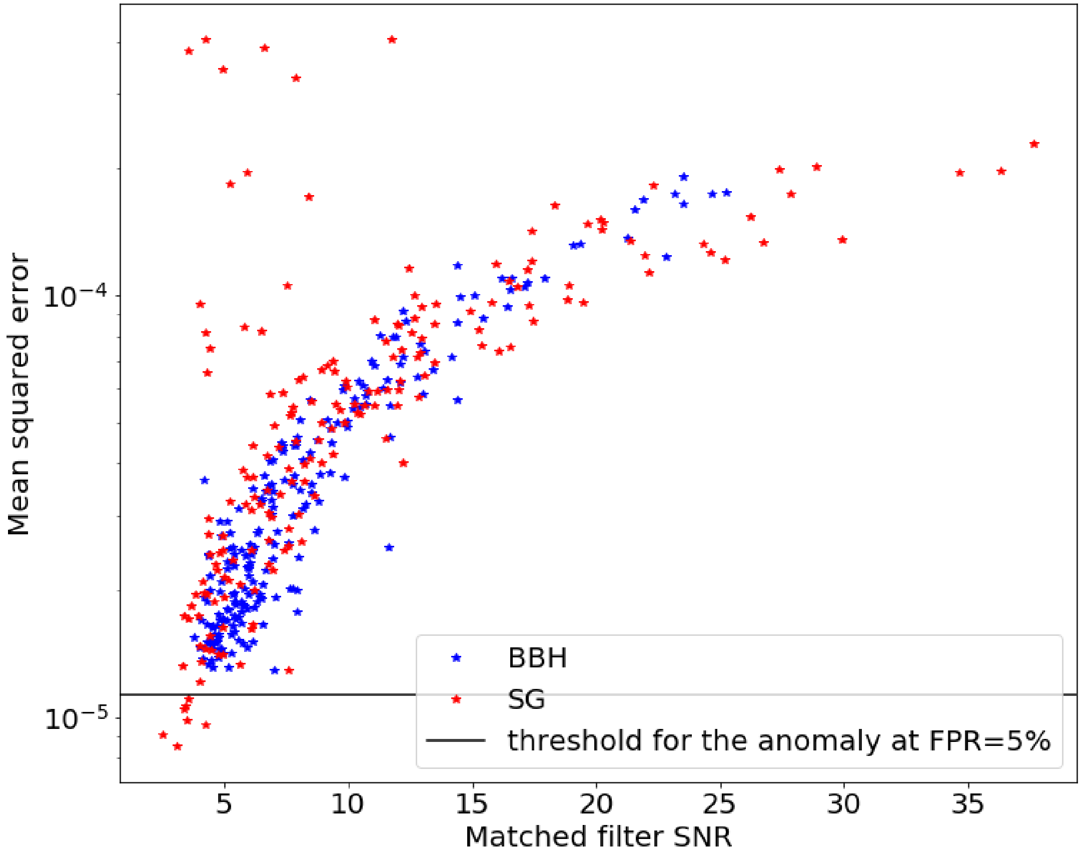
Virgo: MSE distributions



Virgo: anomaly threshold

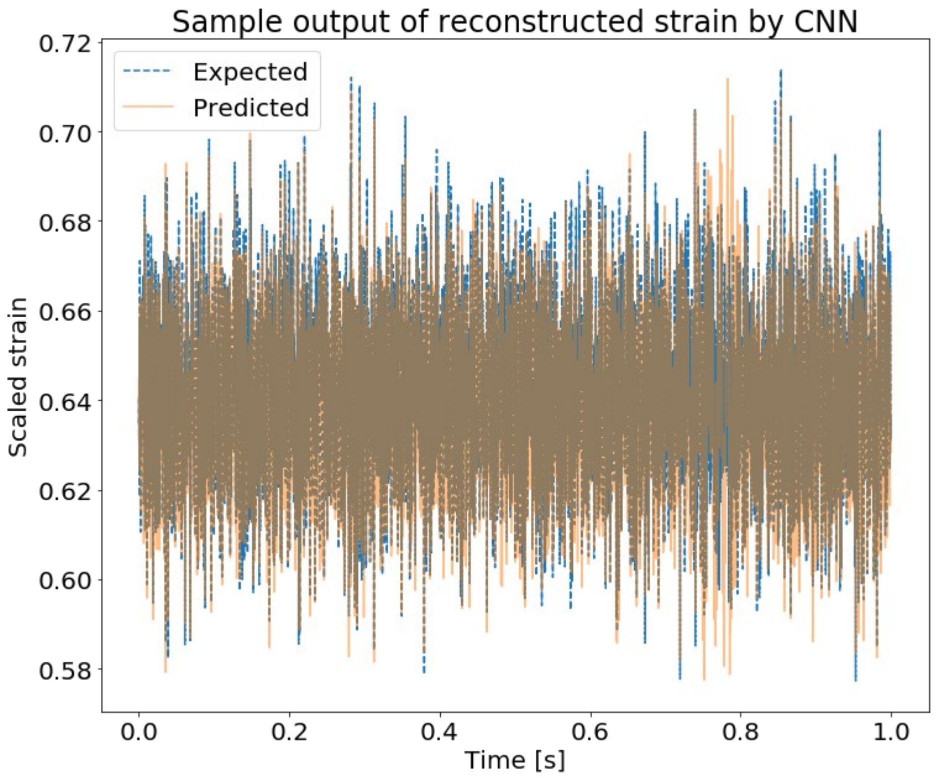


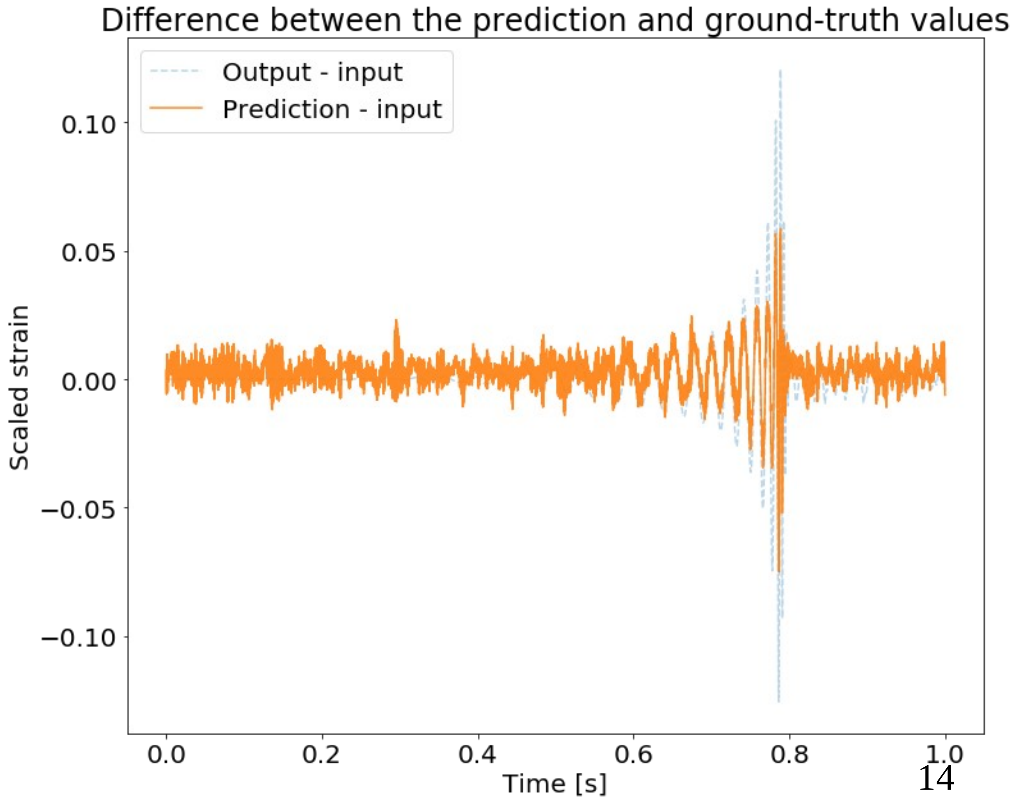
Virgo: MF-SNE vs MSE



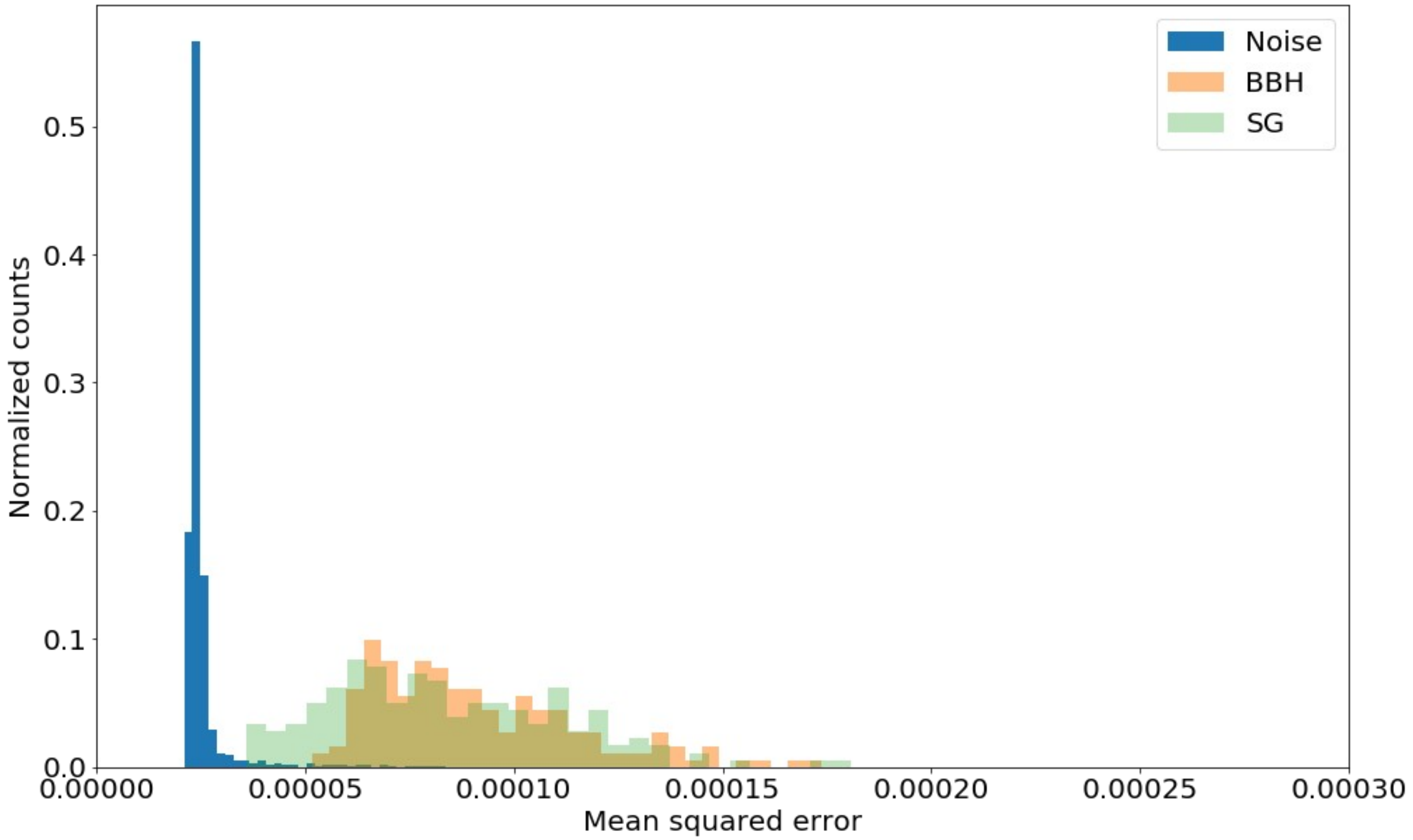
LIGO-Hanford results

Hanford: sample output

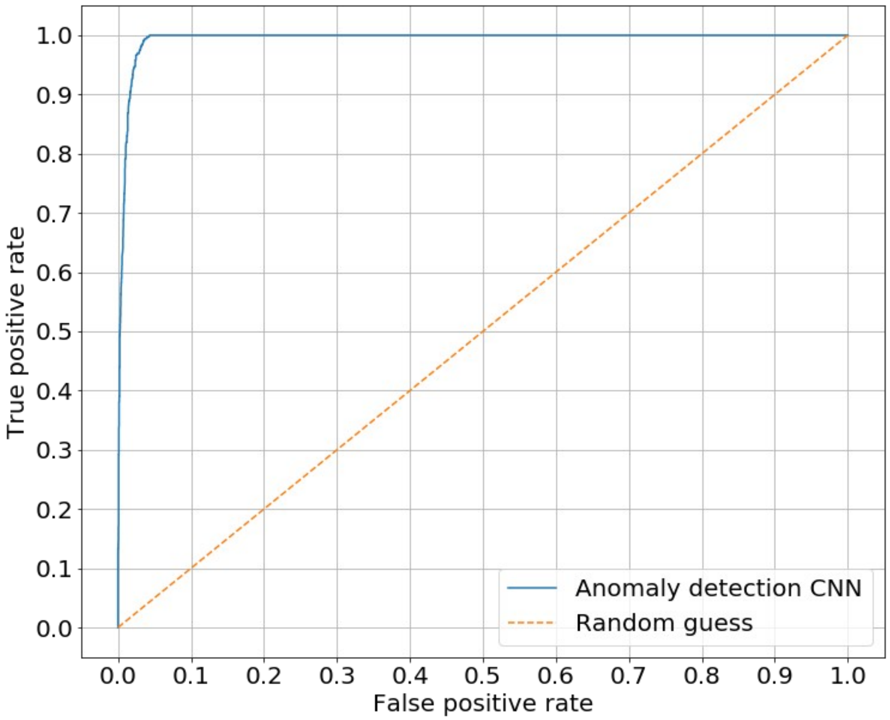




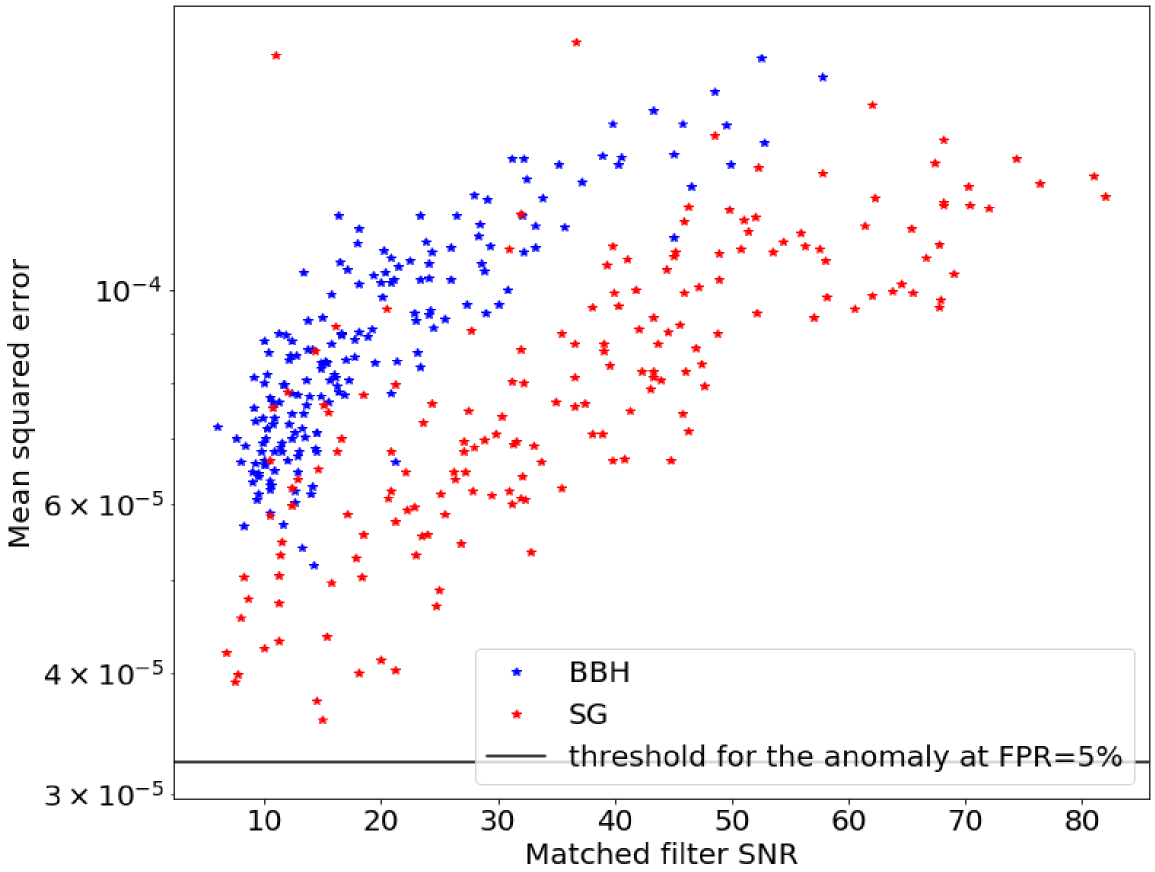
Hanford: MSE distributions



Hanford: anomaly threshold

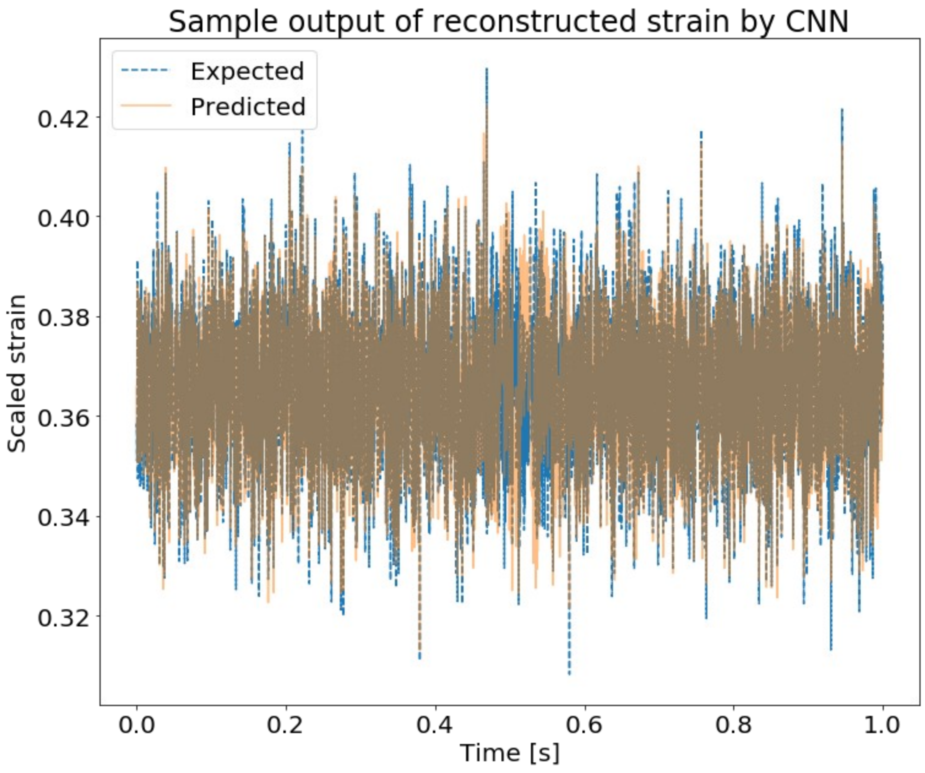


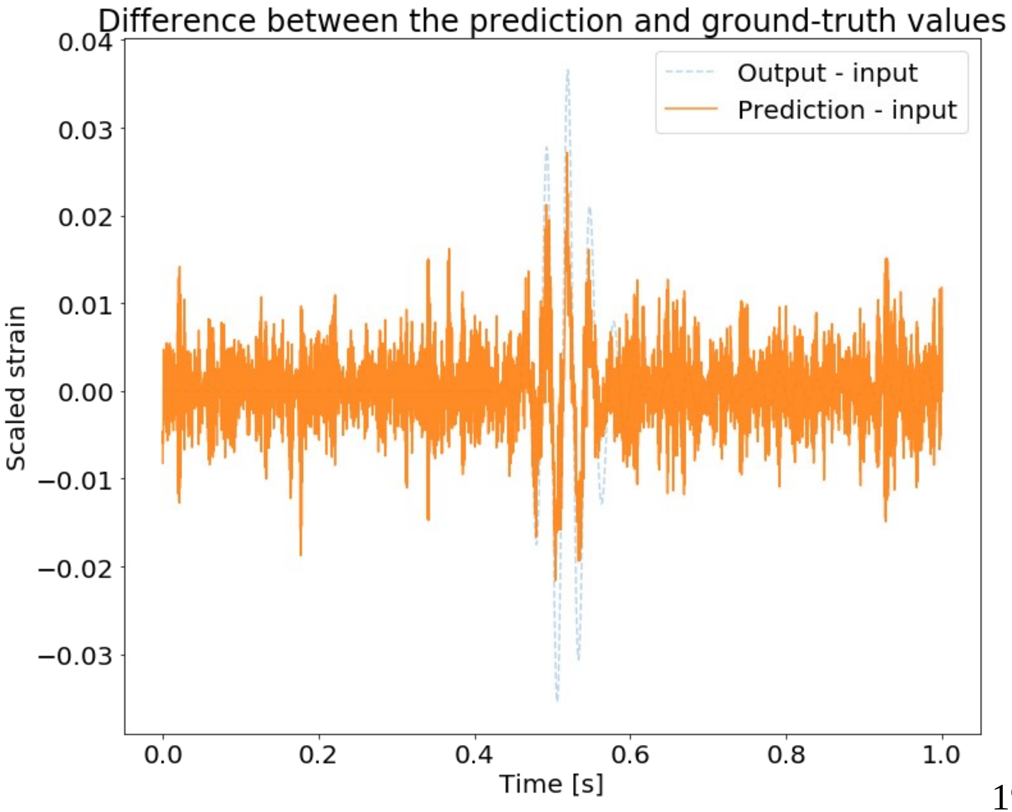
Hanford: MF-SNE vs MSE



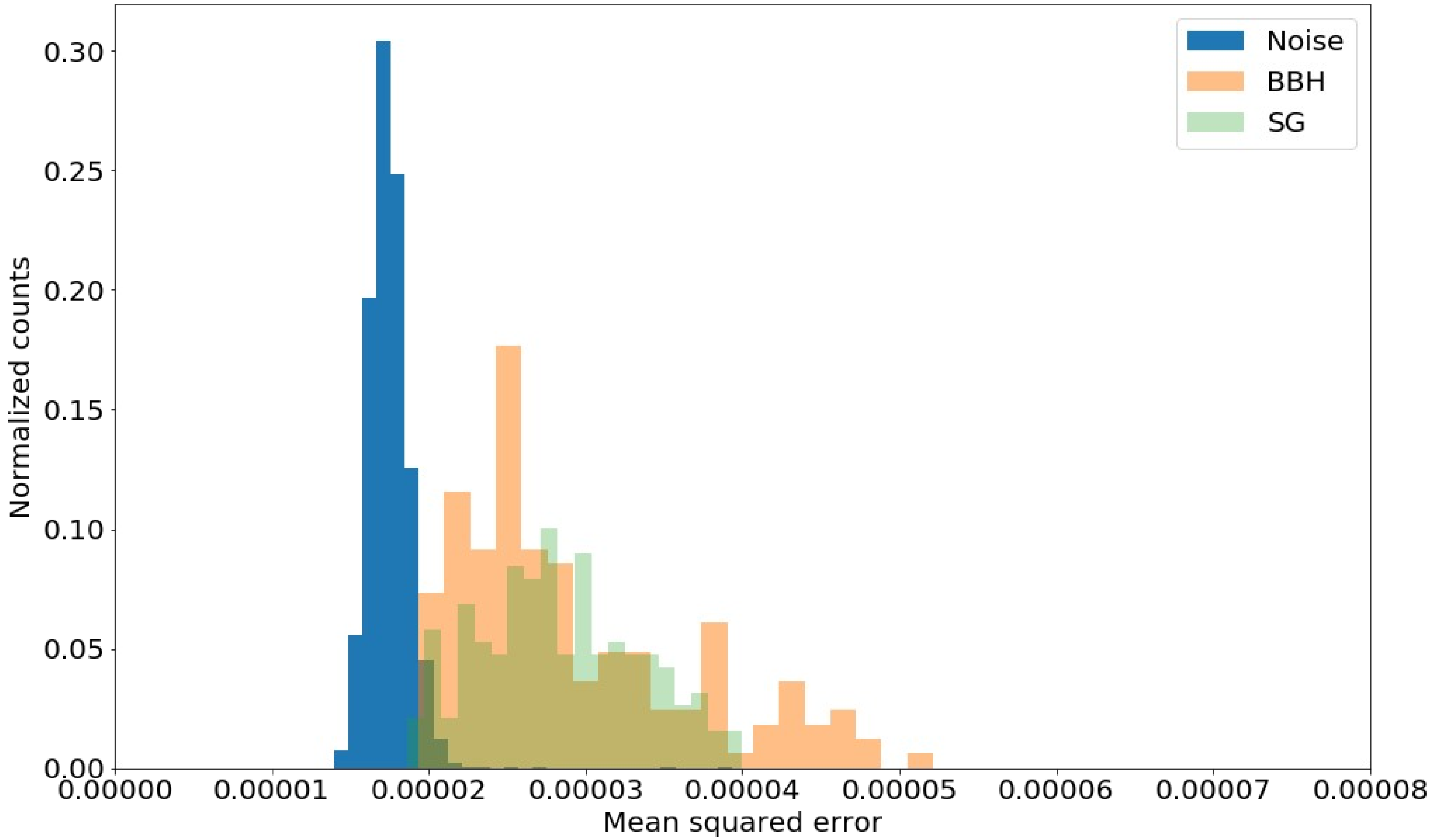
LIGO-Livingston

Livingston: sample output

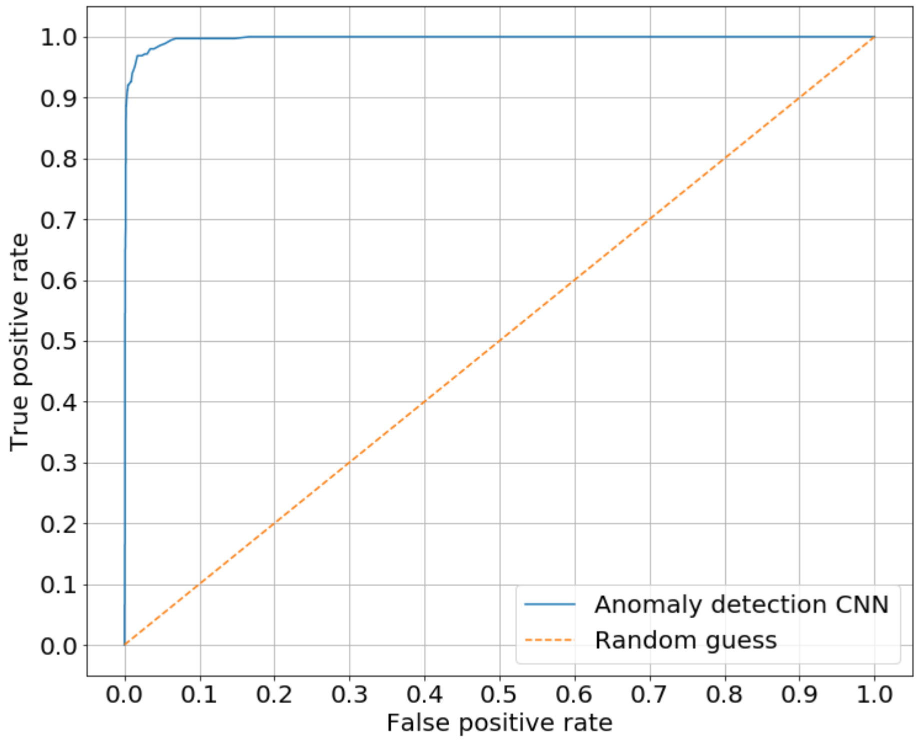




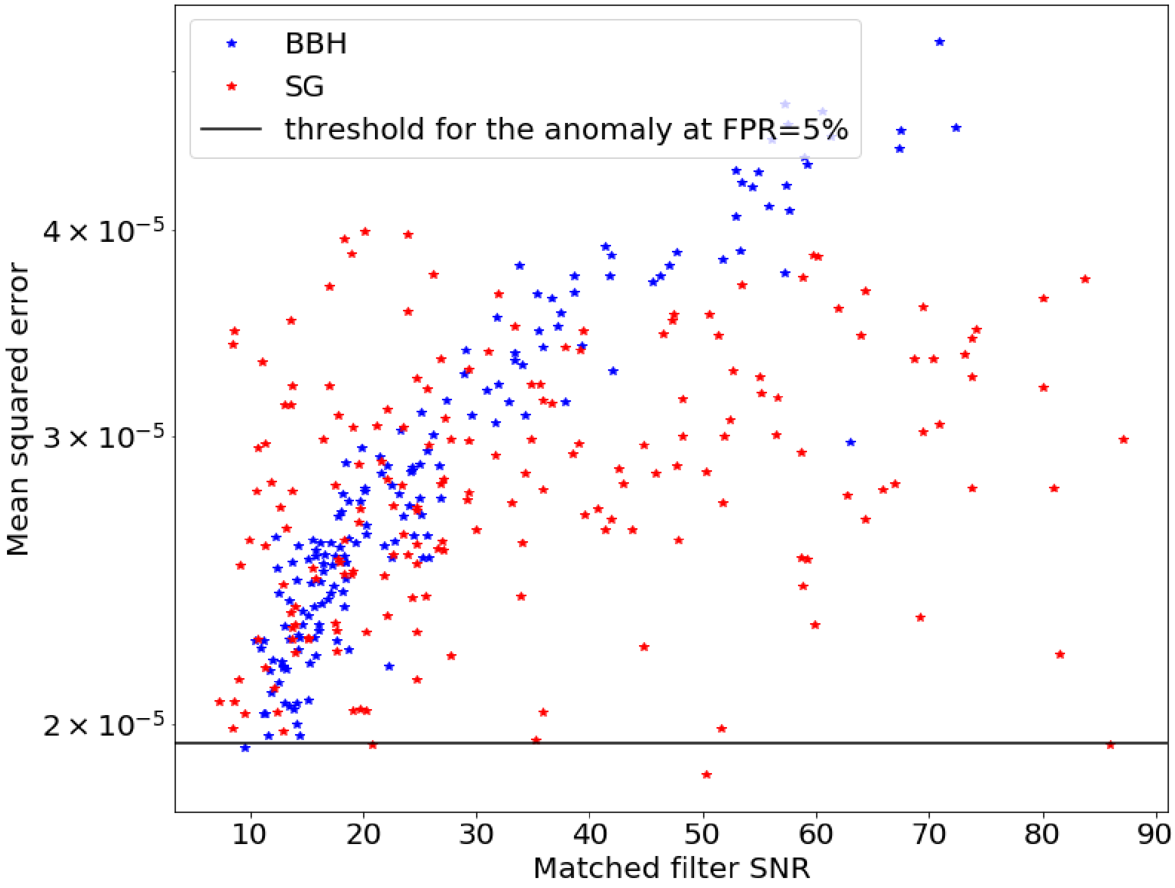
Livingston: MSE distributions



Livingston: anomaly threshold



Livingston: MF-SNE vs MSE



We can detect anomalies using machine learning!