Low Latency Noise Subtraction of Gravitational Wave Data by DeepClean

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in collaboration with
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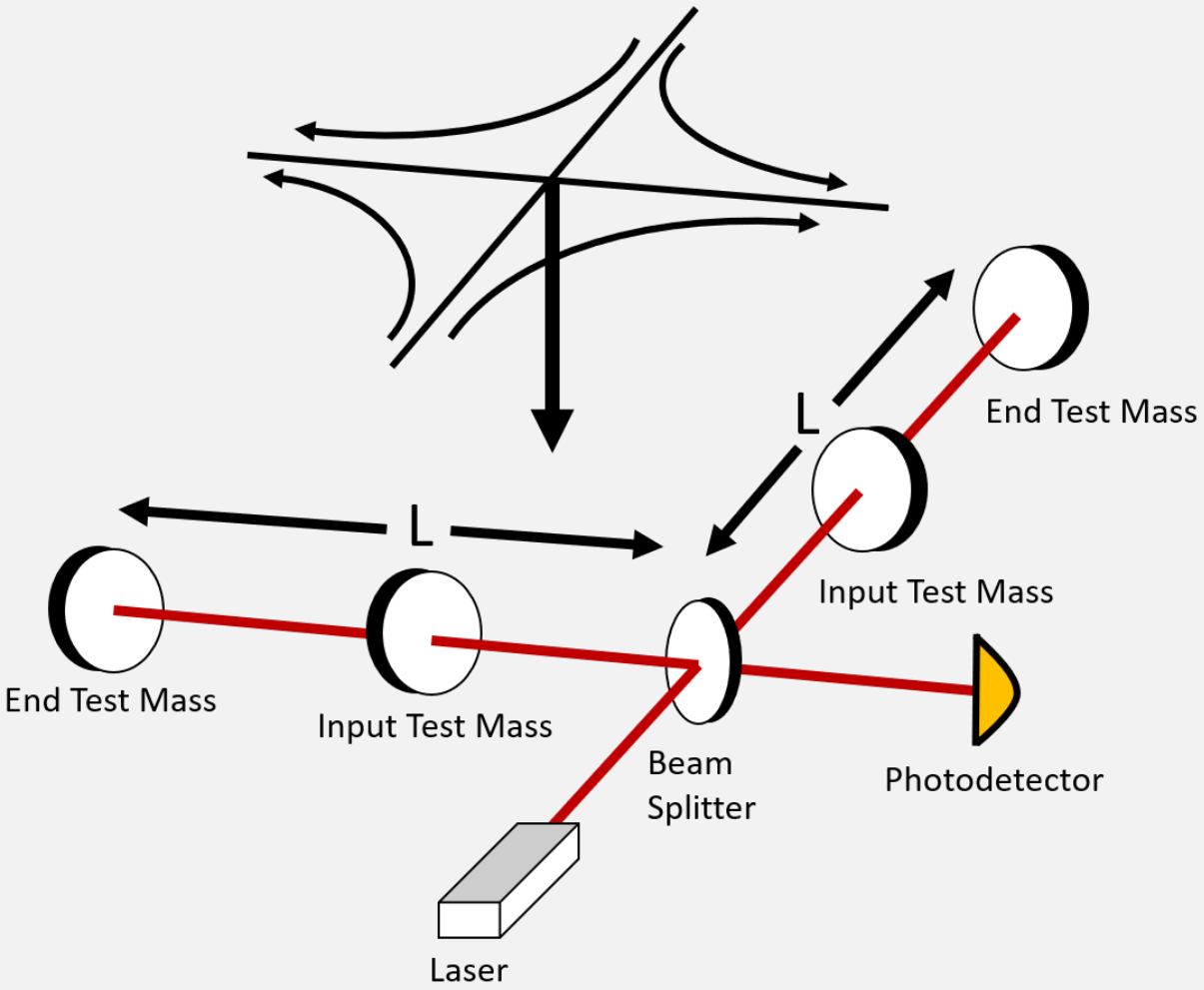
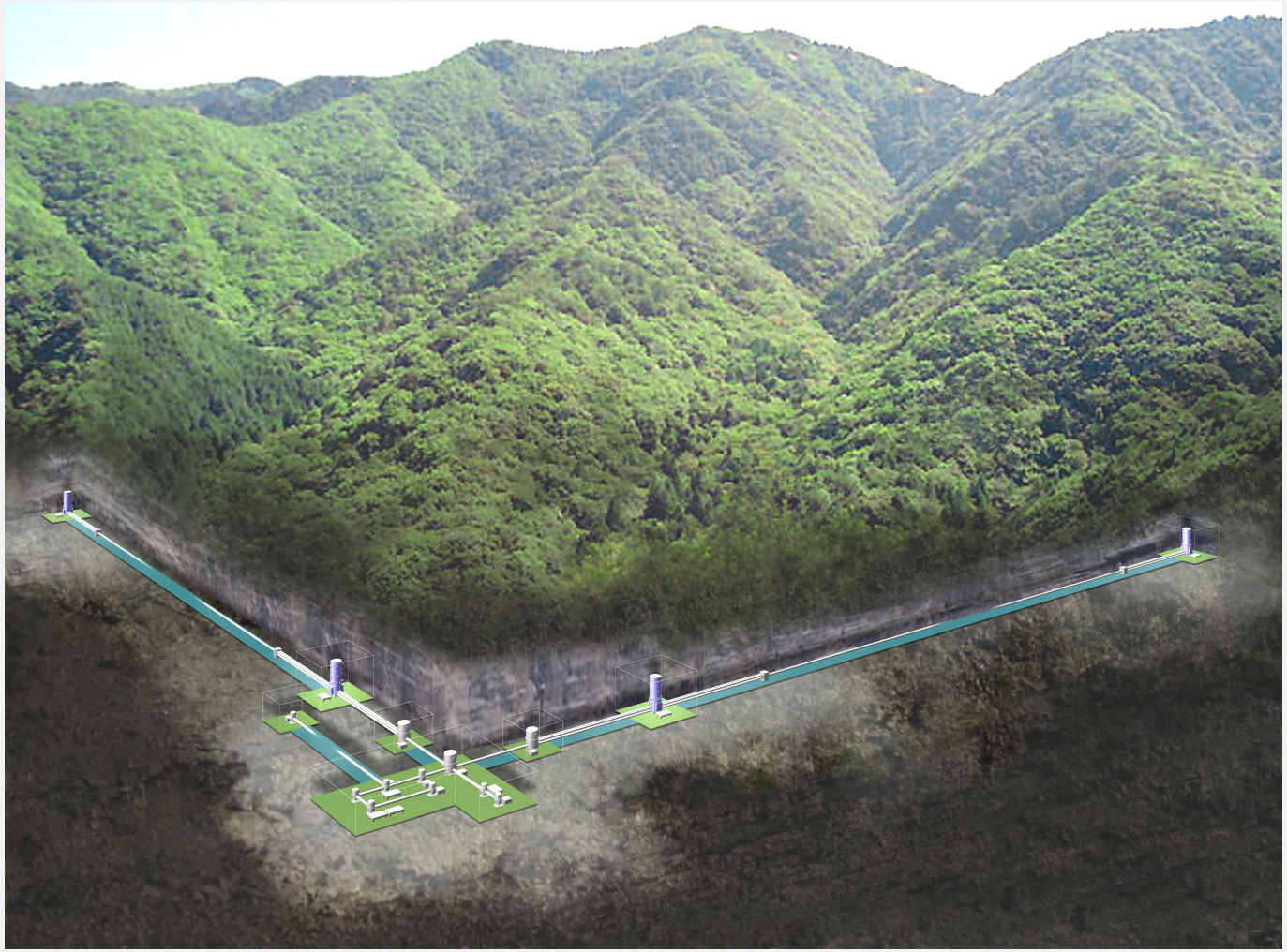
Fast Machine Learning for Science Workshop 2022

Gravitational Wave Detector

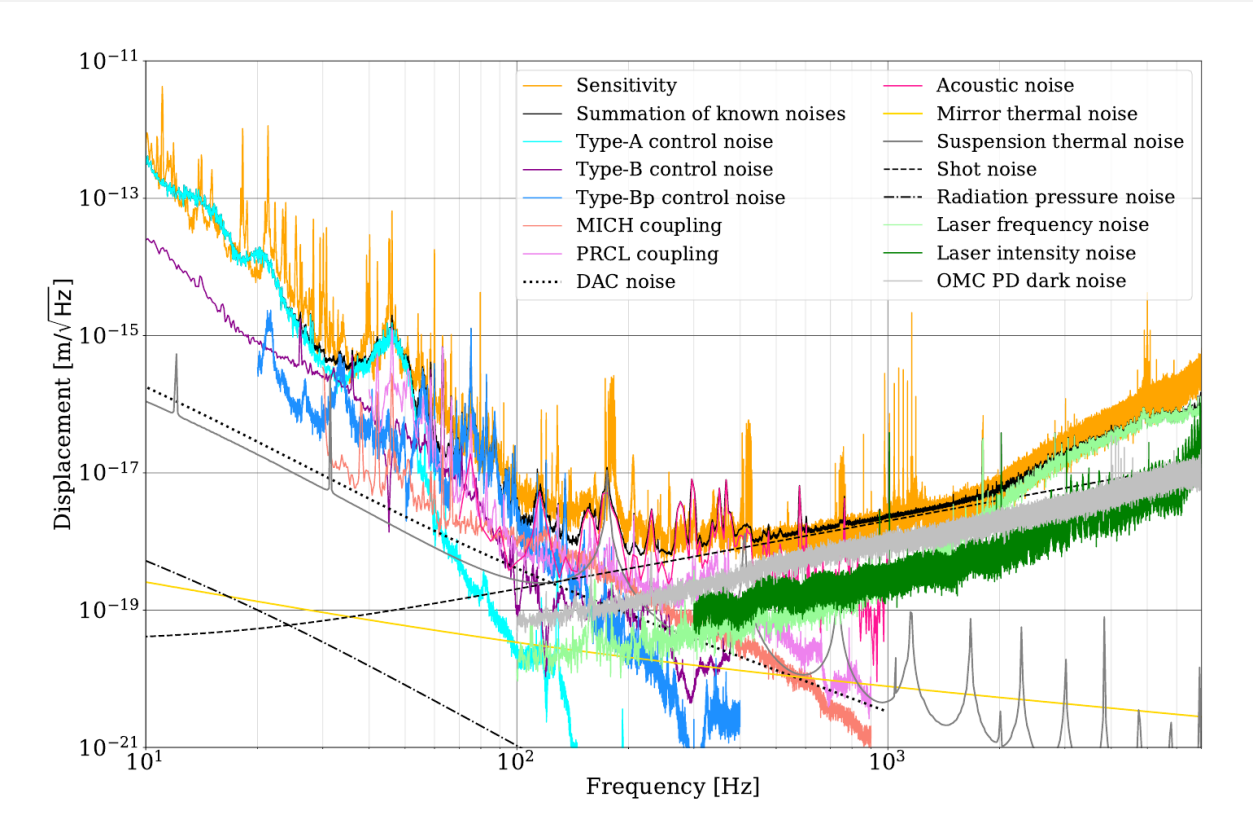


Gravitaional Wave Detector: KAGRA



Gravitational Wave Data: KAGRA

GW strain: $h(t) = \frac{\Delta L(t)}{L} \sim 10^{-22}$.



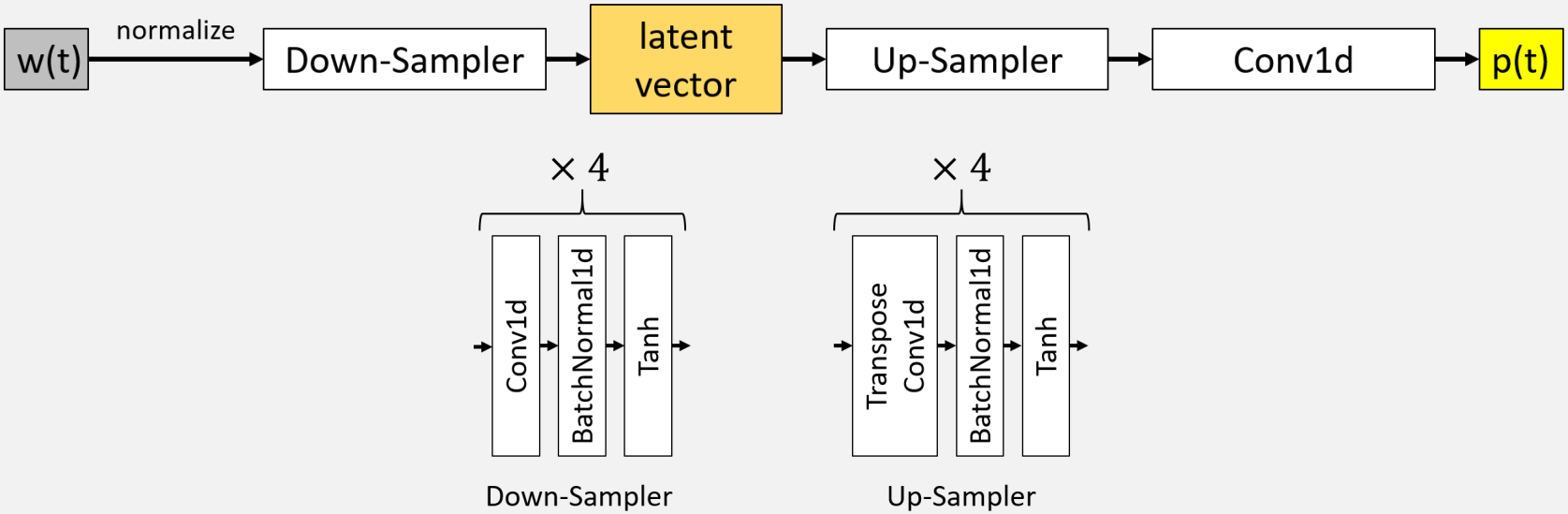
from [2203.07011]

Noise Subtraction by DeepClean in KAGRA

- The goal of KAGRA during O4 run: First successful detection of GW signal.
- Assistance of the noise source investigation.
- Low latency noise subtraction pipeline.

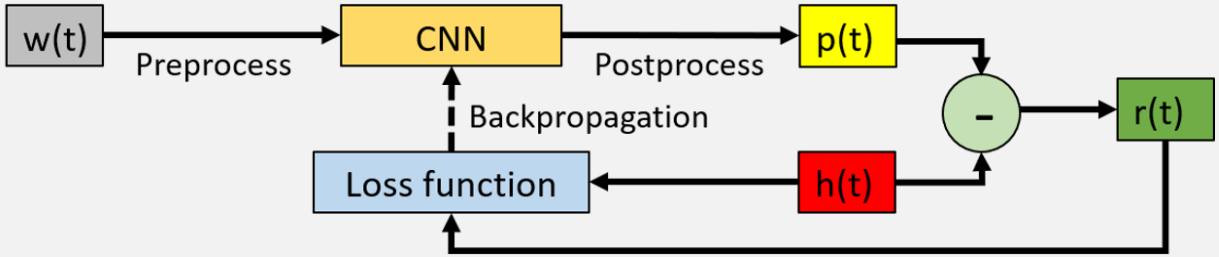
Deepclean

- Convolutional Neural Network (CNN) model.
- w(t) must have high correlation to h(t) and not couple to GW signals.



References: 2005.06534, 2108.12430, deepclean-prod

Deepclean

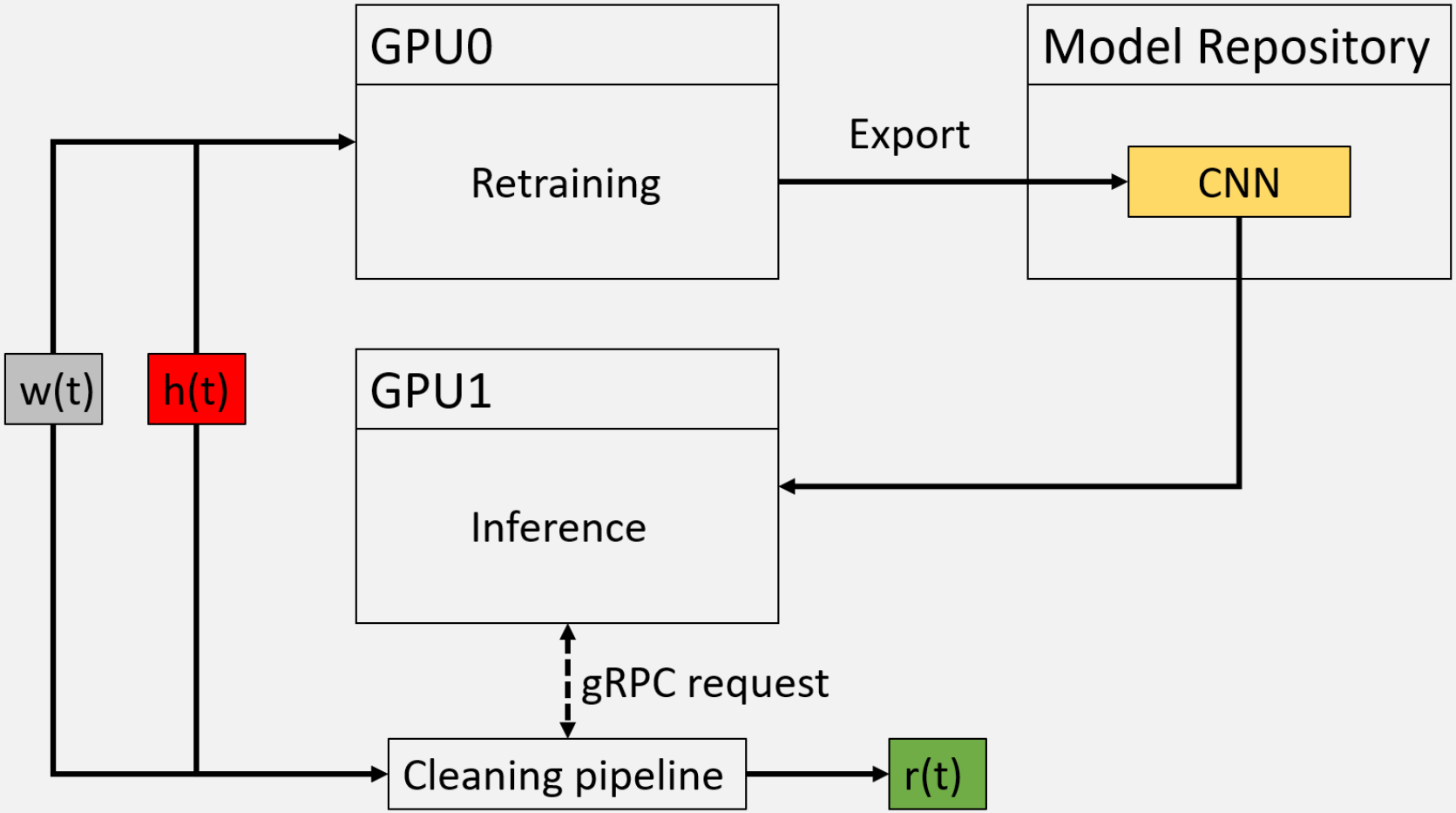


- w(t): witness channels
- p(t): predicted noise
- h(t): raw strain
- r(t): cleaned strain
- Loss function:
  $J = \omega J_{asd} + (1 - \omega) J_{mse}$

$$J_{asd} = \frac{1}{M} \sum_{i=0}^{M-1} \sqrt{\frac{S[r,r][i]}{S[h,h][i]}},$$

$$J_{mse} = \frac{1}{N} \sum_{i=0}^{N-1} r[i]^2,$$

Inference as a Service (IaaS)

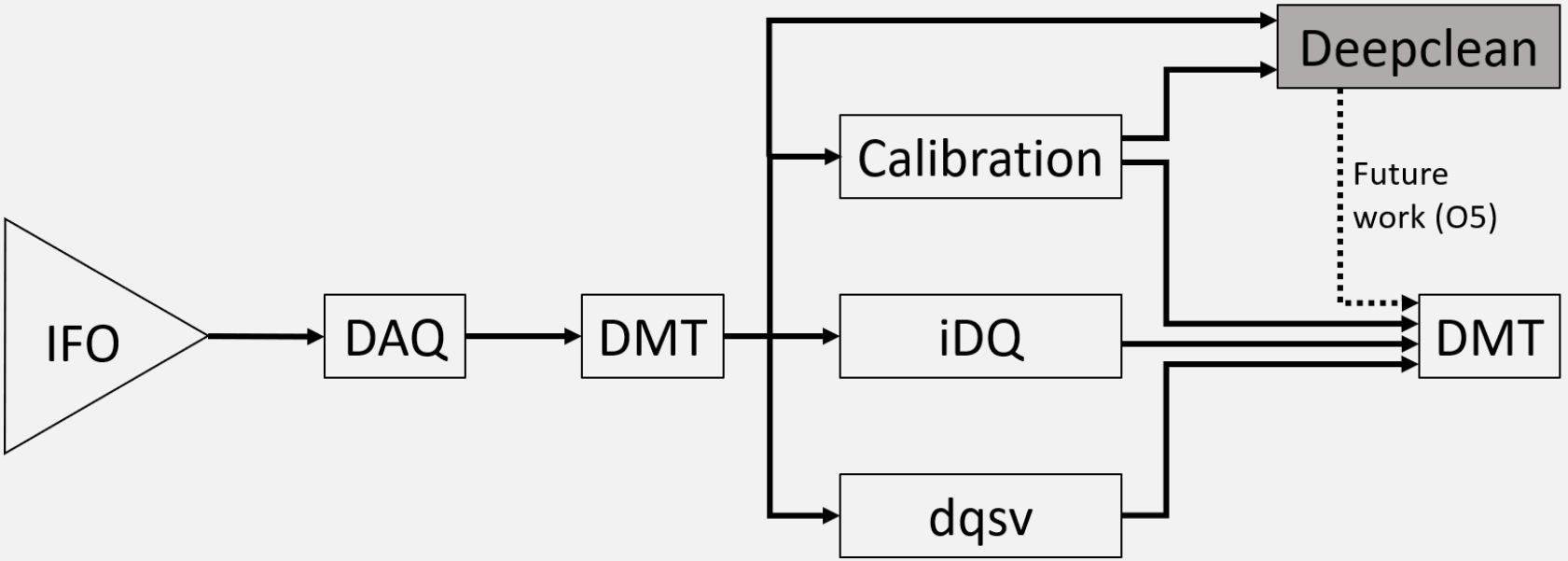


Summary and Future Plans

- Deepclean of AC power noise on the Mock Data Challenge from O3GK run and evaluate the performance by various data analyses of the injected events.
- Establishment of the IaaS pipeline for the O4 run in LIGO and KAGRA.
- Removal of low-frequency suspension noise, acoustic noise, etc..
- Optimizing online Deepclean during O4, aiming for the reliable cleaned strain in low latency.

Thank you

Pipeline in KAGRA during O4



Pilot test on removing AC noise, calibration lines.

Offline Cleaning on O3GK Data

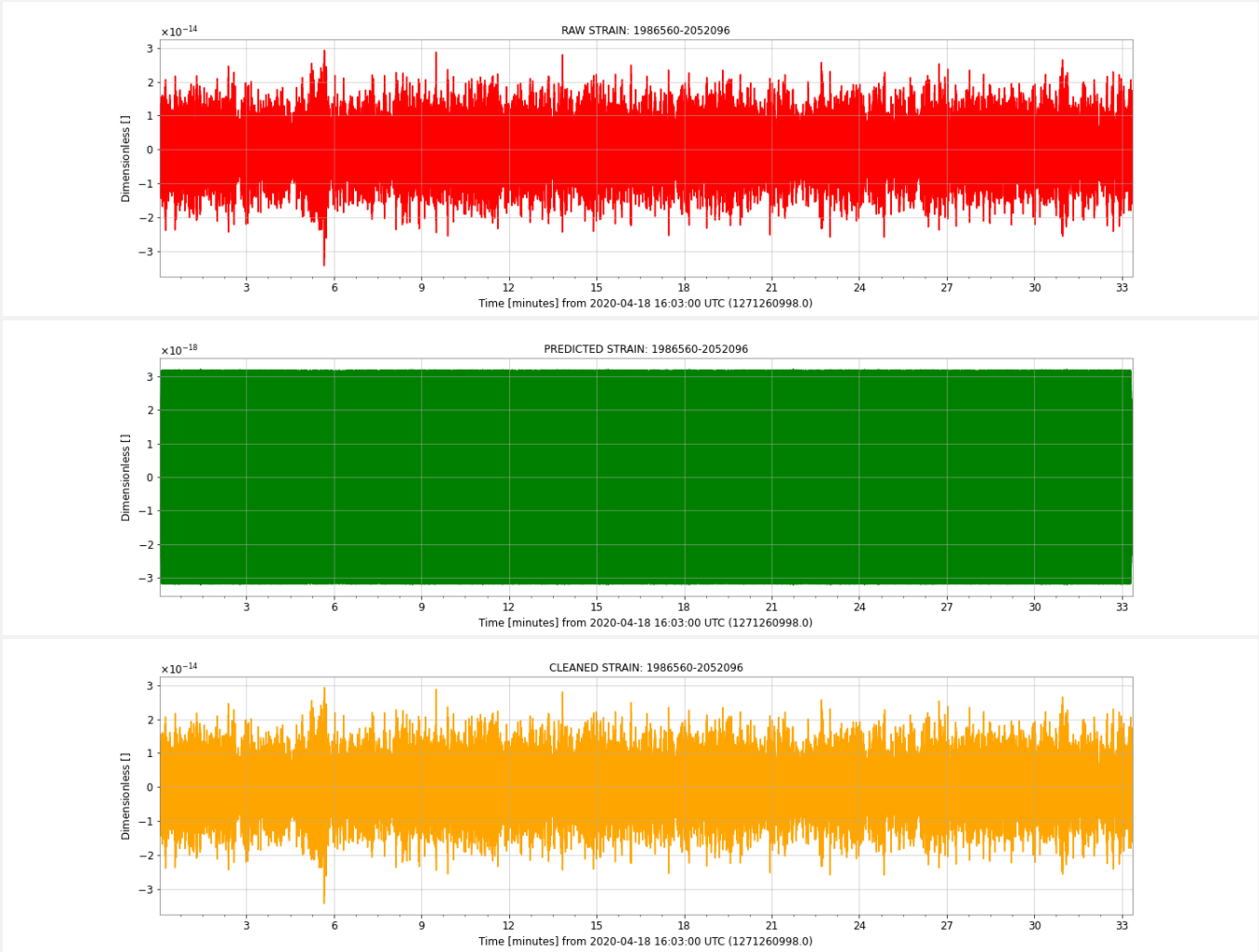
We pick the intervals from O3GK data to test on Deepclean:

- 1271260000 ~1271263000

Subtracting 60Hz AC Power Noise

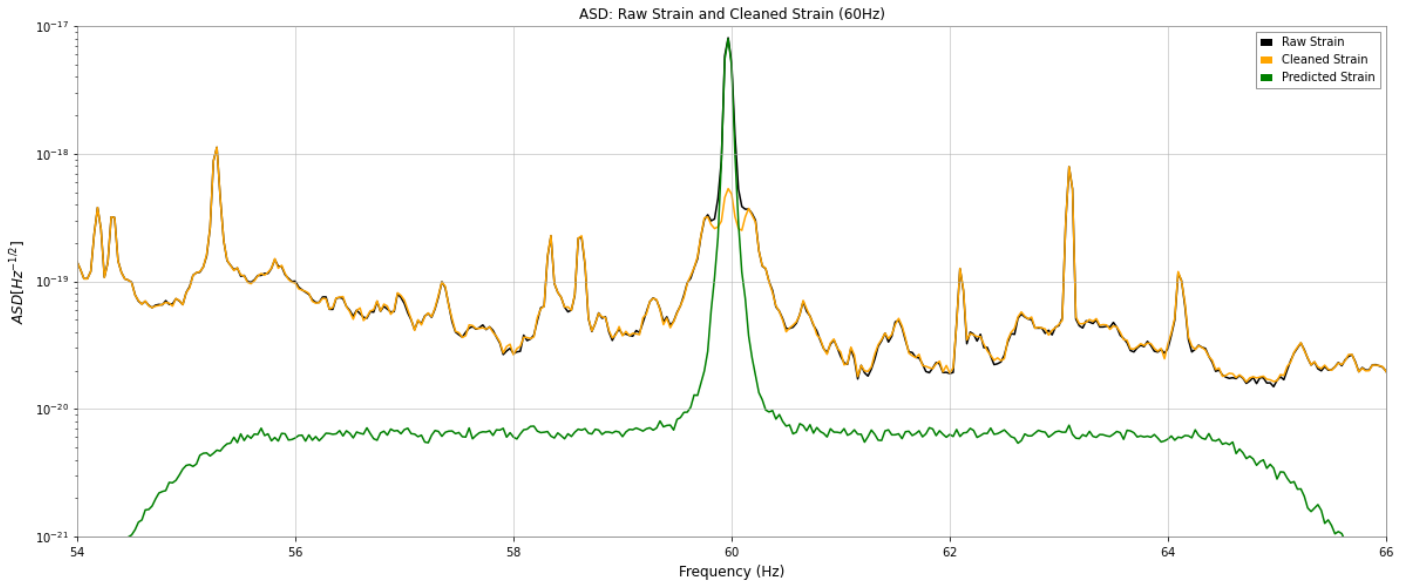
- PEM channels:
  K1:PEM-SENSOR_RACK_OMC1_DSUB(1 ~3)_OUT_DQ,
  K1:PEM-VOLT_PSL_TABLE_GND_OUT_DQ,
  K1:PEM-VOLT_PSL_BOOTH_FLOAT_OUT_DQ,
  K1:PEM-VOLT_AS_TABLE_GND_OUT_DQ,
  K1:PEM-VOLT_OMC_CHAMBER_GND_OUT_DQ,
  K1:PEM-VOLT_REFL_TABLE_GND_OUT_DQ
- Strain channels: K1:DAC-STRAIN_C20
- Sampling rate: 4096Hz
- Bandpass filter: 55Hz ~65Hz
- Batch size: 32
- Epoches: 20
- Loss function: J_{asd}
- Training time: from 1271260000 ~1271261000

Test: Clean from 1271261000 for 2000s



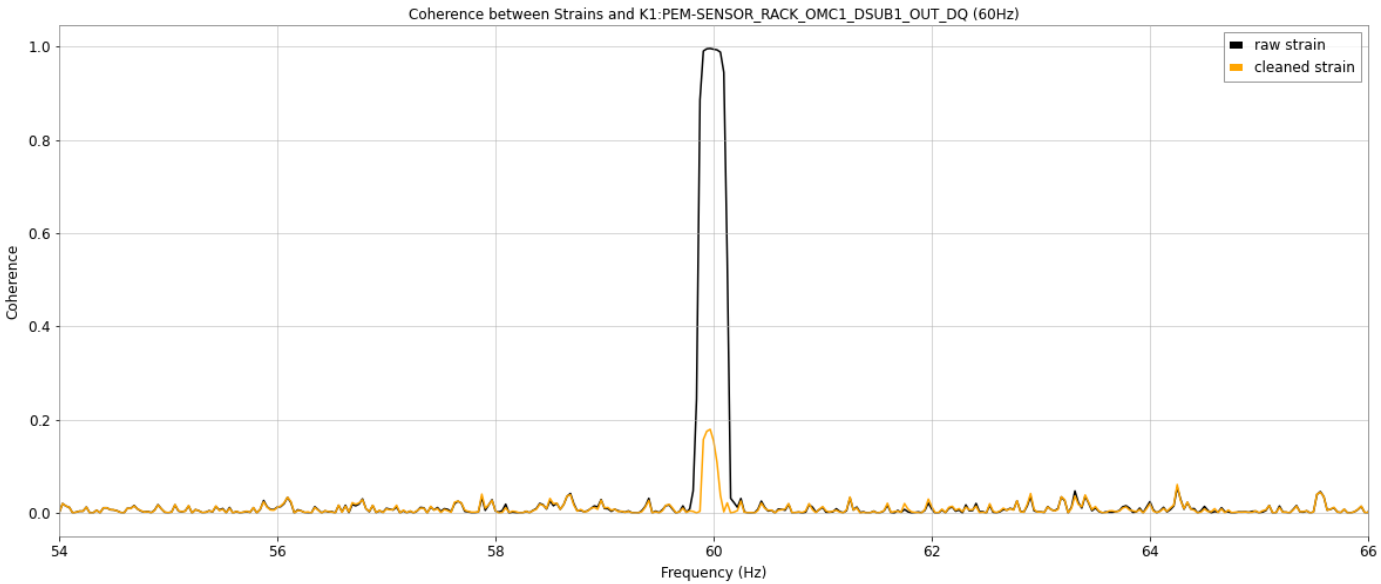
Test: Clean from 1271261000 for 2000s

Amplitude Spectral Density of the strains:



Test: Clean from 1271261000 for 2000s

Coherence between strains and witness channels:



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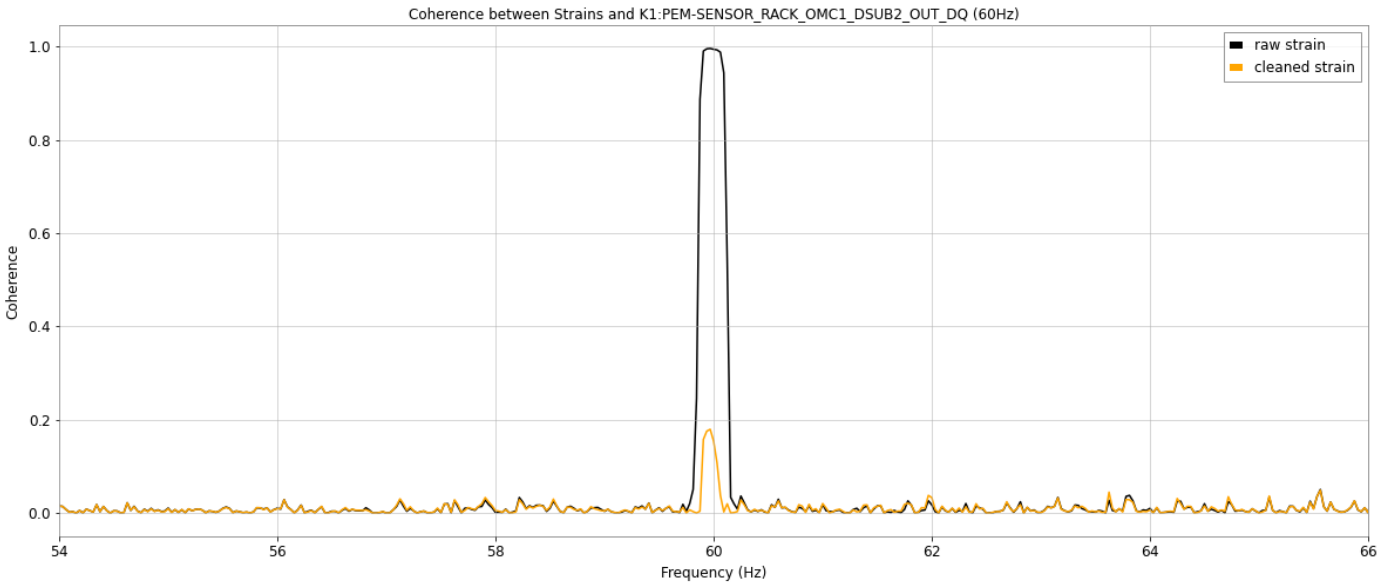

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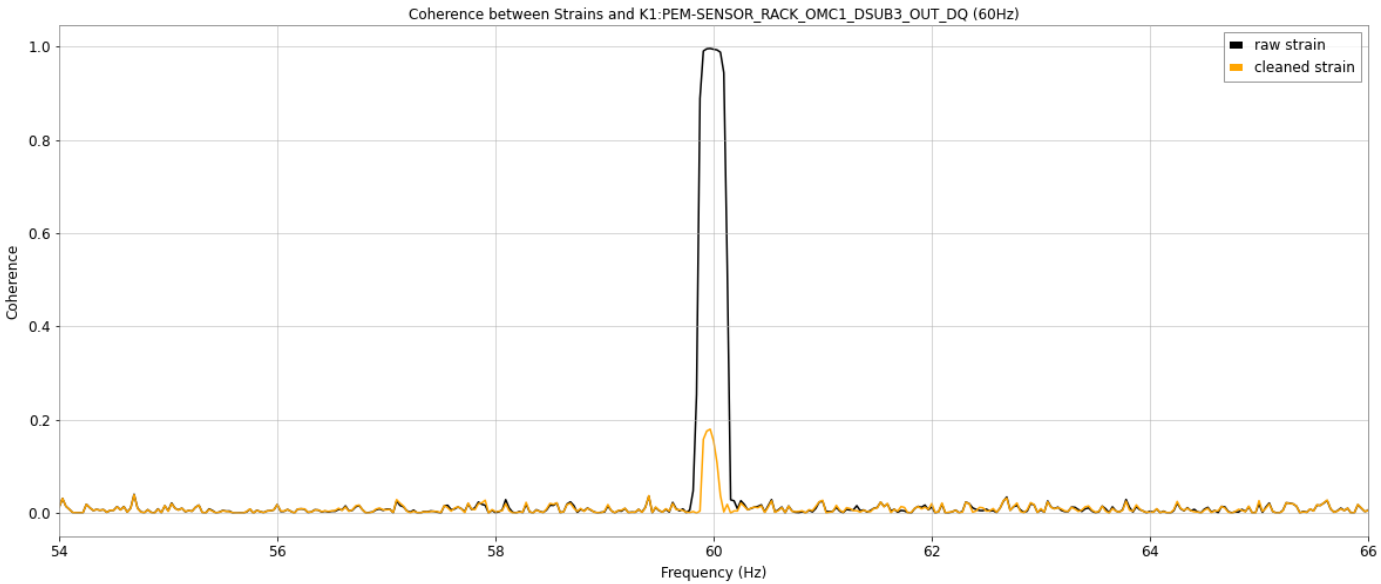

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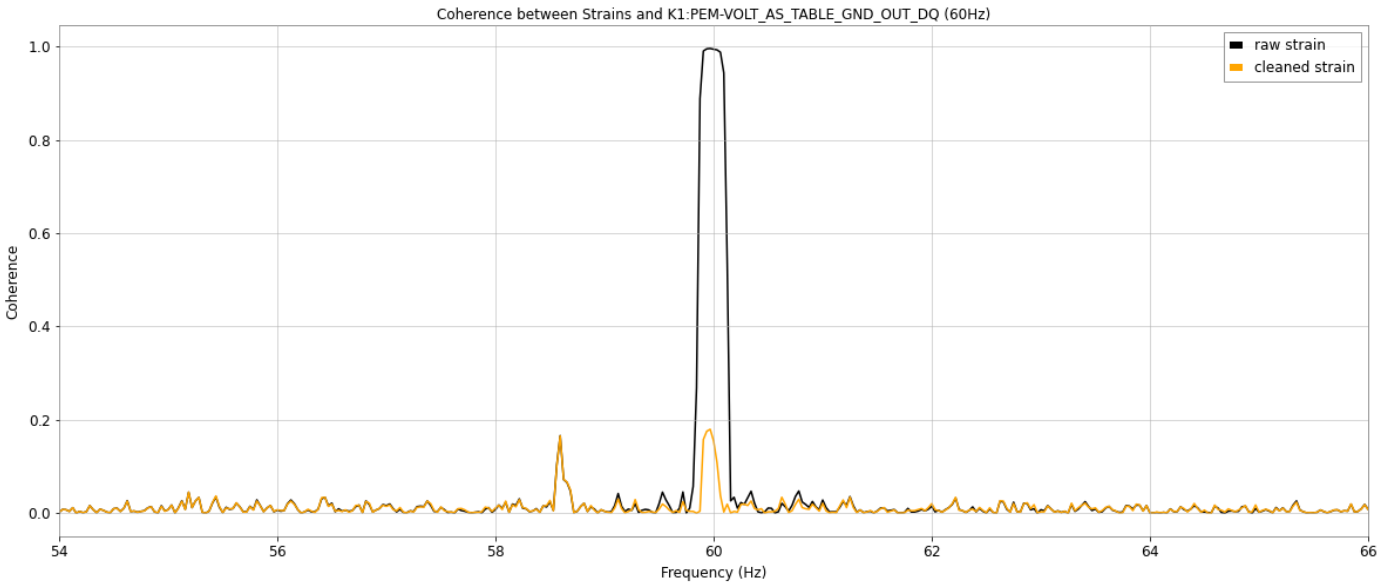

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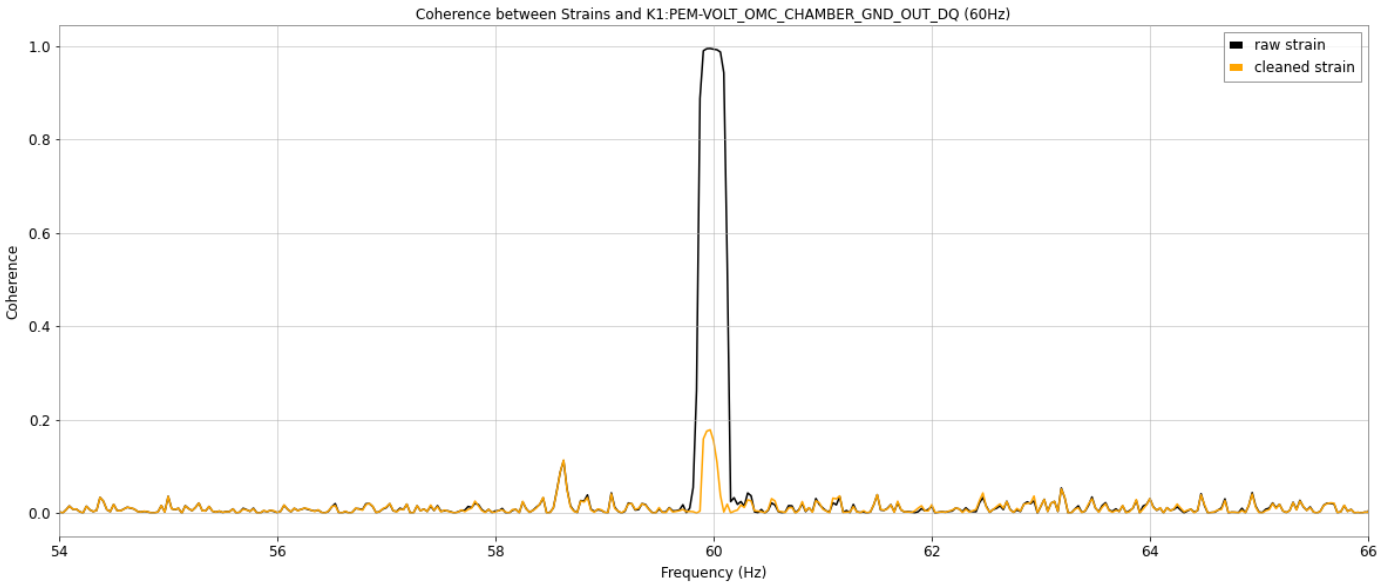

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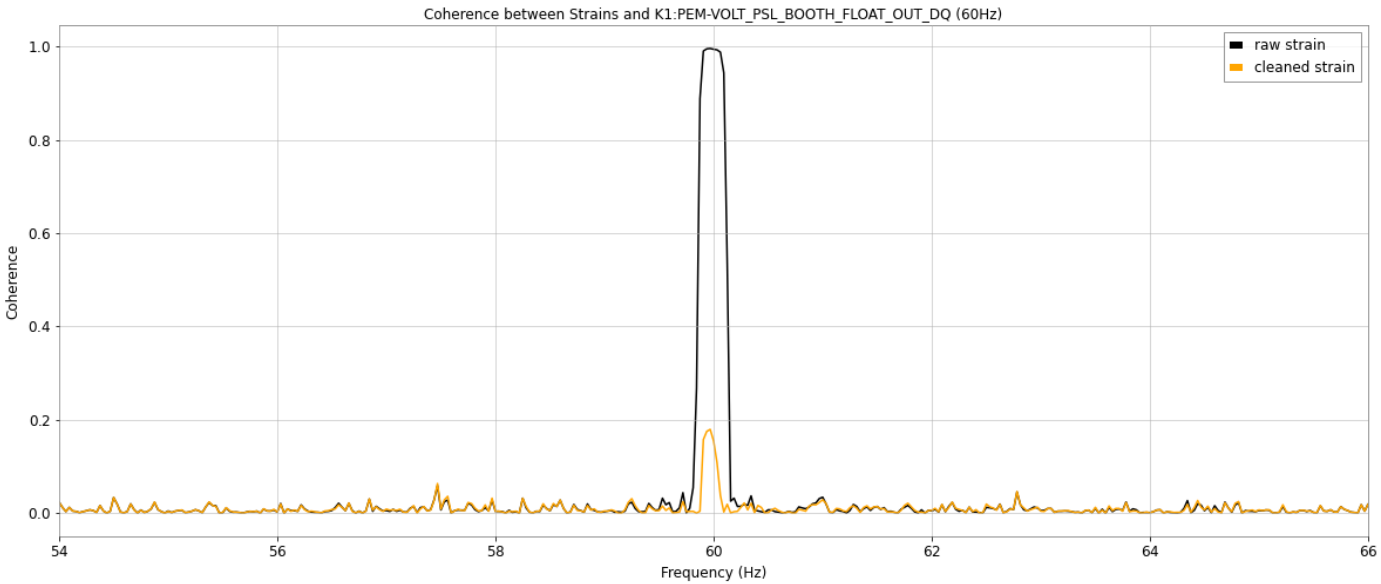

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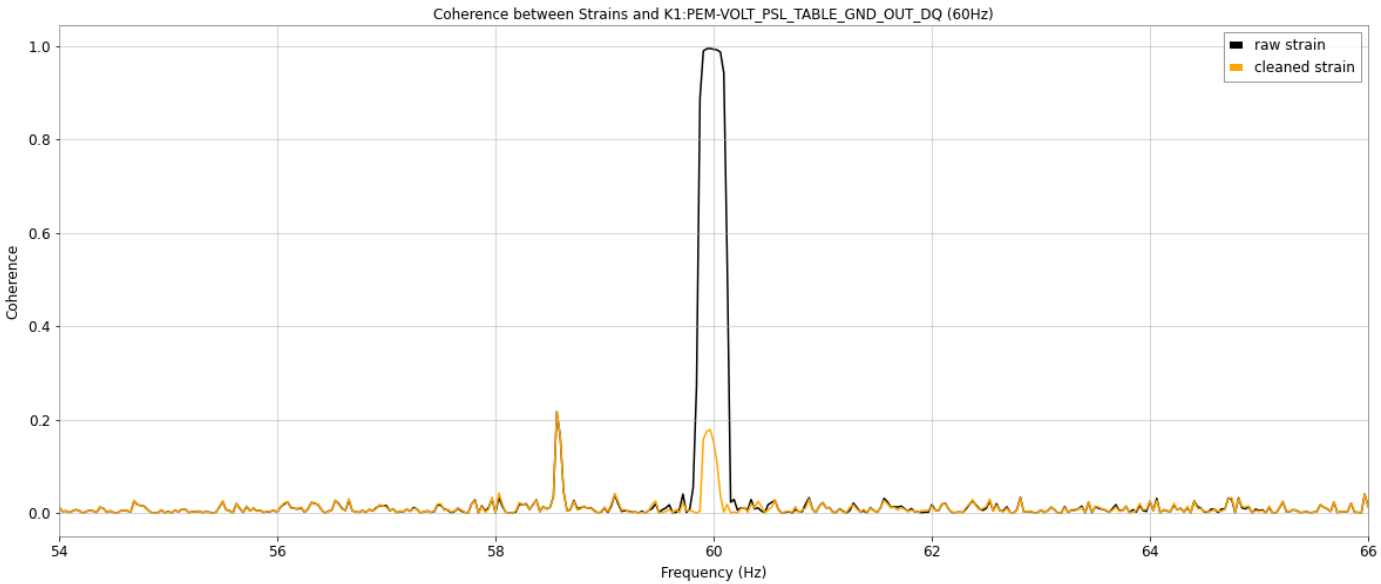

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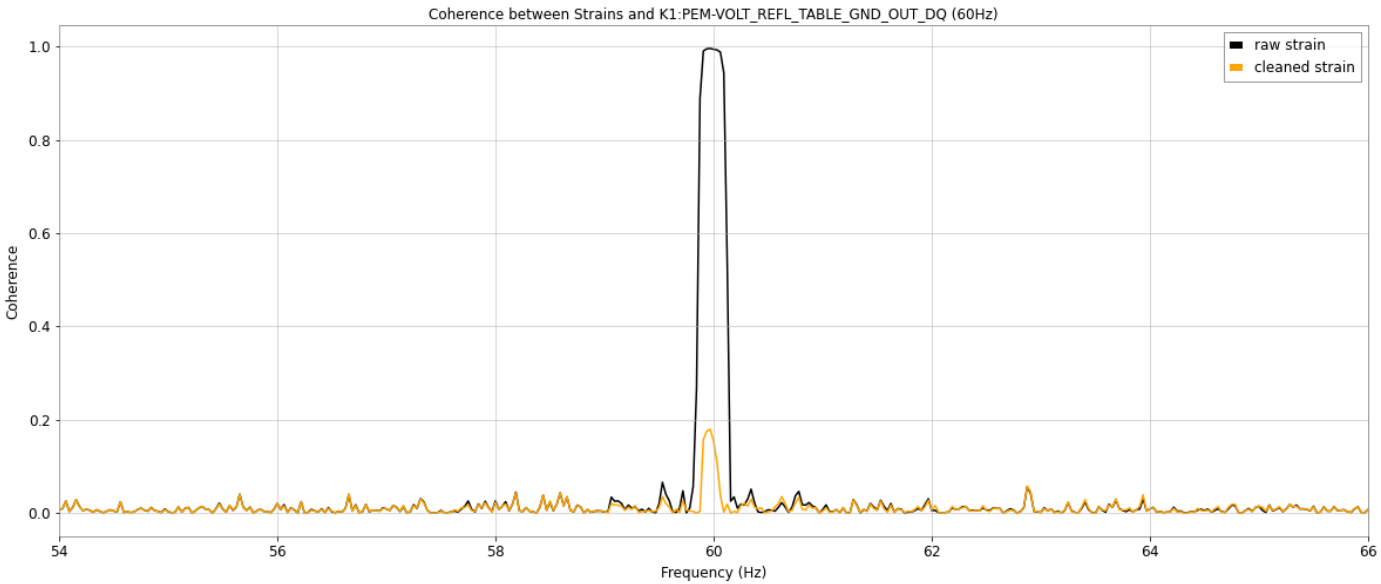
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