Noise Subtraction using DeepClean in KAGRA during O4

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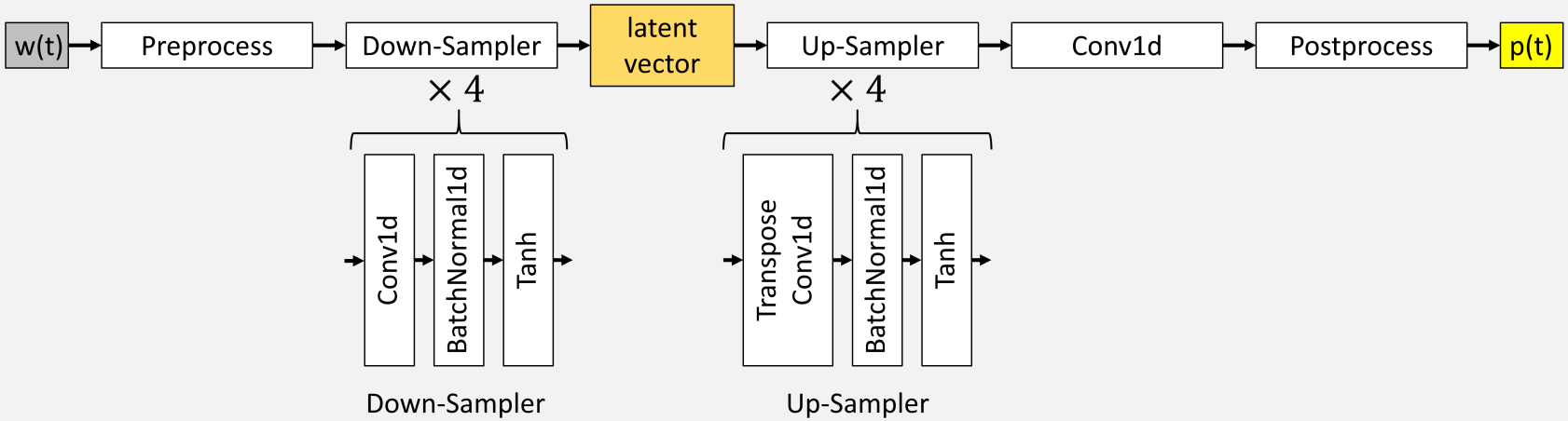
Accelerating Physics with ML@MIT

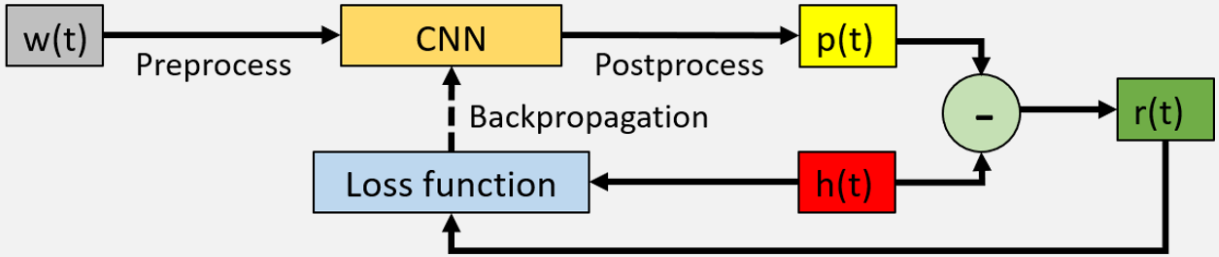
Outline

Deepclean



- Deepclean takes in the witness channels recording the environmental noise and output the noise coupled to the strain channel.
- References: 2005.06534, 2108.12430, deepclean-prod

Deepclean



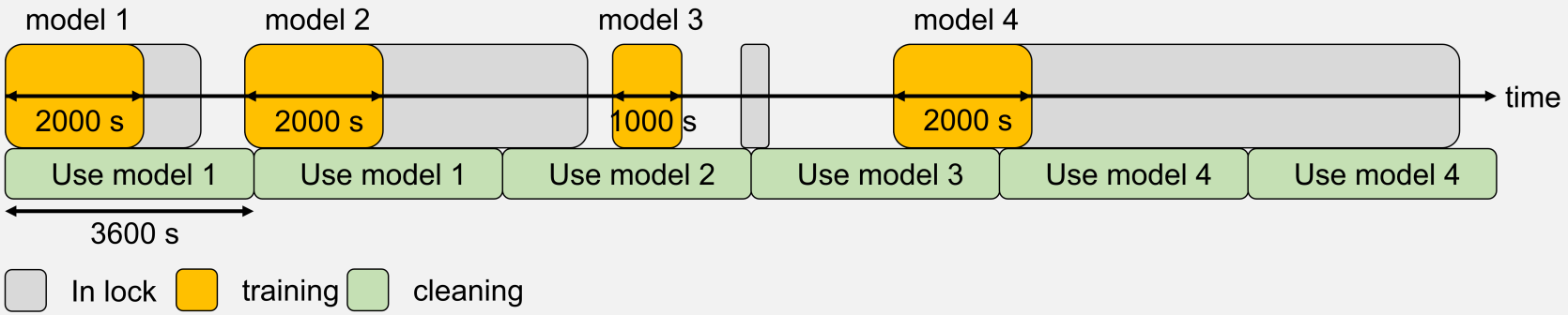
- w(t): witness channels
- p(t): predicted noise
- h(t): raw strain
- r(t): cleaned strain
- Loss function:
  $J = \alpha J_{asd} + (1 - \alpha) J_{mse}$

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

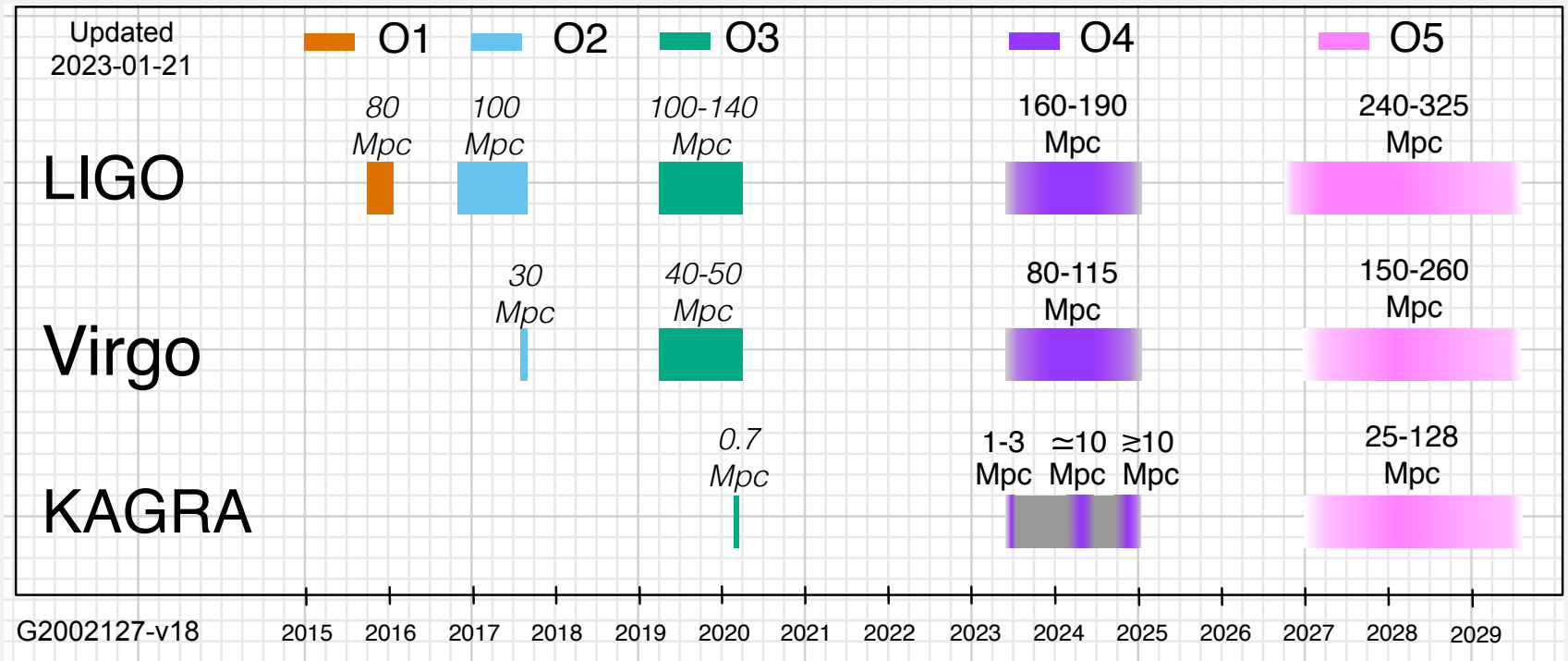
$$J_{mse} = \frac{1}{N} \sum_{i=0}^{N-1} r[i]^2,$$

Deepclean

- The neural network model will be retrained regularly during the observation.



Subtracting 60Hz AC Power Noise



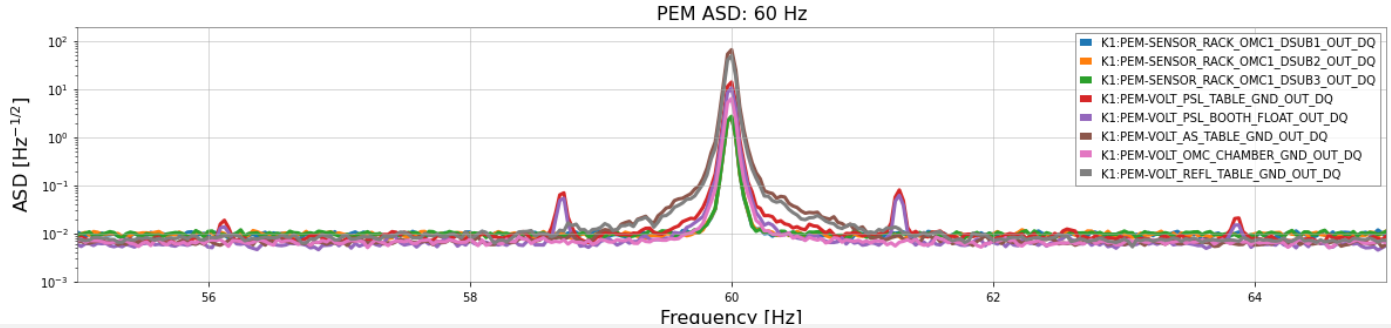
Subtracting 60Hz AC Power Noise

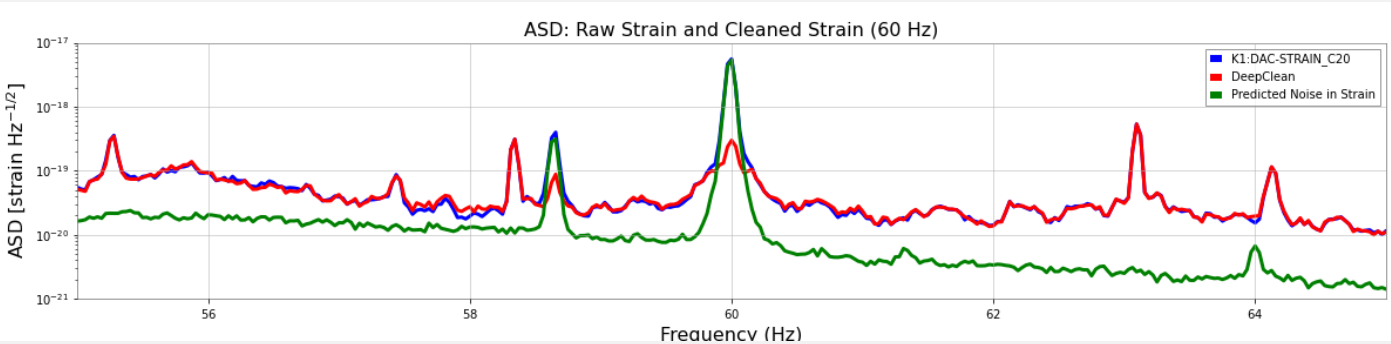
- Training the model from 1271136640 ~1271138688
- Cleaning the strain from 1271138688 ~1271140726
- Witness channels:
  K1:PEM-SENSOR_RACK_OMC1_DSUB(1 ~3)_OUT_DQ,
  K1:PEM-VOLT_PSL_TABLE_GND_OUT_Q,
  K1:PEM-VOLT_PSL_BOOTH_FLOAT_OUT_DQ,
  K1:PEM-VOLT_AS_TABLE_GND_OUT_DQ,
  K1:PEM-VOLT_OMC_CHAMBER_GND_OUT_DQ,
  K1:PEM-VOLT_REFL_TABLE_GND_OUT_DQ,

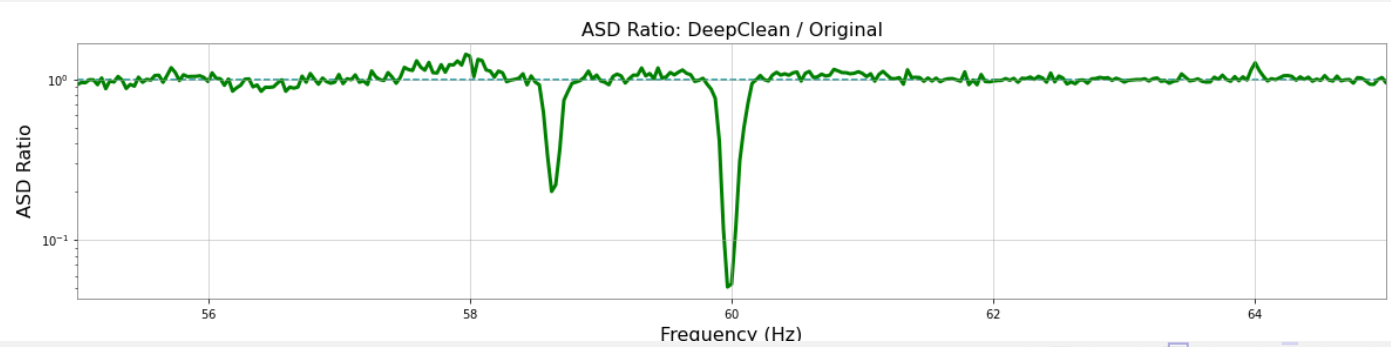
Subtracting 60Hz AC Power Noise

- Strain channels: K1:DAC-STRAIN_C20,
- Sampling rate: 4096Hz,
- Bandpass filter: 55Hz ~65Hz,
- Batch size: 32,
- Epoches: 20,
- Loss function: J_{asd}.

Cleaning the strain from 1271138688 ~1271140726







Removing Calibration Line 29.5Hz

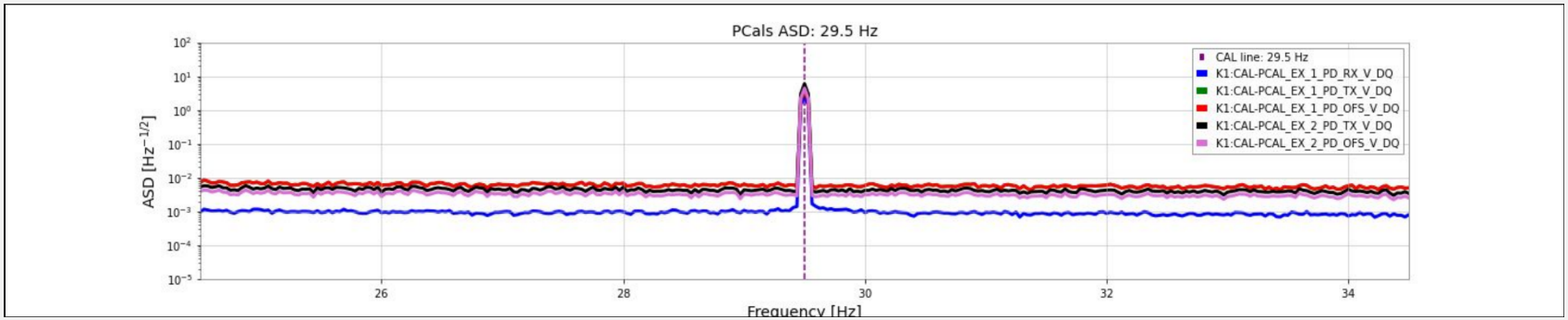
Calibration lines:

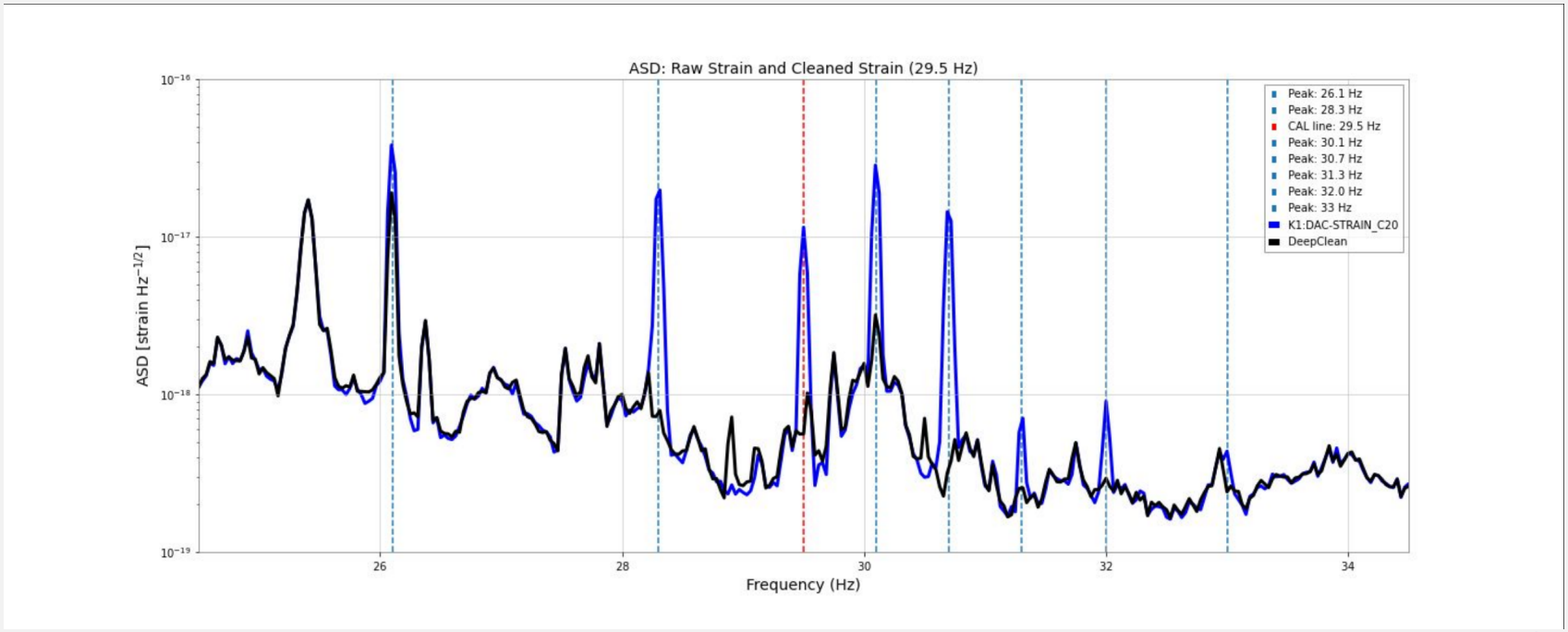
- Through photon calibrator (Pcal) on the ETMX mirror: 29.5Hz, 79.7Hz, 859.7Hz.
- Through actuator: 28.3Hz on ETMX, 30.7Hz on ETMY.

Pcal channels:

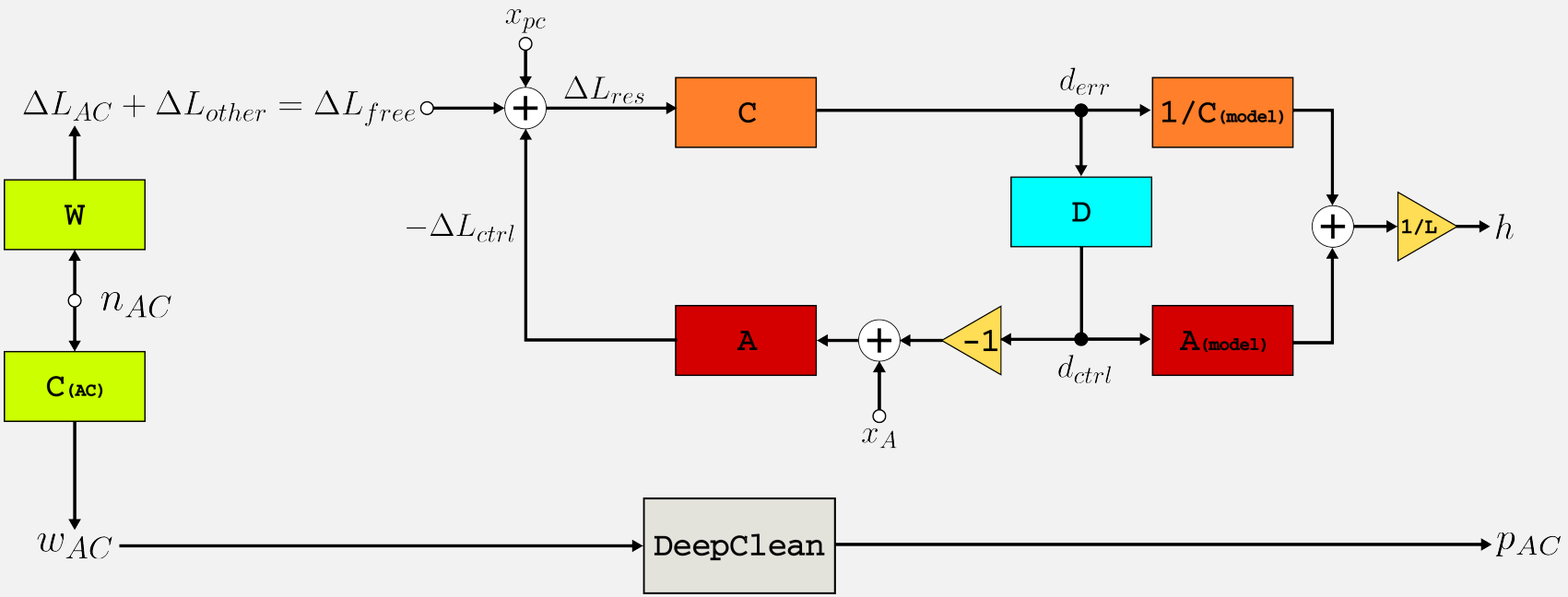
- K1:CAL-PCAL_EX_1_PD_RX_V_DQ,
- K1:CAL-PCAL_EX_1_PD_TX_V_DQ,
- K1:CAL-PCAL_EX_1_PD_OFS_V_DQ,
- K1:CAL-PCAL_EX_2_PD_TX_V_DQ,
- K1:CAL-PCAL_EX_2_PD_OFS_V_DQ.
- Training the model from 1270330400 ~1270332800
- Cleaning the strain from 1270332800 ~1270335200

Removing Calibration Line 29.5Hz





Removing Calibration Line 29.5Hz



Inference as a Service (IaaS)

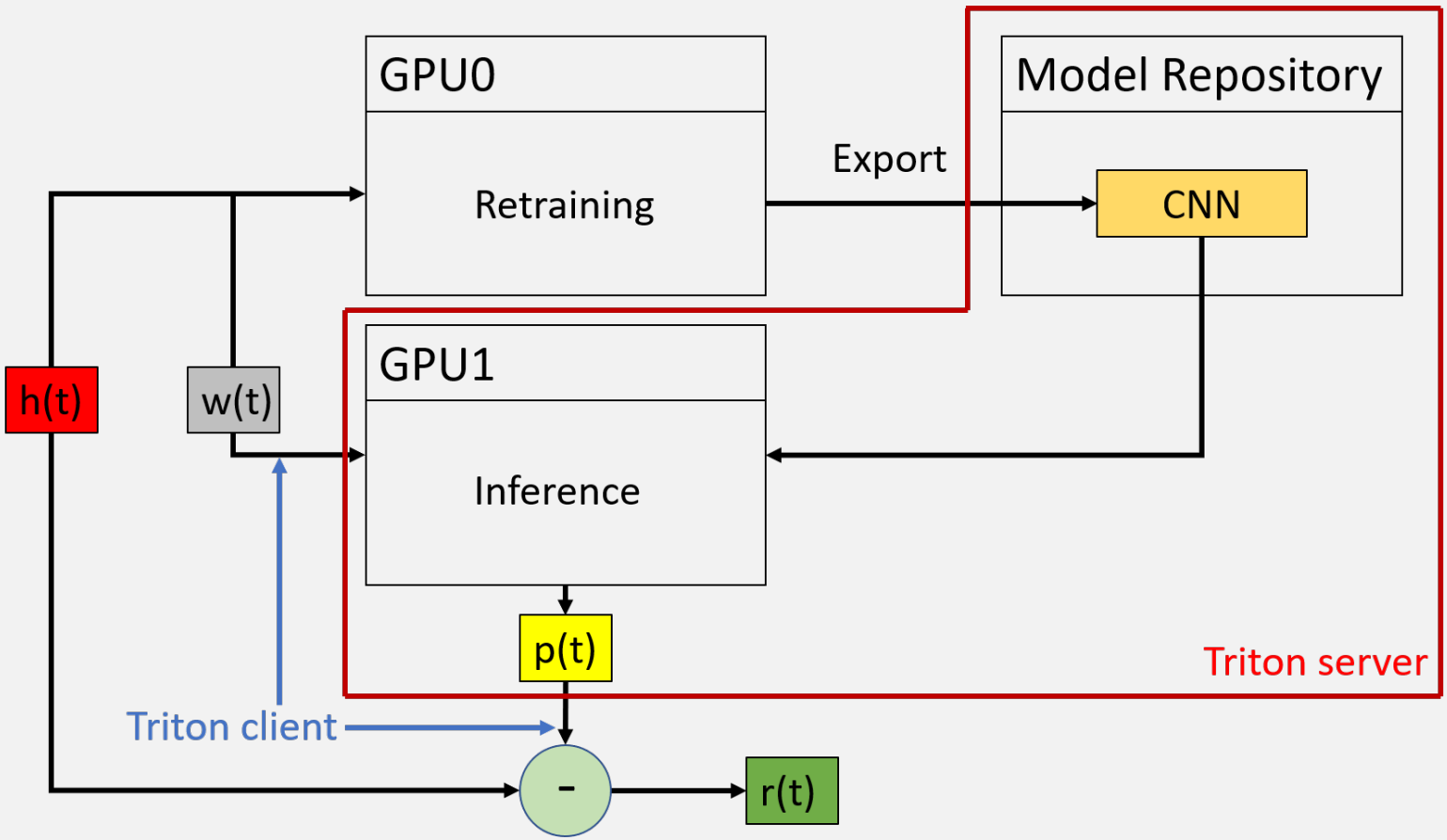


Fig.5 Inference as a Service (IaaS), the online DeepClean pipeline using Nvidia Triton Server.

GPU Server: Spec

- 2 GPUs: NVIDIA Ampere A30 PCIe, 165W, 24GB Passive, Double Wide, Full Height GPU with cable
- Case: 2U DELL R750
- CPU : Xeon Gold 6326 (16 cores 2.9Hz) * 2
- Storage: HDD 2.5” 1.2TB * 2 + 480GB NVME SSD * 1
- RAM: DDR4-3200 ECC REG 32GB * 8 (256GB)
- RAID: H745
- Power Supplies: 1400W

Challenges and Future Plans

- Installation of the GPU server and deployment of the IaaS pipeline.
- PEM Sensors of AC power noise will be updated before O4, we will update the witness channel list to subtract 60Hz noise in low-latency.
- Reliable pipeline of low-latency strain h(t) reconstruction.
- The validation of the calibration line removal using DeepClean.

Thank you

Validation using O3 Mock Data Challenge

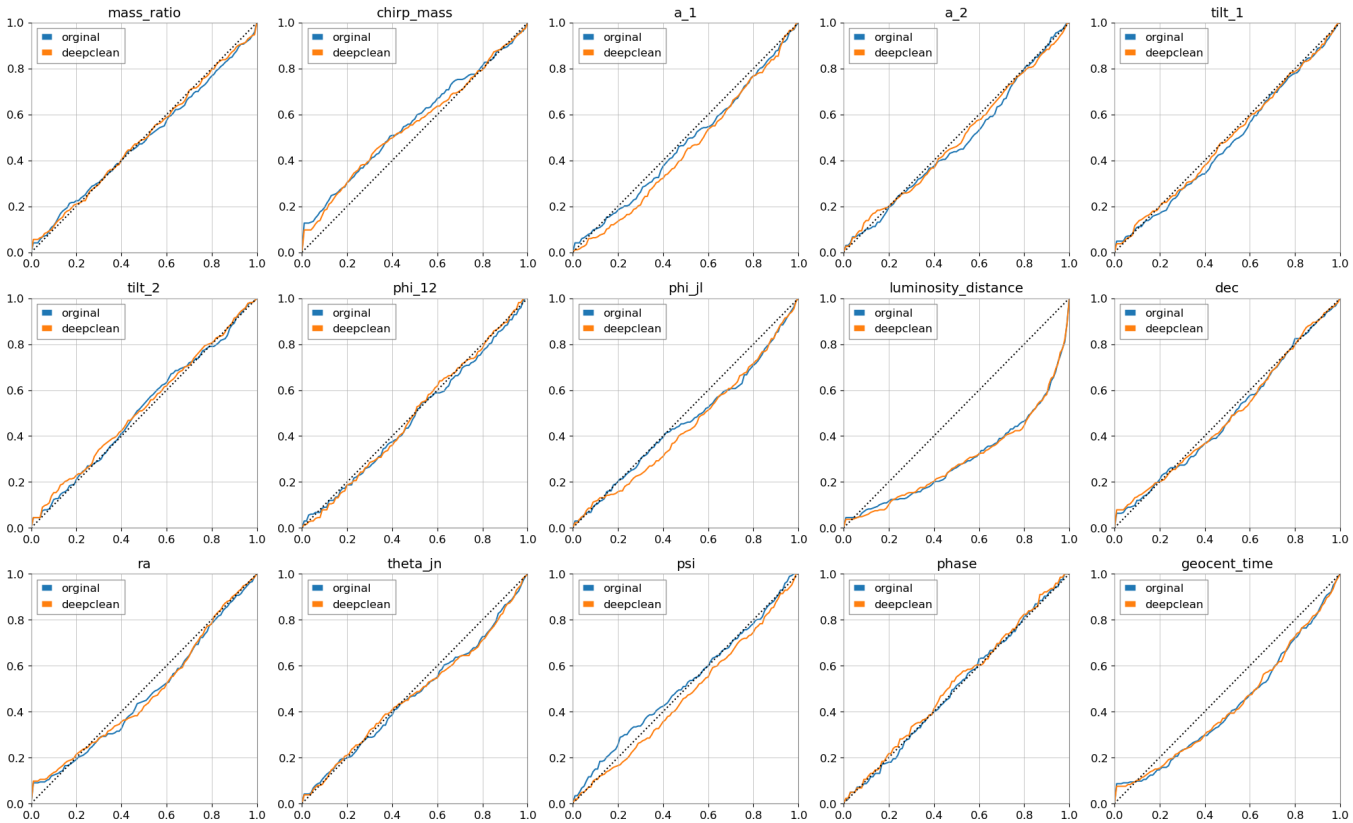
- 25000 CBC events are injected into 20 days of Hanford's and Livingston's strain from 2019/09/01 to 2019/09/20 to make our MDC.
- The 60Hz noise is subtracted using DeepClean.
- We picked 266 events in the active segments and performed the full Parameter Estimation (PE) on both cleaned and uncleaned strain. PE results from the cleaned strain and original strain are similar.

Validation using O3 Mock Data Challenge

witness channels:

- H(L)1:PEM-CS_MAINSMON_EBAY_1_DQ,
- H(L)1:ASC-INP1_P_INMON,
- H(L)1:ASC-INP1_Y_INMON,
- H(L)1:ASC-MICH_P_INMON,
- H(L)1:ASC-MICH_Y_INMON,
- H(L)1:ASC-PRC1_P_INMON,
- H(L)1:ASC-PRC1_Y_INMON,
- H(L)1:ASC-PRC2_P_INMON,
- H(L)1:ASC-PRC2_Y_INMON,
- H(L)1:ASC-SRC1_P_INMON,
- H(L)1:ASC-SRC1_Y_INMON,
- H(L)1:ASC-SRC2_P_INMON,
- H(L)1:ASC-SRC2_Y_INMON,
- H(L)1:ASC-DHARD_P_INMON,
- H(L)1:ASC-DHARD_Y_INMON,
- H(L)1:ASC-CHARD_P_INMON,
- H(L)1:ASC-CHARD_Y_INMON,
- H(L)1:ASC-DSOFT_P_INMON,
- H(L)1:ASC-DSOFT_Y_INMON,
- H(L)1:ASC-CSOFT_P_INMON,
- H(L)1:ASC-CSOFT_Y_INMON.

Percentile-Percentile Plot of the PE Results



Credible Interval Width Ratio of the PE Results