Data conditioning and veto for TAMA burst analysis

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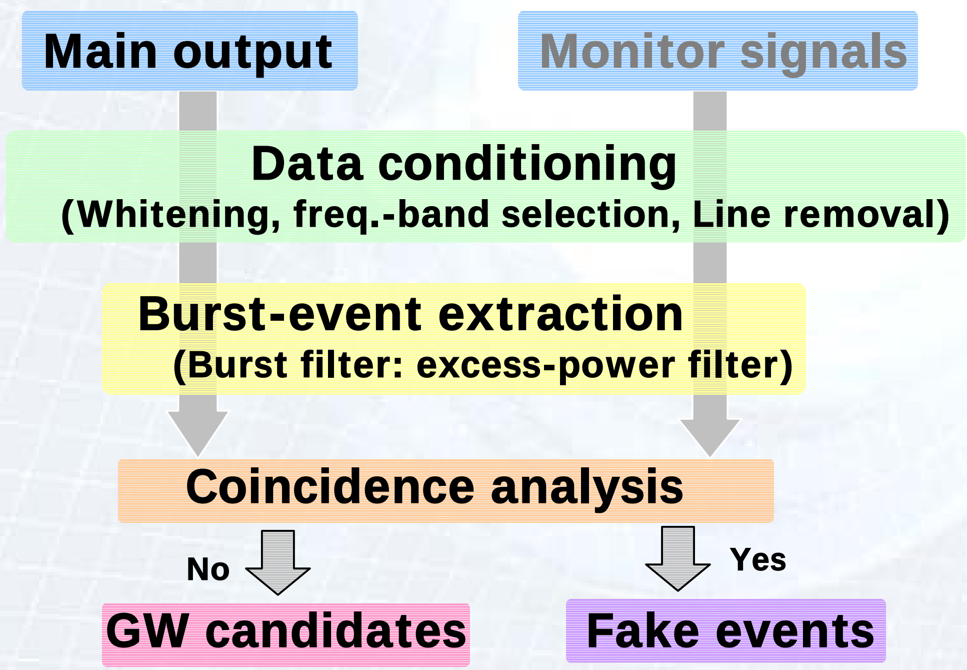
Introduction (1)

- Veto analysis -

- **Veto analysis by monitor signals**

  GW detector is sensitive to
  external disturbances as well as real GWs

  Reject fake events using monitor signals
  recorded together with the main output of the detector



Systematic survey of all monitor channels

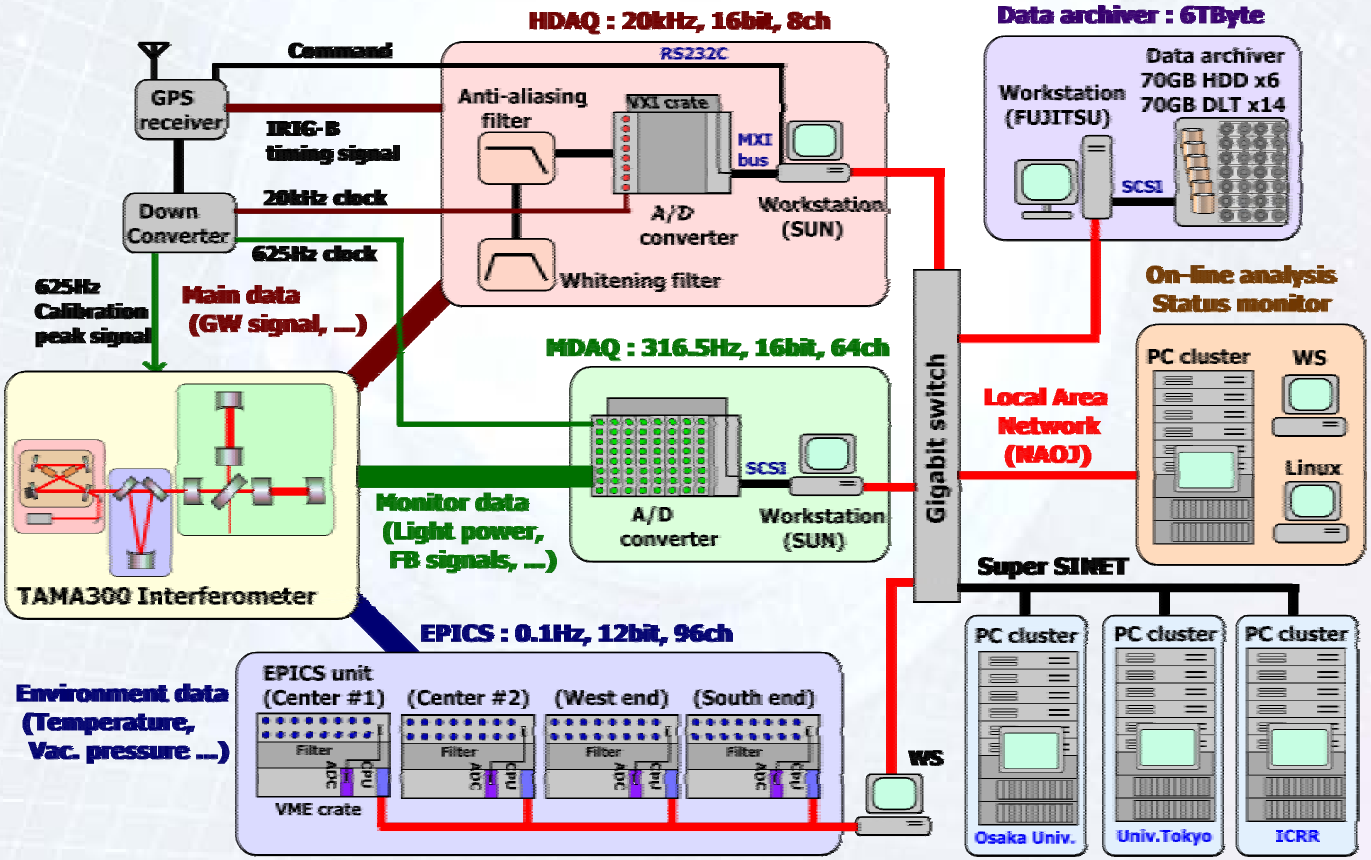
Fake reduction even without understandings of noise mechanisms

Introduction (2)

- TAMA DT9 data -

- **TAMA data acquisition and analysis system**

  Used data in this work: TAMA DT9 (Dec. 2003 – Jan. 2004)
  200 hours of data (HDAQ 8ch, MDAQ 64ch)



Data Conditioning

Data conditioning (1)

- Quality of data from detectors -

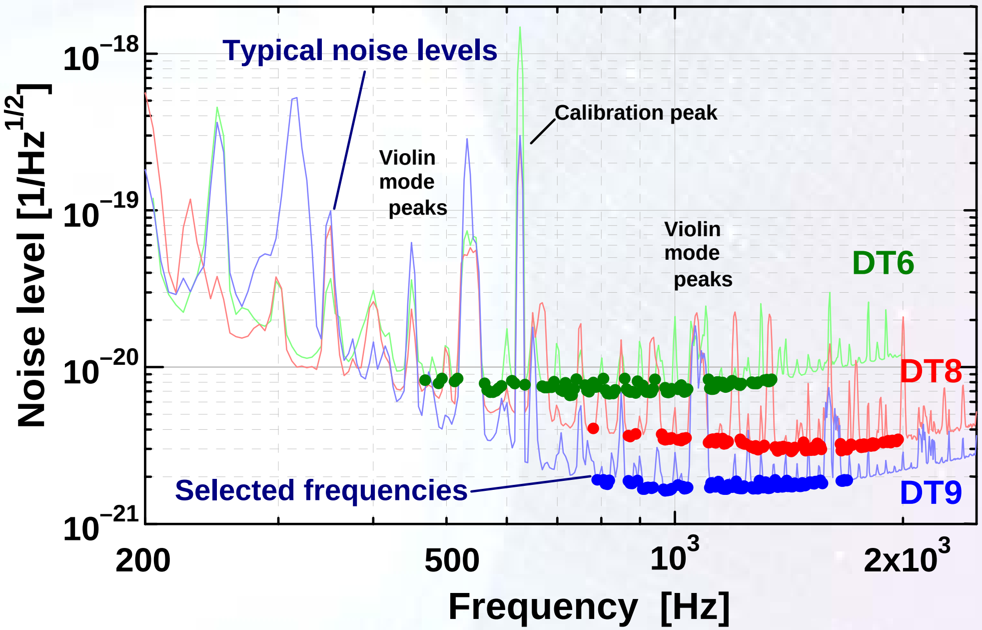
- **Data conditioning**

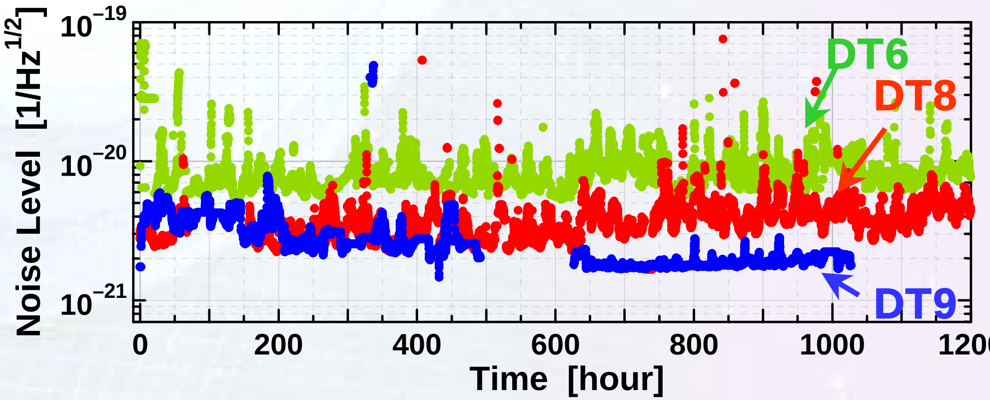
'ideal' data
(predictable behavior known statistics)

Stationary noise
White noise

Real data from detectors

Non stationary behavior
Drift of noise level
Sudden excitations
Frequency dependence
Sensitivity degradation in high and low frequencies
Line noises





⇨ **Data conditioning**

Data conditioning (2)

- TAMA conditioning filter -

- **Data conditioning for TAMA burst analyses**

Normalization of the data
by averaged nose level
→ Remove time and frequency dependence
Line removal
Select frequency band to be analyzed

In addition ...
Calibration : Convert $v(t)$ to $h(t)$
Resampling : Data compression

Requirements
Small loss in signal power
Keep GW waveform

Data conditioning (3)

- Data flow -

- **Data conditioning by FFT-IFFT**

  Frequency selection, Whitening/Calibration, Resampling

Frequency-band selection

Overwrite '0' for unnecessary frequencies

Outside of the observation band

AC line freq. , Violin-mode freq.

Calibration peak

Whitening

Normalize by avg. spec.

Calibration

Convert to h(f)

Fourier transform

72sec data

Inverse Fourier transform

Only below 5kHz

Raw time-series data

20kHz samp.

Whitened time-series data

5kHz samp.

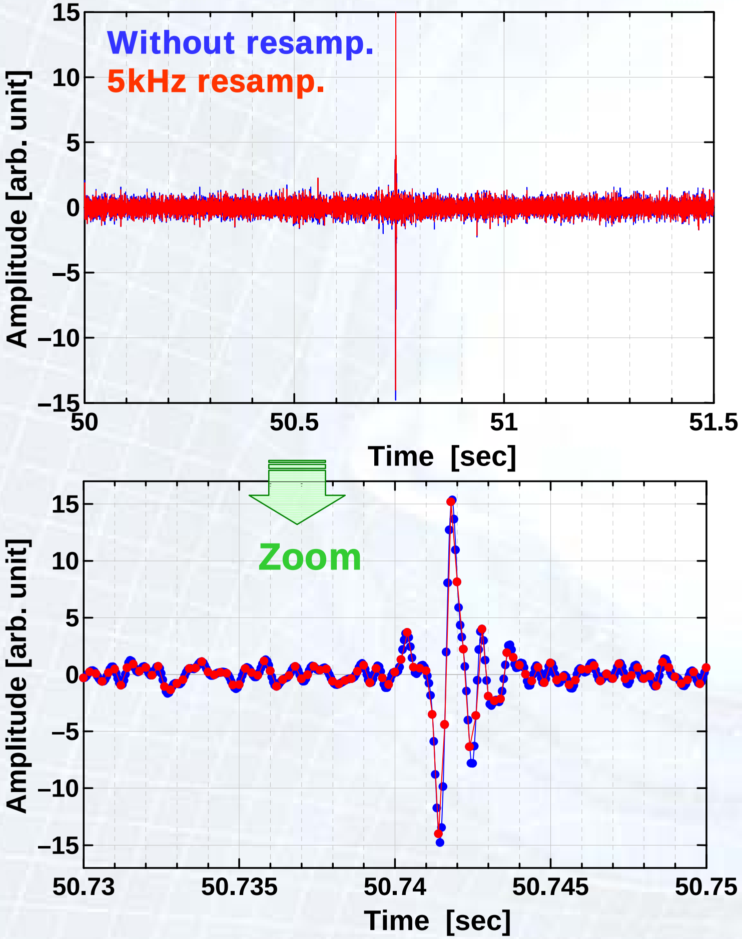
Calibrated time-series data

5kHz samp.

Data conditioning (4)

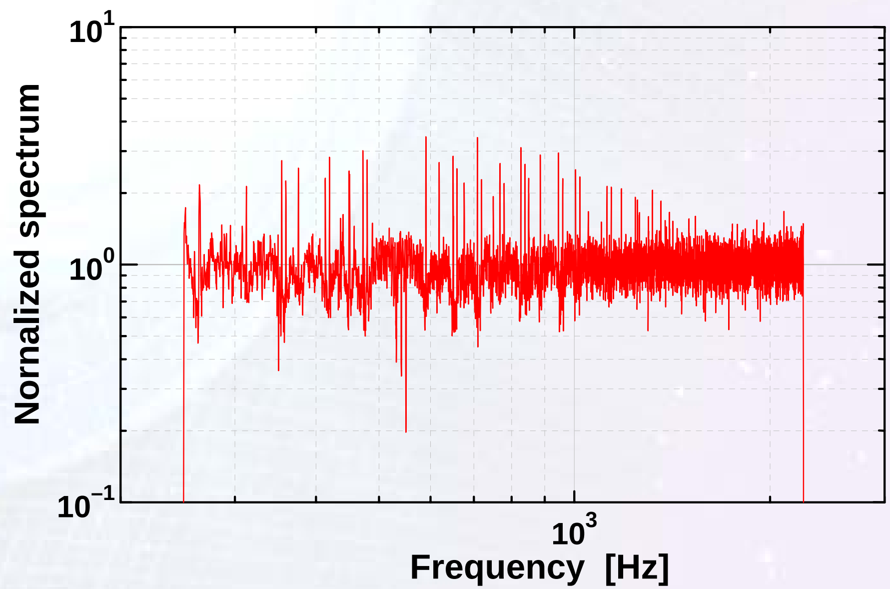
- Results of conditioning -

- **Whitened data**



Time-series data
→ Waveform is maintained with resampling

Spectrum
→ Whitened

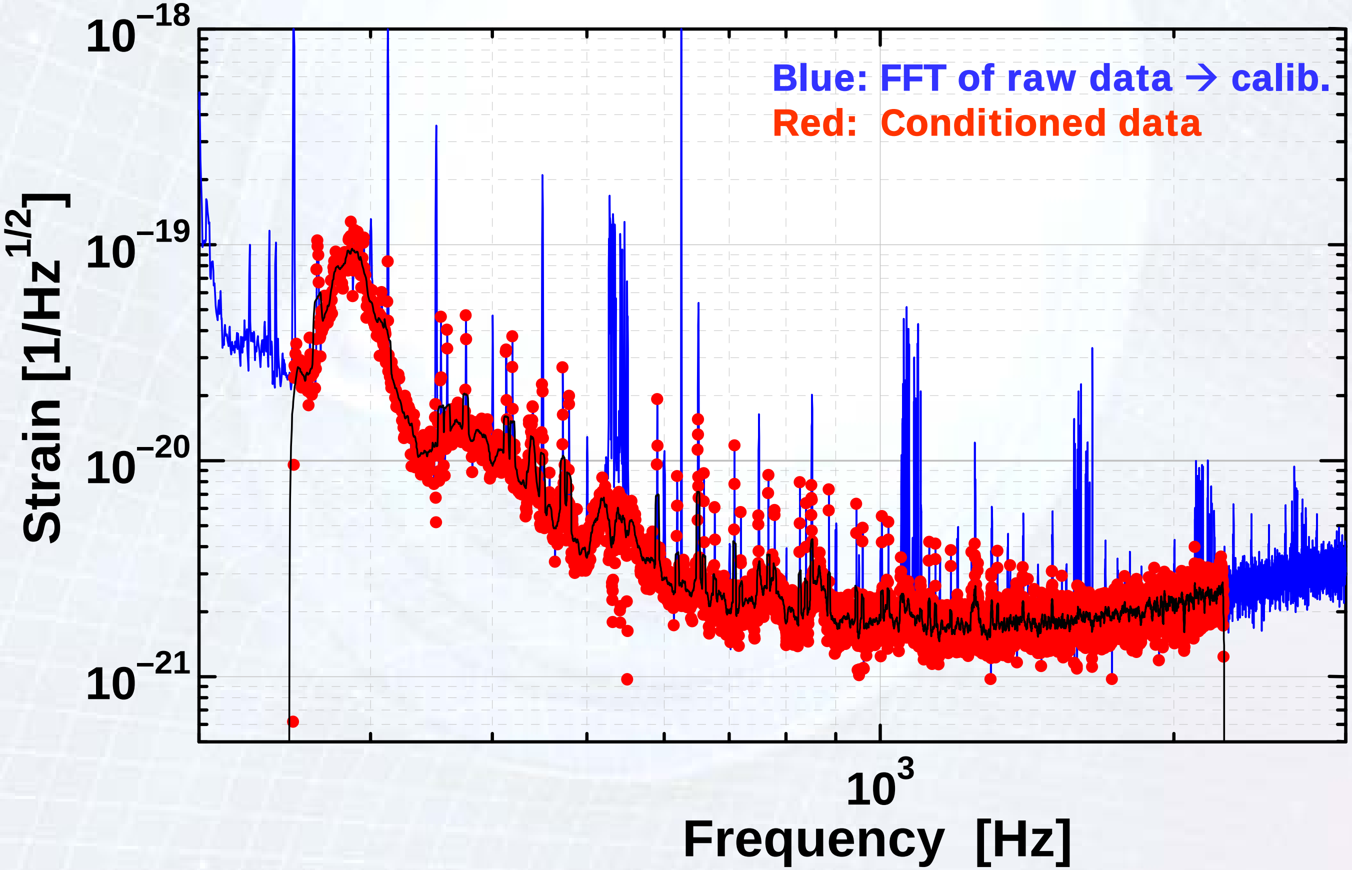


Data conditioning (5)

- Calibrated spectrum -

- **Calibrated data**

Power spectrum of conditioned time-series data and calibrated spectrum of original data



Event extraction

Event extraction (1)

- Excess power filter -

- **Burst event trigger**

  Excess-power filter

  Evaluate power in given time-frequency windows

  → Extract non-stationary events

Data conditioning
time-series data in a given frequency band

⇩

Calculate power in a given time window

⇩

Power in a given time-frequency window
→ SNR

⇩

Threshold, Clustering
→ Burst events

Free selection of time-frequency window

Previous works…
Spectrogram
→ Averaged power

Time-frequency resolution were limited by FFT length

Veto analysis

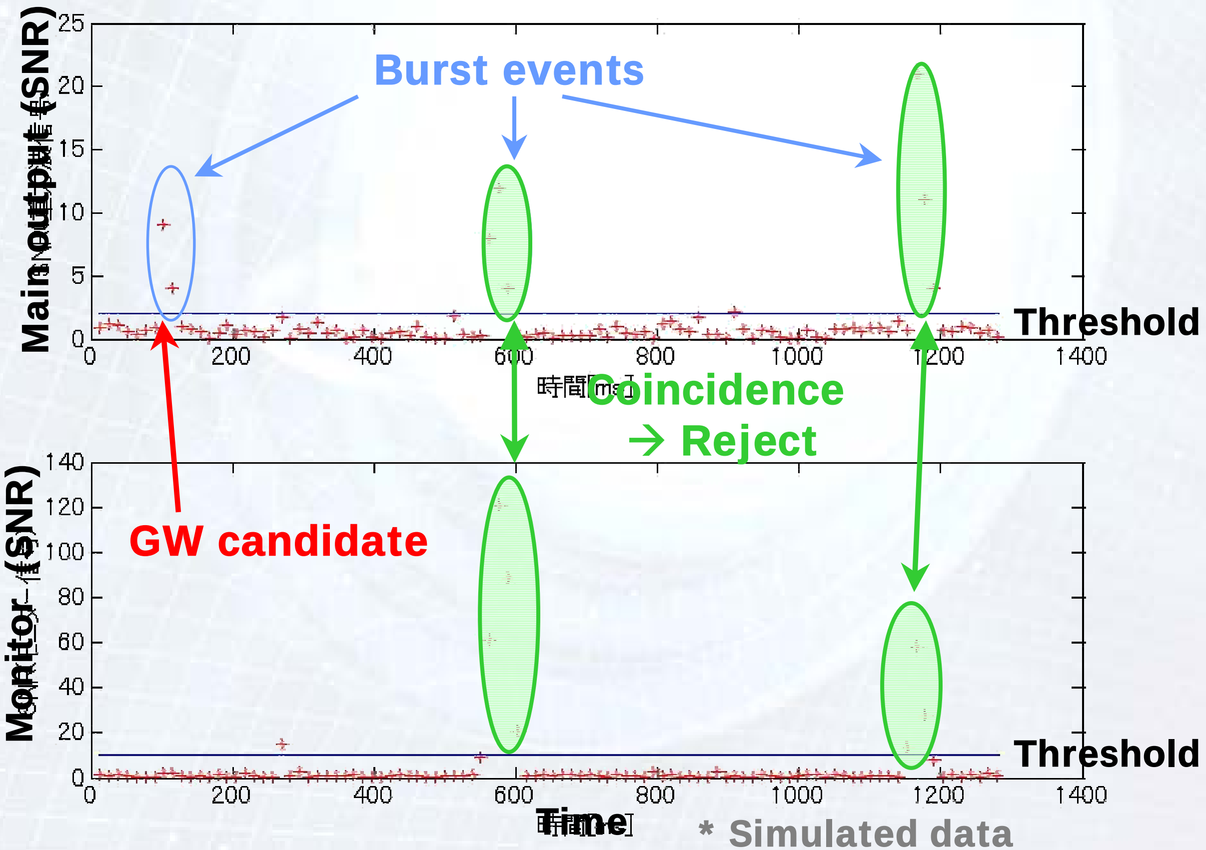
Veto analysis (1)

- Concept -

- **Coincidence analysis**

  External disturbances tend to appear in some monitor signals

  → Reject fake events



Veto analysis (2)
- Parameter optimization -

- **Parameter optimization**

Analysis parameters
- **Time-frequency window**
- **Threshold**

Signals to be used for veto

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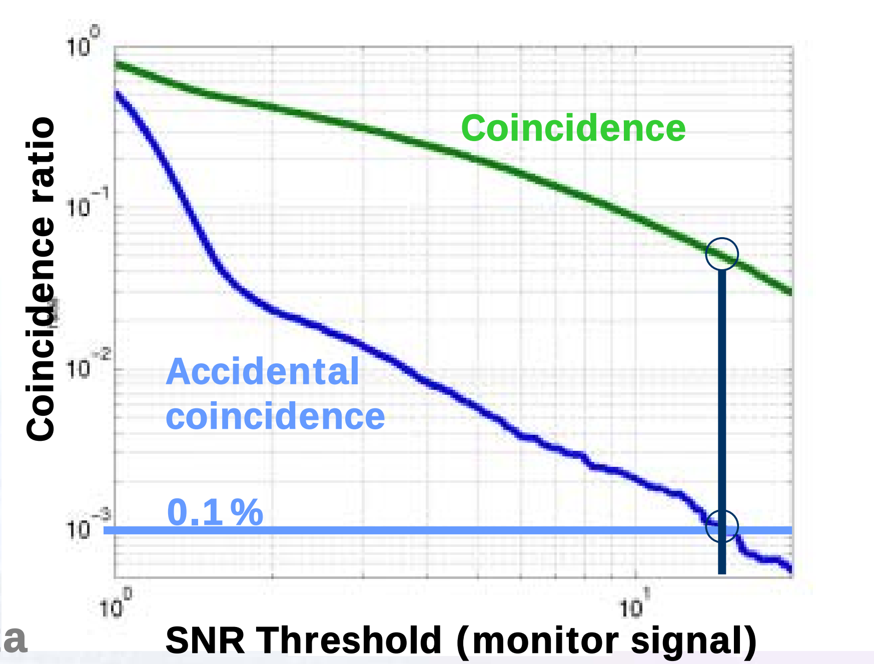
Optimized to have...
- **High fake-rejection efficiency**
- **Low accidental coincidence**

Threshold for monitor signals:
Accidental ~ 0.1%

Time-frequency window:
Highest coincidence rate selected from 50 (18) time-frequency combinations

Playground data (~10%) are used for this optimization

Accidental coincidence: estimated by 1-min.time-shifted data



Veto analysis (3)

- Signal selection -

Signal selection

Even with small accidental rejection prob. (~0.1%) for each, many (~100) monitor signals may lose large amount of data

⇨ Select signals to be used for veto

Intensive fake-rejection with some monitor signals with strong correlations with the main signal

⇨ Re-optimize the threshold

Classify by the coincidence rate...

<0.5 % → Do not use for veto
0.5 - 2 % → Use for veto
> 2% → Intensive veto
with lower threshold: accidental ~ 0.5%

Selected signals

HDAQ: 3 signals
Rec. Pow., L+ FB, Dark Pow.

MDAQ: 9 signals
I- Err., I- FB, I+ Err., I+ FB,
Bright Pow, Rec. Pow., EW Trans. Pow.,
SEIS center Z, Magnetic Field Y

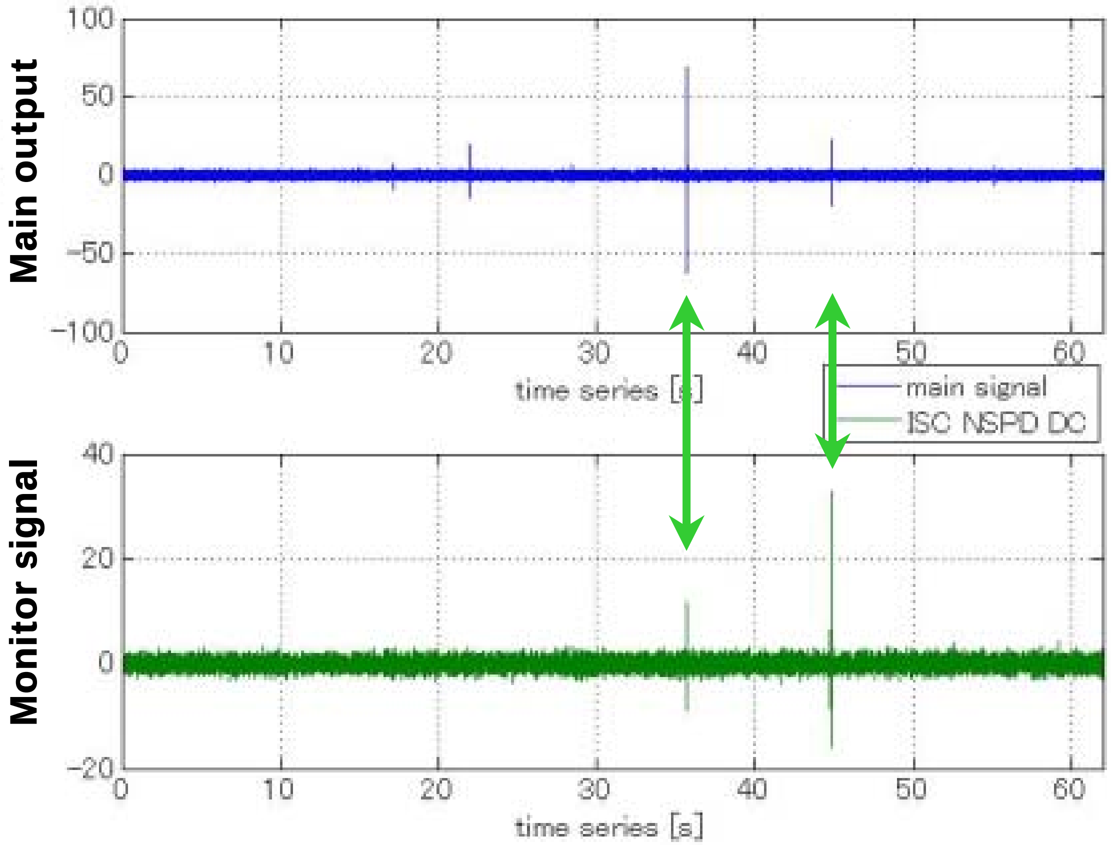
Veto analysis (4)

- Intensity monitor -

- **Example of coincident events**

Intensity monitor in the power recycling cavity

(time series data after data conditioning)



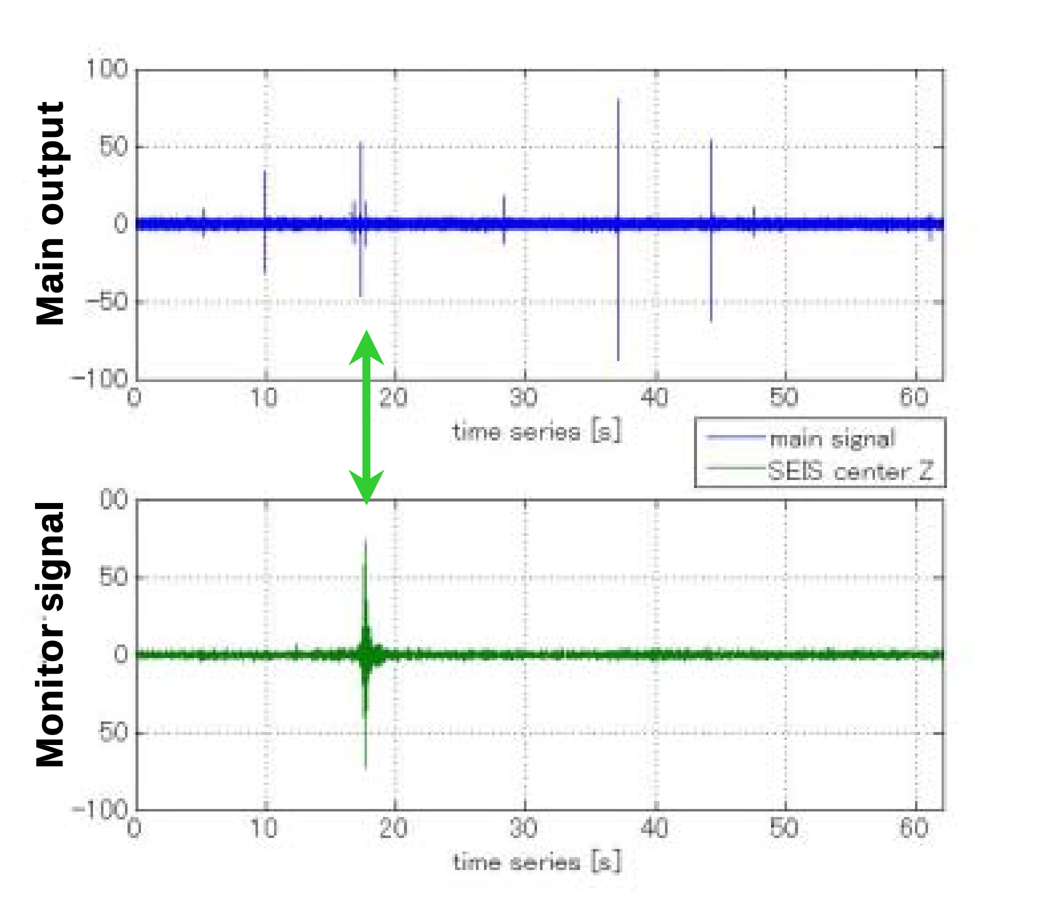
Veto analysis (5)

- Seismic motion -

- **Example of coincident events**

Seismic monitor – center room vertical motion

(time series data after data conditioning)



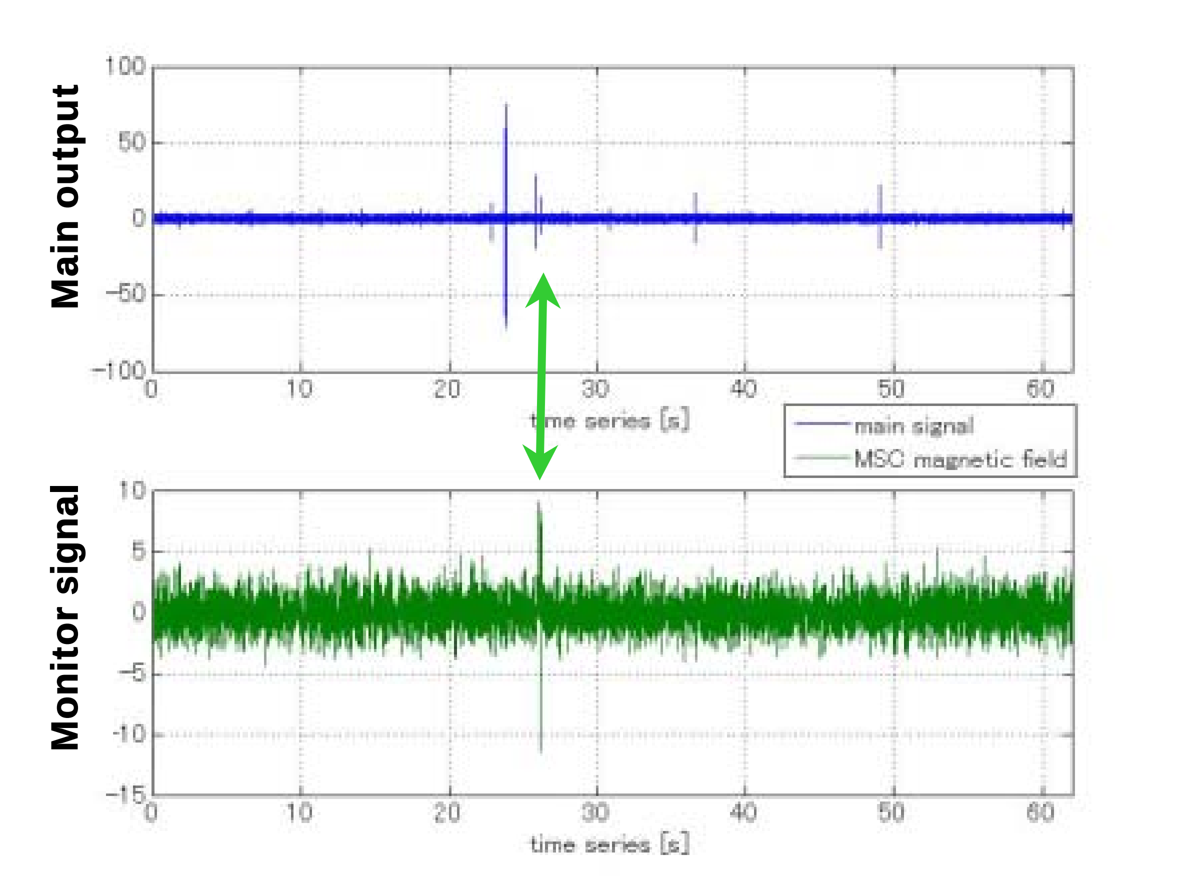
Veto analysis (6)

- Magnetic field -

- **Example of coincident events**

Magnetic field – center room perpend. direction

(time series data after data conditioning)

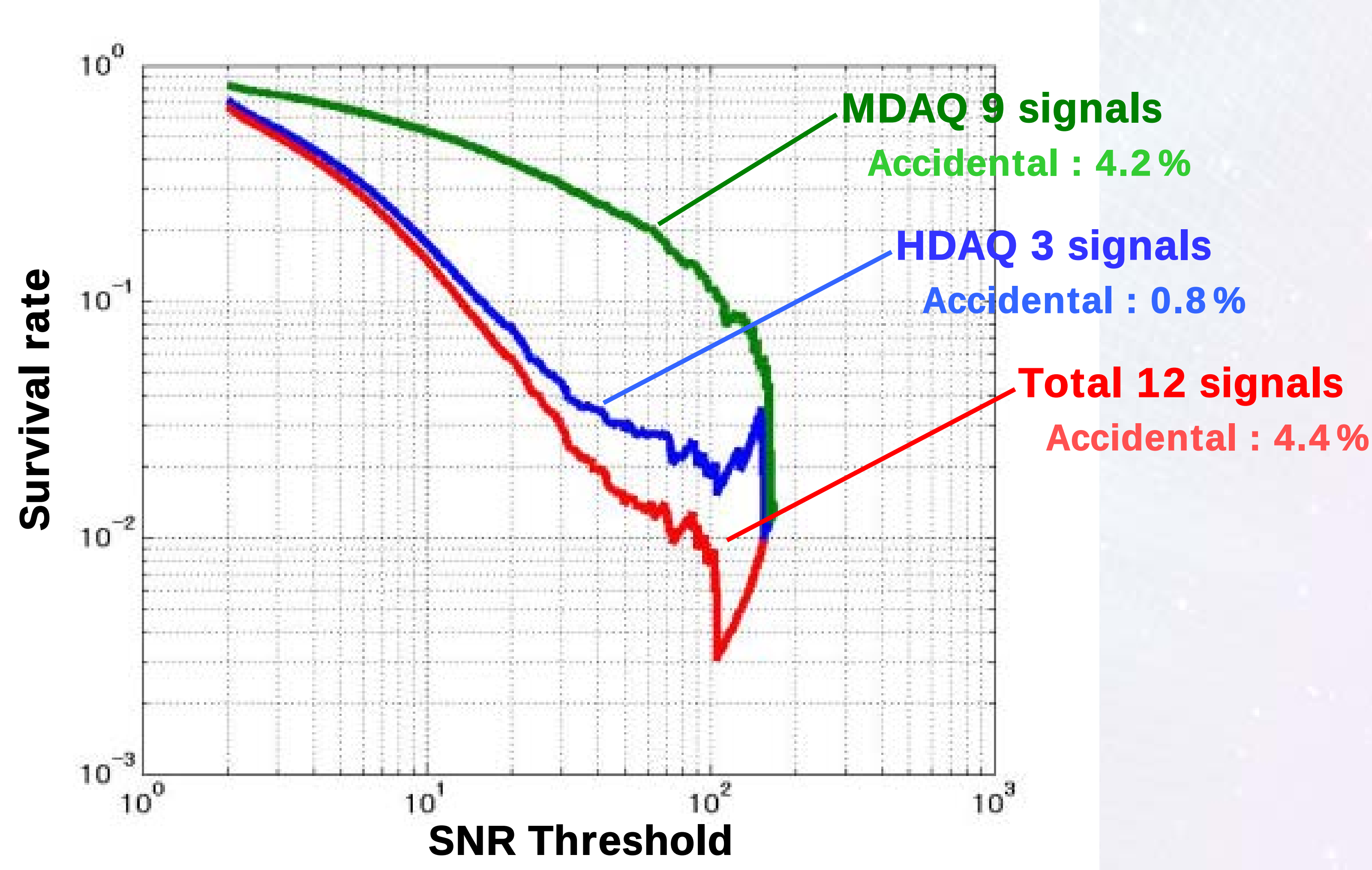


Veto analysis (7)

- Veto results -

- **Survival rate**

Veto results with 178 hours of data



Summary

Summary

- **Summary**

  Systematic survey of monitor signals

  Data conditioning filter
  Excess power burst filter
  Coincidence analysis
  between main and monitor signals
  Optimization of analysis parameters

  Analysis with TAMA DT9 data

  200 hours data (10% are used as playground data)
  Correlations were found in 12 monitor signals
  (Intensity monitor, Seismic motion, Magnetic field)

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  Reject 92% (SNR>10), 98% (SNR>100) fakes
  with 4.4% accidental rejection probability

- **Current tasks**

  Hardware signal-injection test

  → Confirm the safety of veto
  (already done for some of the monitor signals)

End

Burst-wave analysis (3)

- Data conditioning -

- **Data conditioning**

Line removal

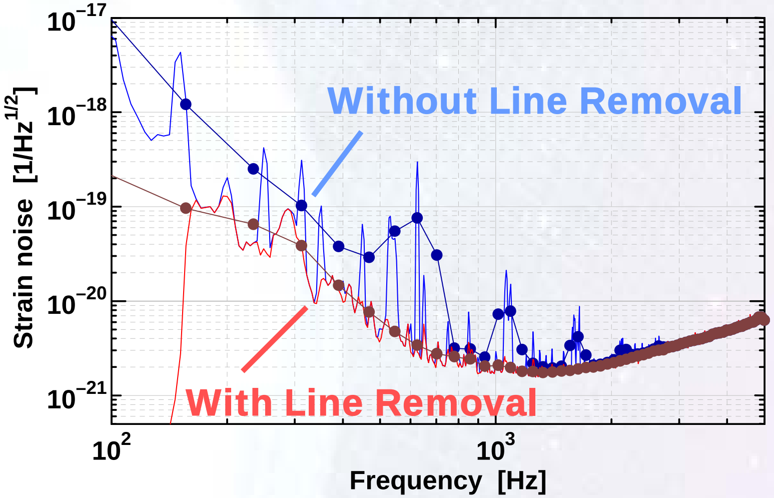
AC line, Violin mode peak,
Calibration peak

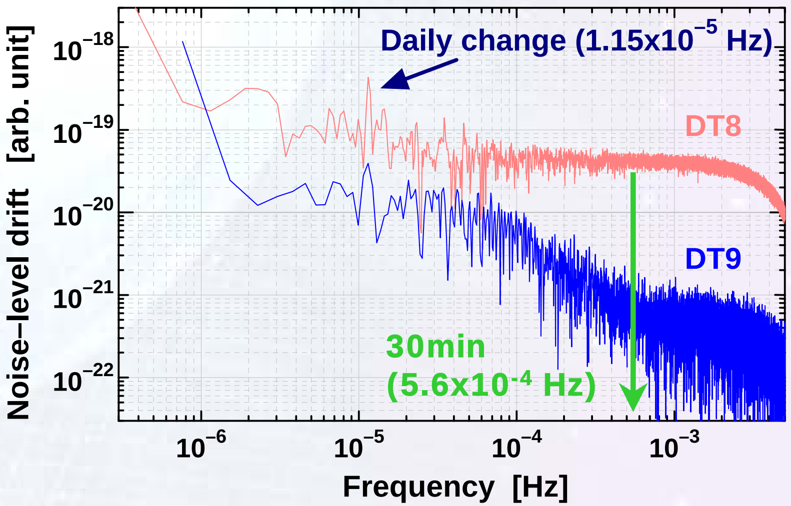
Method
FFT 72sec data
Reject line freq. components
Inverse FFT

Normalization

Track the drift of noise level
→ Each spectrum is normalized by averaged noise spectrum

Use 30min-averaged spectrum





Time series data (after conditioning)