DMRadio-50L Analysis

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DMRadio Collaboration Meeting

October 8, 2025

Outline

1. Principles of Analysis Software
2. Analysis Schematic
3. Run-dmr Status
4. Truncation
5. Immediate to-do’s

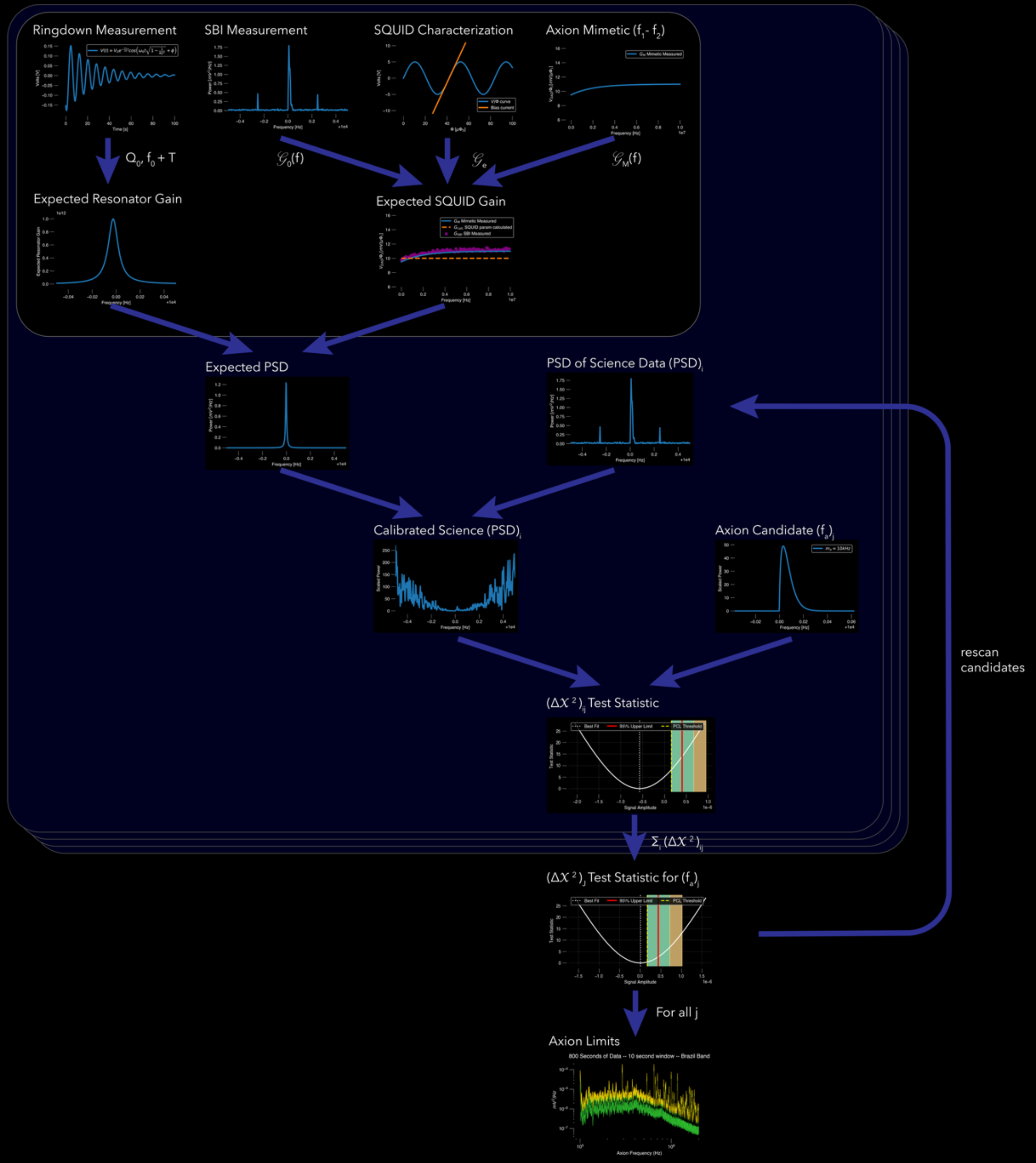
Principles of Analysis Software

- Flexible & Modular.
- Reproducible & Tracible.
- Scalable & Efficient.
- Usable & Well-documented.

Analysis Schematic

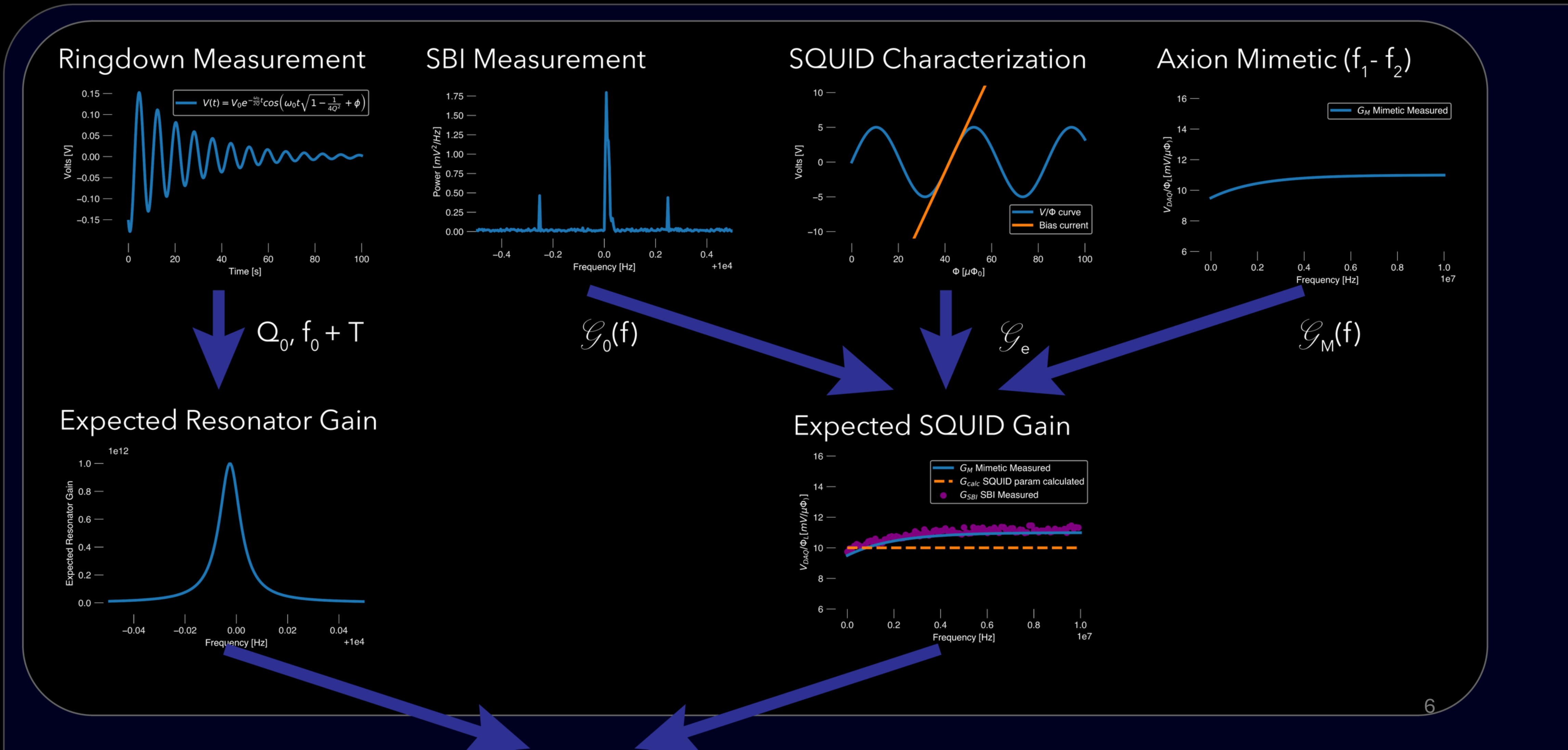
- Software built for baseline standard halo model axion.
- Standard halo model axion search procedure based on ABRA analysis.
  - *“Foster, Joshua W., Nicholas L. Rodd, and Benjamin R. Safdi. "Revealing the Dark Matter Halo with Axion Direct Detection." Physical Review D 97.12 (2018): 123006.”*

Analysis Schematic



[Lucid Chart]

Analysis Schematic



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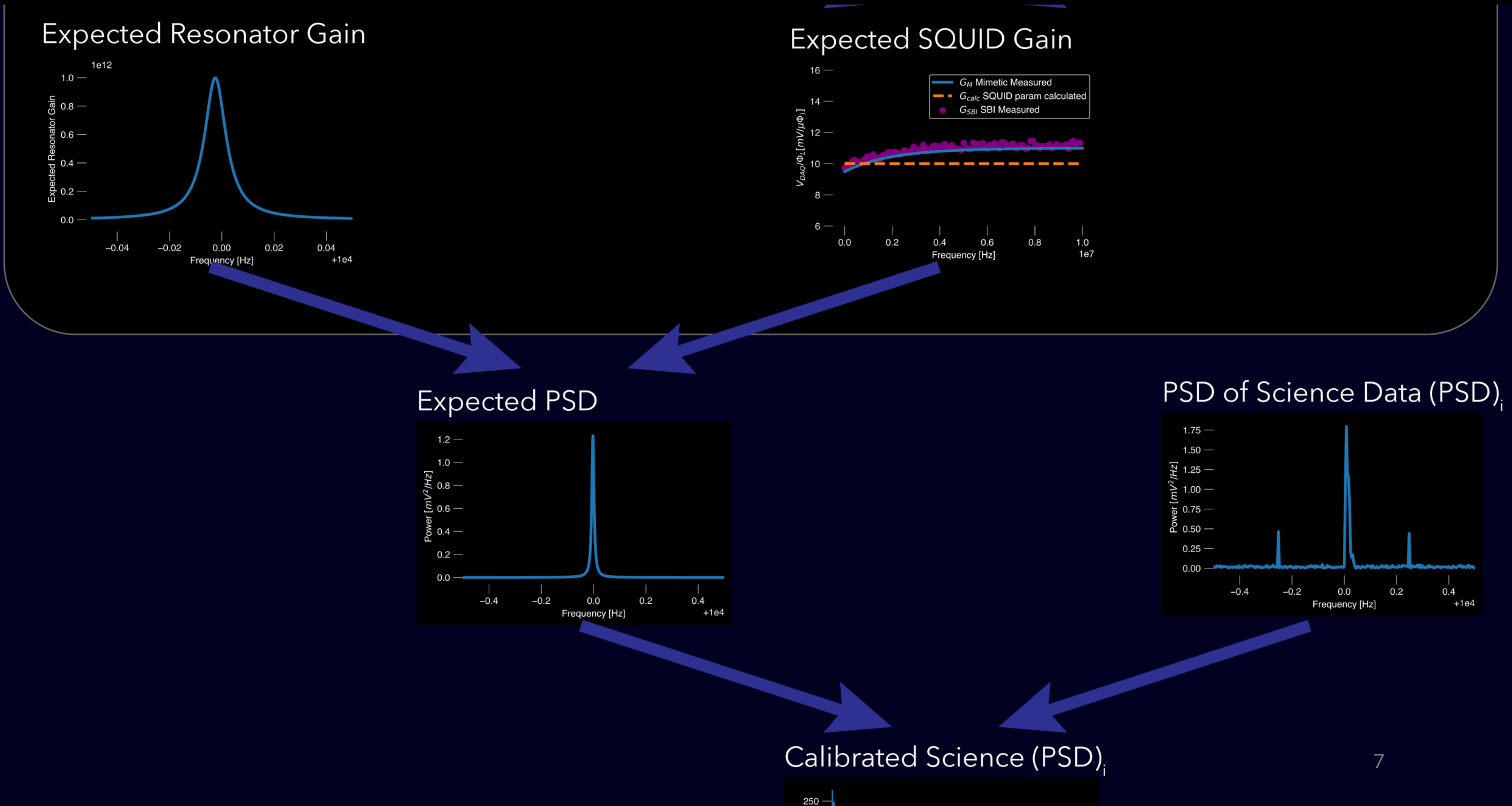

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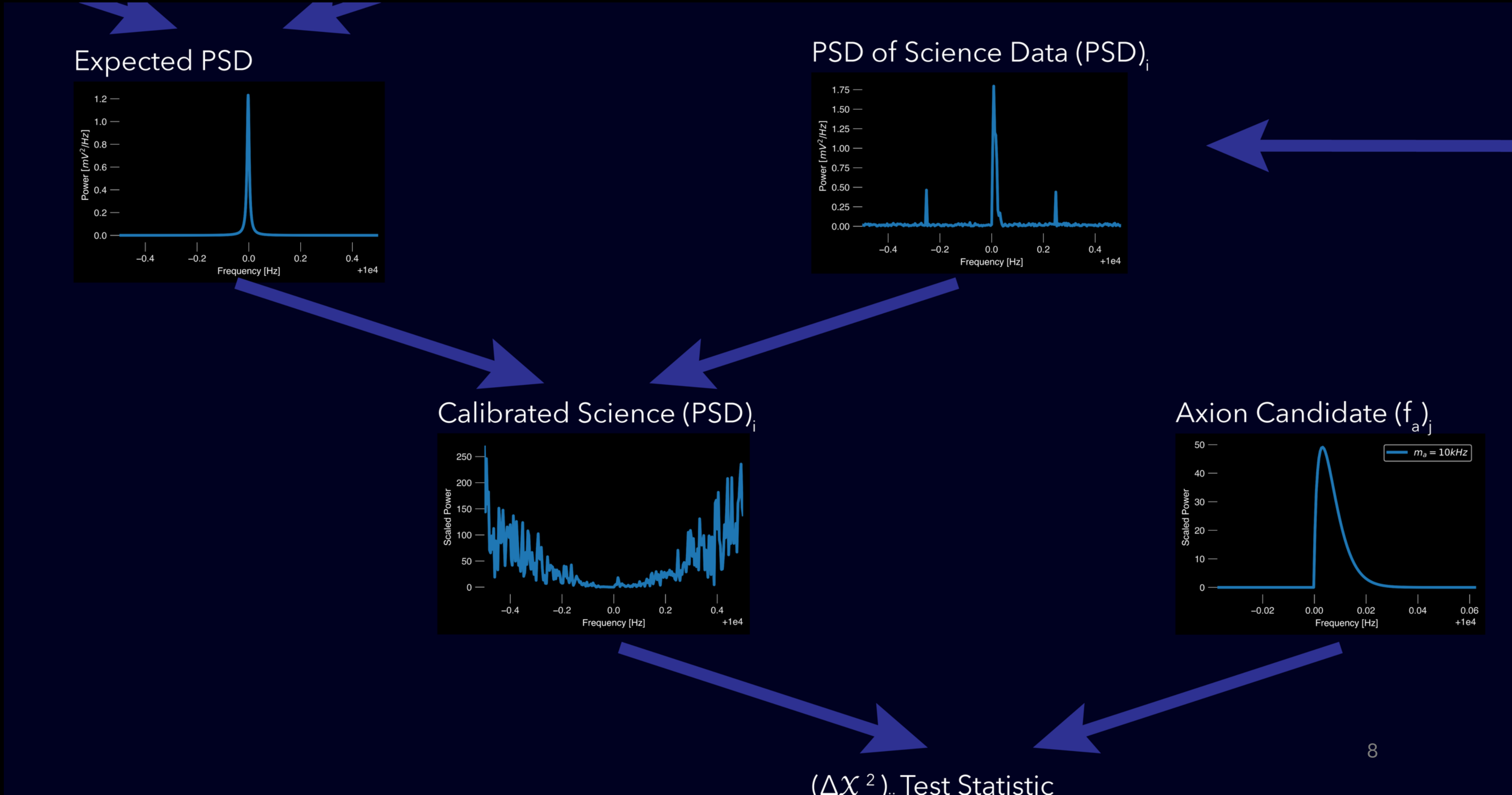
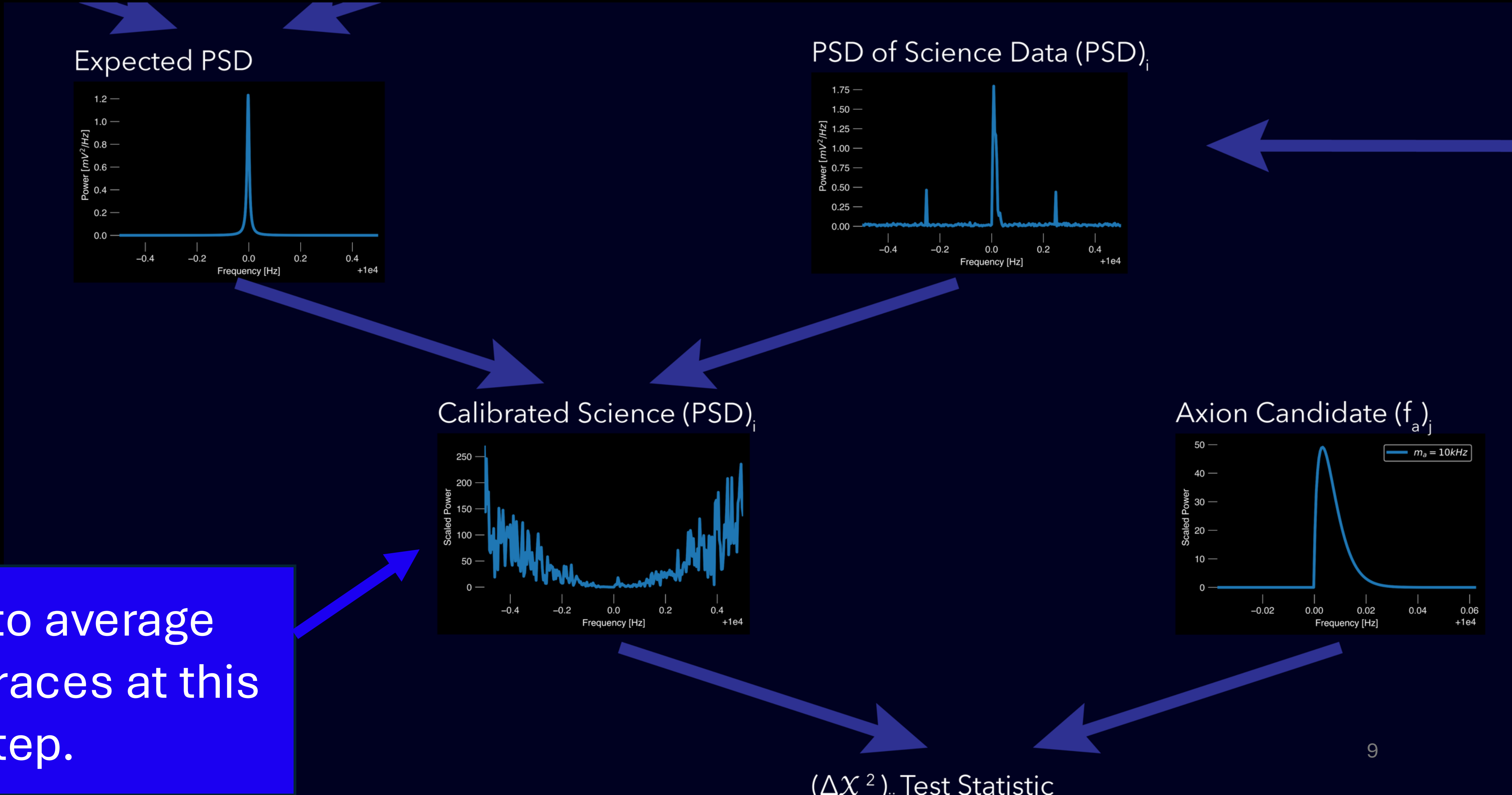


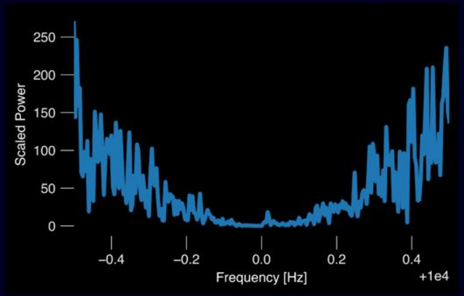
Analysis Schematic



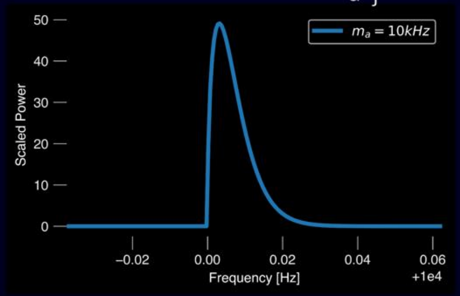
Option to average multiple traces at this step.

Analysis Schematic

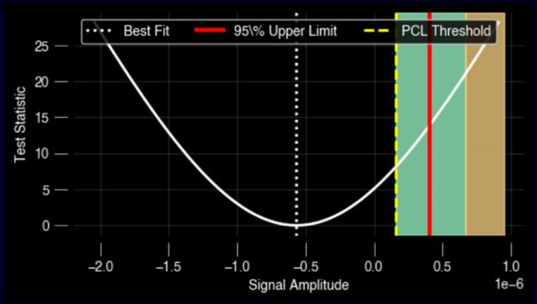
Calibrated Science (PSD)$_i$



Axion Candidate $(f_a)_j$



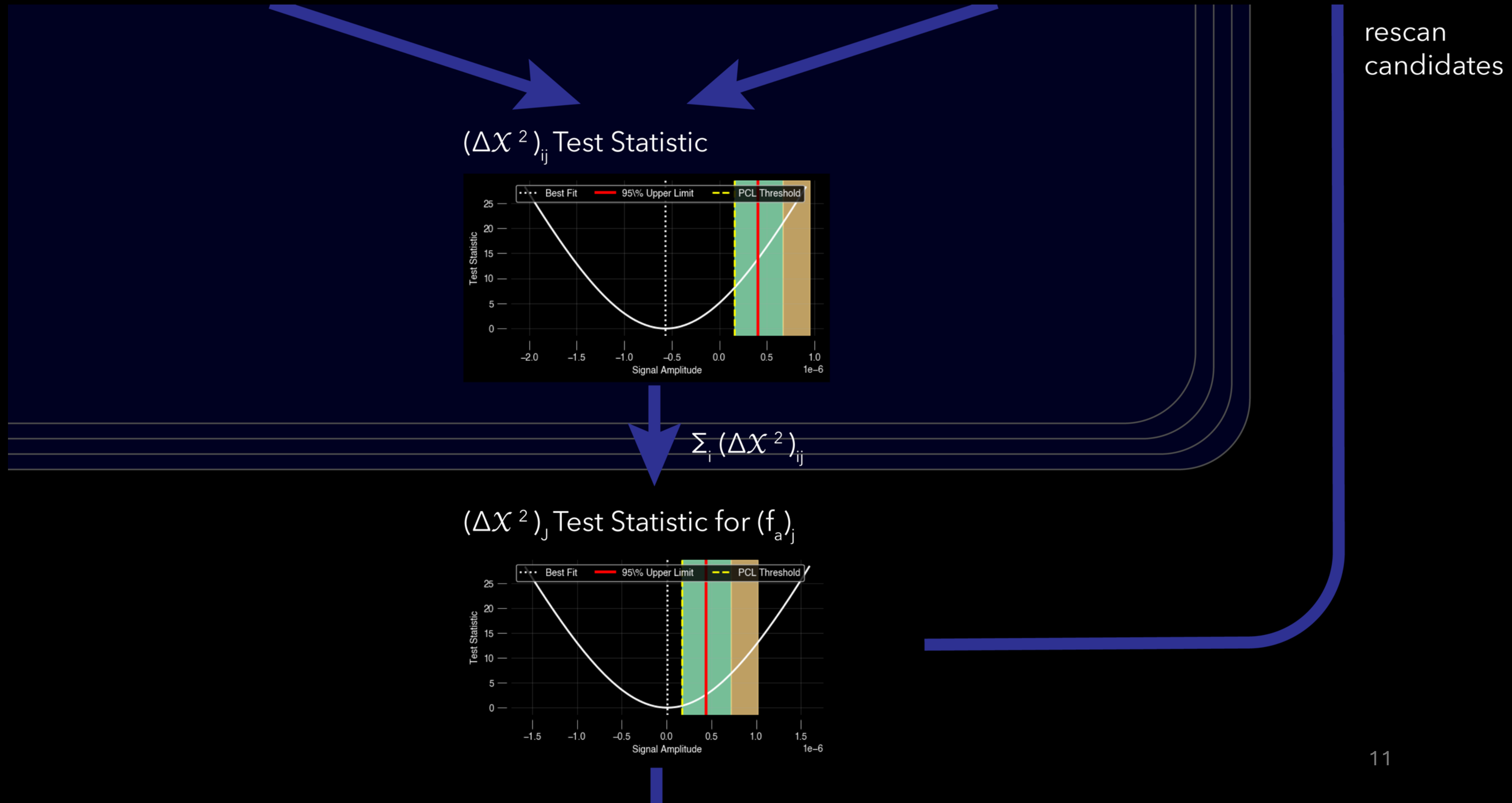
$(\Delta X^2)_{ij}$ Test Statistic



$$\Theta(m_a, A) = 2[\ln \mathcal{L}(d|\mathcal{M}, \{A, m_a, \hat{\boldsymbol{\theta}}_B\}) - \ln \mathcal{L}(d|\mathcal{M}_B, \hat{\boldsymbol{\theta}}_B)], \quad (35)$$

$$\Theta(m_a, A) = 2\sum_{k=1}^{N-1}\left[S^k_{\Phi\Phi}\left(\frac{1}{\lambda_B} - \frac{1}{\lambda_k}\right) - \ln\frac{\lambda_k}{\lambda_B}\right]. \quad (39)$$

Analysis Schematic



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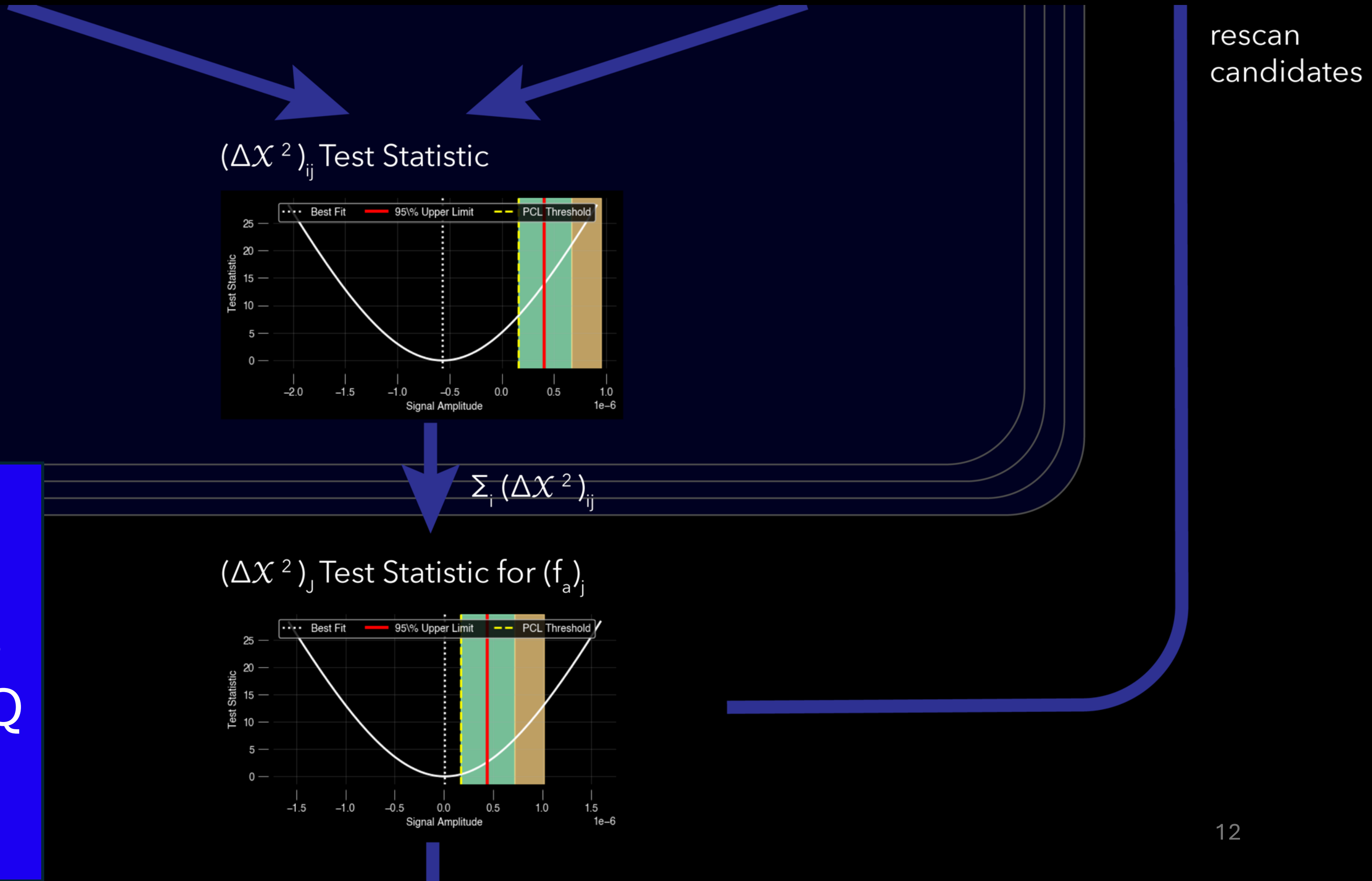
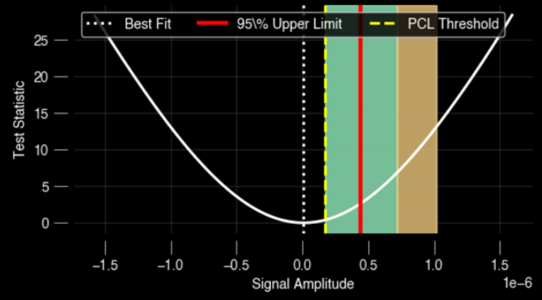


Stacking in test statistic space allows for calibration and DAQ binning flexibility

Analysis Schematic

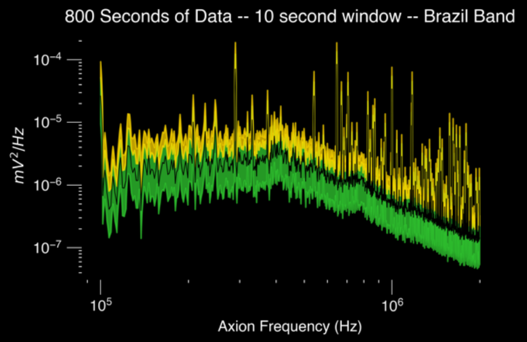
$\Sigma_i (\Delta\chi^2)_{ij}$

$(\Delta\chi^2)_j$ Test Statistic for $(f_a)_j$



For all j

Axion Limits



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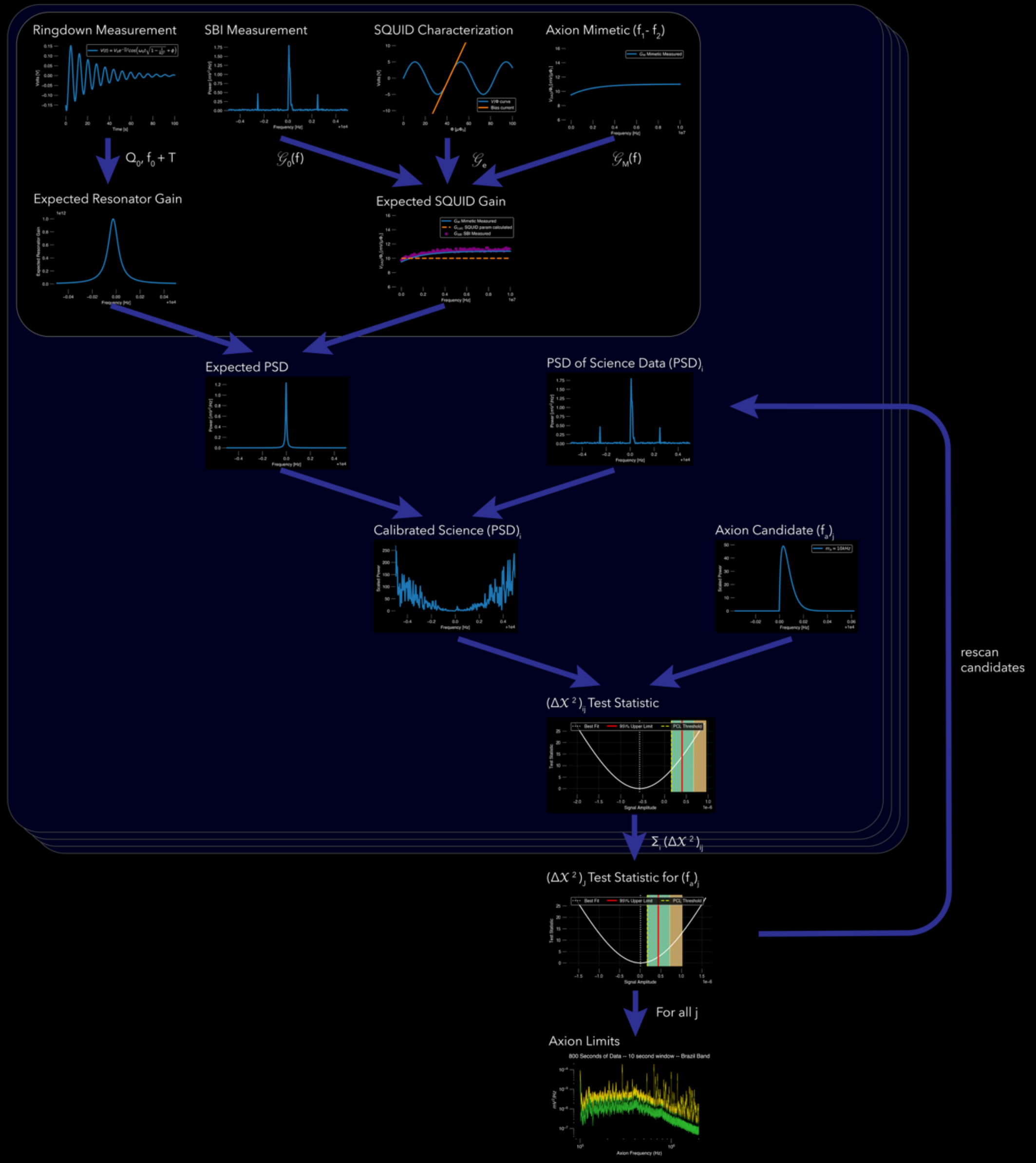

Lucid Chart

Run-dmr Status

- Analysis software package run-dmr → dmr-analysis
- Classes
  - ✓ Constants
  - ✓ Params
  - ✓ DMRTimestream
  - ✓ DMRfft
  - ✓ DMRSpectrum
  - ✓ DMRLikelihood
  - ✓ DMRSignalTemplate
  - ✓ DMRTemplate
  - ✓ DMRCalibratedSpectrum
  - DMRCalibrator
  - DMRGrandLikelihood

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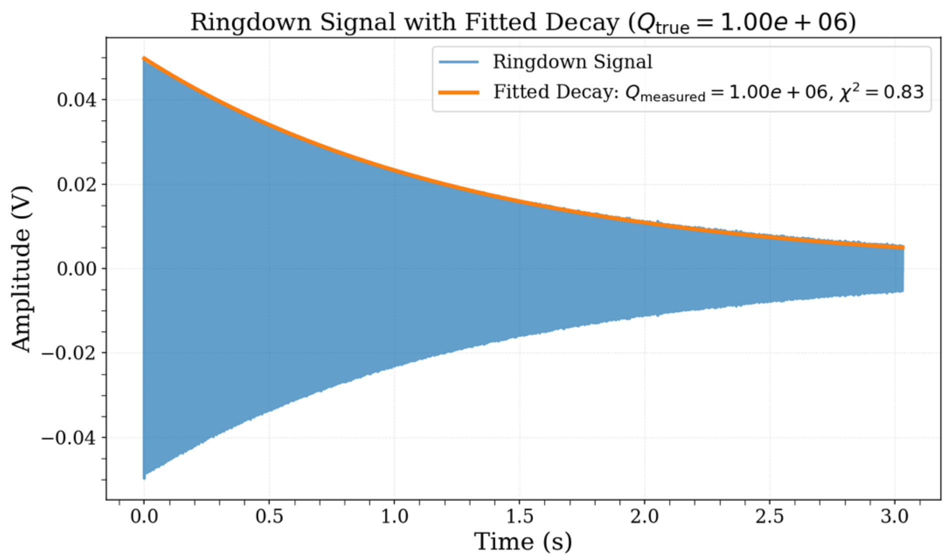
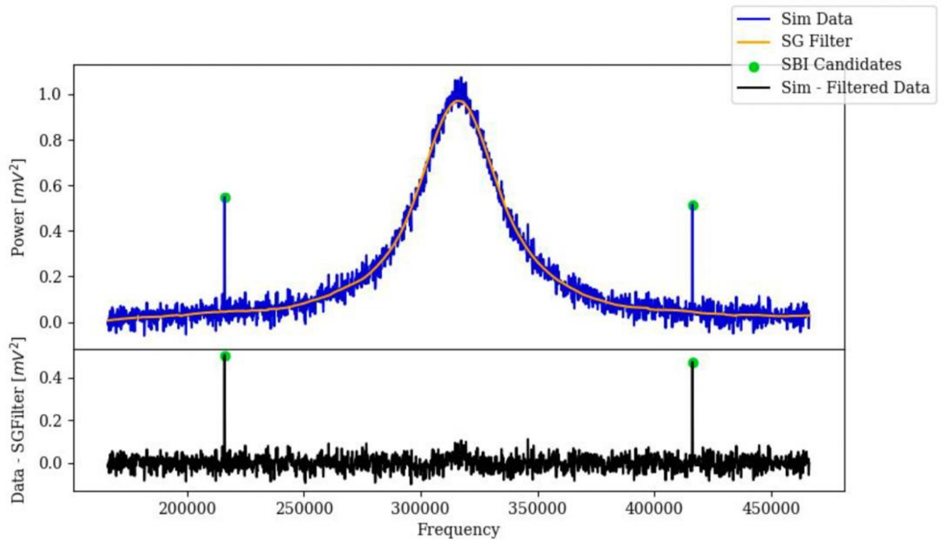
DAQ-athon
Monday Oct 13
You can do an axion analysis of mock data with run-dmr

Calibration

- Ring Down (RD) – Sergio
  - Online calibration completed
  - Optimized for fast performance
  - To do: implement offline reanalysis of RD
- Side Band Injection (SBI) – Shreya
  - Online calibration complete
  - To do: implement offline reanalysis of SBI

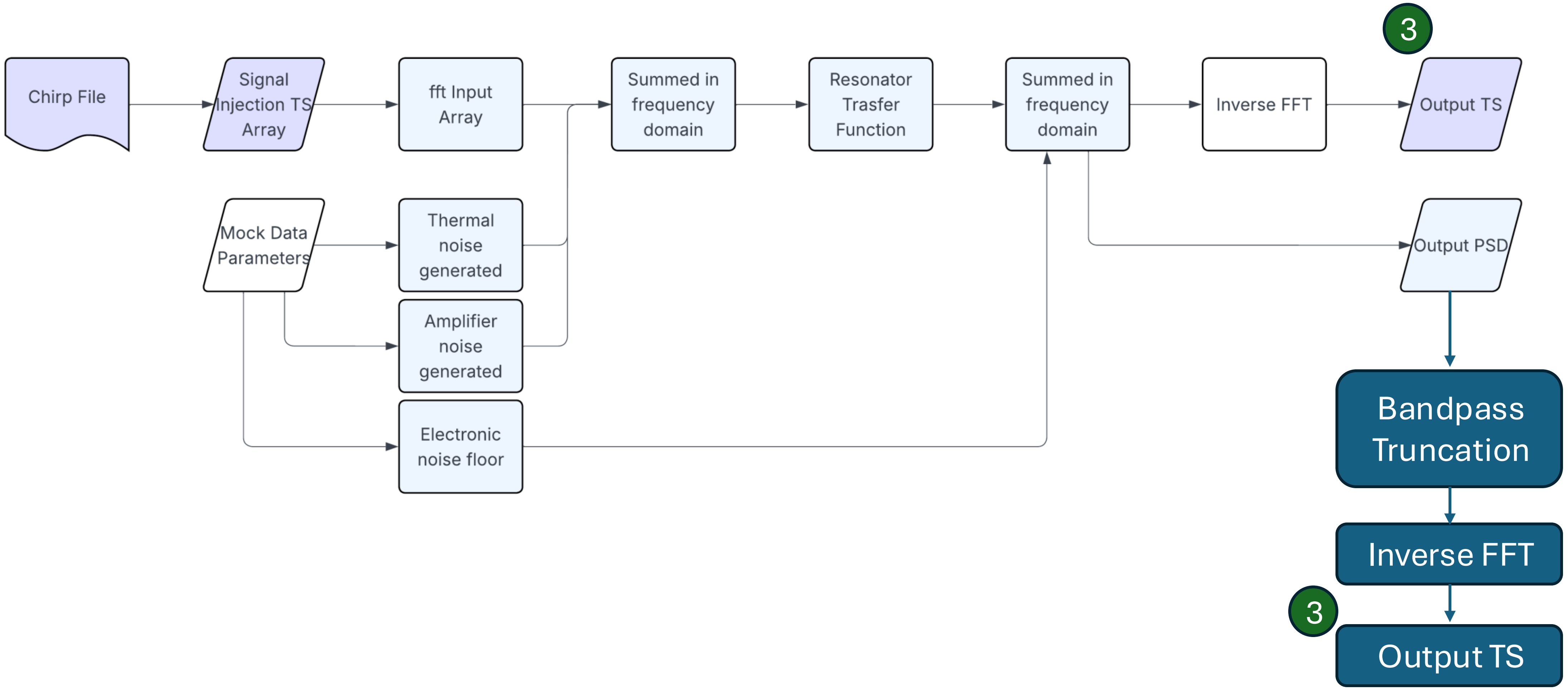




Truncation & GW Search

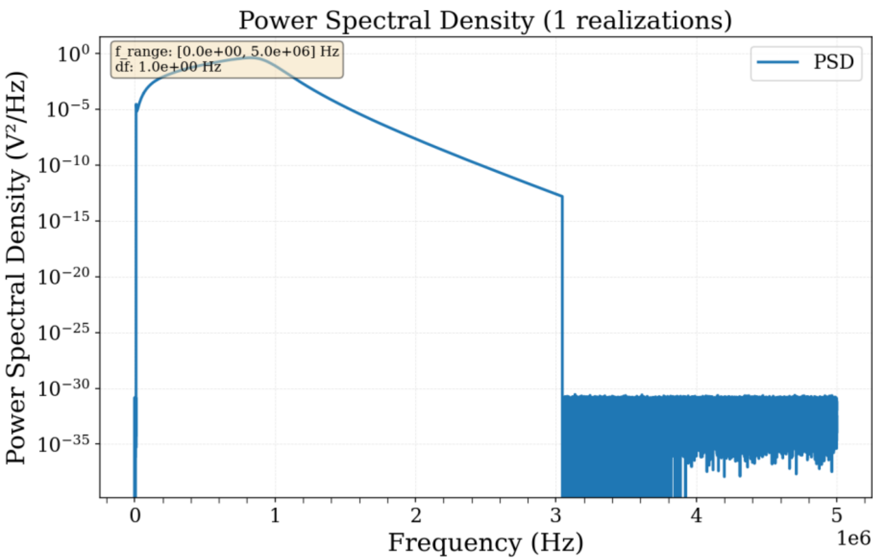
- Follow up to discussion yesterday on data truncation’s affect on analysis.
- Completed an ancillary analysis for time domain signal – gravitational wave (GW) – in DMR.
- Goals:
  1. Test run-dmr mock TS data generation with flexible signal injection.
  2. Determine if we lose non-standard signal sensitivity with psd truncation.

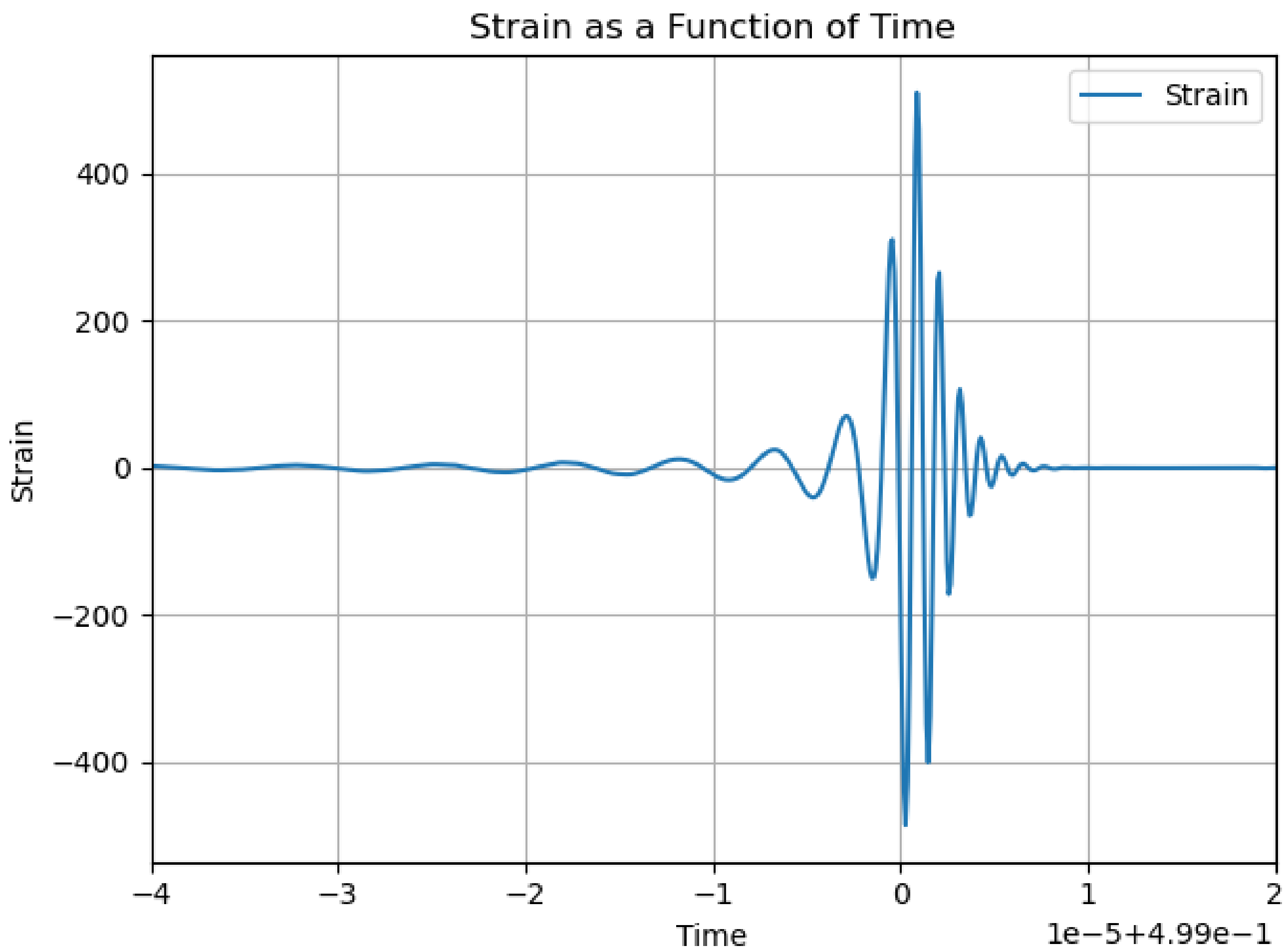
TS Mock Data Pipeline



Signal injection

- Strain signal from Kaliroë
- Inputted via array of V(t) into DMRTimeSeries

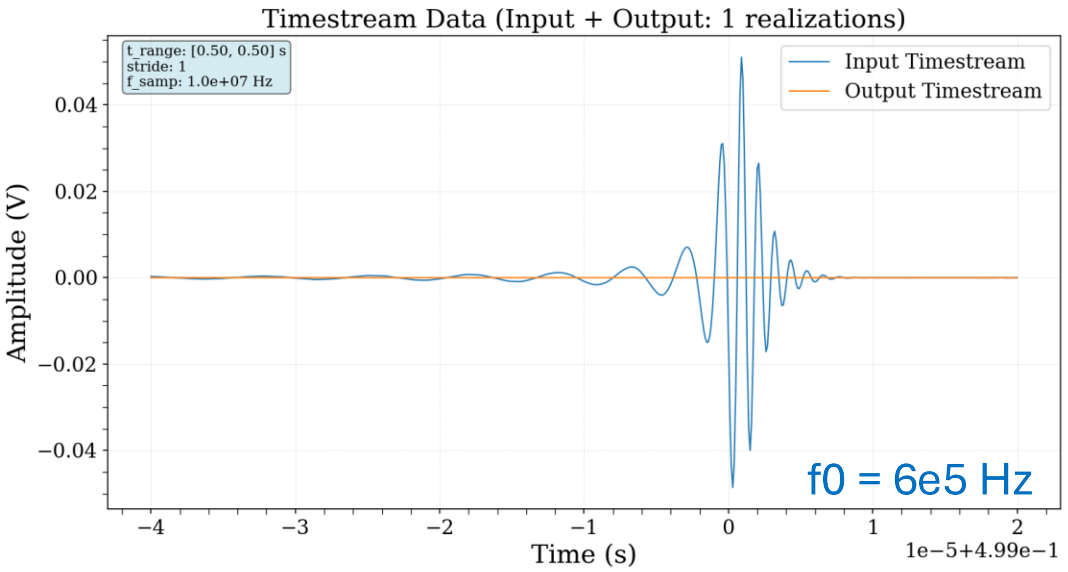


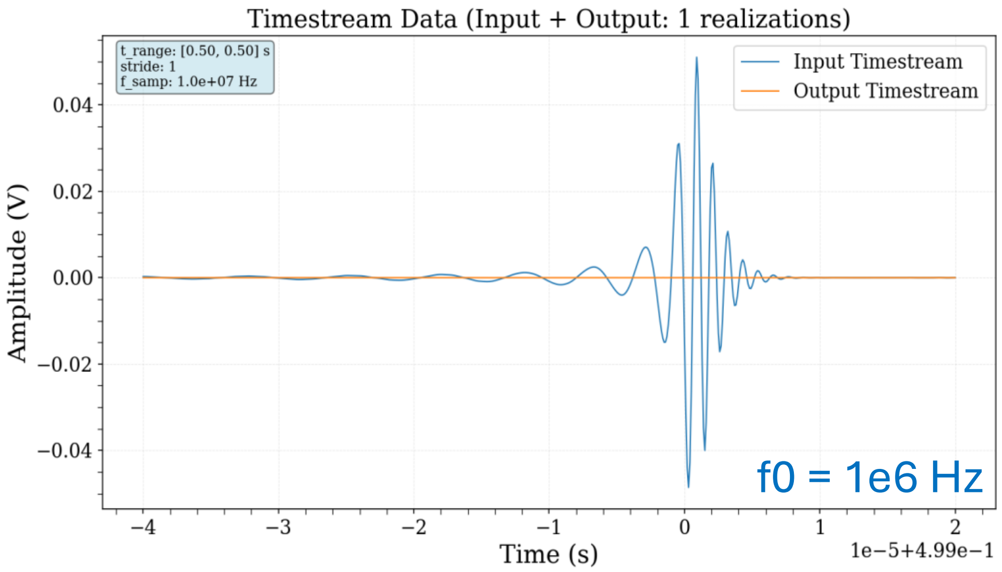


Simple Test

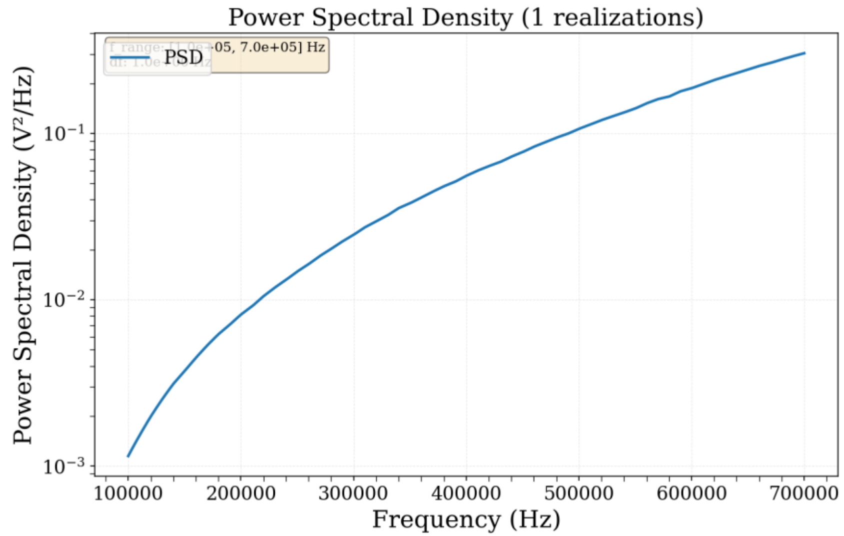
Do I see large chirp in output TS after resonator transfer fn? No.

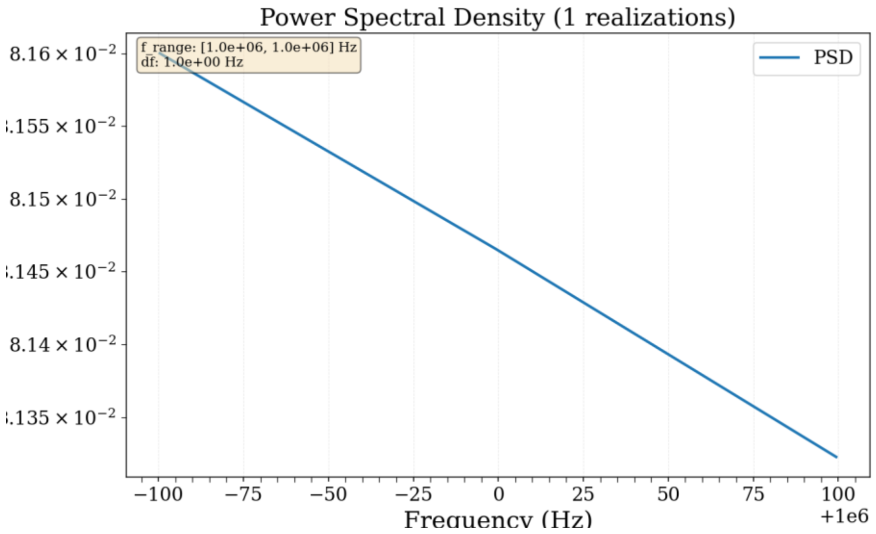
Chirp signal has components from 1Hz – 5MHz. Tested f0 = 600 kHz, 1MHz



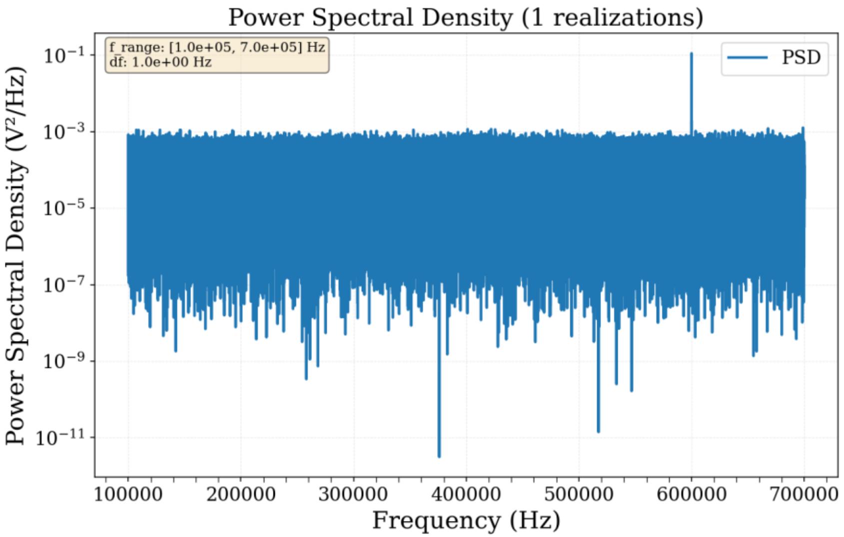


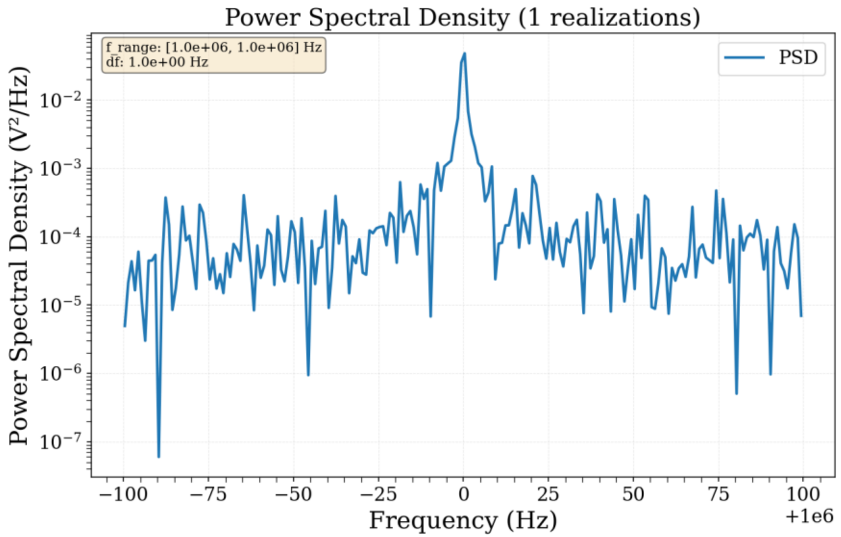
Simple Test Freq Domain





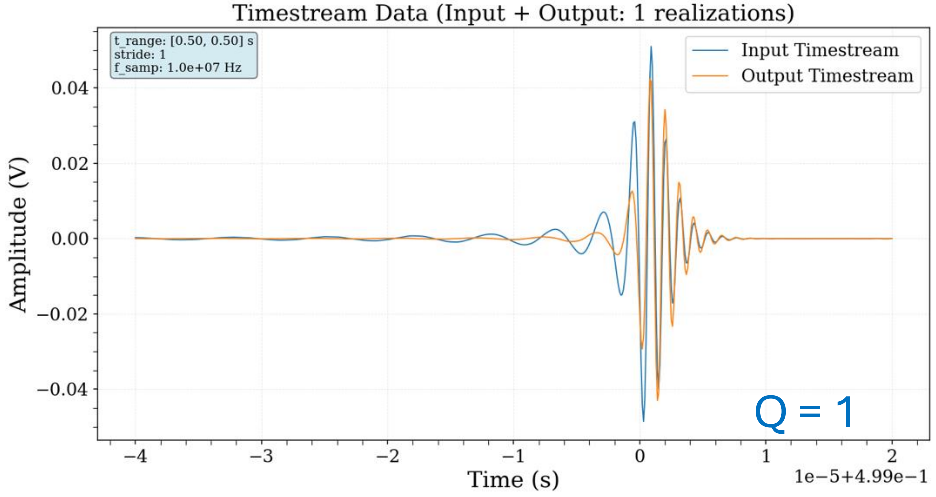
Input PSD

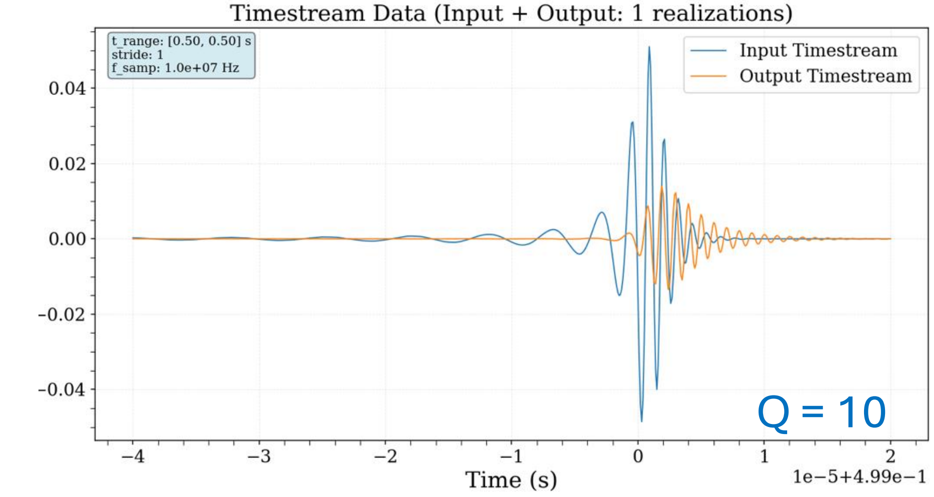


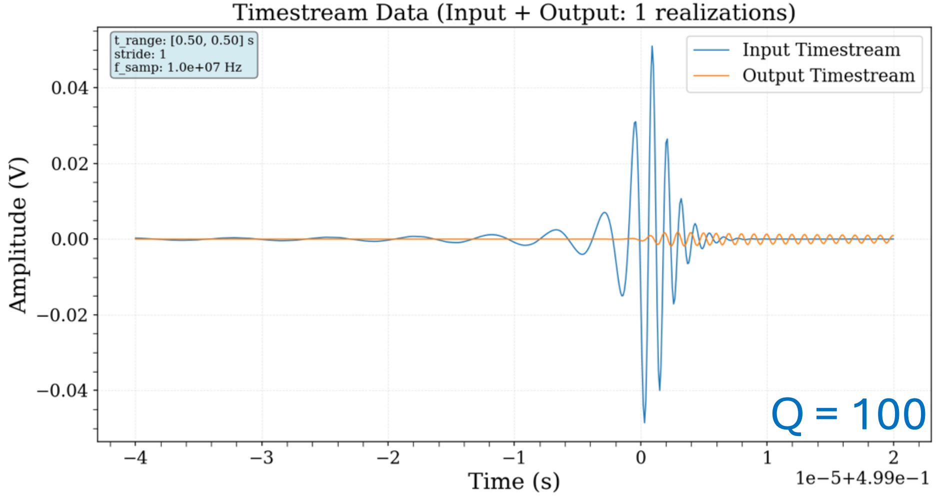


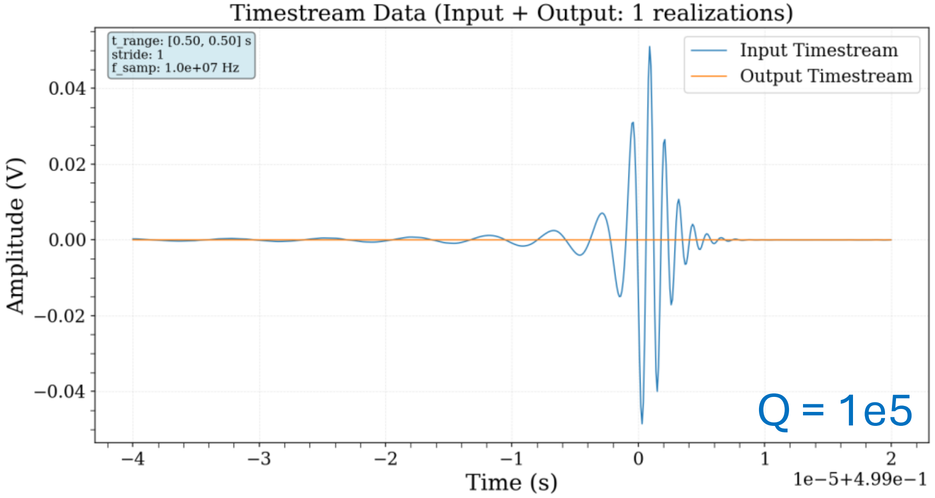
Output PSD

Simple Test Vary Q (f0 = 1MHz)

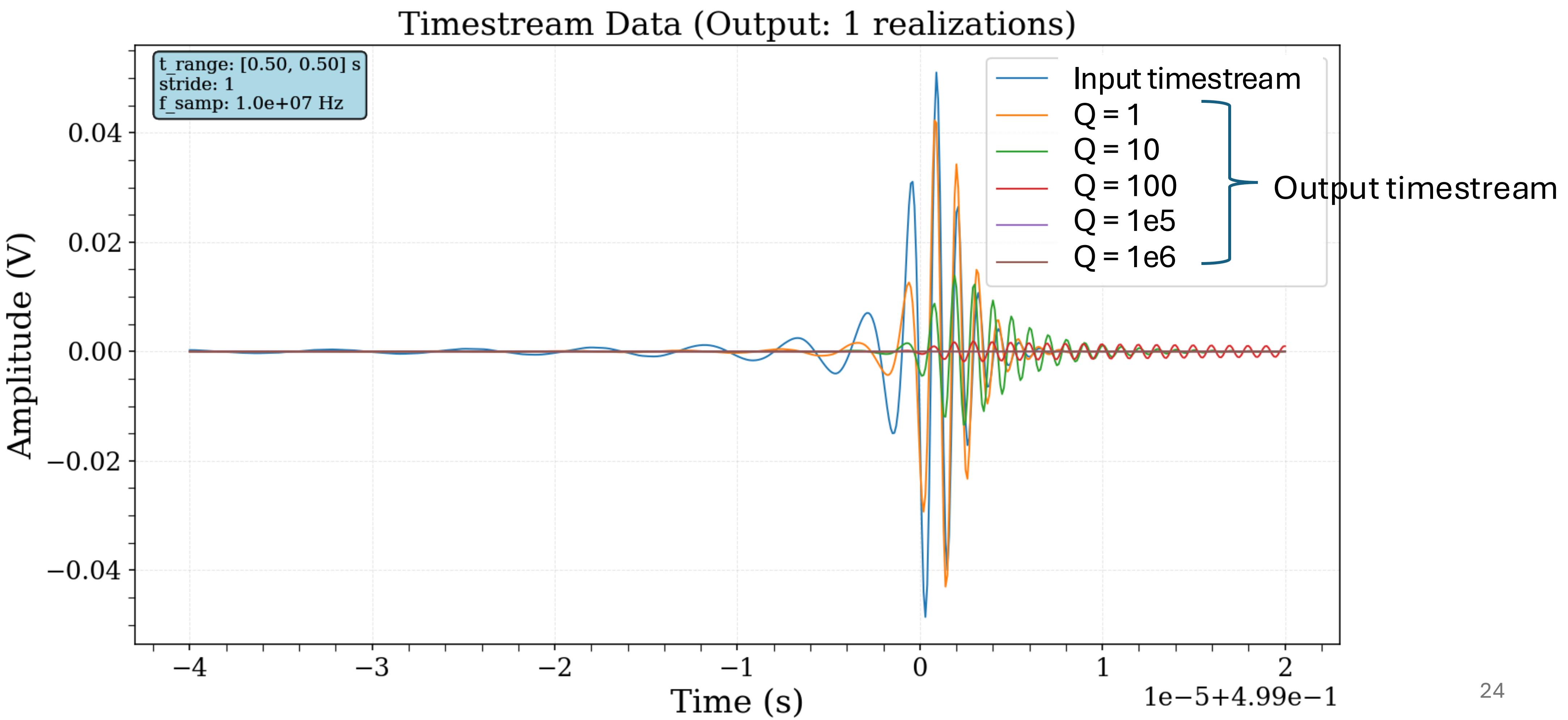




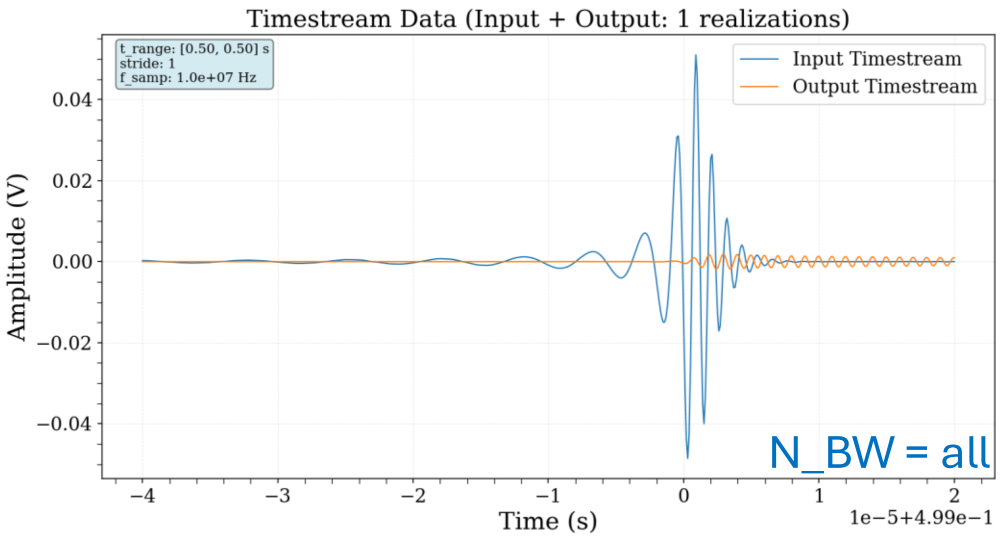


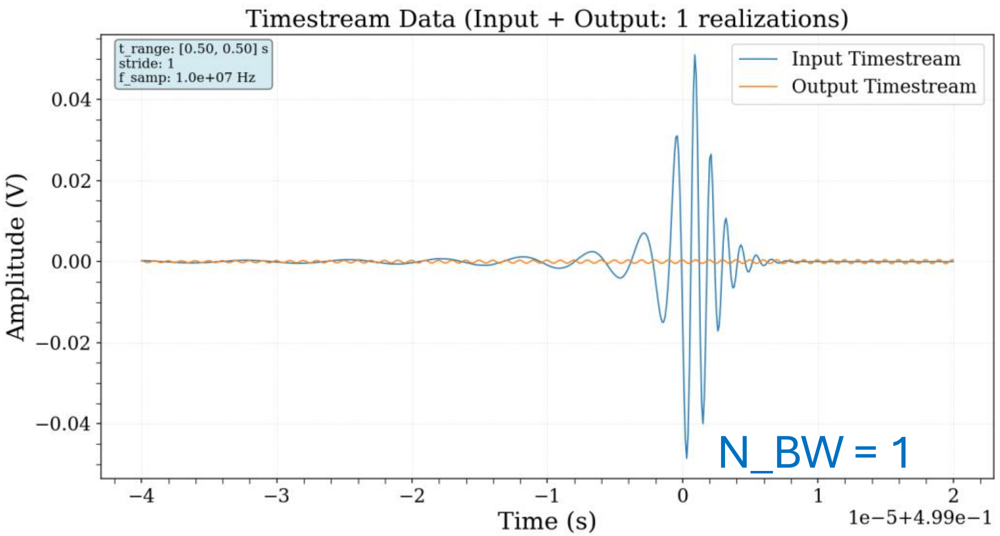


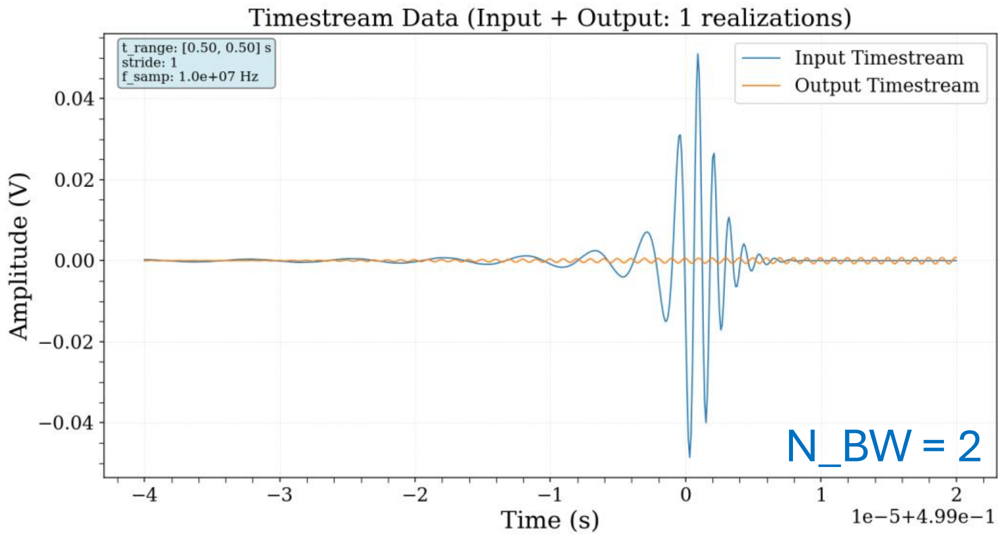
Simple Test Vary Q
(f0 = 1MHz)

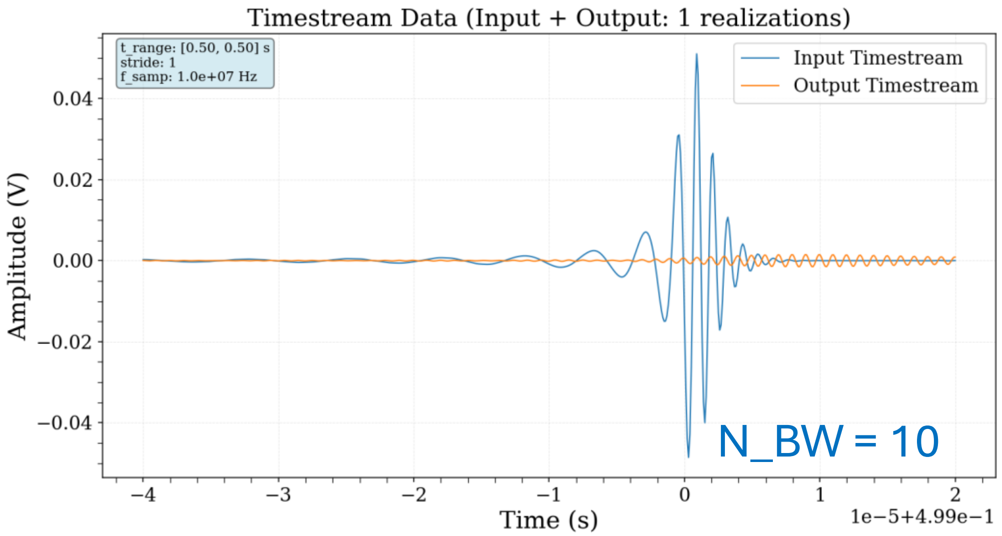


Vary N_BW saved (Q = 100, f0 = 1MHz)

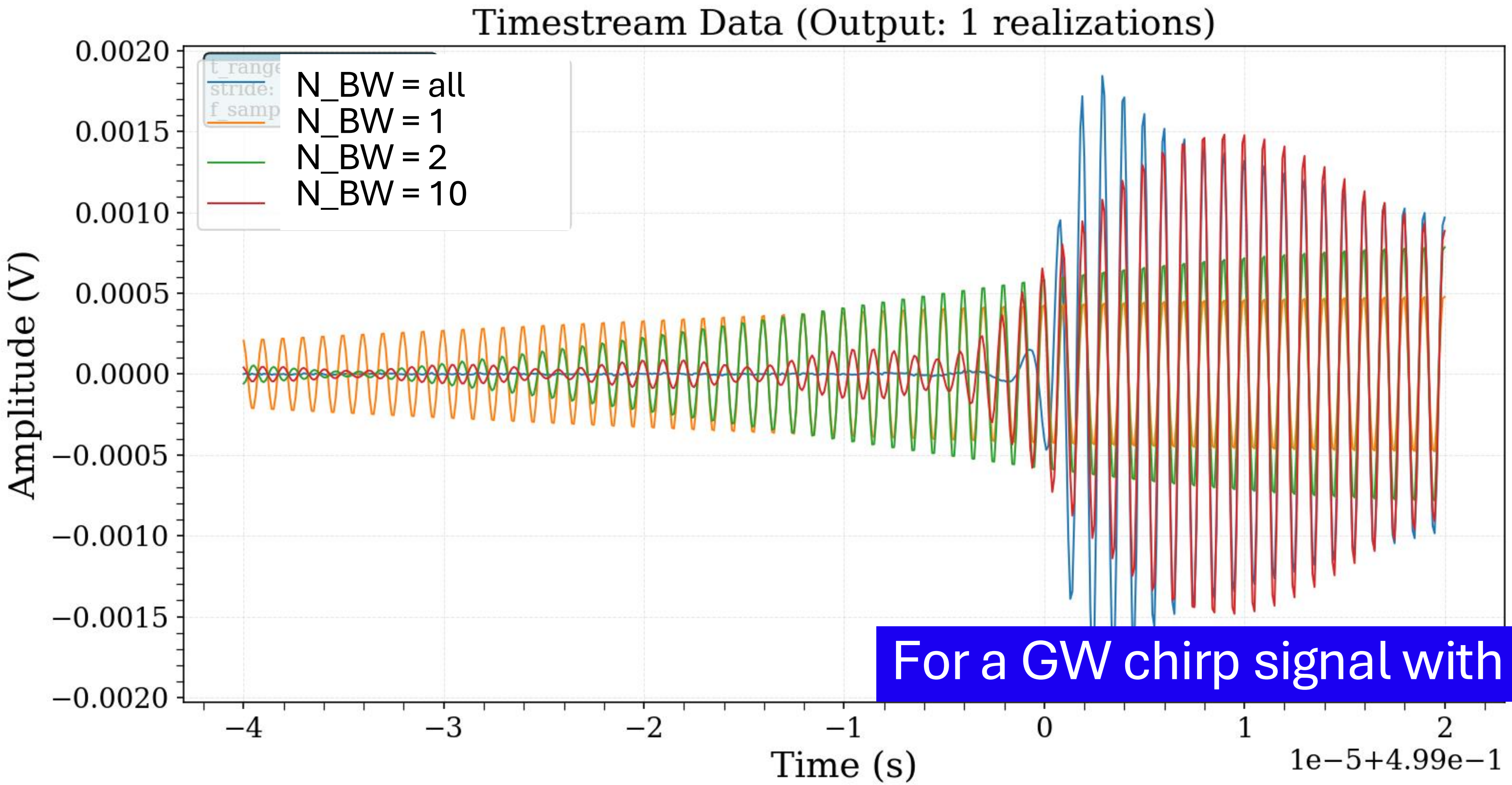








Vary N_BW saved [all, 1, 2, 10] (Q = 100, f0 = 1MHz)



For a GW chirp signal with 5,000 SNR

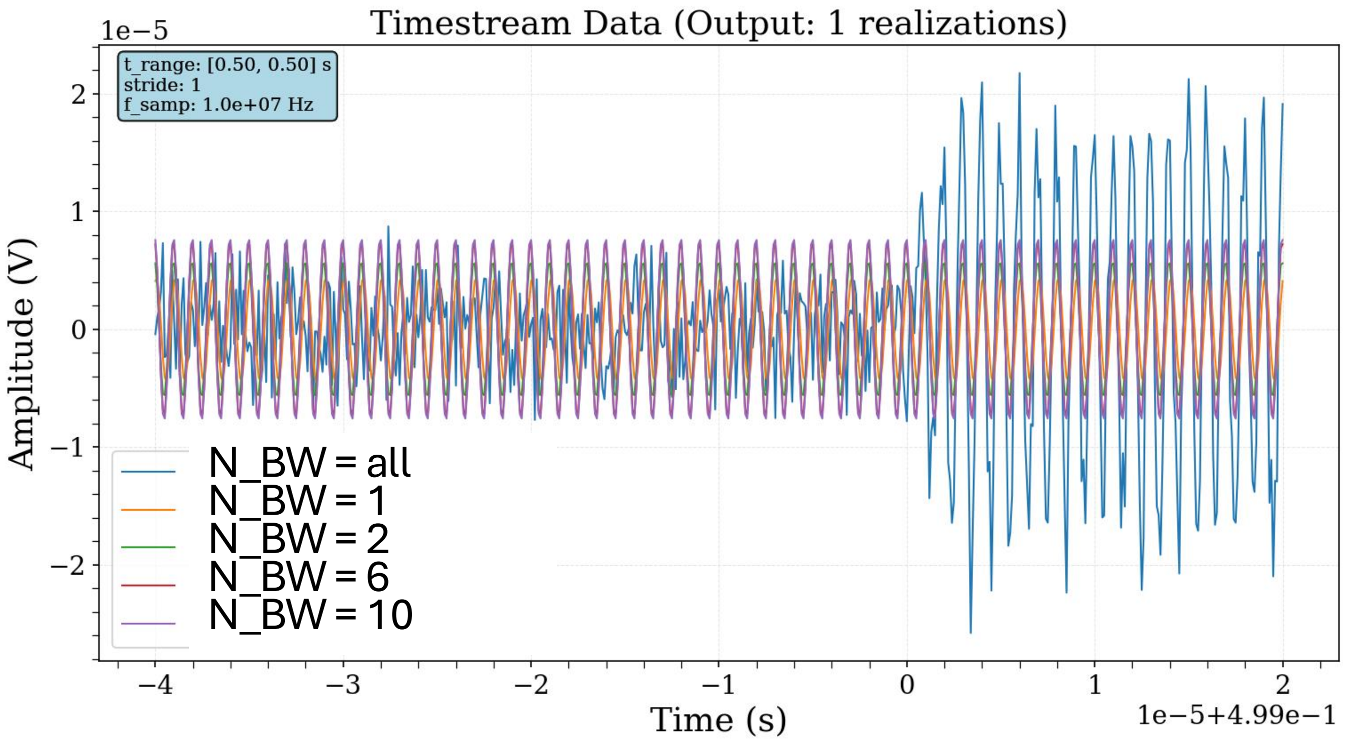
Could we minimize bandwidth of GW signal with astrophysical parameters?

- Higher total mass narrows signal in frequency domain
  - Also decreases absolute frequency -- outside of DMR range
- Equal mass ratio narrows signal band
  - Already are using an equal mass BHM
- Strong anti-aligned spin could reduce bandwidth
  - Change chirp parameters in Ripple
- Could simply observe shorter window around merger – last 0.1ms
  - Change analysis window

Merger Parameter	Value
M_1	$0.01\, M_\odot$
M_2	$0.01\, M_\odot$
Dimensionless spin	0
Time of coalescence	1 ms
Distance to source	100 km
Inclination	0

Could we see a gargantuan signal?

- SNR = 5 V/ 1e-5 V = **500,000**
- GW signal present but highly transformed
- Any amount of band pass truncation washes out signal



Truncation Takeaways

1. **Any reasonable Q erases GW signal with a reasonable SNR**
2. Any amount of truncation reshapes chirp, erasing GW signal

While the truncation of the PSD does erase a GW signal, we aren't even nearly as sensitive to a GW as ABRA because DMR is a resonant search.

There are other narrow band, stochastic GW signals we could search for,

Immediate To Do’s

- Write sensitivity-window-informed grand likelihood scheme.
- Connect to sequencer h5 files.
- Connect to database.
- Complete merge to dmr-analysis.
- Create calibration skeleton.