Status of the LIGO-ALLEGRO Stochastic Background Search

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on behalf of the LIGO Scientific Collaboration

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Outline

I Background/Motivation for LLO-ALLEGRO Search

- Overlap Reduction Function
- LLO-ALLEGRO Pair (proximity, overlap modulation)
- Technical Considerations (sampling, heterodyning, calibration)

II Status of S2 Analysis

- Data Volume by Orientation
- Data Quality
- Expected Sensitivity

Sensitivity to Stochastic GW Backgrounds

- Optimally filtered CC statistic

$$Y = \int df \, \tilde{s}_1^*(f) \, \tilde{Q}(f) \, \tilde{s}_2(f)$$

- Optimal filter $\tilde{Q}(f) \propto \dfrac{f^{-3}\Omega_{\mathsf{GW}}(f)\gamma_{12}(f)}{P_1(f)P_2(f)}$

  (Initial analyses assume $\Omega_{\mathsf{GW}}(f)$ constant across band)

- Optimally filtered cross-correlation method has Ω_{GW} sensitivity

$$\sigma_\Omega \propto \left(T \int \frac{df}{f^6} \frac{\gamma_{12}^2(f)}{P_1(f)P_2(f)} \right)^{-1/2}$$

- Significant contributions when
  - detector noise power spectra $P_1(f)$, $P_2(f)$ small
  - overlap reduction function $\gamma_{12}(f)$ (geom correction) near ± 1

Overlap Reduction Function

$$\gamma_{12}(f) = d_{1ab}d_2^{cd}\frac{5}{4\pi}\iint_{S^2}d^2\Omega\ P^{\mathsf{TT}ab}{}_{cd}(\hat{\Omega})e^{i2\pi f\hat{\Omega}\cdot\Delta\vec{x}/c}$$

Depends on alignment of detectors (polarization sensitivity)

Frequency dependence from cancellations when $\lambda \lesssim$ distance

$\rightarrow$ Widely separated detectors less sensitive at high frequencies
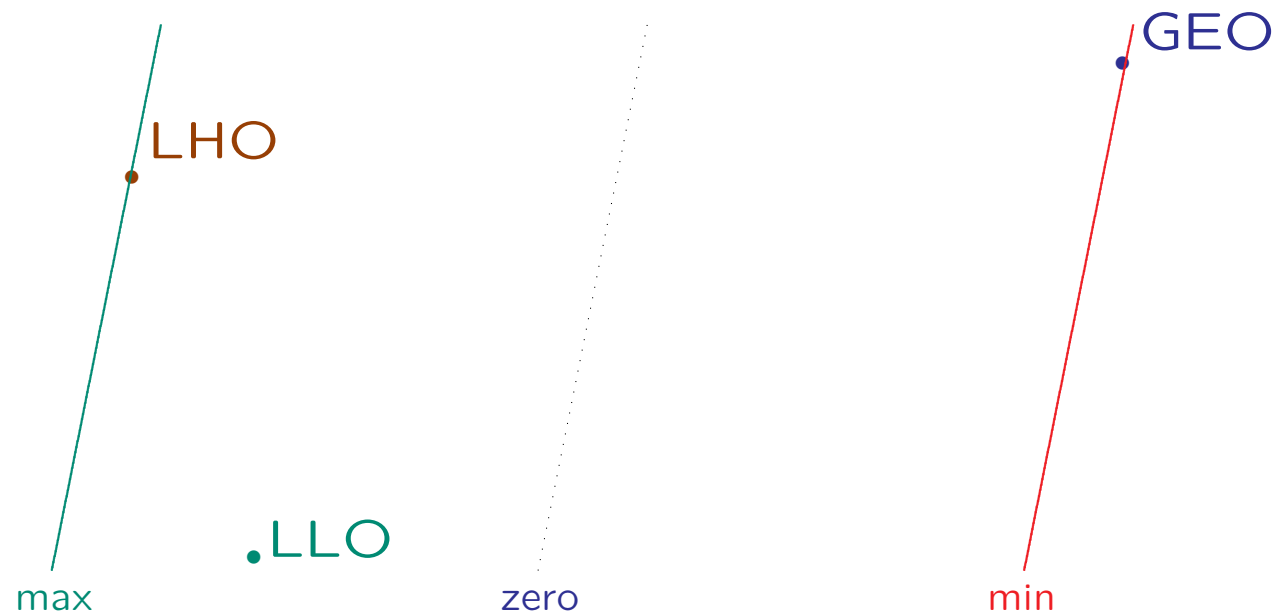
This wave drives LHO & GEO out of phase

Overlap Reduction Function

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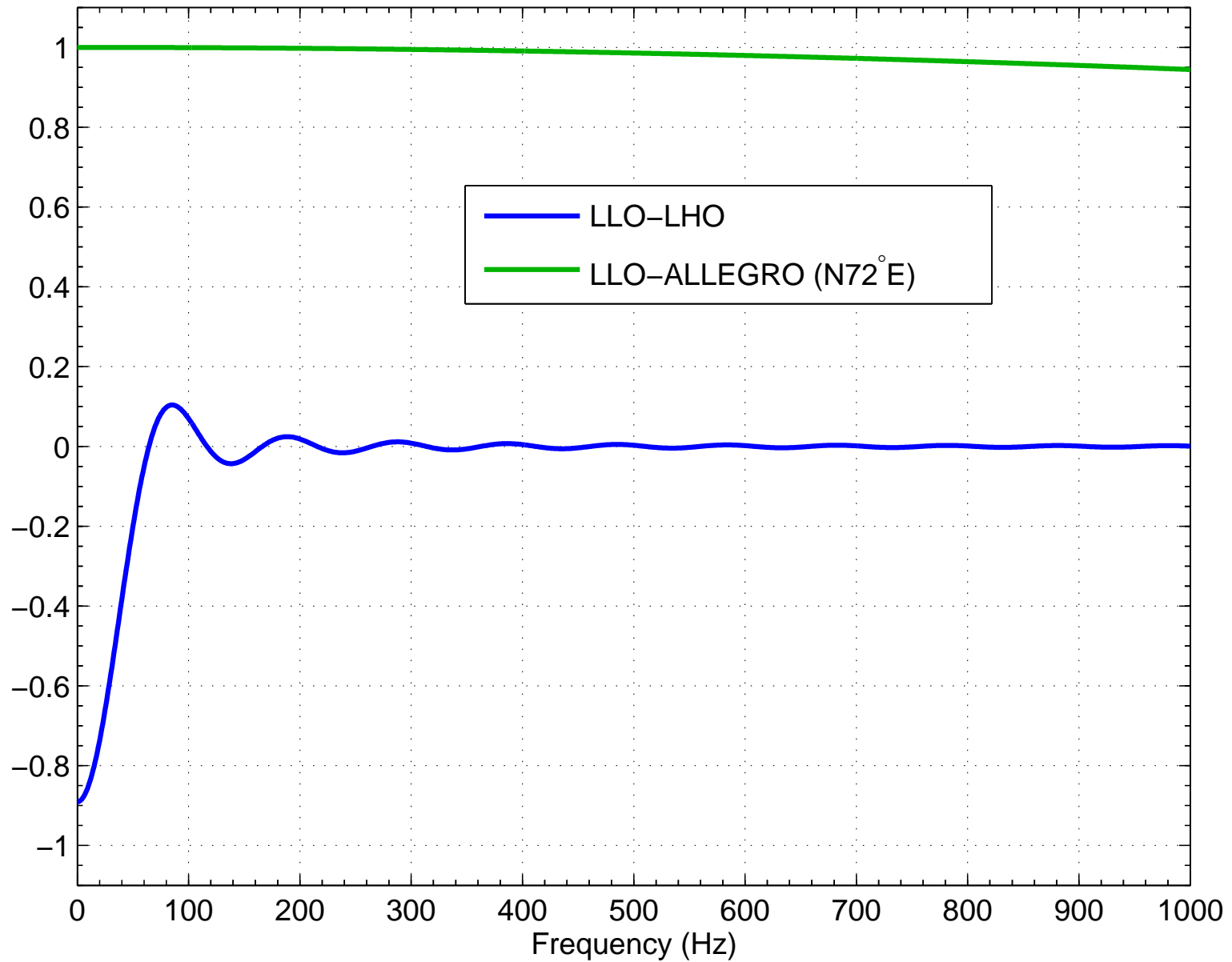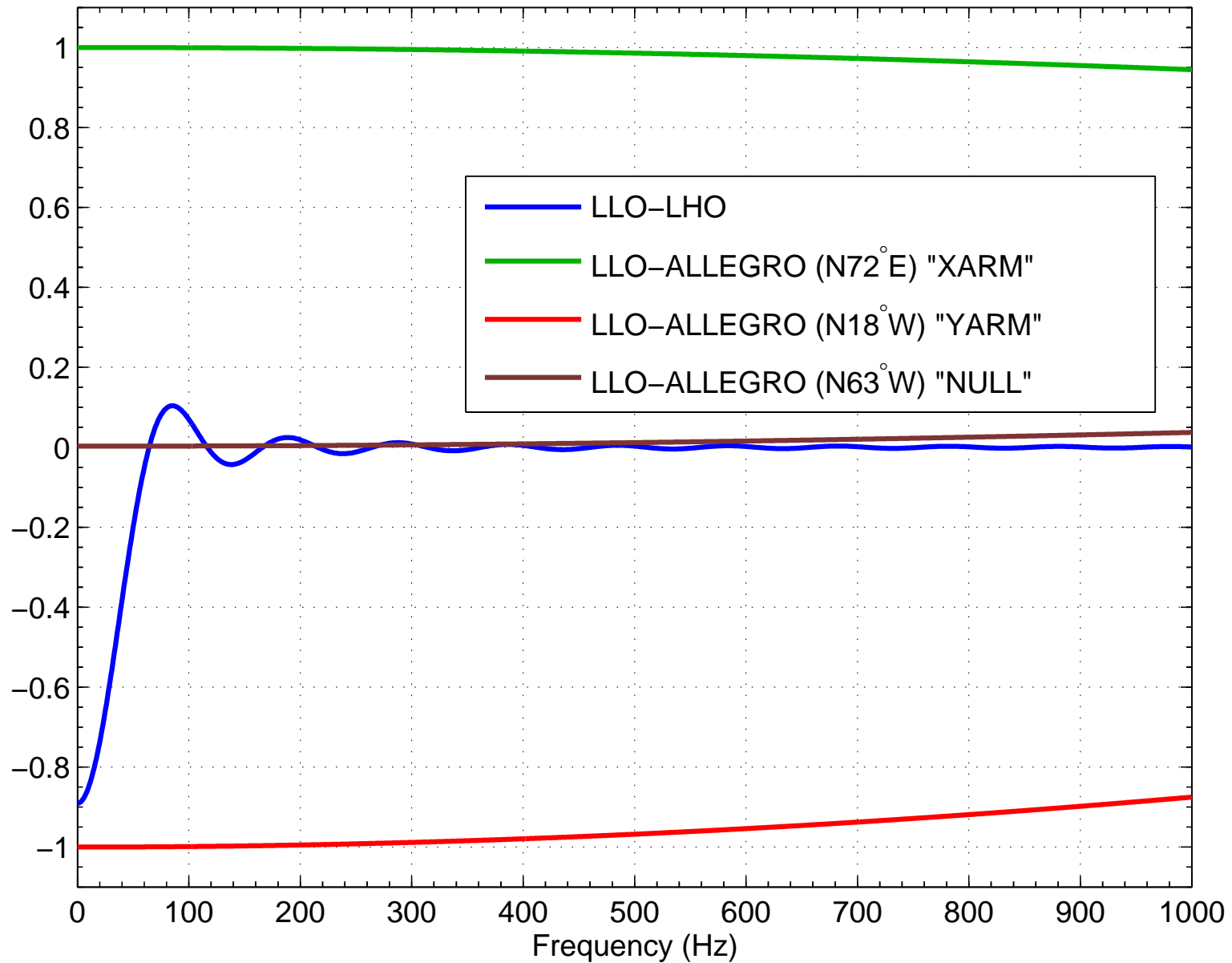
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Frequency dependence from cancellations when $\lambda \lesssim$ distance

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GEO

LHO

max

.LLO

zero
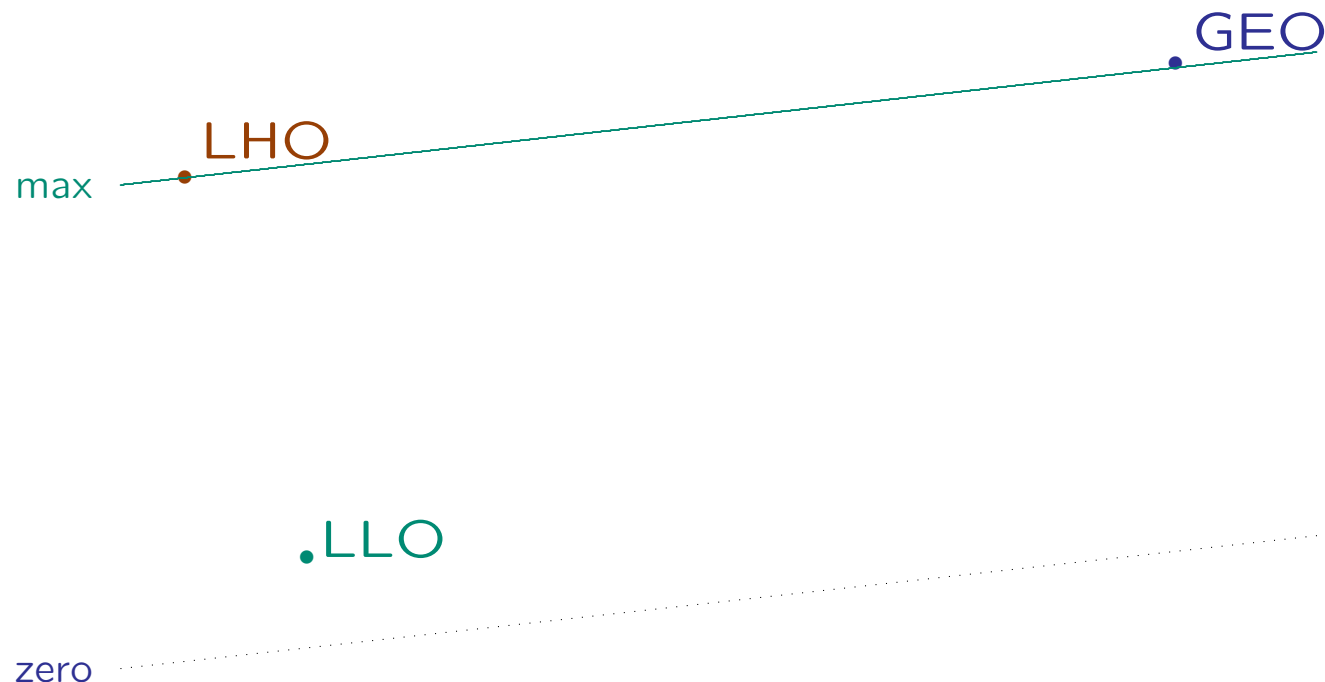
This wave (same λ) drives LHO & GEO in phase

Overlap Reduction Function

Overlap Reduction Function

LLO-ALLEGRO Correlations

- Only $\sim 40\,\text{km}$ apart $\rightarrow \gamma(900\,\text{Hz}) \approx 95\%$ for best alignment
  Sensitive in different freq band from LLO/LHO pair

- Unique experimental technique: rotate ALLEGRO to callibrate
  cross-correlated noise (Finn & Lazzarini)
  - XARM & YARM orientations have opposite GW sign
    $\longrightarrow$ can "cancel" out CC noise by subtracting results
  - NULL orientation has no expected GW signal
    $\longrightarrow$ "off-source" measurement of CC noise

- Currently analyzing S2 (2003 Feb 14-Apr 14) data; ALLEGRO
  was offline for S3 (2003 Oct 31-2004 Jan 9), now running again;
  Further work planned for S4 & beyond

LLO-ALLEGRO: Technical Considerations

- LIGO data digitally downsampled $16384\,\text{Hz} \rightarrow 2048\,\text{Hz}$
  ALLEGRO data heterodyned at $899\,\text{Hz}$ & sampled at $250\,\text{Hz}$
  Time domain resampling undesirable: $2^{10}/5^3$ sampling ratio
  $\rightarrow$ work in freq domain w/overlapping frequencies

- Uncalibrated ALLEGRO data have sharper spectral features
  $\rightarrow$ Work w/calibrated heterodyned strain "$h(t)$" for ALLEGRO

- Calibrating ALLEGRO data is major undertaking
  (Coherent analysis requires more precise calibration than before)
 See McHugh talk for more details

LLO-ALLEGRO data from LIGO S2 Run

- Analysis uses sliding PSD estimator & σ ratio cut
  non-overlapping Tukey windows

- $\sim 10\%$ of data set aside as "playground"

- Non-PG data divided into 60s segments; 3 orientations:
  - "NULL" ($0.028 < \gamma(f) < 0.034$): 3327 min after cuts
    "off-source" data useful for data quality & cross-checks
  - "YARM" ($-0.89 > \gamma(f) > -0.91$): 1652 min after cuts
  - "XARM" ($0.95 < \gamma(f) < 0.96$):] 1548 min after cuts

- Projected $h_{100}^2\Omega$ sensitivity using YARM & XARM data: ~ 5

Avg Calibrated ASD from S2 Playground
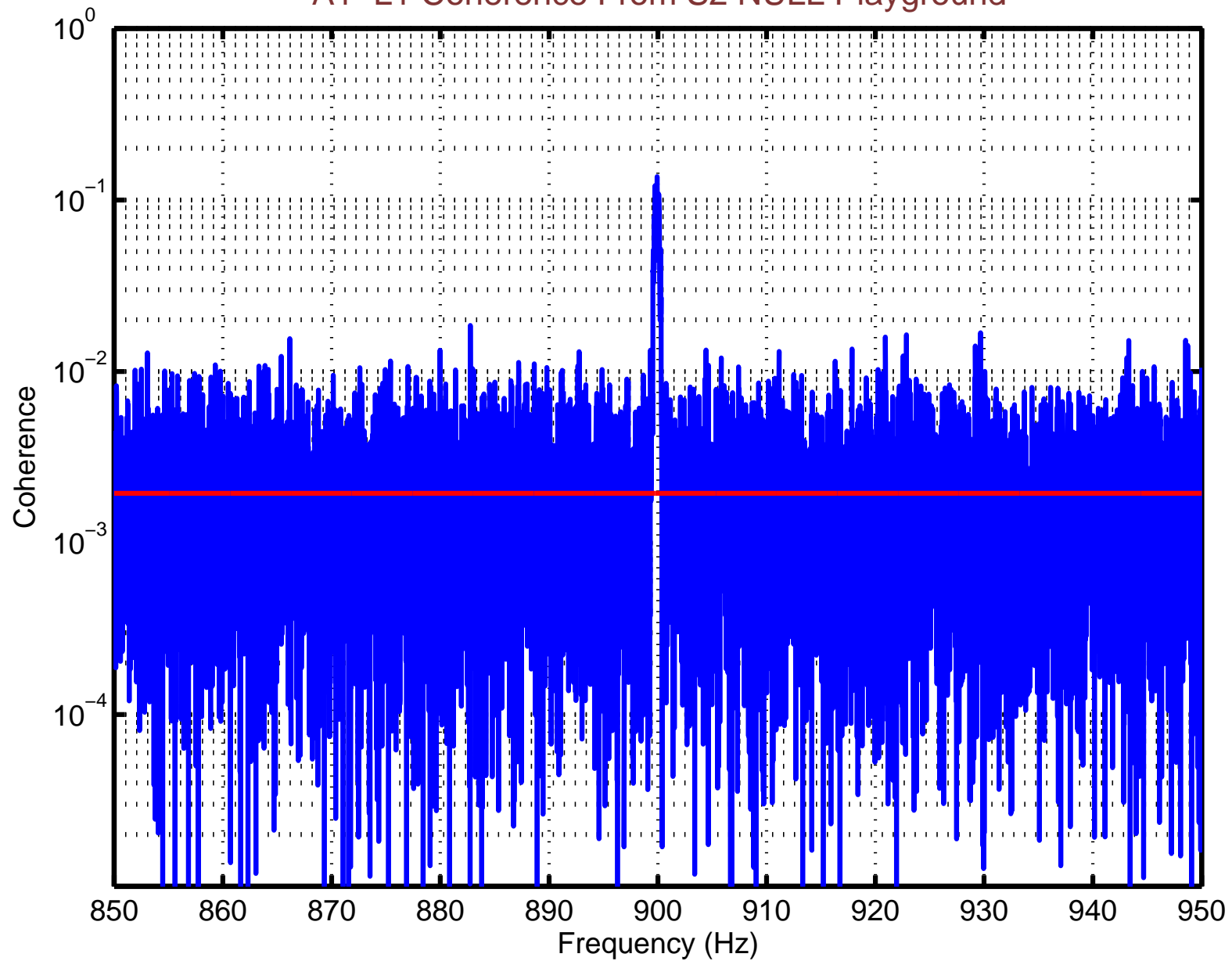
Sensitivity by Segment for YARM Jobs
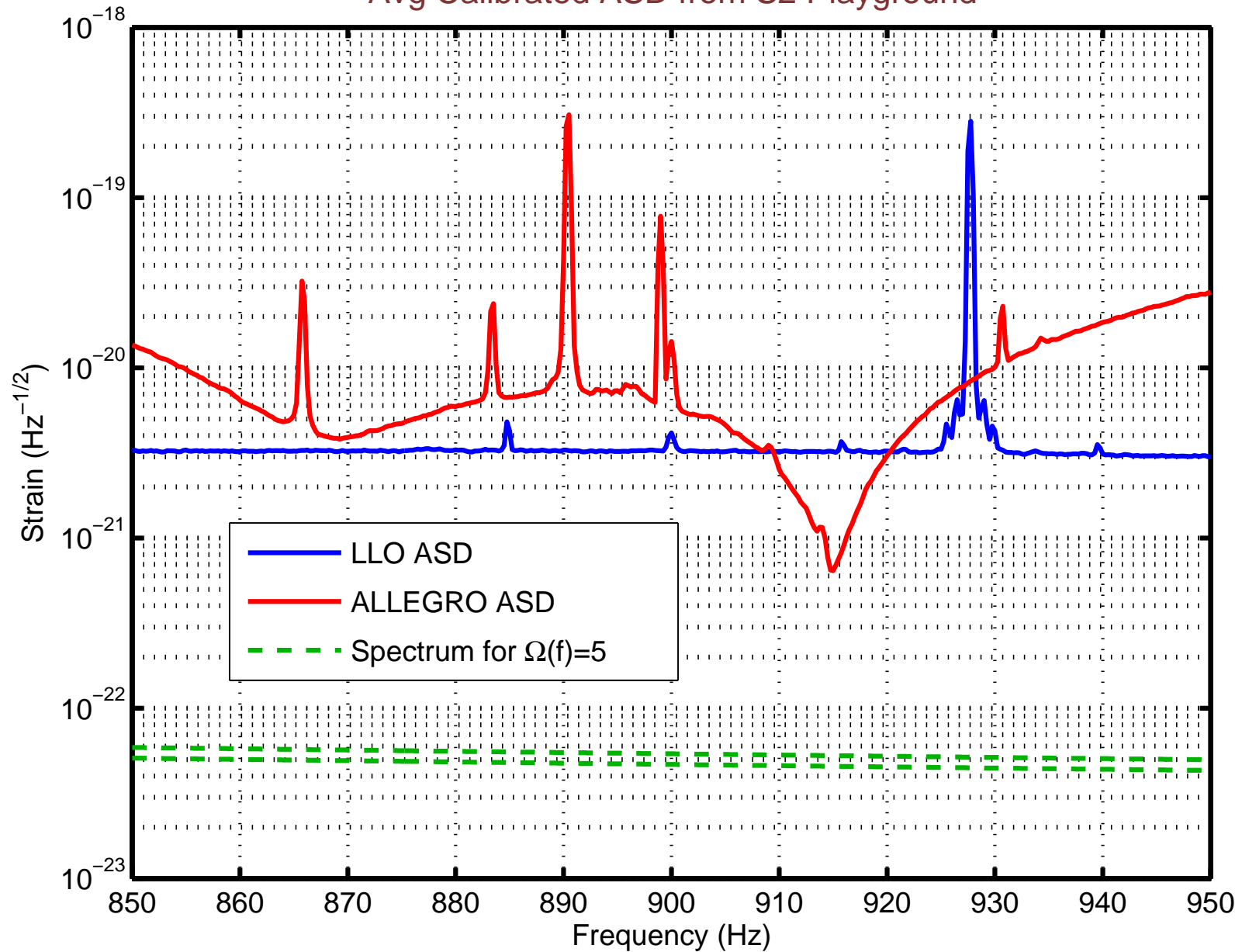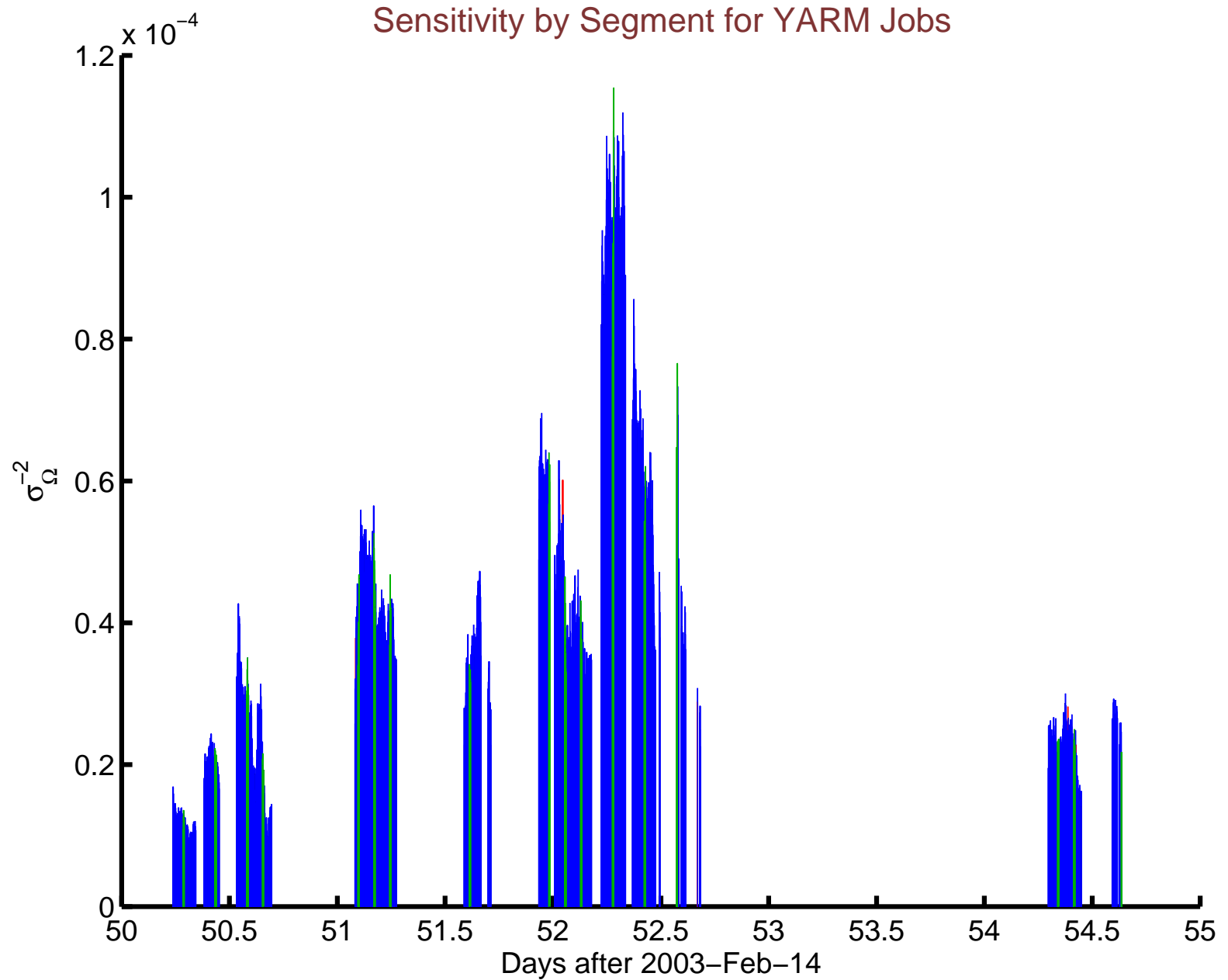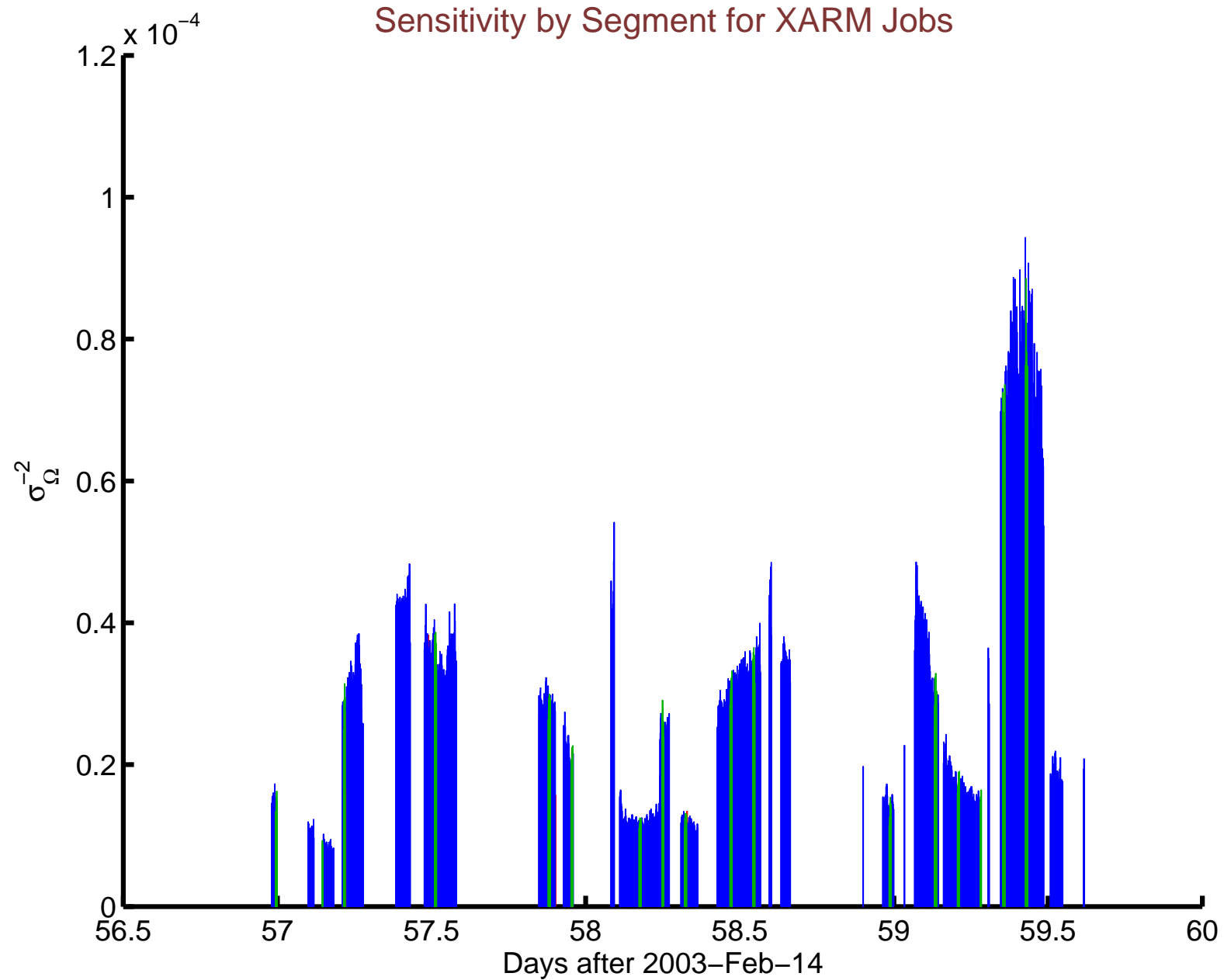
A1–L1 Coherence From S2 NULL Playground

LLO-ALLEGRO: Summary

- First stochastic measurement correlating bar w/ifo data

- Probes higher frequency band than LLO-LHO: $\sim 850 - 950\,\mathrm{Hz}$

- Rotation of ALLEGRO modulates stochastic response
  (data taken in 3 orientations during S2)

- Freq-domain method seems to solve sampling rate issues
  $\exists$ more careful analytic demonstration

- Analyzing S2 data; next coïncident run is S4

- Expected S2 sensitivity from $\sim 54\,\mathrm{hrs}$ of data $h_{100}^2\Omega_{\mathrm{GW}}(f) \sim 5$