E2 Amplitude Calibration of the Hanford Recombined 2km IFO

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LSC Session : Detector Characterization

outline

I. ITM, ETM calibrations
II. Carm, Darm calibrations
III. Swept sines and transfer functions
IV. Sensitivity curves

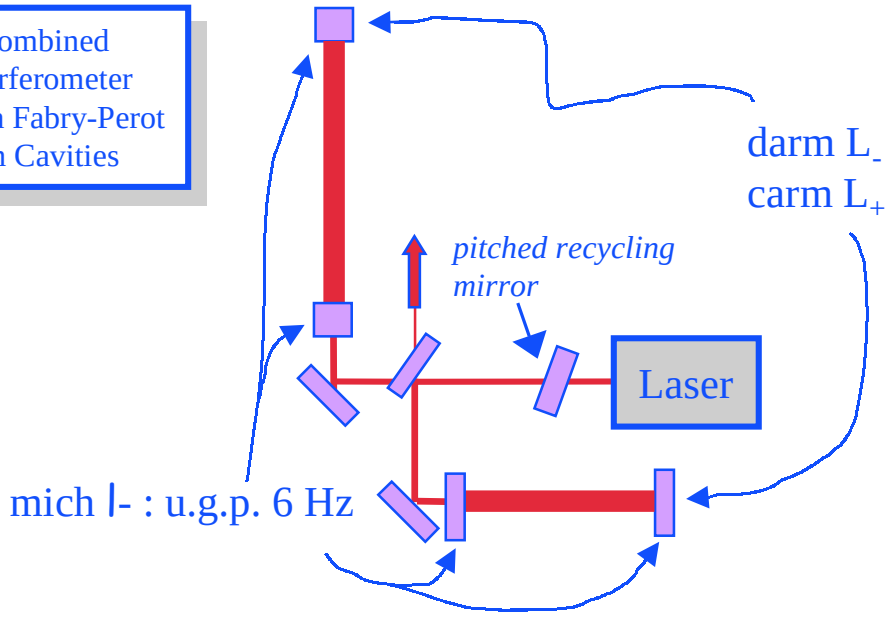
- how good do we need to do? Assume 1-10 events with SNR 10-100, the physical results should not be limited by the systematic uncertainties of the calibration
- +/- 1% amplitude, +/-10 microseconds

Sigg, D. LIGO-T970101-A-D

interferometer control loops

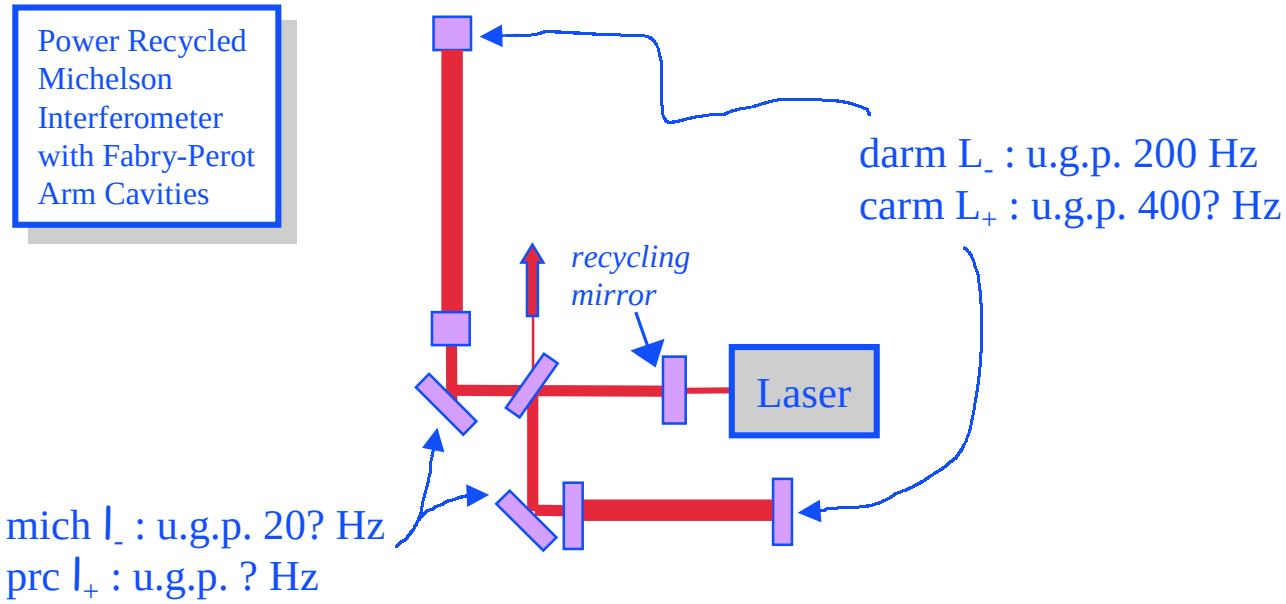
E2:

Recombined Interferometer with Fabry-Perot Arm Cavities



Now (well, pre-quake):

Power Recycled Michelson Interferometer with Fabry-Perot Arm Cavities



ITM calibration

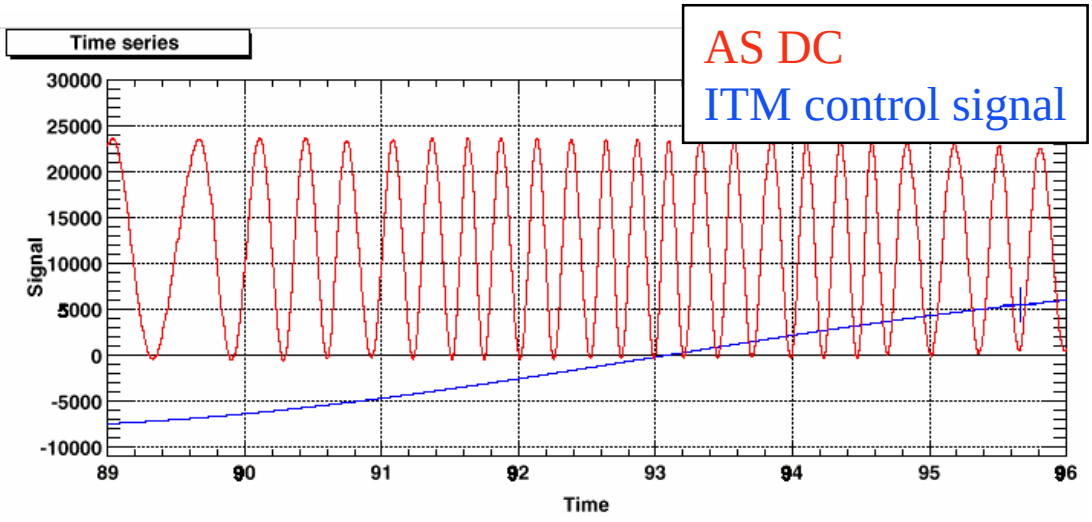
•Basic idea: drive mass with known force and measure displacement

•Drive the ITM with a slow sinusoid (0.1 Hz) and count the number of fringes that are read out at the antisymmetric port.

Calibrations for the ITM's are then

α_{ITMX} = 3.6 +/- 0.2 nm/count

α_{ITMY} = 3.5 +/- 0.2 nm/count



ETM calibration

To extrapolate the calibration of the input test masses (ITM's) to the end test masses:

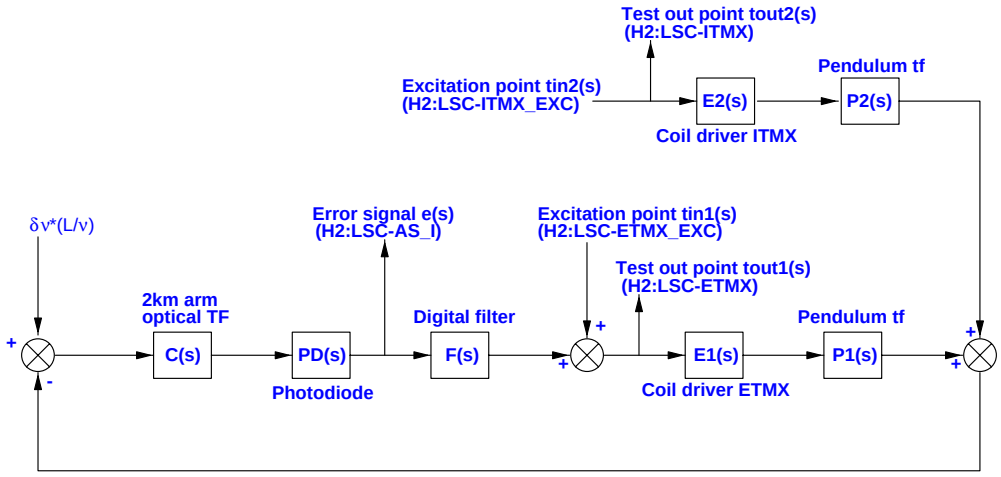
Assuming identical coil drivers (E1=E2) and pendulum transfer functions (P1=P2), and using equal excitations on both masses,

$$\alpha_{\mathrm{ETM}} = \frac{control\_signal_{\mathrm{ETM}}}{control\_signal_{\mathrm{ITM}}} \alpha_{\mathrm{ITM}}$$

Calibrations for the ETM's are then

α_{ETMX} = 2.3 nm/count

α_{ETMX} = 2.0 nm/count



darm, carm calibration

$$\begin{bmatrix} L_- \\ L_+ \end{bmatrix} = \underbrace{\frac{1}{2}}_{\text{nm}} \underbrace{\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}}_{\text{Definition of } L_- \text{ and } L_+} \cdot \underbrace{\begin{bmatrix} \alpha_{ETMX} & 0 \\ 0 & \alpha_{ETMY} \end{bmatrix}}_{\text{ETM calibrations (nm/counts)}} \cdot \underbrace{\begin{bmatrix} 4 & 4 \\ -2 & 2 \end{bmatrix}}_{\text{Output matrix}} \cdot \underbrace{\begin{bmatrix} darm \\ carm \end{bmatrix}}_{\text{Control signals (counts)}}$$

$$\begin{bmatrix} L_- \\ L_+ \end{bmatrix} = \begin{bmatrix} 6.5\,\text{nm/ct} & 2.7\,\text{nm/ct} \\ 2.7\,\text{nm/ct} & 6.5\,\text{nm/ct} \end{bmatrix} \cdot \begin{bmatrix} darm \\ carm \end{bmatrix}$$

Non-diagonal!

$$\underbrace{\begin{bmatrix} 0.82 & 0.82 \\ 1 & 1 \end{bmatrix}}_{\text{New output matrix to diagonalize above}}$$

measurement stability

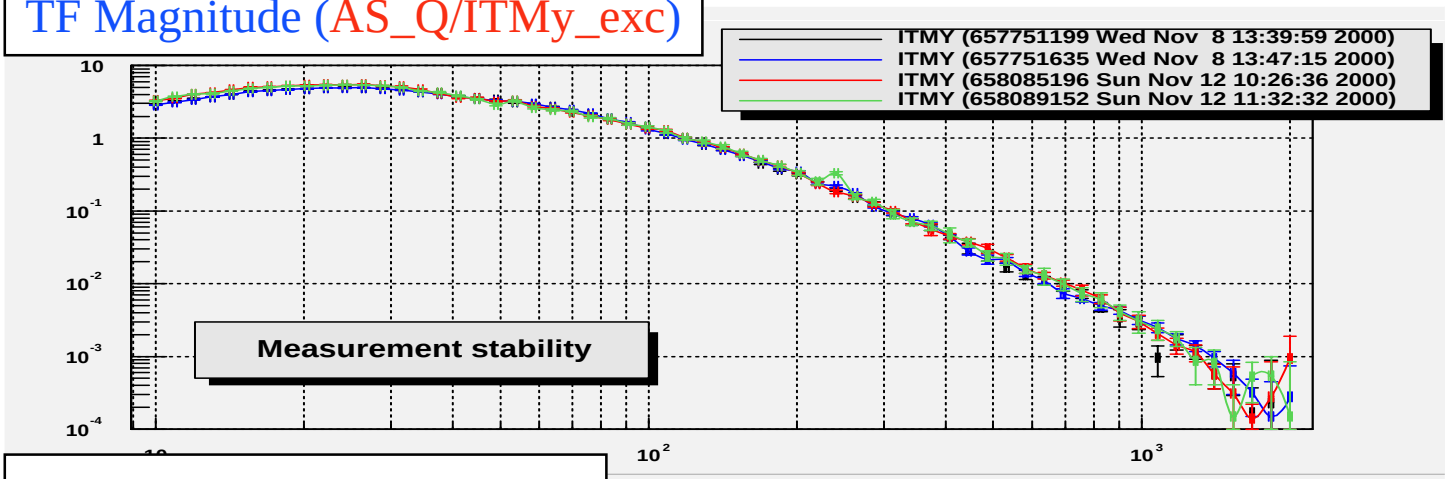
Experiment:

- sweep test mass, take transfer function between AS error signal and excitation

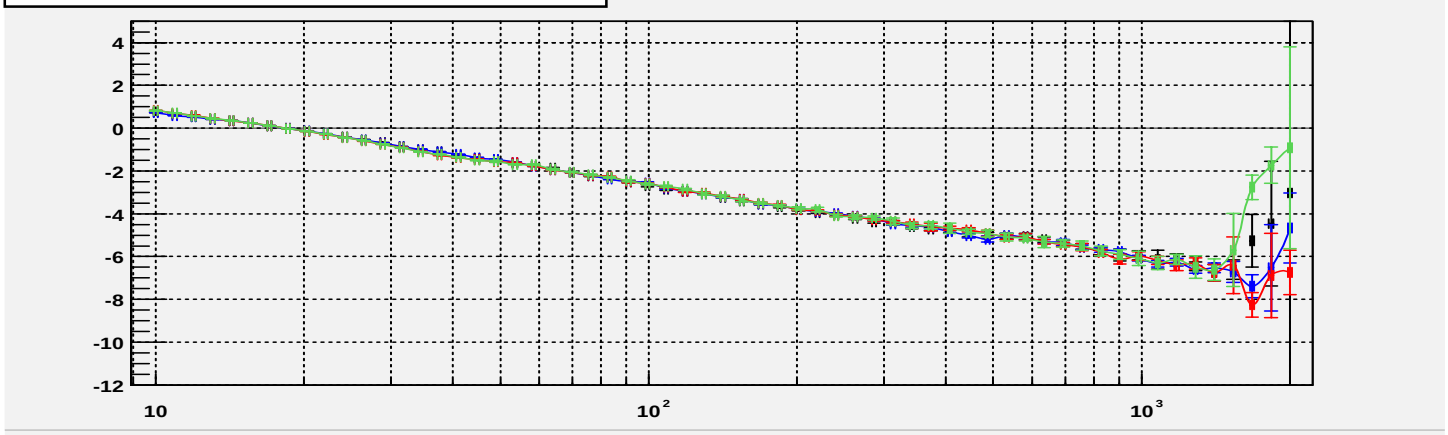
Result:

- stable for measurements made same day
- differences at low frequencies, up to 30% at 15Hz

TF Magnitude (AS_Q/ITMy_exc)



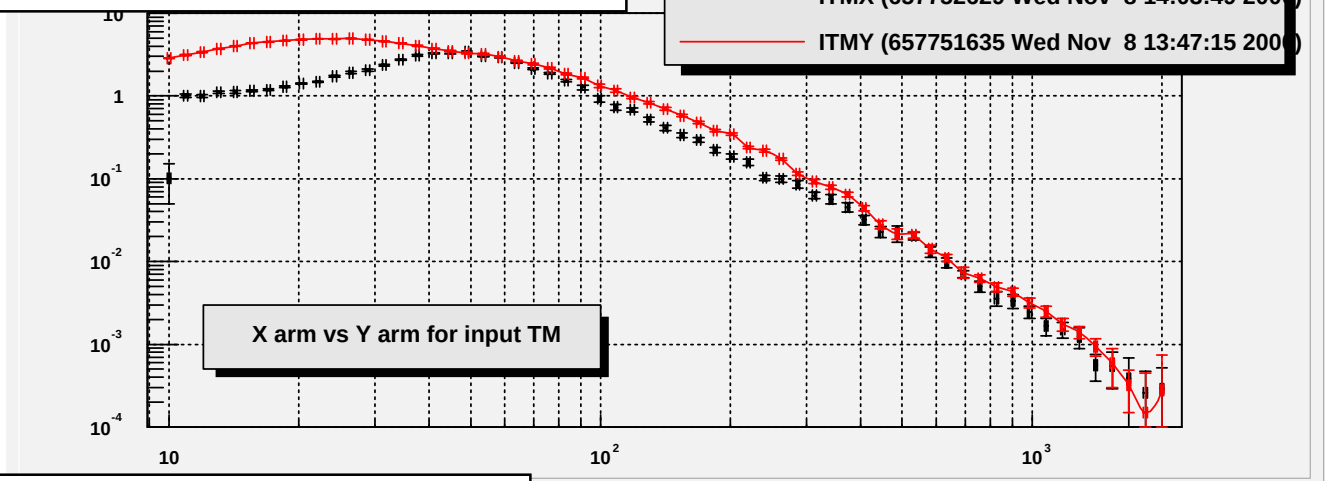
TF Phase (AS_Q/ITMy_exc)



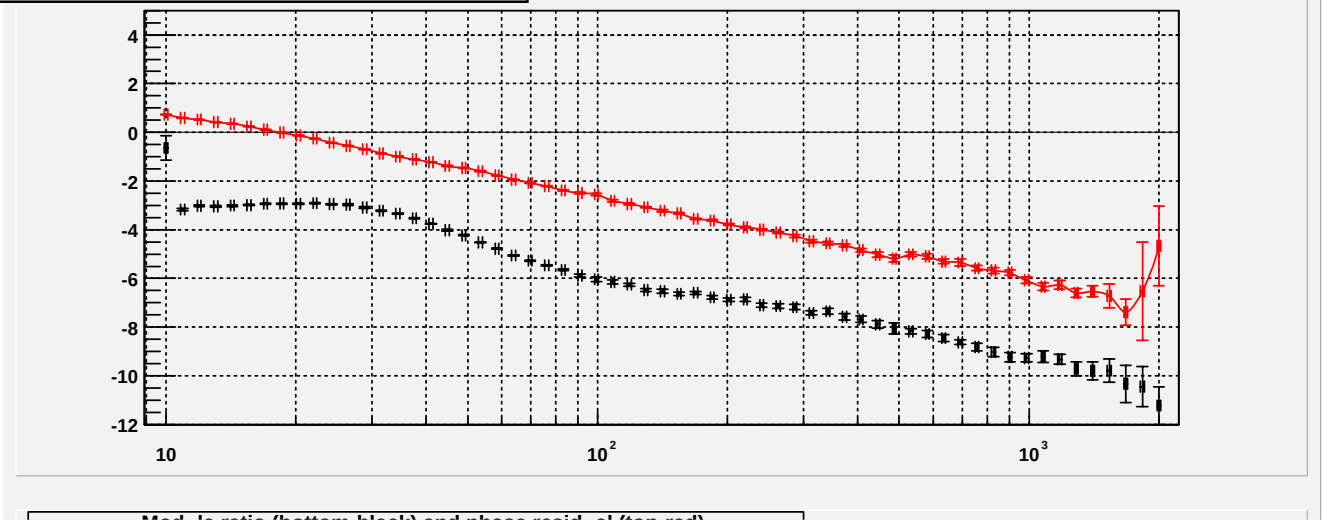
arm comparison

- Significant differences at low frequency

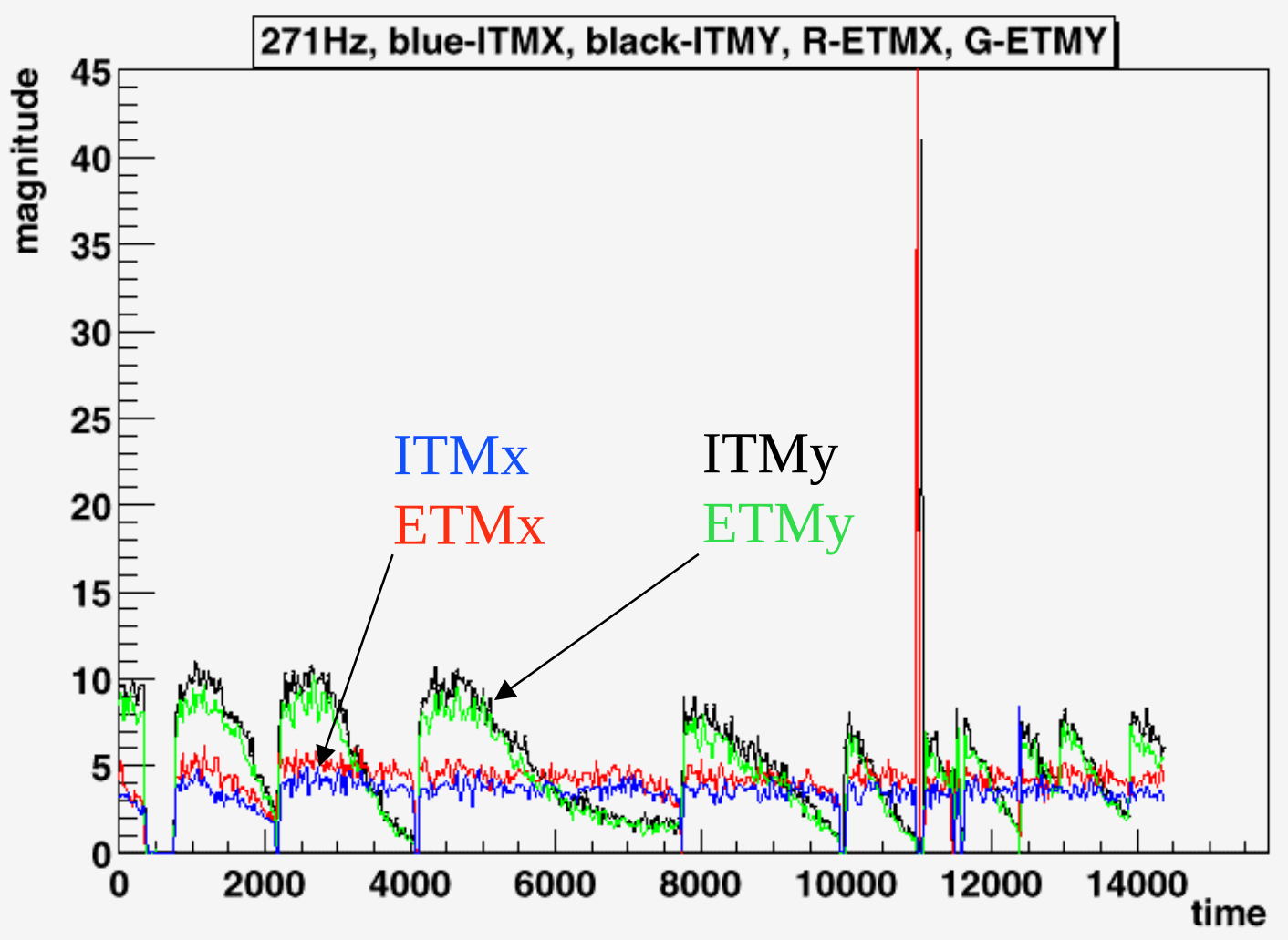
TF Magnitude (AS_Q/ITM_exc)



TF Phase (AS_Q/ITM_exc)



calibration lines

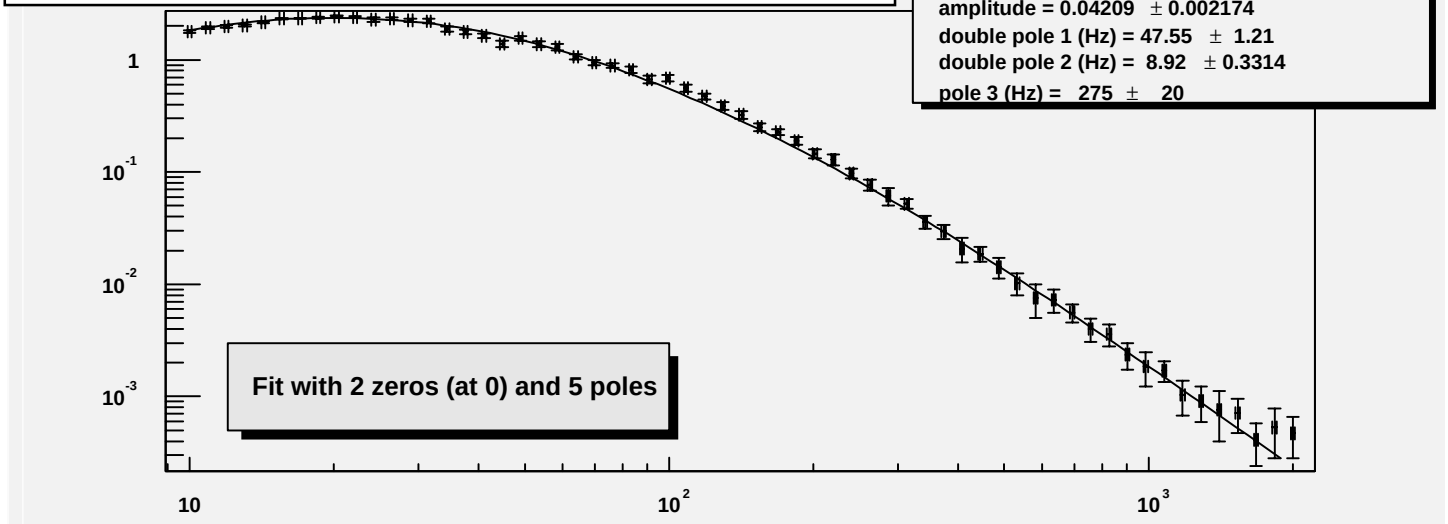


R. Coldwell *et al.*, "Narrow Resonances in the E2 Data", DCC

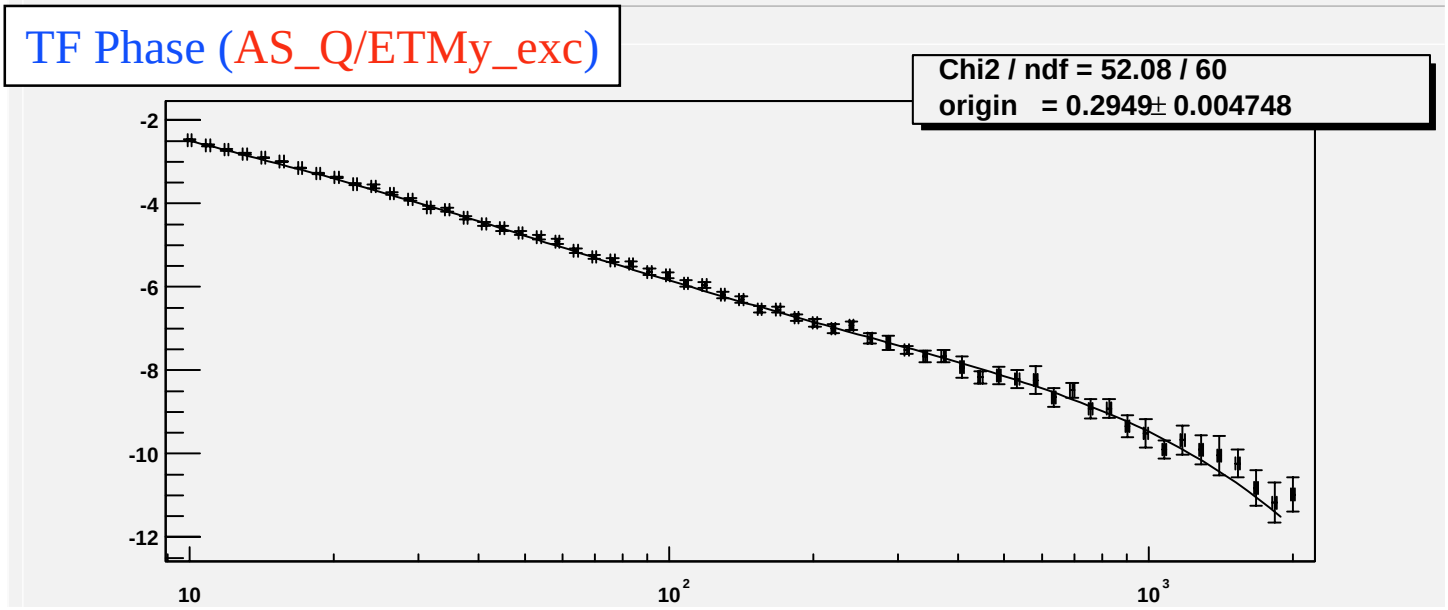
fit to ETM_y transfer function

- Y arm well represented
- fit : 2 zeroes at 0Hz, 5 poles (1 single, 2 double)
- LSC servo : 2 zeros at ~0Hz, at high freq., should see mechanical TF and cavity response

TF Magnitude (AS_Q/ETMy_exc)

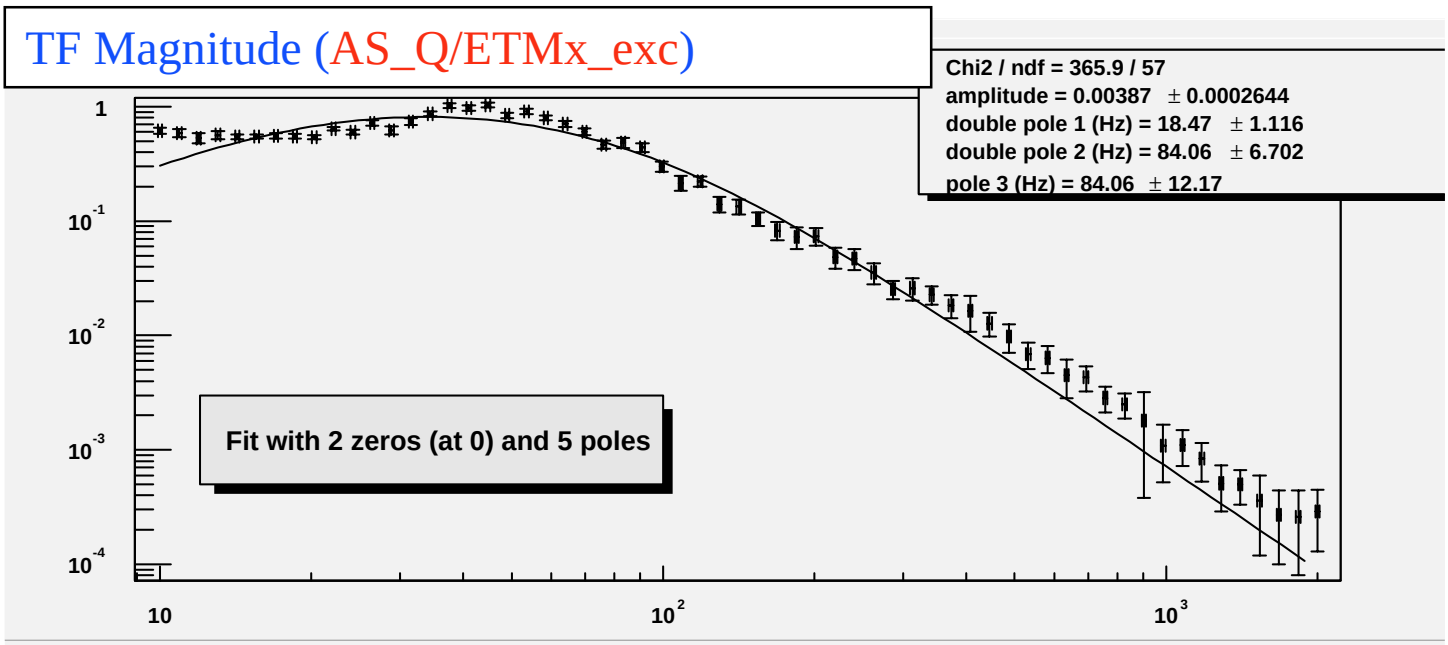


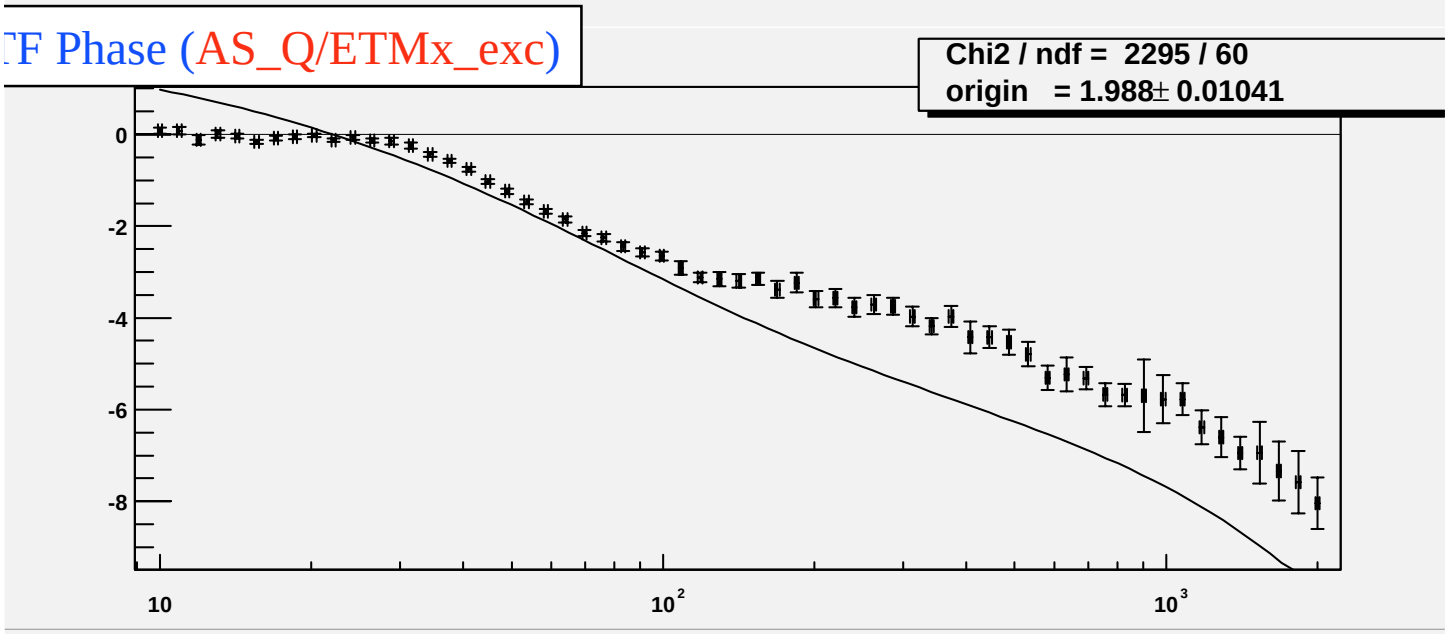
TF Phase (AS_Q/ETMy_exc)



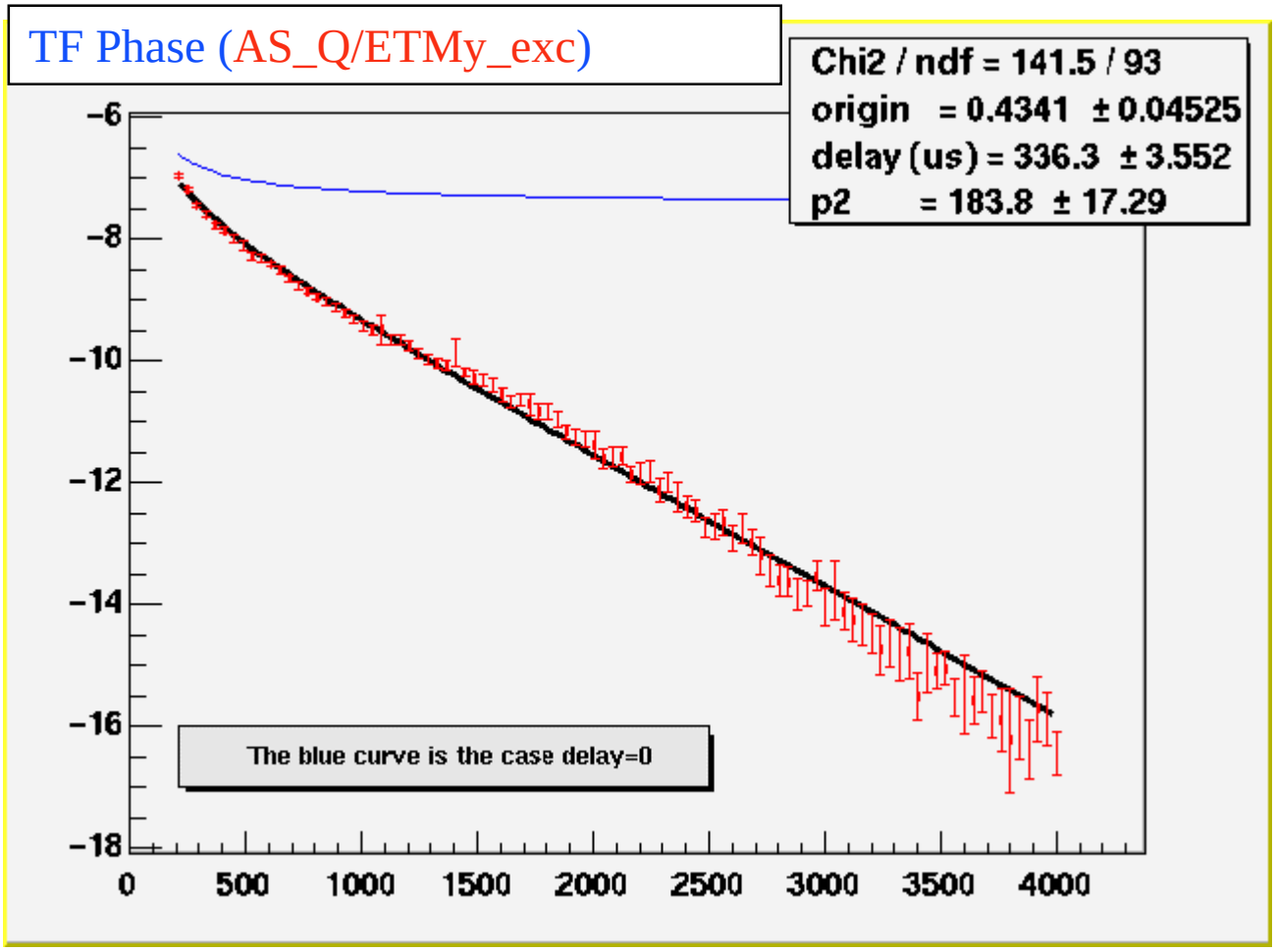
fit to ETM_x transfer function

- X arm more complicated

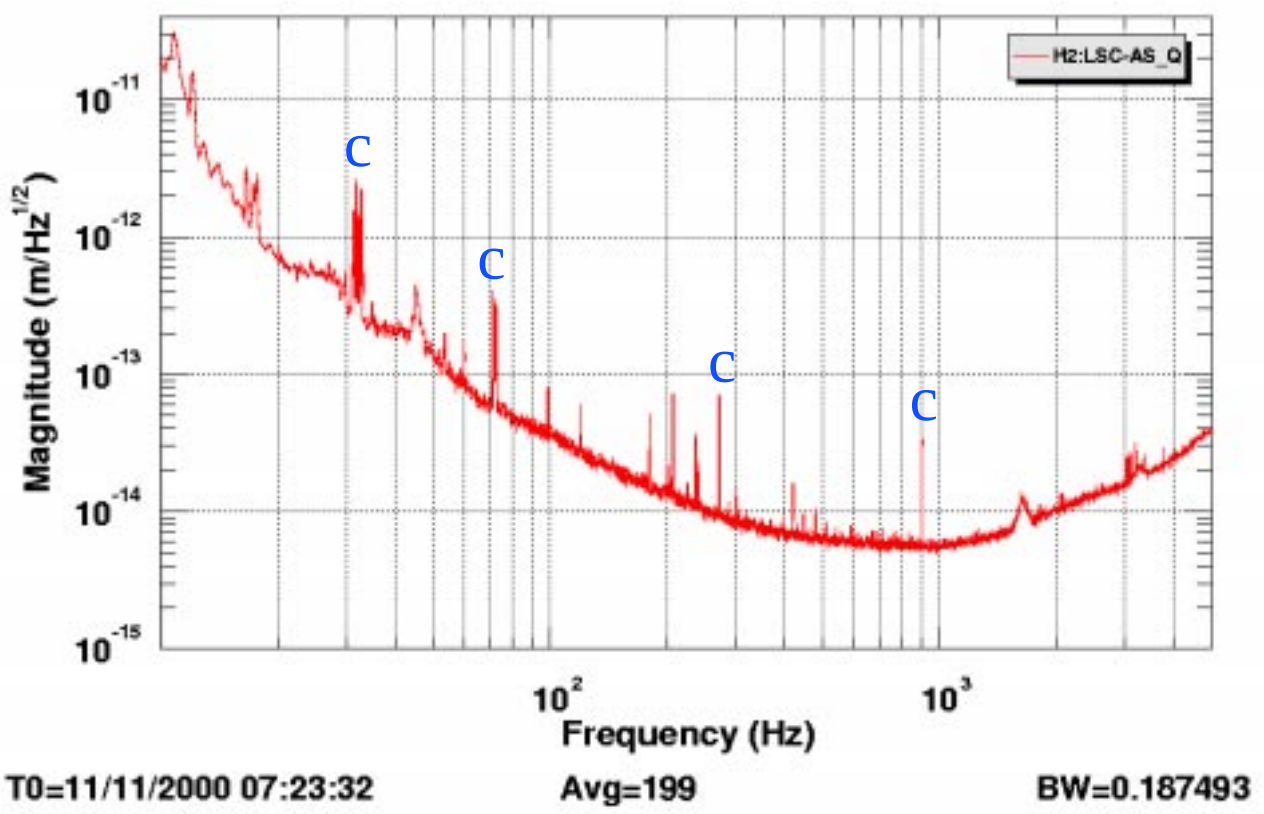




time delay

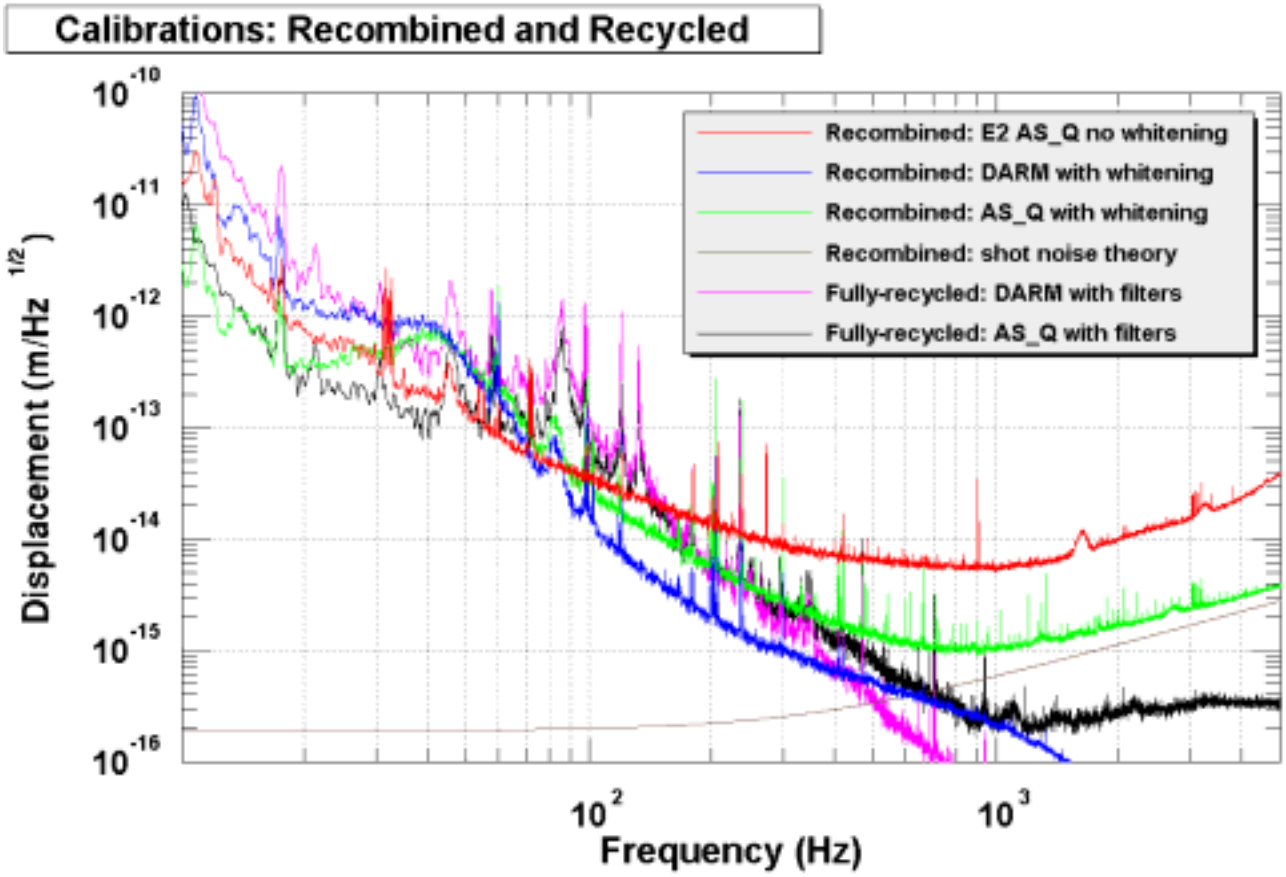

TF Phase (AS_Q/ETMy_exc)
Chi2 / ndf = 141.5 / 93
origin = 0.4341 ± 0.04525
delay (us) = 336.3 ± 3.552
p2 = 183.8 ± 17.29
The blue curve is the case delay=0
-6
-8
-10
-12
-14
-16
-18
0
500
1000
1500
2000
2500
3000
3500
4000

sensitivity



- Sensitivity to y-arm displacement
- Scale set by absolute calibration of ITMy
- Shape set by parametrization
- Visible calibration lines (denoted with“c”)
- approximately 30% calibration accuracy

noise comparison



conclusions

- Recombined IFO best sensitivity during E2 was approximately 6×10^{-15} m/Hz$^{1/2}$ at 1kHz
- carm and darm mixing apparent
- output matrix changed: ETMs given equal push
- calibrations very similar when taken same day, somewhat different days apart
- differences noted in X and Y arms
- earthquakes are bad
- anticipate revisiting of these measurements in order to see the affect of the many changes since E2