Virgo ‘timing’ calibration

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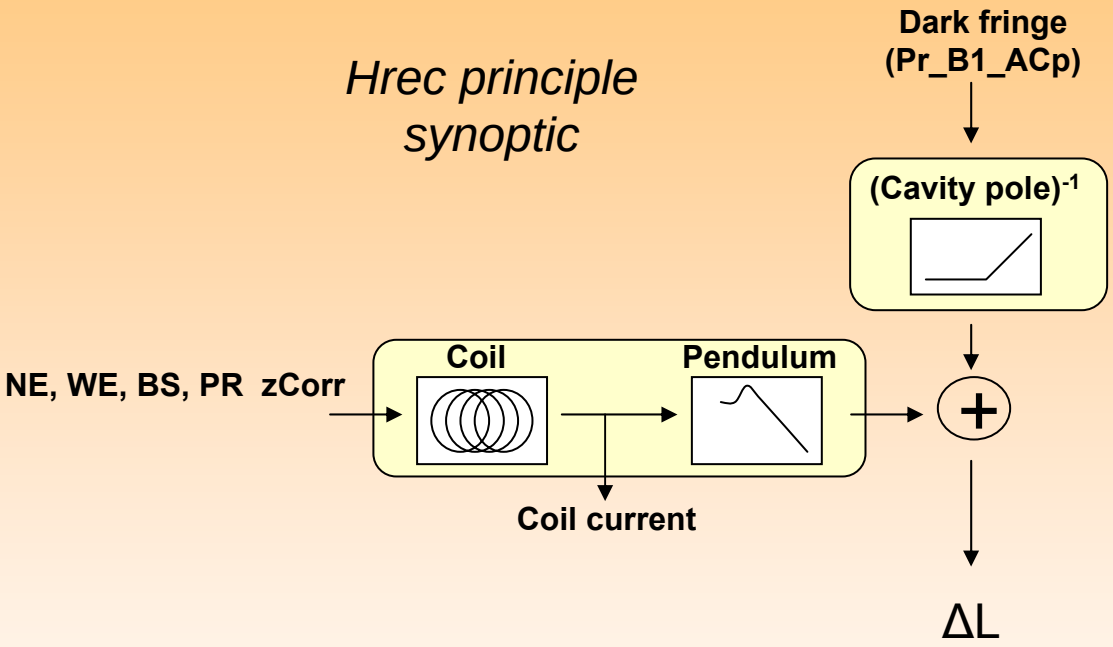
LIGO-G080357-00-Z

Note: Timing calibration during VSR1 in the Virgo codifier (VIR-028A-08, link)

Timing calibration componants

Hrec principle synoptic



Absolute timing of the dark fringe
(for multi-detector analysis)

Delay from actuation to dark fringe

Also used for the global TF measurements

Needs of timing calibration:

- High frequency (> 100's Hz): absolute DAQ timing and dark fringe sensing
- Low frequency (<100's Hz): actuation chain delay
- Mid-frequency: combination of all effects

High frequency timing measurements

DAQ timing

- Monitored during VSR1: 21 µs delay from DAQ
- Systematic errors estimated in February 2008

→± 2 µs error on the DAQ delay

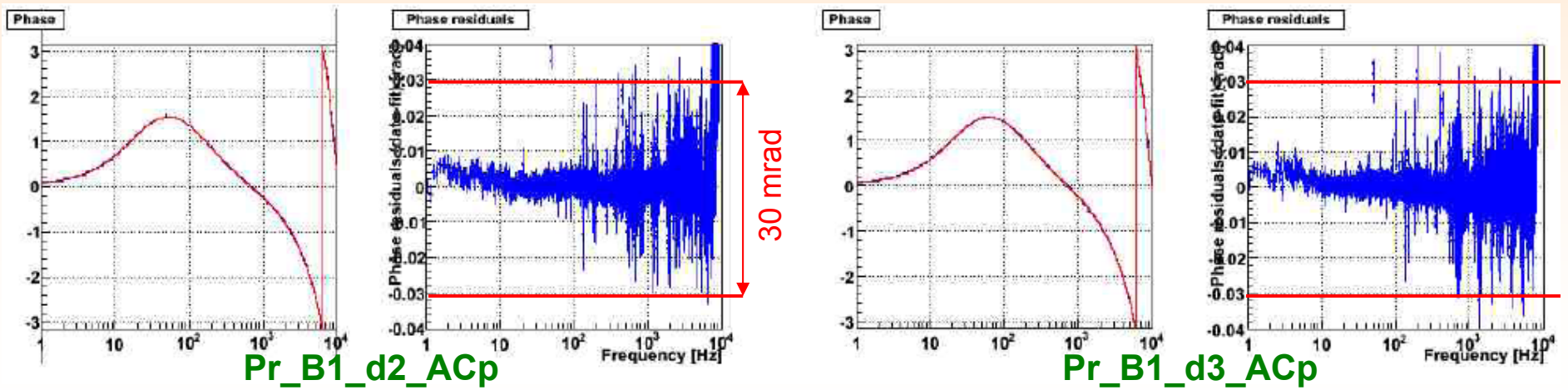
✓ Effect corrected in h(t)

Dark fringe sensing

- Photodiode readout electronics measured in October 2007
- Compensation of the compression and anti-alias filters

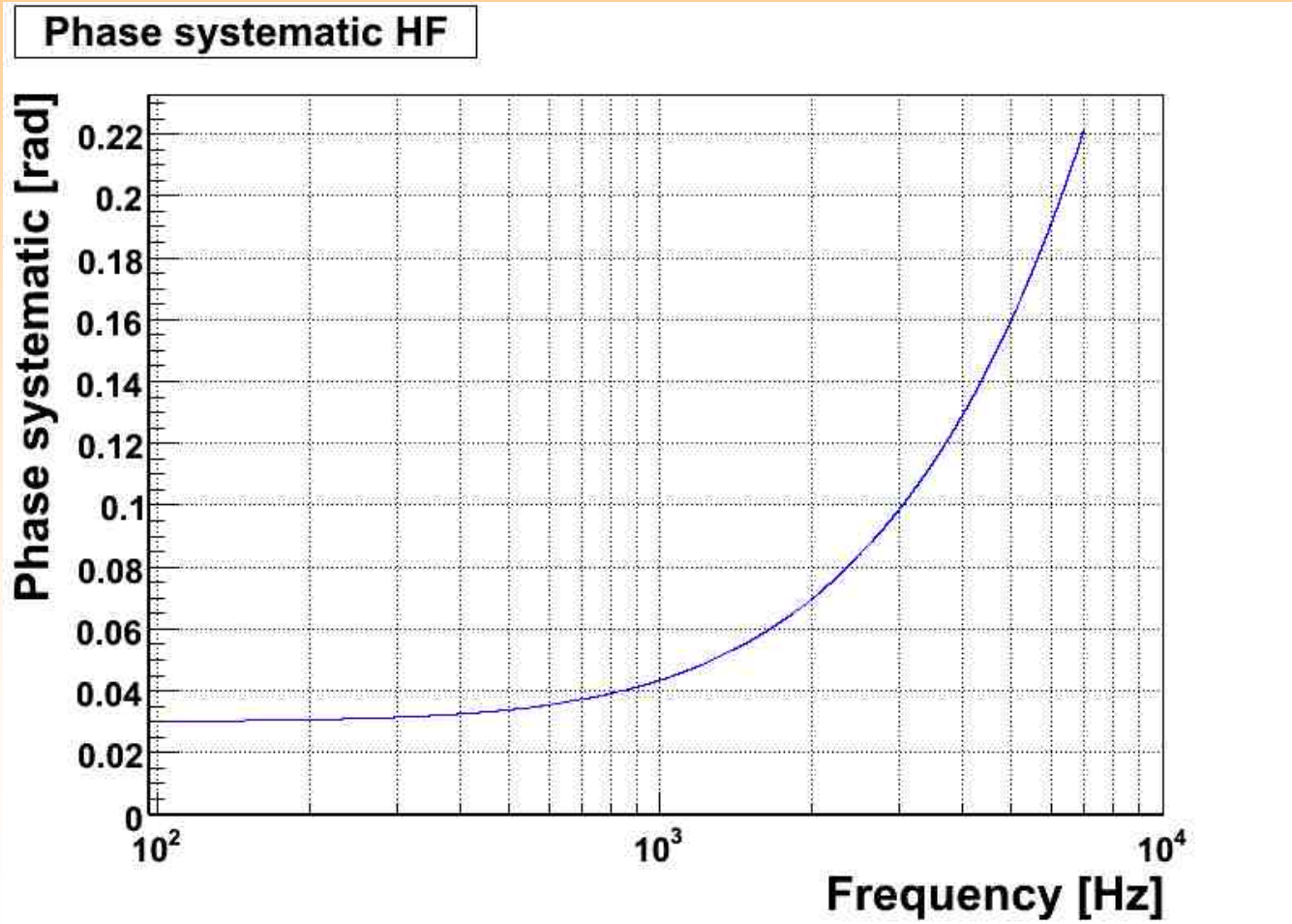
→± 30 mrad systematic errors (fit residuals)
→ ± 3 µs error on the sensing delay (different delays of both photodiodes)

✓ Effect corrected in h(t)

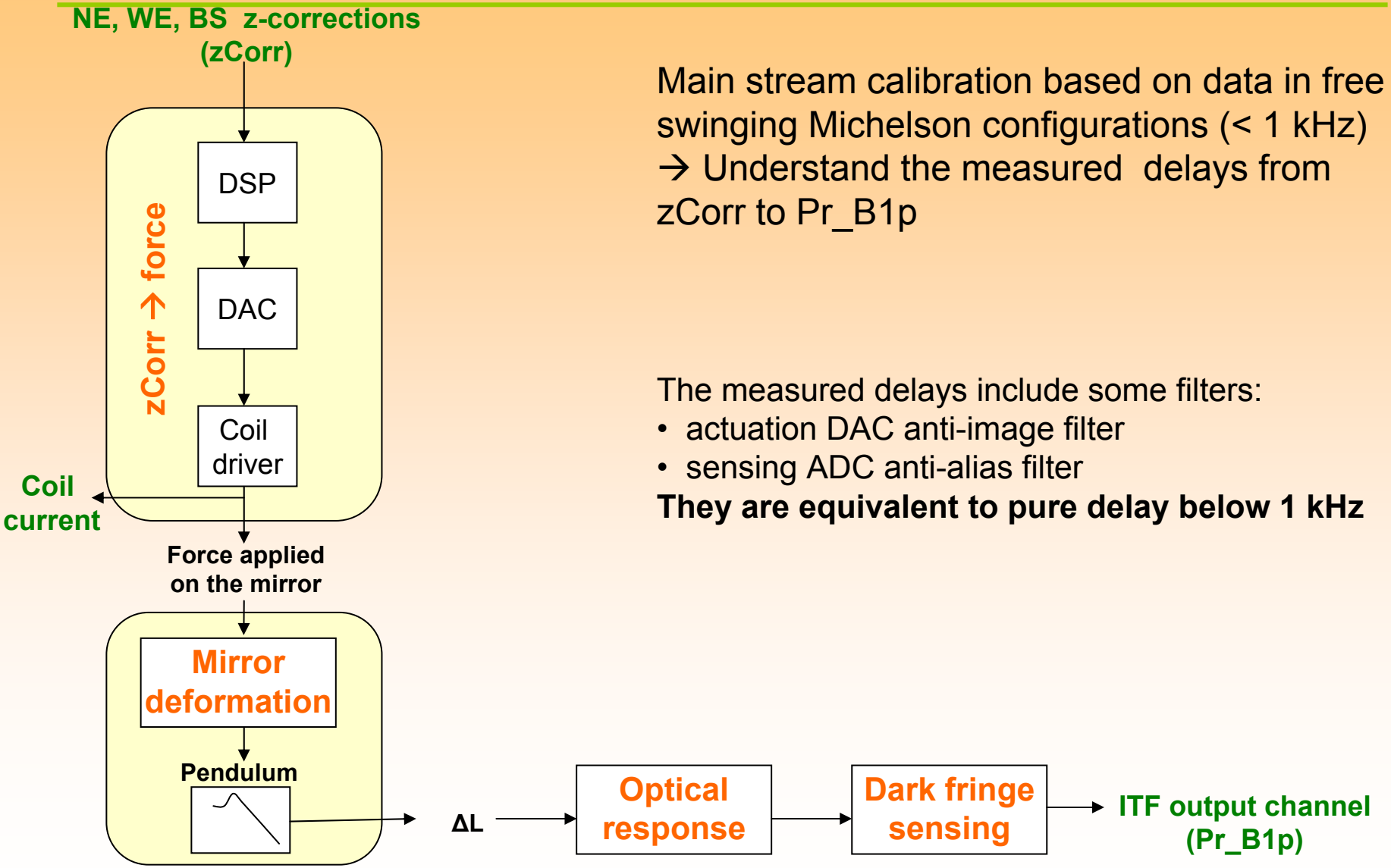


High frequency phase systematics

Residuals from DAQ and dark fringe sensing: ±30mrad and ±5 μs delay



Delay from correction signals to ITF output

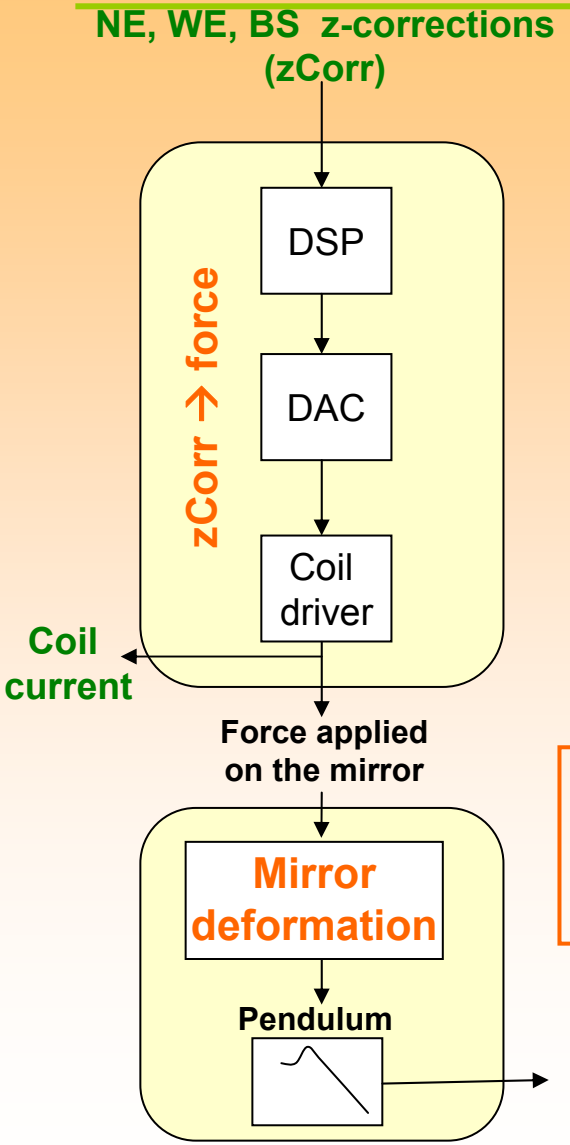


Main stream calibration based on data in free swinging Michelson configurations (< 1 kHz)
→ Understand the measured delays from zCorr to Pr_B1p

The measured delays include some filters:
- actuation DAC anti-image filter
- sensing ADC anti-alias filter

They are equivalent to pure delay below 1 kHz

Actuation timing systematics: measurements



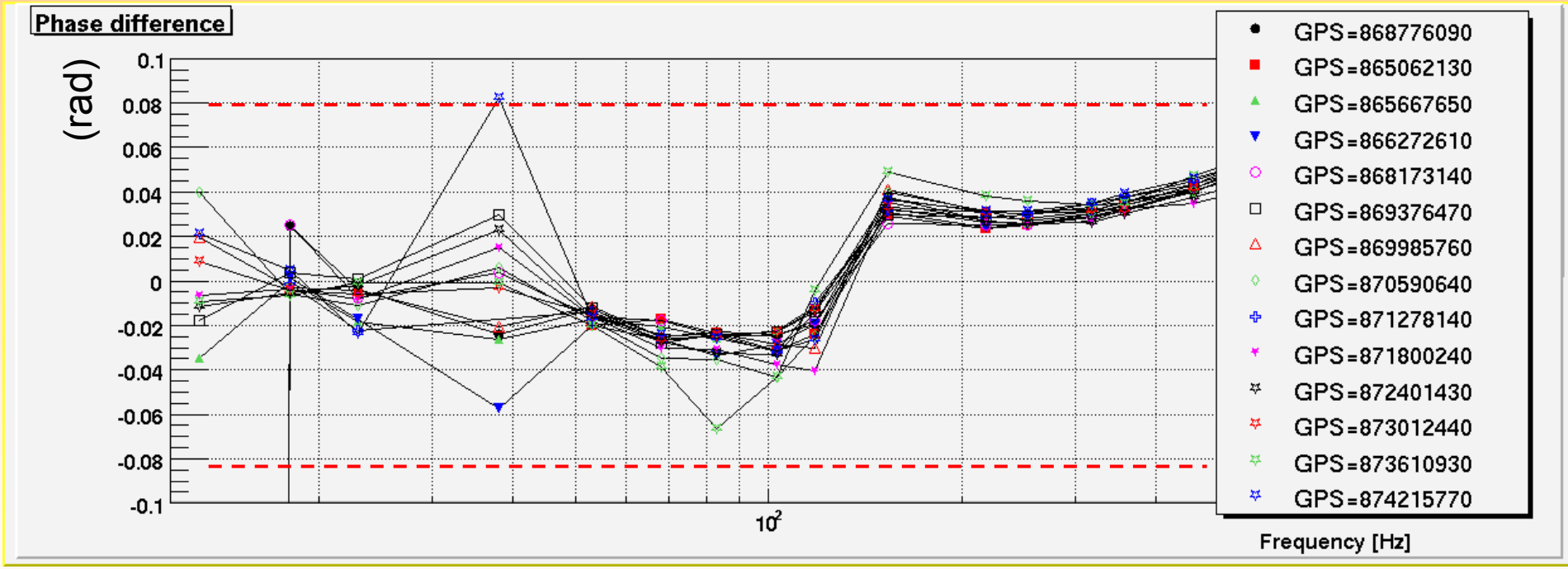
(delays in μs)	NE, WE		BS	
	Expected	Measured	Expected	Measured
zCorr→ force	331	311 ± 5	333	310 ± 5
Mirror deformation	28 ± 3	-	19 ± 3	-
Optical response	10	-	0	-
Dark fringe sensing	75	76 ± 4	75	76 ± 4
zCorr→ dark fringe	444	450.7 ± 1	427	393 ± 1

From calibration main stream

Difference between overall expectations and measurements:
- 7 μs for NE, WE
- 34 μs for BS (20 mrad at 100 Hz)

Combination of actuation errors: phase systematics

Injection of lines on the NI mirror (non-controlled mirror):
comparison of the phase of h(t)/injection to the actuation model phase



→ ± 100 mrad systematic errors

PRELIMINARY

Phase systematic uncertainties vs frequency

ABSOLUTE TIMING SYSTEMATICS
- ➢ DAQ timing: 2 μs delay
- ➢ Dark fringe sensing model: 30 mrad + 3 μs delay

COMBINATION OF SIGNALS
- NE, WE and BS actuation: <35 μs delay
- NI model vs reconstructed phase: <100 mrad
- ➢ Constant phase systematic: less than 100 mrad (conservative estimate)

→ Constant phase error (<100 mrad) up to a few kHz
→ 5 μs delay at high frequency

PRELIMINARY

Pcal checks: timing and sign of hrec V2

Photon calibration injection advantages:
- known side of the mirror
- laser power always positive (known sign of injections)

→ Absolute sign of injections

Use of photon calibration: TF $\frac{h(t)}{\Delta L(t)}$ corrected for:

$$\frac{h(t)}{\text{Phododiode\_readout}(t)}$$

- absolute delay of the photodiode readout channel (not precisely calibrated)
- pendulum mechanical response

Fit of the phase:
- ➢ $\varphi_0 = 0 \pm 0.01$ rad

→ the sign of h(t) is correct

- ➢ delay = 36 ± 4 μs

→ the timing of h(t) above 200 Hz is not completely off