Photon Calibrator
h(t) Preliminary Characterisation

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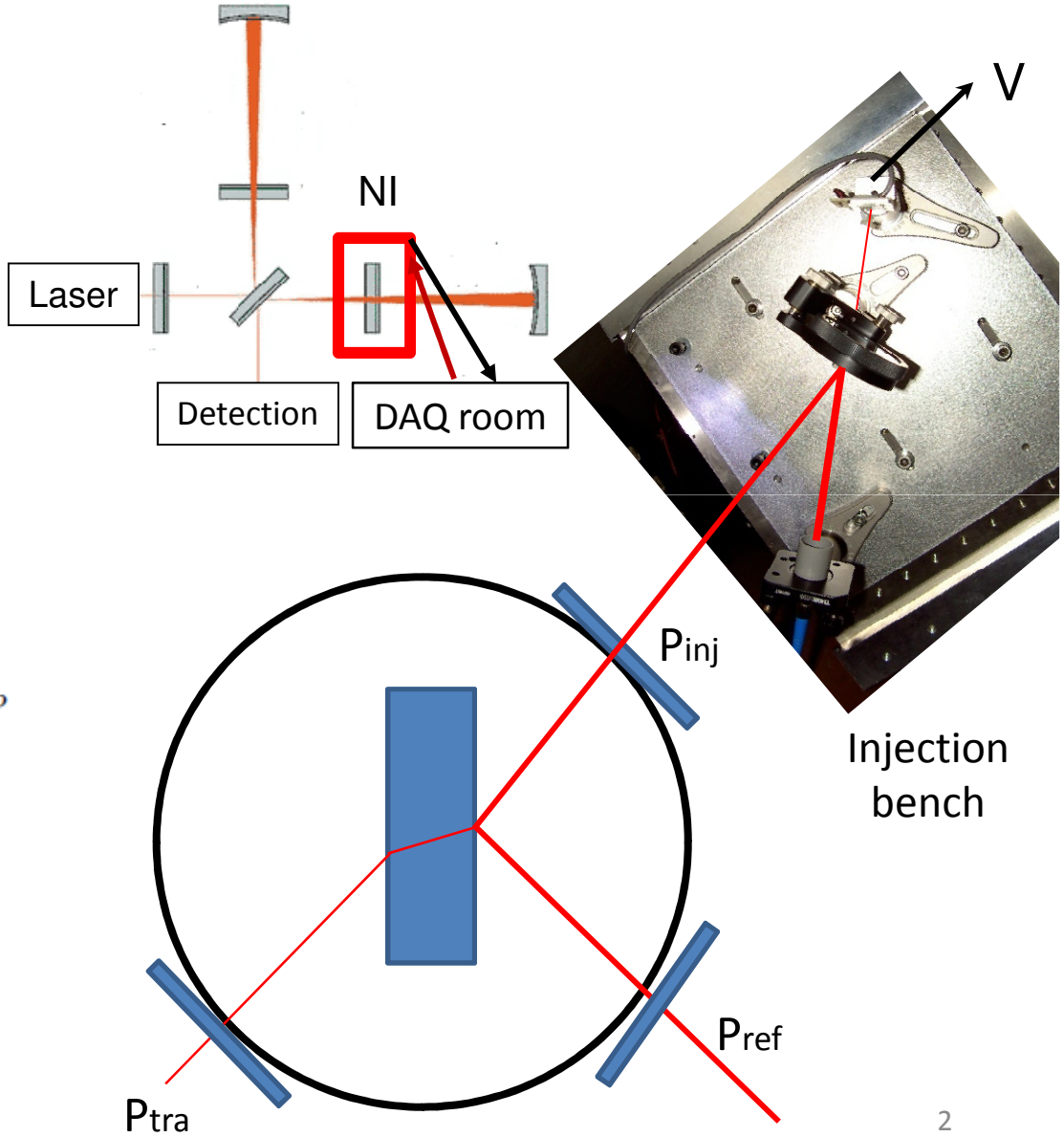
- Setup and Power Calibration
- h(t) Cross-Check

Experimental Setup and Calibration

- **Procedure**
  - Injections of given laser powers
  - Measures :

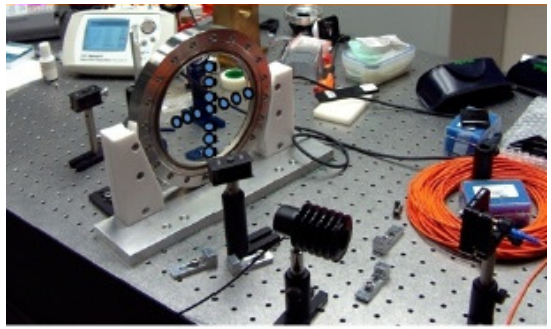
  { Pinj, Pref, Ptra} outside the tower in parallel with the photodiode signal



- **PCal calibration extraction:**

$$\Delta P_{ref} = \mathbf{a}\Delta V$$

$$P_{inj} = P_{ref} + P_{tra} + Losses + Losses_{VP}$$



Build PCal Calibration Maps

Issues: Powermeter centering

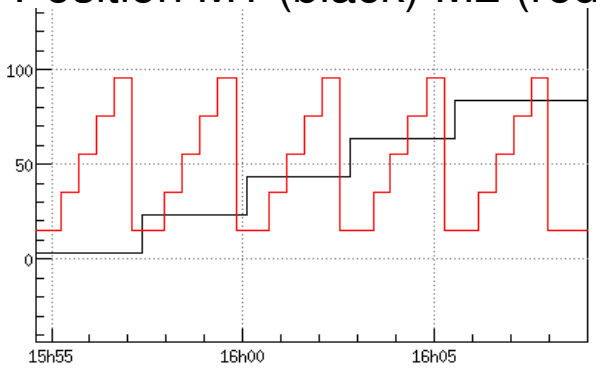
Procedure

- The motorised sensor of the powermeter scans the beam on 5x5 positions
- For each position the conversion factor is measured

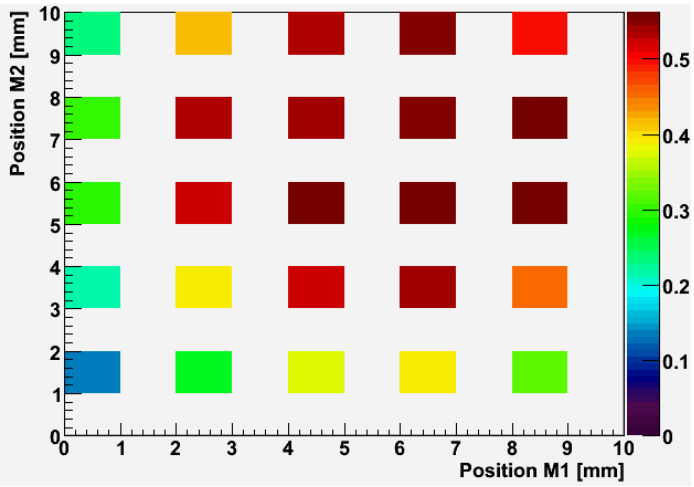
$$a_i = \frac{P_{mes,i} - offset}{Ca\_NI\_PCal_{m,i} - offset}$$

- Build the map

Position M1 (black) M2 (red)



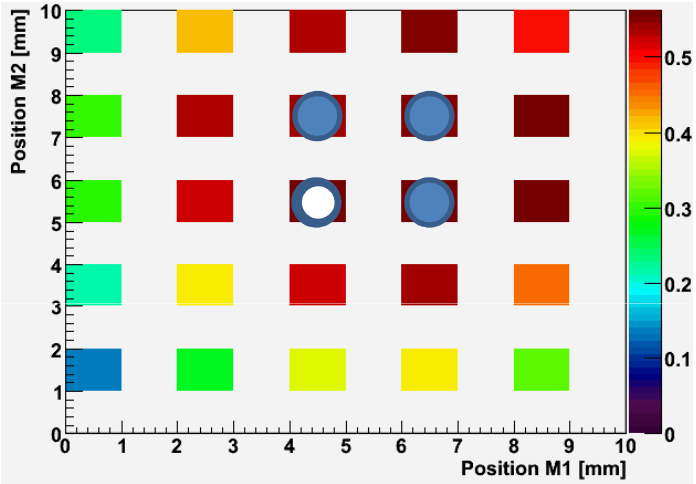
Conversion factor map (W/V)

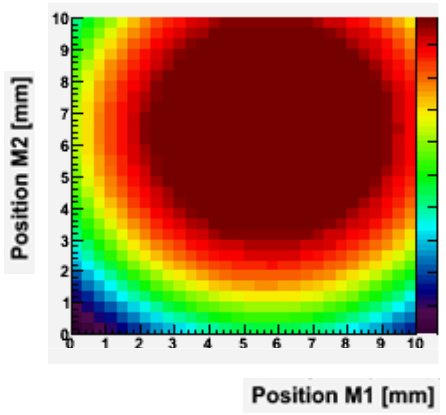


Methods on data selection

→ Fit with a Plateau-Gaussian combined function

Conversion factor map





Fitted Plateau value

→ Average with the 4 closest points to the center (blue)

→ Value of the closest point to the center (white)

For the three viewports, average of conversion factors over the different injected powers

PCal Calibration Results

Reference	Injection (W/V)	**Reflection (W/V)**	Transmission (W/V)	Losses (% of reflection)
Fit (all scans)	0.624	**0.550**	0.082	-0.2

Method	Losses (% of reflection)	Variation of the reflection factor (%)
Fit (scans 80 mW)	-1.3	0.4
Fit (scans 350 mW)	-2.6	0.1
4 points (all scans)	1.3	0.1
1 point (all scans)	1.5	-0.7

Systematic errors ±2.6%

Calibration Systematic Errors

	Systematic errors (+-)
Geometry	1%
Sensor non uniform spatial response	1.5%
Powermeter absolute calibration	3%
Power measurements	2.6%

P_{ref} , ΔL_{pend} is understood within $\pm$ 8.0%

h(t) Characterisation with Photon Calibrator

Principle: Produce known motion by acting NI mirror

Frequency domain comparison:

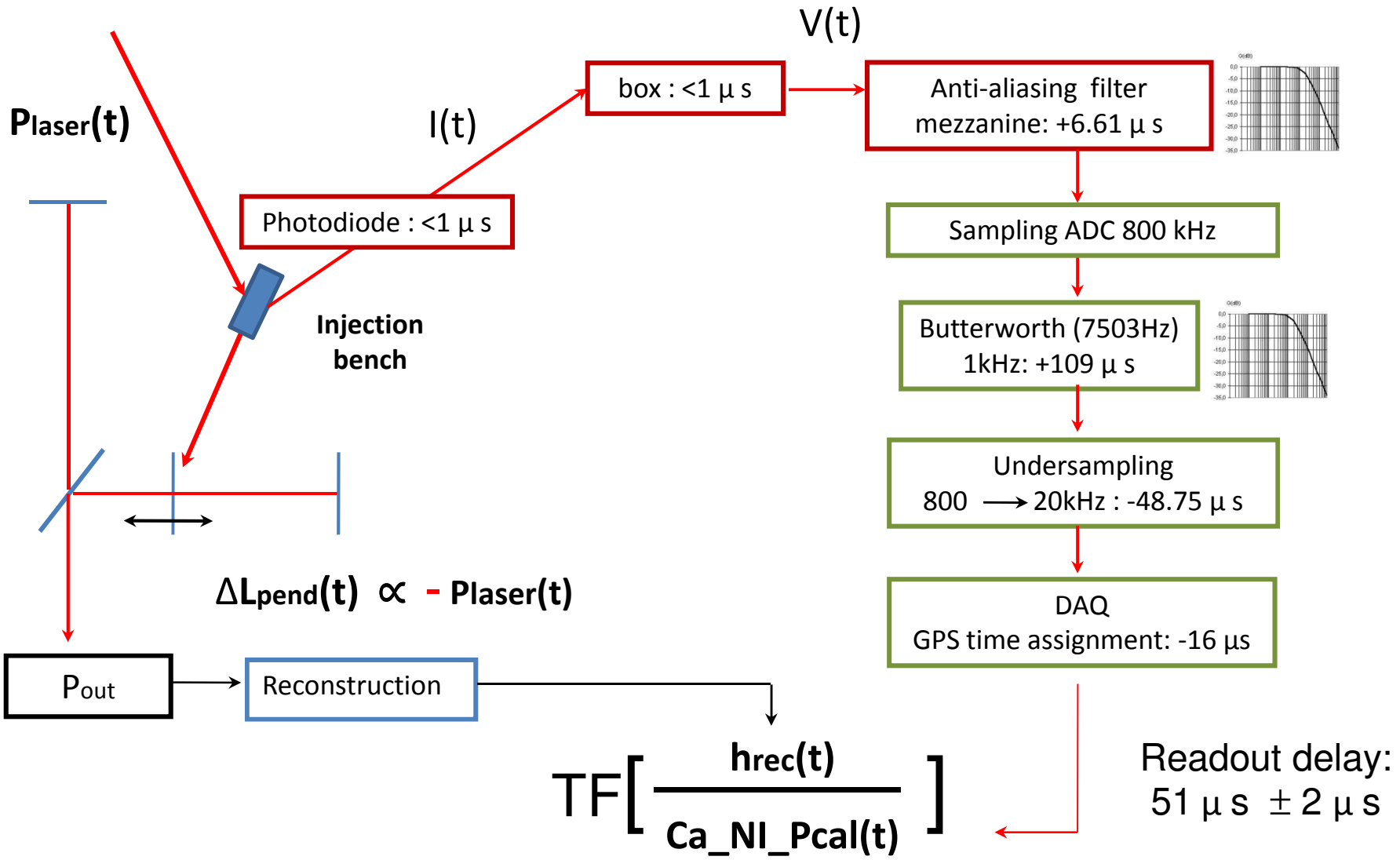
$$\mathbf{TF}\left[\frac{h_{rec}.L}{\Delta L_{pend}}\right]$$

Ideal case:

Modulus → 1
Phase → 0

Evaluation of h(t) reconstruction errors

Building TF: timing



Elastic Deformations Induced by PCal

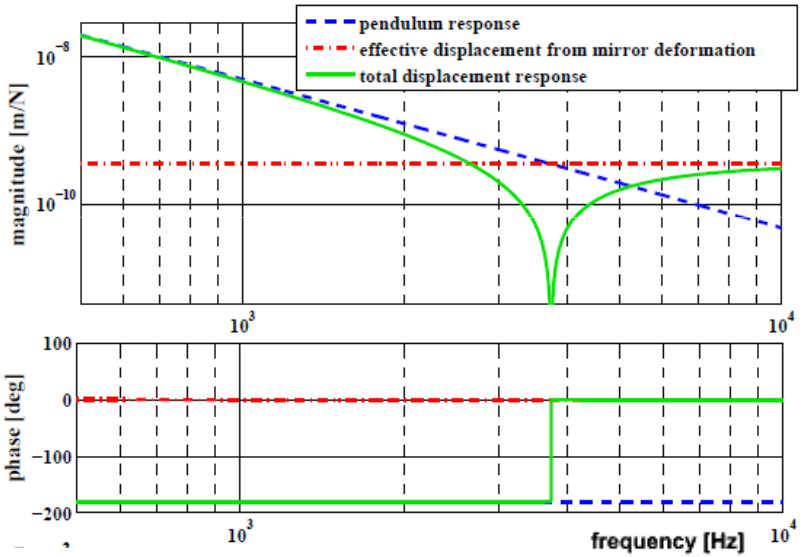
- Origin

Localized force acting on an object induces localized deformations (thermo elastic, in phase with the force, flat in frequency).

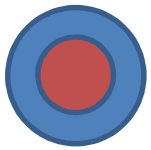
- GEO (Stefan Hild) [1]

Induced deformations with photon calibrator is confirmed

Local deformations are seen and interpreted by the interferometer as a **global displacement**.



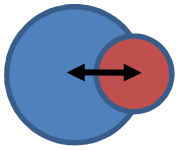
Overlap of ITF beam and deformations



$$\Delta L_{tot} = \Delta L_{pend} + \Delta L_{def}$$

- Our analysis

Beams offset x_0 impact in overlap calculus



$$\Delta L_{tot} = \Delta L_{pend} + \Delta L_{def}(x_0)$$

$$= (1 - \frac{f^2}{f_0^2(x_0)})\Delta L_{pend}$$

$$\frac{\Delta L_{rec}}{\Delta L_{pend}} = (1 - \frac{f^2}{f_0^2(x_0)})$$

[1] Photon pressure induced test mass deformation in gravitational-wave detectors S. Hild and al , Classical And Quantum Gravity (2007)

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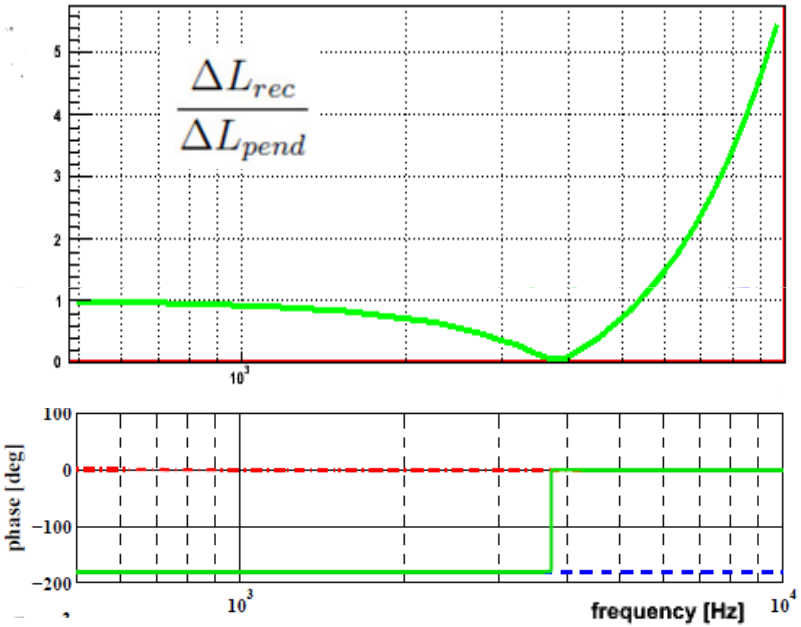

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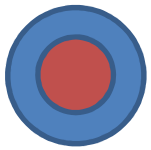

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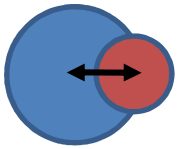

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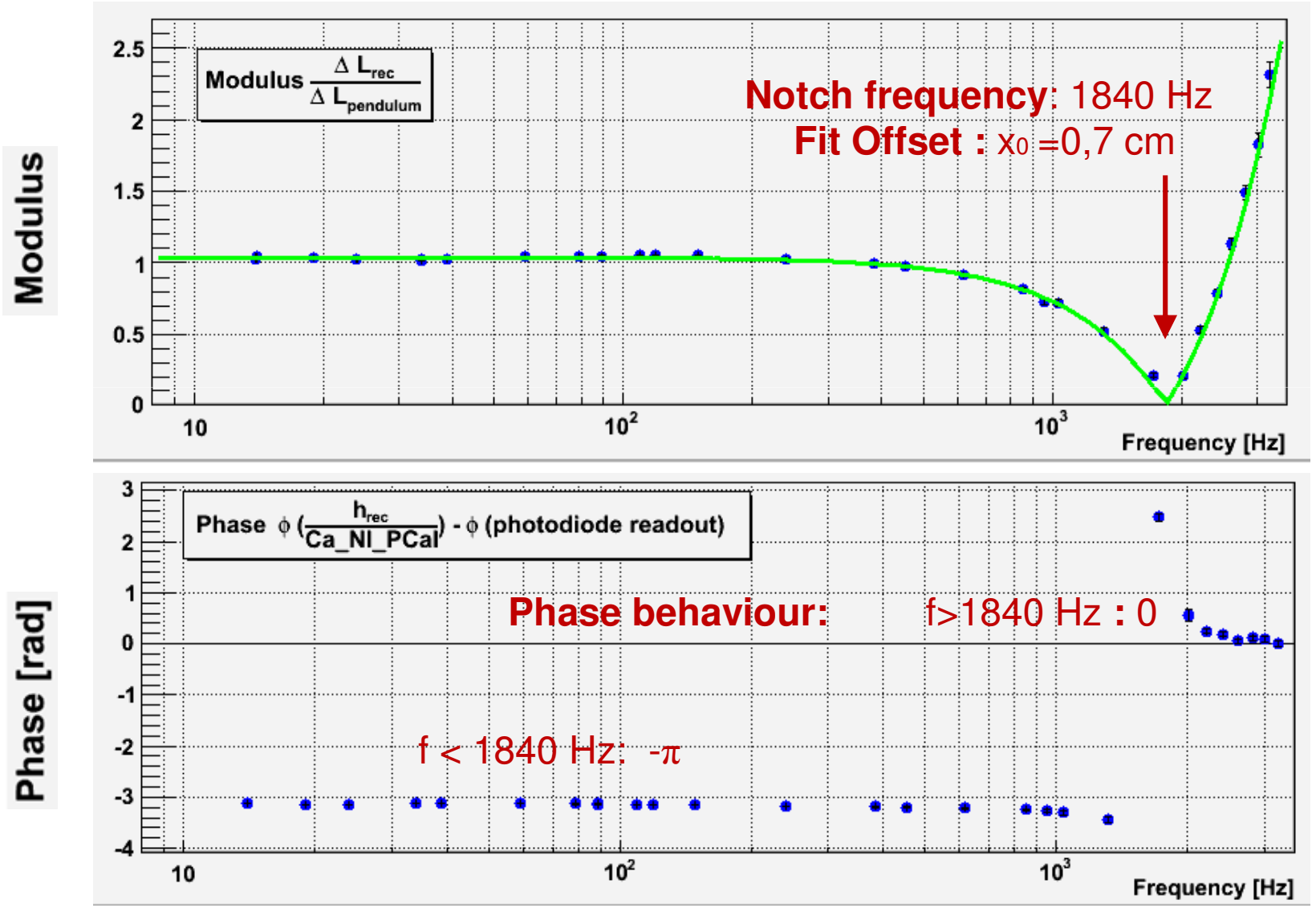
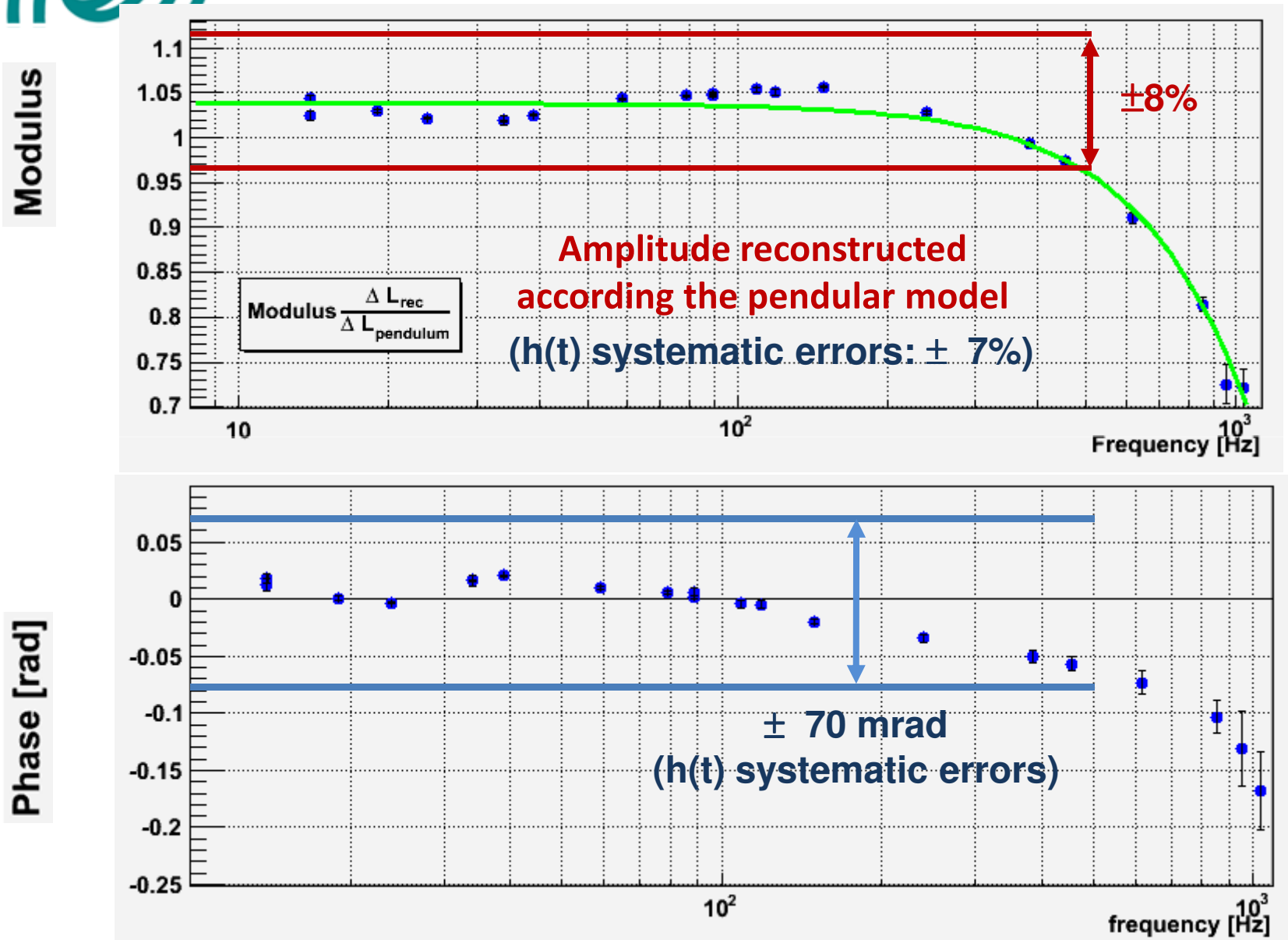
Characterisation of Hrec V2

January measurements



Zoom on Low Frequency



Conclusion

- Photon Calibrator is installed
  - Power calibration: 8 % systematic errors

- h(t) checked with PCal:
  - Amplitude and phase within systematic errors
  - Mirror deformations must be included:
    leading effect above 1840 Hz