

Status of the VSR1 calibration

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Main calibration stream

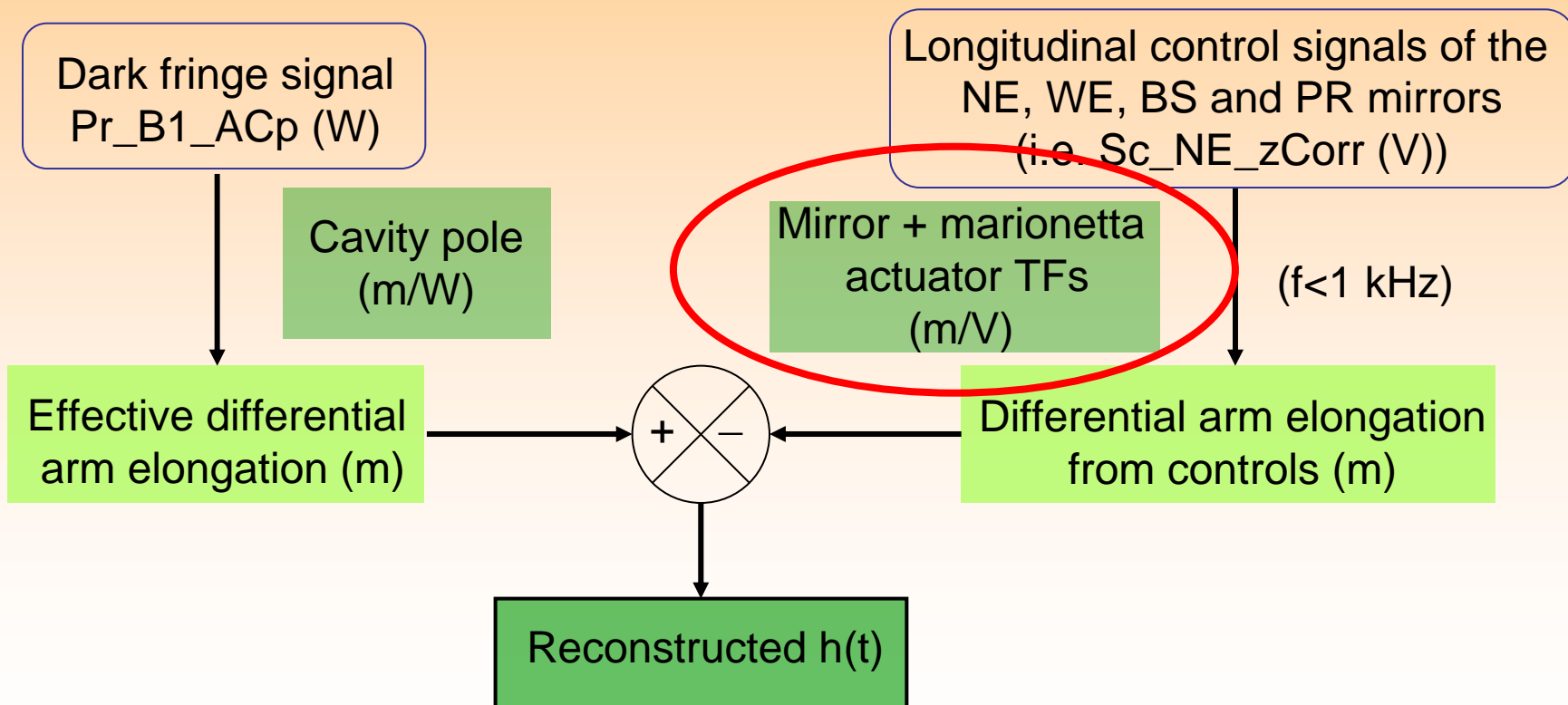
- Mirror actuators (NE, WE, NI, WI, BS, PR)
- End mirror marionnetta actuators (NE, WE)

Photon calibration preliminary results

- [VSR1 calibration note](#) in the Virgo codifier (in the hand of the reviewers) ([link](#))
- Draft of the pcal calibration note in the Virgo working area ([link](#))

Principle of the h-reconstruction

Gravitational wave amplitude $h(t)$ \longrightarrow Differential arm elongation attenuated since ITF in-loop



Synoptic of the mirror actuators calibration

MAIN STREAM

Free Michelson data
in HP mode

Coil driver electronics
measurements

*(Vincenzo Dattilo,
Dominique Huet)*

Mirror actuator TF in HP mode

LN/HP mirror actuator TF ratio

Mirror actuation TF corrected for
the pendulum response:

- $f_0 = 0.6$ Hz
- $Q = 1000$

Mirror actuator TF in LN mode

CHECKS

Free Michelson data
in LN mode
(BS, NI, WI, $f < 100$ Hz)

Injections during
HP/LN switch
In the lock acquisition
(BS, NE, WE, $f > 100$ Hz)

WE mirror actuation in LN mode

Left column: mirror actuator TF

Black points: TF in HP mode
 Red points: TF in LN mode (stat. errors)
 Blue curve: VSR1 online model
 Red curve: new VSR1 model

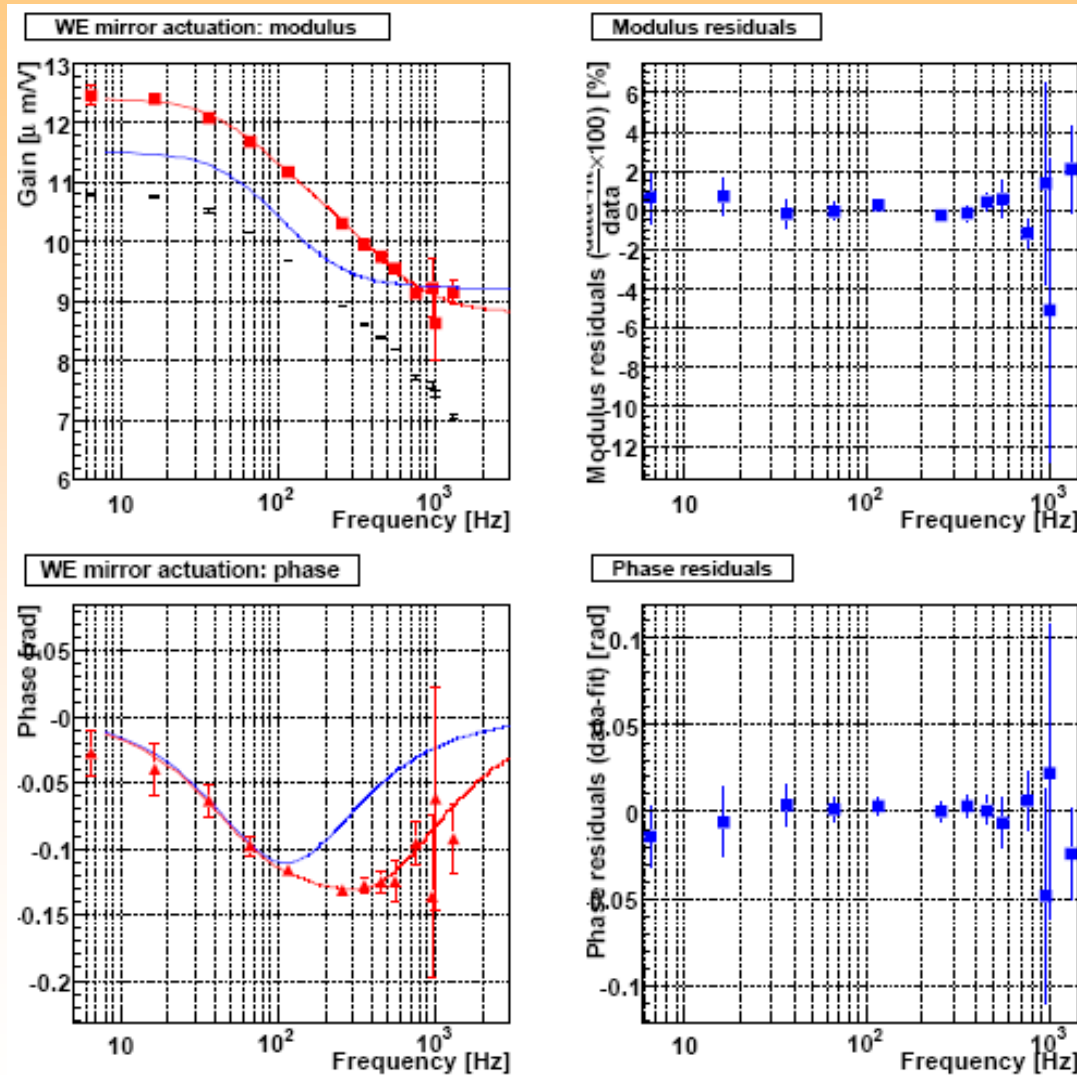
Fit the mirror actuator TF in LN mode
 With 2 poles and 2 zeros

Model residuals below 1 kHz:

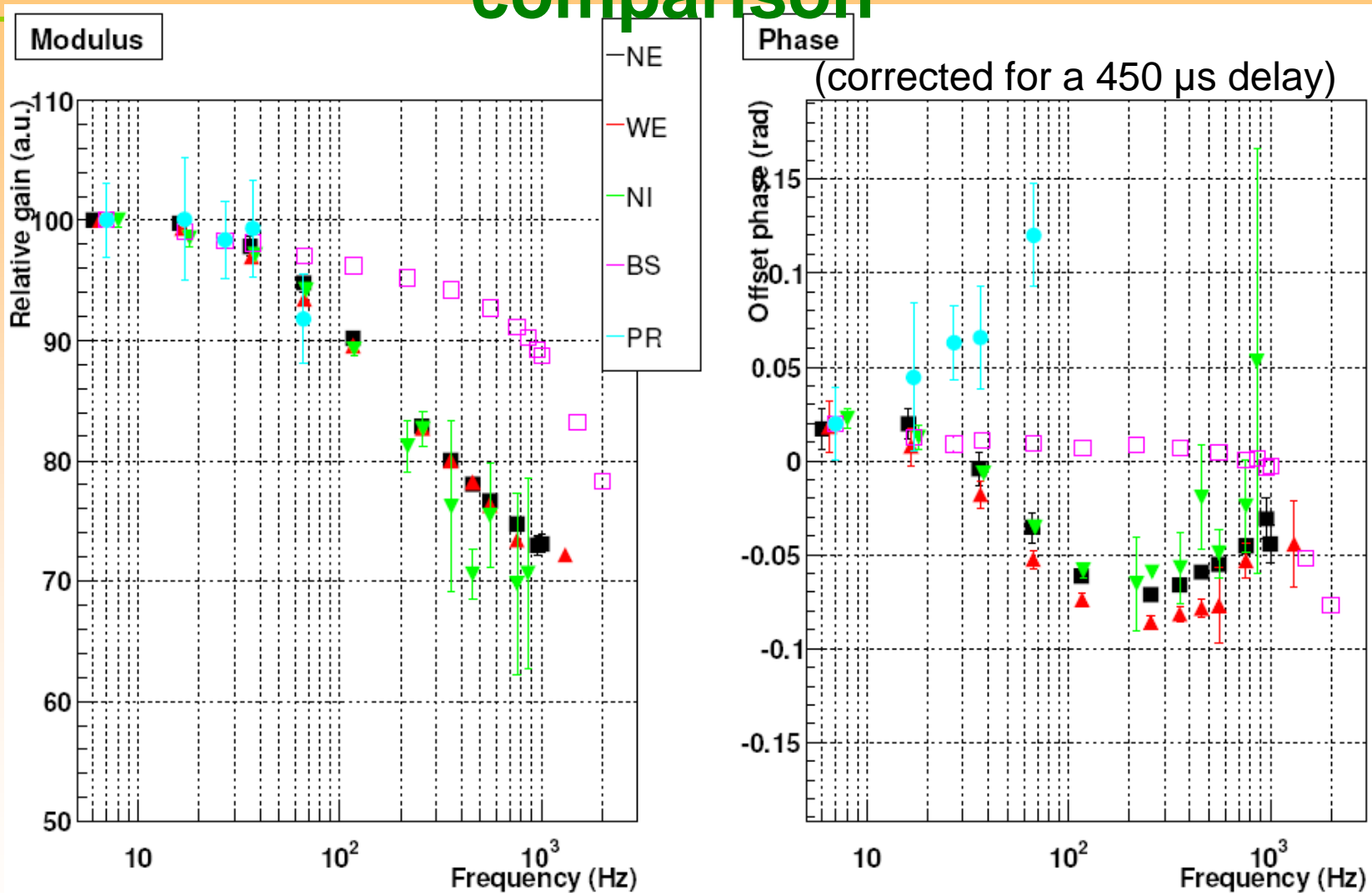
- Modulus residuals $< 2\%$
- Phase residuals $< 1.2^\circ$

→ Horizon decrease by $\sim 7\%$

(the z-controls stop below 1 kHz)



Mirror actuations in LN mode: comparison



- Similar TF for the arm mirror actuators
- Different shape for the BS mirror actuator TF

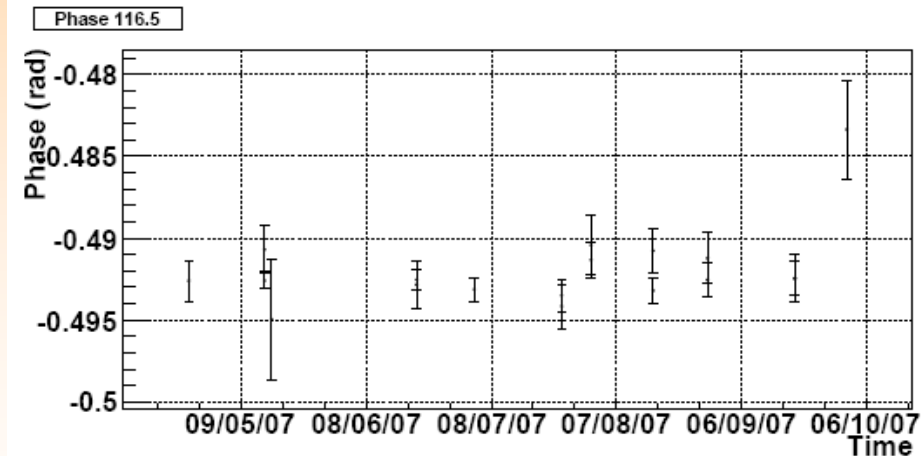
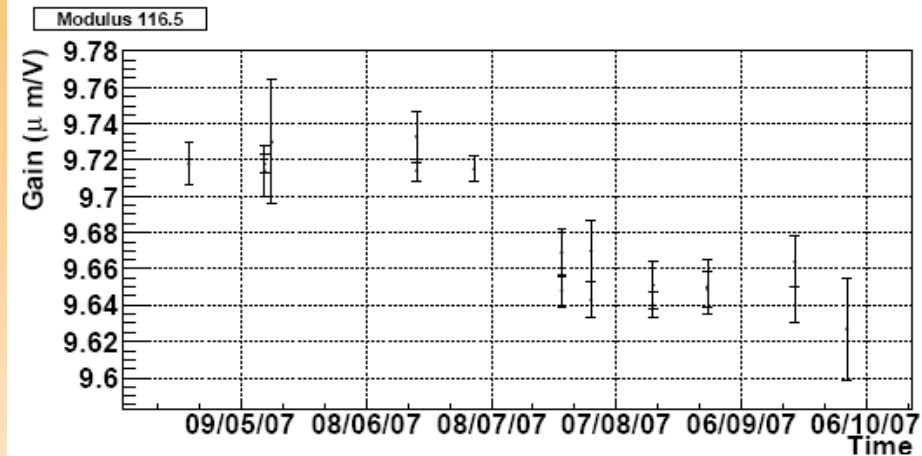
Free Michelson measurement checks

Done:

- ✓ Check of the non-saturation of the injections
- ✓ Check of time stability (within 1% in modulus)

Still to do:

- Check of possible bias in the free Michelson reconstruction



(a) 116.5 Hz

Mirror actuation TF systematics

Free Michelson data

- Use of Pr_B1p signals for the analysis ?
- 10.5 μs systematic delay on the BS TF between different datasets $\pm 10.5 \mu\text{s}$
- $\pm 1\%$ modulus variation with time $\pm 1\%$

Comparison with free Michelson measurements in LN mode

- $\pm 1\%$ difference on the TF modulus $\pm 1\%$
- compatible phase

LN/HP TF ratio: comparison of electronics measurements (R1) and injections during lock acquisition (R2)

- systematic relative difference $(R2-R1)/R1$ of $\sim -2\%$ on the ratio $+0\%$
 -2%

Estimation of the systematic errors of the calibration main stream

Modulus

+2%
-4%

Phase

$\pm 10.5 \mu\text{s}$ delay

PRELIMINARY

Synoptic of the NE, WE marionette calibration

MAIN STREAM

White noise injection
 - on zCorr
 - on zM *(Gabriele Vajente)*

↓ (<100 Hz)

Marionetta/Mirror (LN) actuator TF ratio

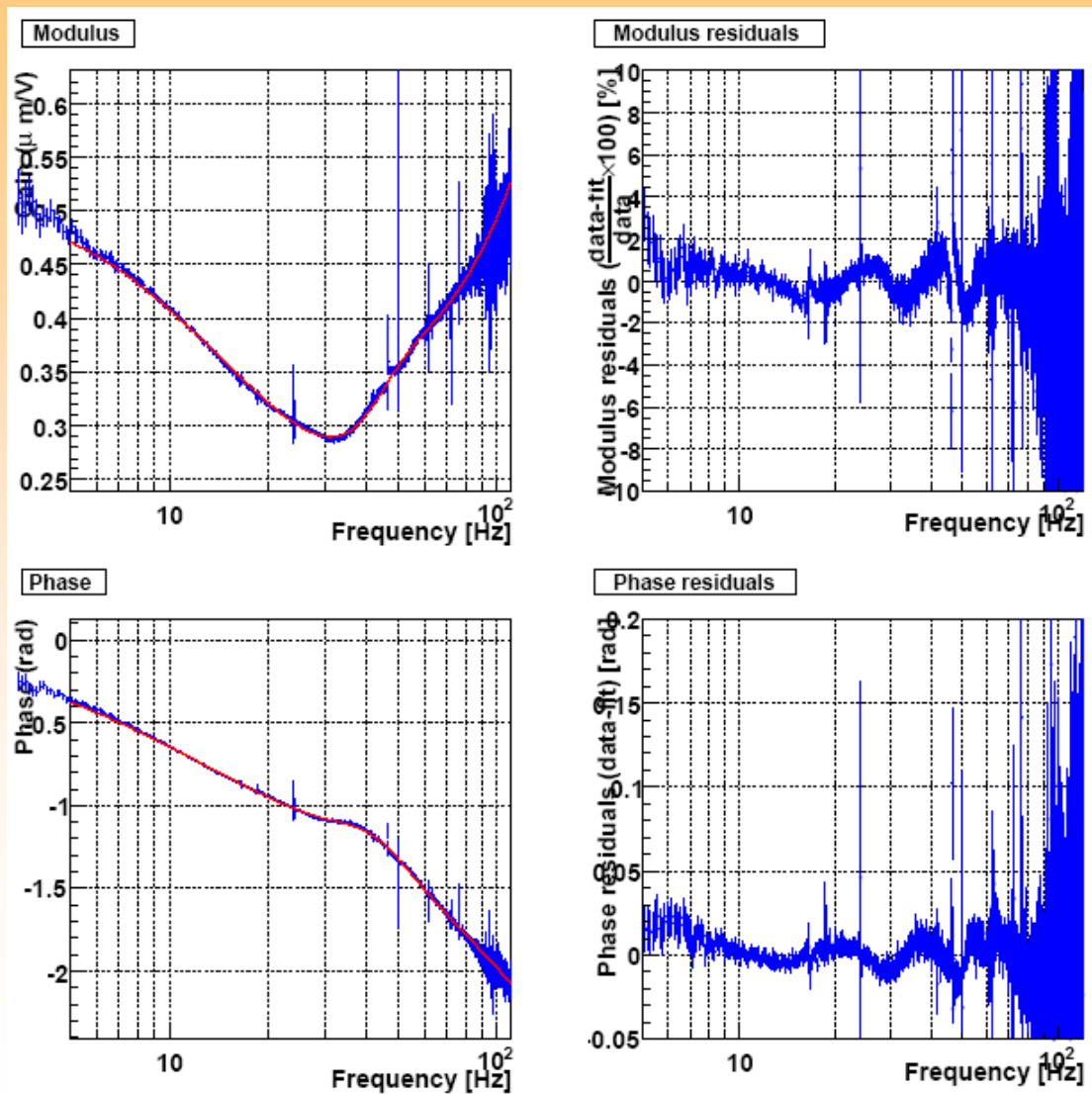
Mirror actuator TF in LN mode

Marionetta actuator TF

CHECKS

Free Michelson data
 ($f < 10$ Hz)

WE marionetta actuation TF fit



TF modulus corrected for a simple pendulum model in $(1\text{Hz}/f)^4$

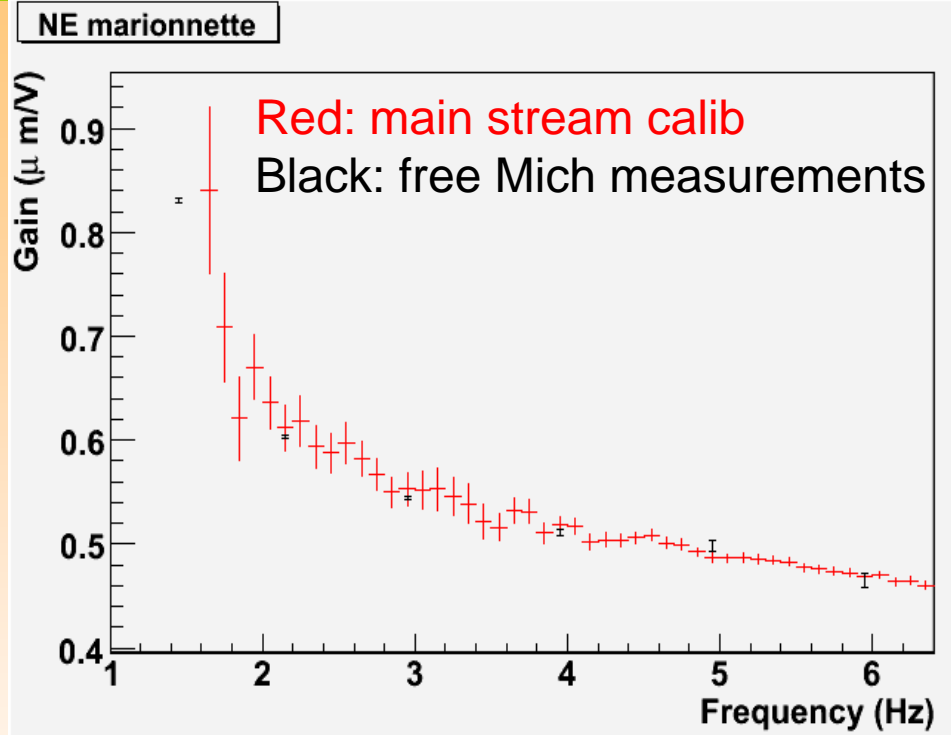
$$\begin{aligned}
 g &= 0.5083 \pm 0.0005 \mu\text{m}/\text{V} \\
 t_d &= 1.070 \pm 0.005 \text{ ms} \\
 f_p &= 8.47 \pm 0.063 \text{ Hz} \\
 f_p &= 16.231 \pm 0.084 \text{ Hz} \\
 f_p &= 44.93 \pm 0.13 \text{ Hz}, Q = 1.2241 \pm 0.0079 \\
 f_0 &= 10.219 \pm 0.065 \text{ Hz} \\
 f_0 &= -50.405 \pm 0.055 \text{ Hz} \\
 f_0 &= 41.29 \pm 0.39 \text{ Hz} \\
 f_0 &= 40.46 \pm 0.12 \text{ Hz}, Q = 1.1915 \pm 0.0071
 \end{aligned}$$

Residuals from 5 to 100 Hz
 → Modulus within 2%
 → Phase within 2°

Marionette actuation TF systematics

Comparison with free Michelson data below 10 Hz:
 → Compatible measurements within statistics
 (4% on the modulus, 2.5° on the phase)

Propagation of the systematic errors of the mirror actuation TF



Estimation of the systematic errors of the calibration main stream

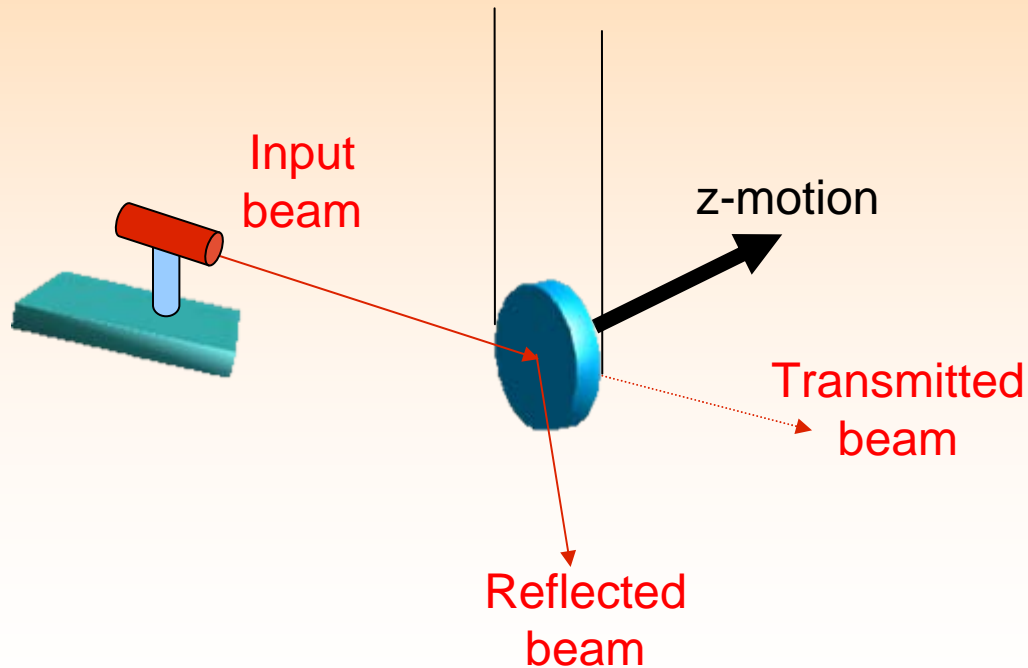
Modulus	Phase
$\pm 4\%$	$\pm 2.5^\circ$

PRELIMINARY

Photon calibration setup for VSR1

Two pcal: NI and WI towers

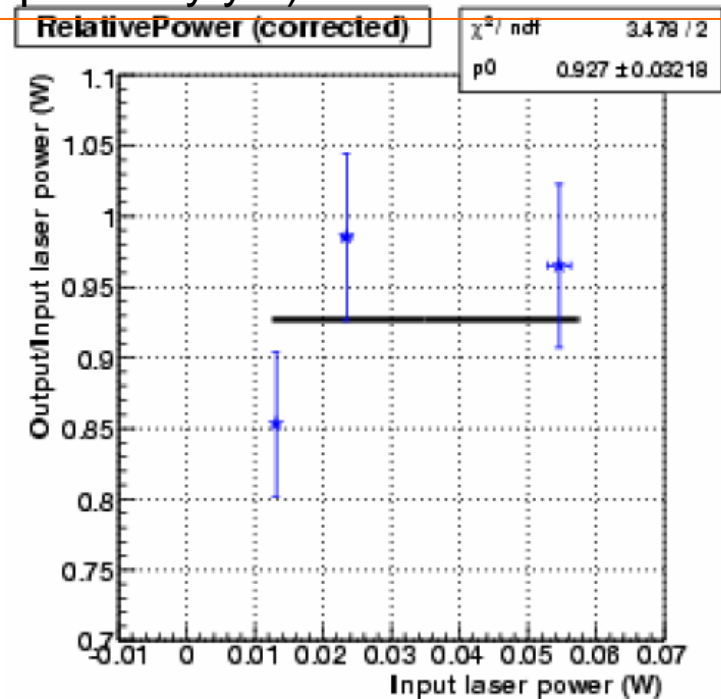
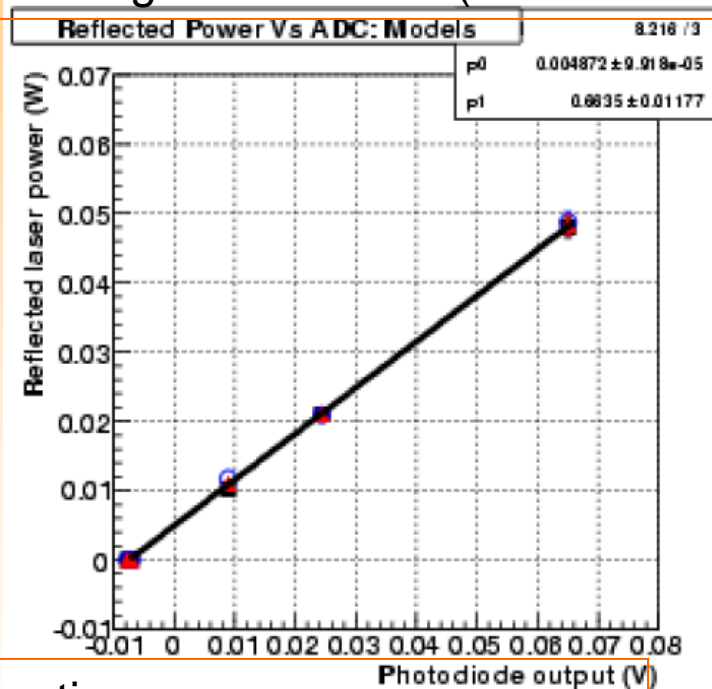
- Single beam (few mm diameter) hitting the center of the input mirror
- Photodiode to monitor the input laser power
- Output beams (reflected and transmitted) visible through view-ports



Calibration of the NI pcal

Calibration issues:

- laser power measurements with power-meter
- view-port transmittivity (extrapolated as function of wavelength) and mirror reflectivity
- beam centering on the mirror (not estimated precisely yet)



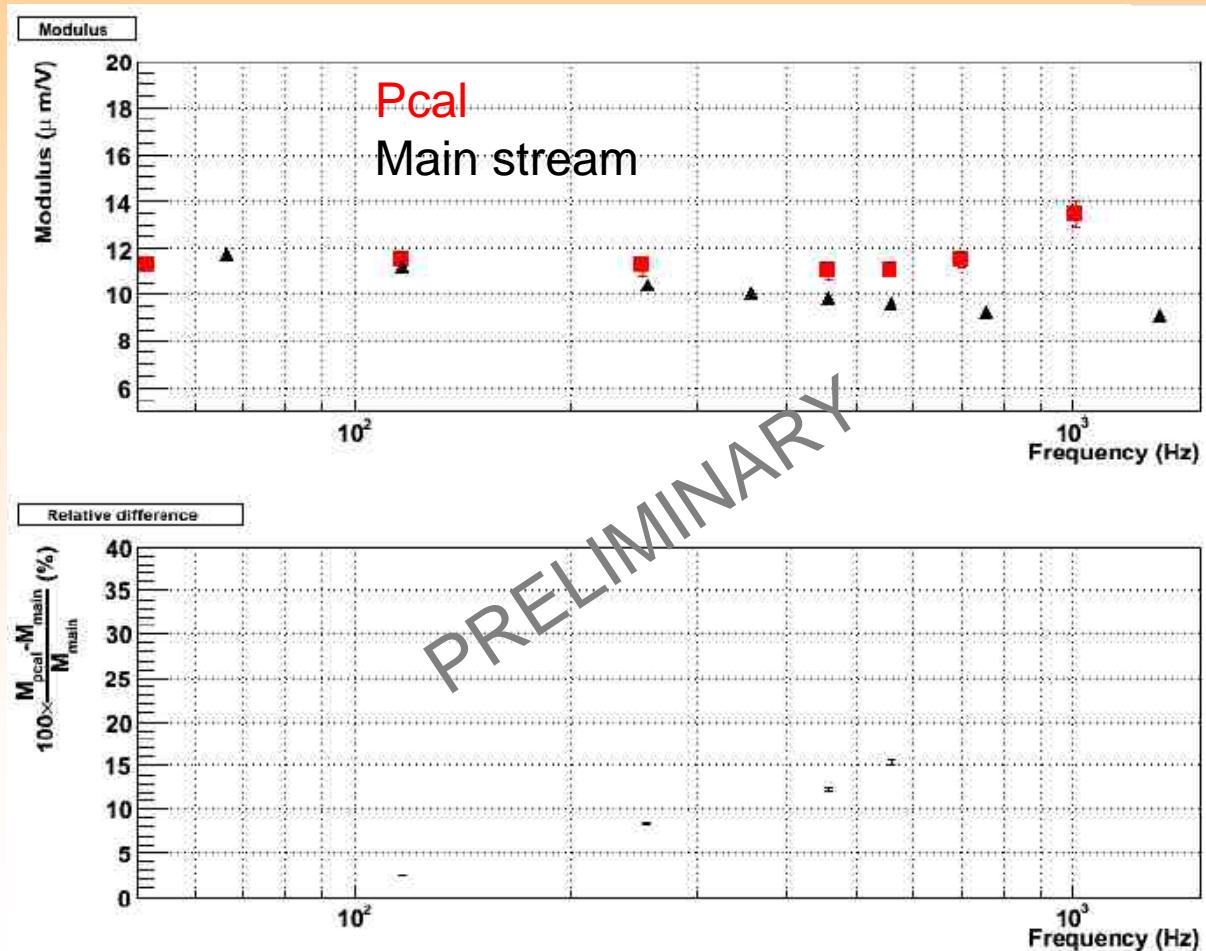
→ Systematics:

- ±2-3% difference between models
- ±8% of power losses (output/input)
- ±5-10% from power measurements ?

(Model 1: input power x transmittivity x reflectivity
 Model 2: output power / transmittivity)

WE mirror actuation calibration with Pcal

Simultaneous close lines injected through the coil actuator and the pcal



Comparison with main calib

- Within 5% below 200 Hz
- Modulus increase at high f:
 \rightarrow mirror deformation ?
 (S. Hild et al, 2007 for GEO)

Conclusions: VSR1 actuator calibration

MIRROR ACTUATION TF (5Hz-1kHz) done

	Modulus	Phase	
Fit (stat. errors)	$\pm 2\%$	$\pm 1.2^\circ$	
Systematic errors	+2% -4%	$\pm 10.5 \mu\text{s}$	PRELIMINARY

MARIONETTA ACTUATION TF (5-100Hz) done

	Modulus	Phase	
Fit (stat. errors)	$\pm 2\%$	$\pm 2^\circ$	
Systematic errors	$\pm 4\%$	$\pm 2.5^\circ$	PRELIMINARY

PHOTON CALIBRATION PRELIMINARY

Agreement with main stream calibration (mirror actuation) within 5% below 200 Hz
 Increasing discrepancy with frequency: mirror deformation ?

On-going activities

- Measurement of the cavity finesse during VSR1
- Review of the VSR1 calibration results
- Modification of the h-reconstruction:
 - New mirror actuation TFs
 - Add the NE and WE marionetta TFs
 - Change high-pass filter that had effect on the phase up to a few 100 Hz