

Newtonian Calibrator Calibration Review, March 2024

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Current calibration systems uncertainties

Table 3. Relative standard uncertainties (%) in displacement factors and contributing parameters (indented) the LHO and Virgo end station Rx sensor outputs. Parameters that are NOT common to both end stations are in blue text.

Parameter	LHO			Virgo	
	X-End	Y-End	Type	Ends	Type
X_X^c and X_Y^c	0.29	0.29	U_{rel}	—	—
X/Y corr. fact.	0.26	0.26	$u_{rel,comb.}$	—	—
X_X and X_Y	0.44	0.37	U_{rel}	0.40	U_{rel}
Deform. mod.	—	—	—	0.30	$u_{rel,comb.}$
Inc. angle	0.03	0.03	$u_{rel,TypeB}$	0.16	$u_{rel,TypeB}$
ETM mass	0.01	0.01	$u_{rel,TypeB}$	0.05	$u_{rel,TypeB}$
Rotation	0.41	0.31	$u_{rel,TypeB}$	0.09	$u_{rel,TypeB}$
Optical eff.	0.03	0.10	$u_{rel,TypeB}$	0.10	$u_{rel,TypeB}$
Rx responsiv.	0.14	0.17	$u_{rel,comb.}$	0.15	$u_{rel,comb.}$

▶ PCal: developed by LIGO and Virgo

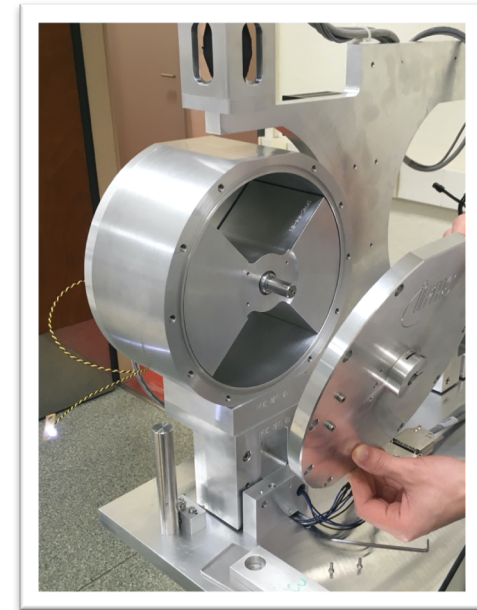
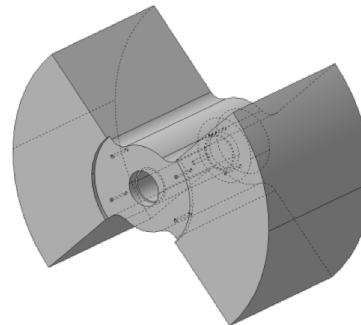
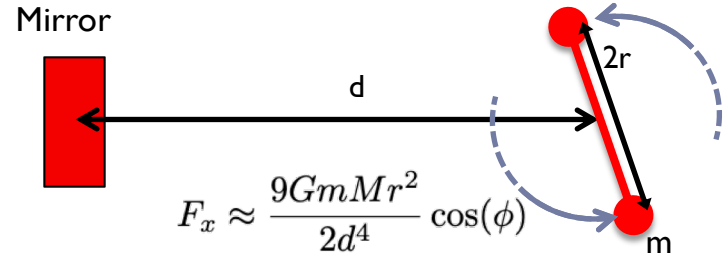
- Push the mirror with an auxiliary laser
- Uncertainties: see [LIGO-P2300412-v7](#)
- Virgo PCal currently at 0.6 % (VIR-0107A-24)
 - ▶ Dominated by optical losses uncertainties

▶ NCal developed in Virgo since O2

- Push the mirror with a variable gravitational field
- Preliminary uncertainty for O4b around 0.2 % (see details later)

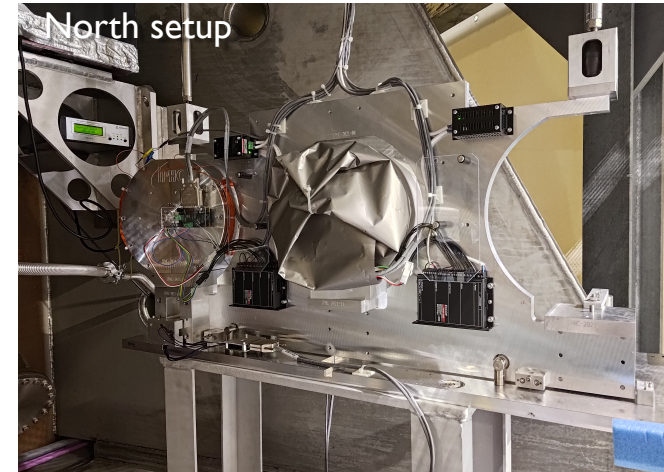
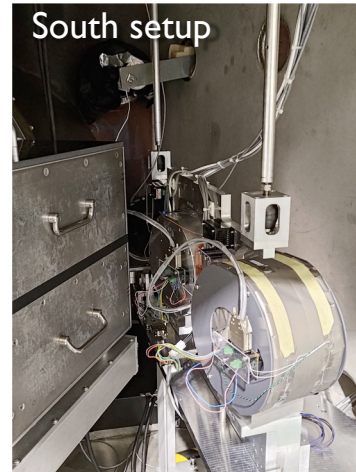
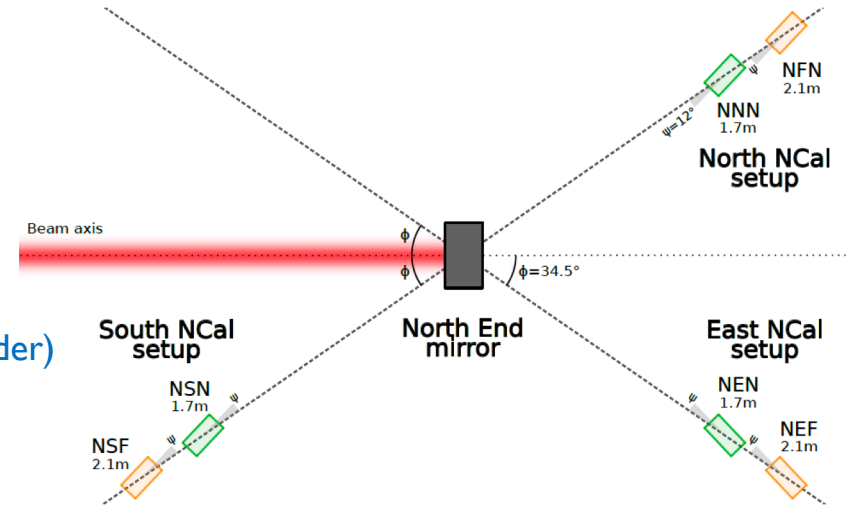
NCal principle

- ▶ Rotor made of two masses
 - Center of mass is not moving
 - The non-linear Newtonian force creates the signal
 - Signal at twice the rotor frequency
 - Signal goes as $1/d^4 \rightarrow$ Mirror to NCal distance is critical
- ▶ Expected benefits
 - Signal depends mainly on the rotor geometry, mass & position
 - ▶ Replace power measurements (PCal) by distance measurement (NCal)
 - Mass of the mirror cancels out
 - No aging effect of the signal
 - Simple interface with the detector (no viewports)
- ▶ Challenges:
 - Metrology
 - Fast rotation
 - Parasitic couplings
 - Reliability



O4b NCal system

- ▶ 6 NCals around the NE mirror
- ▶ 2 couples of NCals along the north-south axis
 - Remove mirror-NCal distance uncertainty (at first order)
 - Near NCal at 1.7 m with PVC rotors
 - Far NCal at 2.1 m with Aluminum rotors
- ▶ East setup dedicated to:
 - Parasitic coupling studies
 - Frequency scan
- ▶ Maximum operating frequency:
 - 120-150 Hz in $h(t)$ for Al rotors
- ▶ Permanent operation since last August
 - PVC rotors installed in February



Detector Monitoring System for NCal

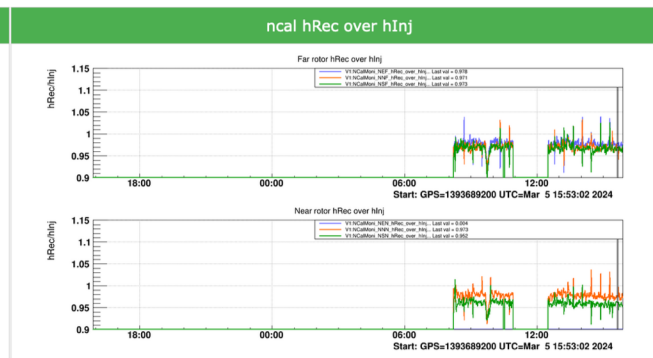
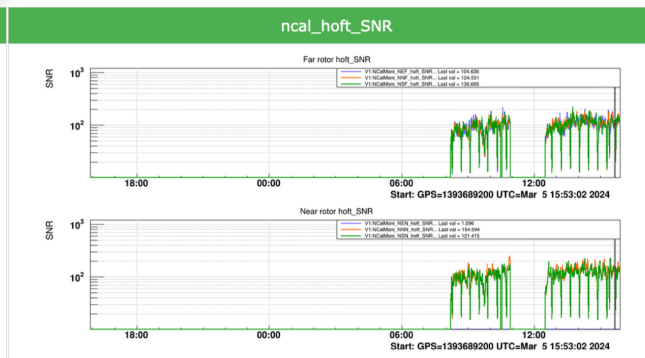
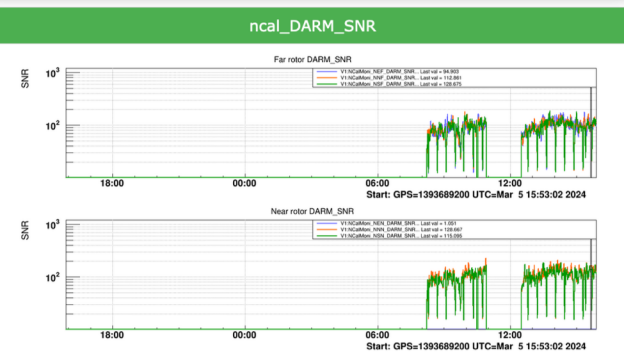
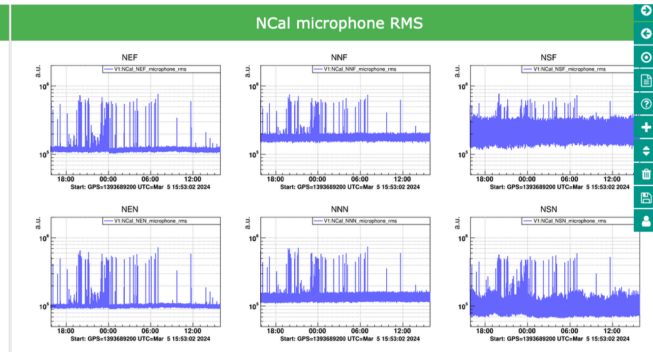
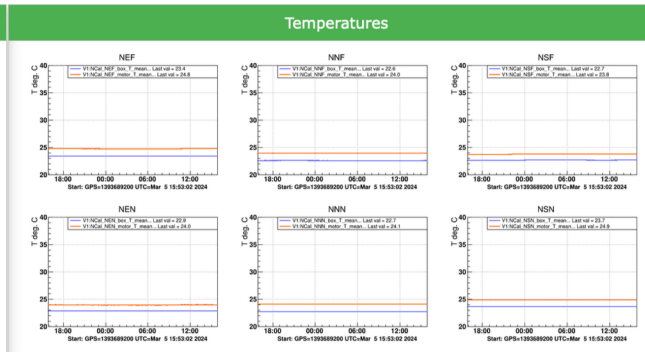
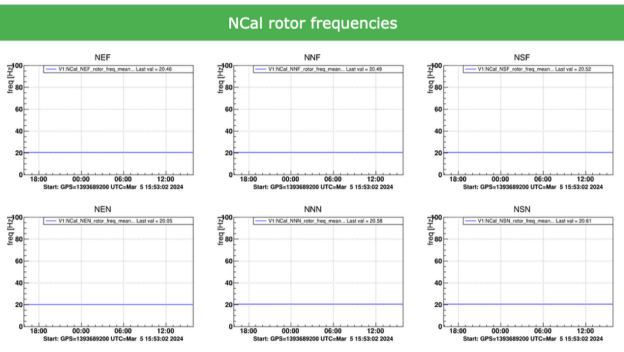
Browser address: https://dms.virgo-gw.eu

ITF Mode: **Commissioning** (1d 1h 37m 57s)

											Warning cond	Error cond			
Injection	ML		SL		PMC		LaserA								
	SLC_Ba_MC_Temp	MC_Power	PSTAB		IMC_AA										
Detection	PD	PD_RF	QPD_B1p	QPD_B2	QPD_B4		v(Hz)					<= 5	<= 1		
ISC	PR_parking		SR_parking		DC										
ALS	NE_ALS_Laser		NE_ALS_ARM		WE_ALS			v-v _{set} (mHz)					>= 2	>= 5	
Suspensions	SIB1_IP	SIB1_BENCH	SIB1_BR		SIB1			phase (mrad)					>= 5	>= 40	
	MC_IP	MC_PAY	MC_BR		MC_V										
	SDB1_IP	SDB1_LC	SDB1_BR		SDB1			Box_T (°C)					>=35	>=40	
	BS_IP	BS_F7	BS_PAY	BS_BR					Motor_T (°C)					>=35	>=40
	NI_IP	NI_F7	NI_PAY	NI_BR											
	NE_IP	NE_F7	NE_PAY	NE_BR											
	PR_IP	PR_F7	PR_PAY	PR_BR											
	SR_IP	SR_F7	SR_PAY	SR_BR											
WI_IP	WI_F7	WI_PAY	WI_BR												
WE_IP	WE_F7	WE_PAY	WE_BR												
Environment	CB_Hall	MC_Hall	TCS_zones	NE_Hall	WE_Hall	WindActivity	Seismon	BRMSMon	QNR						
	INJ_Area	DET_Area	EE_Room	DAQ_Room	MeteoStations	DeadChannel	FlatChannel_EN	Lights	SeaActivity						
Infrastructures	ACS_CB_Hall	ACS_TCS_CH	ACS_TB	ACS_DAQ_Ro	ACS_EE_Roo	ACS_MC	ACS_INJ	ACS_DET	ACS_NE	ACS_WAB	ACS_FCIM				
	UPS_TB	UPS_CB	UPS_MC	UPS_NE	UPS_WE	IPS	FlatChann	ExistChan	Sensors	ACS_WE	ACS_CB_C	ACS_COB	ACS_FCEM	PyHVAC	
SBE	EIB	SIB2_SBE	SIB2_LC	SPRB_SBE	SPRB_LC	SDB2_SBE	SDB2_LC	SNEB_SBE	SNEB_LC	SWEB_SBE	SWEB_LC				
	SQB1_SBE	SQB1_LC	SQB2_SBE	SQB2_LC	FCIM_SBE	FCIM_LC	FCEM_SBE		FCEM_LC						
TCS	NE_RH	WE_RH	SR_RH	NI_CO2_Lase	WI_CO2_Las	NI_AUX_Lase	WI_AUX_Las	Chrocc_PR	Chillers	TCS_Electr					
QNR	LFC	AFC	QNR_GALVO	EQB1_ACTUATO	HD	EQB1Shutters	QNR_SQZ	PLLs	SQZ_INJ						
Vacuum	LargeValves	Clean_Air	TubeStations	TubePumps	MiniTowers	TurboLinks	SQZ	RemDryPMP	VAC_SERVOS	Tiltmeter					
	Pressure	CompressedAir	TowerServers	TowerPumps	CryoTrap	O2_Sensors	Tank	HLS	Vacuum_LAB						
VPM	DetectorSEnvir	ControlRoom	Minitowers	ISC	Squeezer	Injection	TCS	Suspension	Vacuum	Metatron					
	DetectorMonitoring	NewtonNoise	DataCollection	Storage	DataAccess	Automation	DetChar	Calibration-							
DAQ-Computing	Latency	Disk	Timing	Timing_rtpc	Timing_dsp	Fast_DAC	ADCs_TE	Daq_Boxes_TE							
	Domains	DMS_machine	DetOp_machin	olsevers	rtpcs	CoilSwitchBoxe	INF_devices	ENV_devices	VAC_devices	TCS_devices					
Calib_Hrec	CalNorth	CalWest	CalBS	CalPR	CalSR	PCalNorth	PCalWest	HOFT	HOFT_Bias	NCal	NoiseInjection				
ITFOnCall	TemperaturesAl		HumidityAl		DustAl		TestMasses			Test					

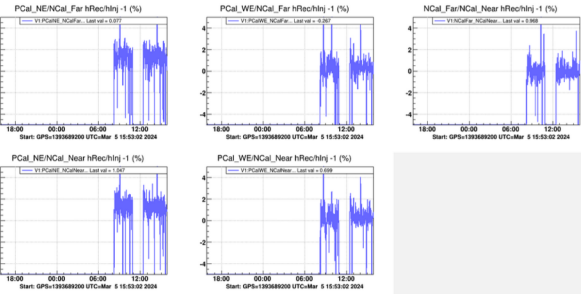
Alert mails are sent on error conditions to IPHC NCal group.

NCal in Virgo Interferometer Monitor

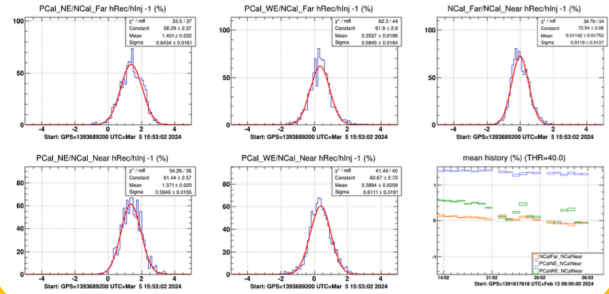


NCal in Virgo Interferometer Monitor

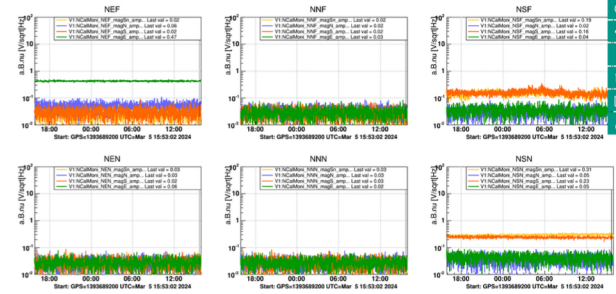
Hrec/Hinj (Pcal/Ncal -1)



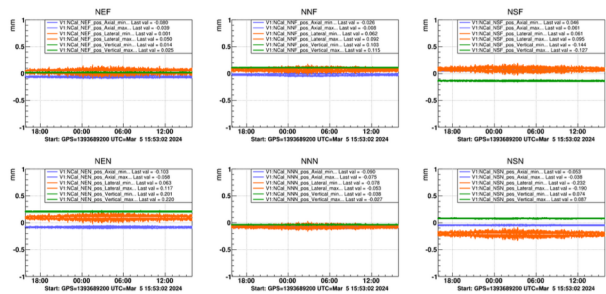
dist [Hrec/Hinj (Pcal/NCal - 1)]



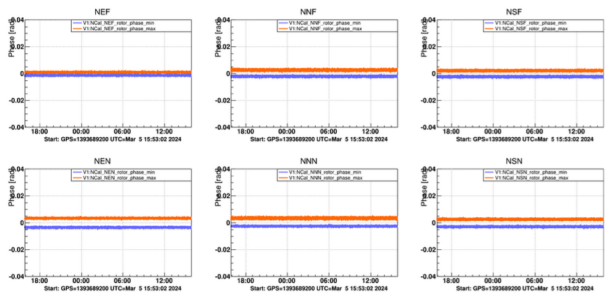
Magnetic amplitudes at 2*Ncal rotor frequencies



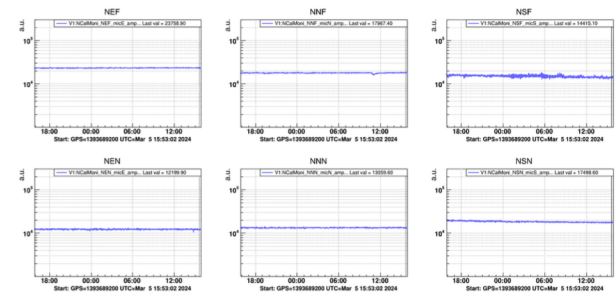
NCal Positions



NCal phases

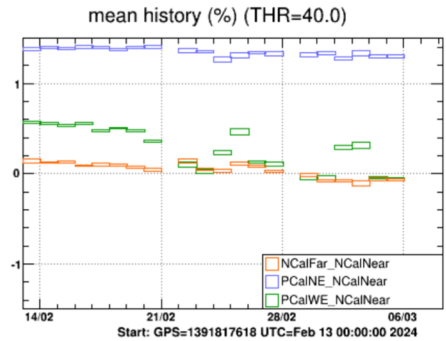
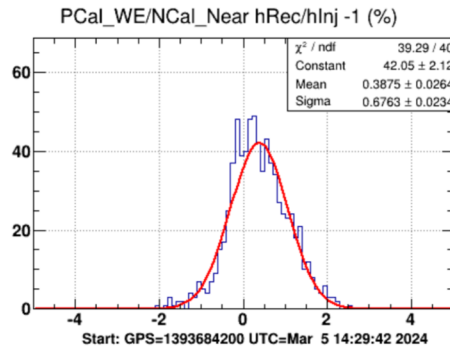
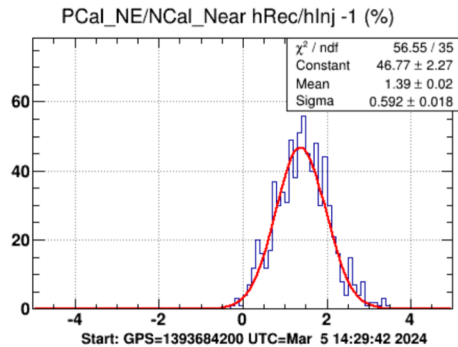
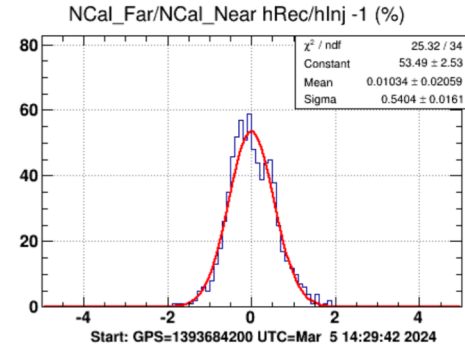
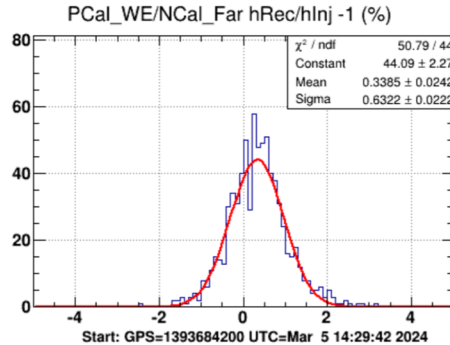
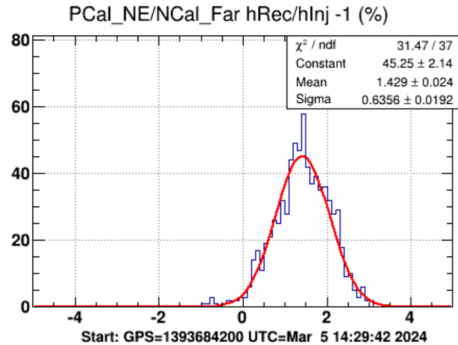


Microphones amplitudes at 2*Ncal rotor frequencies



Comparing Virgo PCal and NCal (Preliminary)

$$R(a) = \frac{hRec(a)}{hInj(a)} \rightarrow SR(a,b) = \left(\frac{R(a)}{R(b)} - 1 \right) * 100$$



Far/Near Fluctuations in full agreement with predicted uncertainties of 0.19% (0.24%) for Near (Far) NCal
 → See Antoine Syx presentation for details