Newtonian Calibrator
Calibration Review, March 2024

F. Aubin, E. Dangelser, B. Mours, A. Syx, P. Van Hove

March 8, 2024

Current calibration systems uncertainties

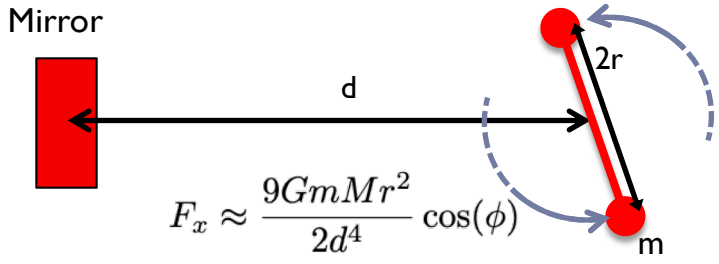
- PCal: developed by LIGO and Virgo
  - Push the mirror with an auxiliary laser
  - Uncertainties: see LIGO-P2300412-v7
  - Virgo PCal currently at 0.6 % (VIR-0107A-24)
    - Dominated by optical losses uncertainties

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.

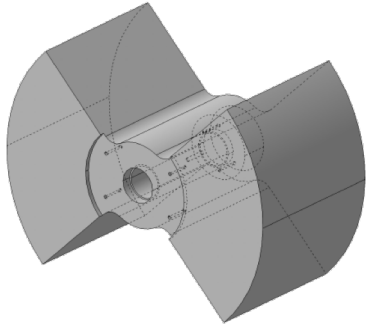
	LHO			Virgo	
Parameter	X-End	Y-End	Type	Ends	Type
X_X^c and X_Y^c	0.29	0.29	U_{rel}	—	—
X/Y corr. fact.	0.26	0.26	$u_{rel,\,comb.}$	—	—
X_X and X_Y	0.44	0.37	U_{rel}	0.40	U_{rel}
Deform. mod.	—	—	—	0.30	$u_{rel,\,comb.}$
Inc. angle	0.03	0.03	$u_{rel,TypeB}$	0.16	$u_{rel,TypeB}$
ETM mass	0.01	0.01	$u_{rel,TypeB}$	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	$u_{rel,\,comb.}$

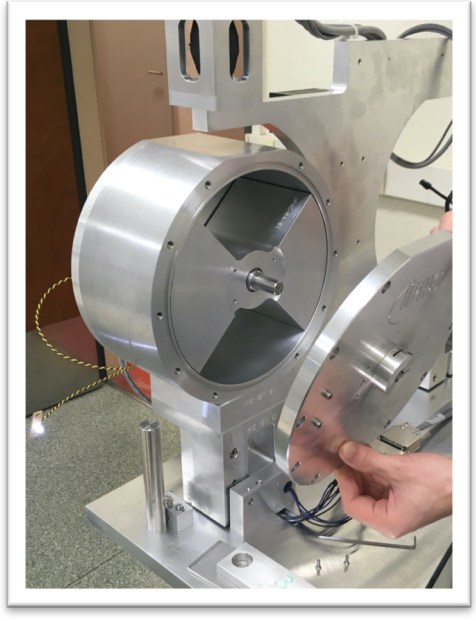
- NCal developed in Virgo since O2
  - Push the mirror with a variable gravitational field
  - Preliminary uncertainty for O4b around 0.2 % (see details later)

NCal principle



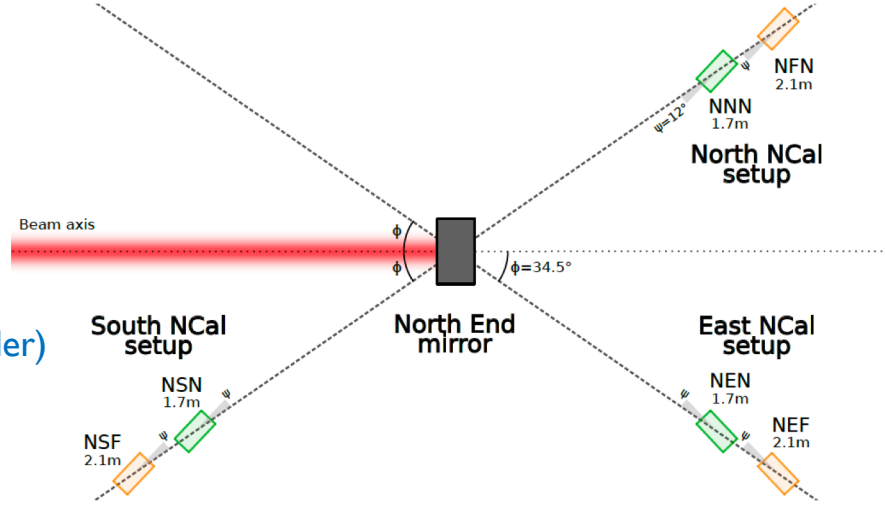
- Rotor made of two masses
  - Center of mass is not moving
  - The non-linear Newtonian force creates the signal
  - Signal at twice the rotor frequency
  - Signal goes as $1/d^4$ → Mirror to NCal distance is critical
- Expected benefits
  - Signal depends mainly on the rotor geometry, mass & position
    - 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

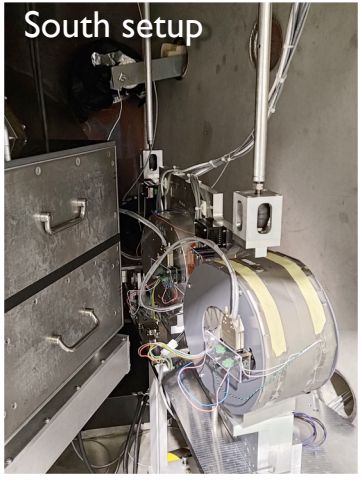


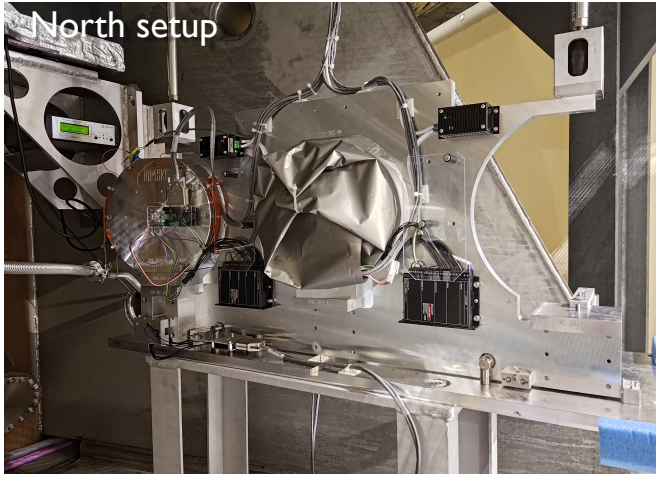


O4b NCal system

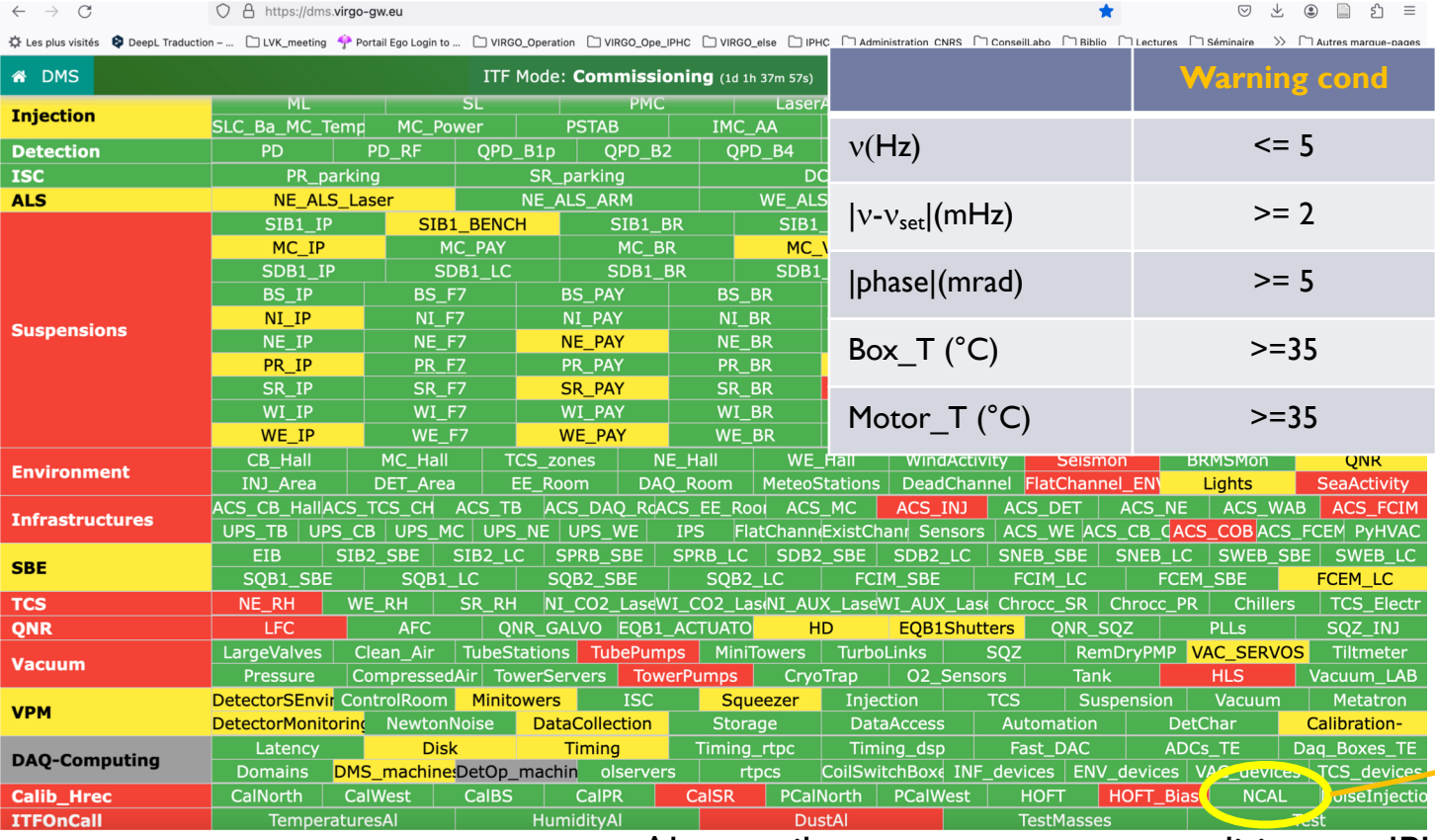
- 6 NCals around the NE mirror
- 2 couples of NCals along the north-south axis
  - Remove mirror-NCal distance uncertainty (at first order)
  - Near NCal at 1.7 m with PVC rotors
  - Far NCal at 2.1 m with Aluminum rotors
- East setup dedicated to:
  - Parasitic coupling studies
  - Frequency scan
- 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

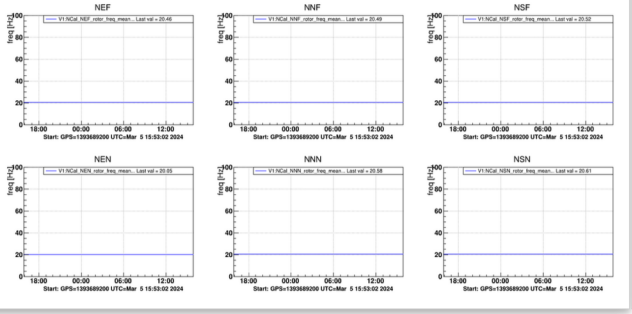


	Warning cond	Error cond
ν(Hz)	<= 5	<= 1
$\lvert\nu-\nu_{set}\rvert$(mHz)	>= 2	>= 5
|phase|(mrad)	>= 5	>= 40
Box_T (°C)	>=35	>=40
Motor_T (°C)	>=35	>=40

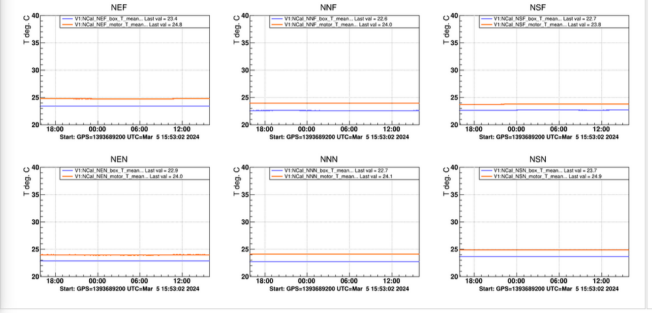
Alert mails are sent on error conditions to IPHC NCal group.

NCal in Virgo Interferometer Monitor

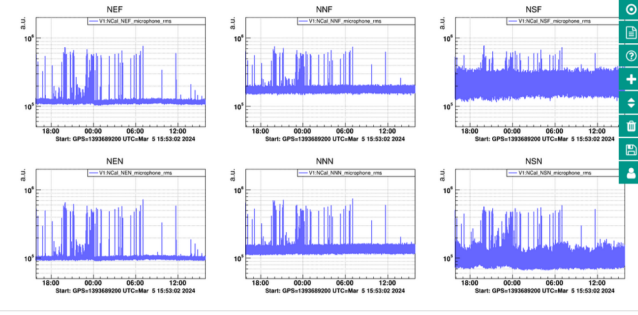
NCal rotor frequencies



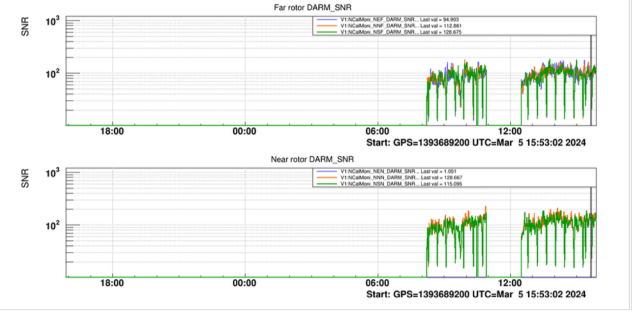
Temperatures



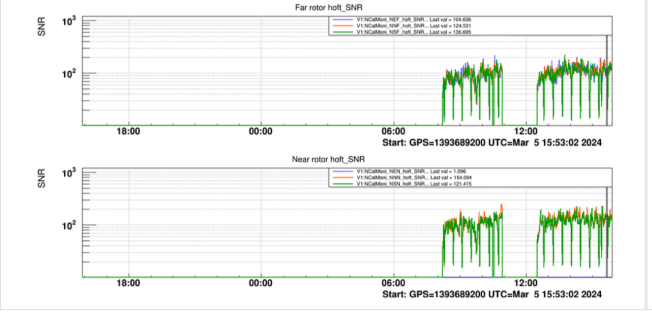
NCal microphone RMS



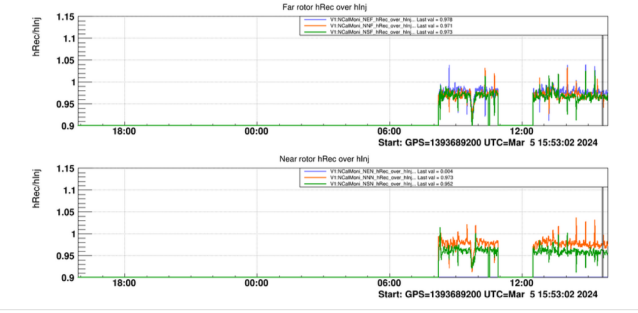
ncal_DARM_SNR



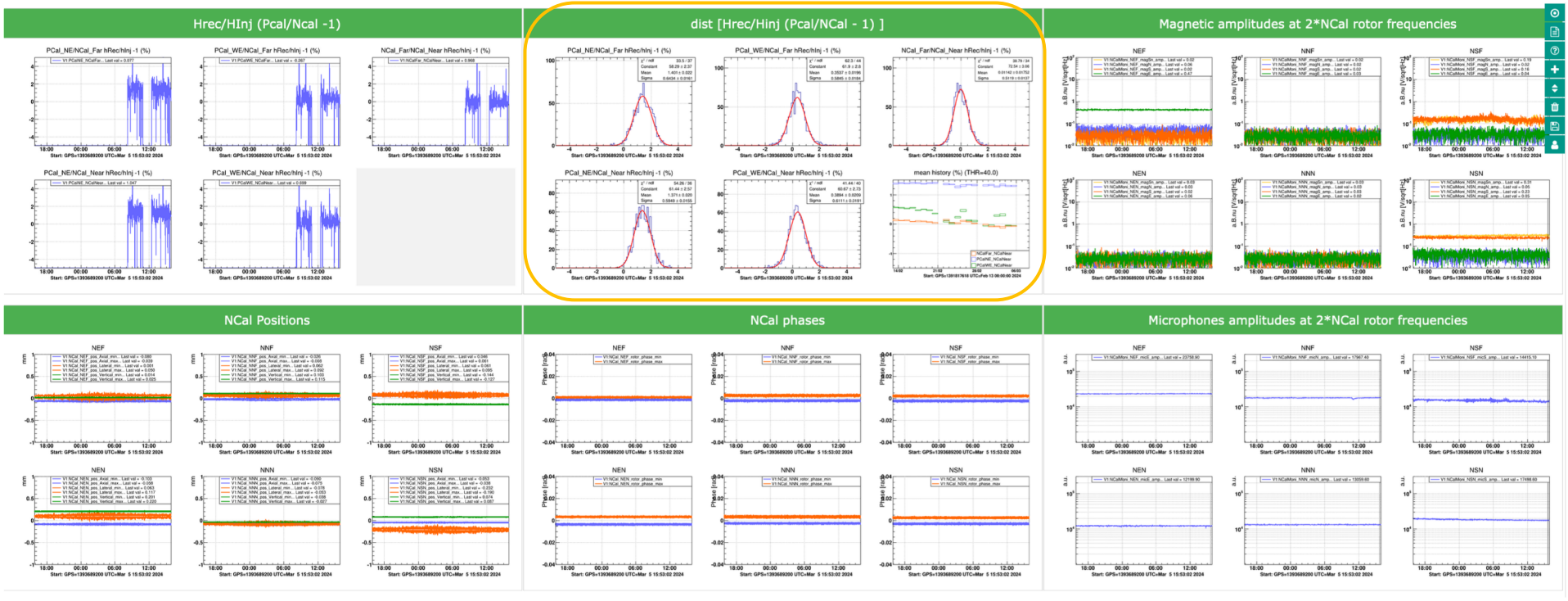
ncal_hoft_SNR



ncal hRec over hInj

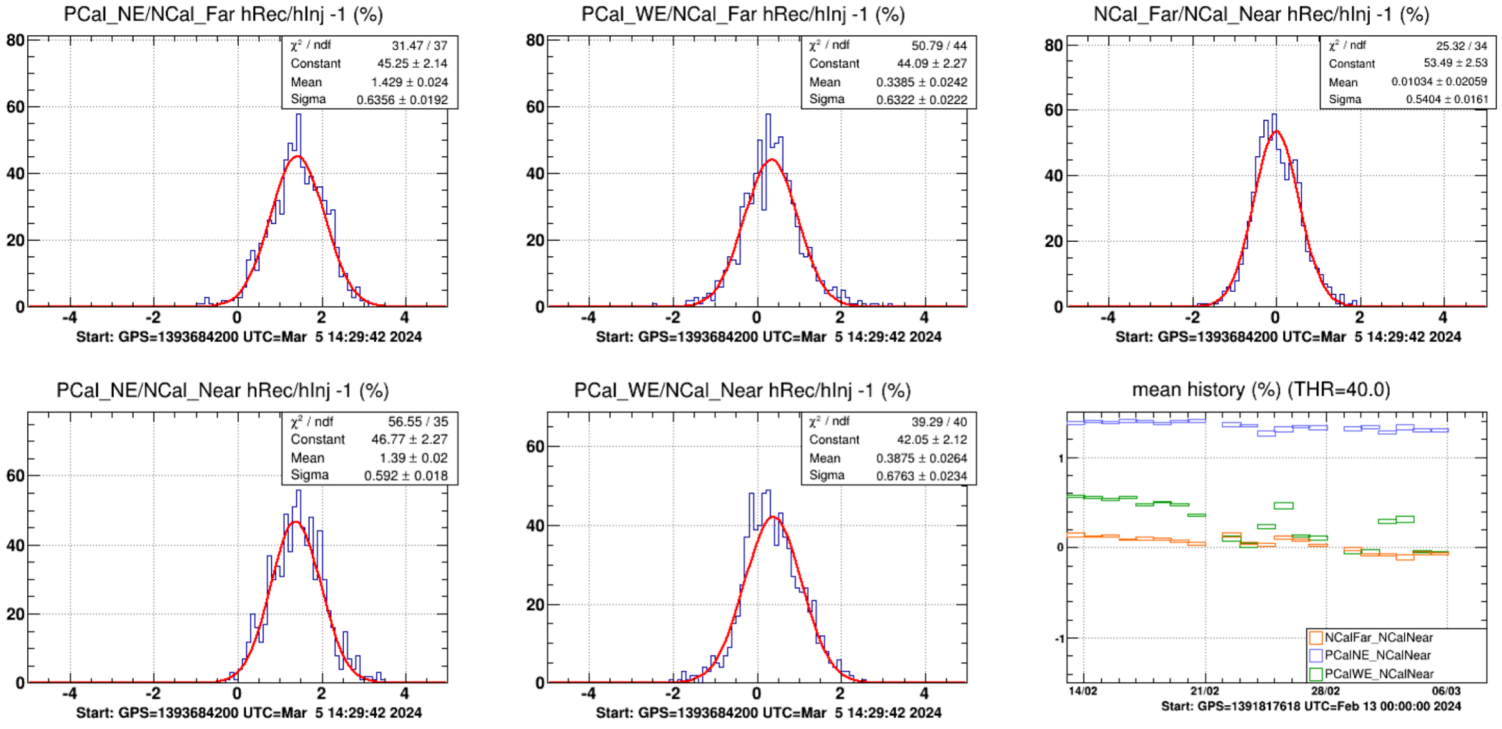


NCal in Virgo Interferometer Monitor



Comparing Virgo PCal and NCal (Preliminary)

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



Far/Near Fluctuations in full agreement with predicted uncertainties of 0.19% (0.24%) for Near (Far) NCal

→ See Antoine Syx presentation for details