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# “ Recent activity on the GINGERino ring laser gyroscope

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# Outline

**GINGERino apparatus**

-Description of the installation

-Optical properties

-The first data

**Recent upgrades**

-Mechanics, mirrors

-Backscattering subtraction performances

**Perspectives**

-Stability improvements

-Towards geodesy

# GINGERino: deep underground ring laser

GINGER-ino (INFN-LNGS)+ Seismometers (INGV)

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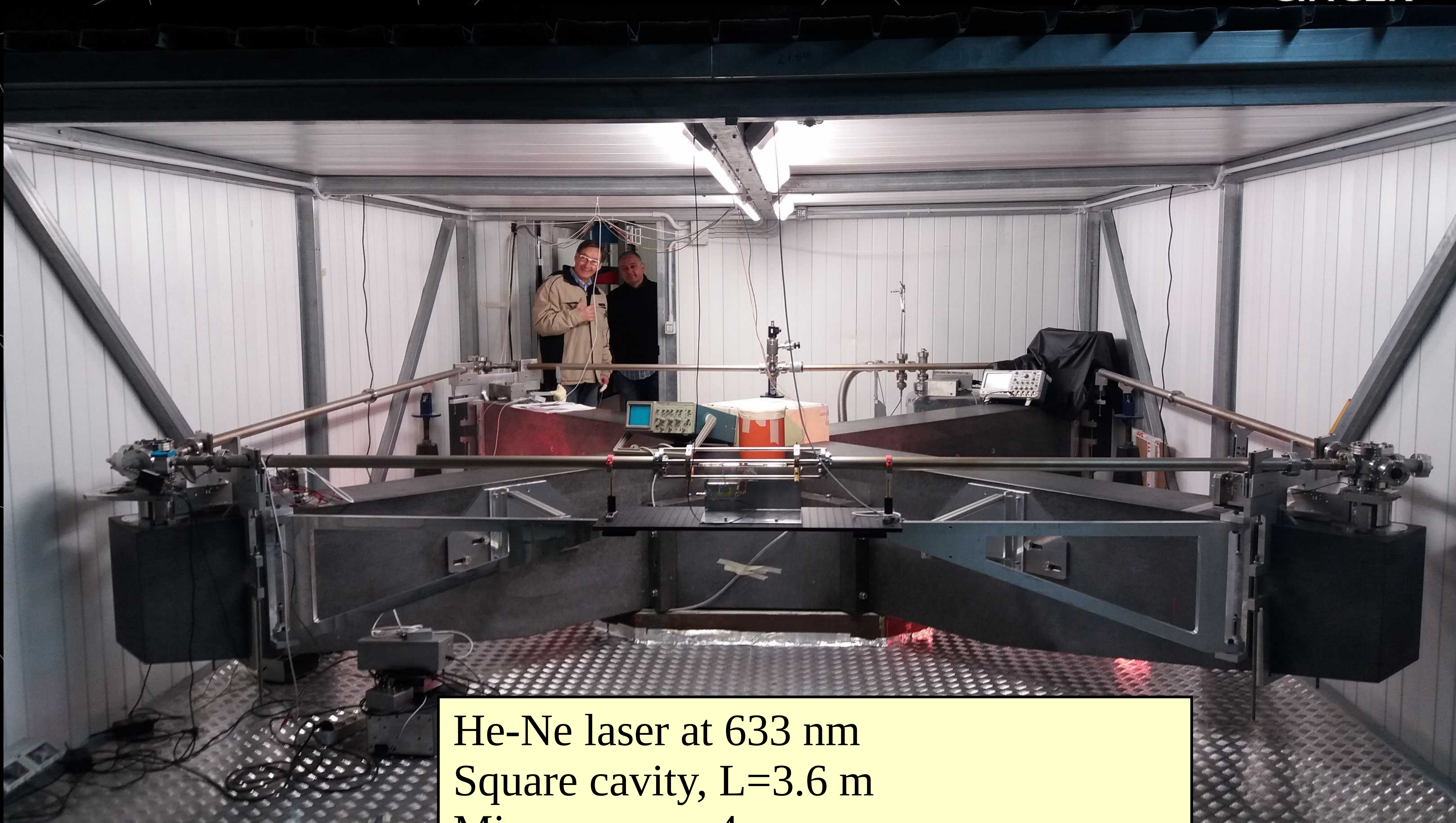
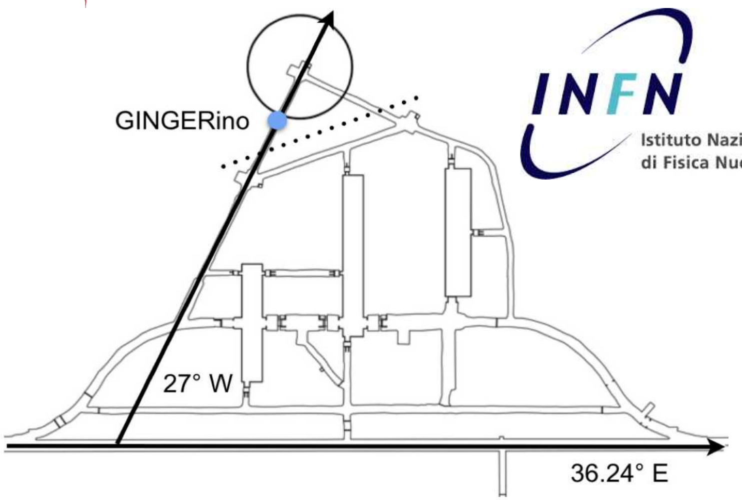
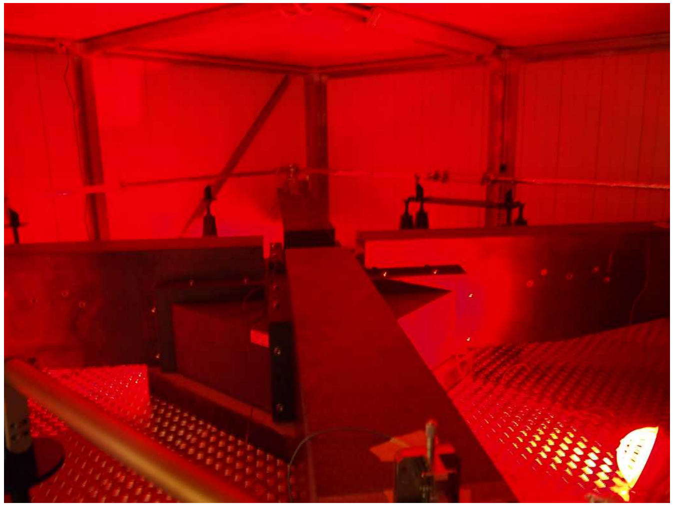


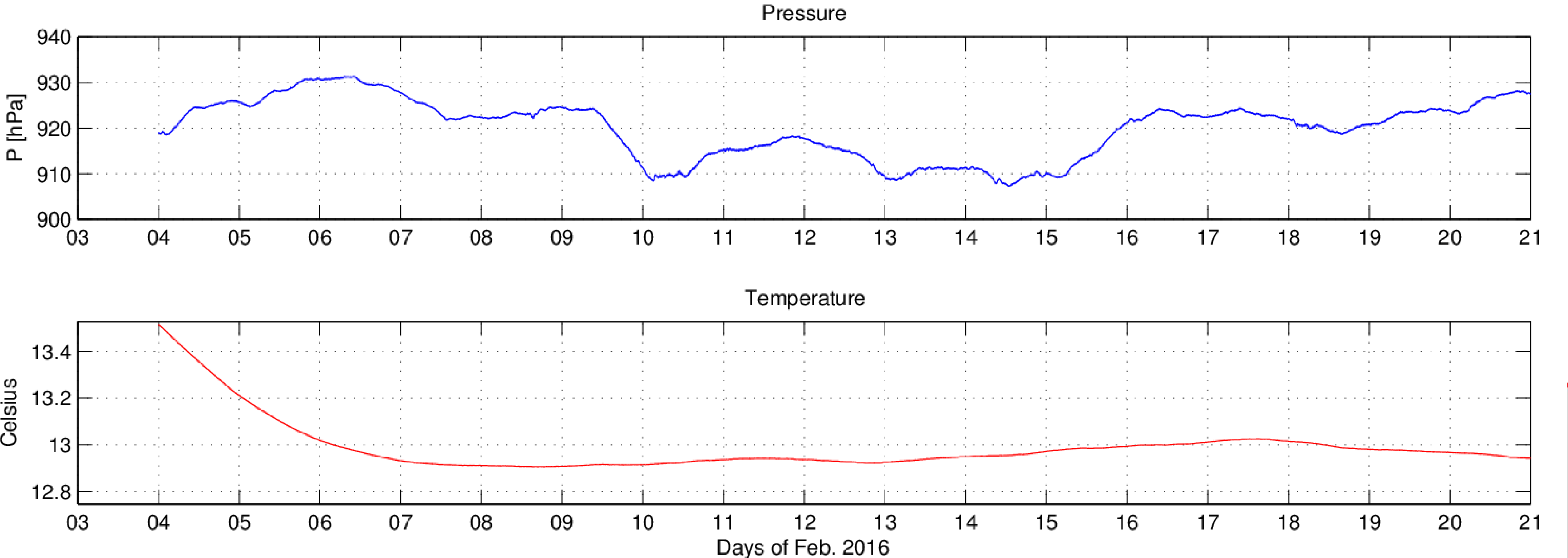
He-Ne laser at 633 nm
Square cavity, L=3.6 m
Mirrors r.o.c= 4 m
Earth rotation Sagnac bias: **fs=280.4 Hz**

# Installation site

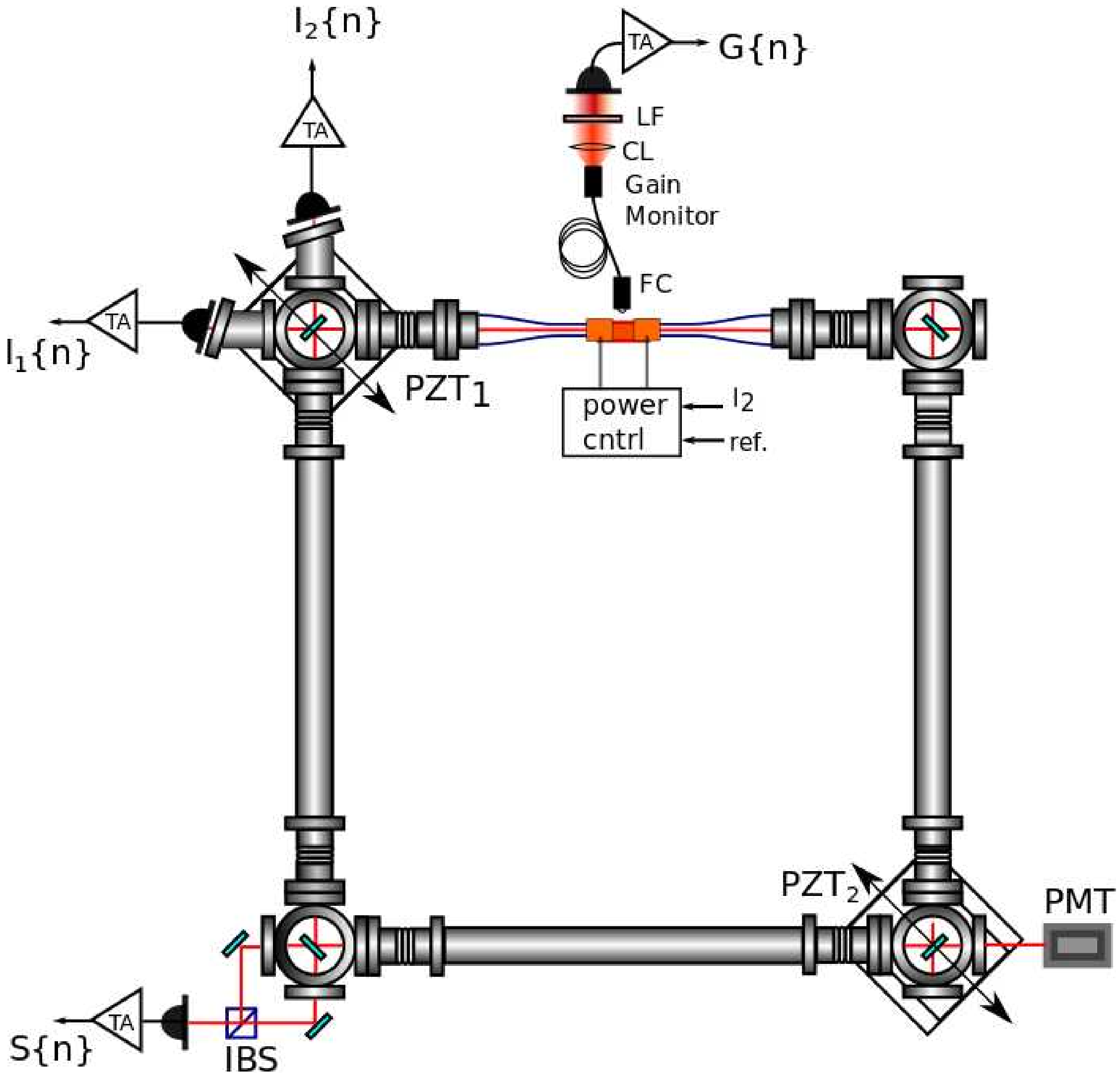


**Internal temperature is** controlled by IR-lamps T: 8°C--> 13°C, relative humidity--> 60%



# Optical setup




Acquired optical signals (5 kS/s)

S(n) = Sagnac interferogram
I1(n) = CCW monobeam
I2(n) = CW monobeam
G(n) = Excitation level

Power Control

Analog PI circuit stabilizing the I2 drifts (t >1 s)

Fast detector (BW >300 MHz) for:

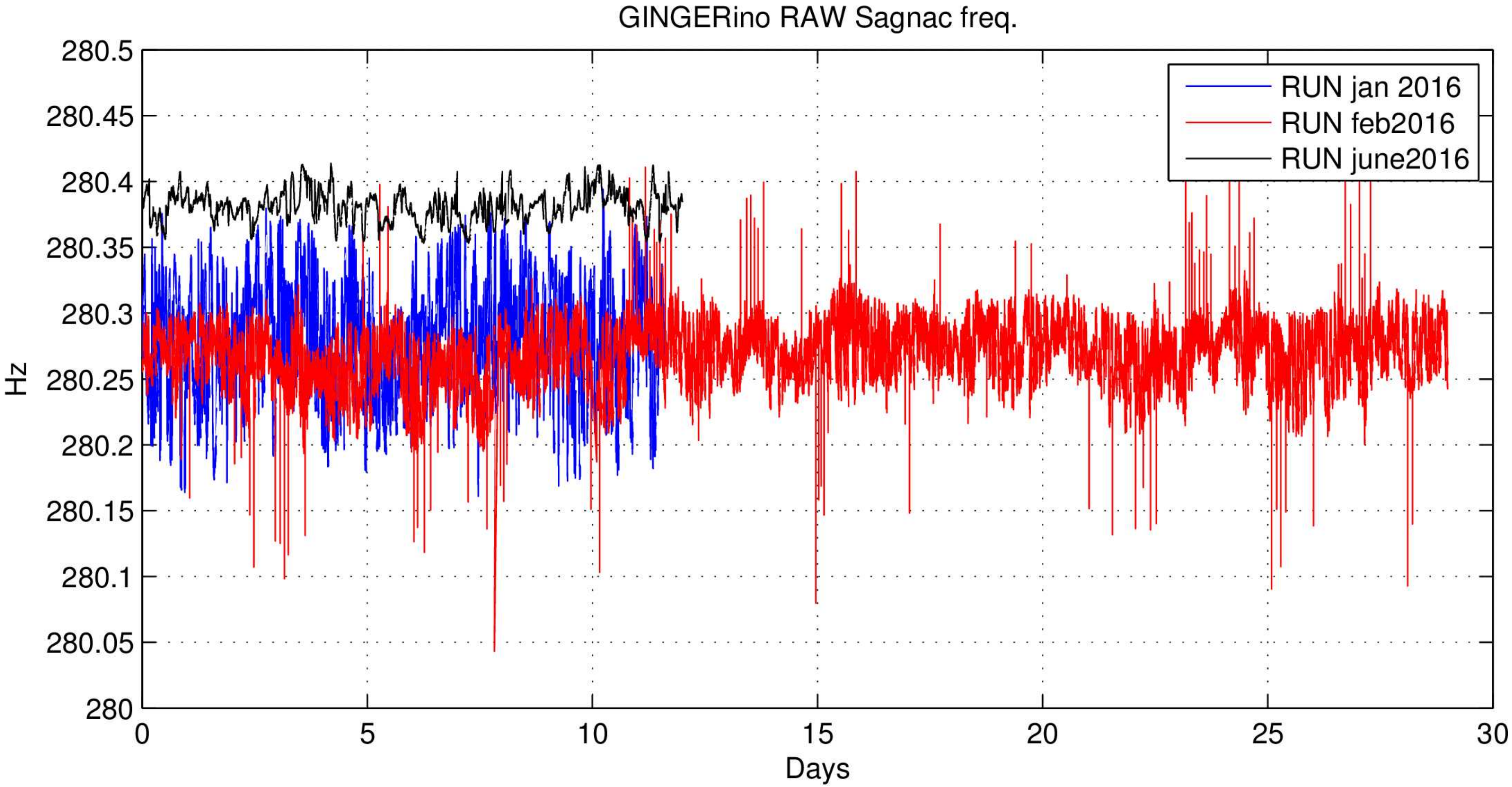
Ring-down-time measurement
Multimode beat detection

# GINGERino first challenges

**March 2015** first laser ignition in LNGS!

..then **problems** with:

**Mirrors transmission, DAQ system, Timing, Getter pumps, Discharge capillary positioning, network and power supply continuity**

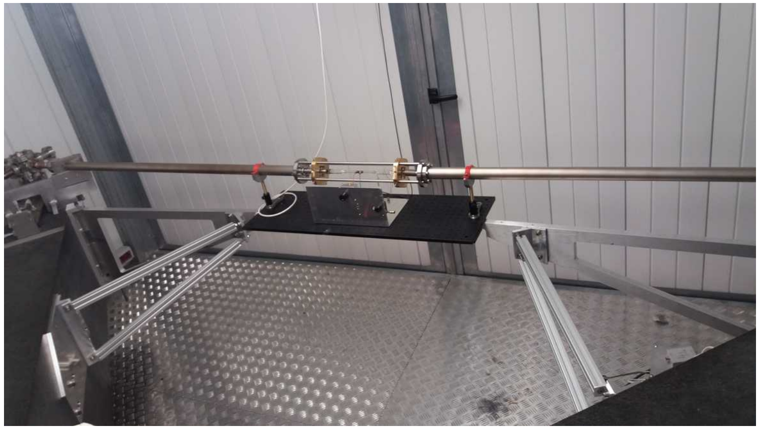



Large amount of Intracavity scattered light

# System upragdes

**Febr. 2016**: New getter-chamber installation (allows for long acquisition runs)

**April 2016**: New support for discharge:
better capillary alignment and
complete decoupling from the floor



**May 2016**: 1 new supermirror (from LMA) in place of the worst one
+ checked transmissivity

REO mirror (coated on 2010) (presently damaged)
T<0.25 ppm

New LMA mirror
**T=0.75 ppm**

Expected Ring Down Time with 4 new mirrors from LMA

$$RDT \sim 600\,us \div 1200\,us$$

Cavity Ring down time=**140 us**

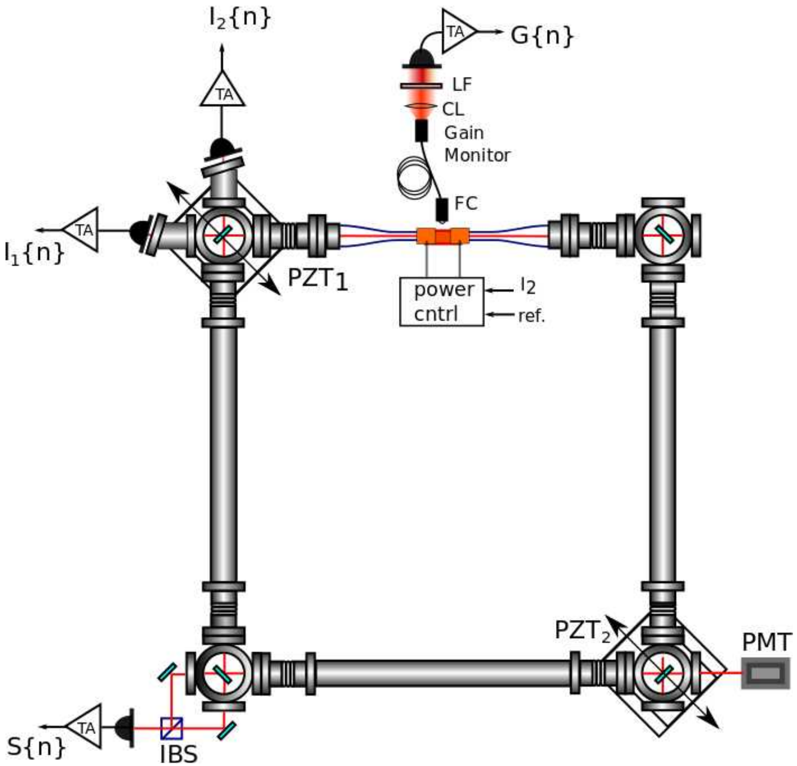
Cavity Ring down time=**360 us**

Present Shot-noise limit: $\Omega_{SN} = 4 \cdot 10^{-10}\, rad/(s\sqrt{Hz})$

# Backscattering subtraction

Perturbative solutions of semiclassical ring laser equations

D. Cuccato et al. Metrologia **51**, 97, (2014)
A. Beghi et al. Applied Optics **51**, 31 (2012)




Identified parameters

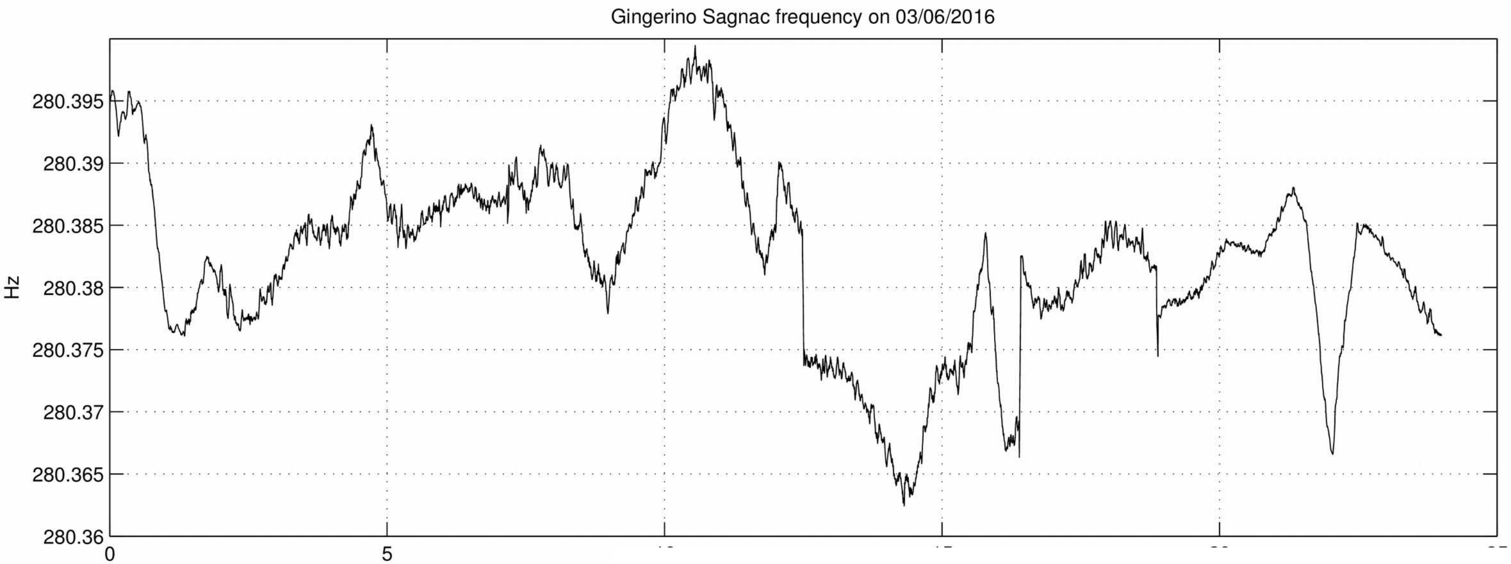
$$\widehat{\varepsilon} = \frac{\phi_1 - \phi_2}{2}$$

$$\widehat{r_1} = \frac{i_2 \omega}{2(c/L)\sqrt{I_1 I_2}}$$

$$\widehat{r_2} = \frac{i_1 \omega}{2(c/L)\sqrt{I_1 I_2}}$$

$$\begin{cases} \mathcal{I}_1(t) \simeq \frac{\alpha_1}{\beta} + 2r_2\sqrt{\alpha_1\alpha_2}\frac{\alpha_1\cos(\varepsilon+\omega_s t) + (\frac{\omega_s}{c/L})\sin(\varepsilon+\omega_s t)}{\beta\left(\alpha_1^2 + (\frac{\omega_s}{c/L})^2\right)} - 2\frac{r_1 r_2 (c/L)}{\beta\omega_s}\sin(2\varepsilon) \\ \mathcal{I}_2(t) \simeq \frac{\alpha_2}{\beta} + 2r_1\sqrt{\alpha_1\alpha_2}\frac{\alpha_2\cos(\varepsilon-\omega_s t) - (\frac{\omega_s}{c/L})\sin(\varepsilon-\omega_s t)}{\beta\left(\alpha_1^2 + (\frac{\omega_s}{c/L})^2\right)} + 2\frac{r_1 r_2 (c/L)}{\beta\omega_s}\sin(2\varepsilon) \\ \Psi(t) \simeq (\omega_s - \frac{2r_1 r_2 (c/L)^2\cos(2\varepsilon)}{\omega_s})t + (c/L)\frac{r_1\sqrt{\frac{\alpha_1}{\alpha_2}}\cos(\varepsilon-\omega_s t) + r_2\sqrt{\frac{\alpha_2}{\alpha_1}}\cos(\varepsilon+\omega_s t)}{\omega_s} \end{cases}$$

# Example: 24 h backscattering correction



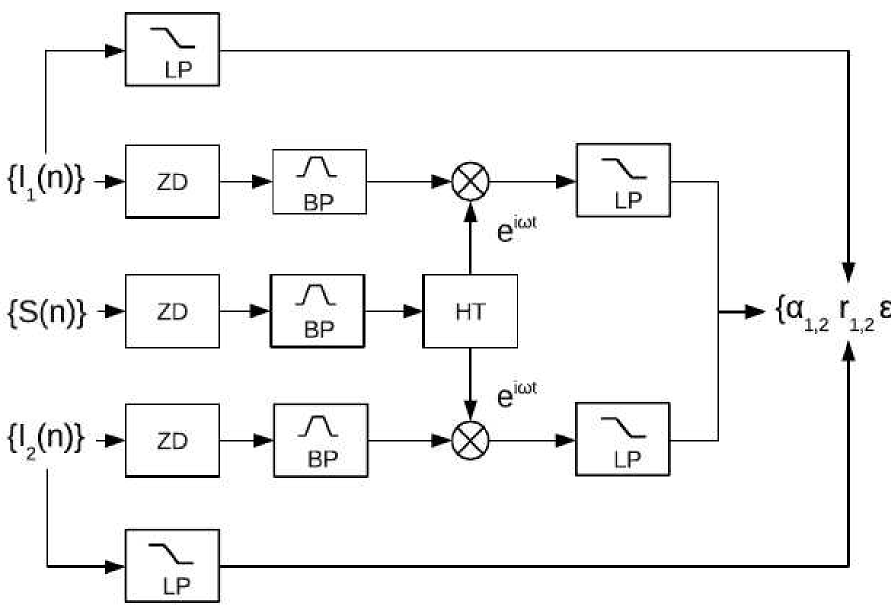
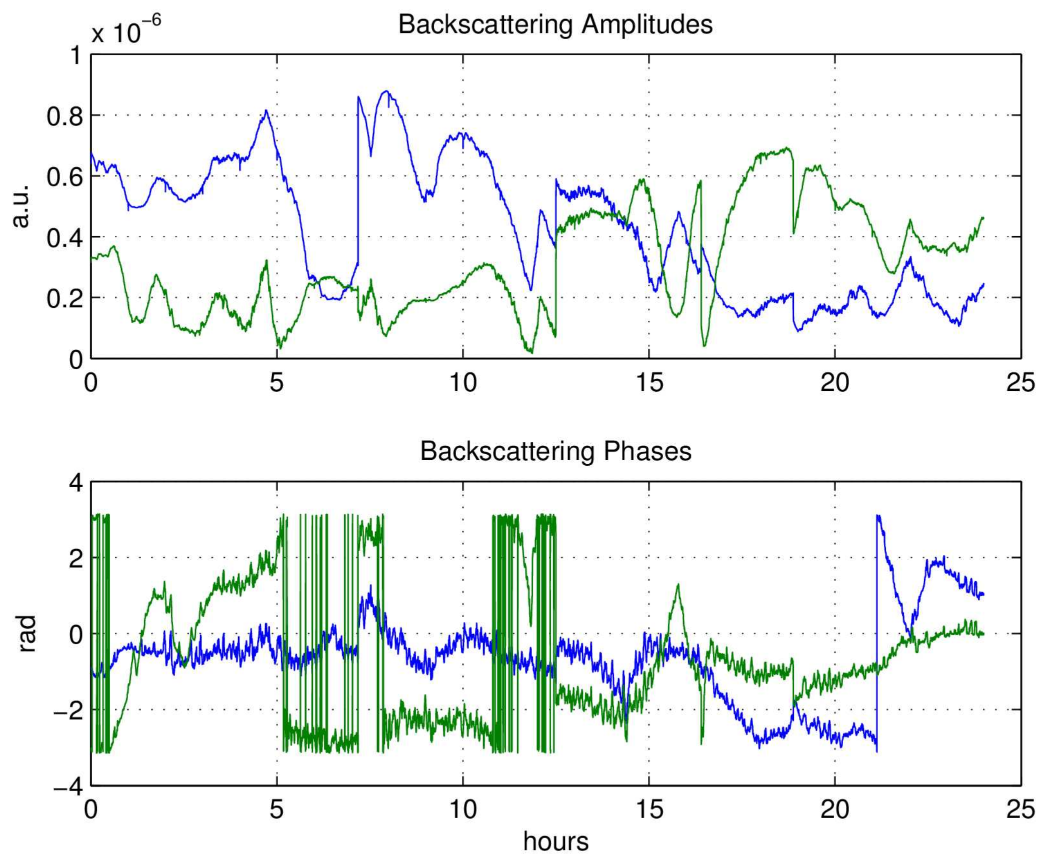




Fig. 3. Schematic of the parameter estimation procedure. I lowpass Butterworth filter; BP, bandpass Butterworth filter; Z zoom and decimation routine; HT, Hilbert transform (see text)



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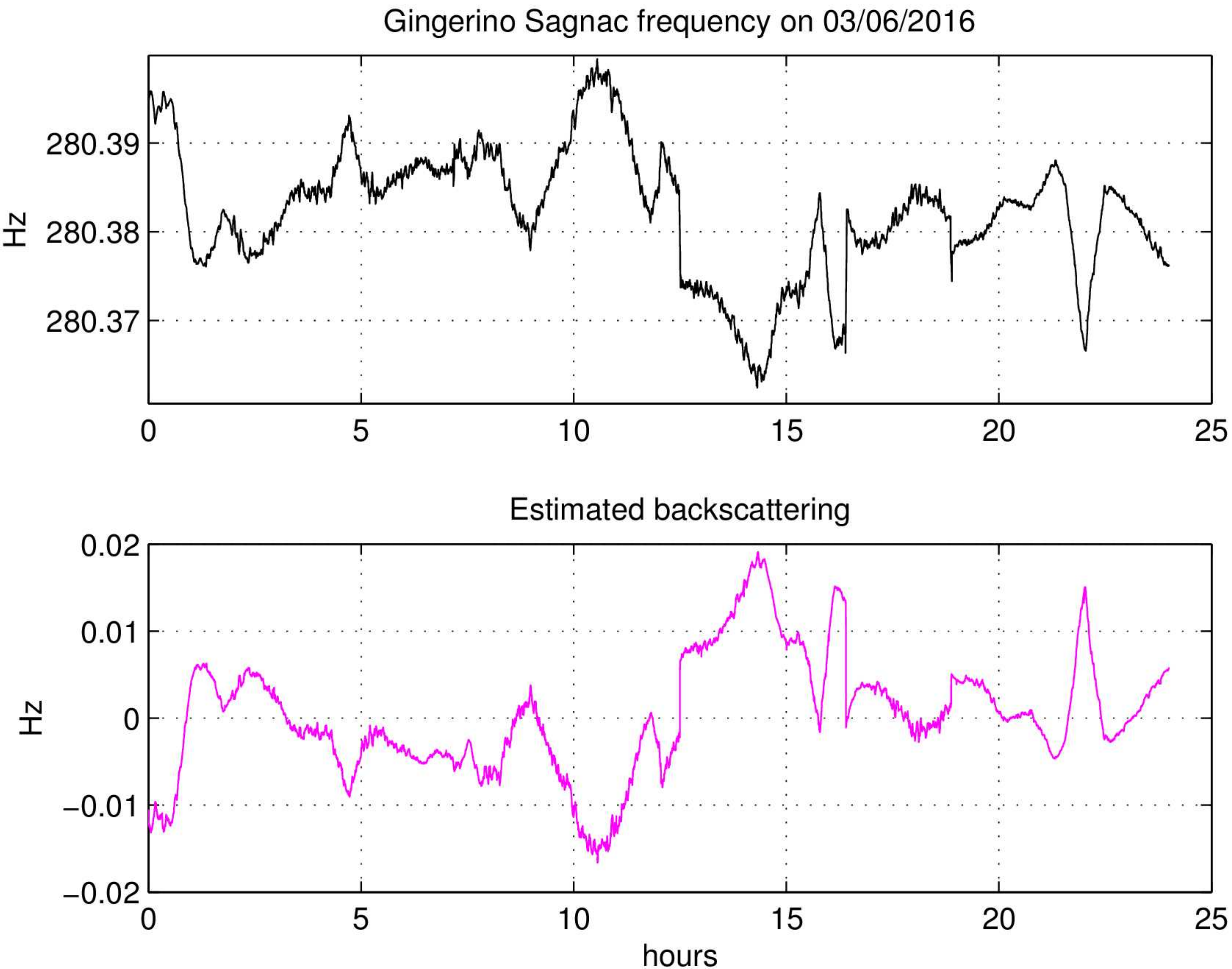

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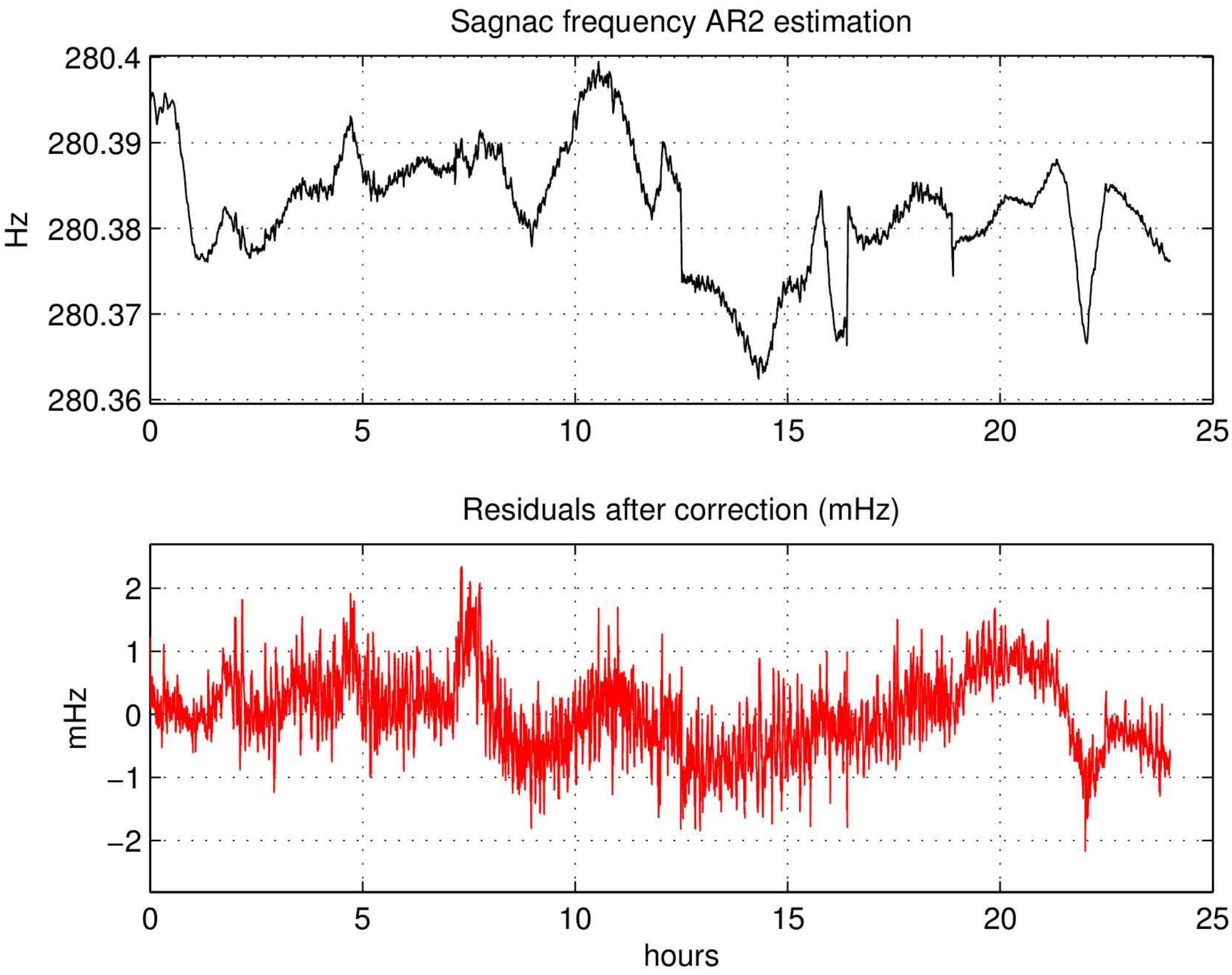
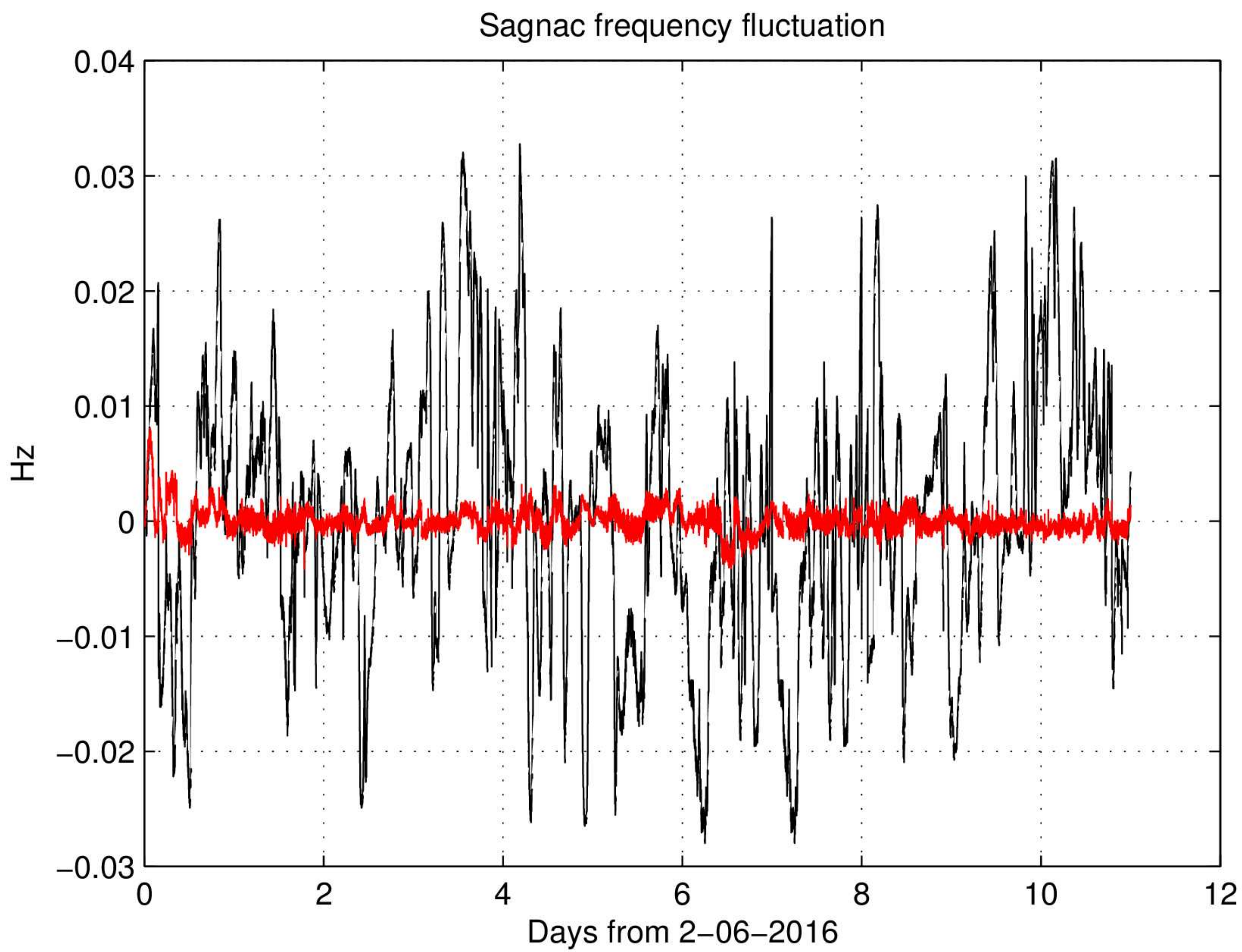


# Long period observations 2-13 june 2016



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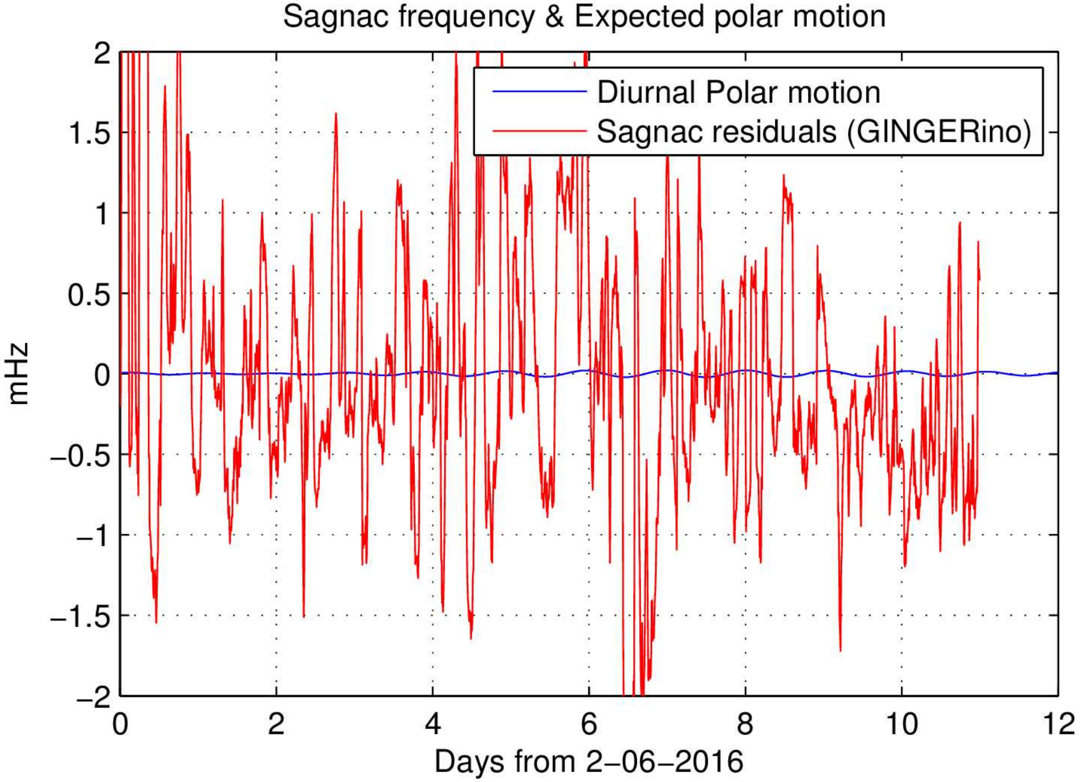


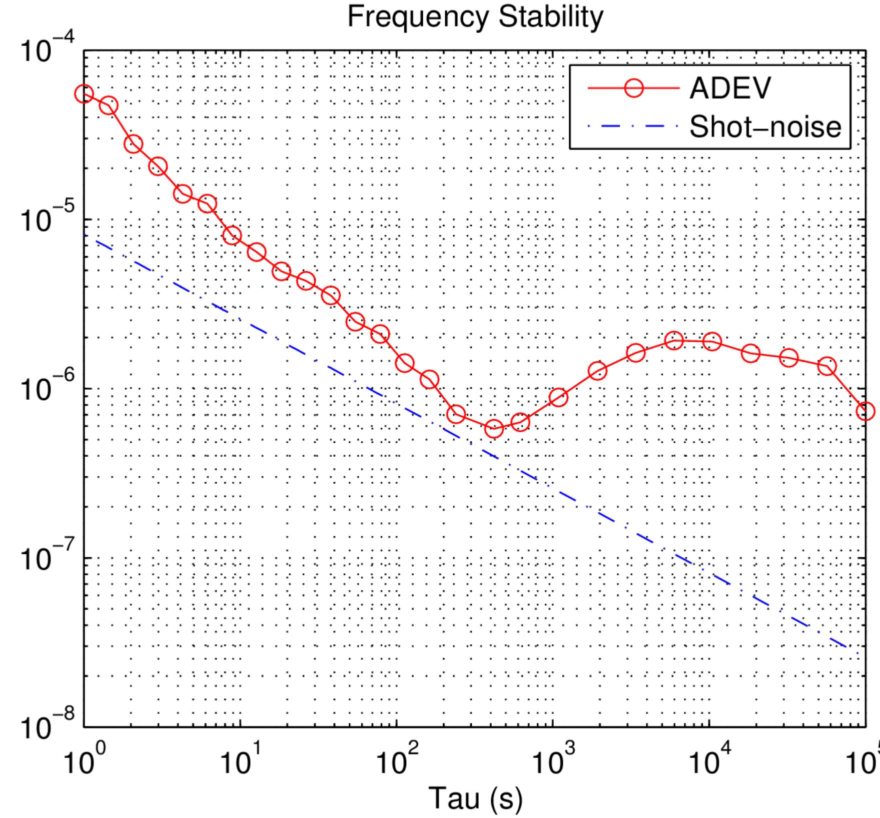


**Maximum resolution:** 0.6 ppm at 500 s of integration time
→ **30 p rad/s**

**Noise limits:**

-Laser optical frequency fluctuations

-Residual fluctuation in the ambient temperature and pressure

-Local Tilts (to be investigated)

# Conclusion

**GINGERino** deep underground ring laser gyro is delivering **high-sensitivity** rotation measurements suitable for **seismological applications** (Beverini and Simonelli's talk tomorrow)

**Recent upgrades**

Replacement of one mirror over four

Discharge mechanical support modification

→ **unattended continuous rotation rate measurements** with good sensitivity

**Achieved Resolution on the Earth rotation**

30 prad/s at 500 s of integration time

→ progress toward **GEODESY**

**Next**

**Perimeter** stabilization (two piezos)

Study **tilt** noise, Replacement of the other three **mirrors**

Improve isolation from **environmental disturbances** (P,T)

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