

Atomic fountains are used for definition units of time and frequency and for time keeping at VNIIFTRI. There are one cesium and five rubidium atomic fountains, two of which is product of collaboration VNIIFTRI, "Vremya-CH" and LNE-SYRTE (2013-2016). **This presentation is dedicated to the atomic fountains developed at VNIIFTRI.**

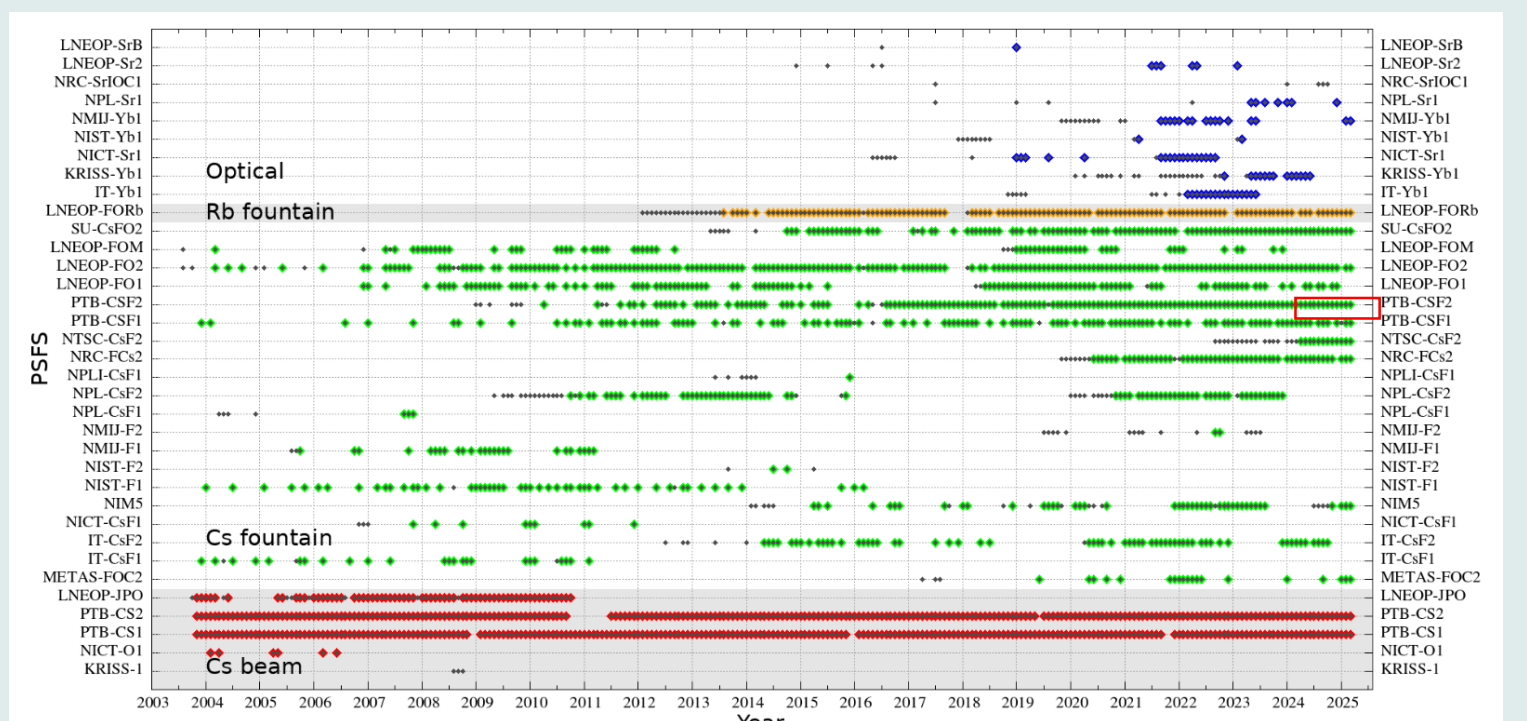


Fig. 3 Primary and Secondary Frequency Standards participating to TAI, since September 2003.
https://webtai.bipm.org/database/show_psf.htm

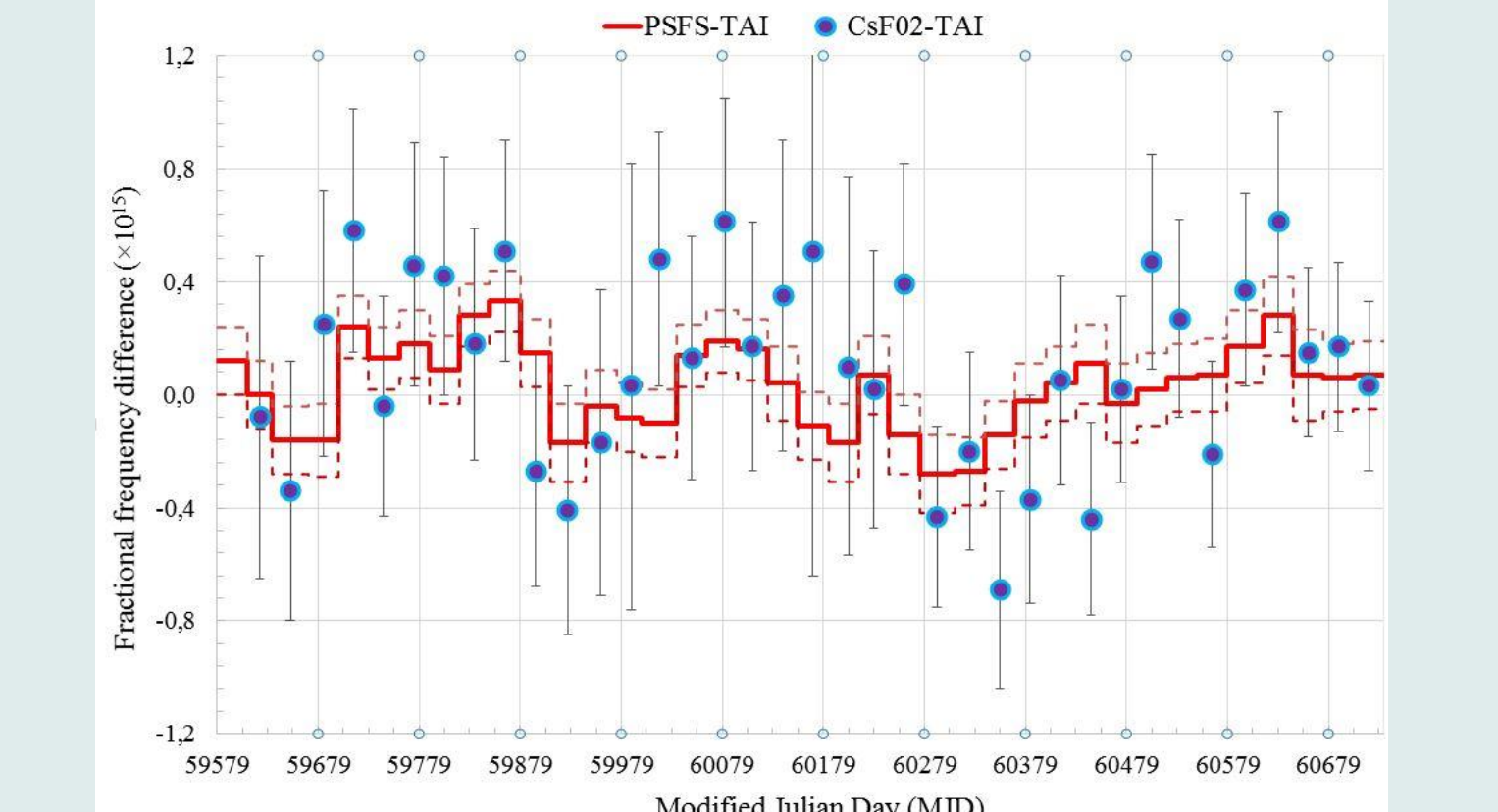


Fig. 4 TAI vs. data from CsFO2 (blue dots) and PSFS (red line) taken from *Circular T*

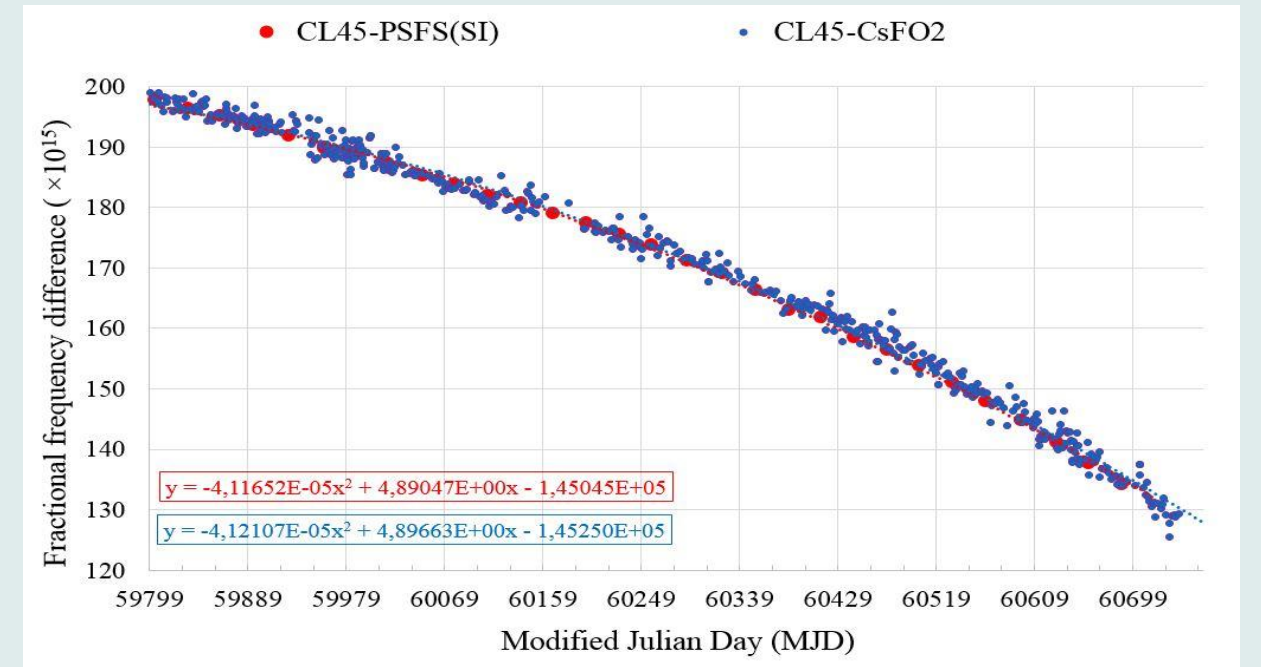


Fig. 2 Frequency measurement of CsFO2 fountain vs. H-Maser. (CL 403845) from August 2022 to June 2024

Physical Effect	Shifts (10 ⁻¹⁶)	Uncertainty (10 ⁻¹⁶)
Second-order Zeeman effect	1066.0	0.1
Black-body radiation	-165.1	0.5
Gravitational shift	244.3	0.5
Resonator pulling	0	0.1
Purity of probe signal spectrum	0	0.1
Light shift	0	0.1
Tilting (DCP)	0	0.1
Collisions with residual gas	0	1
Microwave power dependence	0	1.8
Spin exchange shift	0.19*	0.19*
Total	1145.2	2.2

Table 1 Systematic frequency biases and their uncertainty budgets of SU-CsFO2

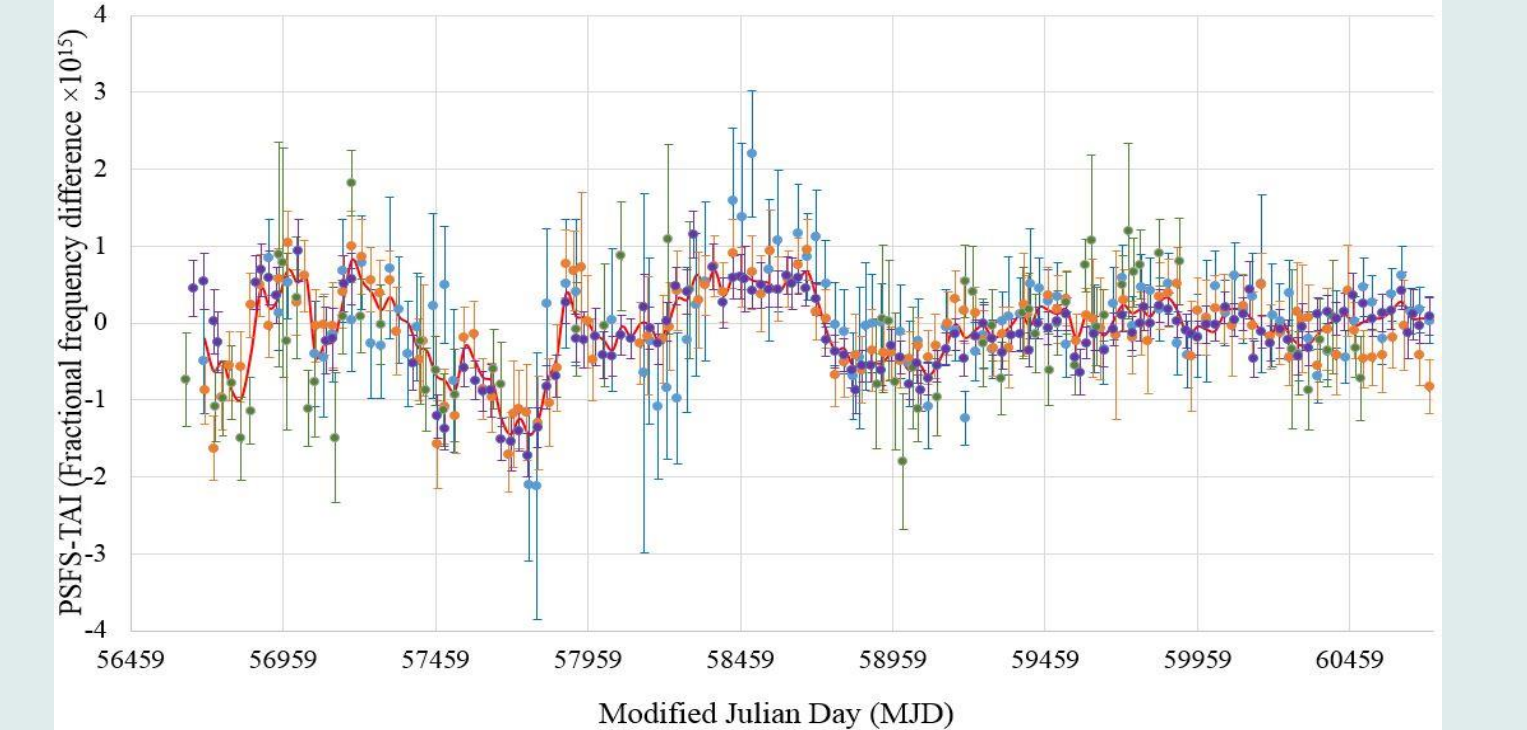


Fig. 5 Calibrations of the TAI by the CsFO2 fountains since February 2014 to May 2024. The data are from BIPM circular T. Each point is the fractional frequency difference between TAI and the SI second as measured by CsFO2 and corresponds to a formal monthly report to BIPM. The red curve is the difference between TAI and the PSFS(SI) second, as computed by BIPM from all available primary standards. For comparison, results from several others primary frequency standards are also shown.



Fig. 6 Rubidium atomic fountain (Rb5):
1 – physical package, 2 – laser system, 3 – microwave source

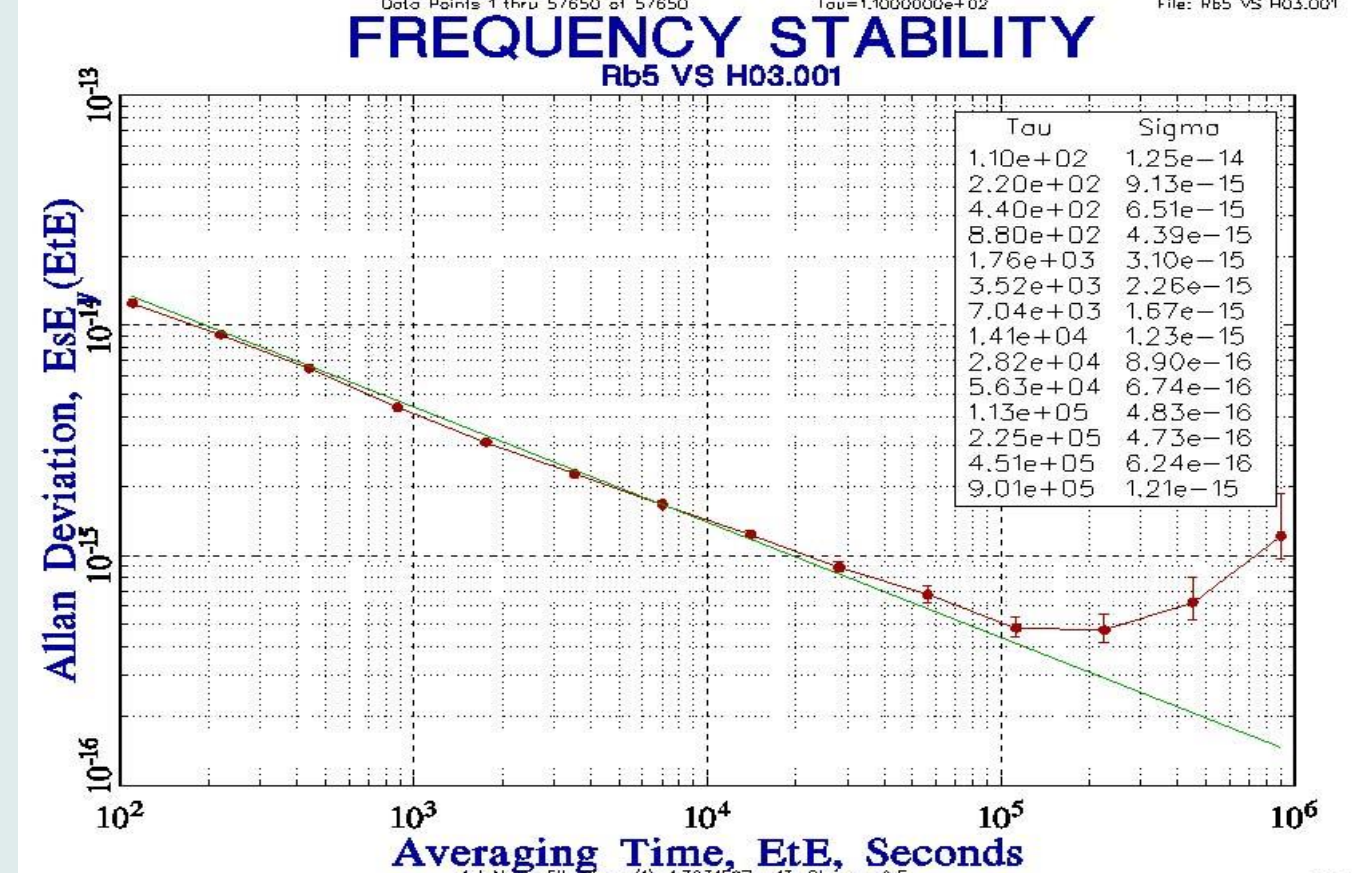


Fig. 7 Allan deviation of the frequency difference between the fountain Rb5 and the hydrogen maser H03. Drift is not removed

Physical Effect	Shifts (10 ⁻¹⁶)	Uncertainty (10 ⁻¹⁶)
Second-order Zeeman effect	1231.5	0.1
Black-body radiation	-121.5	0.7
Gravitational shift	225.1	0.5
Resonator pulling	0	0.1
Purity of probe signal spectrum	0	0.1
Light shift	0	0.1
Tilting (DCP)	0	1
Collisions with residual gas	0	1
Microwave power dependence	0	1.8
Spin exchange shift (under research)	-3	2
Total	1332.1	3.2

Table 2 Systematic frequency biases and their uncertainty budgets of Rb5

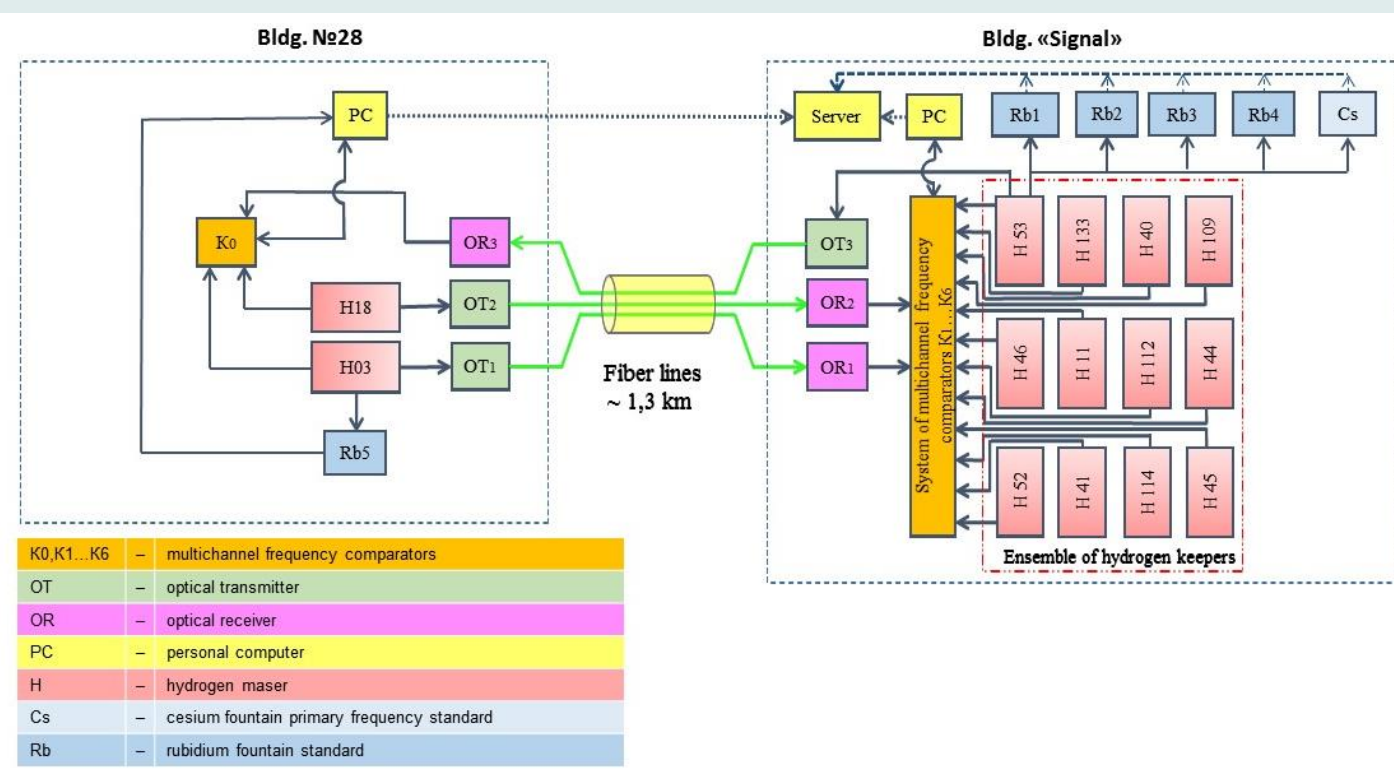


Fig. 8 Comparison scheme

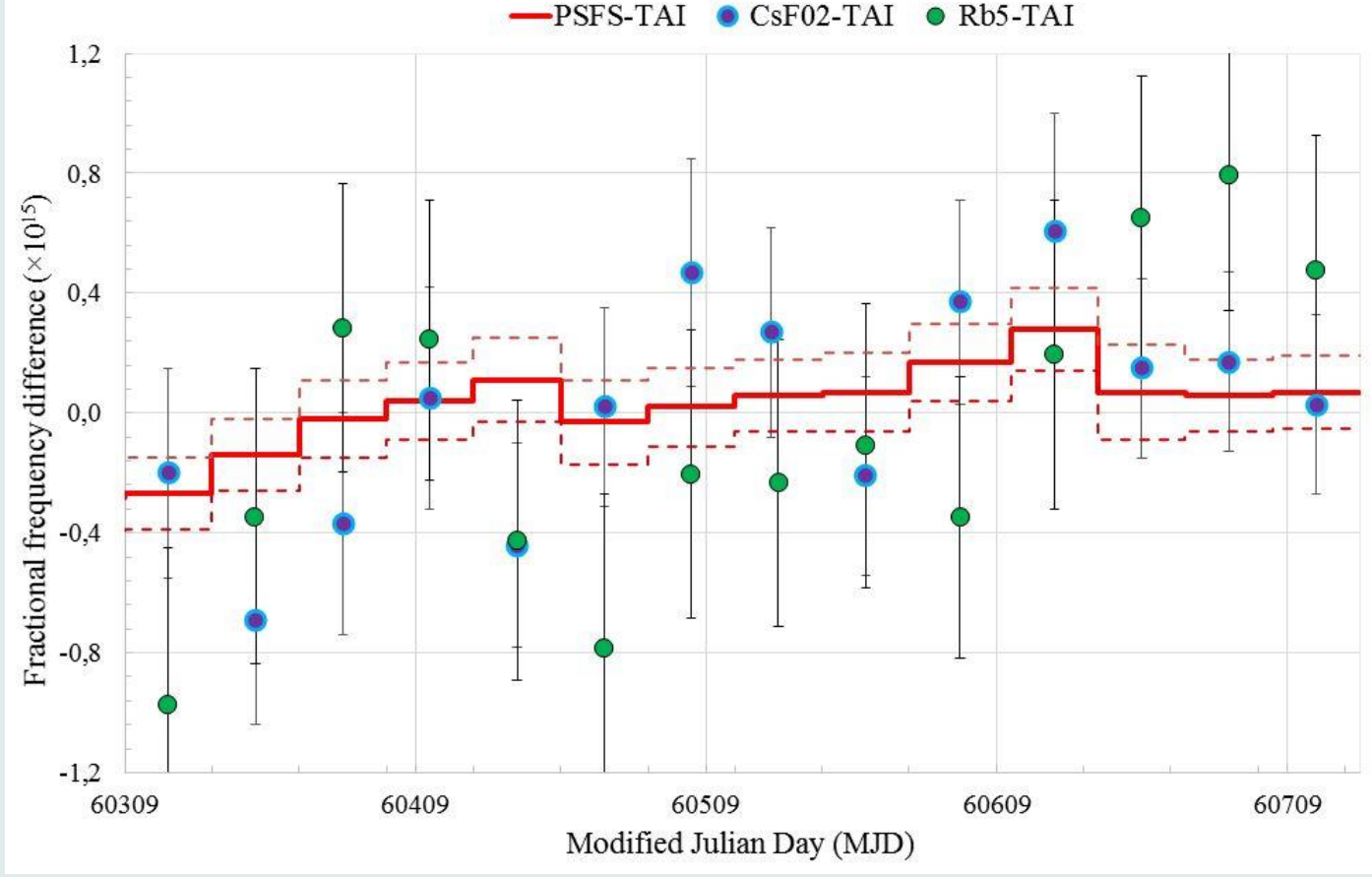


Fig. 9 TAI vs. data from CsFO2 (blue dots) and PSFS (red line) taken from *Circular T*, TAI vs. data from Rb5 (green dots)



Fig.10 The physical packages of the Rb1 and Rb2 (time keeping)



Fig. 11 Rubidium atomic fountain (Rb2)

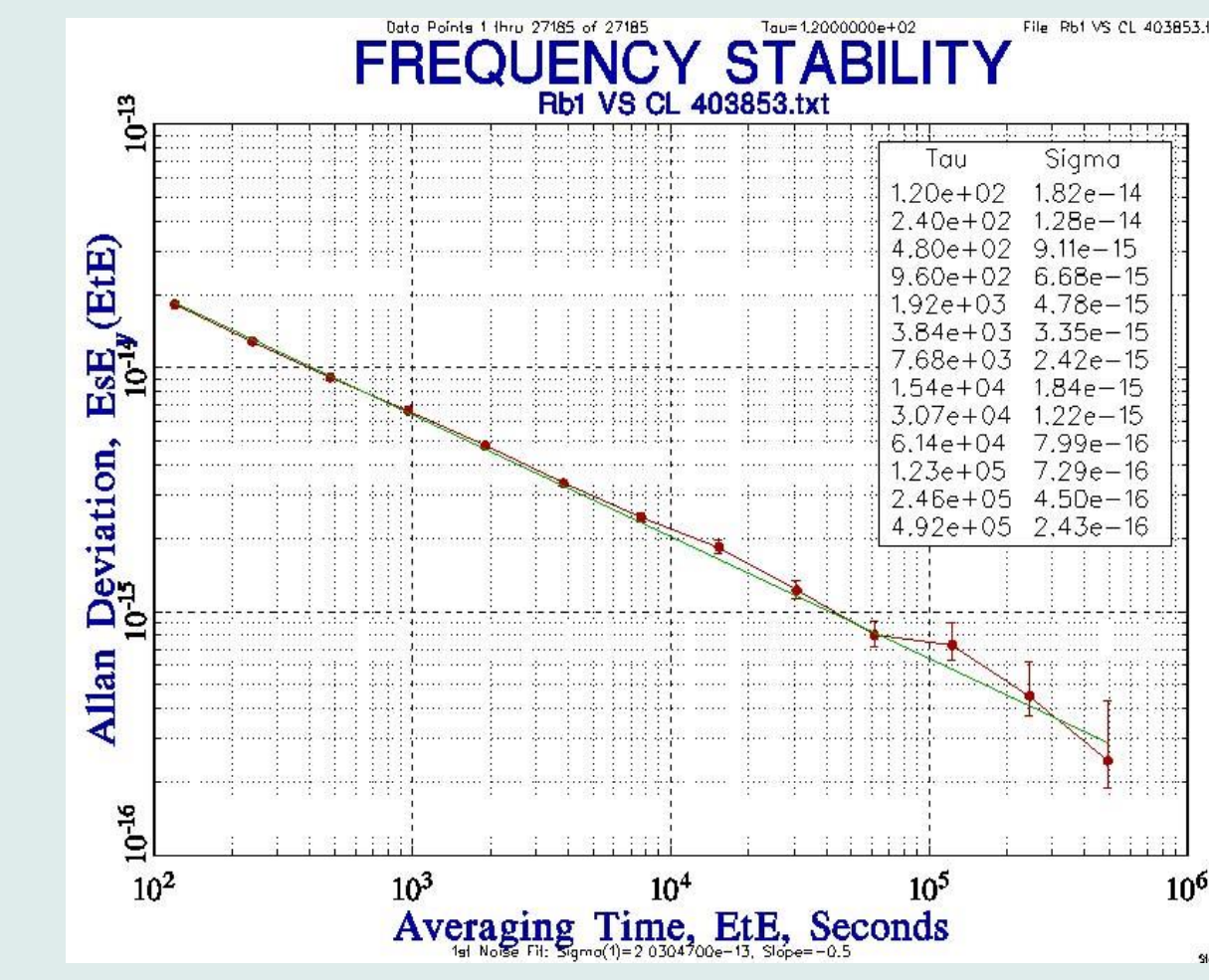


Fig.12 ADev fountain Rb1 and CL403853. Drift is not removed

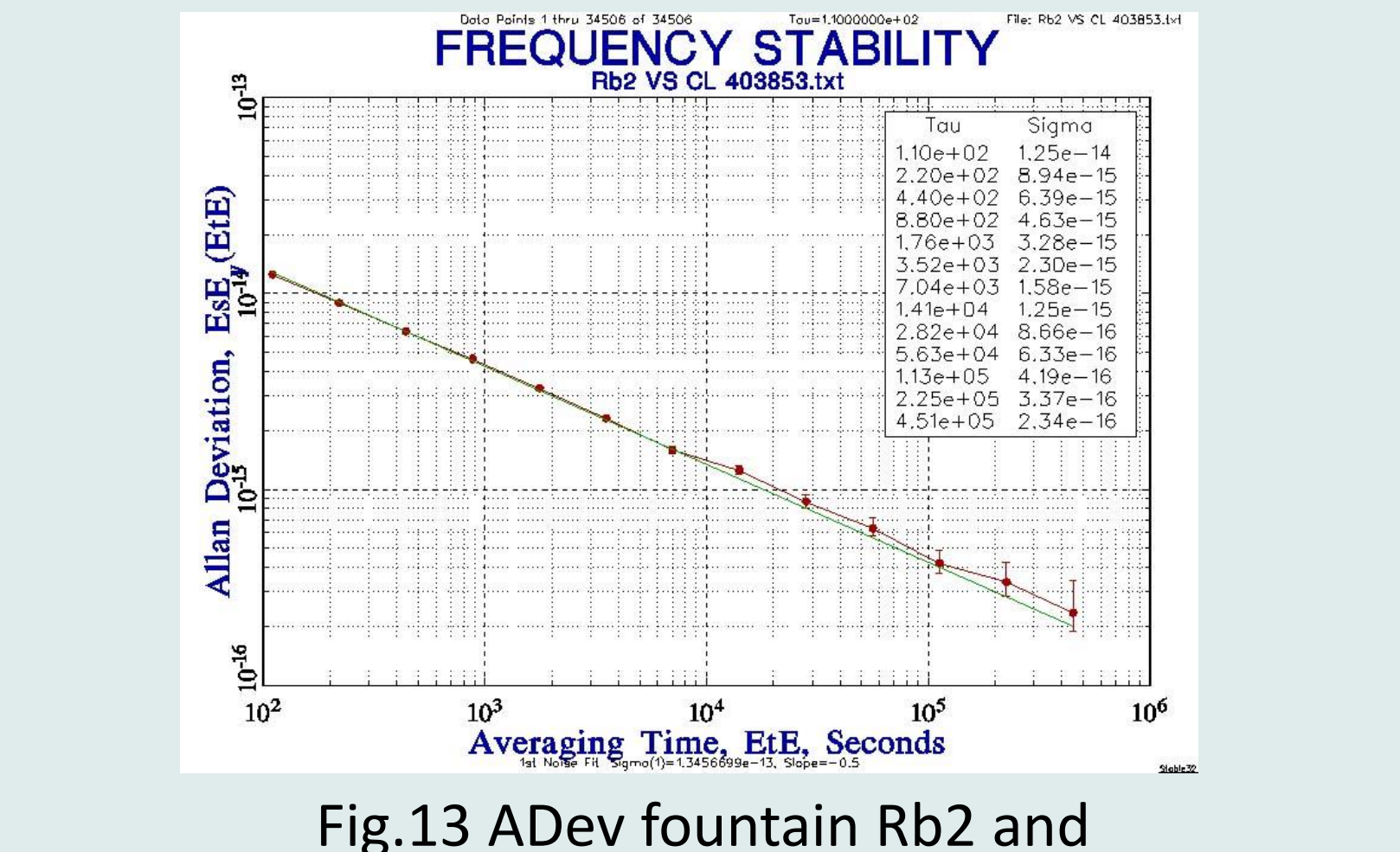


Fig.13 ADev fountain Rb2 and CL403853. Drift is not removed

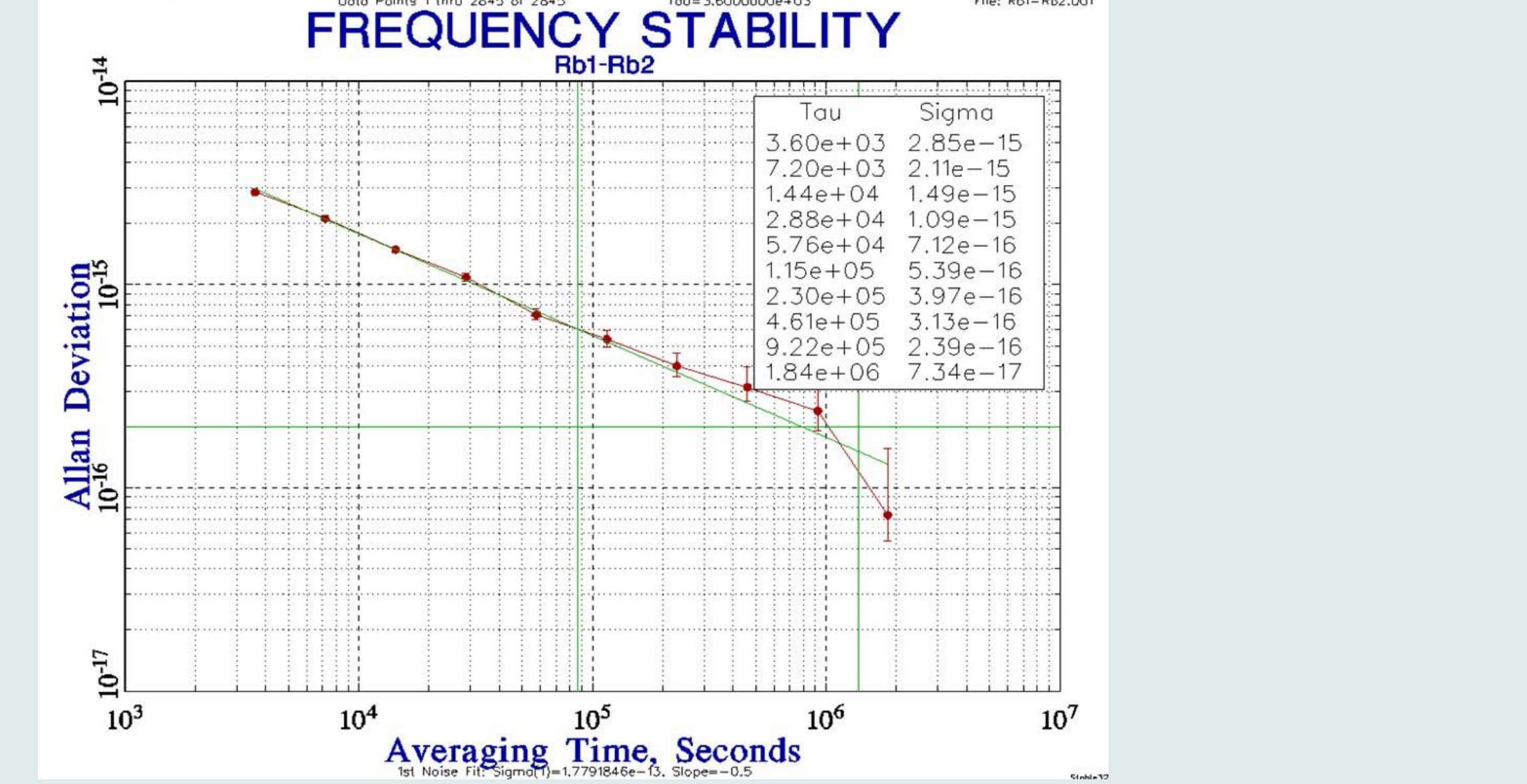


Fig.14 ADev Rb1 vs. Rb2

CONCLUSION

The primary frequency standard **SU-CsFO2** has been operational since February 2014 for external use and long periods of reliable operation have been achieved. The pair of rubidium fountains (**Rb1** and **Rb2**) at the Russian metrological institute of technical physics and radio engineering have been in operation for about 6 years. These device have been used as time and frequency keepers. Each fountain has demonstrated stability at the level below $2 \cdot 10^{-16}$.

It is planned that the comparison data of the rubidium fountain frequency standard **Rb5** will be sent to the BIPM to contribute to TAI.

REFERENCES

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