

Mass metrology in the new SI at LNE

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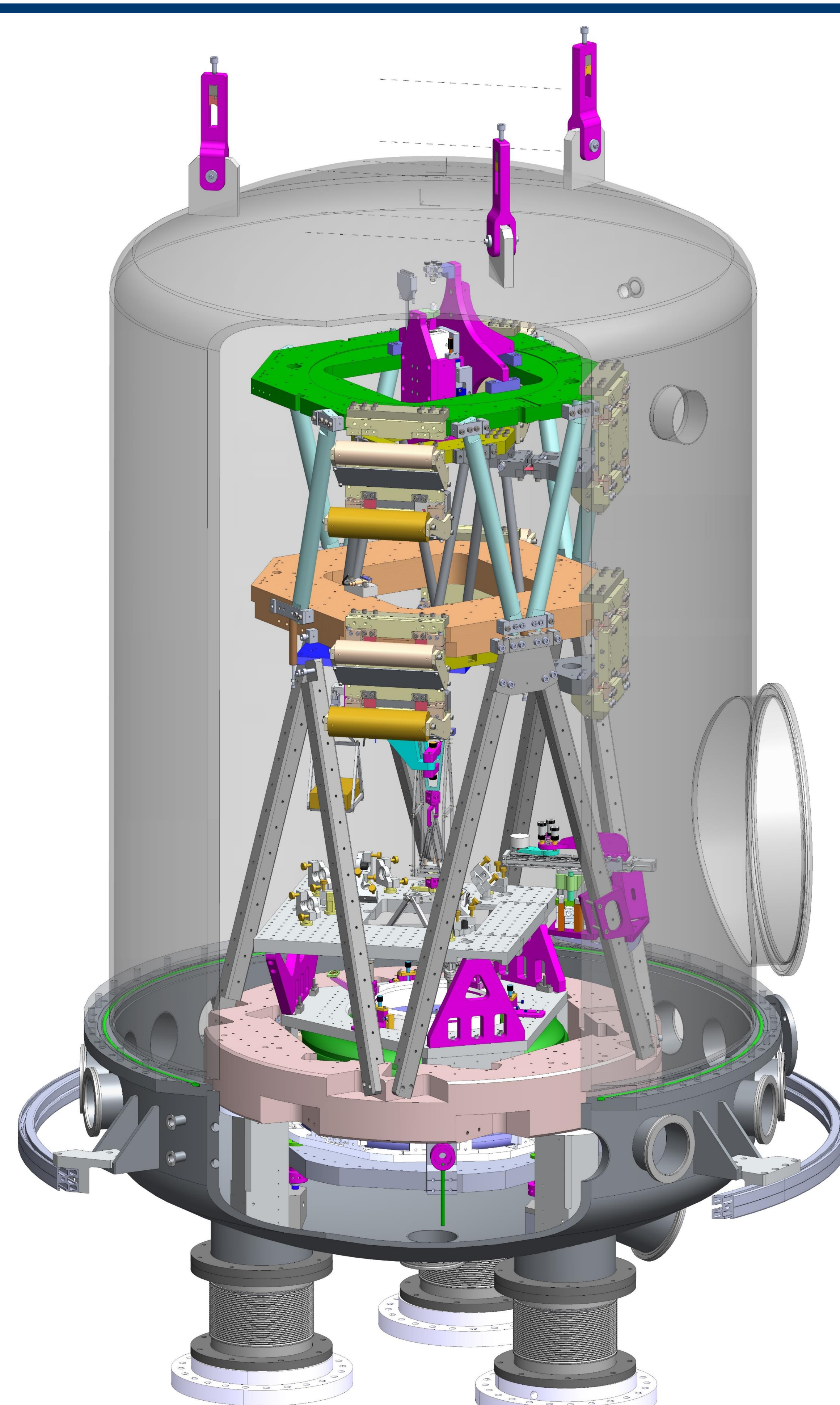
LABORATOIRE
NATIONAL
DE MÉTROLOGIE
ET D'ESSAIS



A Kibble Balance is an electromechanical device which can calibrate a mass standard with a relative uncertainty of some part in 10^8 from the fixed value of the planck constant h , as recommended by the *mise en pratique* of the kilogram.

LNE has begun its **Kibble balance** project in 2002, with the aim of the foreshown SI redefinition. It has contributed to the calculation of the h value of the SI redefinition [1], and now contribute to the international mass comparisons [2-3] for the determination of the consensual value of the kilogram.

As part of its readiness for the redefinition's third phase (independent realizations), LNE has developed a **mass pool artefact** [4]. LNE is also developing an **electrostatic force balance** for milligram-level measurements [5-6].



LNE Kibble balance in its 2025 state

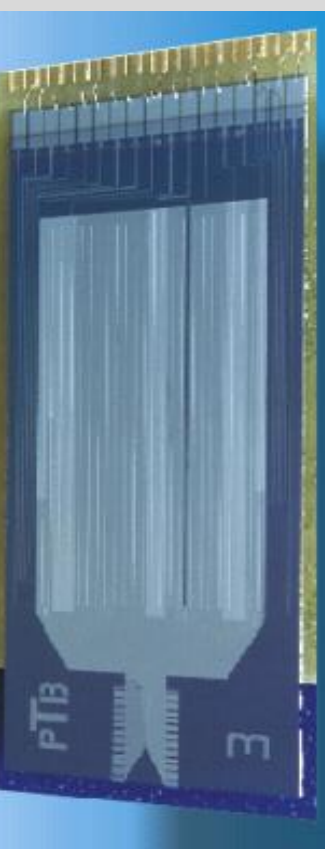
input

U, V

Voltage

8.5 digits digital voltmeter

Josephson standard voltage array SINIS 14 bits



R

Resistance

Transfert resistor standard

Calibrated against QHE standard

(LNE EHQ team)



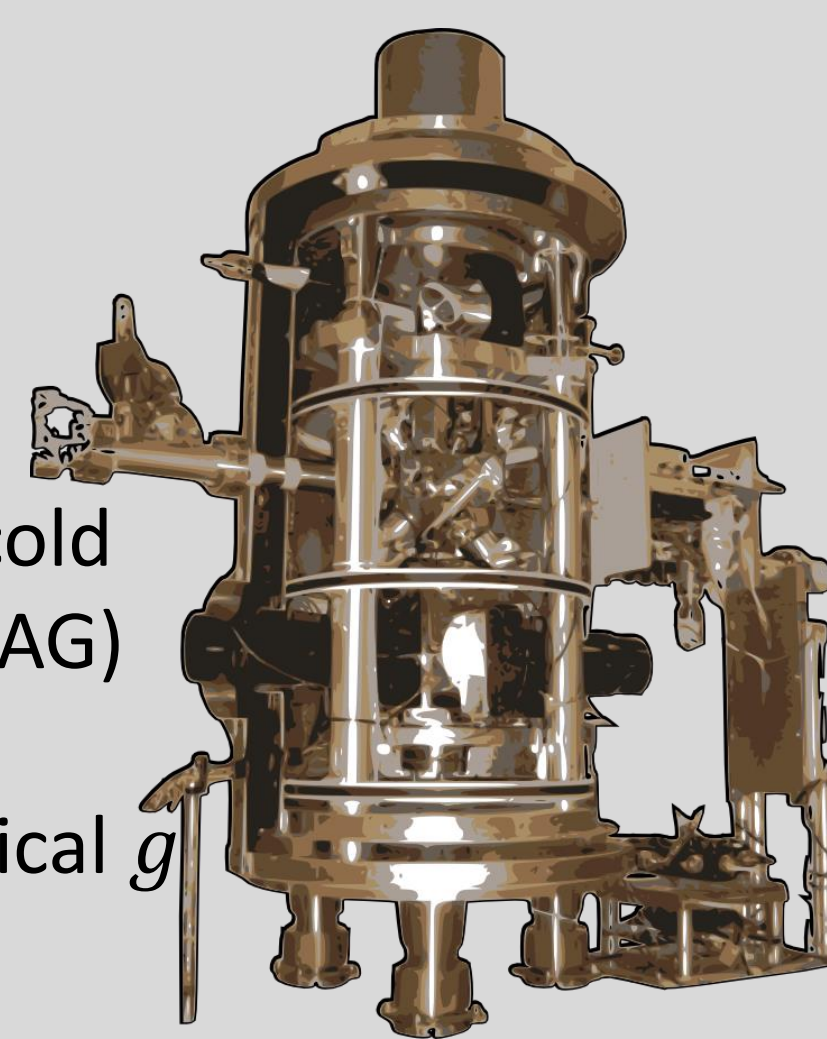
g

gravity

Supraconductive gravimeter (iGrav)
Calibrated against cold atom gravimeter (CAG)

Horizontal and vertical g mapping

(LNE-SYRTE gravimetry team)



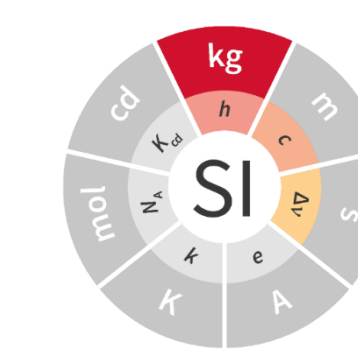
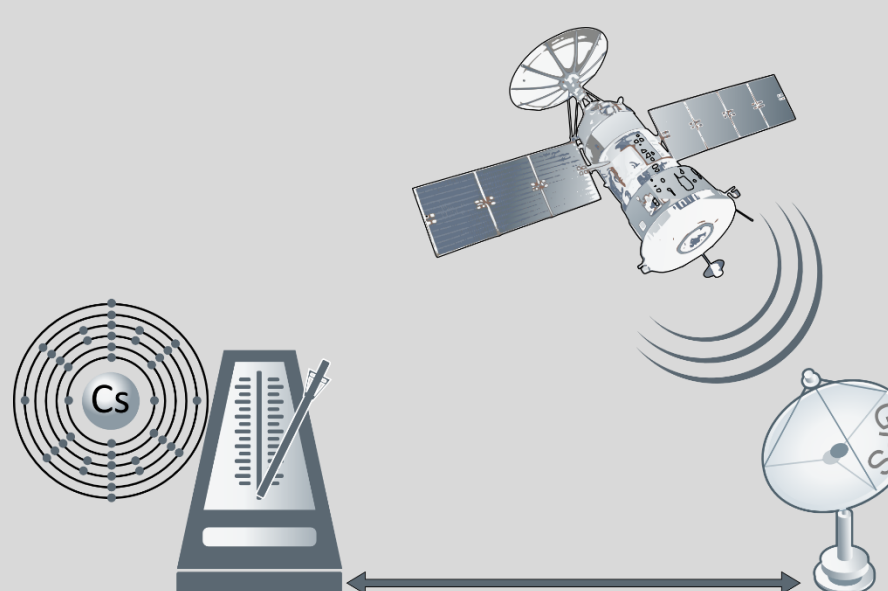
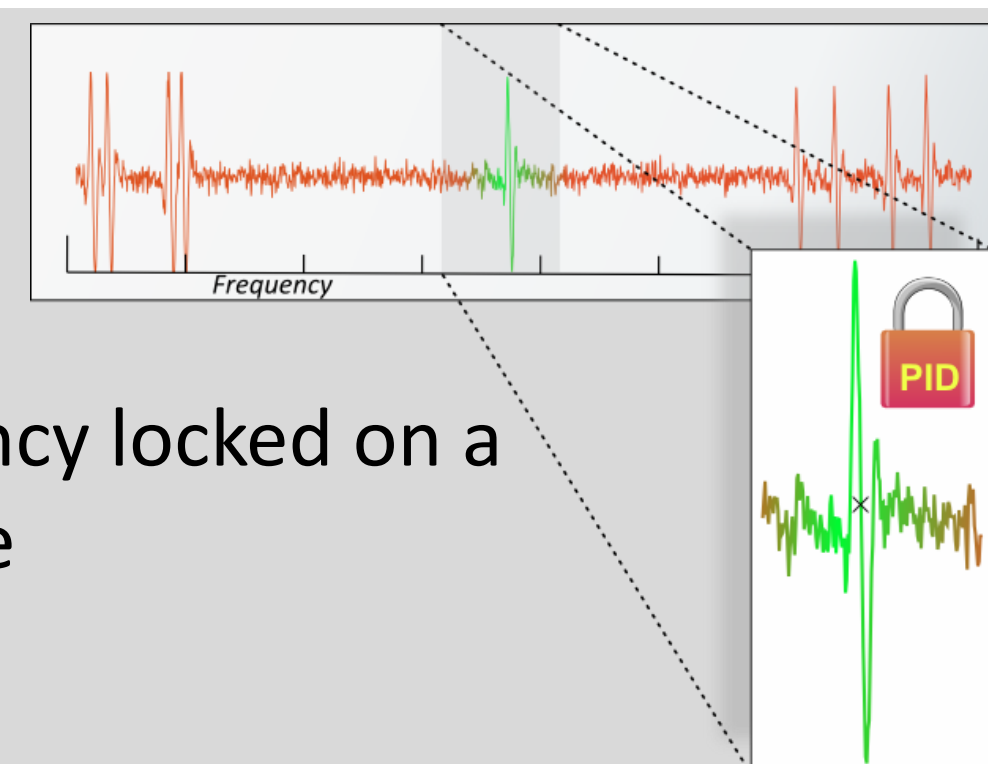
v

Velocity

Laser frequency locked on a reference line

10 MHz Rb clock synchronized on GPS frequency

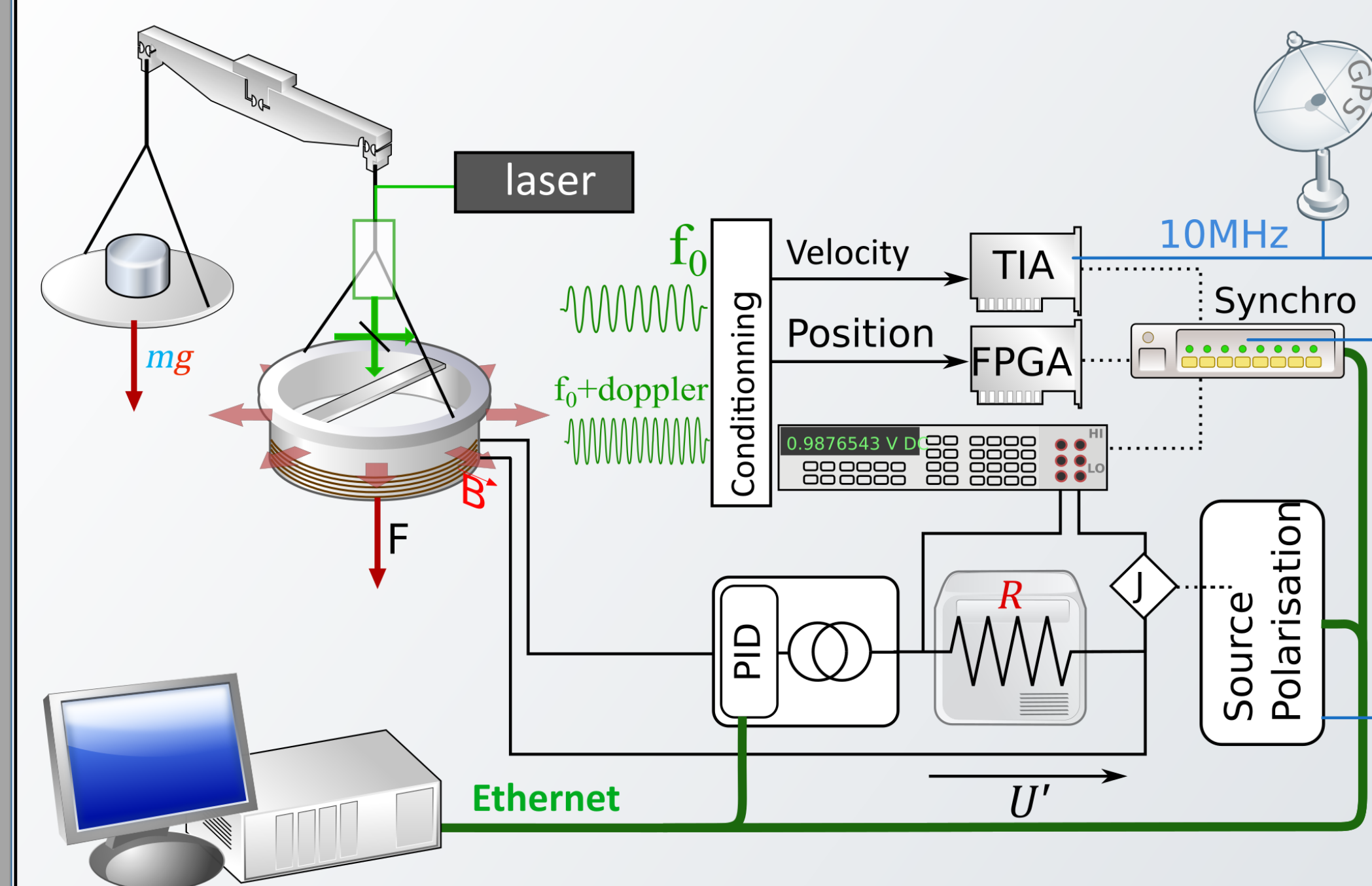
LNE-Syrte ntp server for date



$$m = \frac{1}{g \cdot v} \frac{U \cdot V}{R}$$

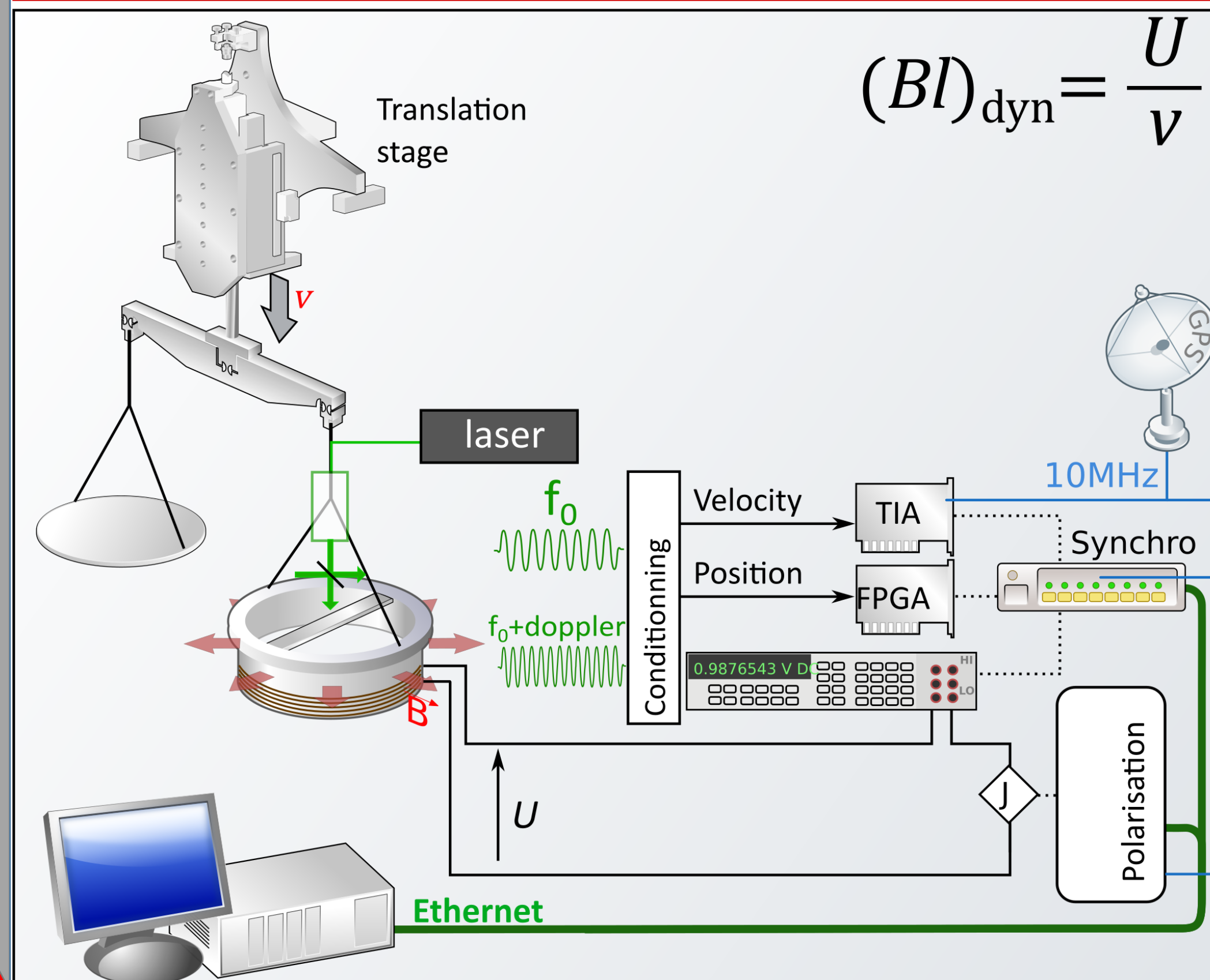
Static phase

$$(BI)_{\text{stat}} = \frac{mg}{I}$$

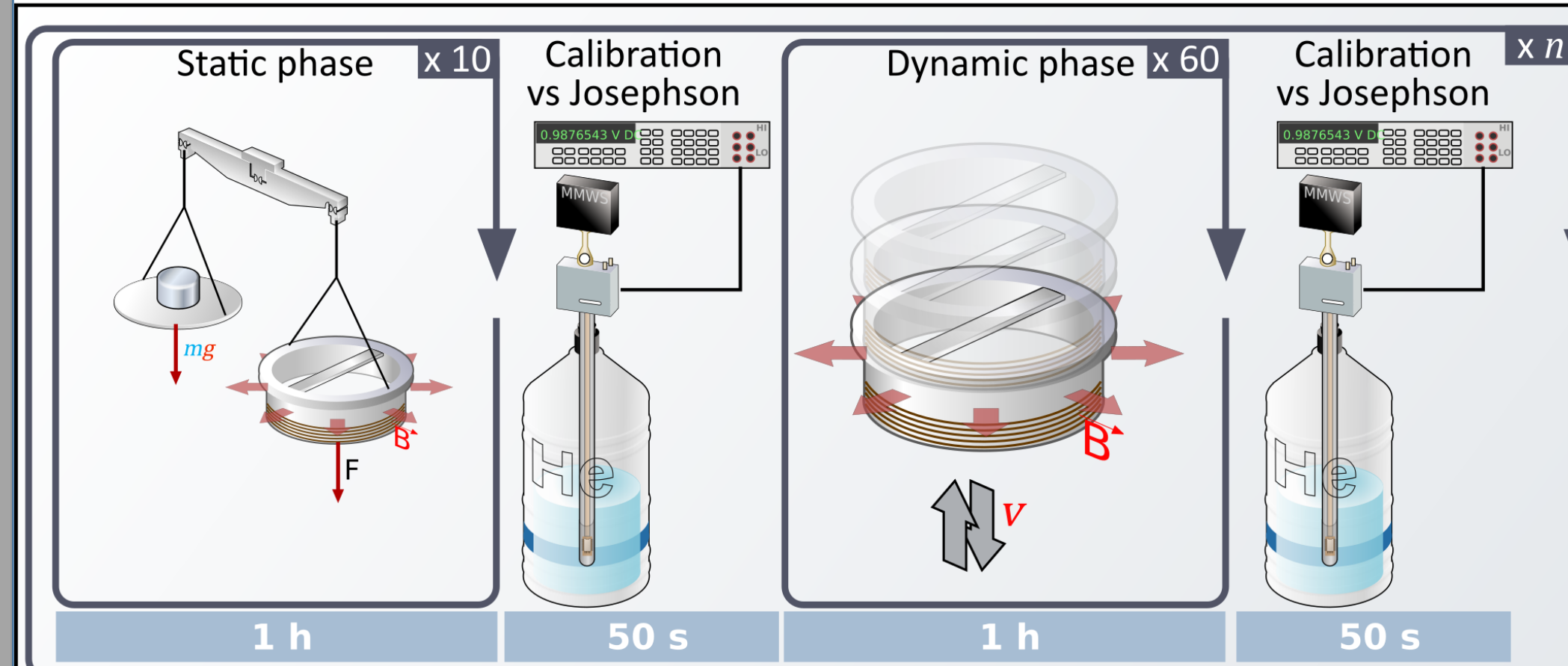


Dynamic phase

$$(BI)_{\text{dyn}} = \frac{U}{v}$$



Sequence



Results: kilogram

Project started in 2002 by the building of a new lab from the ground...
...relative uncertainty of $3.5 \cdot 10^{-8}$ achieved in 2024 [8]

Improvement of uncertainties over years

2015, first determination of h [7]	$3.1 \cdot 10^{-7}$ kg/kg
2016, with Josephson standard [2]	$1.4 \cdot 10^{-7}$ kg/kg
2017, "top notch" in air [1]	$5.7 \cdot 10^{-8}$ kg/kg
2021, first measurement in vacuum [3]	$1.1 \cdot 10^{-7}$ kg/kg
2024, in vacuum [8]	$3.5 \cdot 10^{-8}$ kg/kg

output

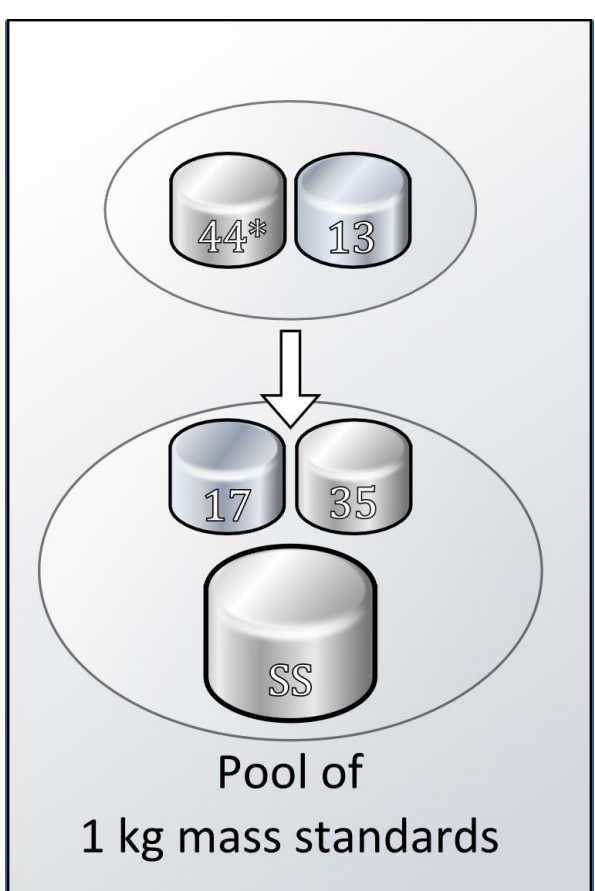
m Transfer of the calibrated mass value...

iridium standards and platinum iridium

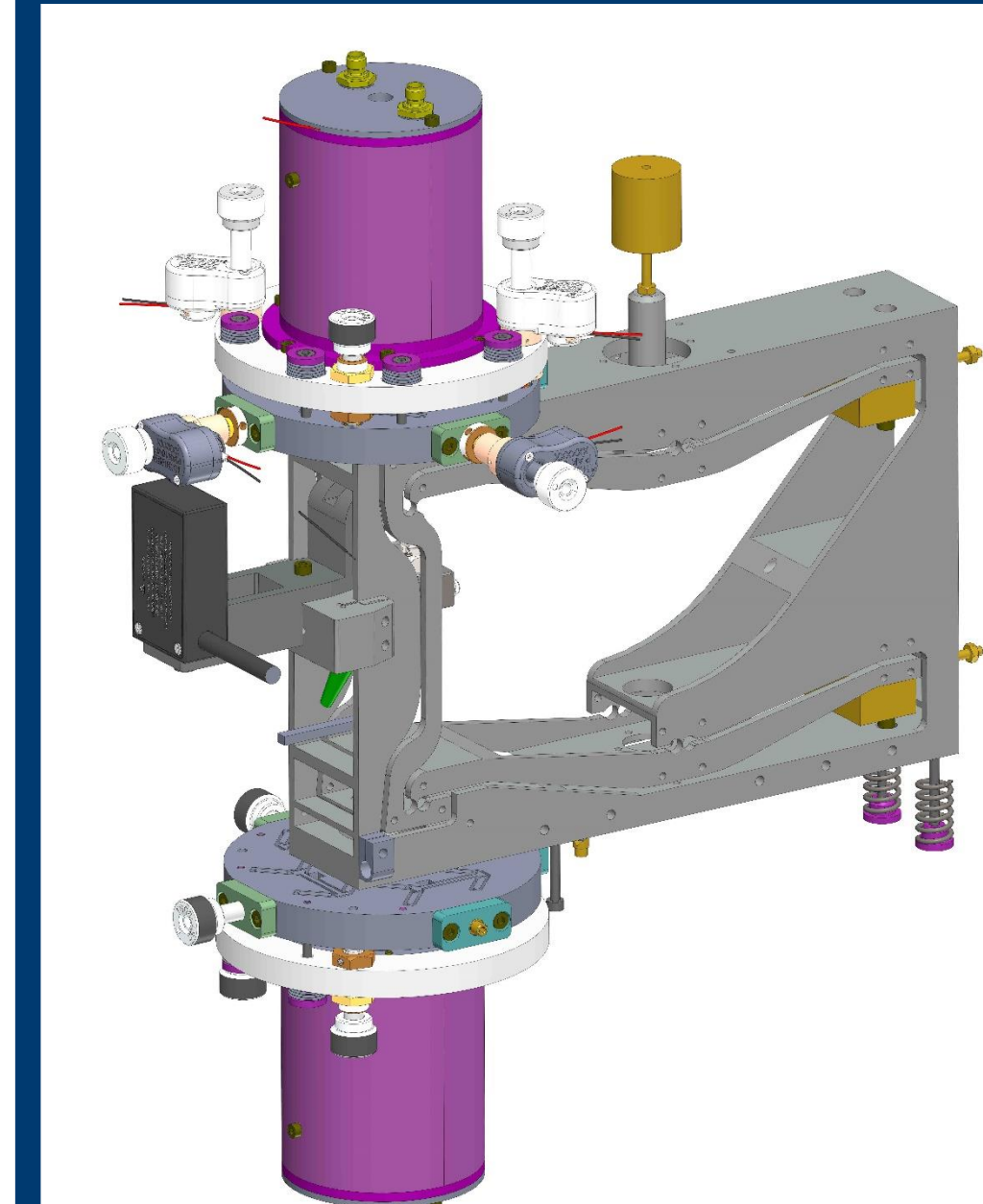
Control of the national reference chain

Mass pool

(LNE mass department)



In dev... mg metrology



Electrostatic balance for mg mass metrology, designed and machined. First weighings in progress.

[1] M Thomas et al 2017 Metrologia 54 468, [10.1088/1681-7575/aa7882](https://doi.org/10.1088/1681-7575/aa7882)

[2] Pilot study, M Stock et al 2018 Metrologia 55 T1, [10.1088/1681-7575/aa9a7e](https://doi.org/10.1088/1681-7575/aa9a7e)

[3] CCM-M-K8.2021, M Stock et al 2023 Metrologia 60 07003, [10.1088/0026-1394/60/1A/07003](https://doi.org/10.1088/0026-1394/60/1A/07003)

[4] Patrick Pinot et al 2016 Metrologia 53 1139, [10.1088/0026-1394/53/4/1139](https://doi.org/10.1088/0026-1394/53/4/1139)

[5] Lecture at SMSI 2023, [10.5162/SMSI2023/B7.2](https://doi.org/10.5162/SMSI2023/B7.2)

[6] Poster at CPEM 2024, [10.1109/CPEM61406.2024.10646030](https://doi.org/10.1109/CPEM61406.2024.10646030)

[7] M Thomas et al 2015 Metrologia 52 433, [10.1088/0026-1394/52/2/433](https://doi.org/10.1088/0026-1394/52/2/433)

[8] in press