

Report on the BIPM Kibble Balance

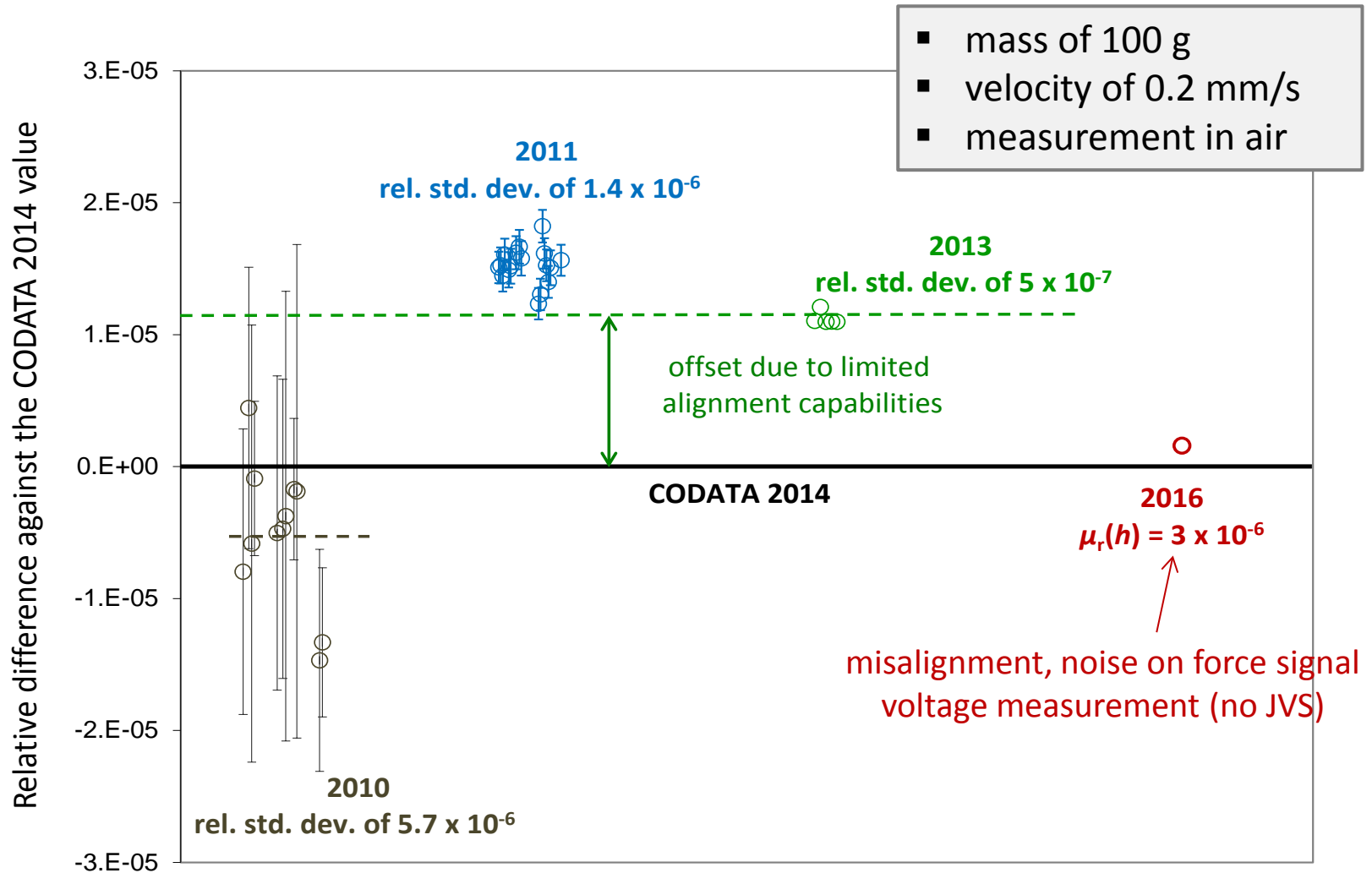
Hao FANG

19 May 2017

16th CCM meeting



Situation in July 2016



Target for this summer

July 2016

- 100 g mass
- velocity of 0.2 mm/s
- measurement in air
- non-optimized alignment
- single coil

$$u_r(h) = 3 \times 10^{-6}$$

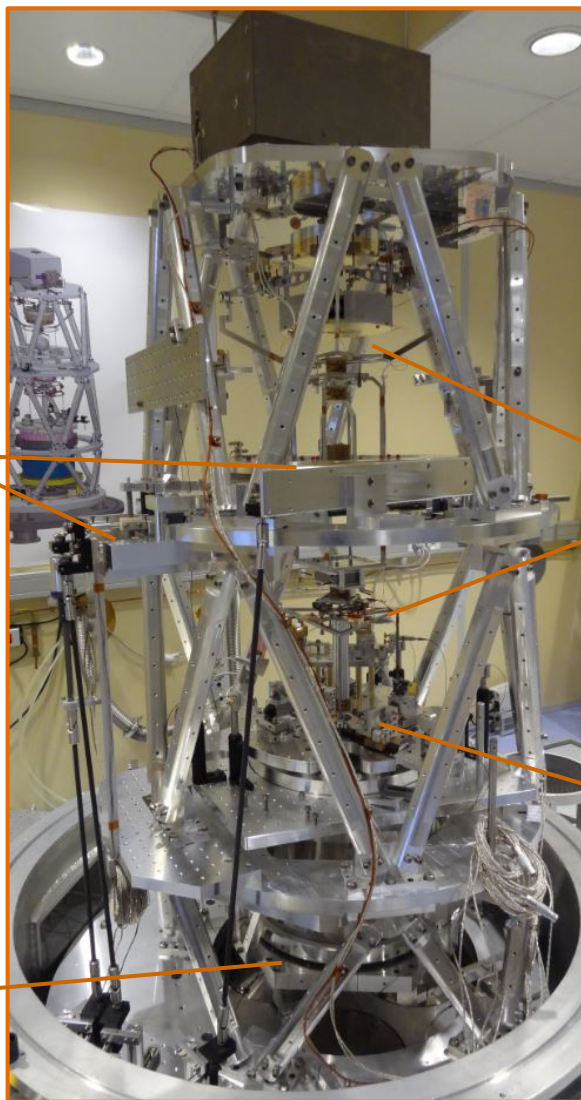
July 2017

- 1 kg mass
- velocity of 1 mm/s
- measurement in vacuum
- improved alignment
- bifilar coil
- PJVs for voltage
- noise reduction in force

target uncertainty

$$u_r(h) = 1 \times 10^{-7}$$

New mechanical set-up



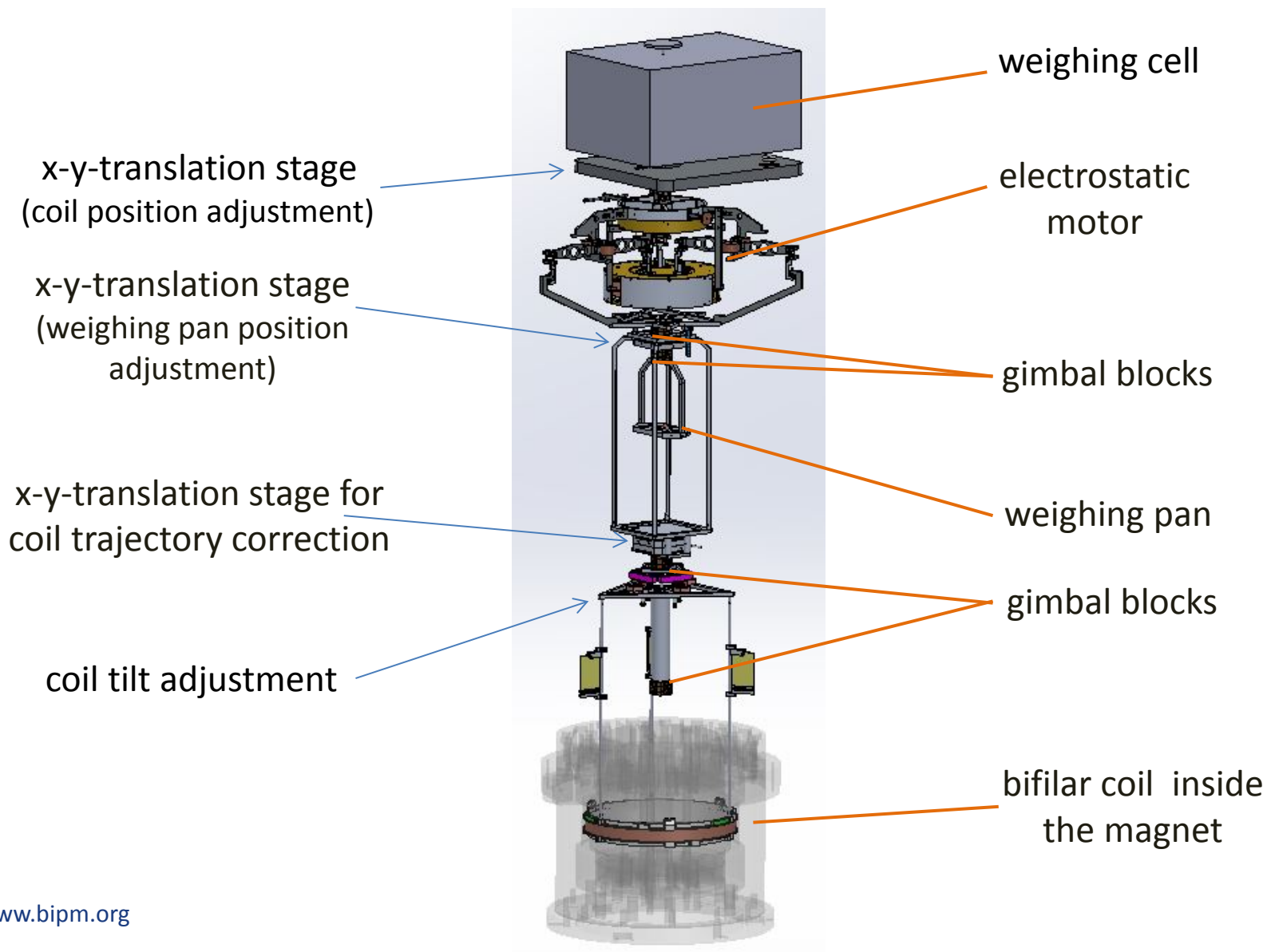
new mass loading & exchanger system
→ 1 kg mass (Pt-Ir)

new suspension
→ improved alignment

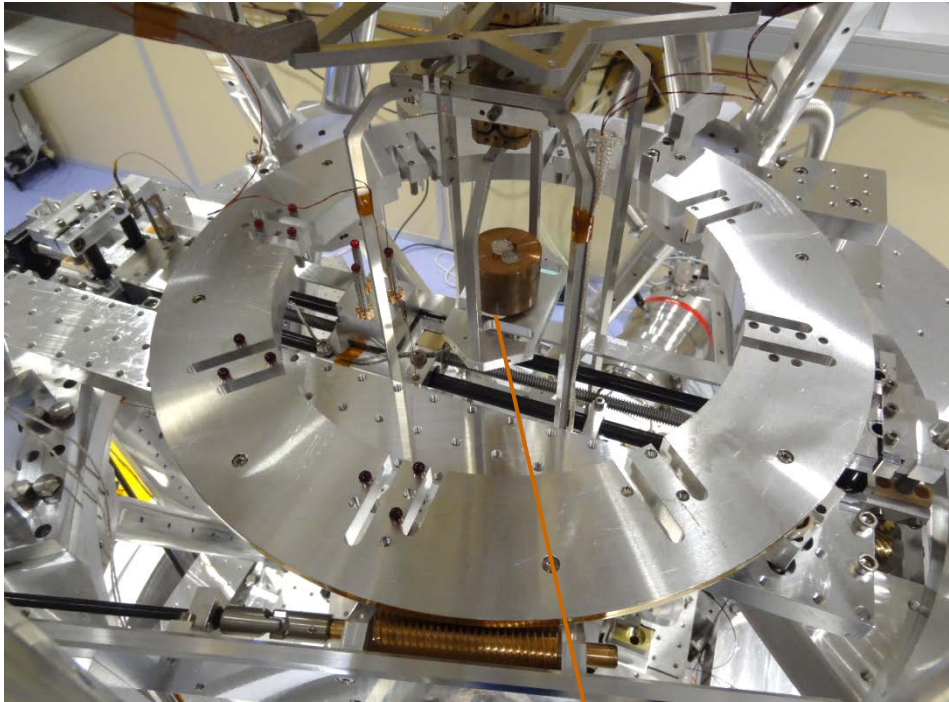
new magnet support
→ vacuum operation

new mounts for optical sensors
→ vacuum operation & easily adjustable

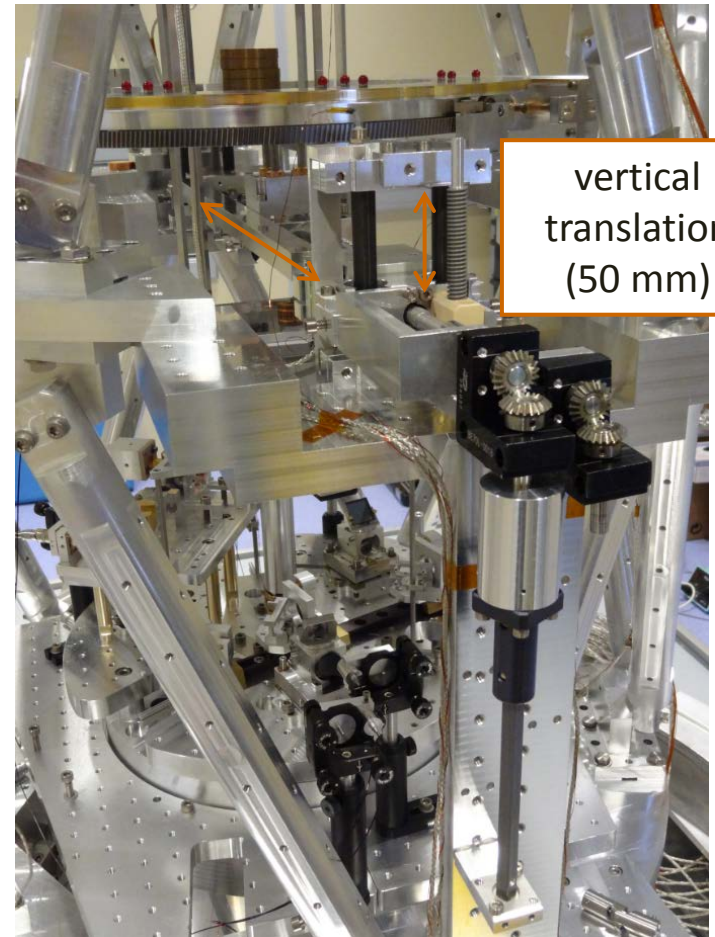
New suspension



New mass loading and exchanger system

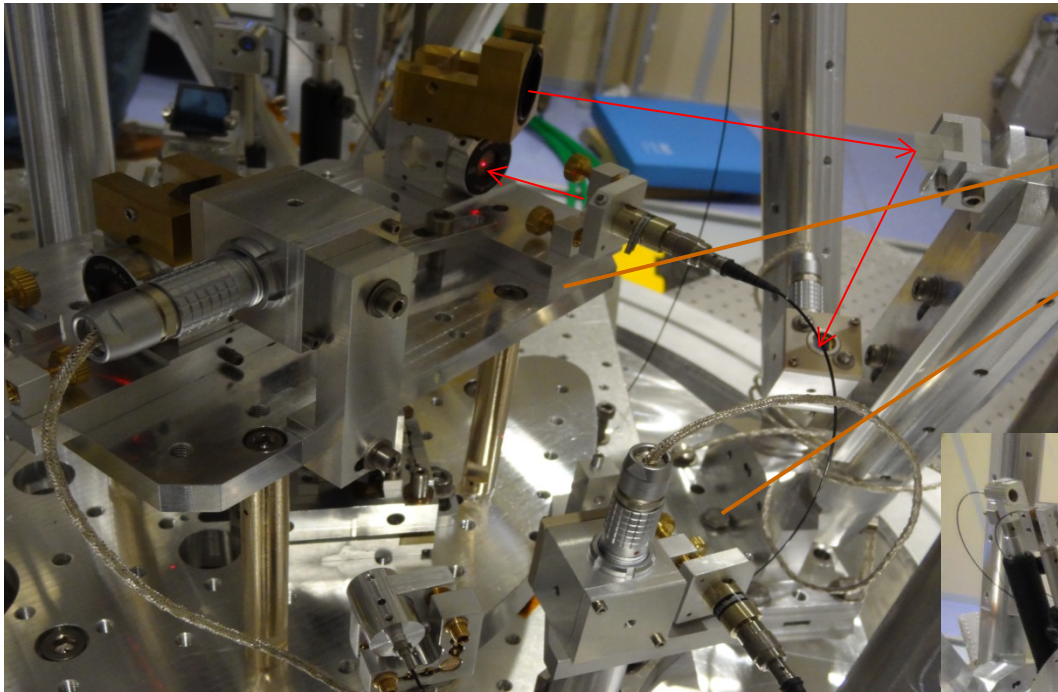


weighing pan
(three Cu-Be balls)



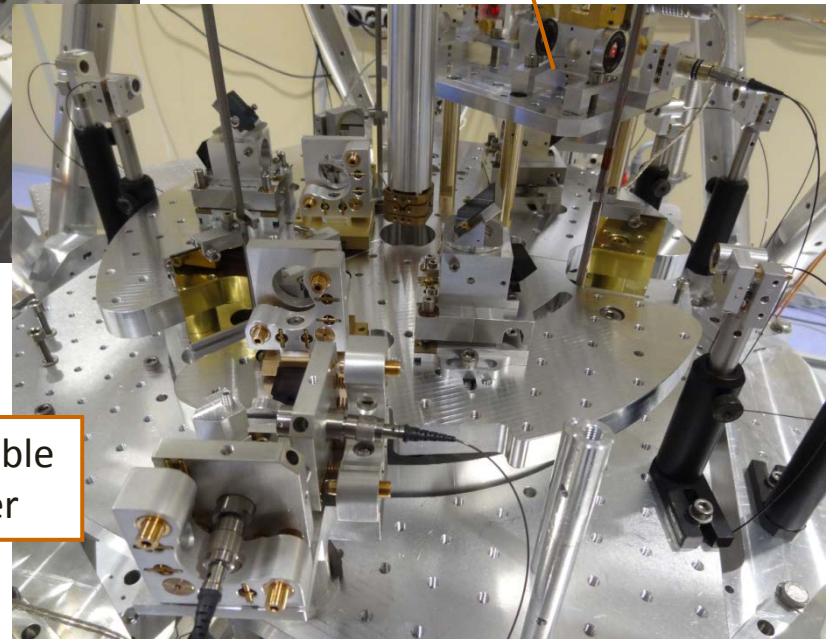
vertical
translation
(50 mm)

New optical sensors

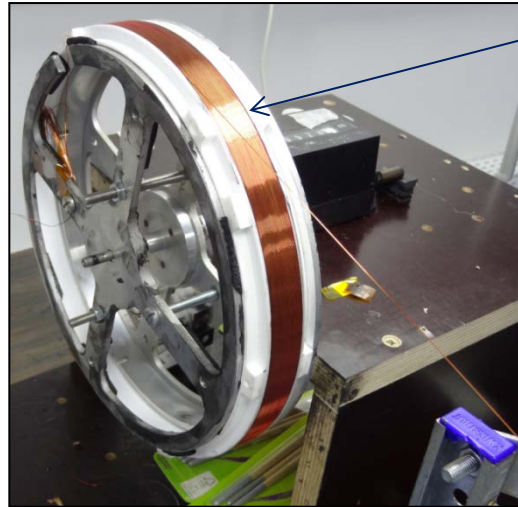
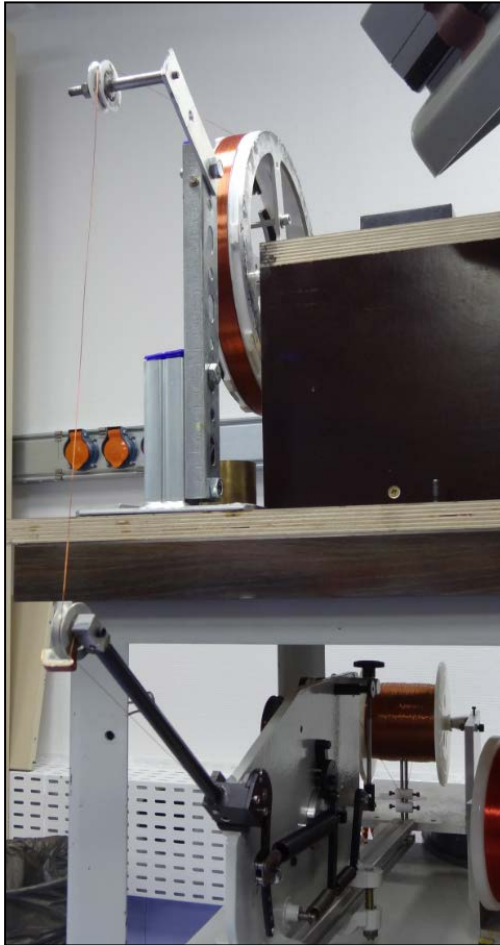


vacuum compatible
position sensors

vacuum compatible adjustable
mounts for interferometer



Bifilar coil



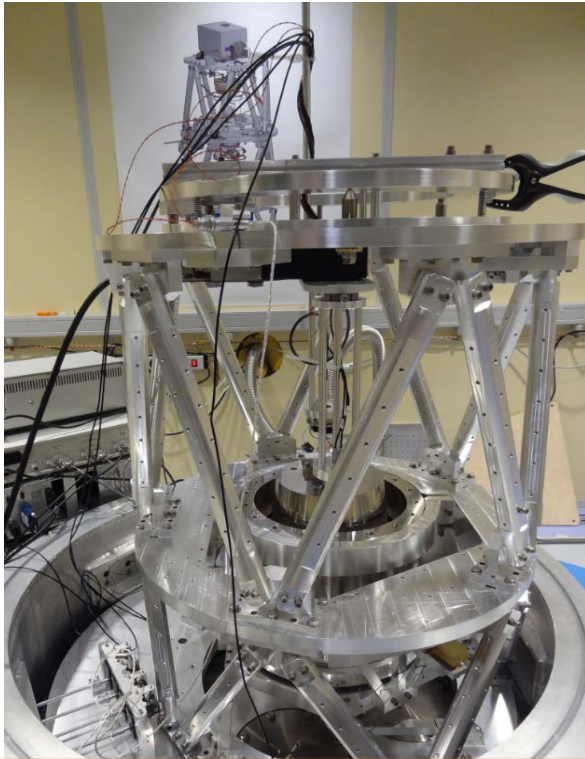
coil former made of Macor
(20 mm in height, 9 mm in width
and 126 mm in mean radius)



two parallel glued wires of
0.2 mm in diameter

- 26 layers, 1057 turns
- isolation between two wires $> 2.5 \text{ G}\Omega$
- resistance of each winding $\approx 600 \Omega$
- decentring of electrical centres $< 1 \mu\text{m}$;
difference in coil inclinations $< 10 \mu\text{rad}$

Magnetic circuit



aligned better than $20 \mu\text{rad}$

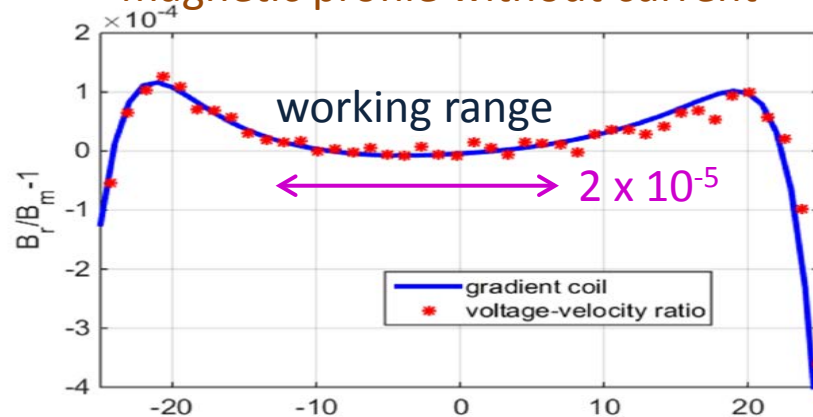
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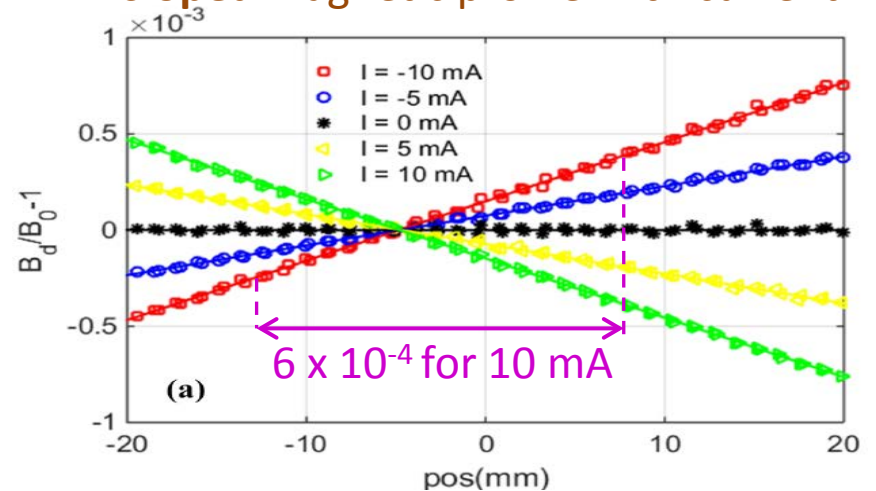
Alignment of the magnetic circuit of the BIPM watt balance

F Bielsa¹, Y F Lu², T Lavergne¹, A Kiss¹, H Fang¹ and M Stock¹

magnetic profile without current



sloped magnetic profile with current



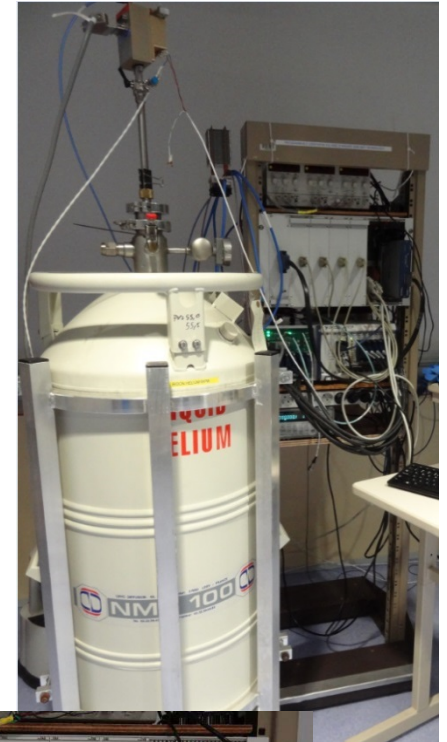
ACCEPTED MANUSCRIPT

A permanent magnet system for Kibble balances

Shisong Li¹, Franck Bielsa², Michael Stock³, Adrien Kiss⁴ and Hao Fang⁵

Programmable Josephson voltage standards

- **JVS for current measurement**
 - ✓ NIST SNS array: 2V, 13 segments
 - ✓ development of a home-made 13 channels bias-source finished and validated
 - ✓ integration inside the balance underway
- **JVS for induced voltage measurement**
 - ✓ NIST SNS array: 1,2 V, 13 segments
 - ✓ assembly of a NIST type bias-source finished and validated
 - ✓ integration inside the balance underway
 - ✓ difference (induced voltage against JVS) directly measured with a DVM



Local acceleration of gravity value

- **Absolute value**

- ✓ update of the ICAG 2009 value measured by 3 AGs (actual test mass position is 8 cm higher and horizontally shifted of 100 mm)
- ✓ calculation of the self-attraction correction due to the balance set-up using FEM analysis
 - 4.7 μGal at central position of the coil trajectory

ACCEPTED MANUSCRIPT

Self-attraction mapping and an update on local gravitational acceleration measurement in BIPM Kibble balance

Shisong Li¹, Franck Bielsa², Adrien Kiss³ and Hao Fang⁴

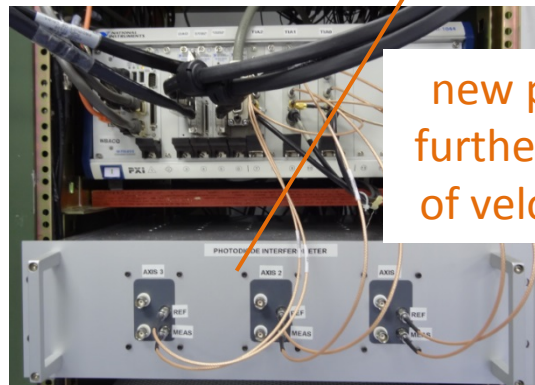
- **Temporal gravity variations by modelling**

- ✓ tidal correction based on local tidal parameters

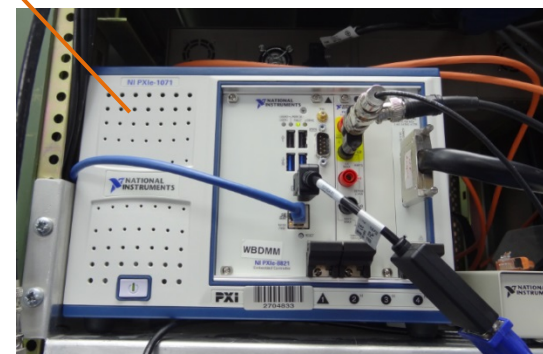
Improved control & measurement system



low emf switches for switching current and voltage measurements between two coils

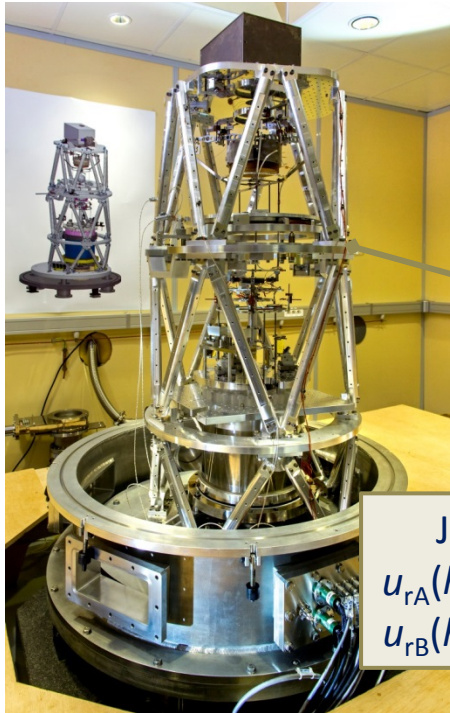


new photo-detectors to further increase S/N ratio of velocity measurement



new digital multi-meter embedded in a real-time controller for force measurement

Outlook



July 2016
 $u_{rA}(h) = 1 \times 10^{-6}$
 $u_{rB}(h) = 3 \times 10^{-6}$

- final alignment and adjustment underway
- finishing JVSs integration
- measurement campaign in vacuum

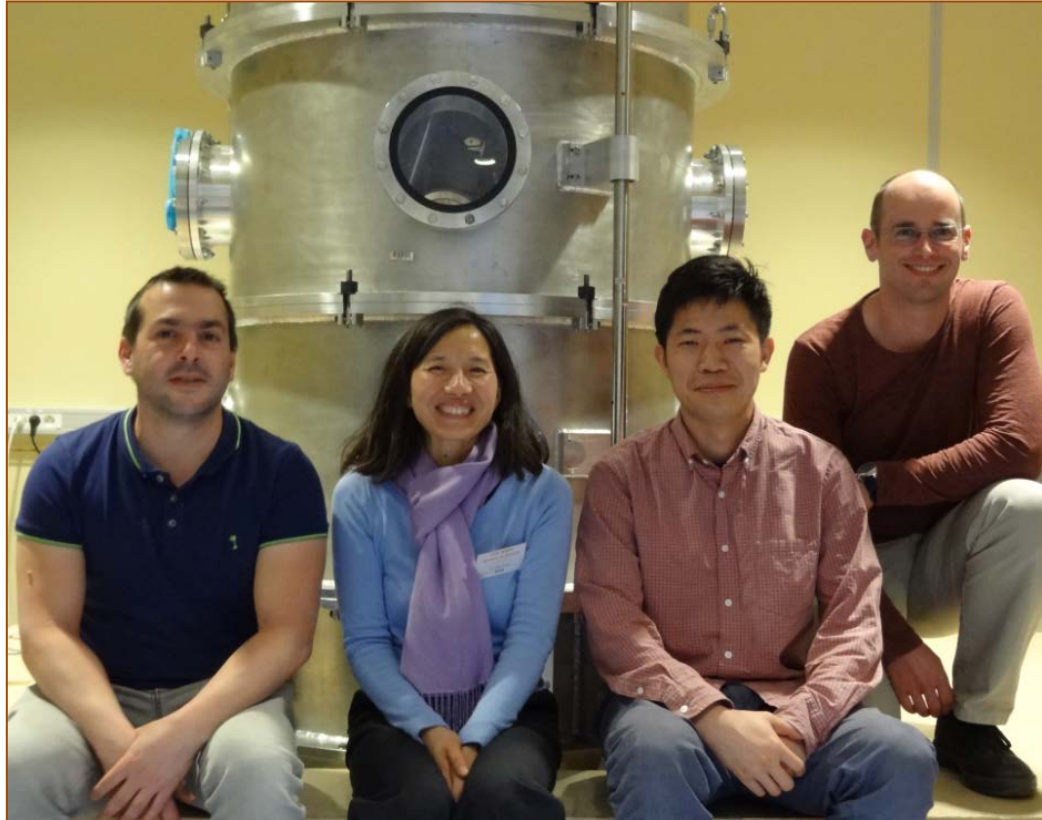
1 July 2017

July 2017
 $u_{rA}(h) = 5 \times 10^{-8}$
 $u_{rB}(h) = 1 \times 10^{-7}$

new motor
new coils with higher L
further improvements (force etc.)

end 2018
 $u_{rA}(h) = 1 \times 10^{-8}$
 $u_{rB}(h) < 5 \times 10^{-8}$

Many thanks to...



also colleagues from BIPM mechanical workshop and Physical Metrology Department
also NIM, NIST (KB team, Boulder), NPL...

Thank you for
your attention!



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