kNOW
kilogram NOW

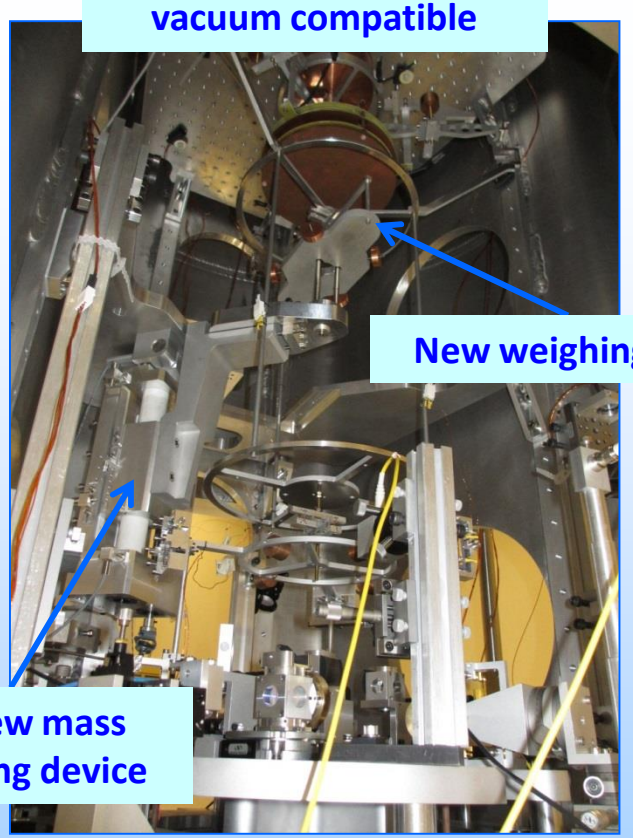
2013 workshop
Italy - Torino

Status of the BIPM Watt Balance

H. Fang, M. Stock

Present apparatus in the new laboratory

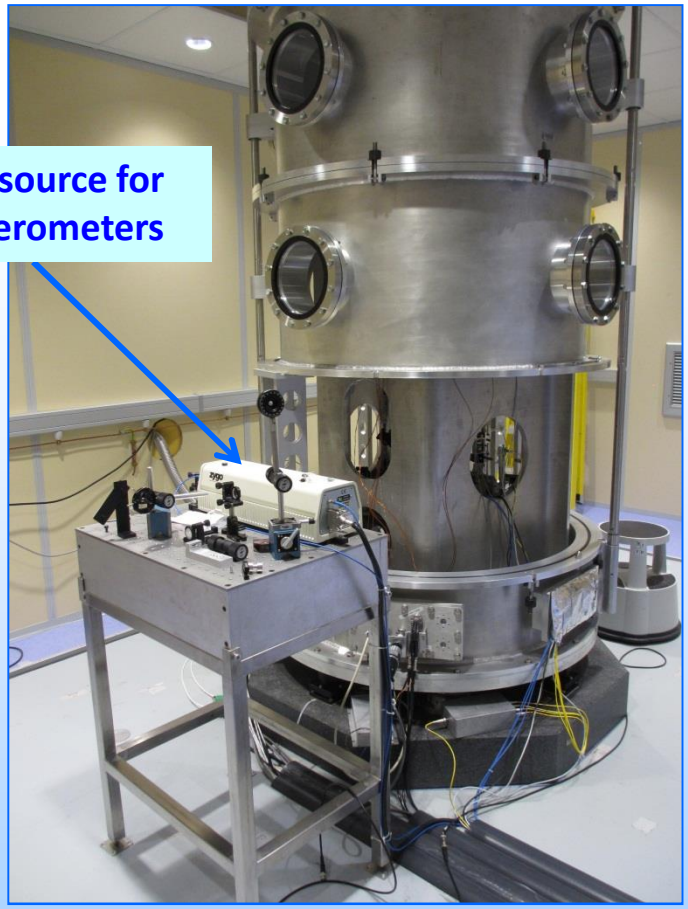
New force comparator, vacuum compatible



New weighing pan

New mass lifting device

Laser source for interferometers



- Modifications made to accommodate the apparatus
- Also some new components
- Fully operational in air

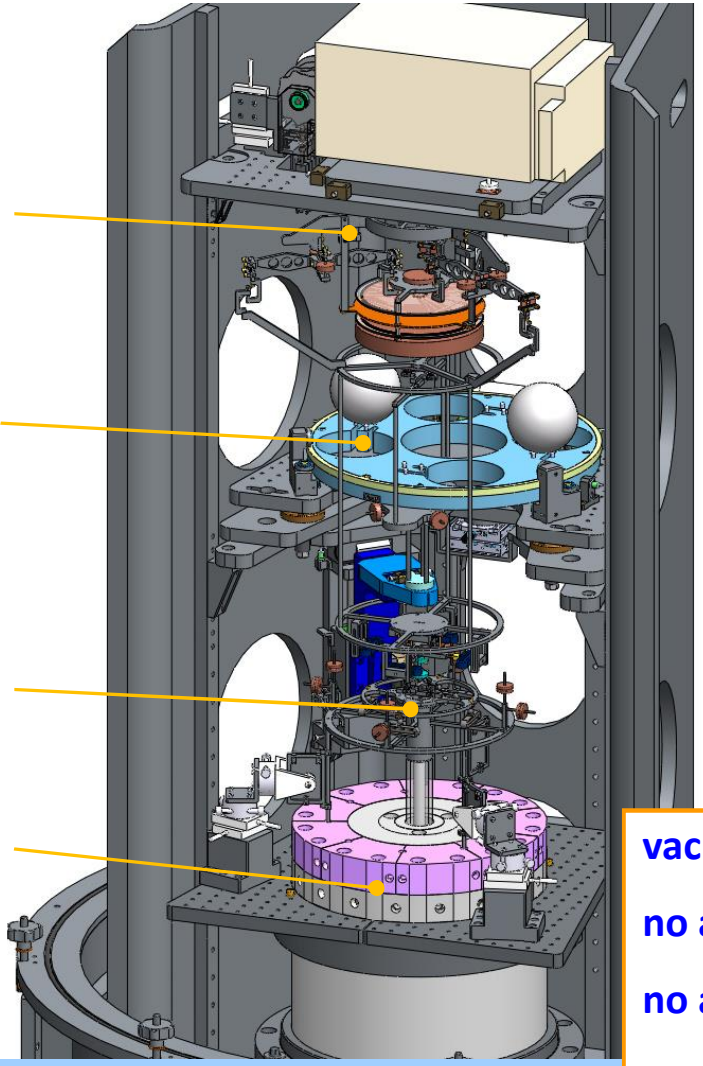
New components for the watt balance

In-situ calibration of weighing cell

Mass exchanger

Dynamic alignment system

New magnet



most mechanical parts available

↓

to be integrated into suspension

↓

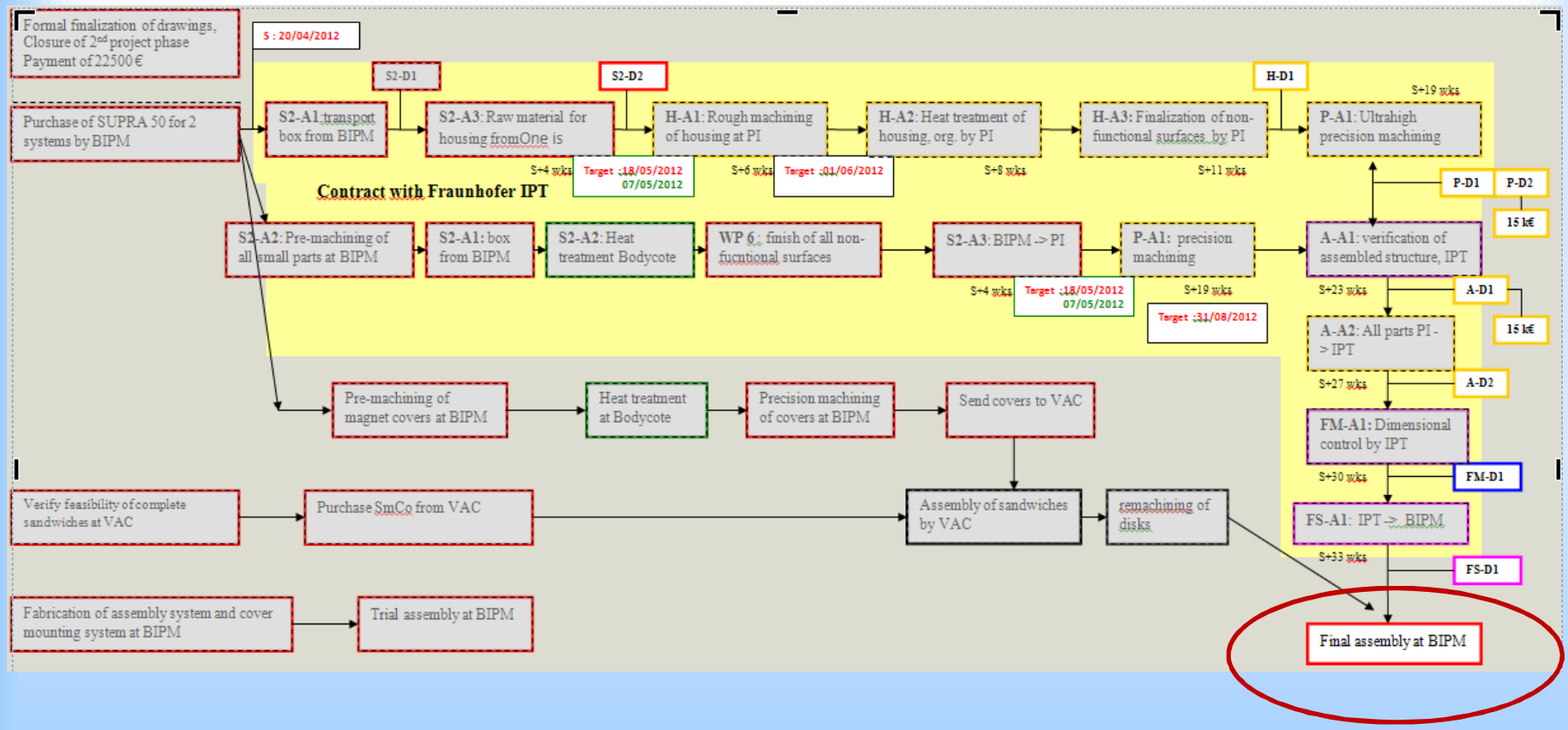
ready for measurements in 2014

vacuum: < 0,01 Pa

no air convection; no air buoyancy

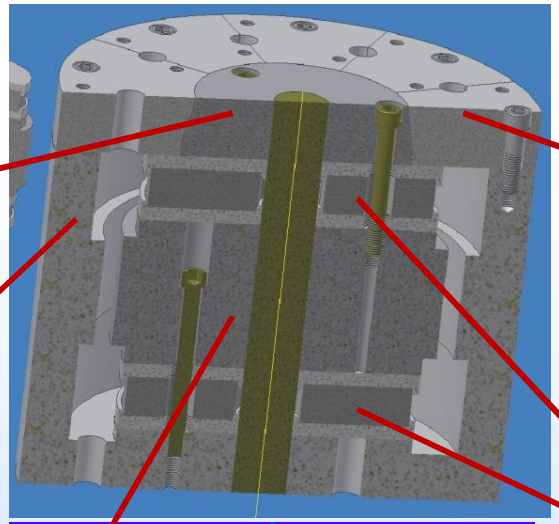
no air refractive index correction

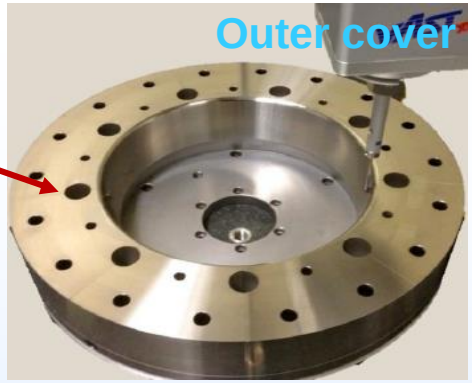
Fabrication planning for the new magnet

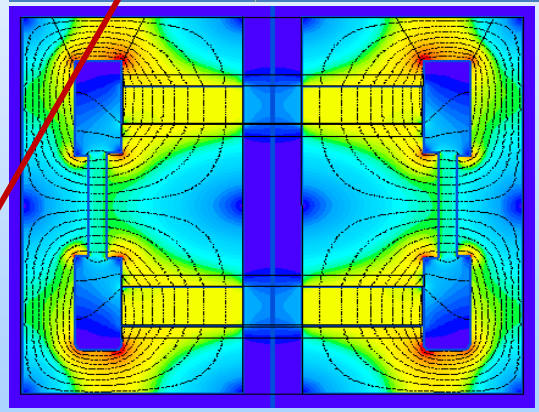


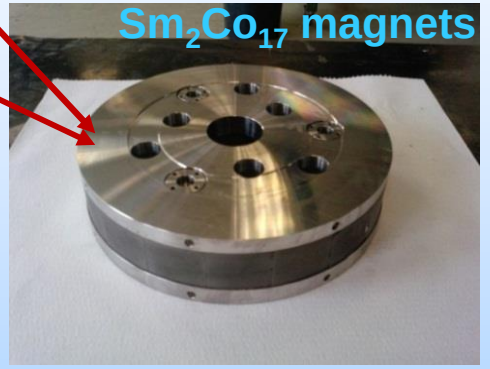
Last step: assembly

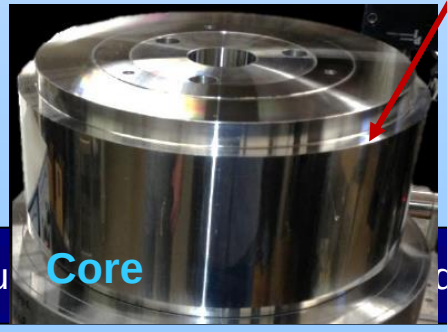
New magnet: fabrication of parts







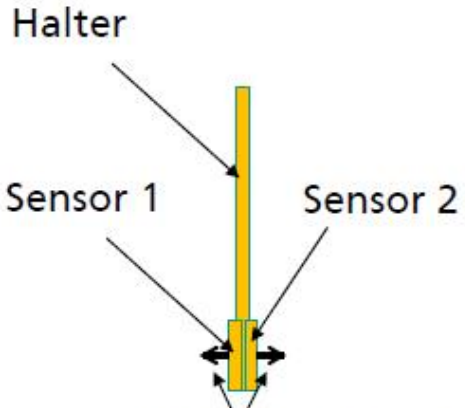




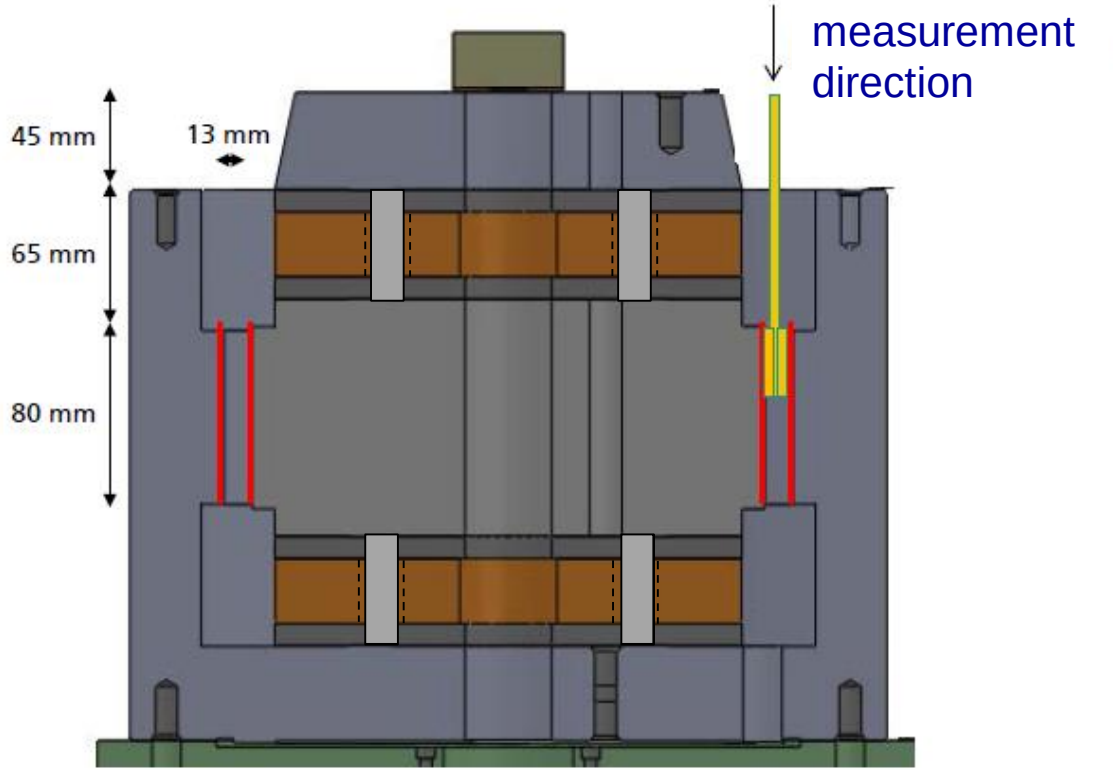
- All parts now at BIPM
- All components meet the specifications
- Trial assembly (without the magnets) and uniformity of the gap width verified (<1 μm)

New magnet: verification

Measurement setup for gap detection (assembly without magnets)



2 capacitive sensors
in opposition

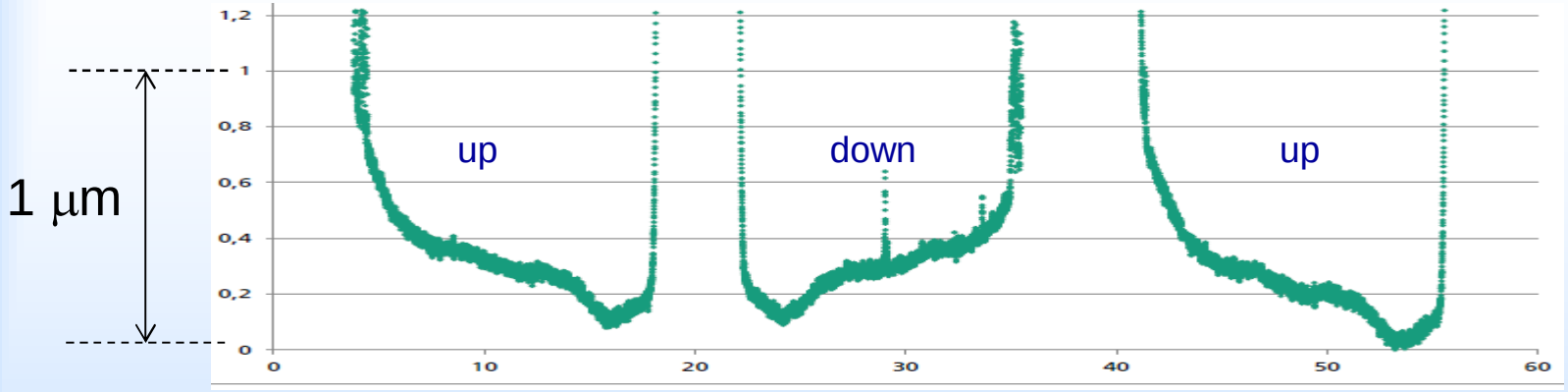


Fraunhofer IPT

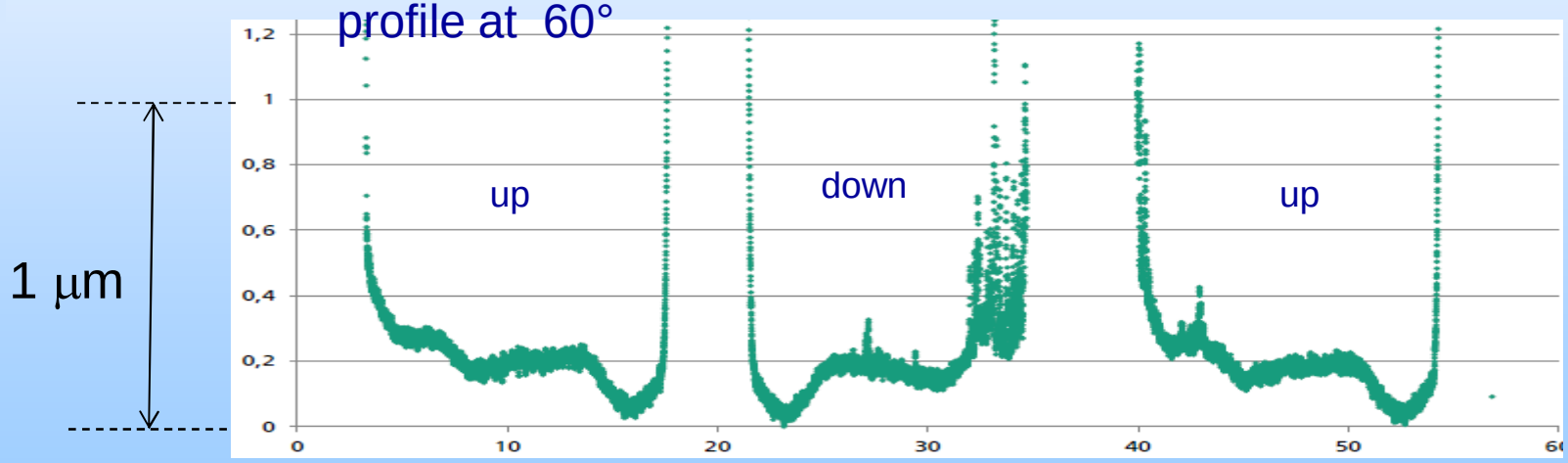
WZL RWTH AACHEN

New magnet: verification

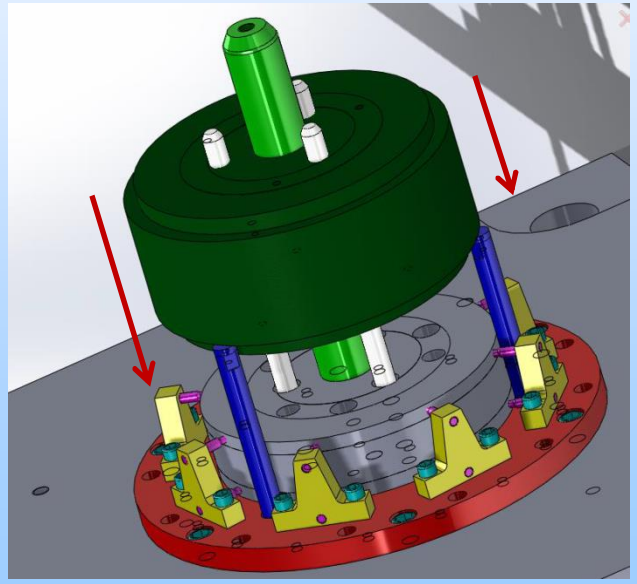
profile at 30°

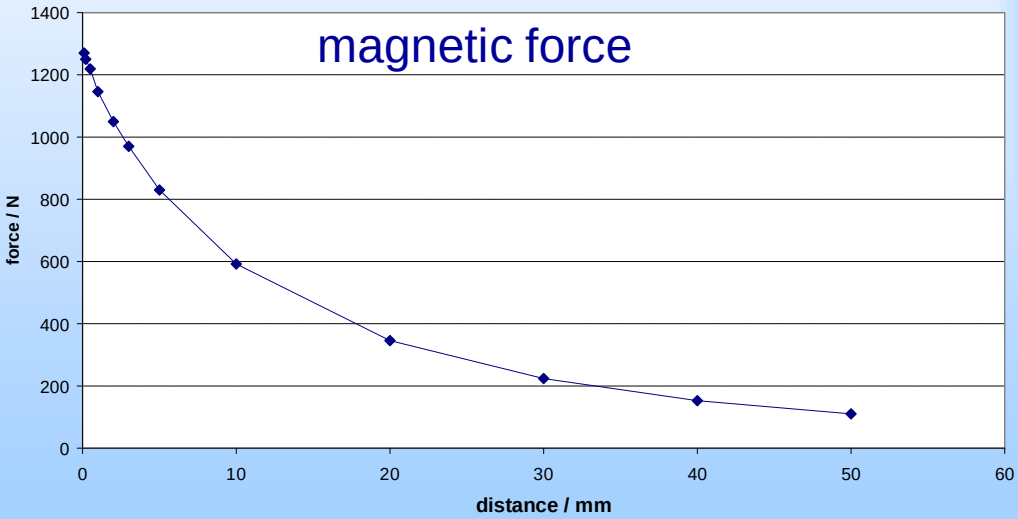


profile at 60°



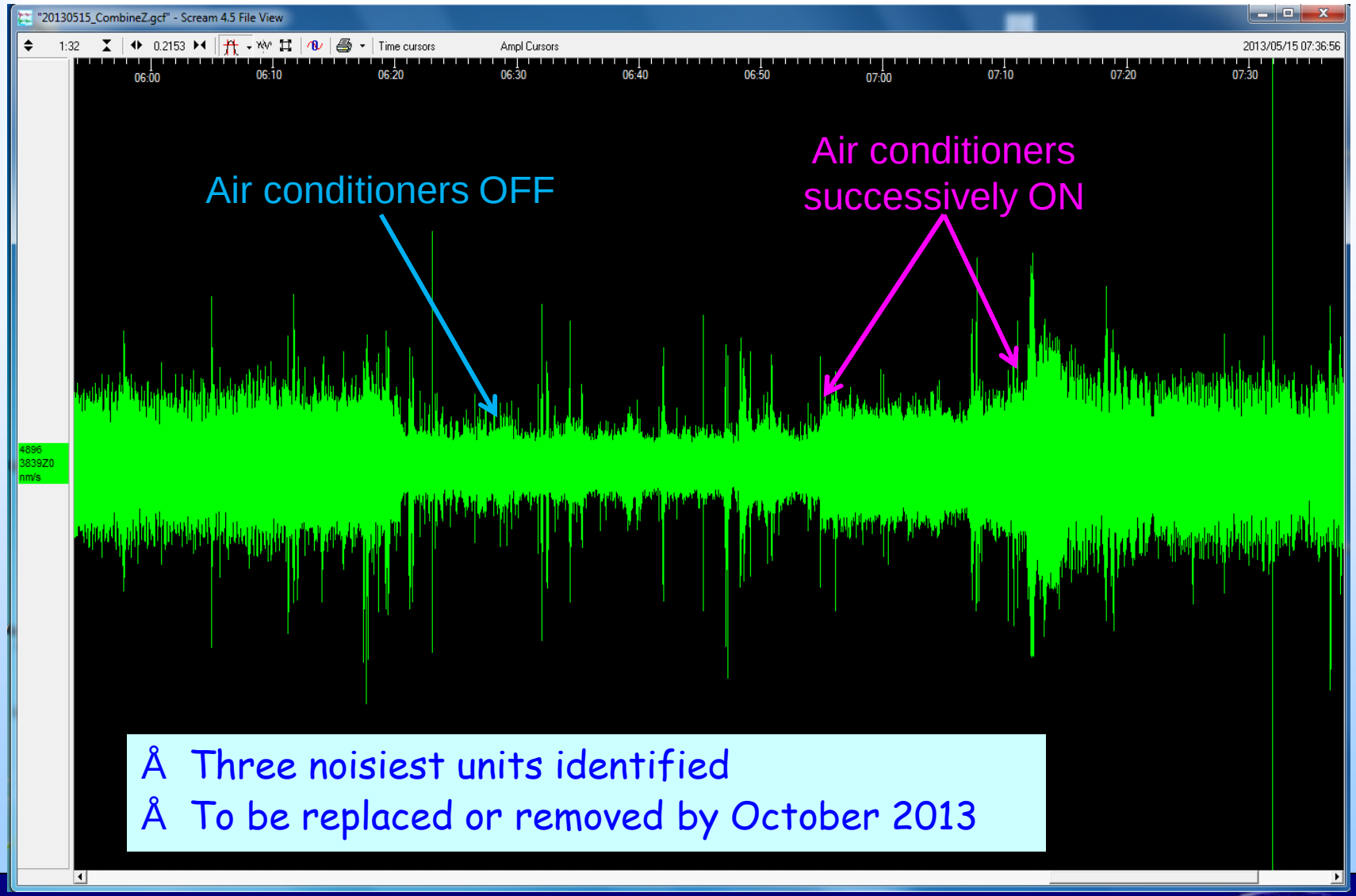
New magnet: assembly nearly finished



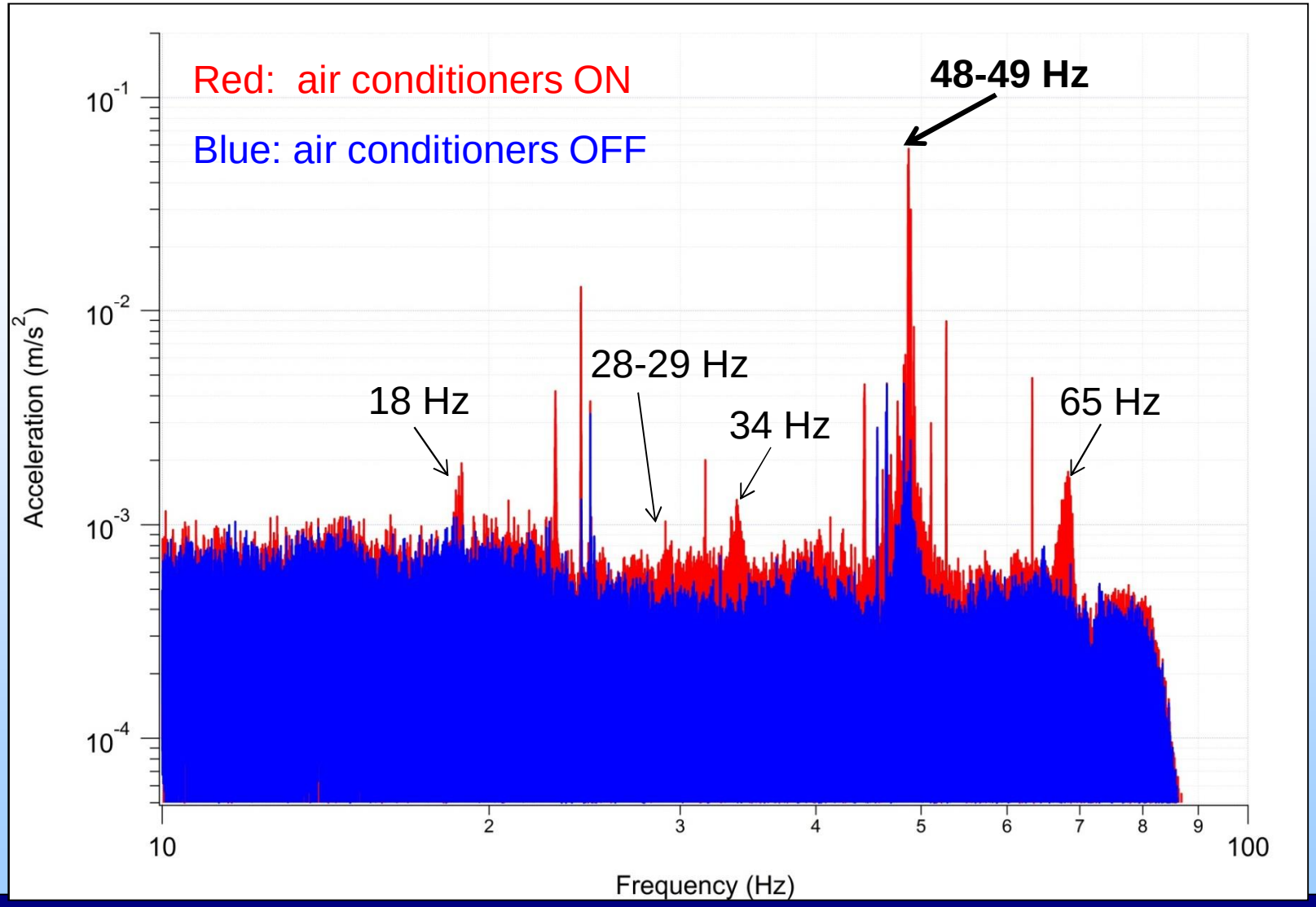


Some problems with too tight tolerances: now solved

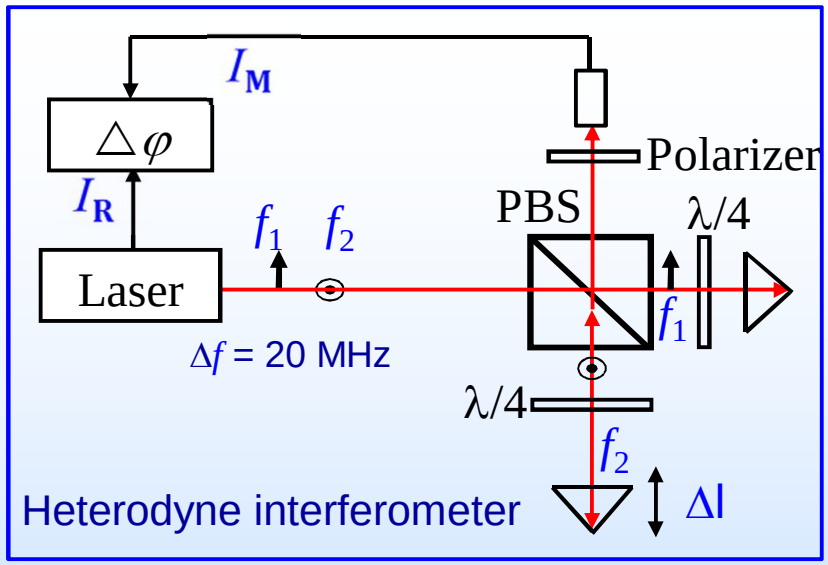
Sources of the surrounding vibration noise (1)

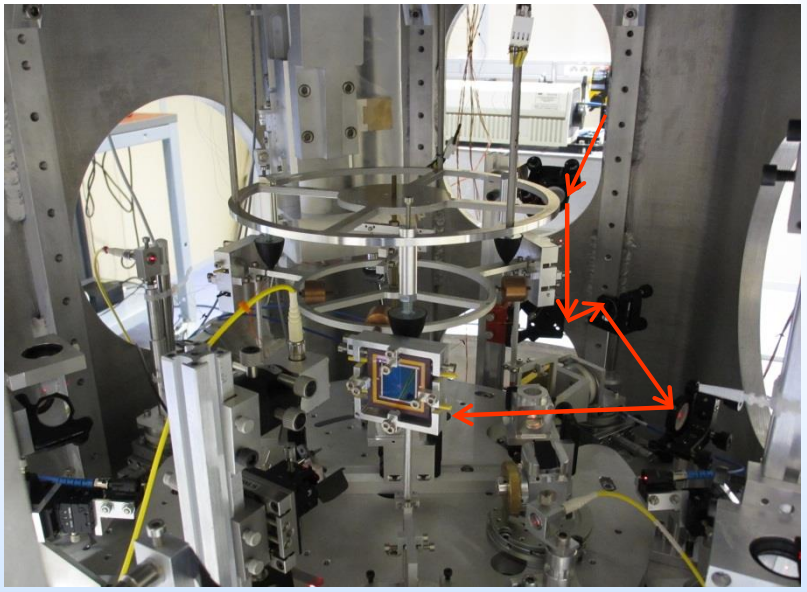


Sources of the surrounding vibration noise



Periodical non-linearity error (1)



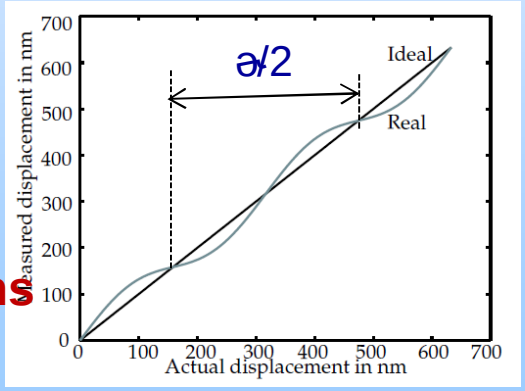


$$\Delta\phi = 4\pi\,\Delta l\,/\lambda_2$$

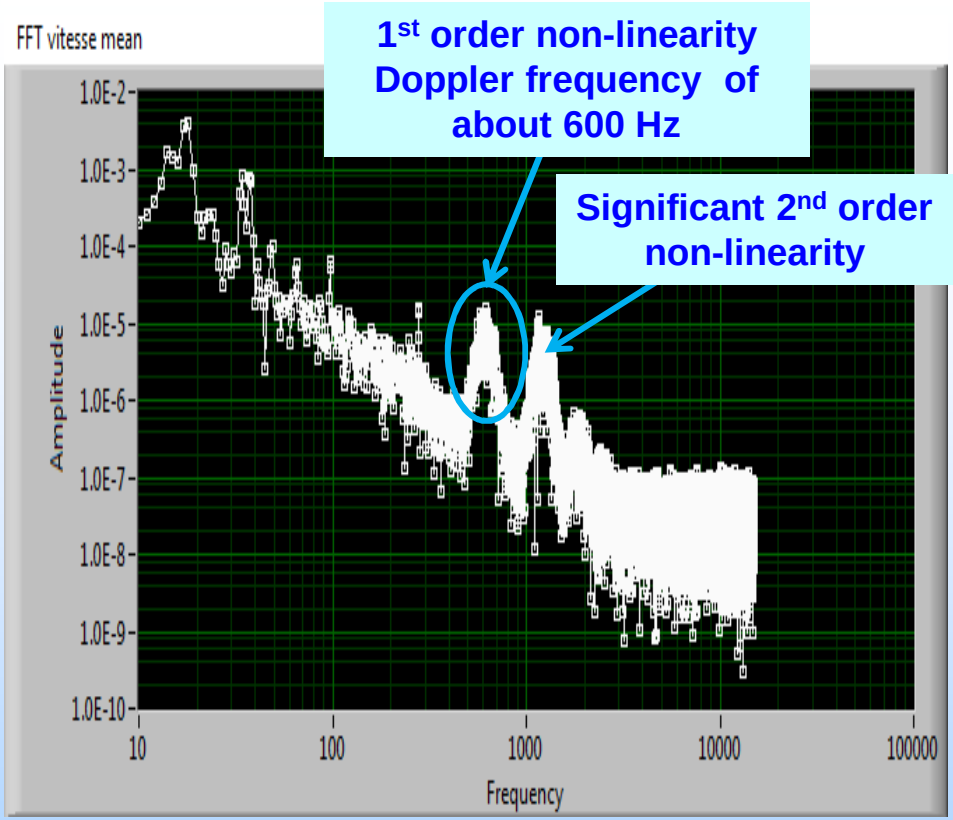
$$I_R = \frac{1}{2} E_0^{\,2}\,[\cos(2\pi(f_2 - f_1)t) + \Delta\emptyset_0]$$

$$I_M = \frac{1}{2} E_0^{\,2}\,[\cos(2\pi(f_2 - f_1)t) + \Delta\emptyset_0 + \Delta\emptyset + \Delta\emptyset_{nl}(\Delta\emptyset)]$$

Extra phase term: periodic deviations (optical quality & alignment)



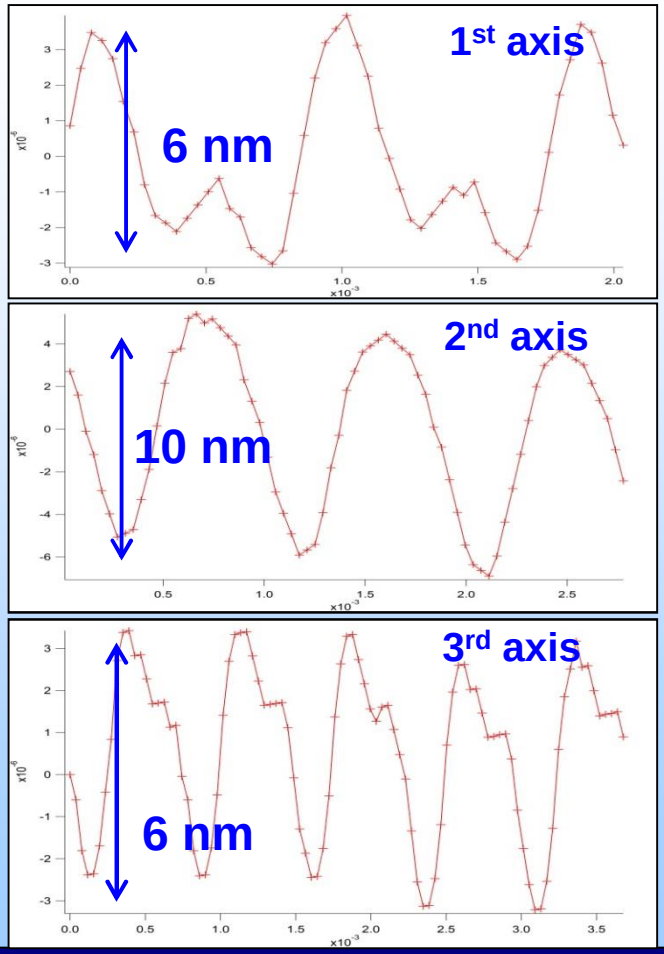
Periodical non-linearity error (2)



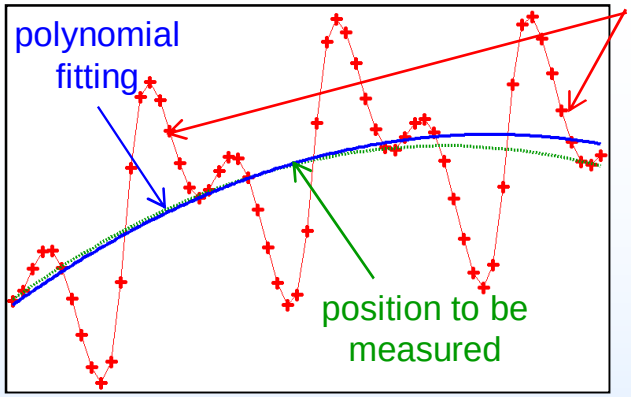
short term: - better alignment
- mathematical reduction

long term: - new interferometer (2014)
with physical separation of beams

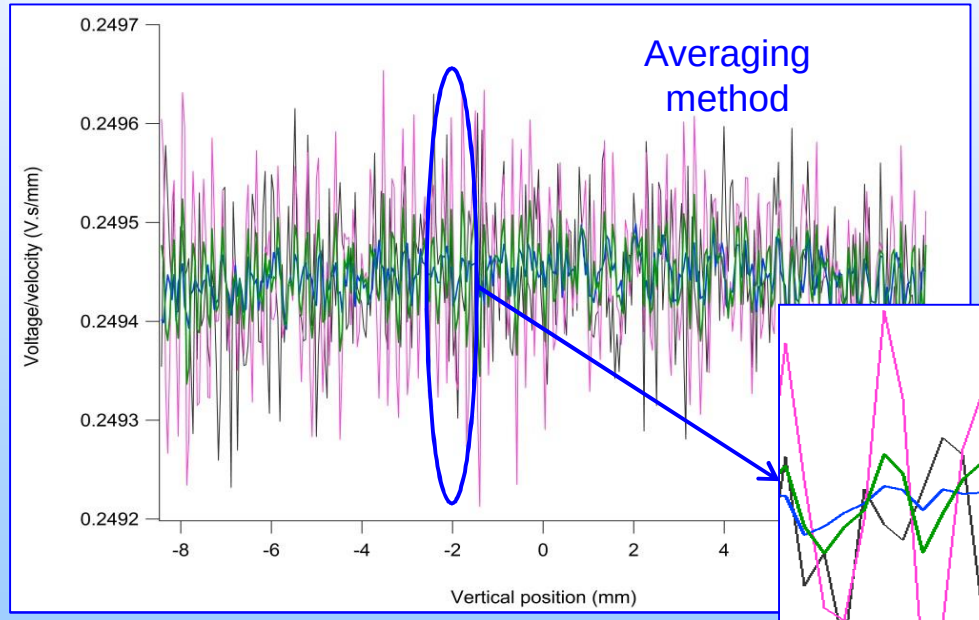
Example of the observed non-linearity errors (sampling rate of 25 kHz)



Reduction by mathematical methods



- Various methods evaluated
- Two of them (averaging and polynomial fitting) used
- Gave similar results in the present measurement conditions



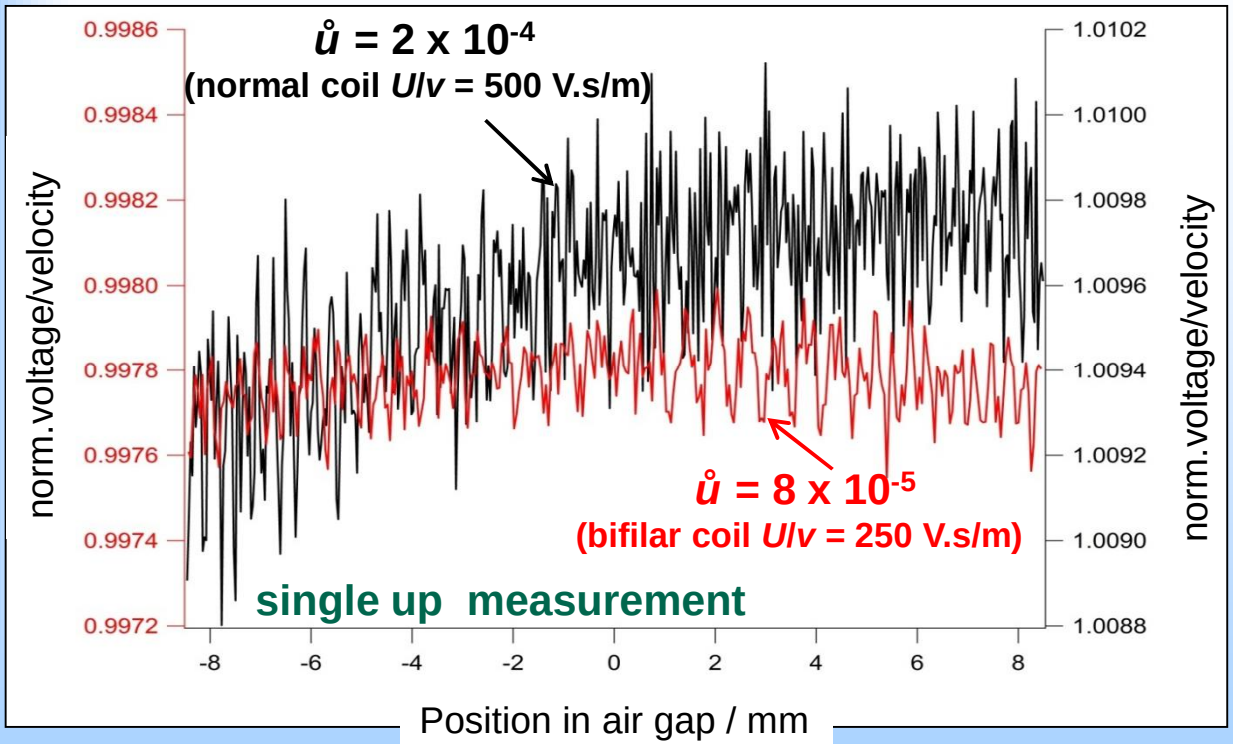
Relative std. dev.
(averaging method):

1 pt	2.8×10^{-4}
2 periods	7.6×10^{-5}
3 periods	9.3×10^{-5}
6 periods	3.2×10^{-4}

Voltage-to-velocity ratio

voltage-to-velocity ratio $\frac{U}{v} = BL$

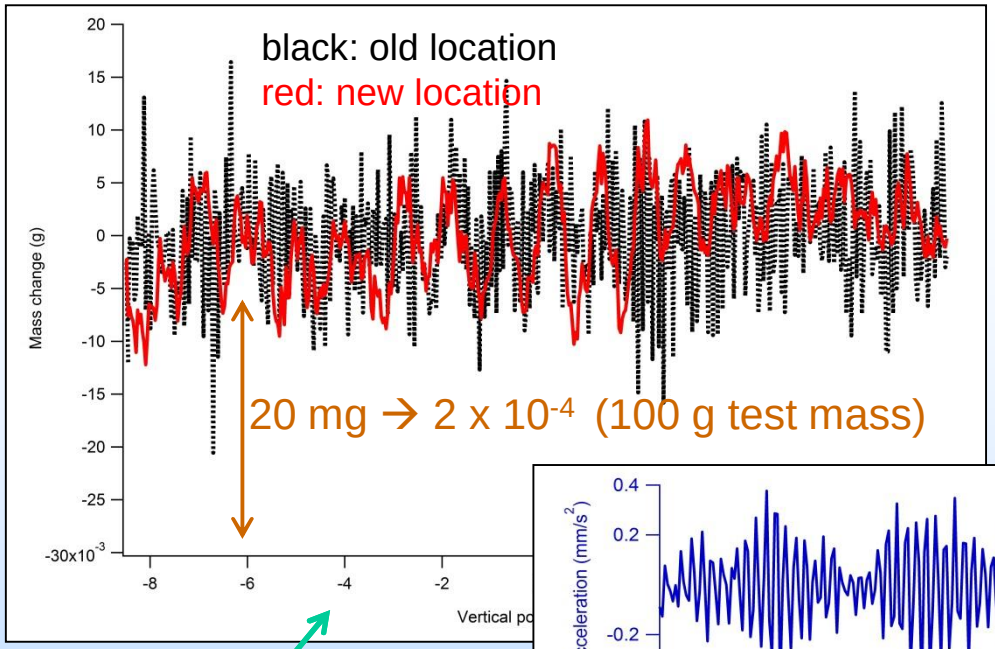
$$\frac{U(z)\,(1+\varepsilon_N(z))}{v(z)\,(1+\varepsilon_N(z))}$$



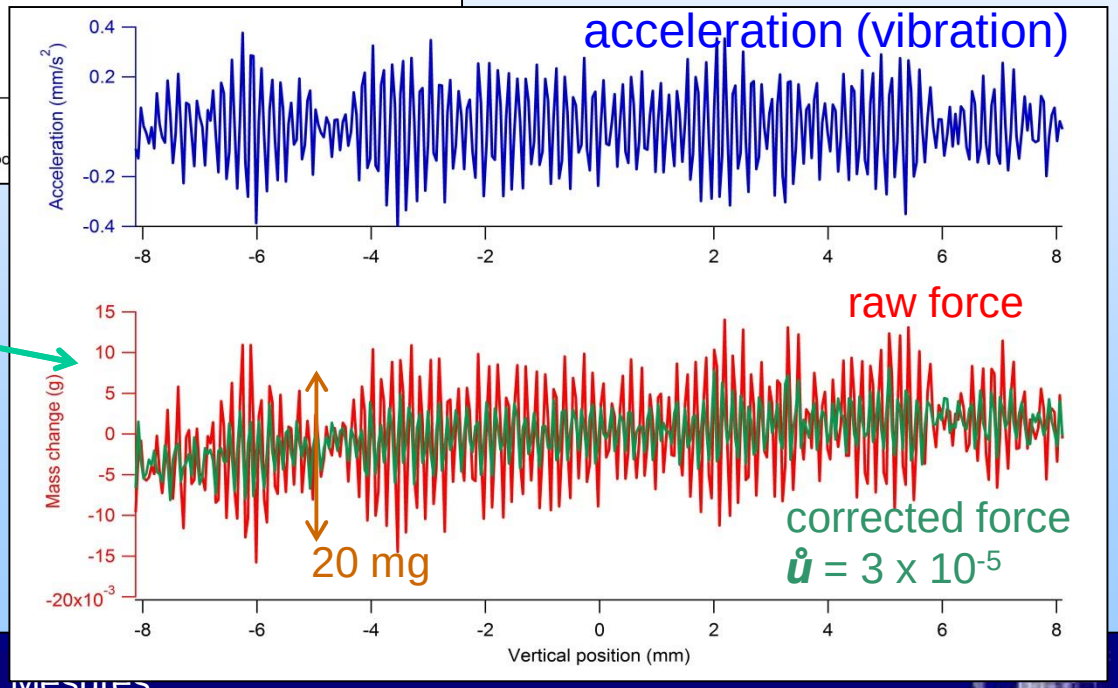
Further reduction

- **28 Hz peak**
  -> stiffer coil (Macor)
- **residual non-linearity error**
  -> new interferometer
- **vibration noise**
  -> investigation under way
- **phase resolution**
  -> better phase detection
- **..etc.**

Force measurement

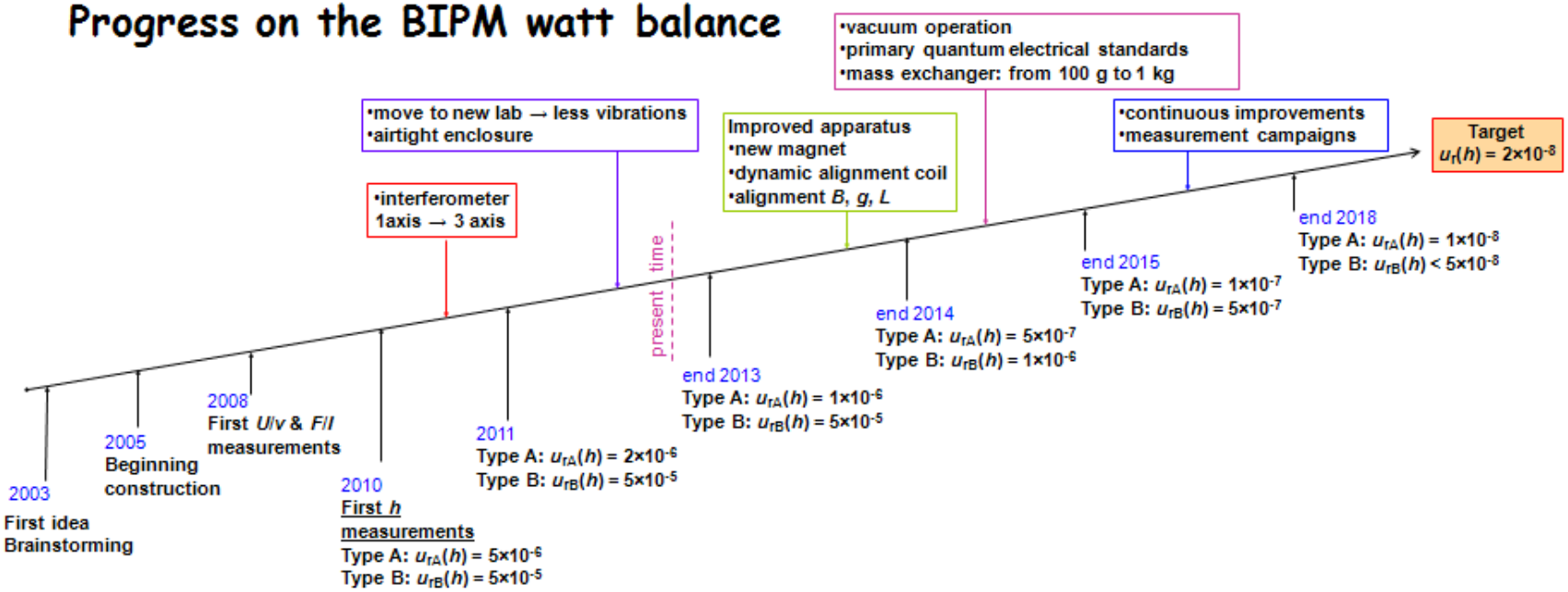


$$\frac{F(z)\,(1+\varepsilon_N(z))}{I\,(z)}$$



single up measurement

Progress on the BIPM watt balance



Next steps

- assembly of the new magnet done
- integration of new measurement facilities
- vibration reduction (repl. of air cond.)
- new stiffer coil done
- new alignment reference
- next *h* measurements spring 2014
- new interferometer (2014)

BIPM watt balance team

Full-time

Hao Fang
principal physicist

Adrien Kiss
engineer

Thomas Lavergne
engineer
(mechanics, since May 2013 for 2 years)

Part-time

Michael Stock
(project leader; magnet)

Lennart Robertsson
(interferometry)

Estefania de Mirandés
(coil alignment, gravimetry)

Stéphane Solve
(JVS)

Régis Charamy
(JVS)