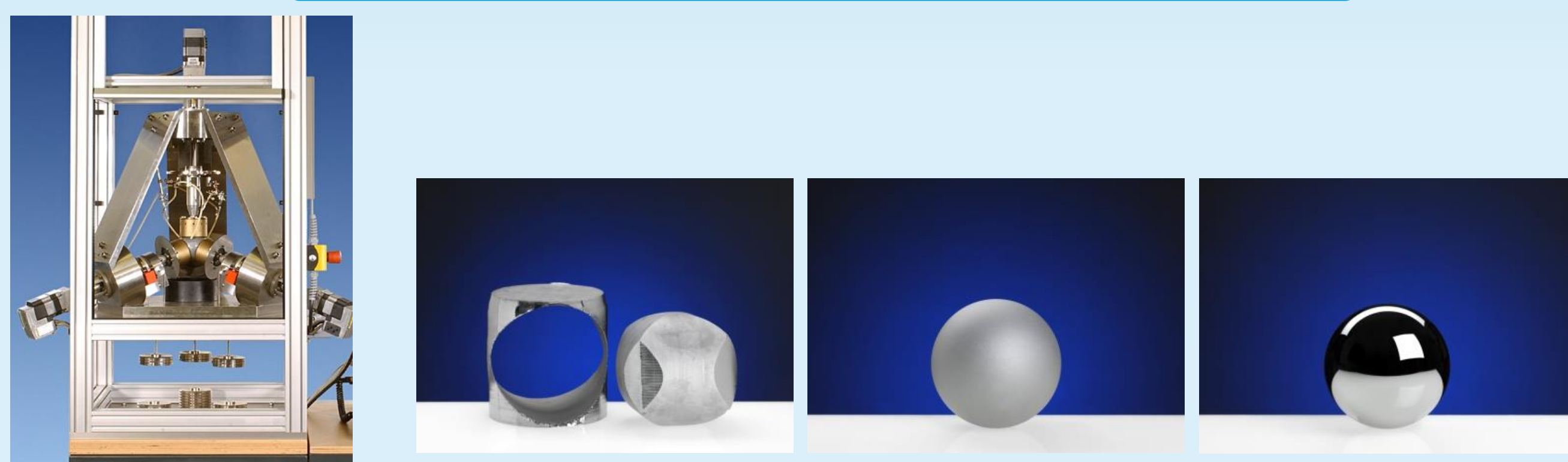


Very stable mass standards

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Manufacturing and Stabilisation



- In contrast to the first ^{28}Si spheres nowadays high-quality silicon spheres for use in mass metrology are manufactured with a slow but effective mechanical process, developed by R. Meeß and his colleagues.
- Results are very round spheres with a very smooth surface
Form deviation $\text{RONt} < 80 \text{ nm}$
Surface roughness $R_a < 1 \text{ nm}$
- Because of the manufacturing process the surface layer is contamination-free and with very low sub-surface damages, consisting of nearly only Silicon oxide.
- Values of the core volume of the sphere (i.e. the Si “kernel”) show a stabilisation of the core volume, i.e. almost complete stop of oxidation of the silicon core after manufacturing
- Possible remaining changes are within the uncertainty of the volume measurements of the used sphere interferometers
- The following diagram shows the stability of the core volume exemplarily at a test sphere made of natural silicon

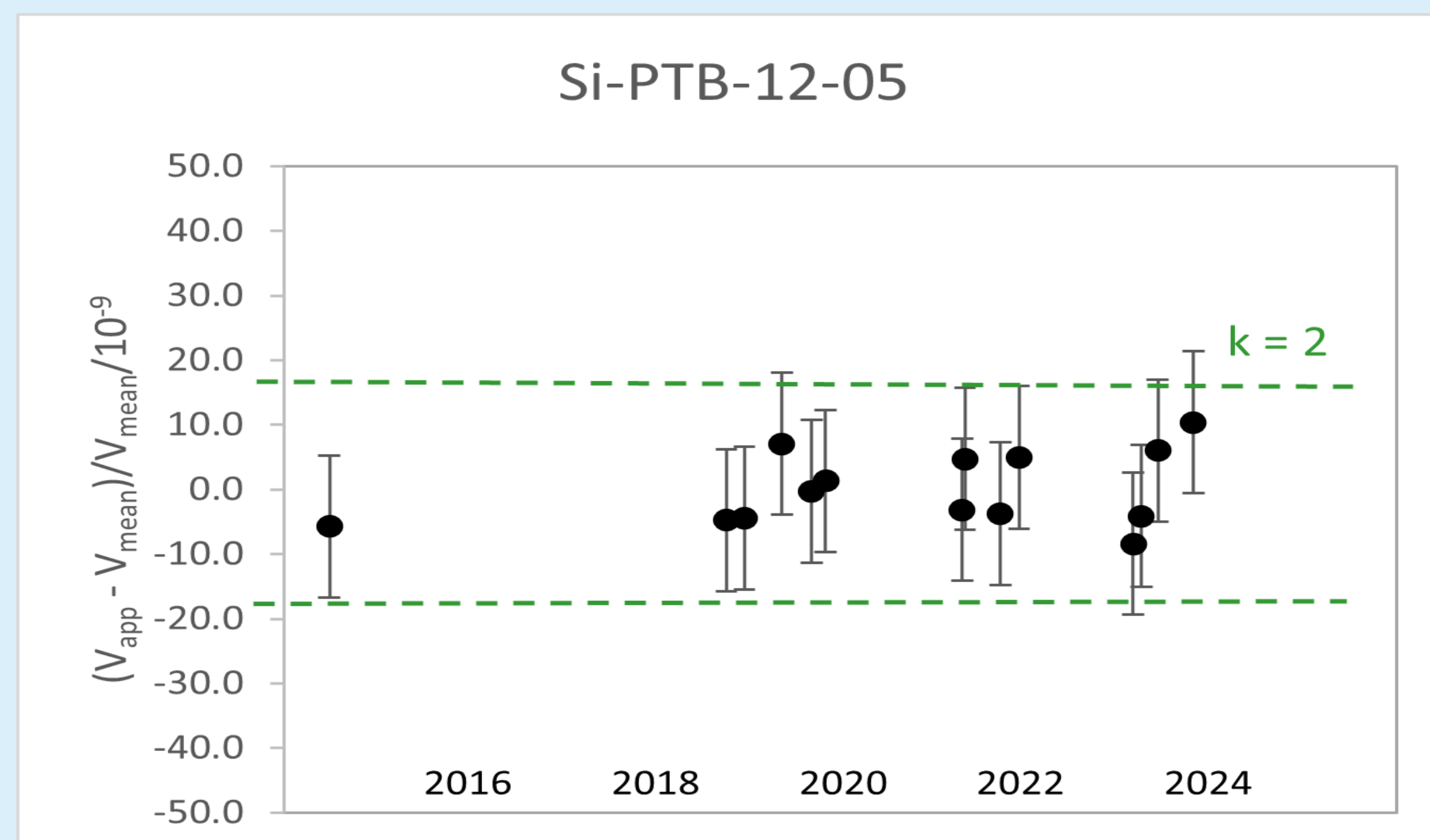


Figure by E. Kuhn, A. Nicolaus, A. Peters

Spheres made of natural silicon



Initial use as “dummies”

- Avoid scratches and other defects on the ^{28}Si spheres
- Check of geometry of measurement and supporting systems
- Investigation of handling measures and cleaning method

Experience of high mass stability even under long term use.

Investigations and Laboratory use

The spheres are in general stable after manufacturing. What are the parameters having possible influences on a “stable” mass standard?

a. Robustness (when using it in a proper manner, like other standards)

- Since the workshop in 2016, individual use and testing of similar spheres made of natural silicon by Si-Trust partners in their labs
- Only condition - use of the recommended tools / cleaning method
- Check of the spheres when back at PTB (after years)
- “use traces” at the surface but so far only neglectable influence on the mass values (a respective publication with Si-Trust partners is in preparation)

b. Stability under different conditions (for example in vacuum, different air conditions,...) – so far no permanent effect recognised

c. Handling including **cleaning** to “reset” the surface of the spheres (see diagram below)

The different density and the larger volume of the spheres require appropriate consideration when comparing masses in air, but it provides a very stable mass reference



Silicon spheres are high stable mass standards even in laboratory use.

Handling investigations

Investigations over almost 5 months show that the best results are obtained using Deconex, ethanol and clear clean cloths, independent of personnel. All values shown are mass differences with an uncertainty of approximately $6 \mu\text{g}$ ($k = 1$),

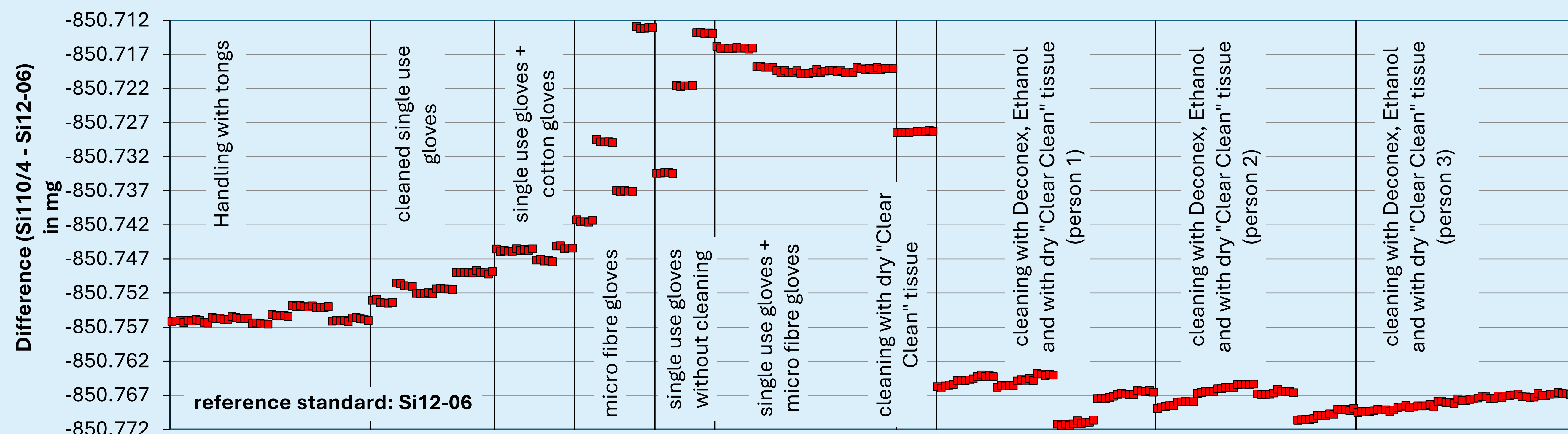


Figure by M. Mecke, M. Hämpke, V. Görlitz