1 Measurement of the Gravitational Constant G

W. Kündig, R. E. Pixley, St. Schlamminger and U. Straumann

The Newtonian gravitational constant G is determined by means of a beam-balance experiment, with an accuracy comparable to that of the best Cavendish-like precise torsion-balance experiments. The gravitational force of two stainless steel tanks filled with $13\,521$ kg mercury on two 1.1 kg test masses has been measured using a commercial mass comparator. The experiment was located at the Paul Scherrer Institute (Villigen, Switzerland) in a 4.5 m deep pit. The pit has thick concrete walls, which provided the thermal and mechanical stability which is essential for the experiment.

The by far largest uncertainty in the determination of G reported earlier from this experiment was due to the assumed nonlinearity of the balance. Since we compare the amplitude of the signal ($784\,\mu$g) to the much larger mass of the calibration weights (both $100\,$mg), any nonlinearity of the balance can produce a systematic error. A rough estimate of this nonlinearity based on information given by the producer *Mettler-Toledo* gave an upper limit of 200 ppm. In order to reduce this large error, we developed a new measurement method which allows to average out the nonlinearity in situ. The amplitude of the signal was measured at many different working points of the balance within the calibration interval. By averaging the different readings, the influence of a possible nonlinearity of the balance is considerably reduced.

The final measurements were done in three different periods with two different test masses made of Copper and Tantalum respectively. Various other systematic effects were investigated, such as sorption effects at the test masses, small temperature dependences and influence of magnetic forces. As a result the final value of G was found [1] to be

$$G = 6.674\,07(22) \times 10^{-11} \;\; \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}.$$

This value is in agreement with other recently published experiments, most of them using a Cavendish type torsion balance (Fig.1.1). The different experimental approaches give rise to completely different systematics. Therefore we can conclude, that most likely there are no significant unknown systematic effects. The experiment, which was originally initiated by W. Kündig, was completed in Summer 2002 and dismantled by the end of 2002. The presently published systematic uncertainties of our experiment are dominated by the nonlinearity of the balance readings and the calculations of the field mass distributions. Walter Kündig and Ralph E. Pixley (both retired) continue to work on the data analysis and try to improve the understanding of all these systematic uncertainties.

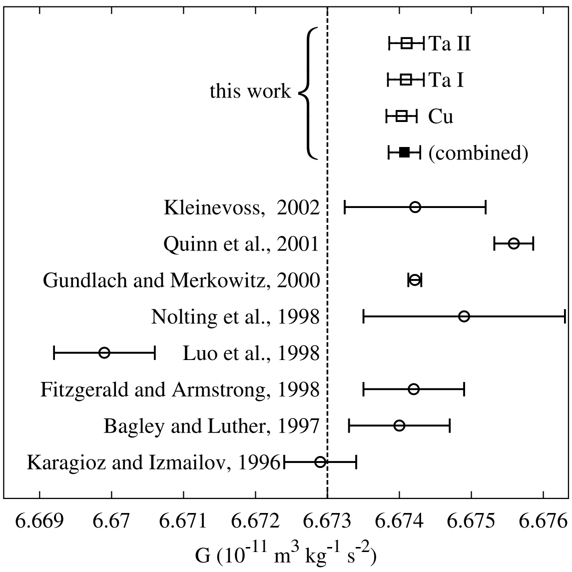

Figure 1.1: *A comparison of recently published values of the Gravitational constant. The dashed line represents the CODATA recommendation of 1998.*

[1] *Determination of the Gravitational Constant with a Beam Balance*
St. Schlamminger, E. Holzschuh, W. Kündig, Phys.Rev.Lett.**89** (2002) Nr. 16, p. 161102.

[2] *Determination of the Gravitational Constant Using a Beam Balance*
Stephan Schlamminger, Dissertation, Zürich, 2002.