

# 1 Determination of Newton's Gravitational Constant

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The measurement of Newton's gravitational constant  $G$  has been an on-going project at our institute since 1994. Walter Kündig directed the gravitation group up until the time of his death in May 2005. Initial interest in this field was motivated by measurements indicating the possibility of a "fifth" force. This prompted measurements at the storage lake in Gigerwald in which the water level varied by 44 m. The experiment involved weighing two test masses (TM's) suspended next to the lake at different heights. No evidence was found (1) for the proposed "fifth" force. But, considering the large distances involved, a reasonably accurate value for Newton's gravitational constant  $G$  was obtained with an uncertainty of 750 ppm.

It was realized that the same type of measurement could be made in the laboratory with much better accuracy with the lake being replaced by the well defined geometry of a vessel containing a dense liquid such as mercury. Equipment for this purpose was designed and constructed in which two 1.1 kg TM's were alternately weighed in the presence of two moveable field masses (FM's) each with a mass of 7.5 tons. The experiment was installed in a quiet area at the Paul-Scherrer-Institut (PSI). A first series of measurements of  $G$  with this equipment resulted in an uncertainty of 220 ppm (2), dominated by the unknown non-linearity of the balance response function.

In a second series of measurements, a system of auxiliary masses was introduced which allowed a systematic variation of the balance loading thereby making possible an estimate of slight nonlinearities in the response function of the balance. A brief report of these measurements has been given in (3) and a more

detailed description in a thesis (4).

Since terminating the measurements, the last three years have been spent in improving the analysis and checking for possible systematic errors. The final analysis results in (5):

$$G = 6.67425(12) \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$$

with a relative uncertainty of 18 ppm. The value is in reasonable agreement with our previously published value (3) which had an uncertainty of 33 ppm. The improvements in the analysis are due to

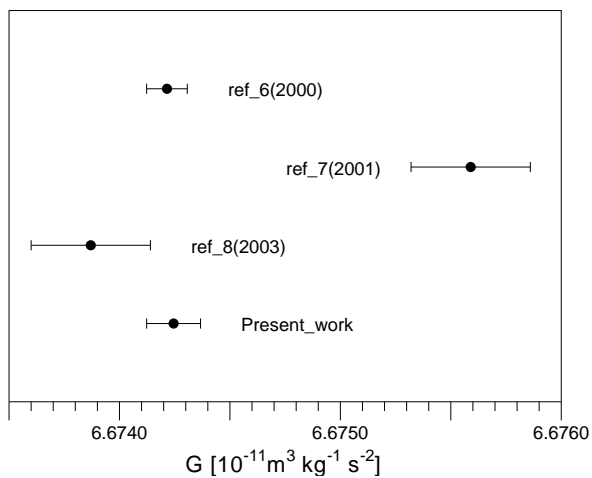
- a more restrictive selection of data,
- a curvature correction for the zero-point drift of the balance,
- a better determination of the response function of the balance and
- the use of the measured mercury density, together with the mass and the volume of the FM's to constrain the mass-integration constant.

The smaller uncertainty obtained for  $G$  was due mainly to an 18 ppm to 6.1 ppm decrease in the relative uncertainty of the response function and a 20 ppm to 6.7 ppm decrease in the relative uncertainty of the mass-integration constant.

In Fig. 1.1, the values of  $G$  obtained in the most accurate torsion balance measurements are compared to that obtained in our beam balance measurement. Due to previous discrepancies in the reported values of  $G$ , all of which were measured with torsion balances, our measurement made with an entirely differ-

ent method is a valuable contribution to the current debate over the true value of  $G$ .

The experiment could not have been carried out without the close support of the Mettler-Toledo company which donated the balance used in this measurement and made their laboratory available for our use. Also, the Swiss Metrological Institute and the Physikalisch-Technische Bundesanstalt, Braunschweig, Germany made a number of certified precision measurements which were very important for this experiment.



**Figure 1.1:**  
Recent measurements of  $G$  with relative errors less than 50 ppm. The labels refer to the experiments described in ref. [6], [7] and [8], respectively.

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See also "Wissenschaftlicher Jahresbericht 2002/3", Physik-Institut Universität Zürich, page 1  
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