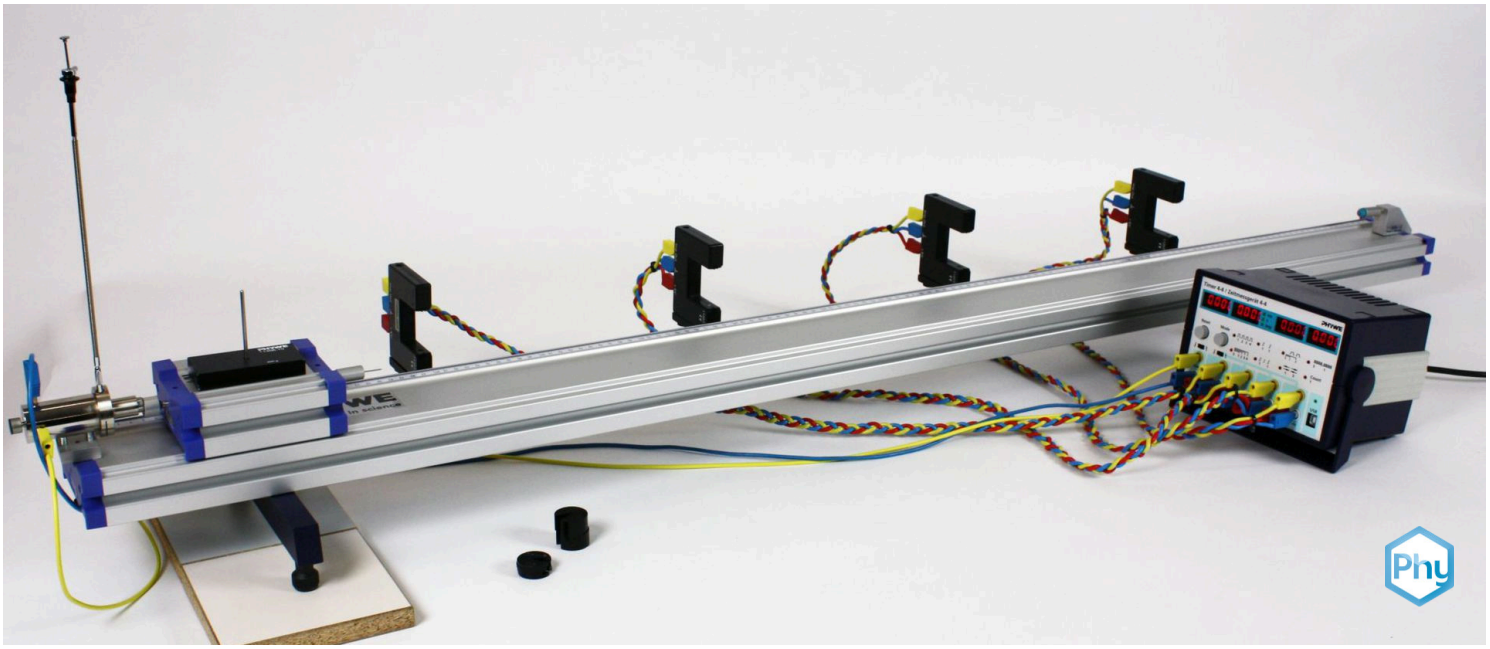
The uniformly accelerated movement with the roller track



Physics > Mechanics > Dynamics & Motion

Difficulty level	Group size	Preparation time	Execution time
medium	2	20 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6004137ef3052e0003c4a255

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General information

Application

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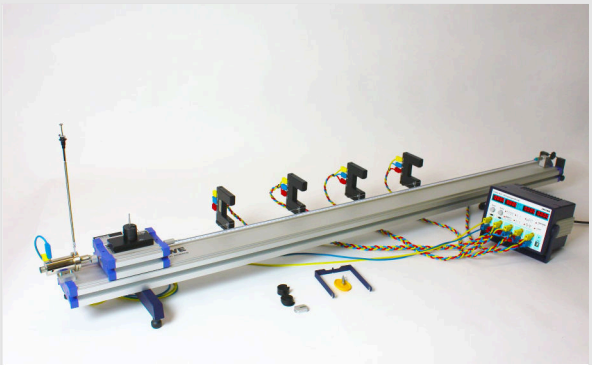

Experiment set-up

If a constant force acts on a body, it experiences a constant acceleration. This will be shown on the roller track by measuring the travel time of a uniformly accelerated car, where its speed increases linearly with time, and the dependence of the distance on time can be described by a parabola.

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Other information (1/2)

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Prior knowledge

Students should be familiar with the basic concept and terminology of classical equations of motion.

Scientific principle

If a constant force acts on an object, its velocity ***v*** changes by the constant acceleration ***a*** and there is a uniformly accelerated movement.

Other information (2/2)

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Learning objective

If a body is accelerated uniformly, the distance covered increases quadratically with time according to the distance-time law. The velocity is linear according to the velocity-time law:

$$s(t) = 0,5 \cdot a \cdot t^2, v(t) = a \cdot t$$

Tasks

1. Determination of the path-time dependence from several time measurements after different distances covered.
2. Determination of the velocity-time dependence from the shadowing time measurement of the light barriers at different positions.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Equipment

Position	Material	Item No.	Quantity
1	Demonstration track, aluminium, 1.5 m	11305-00	1
2	Cart, low friction sapphire bearings	11306-00	1
3	Shutter plate for low friction cart, width: 100 mm	11308-00	1
4	Needle with plug	11202-06	1
5	Tube with plug	11202-05	1
6	Plasticine, 10 sticks	03935-03	1
7	Light barrier, compact	11207-20	4
8	Holder for light barrier	11307-00	4
9	Weight for low friction cart, 400 g	11306-10	1
10	Slotted weight, black, 10 g	02205-01	4
11	Slotted weight, black, 50 g	02206-01	3
12	Slotted weight, blank, 1 g	03916-00	20
13	Weight holder, silver bronze, 1 g	02407-00	1
14	Silk thread, l = 200 m	02412-00	1
15	Holder for pulley	11305-11	1
16	End holder for demonstration track	11305-12	1
17	Pulley for demonstration track	11305-10	1
18	Starter system for demonstration track	11309-00	1
19	Magnet w.plug f.starter system	11202-14	1
20	PHYWE Timer 4-4	13604-99	1
21	Connecting cord, 32 A, 1000 mm, red	07363-01	4
22	Connecting cord, 32 A, 1000 mm, yellow	07363-02	5
23	Connecting cord, 32 A, 1000 mm, blue	07363-04	5

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Set-up and Procedure

Set-up (1/6)

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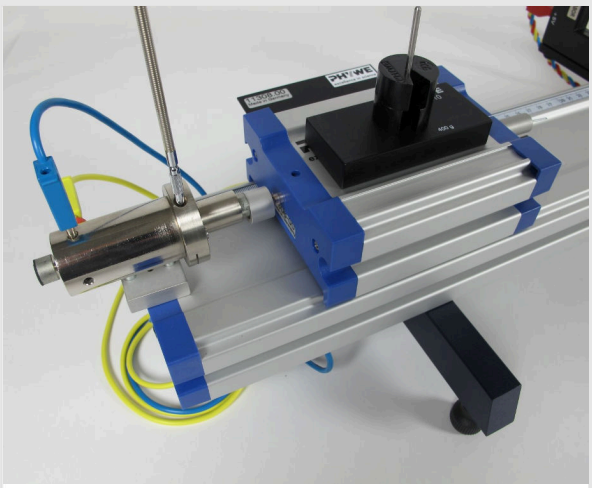

Launching device without shock

1. In order to compensate for minor friction effects, the track must be set at a slight angle using the adjusting screws on the feet so that the measuring carriage just does not start to roll to the right.

2. A launching device shall be installed at the left end of the runway.

Note that to start the trolley with initial pulse, the starting device must be mounted so that the punch moves away from the measuring trolley when triggered.

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Set-up (2/6)

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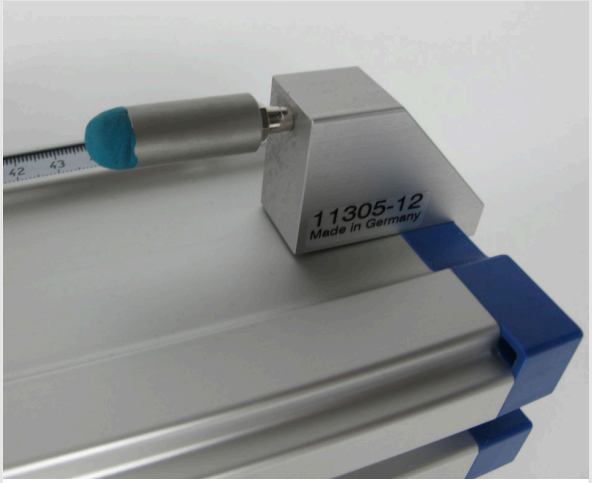

End bracket with plasticine

3. A tube filled with plasticine is attached to the end bracket at the right end of the track to slow the trolley down without hard impact.

4. The deflection roller is attached to the right end of the track with the holder for deflection roller and the incremental wheel is inserted.

Set-up (3/6)

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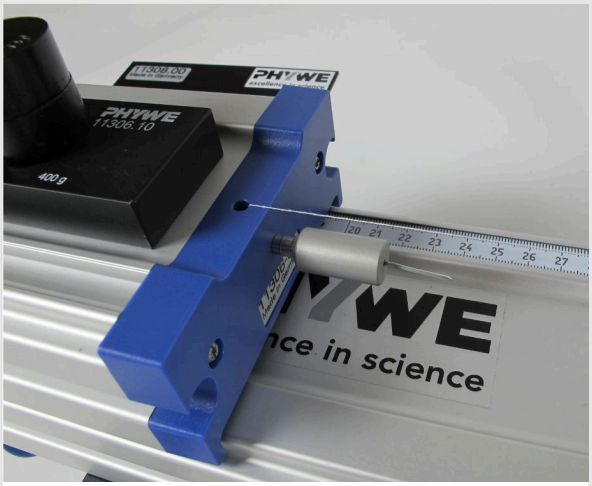

Fastening the thread to the trolley

5. The measuring trolley is equipped with the holding magnet with plug as well as the cover for measuring trolley (b = 100 mm).

6.The beginning of the thread is inserted from above into the vertical hole of the carriage end cap and fixed by inserting the needle with plug from the front.

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Set-up (4/6)

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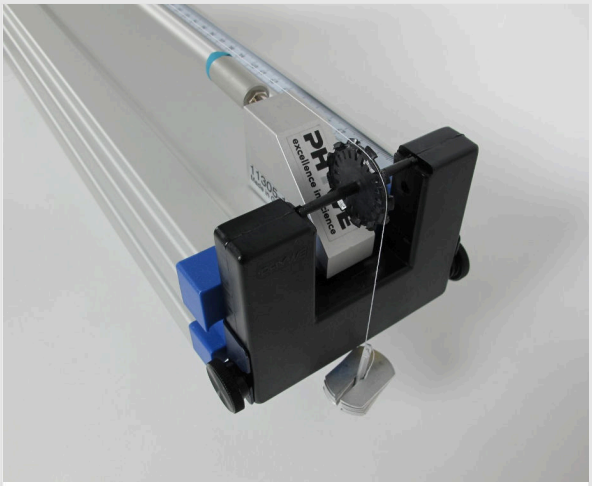

Positioning of the weight plate

7. The thread is placed over the incremental wheel of the deflection pulley and knotted at the end to the weight plate so that it hangs freely directly below the wheel, as shown in the illustration. The weight plate together with the 5-20 slotted weights (1g each) lying on it serve as a constant accelerating force. The thread must run parallel to the track.

8. The mass of the car can be varied by means of the black painted weights.

Set-up (5/6)

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9. The four forked photoelectric sensors are mounted on the roadway with the photoelectric sensor holders and distributed evenly over the measurement section.

When rolling the trolley, make sure that all light barriers can be passed through by the rear part of the screen before the weight plate touches the ground.

10. The forked light barriers are connected from left to right in sequence to the sockets in fields "1" to "4" of the timing device.

The yellow sockets of the light barriers are connected to the yellow sockets of the measuring device, the red sockets to the red sockets and the blue sockets of the light barriers to the white sockets of the time measuring device.

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Set-up (6/6)

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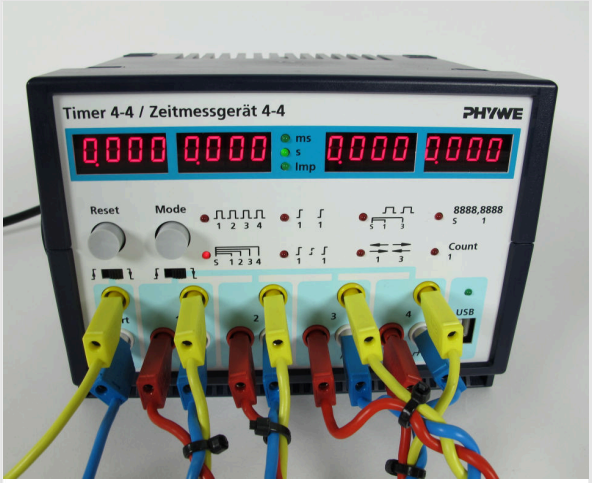

Connecting the light barriers and the starting device

11. The starting device must be connected to the two "Start" connection sockets of the timing device.

Make sure that the polarity is correct.

The red socket of the starting device is connected to the yellow socket of the timing device.

12. The two slide switches on the timing device are set to the right-hand position "falling edge" ( ) to select the trigger edge.

Procedure (1/3)

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1. The distances $s_1 \ldots s_4$ of the light barriers to the start position of the trolley are measured.

It should be noted that the light barriers are only interrupted by the front edge of the panel mounted on the trolley.

For an exact determination of the distances, the following procedure can be followed:

- Move the carriage to the start position and set the value (x_0) on the measuring tape at the right end of the carriage.
- Move the carriage to a position where the right end of the diaphragm just interrupts the light beam of the forked light barrier i and the value (x_i) on the measuring tape at the right end of the carriage.
- $s_i = x_i - x_0$ is the distance the car has travelled from the start to the corresponding light barrier.

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Procedure (2/3)

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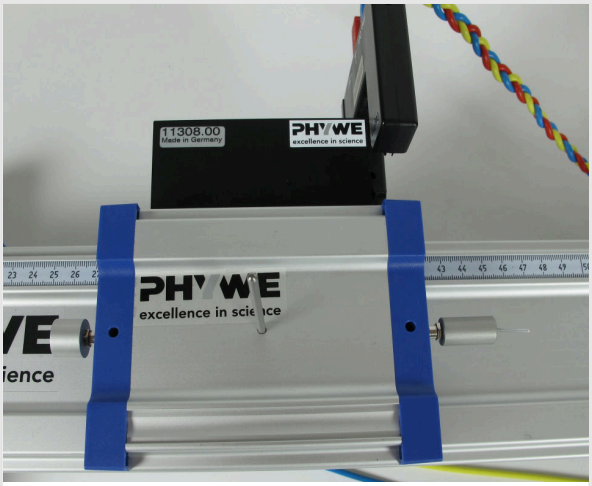

Interruption of the light barrier

2. The measuring carriage is released by the starter and experiences constant acceleration until the weight plate touches the ground. It then continues to roll at a constant speed.

Procedure (3/3)

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3. The times $t_1 \ldots t_4$ which are used to cover the distances $s_1 \ldots s_4$ from the start position to the respective light barrier are determined in mode 2 (S 1 2 3 4). Subsequently, a measurement is performed in mode 1 (1 2 3 4) to determine the corresponding velocities. When performing this measurement, the shadowing times $\Delta t_1 \ldots \Delta t_4$ of the four forked light barriers; the average speed for the corresponding passage can be later calculated via the aperture length (100 mm).

4. The measuring times are recorded for up to five repetitions. Before each execution, press the "Reset" button to reset the displays.

5. The light barriers are now repositioned and another series of measurements is carried out as described above.

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Evaluation (1/5)

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Observation

For increasing distances s_i , the shading times Δt_i become smaller and smaller due to the acceleration of the trolley and the speed of the trolley increases continuously until the weight plate touches the ground.

Evaluation (2/4)

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Measured values

s in m	t_m in s	Δt_m in s	v in m/s	$a = v/t_m$ in m/s²	$(t_m)^2$ in s²	$a=2s/(t_m)^2$ in m/s²
0,23	2,833	0,559	0,179	0,063	8,026	0,057
0,43	3,861	0,424	0,236	0,061	14,907	0,058
0,63	4,665	0,356	0,281	0,06	21,762	0,058
0,83	5,353	0,316	0,316	0,059	28,655	0,058
0,13	2,156	0,71	0,141	0,065	4,648	0,056
0,33	3,442	0,474	0,211	0,061	11,847	0,056
0,53	4,336	0,382	0,262	0,06	18,801	0,056
0,73	5,094	0,332	0,301	0,059	25,949	0,056

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Evaluation (4/5)

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1. From the five measurements each of $t_1 \dots t_8$ and $\Delta t_1 \dots \Delta t_8$, determinethe mean values $t_{1m} \dots t_{8m}$ and $\Delta t_{1m} \dots \Delta t_{8m}$.
2. Determine the velocities from the shading times $v_i(t_{im}) = b/\Delta t_{im}$ with the aperture length b = 0.1 m.
3. For the uniformly accelerated motion, the acceleration can be calculated as a with two different methods. Either via the path-time law $s(t) = 0,5 \cdot a \cdot t^2$ from the running time and the respective position of the light barriers or via the speed-time law $v(t) = a(t) \cdot t$ from the running time and the corresponding speed.

Evaluation (4/5)

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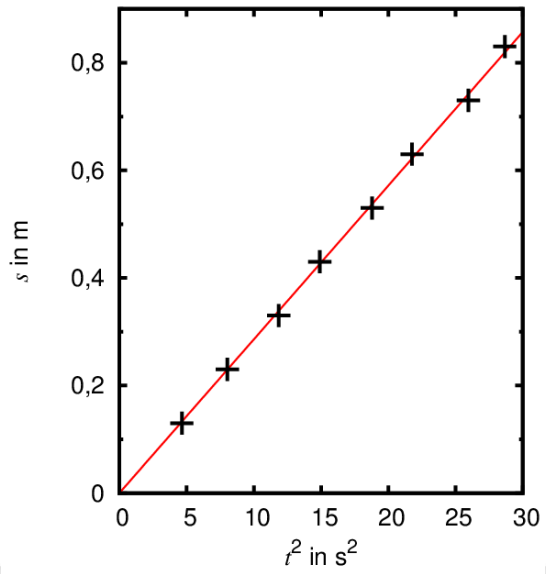
- To verify the displacement-time law, enter the measured values in a (s, t^2) coordinate system. The acceleration a can be calculated graphically from the gradient of the straight line through the zero point $(0, 5 \cdot a)$ as well as by calculation.



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Evaluation (5/5)

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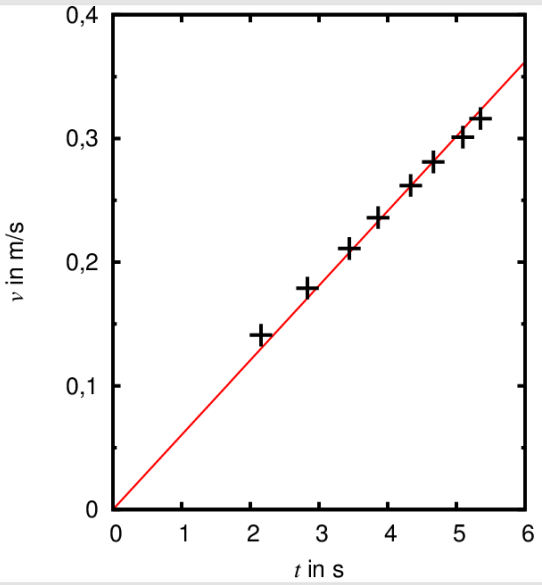
- In a (v, t) coordinate system, plot the determined velocities against the measured time. The velocity-time law is obtained graphically from the slope of the straight line through the zero point or by calculation.



Notes (1/2)

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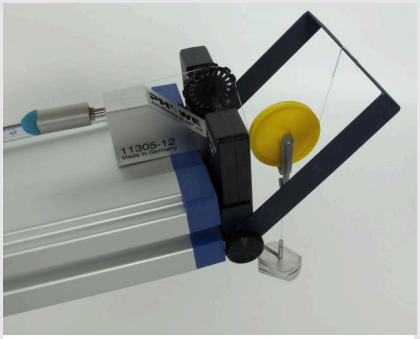

Loose roll for extension

1. If the table height is not sufficient to realize an accelerated movement along the entire length of the web, the acceleration distance can be doubled with the aid of the bracket, which is supplied with the holder for deflection roller, and a loose roller. For this purpose, the bracket is attached to the deflection roller holder.

The end of the thread is now not knotted to the weight plate, but to this shackle. The loose roller, on whose load hook additional weights can be hung, is placed on the thread between the incremental wheel and the bracket as shown in the illustration.

When evaluating, it must be taken into account that only half the weight of the roller and weights accelerates the carriage and on the other hand that the roller and weights only have half the carriage speed.

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Notes (2/2)

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2. This test can be performed with different car and accelerating masses.

3. To reduce the distance between the weight adjuster and the incremental wheel, the thread length can be shortened by turning the needle with plug several times on the carriage, thus winding up the thread.

4. The speeds calculated from Δt_i and v_i are, strictly speaking, not instantaneous velocities, since acceleration continues to act on the carriage as it passes through the light barrier.

The velocities thus proceed from a secant slope, but not from a tangent slope of the graph of $s(t)$. With $\Delta s = 0,1\text{m}$, a systematic error of about 2 % must be expected.

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