# Heating Studies on the HERMES Target Cell

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**Abstract**

Motivated by repeated damage to the target cell in the form of holes, a new cooling circuit has been designed and constructed for the cell in May and June 2006. Since this construction changes the mechanical properties of the target cell, tests to exclude mechanical deformation of the wings were performed. In order to do so, a test stand has been set up in room 406 of the East Hall. Monitoring the behaviour of the wings under heat loads of up to 58 W did not show any measurable deformation. Thus the cell installed in June 2006 has been equipped with this cooling system.

With the cell taken out during the shutdown of June 2006 a heating study has been performed using the same procedure. Here we could monitor the bumps of the thin target cell itself. It was observed that, in fact, the bumps moved significantly (up to 0.9 mm). This happens on a rather short time scale ($\leq 1$ min) when the heating is switched on or off, while the thermometers on the wings show time constants of 20 to 30 min. The effect seems reproducible but the magnitude and recovery time varies. About 60 W power on the heating wire seems to correspond to a typical injection at HERA of 38 mA electron current.

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**Contents**



## 1 Introduction

The target cell for unpolarised gas at the HERMES experiment [1,4] is a dedicated, and very refined construction. It allows to use most gases as an internal windowless target in a lepton beam. A special complication is to provide a smooth impedance for the beam, while shielding the silicon detectors from RF and having very little material for the created particles. These constraints led to the design of a system which is mechanically at the limit of feasibility [5].

Two more-or-less independent activities on the target cell are reported in this document:

- design, construction, and tests of an improved cooling circuit;
- tests on deformation by heating with the previously installed cell.

The common motivation is to understand and hopefully help resolve the three following problems:

- the cell repeatedly developing a hole;
- the temperature on the wings getting so high that quite a few times the beam had to be dumped;
- the silicon detector apparently getting heated by radiation from the cell.

The two latter problems can clearly be tackled by an improved cooling, while there are several scenarios that might explain how the holes were created. One possibility, in which cooling might help, is that the cell gets locally so hot that a crack develops at the weakest point. The fold at the edge of a bump seems a good candidate, as the material is thin there and mechanically strongly stressed. Also, according to calculations [6], the cell will get hottest close to the bumps. This is exactly the location were also the hole in the first target cell was observed. Based on these considerations a new cooling circuit was designed and built. The design and tests are described in Sections 2 and 4.

An alternative theory for the creation of holes is that the thin foil of the cell undergoes some motion due to mechanical stress by heating. As a consequence it may enters the synchrotron fan of the beam. In order to do so the relevant part of the cell has to move vertically by more than one millimetre off its nominal value. After finding a new hole in the second cell dismounted during the June shutdown, we decided to study whether such a scenario is realistic by using the set-up assembled for the test of the cooling circuit (Section 3). The results of the measurements are discussed in Section 5.

## 2 New Cooling Circuit

The new cooling circuit has been designed under the objective to achieve a more efficient and more uniform cooling without requiring any changes to the existing cell. Following this a decision on whether the system should be installed, could be postponed untill the very last moment. This procedure became necessary due to time constraints.

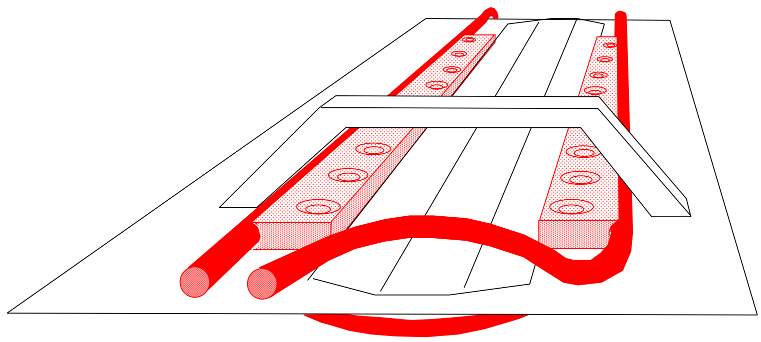


Fig. 1. Schematic view of the cooling pipes (filled red) and mounting rails (dotted red) running along the target cell. The sketch is not to scale and strongly simplified. Please also refer to the photographs in Figure 3.

To improve the cooling circuit several changes were made. By increasing the inner diameter of the pipes to about 3 mm throughout the whole system the water flow could be increased by a factor of 2 (now 1.5 l/s). The larger inner diameter could be achieved using stainless-steel pipes with only 150 $\mu$m wall thickness, purchased from Oxford Instruments, Oxon, OX29 4TL, UK. Mounting the pipes along the whole length of the wings, close to the foil, avoids large temperature gradients on the wings and reduces the temperature at the centre. By clamping cooling strips symmetrically to the top and bottom surface of the target cell deformations to the target wings due to bi-metal effects and temperature gradients should be avoided.

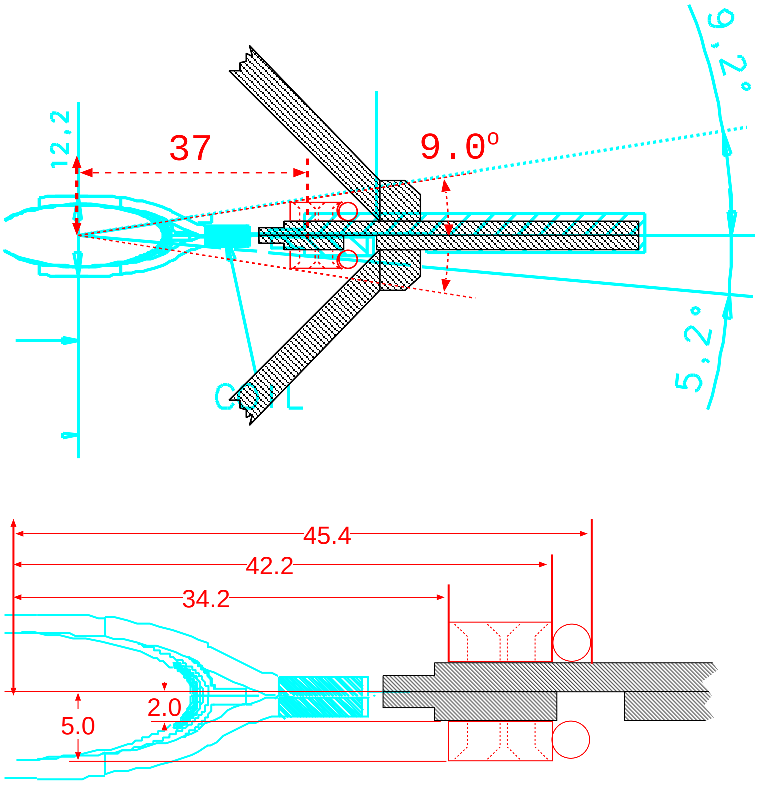



Fig. 2. Downstream cross section of the cooling pipes and mounting rails running below the bridges. In blue: a drawing of the old cell, in black: wings and bridges of the new cell, and in red: the newly added parts.

| coordinate | rails [mm] | straight pipes [mm] | downstream ends [mm] |
|---|---|---|---|
| x | ±(34.2 to 42.2) | ±(42.2 to 45.4) | ±(42.2 to 45.4) |
| y | ±(2.0 to 5.0) | ±(2.0 to 5.2) | ±(2.0 to 10.0) |
| z | –11 to +294* | ∼–23 to ∼+318 | ∼+318 to ∼+358 |

Table 1
Dimensions of the fittings for the cooling circuit in the HERMES coordinate system. The mounting rails are copper while the pipes are stainless steel filled with water. *In the current installation the 4 rails are shifted by 40 mm downstream, i.e. $z = (+29$ to $+334)$ mm

In Figs. 1 and 2 the construction is sketched. A more complete set of drawings can be found in http://www.desy.de/∼inti/share/h/target/cell_design.pdf. The dimensions are listed in Table 1. A single stainless-steel pipe (3.2 mm×0.15 mm, outer diameter × wall thickness respectively) was bend to run up and down along the target. By using sand inside the pipe before bending, a bending radius of below 10 mm could be achieved at the downstream ends, keeping the HERMES acceptance almost unaffected. A quick Monte Carlo study indicates that the cooling pipes with the 10 mm radius at the downstream end are near but outside the hermes acceptance [3]. Copper rails hard soldered to

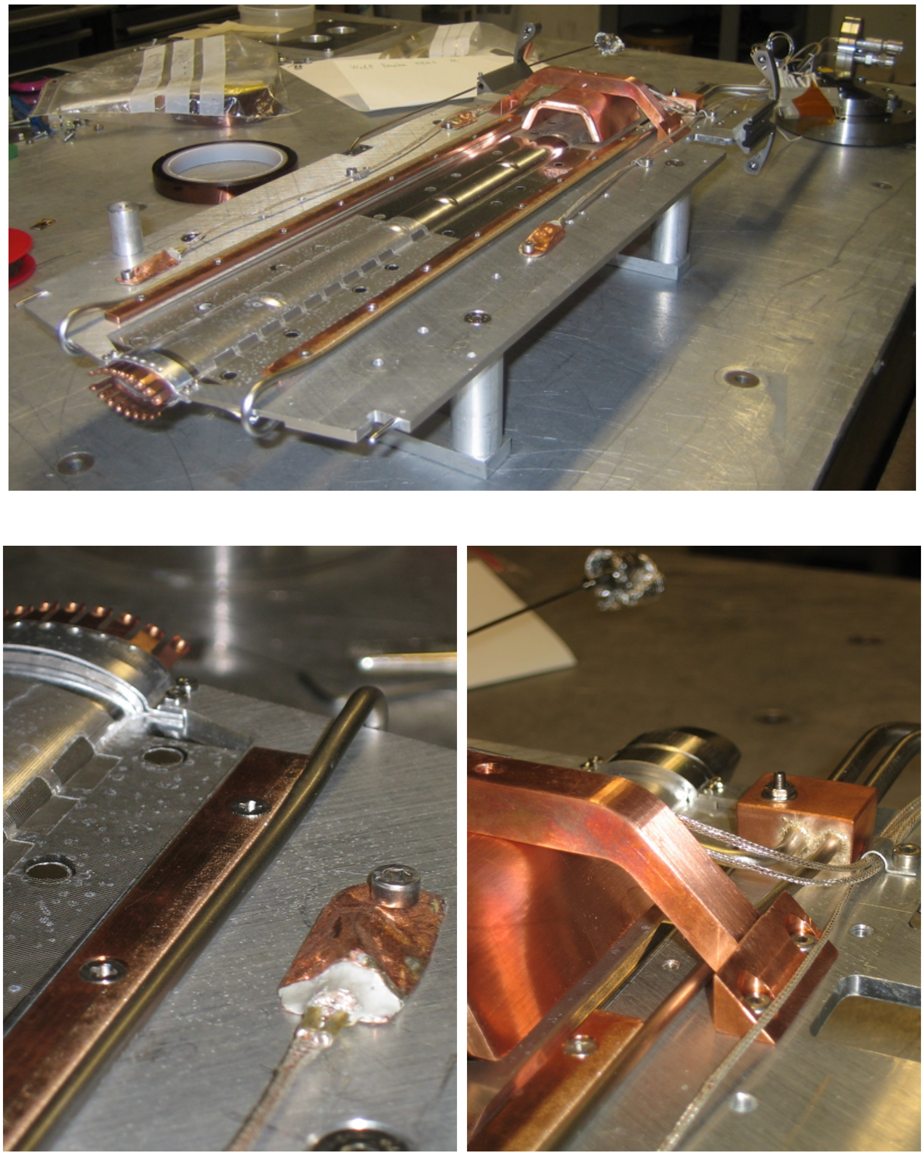


Fig. 3. Photographs of the cooling system as mounted on the target cell installed during the June shutdown.

the straight parts of the pipe are used to connect the pipe to the cell and ensure good thermal contact. The system stays below $\pm 9^{\circ}$ in azimuthal angle $\phi$ (relative to the horizontal plane). Thus it does not impinge on the acceptance of the Recoil Silicon Detector. A copper block at the left upstream part serves the two following purposes: it allows for a transition from the thin-walled pipe on the target cell to the connector pipe, and gives stability to avoid bending forces on the thin pipe. For the connection pipes inside the vacuum and directly outside stainless steel pipes with $4.0\,\mathrm{mm} \times 0.5\,\mathrm{mm}$ were used. [1] The

[1] For the spare system, which is currently under construction a minimum inner diameter of 4 mm will be provided for all connection lines. This could not be achieved

system was leak chased and pressure tested up to 12 bar.

First results from the experiment show that, indeed, the temperatures measured on the wings are significantly reduced after the installation of the new cooling circuit. In Figure 4 two HERA fills are compared: one on the $24^{\text{th}}$ May with a e-beam intensity of $I_e = 21\,\text{mA}$, where we believe that there was no hole yet in the cell (red dotted line), and one on the $28^{\text{th}}$ July with $I_e = 30\,\text{mA}$, where the new cooling system was installed. The longer time needed to heat the wings is expected as the heat capacity was increased due to the addition of material. Furthermore, the sensor has moved by 2.5 cm away from the beam axis. Nevertheless, one can claim that the heating of the wings is significantly reduced. A quantity which is more sensitive to the heat load carried away by the cooling system is the time constant which characterises the time in which the cell cools down after an injection. This "decay time" $\tau$ is reduced from about 40 min to less than 10 min (see the $e^{-t/\tau}$-fits in Figure 4). The cell reaches equilibrium temperatures already in the beginning of a fill, while before the cell stayed warmer untill the very end of a fill.

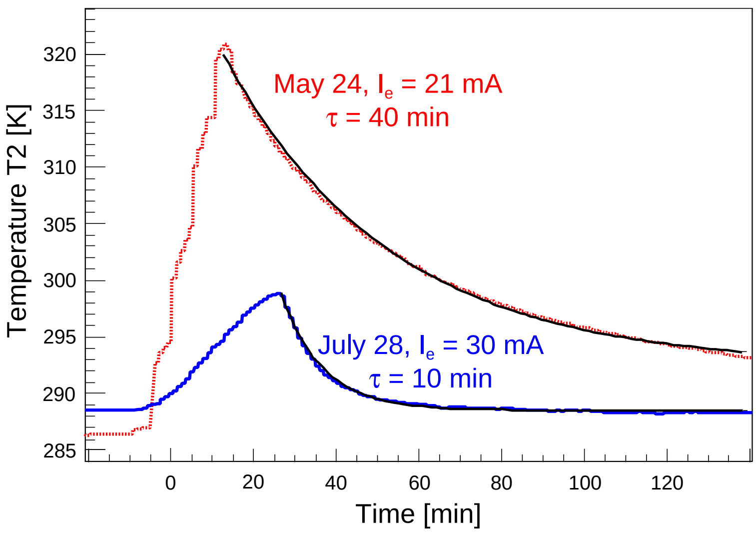



Fig. 4. Temperature development (T2) of the target cell during a HERA injection. The measurements were taken in one of the first fills after the installation in May (red dotted line), and in a fill in July where the new cooling system was in operation (solid blue line). The thin black lines show exponential fits to determine the decay time (see labels and text).

for the first system, as the required new vacuum feed through could not be produced on short notice.

## 3 Set-Up for Cell Studies

In room 406 of the HERA east hall a pumping stand resembling the situation in HERA has been set up. Pressures of a few times $10^{-6}$ mbar were reached when the measurements were performed. Therefore the heat transport by conductance through air can be safely neglected. The dimensions of the scattering chamber and servicing chamber are identical to the system installed in the ring. [2] A heating wire with an active length of 42 cm was spanned through the target cell. The wire was suspended by two independent supports about 10 cm away from the cell and tensioned by springs. By measuring the current applied to the wire and its resistance the total power was calculated. At about 40 W the wire started to glow visibly. A challenge is that the wire is quite stiff and it is difficult to feed it through the cell without deforming it.

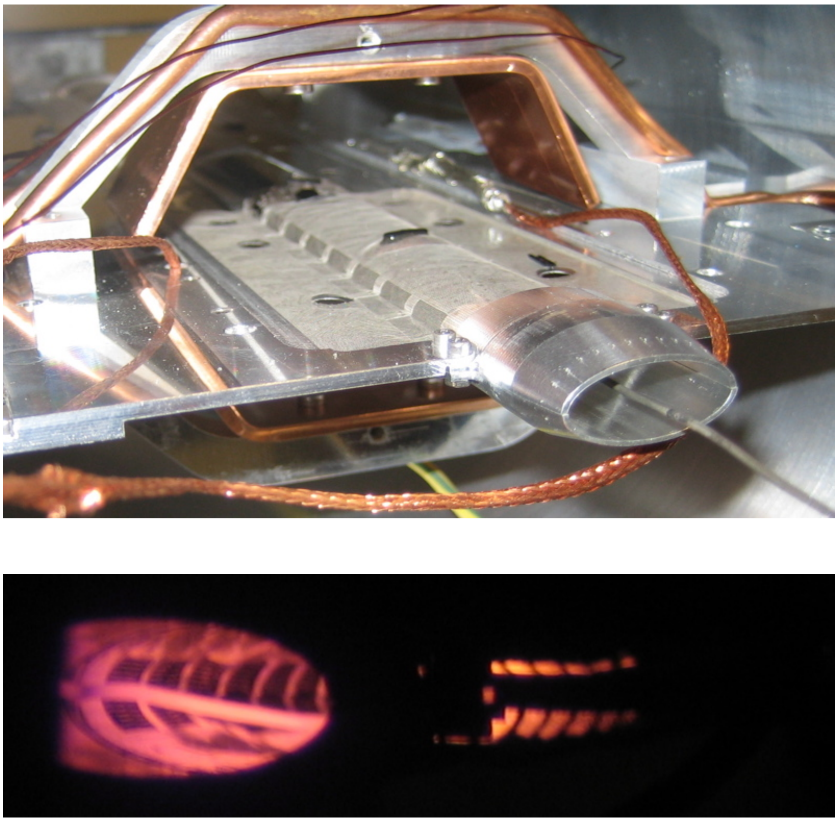


Fig. 5. Photographs showing the wire spanning through the target cell. Lower photograph: when applying a voltage that corresponds to about 70 W to it. The wire is clearly glowing in the dark.

[2] One of the scattering chambers has a manufacturing defect, which impedes the use of 2 pins at the downstream end of the cell. Furthermore, the servicing chamber had to be extended by 5 mm due to a design error.

For the spatial measurements a levelling instrument from the survey group was used. Once adjusted it is sensitive to changes in vertical position of below 100 $\mu$m. The prerequisite to measure several points is that they lie on a single optical path and that they are level within 1 cm. Thus we could measure up to 4 points on one surface of the cell by varying the focus only. Tests showed that, indeed, an accuracy of 100 $\mu$m can be easily reached proceeding this way.

## 4 Tests for the New Cooling

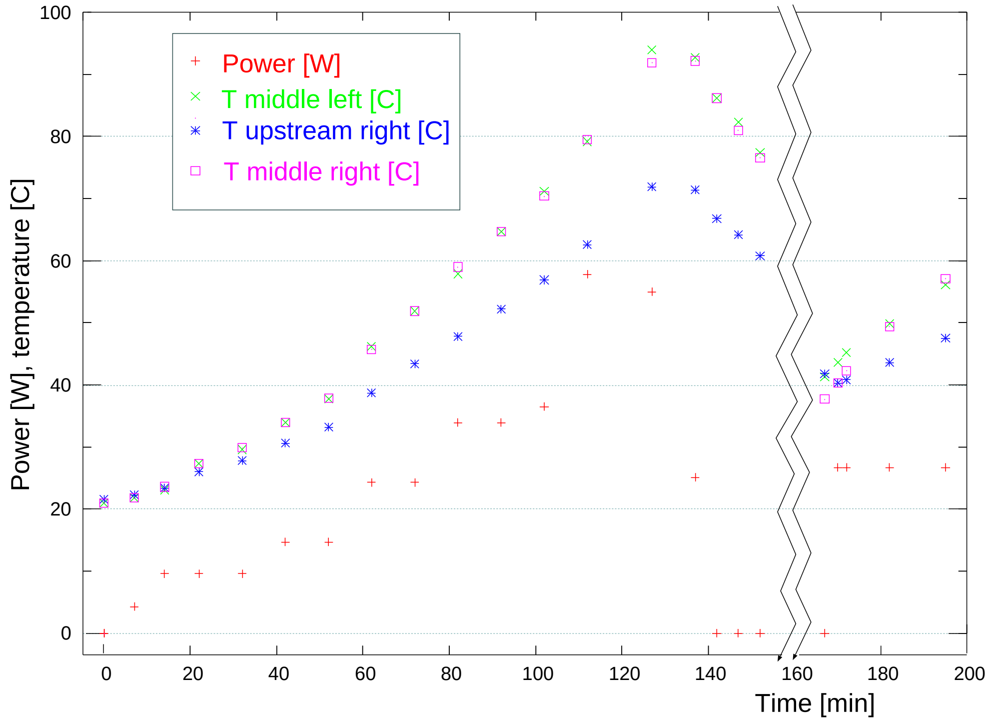



Fig. 6. Power (red crosses) and temperatures on the wings *versus* relative time. At about 160 min a break was taken, which is not reflected on the time axis.

The system was mounted onto the first broken cell (taken out in the May shutdown). This cell was mounted into the pump stand in 406 (see Section 3) and equipped with the heating wire. As cooling feed pipes two 50 cm long copper pipes of dimensions 4 mm×1 mm (i.e. 2 mm inner diameter) were used. Already without the cooling circuit the water flow was below 1 l/min. It was observed that the time constants for changes on the wings were very large. A measurement of the water temperature on the outside surface of the in-and-out lines did not show any effect, except a global temperature rise corresponding to the heating of the whole flange. Thus it seems that the heat conductance of the metal dominates over the cooling due to the water flow. These findings led to a redesign of the feed pipes for the installation at HERMES. There the pipes have the minimal inner diameter of 3 mm for 5 cm length only. This difference has to be taken into account when comparing the current situation at the experiment with the tests described here. Currently at HERA injections ($I_e = 30\,\mathrm{mA}$) the water-output temperature is increasing by less than 0.5 K while the input temperature stays constant.

Three positions along the wing were monitored while changing the heating power. The maximum power of about 56 W was kept for 25 minutes. Although the temperature of the wings increased to a maximum of 100° C (see Figure 6) no change of position could be observed on the wings (see Table 2). This led to the conclusion that the additional stresses imposed by the cooling system on the wings will not result in problems for the mechanical structure of the target.

| power [W] | $T_{ml}$ [C] | $T_{ur}$ [C] | $T_{mr}$ [C] | $y_u$ [mm] | $y_m$ [mm] | $y_d$ [mm] |
|---|---|---|---|---|---|---|
| 0 | 21.0 | 21.6 | 21.0 | 2.1 | - | 4.5 |
| 4 | 21.8 | 22.3 | 21.8 | 2.2 | - | 4.5 |
| 10 | 23.1 | 23.4 | 23.6 | 2.2 | - | 4.5 |
| 10 | 27.3 | 26.0 | 27.3 | 2.1 | - | 4.5 |
| 10 | 29.6 | 27.8 | 29.9 | 2.2 | 3.5 | 4.5 |
| 15 | 34.0 | 30.6 | 34.0 | 2.2 | 3.5 | 4.5 |
| 15 | 37.7 | 33.2 | 37.9 | 2.1 | 3.6 | 4.5 |
| 24 | 46.2 | 38.7 | 45.7 | 2.1 | 3.5 | 4.5 |
| 24 | 51.9 | 43.4 | 51.9 | 2.1 | 3.5 | 4.5 |
| 34 | 57.9 | 47.8 | 59.0 | 2.1 | 3.5 | 4.5 |
| 34 | 64.7 | 52.2 | 64.7 | 2.1 | 3.5 | 4.5 |
| 36 | 71.2 | 56.9 | 70.4 | - | - | - |
| 58 | 79.2 | 62.6 | 79.5 | 2.1 | 3.5 | 4.5 |
| 55 | 94.0 | 71.9 | 91.9 | 2.1 | 3.5 | 4.5 |
| 25 | 92.7 | 71.4 | 92.2 | 2.0 | 3.5 | 4.6 |
| 0 | 86.2 | 66.8 | 86.2 | 2.0 | 3.5 | 4.6 |
| 0 | 82.3 | 64.2 | 81.0 | 2.1 | 3.5 | 4.6 |
| 0 | 77.4 | 60.8 | 76.6 | 2.1 | 3.5 | 4.6 |
| 0 | 41.3 | 41.8 | 37.7 | 2.1 | 3.5 | 4.6 |
| 27 | 43.6 | 40.3 | 40.3 | - | - | - |
| 27 | 45.2 | 40.8 | 42.3 | 2.1 | 3.6 | 4.6 |
| 27 | 49.9 | 43.6 | 49.4 | 2.1 | 3.5 | 4.6 |
| 27 | 56.1 | 47.5 | 57.1 | 2.2 | 3.5 | 4.6 |

Table 2
Measurements of wing deformation with new cooling circuit: Heating power, temperatures ($T_{ml}$, $T_{ur}$, and $T_{mr}$ middle left, upstream right, and middle right, respectively) and vertical coordinates ($y_u$, $y_m$, and $y_d$ for the upstream end, middle, and downstream end of the target, respectively) for all measurement points. The values vary within the expected uncertainty of the measurement of $100\,\mu$m.

## 5 Studies on Foil Deformation

Here the same system was used to study the stability of the cell foil. This time the well prepared scattering chamber (which is identical to the one used at the experiment and allows to hold all the pins) was available and hence used. Thus we mounted the cell with all pins and screws. At a vacuum of a few times $10^{-6}$ mbar we used the construction described in Section 3 to simulate a homogeneous heating along the cell. We also used the cooling circuit as in the experiment, taking even the connector pipes which were used during the last running in HERA. Therefore we can safely assume that the external conditions are quite similar to the ones over the last weeks. However, the nature of the heat source at HERA remains unknown. Therefore the homogeneous heating along the whole length applied in this test is just an assumption.

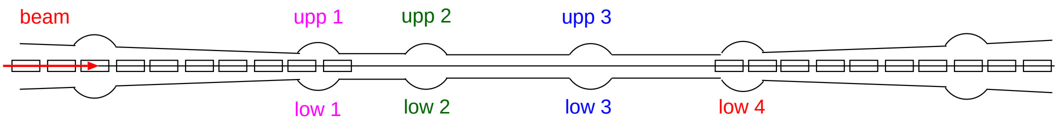
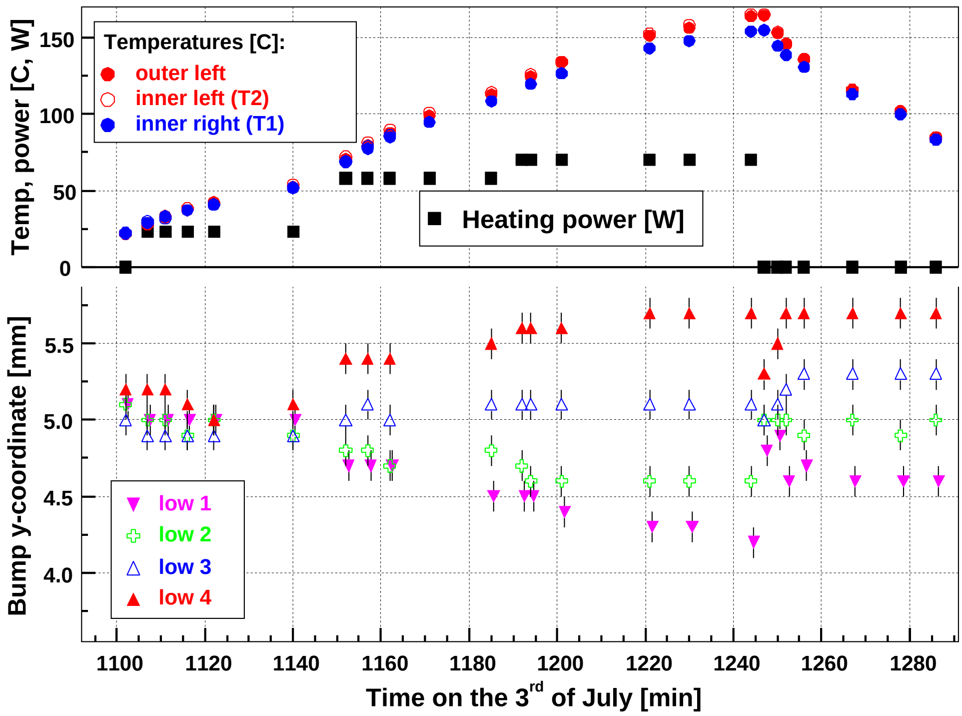



Fig. 7. Sketch of the target cell (side view) showing the bumps which were monitored during the measurements. The hole is located on the edge of bump “upp 1”.

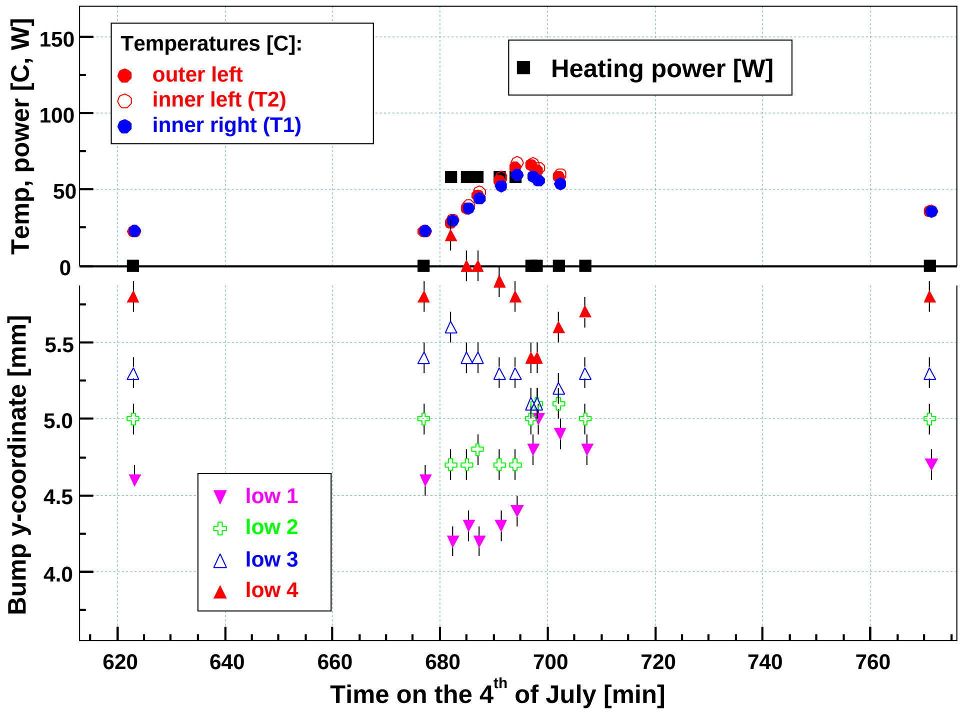
Using again the levelling instrument, we measured the vertical coordinate of the top of the central 4 lower bumps and of 3 upper bumps (see Figure 7). For the lower bumps a heating power of 23, 58, and 70 W was applied to the wire. The temperatures on the wings were recorded simultaneously. The values obtained are listed in Table 3 and plotted in Figure 8. We redid the measurements for the upper bumps with 58 W (see Table 4 and Figure 9). The studies were repeated a few times to check the reproducibility. The behaviour remained unchanged.

The behaviour of the temperature sensors suggests a time constant of the wings of 20 to 30 minutes, i.e. it takes that long for the wings to cool down from 120 to 70 degree Celsius. When comparing the temperature behaviour with the behaviour inside the ring at injections with 40 mA e-beam intensities, we found a similar temperature behaviour using a power of 58 W on the wire [3]. It is most likely that a large fraction of this power is indeed transferred to the cell. Thus we have to assume that we routinely had about 60 W heating at HERA injections. Even if the power transferred was smaller, the experiment using 58 W on the wire reproduces the observed heating of the target cell in HERA.

[3] Note that the inner temperature sensors were used unchanged as in the experiment.




(a) Measurements 3rd July 2006




(b) Measurements 4th July 2006

Fig. 8. Measurements of the lower bump movement with the second cell. Upper part: heating power and temperatures on the wings. Lower part: vertical coordinates of the bump tops ($\text{low}_i$ with $i = 1 - 4$ see Figure 7). Details see text.

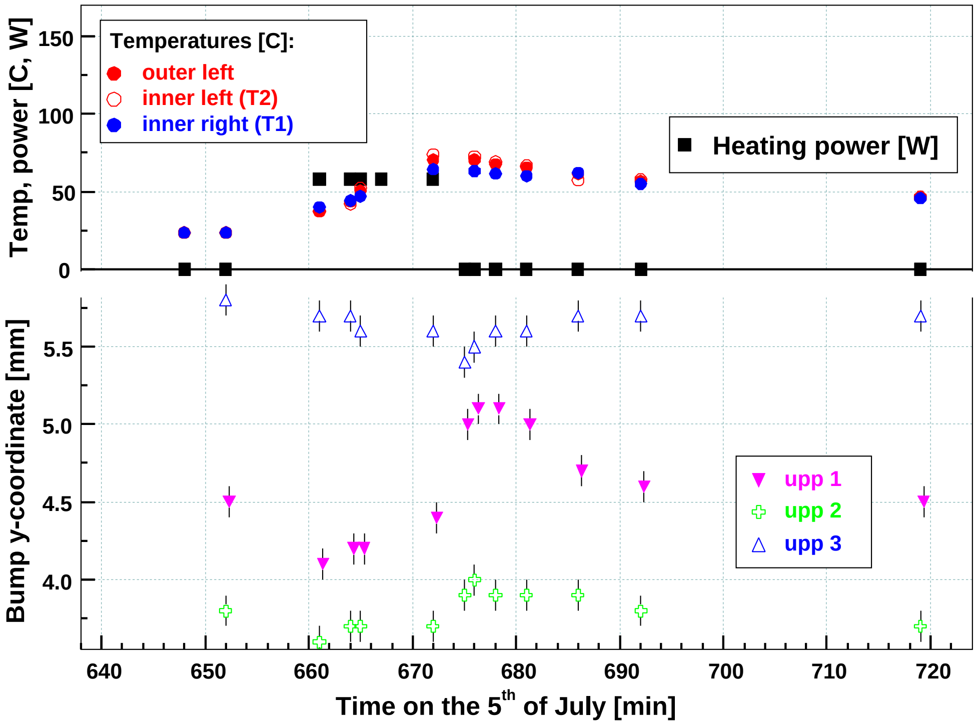



Fig. 9. Measurements of the upper bump movement with the second cell. Upper part: heating power and temperatures on the wings. Lower part: vertical coordinates of the bump tops ($\mathrm{upp}_i$ with $i = 1 - 3$ see Figure 7). Details see text.

The remarkable feature found was that the bumps moved significantly when the heating was switched on or off. This effect occurs on a short time scale (about 30 sec) and is well reproducible. The magnitude of the shifts changes, but a maximum "jump" of 0.9 mm was observed. It seems that the cell starts to relax again several minutes after the change. The first measurements taken may thus not represent the maximum deviation, as we did not measure immediately after switching on. Also the cell does not always come back to its original shape, as observed after the first measurements for the lower bumps (compare the first and later positions at room temperature in Figure 8).

| date | time | power [W] | $T_{ol}$ [C] | $T_{il}$ [C] | $T_{ir}$ [C] | $\text{low}_1$ [mm] | $\text{low}_2$ [mm] | $\text{low}_3$ [mm] | $\text{low}_4$ [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 3/7/06 | 18:22 | 0 | 21.8 | 22.1 | 22.3 | 5.1 | 5.1 | 5.2 | 5.0 |
| 3/7/06 | 18:22 | Switch to 23 W heating | | | | | | | |
| 3/7/06 | 18:27 | 23 | 27.8 | 28.3 | 28.8 | 5.2 | 5.2 | 5.3 | 5.0 |
| 3/7/06 | 18:31 | 23 | 32.2 | 33.0 | 33.0 | 5.2 | 5.2 | 5.3 | 5.0 |
| 3/7/06 | 18:36 | 23 | 37.1 | 38.2 | 37.1 | 5.2 | 5.3 | 5.3 | 5.1 |
| 3/7/06 | 18:42 | 23 | 41.6 | 42.3 | 40.8 | 5.2 | 5.2 | 5.3 | 5.2 |
| 3/7/06 | 19:00 | 23 | 52.2 | 53.5 | 51.4 | 5.2 | 5.3 | 5.3 | 5.1 |
| 3/7/06 | 19:05 | Switch to 58 W heating | | | | | | | |
| 3/7/06 | 19:12 | 58 | 70.4 | 71.9 | 69.1 | 5.5 | 5.4 | 5.2 | 4.8 |
| 3/7/06 | 19:17 | 58 | 79.5 | 81.3 | 77.4 | 5.5 | 5.4 | 5.1 | 4.8 |
| 3/7/06 | 19:22 | 58 | 87.5 | 89.4 | 84.7 | 5.5 | 5.5 | 5.2 | 4.8 |
| 3/7/06 | 19:31 | 58 | 98.7 | 100.5 | 94.8 | | | | |
| 3/7/06 | 19:45 | 58 | 112.5 | 114.0 | 108.3 | 5.7 | 5.4 | 5.1 | 4.7 |
| 3/7/06 | 19:50 | Switch to 70 W heating | | | | | | | |
| 3/7/06 | 19:52 | 70 | - | - | - | 5.7 | 5.5 | 5.1 | 4.6 |
| 3/7/06 | 19:54 | 70 | 124.4 | 125.7 | 119.7 | 5.7 | 5.6 | 5.1 | 4.6 |
| 3/7/06 | 20:01 | 70 | 133.8 | 133.8 | 126.5 | 5.8 | 5.6 | 5.1 | 4.6 |
| 3/7/06 | 20:21 | 70 | 150.9 | 152.2 | 142.6 | 5.9 | 5.6 | 5.1 | 4.5 |
| 3/7/06 | 20:30 | 70 | 156.1 | 158.2 | 147.5 | 5.9 | 5.6 | 5.1 | 4.5 |
| 3/7/06 | 20:44 | 70 | 163.9 | 164.7 | 153.8 | 6.0 | 5.6 | 5.1 | 4.5 |
| 3/7/06 | 20:45 | Switch off heating | | | | | | | |
| 3/7/06 | 20:47 | 0 | 164.2 | 164.9 | 154.8 | 5.4 | 5.2 | 5.2 | 4.9 |
| 3/7/06 | 20:50 | 0 | 152.7 | 153.5 | 144.4 | 5.3 | 5.2 | 5.1 | 4.7 |
| 3/7/06 | 20:52 | 0 | 145.7 | 145.7 | 138.4 | 5.6 | 5.2 | 5.0 | 4.5 |
| 3/7/06 | 20:56 | 0 | 135.8 | 135.6 | 130.6 | 5.5 | 5.3 | 4.9 | 4.5 |
| 3/7/06 | 21:07 | 0 | 115.8 | 115.6 | 113.0 | 5.6 | 5.2 | 4.9 | 4.5 |
| 3/7/06 | 21:18 | 0 | 101.8 | 101.6 | 99.7 | 5.6 | 5.3 | 4.9 | 4.5 |
| 3/7/06 | 21:26 | 0 | 84.7 | 84.4 | 83.1 | 5.6 | 5.2 | 4.9 | 4.5 |
| 4/7/06 | 10:23 | 0 | 22.6 | 22.6 | 22.9 | 5.6 | 5.2 | 4.9 | 4.4 |
| 4/7/06 | 11:17 | 0 | 22.6 | 22.6 | 22.9 | 5.6 | 5.2 | 4.8 | 4.4 |
| 4/7/06 | 11:17 | Switch to 58 W heating | | | | | | | |
| 4/7/06 | 11:22 | 58 | 28.1 | 30.1 | 29.9 | 6.0 | 5.5 | 4.6 | 4.0 |
| 4/7/06 | 11:25 | 58 | 37.7 | 39.5 | 37.7 | 5.9 | 5.5 | 4.8 | 4.2 |
| 4/7/06 | 11:27 | 58 | 46.0 | 48.1 | 44.2 | 6.0 | 5.4 | 4.8 | 4.2 |
| 4/7/06 | 11:31 | 58 | 55.6 | 58.4 | 52.2 | 5.9 | 5.5 | 4.9 | 4.3 |
| 4/7/06 | 11:34 | 58 | 64.4 | 67.5 | 59.5 | 5.8 | 5.5 | 4.9 | 4.4 |
| 4/7/06 | 11:36 | Switch off heating 30 s before measurement | | | | | | | |
| 4/7/06 | 11:37 | 0 | 66.0 | 67.0 | 58.4 | 5.4 | 5.2 | 5.1 | 4.8 |
| 4/7/06 | 11:38 | 0 | 62.3 | 63.9 | 55.8 | 5.2 | 5.1 | 5.1 | 4.8 |
| 4/7/06 | 11:42 | 0 | 58.4 | 59.7 | 53.8 | 5.3 | 5.1 | 5.0 | 4.6 |
| 4/7/06 | 11:47 | 0 | - | - | - | 5.4 | 5.2 | 4.9 | 4.5 |
| 4/7/06 | 12:51 | 0 | 35.8 | 35.8 | 35.6 | 5.5 | 5.2 | 4.9 | 4.4 |
| 5/7/06 | 10:48 | 0 | 23.4 | 23.4 | 23.4 | 5.6 | 5.2 | 4.9 | 4.4 |

Table 3

Measurements of the lower bump movement with the second cell: Heating power, temperatures ($T_{ol}$, $T_{il}$, and $T_{ir}$ outer left, inner left, and inner right, respectively) and vertical coordinates of the bump tops ($\text{low}_i$ with $i = 1-4$ see Figure 7). Details see text.

| date | time | power [W] | $T_{ol}$ [C] | $T_{il}$ [C] | $T_{ir}$ [C] | $upp_1$ [mm] | $upp_2$ [mm] | $upp_3$ [mm] |
|---|---|---|---|---|---|---|---|---|
| 5/7/06 | 10:52 | 0 | 23.4 | 23.4 | 23.4 | 4.5 | 5.2 | 3.2 |
| 5/7/06 | 10:58 | Switch to 58 W heating | | | | | | |
| 5/7/06 | 11:01 | 58 | 37.4 | 37.4 | 39.7 | 4.9 | 5.4 | 3.3 |
| 5/7/06 | 11:04 | 58 | 43.4 | 41.8 | 44.2 | 4.8 | 5.3 | 3.3 |
| 5/7/06 | 11:05 | 58 | 50.6 | 52.2 | 46.8 | 4.8 | 5.3 | 3.4 |
| 5/7/06 | 11:12 | 58 | 70.4 | 73.5 | 64.4 | 4.6 | 5.3 | 3.4 |
| 5/7/06 | 11:15 | Switch off heating 30 s before measurement | | | | | | |
| 5/7/06 | 11:15 | 0 | - | - | - | 4.0 | 5.1 | 3.6 |
| 5/7/06 | 11:16 | 0 | 70.6 | 72.2 | 63.1 | 3.9 | 5.0 | 3.5 |
| 5/7/06 | 11:18 | 0 | 67.5 | 69.1 | 61.6 | 3.9 | 5.1 | 3.4 |
| 5/7/06 | 11:21 | 0 | 65.2 | 66.5 | 59.7 | 4.0 | 5.1 | 3.4 |
| 5/7/06 | 11:26 | 0 | 61.3 | 57.4 | 61.8 | 4.3 | 5.1 | 3.3 |
| 5/7/06 | 11:32 | 0 | 56.6 | 57.7 | 54.8 | 4.4 | 5.2 | 3.3 |
| 5/7/06 | 11:59 | 0 | 46.5 | 46.2 | 45.5 | 4.5 | 5.3 | 3.3 |

Table 4
Measurements of the upper bump movement with the second cell: Heating power, temperatures ($T_{ol}$, $T_{il}$, and $T_{ir}$ outer left, inner left, and inner right, respectively) and vertical coordinates of the bump tops ($upp_i$ with $i = 1-3$ see Figure 7). Details see text.

## 6 Conclusions

The new cooling circuit has been proven to work and also to cool the wings more effectively. The water flow is larger by a factor of 2 and the cooling has moved much closer to the heat source. Recent readings from the experiment show indeed a strongly reduced temperature. Tests with a heating wire inside the target cell show no bending of the wings within the measurement accuracy of 100 $\mu$m.

Another test with the previously installed cell shows that the foil of the cell moves when heating it with a power comparable to the one transfered at typical HERA injections. Instantaneously with switching on or off the heating, changes of up to 0.9 mm were measured. The cell is bowing such that the upstream end bends down while the downstream end bends up when applying the heat load. The behaviour is seen on both upper and lower bumps, and it is vice versa when switching the heating off. Possibly the foil centre is expanding or contracting while the rest of the cell has no time to get into thermal equilibrium and hence does not follow. It is not clear how such a behaviour can be avoided, but the recently increased foil thickness might help (50 $\mu$m Al foil replaced by 75 $\mu$m). Clearly this finding is independent of the cooling of the wings, though a lower overall temperature would help as the expansion coefficient rises with temperature. Currently a modified suspension of the foil is under discussion.

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