# Next Generation of Linear Accelerators

## high precision survey and alignment of upcoming large linear accelerators

awarded **best poster** at SEVENTH INTERNATIONAL WORKSHOP ON ACCELERATOR ALIGNMENT IWAA 2002 SPring-8 JAPAN

**DESY** - the acronym means Deutsches Elektronen-Synchrotron - was established as an independent foundation under civil law in 1959 in Hamburg. It is a research center with 1.500 employees and approximately 3.400 scientists from 280 universities and institutes from 35 countries.


*figure 1: DESY facility*

New and larger linear accelerators demand for new techniques of alignment. At the example of TESLA at DESY currently developed methods for the geodetic survey of the accelerator components will be presented.

TESLA will be a tunnel facility with about 33 km in length in which a superconducting electron-positron-linear-collider with a collision point and a x-ray laser laboratory located in the middle of the facility (see figures 2 and 3).

At the collision point electron (e-) and positron (e+) packages will collide. To monitor reactions a detector for particle physics with the height of approximately 20 m will be installed in the experimental hall, located eight floors below ground level.

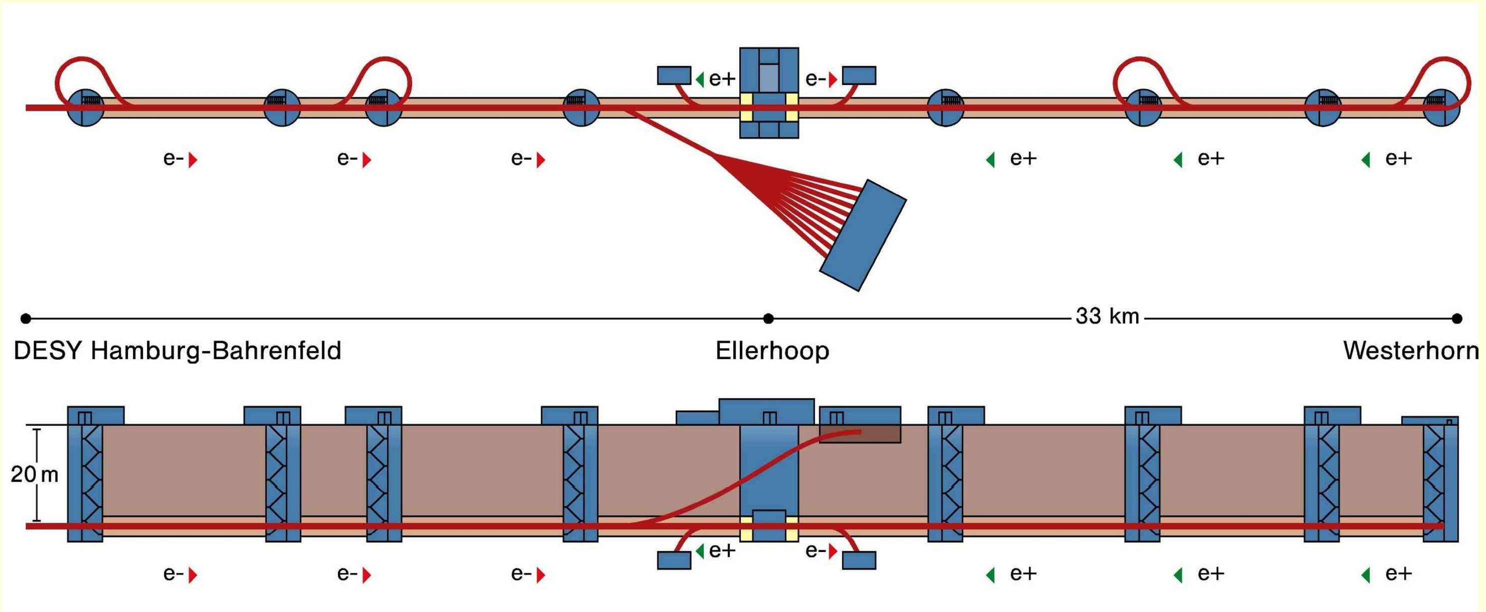


*figure 2: topview and profile*

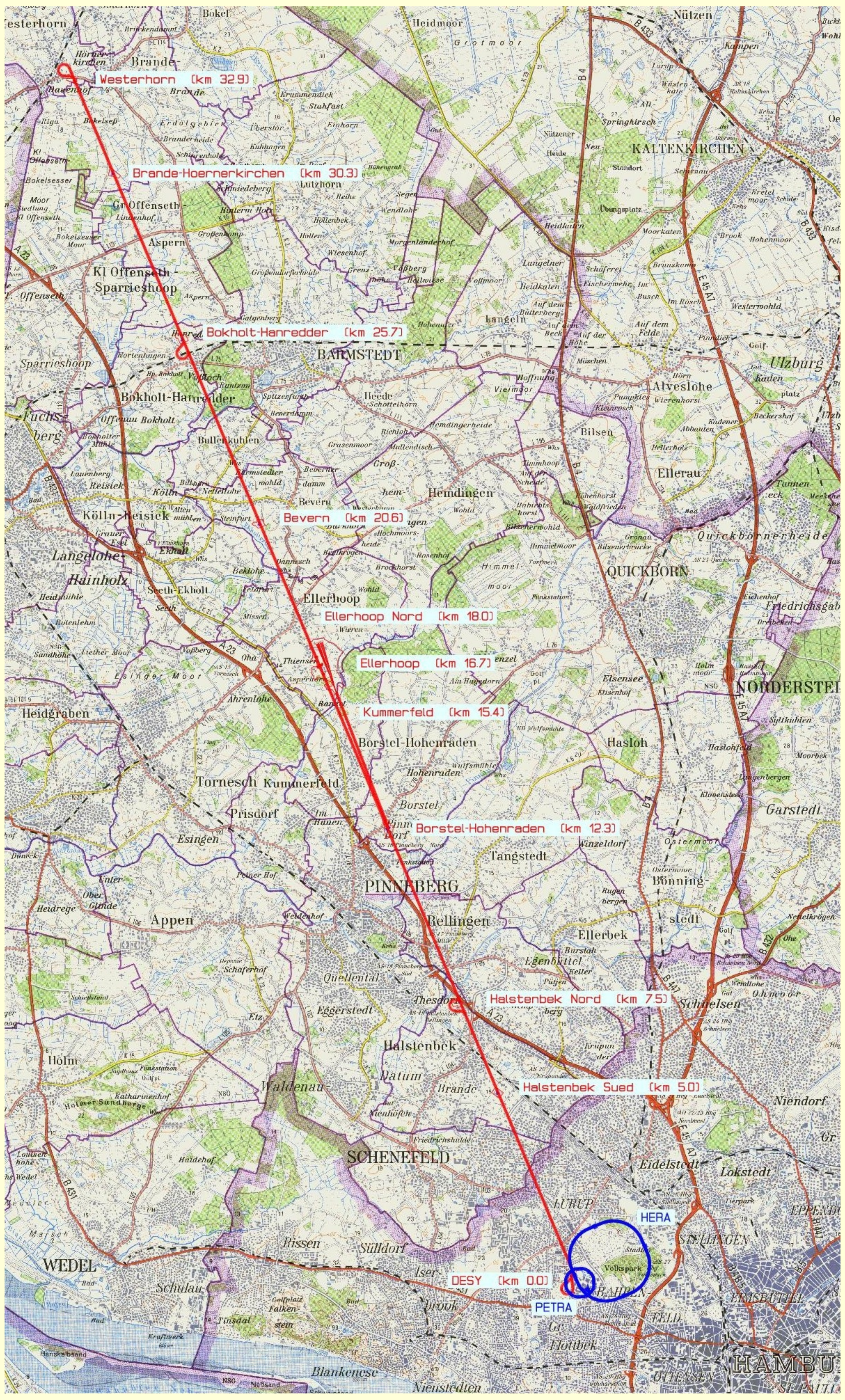


*figure 3: map and desginated track*

### Geodetic Tasks

A very high accuracy is demanded for the alignment of all accelerator components to run the linear collider successfully. The standard deviation of every component is postulated to be

0.5 mm transversal and
0.2 mm vertical

over a range of 600 m (maximum betatron wave length). Because of the influence of refraction, this requirement can not be achieved with any optical survey.


The development of this geodetic survey solution for new large linear accelerators takes place as an international collaboration of the Stanford Linear Accelerator Center (SLAC)[1], CA, United States of America, the Bauhaus-Universität Weimar[2], Germany, the Technische Universität Dresden[3], Germany, in charge of the Applied Geodesy Group at the Deutsches Elektronen-Synchrotron DESY[4], Hamburg, Germany.



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### OVERALL PROJECT

The alignment of the accelerator is split up in two major steps.

The basic network consists of reference points fixed to the tunnel wall in an equidistance of approximately 4.5 m. At first these points will be determined by separate geodetic surveys for the horizontal plane (2D) and the height.

Afterwards the alignment and setting out of the accelerator components will be carried out with a tacheometer, that runs on a movable carriage on a track at the tunnel wall. The position of the tacheometer will be determined by free stationing.

CONCEPT. With the technique of a multi-point alignment the effects of refraction can be reduced by determining the horizontal distances to at least three points.

A moveable bar serves as the basic structure for straightness measurements to the reference points which are mounted in regular distances to the tunnel wall. In every position the distances $s_i$ are measured to the correspondent reference point.

Hence the horizontal angle  and distances d can be calculated for the center point by using the measurement results of $s_i$.

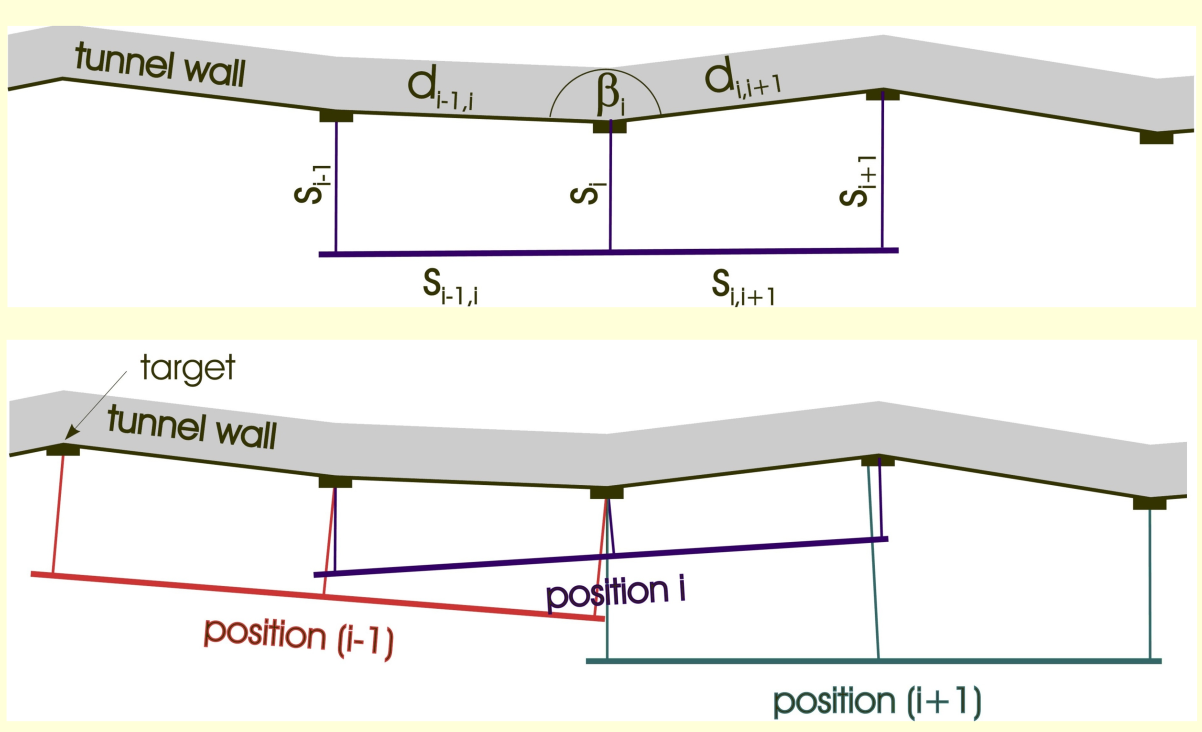


*figure 4: concept of geodetic survey (reference network)*

CONCEPT. Because TESLA is following an equipotential expanse, the height determination could be realized with a Hydrostatic Levelling System.

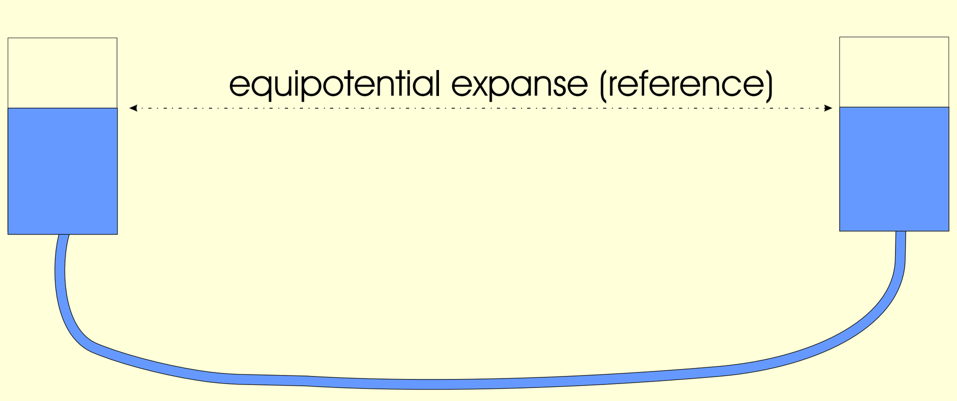


*figure 5: hydrostatic levelling system*

### HORIZONTAL PLANE DETERMINATION

REALISATION. A measuring train with six cars will deliver enough redundancy for every reference point. The straightness reference now is realized by a stretched wire, protected in a pipe.

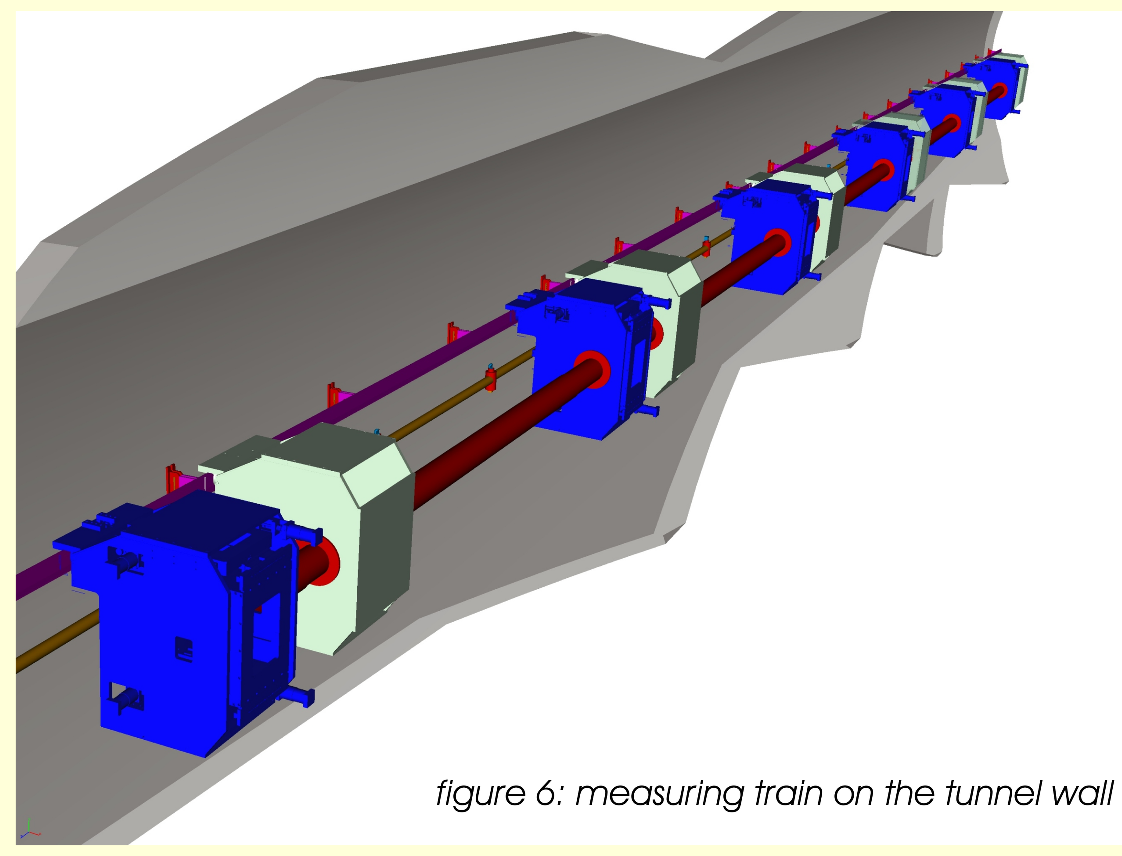

*figure 6: measuring train on the tunnel wall*

The distance between the reference point (A) and the wire (C) is measured with 3D positioning sensors (B, D) and two digital length gauges (E, F).

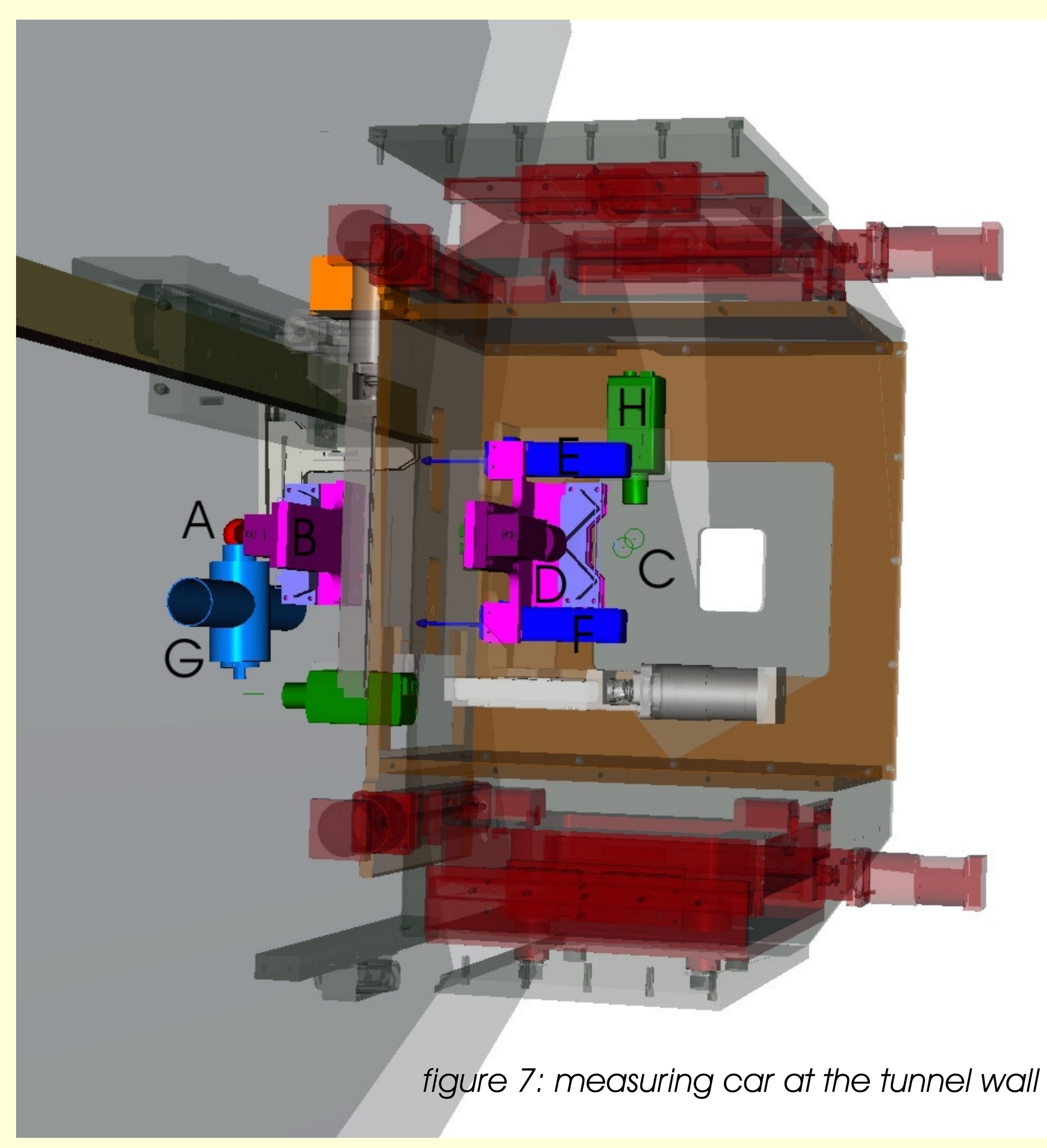


*figure 7: measuring car at the tunnel wall*

Readings of the hydrostatic levelling system (G) are connected to the reference point to create 3D-coodinates.

The movement of the two positioning sensors relative to each other will be measured with the precision of some micrometers with incremental length gauges. A precisely made pillar on the car serves as internal connection for the positioning sensors and the length gauges. An inclination sensor measures the inclination of each measuring car.


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### 3D Positioning Sensor

REALIZATION. To determine the distance between the reference points and the stretched wire with an accuracy of some micrometers, a non-contact, three-dimensional camera system will be used.

A prism system in front of the macro-lens creates split pictures on the CCD chip. A change in the distance to the target ( x) causes a shift of the two points on the CCD chip ( y). This shift is determined and provides an information about the distance between target and camera.

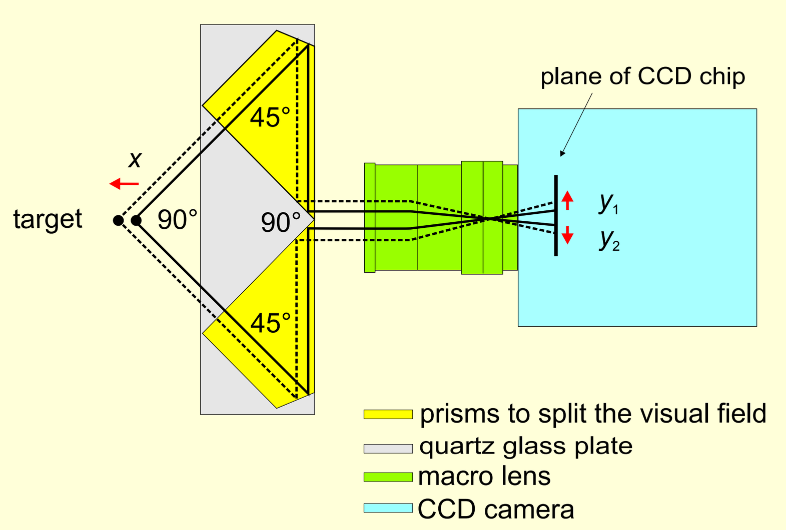


*figure 8: camera and lens system*

### Height Determination

REALIZATION. The mentioned concept has to be slightly modified to please the demand.

To minimize temperature effects on the fluid surface, the vertical columns of fluid had been made zero, that means working with a free surface in a leveled tube.

To eliminate temperature effects on the ultrasonic measurement system, which has been selected as sensor, a concept of "in-situ" calibration has been developed.

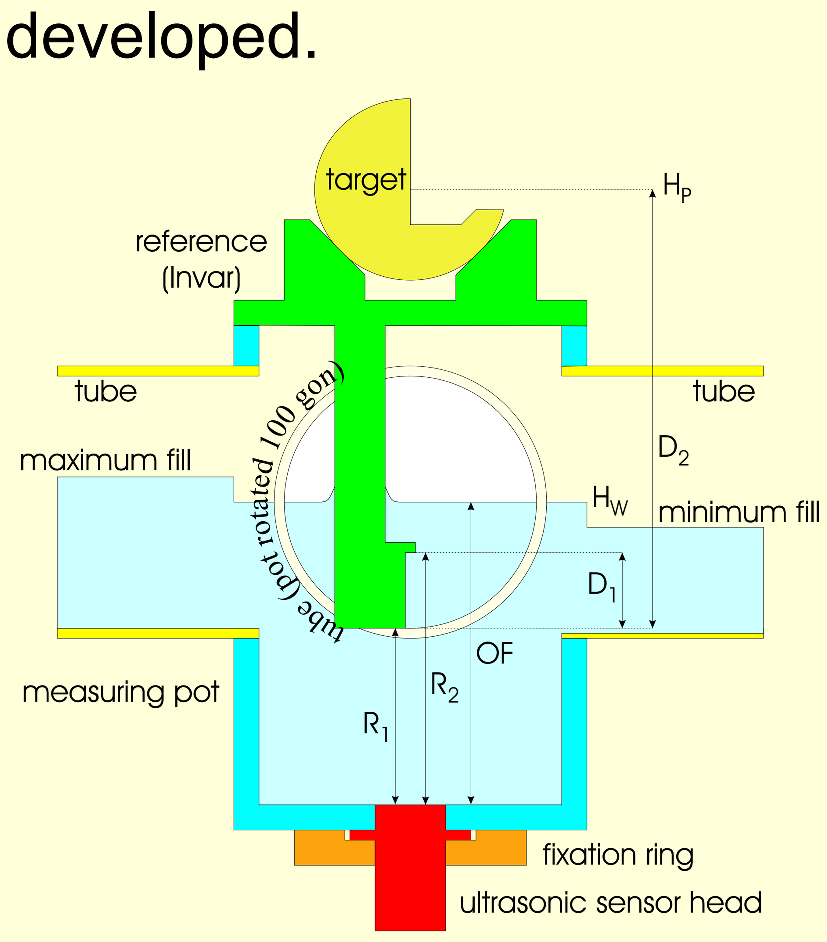


*figure 9: measuring pot*

$$H_P \quad H_W \quad D_2 \quad D_1 \frac{OF}{R_2} \frac{R_1}{R_1}$$

No influence of
- sonic speed / temperature
- position of sensor

### Setting Out of the Beamlines

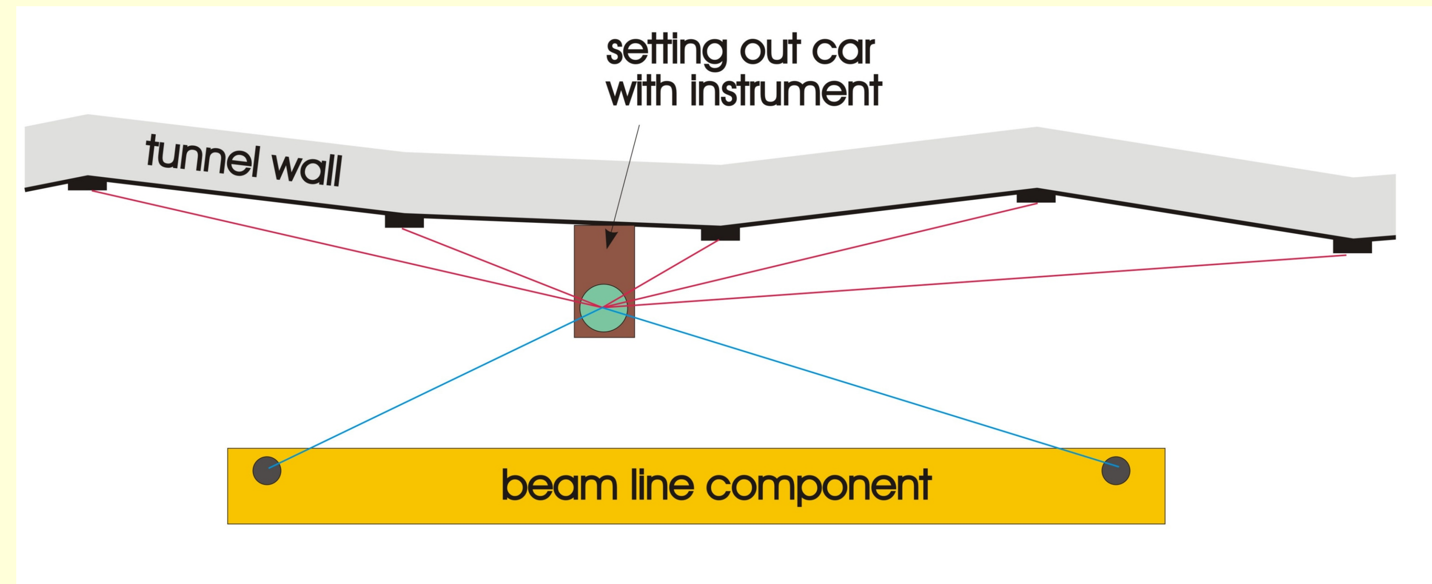


*figure 10: setting out*

After establishing the reference network the components of the various beamlines can be adjusted.

A high-precision tacheometer on a carriage is positioned by free-station survey using the reference points on the wall.

Afterwards the modules will be moved into the right position by comparison of the nominal values and the observed values of the coordinates.

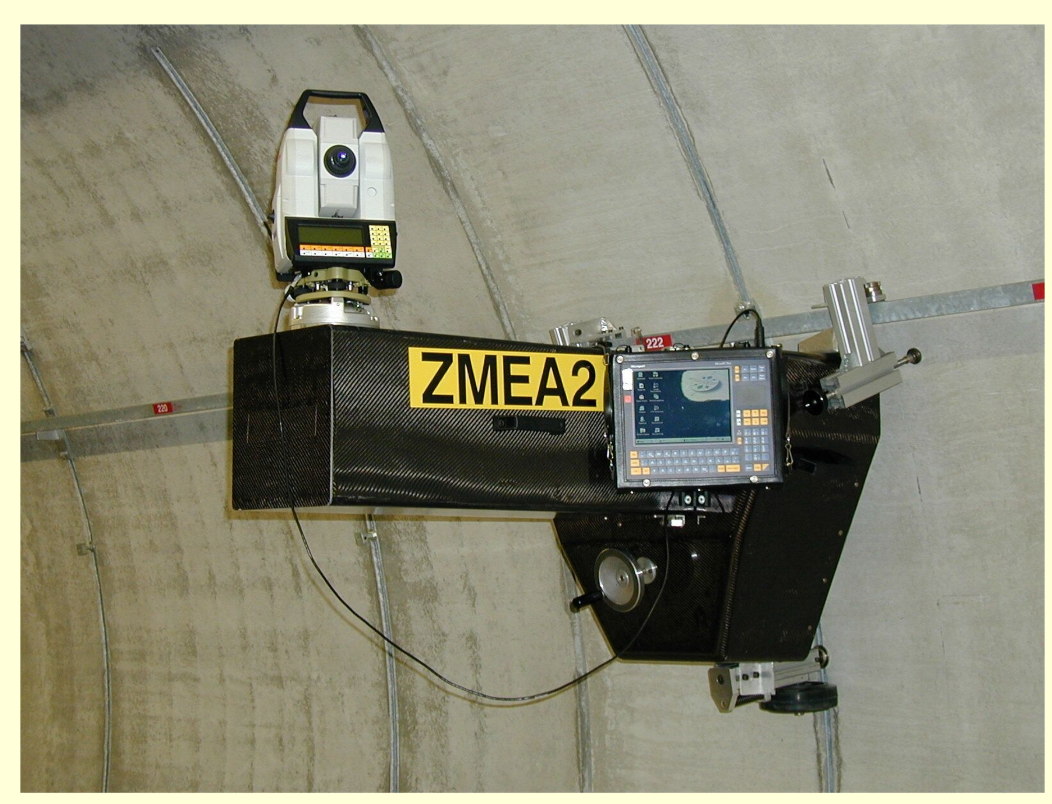


*figure 11: carriage with tacheometer*

### Conclusion

The aim of the project is to build an automatic measurement system for the geodetic survey of a reference network in the tunnel. A high degree of automation is the only possibility to get the efficiency to carry out all surveys during the construction time and the short service periods during shutdown of the machine.

Theoretical contemplations have to be improved and tests of the practicability will be completed with a prototype of the train at the end of 2003.


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