GEODETICAL CONCEPT AND ALIGNMENT OF COSY

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INTRODUCTION

In the Forschungszentrum Jülich (KFA) the proton synchrotron and storage ring COSY is under commissioning. This facility is formed by a Cyclotron with 40 MeV protons as injector and a 184 m circumference synchroton and storage ring with a maximum proton energy of 2.5 GeV.

Electron and stochastic beam cooling techniques provide an excellent beam quality with high luminosity and small phase space for a broad variety of high resolution experimental research in medium energy physics and at lower energies in medical research and application.

Figure 1 gives an overview of the facility.

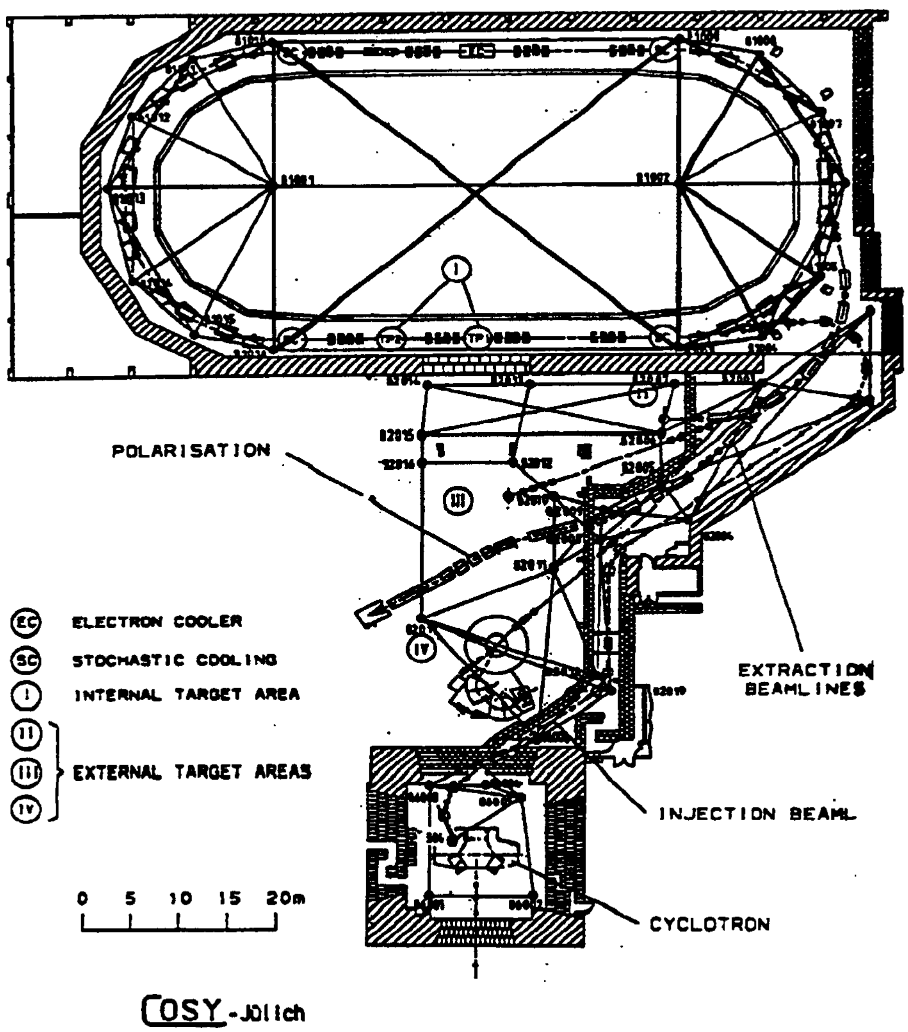

Figure 1 : COSY facility and geodetical lattice

TOLERANCES

Exact positioning of the optical axes of the ring elements with respect to the closed orbit is essential for high beam quality, low losses and easy commissioning of the machine. Theoretical calculations of the misalignment of the ionoptical elements show deviations from the closed orbit of up to ±15 mm horizontal and ±10 mm vertical.

Figure 2 shows the distribution of the deviation due to random misalignment of the magnetic elements over the circumference of the COSY-ring. This simulation assumes a misalignment of dipoles and quadrupole magnets by ±0.2 mm in the vertical plane and a tilt of ±0.1 mrad for quadrupoles and ±0.3 mrad for dipole magnets. Detailed analysis showed a strong dependence of the distortion by misalignment of neigbouring components. Thus the overall alignment tolerances were specified as ±0.2 mm in all directions and maximum twist of ±0.1 mrad. The misalignment between neighbouring components (specially quadrupoles in the telescopes in the straight sections) were limited to ±0.1 mm. Tolerances in the beamlines are less stringent and specified with ±0.3 mm and 0.3 mrad.

Detailed ionoptical calculations with these tolerances randomly distributed over all components in the synchroton gave app. 80 % probability for the protons to survive the first turn.

In addition minimum time for measurement and alignment has been requested not to hinder the operation of the facility by time consuming geodetical work.

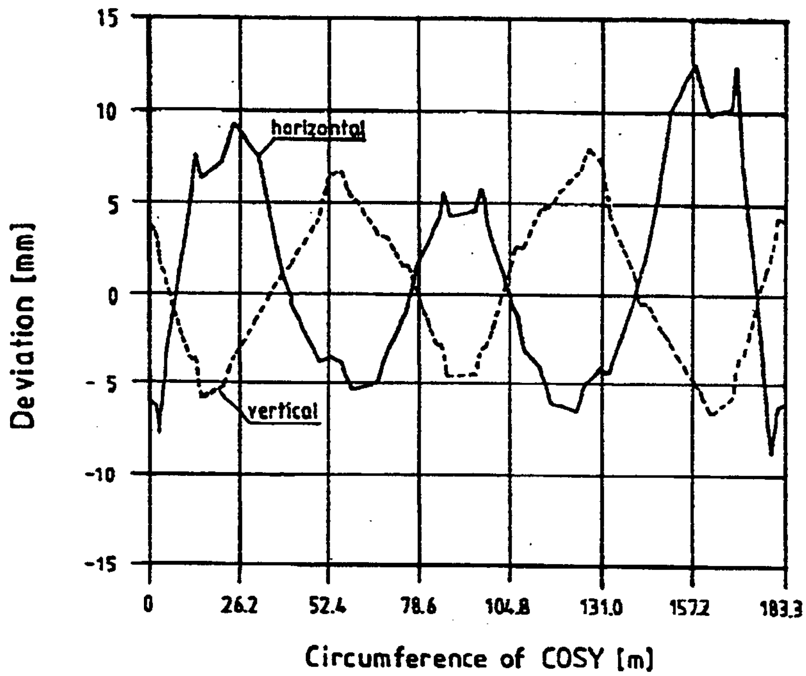

Figure 2: Deviation from the central orbit due to misalignment

LATTICE

A number of 50 reference points form a lattice as a basis of the geodetical measurement and alignment and are the backbone for the required accuracy. Figure 1 shows the distribution of these reference points in injector cyclotron, beam lines, experimental areas and the COSY ring.

Due to the tight tolerances in the storage ring, installation of cabels, hoses and pipes, a common observation height of 2.8 m for all reference and object points was agreed on. Steel pillars with thermal insulation to prevent bending due to asymmetric heat radiation were installed as stable reference points in the ring tunnel. Precision plumbs were used to adjust the bearings for instruments and targets on the pillars.

INSTRUMENTATION

Bearings with a diameter of 30 mm and a tolerance of 0.0005 mm (identical to CERN and PSI /SIN) are used for precise mounting of optical targets and measurement equipment. Different types of optical targets are availiable (rank precision balls, mirrors, illuminated targets etc.), according to the measurement problem.

Standard mechanical tools like gauges and micrometers were used. Levelling was performed with N3 and Na3000; angel measurement was done with T2000 S, T3000, and TC2002; for optical distance measurements ME 5000, TC2002, TC1600 and laser interferometer were used; plumbing was done with Nadirlot NL.

SOFTWARE

All measured data are checked for confidence and plausibility during measurement and stored for detailed calculation with the program system panda[1)]. The program system features are:

- data base management for all measurement periods
- mesh relaxation
- comparison of actual and rated values

[1)] GEOTEC : Forschungsgesellschaft für angewandte geodütische Tecihnologie

- calculation of alignment vectors
- trend analysis

OBJECT POINTS

To achieve highest accuracy possible, extensive measurement of the magnetic fields of all components was performed. The geodetical alignment targets were aligned according to the results of the magnetic field measurements hence with respect to the optical axes of the magnets. This relative positions of the targets with respect to the magnet were used as input of the CAD - system which then delivers directly the actual coordinates of each object point in the COSY coordinate system. These coordinates of the CAD system were then used as rated values for alignment.
Direct data transfer between the computer for geodetical application and the CAD system reduces the errors due to typing mistakes drastical.
In a first step all components were prealigned within an accuracy ± 2 mm. Then the position of the object points were measured with high accuracy from the reference points. The differences between the measured and the rated values were transformed into the local coordinate system of each component to derive the correction values for the position. The new positioning of the components were obtained under control of mechanical gauges. To verify the exact positioning of the components control measurements were performed.

RESULTS

Building

Due to the weight of the building, shielding and the accelerator components differential settlement of the total plant were expected. To measure the settlement and its time dependence several precision nivellements were performed during the construction period.

The recent measurement was done 14 months after finishing the 1m thick baseplate. The results show a decay of the settlement to less than 0.5 mm per half year.
Figure 3 shows the isolines of the COSY area.
For all level measurements an accuracy of 0.1 mm was achieved.

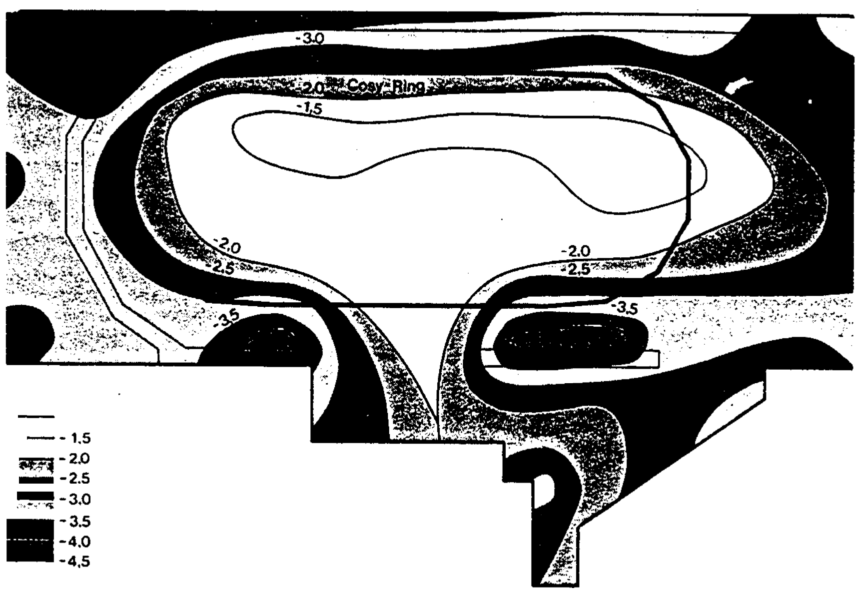

Figure 3: Isolines in the COSY area. Dimensions in cm

Machine

Figure 4 shows the dimensions of the error ellipses of the reference points in the second measurement campaign. The axes of the error ellipses are smaller than 0.05 mm. Thus the alignment errors of the COSY components are slightly better than the specified values. Actually no closed orbit correction element was needed to inject and store the proton beam with the proposed beam current during commissioning.

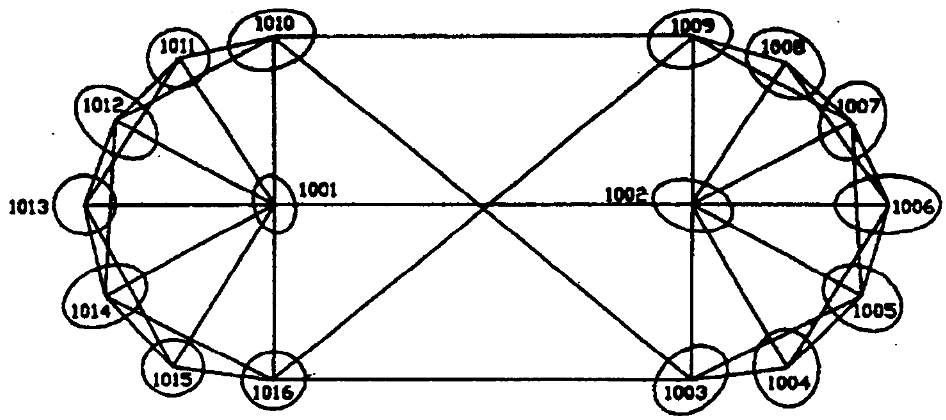

Figure 4: Uncertainty of reference points

A great deal of this success was accomplished by precise geodetical measurement and alignment.