

9. Alignment

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The 28 GeV proton synchrotron, the transfer tunnels and the intersecting storage rings make up one of the two largest complexes in the world designed for sub-nuclear physics research. To the surveyors of the ISR Metrology Group it consists of more than four kilometres of tunnels in which some 1500 components have to be installed with a relative accuracy of a tenth of a millimetre. To achieve this, use is made of 'microgeodetic' or 'macrometrological' methods, most of which have originated at CERN itself since 1954 and have been continuously developed to incorporate the advances made in a technology which is still evolving.

Civil engineering work

The limited width of the site (a ring 300 m in diameter has to be installed in an area of land barely 400 m wide) and the amount of earth-moving involved have made the alignment work difficult. The depth of the excavations — up to 25 m in some places — has disturbed the natural stability of the ground. Movements due to the changes in mechanical balance on the site have been further accentuated by disturbance of the hydro-geological balance. Pillars sunk into the upper layers of the soil on the site, which serve as reference points, moved sideways by as much as two centimetres and vertically by about a centimetre.

Geodetic methods, involving repeated triangulation with a 600 m base to keep the triangulation to scale (Figure 1) have maintained an accuracy of 1.5 mm in the reference points for the axis of the ring and for the transfer tunnels (Figure 2).

Design of measuring instruments

While triangulation has provided an accuracy of 1.5 mm for the civil engineering work, even higher precision (of the order of a tenth of a millimetre) is necessary in the installation of the ISR equipment such as magnets. This requires individual measurements made to within a few tens of microns (a few ten thousandths of a millimetre). Fortunately, improvements in the methods of measuring distances have been made over the past ten years in response to the increasing scale of construction work and of 'scientific equipment' which still impose the same, or more severe, requirements for accuracy.

The whole of ISR alignment is based on distance measurements. The basic standard is a 4 m Invar metal rule on a calibration bench which will be installed in a new air conditioned tunnel. Using this bench it is possible to measure a length of 50 m accurate to within 5 microns. The next step is to transfer the length thus calibrated between the points to be measured, and, to this end, the group's mechanical and electronic workshop has designed some new instruments :

- The 'Distinvar' (which was described in CERN COURIER vol. 7, page 251). This instrument is now fully automatic and is connected directly to a computer. It uses Invar wires and measures to an accuracy of 15 microns over 50 m.
- The mekometer, designed in cooperation with the National Physical Laboratory at Teddington. This electronic distance measuring instrument, which uses the modulation by a high-frequency field of the plane of polarization of light, allows distances from 50 to 600 m

to be measured to within 0.2 to 0.4 mm.

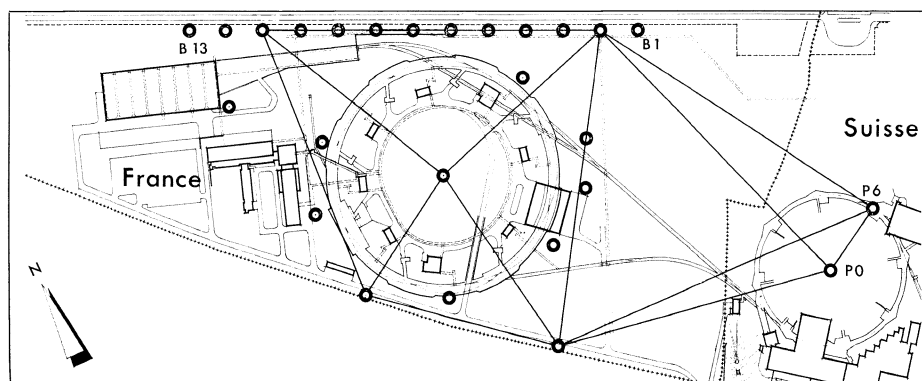
- An alignment instrument using a laser beam for simultaneous measurements in the horizontal and vertical planes. Its accuracy in air up to 40 m is from seven to eight hundredths of a mm.

Metrology

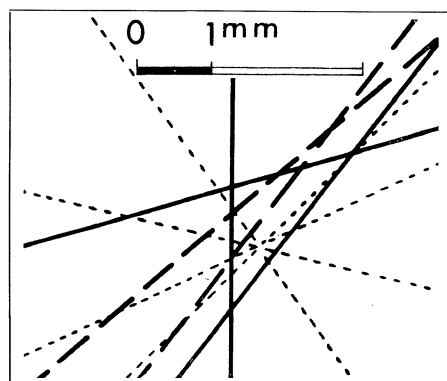
In the tunnel of the ISR itself, a double ring of pillars make up a closed set of braced quadrilaterals (Figure 3) and the six lengths in each quadrilateral will be measured with the 'Distinvar'. Within each quadrilateral, magnets will be installed at positions given by distance measurements taken from the relevant four pillars.

The transfer tunnels (Figure 4) are the most delicate part of the ISR geometry. They involve the alignment of a beam channel consisting of long straight sections followed by curves in which the inclination changes ; the alignment is therefore to be made in three-dimensions simultaneously. The guiding framework will be provided by pillars set up at regular intervals along the beams.

The elimination of angular measurements, which are always troublesome and time-consuming, and the great flexibility afforded by the distance measurements will go a long way towards reducing the time needed to align the ISR components. This saving of time will also apply when experiments are being set up around the intersection regions. There is the possibility of settlement of the ground in these regions when experimental equipment is installed, and time may be required to realign some of the ring components during the installation of the experiment.

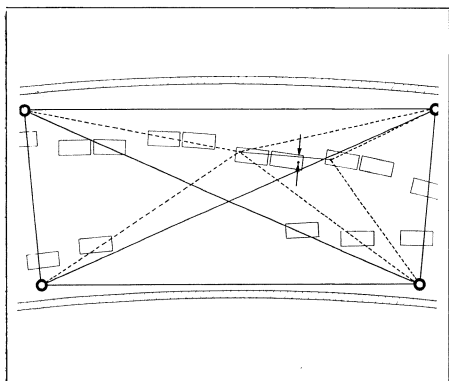


1.

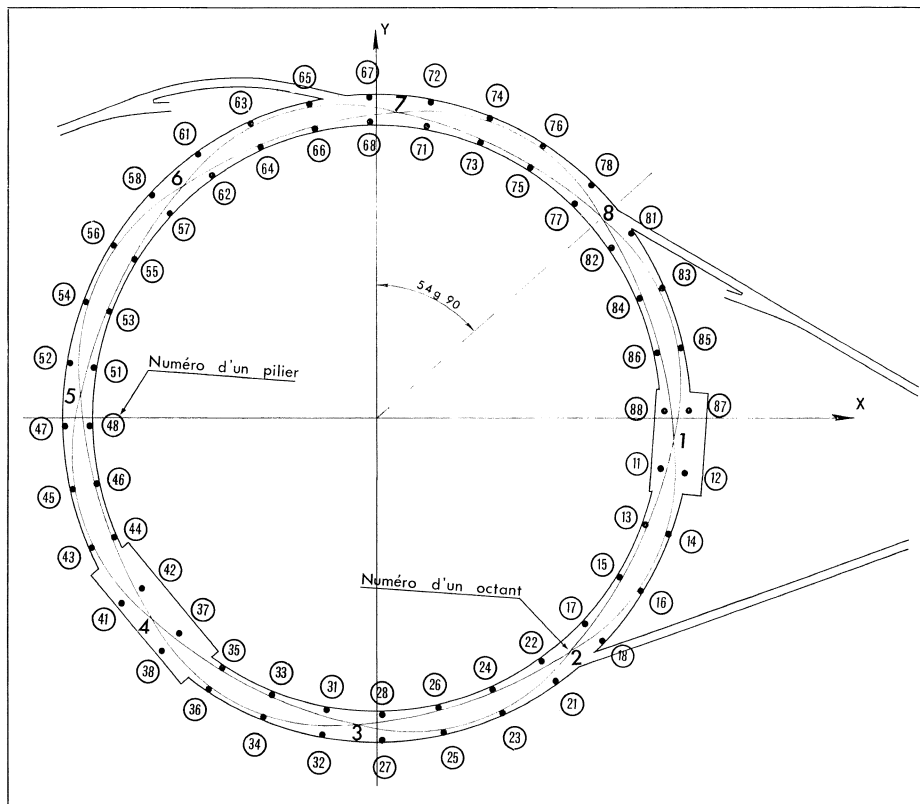


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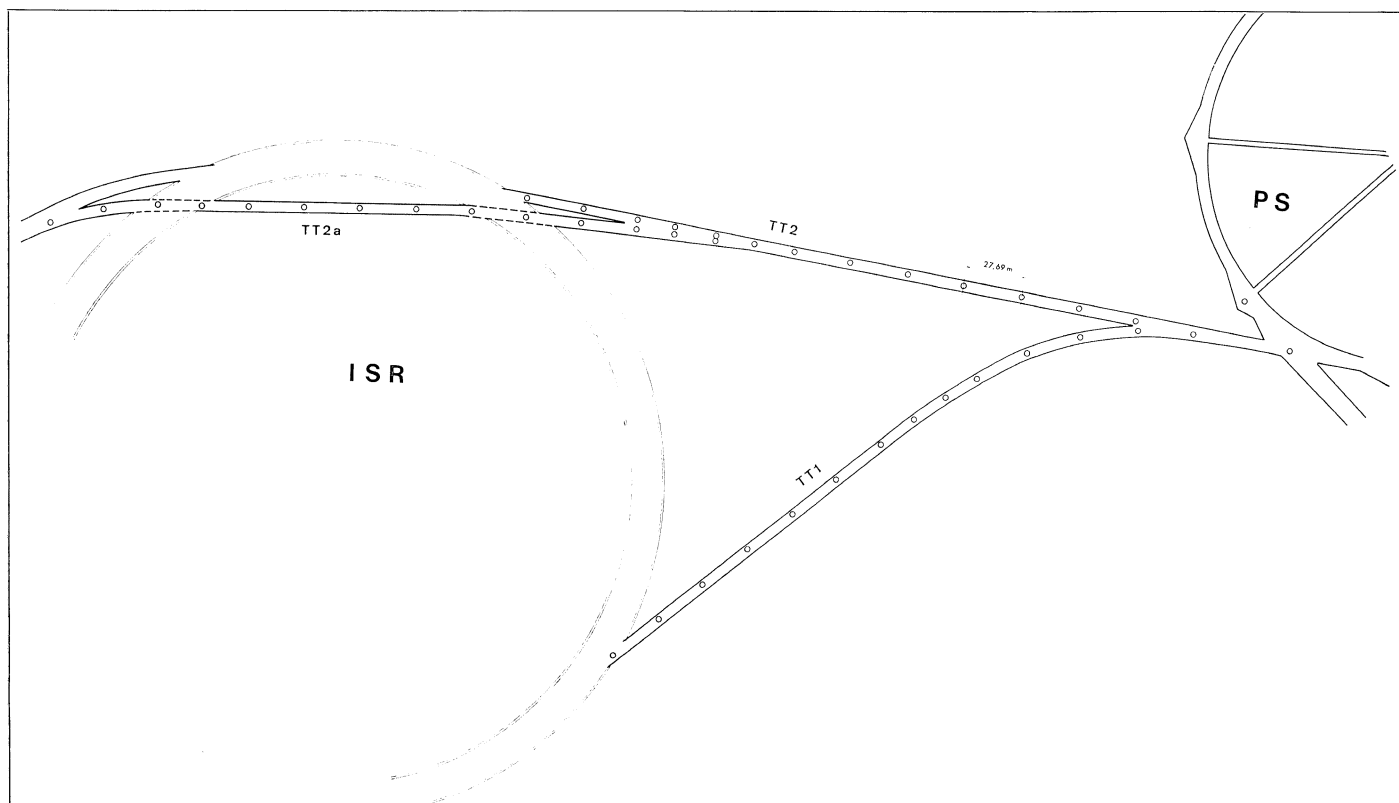
1. The Triangulation scheme used to establish the reference points for the axis of the ring and for the transfer tunnels.
2. Triangulation in action
 - intersection
 - bearing
 - - - - intersection from neighbouring axis points
- 3.a. The double ring of pillars to make up a closed set of braced quadrilaterals to align the ISR components to an accuracy of a tenth of a millimetre.
- b. Alignment of magnets within a quadrilateral.
4. The arrangement of pillars for aligning components in the beam transfer tunnels.



3.b



3.a



4.