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THE SPARC PROJECT ALIGNMENT PROCEDURES

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Abstract

Tools needed to align the various SPARC components and the related procedures with the aim to obtain an uncertainty not greater than 0.05mm are described in this report. Also different strategies on how to perform the alignment are compared and, finally, the different sources of errors are taken into consideration bringing to the maximum allowable alignment error.

1 INTRODUCTION

The SPARC machine will be realized in a rectangular hall with a total length of 36m and a width of 14m. (FIG. 1). The building has been realized about 20 years ago and it is supposed to be stable.

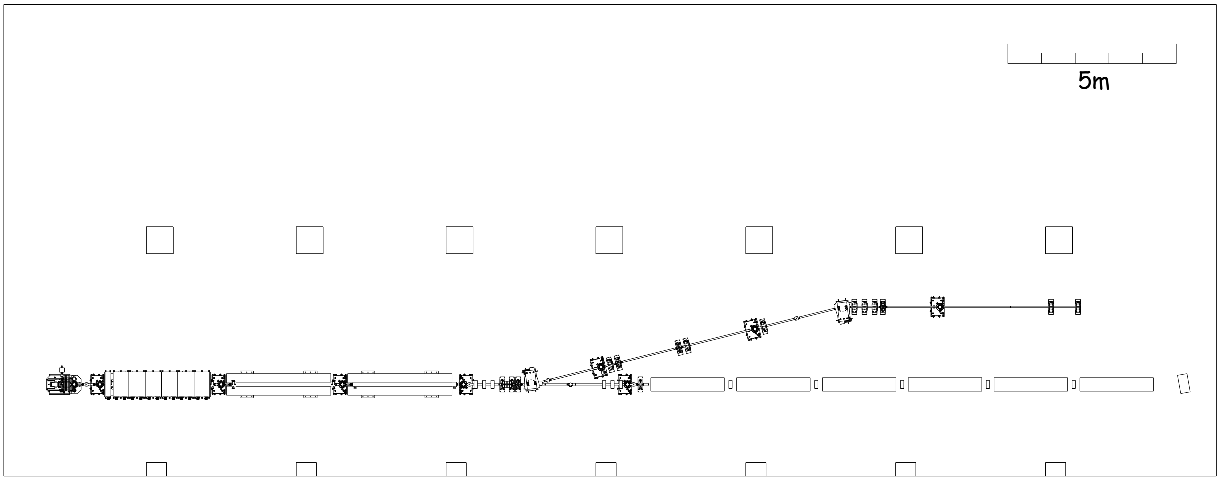

FIG. 1: The SPARC Machine.

The critical part of the machine from the alignment point of view (accelerating sections, undulators, BPMs) is distributed on a unique line.

The physic request is tight: an alignment uncertainty for each component not greater than 0.05mm.

2 PROCEDURAL OVERVIEW

It is possible to distinguish three preliminary phases:

- Designing of the component supports is an important part of the alignment project and it will ask a strong effort.
- References will be mounted in the empty hall or on pillars or in the floor or on brackets. The positions of this references, that will constitute the nodes of a *network* of measures, are defined to permit their use in the easiest and more precise manner during the alignment operation (FIG. 2 and TAB. 1). All the references, apart from 15, 16 and 17, are realized to be adjusted to their nominal position. Their final 3D position will be accurately measured.

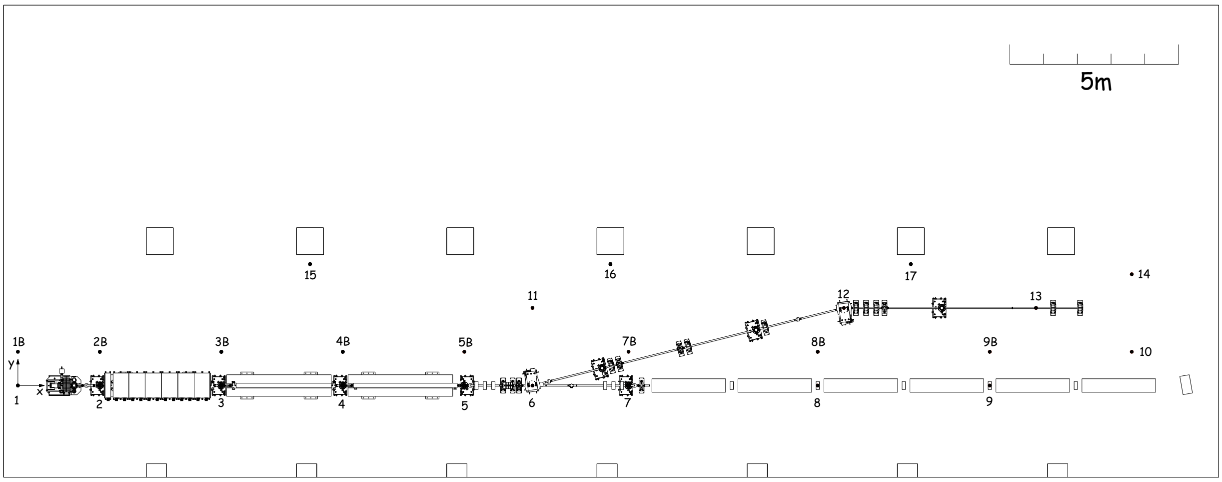

FIG. 2: The network nodes.

TAB. 1: Node coordinates.

node	X [m]	Y [m]
1	0.000	0.000
2	2.428	0.000
3	6.027	0.000
4	9.626	0.000
5	13.226	0.000
6	15.246	0.000
7	18.092	0.000
8	23.698	0.000
9	28.794	0.000
10	33.000	1.000
1B	0.000	1.000
2B	2.428	1.000
3B	6.027	1.000
4B	9.626	1.000
5B	13.226	1.000
7B	18.092	1.000
8B	23.698	1.000
9B	28.794	1.000
11	15.246	2.301
12	24.474	2.301
13	30.163	2.301
14	33.000	3.001
15	8.655	3.550
16	17.555	3.550
17	26.455	3.550

- Mechanical and magnetic measures will be done on components for which it will be necessary to qualify the position of specific references to magnetic geometry of component itself.

The mounting sequence will be ordered, component by component, along the LINAC starting from photocathode, that will be the first component to be aligned; the alignment action will be performed on each component just after its mounting phase, to obtain its best possible visibility.

The principal instruments that will be used are:

- Leica Total Station TDA5005 (angles: ±0.5"; distances: ±0.2mm)

FIG. 3: The Leica Total Station.

- Leica Theodolite (angles: ±0,5")

FIG. 4: The Leica Theodolite.

- Leica Level (levels: ±0.02mm)

FIG. 5: The Leica Level.

- Leica Laser Tracker (angles: ±0.2”; distances: ±0.02mm)

FIG. 6: The Leica Laser Tracker.

3 SUPPORTS

3.1 Description

Any component that has to be aligned shall have an adequate support. The principal characteristics of these supports must be:

- rigidity
- solid anchorage to floor
- adequate adjusting system, that means the regulation must be:
  - fine
  - rigid
  - independent for the two principal movements, in the horizontal plane and in height
  - capable to be locked at the end of adjusting action without introducing elastic deformations.

3.1 Efficiency

It is reasonable to foresee that the adjusting system, even if well realized, will no be perfect. An inefficiency of ±(0.01 ÷ 0.02)mm is reasonable, that is it will be impossible to place the components completely according to what the survey technicians see.

4 NETWORK

4.1 Description

The alignment network will be constituted by five references mounted on pillars (1, 1B, 10, 11, 14). These references will be realized to permit the positioning both of targets than of theodolite.

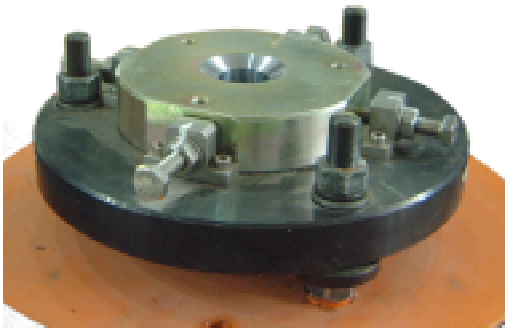

FIG. 7: The pillar reference.

Other 17 references (2, 2B, 3, 3B, 4, 4B, 5, 5B, 6, 7, 7B, 8, 8B, 9, 9B, 12, 13) will be placed on the floor along the Linac axis, along a line at a distance of 1m and along the "Dog Leg" line: all these references will be placed as near as possible their nominal position.

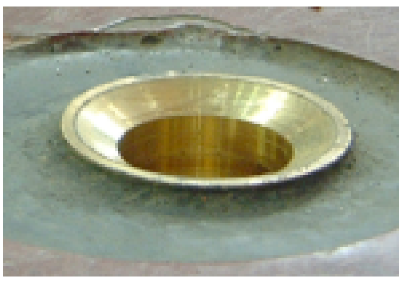

FIG. 8: The floor reference.

Three more references (15-17) will be placed on fixed brackets on the columns along the middle line of the hall; no adjusting is foreseen for them.

FIG. 9: The bracket reference.

The coordinate right-handed system has the x axis placed as the Linac axis and the origin on a vertical line corresponding to the reference 1; the y axis is in the horizontal plane so that the z axis is vertical and looks up.

All these references define the network of measures in the horizontal plane shown in FIG. 10.

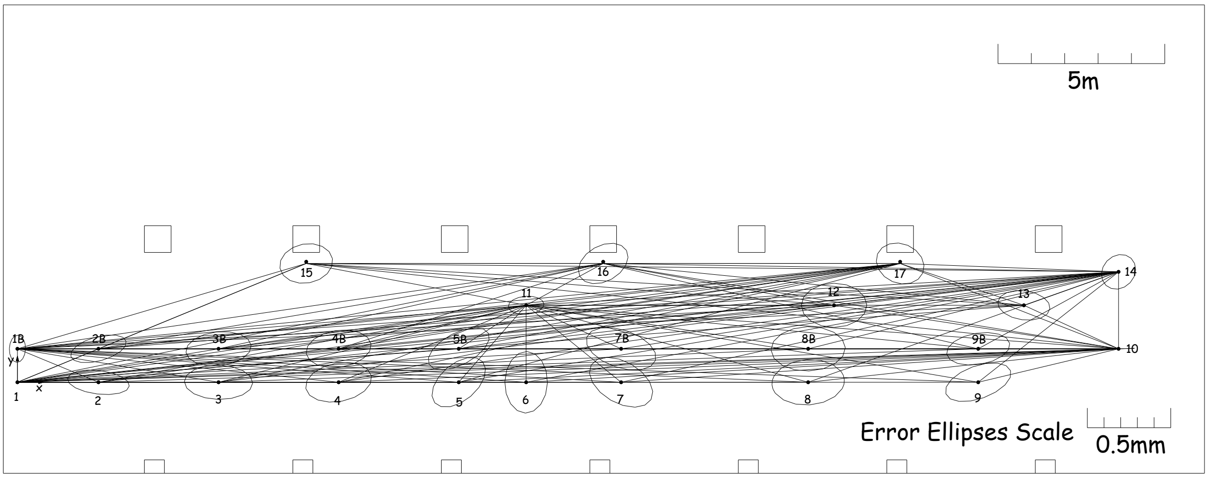

FIG. 10: Network measures.

4.2 Measures

The nodes will be connected by a network of measures, distances and angles in the horizontal plane, that will be analyzed by a program based on a least-squares algorithm. The result will be the knowledge of the node positions in the plane xy with an uncertainty related to the precision of the used instruments and their centring on the nodes.

With TDA5005 this uncertainty will be around 0.2mm (the semi-major axis of the error ellipse for a confidence region of 95%), with 114 angle and 132 distance measures. With a Laser Tracker this confidence region can be not greater than 0.02mm. In a first phase the use of the less precise instrument can be useful to place nodes near their nominal positions. A second phase of measures based on the more precise instrument will give a better knowledge of the node positions. The job will be divided in two phases because we have a TDA5005 but we do not have a Laser Tracker: it will be easy anyway to rent it but its convenient to compress the time of this rental.

The use of Leica level for the z coordinates will allow an absolute uncertainty less than ±0.02mm.

5 COMPONENT REFERENCES

5.1 Description

Any component must have adequate references. They will be realized directly on the component body, for example holes with a tight tolerance in diameter, planes precisely machined, external cylindrical surfaces. These references must be realized with a tight precision referred to the physical geometry of the component or, alternatively, qualified precisely after construction.

Because the visibility of the references can not always be easy or possible, they will be used to connect precise alignment tools in a fixed and repeatable way to the body of component.

5.2 Uncertainty

The uncertainty connected to the qualification of references can vary from ±0.01mm to ±0.02mm. It depends from:

- mechanical construction or mechanical measures;
- magnetic measures, if they are necessary.

If the alignment tool is necessary for a component, it will be better to qualify directly the tool references in relation to physic geometry of the component itself. In this way it is possible to cut the double uncertainty due both to the component references and to the tool references referred to mechanical coupling to component.

6 ALIGNING ACTIONS

6.1 Two strategies

This activity will be performed with two instruments at the same time placed in an adequate position respect to the component to align. Normally they will be a theodolite and a level but it could be necessary to have at the same time two theodolites connected to a computer; in this second configuration the level is useful even if not necessary.

6.1.1 First strategy: theodolite and level

The theodolite is aligned on the machine line in a not prefixed position, that is not in a position corresponding to pillars or floor nodes. The theodolite aligning will be performed through a sliding table with a precision of 0.01mm, which will permit an horizontal movement, transversal to the line, and collimating targets placed on the nodes distributed along the line. The aligning uncertainty will not be greater than ±0.02mm, integrating also the error due to the targets collimation.

The level is placed in an intermediate position between the component and the network node whose height is taken as reference; in this way the potential not perfect horizontality of the instrument does not play any relevant rule.

6.1.2 Second strategy: two theodolites

In case that the component references cannot be seen from the position described before but only laterally, it will be possible to use two theodolites in such a way that they can see at the same time at least three network nodes and the component references. The software that receives in real time the angles read by the two theodolites is capable to compute at first where they are and then where the component references are with an uncertainty not greater than ±0.02mm.

The level it is not necessary, because the two theodolites give a 3D information, but helps to verify and increases the precision in the vertical direction.

6.2 Uncertainty

In any case the general uncertainty in survey based on conventional instruments is comprised in ±0.02mm.

7 CONCLUSIONS

Adding the uncertainty due to:

- component references qualification: ±(0.01 ÷ 0.02)mm
- support efficiency: ±(0.01 ÷ 0.02)mm
- survey: ±0.02mm

any component may be positioned with an uncertainty of about ±0.05mm around its nominal position.

If the Beam Alignment, when the machine will be already aligned and functioning, will suggest to better adjust any component, this will be possible using instruments having a sensibility of 0.01mm like micrometric comparators: the only uncertainty that cannot be removed is that due to support inefficiency.

8 ACKNOWLEDGEMENTS

To C. Sanelli for discussion and suggestions.