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ALIGNMENT OF THE SPARC LINEAR ACCELERATOR

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Abstract

The SPARC project is a collaboration among ENEA, INFN, CNR and Rome “Tor Vergata” University on an R & D activity oriented to the development of a high-brightness photoinjector to drive SASE-FEL experiments [1].

The installation of the accelerator in the SPARC building has begun in 2005 and the last assembling and alignment operations have been accomplished in 2008.

This paper describes the various steps of the installation and provides the fiducialization and layout data necessary for the alignment of the SPARC components.

1 INTRODUCTION

The SPARC machine has been installed in a rectangular hall with a total length of 36m and a width of 14m. The building was built more than 20 years ago and it is supposed to be stable.

The SPARC complex is composed of an RF gun driven by a Ti:Sa laser producing 10ps flat top pulses that hit on a photocathode. The outcoming beam is injected into three SLAC-type accelerating sections to feed a 6-module 12m long undulator. The accelerator layout also includes a dogleg line used for beam compression studies and other experiments.

All the activity on the undulators and on the undulator line, installation and alignment included, is under the responsibility of ENEA and will not be described in this paper.

The alignment of the whole accelerator is based on the use of a network of nodes as a reference frame. Therefore the first step was to accurately design, install and qualify a reference network. The second step was the fiducialisation of all magnetic and RF components in order to determine their magnetic (or mechanical) geometry with respect to targetable fiducial markers. At last the alignment of all components was performed, with a first rough and quick positioning and a subsequent precision alignment using surveying instruments.

A more detailed description of the procedure is given in the following paragraphs.

2 THE REFERENCE NETWORK

A network of reference nodes has been built inside the SPARC hall and it represents the reference frame for all alignment and surveying operations. The network was initially studied and designed to allow alignment and surveying activity performed by means of optical instruments (level, theodolite and total station) [2]. For this reason the network is made of a primary group of nodes which lie on two straight and parallel lines. This primary group of nodes is made of 4 pillar sockets and 17 ground sockets. A schematic layout of the SPARC reference network is shown in **Fig. 1**.

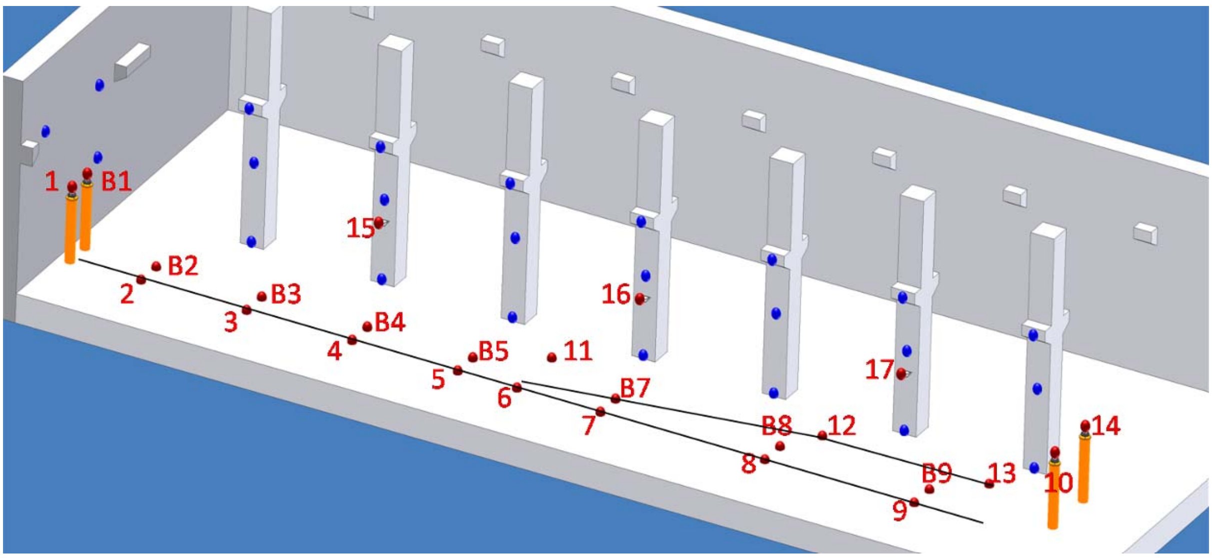


Fig. 1: Schematic layout of the SPARC reference network

The standard LNF pillar socket (Fig. 2) consists of a precise and well-finished conical surface machined in a metallic plate equipped with a fine adjustment system, necessary for initial positioning. In this kind of socket it is possible to place either targets (3.5 inch Taylor Hobson spheres or 1.5 inch Corner Cube Reflectors) or optical instruments (theodolites, levels or total stations) by means of tribrachs which allow centering and repeatable positioning.

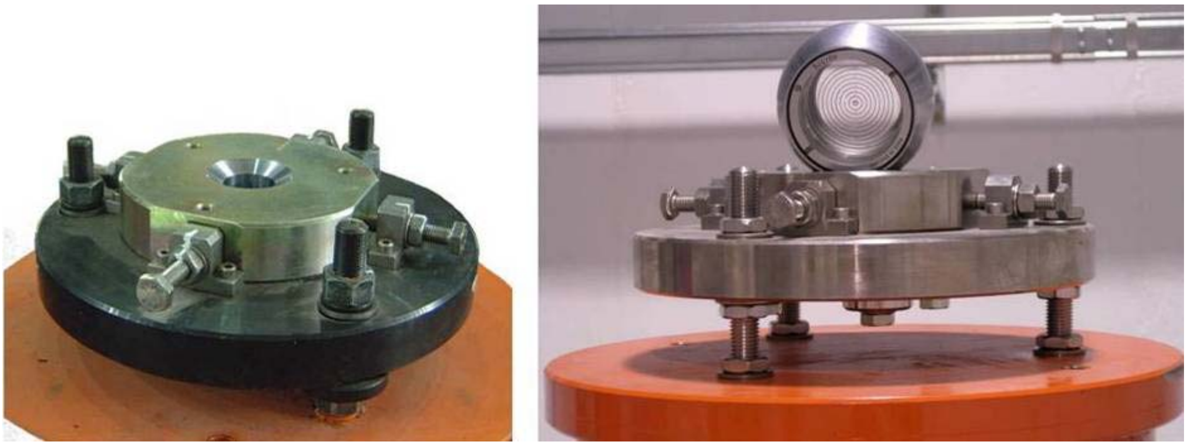


Fig. 2: Standard LNF pillar socket

The ground sockets consist of iron cylindrical elements with a conical cradle where 3.5" radius spheres can be placed. The ground sockets are installed and positioned using supporting devices equipped with adjustment screws which can be removed after having blocked the sockets in position by means of a resin.

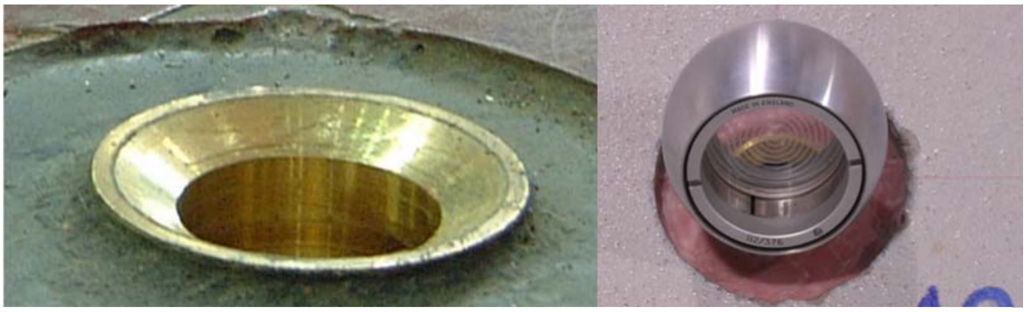


Fig. 3: Ground Sockets

Three more sockets have been mounted on brackets (Fig. 3) on a side of the accelerator hall. By placing optical instruments on tribrachs inserted in these sockets it is possible to perform triangulation checks of the network. Moreover they provide comfortable fixed and qualified sites for optical instrument positioning for alignment and surveying operations.

Fig. 4: Bracket Sockets

A first complete campaign of measurements has been performed by means of theodolites, total station and optical levels. The data have then been analyzed using STAR*NET software. A best-fitting solution of the network has been calculated and the error ellipses of measurements for each point have been evaluated exploiting the redundancy of measurements (Fig.5).

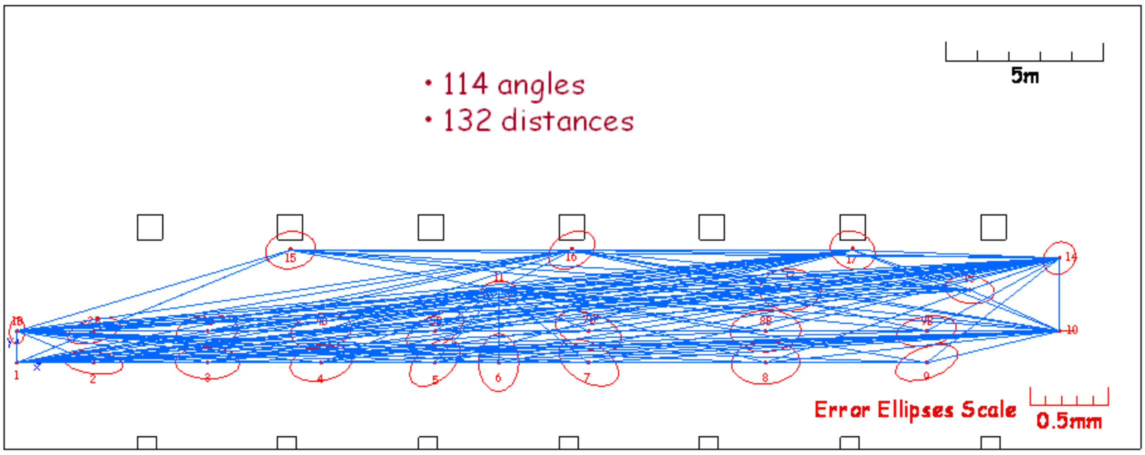
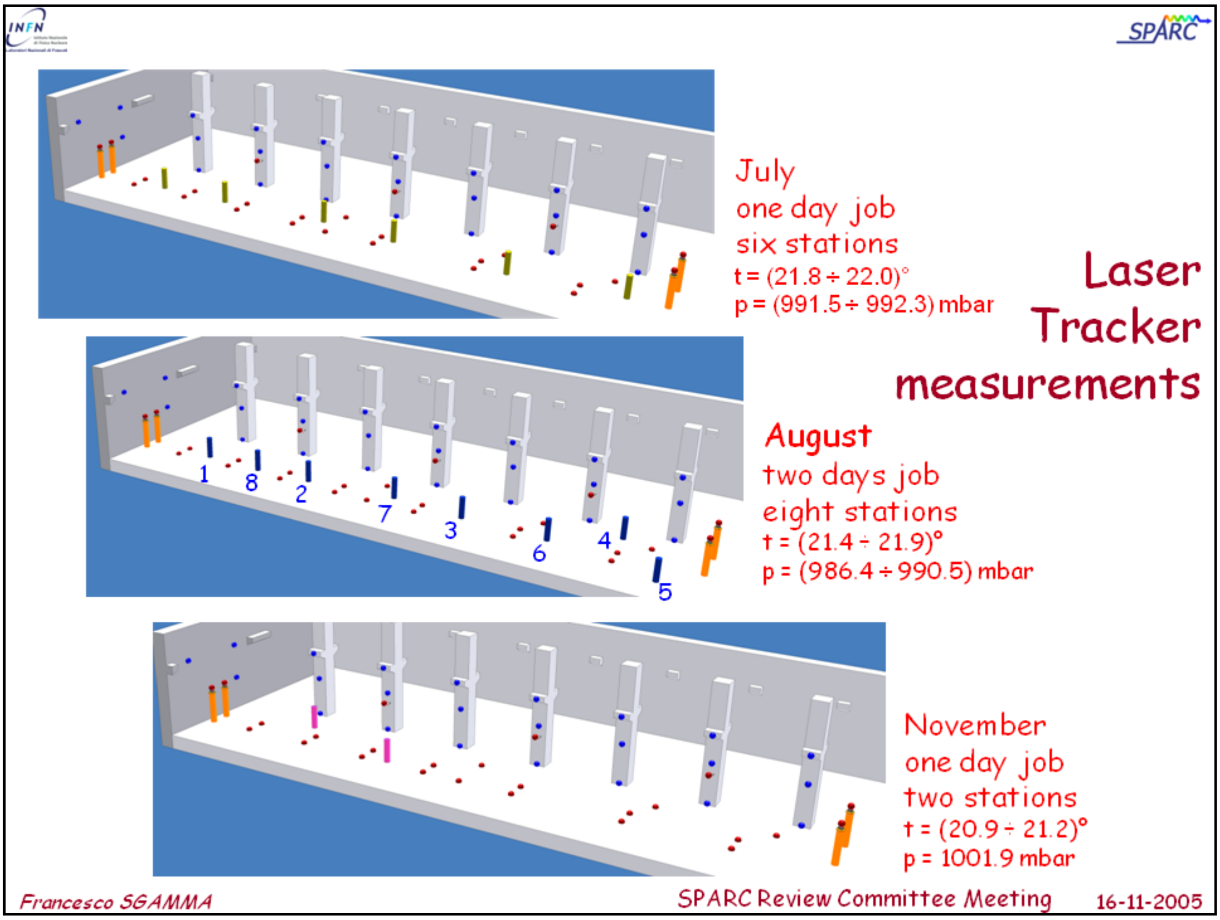


Fig. 5: Network of Optical Measurements

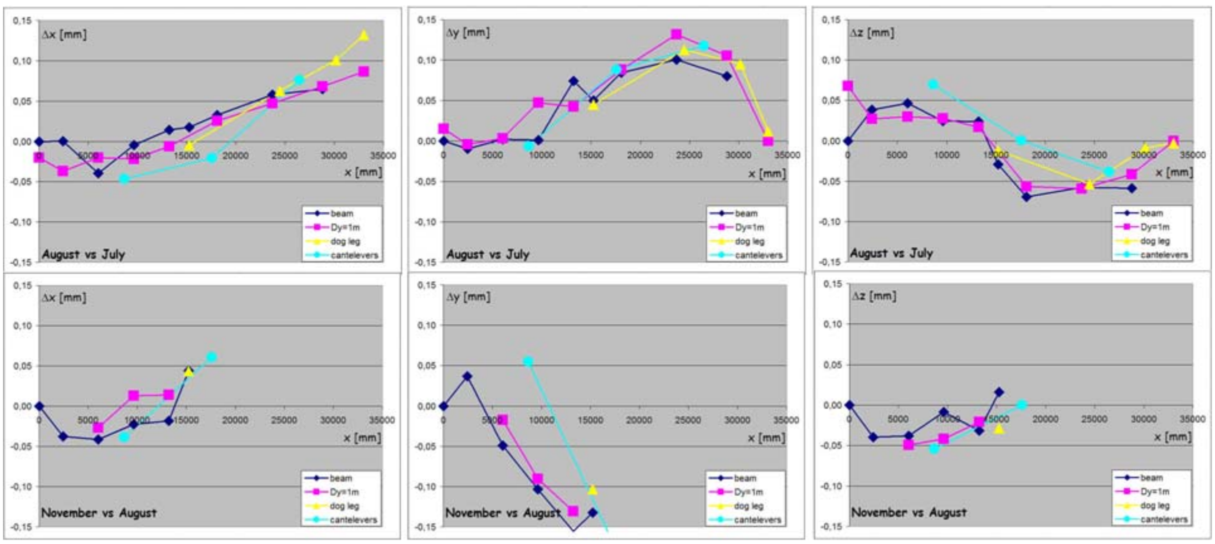
Subsequently other accurate and complete measuring campaigns have been carried out using a laser tracker. At the time of this first measuring campaign (summer 2005) the LNF were not in possession of a laser tracker, therefore the measurements had to be rented. On this occasion some other "secondary" nodes, well distributed on the walls of the SPARC hall, have been added to the network. The latter consist in precisely machined steel cylindrical sockets, with an 8mm internal diameter, embedded in the walls (blue dots in Fig. 1). The use of these sockets, capable of housing only CCR targets by means of appropriate CCR holders (Fig. 6), provided a cheap but efficient solution to have a denser network. The secondary nodes have been added in anticipation of a more intense future use of laser trackers for surveying and alignment operations.

Fig. 6: Secondary Socket and CCR placed in a Secondary Socket with a CCR holder

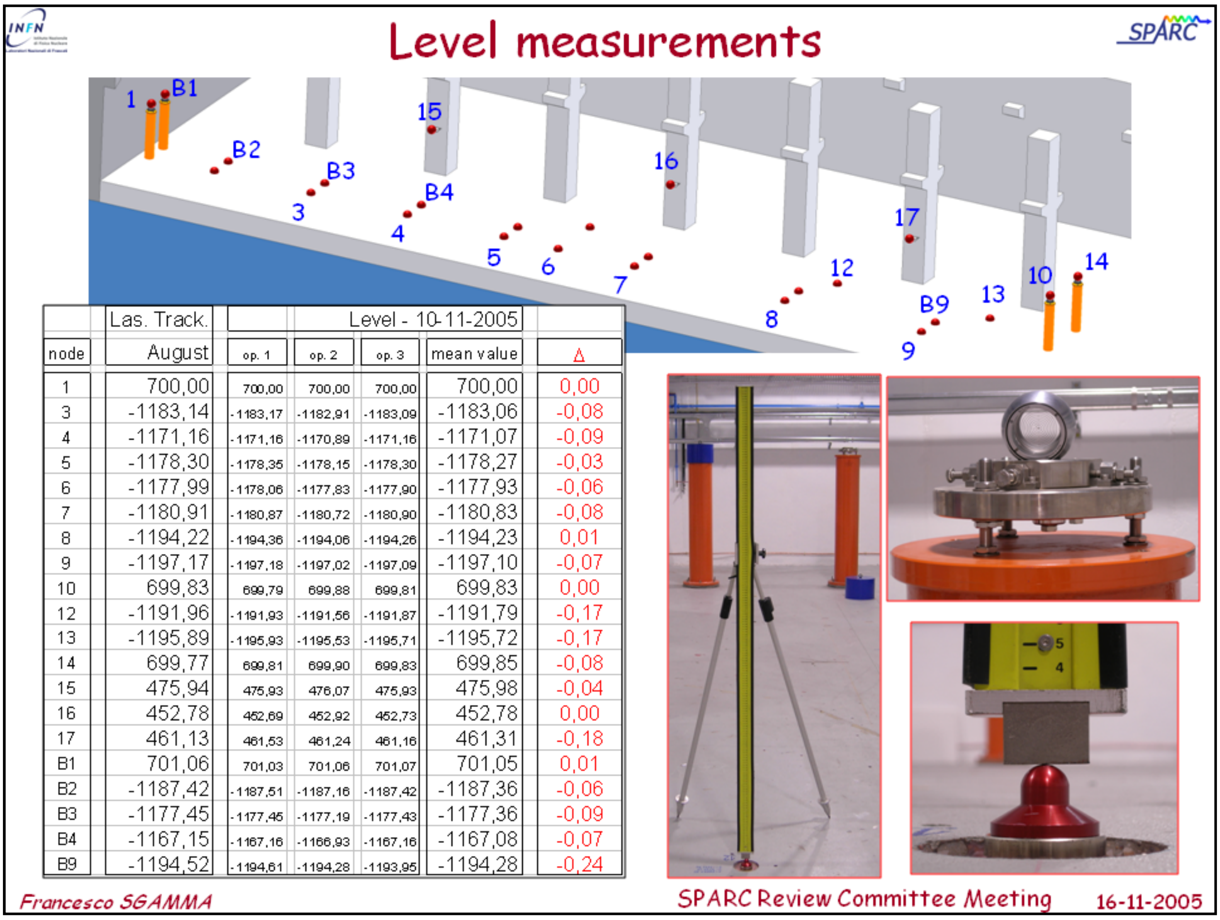
Three complete campaigns of laser tracker measurements of the network have been performed from July to November 2005.



Data have been analyzed and comparisons show that the differences never exceed 0.15mm and are mainly lower than 0.10mm.



Level measurements of the primary nodes have been performed also by means of optical levels. The table below shows the results of three sets of measurements performed independently by three different operators.



	Las. Track.	Level - 10-11-2005				
node	August	op. 1	op. 2	op. 3	mean value	Δ
1	700,00	700,00	700,00	700,00	700,00	0,00
3	-1183,14	-1183,17	-1182,91	-1183,09	-1183,06	-0,08
4	-1171,16	-1171,16	-1170,89	-1171,16	-1171,07	-0,09
5	-1178,30	-1178,35	-1178,15	-1178,30	-1178,27	-0,03
6	-1177,99	-1178,06	-1177,83	-1177,90	-1177,93	-0,06
7	-1180,91	-1180,87	-1180,72	-1180,90	-1180,83	-0,08
8	-1194,22	-1194,36	-1194,06	-1194,26	-1194,23	0,01
9	-1197,17	-1197,18	-1197,02	-1197,09	-1197,10	-0,07
10	699,83	699,79	699,88	699,81	699,83	0,00
12	-1191,96	-1191,93	-1191,56	-1191,87	-1191,79	-0,17
13	-1195,89	-1195,93	-1195,53	-1195,71	-1195,72	-0,17
14	699,77	699,81	699,90	699,83	699,85	-0,08
15	475,94	475,93	476,07	475,93	475,98	-0,04
16	452,78	452,69	452,92	452,73	452,78	0,00
17	461,13	461,53	461,24	461,16	461,31	-0,18
B1	701,06	701,03	701,06	701,07	701,05	0,01
B2	-1187,42	-1187,51	-1187,16	-1187,42	-1187,36	-0,06
B3	-1177,45	-1177,45	-1177,19	-1177,43	-1177,36	-0,09
B4	-1167,15	-1167,16	-1166,93	-1167,16	-1167,08	-0,07
B9	-1194,52	-1194,61	-1194,28	-1193,95	-1194,28	-0,24

The data coming from the laser tracker measurements have been analyzed and treated by means of the Leica Axyz software [3], and have produced the reference table of network node coordinates (table 1). The coordinates are referred to the SPARC Coordinate System (SCS) which is a right handed Cartesian coordinate system (Fig.7) defined by the following parameters:

NODE	X	Y	Z
1	0	0	700.00
10	-	1000.00	699.93
B1	-	-	701.11

The height of node 1 above the beam horizontal plane (700mm) has been arbitrarily chosen. The z coordinates of nodes 10 and B1 come from optical level measurements, while the y coordinate of node 10 has been arbitrarily set.

The last seven nodes in table1 (nodes from N1 to N7) have been introduced into the network and qualified subsequently (August 2007), when the removal of the four pillar nodes (1,B1,10 and 14) has been necessary for safety reasons (after the installation of machine components had been completed, the path to the emergency exits had become too narrow).

3 MACHINE LAYOUT

A layout of the SPARC accelerator is shown in Fig.7. As it has been briefly described before the machine is made of a 1.6 cells s-band RF gun driven by a Ti:Sa laser. The beam coming out of the gun is then injected into three SLAC-type accelerating sections, the first two of which are embedded in 2 arrays of 13 solenoids each, required to produce a magnetic field for additional focusing in order to comply with the "Ferrario working point" matching conditions for emittance compensation [4]. Along the beam line, after the linac, there is an RF deflector necessary for the characterization of the longitudinal and transverse phase space of the beam and a seeding chamber, necessary to match the electron beam with a seeding laser, allowing the facility to generate seeded FEL emissions as well. The electron beam is at last driven through a 6-module 12m long undulator. The accelerator layout also includes a dogleg line used for beam compression studies and other experiments. The latter contains 2 dipole magnets, which produce the 2 14° bendings of the beam line, 8 quadrupoles and several other devices for diagnostics.

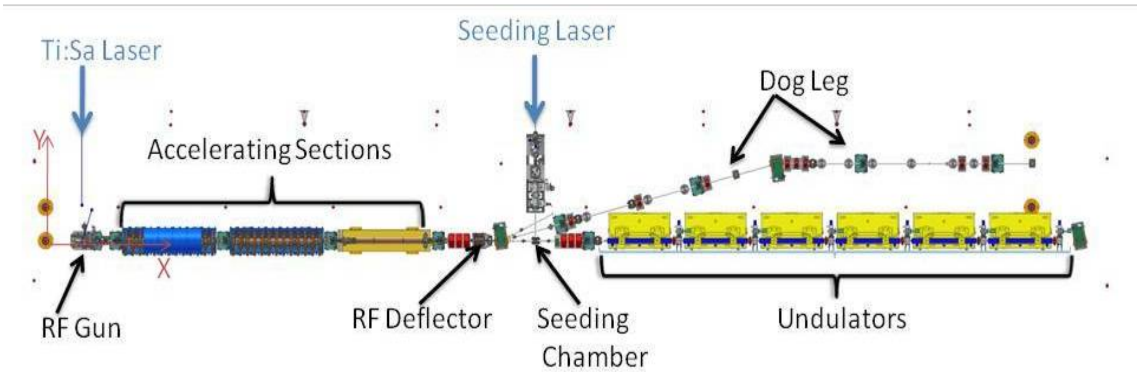


Fig. 7: SPARC Layout

The nominal positions of the center points of the accelerator components are listed in table 2. Their coordinates are referred to the SCS which has been defined and described in paragraph 2 and is shown in Fig. 7 (red arrows).

4 FIDUCIALIZATION OF COMPONENTS

Great attention and care has been given to the fiducialization of SPARC components. As a matter of fact the correct fiducialization of components is as important as their correct positioning since an error in either task will affect the particles' trajectory and these errors cannot be distinguished.

Part of the SPARC components were pre-existing magnets or RF devices, previously installed on other accelerators, another part has been designed and built anew. Fiducialization data for pre-existing components were already known and just had to be checked, and updated if necessary. For newly built components the reference markers have been specifically designed always keeping in mind that fiducials must:

- be clearly and comfortably visible during both fiducialization process and alignment operations in the accelerator hall.
- be extremely stable
- have, as much as possible, a symmetrical distribution around the component axis.

In some cases we have manufactured and fiducialized some auxiliary alignment tools, designed to be attached to the component they were built for, only during the alignment operation.

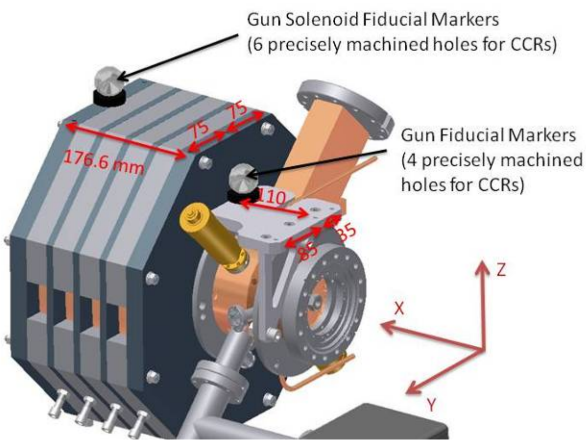
The referencing of fiducial markers with respect to the geometrical axis of components and the checking of data for pre-existing components has been in most part performed by means of laser tracker measurements exploiting the tracking capabilities of this instrument and the versatility of leica Axyz software which offers tools for many types of geometrical analyses. For a part of the newly built components this operation has been accomplished by means of tactile probe 3D coordinate measuring machines in outsourcing. In these cases data on fiducial marker positions, with certified accuracy, have been provided.

In the following paragraphs the fiducialization procedures, component by component (for all the components whose alignment operations were under the responsibility of INFN) will be described showing the positions of the reference markers with respect to local coordinate systems. The fiducialization of the focusing solenoids for the first two accelerating sections has been already described and shown in detail in [5] and will not be considered here.

4.1 Gun and Gun Solenoid

The gun and gun solenoid have been aligned on the basis of design data. The positions of the reference markers with respect to the geometrical axes have been obtained from the drawings. Consistency of design data with LT measured reference marker coordinates has been verified, but no direct fiducialization has been carried out because installation and alignment of the gun began before purchasing the LT.

The Gun has an alignment plate with 4 holes for fiducial markers. Two of these lie on the vertical plane passing through the axis of the gun. The plane of the plate is 114.32mm above the axis.
The Gun Solenoid has 6 holes for fiducial markers with the 2 central ones lying on the axis vertical plane. The horizontal plane containing the holes is 196.44mm above the axis.



4.2 Accelerating Sections

Two of the three accelerating sections of the SPARC linac have been delivered to LNF by Mitsubishi, while the third one comes from SLAC as part of a collaboration agreement. The two Mitsubishi sections have been fiducialized by LT measurements. A continuous mode acquisition of points on the cylindrical surface has allowed to determine the section axis on which the coordinate system has been built. Since these two accelerating sections are surrounded by an array of coils, it has been necessary to build some specific alignment tools (the plates shown in Fig. 8) to make the alignment operations easier and more comfortable, otherwise the reference markers would have been hardly visible after the installation.

The SLAC accelerating section is not embedded in focusing solenoids and its external surface is always clearly visible, therefore it has been possible to perform its alignment operations just by surveying the external cylindrical surface of the section.

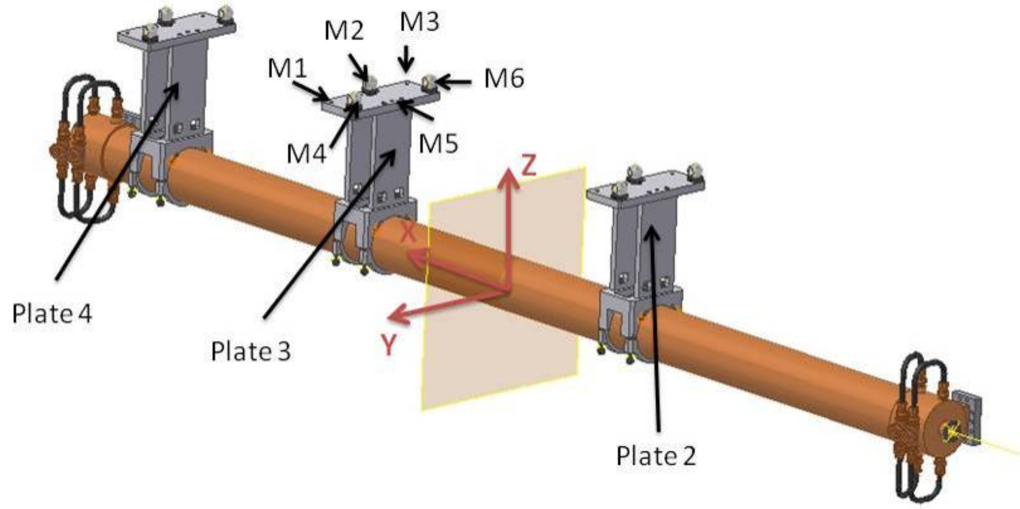


Fig. 8: Alignment tools with fiducial markers mounted on the Mitsubishi accelerating section

			X	Y	Z			X	Y	Z			X	Y	Z
AC1	PLATE 2	M1	-471,95	129,93	390,11	PLATE 3	M1	496,88	129,98	389,97	PLATE 4	M1	1223,99	129,84	389,66
		M2	-472,06	-0,07	390,12		M2	496,79	0,01	389,87		M2	1223,96	-0,09	389,63
		M3	-472,21	-130,03	390,16		M3	496,63	-130,00	389,89		M3	1223,83	-130,08	389,64
		M4	-551,91	129,98	390,08		M4	416,96	130,00	390,00		M4	1144,05	129,85	389,68
		M5	-551,99	-0,02	390,08		M5	416,79	0,02	389,90		M5	1143,95	-0,09	389,65
		M6	-552,13	-129,99	390,11		M6	416,71	-129,97	389,92		M6	1143,87	-130,11	389,70
AC2	PLATE 2	M1	-469,90	130,04	389,92	PLATE 3	M1	499,69	130,63	389,66	PLATE 4	M1	1230,50	130,10	389,81
		M2	-470,00	0,03	389,96		M2	499,59	0,65	389,86		M2	1230,49	0,14	389,83
		M3	-470,12	-129,93	390,03		M3	499,45	-129,34	390,14		M3	1230,41	-129,82	389,89
		M4	-549,88	130,06	389,90		M4	419,73	130,67	389,62		M4	1150,55	130,10	389,87
		M5	-549,93	0,08	389,94		M5	419,65	0,68	389,85		M5	1150,49	0,13	389,91
		M6	-550,05	-129,91	389,99		M6	419,52	-129,30	390,10		M6	1150,45	-129,87	389,95

4.3 Dipole Magnets

The SPARC dipoles were pre-existing magnets, previously installed on the LISA accelerator. The fiducialization data were retrieved from their datasheets and a check of the reference marker positions was performed by means of LT measurements.

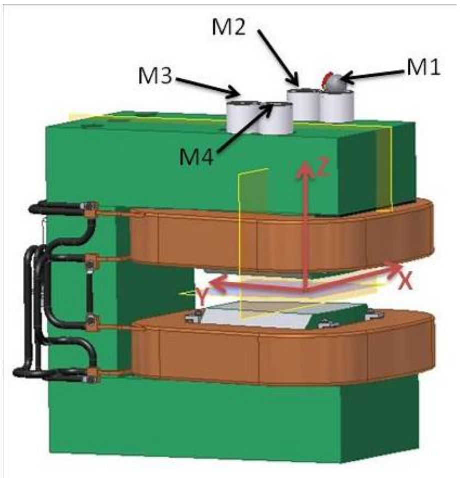


Fig. 9: Dipole magnet

		X	Y	Z
PTLDPL01	M1	112.00	0.00	336.52
	M2	112.00	60.00	336.50
	M3	-112.00	60.00	336.51
	M4	-112.00	0.00	336.42
DGLDPL01	M1	112.00	0.00	336.46
	M2	112.00	60.00	336.56
	M3	-112.00	60.00	336.43
	M4	-112.00	0.00	336.39

4.3 Quadrupole Magnets

The SPARC quadrupoles too were pre-existing components, but some new alignment tools have been added to them (the alignment plate in Fig. 10). A new fiducialization of all the quadrupole magnets has therefore been necessary. The latter has been carried out using the LT.

	DGLQUA01				DGLQUA02		
	X	Y	Z		X	Y	Z
M1	0.30	-88.85	213.38	M1	0.03	-89.11	213.30
M2	-59.80	1.09	213.10	M2	-59.96	0.91	213.14
M3	0.11	91.15	212.65	M3	0.09	90.90	213.01
M4	60.23	1.22	212.95	M4	60.08	0.88	213.22
	DGLQUA03				DGLQUA04		
	X	Y	Z		X	Y	Z
M1	0.27	-90.91	212.54	M1	0.31	-89.04	213.26
M2	-59.84	-0.97	213.20	M2	-59.96	0.78	213.03
M3	0.08	89.12	213.76	M3	-0.20	90.94	212.76
M4	60.20	-0.81	213.09	M4	60.08	1.13	212.99
	DGLQUA05				DGLQUA06		
	X	Y	Z		X	Y	Z
M1	-0.44	-89.08	213.11	M1	0.25	-90.28	212.67
M2	-60.28	1.05	213.11	M2	-59.92	-0.39	213.09
M3	-0.09	90.92	212.48	M3	-0.06	89.73	213.46
M4	59.73	0.81	212.50	M4	60.13	-0.15	213.02
	DGLQUA07				DGLQUA08		
	X	Y	Z		X	Y	Z
M1	-0.36	-89.33	212.97	M1	0.14	-89.94	212.86
M2	-60.77	0.42	213.06	M2	-59.94	0.03	213.26
M3	-1.12	90.68	213.04	M3	-0.02	90.07	213.45
M4	59.28	0.93	212.95	M4	60.10	0.11	213.07

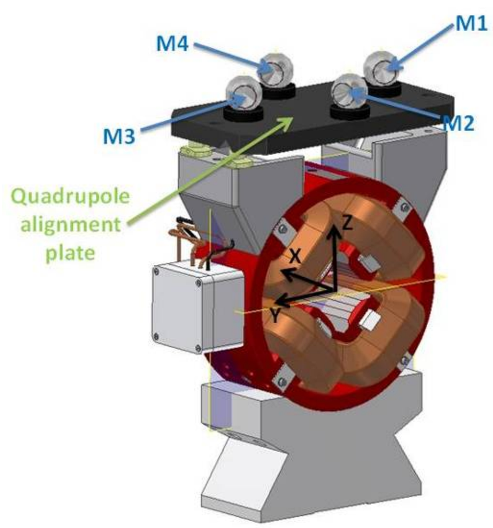
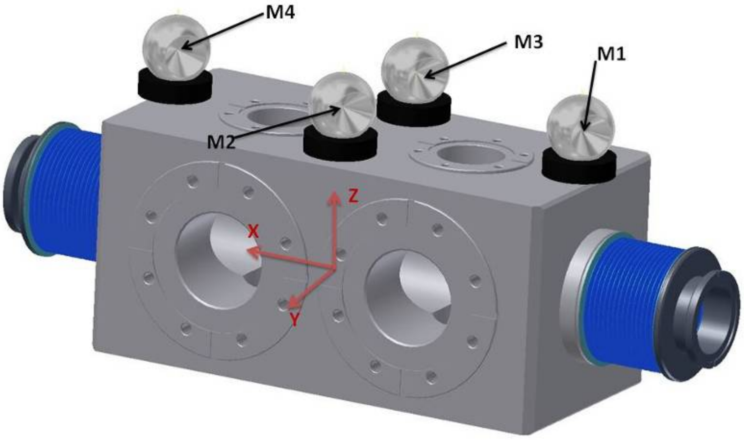


Fig. 10: Quadrupole magnet

4.4 Seeding Chamber, RF Deflector and BPMs

The fiducialization of the seeding chamber, of the RF deflector and of the strip-line Beam Position Monitors has been realized by means of a tactile probe 3D measuring machine by an external firm. Complete datasheets for all these components have been provided. Fig.11,12 and 13 show the reference markers and the local coordinate systems for these components and the tables next to them list the coordinates of the reference markers.



SEEDING CHAMBER			
	X	Y	Z
M1	-127,99	0,04	92,99
M2	0,02	42,00	92,98
M3	0,01	-42,00	92,98
M4	127,99	-0,04	92,98

Fig. 11: Seeding Chamber

RF DEFLECTOR			
	X	Y	Z
M1	-151,38	0,39	158,68
M2	2,52	-38,96	158,68
M3	2,72	39,01	158,68
M4	156,52	-0,42	158,67

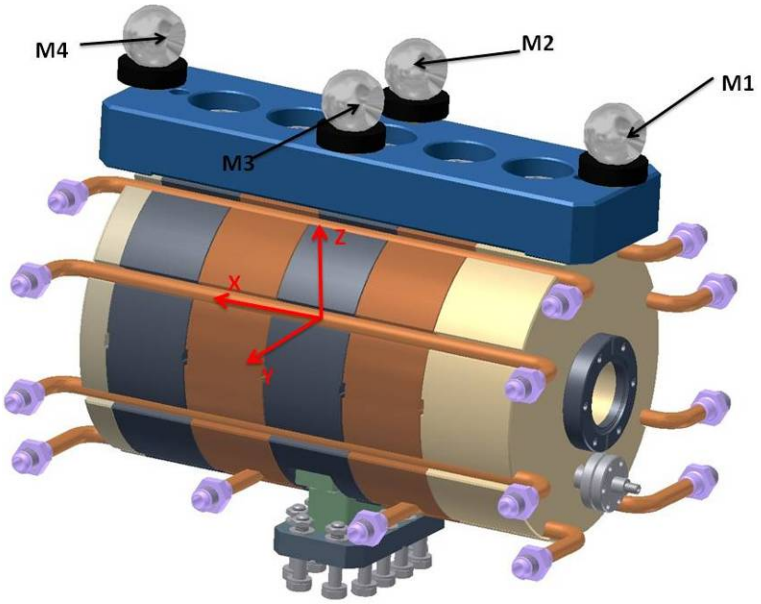


Fig. 12: RF Deflector

Survey operations on the BPMs require the use of 2.5mm thick washers that have to be inserted between the CCR holders and the BPMs themselves. This is necessary to avoid the contact between the stem of the CCR holder and the bottom of the fiducial marker holes. Only the AC1BPM01 (sr. code B), AC2BPM01 (sr. code D) and AC3BPM01 (sr. code 0) do not require them because they already have washers welded to their structures.

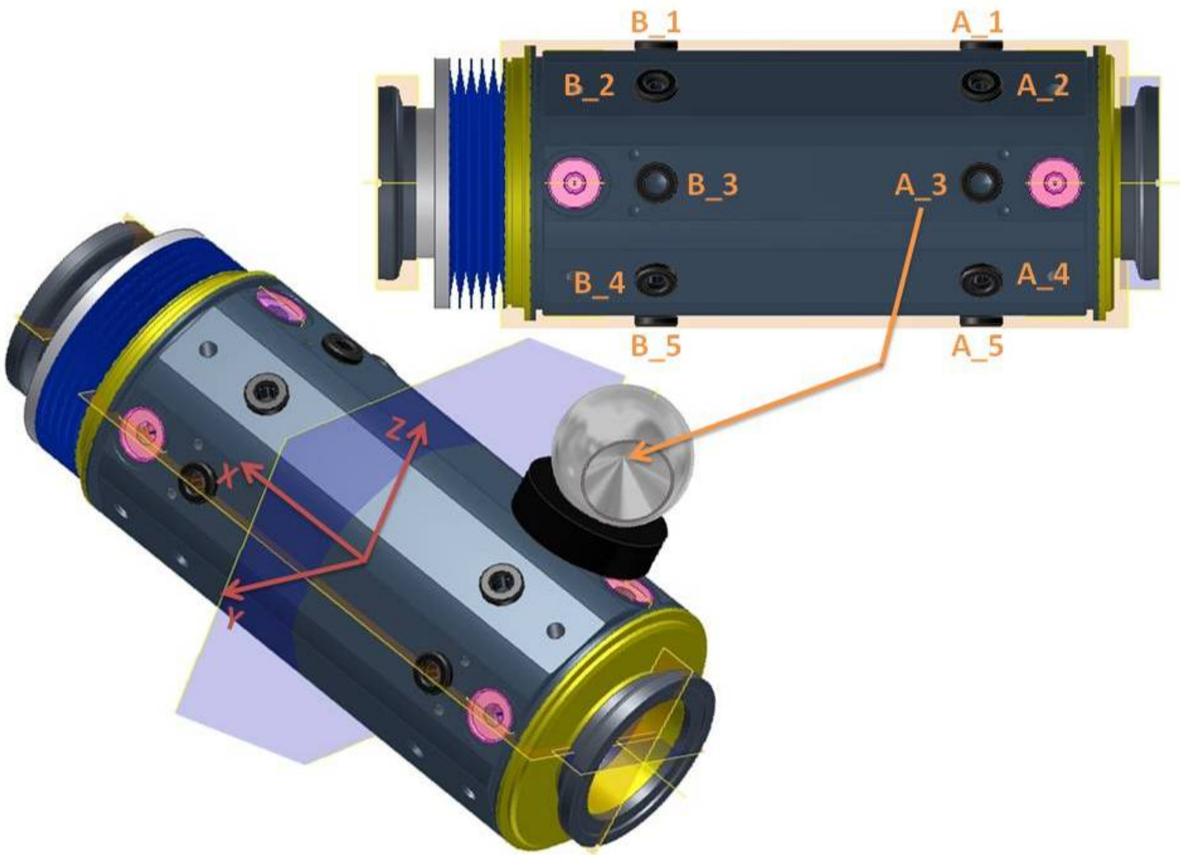


Fig. 13: Strip line Beam Position Monitors

GUNBPM (Sr. Code A)				AC1BPM01 (Sr. Code B)				AC2BPM01 (Sr. Code D)				AC3BPM01 (Sr. Code 0)			
	X	Y	Z		X	Y	Z		X	Y	Z		X	Y	Z
A_1	-45,08	-66,37	-0,13	A_1	-44,05	-66,68	-0,20	A_1	-44,21	-66,65	-0,02	A_1	-43,99	-66,40	0,00
A_2	-45,06	-47,00	46,91	A_2	-44,04	-47,19	47,05	A_2	-43,88	-47,18	47,04	A_2	-43,99	-46,89	47,06
A_3	-45,04	-0,03	66,47	A_3	-44,01	-0,18	66,60	A_3	-44,00	0,08	66,64	A_3	-44,01	0,04	66,46
A_4	-45,11	46,95	47,09	A_4	-44,09	46,97	47,26	A_4	-43,94	47,19	47,03	A_4	-43,79	46,95	47,11
A_5	-45,04	66,54	0,19	A_5	-44,09	66,63	0,17	A_5	-44,05	66,72	-0,01	A_5	-43,92	66,54	-0,22
B_1	43,00	-66,42	-0,09	B_1	43,99	-66,68	-0,20	B_1	43,99	-66,70	-0,03	B_1	44,08	-66,58	0,01
B_2	43,04	-47,02	46,95	B_2	43,97	-47,24	46,98	B_2	43,98	-47,07	47,18	B_2	44,14	-47,04	47,05
B_3	43,02	-0,05	66,46	B_3	44,02	-0,17	66,58	B_3	44,00	0,05	66,63	B_3	44,02	-0,10	66,46
B_4	43,01	46,96	47,12	B_4	43,99	47,00	47,14	B_4	43,91	47,21	47,00	B_4	44,27	47,10	46,89
B_5	43,01	66,56	0,08	B_5	43,95	66,68	0,12	B_5	44,03	66,65	0,27	B_5	44,13	66,48	-0,21
UTLBPM (Sr. Code J)				PTLBPM01 (Sr. Code G)				DGLBPM01 (Sr. Code I)				DGLBPM02 (Sr. Code E)			
	X	Y	Z		X	Y	Z		X	Y	Z		X	Y	Z
A_1	-45,05	-66,43	-0,27	A_1	-44,99	-66,46	-0,07	A_1	-45,07	-66,55	-0,13	A_1	-44,58	-66,42	-0,04
A_2	-45,35	-46,96	46,96	A_2	-45,05	-46,98	47,00	A_2	-45,04	-47,14	46,93	A_2	-44,68	-46,85	47,00
A_3	-45,08	-0,17	66,44	A_3	-44,99	0,02	66,46	A_3	-45,05	-0,23	66,47	A_3	-45,01	0,15	66,46
A_4	-45,39	46,97	47,12	A_4	-45,04	46,99	47,04	A_4	-44,96	46,86	47,11	A_4	-44,52	47,19	46,98
A_5	-45,35	66,59	0,15	A_5	-45,09	66,52	0,02	A_5	-44,94	66,45	0,14	A_5	-44,62	66,64	0,16
B_1	42,83	-66,40	-0,09	B_1	43,06	-66,48	-0,13	B_1	43,00	-66,60	-0,14	B_1	43,37	-66,34	0,03
B_2	42,76	-47,03	46,89	B_2	43,07	-47,04	46,92	B_2	43,10	-47,18	46,93	B_2	43,53	-46,87	46,99
B_3	42,71	-0,07	66,47	B_3	43,09	-0,06	66,43	B_3	43,12	-0,26	66,46	B_3	43,54	0,06	66,51
B_4	42,77	47,08	47,07	B_4	43,02	47,01	47,00	B_4	43,10	46,83	47,11	B_4	43,35	47,11	47,09
B_5	42,69	66,63	0,16	B_5	43,02	66,53	0,02	B_5	43,03	66,45	0,06	B_5	43,48	66,67	0,02

4.5 Steering Magnets

In the SPARC accelerator layout there is a total of 18 steering magnets. 12 of these are installed on the 3 accelerating sections (4 for each section). The section steering magnets (Fig.14) have only one couple of coils and can therefore correct the beam trajectory in only one direction. They are mounted rotated of a 90° angle one with respect to the other in order to correct alternatively the beam on the horizontal plane and on the vertical plane.

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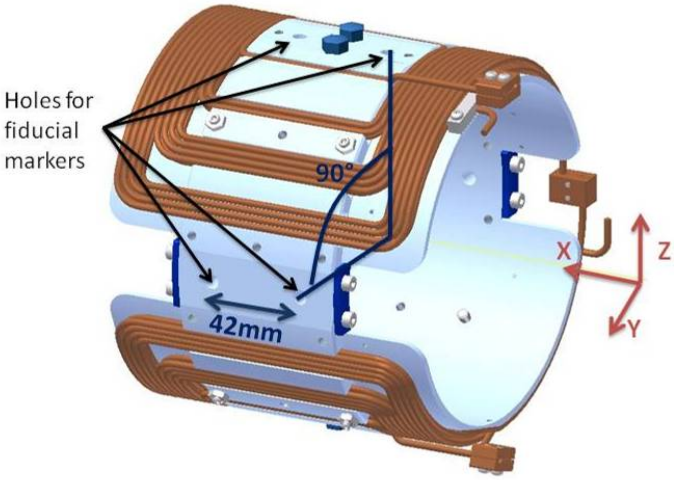


The section steering magnets have 8 holes for fiducial markers, but generally only 4 are visible at the same time by one station of the surveying instrument. 4 fiducials lie on the vertical axis and the other 4 on the horizontal axis. The radial distance of the planes containing the holes from the magnet axis is 83mm.

Fig. 14: Section Steering Magnet

The remaining 6 steering magnets (Fig.15) are 2-layered magnets (i.e. they have two concentric couples of coils, tilted of 90° one with respect to the other) which allow correction of the beam trajectory on both the horizontal and the vertical plane. 5 of these are positioned around the center of beam position monitors. The 6th one is on the 14° line of the dogleg

The BPM steering magnets have 2 holes for fiducial markers. These two holes define the vertical plane passing through the axis of the coils. The holes house the spherical targets without any holder, and the distance of a 1.5” CCR from the axis is 122.10 mm.

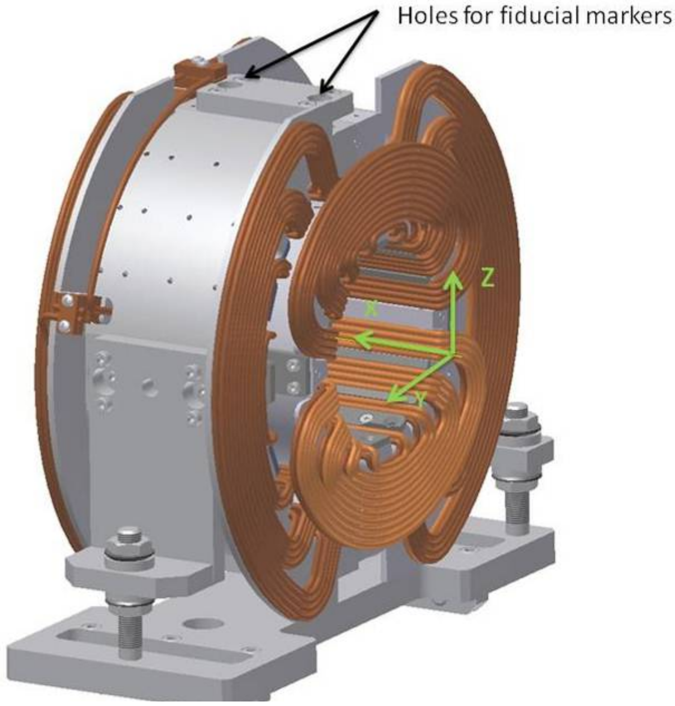


Fig. 15: BPM Steering Magnets

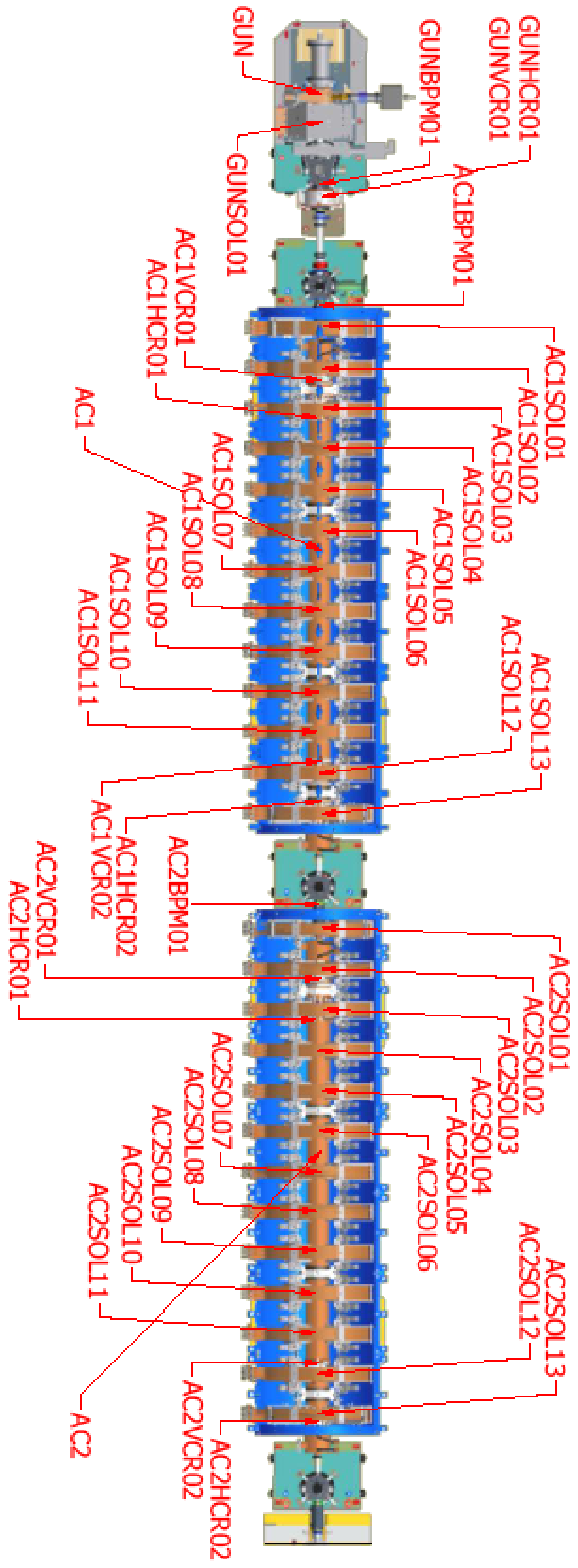
NODE	X	Y	Z
1	0.00	0.00	700.00
2	2427.59	0.05	-1184.51
3	6026.87	0.24	-1183.13
4	9625.57	0.36	-1171.14
5	13225.57	0.29	-1178.29
6	15245.92	0.18	-1177.97
7	18092.01	0.19	-1180.89
8	23698.20	0.32	-1194.19
9	28794.00	-0.14	-1197.13
10	33000.03	1000.00	699.93
11	15245.72	2299.48	-1184.43
12	24473.75	2299.15	-1191.81
13	30163.16	2298.89	-1195.73
14	33000.01	3000.02	699.97
15	8660.27	3487.27	476.14
16	17566.98	3482.88	452.99
17	26481.03	3482.02	461.35
B1	-0.06	999.56	701.11
B2	2427.95	1000.03	-1187.36
B3	6027.08	1000.48	-1177.39
B4	9625.87	1001.72	-1167.09
B5	13225.93	999.99	-1177.27
B7	18091.74	1000.17	-1182.92
B8	23698.01	999.79	-1190.60
B9	28794.11	1000.09	-1194.43
DA1	4227.64	-2273.06	2446.84
DA2	8676.14	-2277.78	2444.20
DA3	13141.71	-2265.18	2438.37
DA4	17560.46	-2255.82	2448.85
DA5	22011.91	-2264.77	2441.42
DA6	26459.90	-2267.15	2441.12
DA7	30920.78	-2295.21	2433.58
DB1	4235.73	-2673.92	-1099.17
DB2	8598.23	-2677.63	-1084.19
DB3	13124.43	-2675.02	-1116.78
DB4	17455.10	-2685.35	-1121.22
DB5	22007.03	-2684.33	-1122.79
DB6	26465.75	-2695.42	-1121.69
DB7	30916.24	-2700.57	-1117.89
DM1	4211.70	-2657.33	689.43
DM2	8679.62	-2661.91	690.60
DM3	13113.35	-2661.81	693.24
DM4	17495.39	-2661.55	698.71
DM5	22011.44	-2659.58	684.26
DM6	26462.18	-2670.25	686.12
DM7	30915.55	-2682.80	689.32
P11	-390.70	-1186.97	2450.80
P12	-368.49	2352.30	2444.89
P13	-372.73	2397.23	565.76
P21	35530.77	2452.19	2435.82
P22	35531.22	-1352.22	2433.63
P23	35529.04	-1326.17	492.83
SA1	4185.13	3454.99	2459.63
SA2	8663.10	3452.29	2446.94
SA3	13085.57	3452.05	2469.65
SA4	17553.85	3447.91	2455.16
SA5	22015.78	3455.05	2444.66
SA6	26469.00	3450.46	2441.74
SA7	30922.76	3450.07	2439.93
SB1	4204.37	3857.97	-1105.20
SB2	8651.81	3855.47	-1101.42
SB3	13107.46	3856.40	-1113.78
SB4	17568.90	3853.00	-1121.22
SB5	22019.39	3853.87	-1130.40
SB6	26466.73	3852.05	-1125.40
SB7	30905.03	3847.00	-1125.11
SM1	4207.21	3858.49	933.96
SM2	8654.09	3857.78	949.89
SM3	13115.95	3855.11	936.59
SM4	17565.49	3855.34	928.22
SM5	22009.71	3855.47	924.71
SM6	26471.07	3851.65	930.07
SM7	30918.01	3854.55	920.54
N1	-380.01	1526.92	50.17
N2	-375.72	1525.74	707.24
N3	-387.02	469.19	119.80
N4	-383.21	454.62	739.44
N5	-389.92	-502.91	116.85
N6	-388.25	-516.85	756.90
N7	2641.24	-2659.17	1178.19

Table 1: Network Nodes in the SPARC Coordinate System (SCS)

COMPONENT	X	Y	ALFA	COMPONENT	X	Y	ALFA
GUN	1247.00	0.00	0	AC3	11478.00	0.00	0
GUNSOL01	1443.00	0.00	0	AC3BPM01	9799.00	0.00	0
GUNBPM01	1884.00	0.00	0	AC3VCR01	10115.00	0.00	0
GUNHCR01	1884.00	0.00	0	AC3HCR01	10455.00	0.00	0
GUNVCR01	1884.00	0.00	0	AC3VCR02	12525.00	0.00	0
AC1	4280.00	0.00	0	AC3HCR02	12865.00	0.00	0
AC1BPM01	2601.00	0.00	0	PTLRFD01	14516.00	0.00	0
AC1VCR01	2931.50	0.00	0	PTLHCR01	14870.00	0.00	0
AC1HCR01	3271.50	0.00	0	PTLVCR01	14870.00	0.00	0
AC1VCR02	5288.00	0.00	0	PTLBPM01	14870.00	0.00	0
AC1HCR02	5628.00	0.00	0	PTLDPL01	15246.00	0.00	7
AC1SOL01	2680.00	0.00	0	SEEDING CH	16306.00	0.00	0
AC1SOL02	2922.00	0.00	0	UTLBPM	18487.00	0.00	180
AC1SOL03	3164.00	0.00	0	UTLHCR01	18486.00	0.00	0
AC1SOL04	3406.00	0.00	0	UTLVCR01	18486.00	0.00	0
AC1SOL05	3648.00	0.00	0	DGLQUA01	17579.56	581.82	14
AC1SOL06	3890.00	0.00	0	DGLHCR01	17816.10	640.85	14
AC1SOL07	4132.00	0.00	0	DGLVCR01	17816.10	640.85	14
AC1SOL08	4374.00	0.00	0	DGLBPM01	19622.03	1091.06	14
AC1SOL09	4616.00	0.00	0	DGLQUA02	19859.76	1150.33	14
AC1SOL10	4858.00	0.00	0	DGLQUA03	22139.95	1718.85	14
AC1SOL11	5100.00	0.00	0	DGLHCR02	22603.80	1834.51	14
AC1SOL12	5342.00	0.00	0	DGLVCR02	22603.80	1834.51	14
AC1SOL13	5584.00	0.00	0	DGLDPL01	24473.51	2300.67	-173
AC2	7879.00	0.00	0	DGLQUA04	24828.51	2300.67	0
AC2BPM01	6200.00	0.00	0	DGLQUA05	25128.51	2300.67	0
AC2VCR01	6538.00	0.00	0	DGLQUA06	25428.51	2300.67	0
AC2HCR01	6878.00	0.00	0	DGLBPM02	25673.51	2300.67	0
AC2VCR02	8522.00	0.00	0	DGLHCR03	25673.51	2300.67	0
AC2HCR02	8862.00	0.00	0	DGLVCR03	25673.51	2300.67	0
AC2SOL01	6279.00	0.00	0	DGLQUA07	30668.51	2300.67	0
AC2SOL02	6521.00	0.00	0	DGLQUA08	31468.51	2300.67	0
AC2SOL03	6763.00	0.00	0				
AC2SOL04	7005.00	0.00	0				
AC2SOL05	7247.00	0.00	0				
AC2SOL06	7489.00	0.00	0				
AC2SOL07	7731.00	0.00	0				
AC2SOL08	7973.00	0.00	0				
AC2SOL09	8215.00	0.00	0				
AC2SOL10	8457.00	0.00	0				
AC2SOL11	8699.00	0.00	0				
AC2SOL12	8941.00	0.00	0				
AC2SOL13	9183.00	0.00	0				

For each component ALFA is the angle (in degrees) of which the component itself has to be rotated (around the vertical z-axis) to make the component x-axis overlap the SCS x-axis. ALFA is positive if it is counterclockwise seen from the z positive side.

Table 2: Nominal Positions of the Center Points of the Accelerator Components in the SCS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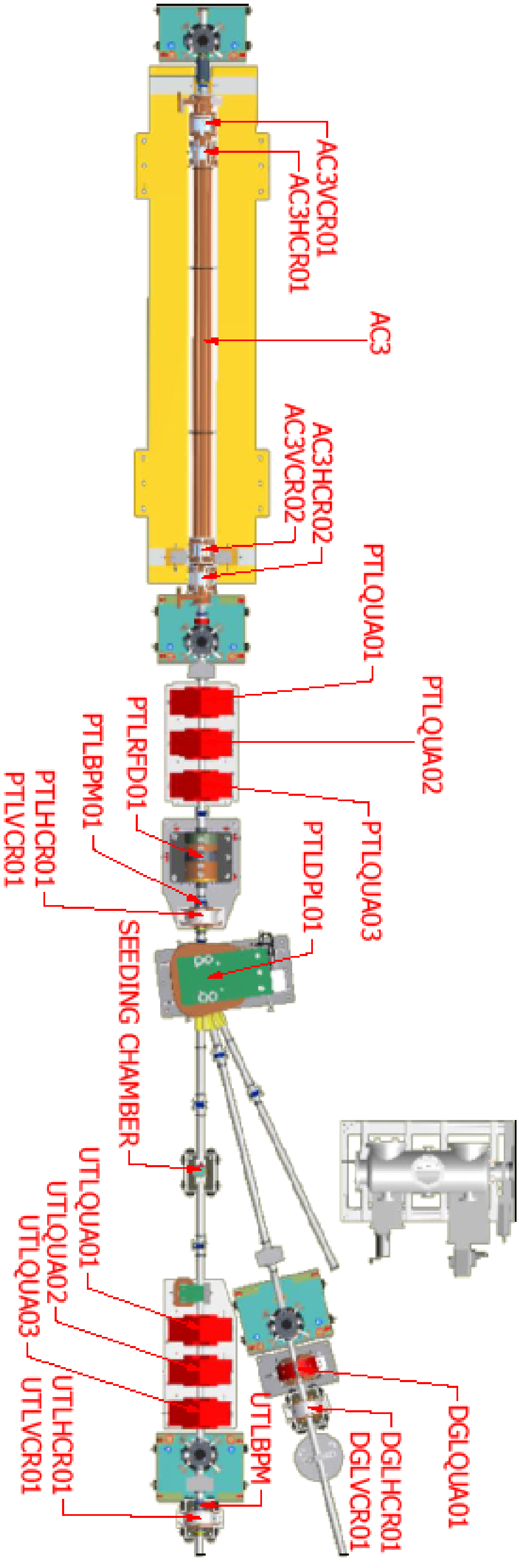
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SEEDING CHAMBER
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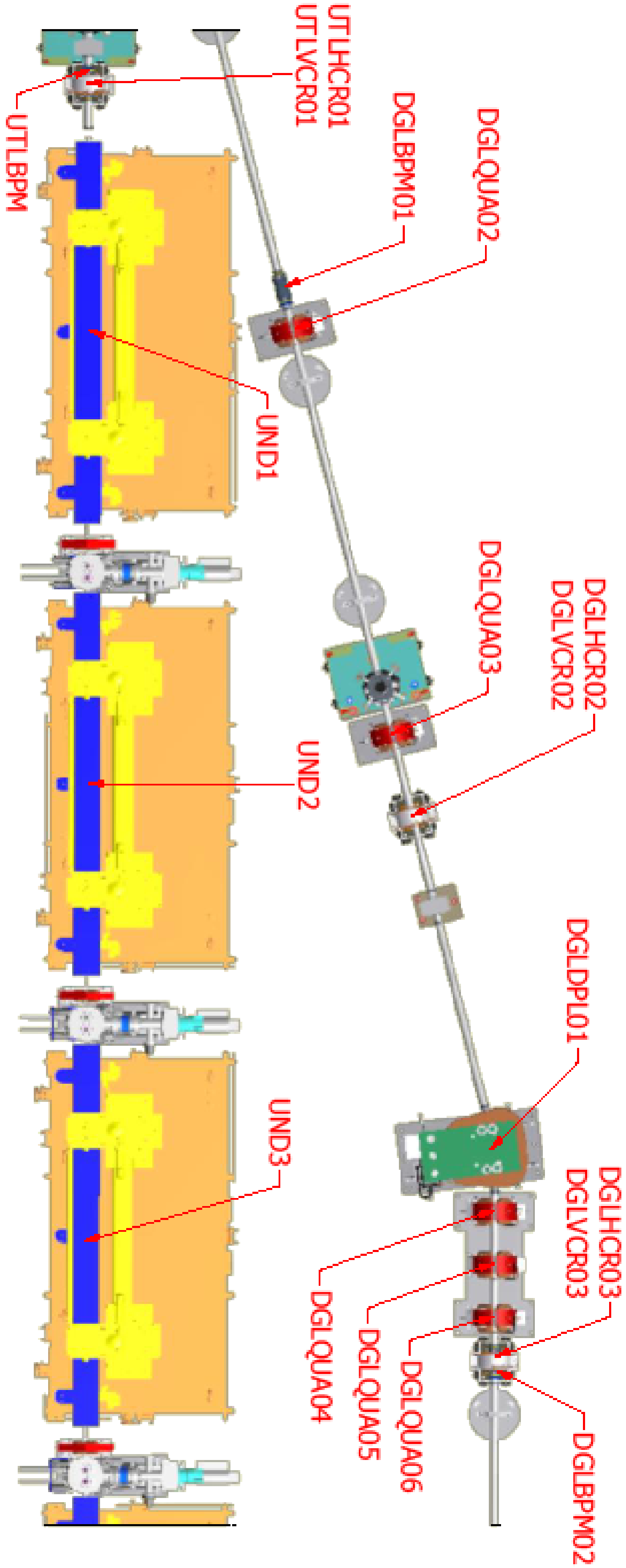
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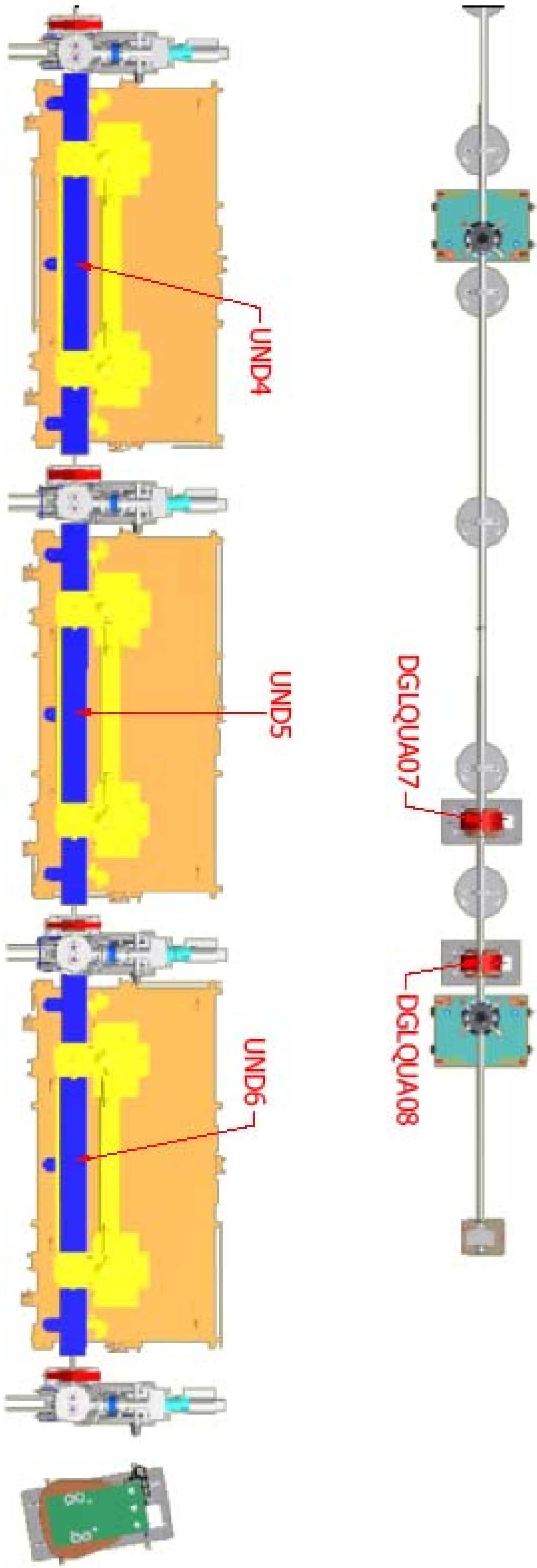
UND4
UND5
UND6
DGLQUA07
DGLQUA08

8 REFERENCES

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