ALBA	**Computing division**

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Title

ALBA Equipment Protection System (EPS)

Abstract

General description of the Interlocks at ALBA

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Record of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*
1.1	22/09/2006	3	Update reference list
		10	Estimation of Transfer Lines Vacuum Interlocks
		19	Layout of SR and Booster Magnets Interlocks
		23	Place BLs Interlocks PLCs outside control cabin
		21	Estimation of IDs Interlocks

References

[1] “Layout of the Service Area”, Alba project document END-BFCESARK-EN-0001

[2]

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[4]

[5]

[6]

Table of Contents

1. Introduction

The present document is a compilation of the mid-level information currently available for the Equipment Protection System (EPS) of the ALBA project. It covers the next systems:

- Storage Ring Vacuum Interlocks
- Booster & Transfer Lines Vacuum Interlocks
- Storage Ring Radio Frequency Interlocks
- Booster/Lab Radio Frequency Interlocks
- Magnets Interlocks
- Insertion Devices Interlocks
- Generic Front-End Interlocks
- Generic Beamline Interlocks

2. Scope and purpose

The purpose of the present document is to provide a detailed view of the EPS from the hardware point of view: distribution, number and type of signals, buses, layout proposal and general requirements. To produce all this, the information regarding the details of the interlock signals has been compiled from different divisions and groups, with as much detail as it's presently available. This shall be valuable information to make a cost estimation of the system.

The logic of the interlocks (state machine, thresholds, etc.) is out of the scope of this document. However, other aspects like IO response time, bus bandwidth, delays, CPU total cycle time, etc. shall be taken into account to take a final decision in terms of manufacturers, topology and distribution of the system.

3. Equipment Protection System general description

The purpose of the EPS can be described with two tasks:

1. To evaluate periodically a number of parameters of the machine, check its state and in case of malfunction drive it (either a subsystem or the whole machine) to a safe state.

2. To prevent the machine (at system and/or subsystem level) from moving to a not allowed state or performing not allowed actions (literally, locking the system until the predefined conditions are reached)

Interlocks are divided in "fast interlocks" (those especially critical that require very short response time (normally in the microseconds range) and that will be hardwired) and "slow interlocks", that are the majority and require response times normally <100ms. The last will be implemented using PLC and related industrial technologies, and are the scope of the present document.

A general layout of the ALBA main building is shown in next page, figure 2. The main features of the building are:

- The tunnel, where the booster and the storage ring are placed, with a diameter of ~83m
- The LINAC (linear accelerator)
- The technical/service areas where all the racks and equipments are placed (control system, power supplies, diagnostics devices, etc.)
- Laboratories
- RF plants

The building is divided in 16 sectors, as shown in figure 1. Each one has its own arrangement of equipment both in the service area and the tunnel (distribution of racks and devices) However, at the present stage, estimation of the total number of inputs/outputs will be done, in general, using one sector as reference and multiplying the results by the proper number depending on the system (vacuum, RF, Beamlines and so on, see the respective sections in the present document)

Many equipments that are placed in the service area will be located in a rack. These are assigned to a particular system (ref. 1):

- Racks 1 to 15 are assigned to Magnets
- Racks 16 and 17 are assigned to Diagnostics
- Racks 18 and 19 are assigned to Vacuum
- Racks 21 and 22 are assigned to Radio Frequency
- Racks 25 are assigned to Front Ends
- Racks 26 are assigned to Controls

4. ALBA General Layout

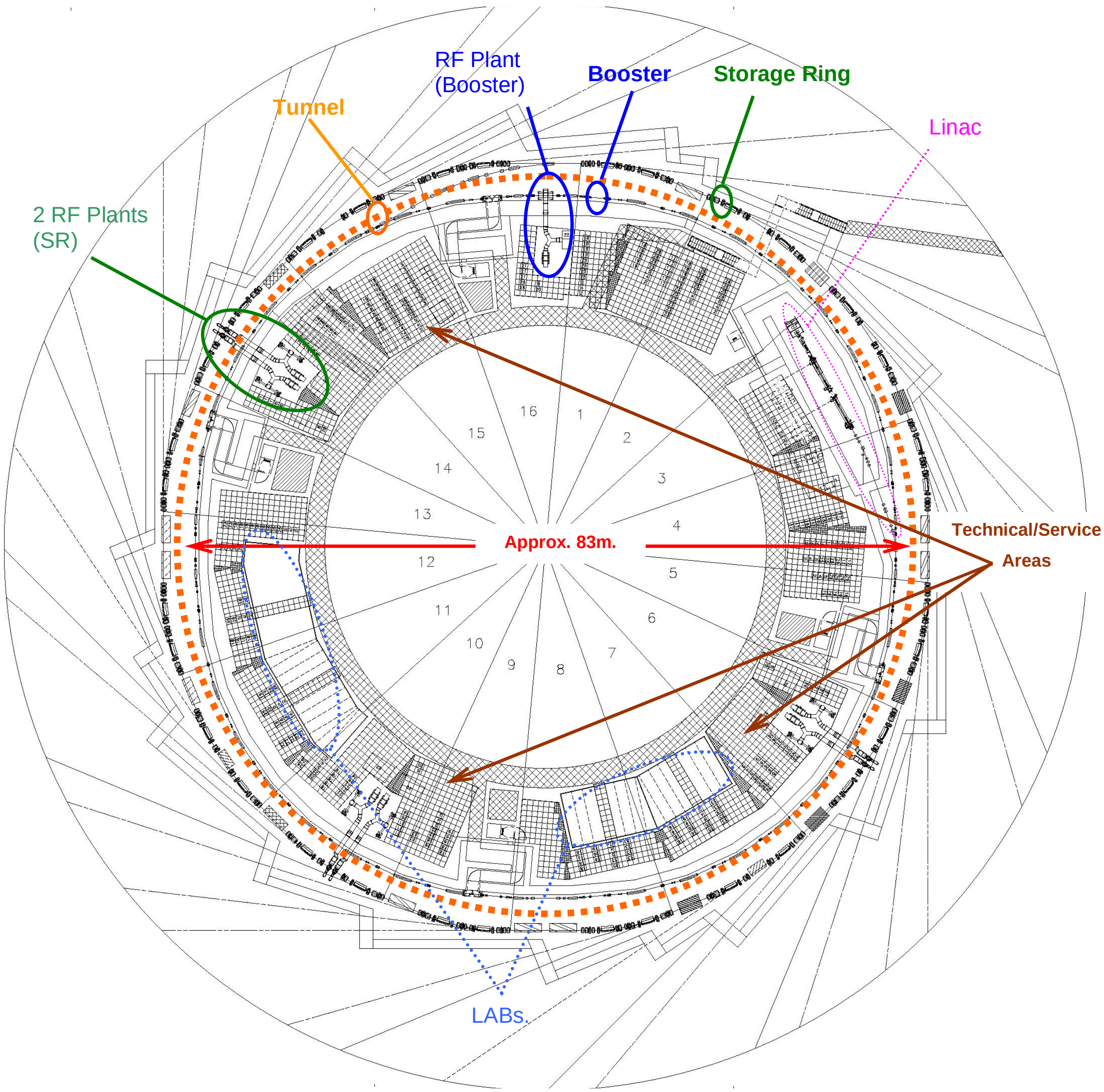

Fig.1: ALBA synchrotron general layout

5. Equipment Protection System general requirements

A general set of requirements have been identified in order to provide some guidelines to the suppliers. These should be fulfilled whenever it's possible; However, for certain cases, proposals outside the requirements can be addressed if they are fully justified and compared against the original proposed layout. More details on these requirements can be found on this document in following sections for each particular system.

R1. Distributed system: For machine coherency and to limit the CPU processing load, the concept of distributed system is adopted thoroughly:

- For SR/Booster/TL Vacuum interlocks one PLC CPU will be used for each sector (total of 16). They will be placed in the racks of the service area (either control racks or vacuum racks, to be defined), and each CPU will be in charge of the vacuum interlock signals of the sector where it is placed.
- For SR/Booster/Lab Radio Frequency interlocks one PLC CPU will be used for each RF plant: two in sectors 6, 10 and 14, one in sector 16 and one in the RF Lab:
  - 6 PLC CPU for the Storage Ring (sectors 6,10 and 14)
  - 1 PLC CPU for the Booster RF plant (sector 16)
  - 1 PLC CPU for the Lab RF plant
- For Magnets interlocks, due to the uneven distribution of signals and the necessity of interconnection, two CPUs will be used in sector 15 (one for the booster and one for the storage ring) and periphery modules in the others (both tunnel and racks)
- For Front-Ends, one CPU will be used for each one (total of 9)
- For Beam Lines, one CPU will be used for each line (total of 9)

R2. Periphery: In principle, the signals coming from/to devices placed in the service area (racks) shall be managed locally in local I/O modules mounted in the CPU racks (this may change if the number of signals make it advisable to use periphery in some cases) The signals coming from the tunnel will be managed always by remote modules. These modules may have some processing capabilities or be just considered as remote dumb I/O; In any case, the solution proposed shall comply with the requirements R4 and R7 and shall be justified.

R3: Integration: The interlock control system will be integrated in the general machine control system, that is based on TANGO (http://www.esrf.fr/Infrastructure/Computing/tango), a fully distributed control system which is maintained by a collaboration between a number of synchrotron radiation facilities. Linux is in principle the preferred operating system but neither OPC server nor industrial scada systems could be used as they are windows based systems. On the other hand, to easily integrate the interlock HW equipment, communication functions have to be available in the programming language of the PLC's CPUs (preferably high level functions) in order to send and receive data from a PC independently of its operating system. Any API (C/C++

libraries or higher level applications) available to directly communicate the CPU with a Linux PC, experience in similar projects or willingness to provide support on the subject will be considered an asset.

R4. Buses: Following the market tendencies, to keep coherency with the general control system of the machine and to optimize cycle times, ethernet (TCP/IP, UDP…) is the preferred communication bus to be used, both between the CPU and the remote periphery and between the CPUs and the ALBA general control system. This does not mean that industrial buses (DeviceNET, Profibus, ASI…) are excluded, but their use shall be justified.

R5. Modules: The majority of the signals to be managed will be Digital Inputs(24V), Digital Outputs(24V) and Analogue inputs (as a reference, 12-14 bits of resolution should be enough). More information on this point can be found in next sections. A number of different modules within one family (e.g. 2xDI, 8xDI, 16xDI modules…) should be avoided, and it’s preferred to have a limited number of modules even if it is less optimum (in terms of percentage of use but better in terms of spares) Ideally, there will be one type of DI module (e.g. 16xDI), one for thermocouples and so on.

R6. Temperature signals: Most analogue inputs will be temperature signals coming from thermocouples or PT-100 sensors. Normally this kind of signals requires dedicated modules; In any case, thermocouple signal acquisition modules shall be compatible with K-type sensors, and should include cold-junction compensation in a way that the signal read by the CPU is already compensated. Specifications for PT-100 (2-wire, 3-wire techniques) are not approved. In both cases, linearization over the full range as well as selectable temperature range must be included.

R7. Time response/CPU load: In general, the EPS will perform simple monitoring tasks (signal levels, digital inputs check) and provide reasonable fast response upon failures. This means that the CPU load will be relatively small (no complex operations) and short cycle times are expected. As a reference figure, reaction time (time between reading the whole set of variables, processing and react accordingly) shall be <100ms

6. Vacuum System Interlocks (Booster, Storage Ring & Transfer lines)

The list of Interlocks signals for the Vacuum system is relatively well detailed. There are seven different equipments that require interface with the interlock system, listed below, as well as the type of signal they require (from the point of view of the controller). Not all the sectors will have exactly the same number of interlocks signals from the vacuum equipment, but it can be considered quite accurate to evaluate the average requirements of one sector and multiply it by the number of sectors, 16 (see tables 1 and 2)

Device	**Location**	**Type and number of interlock signals (type of IO channel required)**	**Number of devices per sector (avg.)**	**Number of signals per sector**	**Total number of signals (16 sectors)**
Pirani Gauges (controller)	Rack	1xDI	2	2xDI	32xDI
IMG Gauges (controller)	Rack	1xDI/1xDO	3	3xDI/3xDO	48xDI/48xDO
Ion Pumps (controller)	Rack	1xDI/1xDO	15	15xDI/15xDO	240xDI/240xDO
NEG Pumps (controller)	Rack	1xDI/1xDO	1	1xDI/1xDO	16xDI/16xDO
			TOTAL	***21xDI Local 19xDO Local***	***336xDI Local 304xDO Local***
Residual Gas Analyzer (RGA)	Tunnel	1xDO	1	1xDO	16xDO
Valves	Tunnel	1xDI/1xDO	3	3xDI/3xDO	48xDI/48xDO
Thermocouples	Tunnel	1xAI (Thermocouple)	30	30xAI	480xAI (Th.)
			TOTAL	***3xDI Remote 4xDO Remote 30xAI (Th.) Rmt.***	***48xDI Remote 64xDO Remote 480xAI (Th.) Rmt.***

Table 1: List of Storage Ring Vacuum Interlocks

Being not yet fully defined, the Transfer Lines Vacuum Interlocks (Linac to Booster & Booster to Storage Ring) are estimated as 1 sector of the Booster Interlocks each TL (see Table 2)

Device	**Location**	**Type and number of interlock signals (type of IO channel required)**	**Number of devices per sector (avg.)**	**Number of signals per sector**	**Total number of signals (16 sectors + 2 Transfer Lines)**
IMG Gauges (controller)	Rack	1xDI/1xDO	<1	DI/DO	12xDI/12xDO
Ion Pumps (controller)	Rack	1xDI/1xDO	8	8xDI/8xDO	144xDI/144xDO
				TOTAL	***156xDI Local 156xDO Local***
Valves	Tunnel	1xDI/1xDO	<1	DI/DO	10xDI/10xDO
				TOTAL	***10xDI Remote 10xDO Remote***

Table 2: List of Booster & estimated Transfer Lines Vacuum Interlocks

Figure 2 in next page shows, as reference, the layout and distribution of the vacuum interlocks signals in sector 1, position of Controls and Vacuum racks and general dimensions. Booster elements, being less in number, are not shown, but must be taken into account when defining the number of IO channels for the vacuum system (both local and remote signals)

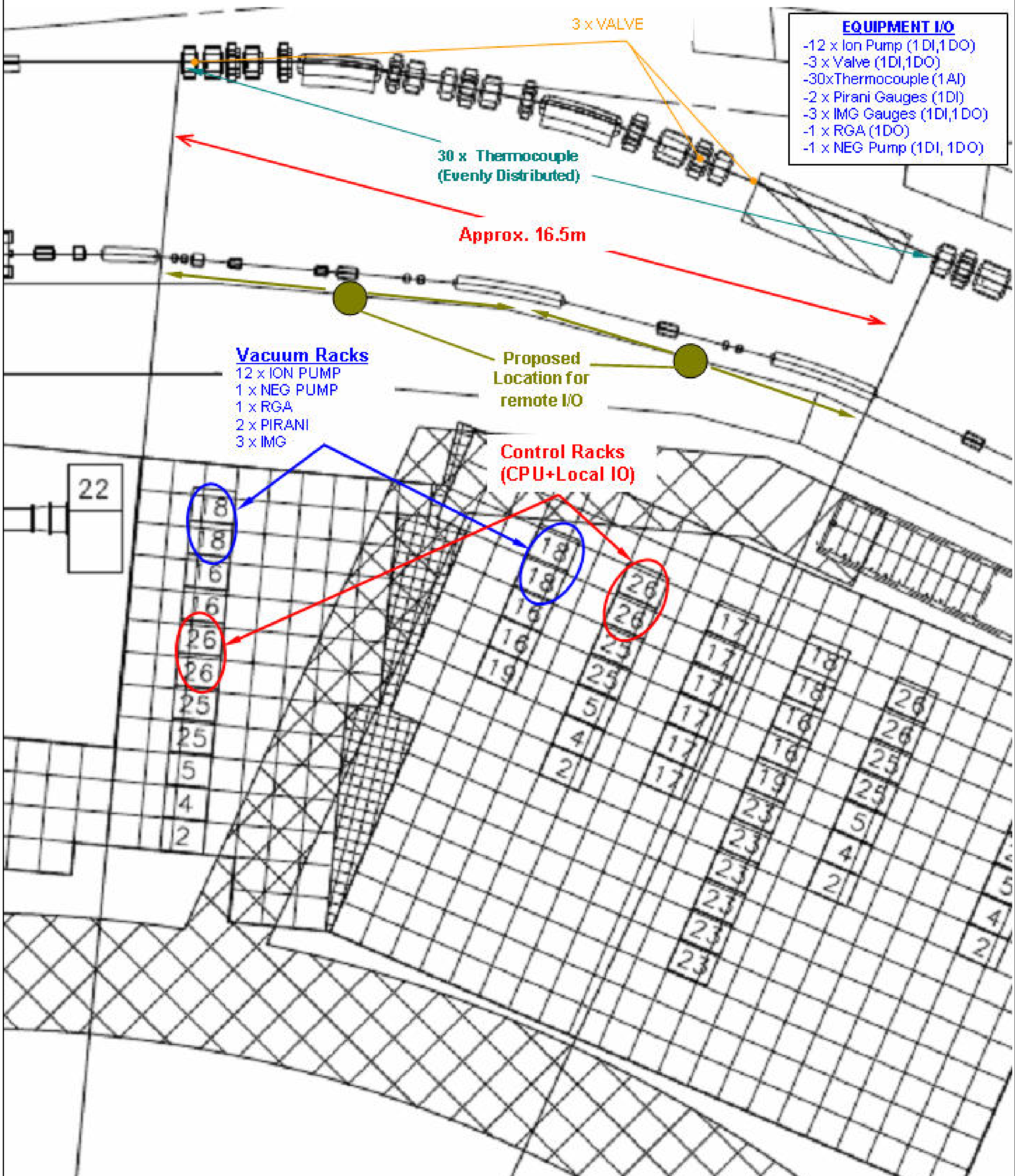

Fig.2: Storage Ring Vacuum Interlock Signals – Sector 1

7. Radio Frequency System Interlocks (Booster, Storage Ring & RF Lab)

Unlike the Vacuum system, Radio Frequency system is not distributed evenly in the tunnel. On the contrary, there are 6 RF plants placed in sectors 6, 10 and 14 for the storage ring (two in each sector), one RF plant is placed in sector 16 for the booster, and another RF plant is placed in the RF Laboratory (sector 7), as a fully functional hot spare. Table 3 shows the list of interlocks for a single RF plant of the Storage Ring. The equipment located in "Service Area" are those not fixed in a rack but somewhere else in the service area (e.g. the RF plant itself)

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices per RF plant	Number of signals per plant	Total number of signals (6 plants for the SR)
Power supply control	Rack	1xDI	6	6xDI	36xDI
Bidirectional Couplers	Service Area	1xAI	16	16xAI	96xAI
Shutter	Service Area	3xDI, 3xDO	1	3xDI, 3xDO	18xDI, 18xDO
Switch	Rack	1xDO	3	3xDO	18xDO
PT100	Service Area	1xAI (PT100)	9	9xAI (PT100)	54xAI (PT100)
Flow Switch	Service Area	1xDI	7	7xDI	42xDI
Arc Detector	Service Area	1xDI	2	2xDI	12xDI
			TOTAL	***16xDI Local 4xDO Local 9xAI(PT100) Loc. 15xAI Loc.***	***108xDI Local 36xDO Local 54xAI(PT100) Loc. 96xAI Loc.***
End-Switch	Tunnel	1xDI	1	1xDI	6xDI
Bidirectional Couplers	Tunnel	1xAI	2	2xAI	12xAI
PT100	Tunnel	1xAI (PT100)	15	15xAI (PT100)	90xAI (PT100)
Flow Switch	Tunnel	1xDI	9	9xDI	54xDI
Arc Detector	Tunnel	1xDI	2	2xDI	12xDI
			TOTAL	***12xDI Remote 15xAI(PT100) Rmt. 2xAI Rmt.***	***72xDI Remote 90xAI(PT100) Rmt. 12xAI Rmt.***

Table 3: List of Storage Ring RF Interlocks

RF plants for the Booster and the RF Lab are a particular case. In both cases, the cavity installed will be different than the one installed in the RF plants of the storage ring, thus with a different type and number of interlock signals.

The RF plant for the booster will always use the so called booster cavity, but the RF plant for the RF Lab may use the booster cavity or the DAMPY cavity (the storage ring cavity), two different configurations. For the first configuration of the RF Lab (RF plant with booster cavity), the interlock signals will be similar to the ones for the booster plant, while for the second configuration (RF plant with DAMPY cavity), the type and number of signals will be different. This means that RF Lab will have two different possible configurations, thus the maximum number of signals (HW configuration) has to be compatible for both, which is already taken into account in table 4.

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices	RF Lab Number of signals
Power supply control	Rack	1xDI	6	6xDI
Bidirectional Couplers	Service Area	1xAI	10	10xAI
Switch	Rack	1xDI, 1xDO	2	2xDI, 2xDO
Shutter	Service Area	3xDI, 3xDO	1	3xDI, 3xDO
PT100	Service Area	1xAI (PT100)	6	6xAI (PT100)
Flow Switch	Service Area	1xDI	4	4xDI
Arc Detector	Service Area	1xDI	1	1xDI
			TOTAL	***16xDI Local 5xDO Local 6xAI (PT100) Loc. 10xAI Loc.***
End-Switch	Tunnel	1xDI	2	2xDI
Bidirectional Couplers	Tunnel	1xAI	2	2xAI
PT100	Tunnel	1xAI (PT100)	15	15xAI (PT100)
Flow Switch	Tunnel	1xDI	15	15xDI
Arc Detector	Tunnel	1xDI	2	2xDI
			TOTAL	***19xDI Remote 15xAI(PT100) Rmt. 2xAI Rmt.***

Table 4: List of maximum RF Lab Interlocks

Table 5 in next page is a compilation of the interlocks signals for the booster RF plant. The difference with the RF Lab interlock signals is minimum, but for coherency and precision, it is presented separately.

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices	Booster RF plant number of signals
Power supply control	Rack	1xDI	6	6xDI
Bidirectional Couplers	Service Area	1xAI	10	10xAI
Switch	Rack	1xDO	2	2xDO
Shutter	Service Area	3xDI, 3xDO	1	3xDI, 3xDO
PT100	Service Area	1xAI (PT100)	6	6xAI (PT100)
Flow Switch	Service Area	1xDI	4	4xDI
Arc Detector	Service Area	1xDI	1	1xDI
			TOTAL	***14xDI Local 5xDO Local 6xAI (PT100) Loc. 10xAI Loc.***
End-Switch	Tunnel	1xDI	2	2xDI
Bidirectional Couplers	Tunnel	1xAI	2	2xAI
PT100	Tunnel	1xAI (PT100)	6	6xAI (PT100)
Flow Switch	Tunnel	1xDI	15	15xDI
Arc Detector	Tunnel	1xDI	2	2xDI
			TOTAL	***19xDI Remote 6xAI (PT100) Rmt. 2xAI Rmt.***

Table 5: List of Booster RF plant Interlocks

Figures 3 and 4 in next pages show the layout and distribution of the RF interlocks signals in sector 6 (for the storage ring) and sector 16 (for the booster), position of Controls and RF racks and general dimensions.

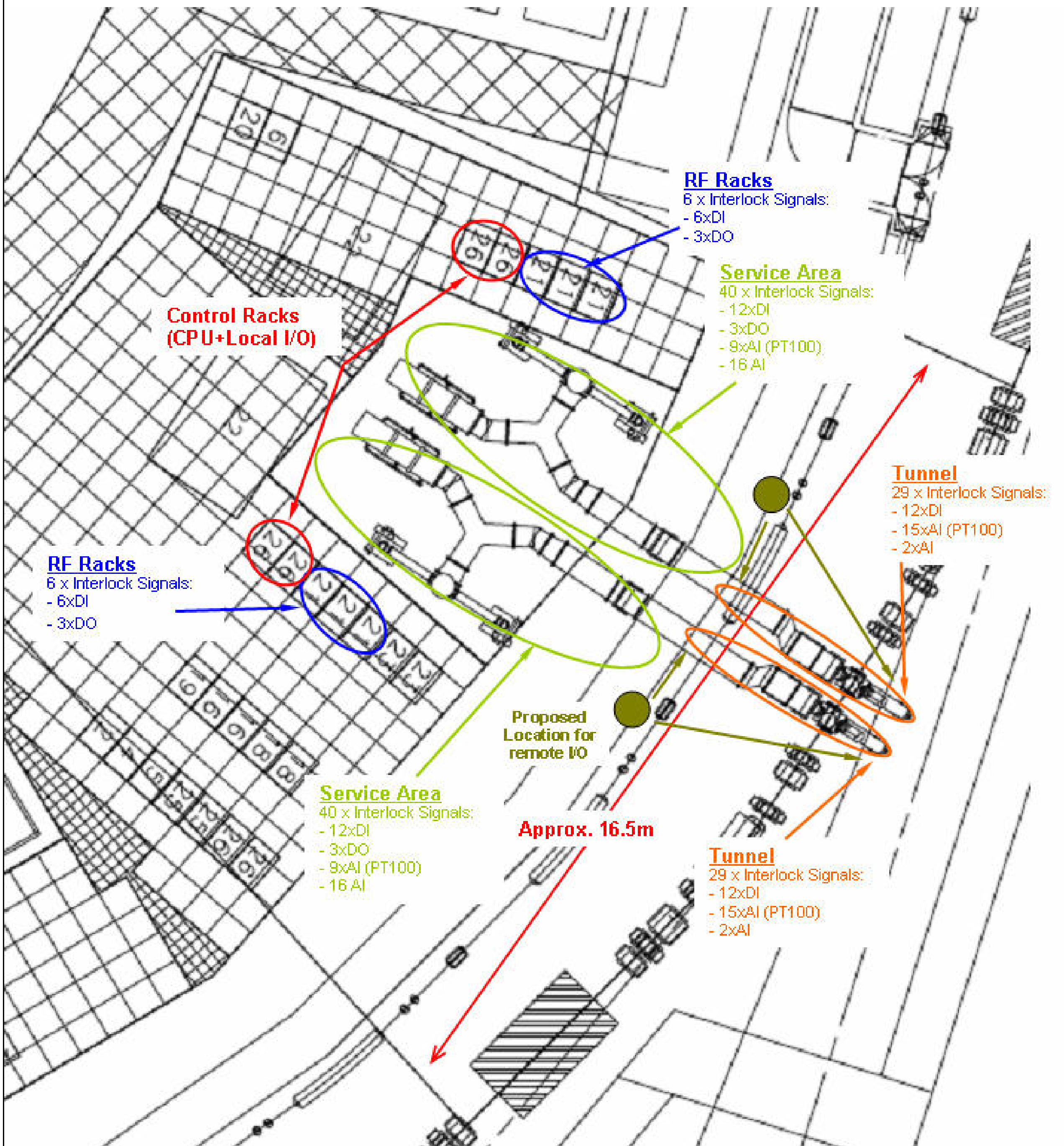

Fig.3: Storage Ring RF Interlock Signals – Sector 6

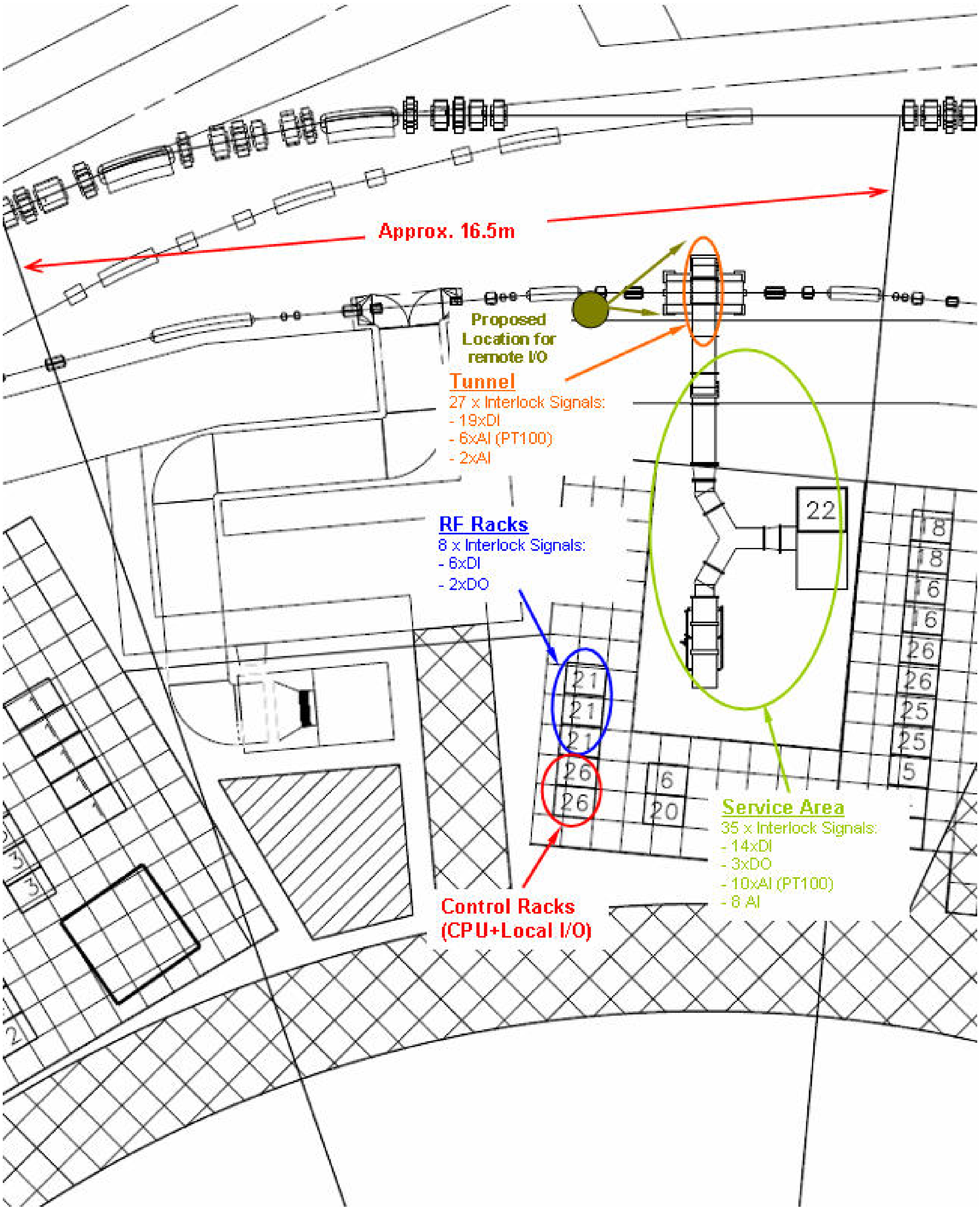

Fig.4: Booster RF Interlock Signals – Sector 16

8. Magnets Interlocks (for Storage Ring, Booster and Transfer Lines)

Magnets have several thermal switches and flowmeters to prevent any malfunction of the cooling system, and damages in the equipments. Regarding the Storage ring, all magnets have 2 interlock signals, one from the flowmeter and the second one from the thermo-switches (there may be several connected in series, but from the outside-world each magnet provides digital signals 24V. Sextupoles of the booster and correctors provide only one interlock signal.

All the magnets are interlocked by means of their respective power supply, which means that while all the PLC inputs are generated in the tunnel, the PLC outputs will be located in the racks, which have a particular distribution depending on the type of magnet:

	TYPE OF MAGNET							
	SR Dipoles	**Booster Dipoles**	**SR Quadrupoles**	**Booster Quadrupoles**	**SR Sextupoles**	**Booster Sextupoles**	**SR Correctors**	**Booster Correctors**
No. Power Supplies	1	1	112	4	9	2	176	72
Racks	1	7	2	8	3	9	4, 5	10
Location	15	15	Evenly distributed (16 sectors)	15	15	15	Evenly distributed (16 sectors)	15

Tables 6 and 7 show the type and number of signals for the Magnets System Interlocks (storage ring and booster). Due to the uneven distribution and since many of the power supplies are grouped in sector 15 and have to be interlocked by signals from magnets coming from all sectors, two CPUs in sector 15 will manage the interlocks logic (one for Storage Ring magnets and the other for Booster magnets), while one periphery modules will be placed in the tunnel in each sector (total of 16, to pick up signals) and one in the service area of each sector (total of 16, to interlock power supplies of correctors and SR quadrupoles), connected via a fieldbus (e.g. Ethernet, Profibus-DP, Modbus…). In principle two options shall be considered:

1. The periphery modules are shared for the two CPUs
2. The periphery will be repeated for the SR and the Booster, depending on the selected CPU, bus and modules performance.

With this distribution, only signals in the service area of sector 15 (racks) will be local, while the rest will be remote in tunnel or remote in service area (rack).

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices	Number of signals (per sector)	Total number of signals
Bending Magnets PS	Rack (sector 15)	1xDO	1 *(total)*	1xDO *(total)*	1xDO
Quadrupoles PS	Rack (sector 15)	1xDO	7	7xDO	7xDO
Sextupoles PS	Rack (sector 15)	1xDO	9 *(total)*	9xDO *(total)*	9xDO
Correctors PS	Rack (sector 15)	1xDO	11	11xDO	11xDO
			TOTAL	***28xDO Local***	***28xDO Local***
Quadrupoles PS	Rack distributed	1xDO	7	7xDO	105xDO
Correctors PS	Rack distributed	1xDO	11	11xDO	165xDO
Bending Magnets	Tunnel	2xDI	2	4xDI	64xDI
Quadrupoles	Tunnel	2xDI	7	14xDI	224xDI
Sextupoles	Tunnel	2xDI	7*(7.5)*	14*(15)*xDI	224*(240)*xDI
Correctors	Tunnel	1xDI	11	11xDI	176xDI
			TOTAL	***44xDI Rmt. tunnel 18xDO Rmt. rack***	***704xDI Rmt. tunnel (16 sectors) 270xDO Rmt. Rack (15 sectors)***

Table 6: List of SR Magnets Interlocks

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices	Number of signals (per sector)	Total number of signals
Bending Magnets PS	Rack (sector 15)	1xDO	1 *(total)*	1xDO *(total)*	1xDO
Quadrupoles PS	Rack (sector 15)	1xDO	4 *(total)*	4xDO *(total)*	4xDO
Sextupoles PS	Rack (sector 15)	1xDO	2 *(total)*	2xDO *(total)*	2xDO
Correctors PS	Rack (sector 15)	1xDO	5*(4.5)*	5*(4.5)*xDO	5xDO
			TOTAL	***12xDO Local***	***12xDO Local***
Correctors PS	Rack distributed	1xDO	5*(4.5)*	5*(4.5)*xDO	68xDO
Bending Magnets	Tunnel	2xDI	3	6xDI	96xDI
Quadrupoles	Tunnel	2xDI	4	8xDI	128xDI
Sextupoles	Tunnel	1xDI	1	1xDI	16xDI
Correctors	Tunnel	1xDI	5	5xDI	80xDI
			TOTAL	***20xDI Rmt. tunnel 5xDO Rmt. rack***	***320xDI Rmt. Tunnel (16 sectors) 68xDO Rmt. Rack (15 sectors)***

Table 7: List of Booster Magnets Interlocks

To clarify the layout of storage ring and booster magnets interlocks, Figure 5 provides an idea of the general distribution of the signals in sectors 15, 16 and 1, that can be extrapolated to the rest of sectors.

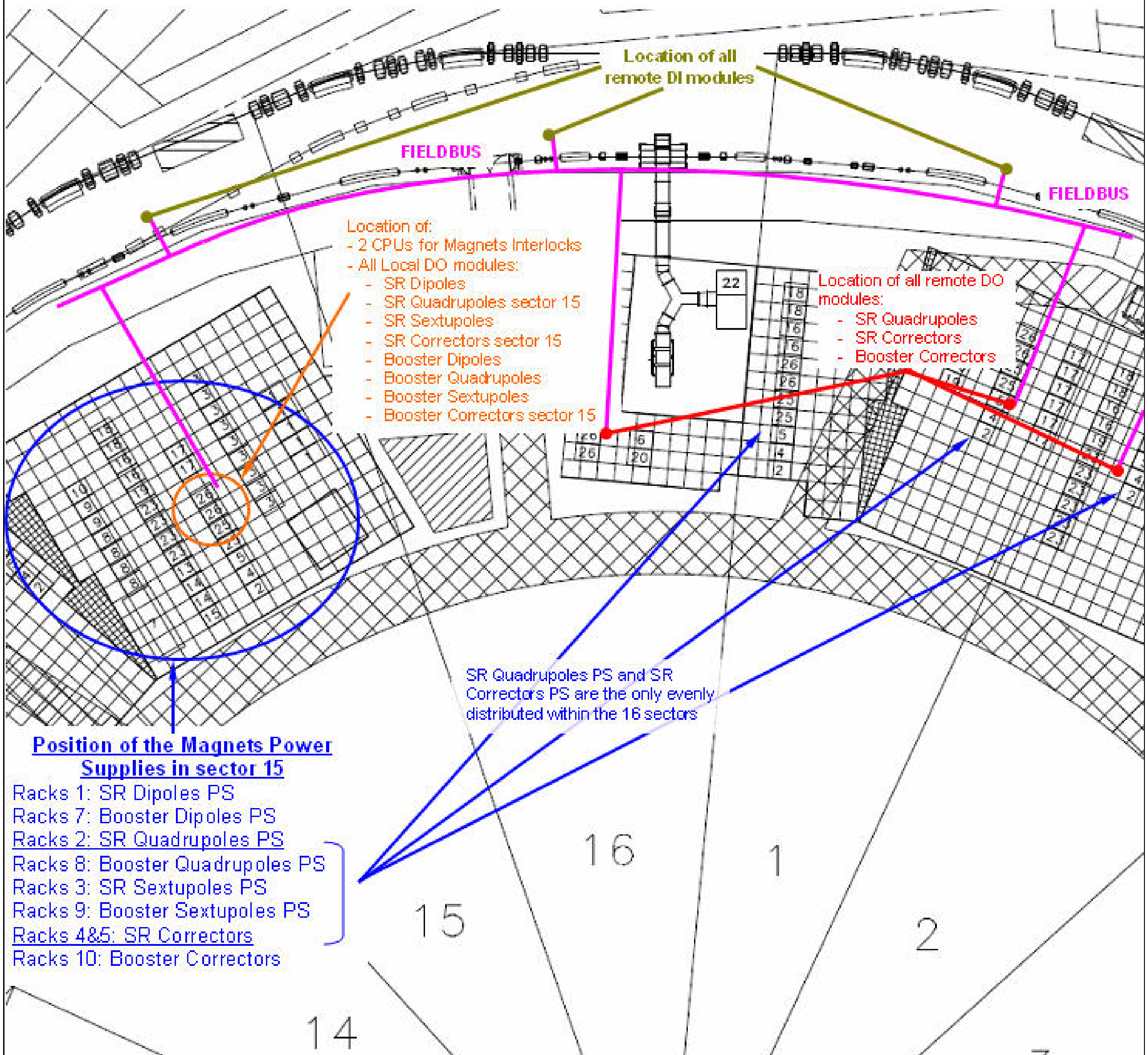

Fig.5: Booster and Storage Ring Magnets Interlocks – Sectors 15, 16 & 1

Transfer lines are placed in sectors 4 (LINAC to Booster, L2B) and 16 (Booster to Storage Ring, B2T). Each of them has a set of magnets with an individual power supply. In this case if an interlock occurs, the corresponding power supply is interlocked (at least). This means that the number of DO in the service area will be equal or bigger than the number of DI in the service area. These interlocks shall be managed by periphery modules in the respective area and the Booster CPU in sector 15. Table 8 shows the type and number of Interlock signals for both transfer lines.

Transfer Line	**Device**	**Location**	**Type and number of interlock signals (type of IO channel required)**	**Number of devices per sector**	**Total number of signals**
L2B	Bending Magnets	Tunnel	2xDI	2	4xDI
L2B	Quadrupoles	Tunnel	2xDI	7	14xDI
L2B	Correctors	Tunnel	1xDI	6	6xDI
L2B	Bending Magnets PS	Rack	1xDO	2	2xDO
L2B	Quadrupoles PS	Rack	1xDO	7	7xDO
L2B	Correctors PS	Rack	1xDO	6	6xDO
B2T	Bending Magnets	Tunnel	2xDI	3	6xDI
B2T	Quadrupoles	Tunnel	2xDI	9	18xDI
B2T	Correctors	Tunnel	1xDI	6	6xDI
B2T	Bending Magnets PS	Rack	1xDO	3	3xDO
B2T	Quadrupoles PS	Rack	1xDO	9	9xDO
B2T	Correctors PS	Rack	1xDO	6	6xDO
			TOTAL	***L2B***	***24xDI Rmt. tunnel 15xDO Rmt. rack***
				B2T	***30xDI Rmt. tunnel 18xDO Rmt. rack***

Table 8: List of Transfer Line Magnets Interlocks

9. Insertion Devices

Insertion Devices are the most frequently used photon sources that feed beamlines in the 3rd generation synchrotron sources. They can have a great diversity of equipment depending on the characteristics of the beamline they are feeding. For the first phase of the project 6 Insertion Devices of 4 different types are foreseen:

- 2 x in-vacuum undulators
- 2 x helical undulators
- 1 x conventional wiggler
- 1 x superconducting wiggler

Each of them has a different set of equipment generating/receiving signals to/from the interlock system, a preliminary estimation of these equipment and interlocks is shown in table 9:

	Device	Type and number of interlock signals (type of IO channel required)	Number of devices per ID	Number of signals per ID	Total Number of signals
In-vacuum Undulators (x2)	Ion Pumps (controller)	1xDI/1xDO	3	3xDI/3xDO	6xDI/6xDO Loc.
	Pirani Gauges (controller)	1xDI	2	2xDI	4xDI Loc.
	Thermocouples	1xAI (Thermocouple)	2	2xAI	4xAI Rmt.
	Flow Switch	1xDI	1	1xDI	2xDI Rmt.
	Gap Switch	2xDI	2	4xDI	8xDI Rmt.
Superconducting Wiggler (x1)	Thermocouples	1xAI (Thermocouple)	4	4xAI	4xAI Rmt.
	He Level Switch	1xDI	1	1xDI	1xDI Rmt.
	Quench Detector	1xDI	1	1xDI	1xDI Rmt.
	Power Supply	1xDO	2	2xDO	2xDO Loc.
	Ion Pumps (controller)	1xDI/1xDO	2	2xDI/2xDO	2xDI/2xDO Loc.
	Pirani Gauges (controller)	1xDI	2	2xDI	2xDI Loc.
	Cryocoolers Flow Switch	1xDI	4	4xDI	4xDI Rmt.
	Gap Switch	2xDI	2	4xDI	4xDI Rmt.
Conventional Wiggler (x1)	Thermocouples	1xAI (Thermocouple)	2	2xAI	2xAI Rmt.
	Gap Switch	2xDI	2	4xDI	4xDI Rmt.
Helical Undulator (x2)	Thermocouples	1xAI (Thermocouple)	2	2xAI	4xAI Rmt.
	Gap Switch	2xDI	2	4xDI	8xDI Rmt.
				TOTAL	***14xDI Loc. 32xDI Rmt 10xDO Loc. 14xAI Rmt. (Th.)***

Table 9: List of Insertion Devices Interlocks

From the distribution point of view, each ID shall be controlled by one CPU, with the correspondent local and periphery modules.

10. Front-Ends Interlocks

Each front end has a number of devices controlled by the PLC. One PLC manages specific actuators as well as the vacuum interlocks of the front-ends. Nine Front Ends are considered (see figure 6), seven for the beamlines, 1 for the optics beamline and one for the diagnostics beamline.

Figure 6 shows the location of the 9 Front-Ends and Beamlines to be considered at this stage of the project:

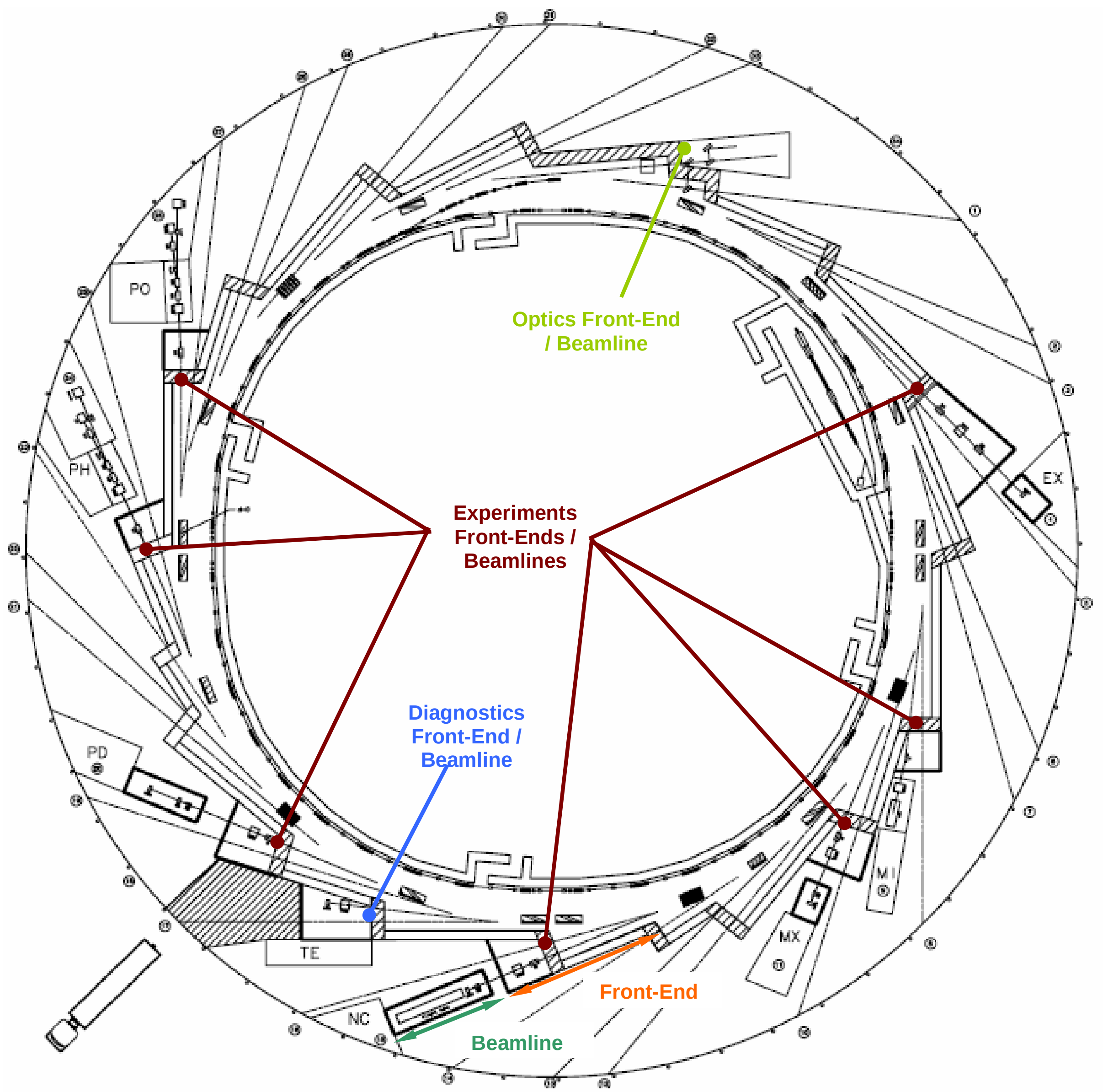

Fig.6: Distribution of the 9 Front-Ends and Beamlines to be considered

The standard equipment of a generic Front-End is listed next:

- 10 Thermocouples
- 6 ion pumps
- 20 Switches
- 6 electrovalves
- 2 pneumatic gate valve
- 1 photon shutter
- 1 bremstrahlung shutter
- 6 Pening
- 4 Pirani

Table 10 below shows the list of interlocks to be handled in each Front End:

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices per FE	Number of signals per FE	Total number of signals (9 FE)
Pneumatic gate Valves	BL	1xDO	1	1xDO	9xDO
End-Switch	BL	1xDI	2	2xDI	18xDI
Bremstrahlung shutter	Service Area	1xDI, 1xDO	2	2xDI, 2xDO	18xDI, 18xDO
Ion Pumps	Service Area	1xDI, 1xDO	6	6xDI, 6xDO	54xDI, 54xDO
Pening	Service Area	1xDI, 1xDO	6	6xDI, 6xDO	54xDI, 54xDO
Pirani	Service Area	1xDI, 1xDO	4	4xDI, 4xDO	36xDI, 36xDO
			TOTAL	***19xDO Local 20xDI Local***	***171xDO Local 180xDI Local***
Pneumatic gate Valves	Tunnel	1xDO	1	1xDO	9xDO
Electrovalves	Tunnel	1xDO	6	6xDO	54xDO
End-Switch	Tunnel	1xDI	16	16xDI	144xDI
Photon shutter	Tunnel	1xDI, 1xDO	1	1xDI, 1xDO	9xDI, 9xDO
Thermocouples	Tunnel	1 x AI (Thermocouple)	12	12xAI	108xAI
			TOTAL	***8xDO Remote 17xDI Remote 12xAI (Th.) Rmt***	***72xDO Remote 153xDI Remote 108xAI (Th.) Rmt***

Table 10: List of Front-Ends Interlocks

11. Beamlines Interlocks

Equipment Protection System (EPS) for the Beamlines are mainly for the vacuum system. As for the Front Ends, each beamline (see figure 6) will have a PLC to manage its own interlocks, placed outside the control cabin in the racks. Beamlines have not a fixed configuration and that depends on the type of experiment to be carried out, but a typical set up is shown in figure 7.

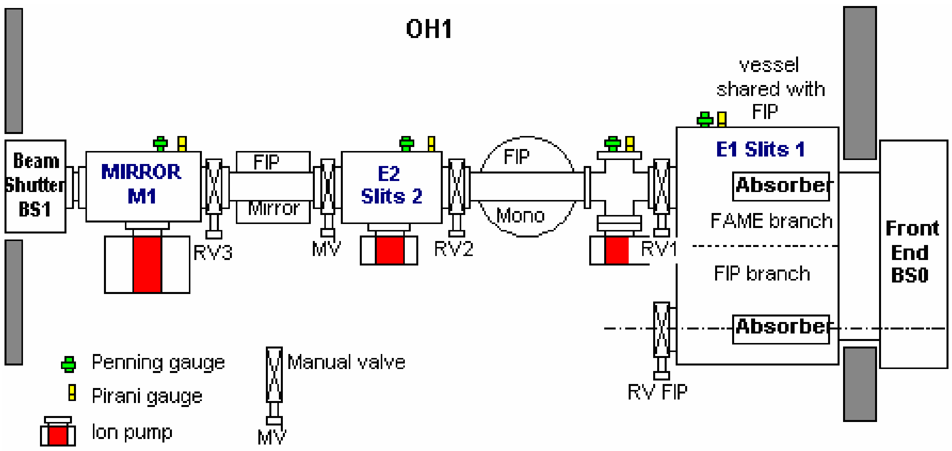

Fig.7: Typical configuration of beamline interlocks

Table 11 below shows the list of interlocks to be handled in each "generic" beamline:

Device	Location	Type and number of interlock signals (type of IO channel required)	Number of devices per BL	Number of signals per BL	Total number of signals (9 BL)
Ion Pumps	Control cabin	1xDI, 1xDO	3	3xDI, 3xDO	27xDI, 27xDO
Pening	Control cabin	1xDI, 1xDO	3	3xDI, 3xDO	27xDI, 27xDO
Pirani	Control cabin	1xDI, 1xDO	3	3xDI, 3xDO	27xDI, 27xDO
Flow Switch	Control cabin	1xDI	2	2xDI	18xDI
			TOTAL	***11xDI Local 9xDO Local***	***99xDI Local 81xDO Local***
Remote Valves (RV)	Beamline	1xDO	3	3xDO	27xDO
Beam shutter	Beamline	1xDO	1	1xDO	9xDO
Thermocouples	Beamline	1 x AI (Thermocouple)	20	20xAI (Thermocouple)	180xAI (Thermocouple)
			TOTAL	***4xDO Remote 2xAI (Th.) Rmt***	***36xDO Remote 180xAI (Th.) Rmt***

Table 11: List of Beamlines Interlocks

12. Summary of Equipment Protection System signals

Table 12 provides a general dimensioning of the EPS in terms of numbers of I/Os, modules and distribution within each system. Notice that this is only useful as a reference for the dimensioning of the project and not to quantify the number of I/O (DI, DO, AI…) modules, since this will depend also on the distribution of the signals for each system, sector and location (see the dedicated sections for each system for details on that). As a general approximation, a "symmetry index" is provided, e.g.: Vacuum system, symmetry of 16, CPUs per unit is 16/16, local DI per unit is 492/16 and so on. On the other hand, this table intends to show the philosophy of the project in terms of complete coherency (hardware separation of different sectors/systems) and distributed control, which any proposal should address.

	Equipment Protection System							
Type of Signal/Module	**Vacuum (÷16)**	**RF (÷8)**	**Magnets (SR+Bo+TL)**	**IDs (÷6)**	**Front-Ends (÷9)**	**Beamlines (÷9)**	**Total**	**Total + 5%**
CPU	16	8	1+1	6	9	9	*50*	***50***
Periphery Coupler	32	8	16+16+2	6	9	9	*98*	***98***
Local DI	492	138	0	14	180	99	*923*	***969***
Remote DI	58	110	1078	32	153	0	*1431*	***1503***
Local DO	460	46	40	10	171	81	*808*	***848***
Remote DO	74	0	371	0	72	36	*553*	***581***
Local AI	0	116	0	0	0	0	*116*	***122***
Remote AI	0	16	0	0	0	0	*16*	***17***
Local AI (Thermocouple)	0	0	0	0	0	0	*0*	***0***
Remote AI (Thermocouple)	480	0	0	14	108	180	*782*	***821***
Local AI (PT100)	0	66	0	0	0	0	*66*	***69***
Remote AI (PT100)	0	111	0	0	0	0	*111*	***117***
						TOTAL CPUs	***50***	***50***
						TOTAL COUPLERs	***98***	***98***
						TOTAL IO CHANNELS	***4806***	***5047***

Table 12: Summary of modules and channels for the ALBA Equipment Protection System