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Design Review for the Low Voltage Control System of the ATLAS Liquid Argon Hadronic End-Cap Calorimeter

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1 Introduction

The experience gained at the LEP experiments at CERN had shown how important is to use a powerful Detector Control System (DCS) [1] and this importance has increased with the size and the complexity of High Energy Physics detectors. The LHC experiments had become too big and too complex to be controlled manually by an operator. In addition, at the LHC era further requirements are put onto DCS, due to the inaccessibility of the equipment and the hostile environment concerning radiation and magnetic field.

In general, at running time, a few operators supervises a whole experiment. These operators usually have only little knowledge of the hardware of the detector at all. But even a hardware expert will only know in detail the part of the detector, which he is involved in. Therefore the usage of DCS must be based on general common sense and must not presume detailed knowledge. Obviously, the earlier problems get detected by the operators, the lesser the consequences are they have and eventually the easier they can be fixed. For this reason it is essential to have regular checking and good control of the hundred thousand parameters of the detector itself. The level of severity of the problems and the action to be taken has to be defined by the experts and not by the operators.

In the LHC experiments, all the functionality described above have been implemented as a system, so-called "SCADA" (Survey, Control and Data Acquisition) system [2], that the DCS groups at CERN will use. The software chosen as a tool for SCADA is a product from an Austrian Company (ETM) called PVSS II [4]. A joint controls project (JCOP) [3] between the 4 LHC experiments and the CERN IT/CO group has been organized to develop a common "Framework" and to use as much components as possible in common for the DCS of the 4 experiments. The JCOP team at CERN has already developed a number of sub-projects to look at various control aspects. Various technologies have being employed by JCOP. Some of these technologies have been chosen to be commercial other are custom solutions.

For the Liquid Argon Hadronic End-Cap Calorimeter (HEC) [5] of ATLAS the control system for the low voltage supplies is based on the system above described. There are 320 preamplifier and summing boards that can be operated and controlled individually or in groups by the PVSS II software. In addition voltages, currents and temperatures can be measured, trended, and archived in a database. Alarms, error messages about over-current or wrong input/output voltages can e.g. be set, displayed and controlled.

2 ATLAS Detector Control System

The slow control of detectors, sub-detectors and components of sub-detectors of ATLAS, one of the 4 LHC experiments, are implemented within the above described DCS - SCADA system, the JCOP Framework, and its software application, PVSS II [1–4].

Hardware links in the detector and connections with its field bus nodes are made with simple cable bus. The ATLAS experiment has chosen to use the commercial CAN as field bus, and its software protocol CANOpen. Many field bus nodes are offered by industry for different purposes. The field bus nodes used for the ATLAS HEC are the customized ELMB128 [6], offered by CERN [7].

In ATLAS DCS the PC is a bus master, its hardware interface board, the Kvaser card, is controlled by a middle-ware, chosen to be the driver software OPC.

3 HEC Low Voltage Control System

3.1 HEC Overview

The supply voltages for the cold front-end electronics of the two ATLAS Liquid Argon Hadronic End-Cap Calorimeter, the HEC A and HEC C wheels, are generated by 8 power boxes, and distributed to a total of 320 preamplifier and summing boards (PSB) inside the crayostats. Each of the HEC wheel is divided in 4 quadrants served by a feed-through with a front-end crate on top of it. One quadrant is equipped with 40 PSBs. Each PSB is delivered with three voltage values: $+7.2\,\mathrm{V}$, $+3.3\,\mathrm{V}$ $-1.6\,\mathrm{V}$. The SCADA-PVSS II [4] software and the JCOP Framework [3] allow to design, and create applications on a PC, so that e.g. with simple graphical windows an operator can remotely control and monitor all our HEC system. The exchange of information between the software and our hardware parts, e.g. the low voltage channels, takes place via the already described field bus nodes, the CAN field bus and its CANOpen protocol. At the moment at MPI we are using the older versions of ELMBs as field bus nodes, and as hardware interface board for the PC, we can use either the Kvaser (recent and new CERN choice) or the NICANII card.

3.2 HEC Control System

In the Hadronic End-Cap Calorimeters (HEC A and HEC C) the following systems are controlled and monitored by the SCADA-PVSS II software, see e.g. the overview panel shown in Fig. 1:

- Power boxes with relative power and monitor boards
  - The field bus nodes (ELMB) present in each monitor board of the power boxes allow to monitor, control, and make measurements of
    - Temperature inside the power boxes
    - Middle voltages delivered by the power boxes
    - Currents coming out from the power boxes.
- Low voltage distribution boards
  - Each quadrant in a HEC wheel has a total of 4 low voltage distribution boards and one power box. Each distribution board has two ELMBs that survey a total of 10 PSBs per distribution board. Each ELMB controls 5 PSBs, and each PSB allows to:
    - Set voltage values, e.g. the following default voltage values per PSB can be adjusted: $+7.2\,V$, $+3.3\,V$, and $-1.6\,V$.
    - Switch on and off the PSB itself
    - Calibrate voltages and currents
    - Monitor, display, and plot voltages and currents
    - Detect problems
    - Gain information and fix and/or report observed problems
    - Archive the collected data and information in a database
    - etc. etc.
- Interlock between the high and low voltage systems
  - To be able to protect the cold electronic of the HEC sub-detector, it is mandatory to have first the low voltage system switched on and later one can operate the high voltage channels. For safety issues, it is also requested that if part of the low voltage system has to be switched off, then the correspondent high voltage channels need to be switched off first. To be able to

control these High Voltage (HV) - Low Voltage (LV) operations, it has been proposed to have a software interlock system. A detailed description of this system is given in Section 5.2, see overview panel in Fig. 6.

- $270\,V$ DC control system
  - A "control" box with one or two ELMBs is expected to be placed in the ATLAS USA15. This box can operate, monitor and control the system that convert the $380\,V/3$ to $270\,V$ DC.
- Any warning, error, and fault of the whole HEC system is supposed to be monitored, controlled and archived.
- In addition to the "default" HEC control system described above, it is foreseen to have an alternative "Serial Interface Control" system, also based on the usage of ELMBs as field bus nodes. This alternative control system should be used only if serious problems occur in operating the default HEC SCADA-PVSS II system. Only an expert can decide when and how to start using this alternative system to control and monitor our HEC channels. The way how this "Serial Interface Control" system is supposed to work and the way how it should be build-ed is still under studies and investigations.

4 Status of the PVSS II HEC Control System

As said in the introduction PVSS II [4] is an industry-neutral, universally implementable process-control system that can be used to help visualize, monitor and control technical sequences. It works across multiple computer platforms, is multilingual and has a modern, totally graphic User Interface. It is characterized by a graphical editor that helps the programmer during the designing phase of his project it has a "data point" structure. In general, a "data point" can be viewed as a variable in the program where all the hardware information are stored. The above mentioned graphical editor allows to create objects and panels that help to e.g. monitor and survey information of a working system, or also allow to operate the system itself (e.g. switch on and off channels), etc. etc. . Usually, behind a graphical object there are scripts that define the actions and/or the operations that need to be taken by the object itself.

For the HEC Low Voltage System, a set of panels and objects have already been created. With these panels we are able to control one quadrant of the HEC A wheel. The idea is to have a good SCADA - PVSS II software build-ed for one quadrant of the HEC low voltage system and without the "Control of the $270\,V$ DC box". Once that this our first "prototype" of software is complete and OK, then we will extend it to control the whole HEC sub-detector, the HEC A and HEC C wheels.

The software we have at the moment has been tested at MPI, and it is supposed to be tested at CERN in the next coming months. Later this software is supposed to be used in the technical run, foreseen for the end of this year 2003, and in the next combined test beam, foreseen for the summer 2004.

Once that our software will be extended to operate and control the whole HEC, this new software will be tested again at CERN. It is foresees to use this complete software to survey our HEC sub-detector during the installation of the ATLAS detector in UX15. In this case the "Control of the $270\,V$ DC box" and the interlocks control system will be part of this software as well.

5 PVSS II Panels for the HEC

In the following some of the control panels already available for the HEC low voltage system are described. These panels at the moment don't comply the new JCOP and ELMB Framework.

5.1 Liquid Argon Calorimeter and Main Panels for HEC A

A graphic view of the all Liquid Argon Calorimeter "Low Voltage System" can be see in Fig. 2 (top). It consists of the two End-Cap wheels and the barrel part of the calorimeter. By mouse clicking on one of the HEC wheels, the operator can open e.g. the main panel for the HEC A Low Voltage control system, see Fig. 2 (bottom). This panel displays the main structure of our HEC A system. By clicking on a graphic object or on an item of this panel the operator can open other windows to learn more information of the system itself and also have full access to hardware components. To distinguish between different types of daughter panels, a color code is applied in this panel: objects in light blue are e.g. action panels, items in light violet and dark gray display hardware details (mechanics, circuit diagram etc.). By clicking on one of the light blue object, e.g. "Control Panel Quad. 1", the operator open the daughter panel shown in Fig. 3 (top). This panel gives an entire overview of one quadrant of HEC A. An operator can use this panel to control and monitor the status of the 40 LV channels related this quadrant of the HEC A wheel, see Fig. 3 (bottom). The operator can switch on and off single or group of channels, can monitor and plot the three voltages and currents measured in each channel. Fault conditions are showed by a blinking red color, the static green color shows that all is fine. In case of faults or problems an expert can click on the "SERVICE NEEDED" button to open a new and a more detailed graphical window, see Fig. 4 (top). This new window allows to open other panels, see e.g. the graphical window shown in Fig. 4 (bottom), and to be able to have more details on the cause and the severity of the observed problem and eventually fix it. Fig. 4 (bottom) shows an ELMB operational panel. This is the panel that will be used to set the three PSB voltage values (e.g. $+7.2$, $+3.3$, and -1.6 V), and also to calibrate the voltages and the current for each of the PSBs present on the ELMB. Only the expert can use this panel.

5.2 HV - LV Interlock System

The supply voltages for the HEC HV system is generated and distributed differently that the above described, see Section 3.1, LV system. Fig. 5 shows a schematic view of the HV system segmentation. Here one wedge of a HEC wheel is divided in 4 sections. Sections 1 and 2 are located in the front part of the wheel, also called HEC 1; sections 3 and 4 are located in a rear part, called HEC 2. Section 1 includes the HV cells numbered from 1 to 8, these cells map our PSB number 1 in the corresponding wedge and quadrant of the same HEC wheel. Section 2 includes the HV cells from 9 to 24 and it maps the PSBs numbers 2-1 and 2-2 of the corresponding wedge and quadrant of a wheel. Section 3 has HV cells numbered from 25 to 32 and our PSB number is here 3. Finally, section 4 includes the HV cells 33 to 40, and they correspond to the PSB number 4 for the LV system. Each cell in each of the HV sections has 4 HV lines. Usually one power supply serves 4 half wedges of a quadrant in a HEC wheel, e.g. either the first 4 two front sections or to the last 4 two rear sections of a quadrant. There are two power supplies for half of a quadrant in a HEC wheel, and a total of 4 HV power supplies in one HEC quadrant. Fig. 6 shows the PVSS II panel created to display the HV - LV interlocks mapping system for the quadrant 1 of the HEC A wheel. The right hand-side of this figure shows a visualization of the HV - LV interlocks mapping system for the considered quadrant, the left hand-side of this figure shows the buttons where one can click to get the links to the 6 corresponding HV - LV mapping tables. These tables are shown in Figs. 7, 8, 9, 10, 11, and 12.

The HV - LV systems are two independent systems, they run two independent PVSS II applications. In general PVSS II allows to configure two independent systems into a sigle, co-operating "PVSS distributed system". In such a case a programmer working on one system can see and use the data point structure of the other system for his own purposes and in his own project. The problem comes with the present version of PVSS II, mainly it doesn't allow a easy way to build a "distributed system". Anyway, a new version of PVSS II will be available soon, maybe before the end of this year. This new version is supposed to make this "distributed system" configuration easier. When this software will be avalable then it will be possible to build a "HV - LV distributed system" between the PVSS II application running at e.g. in Milano, for the HV system, and the other running in MPI-Munich for the LV system. The programmers on both sides can then start to create new interlock panels, and build a good survey of the two systems.

6 Conclusions

We have developed some “preliminary” work for the software HEC control system at MPI. The link between the SCADA software tool, PVSS II, and the ELMBs (via OPC and CAN bus) is operational. We are using at the moment, the older version of ELMB, and we can use either the Kvasar or the NICAN II card as hardware interface board on our PC. At the moment we have panels that can survey, monitor and control the quadrant 1 of the HEC A wheel. We have also build-ed for this same quadrant mapping tables for our foreseen HV - LV interlocks system. As soon as the new version of PVSS II will be available, we will build a “HV - LV PVSS II distributed system” and we will create new panels to properly operate this our HV - LV interlocks system. We foresee to have a good working SCADA - PVSS II system for just one quadrant of the HEC low voltage system and without the “Control of the 270 V DC box”. This software is expected to be tested at CERN and later to be used in the technical run, foreseen for the end of the year 2003, and in the next combined test beam, foreseen for the summer 2004. We will extend our software to be able to monitor and control all or HEC sub-detector and this new software will be used to monitor and control the HEC low voltage system during the installation of the ATLAS detector in UX15. The final aim is to have a good working SCADA - PVSS II system for the HEC in ATLAS.

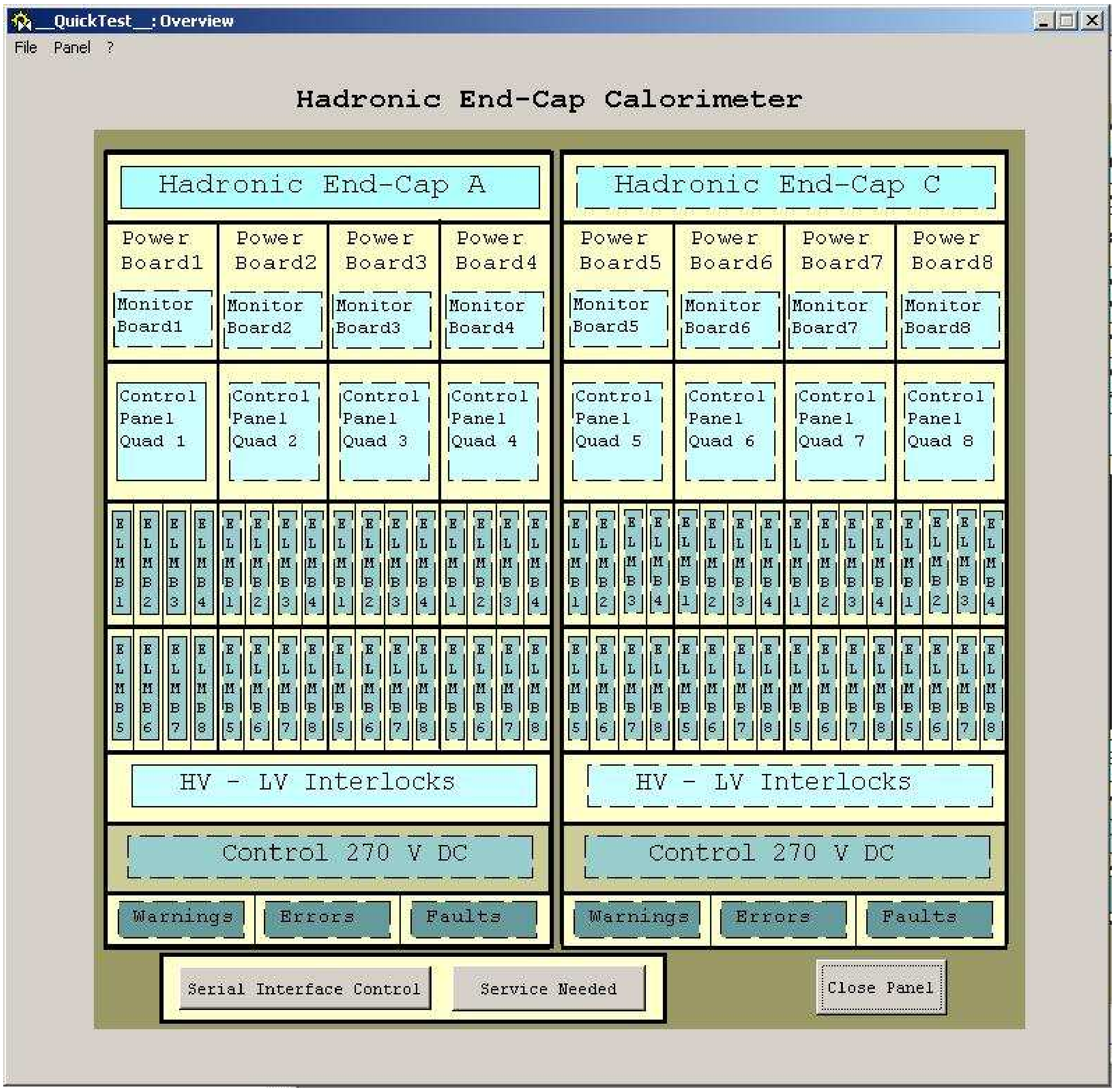

Figure 1: Overview of the control system foreseen for the Low Voltage control of the HEC A and HEC C wheels. By mouse clicking on one of the (light or dark) blue boxes the operator can open an action panel to operate, control, and monitor part of the system. The dashed lines shows the parts of the control system that still need to be developed.

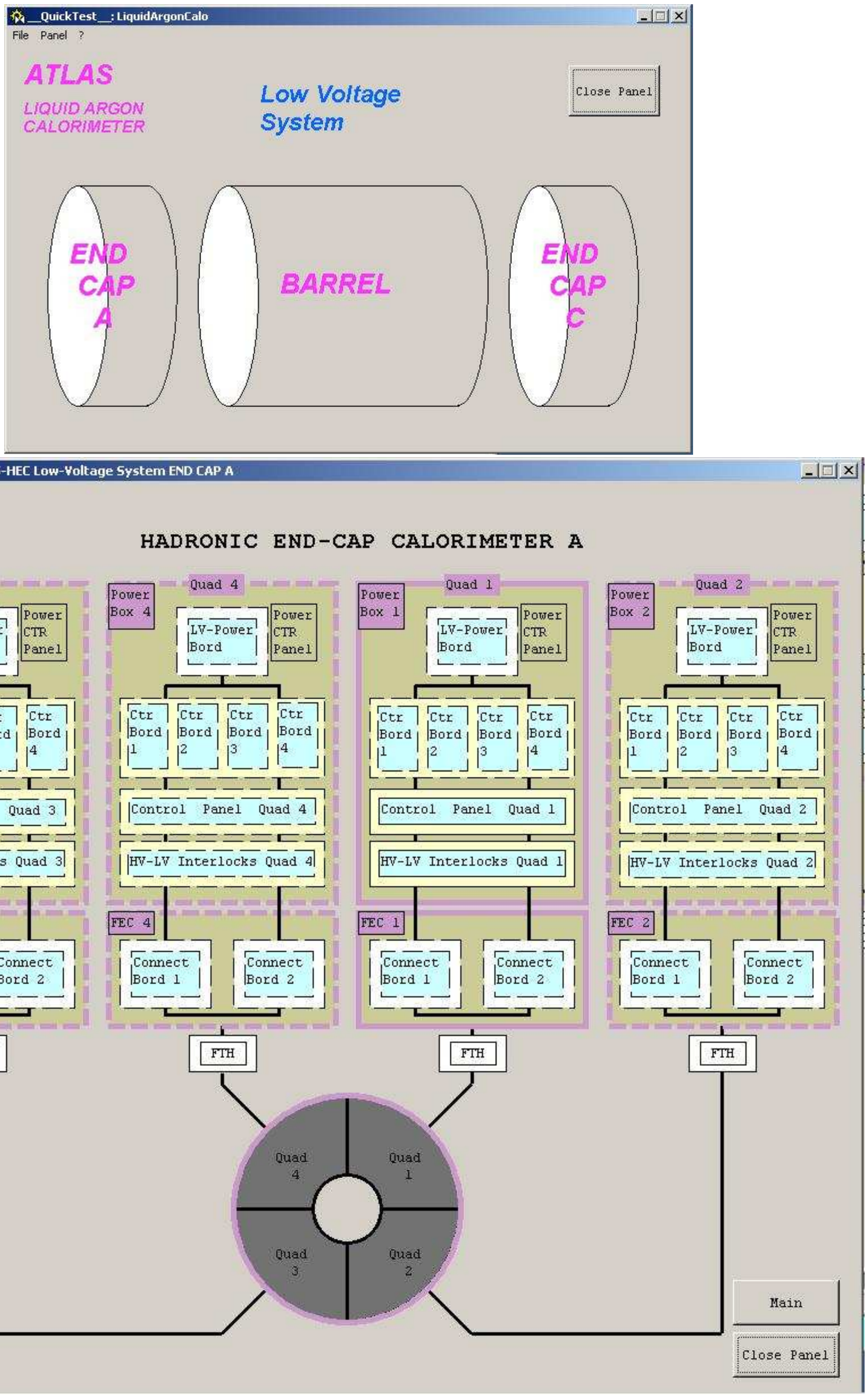

Figure 2: (top) "Start Up" panel, from this graphical window the operator can choose to look at either one of the hadronic End-Cap calorimeters (HEC A or HEC C). (bottom) "Main Access" End-Cap A panel. This panel displays the main structure of our HEC A system. To distinguish between different types of daughter panels, a color code is applied in this panel: objects in light blue are e.g. action panels, items in light violet and dark gray display hardware details (mechanics, circuit diagram etc.). In this figure the dashed lines indicates the parts of the control system that still need to be developed.

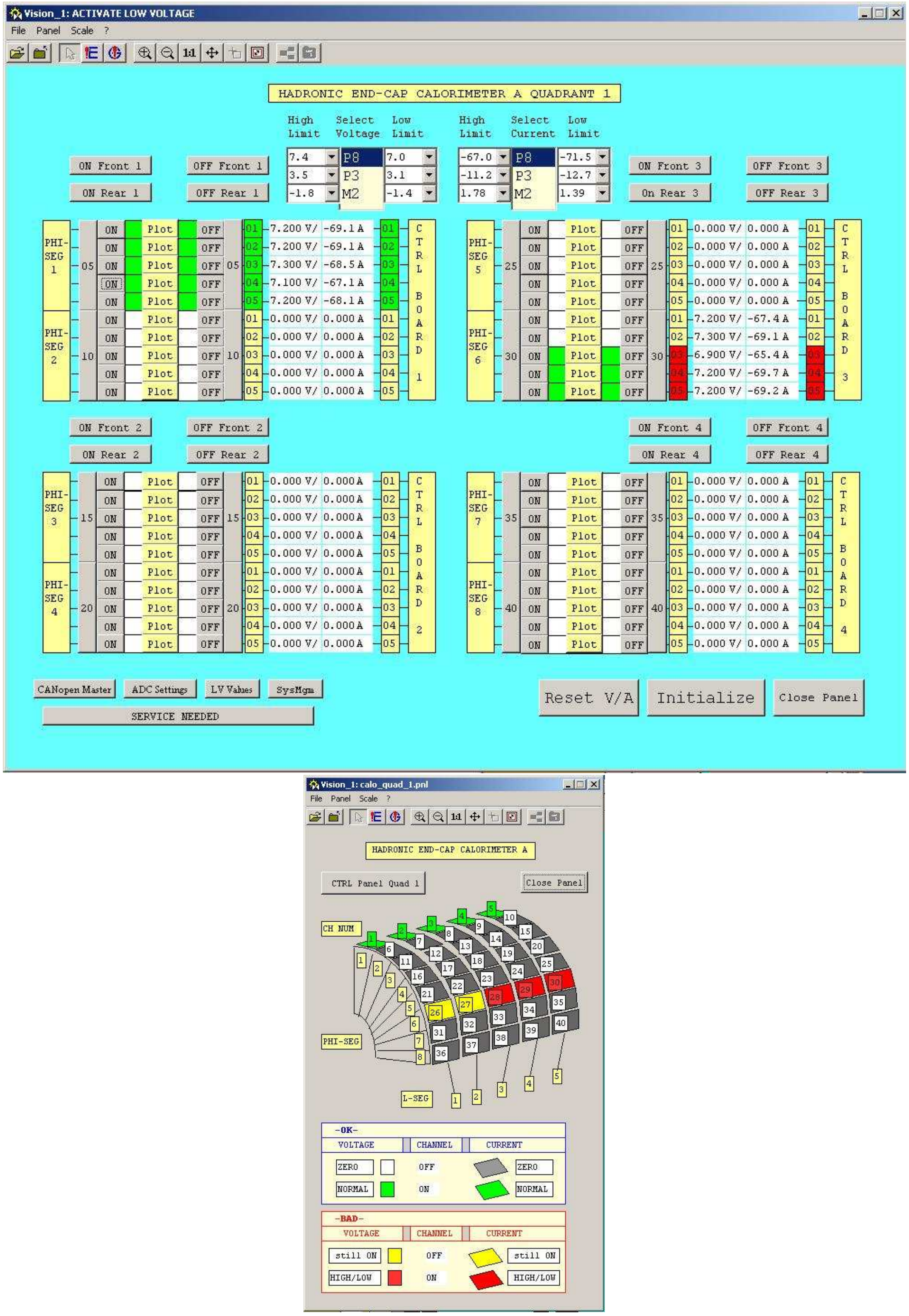

Figure 3: (top) "Channels Control" panel. This panel displays voltages, currents, and eventually in case of problems will also show the faulty channels. It allows to switch on and off channels, to display and plot the voltages and the currents measured in each channel. Other daughter panels can be opened from here. (bottom) Quadrant in 3-Dimensional view with blinking yellow and read lights according the fault status of the detector. Green solid lights show that all the PSBs in the quadrant are on, and OK. Dark grey lights indicate that the PSBs are off.

Figure 4: (top) Detailed panel for one quadrant of the HEC A wheel to be used only by the experts. This panel allows a complete control and survey of the 8 ELMBs in the quadrant. (bottom) ELMB panel, the three voltages for each of the 5 PSBs in the ELMB can be set from here. Voltages and currents calibration is also operated from this panel.

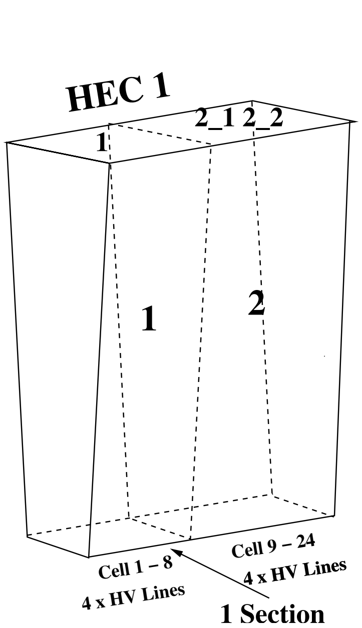

Figure 5: Schematic view of the HV system segmentation. One wedge of a HEC wheel is divided in 4 sections. The sections 1 and 2 are located in the front part of the wheel, HEC 1; sections 3 and 4 are located in a rear part, HEC 2. The figure shows also the number of HV cells present in each section and the corresponding PSB number (1, 2_1 and 2_2, 3, and 4). Each cell in each of the HV sections has 4 HV lines.

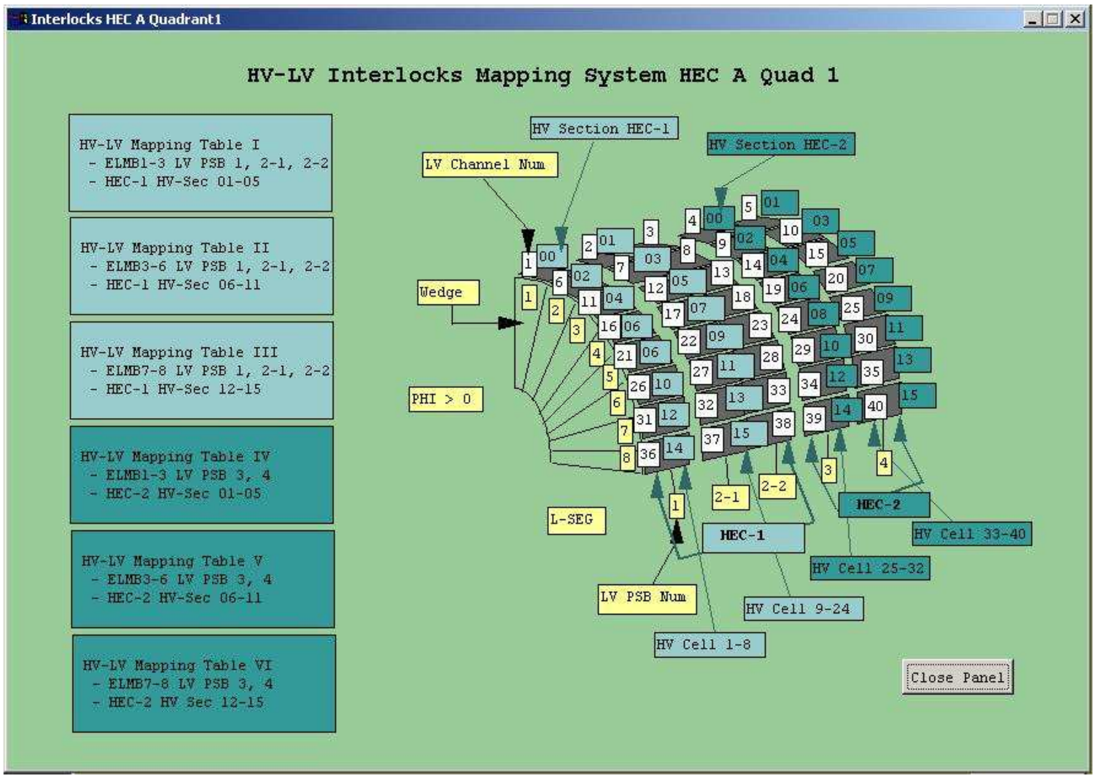

Figure 6: PVSS II panel created to display the HV - LV interlocks mapping system for the quadrant 1 of the HEC A wheel. The right hand-side of this figure shows a visualization of the HV - LV interlocks mapping system for the considered quadrant, the left hand-side of shows the buttons where one can click to get the links to the 6 corresponding HV - LV mapping tables.

HV-LV Mapping Table HEC A Quadrant1

HV-LV Mapping Table I HEC A Quadrant 1

Close Panel

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
1	0	0	00	0	Phi > 0	0	1	AF21	Pad2-Cell 1-8	59-64	1-3	1	14A	ELMB_1	1	1	1
2	0	0	00	1	Phi > 0	0	1	AF21	Est2-Cell 1-8	59-64	1-3	1	14A	ELMB_1	1	1	1
3	0	0	00	2	Phi > 0	0	1	AF21	Est1-Cell 1-8	59-64	1-3	1	14A	ELMB_1	1	1	1
4	0	0	00	3	Phi > 0	0	1	AF21	Pad1-Cell 1-8	59-64	1-3	1	14A	ELMB_1	1	1	1
5	0	0	01	0	Phi > 0	0	1	AF21	Pad2-Cell 9-24	35-46	4-9	1	14A	ELMB_1	2-1 2-2	2 - 3	1
6	0	0	01	1	Phi > 0	0	1	AF14	Est2-Cell 9-24	35-46	4-9	1	14A	ELMB_1	2-1 2-2	2 - 3	1
7	0	0	01	2	Phi > 0	0	1	AF14	Est1-Cell 9-24	35-46	4-9	1	14A	ELMB_1	2-1 2-2	2 - 3	1
8	0	0	01	3	Phi > 0	0	1	AF14	Pad1-Cell 9-24	35-46	4-9	1	14A	ELMB_1	2-1 2-2	2 - 3	1
9	0	0	02	0	Phi > 0	0	2	AF14	Pad2-Cell 1-8	27-32	17-19	2	14A	ELMB_2	1	6	2
10	0	0	02	1	Phi > 0	0	2	AF14	Est2-Cell 1-8	27-32	17-19	2	14A	ELMB_2	1	6	2
11	0	0	02	2	Phi > 0	0	2	AF14	Est1-Cell 1-8	27-32	17-19	2	14A	ELMB_2	1	6	2
12	0	0	02	3	Phi > 0	0	2	AF14	Pad1-Cell 1-8	27-32	17-19	2	14A	ELMB_2	1	6	2
13	0	0	03	0	Phi > 0	0	2	AF14	Pad2-Cell 9-24	3-14	20-25	2	14A	ELMB_2	2-1 2-2	7 - 8	2
14	0	0	03	1	Phi > 0	0	2	AF14	Est2-Cell 9-24	3-14	20-25	2	14A	ELMB_2	2-1 2-2	7 - 8	2
15	0	0	03	2	Phi > 0	0	2	AF14	Est1-Cell 9-24	3-14	20-25	2	14A	ELMB_2	2-1 2-2	7 - 8	2
16	0	0	03	3	Phi > 0	0	2	AF14	Pad1-Cell 9-24	3-14	20-25	2	14A	ELMB_2	2-1 2-2	7 - 8	2
17	0	1	04	0	Phi > 0	0	3	AF33	Pad2-Cell 1-8	123-128	33-35	3	14B	ELMB_3	1	11	3
18	0	1	04	1	Phi > 0	0	3	AF33	Est2-Cell 1-8	123-128	33-35	3	14B	ELMB_3	1	11	3
19	0	1	04	2	Phi > 0	0	3	AF33	Est1-Cell 1-8	123-128	33-35	3	14B	ELMB_3	1	11	3
20	0	1	04	3	Phi > 0	0	3	AF33	Pad1-Cell 1-8	123-128	33-35	3	14B	ELMB_3	1	11	3
21	0	1	05	0	Phi > 0	0	3	AF33	Pad2-Cell 9-24	99-110	36-41	3	14B	ELMB_3	2-1 2-2	12 - 13	3
22	0	1	05	1	Phi > 0	0	3	AF33	Est2-Cell 9-24	99-110	36-41	3	14B	ELMB_3	2-1 2-2	12 - 13	3
23	0	1	05	2	Phi > 0	0	3	AF33	Est1-Cell 9-24	99-110	36-41	3	14B	ELMB_3	2-1 2-2	12 - 13	3
24	0	1	05	3	Phi > 0	0	3	AF33	Pad1-Cell 9-24	99-110	36-41	3	14B	ELMB_3	2-1 2-2	12 - 13	3

HV Power supply unit 0, HV Modules 0 and 1, HV Sections from 00 to 05 - LV PSB numbers 1, 2-1 and 2-2 in wedges 1, 2, and 3 - PHI > 0

Figure 7: HV - LV mapping table I for HEC A quadrant 1. It covers the HEC 1 HV Sections from 00 to 05 (light blue part of the table) and the LV PSB numbers 1, $2-1$, and $2-2$, ELMB 1 to ELMB 3 in wedges 1 to 3 (light yellow part of the table).

HV-LV Mapping Table HEC A Quadrant1

HV - LV Mapping Table II HEC A Quadrant 1

Close Panel

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
25	0	1	06	0	Phi > 0	0	4	AF19	Pad2-Cell 1-8	91-96	51-49	4	14B	ELMB_4	1	16	4
26	0	1	06	1	Phi > 0	0	4	AF19	Est2-Cell 1-8	91-96	51-49	4	14B	ELMB_4	1	16	4
27	0	1	06	2	Phi > 0	0	4	AF19	Est1-Cell 1-8	91-96	51-49	4	14B	ELMB_4	1	16	4
28	0	1	06	3	Phi > 0	0	4	AF19	Pad1-Cell 1-8	91-96	51-49	4	14B	ELMB_4	1	16	4
29	0	1	07	0	Phi > 0	0	4	AF19	Pad2-Cell 9-24	67-78	52-57	4	14B	ELMB_4	2-1 2-2	17 - 18	4
30	0	1	07	1	Phi > 0	0	4	AF19	Est2-Cell 9-24	67-78	52-57	4	14B	ELMB_4	2-1 2-2	17 - 18	4
31	0	1	07	2	Phi > 0	0	4	AF19	Est1-Cell 9-24	67-78	52-57	4	14B	ELMB_4	2-1 2-2	17 - 18	4
32	0	0	07	3	Phi > 0	0	4	AF19	Pad1-Cell 9-24	67-78	52-57	4	14B	ELMB_4	2-1 2-2	17 - 18	4
33	1	2	08	0	Phi > 0	0	5	AF14	Pad2-Cell 1-8	187-192	65-67	5	15A	ELMB_5	1	21	5
34	1	2	08	1	Phi > 0	0	5	CF32	Est2-Cell 1-8	187-192	65-67	5	15A	ELMB_5	1	21	5
35	1	2	08	2	Phi > 0	0	5	CF32	Est1-Cell 1-8	187-192	65-67	5	15A	ELMB_5	1	21	5
36	1	2	08	3	Phi > 0	0	5	CF32	Pad1-Cell 1-8	187-192	65-67	5	15A	ELMB_5	1	21	5
37	1	2	09	0	Phi > 0	0	5	CF32	Pad2-Cell 9-24	163-174	68-73	5	15A	ELMB_5	2-1 2-2	22 - 23	5
38	1	2	09	1	Phi > 0	0	5	CF32	Est2-Cell 9-24	163-174	68-73	5	15A	ELMB_5	2-1 2-2	22 - 23	5
39	1	2	09	2	Phi > 0	0	5	CF32	Est1-Cell 9-24	163-174	68-73	5	15A	ELMB_5	2-1 2-2	22 - 23	5
40	1	2	09	3	Phi > 0	0	5	CF32	Pad1-Cell 9-24	163-174	68-73	5	15A	ELMB_5	2-1 2-2	22 - 23	5
41	1	2	10	0	Phi > 0	0	6	AF24	Pad2-Cell 1-8	155-160	81-83	6	15A	ELMB_6	1	26	6
42	1	2	10	1	Phi > 0	0	6	AF24	Est2-Cell 1-8	155-160	81-83	6	15A	ELMB_6	1	26	6
43	1	2	10	2	Phi > 0	0	6	AF24	Est1-Cell 1-8	155-160	81-83	6	15A	ELMB_6	1	26	6
44	1	2	10	3	Phi > 0	0	6	AF24	Pad1-Cell 1-8	155-160	81-83	6	15A	ELMB_6	1	26	6
45	1	2	11	0	Phi > 0	0	6	AF24	Pad2-Cell 9-24	131-142	84-89	6	15A	ELMB_6	2-1 2-2	27 - 28	6
46	1	2	11	1	Phi > 0	0	6	AF24	Est2-Cell 9-24	131-142	84-89	6	15A	ELMB_6	2-1 2-2	27 - 28	6
47	1	2	11	2	Phi > 0	0	6	AF24	Est1-Cell 9-24	131-142	84-89	6	15A	ELMB_6	2-1 2-2	27 - 28	6
48	1	2	11	3	Phi > 0	0	6	AF24	Pad1-Cell 9-24	131-142	84-89	6	15A	ELMB_6	2-1 2-2	27 - 28	6

HV Power supply unit 0 and 1, HV Modules 1 and 2, HV Sections from 06 to 11 - LV PSB numbers 1, 2-1 and 2-2 in wedges 4, 5, and 6 - PHI > 0

Figure 8: HV - LV mapping table II for HEC A quadrant 1. It covers the HEC 1 HV Sections from 06 to 11 (light blue part of the table), and the LV PSB numbers 1, $2-1$, and $2-2$, ELMB 3 to ELMB 6 in wedges 3 to 6 (light yellow part of the table).

HV-LV Mapping Table HEC A Quadrant1

HV - LV Mapping Table III HEC A Quadrant 1

Close Panel

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
49	1	3	12	0	Phi > 0	0	7	AF23	Pad2-Cell 1-8	251-256	97-99	7	15B	ELMB_7	1	31	7
50	1	3	12	1	Phi > 0	0	7	AF23	Est2-Cell 1-8	251-256	97-99	7	15B	ELMB_7	1	31	7
51	1	3	12	2	Phi > 0	0	7	AF23	Est1-Cell 1-8	251-256	97-99	7	15B	ELMB_7	1	31	7
52	1	3	12	3	Phi > 0	0	7	AF23	Pad1-Cell 1-8	251-256	97-99	7	15B	ELMB_7	1	31	7
53	1	3	13	0	Phi > 0	0	7	AF23	Pad2-Cell 9-24	227-238	100-105	7	15B	ELMB_7	2-1 2-2	32 - 33	7
54	1	3	13	1	Phi > 0	0	7	AF23	Est2-Cell 9-24	227-238	100-105	7	15B	ELMB_7	2-1 2-2	32 - 33	7
55	1	3	13	2	Phi > 0	0	7	AF23	Est1-Cell 9-24	227-238	100-105	7	15B	ELMB_7	2-1 2-2	32 - 33	7
56	1	3	13	3	Phi > 0	0	7	AF23	Pad1-Cell 9-24	227-238	100-105	7	15B	ELMB_7	2-1 2-2	32 - 33	7
57	1	3	14	0	Phi > 0	0	8	CF28	Pad2-Cell 1-8	219-224	113-115	8	15B	ELMB_8	1	36	8
58	1	3	14	1	Phi > 0	0	8	CF28	Est2-Cell 1-8	219-224	113-115	8	15B	ELMB_8	1	36	8
59	1	3	14	2	Phi > 0	0	8	CF28	Est1-Cell 1-8	219-224	113-115	8	15B	ELMB_8	1	36	8
60	1	3	14	3	Phi > 0	0	8	CF28	Pad1-Cell 1-8	219-224	113-115	8	15B	ELMB_8	1	36	8
61	1	3	15	0	Phi > 0	0	8	CF28	Pad2-Cell 9-24	195-206	116-121	8	15B	ELMB_8	2-1 2-2	37 - 38	8
62	1	3	15	1	Phi > 0	0	8	CF28	Est2-Cell 9-24	195-206	116-121	8	15B	ELMB_8	2-1 2-2	37 - 38	8
63	1	3	15	2	Phi > 0	0	8	CF28	Est1-Cell 9-24	195-206	116-121	8	15B	ELMB_8	2-1 2-2	37 - 38	8
64	1	3	15	3	Phi > 0	0	8	CF28	Pad1-Cell 9-24	195-206	116-121	8	15B	ELMB_8	2-1 2-2	37 - 38	8

HV Power supply unit 1, HV Modules 3, HV Sections from 12 to 15 - LV PSB numbers 1, 2-1 and 2-2 in wedges 7, and 8 - PHI > 0

Figure 9: HV - LV mapping table III for HEC A quadrant 1. It covers the HEC 1 HV Sections from 12 to 15 (light blue part of the table), and the LV PSB numbers 1, $2-1$, and $2-2$, ELMB 7 to ELMB 8 in wedges 7 to 8 (light yellow part of the table).

HV-LV Mapping Table HEC A Quadrant1

HV - LV Mapping Table IV HEC A Quadrant 1

Close Panel

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
257	8	16	00	0	Phi > 0	2	1		Pad2-Cell 25-32	53-58	10-12	1	14A	ELMB_1	3	4	1
258	8	16	00	1	Phi > 0	2	1		Est2-Cell 25-32	53-58	10-12	1	14A	ELMB_1	3	4	1
259	8	16	00	2	Phi > 0	2	1		Est1-Cell 25-32	53-58	10-12	1	14A	ELMB_1	3	4	1
260	8	16	00	3	Phi > 0	2	1		Pad1-Cell 25-32	53-58	10-12	1	14A	ELMB_1	3	4	1
261	8	16	01	0	Phi > 0	2	1		Pad2-Cell 33-40	47-52	13-15	1	14A	ELMB_1	4	5	1
262	8	16	01	1	Phi > 0	2	1		Est2-Cell 33-40	47-52	13-15	1	14A	ELMB_1	4	5	1
263	8	16	01	2	Phi > 0	2	1		Est1-Cell 33-40	47-52	13-15	1	14A	ELMB_1	4	5	1
264	8	16	01	3	Phi > 0	2	1		Pad1-Cell 33-40	47-52	13-15	1	14A	ELMB_1	4	5	1
265	8	16	02	0	Phi > 0	2	2		Pad2-Cell 25-32	21-26	26-28	2	14A	ELMB_2	3	9	2
266	8	16	02	1	Phi > 0	2	2		Est2-Cell 25-32	21-26	26-28	2	14A	ELMB_2	3	9	2
267	8	16	02	2	Phi > 0	2	2		Est1-Cell 25-32	21-26	26-28	2	14A	ELMB_2	3	9	2
268	8	16	02	3	Phi > 0	2	2		Pad1-Cell 25-32	21-26	26-28	2	14A	ELMB_2	3	9	2
269	8	16	03	0	Phi > 0	2	2		Pad2-Cell 33-40	15-20	29-31	2	14A	ELMB_2	4	10	2
270	8	16	03	1	Phi > 0	2	2		Est2-Cell 33-40	15-20	29-31	2	14A	ELMB_2	4	10	2
271	8	16	03	2	Phi > 0	2	2		Est1-Cell 33-40	15-20	29-31	2	14A	ELMB_2	4	10	2
272	8	16	03	3	Phi > 0	2	2		Pad1-Cell 33-40	15-20	29-31	2	14A	ELMB_2	4	10	2
273	8	17	04	0	Phi > 0	2	3		Pad2-Cell 25-32	117-122	42-44	3	14B	ELMB_3	3	14	3
274	8	17	04	1	Phi > 0	2	3		Est2-Cell 25-32	117-122	42-44	3	14B	ELMB_3	3	14	3
275	8	17	04	2	Phi > 0	2	3		Est1-Cell 25-32	117-122	42-44	3	14B	ELMB_3	3	14	3
276	8	17	04	3	Phi > 0	2	3		Pad1-Cell 25-32	117-122	42-44	3	14B	ELMB_3	3	14	3
277	8	17	05	0	Phi > 0	2	3		Pad2-Cell 33-40	111-116	45-47	3	14B	ELMB_3	4	15	3
278	8	17	05	1	Phi > 0	2	3		Est2-Cell 33-40	111-116	45-47	3	14B	ELMB_3	4	15	3
279	8	17	05	2	Phi > 0	2	3		Est1-Cell 33-40	111-116	45-47	3	14B	ELMB_3	4	15	3
280	8	17	05	3	Phi > 0	2	3		Pad1-Cell 33-40	111-116	45-47	3	14B	ELMB_3	4	15	3

HV Power supply unit 8, HV Modules 16 and 17, HV Sections from 00 to 05 - LV PSB numbers 3, and 4 in wedges 1, 2, and 3 - PHI > 0

Figure 10: HV - LV mapping table IV for HEC A quadrant 1. It covers the HEC 2 HV Sections from 00 to 05 (light blue part of the table), and the LV PSB numbers 3, and 4, ELMB 1 to ELMB 3 in wedges 1 to 3 (light yellow part of the table).

HV-LV Mapping Table HEC A Quadrant1

Close Panel

HV - LV Mapping Table V HEC A Quadrant 1

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
281	8	17	06	0	Phi > 0	2	4		Pad2-Cell 25-32	85-90	58-60	4	14B	ELMB_4	3	19	4
282	8	17	06	1	Phi > 0	2	4		Est2-Cell 25-32	85-90	58-60	4	14B	ELMB_4	3	19	4
283	8	17	06	2	Phi > 0	2	4		Est1-Cell 25-32	85-90	58-60	4	14B	ELMB_4	3	19	4
284	8	17	06	3	Phi > 0	2	4		Pad1-Cell 25-32	85-90	58-60	4	14B	ELMB_4	3	19	4
285	8	17	07	0	Phi > 0	2	4		Pad2-Cell 33-40	80-84	61-63	4	14B	ELMB_4	4	20	4
286	8	17	07	1	Phi > 0	2	4		Est2-Cell 33-40	80-84	61-63	4	14B	ELMB_4	4	20	4
287	8	17	07	2	Phi > 0	2	4		Est1-Cell 33-40	80-84	61-63	4	14B	ELMB_4	4	20	4
288	8	17	07	3	Phi > 0	2	4		Pad1-Cell 33-40	80-84	61-63	4	14B	ELMB_4	4	20	4
289	9	18	08	0	Phi > 0	2	5		Pad2-Cell 25-32	181-186	74-76	5	15A	ELMB_5	3	24	5
290	9	18	08	1	Phi > 0	2	5		Est2-Cell 25-32	181-186	74-76	5	15A	ELMB_5	3	24	5
291	9	18	08	2	Phi > 0	2	5		Est1-Cell 25-32	181-186	74-76	5	15A	ELMB_5	3	24	5
292	9	18	08	3	Phi > 0	2	5		Pad1-Cell 25-32	181-186	74-76	5	15A	ELMB_5	3	24	5
293	9	18	09	0	Phi > 0	2	5		Pad2-Cell 33-40	175-180	77-79	5	15A	ELMB_5	4	25	5
294	9	18	09	1	Phi > 0	2	5		Est2-Cell 33-40	175-180	77-79	5	15A	ELMB_5	4	25	5
295	9	18	09	2	Phi > 0	2	5		Est1-Cell 33-40	175-180	77-79	5	15A	ELMB_5	4	25	5
296	9	18	09	3	Phi > 0	2	5		Pad1-Cell 33-40	175-180	77-79	5	15A	ELMB_5	4	25	5
297	9	18	10	0	Phi > 0	2	6		Pad2-Cell 25-32	149-154	90-92	6	15A	ELMB_6	3	29	6
298	9	18	10	1	Phi > 0	2	6		Est2-Cell 25-32	149-154	90-92	6	15A	ELMB_6	3	29	6
299	9	18	10	2	Phi > 0	2	6		Est1-Cell 25-32	149-154	90-92	6	15A	ELMB_6	3	29	6
300	9	18	10	3	Phi > 0	2	6		Pad1-Cell 25-32	149-154	90-92	6	15A	ELMB_6	3	29	6
301	9	18	11	0	Phi > 0	2	6		Pad2-Cell 33-40	143-148	93-95	6	15A	ELMB_6	4	30	6
302	9	18	11	1	Phi > 0	2	6		Est2-Cell 33-40	143-148	93-95	6	15A	ELMB_6	4	30	6
303	9	18	11	2	Phi > 0	2	6		Est1-Cell 33-40	143-148	93-95	6	15A	ELMB_6	4	30	6
304	9	18	11	3	Phi > 0	2	6		Pad1-Cell 33-40	143-148	93-95	6	15A	ELMB_6	4	30	6

HV Power supply unit 8 and 9, HV Modules 17 and 18, HV Sections from 06 to 11 - LV PSB numbers 3, and 4 in wedges 4, 5, and 6 - PHI > 0

Figure 11: HV - LV mapping table V for HEC A quadrant 1. It covers the HEC 2 HV Sections from 06 to 11 (light blue part of the table), and the LV PSB numbers 3, and 4, ELMB 3 to ELMB 6 in wedges 3 to 6 (light yellow part of the table).

HV-LV Mapping Table HEC A Quadrant1

Close Panel

HV - LV Mapping Table VI HEC A Quadrant 1

Num	HV_Unit	HV_Mod	HV_Sect	Chan	PHI	FT	Wedge	Mod	Mod_sect	Num	Line	PB_Con	FT	ELMB_num	PSB_num	LV_Chan	Wedge
305	9	19	12	0	Phi > 0	2	7		Pad2-Cell 25-32	245-250	106-108	7	15B	ELMB_7	3	34	7
306	9	19	12	1	Phi > 0	2	7		Est2-Cell 25-32	245-250	106-108	7	15B	ELMB_7	3	34	7
307	9	19	12	2	Phi > 0	2	7		Est1-Cell 25-32	245-250	106-108	7	15B	ELMB_7	3	34	7
308	9	19	12	3	Phi > 0	2	7		Pad1-Cell 25-32	245-250	106-108	7	15B	ELMB_7	3	34	7
309	9	19	13	0	Phi > 0	2	7		Pad2-Cell 33-40	80-84	61-63	7	15B	ELMB_7	4	35	7
310	9	19	13	1	Phi > 0	2	7		Est2-Cell 33-40	80-84	61-63	7	15B	ELMB_7	4	35	7
311	9	19	13	2	Phi > 0	2	7		Est1-Cell 33-40	80-84	61-63	7	15B	ELMB_7	4	35	7
312	9	19	13	3	Phi > 0	2	7		Pad1-Cell 33-40	80-84	61-63	7	15B	ELMB_7	4	35	7
313	9	19	14	0	Phi > 0	2	8		Pad2-Cell 25-32	213-218	122-124	8	15B	ELMB_8	3	39	8
314	9	19	14	1	Phi > 0	2	8		Est2-Cell 25-32	213-218	122-124	8	15B	ELMB_8	3	39	8
315	9	19	14	2	Phi > 0	2	8		Est1-Cell 25-32	213-218	122-124	8	15B	ELMB_8	3	39	8
316	9	19	14	3	Phi > 0	2	8		Pad1-Cell 25-32	213-218	122-124	8	15B	ELMB_8	3	39	8
317	9	19	15	0	Phi > 0	2	8		Pad2-Cell 33-40	207-212	125-127	8	15B	ELMB_8	4	40	8
318	9	19	15	1	Phi > 0	2	8		Est2-Cell 33-40	207-212	125-127	8	15B	ELMB_8	4	40	8
319	9	19	15	2	Phi > 0	2	8		Est1-Cell 33-40	207-212	125-127	8	15B	ELMB_8	4	40	8
320	9	19	15	3	Phi > 0	2	8		Pad1-Cell 33-40	207-212	125-127	8	15B	ELMB_8	4	40	8

HV Power supply unit 9, HV Module 19, HV Sections from 12 to 15 - LV PSB numbers 3, and 4 in wedges 7, and 6 - PHI > 0

Figure 12: HV - LV mapping table V for HEC A quadrant 1. It covers the HEC 2 HV Sections from 12 to 15 (light blue part of the table), and the LV PSB numbers 3, and 4, ELMB 7 to ELMB 8 in wedges 7 to 8 (light yellow part of the table).

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