

## THE UPGRADE OF CONTROL HARDWARE OF THE CERN NA62 BEAM VACUUM

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### Abstract

NA62 is the follow-up of the NA48 experiment, in the SPS North Area of CERN, and reuses a large fraction of its detectors and beam line equipment. Still, there are many new vacuum devices in the beam line (including pumps, valves & gauges), which required a thorough modification of the control system and a large number of new controllers, many of which were custom-made.

The NA62 vacuum control system is based on the use of PLCs (Programmable Logic Controllers) and SCADA (Supervisory Control and Data Acquisition). The controllers and signal conditioning electronics are accessed from the PLC via a field bus (Profibus); optical fibre is used between surface racks and the underground gallery.

The control hardware was completely commissioned during 2014. The nominal pressure levels were attained in all sectors of the experiment. The remote control of all devices and the interlocks were successfully tested.

This paper summarizes the architecture of the vacuum control system of NA62, the types of instruments to control, the communication networks, the hardware alarms and the supervisory interface.

### INTRODUCTION

NA62 will study the rare decay  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  at the CERN SPS. NA62 is built to improve the current experimental precision by measuring kaon decays-in-flight with calorimetry to veto extra particles, very light mass trackers to reconstruct the momenta of the  $K^+$  and the  $\pi^+$  and full particle identification capability [1].

To reach the required sensitivity and acceptance, the vacuum in the decay area needed to be improved by at least two orders of magnitude compared to NA48. Many detectors that would normally be outside the vacuum chamber are now part of the vacuum system leading to a significant increase of the gas load to be pumped. A particularity of NA62 is the distribution of detectors along 250 m (Figure 1).

The NA62 experiment went through a complete refurbishment with the introduction of new detectors filled with gas. Their operation requires a vacuum system, based on turbo molecular and cryogenic pumps. The beam line is divided into 7 sectors, each having specific vacuum requirements. The vacuum equipment in each sector will be described in the next section.

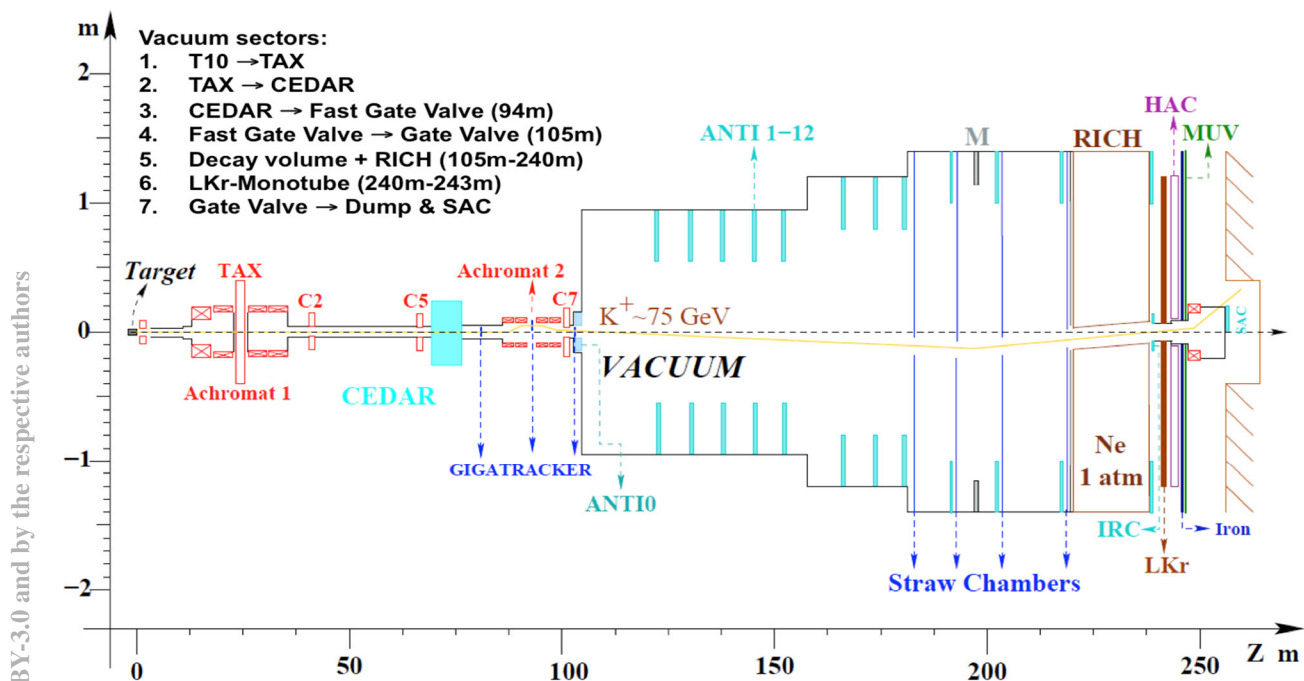


Figure 1: Layout of the NA62 experiment

### VACUUM EQUIPMENT

The upgrade of NA62 beam vacuum comprises more than 200 new instruments (including different types of pumps, valves and gauges) along the beam line. In addition, a large amount of cabling had to be designed, installed and commissioned.

This was a challenging work, as the NA62 beam line measures roughly 270 m from the SPS T10 target to the NA62 beam dump, with also some equipment in a surface building.

In sectors 1 and 2 only passive equipment is used due to the high level of radiation. In sectors 3 and 4, radiation-tolerant active vacuum gauges may be used but not instruments with embedded Profibus interface. Sectors 5 to 7 are radiation-free and allow the installation of controllers and PLCs close to the instruments. The distribution of vacuum devices is shown in Figure 2.

#### Vacuum Pumps

Vacuum pumps are the basic elements needed to achieve high vacuum in accelerators and experiments. Most of the time, several types are combined and assembled together in pumping groups to pump down from atmospheric pressure down to high vacuum. Three types of pumps are used in NA62 (Table 1):

- **Primary or roughing pumps (VPR)** are used to evacuate from 1 bar down to 10<sup>-3</sup> mbar; they are also used as a backing pump for Turbo Molecular pumps.
- **Turbo molecular pumps (VPT)**, are effective in the range 10<sup>-3</sup> to 10<sup>-10</sup> mbar, therefore requiring rough vacuum achieved by a primary pump. A VPR and a VPT are often assembled and controlled together as a turbo molecular pumping group (VPG).

- **Cryogenic pumps (VPC)** are used to achieve very high pumping speeds at low pressures. They only need rough pumping during regeneration, but not during operation. In NA62, a pumping speed of more than 100 000 l/s is required to reach the low 10<sup>-6</sup> mbar pressure range, with the particularly high gas load (Ar, CO<sub>2</sub>) from permeation from the straw detectors. This is accomplished by 2-stage Gifford-McMahon cryocoolers, using gaseous helium closed circuits and cryosorbers on the second stage. A cryogenic pumping group (VPGC) includes heaters, gauges and valves.

Table 1: Summary of vacuum pumps in NA62

Type	Units
VPR	7 (5 rotary vane primary @220V, 2 combined dry screw/roots @400V)
VPT	8 (7 DN 100 for normal operation, 1 DN 250 mainly for leak detection)
VPC	7

#### Vacuum Valves

Apart from the standard electro-pneumatic or electro-magnetic (angle or gate) valves commonly used in accelerators, two special types can be found in NA62.

A fast shutter valve (VVQ) closes within 20 ms, in case of rupture of the thin window that separates the CEDAR detector from vacuum, thus protecting fragile equipment downstream.

The aluminium-sheet valve upstream of the liquid Kr calorimeter must not move unnecessarily, to avoid air-inrush. Its bi-stable actuator does not lose position under a loss of power or compressed air. Also, together with the associated gauges, the controller is powered by an UPS.

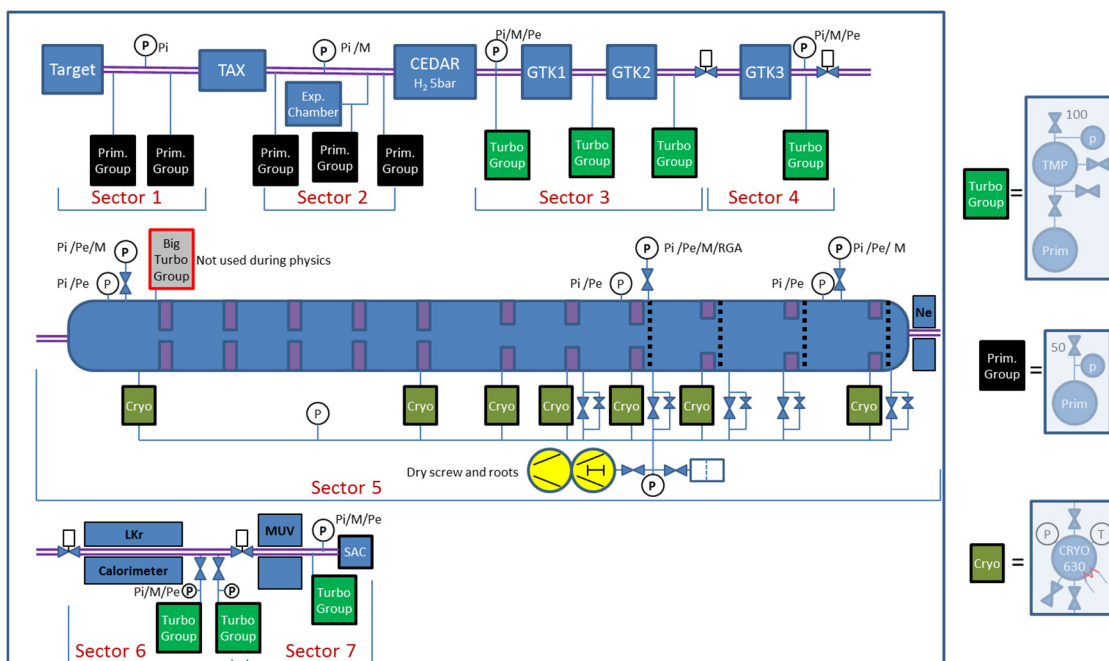


Figure 2: Vacuum equipment layout in NA62 experiment

## Vacuum Gauges

Several types of vacuum gauges are used in NA62 depending on the range of vacuum to be measured. Both passive and active electronics gauges are used depending on the radiation levels. In the NA62 experiment, the following types of gauges can be found:

- Passive Pirani gauges (VGR)
- Passive Penning gauges (VGP)
- Active Membrane gauges (VGM)
- Active Full Range gauge-pairs (VGF)
- Active Profibus interfaced gauges (VGF, VGM)

## CONTROL SYSTEM

NA62 follows the same controls architecture of the LHC [2]. This means that the vacuum controllers are managed using a PLC-based architecture, using the Siemens™ S7-300 series. The human-machine interface is a SCADA (Supervisory Control And Data Acquisition), built with Siemens WinCC OA®, formerly PVSS®.

The PLC architecture of NA62 is based on a master-slave topology. There is one master PLC, 8 slave PLC for the pumping group control and 5 remote I/O stations that have specific functionality and connectivity, depending on the instruments to interface.

Specific control crates are used for each type of instrument. Some of them have been designed, manufactured and tested at CERN while others are commercial. The controllers have been distributed in six racks in a radiation-safe area of the underground gallery, and two racks in the surface building, where the Master PLC is located. Tables 2 and 3 summarize the controller types used in NA62. The VAT VP-3 valve controllers needed an additional UPS to ensure protection of the LKr in case of power cut.

Table 2: Custom-made controller crates for NA62

Name	Description	Units
VRLMS	Master PLC	1
VRLRG	PLC Remote I/O station	5
VRPGMF	VPT controller	8
VRJTB	VPT patch panel	5
VRPPH	VPR controller	2

Table 3: Commercial controllers at NA62

Name	Description	Units
VRPP	Primary pump local crate	5
VRVRC	VAT VF-2 fast valve controller	1
VRGPT300	Pfeiffer-Balzars TPG 300 gauge controller	5
VAT_VP	VAT VP-3 dual-acting valve controller	2
VRPYA	HSR PCA700C VPC controller	7

The installation and commissioning of all control crates took place during spring and summer of 2014.

## COMMUNICATION

For the connexion of all instruments to the respective controllers, a cabling campaign was carried out during spring 2014.

As some equipment (including the Master PLC, one remote I/O station and other controllers) are in a surface building, about 100 m away from the beam line, an optical link was devised to provide fast and reliable communication.

The communication between controllers and PLC is made via Profibus-DP, where there is no radiation hardness (Sectors 5 to 7). Otherwise the communication relies on dedicated individual cables. Three separate Profibus-DP networks have been devised for each specific purpose:

- **Profibus Alarms network (I):** Links the equipment that are source of some type of Alarm. The alarms will actually be generated by the Master PLC that will send them to the Detector Control System (DCS) [3].
- **Profibus VPT network (T):** Establishes the communication between the VPT controllers and the Master PLC.
- **Profibus All-purpose network (A):** Provides the communication interface for Profibus instruments that do not belong to the aforementioned groups (i. e. Profibus gauges).

The interface between the optical and copper Profibus networks is made using Siemens™ Optical Link Modules (OLM).

The management of the VPC controllers was carried out by a remote I/O station using a specific communication protocol based on a Profibus to RS-232 gateway, to interface with the master cryo-controller, which periodically polls the rest of cryo-controllers using a token ring topology [4].

As in other experiments and accelerators at CERN, the Master PLC is connected to the SCADA server via a dedicated Ethernet Technical Network.

The communication networks between vacuum instruments and controllers are summarized in Figure 3.

## SUPERVISORY APPLICATION

The supervisory application of NA62 acts as a user interface that can be accessed from the NA62 control room to monitor the status, history and, depending on the user privileges, act on the control of the vacuum devices. It was developed in WinCC® OA and its main screen is illustrated in Figure 4. All the vacuum devices have been modelled and all the relevant attributes are retrieved from a SCADA database. The pumping groups have also been modelled in detail, showing the status of all the devices in the group, as well as the hardware alarms status and history.

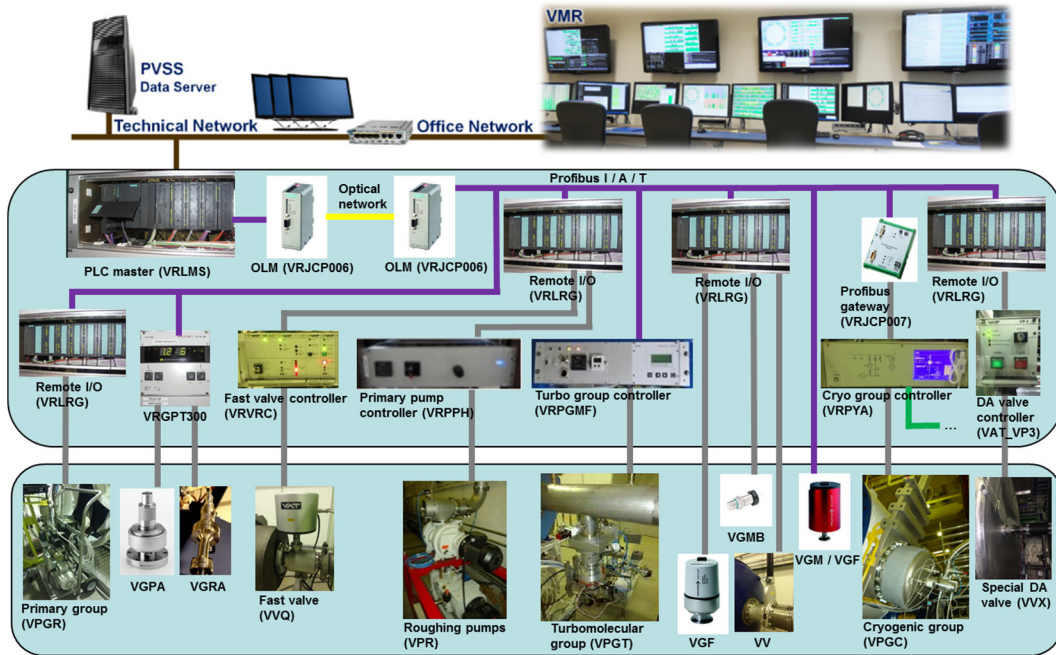


Figure 3: Schematic view of the vacuum controls architecture and communication of NA62.

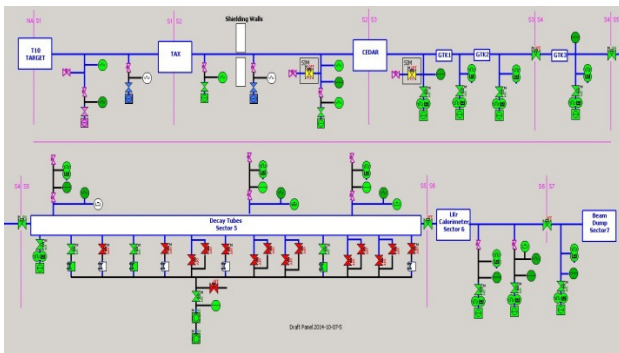


Figure 4: Supervisory application main screen.

### HARDWARE ALARMS

For a safe operation of the experiment, the relevant alarms had to be implemented to prevent damage of equipment in case of hypothetical operation failures. The hardware alarms of NA62 are described in Table 4, indicating if it is an output or an input to the vacuum system. The alarms are hard-wired with a dedicated cable from the master PLC crate to the Detector Control System. The alarms were successfully tested during autumn 2014.

### CONCLUSION

The NA62 control hardware upgrade was a complex task that required the active participation and effort of several groups at CERN, including engineers, technicians, external workshops and industrial partners.

The cabling and control equipment deployment took place in spring 2014. The full system was commissioned during summer 2014. The measured pressure levels meet the nominal specifications [5] in every sector. The alarms are fully operational.

Table 4: Hardware alarms in NA62 vacuum

Output	Enable Inside CEDAR pumping (Sectors 2 and 3 are under vacuum)
Output	Enable GTK cooling (Sectors 3 and 4 are under vacuum)
Output	Enable High Voltage on LAV (Sector 5 atmosphere or under high vacuum)
Output	Enable Inside RICH pumping (Sector 5 is under vacuum)
Output	Enable High Voltage on SAC (Sector 7 atmosphere or under high vacuum)
Input	Pumping Enable for Sector 2 and 3 (CEDAR Window No Rupture)

### REFERENCES

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- [5] S. Blanchard *et al.*, “Vacuum control system for the NA62 – Work Package Description”, CERN Technical Note, (2013); <https://edms.cern.ch/document/1280667/1>