The Miniball Vacuum Interlock

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1 Overview

The interlock was built in two separate parts in Leuven. The first box was built in 2001 and the second in 2007. Some of the features have become obsolete due to changes in the setup. For example, our interlock originally controlled the last valve between us and the accelerator. However, at some time they took this control from us. Also, the second interlock box was built with the PPAC in mind, but this is no longer used. Finally, in 2015, some changes were necessary in order to replace broken Alcatel gauges, which cannot be bought any more, with Pfeiffer ones.

The only change in 2022 was to put some perspex over it, so it is now impossible to touch the live parts.

2 The Purpose of the Interlock

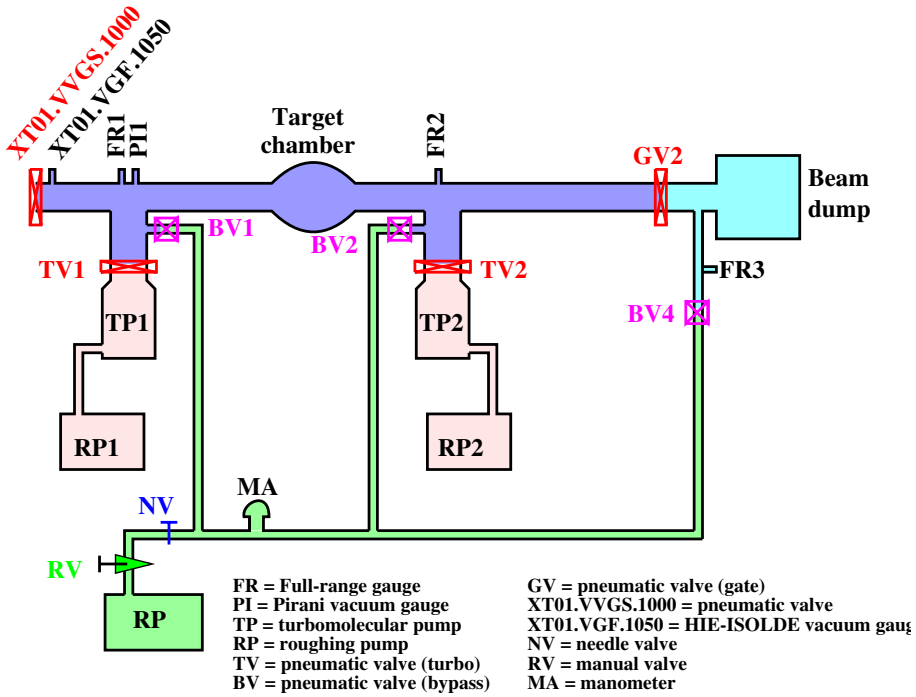

Figure 1: A schematic diagram of the vacuum system.

The purpose of the interlock is as follows:

- Preventing opening the valves between the turbo pumps and the main beam line, when the vacuum in the main beam line is poor (e.g. chamber open).

- Automatically closing those valves, if the vacuum in the main beam line becomes poor (i.e. a leak).
- Preventing opening the valves between the turbo pumps and the main beam line, when the bypass valves are open and vice versa. This is to prevent pumping on a roughing pump with a turbo pump. If the roughihg pump is an oil pump, this could suck the oil into the beam line.
- Preventing opening the gate valve between the main beam line and the beam dump if the vacuum is not good in either of the two.
- Automatically closing this vale, if the vacuum becomes bad.
- Preventing the bypass valve for the beam dump being opened when this gate valve is open and vice versa.

The vacuum system has four vacuum measurement cells:

- PI1 - an Alcatel Pirani gauge at the upstream end. This is not connected to the interlock.
- FR1 - a Pfeiffer full-range gauge at the upstream end. This is also not connected to the interlock.
- FR2 - a Pfeiffer full-range gauge at the downstream end. This has two connections (for one measurement cell) to the interlock. One is used for the interlock on the turbo valves and the other for the interlock on the beam dump valve.
- FR3 - a Pfeiffer full-range gauge at the downstream end. This has one connection to the interlock, used for the interlock on the beam dump gate valve.

There are three pneumatic gate valves, which are controlled by the interlock:

- TV1 - gate valve between the upstream turbo and the main beam line.
- TV2 - gate valve between the downstream turbo and the main beam line.
- GV2 - gate valve between the main beam line and the beam dump.

There are three additional pneumatic valves for the bypass line, which are also controlled by the interlock:

- BV1 - connects the bypass line to the upstream part of the main beam line.
- BV2 - connects the bypass line to the downstream part of the main beam line.
- BV4 - connects the bypass line to the beam dump.

Previously there was also a BV3 and GV1 for the PPAC actuator, but these are no longer used.

Note also that the interlock system was built in two separate parts. The original part controlled just BV1/2 TV1/2 and used only Alcatel gauges. The extra part was for the BV3/4 and GV1/2 and used Pfeiffer gauges. As the Alcatel ones are no longer produced, the interlock system was modified in 2015 to use only Pfeiffer gauges. Consequently, there are two interlock boxes, both mounted in rack 6 (at the beam dump).

3 Interlock box 1

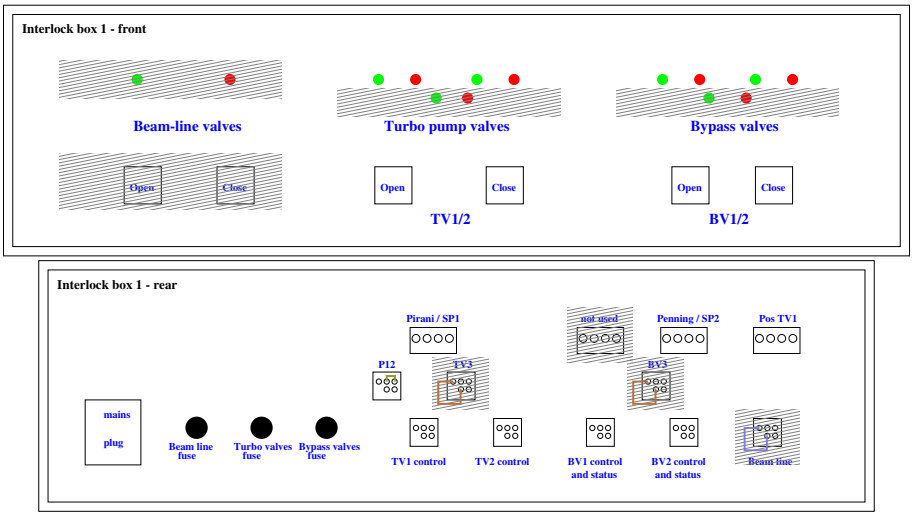

Figure 2: The first interlock box. The greyed out areas on the front are actually taped over and correspond to things which are no longer needed. The greyed out areas at the rear are not actually taped over, but still correspond to things we don't need.

Originally, Miniball only had one interlock box, which had provision for operating three bypass valves (BV1, BV2 and BV3), three turbo valves (TV1, TV2 and TV3), and a beam line valve V5A (connecting the Miniball line to the REX line). There are open/close buttons for the bypass valves which open and close all three bypass valves simultaneously. Similarly, the open/close buttons for the turbo valves operate all three turbo valves.

3.1 The front panel

So on the front panel there are three pairs of open/close buttons for:

- The beam line valve V5A
- The turbo valves TV1, TV2 and TV3

- The bypass valves BV1, BV2 and BV3

Additionally, there seven pairs of red/green LEDs to indicate the status of the seven valves (V5A, TV1, TV2, TV3, BV1, BV2, BV3). Note that the two LEDs have separate sensors, so a stuck valve might be neither open nor closed and neither LED is lit.

We never had the third turbo pump, so we didn't have BV3 and TV3, so the four LEDs for these two valves were taped over.

Later, when REX became a CERN facility, control over the beam line valve V5A was taken from us. So the open/close buttons for this valve and the red/green LEDs are useless and were taped over.

3.2 The power connectors and fuses

At the back, there is the mains plug and three fuses for V5A, all the turbo valves and all the bypass valves, respectively. Additionally, there are four 4-pin Molex connectors and eight 5-pin connectors.

3.3 The rear connectors

Connector	Meaning
P1	TV1 control/status
P2	TV2 control/status
P3	Pirani
P4	BV1 control/status
P5	BV2 control/status
P6	Beam line control/status (V5A)
P7	Penning
P8	TV1 in position
P9	Rotary pump power
P10	TV3 control/status
P11	BV3 control/status
P12	X5-X6, X7-X8

3.4 The control/status connectors for the valves

For each of the seven valves BV1, BV2, BV3, TV1, TV2, TV3 and V5A there is a 5-pin connector with the following pin-out.

Pin number	Position	Meaning
1	Top right	Control live (220 Volts)
2	Top middle	Control neutral
3	Top left	Status closed
4	Bottom middle	Status common
5	Bottom right	Status open

In order to open a valve, the box puts mains voltage on the top right pin. So the solenoids of the valves are connected with a standard 3-core mains cable: brown to the top right pin, blue to the top middle pin and the earth is not connected![1]

As we do not have BV3 and TV3, the common and closed lines are connected, to indicate they are both closed all the time. This is needed as it is not allowed to have any bypass valve when the turbo valves are open and vice versa.

The closed sensors work by shorting the top left pin to the bottom middle one, while the open sensors short the bottom right pin to the bottom middle one. Note that for the bypass valves, these are really two separate sensors, so there are four wires, one from each sensor going to the bottom middle pin and the remaining wire from the open sensor going to the bottom right and the one for the closed sensor going to top left. The bypass valves use five-core cable with grey insulation. Four wires are black and one is yellow/green. The yellow/green one is not used. The other four are for the sensors. For the turbo valves, there are three connectors on the valve itself with a one-to-one correspondence to the pins, so standard 3-core cable is used: brown = closed, yellow/green = ground, blue = open.

3.5 The vacuum gauge connectors

The Molex connectors were used to connect to Alcatel gauges, which had the same kind of connector. The pin-out is:

Pin Number	Position	Meaning
1	Rightmost	Below threshold
2	Second right	Common
3	Second left	Above threshold
4	Leftmost	Ground

The gauge indicates the vacuum is above the threshold by connecting pins 2 and 3 and that it is below threshold by connecting pins 1 and 2.

As the Alcatel gauges are broken and no longer manufactured, we have switched to Pfeiffer ones, which have four set points, each with three pins on a 15-pin D-sub connector, corresponding to pins 1, 2 and 3 of the Molex one.

The first Molex connector (left) was used for a Pirani gauge on the main beam line, which indicated if it was safe to open the turbo valves TV1, TV2 and TV3. As the original Alcatel Pirani is broken and cannot be replaced, we have a Pfeiffer full-range gauge there. We use set point 2 of this gauge to replace the Pirani.

The second one seems to provide mains power on pins 1 and 4. I think this was originally to power the roughing pumps.

[1] This is probably violated the CERN safety standards, though it is not dangerous as long as the valve is bolted onto the beamline!

The third one was connected to a Penning gauge on the main beam line and was used to determine if it is safe to open the beam line valve V5A. This is presumably no longer relevant, as we do not have control over that valve.

The fourth one is not currently used, but it was for a sensor to indicate that TV1 is in position.

3.6 The X5-X6 X7-X8 connector

The X5-X6 X7-X8 connector is used to connect to the second interlock box. It is also a 5-pin connector, but it must have a different pin-out to the others, as the top middle and top right pins are connected together. On the other connectors, these pins are neutral and live (220 Volts), respectively, so that is clearly not the case for X5-X6 X7-X8, or we would have a short circuit.

The first control box puts 22 Volts on the X5 line, when BV1 is closed and 22 Volts on X6, when BV2 is closed. These must be the top left and bottom right pins of P12 of the first control box. They are then connected to the corresponding pins of P23 of the second control box.

Presaumably, the top right and middle right pins are X7 and X8, which are connected together. It is not clear what this is!

4 Interlock box 2

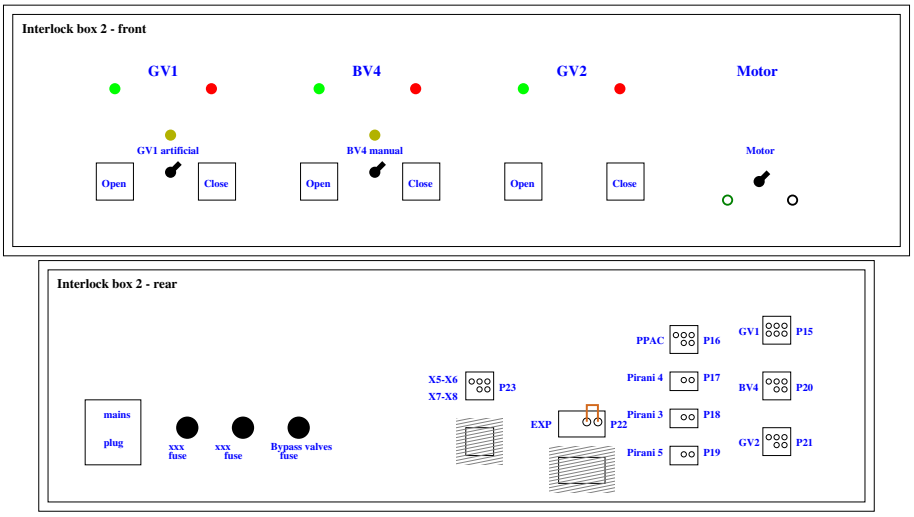

Figure 3: The second interlock box. The greyed out areas on the front are actually taped over and correspond to things which are no longer needed. The greyed out areas at the rear are not actually taped over, but still correspond to things we don't need - actually, they are not wired up on the inside.

The second interlock box was added, when Miniball was moved from the old hall into the new one in 2007. At this time, the PPAC was moved from the main beam line into an actuator and the ionization chamber was placed at the beam dump. To accomodate this, two new bypass valves (BV3, BV4) and two new gate valves (GV1 and GV2) were added. However, we could not use the BV3 and TV3 connectors on the first interlock box, because we needed independent operation of these valves.

The second interlock box was made to use Pfeiffer gauges from day one, but as it needed to know the vacuum on both sides of GV1 and GV2, this meant three additional gauges, one of which was on a cross-piece with the Alcatel Pirani, which interlocked TV1/2.

In 2015, this was modified to remove GV1 and the PPAC vacuum gauge. As, by this time, the main vacuum was monitored by a Pfeiffer full-range gauge, two set points on the same gauge were used to interlock TV1/2 and GV2. As we used an existing cable and broke it a bit, to make it fit, we ended up with set point SP2 interlocking TV1/2 and set point SP1 interlocking GV2.

It is not clear why we need a connection to the first interlock box, since the second box already knows the state of the beam line vacuum. However, there is a connection between P12 of the first box and P23 of the second one.

4.1 The front panel

The front panel is divided into three sections. In the one on the left are the buttons to open and close GV1, the red/green pair of LEDs to indicate the status of this valve, a switch to turn on and off "GV1 artificial" [sic] mode and an LED to indicate if this mode is on.

In the middle section are the two pairs of open/close buttons for BV4 and GV2, the two pairs of red/green LEDs to indicate their status and a "BV4 manual" switch with an LED to indicate its status.

Finally, there is a motor section on the right, which is mostly taped up. I don't remember this ever being used. There was a separate box for controlling the PPAC actuator's motor. It is possible that the design of this part was incorrect.

4.2 The rear connectors

Connector	Number of pins	Meaning
P13	0	Not used or labelled
P14	0	Not used or labelled
P15	6	GV1 control/status
P16	5	PPAC
P17	3	Pirani PI4 (PPAC actuator)
P18	3	Pirani PI3 (Main beam line)
P19	3	Pirani PI5 (Beam dump)
P20	5	BV4 control/status
P21	5	GV1 control/status
P22	4	EXP (right two pins jumpered together)
P23	5	X5-X6, X7-X8 (to P12 of first box)

Note that the three Pirani connectors are labelled "PI3", "PI4" and "PI5" which, unfortunately, look like "P13", "P14" and "P15"!

Note also that the real P13 and P14 are not labelled and anyway have no pins in the connectors. So they are really just dummy connectors.

As the above threshold is never used, the pin is missing (the leftmost one of the three-pin connector) for P17, P18 and P19.

For some reason GV1 has a 6-pin connector. This makes sense, because we have live, neutral and earth for the solenoid and the open, closed and common lines for the status. Note, however, that the pinout is different. The live is now on pin 2 and the neutral on pin 6. Pin 1 seems to be connected internally to pin 1 of P16. However, all the other connnectors for controlling valves (i.e. PPAC, BV4, GV2) have only 5 pins.

As the PPAC had its own gas system, with its own separate interlock, which is undocumented and no longer mounted, it is not clear how the various parts for the PPAC interfaced to the system. Pins 1 and 2 of P16 are used to indicate that the PPAC is retracted.

We do not use PPAC, Pirani 4 or GV1 any more as they were all connected with the PPAC.

5 The Connections to the Gauges and Valves

5.0.1 Connection to FR1

There are no connections to the upstream full-range gauge (FR1).

5.0.2 Connections to FR2

We have a single 15-pole D-sub connector plugged into the downstream full-range gauge (FR2), which has four pins (3, 4, 7 and 8). We already used pins 7 and 8 (set point 2) for the interlock on TV1/2. The other two (i.e. pins 3 and

4 - set point 1) are used for the interlock on GV2. This is actually unchanged.

So two cables are connected to FR2 and one goes to the first interlock box, to indicate the state of the main beam line vacuum for the interlock on TV1/2 and the other does the same job for GV2.

Probably it is best to have set points 1 and 2 set to the same values to avoid confusion.

5.0.3 Connection to FR3

A similar 15-pole D-sub connector is plugged into the beam dump gauge (FR3), but here we only have pins 3 and 4. These provide (via set point 1) the state of the vacuum in the beam dump.

5.0.4 Connections to BV1 and BV2

There is a control cable, which provides mains power to open the valve, when necessary and a status cable for the open/closed status. The control cable is a standard white 3-core mains cable (brown wire = live, blue wire = neutral, yellow/green wire = earth). The status cable is a grey 5-core cable, with one yellow/green wire, which is not connected and four black wires, two for open and two for closed.

5.0.5 Connections to TV1 and TV2

There is a control cable, which provides mains power to open the valve, when necessary and a status cable for the open/closed status. Both cables are white 3-core cables. The control cable is wired as a standard mains cable (brown wire = live, blue wire = neutral, yellow/green wire = earth). The status cable uses brown wire = closed, yellow/green wire = common and blue wire = open.

5.0.6 Connections to BV4

There is a control cable, which provides mains power to open the valve, when necessary and a status cable for the open/closed status. The control cable is a standard white 3-core mains cable (brown wire = live, blue wire = neutral, yellow/green wire = earth). The status cable is a grey cable.

5.0.7 Connections to GV2

There is a control cable, which provides mains power to open the valve, when necessary and a status cable for the open/closed status. Both cables are grey.