

Improving the gas gain monitoring system in multiwire proportional chambers for MUON detector of LHCb experiment

August 19, 2016

Summer Student: Ruvinskaia Ekaterina

Supervisor: Maev Oleg

Abstract

The gas gain monitoring system in multi-wire proportional chambers for MUON detector of LHCb has been constructed and commissioned. It includes an online-monitoring, tools for analysis the archived data and an alarm system on the quality of the gas mixture. Finally, it will be implemented in the main ECS of LHCb for MUON detector and as a part of safety system of LHCb as a permanent online monitor of the quality of the gas mixture in MWPCs. The main advantage of this setup is a monitoring of Gas Gain (GG) in MWPCs with radioactive sources independently from the presence of beam at LHC. It also provides an option for prompt reaction in case of a problem with the gas.

1 Goal of the Project

During my contract at CERN as a summer student, I was a part of the MUON group of LHCb experiment. My project was focused on the improvement of the Gas Gain (GG) monitoring system in Multi Wires Proportional Chambers (MWPCs) for MUON detector.

Particularly, it was participation in installing and commissioning the setup at the Point 8. The main part of my work was a creation of WINCC OA project as a tool for control of that setup, online-monitoring and archiving the data and implementation an alarm system on the quality of the gas mixture. Finally, it will be included in the main ECS (Experiment Control System) of LHCb for MUON detector. Also it will be a part of safety system of LHCb as a permanent online monitor of the quality of the gas mixture in MWPCs. The main advantage of this setup is a monitoring of GG in MWPCs with radioactive sources independently from the presence of the beam at LHC. It also provides an option for prompt reaction in case of a problem with the gas.

2 Introduction

2.1 LHCb

Primary goal of LHCb is a search in the field of the indirect evidence of new physics in CP-violation and rare decays of beauty and charm hadrons [1]. LHCb is a single-arm spectrometer with a forward angular coverage from approximately 10 mrad to 250 mrad in the bending (non-bending) plane. The schematic of the spectrometer is shown in figure 1.

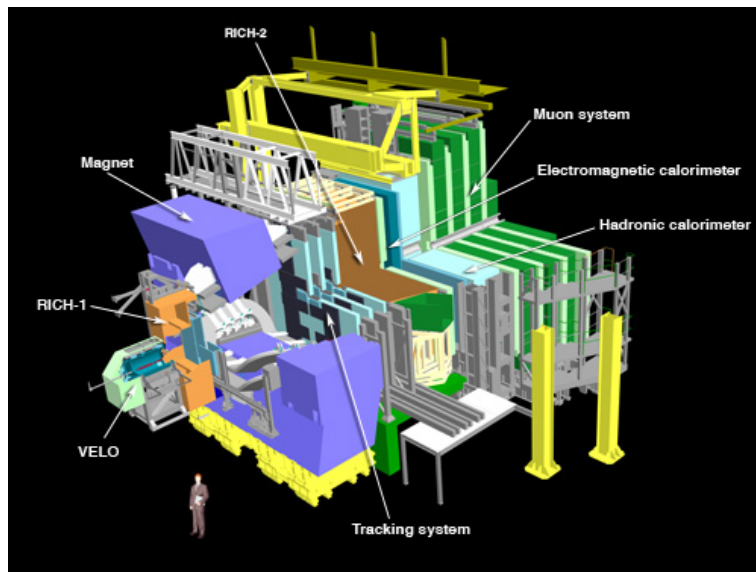


Figure 1: View of the LHCb detector

2.2 MUON system

MUON detector is a key part of the trigger and particle identification system of LHCb. The muon system provides fast information for the high- p_T muon trigger at the earliest level (Level-0) and muon identification for the high-level trigger and offline analysis.

The general schematic of the MUON system is given in figure 2. The system consists of five rectangular stations (M1 – M5), placed along the beam axis. Stations M2 through M5 are positioned downstream of the calorimeters and are separated by 80 cm thick iron absorbers. The properties of the latter are used to identify and trace penetrating muons both in on- and off-line analyses.

Station M1 is placed in front of the calorimeters and is used to improve the P_T measurement in the trigger. Each station consists of two mechanically independent parts, designated side “A” and “C”. Each muon station is divided into four regions (R1 – R4, see figure 3), with increasing distance from the beam axis. The full system

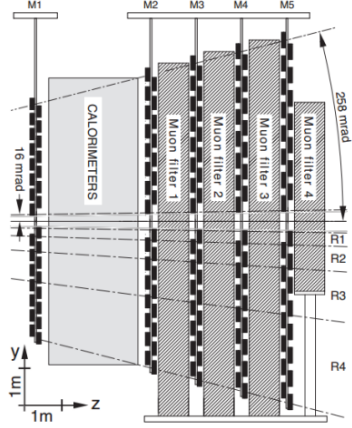


Figure 2: Side view of the muon system

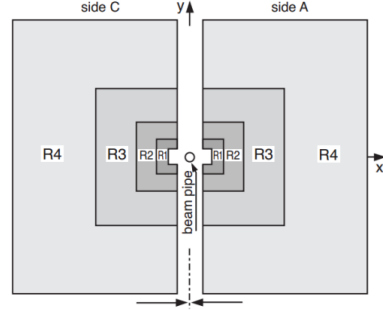


Figure 3: Station layout with four regions R1-R4

comprises 1380 chambers. Each station is equipped with 276 multi-wire proportional chambers (MWPCs) with the exception of M1R1. The latter system, exposed to the strongest radiation flux, is equipped with 12 GEM detectors [1].

3 Method

The method of GG-monitoring actually based on precise measurement of the chamber current induced by radioactive source. Gas gaps of the test MWPCs connected directly to the gas lines of MUON detector. Measured current values normalized to the reference point. Any variations of the normalized current values mean some changes either in the fractions of main components either in the quality of gas mixture (level of impurities etc.). Also, monitoring the ratio of currents on the input and output gas lines could be nice indicator of any leaks/holes in the MUON system.

The detailed study on the gas gain measurements in MUON MWPC was performed long time ago and described in the dedicated article [2]. For a small deviation from the normal gas conditions the gain variation can be calculated as:

$$\frac{\Delta G}{G_0} = \alpha \frac{\Delta \rho}{\rho} = \left(\frac{\Delta P}{P_0} - \frac{\Delta T}{T_0} \right) \quad (1)$$

where G_0 is the normal gain at normal pressure and temperature, α is a coefficient independent of pressure and temperature.

Primary ionization current (I^*) can be calculated as follows:

$$\frac{\Delta I^*}{I_0^*} = \beta \frac{\Delta \rho}{\rho} = \beta \left(\frac{\Delta P}{P_0} - \frac{\Delta T}{T_0} \right) \quad (2)$$

As a result, the chamber current variation due to small variations of pressure and temperature can be obtained as:

$$\frac{\Delta I}{T_0} = (\alpha + \beta) \left(\frac{\Delta P}{P_0} - \frac{\Delta T}{t_0} \right) \quad (3)$$

Using Cs source, the authors [2] were able to assess the value for alpha and beta, as -5.8 ± 0.2 and 0.81 ± 0.03 , respectively. For the setup for Gas Gain Monitor in Muon MWPCs both coefficients have to be computed based on direct measurements at the current conditions.

4 Experimental setup

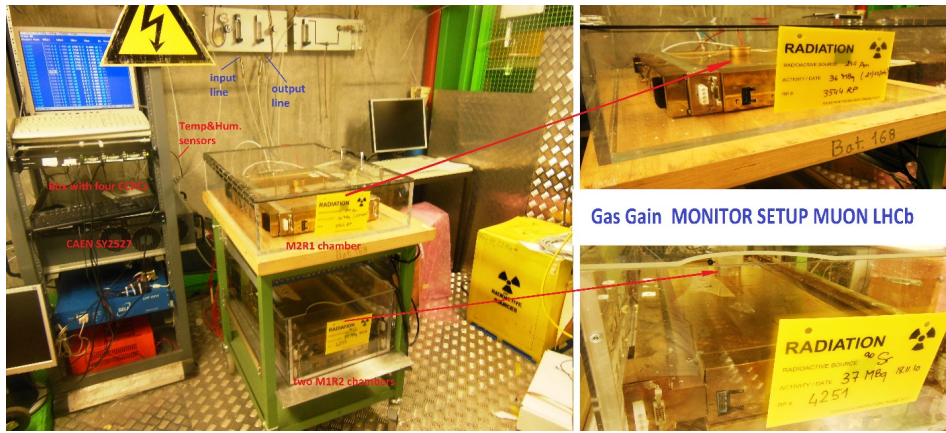


Figure 4: Experimental setup. Left picture presents a common view of the setup with chariot where test chambers placed and rack with HV power supply CAEN SY2527, box with control CCPCs and temperature and humidity sensors. Pictures on the right show test chambers with radioactive sources.

Figure 4 presents the experimental setup. Two two-gap M1R2 MWPCs have been installed on bottom shelf of chariot as a main part of the detector. Both chambers are irradiated with $37\text{MBq } ^{90}\text{Sr}$ ($^{90}\text{Sr}/^{90}\text{Y}$, β -decay, $0.546/2.28$ MeV) source. Upper one is connected to the input of MUON detector gas line, the bottom one connected to the output line. In addition, one four-gap chamber M2R1 has been installed on top of chariot and connected to the output line for the crosscheck. This chamber is irradiated with $36\text{MBq } ^{241}\text{Am}$ (γ -decay, 59.5 keV) source. All gas gaps in the test MWPCs are supplied independently with high voltage from commercial CAEN SY2527 PS. Working HV is 2.75 kV. Temperature and humidity are measured with a commercial sensors from Evaluation kit EK-H5. The data pressure we get from the main sensor in the LHCb cavern.

5 Experiment Control System

The experiment control system (ECS) is in charge of the configuration, control and monitoring of the different sub-detectors and of all areas of the online system. The building blocks of the control system are based on the WINCCOA SCADA System complemented by a JCOP Framework [4].

The WinCC OA package has a modular architecture, as schematized in Figure 5 [3]. Each type of module is a running process, called a manager, handling specific tasks. In the case of alarm handling, the value of each item is coming from any driver (D) processed by the Event Manager (EV). EV handles the alarm generation (e.g. determination if the value is within a "good" or "bad" range). In the case of an alarm generated, EV sends the alarm information to the Data Manager (DB) for archiving, and to all relevant managers for displaying or for processing. Figure 5 shows an example of data flow from a driver D2 through EV, to DB, CTRL and UI2.

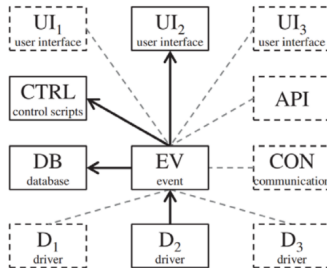


Figure 5: WinCC OA architecture. The continuous show an example of alarm handling data flow

The control of this experimental setup is provided by dedicated ECS project MUD-CSGGAIN hosted at mudcs02 virtual machine (figure 6). The project implements the Gas Gain Check Algorithm which persistently monitoring the currents depending of outer conditions (pressure, temperature) and can produce the alarms, preventing the possible damage for all MUON system which can occur due to a wrong gas mixture. Friendly User Interface allows to adjust the parameters of the algorithm and to manage collected information. It will be operable from the top MUON project MUSIDES.

The chambers are connected to the CAEN SY2527 HV power supply which operated through the OPC server running at muggtst01w CCPC. This CCPC runs both the OPC-server and WINCC OPC-client. OPC (OLE for Process Control) is an open interface based on the OLE/COM (now ActiveX) and DCOM technology. OPC client applications (from WINCC in this case) can communicate with the OPC server (from hardware vendor) to exchange data and control commands in a standard way [5]. This scattered OPC-client connected to the control project MUDCSGGAIN (placed at mudcs02 virtual machine) Event Manager [3].

Measurements of the humidity and temperature are provided by Sensirion sensor

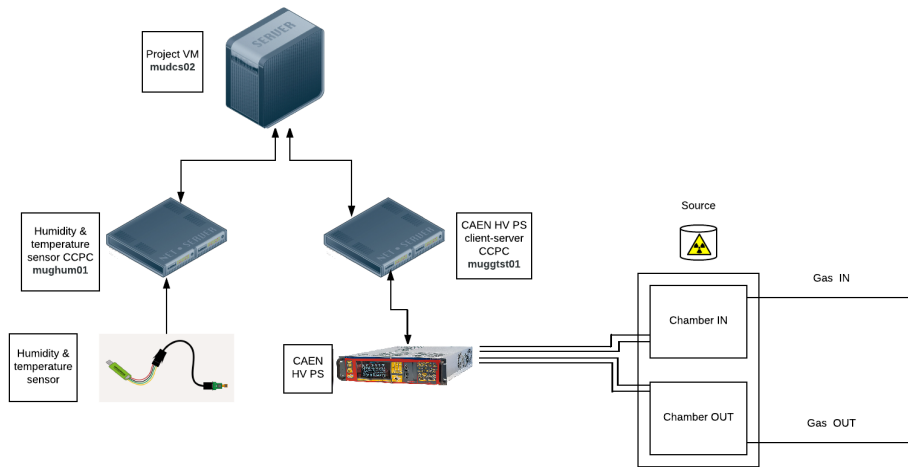


Figure 6: Gas Gain Check installation

(Evaluation kit EK-H5) which controlled by DIM-server running at mughum01 CCPC. WINCC DIM-client at MUDCSGGAIN subscribed to service provided by this server and receive the data from the sensor. DIM (Distributed Information Management) is a portable, light weight package for information publishing, data transfer and inter-process communication [6].

6 Gas Gain Monitoring System User Interface

Figure 7 represents the Main Control Panel interface developed by me as part of this project.

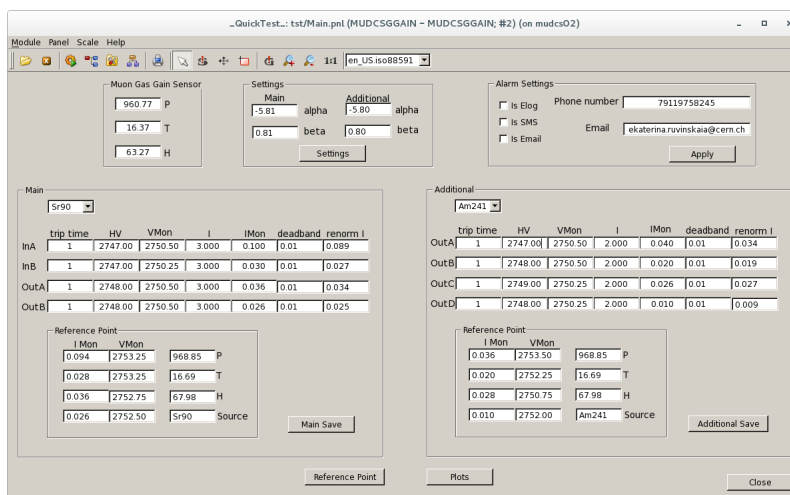


Figure 7: The Main Control Panel interface

Main chamber valve controls are located on the left-hand side of the panel, while the right-hand side panel features similar controls of the additional chamber. In the central part of the panel there are text fields filled with the most important settings and measured values, such as trip time, voltage, current, current deadband, normalized currents and type of the radioactive source.

On the left top there are monitors of actual pressure, temperature and humidity at the area. On the right top - the alpha and beta values, depending on the type of the source, which is currently in use and current features of the setup. Below this values the “Settings” button is located. This button opens the panel (figure 8), where you can set the values of current’s deadband for each channel and the alpha and beta parameters for both type of chambers.

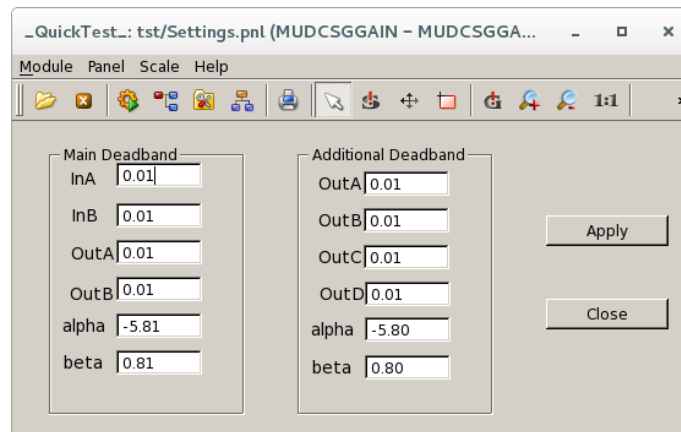


Figure 8: Settings panel

On the right side placed the “Alarm settings” info. If the difference between the actual current and the normalization current is more than a deadband the alarm will be triggered. Corresponding information can be sent via SMS, e-mail, and as logbook entry.

If you change the source, you see reminds that you should change reference point (figure 9).

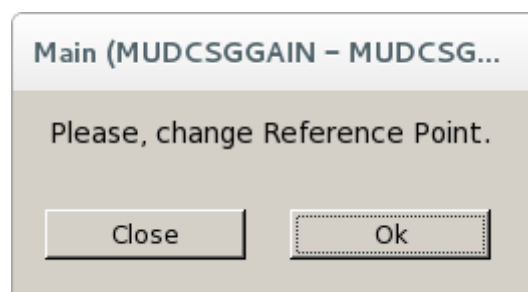


Figure 9: Reminder panel

After that, you will see the reference point management panel (figure 10) which is available from “Reference Point” button. It allows to view all previously stored reference points, to choose the ones desired to be used for normalization (by pushing the “Change RefPoint” button) and to delete the wasted ones. At the bottom of the Main Control Panel one can see the reference points used for normalization of both chamber types. Reference points can be saved into the aforementioned table from the actual state by pushing the save button, also.

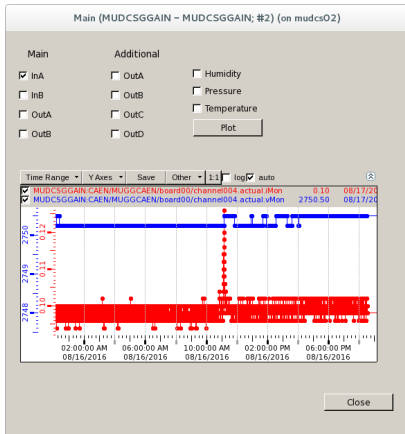
The screenshot displays the Reference Points Panel with two data tables. The top table is for the main chamber and the bottom table is for the additional chamber. Both tables list various reference points with their corresponding date, current, voltage, pressure, temperature, humidity, and source.

Date	Current InA	Voltage InA	Current InB	Voltage InB	Current OutA	Voltage OutA	Current OutB	Voltage OutB	Pressure	Temperature	Humidity	Source
MUDCSGGAIN.ref2016/08/04/16/41/10	0.094	2753.25	0.026	2753.25	0.036	2752.50	0.028	2752.50	958.25	16.81	67.93	Sr90
MUDCSGGAIN.ref2016/08/04/16/42/30	0.132	2803.25	0.040	2803.25	0.052	2802.50	0.038	2802.50	958.75	16.86	67.83	Sr90
MUDCSGGAIN.ref2016/08/04/16/44/05	0.020	2803.50	0.010	2803.25	0.016	2802.50	0.010	2802.50	958.75	16.91	67.80	Am241
MUDCSGGAIN.ref2016/08/04/16/45/02	0.014	2753.50	0.006	2753.50	0.012	2752.50	0.006	2752.50	958.75	16.88	67.80	Am241
MUDCSGGAIN.ref2016/08/08/15/17/01	0.094	2753.25	0.028	2753.25	0.036	2752.75	0.026	2752.50	968.85	16.69	67.98	Sr90
MUDCSGGAIN.ref2016/08/08/15/18/39	0.130	2803.25	0.040	2803.25	0.050	2802.75	0.036	2802.50	969.36	16.67	67.88	Sr90
MUDCSGGAIN.ref2016/08/08/15/19/51	0.022	2803.25	0.012	2803.25	0.016	2802.75	0.010	2802.50	968.35	16.71	67.66	Am241
MUDCSGGAIN.ref2016/08/08/15/21/12	0.014	2753.25	0.008	2753.25	0.012	2752.75	0.006	2752.50	968.85	16.70	67.77	Am241
MUDCSGGAIN.ref2016/08/10/16/55/14	0.094	2753.50	0.026	2753.25	0.036	2752.50	0.026	2752.50	967.09	16.44	52.50	Sr90
MUDCSGGAIN.ref2016/08/10/16/56/47	0.020	2803.50	0.010	2803.25	0.018	2803.50	0.084	2802.50	967.09	16.45	52.67	Sr90
MUDCSGGAIN.ref2016/08/10/16/57/59	0.012	2753.50	0.006	2753.25	0.012	2752.75	0.006	2752.50	966.83	16.42	52.82	Am241
MUDCSGGAIN.ref2016/08/10/16/59/12	0.020	2803.50	0.012	2803.25	0.016	2802.75	0.010	2802.50	967.59	16.45	52.53	Am241
MUDCSGGAIN.ref2016/08/11/16/26/08	0.090	2753.50	0.026	2753.25	0.036	2752.75	0.026	2752.50	970.87	16.52	53.84	Sr90
MUDCSGGAIN.ref2016/08/11/16/27/14	0.124	2803.50	0.038	2803.25	0.050	2802.75	0.038	2802.50	970.87	16.52	54.04	Sr90
MUDCSGGAIN.ref2016/08/11/16/28/07	0.018	2803.50	0.010	2803.25	0.016	2802.75	0.010	2802.50	970.62	16.56	54.21	Am241
MUDCSGGAIN.ref2016/08/11/16/28/55	0.012	2753.50	0.006	2753.50	0.010	2752.75	0.006	2752.75	970.62	16.57	54.07	Am241

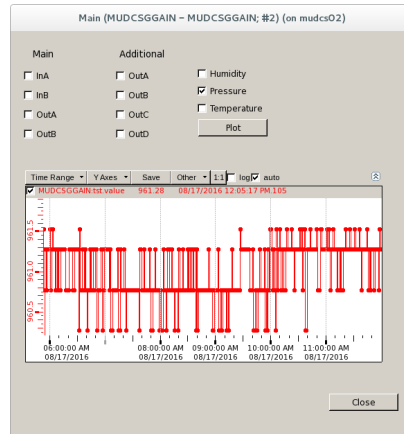
Date	Current OutA	Voltage OutA	Current OutB	Voltage OutB	Current OutC	Voltage OutC	Current OutD	Voltage OutD	Pressure	Temperature	Humidity	Source
MUDCSGGAIN.ref2016/08/04/16/41/11	0.034	2753.25	0.018	2752.5	0.024	2751.25	0.008	2752.25	958.25	16.81	67.93	Am241
MUDCSGGAIN.ref2016/08/04/16/42/31	0.048	2803.50	0.026	2802.5	0.032	2801.25	0.012	2802.00	958.75	16.86	67.83	Am241
MUDCSGGAIN.ref2016/08/04/16/44/06	0.142	2803.50	0.086	2802.5	0.108	2801.25	0.060	2802.25	958.75	16.91	67.80	Sr90
MUDCSGGAIN.ref2016/08/04/16/45/03	0.106	2753.50	0.062	2752.5	0.082	2751.25	0.044	2752.25	958.75	16.88	67.78	Sr90
MUDCSGGAIN.ref2016/08/08/15/17/02	0.036	2753.50	0.020	2752.25	0.028	2750.75	0.010	2752.00	968.85	16.69	67.98	Am241
MUDCSGGAIN.ref2016/08/08/15/18/40	0.050	2803.50	0.028	2802.25	0.034	2800.75	0.014	2802.00	968.85	16.66	67.88	Am241
MUDCSGGAIN.ref2016/08/08/15/19/52	0.138	2803.50	0.086	2802.25	0.104	2800.75	0.060	2802.00	968.85	16.71	67.66	Sr90
MUDCSGGAIN.ref2016/08/08/15/21/14	0.104	2753.50	0.064	2752.25	0.084	2750.75	0.044	2752.00	968.85	16.70	67.77	Sr90
MUDCSGGAIN.ref2016/08/10/16/55/15	0.036	2753.50	0.020	2752.25	0.024	2751.25	0.008	2752.25	967.09	16.44	52.50	Am241
MUDCSGGAIN.ref2016/08/10/16/58/00	0.102	2753.50	0.064	2752.5	0.080	2751.25	0.042	2752.25	966.83	16.42	52.82	Sr90
MUDCSGGAIN.ref2016/08/10/16/59/13	0.140	2803.75	0.084	2802.5	0.104	2801.25	0.058	2802.00	967.09	16.45	52.56	Sr90
MUDCSGGAIN.ref2016/08/10/17/03/02	0.052	2803.50	0.026	2802.5	0.030	2801.25	0.012	2802.25	966.83	16.47	52.50	Am241
MUDCSGGAIN.ref2016/08/11/16/26/09	0.036	2753.50	0.018	2752.5	0.024	2751.50	0.008	2752.25	970.62	16.52	53.84	Am241
MUDCSGGAIN.ref2016/08/11/16/27/15	0.052	2803.75	0.028	2802.5	0.032	2801.50	0.012	2802.25	970.12	16.51	54.07	Am241
MUDCSGGAIN.ref2016/08/11/16/28/08	0.136	2803.75	0.084	2802.5	0.100	2801.50	0.058	2802.25	970.87	16.56	54.21	Sr90
MUDCSGGAIN.ref2016/08/11/16/28/56	0.100	2753.50	0.060	2752.5	0.078	2751.50	0.042	2752.25	970.87	16.56	54.07	Sr90

Figure 10: Reference Points Panel

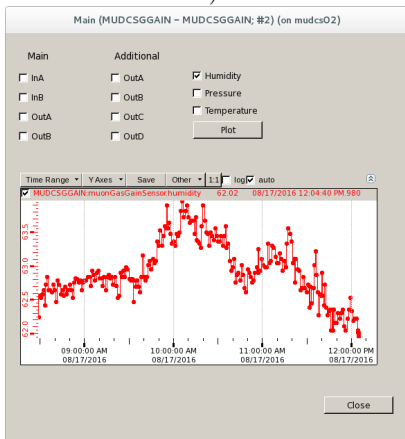
The values of voltage, current, temperature, pressure, humidity are archived either every 60 s, or on change more than 0.5% from the previous value, whichever comes earlier. Trend plots for pressure, humidity, temperature, currents and voltages are available, as it demonstrated in the respective figures (figure 11)



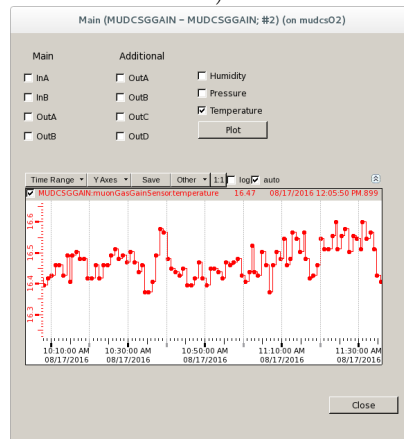
a)



b)



c)



d)

Figure 11: Plots: a) current and voltage, b) pressure, c)humidity, d) temperature

Also, the plots for the current ratio (figure 12) of the channels connected to the input and output lines are available. This information important for system diagnostics, since a change in the ratio is the good indicator of a serious problem in the MUON detector (for example, a leak).

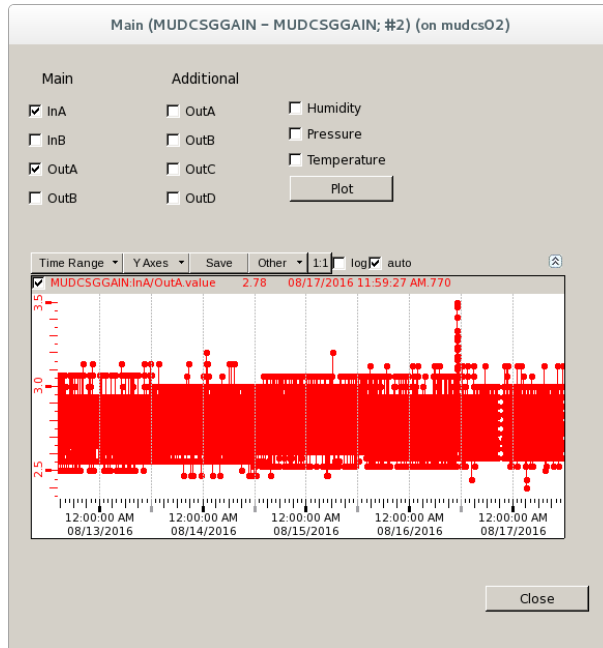


Figure 12: Ratio current plot

7 Conclusions

The setup for online monitor of gas gain in MWPCs of MUON LHCb detector with measuring the chamber currents induced by radioactive sources was successfully installed, commissioned and now it is running as a part of DCS system. It provides a permanent monitor of the quality of the gas mixture in the input and output lines of the MUON gas system. This monitoring is independent from the presence of beam in the LHC ring and from the MUON detector conditions. It allows muon group quickly react in case of any gas problem.

The software solution, developed by me, allows to fine tune the process of the monitoring by adjusting the parameters and reference points used for normalization. The program helps to analyze stored data in archive. The alarm feature allows to avoid any detector damages due to wrong gas mixture into the system. The project itself is very flexible. It is easy to change the radioactive source, adjust normalization at any new conditions and tune the alarm parameters.

8 Acknowledgements

I greatly thank my supervisor Oleg Maev, MUON detector group and online team of LHCb and personally to my colleagues Sofia Kotriakhova and Nikolay Bondar for their constant help and support. Also, I express my gratitude to Beat Jost for writing DIM – server. The warm welcome from the Summer Student Team and MUON group

was greatly appreciated. Finally, I want to thank CERN for the nice lectures and for giving me an opportunity to learn and develop at the forefront of the physical science.

References

- [1] LHCb collaboration, A. A. Alves Jr. et al., The LHCb detector at the LHC, JINST 3 (2008) S08005
- [2] E. Dane, G. Penso, D. Pinci, A. Sarti, Detailed study of the gain of the MWPCs for the LHCb muon system, Nuclear Instruments and Methods in Physics Research A 572 (2007) 682–688
- [3] Burkimsher, Paul.(2014). Training Materials for Win-CC and The JCOP. Part 1: Win-CC Framework. Controls Group, EN Department. CERN, Geneva. Part2: JCOP Framework Framework. Controls Group, EN Department. CERN, Geneva.
- [4] C. Gaspar et al., The LHCb experiment control system: on the path to full automation.
- [5] CAEN SY2527 User's Manual Rev.16 (2012)
- [6] Distributed Information Management (DIM). C. Gaspar and F. Varela on behalf the FWVG (2010)