JOINT INSTITUTE FOR NUCLEAR RESEARCH
Flerov Laboratory of Nuclear Reactions

FINAL REPORT ON THE INTEREST PROGRAMME

Implementation of an automation system for PPAC detectors with data visualization and analysis

Supervisor:
Mr Patryk Szymkiewicz
Student:
Sebastian Owarzany, Poland
AGH University of Science and Technology

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Abstract

Parallel plate avalanche counters (PPACs) detectors in our configuration are used to diagnose the beam position. These detectors was developed over 50 years ago. Their main advantages: cost effective design, good position and timing resolution. Main features of the PPAC detector is that we don’t need a lot of substance in comparison with other kinds of gas detectors.

In this report we develop gas line and LabVIEW exe application for control and monitoring two parallel connected PPACs detector which will be placed in ACCULINNA separator. For this purpose we use a MKS pressure controller, CAEN High Voltage Power Supplies, PFEIFFER gauge controller. After internship our detector system is to be installed on the ACCULINNA separator, and our software is to become part of the ACCULINNA software.

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Introduction

On the ACCULINNA-2 separator is being implemented a system of PPAC (Parallel Plate Avalanche Counter) position-sensitive detectors. Functions of the detectors is to measure a beam's profile and determine its focal point. For the proper operation of the detectors, it is necessary to guarantee the stability of a flow, pressure and power supply of the devices. Changing any of these crucial parameters makes the collected data unreliable. For this purpose, utmost attention is paid to creating a system providing the stability of the detectors operation. During the internship, a control system will be developed (for the already built station) to control the detectors parameters. The PID regulator will also be optimized to make the system resistant to an external interference. Finally, the detectors will be calibrated and prepared to a future application.

Before I was start internship my supervisor create a system containing one PPAC detector, that means my first task was be design system with two detectors. It was necessary to consider the ACCULINNA-2's and detectors' condition of work and requirements while designing an external gas line[1]:

Working gas: C_3F_8 or C_4H_{10}.

Flow rate[1]: 3 to 6 SCCM (standard cubic centimeters per minute).

Gas pressure: 10 Torr.

Voltage: 700-900 V.

[1] for one detector

Project goals:

To develop a system to manage the work of two PPAC position-sensitive detectors.

Scope of work

Familiarization with the experimental station for PPAC gas detectors.
The software for operating with PPAC detectors will be developed.
The created software will control the gas flow, pressure sensors and supplied voltage, and the collected data will be visualized.

Methods:

The first step was to familiarize yourself with the measurement system and understand the principles of operation of PPAC detectors. For this purpose, a series of discussions with the supervisor and the materials concerning the principles of operation of the detector were introduced.

The second step was to design the gas line needed for the proper operation of the detectors based on the previously acquired knowledge. As we can see in the figure below, the line was designed in the form of a puzzle in which each printed element corresponded to the real elements of the line.

The key feature of designing the gas system is to provide safety and stability of a beamline's installation, especially for turbopumps.

Gas line:

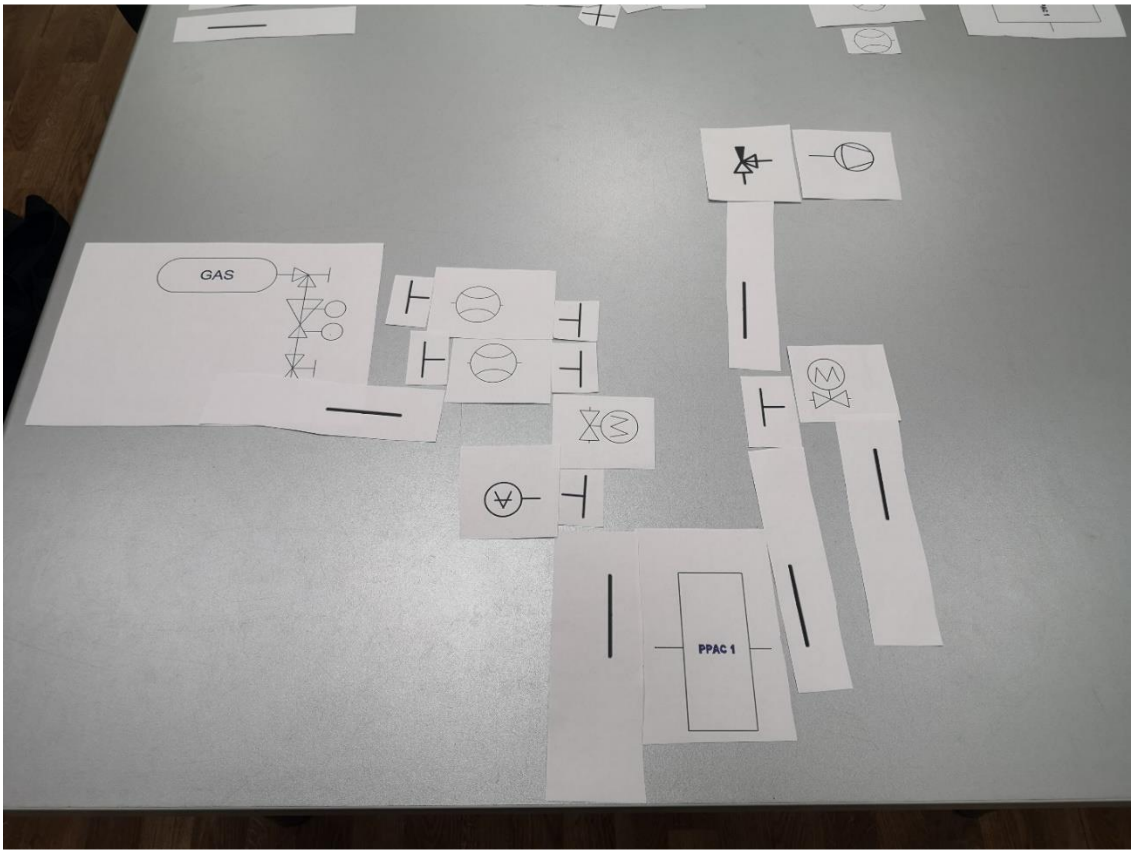

Figure 1. Gas line with one PPAC.

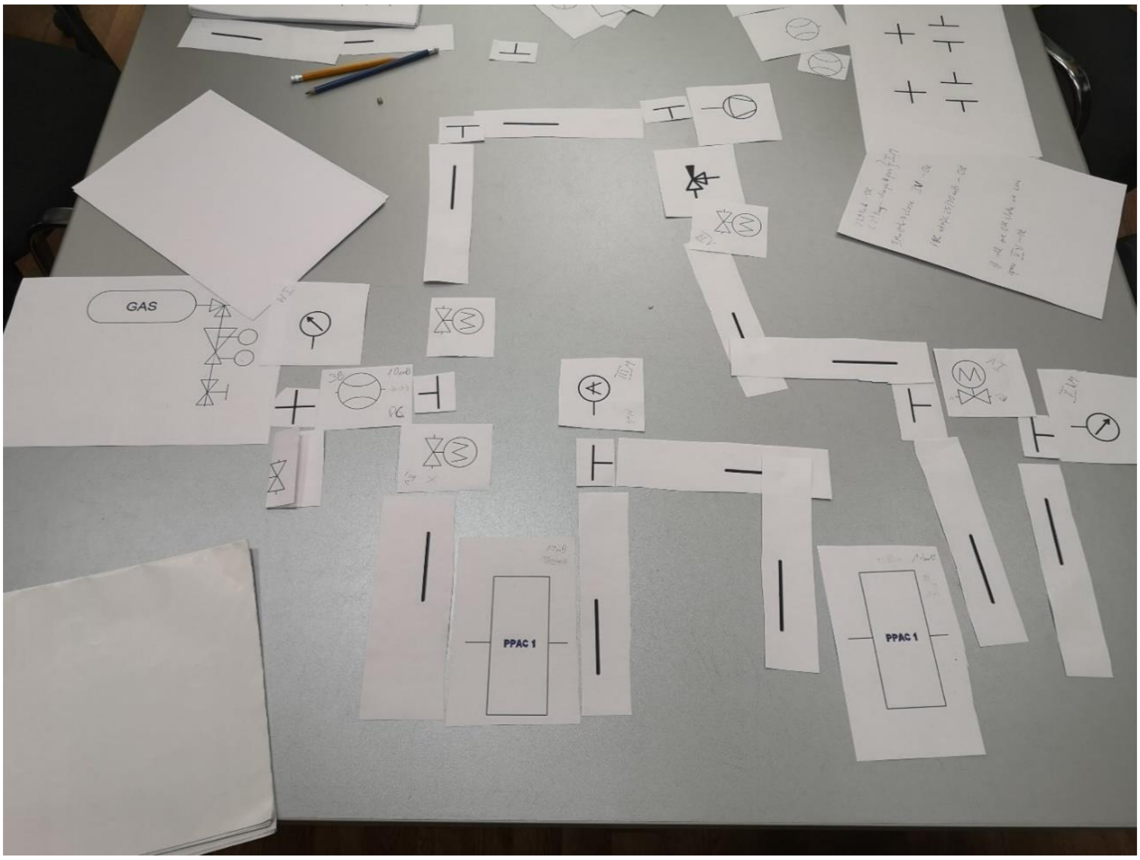

Figure 2. Gas line with two PPACs – our solution.

State machine:

In this step, we developed a state machine. Emergency scenarios, like a power failure or crucial damage of the detector, were also included in the machine state.

DEVICES			NORMAL STATE	CONDITIONS [MBAR or SCCM]	0 - IDLE	POWER UP	1.1 - VENTILATION NO. 1	1.2 FULFILLED WITH GAS	1.3 - VENTILATION NO. 2	1.4 FULFILLED WITH GAS
					P2: 1000; PC: 1000; P3: 1000; P4: 1000		P2: 1000 ↘ 0; PC: 1000; P3: 1000; P4: 1000	P2: 0 ↗ 3000; PC: 1000; P3: 1000; P4: 1000	P2: 3000 ↘ 0; PC: 1000; P3: 1000; P4: 1000	P2: 0 ↗ 3000; PC: 1000; P3: 1000; P4: 1000
VALVE ON A BOTTLE	**V0**		-		CLOSE	CLOSE	CLOSE	OPEN (2)	CLOSE (1)	OPEN (2)
Bellows sealed valves	**V1**		-		CLOSE	CLOSE	OPEN (1)	CLOSE (1)	OPEN (2)	CLOSE (1)
ELECTROPNEUMATIC VALVES	V2		NC		CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
	V3		NC		CLOSE	OPEN	OPEN	OPEN	OPEN	OPEN
	V4		NO		OPEN	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
DOSING VALVE	**VN**		-		CLOSE	SP (1)	SP	SP	SP	SP
M.F.C.			NC		CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
P.C.			NC		CLOSE	SP	SP	SP	SP	SP
MKS RELAYS	**A1:** P3	R1	NO	**P3:** < 12	○	○	○	○	○	○
		R2	NO	**P3:** > 8	○	●	●	●	●	●
	B1: MFC	R5	NO	SET	○	●	●	●	●	●
		R6	NO	SET	○	●	●	●	●	●
	C1: PC	R9	NO	**PC:** < 25	○	○	○	○	○	○
		R10	NO	SET	○	●	●	●	●	●
TPG362 RELAYS	**CH1:** P2	R1	NC (3-2)	**P2:** > 2500	●	○	○	○ → ●	● → ○	○ → ●
		R1	NO (3-4)	**P2:** < 2500	○	●	●	● → ○	○ → ●	● → ○
	CH2: P4	R2	NC (6-5)	**LOW P4:** < 1E-4; **HIGH P4:** >1.5E-1	●	●	●	●	●	●
		R3	NO (10-11)	**P4:** < 1E-5	○	○	○	○	○	○
		R4	NO (13-14)	**LOW P4:** < 5E-5; **HIGH P4:** >1.5E-1	○	○	○	○	○	○
CAEN	HV		OFF		OFF	OFF	OFF	OFF	OFF	OFF
	Interlock		NO	MKS R1 & MKS R2 & MKS R5 & MKS R6	○	○	○	○	○	○
SWITCH (WORK)			DEACTIVATED	TPG362 R1 & TPG R3 & MKS R9 & MKS R10	DEACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED

Figure 3. State machine 1/3.

2.1 VENTING OF MAIN CHAMBER - STARTING OFF	2.2 VENTING OF MAIN CHAMBER - BYPASS CLOSED	2.3 VENTING OF MAIN CHAMBER - CONNECTION	3.1 PERMISSION TO START	3.2 GAS FLOW ON	3.3 HV ON	!EMERGENCY SCENARIO! ELECTRICAL POWER OFF
P2: 3000	P2: 3000	P2: 3000	P2: 3000	P2: 3000	P2: 3000	P2: 3000
PC: 1000 ↘ 0	PC: 0	PC: 0	PC: 0	PC: 0 ↗ 10	PC: 10	PC: 10 ↘ 0
P3: 1000 ↘ 0	P3: 0	P3: 0	P3: 0	P3: 0 ↗ 10	P3: 10	P3: 10 ↘ 0
P4: 1000 ↘ 1E-4	P4: 1E-4 ↘ 5E-5	P4: 5E-5 ↘ 1E-5	P4: 1e-5 ↘ Ultimate	P4: <1e-5	P4: <1e-5	P4: 1E-5 ↗ 1.5E-1
OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
CLOSE	CLOSE	CLOSE	CLOSE	OPEN	OPEN	CLOSE
OPEN	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
CLOSE	CLOSE	OPEN	OPEN	OPEN	OPEN	OPEN
SP	SP	SP	SP	SP	SP	SP
CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
SP	SP	SP	SP	SP	SP	CLOSE
○ → ●	●	●	●	●	●	○
● → ○	○	○	○	○ → ●	●	○
●	●	●	●	●	●	○
●	●	●	●	●	●	○
○ → ●	●	●	●	●	●	○
●	●	●	●	●	●	○
●	●	●	●	●	●	●
○	○	○	○	○	○	○
●	○	○	○	○	○	●
○	○	○	●	●	●	○
○	○	●	●	●	●	○
OFF	OFF	OFF	OFF	OFF	ON	OFF
○	○	○	○	○ → ●	●	○
DEACTIVATED	DEACTIVATED	DEACTIVATED	ACTIVATED	ACTIVATED	ACTIVATED	DEACTIVATED

Figure 4. State machine 2/3.

!EMERGENCY SCENARIO! BREAKING OF PPAC'S FOILS	4.1A SWITCH OFF	4.1B SWITCH OFF WITH RISING PRESSURE	4.2 OPEN BYPASS	5.1 TURN OFF GAS	5.2 VENT GAS LINE	5.3 READY TO OPEN (POWER OFF)
P2: 3000; PC: 10 ↘ 0; P3: 10 ↘ 0; P4: 1E-5↗ (~5E-3 ↘ Ultimate)	P2: 3000; PC: 10 ↘ 0; P3: 10 ↘ 0; P4: <1E-5	P2: 3000; PC: 10 ↘ 0; P3: 10 ↘ 0; P4: 1E-5↗ 1.5E-1	P2: 3000; PC: 0 ↗ 1000; P3: 0 ↗ 1000; P4: 1.5E-1↗ 1000	P2: 3000; PC: 1000; P3: 1000; P4: 1000	P2: 3000 ↘ 0; PC: 1000; P3: 1000; P4: 1000	P2: 0; PC: 1000; P3: 1000; P4: 1000
OPEN	OPEN	OPEN	OPEN	CLOSE (1)	CLOSE	CLOSE
CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	OPEN (1)	CLOSE (3)
PERIODICALLY OPEN	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
CLOSE	CLOSE	CLOSE	OPEN	OPEN	OPEN	OPEN
OPEN	OPEN	OPEN	CLOSE	CLOSE	CLOSE	OPEN
SP	SP	SP	SP	SP	SP	CLOSE (1)
CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE	CLOSE
SP	SP	SP	SP	SP	SP	CLOSE
●	●	●	● → ○	○	○	○
○	● → ○	● → ○	○ → ●	●	●	○
●	●	●	●	●	●	○
●	●	●	●	●	●	○
●	●	●	● → ○	○	●	○
●	●	●	●	●	●	○
●	●	●	●	●	● → ○	○
○	○	○	○	○	○	●
○	○	○	●	●	●	●
● → (○ → ●)	●	○	○	○	○	○
○	●	●	○	○	○	○
OFF	ON → OFF	ON → OFF	OFF	OFF	OFF	OFF
○	● → ○	● → ○	○	○	○	○
DEACTIVATED → (ACTIVATED → DEACTIVATED)	ACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED	DEACTIVATED

Figure 5. State machine 3/3.

The state machine was created in a spreadsheet, which allowed parallel work for several people and clearly presented the possible states.

After creating the state machine, we read technical documentation of all used devices. Next, we selected the proper commands and write a simple application to initiate connection with all devices.

Used device:

Figure 6. The HV power supply used in PPACs' setup.

Figure 7. The I/O NI DAQ used in PPACs' setup.

Figure 8. The PFEIFFER gauge controller used in PPACs' setup.

Figure 9. The MKS vacuum system controller used in PPACs' setup.

Then we start writing the application. At the begin we linked all devices communication protocols to one LabVIEW code. Then, we discuss about block diagram of our program. At the end all functionalities have been implemented into the LabVIEW environment.

Block diagram of software:

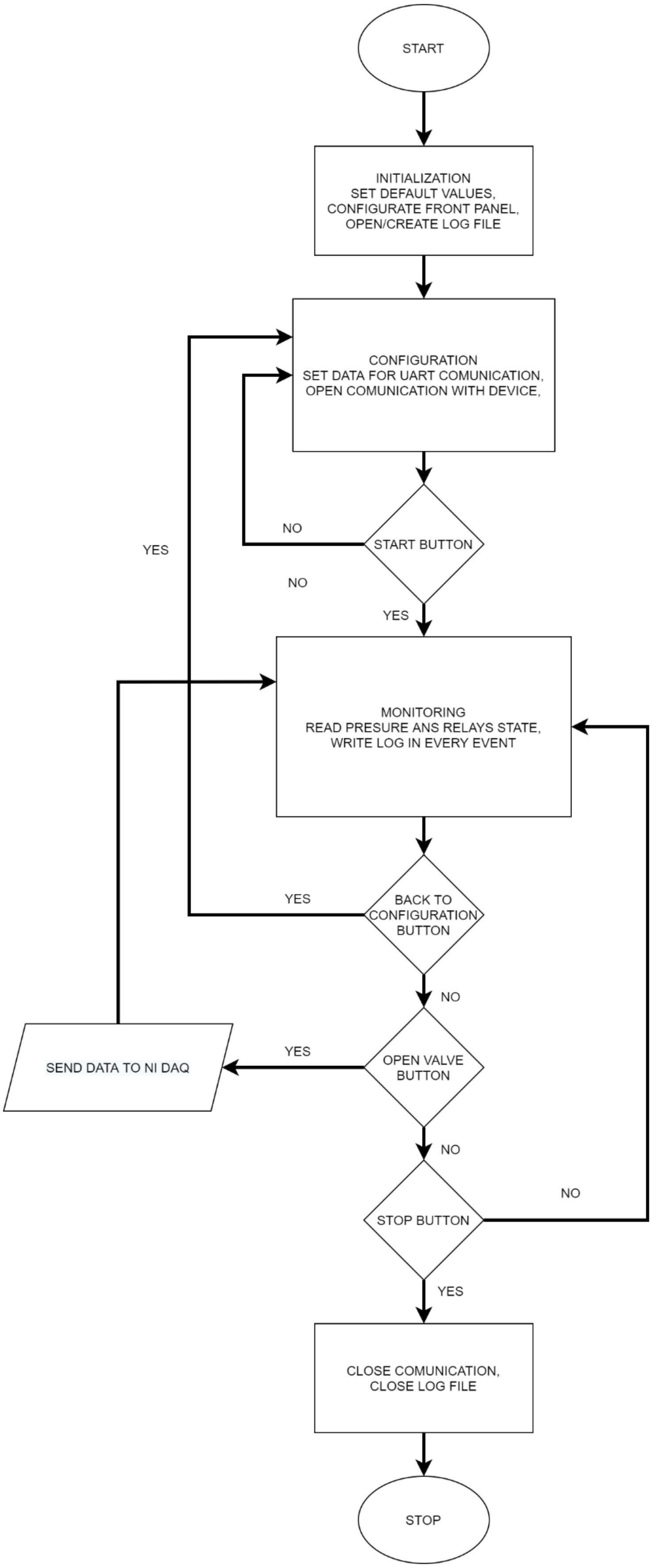

Figure 10. Block diagram of designed software.

The individual parts of the finished code are as follows:
Initialization:

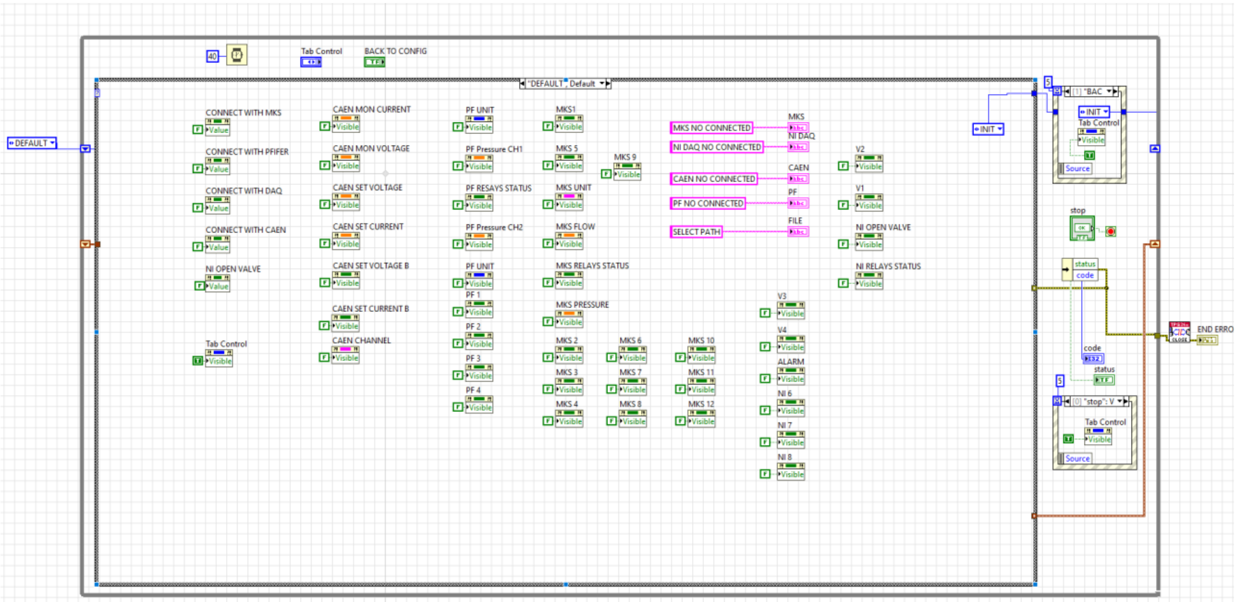

Figure 11. IDLE.

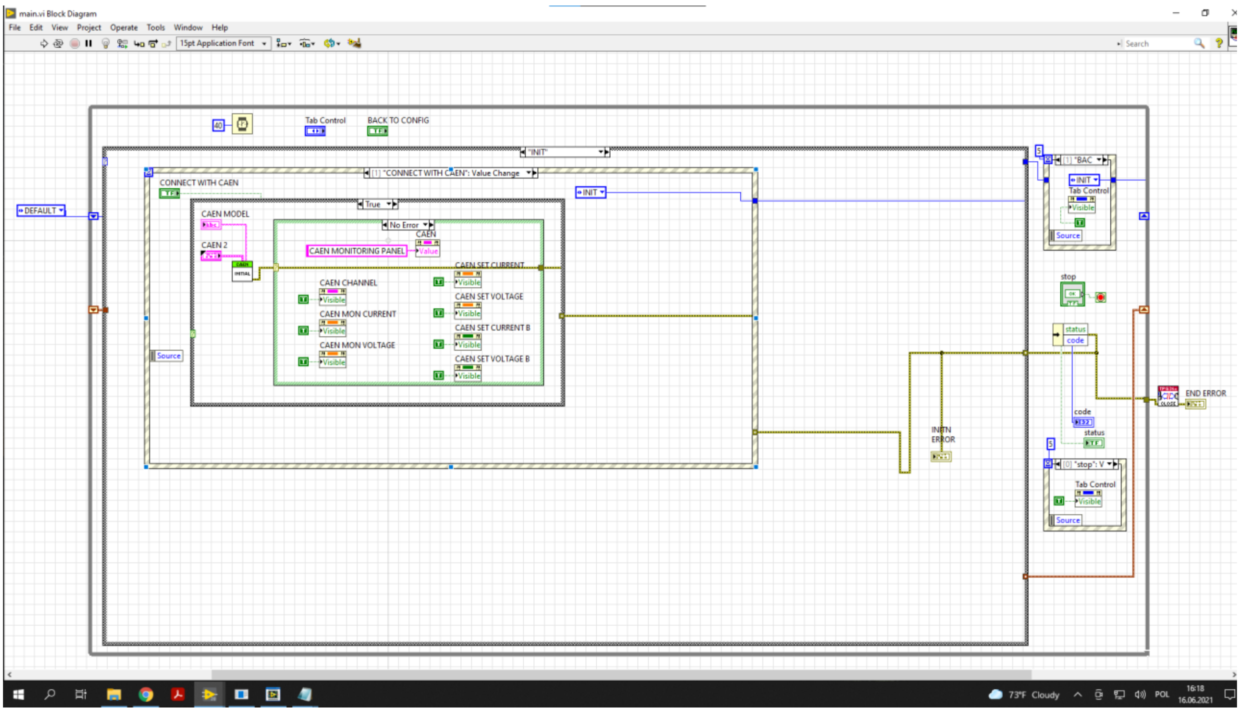

Figure 12. Initialization of the CAEN device.

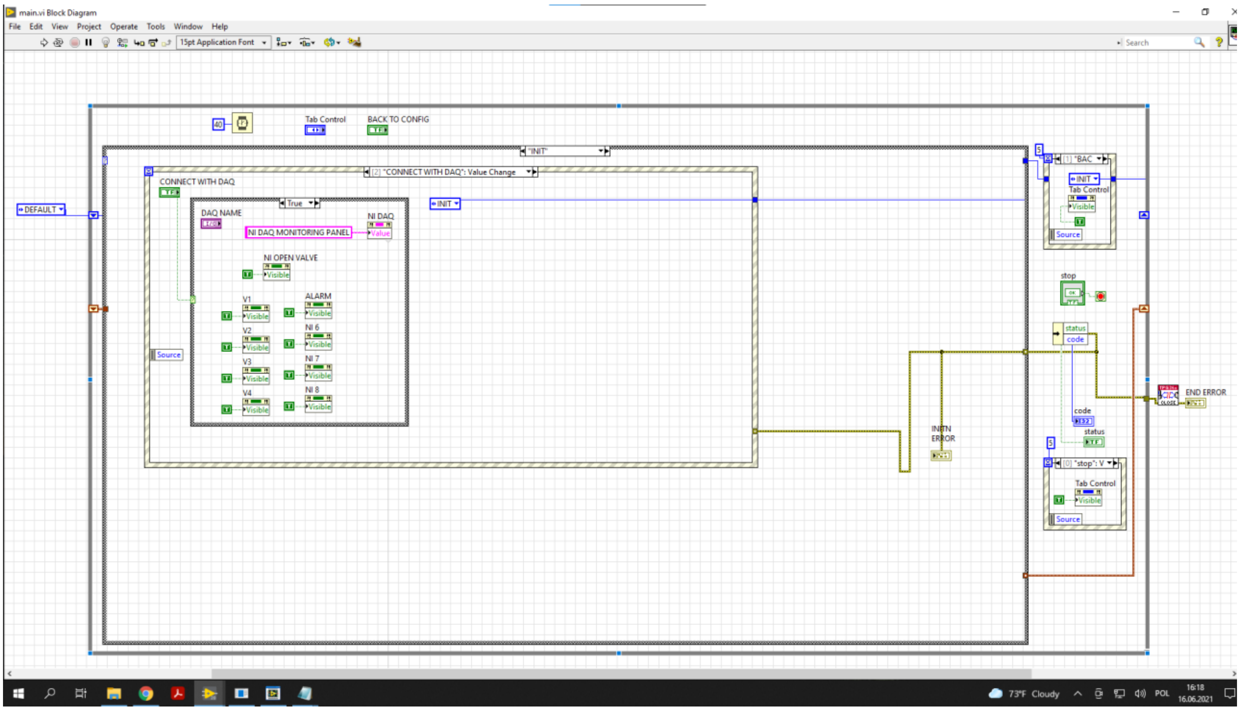

Figure 13. Initialization of the NI DAQ.

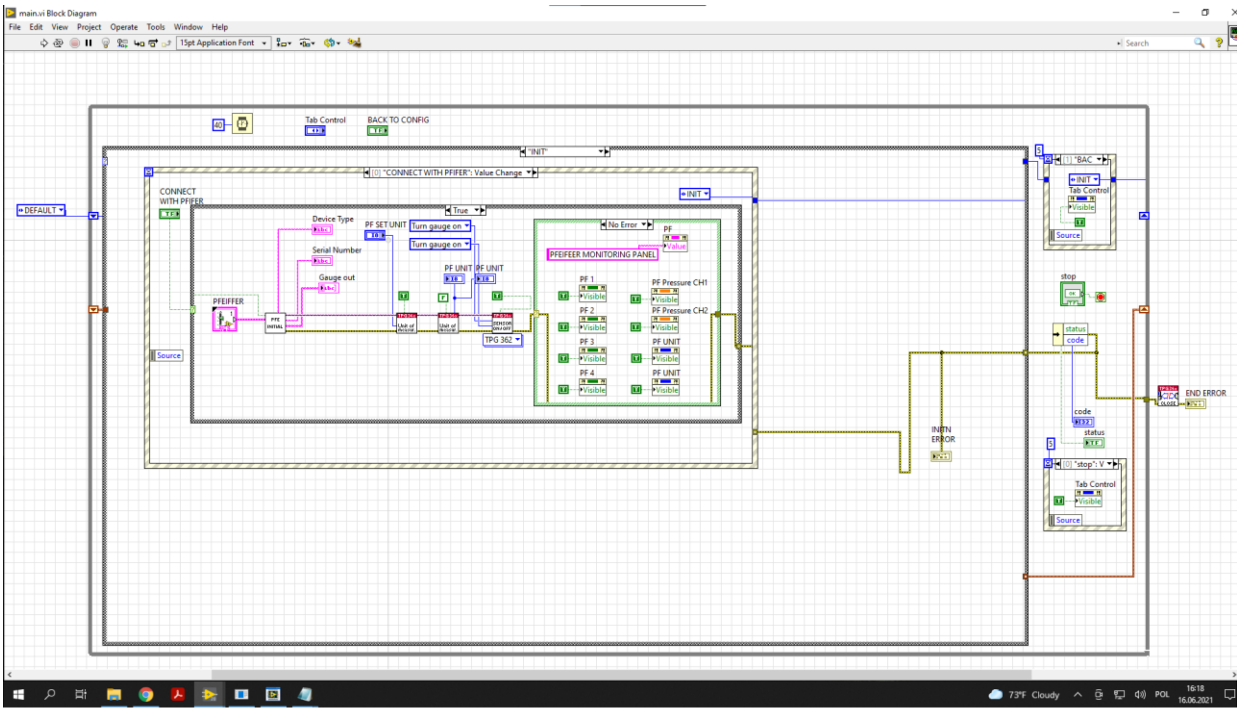

Figure 14. Initialization of the PFEIFFER device.

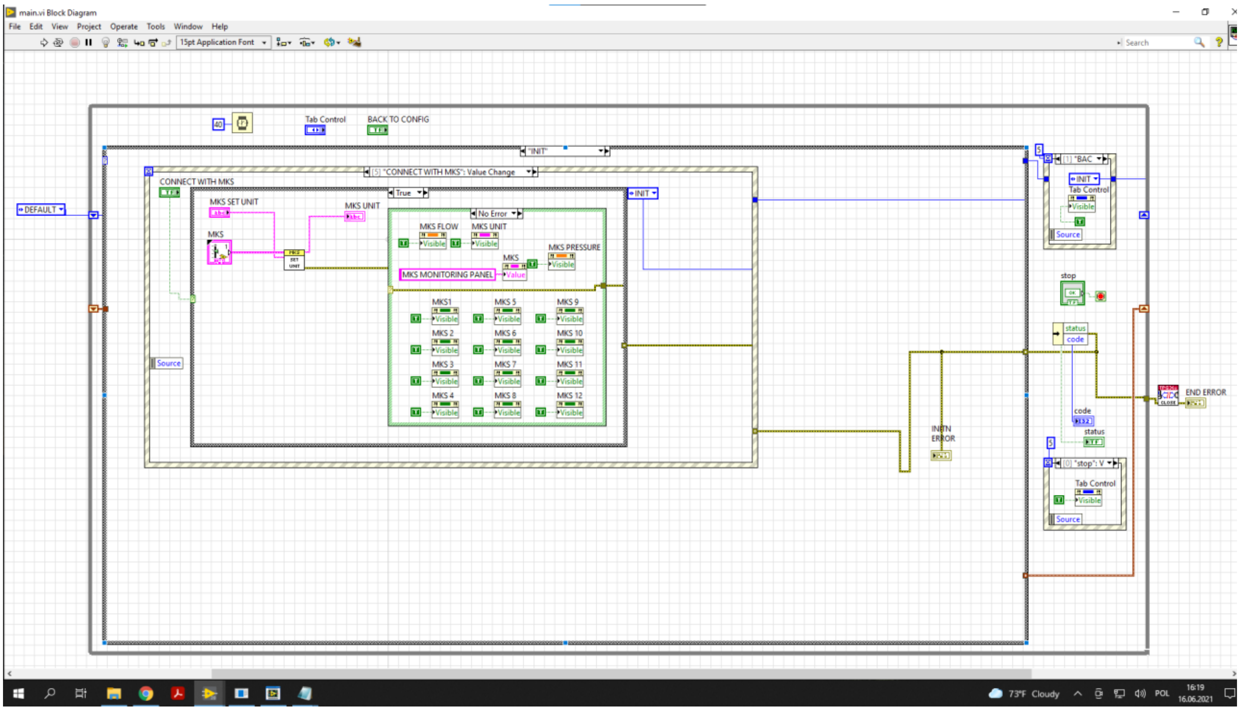

Figure 15. Initialization of the MKS controller.

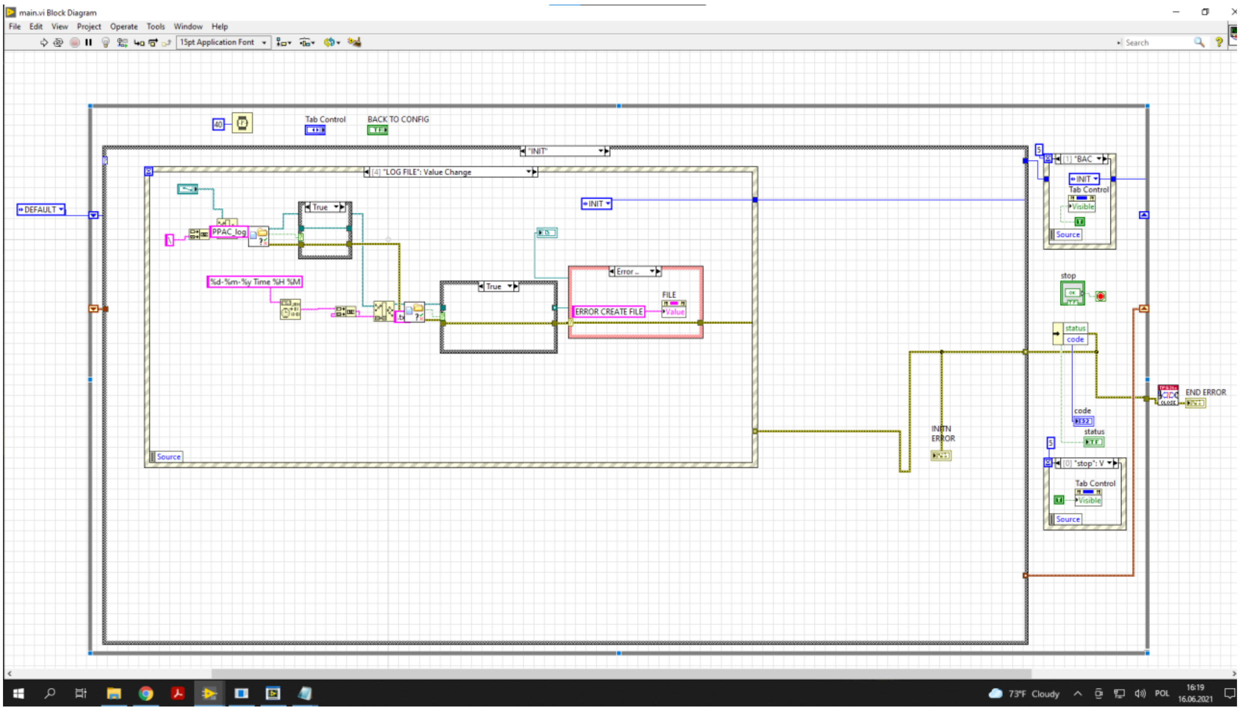

Figure 16. Initialization of log file.

Monitoring:

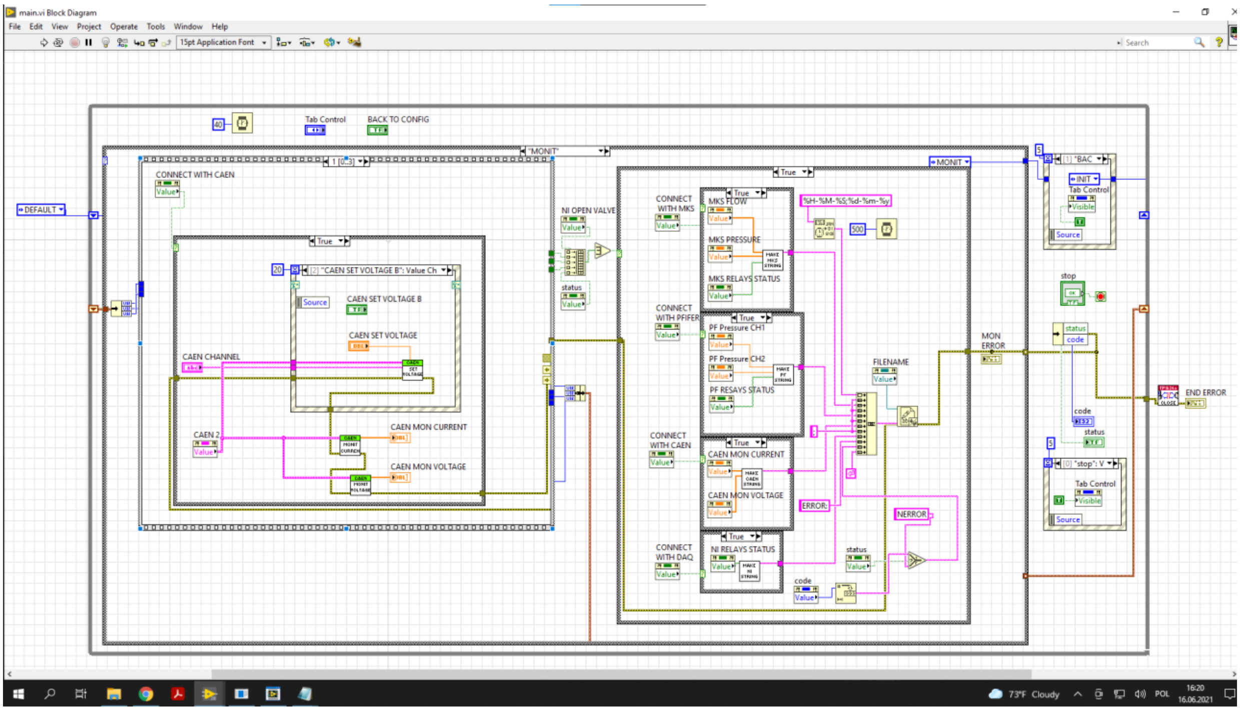

Figure 17. Monitoring of the CAEN power supplier.

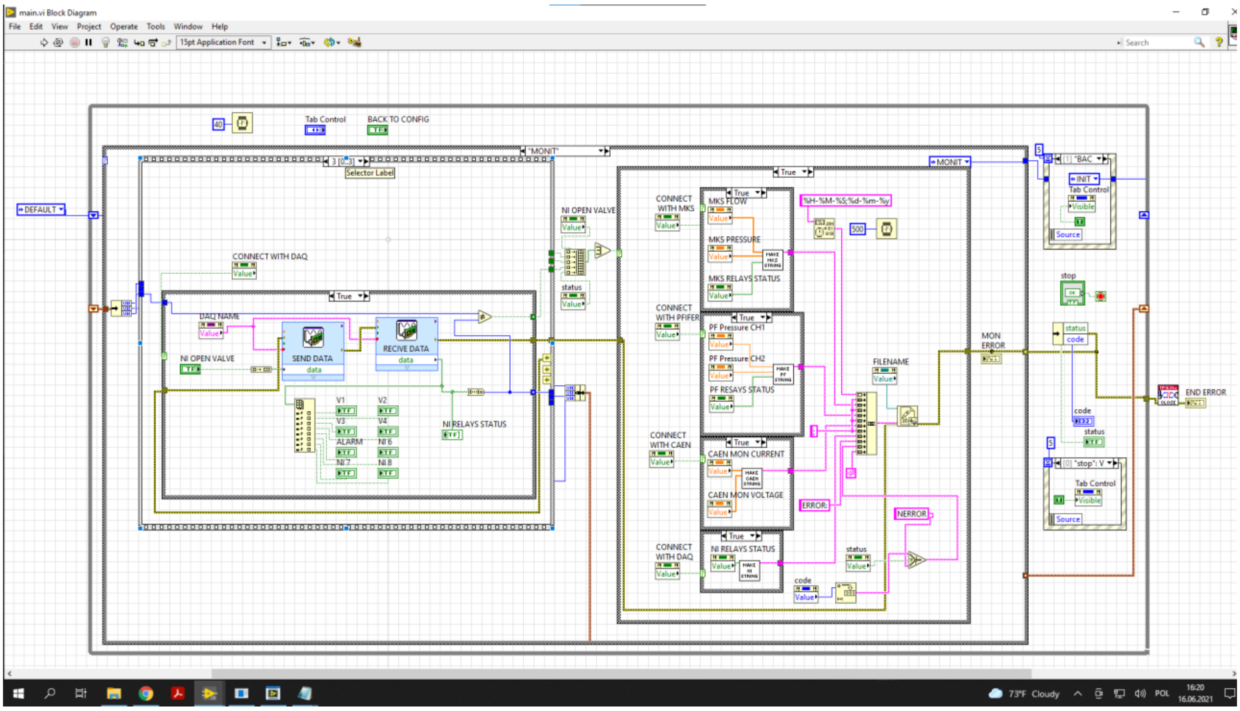

Figure 18. Monitoring of the NI DAQ.

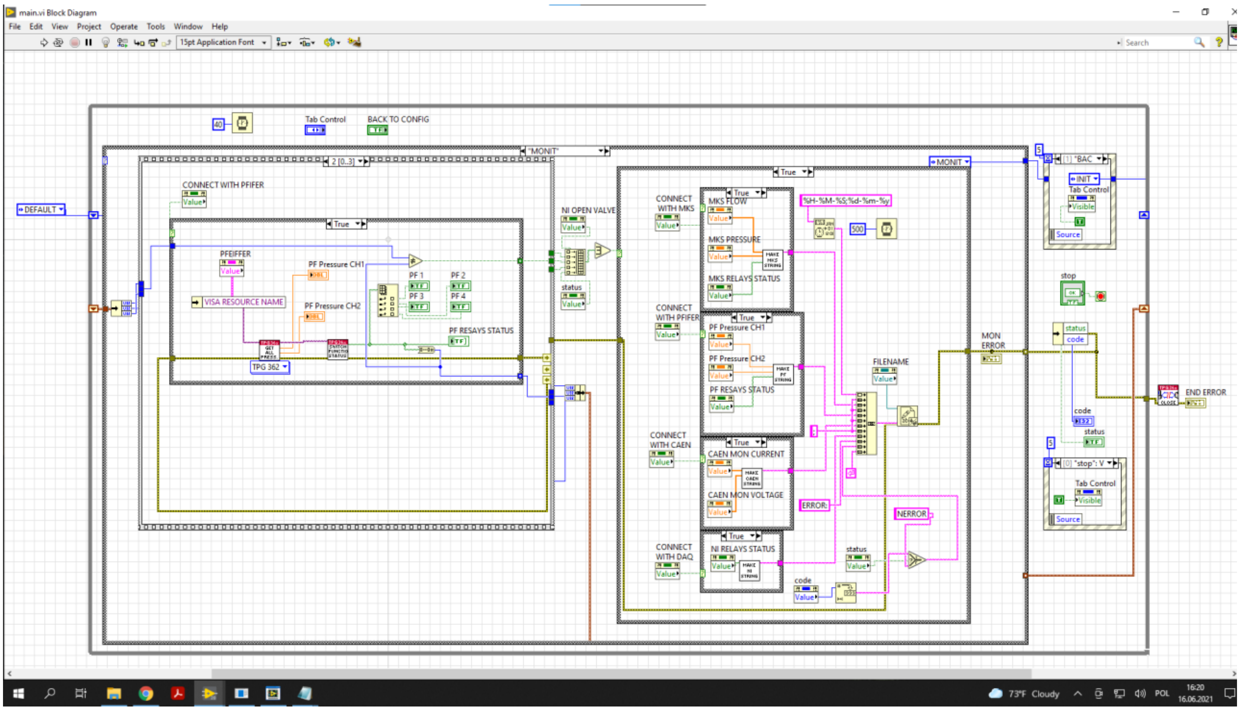

Figure 19. Monitoring of the PFEIFFER controller.

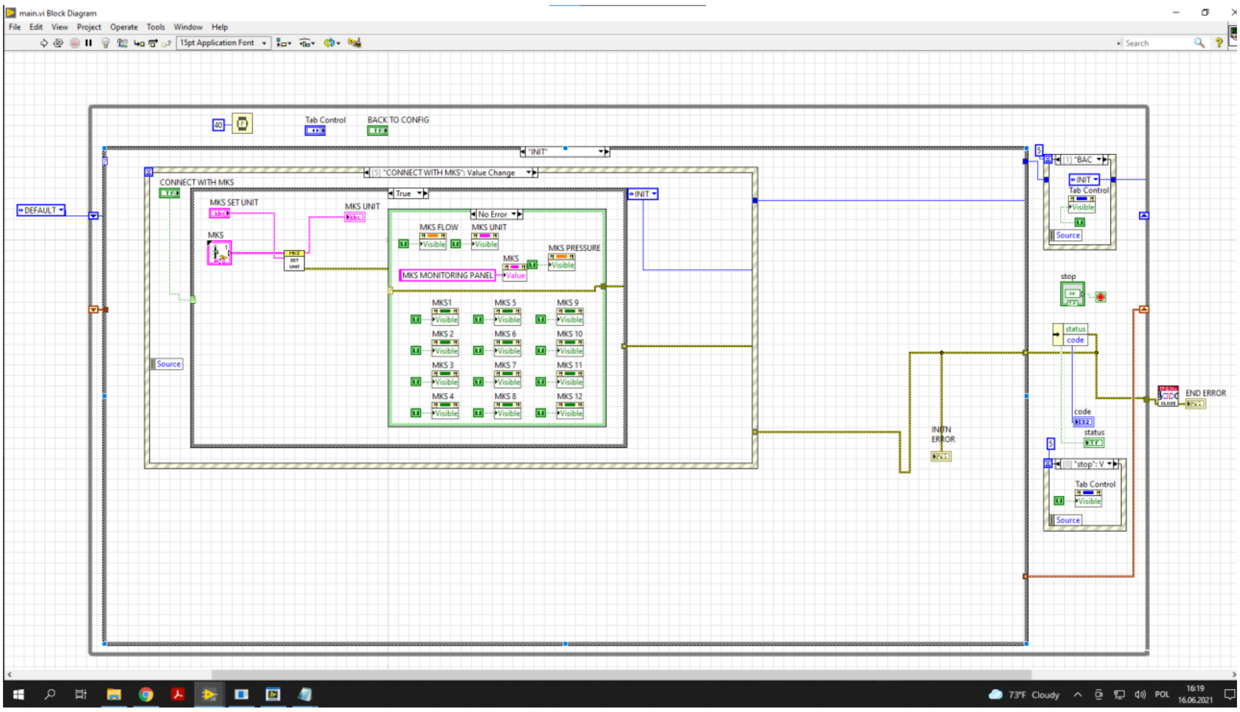

Figure 20. Monitoring of the MKS controller.

Program user interface:

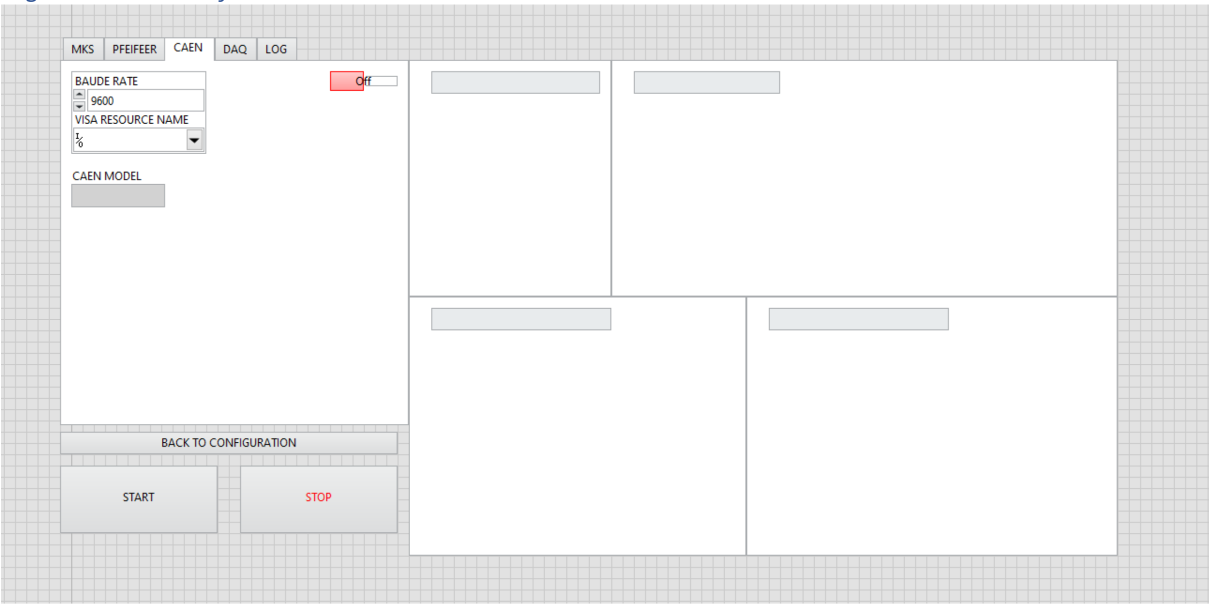

Figure 21. CAEN connection configuration.

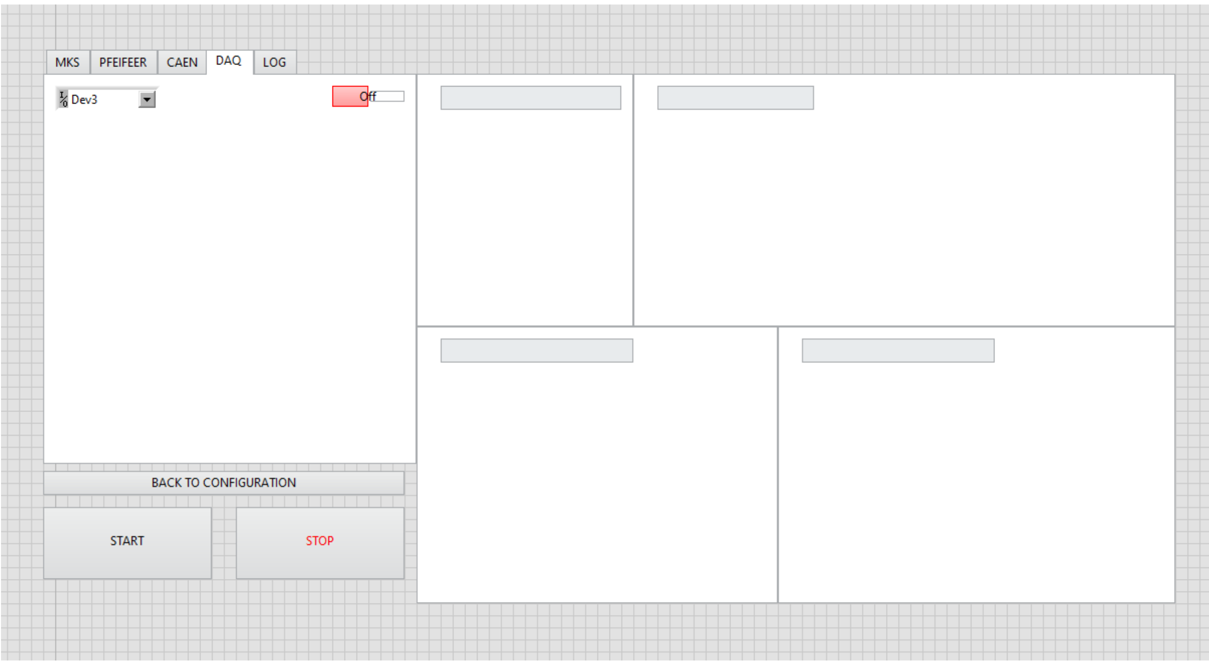

Figure 22. NI DAQ connection configuration.

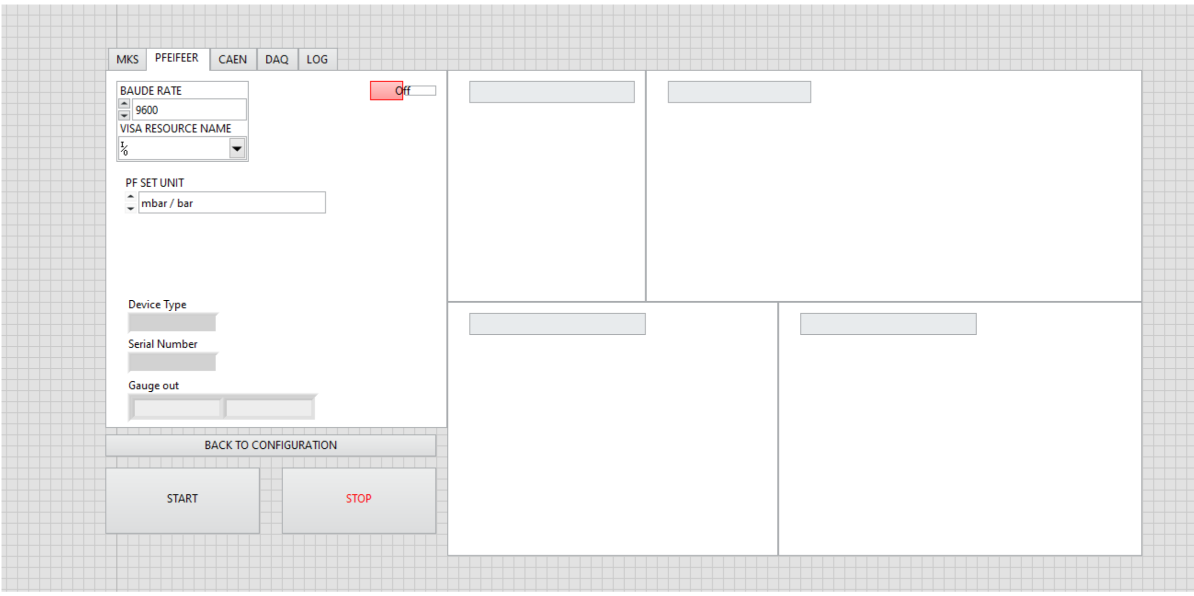

Figure 23. PFEIFFER connection configuration.

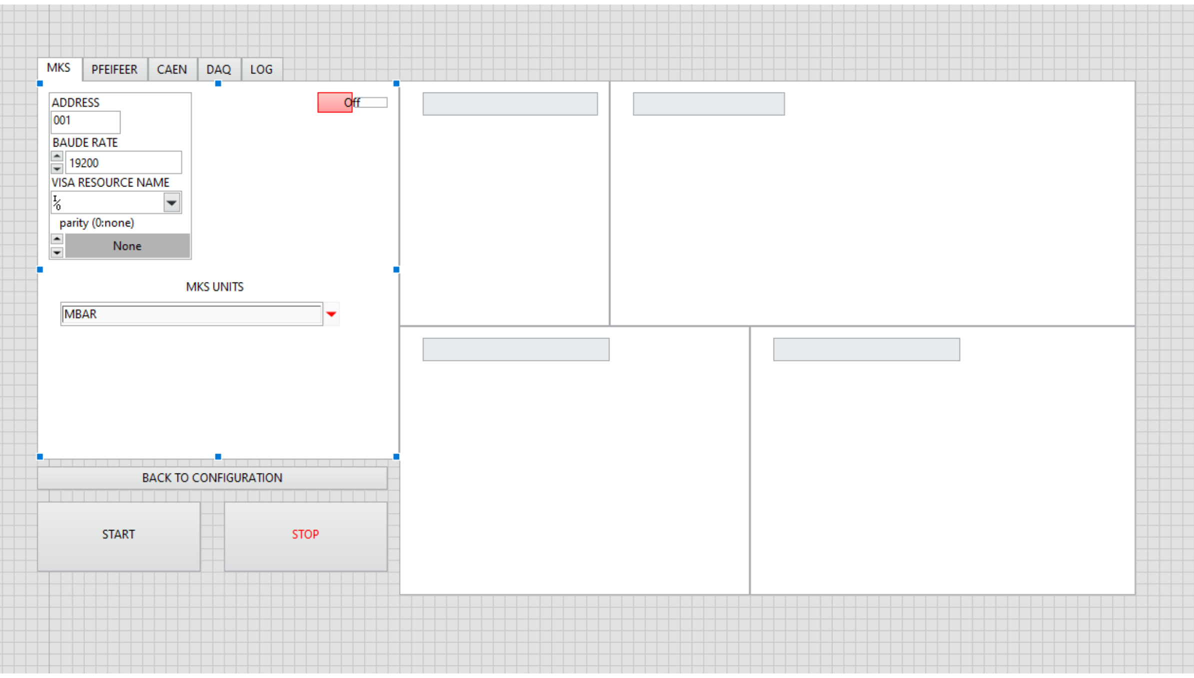

Figure 24. MKS connection configuration.

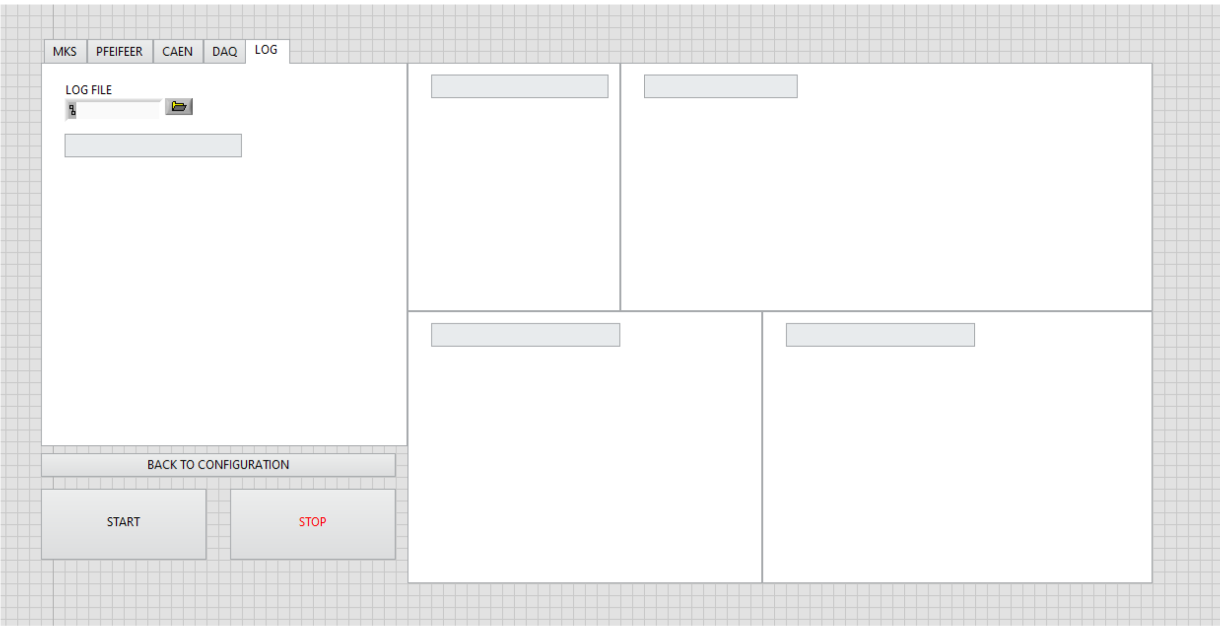

Figure 25. Log file configuration.

While monitoring:

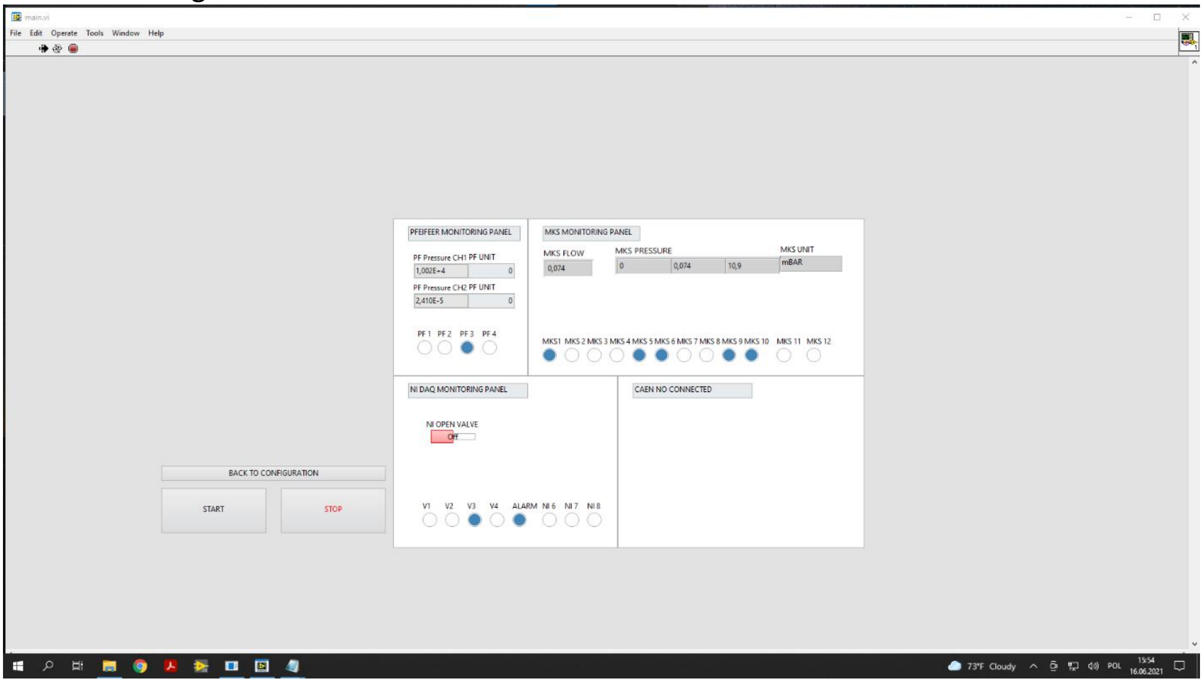

Figure 26. Front panel during monitoring.

The structure of the outgoing data in the form of a log:

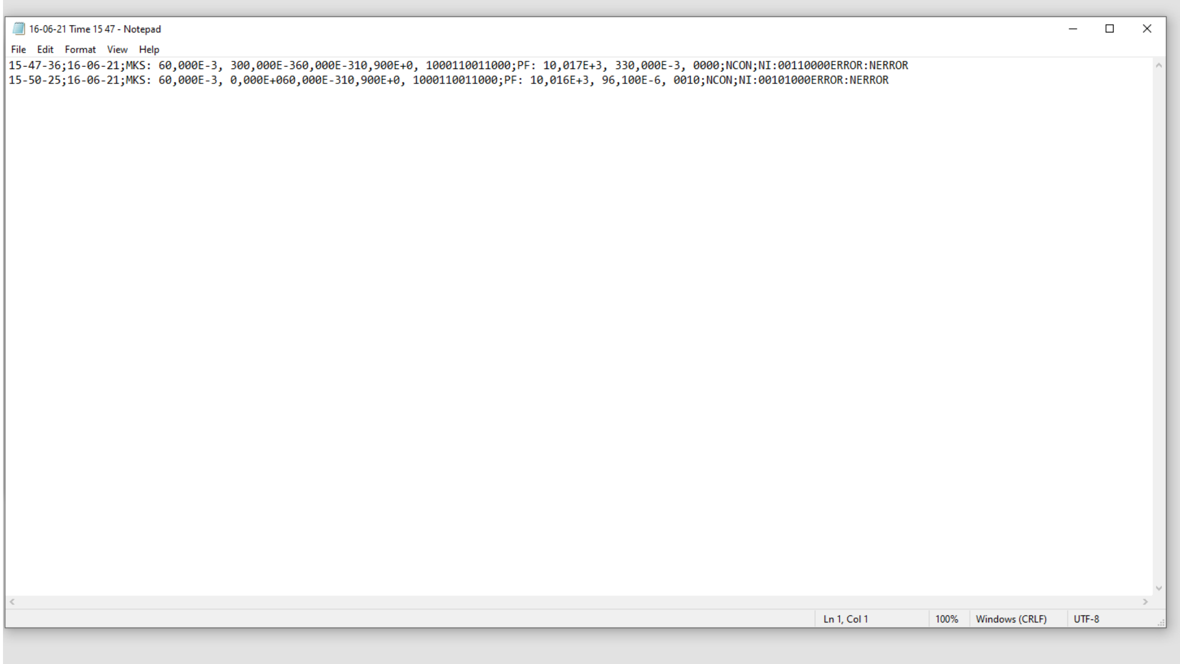

Figure 27. Structure of the outgoing data.

Log will be saved in every switch of state.

The last step was conducting a full test. The prototype stand with the developed app was switched on and all work scenarios were checked.

Experimental stand:

Figure 28. Prototype gas line.

In prototype gas line every part of program working properly.

Results

A part of the project, an application was created in the LabVIEW environment from which we can monitor the condition of our system and control the start of detectors' work.

Conclusion

During the internship I could use a lot of skills gained in University. Beneficial was knowledge of the LabVIEW environment, which I gained at CLAD course I participated in. The biggest problems were understanding the principles of operation of the gas installation and proper communication with all devices.

Working in the LabVIEW environment was simple. For me the main advantages of work in this environment are:

- low entry level,
- compatibility with all devices,
- easy to create graphic user interface and exe application,
- user-friendly for non-programmer people,

The main disadvantages are:

- hard to keep clean code,
- you need to possess an advance knowledge of LabVIEW for data flow optimization,
- software is expensive.

References

[1] Charles Akers,∗ Kwang Bok Lee, Young Jin Kim, Eun Hee Kim, Young Kwan Kwon, Hyo Sang Lee, Jun Young Moon, Jin Hyung Park, Min Sang Ryu, Taeksu Shin and Satou Yoshiteru
Construction and Performance Test of Prototype Parallel Plate Avalanche
Counters at RAON 2017