

EP-DT
Detector Technologies

Qualification of gas sensors in radiation environment at the CERN CHARM Facility

Beatrice Mandelli
on behalf of CERN Gas Team

CERN

RADWG meeting
CERN, 26 November 2018

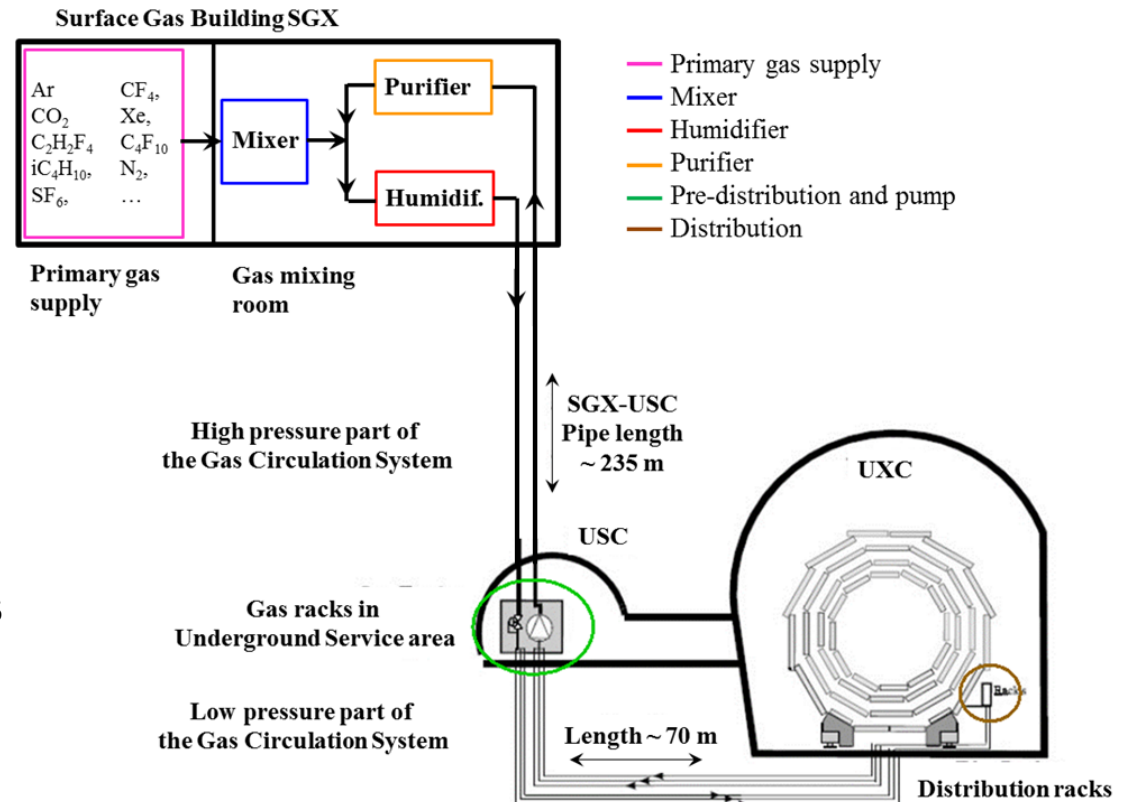
The LHC Gas Systems

At the LHC experiments, each gaseous detector has its own gas systems to deliver the proper gas mixture



~ 30 gas systems (~ 300 racks) for the LHC experiments
Reliability has to be ~100%

- Gas system distributed in three levels
 - Surface (SG)
 - Gas Service room (USC)
 - Experimental cavern (UXC)
- Complex systems that have to ensure an extremely high reliability in terms of stability and quality of the gas mixture delivered to the detectors



Goal of the test

Some racks of the gas systems are installed in the experimental caverns and therefore they are subject to radiation

- These racks can contain pressure sensors, flowmeter, ELMB, etc
 - These sensors have been tested for radiation damage in 2001
 - HL-LHC was not taken completely into account during the test
- In the coming years some of these sensors will be replaced
 - They will be very old
 - Electronics could not be the same of 20 years ago...
- Need to test these new sensors for radiation damage

Experiment	Expected Dose at gas rack locations to end of LHC (Gy)
ALICE	12
ATLAS	5
CMS	60
LHCb	24



Set-up to monitor the performance of the sensors in an accelerated radiation environment similar to the one of the experiments where they are installed

Example of failure during LHC Run 2

- ± 10 mbar pressure sensors: used to regulate pressure at detector level
 - 500 in the experimental caverns
 - Very critical
 - Redundancy is necessary
- Some failures already present in the experiments
 - Example LHCb RICH1 and RICH2: implementation of system with two pressure sensors
 - Automatically switch of pressure sensor if first one fails

Message ID: 1439	Entry time: 30/08/2018, 15:50
Author:	Patrick CARRIÉ
Experiment:	LHCb
Detector:	RI2
Gas System Module:	Distribution
Start time of Intervention:	
Actual System Down Time (Hours):	0
Type Of Intervention:	OTHER(specify)
Type of Operation:	Electrical
Status:	Done
Assigned to:	
Title:	Liste des Erreurs capteurs PT6104 /1 & /2 depuis 8-03-2018

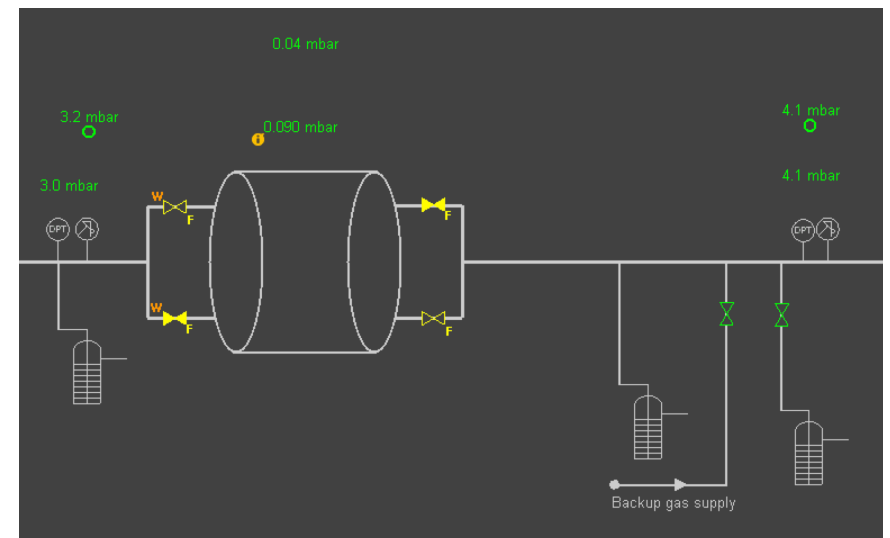
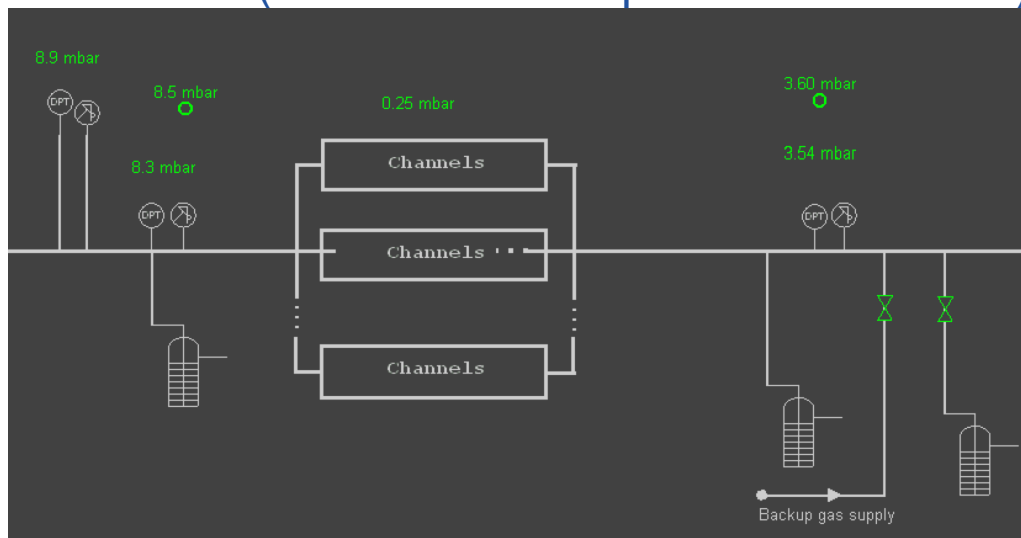
Rich2 Listes des Erreurs sur les capteurs du Detecteurs PT6104/1 & /2

Nouveaux capteurs mis en place le 8-03-2018

18-08-18	6 :07	PT6104/1 Erreur	reset a 16 :16
10-08-18	3 :45	PT6104/1 Erreur	reset a 11 :01
9-08-18	14 :49	PT6104/1 Erreur	reset a 15 :09
2-08-18	5 :10	PT6104/2 Erreur	reset a 17 :53
18-05-18	10 :09	PT6104/2 Erreur	reset a 15 :07

LHCb RICH2

CMS RPC (~ 25 racks in experimental cavern)



Tests performed in the past



Gas System Controls

Pressure Sensors Results

Radiation dose: 80gray/week

Manufacturer	Range	Type	Output	Transducer	Result
JUMO	0-250mbar	Diff.	4-20mA	PIEZO	+ve Drift
JUMO	0-400mbar	Diff.	4-20mA	PIEZO	OK
HAENNI	±1bar	Diff.	4-20mA	PIEZO	-ve Drift
HALSTRUP	0-200mbar	Diff.	0-10V	CAP.	FAIL
SENSORTEC	±10mbar	Diff.	4-20mA	RES.	OK

C.Zinoni / GWG

RADWG DAY

7/12/01

- Validation up to 80 Gy
- Enough for LHC Runs
- Components validated are nowadays in use in the gas systems
- But... some components not anymore available on the market

EDMS document:

<https://edms.cern.ch/document/575175/1>



Gas System Controls

Electronic components

Radiation dose: 80gray/week

Manufact.	Component	Description	Part#	Result
AGILENT	Optocoupler	Photodiode	HCPL-2730	OK
NAIS	Optocoupler	MOSFET	AQW210	FAIL
NAIS	Optocoupler	MOSFET	AQY272	FAIL
ISOCOM	Optocoupler	Phototransistor	H11B1	FAIL
Nat.Semic.	Volt Regulator	Adjustable	LM317L	OK
Nat.Semic.	Volt Regulator	Fixed 5V	LM7805	OK
Fairchild	DeMUX	Analogue MUX	CD4051BC	OK
SIEMENS	I/P positioner	Profi-PA coupler	PS2-PA	OK after reset
Omron	2*PSU	220Vac/24Vdc	S82K	DRIFT
SHIELE	PSU	220Vac/24Vdc	2423-418	FAIL

C.Zinoni / GWG

RADWG DAY

7/12/01

CHARM Radiation for our set-up

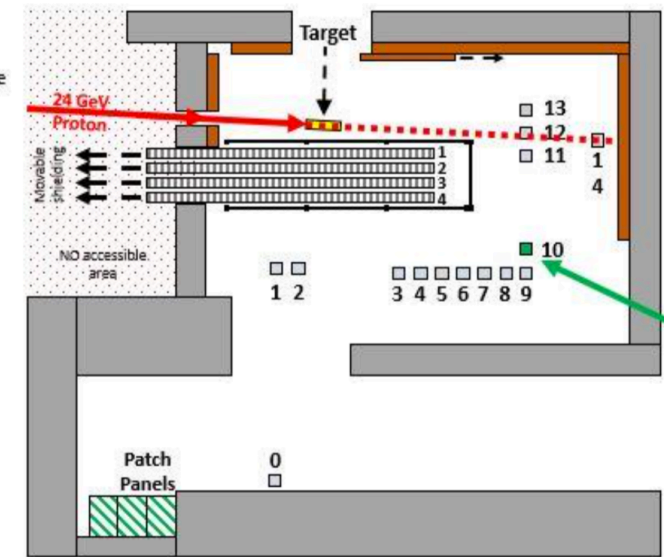
POSITION R10 - Cu0000	
RADIATION LEVEL	Target inside 25-04-2018 13:49
	Target removed 30-04-2018 21:01
Dose (Gy)	168
1MeVeq. fluence (cm ⁻²)	1.6·10 ¹²
HEH fluence (cm ⁻²)	5.4·10 ¹¹
R factor	0.8
Total POT*	1.17·10 ¹⁶

*POT is the total number of protons hitting the target.

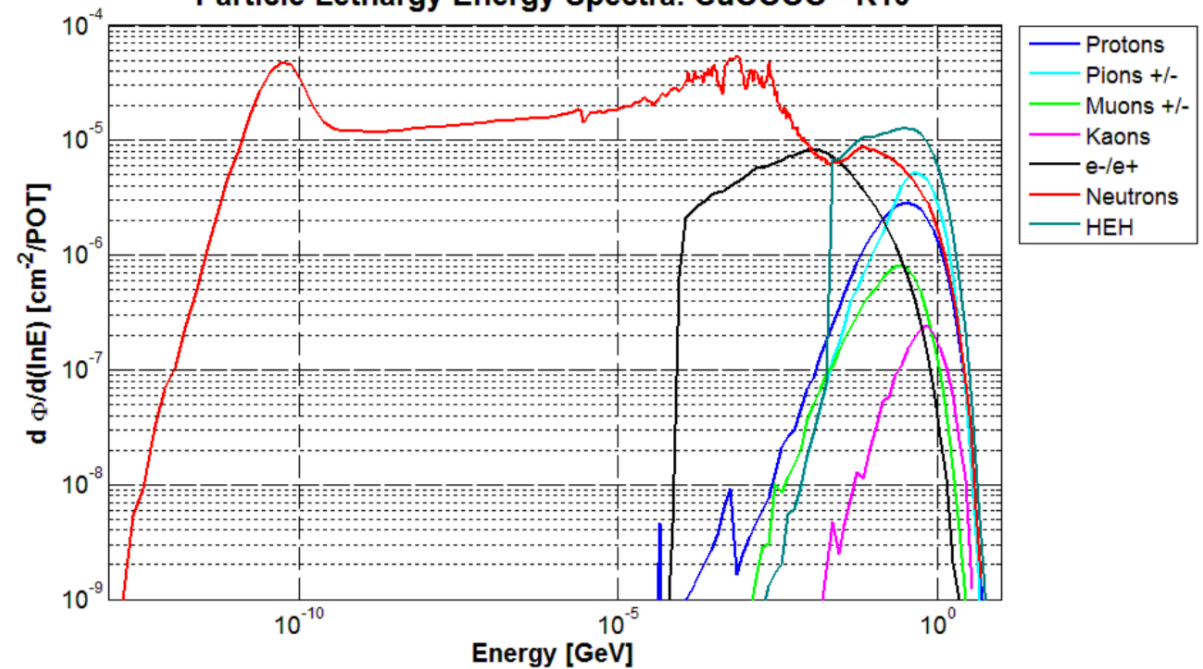
Target configuration
 NT - Empty
 AlH - Aluminium Hole
 Al - Aluminium
 Cu - Copper

Type of shielding:
 1 - Concrete
 2 - Iron
 3 - Iron
 4 - Concrete

Shielding Configuration:
 Inside
 Outside



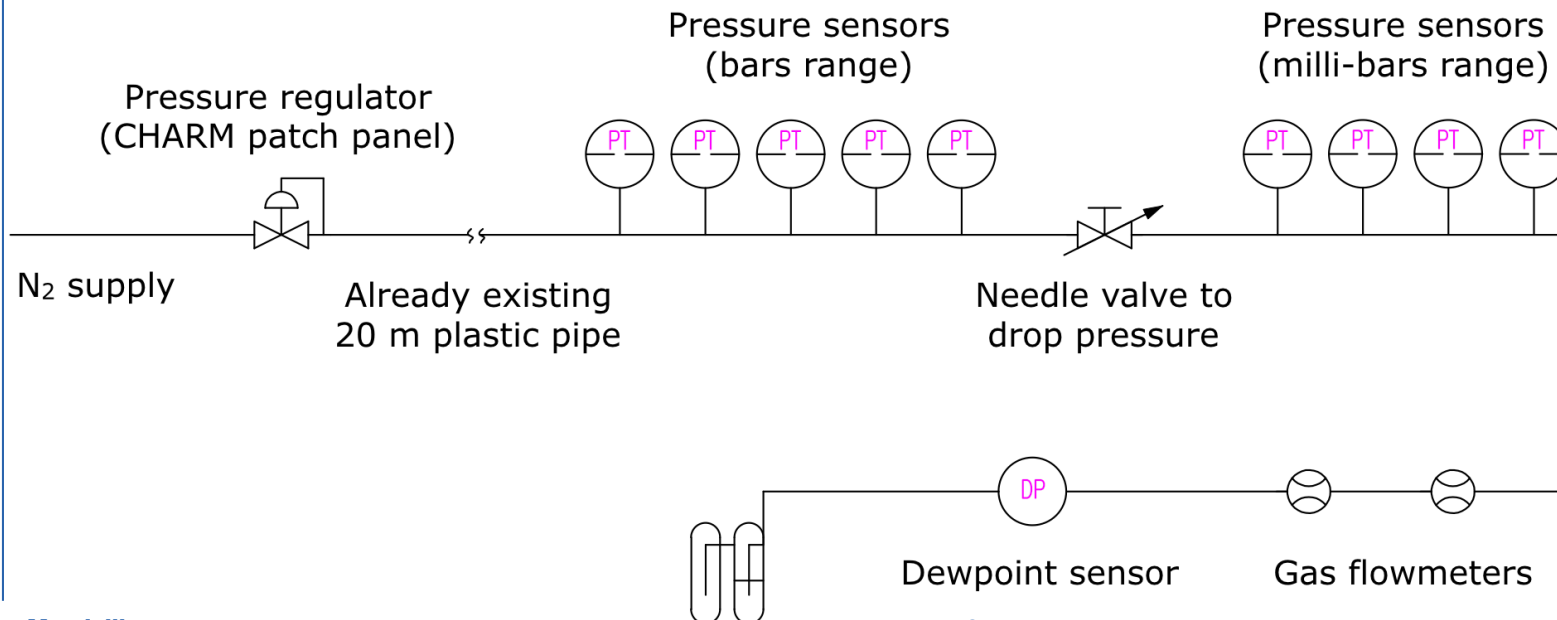
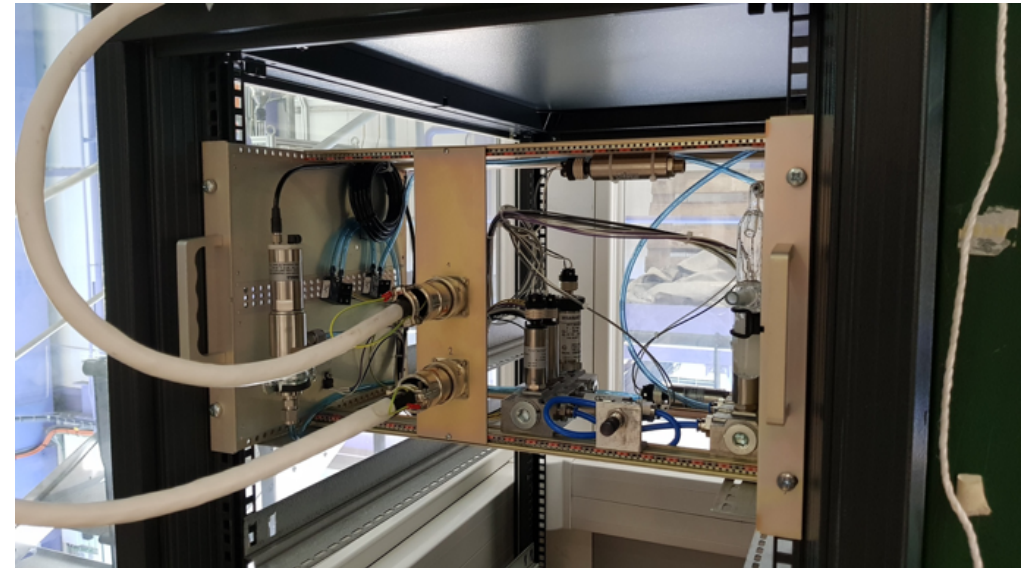
Particle Lethargy Energy Spectra: Cu0000 - R10



Set-up: overview

Once the set-up is installed in CHARM, NO possibility to access it for the full week of test.
Fundamental that system is reliable and works correctly

- Set-up to test different types of sensors
 - Pressure sensors, flowmeters, H₂O sensors, etc
 - New VS old generation (electronics)
- Cables for power supply and transmission of output signals
 - Each sensor powered individually
- Process control
 - Schneider PLC (UNICOS CPC 6 framework)
 - WinCC OA Scada system

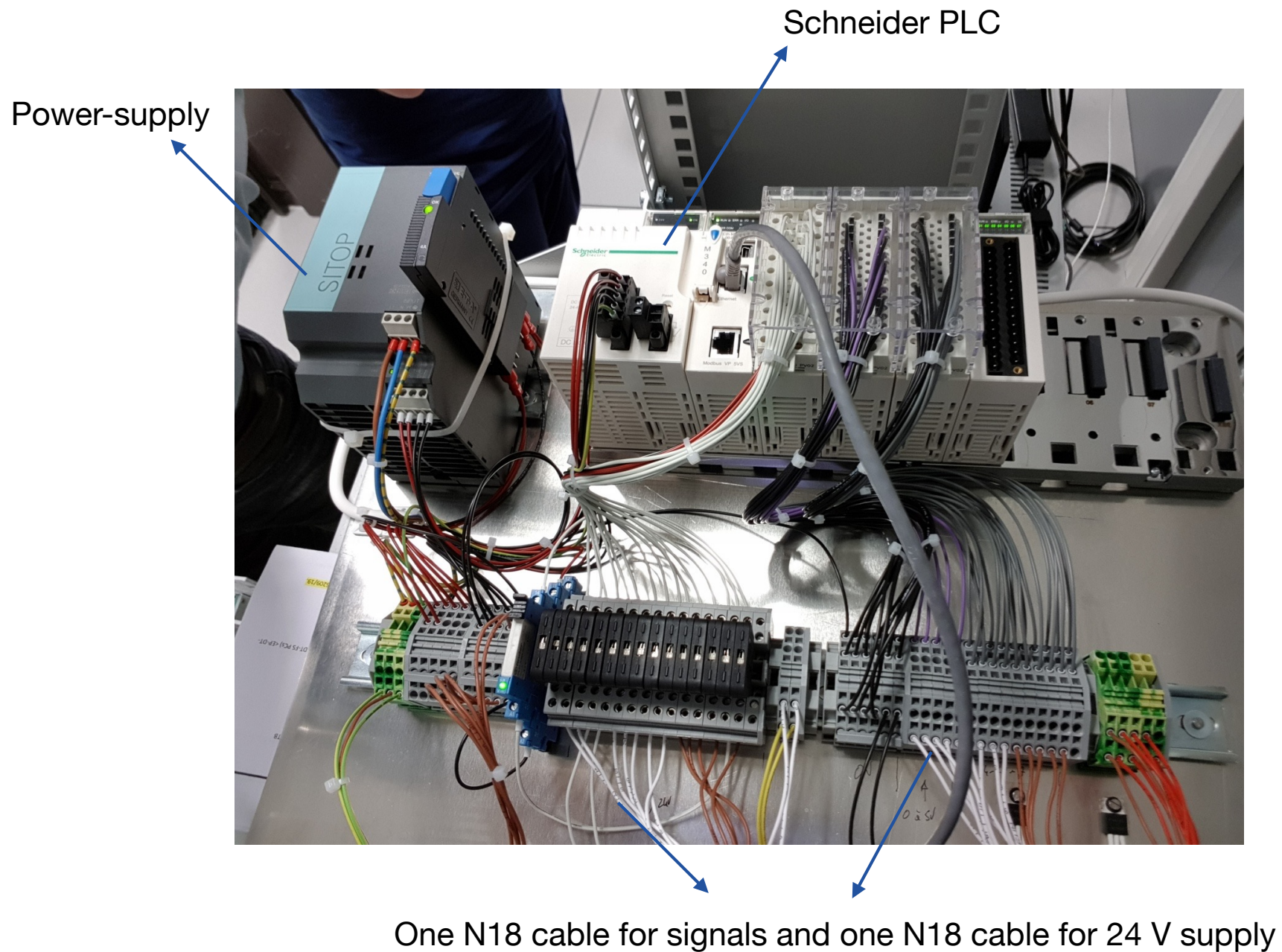


scem: 22.64.11.xxx
scem: 22.64.12.xxx

Set-up: sensors tested

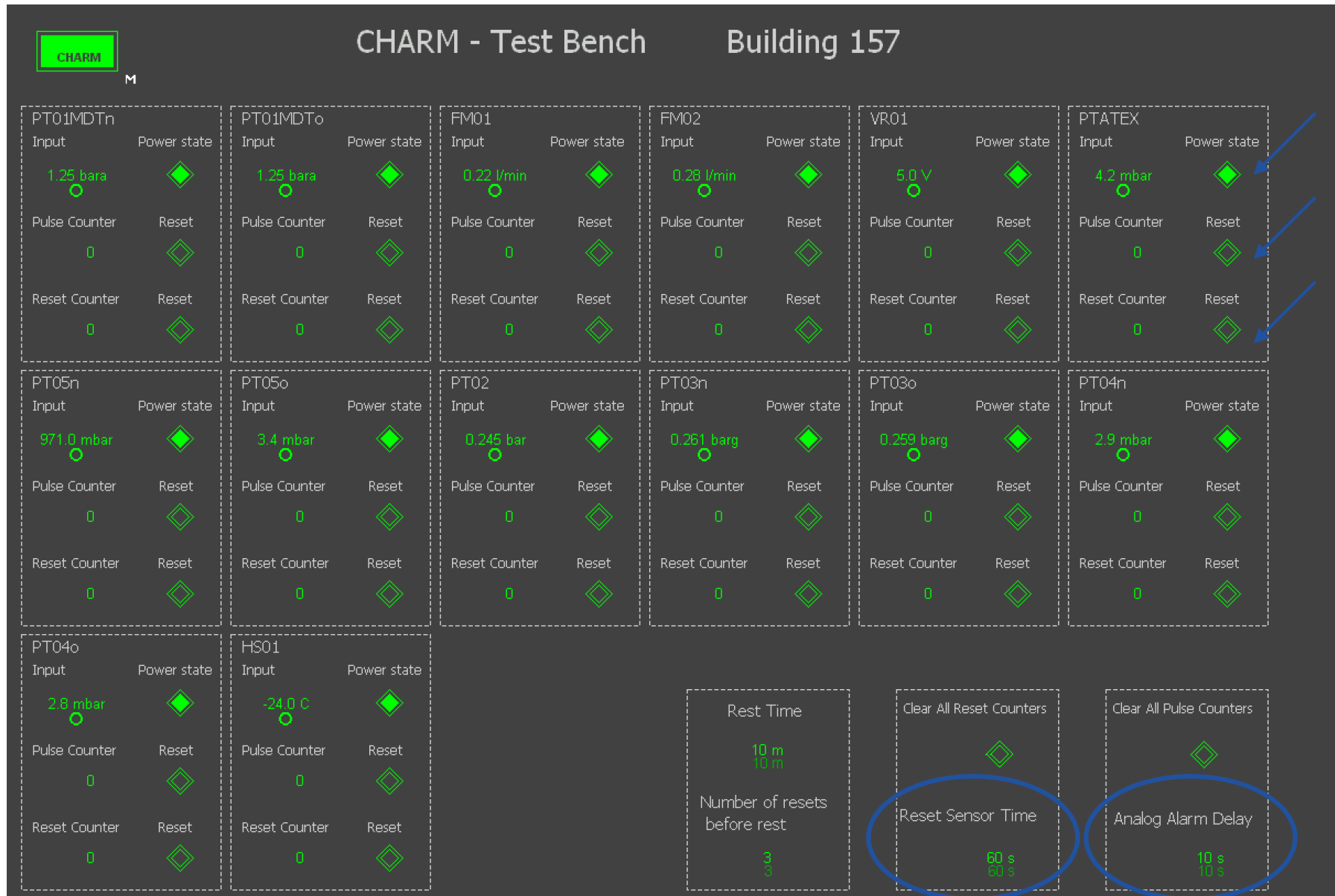
Name	Type	Manufacturer	Reference	Range	Output Signal
PT01MDTn	Pressure sensor of ATLAS MDT (new electronics)	First Sensor (old Sensor Technics)	CTE90005AQ7	0 – 3.5 bara	0 – 5 V
PT01MDTo	Pressure sensor of ATLAS MDT (old electronics)	Sensor Technics	CTE90005AQ8	0 – 3.5 bara	0 – 5 V
PT02	Pressure sensor Krohne	Krohne	Optibar P10101C	0 – 5 bar	4 – 20 mA
PT03n	Pressure sensor 3 (new electronics)	First Sensor (old Sensor Technics)	CTE9001GQ4	0 – 1 barg	4 – 20 mA
PT03o	Pressure sensor 3 (old electronics)	Sensor Technics	CTE8001GQ4	0 – 1 barg	4 – 20 mA
PT04n	Pressure sensor 4 (new electronics)	First Sensor (old Sensor Technics)	CTEM7N01GQ4	-10 – +10 mbar	4 – 20 mA
PT04o	Pressure sensor 4 (old electronics)	Sensor Technics	CTEM7N01GQ4	-10 – +10 mbar	4 – 20 mA
PT05n	Pressure sensor 5 (new electronics)	First Sensor (old Sensor Technics)	-	900-1200 mbar	4 – 20 mA
PT05o	Pressure sensor 5 (old electronics)	Sensor Technics	-	0 - 40 mbar	4 – 20 mA
PTATEX	ATEX pressure sensor	VEGA	VEGABar17	0 - 100 mbar	4 – 20 mA
FM01 FM02	Flowmeters (x2)	Mouser	D6F-P0001A1	0.5 – 2.5 V	0 – 1 l/min
HS01	Humidity sensor	Vaisala	DMT143	-80 - +20 C	4 – 20 mA
VR01	Voltage regulator	-	-	0 – 5 V	0 – 5 V

Set-up: controls

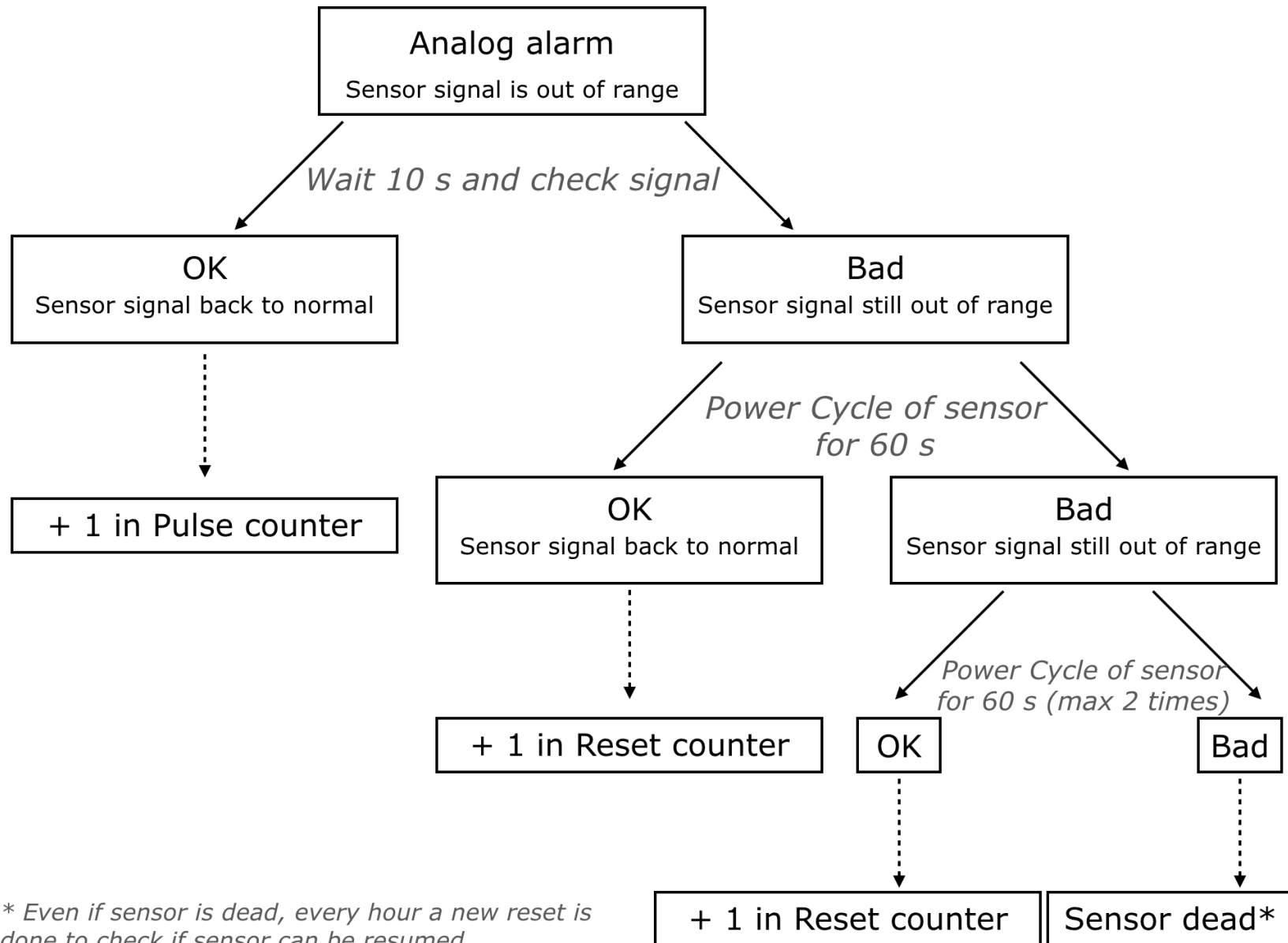


Set-up: controls

Win-CC OA application



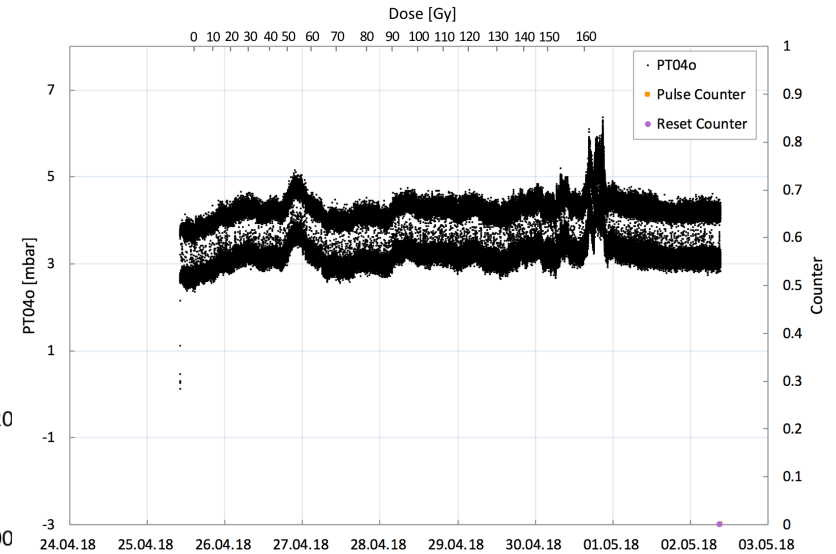
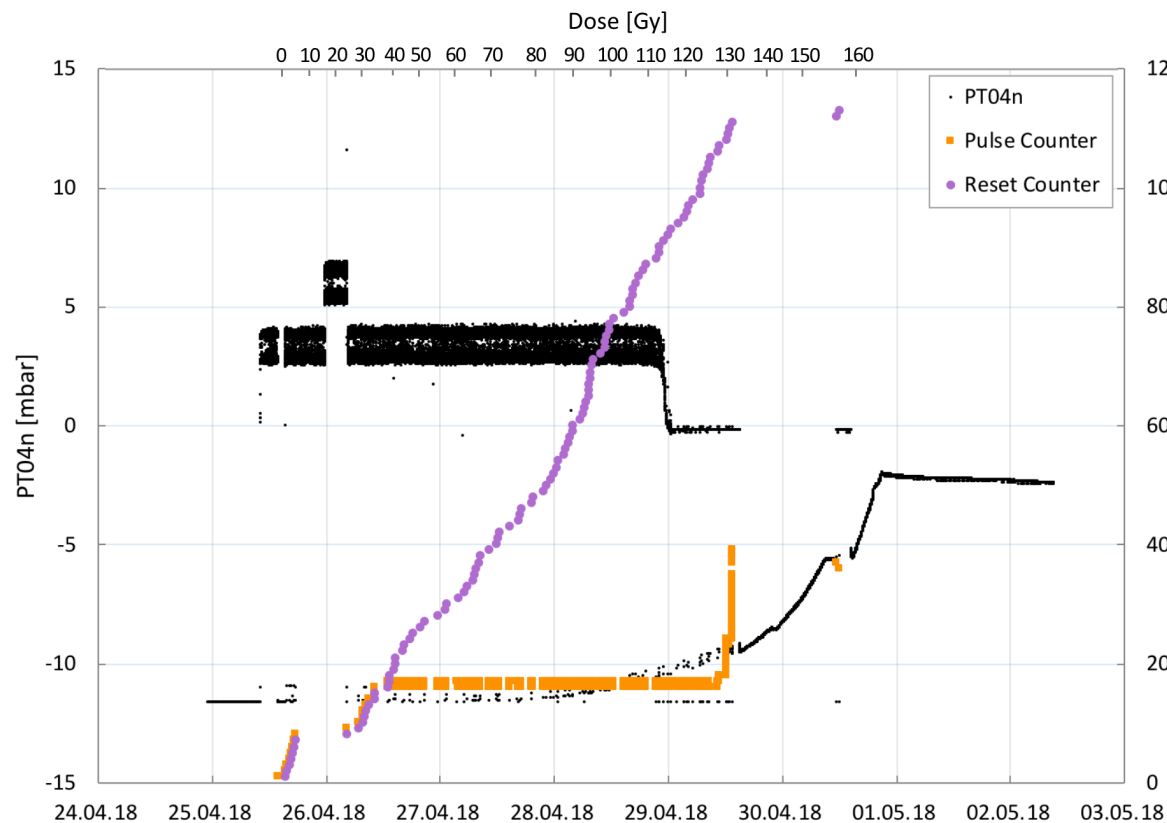
Test methodology



* Even if sensor is dead, every hour a new reset is done to check if sensor can be resumed

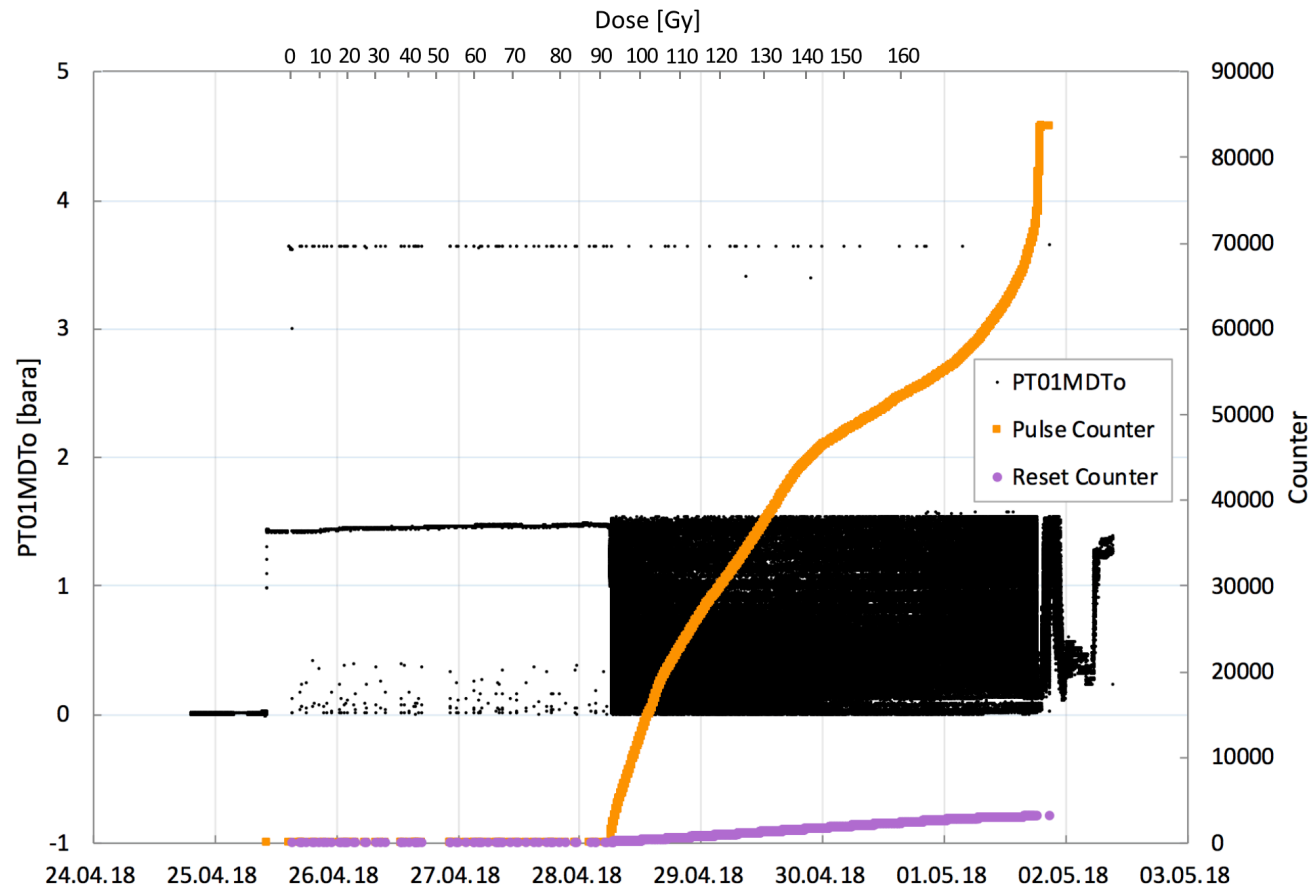
Experimental results: PT04 (± 10 mbar)

- Used for the gas systems (distribution module): 500 sensors
- Very critical for detector pressure regulation
- Some failures already present
- Redundancy compulsory
- Difference between old and new electronics



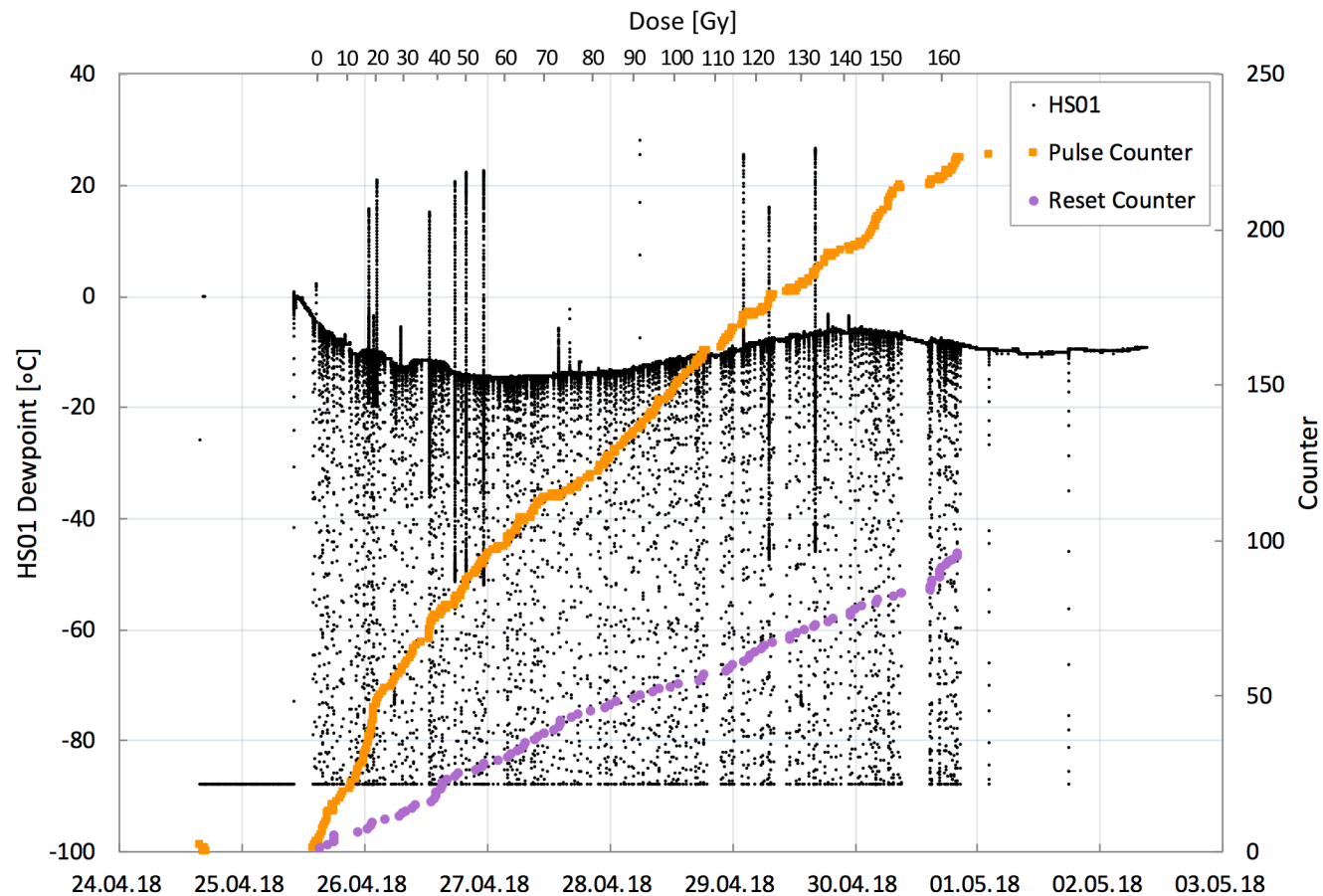
Experimental results: PT01

- Only used for the ATLAS MDT Gas systems: 300 sensors
 - Output 0 -5 V
- Some failures already present (10 during Run 2)
 - After a power reset usually sensor works again
 - But power reset possible only with access in the cavern
 - Some old pressure sensors changed with new generation: several failures



Experimental results: humidity sensor

- Electronics integrated with the sensor
 - Already before test, suspect of failure



Experimental results: summary

Sensor	Dose at which fails (Gy)	Pulse Counter	Reset Counter	Type of failure	After radiation
PT01MDTn	90	28750	207	Unstable reading	Back to normal operation
PT01MDT0	100	12457	251	Unstable reading	Back to normal operation
PT02	160	87	90	Run out of range	Dead
PT03n	100	25893	118	Run out of range, unstable reading	Back to normal operation
PT03o	120	116	81	Unstable reading	Back to normal operation
PT04n	120	16	96	Drift in reading	Drift in reading
PT04o	>160	0	0	OK	OK
PT05n	150	24	24	Drift in reading	Drift in reading
PT05o	>160	0	0	OK	OK
PTATEX	>160	0	0	Suspected minor drift	OK

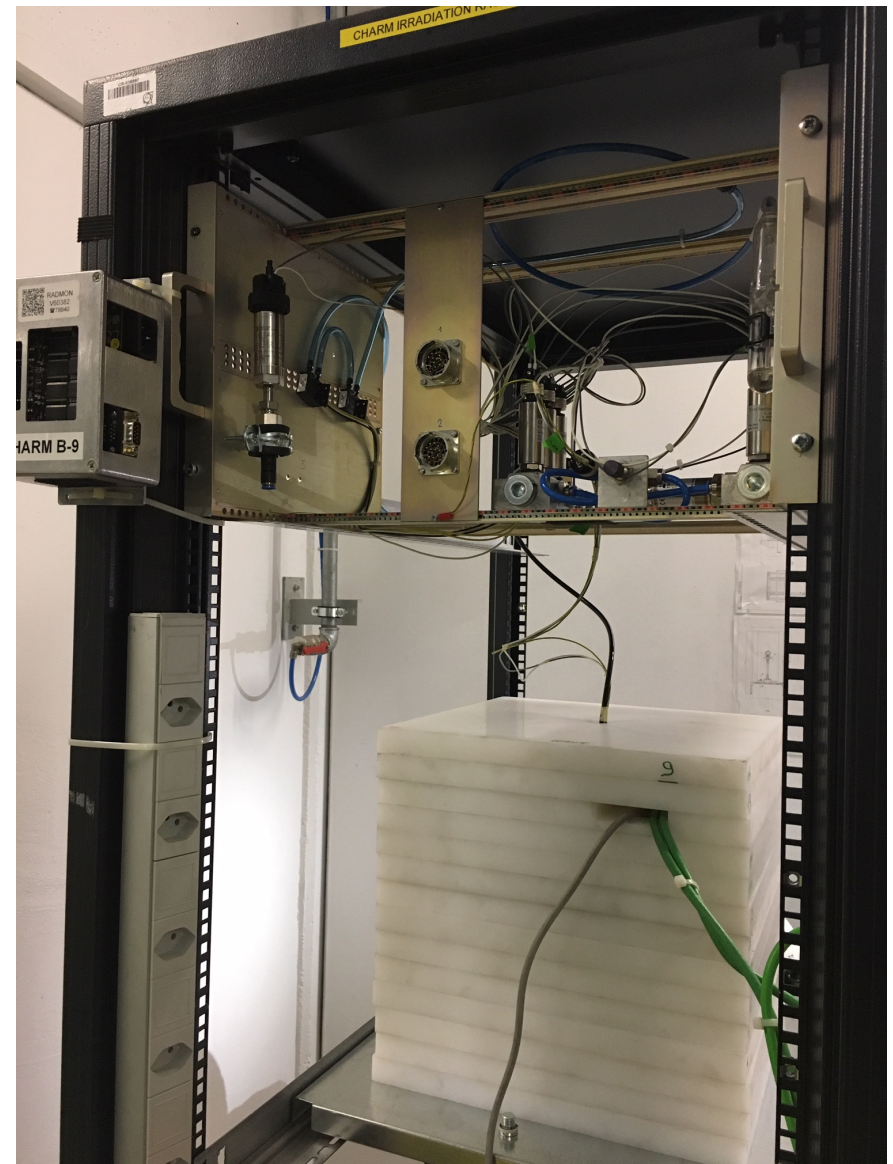
Second test

Difference between same pressure sensors but with old and new electronics!

- Company of pressure sensors (FirstSensor) contacted to produce special set of pressure sensors with old electronics
 - 0-40 mbarg, +/- 10 mbarg, 0-100 mbarg
- New test necessary to validate this special set of pressure sensors
 - Same working principle and electronics of pressure sensors of ~10 years ago
- In parallel try to test pressure sensors with new electronics but with a shielding
 - New pressure sensors failed the first radiation test
 - But check if eventually can be used if shielded
 - Decided to shield only for neutrons

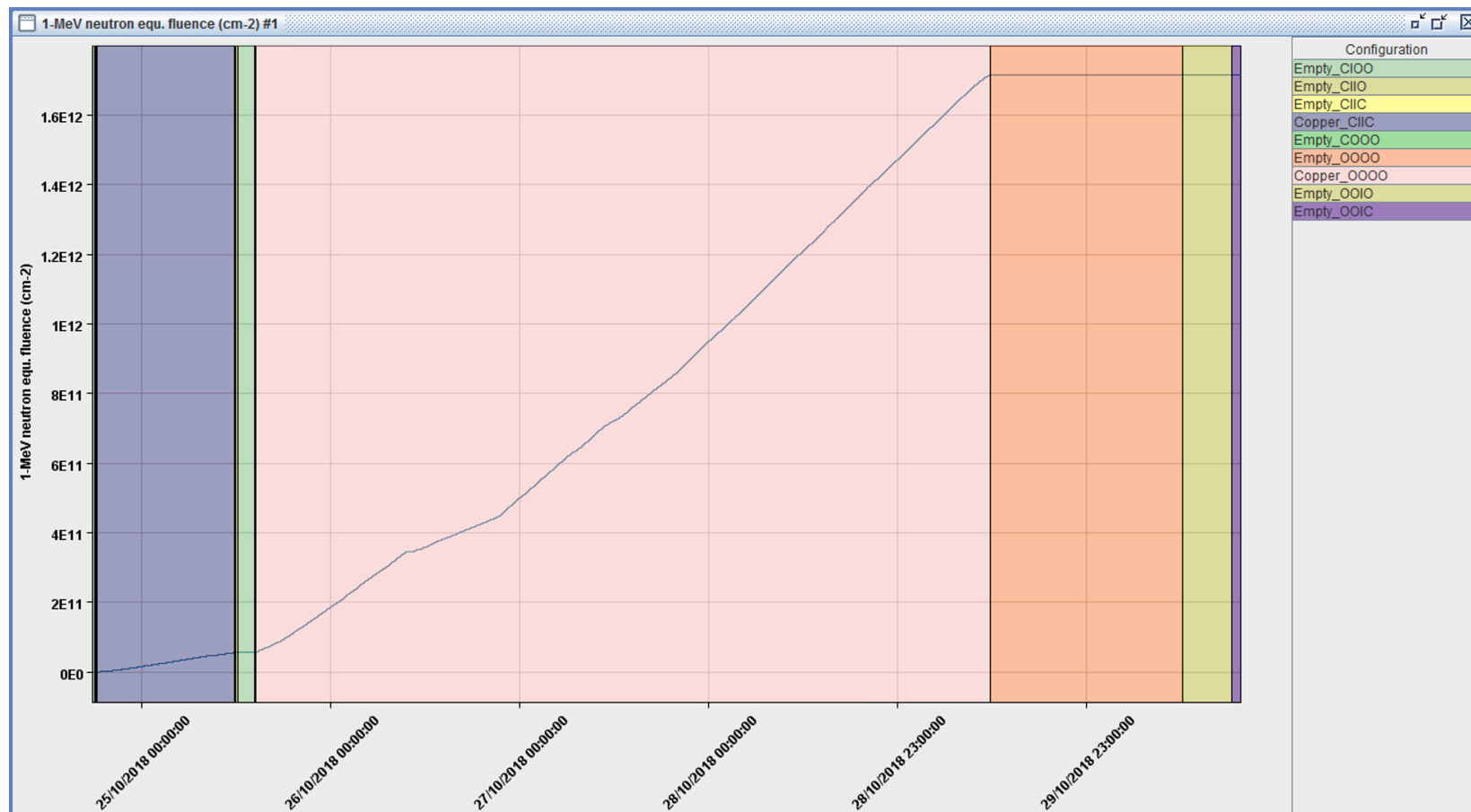
Set-up of second test

- Exactly the same set-up of first test
 - New VS old generation (electronics)
 - Same logic
- Test of only pressure sensors
 - 6 new pressure sensors with old electronics
 - 1 new pressure sensor
 - 1 new pressure sensor shielded
- Shielding
 - Idea was to shield for neutrons —> choose Polyethylene
 - Polyethylene Cross-Sections: $0.118605351 \text{ cm}^{-1}$
 - —> shielding block of $30 \times 30 \times 30 \text{ cm}^3$
 - RADMON sensor installed inside the shielding

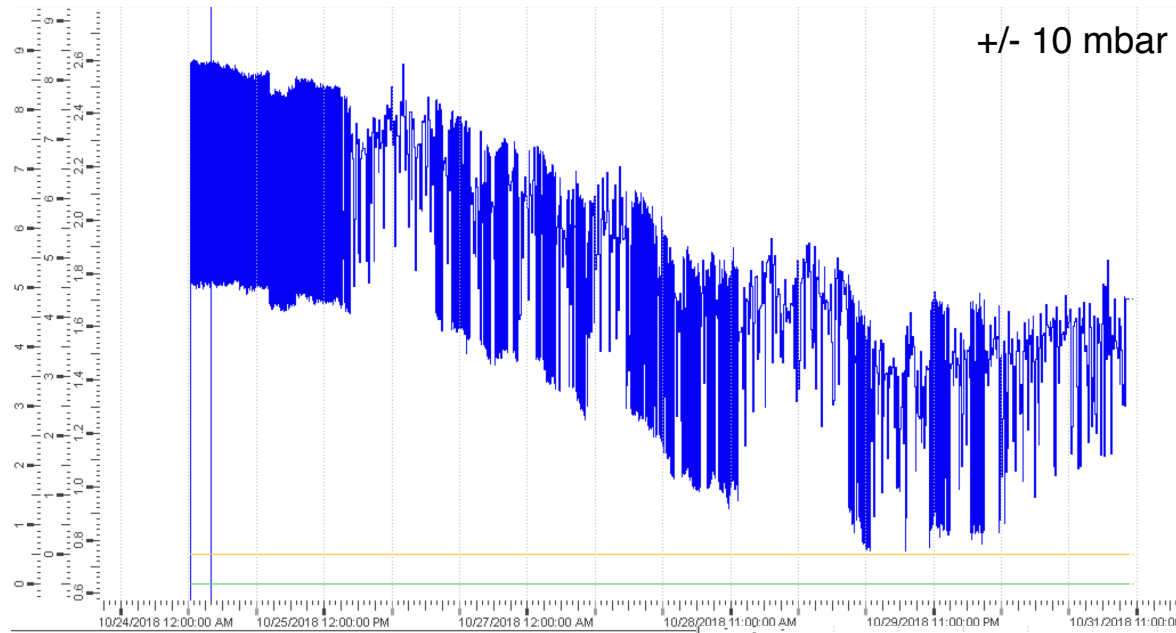


CHARM Radiation for our set-up

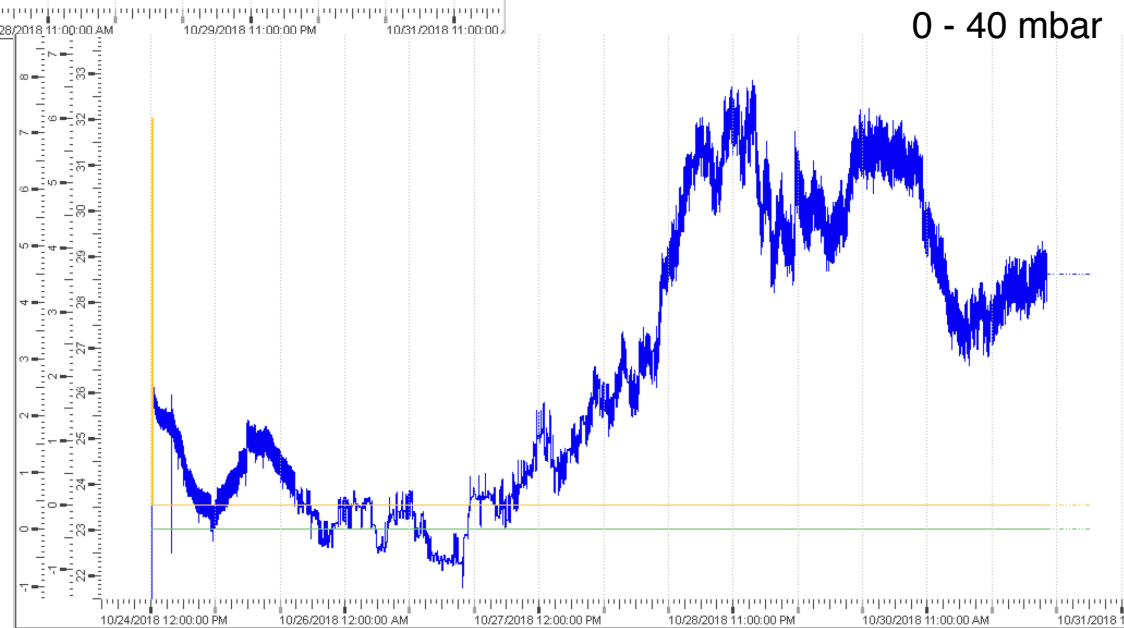
- We run with three different configurations:
 - CI00, CIIC, C000
- Goal was to check behaviour of sensors with different radiation
 - Shielding was done for neutrons



Results: new sensors with old electronics

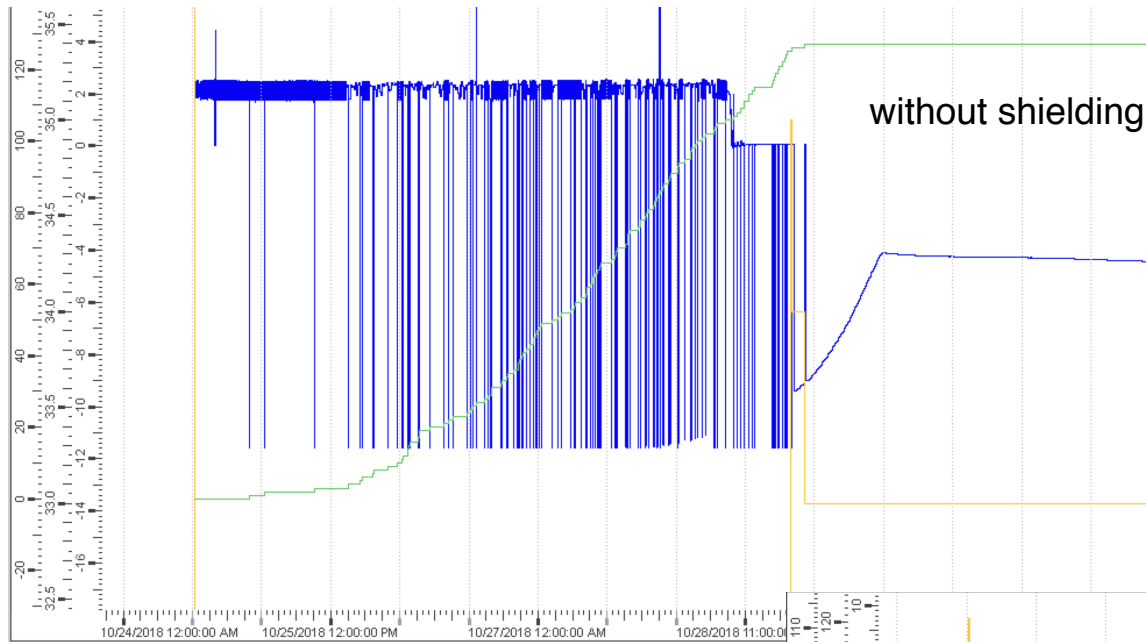


10/31/2018 10:38:26 AM .972
 GSCa_157_PT05n_AA.PosSt 1.7
 GSCa_157_PT05n_ACS.PosSt 0
 GSCa_157_PT05n_ACL.PosSt 0

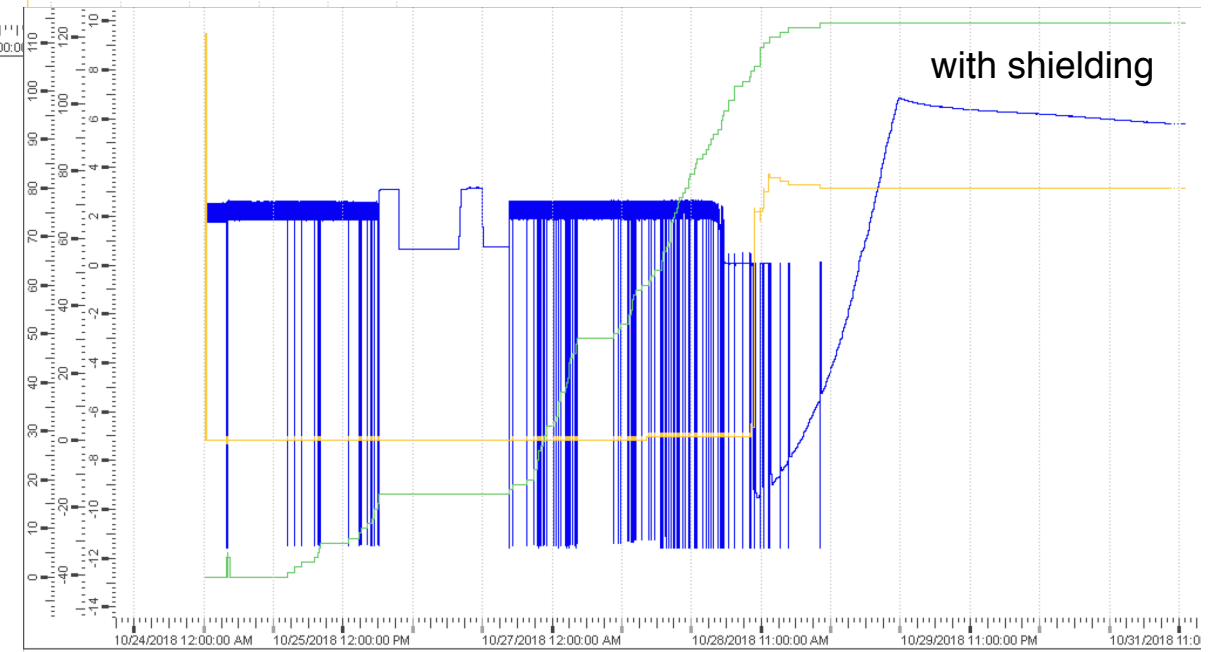


10/31/2018 5:13:59 PM .630
 GSCa_157_PT04n_AA.PosSt 28.6
 GSCa_157_PT04n_ACS.PosSt 0
 GSCa_157_PT04n_ACL.PosSt 0

Results: sensor with new electronics and shielding



10/31/2018 10:47:46 AM .698
GSca_157_PT050_AA.PosSt -4.4
GSca_157_PT050_ACS.PosSt 33
GSca_157_PT050_ACL.PosSt 127



10/31/2018 12:02:31 PM .205
GSca_157_PT02_AA.PosSt 5.79
GSca_157_PT02_ACS.PosSt 75
GSca_157_PT02_ACL.PosSt 114

Conclusions

- Successful radiation campaigns
 - Very interesting and useful results
- Several types of sensors installed in LHC gas systems tested
 - Pressure sensors (old and new electronics)
 - Flow sensors
 - Humidity sensors
- Difference between pressure sensors with old and new electronics
 - The ones with old electronics stand to much more radiation
- Company of pressure sensor contacted to produce special set of pressure sensors with old electronics
 - Second test at CHARM done
- Test revealed that old electronics is radiation-hard
 - For experimental cavern we will use these pressure sensors with old electronics
 - In contact with company for special production

EDMS document:

<https://edms.cern.ch/document/2021919/1>

Thanks to the CHARM and CERN GAS team