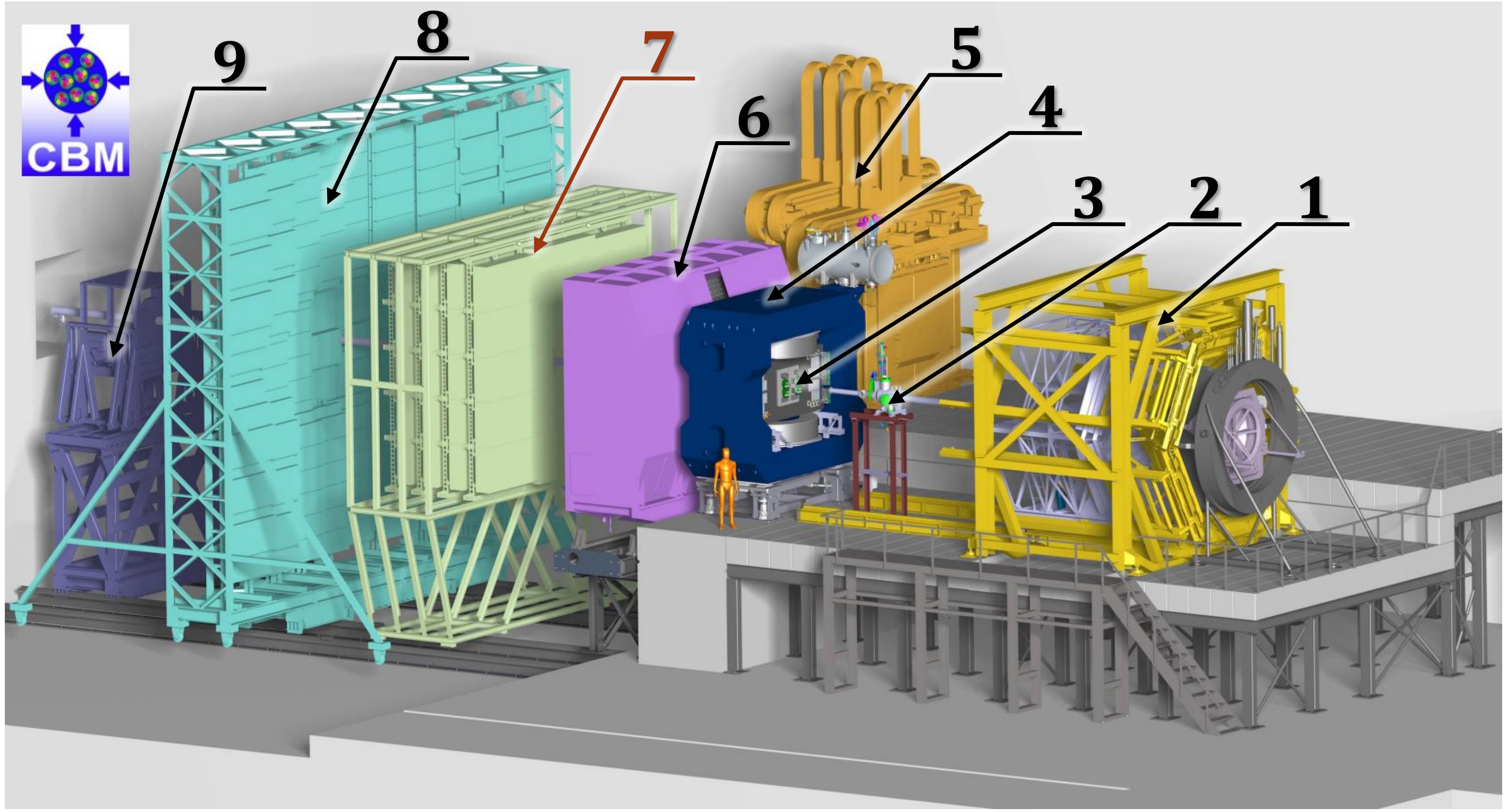
DEVELOPMENT OF A GAS SYSTEM FOR THE TRANSITION RADIATION DETECTOR OF THE CBM EXPERIMENT

Nikolai Podgornov

Prof. James Ritman

Dr Peter Wintz

COMPRESSED BARYONIC MATTER EXPERIMENT



1. HADES
2. Time-Zero Detector & Beam Diagnostics
3. Micro-Vertex Detector (MVD) and Silicon Tracking System (STS)
4. Superconducting Dipole Magnet
5. Muon Chamber System (MUCH)
6. Ring Imaging Cherenkov Detector (RICH)
7. Transition Radiation Detector (TRD)
8. Time-Of-Flight System (TOF)
9. Forward Spectator Detector (FSD)

TRANSITION RADIATION DETECTOR

CBM-TRD geometry consist of one station with four layers of detectors, each layer consists:

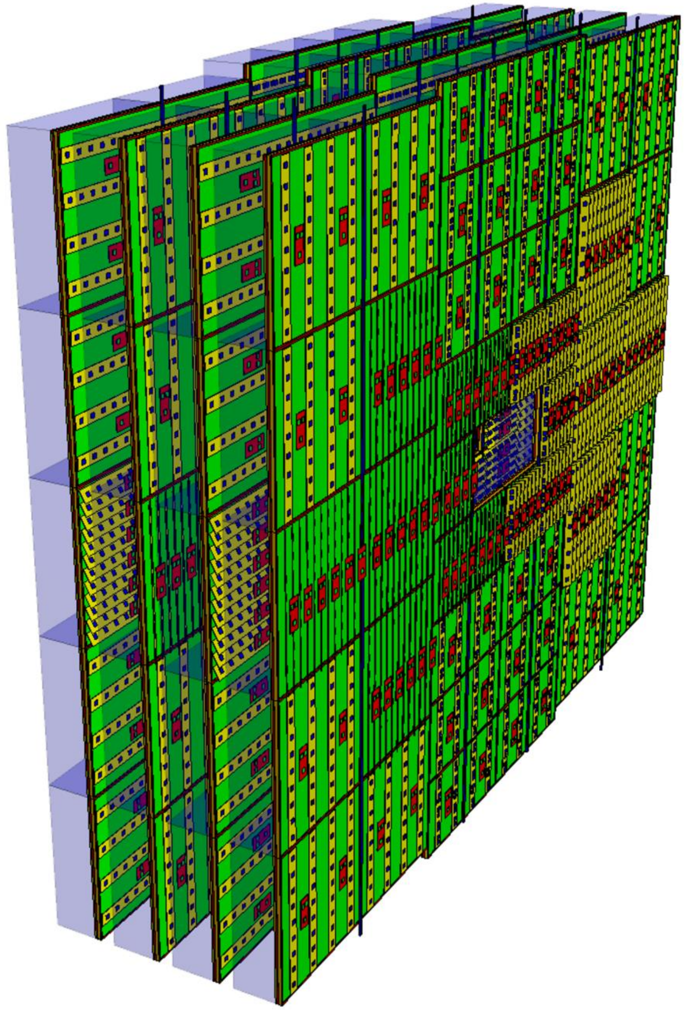
- ➢ Transition Radiation (TR) – radiators
- ➢ Multi Wire Proportional Chambers (MWPC) as Read-Out Chambers (ROC)

Purposes:

- Electron-identification in the high momentum region (p > 1 GeV/c)
- Identification of light nuclei via specific energy loss
- Tracking device, bridging the region between STS and TOF

Requirements:

- Pion suppression factor of 20 at 90% electron efficiency and $p \geq 1.5$ GeV/c
- Space point resolution of 300 μm
- Energy loss resolution better than 30% above $p = 1$ GeV/c
- Maximal signal collection time: 300 ns
- Maximal hit rate < 100 kHz
- Maximal cell occupancy < 10%

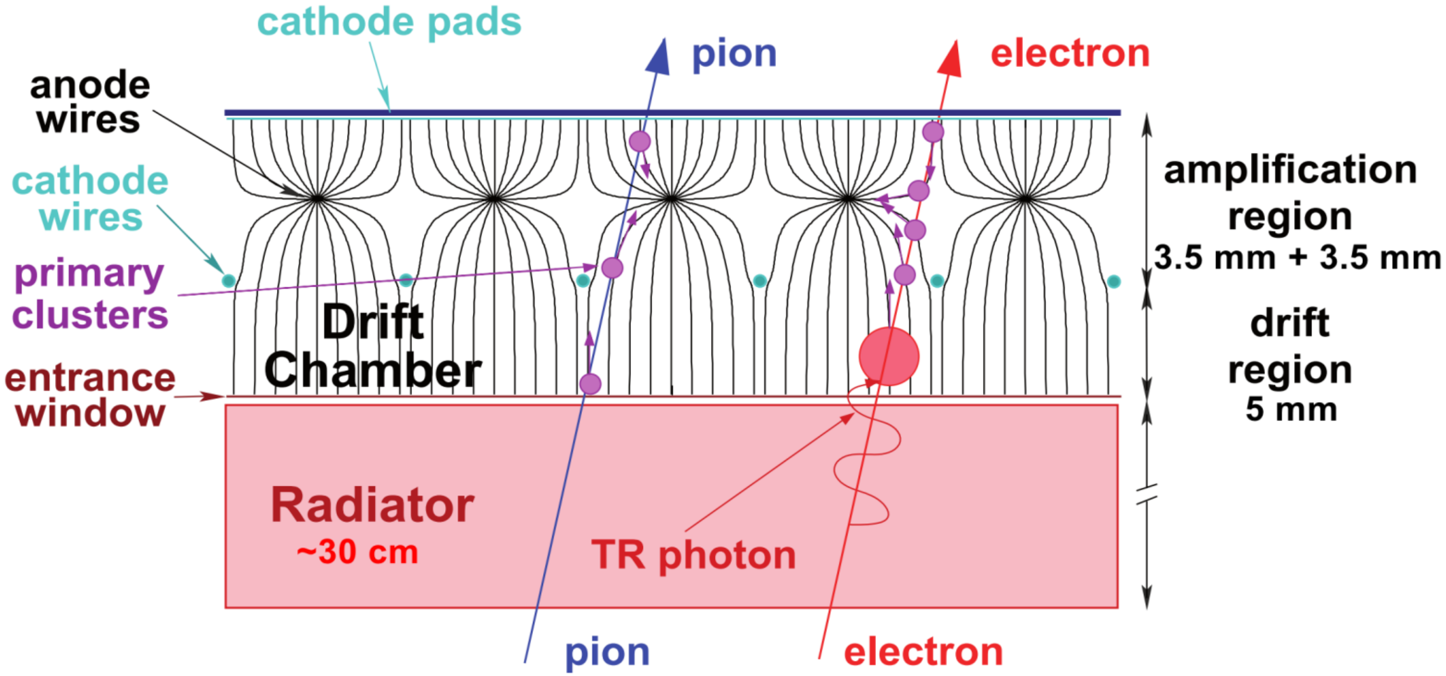


The reverse side of TRD shows the back panels of the ROCs together with the front-end electronics.

The radiators are represented schematically by blue boxes.

TRD WORKING PRINCIPLE

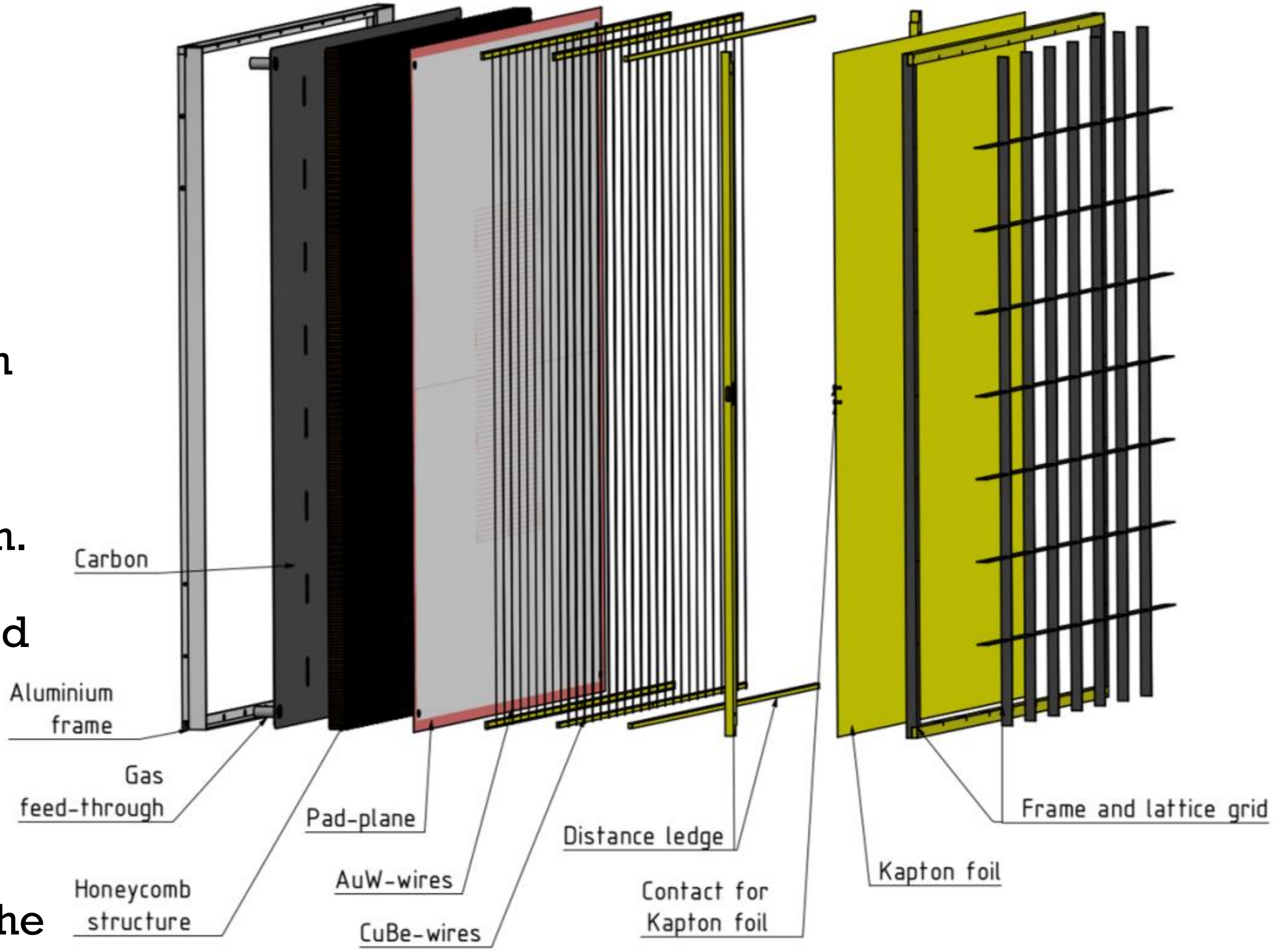
Transition radiation is a form of electromagnetic radiation emitted when a charged particle passes through inhomogeneous media, such as a boundary between two different media.



- TR photons are generated in the radiator by electrons, while the heavier pions pass through without producing any TR
- To efficiently absorb the TR photons in the gas volume of the ROC, a xenon gas mixture, having a high absorption cross section for TR photons is used as a counting gas
- On top of the TR signal, the ROCs also collect the charge released via the specific energy loss caused by primary ionization processes in the gas
- Differences in the energy loss between electrons and pions additionally enhance the separation power between the two and also extend the electron identification
- The energy loss measurement can be used to support the identification of nuclear fragments

TRD READOUT CHAMBER

- The entrance window made from a 25 µm thick Kapton foil, coated with 0.05 µm aluminium on a single side
- The cathode wires are made of a Copper Beryllium alloy. They have a diameter of 75 µm, and also a distance of 2.5 mm between each other
- The anode wires are made of Gold plated Tungsten. They have a diameter of 20 µm and a distance to each other of 2.5 mm. The anode wire grid is shifted by 1.25 mm compared to the cathode wire grid
- The back pad-plane of the detector has a substructure of small rectangular pads. The dimensions of those rectangular pads depend on the chamber model which is used

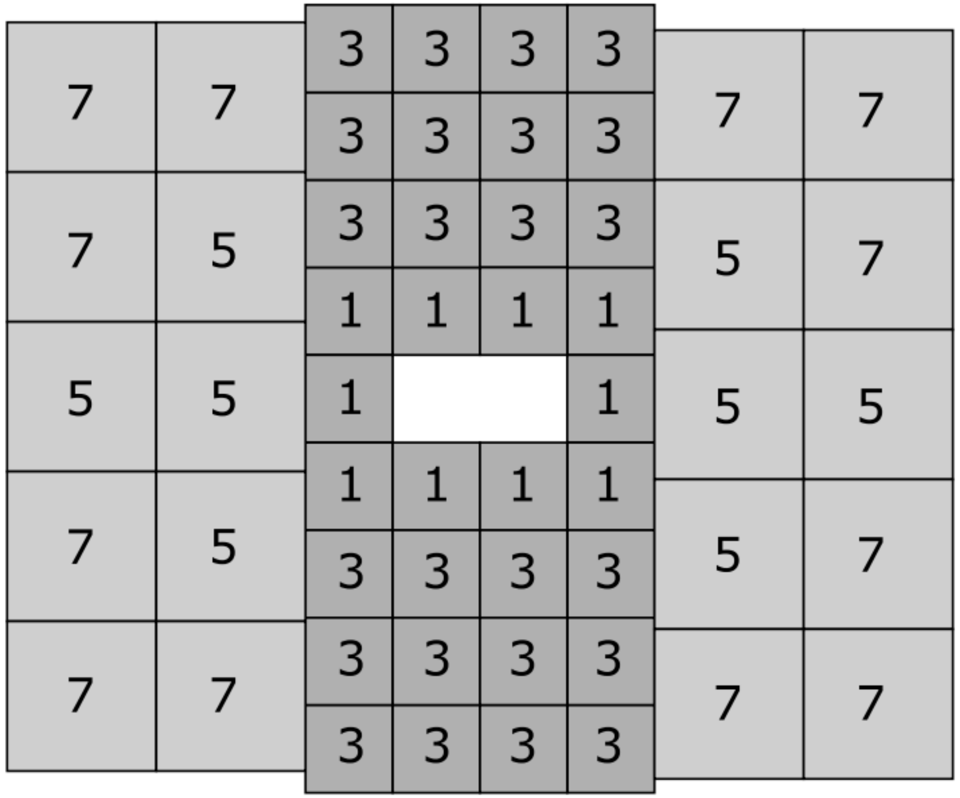


Exploded view of the TRD ROC

TRD DESIGN

- Four detector layers, thickness of one layer = 0.45 m
- maximal height = 5.15 m / maximal width = 6.25 m
- 54 modules per layer (216 total)
  - 20 large types (99 x 99 cm^2)
  - 34 small types (57 x 57 cm^2)
- Fast MWPCs as readout chambers (12 mm gas thickness)
- Total number of readout channels: 329 728
- Total active area of detector: 113.4 m^2
- Total gas volume: 1.36 m^3
- Material budget: < 5% X_0 per layer
- Polyethylene (PE) radiator with a thickness of 30 cm

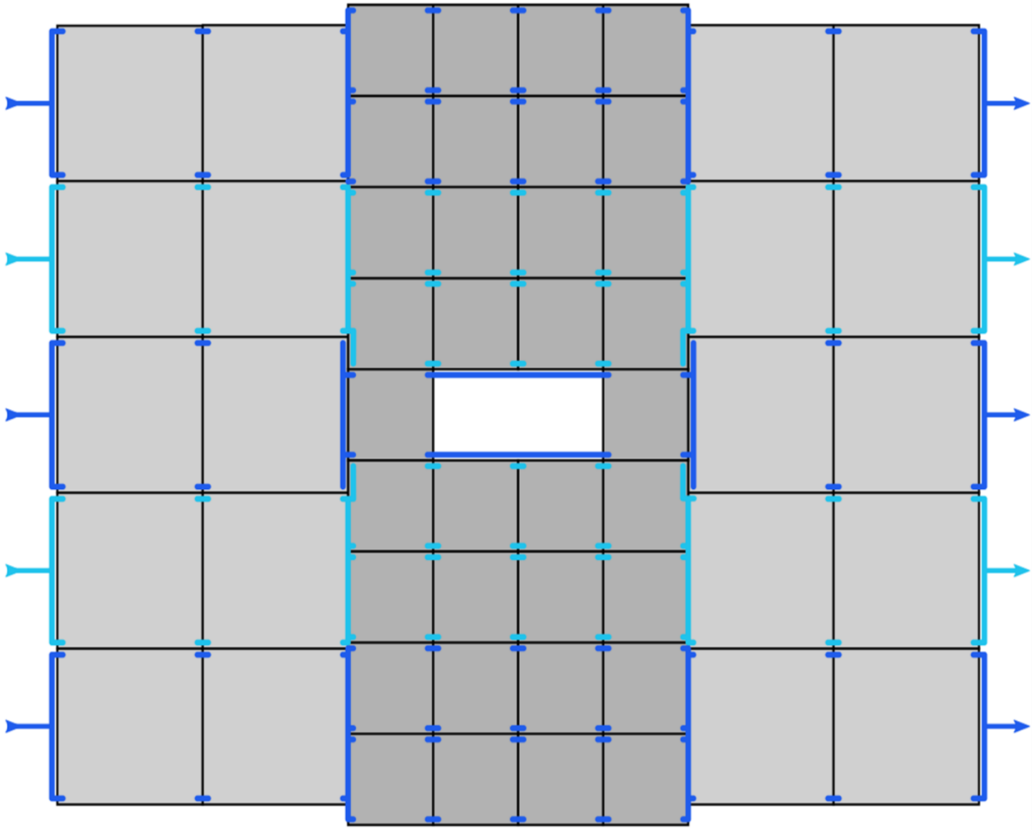
Module type	Modules per layer	Number of readout channels	Pad dimensions HxW (cm)	Pad area (cm^2)
1 - small type	10	25,600	1,75 x 0,68	1.2
3 - small type	24	15,360	6,75 x 0,68	4.6
5 - large type	8	27,648	4.00 x 0.67	2.7
7 - large type	12	13,824	12.00 x 0.67	8.0



The arrangement of the different module types in one TRD layer

TRD GAS SYSTEM REQUIREMENTS

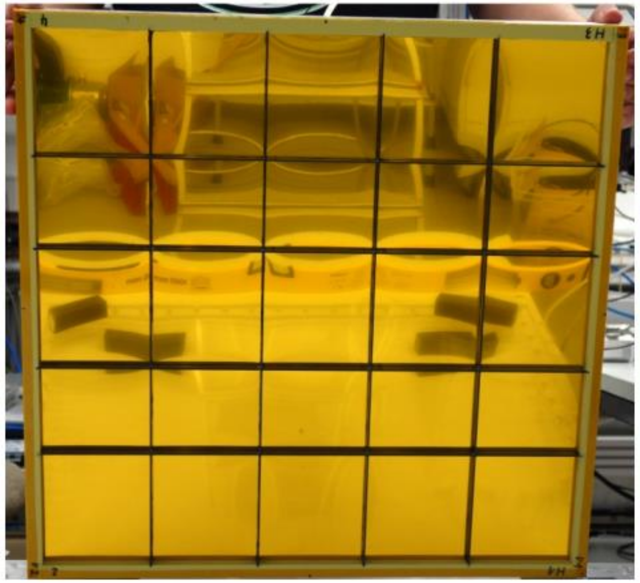
- Overpressure within 0.5 mbar ± 0.2 mbar relative to the atmosphere
- Correct gas mixture of 85% Xenon & 15% CO_2
- Separation of a detector layers into 5 independent levels
  - Xenon is a heavy gas - density about 4.5 times of the atmosphere
  - Every 1 m of height, hydrostatic pressure increases by about 0.4 mbar
  - Serial connections to minimize material budget
- Flow 15 l/h per layer or 60 l/h per level, sufficient to remove humidity
- The gas system will be located 18m above the detector, on a floor not exposed to radiation. Parts and devices in proximity to the detector must be radiation-hard
- Long tubing since the total distance between the CBM cave and the system is approximately 50m
- Closed gas circuit with recuperation of Xenon and purification of the gas mixture
- Safety concerns (Power shut down, Leakage...)

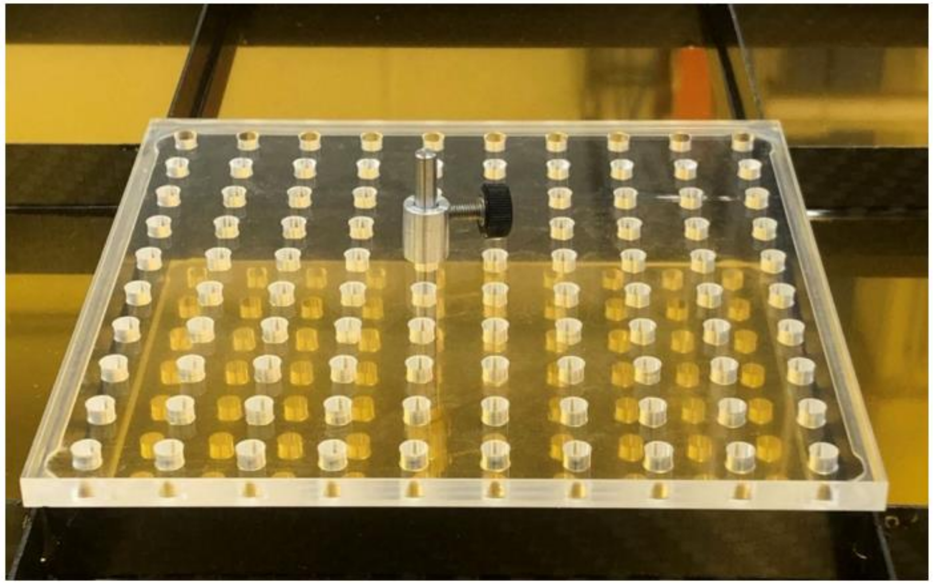


TRD modules Connection

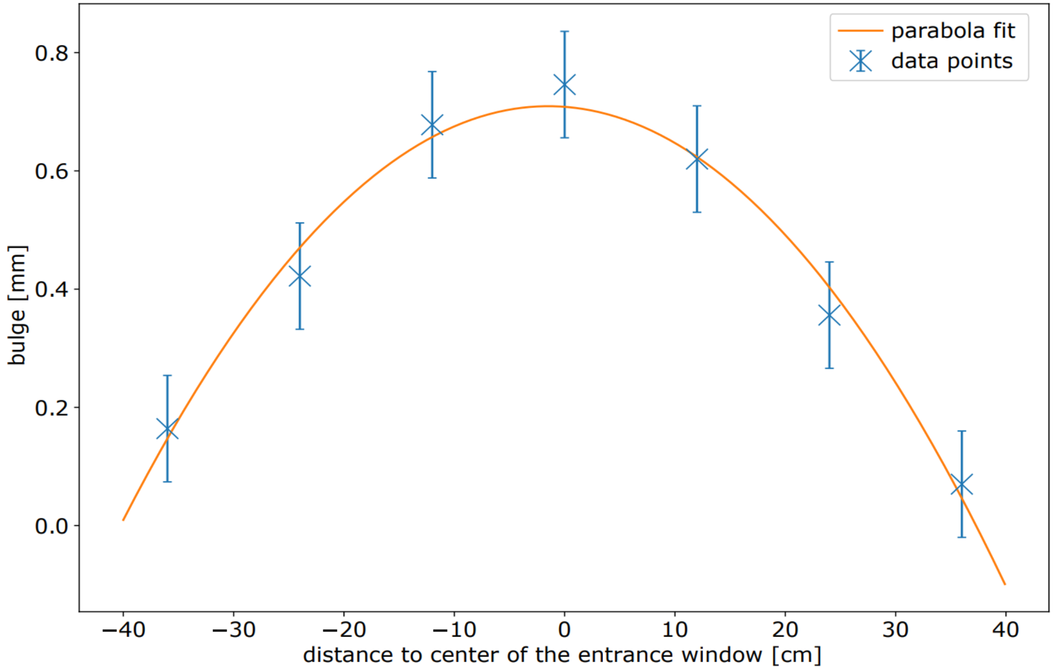
TRD GAS SYSTEM PRESSURE RANGE

- The large chamber has a volume of 11 liters
- Overpressure causes the bulging of the foil entrance window





According to calculations, the maximum permissible bulging is about 1 mm. In this case, distortion of the geometry of field lines and an increase in the path length for a particle does not require recalibration.



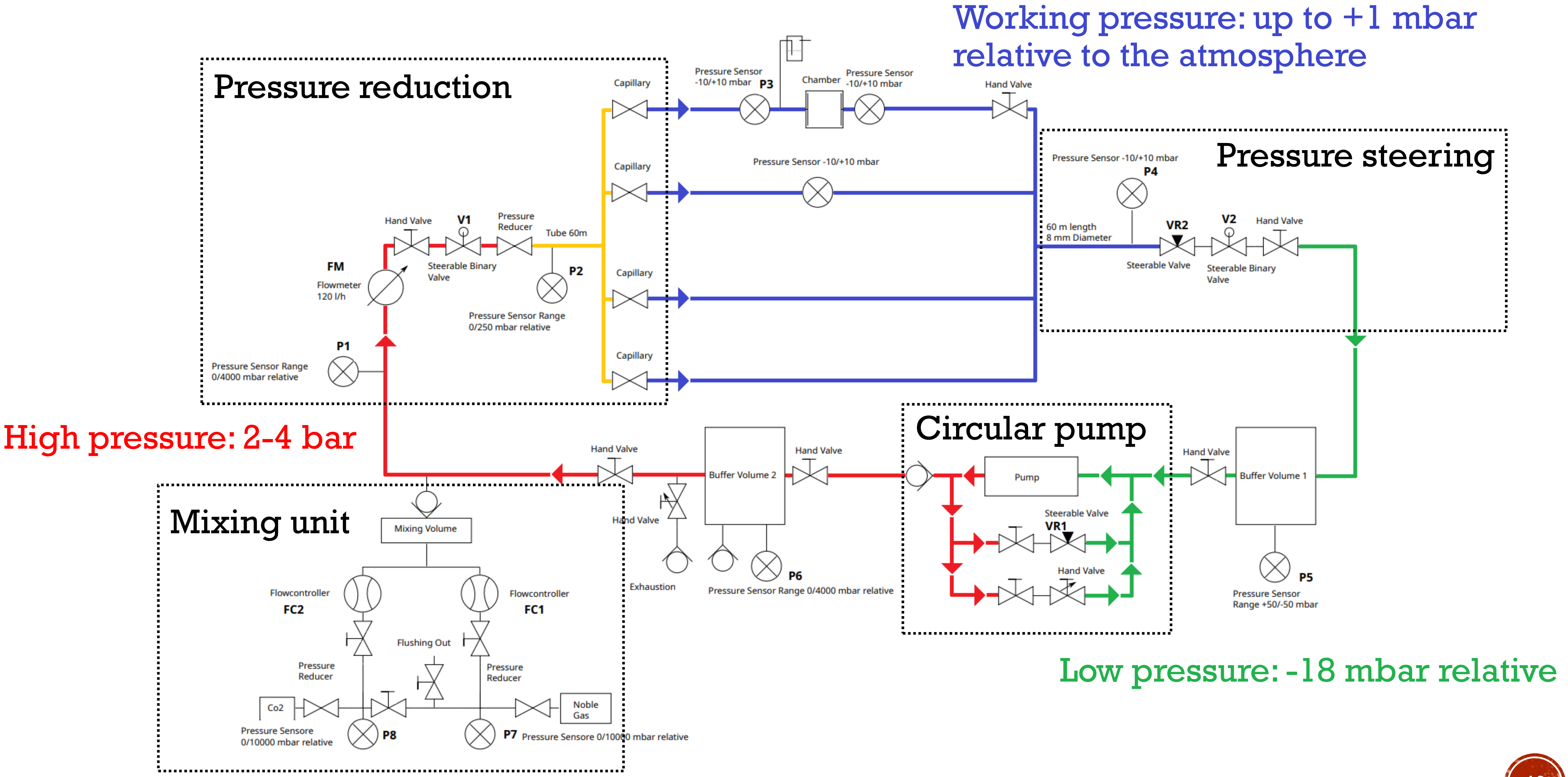
According to measurements, this requires overpressure below 0.7 mbar relative to atmospheric, which can increase the volume by 0.86 liters (~8%)

TRD GAS SYSTEM TEST LINE

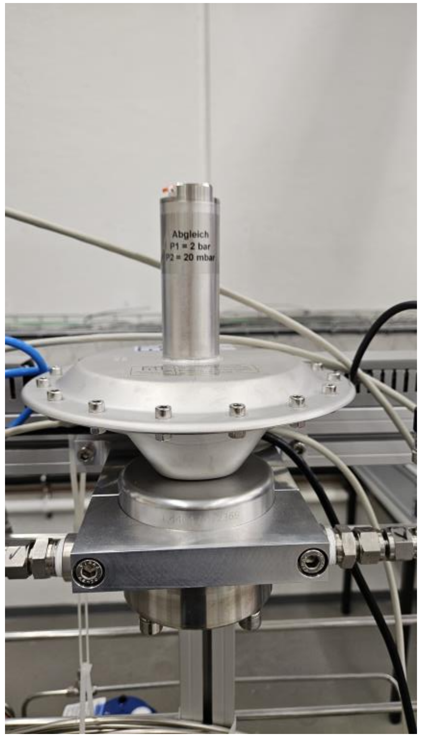
A team from Westfälische Wilhelms-Universität Münster has already developed a prototype of the gas system according to the requirements

The system is fully functional, it is capable of maintaining four TRD layers of a single level (at the same height)

TRD GAS SYSTEM TEST LINE LAYOUT



TRD GAS SYSTEM TEST LINE PRESSURE CONTROL



In the inlet zone, the pressure is reduced in two stages:

- The static pressure reducer reduces the pressure to 20 mbar
- In a ~60m pipe (4mm Ø), the pressure drops for a few more mbar

In front of the detector modules, a thin capillary tube (1mm Ø) is used, of a strictly selected length, to reduce the input pressure to 1 mbar

Sensors monitoring the pressure in each line

A bubbler is used here as an emergency fuse

The outlet zone includes a ~60m pipe (8mm Ø)

This is followed by a zone in which the pump creates an underpressure to suck out the gas mixture from the cave

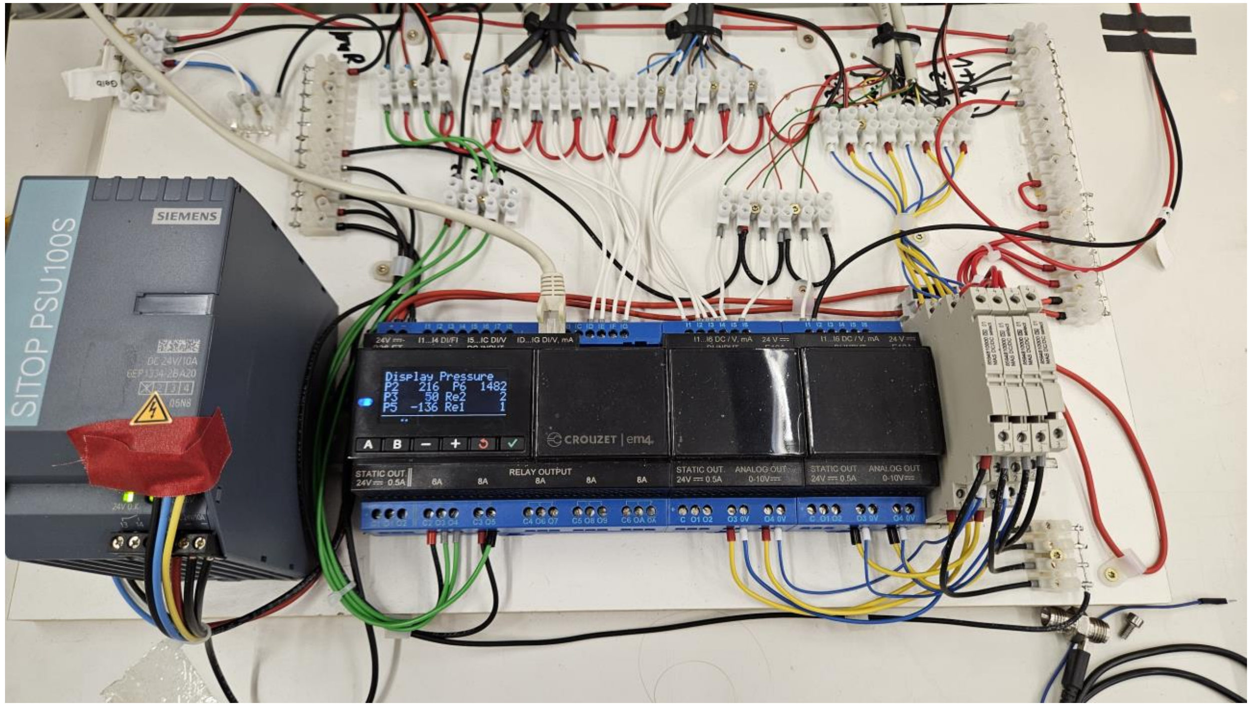
The steerable valve releases exactly as much gas as necessary to maintain the required pressure in the ROCs

TRD GAS SYSTEM TEST LINE CONTROLLER

The control system used is PLC Crouzet em4

It works fine with the prototype, not usable for the final gas system at CBM:

- Not enough inputs/outputs
- No good communication interface

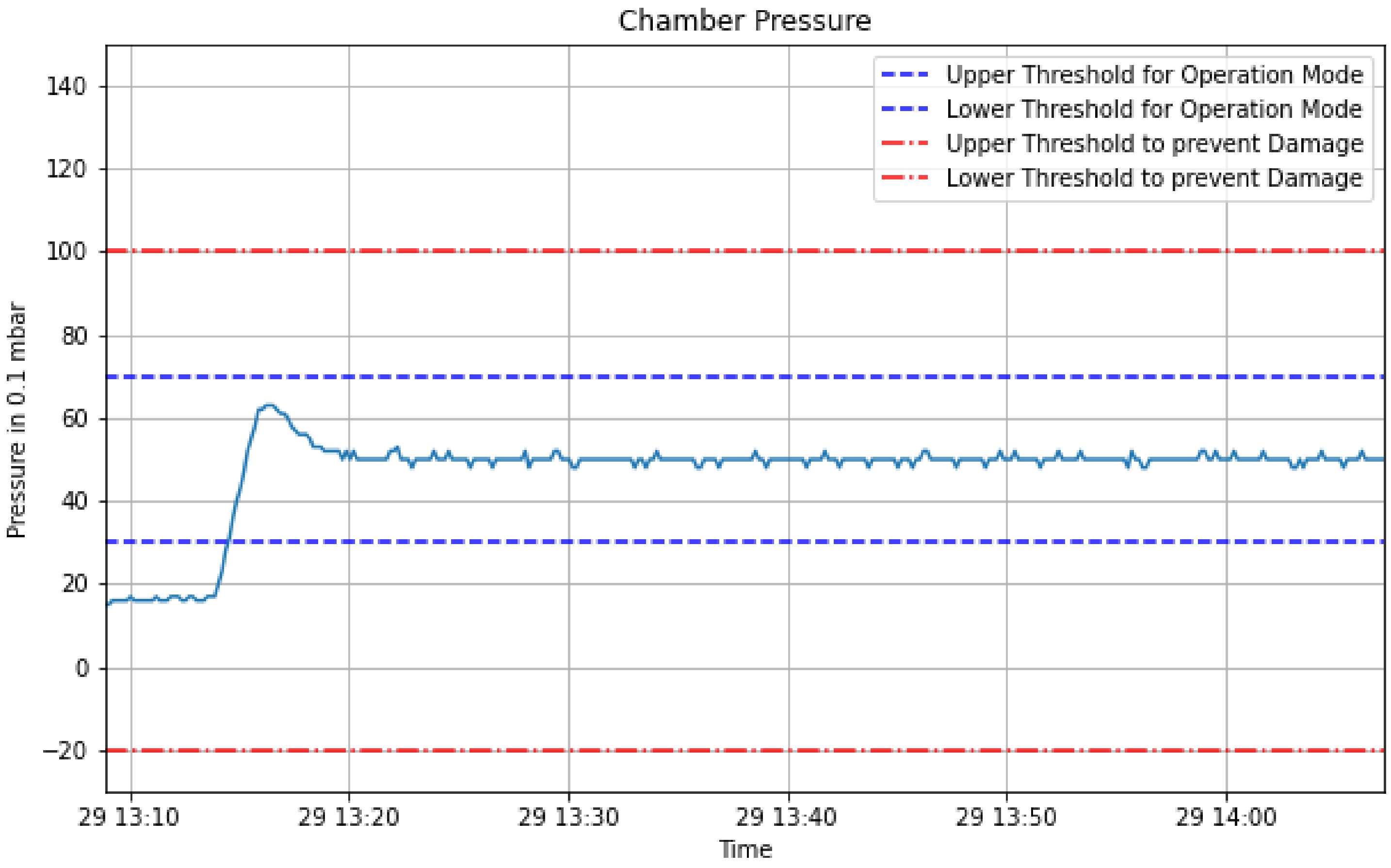


It is necessary to find a suitable control system that meets industrial standards for compatibility with gas system equipment

A significant part of my work will involve developing and customizing the software to control the gas system. This will be based on EPICS, which is the leading solution for slow control in large experiments

TRD GAS SYSTEM TEST LINE OPERATIONAL

- Filled with 82% Argon & 18% CO_2
- Fluctuations in ambient pressure of about 10 mbar over several days have been compensated easily within the operation conditions during long-term measurements
- No gas was lost during a test run
- Safety tests:
  - Disconnected tubes in the detector region
  - Disabling the pump
  - Power failure



pressure fluctuations during initialization

TRD GAS SYSTEM TEST LINE PLANS

Noteworthy progress:

- Participation in testing the pressure control and pump systems with dummy ROCs and conducting safety tests, including power cut-offs, leak detection, and pump failures
- Development of a system for monitoring the stability of atmospheric pressure and humidity
- Preparation for moving the prototype to the laboratory in Jülich

Key tasks ahead include:

- Finding a suitable control unit
- Development of a control program in the EPICS paradigm
- Integration of gas mixture analysis, purification, and recuperation systems