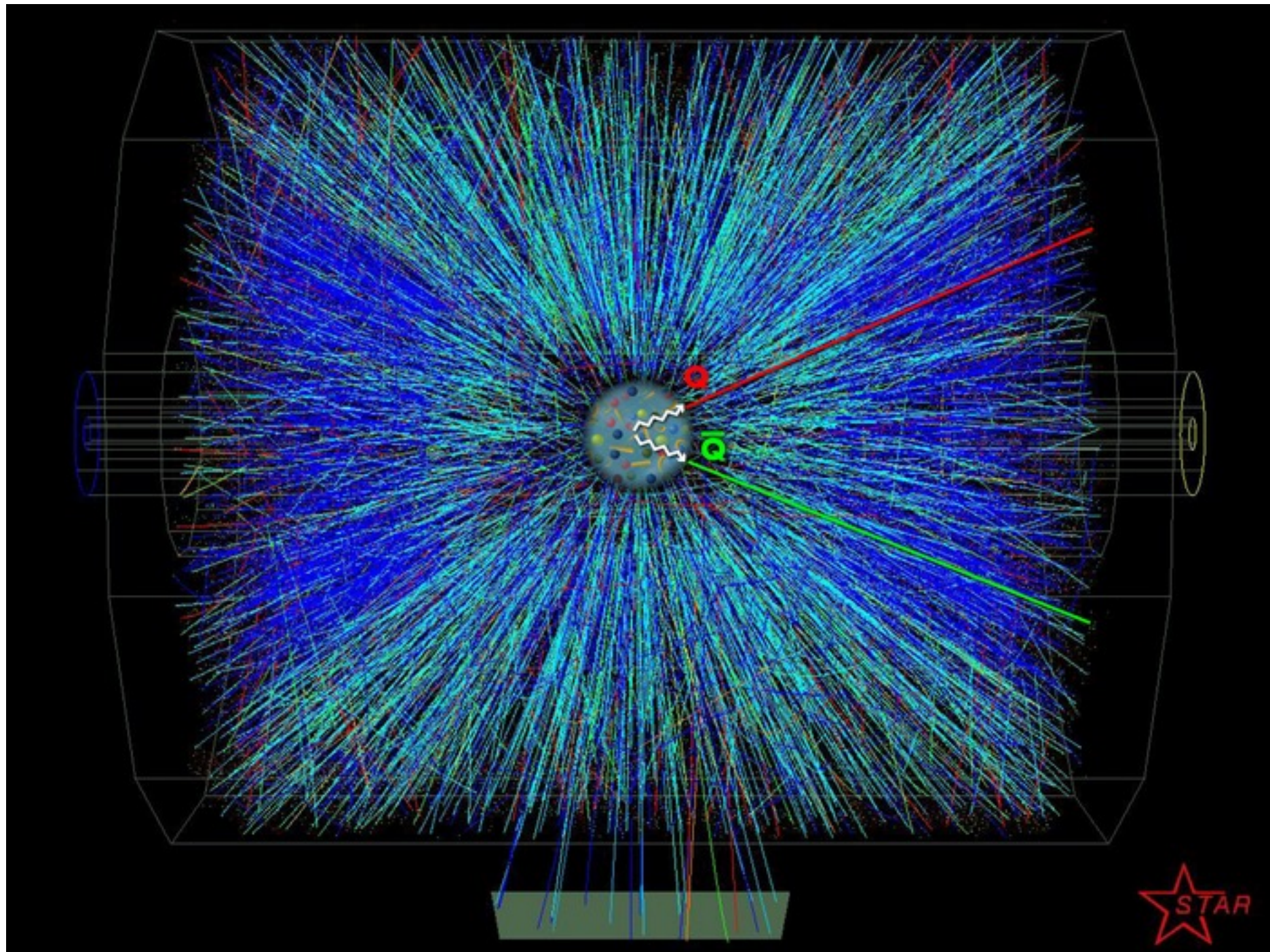
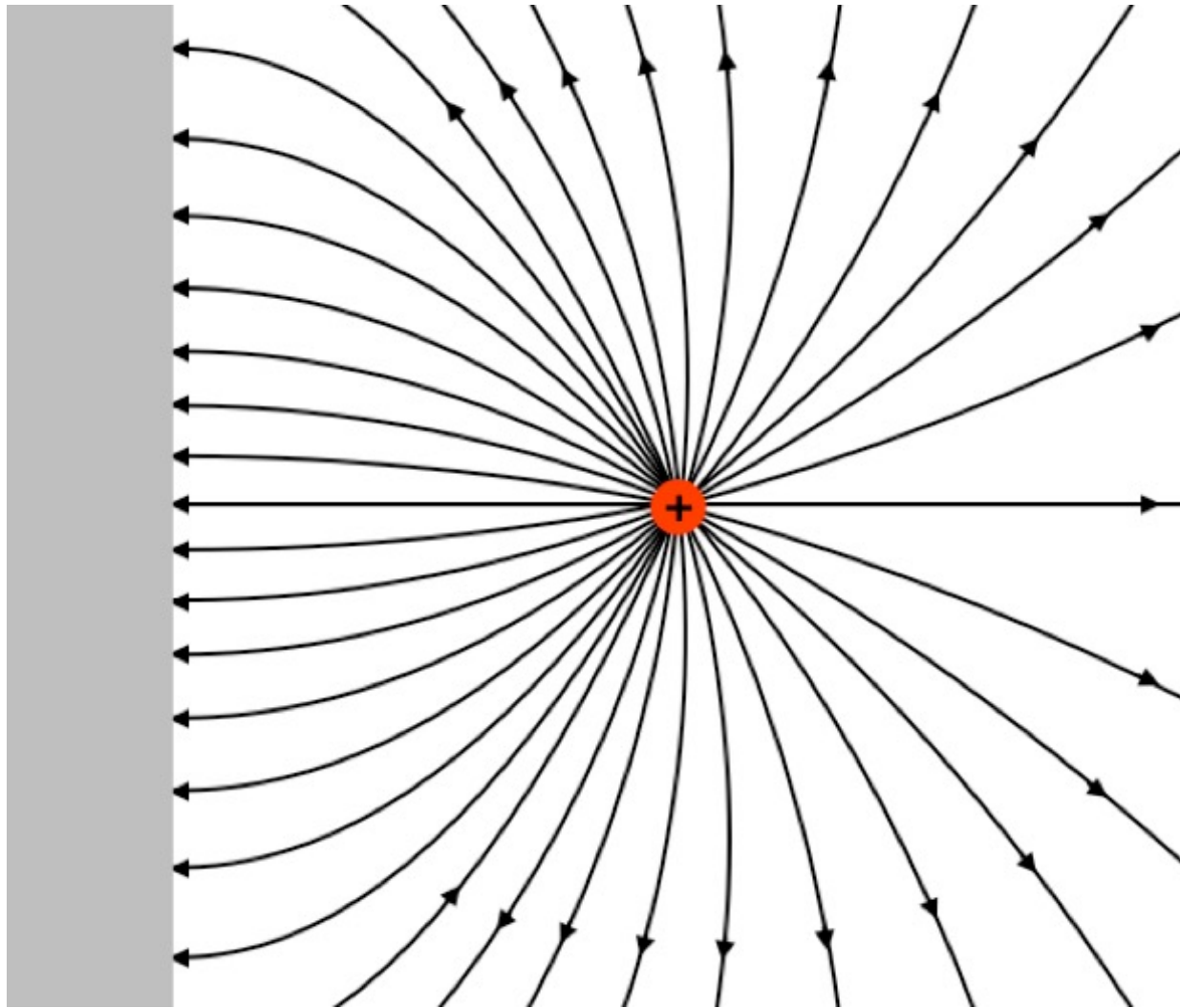


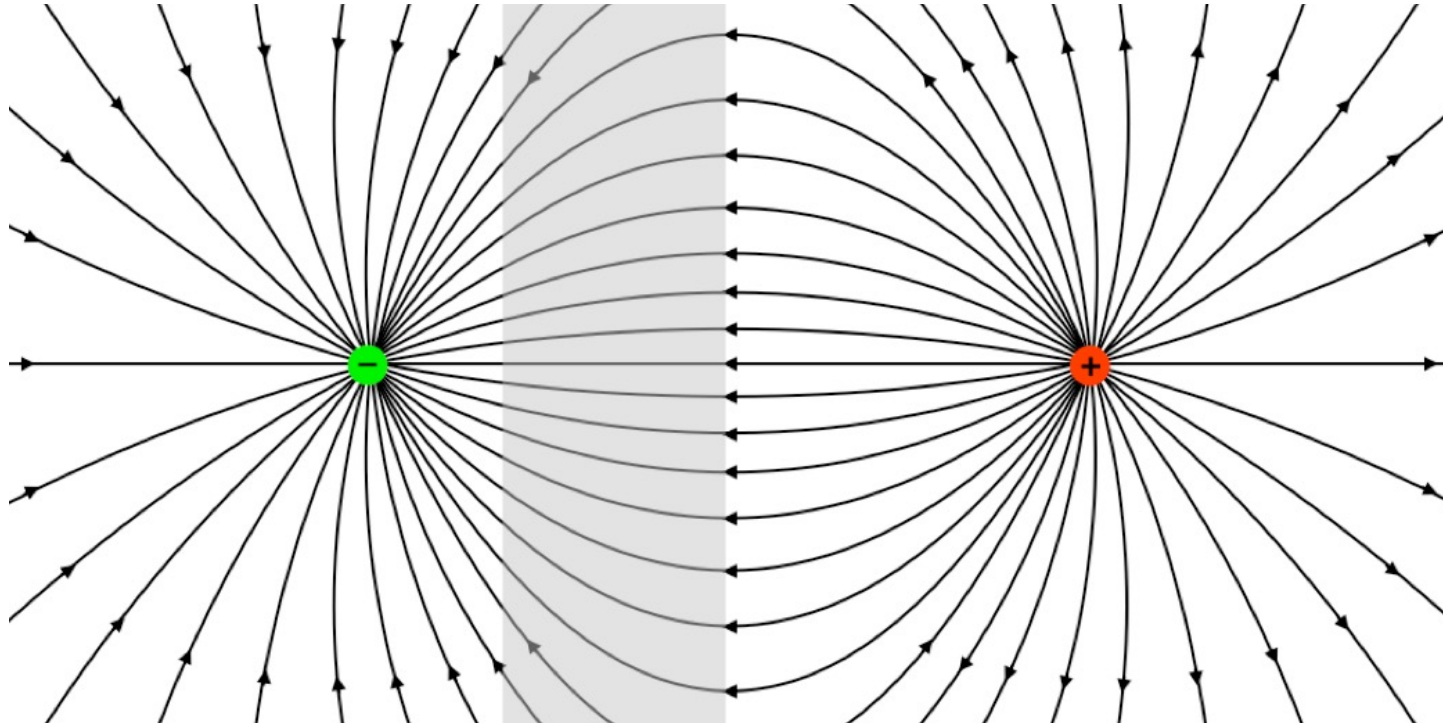
# Small-Strip Thin Gap Chamber (sTGC)

Prashanth Shanmuganathan





# Image Charge

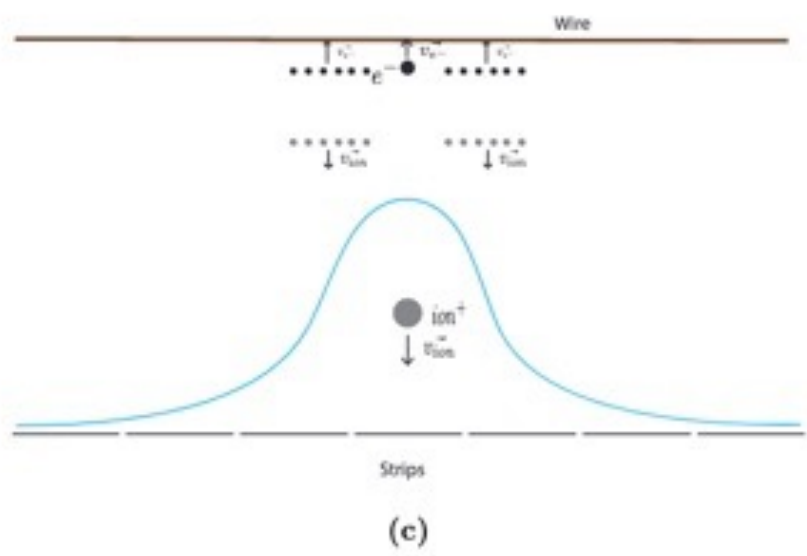
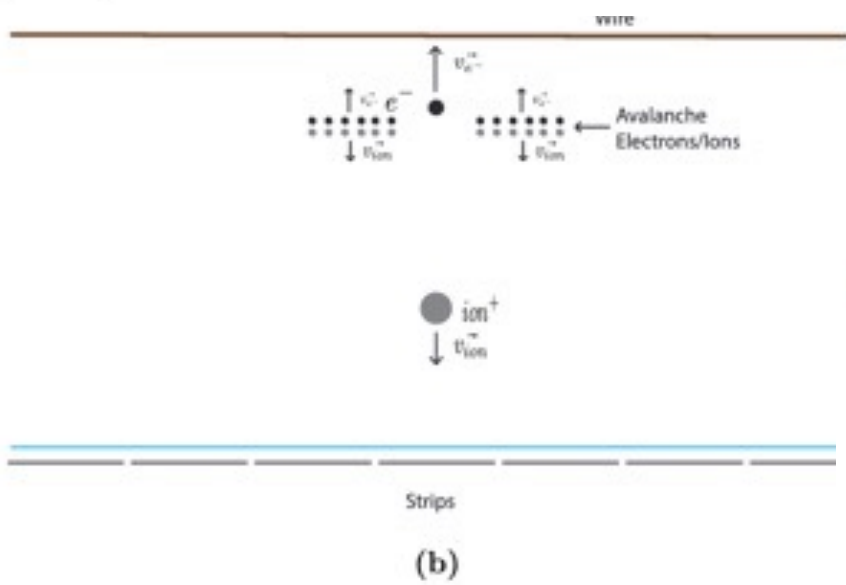
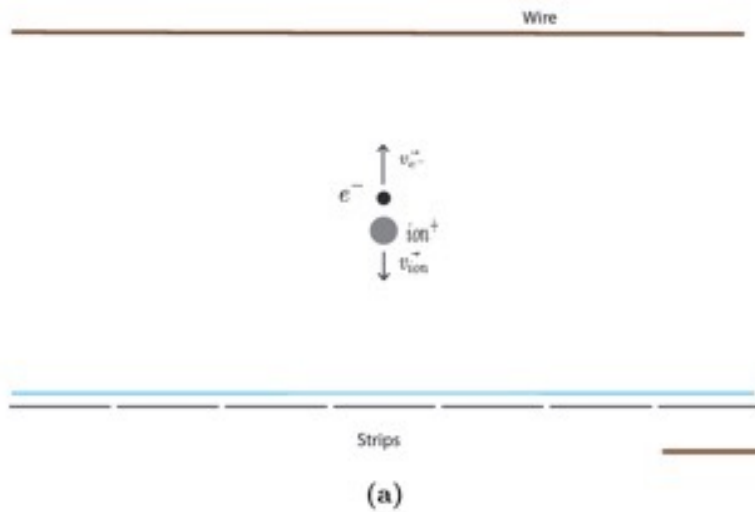


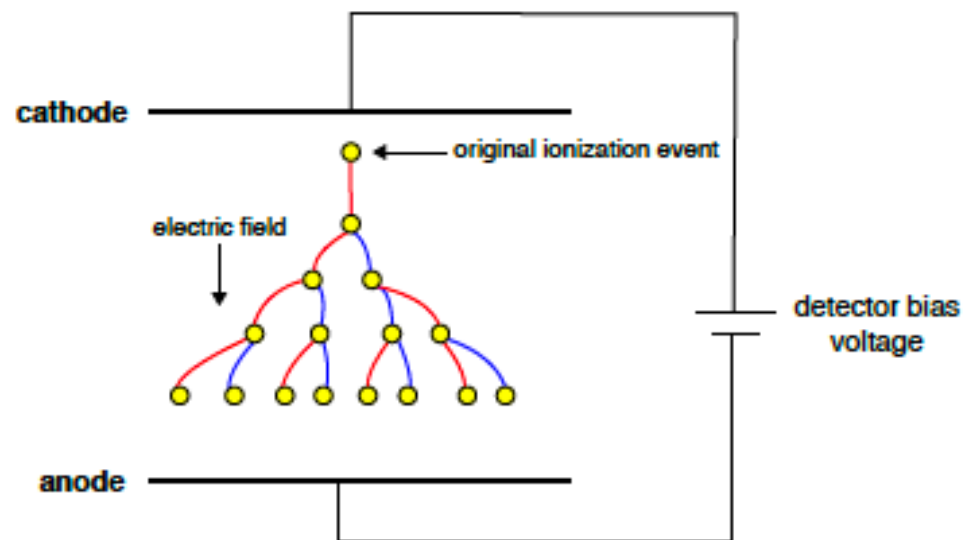
## A Clever Trick

The equivalence of these two fields provides us with an opportunity to use a clever trick for analyzing physical situations involving electric charges near flat conductors. For a point charge, this trick involves introducing an imaginary *image charge* reflected across the conducting surface, and using that charge to derive the actual field outside the conductor surface.

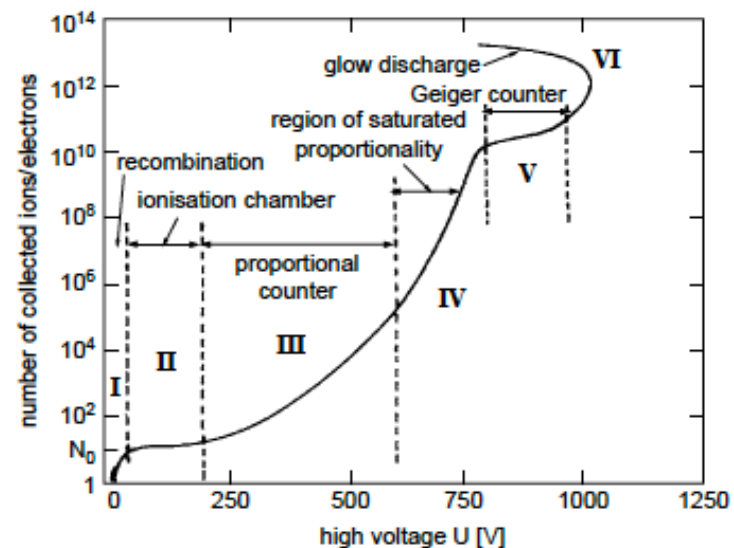
### Alert

*It can't be stressed enough that this trick does not involve introducing an actual physical charge, any more than constructing a gaussian surface involved constructing an actual physical surface. These are techniques for performing calculations, and one should always keep in mind what the actual physical circumstances are.*

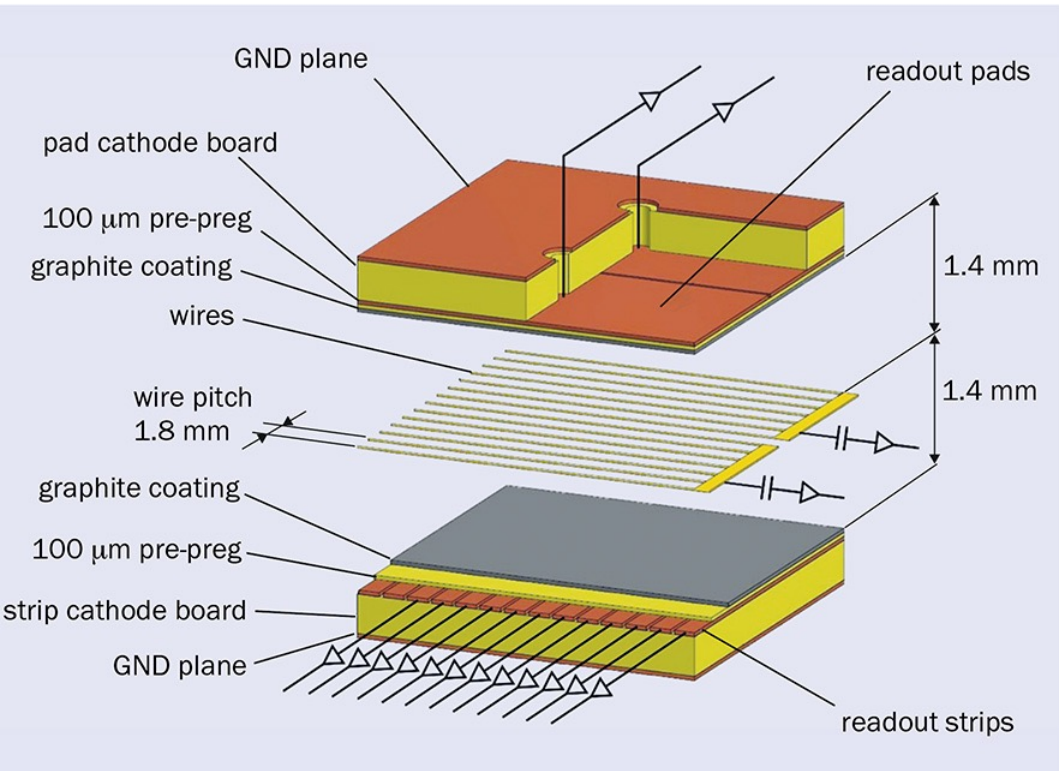


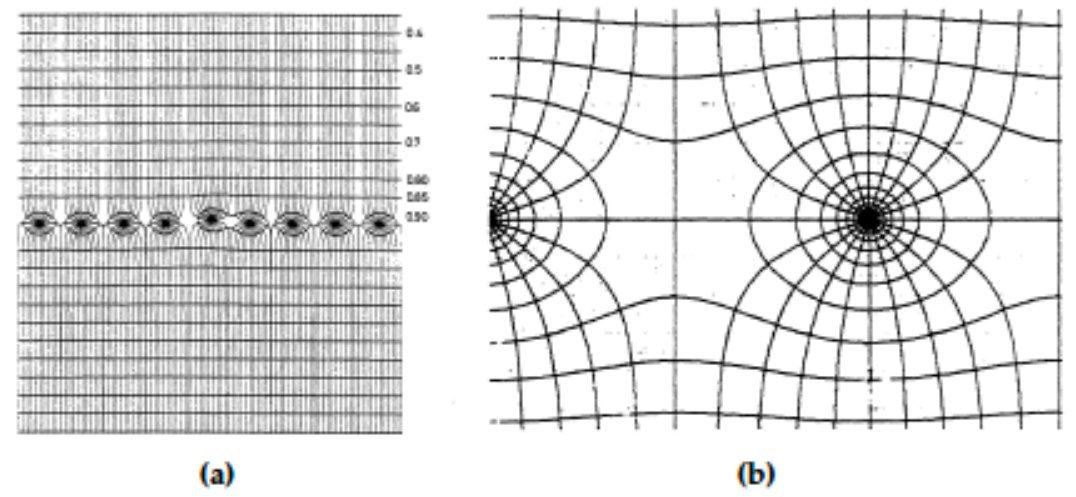
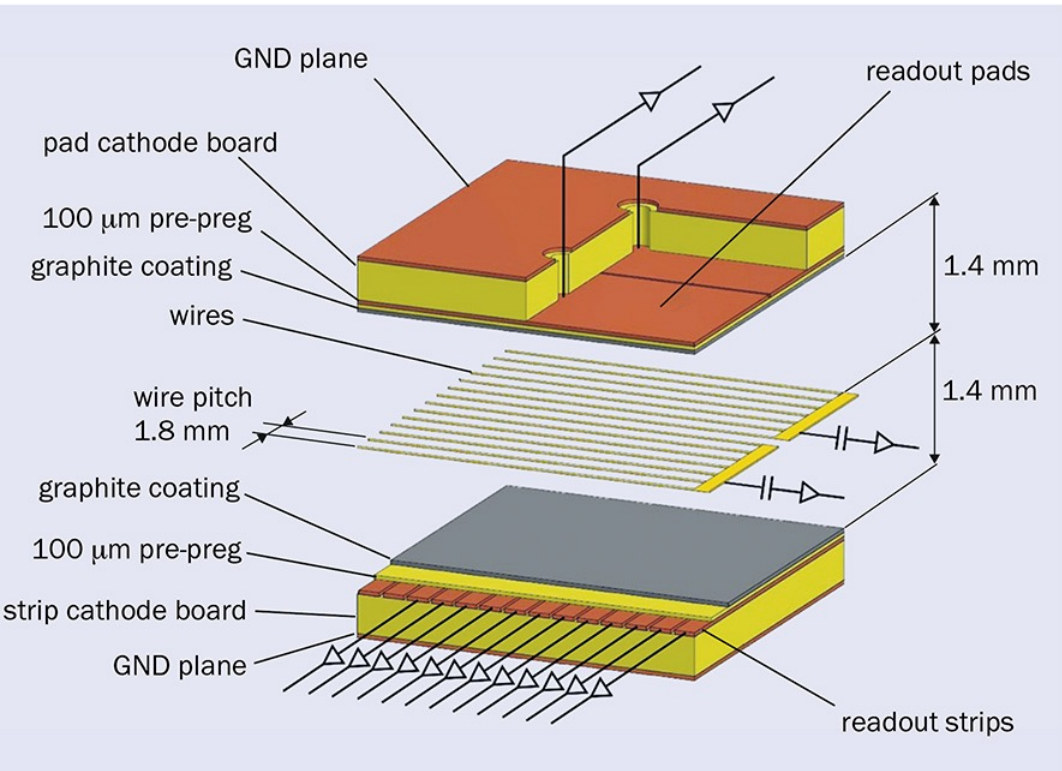


**Figure 2.6:** Schematic diagram of a Townsend avalanche. A strong electric field permeates the gaseous medium between the anode and the cathode. The yellow disks represent ionization events caused by an incident electron (red lines). Freed electrons (blue lines) produce more ionization events as they drift in the electric field. The total ionization approximately doubles at each step of the avalanche.



**Figure 2.7:** Ionization yield as a function of voltage for a typical ionization detector following the passage of a mip with a primary ionization  $N_0 \sim 10$  [32].

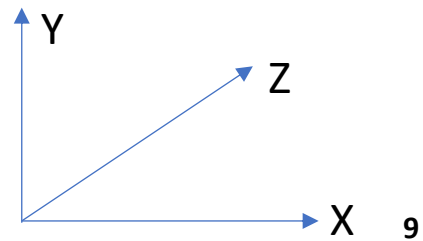
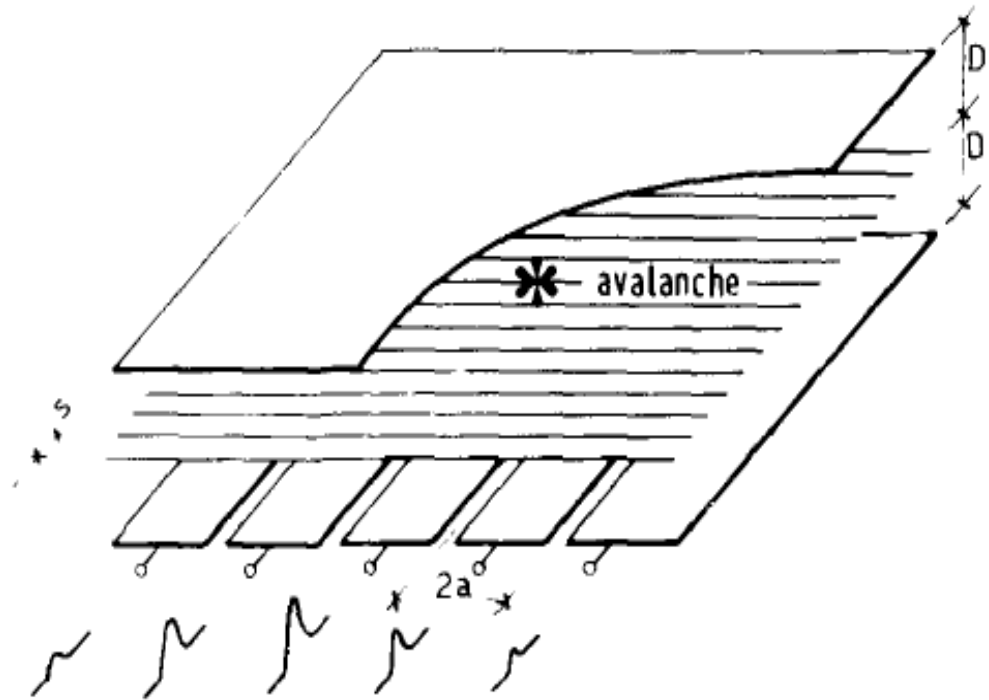




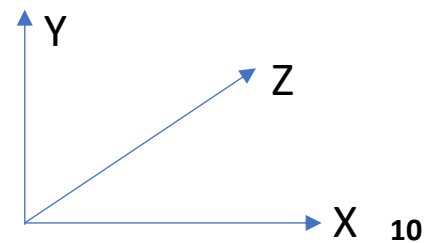
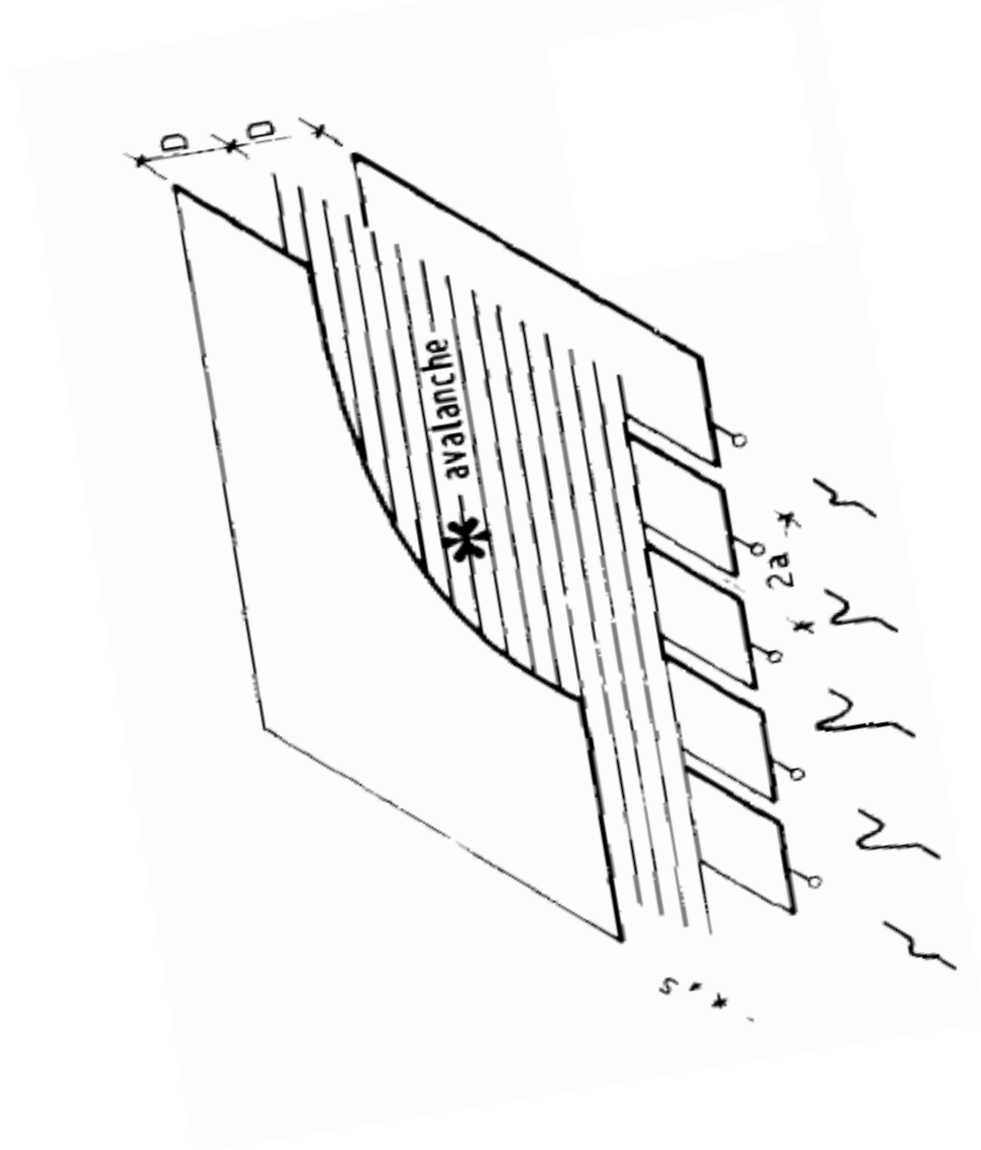
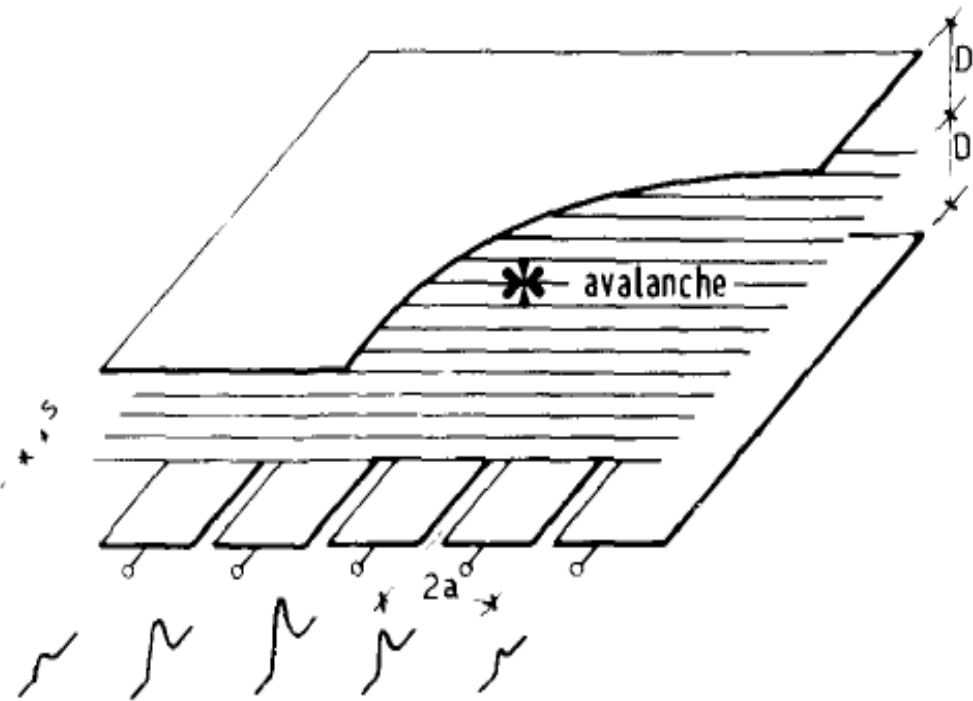
**Figure 2.11:** (a) Electric field lines and equipotentials in the gas volume of a multi-wire chamber. The electric potential relative to the anode wire potential, or value of  $V_0$ , is indicated. The effects of a minor displacement of one anode wire are shown. (b) Enlarged view of the same figure in the vicinity of a wire [14].



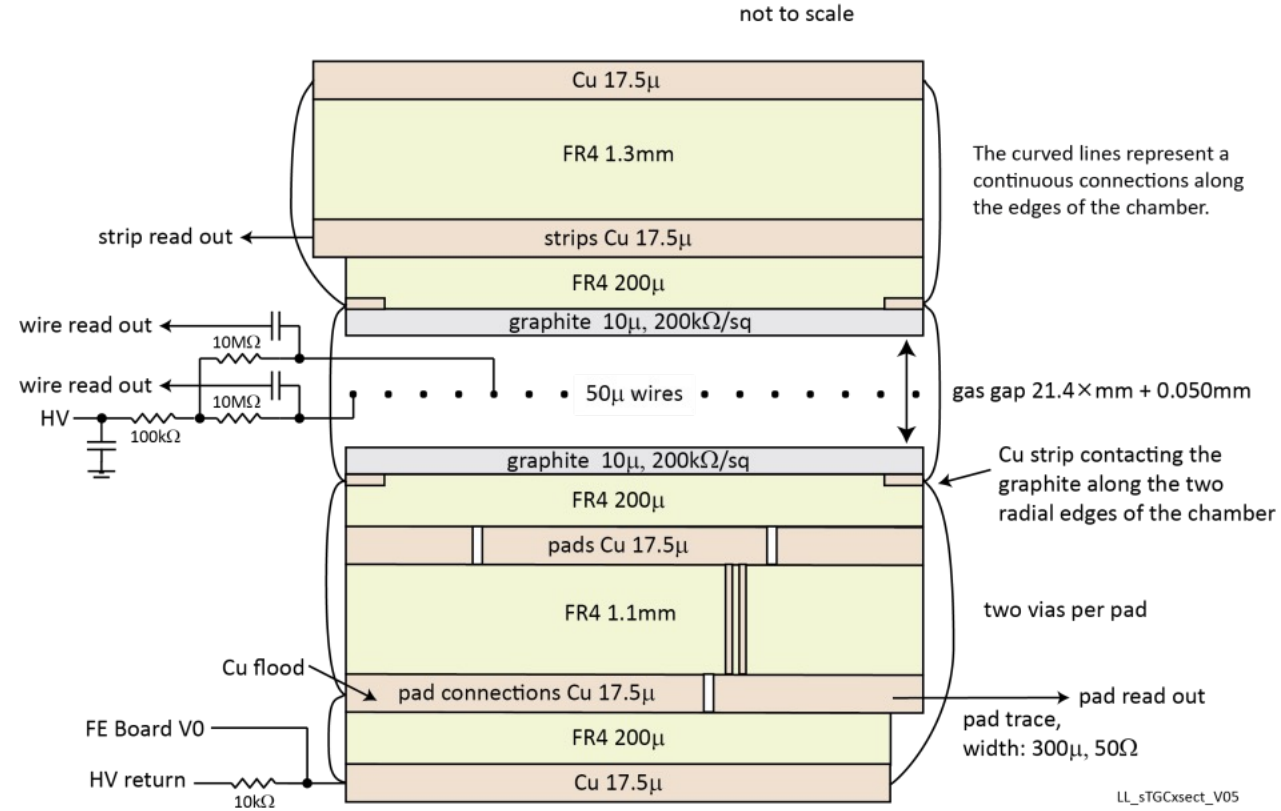
# Track reconstruction



# Track reconstruction



# sTGC cross-section



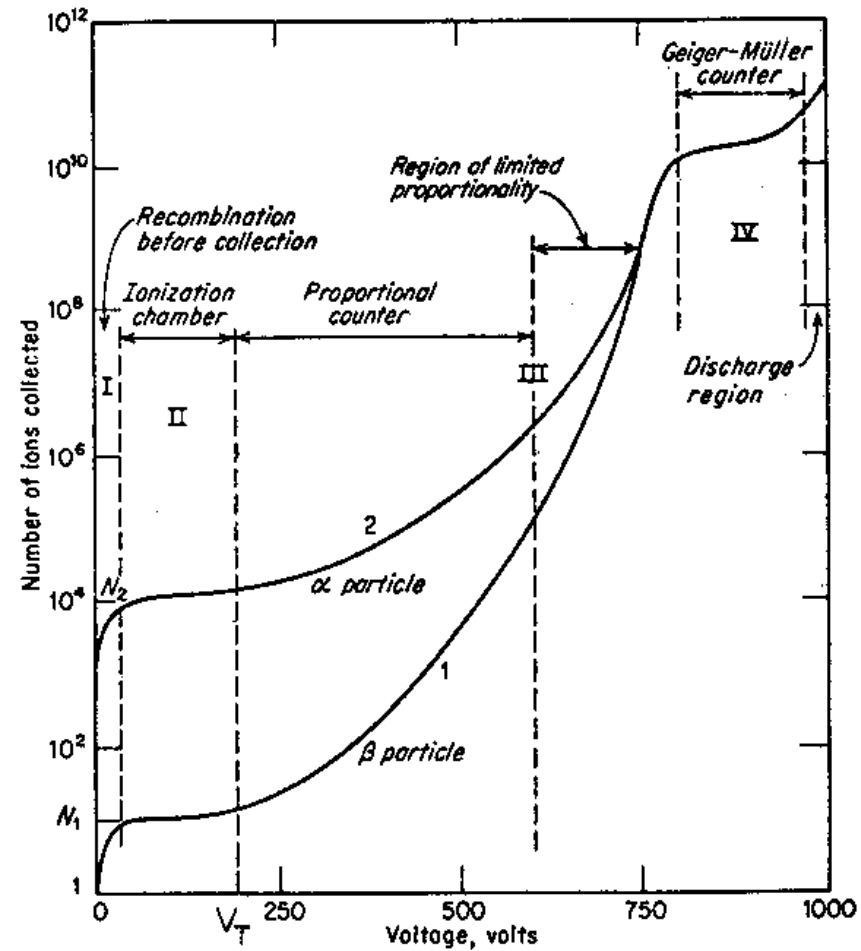


Fig. 50 Gain-voltage characteristics for a proportional counter, showing the different regions of operation (from W. Price, see bibliography for Sections 2 and 3).

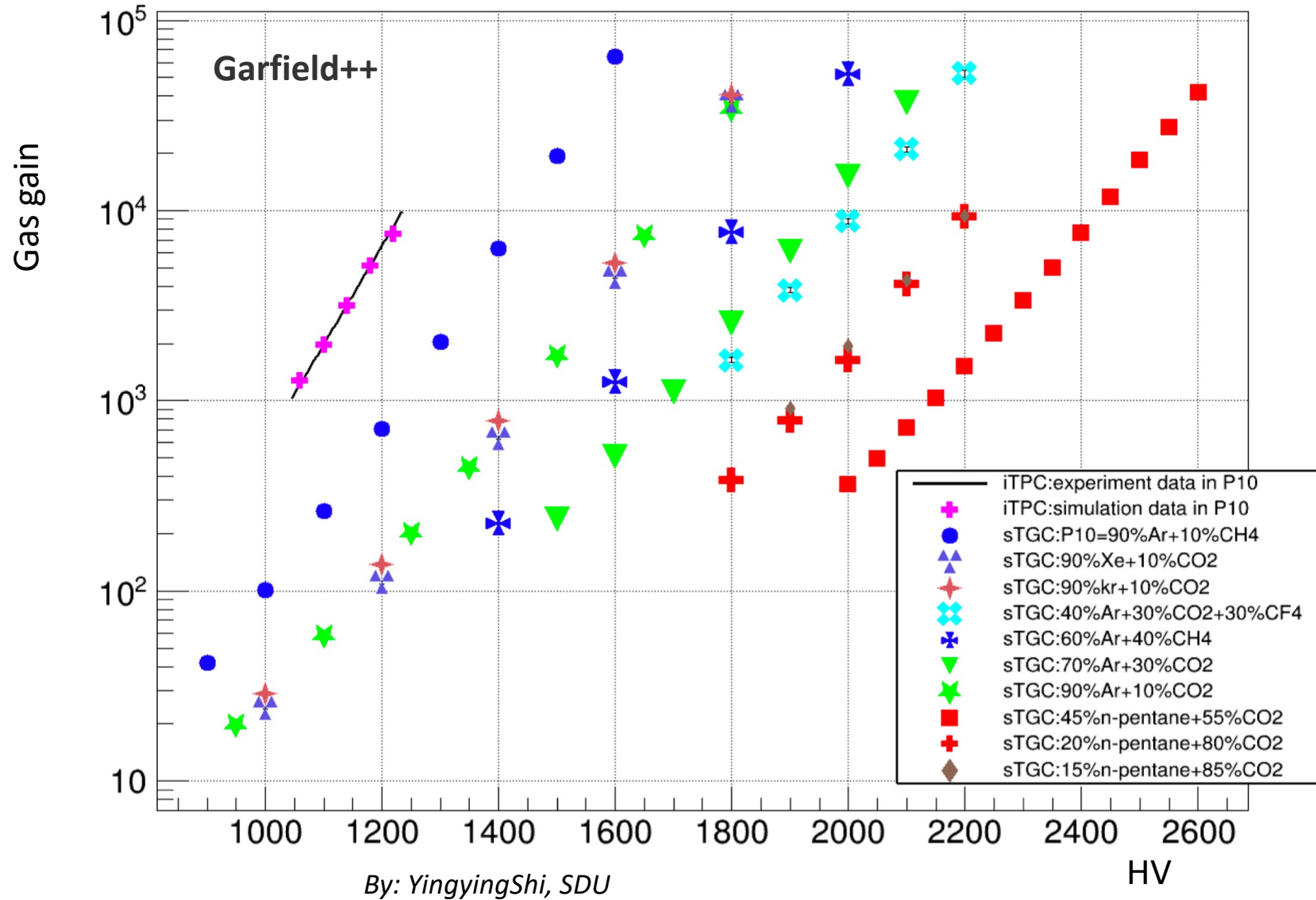
Table 1

Properties of several gases used in proportional counters (from different sources, see the bibliography for this section). Energy loss and ion pairs per unit length are given at atmospheric pressure for minimum ionizing particles

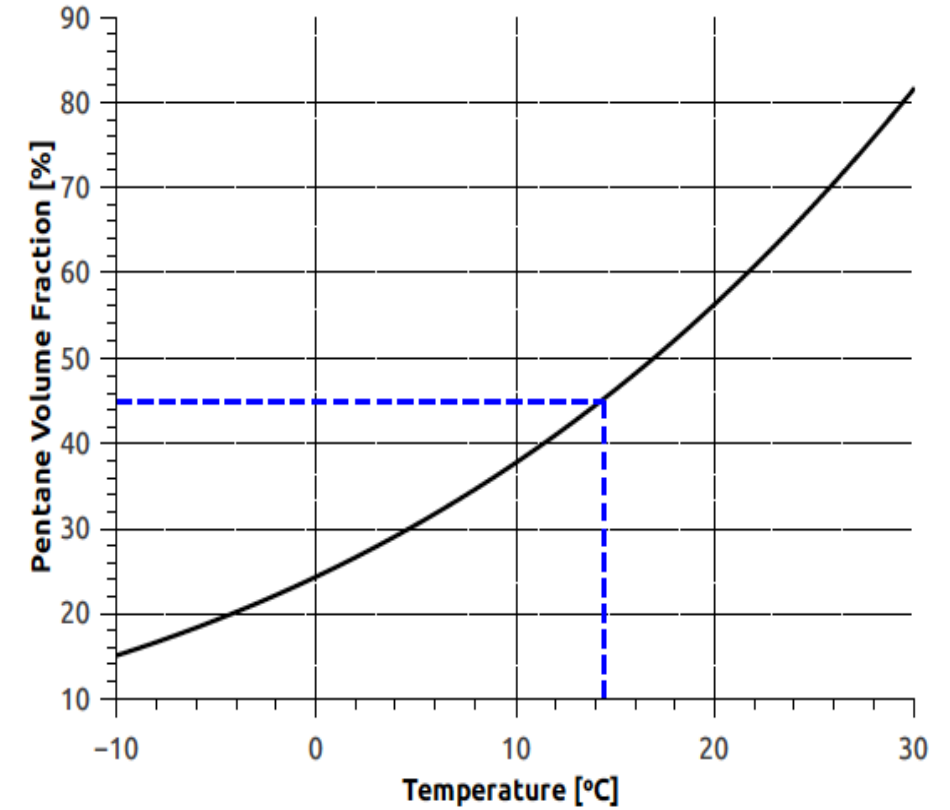
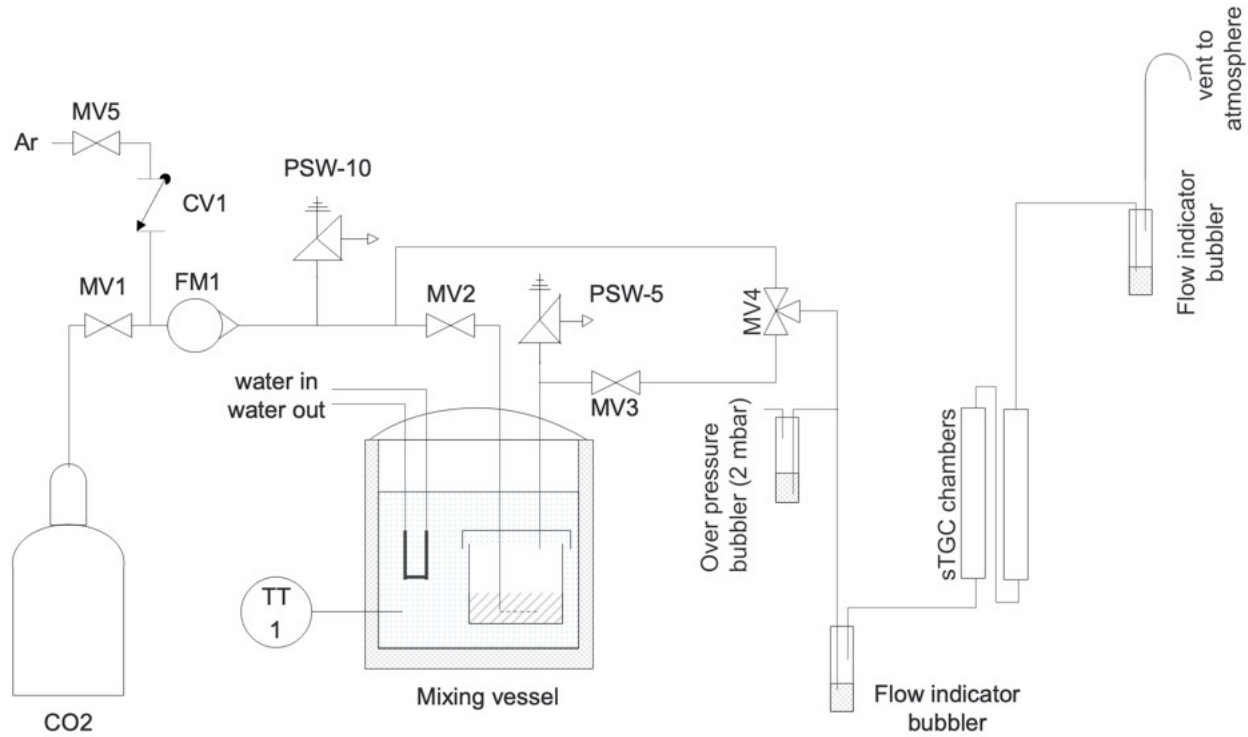
Gas	Z	A	$\delta$ (g/cm <sup>3</sup> )	E <sub>ex</sub>	E <sub>i</sub>   I <sub>0</sub>		W <sub>i</sub>	dE/dx		n <sub>p</sub> (i.p./cm) <sup>a)</sup>	n <sub>T</sub> (i.p./cm) <sup>a)</sup>
					(eV)			(MeV/g cm <sup>-2</sup> )	(keV/cm)		
H <sub>2</sub>	2	2	8.38 × 10 <sup>-5</sup>	10.8	15.9	15.4	37	4.03	0.34	5.2	9.2
He	2	4	1.66 × 10 <sup>-4</sup>	19.8	24.5	24.6	41	1.94	0.32	5.9	7.8
N <sub>2</sub>	14	28	1.17 × 10 <sup>-3</sup>	8.1	16.7	15.5	35	1.68	1.96	(10)	56
O <sub>2</sub>	16	32	1.33 × 10 <sup>-3</sup>	7.9	12.8	12.2	31	1.69	2.26	22	73
Nc	10	20.2	8.39 × 10 <sup>-4</sup>	16.6	21.5	21.6	36	1.68	1.41	12	39
Ar	18	39.9	1.66 × 10 <sup>-3</sup>	11.6	15.7	15.8	26	1.47	2.44	29.4	94
Kr	36	83.8	3.49 × 10 <sup>-3</sup>	10.0	13.9	14.0	24	1.32	4.60	(22)	192
Xc	54	131.3	5.49 × 10 <sup>-3</sup>	8.4	12.1	12.1	22	1.23	6.76	44	307
CO <sub>2</sub>	22	44	1.86 × 10 <sup>-3</sup>	5.2	13.7	13.7	33	1.62	3.01	(34)	91
Cl <sub>4</sub>	10	16	6.70 × 10 <sup>-4</sup>		15.2	13.1	28	2.21	1.48	16	53
C <sub>4</sub> H <sub>10</sub>	34	58	2.42 × 10 <sup>-3</sup>		10.6	10.8	23	1.86	4.50	(46)	195

a) i.p. = ion pairs

# Gas Choices

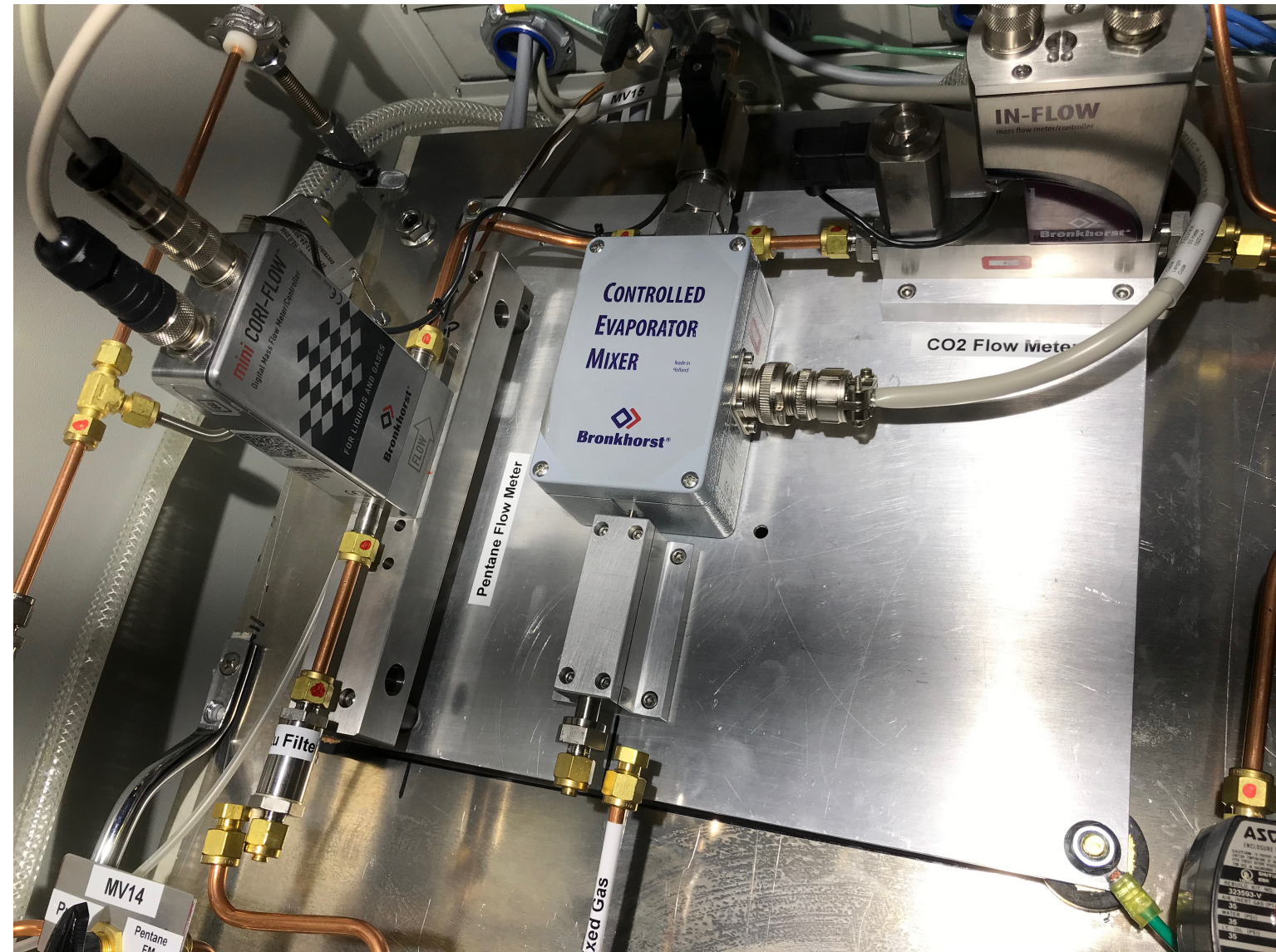
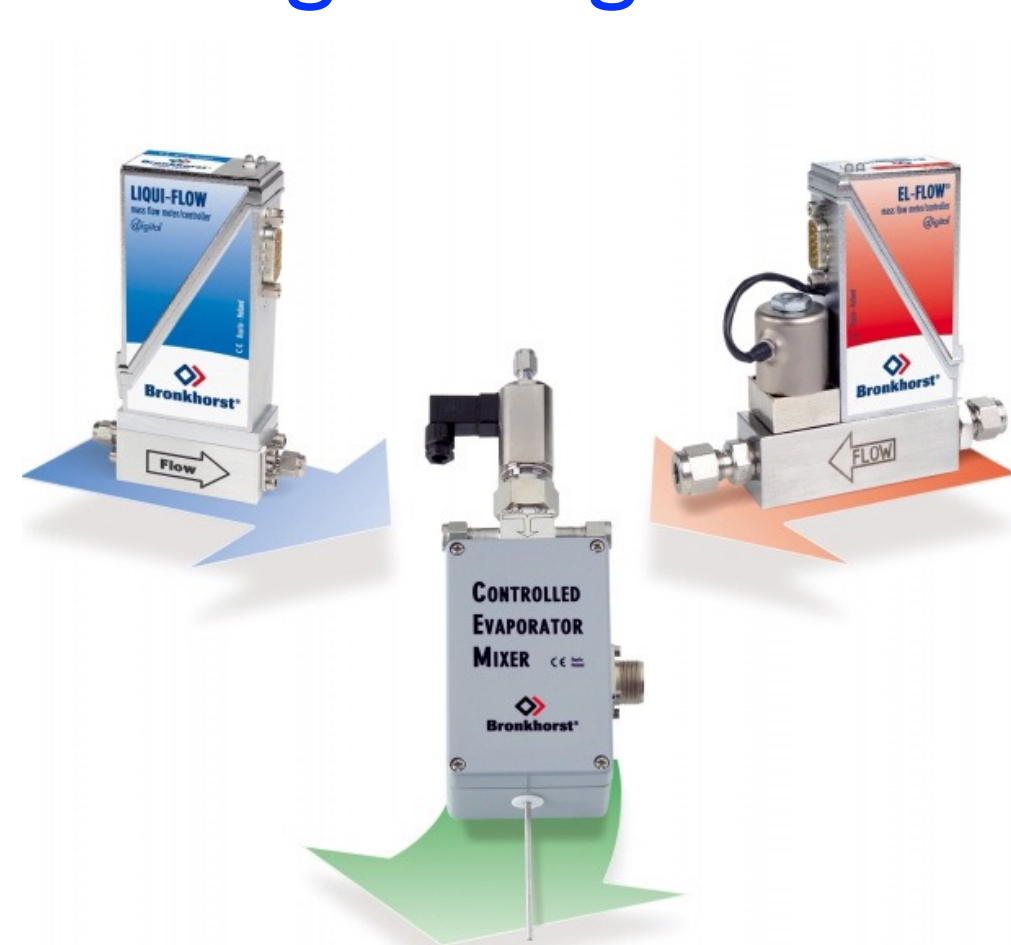


# Getting the right mixture



arXiv:1702.01240v3 [physics.ins-det]

# Getting the right mixture



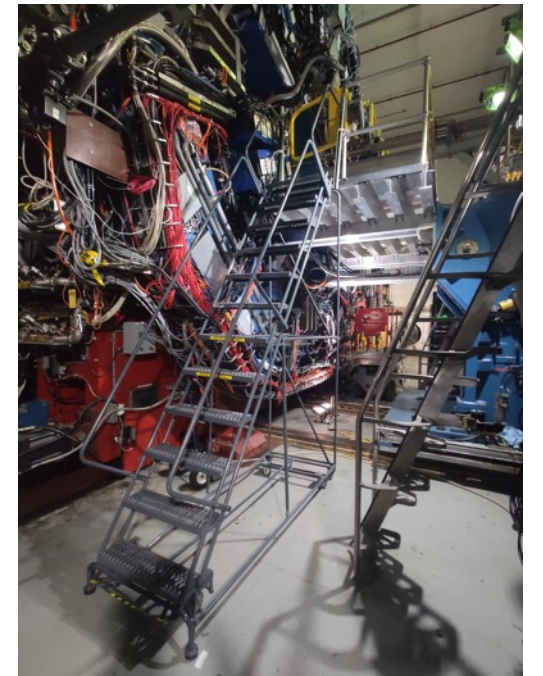
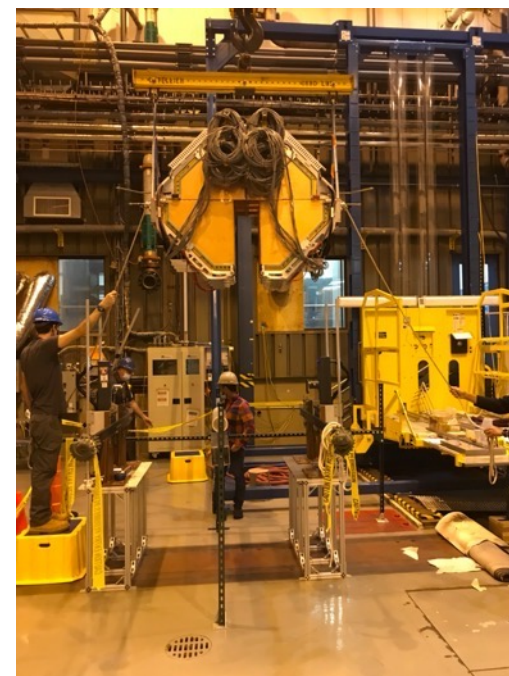
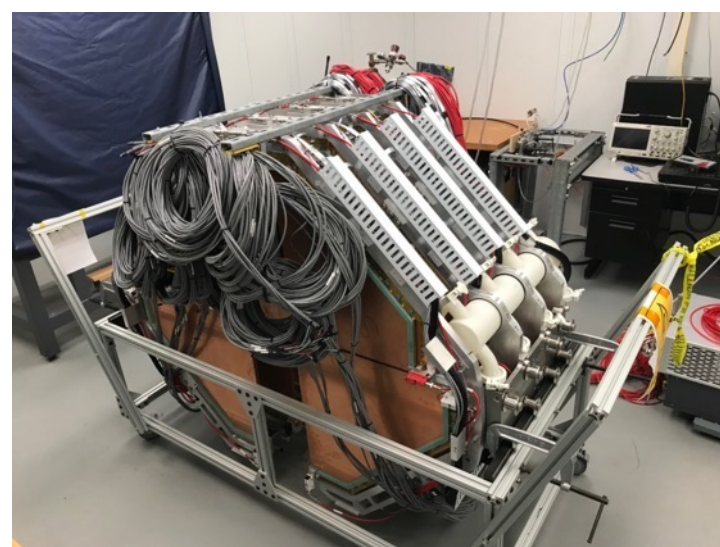
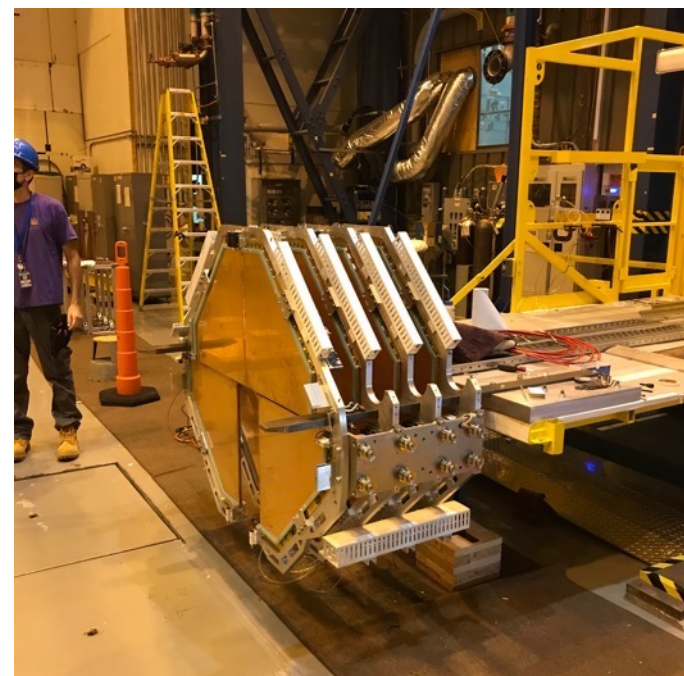
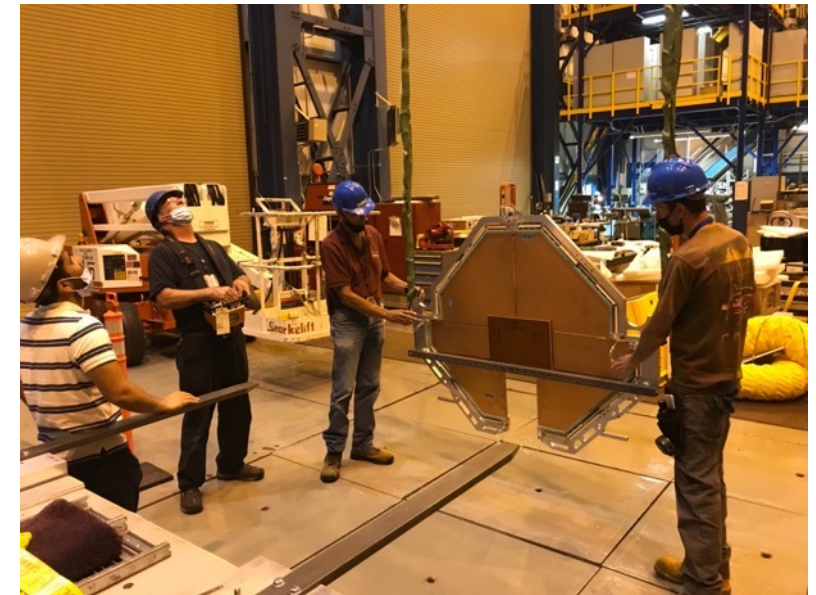
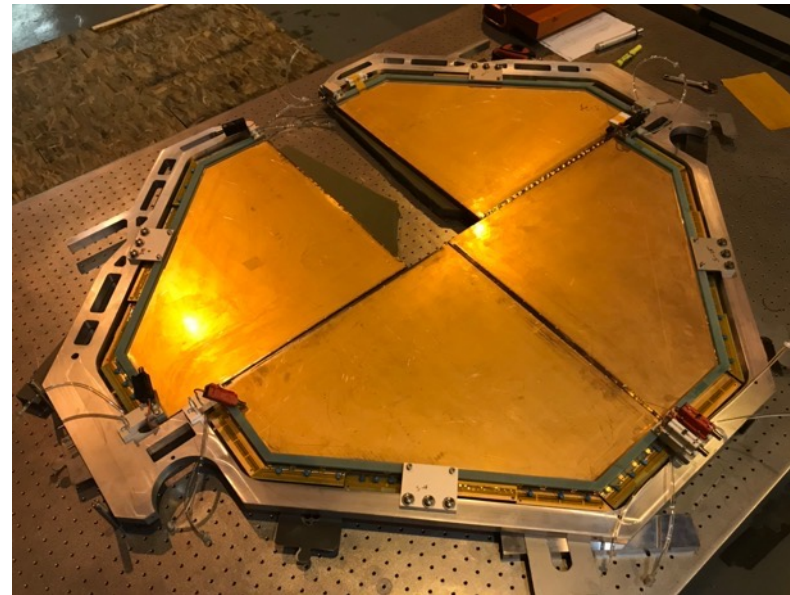
Bronkhorst components assembled in the gas cabinet



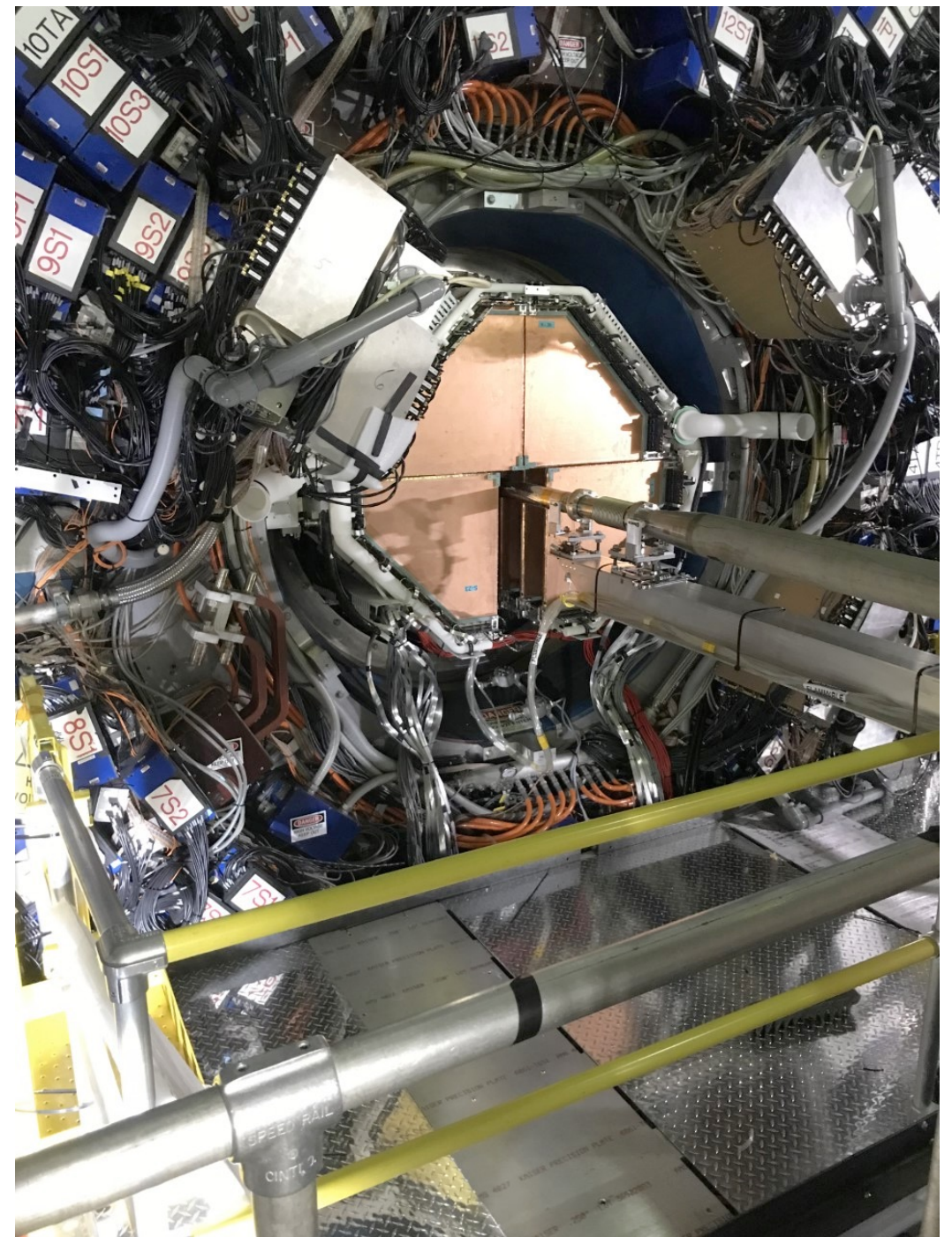
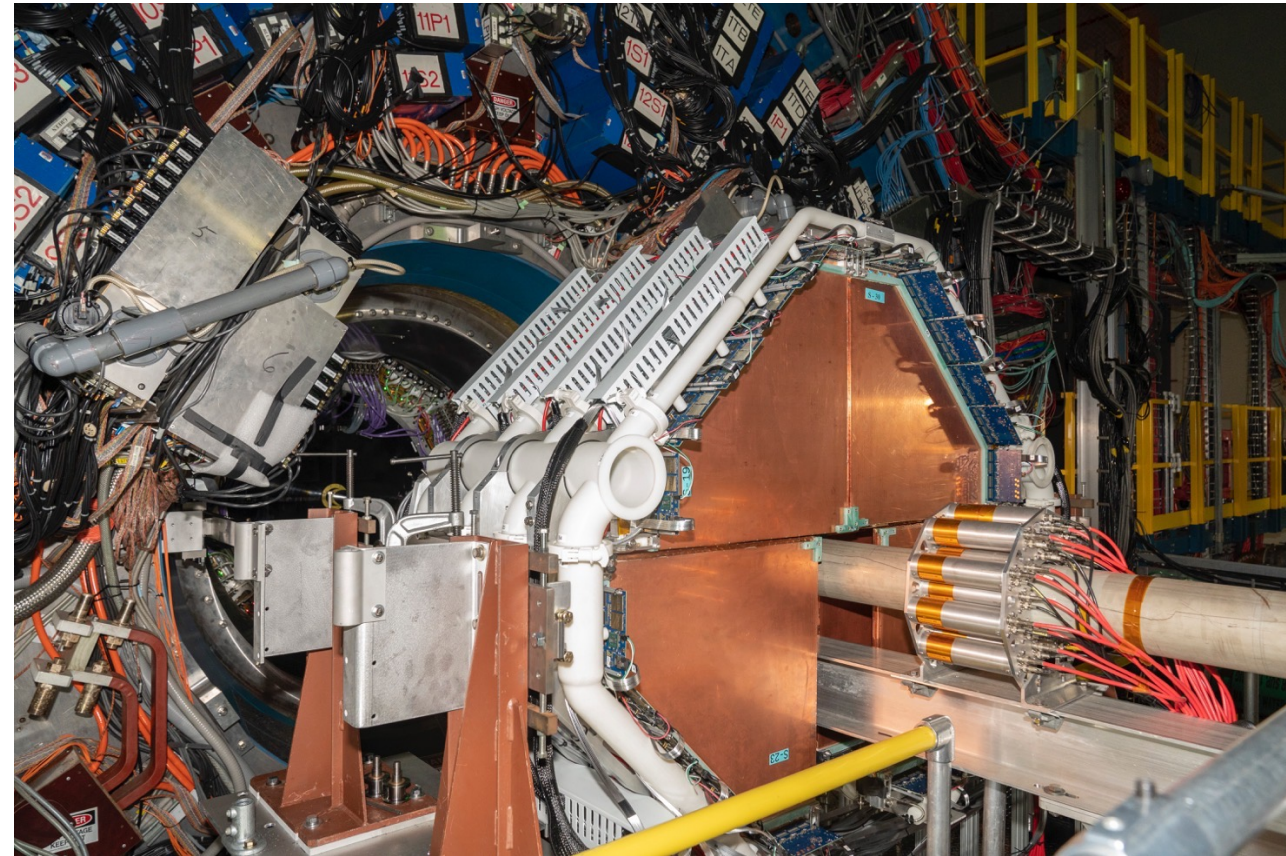
# sTGC Operations Reequipments

- Anode (HV): 50  $\mu\text{m}$  gold-plated tungsten wires held at a potential of  $\sim 2900\text{ V}$
- Working gas: n-Pentane+CO<sub>2</sub>= 45:55% by volume
- Supply pressure 2 mbar above atm
- Flow about 50 cc/min

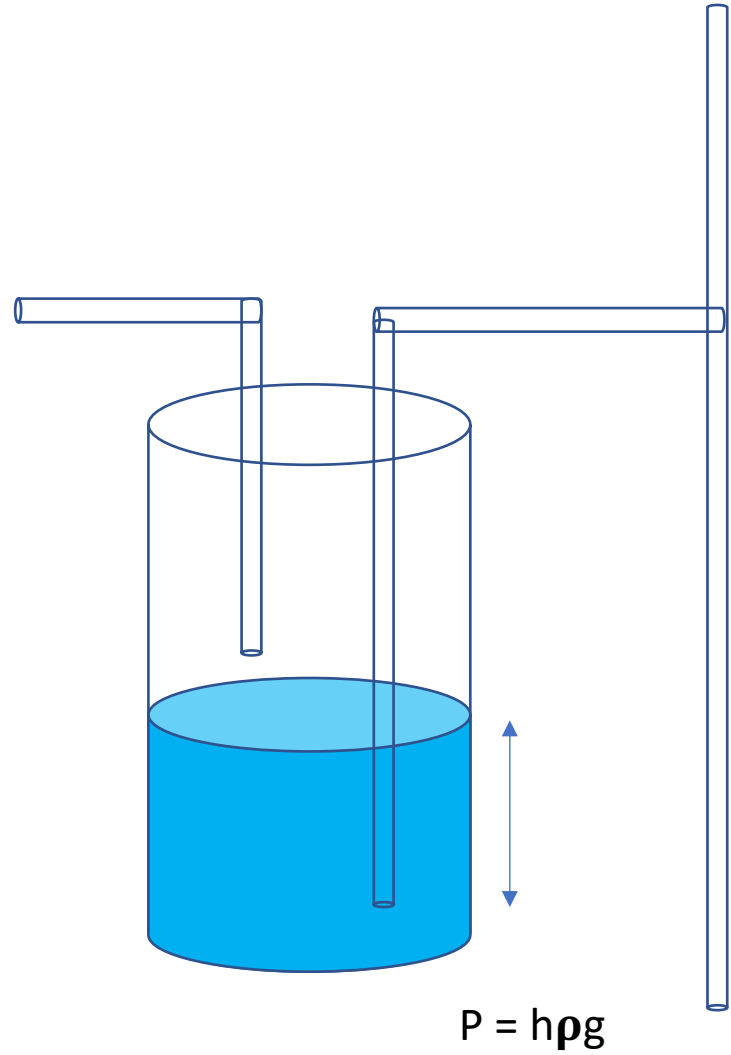
# sTGC Detector Assembly



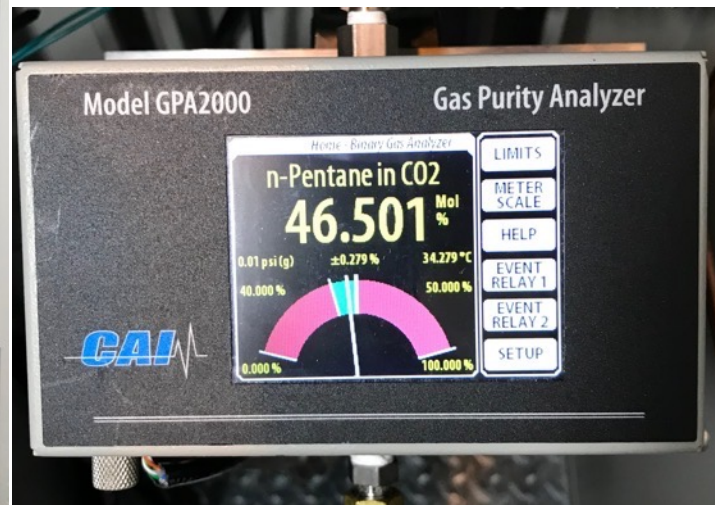
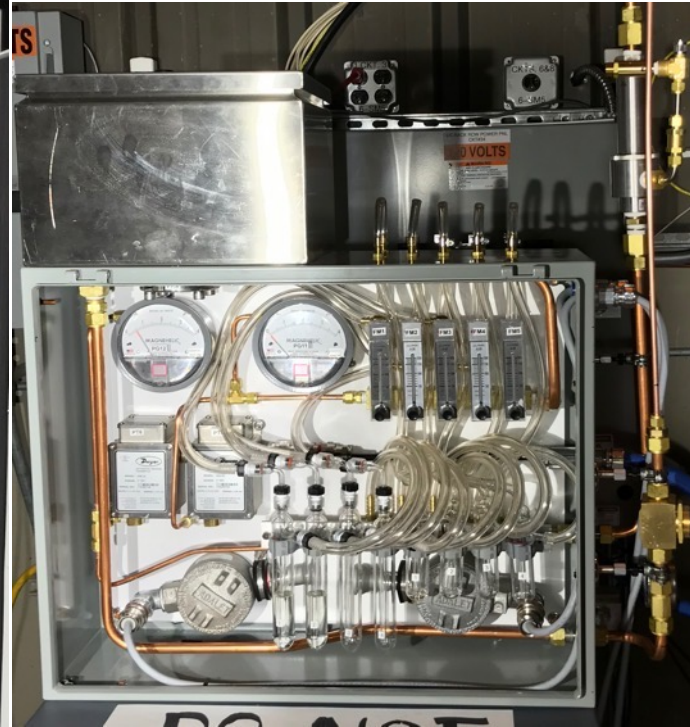
# sTGC Detector Assembly



# Protecting the chambers from over pressure



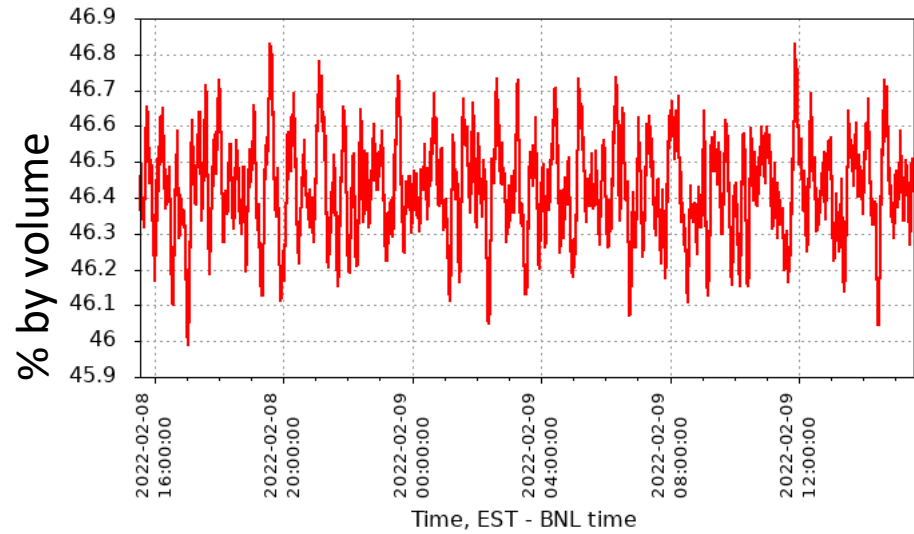
# Gas System



## n-Pentane

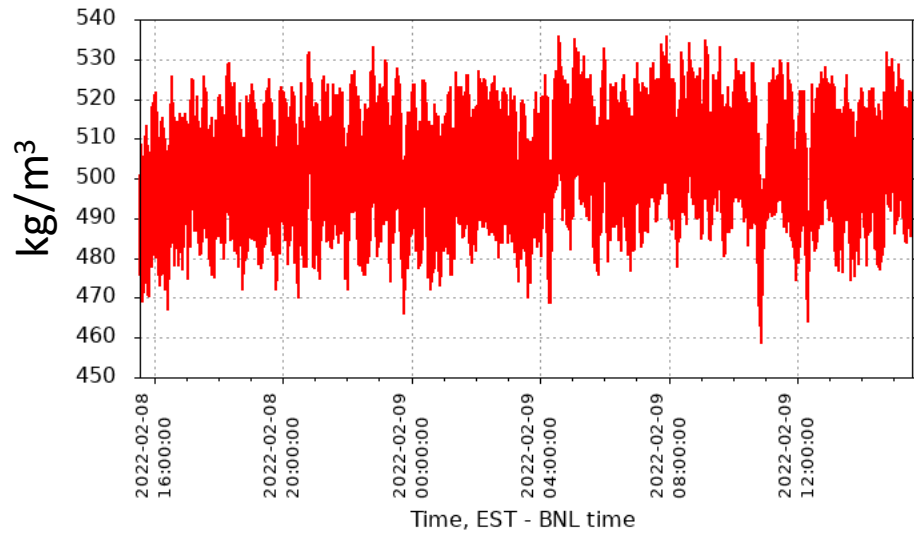
- n-pentane isomer formula  $C_5H_{12}$
- Is a highly flammable liquid and vapor
- Boiling point of pentane is  $97^{\circ}F$  ( $36^{\circ}C$ )
- Density of pentane is  $0.626 \text{ g/ml}$
- The pentane vapor is heavier than air
  - It sinks if released to atmosphere
- Explosive limits of pentane by volume in air: 1.4-7.8%

# sTGC Gas System



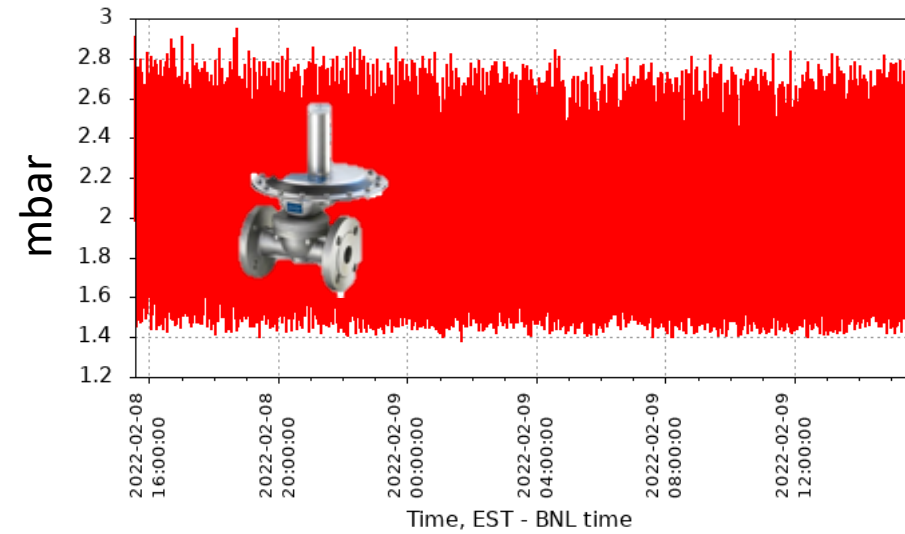
n-Pentane/CO2 Ratio

sTGC:Gas:GPA:ratio, %



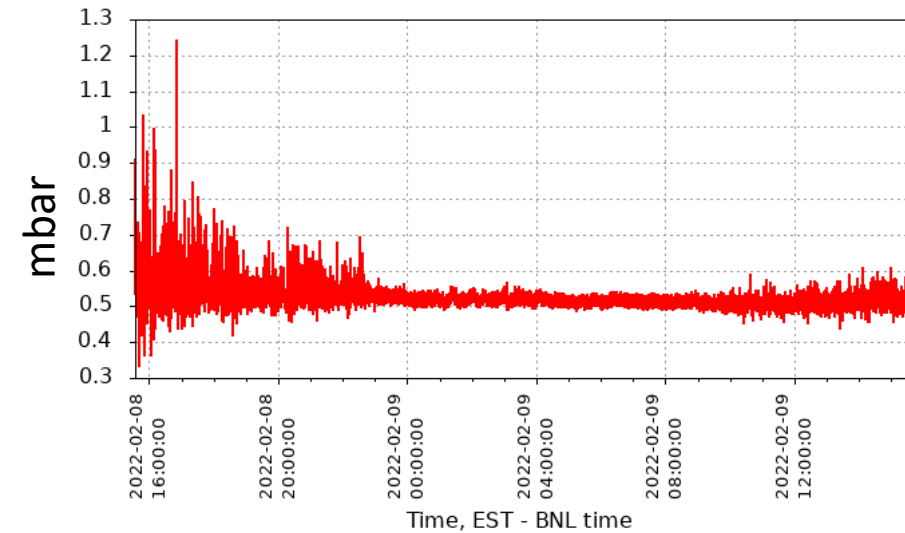
Measured density of n-Pentane

sTGC:Gas:Pentane:Density, kg/m3



Chamber input pressure

sTGC:ADAM:PT-6:pressure, mbar



Chamber vent pressure

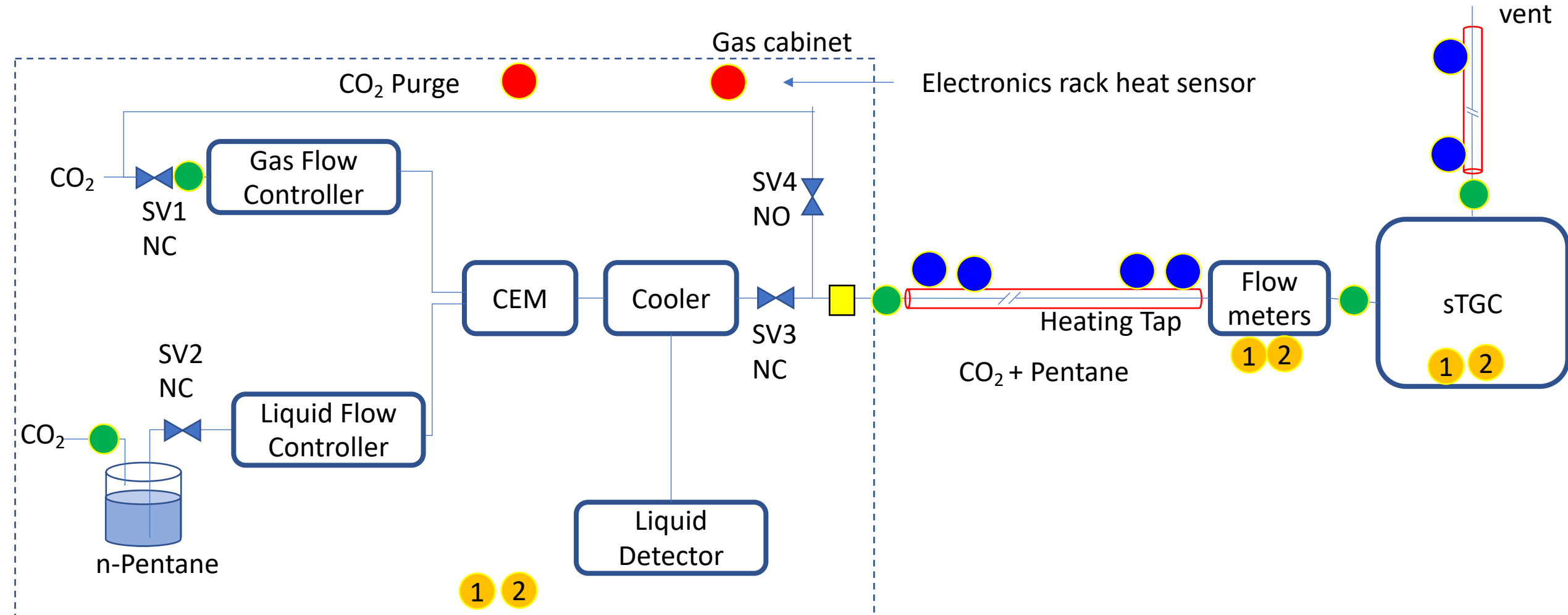
sTGC:ADAM:PT-5:pressure, mbar

# Safety System

Status During Interlock		sTGC Purge		sTGC No Flow		sTGC LV Permissive		sTGC HV Permissive		UPS Power for Control Cabinet		Audible & Visible Alarm	
		Mixing	Mixing	Enable	Enable	On	Off						
1	Normal status												
<b>Interlocks</b>													
<b>Fire/Heat Detection</b>													
2	Heat in gas cabinet	X		X	X							X	
3	Heat in electronic cabinet	X		X	X			X					
<b>Pentane Gas Leak Detection</b>													
4	15% of LEL in pentane sniffer 1 - Gas cabinet	X		X	X							X	
5	15% of LEL in pentane sniffer 1 - Flow meters	X		X	X							X	
6	15% of LEL in pentane sniffer 1- sTGC chambers	X		X	X							X	
7	15% of LEL in pentane sniffer 2 - Gas cabinet	X		X	X							X	
8	15% of LEL in pentane sniffer 2 - Flow meters	X		X	X							X	
9	15% of LEL in pentane sniffer 2 - sTGC chambers	X		X	X							X	
10	Pentane sniffer 1 malfunction w/5 min delay	X		X	X							X	
11	Pentane sniffer 2 malfunction w/5 min delay	X		X	X							X	
<b>Gas mixing and Delivery</b>													
12	Liquid pentane present after mixing	X		X	X							X	
13	Supply line heat tap -LOW/HIGH	X		X	X							X	
14	Vent line heat tap -LOW/HIGH	X		X	X							X	
<b>Pressure</b>													
15	sTGC Supply over pressure (PT5)		X	X	X							X	
<b>STAR global interlock (SGIS)</b>													
16	From SGIS	Appropriate action to be determined, not implemented for Run21											
17	To SGIS	Appropriate action to be determined, not implemented for Run21											

State Table

# Safety Sensors



SV – Solenoid valves  
 NC – Normally closed  
 NO – Normally open

● Pentane Sniffer,  
 1 & 2 are independent monitoring  
 ● Heat sensor

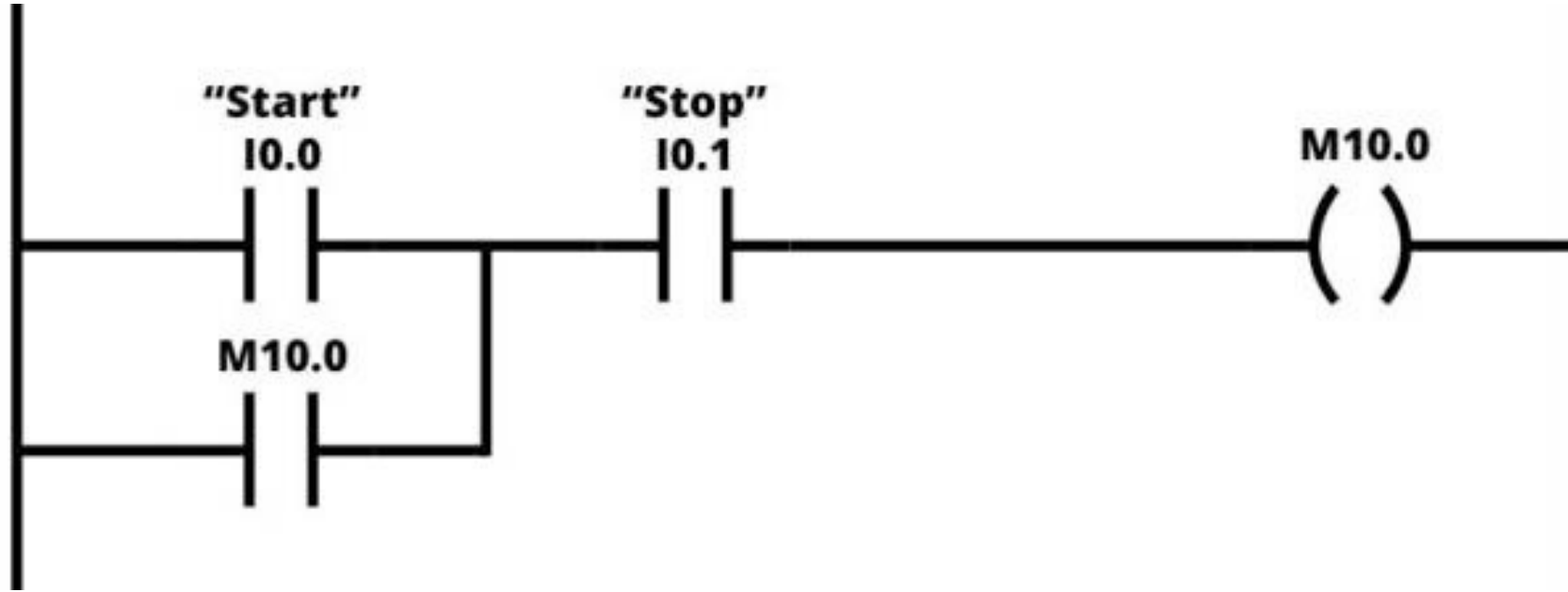
● Thermocouple  
 ● Pressure transmitter

■ Liquid detector





# PLC – Ladder Diagram



# PLC - Controls

This screenshot shows the PLC control interface in the 'Valves Purging' state. The top navigation bar includes 'Home', 'Active Alarms', 'Bypass', 'Pressure', and 'Alarm History'. The main display area shows a schematic of the system with various components like solenoid valves (SV1, SV2, SV3, SV4), pressure transmitters (PT1, PT2, PT3, PT4, PT5), and flow meters (CO2 FM, Pentane FM, CEM). The 'sTGC' (Storage Tank Gauge Controller) is also visible. At the bottom, there are four large buttons: 'Start Mixing' (green), 'Start Purging' (blue), 'Stop Flow' (yellow), and 'Alarm Silence' (red). A 'Login required' message is displayed at the bottom center. On the right side, there are two green indicator lights labeled 'HV' and 'LV', and a 'Pressure transmitter reading' indicator. A 'Login button' is located at the top right. On the left side, there are labels for 'Screen tabs', 'Message window', 'Solenoid valves' (Blue closed, Green opened), and 'Alarm icons'.

Screen tabs

Message window

Solenoid valves  
Blue closed  
Green opened

Alarm icons

Login button

High/low voltage permissive indicator

Pressure transmitter reading

User buttons

Login required

This screenshot shows the PLC control interface in the 'Valves Mixing' state. The top navigation bar is the same as in the previous screenshot. The main display area shows the same schematic, but the 'Start Mixing' button is now disabled (greyed out). A red alarm icon is present in the top right corner, and a red message 'Alarm(s) Active' is displayed. Below the alarm message, it says 'Time to purge 1:22'. The 'HV' and 'LV' indicator lights are now green. The 'Start Mixing' button is disabled. On the left side, there are labels for 'Valves mixing, but heat alarm present in the cabinet. One minute and 22 seconds left for automatic start of purging' and 'Heat alarm is active'. On the right side, there is a label for 'HV/LV permissive is given when the system is in mixing state'. At the bottom, there is a label for 'Mixing button is disabled'.

Valves mixing, but heat alarm present in the cabinet. One minute and 22 seconds left for automatic start of purging

Heat alarm is active

Mixing button is disabled

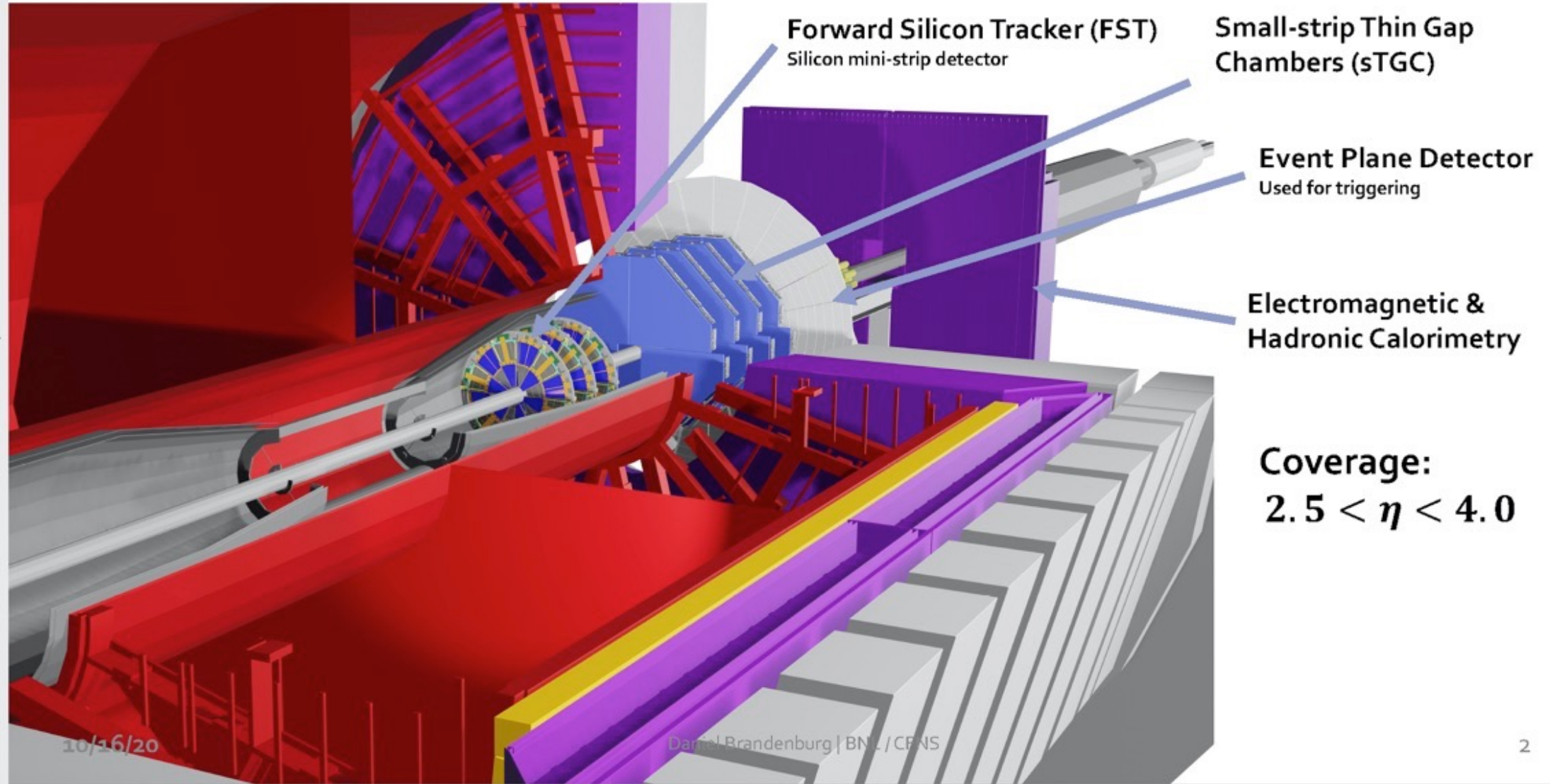
HV/LV permissive is given when the system is in mixing state

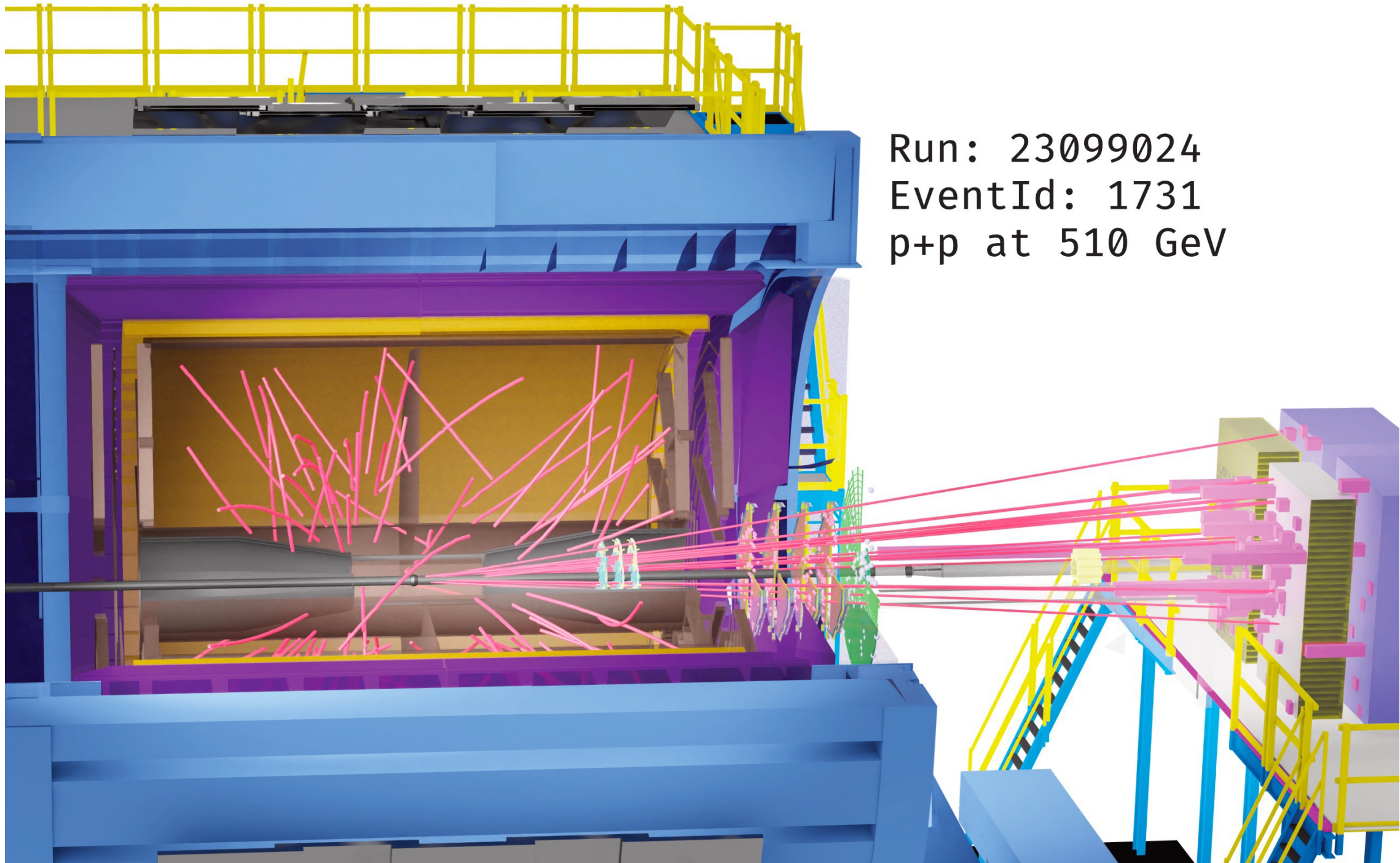
# PLC - Controls

The screenshot displays a PLC control interface with a top navigation bar containing buttons for Home, Active Alarms, Bypass, Pressure, and Alarms History. A 'Log on' button and a status bar with two red 'X' icons and the time '2:28:40 AM 2/16/2021' are also present. A prominent pink banner at the top reads 'Bypass Key Disabled'. Below this, several monitoring panels are visible: 'Gas Sniffer' with Controller and Sniffer sections, each containing six numbered green indicator lights; 'Liquid Level' with 'Liquid present' and 'Malfunction' indicators; 'Heat Detector' with a 'Gas cabinet' indicator; 'Pressure Transmitter' with six numbered green indicator lights; 'SGIS' with 'To' and 'From' indicators; 'Control Alarms' with indicators for 'Valves fault' (Mix, Purge, NoFlow), 'HV control fault', and 'LV control fault'; and a 'Manual Control' section with indicators for 'Valves' (SV1-SV4) in 'Open' and 'Close' states, 'Enable' and 'Disable' for HV and LV, and 'SV Power Reset'.



# STAR Forward Upgrade





Run: 23099024  
EventId: 1731  
p+p at 510 GeV

# HW

- Sketch a diagram for 10 mbar overpressure protector?
- A point charge  $q$  located near infinite grounded conducting plate, what are the
  - $E(r)$
  - $V(r)$