Study of gas aging impact on detector performance:

development of a new gas circulation system for ACTAR-TPC at GANIL

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3rd International Conference on Detector Stability and Aging Phenomena in Gaseous Detectors

Outline

01 Introduction

02 Experimental approach

03 Data analysis

04 Results and discussion

05 Summary and perspectives

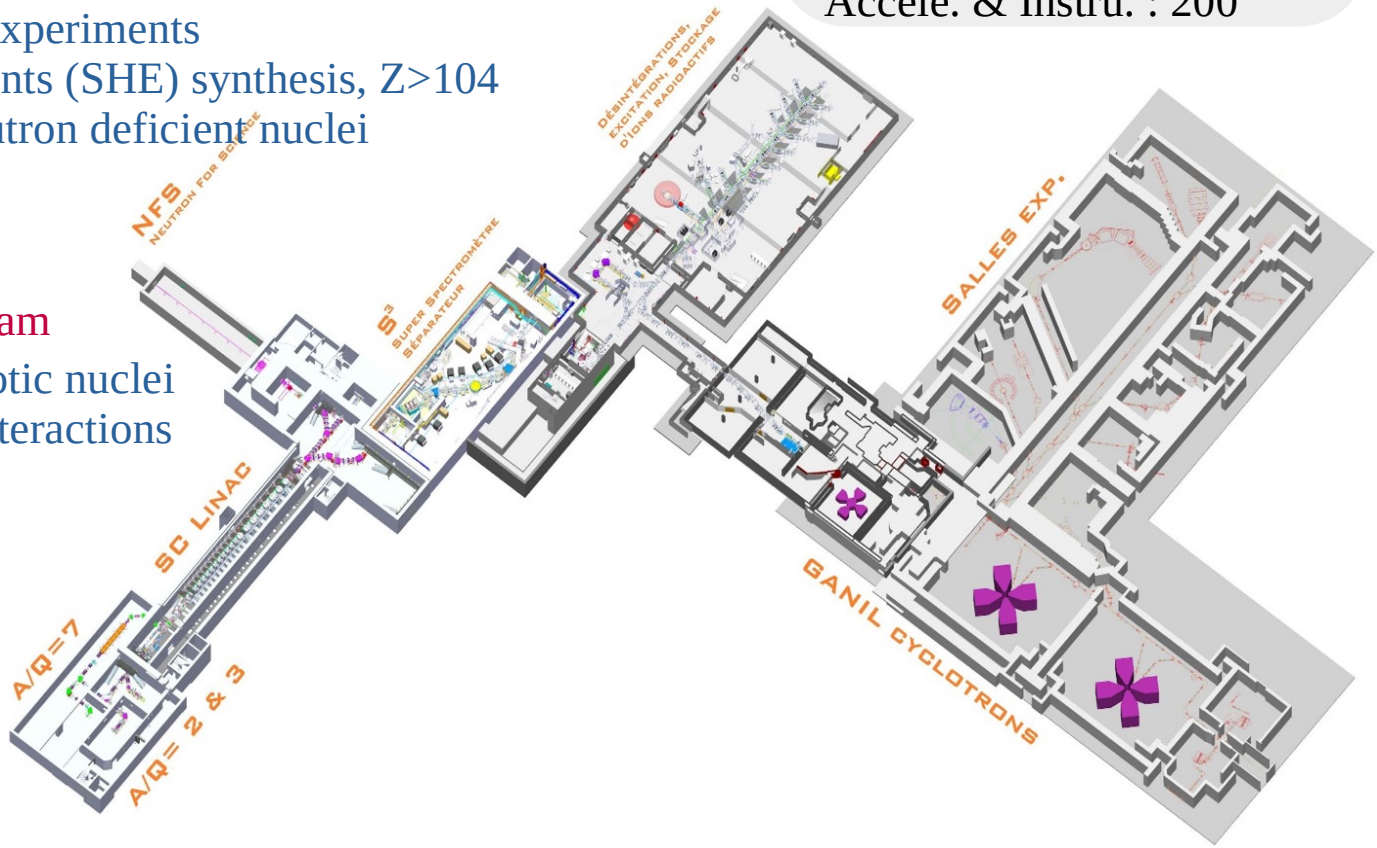
ACTAR-TPC system

Introduction

1. GANIL cyclotrons: Stable and unstable beam
   < 1 MeV/A upto 95 MeV/A
   Nuclear structures and reaction studies
2. NFS: Neutron beam (upto 30 MeV)
   Neutron induced fission, neutron therapy, industrial study
3. S^3: Stable beam from SC LINAC
   Low cross-section experiments
   Super-Heavy Elements (SHE) synthesis, Z>104
   Spectroscopy of neutron deficient nuclei
4. DESIR: Low-energy beam
   Structure of exotic nuclei
   Fundamental interactions
   Astrophysics

232 permanent staff
(researchers, engineers, tech.)
55 temporary staff
(Tech., PhD, postdocs)

Researchers : 59
Administration : 28
Accele. & Instru. : 200



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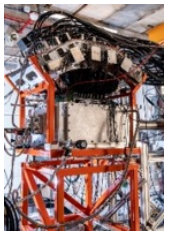
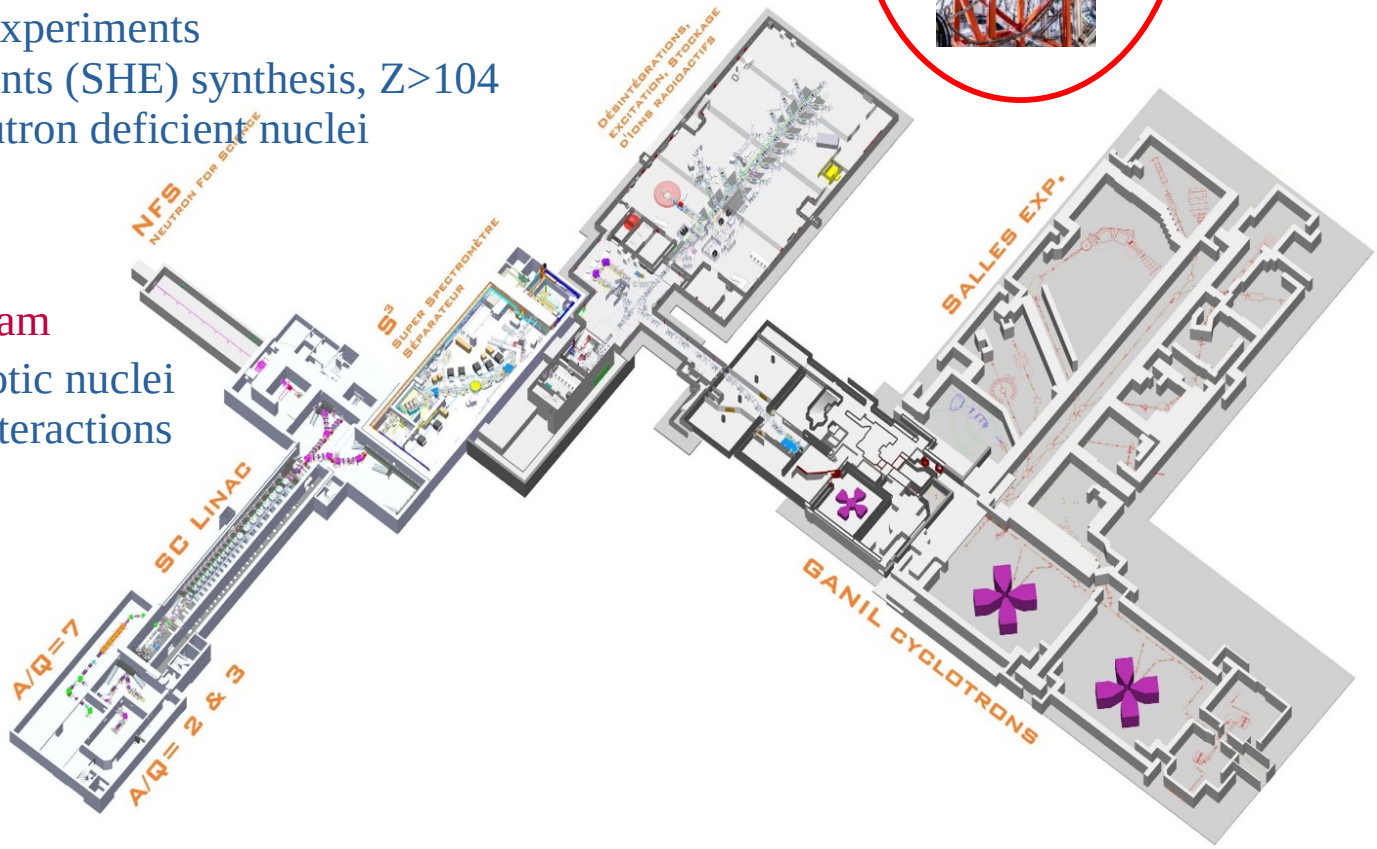
ACTAR-TPC





Introduction

- Active target detector : gaseous detector
  - ➡ atoms of the gas serve as target
  - ➡ study with low intensity beams (RIB/10^4 pps)

- ACTAR-TPC at GANIL → cubic reaction chamber
  - ➡ segmented collection plane (128x128 pads)
  - ➡ uniform drift electric field (2-layers wire field cage)
  - ➡ signal amplification with micromegas
  - ➡ signal registration by GET electronic

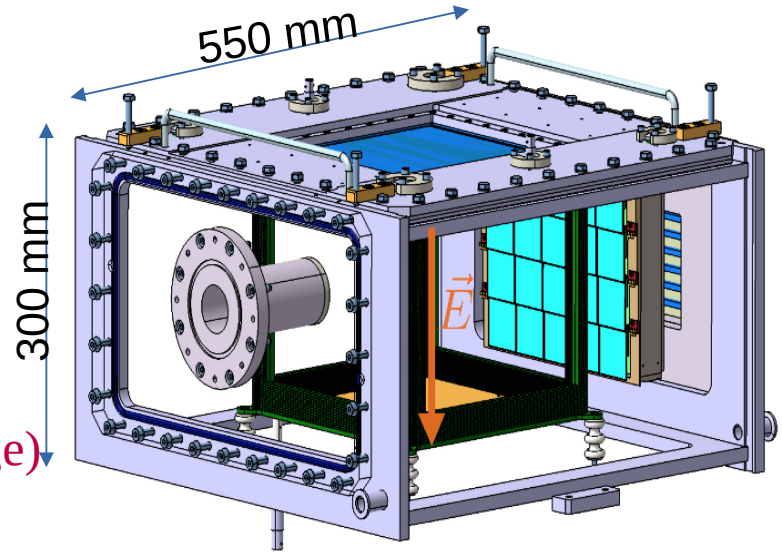


Fig : ACTAR-TPC.
(Figure ref: B. Mauss et. Al, Nuclear Inst. and Meths. in Phys. Res., A 940 (2019) 498–504)

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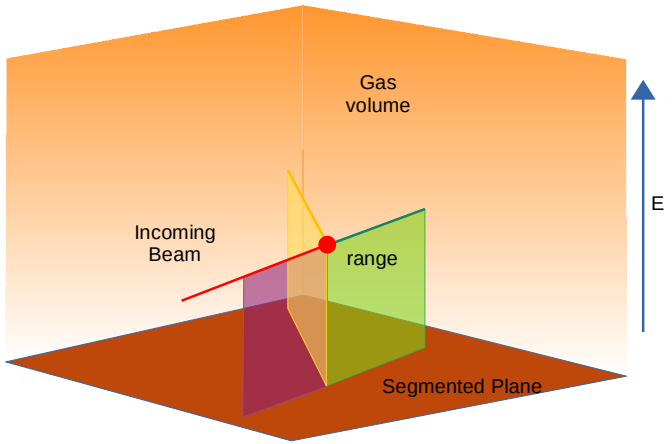
  - ➡ exploration of nuclei near the drip lines
  - ➡ decay studies, resonant scattering, etc



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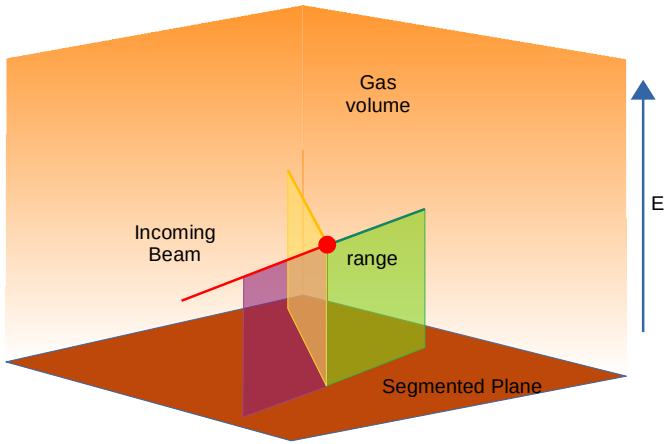

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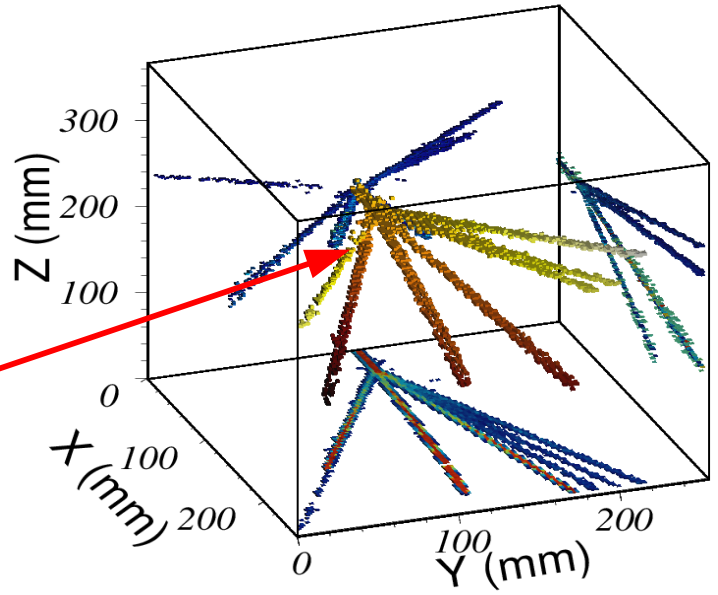
Constructed α-tracks from the fragmentation of C and O.



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  - ⇨ due to outgassing and leakage in the system.
  - ⇨ because of the continuous irradiation and the electron avalanche.

- The impurities can compensate the detector's performances like deterioration in the gain factor or resolution.
  - ⇨ gas purity is a key factor in ensuring optimum detector's performance.

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- Certain nuclear physics experiments require expensive gases, deuterium (^{2}H), helium-3 (^{3}He), xenon (Xe), etc.
  - ➡ recycling of gas becomes significantly important

- Another significant concern is the use of green house gases (GHG) like CF_4, C_3F_8, etc in certain experiments.

- Gas recycling :
  - ➡ can reduce the operational costs and it will enable the use of expensive gases.
  - ➡ can manage the GHG emissions as well.

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- Gas recycling :
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  - ➡ can manage the GHG emissions as well.

- **Aim : Development of an advanced gas regulation system for ACTAR-TPC.**
  - ➡ Investigate the effect of gas aging on detector performance and characterization of gas filters was carried out to ensure their suitability for adoption in gas recycling.

Experimental approach

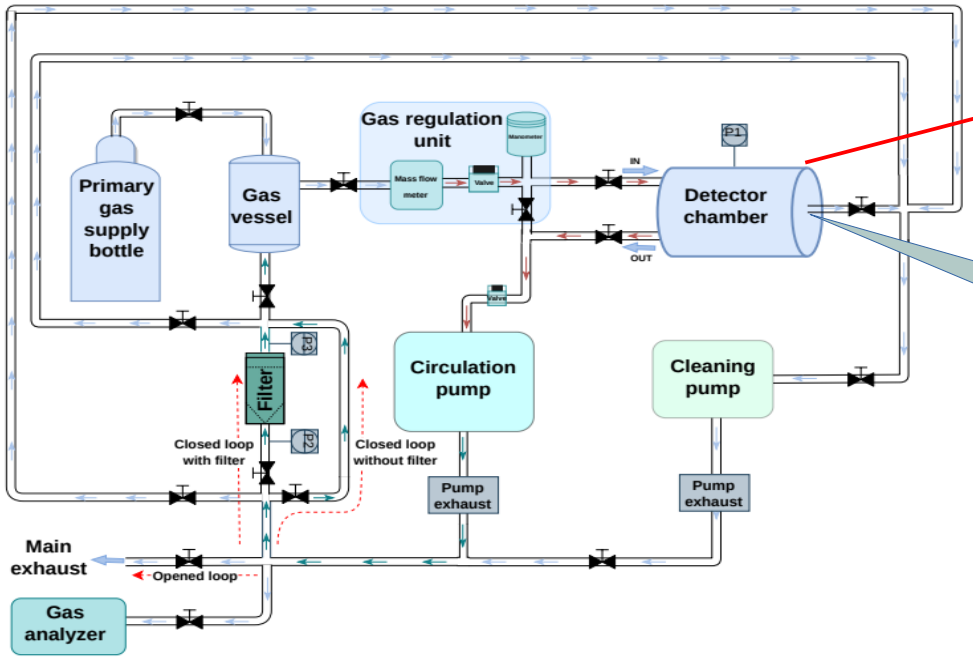
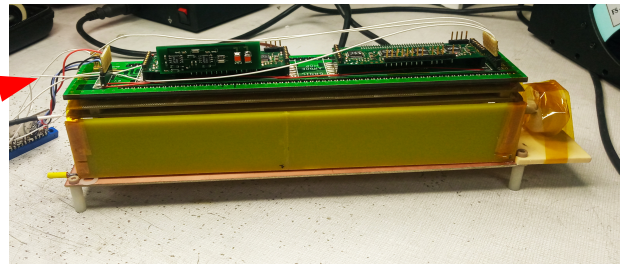


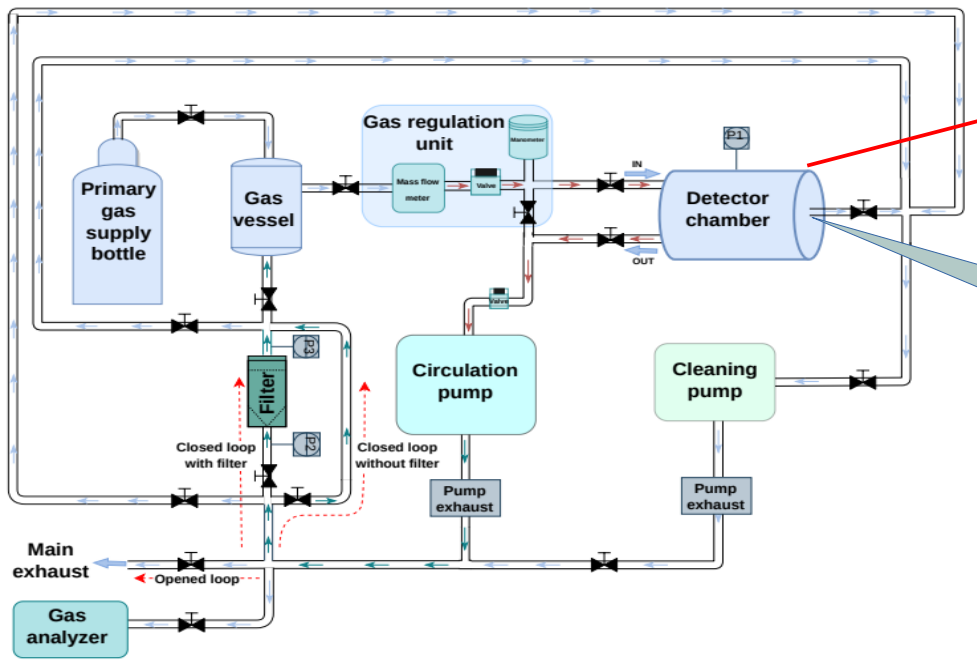
Fig: Gas regulation system.



Circulation mode : regular circulation of gas at constant desired pressure

Static mode: gas is filled at a desired set pressure

Experimental approach



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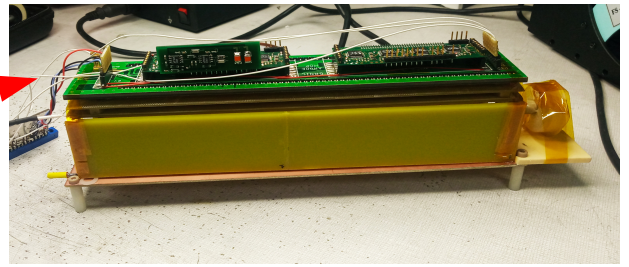

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➡ **In circulation mode, the system can be operated in three different routes**

- **Circulation in opened loop :** Exiting gas is either release in the atmosphere or collected to a gas bottle.
- **Circulation in closed loop without filter :** Exiting gas is sent back to the chamber without prior cleaning.
- **Circulation in closed loop with filter :** Exiting gas is sent back to the chamber after cleaning by passing through a gas filter unit.

Experimental approach

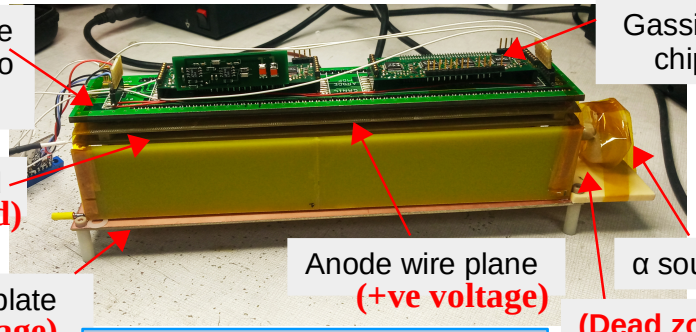
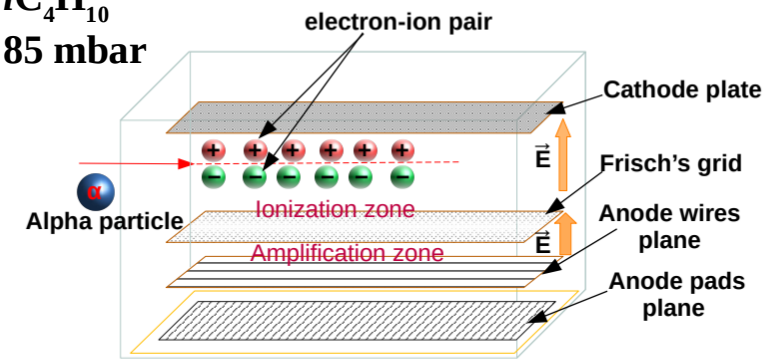
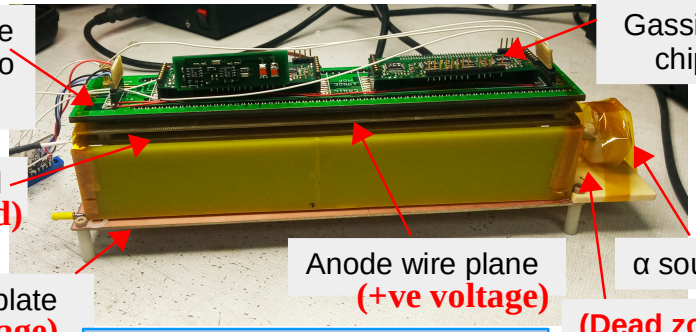


Fig: MAYAITO detector.



- Electrons move towards the anode wires where it creates an electron avalanche.
- Induce charge signals to the anode pads which are read through Gassiplex chips
- The Gassiplex chips generate multiplexed signals which are read by Numexo2.

Experimental approach



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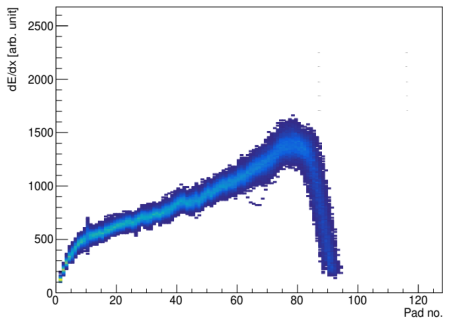


Fig: Total Bragg's curve.

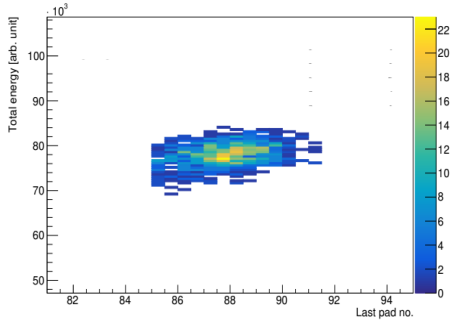
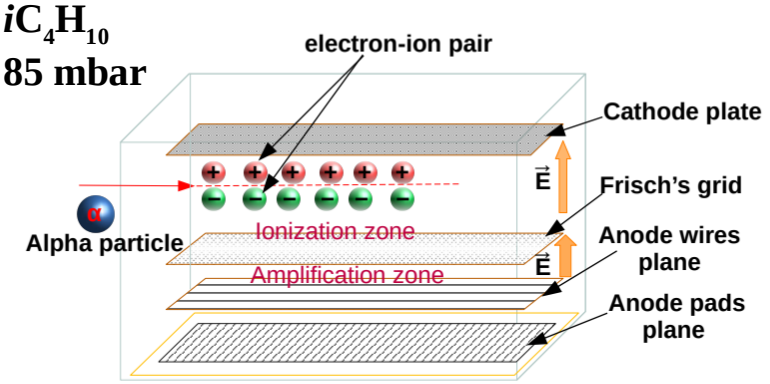


Fig: Last pad vs. Energy.

- Energy loss profile of the α particles will give Bragg curves.
- Energy distribution, its resolution and stopping point (last pad) of the α particles in different conditions are analyzed.



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- Mean energy :
  - Oscillation and it follows day and night time of the run period.
  - Overall decrease with progressing run time.
- Last pad (stopping point) :
  - No significant change in static mode.
  - Oscillation in circulation mode.
- Energy resolution :
  - No considerable change in both modes.

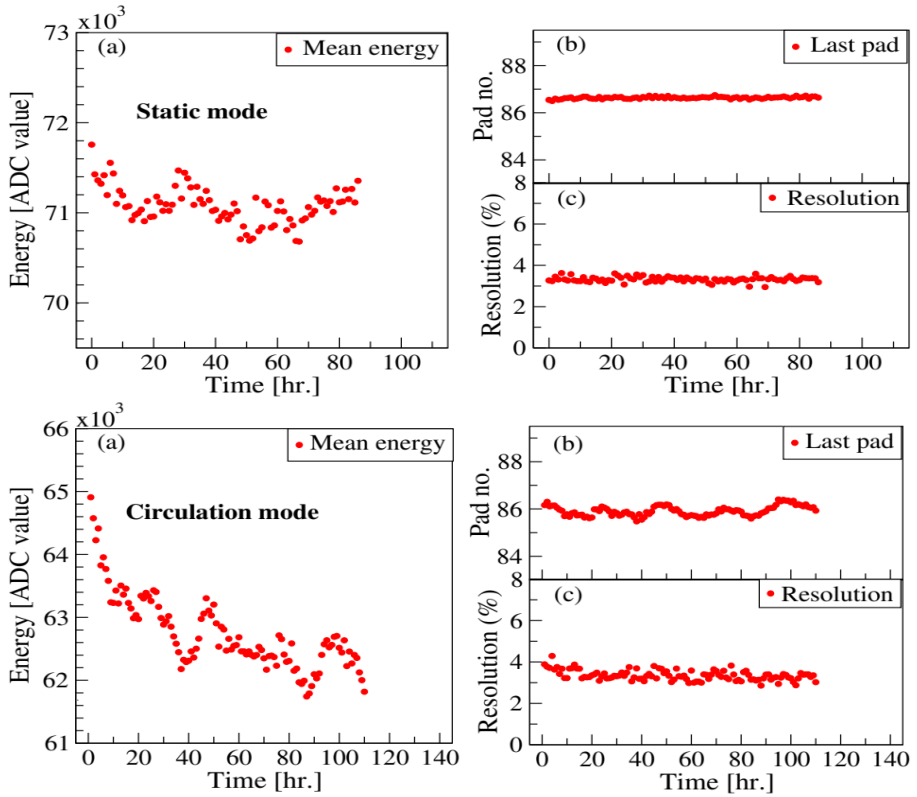

Fig : Variation in measured (a) Mean energy (b) Last pad and (c) Energy resolution with time.

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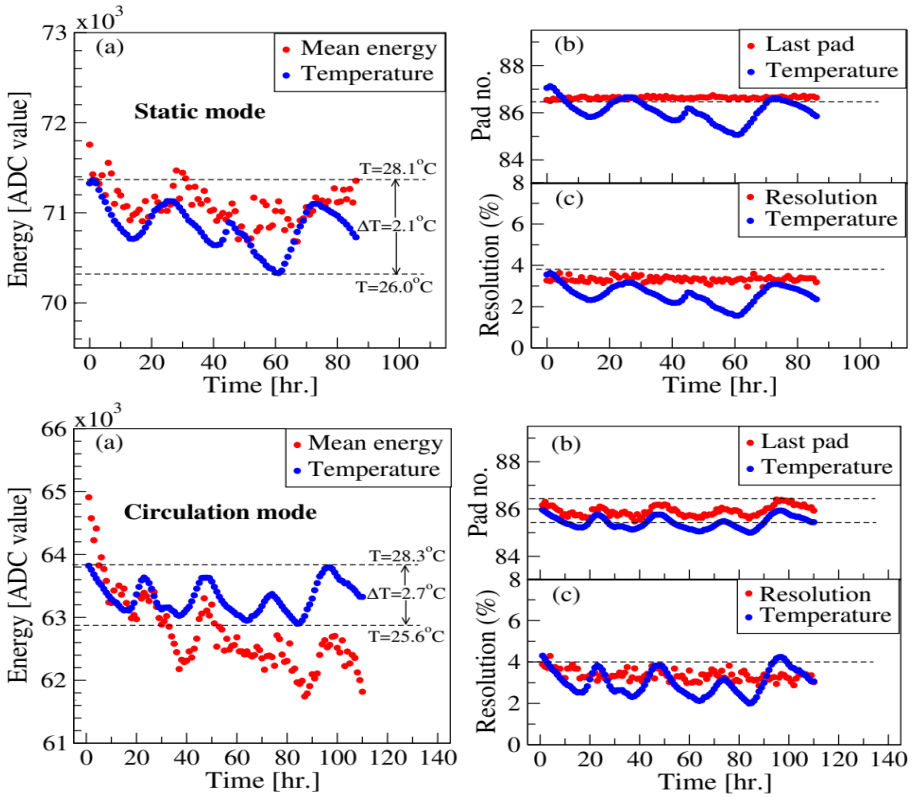

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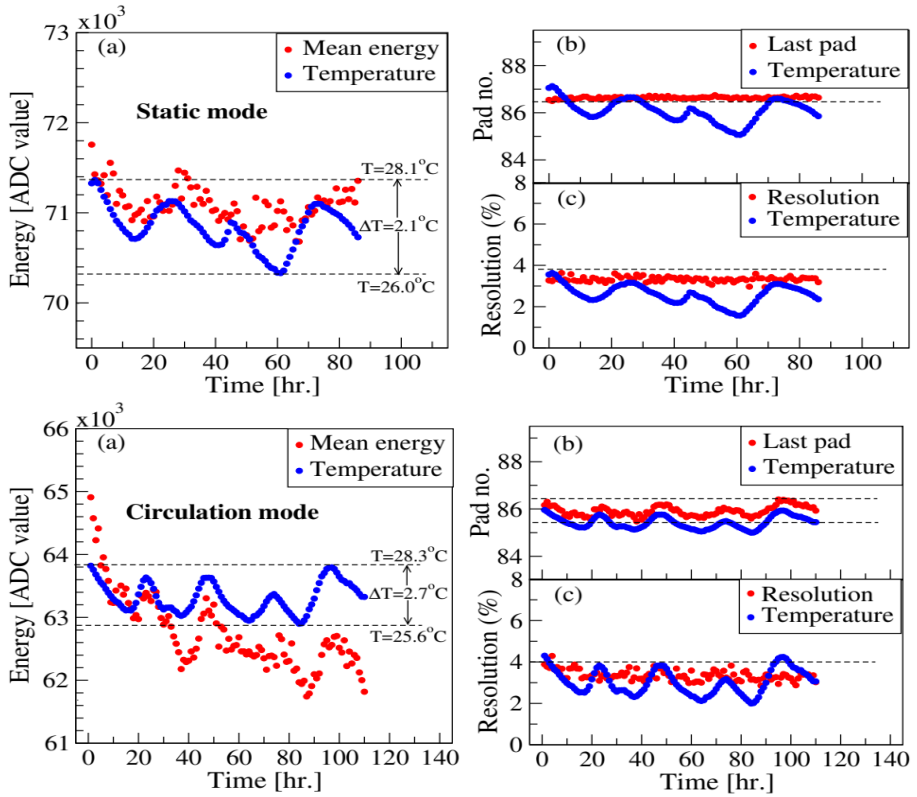

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Oscillation :

⇒ **temperature dependence of electronic components as well as gas condition.**

Data analysis

Pulse signal

Gassiplex **Numexo2**

➡ clear indication of temperature dependence in the measurement

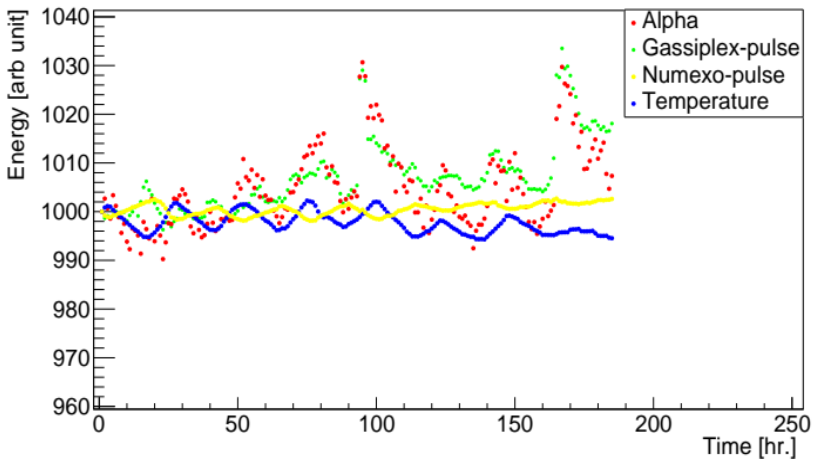
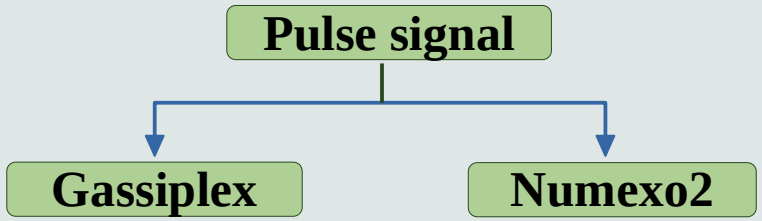


Fig : Variation in measured alpha and pulse mean energies as a function of time.

Data analysis



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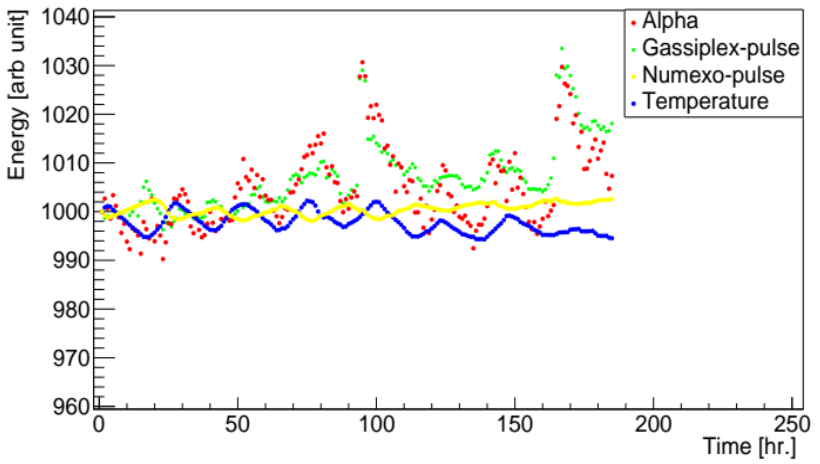
Data analysis steps :

- Baseline (BL) correction of the alpha, Gassiplex-pulse and Numexo-pulse mean energies.



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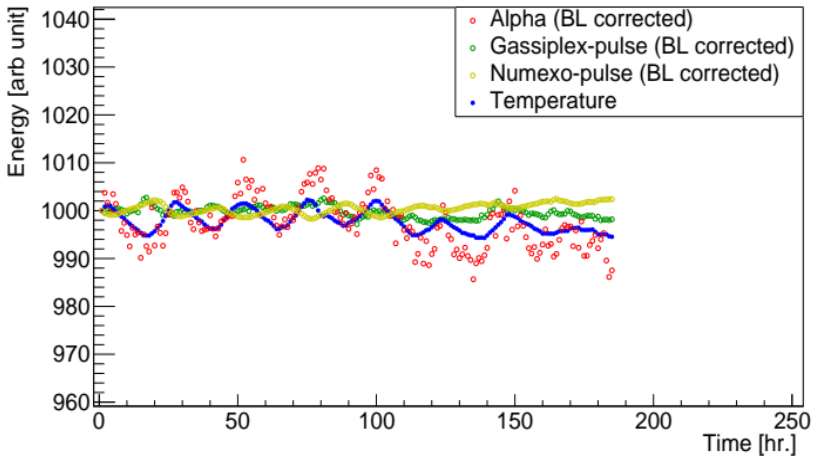
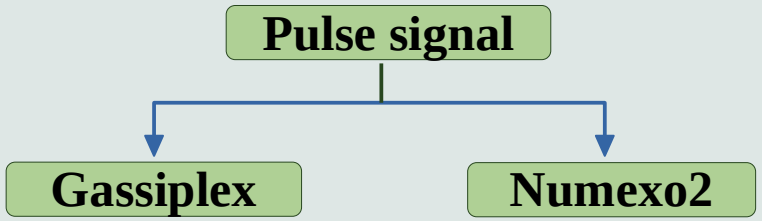


Fig : Alpha and pulse mean energies after baseline (BL) correction.

Data analysis



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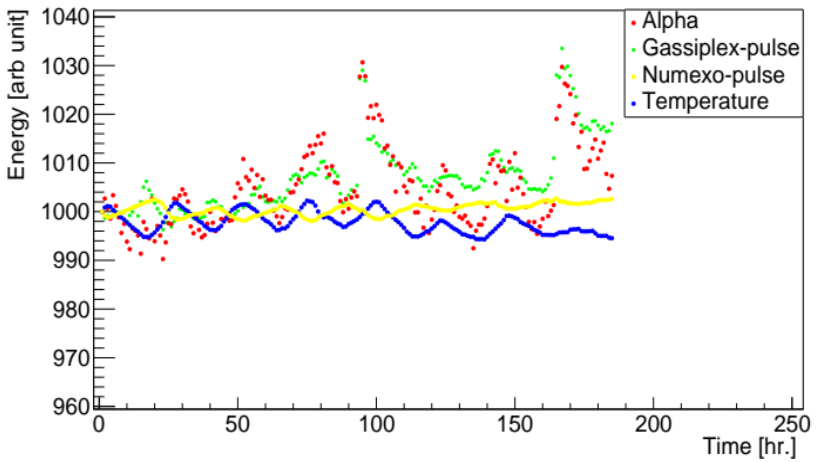
Data analysis steps :

- Baseline (BL) correction of the alpha, Gassiplex-pulse and Numexo-pulse mean energies.
- Correction in Gassiplex-pulse mean w.r.t. Numexo-pulse mean to rectify any change in pulse height.
- Correction in alpha mean w.r.t. corrected Gassiplex-pulse to take care the variation in Gassiplex performance.



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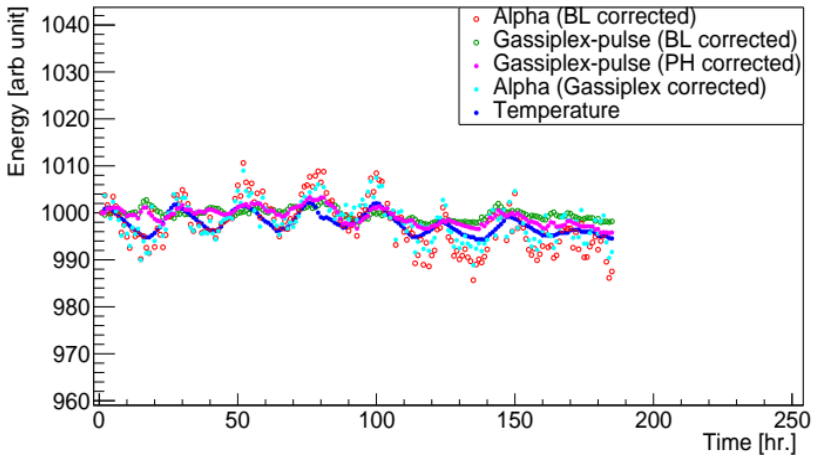


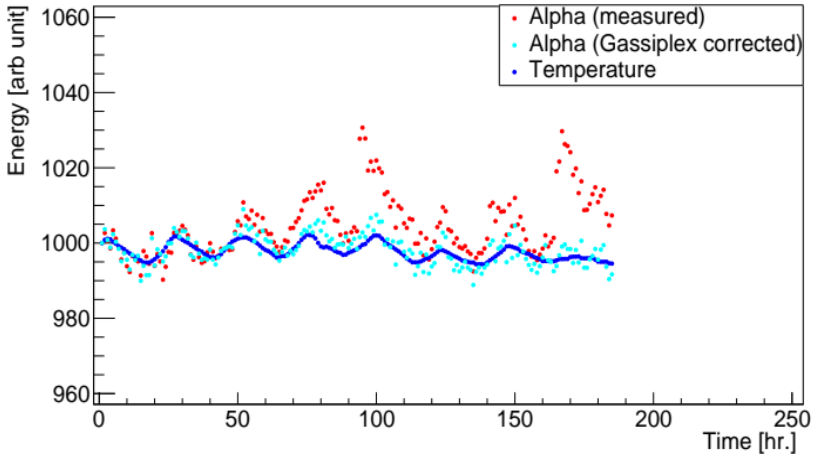
Fig : Alpha and pulse mean energy after BL and Gassiplex correction.

Data analysis

- There is temperature (T) dependence in the measured alpha mean energy.

PV=nRT

⇒variation in gas density due to temperature change.



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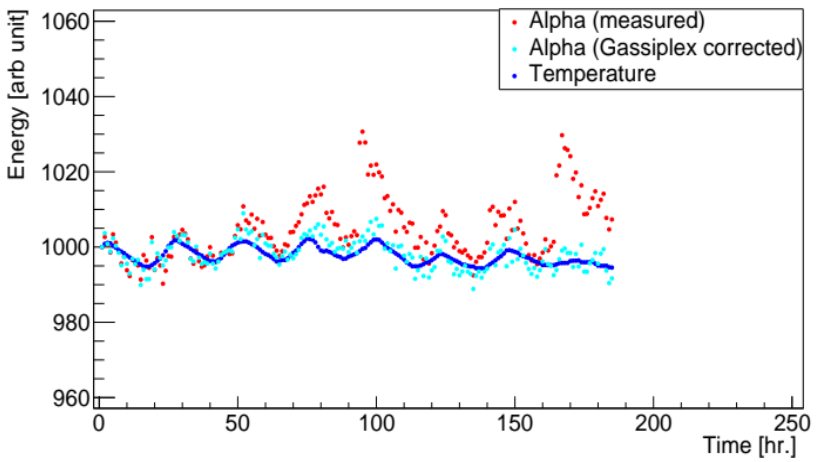
Density variation

- Energy lost in the dead zone, E_{DZ}
- Detector gain

- **Circulation mode :**

⇒ Correction in alpha mean energy (after Gassiplex correction) was performed to rectify the temperature effect.



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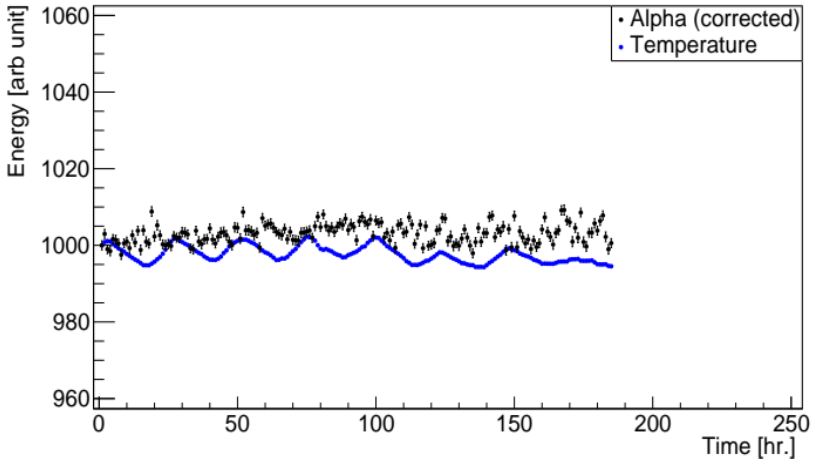

Fig : Corrected mean energy

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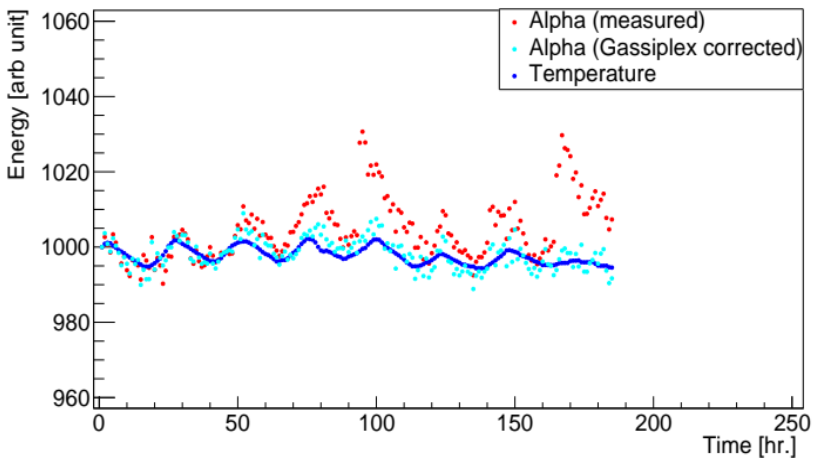
- **Circulation mode :**

➡ Correction in alpha mean energy (after Gassiplex correction) was performed to rectify the temperature effect.

- **Static mode :**

➡ Alpha mean energy does not show any temperature dependent, after the Gassiplex correction.



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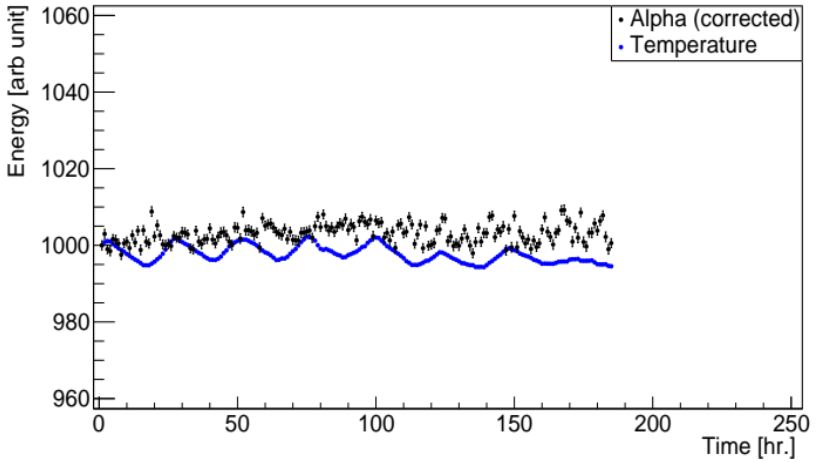


Fig : Corrected mean energy

Results and discussion

Run in static mode

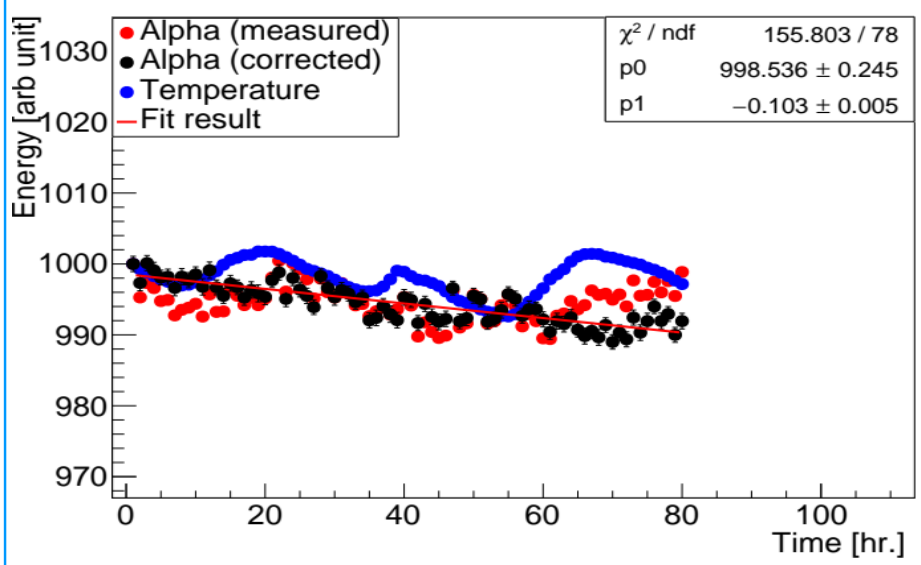


Fig : Measured and corrected mean energy

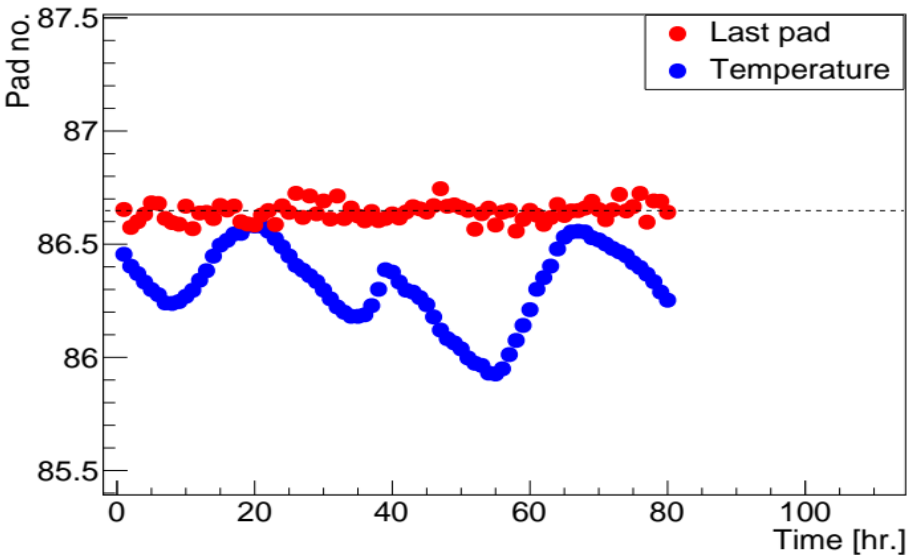


Fig : Measured last pad (SP).

- No temperature dependence in the mean energy after the Gassiplex correction.
- Small degradation in gain was observed.
  - ⇨ Due to leakage/outgassing
- No significant change in stopping point.

Gas density is fixed in static mode

Results and discussion

Run in circulation mode without filter

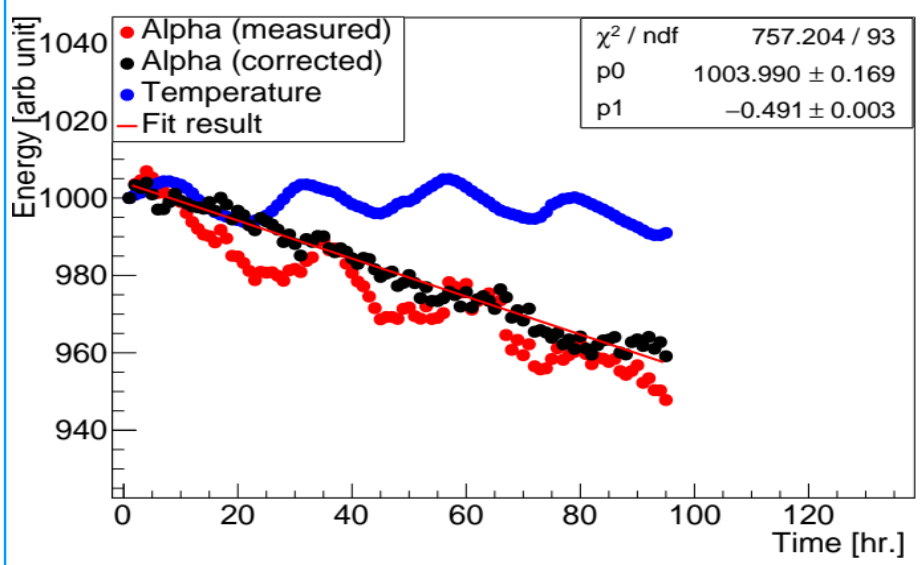


Fig : Measured and corrected mean energy

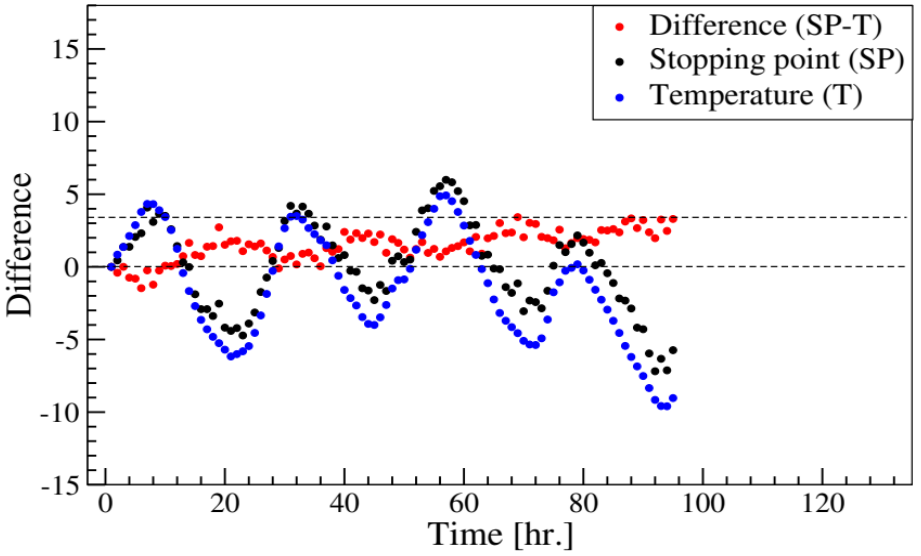


Fig : Difference of SP and temperature.

- Degradation in gain was observed.
  - ⇨ more than the run in static mode.
- Continuous increase in stopping point.
  - ⇨ light molecule contamination due to leakage (mostly O_2, N_2).

Results and discussion

Run in circulation mode without filter

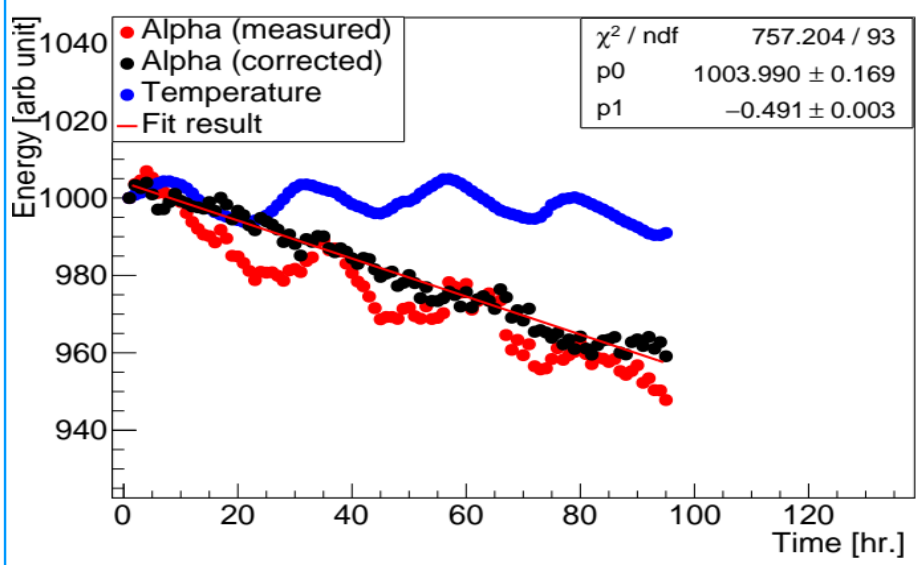


Fig : Measured and corrected mean energy

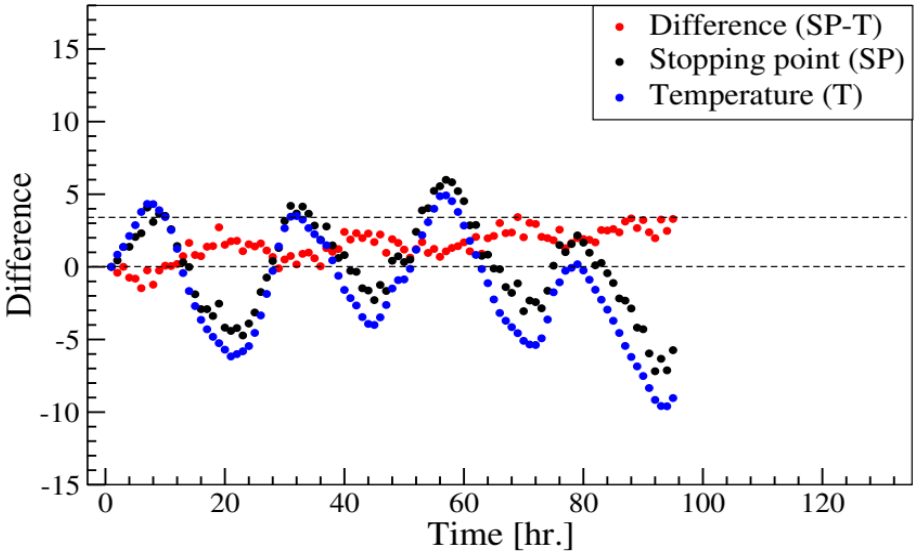


Fig : Difference of SP and temperature.

- Degradation in gain was observed.
  - ⇨ more than the run in static mode.
- Continuous increase in stopping point.
  - ⇨ light molecule contamination due to leakage (mostly O_2, N_2).
- System runs at low pressure.
- Even a small leakage in the system creates significant effect to the measurement over long time period.

Results and discussion

Run in circulation mode with filter (leakage)

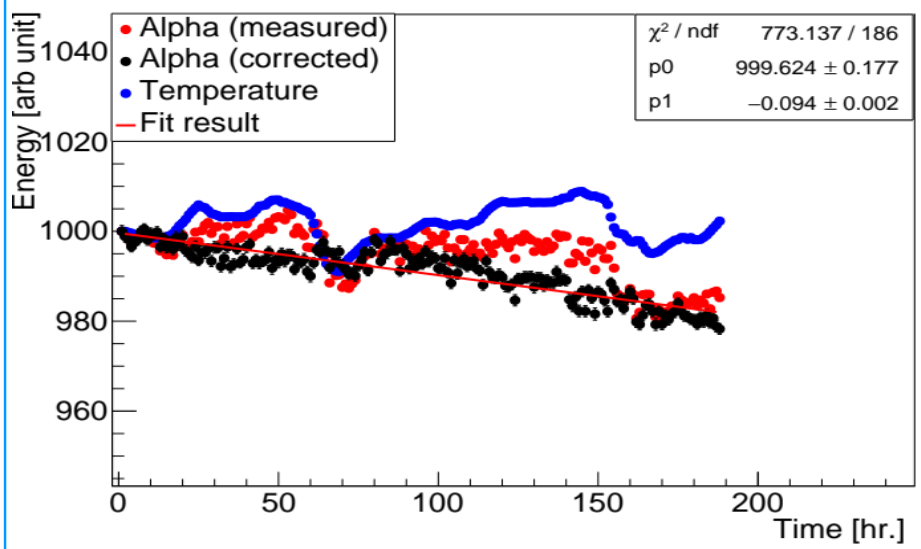
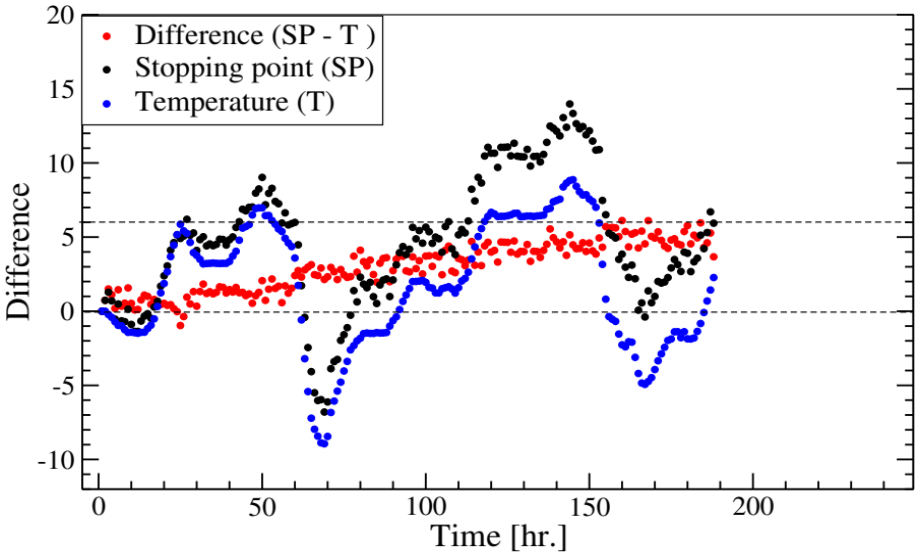


Fig : Measured and corrected mean energy



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Results and discussion

Run in circulation mode with filter

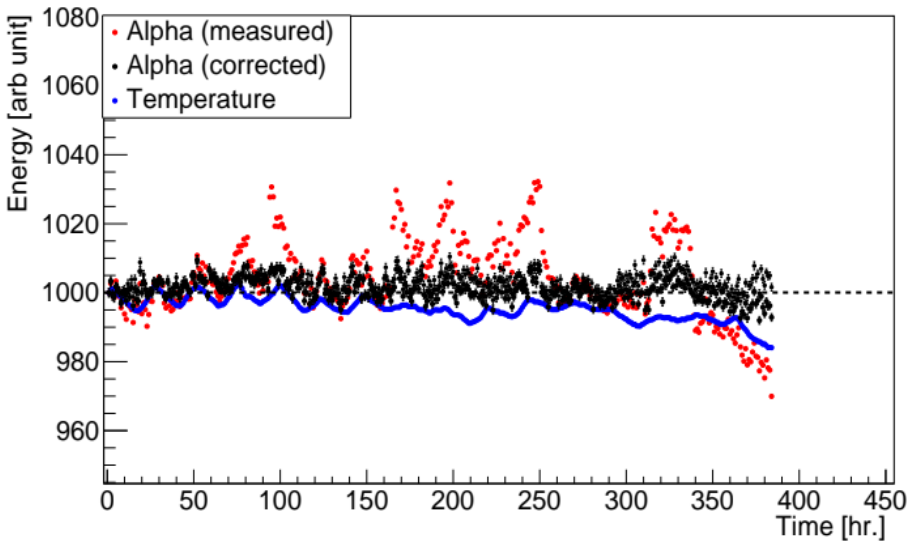

Fig : Measured and corrected mean energy

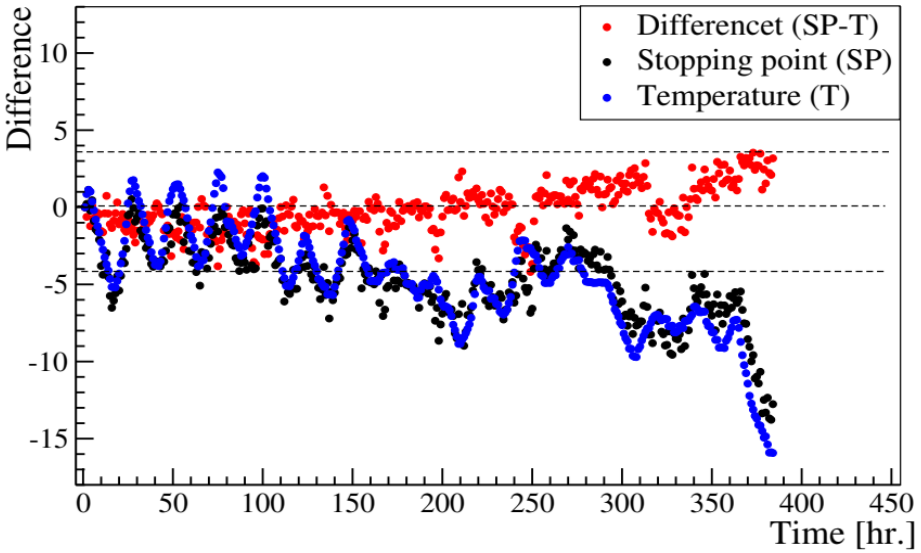

Fig : Difference of SP and temperature.

- Improvement in the set-up.
  - ➡ clean circulation pump and detector chamber, leak test, etc.
- Increase in SP was observed after ~ 200 hrs.
  - ➡ indication of minor leakage in the system.

Results and discussion

Run in circulation mode with filter

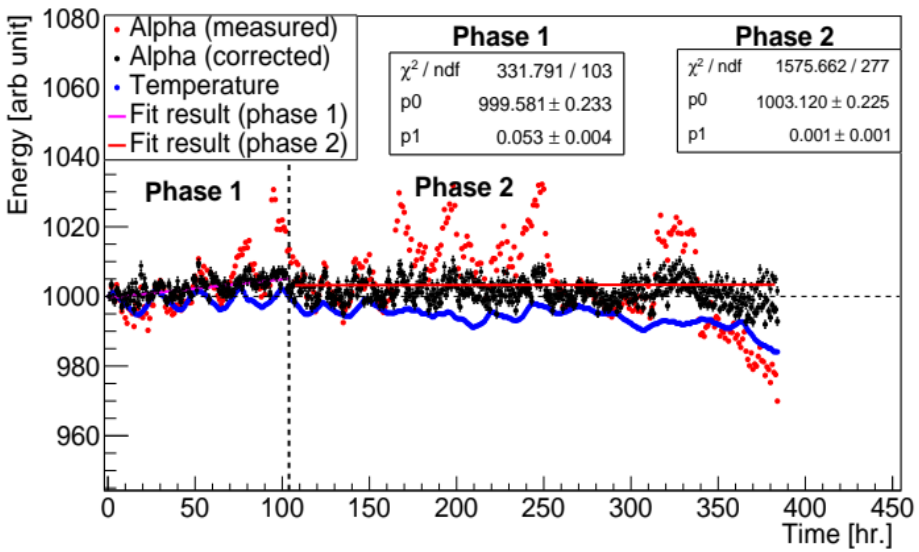

Fig : Measured and corrected mean energy

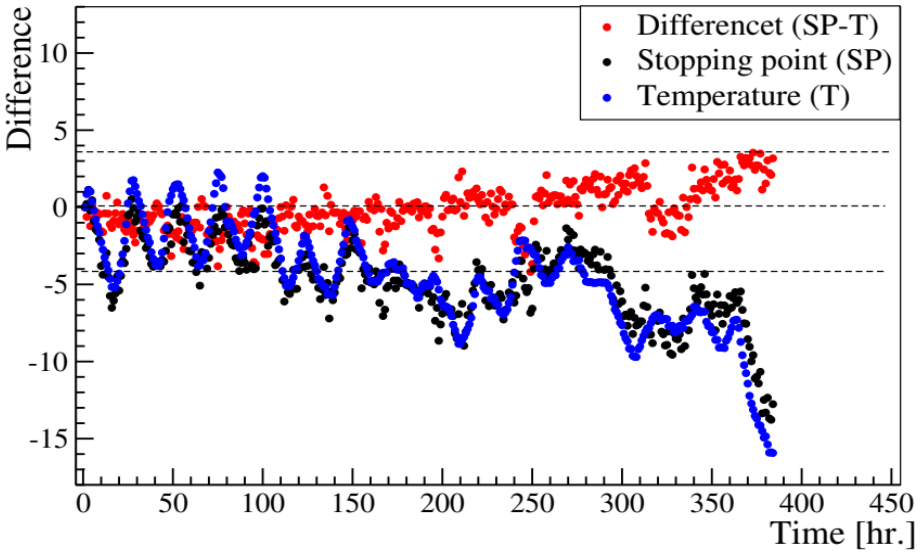

Fig : Difference of SP and temperature.

- Improvement in the set-up.
  ➡ clean circulation pump and detector chamber, leak test, etc.
- In the initial period the gain increases.
  ➡ cleaning the intrinsic impurities present in the supply gas bottle.
- Increase in SP was observed after ~ 200 hrs.
  ➡ indication of minor leakage in the system.
- Afterward, gain is almost constant.
  ➡ able to maintain an optimal level of gas purity with the filter.

Summary and perspective

- A gas regulation system incorporated with a gas purifying/cleaning unit was set up
  → understand the system in close-loop gas regulation mode

- Stable gain with gas recyling for ~ 15 days (average run time for nuclear physics experiment)

- Gain degradation rate:

Regulation mode	Degradation per day (%)
Static	0.24
CL without filter	1.17
CL with filter	Phase 1 : Gain improve Phase 2 : Constant gain

Summary and perspective

- A gas regulation system incorporated with a gas purifying/cleaning unit was set up
  → understand the system in close-loop gas regulation mode

- Stable gain with gas recyling for ~ 15 days (average run time for nuclear physics experiment)

- Use of expensive isotopic gas will enforce the system to run in pure form without quencher
  → lower gain and sparking limit

- Upgradation in amplification methode
  → study with Multi-layer thick gas electron multiplier (ML-THGEM)

- Gain degradation rate:

Regulation mode	Degradation per day (%)
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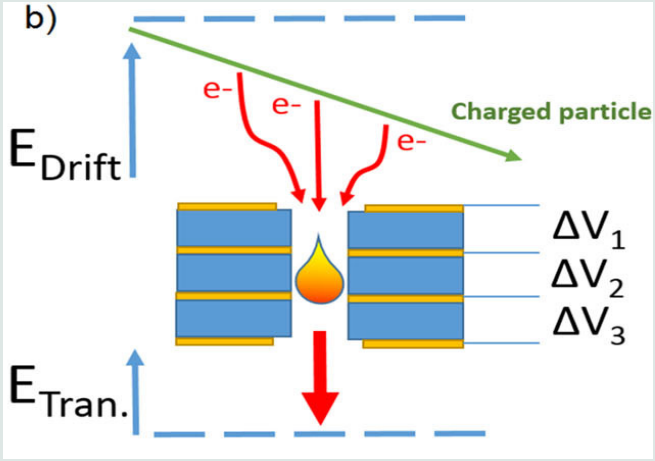

Fig: 3-layer ML-THGEM detector. (Fig. Ref. M. Cortesi *et.al*, Rev. of Sci. Inst. 88, 013303 (2017)).

Acknowledgments

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THANK YOU
for your attention !