CHARACTERIZATION OF ALTERNATIVE GAS MIXTURES FOR FUTURE TRACKERS

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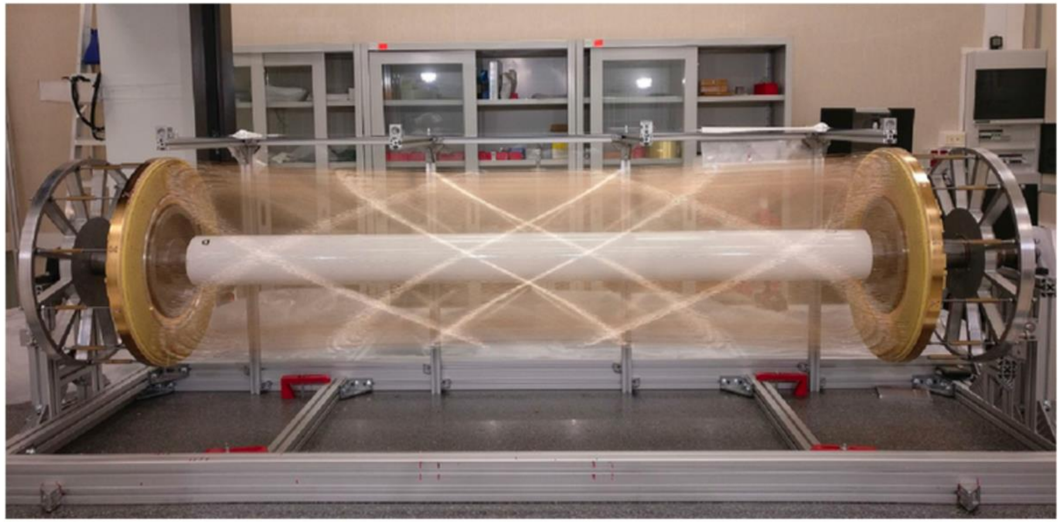
WHAT IS THE AIM?

- The aim of this study is to **characterize alternative gas mixtures** for future trackers

- We started with **the characterization of the gas mixture used in the CDCH of the MEG II experiment**

- It is a **He:Isobutane 90:10** mixture with the addition of a **1.5%** concentration of **Isopropilic alcohol** and a **0.5%** concentration of **Oxygen**
  - The additives are necessary to guarantee operational stability

- The interesting aspect of these additives is that they slowed down the ageing of the chamber

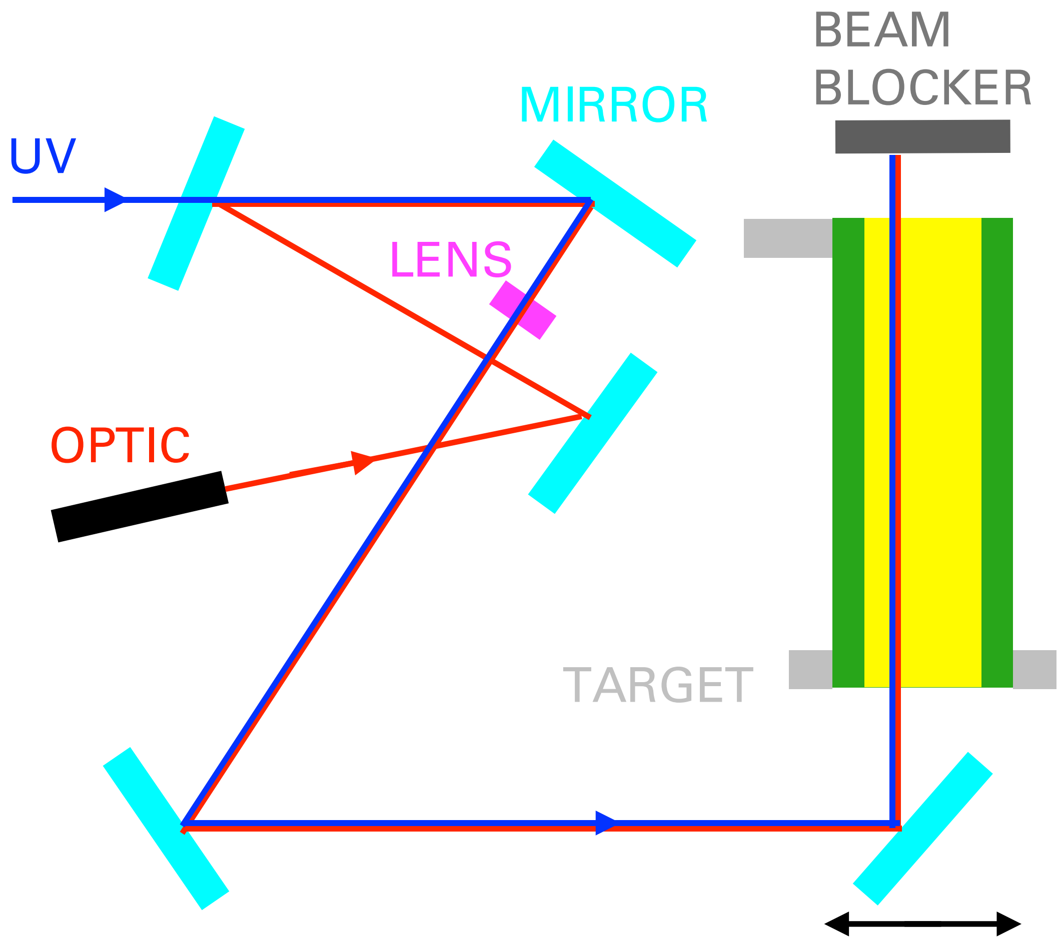


MEASUREMENTS

- To have a complete characterization of the mixtures, we are interested in the study of
  - **Drift velocity**
  - **Attachment coefficient**
  - **Ageing rate**

- To perform the first two measurements we used a small time projection chamber (TPC) illuminated by a laser with pulses at 355 nm
  - In this way we can ionize locally at a fixed position

- Ageing rate will be measured using an x-ray source



MEG-II GAS MIXTURE CHARACTERIZATION

- From now on we will focus on the MEG-II drift chamber's gas mixture
- To broaden the literature, we want to explore a wider range of oxygen concentrations at different drift fields
  - Oxygen concentration: 0.2%, 0.35% and 0.5%
  - Drift field: 700 V/cm, 1000 V/cm, 1250 V/cm and 1500 V/cm
- The paper taken as a reference for our measurements is V. Golovatyuk et al. (2001)

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Influence of oxygen and moisture content on electron life time in helium–isobutane gas mixtures

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Abstract

The presented results refer to 90% helium and 10% isobutane gas mixture. Single electrons have been used to measure the attachment coefficient and drift velocity in homogeneous electric fields in the range from 100 to 1000 Vcm^{-1}. Water vapor and oxygen concentrations varied from 350 ppm up 1.1%, and from 5 to 900 ppm, respectively. © 2001 Elsevier Science B.V. All rights reserved.

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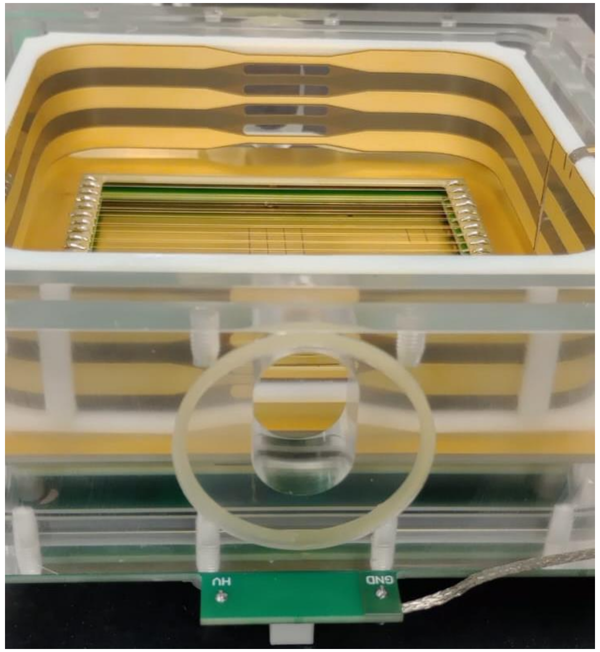
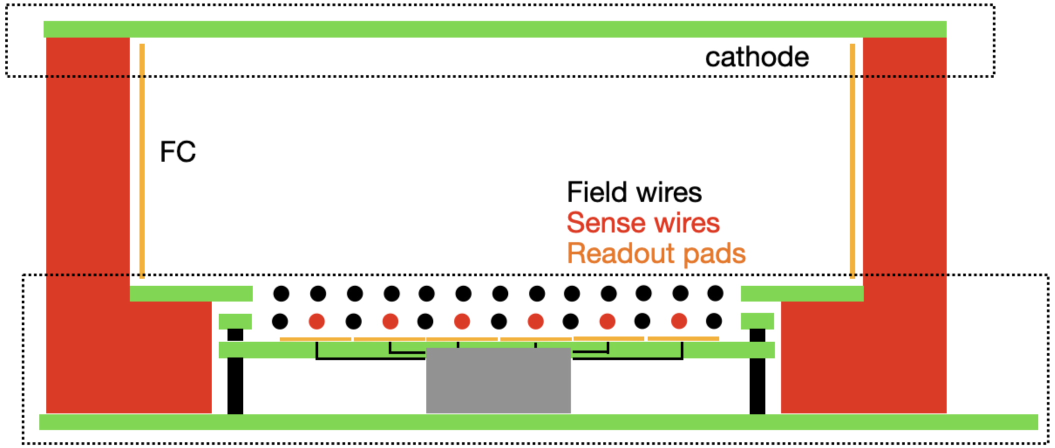
Keywords: Drift velocity; Electron attachment; Oxygen; Water vapors; Gas detectors

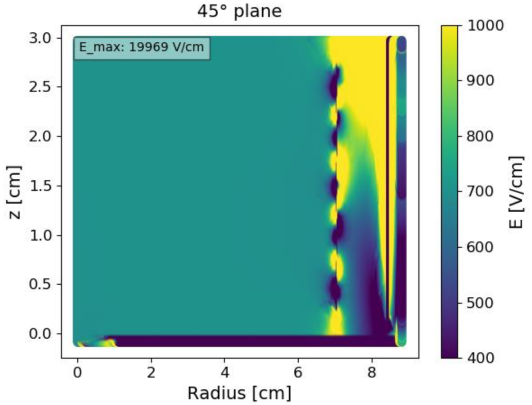
SET-UP SIMULATION

- The detector chosen for these measurements is a **small TPC**
  - A wired 16x16x5 cm^3 plexiglass chamber closed by a cathode and an anode board

- It was first necessary to **simulate the electric field** inside the chamber to check that no discharges occur inside the volume
  - To do so we used ANSYS, a Finite Element Analysis software



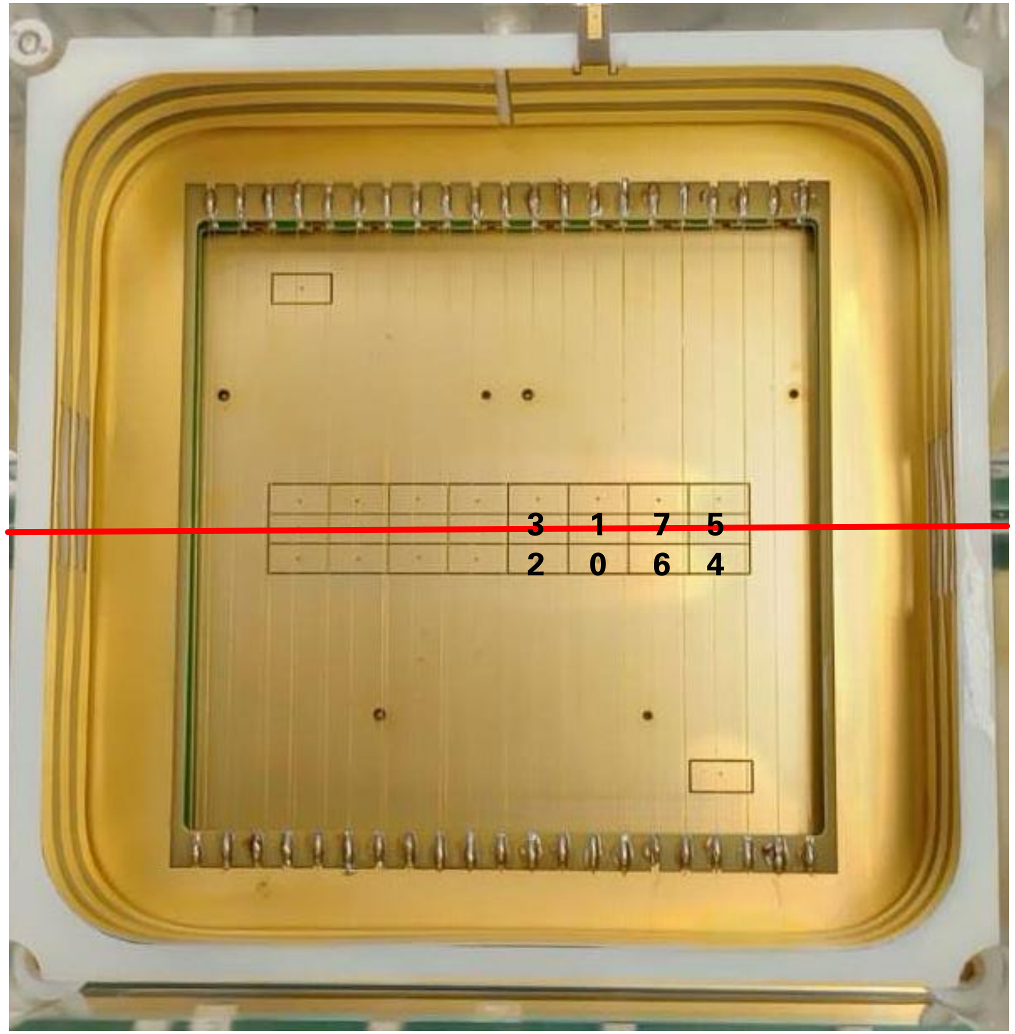




READ-OUT PADS

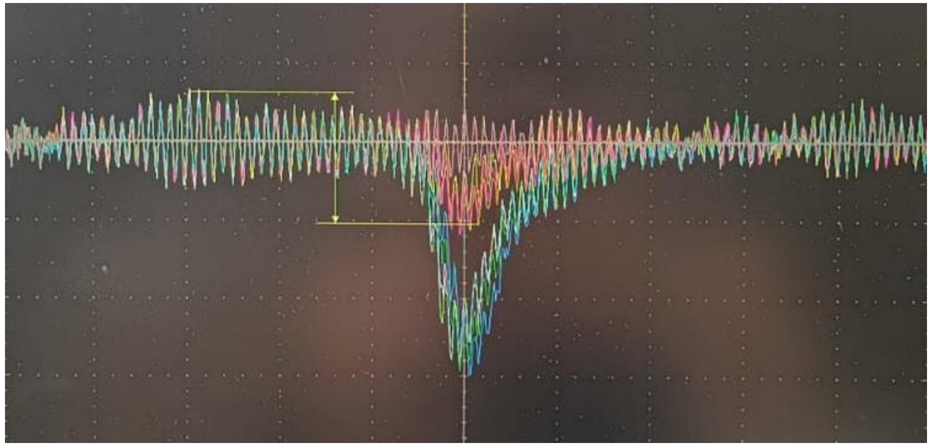
- We could **read the data through a wavedream** which displays the signal collected
  - The pad can be connected to three wavedreams but due to an excess of noise we chose to use only one
  - The **readout channels** are only those **enumerated in the picture**

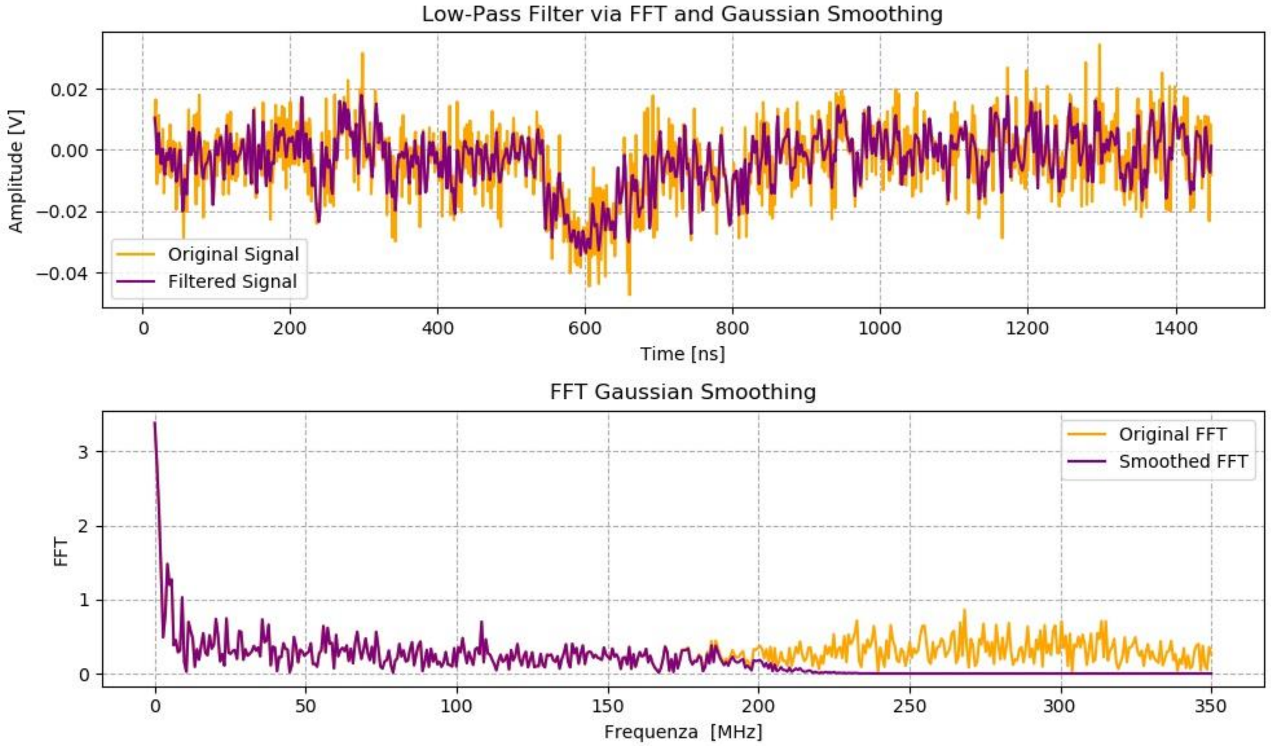
- **Channel 2 is a reference** channel used to subtract the noise
  - It is actually connected to the pad in the bottom right corner



DATA ANALYSIS - SMOOTHING

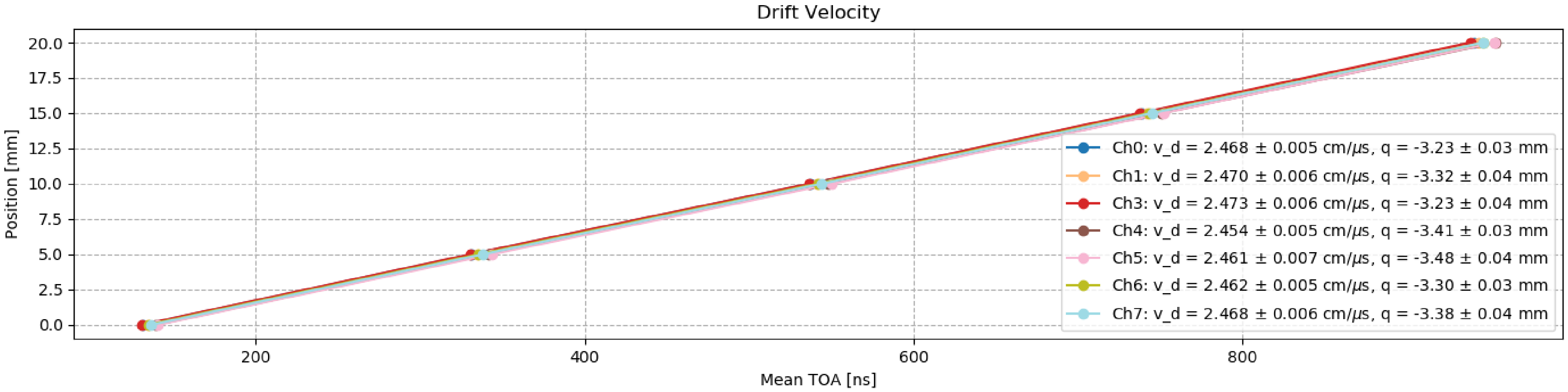
- To clear the signal first I subtracted the noise and then I smoothed the FFT spectrum





DATA ANALYSIS – DRIFT VELOCITY

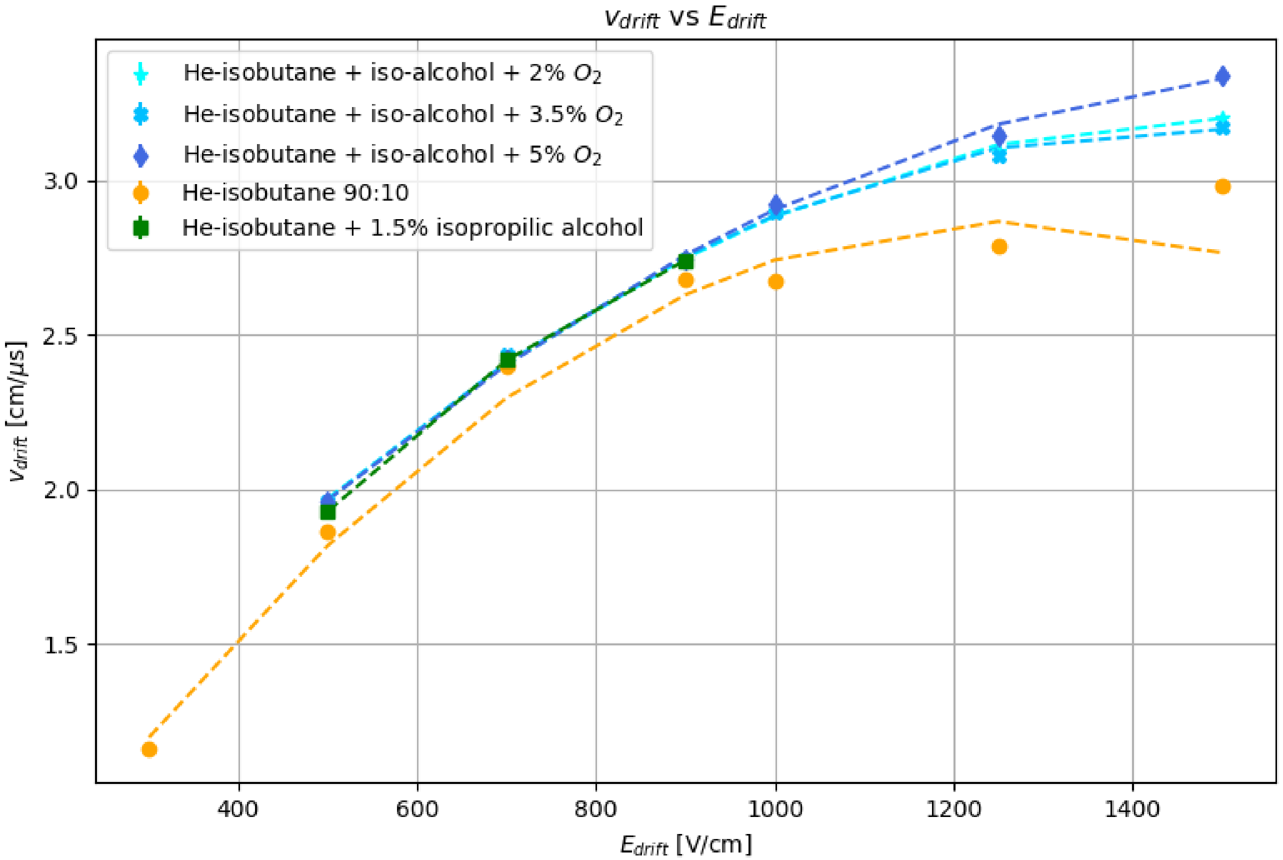
- To extract the **drift velocity** for each mixture we collected data at different distances with respect to the read-out pads and then we extracted the time of arrival from the signal distribution



Example of a linear fit to obtain the drift velocity

DATA ANALYSIS – DRIFT VELOCITY

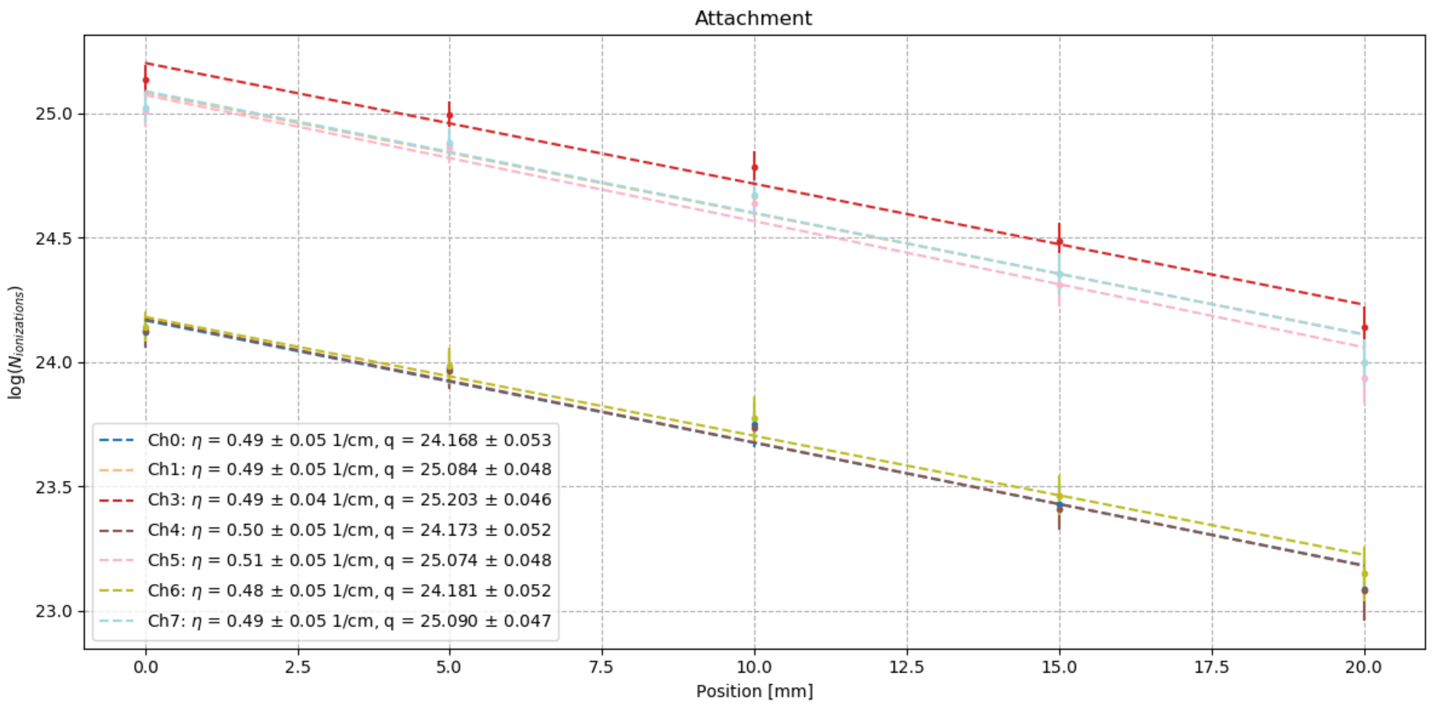
- **Drift velocity vs drift field**
  - The pure mixture measurements are not aligned: it might be related to a non-homogeneity of the mixture at the time



DATA ANALYSIS - ATTACHMENT

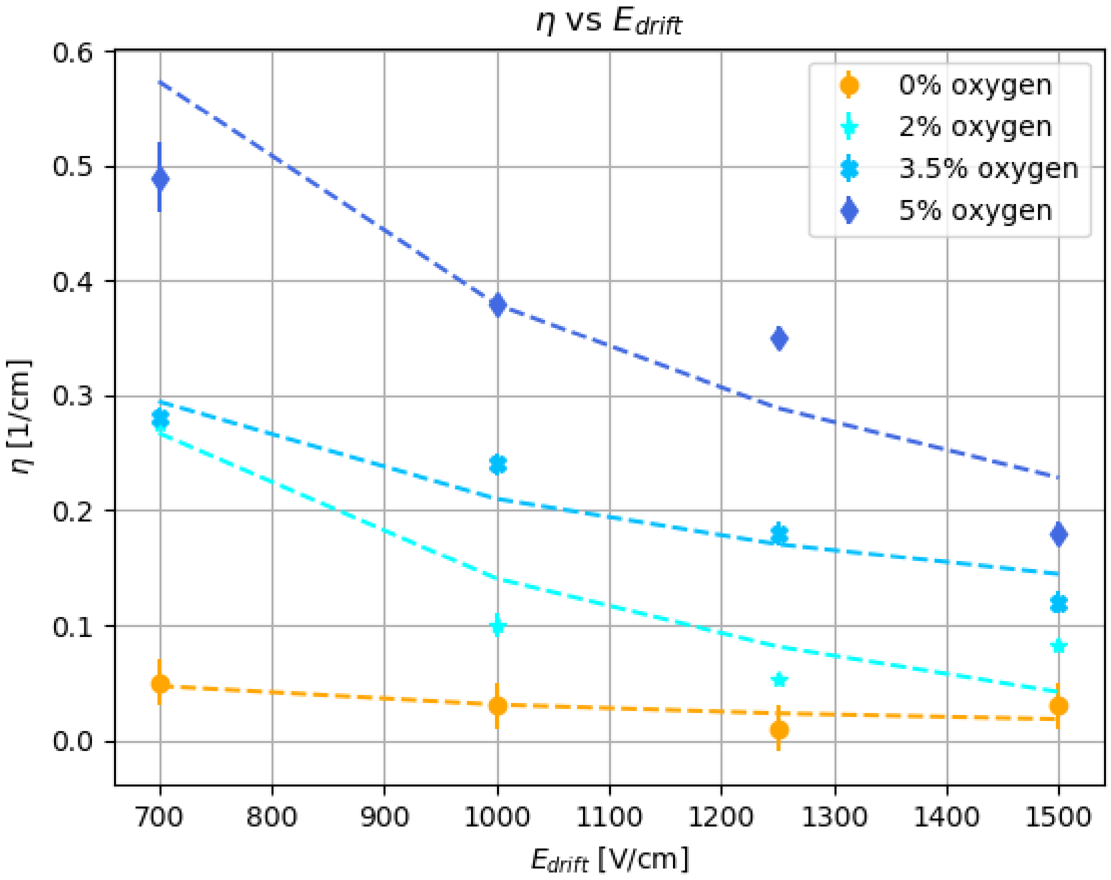
- To obtain the **attachment coefficient** I studied how the amplitude of the signal changes with respect to the drift length
  - The result must depend on the mixture composition, in particular on the Oxygen concentration

- The relation between the number of ionizations and the attachment coefficient is described by $N(d) = N_0 e^{-\eta d}$
  - The fit function, then, is $\log\left(N(d)\right) = \log(N_0) - \eta d$



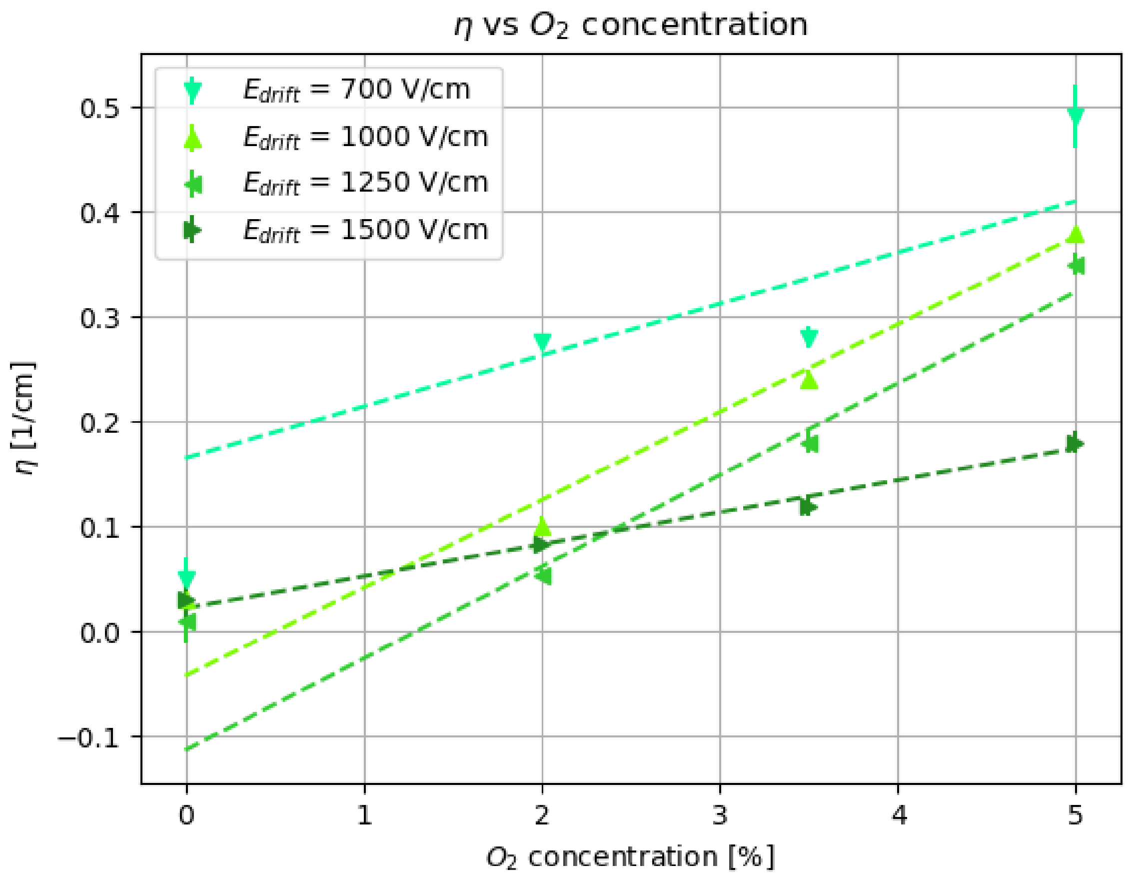
DATA ANALYSIS - ATTACHMENT

- **Attachment coefficient vs drift field**
  - The data collected have a hyperbolic behaviour, as expected



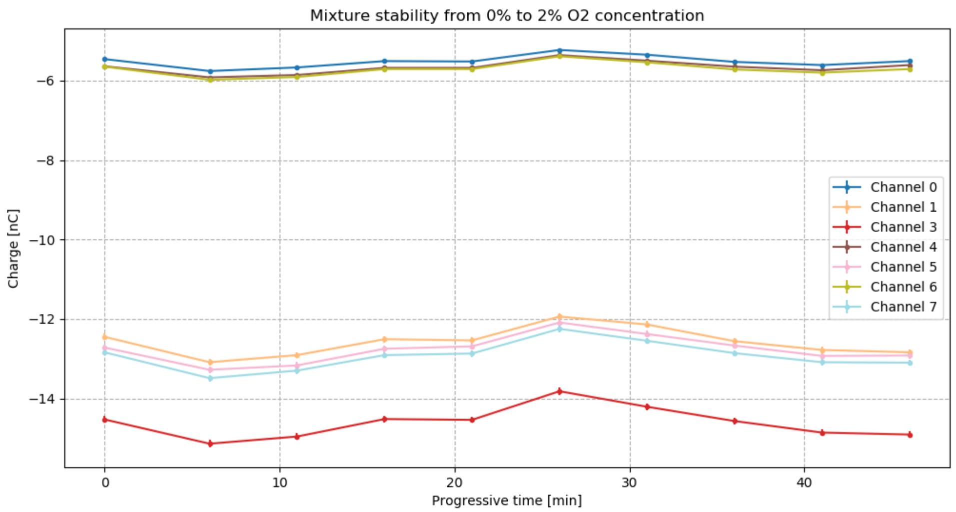
DATA ANALYSIS - ATTACHMENT

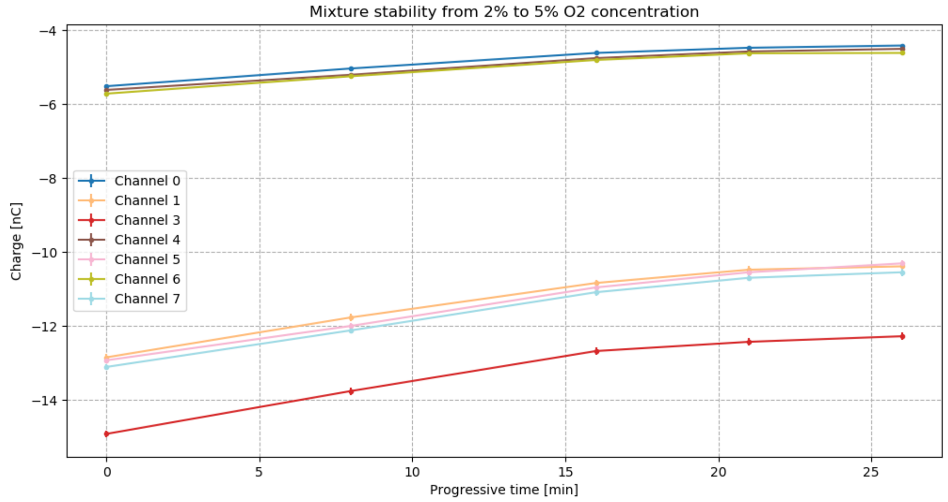
- **Attachment coefficient vs oxygen concentration**
- In the plot of the attachment coefficient vs the Oxygen concentration we would expect a linear behaviour
- The discrepancy with respect to the expected behaviour is most likely due to the fact that we were not in full control of the Oxygen concentration

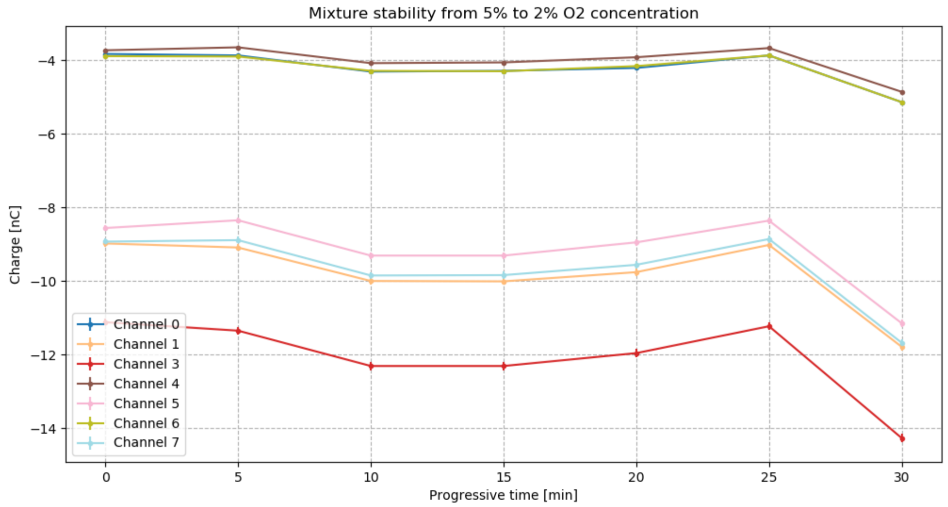


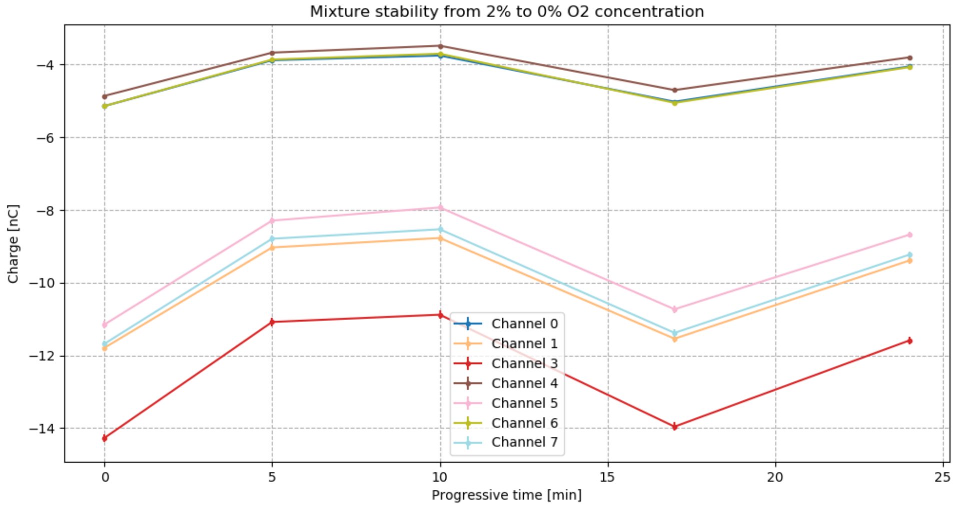
MIXTURE STABILITY

- Here a possible explanation of what we have just seen
- The mixture needs some time to stabilize
- Moreover with our instrumentation we are not very sensitive to the 0% to 2% transition









WHAT IS NEXT?

- From these results we could understand the **limitations** of our set up
  - The drift velocity behaves as expected while the **attachment shows some discrepancies**
- It is crucial to **know the actual oxygen concentration** inside the mixture
  - This can be done introducing an oxygen analyser after the chamber
  - We could also add an intermediate step between the mixer and the chamber so that the mixture is homogeneous when enters the detector
- The **laser instabilities** effects must be reduced
  - To do so we can split the laser beam: one half is set at fixed position while the second one can be moved to perform the measurements needed

FUTURE

- The very next step will be to **set up the ageing rate measurements** using an x-ray source

- We will also test other alternative mixtures
  - They must be **hydrocarbon-free** and **eco-friendly**, of the kind He:CO2:HFO
  - An example of HFO is R-1234ze which is already used in RPCs

- This study is in the interest not only of the MEG-II collaboration but also for other future experiments

AKNOWLEDGMENTS

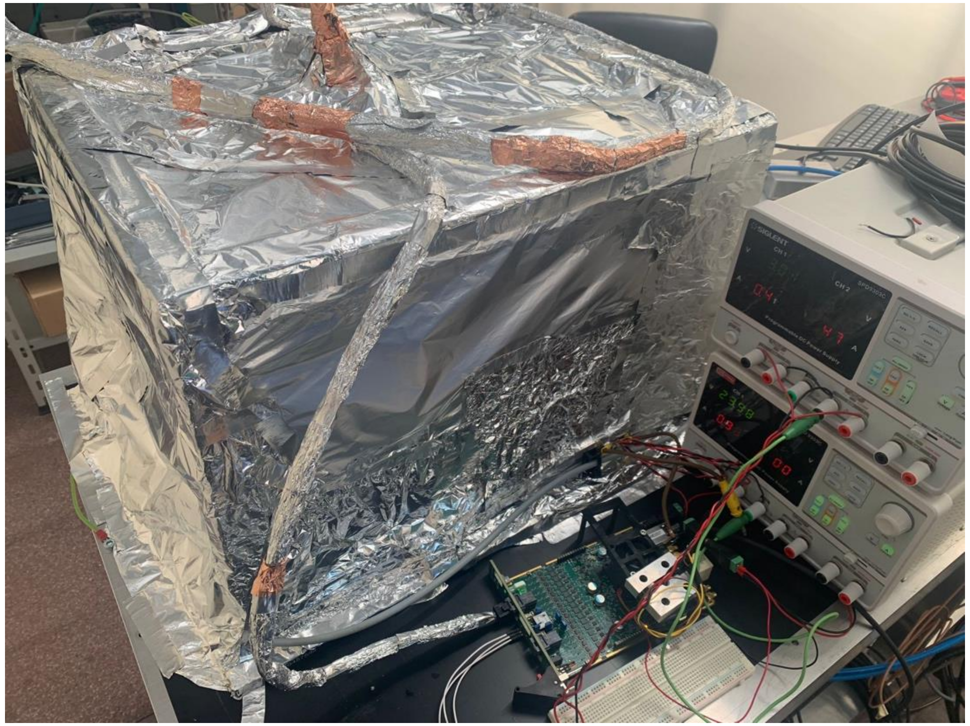
A special thanks to the **aMUSE, CYGNO** and **CMS** collaborations for their hospitality and support at the LNF

THANK YOU FOR YOUR ATTENTION!

BACK UP SLIDES

SETTING

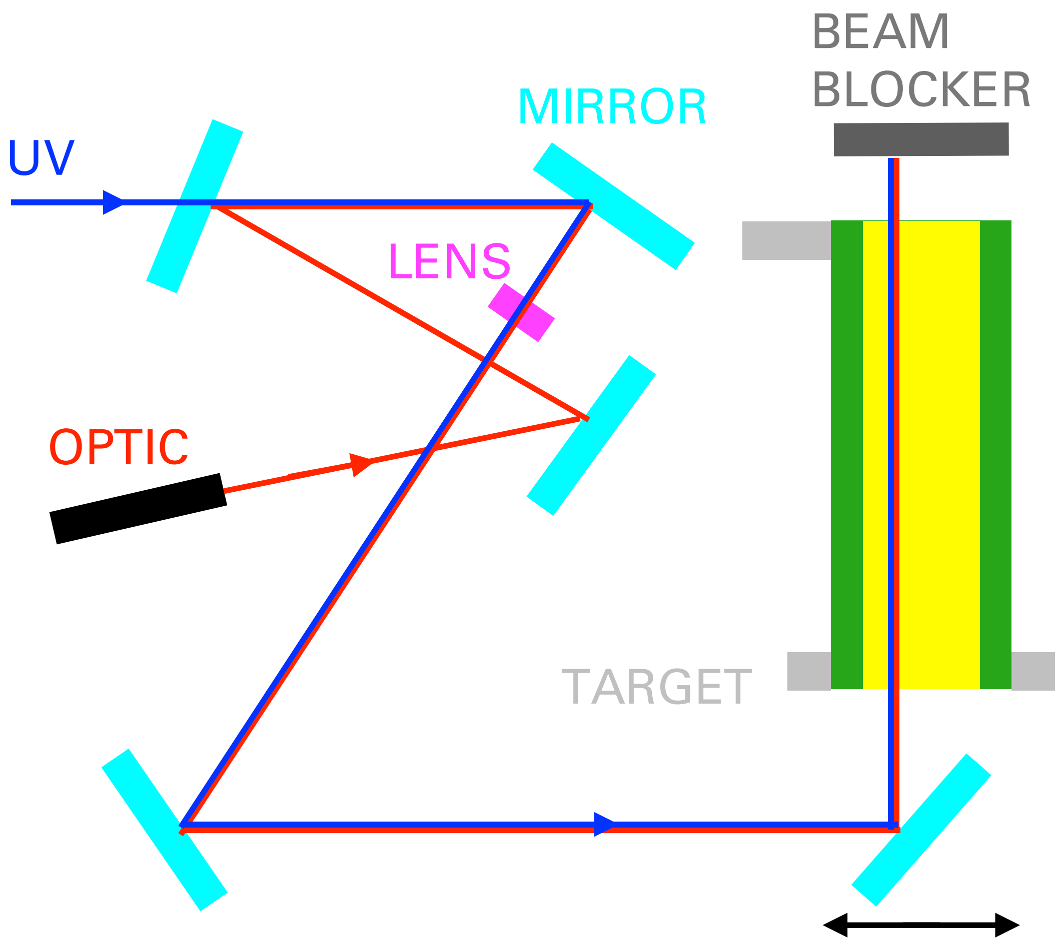
- In the first period we reduced the noise by shielding the whole apparatus: the price to pay is that you can no longer disconnect the box
- Then we improved the internal soldering in order to be able to raise the voltage to 5000 V: in this way we can safely explore drift ranges of 1500 V/cm
- The anode can reach 1500 V but we have always worked at 1300 V



LASER ALIGNMENT

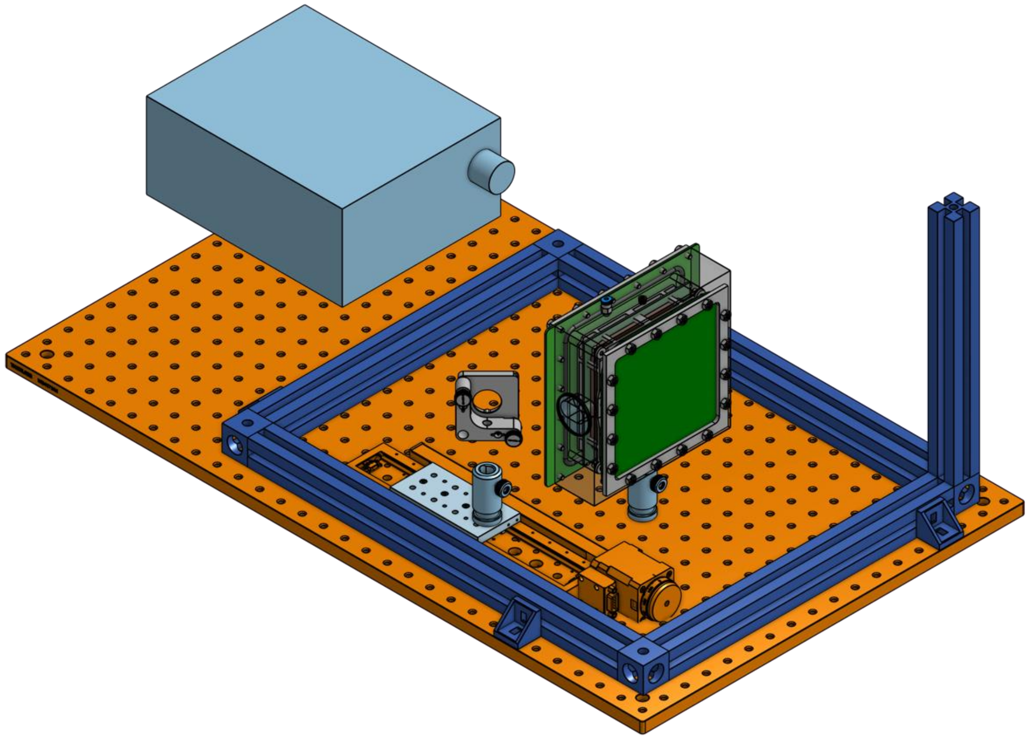
- Since the box cannot be opened, we performed the alignment by inserting the optical laser inside the box and arranging mirrors and lenses appropriately

- If we want to add the reference beam, we will have to replace the beam blocker with a mirror and insert a beam splitter in the diagram

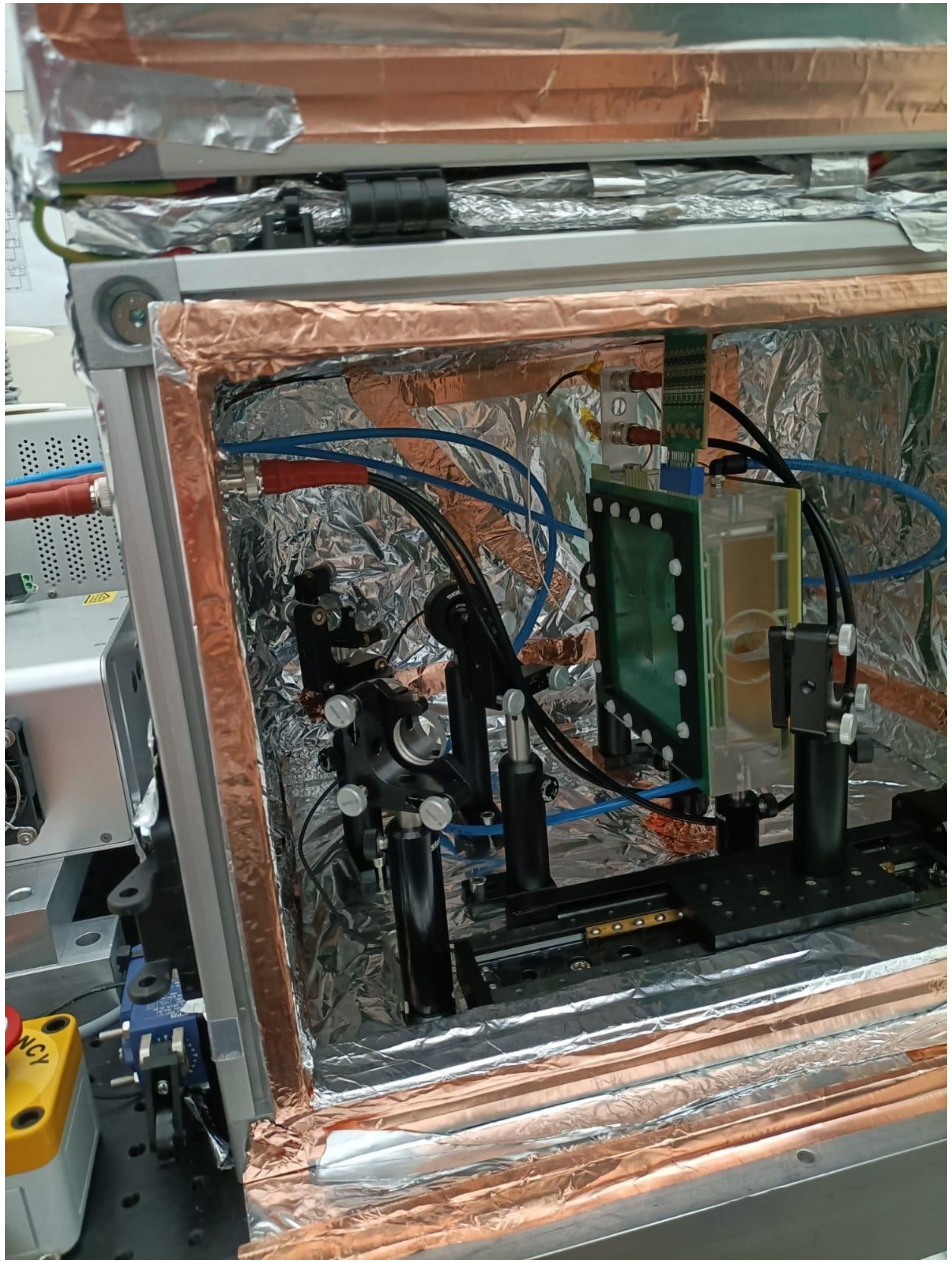


SECOND STEP – WIRING AND LASER ALIGNMENT

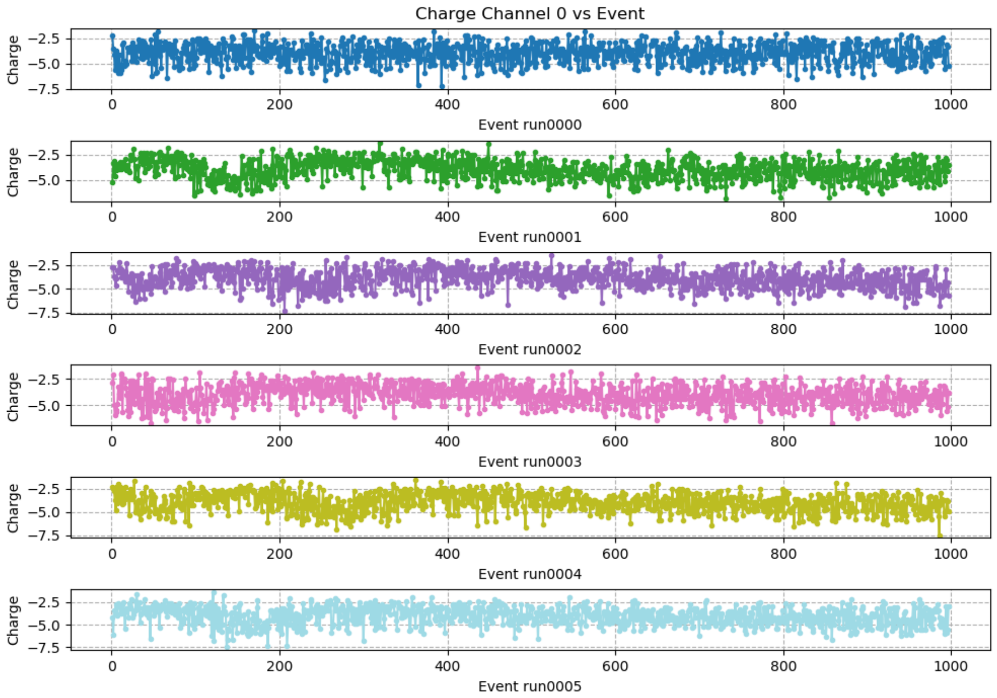
- Due to logistic reasons we had to choose the **wires configuration** as our read out
- After the wiring of the detector we could set the apparatus at LNF, including the UV laser needed to perform the measurements of drift velocity and attachment coefficient
- The UV laser ionizes the gas locally and maximizes the statistics collected



SET UP

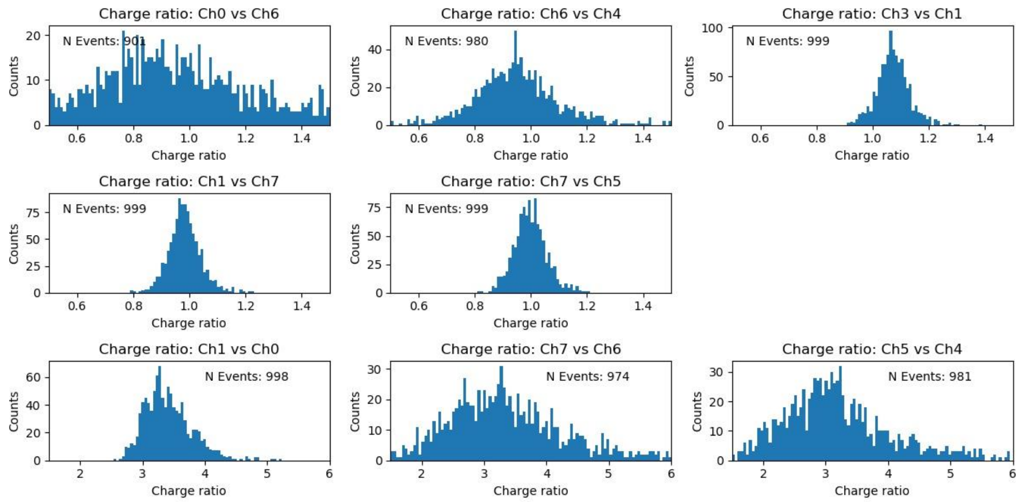


PRELIMINARY ANALYSIS



- In the picture above we see that the charge collected do not have any bias throughout several events

- The picture below shows the ratio of the charge distributions between near-by channels
  - It is clear that some instabilities, connected to the laser, spread the distribution
  - The solution is to split the beam and perform the measurements having a fixed reference



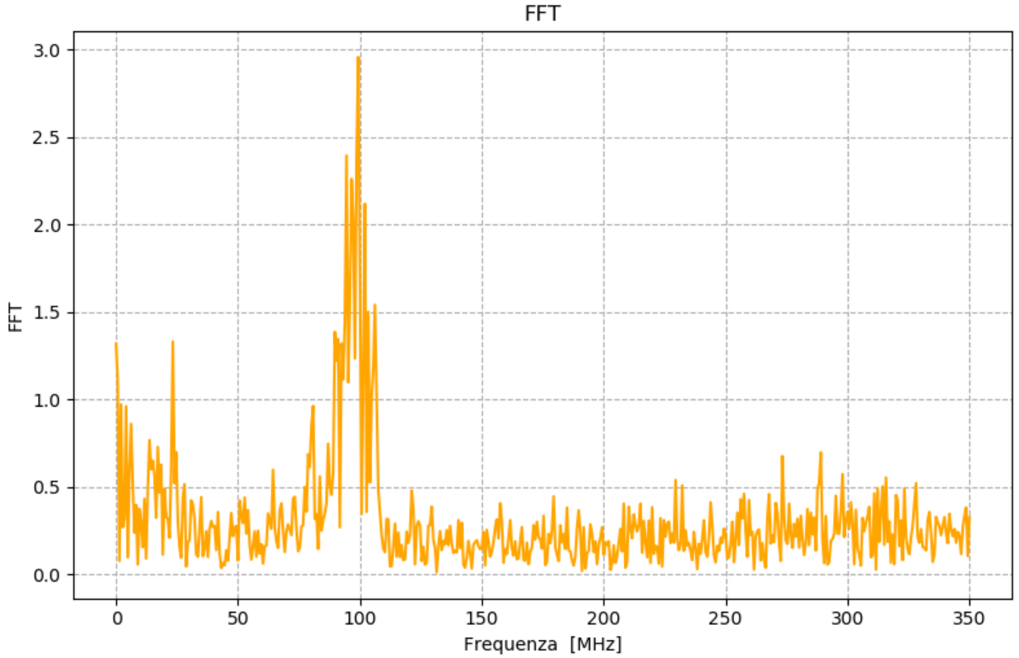
VELOCITÀ DI DRIFT

Confrontando i valori ottenuti per v_drift in diversi scan si osserva una certa variabilità nei risultati specialmente cambiando il flusso della miscela

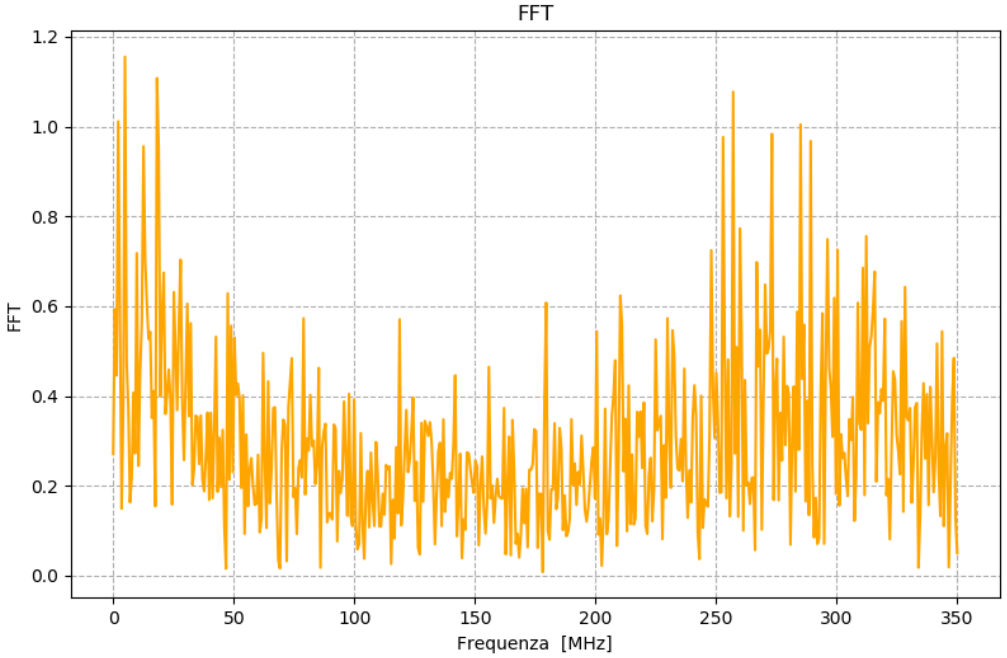
Run	Miscela	Flusso Miscela	E_drift	V_drift
0006-0010	He:isobutano	30 sccm	700 V/cm	2.113 ± 0.002 cm/μs
0023-0027	He:isobutano	30 sccm	700 V/cm	2.133 ± 0.002 cm/μs
0033-0037	He:isobutano	100 sccm	700 V/cm	2.416 ± 0.007 cm/μs
0048-0052	He:isobutano, alcool 1.2%	100 sccm	700 V/cm	2.409 ± 0.008 cm/μs
0063-0067	He:isobutano, alcool 1.2%, O2 2%	100 sccm	700 V/cm	2.40 ± 0.01 cm/μs
0068-0072	He:isobutano, alcool 1.2%, O2 2%	100 sccm	700 V/cm	2.428 ± 0.008 cm/μs
0083-0087	He:isobutano, alcool 1.2%, O2 3.5%	100 sccm	700 V/cm	2.427 ± 0.007 cm/μs
0098-0102	He:isobutano, alcool 1.2%, O2 5%	100 sccm	700 V/cm	2.416 ± 0.007 cm/μs
0143-0147	He:isobutano	100 sccm	700 V/cm	2.400 ± 0.003 cm/μs
0163-0167	He:isobutano, alcool 1.4%, O2 2%	100 sccm	700 V/cm	2.451 ± 0.005 cm/μs
0183-0187	He:isobutano, alcool 1.5%, O2 3.5%	100 sccm	700 V/cm	2.465 ± 0.006 cm/μs
0203-0207	He:isobutano, alcool 1.6%, O2 5%	100 sccm	700 V/cm	2.415 ± 0.005 cm/μs
0225-0229	He:isobutano, alcool 1.6%, O2 5%	100 sccm	700 V/cm	2.348 ± 0.004 cm/μs

FFT SPECTRA NO SIGNAL RUN

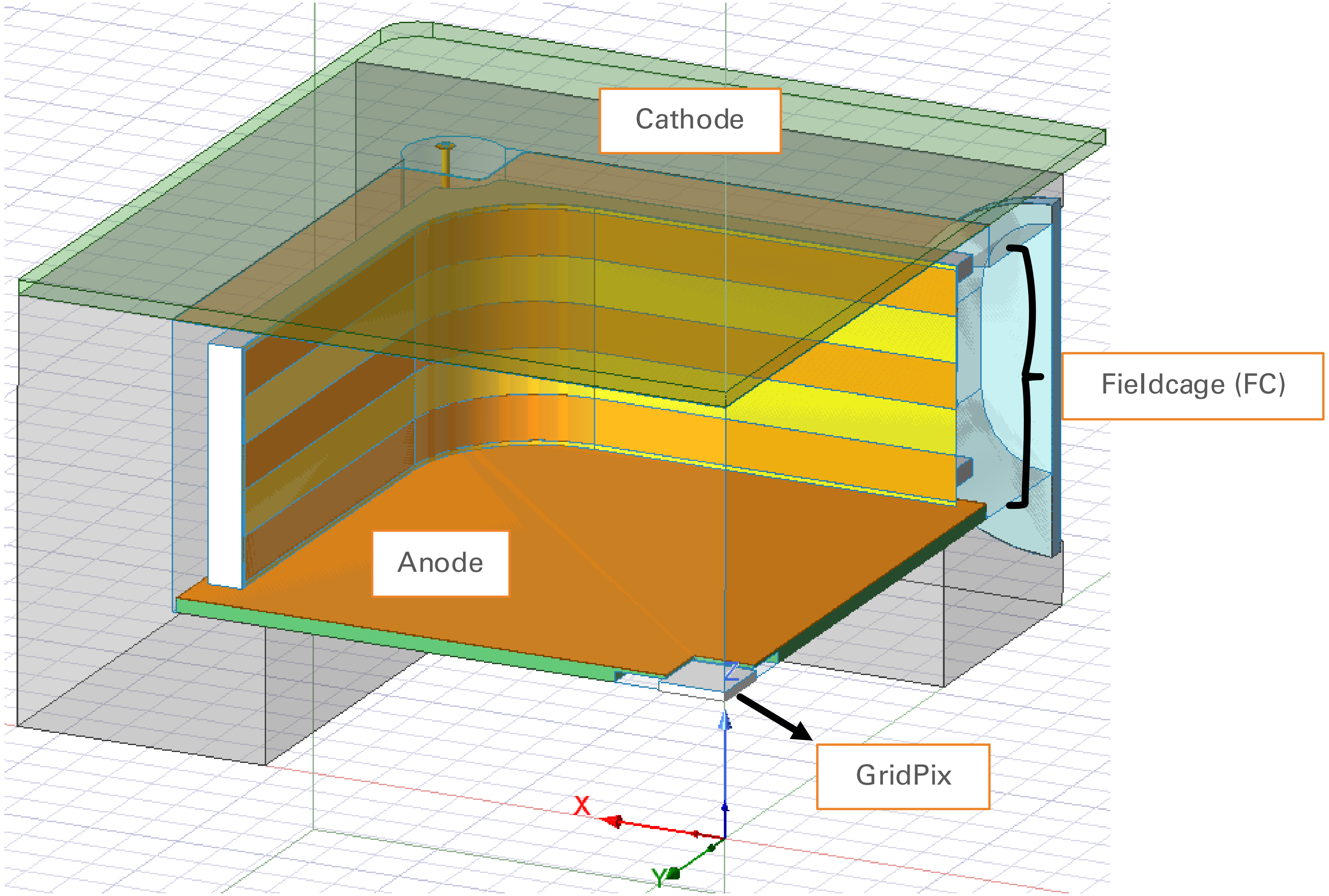
Before noise subtraction



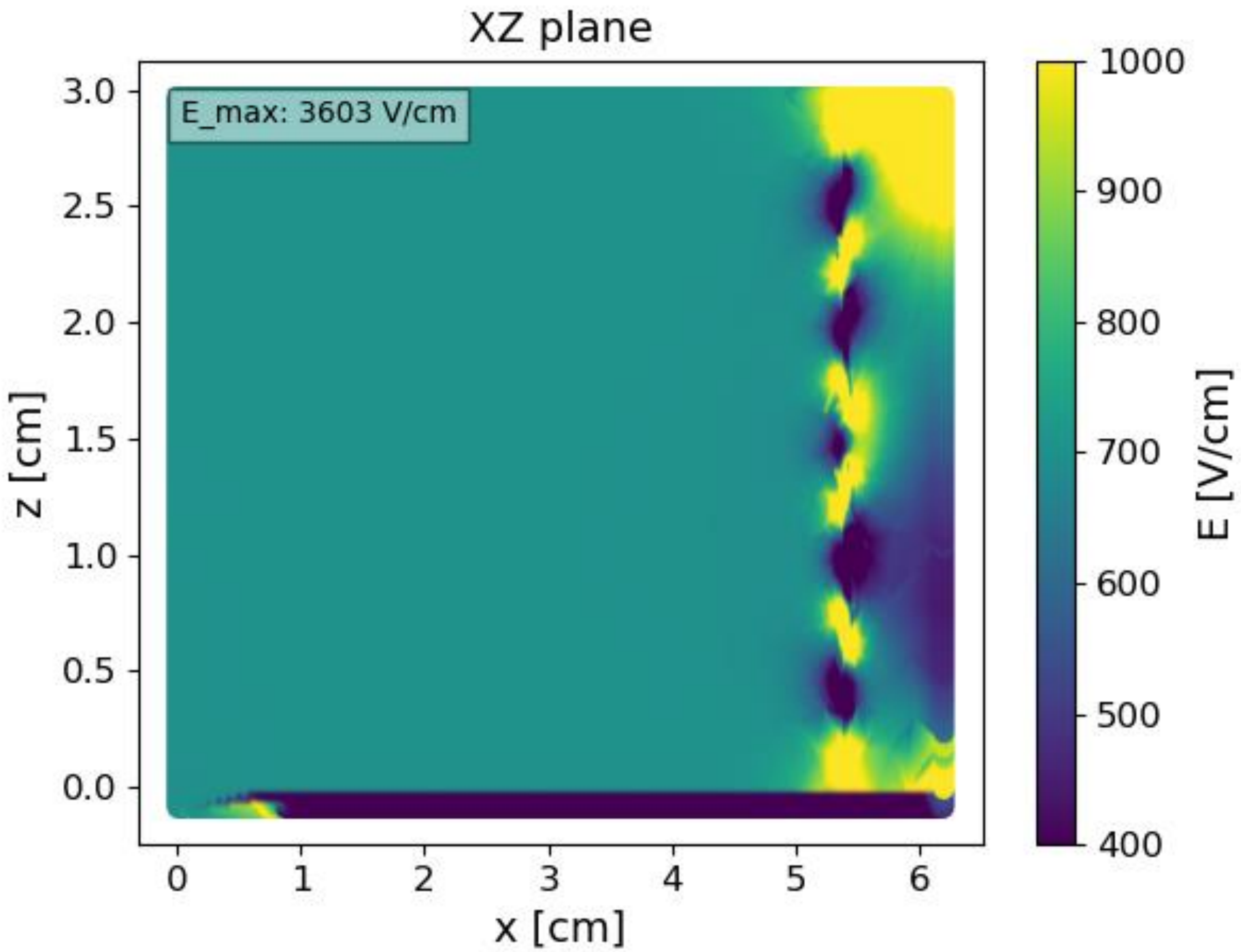
After noise subtraction



SIMULATION MODEL



E_FIELD SIMULATION



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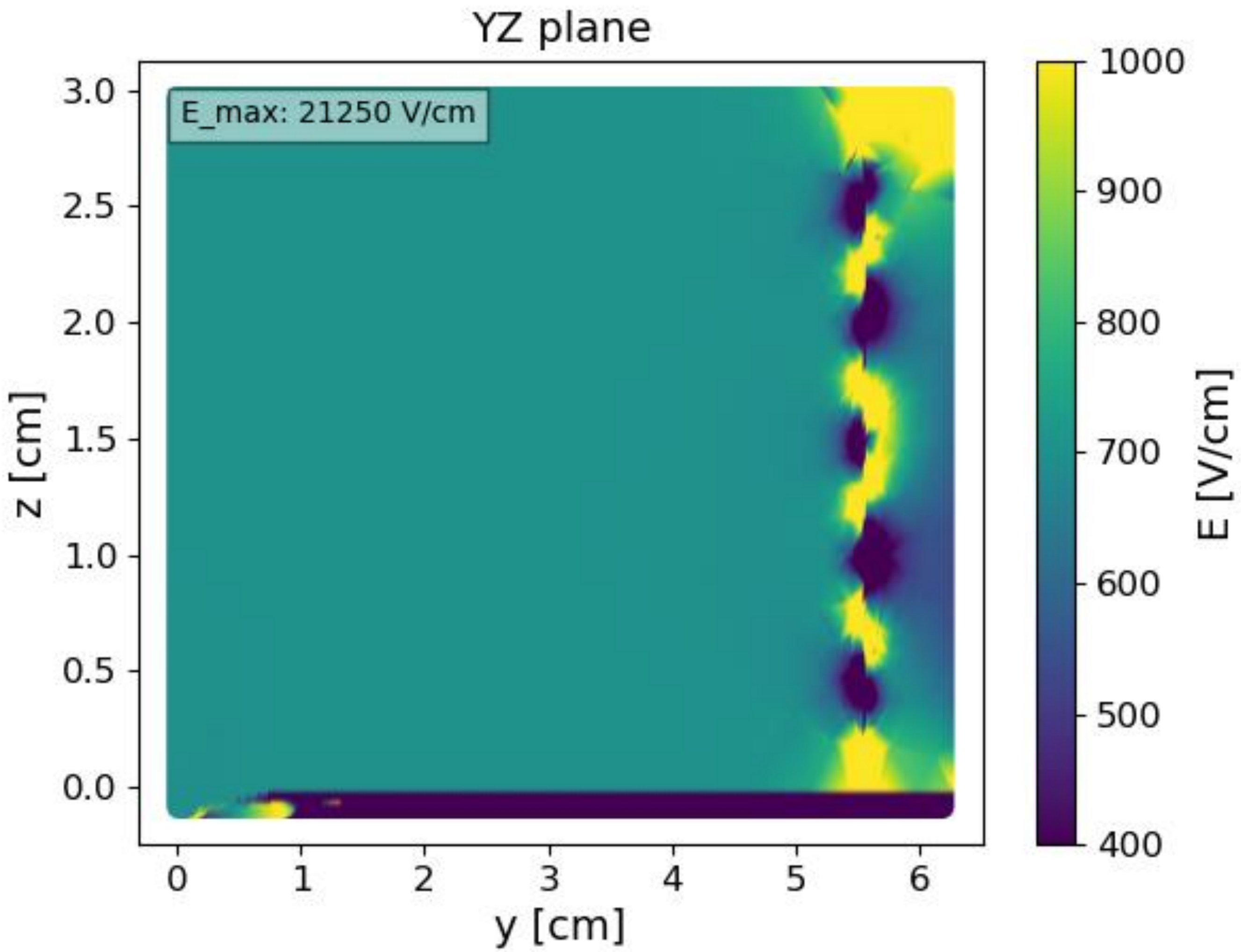

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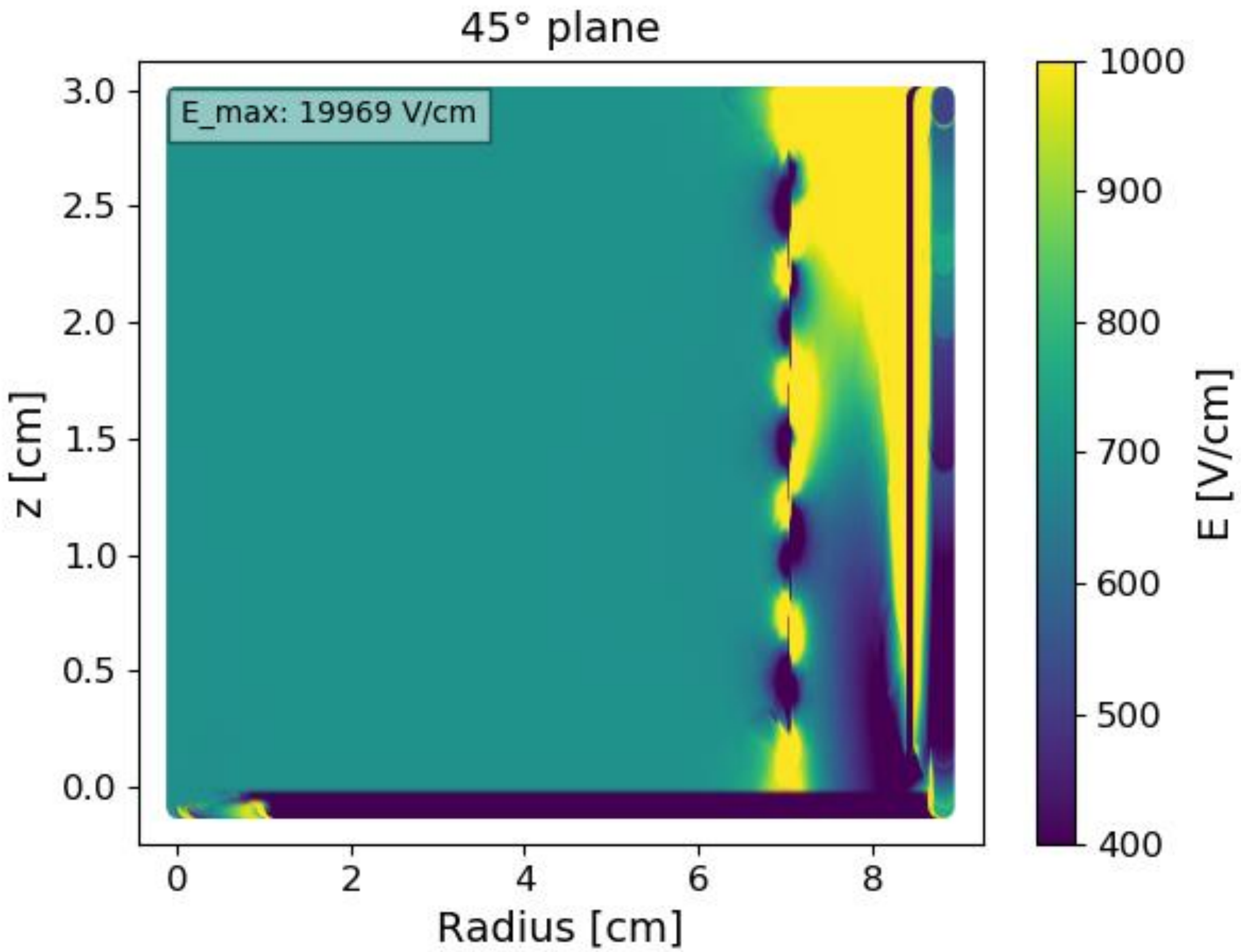

FIELD CAGE

- This is the field cage which is an innovative technology to be explored
- Unfortunately, we were not able to test it since it causes discharges inside the chamber at relatively low voltages