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Drift time studies for TRD@CBM using the Garfield simulation package

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Drift time studies for TRD@CBM using the Garfield simulation package

Mihai PUSCAS

1. Introduction

The TRD provides electron identification and tracking of all charged particles. It has to provide, in conjunction with the RICH detector and the electromagnetic calorimeter, sufficient electron identification capability for measurements of charmonium and low-mass vector mesons. The required pion suppression is a factor of about 100 and the required position resolution is of the order of 200-300 um.

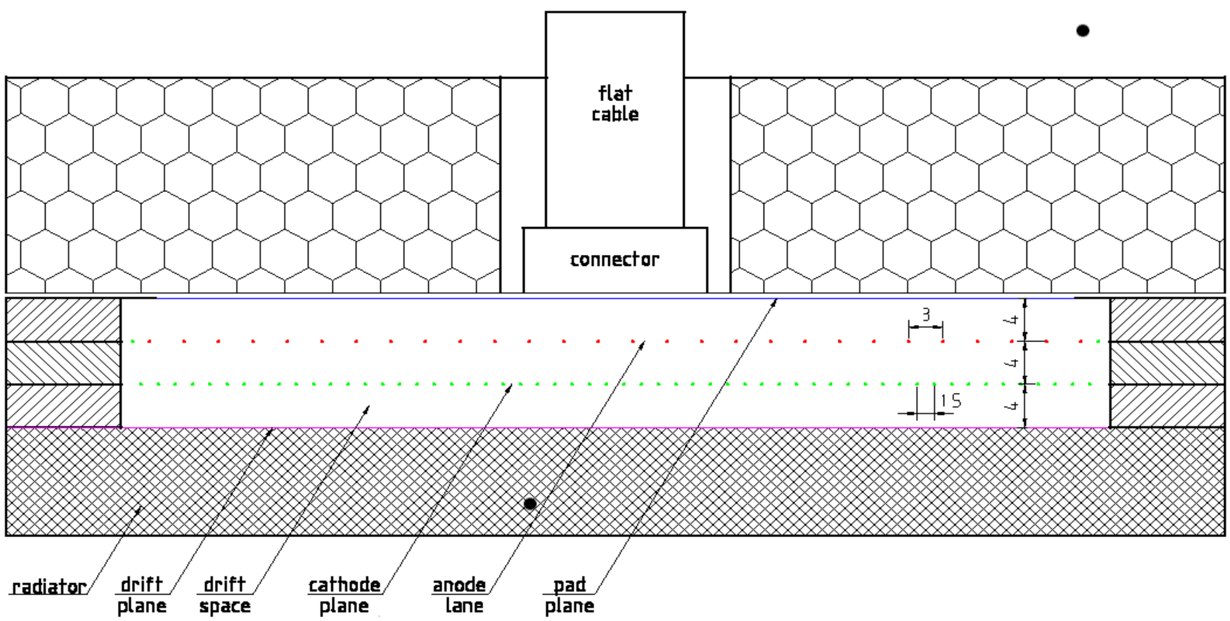
In order to fulfill these tasks, in the context of the high areas and high particle multiplicities in CMB a careful optimization of the detector is required.

Garfield is used to simulate this chamber and use the resulted data to optimize the design.

2. Garfield

Garfield is a computer program for the detailed simulation of two- and three-dimensional drift chambers.

Originally designed for two-dimensional chambers composed of wires and planes with known exact fields, it is interfaced with the neBEM program and can accept 2d and 3d field maps computed by third party programs such as Maxwell, Tosca, QuickField,



FEMLAB for handling more complex 3d configurations.

An interface with the Magboltz program computes electron transport properties in different gas mixtures by solving the Boltzmann transport equation under the influence of electric and magnetic fields. The interfaced Heed program simulates ionization of gas molecules by particles transversing the chamber.

A Garfield program is composed of different sections, each opened with a different header: &CELL, &DRIFT, &GAS, &MAGNETIC , &FIELD, &SIGNAL.

-&CELL: defines chamber layout, the first stage in most simulations.

-&MAGNETIC: sets up the magnetic field.

-&GAS: establishes the gas mixture to be used when drifting charged particles. The Magboltz program will calculate the electron drift velocity, diffusion, Townsend and attachment coefficient.

-&FIELD: section used to inspect the electrostatic character of the chamber

-&DRIFT: displays the behavior of electrons and ions in the chamber. Gas and cell data are needed in the computations.

-&SIGNAL: performs signal calculations.

-&MAIN: top level of program input.

3. TRD Simulation.

Main program level:

```
&MAIN
Global gas_file `trd3XE.gas`          *magboltz gas file defintion
Global ny=24                          *number of parallel with the x axis tracks equally spaced on the y axis
Global nx=200                         *number of primary ionizations per track
```

The chamber is defined in Garfield:

```
& CELL
*echipotential planes
plane y=0. v=-400.
plane y=1.2 v=0 label q

*28 Anode wires, 57 cathode rows
S 28 0.002  .3*i+0.25 0.8 +1800
*anode wires  - width ; X ; Y; potential
P 57 0.007 .15*i+0.175 0.4 0
*cathode wires
CELL-ID "TRDAR"
```

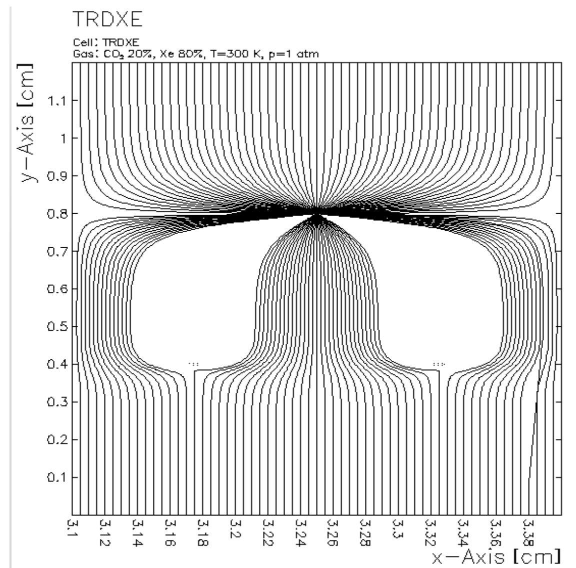
Gas options are stated, the magboltz program is run yielding electron transport properties

```
*gas options
& GAS
pl-opt noion-mobility
opt gas-plot

*pressure, temperature
temperature 300 K
pressure 1 atm

*magboltz simulation is time consuming, the program checks if the gas file is already computed.
Call inquire_file(gas_file,exist)
If exist Then
 Say "Gas file {gas_file} exists, retrieving..."
 get {gas_file}
```

```
Else
Say "Gas file {gas_file} not found, generating..."
*magboltz simulation
 magboltz argon 80 co2 20
*heed distribution initialization
 heed argon 80 co2 20
*gas mix
add ion-mobility 0.57e-6
write {gas_file}
Endif


heed argon 80 co2 20
write {gas_file}

*readable gas file
opt gas-plot
>gasAR.print
>
```

Drift line calculations are done using a linear track at different heights, the data is dumped into a text file.

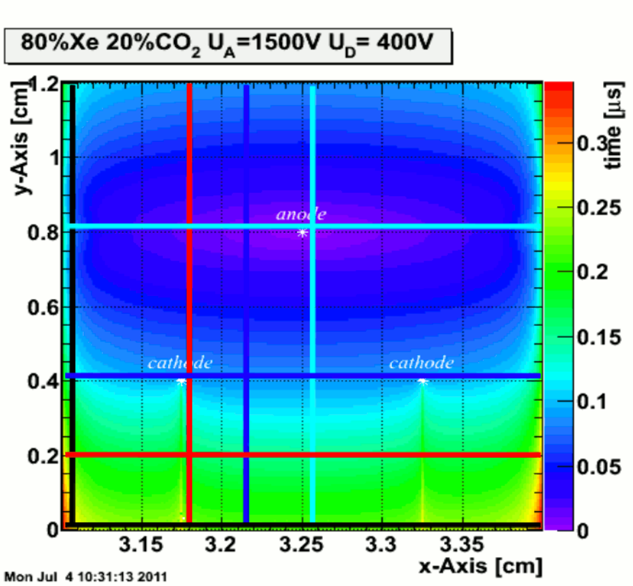
```
& DRIFT
Global Length            *defining used variables as global
Global Stat
Global Time
Global Diff
Global Ampl
Global NS
select S                 *selecting the S(sensing/anode) wires
area 3.1 0 3.4 1.2       *selecting plot area (Xmin, Ymin, Xmax, Ymax)
* Call plot_drift_area   *starts a plot
> test.dat               *all output directed to this file
For j From 0 To ny Do
  Global y=j*1.2/ny
  For i From 0 To nx Do
   Global x=i*0.3/nx+3.1
   call drift_electron({x}, {y}, Stat, Time, Diff, Ampl)   *creates a new drift line starting at x, y, calculates drift time, velocity, diffusion and avalanche coefficient.

  call drift_information(`PATH-LENGTH`, Length, `STEPS`, NS)
   say "{x} {y} {Time} {Length} {Diff} {Ampl} {NS} {Stat}" *outputs selected variables

 Enddo
Enddo
>
**batch NIHAM - ~abercuci/Garfield
```



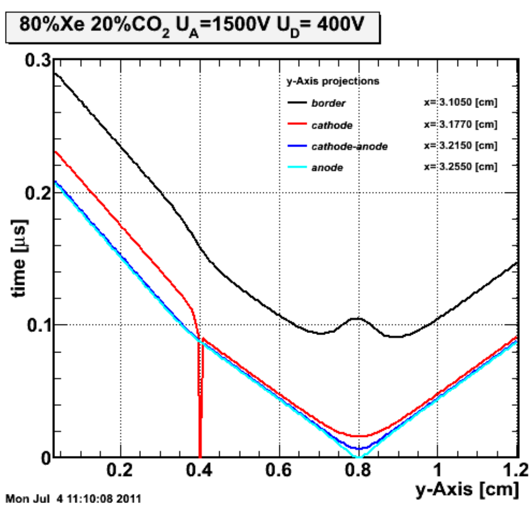
Plot of drift lines starting from two different linear tracks: one at y=0 and the other at y=1.2, showcasing the chamber electric field map.

4. Data analysis and systematics.

The Garfield data output files are read and stored into a ROOT file. ROOT is used because of the more varied data analysis tools available.

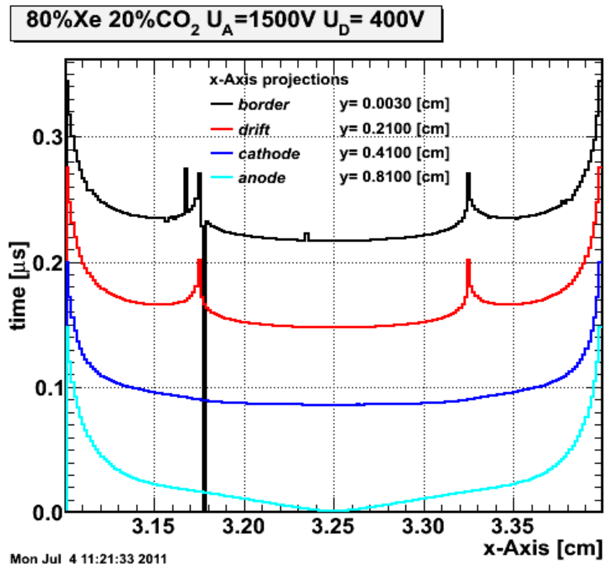


Time histogram of two TRD cells filled with a mixture of Xe (80%) and



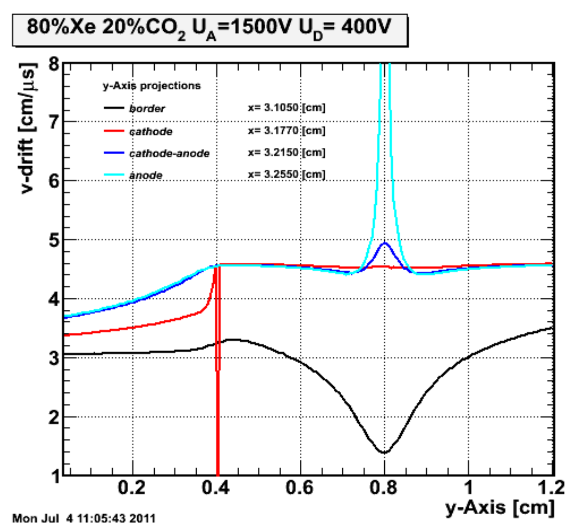
CO_2 (20%). The pad plane at y=0 is held at -400V, cathode wires at 0V and the anode wire at +1500V.

The cuts represent X and Y projections of areas of interest. The colors in the projection plots correspond to those of the cuts.

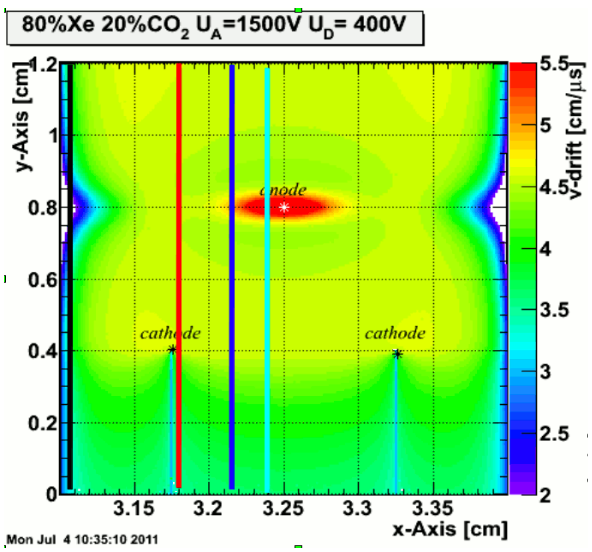


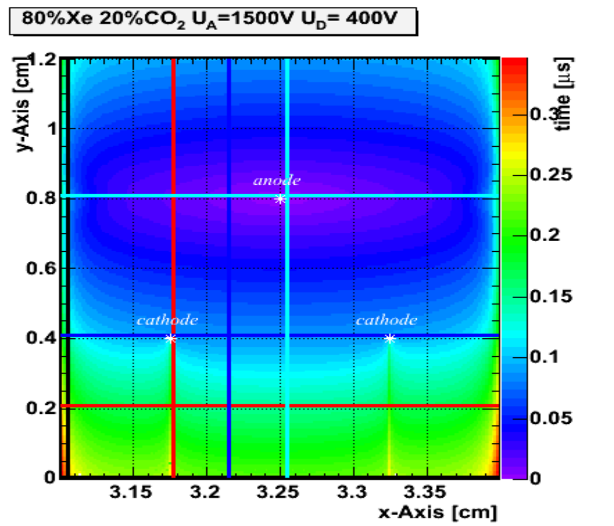
Drift speed histogram.

Y axis projection

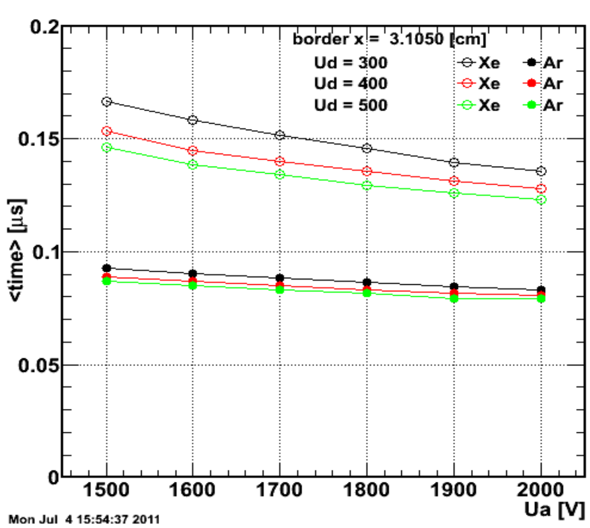


Collating data gathered for different electric potential settings (anode: 1500-2000V, 100V step; pad plane 300-500V, 100V step) and averaging bin values in the previously discussed projections yields data about gas performance.

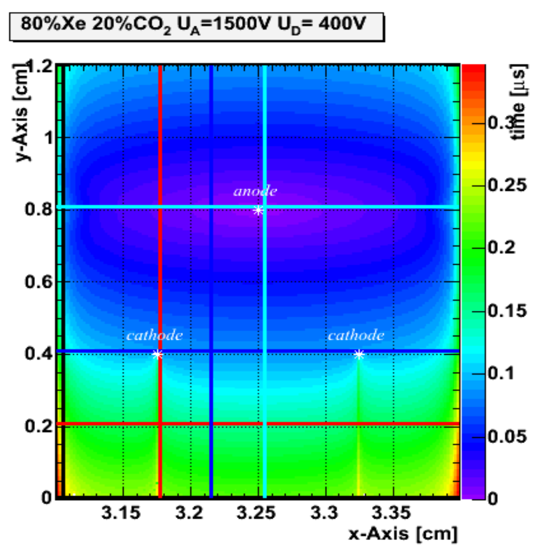


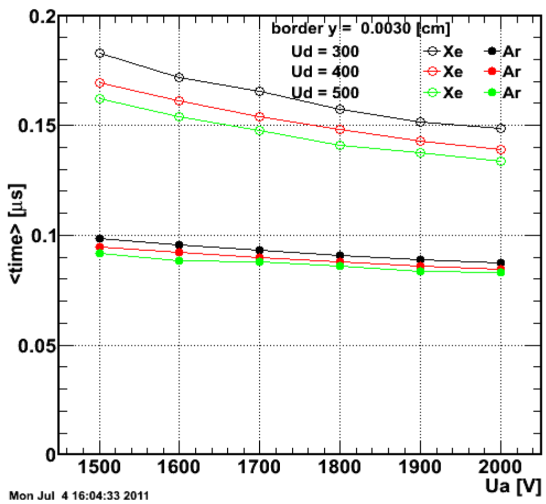


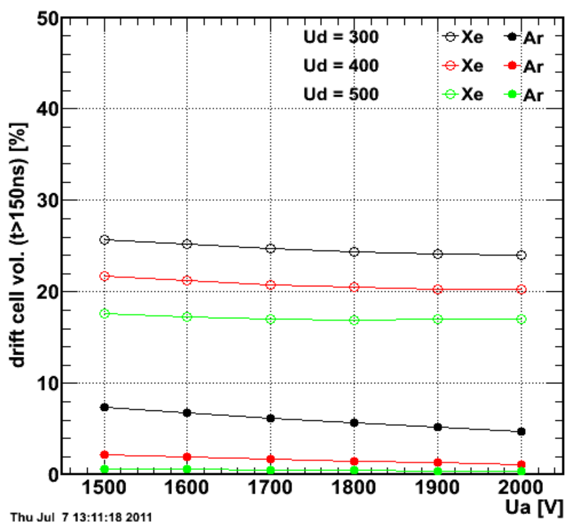
Perpendicular drift time systematic (y projections):



Parallel drift time systematic (x projections):







Percentage of drift cell that can be excluded when fast electronic read-out is used

[tau=150ns]

On average, Xenon mix filled chambers are substantially slower than the Argon mix ones. Particular areas of interest are the lower edges of the chamber (avg XE drift time > 200ns) and the whole area below the cathode plane (screened area).

The Argon gas mix , while much cheaper and allowing for substantially faster detectors , has lower ionization efficiency than the Xenon gas mix. A TRD using Ar-CO2 has lower performance in particle identification (PID) and track detection than one using Xe-CO2.

5. Conclusions

The Garfield package is a powerful tool for simulating different detector geometries. For the R&D studies of the TRD detector at CBM this has shown important features of the geometry of the drift cell which are of paramount importance for the design of the associated electronics read-out and for the dynamic range in which the detector can be operated.

The Xe gas has been shown to perform worse in terms of applications for detectors in high counting rate environments as compared with Ar (also tested in current simulations) but its higher efficiency for ionizing particle detection makes it a candidate for a gas fill. The volume of the drift cell which might be excluded using Xe when fast

electronic read-out [tau =150ns] is used
is of the order of 20%.

6. Bibliography

1. Garfield User's Guide version 4.29
- Rob Veenhof;
2. Garfield online help.

Drift time investigation for CBM single-sided TRD

Cristi SCHIRIAC, Filip PUICEA
Politehnica University of Bucharest

Drift time investigation for CBM single-sided TRD

Cristi SCHIRIAC , Filip PUICEA

1. Introduction

As future physicists we considered that a few weeks experience at The National Institute for Physics and Nuclear Engineering will be a great opportunity for us to see what does research assume and what is the actual knowledge level.

During the three weeks stay at DFH department we learned about particle detectors, we were introduced to drift time investigation experiment and also got the chance to experience the world of electronics design.

To start with, we will make a short presentation of the actual research stage and then we will present the experimental setup used by us and results with pictures and explications.

The research program of the Compressed
Baryonic Matter (CBM) experiment at FAIR is focused on the measurement of diagnostic probes of the early and dense phase of the fireball evolution. The goal of the experiment is to measure multiplicities, phase-space distributions and flow of protons, pions, kaons, hyperons, hadronic resonances, light vector mesons, charmonium and open charm including their correlations and event-by-event fluctuations in heavy-ion collisions. The technical challenge of the CBM experiment is to identify both, hadrons and leptons, and to filter out rare probes at reaction rates of up to 10 MHz with charged particle multiplicities of up to 1000 per event.

The heart of the experiment will be a silicon tracking and vertex detection system installed in a large acceptance dipole magnet. The Silicon Tracking System (STS) consists of low-mass silicon micro-strip detectors possibly complemented by one or two hybrid-pixel detector layers providing unambiguous space point measurements. The STS allows for track reconstruction in a wide momentum range from about 100 MeV up to more than 10 GeV with a momentum resolution of about 1 %.

The Micro-Vertex Detector (MVD) is
needed to determine secondary vertices with high precision for D meson identication. The MVD consists of two layers of ultra-thin and highly-granulated Monolithic Active silicon Pixel Sensors (MAPS) which are located close to the target. The measurement of electrons will be performed with a Ring Imaging Cherenkov (RICH) detector (for momenta below 8-10 GeV/c) together with Transition Radiation Detectors

(TRD) for electrons with momenta above 1.5 GeV/c. Charged hadron identification will be performed by a time-of-flight (TOF) measurement with a wall of RPCs located at a distance of 10 m behind the target.

The setup is complemented by an Electromagnetic Calorimeter (ECAL) in selected regions of phase space providing information on photons and neutral particles, and by a Projectile Spectator Detector (PSD) needed for the determination of the collision centrality and the orientation of the reaction plane.

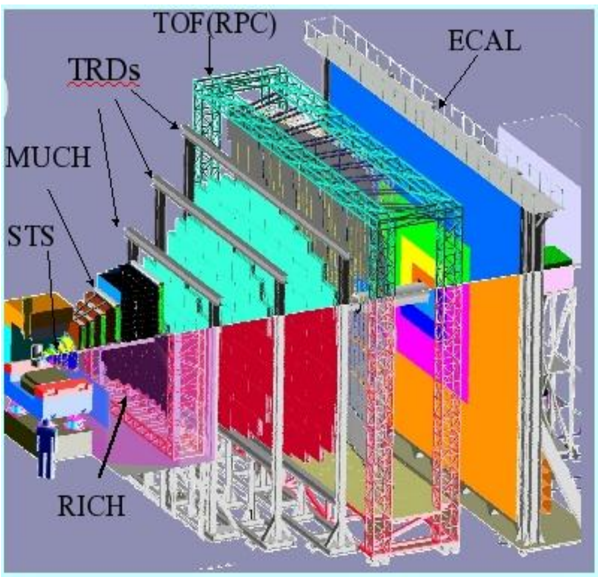


Fig 1. *The CBM setup consists of a large acceptance dipole magnet, radiation-hard Silicon pixel/strip detectors for tracking and vertex determination (STS, MVD), a Ring Imaging Cherenkov detector (RICH) and Transition Radiation Detectors (TRD) for electron identification, Resistive Plate Chambers (RPC) for time-of-flight measurement, an Electromagnetic Calorimeter (ECAL) for photon identification.*

2. The Transition Radiation detector (TRD)

In the CBM experiment at FAIR, a Transition Radiation Detector (TRD) is foreseen for tracking and electron-pion discrimination. Up to twelve detector layers are considered, each with a thin gas volume in order to have a sufficiently fast readout for the intended high collision rates.

For discriminating electrons from pions in the momentum region of a few GeV/c, a TRD profits from their different energy loss through ionization, but mostly from the additional transition radiation produced by electrons.

Detector geometry

The TRD prototype developed in the DFH department combines a proportional multiwire chamber with a drift zone, the separation being made by the multiwire cathode plane.
The structure of the detector can be followed in the lower part of **Fig. 2**.

The anode plane is made by gold plated tungsten wires of 20 μm diameter with an anode wire pitch of 3.0 mm. The cathode is made from Cu – Be wires of 75 μm diameter with a cathode wire pitch of 1.5 mm.

Aluminized kapton foil (25 μm) glued on a Rohacell plate is used to close the gas volumes providing at the same time the outer cathode of the re-spective MWPCs. The anode-cathode distance is 4 mm. The readout electrode

(Fig. 2 , upper part), has a pad structure. Each rectangular pad of 10 x 80 mm^2 is split on diagonal, each triangle being readout separately. The choice of triangular-pad geometry allows for position determination in both coordinates, across and along the pads, respectively. The readout electrode has 72 triangular pads.

It is known that a signal amplitude at the amplifier output depends also on its shaping time constant. For the TRD prototype with a double sided architecture based on simple multiwire proportional chamber geometry [2], the small drift time of the charge carriers fit the 40 ns amplifier shaping time constant and assures proportionality between the obtained signal at the amplifiers output and the created charge detected in one event.

In case of the prototype investigated by us - proportional multiwire chamber coupled with a drift zone- the field in the drift region is less intense than that from the amplification region and has the only purpose of drifting the charge carriers to the anode multiplication zone.

In general, for a minimum ionizing particle the region where drift electrons are created is different for each event. This is due to the fact that the distance between two ionizations along the particle track is Poisson distributed. The primary ionization creates charge clusters in the drift zone, randomly distributed over the thickness of the drift region. Depending on the applied drift field and the used detection, gas type, the drift time may vary.

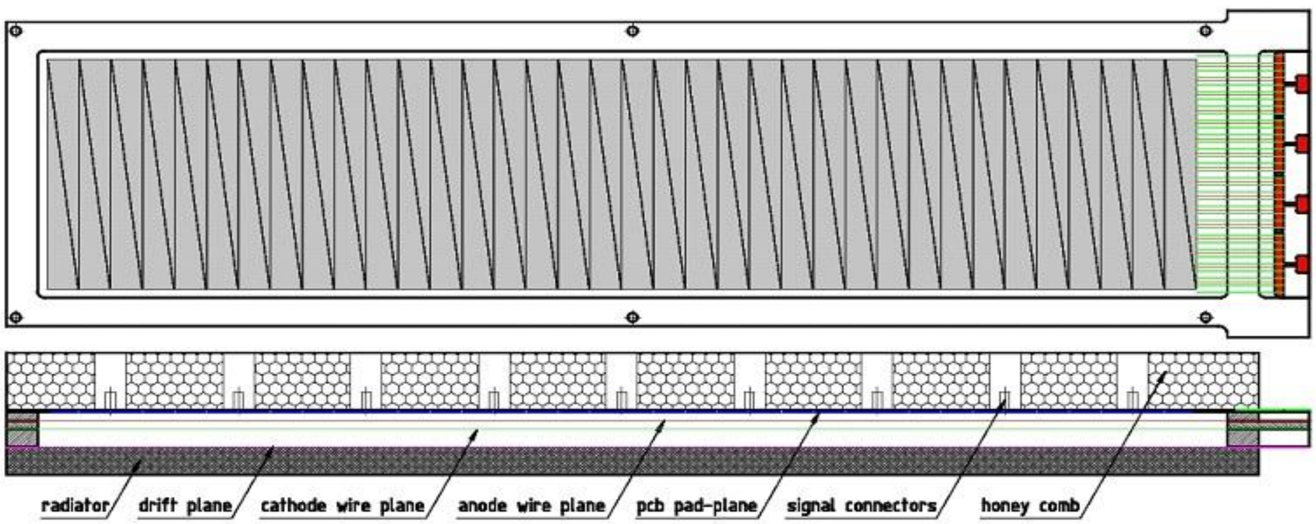


Fig 2. *The pad plane design and the cross- section trough the detector - perpendicular to the direction of the anode wire.*

In consequence, for a given gas mixture and applied drift voltage, the charge carriers` drift time depends on the primary ionization position relative to the anode/cathode wire plane. If this drift time is too large (more than 2.5 x shaping time constant), the proportionality between the output signal and the deposited energy along the particle track is lost.

3. Experimental setup

The experiment aims to estimate the drift time of the electrons towards the anode for this particular TRD architecture (multiwire chamber coupled with a drift zone).

The drift time of electrons towards the anode is measured (Fig. 3) . Therefore an external trigger is needed which determines the time of the particle's passage. The trigger signal is taken from another detector (usually scintillators), from the time when the particle was created. The difference in time between trigger and measured signal can be translated into the drift time of the charge carriers.

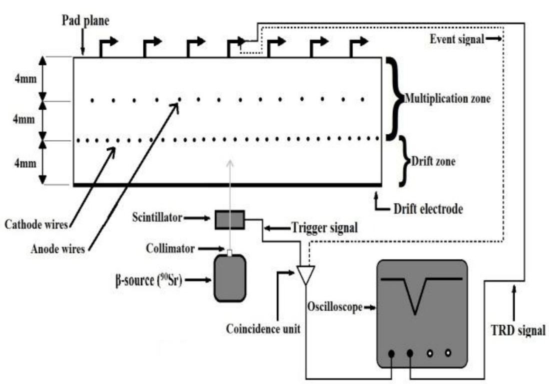


Fig. 3 *The experimental scheme*

If a particle crosses a drift chamber it will produce free electrons by ionization along its track. Usually the electrons from the point with the shortest distance to the anode wire will reach it first.

In our experiment we used as a β-source ^{90}Sr which has half-life period of 28,5 year. ^{90}Sr decays per β-radiation into $^{90}_{39}Y$ with a maximum kinetic energy of the β particles of 546 KeV. $^{90}_{39}Y$ decays into $^{90}_{40}Zr$ in a half life period of 64.10 h and a maximum kinetic energy of the β particles of 2283 KeV.

In front of the source there is a round collimator with a diameter of 1 mm and a length of 17 mm. The outgoing β-electrons pass a scintillator and create light in it. The light is detected by a photmultiplier optically coupled with a plastic scintillator. The coincidence between the output signal of the scintillator and the event signal from FASP was used as trigger for the oscilloscope.

A gas mixture of 80%Ar+20%CO_2 was circulated through the TRD prototype at atmospheric pressure. The applied anode voltage was 1900 V; the value of the drift voltage was set to 500 V, (1.25 kV/cm). A 1500 V high voltage was applied to the photomultiplier.

For amplification of the signal induced on the pads of the TRD prototype, a front end electronics (FEE) based on a 8 channel input/output ASIC (Application Specific Integrated Circuit) CHIP developed in DFH for CBM-TRD subdetector was used. It can provide two types of outputs: a "fast output" with a semi-Gaussian shape and a flat top output and two different shaping times: 20 ns and 40 ns. For the present tests, the flat top output was used and the shaping time constant was set to 20 ns.

As a first step of the investigation, a first qualitative analysis using a 1 GHz LeCroy digital oscilloscope was performed.

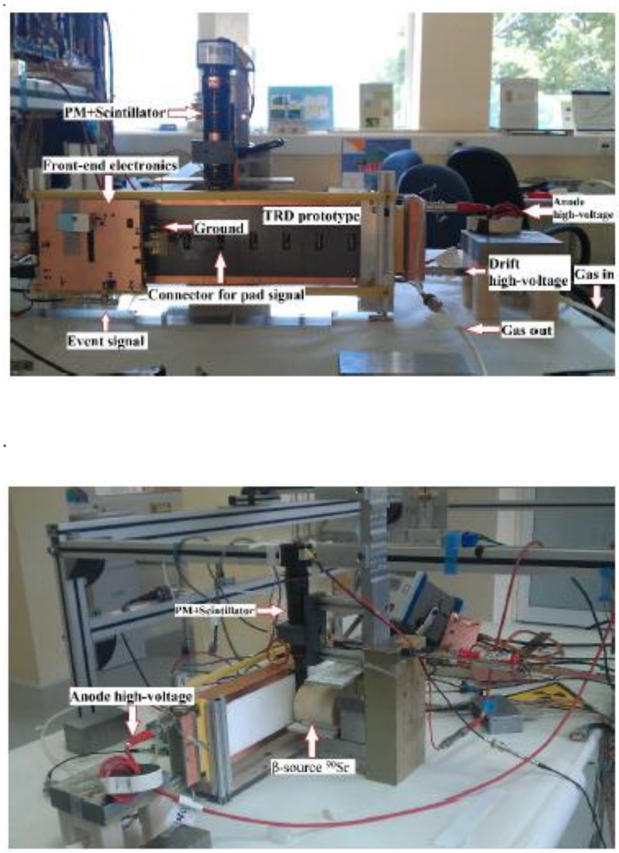


Fig. 4 *-upper picture - view from the readout electrode; -lower picture - view from the drift electrode*

4. Experimental results

Using the 20 ns shaping time constant and the logic event signal provided by the FASP we recorded in the persistent mode of the oscilloscope triggered with FASP event signal, the time spreading of the the plastic scintillator signal, as can be seen in Fig. 5 The FASP threshold was set at a value that suppresses the noise rate.

We observe a spreading of the plastic scintillator signals over a time range of ~130 ns. This value includes the intrinsic spreading of different drift time values given by the different position of the charge clusters in the detector and the time jitter given by the dependence of the point of time when the signal crosses the FASP threshold.

Because the ^{90}Sr source has a continuum spectrum with a maximum kinetic energy of ~2.28 MeV, the amplitude of the induced signal depends on the energy of the incident particle.

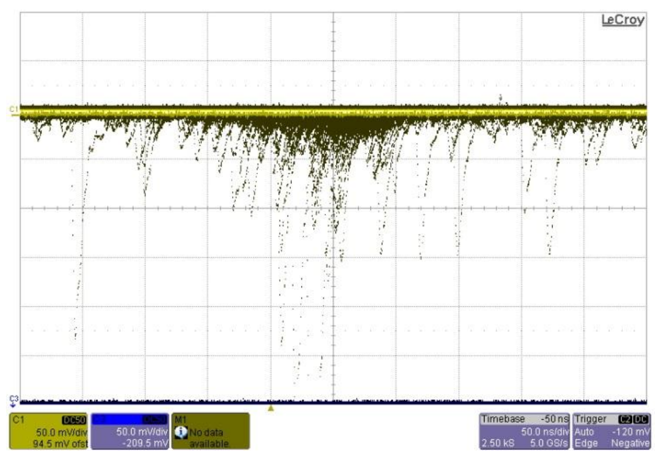


Fig. 5 *Spreading of the plastic scintillator signals triggered with the FASP event signal*

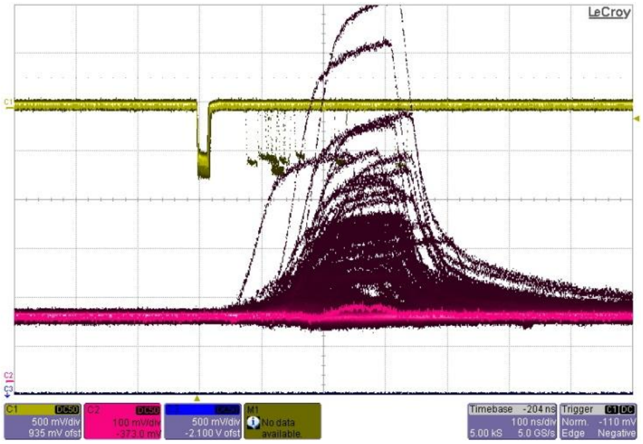


Fig. 6 *Time spreading of the flat top output signals of the TRD prototype*

Thus the point of time when the signal crosses the FASP threshold depends on the signal amplitude. This dependence can be followed in Fig.6 which show the signals of a readout pad processed by the FASP, recorded triggering the oscilloscope with the coincidence between the FASP event signal and the scintillator.

From the time difference between the begin of a low amplitude signal and a high amplitude signal (Fig. 6) there is a maximum time difference of about 50 ps. In some previous electronics pulser tests it was estimated that the time jitter due to the amplitude dependence is around 50 ns. So, the observed time spreading could be mainly due to the mentioned effect.

5. Introduction in OrCAD Cadence Software

In our three weeks' stay in this department we have also been introduced in OrCAD (Cadence Software). We learned the basics principles of PCB design in Schematic, Layout and PCB Editor (subprograms of OrCAD suite). OrCAD products are available in convenient suites tailored to address specific design tasks of both PCB designers and electrical engineers. With these powerful, intuitive tools that integrate seamlessly across the entire PCB design flow, we can easily move products from conception to final output. As a matter of fact the readout electrode for the TRD-CBM prototype is done in DFH using the OrCAD software.

We participated to the design activity of a connector PCB plate. Our contribution is included in the figure bellow; we learned how to design some tracks of the shown connectors, using PCB Editor.

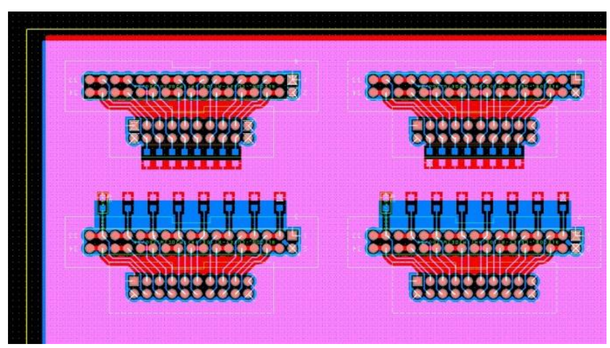


Fig.7 *Design of the connectors on a PCB plate*

6. Conclusions

The qualitative investigations showed:

- using the FASP analog signal processor with a shaping time of 20 ns, we estimated roughly a spreading of the drift time values of about 130 ns for an Ar based gas mixture. This estimation includes the dependence of the time information on the amplitude of the signal, roughly estimated to be around 50 ns.

For a quantitative determination of the drift time of the charge carriers in the drift region of the TRD prototype we need further simultaneous time and amplitude spectrum measurements using the acquisition system in order to correct for the dependence of the time information on the signal amplitude.

We have also been introduced in a the basic principles of PCB design using a powerful and intuitive toll as it is OrCad software.

7. Acknowledgments

Our work was supported by The National Institute for Nuclear Physics and Engineering. We would like to thank the members of the DFH department for all their support and time spend with us during this period.

8. References

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[2] M. Petrovici, M. Petris et al. - A high-efficiency Transition Radiation Detector for high-counting-rate environments, National Institute for Nuclear Physics and Engineering, Bucharest, Romania.

[3] FAIR Baseline Technical Report, www.gsi.de/fair/report/btr.html

[4] CBM - Technical Status Report, 2005.

CBM Double Sided TRD prototype – Monte Carlo simulation for electron-pion discrimantion

Dorin CONONENCO
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CBM Double Sided TRD prototype – Monte Carlo simulation for electron-pion discrimination

Dorin CONONENCO

1. Introduction

The Compressed Baryonic Matter (CBM) is an experiment designed for the investigation of highly compressed nuclear matter at the future Facility for Antiproton and Ion Research (FAIR) at Gesellschaft für SchwerIonenforschung (GSI), Darmstadt, Germany [1].

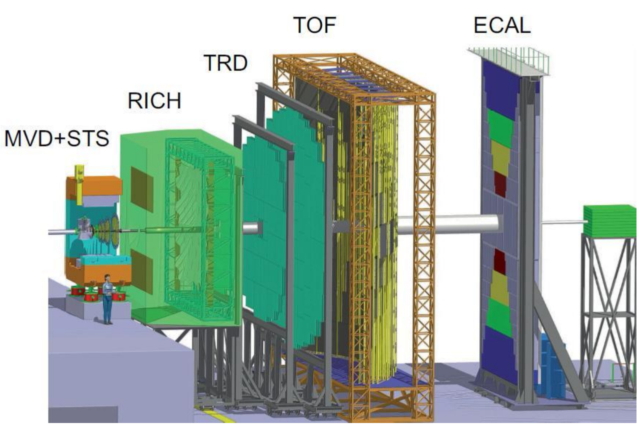

Fig. 1 *The CBM scheme*

Used in the CBM experiment, the Transition Radiation Detector (TRD) subdetector will provide the electron identification (with a pion misidentification probability below than 1%) and – together with a Silicon Tracking System (STS) – the tracking of all charged particles[1]. In order to fulfill these tasks, in the context of the high rates and high particle multiplicities in CBM, a new TRD prototype was developed and tested in Hadron Physics Department (DFH) from IFIN-HH.

2. Double sided TRD prototype

The double-sided TRD is a prototype based on a symmetric arrangement of two Multi-Wire Proportional Chambers (MWPC) with a double-sided central pad readout electrode [2]. It was designed to resolve the small absorption probability for the transition radiation of the previous TRD prototype based on a single MWPC [3]. The counting rate performance of the mentioned prototypes was obtained by reducing the gas thickness of the MWPCs in order to reach the required speed and to reduce space-charge effects caused by positive ions.

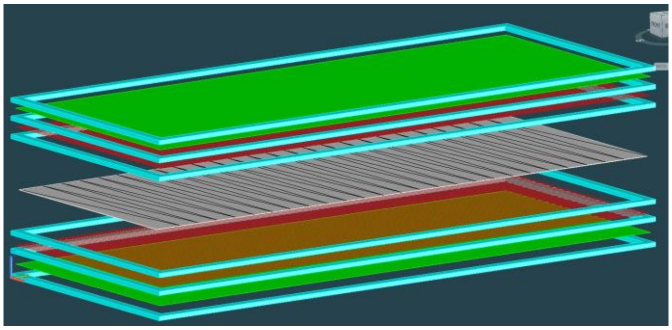

Fig. 2 *Double-sided TRD prototype*

In Fig. 2 can be seen details on the construction of the TRD prototype with double-sided architecture. In the middle there is the double-sided readout electrode with triangular pads on both sides. This triangular shape of the pads allows to obtain two dimensional position information with a single TRD layer.

This prototype was tested with minimum ionizing particles in the in-beam tests performed at T10 beam line of PS accelerator at CERN, Geneva in a joint measurement campaign of CBM Collaboration. Details on the position of the DFH TRD prototypes in the experimental setup are shown in Fig. 3.

There are 3 MWPCs with 72 triangular pads each, with a total area of 36x8 cm2. Two regular foil radiators were used for these measurements. As front end electronics (FEE) we used the Fast Analog Signal Processor (FASP) developed in IFIN-HH DFH.

Two types of gas mixtures, based on Ar(80%)/CO_2(20%) and Xe(80%)/CO_2(20%) were used in the measurements.

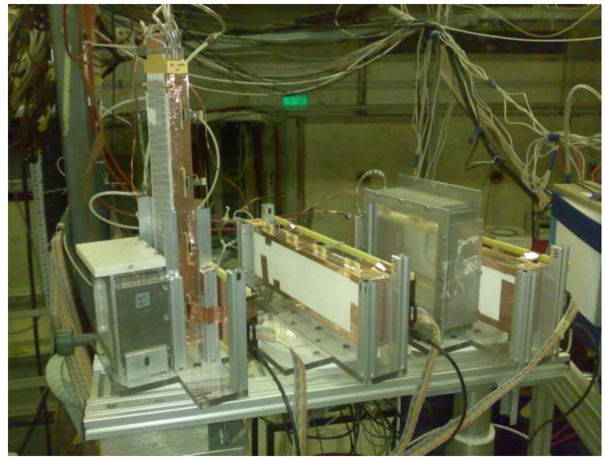

Fig. 3 *IFIN-HH DFH double-sided TRD test scheme*

The pulse height distributions for electrons and pions for the prototype with double-sided architecture and a Xe(80%)/CO_2(20%) gas mixture are presented in Fig. 4.

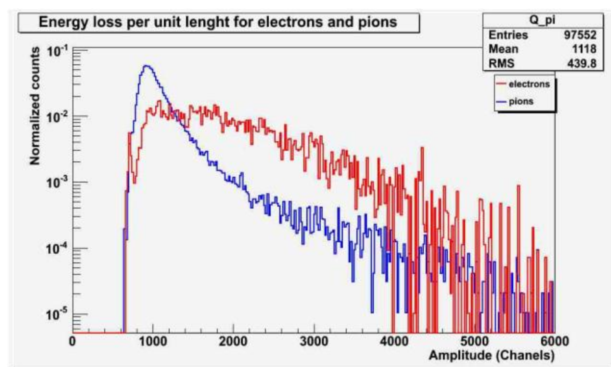

Fig. 4 *The pulse height distributions for e and pi*

Electrons and pions are separated with an air-filled Cherenkov counters and a Pb-glass calorimeter by setting thresholds.

These thresholds were decided to be able to define as many number of electron events and pion events as possible and to avoid each event class being misidentified as little as possible.

3. Electron identification

The pion rejection factor is defined as the inverse of the pion misidentification probability, which is the ratio of number of pion events in the region defined by a certain electron efficiency (usually 90%) to the total pion events.

Electron efficiency, E_{eff}, is defined as follows:

$$E_{eff}(p) = \frac{N(e|p \le P_e \le 1)}{N(e|0 \le P_e \le 1)}$$

where P_e is the electron probability that a certain event is to be an electron and covers from 0 to 1, N $(e|p \le P_e \le 1)$ is the number of electron events whose electron probability is more than p and $N(e|0 \le P_e \le 1)$ is total number of electron events.

Pion misidentification probability, $P_{\pi\to e}$ is defined as follow by using the electron probability where electron efficiency becomes 90%:

$$P_{\pi\to e} = \frac{N(\pi|p_{90\%} \le P_e \le 1)}{N(\pi|0 \le P_e \le 1)}$$

where $N(\pi|p_{90\%} \le P_e \le 1)$ is the number of pion events whose electron probability is more than $p_{90\%}$, $N(\pi|0 \le P_e \le 1)$ is the total number of pion events and $p_{90\%}$ satisfies the following relation:

$$0.9 = \frac{N(e|p_{90\%} \le P_e \le 1)}{N(e|0 \le P_e \le 1)}$$

Pion rejection factor = $\dfrac{1}{P_{\pi\to e}}$ [4].

4. Likelihood method

In order to estimate the pion rejection factor as a function of number of TRD layers, I used the in-beam experimental data obtained for a single TRD layer as input for the Monte Carlo simulations. We assume that the used layers have identical performance and that there is no correlation between the layers.

The likelihood (to be an electron), L for a given number n of TRD layers, is given by:

$$L = \frac{P_e}{P_e + P_\pi}$$

where:

$$P_e = \prod_{i=1}^{N} P(E_i|e) \quad ; \quad P_\pi = \prod_{i=1}^{N} P(E_i|\pi).$$

$P(E_i|e)$ is the probability that - for a certain energy deposit E_i, (in layer i) - it was produced by an electron and $P(E_i|\pi)$ is the probability that it was produced by a pion[5].

Using this method a Monte Carlo simulation based on likelihood method was used. I implemented this simulation in a C++ language (root program code[6]).

The experimental data for a single TRD layer used as input are the normalized pulse height distributions for electrons and pions showed in Fig. 4.

The obtained likelihood distributions for a number n=6 TRD layers are shown in Fig. 5.

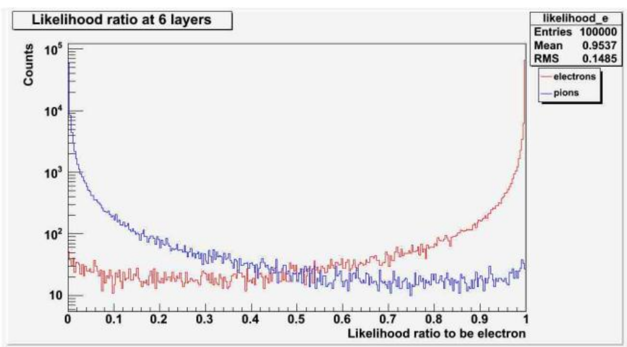

Fig. 5 *Likelihood distributions for electrons and pions in case of 6 TRD layers*

Table1: the pion misidentification probabilities at 90% electron efficiency:

Number of layers	Bin threshold (maxim = 100)	Pion misidentification probabilities (%)
1	22	41.743
2	38	18.039
3	51	8.260
4	69	3.522
5	82	1.472
6	91	0.588
7	96	0.238
8	98	0.082

The obtained pion misidentification probability as a function of number of TRD layers is listed in Table 1 and shown in Fig. 6 up to a number of 8 TRD layers.

We can see that for a 6 TRD layers configuration we obtain a pion rejection factor of 0.588%. This value fulfills the requirements of the TRD CBM subdetector in terms of pion efficiency. As the number of TRD layers increases, better separation is achieved.

The optimum number of layers will be decided taking in consideration the required performance in terms of pion rejection factor, but also the cost constrains for building the CBM TRD subdetector.

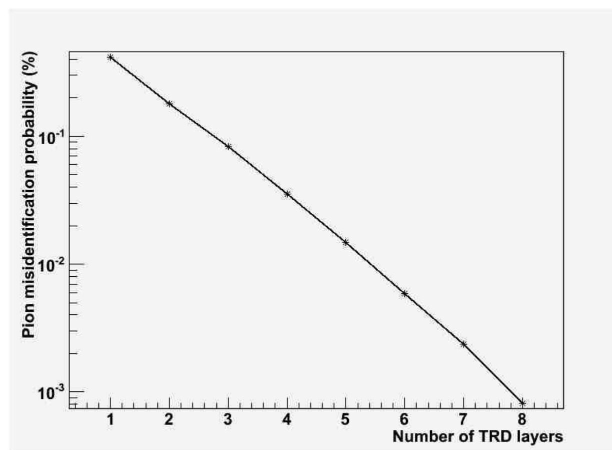

Fig. 6 *Pion misidentification probability as a function of number of TRD*

5. Conclusions

The data obtained from the programs I've developed is in the estimated range; the obtained pion misidentification probability for 6 TRD layers (0.588%) fulfills the CBM requirements (below 1%).

6. Acknowledgements

During my time spent here I've deepened my C++ code language and nuclear physics knowledge.

I would like to thank the DFH team for all their support during my work here, for their patience and pleasure showed while teaching me.

7. References

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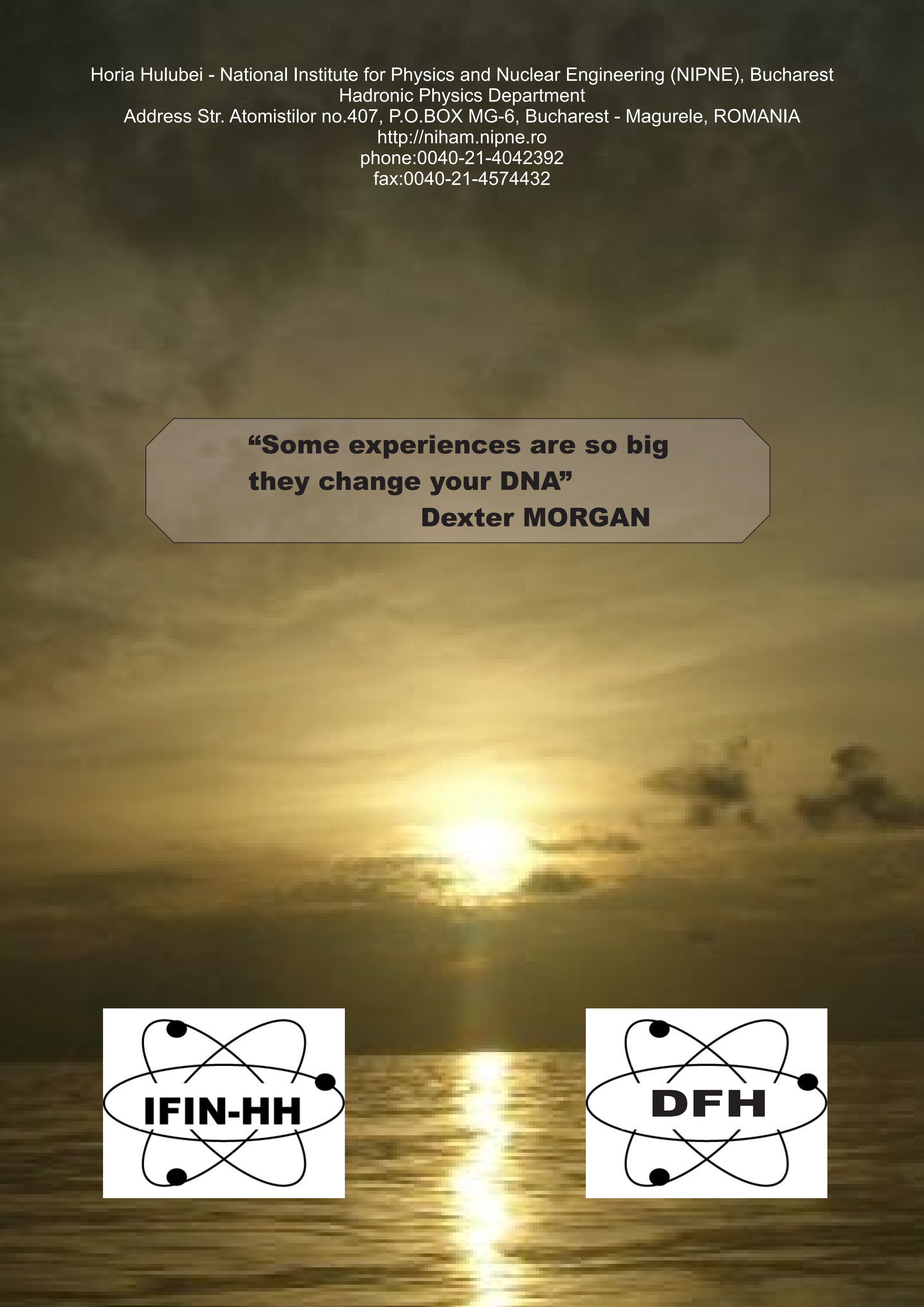

“Some experiences are so big they change your DNA”
Dexter MORGAN

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