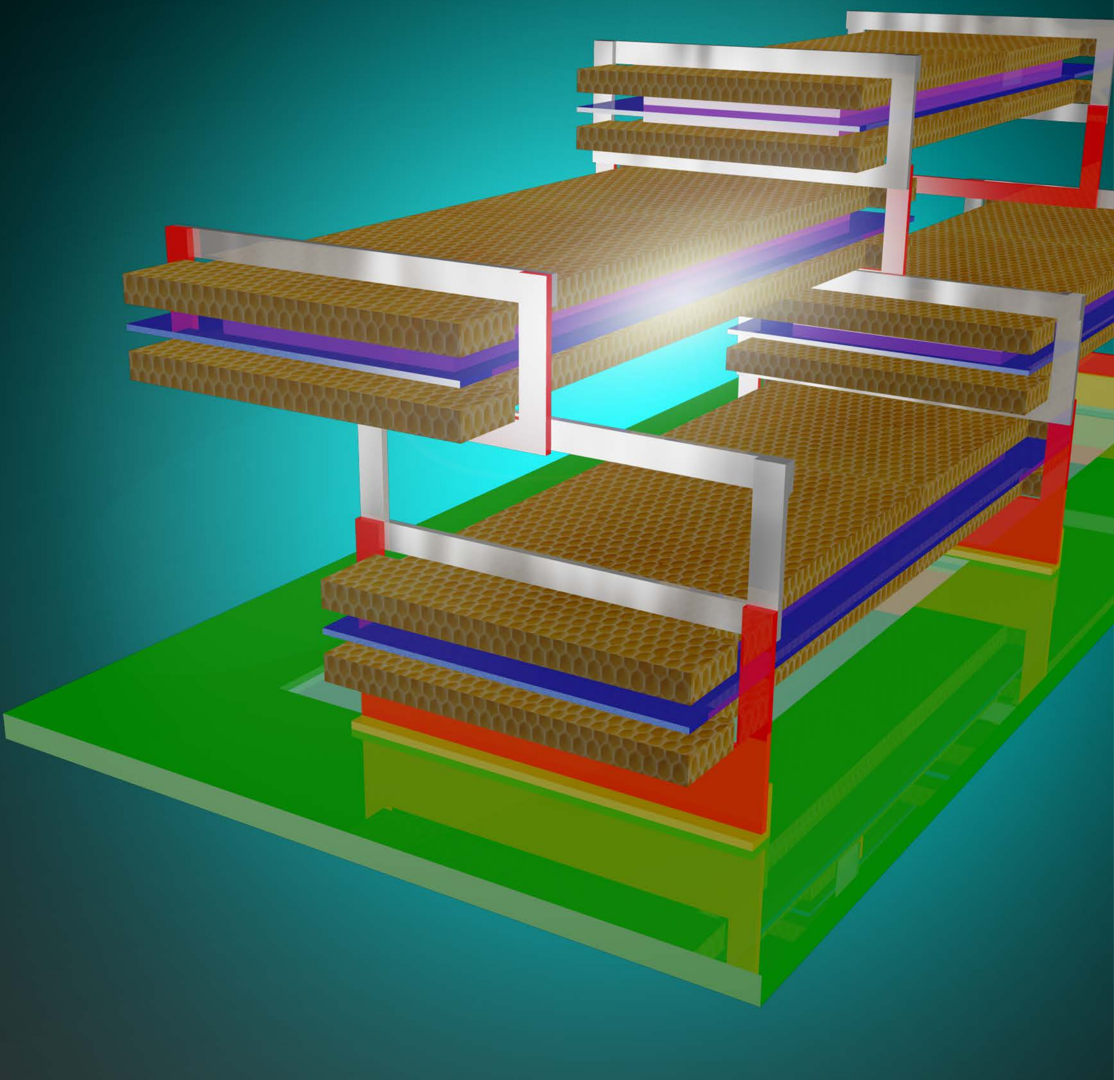
Hadron Physics internship

2012



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INTRO

[A general presentation of detectors]

Bordescu Dragoș

1. How does an accelerator work ?

Accelerators were invented to provide energetic particles to investigate the structure of the atomic nucleus. Since then, they have been used to investigate many aspects of particle physics. Their job is to speed up and increase the energy of a beam of particles by generating electric fields that accelerate the particles, and magnetic fields that steer and focus them.

An accelerator comes either in the form of a ring (circular accelerator), where a beam of particles travels repeatedly round a loop, or in a straight line (linear accelerator), where the beam travels from one end to the other. A number of accelerators may be joined together in sequence to reach successively higher energies, like the accelerator complex at CERN.

The main components of an accelerator include:

Radiofrequency (RF) cavities and electric fields – these provide acceleration to a beam of particles.

RF cavities are located intermittently along the beam pipe. Each time a beam passes the electric field in an RF cavity, some of the energy from the radio wave is transferred to the particles.

Vacuum chamber – this is a metal pipe (also known as the beam pipe) inside which a beam of particles travels. It is kept at an ultrahigh vacuum to minimise the amount of gas present to avoid collisions between gas molecules and the particles in the beam.

Magnets – various types of magnets are used to serve different functions. For example, dipole magnets are usually used to bend the path of a beam of particles that would otherwise travel in a straight line. The more energy a particle has, the greater the magnetic field needed to bend its path. Quadrupole magnets are used to focus a beam, gathering all the particles closer together (similar to the way that lenses are used to focus a beam of light).

Collisions at accelerators can occur either against a fixed target, or between two beams of particles. Particle detectors are placed around the collision point to record and reveal the particles that emerge from the collision.

2. How does a particle detector work ?

The job of a particle detector is to record and visualise the explosions of particles that result from the collisions at accelerators. The information obtained on a particle's speed, mass, and electric charge help physicists to work out the identity of the particle.

The work particle physicists do to identify a particle that has passed through a detector is similar to the way someone would study the tracks of footprints left by animals in mud or snow. In animal prints, factors such as the size and shape of the marks, length of stride, overall pattern, direction and depth of prints, can reveal the type of animal that came past earlier. Particles leave telltale signs in detectors in a similar manner for physicists to decipher.

Modern particle physics apparatus consists of layers of sub-detectors, each specialising in a particular type of particle or property. There are 3 main types of sub-detector:

Tracking device – detects and reveals the path of a particle.

Calorimeter – stops, absorbs and measures the energy of a particle.

Particle identification detector – identifies the type of particle using various techniques.

To help identify the particles produced in the collisions, the detector usually includes a magnetic field. A particle normally travels in a straight line, but in the presence of a magnetic field, its path is bent into a curve. From the curvature of the path, physicists can calculate the momentum of the particle which helps in identifying its type. Particles with very high momentum travel in almost straight lines, whereas those with low momentum move forward in tight spirals.

Tracking devices

Tracking devices reveal the paths of electrically charged particles through the trails they leave behind. There are similar every-day effects: high-flying airplanes seem invisible, but in certain conditions you can see the trails they make. In a similar way, when particles pass through suitable substances the interaction of the passing particle with the atoms of the substance itself can be revealed.

Most modern tracking devices do not make the tracks of particles directly visible. Instead, they produce tiny electrical signals that can be recorded as computer data. A computer program then reconstructs the patterns of tracks recorded by the detector, and displays them on a screen.

They can record the curvature of a particle's track (made in the presence of a magnetic field), from which the momentum of a particle may be calculated. This is useful for identifying the particle.

Calorimeters

A calorimeter measures the energy lost by a particle that goes through it. It is usually designed to entirely stop or 'absorb' most of the particles coming from a collision, forcing them to deposit all of their energy within the detector.

Calorimeters typically consist of layers of 'passive' or 'absorbing' high–density material (lead for instance) interleaved with layers of 'active' medium such as solid lead-glass or liquid argon.

Electromagnetic calorimeters measure the energy of light particles – electrons and photons – as they interact with the electrically charged particles inside matter.

Hadronic calorimeters sample the energy of hadrons (particles containing quarks, such as protons and neutrons) as they interact with atomic nuclei.

Calorimeters can stop most known particles except muons and neutrinos.

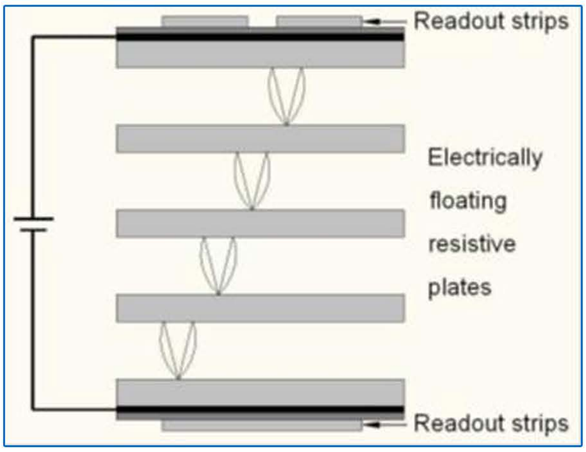
Particle identification detectors

Two methods of particle identification work by detecting radiation emitted by charged particles:

Cherenkov radiation: this is light emitted when a charged particle travels faster than the speed of light through a given medium. The light is given off at a specific angle according to the velocity of the particle. Combined with a measurement of the momentum of the particle the velocity can be of the particle. Combined with a measurement of the momentum of the particle the velocity can be used to determine the mass and hence to identify the particle.

Transition radiation: this radiation is produced by a fast charged particle as it crosses the boundary between two electrical insulators with different resistances to electric currents. The phenomenon is related to the energy of a particle and distinguishes different particle types.

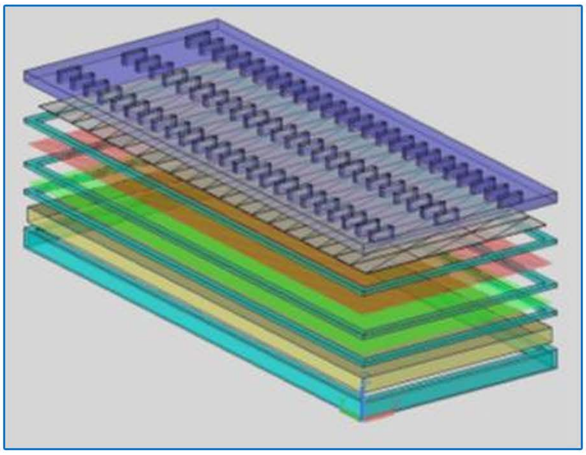
3. RPC Summary



RPC is short for resistive plate chamber, and is a type of particle detector designed and used for it's great time resolution and high granularity. The current setup for this particular detector is MS-MGRPC , short for multi strip multi gap resistive plate chamber, the reason for this setup is : using a multi strip setup with individual readouts gives us more accurate data, and the multi gap gives us a better electron avalanche and more control over the factors regarding the experiment.

The Rpc is composed of a 2 hv anodes , 2 Hv cathodes , resistive glass , mylar foil and a couple of unplugged anodes and cathodes.

4. TRD Summary



TRD meaning Transition Radiation Detector is a type of detector used for its good position and impulse readings.

Transition radiation is a phenomenon that occurs when a charged particle transitions from a media with a dielectric constant to a media with a different dielectric constant, the transition taking place with the emission of a photon.

In our case we are talking about electrons with a Lorrentz factor greater then thousand, the resulting photons being in the x- ray wavelength. This is an important phenomenon because it can be used to discriminate between electron and pions.

At the energy levels of the experiment, the electrons have a greater chance of emission than the pions, so the discrimination is based on the fact that the electrons emit photons and the pions don't.

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http://public.web.cern.ch/public/en/Research/Detector-en.html

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CAD

[Computer-aided Design]

Vasilescu Miron

1. What is CAD?

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided drafting describes the process of creating a technical drawing with the use of computer software. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print or machining operations. CAD software uses either vector based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. [1]

2. AutoCAD

AutoCAD is a software application for computer-aided design (CAD) and drafting. The software supports both 2D and 3D formats. The software is developed and sold by Autodesk, Inc., first released in December 1982 by Autodesk in the year following the purchase of the first form of the software by Autodesk founder, John Walker. AutoCAD is Autodesk's flagship product and by March 1986 had become the most ubiquitous microcomputer design program in the world, utilizing functions such as "polylines" and "curve fitting". Prior to the introduction of AutoCAD, most other CAD programs ran on mainframe computers or minicomputers, with each user's unit connected to a graphics computer terminal.

According to its own company information, Autodesk states that the AutoCAD software is now used in a range of industries, employed by architects, project managers and engineers, amongst other professions, and as of 1994 there had been 750 training centers established across the world to educate users about the company's primary products. [1]

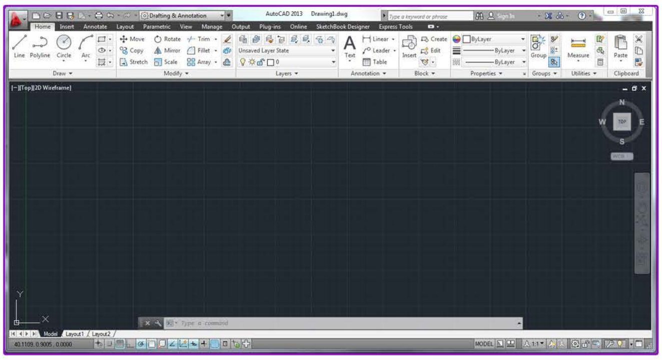


Fig. 1 - Autodesk Autocad 2013 running on Windows-based machine [2]

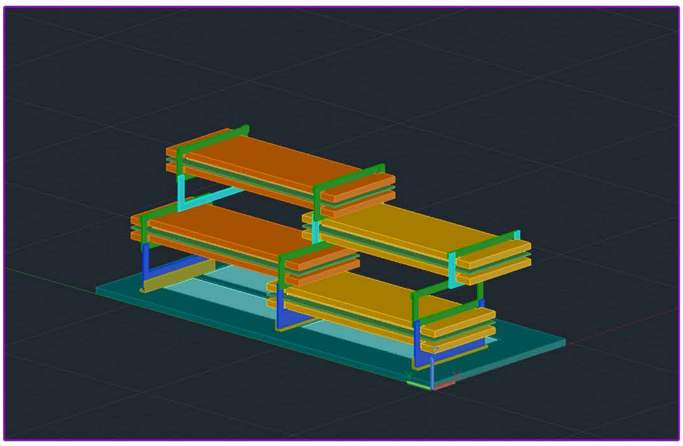
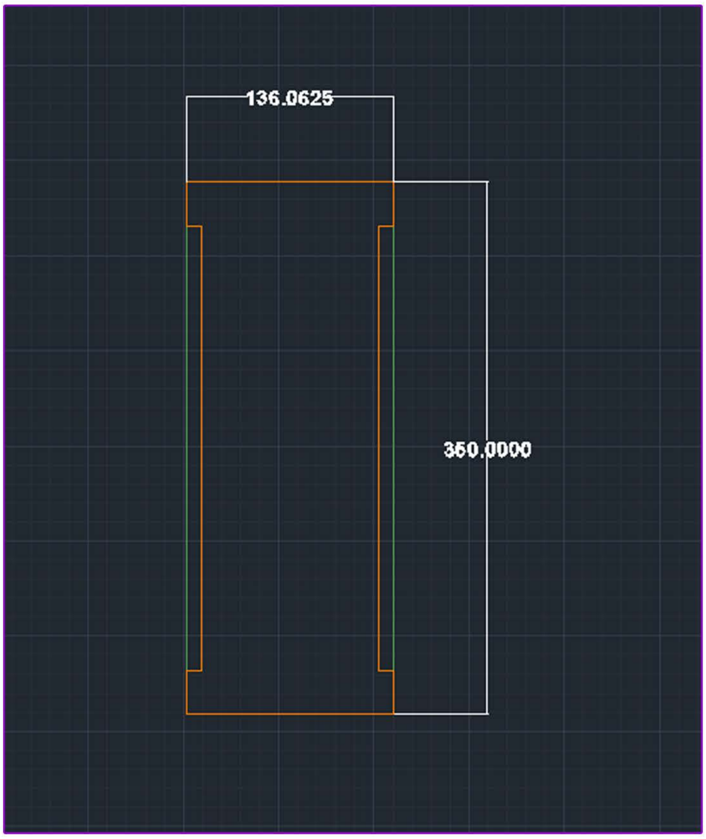
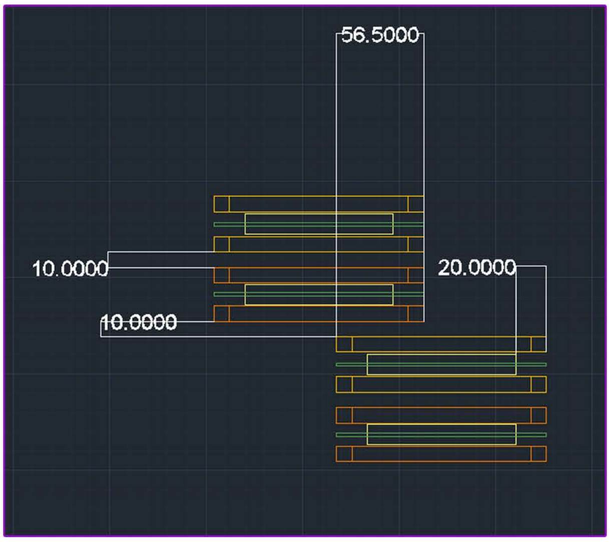


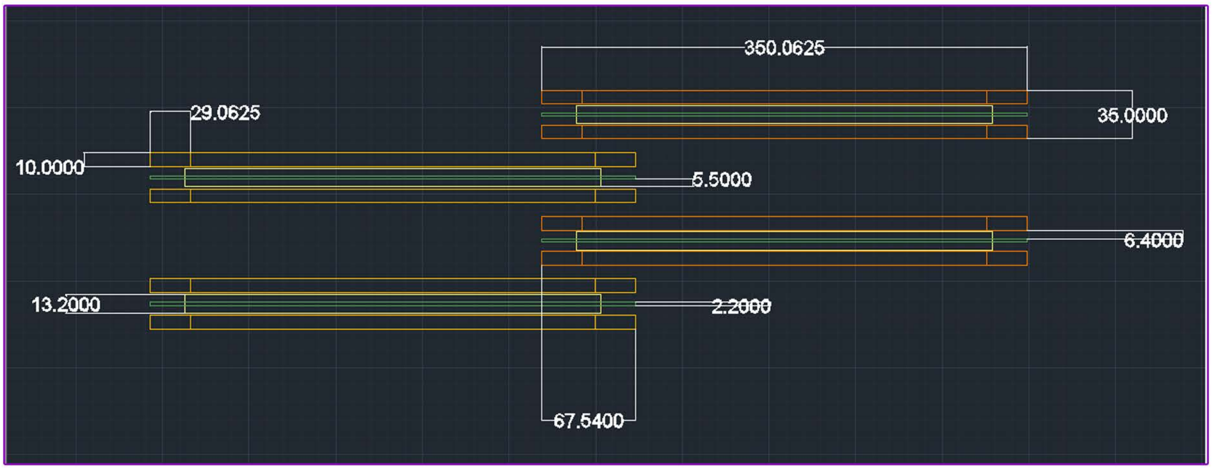
Fig. 2 - RPCs implementation (without box cover)



RPC - Top



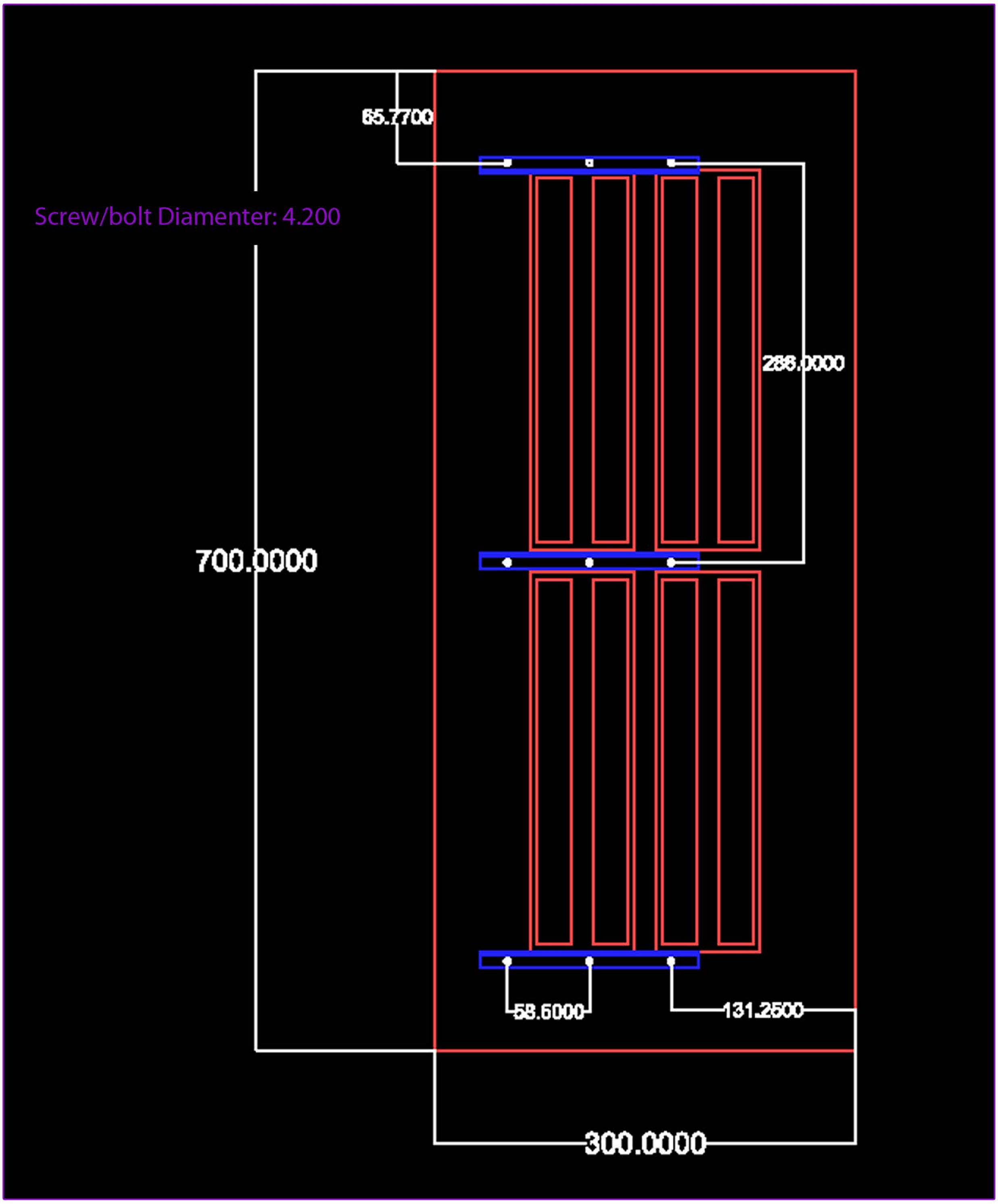
RPCs Implementation - Back



RPCs Implementation - Right

Motherboard - Front

Setting up the connection between the RPCs Implementation and Motherboard



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TRD

[Transition Radiation Detector]

Part. 1

Călin Bogdan Ștefăniță

1. Introduction

The transition radiation is produced at the crossing of the interface of two media with different dielectric constants by relativistic/ultrarelativistic particles. This radiation strongly depends on the γ factor of the incident particles. This is put in use by the TRD for particle identification at higher energies, where time of flight method (TOF) or Cherenkov radiation detection no longer work. The number of produced photons per interface crossing is quite small, therefore introducing some difficulties in the data acquisition processes. However, in the case of the TRD, a radiator is used to achieve a higher number of photons in a smaller solid angle. This radiator may be a multilayer dielectric radiator, constructed in such a way to increase the radiation yield cumulatively, by placing foils of very precise thickness and separation, therefore coherence effect modifying the transition radiation's spectral and angular characteristics, or it may be an irregular radiator made of foam or fibers. The multilayer radiator is more efficient, yet it is quite expensive and heavy. For ALICE (A Large Ion Collider Experiment), foam radiators were used, while for the CBM experiment (Condensed Baryonic Matter) regular foil radiators seem to be a more attractive design option, due to several reasons.

In the next two chapters, however, data analysis including particle discrimination and position reconstruction shall be emphasized, rather than the details regarding the TRD configuration, although its construction will be described concisely.

As a brief description the next two chapters will contain some information about the construction, the physical phenomena taking place inside, particle discrimination, position reconstruction, modifications and improvements brought to this type of detector over the years.

2. TRD Design

From what we know so far, charged particles and photons can only be detected indirectly, by considering their loss of energy due to their interaction with matter. This is what the TRD uses as well to get information about the particles passing through. The images below (Figure 1 and Figure 2) describe the geometry of one of the TRD modules, with accurate geometric proportions and field lines in the Drift Chamber (DC), and schematic signals produced by a pion and an electron.

As we can see in the first figure, the TRD has two main sections: the radiator and the photon detector, or the drift chamber (DC). The DC is composed of the drift region, which is of about 4 mm long, and the amplification region, which is 8 mm long, as described in the figure. The shown electric field lines are calculated with GARFIELD, which is a computer program used for detailed simulations of drift chambers.

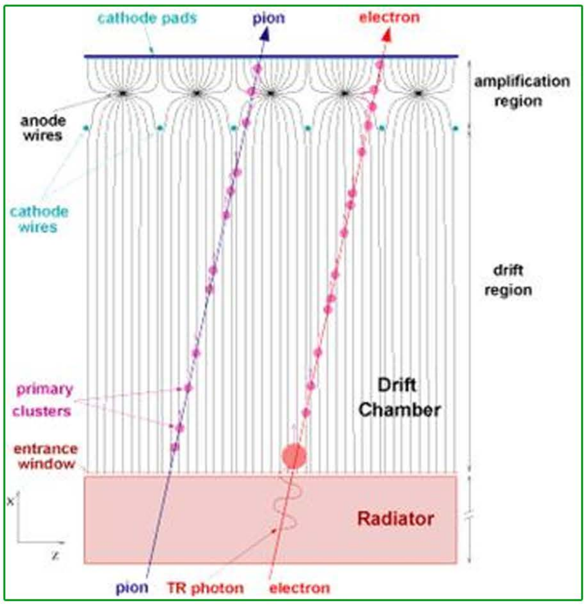

Figure 1: TRD Geometry [3]

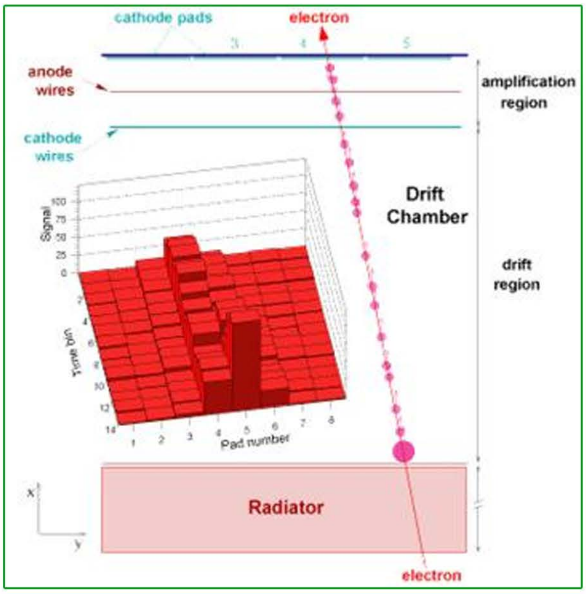

Figure 2: Signal schematic [3]

As we can easily observe, only the electron produces transition radiation. The reason behind this is very simple. The TRD detects charged particles as they pass through it, yet it cannot detect which particle it was (in theory), in this case electron or pion. By detecting the energy deposited inside the drift chamber, the resulted distribution is a combined distribution of both electrons and pions. The peak of the electron distribution is very close the peak of the pion distribution, sometimes the electron distribution being "covered" by the pion distribution, therefore creating difficulties in the particle discrimination. By depositing more energy through the transition radiation, the "electron, or a pion. By using a series of detectors, instead of just one, probability theory dictates that the discrimination, or rather the probability to be a certain particle, increases abruptly.

To briefly describe the physical phenomena inside the TRD, let's say that the incident particle is just a charged particle. When it enters the detector, if the required conditions are met, the transition radiation is produced, whose photons roughly follow the same trajectory. Once in the DC, ions and electrons appear as an effect of the collisions of the particles with the gas's atoms. The electric potential between the cathode and the anode is set such that the resulted electrons will drift along the field lines until they get in the amplification region, close to the anode wires, where, depending on the voltage applied to the anode wires, avalanche multiplication may occur.

The positive ions left over in the trail of multiplying electrons move towards the cathode, inducing image charges in the surrounding electrodes and therefore resulting in negative signals on the wire where the avalanche originated, that being the anode. This signal gives information on one coordinate of this event, the second coordinate, needed for localization, is given by a second detector, whose anode wires are perpendicular to the first one.

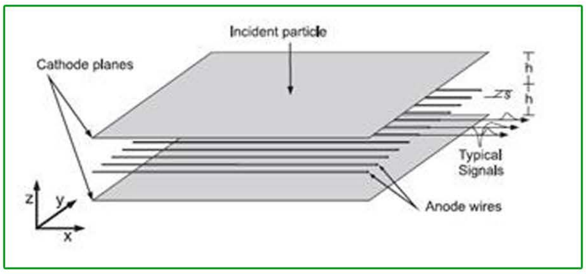

Figure 3: Configuration of a multiwire proportional chamber (MWPC) [2]

The induced image charges appear in the cathode pad as well. However, in Figure 3, the signal from once cathode plane does not give information on the position of the avalanche. The coordinate of the induced charge can be obtained by a subdivision of the cathode into readout pads that are perpendicular to the anode wires, as shown in the figure (page 8).

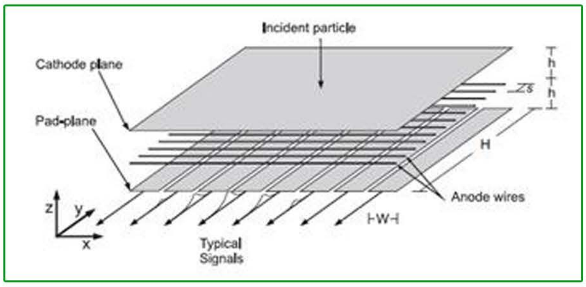

Figure 4: MWPC with a cathode segmented into pads perpendicular to the anode wires [2]

The induced charge distribution is shared between several adjacent pads in order to obtain a better position resolution in the Cartesian coordinate system of the cathode pad plane.

3. Electron/pion discrimination

In order to process and interpret experimental data, we used ROOT, which is an object-oriented program and library developed by CERN, originally designed for particle physics data analysis, although now its applications have extended a bit into other domains. More information about ROOT can be found in the next chapter.

As it was mentioned before, the TRD identifies particles by the energy they deposited in the DC. The electron and pion events are selected using signals given by the Cherenkov and Pb-glass detectors. Electrons can be identified by their larger energy deposit in both detectors. In the test beam, both electrons and pions have the same momentum, yet because the pion's mass is roughly around 273 times larger than the electron's, they have different velocities. At the momenta used in the CBM experiment (Condensed Baryonic Matter) only electrons produce TR, therefore producing larger signals. In the Pb-glass calorimeter, electrons generate electromagnetic showers and deposit most of their energy. This can be easily visualized in the following image.

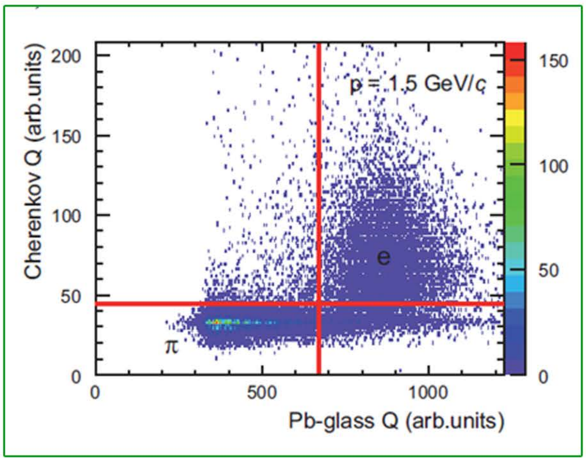

Figure 5: Signal correlation between Cherenkov detector and the Pb-glass calorimeter. [1]

As you can see, the 2-dimensional histogram shown above depicts the thresholds used to identify pions and electrons, which in this case are plotted for a momentum of 1.5 GeV/c.

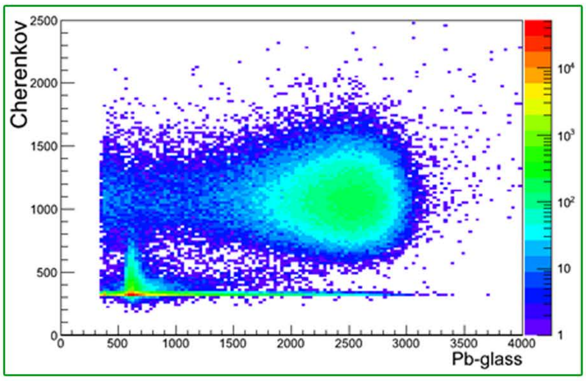

Figure 6: Signal correlation from the available data files.

Figure 6 shows the results I obtained by making a simple program using a certain data file (axes are the same). It is already obvious that the larger area in both histograms represents the electrons, while the area in the lower left corner represents the pions.

Before plotting the distributions of the integrated charge deposit, of course, using the same data file, I made a program in order to find out which pad receives the maximum charge. The program basically plots the beam profile. The resulted histogram is shown on page 9.

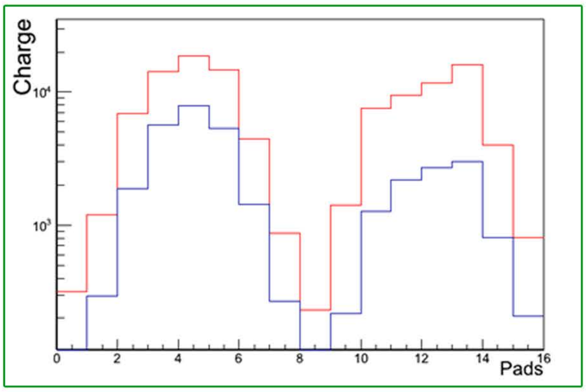

Figure 7: Beam profile

Pions are depicted by the red line, and electrons by the blue one. On the X axis, there are the pads. The pads are arranged as shown below, which will make the previous histogram clear.

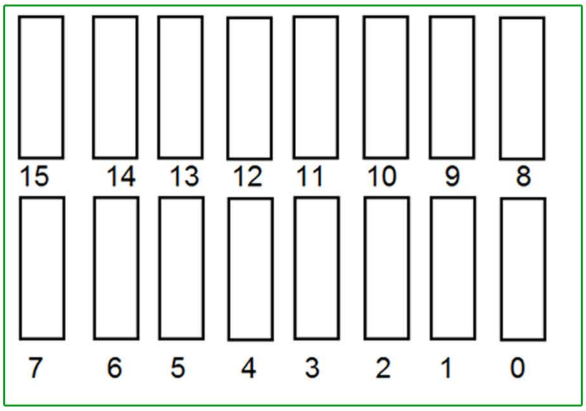

Figure 8: Pads (cathode)

From the histogram showing the beam profile, I was able to select the pad with the highest charge, and therefore I was able to choose the adjacent pads. Then, I was able to use these information to plot the integrated charge distributions of electrons and pions, considering the pads mentioned above.

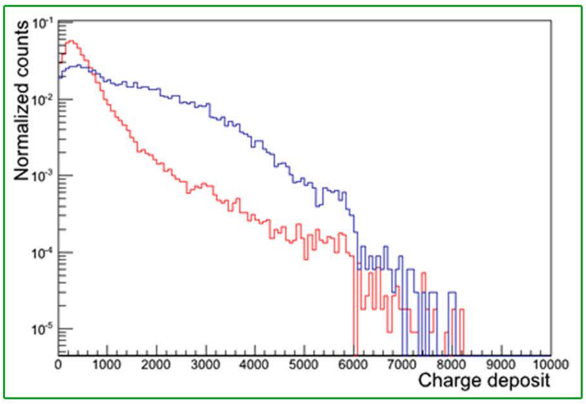

Figure 9: Integrated charge distributions of electrons (blue) and pions (red) (4 GeV/c)

Both distributions are normalized. On the Y axis are the normalized counts, while on the X axis it's the charge deposit. The data file used in this program represented some experimental results for a momentum of 4 GeV/c. As we can see, the electrons deposit a larger charge than the pions, which further on enables a better pion-rejection performance. These charge-deposit distributions can be used as probability distributions to determine the pion-rejection factor of the TRD prototypes.

To further test the programs I have made, I was given several other data files that stood for experimental results with a different momentum. For example, the results using a data file for a momentum of 8 GeV/c are depicted in the following histogram.

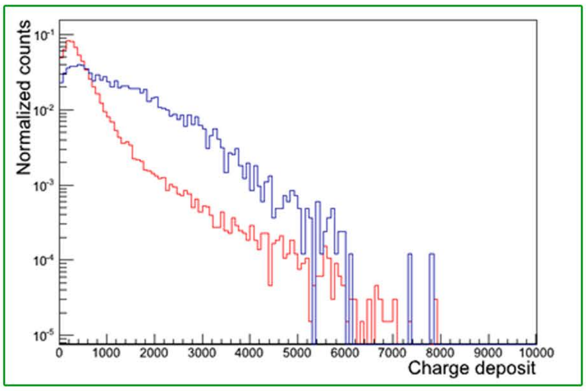

Figure 10: Integrated charge distributions of electrons (blue) and pions (red) (8 GeV/c)

As it can be seen, the shape of the distribution is roughly the same. As for the programming part, I can say there weren't too many difficulties, things have gotten complicated when I started using trees and creating files to save and use the data instead of creating and using all the information while the program was running. This shortened the processing time of the program, therefore making it more efficient, and all the information I used was saved in a .root file, ready to be access anytime. Although the programs are working, I still didn't actually finish them, as the code is quite messy and not optimized, which makes the program rather time, processing power and memory consuming, compared to what it should be like.

4. Conclusions and personal review

The TRD detector is still in continuous development and improvement. It is a vital component for conducting experiments, or, to be more specific, for collecting important and sensible information regarding particle interactions. The TRD is mostly used for particle discrimination. In the few pages above, I tried to create a general and rather informative view of this particular detector and its data analysis, without going through all the complexities that come with it. The physical phenomena happening inside the detector are rather simple, yet things get very complicated when it comes to data acquisition. For systems this sensible, collected signals usually comes in with great noise/errors, making the data acquisition and data analysis very important. As I mentioned before, for the data analysis, ROOT is used, although there is a growing tendency towards other programming languages, wrappers and libraries. At NIPNE-HH (National Institute of Physics and Nuclear Engineering "Horia Hulubei"), the Hadronic Physics Department, to be more specific, we were assigned different tasks, which got me and a friend into TRD data analysis using ROOT. Along with the programming part, we obviously learned about the TRD's construction, the particle interactions inside it, the physical phenomena and of course some bits of information about the data acquisition process, which led us to better understanding of the analysis of the experimental data files. Furthermore, we had to learn a bit about the experiments conducted at CERN, as well as bits of particle physics and notions related to elementary particles.

References

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[Transition Radiation Detector]

Part. 2

Roibu Theodor Mihai

1. Introduction

The Transition Radiation Detector is a particle detector based around the principle of transition radiation. This type of radiation is emitted by a relativistic charged particle when it encounters a new medium with a different refraction index. The amount of energy lost on the emission of TR radiation depends on the Lorentz factor of the particle itself.

The radiator contains many layers of materials differing in refraction indices. When the relativistic particle crosses the many interfaces successively, the probability of TR photon emission increases, depending on the particle's Lorentz factor. Thus, particles with a high Lorentz factor, like an electron, will emit a large number of TR photons, while particles with a low Lorentz factor, like a pion, will emit a smaller number of TR photons. This allows easier differentiation between electrons and pions, if the TR photon energy is added to the total energy resulting from ionization.

Position reconstruction is the other main feature of the TRD. Besides finding out what the particle was, it is important that we are able to trace the path it took through the detector.

2. Triangular Pad Readout

For easier position reconstruction, the rectangular pads are split into two triangular pads each, read independently and combined together through software.

Assuming rectangular pads, for the three pads on the same row in which the most energy has been deposited, it is trivial to calculate the position relative to the pads, due to the energy deposit being easily approximated using a Gaussian curve. Assuming W is the width of the pads, Q_i is the energy deposited in the maximum charge pad, and Q_{i+1} along with Q_{i-1} are the neighbors of that pad, the formula is[1]:

$$d = \frac{W}{2} \cdot \frac{ln(\frac{Q_{i+1}}{Q_{i-1}})}{ln(\frac{Q_i^2}{Q_{i-1} \cdot Q_{i+1}})}$$

This formula needs to be applied for the three pads on the same row with the maximum discharge during the detection, and will return the horizontal offset from the center of the pad with the maximum charge.

The algorithm for detecting the position a particle passed through the pad layer in a given event is the following[2]:

1. find the rectangular pad where the most energy has been deposited in the system;

2. from this maximum charge pad, find out where the particle was, on the horizontal axis relative to the center of the pad, through the formula given before;

3. for each half of the maximum rectangular pad, take another half from one of the neighboring pads, and determine in which there has been a greater energy deposit;

4. for that maximum slanted rectangular pad, find out where the particle was, on the horizontal axis, through the same formula as before;

5. using the two values, it is easy to discern the true position of the particle, due to one of the lines being slanted at a known angle.

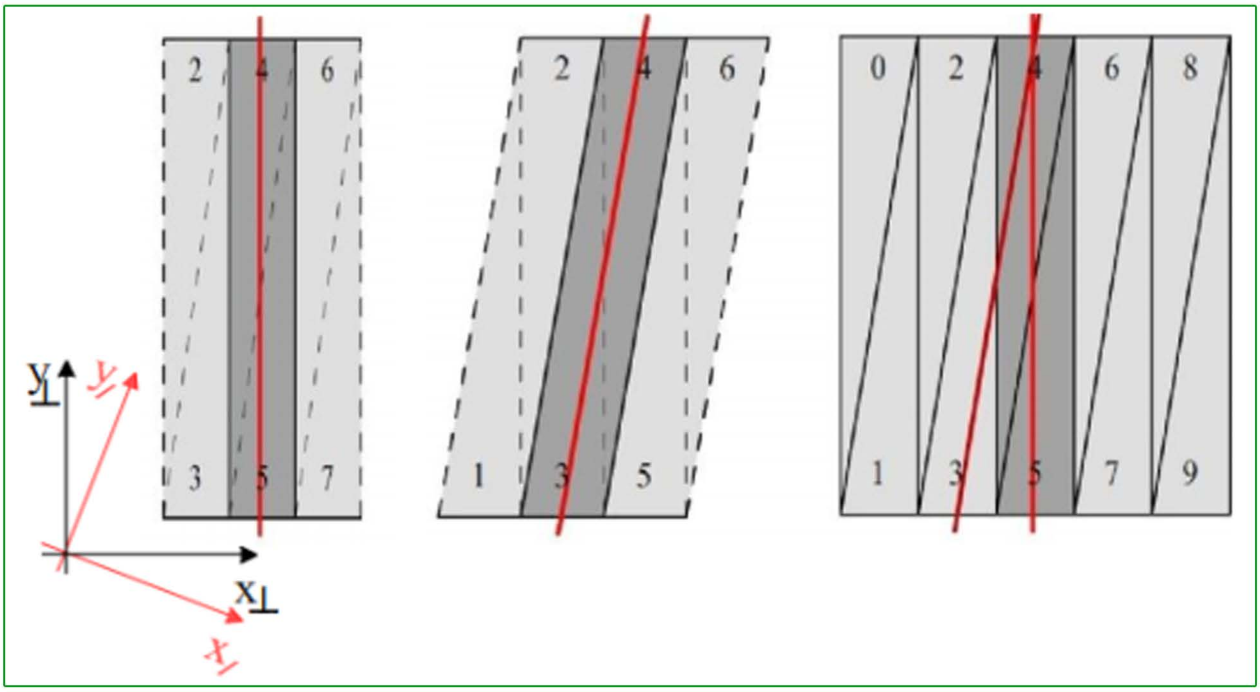

Fig.1: Determination of the particle (x, y) coordinates[2]

A similar method is used for when the particle hits the space between two rows of pads. Rather than just taking three pads into account, all six surrounding the hit are considered .

3. Software Details

The main tool for analyzing data in the manner described above is currently the ROOT system[3], a set of object-oriented frameworks designed to deal with a large amount of data in a very efficient way.

To start with, the actual input/output system is based around the principle of only loading into memory what is necessary, and this is reflected in the tree system for storing and retrieving data.

A "tree" represents a whole set of data for one run of an experiment, usually. This tree contains "branches" which represent the sets of data the experiment actually records or uses. Each branch contains "leaves", which are the individual measurements recorded or used.

For example, in a simple single TRD detector there would be one simple tree, with one branch labeled "pads", and 16 leaves in the branch, one for each pad. Each "entry", basically one run of the data acquisition system, or one iteration of the input algorithm, fills out each leaf with the total value of energy deposited on each pad.

The reason this is superior to typical ways of storing information in files is the ability to only load the data relating to one single entry at a time, if needed, or the ability to run one command (summing up the energies into a histogram, for example) without loading up the entire file into memory. Considering that a typical experimental file can contain many gigabytes of data, this is a very important point.

Moving on, the ROOT system also provides an easy way of creating varied graphical representations of data (Fig.2), for both debugging and presentation purposes. The built in modules support a great number of things, from 1-3 dimensional histograms and graphs to overlaid graphics.

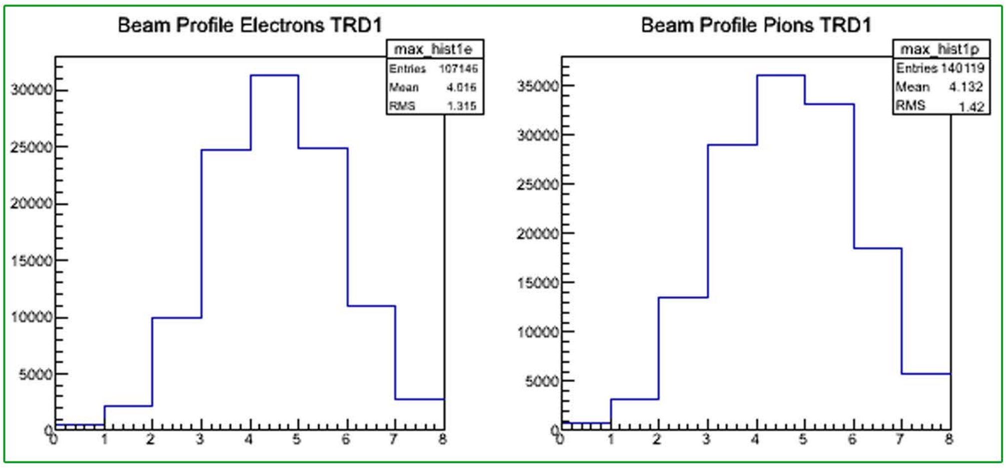

Fig.2: Beam profile.

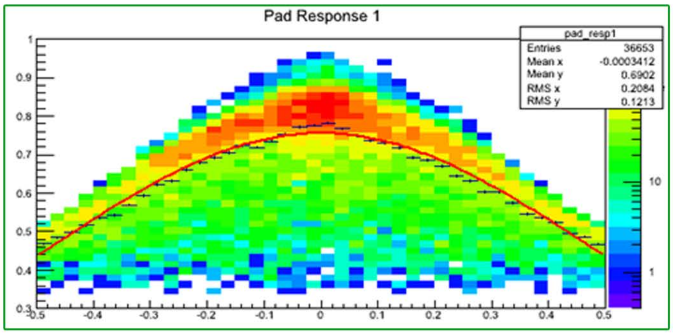

Fig.3: Pad Response Function.

The ROOT fitting framework also allows interesting analysis choices, like "fitting" a function, such as a Gauss curve, onto a histogram, and thus obtaining valuable data, like the most probable value taken by the function, its width, etc.

This allows for easy probabilistic analysis of data. For example, Fig.3 contains a two-dimensional histogram plotting pad units on the horizontal axis (offset from the center of the pad with the maximum charge for each particle hit), and a ratio of the energy of the main pad with regards to the summed energy of all three considered pads on the vertical axis. The color dimension represents the relative amount of events for each combination of properties.

On top, a profile of the X axis was overlaid, with what amounts to the most probable Y values for an event to take for any given X value. This profile was then fitted with a simple Gauss curve, and the sigma parameter of it was retrieved, approximate value 0.5, showing the average width of the Gauss curve.

With subjective interpretation, this means that the majority of the energy deposited on the pads is spread out a quarter of a pad out both left and right from the location of the hit.

4. References

• [1] - Cyrano Bergmann, "Development and Test of a Transition Radiation Detector Prototype for CBM @ FAIR"

• [2] - "Preliminary Results of 2011 CBM TRD Test-Beam @ CERN"

• [3] - Rene Brun and Fons Rademakers,
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RPC

[Resistive Plate Chambers]

Burcescu Diana Cătălina

Design and Working Principles

1. What are RPCs?

The term RPC (Resistive Plate Chambers) was coined in 1981 and served as a denomination for a specific type of particle detectors, which would serve as an alternative to the localized discharge spark counters.

An RPC is a particle detector which utilizes a constant and uniform electric field produced by two parallel electrodes of high volume resistivity such as glass or bakelite.

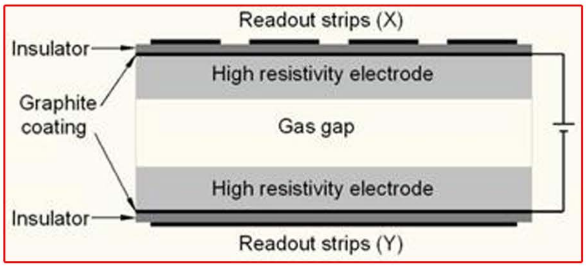


Figure 1: Constructional schematic of a basic Resistive Plate Chamber

The features of these detectors are: large signal output, excellent time, position resolution and low cost. RPC are simple to construct and operate.

2. Types of RPCs

According to their application in an experiment, RPCs can be classified as following: trigger RPC and timing RPC.

Trigger RPCs

Trigger RPCs are employed at detecting the passage of Minimum Ionizing Particles (for example muons) and at signaling to other co-detectors and at their data acquisition systems to record their data.[1]

The design of the Trigger RPC can be rendered as:

- time resolution: ~ 1 ns;
- spatial resolution: mm÷ cm;
- detection efficiency: >95%.[2]

Timing RPCs

In comparison with Trigger RPCs, Timing RPCs are expected to provide much better timing resolution. Therefore, they are typically used as Time of Flight (TOF).[3]

The design of the Timing RPC can be rendered as:

- time resolution: <100ps;
- spatial resolution: 200 – 400 μm;
- detection efficiency: >95%.[4]

3. Gas Mixture

The gas mixture inside the RPC features a high absorption coefficient for ultraviolet light, which is flown through the gap between electrodes.

When the gas is ionized by a charged particle crossing the chamber, free charge carriers that are deposited in the gas gap trigger avalanches of electron in the externally applied electric field and originate a discharge.

Because of the high values of the resistivity of the electrodes, the electric field drops down to the area where the discharge occurred.

4. RPC Designs

Single Gap RPC

The original design of the RPC included a single gas gap, which was delimited by bakelite potential electrodes. A semi-resistive layer was utilized at applying electrical potential to the resistive electrodes. The main advantage of this design is represented by the absence of high-light voltage capacitors. Thus, the need for high-voltage insulation of the strips can be avoided.

Hardly any effort at all had been made to optimize the signal pickup hardware, which was used at obtaining the best position resolution from an RPC detector.

Double Gap RPC

Double gap designs consisting of larger numbers of elements allow for more varied chamber structures. The double gap structure was created in order to improve the detection efficiency and the avalanche mode of operation.

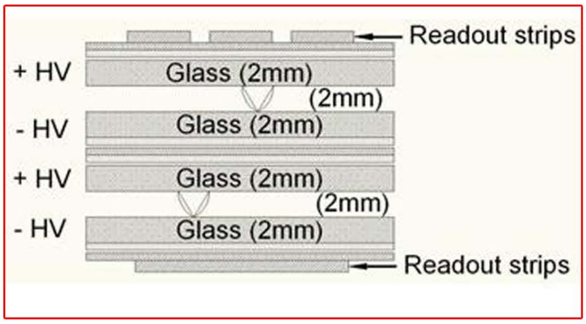


Figure 2: Schematic of a double gap Resistive Plate Chamber

Multi-Gap RPC

The particularity of the single gap RPC is that only one merged avalanche takes place within them, whose size is dominated by its fluctuations.

What separates the multi gap RPCs from the other two types of detectors is the fact they include resistive, electrically floating electrodes, which divide the gas volume into a number of individual gas gaps, without the need of any conductive electrodes.

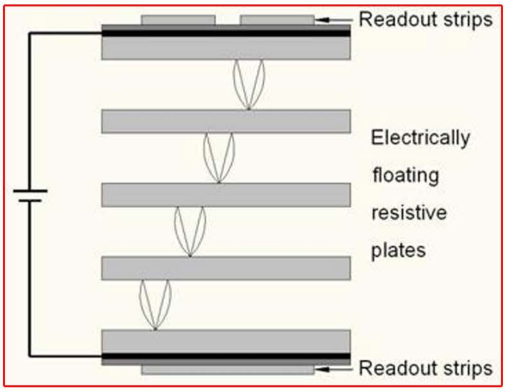


Figure 3: Schematic of a multi-gap Resistive Plate Chamber

The intermediate plates for avalanche signals are transparent, which make the induced signals on external anode and cathode be the analogue sum of avalanches in all gaps. Therefore, the avalanches in different gaps have the same time development.

The drawbacks of this design are represented by the large voltages required and the domination of the stabilizing mechanism at low ionizing particle by the dark counting rate.

Besides the three types of RPCs described above, other three should also be mentioned, namely: Hybrid RPC, Micro RPC and Special RPC[5].

5. The RPC Prototype Developed by the Hadronic Physics Department

The RPC Prototype developed by HPD has a multi-gap structure and a pickup electrode signal which has the high granularity of multistrip configuration, with differential read out of signal.

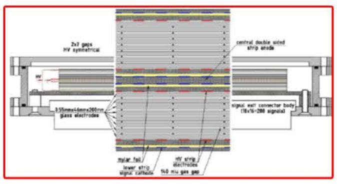


Figure4: Perpendicular transverse section through the signalling strips in the RPC detector prototype

The detector is made from two external pickup electrodes (cathodes) and one central electrode (anode) which separates the structure into two symmetrical halves. The cathodes have the strips only on one side, while the anode has strips on both sides.

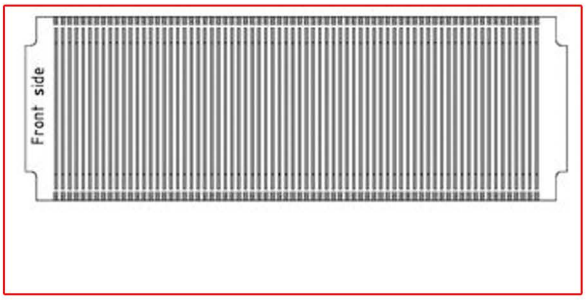


Figure5: The multistrip structure of the anode

Each half of the structure contains 8, respectively 6 electrodes made from high resistivity glass. The electrodes are separated by electrostatic wire insulator.

The internal electrodes are in contact with the strips of high voltage electrodes for positive voltage and the external electrodes are in contact for negative voltage.

The high voltage electrodes have the same structure of strips as the pickup signal electrodes.

References

[1], [3], [5] –Satyanarayana Bheisette, “Design and Characterisation Studies of Resistive Plate Chambers”, PHD Thesis, Indian Institute of Technology Bombay, India

[2], [4] – Mariana Petris, DFH, Seminar, July 2010

[Resistive Plate Chambers]

Data Aquisition and Analysis

Teleanu Elena Luiza

1. The steps to RPC

The history of particle detectors dates back to the discovery of X-rays and radioactivity. The first detectors used optical methods (for example scintillator counters) which were afterwards replaced by electrical methods. This second type of detection is based on the ionization of a gas when the radiation passes through it. Such a detector is the wire proportional chamber which has a wire-like anode. The position resolution was very good in this case, but the time resolution was better for the scintillators. The solution found for this problem was the use of an uniform electric field instead of a charged wire: a high voltage was applied to two metal electrodes which had a gas between them. In order to prevent the electrodes from a short-circuit, the metal was replaced with a resistive material, and the gas with a certain mixture of freon, hexafluoride and isobutane. This is called a resistive plate counter (RPC). The first prototype had a single gap, and in the process of development multi-gap, and multi-strip RPCs were designed.

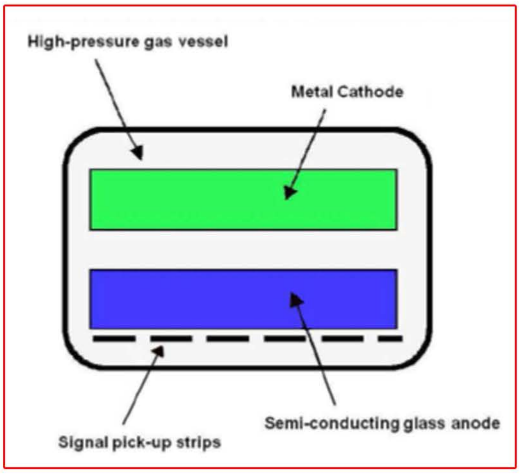


Fig1. Pestov counter [1]

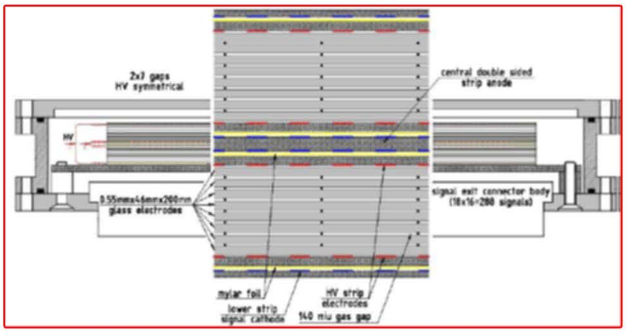


Fig 2. Multi-gap multi-strip RPC [2]

2. How does it work?

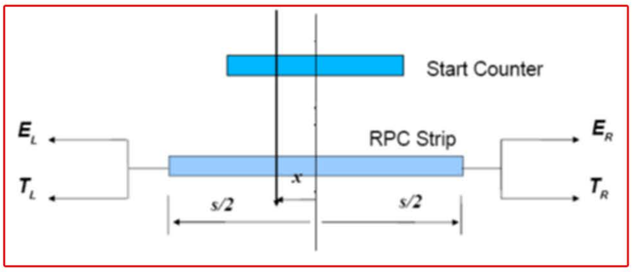
The working principle of an RPC is based on the fact that at the passing of the radiation the gas between the two electrodes will be ionized, so pairs of electron-positive ion will be formed. The positive ions move towards the cathode and the electrons towards the anode. The anode has 32 pick-up strips: the avalanche of electrons will hit an area on this strips and will produce a discharge in that area, which is taken by the front-end electronics. A NINO chip amplifies the signal and discerns between "good" signal and noise by comparing it to a minimum value. This chip also offers information about the period of time corresponding to the length of the entry signal (time over threshold - ToT). The signal will be more prominent on a certain strip where the radiation has hit and less on the neighboring strips. The RPC is used to give information about the time of flight (TOF) and the position of the hit.

3. Time of flight method

This method uses two detectors (a scintillator and an RPC) positioned at a given distance will each detect the moment when the particle hits them and by subtracting one from the other we will know the time it takes for the particle to walk that distance. This way the speed of the particle will be determined and if knowing the momentum the mass can be calculated.

4. Position along the strip

The signal is collected from both ends of a strip and sent to the front end electronics. Considering for example that the avalanche will hit to the left from the center of the strip: the signal will arrive first to the left and afterwards to the right of the collecting conductors. The position can be determined from this simple algorithm:



$$T_L = ToF + (s/2 - x)/v_s$$
$$T_R = ToF + (s/2 + x)/v_s$$
$$T_{mean} = (T_L + T_R)/2 = ToF + s/v_s$$
$$T_{diff} = (T_R - T_L) = 2x/v_s$$

Position reconstruction algorithm [3]

The data provided from each end of the strip is translated using root into a histogram.

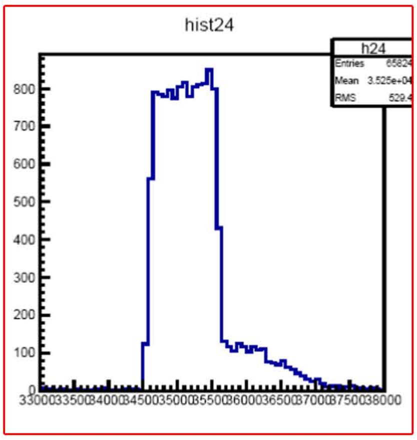


Fig3. Typical form for a histogram of events from a strip of an RPC

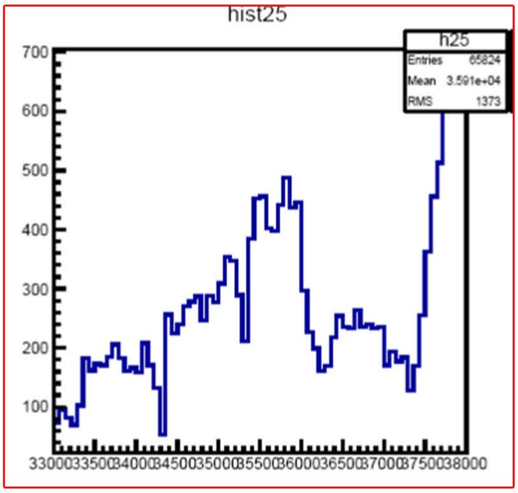


Fig4. The histogram shows that the strip 25 is not properly working

The position of the particle is obtained by fitting with a Gauss curve the difference between the events distributions from the two strip ends.

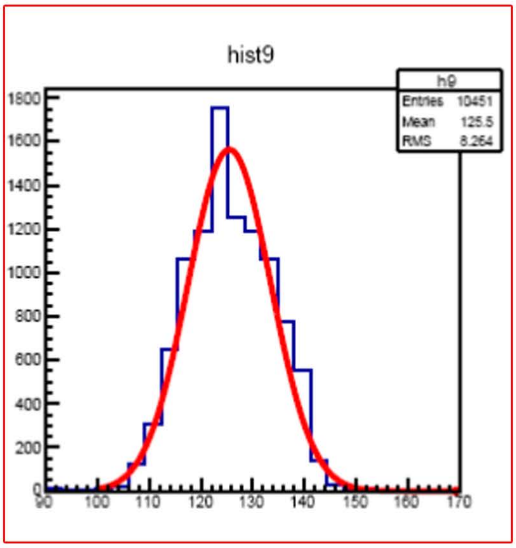


Fig5. Histogram fitted with a Gauss function for strip no 9

5. Position across the strips

As we said before, the avalanche will set a signal not only on one strip, but on an area on the anode. The distribution of the discharge on each strip giving the position for the hit is represented in figure 6.

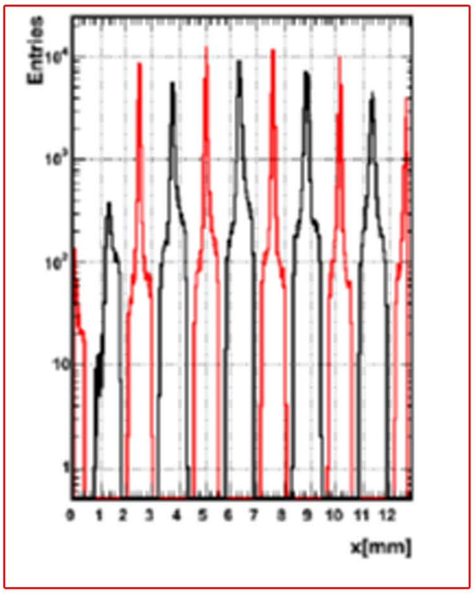


Fig6. Position reconstruction for five strips [4]

The position reconstruction is made using the ToT method, taking into consideration that this time is proportional with the charge induced on the strips.

6. Conclusions

The RPCs are an important detector in many experiments, replacing, successfully, in some cases scintillators. Their main advantages are lower costs than scintillators (produced with common materials such as china glass and operate at atmospherical pressure), and the fact that they offer good time and position resolution.

The development process is not finished as methods of improving this detectors are taken into consideration.

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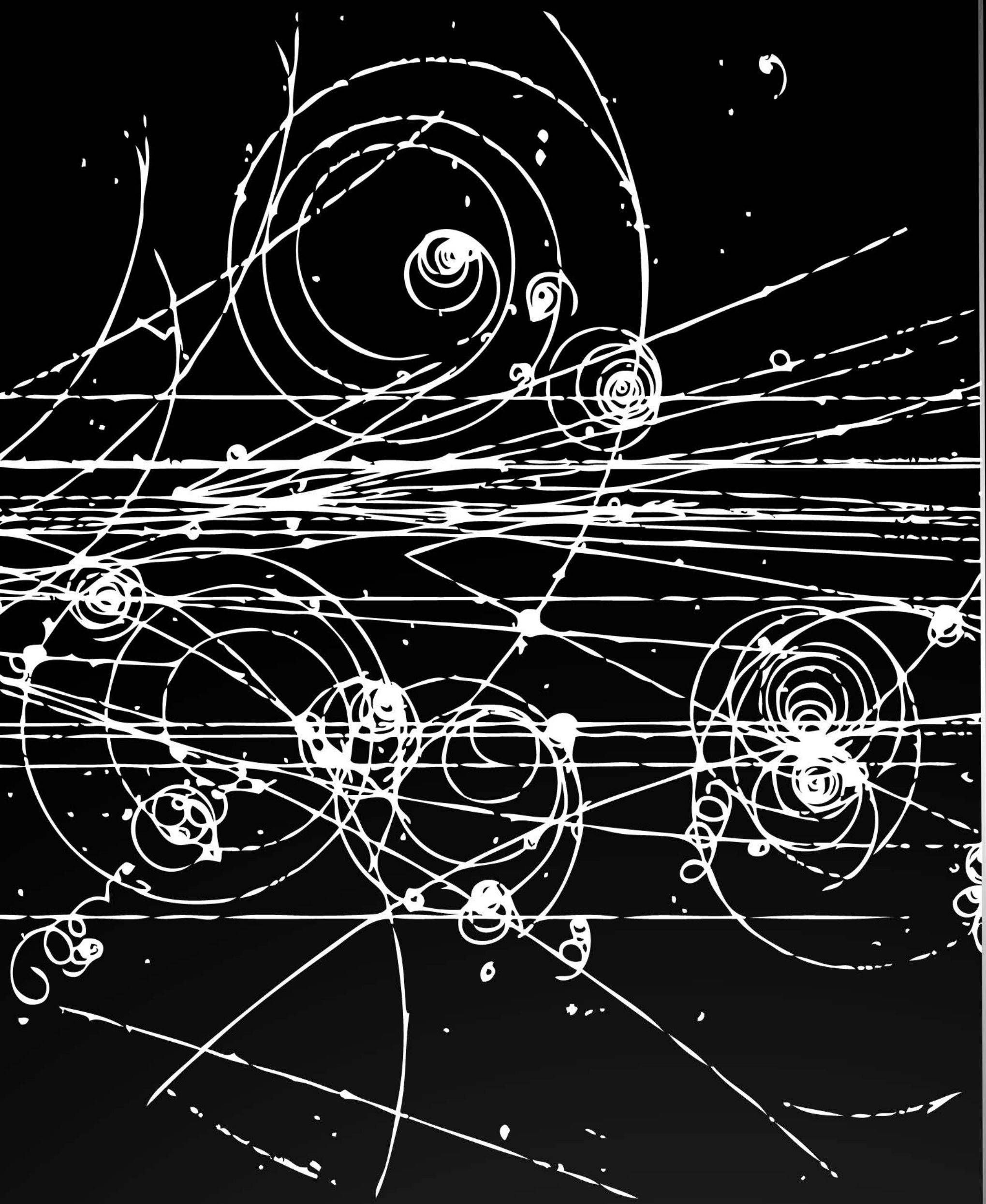
[3]Mariana Petris, RPC-General presentation, Seminar DFH, July 27



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