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Computational Particle Physics and Detector Simulations

Term Assignment

Description

The muon spectrometer of the ATLAS experiment uses Monitored Drift Tube (MDT) chambers to accurately monitor the trajectory of muons. Each MDT chamber contains 6 to 8 tube layers, organized in 2 multi-layers of 3 (or 4) tubes. The tubes contain $Ar : CO_2$ gas at 3 bars of pressure and have a wire crossing through their centers were a 3000V voltage is applied.

The procedure to recreate the trajectory of a muon is as following: a muon enters the chamber and the tubes causing ionizations in each tube it passes through. The primary electrons (of the ionization) accelerate towards the anode (the wire) causing secondary ionizations and finally a signal is produced from the current that accumulates in the wire. Thus, for each tube that the muon crossed we know its (closest) distance but not its actual path, which can then represent as a circle in the tube. This happens for every tube, and the trajectory must be tangent to all of this circles, so its path can be derived.

Assignment

Create a BIS muon chamber (x-y cross-section) with 4 layers of tubes, each with 30 tubes, in a 2 multi-layer configuration each containg 4 layers. The distance of two multilayers is 8mm. Each tube has a diameter of 3cm.

Create random trajectories of muons (cosmic muons) which pass through at least one multi-layer of the chamber.

For each trajectory that passes through the chamber, find the tubes that the muon interacts with and, thus, produce a signal. After finding the distance of the trajectory from the wire, draw the aforementioned circles on the graph with the circle's center being the wire of each tube and the distance representing the radius.

Use the r-t relation provided to find the time for each tube. Fill a histogram in live-time.

The surface of the chamber is $2m^2$.

Solution

The solution was implemented in ROOT programming language. The attached files provide the source code, with the `c_sol` containing the `src` and `lib` subdirectories.

To run the code, change the directory to `src` and open a ROOT prompt. Then:

```
root [0] .L erg_main.cpp
root [1] main()
```

The `src` directory contains the `erg_main.cpp` file which is simply a wrapper around the rest of the project.

The `lib` directory contains header files used in creating a simulation of the chamber, drawing data, fiting and mathematical operations.

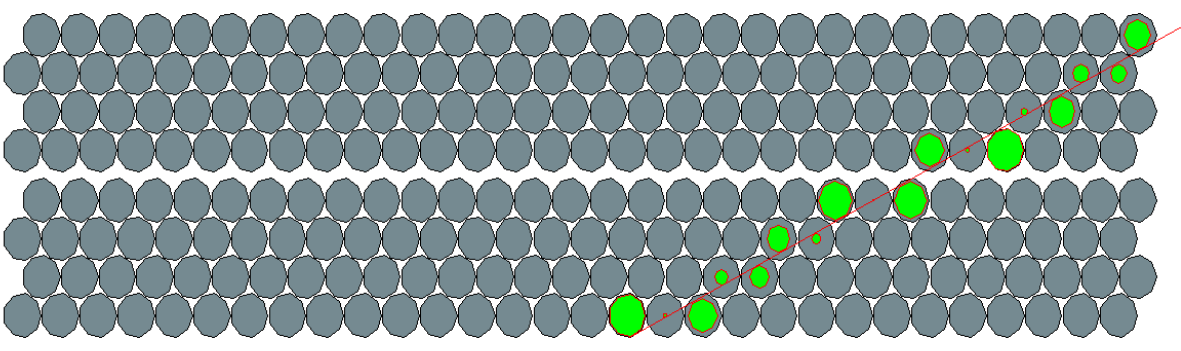
More specifically, `MDTChamber.hpp` contains methods used to initialize the chamber, draw the results (chamber simulation, fitted data and the histogram), produce random trajectories and generally manage the results of the measurement. The "vertical" (y-axis) distance between the tubes of the same multi-layer was calculated as a value less than a whole diameter, taking into account that the tubes are stacked with an off-set in the x-axis.

`MDTMath.hpp` contains methods used to calculate the trajectory of the muon, the distances of the calculated trajectory from a given point and and extrapolating that line.

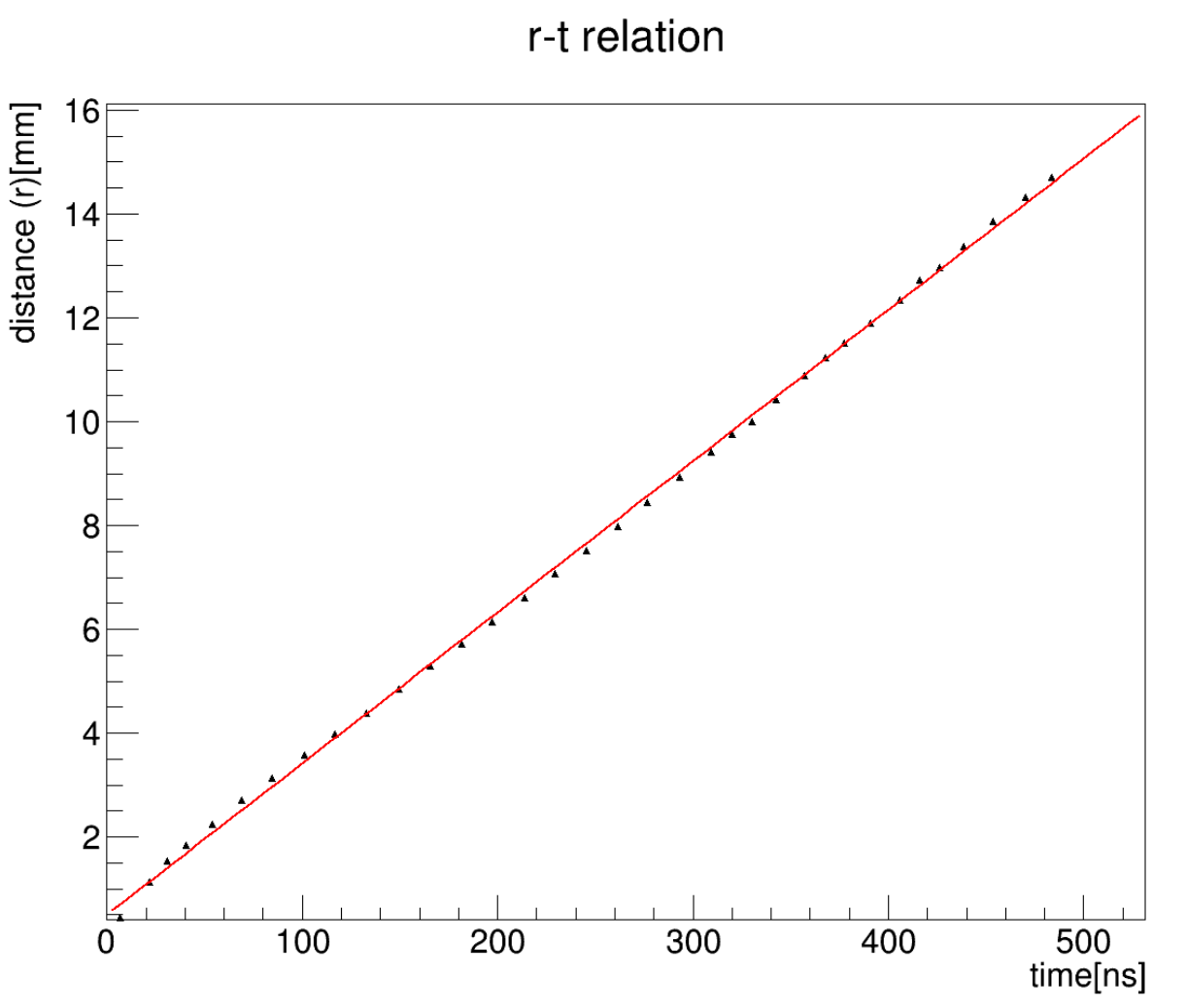
Finally, `MDTFit.hpp` contains data required to calculate the r-t relation (data was gathered from figure 5-68 from the provided technical paper using an online tool which extracts data from plots).

Results

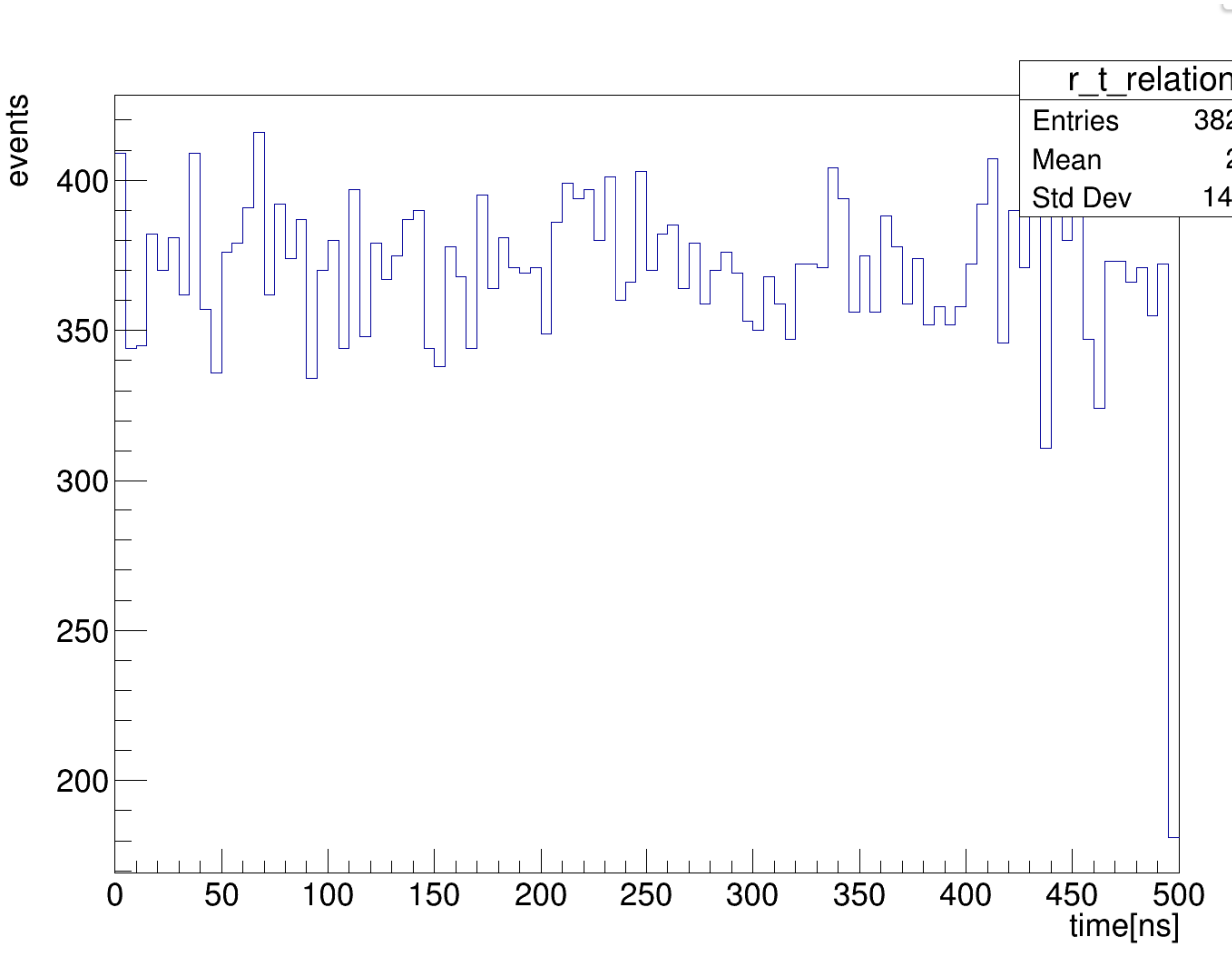
The simulation of the chamber is presented below, with the trajectory of one randomly generated muon appearing as a red line. The green circles with the red outline represent the tubes "hit" with their radius representing the distance as discussed above.



The reconstructed graph 5-68 from the paper is presented below. The parameters of the fitted line were used to create a relation between the distance from the tubes center with the time it takes for the signal to appear (r-t relation).



The final state of the produced histogram of signal times is presented below (time is measured in nanoseconds). The histogram contains data on how long it took for a signal to appear based on the distance of the trajectory from the wire, calculated through the use of the r-t relation discussed above.



The values appear almost uniformly, but that was an expected result given the random generation of muon trajectories and the linear relation between distance and time.

Figure 5-73 from the technical paper suggests a different (non-uniform) number of events per time unit, but the gas mixture is different. Also a different r-t relation might have been used using a higher degree polynomial.

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