M2 defense: Creation of a realistic detector response for COMET Phase-I Detector

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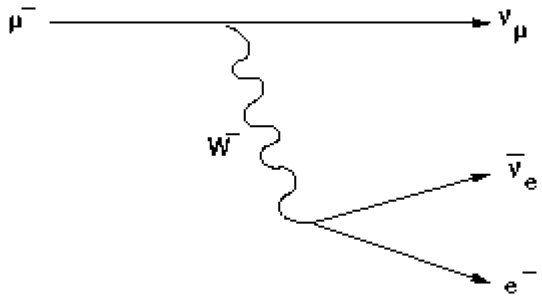
Outline

- Introduction
- COMET Experiment
- Work
- Result
- Outlook

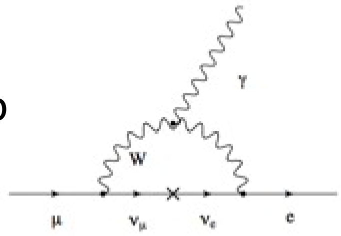
Introduction

Discovery of muons(1936) and neutrinos(1956) → Search for neutrino-less decay of muon into electron:



→ Not observed : Lepton flavor conservation

Neutrino oscillation(1998) → Lepton flavor not conserved
Charged lepton flavor violation possible, predict branching ratio around 10^{-54}



Discovery of such a transition → New physics discovery

COMET Experiment

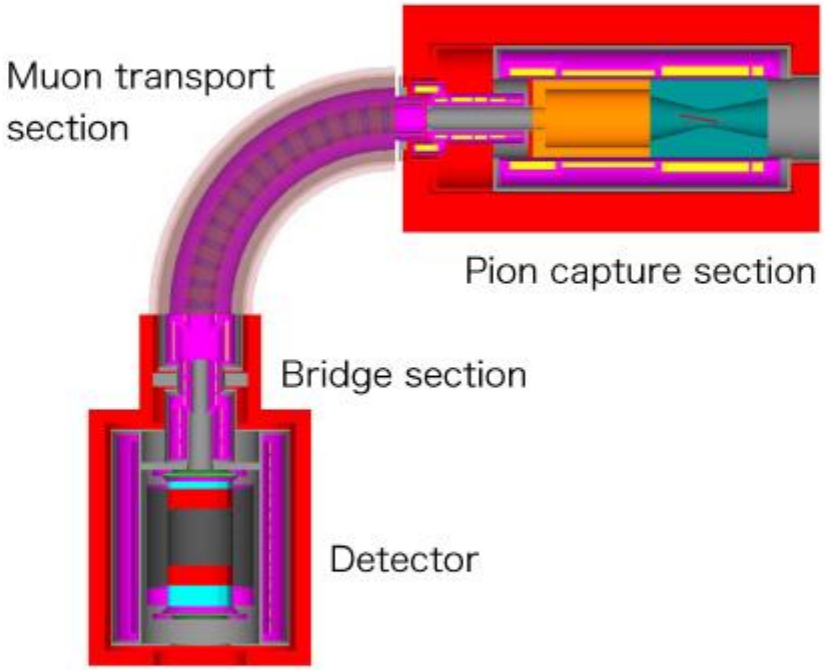
The COMET(COherent Muon to Electron Transition) search for

$$\mu^- + N \rightarrow e^- + N$$

Electron energy given by :

$$E_e = m_\mu - B_\mu - E_{\text{recoil}}$$

$E_e = 104{,}97\ MeV$ for aluminum target

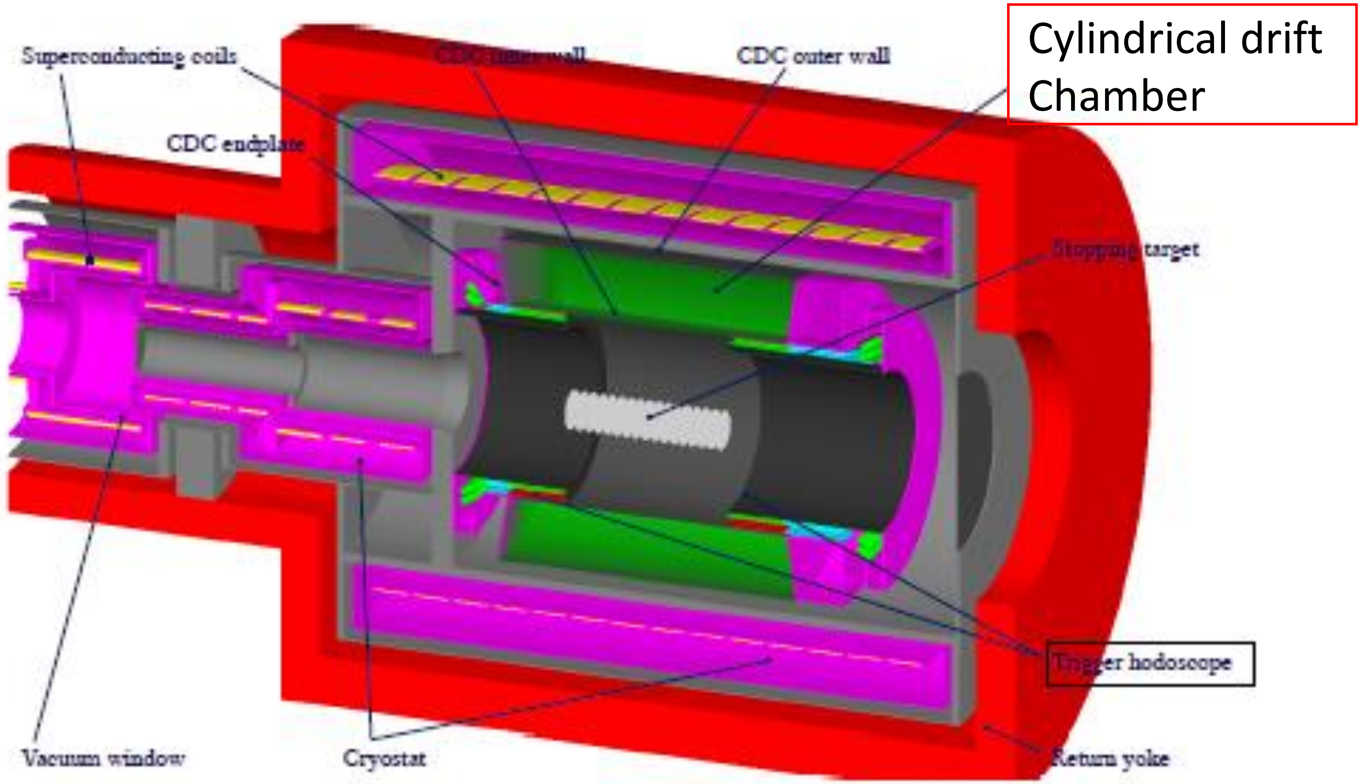


Layout of COMET Phase-I experiment

Goal:

- Intermediate search with single event sensitivity of 3×10^{-15}
- Check background for Phase-II
- Check muon beam and its performance
- Test detector prototype of Phase-II

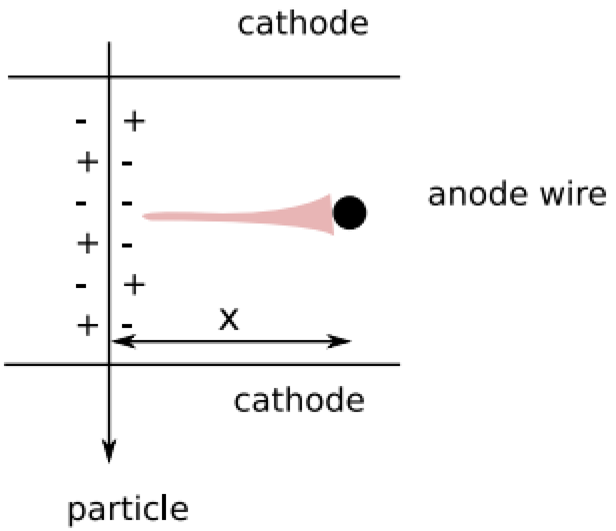
COMET Experiment Phase-I detector



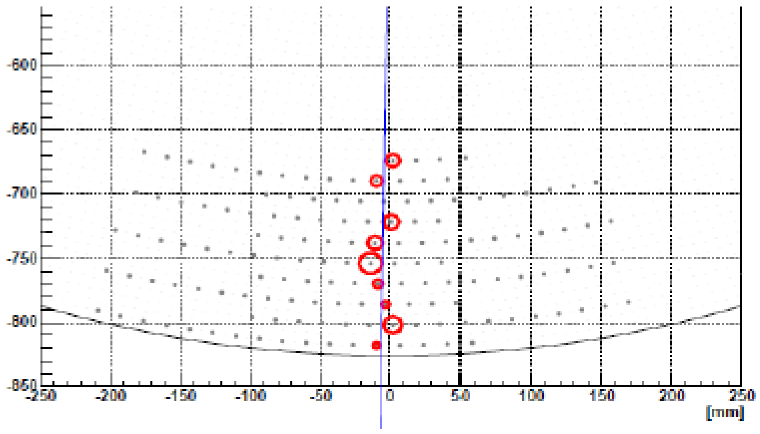
Layout of COMET Phase-I detector

Drift Chamber operation principle

Charged particle ionized the gas.
Drift of electron toward the anode wire.
Electron avalanche around the anode wire.



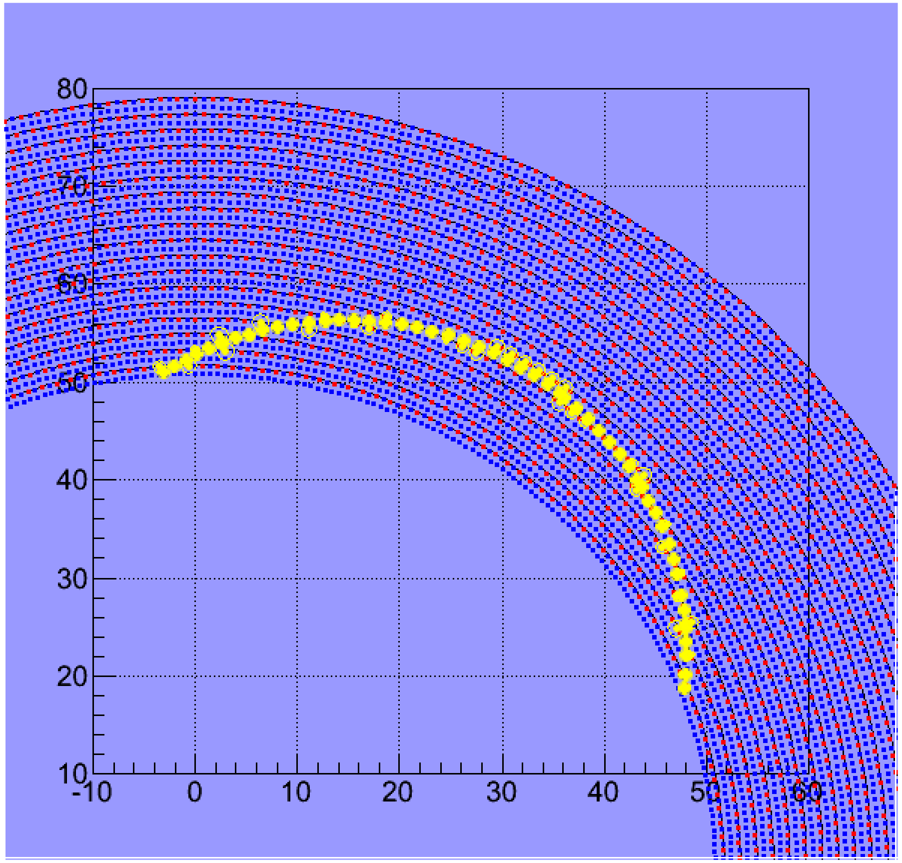
Measuring the drift time → Greater precision on the tracking



Cylindrical Drift Chamber

Purpose:

- Tracking the signal electron, measurement of the electron momentum
- Avoid low energy electron from muon decays

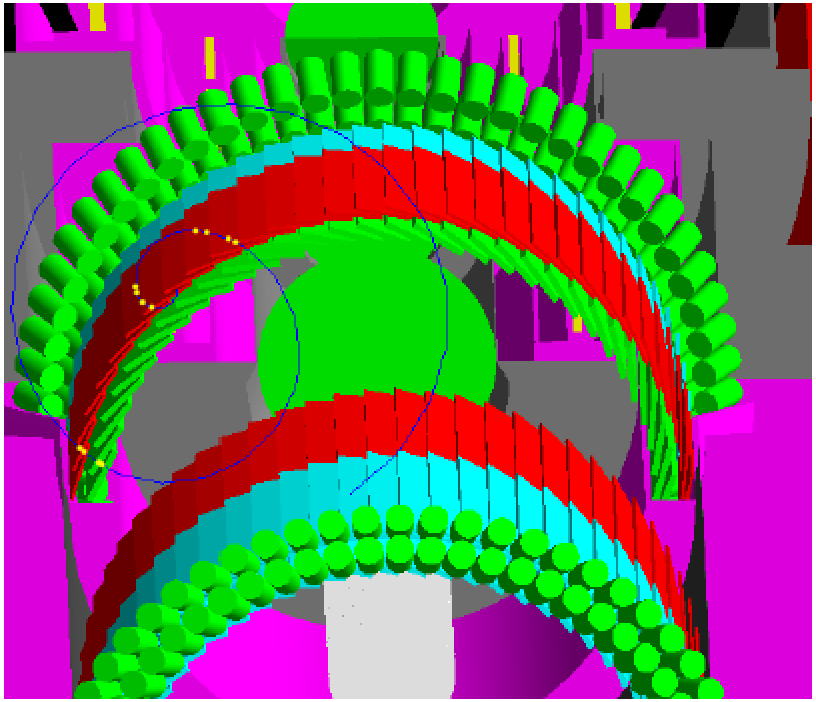


20 sense layers
4 986 senses wires
14 562 field wires
Stereo angle ± 64-75 mrad → resolution of 3 mm along the beams axis

Cylindrical Trigger Hodoscope

Purposes:

- Trigger
- Identify electron from other particles
- Measure electron energy

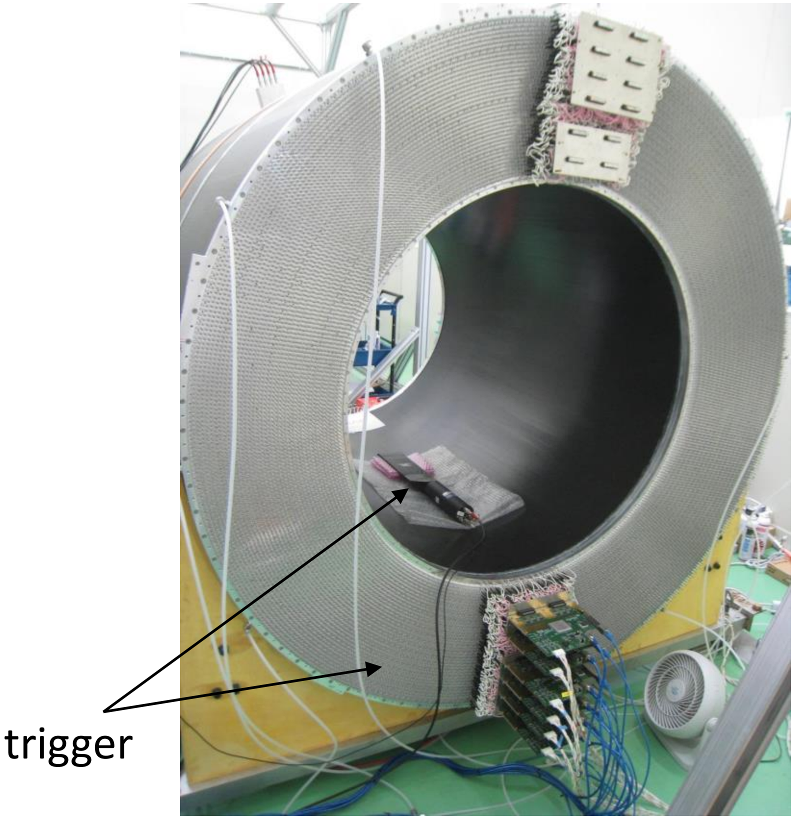


2 hodoscopes at each end of the cylindrical detector. Each hodoscope composed of 64 triggers hodoscope modules.
Module made of a pair of plastic scintillator and a Lucite Cherenkov counter

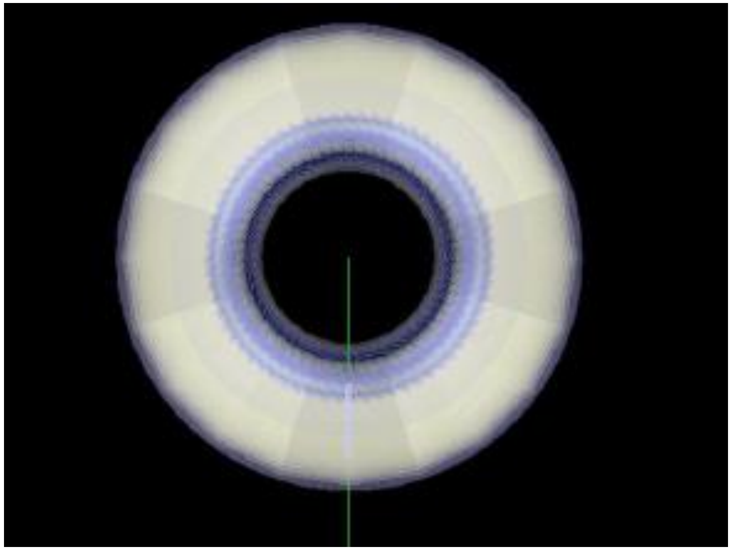
Work

Calibration of the CDC using cosmic muon

Experiment setup

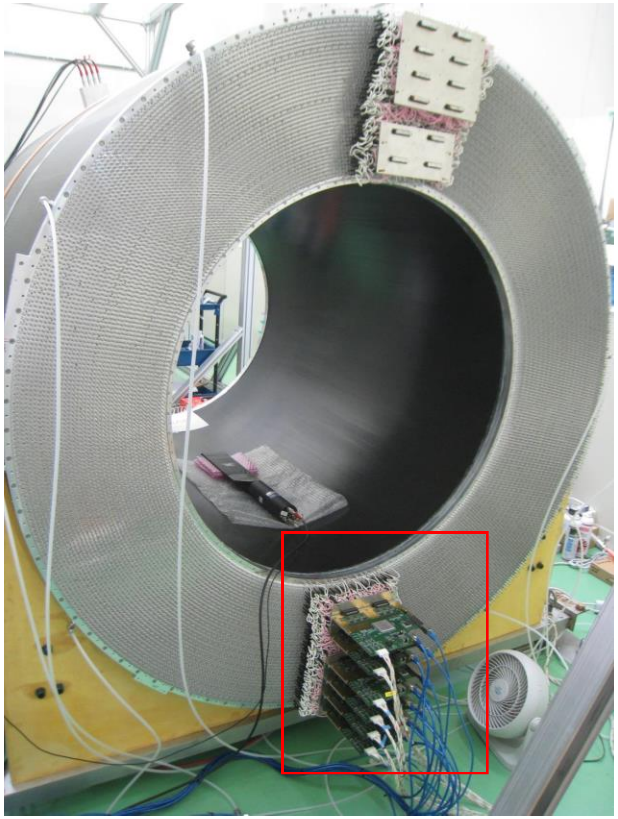


Simulation setup



Cosmic muon launch with energy uniformly distributed between 300-700MeV

Readout Electronics



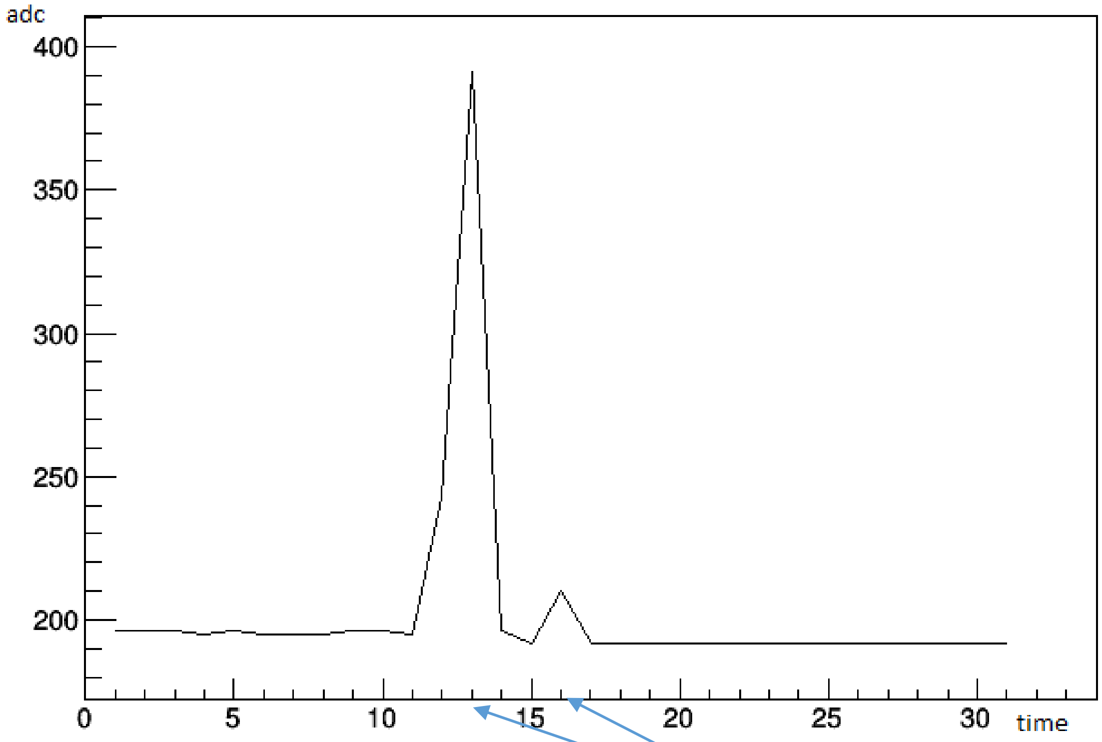
ADC and TDC value.

ADC (Analogue to Digital Converter) → $\frac{dE}{dx}$

TDC (Time to Digital Converter) - trigger time
→ Drift time

Signal exemple

Example of adc signal



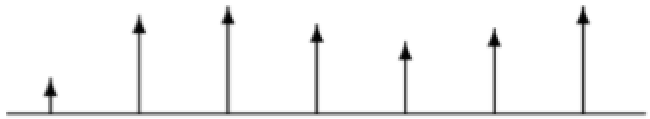
Clock number drift time ± 33ns

Signal simulation

Simulation:

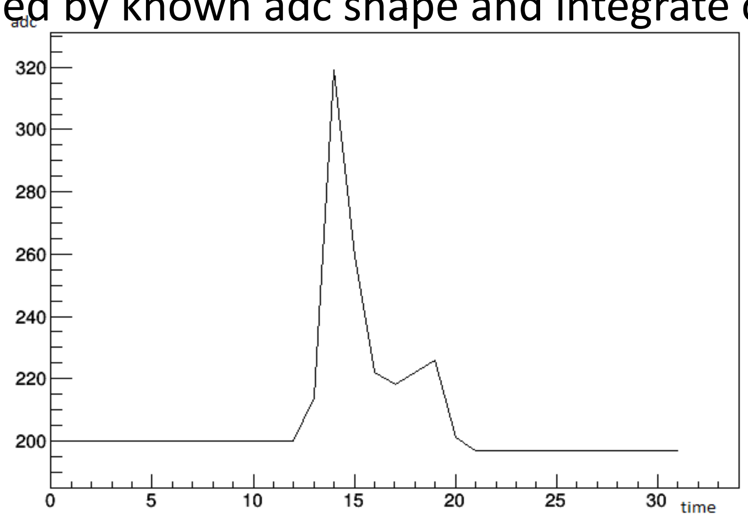
- Creation of hit inside the gas with energy deposit . Creation of ion-electron pair according to Poisson law and Gas ionization potential.

- Creation of electron avalanches → $N = N_0 \times 10^5$. Where N_0 is the primary number of ion-electron pair. Electron from the same avalanche arrives at the same time.
  Combining different hit on the same wire → Dirac comb



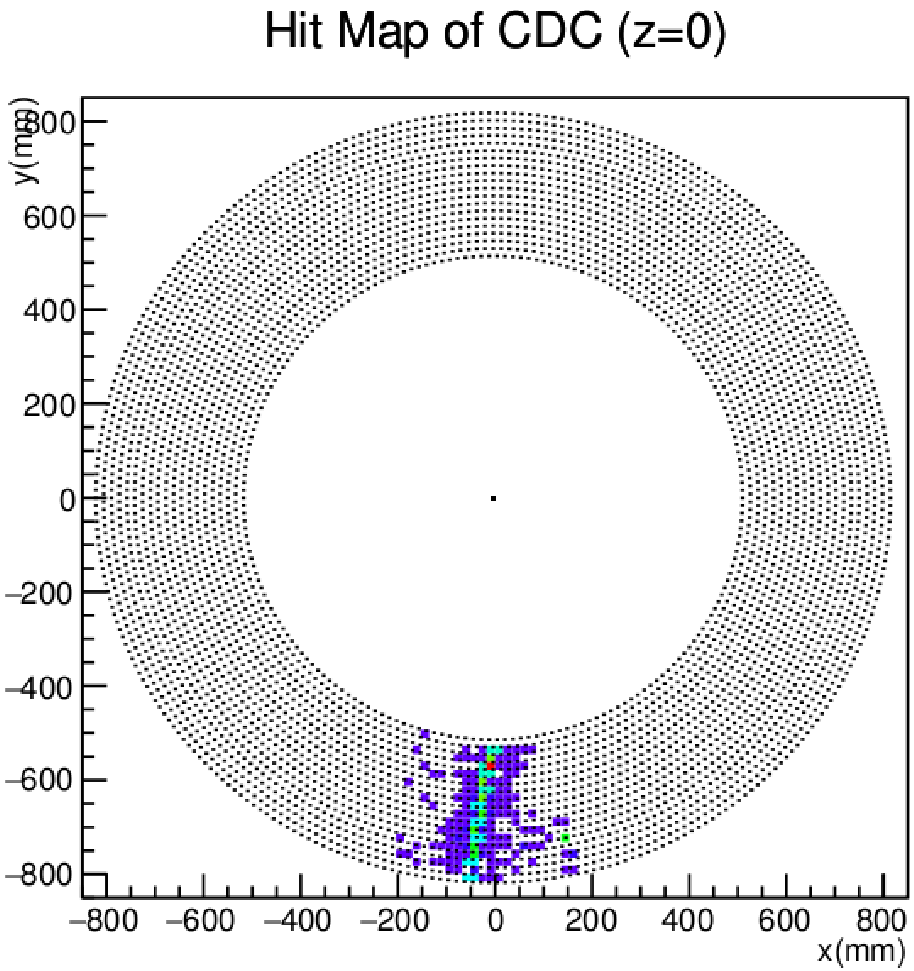
- Linear conversion (10^{-5}) of the charge into adc unit (volt)

- Pulse multiplied by known adc shape and integrate over dt (33 ns adc clock time)

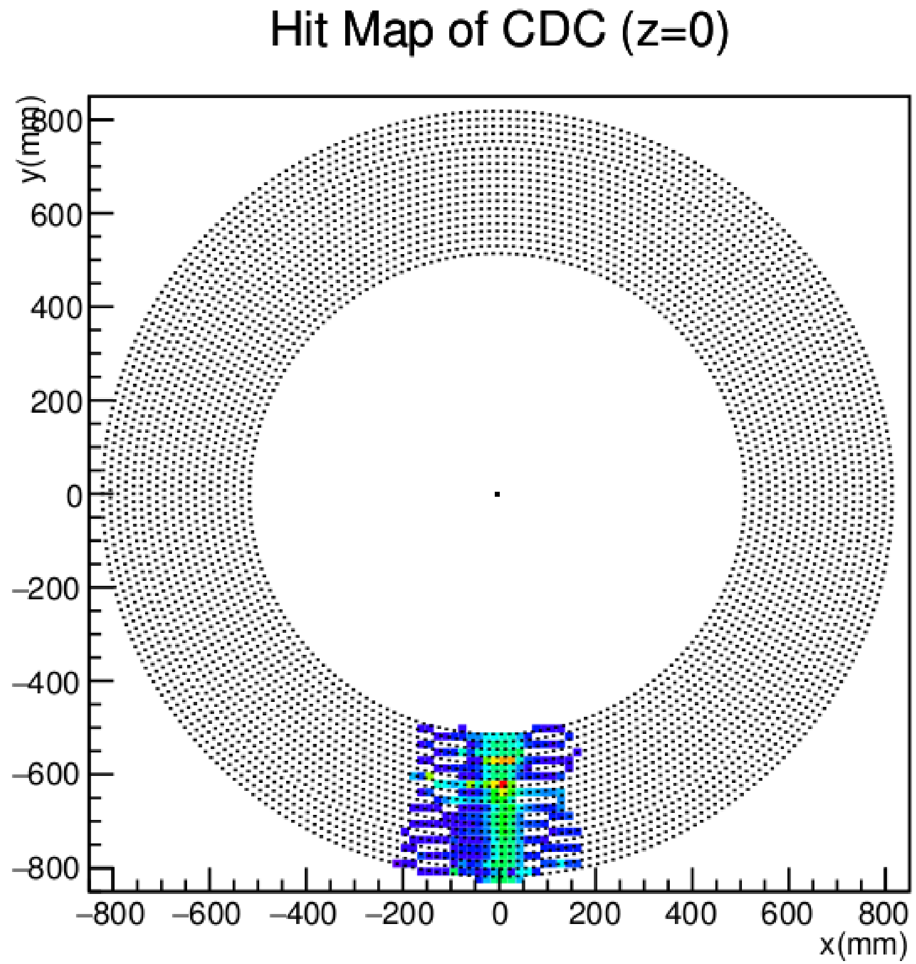


Simulated adc signal

Results



Simulation ~ 1000 events

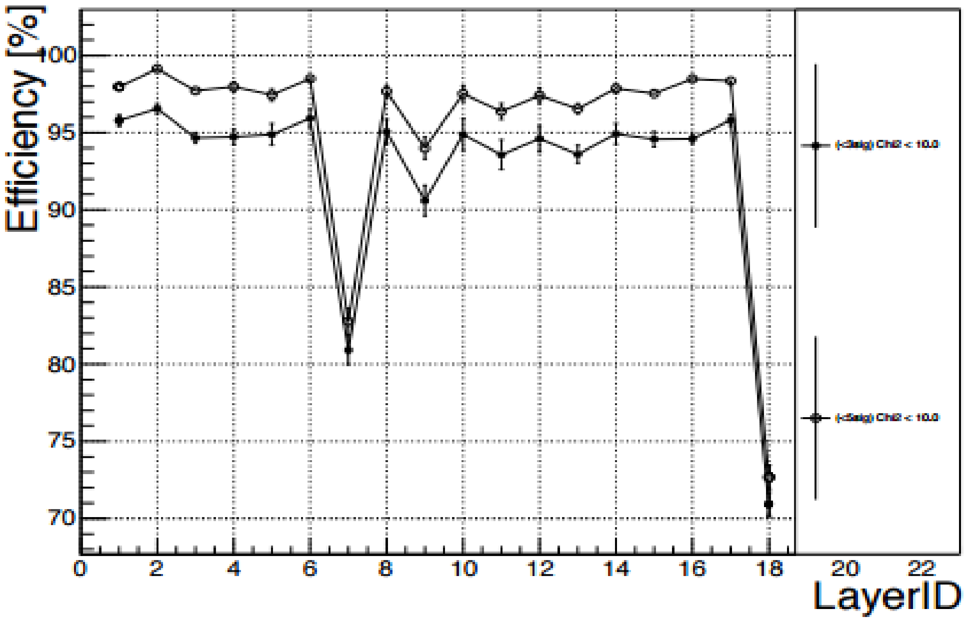


Experiment ~ 25 000 events

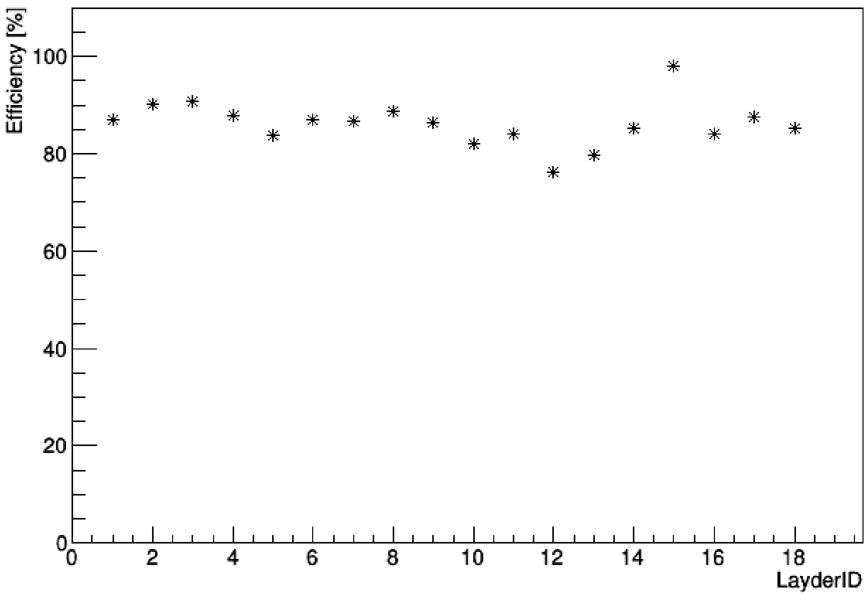
Results

Efficiency of the track fitting by test layer

Experiment



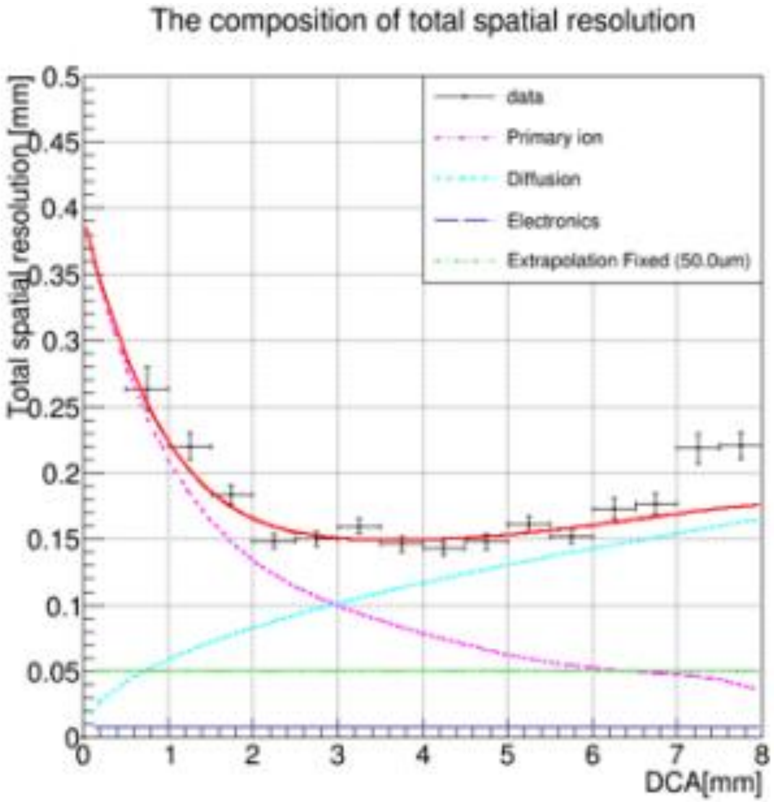
Simulation



Simulation resolution ~ 77 – 98 %

Result

Experimental intrinsic spatial resolution

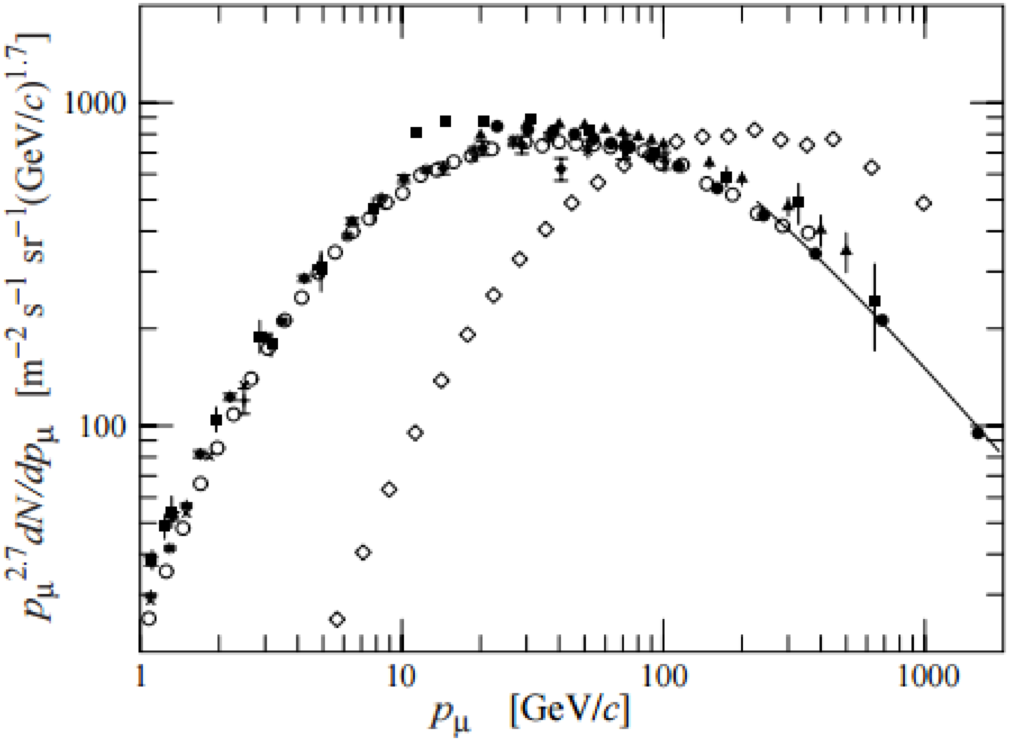


Goal to achieve the same spatial resolution in the simulation. 3 majors contribution to the uncertainty:

- Primary ion pair statistics
- Electron diffusion in the gas
- Electronics dispersion

Outlook : experiment simulation

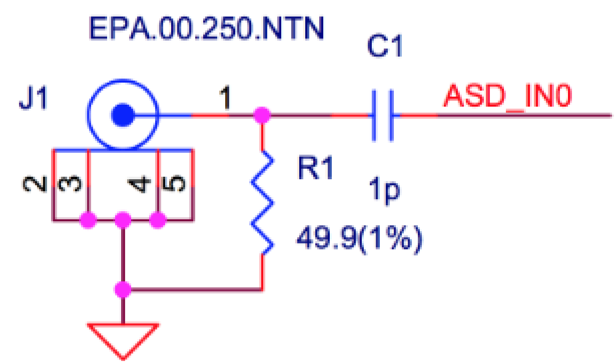
Real cosmic distribution or muon event data from CERN or KEK



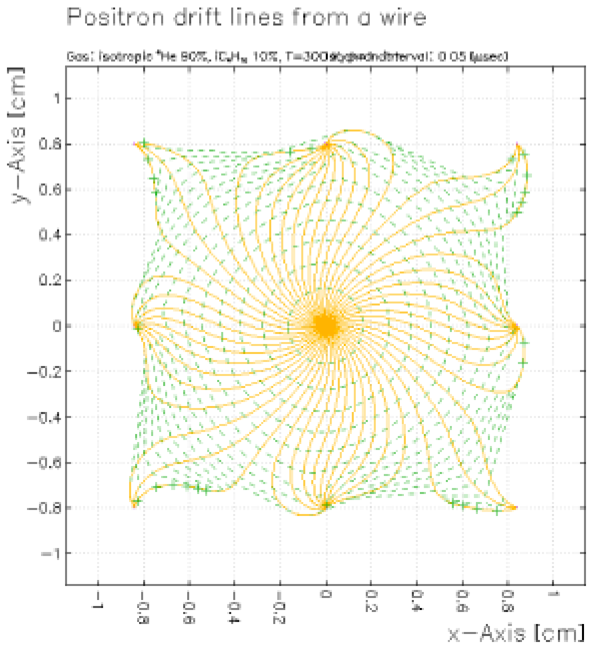
- Avalanche construction → $N(x) = N_0 \exp(\alpha x)$; $\alpha = \frac{1}{l_0}$, where l_0 is the mean free path. Poisson distribution around $N(x)$.

- Smearing of avalanche arrival time → current creation

- Create the real electronic answer of the wire →



- Creation of the signal under the magnetic field.



THANK YOU FOR YOUR ATTENTION

Doors open to question

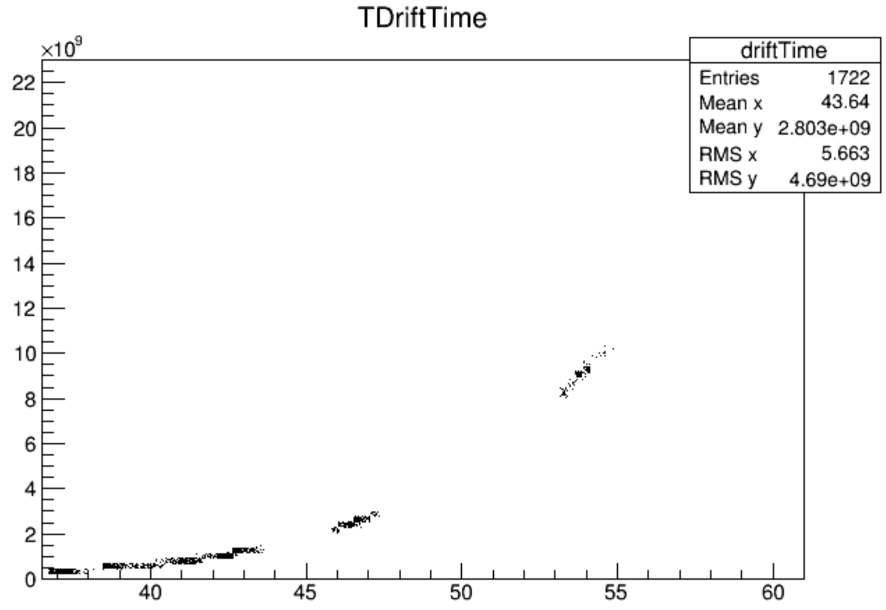
CM22:

BACKUP SLIDE

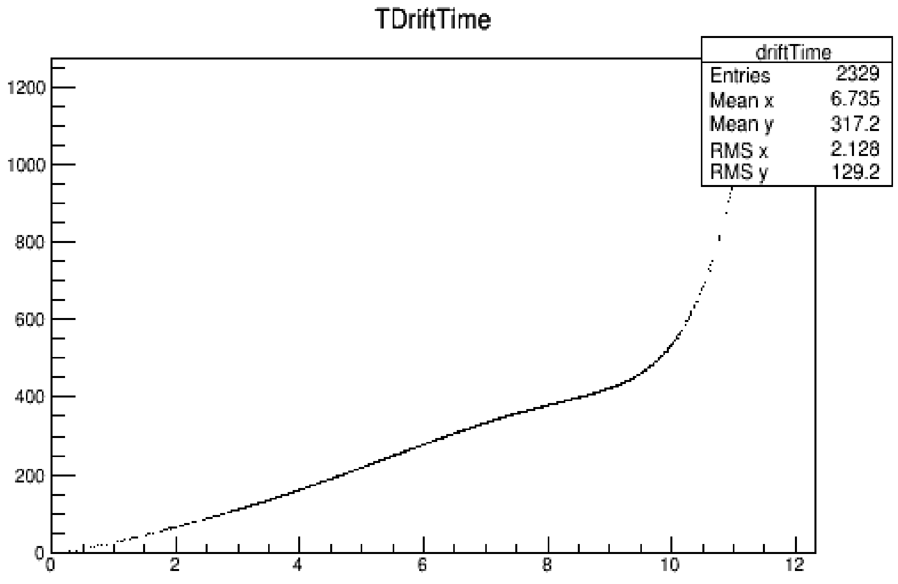
Issue with the drift time and drift distance

When using only the CDC, the truth information give really strange result. As if some of the wires are disconnected or some physics is disable in the CDC only mode.

CDC Single Component x-t relation



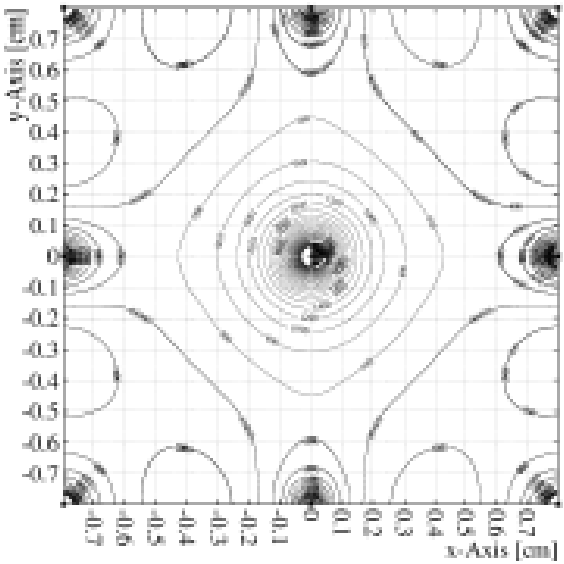
Phase-I geometry x-t relation



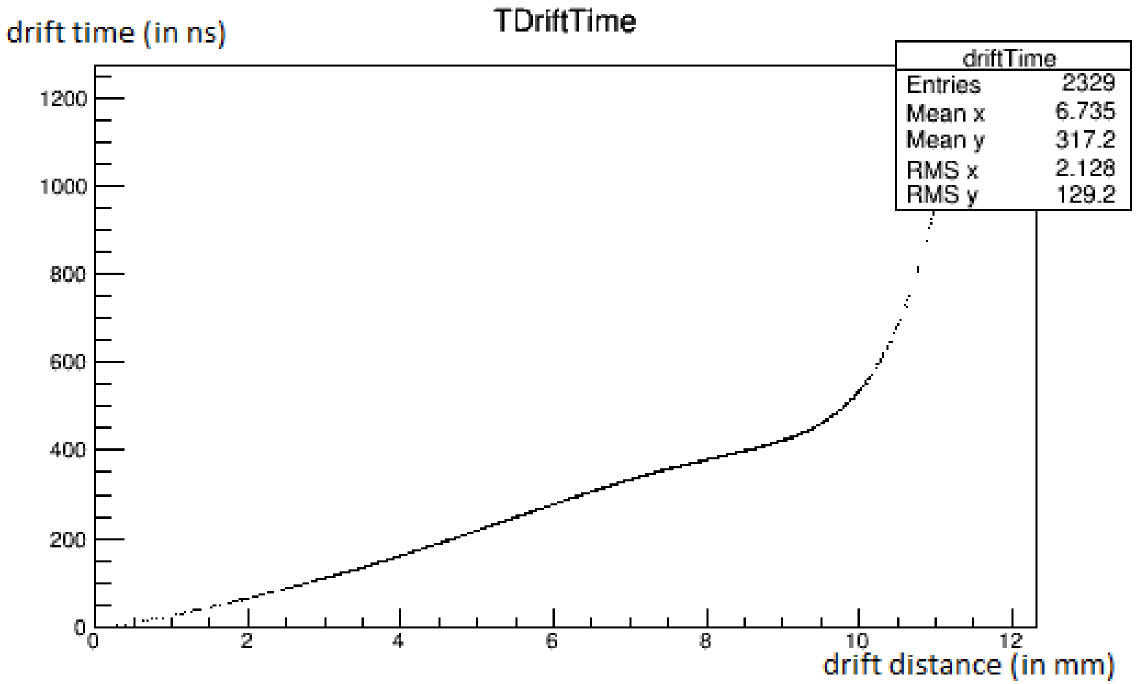
So for the rest of the study I had to start using the full geometry and withdraw some element that could cause trouble as the cosmic ray veto or the production target

Drift time calculation

We know the drift velocity of electron in the CDC gas, so combining the distance between the hit and the nearest wire, with the electric field of the cells we can deduce the drift time of the hit.



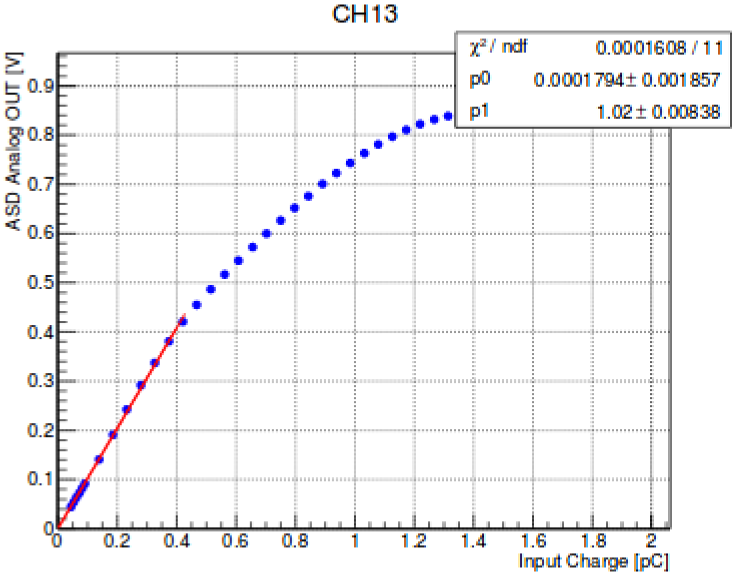
Electric field contour of a CDC Cells



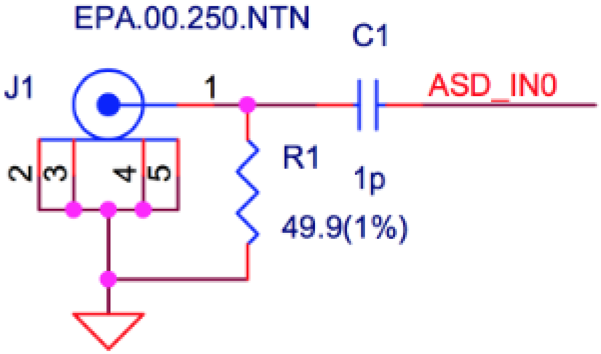
XT relation

Changement needed for adc

For now the SimDetectorResponse code threat the collected charge and the adc as if they were proportional. But this is only the case for small charge:



The simulation need to use a realistic answer. So the electronic chain has to be taken into consideration:



Issue with current simulation

There is strong issue related to using the adc for tdc. So the tdc should be simulated properly here is an example: