Un trajectographe de recul pour particules basse énergie à CLAS12

ALERT: A Low Energy Recoil Tracker

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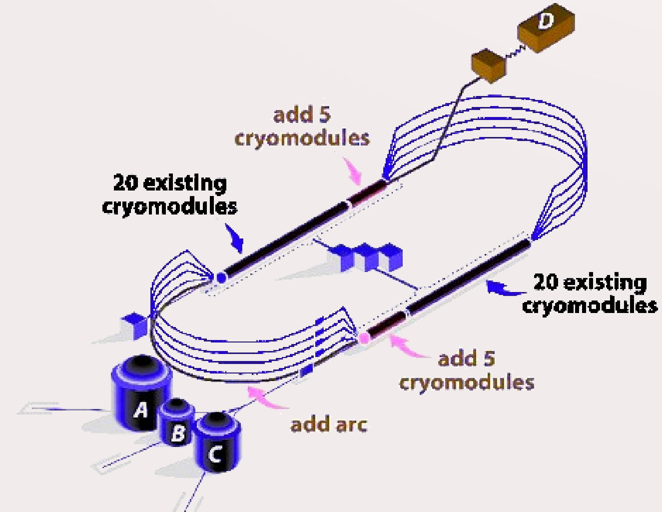
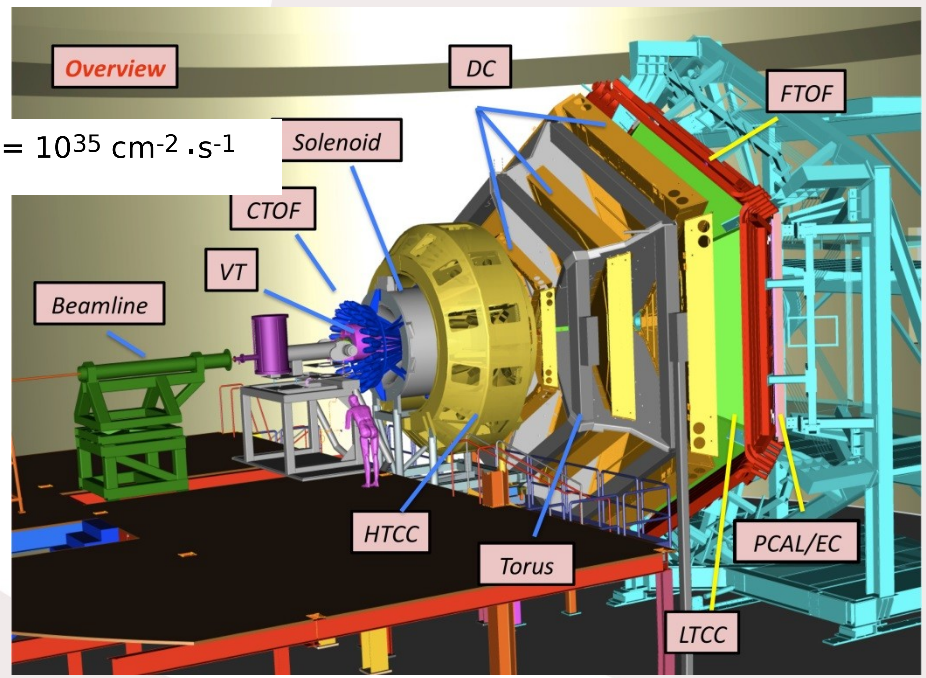
Journée d'instrumentation de P2IO 20/11/2015

Jefferson Laboratory, Virginia, USA



12 GeV continuous electron beam

L = 10^{35} $cm^{-2}.s^{-1}$



Scheme of CLAS12 (Hall B)

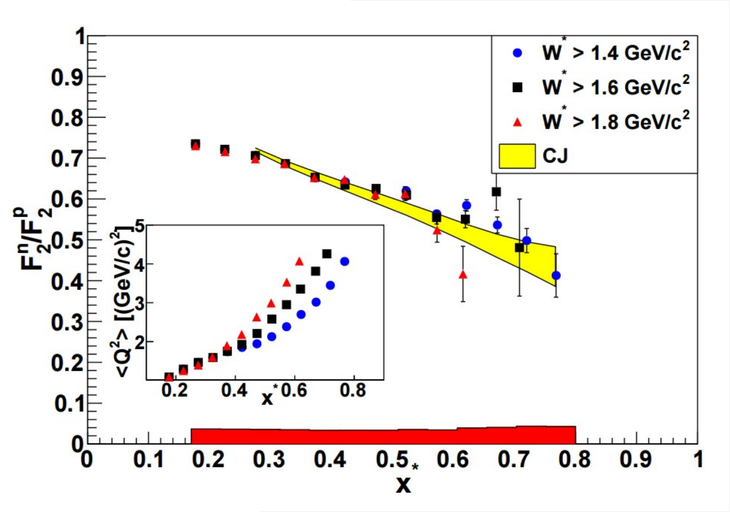
The Hall B will adress the following questions:

- What is the longitudinal and transverse structure of the nucleon?
- What is the 3D structure of the nucleon?
- What is the hadronic spectrum?
- What can we learn about hadrons and cold nuclear matter?

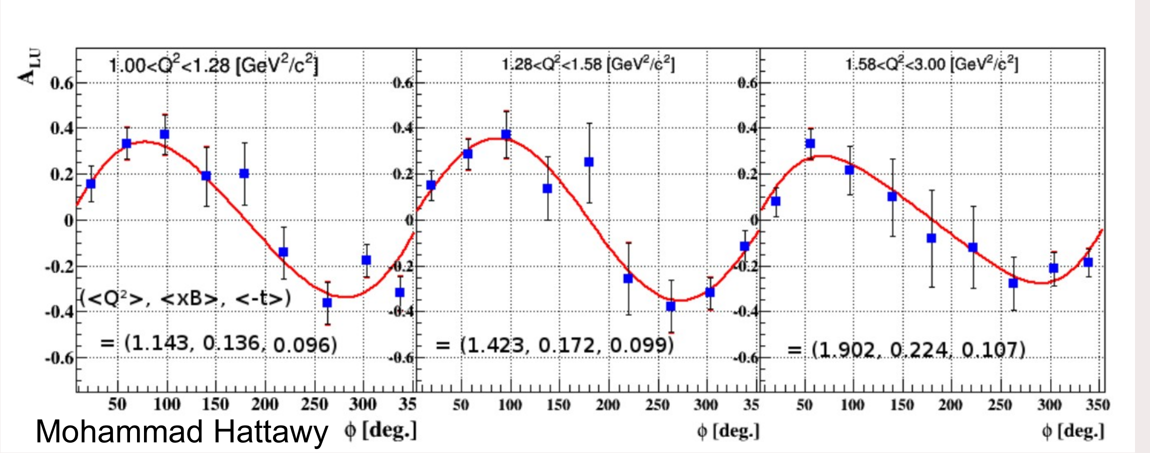
Physics motivation

First generation of experiments measuring nuclei fragments at CLAS has given results in the recent years. They used a rTPC.

Tagged proton at low energy



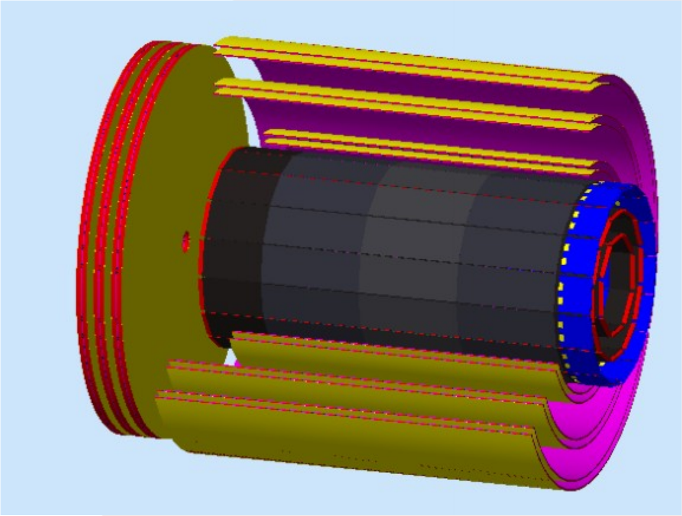
DVCS on Helium 4



A collaboration has started to perform the second generation of measures requiring low momentum particle measurements at JLab

Coherent phi production on He4 (Temple University)
DVCS on He4 (Argonne, JLab, Orsay)
DVCS on N (Argonne, UTFSM)
Tagged EMC (Argonne, JLab, Orsay)

Central detector



The planned central detector for CLAS12:

- 4 layers of silicon detector
- 6 layers of central cylindrical Micromegas
- 6 layers of forward Micromegas
- CTOF
- Neutron detector
- 5 T magnetic field
- Separate protons, kaons, pions
- Detect neutrons
- Momentum threshold 200-300 MeV/c

Momentum threshold needs to be reduced for certain experiments

+

Keep the possibility to be included in the trigger

+

Separate protons, deuterium, tritium, alpha, helium 3

Which detectors?

After a comparison between existing detectors a **drift chamber and an array of scintillators** have been chosen.

It has the following advantages:

- Low material tracker
- Fast detector if wires are not too far and gas well chosen
- Both detectors can be included in the trigger
- Separate protons, deuterium, tritium, alpha, helium 3

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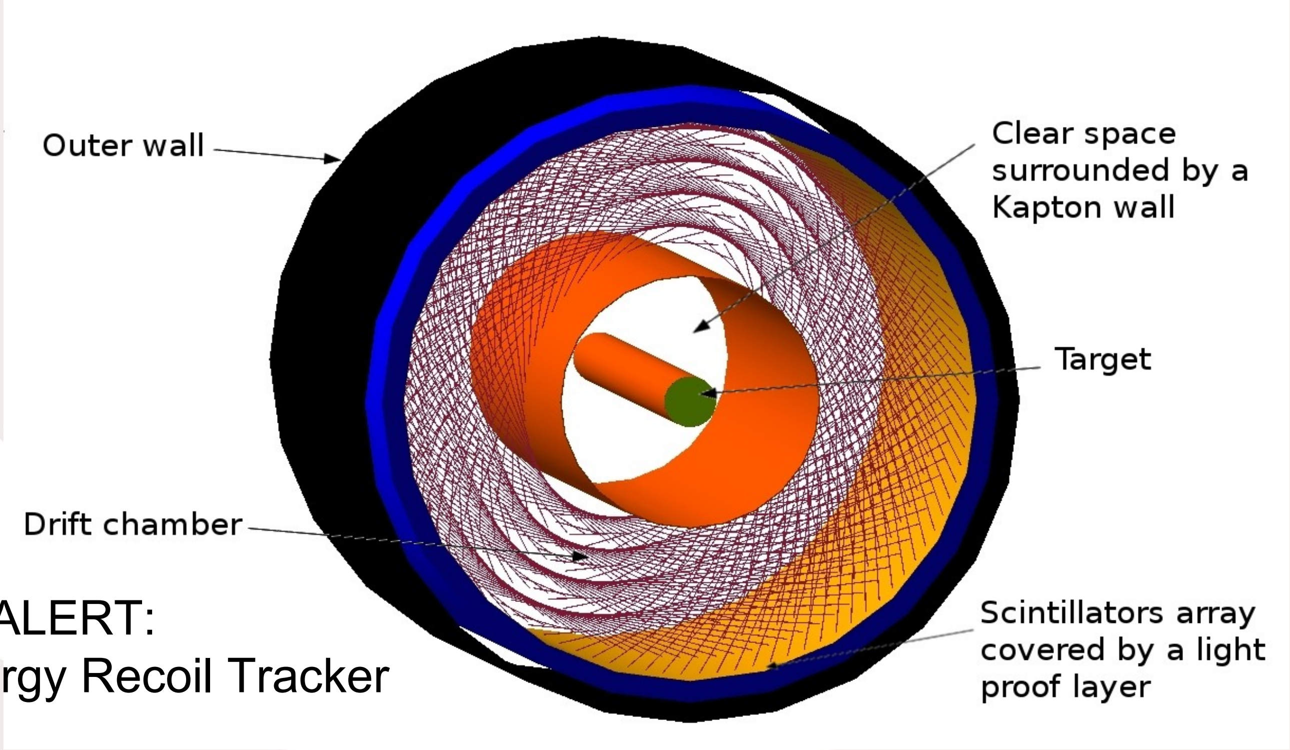
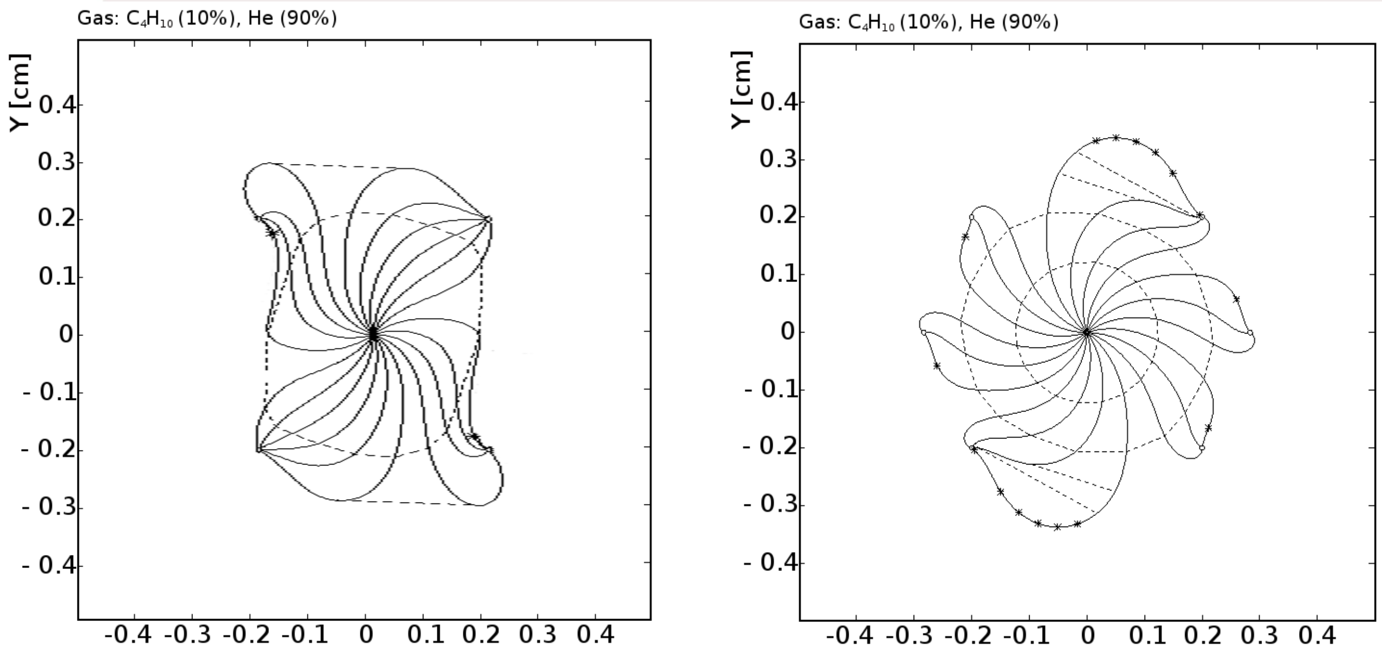


ALERT:
A Low Energy Recoil Tracker

Drift chamber layout (1/2)

Use stereo angle to determine the position along the beam axis
Space between two wires of different potential: 2 mm

Layout of the wires (elementary cell)

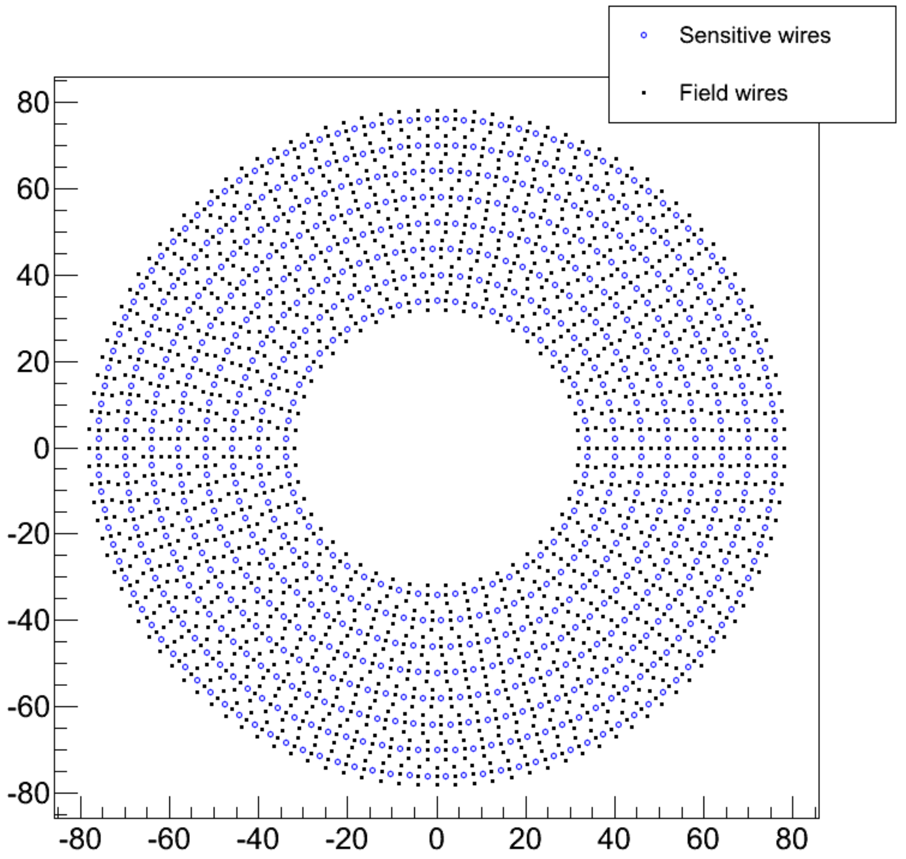


GARFIELD simulations of the electron drift lines, G. Dodge

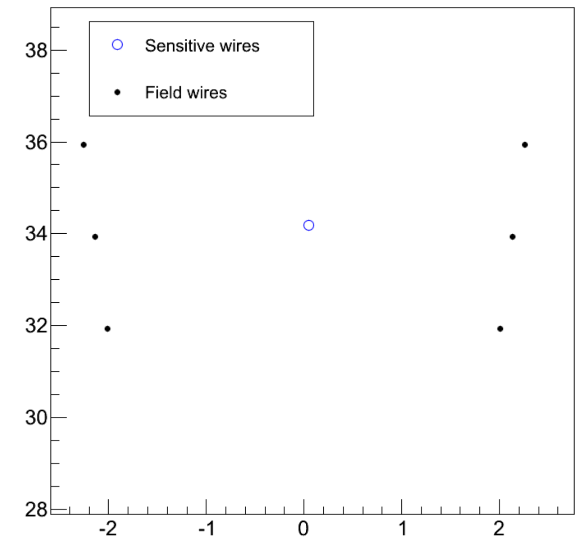
Maximum drift time estimated to be 200 ns

A prototype with different cell configuration is being designed.

Drift chamber layout (2/2)



Example of a layout. In this configuration there are 662 sensitive wires and 1986 field wires



View of one cell

To ensure a 20 microns sag, the total weight on the end plate due to the tension is about 600 kg. **Tests will be performed to use lighter wires.**

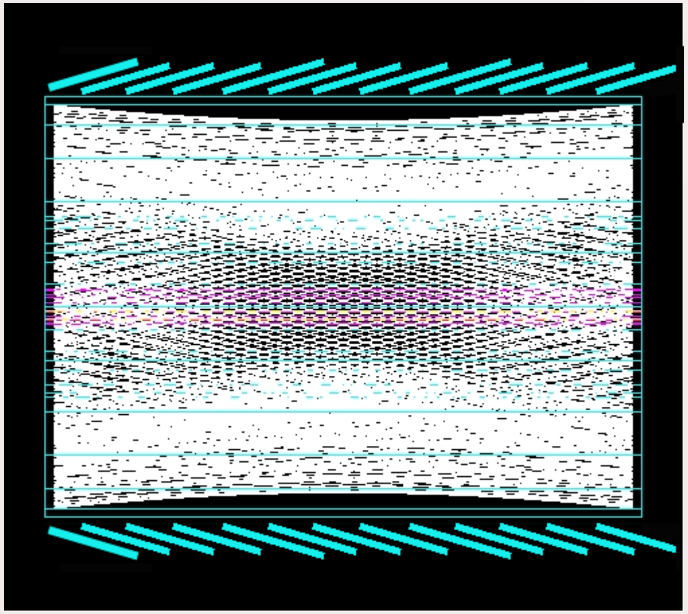
Scintillators layout

Configuration under study, signal readout by APDs

Several layers are superimposed which allow to measure dE/dx and help to identify particles.

The granularity needs to be determined.
It depends on:

- the time resolution
- the rate
- matching with the drift chamber.



The scintillators must also have the ability to detect particles from alphas to protons. A multi-layer scintillator may be needed.

Simulation software

or trying to understand what to expect from ALERT

Software status

Developed in pure Geant4, available in a Git repository.

Three post-docs implied in its implementation:
- everything about scintillators is done at Argon
- everything about the drift chamber geometry, reconstruction algorithm and fitting algorithm is done at Orsay

Definition of the scintillators geometry has just started.

A reconstruction algorithm is nevertheless already available using a global helix fit for the drift chamber. A Kalman Filter will be used in the future.

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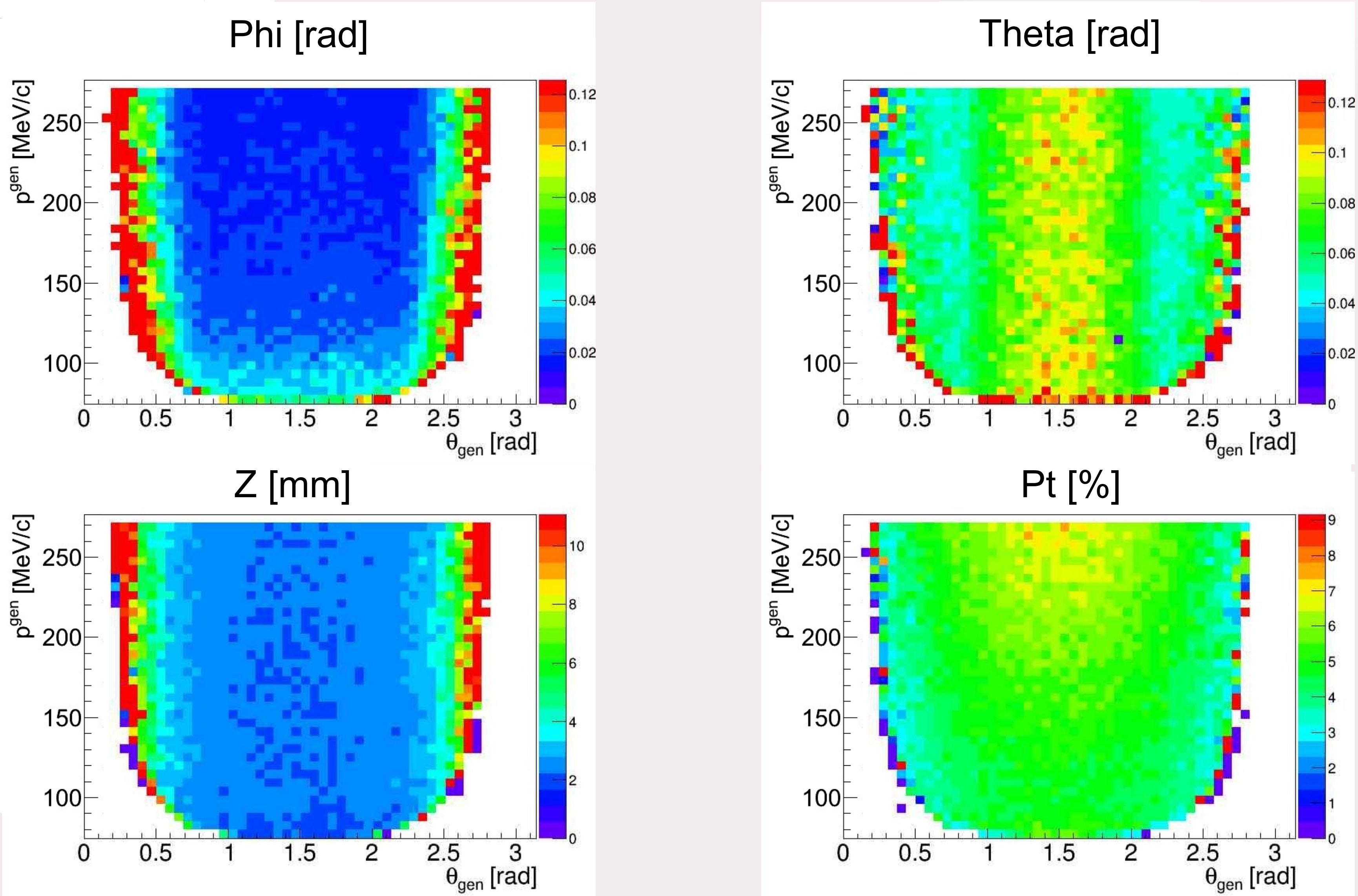
ORSAY

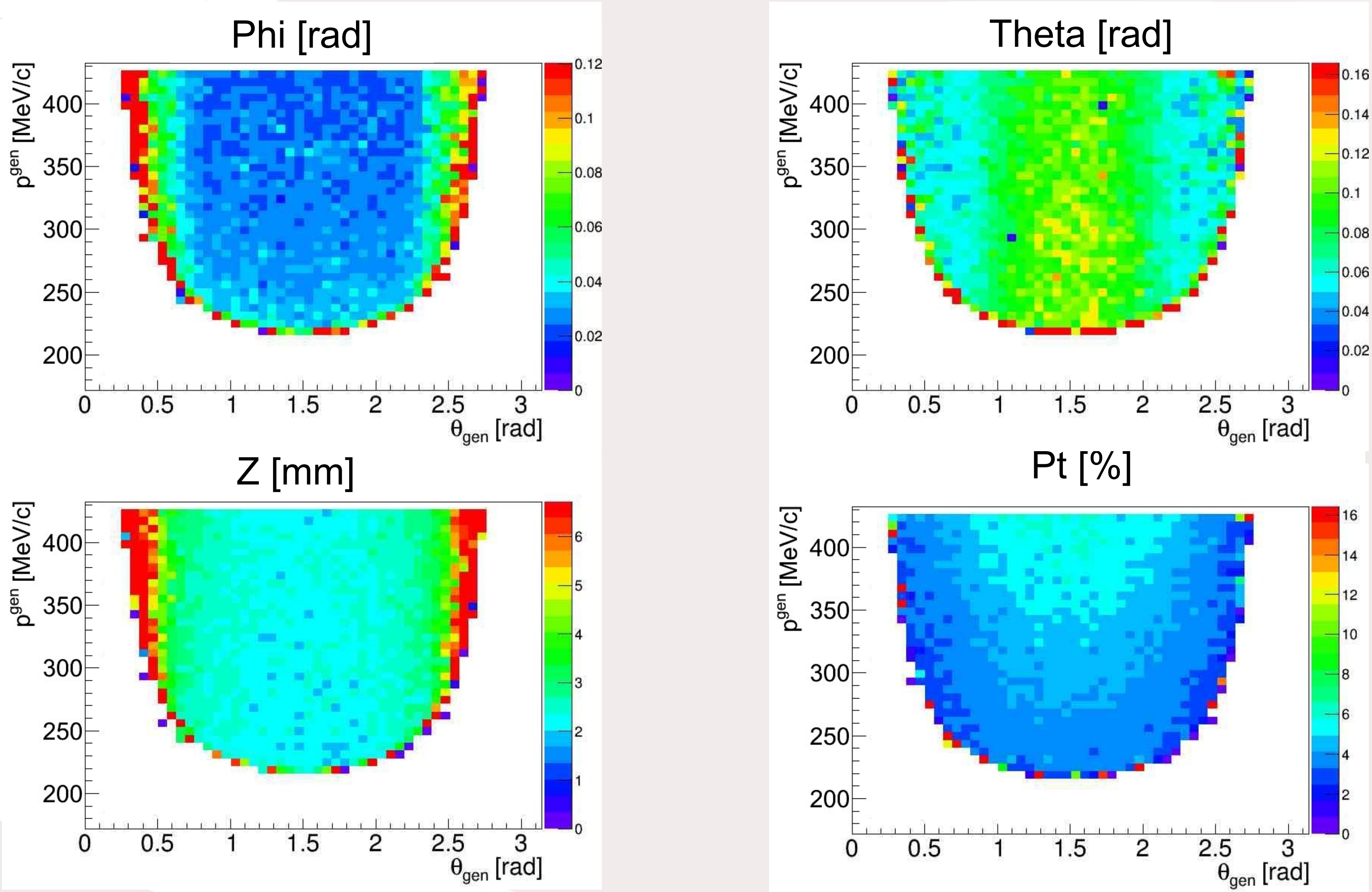
Simulated resolutions for protons

(based on a simplified simulation)



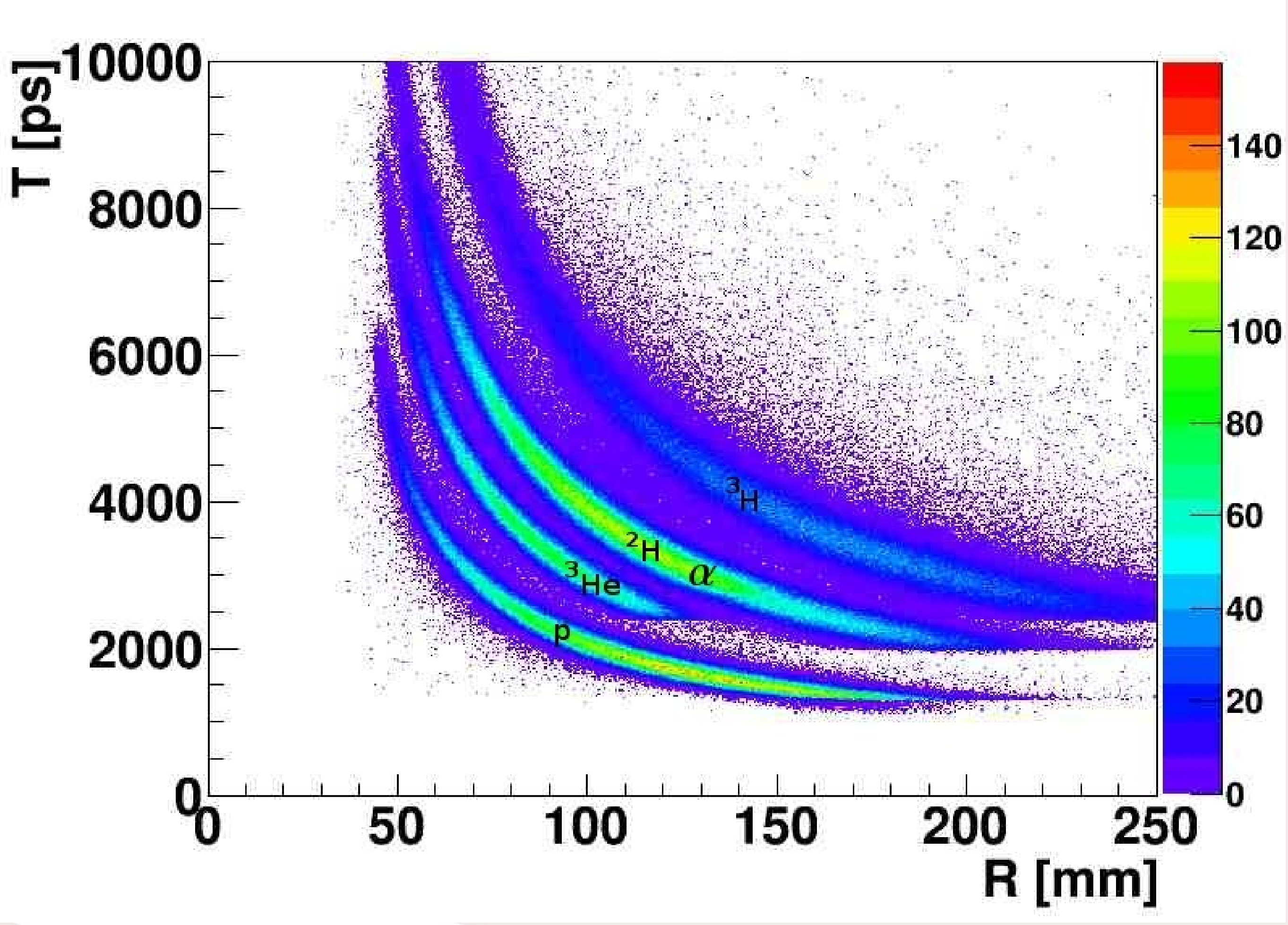
Simulated resolutions for alphas

(based on a simplified simulation)



Particle identification

Using the reconstructed radius in the wire chamber and the time of arrival in the scintillator, protons, helium 3 and hydrogen 3 can be separated.



Particle identification: results

In an experiment where ALL 5 species would be present.

With a 150 ps time resolution and a 10% energy resolution of the scintillator

99% of protons identified are protons
92% for helium 3
98% for hydrogen 3

85% for deuterium
88% for alphas

With a 200 ps time resolution and a 10% energy resolution of the scintillator

97% of protons identified are protons
89% for helium 3
97% for hydrogen 3

83% for deuterium
86% for alphas

Can be improved using the information carried by the energy deposition in the drift chamber and fine tuning the parameters.

FastMC available and being used by collaborators.

Hardware

or trying to understand how to build ALERT

Electronics

Main requirements:
- interfaces with CLAS12 readout structure
- has a 10 ns or less time resolution
- stands a few MHz of particle flux
- can be included in the trigger
- can work in magnetic field or can be deported

Use existing electronics DREAM of the **CLAS12 Micromegas developed at Irfu:**
- only a few updates necessary
- fulfill all the requirements above
- will already be in place

Tests will be performed using a small drift chamber between January and March 2016.

Wires

In order to reduce the weight on the end plate and increase the acceptance, we want to use **carbon wires**.

Trying to mount them is the very first step to check the possibility to use carbon wires.

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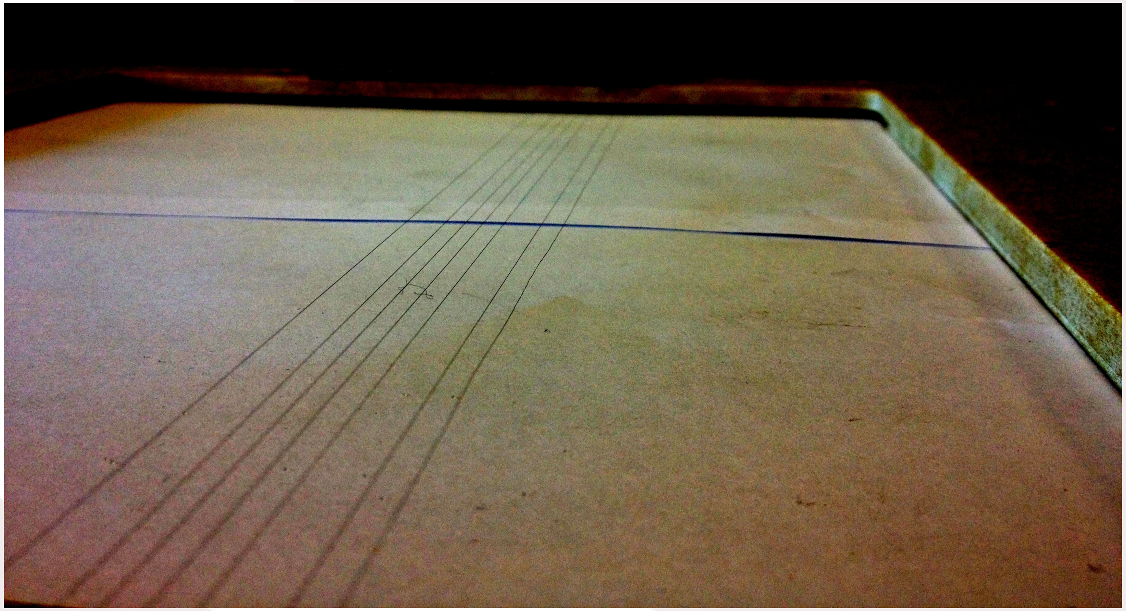
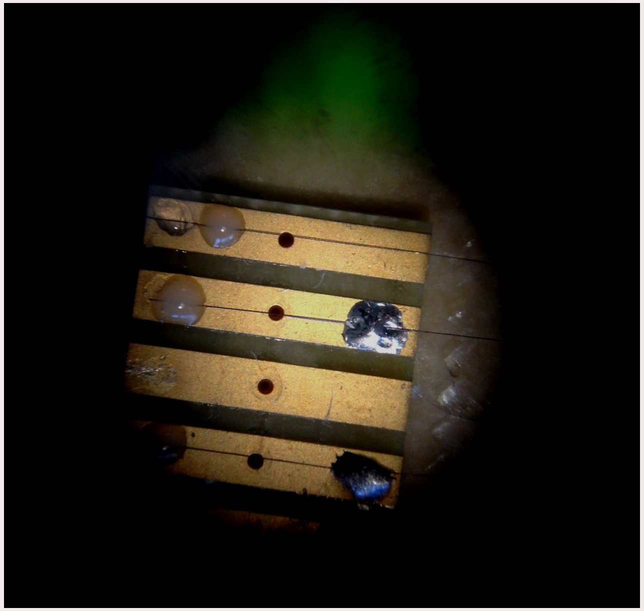
Trying to mount them is the very first step to check the possibility to use carbon wires.

M. Imre and A. Maroni were able to stretch 34 microns diameter carbon wires over 300 mm.





Propagation speed in carbon wires

Setup a small test bench with E. Rauly to evaluate the propagation speed in carbon wires as it could be a complication if it is too low.

After calibration the propagation speed was measured to be **6.6 ns/m.**

For comparison for a coaxial cable, the speed is 5 ns/m.

For our detector, it means the maximum propagation time is 2 ns, that can be added to uncertainty on the position measurement (10 ns) BUT with some work can also probably be reduced once the position along the wire is known. **So it should not be an issue.**

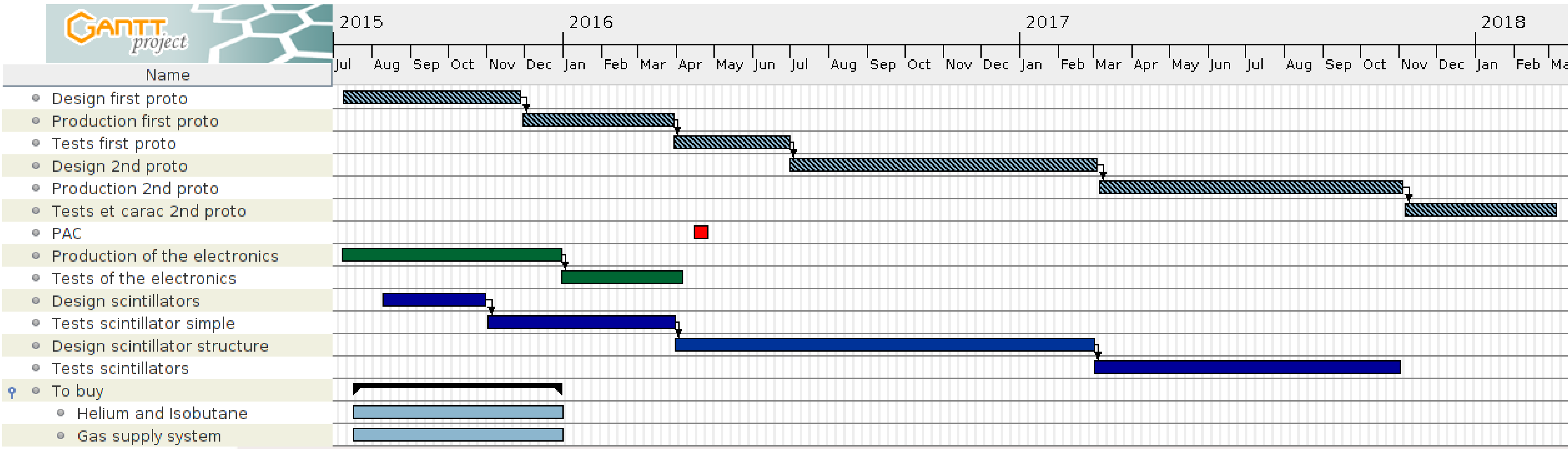
Schedule

or trying to understand when to build ALERT

Schedule

Project granted by P2IO, which will be enough to support the R&D.

Schedule for our R&D:



With the participation of: David Attié (Irfu), Laurent Audouin (IPNO), Pascal Baron (Irfu), Julien Bettane (IPNO), Gabriel Charles (Irfu), Raphaël Dupré (IPNO), Bernard Genolini (IPNO), Michel Guidal (IPNO), Irakli Mandjavidze (Irfu)

■ Submission of a proposal to Jefferson laboratory to obtain beam time for at least three experiments that would use ALERT.

Conclusion

The preliminary design for A Low Energy Recoil Tracker (ALERT) has been done

Simulation shows the resolutions for particles with a mass between proton and alpha

ALERT can separate protons, hydrogen 3, helium 3, helium 4 and deuterium

A Fast Monte Carlo implementing the resolutions, acceptance and soon the identification efficiency is available.

The founding provided by P2IO will permit

- to perform the first tests using carbon wires as well as produce a large prototype
- to optimize existing electronics to a wire chamber
- to build a second drift chamber, hopefully using 100% of carbon wires

This research will also benefit to experiments measuring low energy heavy nuclei.

Scope of use

The main idea is to develop a detector that could be used for several experiments in Hall B at JLab:

- BoNuS ⇨ need to detect and trigger on low energy protons but not on electrons
- Tagged EMC ⇨ need to detect and distinguish ^{3}H and He^3
- DVCS on He4 ⇨ need to detect alphas

Specifications are mainly constrained by BoNuS12 experiment:

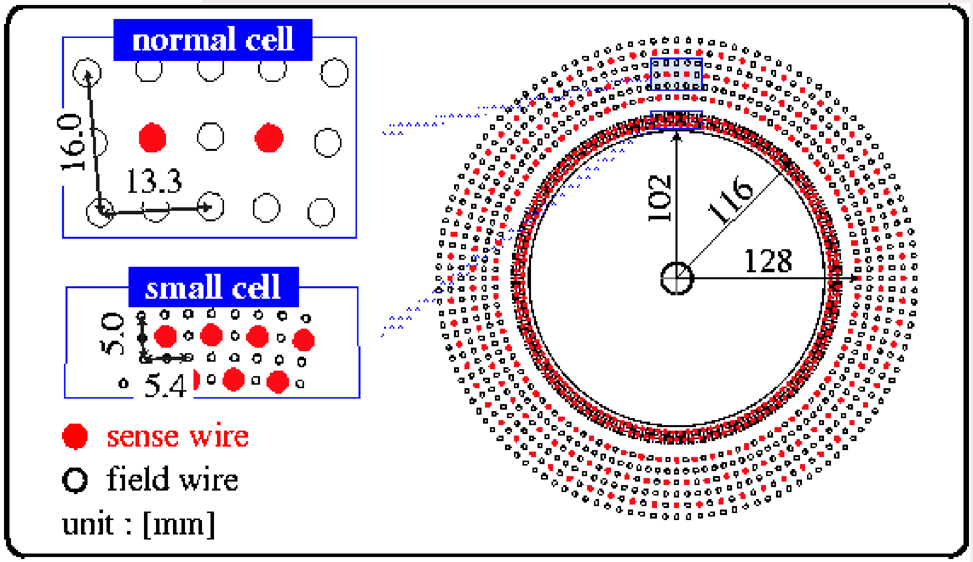
- 10% momentum resolution at 100 MeV/c
- Minimum energy detection must be around 60-70 MeV/c
- 3 mm resolution on the Z vertex position
- Possibility to trigger only on protons and not on electrons, this last point is not in the requirements but should allow to acquire more data
- Separate protons, deuterium, tritium, alpha, helium 3
- Forward end plate should be as thin as possible

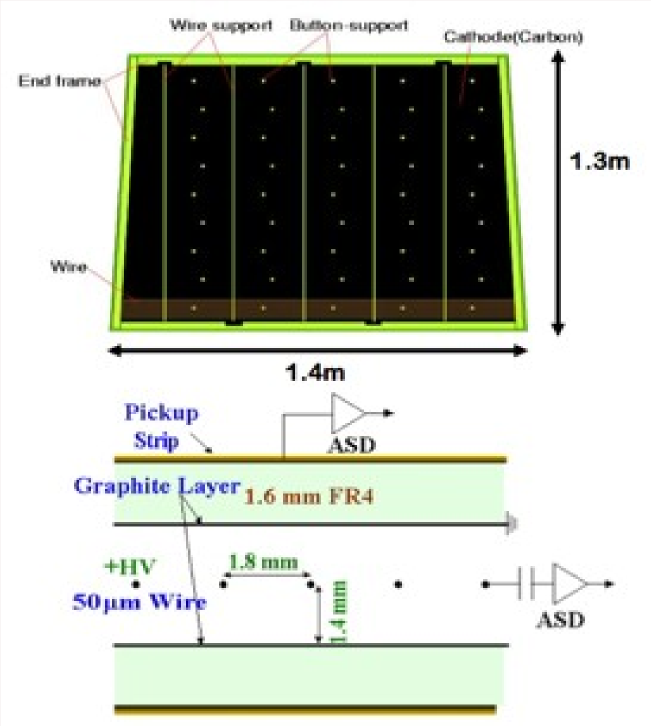
What kind of wire chamber can be built?

- Dimuon arm of ALICE built and designed at Orsay

- ATLAS small wheel: 2 mm gap over about 1.3 m

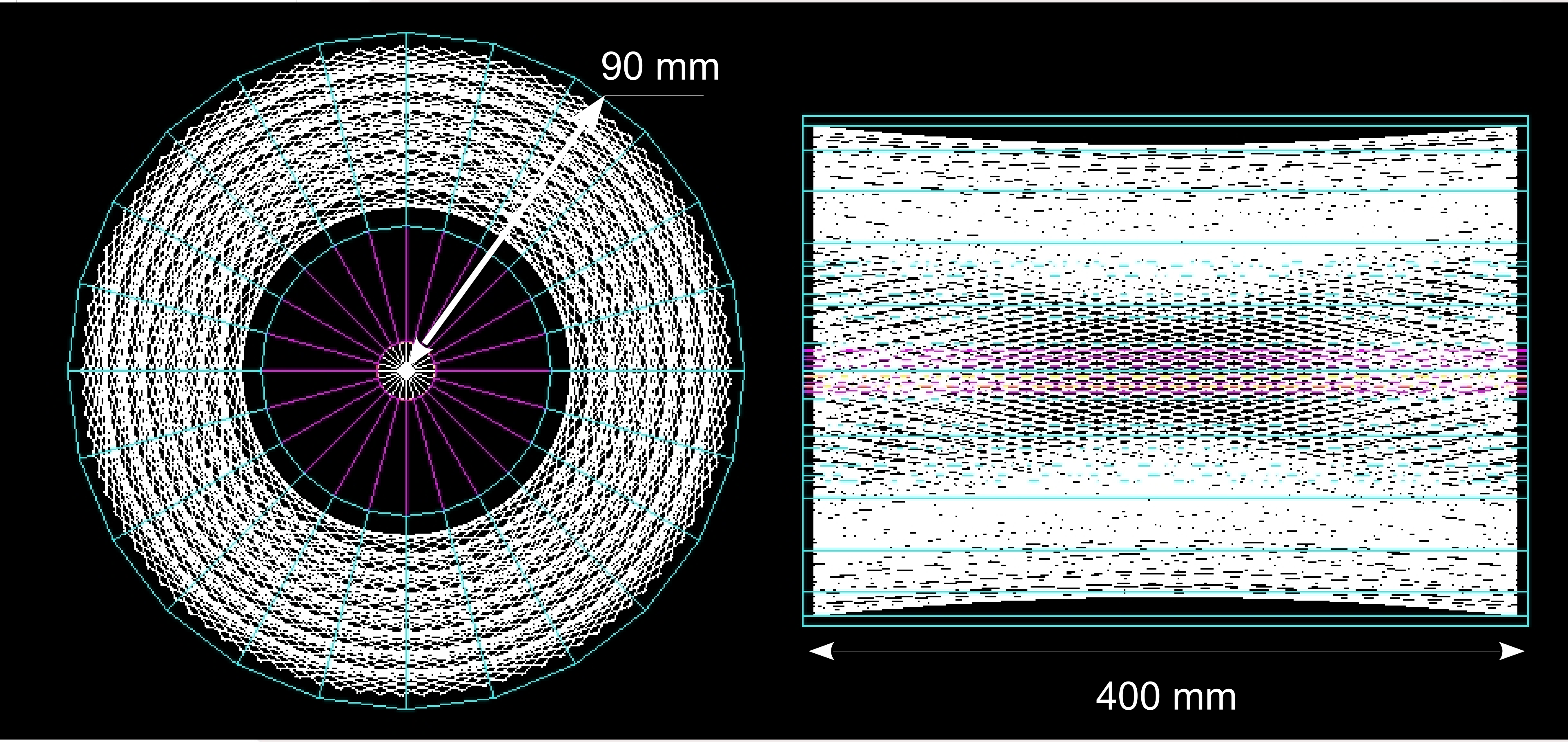
- Belle II (KEK-Japan) small-cell drift chamber:





- Ingineers and technicians at Orsay are building by hands small “paddles” where the gap between wires is 1 mm.

Detector simulation in Geant4

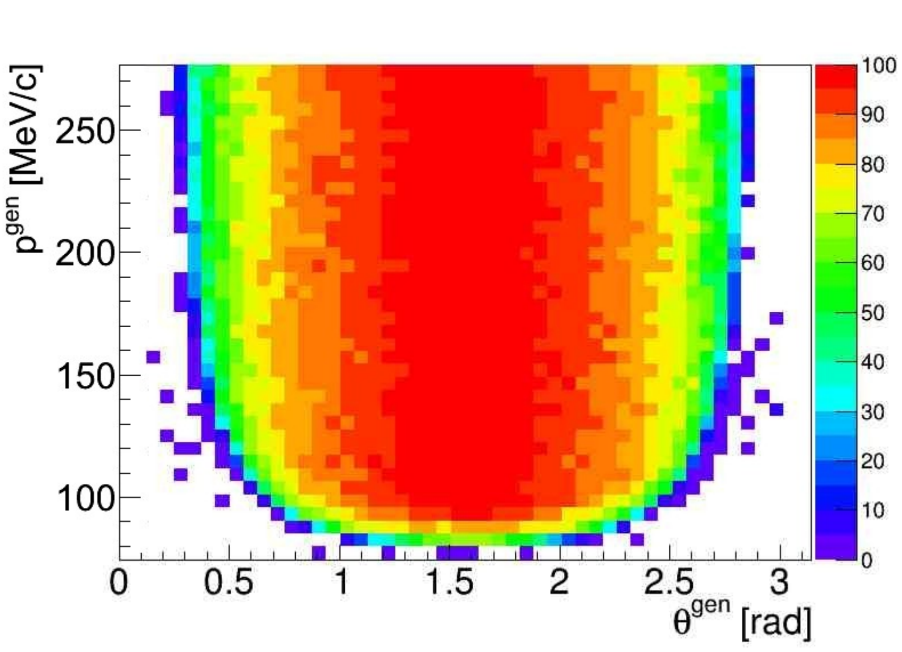


Geant4 is used to simulate particle path and energy loss of particles in the target, clear space and detectors.

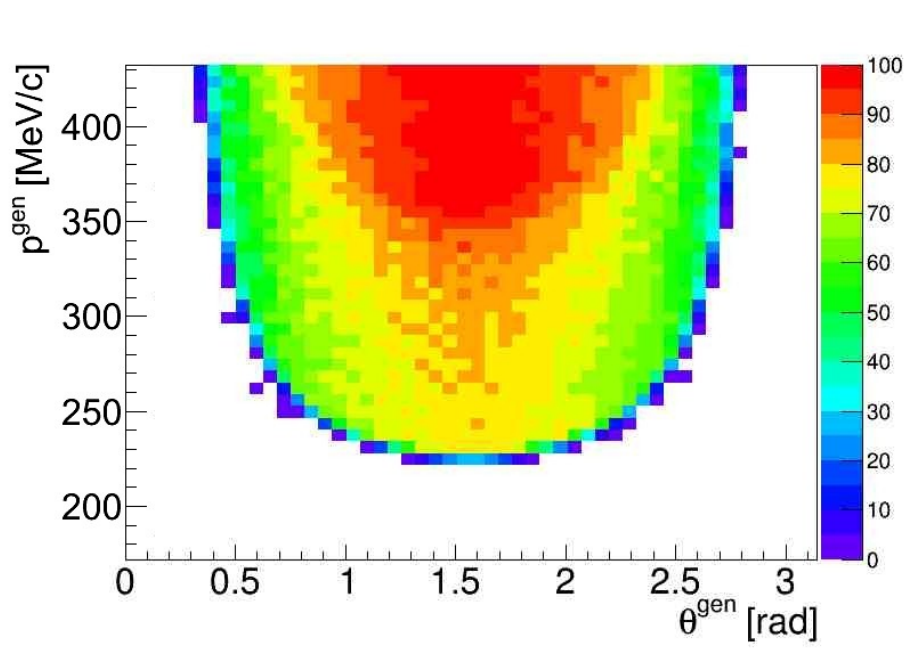
There are 6 layers of wires alternatively having a negative or positive stereo angle of 10°. The wires are spaced by 3 mm.

Acceptance

Acceptance condition: the particle reaches the scintillator



Protons (integrated over z)

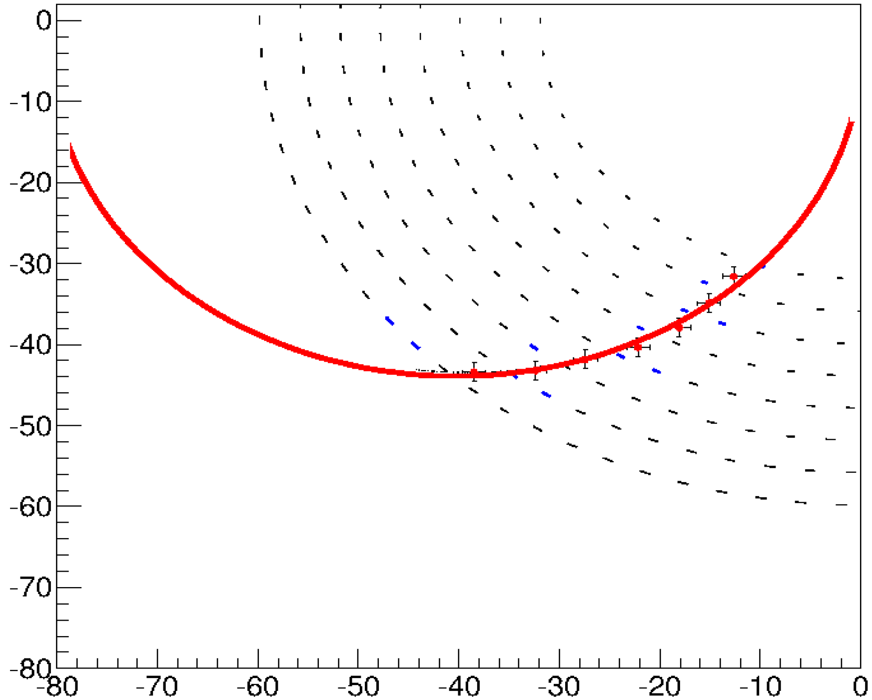


Alphas (integrated over z)

Reconstruction (wire chamber mode)

Consider two consecutive layers, define their "intersection" as the position of the particle
Repeat for all layers
Add a point at the center of the detector (origin of the particle)
Fit the points with a circle

Example of a fit by a circle

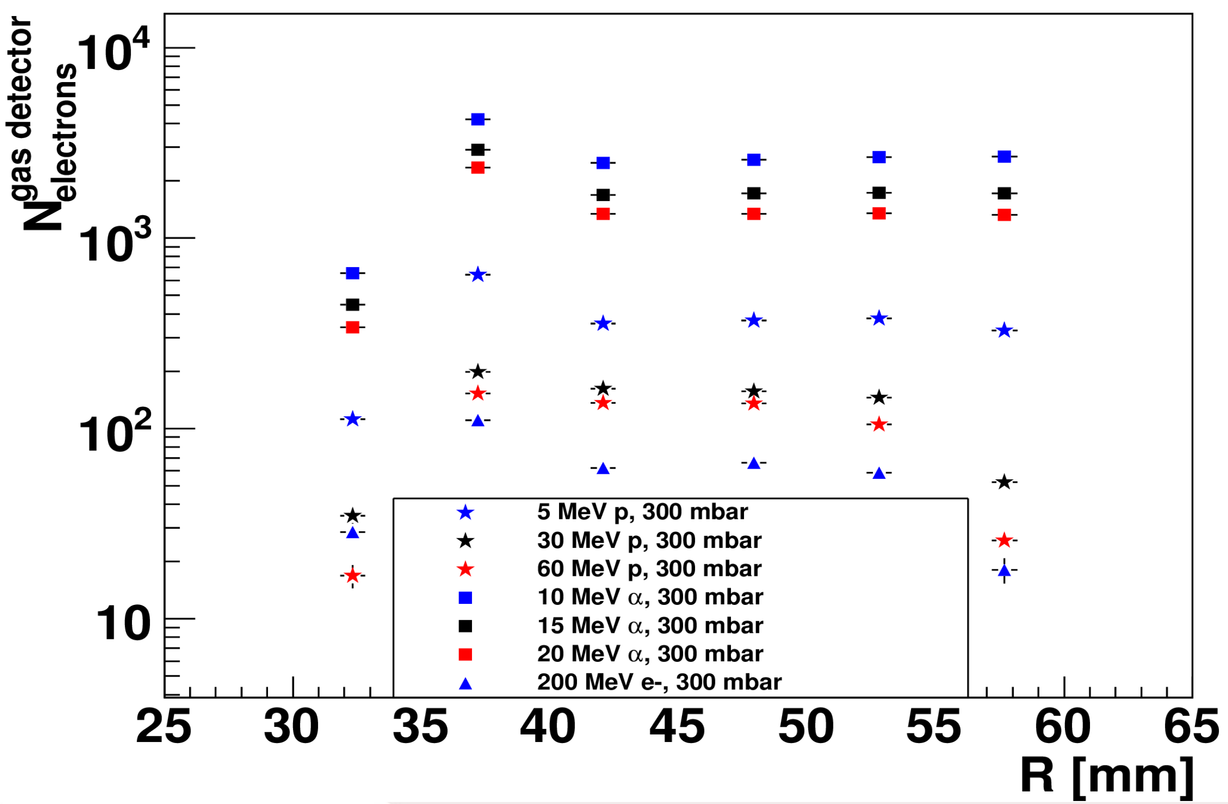


Section view of the wire chamber

- blue wires have seen a signal
- red points are obtained from hit wires
- red line is the circle fit

How to trigger only on protons?

Initial idea: work at lower pressure to reduce energy deposition of electrons

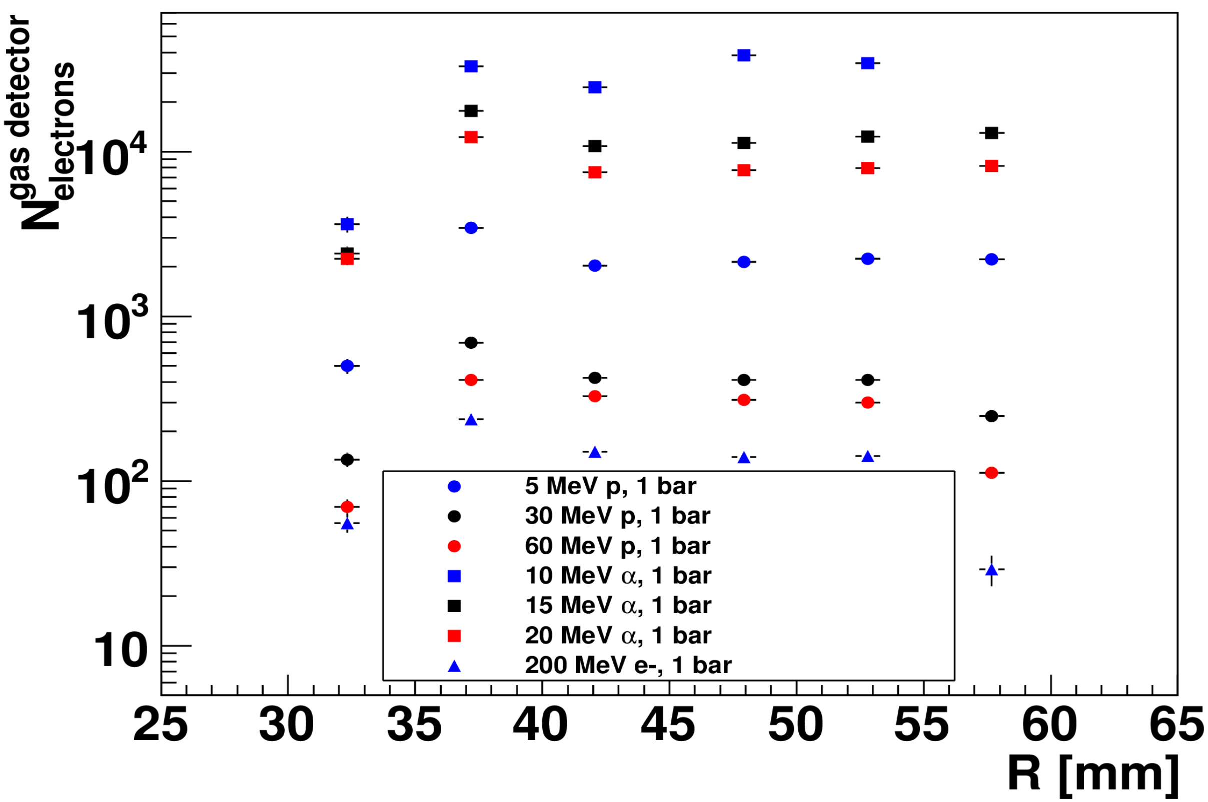


On the side of the theory: electrons deposit energy via Bremsstrahlung (~Z²/A) while other particles interact via ionisation (~Z/A), so a light gas mixture is preferable. But for the moment nothing about the pressure.

The best gas mixture/pressure couple must be determined taking into account three parameters: **drift speed**, **gas gain** and **distinction between protons and electrons**.

How to trigger only on protons?

Initial: work at lower pressure to reduce energy deposition of electrons



On the side of the theory: electrons deposit energy via Bremsstrahlung (~Z²/A) while other particles interact via ionisation (~Z/A), so a light gas mixture is preferable.

All the results showed after are for iC_4H_{10} at 1 bar.

The best gas mixture/pressure couple must be determined taking into account three parameters: **drift speed**, **gas gain** and **distinction between protons and electrons**.

Digitization

The root output file of Geant4 contains the event number, the hit number and for each hit:

- the energy deposited
- the particle id
- the hit position (x,y,z)
- the hit time (relatively to its creation)
- the vertex position of the particle
- the vertex momentum direction of the particle
- the vertex energy of the particle

Using only the hit position the closest wire is found and identified as a wire with signal. A time is associated to it, it is the minimum time of all hit for this wire. Thus a new root file is created containing for each hit all of the above plus:

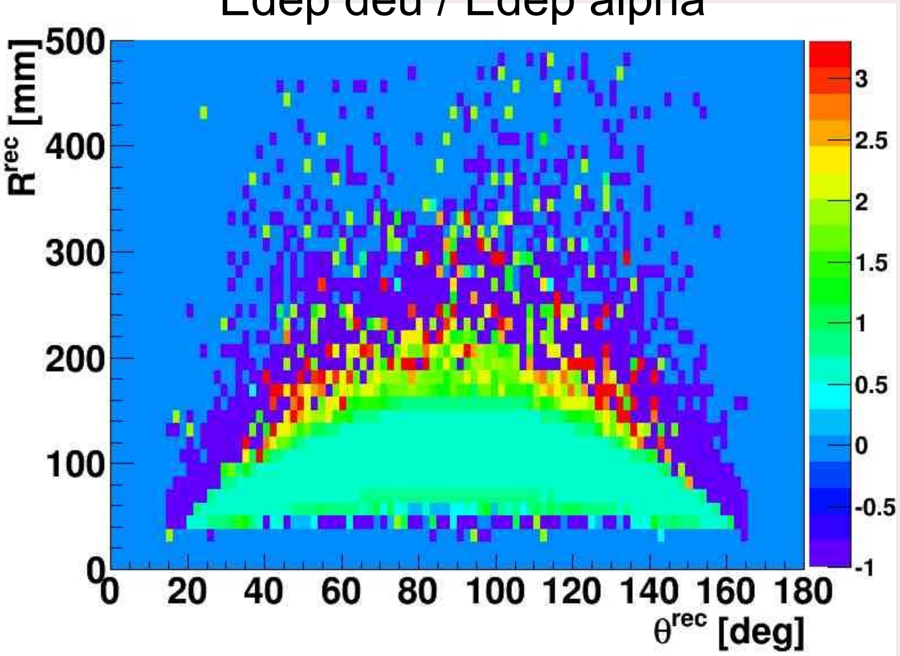
- a minimum time for each hit
- the wire layer
- the wire angle
- the drift distance infered from drift speed and drift time (not used for the moment)

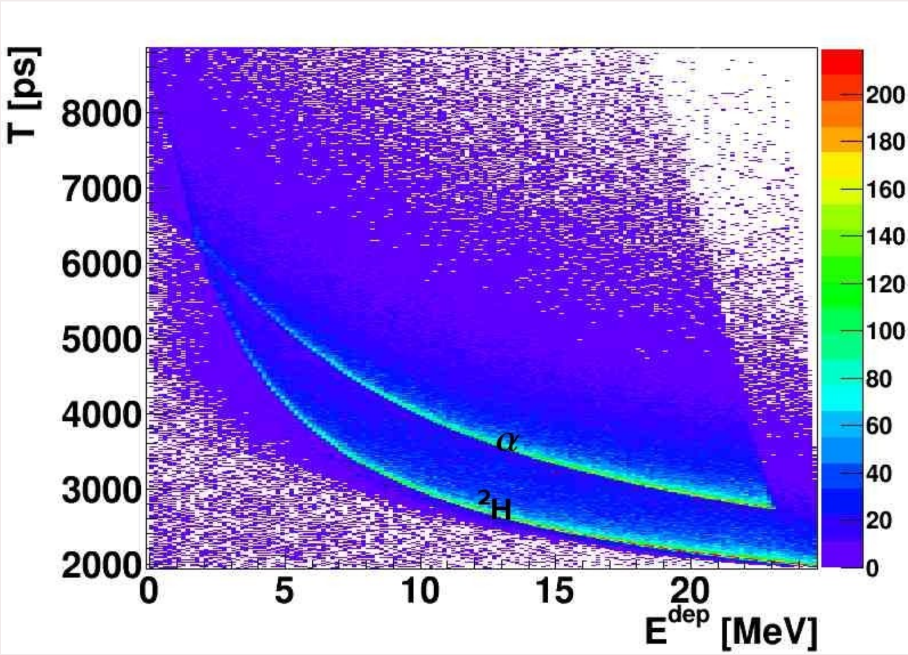
Particle identification: method (1/2)

To distinguish alphas from hydrogen 2, two methods are used:

Edep(R, Theta) if R<Rth
T(Edep) if R>Rth

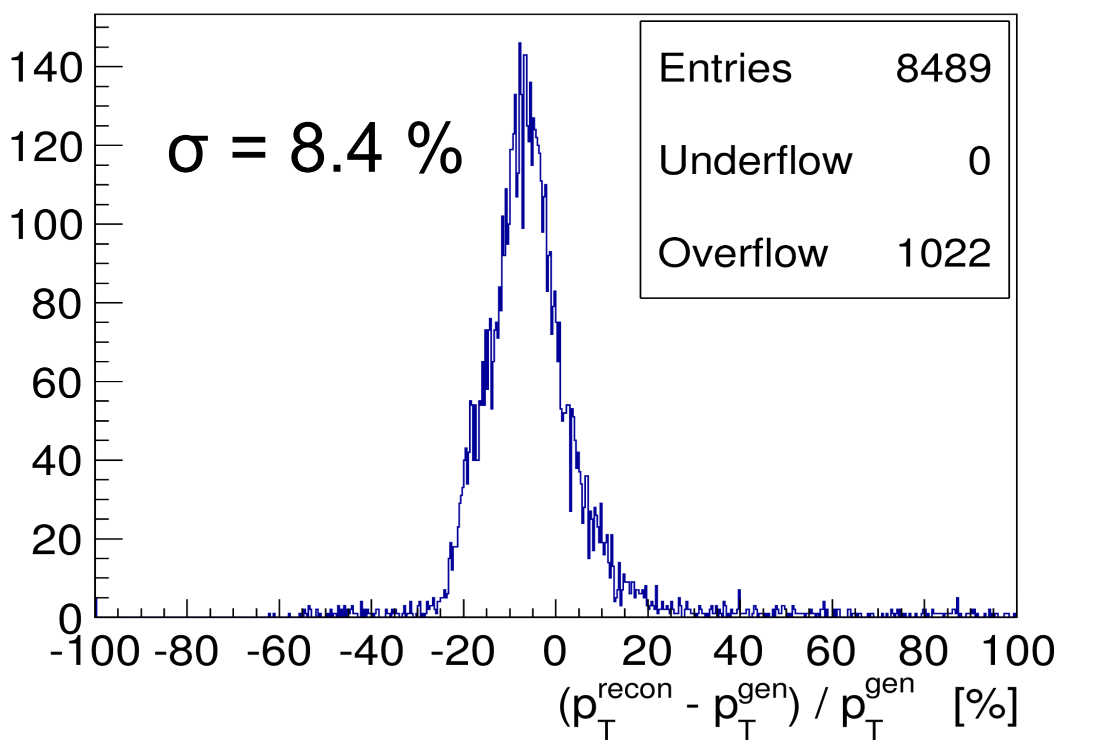
Edep deu / Edep alpha





Transverse momentum resolution

6 MeV (about 100 MeV/c) protons are emitted in all direction from all the target, no cut is applied, nor energy loss correction. Only the hit wire information is used.



The fitting algorithm using the time information is quiet complicated and will depend on the field lines. The resolution should be improved when the algorihm will be ready. To evaluate the Z resolution a fastMC has been used.

Fast reconstruction algorithm

Using Geant4 root file, particle position is determined at each radius of a wire layer. The position is smeared according to the expected resolutions:

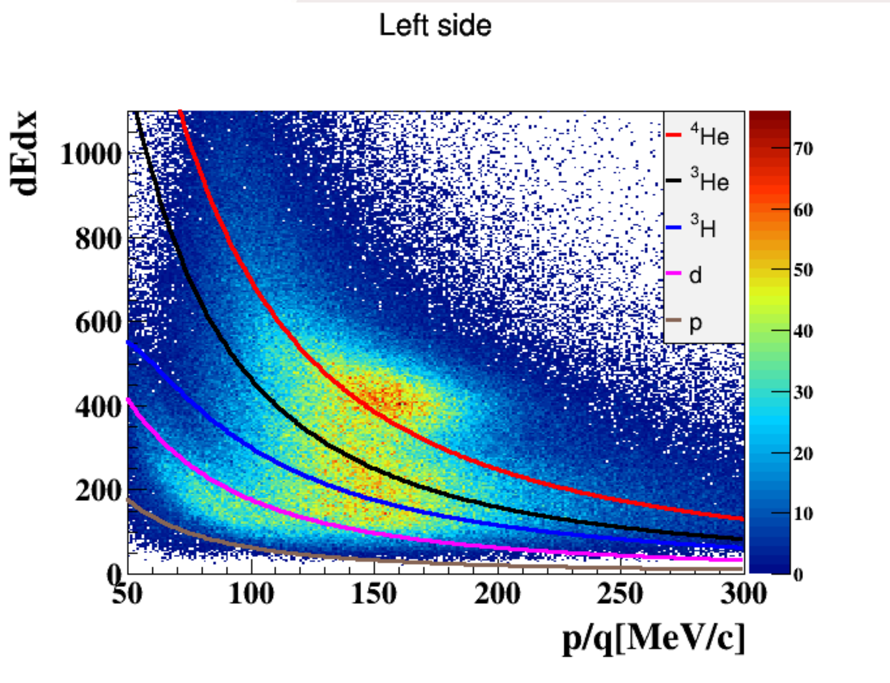
$\sigma_r = \Delta R / \sqrt{12}$ $\sigma_{r\varphi} = v_{drift} * \sigma_t$ $\sigma_Z = \sigma_{r\varphi} / \sin(\psi_S)$

ΔR: distance between the wire
v_{drift}: drift speed
Ψ_S: stereo angle

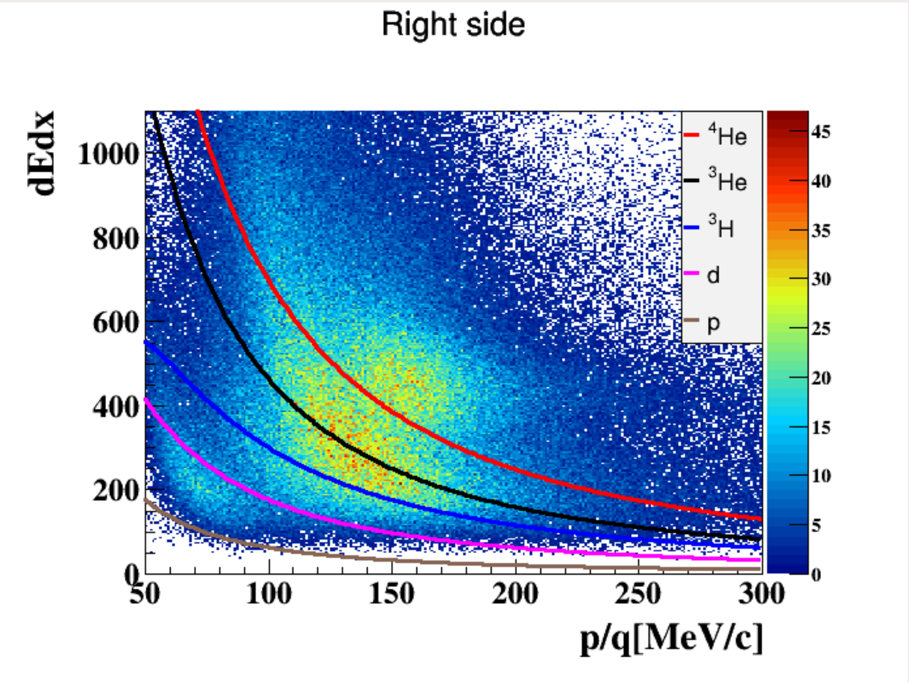
σ_r is over estimated as it should also be $v_{drift} * \sigma_t$
v_{drift} is taken equal to 5 cm/μs which is the saturation speed for gases
σ_t is taken equal to 3 ns but we expect it to be 1 ns, nevertheless as it changes the spatial resolution and that magnetic is, for now, unknown it is a safer value

The track is then fitted using a global helix fit (work in progress to use a Kalman Filter).

Pid in BoNuS



Left side
dEdx
1000
800
600
400
200
0
50
100
150
200
250
300
p/q[MeV/c]
4He
3He
3H
d
p
70
60
50
40
30
20
10
0



Right side
dEdx
1000
800
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400
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0
50
100
150
200
250
300
p/q[MeV/c]
4He
3He
3H
d
p
45
40
35
30
25
20
15
10
5
0