A Low Energy Recoil Tracker (ALERT)

ie a presentation about detector physics

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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
- **Your experiment!**

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
- Your specifications

Which detector?

After a comparison between existing detectors a **drift chamber** for tracking has been chosen.

It has the following advantages:

- Low material
- The drift time can be short if wires are not too far and gas well chosen
- Can be included in the trigger with a short drift time

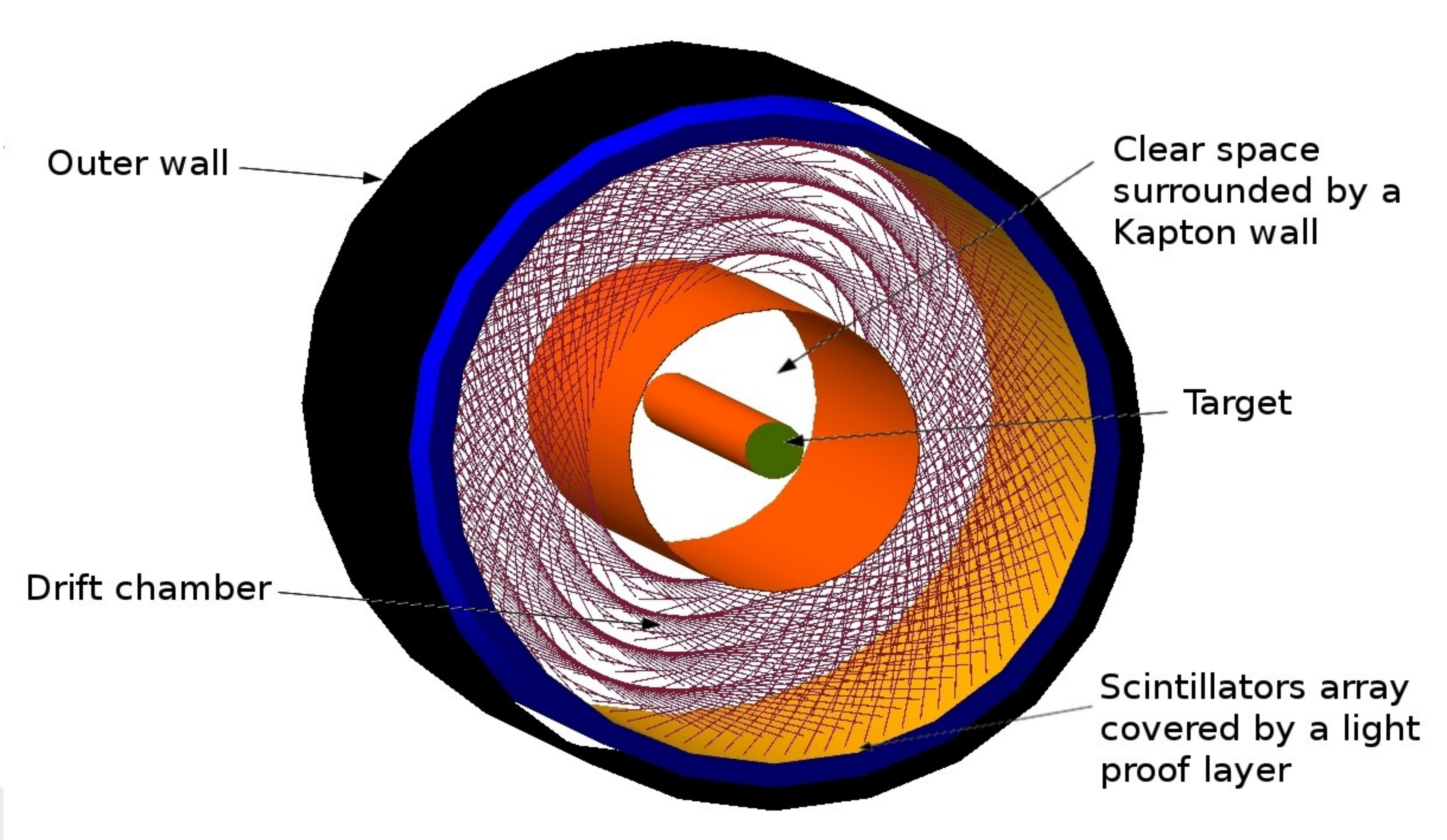
The drift chamber is completed by **scintillators** for particle identification.

From what has been read in the sources, in our case the main challenges are:

- Magnetic field, hard to get good spatial and time resolutions
- Construction, sensitivity to broken wires
- Discharges

ALERT layout

All elements are about 300 mm long and place in a 5 T longitudinal magnetic field

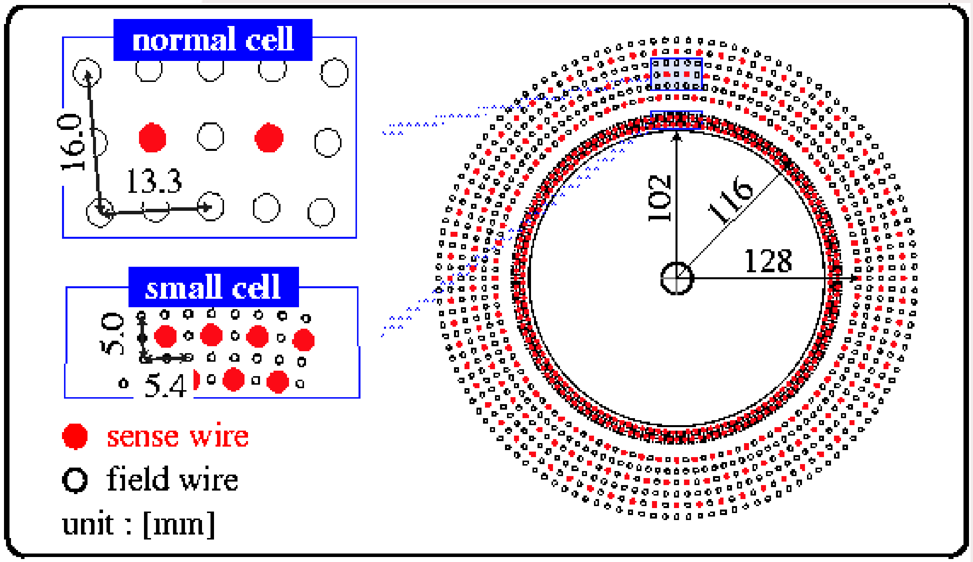


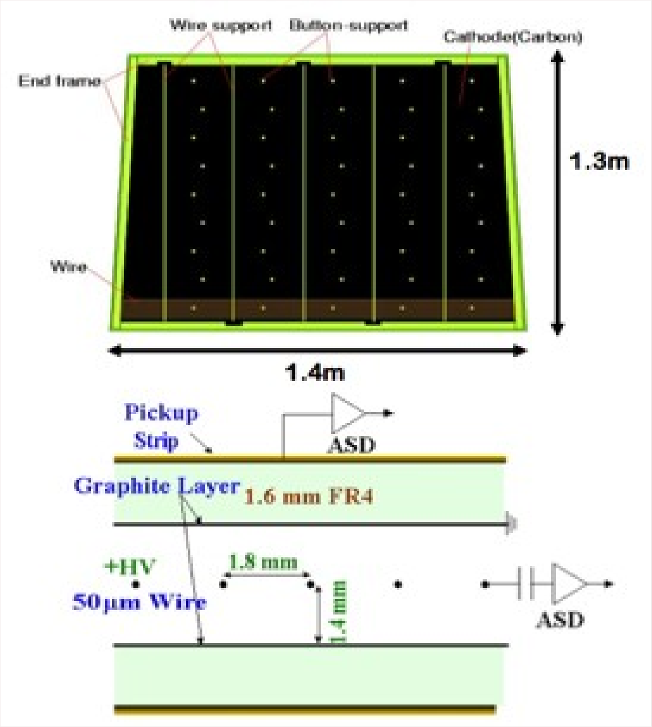
What kind of wire chamber can be built?

- 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:



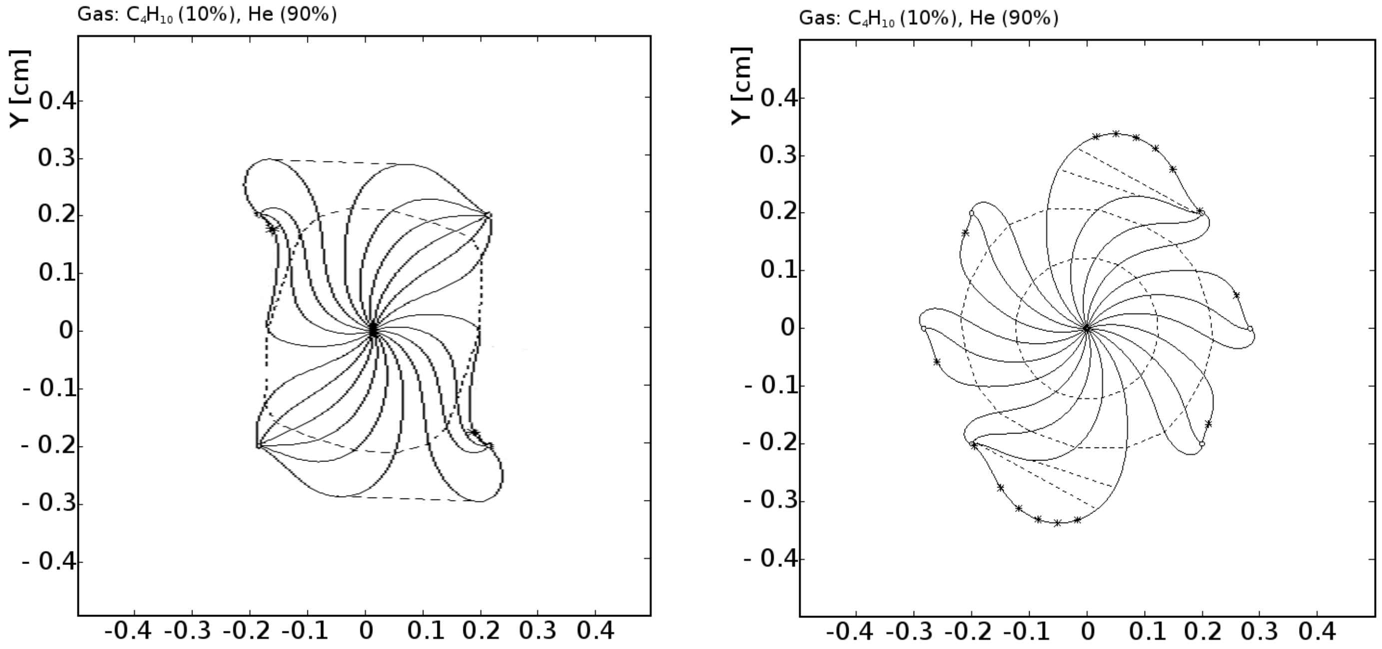


- Ingineers and technicians at Orsay are building by hands small “paddles” where the gap between wires is 1 mm.

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)

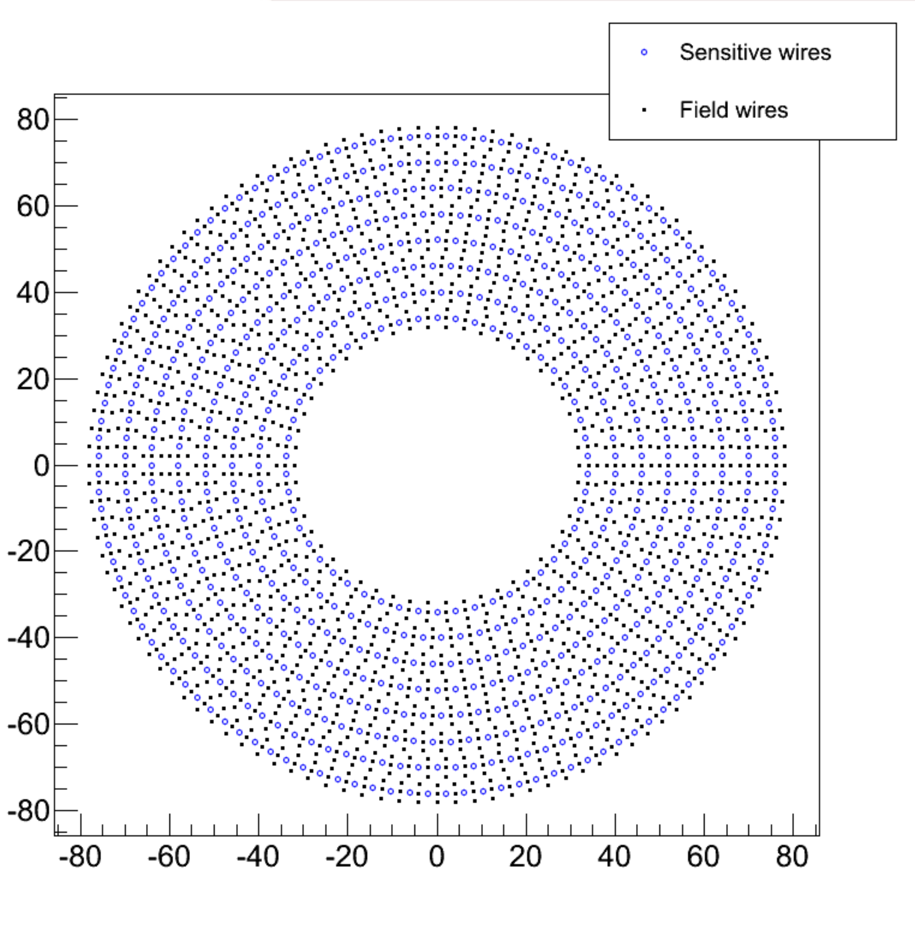


GARFIELD simulations of the electron drift lines, G. Dodge

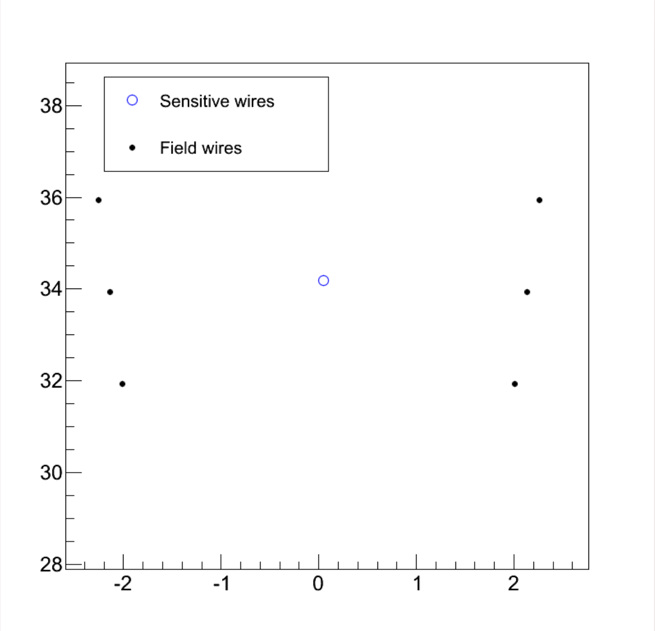
Maximum drift time estimated to be 200 ns

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 200 kg. **Tests will be performed to use lighter wires.**

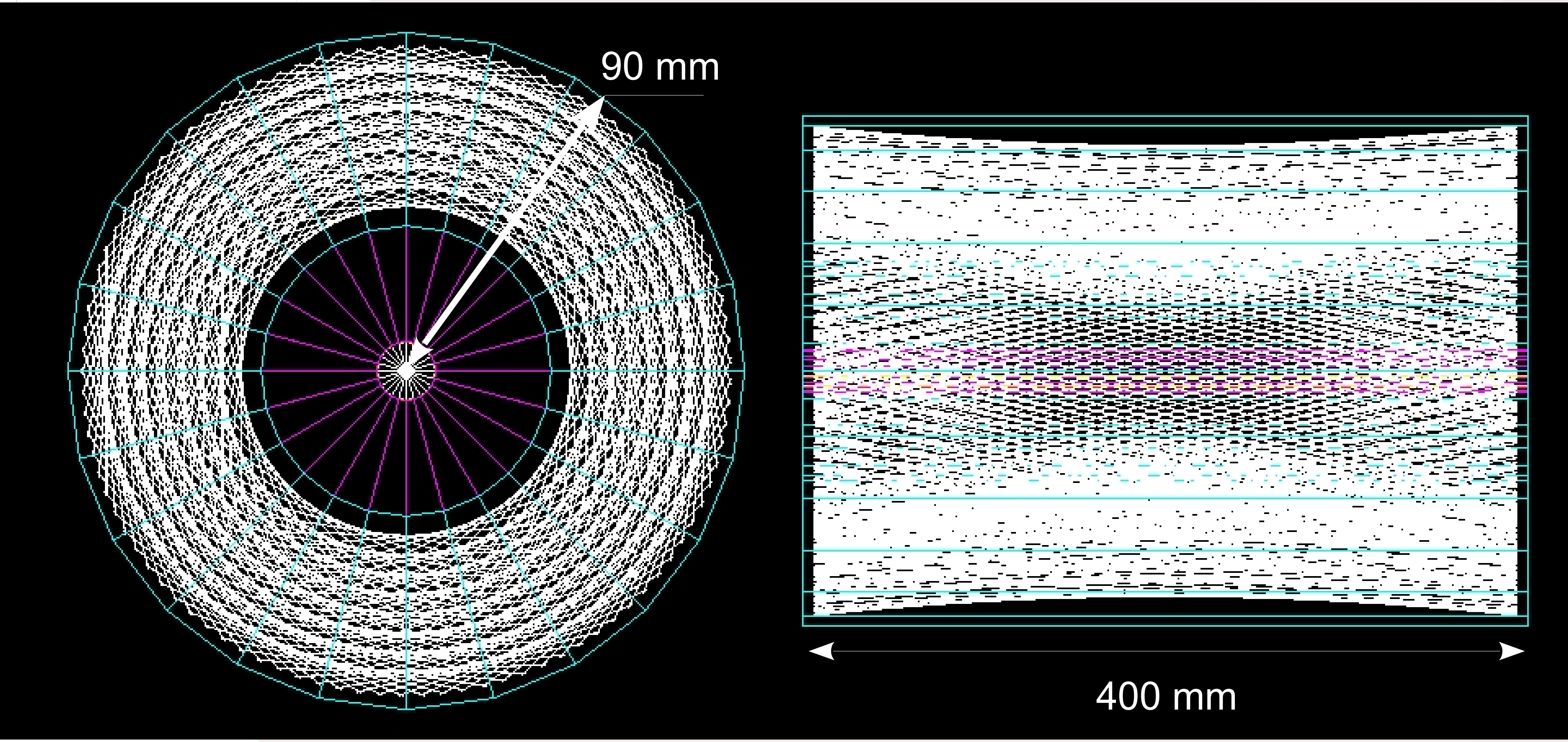
Scintillator layout

TBD …

Based on results from the simulation, we will determine the required granularity to match tracks from the drift chamber. The scintillators must also have the ability to detect particles from alphas to protons. A multi-layer scintillator may be needed.

Hardware → software

Detector simulation in Geant4

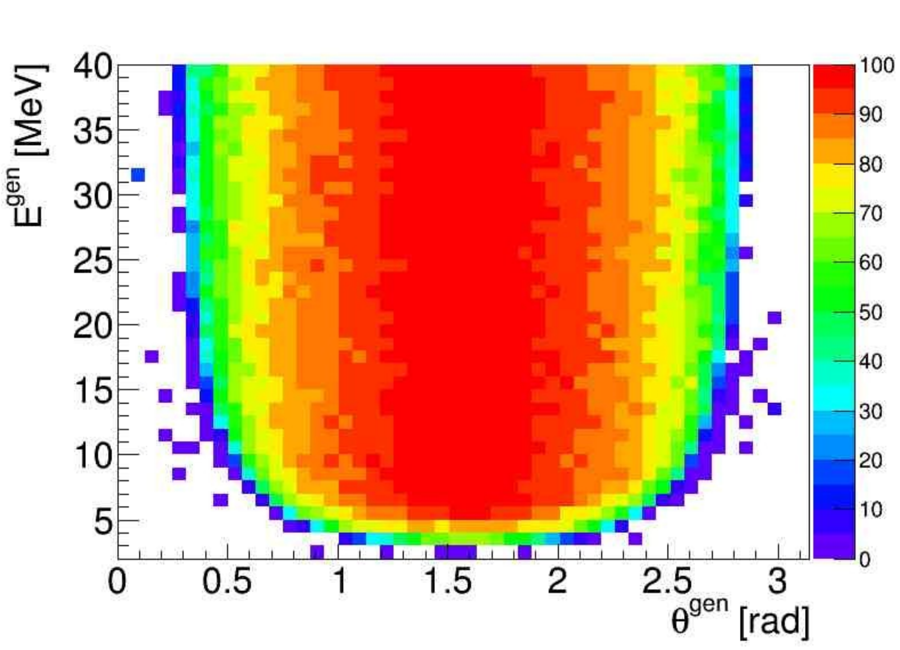


Geant4 is used to simulate particle path and energy loss of particles in the target, clear space and detectors.

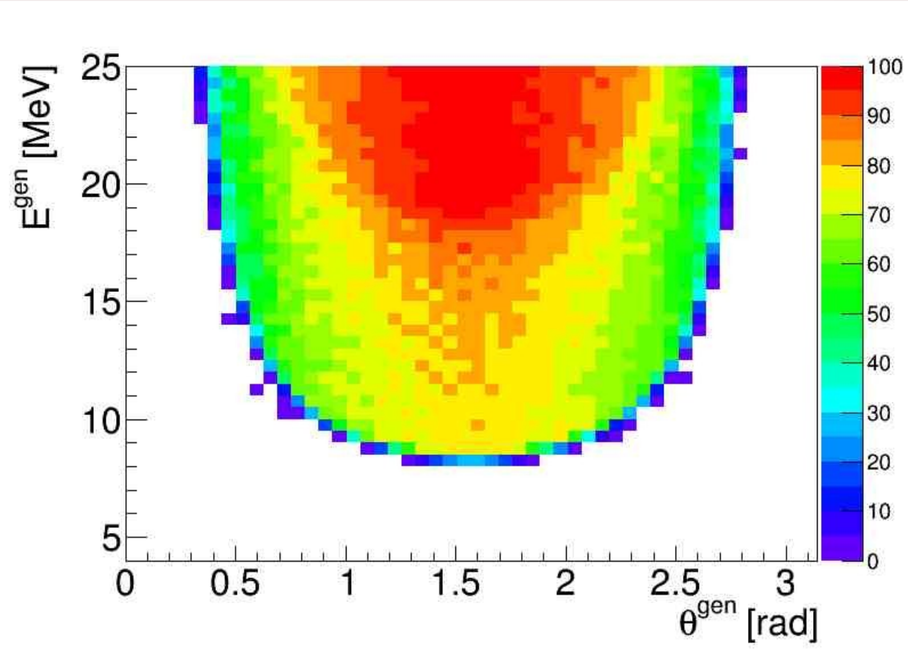
There are 6 layers of wires alternatively having a negative or positive stereo angle of 10°. The wires are spaced by 3 mm, thus the spatial resolution is lower and the acceptance a bit larger than with a 2 mm gap.

Acceptance

Acceptance condition: the particle reaches the scintillator



Protons (integrated over z)

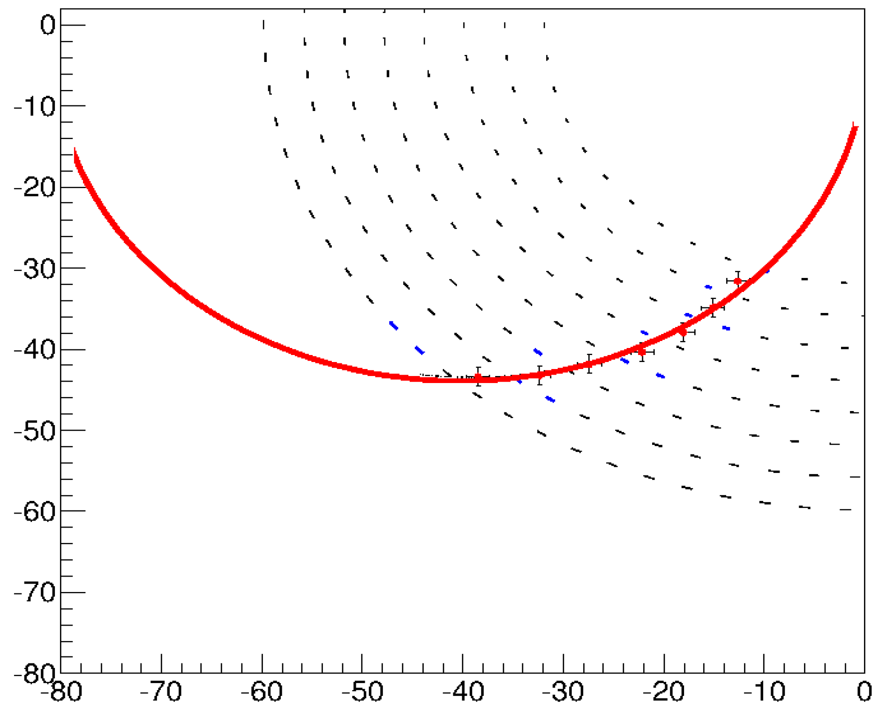


Alphas (integrated over z)

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

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:

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

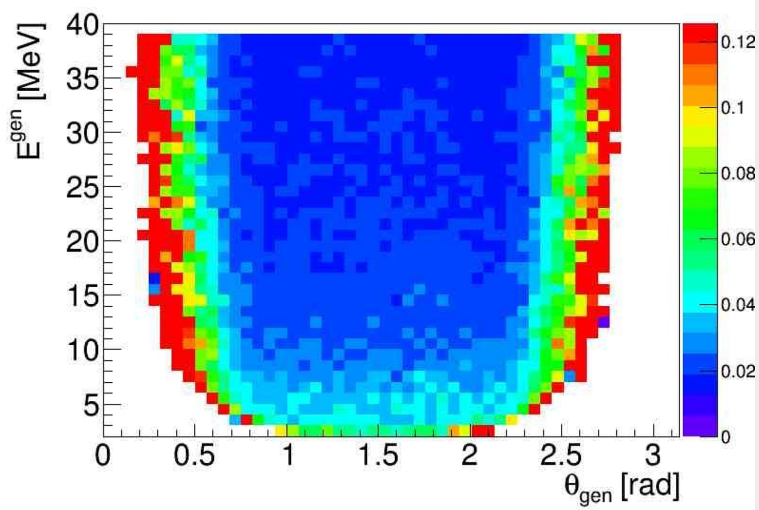
ΔR: distance between the wire
v_{drift}: drift speed
Ψ_S: stereo angle

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

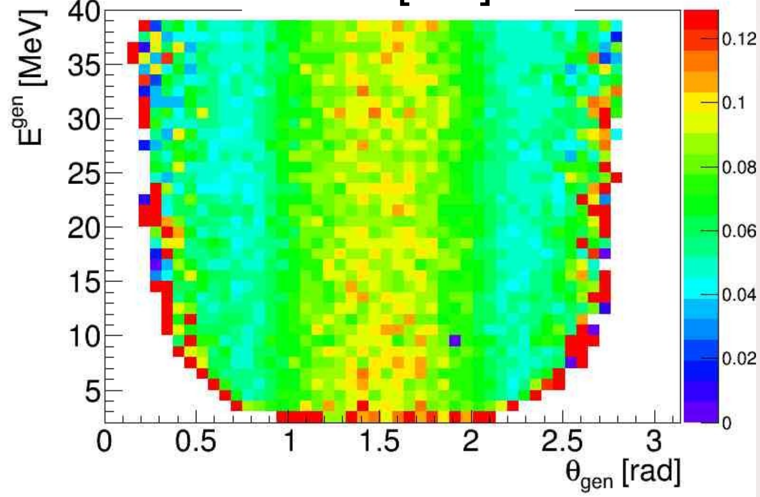
The track is then fitted using a global helix fit.

Resolutions for protons

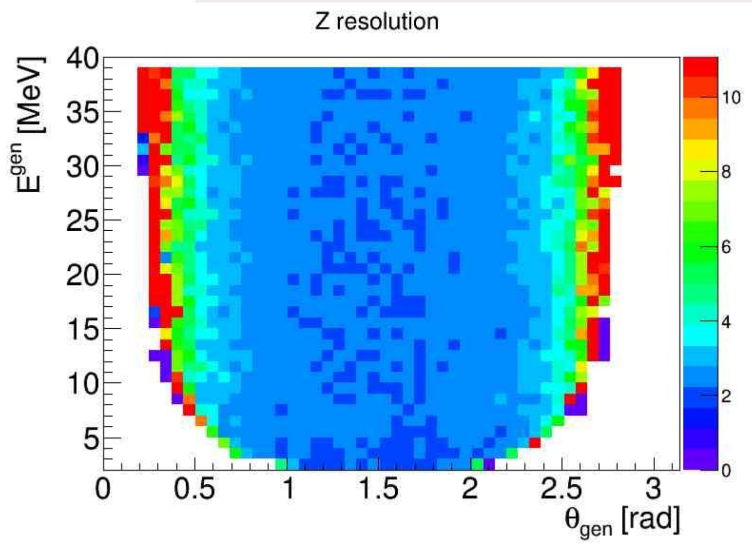
Phi [rad]



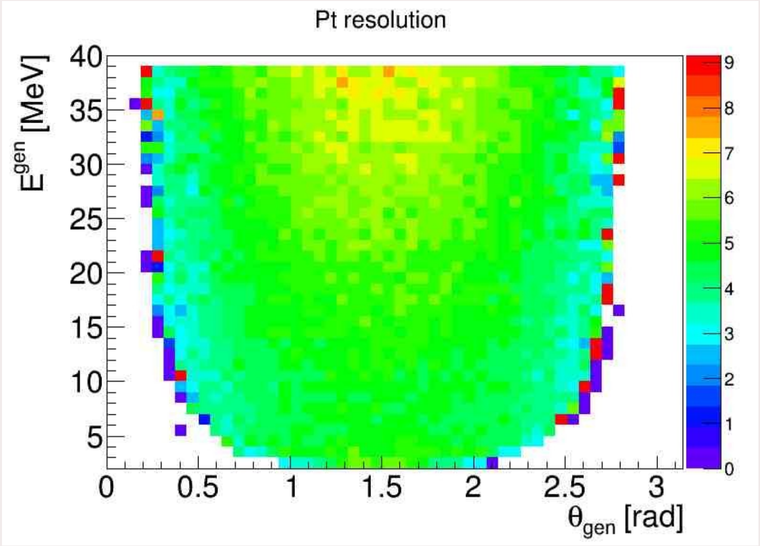
Theta [rad]



Z [mm]

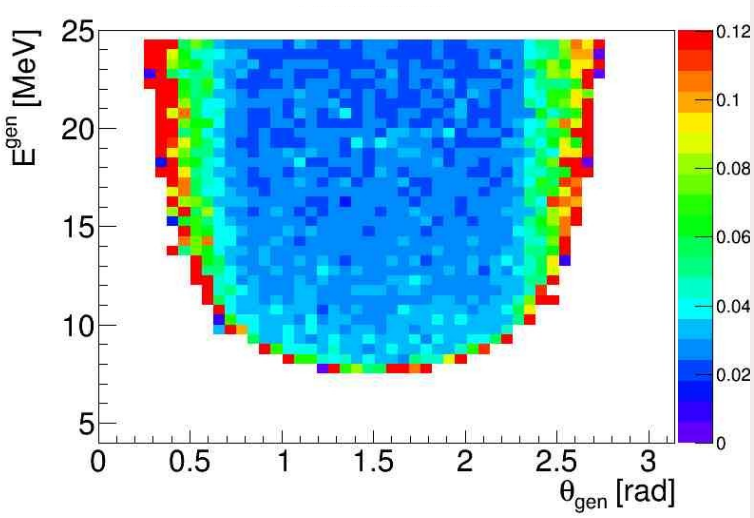


Pt [%]

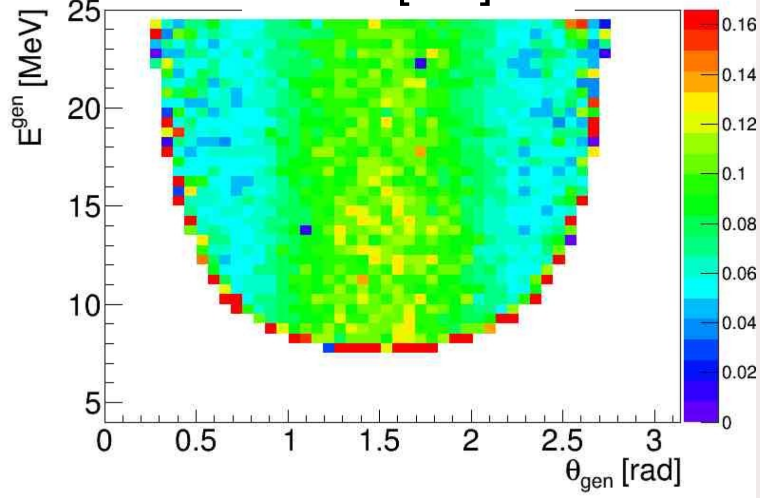


Resolutions for alphas

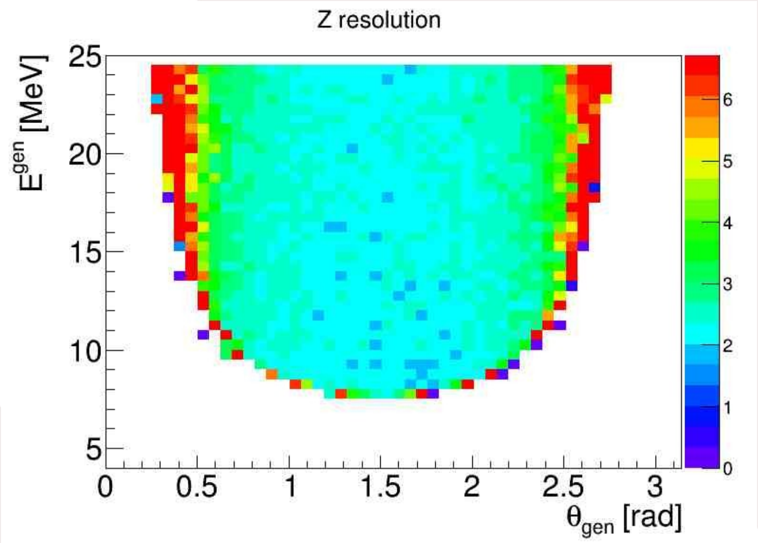
Phi [rad]



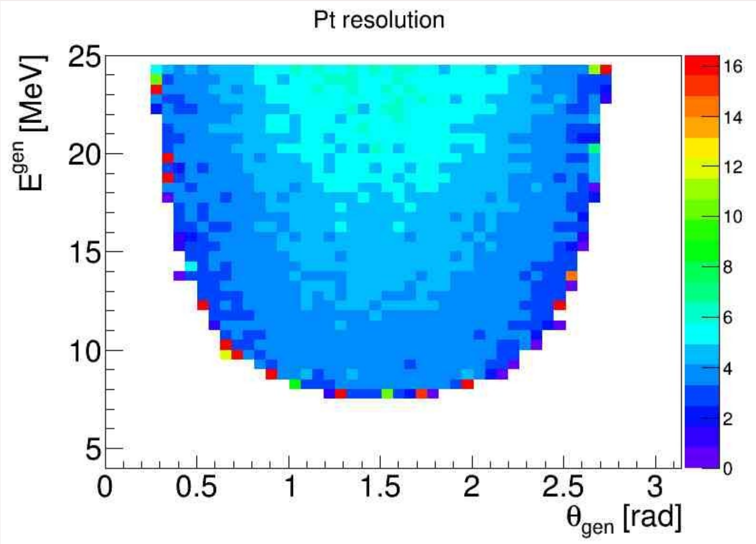
Theta [rad]



Z [mm]

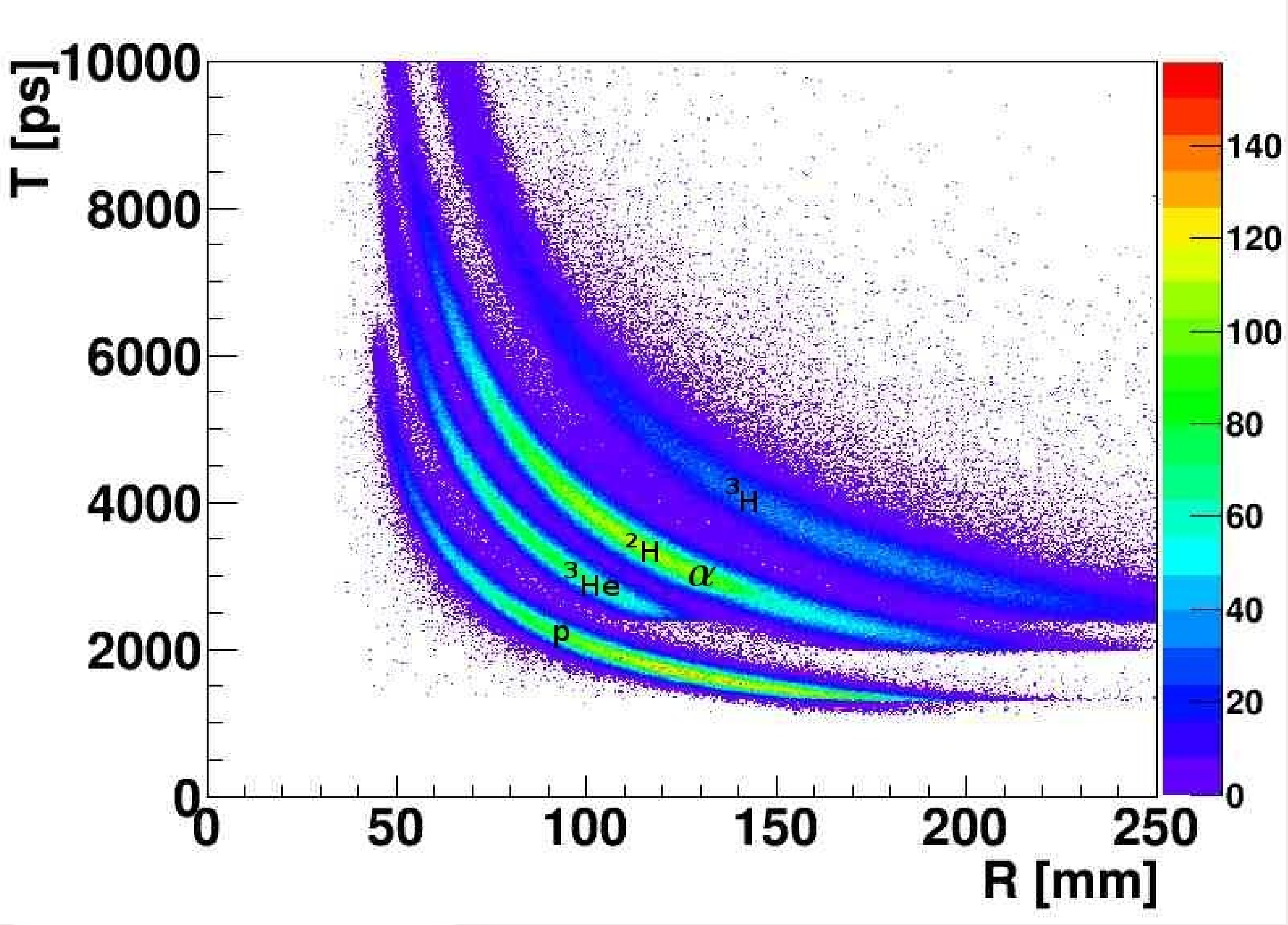


Pt [%]



Particle identification: method (1/2)

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.

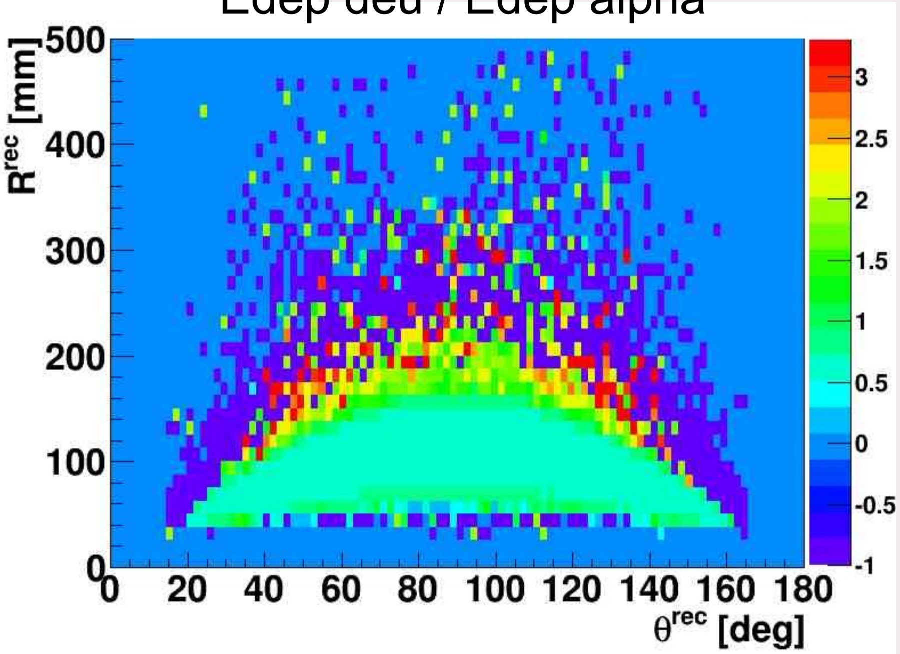


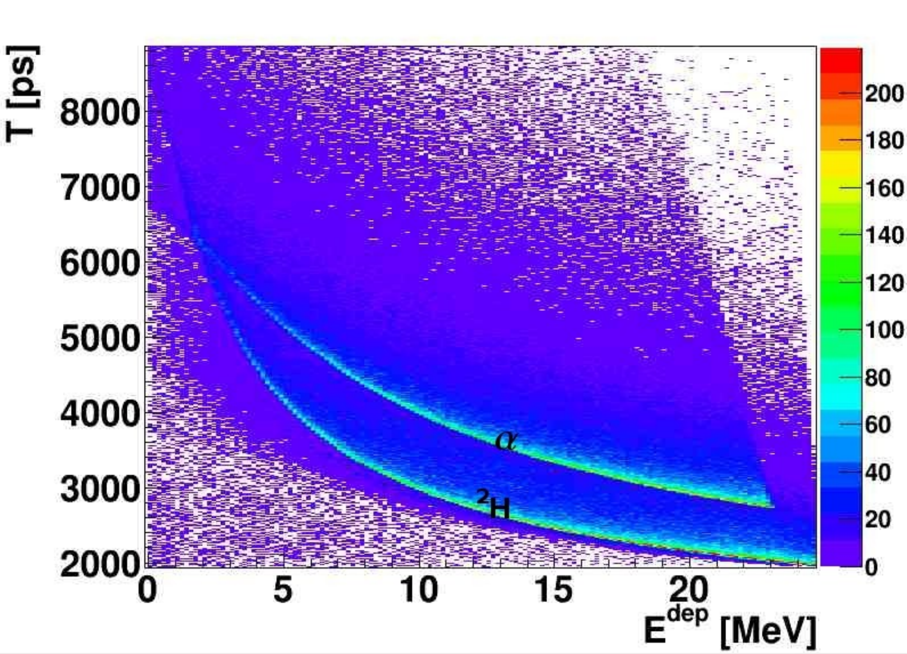
Particle identification: method (1/2)

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





Particle identification: results

With a 100 ps time resolution and a 10% energy resolution of the scintillator

99% of protons identified are protons
95% for helium 3
98% for hydrogen 3

86% for deuterium
88% for alphas

With a 75 ps time resolution and a 5% energy resolution of the scintillator

99% of protons identified are protons
95% for helium 3
98% for hydrogen 3

87% for deuterium
90% for alphas

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

Could be essential for your experiment.

FastMC available.

Conclusion

The preliminary design for A Low Energy Recoil Tracker (ALERT) has been investigated and several geometry are going to be tested.

Simulation has shown that the resolutions for proton of the drift chamber could be:

$\sigma_z \sim 3$ mm $\qquad \sigma_\theta < 0.1$ rad $\qquad \sigma_{P_T} < 8$ %

ALERT can identify protons, hydrogen 3, helium 3, helium 4 and deuterium with a probability close to 90% for the two last ones and higher for others.

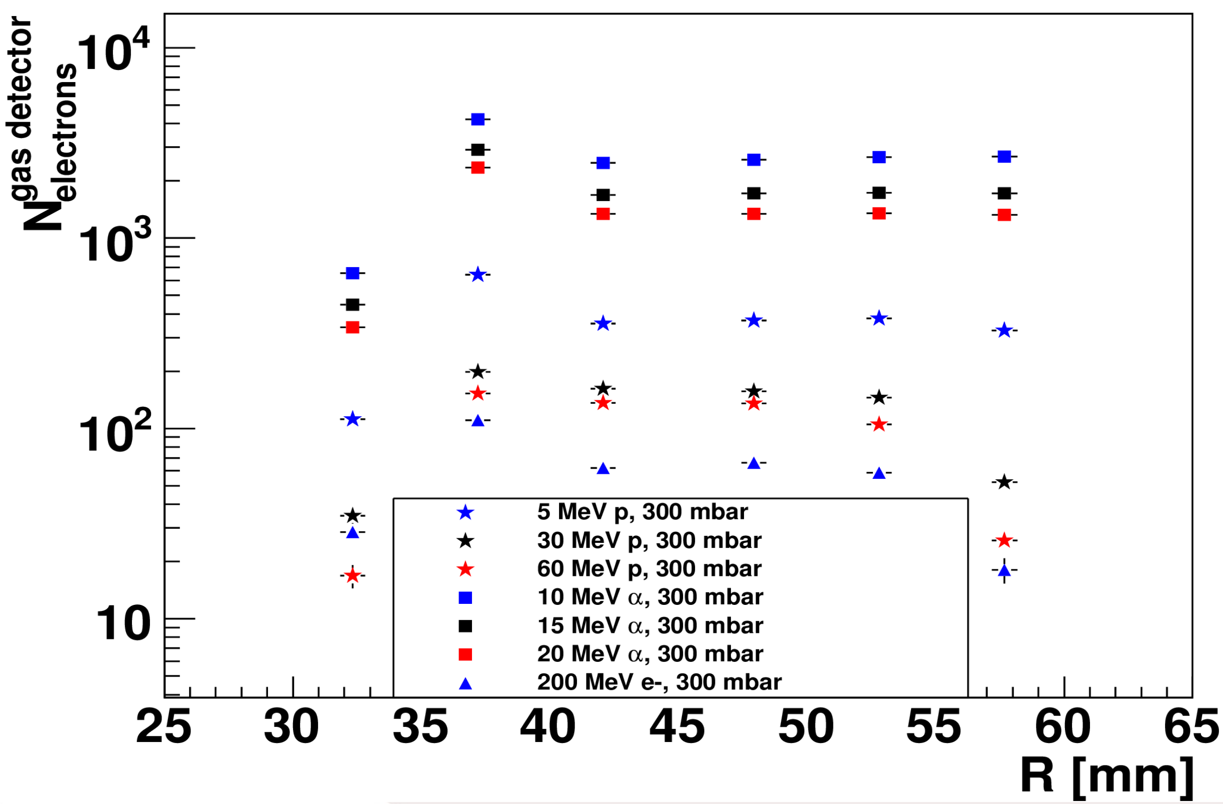
A Fast Monte Carlo, very simply to use, implementing the resolutions, acceptance and soon the identification efficiency is available.

On going work:

- build a small prototype to test several cell layout, test different electronics and try with lighter wires
- write a more precise simulation as well as a better fitting algorithm

How to trigger only on protons?

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

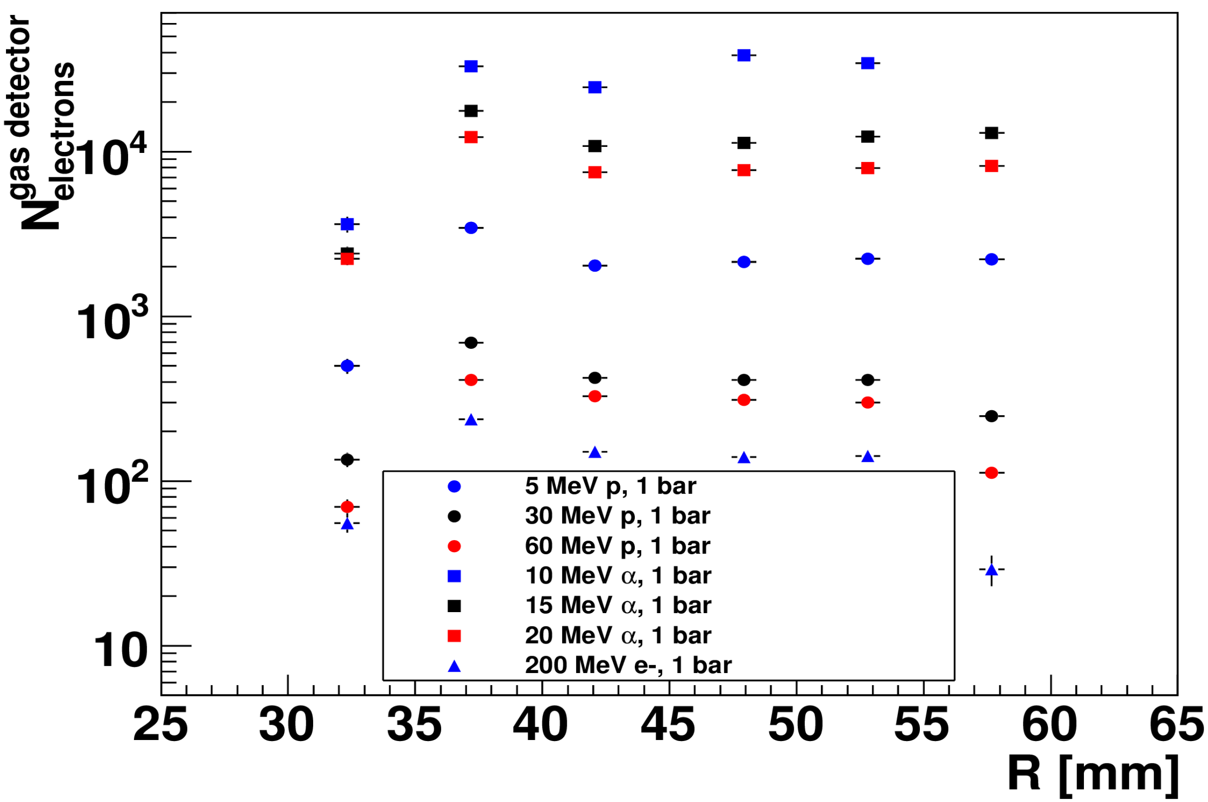


On the side of the theory: electrons deposit energy via Bremsstrahlung ($\sim Z^2/A$) while other particles interact via ionisation ($\sim Z/A$), so a light gas mixture is preferable. But for the moment nothing about the pressure.

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 (~Z^2/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:

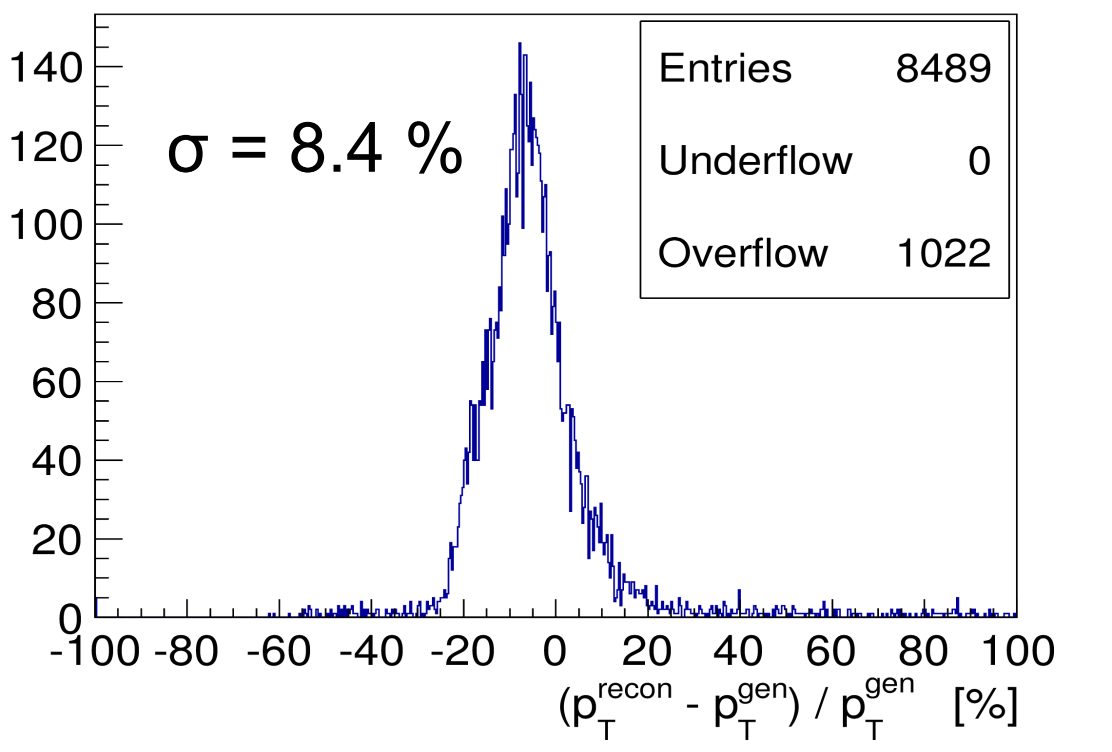
- the energy deposited
- the particle id
- the hit position (x,y,z)
- the hit time (relatively to its creation)
- the vertex position of the particle
- the vertex momentum direction of the particle
- the vertex energy of the particle

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)

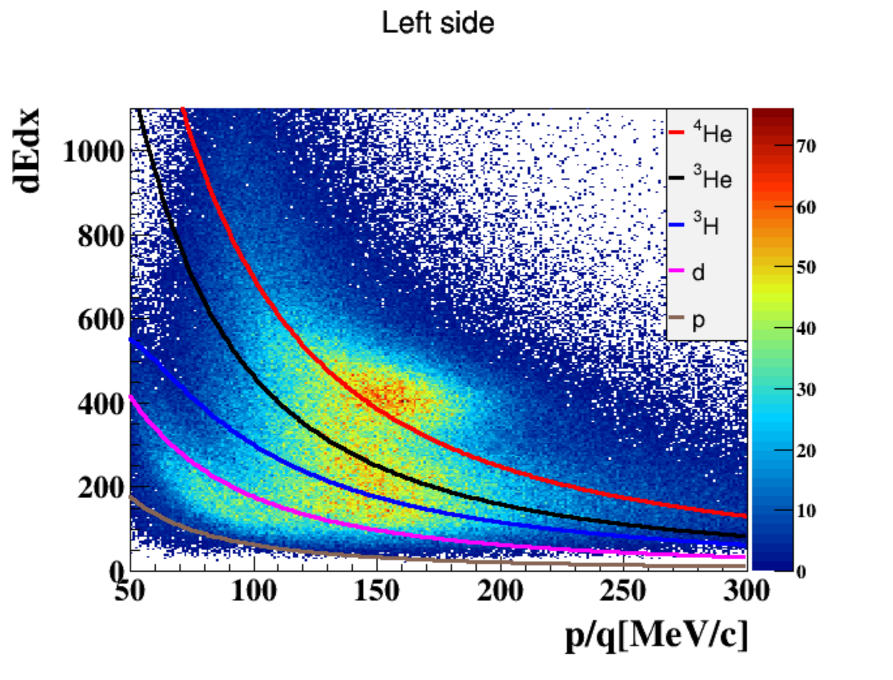
Transverse momentum resolution

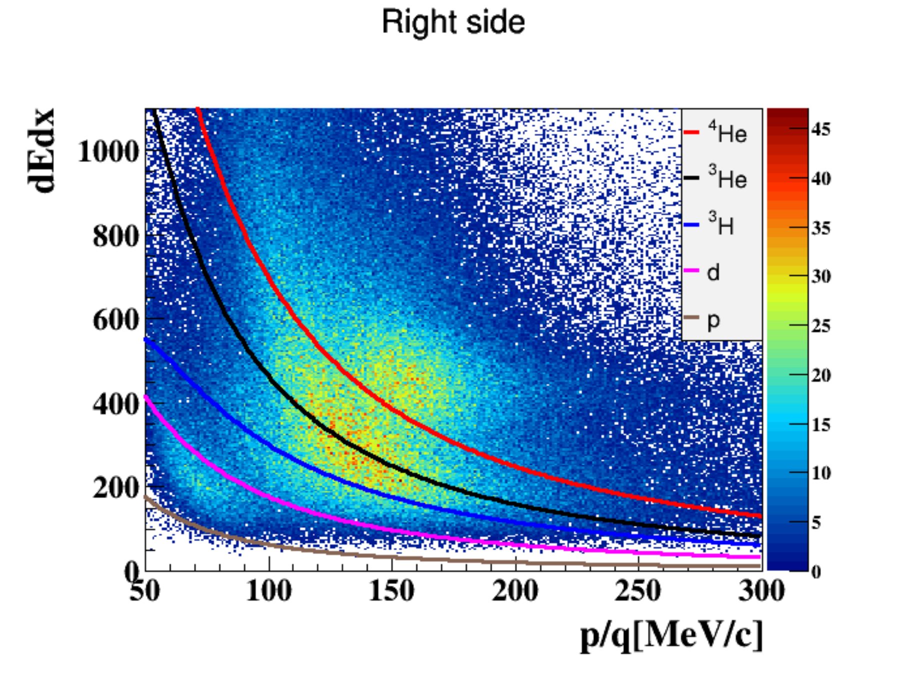
6 MeV (about 100 MeV/c) protons are emitted in all direction from all the target, no cut is applied, nor energy loss correction. Only the hit wire information is used.



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.

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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p/q[MeV/c]
4He
3He
3H
d
p
45
40
35
30
25
20
15
10
5
0