A Low-Mass Vertex Wire Chamber for BONuS12

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Scope of use

The main idea is to develop a detector that could be used for several experiments:

- 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

This presentation is a **preliminary** study focused on the BoNuS specifications:

- 10% momentum resolution at 100 MeV/c
- 3 mm resolution on the Z vertex position
- Minimum energy detection must be around 60-70 MeV/c
- 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

Why a wire/drift chamber?

After a comparison between existing detectors a wire chamber has been chosen for its following advantages:

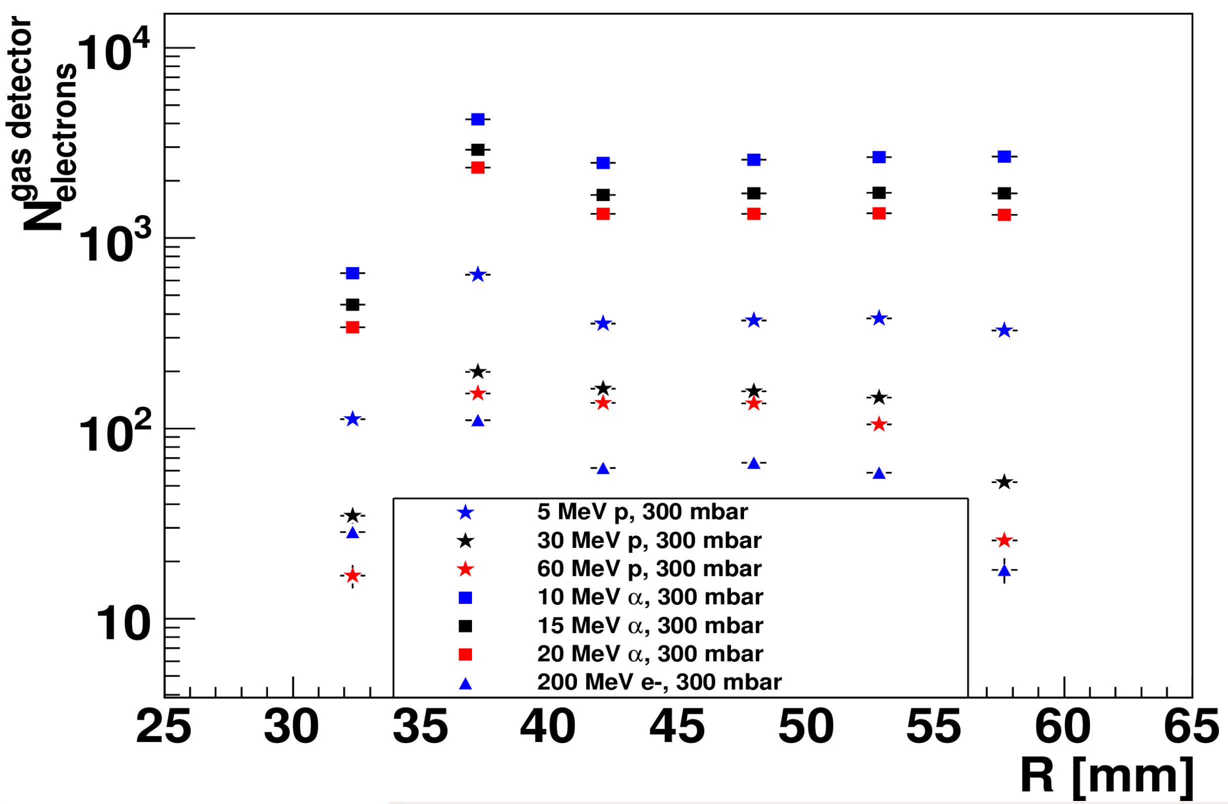
- Low material
- The drift time can be short if wires are not too far and gas well chosen
- Can be included in the trigger with a short drift time

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

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

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 (~Z^2/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**.

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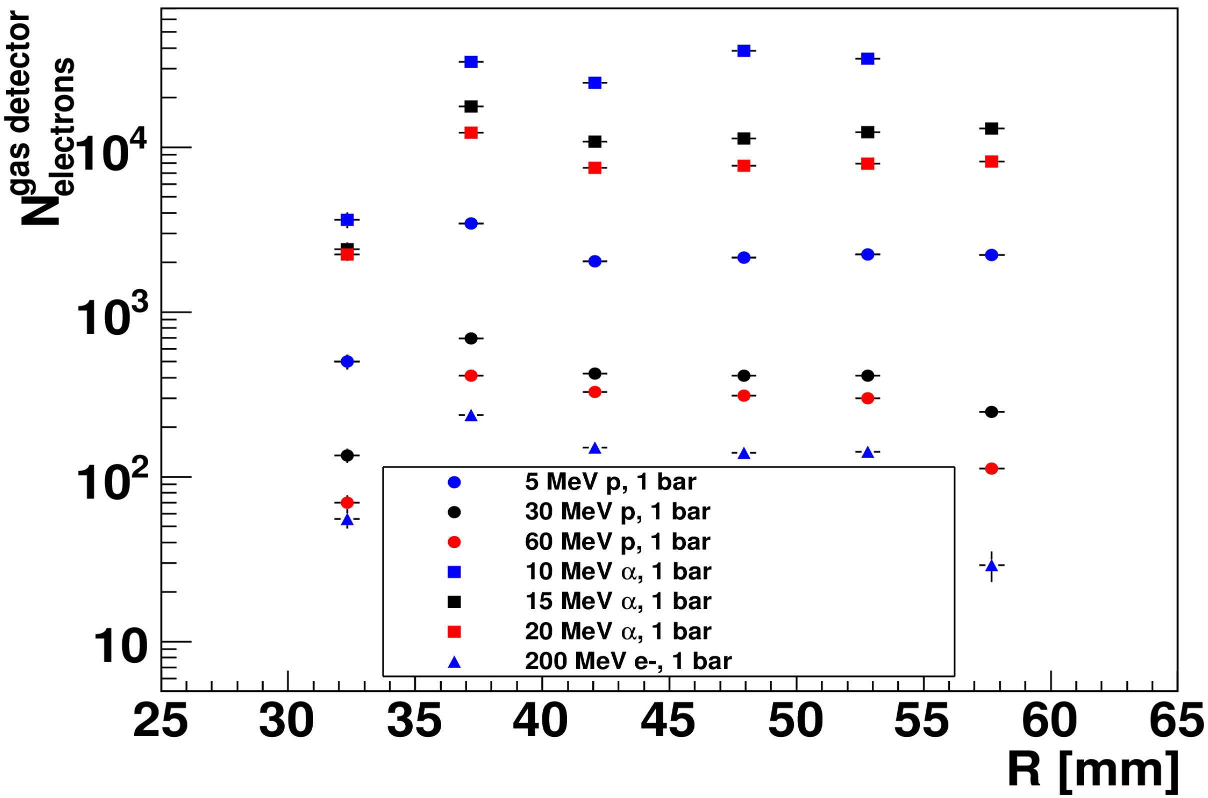

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All the results showed after are for iC_4H_{10} at 1 bar.

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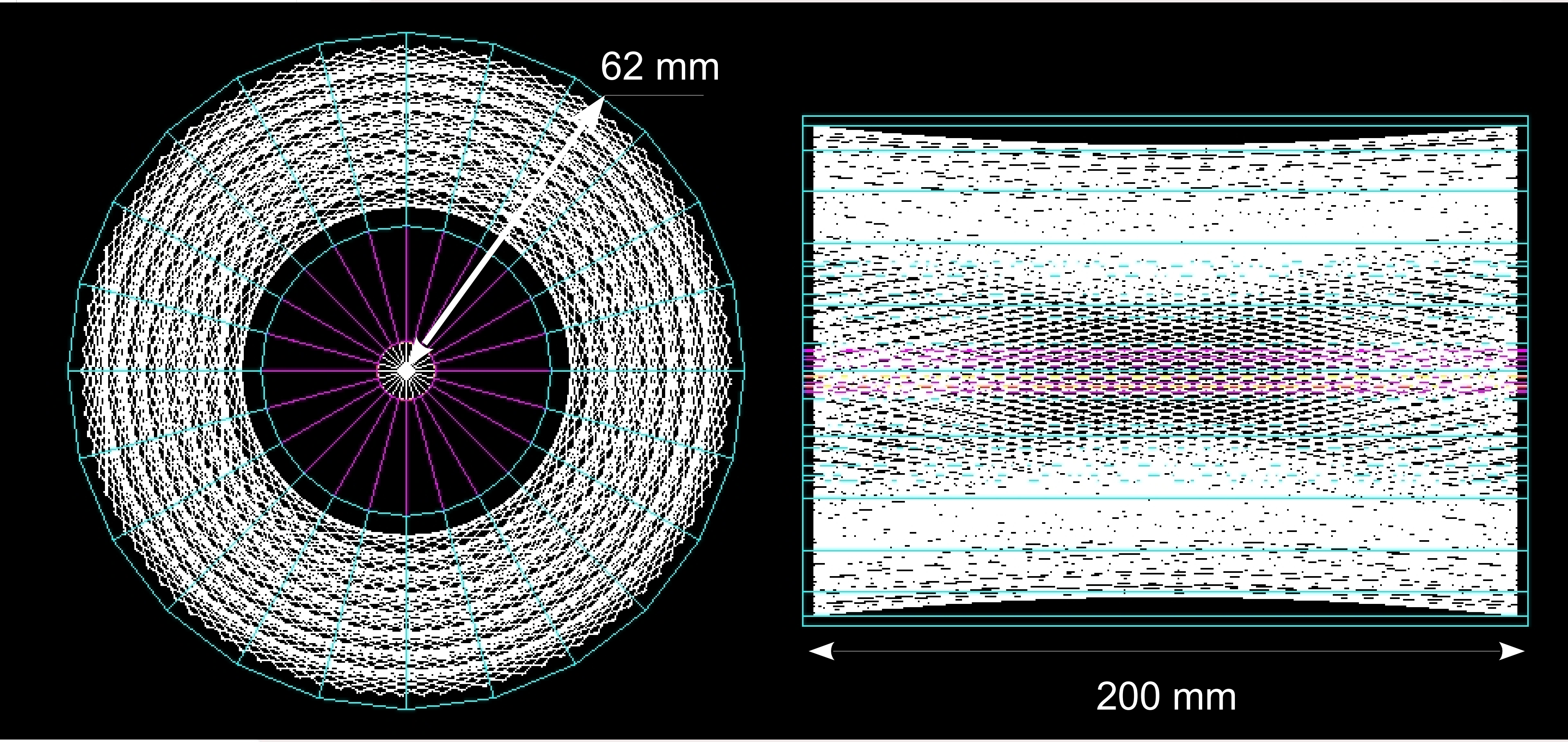
Detector simulation in Geant4



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

There are 8 layers of wires alternatively having a negative or positive stereo angle of 10° to 15°. The 574 signal wires are 4 mm apart from each other. Ground wires will be placed later.

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

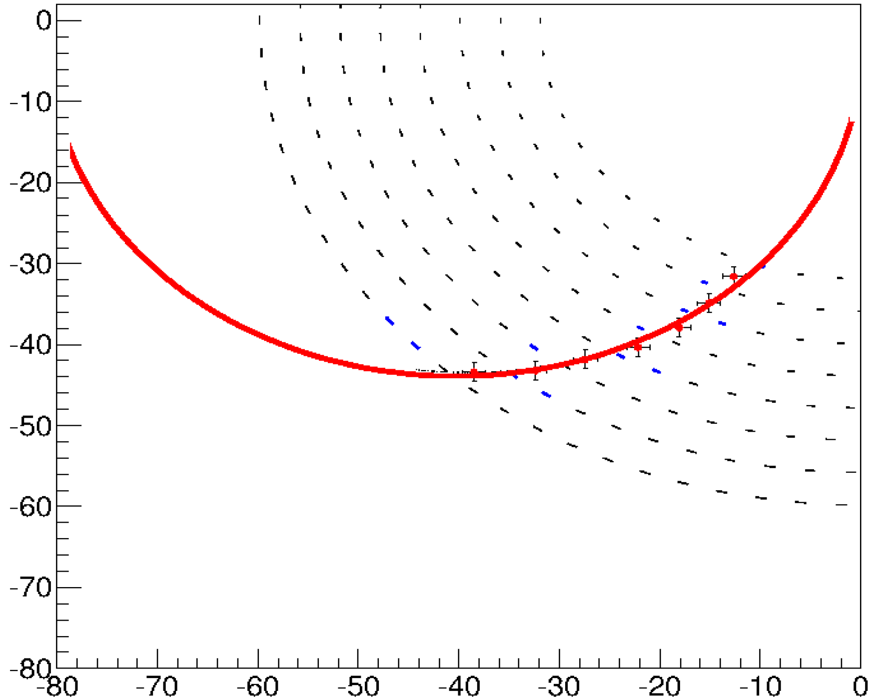
Using only the hit position the closest wire is found and identified as a wire with signal. A time is associated to it, it is the minimum time of all hit for this wire. Thus a new root file is created containing for each hit all of the above plus:

- 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)

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

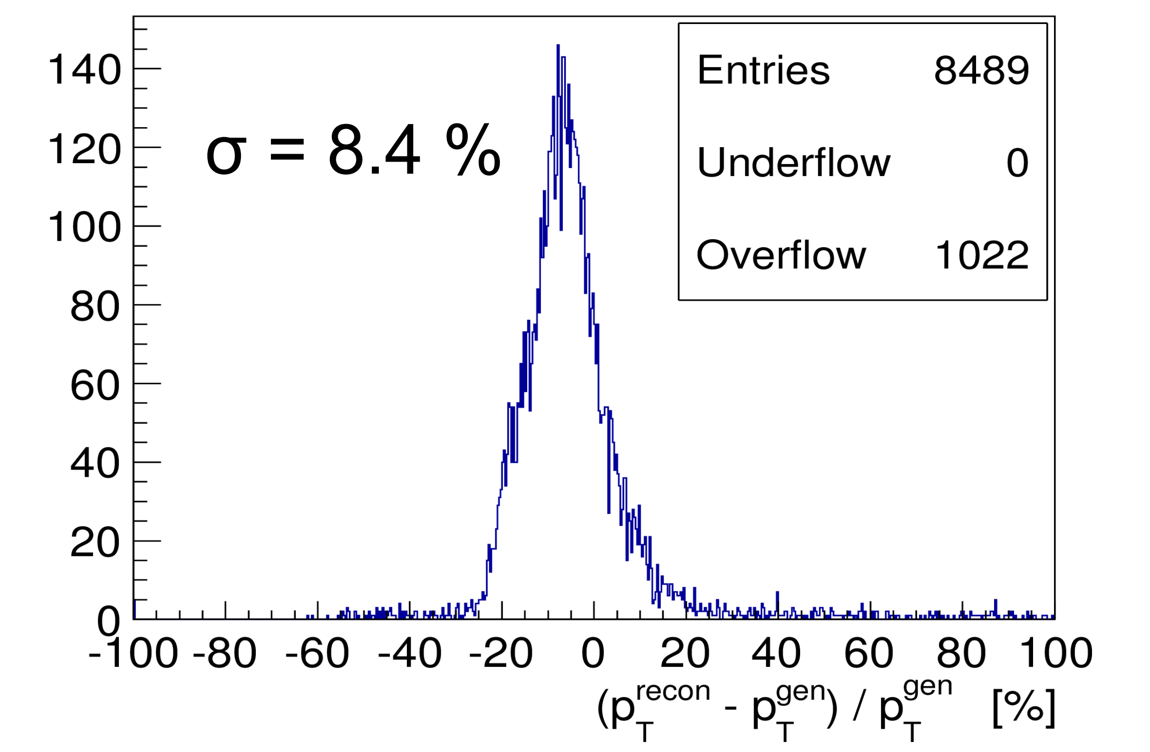


Section view of the wire chamber

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

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.

FastMC

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

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

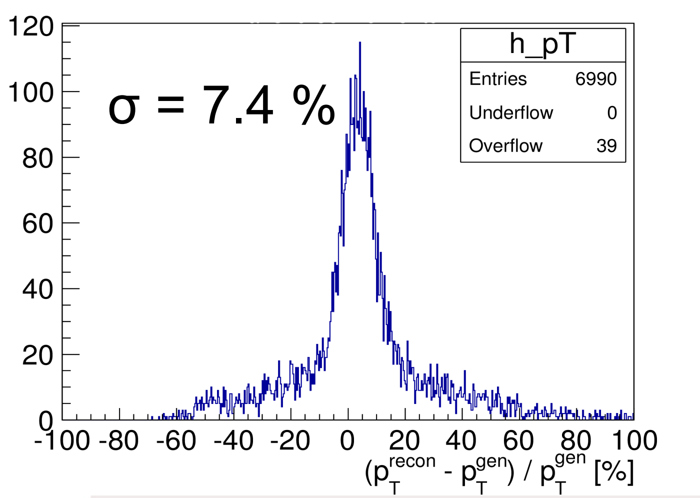
ΔR: distance between the wire
v_{drift}: drift speed
Ψ_S: stereo angle

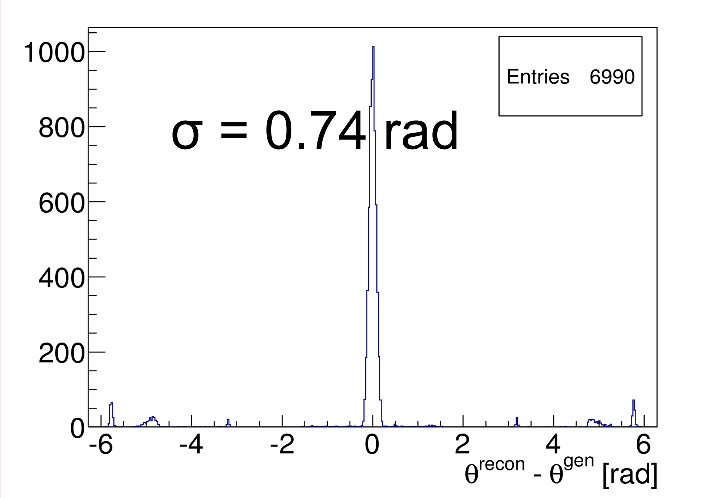
σ_r is over estimated as it should also be $v_{drift} * \sigma_t$
v_{drift} is taken equal to 5 cm/µs which is the saturation speed for gases
σ_t is taken equal to 3 ns but we expect it to be 1 ns, nevertheless as it changes the spatial resolution and that magnetic is, for now, unknown it is a safer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

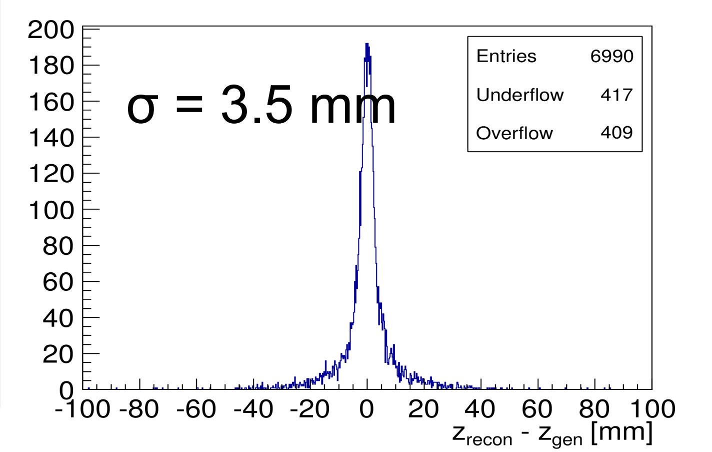
The curvature of the track and the z position are fitted independently.

Resolution with fastMC

The same input is used than for digitization, the particles are 6 MeV protons generated all over the target in all directions.





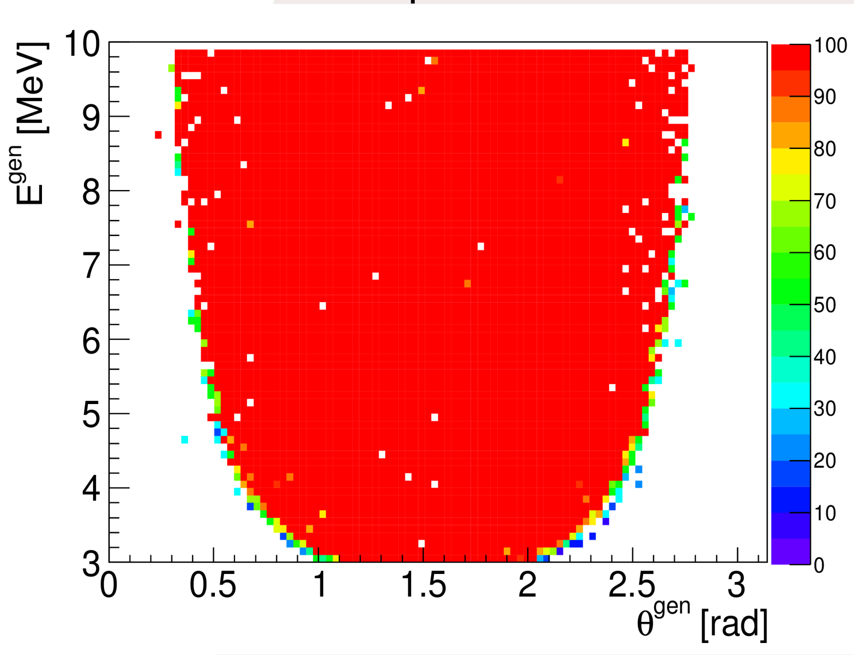


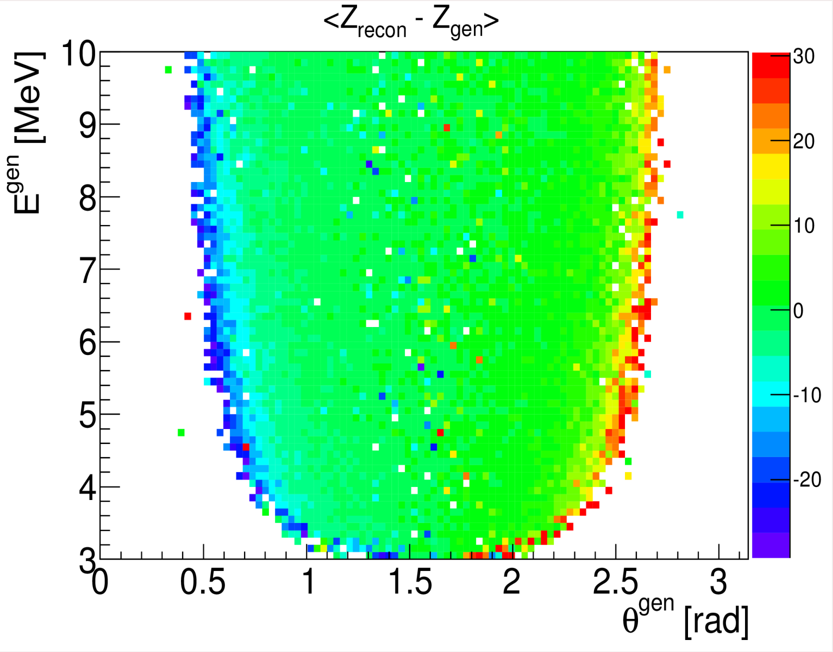
Can be improved using (x,y) vertex position.

Acceptance (with FastMC)

Cut: all wires have seen a signal

Acceptance





Electronics

These are preliminary numbers

A very preliminary study on the electronics has been performed by E. Rauly.

It seems that the HPS current sensitive preamplifiers could be used:

- their gain is 0.63 mV/fC (can be increased by 30%)
- considering that the gain on a wire can be set to 10^3
- considering the use of the same electronics than for HPS 1024 channels coding 1V
- electrons would have a signal of about 9 ADC
- protons would have a signal of about 16 ADC
- the electronics and statistics noise would lead to a noise of 3 ADC

Mechanics

In the current design the wires are 4 mm apart over 200 mm.

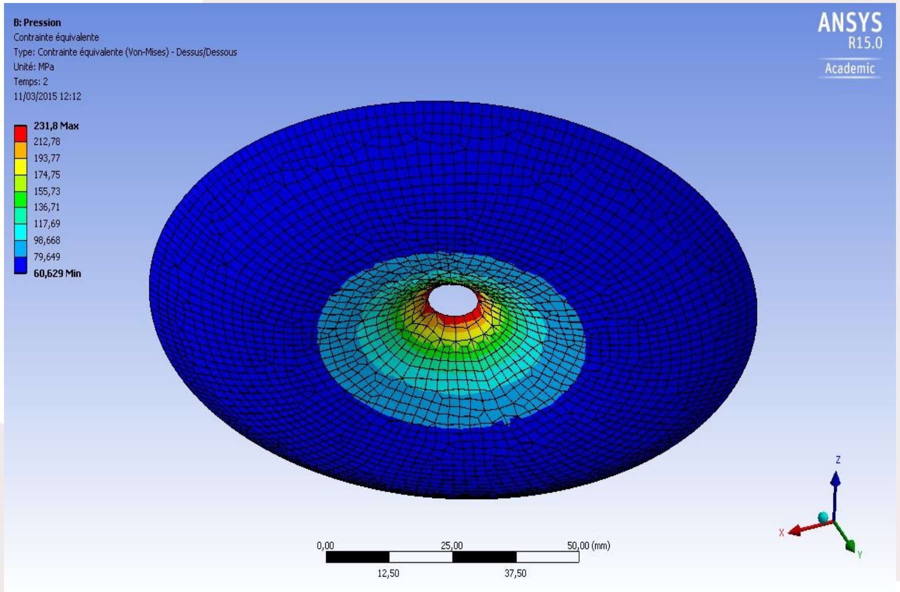
Several experiments had wires 2 mm apart over 2 000 mm !

The tension necessary to stretch a wire in a certain electric field and the corresponding sag can be computed.

The corresponding force has been evaluated to 0.5 N for all wires.

The main problem is the construction of a thin window.

J. Bettane has carried out constraint simulations



A 75 µm Mylar foil is necessary to stand the pressure difference between the inner and outer part of the chamber.

Conclusion

A simple simulation has shown that the resolutions of the drift chamber could be:

σ_z = 3.5 mm	σ_θ= 0.74 rad	σ_{P_T} = 7.4 %

Nervertheless more must be done before concluding on the feasibility:

- perform field studies to evaluate drift lines, drift speed and the time resolution. It will also permit the design of “ground” wires and define the gain on the wires

- develop a 3D fitting algorithm that would take time into account

- check the occupancy

- play with the code to optimize the detector
- add a solid detector and study the resolutions for other particles
- design the electronics when the wire gain will be known
- design the detector when the position of the ALL wires will be known