Frontier Detectors for Frontier Physics
14th Pisa meeting on advanced detectors
La Biodola • Isola d'Elba • Italy
27 May - 2 June, 2018

Improving spatial and PID performance of the high transparency Drift Chamber by using the Cluster Counting and Timing techniques

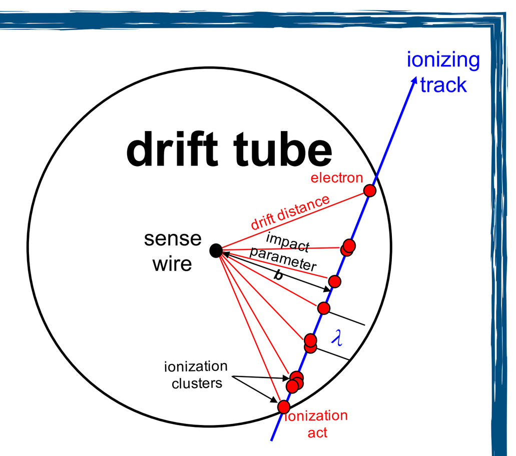
G. Chiarello [a,b,c,d], A. Corvaglia [a], F. Grancagnolo [a], A. Miccoli [a], M. Panareo [a,b], C. Pinto [a,b], F. Renga[c,d], G.F. Tassielli [a,b] and C. Voena [c,d].

(a)Istituto Nazionale di Fisica Nucleare Sezione di Lecce, Via Arnesano, Lecce, Italy
(b)Dipartimento Matematica e Fisica Ennio De Giorgi, Università del Salento, Lecce, Italy
(c)Istituto Nazionale di Fisica Nucleare Sezione di Roma, Piazzale A. Moro, Roma, Italy.
(d)Dipartimento di Fisica, Università Sapienza, Roma, Italy

The Helium based ultra-low mass and high granularity Drift Chamber are an optimal solution as tracking systems of modern High Energy Physics experiments for the search of extremely rare processes (MEG-II) and for experiments at future high luminosity e^+e^- colliders (FCC/CEPC). For the search of rare processes in the CLFv sector the tracking resolutions are dominated by multiple scattering contributions and this impose the use of a ultra-light tracking system. For the future colliders in addition to a high tracking performance a good PID capabilities can have a great impact. We present how, in Helium based gas mixtures, by counting and measuring the arrival times of each individual ionization cluster and by using statistical tools it is possible to have a bias free estimate of the impact parameter and a better PID by using the dN/dx technique instead of the dE/dx.

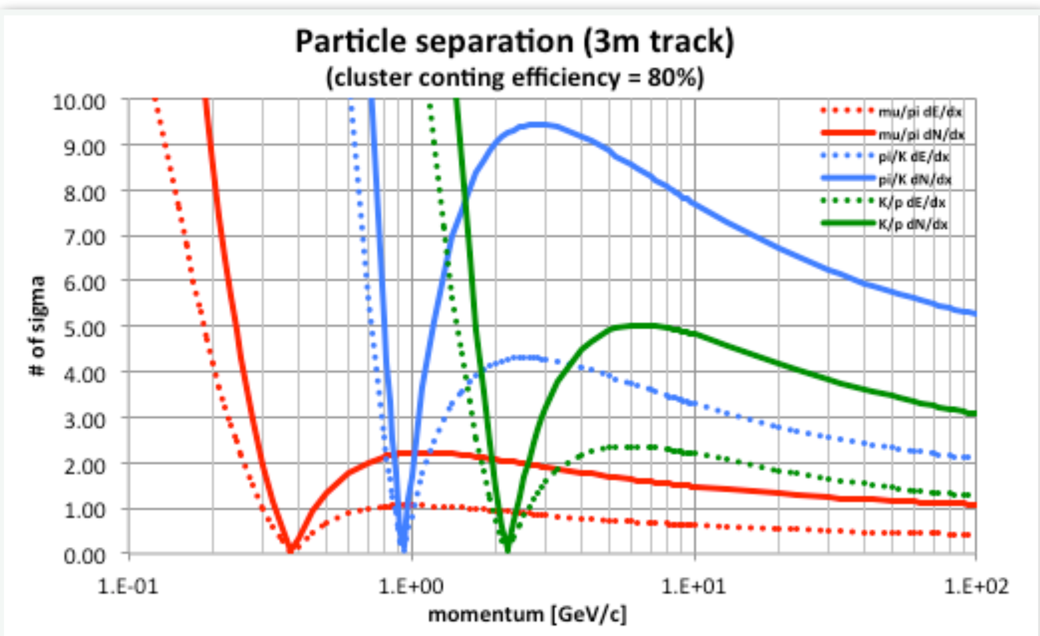
DRIFT CHAMBER OPERATION

"A charged particle, passing through the gas of a drift chamber, creates ion-electron pairs along its path. Depending on the released energy, for each ionization act, the particle creates one or more ion-electron pairs, indicated as clusters. The distance between two consecutive clusters follows an exponential distribution, the parameter of which depends on the gas nature, pressure and temperature. The time separation between consecutive ionization acts, in helium based gas mixture varies from a few ns, near the sense wire, to tens of ns, far away.



PID AND SPATIAL RESOLUTION

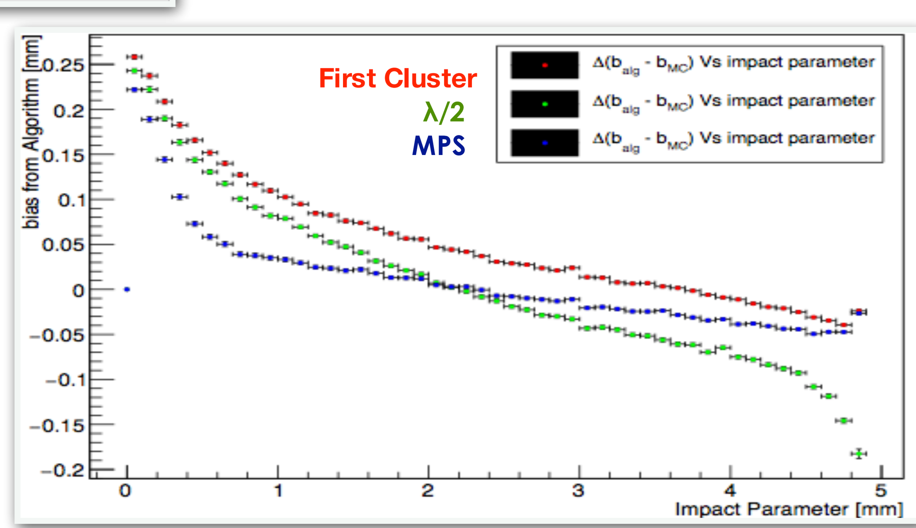
expected PID performance comparison with dE/dx for a track length of L=3m
Assuming a C.C. efficiency ε = 80%
$\sigma_{dN_{cl}/dx}/(dN_{cl}/dx)=1/\sqrt{\varepsilon \times L \times 12.5/\mathrm{cm}}=1.8\%$



Experimental results show a clear improvement of cluster counting over dE/dx (by a factor 2 in π/μ separation at p=200MeV/c) limited only by the cluster recognition performance [NIM A386 (1997) 458-469].

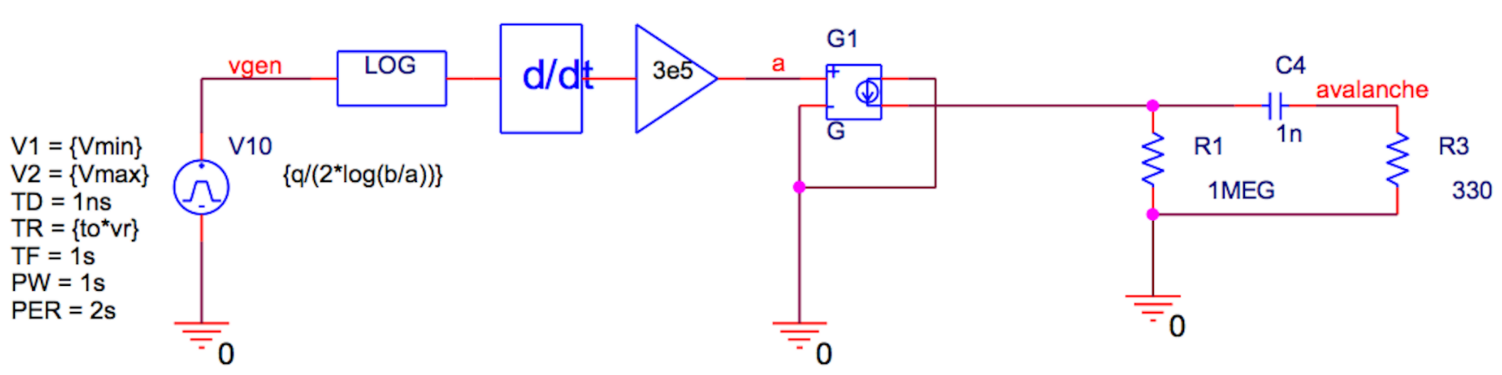
Cluster counting outperforms dE/dx by at least a factor 2.

In a conventional drift chamber, only the time of the first cluster is used to estimate the track impact parameter, resulting in a systematic biased overestimate. Cluster timing technique use statistical tools in order to improve the bias estimate by using the information of different clusters



WAVEFORM GENERATOR

Using PSpice software, we simulated the single cluster signal propagation along the drift cells convoluted with FE transient function



The convoluted signal is parameterized as follows:

$$a(t) = \frac{V_0}{k}\frac{\tau_{D1}+\tau_{UP}}{\tau_{UP}+\tau_{D2}}\left(1-e^{-(t-t_0)/\tau_{UP}}\right)\left[\frac{R}{\tau_{D1}}e^{-(t-t_0)/\tau_{D1}}+\frac{1-R}{\tau_{D2}}e^{-(t-t_0)/\tau_{D2}}\right]$$

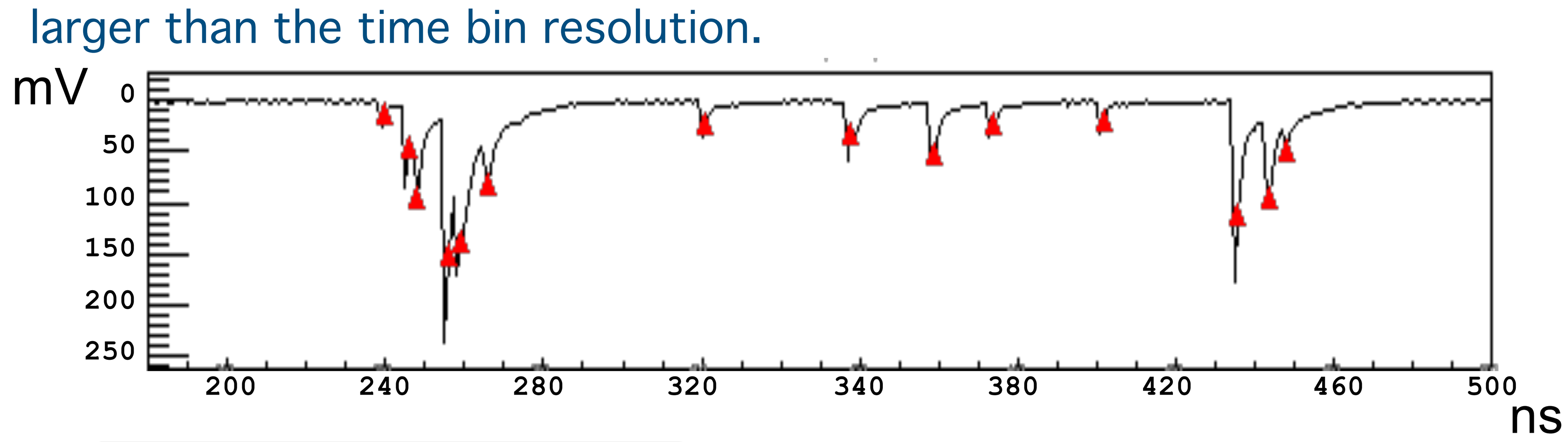
- Signal waveforms are generated according to:
- Cylindrical cell geometry with 9.75 mm radius
- $He\text{-}iC_4H_{10}$ = 90-10 at 4 · 10^5 gas gain
- Number of clusters from Poisson distribution with mean = 12 cls/cm
- Single electron diffusion as function of drift time
- Single avalanche gain fluctuations

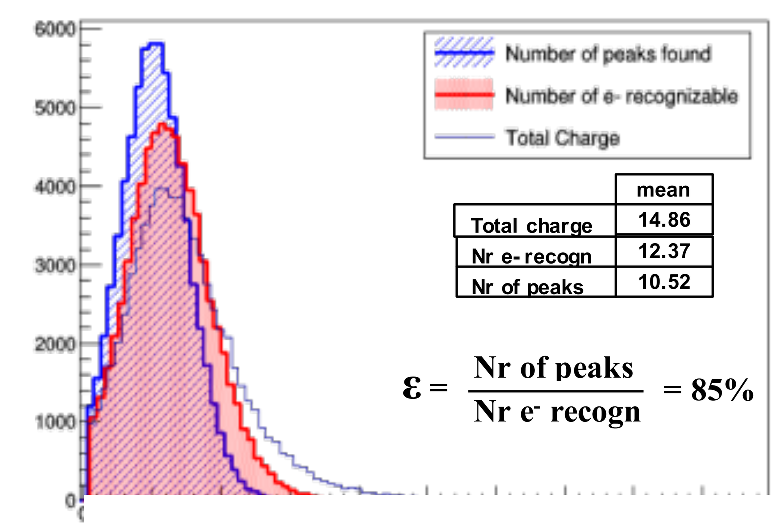
CLUSTER FINDER APPROCH

A simple peak finder algorithm, based on the first and second derivative of the digitized signal function f, is defined for each time bin i, Δb being the number of bins over which the average value of f is calculated:

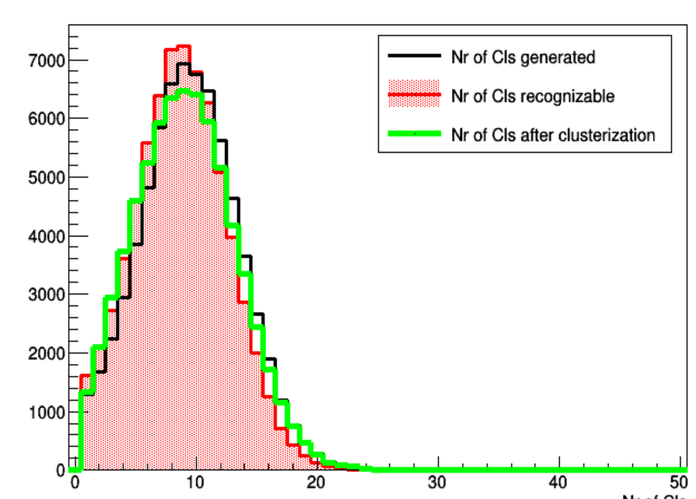
$$f'(i) = \frac{f(i)-\bar{f}(i-\Delta b)}{\Delta b} \qquad f''(i) = f'(i) - f'(i-1)$$

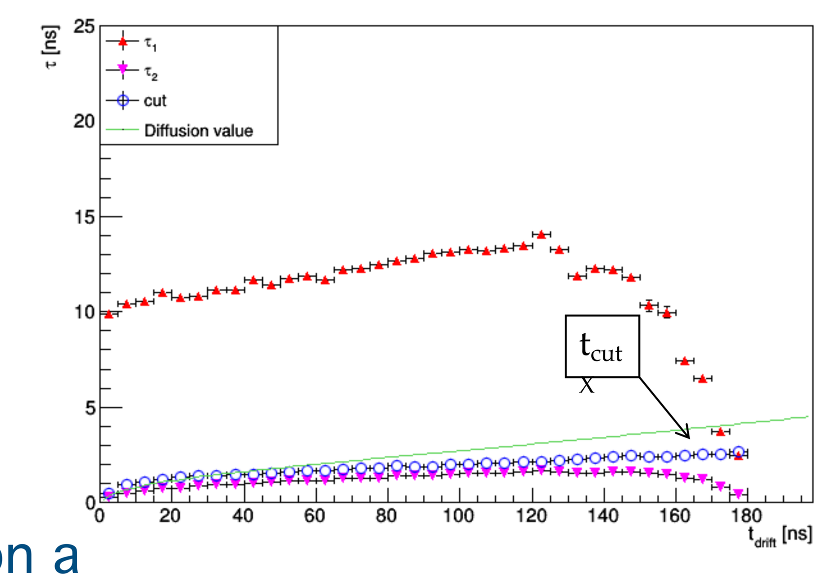
A peak (assumed to be an ionization electron) is found when Δf, f' and f" are above a threshold level, defined according to the r.m.s. noise of the signal function f, and the time difference with a contiguous peak is larger than the time bin resolution.





The association of electrons in clusters is based on the time difference between consecutive electrons. Electrons belonging to same cluster are separated by time differences compatible with single electron diffusion.

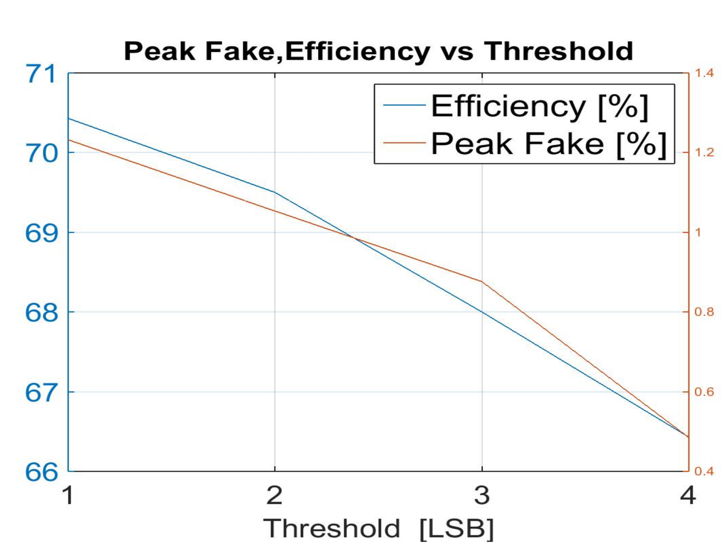




The algorithm has be implemented on a Virtex6 FPGA, interfaced with a 12 bit ADC.

The algorithm:

- identifies, in the digitized signal, the peaks corresponding to the different ionization cluster
- stores each peak amplitude and time in an internal memory
- sends the data stored to an external device when specific trigger signals occur.



for information and details contact: gianluigi.chiarello@roma1.infn.it