CLUCOU: study of cluster counting/timing technique for improvement of spatial resolution in drift chambers

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The *CluCou* group is studying the possibility to improve the spatial resolution of drift chambers to the physical limit, by measuring the drift times of all clusters that can provide a number N_{cl} of independent measurements of the impact parameter per drift cell. As illustrated in Ref. [1,2], by taking advantage of the sufficiently low electron drift velocity, together with the low enough ionization density along the track in He-based mixtures, if the signal read-out is performed with a $\sim 1ns$ resolution on the individual sense wire, then the single electron structure of the signal can be analyzed. The *CluCou* program is studying these potentialities, by means of simulations, development of appropriate front-end electronics, and experimental tools in preparation of prototyping the drift chamber. In particular, extensive simulations have been performed and are in progress by means of consolidated standard tools, like Garfield with Magboltz [3], in order to gain control of all relevant parameters: gas drift velocity, gain, cluster statistics; electrical characterization of drift cells; measurability of single electrons; front-end electronics transfer function. Algorithms for signal analysis and peak counting are under development (current efficiency with noise is at the level of 94%) and show that we get results consistent with expectations. In fact, the cluster number distributions (Fig.1) and the electron number statistics (Fig.2) for He-based gas mixtures with different isobutane content show typical poissonian character and Landau-shaped behaviour, respectively. Furthermore to approach experimentally the cluster counting technique a drift tube has been instrumented, at the beginning in a simple set-up for cosmic rays measurements. The trigger is made by a pair of scintillators and the drift tube signal is read by a digital scope with high sampling rate, that allowing us to acquire and store waveforms for off-line analysis. The signal is picked up from the sense wire through a 10× amplifier with 500 MHz bandwidth. Slow control parameters (high voltage, low voltage, pressure, gas flow) is continuously monitored. Preliminary measurements with such a simple device are consistent with simulations, as illustrated (Fig.3) for a measurement of the drift time spectrum with a 1.4 cm radius tube in Helium/Isobutane 90/10 mixture. As the next step, a microstrip Si telescope is being prepared, in order to have precision tracking measurements at the level of 30 μm for an independent impact parameter measurement. The mechanical assembly of the telescope is ready, and the read-out is in development. The experimental plan devises detailed studies with the Si strip telescope using drift tubes until a small scale prototype of the drift chamber is ready. To be able to use the cluster counting technique on a large scale drift chamber, a low cost, high speed front end electronics is needed and is been started to be studied. A CMOS 0.13 μm integrated circuit with a core area of 2.4 mm^2, made of a fast preamplifier section plus a 1 GSa/s $6-bit$ ADC has been designed [4][5]. The preamplifier yields a programmable DC-gain between 0 and 20 dB, a 500 MHz bandwidth at -3 dB, an input-referred noise of 52 μV_{rms} versus a typical drift tube output noise of 100 μV_{rms}. The design speed and accuracy of the *CluClou* CMOS are reached with

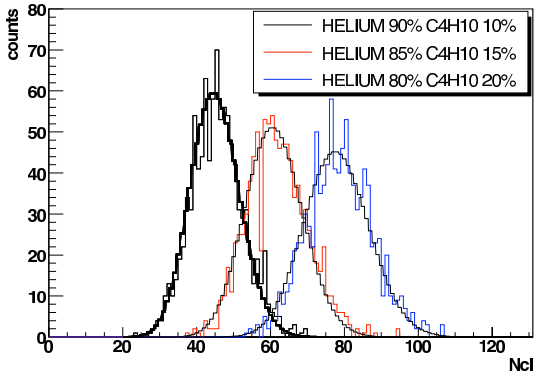

Figure 1. Number of clusters as simulated in a 4cm gas layer superimposed with the Poisson distribution functions.

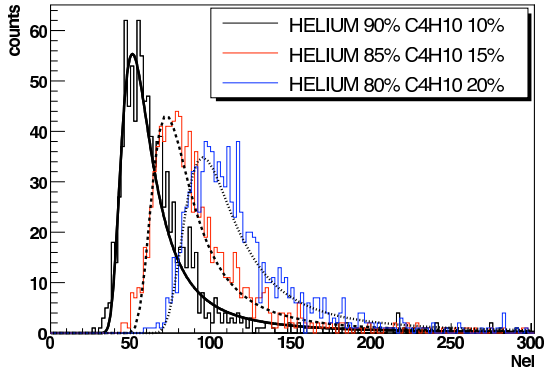

Figure 2. Number of total electrons as simulated in a 4cm gas layer fitted with Landau distribution functions.

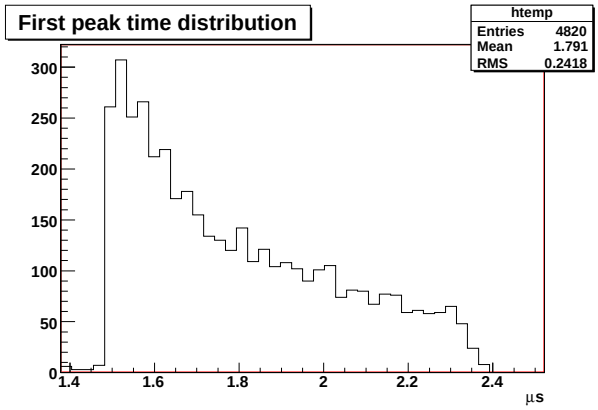

Figure 3. Measured drift time spectrum for a drift tube of 1.4 *cm* radius in He/isobutane 90/10. Time span of the spectrum, corresponding to largest drift time, is 900 *ns*.

a power consumption of only 45 mW per channel. 70 pre-production chips have been delivered and currently under bench tests, including control of current absorption and output voltages, preamplifier characterization, frequency response at different gains, noise and linearity, ADC characterization. Once understood the bench behaviour of the chips, they are planned to be used as front end of test drift tubes, in view of building a small prototype chamber, with at least 50 channels equipped for cosmics and beam tests.

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