SOME LIMITS IN THE LOCALIZATION OF CHARGED PARTICLES

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I. Multiwire Chambers

Localization accuracy

Each gap has intrinsically a two dimensional capability with quite different properties.

(a) For large chambers the closest practical wire distance is 2 mm. For 20 × 20 cm it is about 1 mm. At atmospheric pressure we have an example of 12 × 12 cm^2 with 0.5 mm spacing. It is very difficult to operate it and the reduction in gaseous gain and use of low noise amplifiers has led to the necessity of 50 nsec resolution, instead of 30 nsec for 1 mm wire spacing. It is excellent indeed for particle separation.

At high pressures the situation is different (J. Sandweiss) and 4 wires/mm can be operated, with very small surfaces, so far.

The recent progress in the reflection of the pulses induced on the cathodes and neighboring wires (CERN and Brookhaven) leads to a lifting of the right-left ambiguity and a subsequent gain in accuracy by a factor of 2. Thus 1 mm wire spacing leads to $\sigma \sim 150\ \mu\mathrm{m}$!

(b) The measurement of the coordinate along the wire permits accuracies of $\sigma \sim 50\ \mu\mathrm{m}$ with time resolutions of 30 to 50 nsec.

It seems realistic to foresee the utilization of square meter chambers with this readout, thus competing directly with the drift chambers. The advantage is in the much better occupation time, in the two-dimension character of every chamber with a good accuracy in all directions. The disadvantage is in a poorer separation, however. It is of the order of the anode-cathode gap ~ 6 mm for large chambers.

A combination of drift time and centroid readout would permit the construction of large planes within two-D 100 μm accuracy. This fulfills precisely the needs that can be forseen in scaling up some types of experiments for 400 GeV to 20,000 GeV, as illustrated by the example given by L. Lederman about the dilepton experiment. In this particular case the reduction in magnet volume (due to the contraction of the lateral dimensions), combined with 50 μm to 100 μm detectors leads to a reduction in the cost of the spectrometer.

Rate limitations

They come from two factors:

- The anode-cathode gap of about 6 mm leads to occupation times of about 150 nsec which are the main source of accidentals for large chambers.

- The space charge limitations due to the slow motion of positive ions is about 10^4/sec mm of wire. This is the dominant factor for small surface detectors with high rates and high multiplicities in narrow cones. We will see that this is precisely the effect eliminated by present development of multistep chambers.

Particle separation

It is a function of wire separation and can be estimated to two or three wires. For the coordinate along the wire it is of the order of anode-cathode gap, i. e. ~ 6 mm for large chambers.

II. Drift Chambers

An accuracy of ~ 50 μm is claimed at atmospheric pressure. The work of Heintz et al. and Dolgoshein et al. show that at high pressures accuracies of about 15 μm can be reached. This is due to the reduction in range of the δ -electrons. This improvement can also possibly be exploited in the charge centroid method. More research is indeed required to investigate the practical difficulties in exploiting this intrinsic accuracy but it seems a safe path if such accuracies are requested.

The track separation in drift chambers is 2 mm. It is probably by far the best that can be obtained in large surface detectors, since with MWPC the wire spacing has to be > 2 mm. It may appear as the most important property justifying the drift chambers. It will also scale down at higher pressures (with thinner anode wires). This particle separation power is the main advantage over centroid readout chambers which have the serious advantage of better resolution times.

III. Multistep Gaseous Detectors

Recent developments at CERN have shown that it is possible to preamplify by a factor of ~ 1000 the initial ionization in a parallel grid gap and to transfer around 20 % of the electrons to various proportional detectors: wire chambers or parallel grid gaps, without any amplifying wires. The first advantage of this scheme is that it permits amplifying in the final stage only selected events thus eliminating the space charge limitation introduced by the more intense primary beam.

In the case of two parallel grid gaps the intrinsic jitter due to wire spacing in MWPC is eliminated. The presently attained time resolution of

10 nsec (FWHM) is probably preliminary to the final stage that can be reached by further research. The fantastic time resolution reached by parallel plate counters of various kinds (~ 100 psec for the parallel plate spark counter developed at Novosibirsk, ~ 200 psec for low pressure counters and with heavily ionizing particles) is in this respect very stimulating.

The possibility to drift the final electrons through successive readout wire grids external to the amplification region opens the way for convenient 2-D read out in non-planar structures since the exact parallelism of the readout surfaces is not a must anymore.

The spatial accuracy with the multistep detector has been measured to be 100 microns FWHM for charged particles. The separation power is degraded by the lateral propagation specific to the amplification process (~ 2 mm).

Single electrons are easily detected and localized and this offers promising features for the detection of the Cerenkov rings.

IV. Exotic Developments

Although the above mentioned developments in gaseous detectors offer promising perspectives in fulfilling some needs foreseen with higher energy machines in terms of spatial resolution or rate limitations they differ from severe drawbacks when very complex configurations with huge multiplicities are contemplated. The need to multiply the number of wires poses serious problems of reliability for large size systems. It is worth mentioning at this stage the project at Brookhaven of a 250,000 wire system. Each wire is inbedded in an independent thin aluminum tube, thus improving considerably the reliability by making the breaking of individual wires insignificant. The high accuracy in localization is obtained from drift time measurement and the mass integration of electronic circuits permits a full exploitation of all the information at a reasonable cost: time measurements and pulse height measurements whose importance is great as can be seen from Willis's report. However, different solutions are under investigation and may prove most important 10 years from now.

Solid state avalanche detectors of the type developed by Ch. Gruhn (Los Alamos) aim at 20 μm resolution with time resolution well below 1 nsec. The particle separation will be < 100 μm.

Scintillator filaments of 100 μm, with large attenuation lengths, coupled to silicon photodiodes (Willis) should permit an enormous gain in resolution, separation, complexity. Various other daring undertakings are listed in the reports of K. Lanius and W. Willis showing that by the time the machines are built the landscape may have changed in particle detectors since the changes there can be more rapid than in machine construction!