EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN - SPS DIVISION

(0081B)

CERN LIBRARIES, GENEVA

CERN SPS/83-6 (ELE)

CM-P00061371

LASER CALIBRATION OF DRIFT CHAMBERS

R. Desalvo

Abstract

A nitrogen laser is used to simulate tracks of charged particle in a drift chamber. With this technique it is possible to test a drift chamber with high spatial resolution in its entire volume. By changing the amount of ionization the behaviour of the chamber has been tested at the lower limit and the response of the whole read-out chain has been adjusted for all the range of signal amplitudes of the Landau distribution. A very precise drift speed measurement has been performed in different conditions of drift voltage and gas concentrations.

Presented to WIRE CHAMBER CONFERENCE - VIENNA (Austria) 15-18.02.1983

Prévessin, 27 January 1983

C O N T E N T S

	<u>Page</u>
1. INTRODUCTION	1
2. THE LASER BEAM	1
3. EXPERIMENTAL RESULTS	3
4. CONCLUSIONS	5
5. ACKNOWLEDGMENTS	5
FIGURE CAPTIONS	6
BIBLIOGRAPHY	9

Our 25 $\mu\text{J}/\text{pulse}$, 300 ps pulse-duration nitrogen laser delivers a beam with an almost rectangular profile 1.70 mm times 5.5 mrad in the vertical direction and 2.7 mm times 10 mrad in the horizontal direction^{*)}.

A rectangular collimator reduces the excessive divergence of the beam and cuts out the halo while a two lens telescope squeezes the beam dimensions and generates a long caustic in the drift chamber volume.

The mylar window cuts out 30% of the intensity of the laser beam still the pulse energy in the drift chamber is 5 $\mu\text{J}/\text{pulse}$ ^{**)}.

The resulting caustic power density is enough to free electrons in the gas and, except for delta rays, closely simulates the electron distribution delivered by an ionizing track of a high energy particle^[10-12]. The quadratic dependence on the light intensity of the ionization^[7-8] helps to produce a well confined track.

The chamber is mounted on a x-y movable support and scanned under computer control with a positioning accuracy of 50 μm while the laser beam is kept fixed in space.

The short duration of the laser shot provides an almost instantaneous ionization source in the drift speed time scale. An accurate timing of the readout electronics is possible either by triggering the front-end trigger scintillator of the chamber with part of the laser lightpulse or via a photodiode. For the laboratory tests the photodiode has been chosen because of its higher speed (better than 1 ns risetime).

^{*)}The drift direction in the chamber is vertical so that it matches the small dimension of the laser beam profile.

^{**)}Measured with a Molelectron Joule-meter.

1. INTRODUCTION

Small high precision drift chambers have been built by a collaboration of CERN and the University of California Riverside for monitoring the elastic scattering and hence the luminosity of the SPS p-p̄ collider at CERN^[1].

These drift chambers (see Fig. 1) are 200 mm deep, 126 mm high, 65 mm wide with four drift planes 44 mm apart, each plane being divided into three independent drift cells 42 mm high, 6 mm deep.

The gas is a 50-50% volumetric mixture of argon and ethane and a drift field of 950 V/cm is applied.

The sense wire at the center of each cell is a resistive (25 Ω /cm) Cr-Ni wire that allows charge-division position reconstruction and the readout is a multi-hit peak-sensing digitizing system^[2].

Since a focused nitrogen laser shot is able to free electrons in drift chambers gas mixtures^[3-9] it provides a versatile and easily controllable calibration tool, which is especially well-suited to our needs because of the physical characteristics of our chambers. Thanks to the front-end 100 μ m thick mylar windows, the interior of our chambers is visible and hence reachable by a laser beam. The small dimension of our chambers made possible the use of the high divergence nitrogen lasers existing two years ago. The expected resolution of these drift chambers (better than 100 μ m and 1 mm in the drift and charge division directions respectively) required a very accurate calibration.

2. THE LASER BEAM

A laser test bench was built and proved appropriate to check the efficiency, resolution and accuracy of the chambers throughout all their active volume and to measure the electron drift speed with less than 0.3% error. The layout of our test bench is sketched in Fig. 2A.

The drift speed was measured for different drift fields and gas concentrations in order to check the appropriateness of the working point chosen for our chambers ; the results are shown in Fig. 5.

At the nominal conditions (gas mixture of $51 \pm 0.5\%$ Argon and $49 \pm 0.5\%$ Ethane and a drift field of 950 V/cm) a drift speed of $53.25 \pm 0.15 \text{ } \mu\text{m/ns}$ was found.

The multiplication factor of the sense wire (see Fig. 6) was found to increase by one order of magnitude every 200 V .

By varying the laser power the resolution and the accuracy of the read-out could be tested at different pulse-heights (see Fig. 7) ; a pulse-height dependent shift of the charge-division reconstructed position was observed^[2,13] and then corrected.

Attenuating the laser beam it was possible to free a single electron per shot^{*)} and the Single Electron Response (S.E.R.) could be measured.

The advantage of using a laser in this case is that it gives the temporal information of when the electron is possibly freed and an external gate can be used.

An example of a S.E.R. spectrum taken with a positive 1750 V potential on the $25 \text{ } \mu\text{m}$ diameter sense wire is shown in Fig. 8.

A fit made to the data with a Polya function^[14-17]

$$p(g) = \frac{b^b}{G \cdot \Gamma(b)} \cdot \left(\frac{g}{G}\right)^{b-1} \cdot \exp\left(-\frac{b \cdot g}{G}\right)$$

gives a value for the parameter $b = 1.64 (\pm 0.02)$ and a mean multiplication factor $G = 330.000$. A 10% systematic error is assumed mostly because of the inaccuracy of the amplifier gain calibration.

*)The laser was attenuated until an efficiency as low as 20% was obtained.

3. EXPERIMENTAL RESULTS

Care must be taken because many electrons can be freed by the photoelectric effect if the field wires are hit by the laser beam. These huge pulses come later in respect to the in-gas freed electrons and are only partly detected by the peak sensing electronic (see Fig. 3^{*)}). This indicates that the useful volume of our drift cells is less deep than the volume delimited by the planes of the field wires.

A standard computer-controlled test-procedure was developed to test each cell of every chamber and its associated readout electronics (see Fig. 4).

Even though it was possible to test the chambers close to the field wires and up to 100 μm from the walls (see Fig. 3) it was chosen to fire the laser beam in between the 2 mm spaced field wires and at least at 1 mm from the walls in order to avoid spurious effects due to the photoelectrons.

In parallel with the laser test a simulated test with injection of charge on the sense wire was performed in order to provide a comparative point for the experimental area test pulse operation [2].

A limitation of this set-up, due to the high divergence of the laser, was that at best tracks with 70 μm RMS dispersion can be generated.

As in the tests made at Nikhef-H by J.C. Guo et al. [12] a strongly focused beam (see Fig. 2B) was used in order to generate very localized high density charge clusters and test the ability of the chamber to localize them. Drift resolution better than 50 μm could be checked in this way. No further effort was done in this direction because the resolution is already below the dispersion of the charge freed in a high energy track.

*)The photoelectrons drift in the plane of the field wires and are delayed by the field non-uniformities there present.

FIGURE CAPTIONS

FIGURE 1 - DRIFT CHAMBER VIEWS

- 1A - Perspective view of one of the luminosity drift chambers.
- 1B - Vertical cross section

FIGURE 2 - LAYOUT OF THE EXPERIMENTAL SET-UP

2A - Slightly focused laser beam

The laser is a PRA LN 100 Nitrogen laser. Its beam is reduced by a 3.5 times 15 mm rectangular collimator (C).

A fast timing photodiode (TPD) placed in the beam halo provides a precise timing pulse.

A two lens telescope made up by a 200 mm focal-length lens (L1) and a 100 mm focal length lens (L2) shrinks the beam and generates a long caustic in the drift chamber (DC) volume.

The beam profile, measured on heliographic paper, was almost rectangular and was found to be 1500 times 450 μm FWHM for the two external drift planes (cut AA' and DD') and 1100 times 300 μm FWHM for the internal two (cut BB' and CC').

Longer caustics could not be generated because of the high divergence of the laser.

2B - Strongly focused laser beam

A single-lens (L3) focalizes the laser beam into the first drift plane ; this geometry gives a very narrow focus but a short caustic.

With a 200 mm focal-length lens we had a beam profile of 175 ± 25 times 450 ± 100 μm FWHM over few mm of focal depth.

Because of the higher power density, in order not to generate an excessively high ionization, we had to add some attenuators (ATT).

4. CONCLUSIONS

The laser brings into the laboratory a good simulation of a test beam which is very useful for development and tuning. Coupled with precision movements it proved valuable for absolute calibrations.

It must be remembered that the physical process that frees the electrons in a high energy particle track is quite different from that in a laser beam. A laser beam frees electrons with an almost gaussian profile and no delta rays are generated.

As a consequence a laser test is by no means a test of the capability of a chamber as a particle detector but rather measures the capability of the chamber to reconstruct the position in which a charge is freed.

Nevertheless, the laser is useful to test the behaviour of the chambers and of the readout chain under extreme conditions.

The old high-divergence laser used here needed delicate optics and proved able to generate only short tracks.

A new generation of small diffraction-limited two-stage nitrogen lasers developed at CERN in collaboration with Mr. Neracher has made possible to generate caustics of a few microns diameter of alternatively sub-millimeter tracks over lengths of more than one meter.

These new generation nitrogen lasers^[11] virtually need no optics to generate long tracks and the same laser set-up can be used both in the laboratory for bench tests and in the experimental areas for continuous monitoring of the detectors.

5. ACKNOWLEDGMENTS

I'd like to thank Dr. D. Schinzel for initiating me in the drift chamber physics and their laser tests, Dr. P. Gutierrez for fruitful discussions, Mr. G. Caniac for his software support, Miss K. Morgan, Mr. A. Manarin and Mr. G. Vismara for the continuous technical support that made possible this work.

FIGURE 5 - DRIFT SPEED IN DIFFERENT CHAMBER CONDITIONS

- 5A - Drift speed versus drift field measurement
- 5B - Drift speed versus gas concentration measurement

FIGURE 6 - GAIN VERSUS SENSE WIRE HIGH VOLTAGE

The fit gives a factor of ten gain increase for 213 volts increase on the sense wire.

FIGURE 7 - CHARGE DIVISION RECONSTRUCTED POSITION VERSUS PULSE HEIGHT

The progressive attenuation of the laser beam showed that the normal resolution decrease due to the worsening signal to noise ratio was accompanied by an abnormal pulse-height dependent shift. This shift could then be corrected.

FIGURE 8 - SINGLE ELECTRON RESPONSE SPECTRUM

The laser is attenuated down to 20% efficiency so that the poissonian probability of a double photon contamination is less than 1%.

The charge sensing ADC is gated by the delayed laser timing signal.

The pedestal, almost confined in 1 channel, has been depressed by a factor of 100.

The fit, performed with a Polya function, converged for a parameter $b = 1.64$ and a mean gain of 330.000.

FIGURE 3 - DRIFT SPEED MEASUREMENT

Drift speed calibration plots.

3A - Drift plane 1

The huge photoelectric signal is visible in correspondance with the field wires that are near the sense wire.

The photo-electrons coming from far away are slowed down by the electric field non-uniformities surrounding the field wires. Thus they are not visible to the peak-sensing read-out. Since the photoelectron component of the signal affects only the trailing edge of the pulses, the drift-speed measurement is not perturbed on the first plane.

3B - Drift plane 3

On the other planes the laser beam is shadowed by the wires of the first one, both the in-gas and photoelectric signals are weakened in correspondance with the field wires and the time digitalization is either missed or triggered by the delayed photo-electrons.

FIGURE 4 - STANDARD CHAMBER TESTS

The calibration of all the four drift planes is done at the same time. A complete test lasts about one hour per chamber.

4A - Drift speed measurements

The measured points have been taken at 2 mm steps firing thirty shots per position. The drift-time dispersion of each position (not visible in this scale) is of the order of 1-2 ns. The deviation from the fit of the measured points is shown on the expanded scale.

4B - Charge division calibration

The amplifier dependent calibration constants of charge division are determined with this measurement.

A 2% non linearity of the charge division readout required a quadratic fit.

The dispersion of the measured points and their deviation from the fit are shown separately on the expanded scale.

- [12] J.C. Guo et al.
NIKHEF - H/82-35 (1982), Amsterdam

- [13] R. Desalvo et al.
CERN report, UA1/TN82-19 (1982)

- [14] R. Bouclier et al.
Submitted to N.I.M. (1982)

- [15] A. Peisart
Cerenkov ring imaging for particle identification in the investigation
of elementary parton-parton interaction Thesis n. 2056
presented at the University of Geneva, 1982 (available at CERN).

- [16] W. Legler
Brit. J. Appl. Phys. 18, (1967) 1275

- [17] G.D. Alkhzov
N.I.M., 89, (1970), 155

B I B L I O G R A P H Y

- [1] K. Morgan
CERN report UA1/TN82-35 (1982)

- [2] A. Manarin et al.
Report presented to the Vienna Wire Chamber Conference (1983)

- [3] H. Anderhub et al.
N.I.M., 166, (1979), 581

- [4] H. Anderhub et al.
N.I.M., 176, (1980), 323

- [5] H.J. Hilke
N.I.M., 174 (1980), 145

- [6] J. Bourotte, B. Sadoulet
N.I.M., 173, (1980), 463

- [7] M. Desalvo, R. Desalvo
N.I.M., 201 (1982), 357

- [8] C. Cochet et al.
CERN report UA1/TN82-14 (1982)

- [9] B. Sadoulet
Physica Scripta, 23, (1981), 434

- [10] T. Markiewicz et al.
CERN report UA1/TN82-20 (1982)

- [11] D. Brozzi et al.
CERN report UA1/TN82-14 (1982)

Fig. 1 B

Fig. 2A

Fig. 2B

FIG. 3 B

FIG. 3 A

Fig. 4A

Fig. 4B

Fig. 5A

Fig. 5B

Fig.6

Fig.7

Fig. 8