Charge Division measurements in a 2 m long CDC prototype for z-position tracking in GlueX

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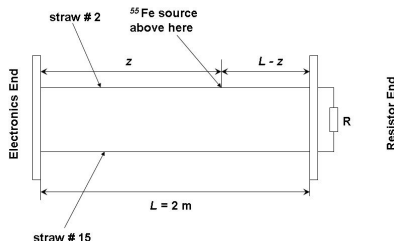GlueX Collaboration Meeting

Outline

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Schematic Setup of Charge Division

- X-ray radiation from ^{55}Fe source ionizes (Ar/CO_2) gas mixture inside straw tube.

- Electrons drift towards the wire inside straw tube held at a positive high voltage (HV $\sim$ 1650 V). Net charge "Q" accumulated at position z.

- Charge Q has two ways to flow out to the HV board at the "electronics end" :

  – flow out *directly*, $R_{dir} = \rho z$
  – flow out thru' *coupled wire*, $R_{indir} = \rho(L - z) + R + \rho L$

R – resistance coupling the two wires; ρ – resistance/length of wire; L – length of each wire

CHARGE DIVISION FORMULA

- If q_{dir} and q_{indir} are the charges flowing out at the two ends, then the charge is *inversely proportional* to the resistance:

$$\frac{q_{dir}}{q_{indir}} = \frac{R_{indir}}{R_{dir}} \quad (Q = q_{dir} + q_{indir})$$

- Convert charge into signal amplitude $\mathcal{A}$ by a pre-amplifier, so that:

$$\zeta(z) = \frac{\mathcal{A}_{dir}}{\mathcal{A}_{indir}} = \frac{R_{indir}}{R_{dir}} = \frac{\rho(2L-z)+R}{\rho z}$$

- Thus, the measured signal ratio $\zeta(z)$ should be a linear function of $1/z$ with a slope of -1.

- Our aim is to do a "$\zeta(z)$ vs. z" calibration for several different "coupled straw pairs" and then use these calibration curves for z-position tracking later on.

OUTLINE
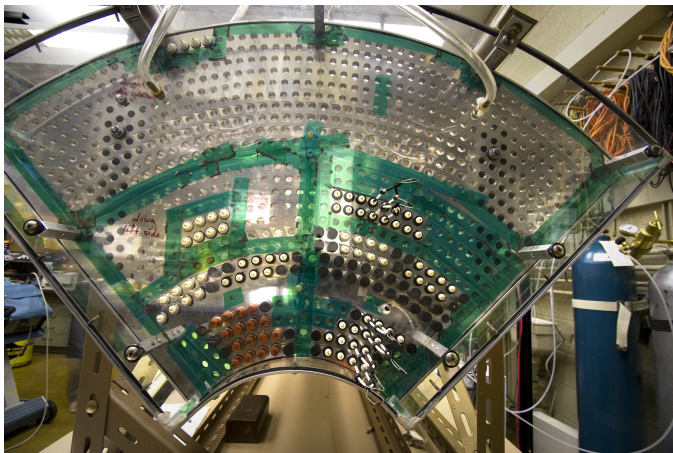
1 INTRODUCTION

2 EXPERIMENTAL SETUP

3 INITIAL RESULTS

4 FINAL RESULTS

5 SUMMARY
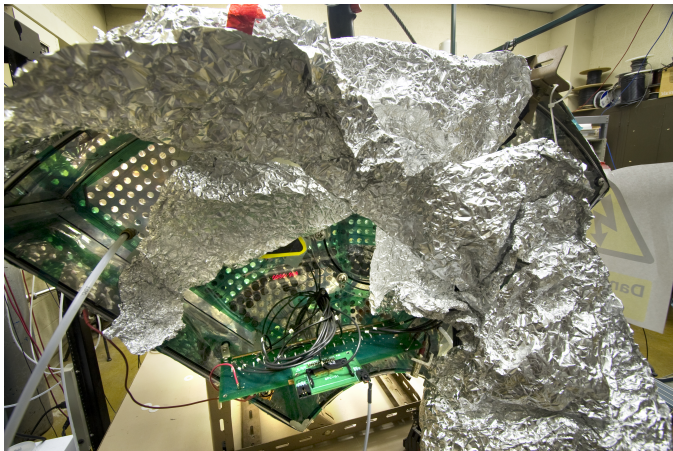
THE CDC PROTOTYPE
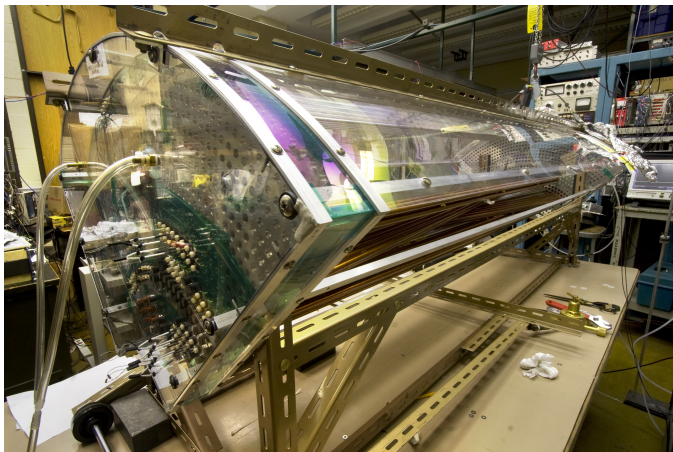
The 2 meter long Central Drift Chamber (CDC) prototype at Carnegie Mellon

THE "RESISTOR END"

The "resistor end" of the prototype. The coupled straw tube pairs,

using resistors ($\sim 50\ \Omega$) can be seen here.

THE "ELECTRONICS END"

The "electronics end" of the prototype. The High Voltage (HV) board can be seen here. The interposer is not connected though. Also note the Aluminum foil, for noise insulation.

THE CDC PROTOTYPE CONTD.
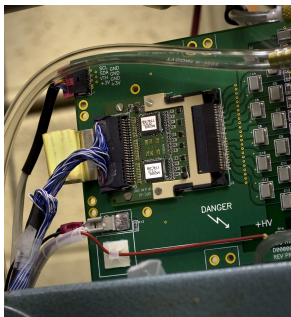
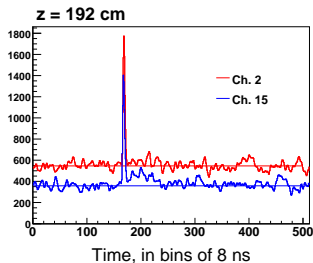The %2 interposer (connected to a different HV board here).


The ^{55}Fe source with the collimator.

Outline

1. Introduction

2. Experimental Setup

3. **Initial Results**

4. Final Results

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# SIGNALS FROM COUPLING CH.2 AND CH.15

z = 192 cm

Time, in bins of 8 ns

- Couple Channels 2 and 15
- Read out signals from flash-ADC
- ^{55}Fe source above Channel 2
- Signal in Channel 15 is the reflected signal by Charge Division

SIGNALS FROM COUPLING CH.2 AND CH.15
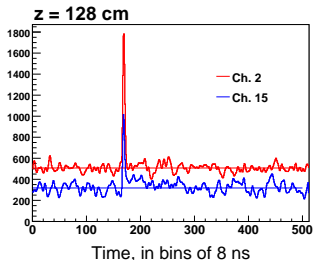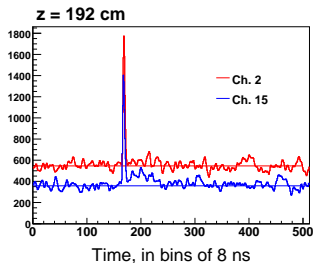
z = 192 cm

- Couple Channels 2 and 15
- Read out signals from flash-ADC
- ^{55}Fe source above Channel 2
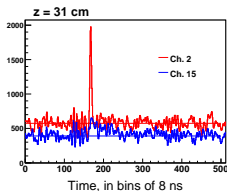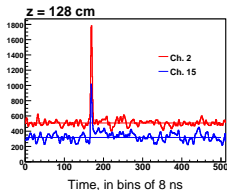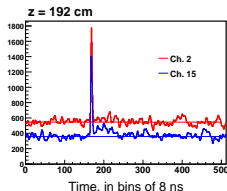- Signal in Channel 15 is the reflected signal by Charge Division
- Do this for different z-positions
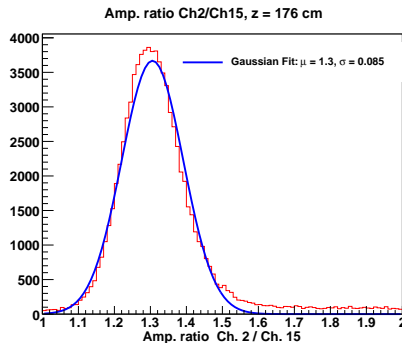

z = 128 cm

z = 31 cm
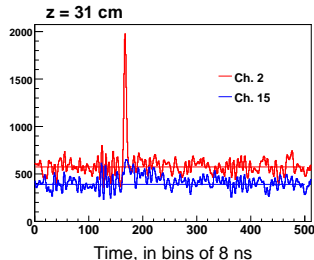
SIGNAL FEATURES

- Signal in Ch.2 is always higher, as expected, because source is above Ch.2

- As z decreases, the ratio $\mathcal{A}_2/\mathcal{A}_{15}$ increases – also, as expected from our Charge Division formula

- Both channels have a "tail" (more prominent for Ch.15)

- Significant presence of noise (we tried to insulate the HV board as best as we could)

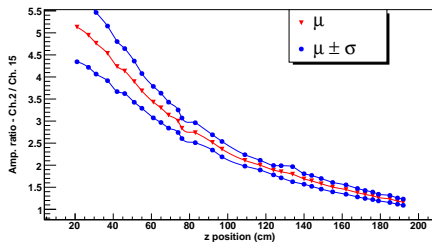- At lower z, the noise level is comparable to the signal in Ch.15

CALIBRATION PROCEDURE

- For every event, extract the ratio $\zeta = \mathcal{A}_2/\mathcal{A}_{15}$
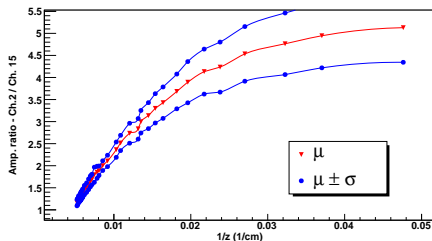
- Plot the $\zeta(z)$ distribution for a given z:

Amp. ratio Ch2/Ch15, z = 176 cm

Gaussian Fit: $\mu = 1.3$, $\sigma = 0.085$

Amp. ratio Ch. 2 / Ch. 15

- μ and σ from a Gaussian fit gives estimated values of ζ and $\Delta\zeta$ at that z.

CALIBRATION CURVE

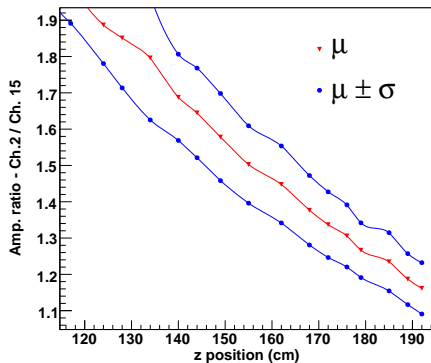Plot $\zeta(z)$ vs. z

Plot $\zeta(z)$ vs. $1/z$

CALIBRATION CURVE CONTD.
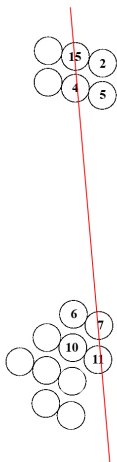
A zoomed in look at $\zeta(z)$ vs. z

Estimated $\Delta\zeta$ resolution from this method is $\sim \pm 10$ cm, or $\approx 2.5\%$.

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THE FOUR PAIRS OF COUPLED STRAWS

- Straws (channels) with broken wires, dead spots, sagging, etc. limited our choice

- We finally chose four pairs of adjacent straws to couple. These are given below:

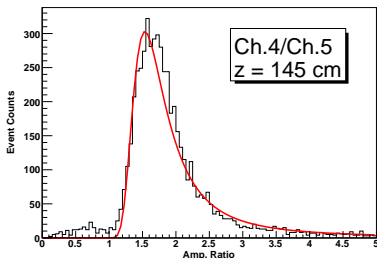| Coupled channels	^{55}Fe source placed above
Ch. 15, Ch. 2	Ch. 15
Ch. 4, Ch. 5	Ch. 4
Ch. 7, Ch. 6	Ch. 7
Ch. 11, Ch. 10	Ch. 11

View from the "resistor end"
(hypothetical track in red)

GAUSSIAN VS. LANDAU FITS

- Recall, that we extract a mean $\bar{\zeta}$ by fitting the ratio distribution to a Gaussian.
- For the pair Channel 4/Channel 5, it seems that a Landau fit works better than a Gaussian
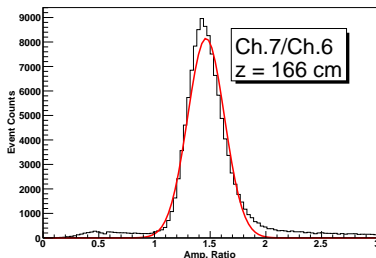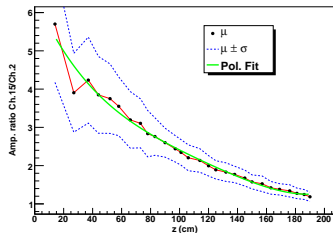

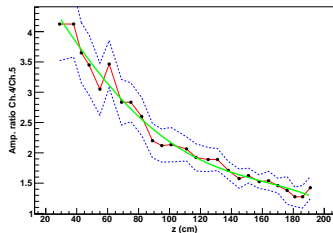Gaussian fit   Landau Fit

- A *possible reason* for this behavior could be that straw #4 lies beneath straw #15 and this causes additional scattering
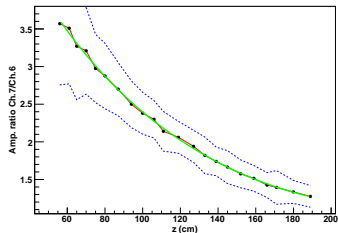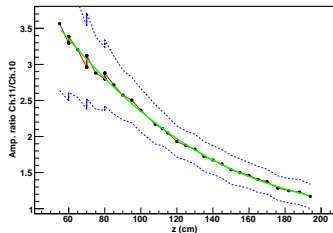
Final calibration curves
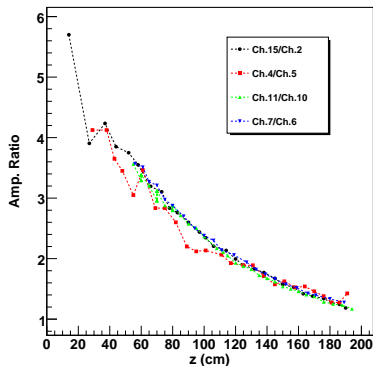
Comparison

- Compare all four calibration curves:

- Good agreement for all four pairs.
- Ch.4/Ch.5 looks noisiest. However, this *might* be due to the same reason given earlier.

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To Summarize...

- We have carried out Charge Division measurements with a 2 *m* prototype of the Central Drift Chamber prototype for GlueX

- Our studies show that we can get $\approx \pm 10$ *cm* resolution in *z*-position using this method

- However, we know that this prototype has issues with noise, so even this result looks very encouraging

- In the final version, we have calibrated four pairs of coupled straw channels that are geometrically collinear

- Current results are documented in GlueX-doc-1220 and GlueX-doc-1332.

- We are currently in the process of taking cosmic ray data to do tracking using the calibration curves that we have obtained here

AMPLITUDE RATIO VS. INTEGRATED ENERGY RATIO