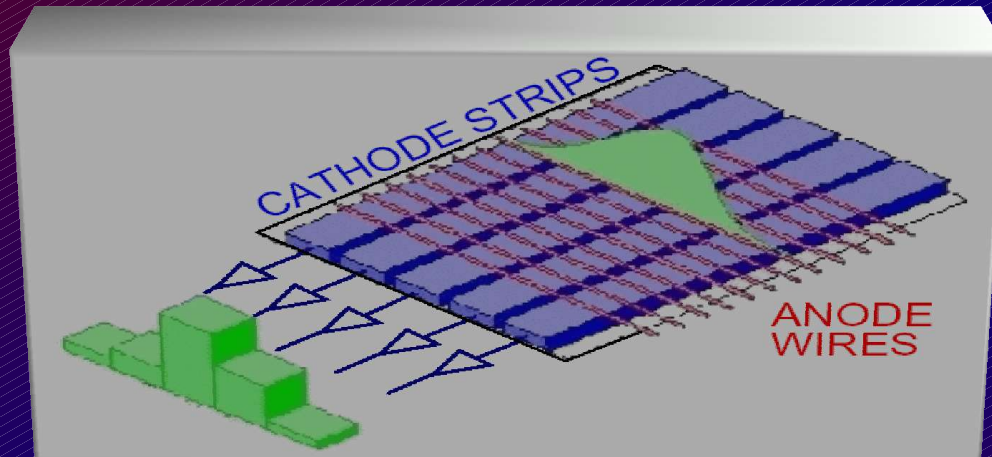


FDC Status



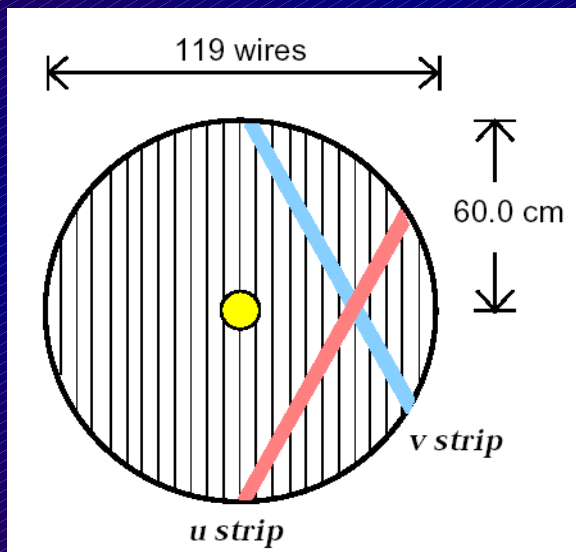
Simon Taylor and Daniel S. Carman
Ohio University

GlueX meeting
November 10, 2005

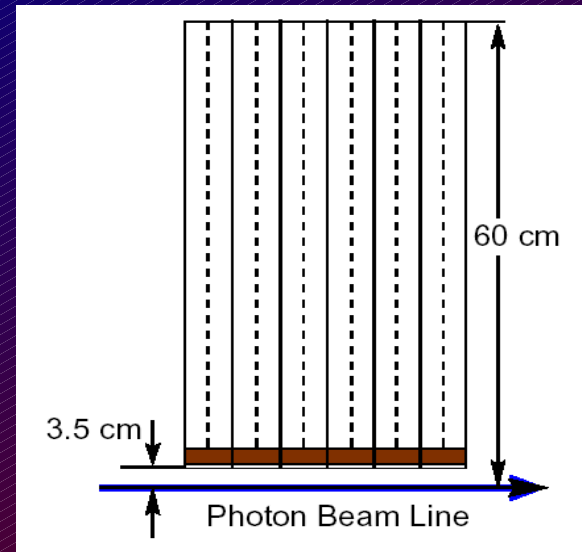
Overview

- Purpose: measure momenta of forward-going tracks up to $\sim 20^\circ$ (relative to photon beam line)
 - Sandwich design: 6 layers/package
 - Each layer: cathode / anode / cathode
 - Cathode planes divided into strips
 - Nominal configuration: read out strips with Flash ADCs, anode wires with TDCs
 - Adjacent layers rotated by 60° with respect to each other
 - 4 packages (currently) equidistant along z

Front



Side

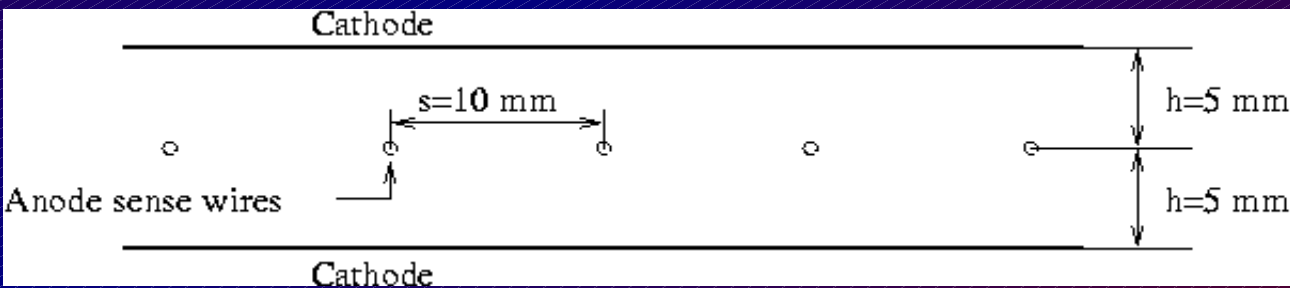
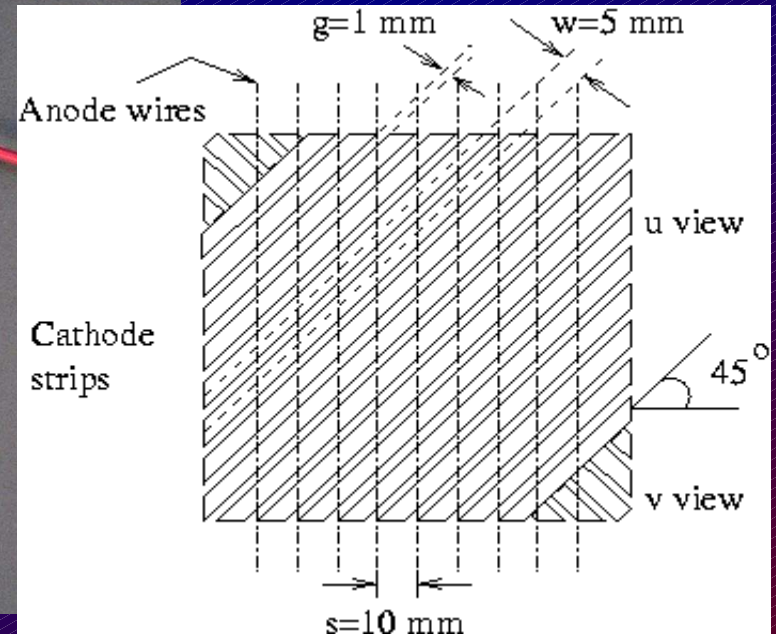
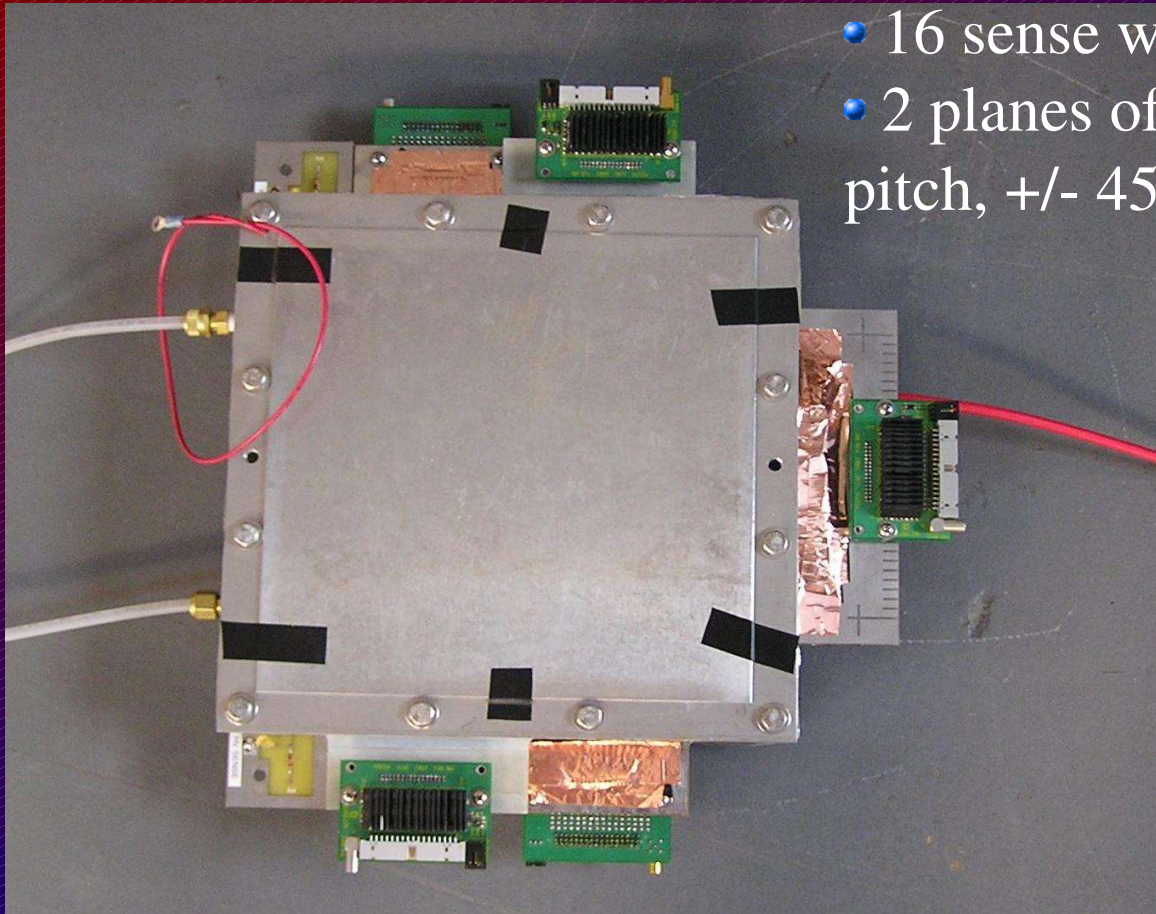


FDC design parameters as of Oct 24

Parameter	Value
Wire spacing s	10 mm (anode-anode), 5 mm (anode-field)
Anode-cathode distance, d	5.0 mm
Cathode readout pitch, w	5.0 mm
Gap between cathode strips, w_g	1.0 mm
Width of cathode strips	4.0 mm
Capacitance between strips	21 pF/m
Total strip capacitance	56 pF/m + 8 pF
Resistance between strips	$\sim 20 \text{ M}\Omega$
Anode wire radius, r_a	0.010 mm
Wire capacitance per unit length, C_0	$\sim 9 \text{ pF/m}$
Gas gain	5×10^5
Operating voltage at nominal gain	1800 V
Electric field at cathode, E_c	$< 1 \text{ kV/cm}$
Electric field on anode wire surface	280 kV/cm
Field-shaping wire radius	0.040 mm
Electric field on field-shaping wire surface	15 kV/cm
Positive ion mobility, μ^+	$1.3 \text{ cm}^2/\text{V/s}$
Total ion pairs	94/cm
Minimum wire tension	50 gm
Total charge collected	$\sim 15.5 \text{ pC}$
Charge collected in 30 ns (%)	$\sim 20\%$

FDC prototype

- 16 sense wires with 10 mm pitch
- 2 planes of 32 cathode strips with 5 mm pitch, $\pm 45^\circ$ with respect to the wires

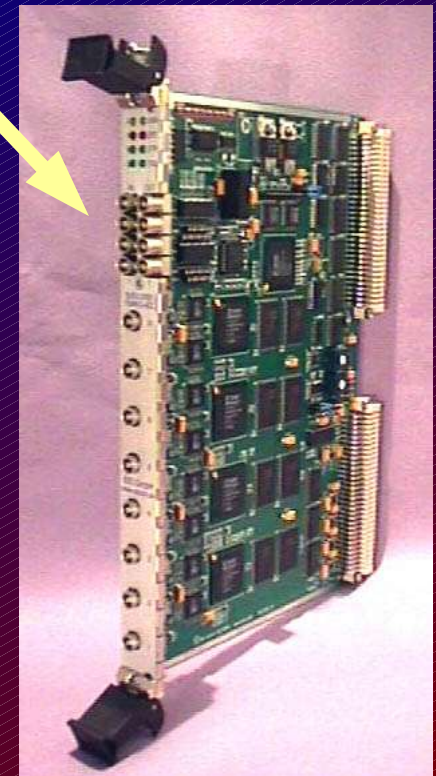
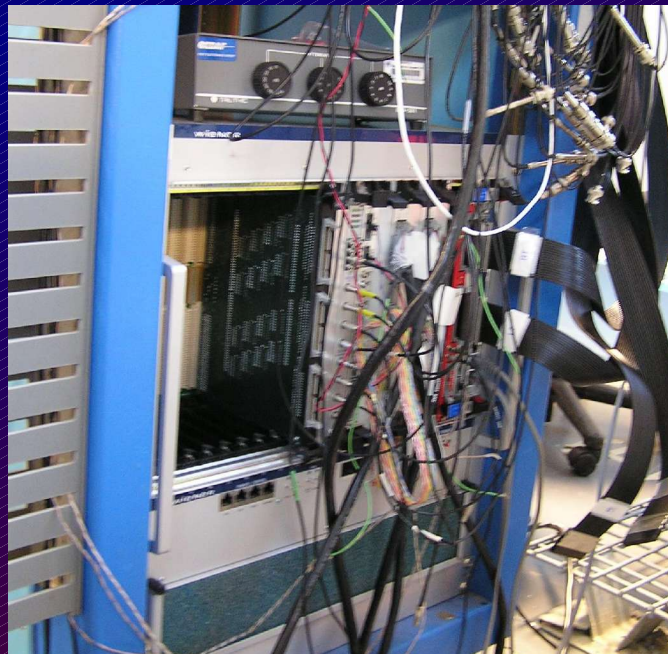


Goal: measure space point with $<150\ \mu\text{m}$ resolution in each coordinate

Standard configuration in literature: no field wires...

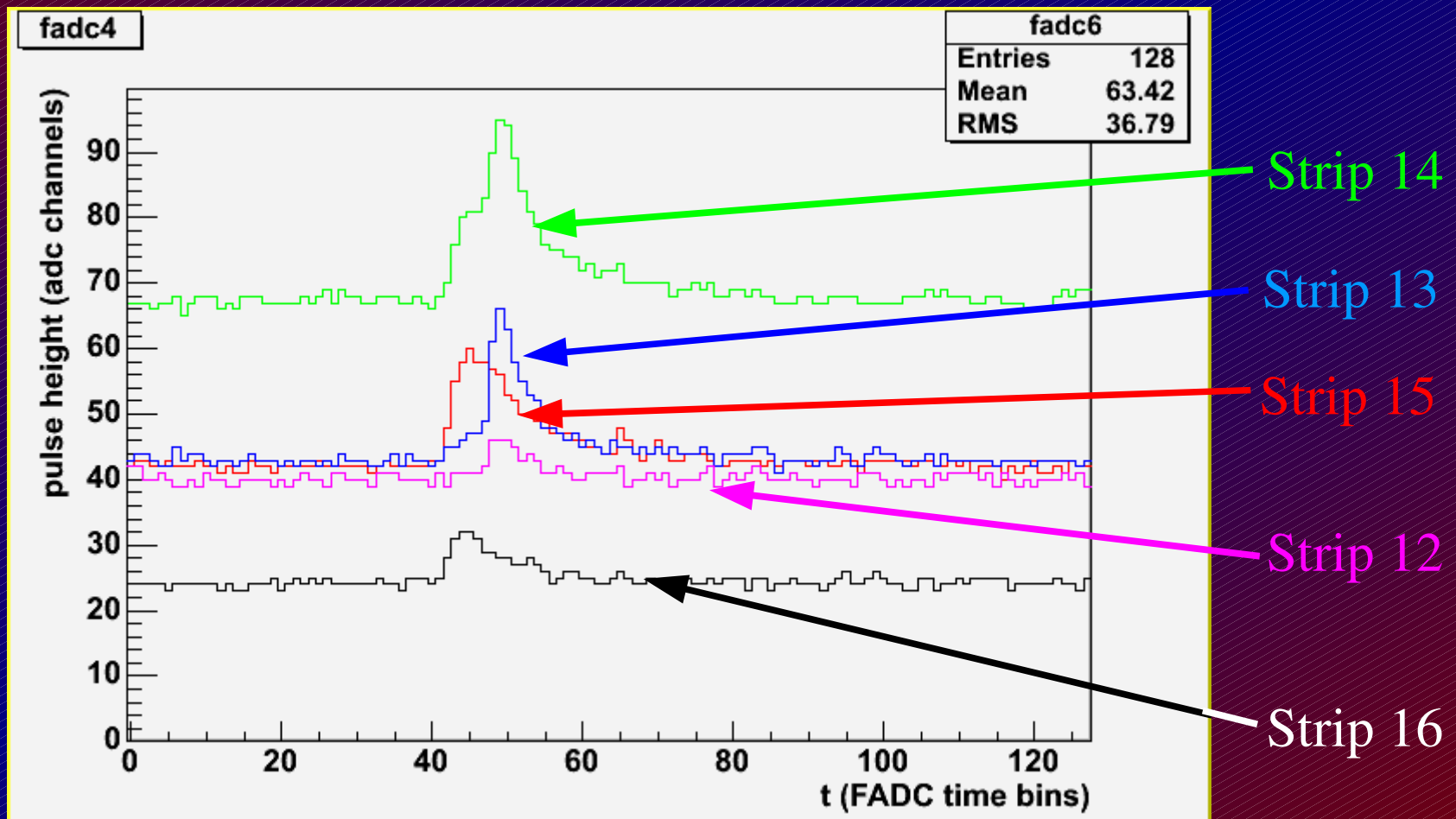
Upgrades to FDC daq

- Readout hardware completely in VME (no more FASTBUS!)
 - Cathode signals integrated using CAEN V792 (charge-integrating) ADCs
 - FDC anode wire timing signals and test stand chamber signals digitized using F1 TDC modules
 - Some cathode signals read out with **Struck SIS3300 FADC**
 - 8 channels @ **105 MHz** per channel
 - (1 MHz - 105 MHz configurable)
 - 2 banks x 128K samples/channel memory
 - $0 \leftrightarrow -5$ V input range



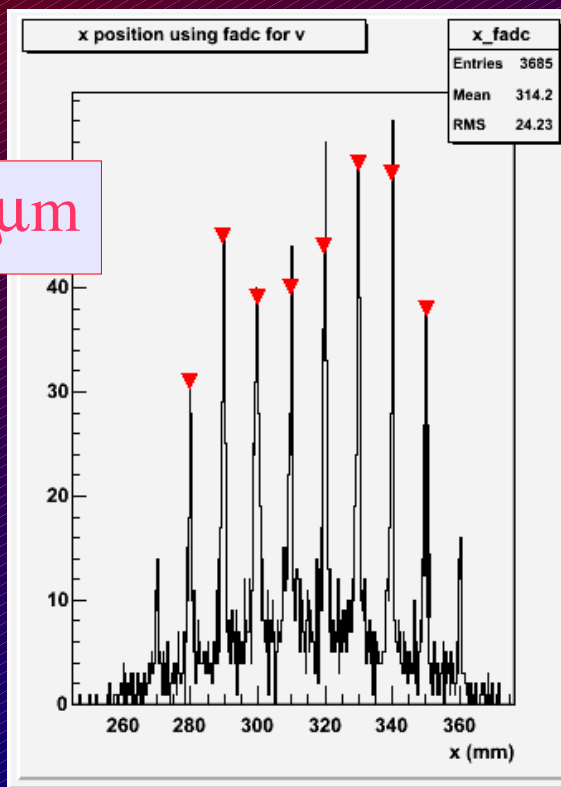
Sample Event with FADC readout

Six adjacent strips (11-16 on top view) read out with Flash ADCs.
(minimum postamp gain for comparison to previous data)



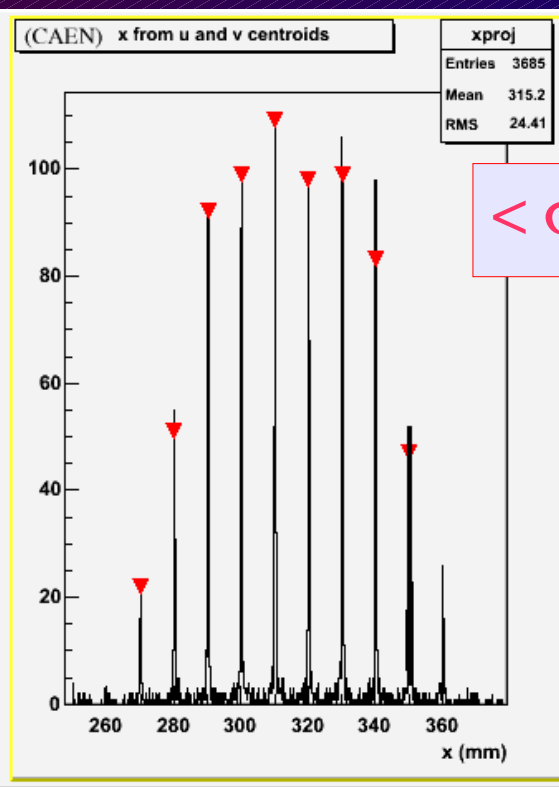
Position resolution (no cut on #wires)

$\langle \sigma_x \rangle = 549.3 \mu\text{m}$



FADC readout
for one view

$\langle \sigma_x \rangle = 173.2 \mu\text{m}$



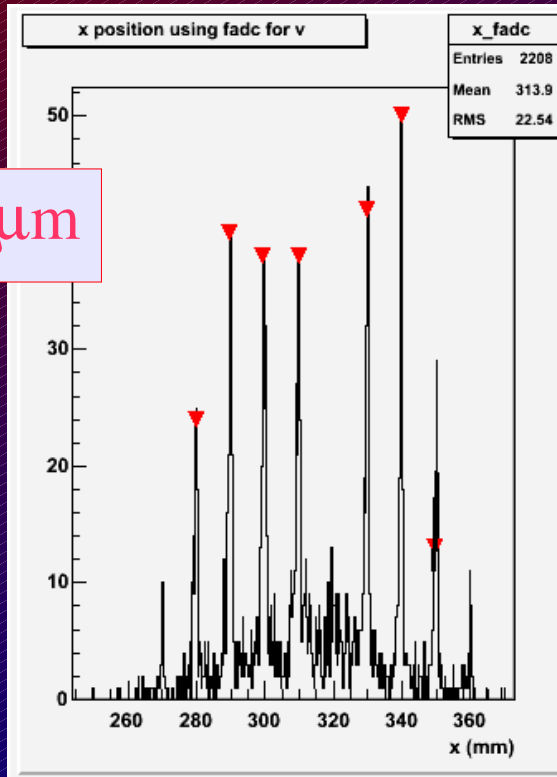
CAEN readout
for both views

VPI postamp
set to minimum
gain (≈ 1)

x (mm)	σ_x (with FADC) (μm)	σ_x (w/o FADC) (μm)
270.1	660.8	175.5
280.1	464.1	174.3
290.2	558.8	168.5
300.1	630.1	176.9
310.1	672.2	199.5
320.1	682.5	171.8
330.2	487.3	149.8
340.2	373.3	161.7
350.2	427.1	180.5
average:	549.3	173.2

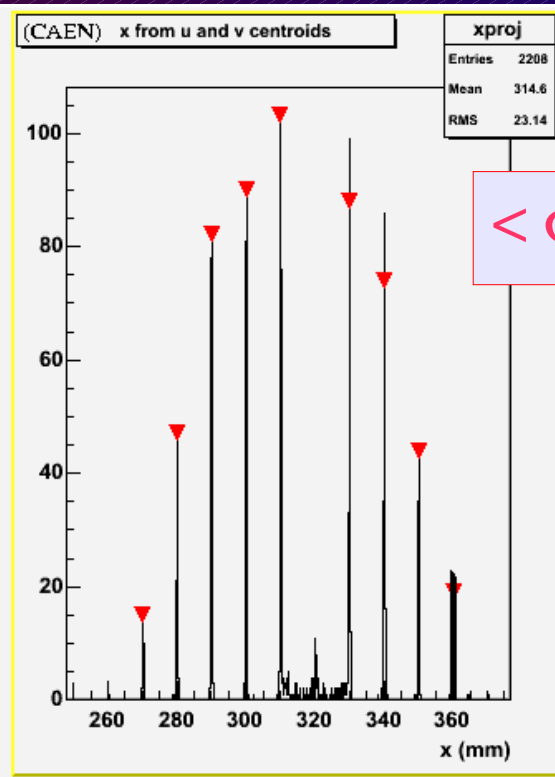
Position resolution (one wire required)

$\langle \sigma_x \rangle = 505.8 \mu\text{m}$



FADC readout
for one view

$\langle \sigma_x \rangle = 151.5 \mu\text{m}$



CAEN readout
for both views

VPI postamp
set to minimum
gain (≈ 1)

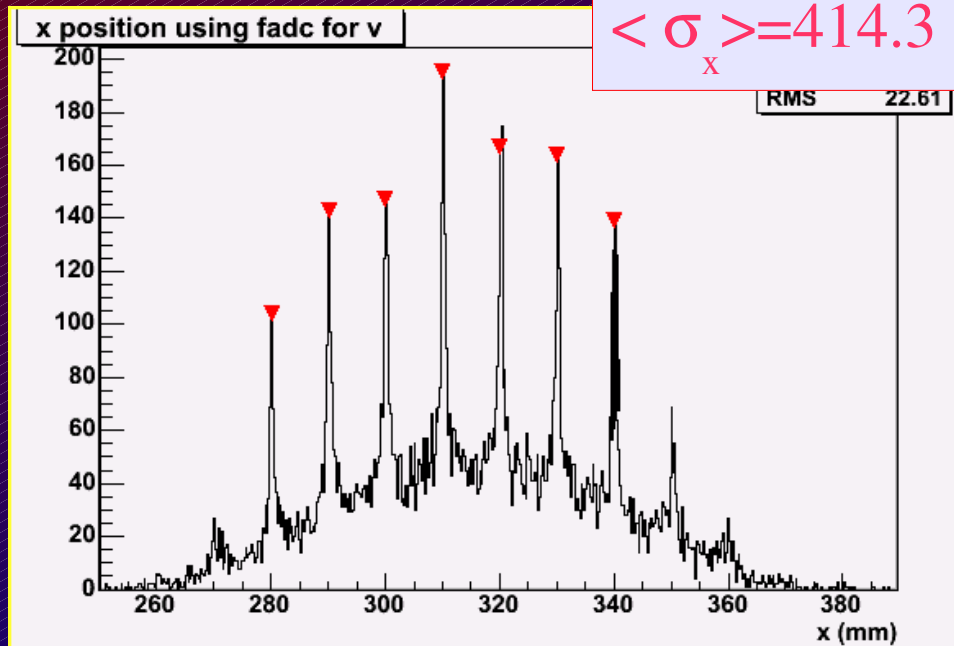
x (mm)	σ_x (with FADC) (μm)	σ_x (w/o FADC) (μm)
270.1	398.6	159.0
280.1	560.6	150.9
290.1	489.1	156.6
300.1	760.0	162.9
310.2	644.5	175.6
330.2	444.0	145.6
340.2	349.6	150.3
350.2	640.6	144.4
360.2	265.8	117.8
average:	505.8	151.5

Design
resolution
achieved!

Effect of increasing postamp gain

Increased postamp gain to maximum for strips read out by FADC

- Postamp gain ~ 6-8

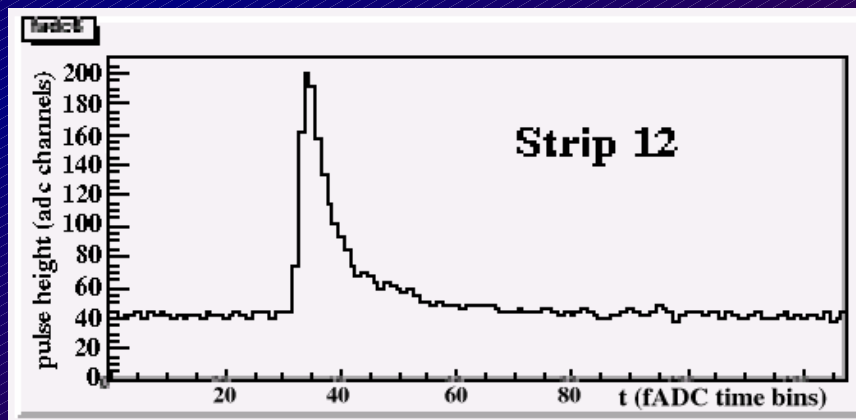


$\langle \sigma_x \rangle = 414.3 \mu\text{m}$ ← compare to 549.3 μm

No cut on # of anode wires

x(mm)	$\sigma_x(\mu\text{m})$
280.1	362.6
290.2	457.1
300.1	397.2
310.1	394.4
320.2	403.3
330.2	477.9
340.2	407.7

Sample FADC distribution:

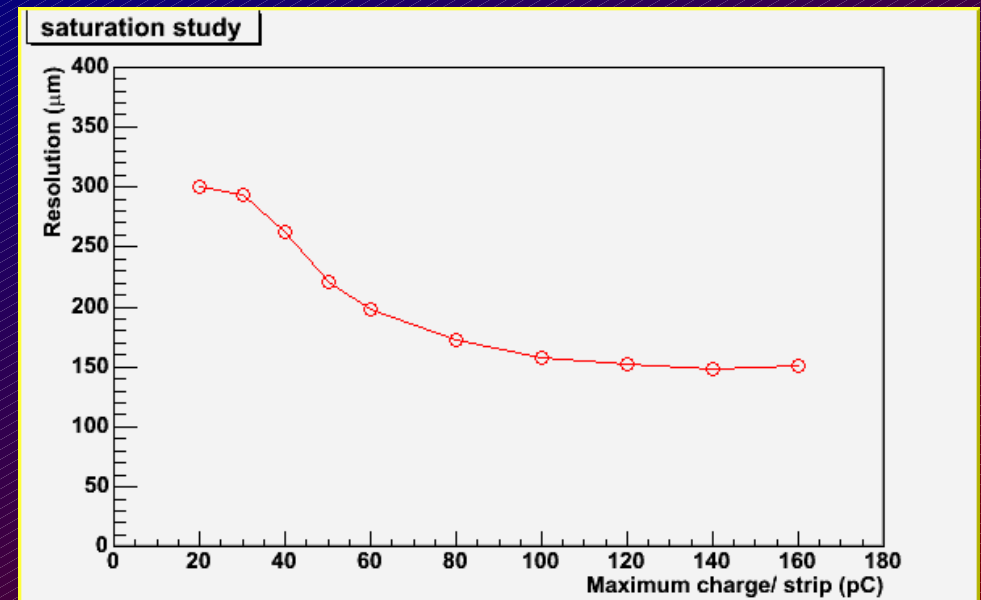
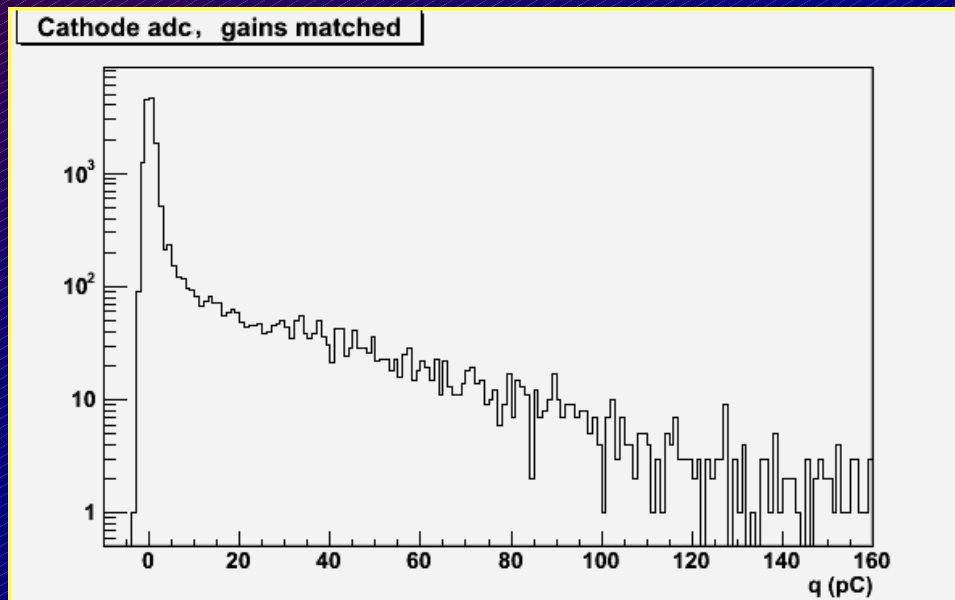


Pulse heights still cover small fraction of 12 bit range
 → modify input range of FADC (to 0 \leftrightarrow -0.5 V?)

Charge saturation study

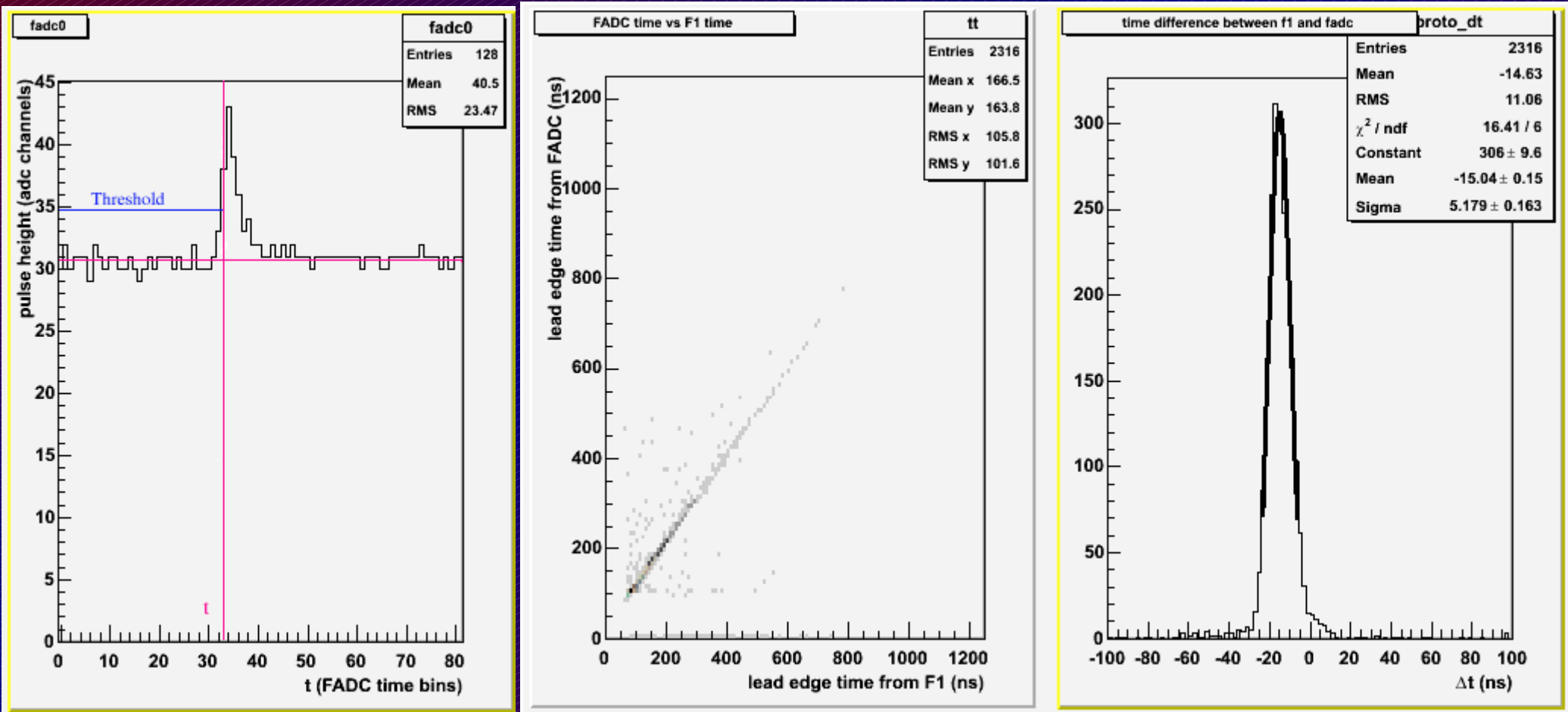
Studied effect of “clipping” of cathode strip signals

- Varied maximum charge allowed per strip
- Strip charge set to maximum if it exceeds this threshold
- Used CAEN ADCs for both views
- Required only one anode wire/event



Leading-edge timing for Wire 11

- Used low gain output of postamp for flash ADC
- Flash ADC time: center of bin at which pulse height exceeds 4 counts above background.
- Compare to time from F1 TDC using leading-edge discriminator

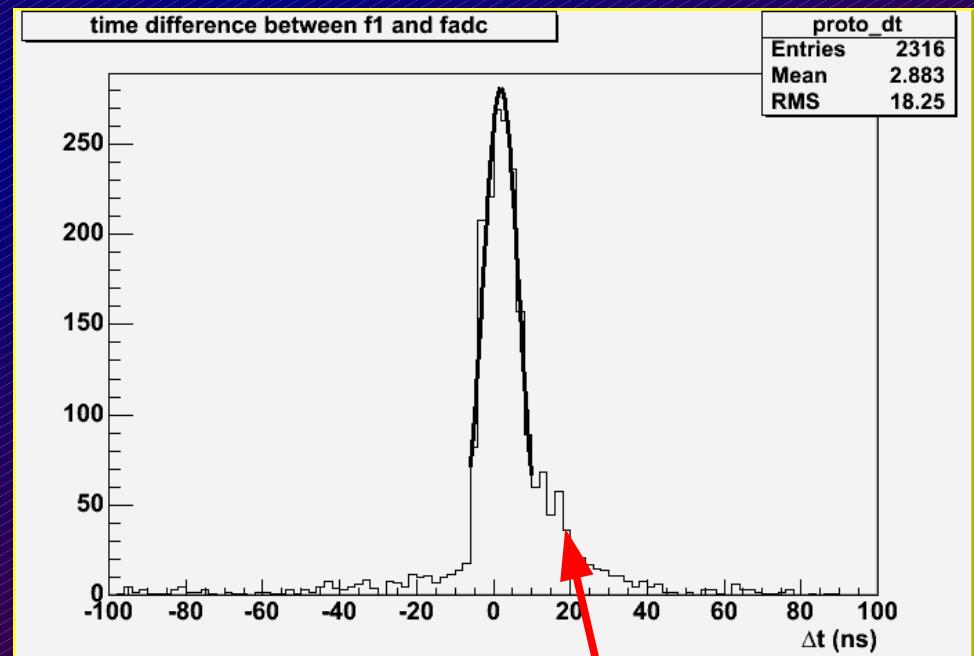
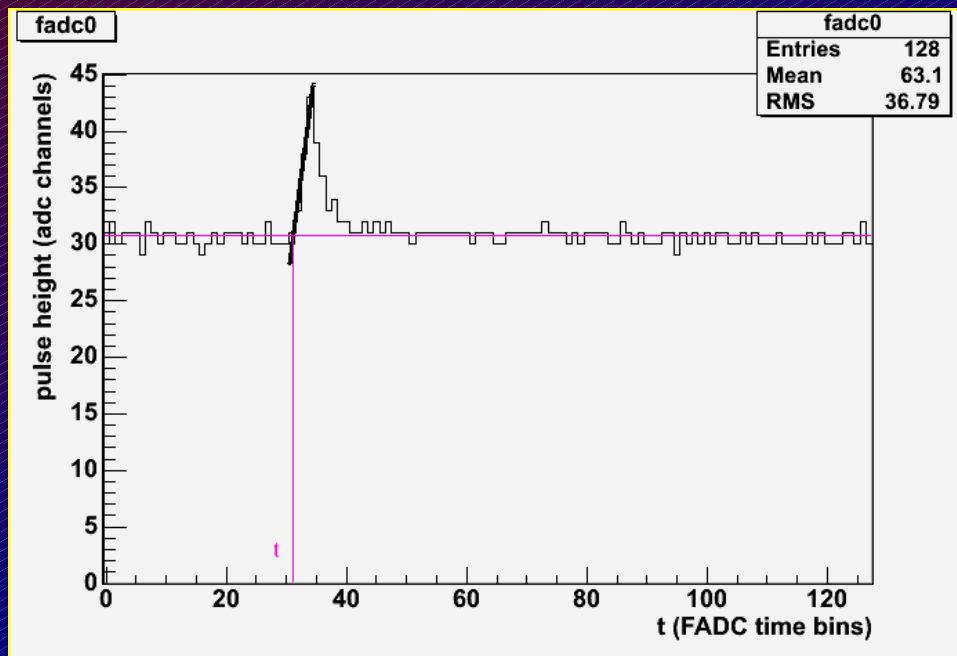


Resolution of timing peak ~ 5.2 ns...

Wire 11 timing, method 2

Linear fit starting at time bin containing maximum amplitude and 2 bins before, extrapolate to point where line crosses background level.

Same postamp gain condition as before

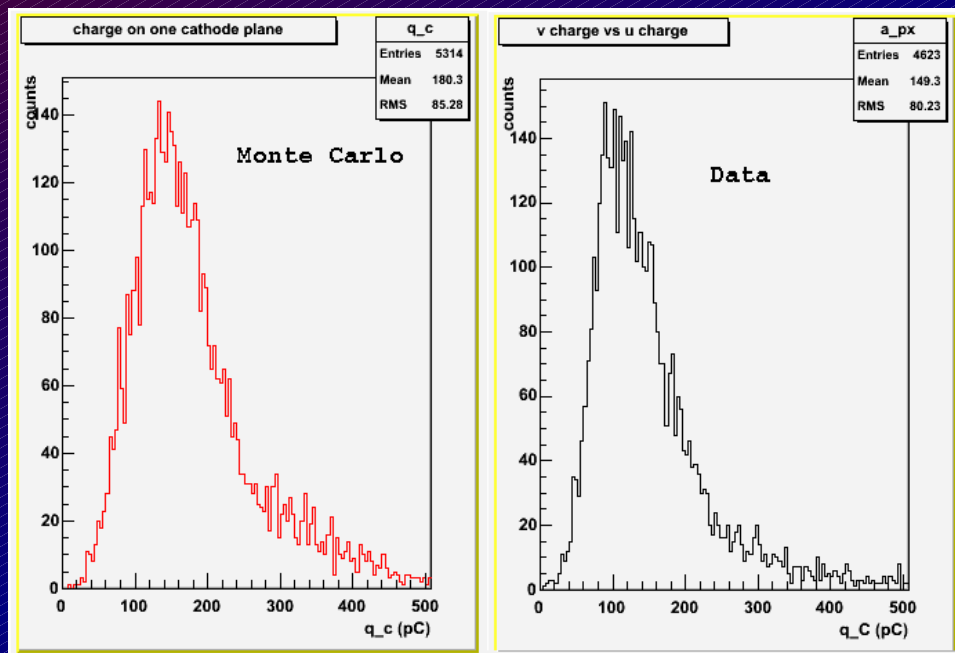


Asymmetric tail...

Resolution ~ 4.7 ns, no better than simple leading edge method

Monte Carlo development

- Modifications to HDGeant:
 - Approximation for ion-pair statistics → Compound Poisson Distribution
 - Ignore time-development of anode signal
 - Gas gain based on prototype studies using Sauli gain formula
 - Induced charge on cathode planes based on Gatti/Mathieson formula
 - Overlapping distributions summed in strips where overlap occurs



Purpose: to provide more realistic hits for development of FDC reconstruction algorithms and for use in tracking instead of cheat hits...

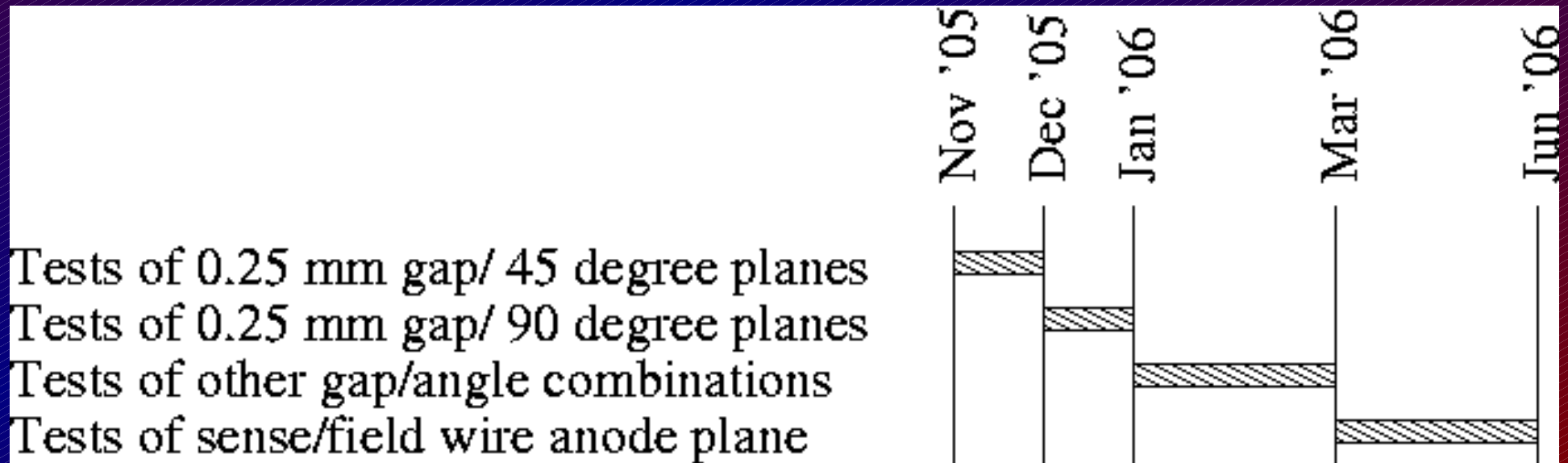
Induced charge on one cathode plane
(~minimum ionizing particles)

Electronics meeting at Ohio U.

- GEANT simulations (Ryan Mitchell) → factor for estimated range of expected signals:
 - CDC=30, FDC anodes=10, FDC cathodes=100
- Need full simulation: track through gas volume → clumped ionization → drift trajectories → current waveforms
 - Optimize preamp shaping time / sampling rate / bit depth
- Want dE/dx information from FDCs to plug PID holes
 - Problematic to use cathodes?
 - Recommended instrumenting anode readout with Flash-ADCs
- Timing: goal = 2 ns resolution → need 125 Msample/s FADCs?
- Gerard Visser: preliminary design for 65 Msample/s FADC
 - 96 channels in 6U VME64x module
- Proposed purchase more Struck FADCs for prototype studies
- Full scale FDC prototype design: how make/support cathode planes?

Plans for immediate future

- Study different gap configurations (gap between cathode strips)
 - Compare 1 mm gap to 0.25 mm (currently in place) and 0.5 mm
- Study different strip orientation (45° w.r.t. wires or 90° w.r.t. wires?)
 - 0.25 mm gap with 90° orientation next set to be studied
- Study different wire plane configuration (alternating sense/field wires)
 - Repeat tests with various cathode planes
 - Can we obtain same resolution as for sense-wire only configuration?



Biasing the cathode boards

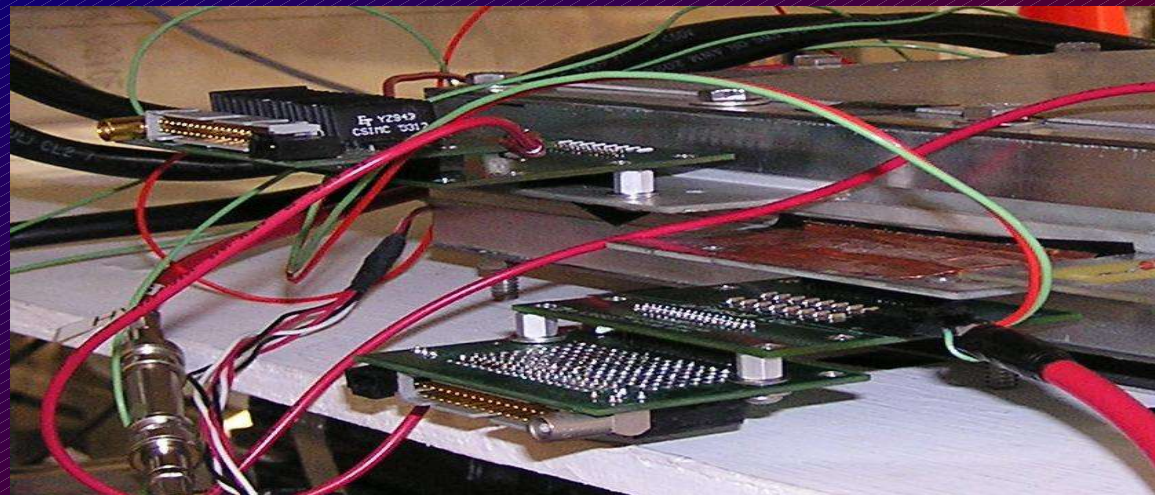
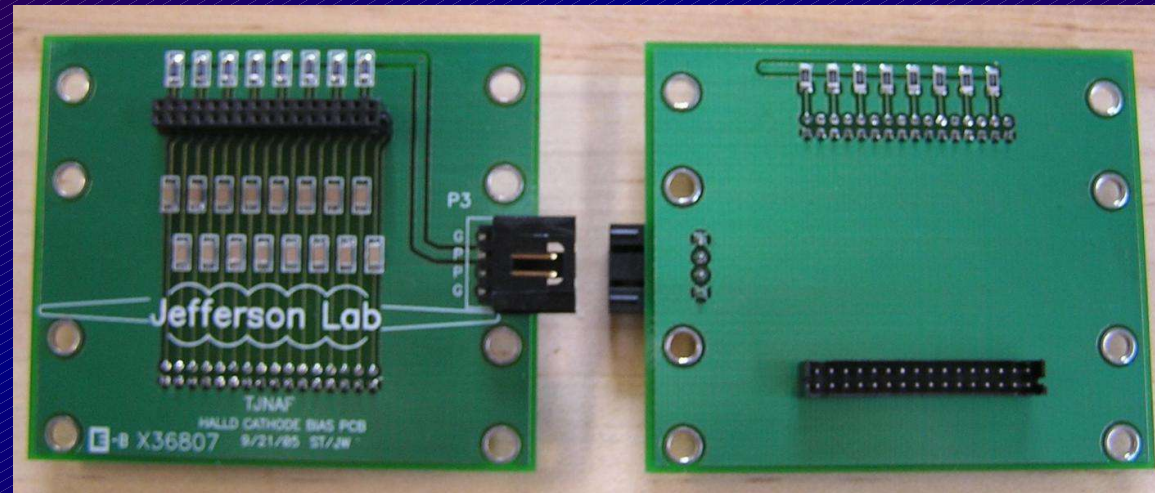
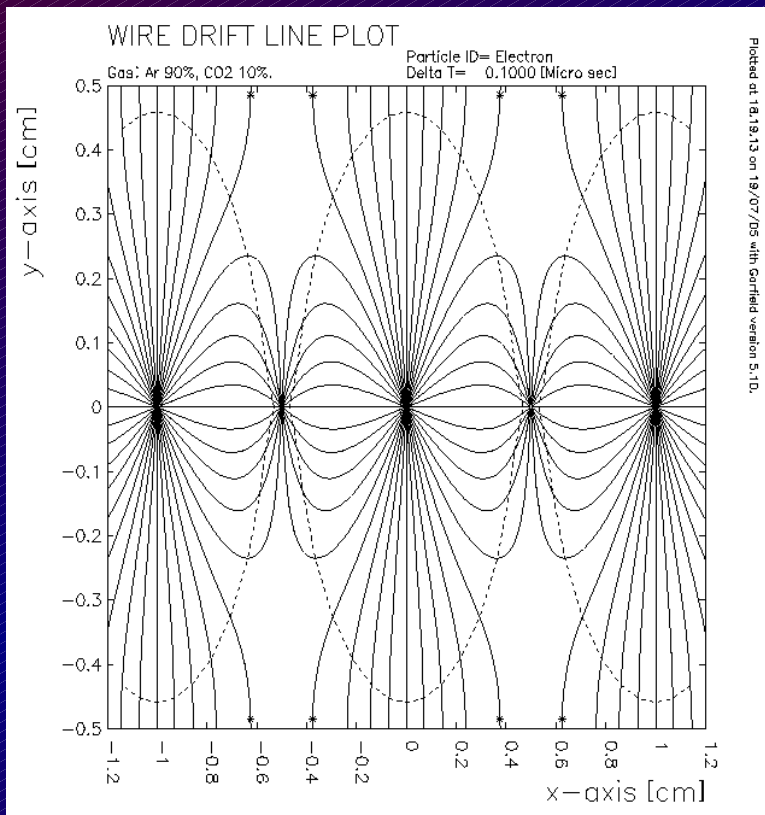
Planned anode plane configuration: both sense and field wires

- For optimal electric field configuration, need to bias cathode planes

Intermediate board designed by Jeff Wilson:

Garfield calculation with

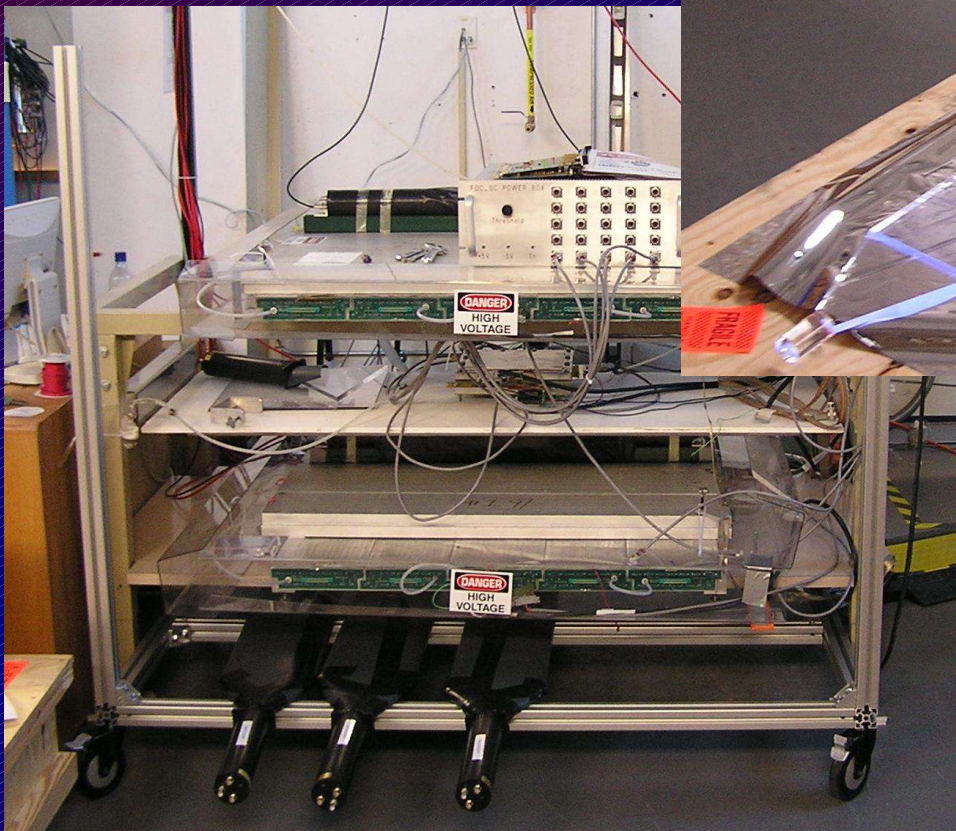
$$V_s = +1500 \text{ V}, V_f = -750 \text{ V}, V_c = -200 \text{ V}$$



Scintillator hodoscope upgrade

12 scintillator array under construction

- Each scintillator = 1.3 cm × 20 cm × 120 cm
- 6 above prototype, 6 below
- Designed to cover 1.2 m diameter full-scale FDC prototype
- Plan: study resolution vs. angle of incidence



New HV
mainframe:



Three-year plan

- Stage I: detailed studies of small-scale prototype
 - Goal: optimize chamber electrode structure to satisfy resolution requirement
 - Define chamber pulse characteristics
 - Define necessary electronics capabilities
 - Define operating points for different gas mixtures
 - Time frame for completion ~ 1 year
- Stage II: design and construction of full-scale prototype
 - Determine method for supporting cathode strips over 1.2 m with $\sim 50 \mu\text{m}$ level flatness
 - Complete circuit board design
 - Cosmic ray tests with wide trigger scintillator coverage
 - Tests in magnetic field
 - Beam tests for dE/dx studies
 - Time frame for completion ~ 3 years
- Personnel: Simon Taylor and Daniel S. Carman, Ohio U.
 - **Need additional design manpower to complete project within time frame!**

Very Preliminary Budget guesses

- Stage I R&D: ~ \$20K
- Stage II R&D:
 - Wire: \$15K
 - Cables: \$10K
 - PC boards : \$30K?
 - Flex boards: \$40K?
 - Preamps @ \$5?/ch = $\$5 \times (714 + 2856) = \$17.9K$
 - Frames: \$10K
 - Gas System: \$10K?
 - Stringing: \$15K? (at Fermilab??)
 - Manpower: \$60k/yr for 3 years
 - Electronics design: \$40K
 - FADCs @ \$52/ch x 12 x 238 = \$148.5K (???)
 - TDCs?? @ \$3.7K/module x 6 x 119/64 ~ \$40K
 - Crates ~ 60 vme modules/ 20 modules/crate x \$10k/crate???= \$30K
 - High voltage...

Backup slides

Cathode charge after amplification

$$Q = N_{ion} \cdot F_{att} \cdot F_{ind} \cdot F_{sh} \cdot \mathcal{G}_{amp} \cdot \mathcal{G}_{gas} \cdot 1.60 \times 10^{-19} \text{ C/e.}$$

- Estimate from Sauli: $N_{ion} = 94$ ion pairs/cm (minimum ionizing particles)
- $1 - F_{att}$ = fraction of drift electrons lost due to reattachment to chamber gas molecules. Assume $F_{att} = 1$ (pure ArCO₂ gas)
- $F_{ind} = 0.5$, fraction of anode charge induced on one cathode plane
- F_{sh} = fraction of anode charge collected for a given pre-shaping time
 - Assume $F_{sh} = 1$ (no pre-shaping currently used)
- Electronic amplification: assume postamps have gain of 1.

Preamp gain: $\mathcal{G}_{amp} = 2.2 \text{ mV}/\mu\text{A} \cdot \frac{1}{50 \Omega} = 44$

Estimate of gas gain

$$Q = N_{ion} \cdot F_{att} \cdot F_{ind} \cdot F_{sh} \cdot \mathcal{G}_{amp} \cdot \mathcal{G}_{gas} \cdot 1.60 \times 10^{-19} \text{ C/e.}$$

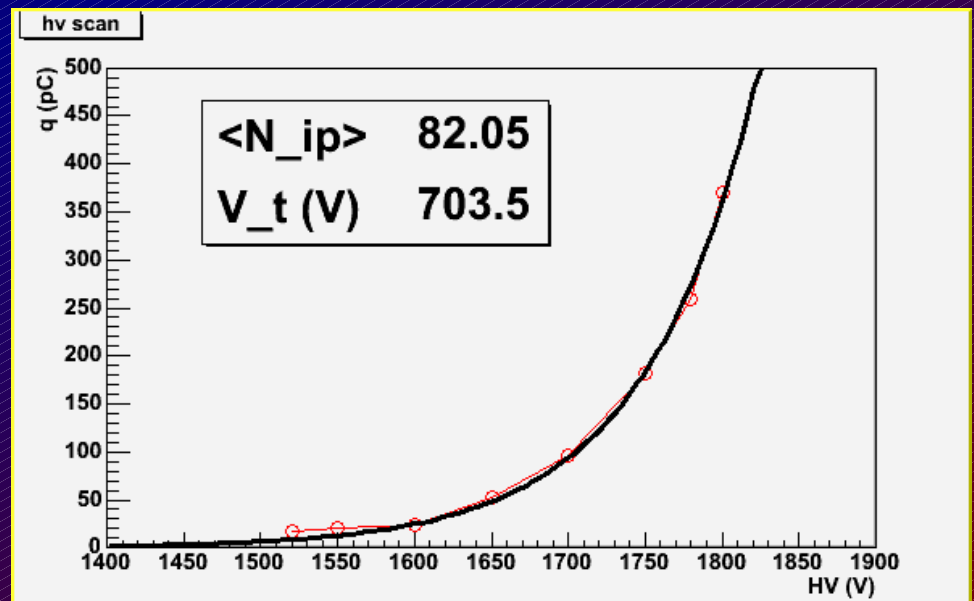
Gas gain from Sauli and fit to prototype data:

$$\mathcal{G}_{gas} = \exp \left[2 \sqrt{\frac{kNCV_0a}{2\pi\epsilon_0}} \left(\sqrt{\frac{V_0}{V_T}} - 1 \right) \right]$$

- V_0 = operating voltage = 1.8 kV
- V_T = threshold voltage

- $a = 0.001 \text{ cm}$ = anode wire radius
- $k = 1.8 \times 10^{-17} \text{ cm}^2/\text{V}$
- $N = 2.42 \times 10^{19} \text{ molecules/cm}^3$ (30°C)
- $\epsilon_0 = 8.85 \text{ pF/m}$
- $C = 8.34 \text{ pF/m}$

$$\text{Gas gain} = 4.7 \times 10^5$$



Cathode charge before amplification

$$Q_{\text{cathode}} = N_{\text{ion}} F_{\text{ind}} G_{\text{gas}} \times 1.6 \times 10^{-19} \text{ C} = 94 \times 0.5 \times 4.7 \times 10^5 \times 1.6 \times 10^{-19} \text{ C}$$
$$= 3.53 \text{ pC}$$

(after preamp/postamp = 155.3 pC)

Assuming that most of charge is distributed over 3 adjacent strips:
Estimate for “typical” charge on a strip for single tracks = 1.18 pC