

CVD Diamond Pixel Detector Development

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for the RD42 Collaboration

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- Diamond Properties
- Diamond Detector Construction
- Beam Test Results
 - Pulse Height Distribution
 - Hit Efficiency
 - Position Resolution
- Future Efforts

Properties of Diamond vs. Silicon

Property	Diamond	Silicon
band gap [eV]	5.5	1.12
energy to create e-h pair [eV]	13	3.6
electron mobility [$\text{cm}^2\text{V}^{-1}\text{s}^{-1}$]	1800	1350
hole mobility [$\text{cm}^2\text{V}^{-1}\text{s}^{-1}$]	1200	480
saturation velocity [$\mu\text{m}/\text{ns}$]	220	82
dielectric constant	5.6	11.9
resistivity [$\Omega\text{-cm}$]	$> 10^{11}$	$< 10^5$
mass density [gm/cm^3]	3.5	2.33
thermal cond. [$\text{W m}^{-1} \text{K}^{-1}$]	1000-2000	150
charge deposited/0.1% X_o [e]	4500	8400

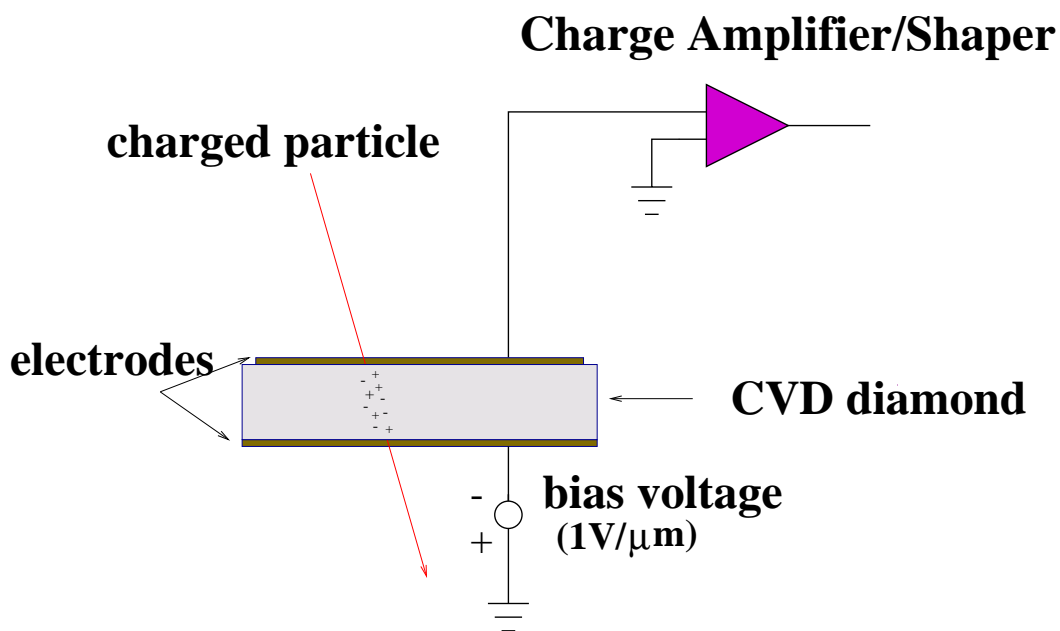
Advantages of CVD Diamond

- High mobility: fast signal collection
- High resistivity: insignificant dark current
- High thermal conductivity: easy to cool
- Could operate at room temperature
- Reusable
- High radiation tolerance

Disadvantages

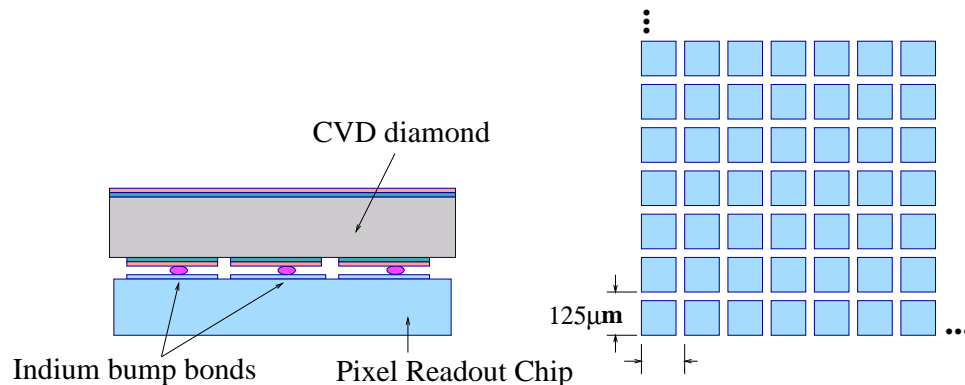
- Smaller signal: $< 1/2$ Silicon
- Spatial non-uniformity of charge collection
- Relatively new material:
 - few manufactures can produce detector quality diamond
 - cost?

Simple Diamond Detector



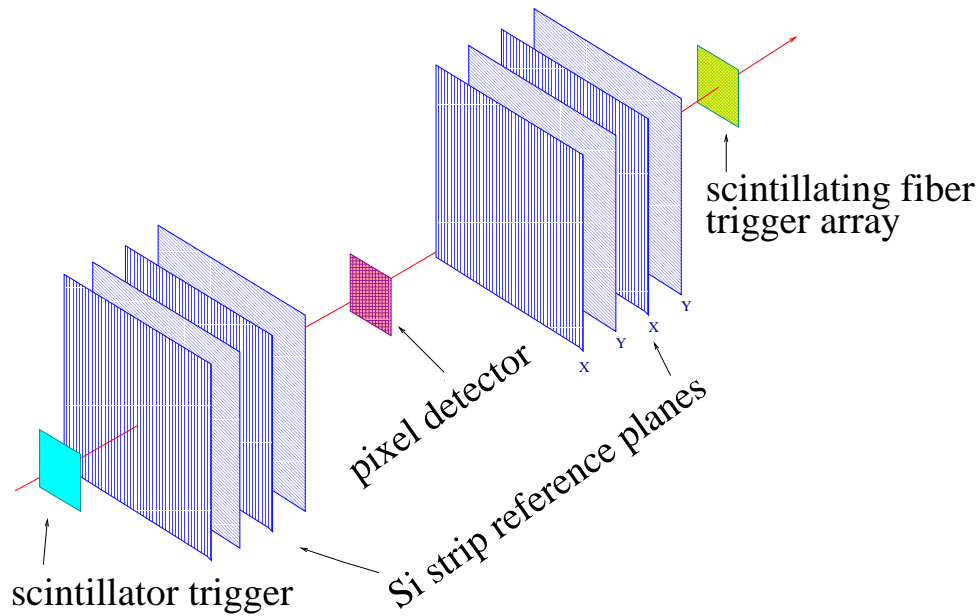
- Charge deposited: 36 electron-holes/ μm
- Signal collected may be less due to charge trapping
- Electrodes are easily sputtered on
- Diamond is reusable: re-metallize

Structure of Diamond Pixel Detector



- Thickness: $500 \mu\text{m}$
- No guard rings needed
- Diamond metallization: Ti–W
- Bump bond: $\approx 20\mu\text{m}$ diameter Indium
- CMS Pixel Readout chip:
 - PSI30 (Honeywell version)
 - $125 \times 125 \mu\text{m}$ pitch
 - 22 columns \times 32 rows
 - 3-bit adjustable threshold for each pixel

Rutgers Tracking Telescope

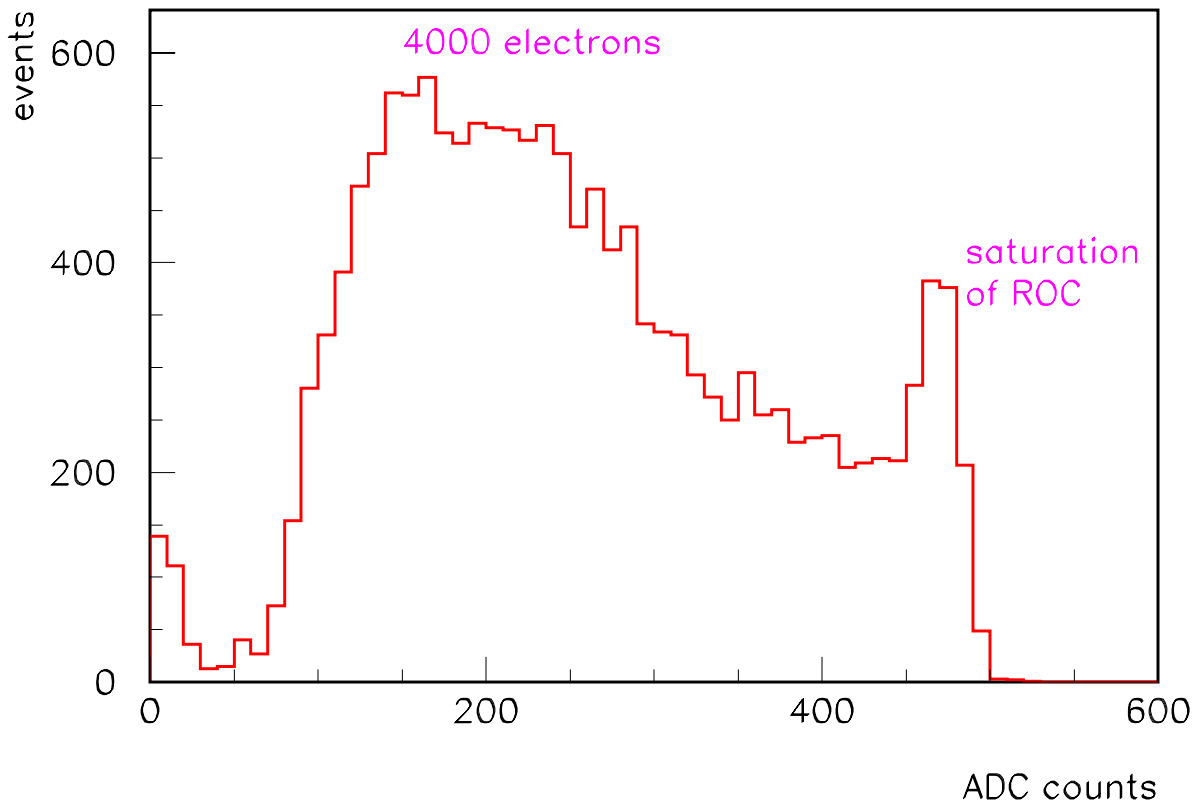


- 4 X and 4 Y Silicon strip ($50 \mu\text{m}$ pitch) reference planes
- better than $2 \mu\text{m}$ extrapolation accuracy in pixel row coordinate
- $3.5 \mu\text{m}$ extrapolation accuracy in pixel column coordinate
- scintillating fiber array trigger
 - 2 x-planes, 2 y-planes of 1 mm diameter scintillating fibers
 - Nim-selectable trigger area from 1 mm^2 to 60 mm^2

CERN SPS Testbeam: Summer 2000

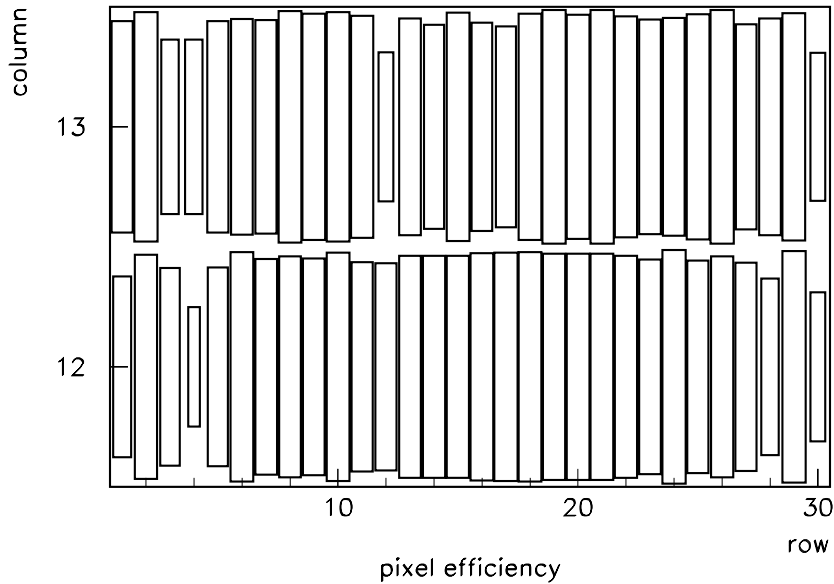
- Pixel detectors:
 - 2 diamond detectors tested (DeBeers)
 - 2 to 8 columns X 32 rows enabled
 - overall threshold at 2500 ENC
 - total noise: 320 ENC
 - common mode: 220 ENC
- Data collected:
 - data taken with beam at normal incidence and at 10° from normal
 - data rate 150 Hz
 - >300 hits/pixel

Diamond Pixel Pulse Height

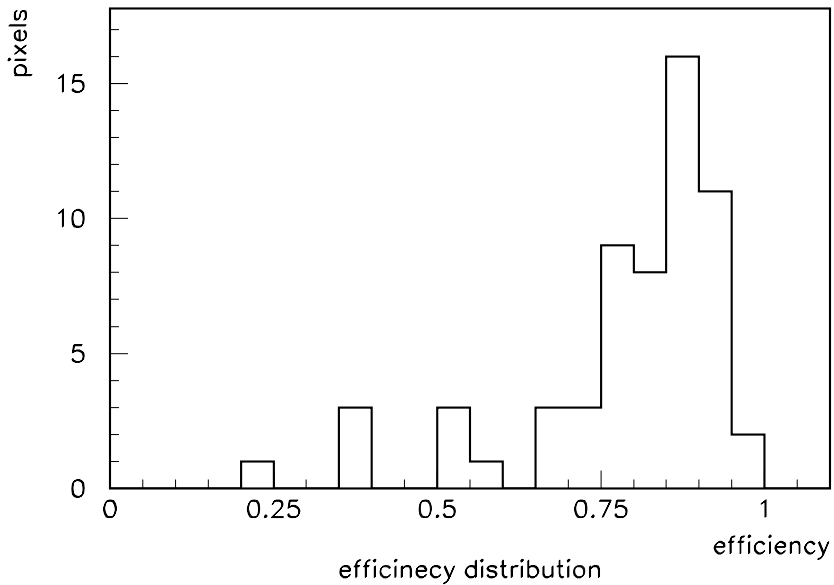


- Detector at normal incidence to beam
- $23 e^-$ per ADC count calibration
- Peak near 500 ADC counts is readout chip saturation ion
- Effect of threshold ($2500 e^-$) in low side tail

Efficiency Map

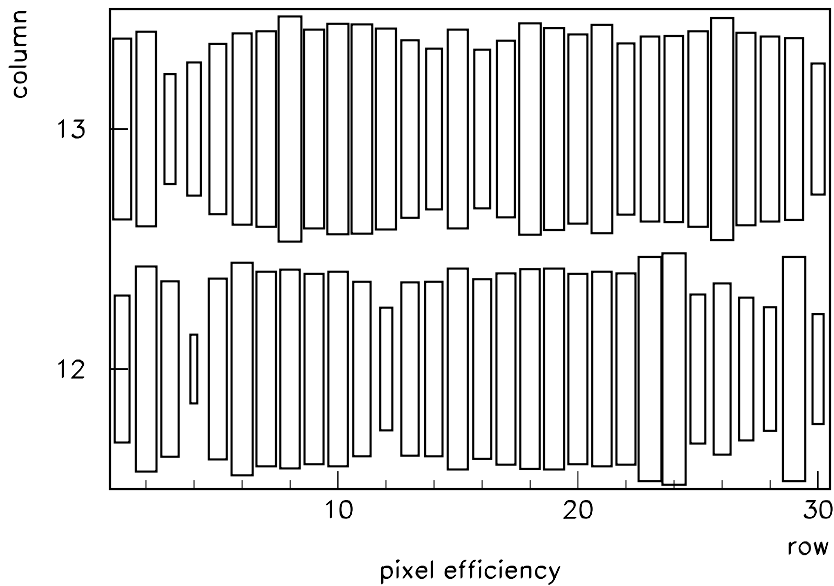


Efficiency Distribution

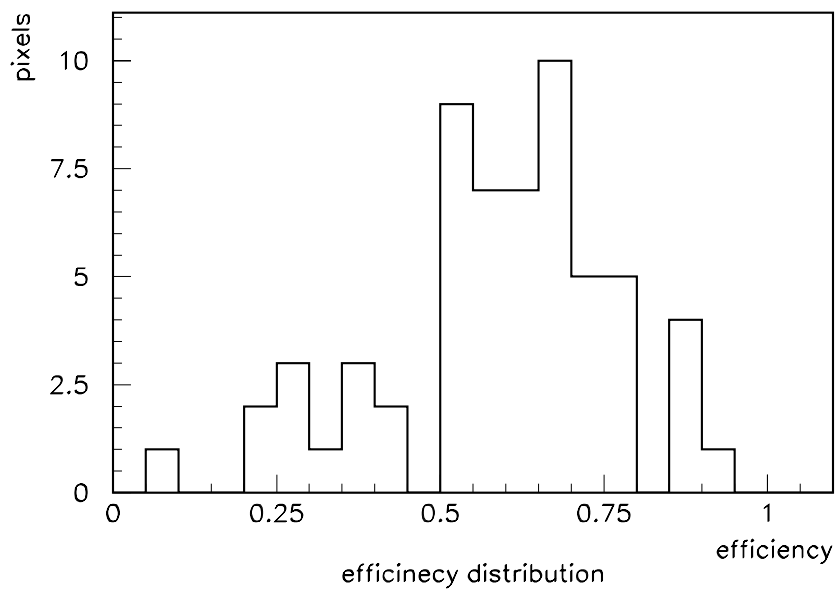


- About 150 hits per pixel
- No dead pixels in this column
- 85% most probable
- Threshold at 2500 ENC

Efficiency Map

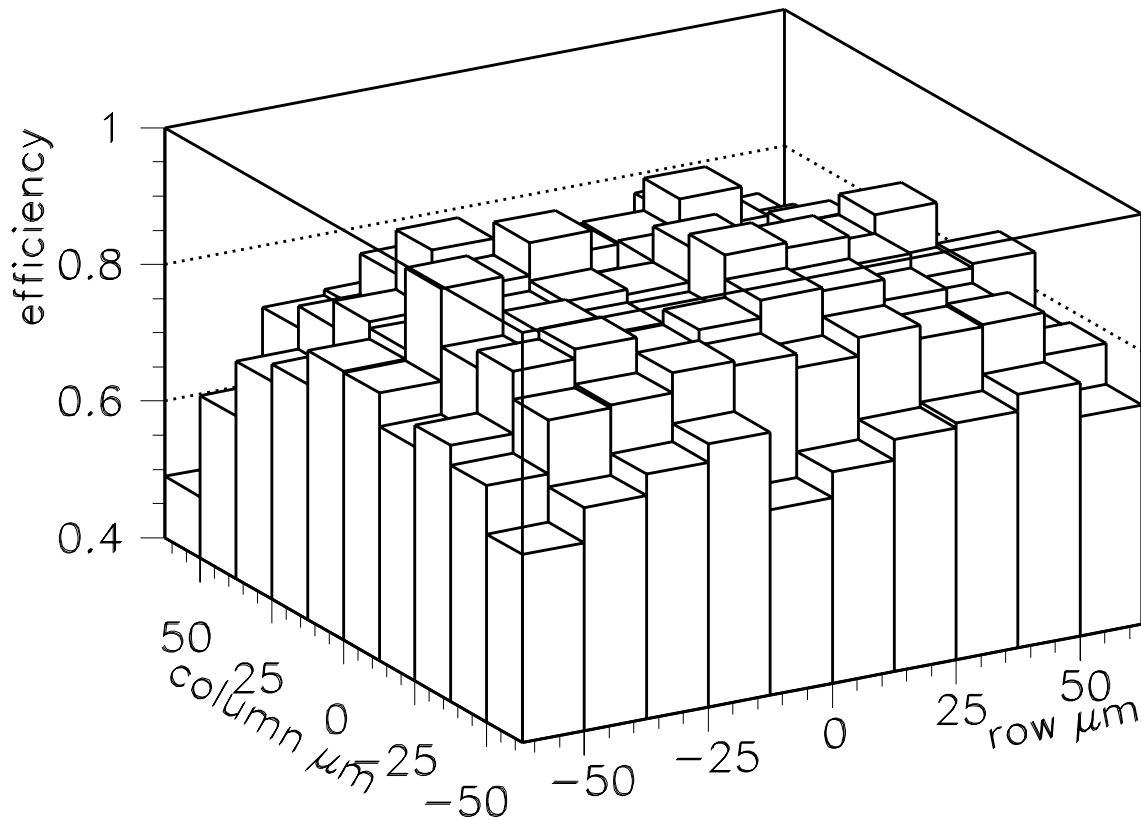


Efficiency Distribution



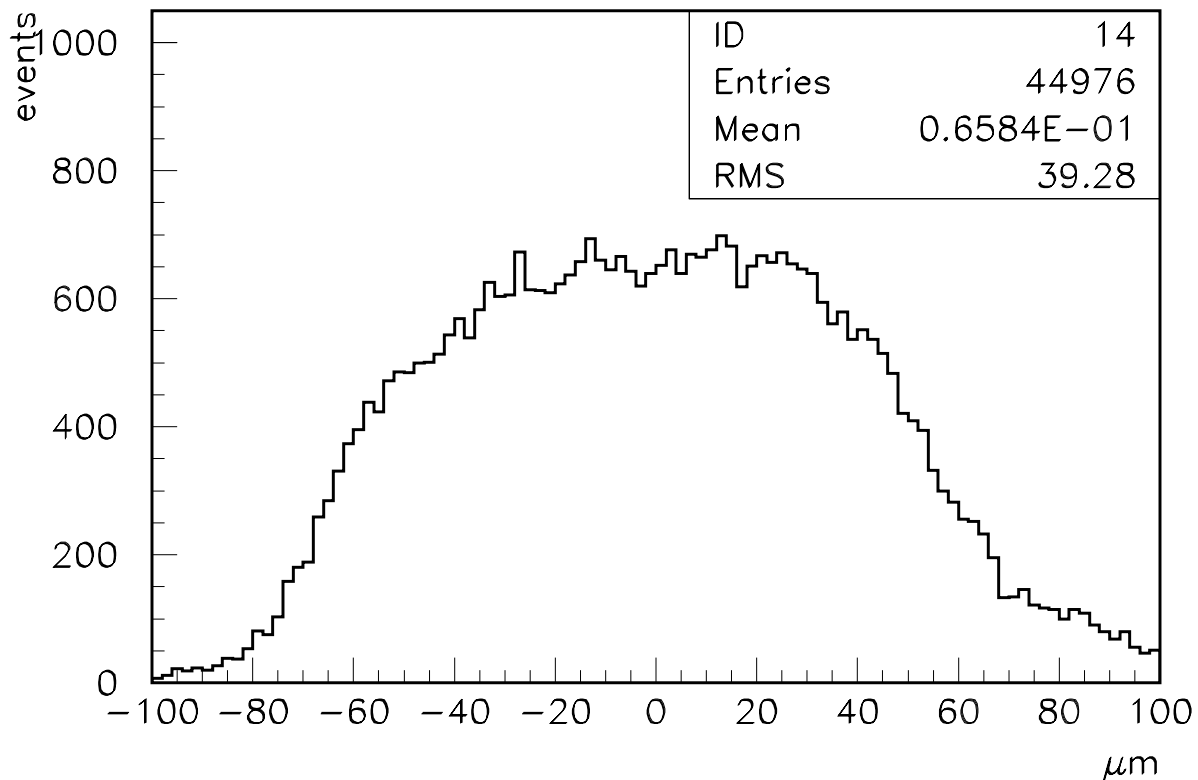
- Threshold at 3000 e-
- Efficiency improved at lower threshold

Position Dependence of Efficiency



- Map of efficiency within pixel, but averaged over all pixels
- Lower at edges and corners due to threshold

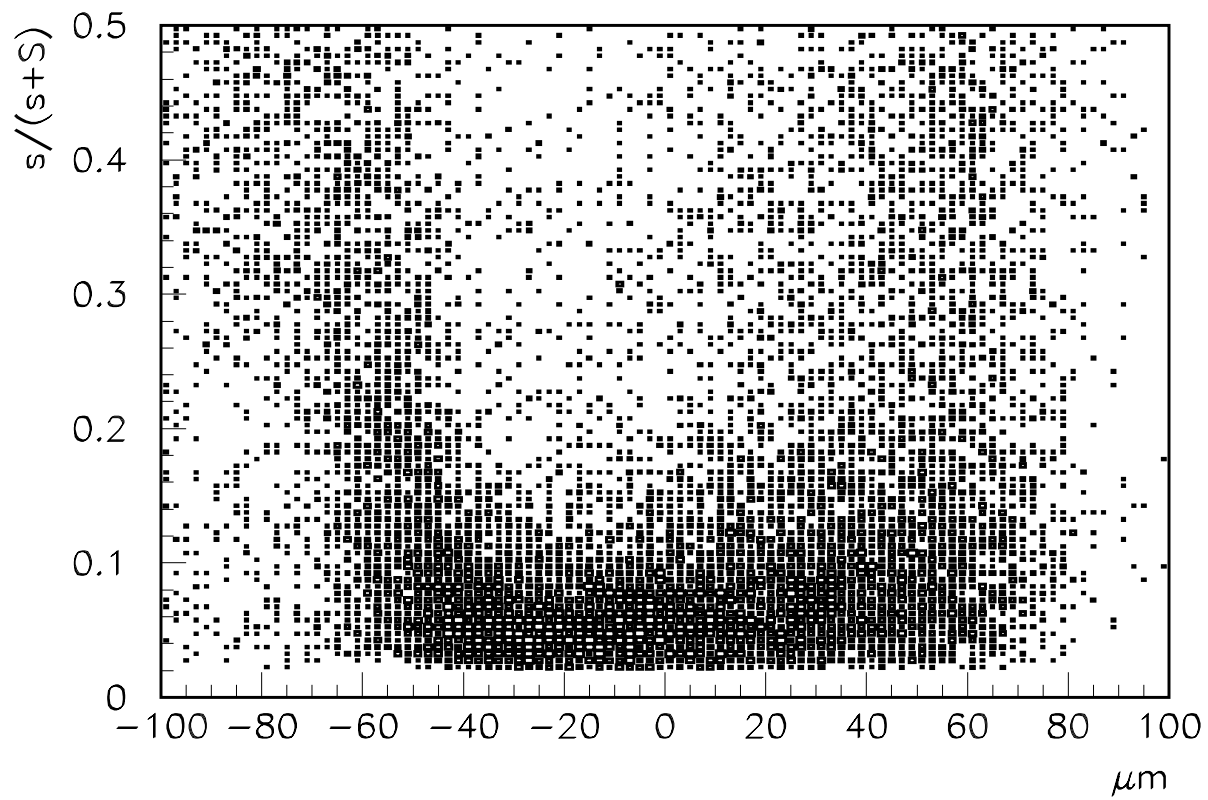
Diamond Pixel Position Resolution



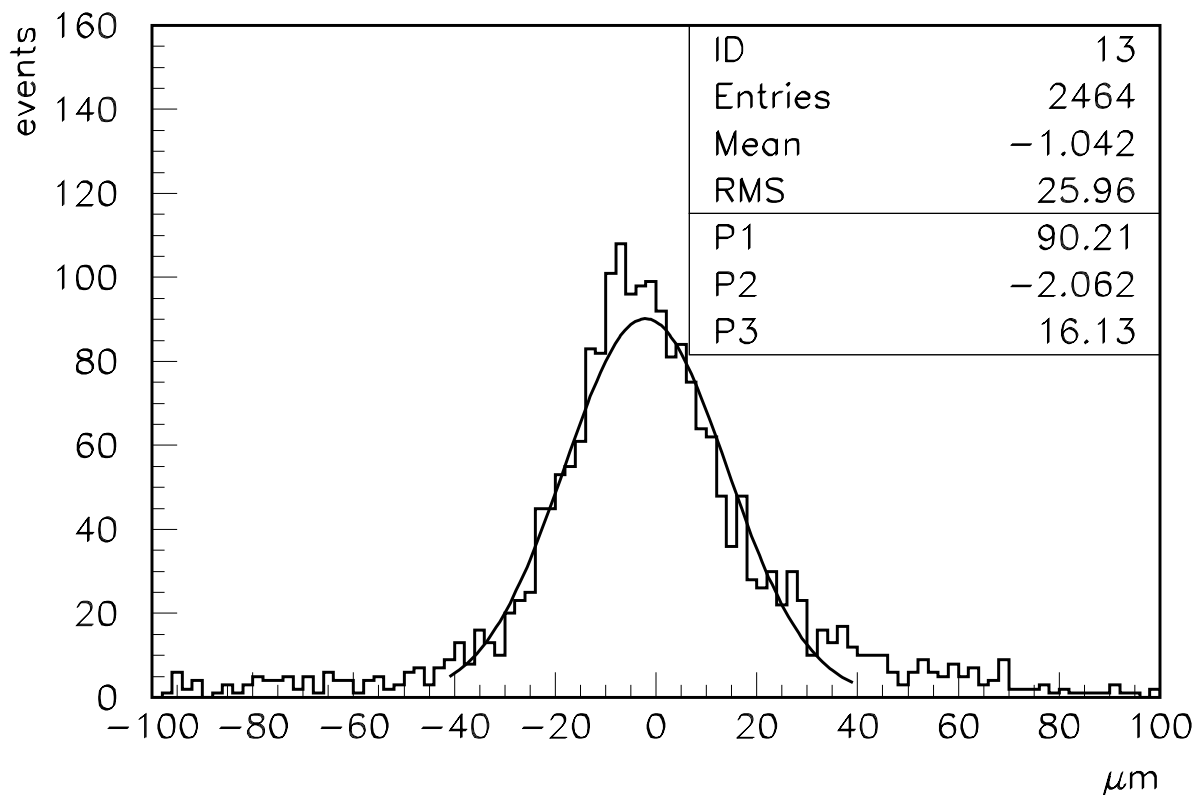
- Rotated 10° from normal incidence
- Analysis from a single pixel
- Digital resolution:

$$125 \mu\text{m} / \sqrt{12} = 36 \mu\text{m}$$

Fraction of Charge in Adjacent Pixel vs Track Position

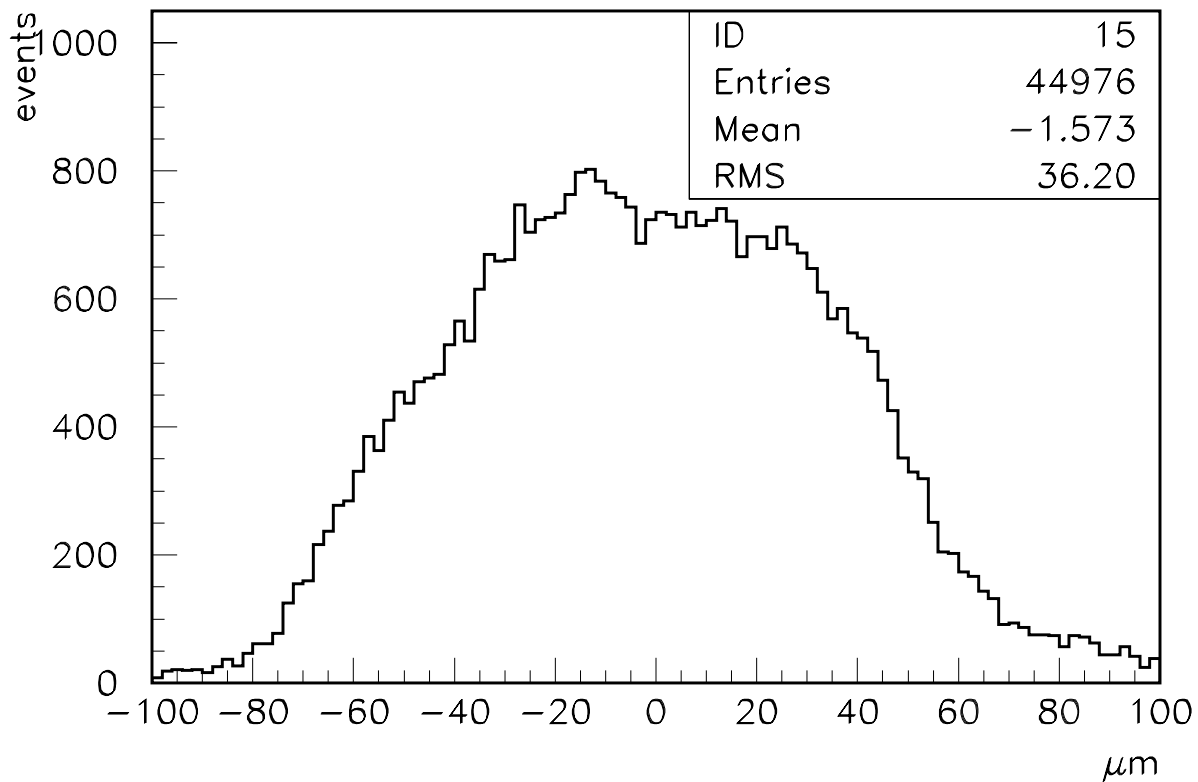


Resolution from Charge Sharing Events



- Cut on all events below 0.15 charge share
- Fraction of total events above cut: 5%
- Analysis using signal center-of-gravity

Final Resolution Using All Events



- Digital resolution for single pixel events
- C.O.G for charge sharing events

Near Future Plan

- Test newest diamond material
 - Reduce noise, threshold, and threshold spread
 - Better understand charge sharing in rotated data
 - Test irradiated detector+ROC
 - Measure resolution with Lorentz drift from 3 Tesla field
 - Use improved ROC when available
- Need side-by-side comparisons with Silicon pixel detectors