

# CVD Diamond Pixel Detectors

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- CVD diamond as a detector material
- Pixel detector development efforts
- Recent test results

## CVD Diamond as a Detector Material

property	diamond	silicon
band gap (eV)	5.5	1.12
energy to create e-h pair (eV)	13	3.6
breakdown field (V/cm)	$10^7$	$3 \times 10^5$
resistivity ( $\Omega/\text{cm}$ )	$10^{11}$	$2.3 \times 10^5$
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
signal created by MIP. (e/ $\mu\text{m}$ )	36	89
cohesive energy (eV/atom)	7.37	4.63
mass density ( $\text{gcm}^{-3}$ )	3.5	2.33
dielectric constant	5.7	11.9
radiation length (cm)	12.0	9.4
thermal expansion coefficient	$8.0 \times 10^{-7}$	$2.6 \times 10^{-6}$
thermal conductivity ( $\text{Wm}^{-1}\text{K}^{-1}$ )	1000-2000	150

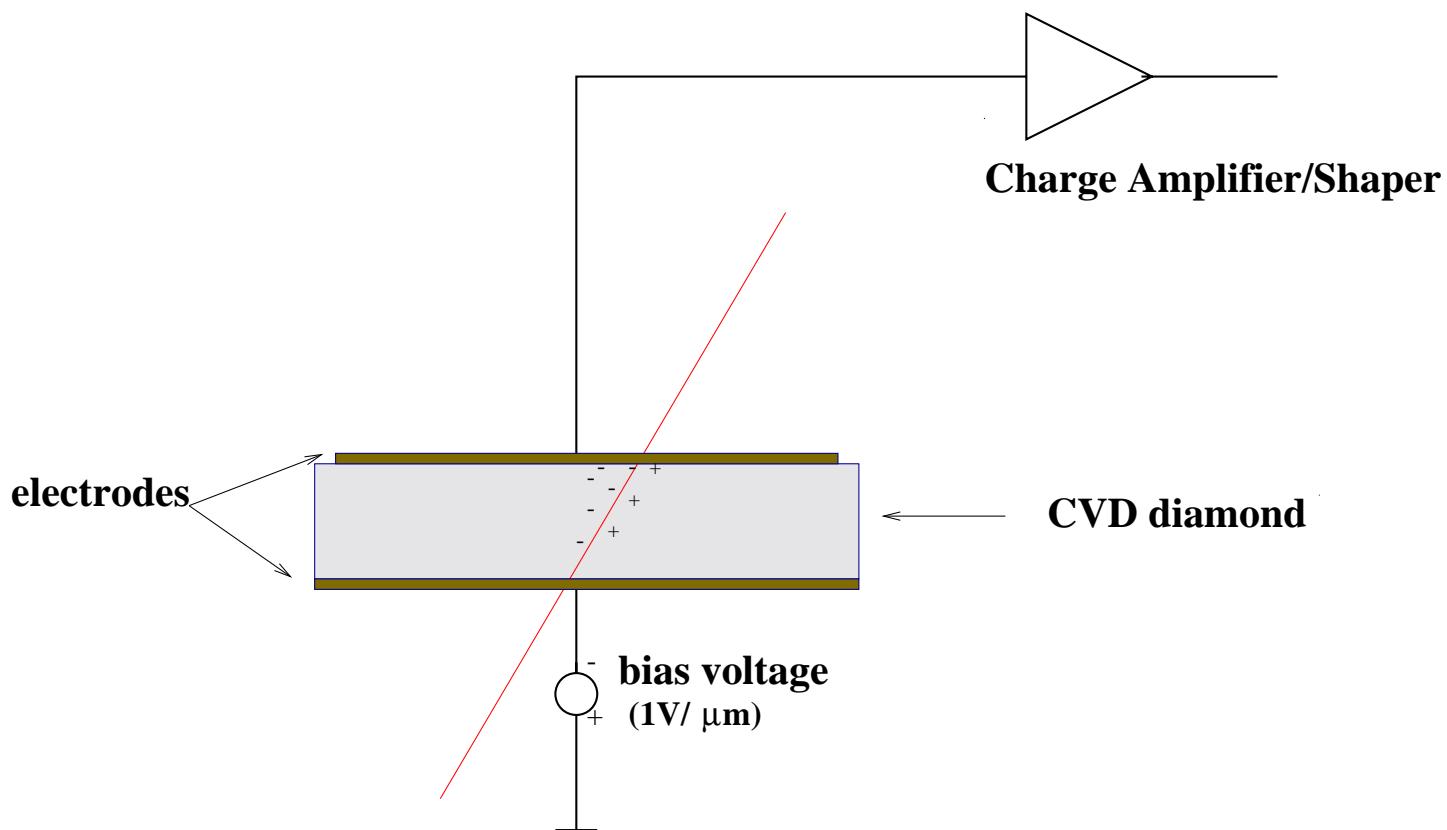
## Advantages:

- Large mobility: fast signal
- Good thermal conductivity: better cooling
- Low dielectric constant: low noise
- High resistivity: low leakage current
- Radiation tolerant

## Disadvantages

- Smaller signal (  $\approx \frac{1}{3}$  of Si)
- Polycrystalline (non-uniform)
- Relatively new material:
  - only one manufacturer (De Beers) produces highest quality CVD diamond

## Principle of Operation:

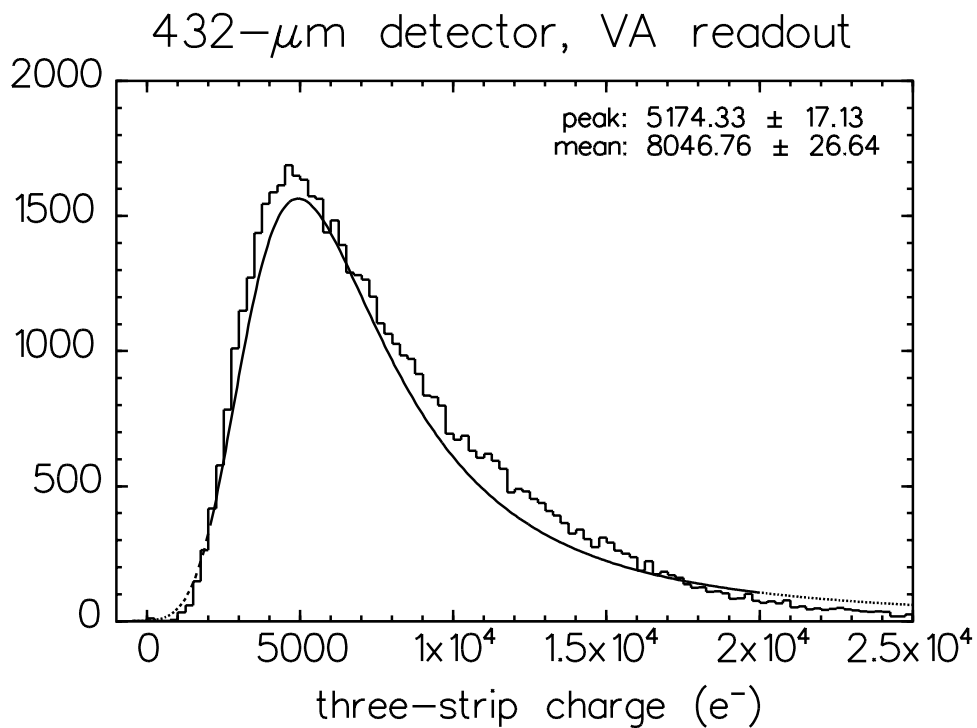


36 e-h pairs per micron for MIP.

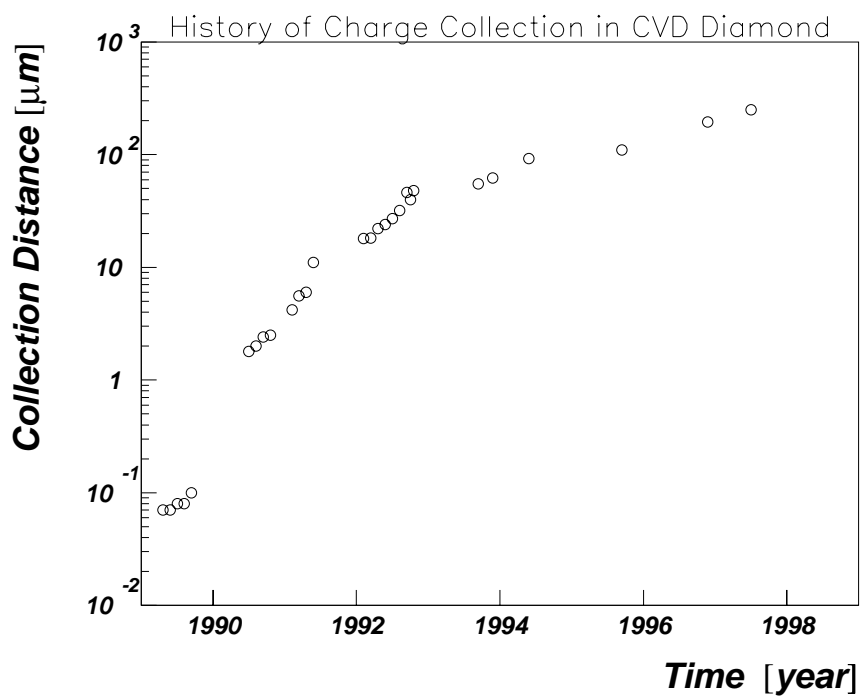
Signal is limited by the collection distance

Simple fabrication technique.

Diamond is reusable

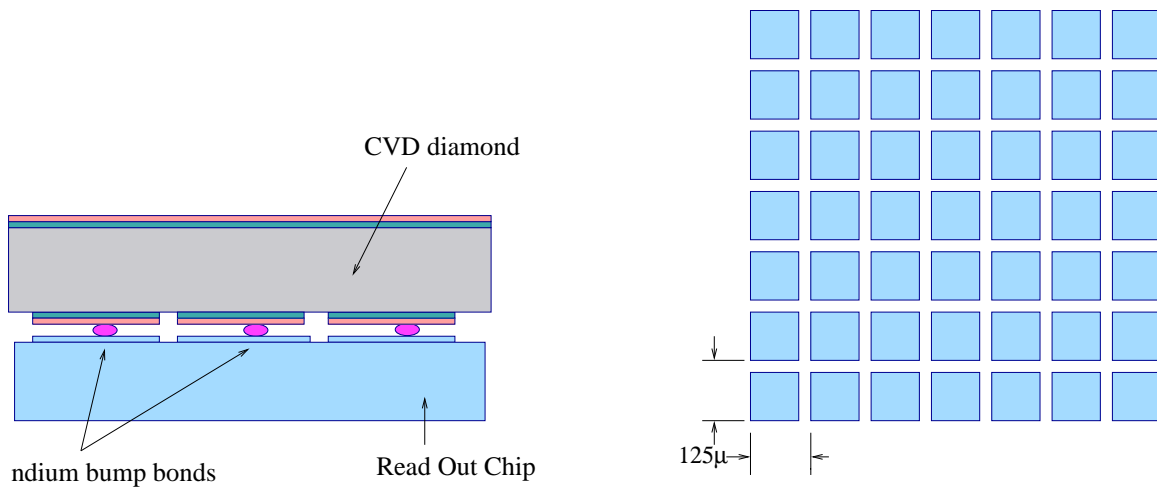


Signal distribution from a CVD diamond detector



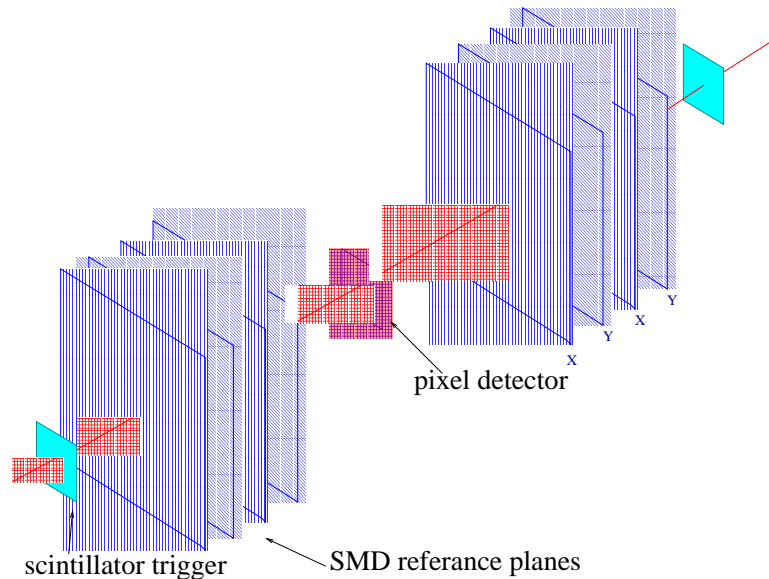
Collection distance has improved significantly

# CVD Diamond Pixel Detectors



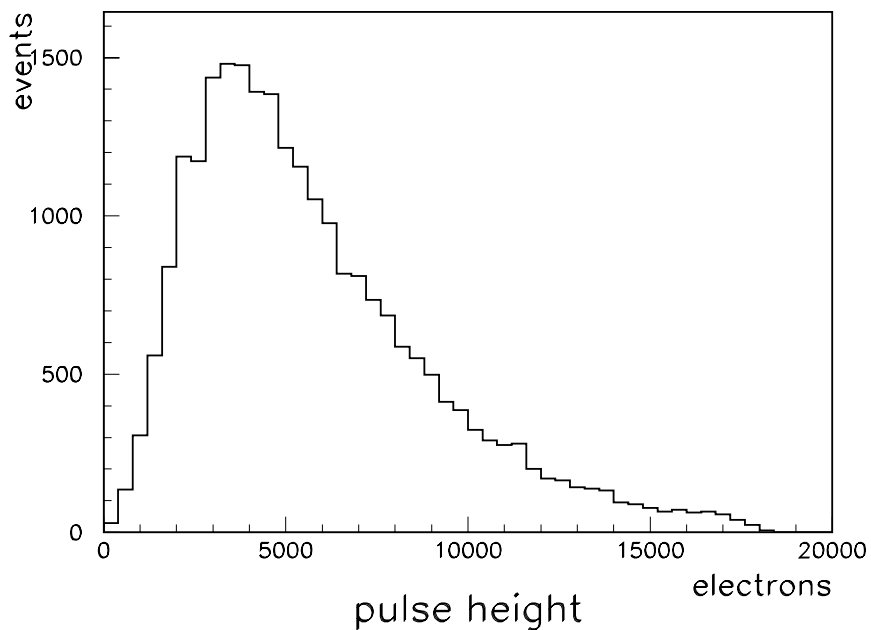
- $125 \times 125\mu\text{m}$  pixels (W/Ti)
- Indium bump bonded to prototype CMS pixel readout chip
  - PS130 (Honeywell version)
  - pitch  $125 \times 125\mu\text{m}$
  - active area 22 columns  $\times$  32 rows
  - adjustable threshold for each pixel

# First Beam Test Jan. 3-14 at Fermilab test beam



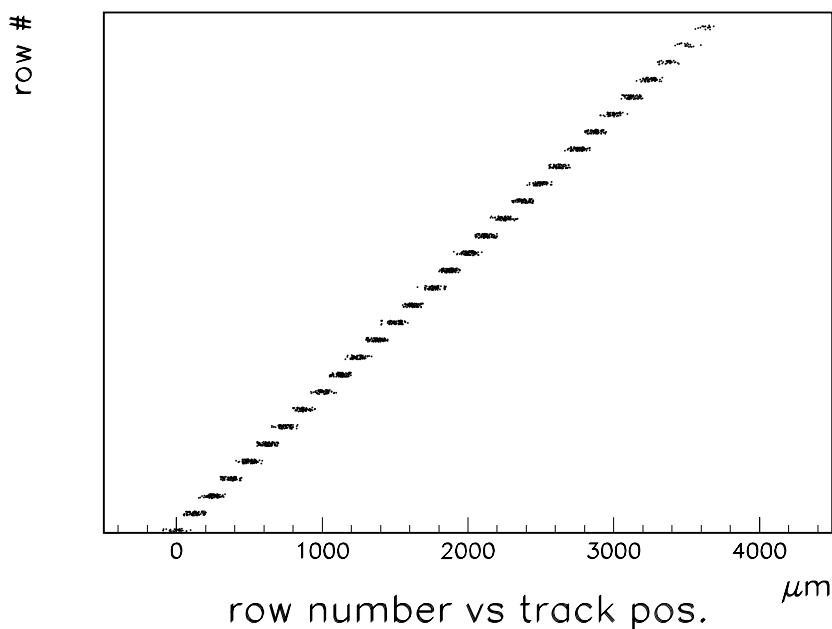
- Rutgers tracking telescope:
  - 8 SMD reference planes
  - better than  $7\mu\text{m}$  extrapolation accuracy
  - scintillator (fiber) trigger
  - data rate 150 Hz
- Pixel detector:
  - active area 12 columns  $\times$  30 rows (half of chip)
  - pixel thresholds at  $\approx 2000$  e
  - pixel threshold rms spread  $\approx 600$  e
  - Noise: 750 e ( common mode 500 e)
- Data collected:  $> 100$  hits/pixel

## Test Beam Results



Diamond pixel signal:

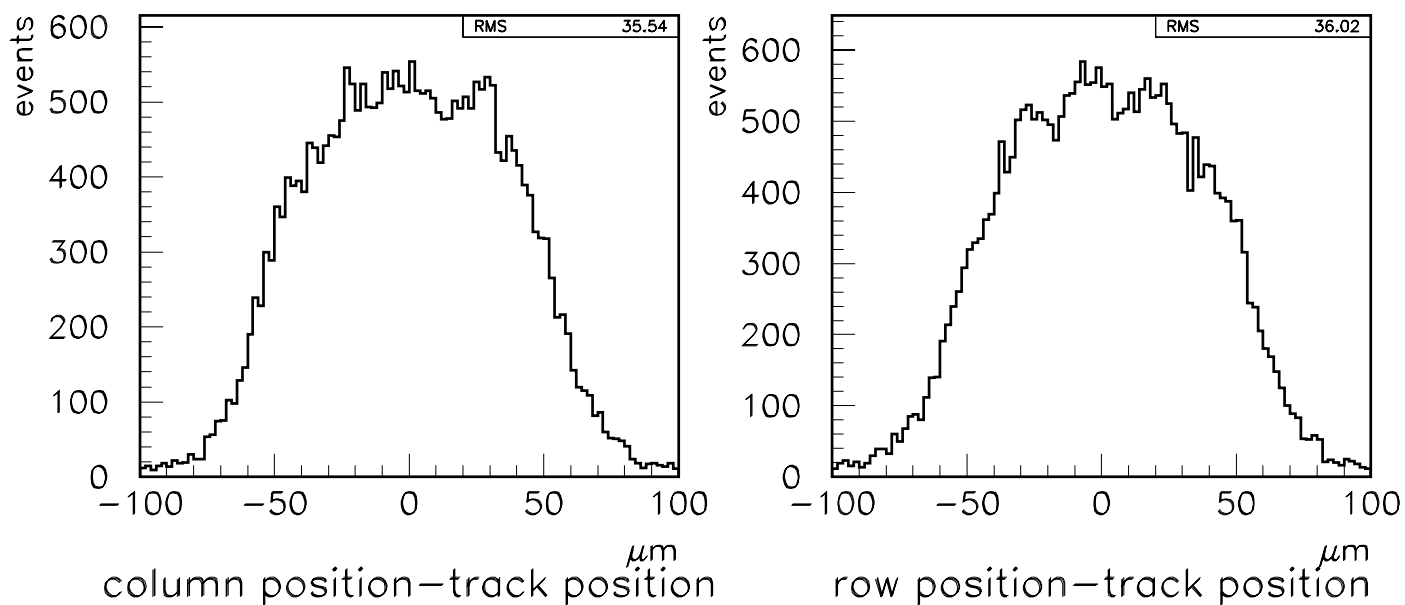
- Lower slope may be affected by thresholds/noise



Good track and pixel hit correlation



## Position Resolution of Diamond Pixel Detector

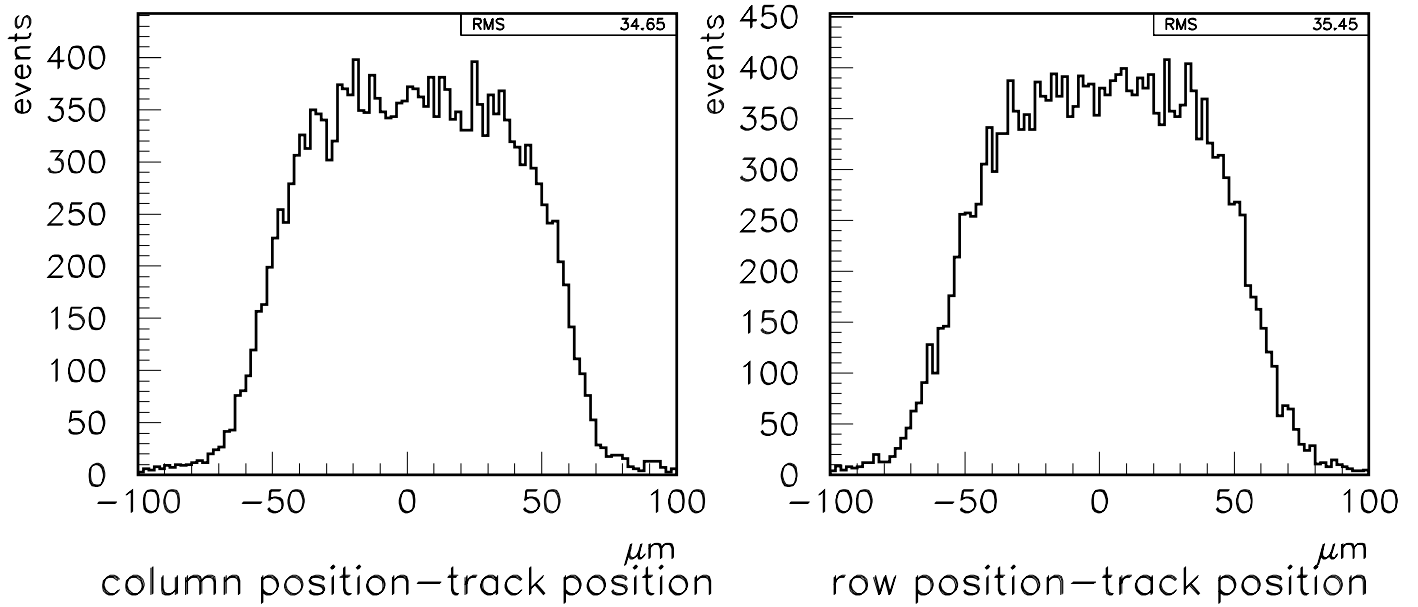


digital resolution:

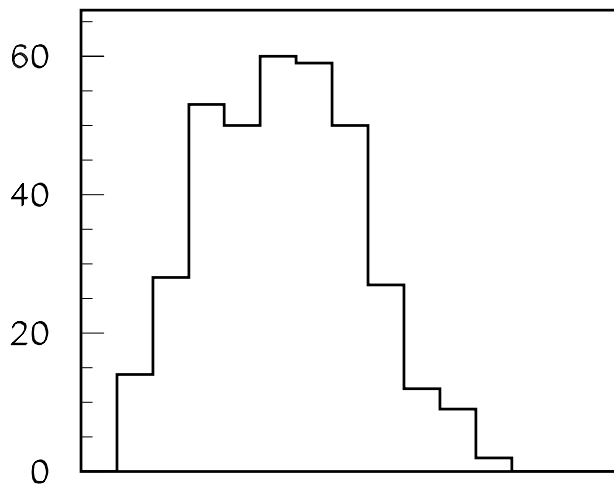
$$125\mu\text{m}/\sqrt{12} = 36\mu\text{m}$$

Similar to silicon

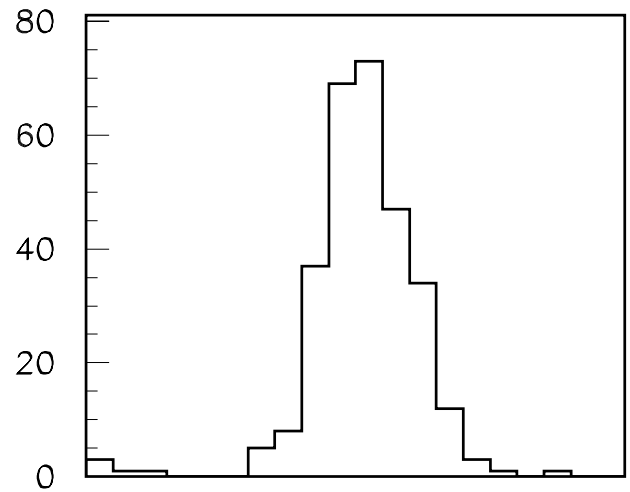
# Position Resolution of Silicon Pixel Detector



## Pixel Efficiency



Diamond pixel efficiency

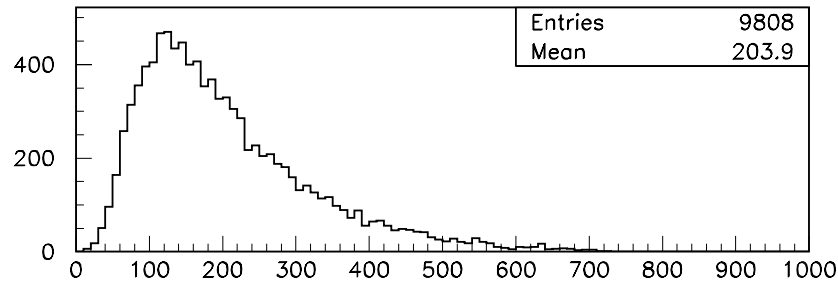


Si pixel efficiency

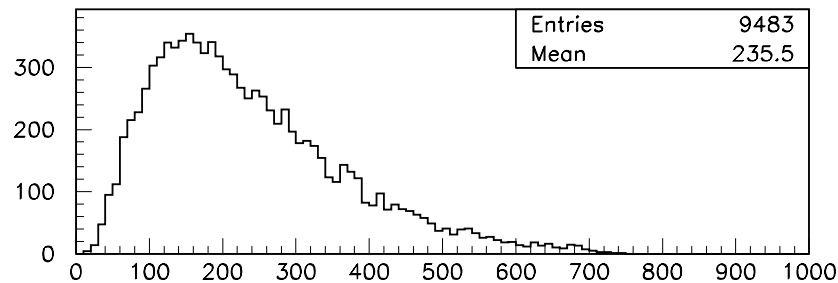
**NOTE:** Efficiencies are not normalized

Diamond efficiency spread larger than of Si.

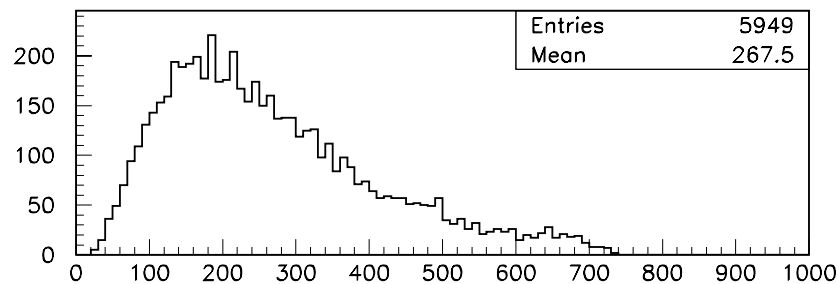
# Efficiency and Signal level.



pulse height (low effi. pixels)



pulse height (moderate effi. pixels)

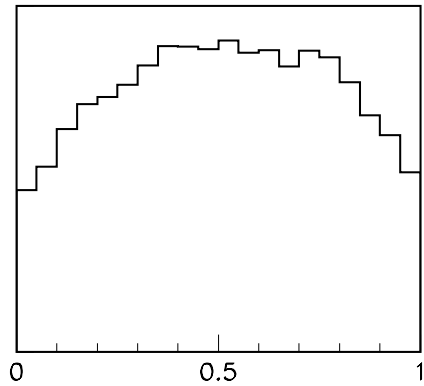


pulse height (high effi. pixels)

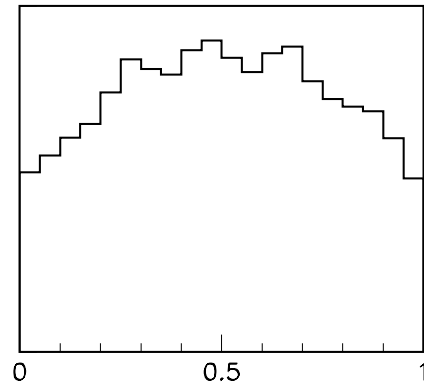
Variation in efficiency:

- consistent with the variation of signal level
  - non uniformity of signal from diamond
  - threshold/gain/contact variations
  - charge spread in diamond

## Efficiency and hit position



Efficiency vs position in column



Efficiency vs position in row

Efficiency is lower near pixel boundaries

⇒ charge spreading.

- Current results are from a preliminary run
- Number of beam tests are planned:
  - CERN X7 beam line  
taking data now
  - CERN X5 beam line  
June/July - proton irradiation in between
  - CERN H2 beam line  
August - in a 3 Tesla magnetic field

## Goals of Future Beam Tests.

- Use improved sensor material
- Higher statistics ( $>1000$  hits/pixel)
- Tune/reduce ROC threshold (reduce threshold spread)
- Reduce noise
- Measure resolution with sensor rotated wrt beam (with charge sharing)
- Measure resolution with Lorentz drift in 3 Tesla field
- Study radiation damage ( $10^{15}/\text{cm}^2$  particle fluance)

All with side-by-side comparison with silicon.

