Silicon's Limitations

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SLAC NATIONAL ACCELERATOR LABORATORY

LELAND STANFORD JUNIOR UNIVERSITY

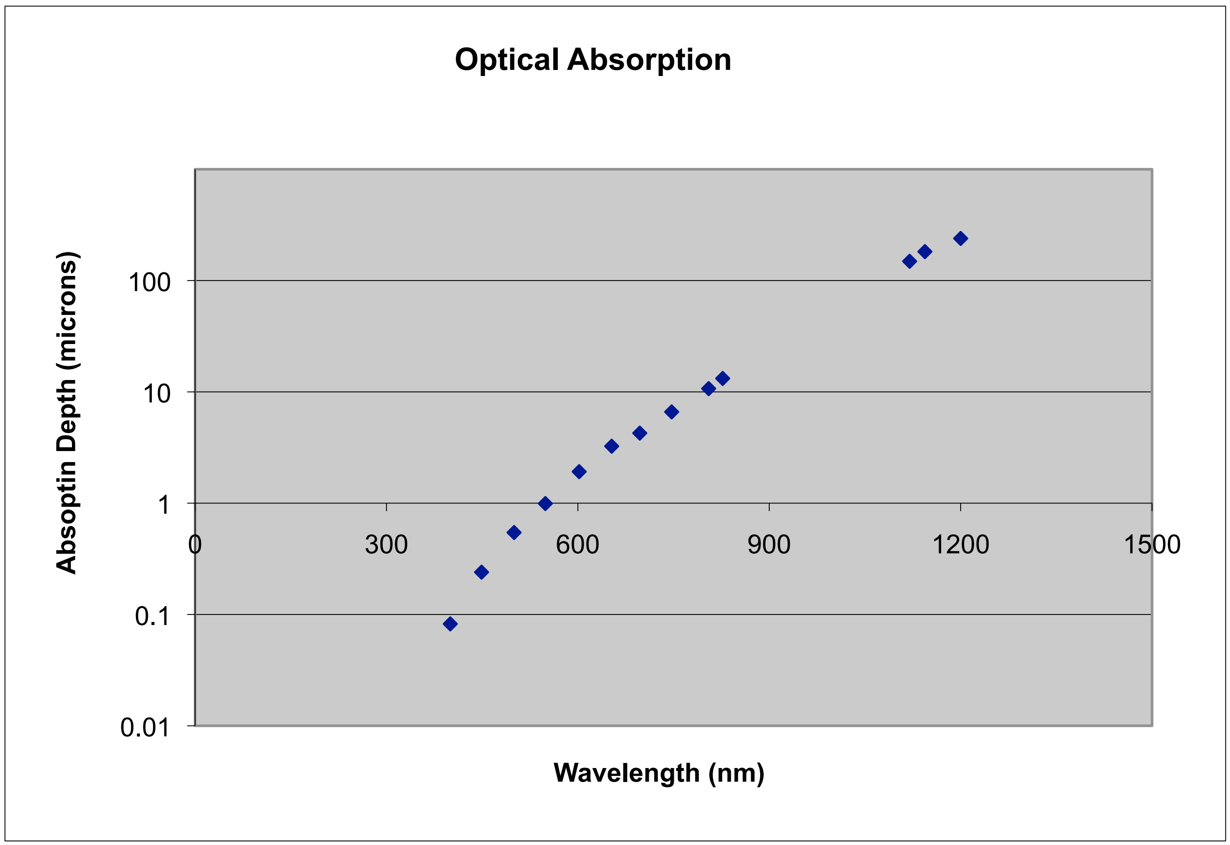
Key Parameters

- Material properties: mobilities, band gap, dielectric constant is 12!
- Geometry of device
- Operation: fields, temperature

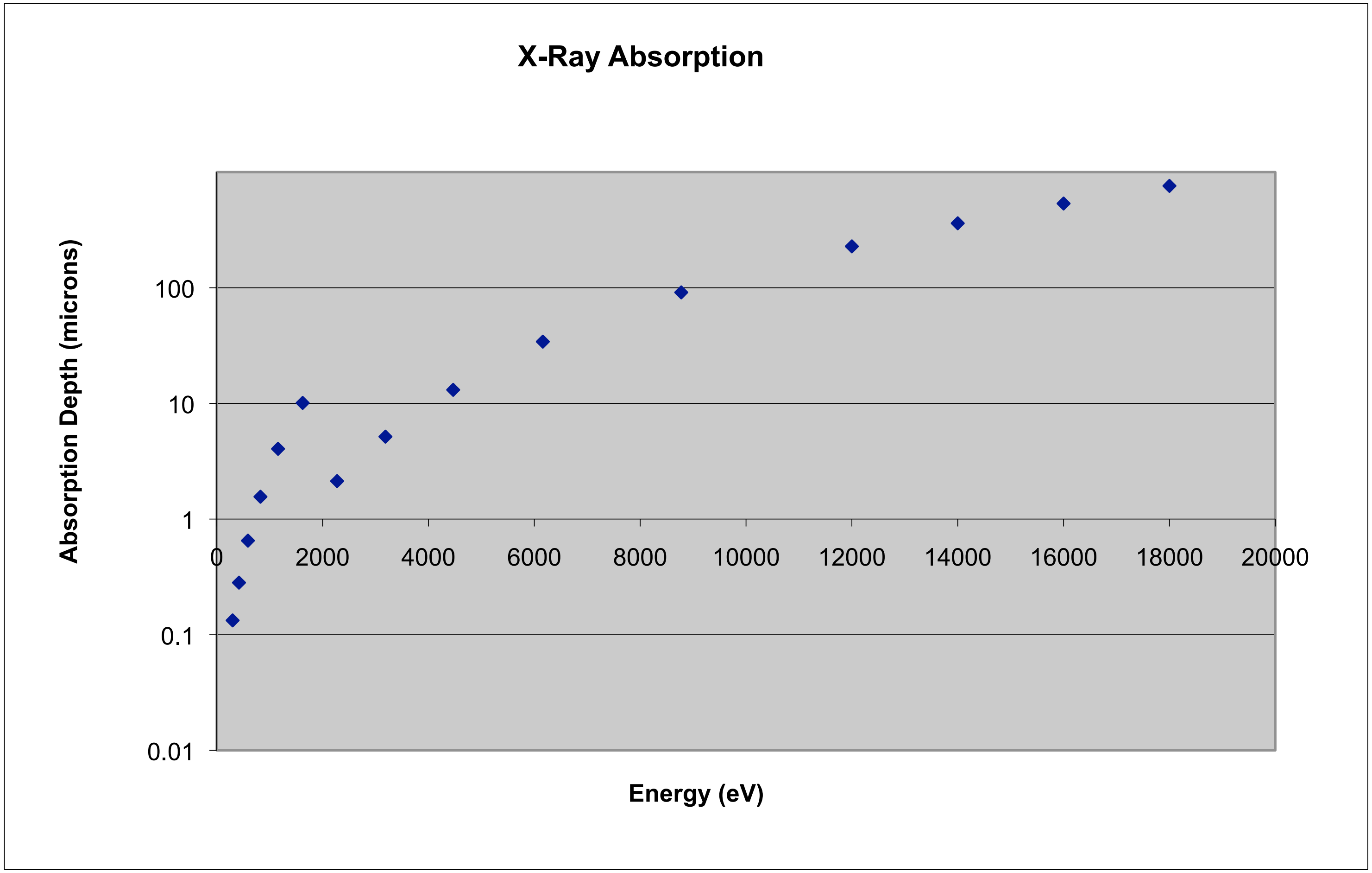
GLAST/FERMI
prior to launch

Optical Light Absorption

- Very sensitive to wavelength



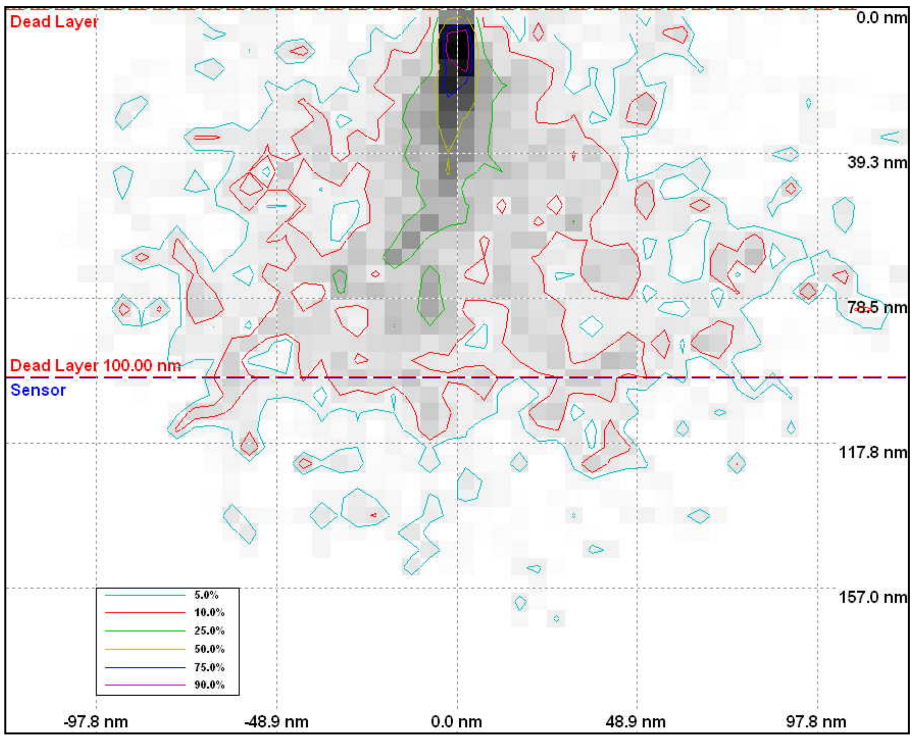
X-ray Absorption

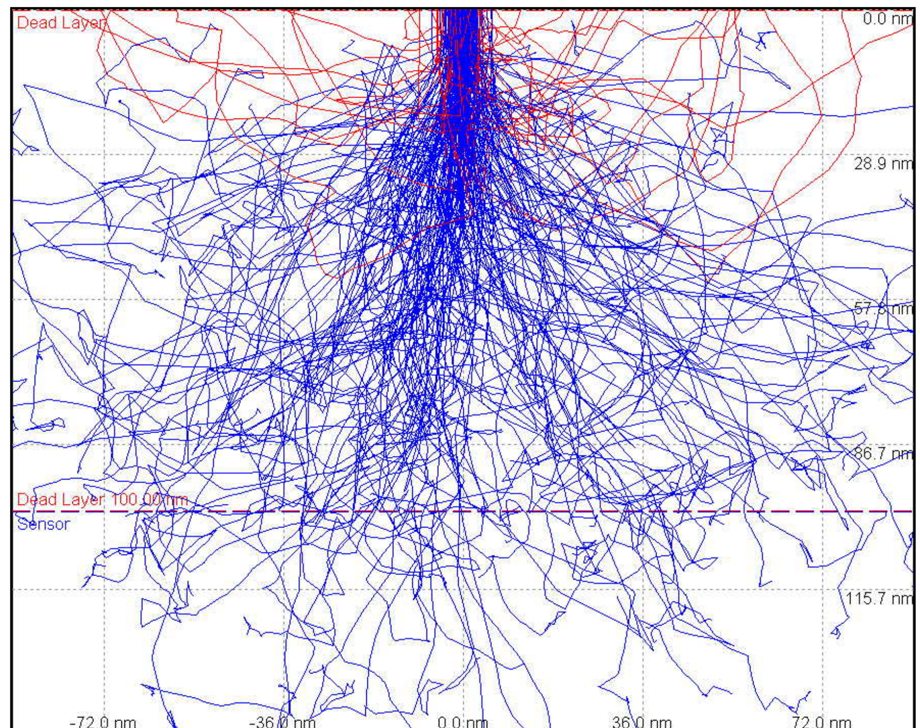


Electron Absorption

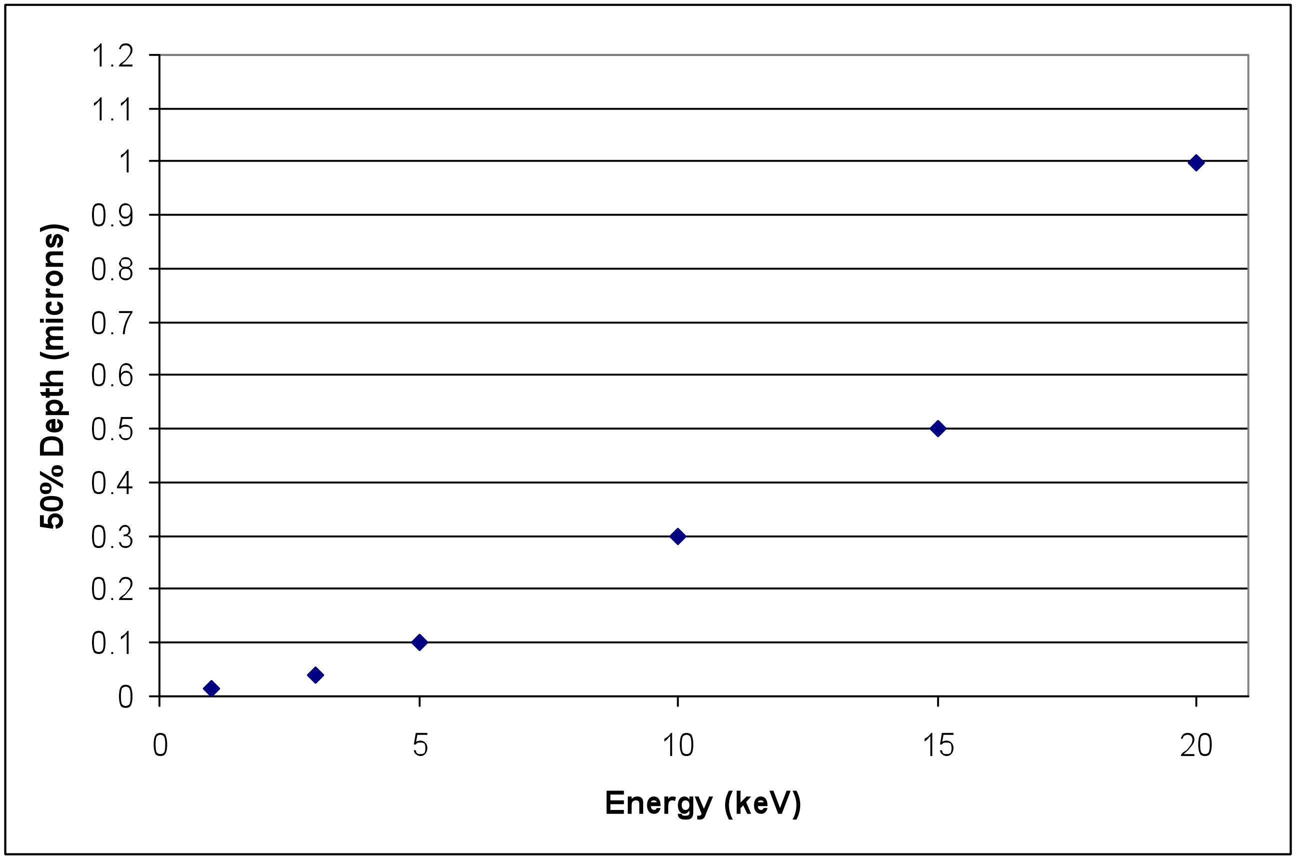
3 keV electrons from Casino

Almost all energy deposited in a sphere with a 100 nm diameter



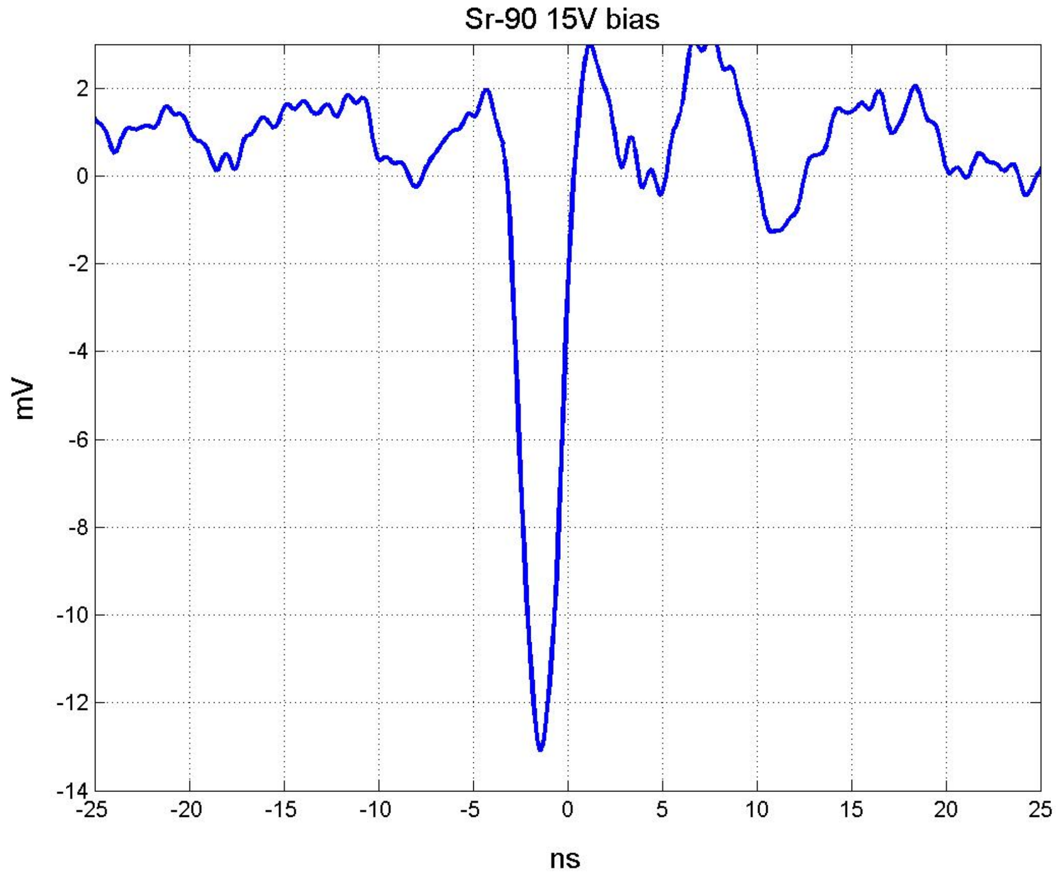


Electron Absorption



Direct Sensing

- Primary, science particle is absorbed in silicon
- Match



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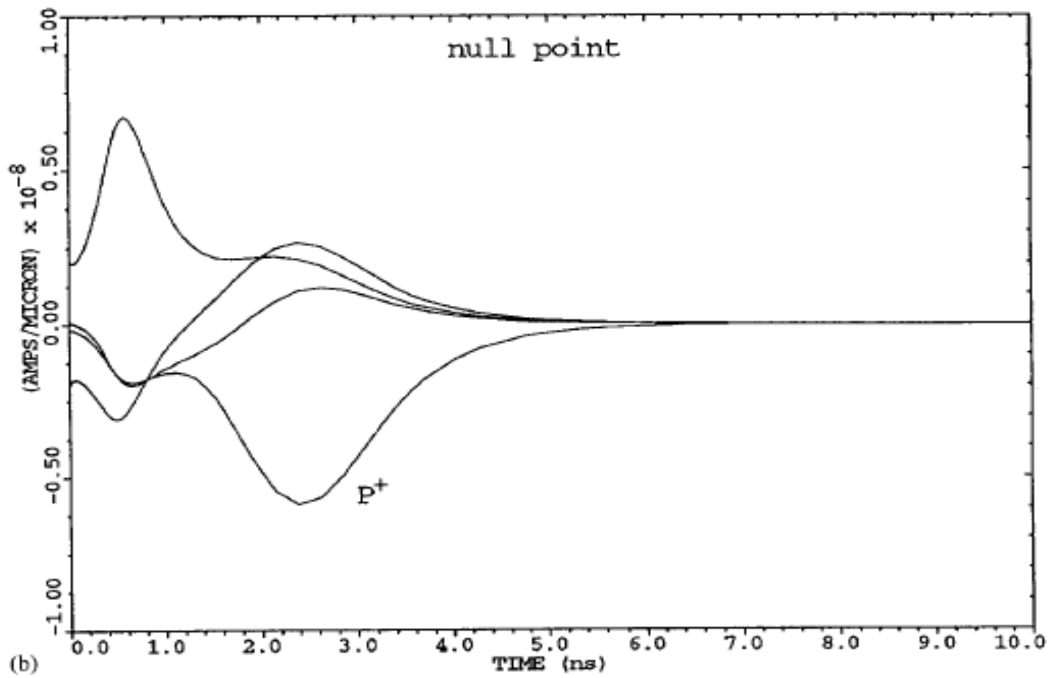
Current pulse

3D sensor

Field null point

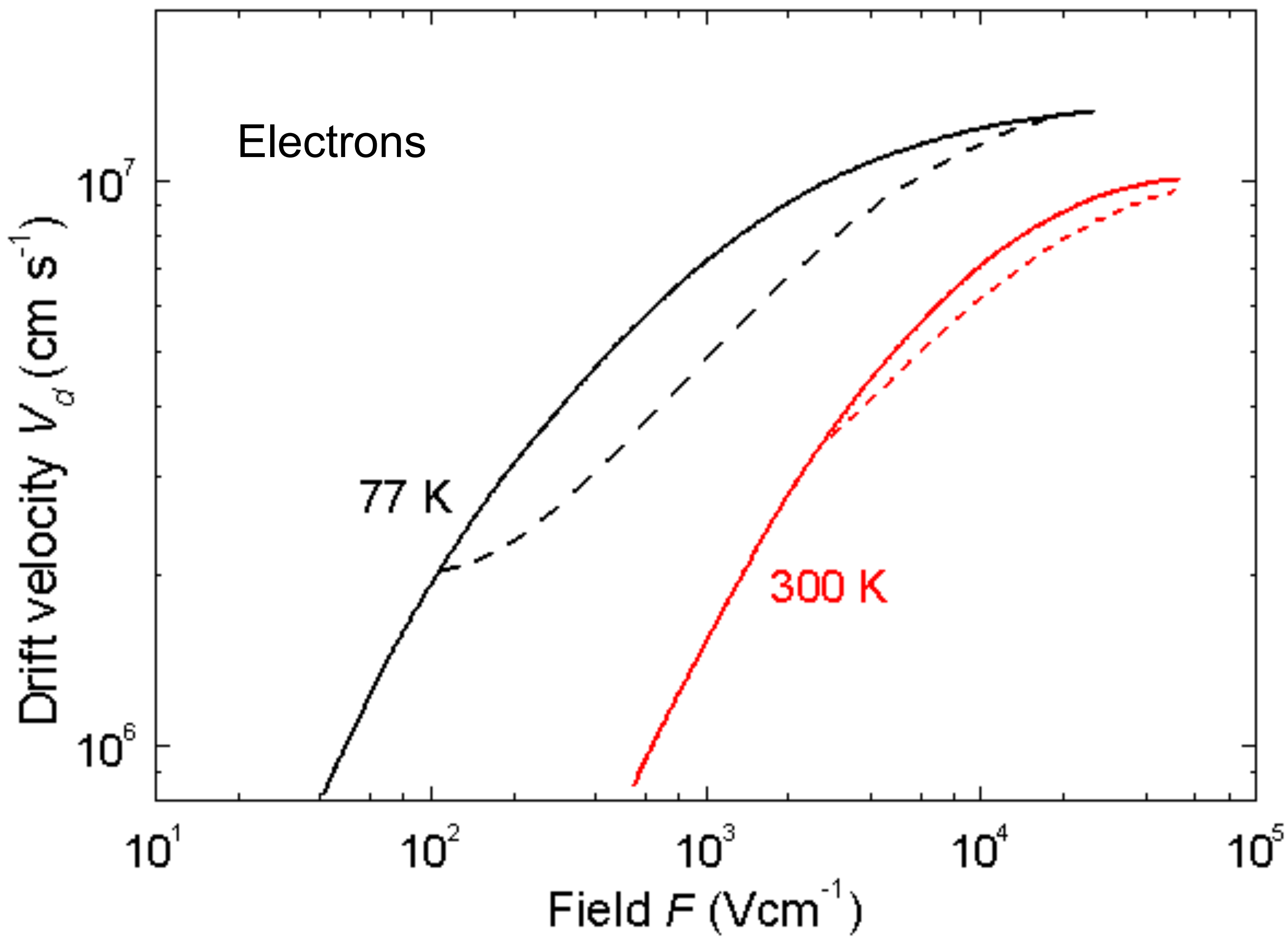


Avalanche Mulitplication

- Intrinsically limited to thin regions
- Electron multiplication factor much higher than for holes
- Requires careful device design and fab
- Can have slower recovery time
- Can add extra noise

Mobility - Electrons

Colder is faster



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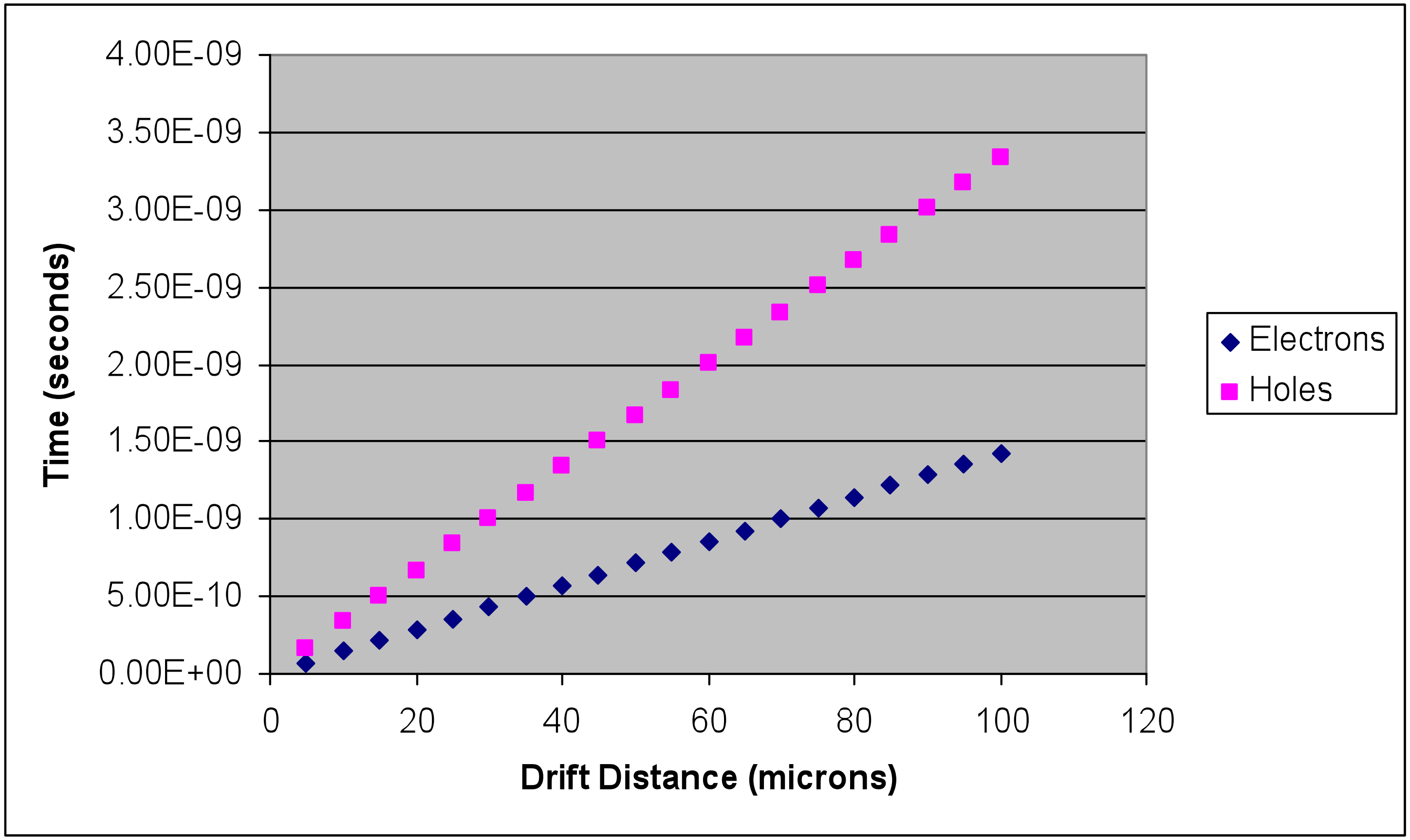
Electrons go the distance

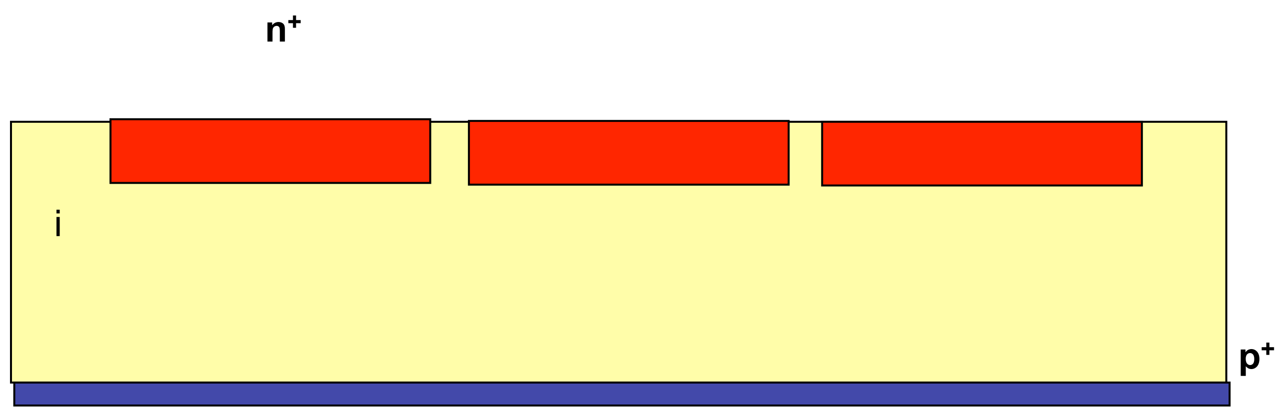
- Time for complete signal charge higher for holes



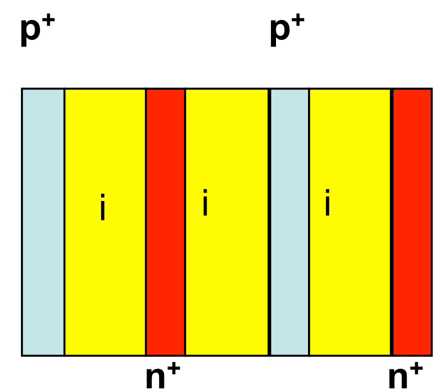
Electrons go the distance

Collect electrons on the far face, if there is one.

Minimize hole drift distance and maximize electron drift distance for a given thickness



3D Sensor

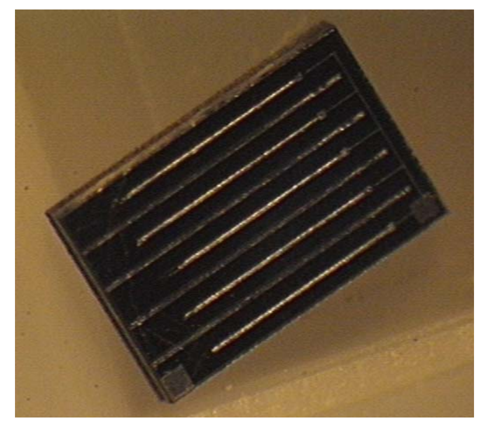


Use 200 microns thick sensor

100 micron pitch

50 micron n-to-p electrode spacing

Trench electrodes = uniform electric field



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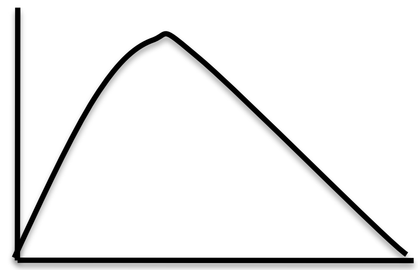
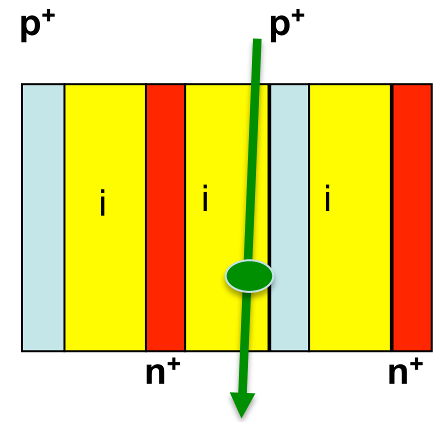
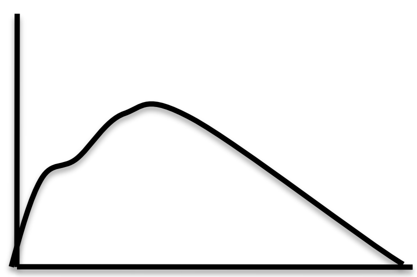
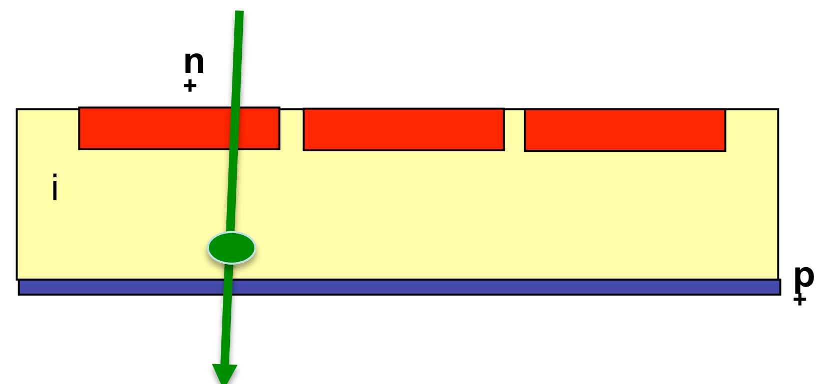
Delta Rays

- Changes total charge
- 3D scales waveform
- Planar introduces waveform distortion
- Large energy deltas will always degrade the timing







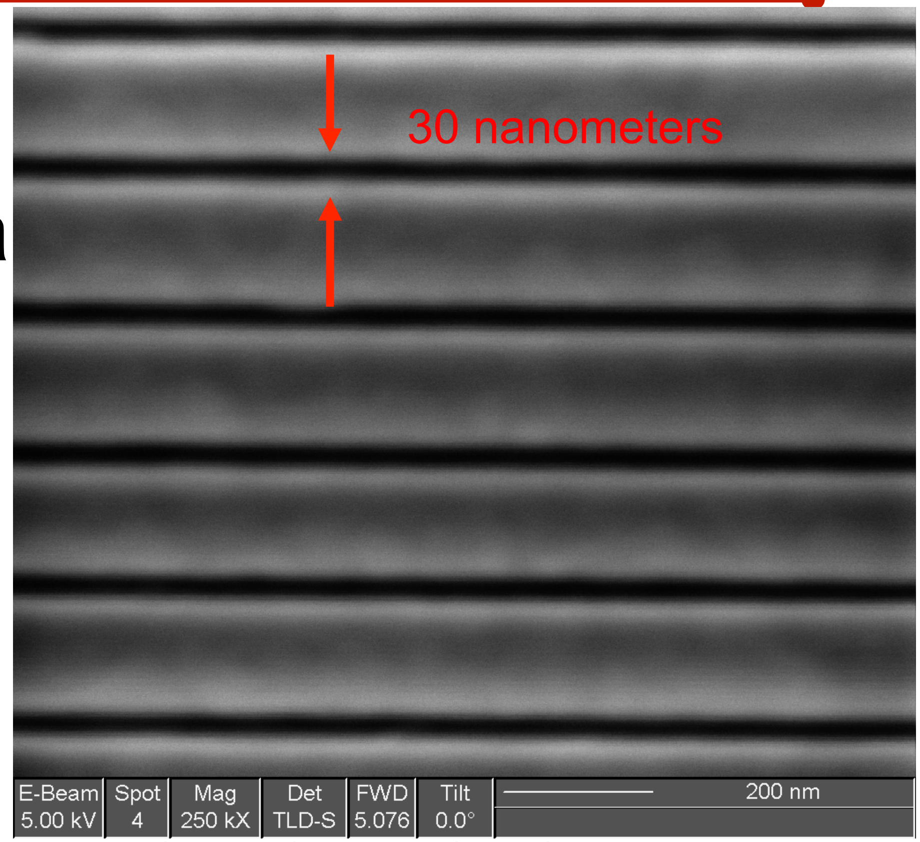


Entrance Face

- Dielectrics – bad for electrons
- Metals – bad for photons and electrons
- Heavily doped silicon – bad for both – inefficient and slower
- Anti-reflection coatings critical for optical photons

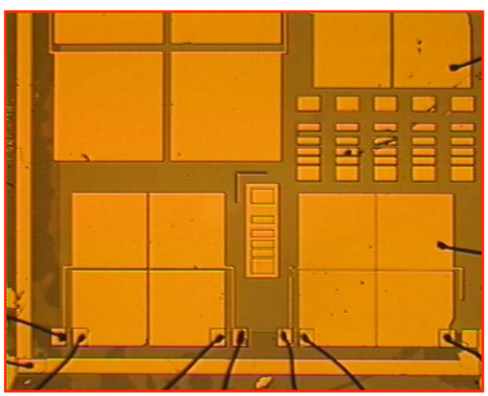
Diamond

- Higher mobilities
- Lower dielectric consta
- Higher bandgap
- Optical transparency
- Easy of fabrication?



Platinum (3000A) on Mo (30 A)
18 Microns Thick Diamond

Collaboration with D. Pickard Nat. Univ. Singapore



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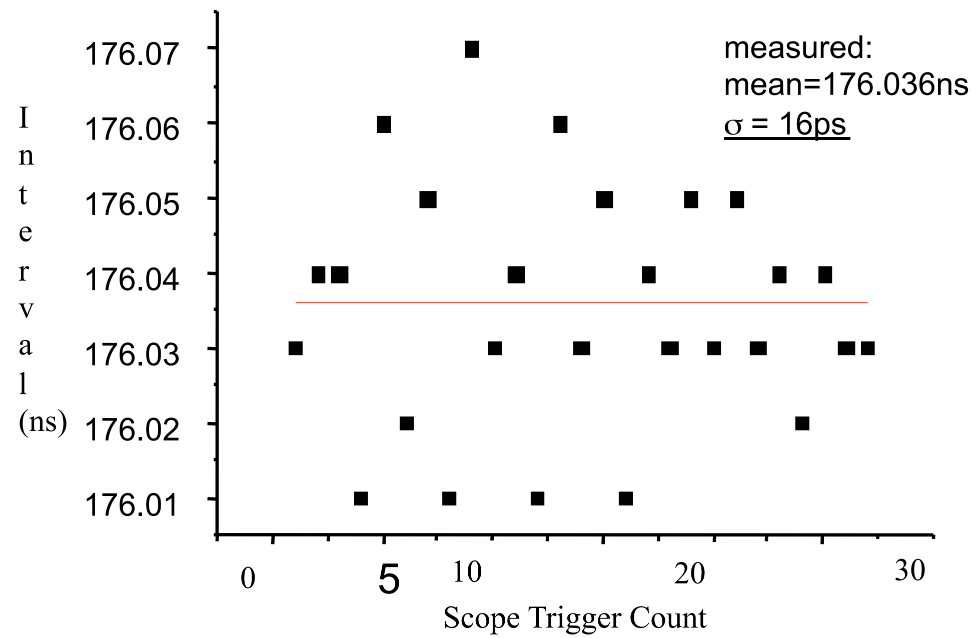
ESRF Test

Placed in synchrotron beam

Attached to fast, discrete amplifier

Recorded bunch spacing period



σ = 16 ps

Collaboration with J. Morse of ESRF

Signal to Noise

- Noise often limits the achievable resolution
- Encourages indirect sensing after multiplicative amplification of the primary
- Capacitance can be critical
- Entrance face loss of electron energy

Ideal

- Secondary electron accelerated to 3 keV – decent signal
- 300 nm sensor thickness
- All singal charge collected within 5 picoseconds
- Current pulse will have a rise time several times faster

Summary

- Match absorption thickness to particle
- Maximize electric fields
- Run cold
- Choose between direct and indirect sensing
- Entrance-face dead layer must be minimized
- Have electrons transit the long way
- Beware of capacitance

Personnel

Sherwood Parker, Gary Varner, John Morse, Ed Westbrook, Al Thompson, Jasmine Hasi, Cinzia Da Via, Angela Kok, Giovanni Anelli, Dan Pickard, Niels van Bakel