Silicon Sensors for NLC Pair Monitor

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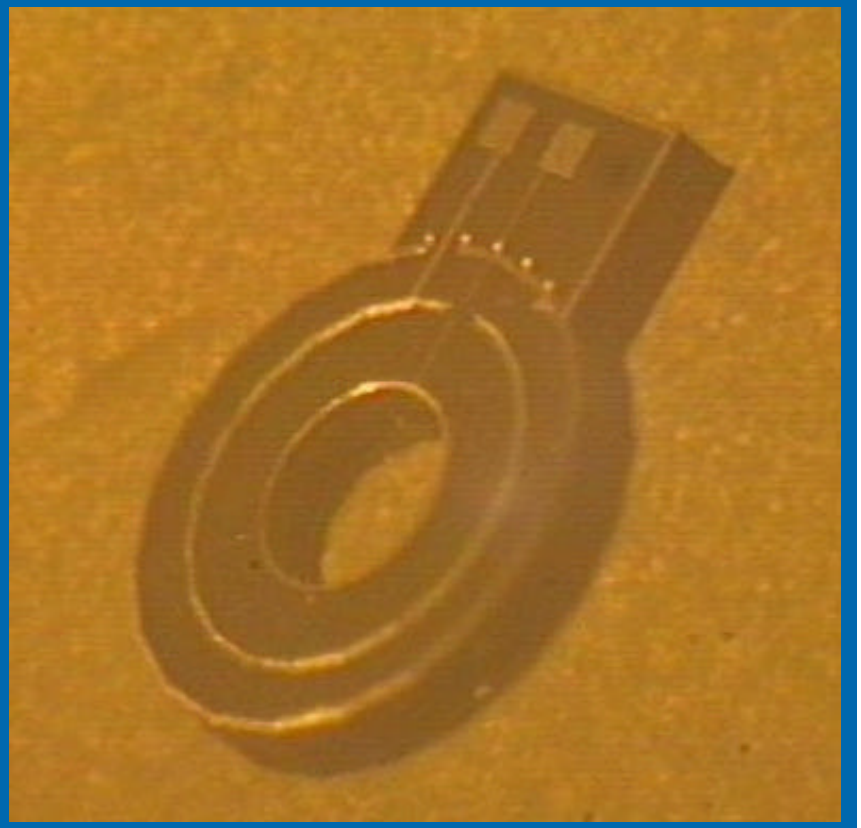


Main Requirements for Pair Monitor

Sensitive to 1 MIP

Radiation Hard to 1 GigaRad

Sub Nanosecond Timing

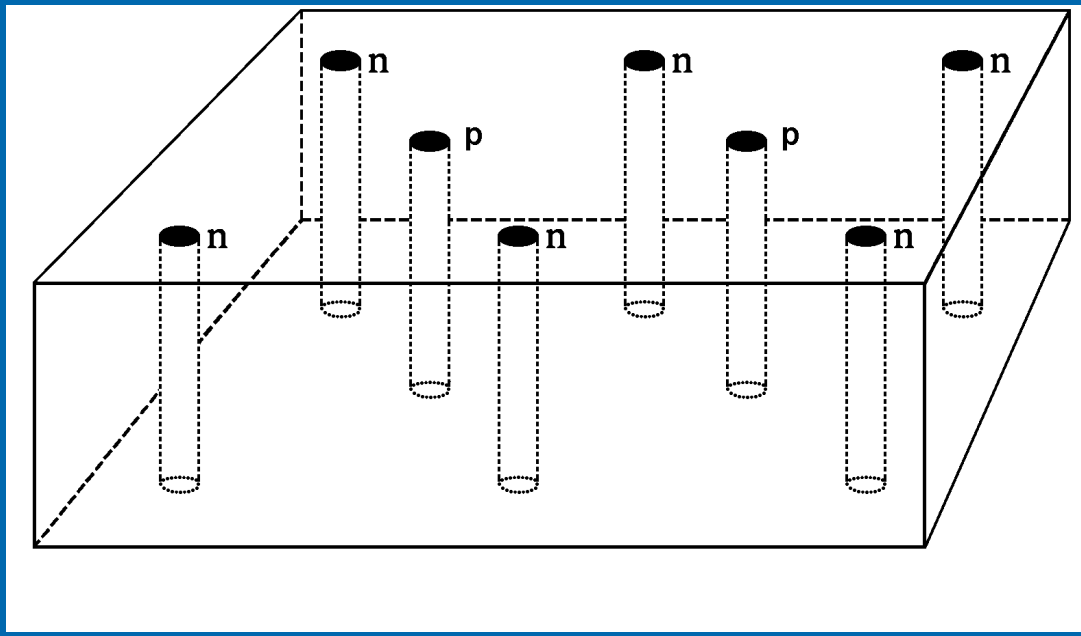
Modest to Large Area

3D Solution

Decouple Drift Distance from Thickness

Horizontal Fields

Short Drift Distance



Short Depletion Distance

3D Solution

Depletion Voltage Scales as 1/D2

If Maximum Drift Distance is 75 microns

Then 16 Times More Radiation Hard then Typical 300 micron Thick Planar Sensor

Horizontal Fields

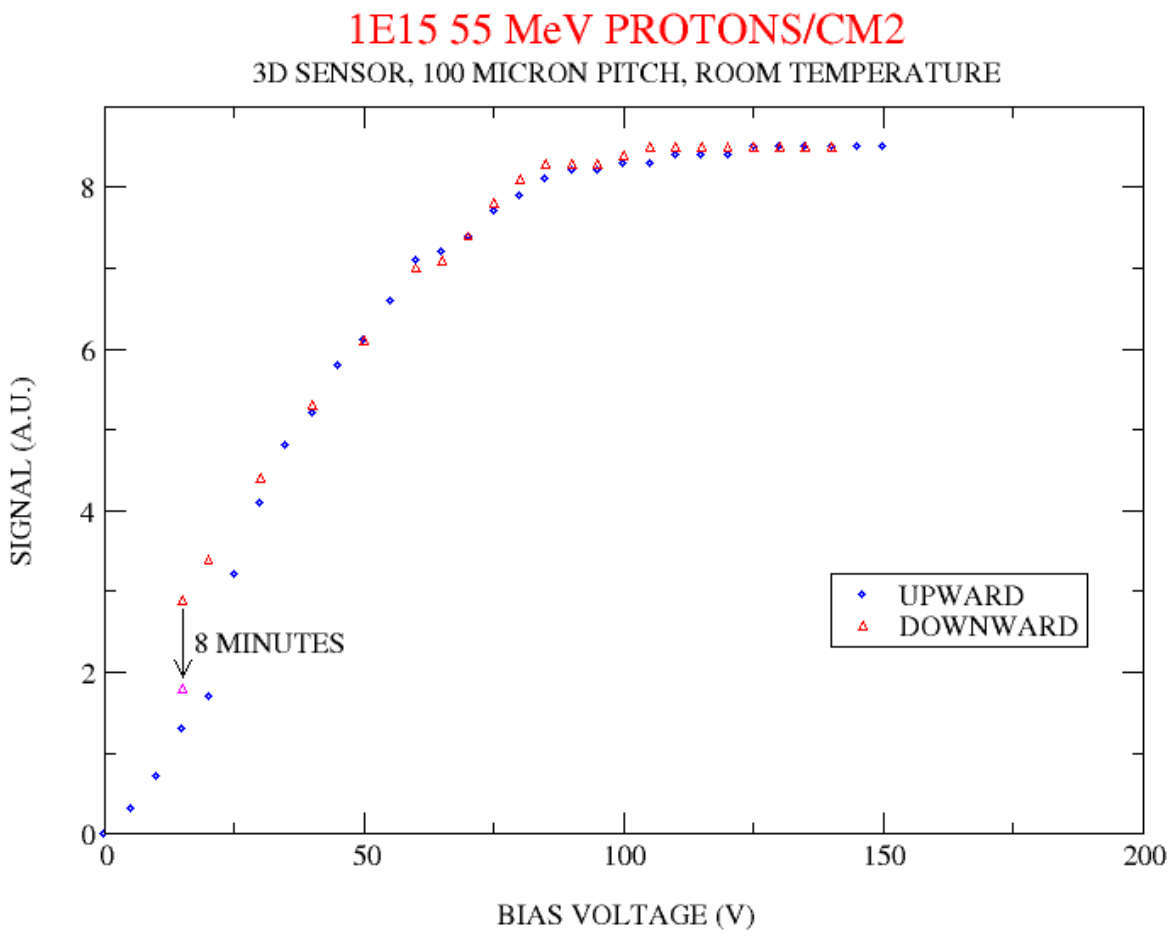
3D Radiation Tests

Depletes at 100 Volts

Non-Optimal Geometry

No Oxygen Doping

No Beneficial Annealing

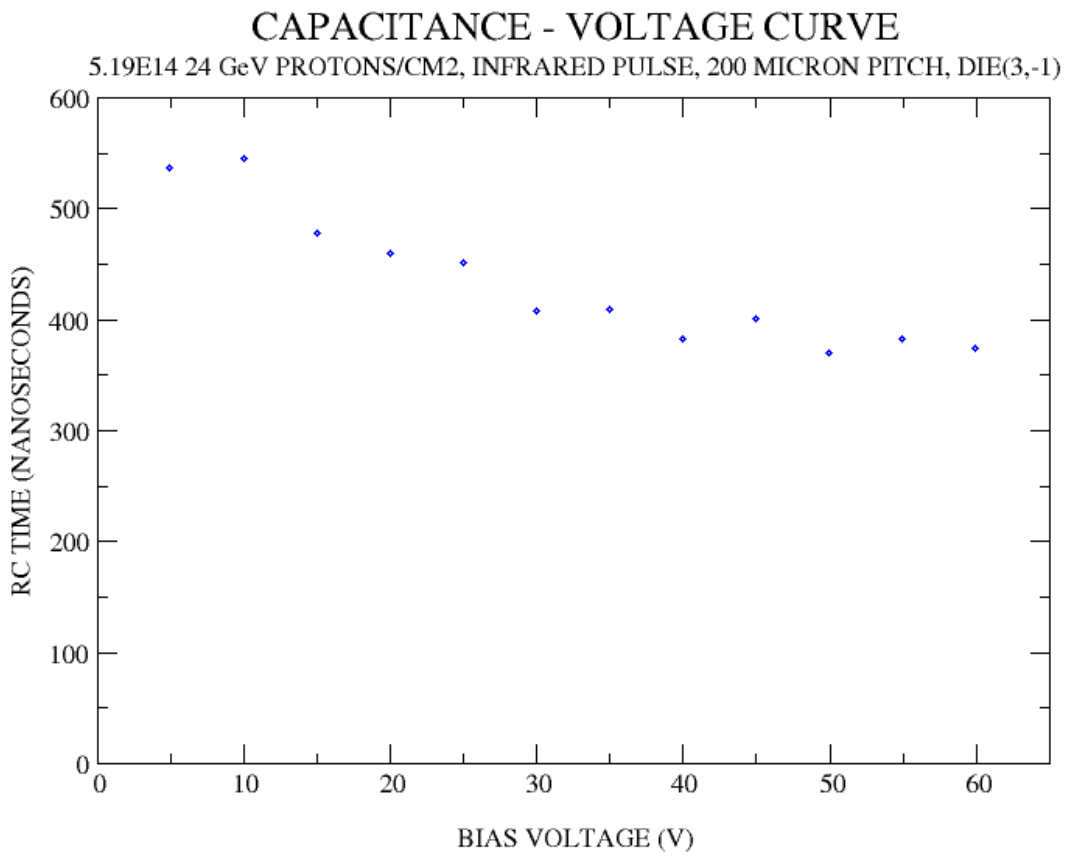


Equivalent to 1.8e16 high-energy electrons

3D Radiation Tests

Depletes at 45 Volts

Larger Pitch Than Sensor on Previous Page



Equivalent to 0.8e16 high-energy electrons

How Fast? – Back of Envelope

Silicon Breakdowns at 3e5 V/cm

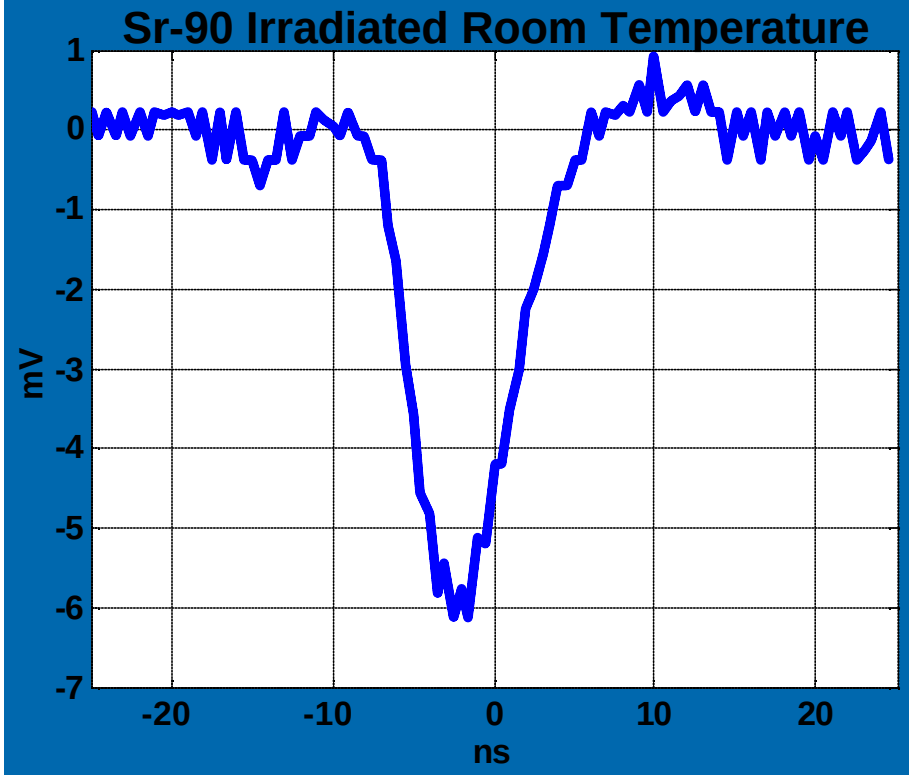
Assume Field of 2e4 V/cm (Factor of 15 Below Breakdown)

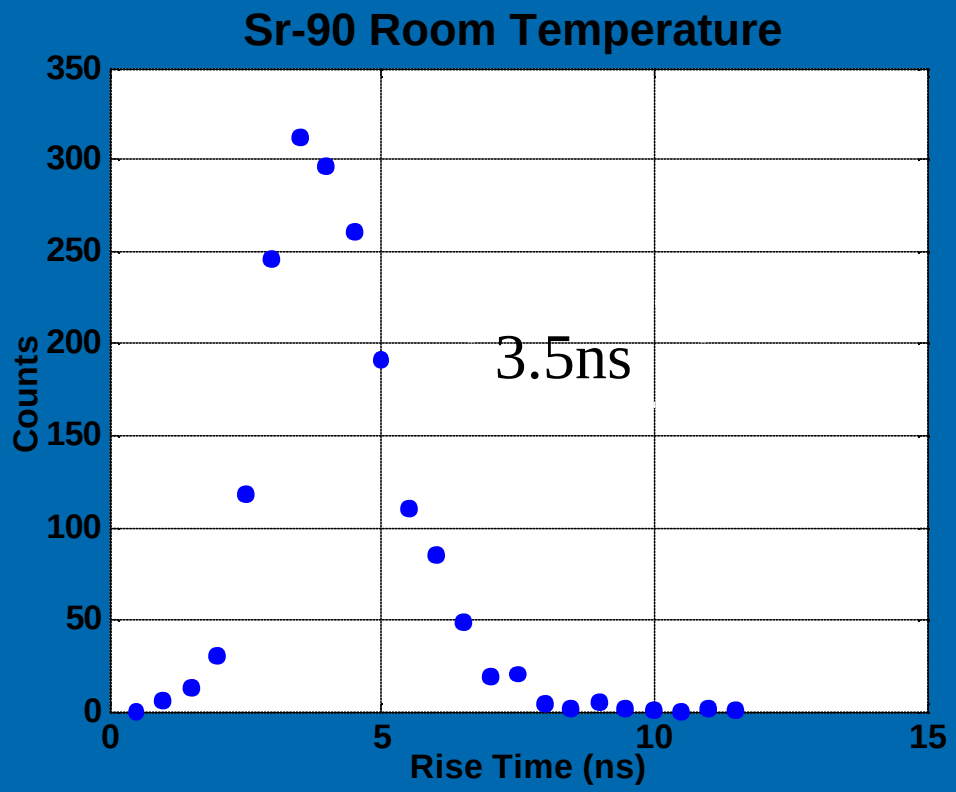
Electron Velocity = 1e7 cm/s; Hole Velocity = 6e6 cm/s

(These values are below the Saturation Velocities)

All Charge Collected from 100 microns in one nanosecond!

How Fast? – Beta Studies



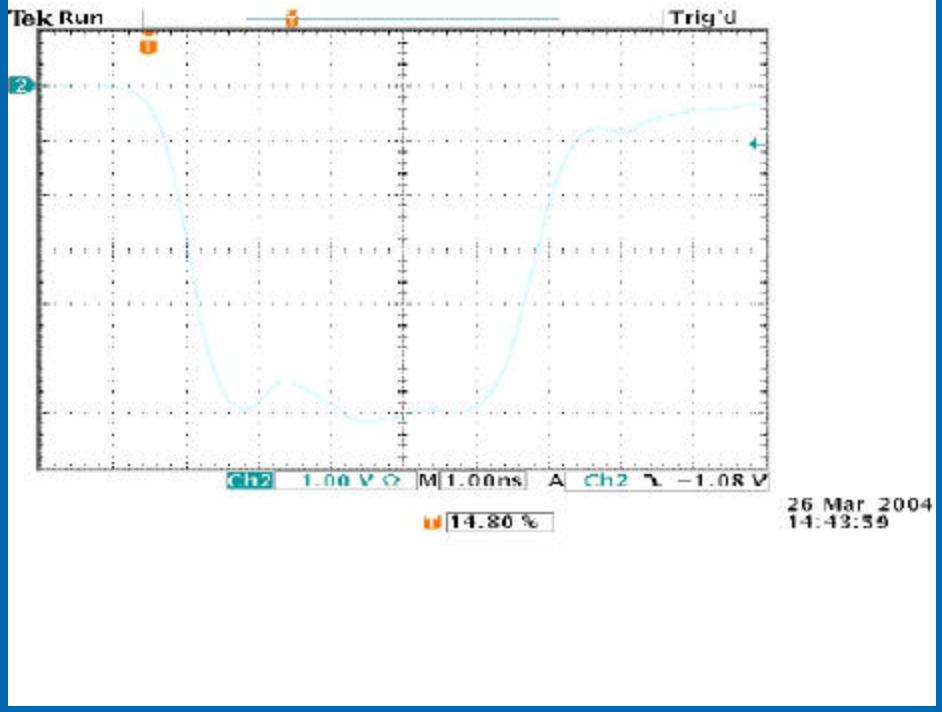


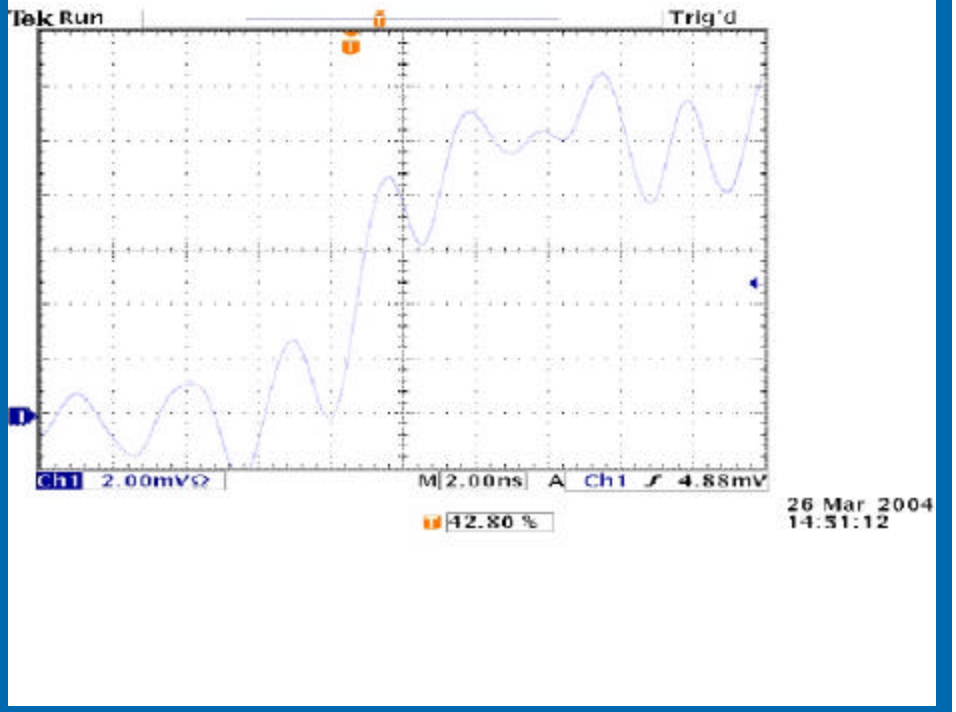
Read Out with 0.25 Fast CMOS – Time Response was Dominated by the Electronics not the Sensor

Irradiated with 1e15 24 GeV Protons = 6e15 GeV Electrons

Collection Efficiency of 57 Percent

How Fast? – Laser Studies





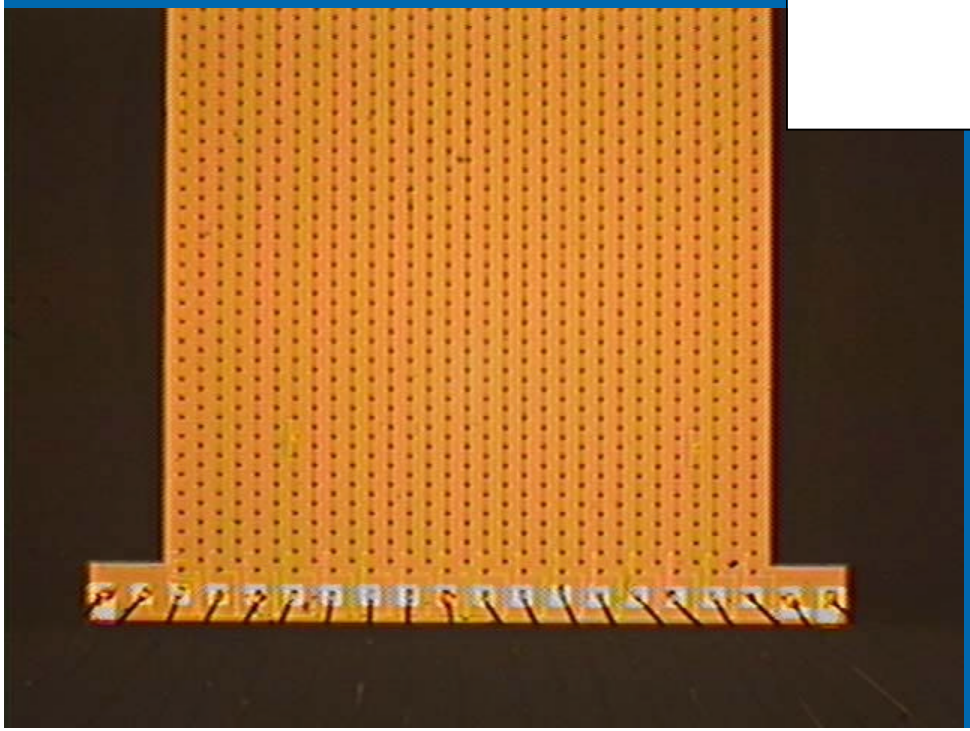
Infrared Laser Pulse on Left 4 ns FWHM; FW=5 ns

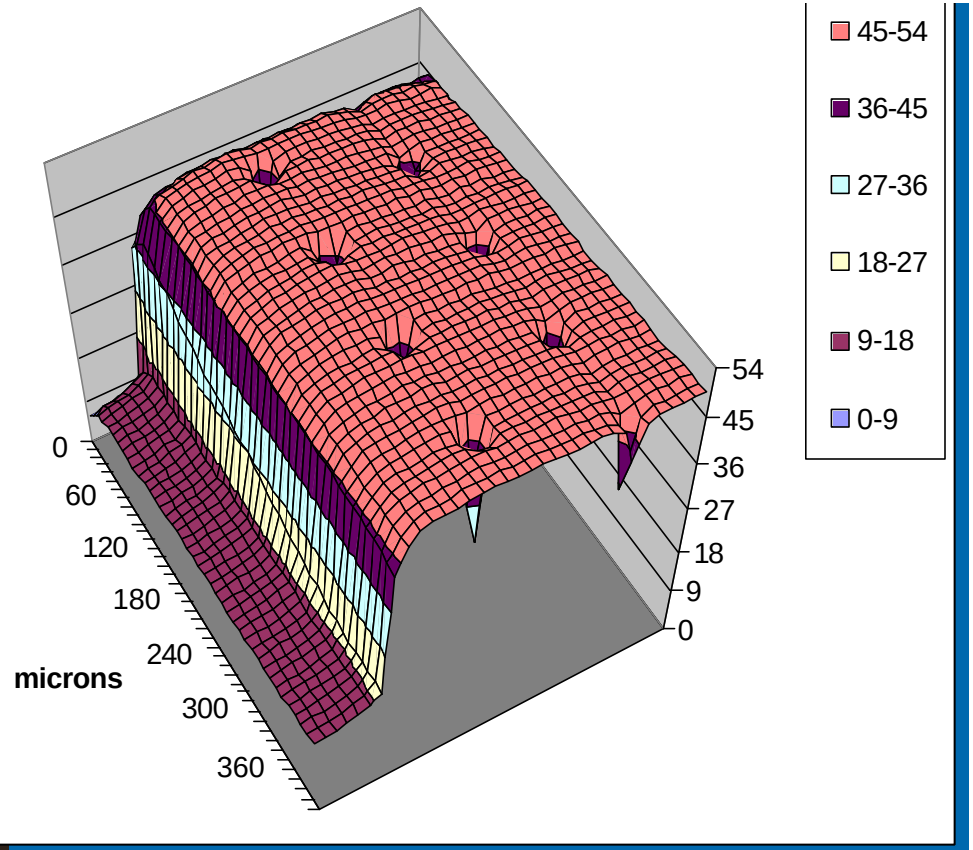
Silicon Output on Left = Less than 6 ns 10-90 Rise Time

Active Edge - Synchrotron X Rays

No Insensitive Edge

Confirmed with Pions at SPS





Slight Insensitivity in Electrodes

3D Silicon Summary

Operates after 1.8e16 GeV Electrons per cm2

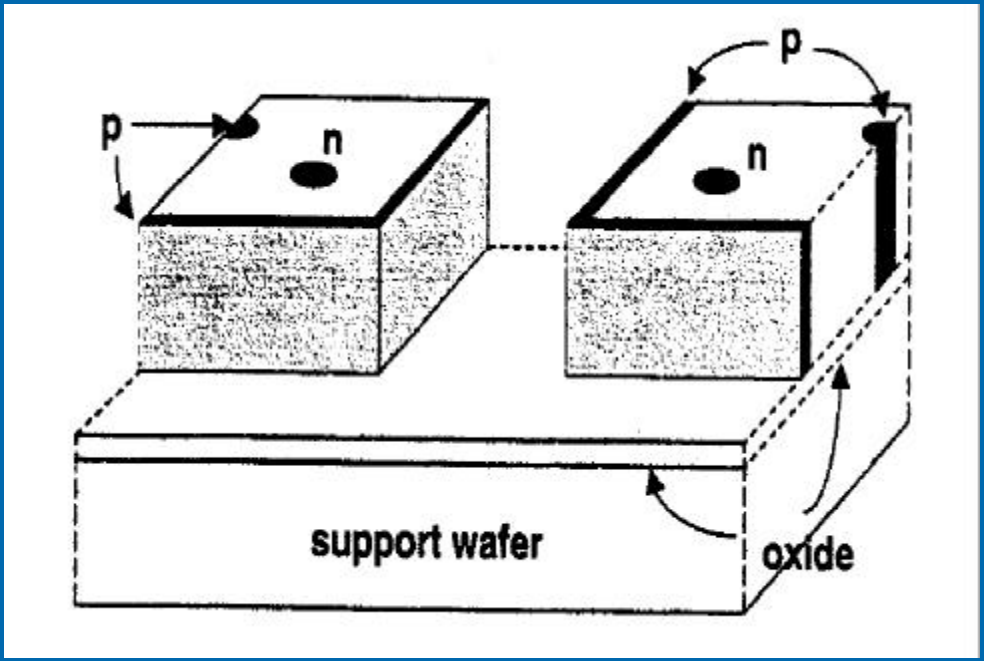
Full Charge Collection in Under 1 nanosecond

No Insensitive Edge

Thin Planar Silicon

Developed Thin Sensor Process using Fusion Bonding

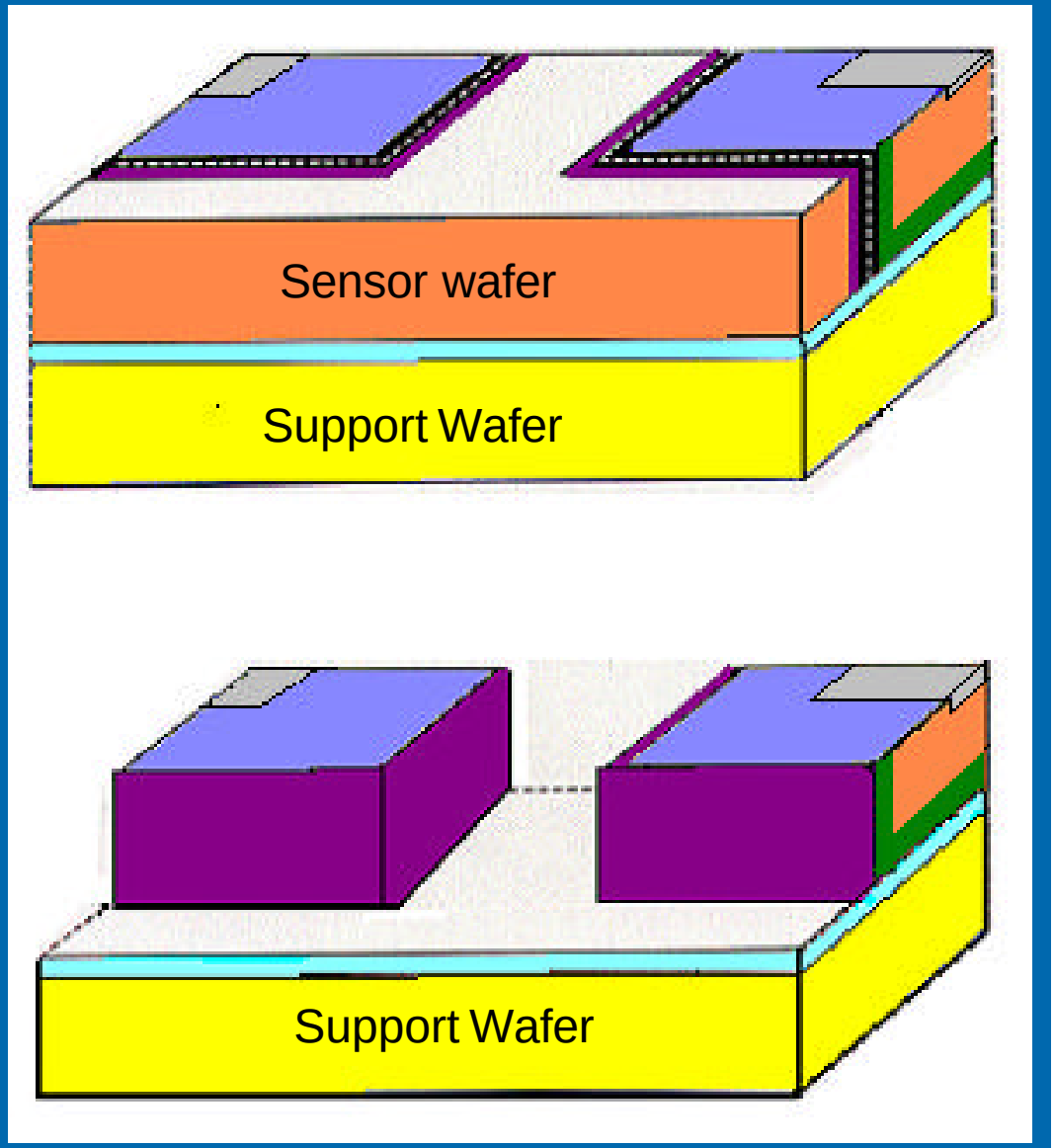
Similar Advantages as 3D but Achieved by Reduced Sensor Thickness



Corners of the two sensors after dicing by etching large trench, showing doped sidewalls (sensors still on support wafer)

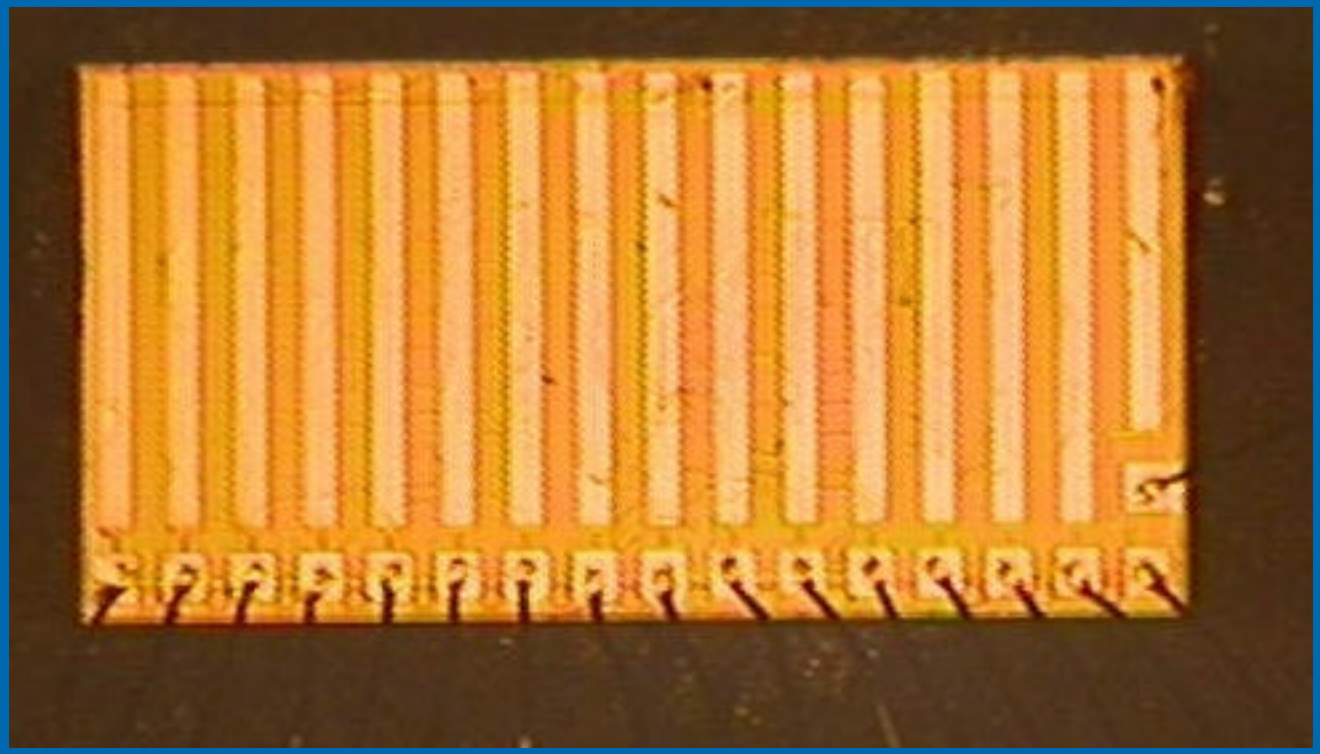
Fabrication

- Use Suppport Wafer
- No Sawing
- Plasma Dice Instead
- Dope and Grow Field Oxide on Edges
- Otherwise same as Standard Planar



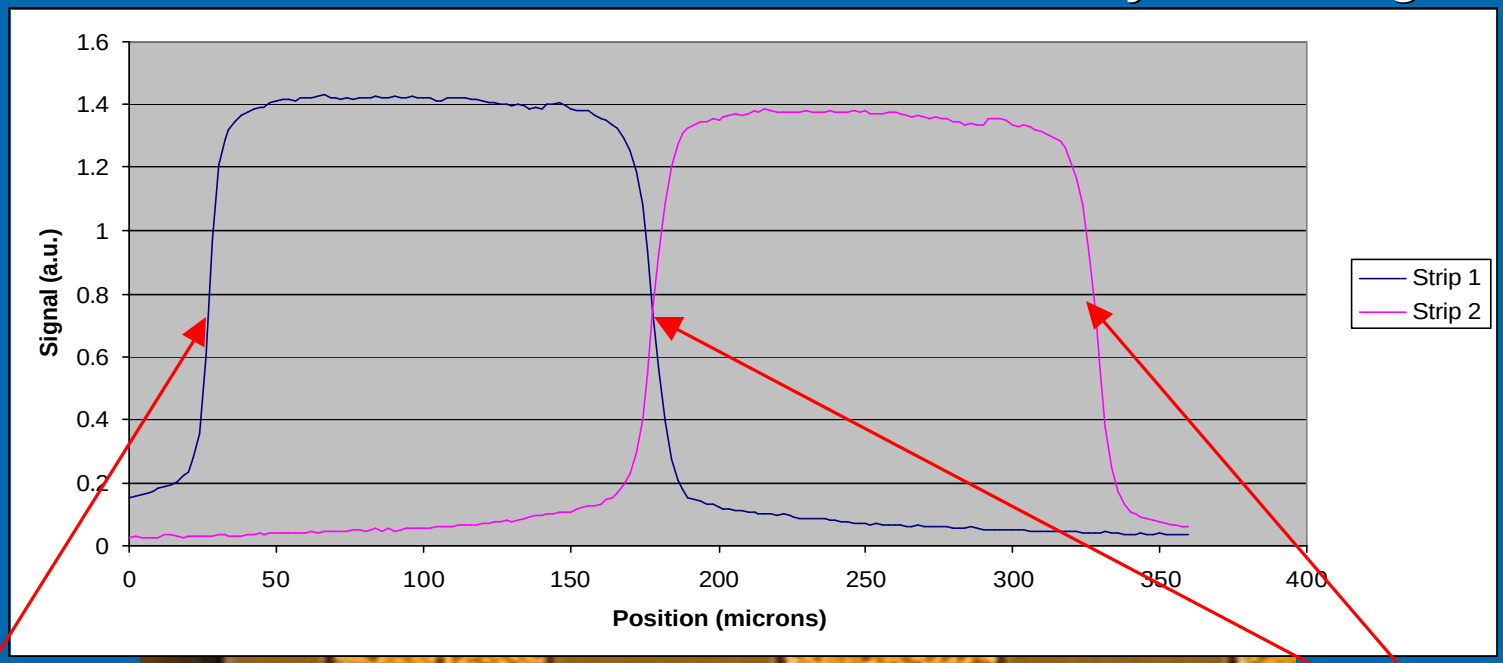
100 microns Thick

Any Thickness is Feasible

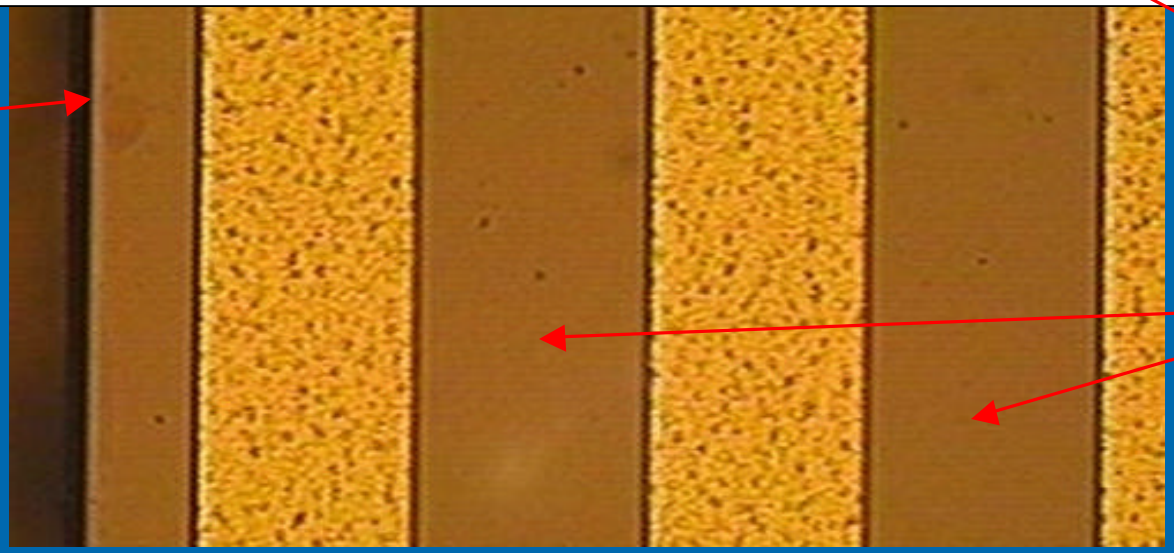


12.5 KeV X-Ray MicroBeam At Advanced Light Source
Scanned Across Active-Edge, Strip Sensor

Active To Within 5 Microns from the Physical Edge!



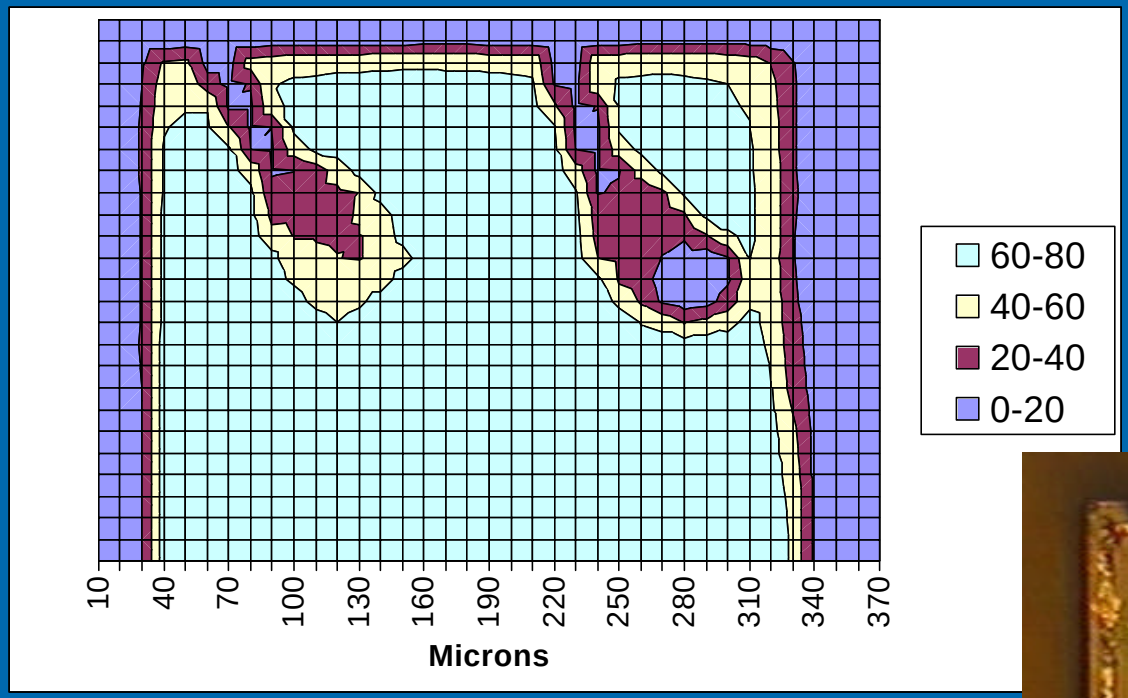
Physical Edge



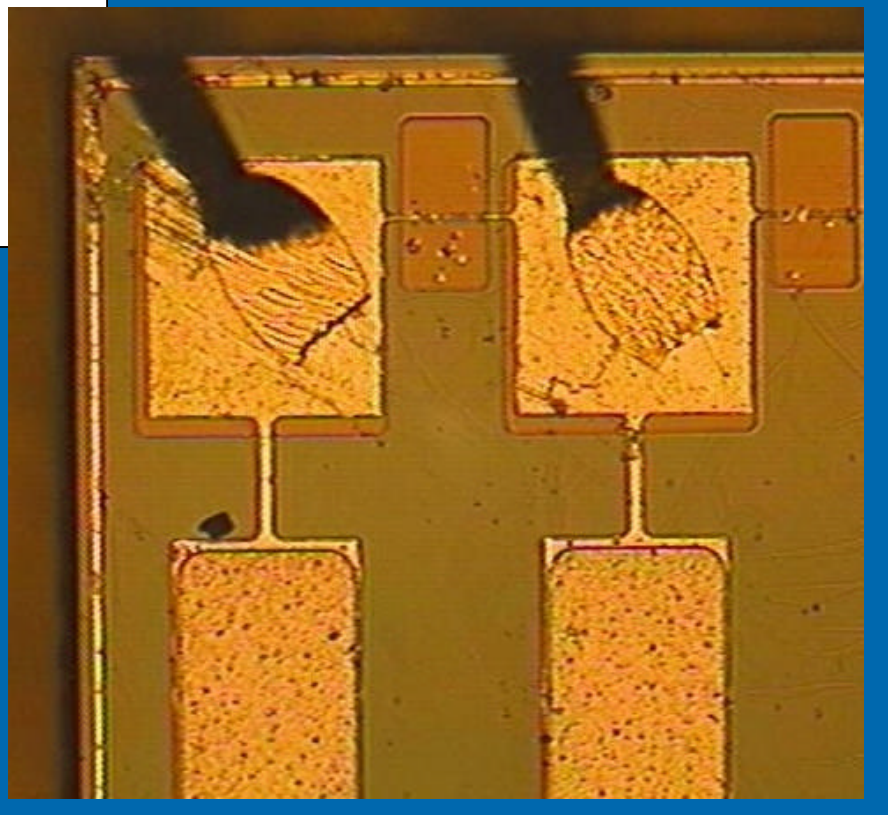
Inter-Strip Electrical Boundary

12.5 KeV X-Ray MicroBeam At Advanced Light Source Scanned Across Active-Edge, Strip Sensor

Wire Bonds



2 μm Grid



- Sensitive up to Edge
- Even With No Implant!