3D Sensor Measurements at Univ. New Mexico

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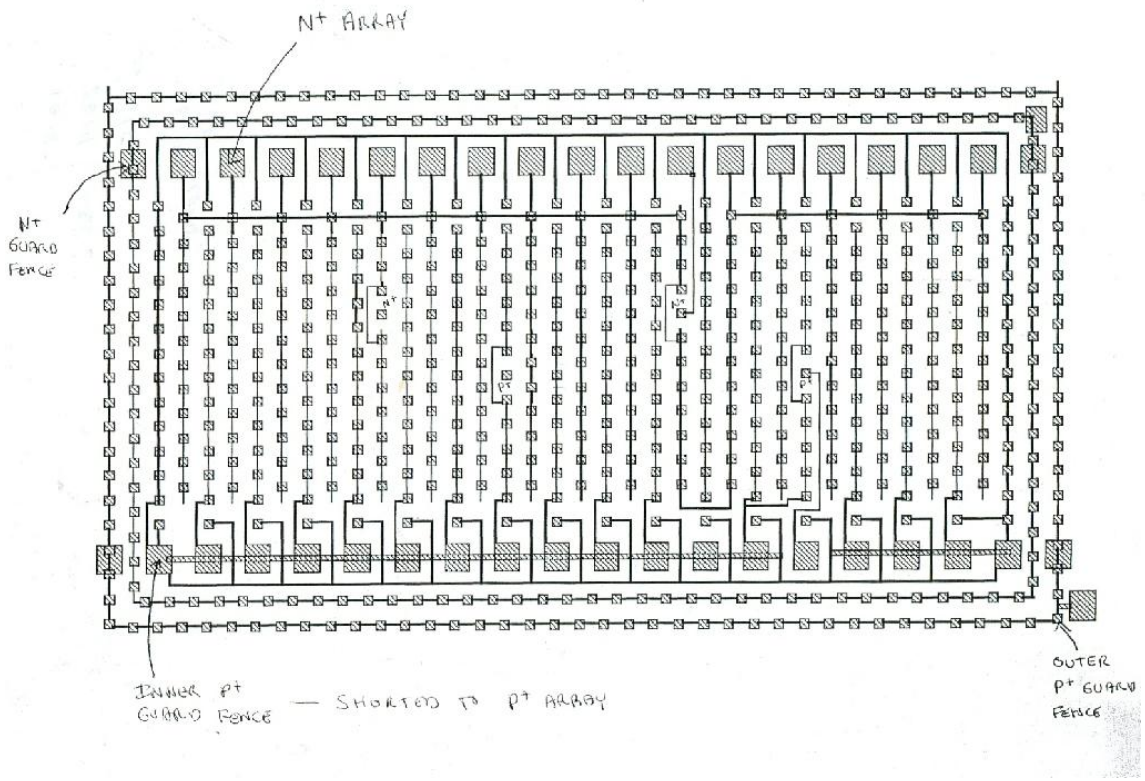
Introduction

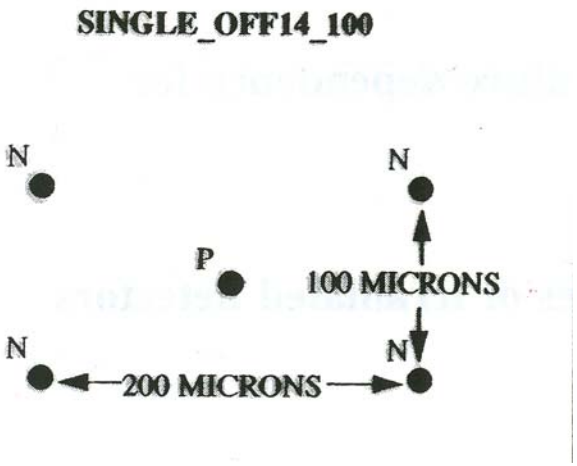
- Framework: to assist ATLAS in selecting a technology for pixel sensors in the upgrade era.
- Specifically: to evaluate 3D sensors with respect to
  - Leakage Current
  - Depletion Voltage
  - Capacitance
  - Charge Collection
- Activities 2004-2005
  - Received unirradiated and irradiated (10^{14} , $2x10^{14}$, 10^{15} cm^{-2} 55 MeV p) 3D sensors from Sherwood Parker.
  - Performed initial measurements, saw the need for increased precision.
  - Purchased new equipment totaling approximately $40k (UNM funds)
    - Kentech APG1 Pulser (300pS pulse width)
    - Picoprobe Model 35 (26GHz bandwidth, 14pS rise time, 0.05pF capacitance)
    - Tektronix 7254B Oscilloscope (2.5GHz bandwidth)
    - Various other items (960nm IR laser, 12GHz Photoreceiver)
  - Obtained much improved results.

3D Sensor Configuration

- Configuration of Measured Devices

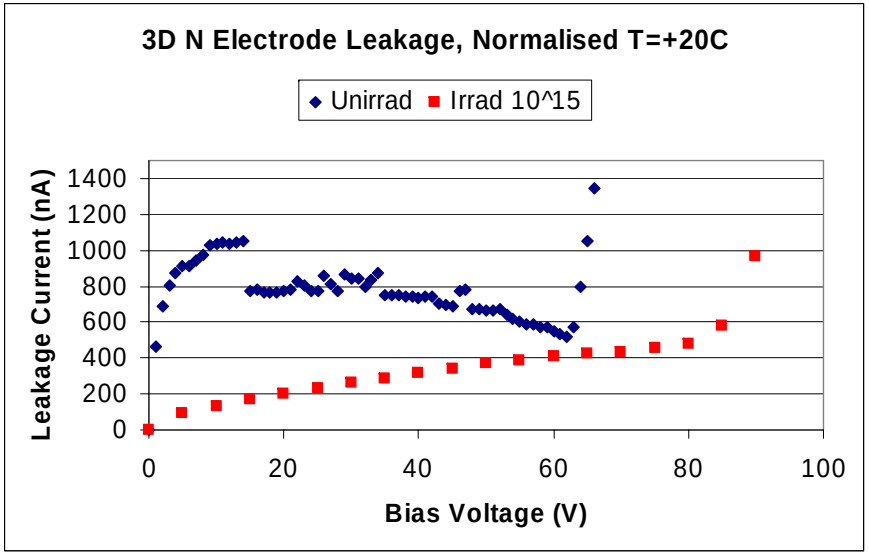


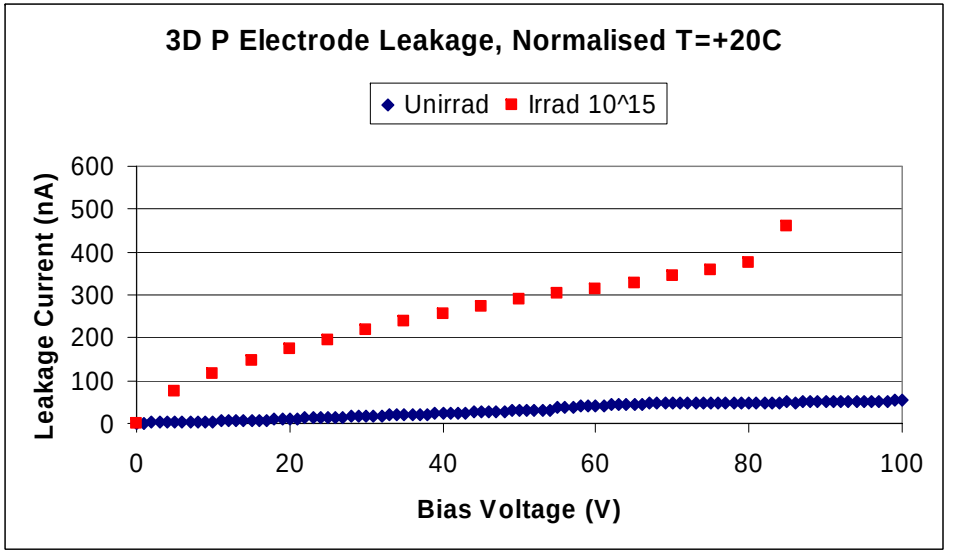
- Top view layout



- Layout dimensions

Leakage Current (preliminary)

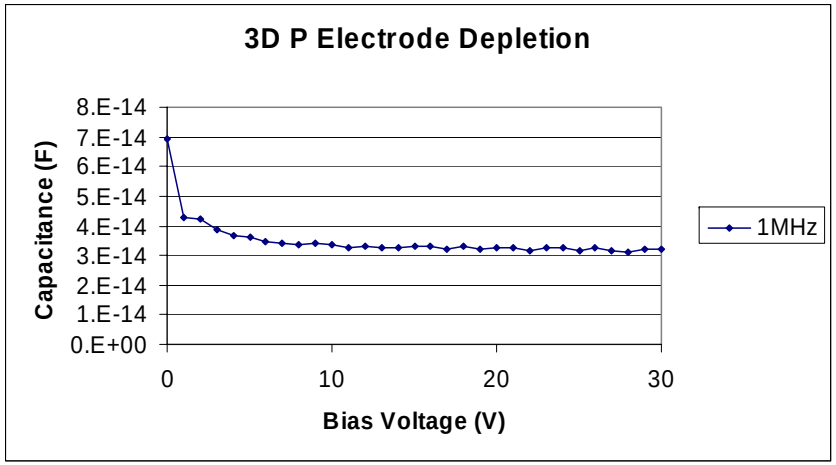


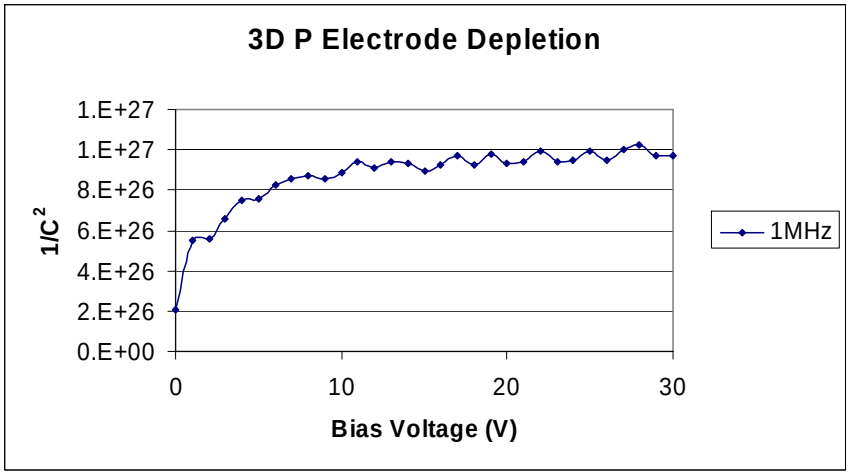


- N Electrode
  - Unirrad: n electrodes not isolated
  - Irrad: n electrodes isolated
- P Electrode
- Result: low values of leakage
  - Ileakage Irradiated 10^{15} N ~ 400nA (+20^{o}C), ~ 68nA (0^{o}C)
  - Ileakage Irradiated 10^{15} N ~ 300nA (+20^{o}C), ~ 51nA (0^{o}C)

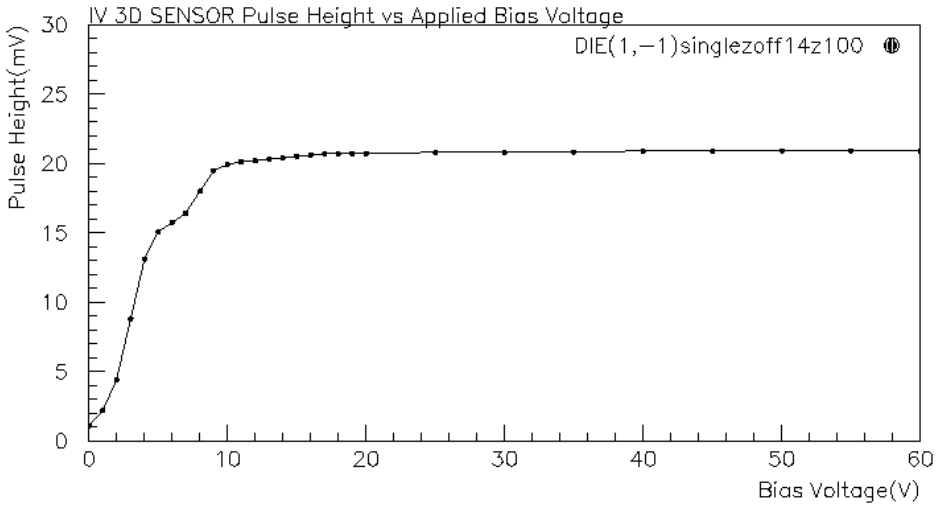
Depletion (preliminary)

- CV Measurement: Unirradiated P Electrode Depletion ~ 10V



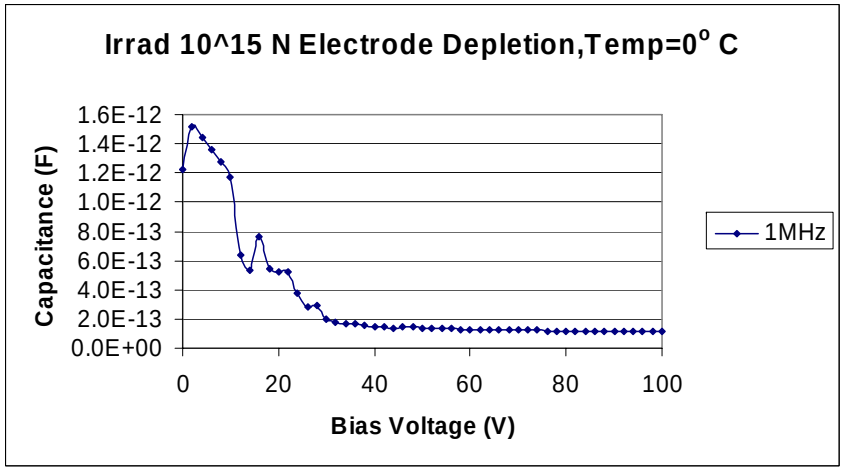


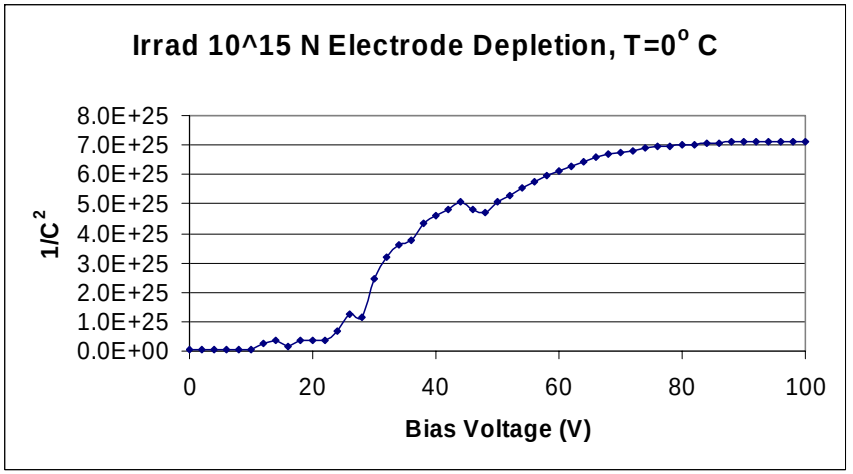
- CV measurement is confirmed by laser pulse height vs Bias result



Depletion (preliminary)

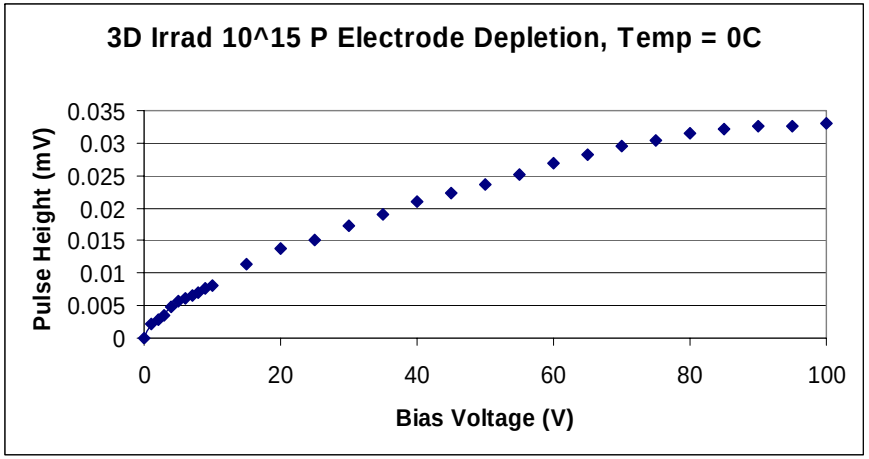
- CV: Irradiated 10^{15} 55MeVp N Electrode Depletion ~ 80V





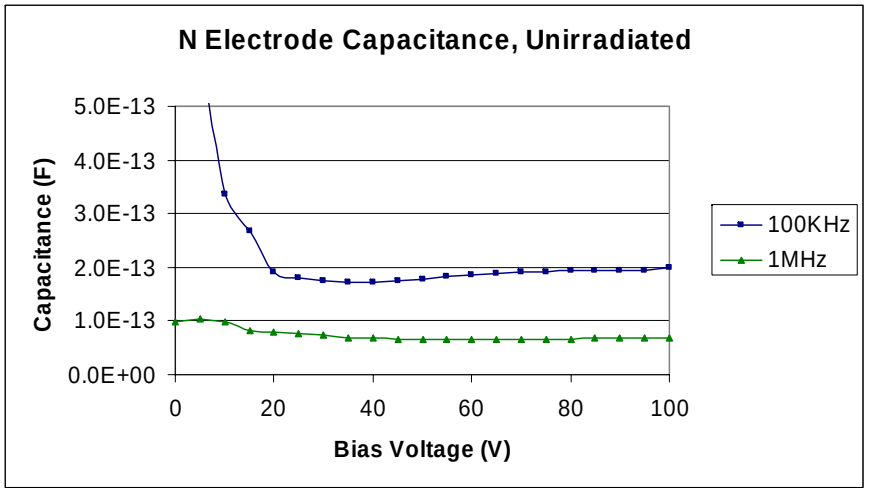
- Laser pulse height vs bias on Irradiated 10^{15} 55MeVp P Electrode Depletion ~ 80V

- **Result: very low depletion**
  - **Vdepletion = 10V Unirradiated**
  - **Vdepletion = 80V Irradiated 10^{15}**

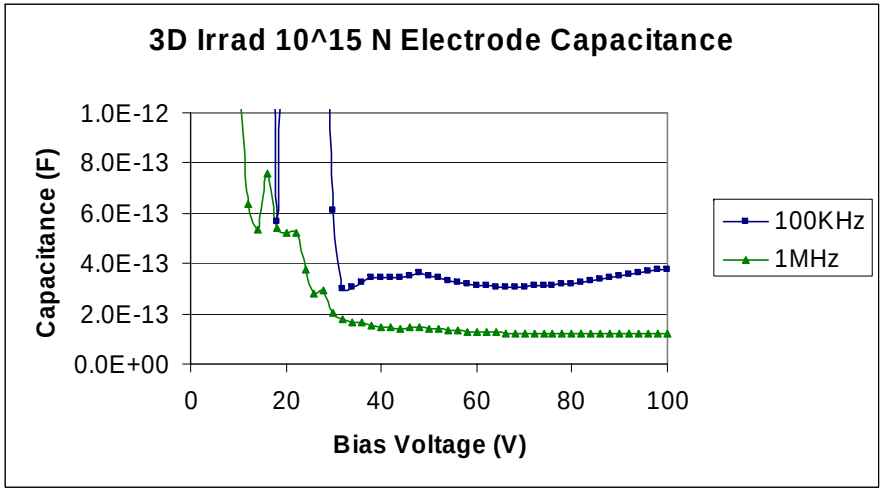


Electrode Capacitance(preliminary)

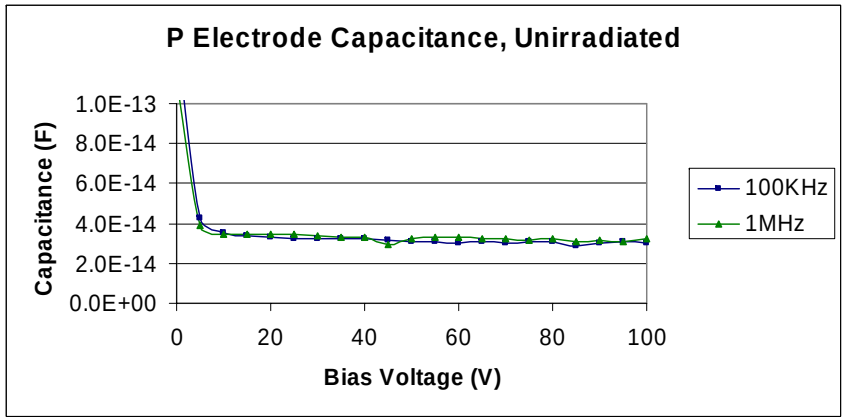
- Direct Measurement using LCR meter
- Unirradiated: N Electrode



- Irradiated 10^{15} 55MeVp: N Electrode



- Unirradiated: P Electrode



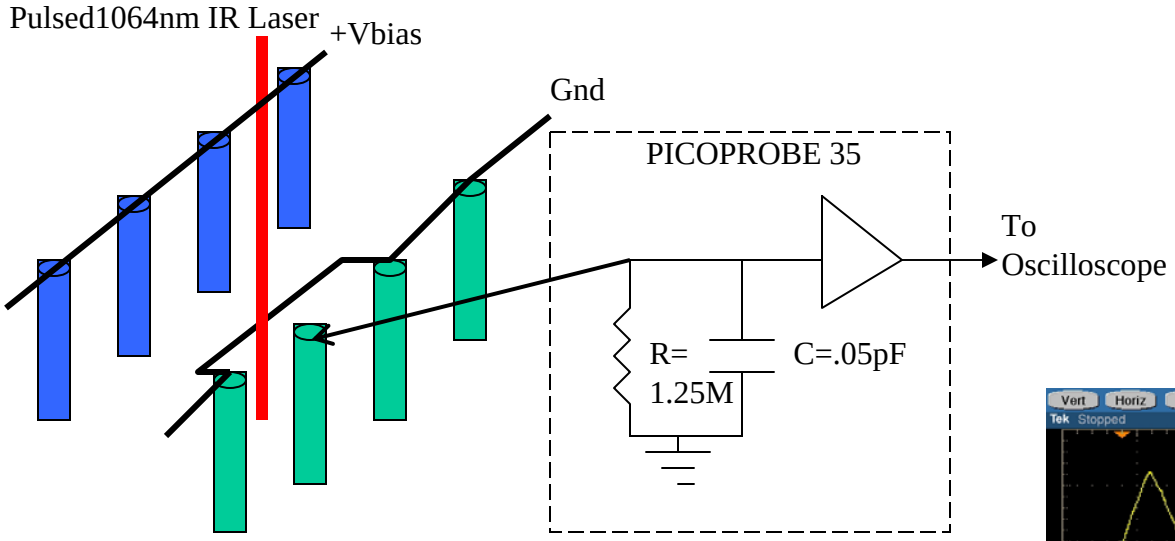
Result: very low electrode capacitance

- **Cunirradiated P ~ 32 fF**
- **Cirradiated 10^{15} P ~ 59 fF**
- **Cunirradiated N ~ 68 fF**
- **Cirradiated 10^{15} N ~ 120 fF**

- Plans: Measure capacitance vs temperature and frequency

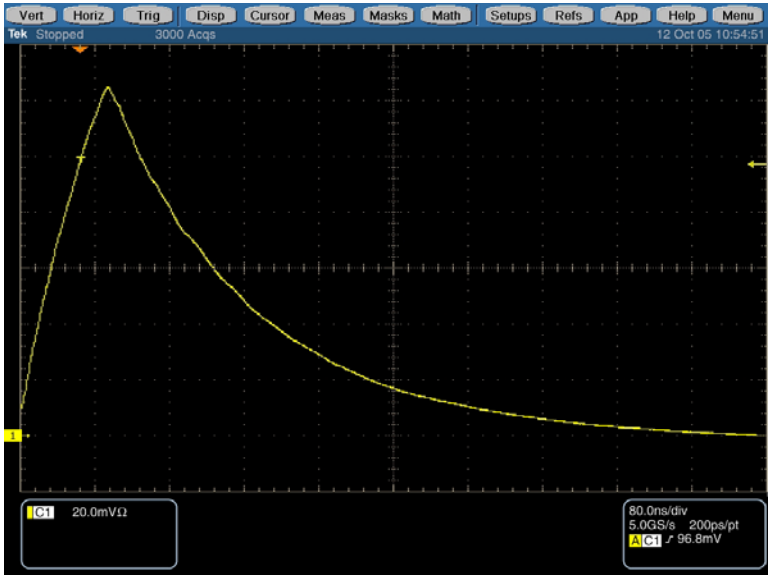
Electrode Capacitance(preliminary)

- Indirect Measurement using Decay Time of Picoprobe



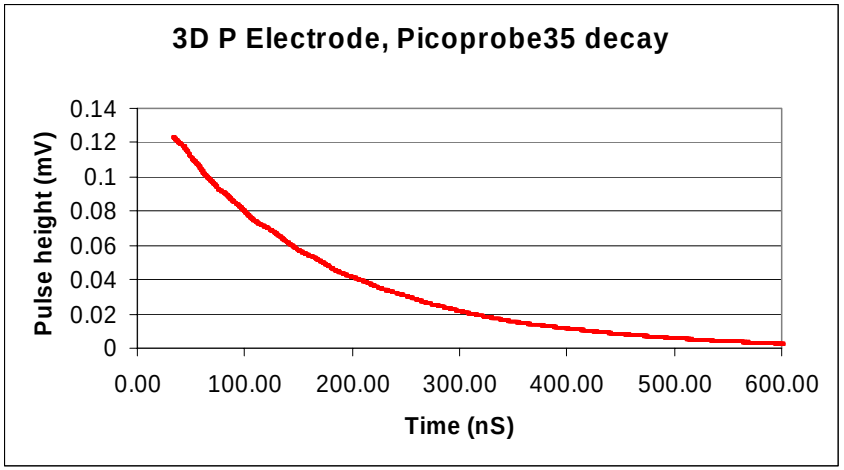
- Time Const = $R*(C+C_{3D})$

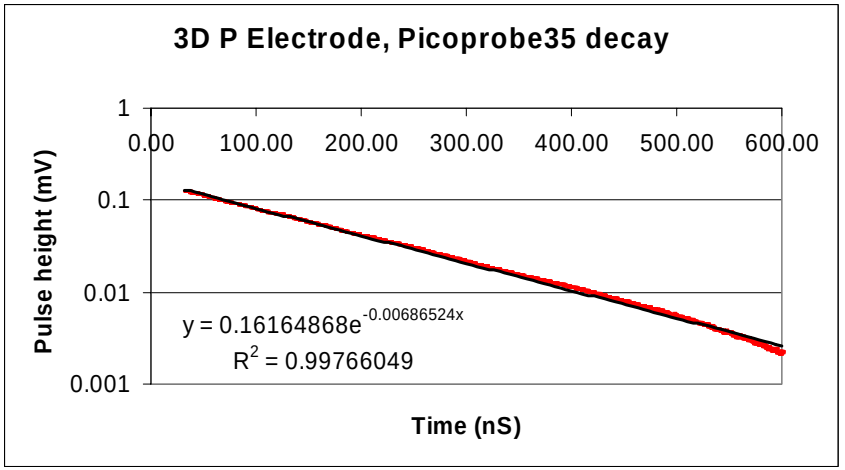
- Extract C3D from the decay time constant and using values of probe resistance and capacitance

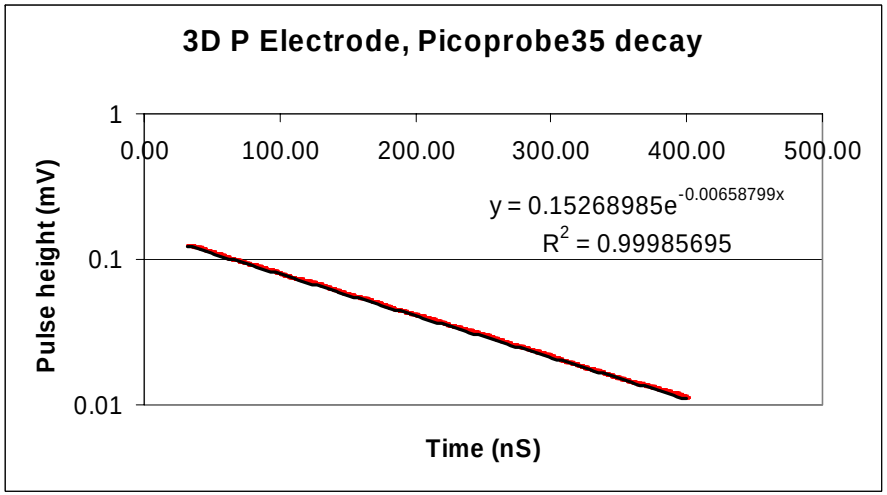


Electrode Capacitance(preliminary)

- Indirect Measurement using Decay Time of Picoprobe





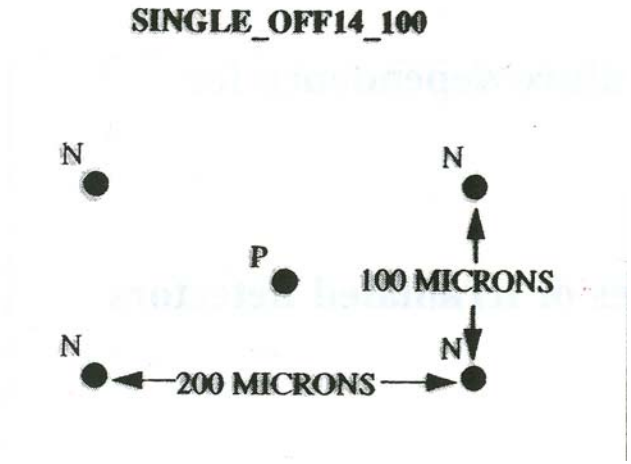


- Time Const = $R*(C+C_{3d})$= 152nS

Result: C_{3D} = 71 +/- 16 fF
(probe values of R and C +/- 10%)

Electrode Capacitance(preliminary)

- 2D and 3D Electrostatic Calculation:
  - P Electrode Length = 120 um
  - P Electrode Diameter = 20 um
  - Center electrode to nearest neighbors



Result:

2D calculation C_{3D} P electrode = 28 fF

3D calculation C_{3D} P electrode = 31 fF

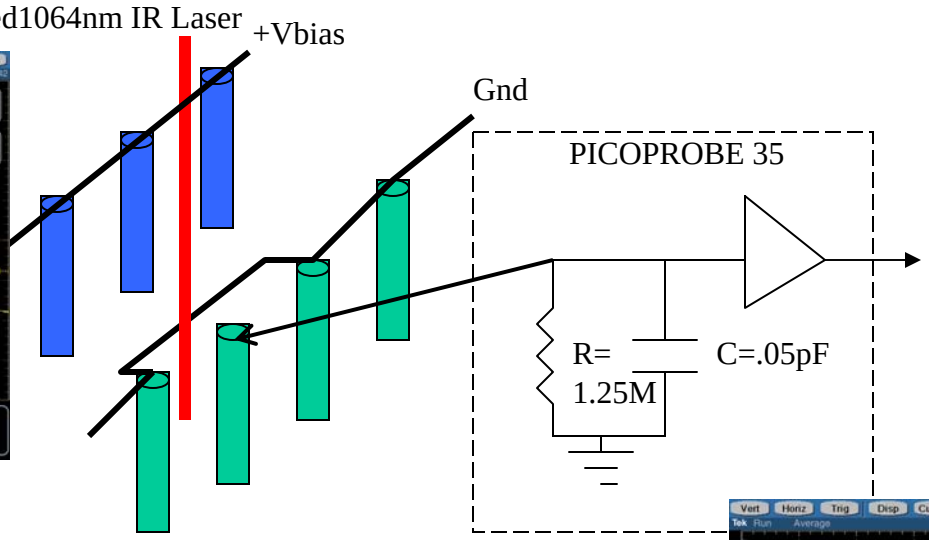
Electrode Capacitance(preliminary)

- Summary: Unirrad Vbias=40V 1MHz; Irradiated, Vbias=80V, 1MHz

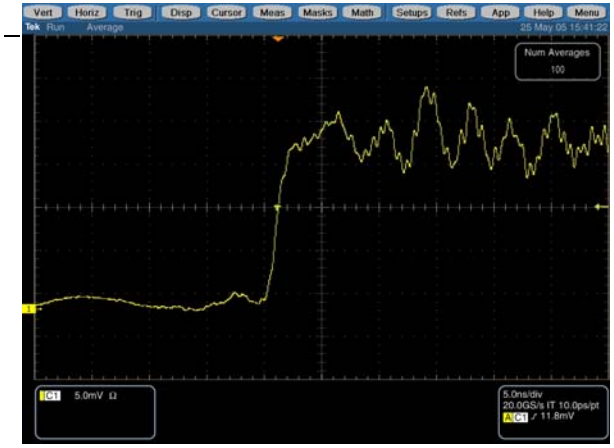
	Unirrad	Irrad
LCR meter, N electrode	68 fF	120 fF
LCR meter, P electrode	32 fF	59 fF
Picoprobe 35, P electrode	71 +/- 16 fF	80 +/- 17 fF
2D calculation, P electrode	28 fF	
3D calculation, P electrode	31 fF	

Charge Collection (prelim)

- Pulse the IR Laser as fast as possible and observe the rise time of the signal

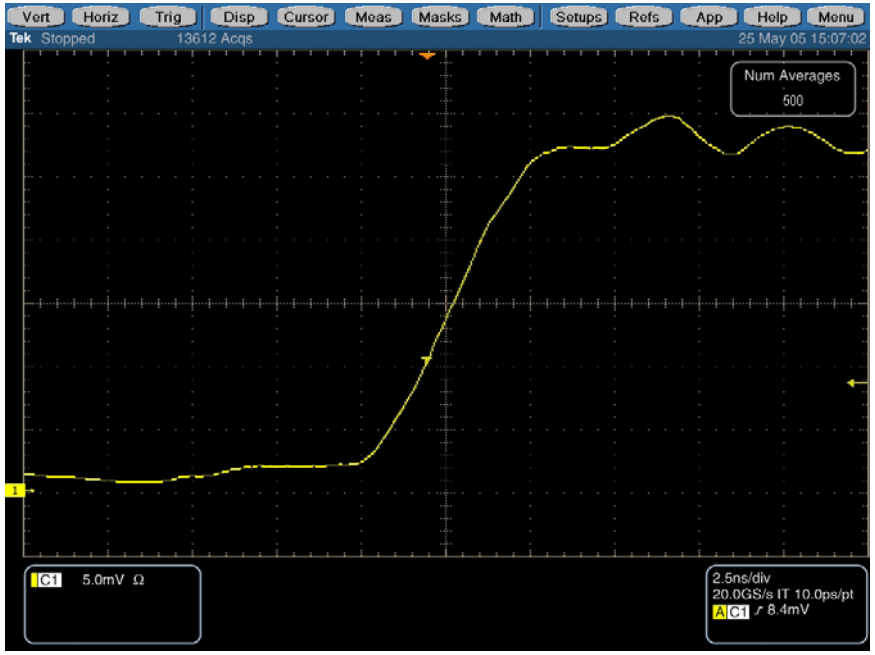


- Measure the output rise time while lowering the laser pulse duration



Charge Collection (prelim)

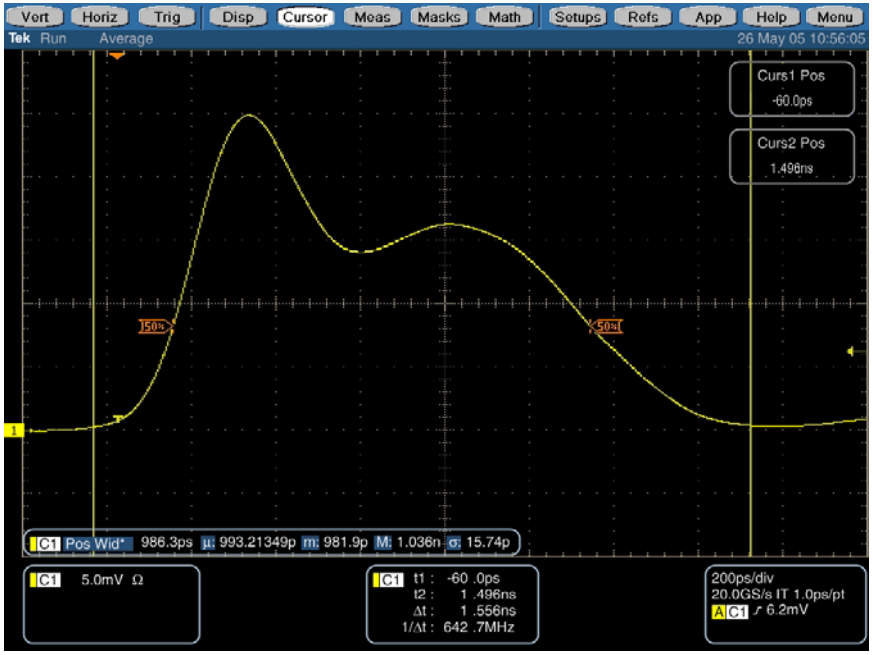
- Example: 4.1 nS laser duration, ~ 5.5 nS output rise time

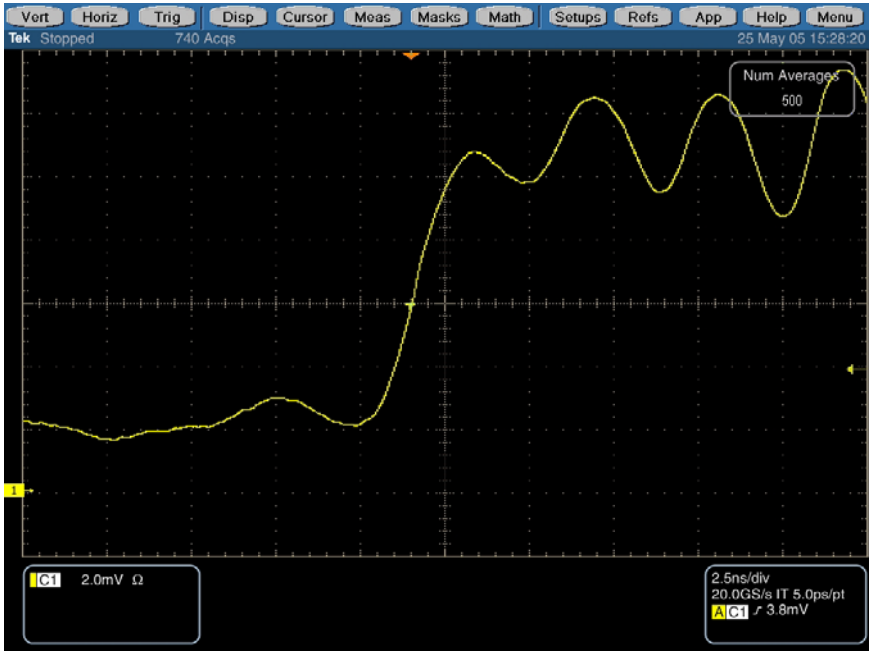


- Input laser pulse width
- Output Unirradiated P Electrode

Charge Collection (prelim)

- Input: 1.5 nS laser duration, ~ 3.5 nS rise time

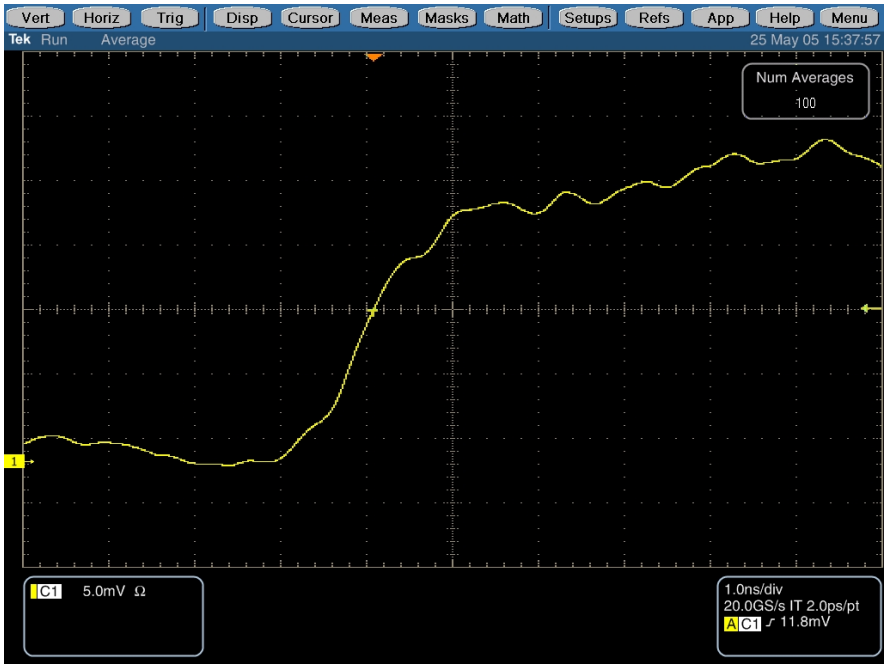


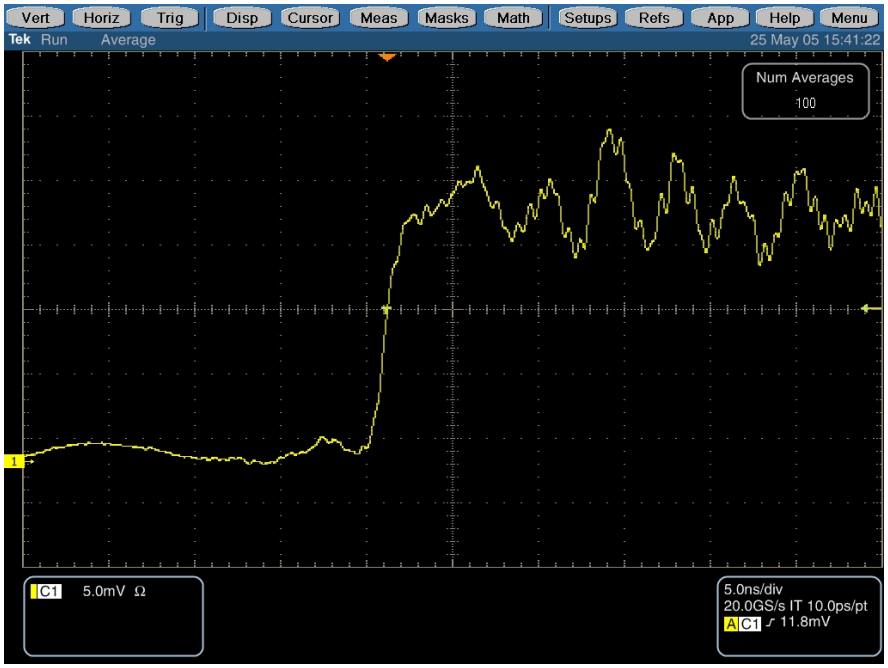


- Input laser pulse width
- Output Unirradiated P Electrode

Charge Collection (prelim)

- Input 0.3 nS laser duration, ~ 2 nS rise time



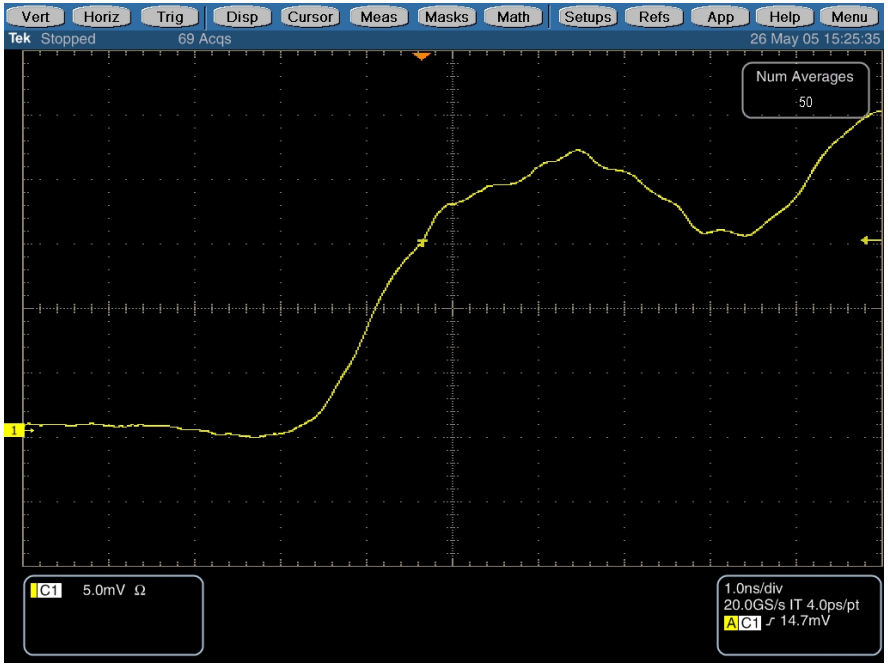


- Output Unirradiated P Electrode

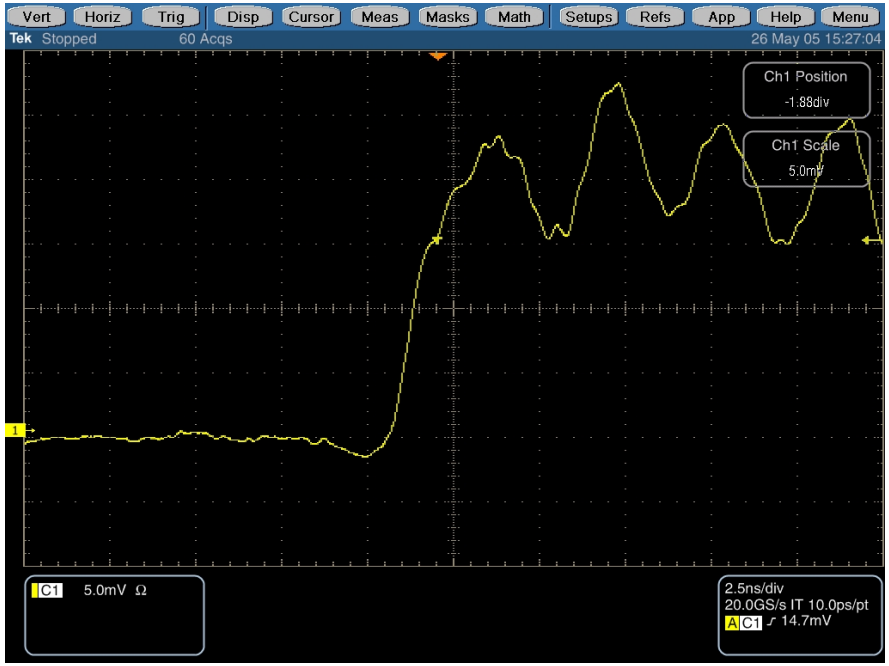
- Output Unirradiated P Electrode

Charge Collection (prelim)

- Input 0.3 nS laser pulse duration, ~ 2.5 nS output rise time



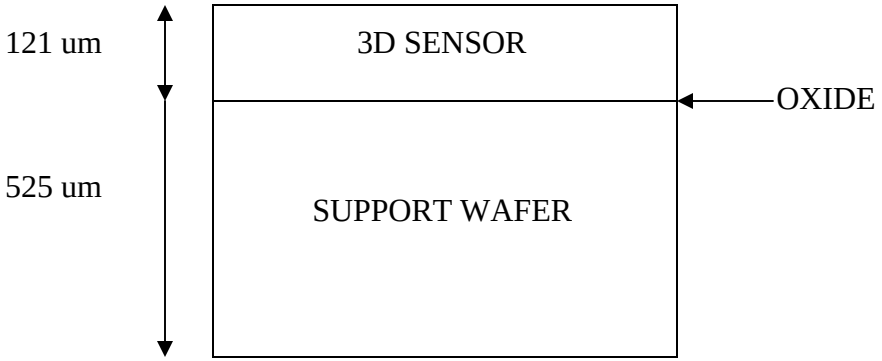
- Output Irradiated P Electrode



- Output Irradiated P Electrode

Charge Collection (prelim)

- The IR laser has a 1064 nm wavelength and penetrates approximately 500 um in Si



- Could the slow rise be related to the sensor/support interface?

- We have purchased a 960 nm IR laser, has only ~ 100 um penetration in Si to investigate this.

Summary of Irradiated Meas.

- Leakage current is very low (300-400 nA for sensor Irradiated to 10^{15} cm^{-2} 55MeVp)
- Depletion Voltage is very low (75V for sensor Irradiated to 10^{15} cm^{-2} 55MeVp)
- Electrode Capacitance is very low (70-120 fF for sensor Irradiated to 10^{15} cm^{-2} 55MeVp)
- Charge Collection Time is very fast (~ 2.5 nS for sensor Irradiated to 10^{15} cm^{-2} 55MeVp)
- Performance of 3D Sensor is Very Impressive

- Present Work,
  - We are almost ready to take data with the new 960nm laser
  - Are in the process of measuring the other three Irradiated sensors
  - Developing capture time measurements