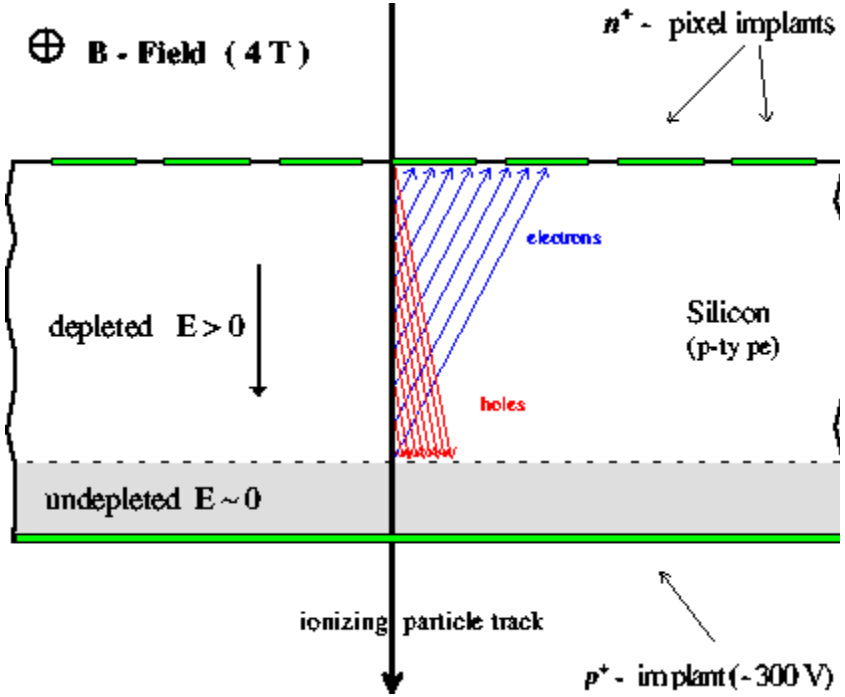
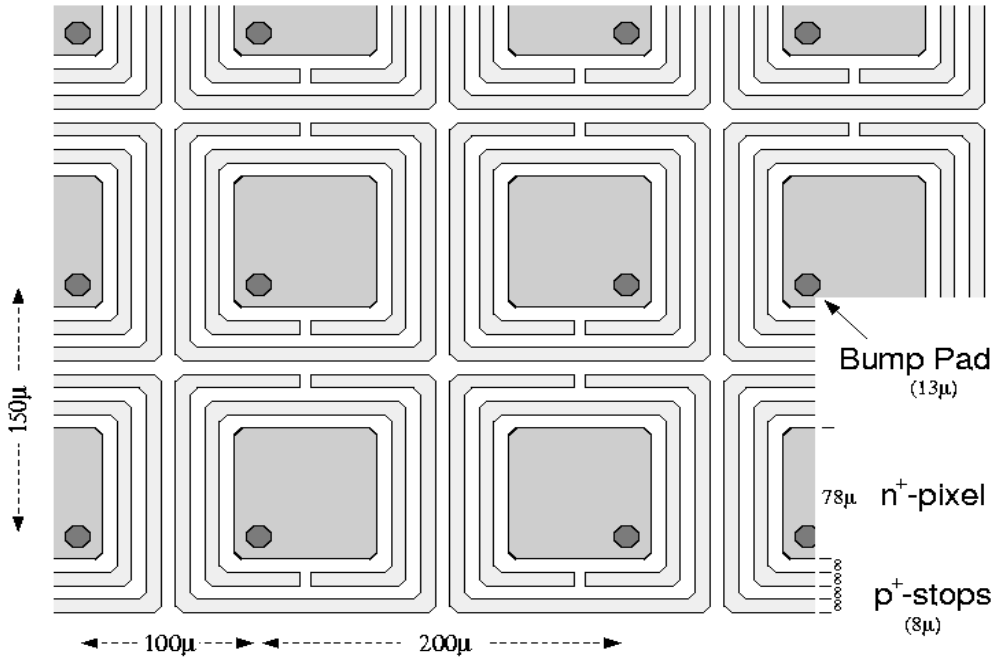
CMS Pixel Sensors

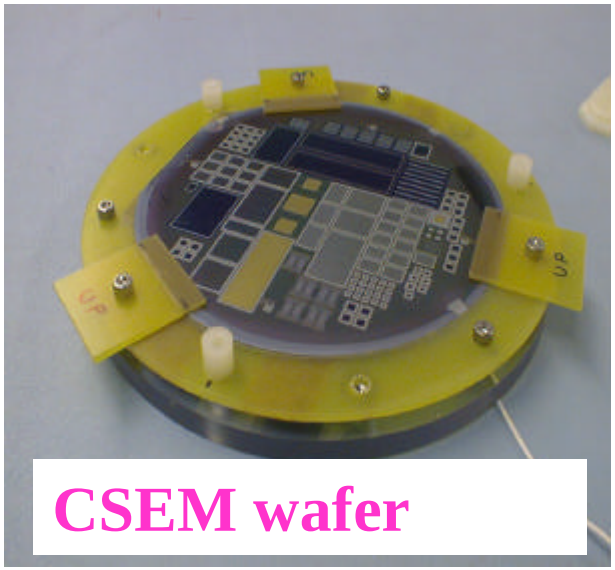
- **Baseline CMS design: n^+-n pixels for partial depletion operation and increased Lorentz angle in high B field.**
  - **78 mm n^+-implants. Two open p-stops rings provide isolation and a resistive path »O(100KW) for biasing.**
  - **Bump Pad »13 mm shifted by 25 mm for double column ROC**





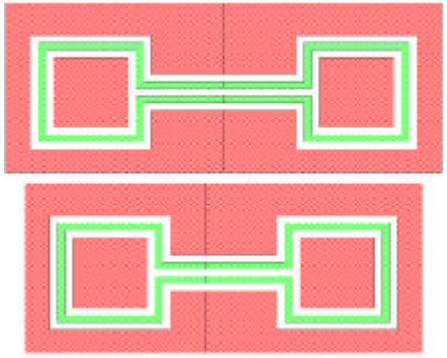
Prototype sensors

- SINTEF and CSEM Þ 15 wafers (3 oxygenated)
  - Thickness: 300 mm
  - Resistivity: 1.0-2.5 kWcm
  - Breakdown: >300 V
  - Leakage current @ 1.5 V_{dep}: <50 nA/cm²
- Optimize processing and test ROC
  - Double open ring p-stop
    - bias structure for probing
    - unbonded channels grounded
  - Guard ring design

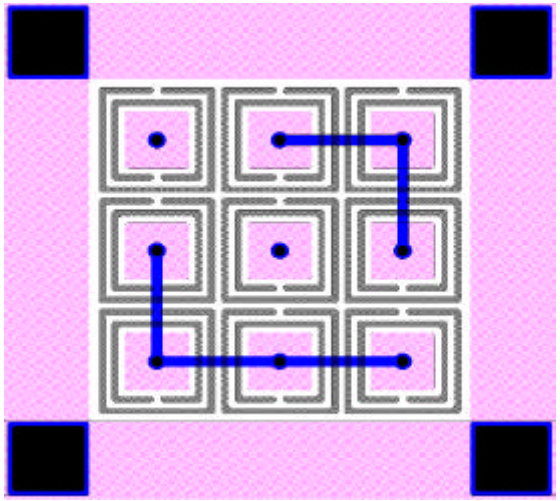


Test Structures

- **Understand bulk and surface damage:**
  - **Interpixel resistance**
  - **Interpixel capacitance**
  - **Multiguards diodes (IV & CV)**
  - **Single guard diodes (IV & CV)**
  - **MOS capacitors (CV)**
  - **Gated diodes (IV)**
  - **Transistors (Subthreshold)**
  - **Fan Out pixel arrays (Strip ROCs)**



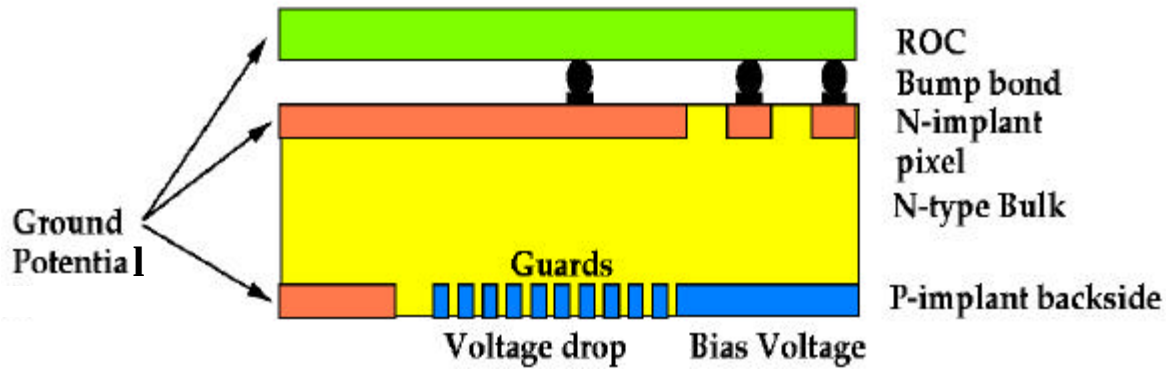
Interpixel resistance

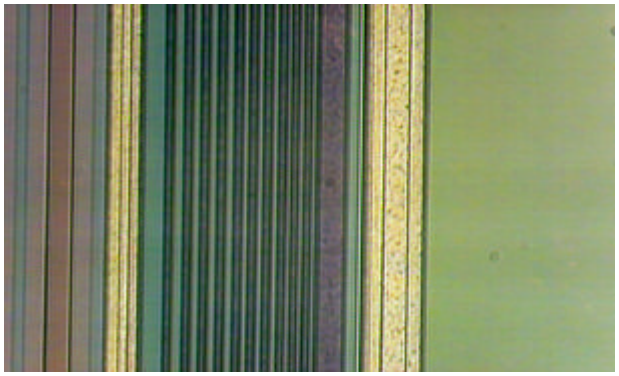


Interpixel capacitance

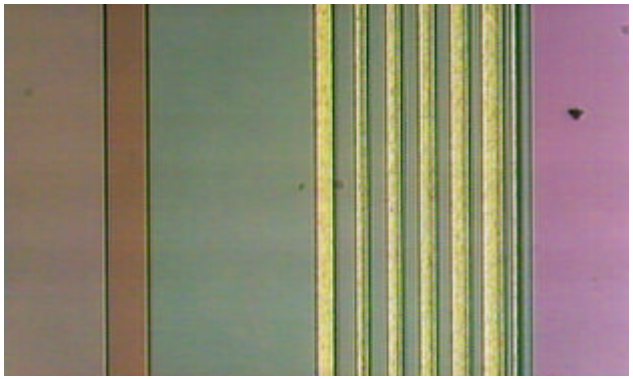
Guard ring design

- **Requirements:**
  - **Breakdown voltage > 300V**
  - **Read-out side grounded**
  - **Voltage drop on guards on the backside**





11 guard rings

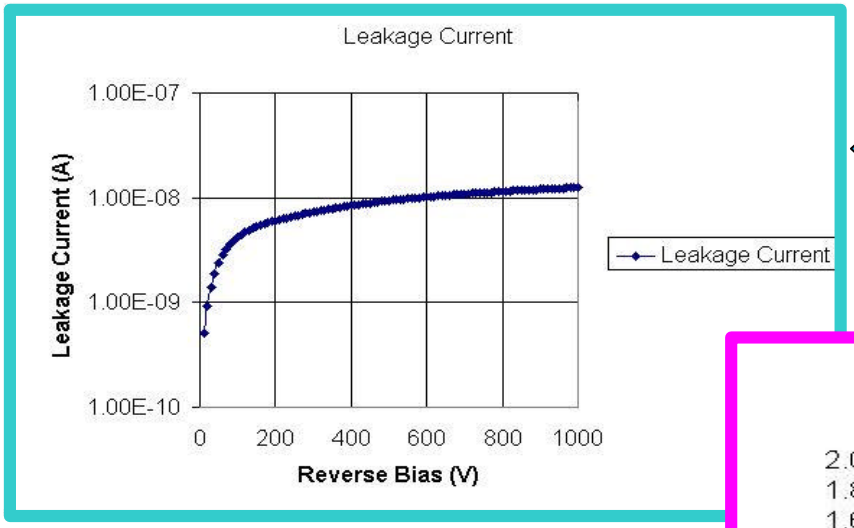


6 guard rings

- **Test four different designs**

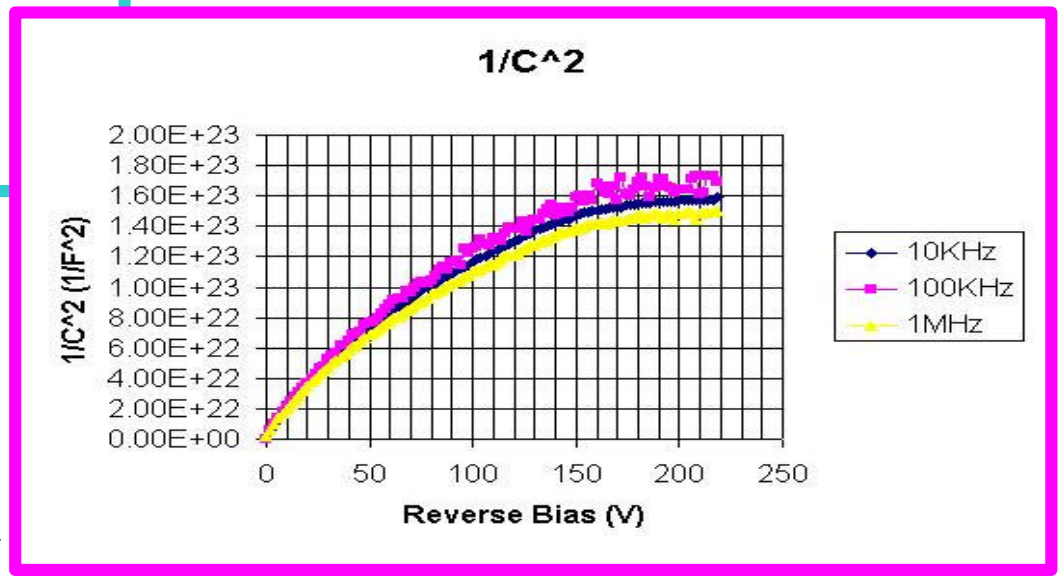
Guard ring performance

- **Measurement of diodes**



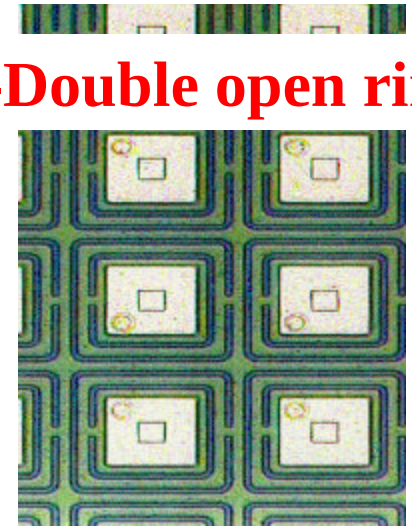
- **IV measurements:**
  - **$V_{breakdown}$>1000V**
  - **I/cm^2 »68 nA/cm^2**

- **CV measurements:**
  - **$V_{depletion}$=155 V**

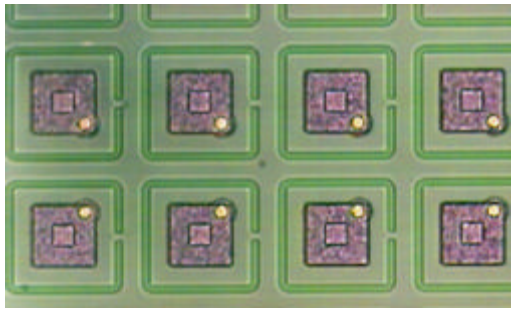


P-stop design

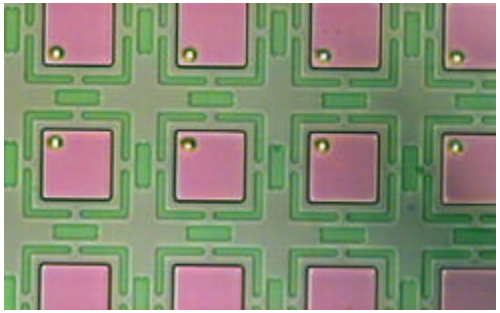
- **Prototypes have several p-stops options.**
  - **Verify performance after irradiation**
  - **Optimize the length and width of the resistive channel**
  - **Compare with standard p-stops**



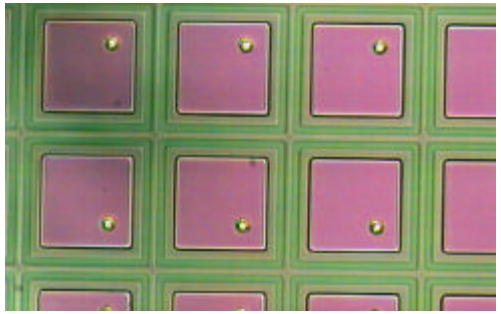
A-Double open ring



F-Single open ring



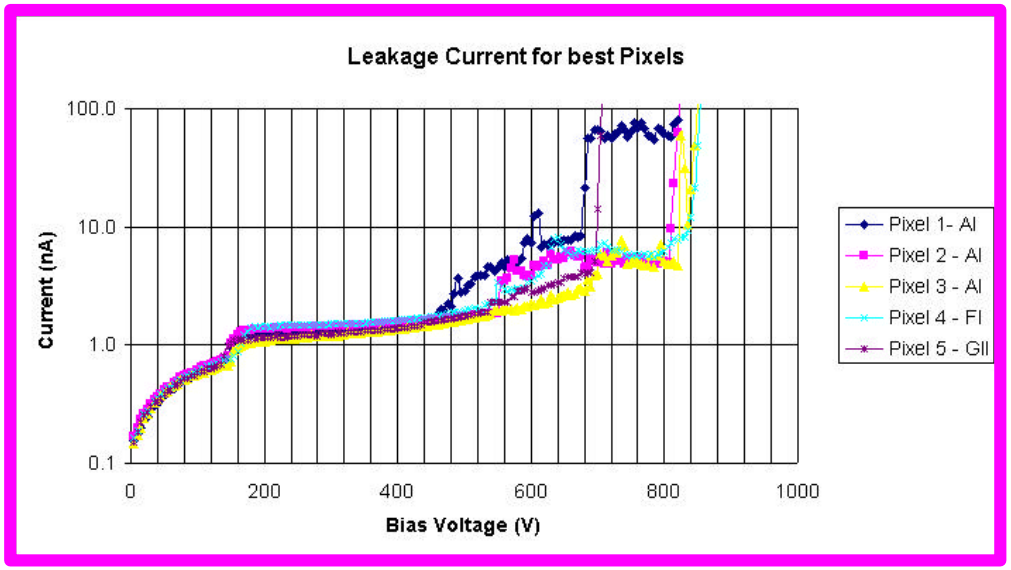
E-Step p-stop

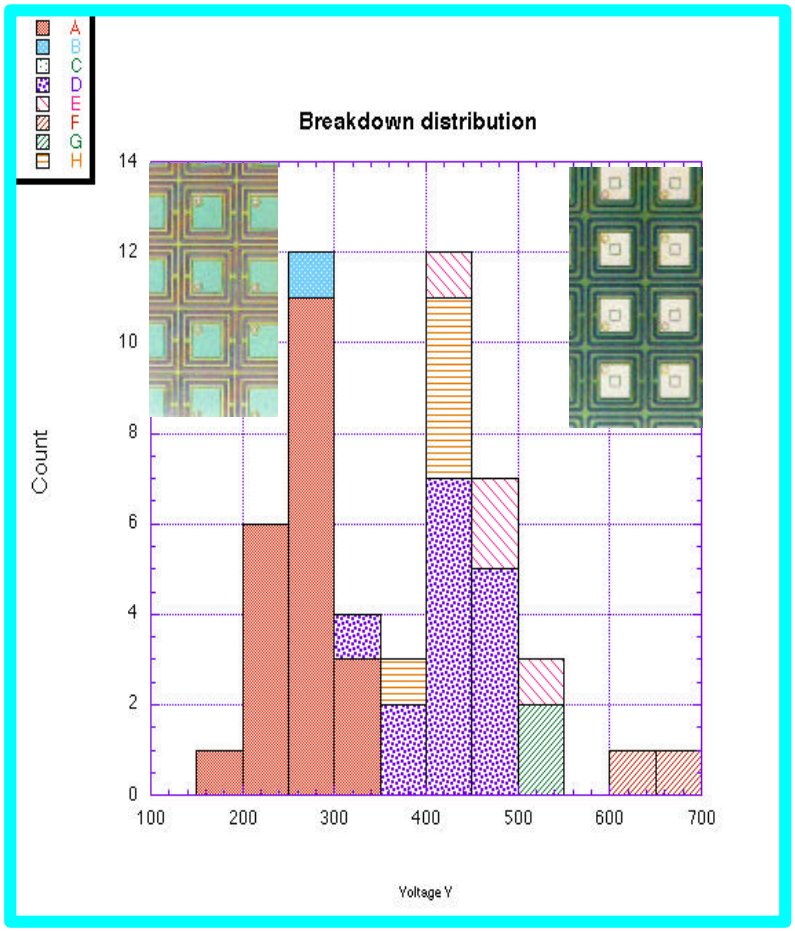


Standard p-stops

P-stop Performance

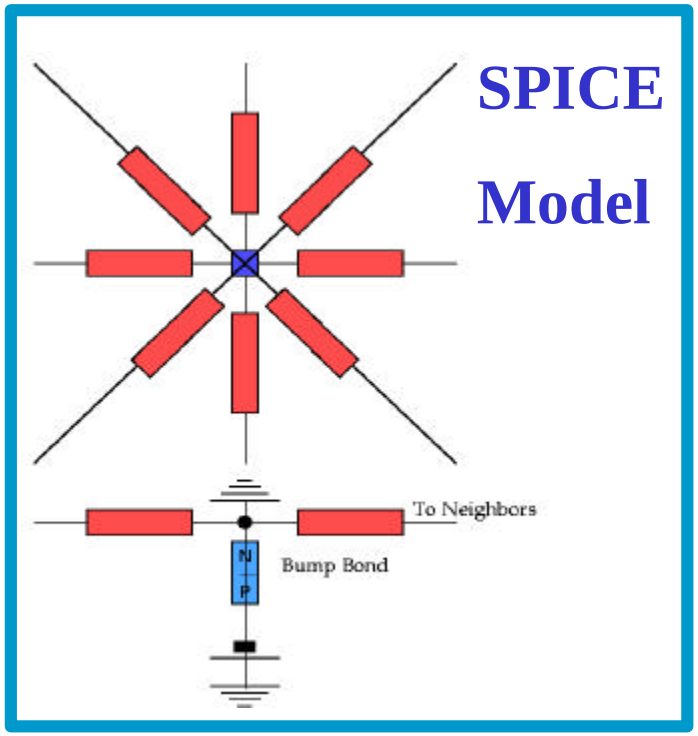
- **IV on Pixel sensors:**
  - **60% of the sensors with $V_{breakdown}$> 300V**
  - **Best have $V_{breakdown}$ »800 V**
  - **I/cm² »3-6nA/cm² at 1.5 V_{dep}**

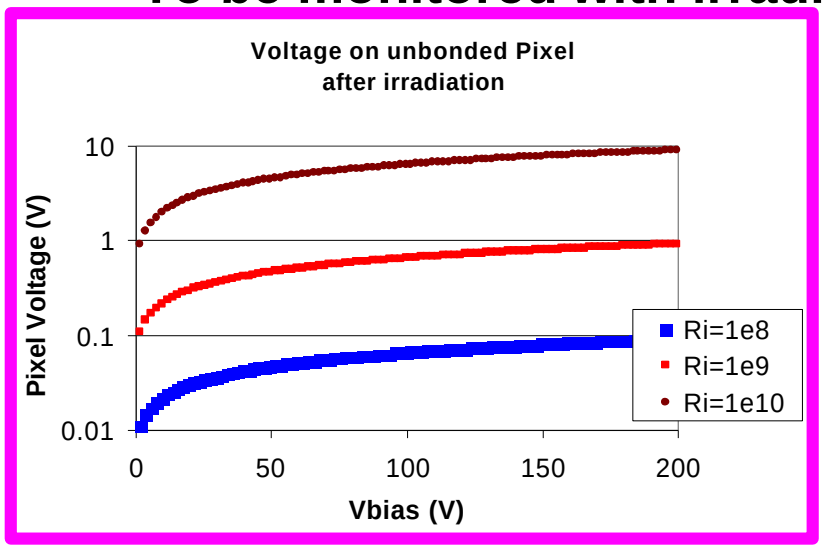




SPICE simulations

- **SPICE simulations show that R(interpixel) < 100 MW is required**
  - **Sheet resistance of the accumulation layer 50-500 KW**
  - **30 squares from pixel to pixel**
  - **1.5 to 15 MW interpixel resistance**
  - **To be monitored with irradiation**

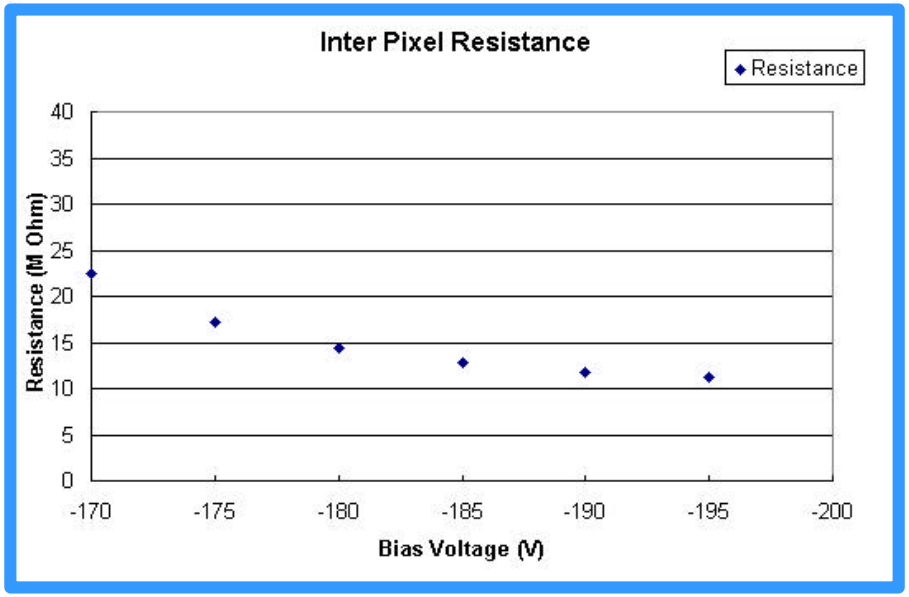


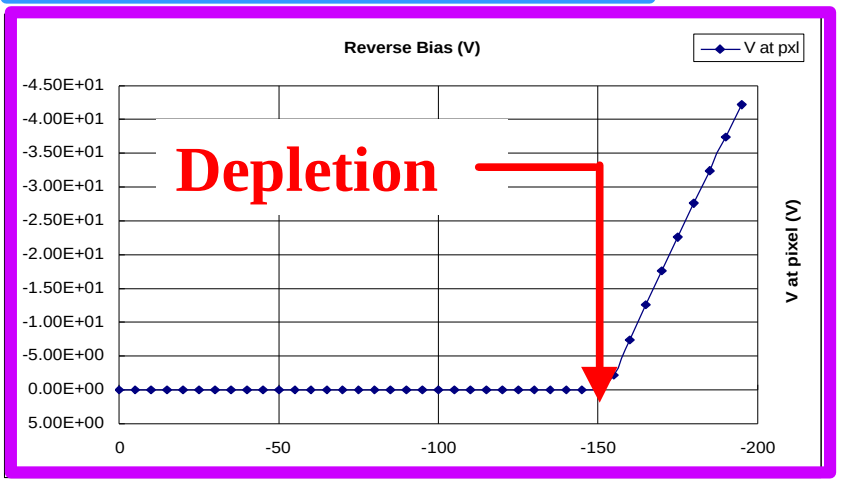


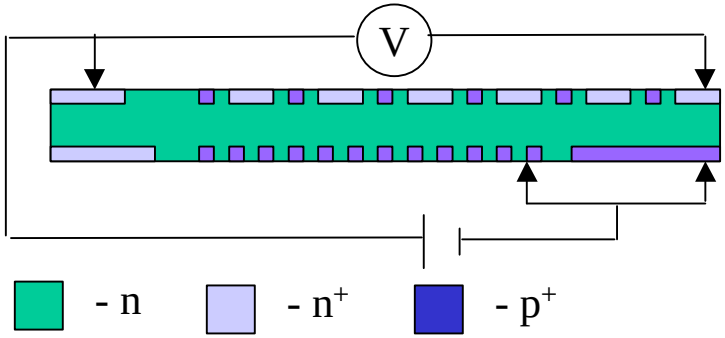
- **Assume single pixel current:**
  - **10^{-11} A before irradiation**
  - **10^{-8} A after irradiation**

Pixel Measurements

- R(interpixel)=12-18 MW



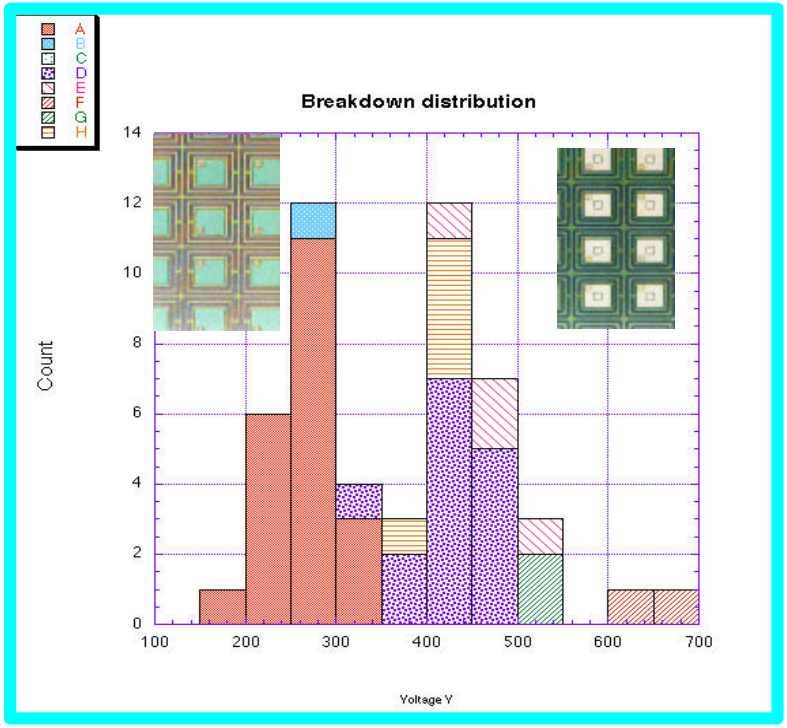


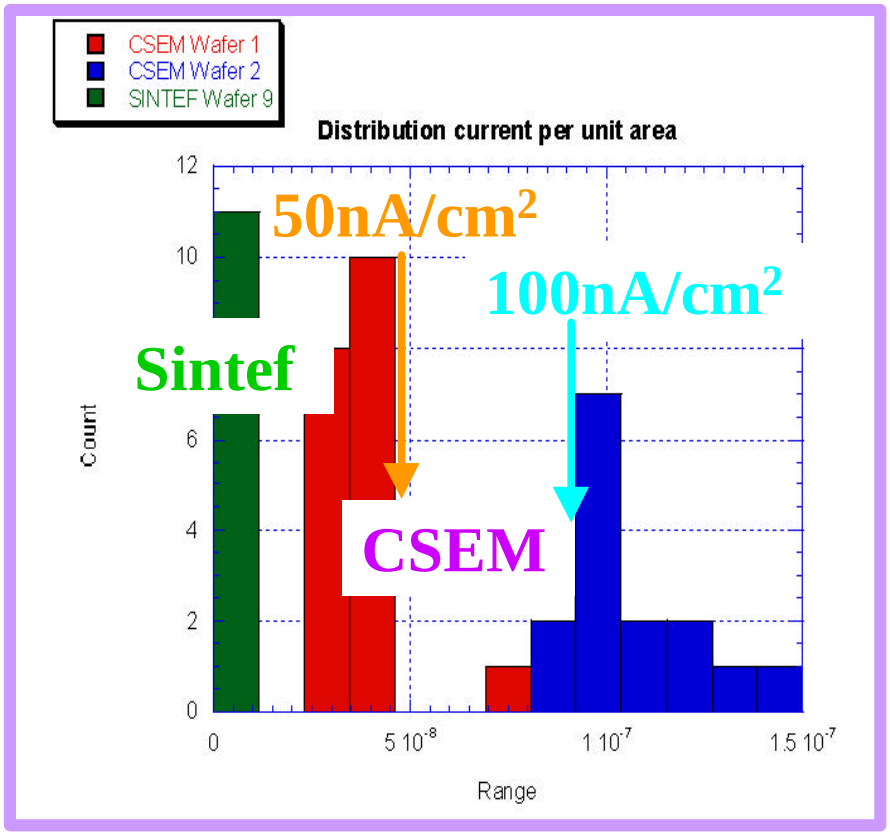


- DV pixel w.r.t. n-ring. Biasing mechanism is working

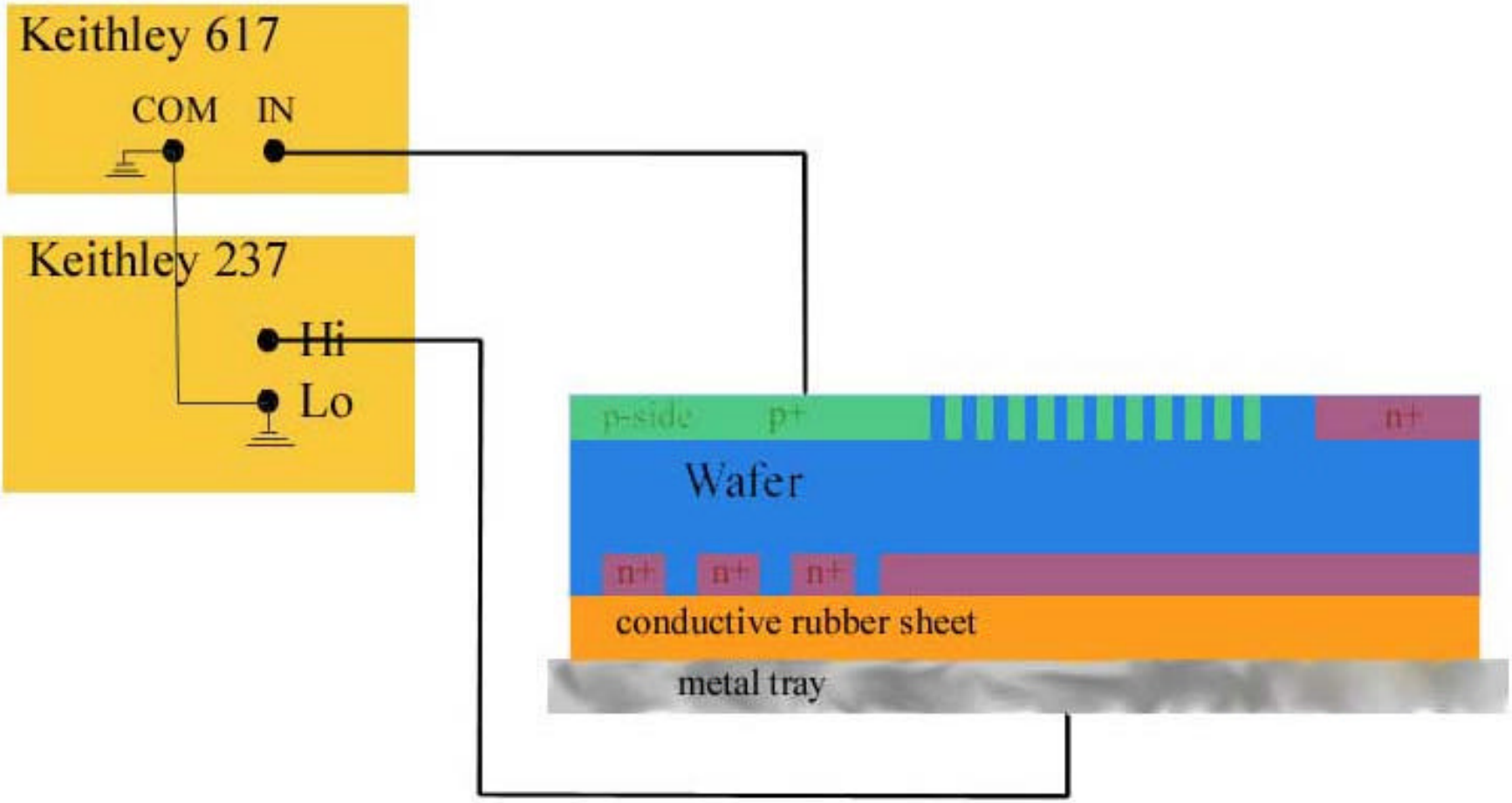
Summary

- Prototype sensors meet specifications
- Irradiation in progress
- Beam test Summer 2000

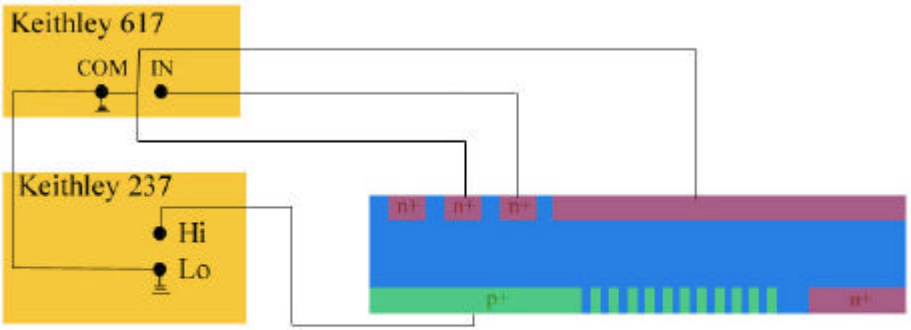


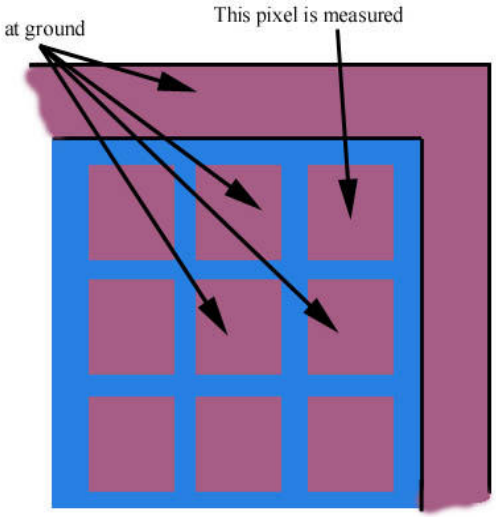


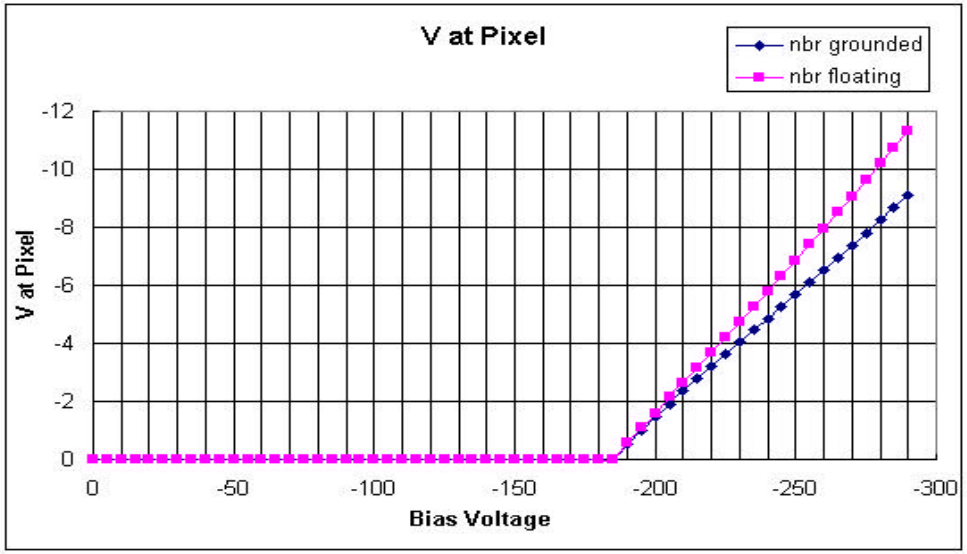
Measurements setup



Interpixel Measurements

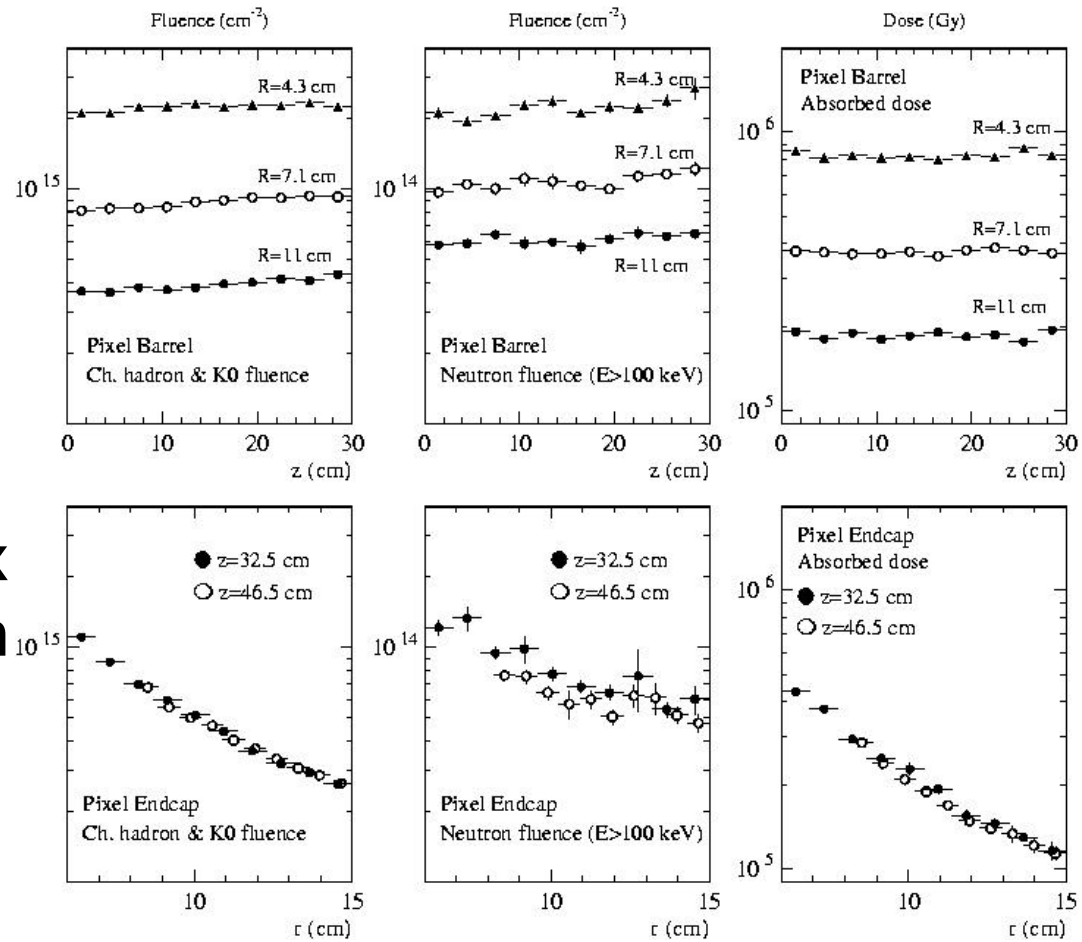




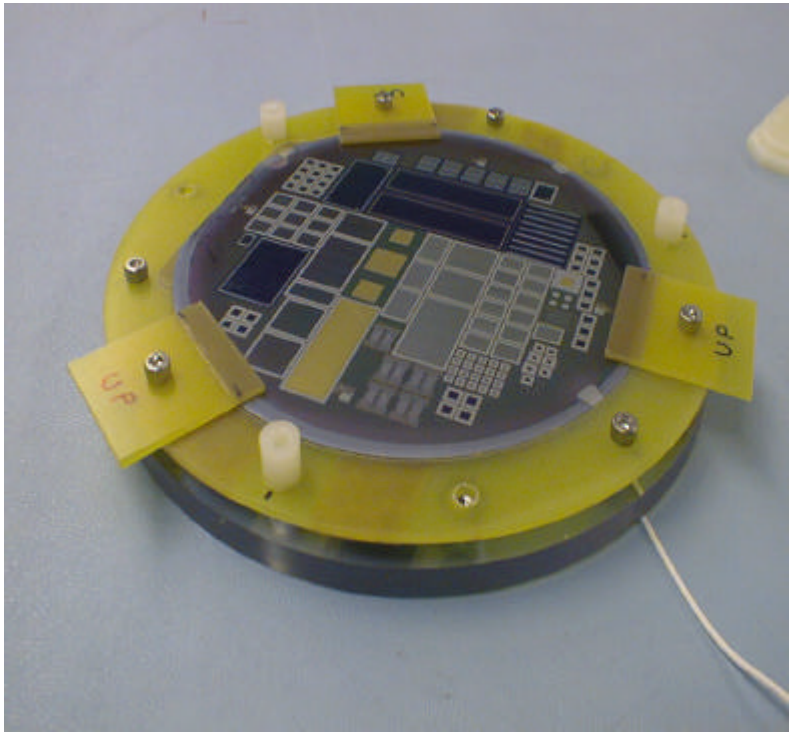


LHC environment

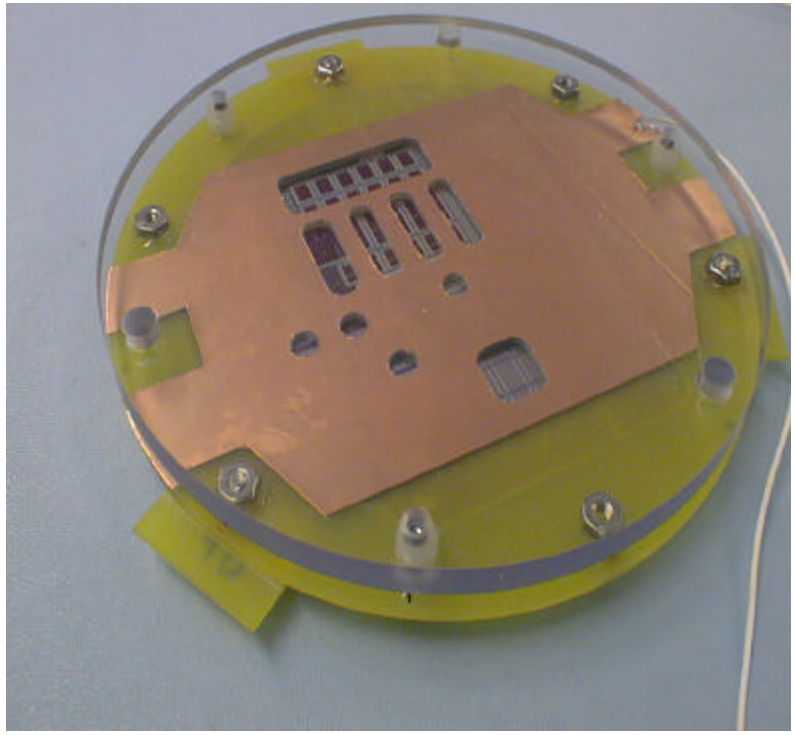
- **SIMULATION**
  - **Radiation environment dominated by pp secondaries**
  - **L=5 ´10^5 pb^{-1} Þ »6 ´10^{14} cm^{-2} in six years of operation at r=7 cm**



N-side measurements



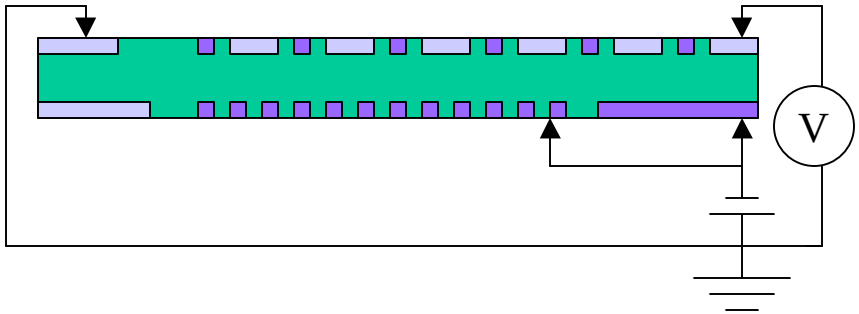
n-side

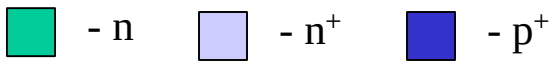


wire bonds to p-side

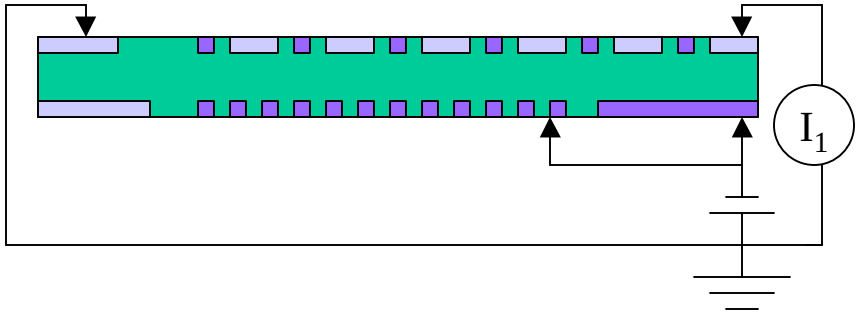
Single Pixel Measurements

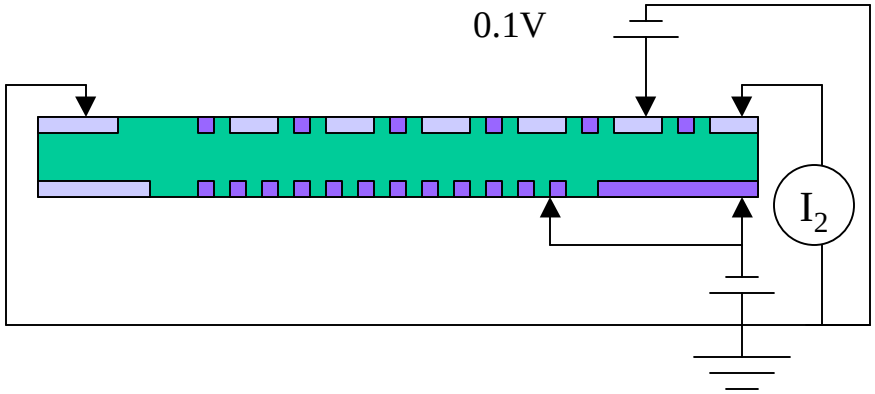
1. **Measurement of Voltage at a pixel in the middle**





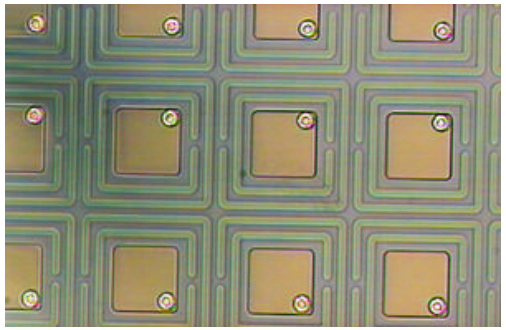
2. **Measurement of Interpixel Resistance**



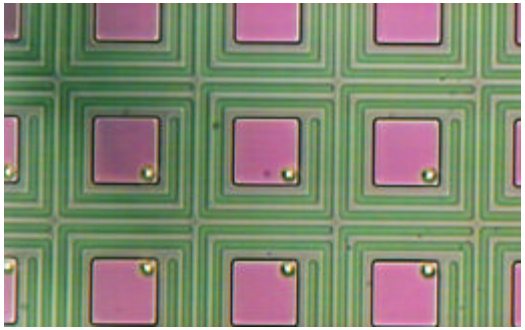


$$R = (I_2 - I_1)/0.1$$

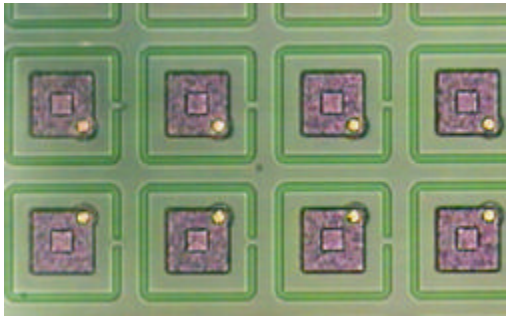
Pixel Design



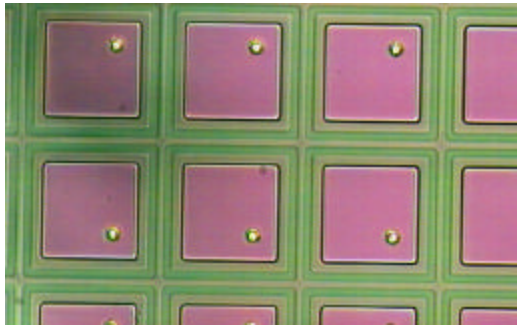
Design A



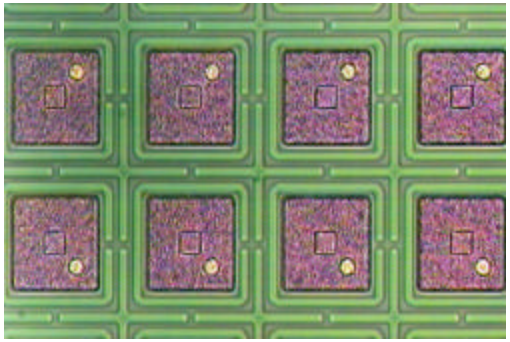
Design D



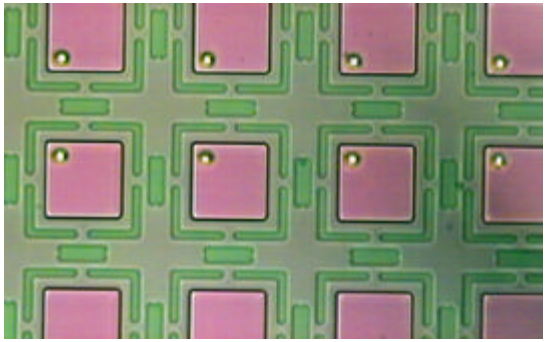
Design F



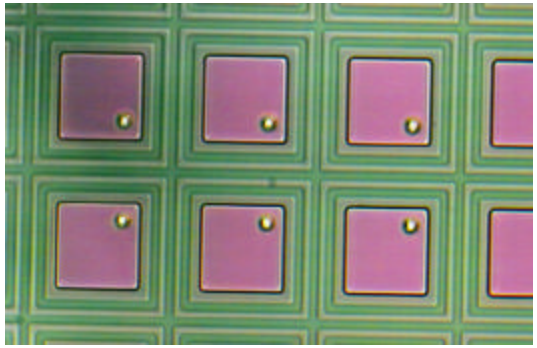
Design B



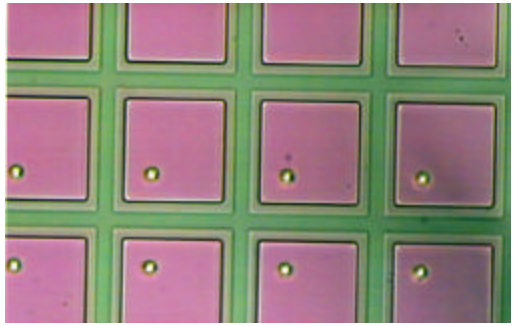
Design G



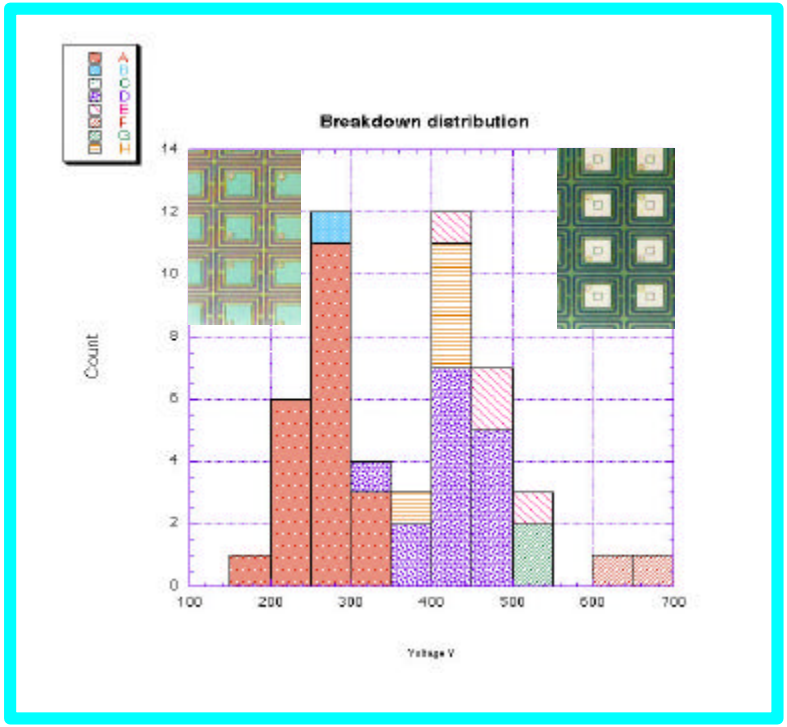
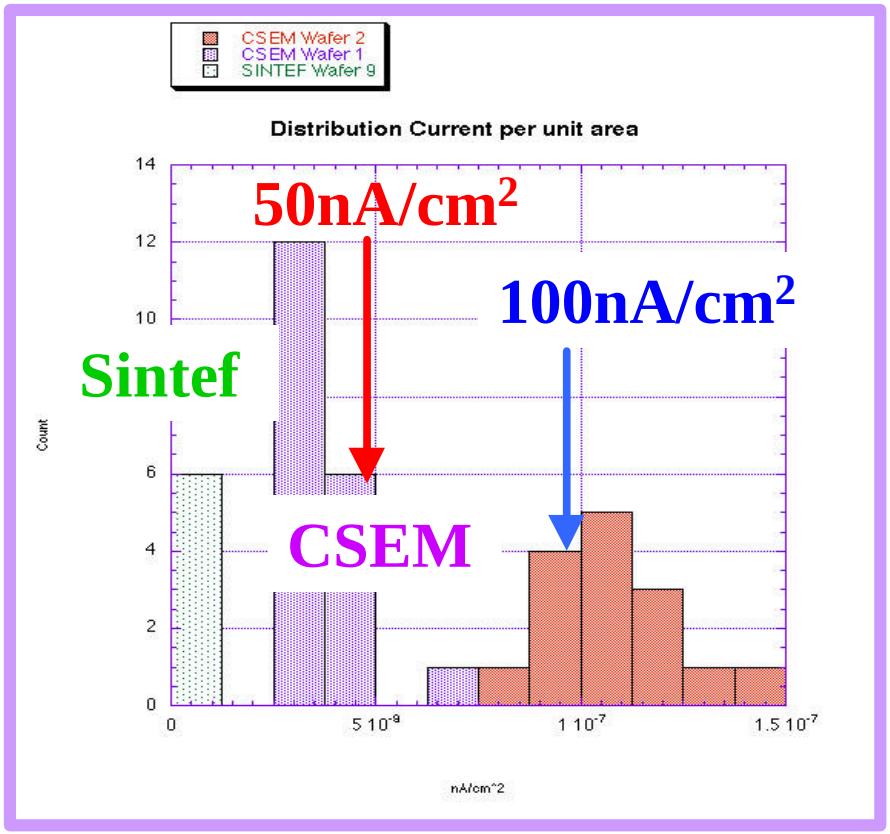
Design E



Design C



Design H

Summary

- Prototype sensors meet specifications
- Irradiation in progress
- Beam test Summer 2000