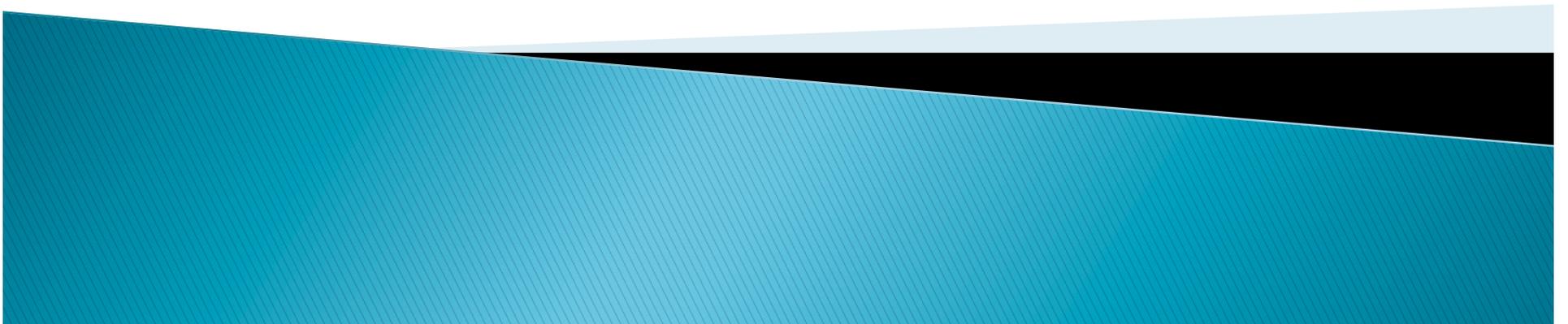
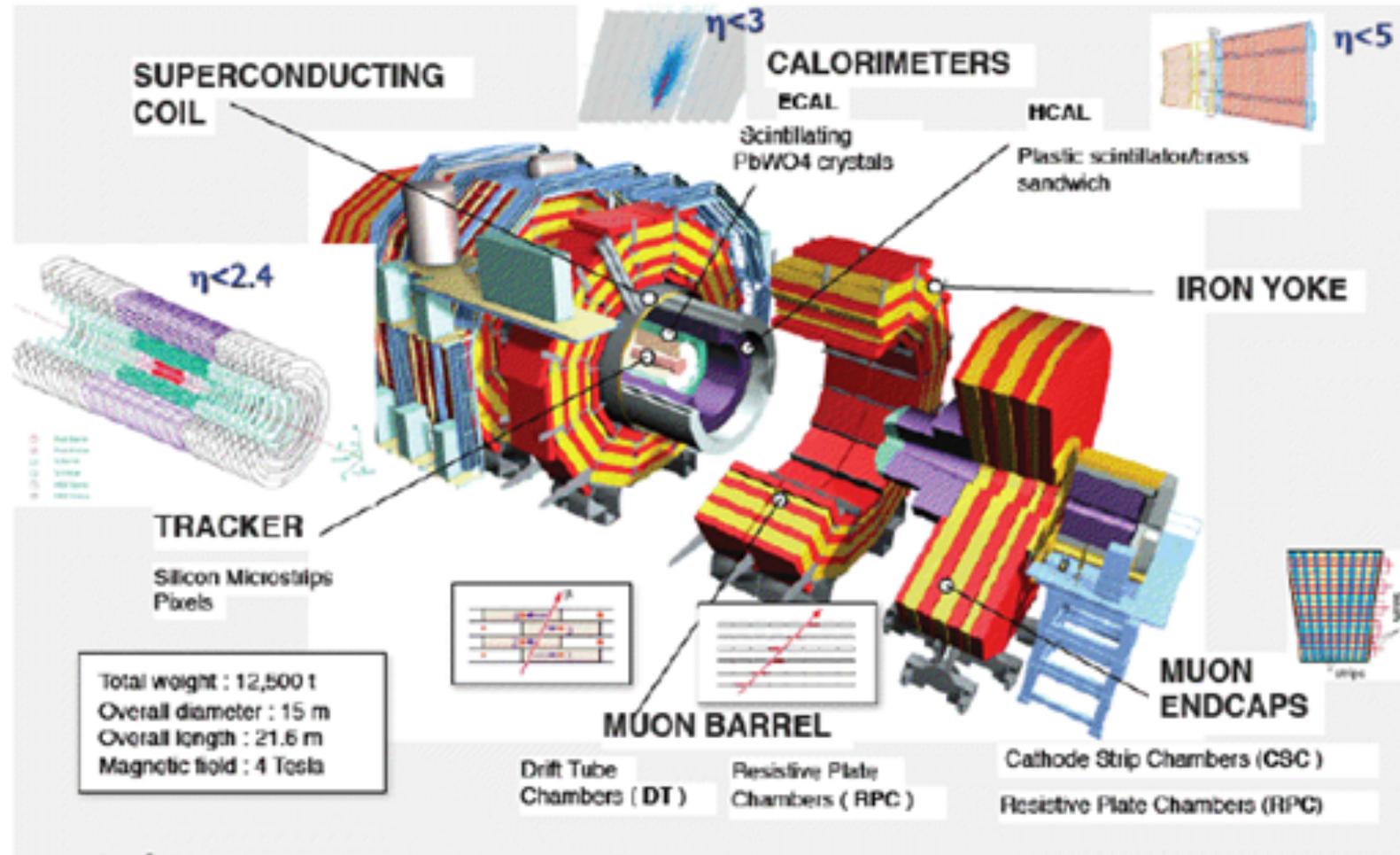


CMS Tracker Upgrade at Fermilab

Alwina Liu
Internship for Physics Majors



Overview of the CMS Detector



What's going on with CMS

- ▶ Major shutdowns around 2016 and after 2020 during which the CMS tracker will be upgraded
- ▶ In preparation, research is currently being done to upgrade the pixels and sensors
 - Radiation hardness
 - Good signal
- ▶ Effects of radiation damage
 - Increased leakage current: more noise
 - Increase in depletion voltage



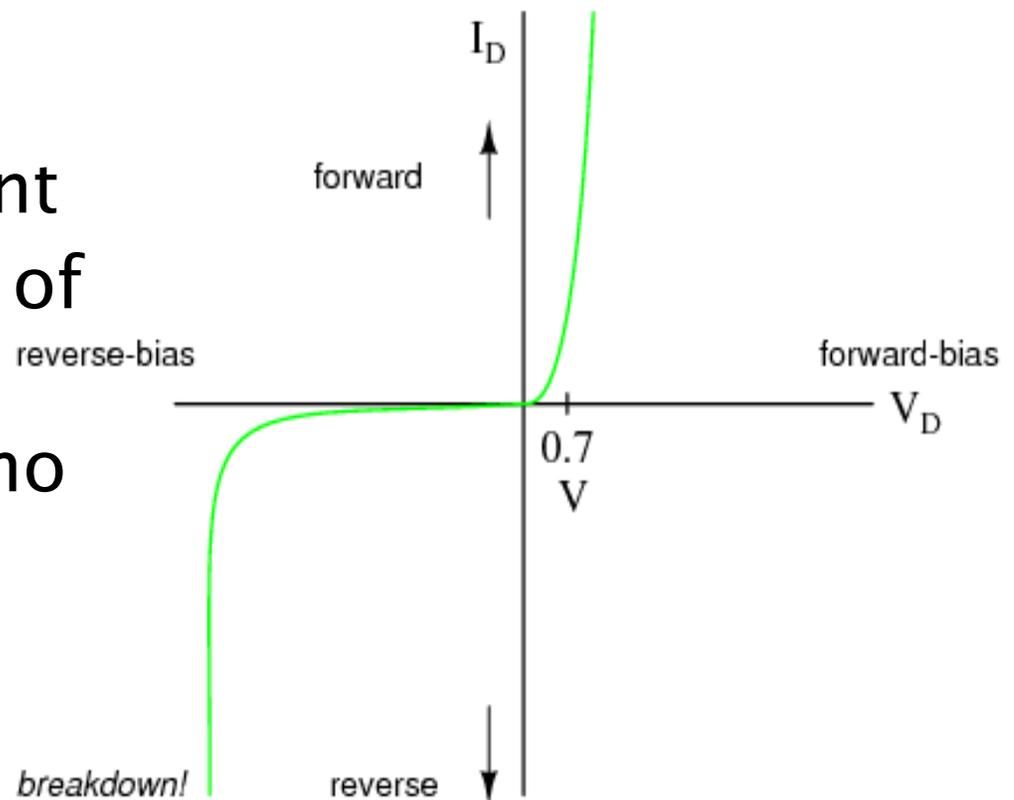
What's going on with CMS

- ▶ Tests that are being done: CV (capacitance vs voltage), IV (current vs voltage), source measurements
- ▶ Tests will be done before and after irradiation and annealing (heating to repair defects)



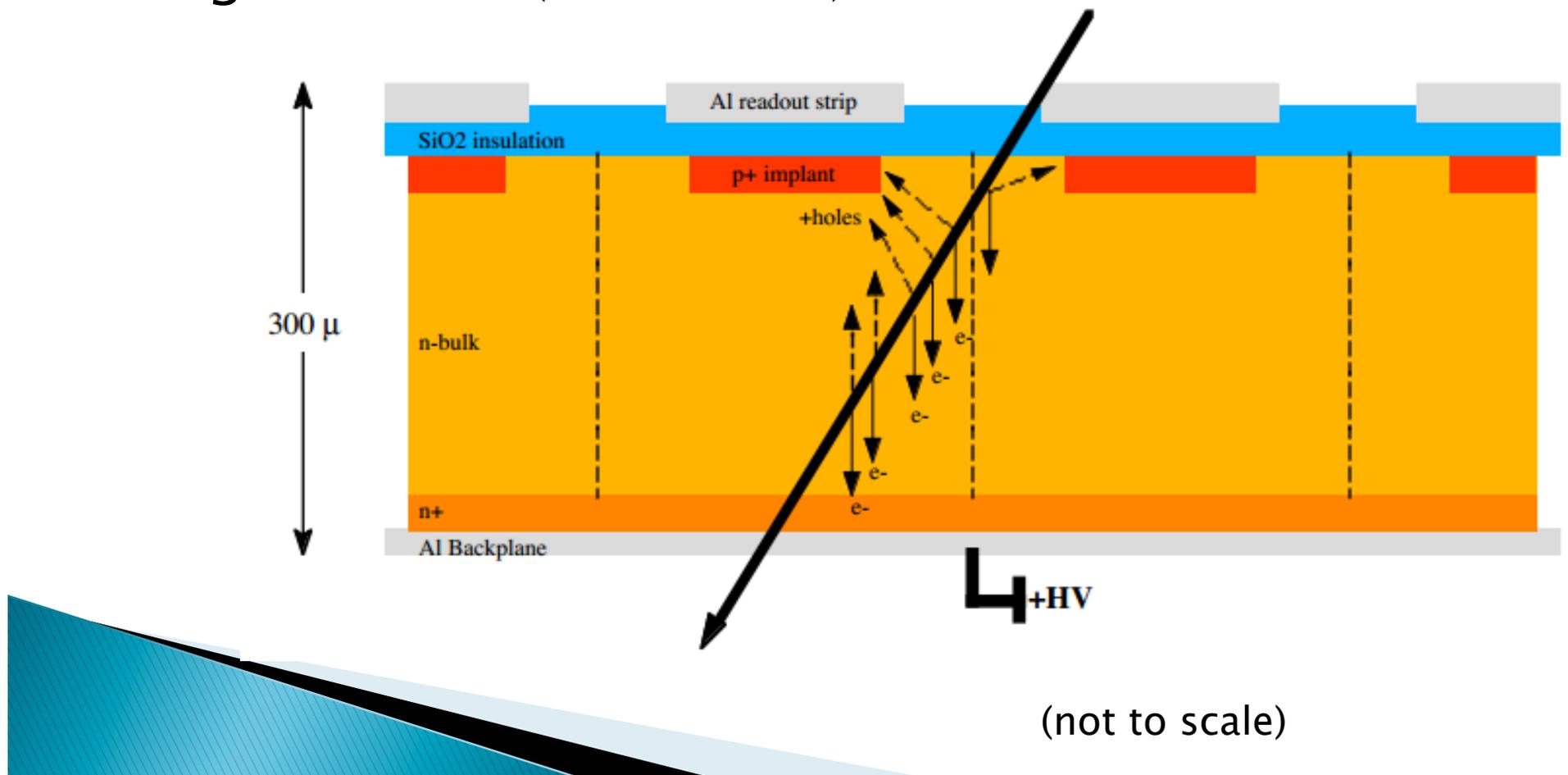
How a silicon detector works

- ▶ More expensive than other methods, but better resolution and more radiation tolerant
- ▶ Reverse bias an array of diodes
- ▶ Create a region with no charge carriers

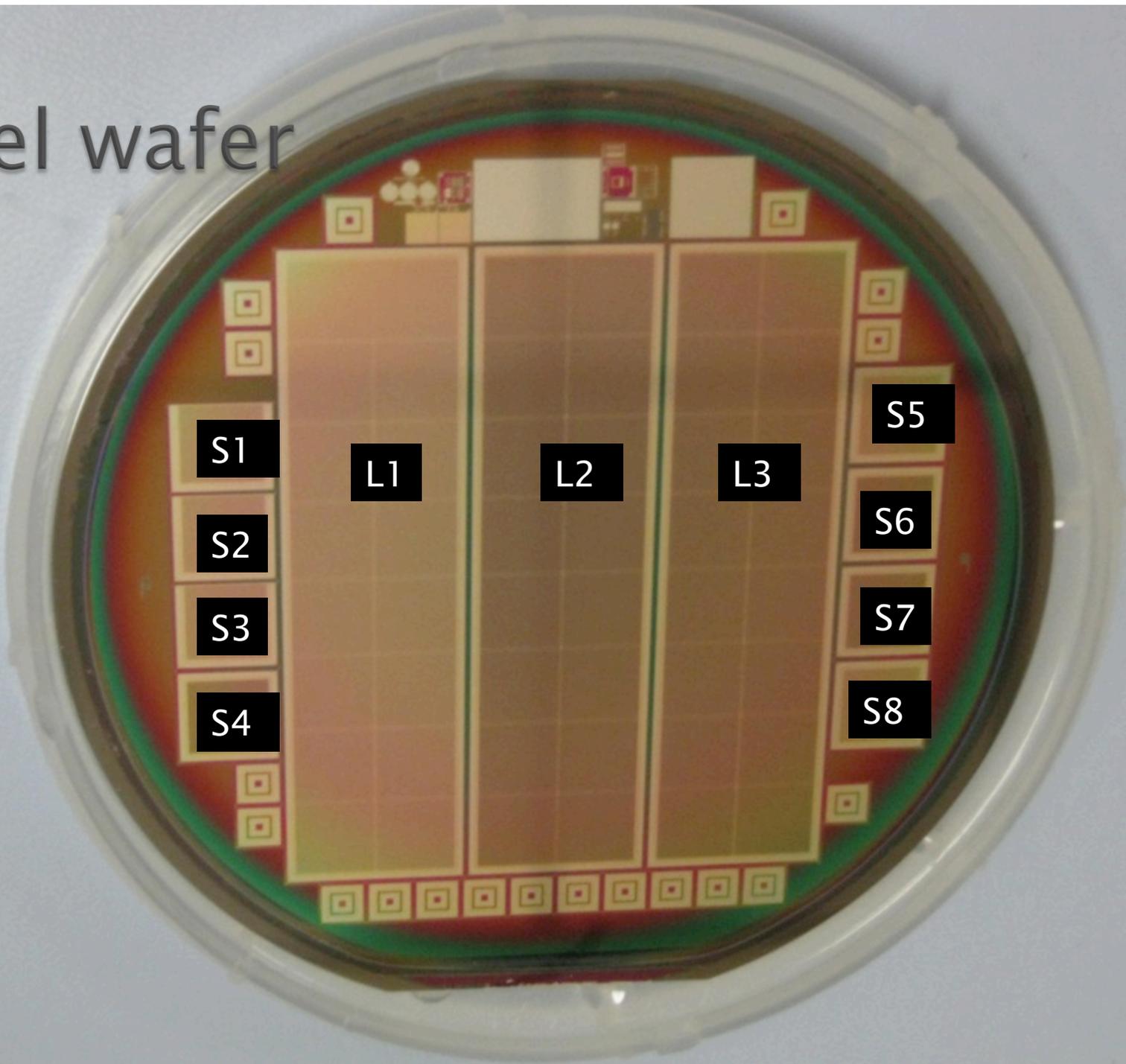


How a silicon detector works

- ▶ Charged particle traveling through region creates charge carriers (ionization) that can be detected

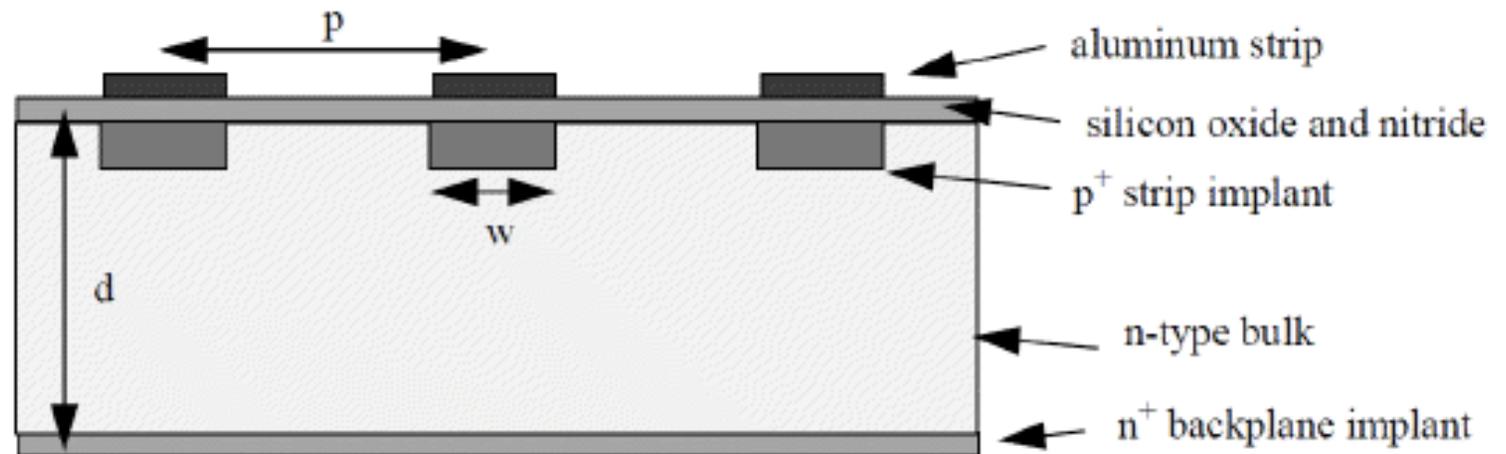


Pixel wafer

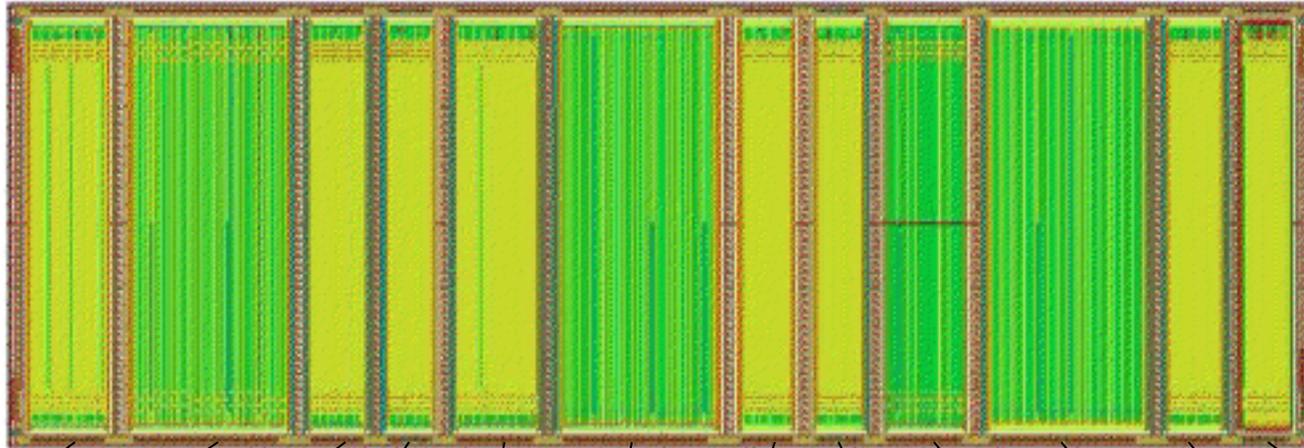


Strip sensor properties

- ▶ Method of growing silicon
 - Float Zone, magnetic Czochralski, epitaxial
- ▶ N-type, two types of p-type: p-stop and p-spray
- ▶ Different thicknesses
- ▶ For testing: multi-strip sensors with different pitches and widths in each region



Strip Sensor



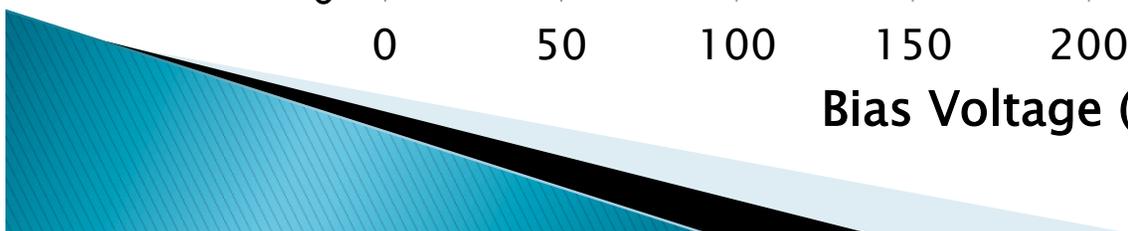
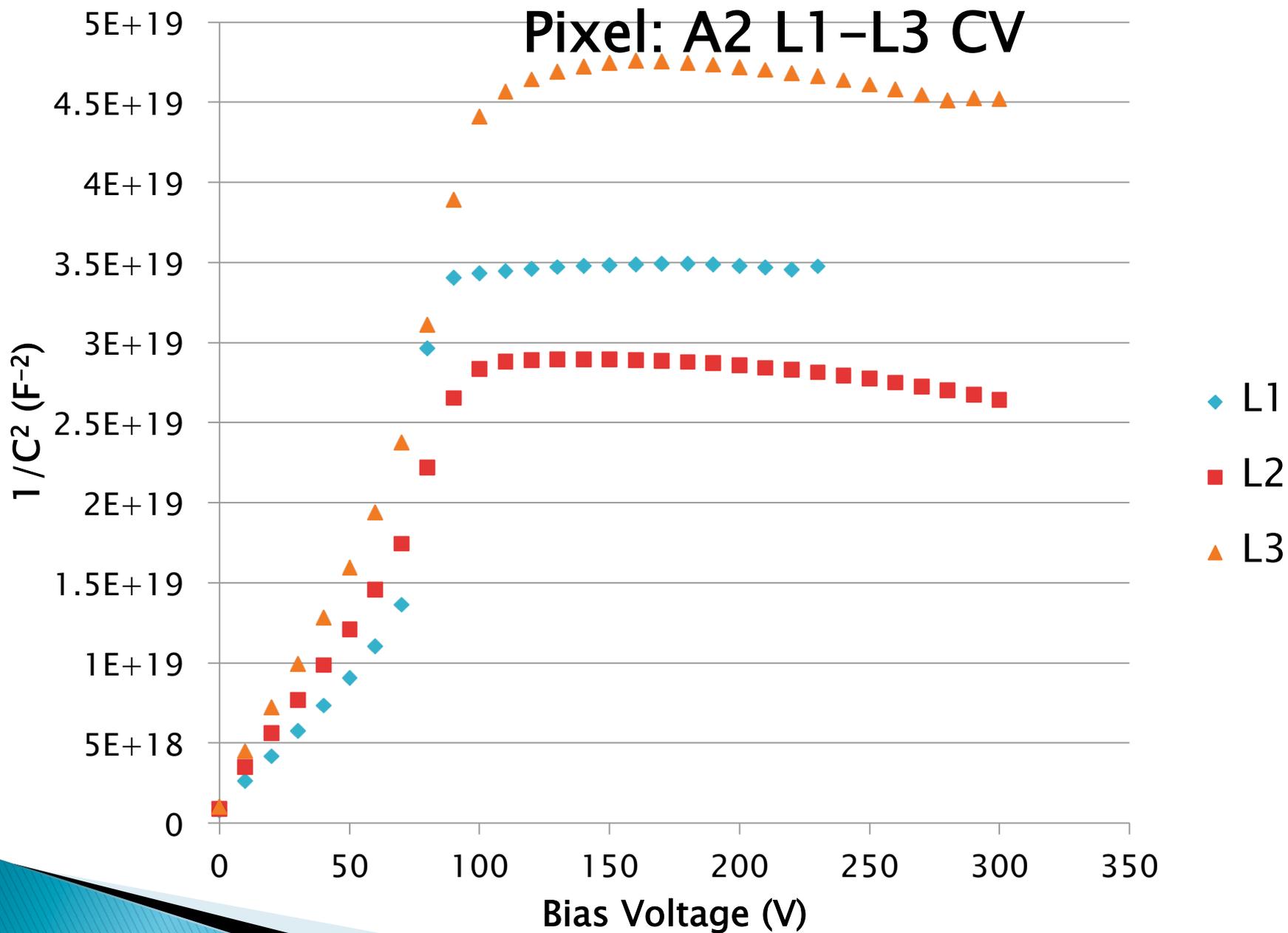
Region	1	2	3	4	5	6	7	8	9	10	11	12
Width (μm)	16	34	10	8.5	28	58	18	15.5	40	82	26	22.5
Pitch (μm)	120	240	80	70	120	240	80	70	120	240	80	70
Al (μm)	29	47	23	21.5	41	71	31	28.5	53	95	39	35.5
Al/W	1.81	1.38	2.30	2.53	1.46	1.22	1.72	1.84	1.33	1.16	1.50	1.56
W/P	0.13	0.14	0.13	0.12	0.23	0.24	0.23	0.22	0.33	0.34	0.33	0.32

CV (Capacitance vs voltage)

- ▶ Separation of charges – can measure capacitance
- ▶ After **depletion** voltage, the capacitance does not change much
- ▶ Full depletion is when there are more or less no charge carriers in the largest possible region

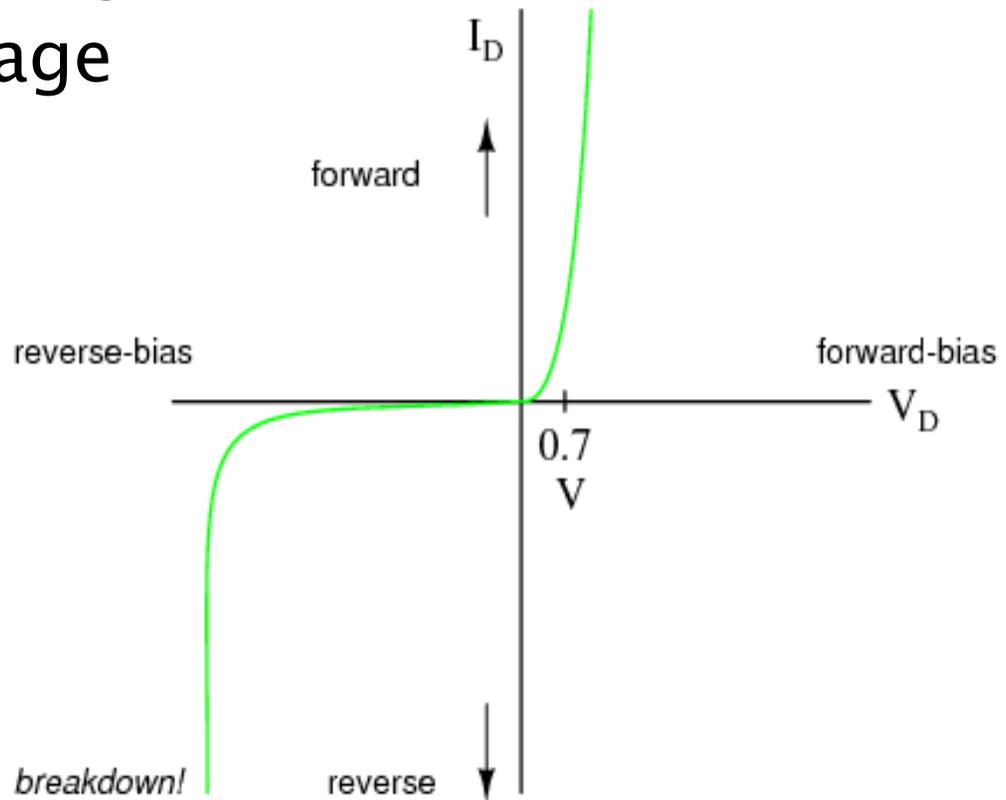


Pixel: A2 L1-L3 CV

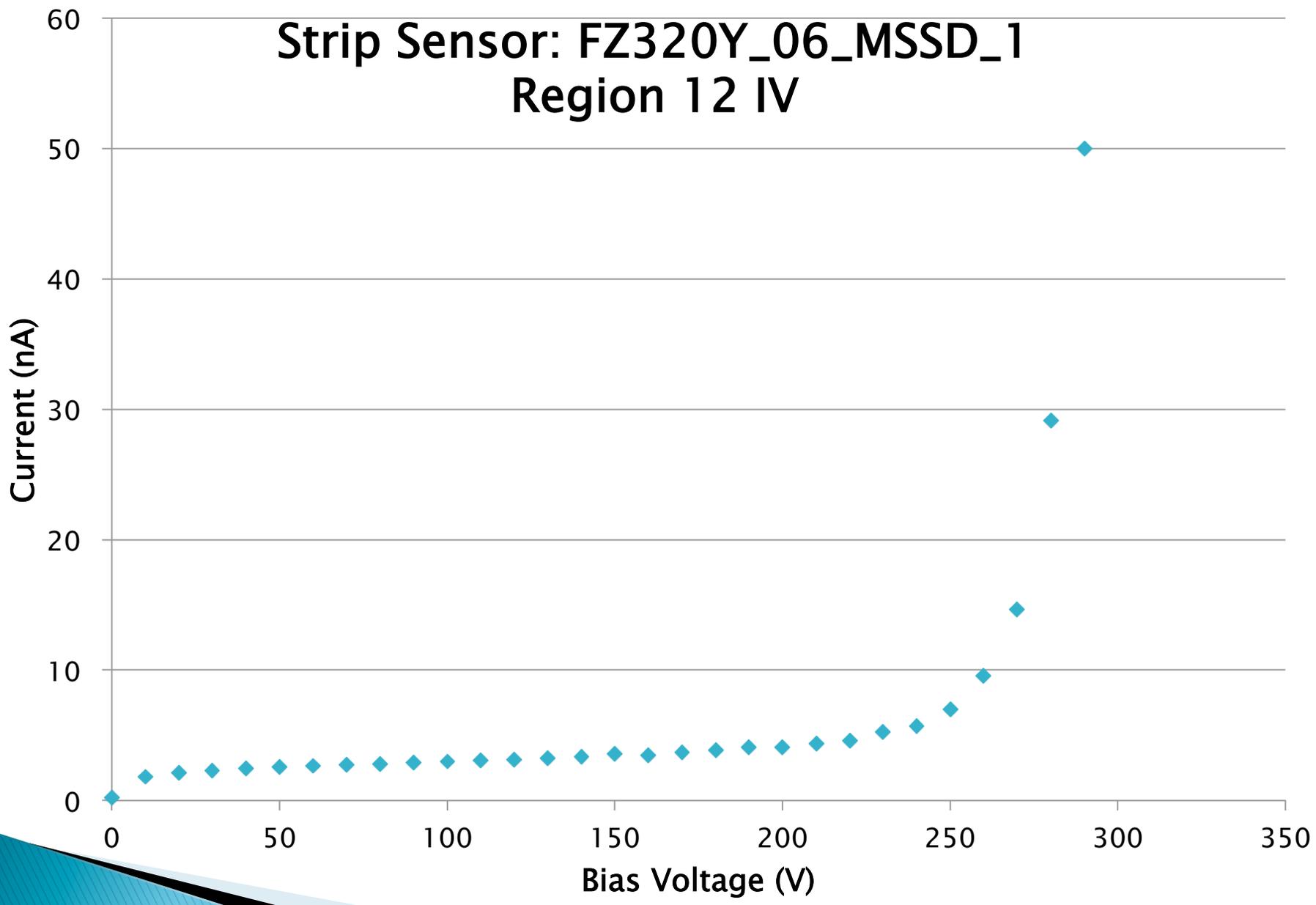


IV (Current vs voltage)

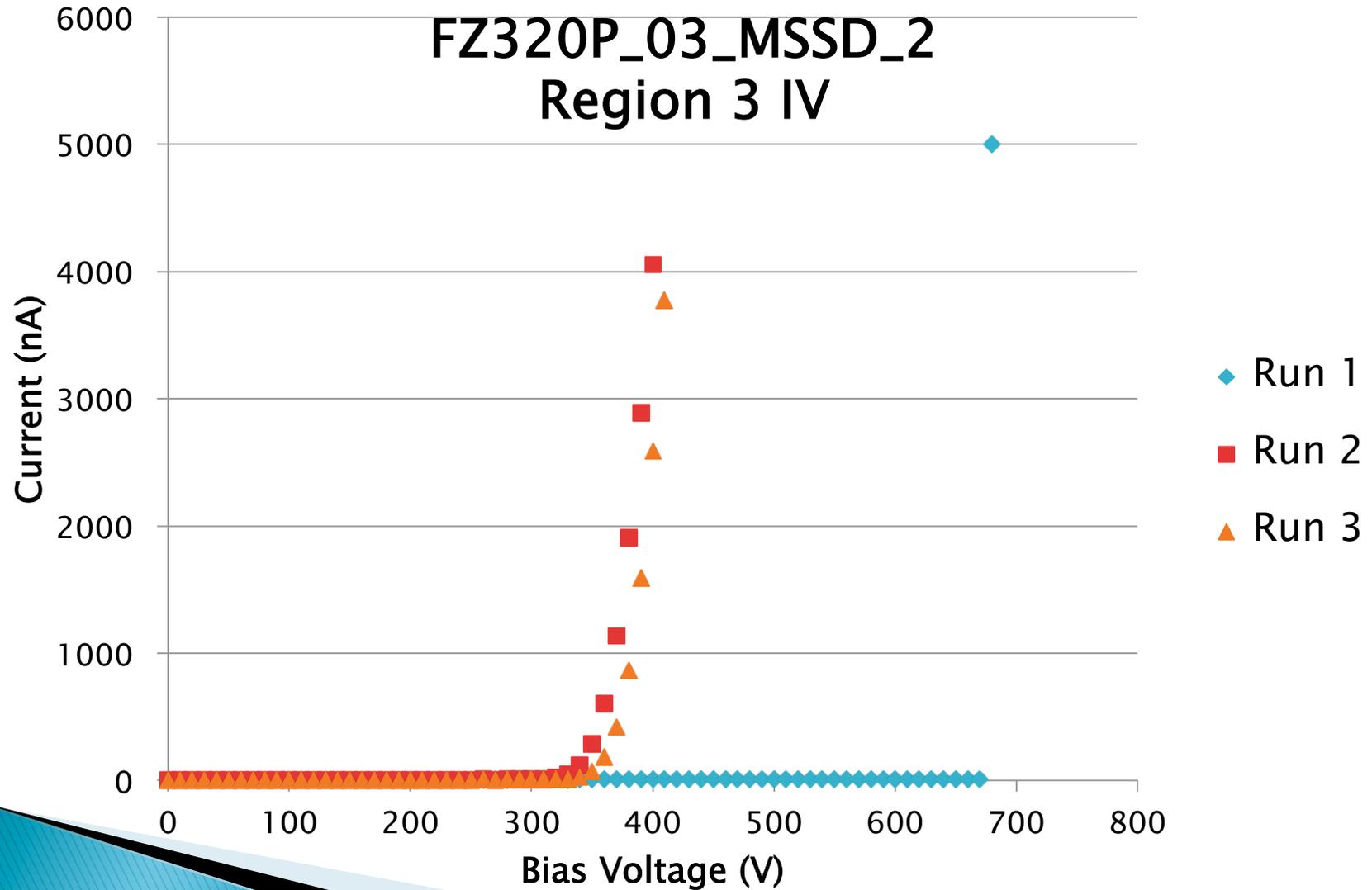
- ▶ Reverse bias at different voltages
- ▶ Measure the leakage current
- ▶ Breakdown voltage



Strip Sensor: FZ320Y_06_MSSD_1 Region 12 IV



Conditioning study



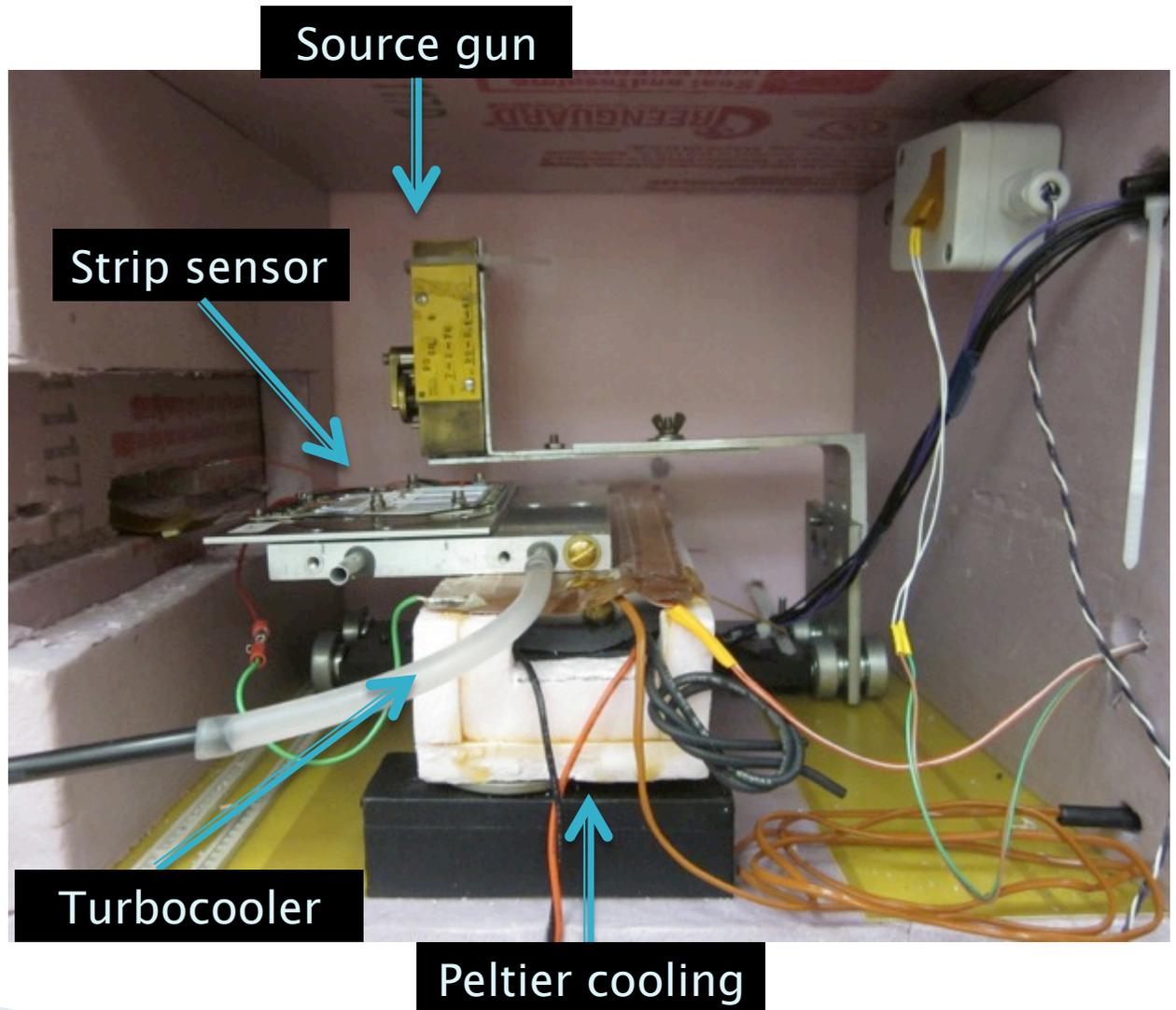
Conditioning study

- ▶ Changing breakdown voltage
- ▶ Set a voltage for 16+ hours (conditioning), track leakage current throughout
- ▶ Post-conditioning measurements usually show regular IV behavior
- ▶ N-type tends to be less affected and more stable
- ▶ P-spray is less stable and more easily damaged
- ▶ P-stop is more stable than p-spray



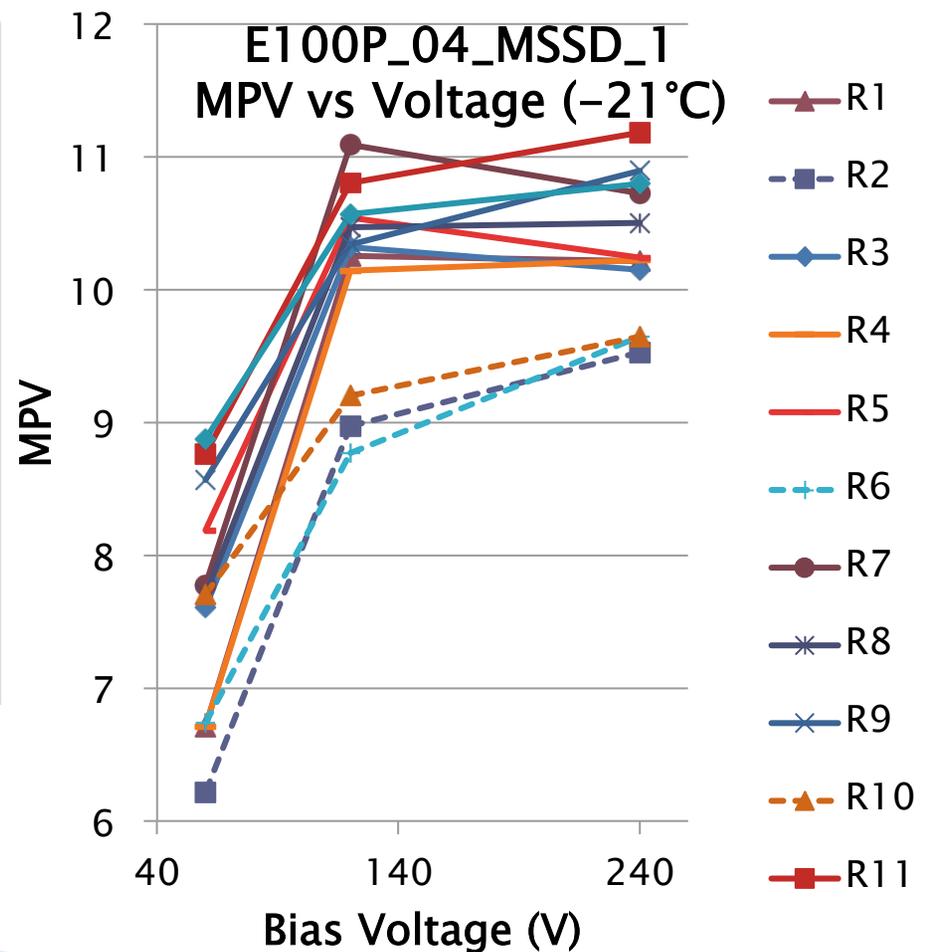
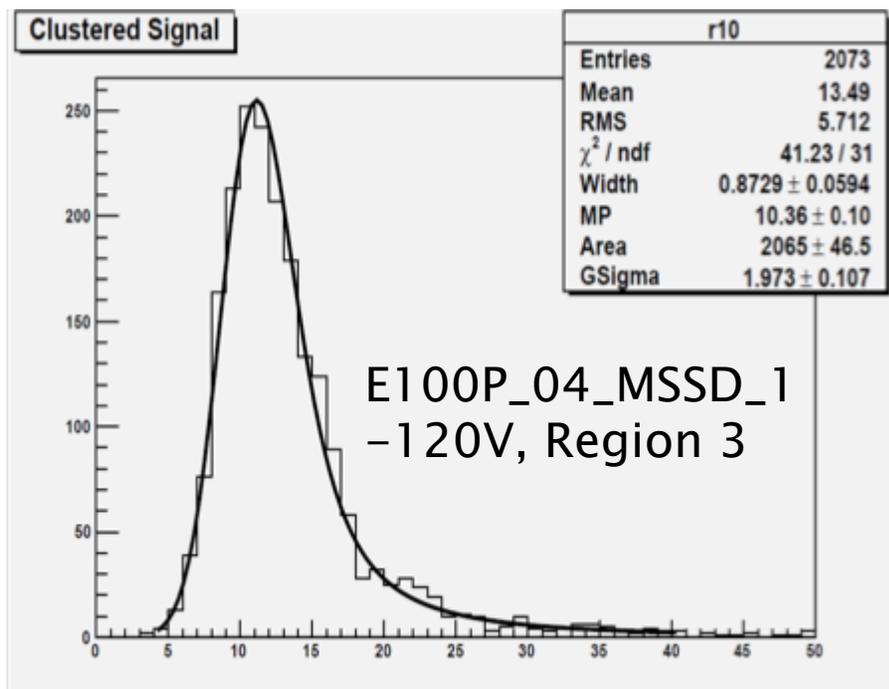
Source Measurements

- ▶ Sr-90 source
- ▶ Measurements at both room temperature and -21°C
- ▶ Doing measurements cold reduces current

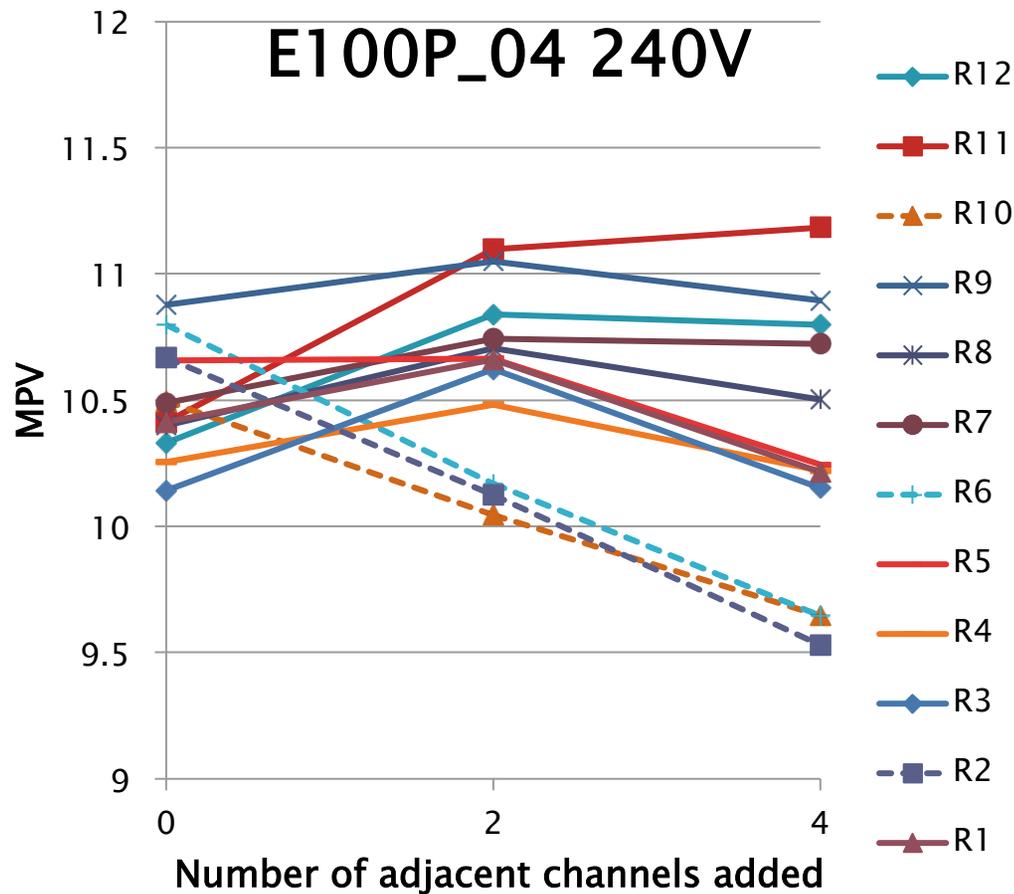


Source Measurements

- ▶ Take measurements at full depletion, half depletion, and twice depletion

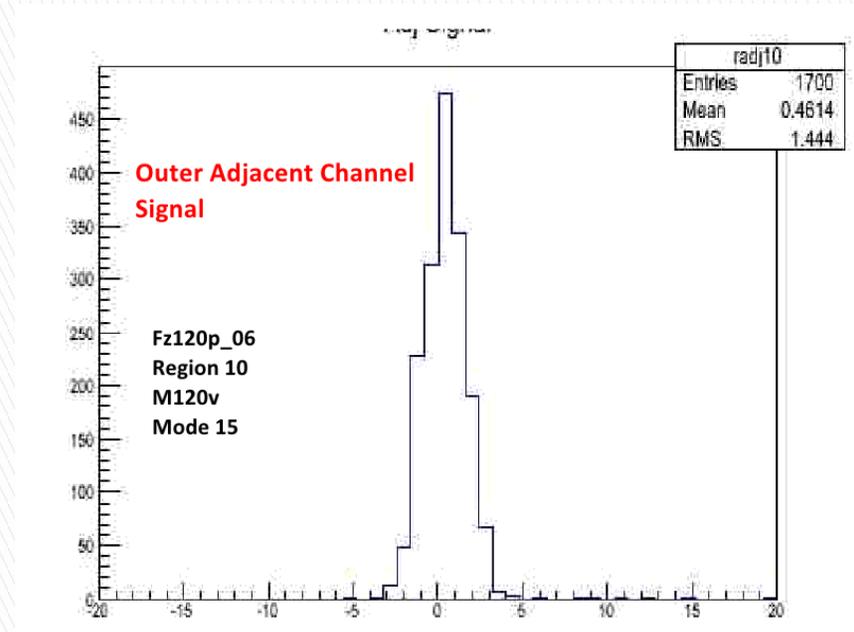
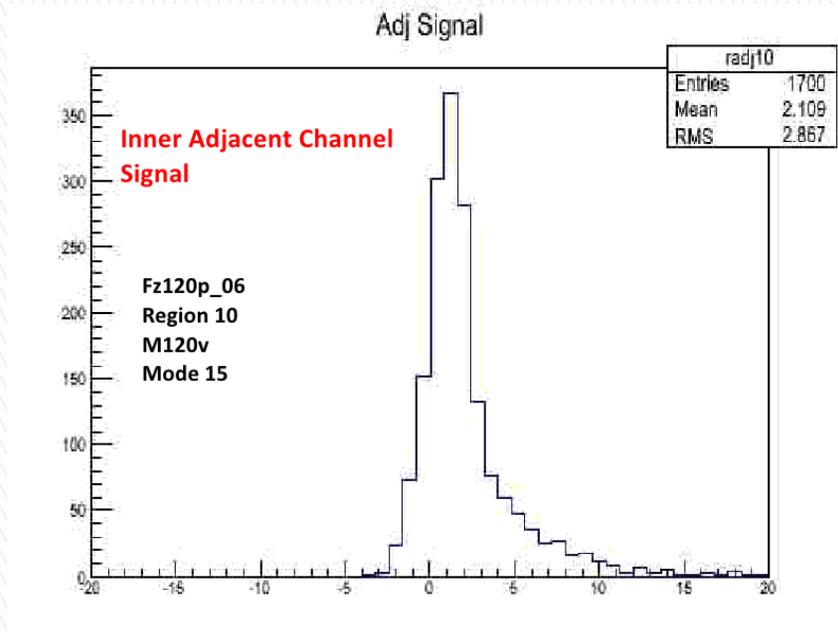


Adjacent Channel study



- ▶ Looked at the effects of adding different numbers of adjacent channels (0, 2, 4)
- ▶ Found that adding 2 adjacent channels adds signal, but adding 4 adds a lot of noise

Adjacent Channel study



Signal

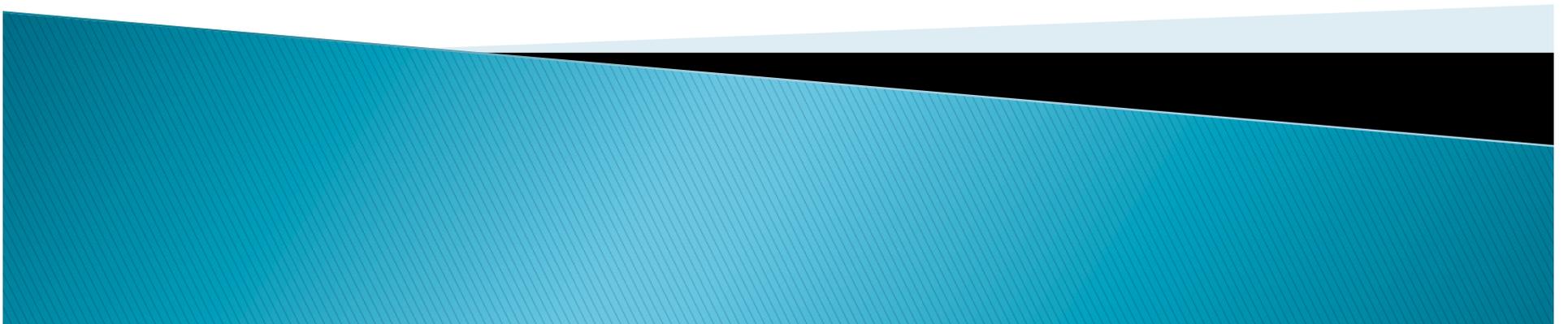
Noise

Acknowledgements

- ▶ Al Ito
- ▶ Selcuk Cihangir, Lenny Spiegel, Simon Kwan, Konstantin Androsov, Wei Zou, and Elena Graverini
- ▶ Erik Ramberg, Roger Dixon, and Carol Angarola



Additional Slides



Methods of growing silicon

- ▶ **Czochralski**
 - within magnetic field: take a seed crystal, put it into molten silicon w/ dopants, and draw out to form crystal
 - most commercially grown silicon is Czochralski
 - speed and low cost of production, radiation hardness
- ▶ **Float zone**
 - seed crystal and high-purity silicon rod, partially melted, draw crystal out
 - currently used in detectors
- ▶ **Epitaxial**
 - deposit silicon from compounds onto seed crystal



Timeline

- ▶ Research began around 2008
- ▶ Phase I: Pixel upgrade
 - At the end of this now
 - Research done by 2013, production done by 2016
- ▶ Phase II: Strip upgrade
- ▶ Short term: receive irradiated sensors from CERN, test all, anneal half

