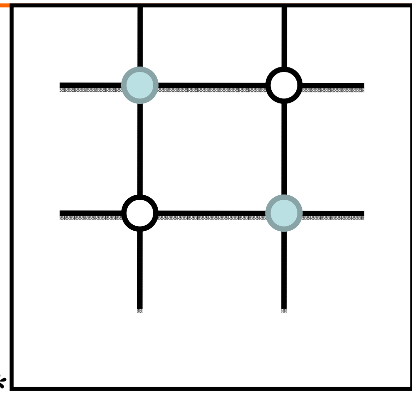
Lecture 4

Why it's cool to be in particle physics…
...a few remarks on Detector Instrumentation

Reference for this lecture:
"Knowledge and Wonder" – Victor Weisskopf, MIT Press

Silicon Pixel Detectors and SiPM



Good: p^+ pads embedded as a 2-dimensional matrix in an n-type substrate

Typical size of pads (pixels) is ~ $50\text{-}200\ \mu m$.

Each pixel provides a unique (x,y) readout.

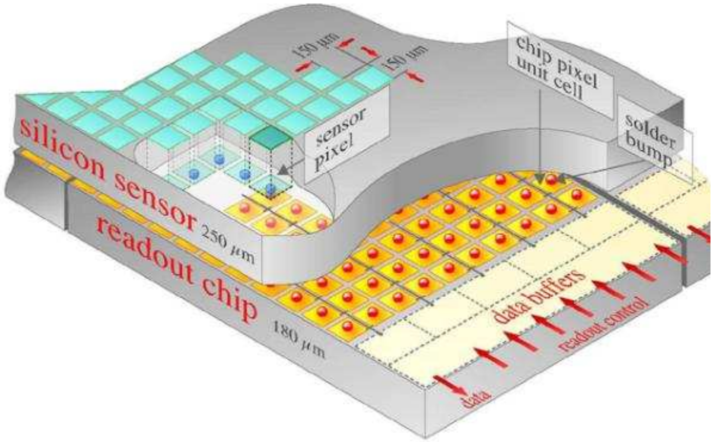
Bad:

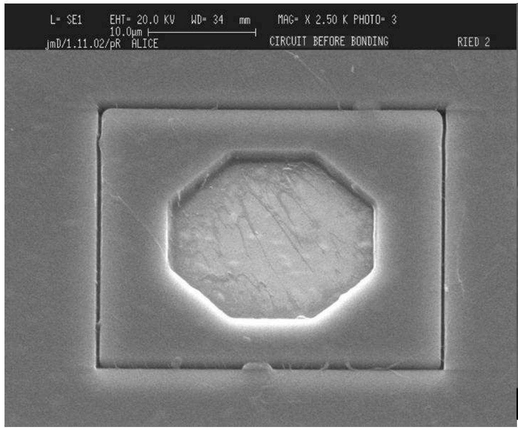
Drastically larger number of readout channels and bonds! $2n \rightarrow n^2 = \$\$$

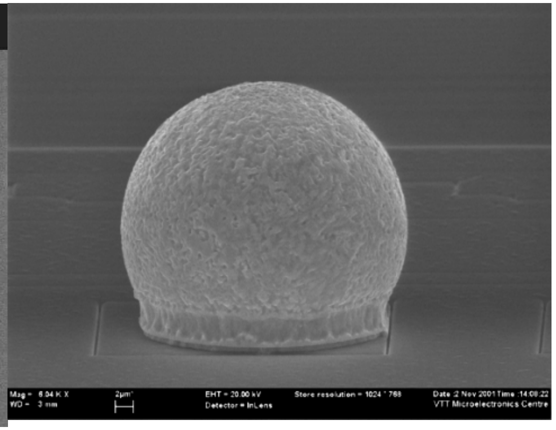
Readout wires run near adjacent pixels – cross-channel capacitive pickup a problem*

*Solution: Bump bonding:

ATLAS @ LHC : 1.4 X 10^8 pixels







SiPM : Silicon PhotoMultiplier – same principle, responds to light instead of c.p. radiation

see: http://www.slac.stanford.edu/pubs/icfa/fall01.html

Diamonds are forever

- We have focused on doped Silicon as the semiconductor material.

- For Diamond,
  band gap is 5.5 eV and average energy needed to create an e^-/h pair is 13.6 eV.
  So average thermal 1000 e^-/h pairs/cm^3 in diamond at room temp.
  33000 e^-/h pairs produced by MIP

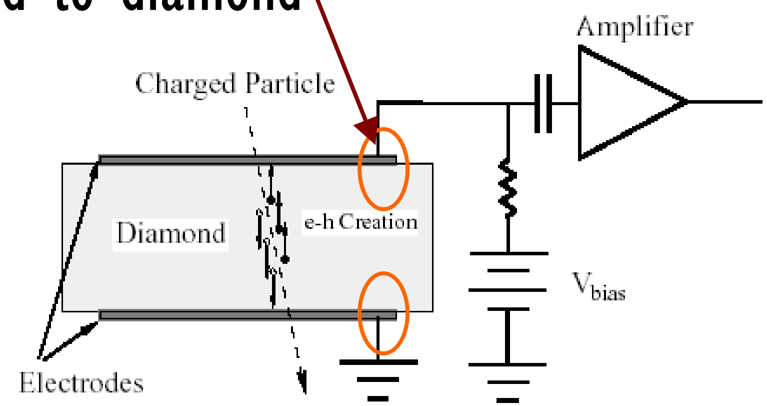
- → *Undoped diamond already has a S/N of ~ 33:1*

- A big advantage of using an undoped material is that it is much more resistant to radiation damage.
  High dosage of radiation creates crystal defects in thesemiconductor – knocking the dopant ions out of place: the semiconductor relies on the dopant for it's properties.

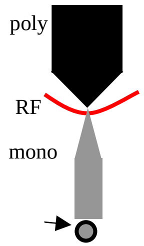
So why doesn't everyone use diamonds?

$$$

Very hard to do VLSI lithography
& bond to diamond



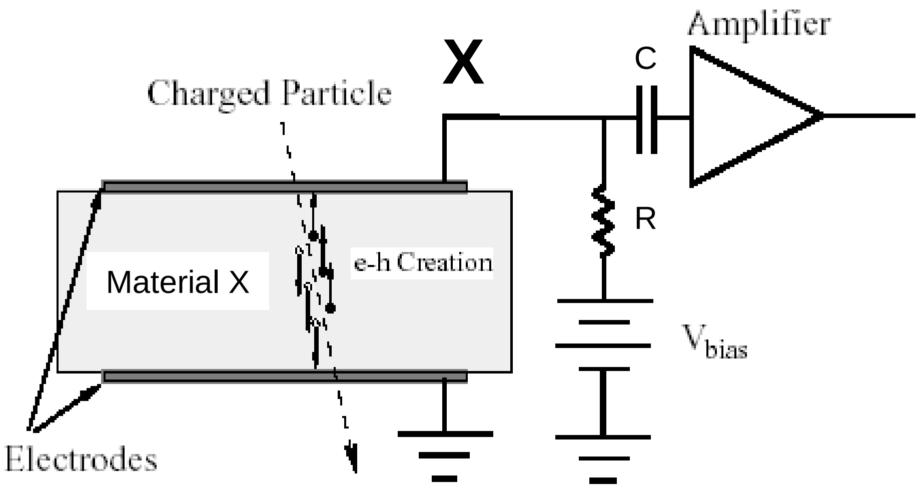
Much higher temp



Precise cut?

How to extract signals from a solid-state detector

This is a general circuit for reading out a solid-state detector. We would like to determine the shape of the signal at point **X** *– the signal characteristics beyond that are determined by the amplifier electronics*



- *C: DC blocking capacitor to reject leakage current from the detector*
- *R high value ~ MΩ resistor to decouple bias between different channels.*

You <u>choose</u> the readout electronics design based on the signal shape at **X**.

The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living.

- Henri Poincaré

The Value of Science New York, The Science Press 1907; Dover Thrift Edition 1958