Adrian Bevan, Fred Gannaway, Karen Hayrapetyan

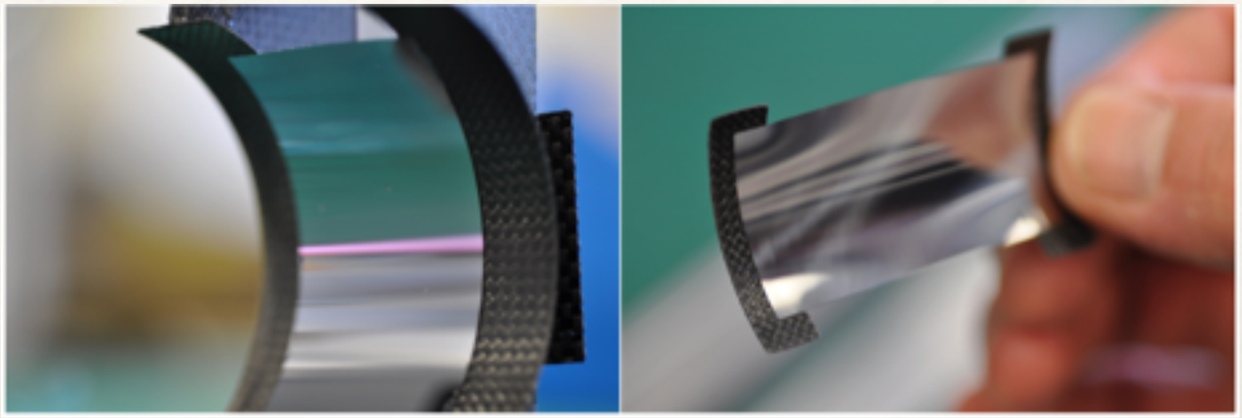
ZeroMass (Support) Detectors

ILC UK Silicon Detector Meeting, March 2017

Queen Mary
University of London

Concept

- Silicon detectors are a combination of:
  - Active sensor material
  - Support structure
  - Cooling infrastructure
  - Power/readout structure

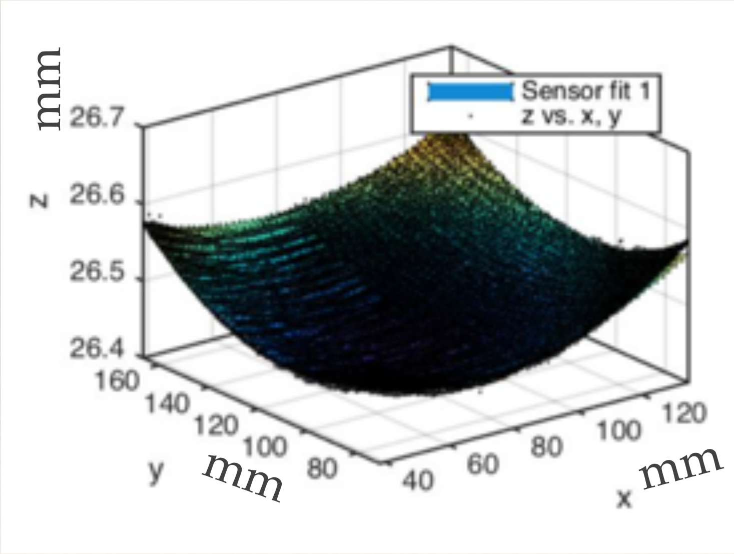


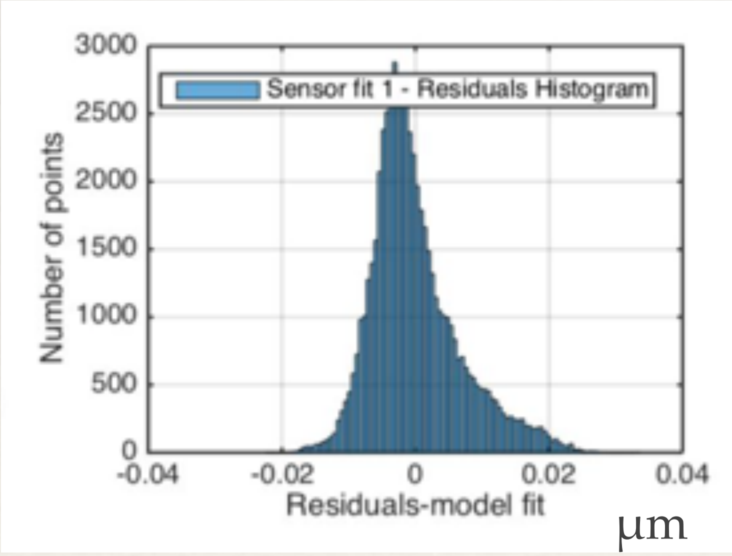
2cm x 5cm x 50μm tokens prepared by Arachnid, 2012

- For an ILC style detector the readout requirements are not as stringent as the LHC, meaning passive cooling options can work for some subsystem technology choices.
- Silicon sensor thickness and mechanical structure can then dominate the material budget.
- Silicon is a crystal lattice that provides strength up to a point; thin silicon becomes flexible until you stress it. Then it becomes rigid (shown by Arachnid).
- Ideal goal - take a CMOS MAPS device and use that as the structure for the module; with formers to keep shape sufficiently rigid to mitigate the need for support material everywhere.

Understanding Shape

- Fabrication of large scale sensors results in a non-trival shape:
  - depends on process: implantation, metalisation etc.
  - Even 300μm thick sensors have non trivial bowing up to 150-300μm over a 6-10cm range (ATLAS SCT / ATLAS ITk sized strip sensors).
  - Concave vs convex bowing varies from fab to fab.
- Can measure shape with a smartscope: optical / laser syst to ~2μm (systematic study made using an ATLAS mini).





Have also measured the Arachnid tokens and can model the shape, following work done on ATLAS.

Understanding Limits

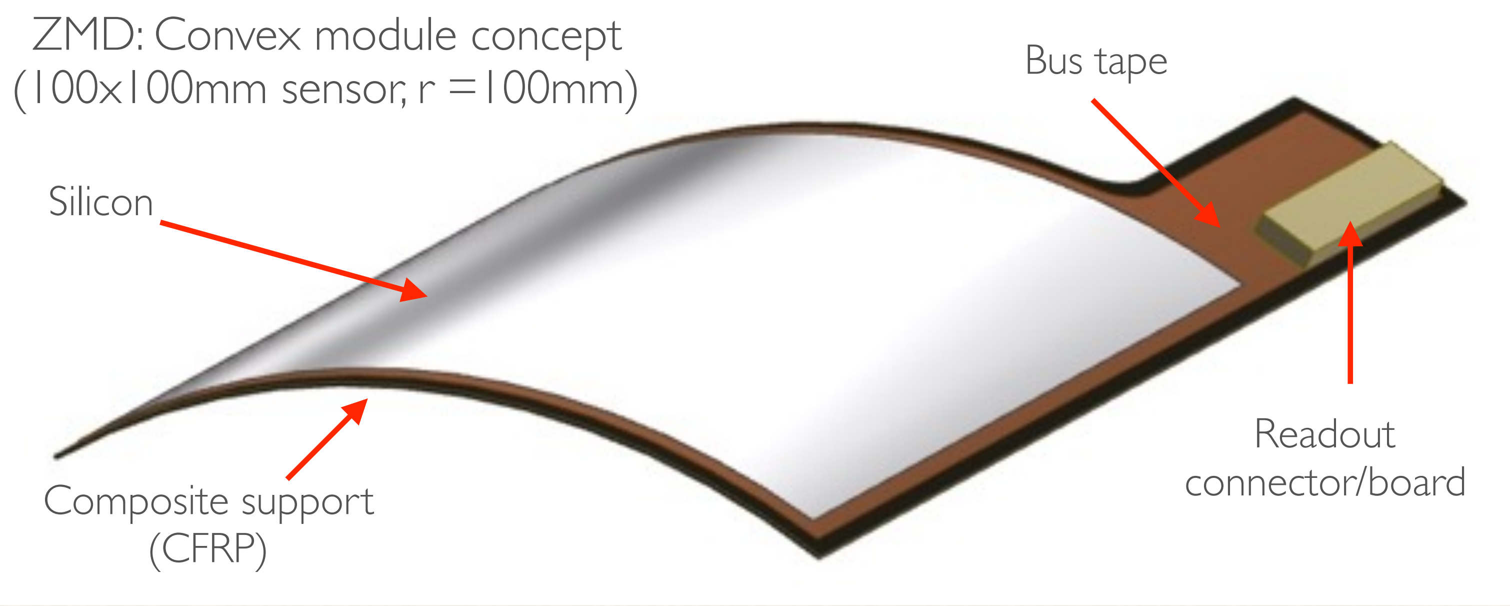
- Tested bending 50μm (and some 25μm) thick samples round formers of the following dimensions.

Diameter (mm)	26	28	30	35	50	95
Radius (mm)	13	14	15	17.5	25	47.5

- Able to do this successfully for intrinsic and doped silicon wafers (not processed).
- Note: Arachnid tokens have r=25mm.
- Next step - look at electrically viable devices.

Module Concept

- V0 is a flat module, reading out all channels. This provides a reference.
    - No technical developments required - straightforward to fabricate and readout.
- Mitigate risk with curved modules by opting for a curved device that is fully supported, and with a large r~75mm (V1).



- V1.1 would then be partially supported; iterate from there.

Sensors

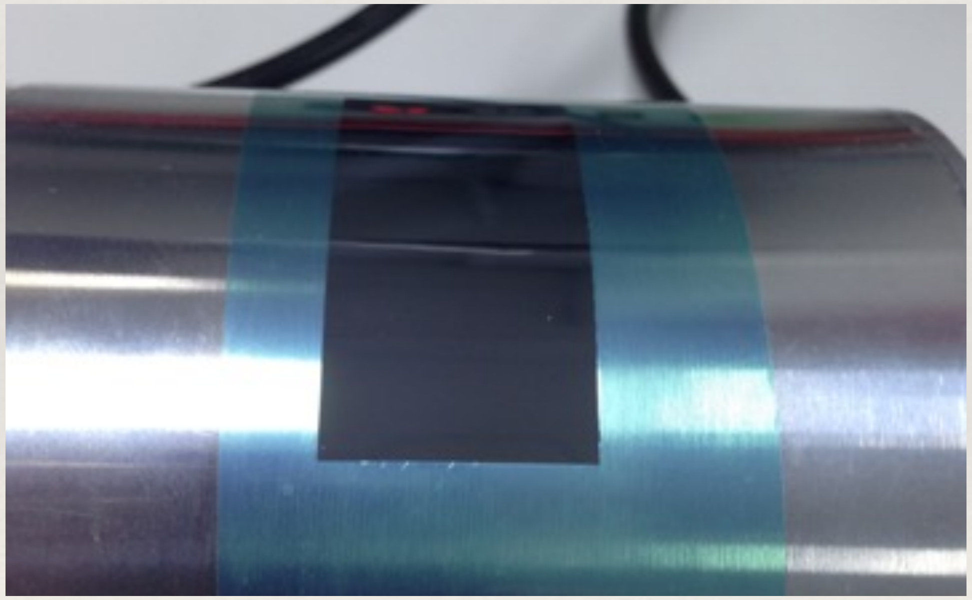
- CMOS MAPS not an ideal starting point;
  - Complicated multi-layer fabrication.
  - Most chips available are reticle sized.
  - Much smaller than one would want for a large tracking volume demonstrator.
  - Complicated to read out.
- Opt for a silicon strip detector as a starting point to validate basic concept; use that as a spring board to more complicated (interesting) technology for a detector.
  - Working with Micron Semiconductor Ltd. for this.

Sensors

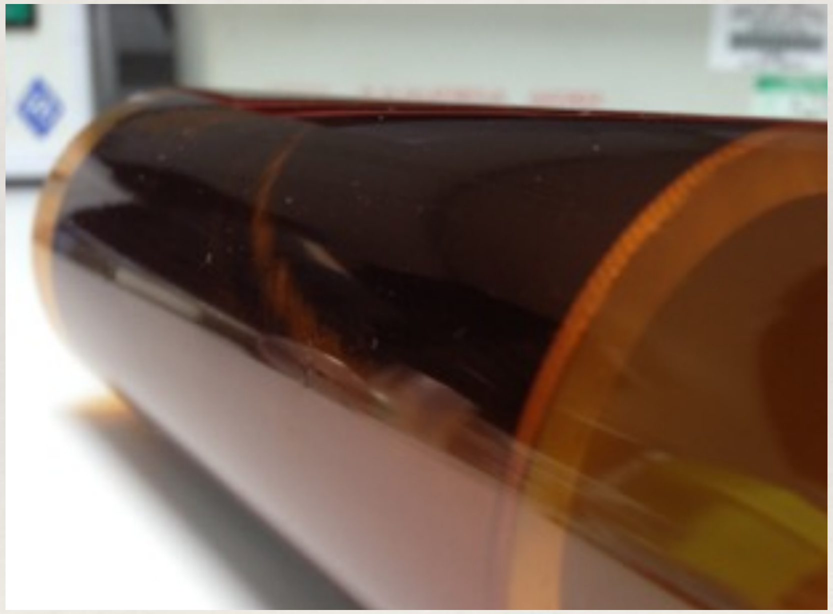
- Agreed a baseline spec to work with for these sensors to ensure a high chance of success.
  - 100 x 100 mm sensor size.
  - 32 strips.
  - 3mm strip pitch.
  - 50μm thickness with 3um maximum variation in thickness across sensor.
  - <100> silicon; N type with 5KΩ resistance.
  - Bias voltage ~40V.
  - 1μs shaping for signals from ^{241}Am.
- Requires DC readout (no polysilicon resistors at this stage as these are hard to implant in thin devices; and we want to probe a simple device and build complexity).
- 4 sensors on order; delivery due this month.

Jigs

- We have several types of jigs; primitive ones work, but are of limited use when it comes to module construction.
- Investing effort into developing vacuum jigs; method needs a little refinement, but is promising so far.



50μm thick silicon sample (20x50mm held on a vacuum jig; r=45mm)



25μm thick silicon sample (100x100mm held on a primitive jig; r=25mm)

QMUL Resources

- PPRC Clean room:
  - BJ820 Wire bonder on order (delivery before end of FY)
  - Alessi probe station
  - Single and multi channel readout (not ASIC driven, but good enough for us to start this work; ASIC based readout of devices can be acquired as we evolve).
- Silicon detector labs + workshop facilities.

- Paid for NRE and a few sensors out of QMUL funds, ILC UK have kindly given £6K for 2 additional sensors to be purchased (mitigates risk of failure given the nature of the project).
  - Note: collect sensors from MSL by hand as initial shipping test proved to be unsuitable.

Next Steps…

- Next steps:
    - Design kapton bus tape
    - Make CFRP support for flat reference sample
    - Make vacuum jig for 150mm radius module
    - Construct mechanical mock ups to validate jigs
    - Characterise sensors on arrival from MSL
    - etc.
- Long term: decide if we jump from these simple sensors to (small) CMOS MAPS devices, or if there is merit in going to AC coupled sensors to explore reliability of e.g. variants of the ATLAS sensors thinned appropriately.