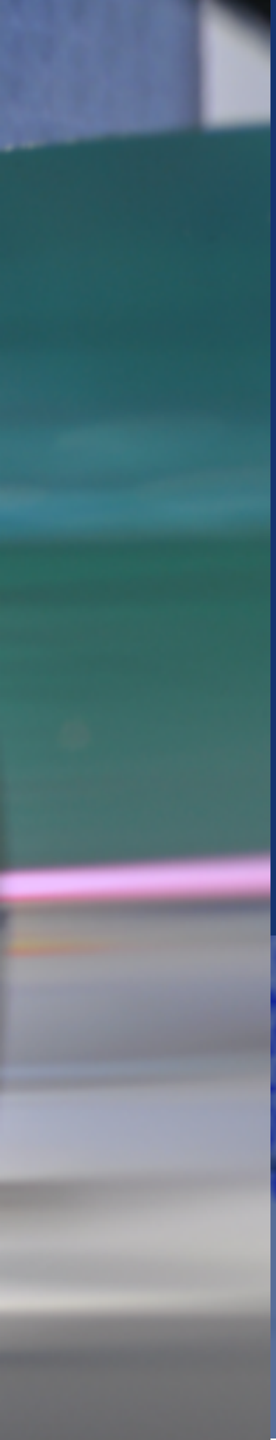

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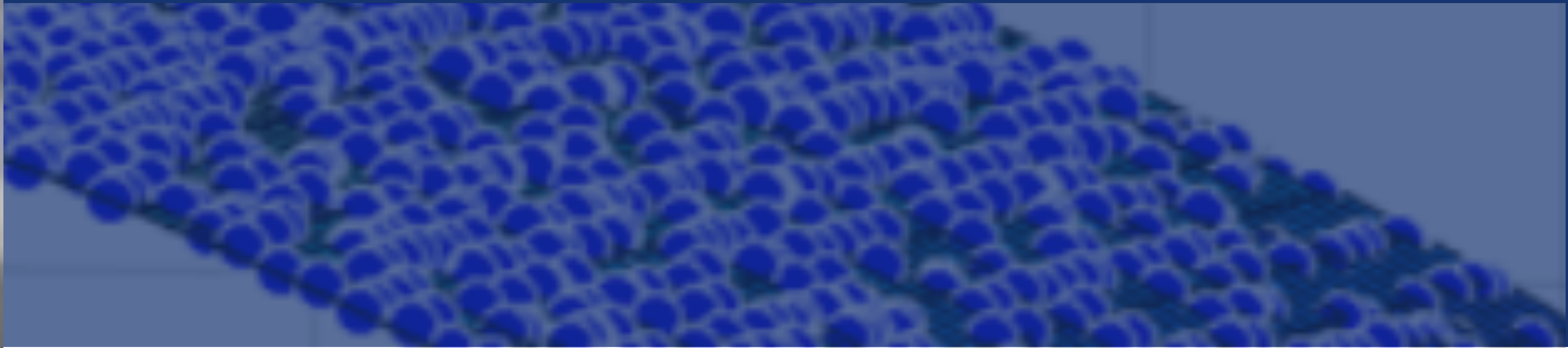
ZeroMass Detector (ZMD) concept

Adrian Bevan



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Background

QMUL has a long history of building silicon detectors with other UK institutes including:

- OPAL Vertex Detector (with Cambridge);
- ATLAS SCT;
- ATLAS Upgrade.

We also have worked on R&D projects and detectors that did not get built:

- Arachnid - CMOS MAPS development that led to the ALPIDE chip design for ALICE ITS (with RAL, Daresbury Laboratory, and Bristol);
- SuperB - Pixel and strip detector a next Super B Factory (RAL and Italy);
- ZeroMass Detector Concept - will talk about this today.

What is ZeroMass

“The problem with you physicists is you want us to engineer a detector where your silicon floats in space”

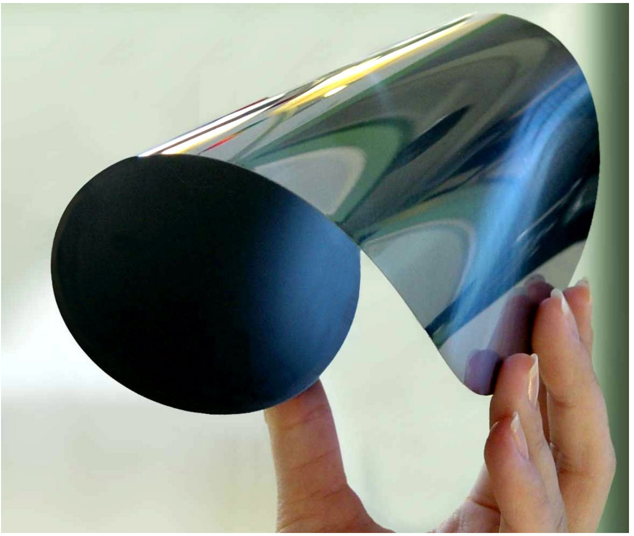
(One of our engineers reflecting, on the ITk strip tracker)

The ideal physics requirement for a detector is that we build a device that has only silicon and our readout electronics; no mechanical support.

Conventional wisdom is that silicon needs mechanical support;

- thick silicon wafers need to be held in place

- thin silicon is flexible, but needs support.



Adrian Bevan: a.j.bevan@qmul.ac.uk

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What is ZeroMass

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ZeroMass Detectors (ZMD) is an R&D programme at QMUL in collaboration Micron Semiconductor Ltd.

Takes thin film theory and puts it into practice from the perspective of mechanical stability studies and demonstrators.

→Spun out of the STFC funded Arachnid project:

Phase 1: focus on mechanical aspects for making dummy modules.

Phase 2: introduces silicon sensors to add to complexity and move to explore other physics issues:

- Our partner MSL have developed silicon strip sensors specifically for this project.

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Phase 1: Mechanics

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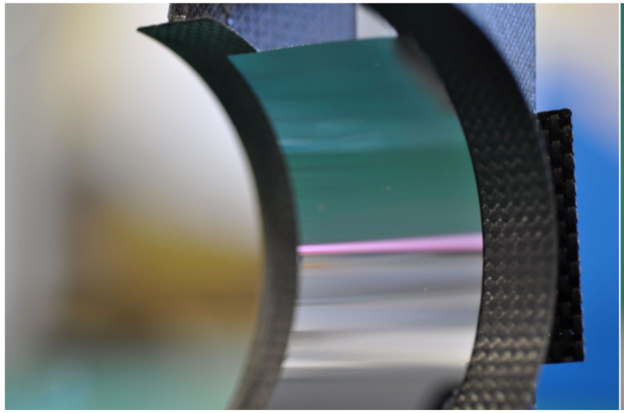
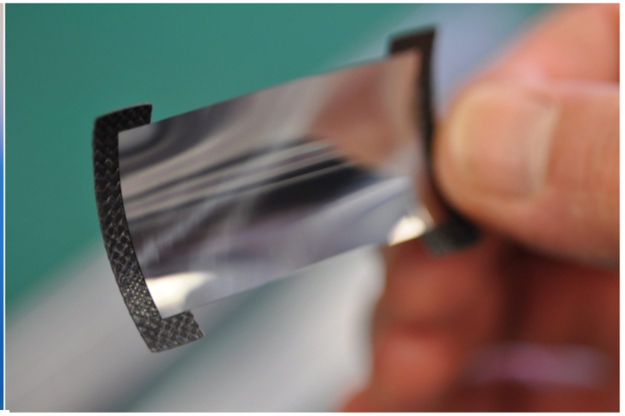
Thin films are intrinsically strong.

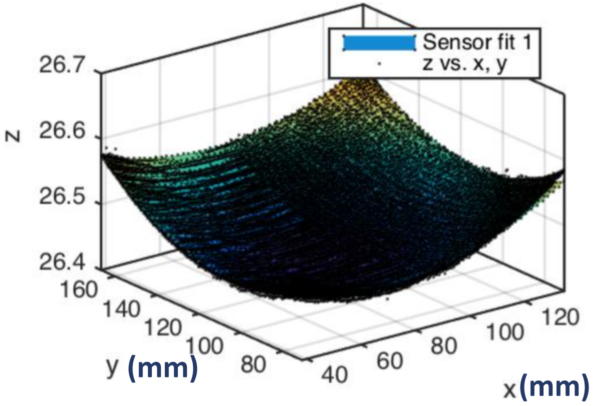
Build structures utilising the strength; study stability and longevity issues with mechanical models to answer basic questions about feasibility.

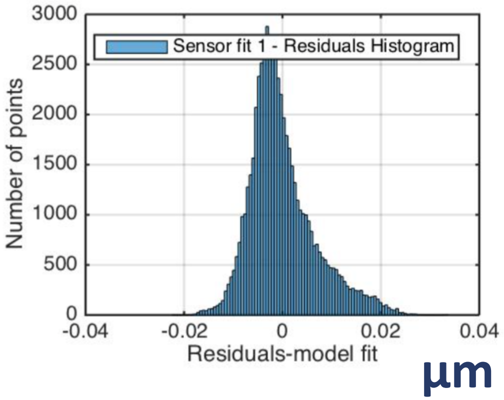
Early tokens using 2x5cm silicon demonstrated potential to mechanically support vertex detectors with minimal frame material.





Through ZMD and ATLAS we have extensively validated the ability to measure the surface shape of silicon sensors and non-planar modules.



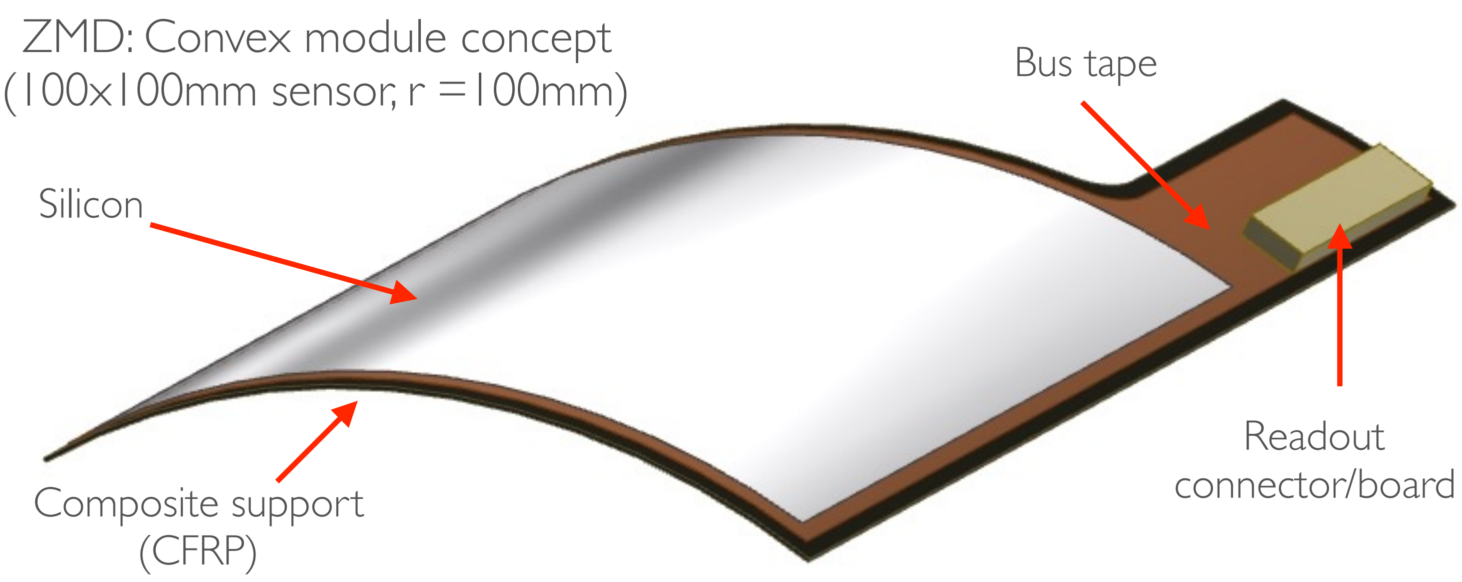


Adrian Bevan: a.j.bevan@qmul.ac.uk

Phase 1: Mechanics

Mechanical tokens have been constructed (and stored) since 2013 with radii 1.3cm up to 4.8cm.

Recent work has focused on large area thin devices (10x10cm) with a radius of curvature of 15cm.



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Phase 1: Mechanics

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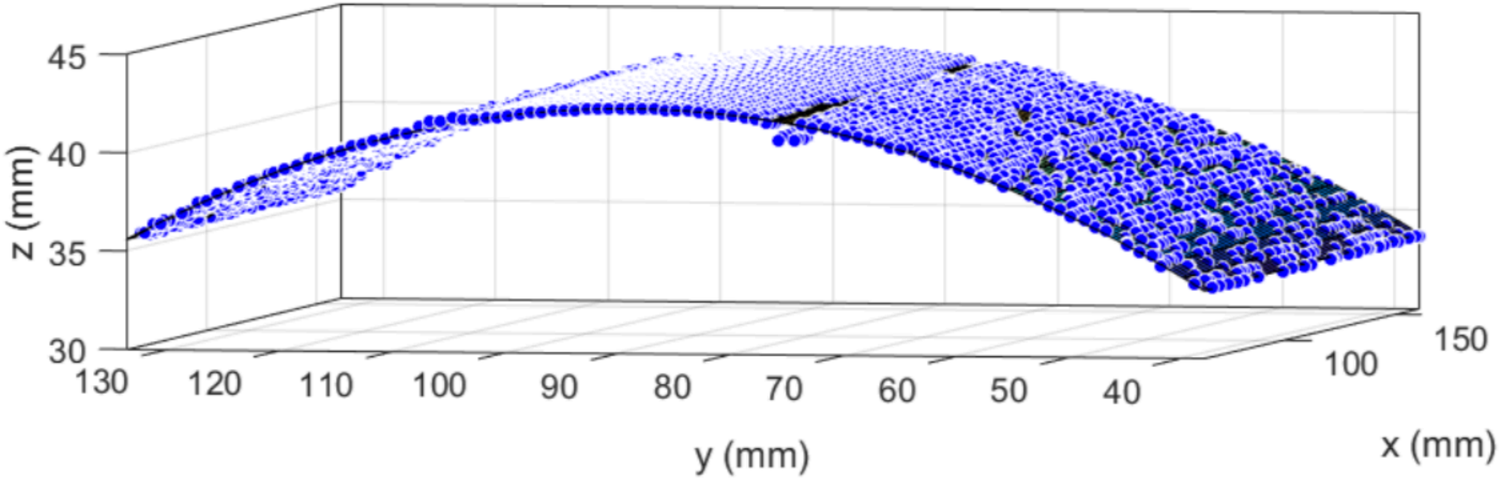
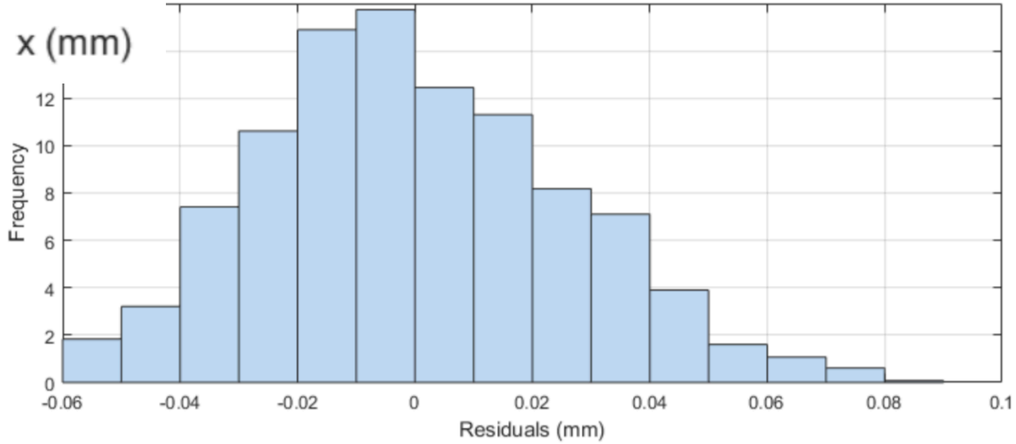


Studied a number of different assembly methods to identify an optimal solution for constructing modules.

Able to measure surface and build models of the shape of modules for alignment and geometry definition.

Mechanical modules in lab stable for a few years.



Adrian Bevan: a.j.bevan@qmul.ac.uk

Phase 1: Mechanics

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Prototype modules made come in two types: with and without embedded RF shielding mesh for modules close to beam pipes).

Material	Thickness (μm)	Radiation length X_0 (mm)	% of X_0
Silicon	25 ± 0	93.7	0.027%
	50 ± 0	93.7	0.053%
Silicon oxide	<1	98.8	negligible
Kapton	75 ± 0	285.8	0.076%
Aluminium strip	1 ± 0	89.0	0.001%
Copper	437 ± 1	14.4	3.035%
CFRP	761 ± 1	213.6	0.356%
ARALDITE 2011 epoxy resin	69.5 ± 3.8	335.0	0.021%
Steel reinforced	25.2 ± 2.5	335.0	0.008%
epoxy resin	42.8 ± 4.3	335.0	0.013%

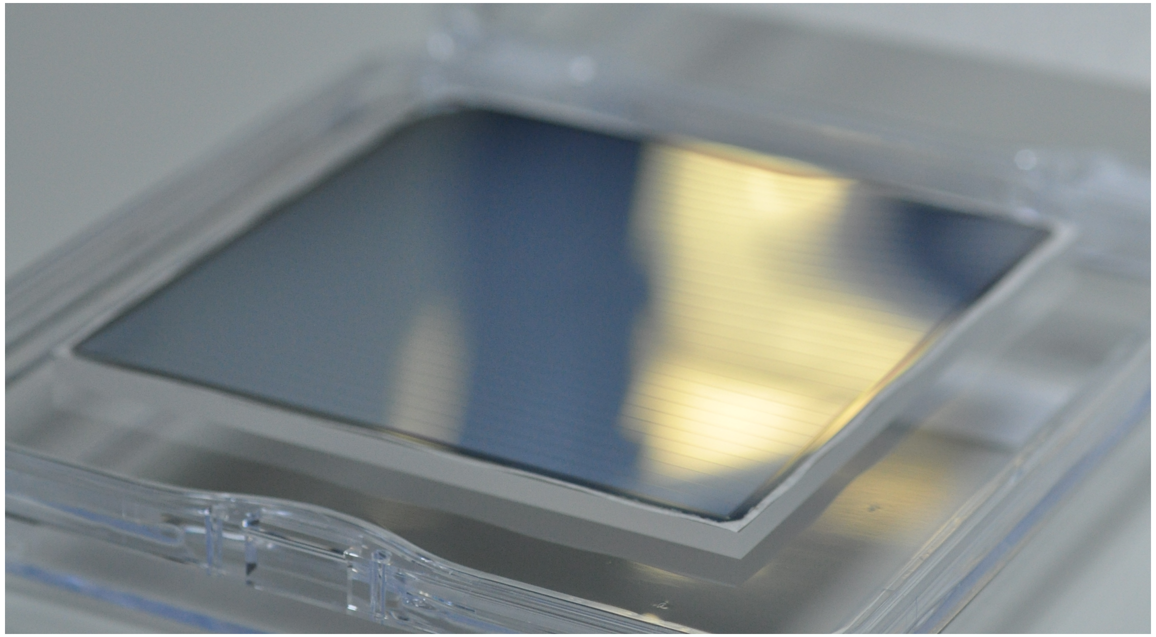
With CFRP support we have modules that have X_0 ~ 0.50-0.53 (no RF shield).

Potential to reduce this further to ~0.2 X_0 (or less); ideal best is ~ 0.05 X_0, but will require some minimal edge frame.

Yield for 25μm silicon is very poor; now the focus on ~50μm modules, where the mechanical assembly fabrication yield is high.

Phase 2: Sensors

Next steps - systematically work through testing sensors and making electrical modules to explore the next level of detail.



Several thin silicon detectors from MSL in-house to start the next phase of this programme.

Aim is to understand how deformation of silicon changes the properties with regard to radiation detection, S/N etc.

Devices procured are simple on purpose - few elements, limited number of processing steps etc.

After this set of qualifications - will move to more complicated structures to explore applications beyond (e.g. micro-strips and CMOS MAPS).

Adrian Bevan: a.j.bevan@qmul.ac.uk

Summary: ZMD

Phase 1:

- Developed methods for routinely making large area cylindrical silicon sensor modules with X_0 ~ 0.5% achieved, 0.05 X_0 ideal target, aim for less than $0.2X_0$ once we have started work on phase 2.
- Assembly yields are now acceptable for large area modules for production (from the mechanical perspective).
- Metrology validation established to show that we are able to measure the surface shape for modules, and can model this parametrically with an acceptable residual distribution.
- Longevity tests:
  - Tokens have survived in laboratories since 2013 without self-destructing (supports theory of crack propagation in thin films; pre-cursor to moving to higher TRL phases of the programme).

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Summary: ZMD

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Phase 2:

- Procured silicon sensors to start building electrical modules for testing at the next level.

Potential benefits for a tracker:

- Low mass support structures, where the silicon crystal becomes an integral part of the support structure.
- Move toward cylindrical tracker design.
- Adaptable concept to other technologies (e.g. going back to CMOS devices); so strip and pixel trackers could benefit if we solve the technological challenges we face.

- **Would like to explore possibility of bringing this concept into the context of a real programme like the CEPC, as an option for consideration.**