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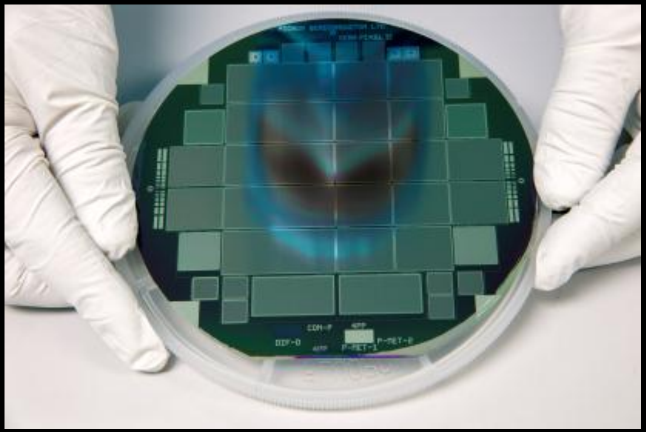
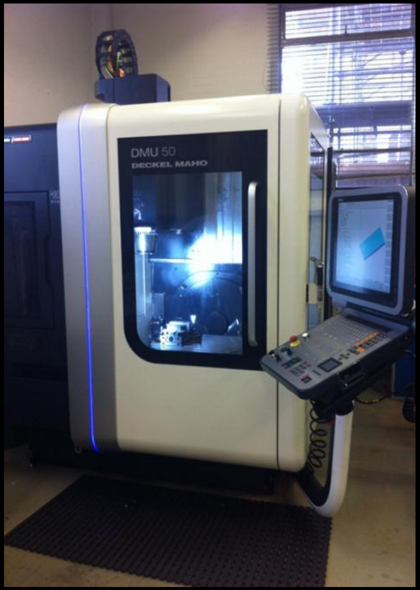
COSY Meeting

Themis Bowcock

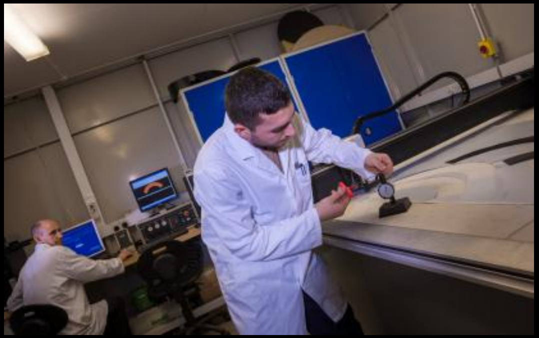
Capabilities in backup slides

Liverpool Semiconductor Detector Centre





Detector Manufacturing Facility



Advanced Materials Laboratory

Detector Development (Si)

Silicon

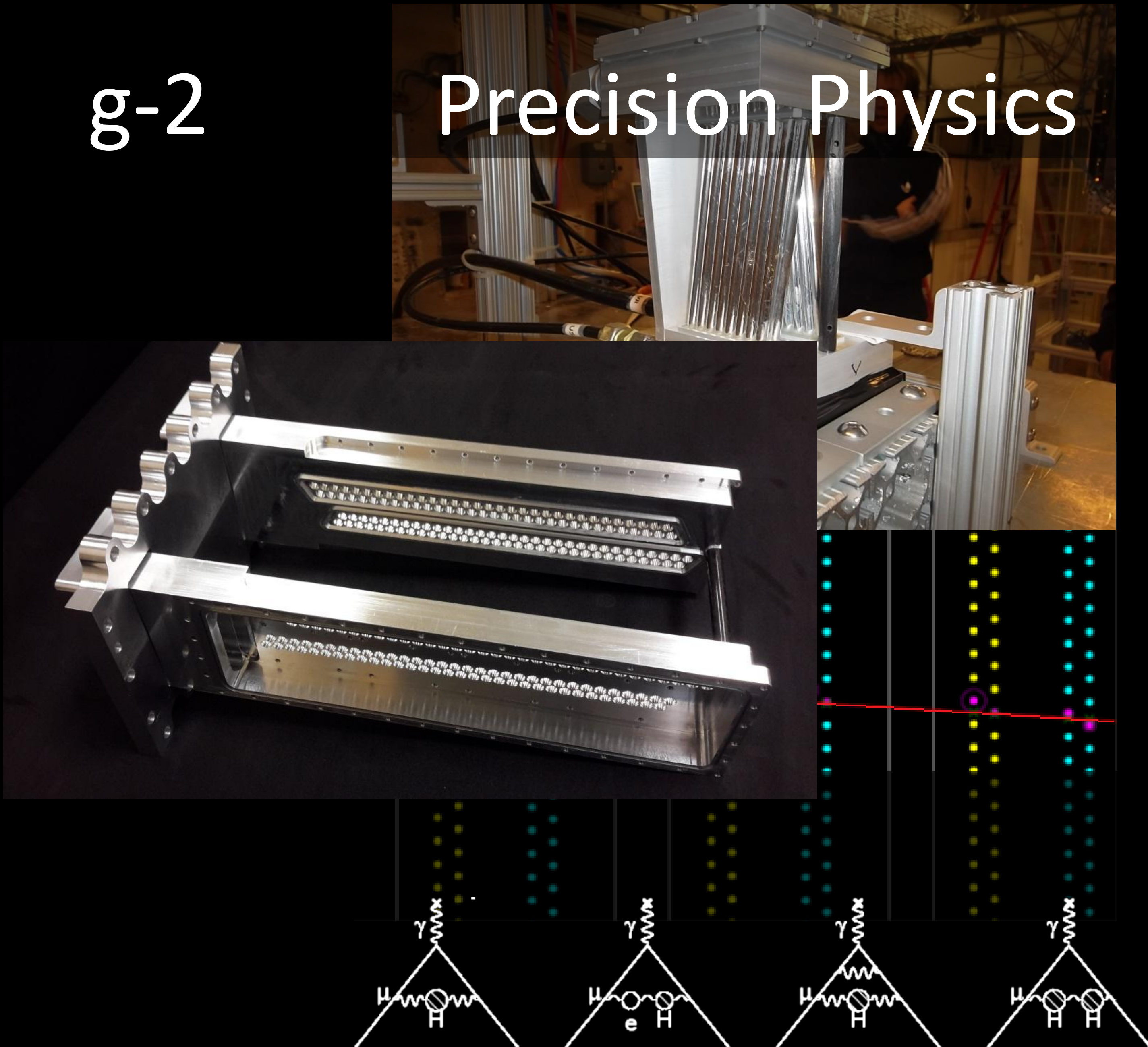
- RD50
- ATLAS
- LHCb

New Technologies

- Hybrid pixels
- HV-CMOS
- Live-emulsion”

g-2

Precision Physics



Bowcock	50%
King	100%
Maxfield	100%
Teubner*	10%

1 postdoc

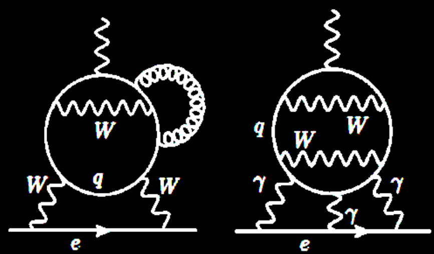
3 PG students

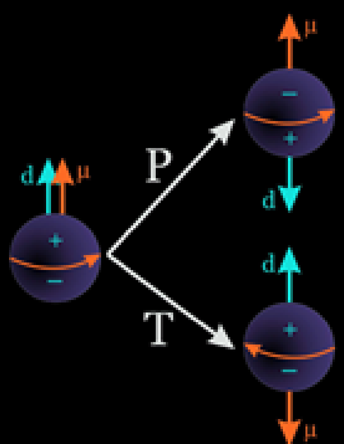
4 Technical posts

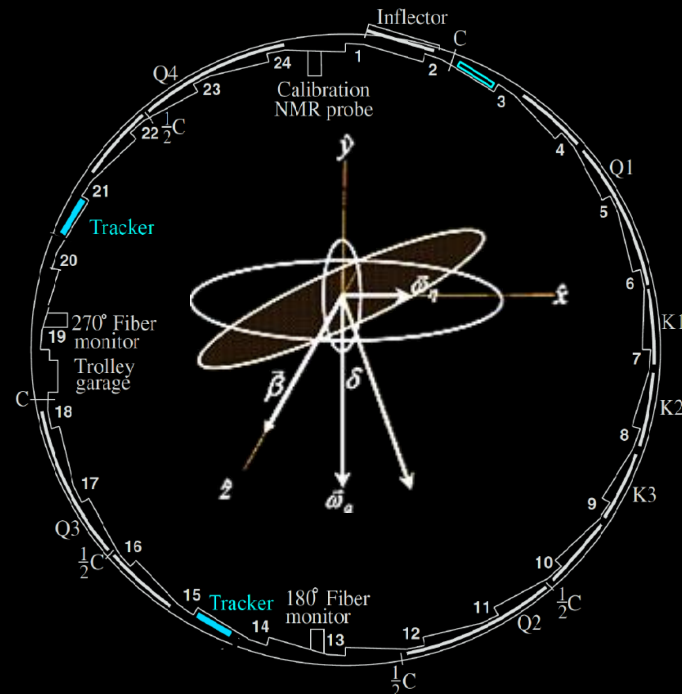
Additional 3 FTE engineering support

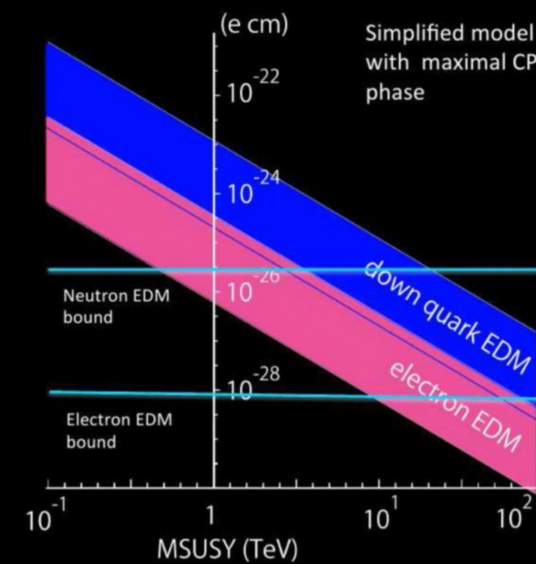
Supported by O($0.25M) capital

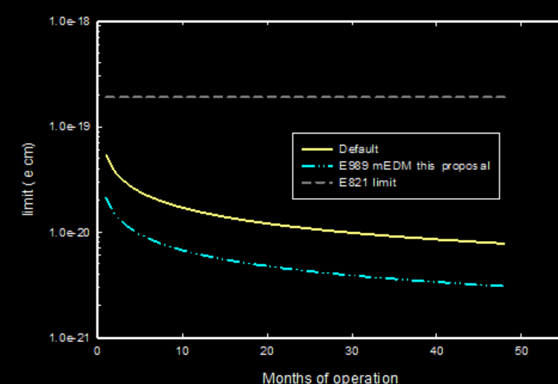
E989 Precision Physics mEDM











Request to EU for funding 2015

UoL polarimeters & HVCMOS

- Areas of interest for Liverpool
  - "compact trackers" for polarimeter (solid state)
  - New team (HVCMOS) which will also look at applications to solid-state tracker

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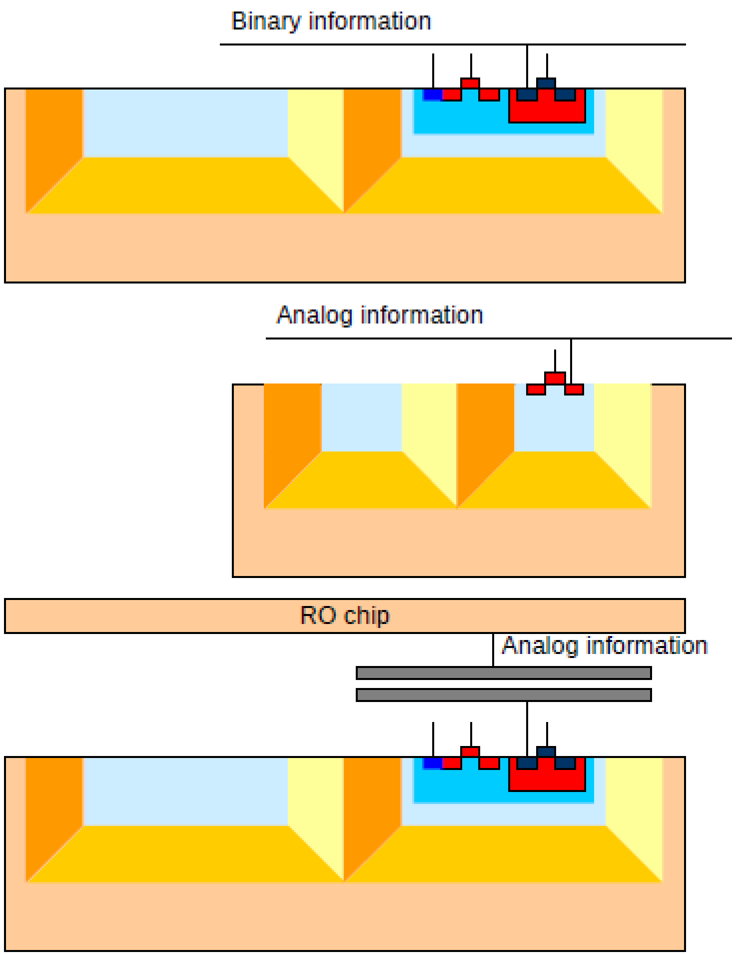
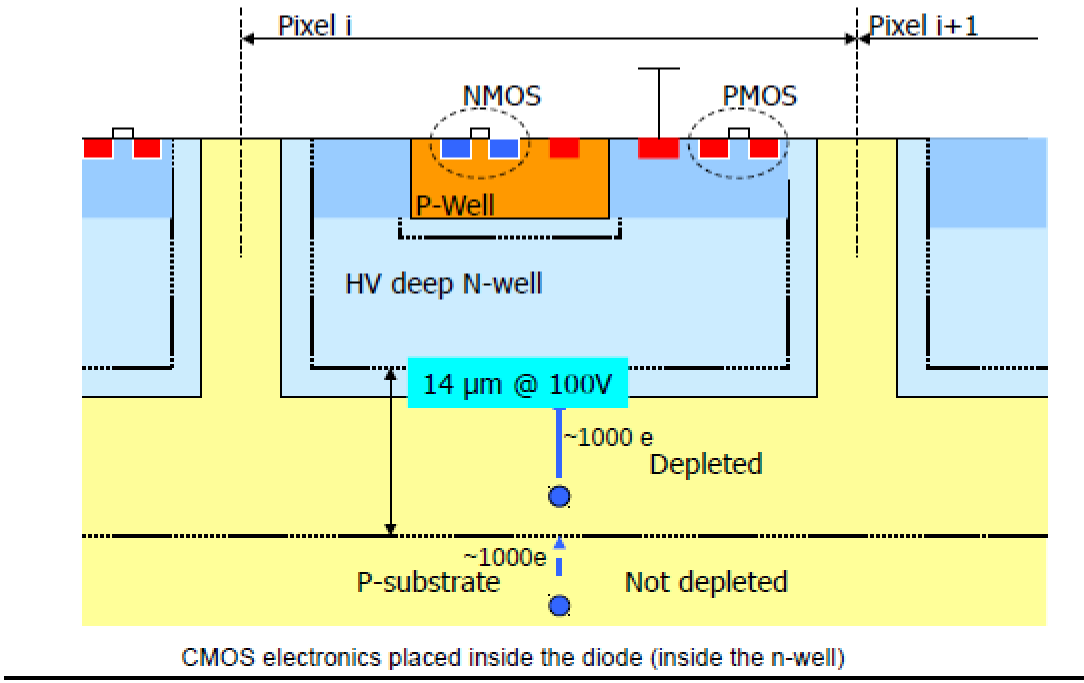
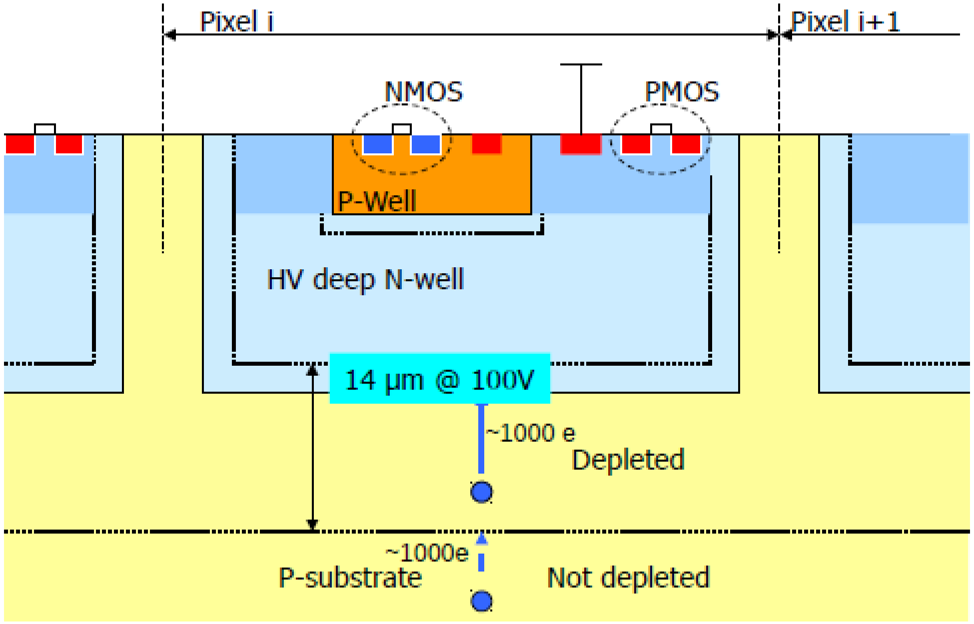
HV-CMOS: Deep depletion (10-200 μm) for speed and increased sensitivity (better S/N)





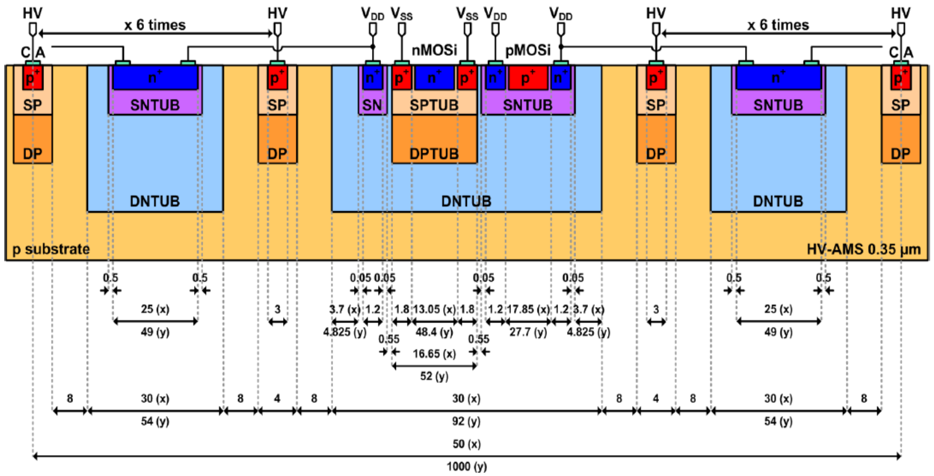
Signal collection by drift

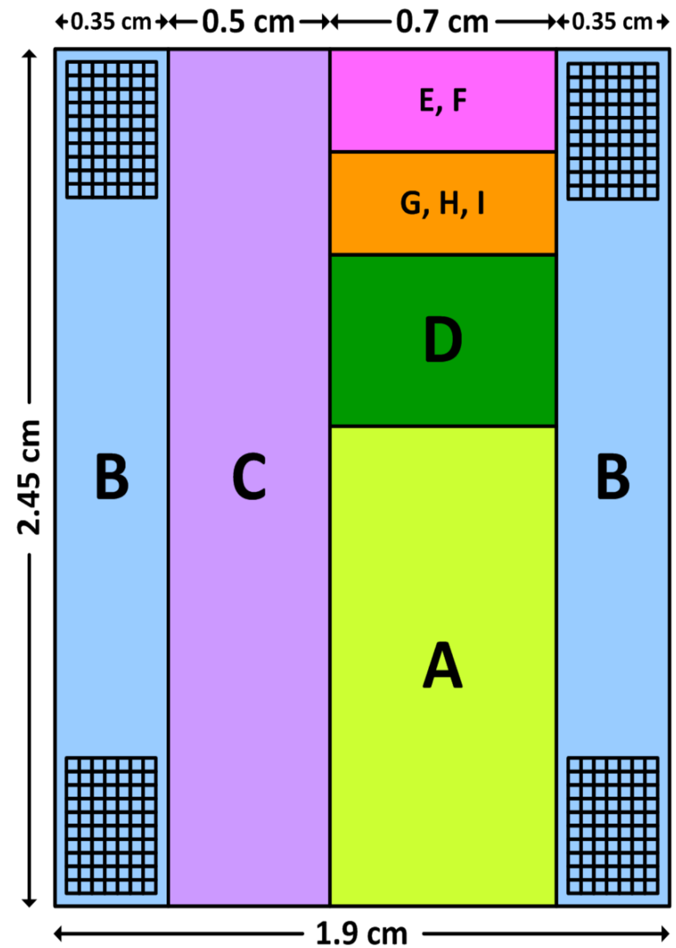
Motivation:
Radiation hardness at lower cost, tuneable resolution (geometry) with reduced number of channels, possibility of very thin devices, reduced mass in systems (variable channel size, signal height encoding) lower power dissipation.



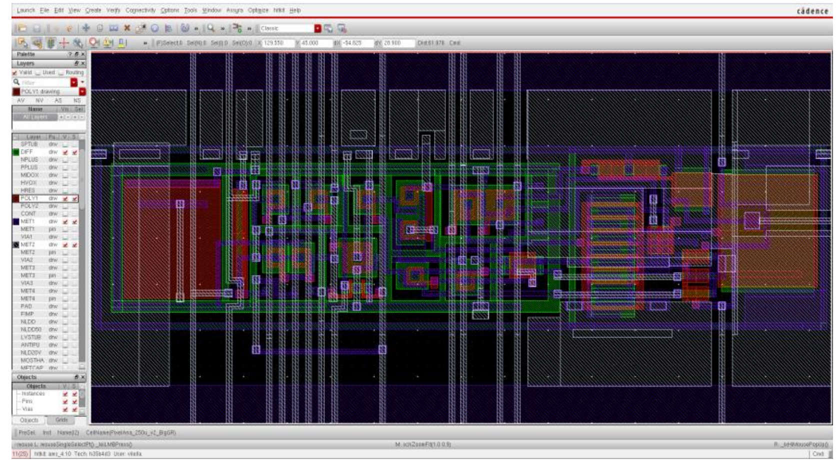
CMOS electronics placed inside the diode (inside the n-well)

Current submissions: pixel and strip (strixel) sizes

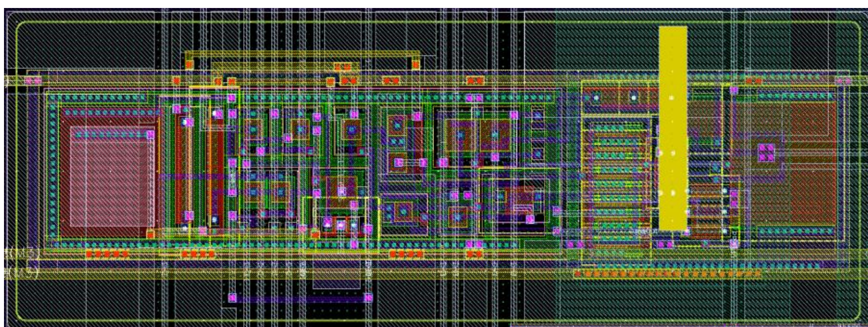


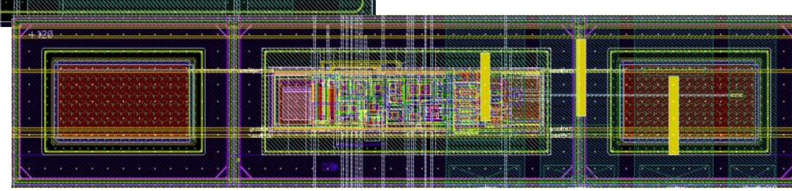


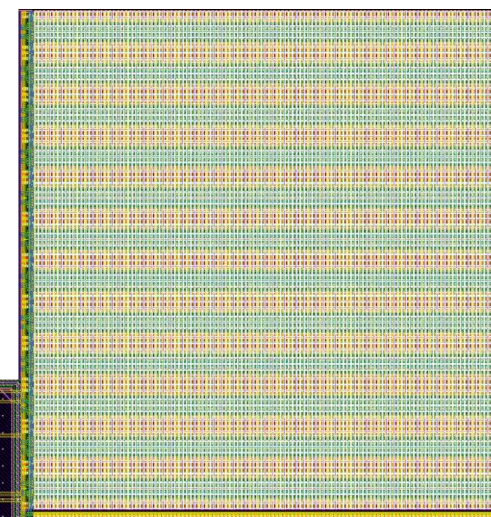
Current submissions: AMS .35 μm technology



Radiation hard design implemented. Several gain and speed variation. Readout with hybrid electronics (AC coupled to amplifier ASICs for pixels) or standalone solutions (HV-MAPS, monolithic active sensors). Design simulated. Optimisation for speed, noise reduction, full area coverage.







Low Mass Local Supports for the ATLAS Upgrade Inner Silicon Barrel Tracker, Forward Pixel and a concept idea for the pEDM Polarimeter

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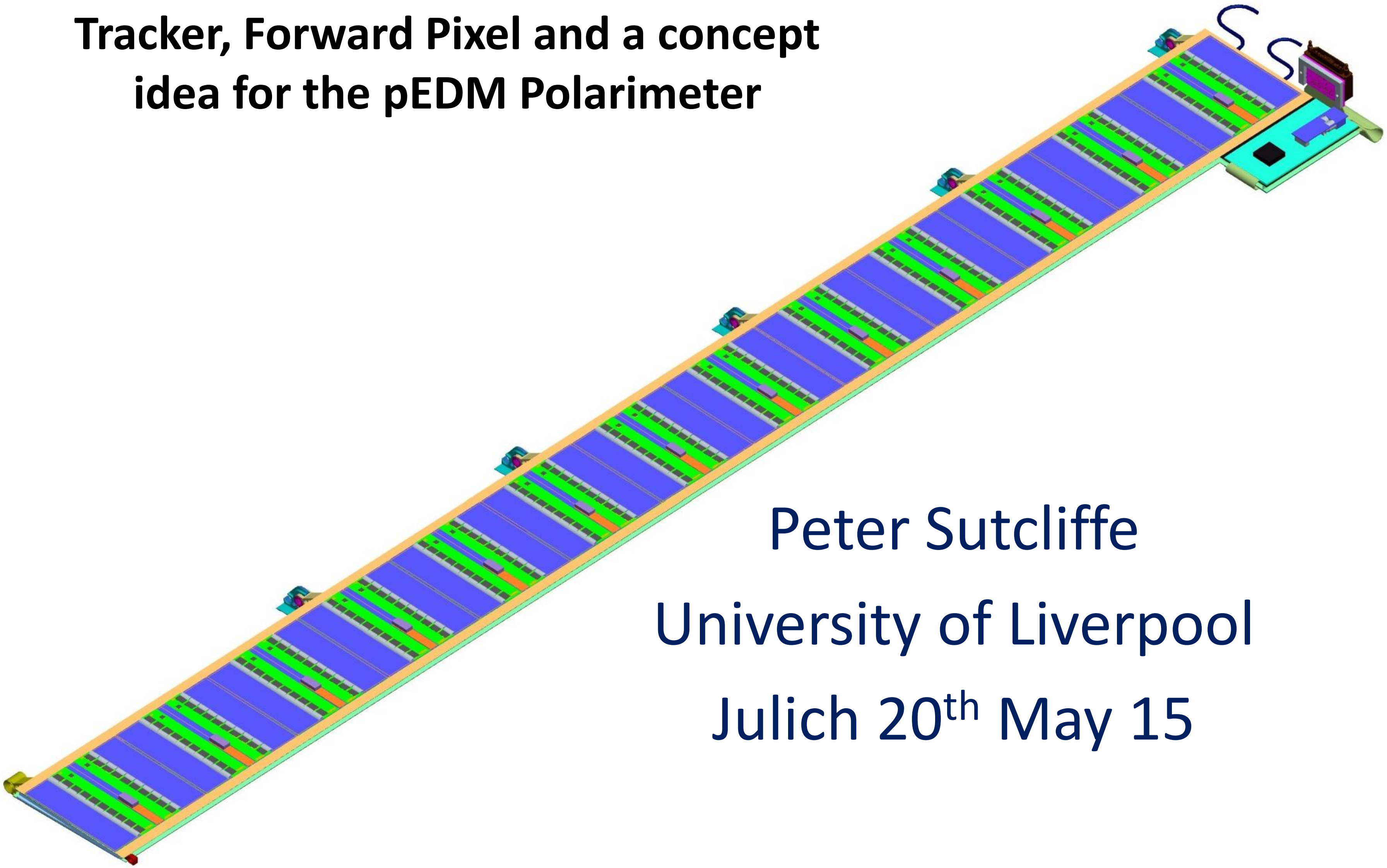
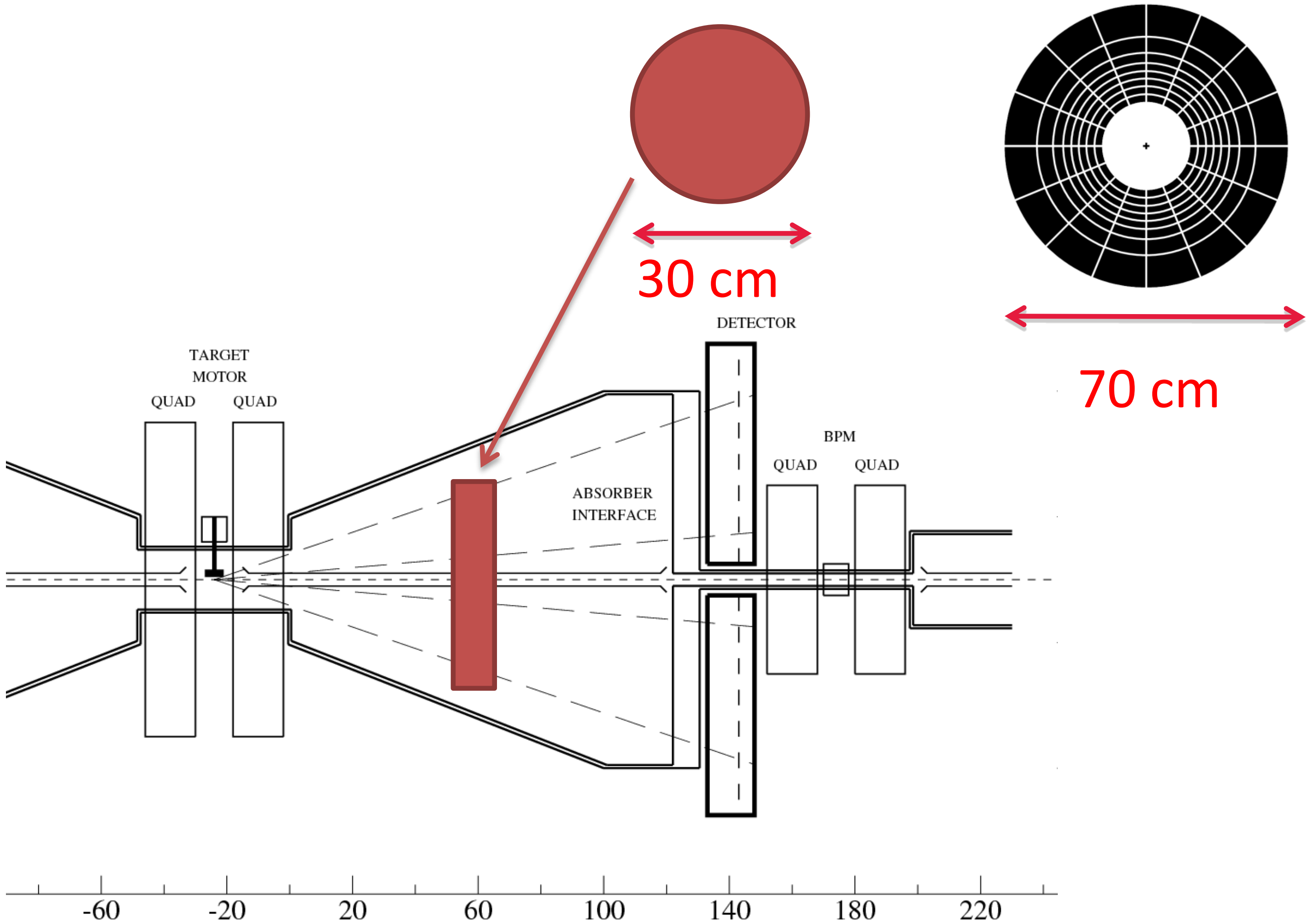


Peter Sutcliffe
University of Liverpool

Julich 20th May 15

Polarimeter Position:

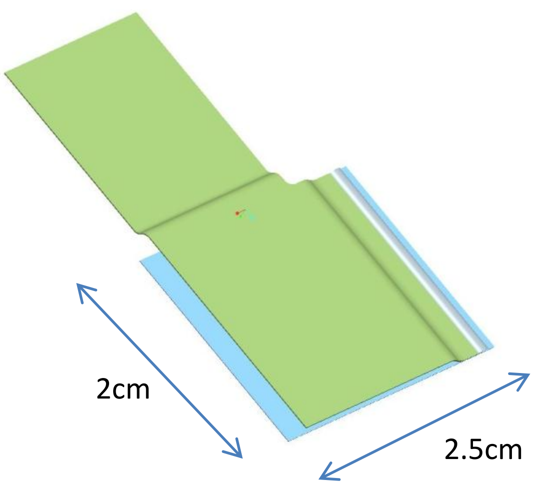
- could it be positioned close to the target?
- high resolution

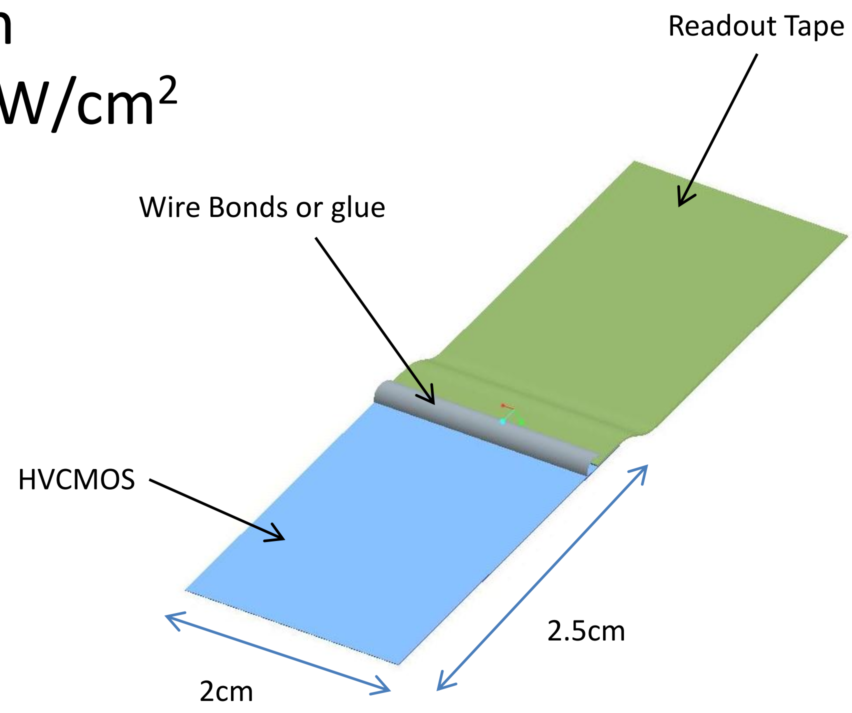


HVCMOS Sensor

Mechanical constraints

- HVCMOS MAPS (monolithic active pixel sensor) around 50um thick
- Sensor size around 2 x 2cm
- Power consumption < $10uW/cm^2$
- No connectors, all bonded construction





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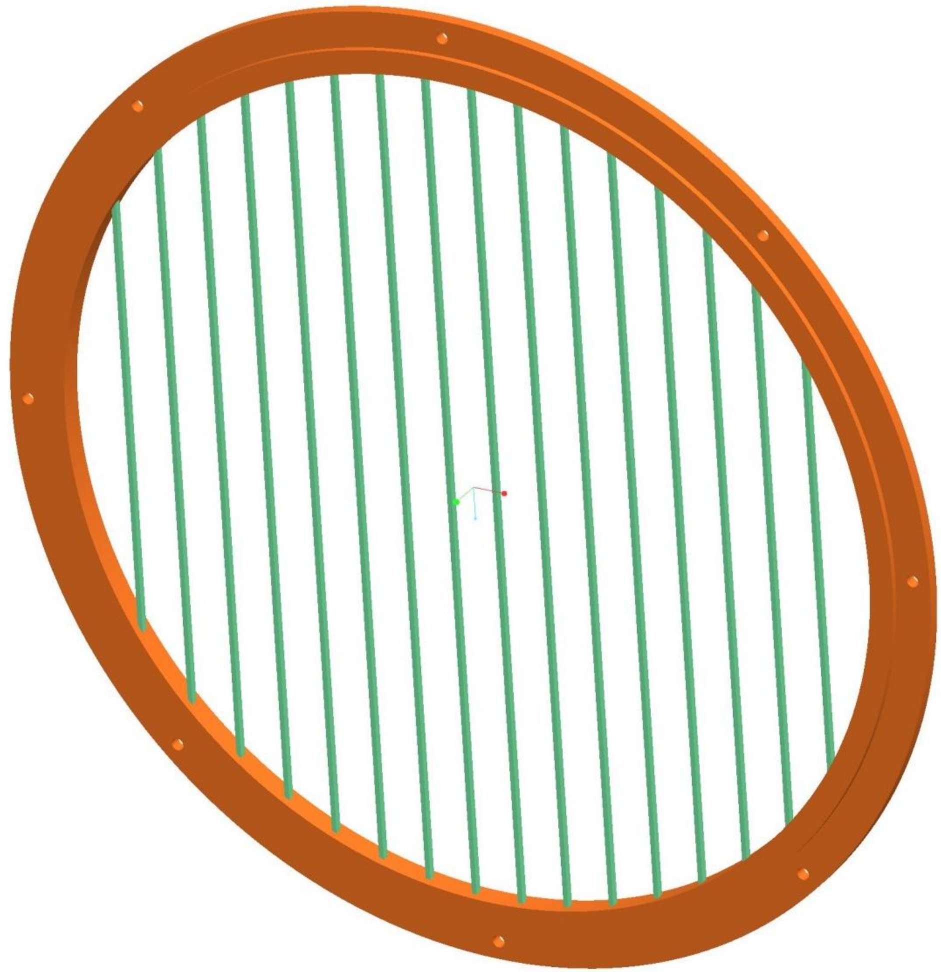
Thin wall carbon square tubes with a carbon outer support ring



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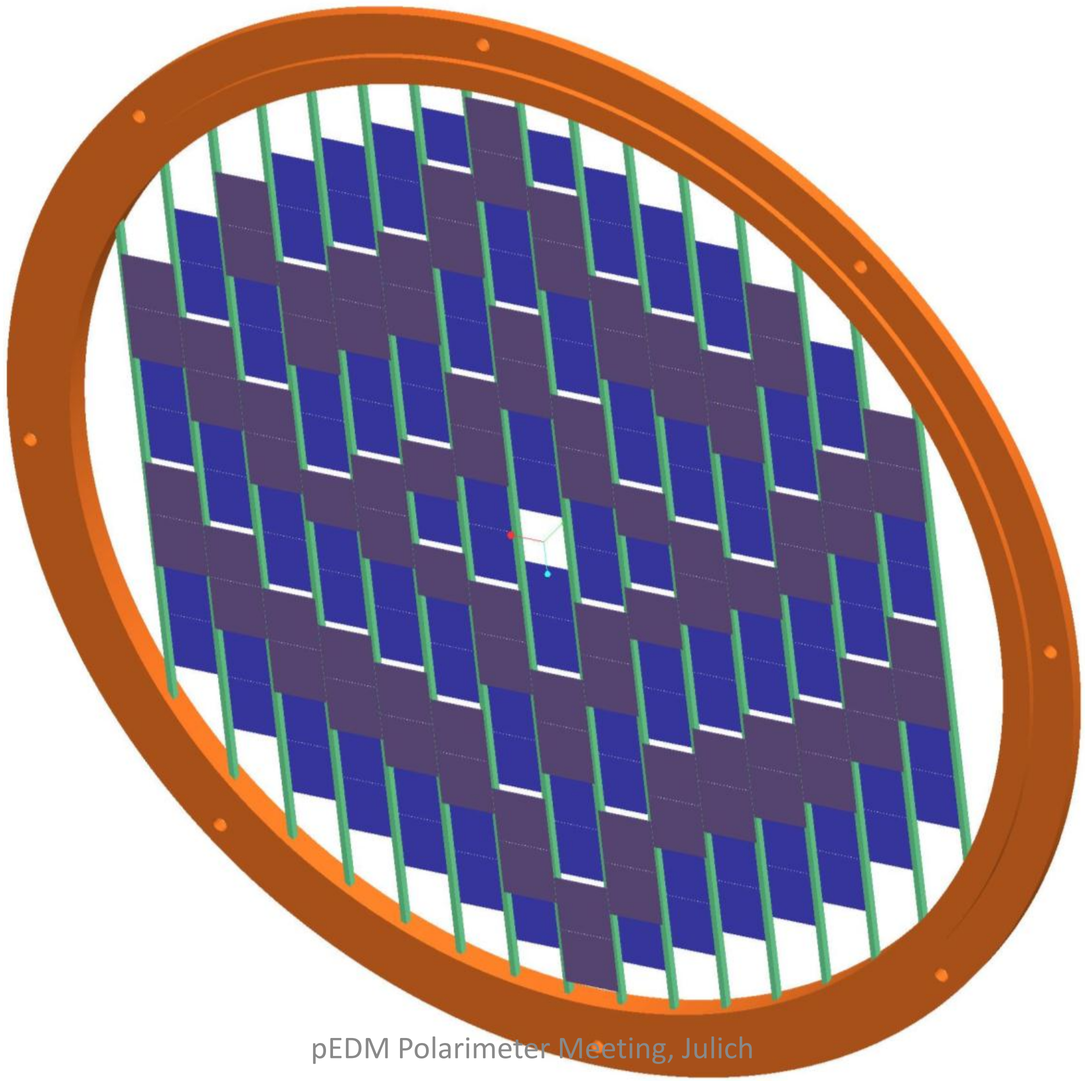
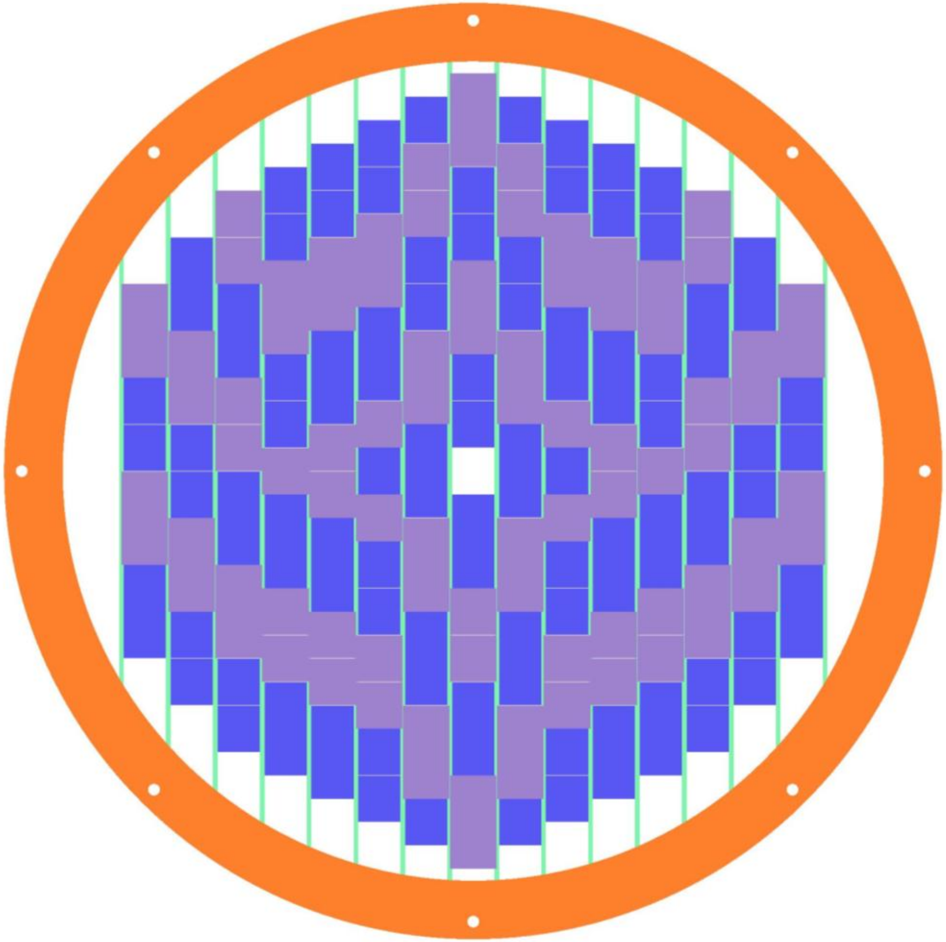
2x2cm x 50um thick

Mainly in pairs, but with some singles





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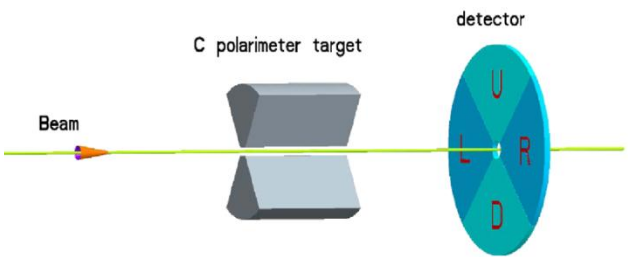

$$\varepsilon_H = \frac{L-R}{L+R}$$

carries EDM signal
increases slowly with time

$$\varepsilon_V = \frac{D-U}{D+U}$$

carries in-plane (g-2) precession signal

Section

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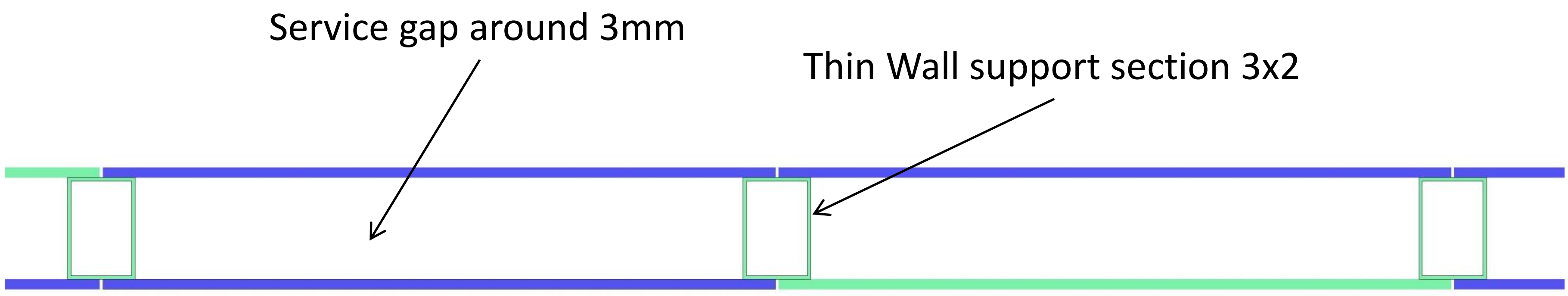
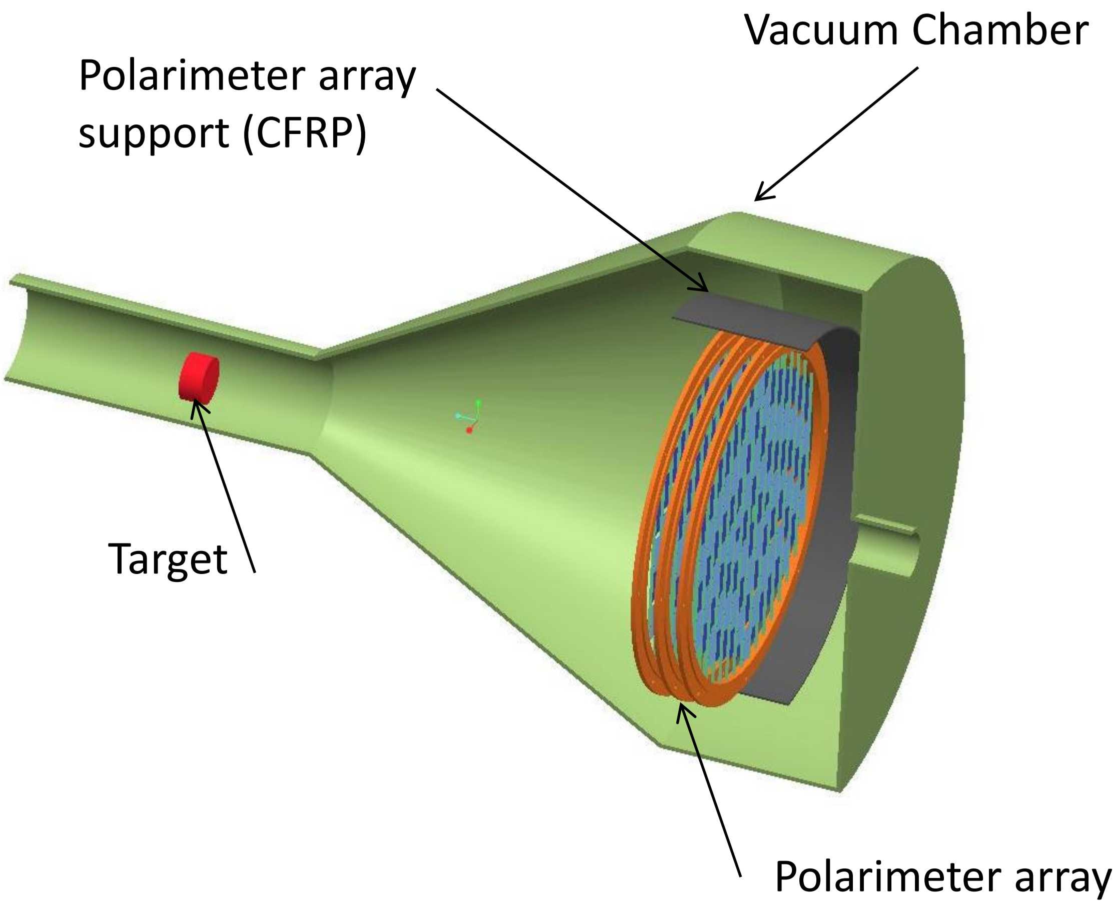
Thickness of sensors has been exaggerated



Polarimeter Assembly



Proposed Resources

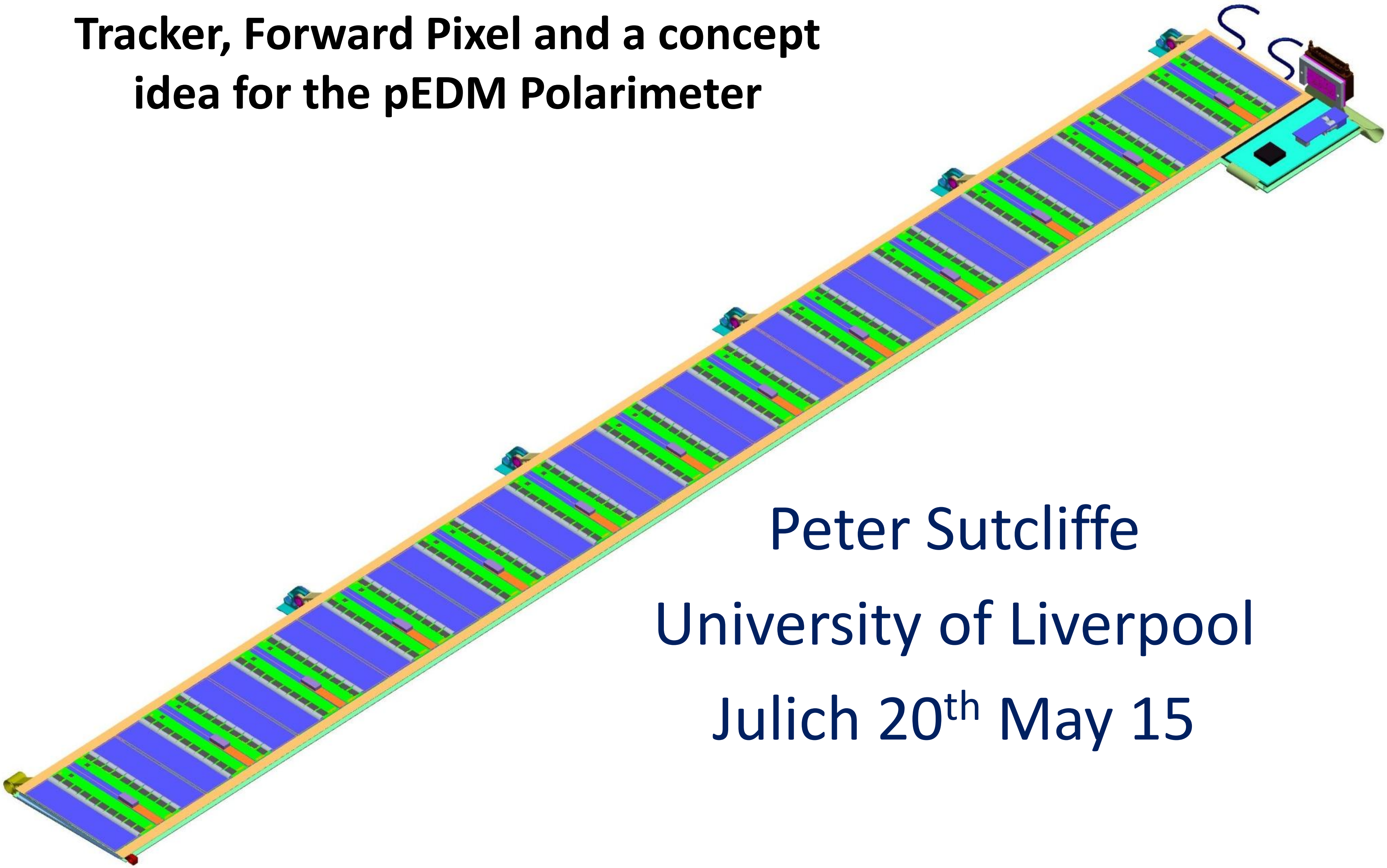
- Under discussion here….

UK Groups we work closely with…

- Cockcroft Institute
  - Lancaster
- g-2 groups
  - UCL (DAQ)
  - Oxford

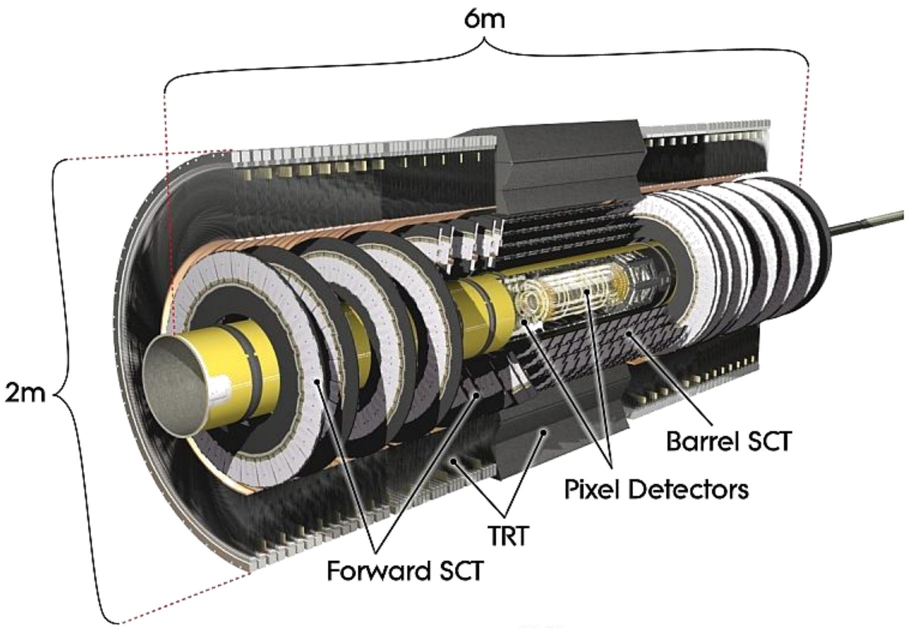
Thanks for invitation …

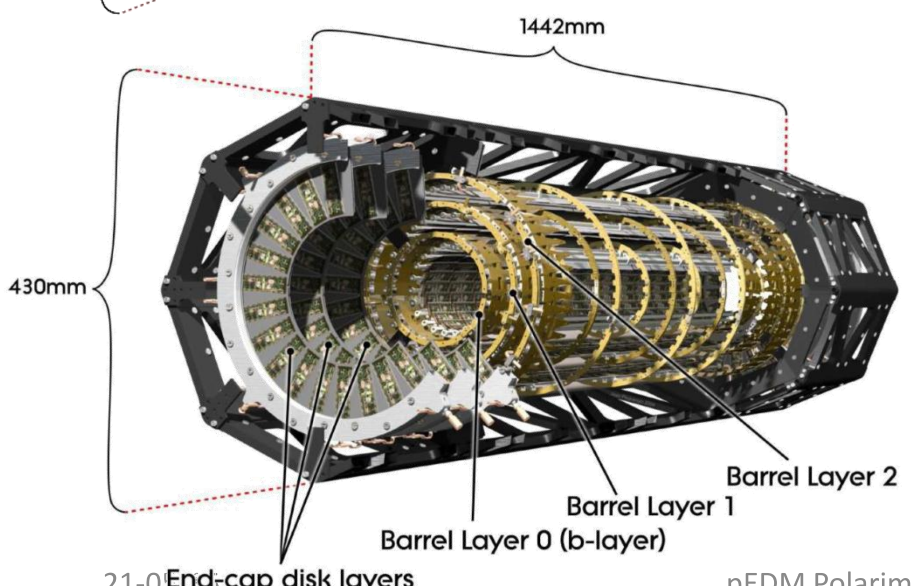
Low Mass Local Supports for the ATLAS Upgrade Inner Silicon Barrel Tracker, Forward Pixel and a concept idea for the pEDM Polarimeter



Peter Sutcliffe
University of Liverpool
Julich 20th May 15

Current ATLAS Tracking



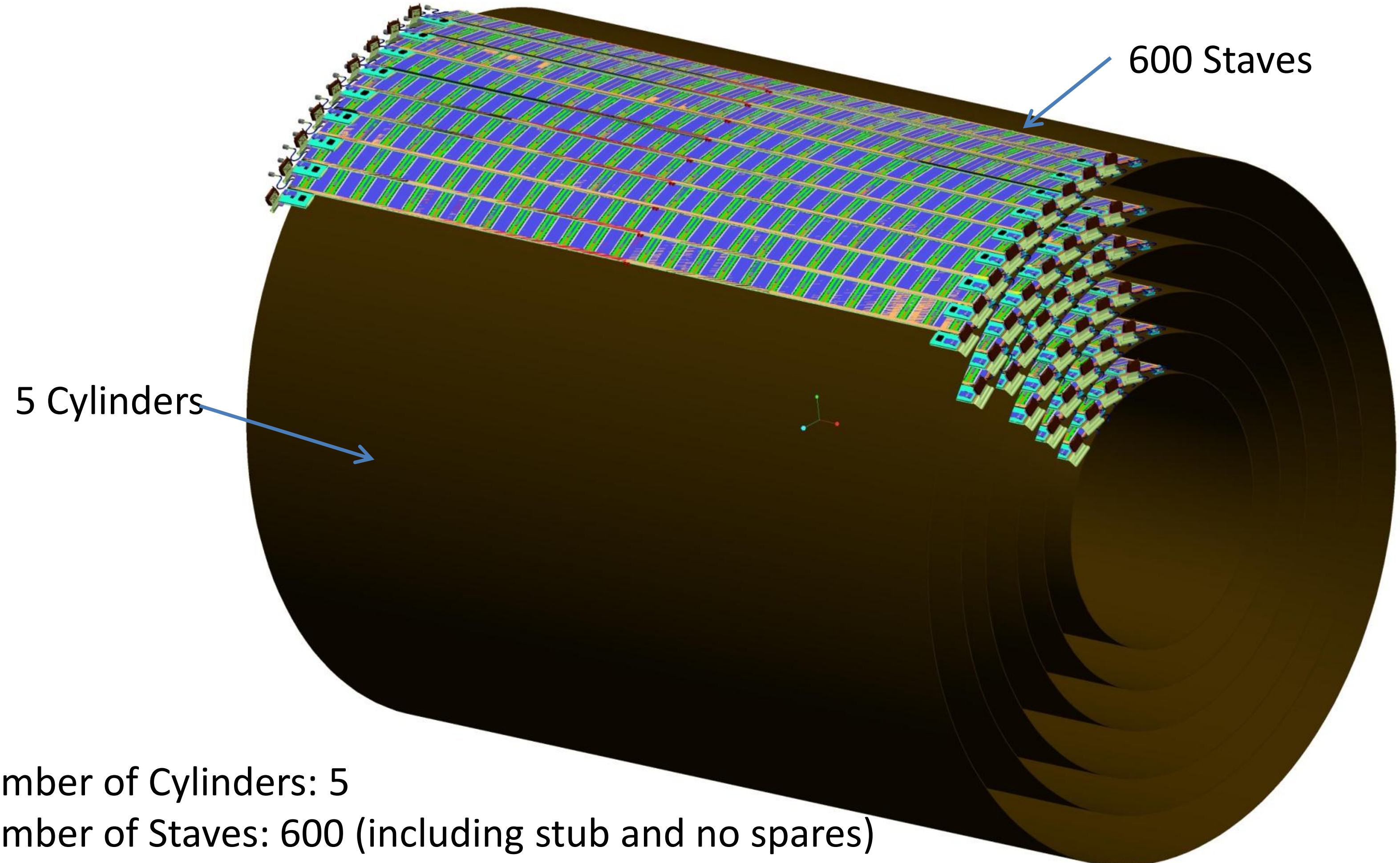


- SCT
  - **61m²** of silicon with 6.2 million readout channels
  - **4088** silicon modules arranged to form 4 Barrels and 18 Disks (9 each end)
  - Barrels : 2112 modules (1 type) giving coverage $|\eta| < 1.1$ to 1.4
  - Endcaps : 1976 modules (4 types) with coverage 1.1 to $1.4 < |\eta| < 2.5$
  - $30cm < R < 52cm$
  - Space point resolution r ~16μm / Z~580μm
- Pixels
  - **1744** Pixel Modules on three barrel layers and 2 x 3 discs covering **1.7m²**
  - 80M readout channels

ATLAS Upgrade
Outline of Local Supports

- The local support, or stave is a fully integrated structure.
  – i.e. Stave is a glued assembly, no screws
- The stave is manufactured from low mass, polymeric materials.
- Staves are mounted onto support cylinders using locking points.

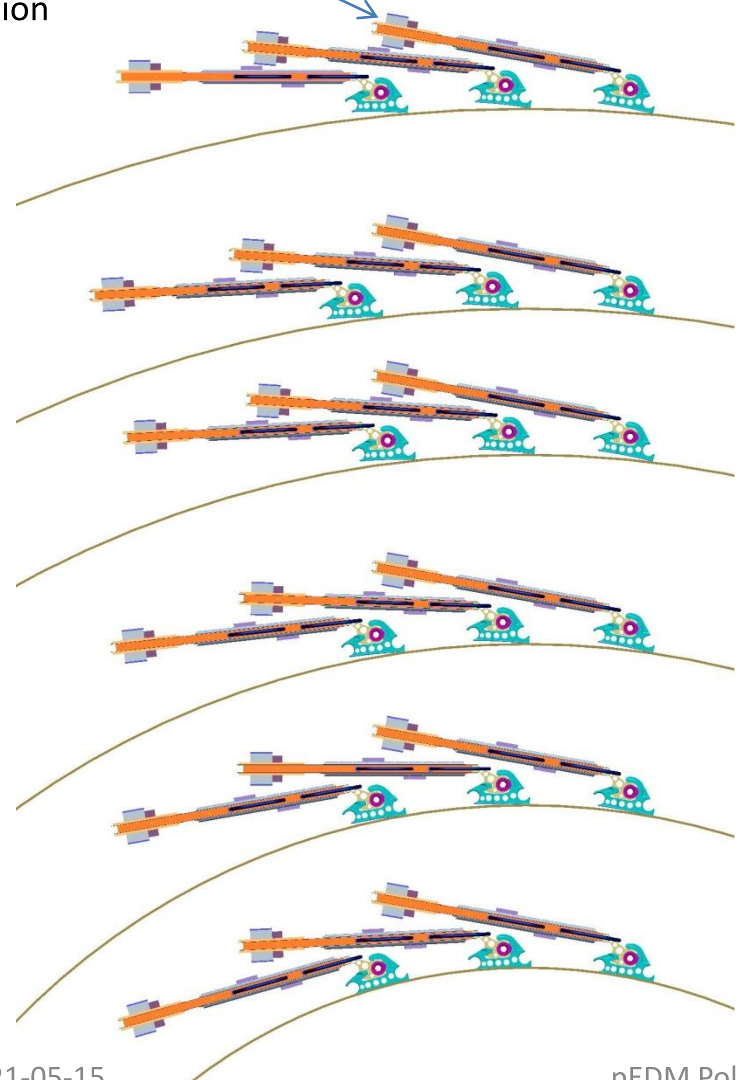
Cylinders and Staves



- Total Number of Cylinders: 5
- Total Number of Staves: 600 (including stub and no spares)
  - currently 8 different stave flavours
- Total Number of Modules: 12784
  - 13 Modules per side of stave = 26 modules per stave
  - 2 Modules per side of stave for a stub

Stave positions on cylinders angle and clearances *

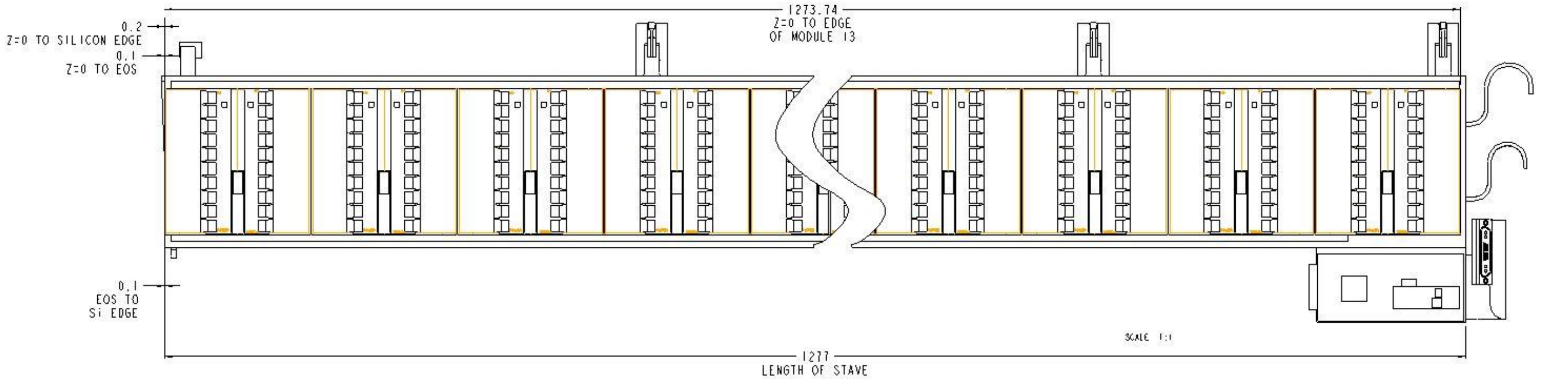
Opto package will change to a slimmer version



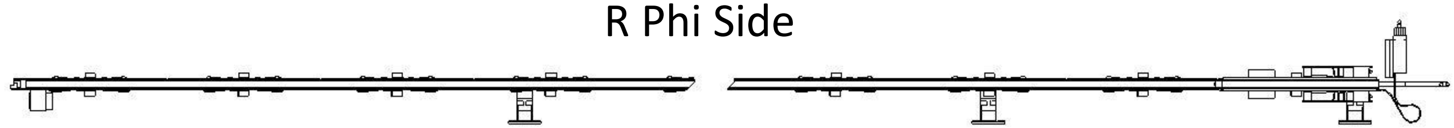
Layer	No of Staves in 360°	Radii to Centre of Stave
0	28	405
1	36	519
2	44	631
3	56	762
4 (Stub)	64	862
5	72	1000

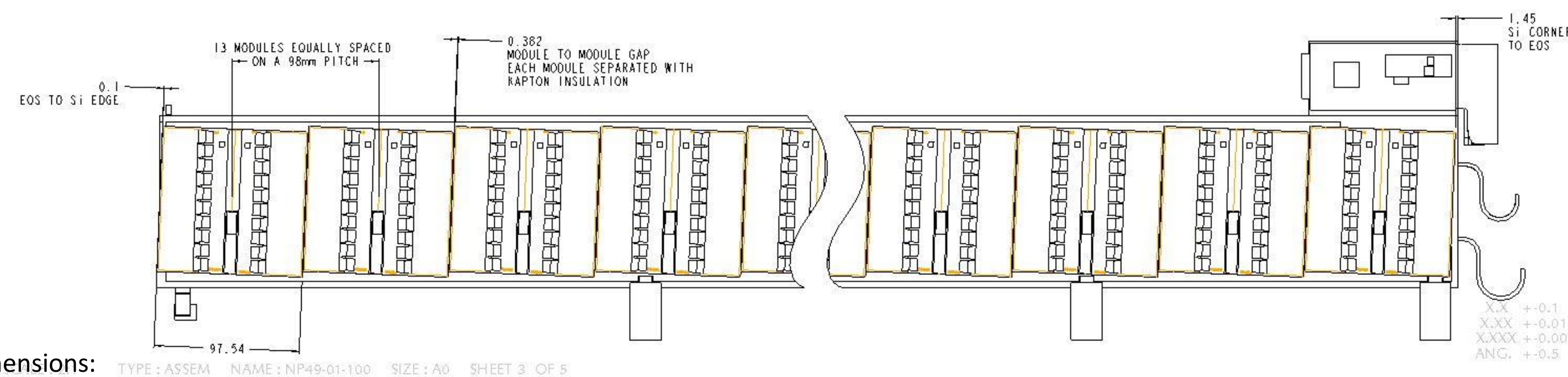
* Minimum clearance between staves to be around 2mm with a 10° tilt angle

Stave Geometry



R Phi Side



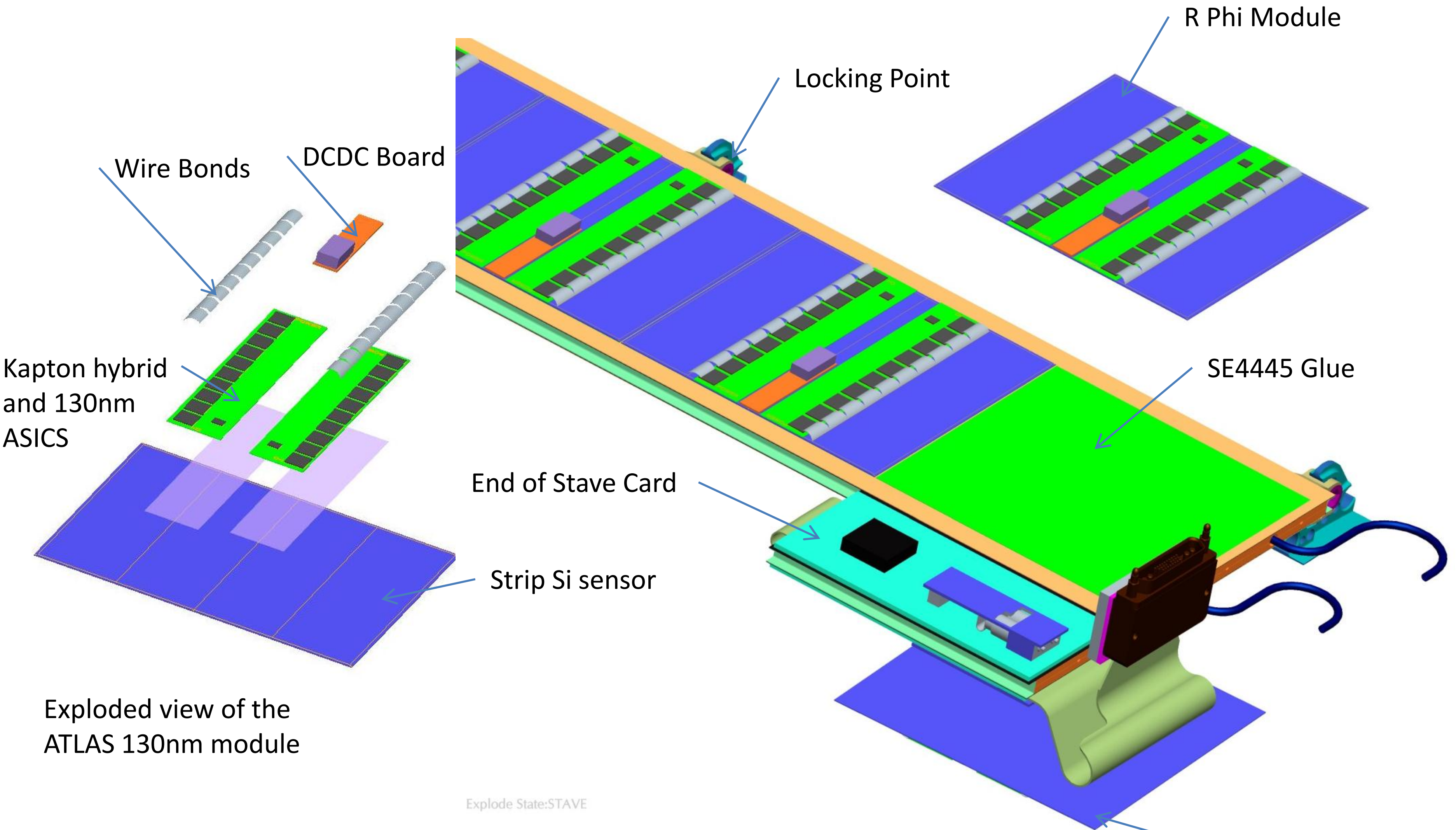


Critical Dimensions:

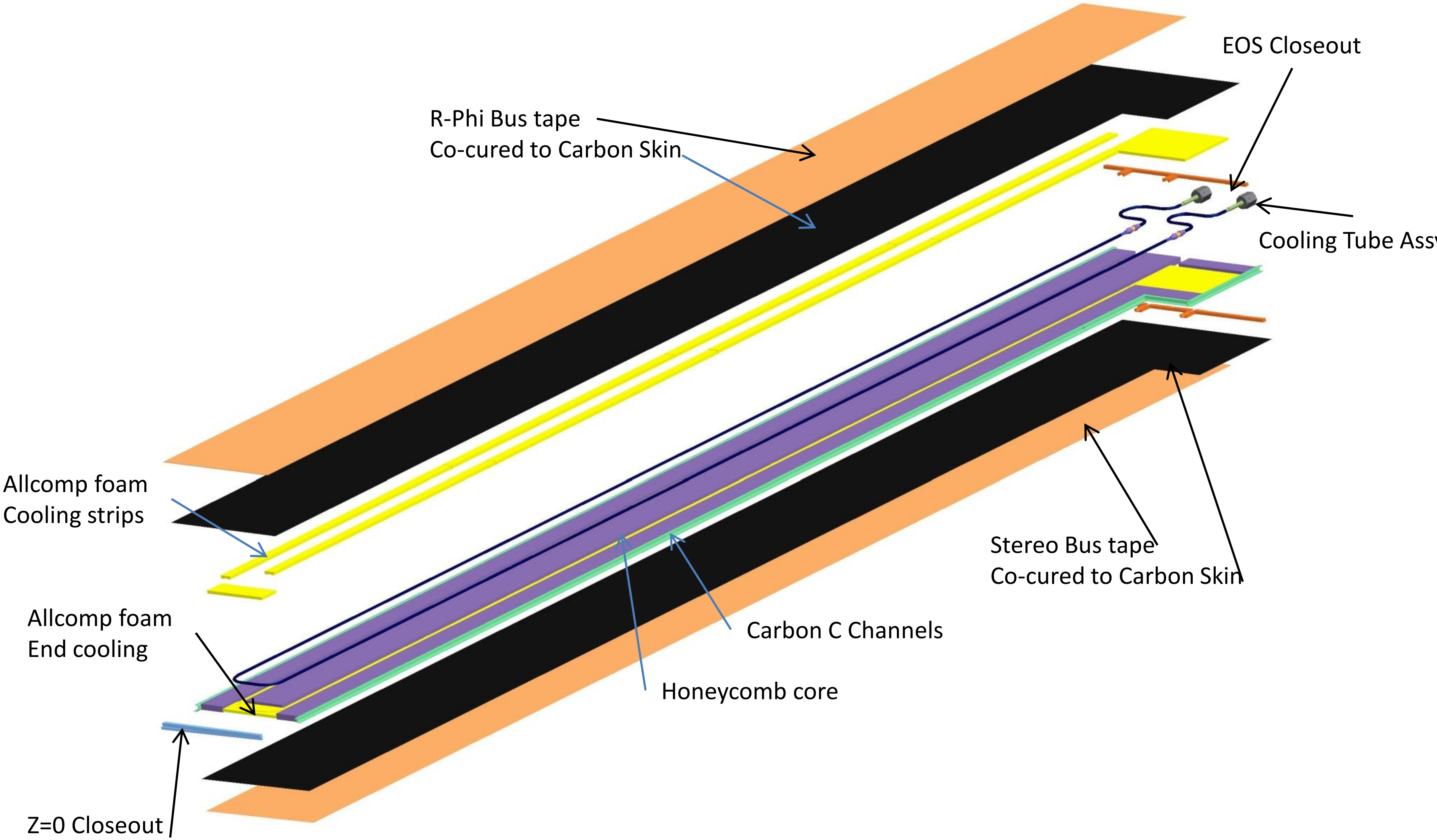
- Overall Length 1277
- Width 115
- EOS at Z=0 to Silicon Edge 0.1mm
- Module to Module Gap 0.46mm
- Pitch of Modules 98mm

Stereo Side

Modules, End of Stave Cards and Locking Points



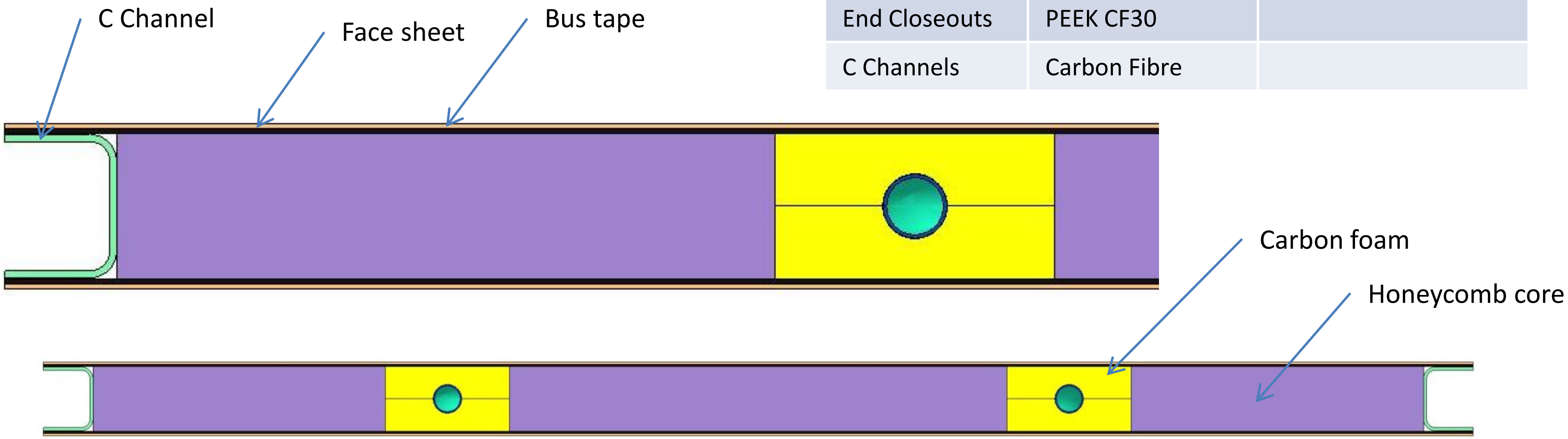
Stave Detail



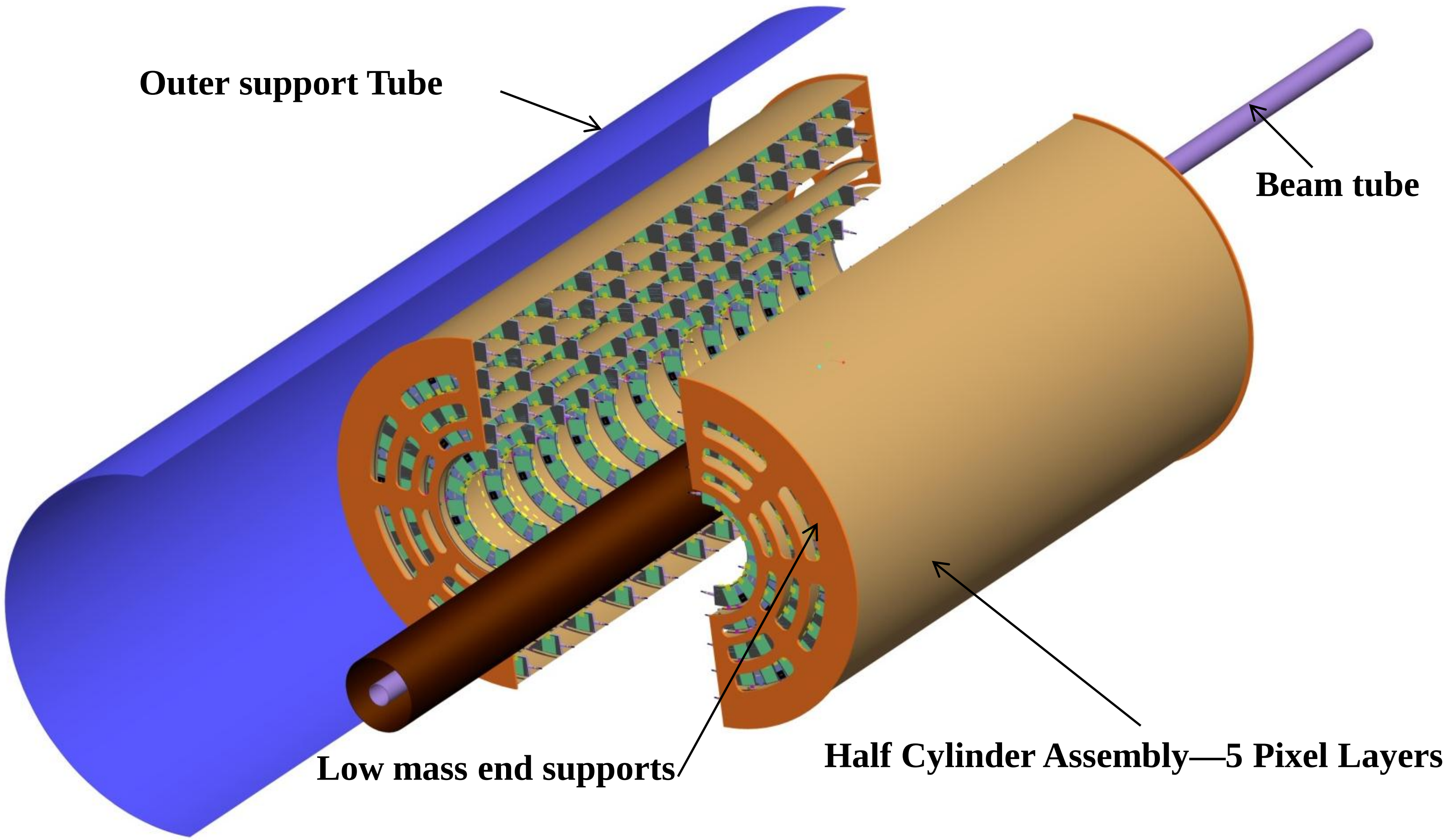
Stave Construction and Materials

- Stave is manufactured from 2 UD Carbon and kapton face sheets with a core manufactured from Ultracor Honeycomb and Allcomp Foam

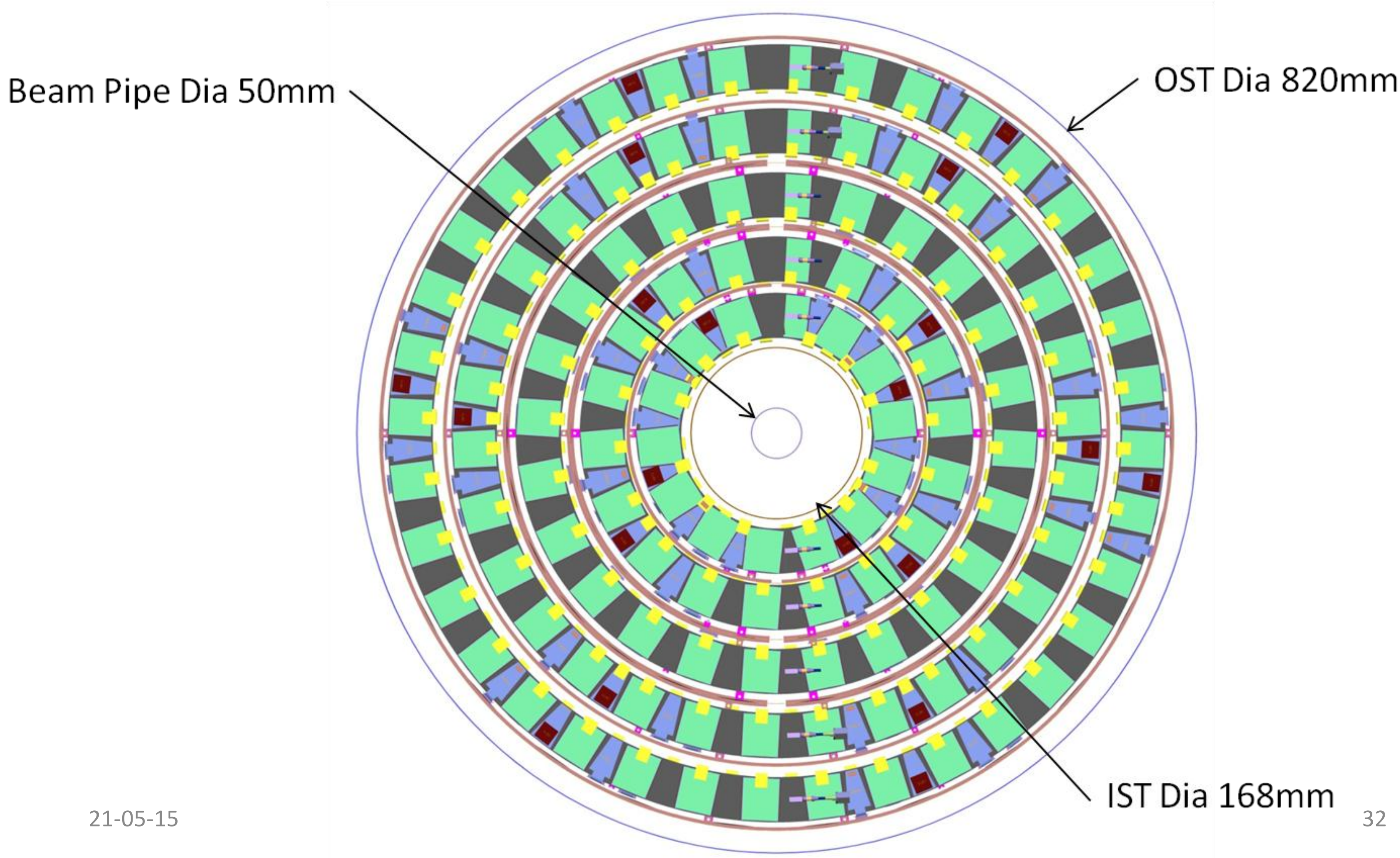
Component	Material	Remarks
Carbon Face sheet	Tencate K13C2U 45g/m^2 EX1515 Resin	3 layers 90/0/90 total thickness 0.15mm Co-cured onto a kapton bus, thickness 0.2mm
Honeycomb Core	Ultracor Carbon Honeycomb UCF-126-3/8-2.0	Final thickness 5.2mm
Carbon Foam Core	Allcomp K9	Final thickness 5.2mm
Cooling tube	Titanium CP2	2.275 x 0.125 wall
End Closeouts	PEEK CF30	
C Channels	Carbon Fibre	



ATLAS Forward Pixel concept

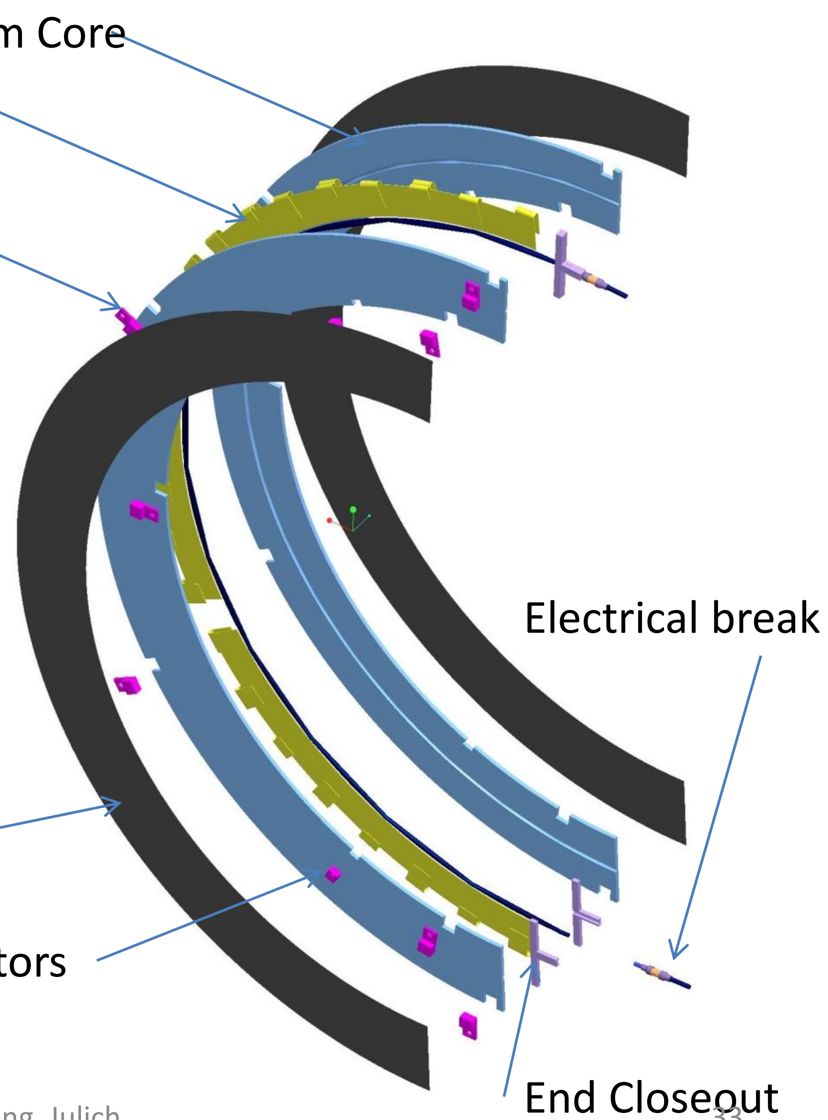


Forward Pixel Array



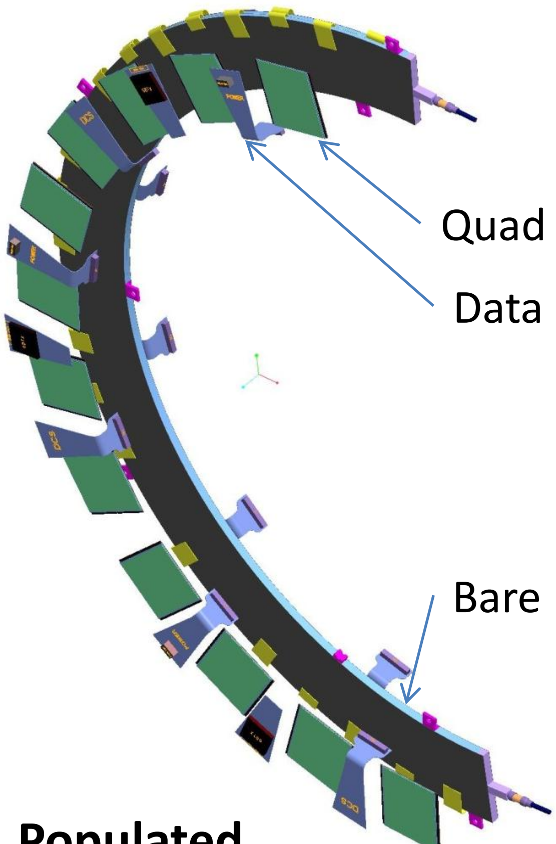
Pixel Half Ring Structure

- *Foam Core - Low mass carbon foam for heat conduction*
- *Carbon Skin - High Modulus Low mass skins, typically 0.15mm thick for 3 layers*
- *Electrical Break - for ensuring Grounding and Shielding Specifications are met*
- *Bus Tape - Fully integrated into the structure*
- *Cooling Tube - 2.275mm thin wall tube, low mass and low CTE Titanium*

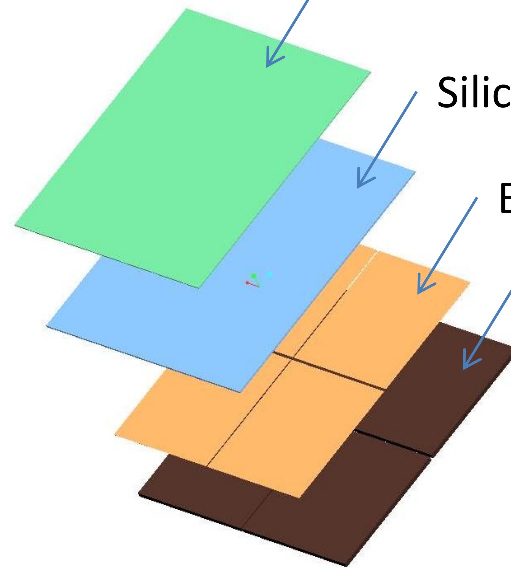


Bare half ring

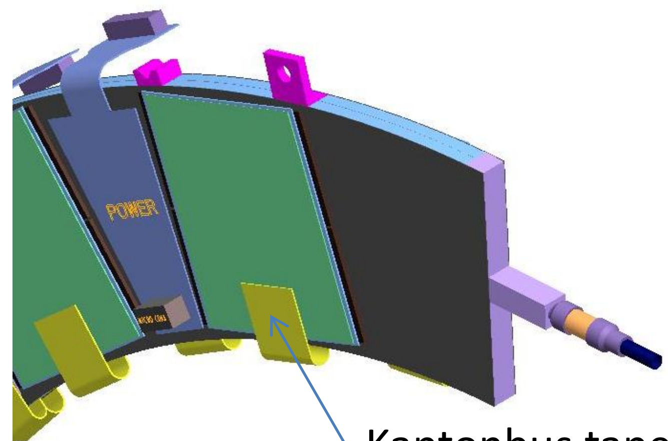
Populated pixel half ring



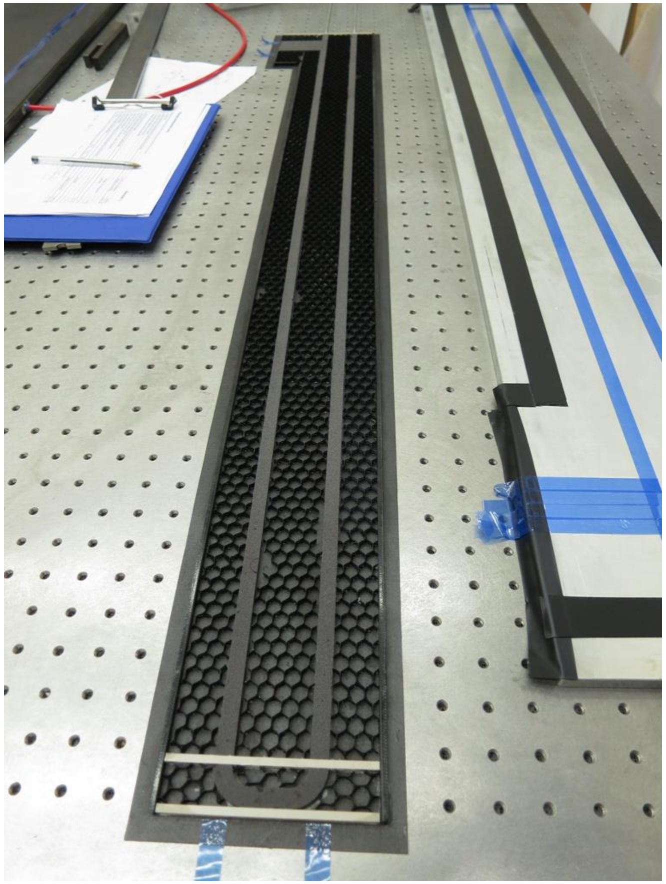
Populated half ring



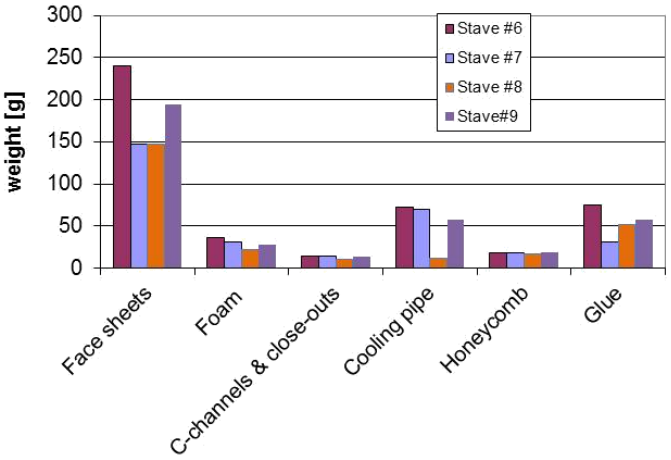
Quad Pixel Module

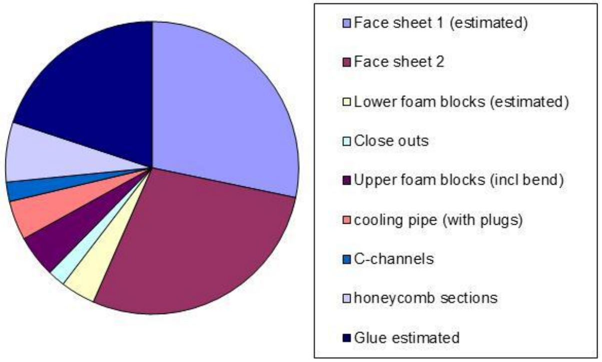


Plank #9 manufacture



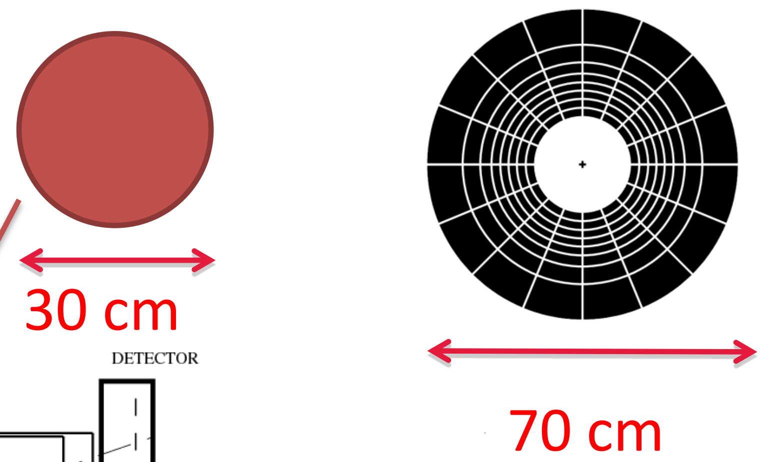
- Total weight of stave 330.37g

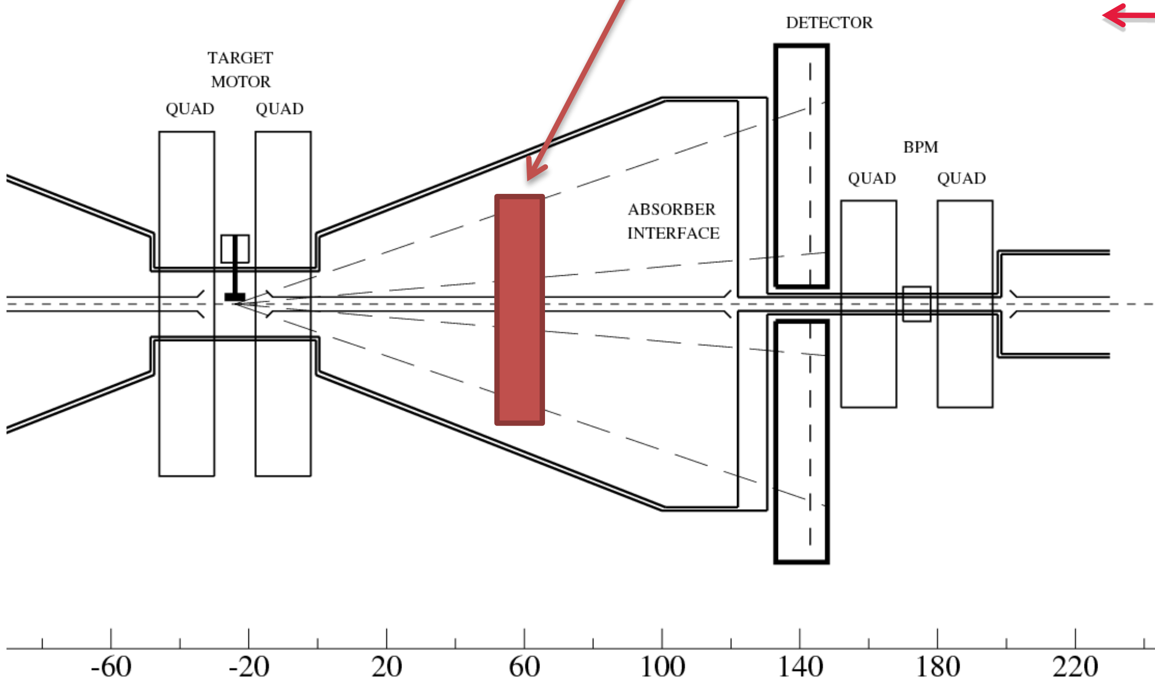




Polarimeter Position:

- It is thought that with a high resolution HVCMOS chip the detector can be positioned closer to the target





HVCMOS Sensor

Mechanical constraints

- HVCMOS MAPS (monolithic active pixel sensor) around 50um thick
- Sensor size around 2 x 2cm
- Power consumption < $10uW/cm^2$
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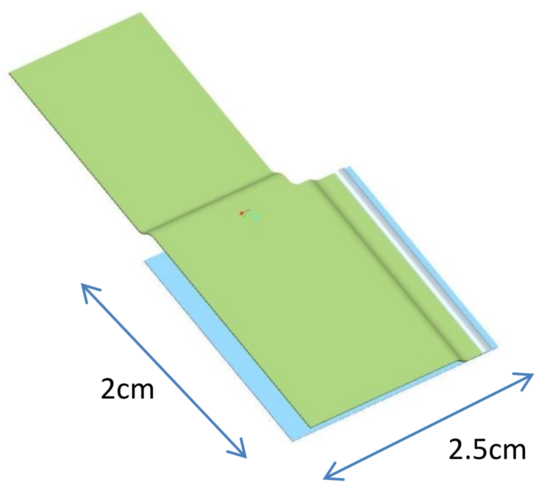

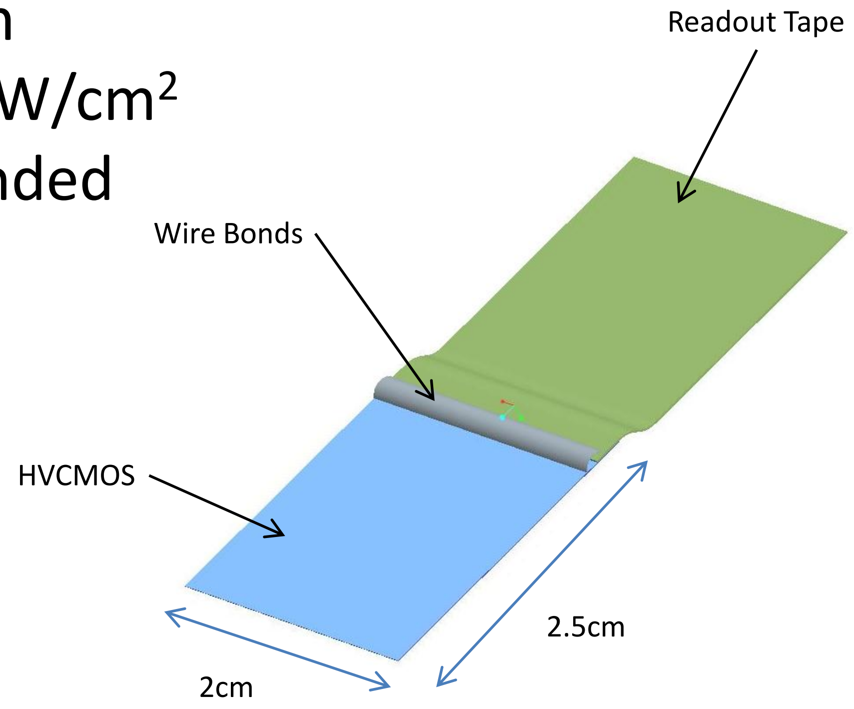

Support Structure idea

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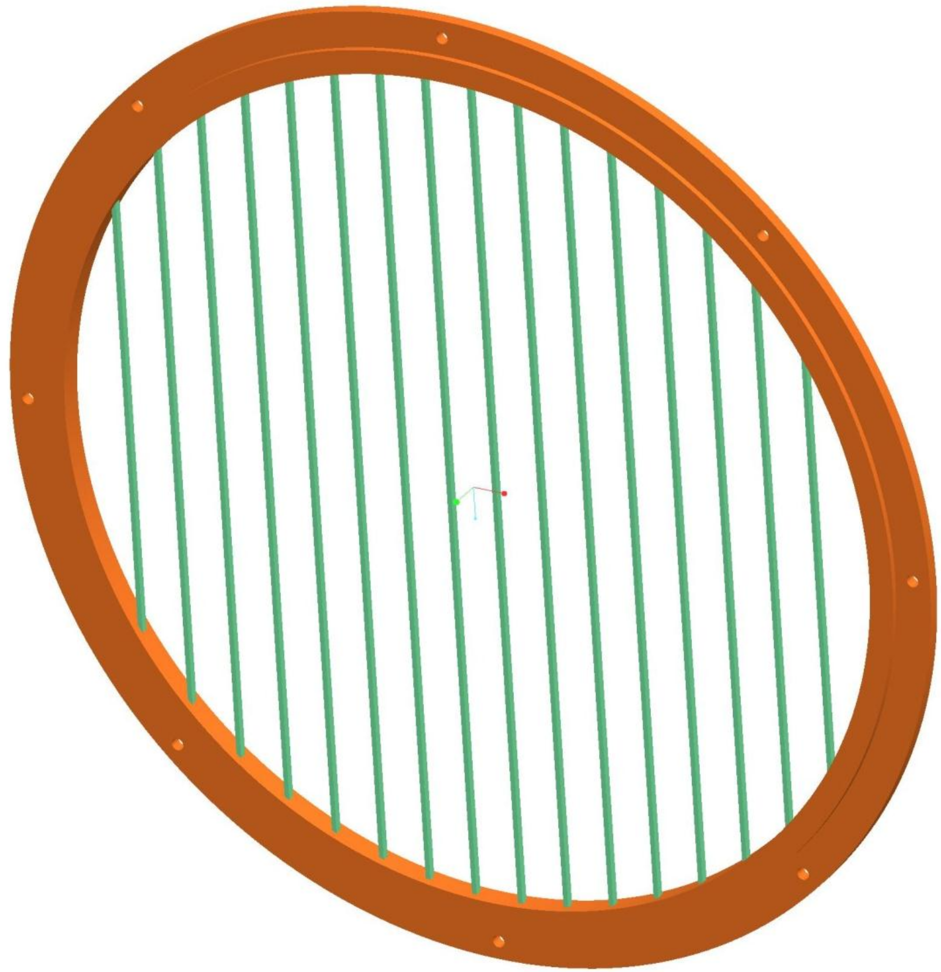

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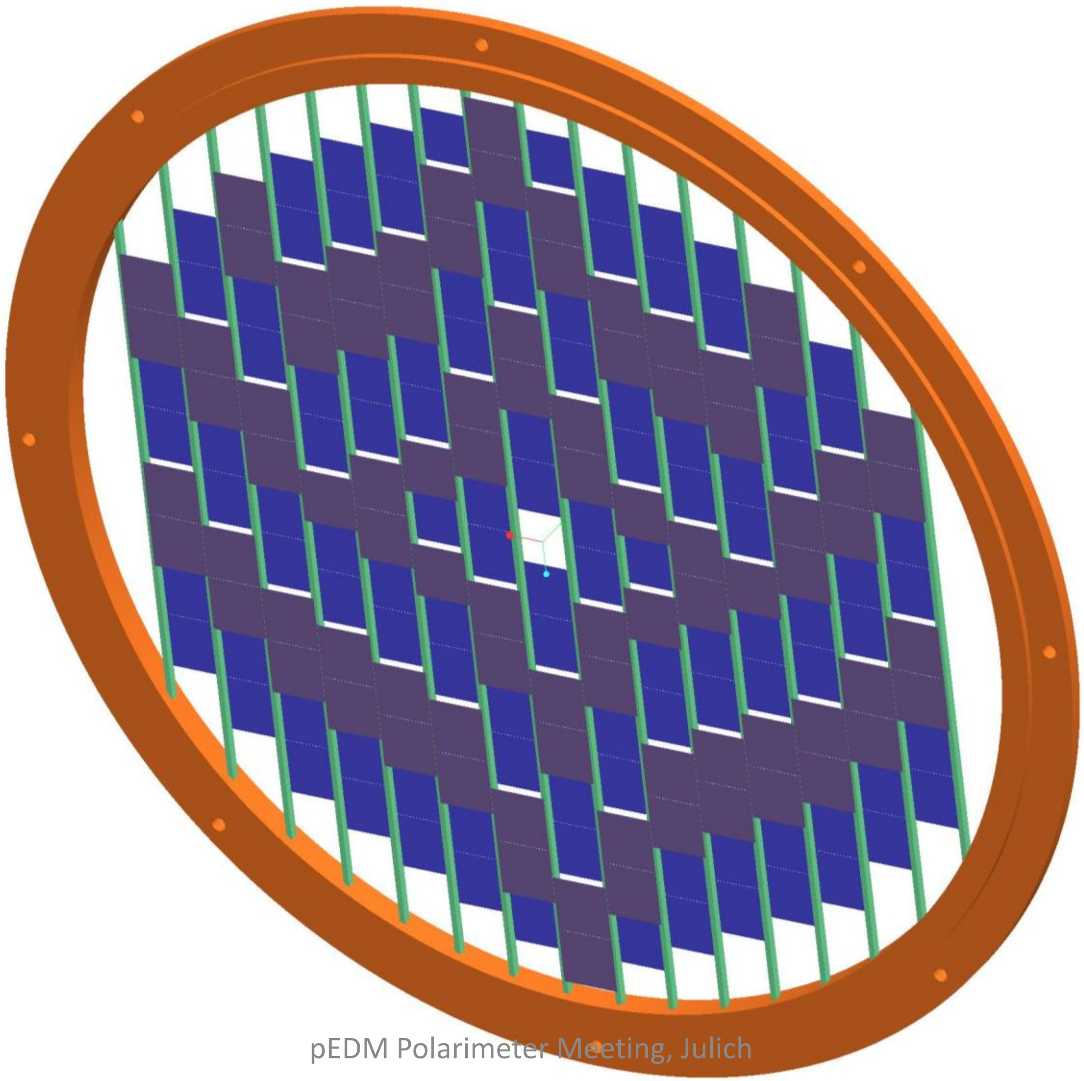

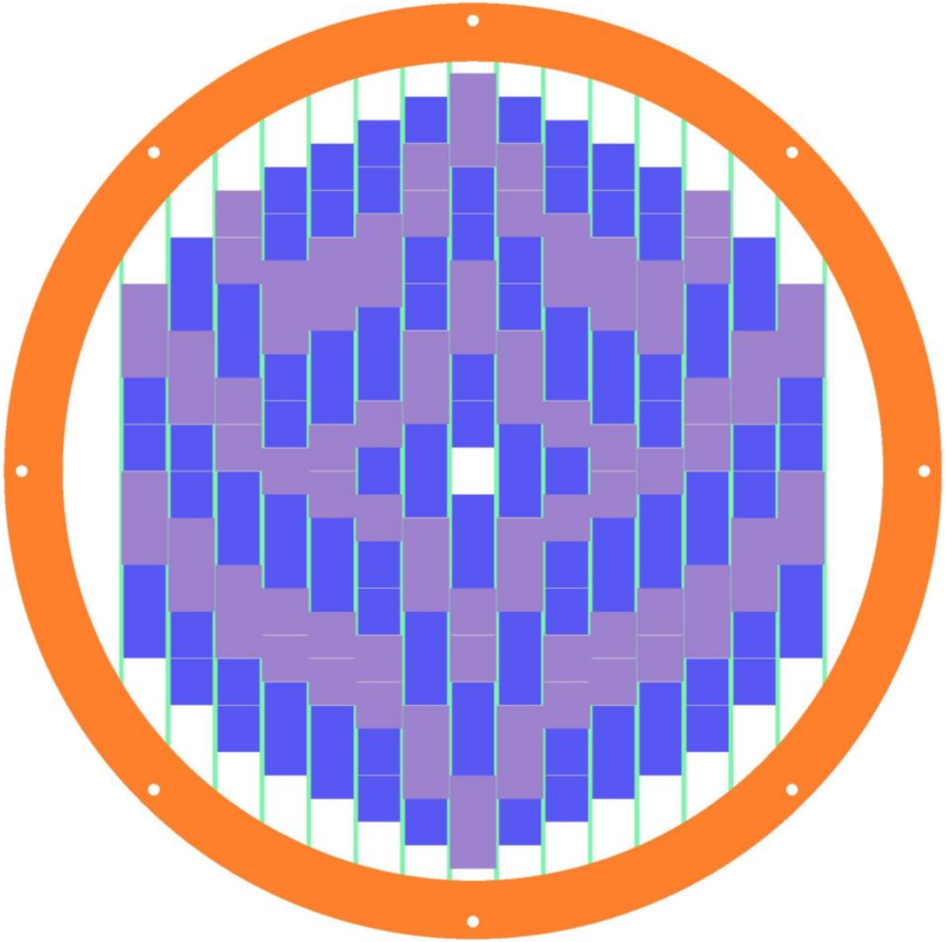

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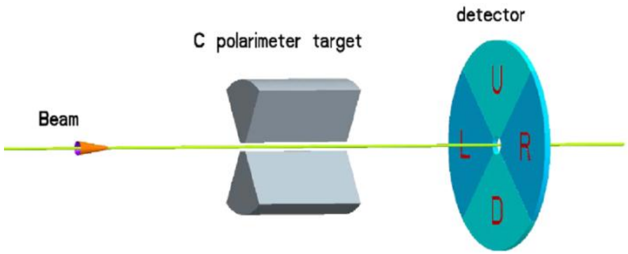

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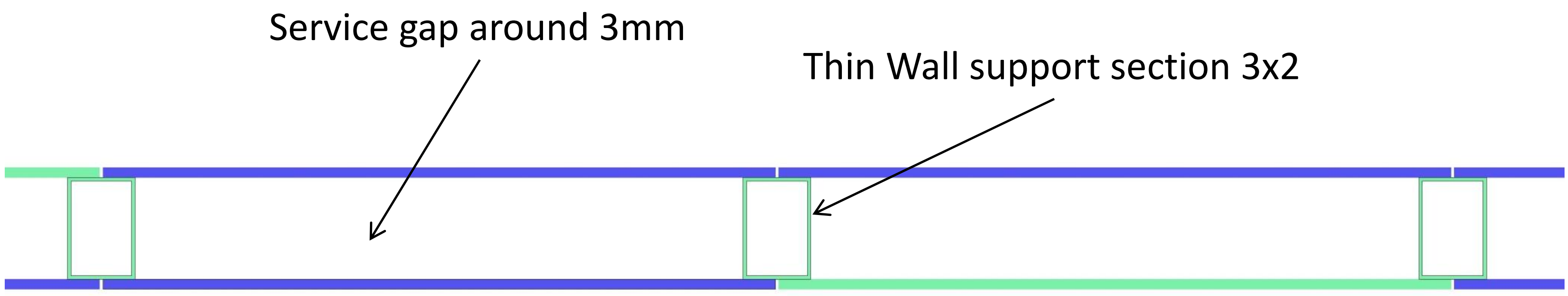
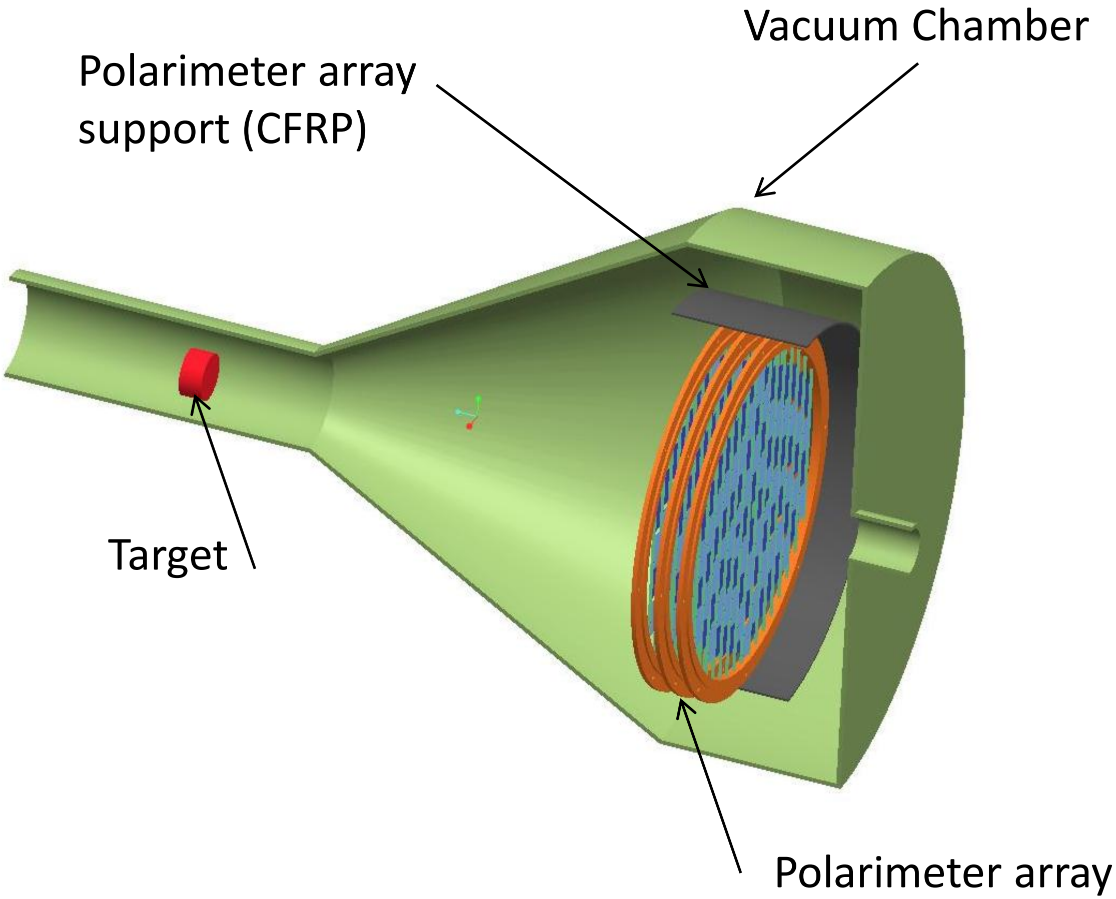


Polarimeter Assembly



Summary and Conclusions
(*Low mass structures.....)*

- The fully integrated structure reduces potential failure points, such as not having screwed HVCOMOS modules and replacing connectors with wire bonds
- Around 10 prototype full size staves and mechanical, thermal and electrical prototypes have been made and have proved to be mechanically and thermally stable.
- Throughout the prototype stages, improvements have been made and major changes such as the change from 250nm chip to 130nm.
- We are now at the stage of producing a 'final' design, which can be transferred to a full scale production of 500 staves of 8 different flavours.
- All the strip stave work can be readily transferred to other low mass structures.

Detector Assembly at Liverpool

May 2015

Facilities for Detector Assembly at Liverpool

- Engineering Design Team
  - Engineering support (mechanical & electronic) for detector development
- Physics Mechanical Workshop
  - Precision manufacture in metals & plastics using conventional machine tools (milling & lathe) and EDM
- Advanced Materials Laboratory
  - Development and manufacture of carbon-fibre composite structures
- Liverpool Semi-conductor Detector Centre
  - Precision assembly and interconnect technology for detector components and sub-system macro-assembly

From World-leading R&D to the Delivery of Full-scale Detector Sub-systems

- Co-location of all facilities makes effective use of manpower during research and development phases.
  - Academic, research & technical staff all participate equally in the development process and with minimal ‘overhead’
- Migration from R&D to production using same staff and equipment as in the development phase
  - Simpler project management, more effective planning and project monitoring
  - Scale of facilities at Liverpool allows even quite large projects to be handled completely in-house whilst maintaining other lines of R&D

Engineering Design Team

- Team of mechanical and electrical engineers allocated to projects to ensure complete coverage of all aspects of overall system design
  - Senior engineers expected to take major technical roles in project management structures both locally and internationally

- Capabilities
  - Mechanical:
    - 3D geometric modelling using ProEngineer
    - Structural and Thermal FEA using ANSYS (including Composite Pre/post)
  - Electrical
    - ASIC design
    - Copper/kapton hybrid flex circuit and PCB design
    - FPGA and DAQ system development

Physics Mechanical Workshop

- Aim is to support the development and assembly of precision tracking detector systems through the manufacture of high-precision tooling and parts
- Staff: 5 fully-trained staff to ‘toolmaker’ level
  - Effective apprentice training programme to develop young machinists
- Capabilities
  - 3, 4 and 5 axis CNC milling
  - Manual & CNC turning
  - Wire EDM
  - Plastics (laser cutter, FDM rapid prototyping, subtractive rapid prototyping)
- Bid submitted to University for new investment
  - Machining of CFRP & ceramics
  - Large-scale precision machining of metals

Advanced Materials Laboratory

- Aim is to support the development of low-mass high stability support structures for High Energy Physics experiments
  - Outreach activity through the support for Liverpool mechanical engineering students participating in the Formula Student race car and Human Powered Vehicle projects

- Staff: 2

- Materials
  - UD & woven pre-preg
  - Epoxy & cyanate ester (low CME) resin systems
  - Vacuum resin infusion

- Capabilities
  - 1.7m (L) x 0.65m(dia) autoclave
  - 1.5 x 0.4 x 0.4 and 3.0 x 2.0 x 2.0 oven
  - Pattern cutter
  - Dedicated temperature controlled room for lay-up
  - Separate room equipped with dust mitigation for part finishing

Liverpool Semi-Conductor Detector Centre (1)

- Aim is to provide the facilities needed to allow the delivery of projects ranging from small-scale prototyping all the way up to fully physics-ready detector sub-systems for major international laboratories.

- Scope: 100 m^2 Class 5 + 250m^2 Class 7 clean room suite

- Staffing:-
  - Support staff for day-to-day operations & maintenance
  - Machine operators from project staff

- Equipment for Module Assembly;
  - Sensor characterization (probe stations & parametric analysers)
  - Precision mechanical assembly
  - Wire-bonding (2 x H&K 710 & 1 x H&K BJ820)
  - Optical metrology (OGP SmartScope CNC 624)

Liverpool Semi-Conductor Detector Centre (2)

- Equipment for Sub-system Assembly
  - Large optical breadboards for sub-system assembly
  - 2 x Wenzel touch-probe CMMs for geometric metrology
  - 3 x 2 x 2m cold room for system tests

- Equipment for Structural Analysis
  - Universal materials tester
  - Dantec Dynamics 3D Digital Image Correlation System
  - Netzsch Differential Scanning Calorimeter
  - DataPhysics SignalAce vibration analyser
  - FLIR Thermal cameras (3)
  - Ultrasonic flaw detector, Surface tension analysis, adhesion tester, etc…