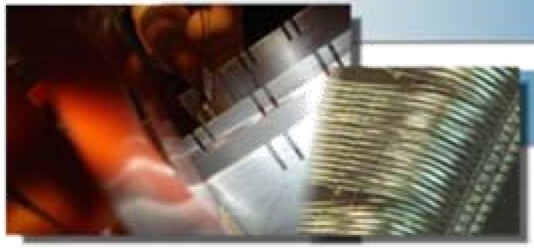
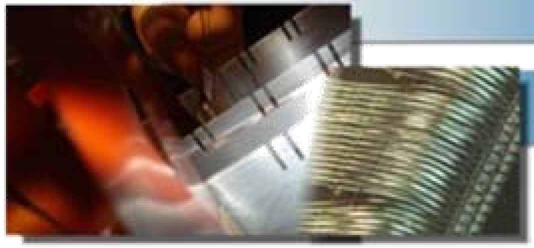


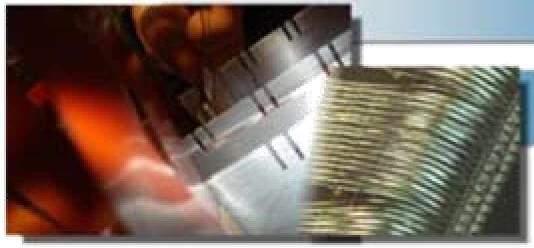
LHCb Vertex Detector

T. Bowcock



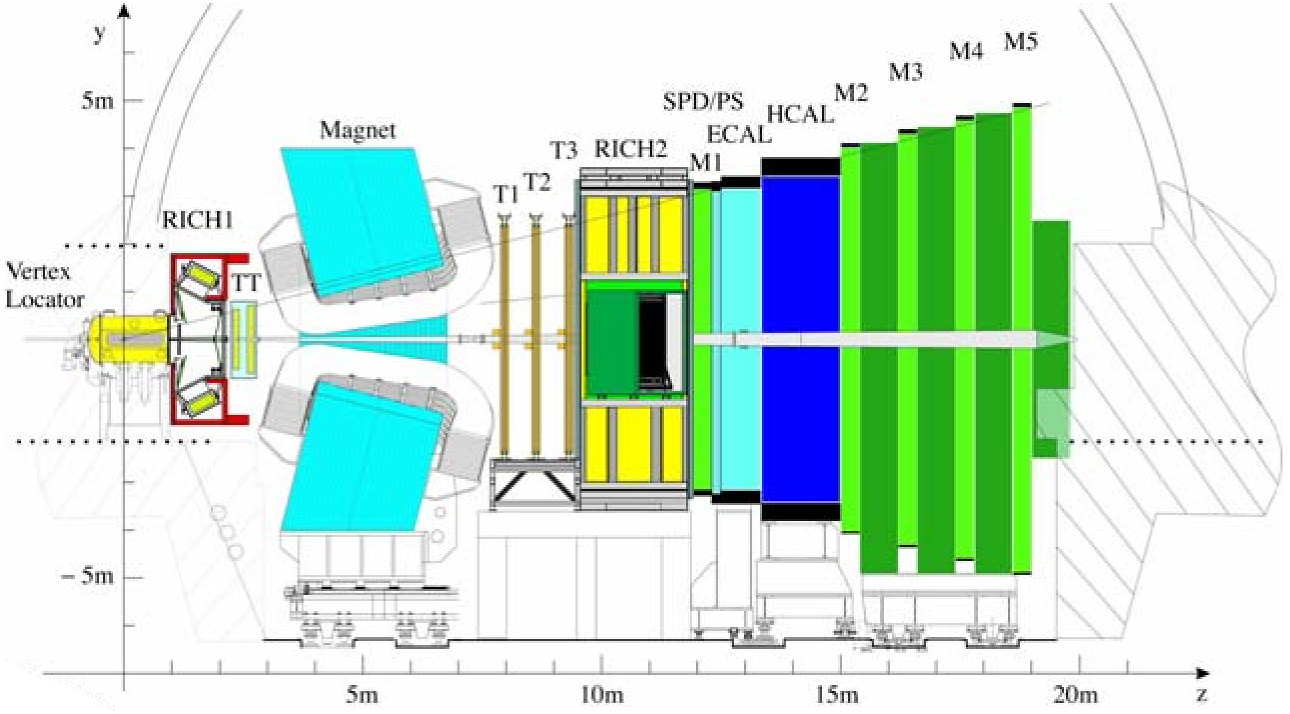
Overview

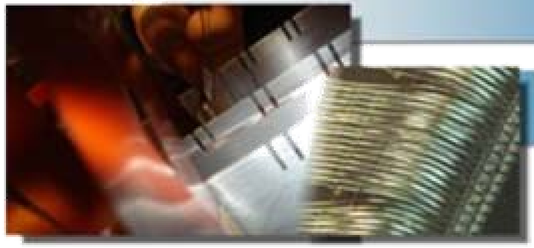
- LHCb
- Requirements for the Vertex Detector
- Design
- R&D
- Production
- Lessons ...



LHCb

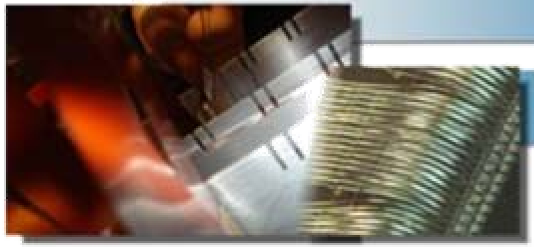
- Experiment





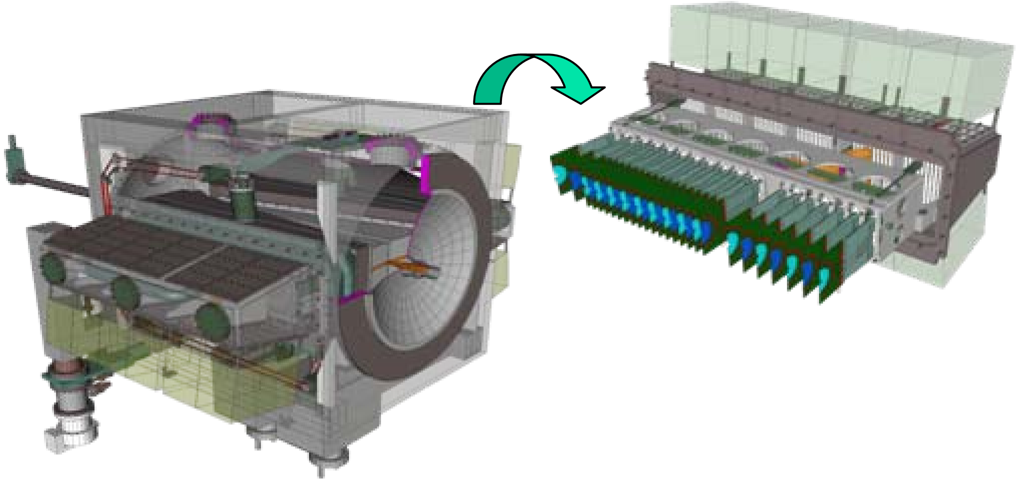
Requirements
Vertex Detector

- Resolution
- Mass
- Radiation tolerance
- Geometry
- Cost

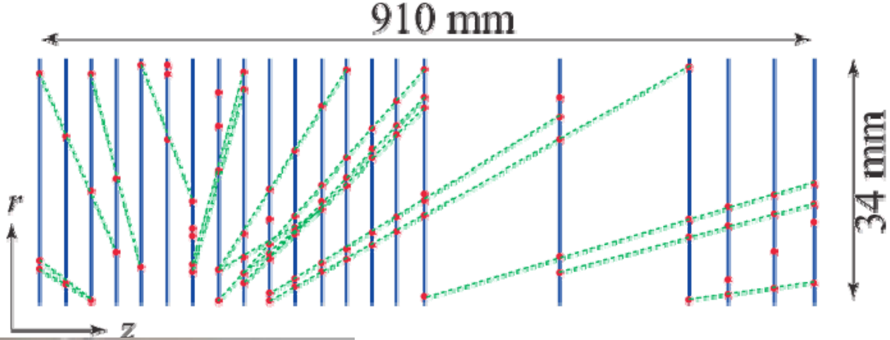


Vertex Locator

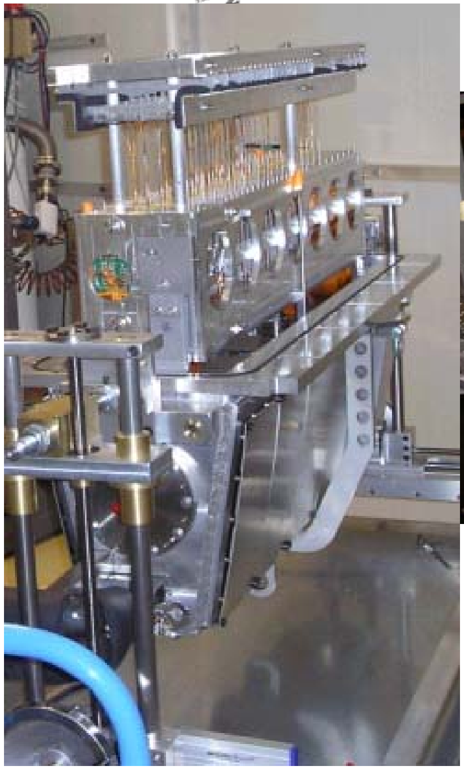
- Detector with ~40fs resolution
- IP ~100microns or better

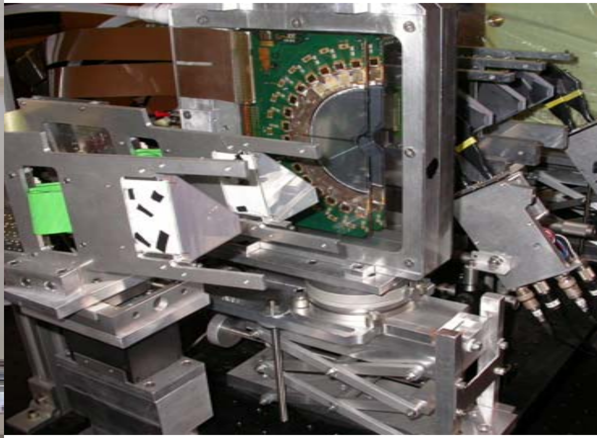


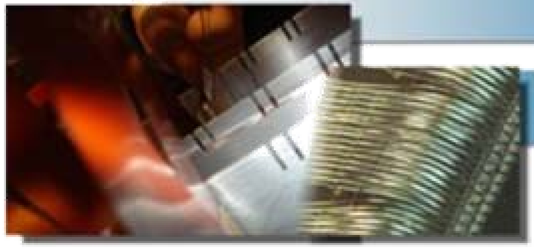
Vertex Locator



- vertex locator
- 8mm from LHC beam
- Vacuum

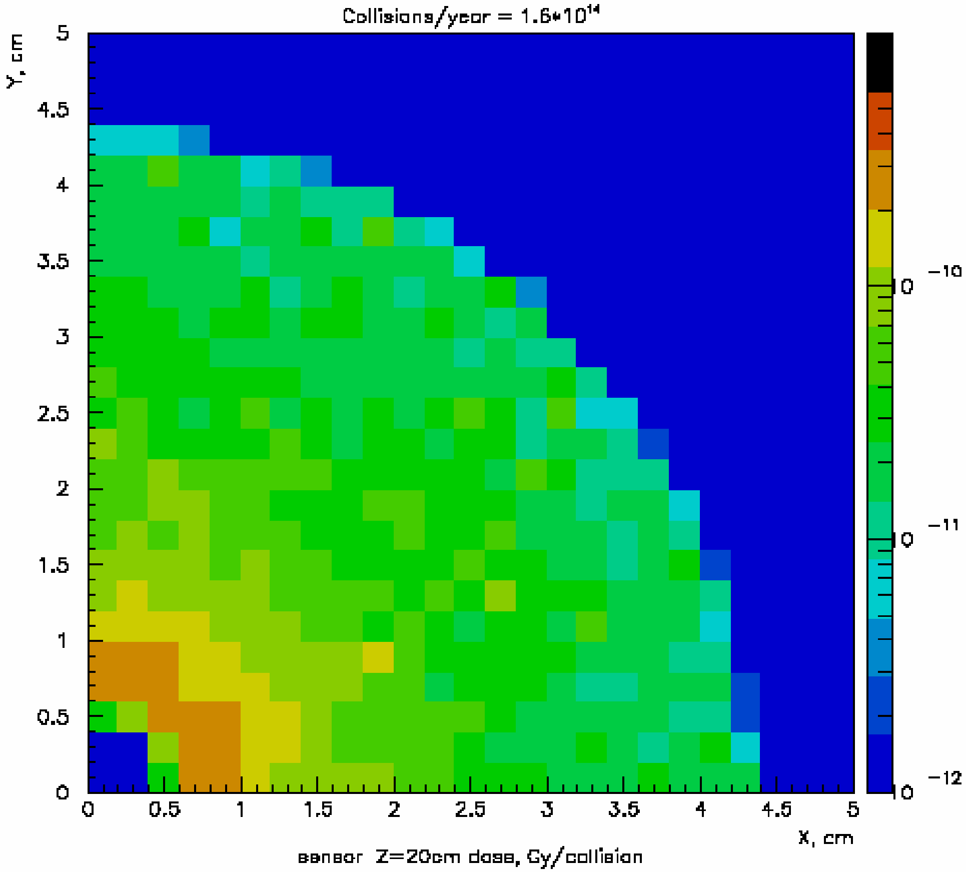


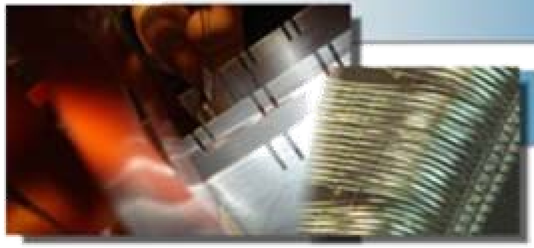




Radiation Levels

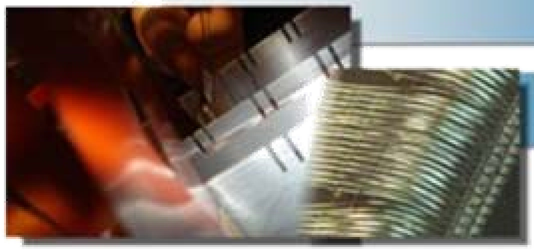
- maximum dose of ~10^{15}p/cm^2
- non uniform
  - $1/r^2$
- Sensors need t run ~-7°C
  - Reverse annealing
  - Thermal runaway





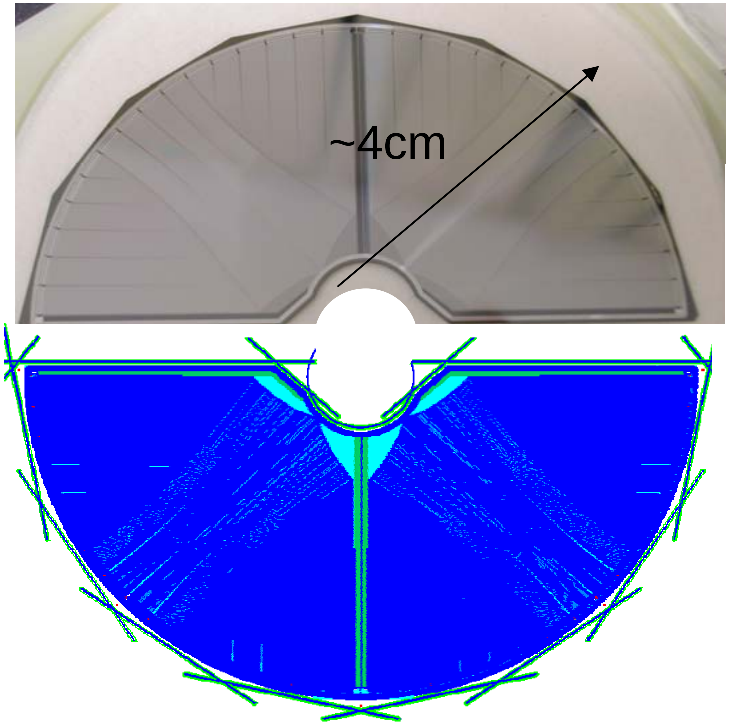
Design of Si

- Sensor needed to be used in the trigger
    - Pixels (too costly and not necessary)
- Strips
- R-Phi geometry for trigger (rather than x-y)
- Resolution 5-10microns
- 250,000 channels
- Readout at edge
- Close to beam (tight tolerances)

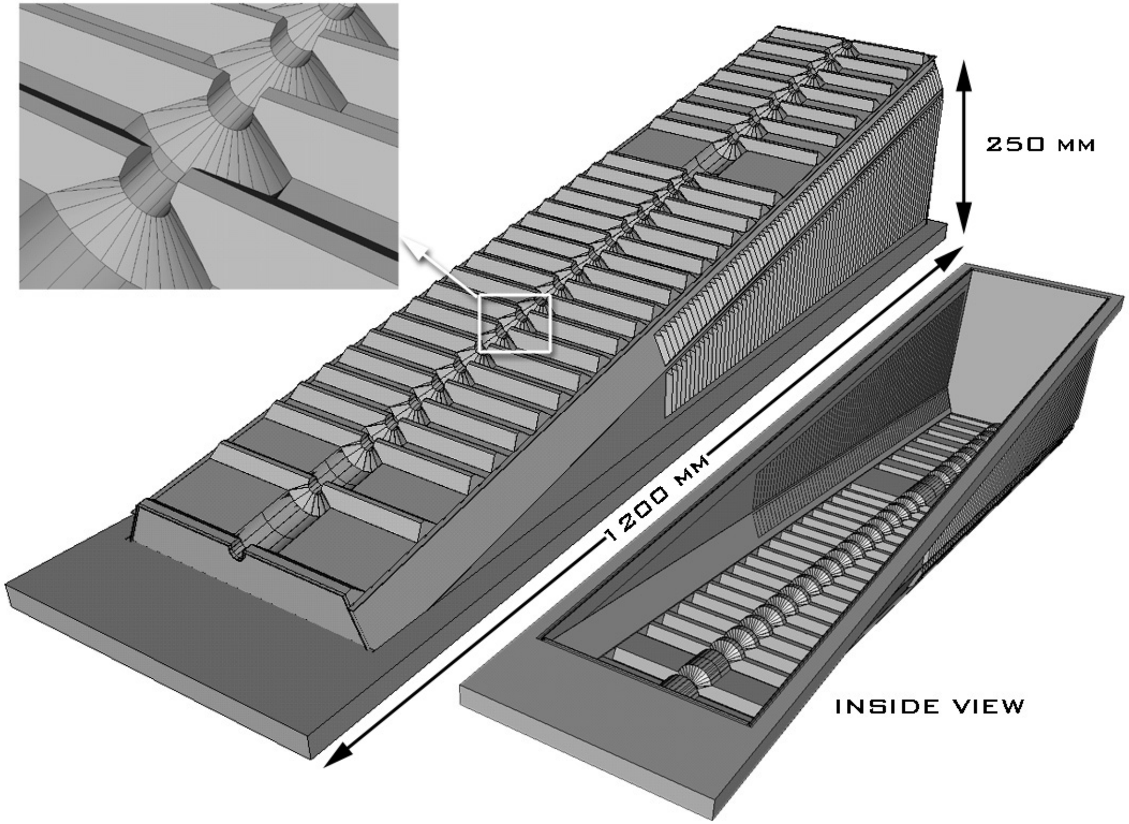


Silicon Sensor

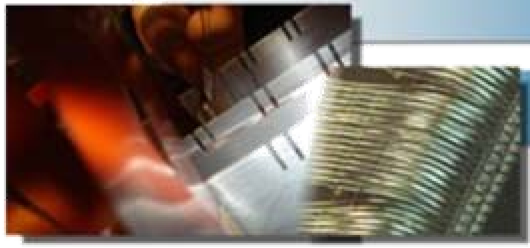
- highly segmented
- double metal layer
- 2048 strips/sensor
- Two designs
    - R-measuring
    - Phi-measuring



Detector Foil

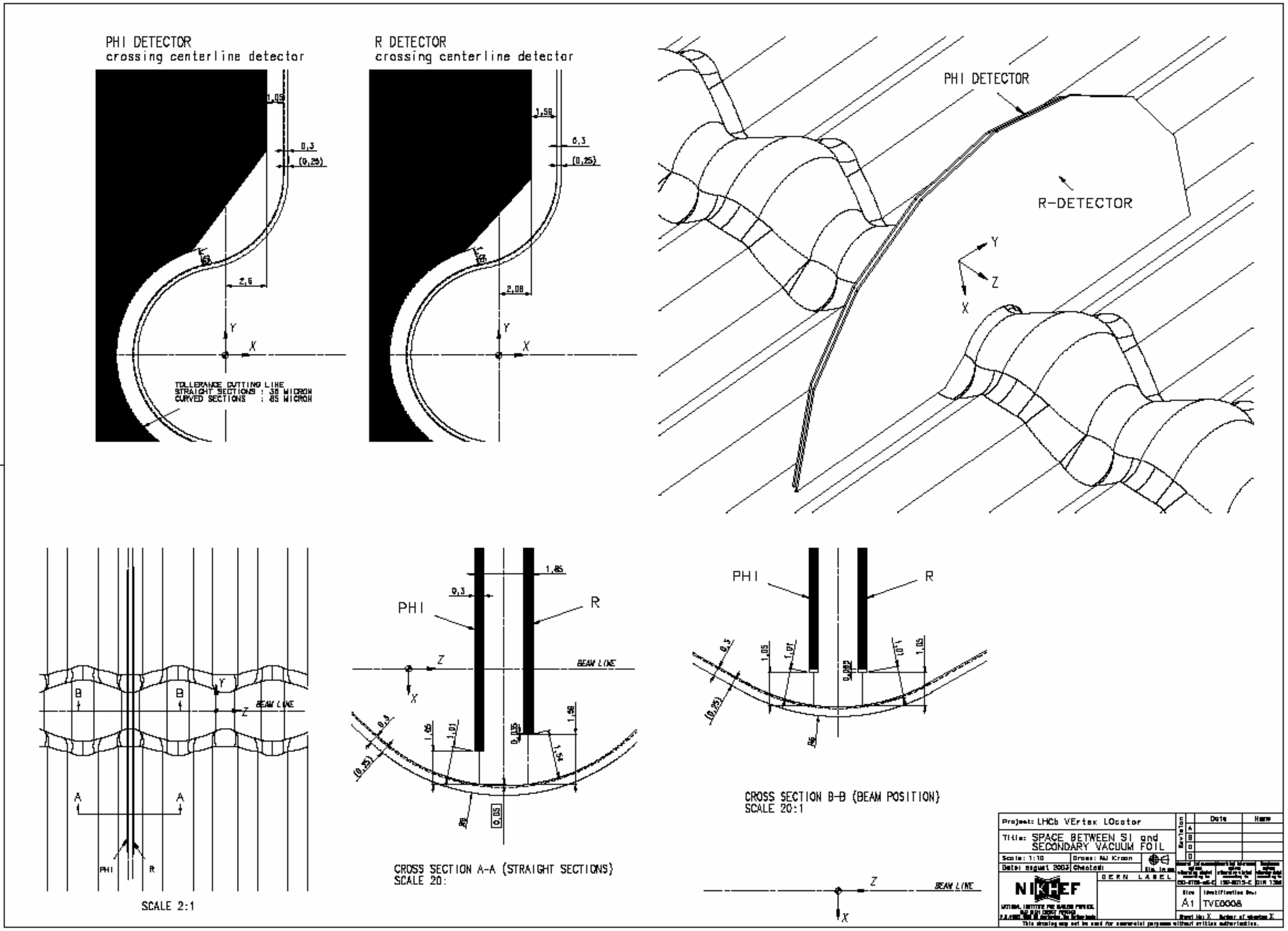


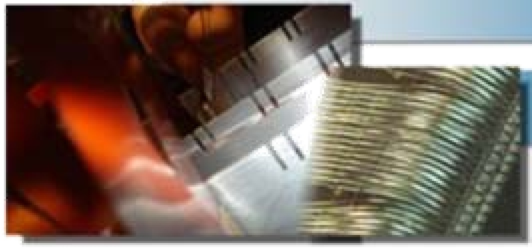
NIKHEF Image



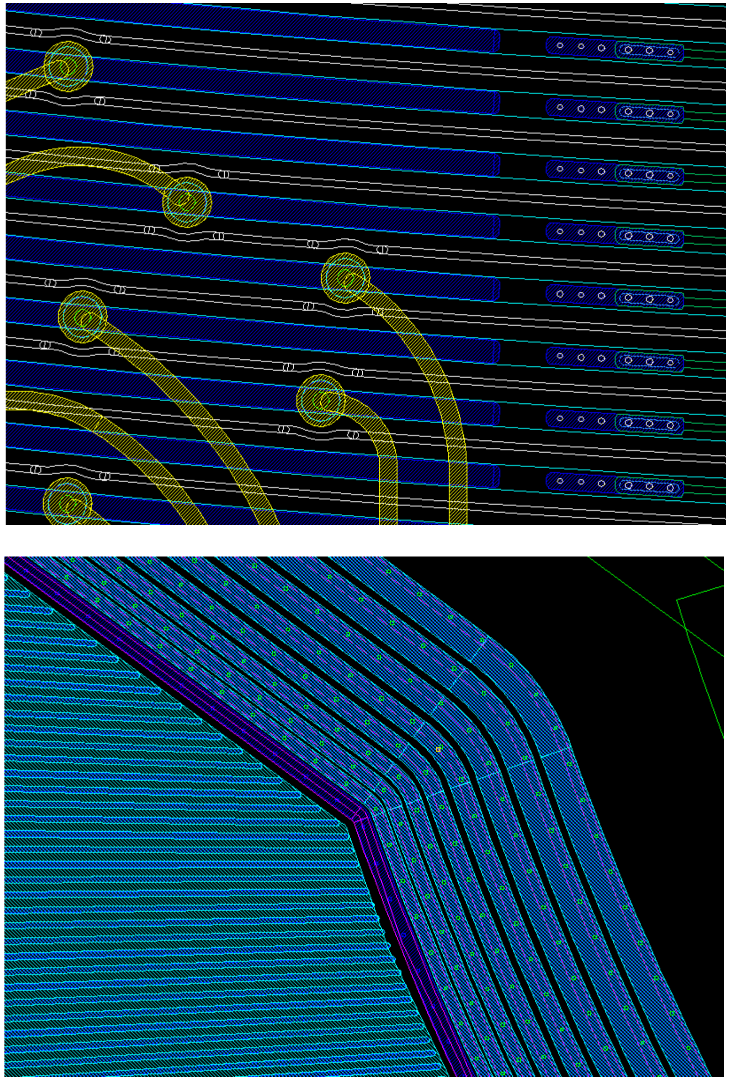
Envelope

NIKHEF drawing TVD0008

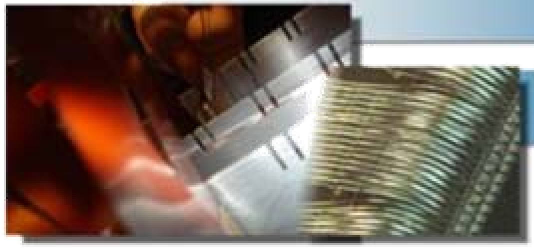




Design

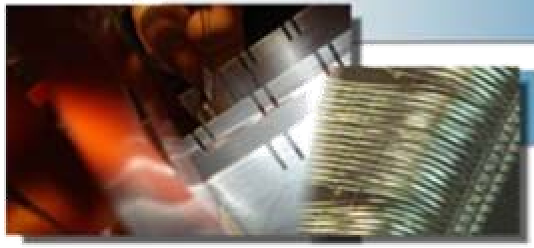


- complex
- highly automated
- Simulated ISE-TCAD
- Designed in-house
  - Collaboration with Micron



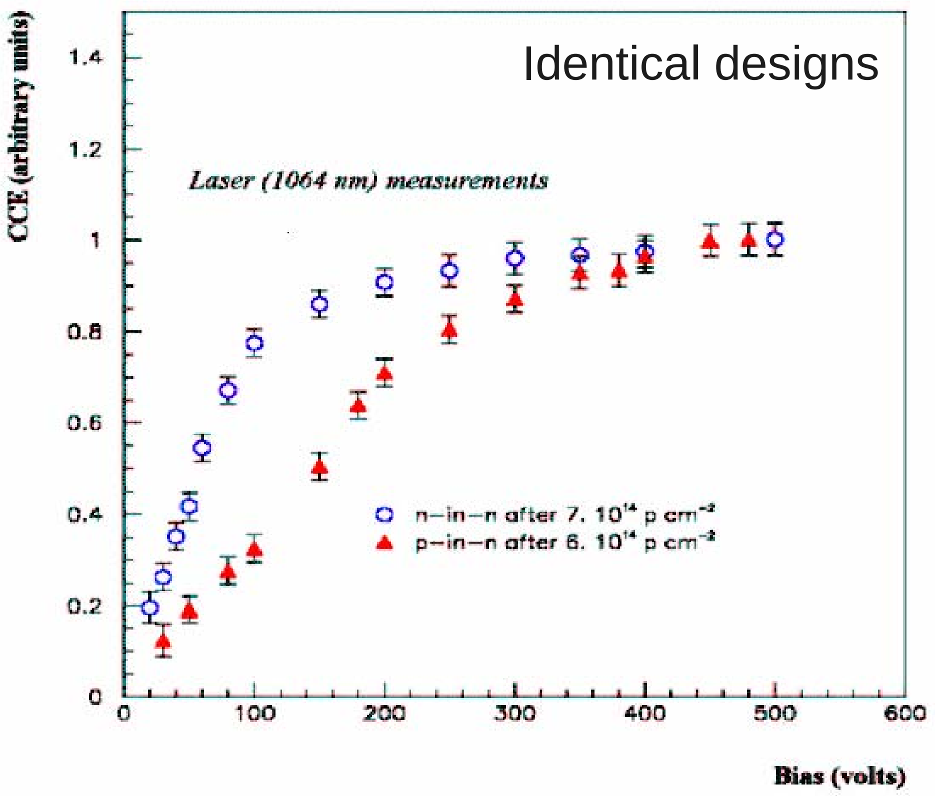
Fabrication

- earliest n$^+$n prototype Hamamatsu Photonics
  - n$^+$n not available since ~2000
- later n$^+$n and p$^+$n designs Micron Semiconductor
  - Production with Micron
  - Delivery to schedule (almost complete)

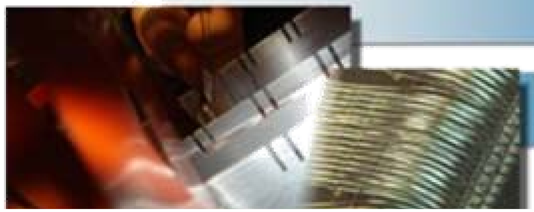


Technology Choice (2001)

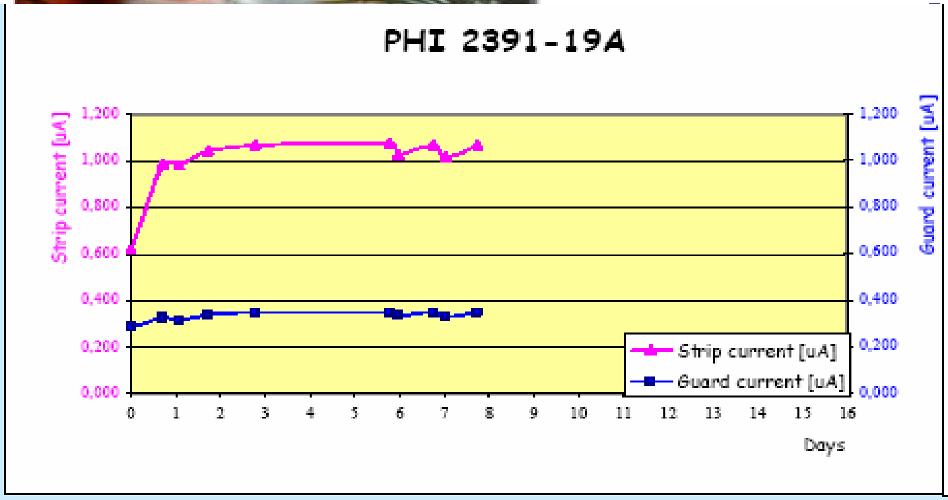
- ac coupled
- n^+n
- p^+n
- oxygenation



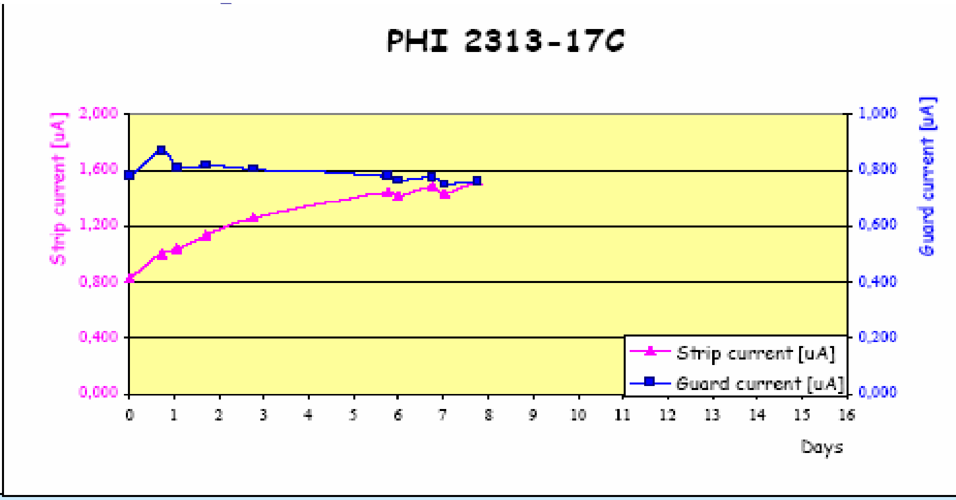
Identical designs



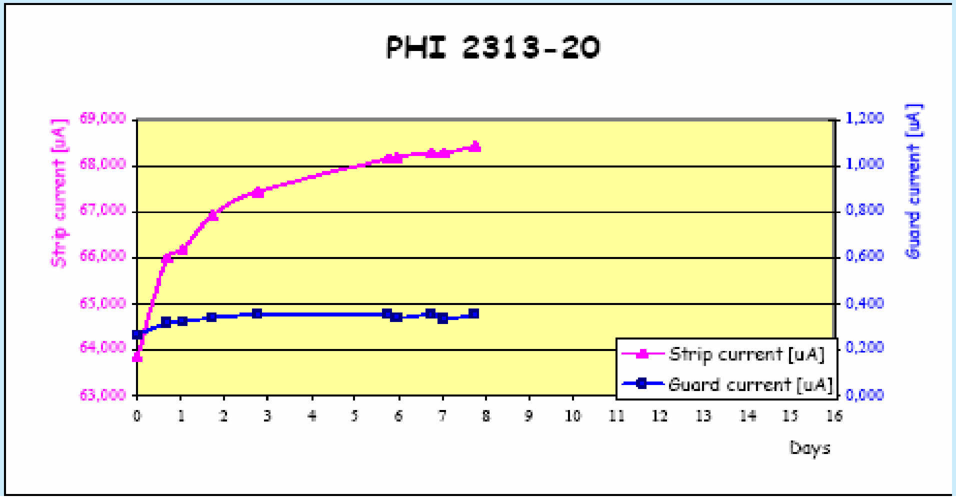
Vacuum tests



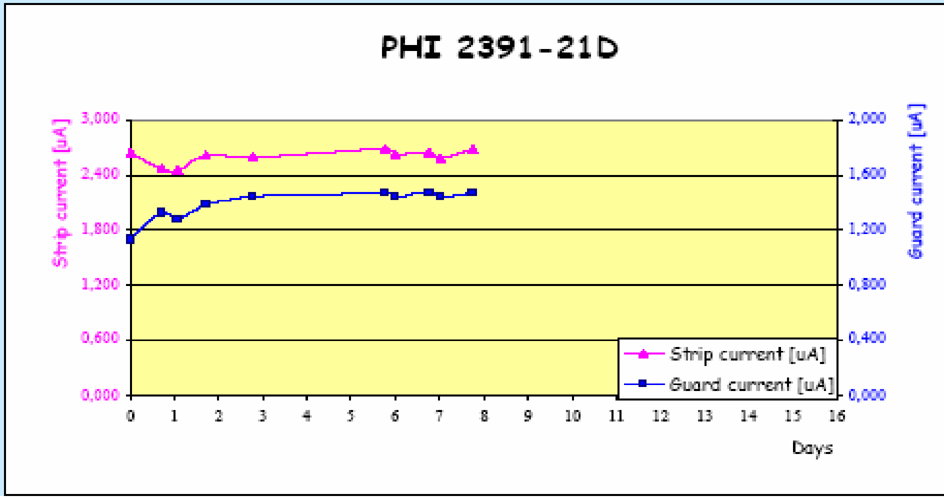
PHI 2391-19A



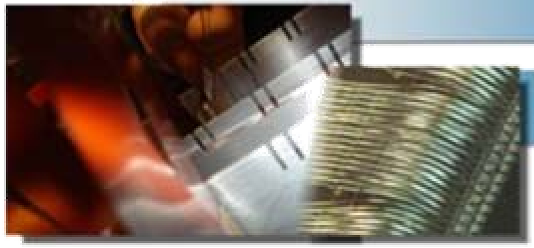
PHI 2313-17C



PHI 2313-20

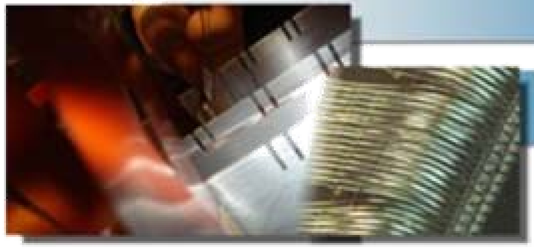


PHI 2391-21D



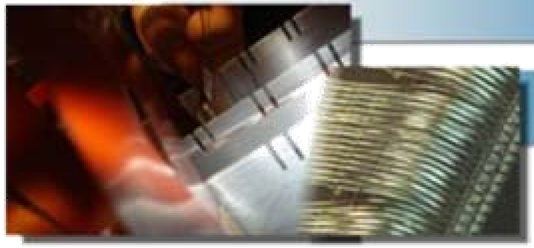
Requirements: Cost

- Entire R&D and production ~1MChF
  - Controlling cost v ease of production
  - Prototyping

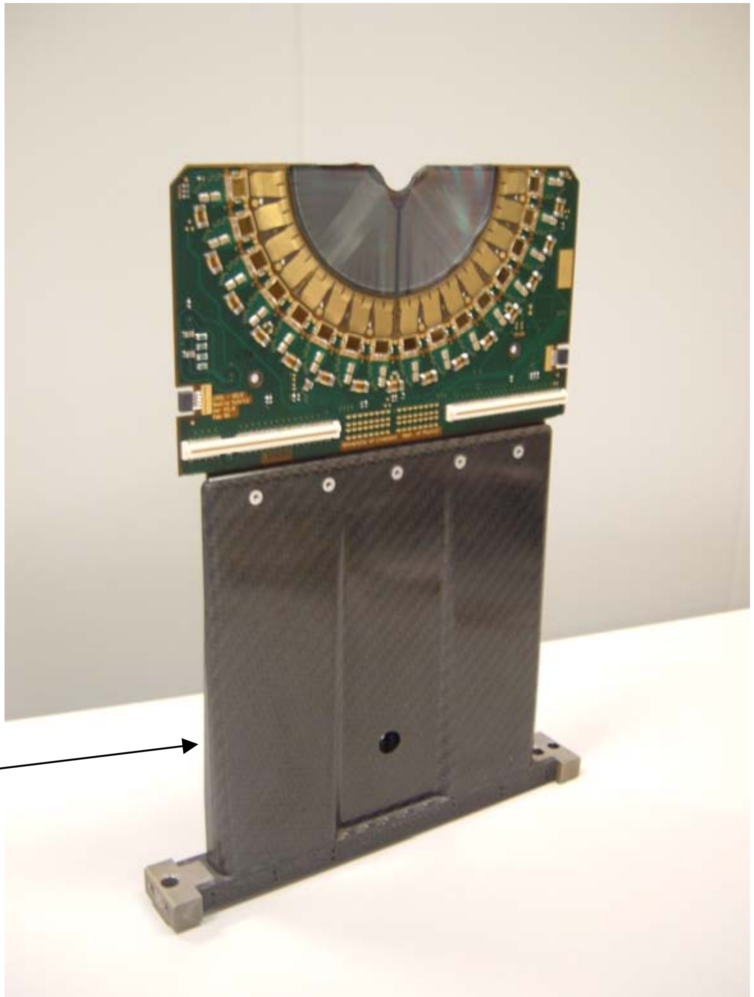


R&D

- Sensors
- Mechanical
  - Cooling
  - Precision Construction - Composites
- Electrical
- Module Construction Techniques

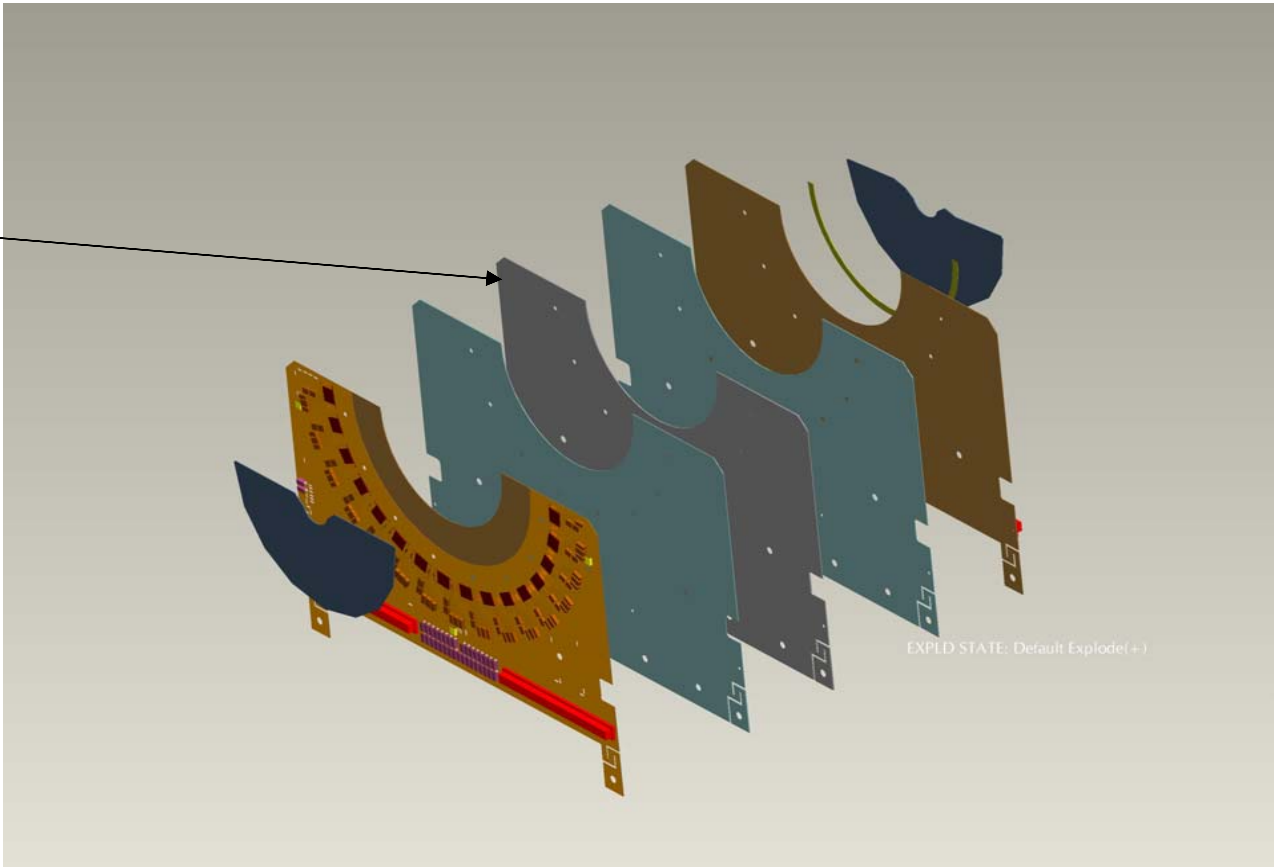


Module



Paddle=support

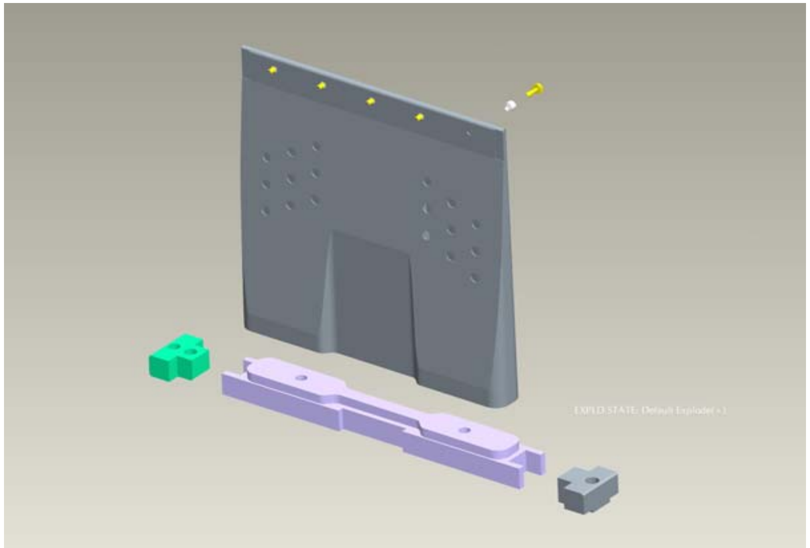
Hybrid make up

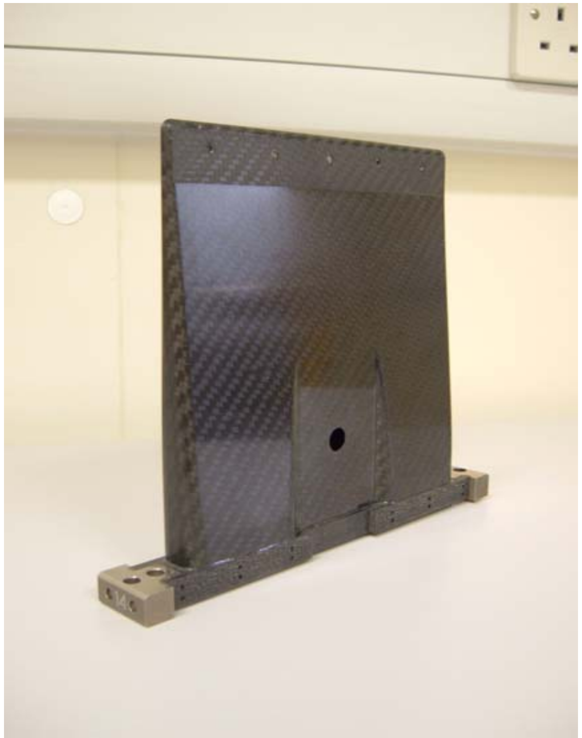


400 micron

TPG core

Support pedestal



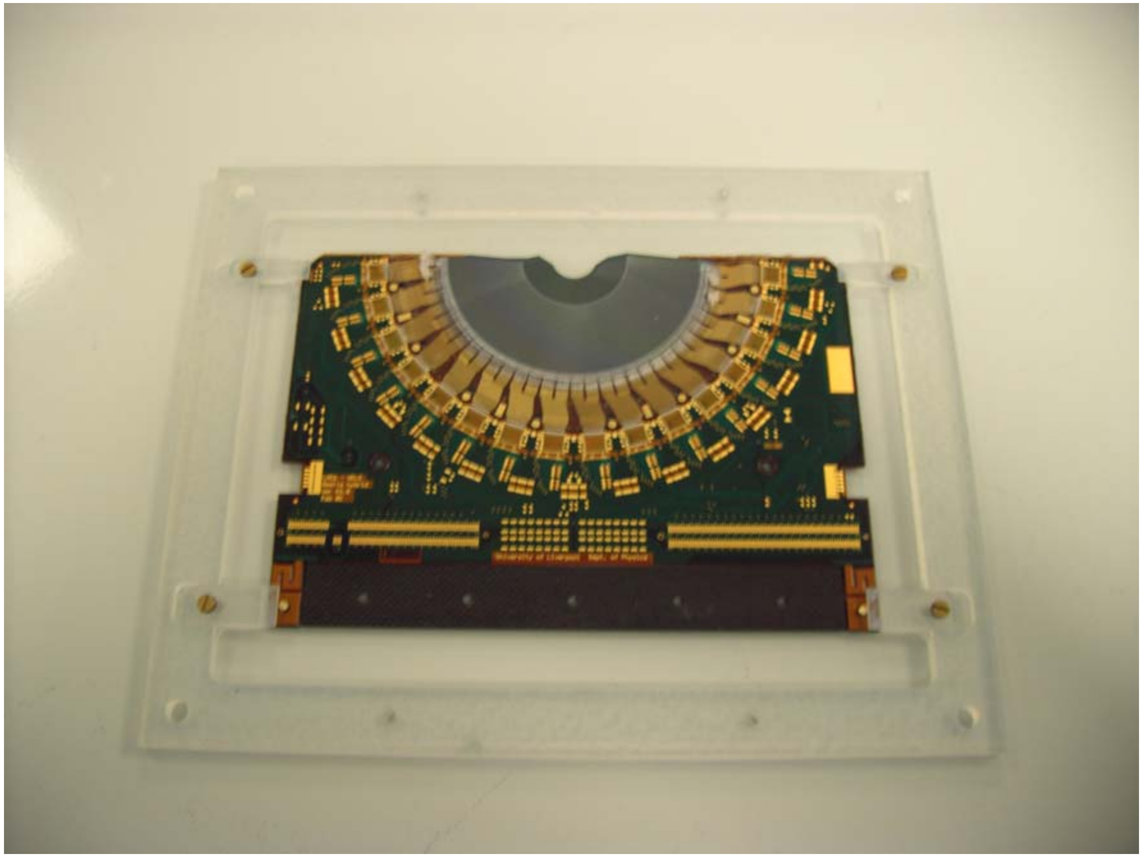


To keep alignment

0 CTE

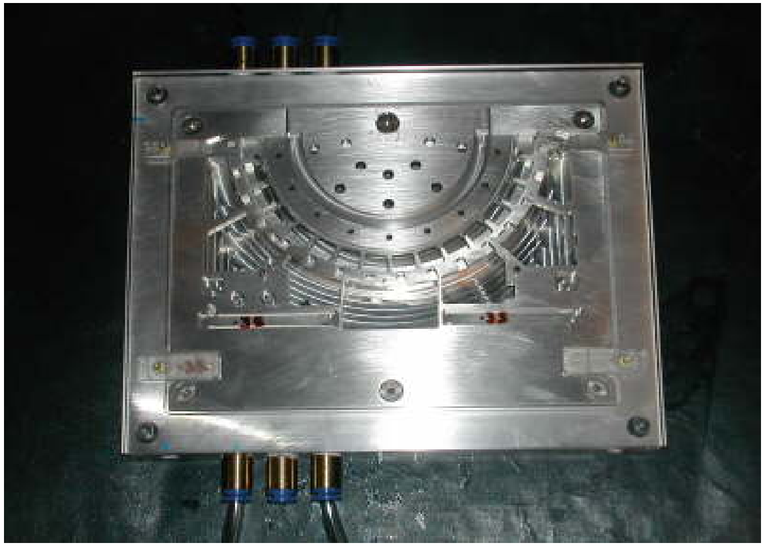
Frames

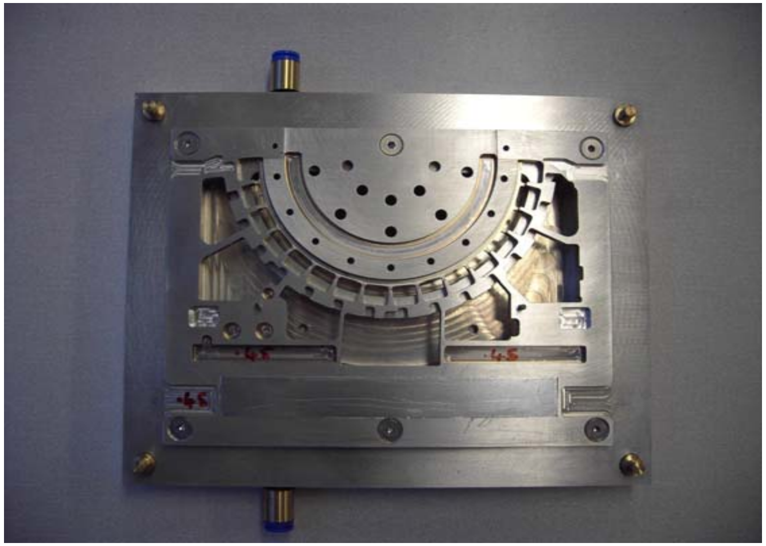
Plastic Handling Frame Designed Double Sided Use



Bonding Jigs

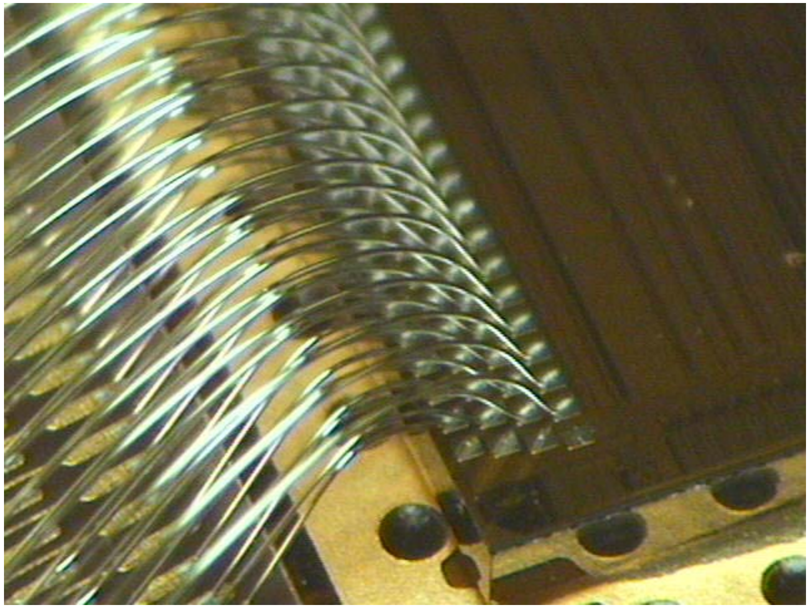
Second Generation Bonding Jig Now Capable of Accepting The Handling Frame

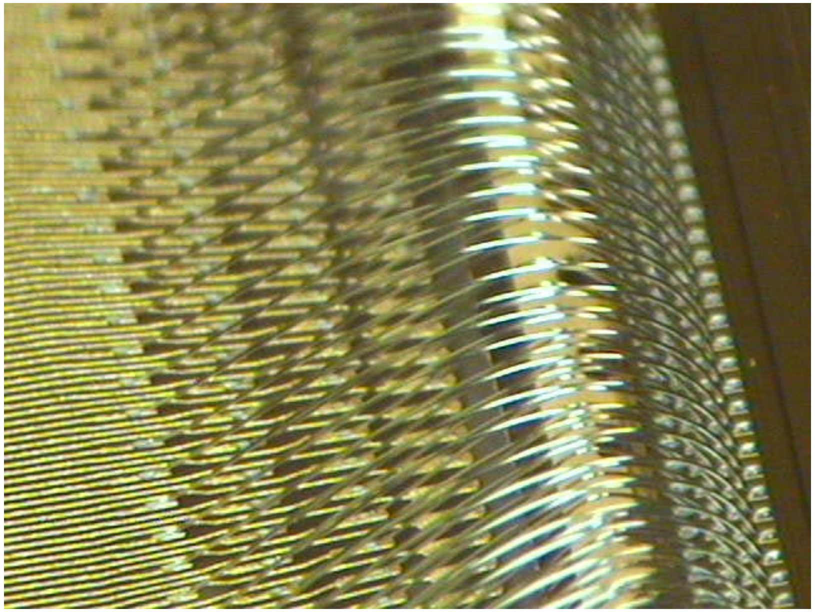




Bonding

Closer look at chip to pitch adaptor bonds



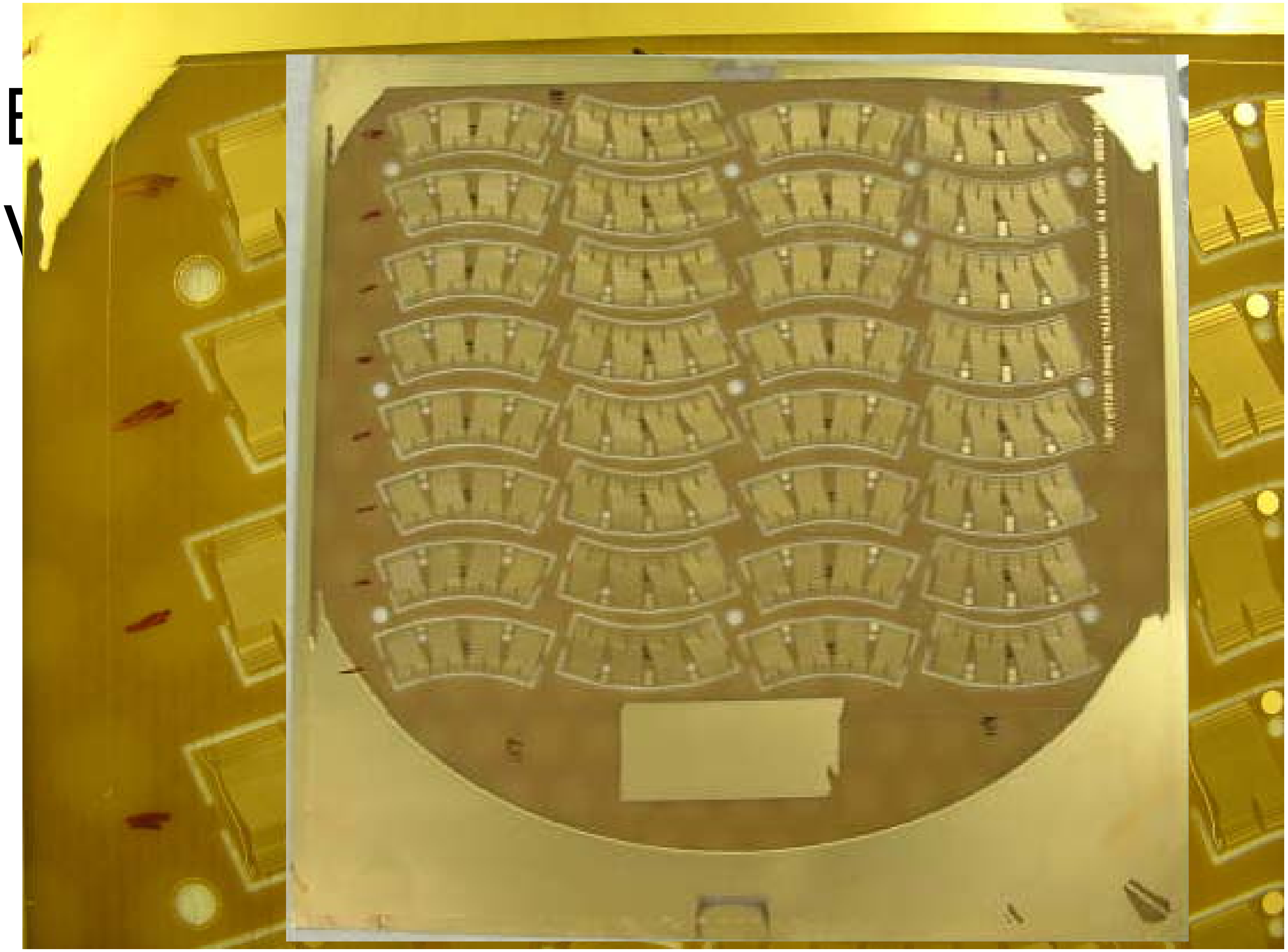


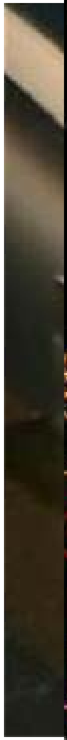
Production

- Testing

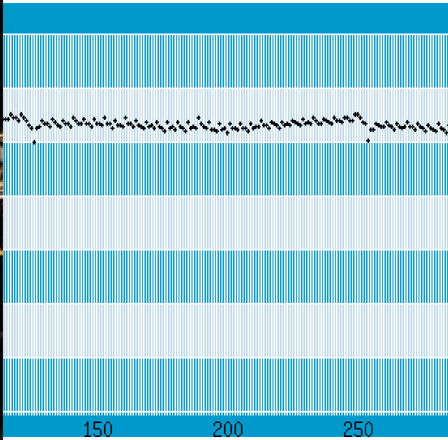
Pitch Adaptors

- E
- V



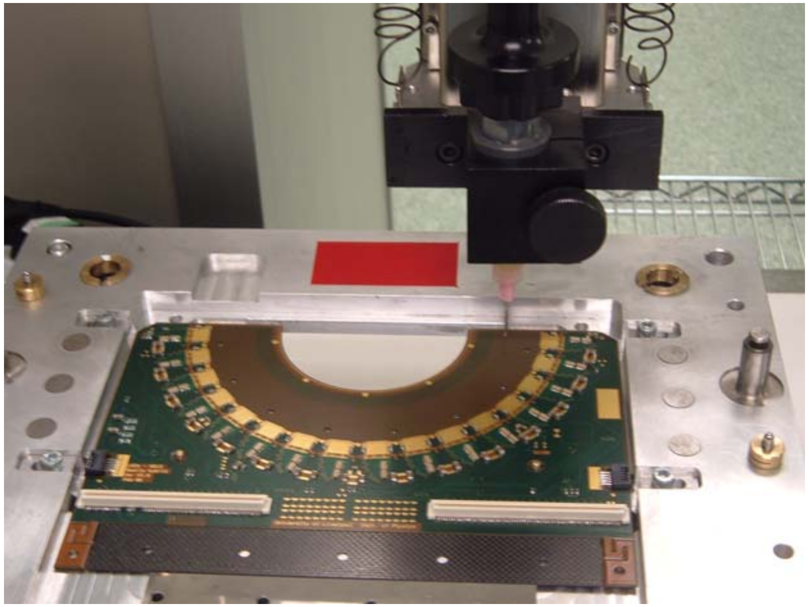


sts

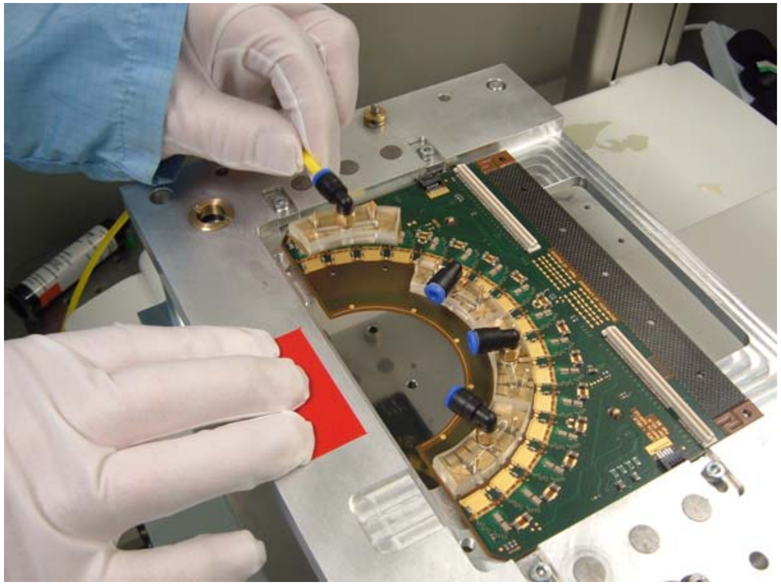


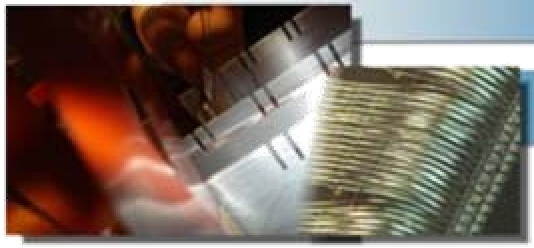
Process

- Dispense Glue



- Place pitch adaptors





Circuit layout

Layout showing top layer metal and inner layer traces

Unusual build up-

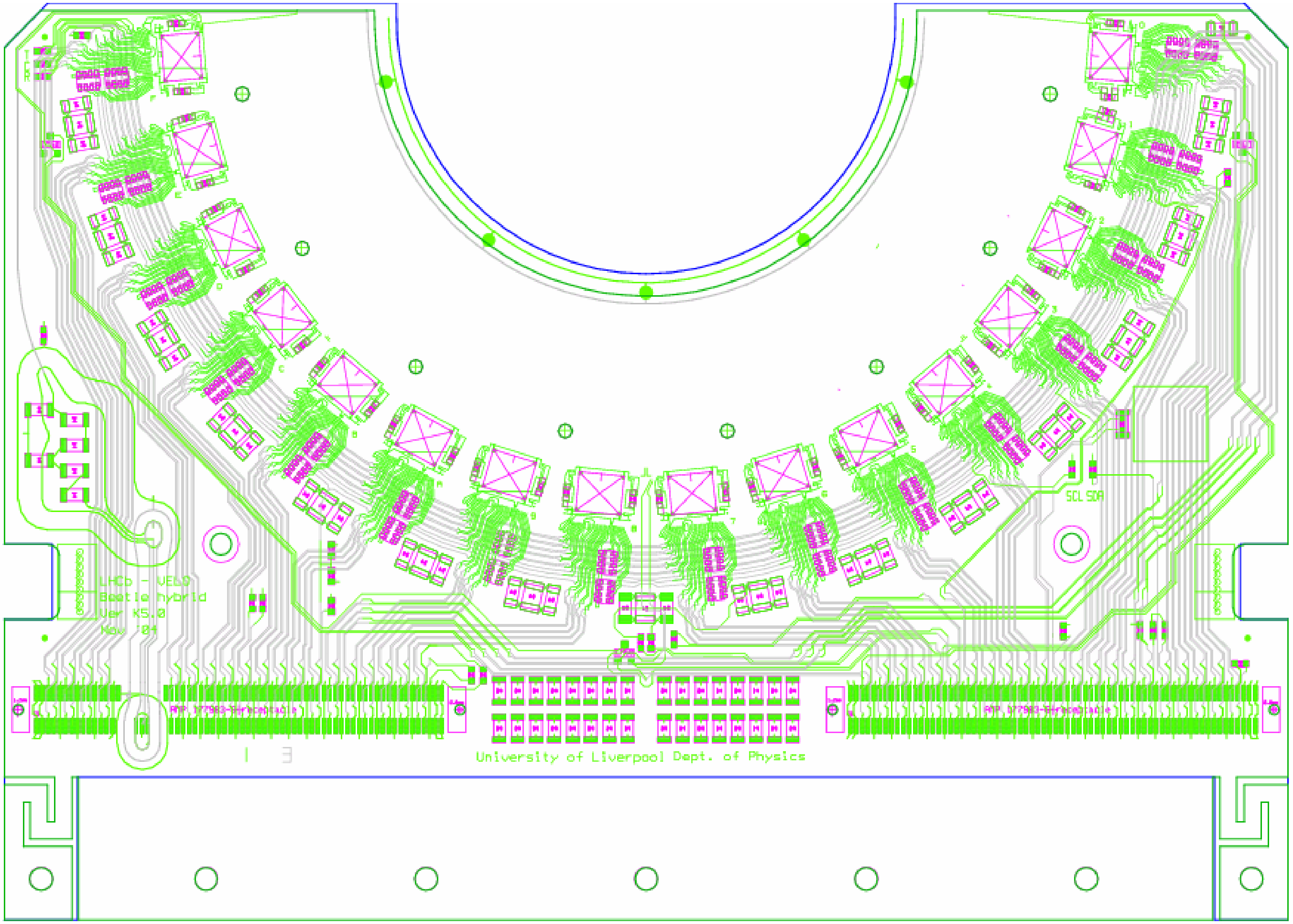
Top -Traces

layer 2 - Vcc plane (split in 4)

Layer 3 - inner traces

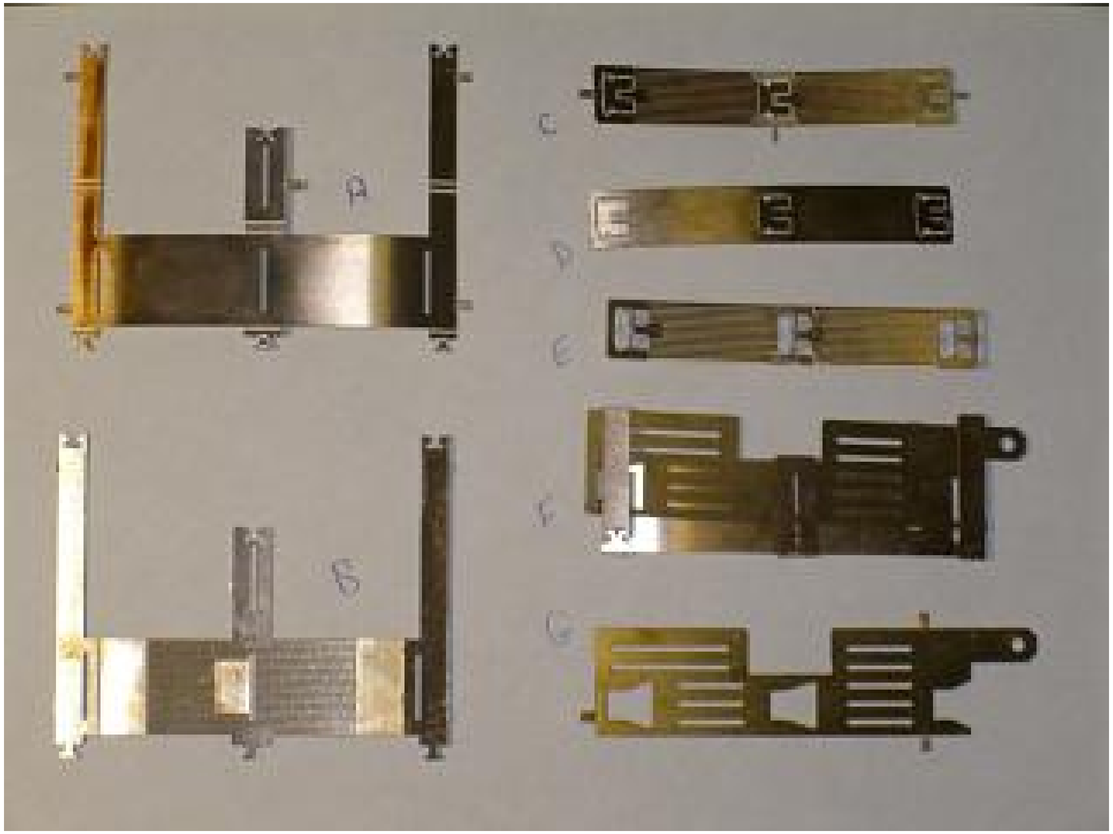
Layer 4 – GND plane

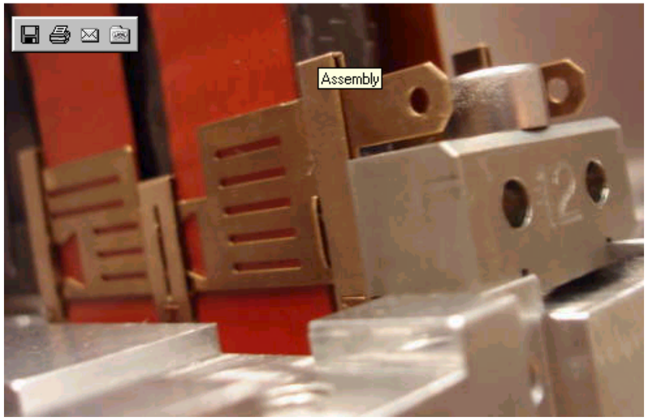
Circuits on both sides identical



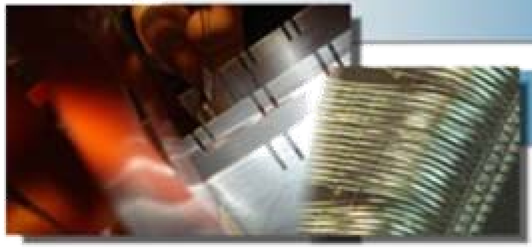
Clamps

Cables are manufactured by Photofabrication

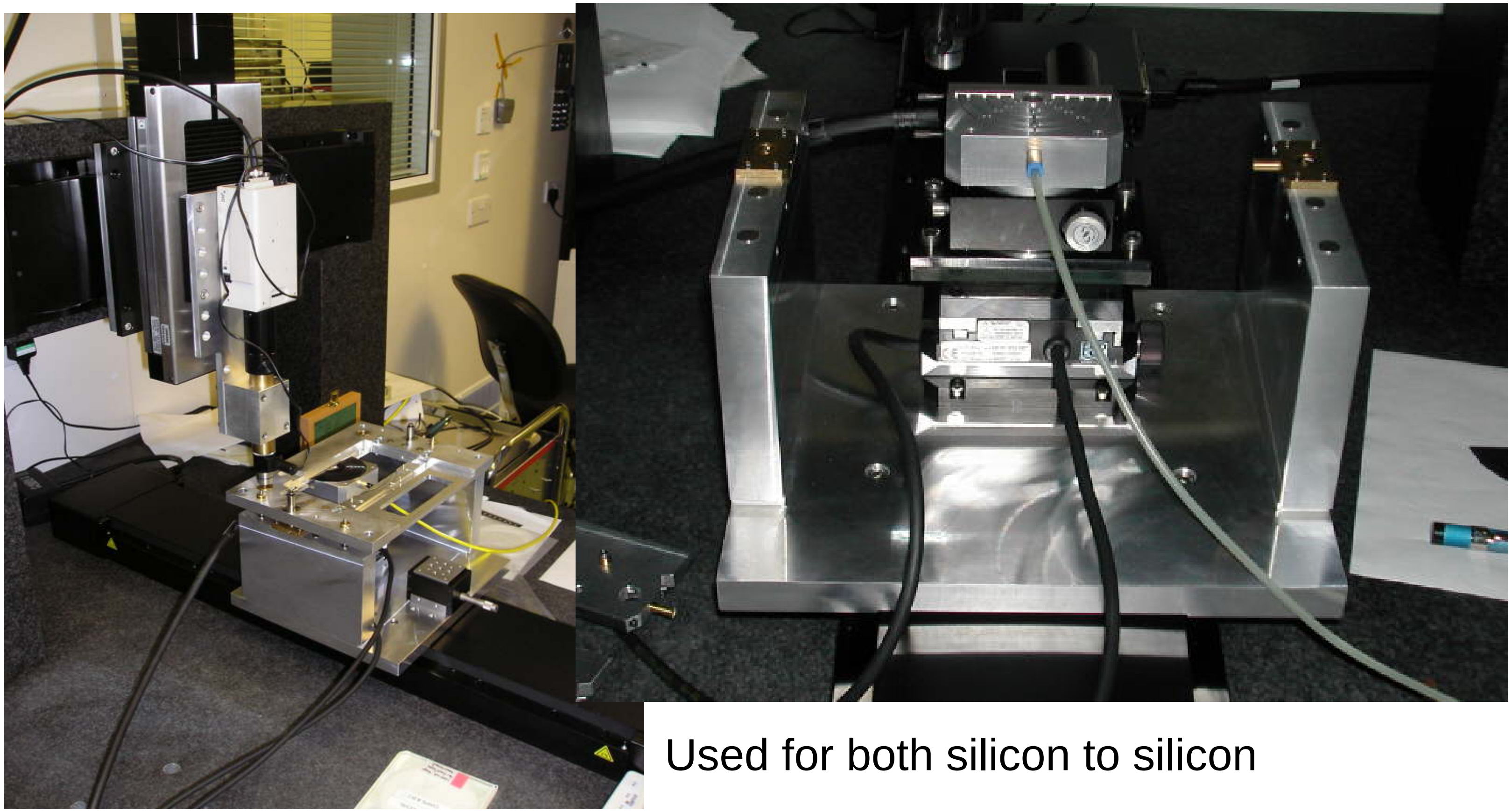




Cable and clamp assembled
and locked to the module base

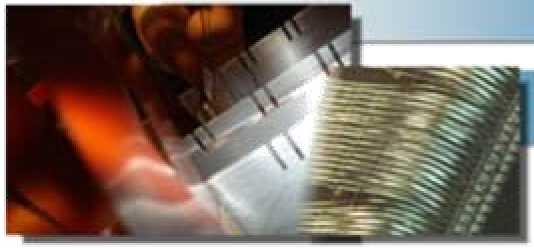


Assembly Station



Used for both silicon to silicon

and hybrid to pedestal alignment



Results Gluing

- RMS of all modules:

midRx=5.14 microns

midRy=11.62 microns

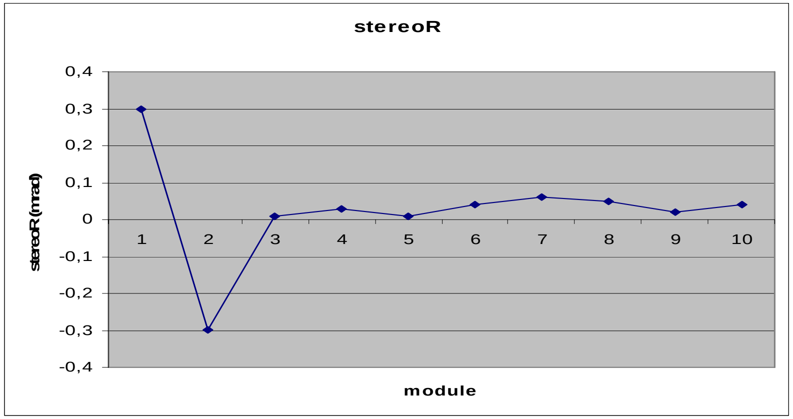
stereoR=0.14 mrad

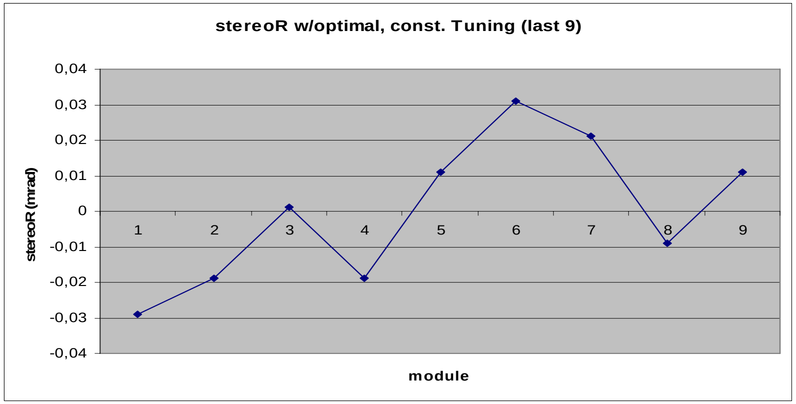
- RMS of last 9 modules with optimal tuning:

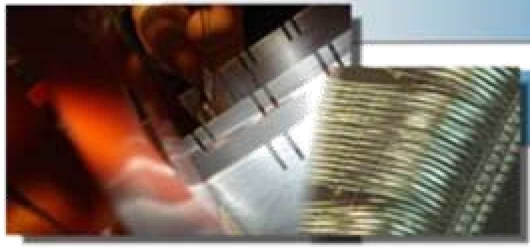
midRx=2.27 microns

midRy=2.71 microns

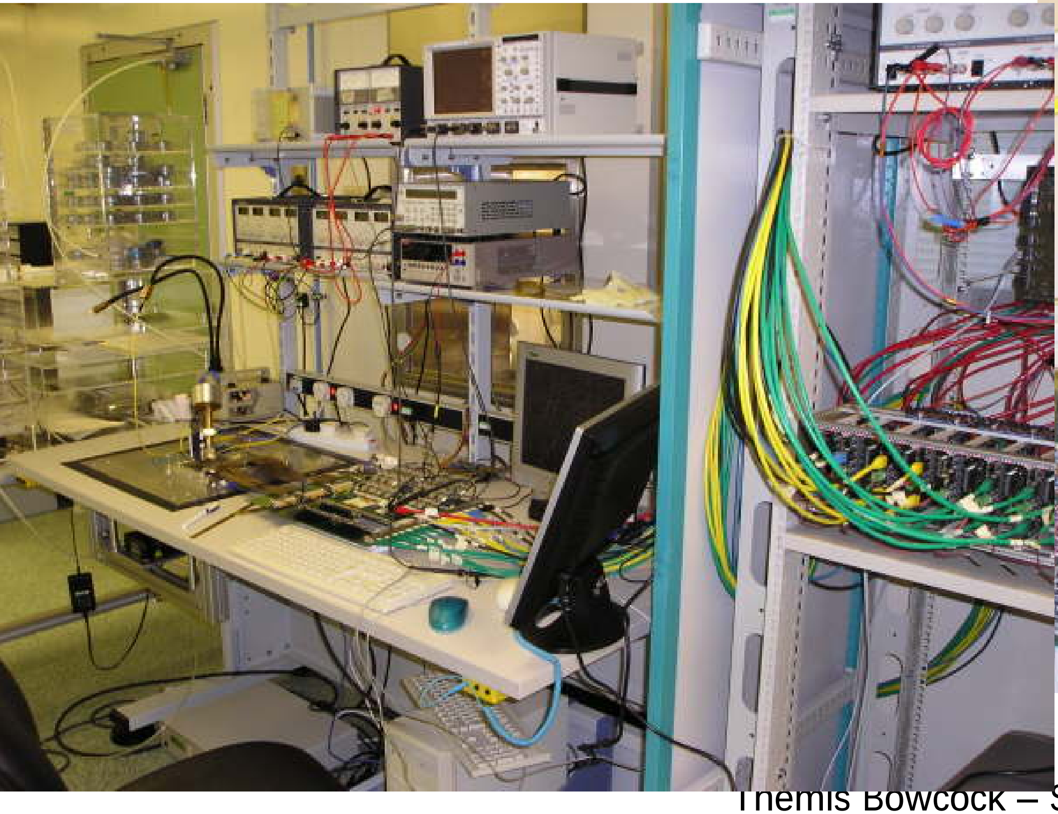
stereoR=0.02 mrad

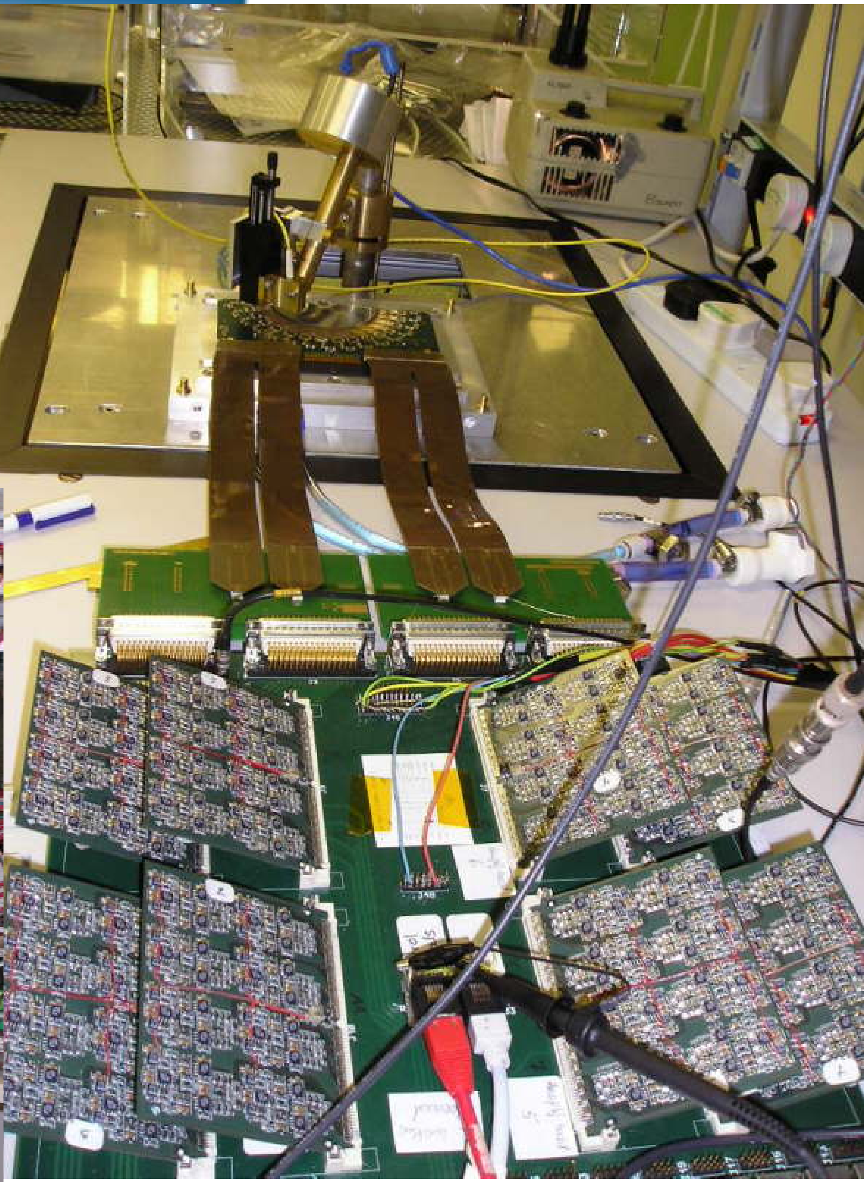




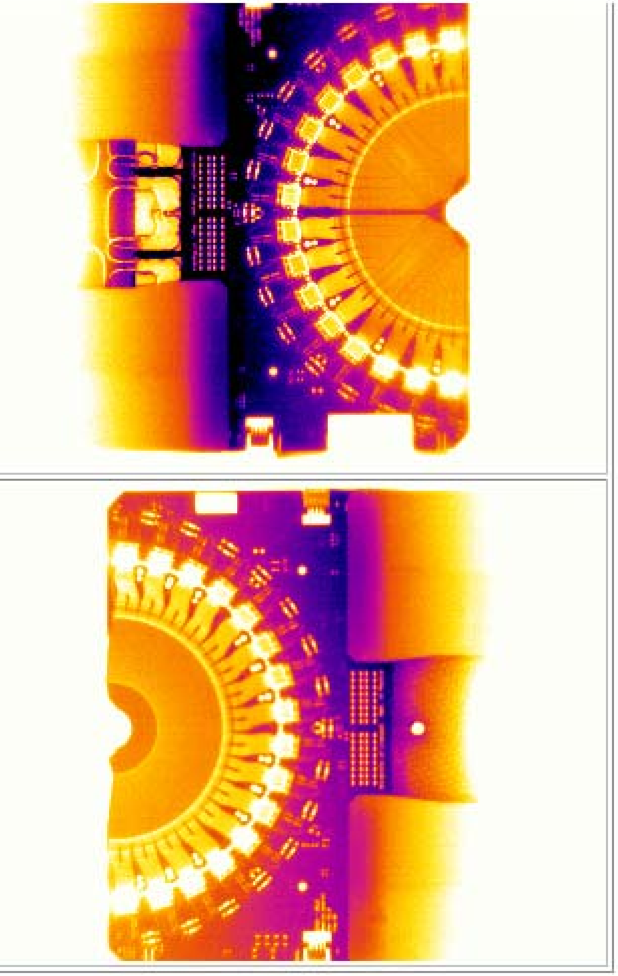


LASER Tests

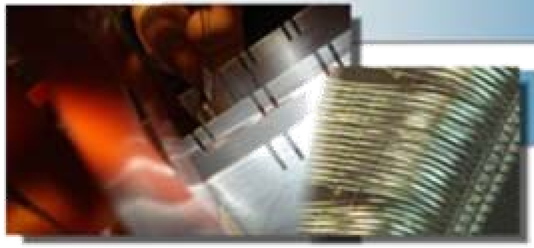




Burnin

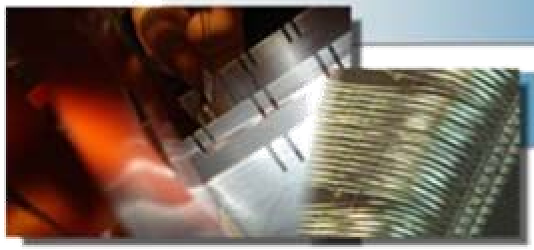


- Thermography
- Undervacuum
- Read out
- Noise compared with laser etc
- ~24W in module
  - Cooling with biphase CO2
- Thermal connection hard to make



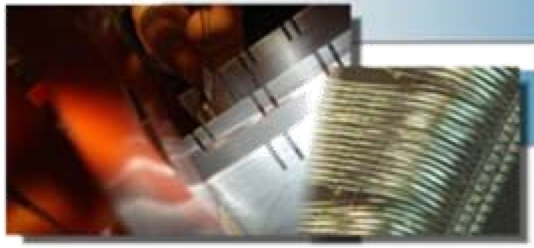
Status

- Started production
  - Staff ~14 FTE
- Achieve 2+ modules/week
- Slower than expected...



Lessons

- Building the modules need not be expensive BUT:
  - R&D is fixed cost not fractional!
  - Need to build many modules before production
  - Don’t underestimate the cost…!
- Thermo-mechanical (cooling) and low mass + 0 CTE hard to achieve
  - New materials/processes hard and expensive to develop
  - Diamond?
- High tolerances (and above) make life complicated
  - Ideally separate cooling, mechanical and electrical function
- Huge time investment in getting tooling right for production
  - Bonding critical
  - Spare identical bonding machines crucial. 3 minimum for a production site.
- Safety
- Quality/Process Control and databasing crucial
- Advantage to having single (few) production site
  - But corollary is this can give “collaborative” problems
    - support, interactions, shared understanding etc
- Design for ease of production
- Develop detailed specifications as early as possible
- Long R&D/production cycle can lead to human “burnout” (VELO started 1996)



Summary

- VELO a complex strip detector with high resolution
- Close cooperation with silicon manufacturer (Micron) was/is critical for success
- Extensive use of composites
- Completion in ~6 months