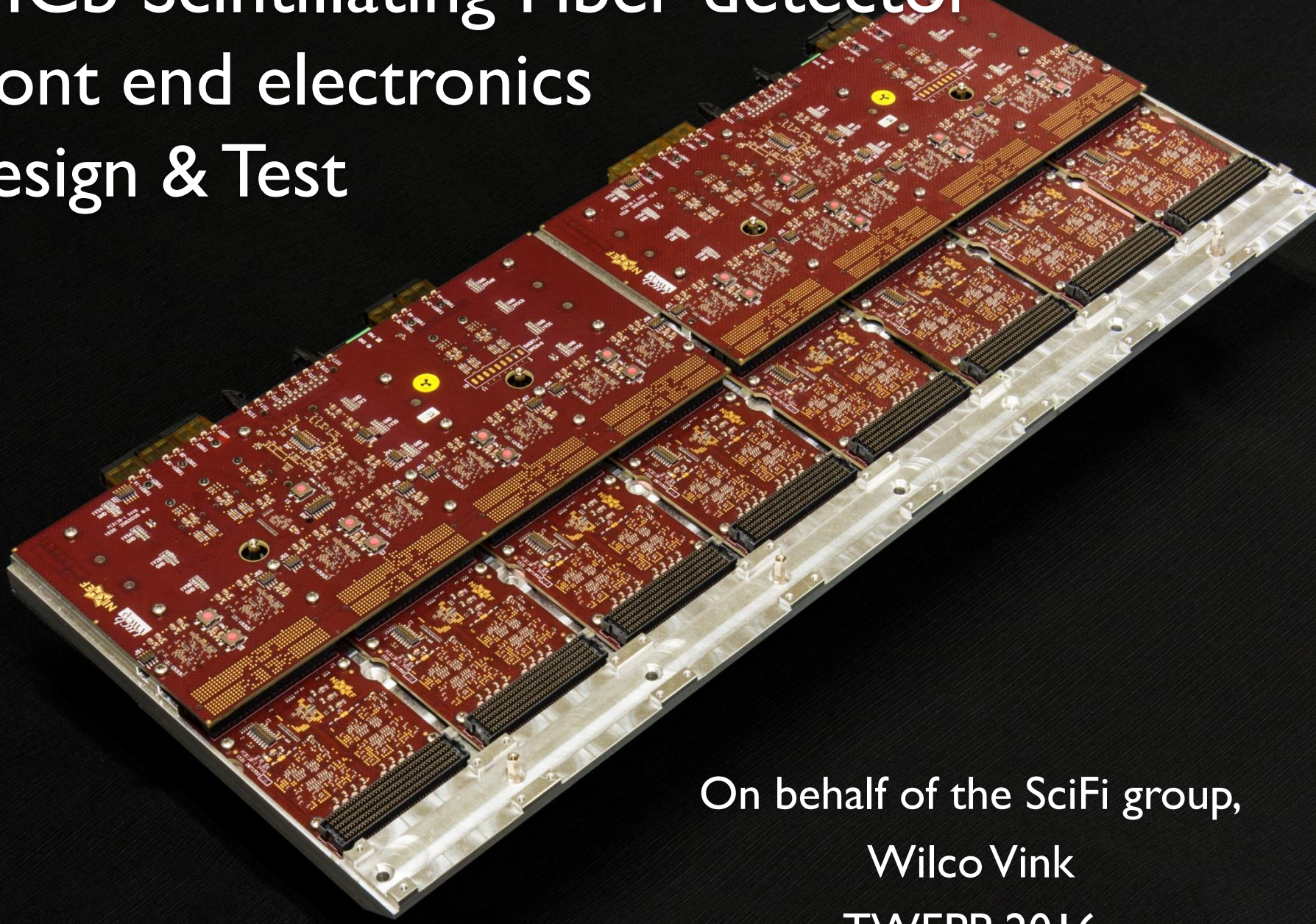
LHCb Scintillating Fiber detector Front end electronics Design & Test

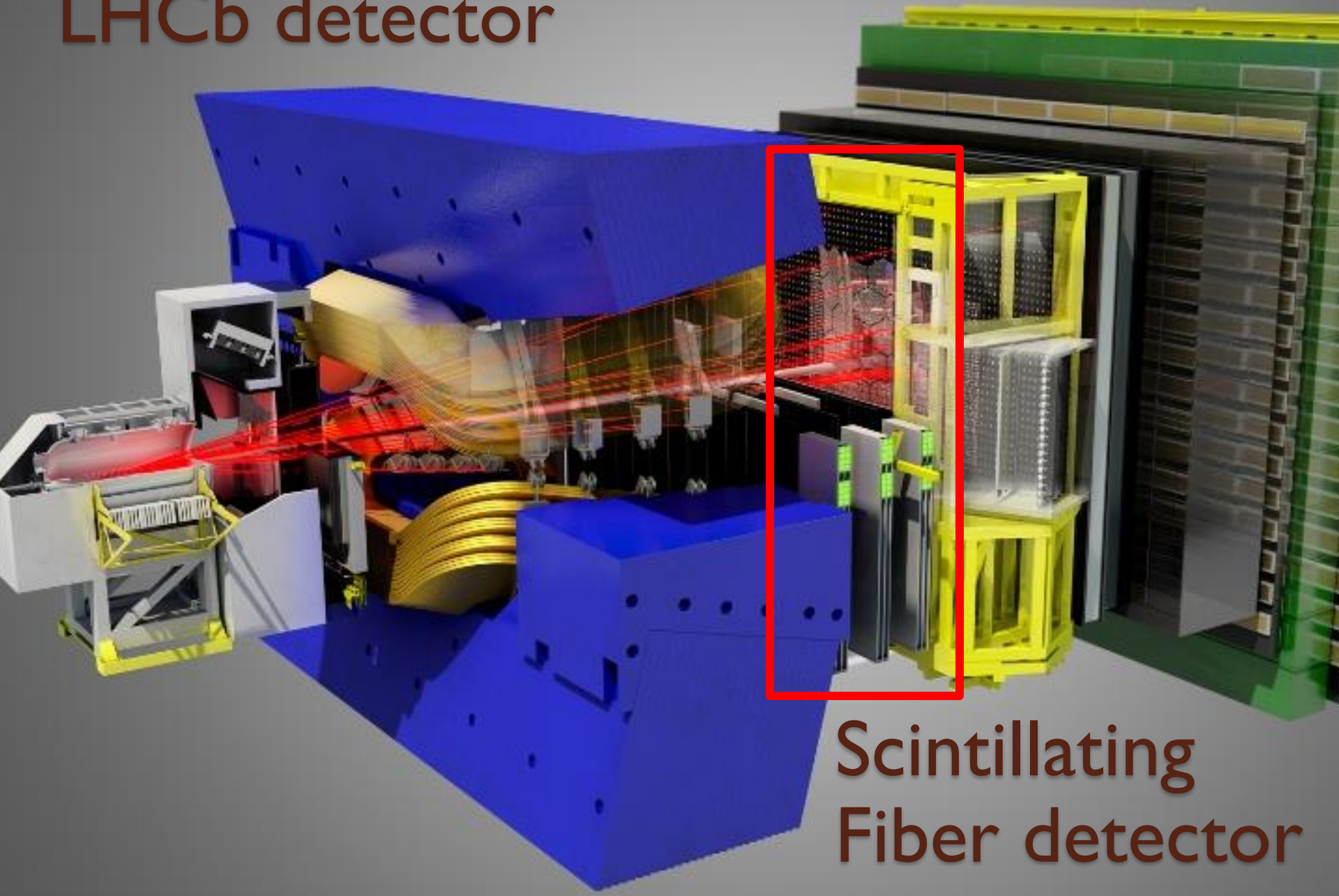


On behalf of the SciFi group,
Wilco Vink
TWEPP 2016

Outline

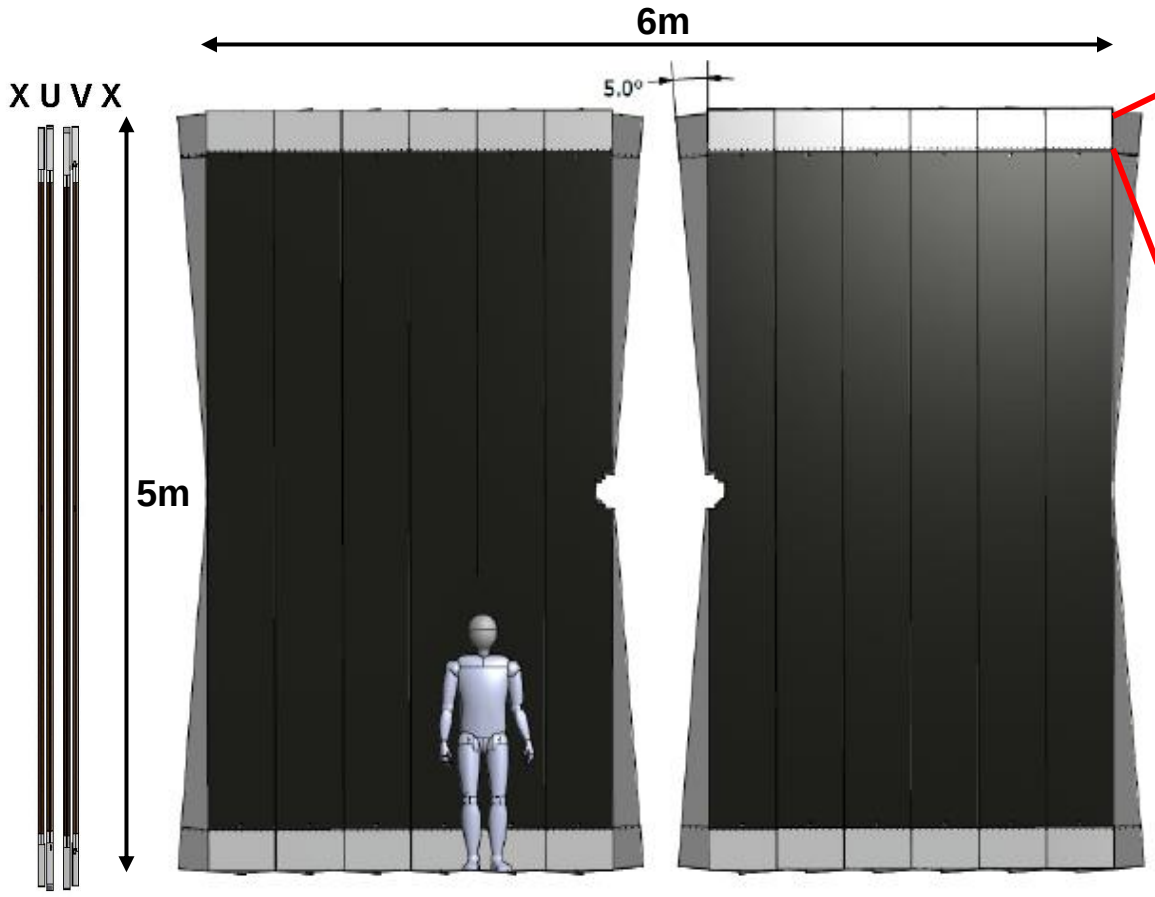
- LHCb SciFi detector overview
- The various boards in a Read Out Box
- Design, production and test of the prototype PCBs
- Front end electronics test system

LHCb detector

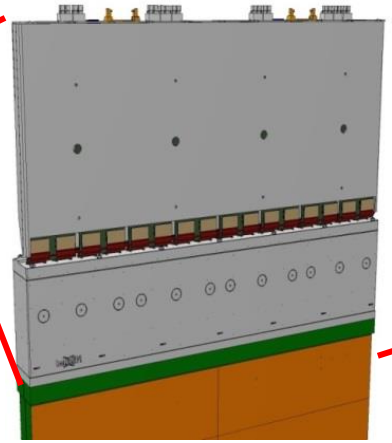


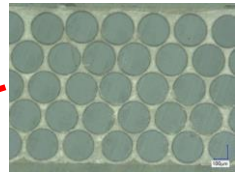
Scintillating Fiber detector

Scintillating Fiber Detector (SciFi)



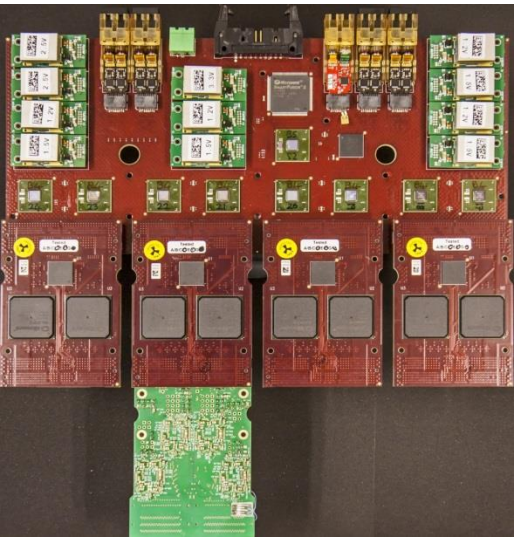
One station

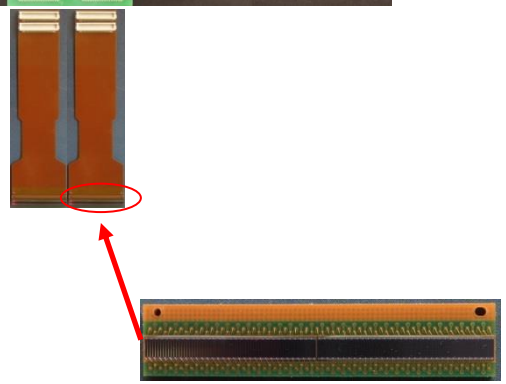


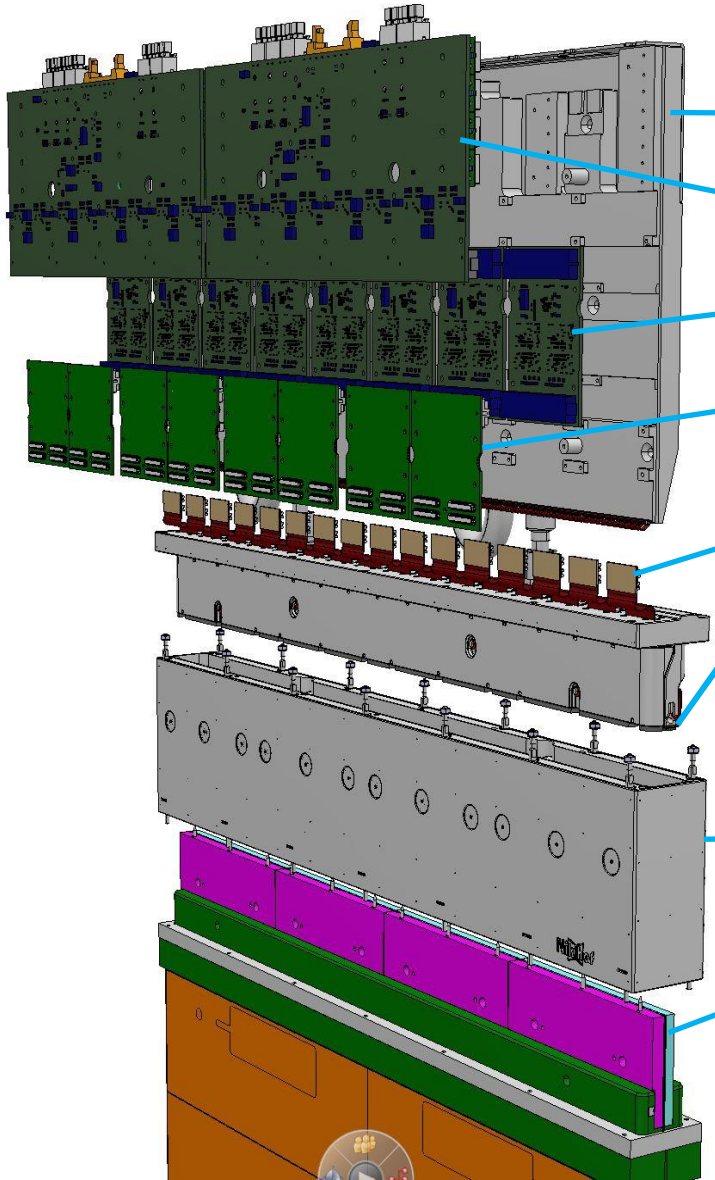


- 3 stations x 4 detector planes
- 24 modules and Read Out Boxes per plane
- 250 um thick, 2,5 m long scintillating fibers
- Mirror in the middle

Exploded view: Read Out Box (ROB)







Cooling Plate

Master Boards

Clusterization Boards

PACIFIC Boards

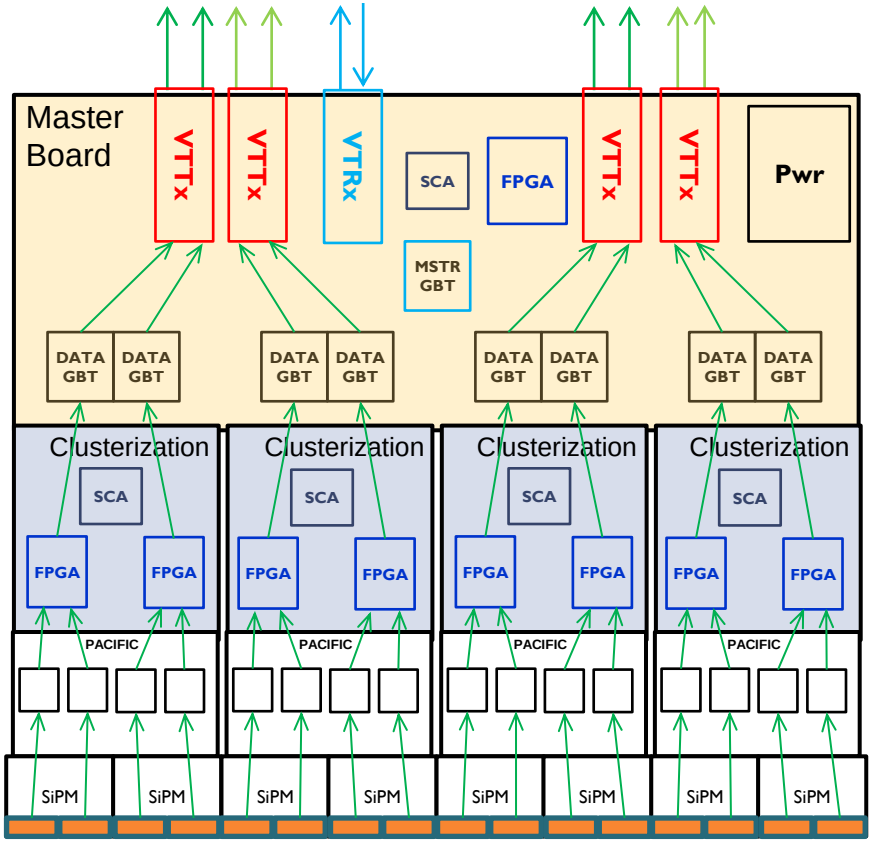
SiPMs on flex cables

Cold box

Scintillating Fibers

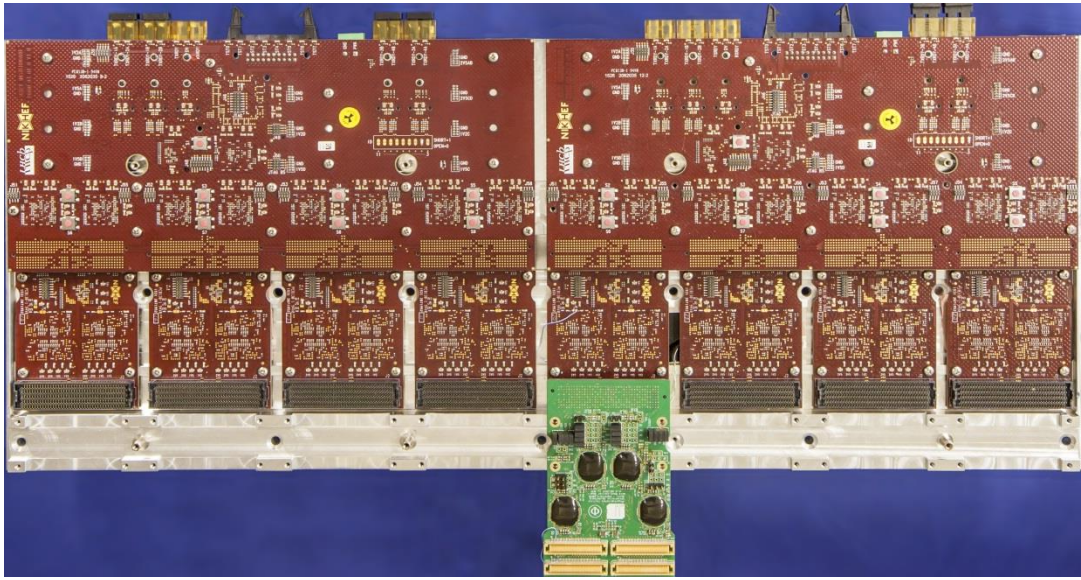
½ ROB electronics

- Master Board
  - Master GBTX → Timing, Fast and slow controls distribution
  - Data GBTXs → Data serialisation
  - Power supplies (11 FeastMP modules)
  - Versatile link optical components
- Clusterization board
  - Microsemi IGLOO2 FPGA based Clustering algorithm
  - SCA for slow controls → Clusterization FPGAs and PACIFIC ASICs
- PACIFIC Board
  - Amplifier, shaper, integrator and ADCs, 2b/channel output based on three threshold values
- SiPM: Silicon Photo Multiplier modules
  - 2 arrays of 64 channel avalanche photodiodes



Some numbers

- 288 Read Out Boxes:
  - 2 Master Boards
  - 8 Clusterization Boards
  - 8 Pacific Boards
  - 16 Silicon Photo Multipliers (SiPMs)
- Total:
  - 576 Master Boards
  - 2304 Clusterization and Pacific Boards



How can we produce and test the electronics?

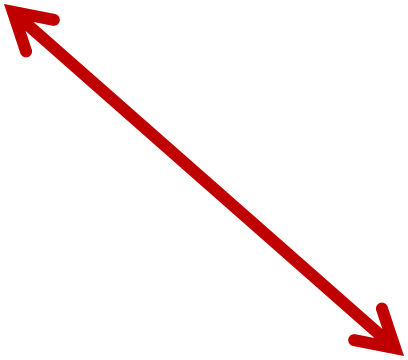
Board and system testability

- Optimize PCBs and PCBAs for production
  - Design For eXcellence (DFX)
    - Early design involvement

- After the ROBs electronics have been assembled we test them with a full functional tester before mounting them on the detector

Design For eXcellence (DFX)

- Manufacturability
- Minimize cost
- High first pass yield
- Re-produceable
- Highly testable (electrical)
- Reliable product
- Early Feedback
- Process efficiency

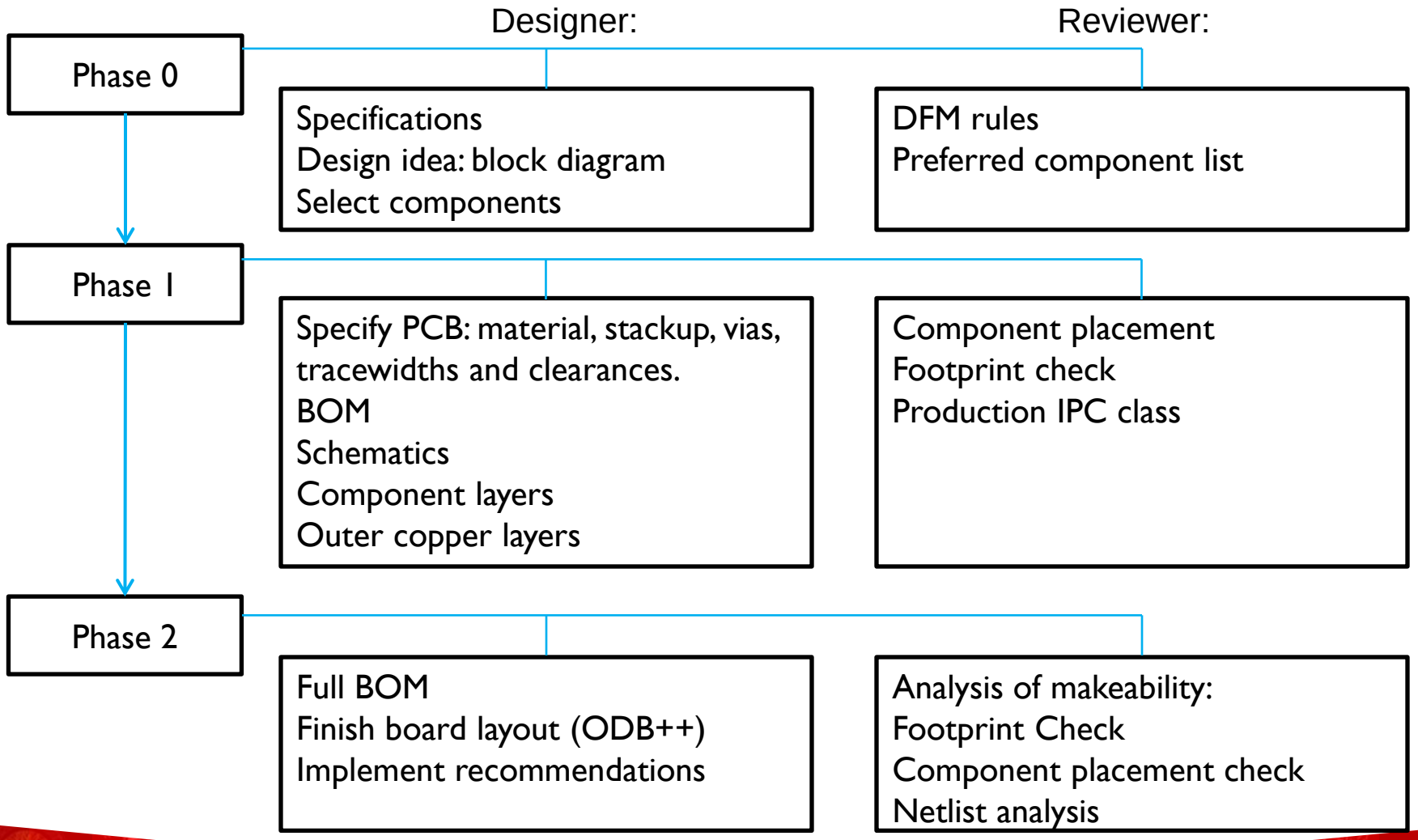


- Design For Manufacturability (DFM)
- Design For Testability (DFT)

PCB Design : DFM

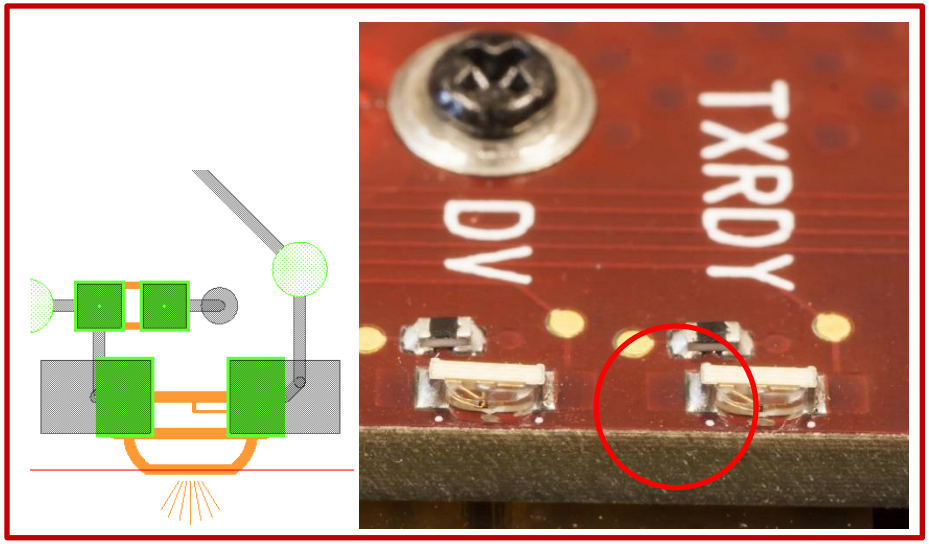
- Design For Manufacturability (DFM)
  - Design with many nets: ten 400 pins 0,8mm pitch BGAs and four 400 pins high pin count connectors
  - High density of 0402 parts under BGAs
- Board design: component placement and footprints optimized for assembly process
  - Minimize the risk of errors during assembly
  - Minimize assembly stages → minimize the cost

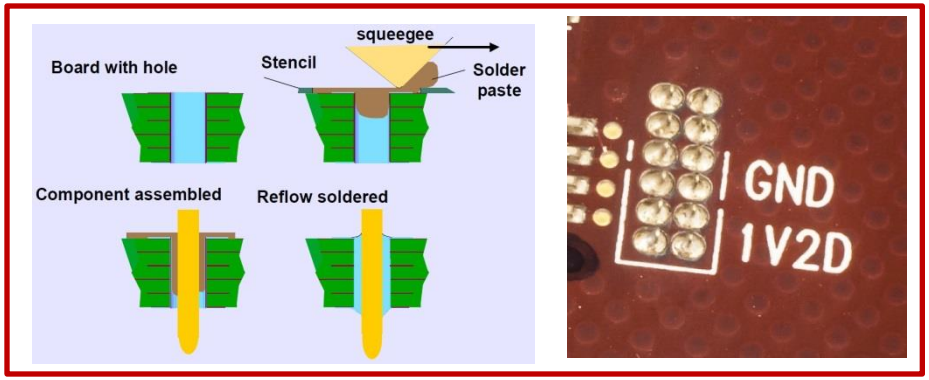
DFM design flow



DFM: lessons learned

- Design improvements due to DFM analysis
  - PCB specifications in cooperation with manufacturer
  - Changed footprints of some components
  - Use Pin In Paste(PIP) for through hole components → no wave soldering needed



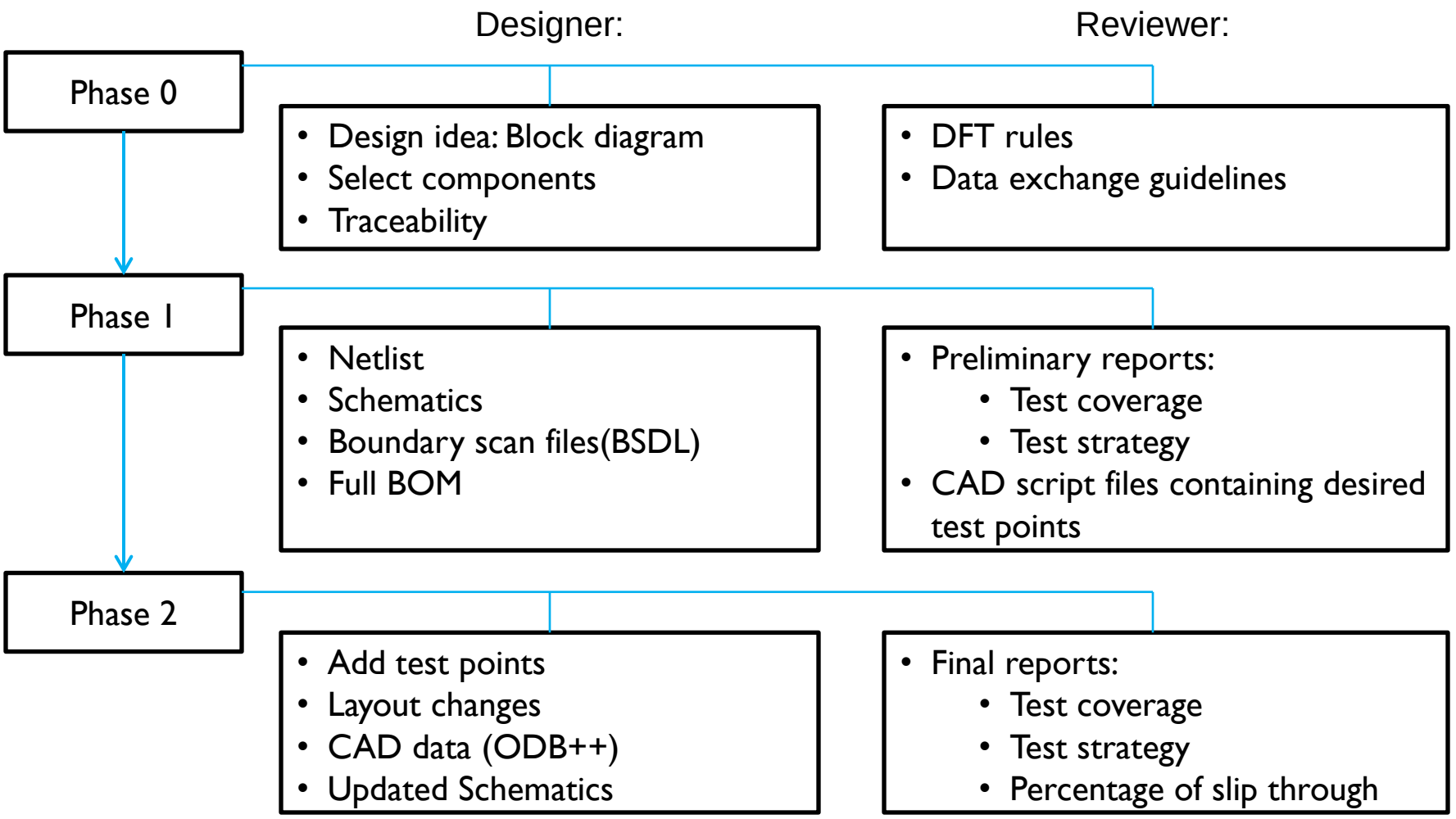


Design For Test (DFT):

- DFT
  - Design optimized for test during & after assembly
    - Optimize for test connectivity between Boundary scan capable devices
    - Place test points for probe access, when not possible component pads can be used

- DFT checks during and after assembly:
  - 3DAOI : 3D Automated Optical Inspection
    - Optical inspection at three different stages of the assembly process, after:
      - applying paste
      - component placement
      - reflow soldering process
  - Automated X-ray inspection(AXI)
  - Flying probe test
    - Test electrical connections and component values
  - In Circuit Testing(ICT)
    - Dedicated needle card
  - EBST : Extended Boundary Scan Test
    - Test electrical connections between components. Active loopback board(s) are used for routing to connectors.

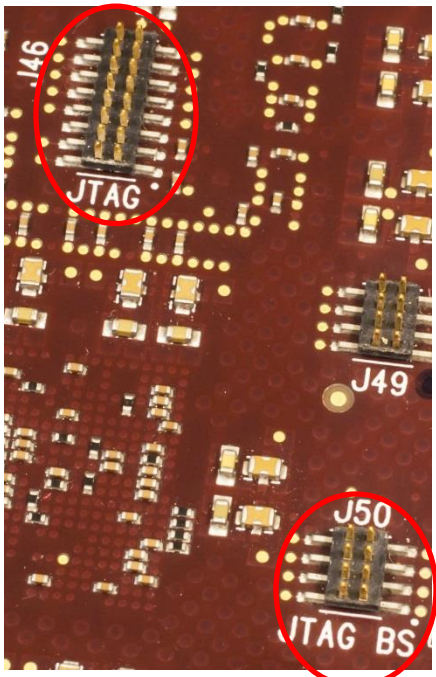
DFT design flow

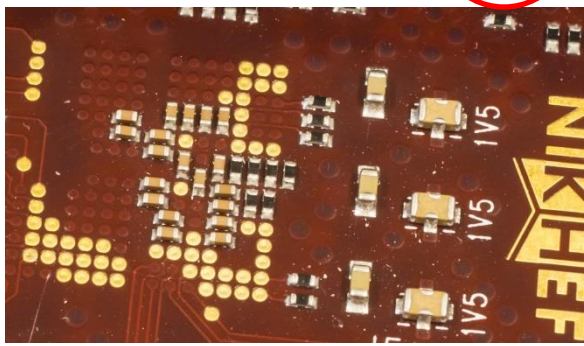


DFT: lessons learned

- Applied changes for DFT:
  - Two JTAG chains
    - One for remotely re-programming the FPGA and for BS
    - One additional BS chain for 9 400 pins BGAs
  - Test points for flying probe access, minimized the usage of component pads for test access.

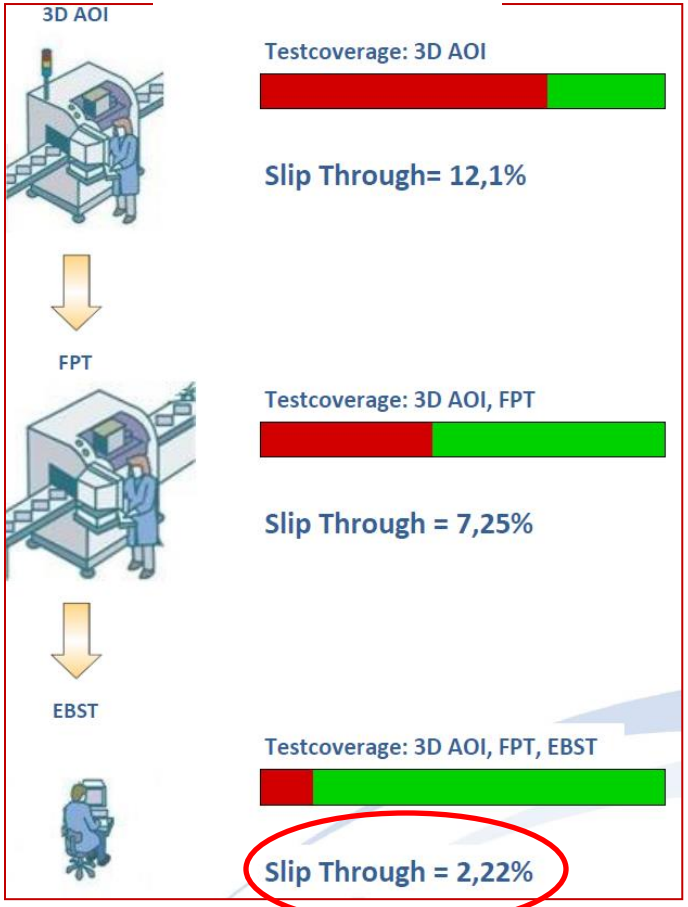
- Advised Test strategy:
  - 3DAOI : 3D Automated Optical Inspection
    - Optical inspection at three different stages of the assembly process, after:
      - applying paste
      - component placement
      - reflow soldering process
  - Flying probe test (FPT)
    - Test electrical connections and component values
  - EBST : Extended Boundary Scan Test
    - Test electrical connections between components. Active loopback board(s) are used for routing to connectors.



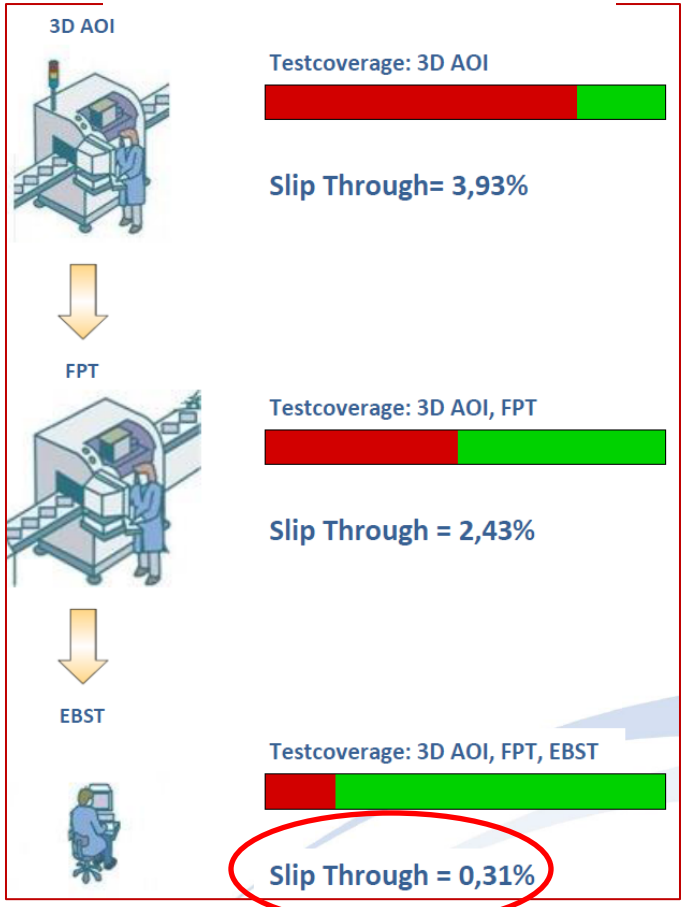


DFT reports

Master Board

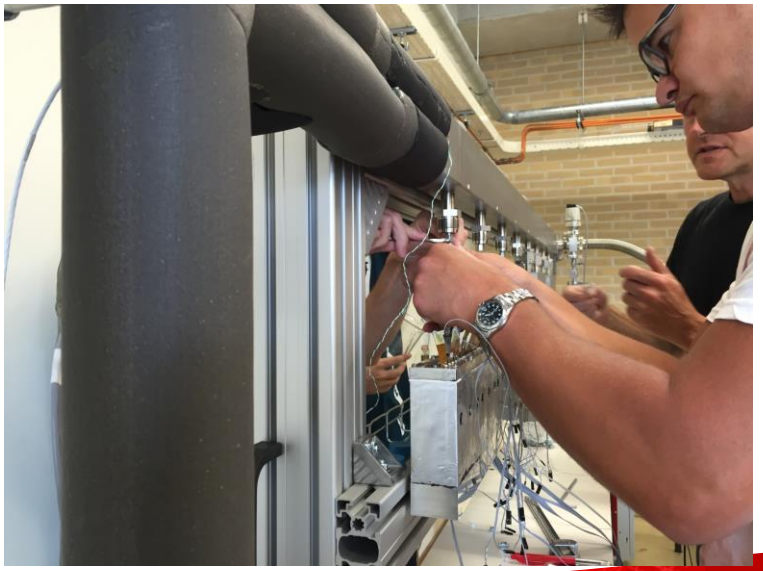


Clusterization Board



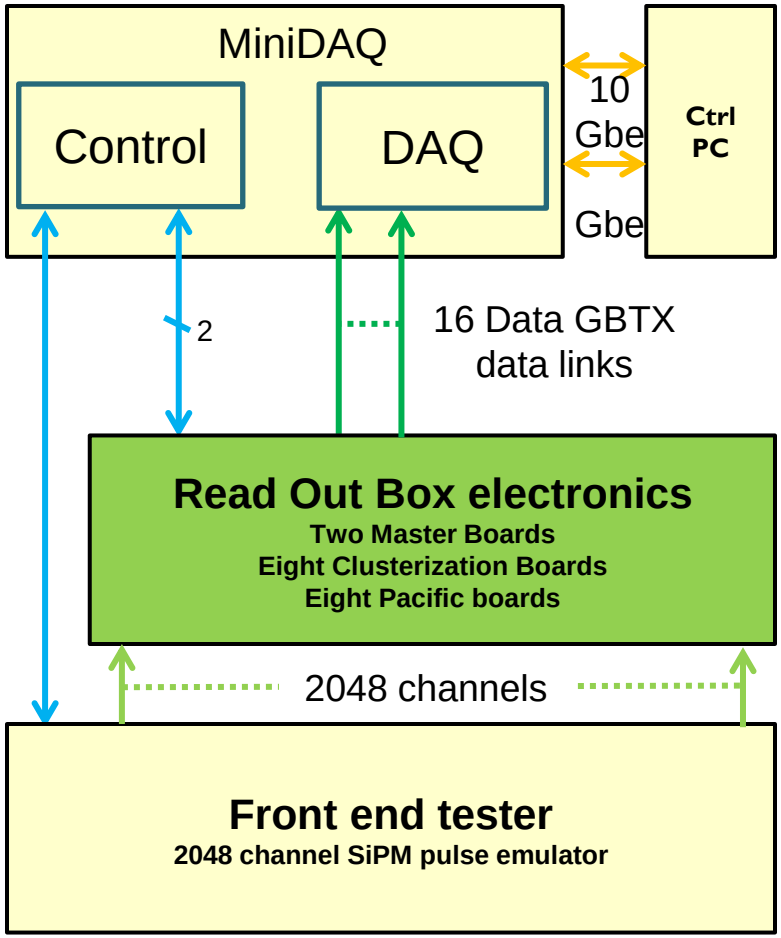
ROB tester

- Full functional tester of the ROB electronics
  - The electronics will be mounted at the detector frame on top of the coldbox
  - Sixteen SiPM flexcable connections between electronics and cold box
  - Full functional test is required prior installation of the electronics, therefore we are designing a **front end tester** to inject individual test pulses at all 2048 channels of a ROB



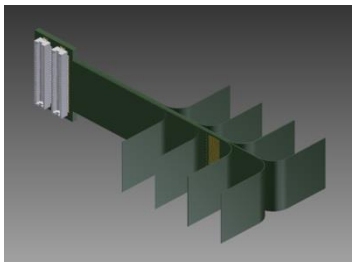
ROB electronics full functional test

- Full functional test of the ROB electronics
- Based on standard LHCb control and readout via MiniDAQ. Both hardware and software
- Front end tester:
  - 2048 injector circuits for individual pulse injection
  - Design challenges
    - Tuneable SiPM pulse emulator
    - board space required per channel does not fit the available width 512mm

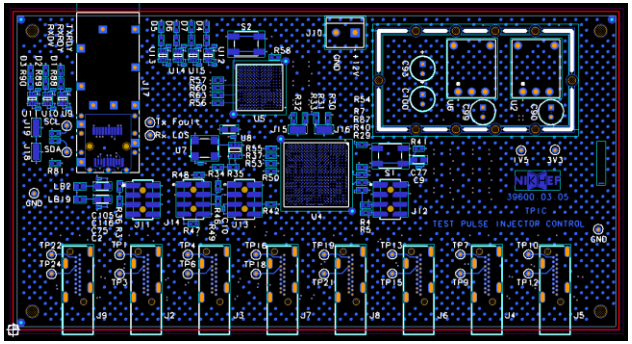


Front end tester

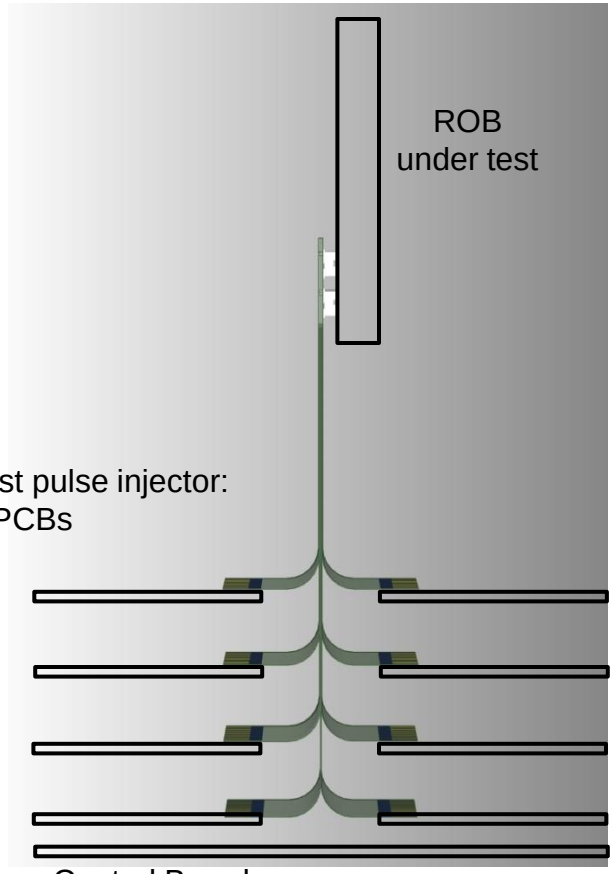
- Two types of boards and a flex cable to connect the ROB under test
  - Eight pulse injector PCBs developed, 256 pulse injectors per board
  - Control board based on the same electronics as our front end board to be able to reuse control software
  - GBTX and GBT SCA chipset, Controls distributed via eight cables to pulse Injector boards
  - 16 Flex cables, each cable fan-out 128 inputs to eight boards which each 16 pulse injectors



3D image of the Flex cable



Test Pulse Injector Control board(TPIC)
84 x 160 mm;



Conclusion

- Boards can be mounted in the Read Out Box after assembly
  - Not needed to test them individually
- Full functional tester in development
  - Used to test ROBs after assembly, and a second time prior installation on the detector.
- The percentage of slip through fits in the number of spares, which gives us the ability and time to further investigate and repair faulty boxes

Thanks for your attention!

Acknowledgements:

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