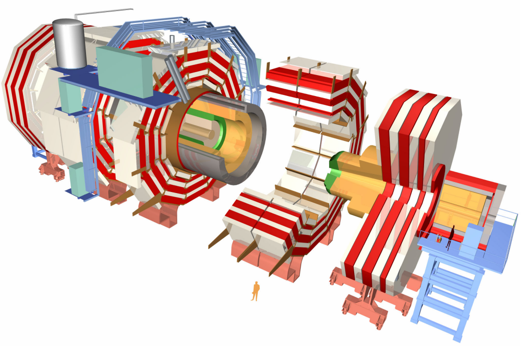
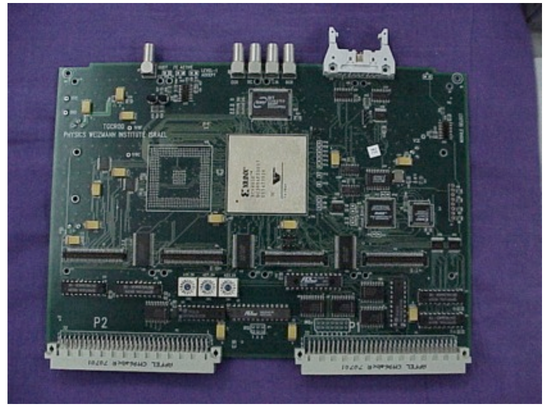
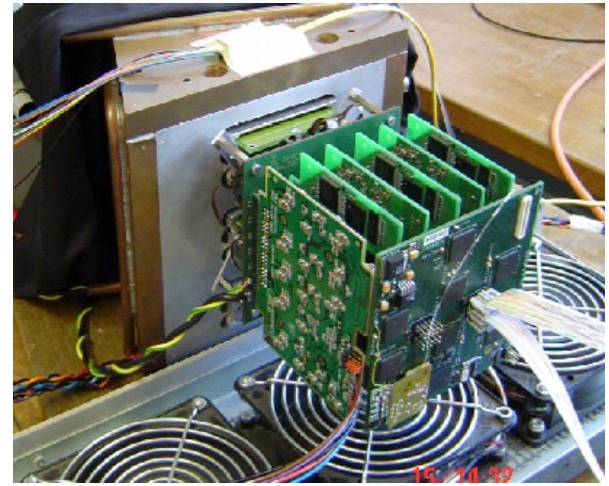


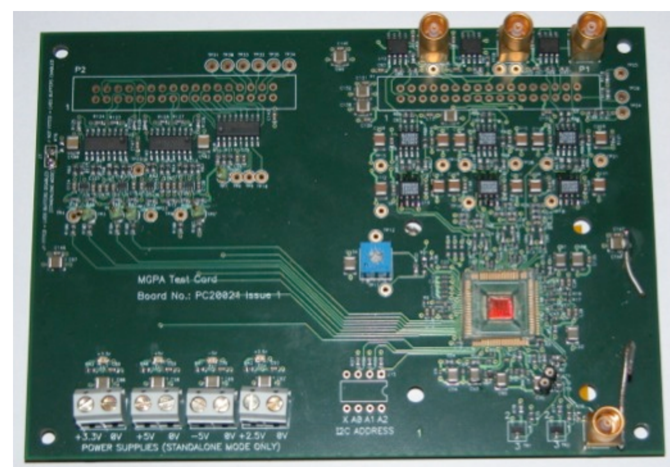




Electronics procurements

24 October 2014

Geoff Hall



Procurements from CERN

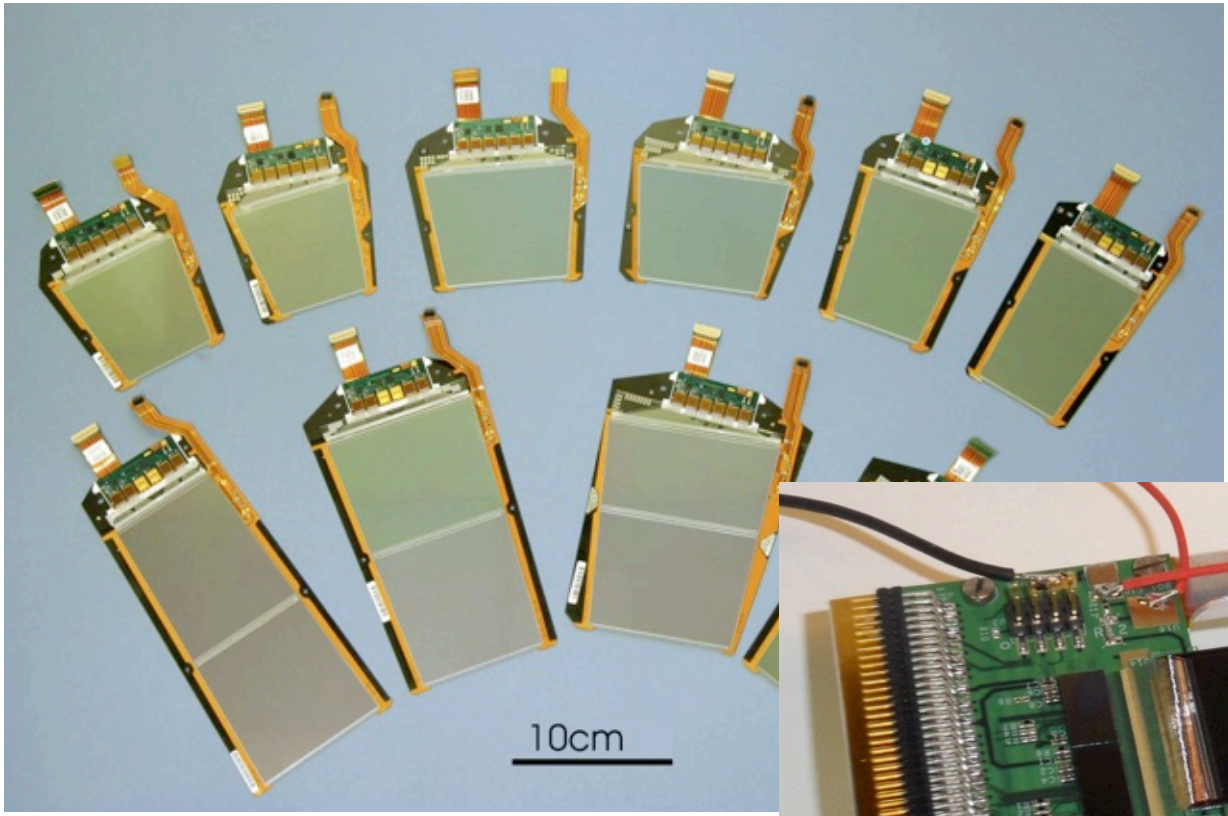
- There are a wide range of electronics items procured by CERN
  - but we are familiar with only some of them
- Probably two main categories:
  - for experiments: mainly, but not only, LHC where users and CERN staff are building their experiments
    - mostly customised items, specific to the project
    - but also less customised parts, such as power supplies, controls, crates, optical links
  - for accelerators:
    - we are less familiar with their requirements, and may be even larger than experiments
    - some of it does resemble experiment procurements, i.e. customised, often located in radiation zones
    - other parts are probably more standard, such as PS, controls, etc

Experiment requirements

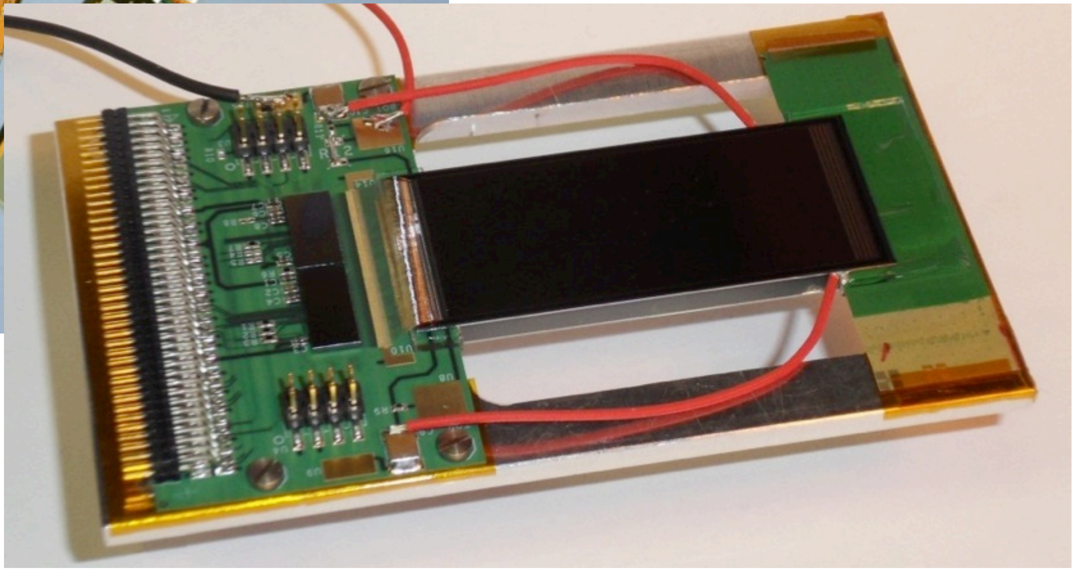
- Use examples from CMS – only time for a few illustrations
- Several types of electronics purchases, including:
  - custom integrated circuits (ASICs) – radiation zone
    - sometimes packaged, or custom assemblies
  - multi-layer hybrids (electromechanical support for ASICs) to attach to sensors – radiation zone
  - board-based (VME/µTCA/ATCA/…) off-detector digital electronics
    - heavy use of FPGAs, processing and control functions
  - data transmission via high speed optical links, and electrical assembly
- We are by no means responsible for all of them!
  - but hopefully can provide some insight, or links to contacts
  - several technical experts present today

Silicon tracker detectors

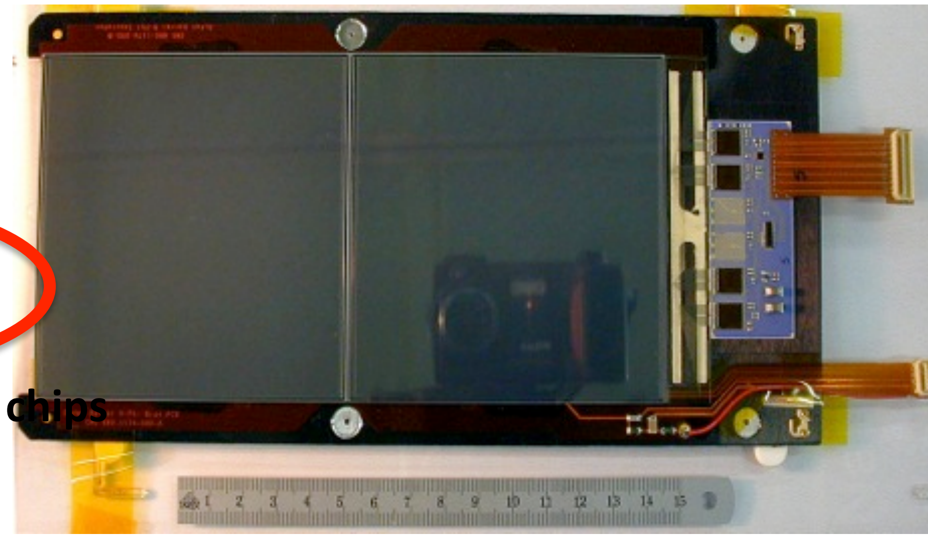
- Very large systems in CMS, ATLAS and also LHCb and ALICE

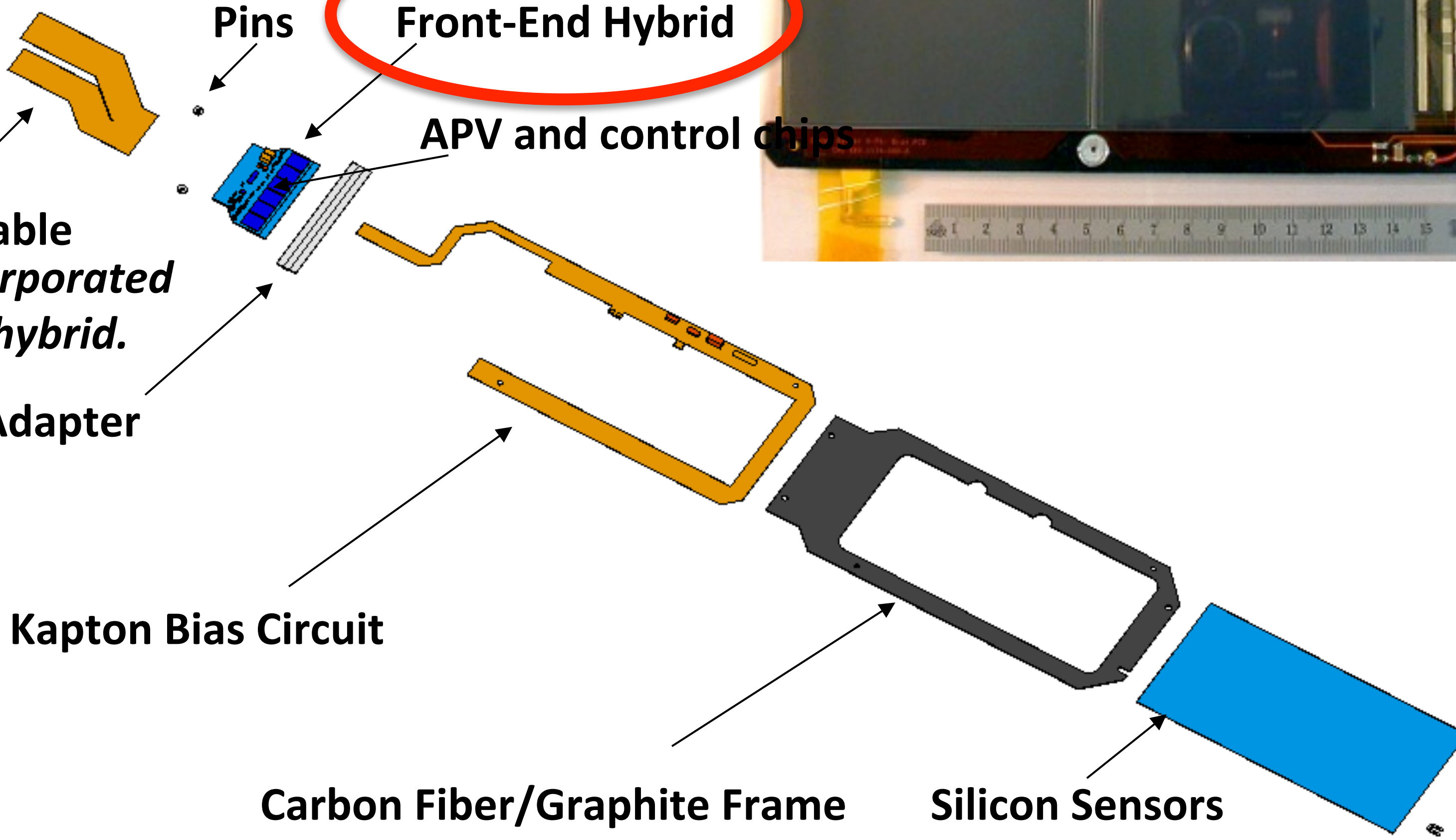


p-n diode arrays, finely segmented into microstrips (pitch ~100μm) assembled into modules with ASICs

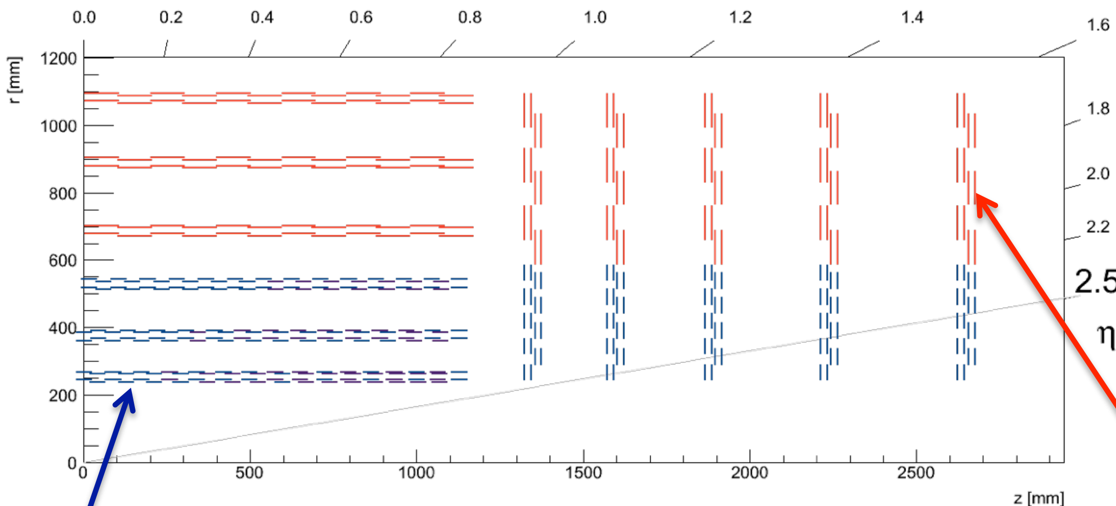


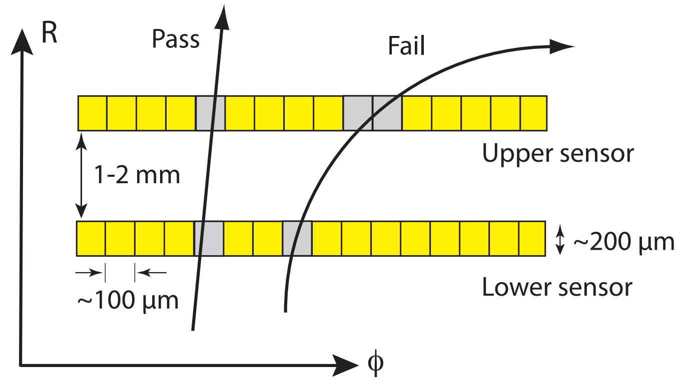
Typical module components





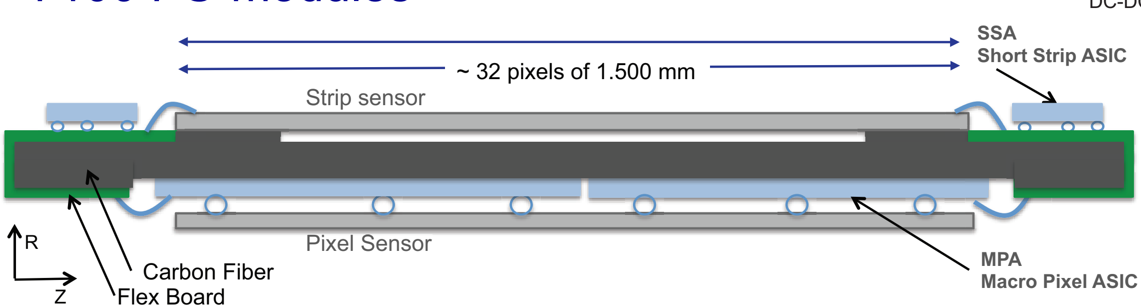
New types of module under development

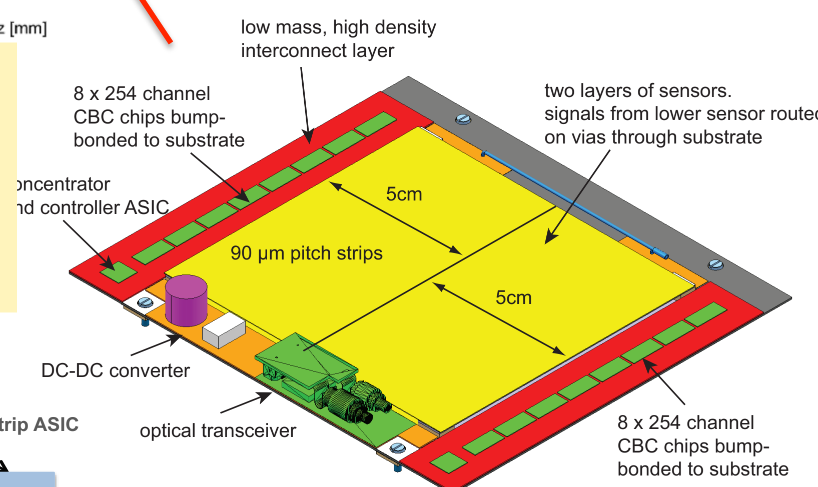




- ~15000 modules transmitting
  - p_T-stubs to L1 trigger @ 40 MHz
  - full hit data to HLT @ 0.5-1 MHz

~7100 PS-modules

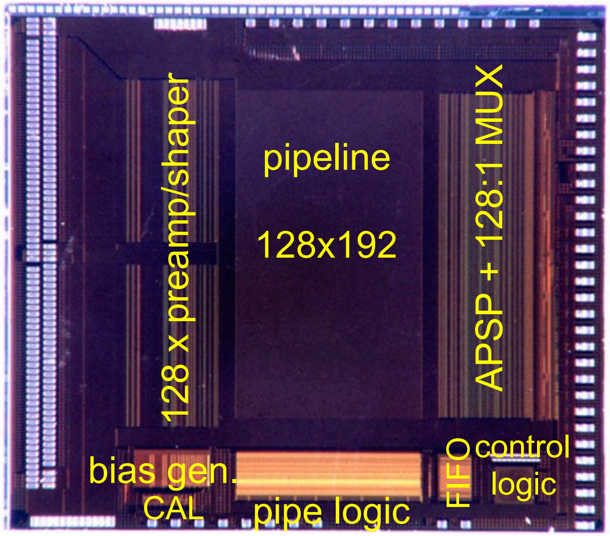




~8400 2S-modules

CMS Tracker ASIC evolution

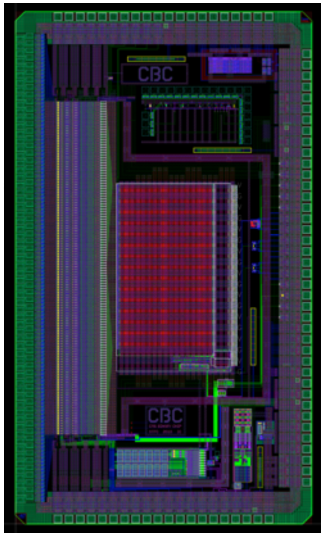
- 1999: APV25 0.25µm
  - 7 mm x 8mm (128 chan)



programmable settings (now standard)
analogue data
~4 µs latency
wire-bondable
pulse-shaping choice

2011: CBC 0.13µm

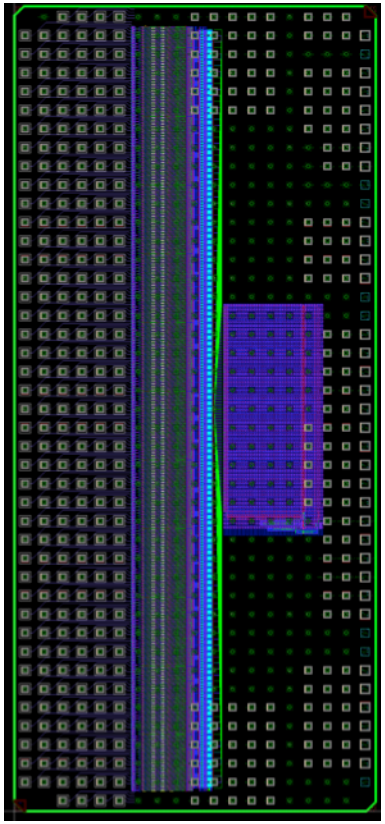
7mm x 4mm (128 chan)



binary data,
6.4 µs latency
wire-bondable

2013: CBC2 0.13µm

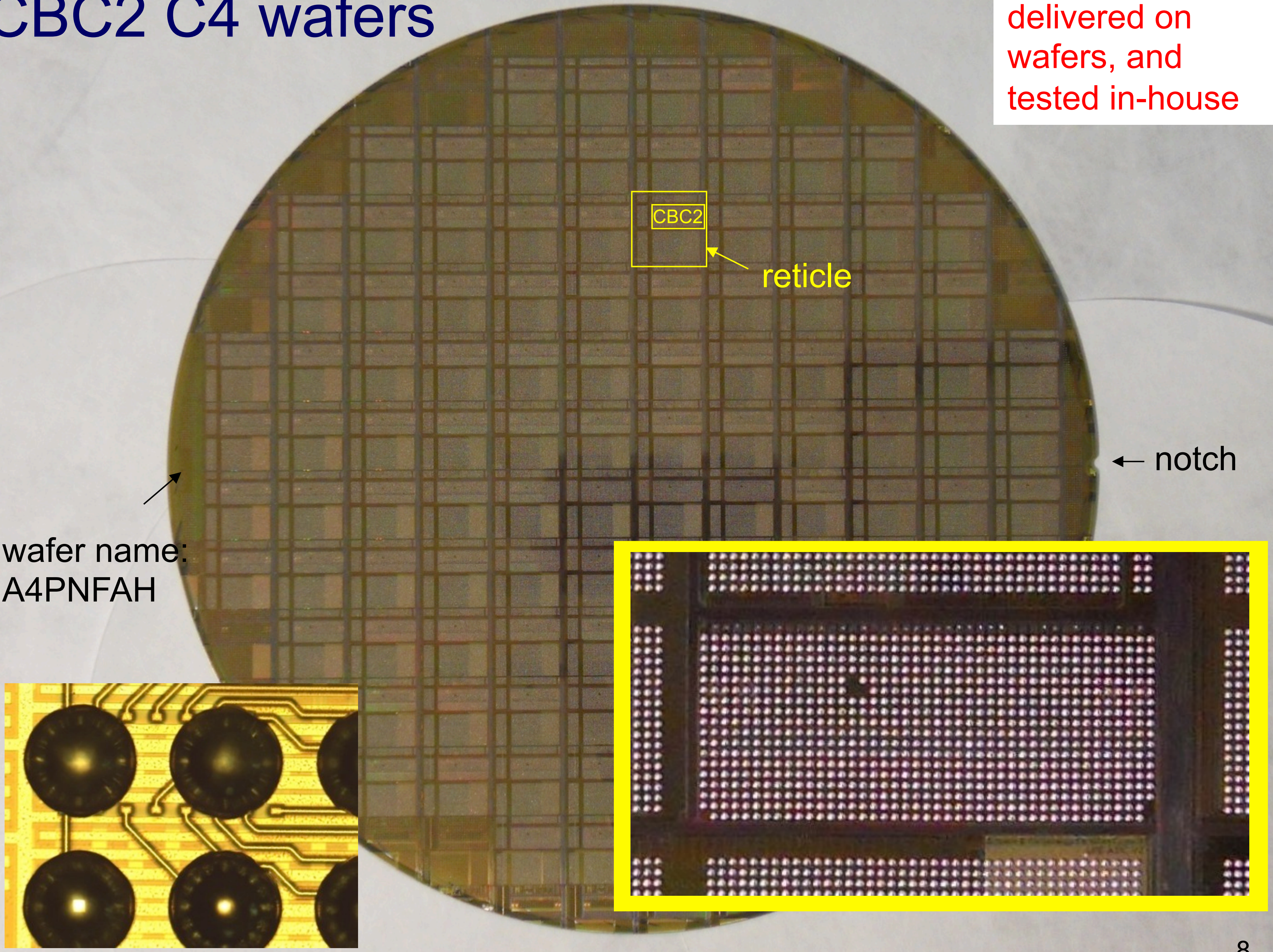
11mm x 5mm (254 chan)



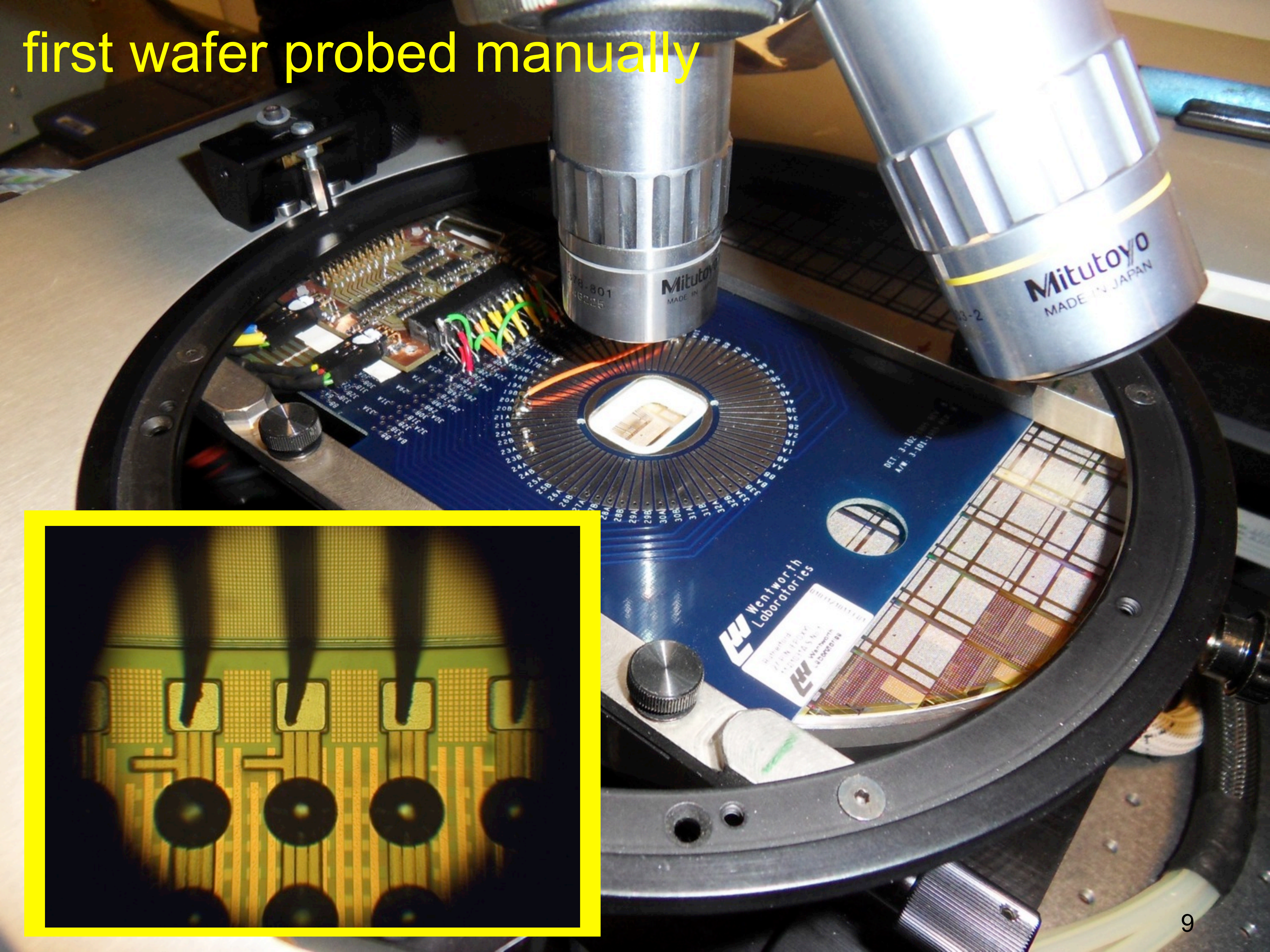
bump-bondable,
cluster & correlation logic

CBC2 C4 wafers

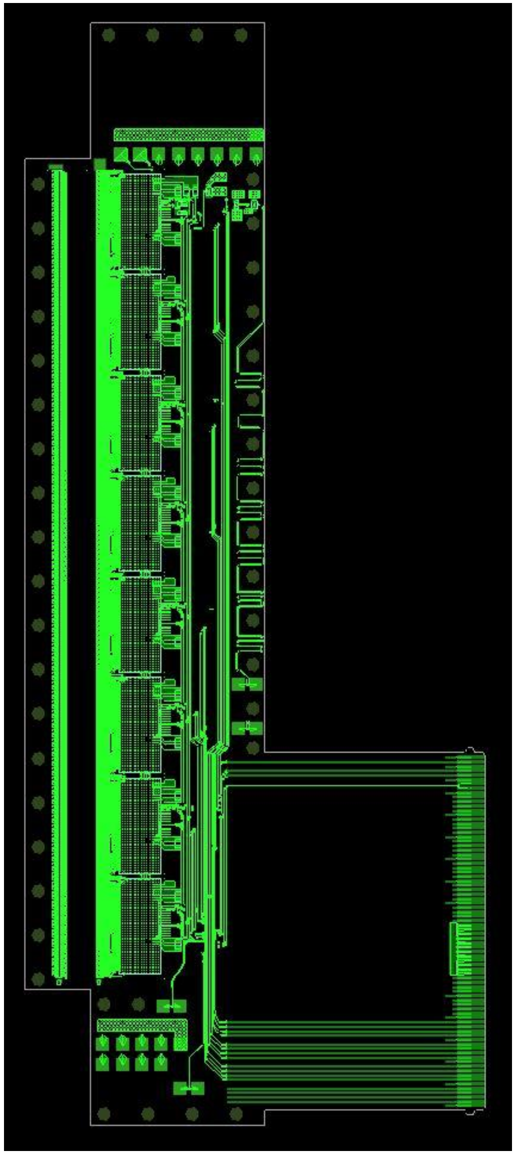
delivered on
wafers, and
tested in-house



first wafer probed manually



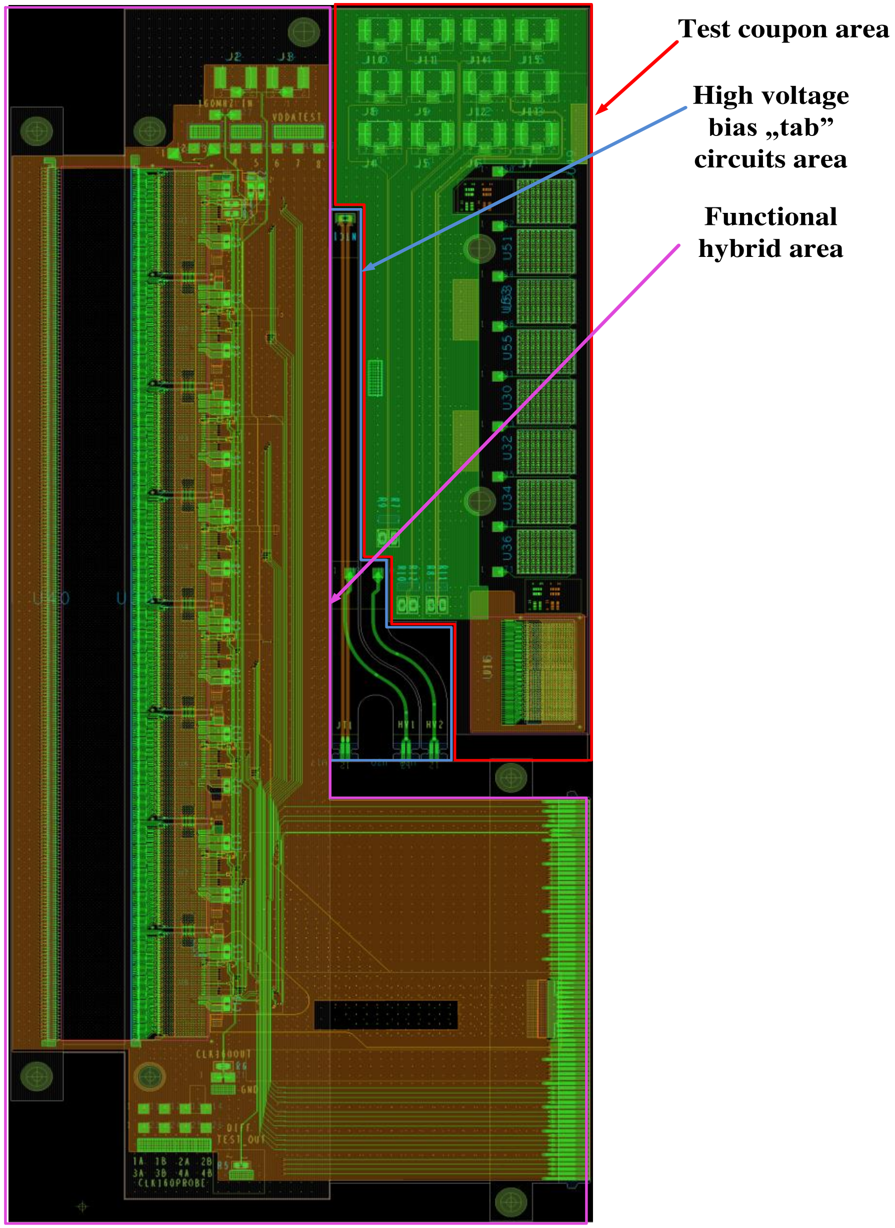
More advanced hybrids



Existing prototype

- **The existing 8CBC2flex design has been produced by AEMtech-SwissPCB consortium successfully.**
- **The flexible substrate with fold-over is proved to be a feasible solution for 2S readout.**
- **The prototype is designed for 1,8mm sensor spacing.**
- **Few observations for improvement (fold over length, alignment holes, fiducials...)**
- **A GLIB test system have been developed with a suitable interface card connecting to the FPC ZIF connector**

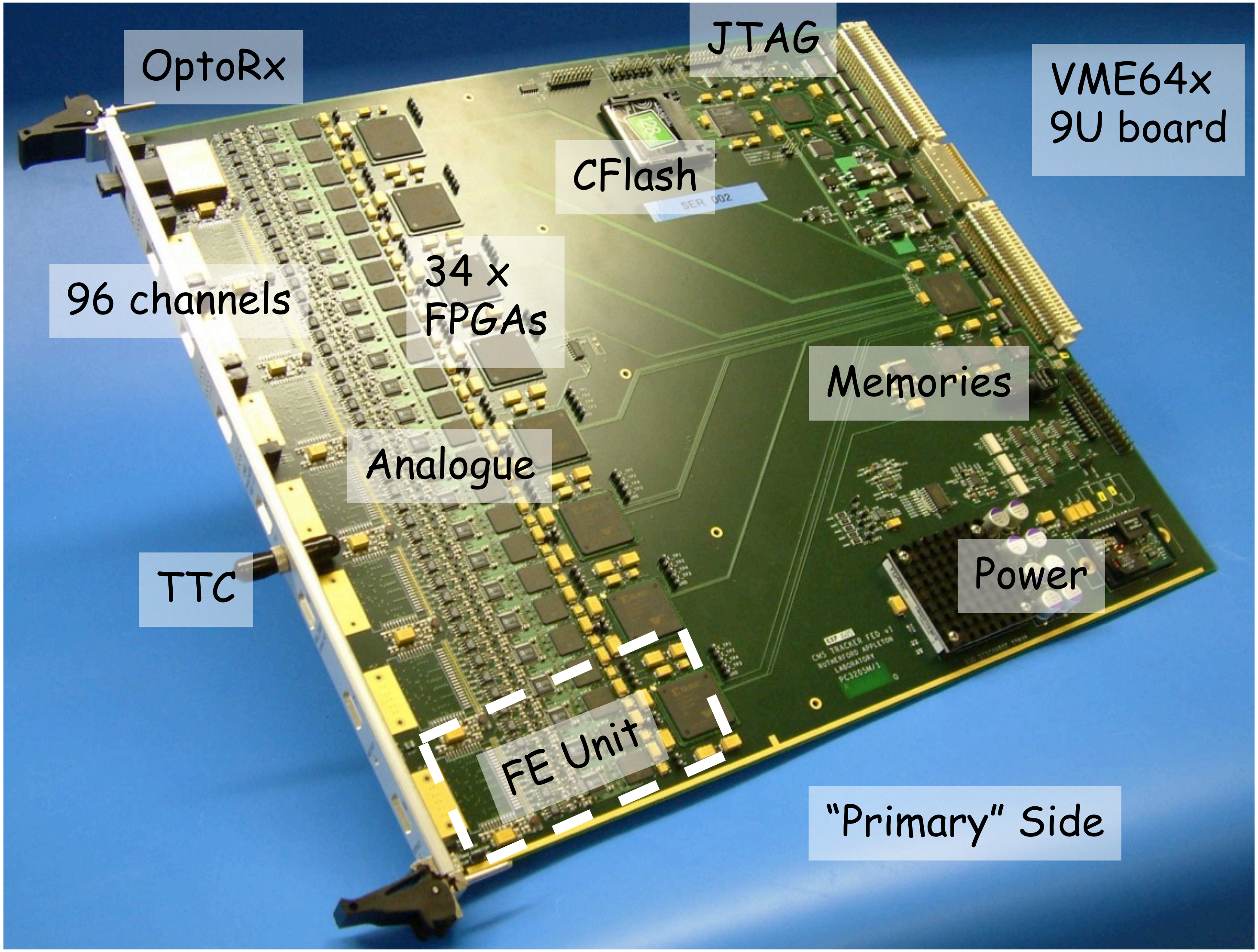
Some requirements



- Fine pitch
- dense layout
- multi-layers
- impedance control
- …

Supplemented by off-detector digital boards…

- typical of many other CMS modules



MP7 (Virtex-7 XC7VX690T)

future generations will improve, but don't yet know precisely how

purpose-built µTCA card for CMS upgraded L1 calorimeter trigger

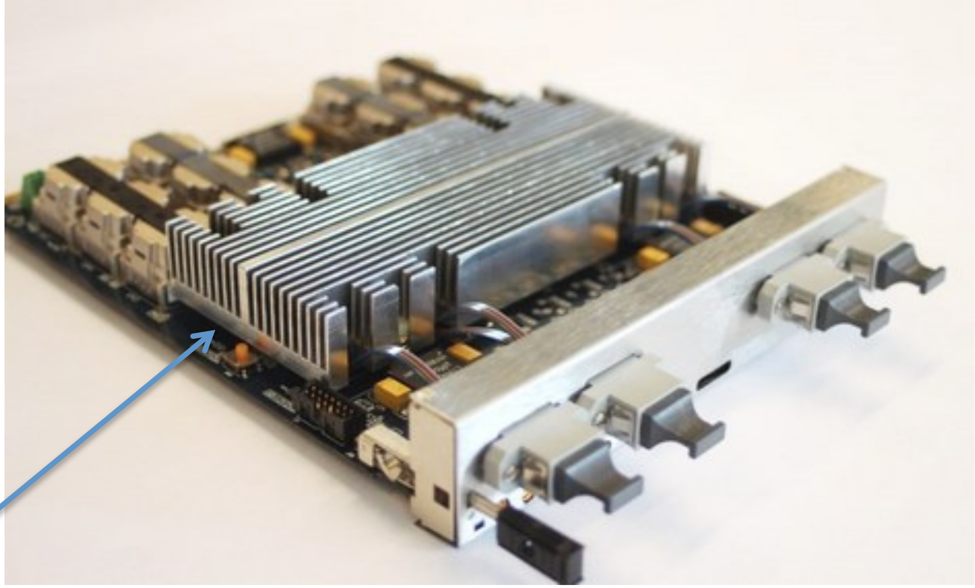
TM performance & calo algorithms demonstrated in recent integration tests

- **72 input/72 output** optical links

-all links operate at 12.5 Gbps
(10 Gbps in CMS)

- total bandwidth **> 0.9 Tbps**

tested, currently in production

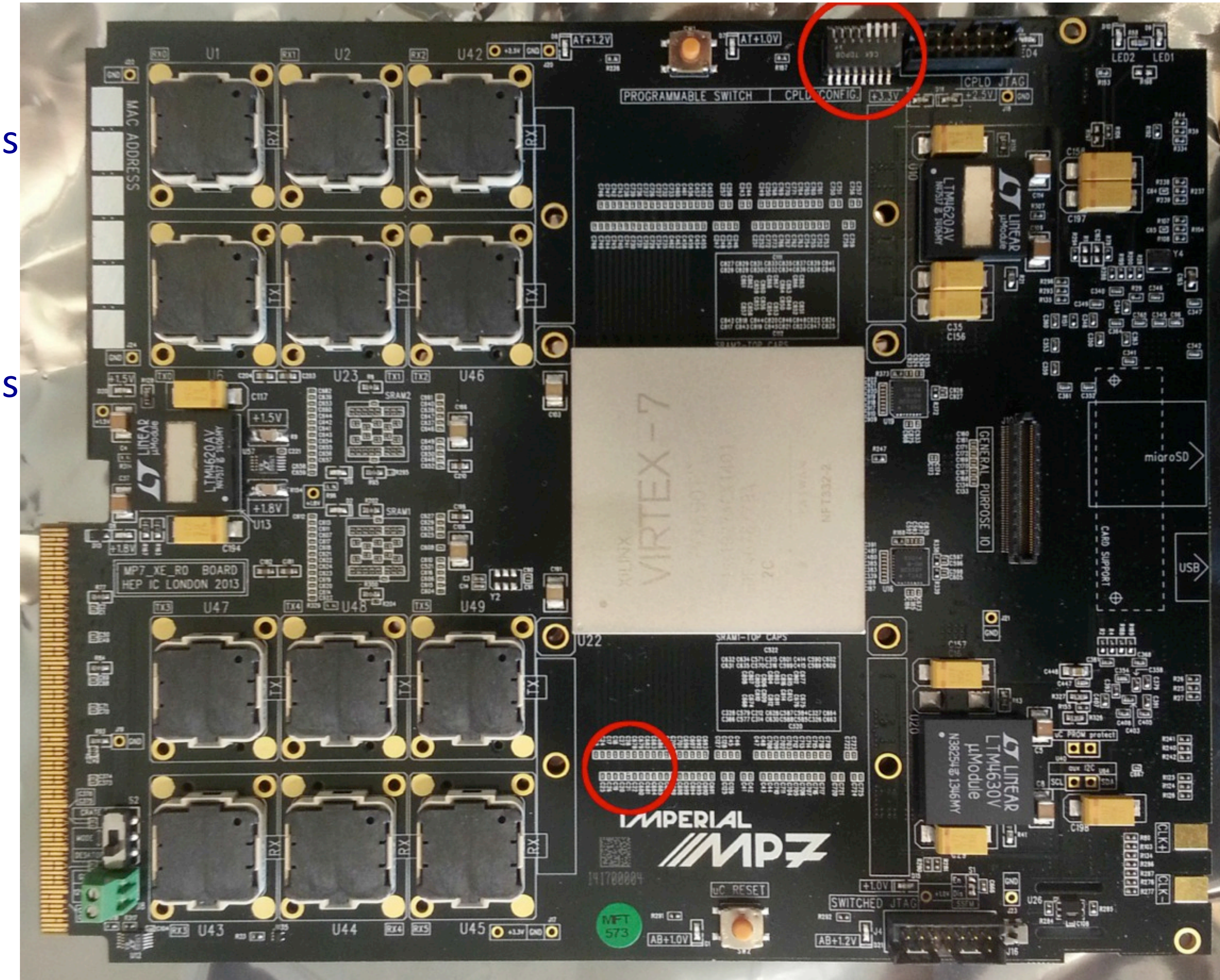


NB good cooling required!

G Iles et al

MP7 2013

- IN
- 72 x 12.5 Gbps = 0.9 Tbps
- OUT
- 72 x 12.5 Gbps = 0.9 Tbps
- flexible processing
- NB smaller form factor than 9U FED
- Power similar

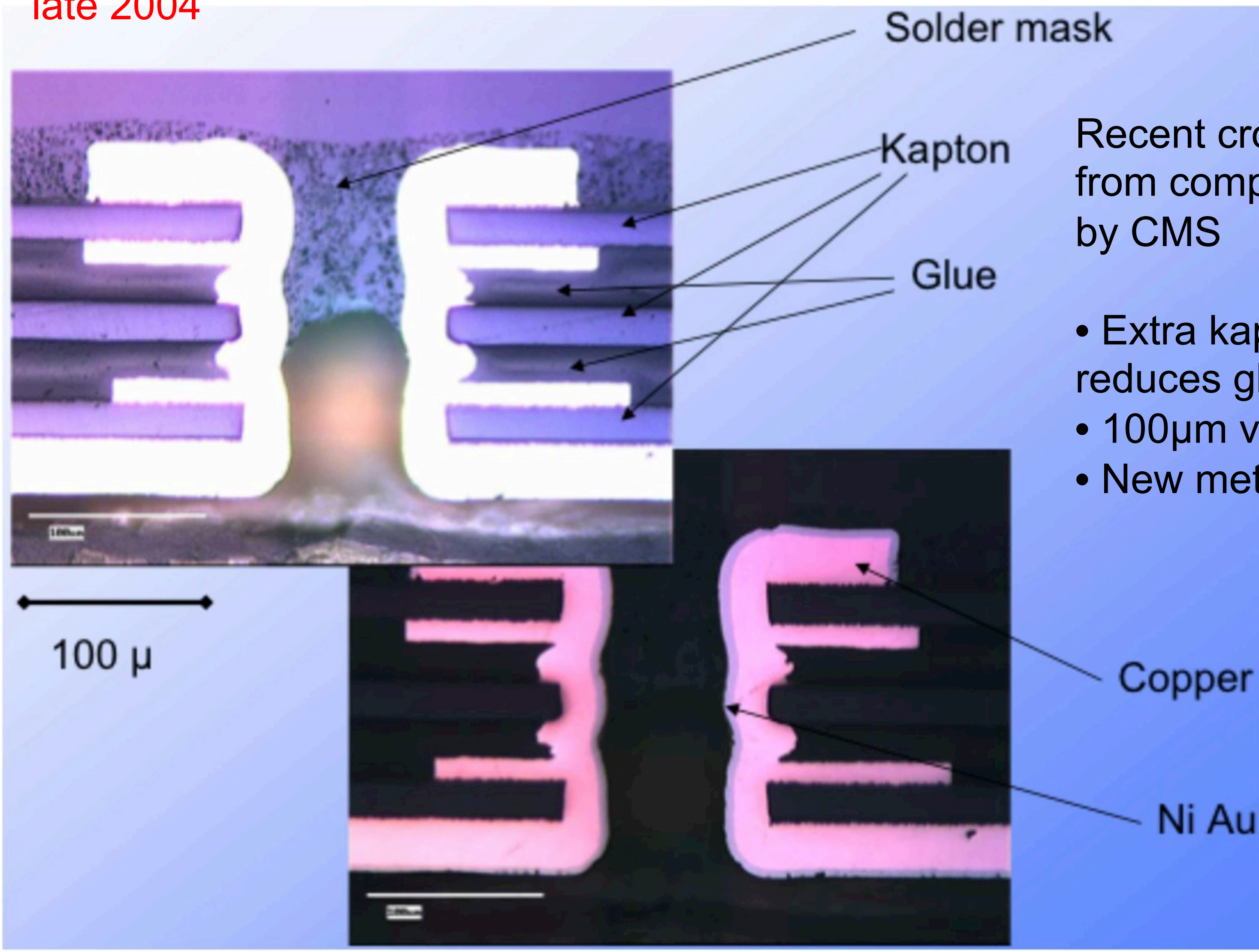


Not always problem-free

- Sensors: two major contracts with very different production quality
- Hybrids: flexible kapton-metal layer structure
  - subtle problems in through-via manufacture identified at late stage
- ASIC yield: variations after initial very good beginning
  - worked with company to understand and solve
- Cooling plant performance: manufacture weakness
  - failures in plant and components which could have had major repercussions
- QA issues – picked up by monitoring, in time
  - early attention to minor details is crucial to avoiding costly delays
  - all highly specialised items with few, or no, second sources

Hybrid cross-section – after actions

late 2004



Recent cross-sections from company, confirmed by CMS

- Extra kapton layer, reduces glue
- 100µm vias -> 120µm
- New metal process

FC7: design motivations (II)

principally designed with two CMS users in mind

- the **Trigger Control & Distribution System (TCDS)** –

  distribution of LHC clock, fast (e.g. trigger) and slow commands, reception of synchronous detector status,…

- the **Pixel Front End Driver (pixFED)**

  - – replacement front end board to acquire data from the upgrade pixel detector, to be installed in 2017;

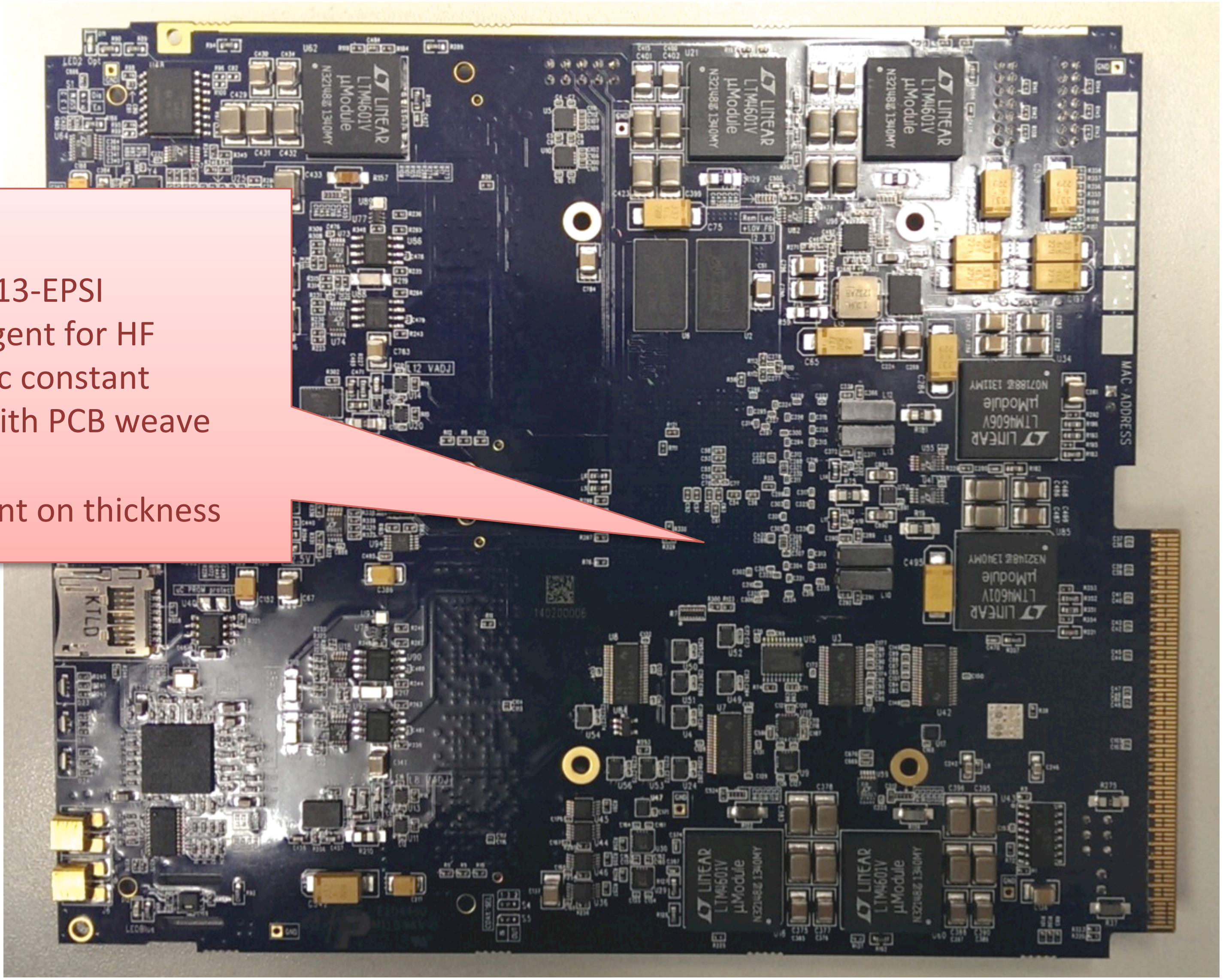
- compatibility with uTCA for CMS (AMC13)

- low jitter clock distribution & deterministic latency

- **capability to run 10Gbps SERDES links**

16 layer PCB
Nelco N4000 13-EPSI
- low loss tangent for HF
- low dielectric constant
-misaligned with PCB weave

strict constraint on thickness



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submitted prototype and pre-production series runs with two different manufacturers

- one well known to CERN/UK, one with no prior experience of
- experimented with two PCB materials compatible with the impedances & high speed signal integrity required

large fraction of development period dedicated to tracking down & resolving manufacturing issues

- two manufacturers extremely useful to identify manufacturing vs. design faults (whether due to designer error or board complexity)
- have learnt the importance of good, two-way communication with your supplier

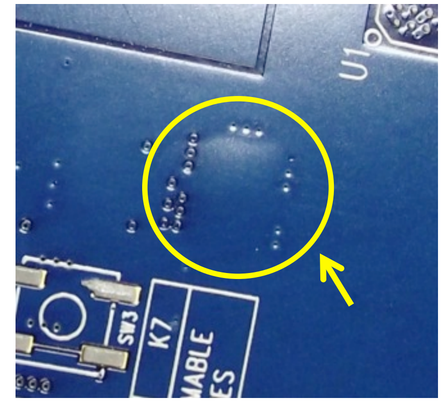
<u>for 10Gbps we can't use simple FR4…</u>

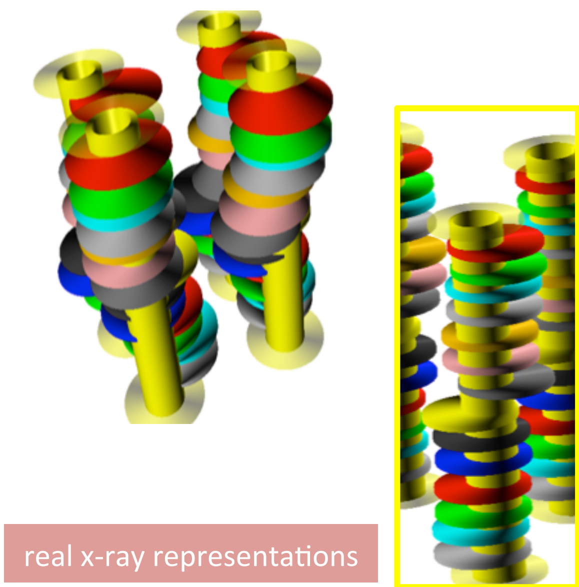
Nelco N4000 laminate (Park) has very good high frequency characteristics but now known to be susceptible to **delamination & registration defects**

- also expensive material, low yield
- requires **careful handling during manufacture & assembly;**

TU-872 SLK laminate (TUC) trialled successfully but also tends to suffer similar registration defects –

<u>key is building communicative relationship with supplier</u>





real x-ray representations

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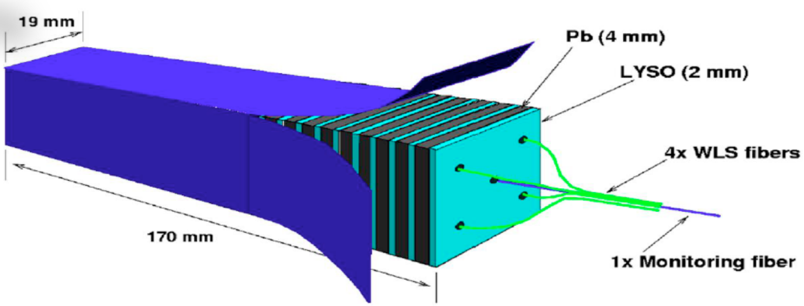
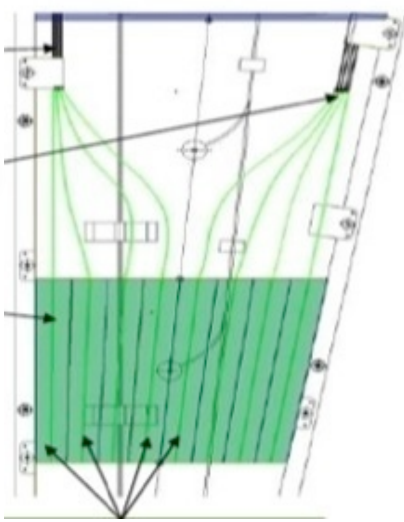
Other projects

Endcap Calorimeters

- Two approaches

1. Maintain tower geometry - develop rad-tolerant solutions for 3000 fb^{-1}
   - EE towers e.g. in Shashlik design (crystal scintillator: LYSO, CeF)
   - Te build HE with more fibers, and rad-tolerant scintillator





2. Alternative geometry/concepts
   - Potentially improved performance and/or lower cost
     - Dual fiber read-out: scintillation & Cerenkov (DROC) – alla DREAM/RD52
     - Particle Flow Calorimeter (PFCAL) – following work of CALICE

Upgrade project status

- R&D underway, especially in UK, for at least 5 years
  - prototyping ASICs, board based electronics, detector modules, trigger and readout systems
    - NB includes much FPGA firmware and online software, as well as simulations of future detectors and their physics performance
- New detectors should be installed and be operational in 2023
  - several years of procurement, construction, assembly, qualification, commissioning tests are needed before installation
    - followed by commissioning in the experiment, then operation
  - approval of construction funding is still at an early stage
    - although under discussion for some years
    - Technical Design Reports, for final approval, expected 2016-2017
- R&D funds in place in many agencies
  - expect this to grow further in the coming years