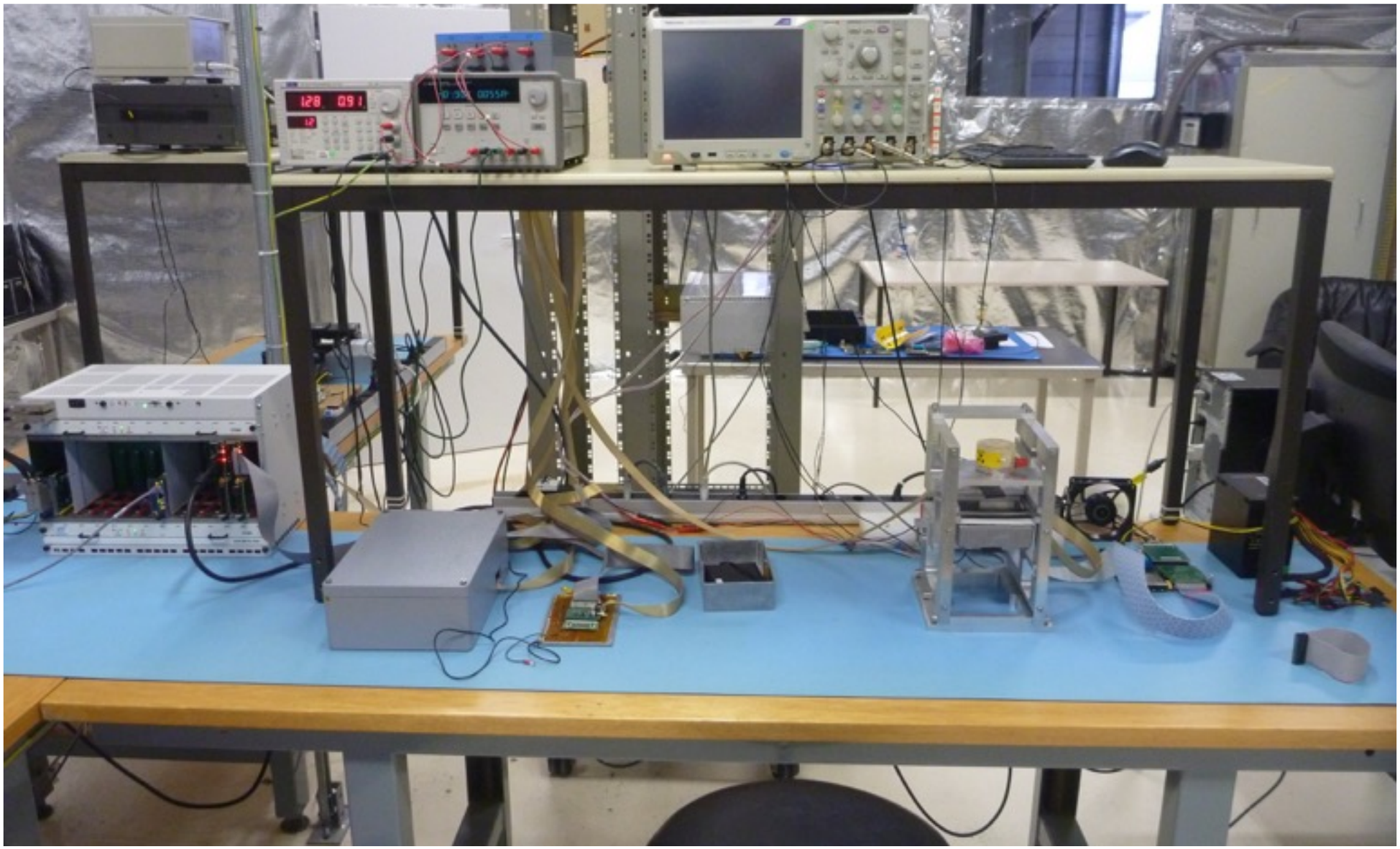

CMS Tracker module / hybrid tests and DAQ development for the HL-LHC

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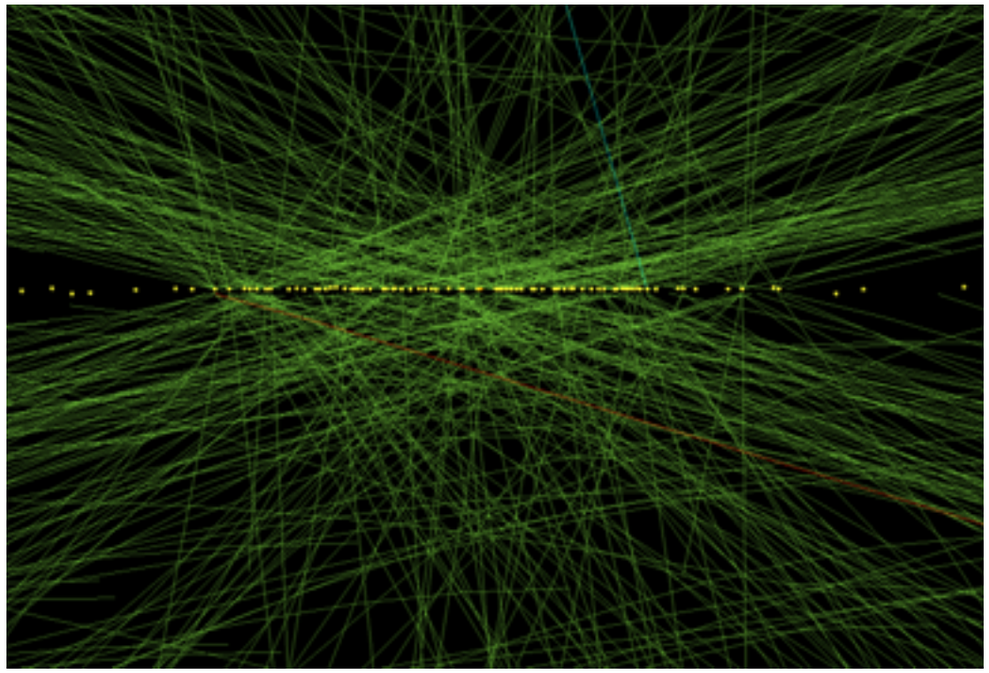
Outline

- Reminder: the Ph2 CMS Tracker upgrade
- pT Modules: principle, elements, electronics
- DAQ System: components, architecture, prototypes
- Testing activities: test stands, software, commissioning, towards production
- Summary & Outlook

Reminder: Ph2 Tracker upgrade I

why upgrade?

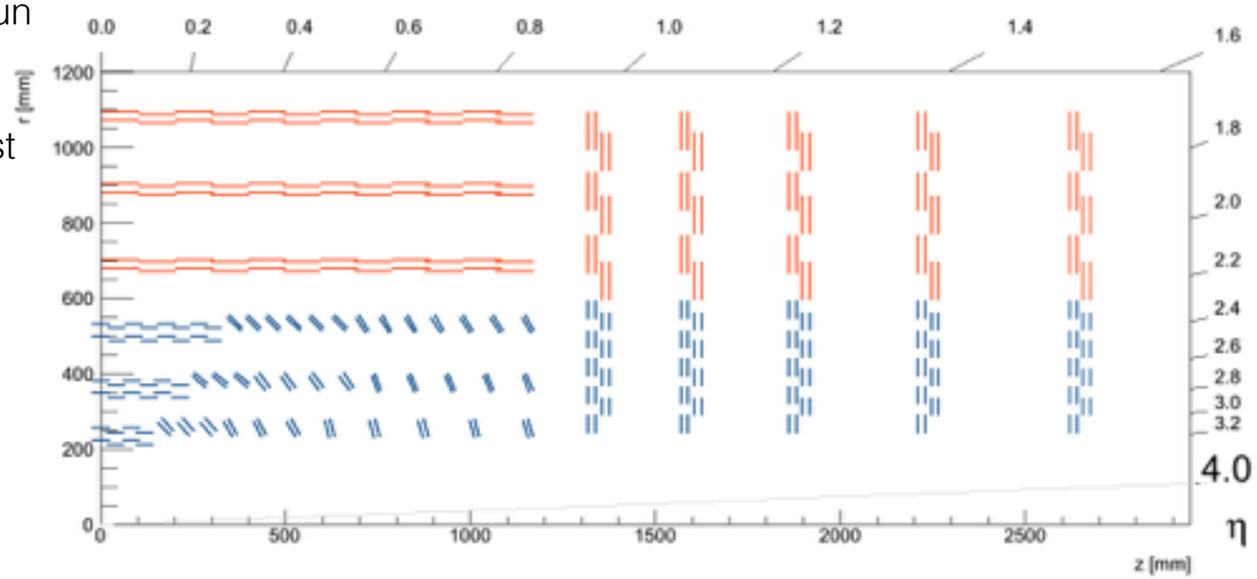
- HL-LHC will increase **luminosity** by factor of ~**10**
  - leads to **higher pile-up** (-> 140 - 200) -> need detector with **finer granularity** and more read-out channels (binary read-out)
  - need more **radiation-hard** sensors
  - need to include **tracker information** in the **L1 trigger** -> pT modules
  - need to run at **higher trigger rate ->** need more bandwidth for read-out



as we are at it:

- let's build a **lighter** tracker that consumes less power and can run **cold** at -20C
- let's improve the overall tracking performance & implement latest technologies
- optimize layout

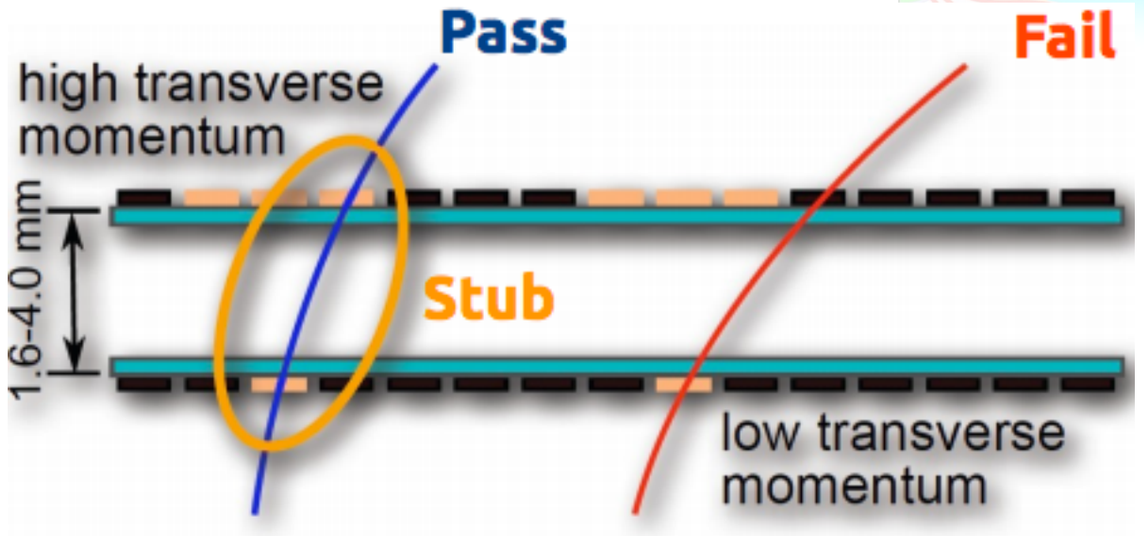
-> completely replace the tracker

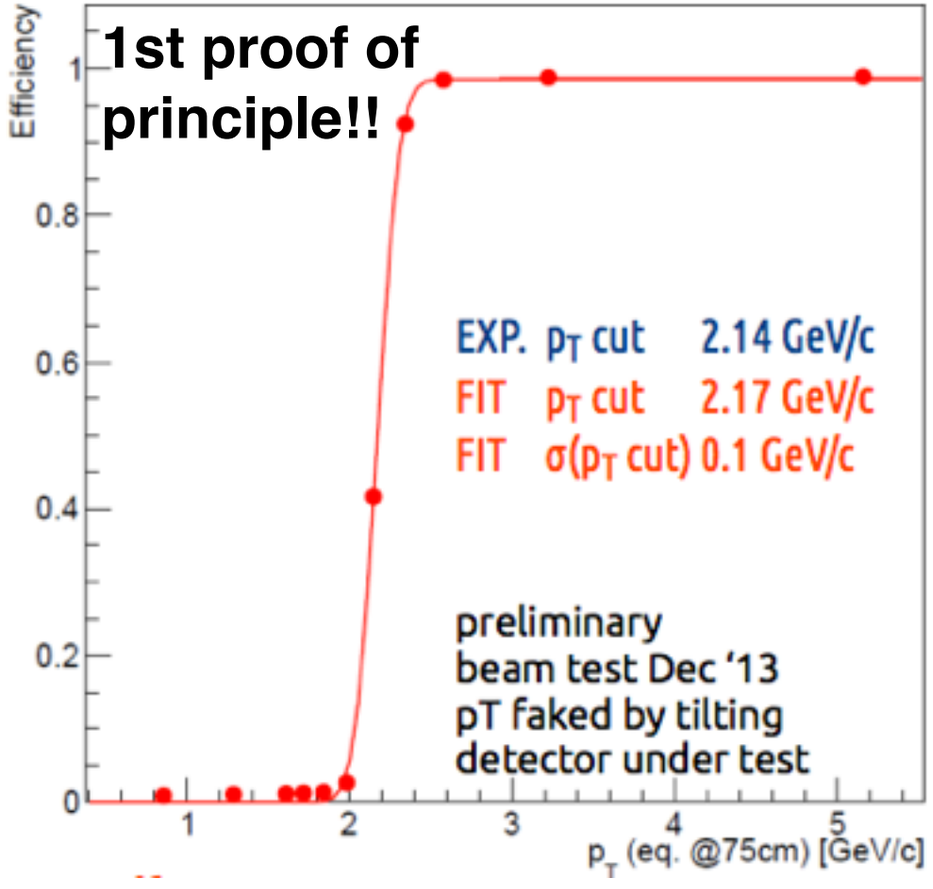


see Duccio's Talk yesterday

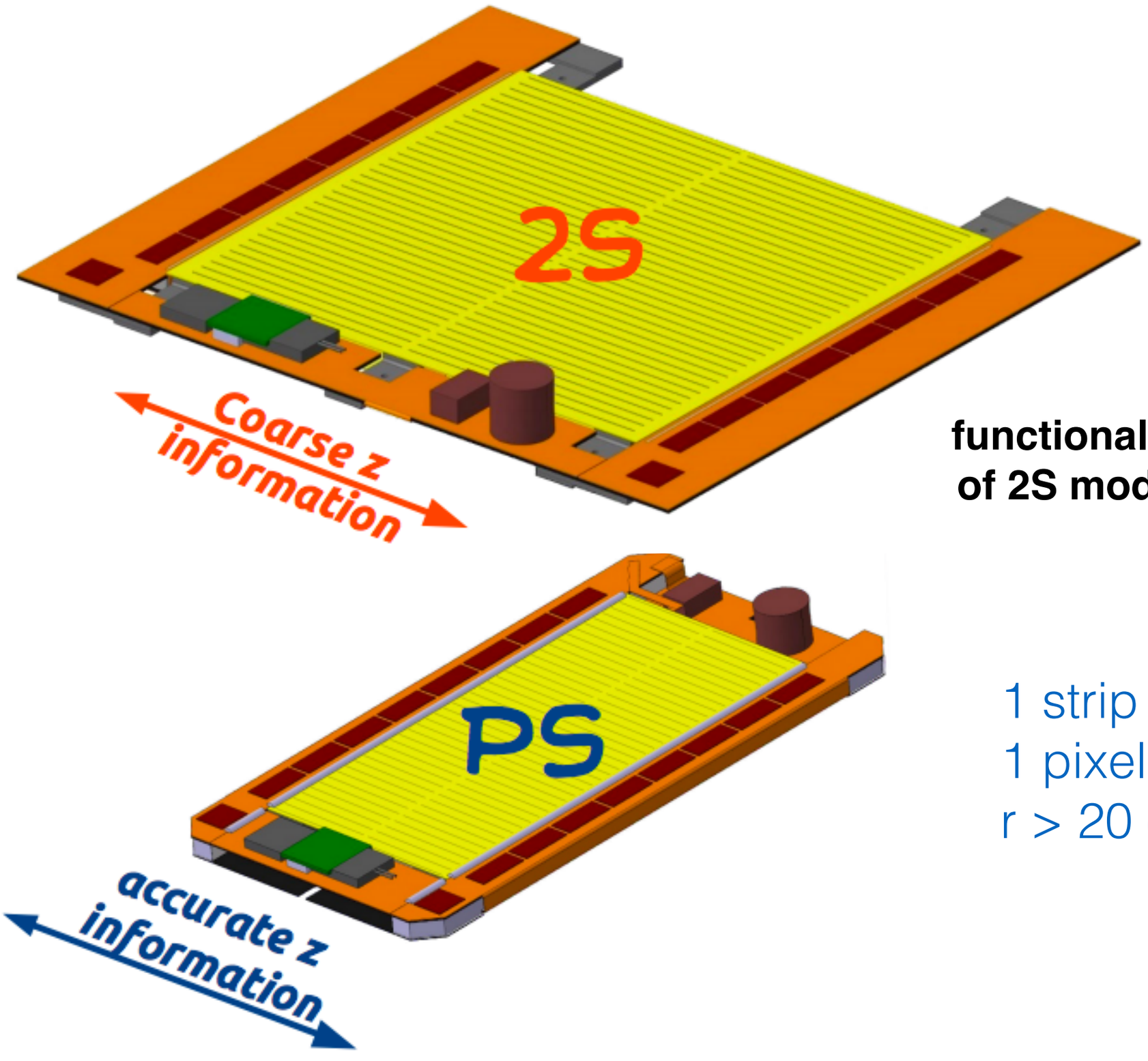
The p_T modules: the principle

- contribution to the L1 trigger requires **tracker hits @ 40MHz**
- all hits would exceed bandwidth limits & complicate tracking
- only send **high-pT hits to trigger**: modules need to detect high momentum tracks:
  - **correlate hits** on 2 closely spaced sensors connected to the **same read-out chip** -> stubs
  - ship **stubs to back-end** electronics for fast **track reconstruction**





The p_T modules: 2S / PS



2 strip sensors
5cm x 90 um
r > 40 cm

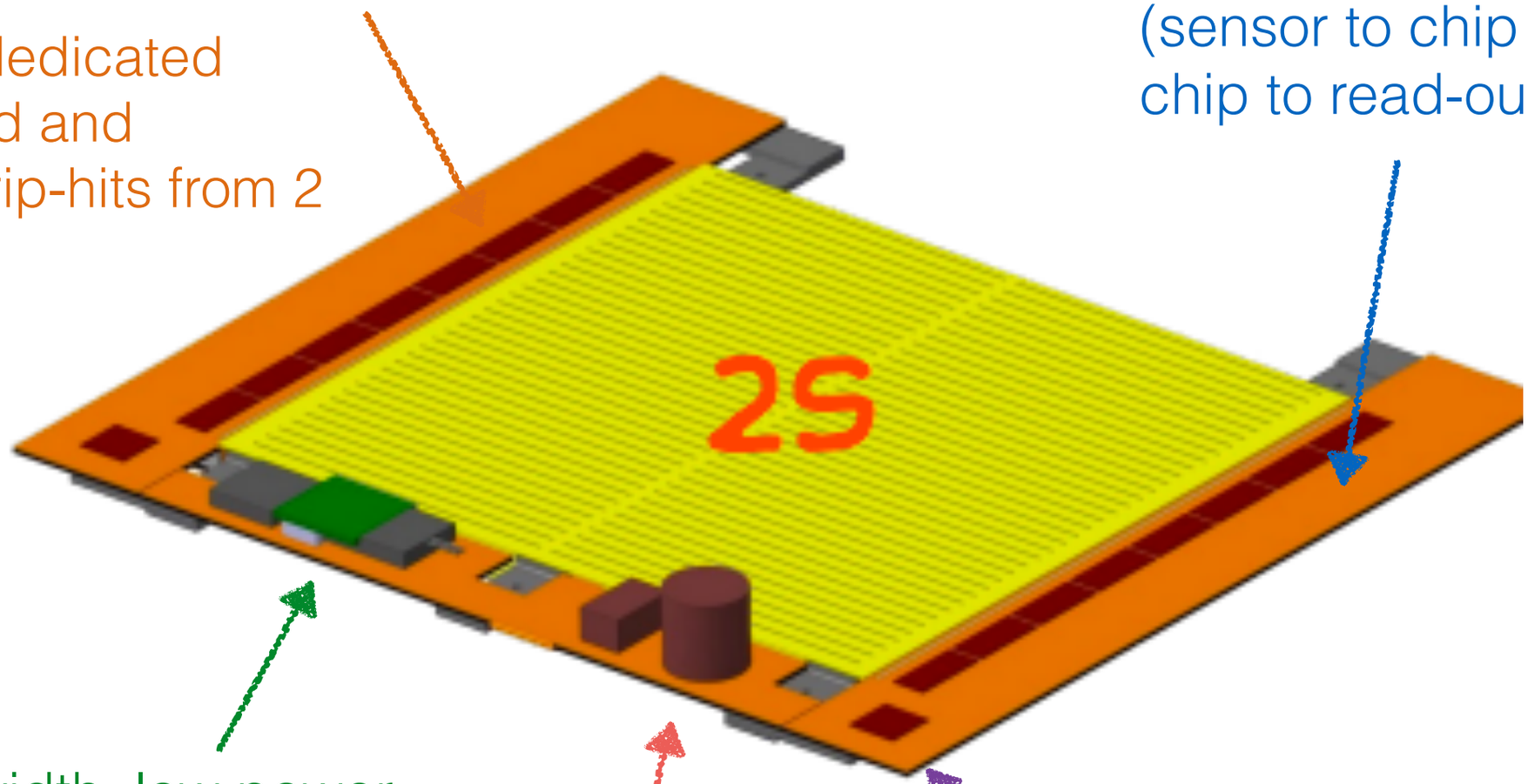
functional prototype of 2S module exists

1 strip (2.5cm x 100 um)
1 pixel (1.5mm x 100 um)
r > 20 cm

The p_T modules: electronics

"intelligent modules" require lots of dedicated electronics:

- CBC (2S): dedicated ASIC to read and correlate strip-hits from 2 sensors
- "hybrid": circuit that holds the chips, services & all routing (sensor to chip and chip to read-out)

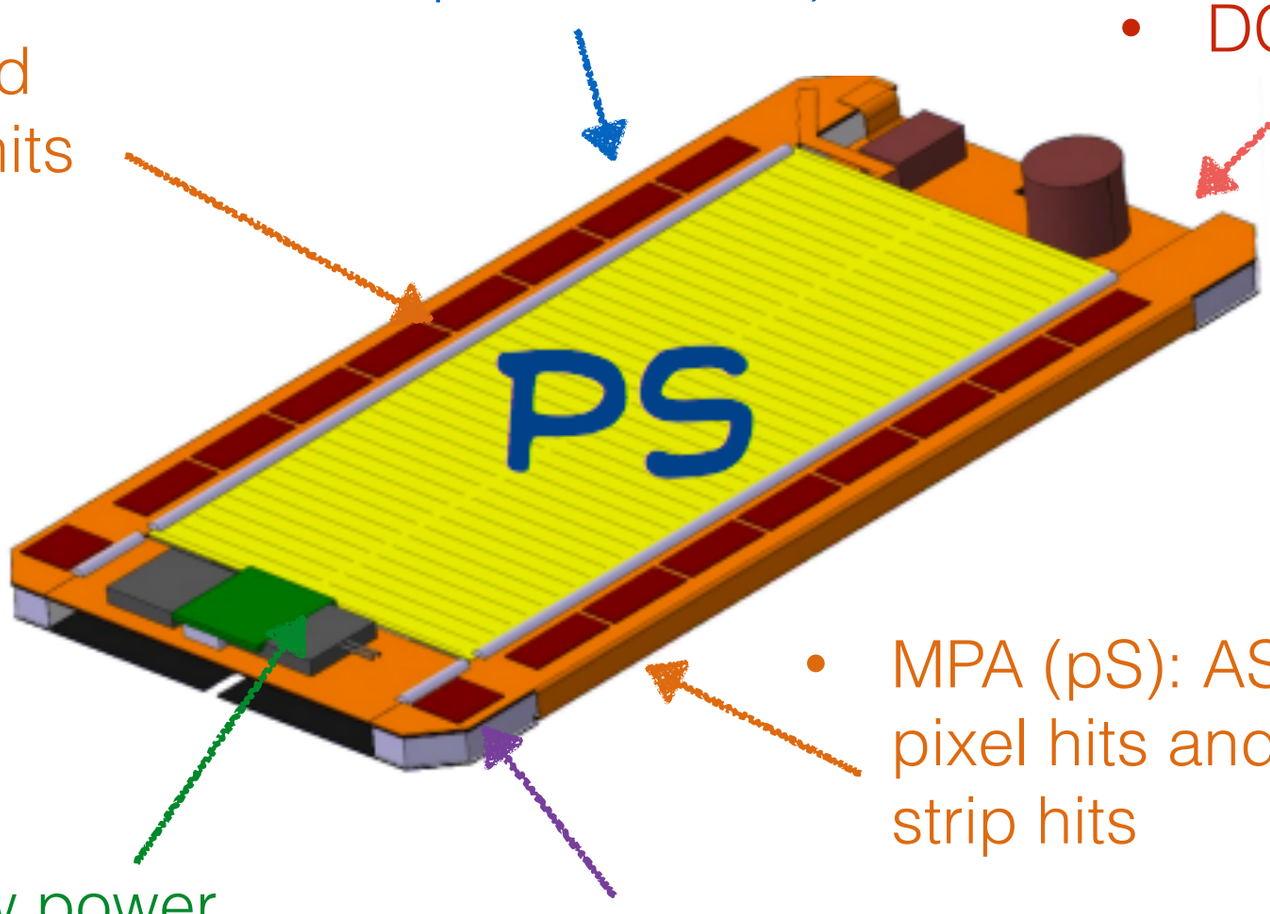


- high-bandwidth, low power bi-directional optical link
- DC-DC converter
- concentrator ASIC: data packing, stub-sorting

The p_T modules: electronics

"intelligent modules" require lots of dedicated electronics:

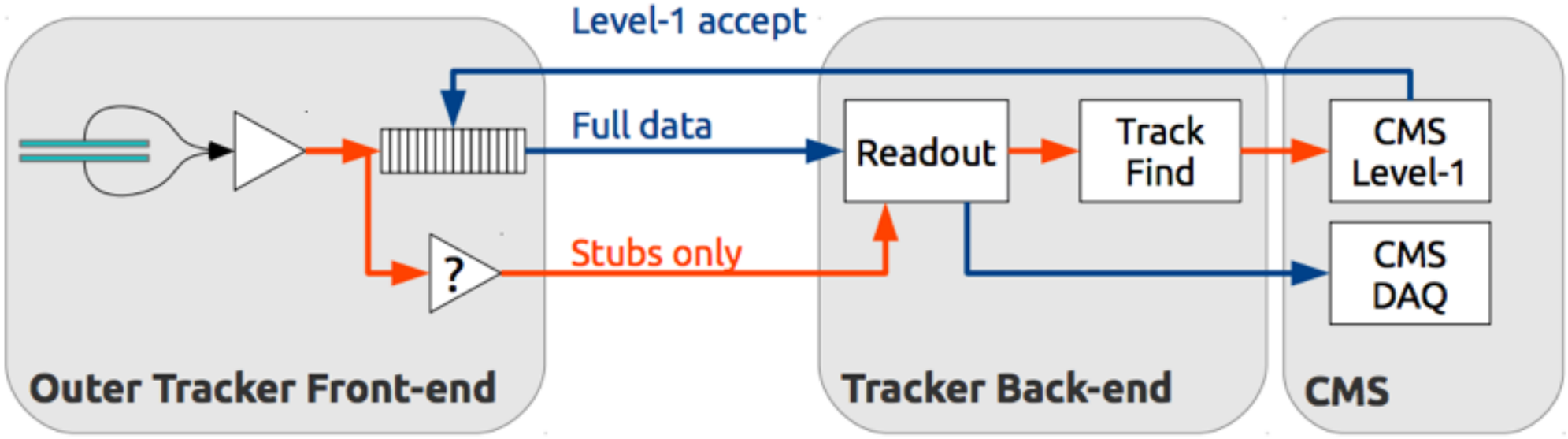
- "hybrid": circuit that holds the chips, services & all routing (sensor to chip and chip to read-out)
- DC-DC converter
- SSA (pS): dedicated ASIC to read strip-hits from 1 sensor



- MPA (pS): ASIC to read pixel hits and correlate with strip hits
- high-bandwidth, low power bi-directional optical link
- concentrator ASIC: data packing, stub-sorting

DAQ system: concept

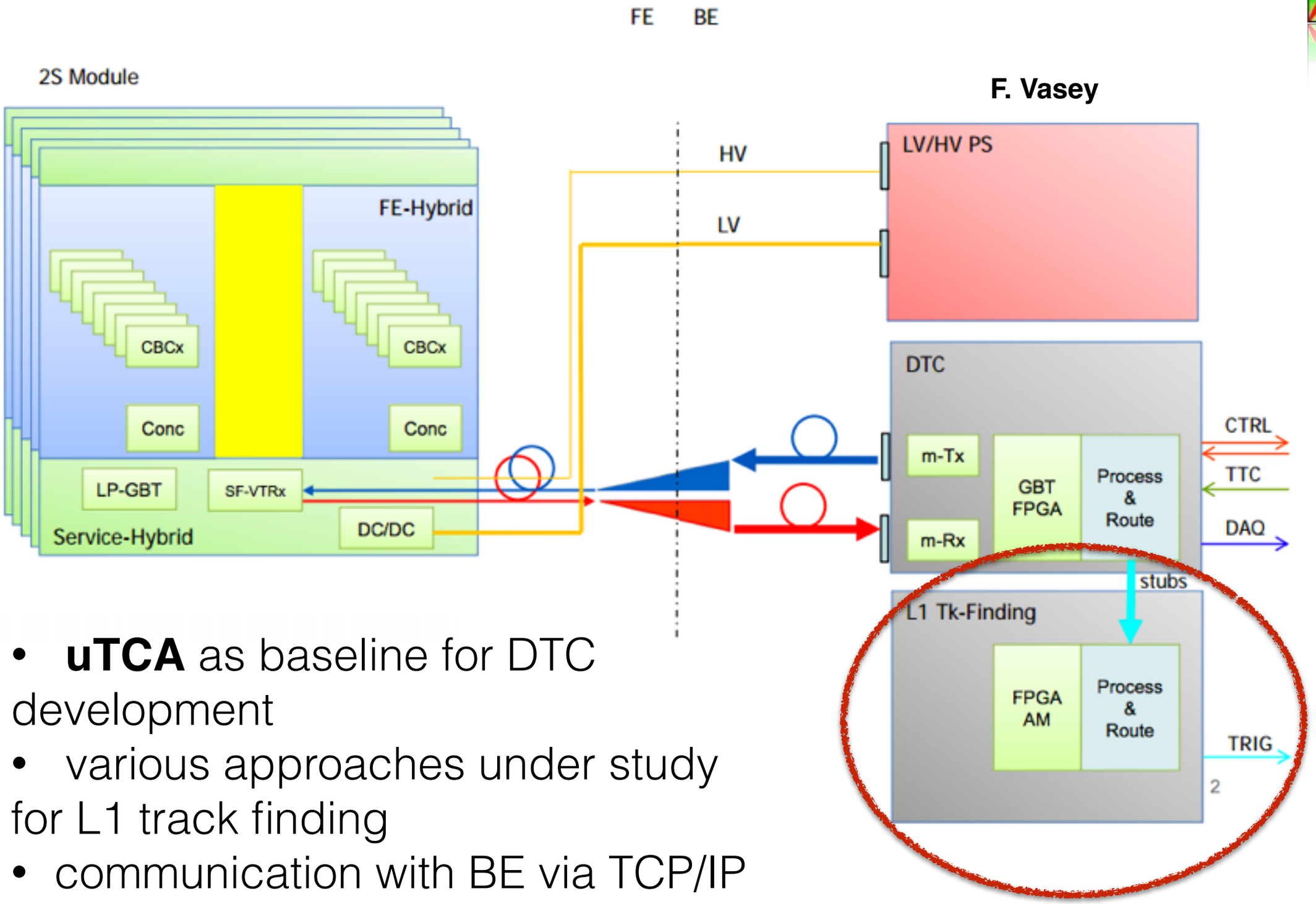
- use **bi-directional** optical link for **control & read-out** - high (asymmetric) bandwidth
- 2 dedicated read-out paths required (stubs + L1A data) via the same optical link (data formatting in concentrator ASIC)
- run **track-reconstruction** on the **back-end** electronics (low latency - very challenging!)



S. Mersi

@ 40 MHz – Bunch crossing
@ 500 kHz (1 MHz) – CMS Level-1 trigger

DAQ system: components

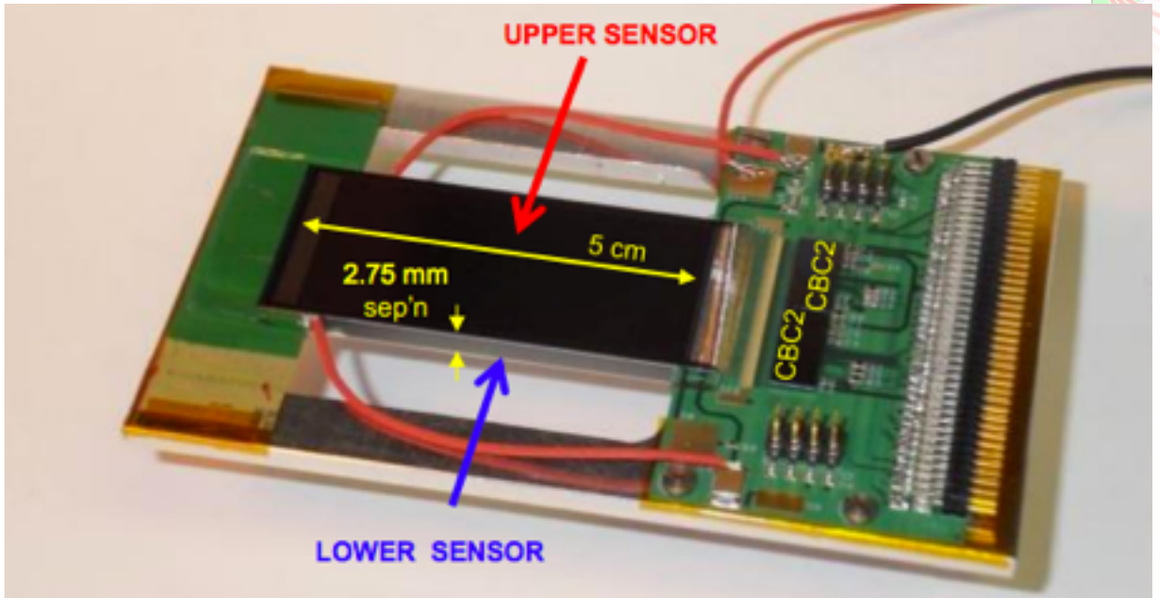


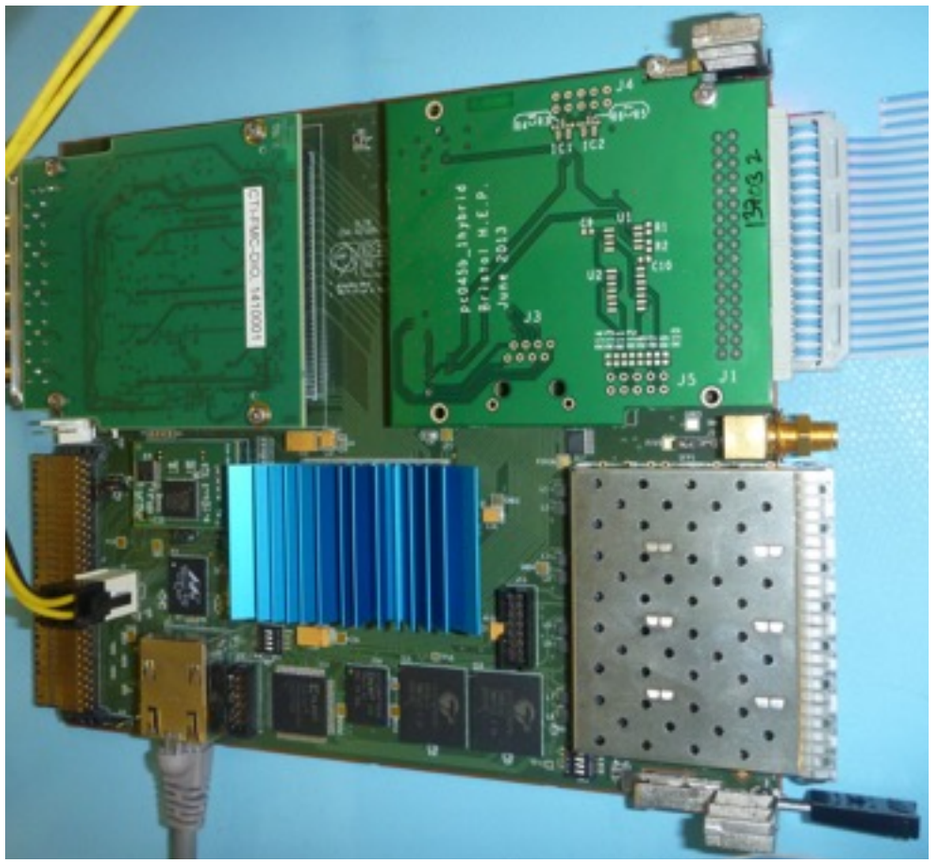
- **uTCA** as baseline for DTC development
- various approaches under study for L1 track finding
- communication with BE via TCP/IP

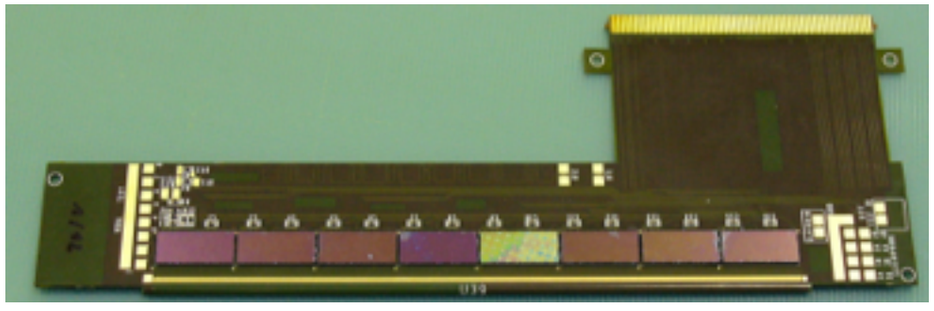
extremely challenging!!

DAQ development: prototypes

- have first **functional 2S modules in hands**:
  - CBC2: correlation logic implemented, no stub information (just 1 bit)
  - no concentrator ASIC: unsparsified data
  - read-out via LVDS signals, no DC-DC converter
- DAQ board under development:
  - CBC2 read-out implemented on **GLIB** board (uTCA AMC) for beam tests, R&D
  - no track finding
- 2xCBC2 PCB hybrid (R&D)
- **functional 8xCBC2 flex hybrid prototypes**





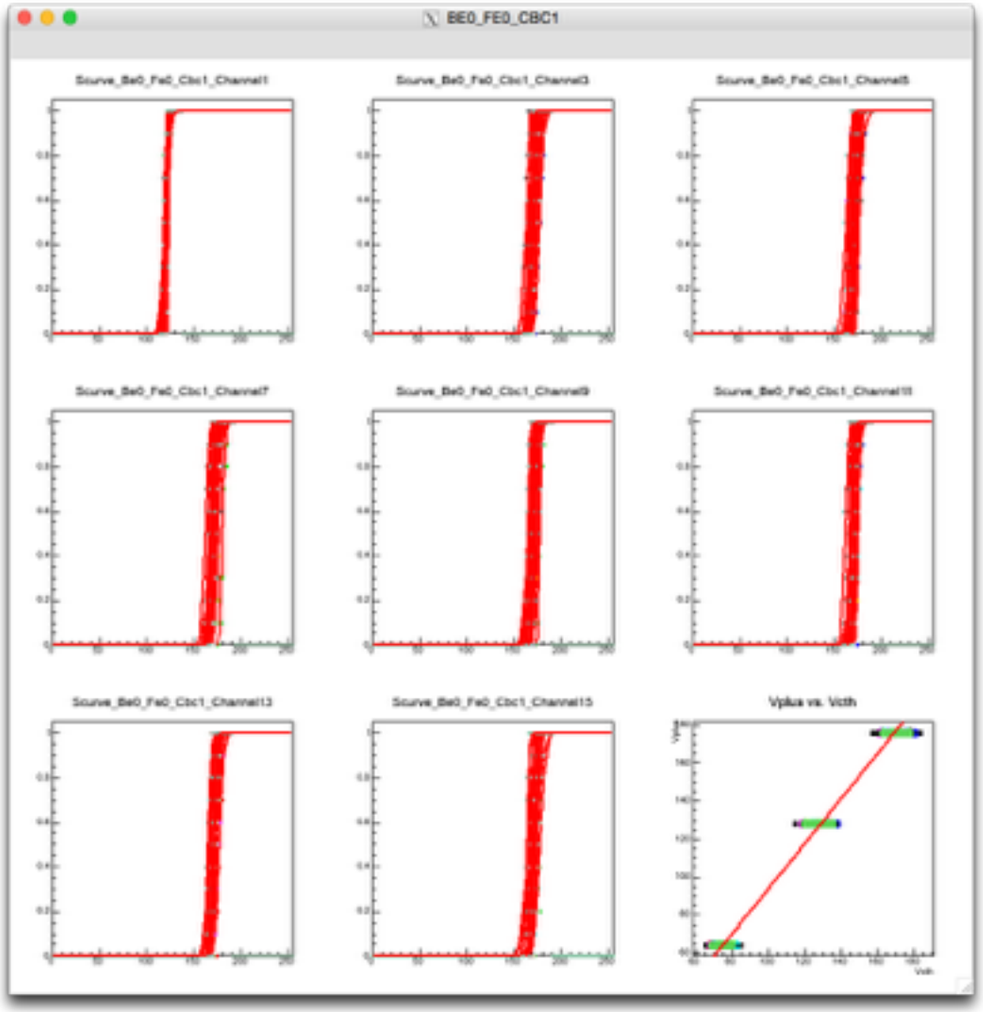


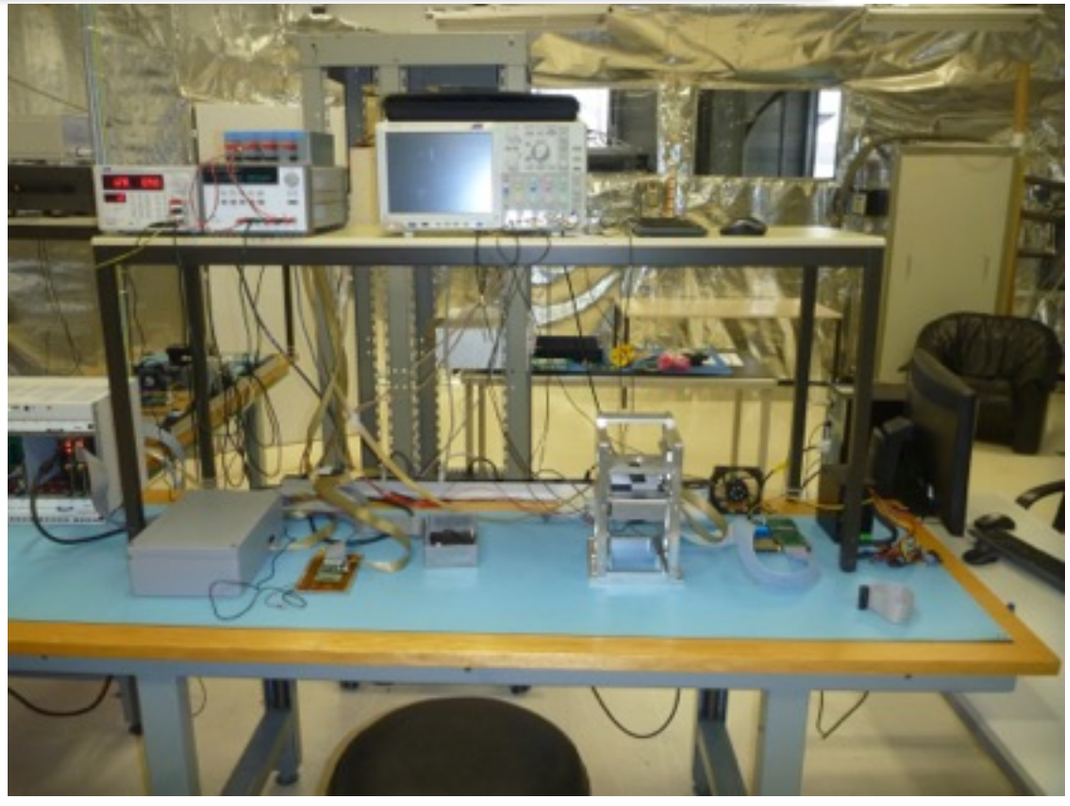
Testing Activities

now we have all these prototypes - what to do with them?

- **testing** (beam tests, RA source, cosmics) - need to understand behavior
- **software development** - control- & DAQ SW
- develop **calibration & commissioning** procedures
- study **performance**
- develop **tests for production** (QA) - need to qualify parts before assembly (~15k modules!!)

-> have set up a dedicated lab for DAQ development, system- & module testing

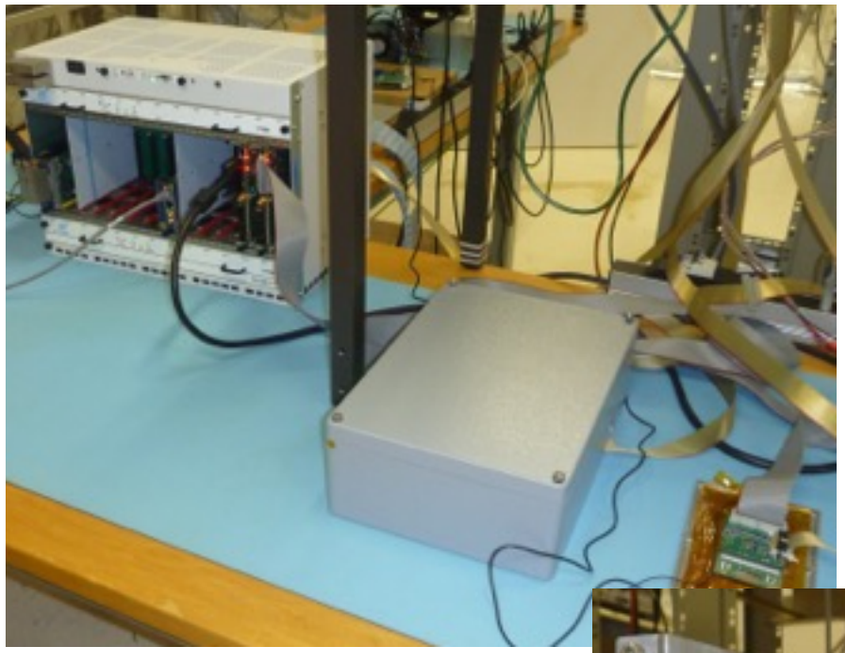


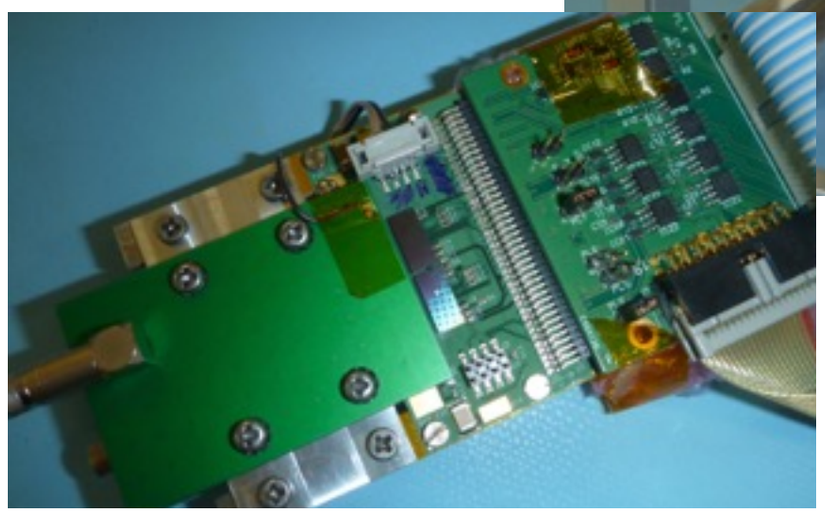


Test stands @ CERN

we are operating **several test stands** for R&D:

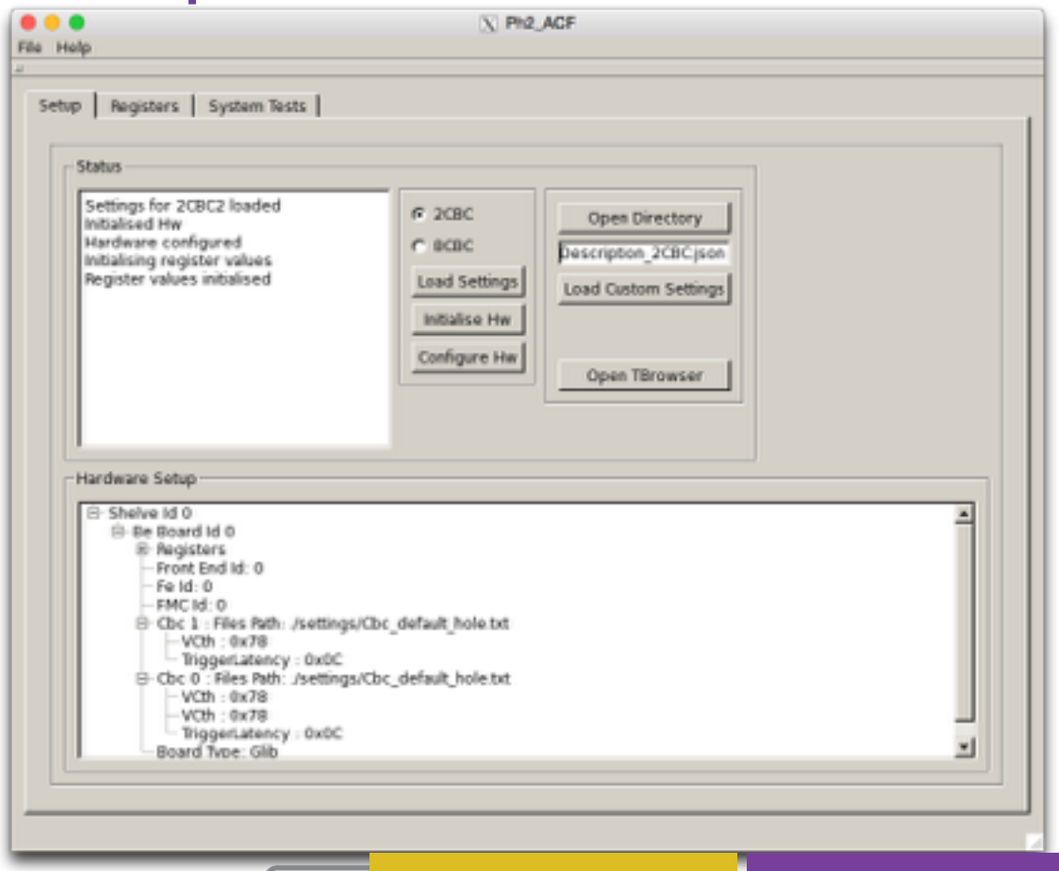
- **system level**: general R&D, testing, SW development
  - only hybrids, no sensor, 2xCBC, 8xCBC
  - uTCA infrastructure
- **radioactive Sr90 source / cosmic rays**: testing of assembled mini-pT-modules with particles
  - scintillator trigger, HV supplies
  - preparations for beam tests
- **hybrid testing**: development of quality assurance procedures for front-end hybrids
  - signal induced via antenna setup

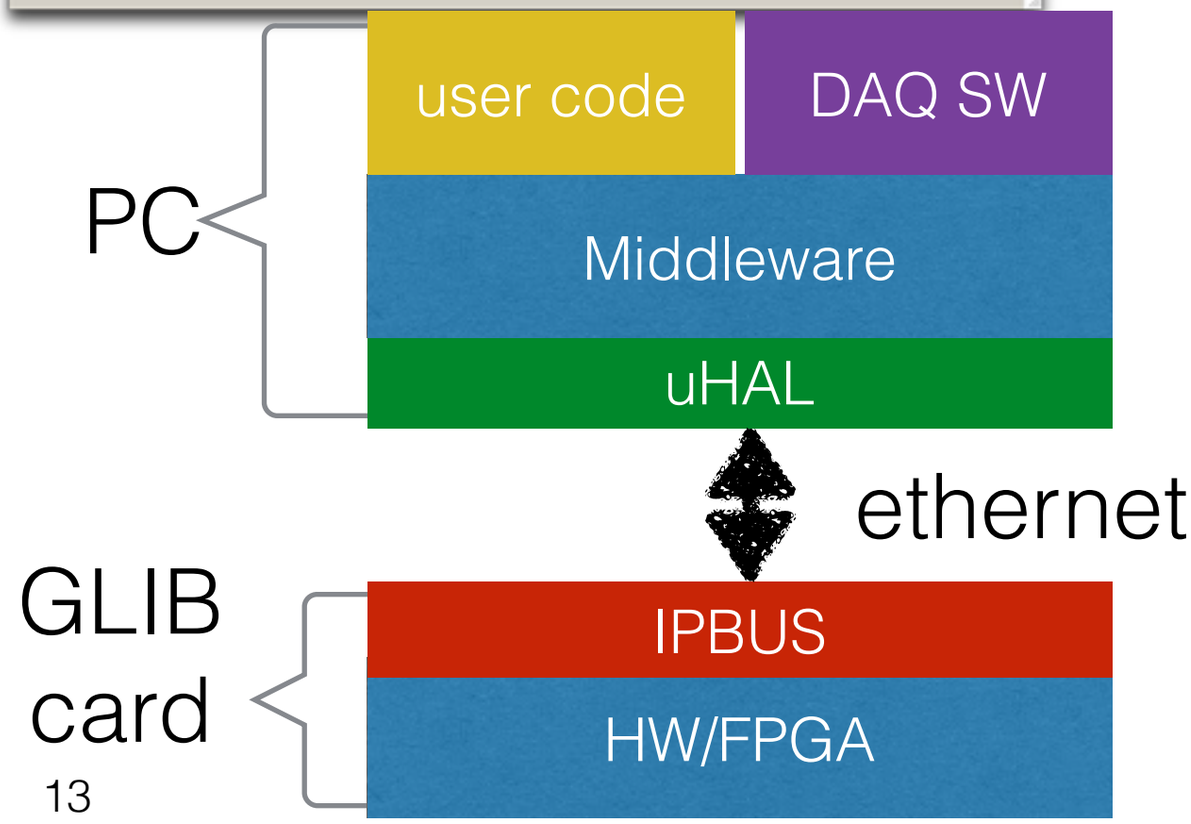




Control software development

- control system and DAQ FW need to interact with PC
- using **IPBUS** (FPGA) & **uHAL** (PC) protocol to communicate via ethernet
- developed a set of libraries with abstracted methods for interaction of user with HW: BE electronics, CBC chips
- on top of these: calibration routines, testing routines, graphical user interface, full scale (distributed, CMS conform) data acquisition SW
- development started as **summer-student project**
- large community of users and active developers





Calibration & commissioning

operation in the future **requires understanding** of steps necessary to **calibrate and commission** a sensor module:

- CBC only flags signals above a given threshold as hits:

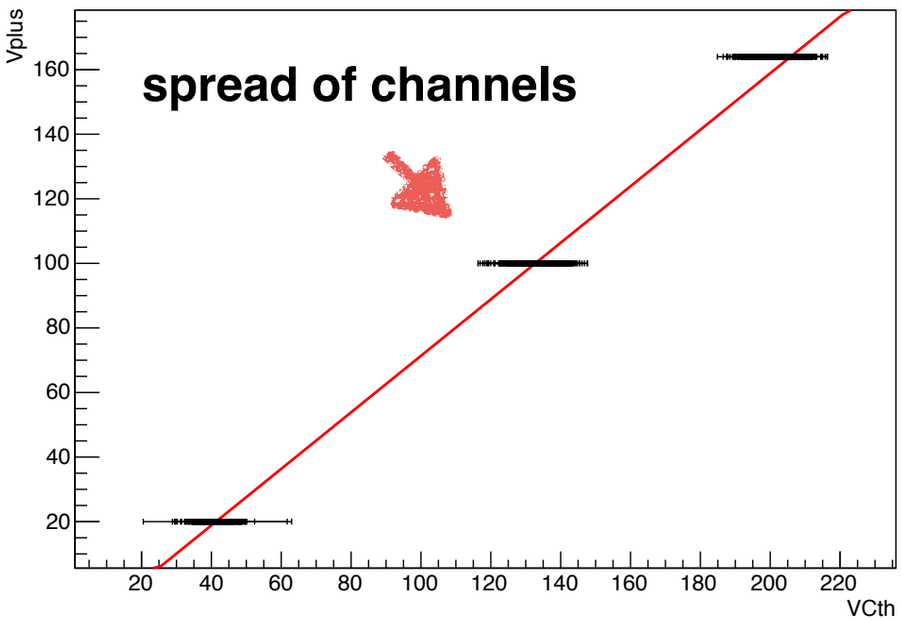
  - need to **calibrate all channels** to the same threshold (charge)

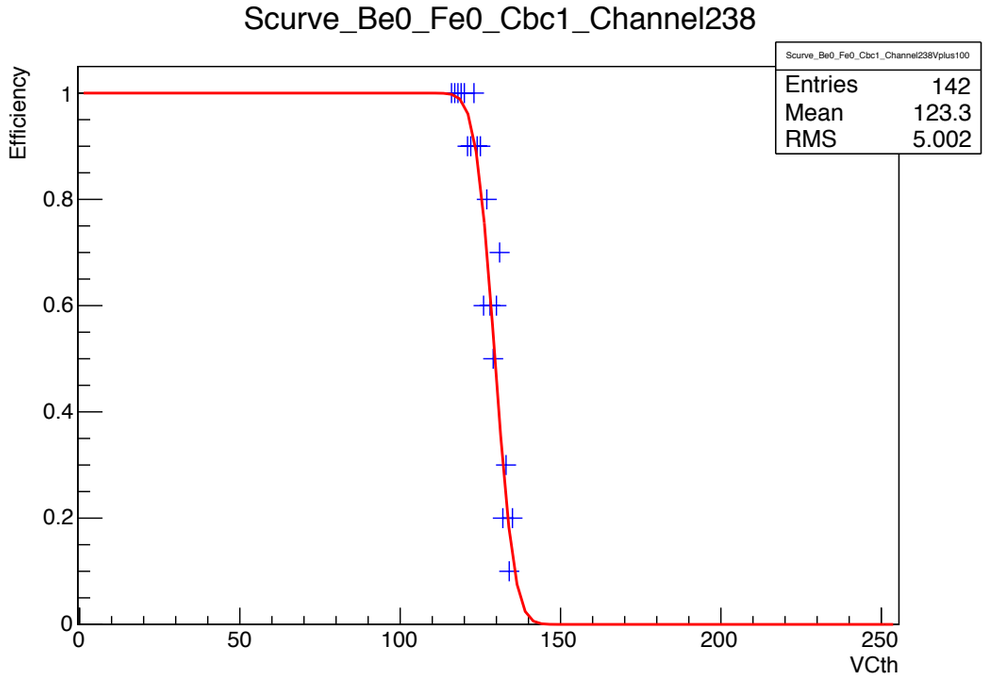
- want to measure only signals induced by particles:

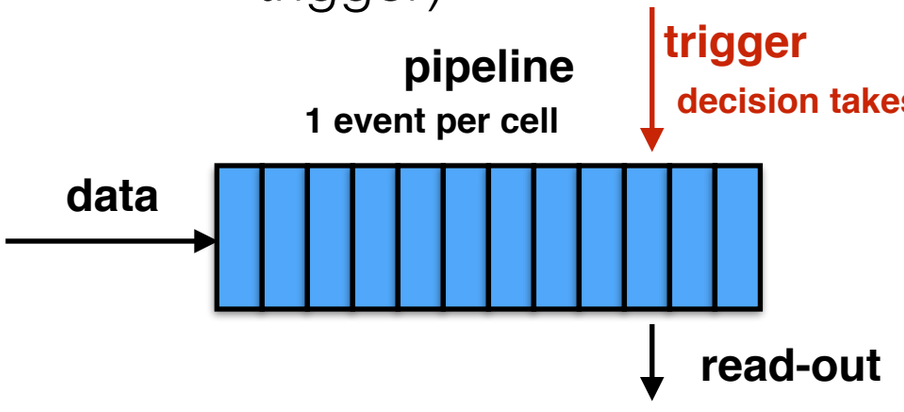
  - threshold scan to suppress noise

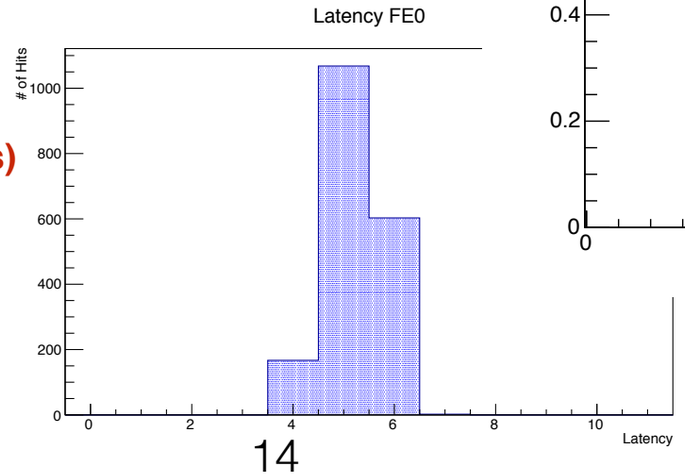
- want to read the right data for each trigger

  - latency scan (time between event & arrival of trigger)









Understanding the performance

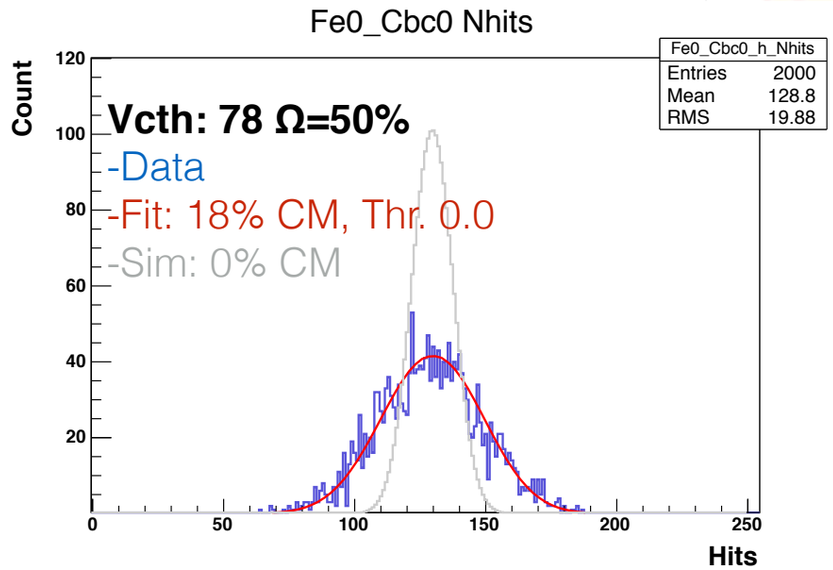
prototypes allow to **study behavior** of individual components, **spot issues**, etc..

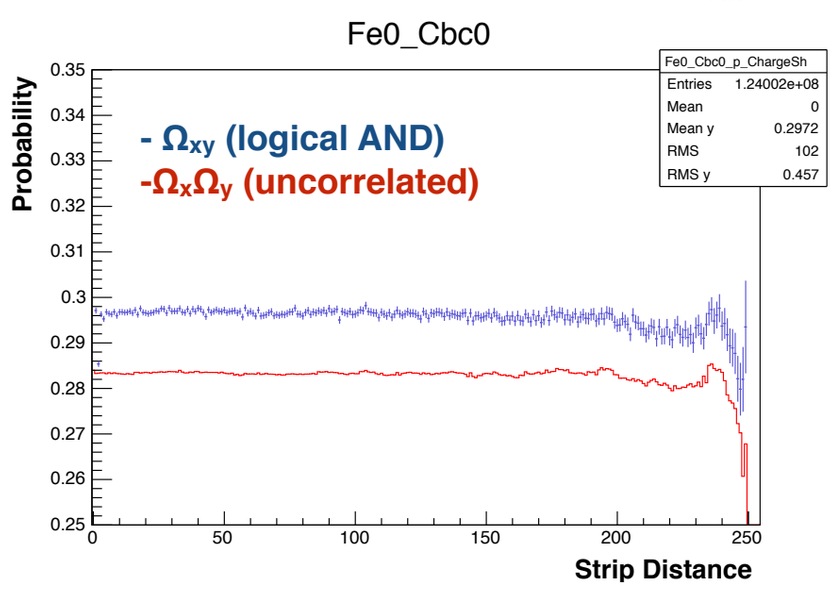
examples:

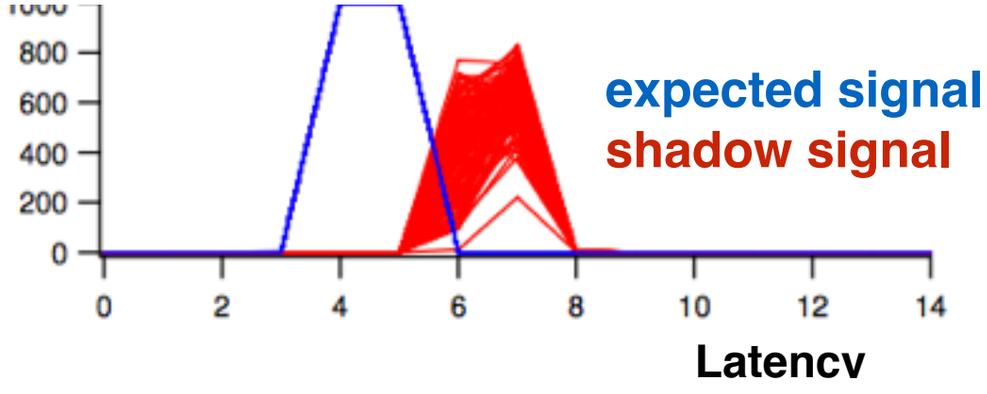
- observed **stronger correlation of CBC channels** than expected (depending on mode of operation) -> will be fixed in the next version

- spotted problems in **I2C communication** between BE electronics & CBC -> change resistors on hybrid

- observed **“shadow” effect in CBC**: chip in sensitive to amplifier overshoot -> will be fixed



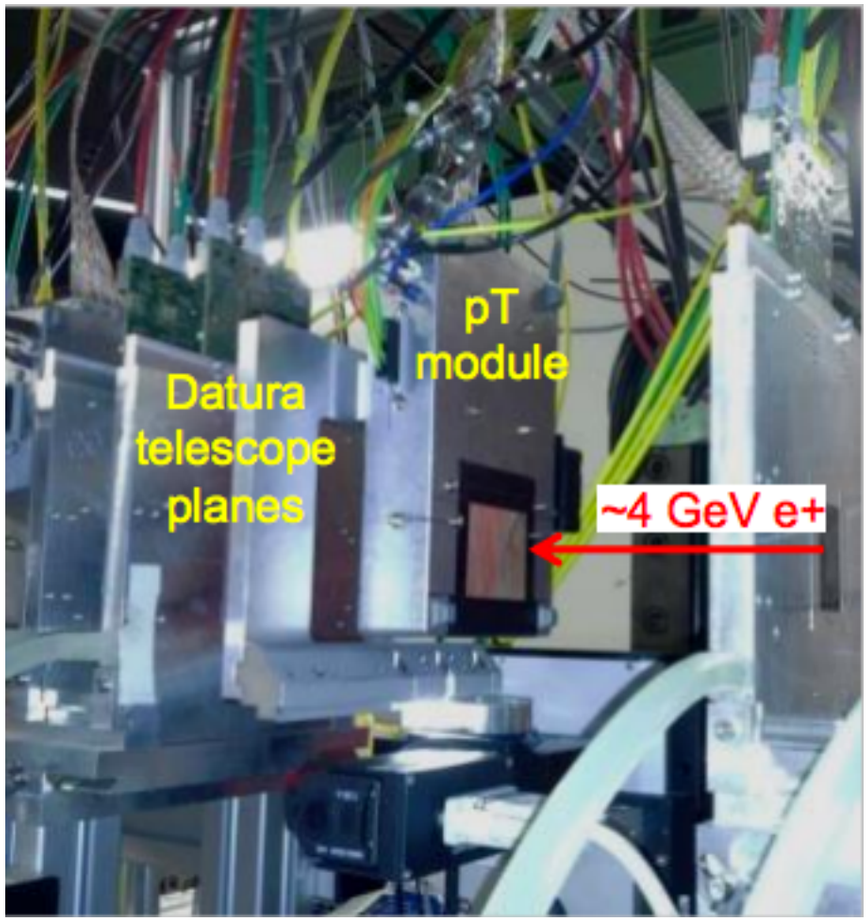




Preparations for beam tests

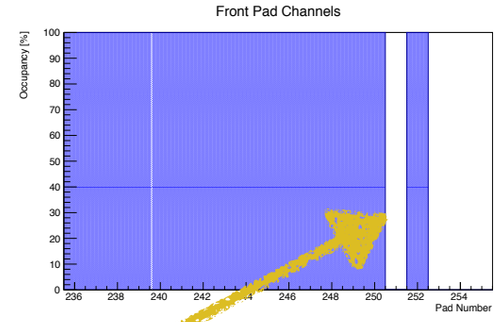
- **cosmic ray** setup allows operation **similar** to the conditions in **beam test**:
  - external trigger, correct timing, properly set thresholds
  - allows to commission and test everything before precious beam time

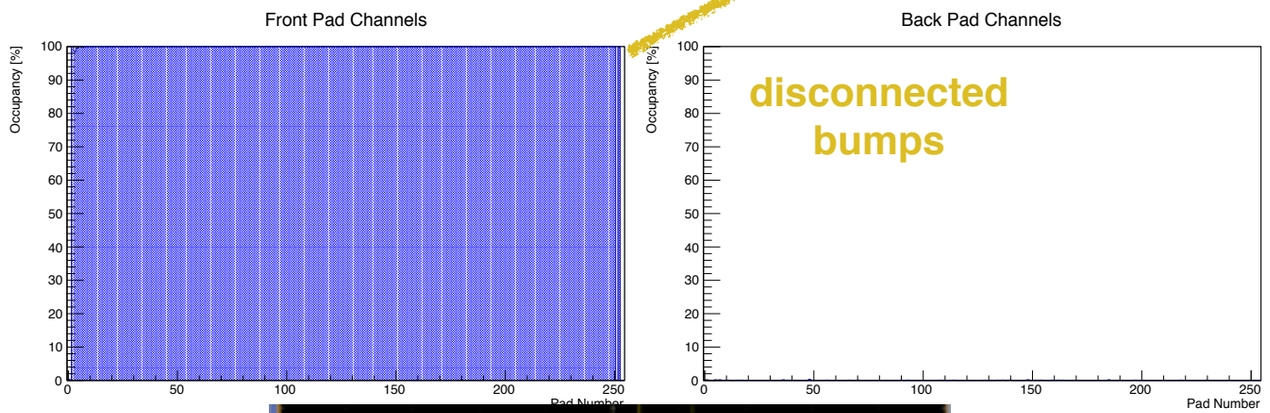
- **next dates: June & November ‘15**

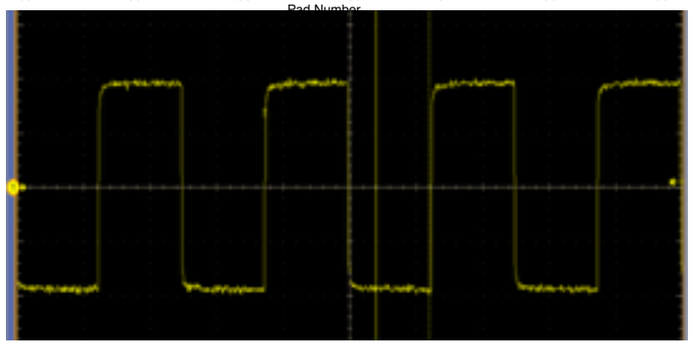


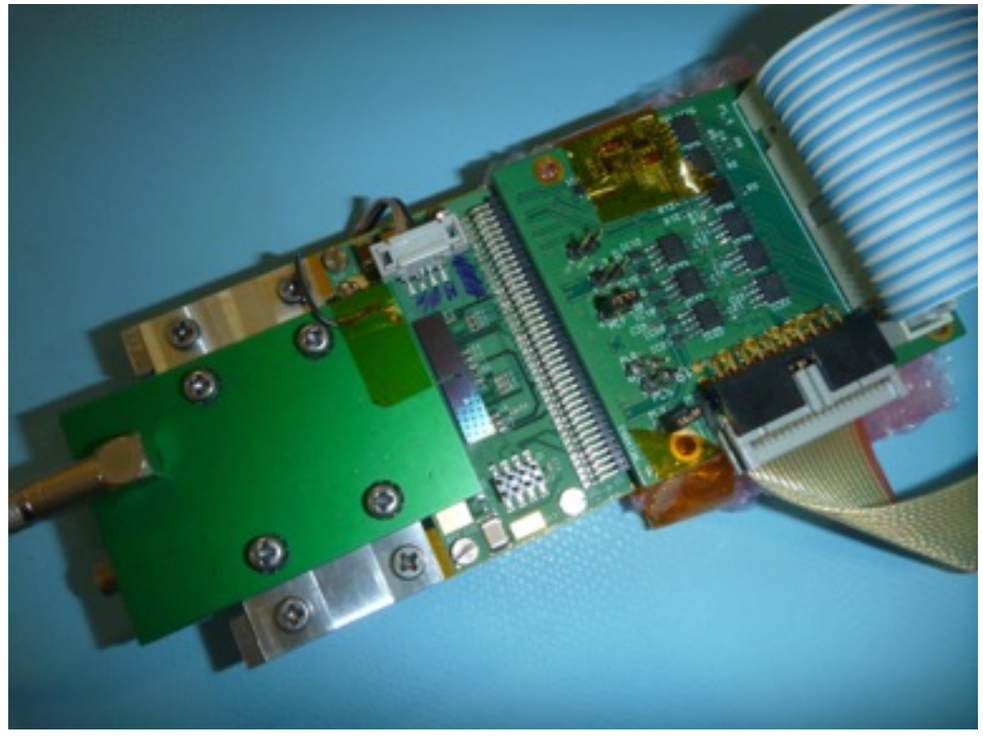
Towards production

- for the final Ph2 outer tracker ~**15 000** modules will have to be built
- **quality assurance** absolutely necessary:
  - hybrids are a highly integrated piece - high trace density, lots of bonding bumps and components
  - can not afford to build a module with a hybrid that has faults (disconnected channels etc…)
  - -> need to develop **reliable procedure to test components** / hybrids & and modules after each step of assembly
  - **idea**: verify connectivity from sensor pad to chip via signal induced by antenna - should allow to spot disconnected channels
- group involved in definition of QA standards









Summary & Outlook

- CMS tracker needs **complete replacement for HL-LHC** era to cope with conditions
- features: higher trigger rate, **contribution to L1 trigger**, **on-module pT discrimination**, new DAQ & control system
- first **prototype 2S modules exist**
- **CERN** set up **dedicated, well equipped lab**
- **Activities:**

present

- DAQ system development / testing
- SW framework
- development of commissioning procedures
- module / component / system testing

future

- full size 2S module prototype to be tested this fall
- modules with irradiated sensors
- system-level tests: data packing algorithms, data-loss studies, etc…
- integration of new components as they become available (CBC3, concentrator ASIC, DC-DC converters, optical links)
- expect first functional PS module prototypes in the nearer future: need to develop similar DAQ prototype / software

- different **test stands** available
- lot's of **interesting work** to be done
- large community of users and developers in the project

Backup: Flex Hybrid