The CBC2 ASIC for
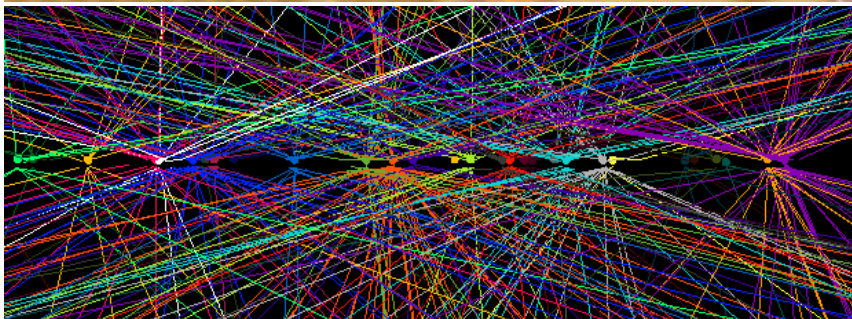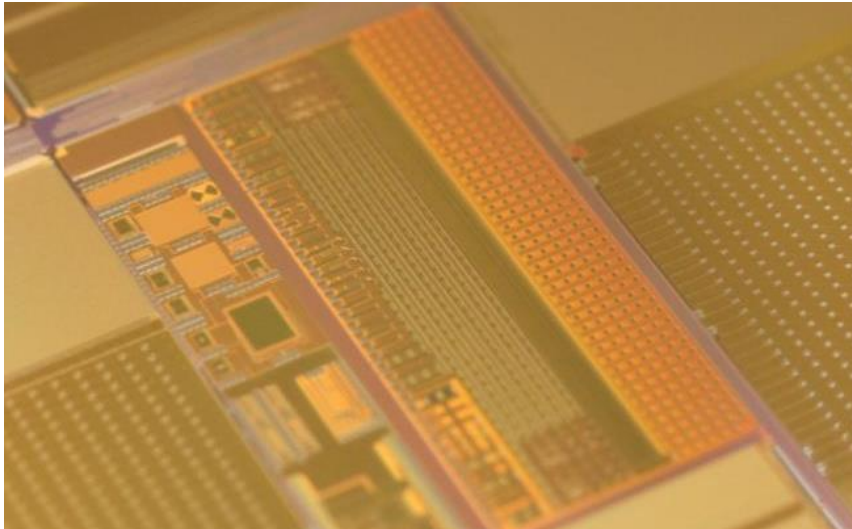
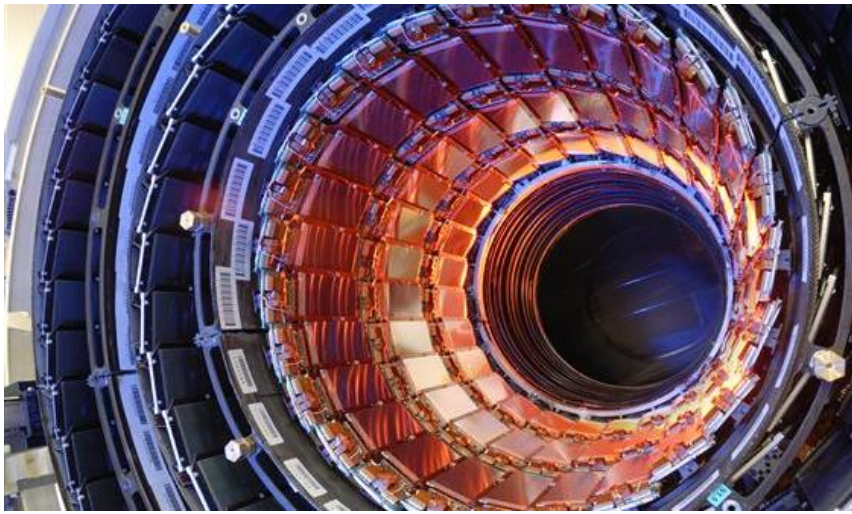# 2S Modules at HL-LHC

Davide Braga
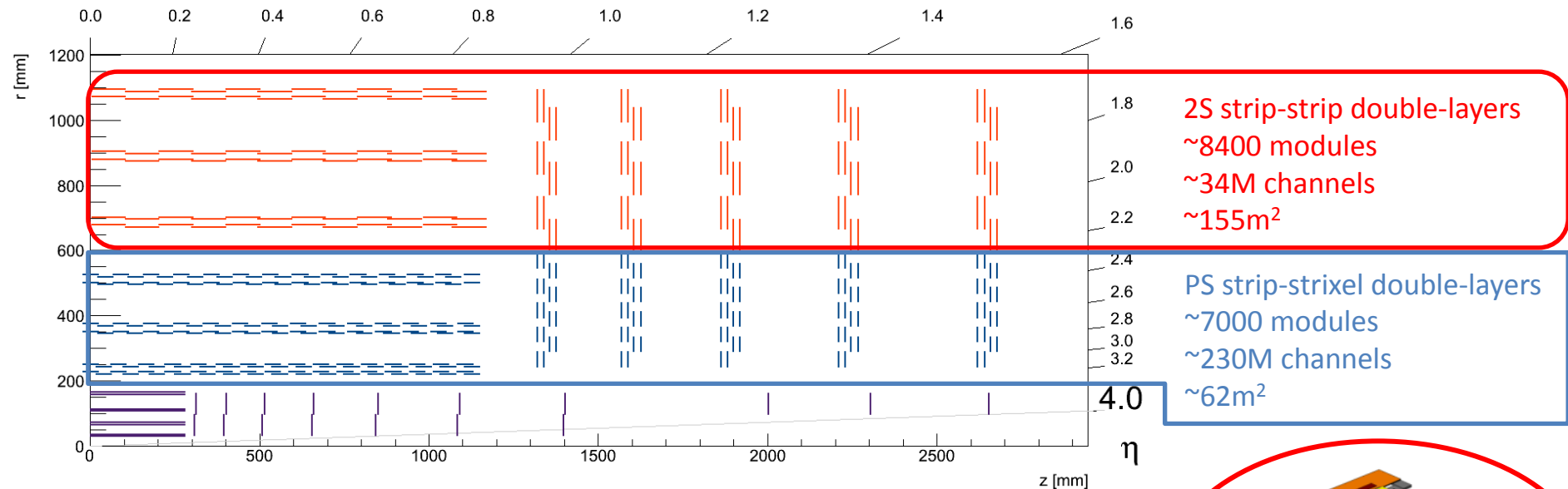
CMS
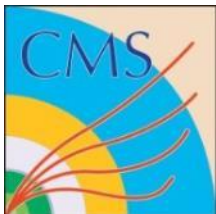
Imperial College
London

Science & Technology
Facilities Council

Outline

- **Tracker upgrade & detector module**

- **The CMS Binary Chip (CBC) v.1 & 2**

- **CBC2: architecture & performance**

- **CBC2 testing**
  - **Beam test**
  - **TID test**

Phase-II upgrade of the CMS Strip Tracker

2S strip-strip double-layers
~8400 modules
~34M channels
~155m^2

PS strip-strixel double-layers
~7000 modules
~230M channels
~62m^2

- Baseline design: Barrel+5Endcaps

- Based on 2 module types only

- Provides at the same time:
  - *readout data* upon receipt of L1 trigger
  - *trigger data* @40MHz (10 trigger hits up to η=2.5)
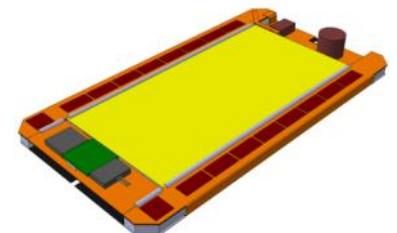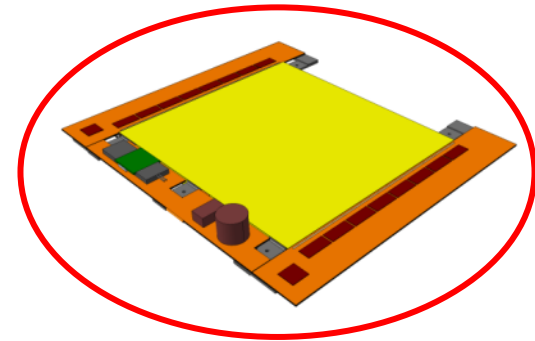
Basic trigger module concept
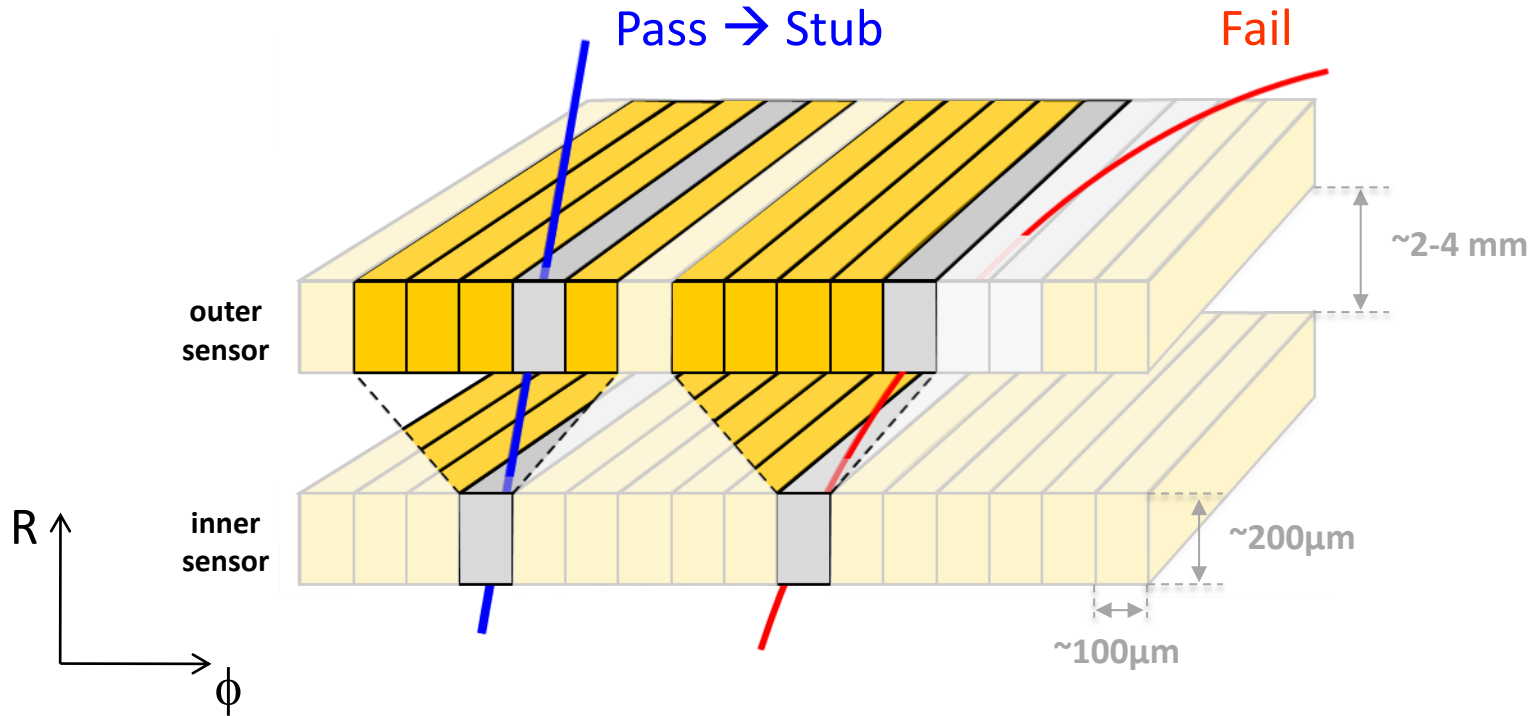
- High-PT tracks (stubs) can be identified if cluster centre in top layer lies within a search window in R-Φ (rows)

- p_T cut given by: module radius (z), sensor separation and correlation window

CMS Binary Chip (CBC)

2 versions have now been produced - both in 130nm CMOS

CBC1 (2011)

- 128 wire-bond pads, 50 mm pitch
- front end designed for short strips, up to 5 cm
    DC coupled, up to 1mA leakage tolerant, both sensor
    polarities
- binary unsparsified readout
- pipeline length 6.4 msec

- chip worked well in lab and test beam
- no triggering features

CBC2 (January, 2013)

- 254 channels
- ~same front end, pipeline, readout approach as CBC1

- bump-bond layout
- includes triggering features

4 mm

7 mm

CBC1

5 mm

11 mm

CBC2
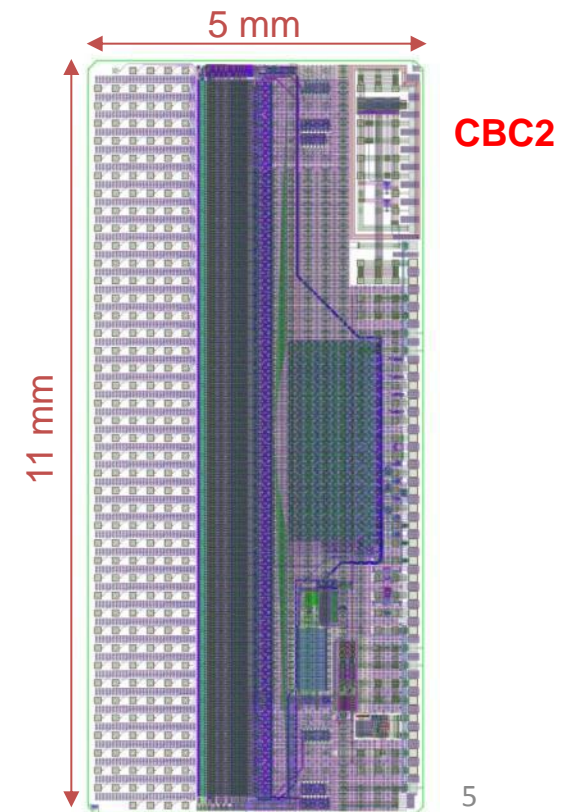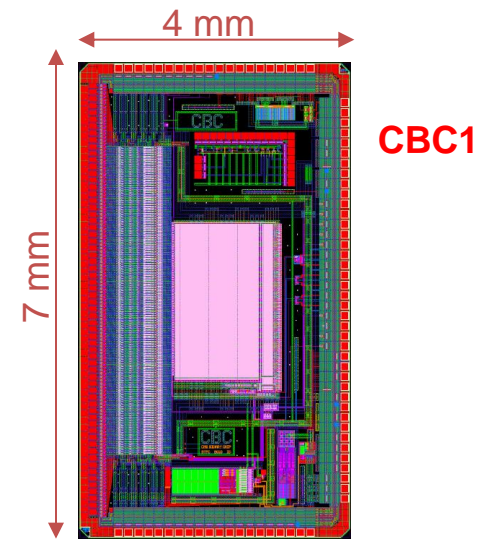
Stub finding logic
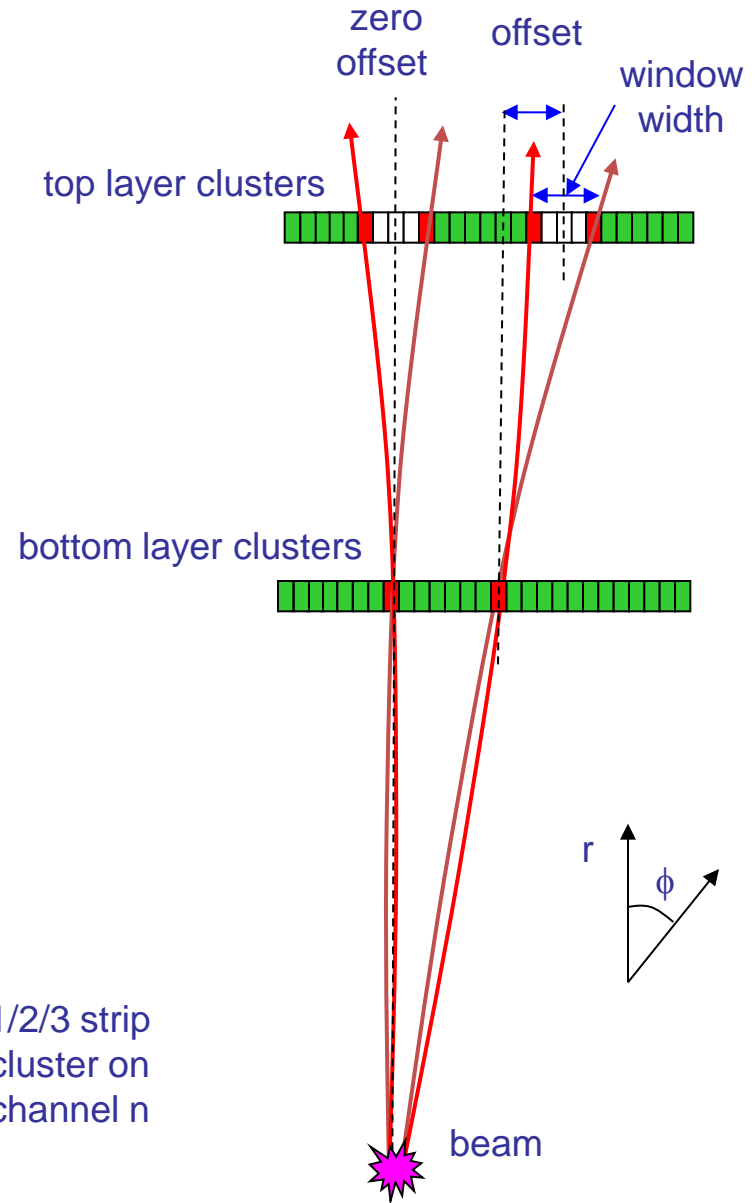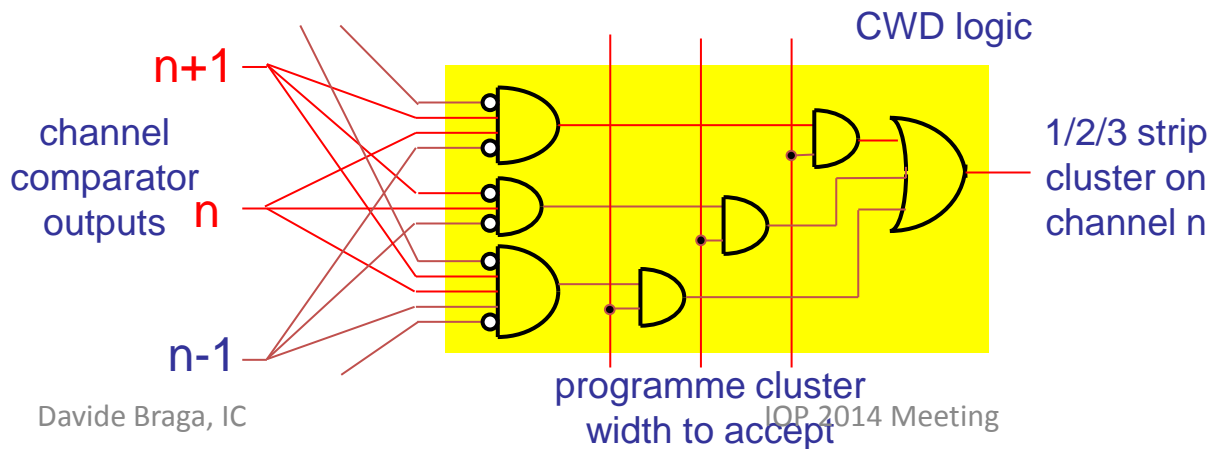
Cluster width discrimination (CWD) logic

exclude clusters with hits in >3 neighbouring channels
wide clusters not consistent with high pT track
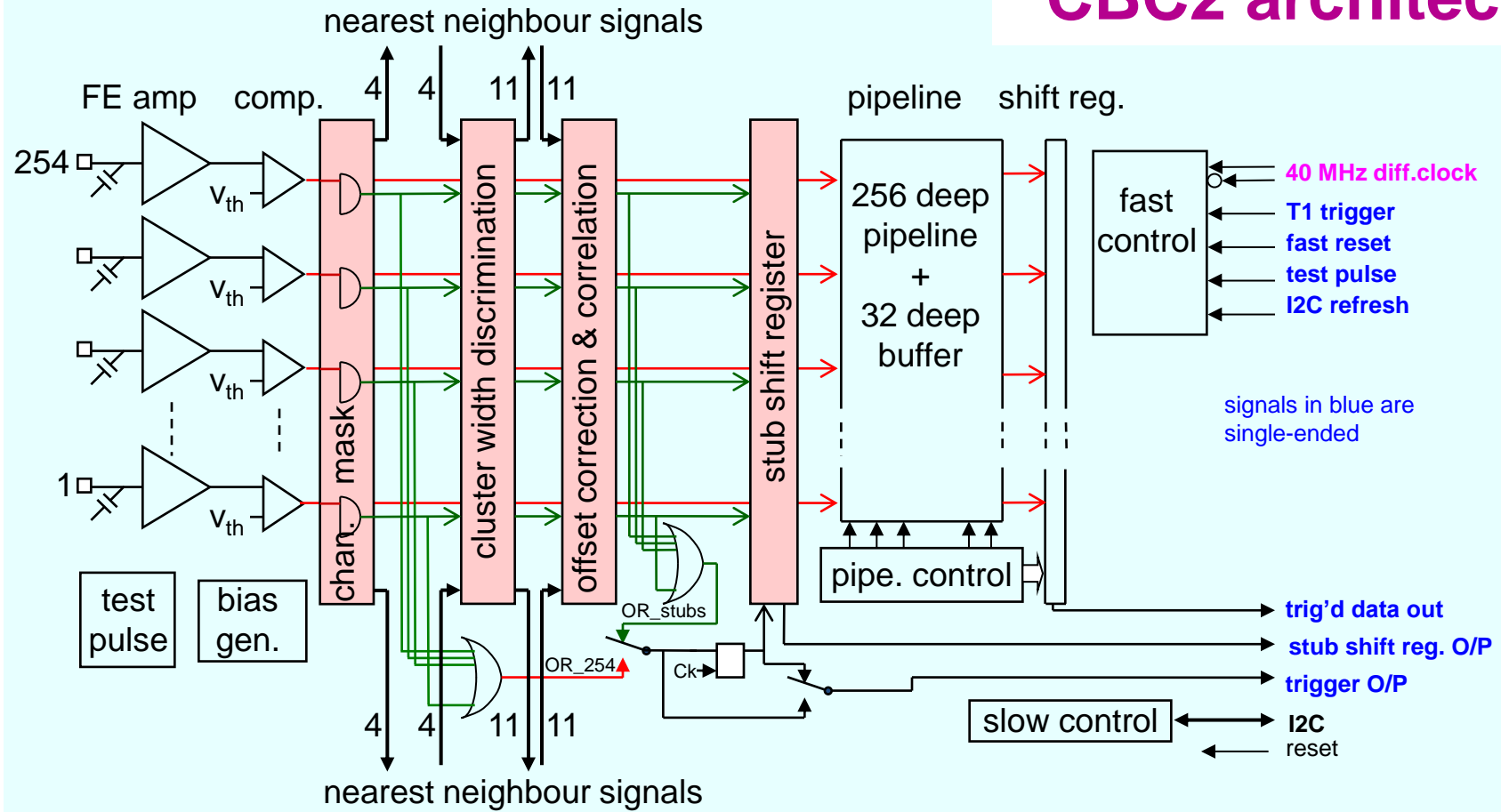
Offset correction & correlation logic

for a cluster in bottom layer, look for correlating cluster occurring in window in top layer

window width controls pT cut
stub found if cluster in bottom layer corresponds to cluster within window in top layer

window width programmable up to ± 8 channels

offset defines lateral displacement of window across chip

programmable up to ± 3 channels

zero offset   offset   window width

top layer clusters

bottom layer clusters

r   φ

beam

CWD logic

n+1

channel comparator outputs   n

n-1

1/2/3 strip cluster on channel n

programme cluster width to accept

254 channels: 127 from each sensor layer
channel mask: block noisy channels from trigger logic
CWD logic: exclude wide clusters >3
correlation logic: for each cluster in lower layer look for cluster in upper layer window
trigger output: 1 bit per BX indicates correlation logic found one (or more) stubs
**triggered data out:**   unsparsified binary data frame in response to L1 trigger
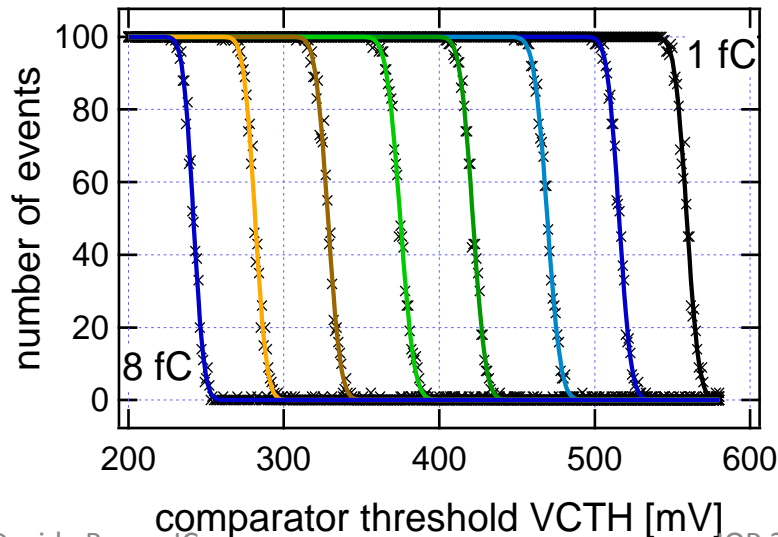
CBC2 performance

M. Raymond

- All core functionality meets requirements

- Correlation functionality verified with test pulses, cosmics (backup), and in test beam

- Analogue performance close to simulation and specifications

  e.g. **1000e** noise for 5 cm strips (~8 pF) achievable for total channel power of **350 uW**
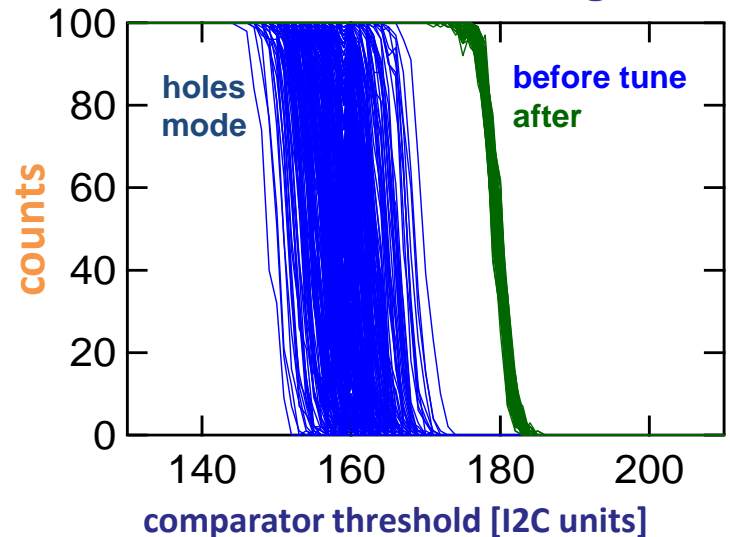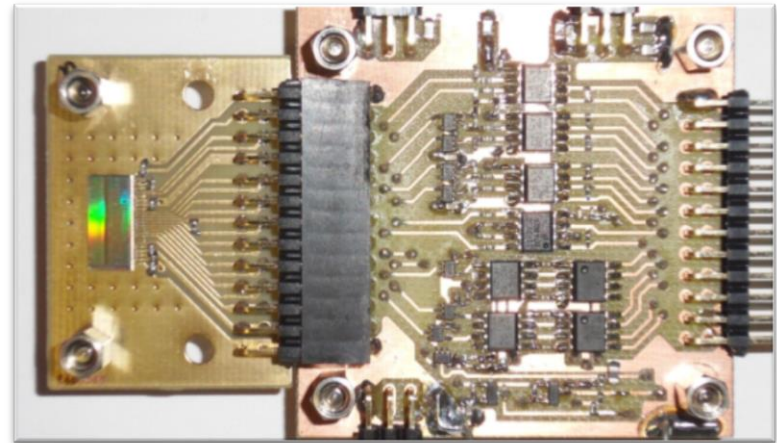
noise & power vs. external capacitance
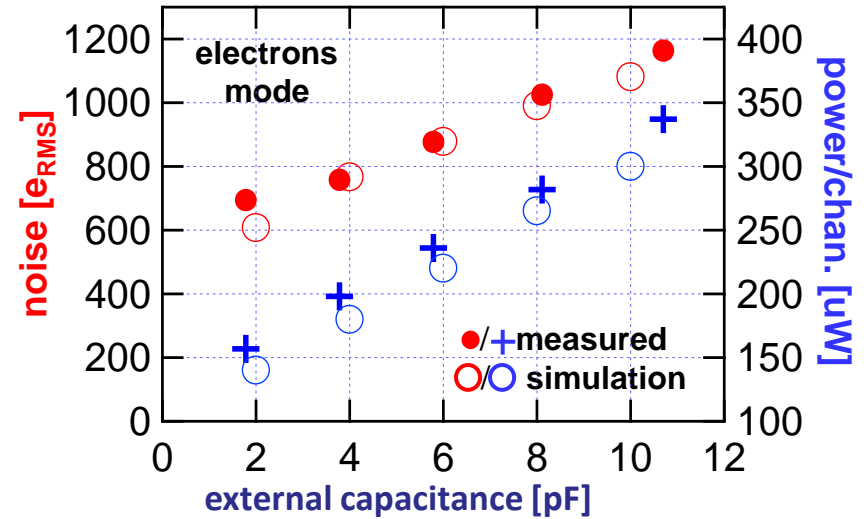
channel offsets tuning

S-curves

CBC2 testing activities

Wire-bond CBC2

- **Useful to develop wafer probe procedures**
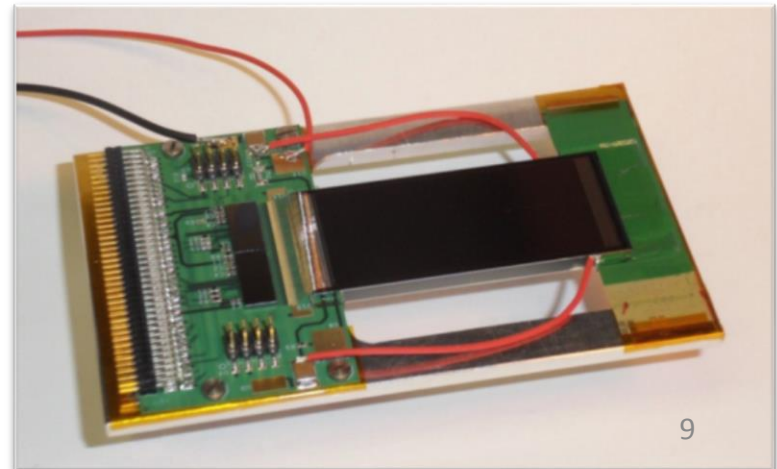- **X-rays TID testing**

2xCBC2 hybrid

- **Hybrid characterization and chip integration**
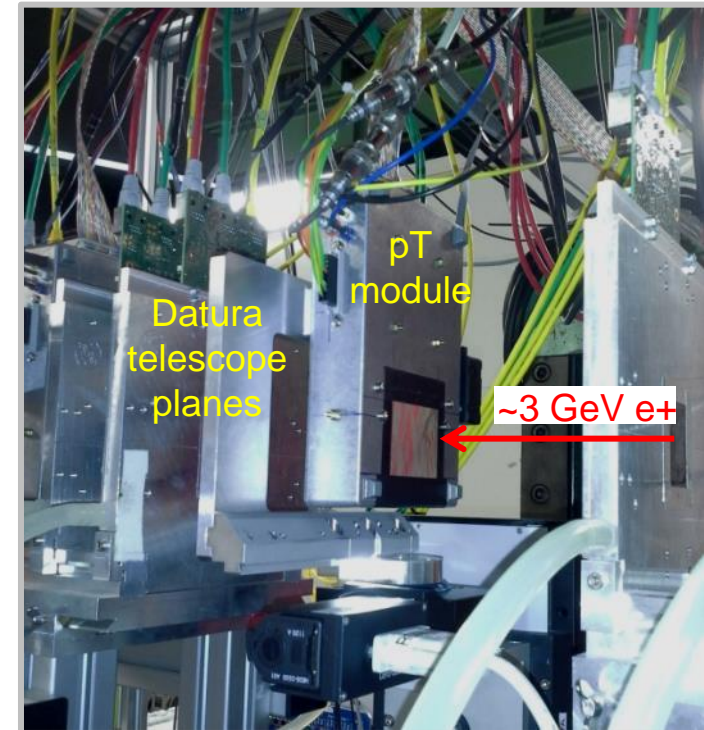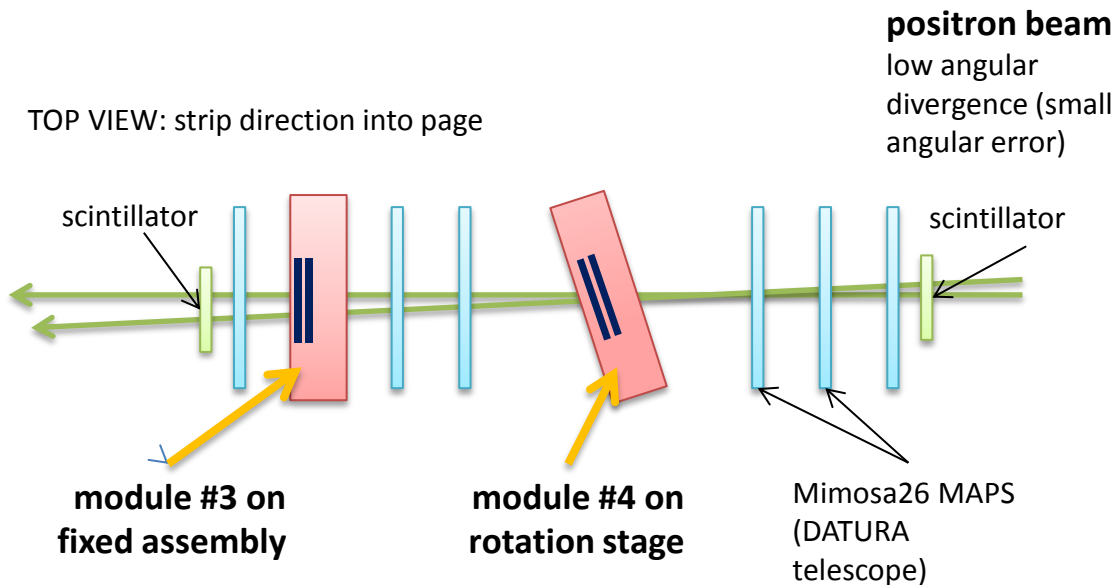- **Bump-bonded ASICs**
- **Inter-chip links & logic**

2xCBC2 mini-module + sensor

- **Sr-90 source**
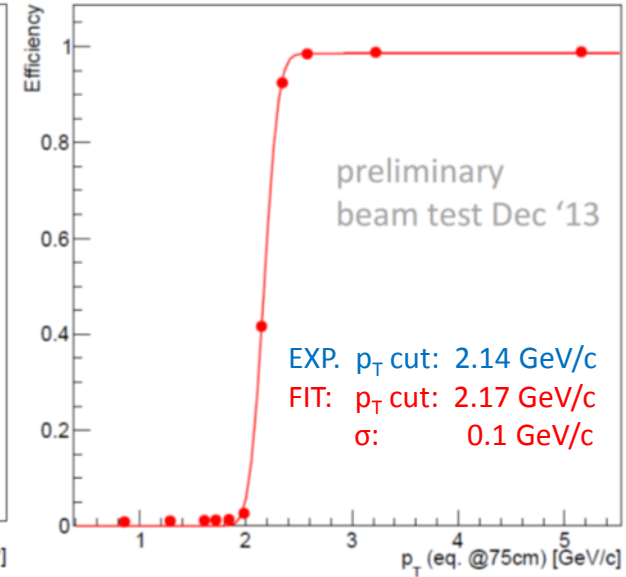- **Cosmic rays**
- **Beam Test**

Pt module beam test at DESY

- December 2013
- 4 GeV positron beam
- Datura telescope + 2 pT modules (1 rotatable to simulate B-field effect) + 2 different strip sensors
- Custom control and DAQ

TOP VIEW: strip direction into page

positron beam
low angular divergence (small angular error)

scintillator

scintillator

module #3 on fixed assembly

module #4 on rotation stage

Mimosa26 MAPS (DATURA telescope)

Datura telescope planes

pT module

~3 GeV e+
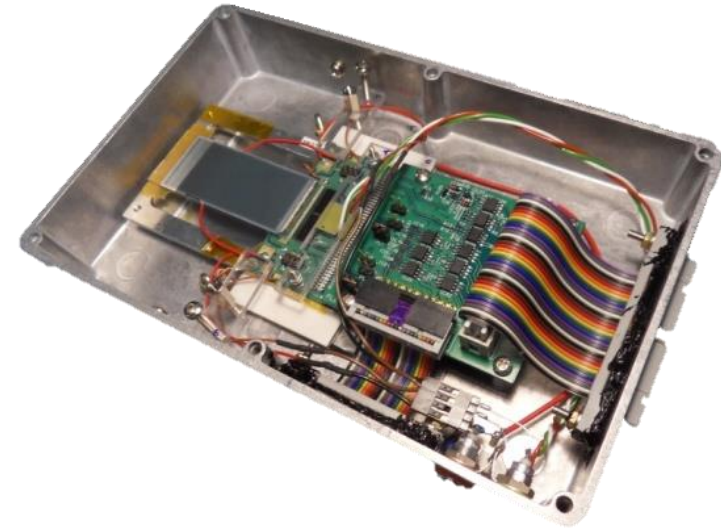
Beam test results

M.Pesaresi

Turn-on curve for tracker barrel layers

S. Viret

Layer 4
Layer 5
Layer 6

preliminary
beam test Dec '13

preliminary
beam test Dec '13

EXP. p_T cut: 2.14 GeV/c
FIT: p_T cut: 2.17 GeV/c
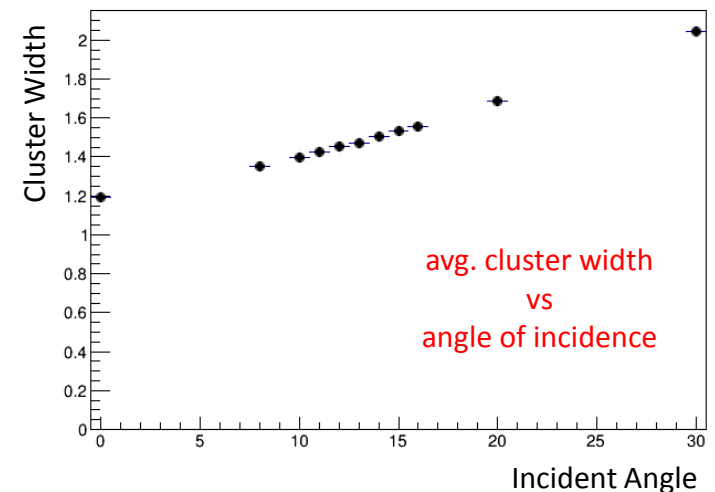σ: 0.1 GeV/c
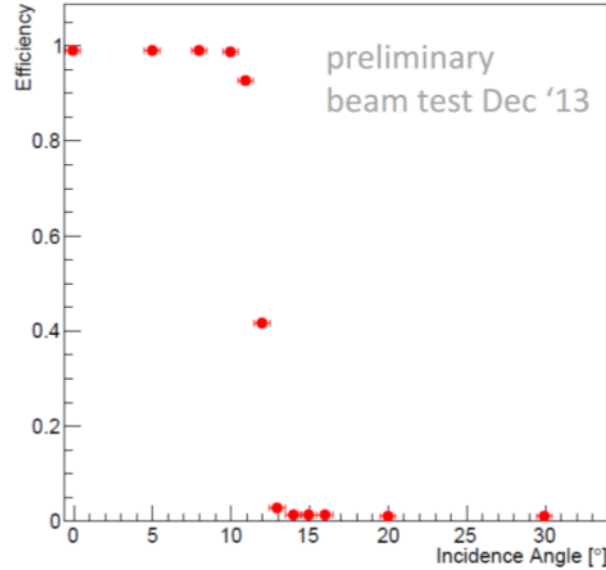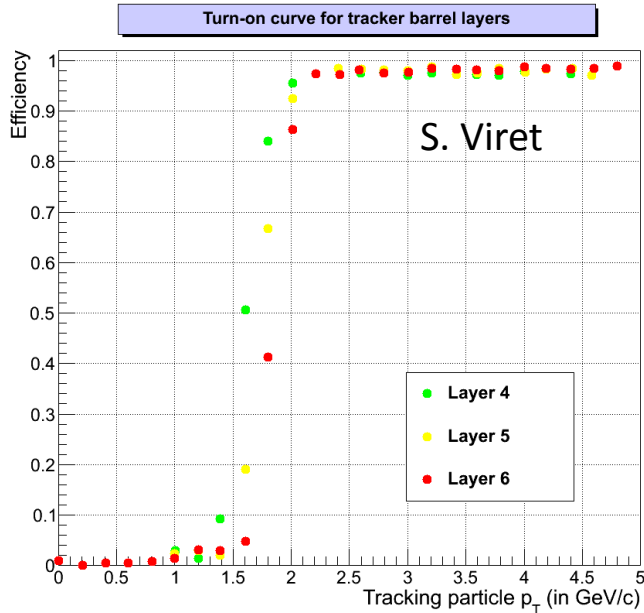
Pt Selection cut: simulation ⟹ **measured efficiency** ⟹ **reconstructed p_T cut of r=75cm layer**

Other measurements include:

- **Study of cluster width**

- **System noise**

- **Beam profile**

avg. cluster width
vs
angle of incidence

Total Ionizing Dose test

- **First xray irradiation to 10 Mrads**

- **CBC2 operated continuously during irradiation**

- **monitored currents, biases, pedestal, noise**

- **no significant change in performance, moderate increase in current before annealing**

- **Next: TID test up to ~50 Mrads**
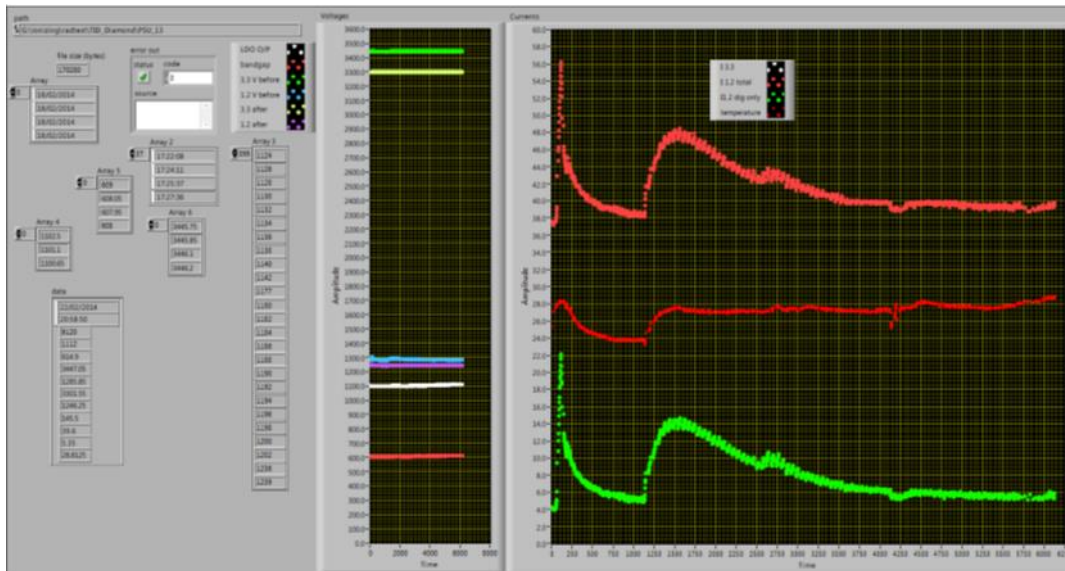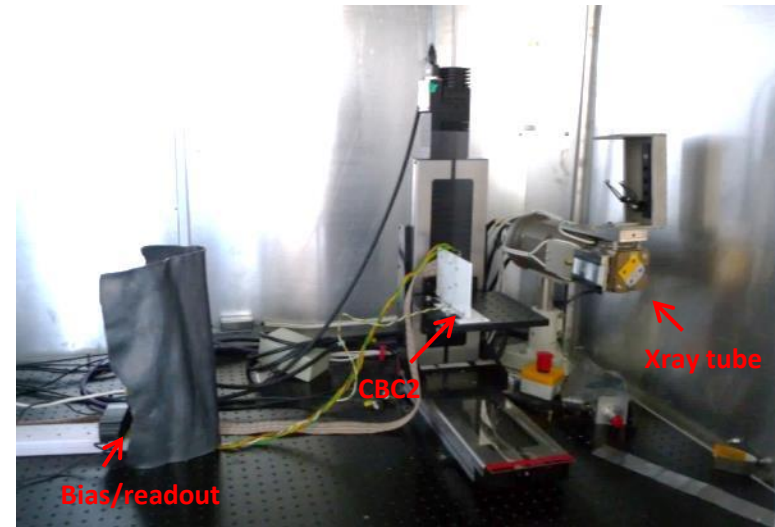
Conclusions and Future Work

Milestones so far:

- ✓ **CBC2 working to specs**
  - ✓ **Stub finding logic functioning**
  - ✓ **TID dose irradiation test under way**
- ✓ **First prototype version of 2S module extensively tested**
  - ✓ **Beam test at DESY successful**
  - ✓ **Pt selection cut and stub logic demonstrated**
  - ✓ **DAQ working well**
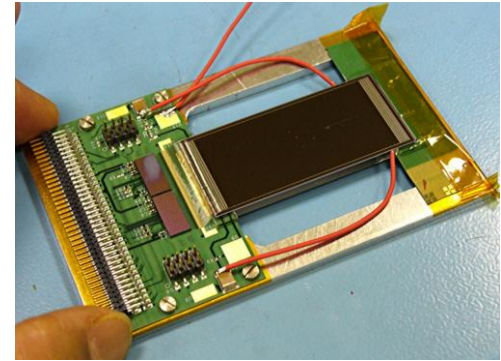
Future work:

- • **Continue with 2S module prototyping**
  (8chip hybrid from CERN)
- • **SEU test of CBC2**
- • **CBC3: final prototype version with full stub readout**

A. Honma
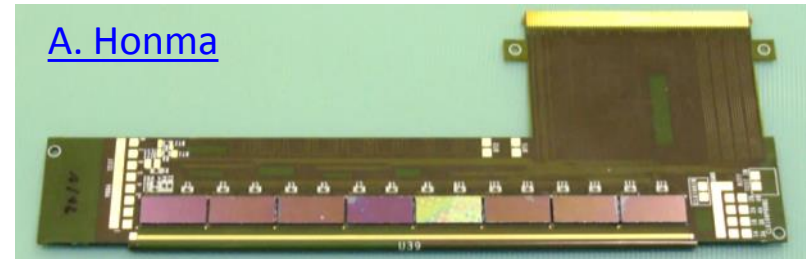
**First results to prove the track-trigger concept
        a very new idea never before implemented**

→ CMS ambitious plans for a track trigger look promising