CMS Binary Chip 2:

Tracker readout with trigger primitives for the HL-LHC

D. Braga[a,b], G. Hall[a], P.Murray[b], M. Pesaresi[a], M. Prydderch[b] and M. Raymond[a]

a: Imperial College of London
b: Rutherford Appleton Laboratory
email: davide.braga@stfc.ac.uk

Abstract: CBC2 is the current version of the CMS Binary Chip ASIC for the readout of CMS Tracker phase-II upgrade. CBC2 is designed to instrument double layer modules in the Outer Tracker, consisting of two overlaid silicon sensors with aligned microstrips, and incorporates the logic to identify L1 trigger primitives in the form of "stubs": high transverse-momentum candidates which are isolated from the low momentum background by selecting correlated hits between two closely separated microstrip sensors.

CMS Silicon Tracker phase-II upgrade:

The high-luminosity (HL) upgrade of the LHC will set stringent requirements for the CMS silicon tracker, such as higher granularity, new power distribution and trigger capabilities. To maintain the first level trigger (L1) average rate at 100 kHz, it is envisaged that the silicon tracker will contribute to the L1 trigger by providing basic tracking information in the form of high transverse momentum (Pt) track primitives called stubs.

A promising way to identify stubs is the stacked module approach, by which high-Pt tracks are isolated from the low-Pt background by looking at the coincidence between hits on two closely separated sensors (figure 1b).

A threshold of ≈2GeV/c should achieve a reduction factor of one order of magnitude.

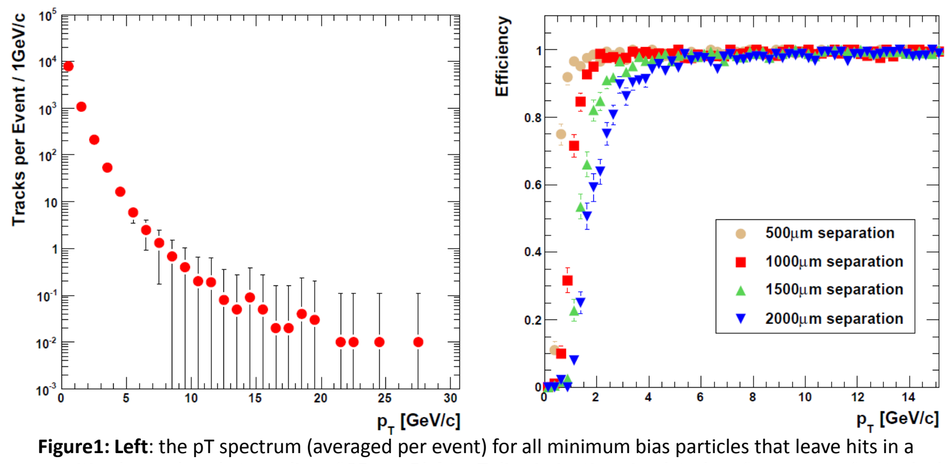

Figure1: Left: the pT spectrum (averaged per event) for all minimum bias particles that leave hits in a sensitive layer placed at a radius of 25 cm. **Right**: pT discrimination simulated performances of a stacked layer for single μ tracks at various sensor separations (stacked layer at 25cm) [*Pesaresi and Hall, JINST 5 C08003, 2010*]

Figure2: a) Pt selection concept. b) Stacked module for strip sensors and data transfer (ASICs in green). c) Edge view of sensor connections.

Module design:

Figure2b shows one of the stacked modules currently being developed for the outer barrel tracker (R>500mm), designed to be lightweight and to rely on commercial interconnection technology.
The Pt threshold for stubs selection can be adjusted by changing the width of the coincidence window in the upper layer (programmable in CBC2) and the separation between silicon sensors. The optimal sensor separations vary in the range 1-4mm in the barrel and 1-5mm in the endcaps, depending on the Pt cuts required and the radius of the layer/disk. The strip sensors are wire-bonded to the substrate and read out by 16 CBC.
[Abbaneo et al., 2011 JINST 6 C12065]

CBC2 architecture:

• The CBC2 is a 254-channel binary prototype ASIC for the readout of silicon strip detectors.
It develops from a previous 128-channel version which achieves ≈800 e_{RMS} noise with a total power of less than 300μW/channel.
• Front-end channels consist of charge amplifier, gain amplifier and comparator, and can be AC or DC coupled to sensors of either polarity. The output pulse shape has a peaking time of ≈20ns.
• The CBC2 block diagram is shown in figure 3. Binary data from the front-end comparators are synchronized with the bunch crossing clock and then follow two parallel paths: one for triggered readout (in red) and the other for stub finding (in green). In the former data are continuously written into a 256-deep FIFO pipeline RAM, for a maximum trigger latency of 6.4μs. When a L1 trigger is received, the pipeline control logic transfers the relevant data to a 32-deep buffer memory, where it is stored before being read out, un-sparsified, at 40MHz.
In the other data path several blocks of combinatorial logic identify stub candidates before writing them into a shift register for serial read out.
• The operation of the stub-finding logic is based on a simple procedure:
1) the first stage rejects wide clusters of hits on both inner and outer sensors;
2) for every valid cluster on the inner sensor the logic looks for a hit in a coincidence window on the outer sensor;
3) if a hit is present within this window, the inner strip is considered a valid stub.

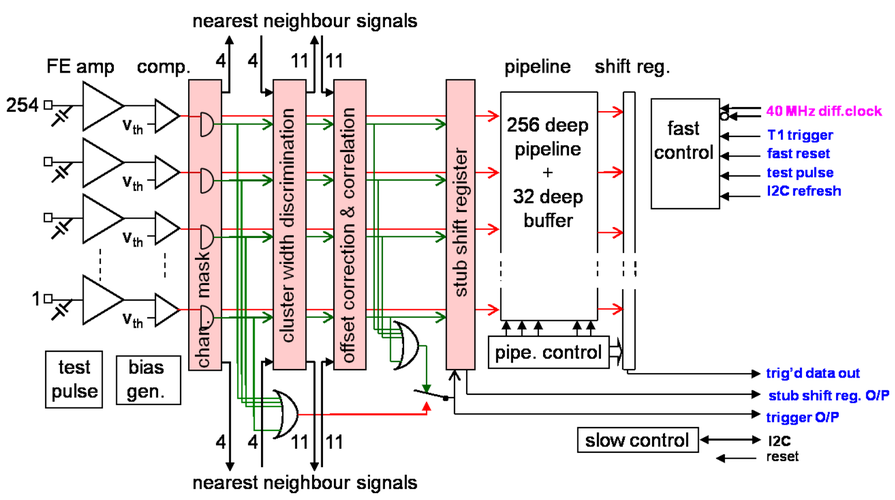

Figure3: CBC2 block diagram

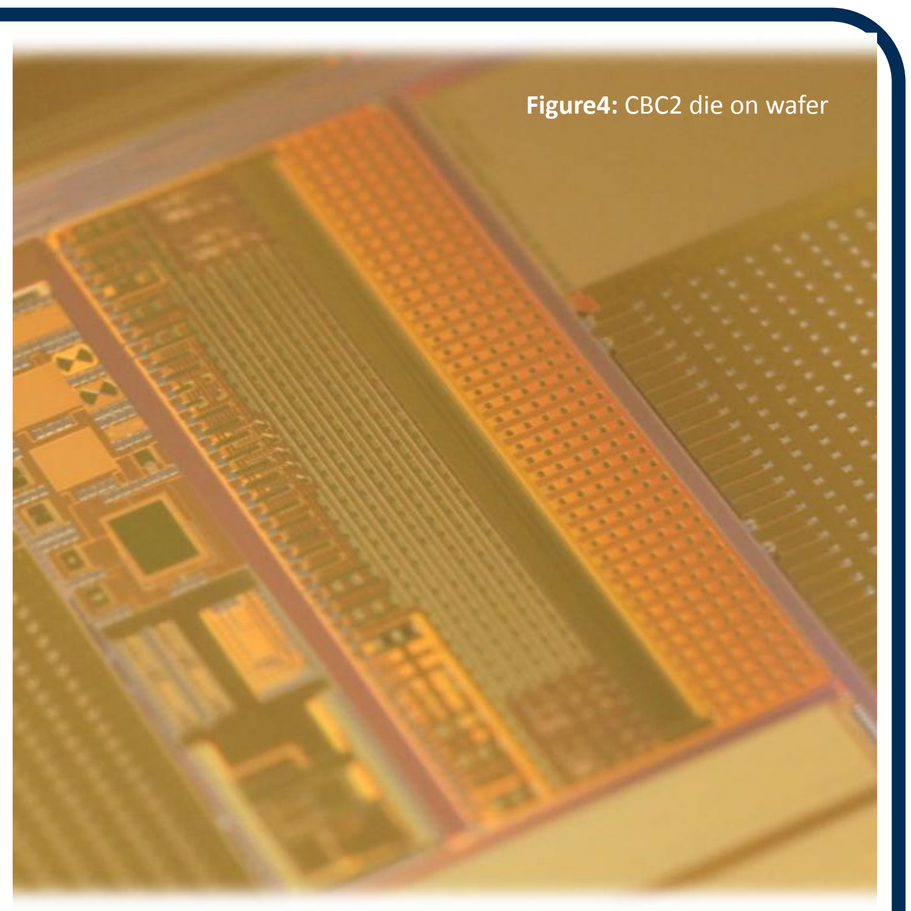

Figure4: CBC2 die on wafer

Future Work:

- CBC2: •Test beam and total dose irradiation
- CBC3: •Full stubs readout
  •½ strip resolution
  •Bend information for stubs
  •Stubs priority encoding
- CBC4: •Pre-production version

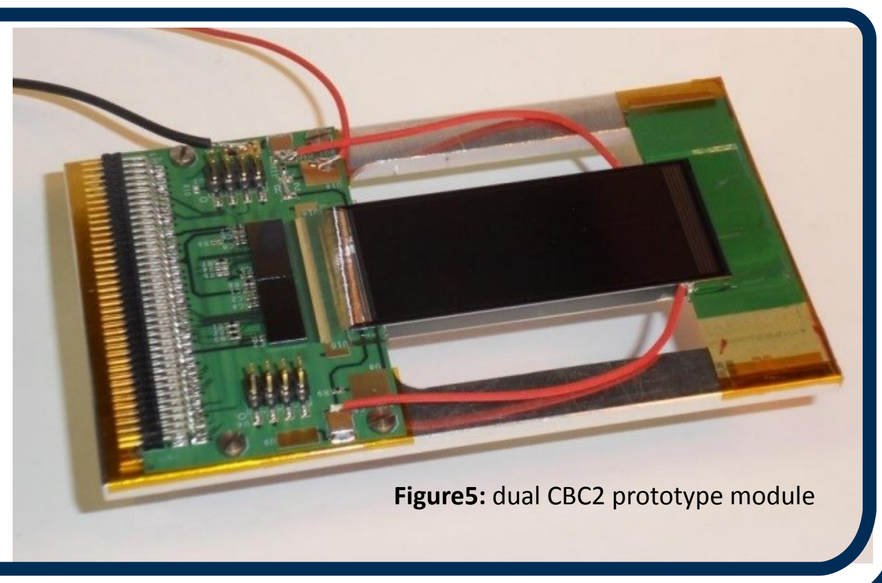

Figure5: dual CBC2 prototype module