A SYSTEM FOR BEAM ABORT AND LUMINOSITY DETERMINATION AT THE HL-LHC BASED ON POLYCRYSTALLINE CVD DIAMOND

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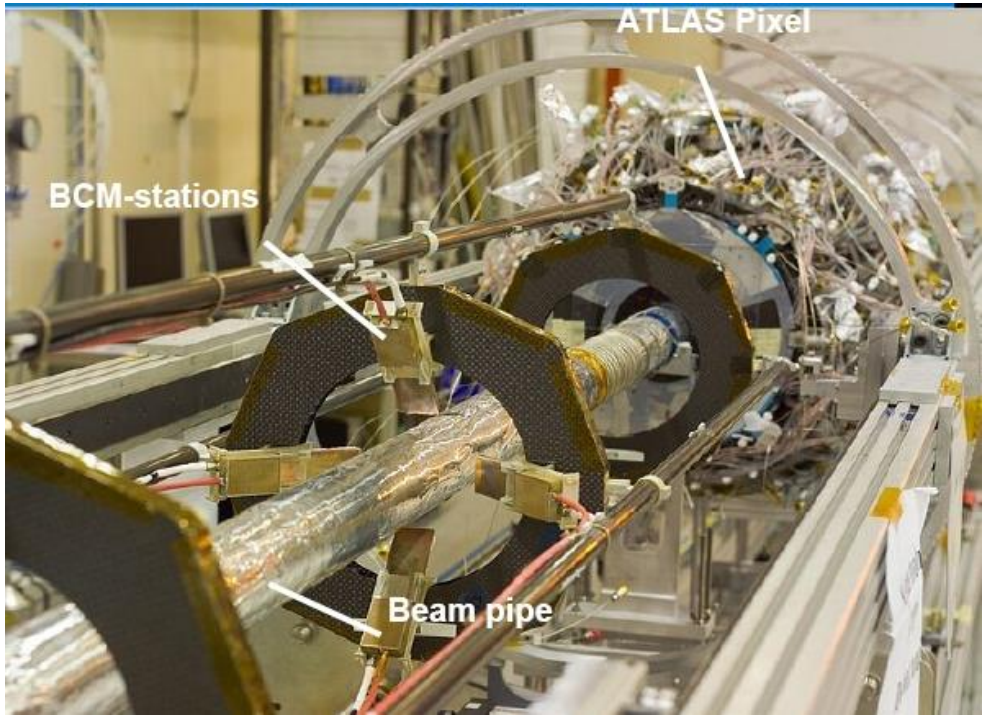
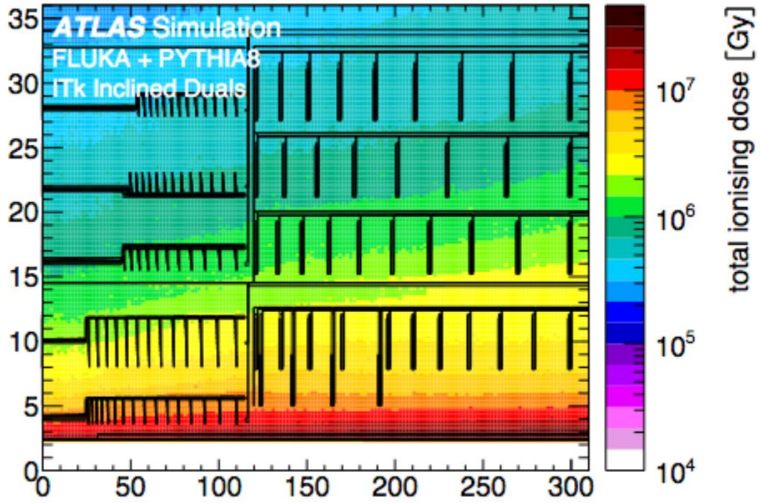
CONTRIBUTORS

THE BCM'

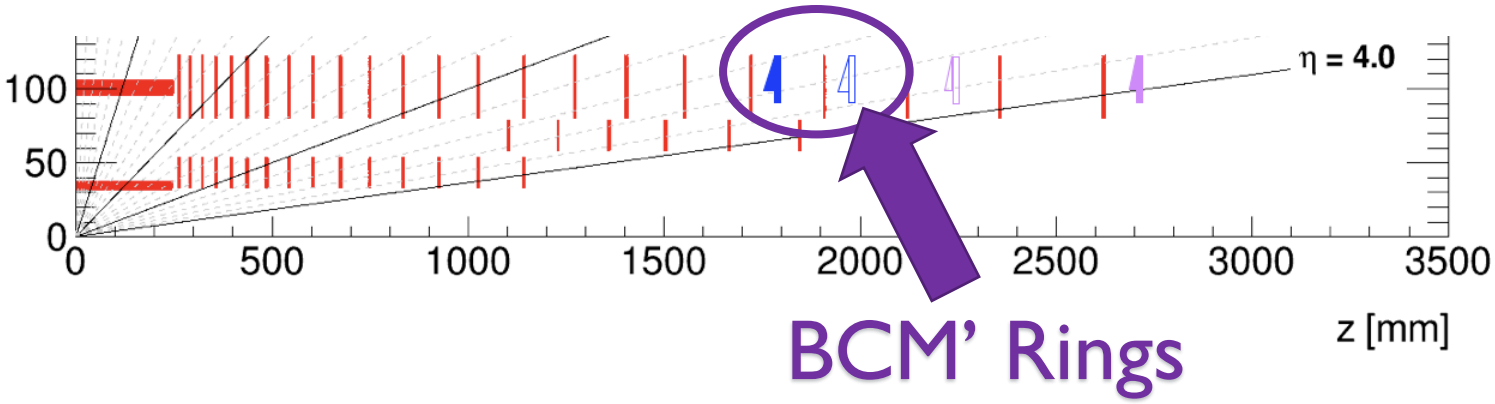
- BCM' = The ultimate ATLAS Beam conditions monitor
- Provides:
  - Fast bunch-by-bunch safety system
  - Background monitoring
  - Luminosity measurement
- Development for the HL-LHC = more particles per bunch crossing
- Location in the ATLAS ITK

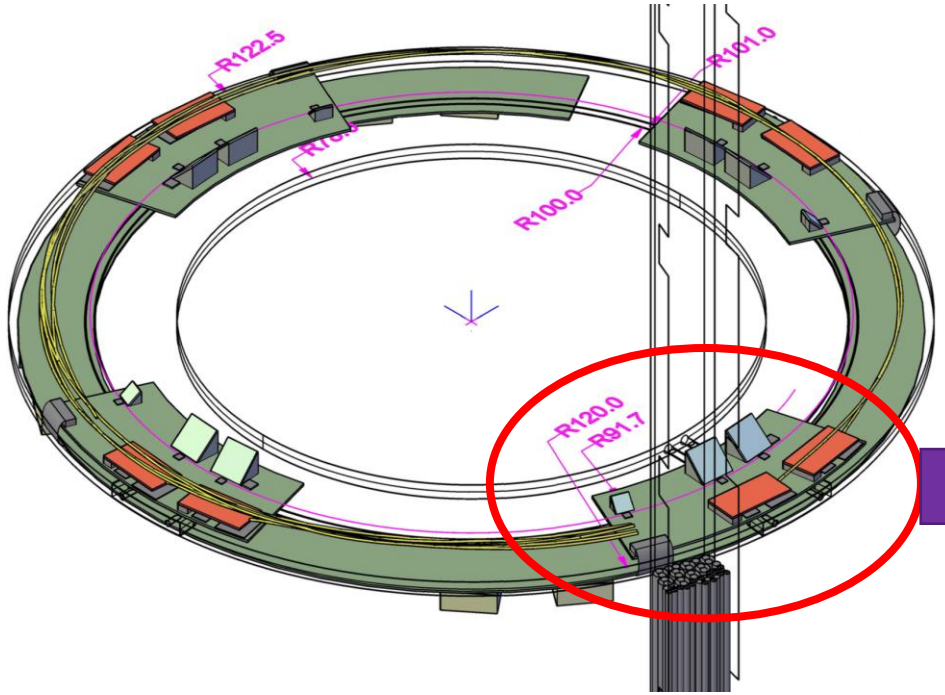


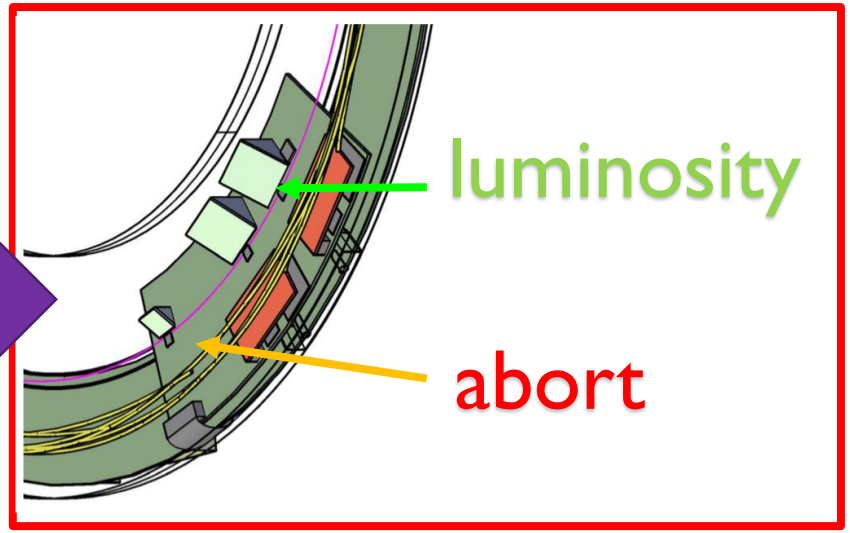


BCM' WITHIN ATLAS

- BCM' position within the removable inner pixel at z~1875mm to be close to 6.25ns timing sweet spot
- r~100m gives **μ~3.6**
- 4 modules per station, 8 in total
  - φ=0°,90°,180°,270°





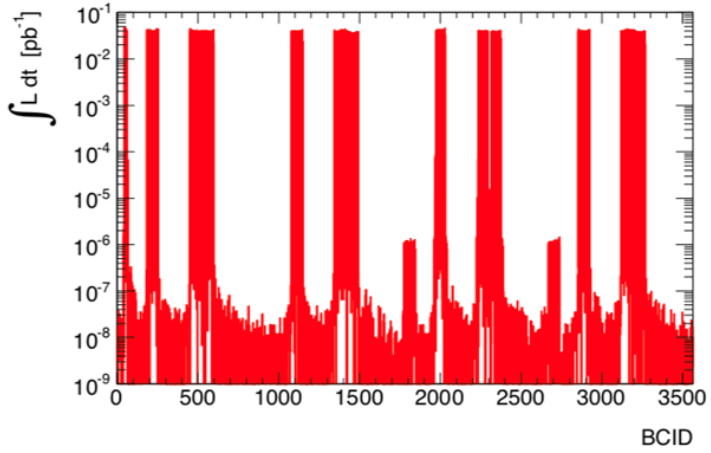


- Each Module hosts all functionalities:
  - Luminosity
  - Abort
  - Amplification
  - Digitisation
  - Transmission

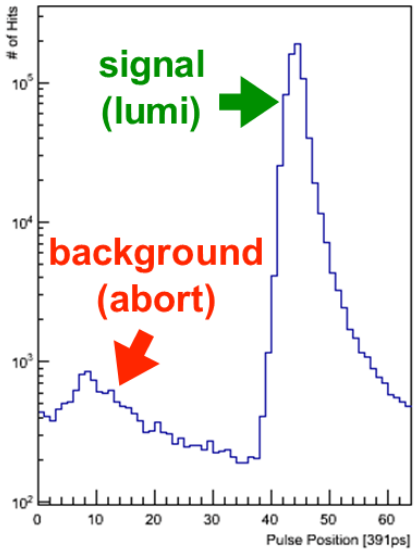
THE PAST – ATLAS BCM

- Currently installed in ATLAS is a fast pCVD based system with asynchronous 2.56 GB/s readout
  - 4 modules per side, 1.9m from interaction point
  - 500ps time resolution
  - Installed into ATLAS Pixel support tube in 2007
- Performance:
  - Post-mortem diagnostics – buffer after each dump triggered by machine's BLM
  - Aborts at danger level – induced by UFO's
  - Beam background diagnostics – 500ps timing resolution cleanly resolves background
  - Luminosity measurement – stability problems in Run 2 conditions, low S/N ~10
  - Abort&Lumi functions coupled
- Suffers from abort<->lumi **incompatibility**
  - Higher abort thresholds have to abandon lumi
  - Fast timing for abort lowers SNR limiting lumi stability

Design Details:
JINST 3 P02004 (2008)

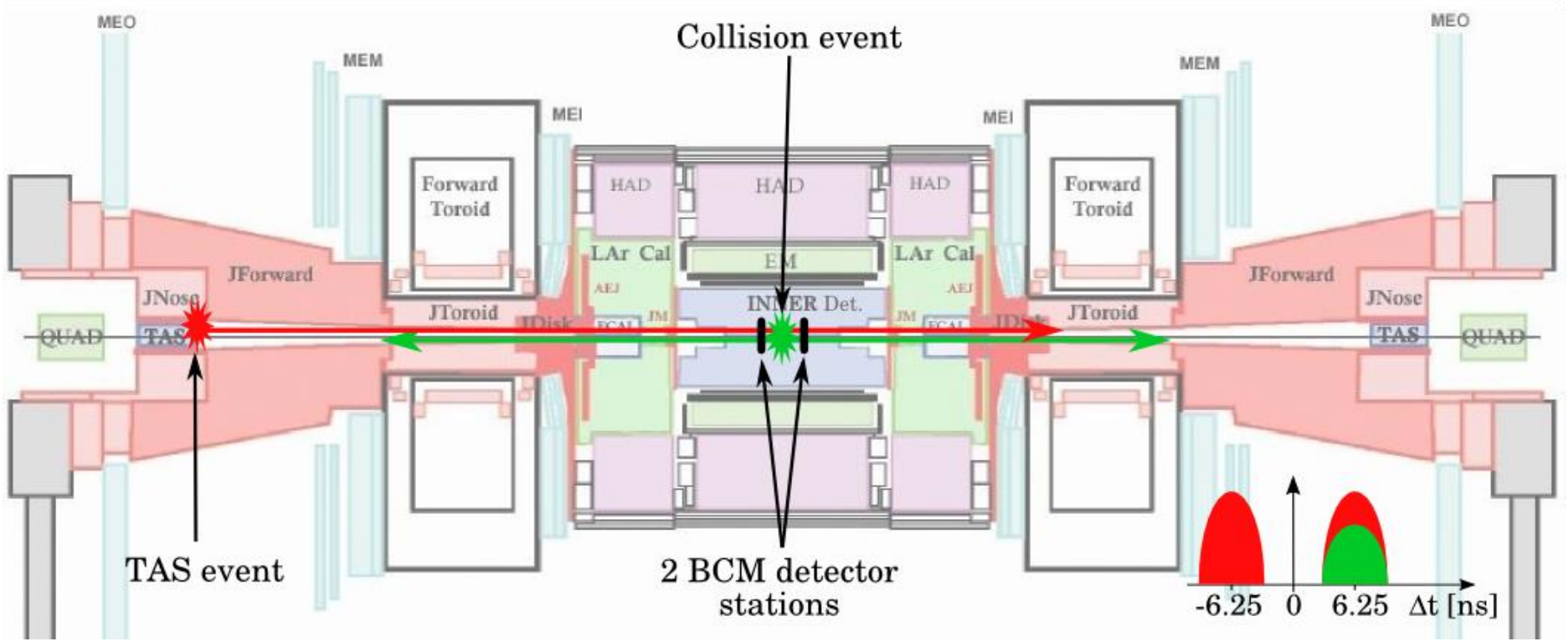


Separate functionalities for HL-LHC keeping commonality in a ***station***



FUNCTIONALITY

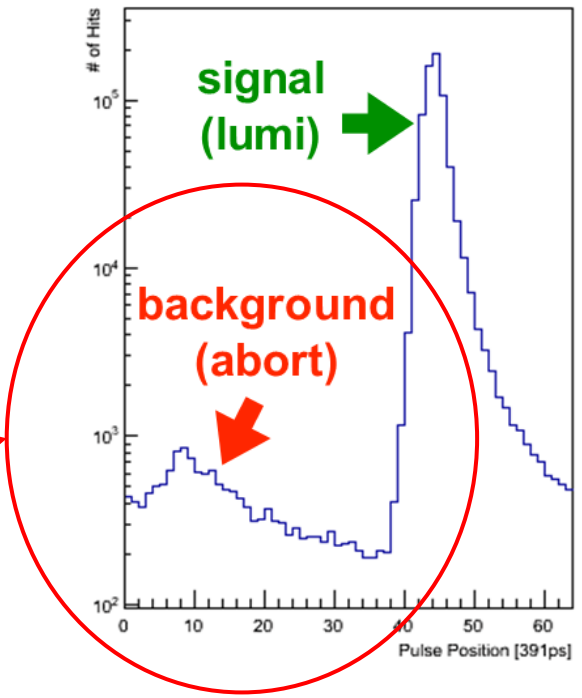
- BCM Time of Flight (TOF) concept:
  - **Out of time signals :** are indicative of non-collision background (NCB) → abort
  - **In-time signals :** carry physics information → luminosity



FUNCTION (1) - BEAM ABORT

- **Protection** of inner detectors
- Out of time signals ~6ns **before** a collision
- Abort on out-of-time activity above the danger threshold
  - Pretty high ~ 25k/cm^2/bunch crossing which is 4000x lumi induced signal
  - More sophisticated algorithms can be used to improve response for different fault scenarios
- Threshold settings need to be **flexible**
- Include machine style Beam Loss Monitor (slow 40μs integrating)

debris from collimators, beam gas, UFO, parasitic collision, etc…

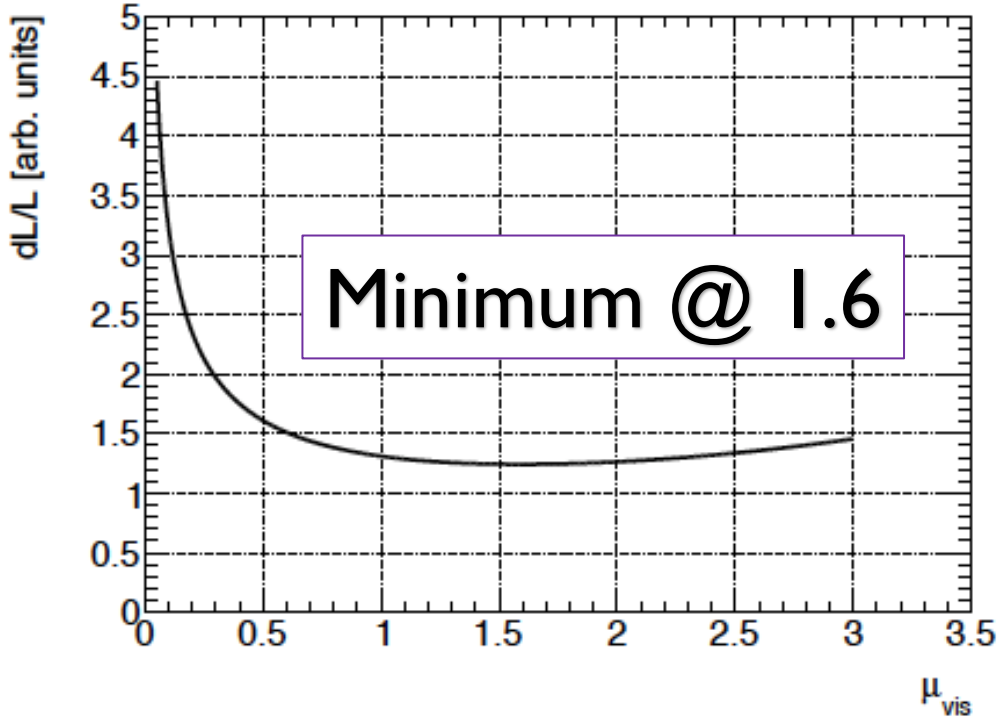


FUNCTION (2) - LUMINOSITY

- Luminosity and background measurements require **MIP sensitivity**
- In-time signals (+6ns) carry **physics information**
- Out-of-time (-6ns) signals carry **background information** (NCB)

- Approach using **event-counting algorithms**
  - Statistics of in-time signal / absence of signal
  - Maximal statistical sensitivity r~0.2 = ~ 1.6 hits/cell

- Need a robust device, signal stability is paramount
- Have to consider a large range of μ
  - Calibration in VdM scan ~0.01 in tails
  - Ultimate HL-LHC lumi μ = 200



BCM in ATLAS Luminosity determination:
Eur. Phys. J. C (2016) 76:653

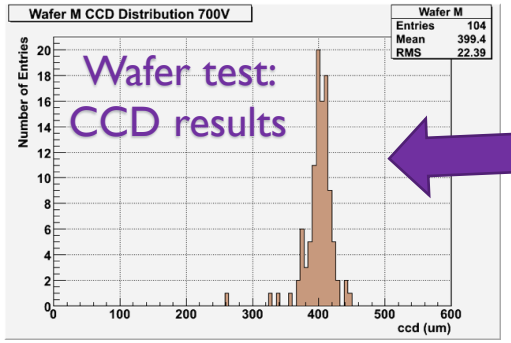
DIAMOND DETECTORS

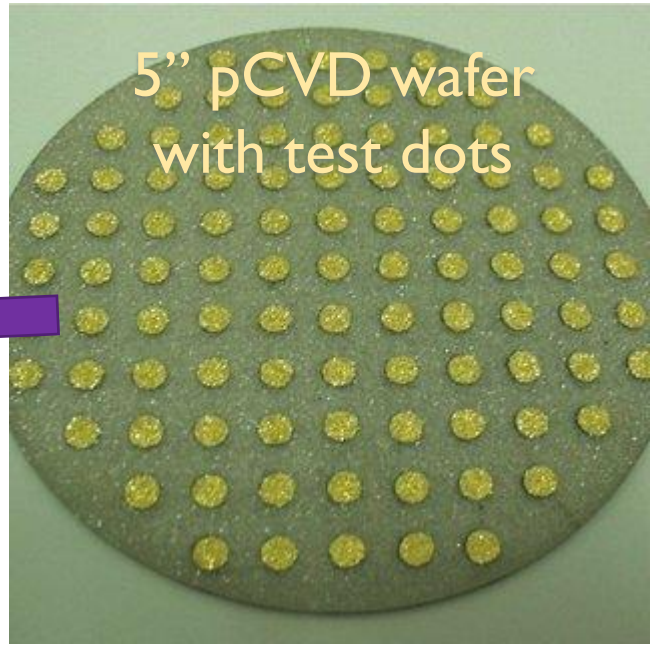
- Polycrystalline chemical vapour deposition diamond sensors (pCVD)
  - Robust, low capacitance, low leakage current, fast signal, radiation hard and no cooling
  - 1-2 wafers grown for the project
- Charge collection evaluated to be ~9ke @ 2V/μm
- 4 types of sensor on the station
  - Luminosity:
    - 3-pad segmented diamond 10 x 10 mm^2 (max ~50 mm^2, min~ 1mm^2)
    - 1 x 1 mm^2 3D detector
    - Small silicon detector

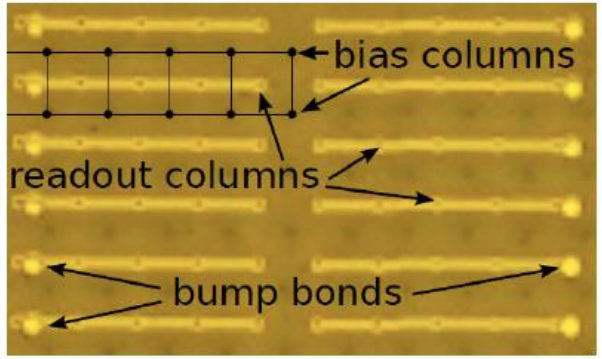
Dynamic range

  - Abort:
    - 5 x 5 mm^2 with 4-pad segmentation

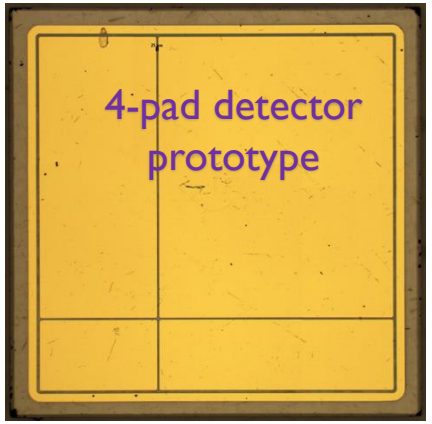
Reliability





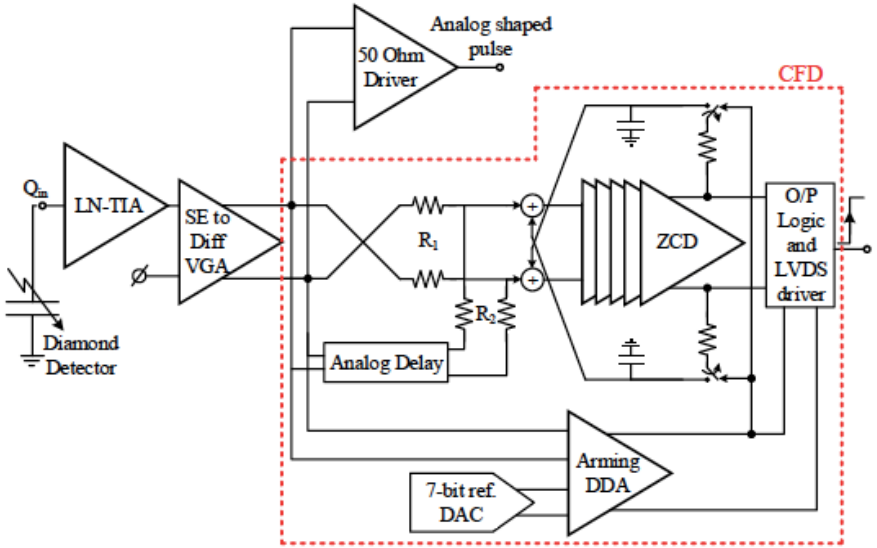


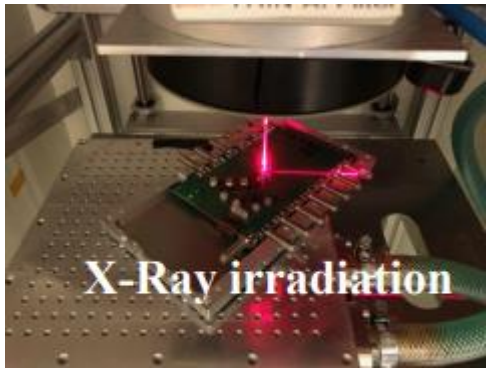
3D pCVD diamond

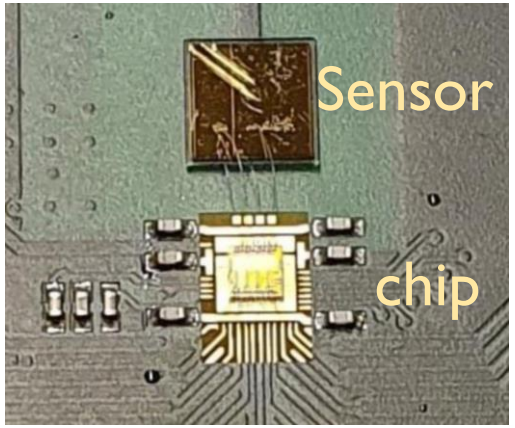


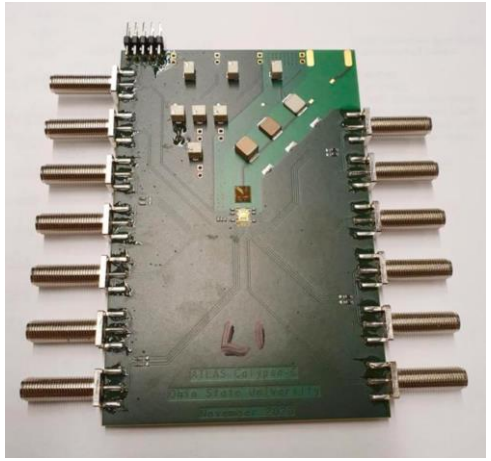
CALYPSO ASIC

- Radiation hard analogue front end – third iteration now tested = "*Calypso C*"
  - Designed by OSU
  - Separate functionality for abort (high signals) and luminosity (low noise)
- Specs:
  - Optimised for 2-5pf detector capacitance
  - Current amplifier: <1ns rise time, fast <15ns settling time @2pF
- Tested with multiple powering schemes to be radiation hard to 200Mrad









	noise [e]	range[e]
lumi	110+55/pf	50k
abort	830k	750M

BCM' module = sensor + analogue front end + PicoTDC +lpGBT + VTRx + optical fibre in/out

SUMMARY

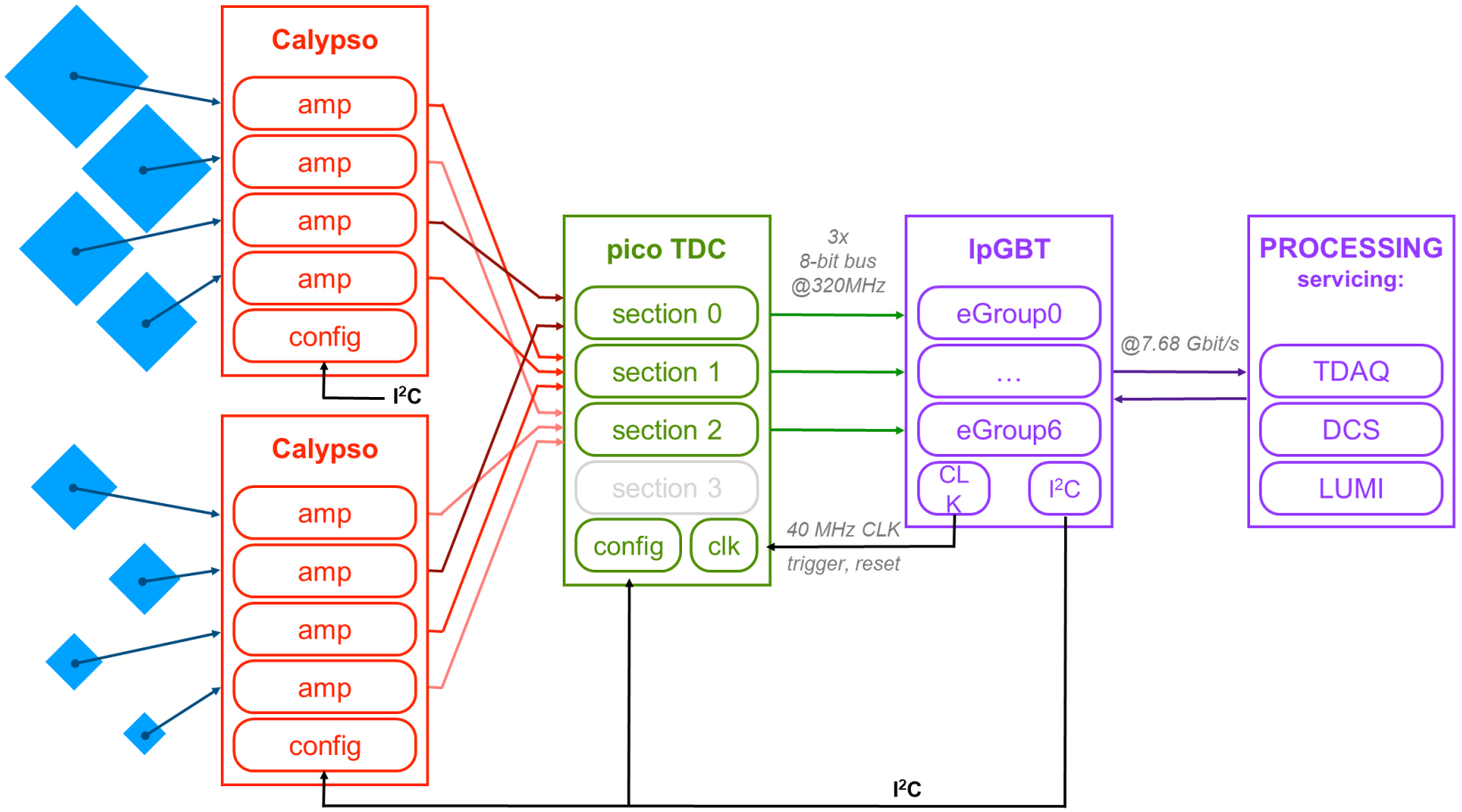
- The BCM' is a fast protection and luminosity measurement device inside the ATLAS ITk inner pixel end cap
- Offers advanced per-bunch luminosity measurement in a robust and flexible way
- All components in progress and coming together
- To be ready for installation in 2023

Thank you for your attention!

BACKUP

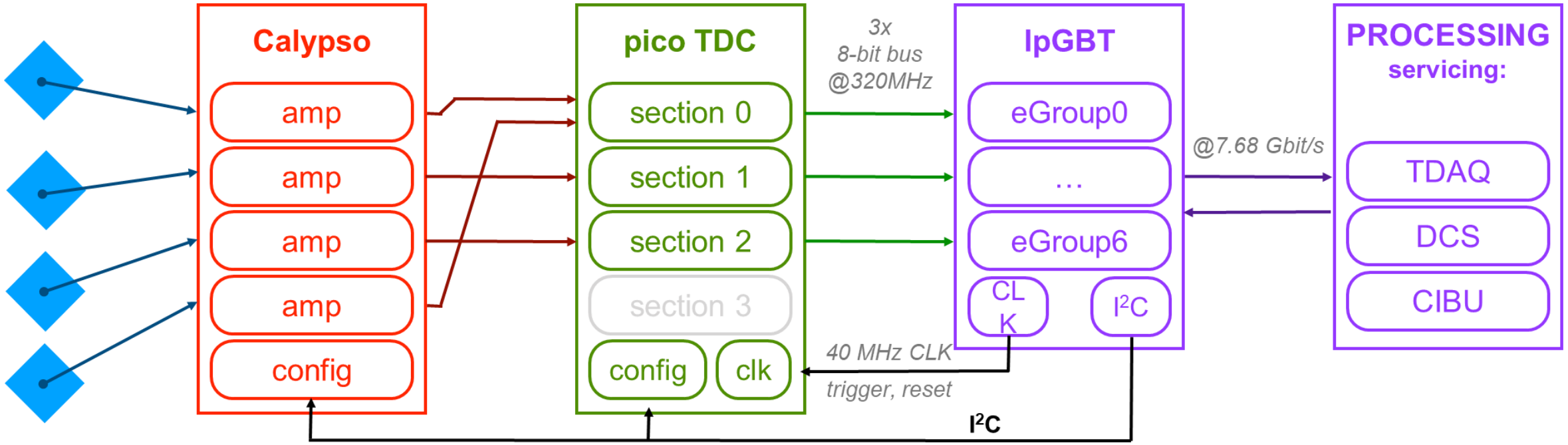
READ OUT - LUMINOSITY

- The number of channels and their selection chosen at config time: 3 or 6 out of 8
- Able to tune the dynamic range to optimal coverage of the running parameters of LHC



READ OUT - ABORT

- Smaller number of pads - emphasis on redundancy not dynamic range
- A separate picoTDC so the data composition (rise-time/width) can differ from the one for luminosity - flexible



BACK UP – ANTICIPATED INSTALLATION DATE