Beam Conditions Monitor for the Upgraded Inner Tracker of the ATLAS Detector

F9 Strategic Meeting 2026

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On behalf of
BCM' team
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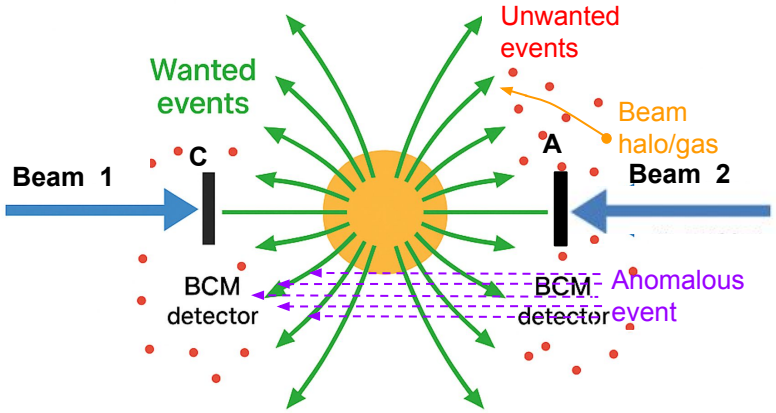
Outline

- Motivation
- Calypso readout ASIC
- 3-chip module and BCM’ ring
- Testbeam results
- Summary and future plans

BCM’

Motivation

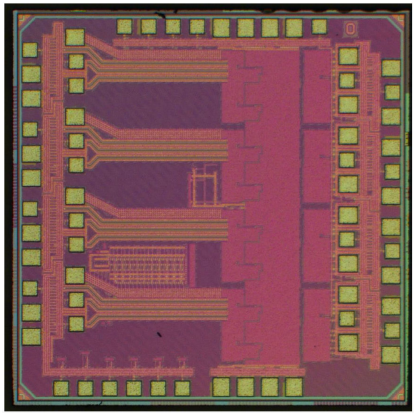
- Measuring the collision and background particles
- Collision particles:
- coming from p-p collisions
- Used for luminosity measurement required for Physics analysis
- Background particles:
- Normal background particles(beam gas, halo etc)
- Anomalous beam events(~1e^5 MIPs) potentially damaging the Inner Tracker(ITk)

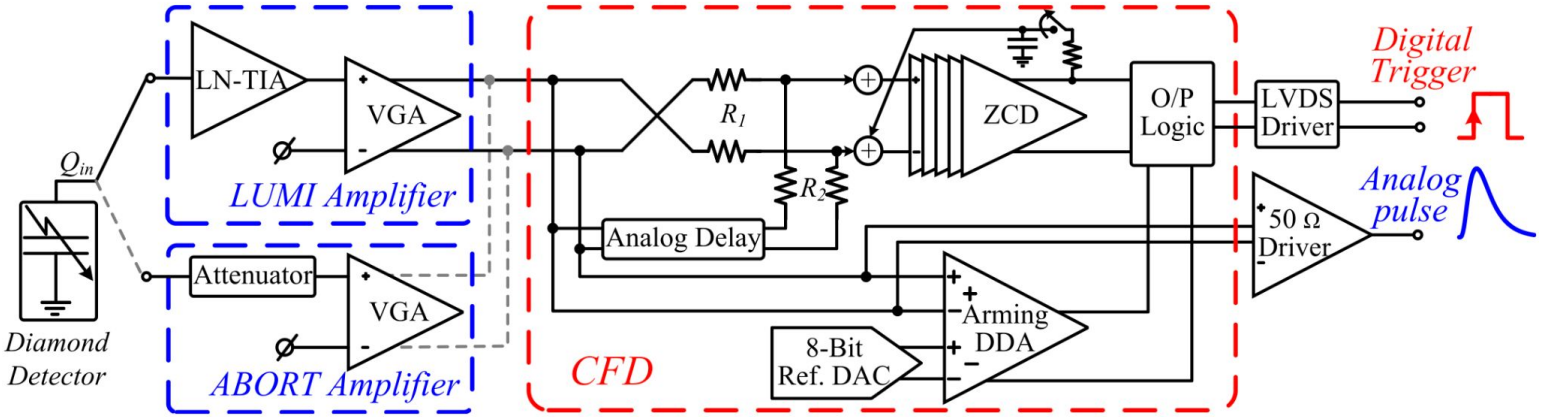


Calypso read-out ASIC

- 4 channels:
- High gain amplifier(Single MIP sensitive)
- Low gain amplifier(Abort function)
- Fast rise time(1.25ns)
- Small jitter(200ps)
- Low load capacitance(<5pF)

Calypso_E ASIC





BCM’ 3-chip module

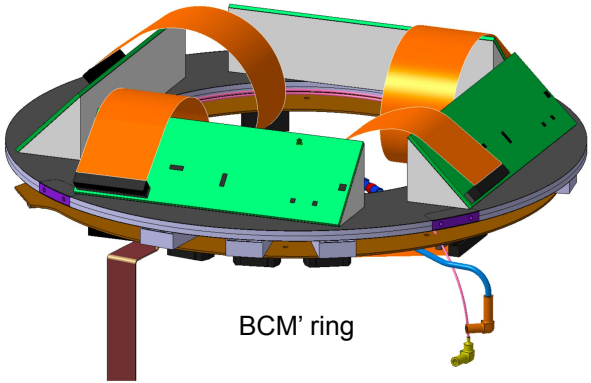
[1]IEEE TNS 70(2023)1514

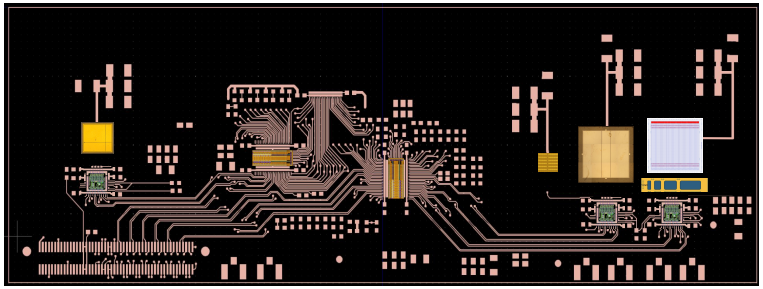
- BCM’ is equipped with:
  - 3 Calypso_E’s:

    Fast (200 MHz BW) FE, CFD circuitry providing ToA and ToT encoded in asynchronous LVDS output and analogue monitoring [1].
  - pCVD Lumi(10x10 mm^2) and Abort(5x5 mm^2)
  - sensors.
  - Silicon mini-strip sensor:

    From ATLAS ITk strips QA of 10x10 mm^2 with 80 µm pitch.
  - 2 LAPA’s:

    LVDS 5 GHz driver chip for driving the signal over 5 m twinax cable.

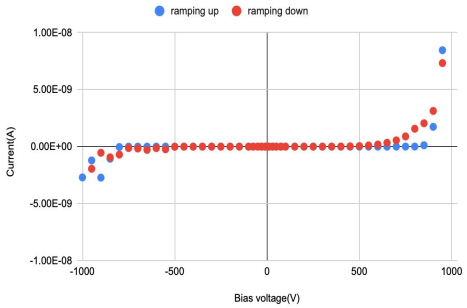




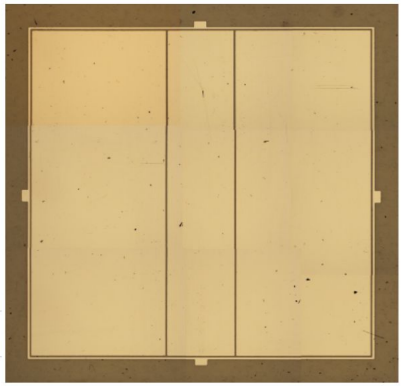
BCM’ 3-chip module

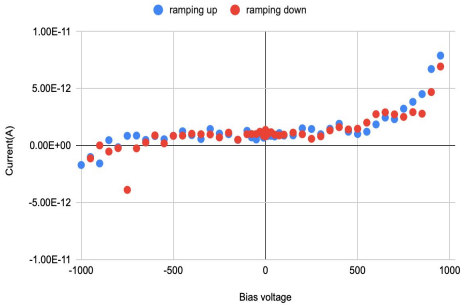
pCVD diamond sensors

- Radiation tolerant
- Large band gap, Low leakage current(no cooling is required).
- Low capacitance, low noise

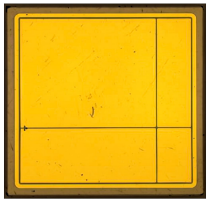


Lumi 10x10mm^2





Abort 5x5mm^2



BCM' location in the ITk

- 4 BCM' detector modules on each side of the pixel detector
- Mounted on Pixel Inner System End Cap(IS EC)

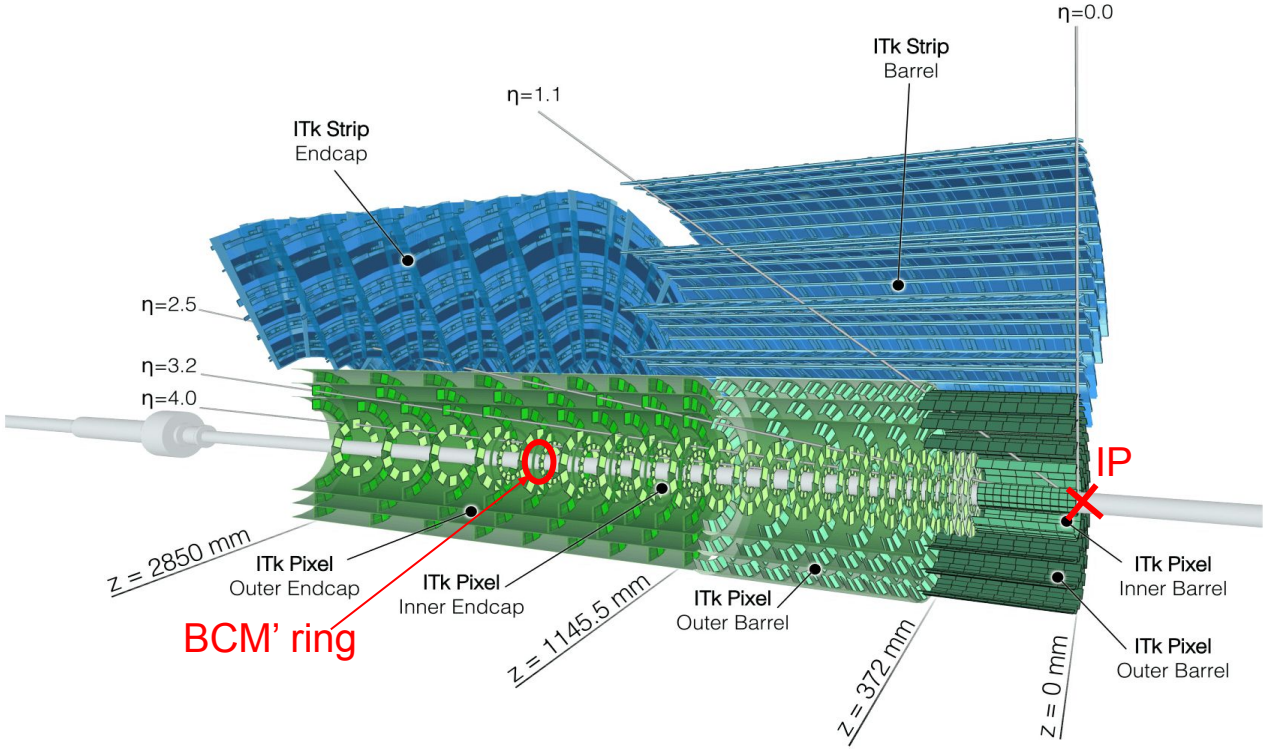
  ring located at

  z = ±1.9m, sensors at

  r = 10cm

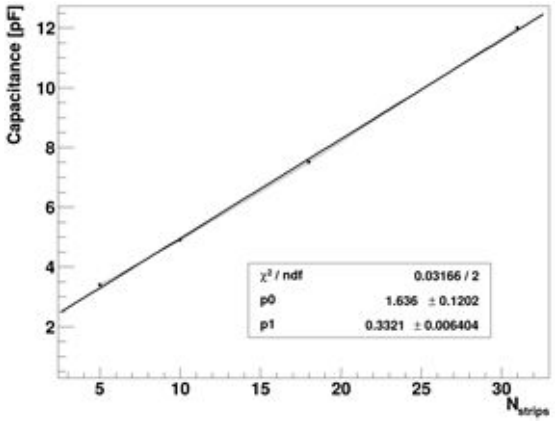
- Sensors at 45° towards

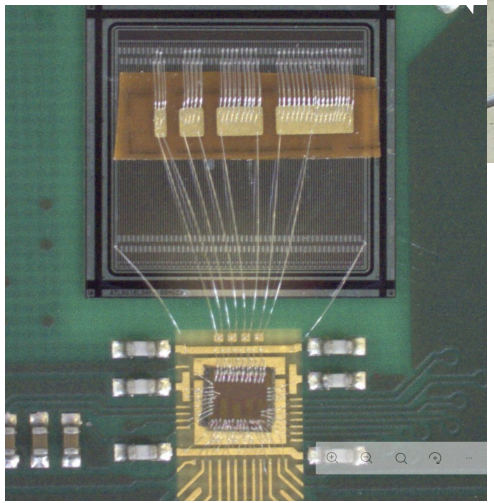
  the beam



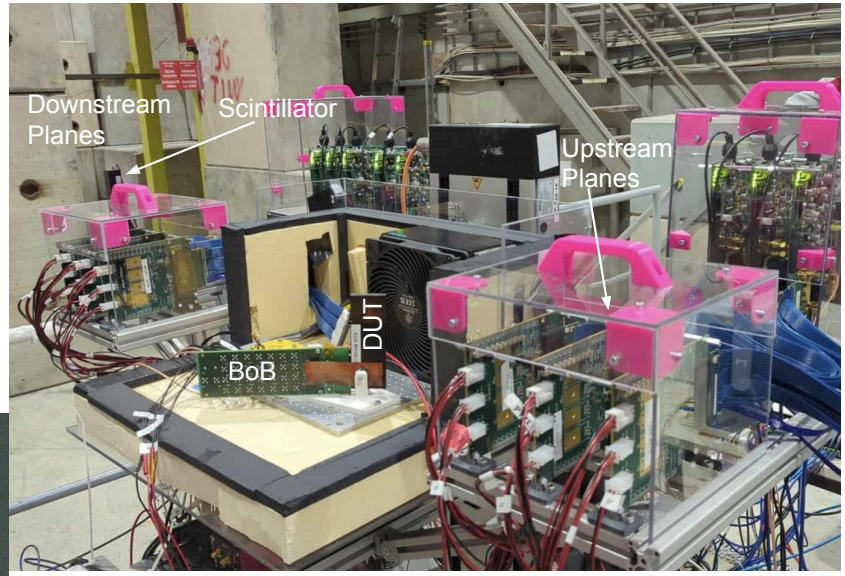
Testbeam setup for BCM'

- DRS4 boards daisy-chained for readout.
- DUT set at 45°(longer ionizing path).
- Bias voltage: -350V with I_{leak}< 1µA.
- LAPA and Calypso require 1.8V and 1.2V respectively.





Calypso wire-bonded to Si-ATL18

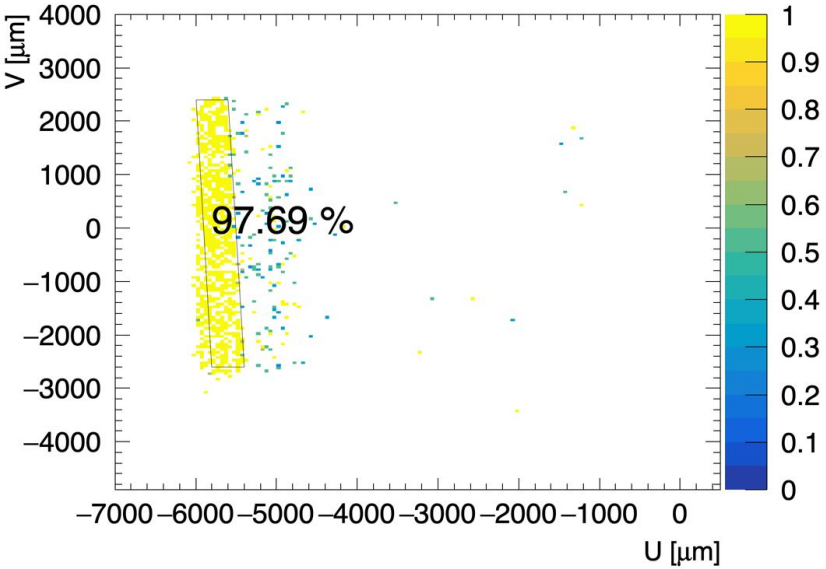


MALTA setup in H6(PPE146)

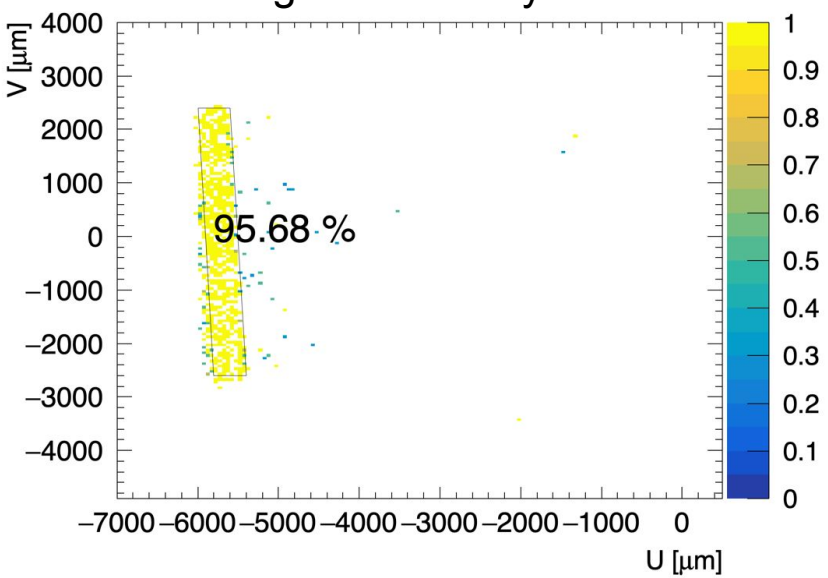
Channel	No.of strips
Ch0	5
Ch1	10
Ch2	20
Ch3	32

Results for 3-chip module(Ch0)

Analogue efficiency



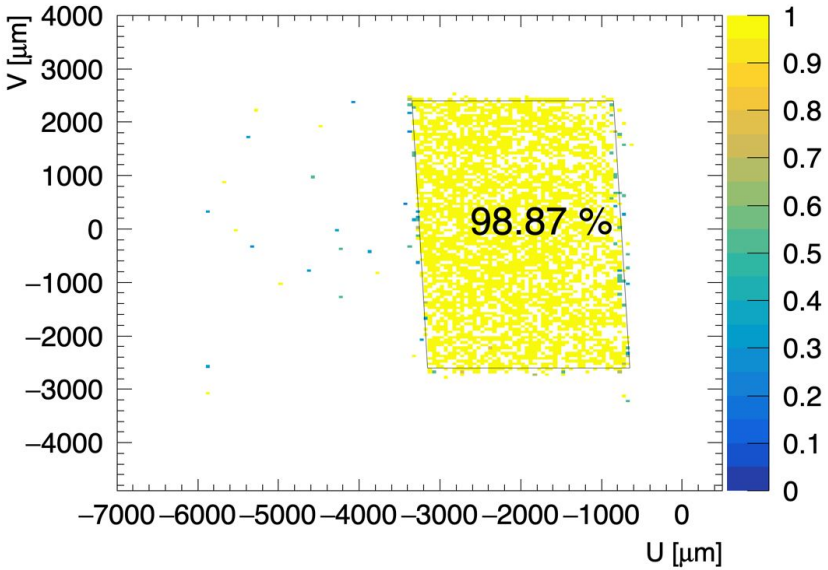
Digital efficiency



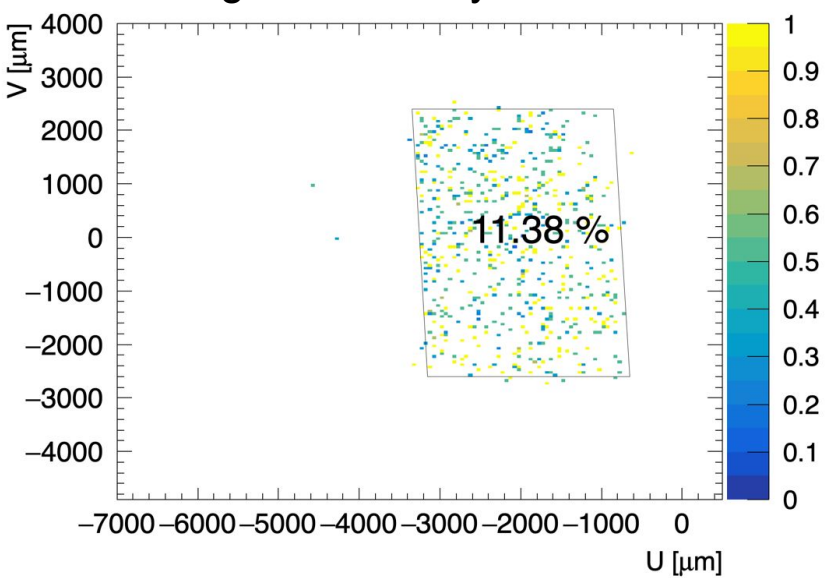
$$\text{Efficiency} = \frac{\text{Number of matched clusters on the DUT}}{\text{Total number of reconstructed tracks}}$$

Results for 3-chip module(Ch3)

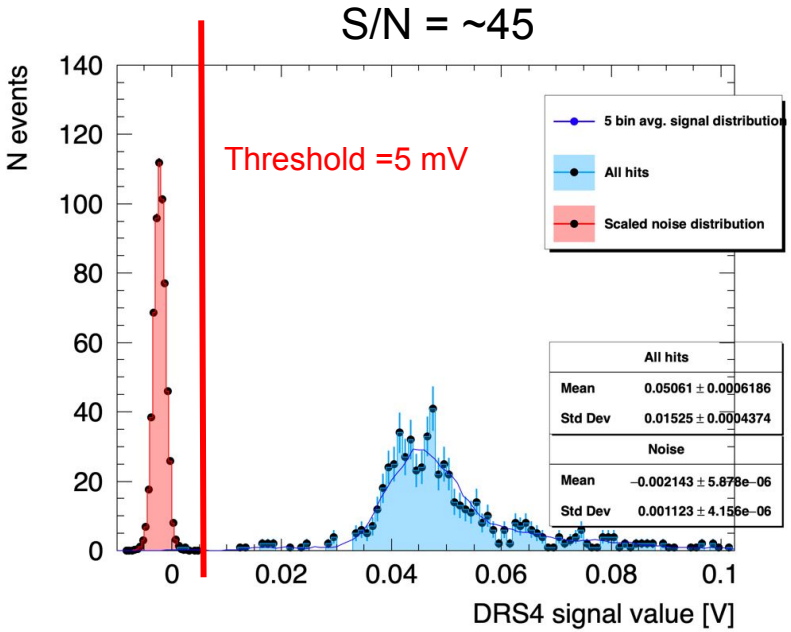
Analogue efficiency

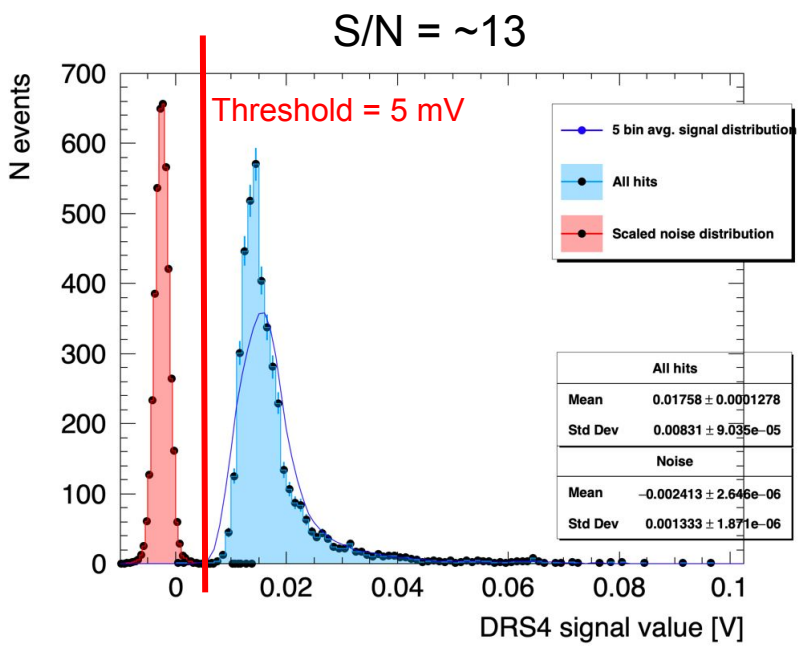


Digital efficiency



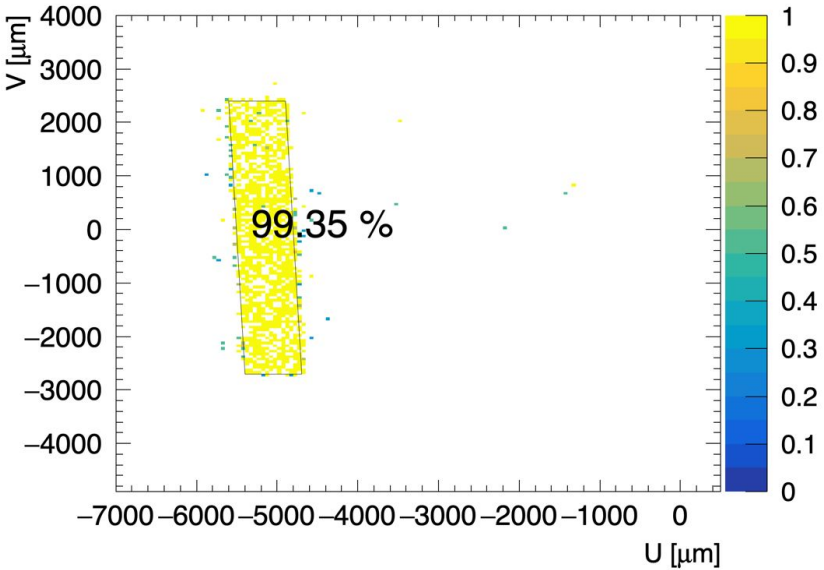
Results for 3-chip module(Ch0)



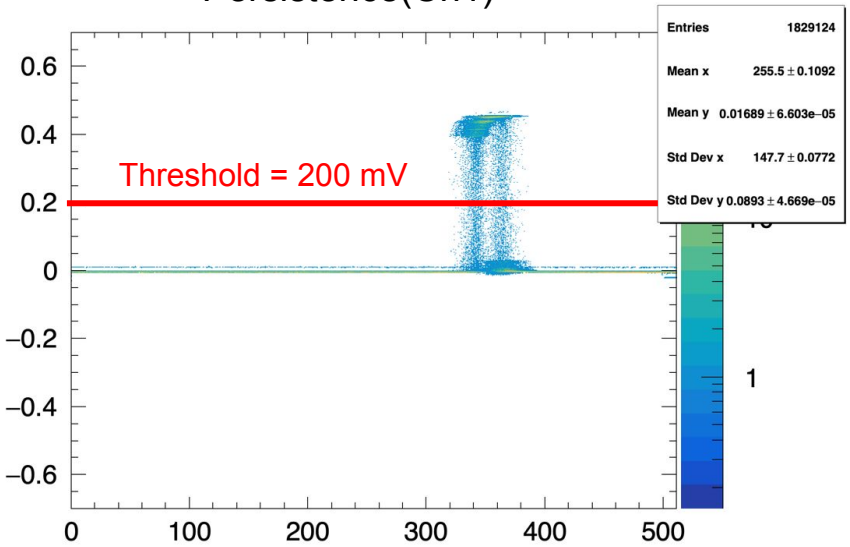


Results for 3-chip module(Ch1)

Digital efficiency(Ch1)

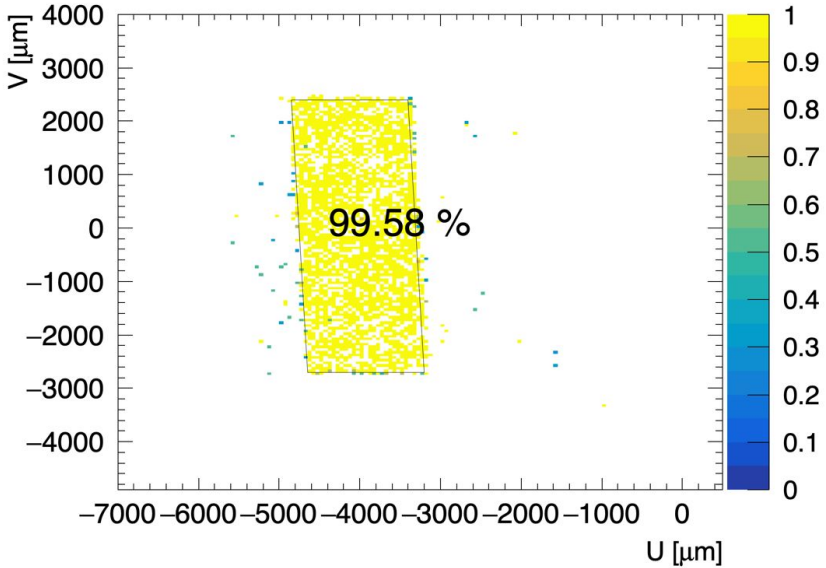


Persistence(Ch1)

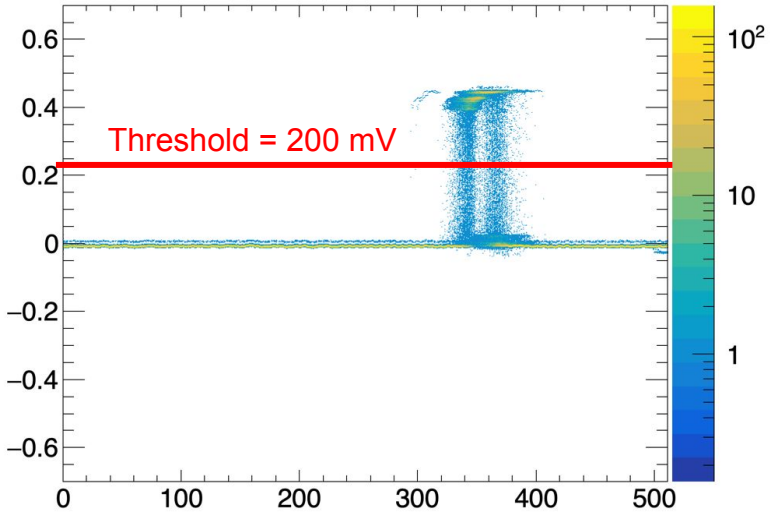


Results for 3-chip module(Ch2)

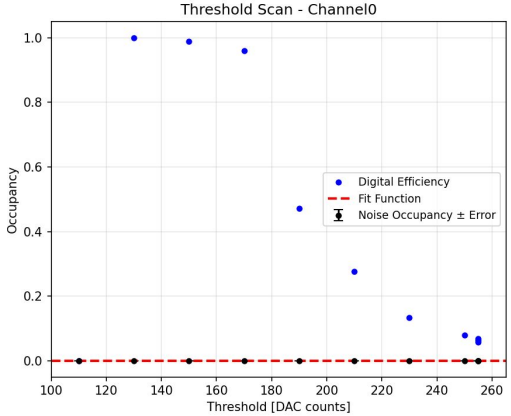
Digital efficiency(Ch2)

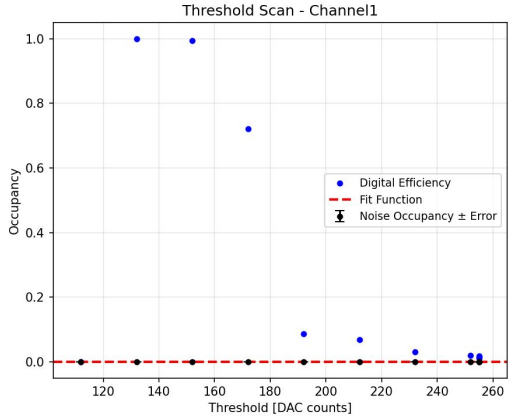


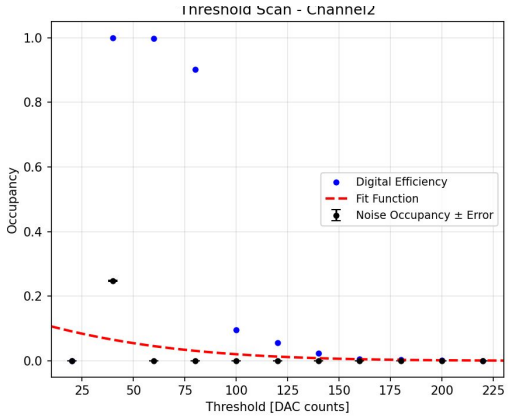
Persistence(Ch2)

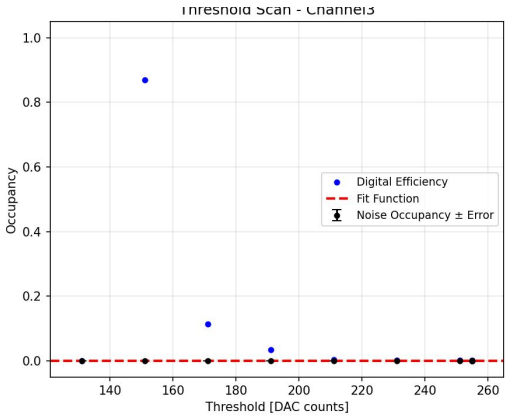


Digital efficiency vs Threshold









Summary and future plans

- In total, four test beams have been carried out this year(April & June) in which we succeeded to measure 4 single-chip modules(Calypso_E) and the new 3-chip module(Calypso_E) with Silicon mini-strip sensor.
- We currently plan to have the final design review in December(we have all the required components in production)
- We need to show the system works with system test.
- We will build more ‘’final’’ modules(2?)
- Load modules on two rings and install the rings in pixel inner system.
- Commission detector.

References

[1]

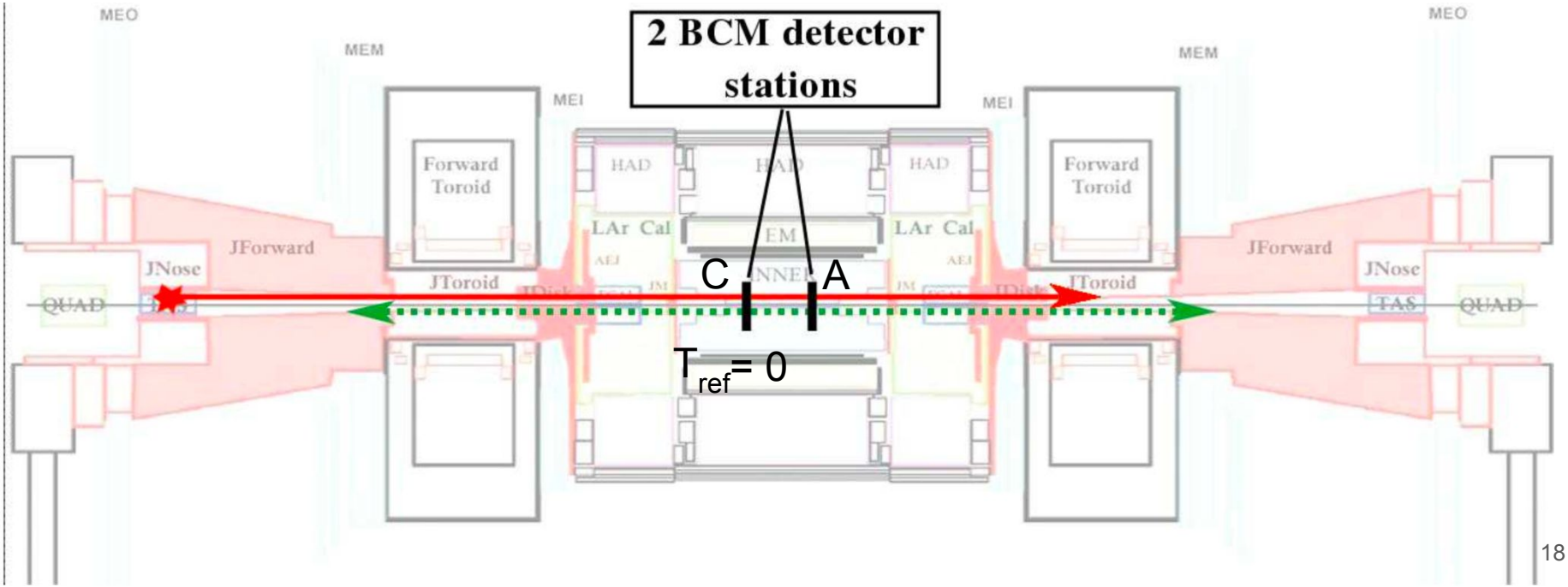
[2] Milou van Rijnbach (CERN and Oslo U.), Giuliano Gustavino (CERN), Phil Allport (Birmingham U.), Igancio Asensi (CERN), Dumitru Vlad Berlea(DESY, Zeuthen) et al.,"Performance of the MALTA telescope".

[3] The Super Proton Synchrotron "https://cds.cern.ch/record/1997188".

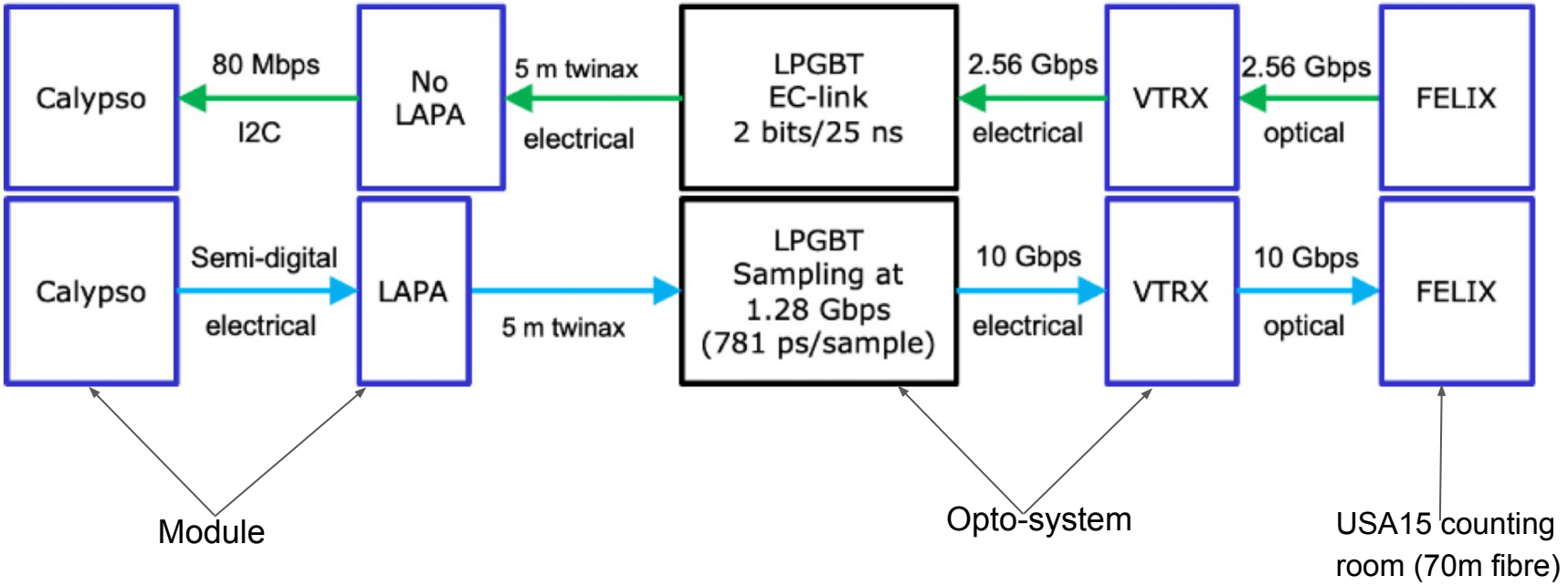
Back up

Working principle of BCM’

- **Time of flight measurement** to distinguish between normal collision and background events (beam gas, halo etc).
- **In-time hits** particles from collisions at interaction point (IP) reach both stations($\pm z_{BCM}$) at the same time(6.25 ns after collisions at IP).
- **Out-of-time hits** particles from background interactions occurring at $|z_b| > |z_{BCM}|$ reach the near(upstream) station 12.5ns before particles from collisions at IP (6.25 ns before collisions).



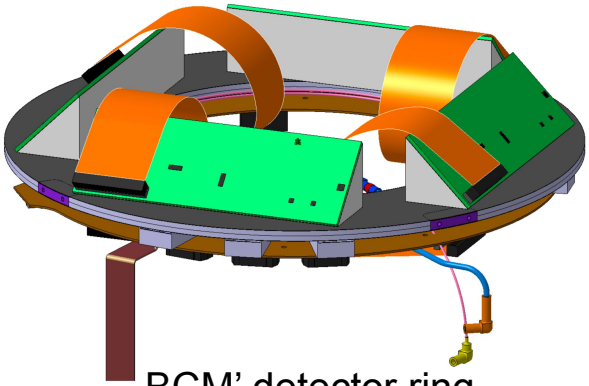
Flow diagram for BCM’



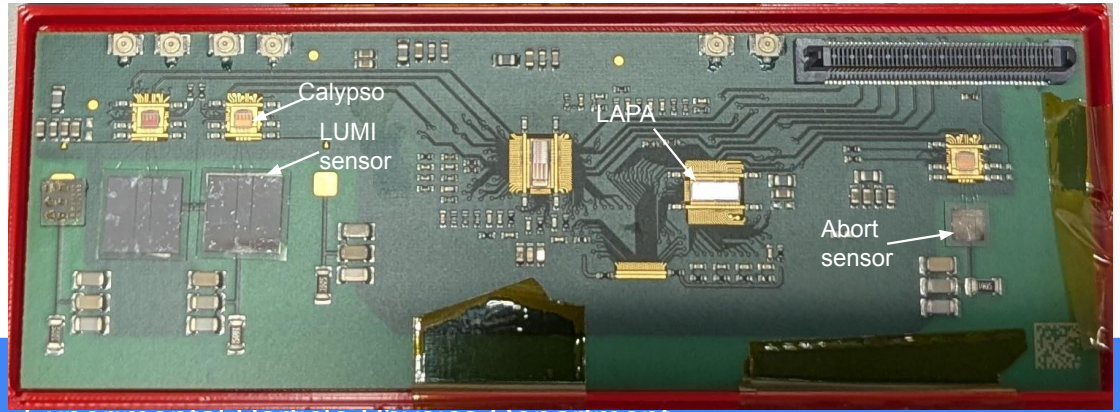
Channel	45°		90°	
	Signal(MPV)[mV]	Noise(σ)[mV]	Signal(MPV)[mV]	Noise(σ)[mV]
Ch0	263.4	9.1	197.4	8.5
Ch1	214.4	10.3	152.4	10.0
Ch2	168.7	11.6	117.9	10.6
Ch3	122.7	11.6	90.9	10.6

BCM' 3-chip module

- 3 Calypso's and 2 LAPA's(LVDS ATLAS Pixel Apparatus)
- 2 lumi diamonds(10x10mm^2)
- 1 abort diamond(5x5mm^2)
- 1.2V for Calypso, 1.8V for LAPA
- Upto ±1000 for high voltage
- Felix for I2C communication



BCM' detector ring



BCM' detector module