Update on Silicon Tracker Detector R&D

Fergus Wilson¹ on behalf of CEPC silicon tracker community Joint Workshop of the CEPC Physics, Software and New Detector Concept

23rd – 25th May 2022

¹ Rutherford Appleton Laboratory, STFC/UKRI, UK



Outline

- 55nm development work
 - Schedule and plans
- ATLASPIXv3 test beam at DESY
 - Reminder of ATLASPix v3.0 and v3.1 sensor
 - Test beam setup with ATLASPix v3.1 sensors.
 - Very preliminary results.
- Modules, powering, thermal evaluations, etc...
 - No updates in this talk.



Development using 55nm technology

- HLMC a Chinese foundry offers 55nm HVCMOS with similar layers as TSI
- Design efforts aiming for MPW in August 2022 (KIT, IHEP and HNU)
 - An area of 3mm*4mm is targeted
 - Design and optimization on-going at KIT
 - Adding some passive sensors and simple readout structure.



KIT design for test sensors



IHEP simulation for 6-pixel test structure



24th May 2022

CEPC Joint Workshop 2022

ATLASPix v3 reminder

- ATLASPIX3 sensor was originally developed for ATLAS, it is now used as technology demonstrator for HVCMOS, several sensors are based on ATLASPIX3 design.
- Pixel pitch:
 - Columns x: 150µm x 132 pixels
 - Rows y: 50µm x 372 pixels
- Single sensor size: 2.2 cm x 2.0 cm
- 25 ns compliant.
- Pixels contain amplifiers and comparator with threshold tune circuit
- Comparator is NMOS only
- Data output 1.28 Gbit/s 64b/66b (triggered), or 1.6 Gbit/s 8b/10b (untriggered)
- Serial powering
- Clock data recovery from command in
- Power consumption 140 mW/cm²

Two versions: 1) ATLASPix3.0 2) ATLASPix3.1





- submitted in Dec 2020, delivered in Feb 2021- selected improvements: VDDA/VDDD regulators



ATLASPixV3.1 KIT-GECCO single board system



- O(65) GECCO boards and single chip carriers produced in China and distributed globally
- Many institutes have commissioned lab test stand and started electrical measurements
 - Threshold tuning (global and pixel matrix)
 - Source measurements, e.g. γ-source from 241Am, β-source from 90Sr, and cosmic muons
- See <u>here</u> and <u>here</u> for more details of bench tests.



DESY Testbeam April 4th-10th 2022 with ATLASPix v3.1

• Telescope:

- Used ATLASPix v3.1 sensors. One GECCO board can read out 4 ATLASPix v3.1 sensors.
- Created two 4-sensor telescopes (did not use EUDAQ telescope / TLU).
 - "UK telescope" : sensors thinned to 150µm.
 - "KIT telescope" : 750µm
- One week of data-taking at <u>DESY II Test Beam Facility</u>
 - Beamline 24 : 4th-5th April (1-3 GeV e)
 - Beamline 21 : 6th April onwards (1-6 GeV e)
 - About 50 datasets recorded.
- Data-taking setups:
 - 4-sensor telescope
 - 2 x 4-sensor telescope
 - Different orientations of the telescope with respect to beam.
 - Different sensor settings (voltages etc...)
 - Single and quad-sensor



6

Test beam team at DESY: Ruoshi Dong², Attilio Andreazza³, Fabrizio Sabbatini³, Riccardo Zanzoterra³, Jaap Velthuis⁴, Lingxin Meng⁵, Harald Fox⁵

Support team at DESY and UK: Ivan Peric², Jens Dopke¹, Fergus Wilson¹, Daniel Muenstermann⁵, Yanyan Gao⁶

¹RAL, ²KIT, ³Milano, ⁴Bristol, ⁵Lancaster, ⁶Edinburgh

DESY Test beam April 2022 - telescope



Tabletop telescope:

One GECCO system can readout 4 sensors. Sensors can be interleaved and angled. Quad sensor (used in some datataking)

z and beam direction





DESY Testbeam April 2022





24th May 2022

CEPC Joint Workshop 2022

Preliminary results

- Data has been analysed using <u>corryvreckan</u>.
- Changes to corryvreckan implemented:
 - Code to read in ATLASPIx3.1/GECCO data format.
 - Code to remove hard-coded 4 sensor limit.
 - Code to deal with glitches in data.
 - Code to define an event and to speed up event analysis.
 - Modifications to default histograms to match ATLASPixv3.1 dimensions.
- Caveats:
 - These results are very preliminary.
 - The sensors were not optimized/calibrated before data-taking.
 - Only showing data from one early run using "UK telescope".



DESY test beam and energy distribution





24th May 2022

CEPC Joint Workshop 2022

Hit distributions per sensor



A few noisy channels in columns.

No masking or noise threshold implemented yet.

Sensors 1-3 show structure in hits per row. Step changes at rows 124 and 248 could be correlated with change in output signal routing.

Other datasets still to be investigated.



Science and Technology

Technology Facilities Council 24th May 2022 CEPC Joint Workshop 2022

Clustering - width distributions



Cluster algorithm has no minimum seed value.

Typically only 1 pixel hit in x (150μm pitch). Slightly more pixels hit in y (50μm pitch)

Cluster algorithm has no minimum seed value.

- ⇒ Noise, cross-talk is counted as a cluster.
- \Rightarrow May affect tracking



Science and Technology

Technology Facilities Council 24th May 2022 CEPC Joint Workshop 2022

Tracking – residuals in y (50 µm pitch)



•



24th May 2022

CEPC Joint Workshop 2022

Fergus Wilson

13

Tracking – The bad / not understood yet news





Conclusion

- Work progressing on 55nm HVCMOS sensor targetting HLMC foundry
- Preliminary results on DESY testbeam ATLASPix v3.1 have been presented.
 - Initial results on hit distributions, clustering, alignment and tracking resolutions.
 - Many improvements identified.
- Lots more test beam data still to be analysed:
 - 2-telescope, 8-sensor setup.
 - Changes in sensor settings.
 - Quad sensor.

Science and Technology Facilities Council