# Detector concept inputs: CLD

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Many thanks to Jessy Daniel, Gaelle Boudoul, Jan Eysermans, Stefano Franchellucci , Tupendra Oli, and others

# Requirements of the FCC-ee research program

- The FCC-ee experiments are aiming to measure a range of processes with extreme accuracy (low systematic uncertainties).
- Therefore, the TDAQ system can not contribute to the systematic uncertainty more than about $10^{-5}$.
- That's a major challenge for design of the TDAQ systems.
- Fixed-latency (aka "hardware") triggers may contribute to the systematic uncertainty. These uncertainties are definitely larger than 1e-5 for the LHC experiments.
- A trigger-less system (with data processing and filtering in an off-detector computer farm) may minimize the uncertainty on the trigger/filter efficiency.
- There is a great comparison of the TDAQ architectures in a recent talk from Christoph: https://agenda.infn.it/event/47923/contributions/276355/attachments/141997/215087/triggerless.pdf
- Data losses of the DAQ system also contribute to the uncertainty.
  - Data losses due to the event size fluctuations need to be minimized and tracked
  - Data losses due to hardware failures should also be minimized and recorded.

# Can we go triggerless?

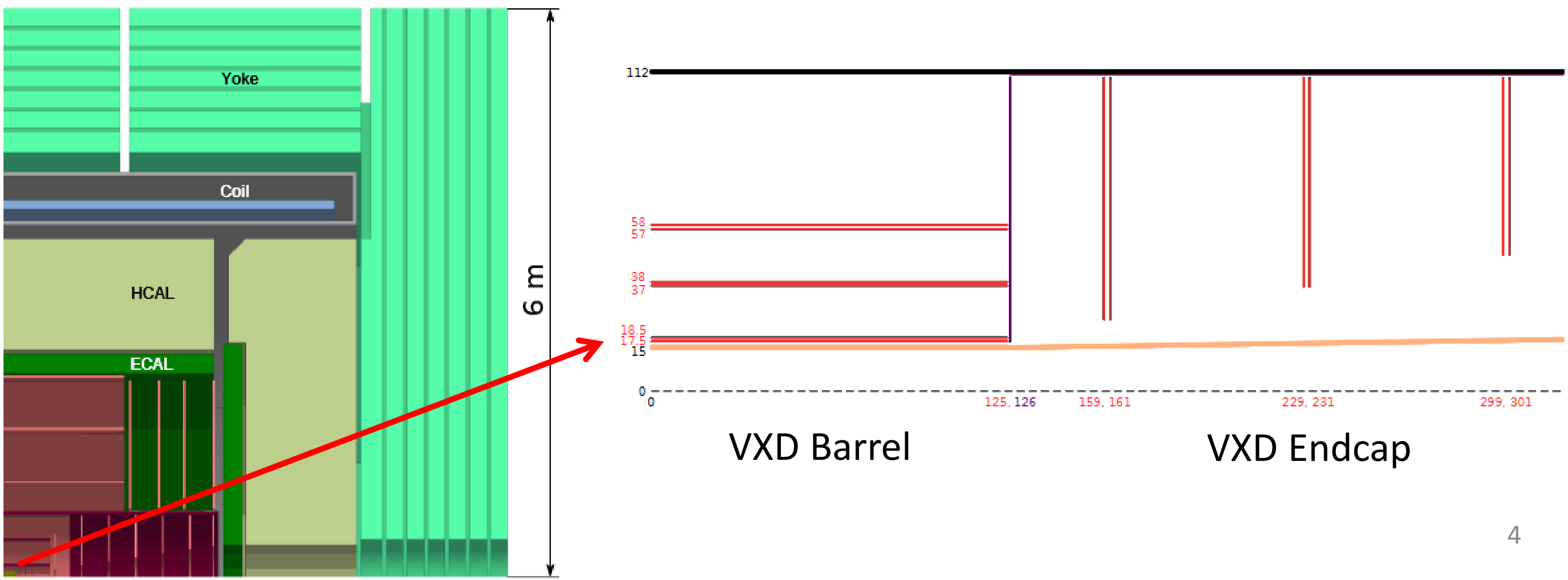
- Fixed-latency hardware trigger is replaced with data processing and filtering with software.
- The giga-Z program requires full detector readout at 50 MHz. That's the most challenging regime in terms of data rate, but not event size.
  - The hard scatter rate is only ~200 kHz so there is a lot of room for off-detector filtering.

1. **Is it technologically feasible to stream data from all the detector systems to commodity off-detector computing?**
2. **Is it affordable to process, filter, and store the data with the commodity computing?**

- Please keep in mind that cost and performance of the off-detector

# CLD refresher

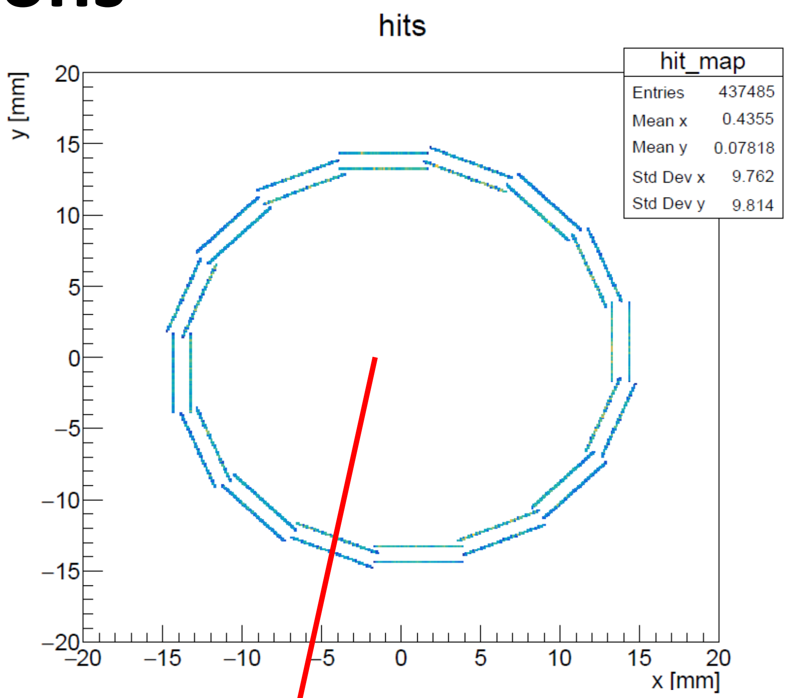
- [https://arxiv.org/abs/1911.12230](https://arxiv.org/abs/1911.12230)
- CLIC-like detector = one of the detector concept for FCC-ee
- All-Silicon Vertex detector and Tracker in 2T magnetic field.
- Sampling calorimeters
- The beam backgrounds (incoherent pair production) are dominating the data rate from the 1$^{st}$ layer of the vertex detector. → **Arguably the hardest to readout!**

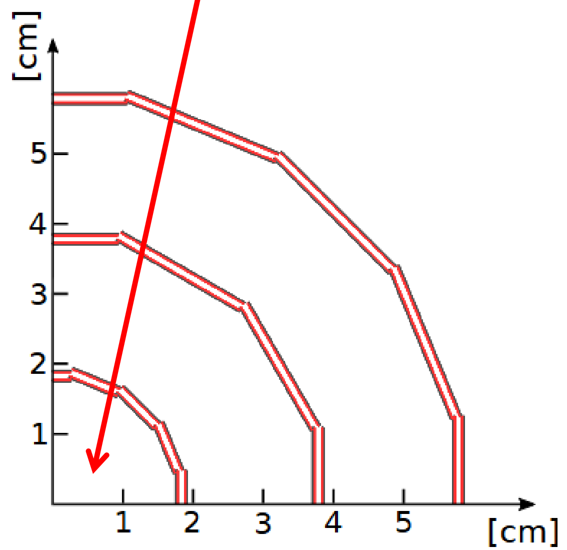



VXD Barrel VXD Endcap

# CLD simulations

- Proper GEANT-4. ddsim
- The beam background samples are kindly provided by the MIT and UniGE team (thanks to Jan and Stefano).
- The Vertex Detector digitization is implemented by the Lyon team (thanks to Jessy Daniel, Gaelle Boudoul, and others).
- The simulation uses 25x25 um2 pixels.
- Somehow, the vertex detector dimensions are slightly different than the CLD paper.
- Please take my calculations with a grain of salt. I was careful but there may be bugs.

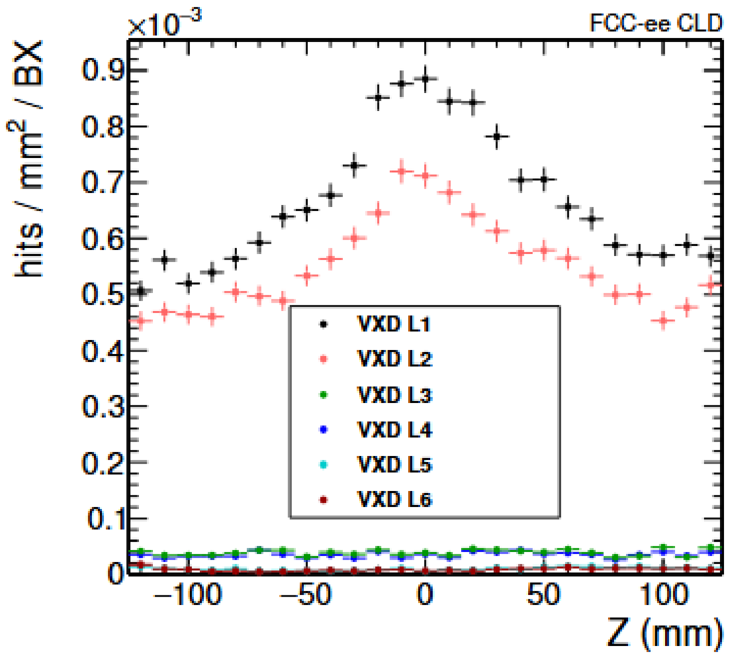


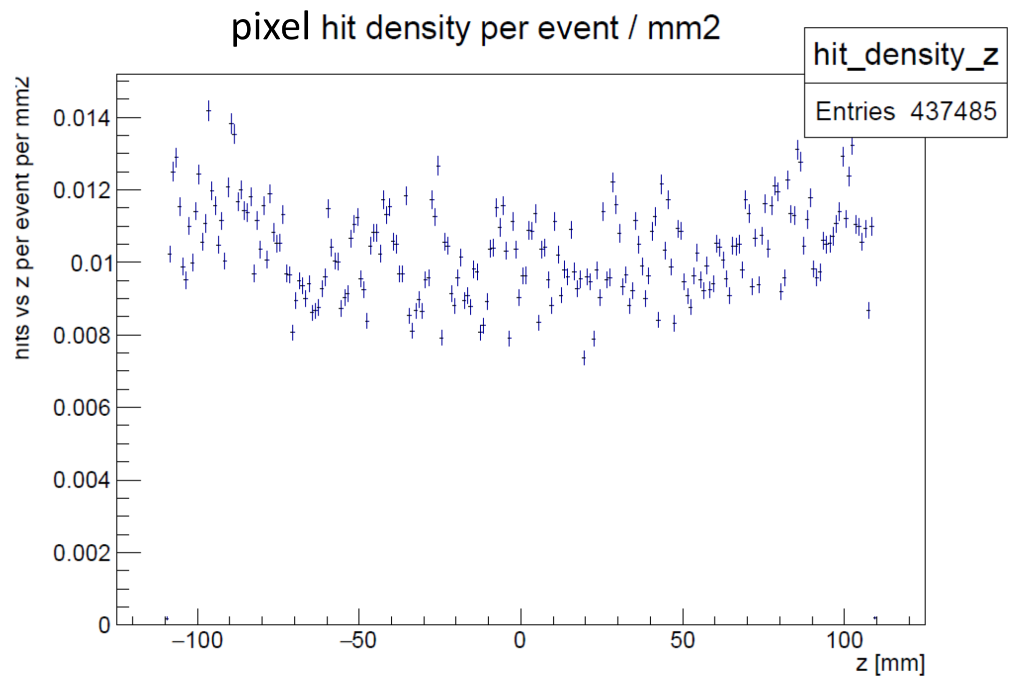




https://agenda.infn.it/event/47923/contributions/276264/attachments/141923/214924/WS_VertexDetector_RD_301025.pdf

# Hit densities per bunch crossing in VXD

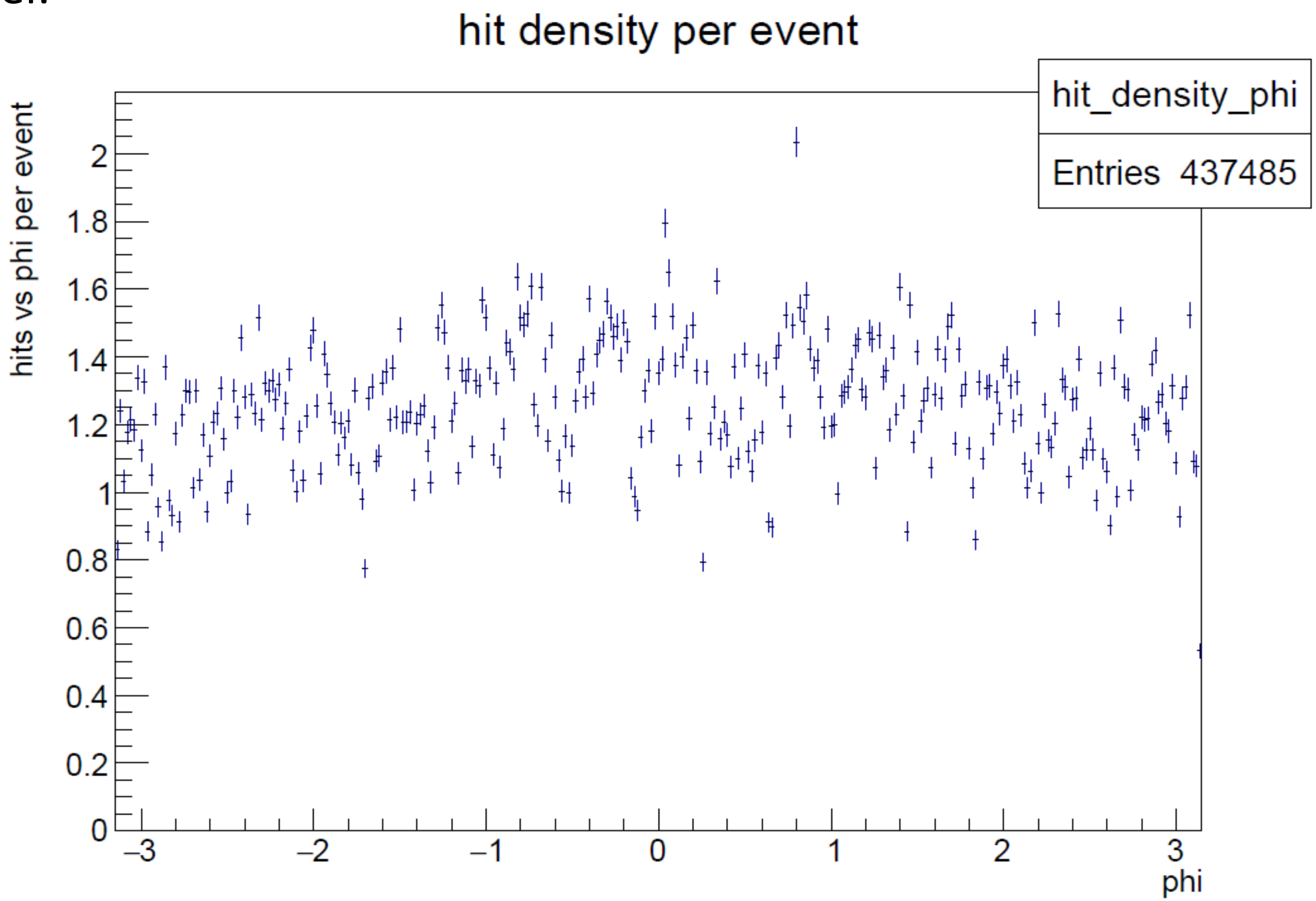
- Our L1 has smaller radius so the beam backgrounds (incoherent pairs) may produce slightly more hits.
- The CLD paper assumed 3 pixels per cluster. There was no digitization.
- My distributions are for pixels hit.
- My pixel hit rate is be about factor of 3 larger than that in the paper.



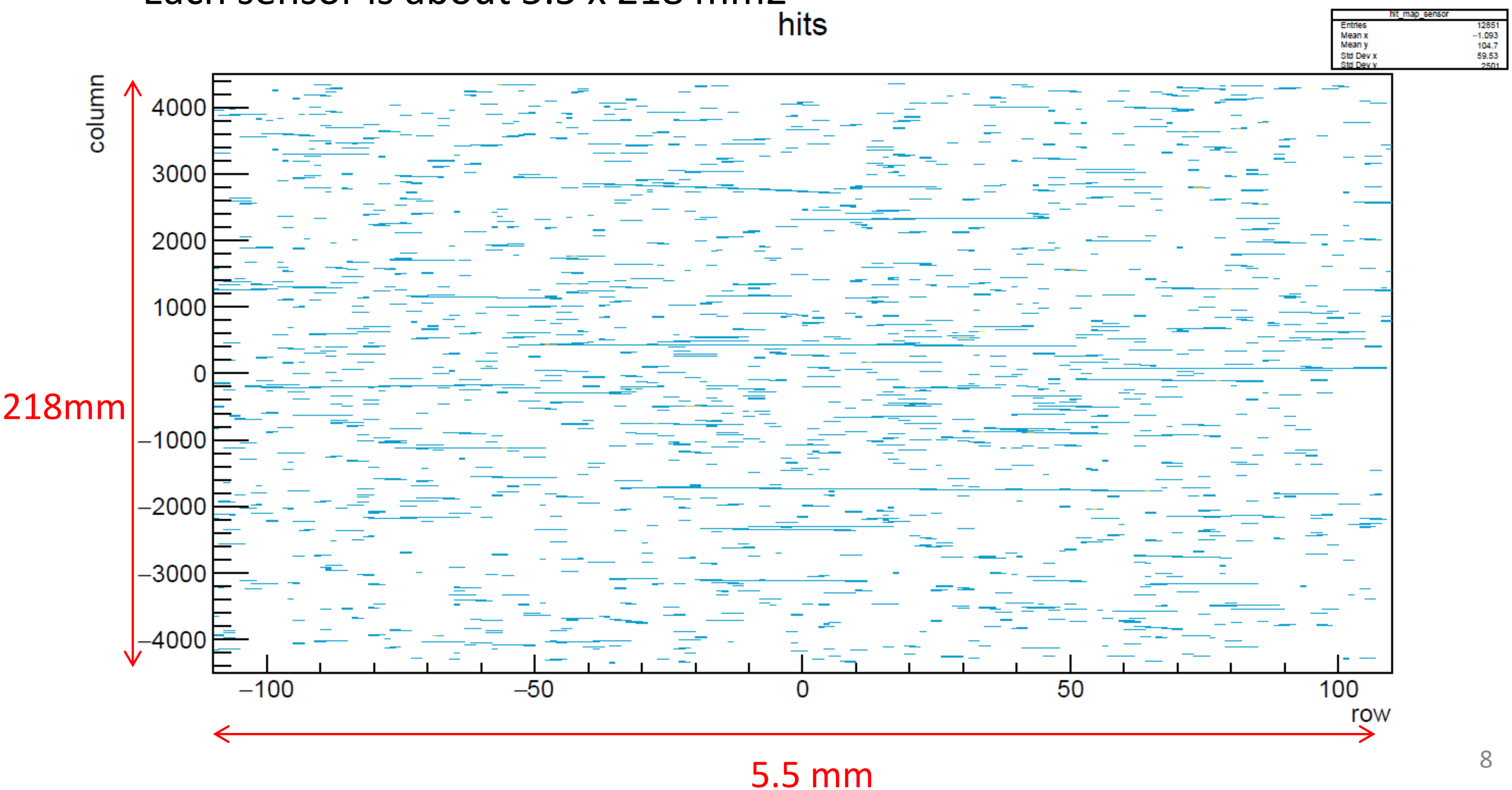
# Hit densities per bunch crossing in VXD

- More or less flat in phi
- There are correlations because the individual pixel hits are next to each other.



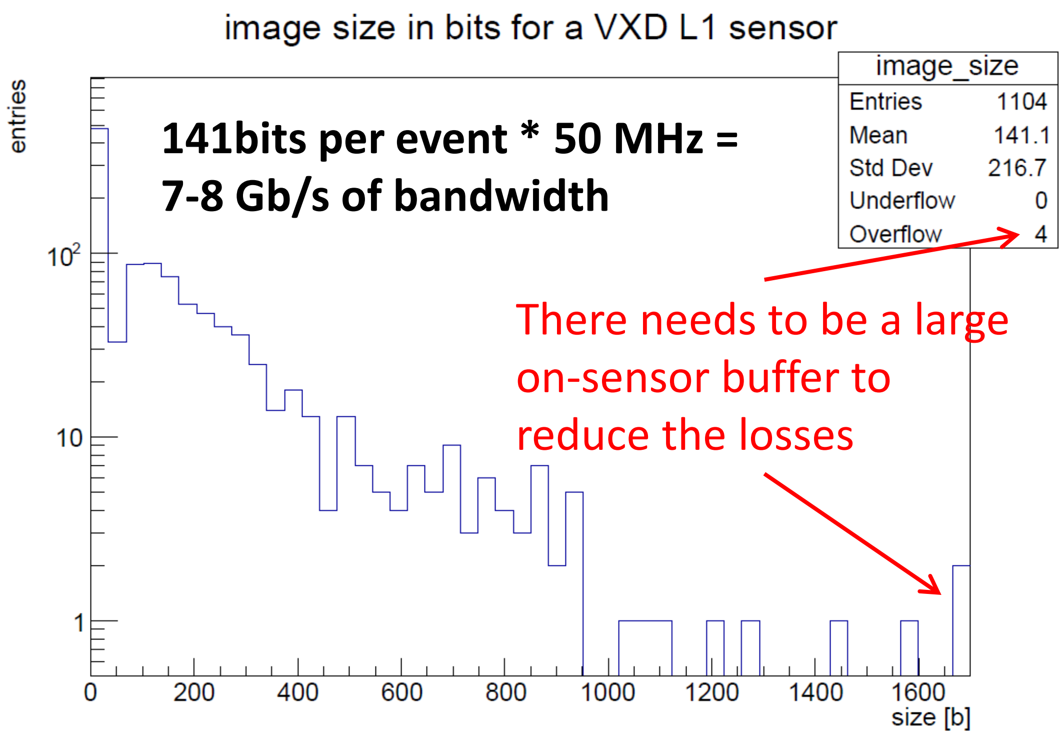
# Single-sensor image

- The clusters from the soft electrons seem to be long in phi.
- The 3 pixels per cluster assumption may not be accurate.
- Each sensor is about 5.5 x 218 mm2



# Bandwidth calculation for a sensor

- The sensor is segmented in 2x8 blocks of pixels. If there is a hit pixel in a block the sensor generates 34 bits of data (no ToTs). The 8-pixel side is along the phi direction. This is similar to the ITkPix readout.
- The data volume is calculated for each event each sensor separately.
- The on-sensor buffering needs to be calculated for the ttbar regime.



# Bandwidth calculation for VXD L1

- Let’s round the bandwidth per a 5.5x218 sensor to 10 Gb/s.
- There are 32 sensors (links) in the Layer-1. => The total bandwidth is 32Gb.
- That’s not hard to handle event with contemporary technology; e.g. with 1.5 of FLX155 cards
- The other layers will suffer less from the beam backgrounds and the total bandwidth will not be a challenge. The whole tracker can probably the handled by a handful of FPGA cards like FLX-155.
- In comparison, ATLAS ITk is to be readout by 100’s of FLX-155 cards and the data is processed off-detector for larger bandwidth.

# Outlook

- We are taking advantage of the latest simulations of the pixel digitization and beam backgrounds to explore the CLD readout.
- The L1 of VXD is one of the most challenging components to readout.
- Tentatively, the bandwidth per sensor (stave) does not look that bad (~10 Gb/s).
- We need to extend the calculations to the other components of the CLD detector.
- However, with the numbers above, the triggerless readout seems possible even with the contemporary TDAQ technology. It will be easier in 10-20 years.
- We need feedback from the sub-detector groups on accuracy of the simulations and technical feasibility of the data links.