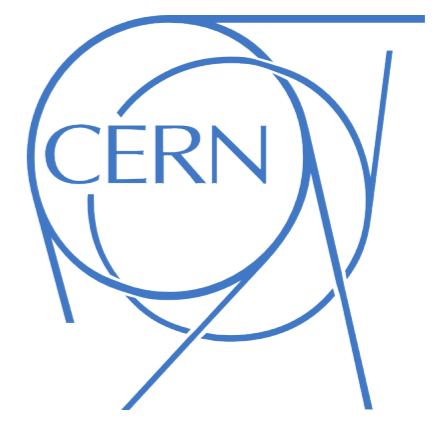


Design and perspectives of the CMS Level-1 trigger Data Scouting system



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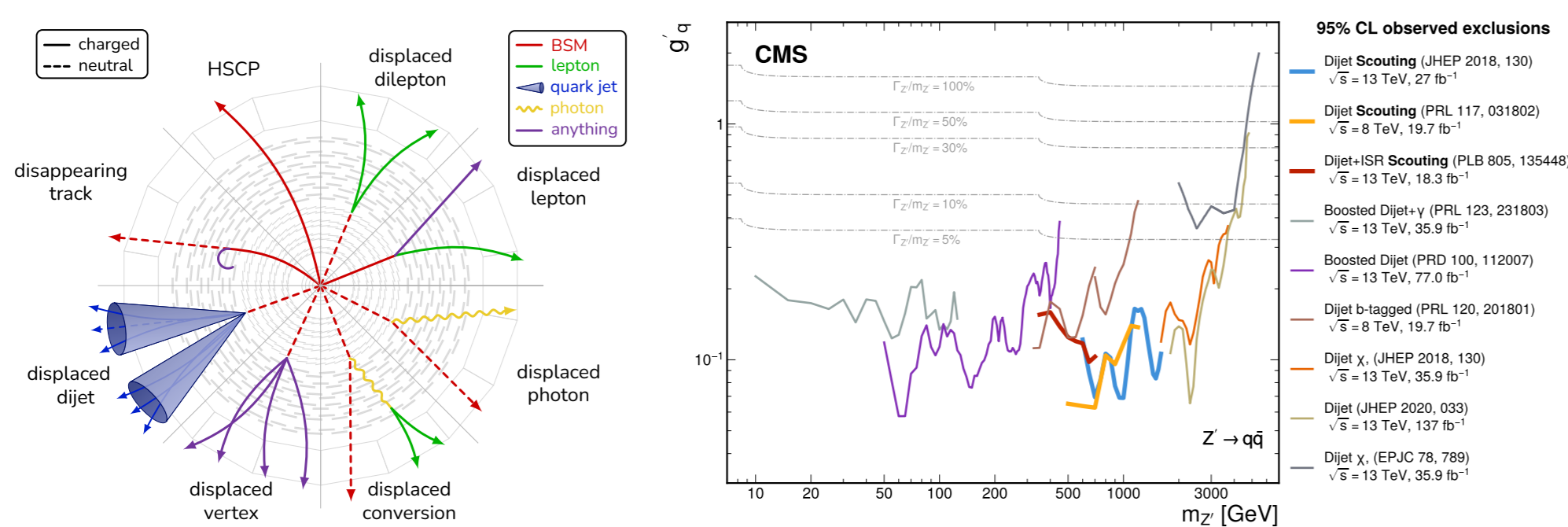
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1. Motivation

Events discarded by CMS trigger are LOST FOREVER

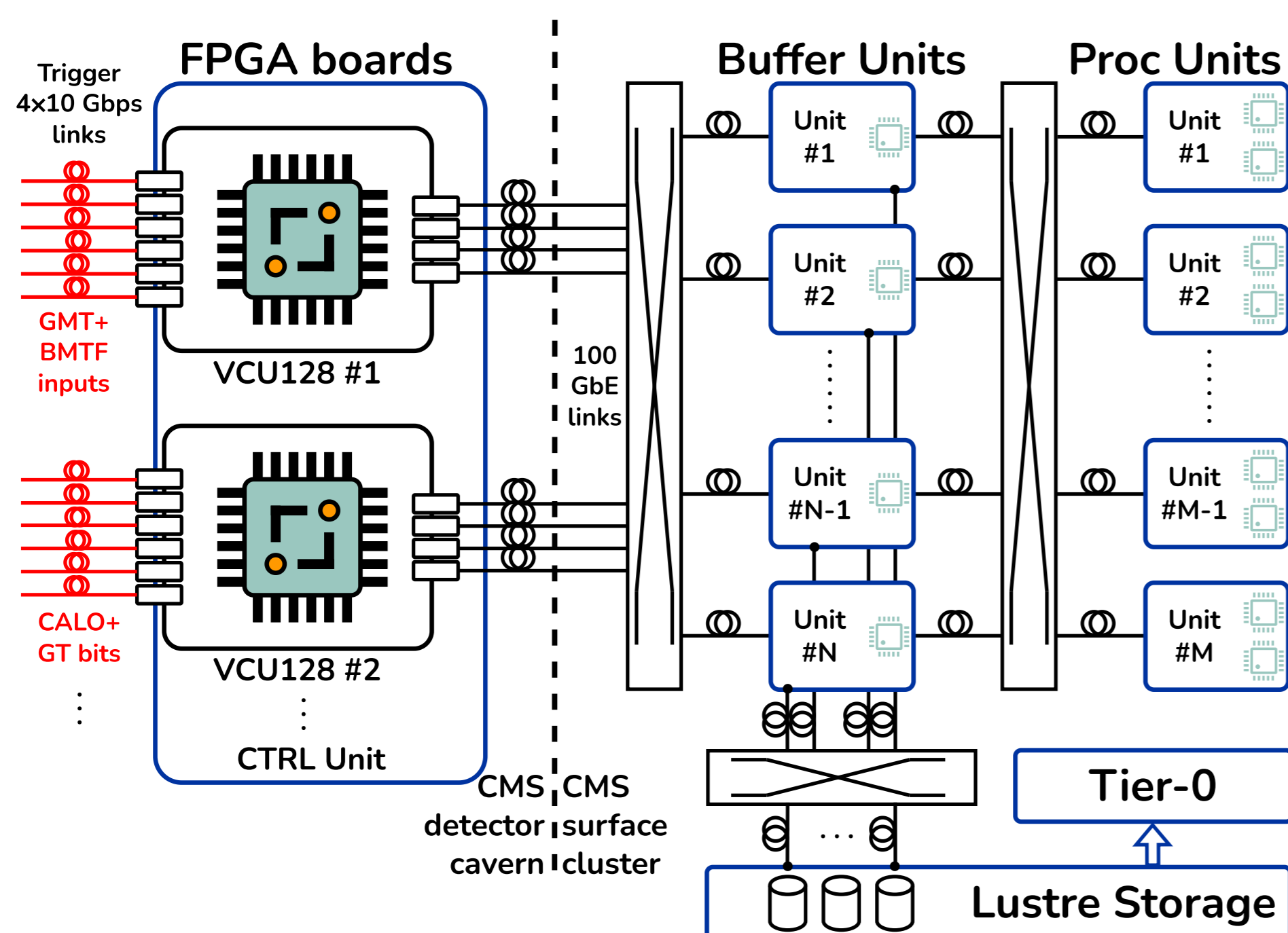
- Level-1 discards ~99.75% of events
- Only ~0.0025% of collisions are saved
- Triggering unexpected physics not always efficient!
- Some interesting signatures too frequent for L1 budget
- ⇒ Uncovered phase-space regions for constraints on BR/couplings



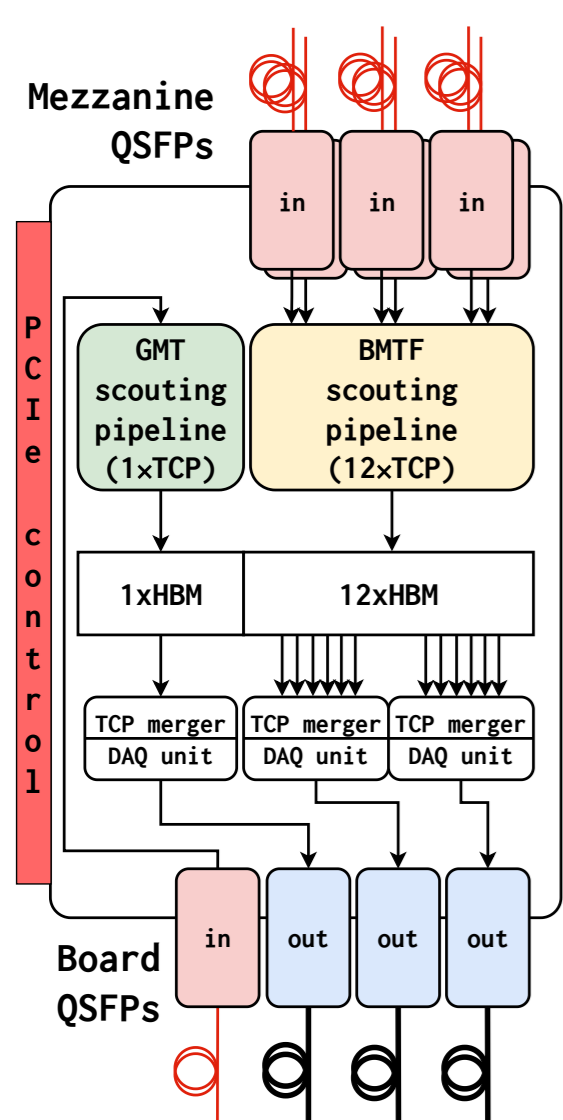
2. L1T Data Scouting demonstrator for Run-3

Real-time analysis using L1 trigger objects

- FPGA: concentrate Global Muon and Calorimeter Trigger objects, Barrel muon track segments, Global trigger decision bits
- Buffer units: receive 100 GbE links and basic processing
- Processing units: event building and online selections



3. Scouting FPGA firmware design



VCU128 scouting boards

- Similar to 1/2 DAQ-800 CMS Phase-2 DAQ read out board
- XCVU37P FPGA with 8 GB of HBM
- 10 QSFP slots for input/output

Flexible firmware implementation

- "Scouting pipeline" for inputs alignment and pre-processing
- HBM big temporary buffer before TCP/IP logic
- TCP streams merged into DAQ units (100 GbE)

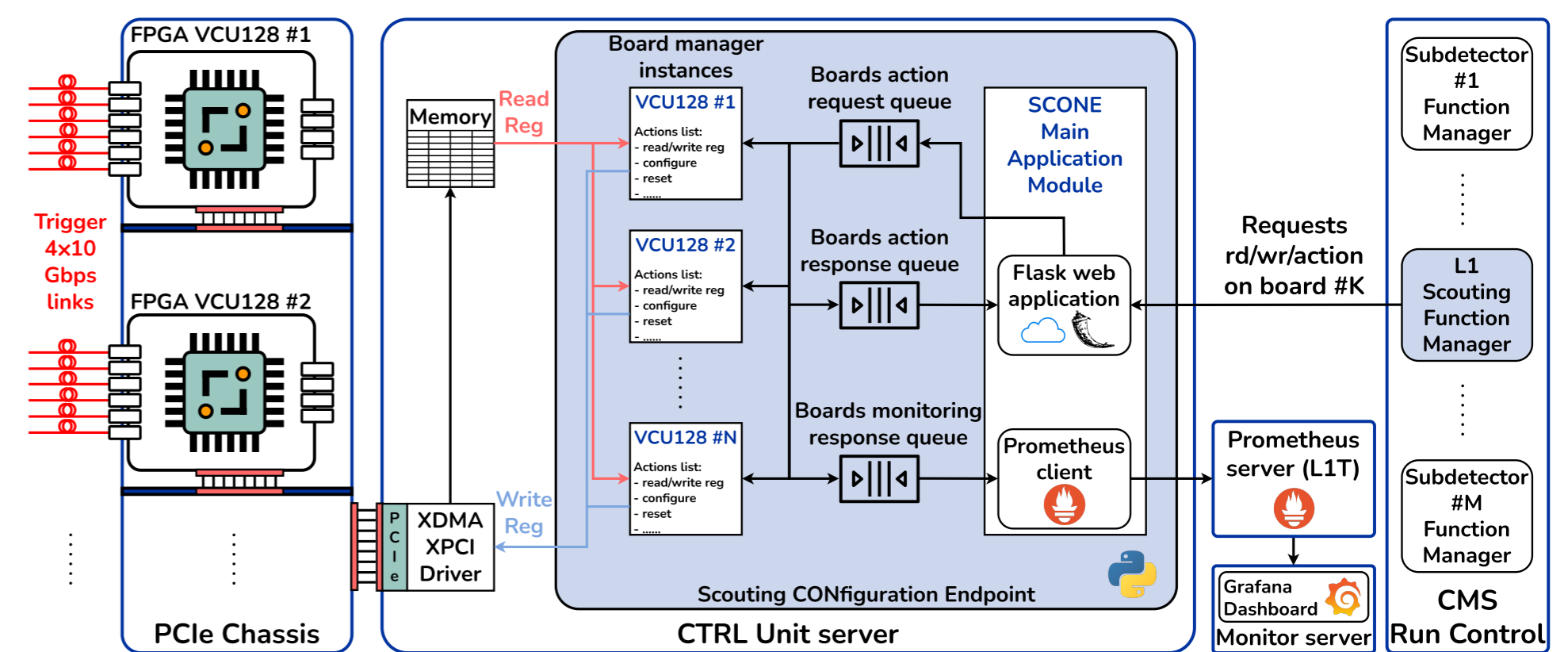
Machine Learning algos in scouting pipeline

- Deploy neural network inference applications on FPGA using hls4ml

4. Restful board Monitoring and Control

Scouting CONFIGuration Endpoint (SCONE)

- Interacting with CMS Run Control and Monitoring System
- Handle board reset/configure/start/stop, monitor metrics



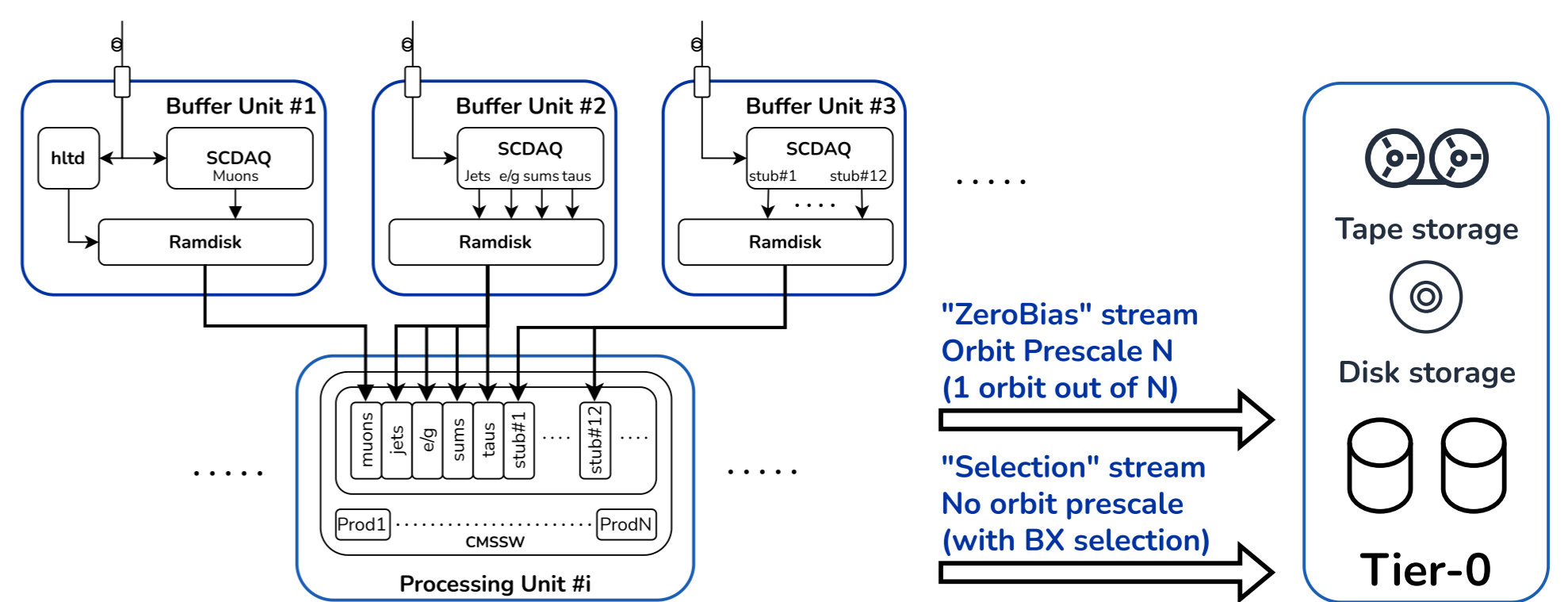
5. DAQ software and Online processing

Intel TBB-based DAQ software (SCDAQ) running on Buffer units

- Every TCP stream injected into a "pipeline" unit, decoding input packets, applying basic processing and writing raw data files

Orbit builder and Online selections on Processing units

- Merge data from all scouting streams and build event with LHC orbit as unit ⇒ Possible to look at correlations across different BXs in orbit
- Produce a prescaled "Zero-Bias" stream (keep 1 orbit every N) ...
- ... and an unprescaled "Selection" stream (BXs with certain signature)
- Move data to Lustre, which has link to CMS Tier-0
- Data available for analysis via CMS Data Aggregation System



6. Public results and Outlook

System demonstrated during LHC Run-3 with validation studies

- Understanding L1 objects and BX occupancy/multiplicity studies
- Standard Model candles like $Z \rightarrow \mu\mu$, $Z \rightarrow ee$ clearly visible at L1
- L1 trigger monitoring at the full BX collision rate

Plan to perform physics measurement already with Run-3 data

- Di-jet studies at low invariant mass $m_{jj} < 400$ GeV

Fully exploit potential of L1T Data Scouting during CMS Phase-2

- Phase-2 L1 objects close to offline level resolution!

