Track 1 highlights: online and real-time computing

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Thank you!

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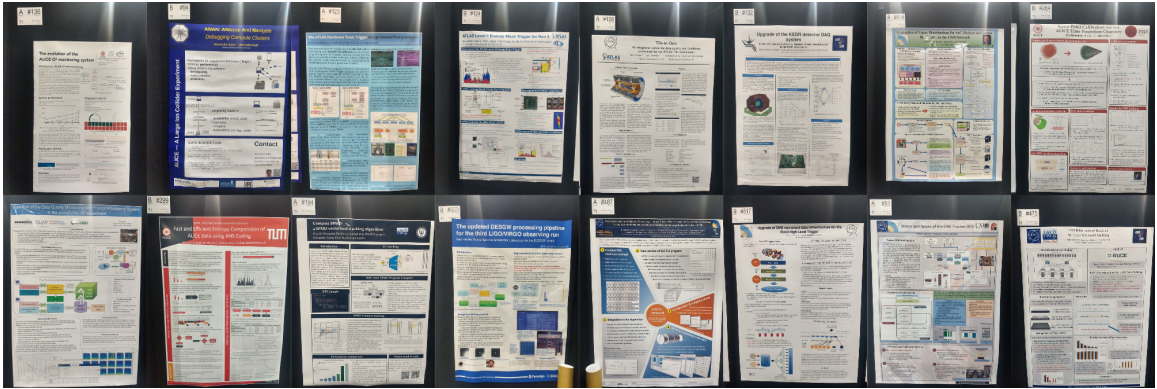
- Thank you to everyone who:
  - Contributed a talk (42) or poster (16)
  - Participated in the session discussions
  - Attended the poster sessions
  - Joined one of the two Birds of a Feather events
- Your involvement is really what made Track 1 so interesting!

- Additionally, thank you very much to:
  - My co-chairs: Chunhua Li (Liaoning Normal University), Jennifer Ngadiuba (CERN), and Yu Nakahama Higuchi (Nagoya University)
  - The CHEP organizers and PC chairs for all of your support, organization, and guidance

16 interesting posters



Sessions

- Data acquisition
- Monitoring and control systems
- Trigger farms and networks
- Real-time analysis
- Detectors, performance, and analysis
- Hardware acceleration and machine learning
- Future upgrades
- Birds of a Feather

Data acquisition

Data acquisition

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- Increasing cross-experiment commonalities
  - FELIX being used by both ATLAS and DUNE, others may be on the way
  - DAQling being used for FASER, RD51, and NA61/Shine at CERN
- DUNE needs to support two very different readout modes
  - Normal readout when the beam of neutrinos arrives from Fermilab: 3 ms windows
  - Supernova bursts: 100 s continuously persisted data stream
  - Five orders of magnitude difference in readout length / data volume
  - Solution: put special storage close to read-out in case of supernova triggers

Monitoring and control systems

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Monitoring and control systems

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- Community converging around two message passing options
  - FairMQ for heavy ion experiments, ZeroMQ for everyone else
- Live monitoring is a CPU-expensive task
  - Huge amount of monitoring data (often histograms), updated frequently
  - Effort is being invested into reducing computing costs
- Increasing effort to reduce shifter dependencies
  - LHCb already requires minimal shifters due to being predominantly automated
  - CMS is developing DAQExpert to resolve DAQ-related problems faster than shifters
  - Belle II is working to automate PXD and SVD DAQ, ideally reducing shifters

Trigger farms and networks

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Trigger farms and networks

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- Trigger farms seem to increasingly be integrating GPUs
  - ALICE: farm is based upon GPUs, note that no actual "trigger" rather just data compression
  - CMS: HLT farm will contain 1x GPU per server
  - LHCb: full software trigger (no hardware trigger), first level potentially fully GPU-based
- Servers and their configurations are very complex to thoroughly optimize
  - Reading the server specifications is not even close to the full story
  - ALICE presented a very nice study showing dependencies on severs and their configurations
- Trigger networks primarily studying usage of 100 Gbps, mixture of RoCE and Infiniband
  - Very few places where 200 Gbps Infiniband is used

Real-time analysis

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Real-time analysis

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- Real-time analysis is a topic that crosses domains
  - Contributions from particle physics, LHC machine, and astronomy
  - Timescales and data sizes vary, but challenges are similar $\implies$ opportunities to collaborate

- Addressing two main use cases
  1. How can we analyze and store **all of the data** we are receiving
     - Can we process it as it's arriving, in preparation for later use?
     - Reduce data sizes, store only aggregated information, calibrate real-time for final usage, etc
     - HEP and astronomy overlap in $\sim$all of these concepts
  2. How can we **quickly react** to the data we are receiving
     - Need for very fast decision making that influences the recording environment
     - Example: react to LHC beam monitoring conditions

Detectors, performance, and analysis

Detectors, performance, and analysis

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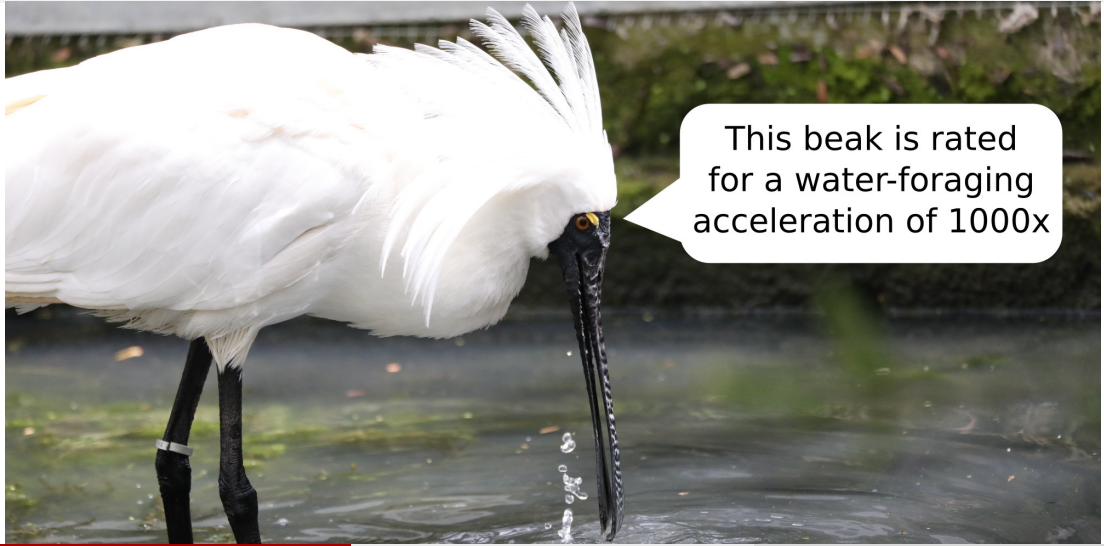
- Detector calibrations and object performance continue to be refined
  - Track reconstruction at PANDA, lepton reconstruction at ATLAS
  - EM calorimeter workflows at both CMS and SND
- CMS used "data parking" to record 10B unbiased B-meson decays
  - Recorded but not reconstructed during data-taking, reconstructed during shutdown
  - The potential of this very high statistics sample is only now starting to be studied
- Discussion on LLP triggering strategies
  - Many very interesting and well-motivated physics signatures
  - In many cases, they are not easy to trigger on with traditional approaches
  - Improved trigger capabilities and heterogeneous resources should help going forward

Hardware acceleration and machine learning



Hardware acceleration and machine learning

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- Growing usage of GPUs and FPGAs in trigger applications
- Key use-case #1: track reconstruction on GPUs or FPGAs
  - Tracks are key to success in high-pileup environments
  - This is an expensive and slow process on CPUs $\implies$ accelerate it!
  - GPU-based tracking planned by multiple groups in the coming years (more on this later)
  - CMS has shown a FPGA-based tracking study for the hardware trigger (running at 40 MHz) for the HL-LHC; FPGA tracking is working up to 300 simultaneous collisions
- Key use-case #2: machine learning in FPGAs
  - Regressions, classification, etc all appear very promising to improve trigger performance
  - Integration into currently-simplistic hardware trigger algorithms allows for large gains
  - FPGA implementations of NNs studied with several different approaches: HLS4ML or direct

Future upgrades

Future upgrades

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- The amount of data is only increasing, often by order(s) of magnitude
  - Need to prepare for this increase in data, regardless of experiment
- Common trend: counter large data rates with more precise hardware filters/triggers
  - Very quickly identify what you want to keep
  - LHC: tracking or global selections on FPGAs to handle the pileup challenge
  - Many users: machine learning on FPGAs for any number of powerful uses
- Also studying ways to enhance usability of large datasets
  - Economical cost of tape storage is nice, but tape is very slow
  - Developing a tape+disk synchronization system that mitigates tape access

Birds of a Feather

Birds of a Feather

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- Tuesday: triggers and real-time analysis
  - Significant interest and growing area of study
  - Typically requires non-CPU hardware to really develop
  - Lack of easy interactive access to GPUs/FPGAs is a barrier to many people for developing and prototyping new approaches
- Thursday: tracking at the trigger level (real-time tracking)
  - ALICE, CMS, LHCb looking in the direction of GPUs for Run 3
  - ALICE: economical choice, necessary to meet farm requirements
  - LHCb: considered FPGAs, but prefer GPUs as don't need fixed latency
  - CMS also looking into FPGAs for HL-LHC tracking in first hardware trigger

Summary

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- Online and real-time computing is only growing in importance
  - The data rate is growing; quick processing is crucial
- However, increased online processing does raise some concerns
  - What if we are removing new physics with our processing?
  - Can be mitigated with full real-time analysis if you know what you want to look for
  - Other more general mitigation strategies are also starting to appear
- It will be interesting to see where we are by CHEP 2021!


What a busy week...
It's time for some rest!