



TDAQ group report

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for the Mu2ell tdaq subgroup



Outline

- The current working group
- Summary of the Mu2e TDAQ expected performance
- Recap of the previous workshops
 - PIP II implications for the beam structure
 - Ideas discussed so far
- Plan



Current members

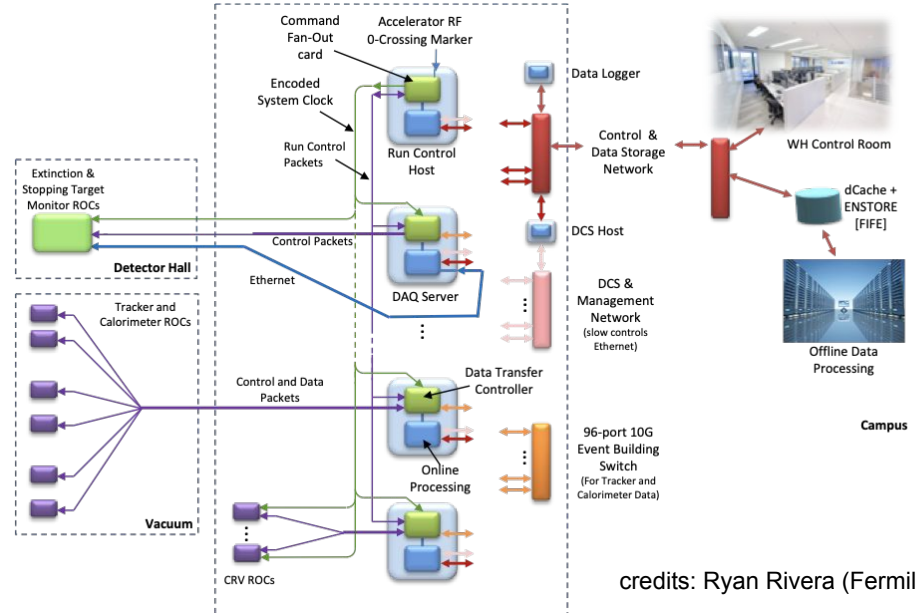
- Co-conveners:
 - Antonio Gioiosa: Mu2e L3 TDAQ, OTS developer in Mu2e, g-2 Slow Control Responsibility
 - Gianantonio Pezzullo: Mu2e Trigger co-convener, OTS/mu2eartdaq/Online developer
- Members:
 - Rebecca Chislett: g-2 TDAQ developer
 - Ryan Riveira: Mu2e L2 TDAQ, CMS, Meson Beam Test facility, OTS developer

Interested in joining?

- Mailing list: mu2eii-tdaq@fnal.gov
- Slack channel: [#mu2eii_tdaq](#)

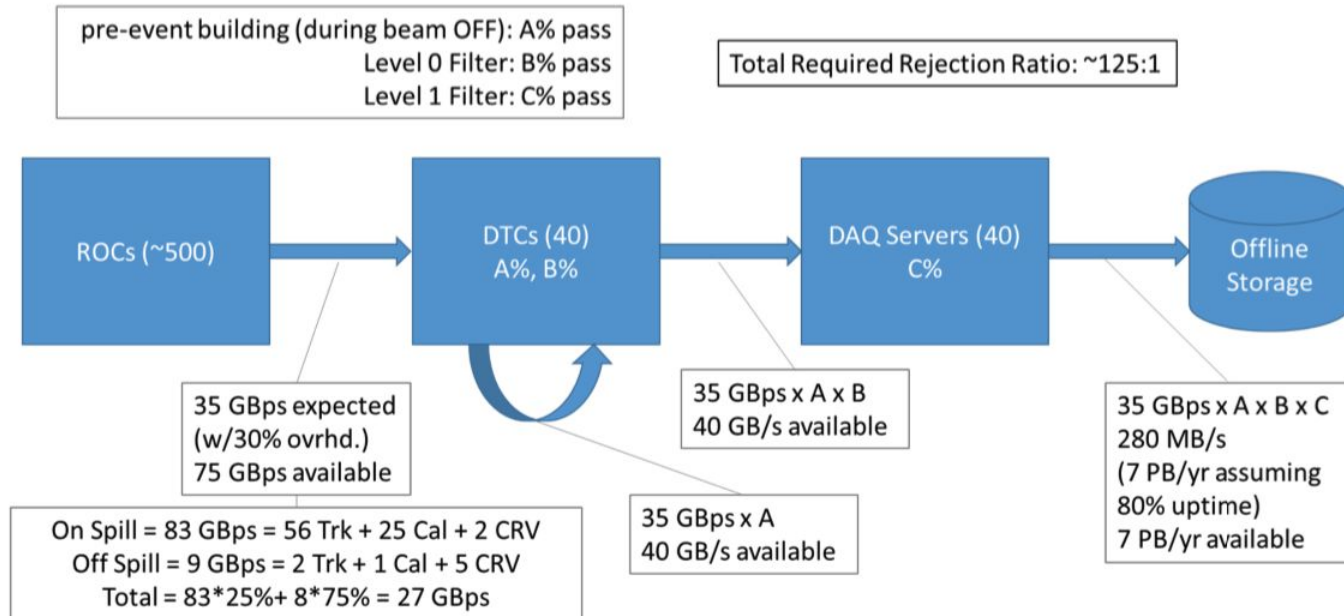
Mu2e TDAQ: system architecture

- Continuous stream of data from the tracker/calorimeter ROCs to the DTCs
- The data of a single event is grouped in a single server via a 10GB switch
- Online reco is run on multiple threads and the trigger decision is made
- Pull CRV data if an event is triggered



credits: Ryan Rivera (Fermilab)

Muze TDAQ: system architecture





Mu2e TDAQ: expected performance

- The current system is based on track triggers
- The expected trigger rate is below 300 Hz, with a few Hz of fake events
 - The rate can go further down if decide to reduce the rate of DIO from the Stopping Target
 - Development ongoing to reduce even more the rate of fake events
- The timing performance is the current issue under study. The limit is ~ 5 ms/event and we are currently at 6.5 ms/event
 - Mitigation strategy already in place, BUT it would affect the signal efficiency
 - Work is ongoing to reduce it

Beam structure for Mu2e

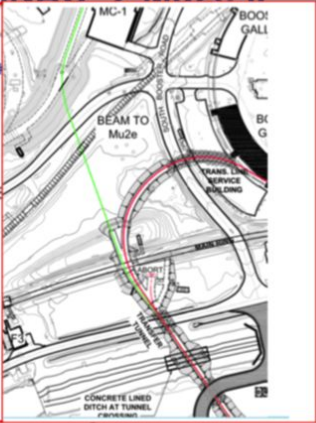
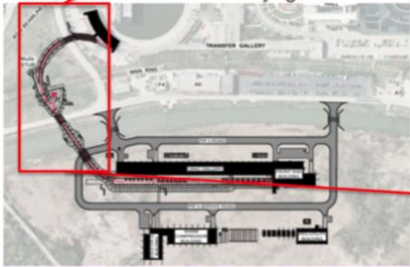
Accelerator layout: direct shot LINAC \rightarrow Mu2e-II

PIP-II Components

- 800 MeV linac
- Linac-to-Booster transfer line

Upgrades to Booster, Recycler & MI

- Conventional Facilities
- Cryogenic Plant



4 2 March 2018 Paul Derwent | PIP-II Mu2e and Extinction

- No Booster
- No Recycler Ring
- No Delivery Ring
- No slow extraction



Beam structure for Mu2ell

Summary of accelerator changes: Mu2e → Mu2e-II

- Duty factor
 - Mu2e : 29%
 - Mu2e-II: 97%
- Accelerator RF
 - Mu2e : 2.36 MHz (DR RF)
 - Mu2e-II: 162.5 MHz (6.15385 ns)
- Accelerator RF phase shift
 - Mu2e : yes (just prior to each spill)
 - Mu2e-II: no
- Microbunch structure
 - Mu2e : 3.9e7 protons in 250 ns wide pulse
 - Mu2e-II: N filled pulses spaced in 6.15ns steps (N and spacing tunable)
- Microbunch spacing
 - Mu2e : 1695 ns (4x DR RF period)
 - Mu2e-II: M empty pulses spaced in 6.15ns steps (M and spacing tunable)



Implications for the TDAQ

Larger detector occupancy & beam-duty cycle

- Larger bandwidth needed to handle expected data flux
 - x3-5 in the instantaneous rate, x3 duty cycle
- Higher rejection needed
 - Guidance: no more than x2 in data storage 14 PB/y
 - we need a factor x5 in the rejection
- Higher radiation delivered to the ROCs

PIP-II beam structure with no phase shift in timing

- Consider to lock system clock to 162.5 MHz accelerator clock IF ok with electronics
- Reduced OFF Spill periods (to no OFF Spill time?) implies less advantage to large front-end buffers for streaming data



Architectures proposed so far

Two TDAQ architectures proposed so far:

1. Expand current Mu2e architecture (1 level software trigger):
 - a. assuming x2 gain in tech, extrapolation of Mu2e system requires x5 more hardware
 - b. larger DAQ room, power and cooling
 - c. 100 Gb switches (vs 10 Gb of today system)
 - d. Will existing algorithm performance scale (now few ms/evt)? With retuning?
2. 2-level Trigger (L1 Trigger + HLT)
 - a. do some processing on FPGA and the remainder on software
 - b. where are the boundaries?
 - c. can we make a L1 trigger decision at FPGA level?
 - d. track pattern-recognition on FPGA?
 - e. Need to develop FPGA algorithms

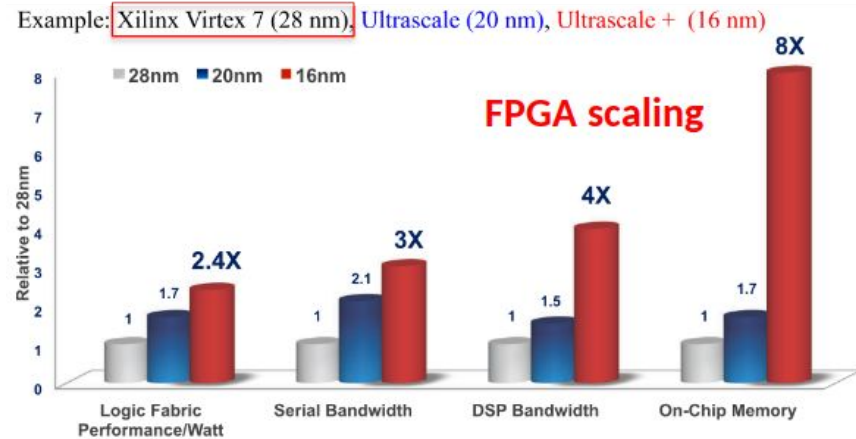


Where are the FPGAs for Mu2ell?

- At the detector front-ends, need rad-hard ASICS (Maybe already too late to design a new one) or FPGAs
- Low-Latency trigger
- Data concentration
- Event building
 - Can do custom application specific switching behavior
- High Level Trigger preprocessor/co-processor?
 - Other co-processors? GPUs?

Some considerations

- High Level Synthesis (HLS) is now good enough to rival manual VHDL or Verilog algorithm development.
- Allows physicists to easily develop FPGA algorithms
 - development can take place now – hardware is not needed!
- CMS is heavily investing in HLS
 - [hls4ml](#) collaboration developing NN tools using HLS





Previous Mu2e II workshops

- Experiment "standard" for data transmission between ROCs and DTCs is the VTRx from CERN
 - We need rad hard optical link for Tracker and Calo ROCs
 - For Mu2e II we can follow CMS development for the next generation of rad hard optical links
- Other open questions on Mu2e-II TDAQ
 - Evaluate performance/costs of the proposed architectures
 - Cosmic rays study for CRV trigger
 - Sim inputs for evaluating the expected doses in the ROCs



Plan - outline

- Report/interact progress also at the Snowmass Instrumentation Frontier group
- Send LOI request to groups/collaborators (also outside Mu2e!!)
- Organize a mini workshop the 2nd week of September



Plan: Snowmass IF04-tad group interactions

- We started advertising the Mu2ell-tdaq group at the kickoff meeting
- Mini workshop upcoming the 6th of August: <https://forms.gle/rBUyFAhDcdTXiCrT9>
- Slack channel: <https://join.slack.com/share/zt-ggor9fq8-vbY4k4NeD1hHvNwWj~OI9Q>



Plan: Mu2ell-tdaq LOI

- We want to draft an email for inviting groups to submit new ideas for the Mu2ell TDAQ system
- We need to outline in a clear way the:
 - Requirements of the system
 - The challenges of the Mu2ell experimental setup

- It will be great to agree with the Mu2ell committee on a general set of assumptions we should use to outline a set of requirements



Plan: Mini-workshop

- Event for discussing the LOIs submitted specifically for Mu2ell-tdaq
- Hear experience from:
 - other experiments that implemented TDAQ system with high data rate
 - R&D projects developing (track) trigger algorithms for high rate experiments
- We are currently working on a list of possible speakers to contact



Summary

- We identified the next steps to focus on the coming months
 - Send a invite for the LOI
 - Finalize the mini-workshop draft agenda
 - Keep involved with the Snowmass IF04_tdaq group
- We need to agree on a set of assumptions that we can use to instruct people writing the LOI
- We aim to enlarge the participation!