DUNE SAND DAQ, trigger, timing and Slow Control

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List of topics that deserve discussion

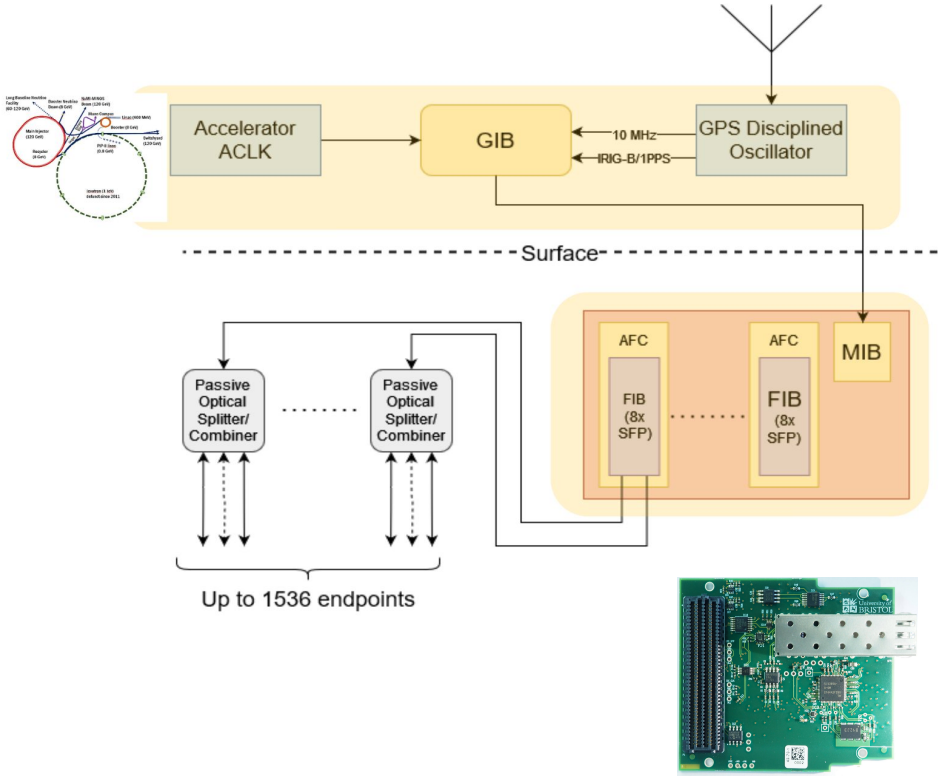
- Hardware layout and implementation of data readout in SAND
  - N. Tosi proposed a modular implementation of the readout HW: https://indico.fnal.gov/event/62345/
  - Based on Zynq Ultrascale
  - Allows to share a large part of FW/SW among the SAND subsystems
  - Can be integrated with the DUNE-DAQ and DUNE-TIMING system
- Timing (this meeting)
  - It seems reasonable to adopt the DTS in SAND, but no decision taken yet
  - We would like to identify and quantify the SAND timing requirements
  - We also need to make some progress about how to syncronize with the beam
- Data acquisition software
  - We will use DUNE-DAQ, but none of the details have been defined yet
- Slow control
  - Waiting for the FD to make a choice about the SCADA to adopt
  - Also some constraint could come from Fermilab, that uses Ignition for the cryogenics
- Trigger requirements, logic and implementation
  - The discussion on this topic hasn't started yet

Timing – Recent events

- Discussion started before the DUNE general meeting in September 2023 to define the timing requirements of the detectors of the DUNE-ND complex
- Trying to figure out if and how the DUNE-TIMING system (DTS) can be used for the ND
  - The DTS was designed having in mind the DUNE-FD
  - Implements a multi-endpoint timestamp and clock distribution
  - Based on a 62.6 MHz clock, not synchronized with the beam
- We gathered some information from the SAND subsystems
  - The DTS specs might meet the SAND requirements
  - This is especially true if we consider a limited number of endpoints internal subsystem synchronization
- Another round of discussion took place in a meeting with the DUNE-TIMING system WG
  - https://indico.fnal.gov/event/61796/
  - One important point of discussion was the synchronization with the beam

DTS specs overview

- The DTS can sync up to 1536 endpoints using a uTCA crate
- Firmware and hardware components are available to integrate the DTS with the different detector subsystems
- The delay between the endpoints is measured and corrected for continually
- The residual long term clock uncertainty is O(100ps), both between multiple end points and within the same endpoint
- The short term uncertainty (within a spill) for a single end point is much smaller, O(10ps)
- The short term uncertainty (within a spill) between different endpoints can be made O(10ps) if the two endpoints belong to the same passive fiber splitting connector
- With the present DTS design a passive splitter can handle up to 8 endpoints



Our requirements for timing

- We asked for O(10)-O(100) ps rms depending on subdetector
  - Both **between** and **within** subdetectors
  - Our strongest requirement applies only within a spill
  - DTS only “promised” O(100) ps
  - But they meant long term (i.e. drift), short term is better

- **The requirement can be met**
  - Within a spill, and a group of endpoints

PLL BW	Skew stdev.
100Hz	31 ps
400Hz	6.9 ps
1kHz	2.8 ps
4kHz	1.8 ps

From https://indico.fnal.gov/event/61796/

Synchronization with the beam

- Beam sync is not much relevant for the FD system (GPS is used in that case)
- Presentation about the beam sync was given at the DUNE GM in September by accelerator people (here), 2 options were proposed:
  - MIBS: 7.5 MHz clock, synchronous to Main Injector Beam RF (suggested as preferred solution)
  - ACLK: 650 MHz GPS-disciplined clock, not beam-synchronous (suggested as backup solution)

- The issue of the beam sync was discussed again in the DTS meeting in november
- A beam sync signal could be integrated in the DTS and distributed to the DTS endpoints
- However the accelerator-provided sync signal does not seem to meet the ND requirements
- During the meeting it was discussed the possibility to implement a dedicated instrumentation for beam signal pickup
- An ad-hoc system can probably achieve better performance with respect to sync mechanisms proposed by accelerator people
- No one is taking care of it at present, but this problem is relevant for the whole DUNE-ND complex
- Might be a joint effort of several DUNE-ND complex subgroups

Topics for today's discussion

- What are the parameters of the DTS that we would like to know in order to decide whether to adopt it?
- Can we define some measurement procedures for these parameters?

- What are steps we should go through before adopting the DTS in SAND?
- Do we have a deadline for taking this decision?

- How much the definition of the layout and modularity of the readout of the SAND subsystems is tied to our decision on the adoption of the DTS?

- How much can we benefit from a collaboration with other detectors of the ND complex?

Backup slides

SAND subsystems

ECAL:

Constraints:
- Signal dynamic range: N P.E: 2 up to ~2000
- maximum HV for PMTs divider: 2300 V
- Time distribution: < 100 ps

Readout:
- ToT with picoTDC
- Slow Waveform Digitizer: 125 MS/s + signal shape

STT:

Constraints:
- Time distribution O(100) ps

Readout:
- Front-end (FE) electronics based VMM3 or Tiger ASICs

GRAIN:

Constraints:
- time distribution < 50 ps

Readout:
- First tests are ongoing with the ALCOR ASIC
- Final Asic not yet developed;

Questions about timing

Questions		DUNE SAND Subdetectors		
		GRAIN	STT	ECAL
How many and which electronics do you expect to be connected to the timing system? Roughly how many endpoints of each system are expected?		GRAIN Interface board, custom, not designed yet, likely equipped with Xilinx FPGA/Zynq, Located on detector on cryostat periphery (not accessible during run). 8-10 endpoints max. (synchronization of individual ASICs is handled internally by the Interface Board)	450 FE boards (reading up to 512 straws). The timing should be distributed to the individual FE boards. ~450 end points	Design of ECAL FEE not finalized yet. Most likely max. 200 endpoints.
What clock/timestamp alignment do you require within your detector		< 50 ps	o(100) ps	<100 ps
What clock/timestamp alignment do you require with respect to the neutrino spill start?		o(100) ps	o(100) ps	<100 ps
Will you need to be able to identify bunches within the spill by timing?		Yes	Yes	Yes
What clock jitter (preferably expressed as phase noise spectrum) can you tolerate at each timing endpoint?		< 10 ps RMS	o(10) ps	o(10) ps
What clock/timestamp alignment do you require to any other ND detector (eg TMS to NDLAr)		Sufficient for bunch matching	TMS - ?	100-200 ps, e.g. for punch-through muons study