Vertical Drift Top Drift Electronics Numerology

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4/11/21

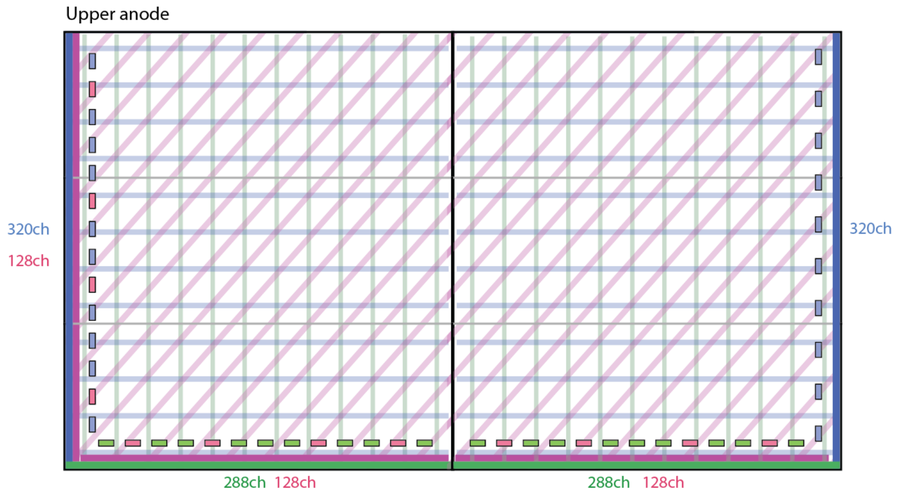
- Apologies for having postponed so many times
- These slides some facts, numbers and formats of the Top Detector Electronics from the DAQ perspective to start building a common understanding of what's defined and what's not
- And start thinking where we want to go…

Nota bene

- The TDE electronics descends from the NP02 Dual Phase electronics
  - strictly speaking - it's EXACTLY the same
- In NP02 the AMCs responsible to buffer data and responding to triggers
  - See Dario's presentation: https://indico.fnal.gov/event/50169/contributions/220266/attachments/145752/185674/TDE_data_transmission.pdf
- The AMCs will operate in a different mode in DUNE VD (streaming)
  - and interface with DAQ (DUNE, not theirs)
- TDE numbers has to be taken with a grain of salt
  - Data formats, protocols, etc have to be adapted/reoptimised
  - Some modifications have been already made (no compression, 40G MCH, etc…) but the underlying firmware is ~the same
  - No overhauls expected, but we've started the discussion

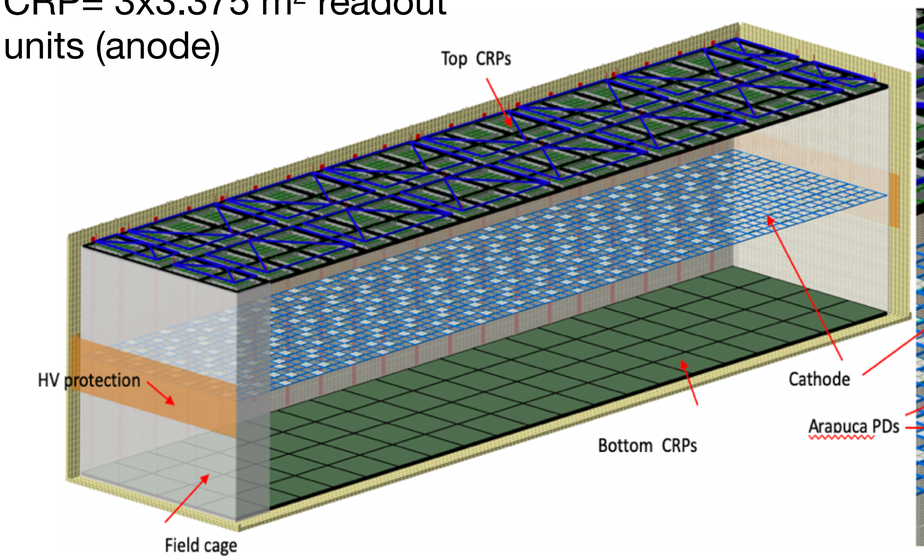
VERTIGAL DRIFT DETECTOR LAYOUT

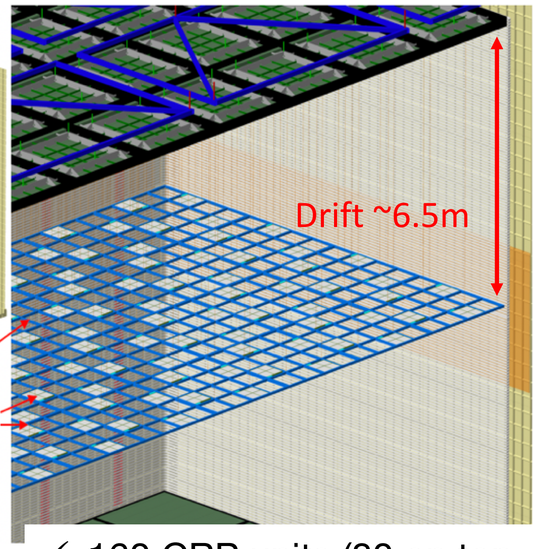
- 80 CRP/drift volume
  - Charge Readout Plane
- 1 CRP made of 2 CRUs
  - Charge Readout Unit

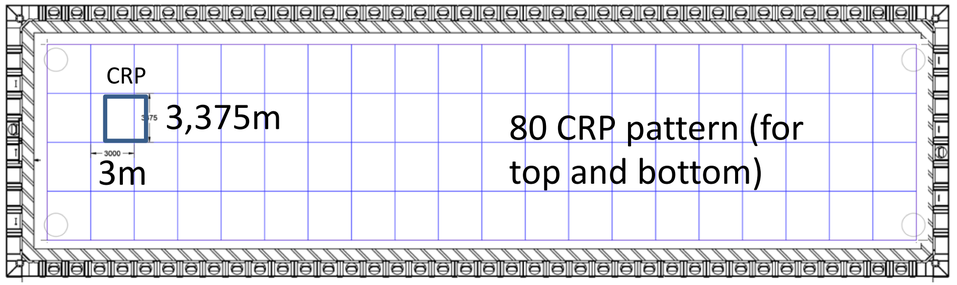


1 CRU

CRP= 3x3.375 m^2 readout units (anode)

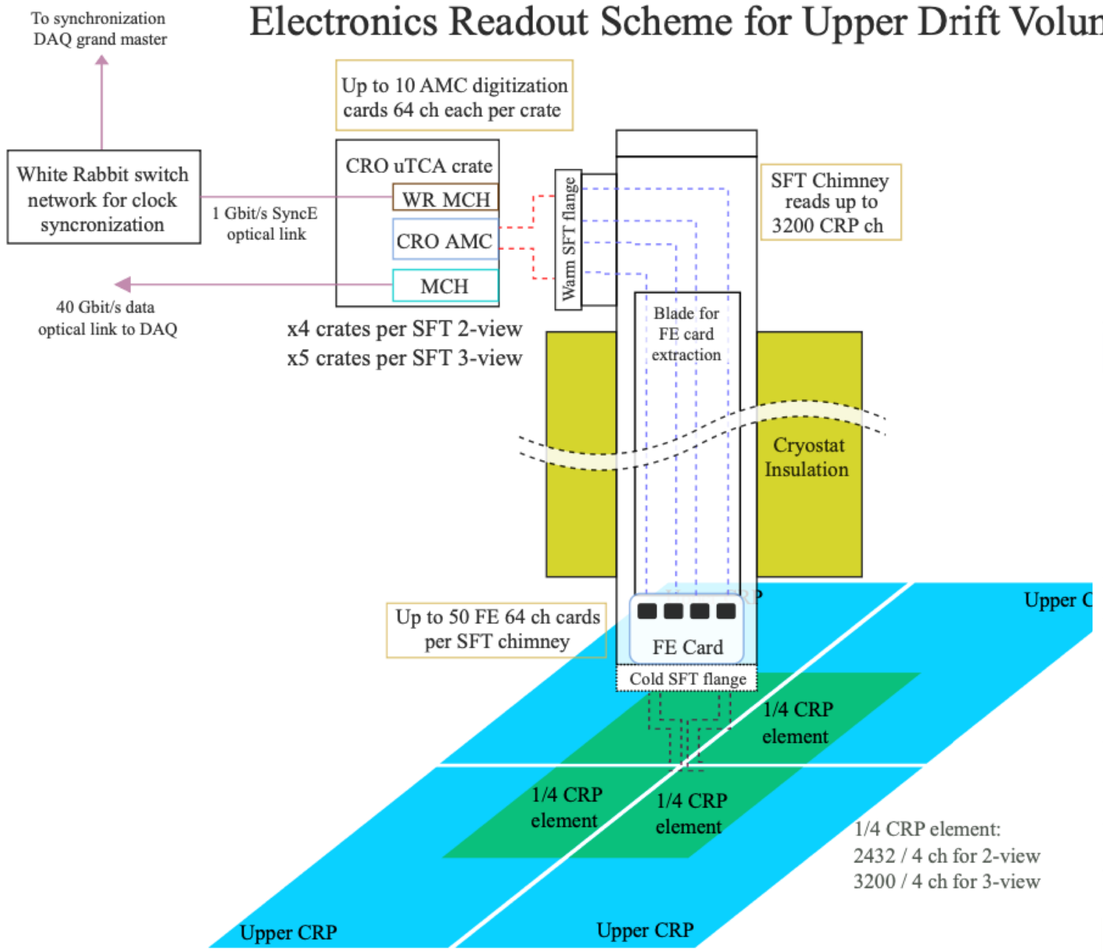






- ✓ 160 CRP units (80 on top, 80 at the bottom)
- ✓ PD on Cathode and/or cryostat membrane (~14% coverage)
- ✓ Active drift volumes 2 * 5'265 m^3 ~ LAr 14.74 Kt

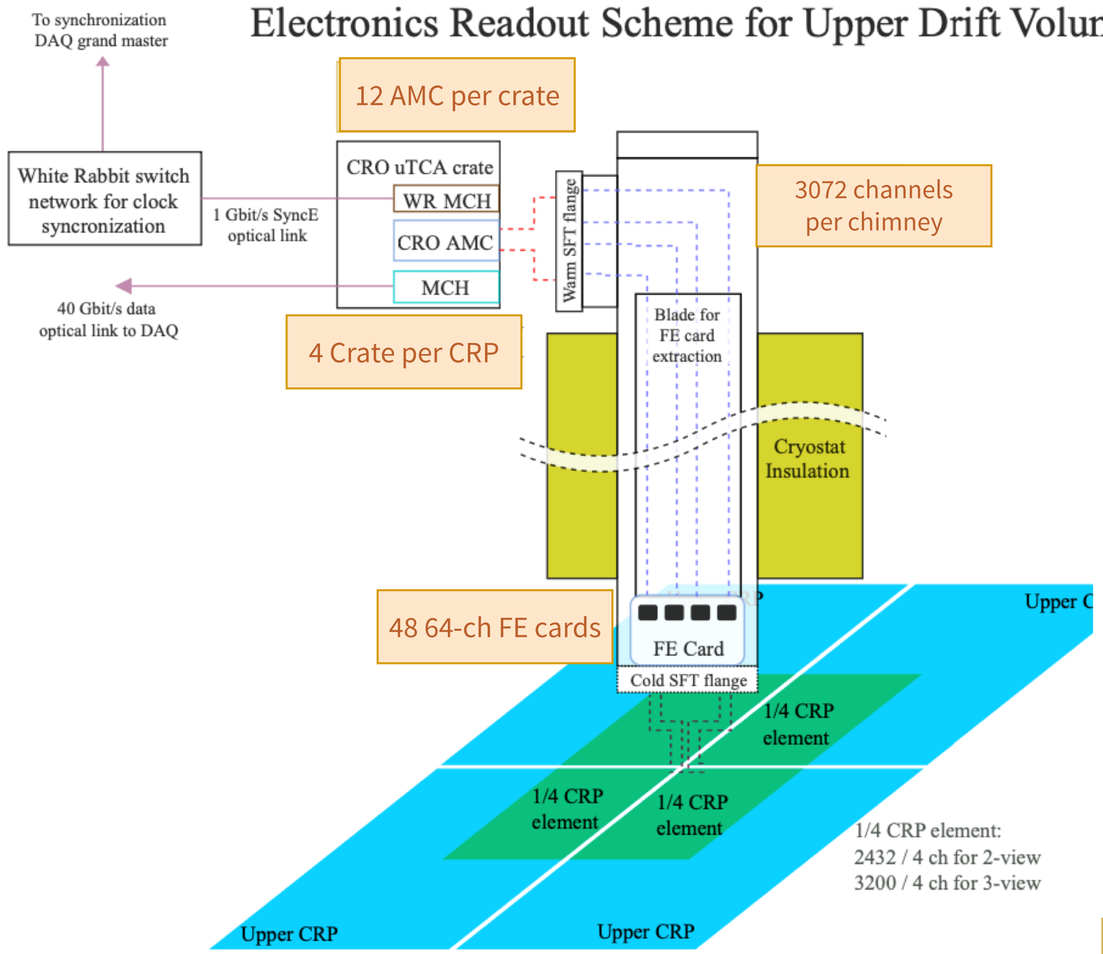
Top Drift Electronics Numbers



Item	Quantity
1.5 m x 1.7 m CRUs in the top drift	320
Anode channels per CRP	3200
Channels per FE card or AMC card	64
FE cards or AMC cards per CRP	50
Number of SFT	105
FE card slots per SFT	50
Installed FE cards per SFT	50
μTCA crates	400
AMC cards per crate	10
WR-MCH	400
40 Gb/s data links	400
Anode channels in the top drift	256,000

Sampling frequency:
~2 Mhz =125 Mhz/64

NEW CRT LAYOUT TOP DRIFT ELECTRONICS NUMBERS



- CRP layout optimised in summer to better match BDE electronics modularity
  - ~4% reduction in # of (used) channels
  - 20% reduction in detector electronics
- Sampling frequency unchanged

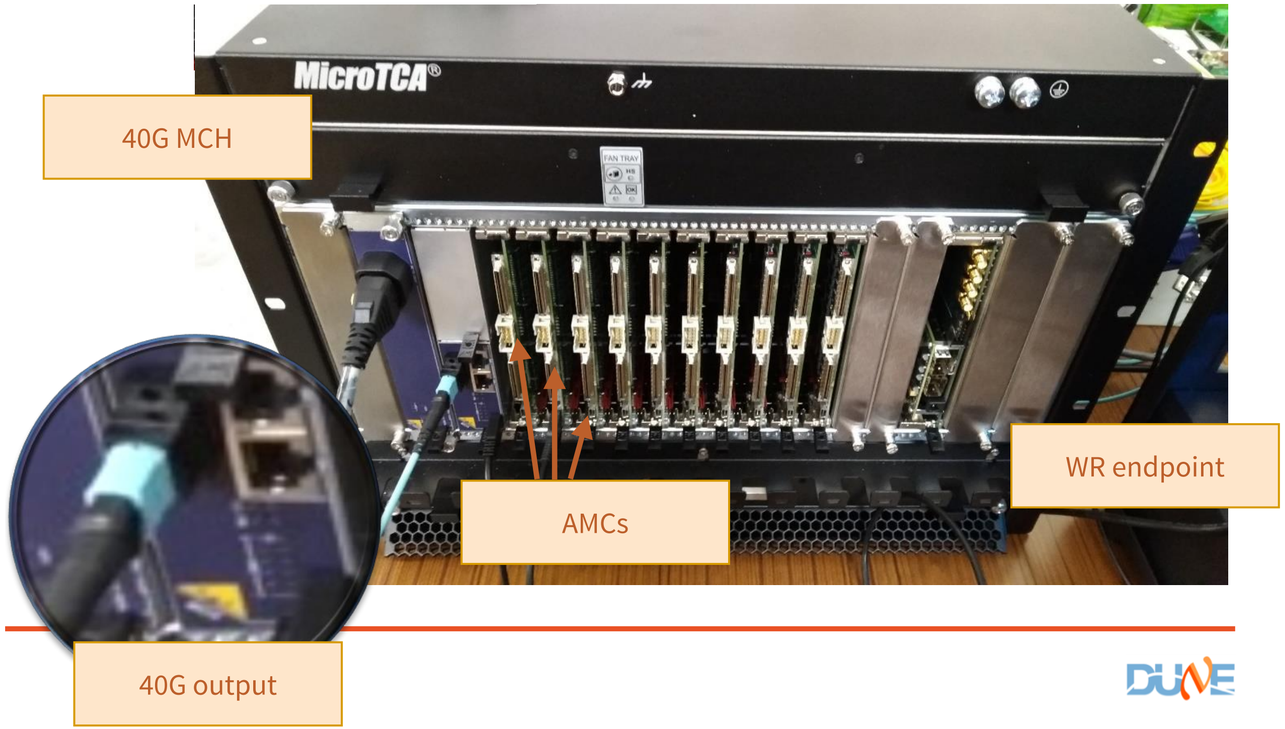
Item	Quantity	
1.5 m x 1.7 m CRUs in the top drift	320	
Anode channels per CRP	~~3200~~	3072
Channels per FE card or AMC card	64	
FE cards or AMC cards per CRP	~~50~~	48
Number of SFT	105	
FE card slots per SFT	~~50~~	48
Installed FE cards per SFT	~~50~~	48
μTCA crates	~~400~~	320
AMC cards per crate	~~10~~	12
WR-MCH	~~400~~	320
40 Gb/s data links	~~400~~	320
Anode channels in the top drift	~~256,000~~	245,760

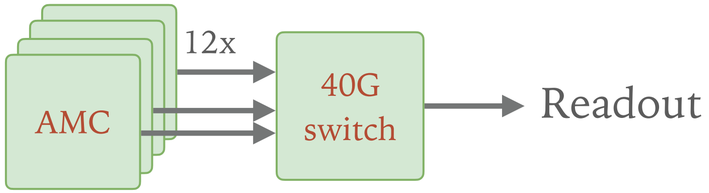
Sampling frequency:
~2 Mhz =125 Mhz/64

TDE Crate

- Picture from TDE CDR in June
- Each AMC
  - Sampling 12b@2 Mhz
  - 64 channels
  - 1,5 Gb/s output stream
- Each Crate
  - 1 x 40G MCH
  - 12 AMC
  - “Pure” data throughout : ~18 Gbps (packaging, protocol, encoding)
    - Closer to 24 Gbps
  - Aggregated by the on-board MCH switch

40 Gbps crate at IP2I Lyon (MCH-40G-XAUI)





DATA SAMPLING AND TRANSMISSION

- Each AMC acquires all **64 channels @ 2MHz** in parallel
- Channel data buffered in the on-board RAM;
  - Storage capability of several ms of data
    - Unclear if needed in streaming mode
- Streamed out to the MCH switch, **1 channel at a time**, in **round-robin**;
  - Each board acts as source of 64 “independent" UDP streams
- **Number of samples per channel** is configurable
  - Requirements maximises bandwidth efficiency and minimise transmission complexity
  - Setting the @samples such that size(1 pkt) = 1 Jumbo Frame (MTU 9000) looks like the best option.
    - Discussed with TDE experts, no objections

Proto DUNE UDP DATA packet Format

IP/ UDP Header + Data Header 48 bytes (64 bits aligned)								Source IP[2] = 32+ChassisNum Source IP[3]= AMC slot + 12 Source MAC[4] = chassisNum+1 Source MAC[5] = AMC slot + 12	
UDP Lenght	UDP lenght	0xD (4 bits)	0xE (4 bits)	0xF (4 bits)	Total Packet Number (6 bits)	Current Packet Number (6 bits)	ADCchannel (6 bits)	Global Packet Counter (MSB)	Global Packet Counter(LSB)

ADCs or Encoded Huffman Sequence
(10000 samples for protoDUNE)

No compression => 2 packets of 8000 bytes (4000 samples)
+ 1 packet of 4000 bytes (2000 samples)

Compression => 1 packets of 8048 bytes max
Size of Huffman Sequence is the UDP length – 6 bytes

DP Data Format

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<tr><td>0</td><td colspan="64">MAC Header</td></tr>
<tr><td>1</td><td colspan="16">UDP Header</td><td colspan="48">MAC Header</td></tr>
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<tr><td>3</td><td colspan="64">UDP Header</td></tr>
<tr><td>4</td><td colspan="64">UDP Header</td></tr>
<tr><td>5</td><td colspan="48">48bit DP Data Header</td><td colspan="16">UDP Header</td></tr>
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<tr><td>1126</td><td colspan="64"></td></tr>
</table>

- My attempt to put the numbers on a spreadsheet
  - Chances are it's all wrong :)
- Known issues:
  - Source information are part of the IP/UDP header (problematic on many levels)
  - The DP data header holds information relevant to the old DP daq
  - Nota bene: This is NOT what will be used for the VD ethernet readout, but it's the starting point

INTERVALLO : STANDARD RAW DATA HEADERS

- Sadly we don't one
- It's becoming clear that this has to change, or to run at the risk of overcomplicating data processing and bookkeeping
- Initiated discussion with offline last week
  - The picture below is a proposal for a header format uniquely identifies source and creation time of any data fragment (Far and Near detector)
  - To be discussed with detector experts

- DET data formats
  - Agree on a minimal common header with all detectors

K/D	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	Link						Slot				Crate										DetID						Version					
1	DTS timestamp[31:0]																															
2	DTS timestamp[63:32]																															

  - This breaks backward compatibility but we are sure that it will be very beneficial for the future

A Possible Ethernet Format?

- If one puts things together…
  - DISCLAIMER: Not discussed with TDE experts yet

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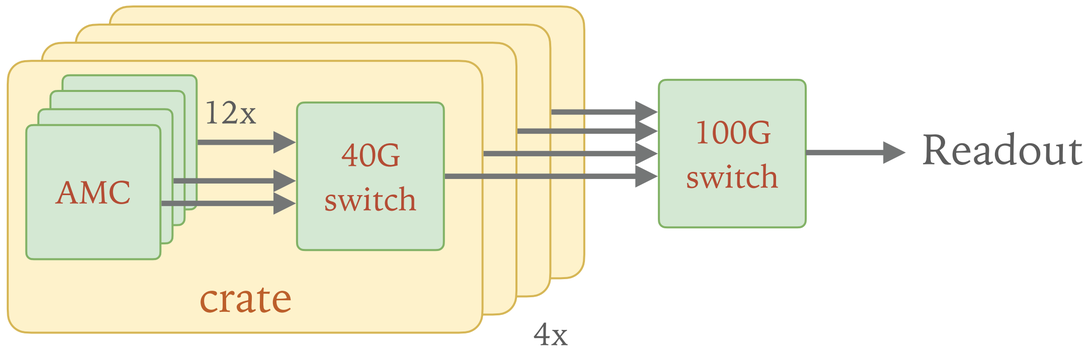
- Note: in the example, samples size is artificially blown up from 12b to 16b to favour byte alignment
- Alas: 12b->16b blows increases the crate throughput from ~18Gbps to ~25Gbps
  - Very close to the 100Gbps limit, some thought required

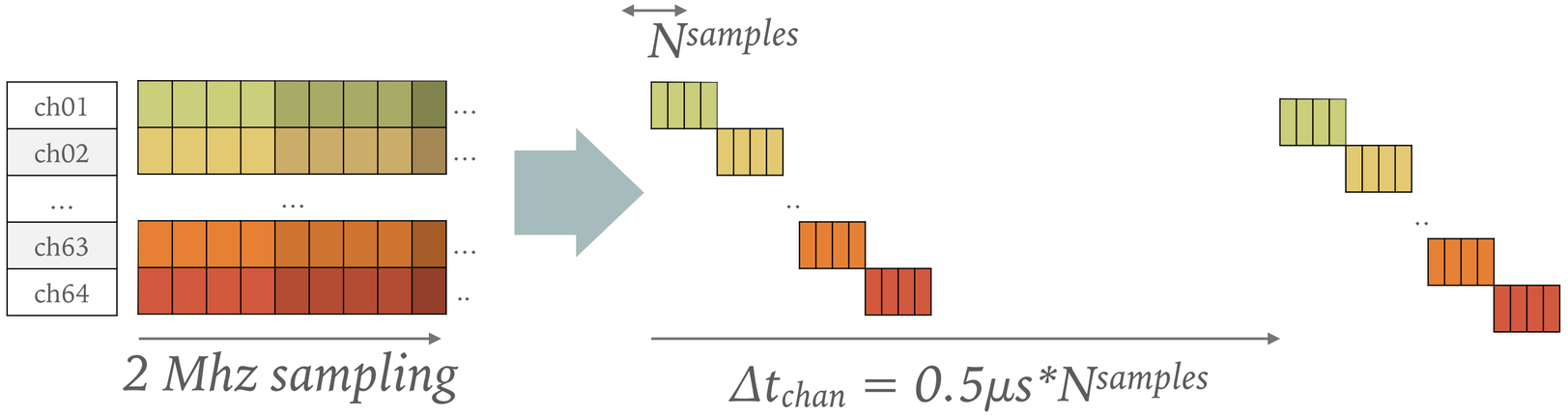
Some thoughts about traffic

- AMC streams out data from each channel as an independent UDP stream
  - i.e. 768 per Crate, 3072 for each CRP
- Modularity and bandwidth arguments point towards aggregating 4 crates in a 100 G readout unit
  - Each Ethernet 100G readout unit would receive 3072 independent UDP stream
  - Streams interleaved with each other



What does it mean for packet ordering?

- More or less like



- Assuming, MTU=9000B, 2B/sample (conservative), the interval between packets from the same channel is Δt_{chan}=2.25 ms
  - Note: transmitting 9000B at 100 Gbps should take much less, O(10μs)
- Risk of packets arriving out of order seems small
- Any attempt of reordering would have to deal with “large” gaps between packets from the same stream
  - Does this make sense?

Fin