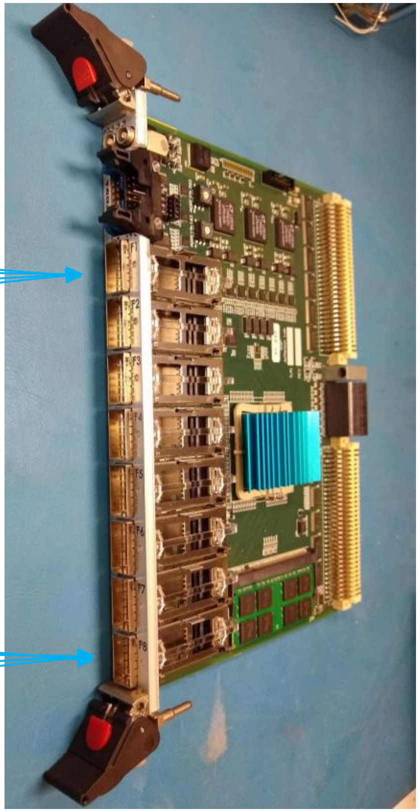
High-speed GEM DAQ
Feb 17, 2021

Benjamin Raydo
FEDAQ Group (Physics Division)

MPD Optical Readout

MPD:

SSP:



VME readout @ 2eSST320
*240MB/s limit expected

Up to 32MPD per SSP
***less expected due to bandwidth limits**

Optical cable:
1 SSP QSFP Port <-> 4 MPD 4 SFP Ports

Why optical readout?

MPD VME readout limit:

- With 15APV per MPD, 128 strips per APV, and 6 samples (32bit word per sample) MPD event size = 46kBytes
- UVA+INFN GEM APV count = 988 given a total event size of ~3MB
- Distributing these across 8 crates, the trigger rate limit would be ~500Hz (if all crates had 10GbE equipped readout controllers and readout used 2eSST320)

To reach ~4kHz 30% occupancy target:

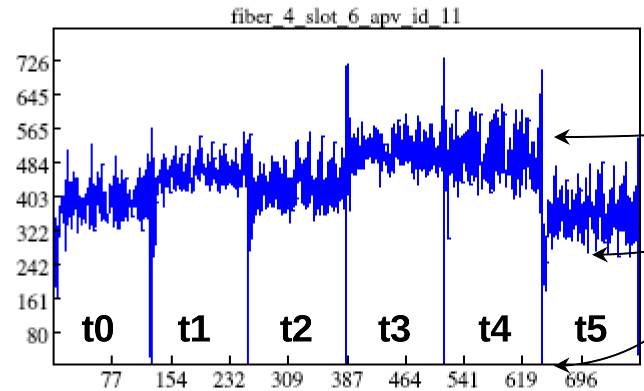
- Zero suppression requires, but this is complicated by common-mode "noise"
- MPD resources are very limited – doesn't look feasible to fit algorithm
- Using the optical link, event data can be sent to another device where more resources can apply zero suppression with common-mode subtraction

* Thanks to Holly for taking test runs to gather these numbers!

APV Data Processing on SSP

Raw APV data

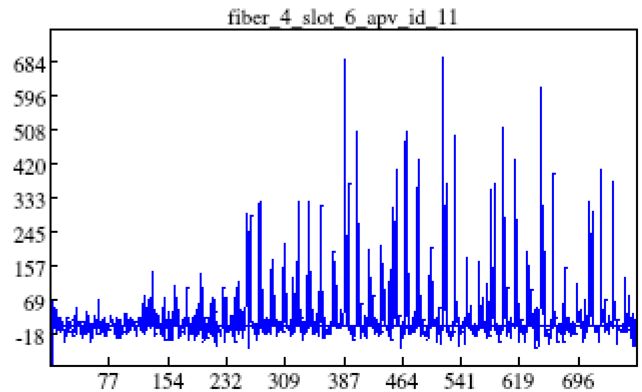
(single APV chip, 129 strips x 6 samples)



- **Different time slices (t0-t5) can have different offsets**
- **Individual strips have different offsets and noise levels**

Processed APV data

(pedestal & common-mode subtraction)



- **Apply individual strip offsets (constants loaded from files at start of run)**
- **Compute pedestals/common-mode for each time slice and use to remove offset for each time slice (done each event/time sample)**
- **Real hits shouldn't be part of the pedestal calculation (notice the pedestal still centered around 0 even in the presents of hits)**

APV Data Processing on SSP - offsets

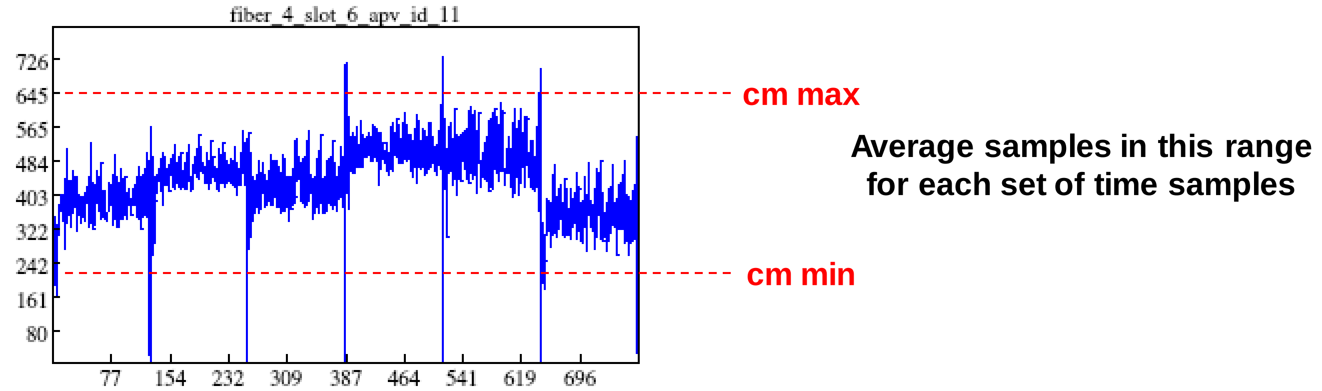
Credit goes to Danning Di (at UVA at the time) for this algorithm and time spent testing!

1) Apply APV strip offset correction constants

- Offsets are loaded into the SSP firmware during the DAQ startup
- For each MPD (SSP fiber), there are 15 x 128 offsets (15 APV x 128 strip)

2) Compute average "A" (i.e. initial pedestal estimate):

- Form an average of strips with APV values between common-mode min & max ranges (small amplitude physics pulses may be averaged here)
- Common-mode min & max constants are loaded during DAQ startup
- For each MPD & APV chip there is a min & max constant
- For example:

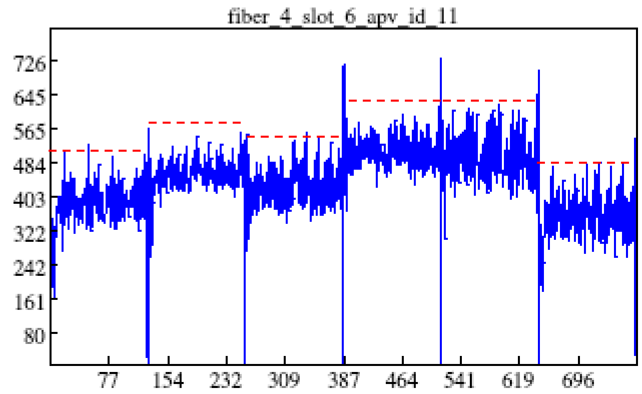


APV Data Processing on SSP common-mode

3) Compute average "B" (i.e. refined pedestal estimate, remove low amplitude real hits):

- Form another average of strips with APV values < (averageA + strip threshold)
- strip threshold is per strip and set by factor * RMS noise
- This new average is intended to ignore potential physics pulses that were included in the first
- This common average "B" value is subtracted from APV samples in the corresponding time bin

Average samples below thresholds to determine common-mode for time bin

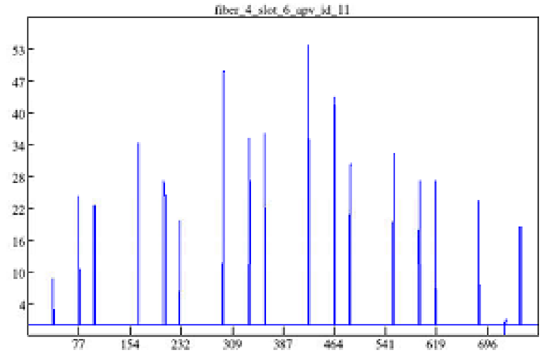


APV Data Processing on SSP zero suppress

4) Zero suppress reported strips

- **If peak is at first or last sample, suppress (out of time hit)**
- **If sum of 6 samples < 6*threshold, suppress**

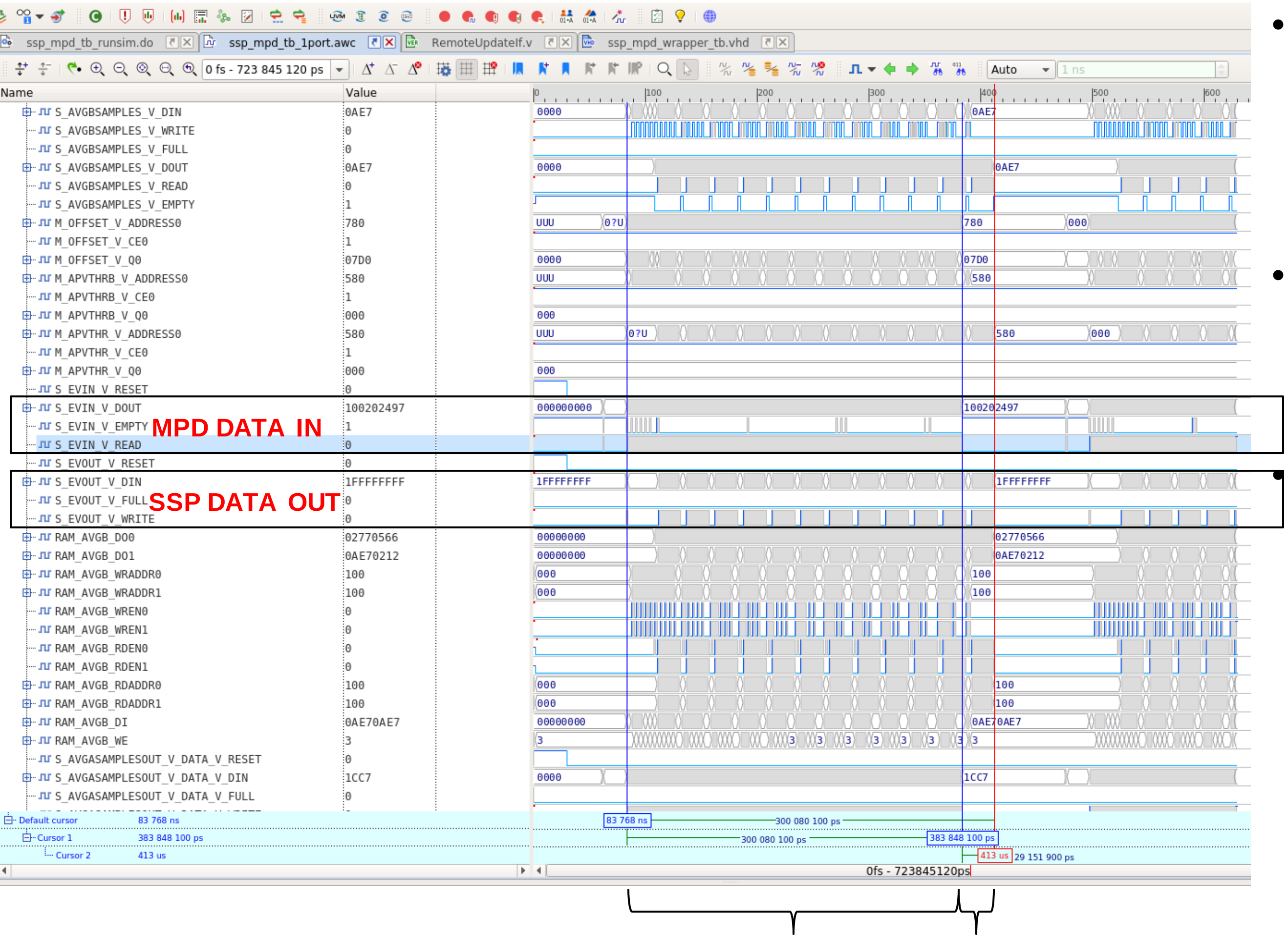
An example APV zero suppressed frame (probably noise)



Note: these features can be disabled to test effects one at a time. Important to take data and analyze with these features in place to make sure all effects are understood (particularly any as occupancy creeps up).

MPD Optical Rate Limit

SSP + MPD firmware simulator:



MPD Frame (12 APV, 6 time samples) = 300us

SSP Data Processing delay = 30us

- **Originally MPD used a 2.5Gbps link to SSP and could achieve ~5kHz event rate**
- **Optical link stability forced it to 1.25Gbps, now rate limit is ~2.5kHz**
- **SSP processing is also slowed by factor 2 going from 2.5Gbps -> 1.25Gbps**

Rate Limits

Currently with firmware/setup running in TEDF

- **88 APV, 7 MPD, 1 SSP**

100% occupancy: 850Hz, 120MB/s

Thanks to Holly for running these test!

50% occupancy: 984Hz, 75MB/s

10% occupancy: 2.5kHz, 37MB/s

- **~2.5kHz and 120MB/s is a limit of the MPD due to the 1.25Gbps link speed and 1 hit per 32bit word.**

Next step: pack 2 hits per 32bit word on MPD, expected to double trigger rate limit (to ~5kHz) and readout bandwidth limit (to 240MB/s - won't help with 10Gbps Ethernet on CPU though)

Rate Limits – part 2

Doubling the trigger rate and readout bandwidth isn't enough to support 4.5kHz 30% occupancy unless:

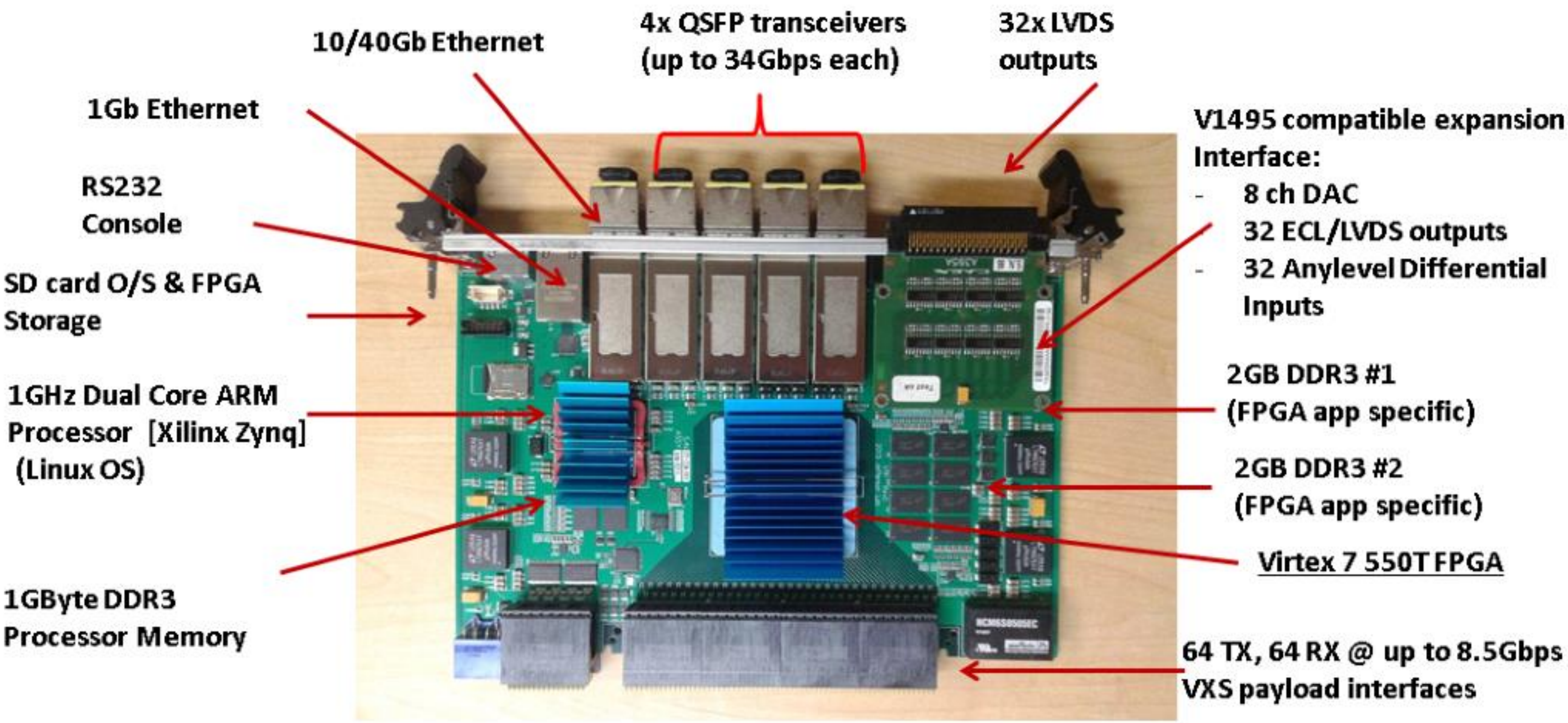
(988 APV * 4.5kHz, 30% occupancy would be ~2GB/s)

- **We can get 240MB/s from the SSP, that would require 9 separate SSP & crates (and 10GbE enabled Intel Controllers)**

SSP is a large FPGA + Optical transceivers + Memory, but VME readout

- **VTP is a newer design that has a larger FPGA, more optical transceivers, more memory, and 10Gbps Ethernet**
- **Has been in use for a few years in CLAS12, HPS, Hall A Compton, Streaming DAQ, and other experiments**

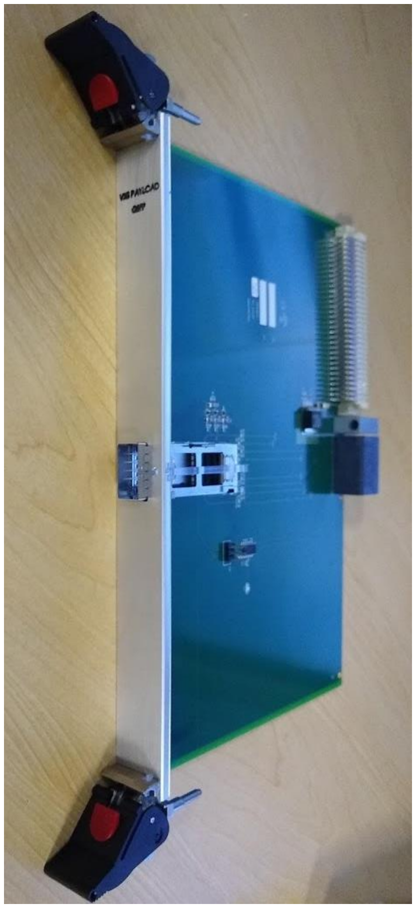
VTP Resources



- **VTP runs Linux (setup/maintained by Bryan Moffit) and is used as a CODA ROC in Hall B (~30 crates) as well as Hall A Compton, but it only used the 1Gbps Ethernet readout for the CODA ROC**
- **VTP 10Gbps has been used in streaming DAQ tests in 2019 and now we are changing the VTP CODA ROC to utilize that. Firmware is completed, but under simulation and soon to be tested in the lab.**

Optical readout with VTP instead of SSP

QSFP -> VXS adapter (supports 4 optical links to MPDs per VXS/VME slot)



Up to 16 cards per crate/VTP

VTP

Up to 80 MPD per VTP, but realistically better to support 32 MPD if we use a single 10Gbps Ethernet link

- **We have 32 QSFP -> VXS on site for the SBS/GEM setup**
- **Will need 3 VTPs and VXS readout crates to support the ~78 MPD readout system**
- **26 MPD per VTP/10Gbps Ethernet link would support 4.5kHz @ 30% occupancy**
- **SSP MPD processing firmware ports easy (Xilinx FPGA -> Xilinx FPGA)**
- **...hopefully the backend CPU/storage is designed to handle ~2GB/s!**

Plans

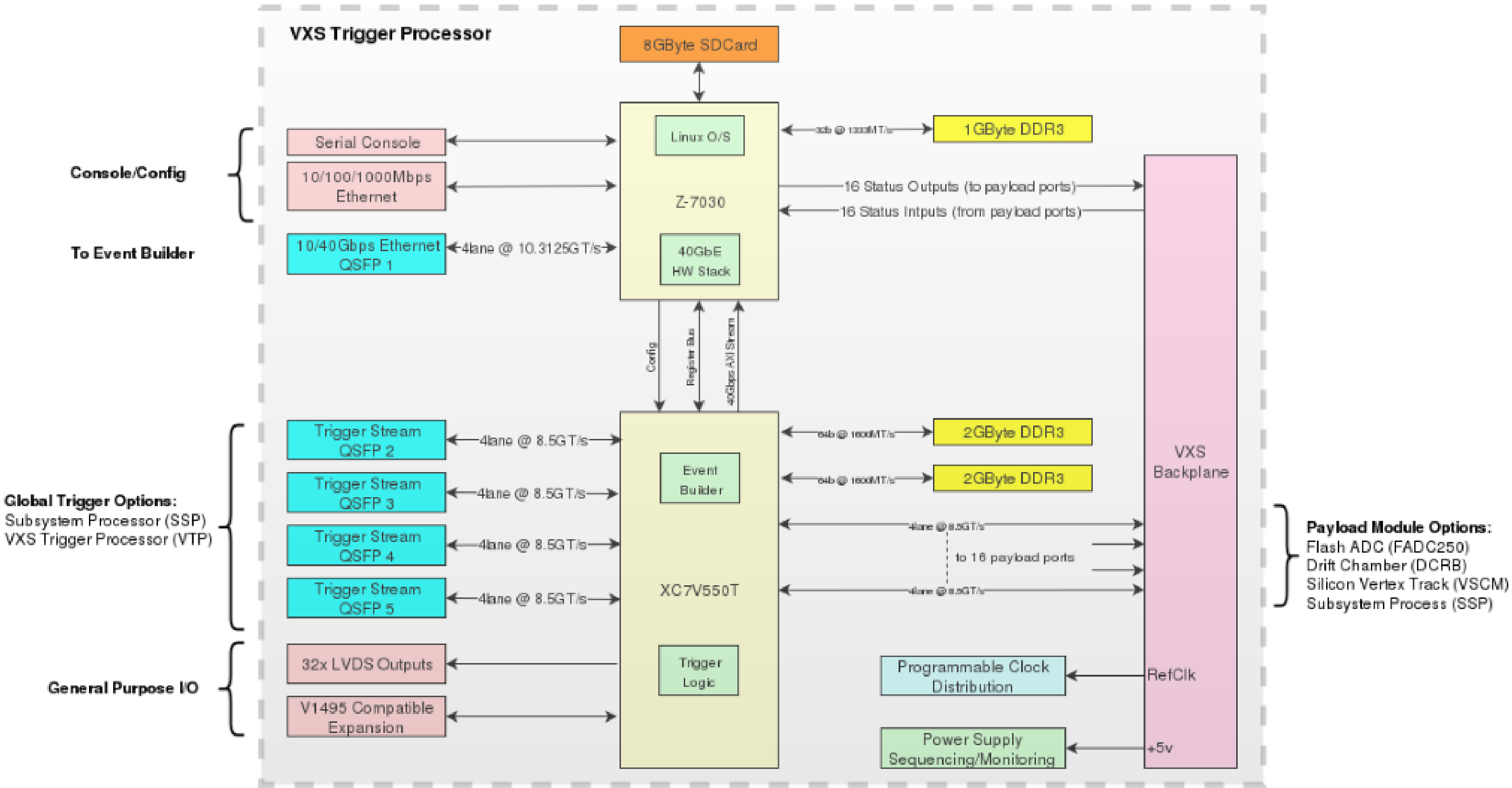
Continue support MPD readout via SSP

- Implement double packed MPD words and test with SSP to ensure trigger rate & data rate double as expected (expected to be ready next week)
- Allow users to use SSP DAQ for testing, data taking, and verify common-mode and zero suppression work properly

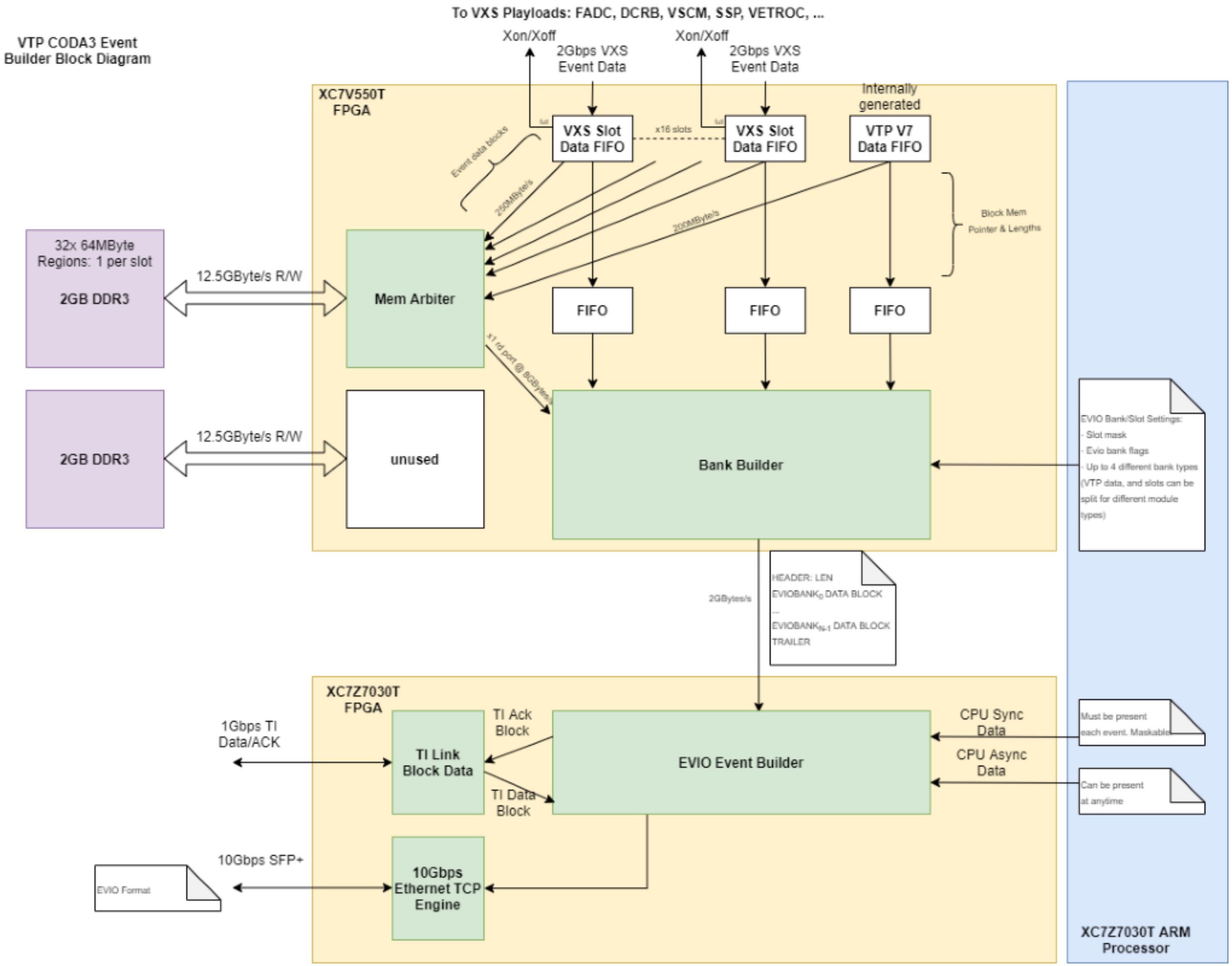
Focus effort on porting readout to VTP

- This will ensure high rate DAQ requirements can be met if trigger/data rates end up on the high side of estimates
- Data format from VTP will be identical to SSP (only ROC ID will change) - so decoders that work with the SSP will have no problem when the VTP is put to work
- Hardware (VXS crates, VTP, QSFP->VXS cards) can be setup now, software development will take several weeks at least

VTP Hardware Diagram



VTP Hardware CODA ROC



VTP FADC Streaming