Hypernuclear DAQ

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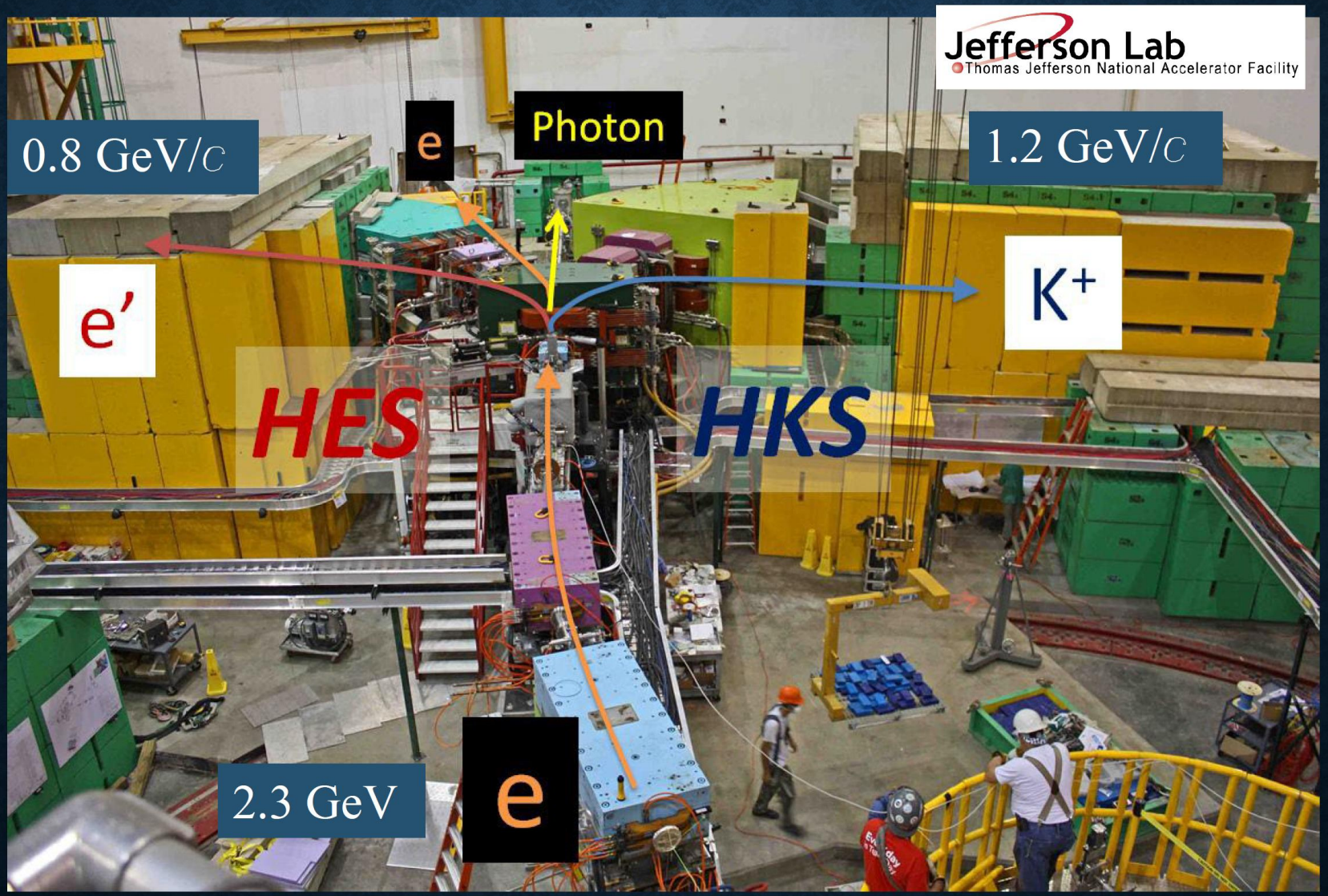
ERR preparation meeting

November 14th 2023

Outline

- Experiment overview
- Channel count
- Overview pipelined electronics
- Trigger overview
- To do
- Conclusion

Experimental setup for E05-115 (2009) at JLab Hall C



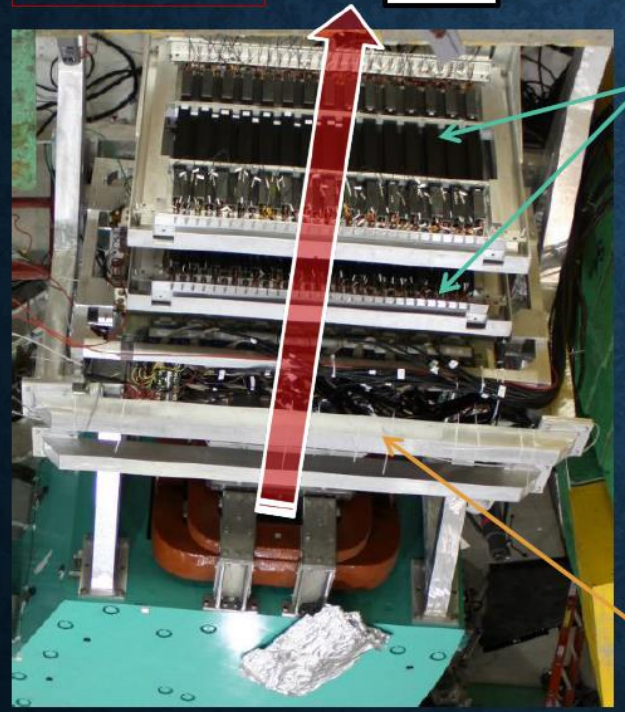
PARTICLE DETECTORS

HES

e^-

HKS

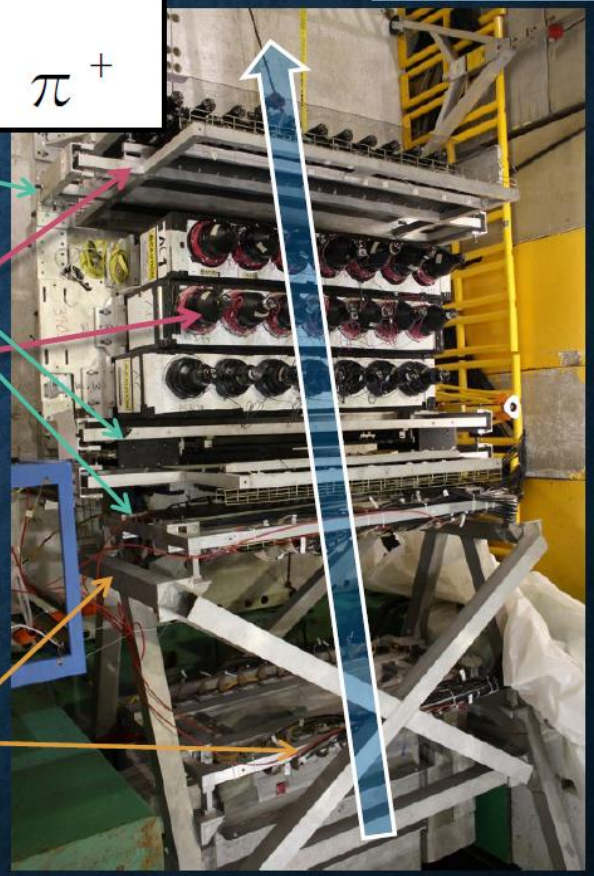
K^+
p, π^+



TOF walls
(Plastic scintillators)

Cherenkov detectors
- Aerogel (n=1.05)
- Water (n=1.33)

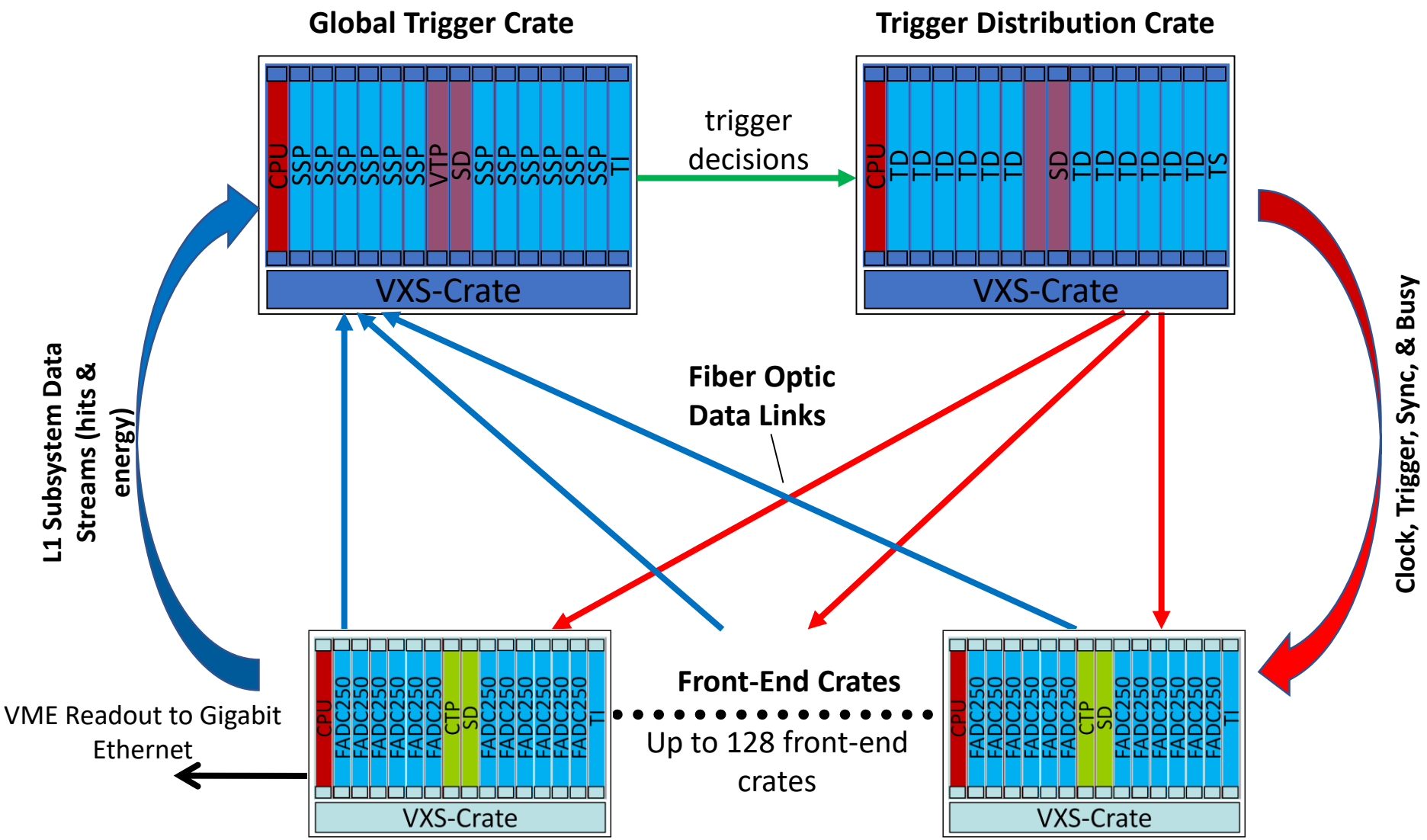
Drift chambers



Channel count

	Detector	Current status	No. of channels		Ready?
			ADC	TDC	
HKS	Drift Chambers	To be tested	N/A	360 + 360	
	TOF counters	All PMTs were checked	88	88	
	Aerogel Cherenkov	Test done	42	42	Yes
	Water Cherenkov	New boxes under construction	48	48	
HES	Drift Chambers	To be tested	N/A	1098+360	
	TOF counters	To be tested	116	116	

Level 1 & Trigger Distribution



Crate Level – Signal Distribution

- VXS Based, 20 Slot Redundant Star Backplane

- VME64x backplane w/VXS (VITA 41 Standard) provides standard with high speed serial extension (new J0 connector)

- 18 Payload slots w/VME64x, 2 Switch slots

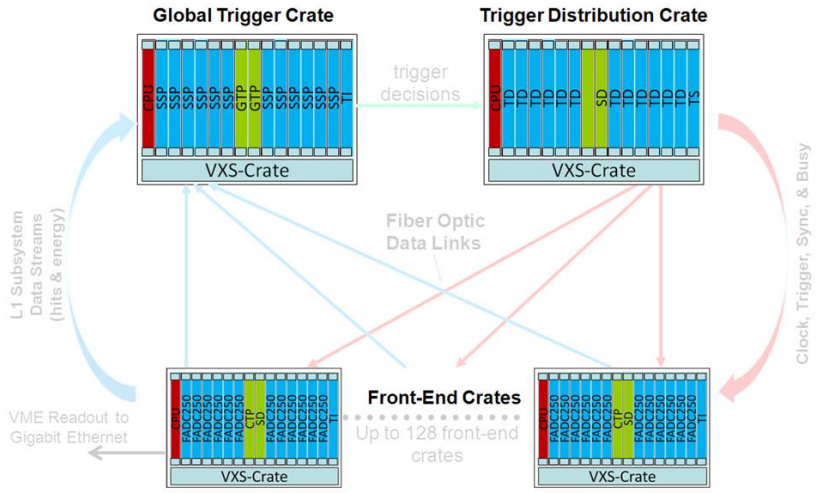
- Each payload slot has 8 high speed capable links (10Gbps each) to both switch slots

Crate Level Use:

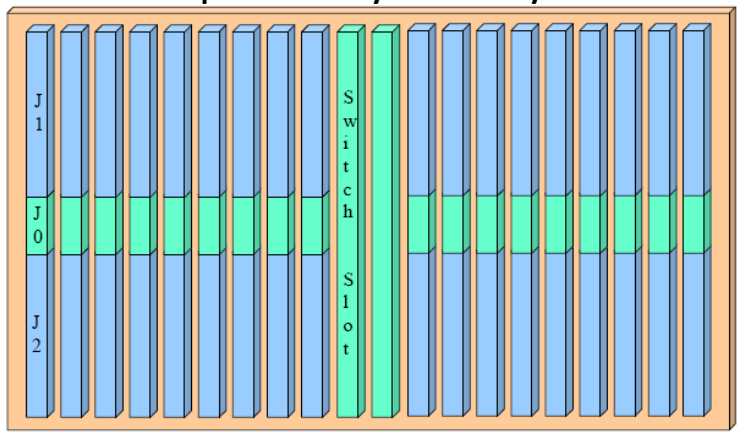
- VME64x used for event readout

- VXS: Low jitter clock & trigger distribution

- VXS: Gigabit serial transmission for L1 data streams to switch slot for processing



VXS Backplane Physical Layout:



VXS (VITA 41 standard)
VME64x + high speed
serial fabric on J0

Capturing the Pulses…

Existing System:

Expensive, bulky delay cable dispersive & attenuates

Non-pipelined electronics guarantee dead-time (conversion time)

Gate

Delay line

detector signal

Splitter

QDC

Discriminator

TDC

to primitive trigger logic

Very limited channel resolution used in trigger

multiple modules for time & energy

New System:

(for timing >500ps)

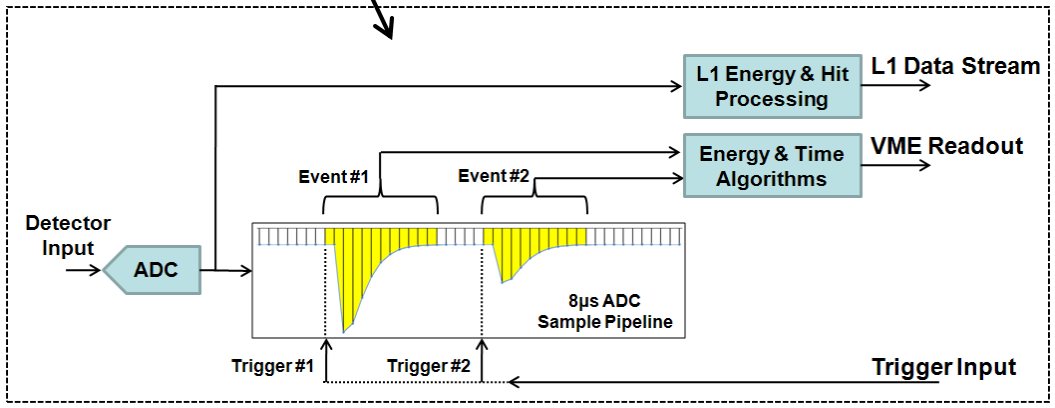
CLAS TOF has >150,000ft delay line!

detector signal

FADC250

to smart trigger logic

Time, energy, trigger output in 1 module

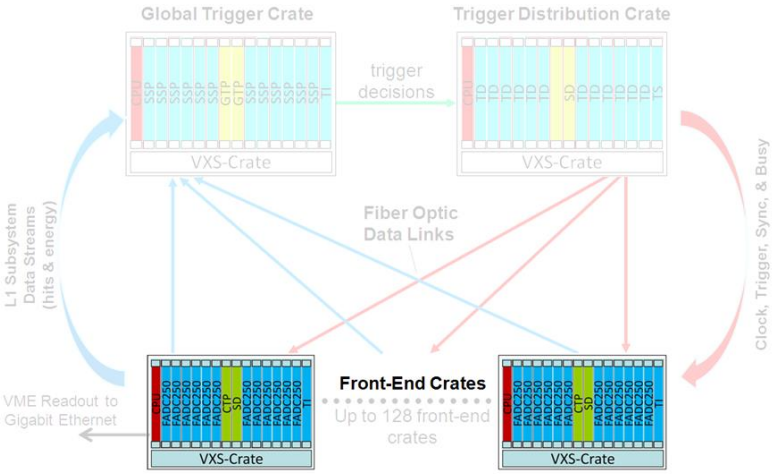


- **Pipelined sampling, readout, & trigger -> no dead-time**
- **Digitization retains original signal integrity**
- **Long pipeline allow more time for complex triggers**

Front-End Electronics: fADC250

- 16 Channel 12bit, 250Msps Flash ADC
- 8µs raw sample pipeline, >300kHz sustained trigger rate (bursts @ ~15MHz)
- Post-processing in customizable firmware to extract time, charge, and other parameters minimizing event size
- Module supports 2eSST VME transfers at 200MB/s transfer rate
- Large event block sizes (>100) to minimize CPU interrupt handling
- VXS P0/J0 outputs 5Gbps L1 data stream (hit patterns & board sum)

- Used in existing 6GeV program:
  - Hall A BigBite
  - Upgraded Hall A Moller Polarimeter



JLab-FADC250:

Channel count

	Detector	Current status	No. of channels		Ready?
			ADC	TDC	
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	Aerogel Cherenkov	Test done	42	42	Yes
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HES	Drift Chambers	To be tested	N/A	1098+360	
	TOF counters	To be tested	116	116	

FADC = 88 + 42 +48 +116 = 294 channels = 19 FADCs = 2 VXS crates (NPS)
V1190 = 2268 channels = 18 V1190 = 1 VME64X crate (HMS/SHMS/SBS could use CDET VETROC)
TOF = 204 channels = 7 V1290 = 8 F1 = 3 VETROC (SBS GRINCH)

Will be running during Moller : NPS,SBS,SoLID hardware available, most likely enough FADCs
Can use HMS/SHMDS electronics
BPM rasters : 2 FADC

Trigger rates

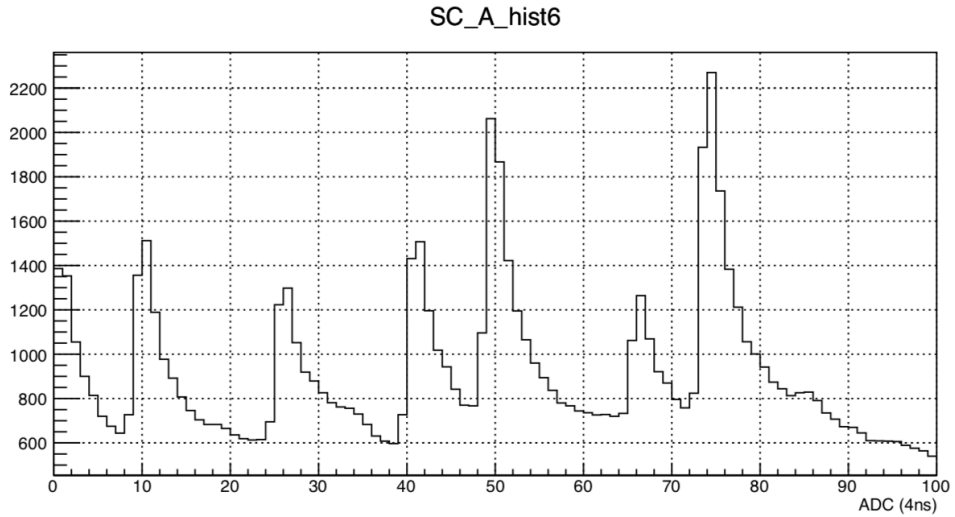
Target	Areal density [/(g/cm^2)]	Beam intensity (/ μA)	HES rate (/kHz)	HKS rate (/kHz)			Accidental coincidence$^{(*)}$ (/kHz)
			e'	π^+	K^+	p	
^{6}Li	100	50	120	22	0.27	28	**1.0**
^{9}Be			140	21	0.26	27	**1.8**
^{11}B			170	21	0.25	26	**2.1**
^{27}Al			930	20	0.24	25	**10.5**
^{40}Ca	150		1100	26	0.31	33	**14.8**
^{48}Ca			940	25	0.31	32	**13.8**
^{208}Pb		20	1300	8.2	0.24	10	**4.9**

(*) Assuming,
HES: 30 ns width
HKS: 200 ns width

Data rates

- Rough estimates
  - HKS = 1 MHz
  - HES = 1 MHz
  - Coincidence = 1MHz x 1 MHz x 20 ns = 2 KHz

- Plan for up to 20 KHz desirable
- If no waveform could take 200 KHz
- Using CODA3 and event blocking should be doable (similar to CLAS12) will be tested during NPS
- Need to evaluate detector occupancies
- If useful can record full FADC waveforms



Example scintillator SoLID beam test

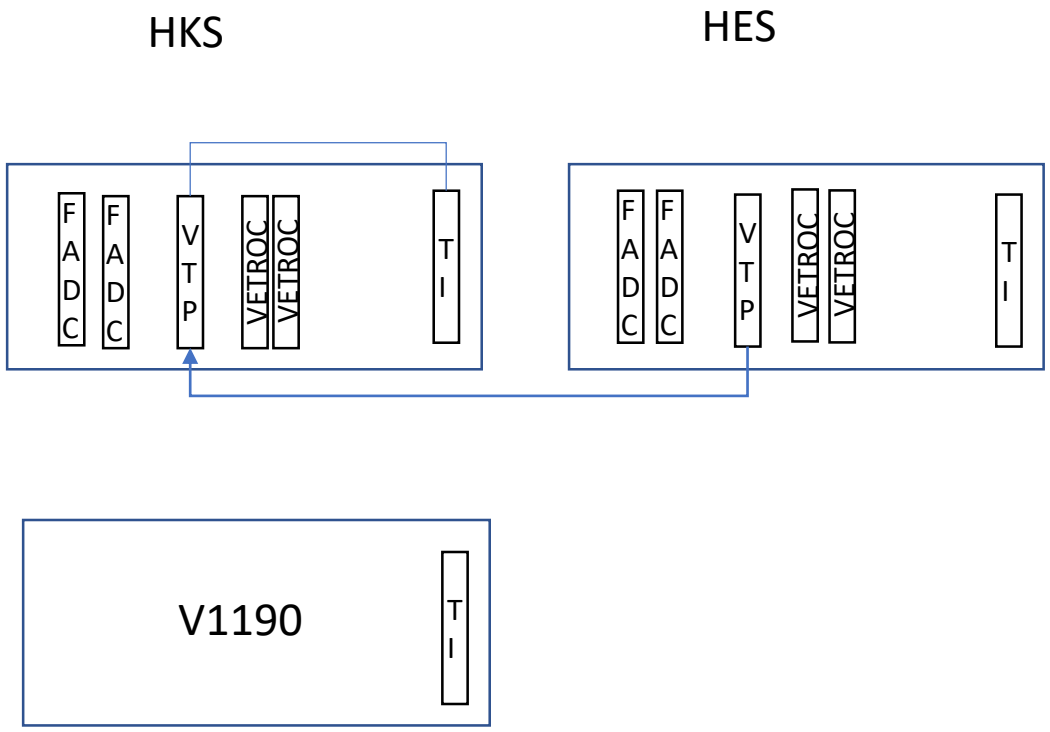
Data rates with full sampling

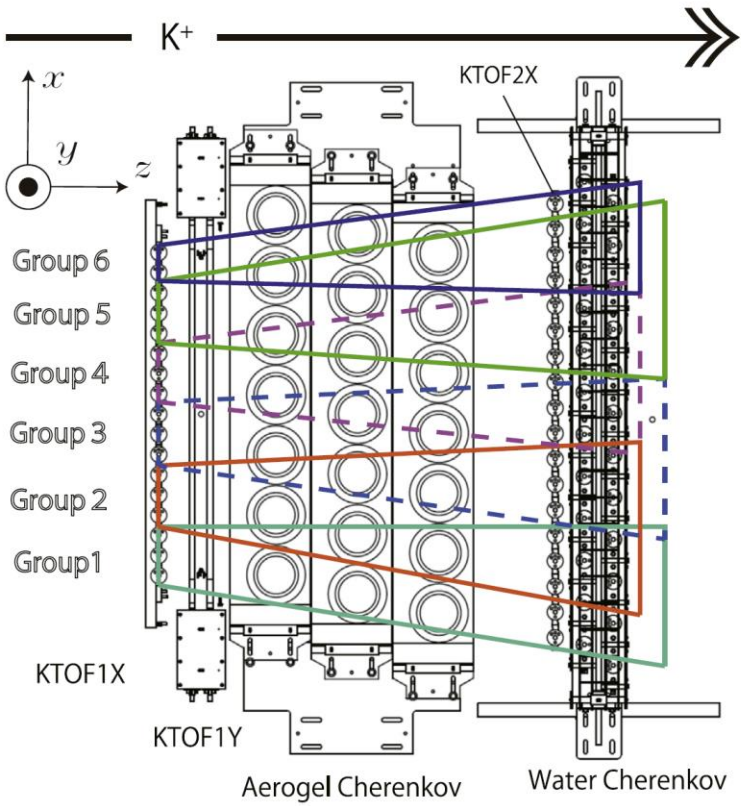
- Event size
  - 57 kB with 40 samples 100 % occupancy
- Max trigger rate : 15 KHz
- Data rate : 860 MB/s
- Tape : 12 PB

Data rates with time / integral

- Event size
  - 13 kB with time and amplitude 100 % occupancy
- Max trigger rate : 15 KHz
- Data rate : 190 MB/s
- Can be handled now
- Tape : 2.6 PB

Trigger





Can program VTP for coincidences between scintillators
If use VETROC instead of V1190 could add Drift Chamber to trigger

Additionnal electronics

- Beamline info
  - Target BPM
  - Raster
  - 1C12 BPM cabling

To do / Testing

- Bench testing and testing with detector VETROC
- Setup FADC trigger with VTP
- Setup testing in ESB

Additionnal detectors

- MCP PMTs
- MRPC
- Would need dedicated new electronics

Conclusion

- HKS and HES
  - FADC = 88 + 42 +48 +116 = 294 channels = 19 FADCs = 2 VXS crates
  - V1190 = 2268 channels = 18 V1190 = 1 VME64X crate
  - TOF = 204 channels = 7 V1290 = 8 F1 = 3 VETROC
  - Could use HMS/NPS/SBS hardware
- CODA3 with event blocking should allow 20 kHz trigger rate (200 KHz with time and amplitude)
- Digital trigger using FADC and VTP
- If use VETROC instead of V1190 can include in L1 trigger (High res TOF and Drift Chamber)

Backup

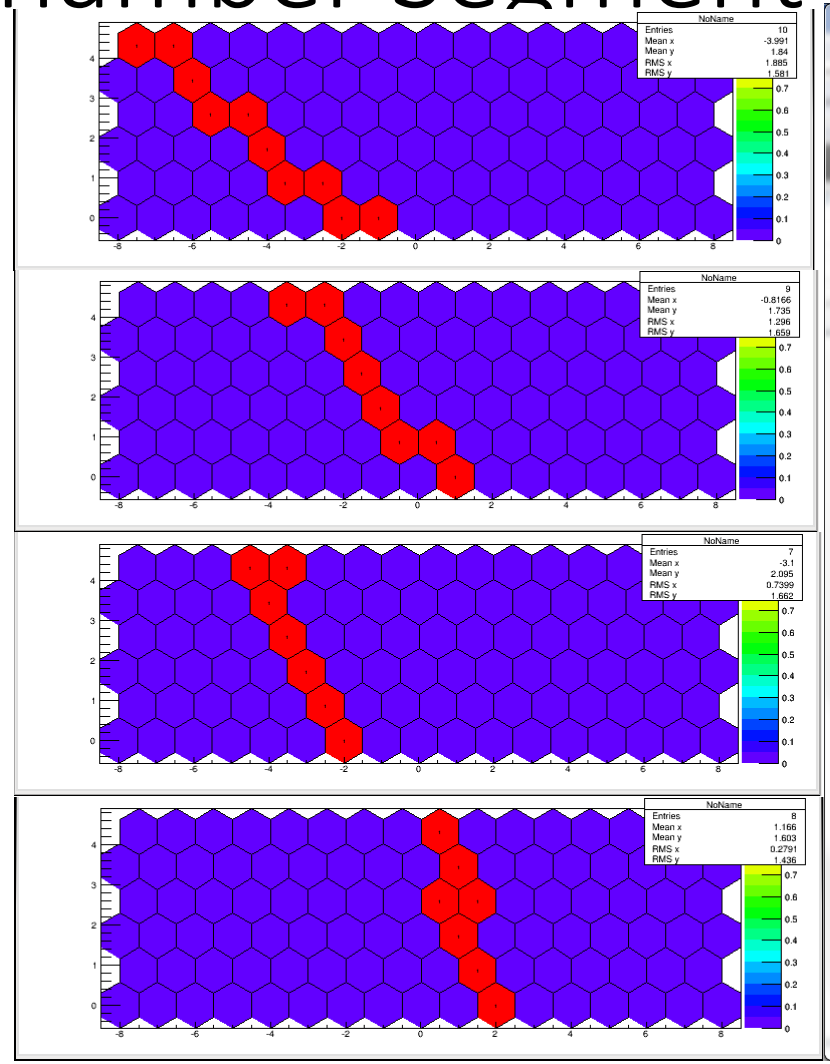
CLAS12

Detector	Can be in trigger?	Will be in trigger?	Trigger Algorithm
ECAL/PCAL	Yes	Yes	U/V/W Clustering
DC	Yes	Yes	Segment Position/Angle Finding
CTOF/FTOF	Yes	Yes	Hit based
HTCC/LTCC	Yes	Yes	Hit based
FT	Yes	Yes	3x3 Clustering
CND	Yes	No	N/A
SVT	Yes	No	N/A
RICH	Yes	No	N/A
MicroMegas	No	No	N/A

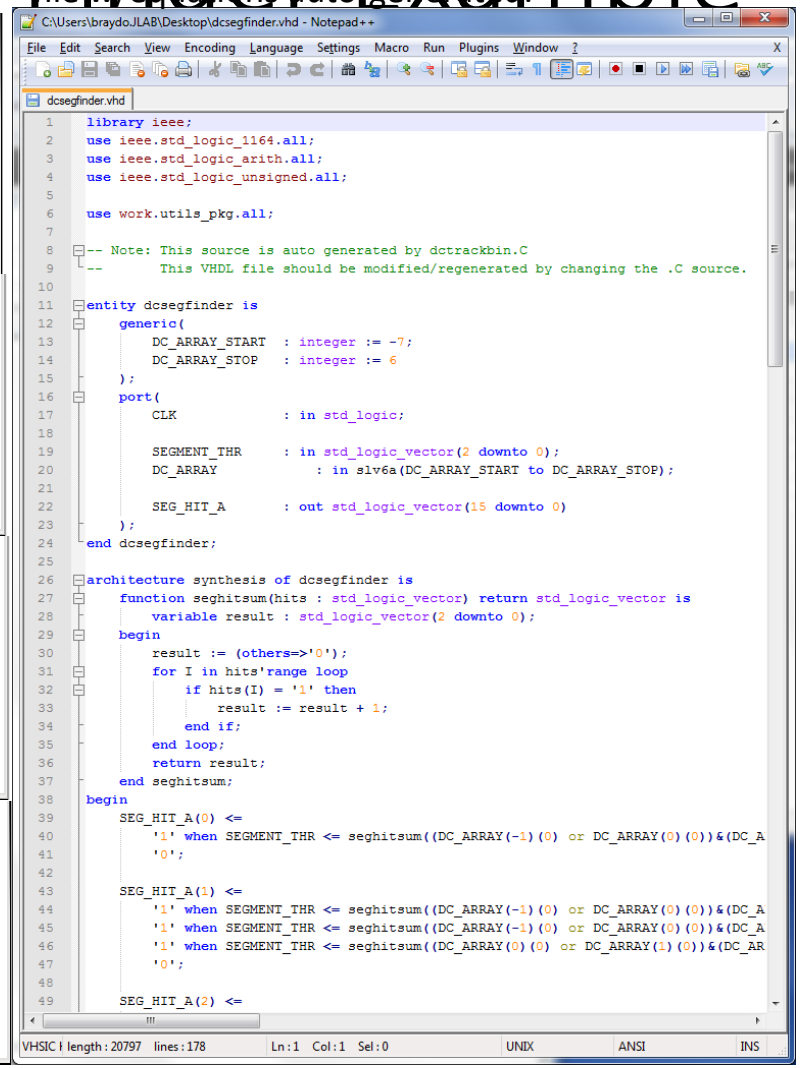
- CLAS12 triggering will support geometric matching (e.g. drift chamber segment points to clusters, etc…)

Drift Chamber Segment Finder Example

sweeps angle and wire offset:



valid segments are binned into common angle, VHDL file w/equations autogenerated:



Dri egn ndi ger

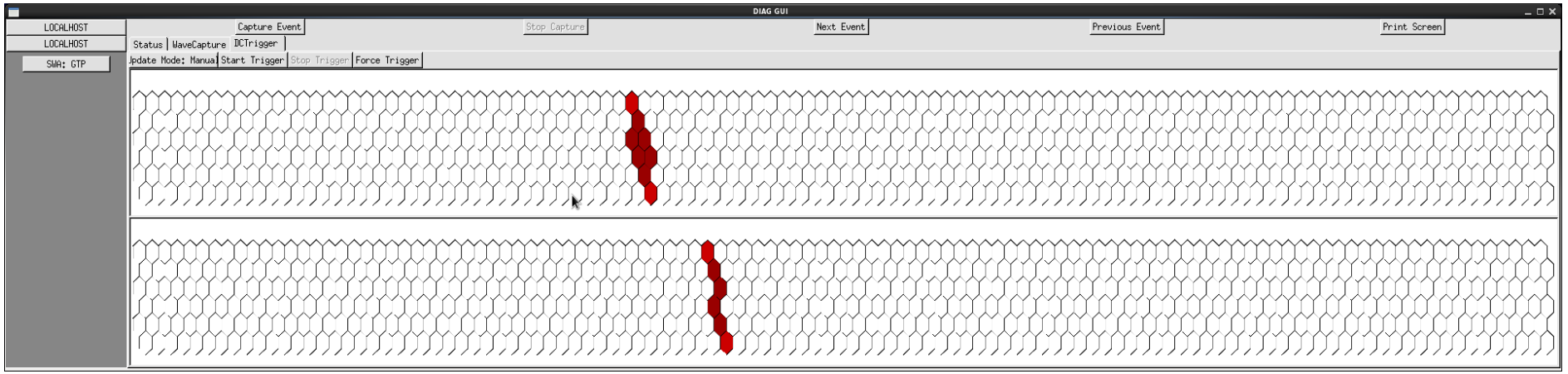
x14 DCRB

70Gbps
(DC Hits)

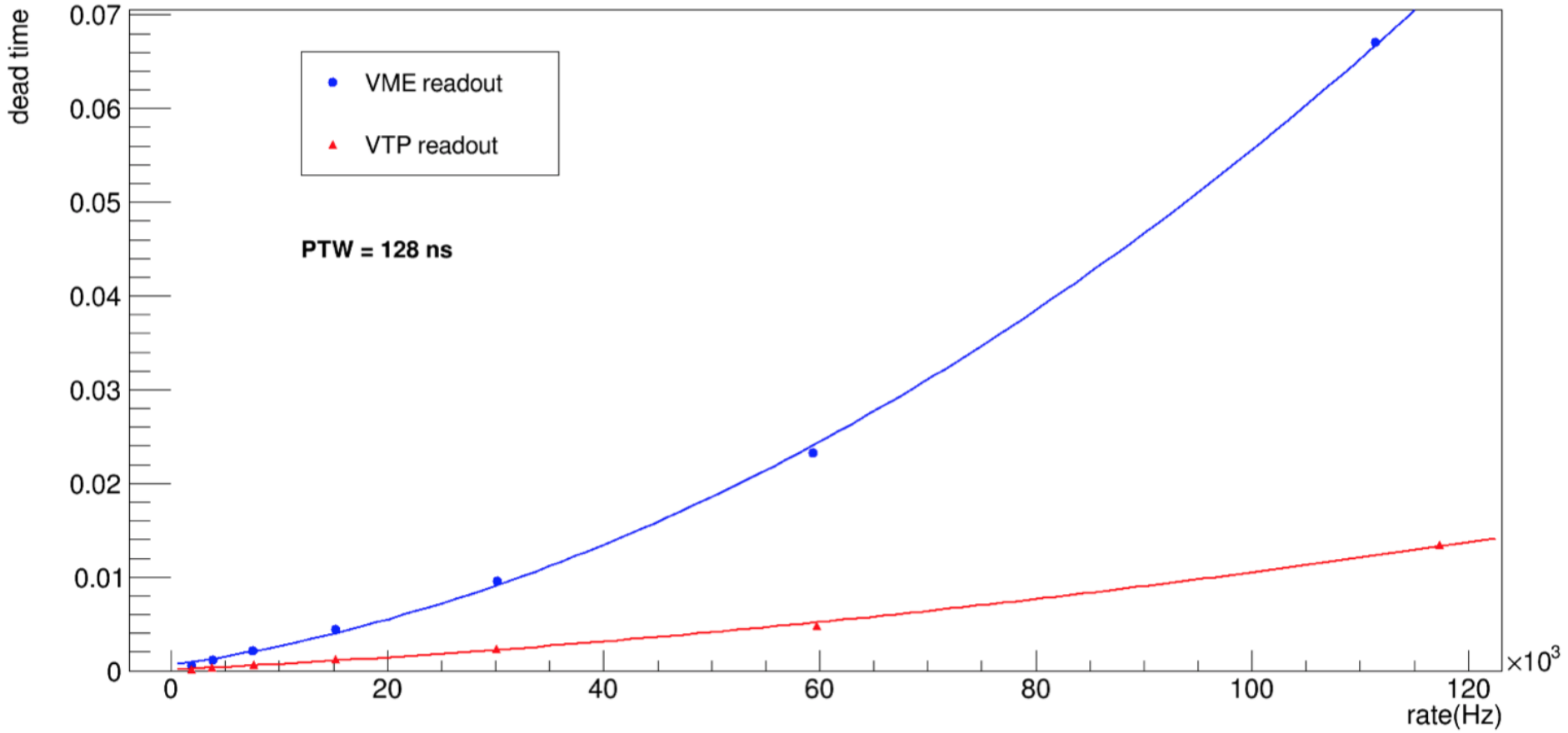
GTP:
prototype VXS
concentrator card

- Receives all DC hits from DCRB
- Searches for track segments and reports position/angle to next trigger stage
- VTP (mentioned later in talk) with be used in CLAS12

- Scope like interface on GTP allows real-time display of found segments by trigger logic
  - Cosmic event shown where only 1 segment was the trigger condition



FADC deadtime with waveforms



		ADC	TDC		Event size										
HKS															
	Drift chamber		720		2880										
	TOF counter	88	88		14432										
	Aerogel Cherenkov	42	42		6888										
	Water Cherenkov	48	48		7872										
HES	Drift Chambers		1458		5832										
	TOF counter	116	116		19024										
		294	2472		56928			853.92	MB/s max		12210372864		12.21037		12 PB
	High resolution		204												
	Low resolution		2268												
	FADC	19													
	V1190		18												
	VETROC		3												
	V1290		7												
	F1		4												

		ADC	TDC		Event size							
HKS												
	Drift chamber		720		2880							
	TOF counter	88	88		1056							
	Aerogel Cherenkov	42	42		504							
	Water Cherenkov	48	48		576							
HES	Drift Chambers		1458		5832							
	TOF counter	116	116		1392							
		294	2472		12240			183.6	MB/s max			
	High resolution		204									
	Low resolution		2268					2625333120	MB		2.625333	PB
	FADC	19										
	V1190		18									
	VETROC		3									
	V1290		7									
	F1		4									