SoLID DAQ for Transversity and PVDIS

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SoLID Dry Run

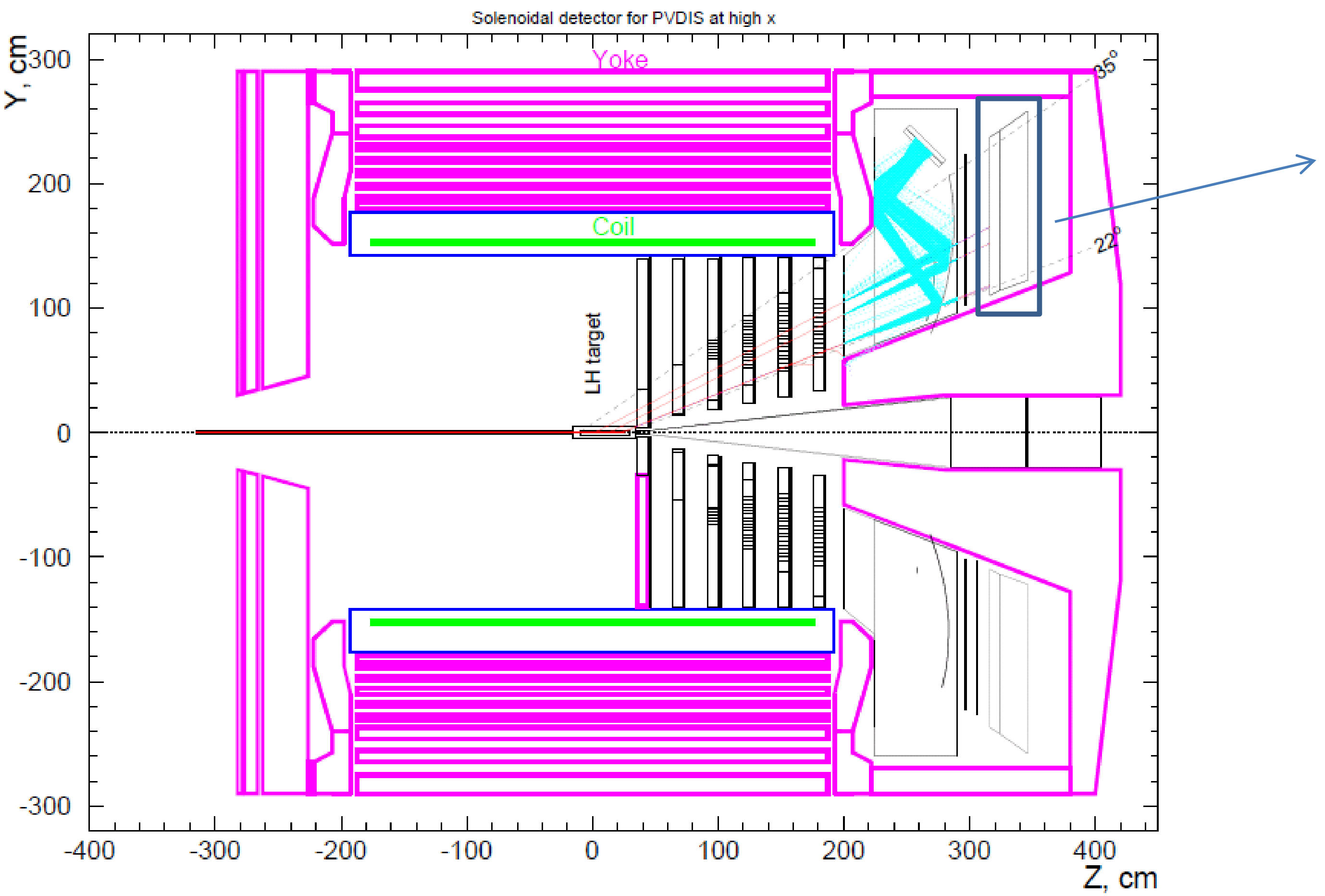
June 13th 2012

Overview

- Requirements overview
- Hall D electronics
- GEM
- Electronics layout
- Budget
- Test stands and timeline
- Conclusions

REQUIREMENTS FOR SOLID DAQ

Detector layout and trigger for PVDIS



Trigger

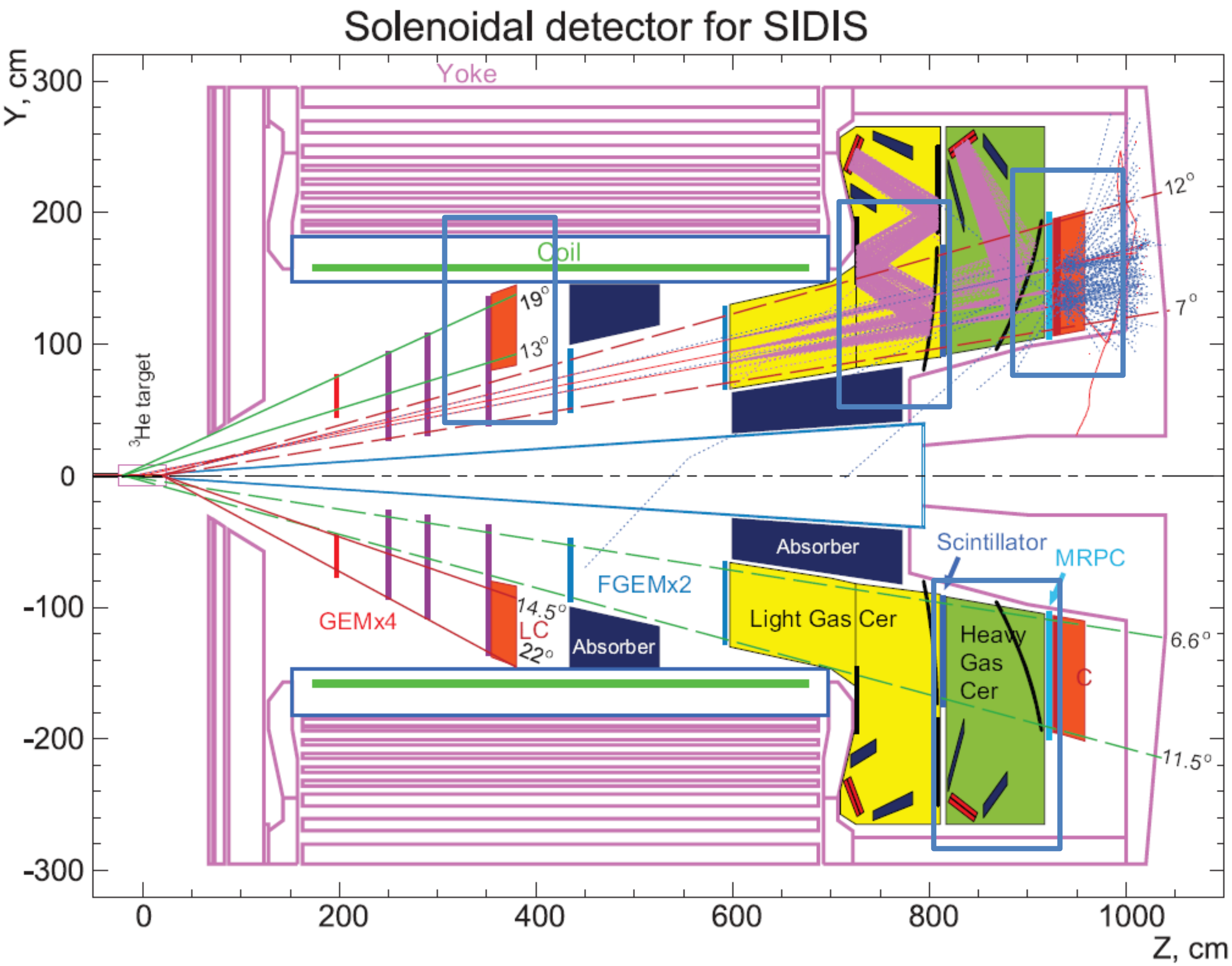
Calorimeter

200 to 500 KHz of electrons

30 individual sectors
to reduce rate

Max 17 KHz/sector

Detector layout and trigger for SIDIS



Trigger

Calorimeter

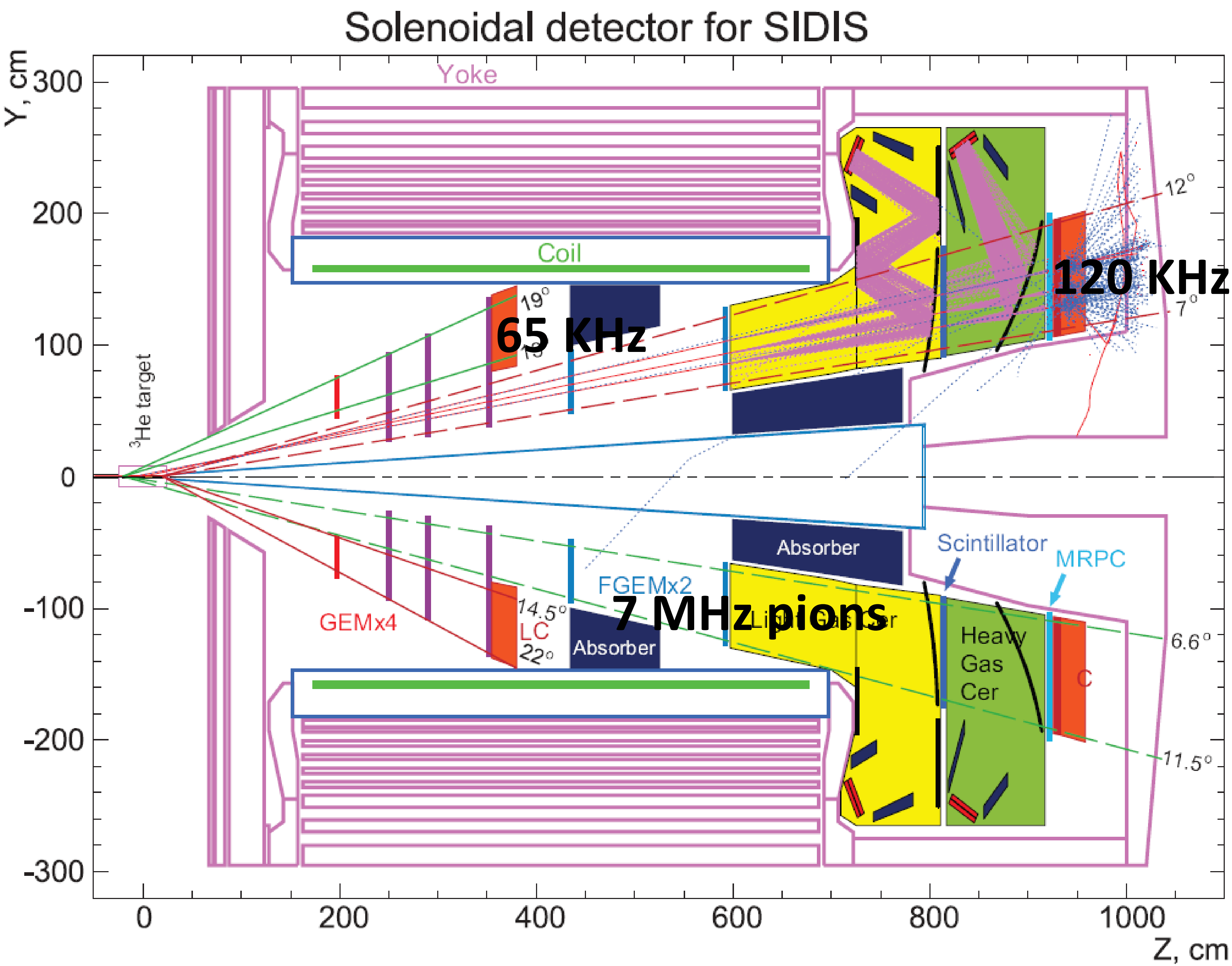
+

Cerenkov

+

MRPC

Max rate 200 KHz
With tuning of threshold and coincidence
50 KHz


Solenoidal detector for SIDIS
Yoke
Coil
Y, cm
Z, cm
300
200
100
0
-100
-200
-300
0
200
400
600
800
1000
³He target
19°
14.5°
22°
12°
7°
6.6°
11.5°
GEMx4
LC
FGEMx2
Absorber
Absorber
Scintillator
MRPC
Heavy
Gas
Cer
C
65 KHz
120 KHz
7 MHz pions

SIDIS rates Summary

	Rates @ 11 GeV
Large Angle > 3.0 GeV	44 kHz
Large Angle with GEM Pad	13 kHz
Forward Angle:	125 kHz
Forward Angle @ 2 GeV	64 kHz
Forward Angle with P.D.S. Cut	77 kHz
Forward Angle with P.D.S. Cut + 2.0 GeV	51 kHz

P.D.S: position dependent shower cut.

Recommendation I: GEM Pad R&D is important to DAQ

Recommendation II: 2 GeV cutoff or P.D.S. would reduce single rate by ½. Both can work for us

Recommendation III: Coincidence trigger would improve by a 70% at full luminosity. (More effective, if one has to reduce current.)

SIDIS: Hadron trigger

- Calorimeter + MRPC + Scintillator
- Hadron rate : 7.7 MHz
  - Charged hadron: 6.1 MHz (dominated)
  - Electron: 0.1 MHz
  - Photon: 1.5 MHz (after MRPC and Scintillator)
- Dominated by inclusive hadrons

SoLID SIDIS Detector Rates

Detector	Rate	Hits	Type	Data Size per hit
GEM	4.4 GHz	220	Hits (time)	4 Byte x 2 (X/Y)
LC	120 kHz	1	Energy, Hits	8 Byte x 2 (PS/SH)
FC	200 MHz	10	Energy, Hits	8 Byte x 2 (PS/SH)
LGC	40 MHz	3	Energy, Hits	8 Byte x 2 (split)
HGC	60 MHz	4	Energy, Hits	8 Byte x 2 (split)
MRPC	850 MHz	45	Hits	4 Byte
SC	300 MHz	15	Energy, Hits	8 Byte
Total				2.5 kB

With header and other over head
event size is ~ **4 kB**

SIDIS: Coincidence @ 35 ns window

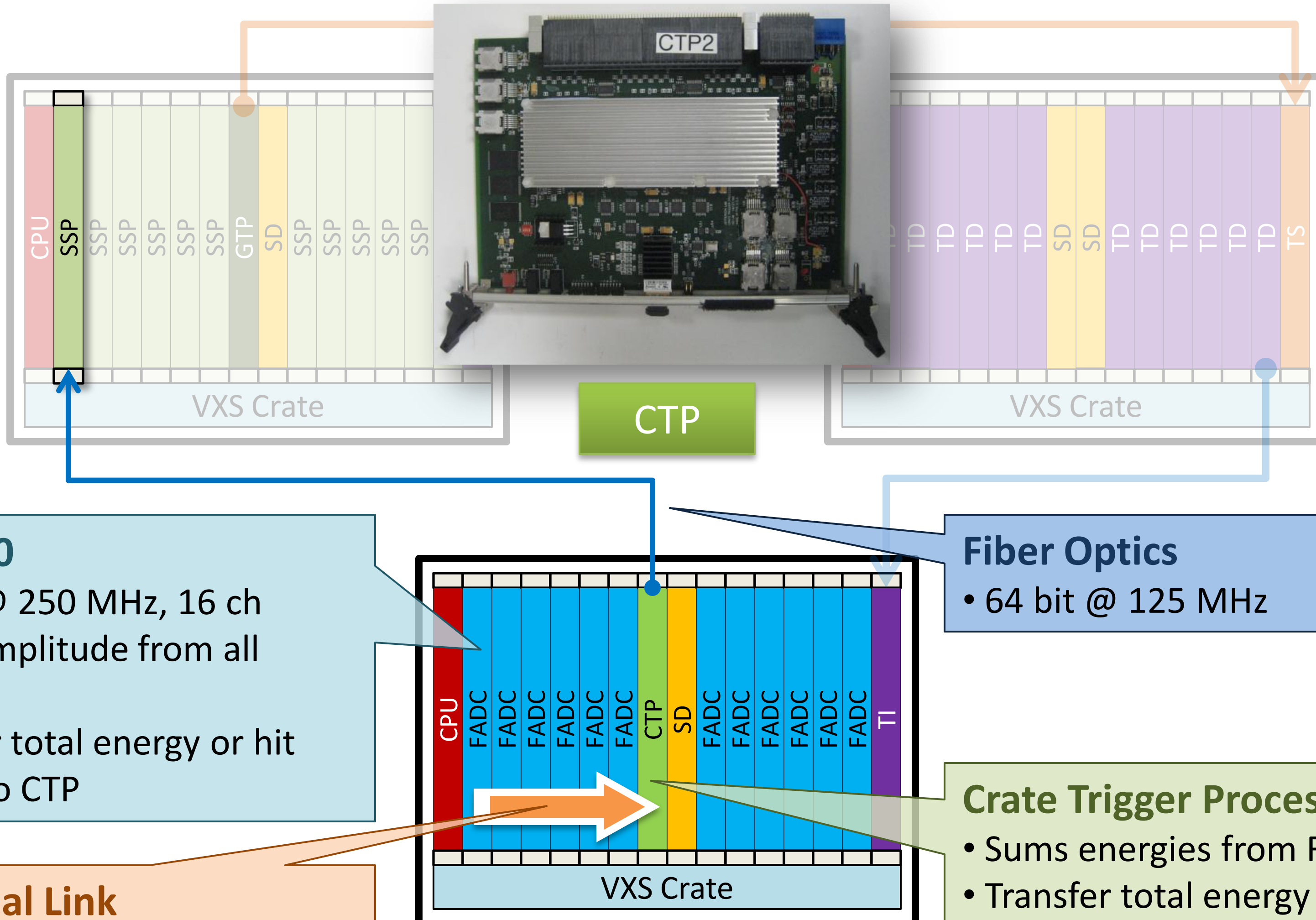
- Coincidence rate: 7.7MHz x 200KHz x 35 ns = 54 kHz
- Given the safety margin, expected to handle about 100 kHz.
  - Include some single trigger to study detector performance etc.
- 4kB * 100 kHz ~ 400 MB/s to disk
  - Goal to reduce things to 50 MB/s by L3 farm

Requirements

- High rates and no dead time
  - Up to 100 KHz
- Coincidence between detectors
  - PID
  - Local thresholds
- Need to reduce event size to put on tape

Hall D pipeline electronics with CODA 3

L1 Trigger Diagram



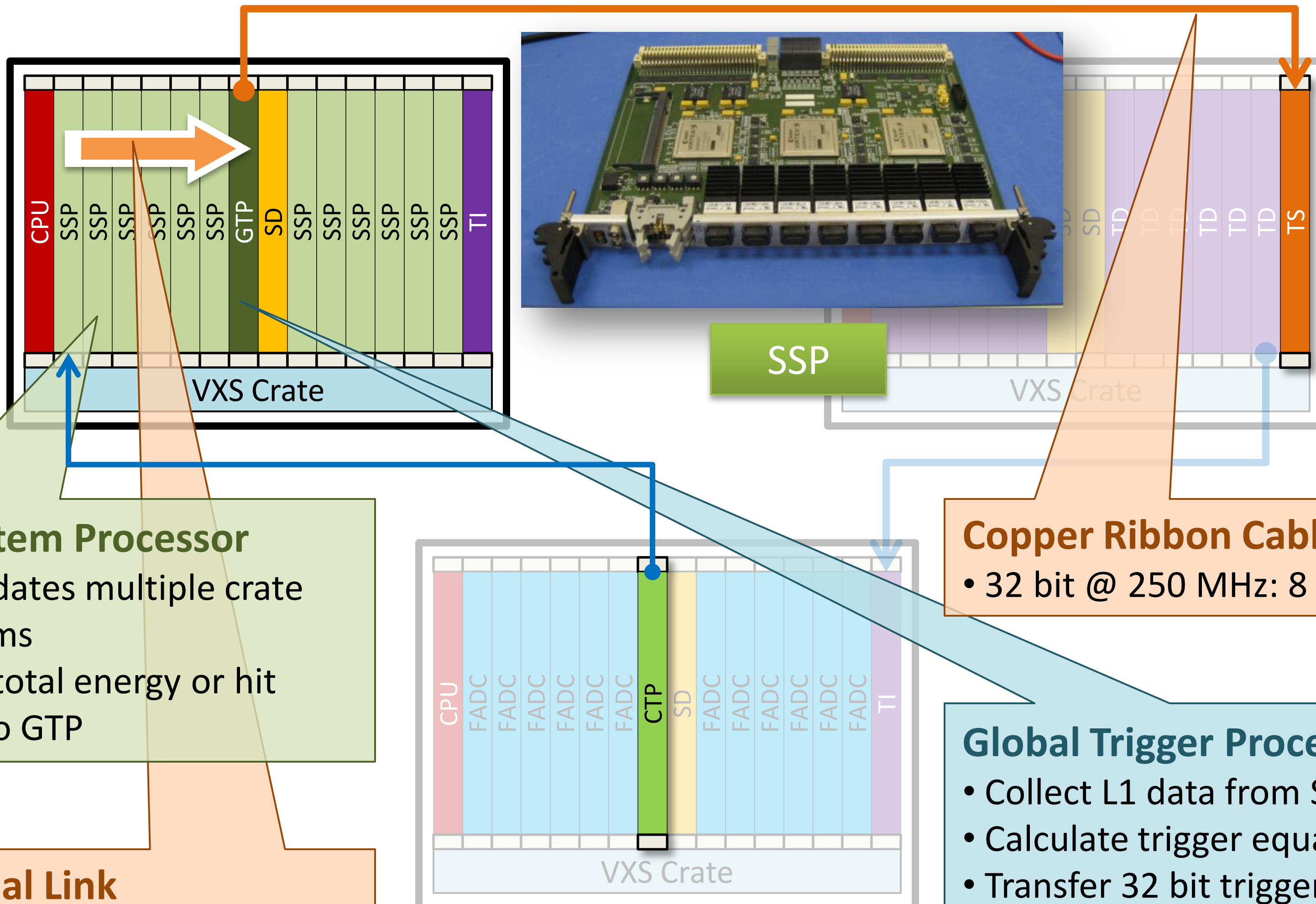
FADC250
- 12 bit @ 250 MHz, 16 ch
- Sums amplitude from all channels
- Transfer total energy or hit pattern to CTP

Fiber Optics
- 64 bit @ 125 MHz

VXS Serial Link
- 16 bit @ 250 MHz: 4 Gbps

Crate Trigger Processor
- Sums energies from FADCs
- Transfer total energy or hit pattern to SSP

L1 Trigger Diagram



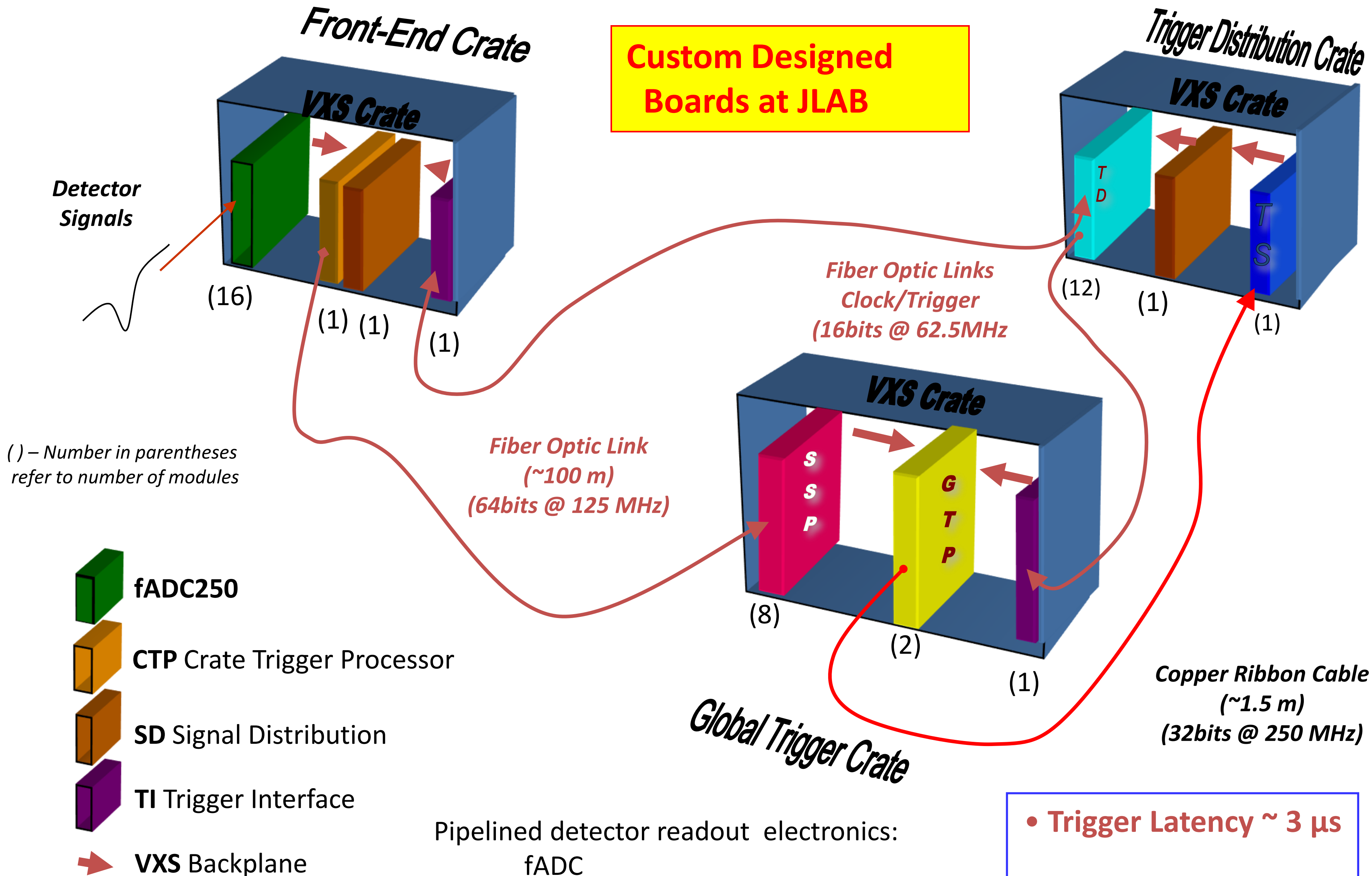
Sub-System Processor
- Consolidates multiple crate subsystems
- Report total energy or hit pattern to GTP

VXS Serial Link
- 32 bit @ 250 MHz: 8 Gbps

Copper Ribbon Cable
- 32 bit @ 250 MHz: 8 Gbps

Global Trigger Processor
- Collect L1 data from SSPs
- Calculate trigger equations
- Transfer 32 bit trigger pattern to TS

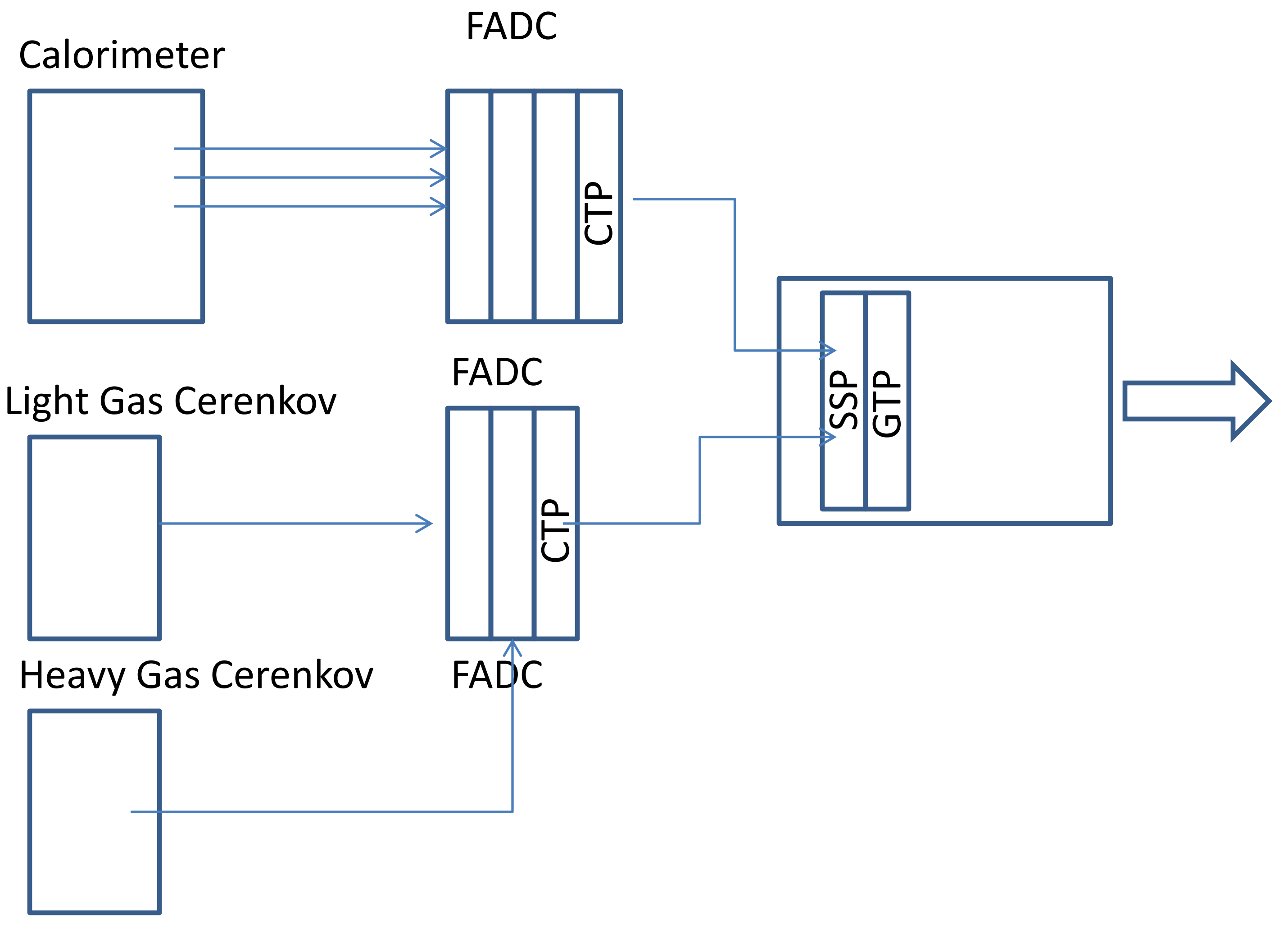
Level-1 Trigger Electronics



Pipelined detector readout electronics:
fADC

- Trigger Latency ~ 3 μs

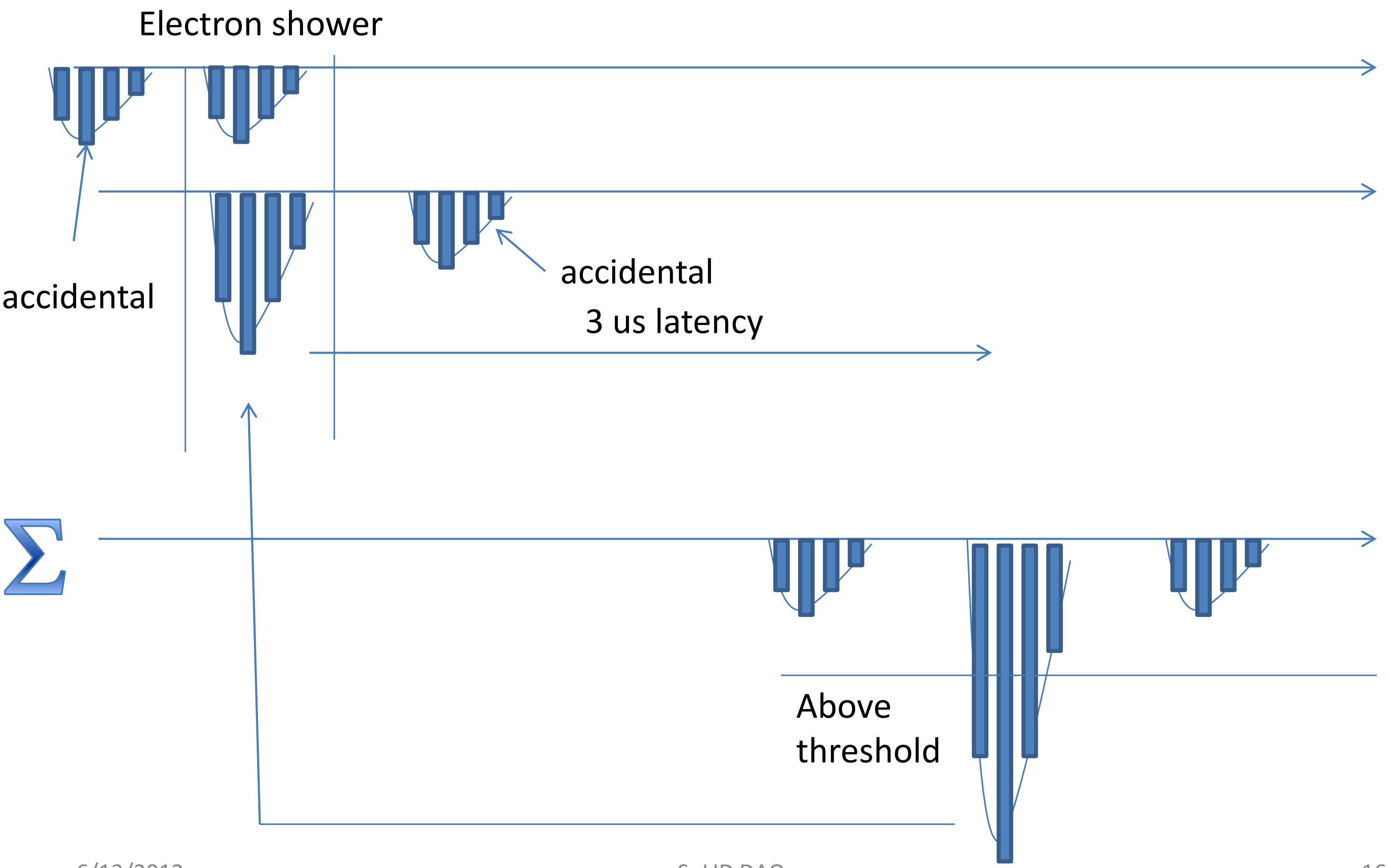
Pipelined Hall D DAQ



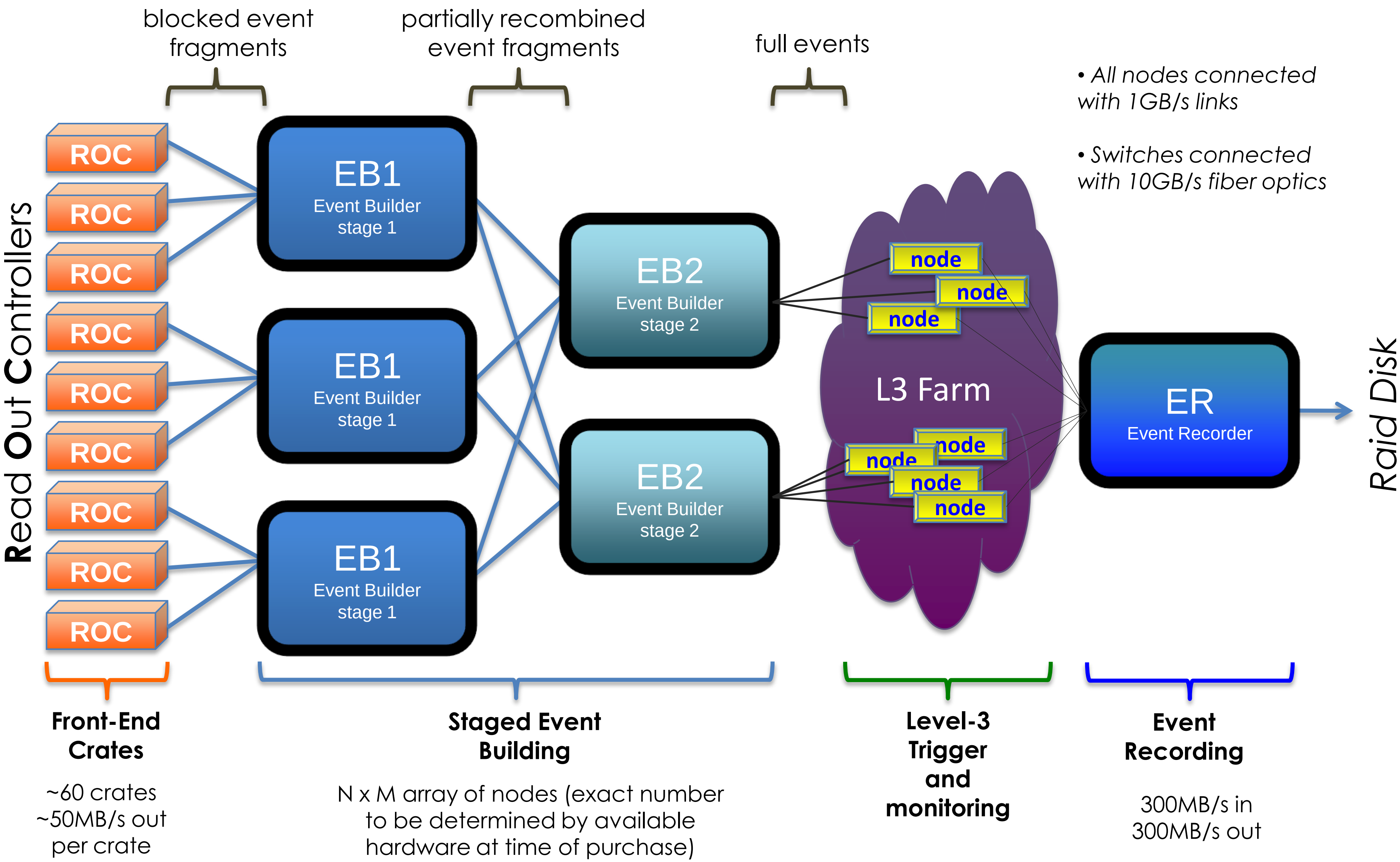
L1 trigger

Calorimeter
+
Cerenkov
+
Pion
In
3 us

Pipelined Hall D DAQ



L3 Farm



blocked event fragments
partially recombined event fragments
full events
• All nodes connected with 1GB/s links
• Switches connected with 10GB/s fiber optics
Read Out Controllers
ROC
ROC
ROC
ROC
ROC
ROC
ROC
ROC
ROC
EB1
Event Builder stage 1
EB1
Event Builder stage 1
EB1
Event Builder stage 1
EB2
Event Builder stage 2
EB2
Event Builder stage 2
node
node
node
L3 Farm
node
node
node
node
ER
Event Recorder
Raid Disk
Front-End Crates
~60 crates
~50MB/s out per crate
Staged Event Building
N x M array of nodes (exact number to be determined by available hardware at time of purchase)
Level-3 Trigger and monitoring
Event Recording
300MB/s in
300MB/s out

GEM READOUT

GEM readout

- APV25 + VME module based
- Up to 164 000 channels
- APV 25 : 128 channels
- Readout
  - VME based readout : 8 APV25 = 2048 channels
  - SRS readout : ethernet /PC based = 2048 channels
- 1 crate per sectors for FADC and GEM

Other GEM readout chips

- APV25 limiting factor
    - Need to evaluate
    - Optimize

- Chip in development

    - CLAS12 Dream CEA/Saclay
    - ATLAS VMM1 BNL
    - ….

- SRS readout compatible with other chips
    - Ethernet + PC based

APV25 readout

- Buffer length 192 samples : 4.8 us Look back 160 samples : 4 us

- Estimated occupancy : 220 hits per trigger, X Y data strips

GEM : 6 Layers 164 000 channels total, 28 000 channels planes

Occupancy : 1.6 %

- APV readout time :

t_APV = 141 x number_of_sample / 40 MHz

t_APV(1 sample) = 3.7 us.

Max rate APV front end :

270 KHz in 1 sample mode

90 KHz in 3 samples mode

Will be triggered by coincidence trigger around 50 KHz

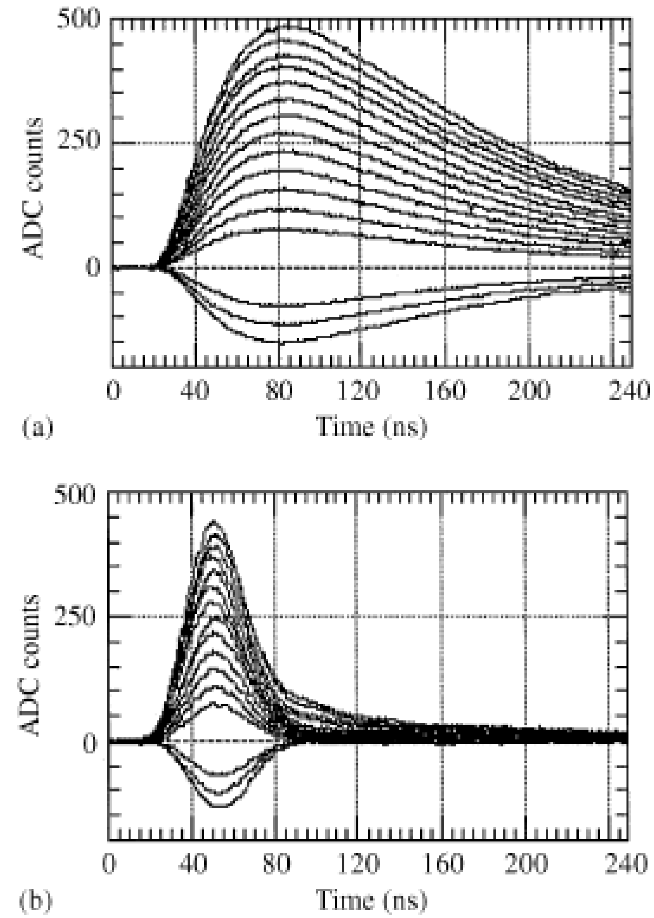
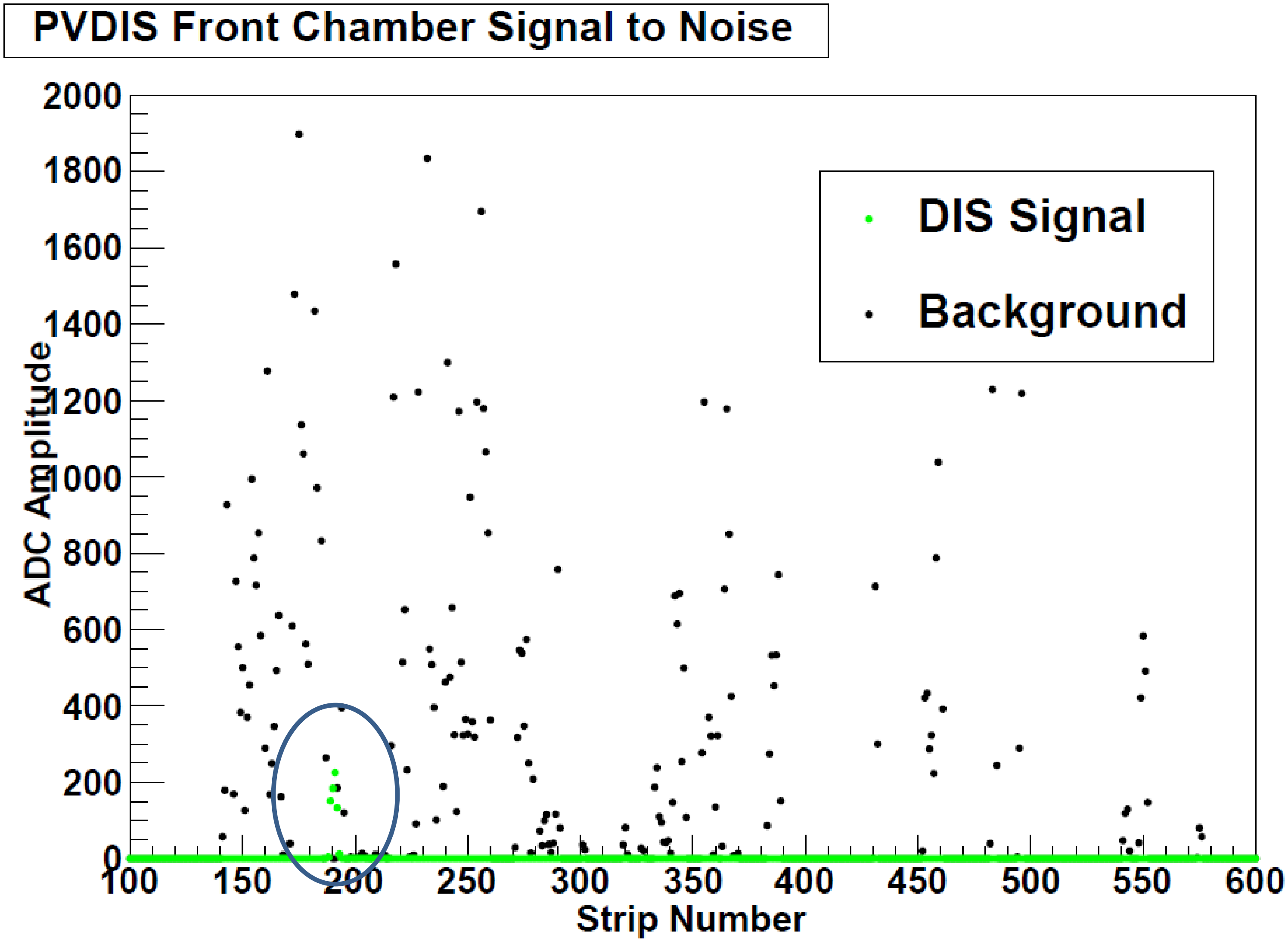
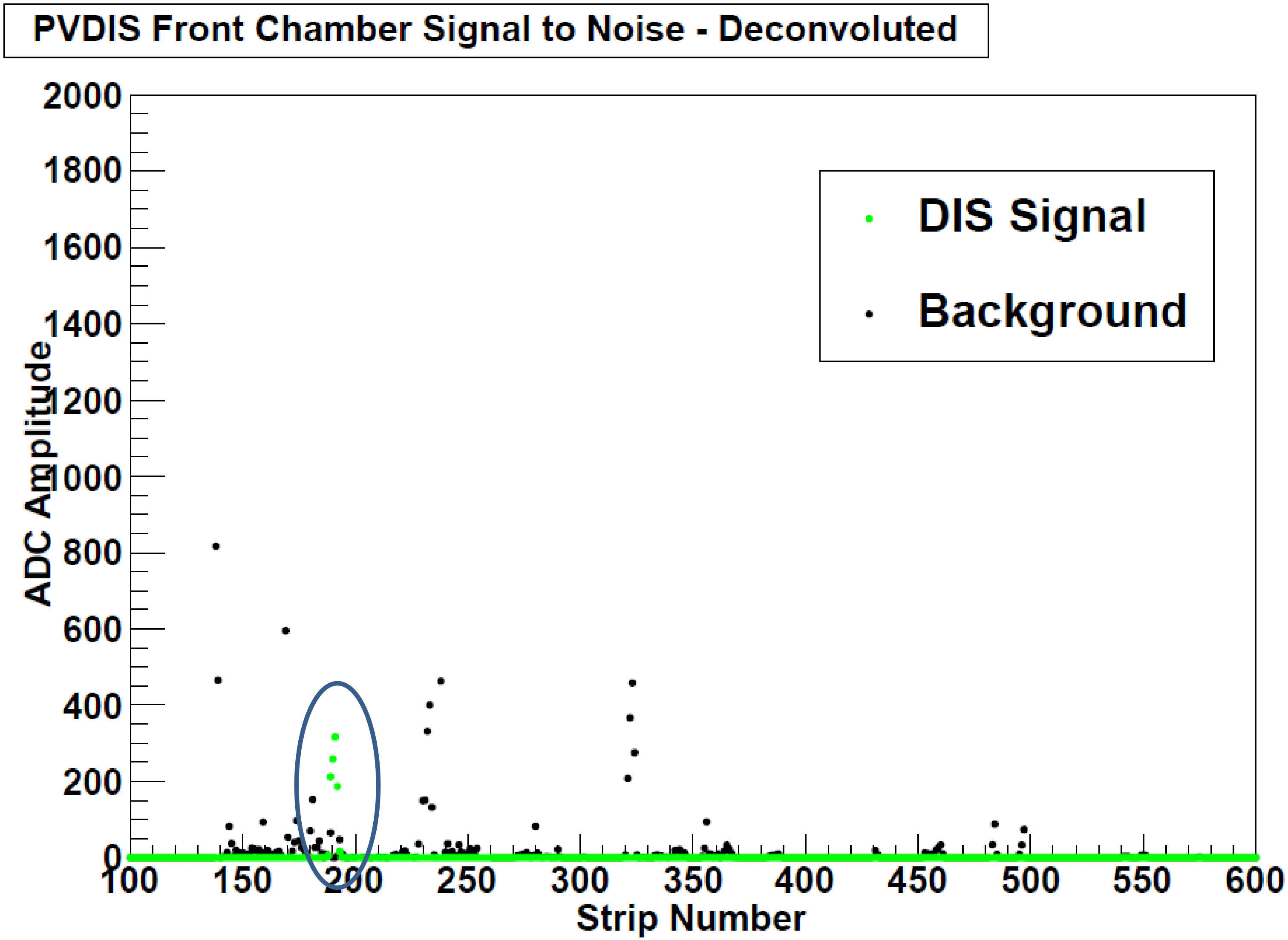


Fig. 5. Response curve of the APV25 as a function of the input signal. (a) Peak mode, (b) deconvolution mode.

Chamber occupancy



Chamber occupancy using APV25 deconvolution



GEM in trigger

- Use signal of last GEM plane HV for fast trigger
  - Large angle trackers
  - GEM based Cerenkov
- Quality of signal to be tested (signal / background)
- Could reduce rate in Large Angle from photon calorimeter by 50 KHz
- Additional FADC or discriminator channels to put in trigger

Chamber occupancy

- About 20 hits per planes
- 6 planes
- Use Shower information
- 3 samples would be useful, but 1 sample with seem sufficient
- See tracking talk (Ole Hansen), simulation talk (Seamus Riordan)
- All software ready : final results within a month

ELECTRONICS LAYOUT AND BUDGET

SIDIS channel count

Detector	Module type	Number of channels	Number of FADC
Forward Calorimeter	FADC	1896	119
Large angle calorimeter	FADC(+TDC)	920	58
Light Gas Cerenkov	FADC	120	8
Heavy Gas Cerenkov	FADC	270	17
Scintillator	FADC	120	8
MRPC	Custom TDC	2550	

The FADC of LC can be programmed to produce timing signals with ~400ps resolution (already demonstrated by simulation) to remove the needs of TDC.

DAQ/Trigger for SoLID SIDIS

Trigger Crate				
CPU	SSP x3: LC x1 + FC x2	GTP	TS	TD X4+1

LC Trigger Crate x4				
CPU	FADC x15	CTP	SD	TI

FC/GC/HG/SC/MRPC Crate x15					
CPU	FADC X10: GC x8 + GC/HG/SC x2	MRPC ?	CTP	SD	TI

GEM Tracker Crate x11			
CPU	APV25 X 16	SD	TI

+ ?

LC Discriminator VME64X Crate x3	
CPU	DIS x20

LC Timing Crate x1			
CPU	V1190 x15	SD	TI

Total Crate + CPU: 31+4

FADC: 210	TI: 30+1
DIS: 0+60	SSP: 3
F1TDC: 0+30	GTP: 1
CTP: 19	TS: 1
SD: 30+1	TD: 4+1

SIDIS electronics

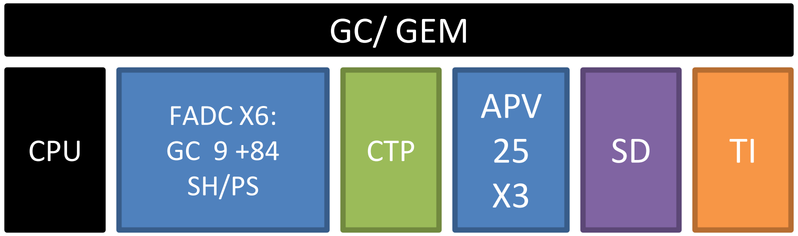
Module	Unite price	Quantity	
FADC 250	4500	210	$945,000
CTP	5000	19	$95,000
SSP	5000	3	$15,000
GTP	5000	1	$5,000
VXS crate	11500	1	$11,500
TS	3500	1	$3,500
TI	3000	30	$90,000
TD	3000	4	$12,000
SD	2500	30	$75,000
VXS crate	11500	30	$345,000
VME CPU	3400	31	$105,400
L3 farm node	5000	12	$60,000
		Total detectors	$1,762,400
VXS crate	11500	1	$11,500
Discriminators	2500	60	$150,000
VME64X crate	8100	3	$24,300
V1190	11010	15	$165,150
VME CPU	3400	4	$13,600
TID	3000	1	$3,000
SD	2500	1	$2,500
			$370,050
		Grand Total	$2,132,450

JLAB electronics PVDIS

Detector	Channel	Module	Unit price	Total modules	Total price sector	Total price 30 sectors
Calorimeter	84	6	4500	180	27000	810000
Cerenkov	9					
TID		1	3000	30	3000	90000
SD		1	2500	30	2500	75000
VXS		1	11500	30	23000	345000
VME CPU		1	3400	30	3400	102000
CTP		1	5000	30	5000	150000
GEM	4700	3	UVA	90	UVA/China	UVA/China
Total price					52,400$	1,572,000$

DAQ/Trigger for SoLID PVDIS

VXS crate + CPU: 30
FADC: 210 TI: 30
CTP: 30 CTP SD: 30



30 individual DAQ systems : only 20 KHz trigger rates
No major issues

SIDIS + PVDIS electronics

Module	Unite price	Quantity	
FADC 250	4500	210	$945,000
CTP	5000	30	$150,000
SSP	5000	3	$15,000
GTP	5000	1	$5,000
VXS crate	11500	1	$11,500
TS	3500	1	$3,500
TI	3000	30	$90,000
TD	3000	4	$12,000
SD	2500	30	$75,000
VXS crate	11500	30	$345,000
VME CPU	3400	31	$105,400
L3 farm node	5000	12	$60,000
		Total detectors	$1,817,400
VXS crate	11500	1	$11,500
Discriminators	2500	60	$150,000
VME64X crate	8100	3	$24,300
V1190	11010	15	$165,150
VME CPU	3400	4	$13,600
TID	3000	1	$3,000
SD	2500	1	$2,500
			$370,050
		Grand Total	$2,187,450

Other projects

- SuperBigBite
  - 242 hadron calorimeter
    - 16 FADC
- Hall A BIA
  - VDC 2944 channels
    - 24 V1190 TDC
  - 34 FADC
  - CTP, TS, TD,SD, 2 VXS crates

Production Board Quantities – per C. Cuevas

Board ID	Hall D (Spare)	Hall B (Spare)	Hall A	Hall C	'Physics' FEG DAQ	Totals $FY12	SOLID
FADC250	350 * (36)	310 ** (25)	4 50	46	16	726	210
Trigger Interface	57 (8)	64 (8)	2	2	6	131	30
Signal Distribution	57 (8)	49 (9)	2	2	2	112	30
Crate Trigger Processor	23	21	1	2	2	49	30
Sub-System Processor	8	14	1	1	1	25	3
Global Trigger Processor	2	2	1	1	1	7	1
Trigger Distribution	10	10	1	1	2	24	4
Trigger Supervisor	2	2	1	1	1	7	1

50 → Hall A DAQ upgrade (16 of which used for SBS)

Production Board Notes – per Chris Cuevas
Other 12GeV Proposed Detectors

** CLAS12 'baseline' FADC250 board count is 239

- Central Neutron Detector is 288 channels or 18 boards
- Forward Tagger (PbWO4) calorimeter is 424 channels or 28 boards
- Total on previous page is 310 boards
- So, 25 boards are spare

* Hall D 'baseline' FADC250 board count is 282

- BCAL readout Change Request adds one layer or 32 boards
- Total on previous page is 350
- So, 36 boards are spare

+ Hall C 'baseline' FADC250 board count for SHMS is 16

- HMS is 13 boards, plus 2 spares → ordered 15 spares
- User request of ~40 boards through NSF/MRI for (PbWO4) π^0 spectrometer

Note: In FY12 thirty-five (35) Pre-Production units were purchased and will most likely not be used for the final hall installations. These units are functionally equal to the production units, but need a few very minor circuit corrections.

Potentially : 25 + 36 + 15 + 50 +35 = 161 = 145 FADCs (10 % spare)

SoLID electronics

Modules	Unit price	Quantity	Price	Borrow
FADC 250	4500	66	$297000	JLAB
CTP	5000	28	$140,000	HRS
SSP	5000	2	$10,000	HRS
GTP	5000	0	$0	HRS
VXS crate	11500	0	$0	SBS
TS	3500	0	$0	HRS
TI	3000	24	$72,000	HRS
TD	3000	2	$6,000	HRS
SD	2500	24	$60,000	HRS
VXS crate	11500	24	$276,000	HRS
VME CPU	3400	19	$64,600	HRS
L3 farm node	5000	12	$60,000	
		Total	$985,600	
VXS crate	11500	0	$0	HRS
Discriminators	2500	50	$125,000	HRS
VME64X crate	8100	0	$0	HRS
V1190	11010	0	$0	HRS
VME CPU	3400	0	$0	HRS
TID	3000	0	$0	HRS
SD	2500	0	$0	HRS
		Total timing	$125,000	
				With 10 % spare
		Total detectors	$1,110,600	$1,332,720

Man power / Ressources

- JLAB
  - Alexandre Camsonne
  - Yi Qiang
- UMass
  - Rory Miskimen

Time line

- 2012
  - 5 intel VME CPU received
  - GEM + APV25 GEM tests during g2p (SRS data taken , CODA with INFN MPD , CODA with SRS in progress, FPGA data processing)
  - FADC tests PEPPO experiment
  - HCAL Trigger development (SBS funding accepted)
  - UMASS Hall D test stand (380 FADC to be tested)
  - 4 JLAB FADC250
- 2013
  - Small scale setup for testing : FADC + trigger + fastbus + APV25 + L3 farm
- 2014
  - A1n :
    - Full scale test of GEM
    - Digital Trigger electronics test parasitic
  - DVCS : test intel VME CPU for large amount of data
- 2015
  - Full scale system

Conclusion

- SoLID requires high rate low dead time, flexible trigger capability
- Rates optimization for SIDIS but push for highest rate depending of GEM chip performances
- Hall D electronics perfectly suited
  - Total cost around 2.5 M$
  - shared resources between experiments can save significant amount of money reduce to 1 M$
- GEM electronics R&D
- PVDIS has no major issue, SIDIS limited by GEM readout but could work with APV25 with no major loss
- On going testing

Backup slides

Production Board Notes – per Chris Cuevas
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SIDIS: Singles Electron Trigger

- Large Angle: 65 kHz @ 11 GeV
  - Calorimeter only
  - Electron: 11 kHz
  - High energy photon: 51.5 kHz
    - (possible to be rejected by including GEM in trigger, need study)
  - Hadron: <3 kHz (energy cut)
- Small angle: 120 kHz @ 11 GeV
  - Calorimeter + Gas Cherenkov
  - Electron: 90 kHz
  - High energy photon: 16 kHz (after Gas Cherenkov)
  - Hadron: 15 kHz (after Gas Cherenkov and Calorimeter)
- 8.8 GeV gives about 240 kHz

DAQ electronics projects at UMass: spring and summer 2012
R.Miskimen

- UMass is responsible for the final assembly and testing of all *380 FADC modules* for Hall D. This activity will take place at UMass summer 2012, probably stretching into the fall.

- An undergraduate, Fabien Ahmed, spent the summer of 2011 at JLab working with the electronics group on FADC tests. A graduate student, Bill Barnes, and team of undergraduates will work on the electronics tests at UMass.

- Operations at UMass will include mechanical assembly of the VME boards, programming the FPGA's, verifying board operation, measuring and recording noise levels.

- Readout through a Wiener USB board in the VXS crate, connected to PC

DAQ electronics projects at UMass: connection to SOLID

• This activity helps Hall D, only helps SOLID by building expertise in the collaboration for working with and debugging DAQ electronics

• With support from Hall A, we would develop a CODA based DAQ test station at UMass: <u>replicate the one VXS crate/sector readout for PVDIS/SOLID</u>

Need CODA, and to borrow CTP, SSP, and CPU

Test DAQ rates, triggers, software for FADC

Hall A HRS DAQ Test stand

- Injector Compton
  - 2 FADC and SD boards
- Ordered parts
  - 2 VXS crates
  - 4 FADC
  - 2 TI, SD, TD

  - CODA3 still in the work (maybe out at end of February) : test L3 Farm

L1 Trigger

- Electron Singles Trigger:
  - LC > 400 MeV || (FC > 400 MeV && LGC)

$$T_L^e|_{11(8.8)GeV} = Y_L^e + Y_L^\gamma + \frac{Y_L^h}{R_{LC}} = 11 + 52 + \frac{56}{20} = 66(55)kHz$$

$$T_F^e|_{11(8.8)GeV} = Y_F^e + \frac{Y_F^\gamma}{R_{LGC}} + \frac{Y_F^h}{R_{LGC} \cdot R_{FC}} = 89 + \frac{620}{40} + \frac{6100}{40 \cdot 10} = 120(180)kHz$$

  - Total event rate: 190 - 240 kHz
  - Frontend data rate: 800 – 1000 MB/s
  - ROCs can barely handle this rate
    - Assuming 10 VME crates, 100 MB/s per ROC
    - add more crates since PVDIS uses > 30
  - Maybe a little bit too much to write to the tape
  - Not much room for improvement, already very close to electron yield.

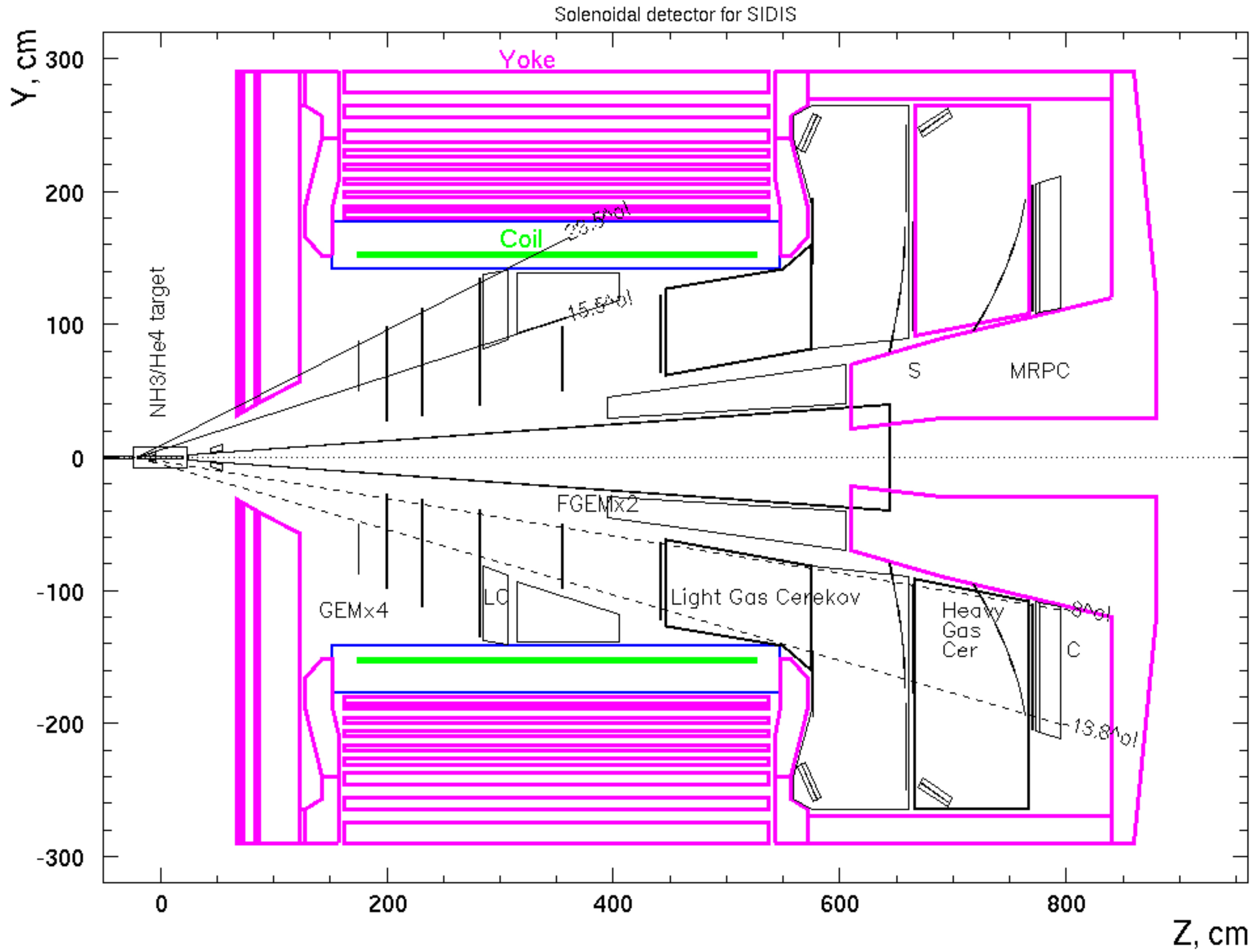
Reduce L1 Trigger: Two Options

- Make coincidence with another charged particle in Forward detector
  - FC > 200 MeV && MRPC && Scintillator

$$T_F^h|_{11(8.8)GeV} = Y_F^h + Y_F^e + \frac{Y_F^{\gamma all}}{R_{MRPC} \cdot R_S} = 6 + 0.1 + \frac{200}{20 \cdot 6.5} = 7.7(6.9)MHz$$

  - Coincidence rate with 35 ns window ~ 50 kHz
- Use L3 farm
  - With powerful parallelism computing, we can easily reduce the rate by a factor of 5
  - Reduce the difficulty to put MRPC (customized VME board) into the trigger logic
- Both options give 200 MB/s data rate to the tape

BABAR Setup With Collimator



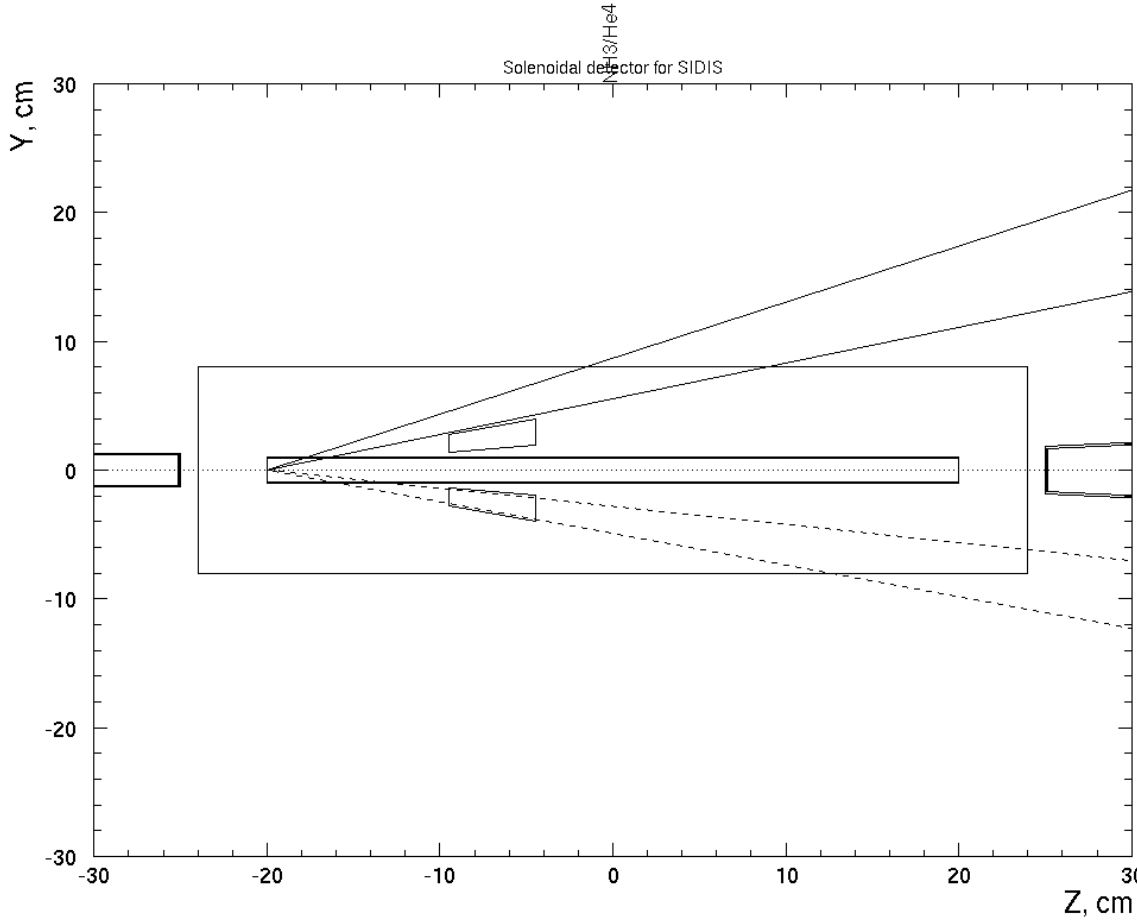
Note the opening angle of front yoke is determined by target, It is OK to cut some large angle acceptance. PAC34 proposal.

SIDIS rates

Process	Rate Forward angle 11 GeV	Rate Large angle 11 GeV	Rate Forward angle 8.8 GeV	Rate Large angle 8.8 GeV
(e,eπ^+)	1467 Hz	192 Hz	810 Hz	117 Hz
(e,eπ^-)	1010 Hz	120 Hz	554 Hz	73 Hz
single e^-	88.5 kHz	11.0 kHz	151 kHz	16.5 kHz
high energy photon	623 kHz	51.5 kHz	596 kHz	37 kHz
single π^+	2.90 MHz	20.2 kHz	2.5 MHz	13.4 kHz
single π^-	1.77 MHz	14.5 kHz	1.47 MHz	9.2 kHz
single K^+	226 kHz	5.9 kHz	185 kHz	4.1 kHz
single K^-	54.6 kHz	1.2 kHz	39.9 kHz	0.6 kHz
single proton	1.15 MHz	13.8 kHz	0.99 MHz	9.4 kHz
low energy photon	200 MHz	-	200 MHz	-

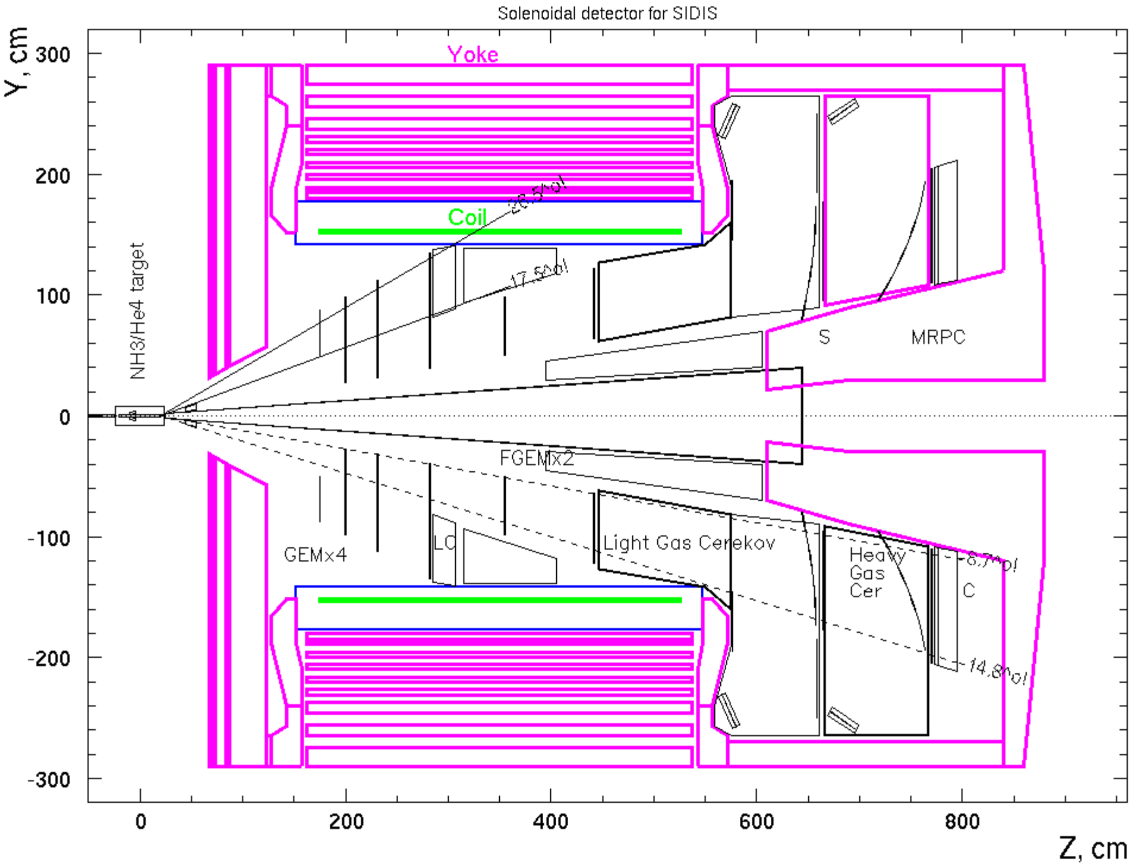
Table 3: Total coincidence rate and single rates for both positive/negative charged particles and low/high energy photons with 11 and 8.8 GeV beam. The high energy photon cutoffs are 0.9 (3.5) GeV at forward (large) angle. The low energy photon cutoff is 200 MeV.

Zoom in for collimator part

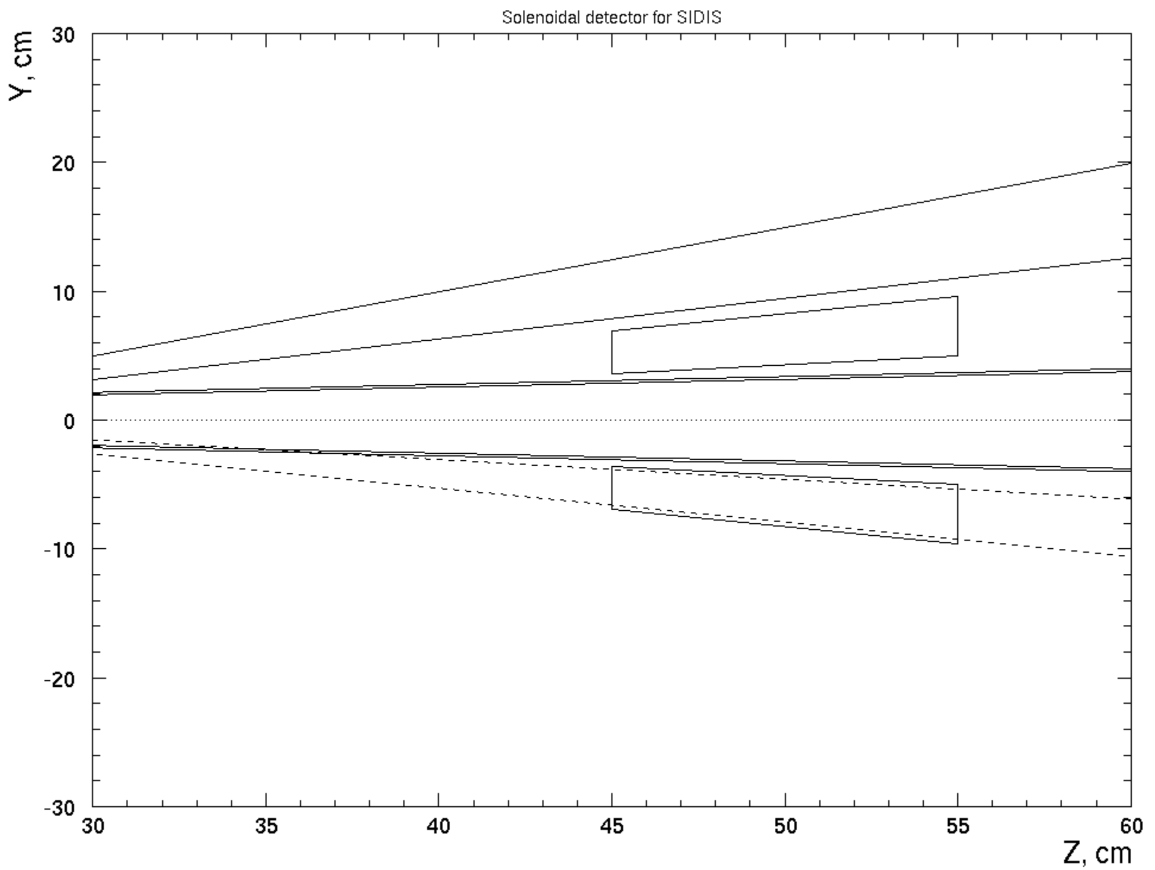


Block the forward angle, since it is limited our rates and background.

Down stream part



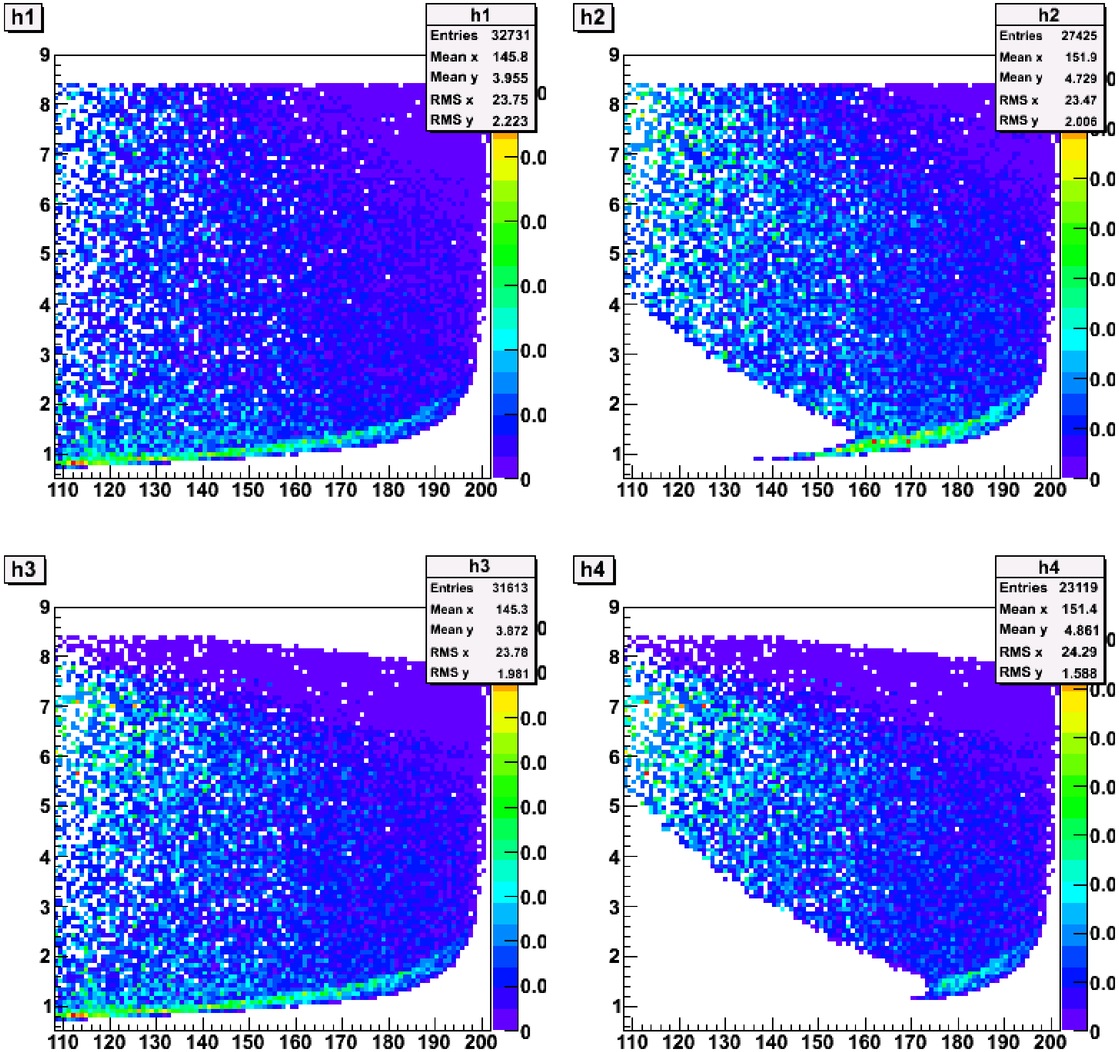
Downstream with collimator



Calculate Single Rate

- Electron:
  - Conditions:
    - Turn off most physics processes
    - Black hole treatment for collimator and magnets etc.
  - Rate calculation: QFS/whitlow
  - Each target wall is assume to be the same thickness as 3He gas.
  - Results:
    - Forward angle @ 11 GeV: 55 kHz
    - Large angle @ 11 GeV: 13.0 kHz with 3.0 GeV cutoff
    - Forward angle @ 8.8 GeV: 91 kHz
    - Large angle @ 8.8 GeV: 14.3 kHz with 3.0 GeV cutoff

Look the hit position in forward angle



X: position in forward angle calorimeter
Y: momentum

Top two: 11 GeV
Bottom two : 8.8 GeV
Left panels: no cut on Q2
Right panels: Q2 > 0.9

Rates:
11 GeV: 55 kHz
11 GeV with Cut: 41 kHz
Large Angle: 13.0 kHz

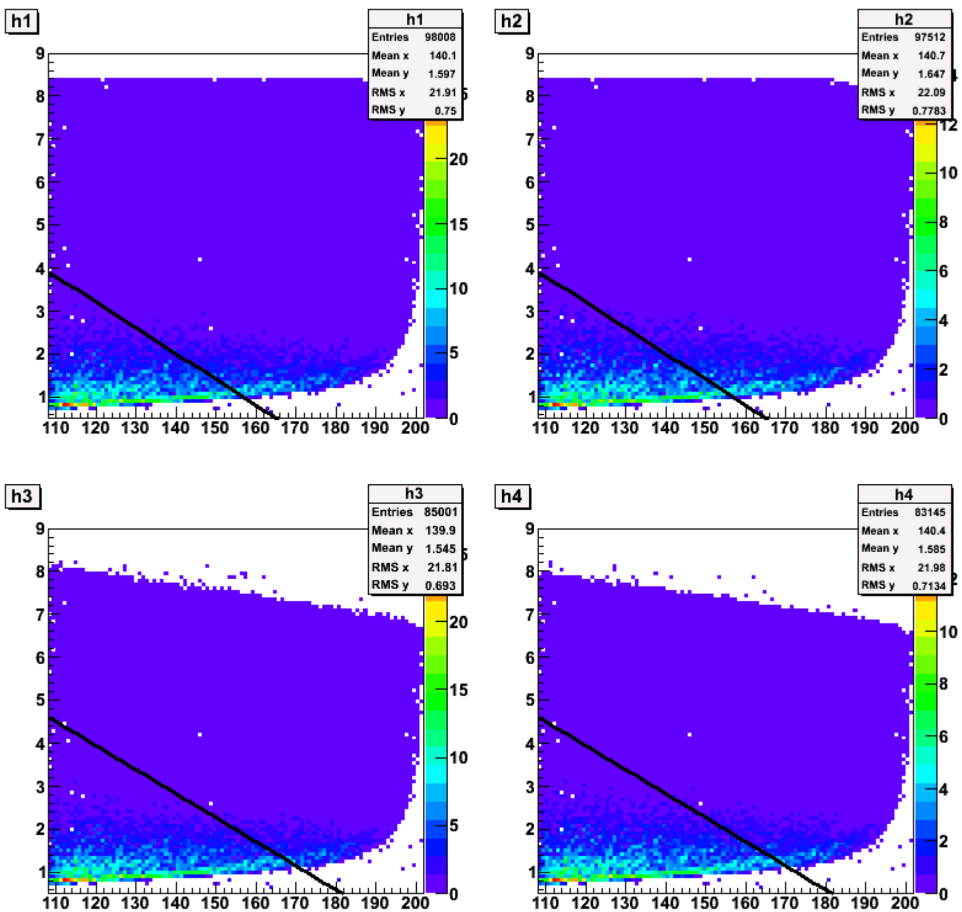
8.8 GeV: 91 kHz
8.8 GeV with Cut: 61 kHz
Large angle: 14.3 kHz

This would require a position dependence threshold cut.

Calculate Pion Rate

- Similar as Electron except
  - Collimator is not a black hole now
  - Turn off hadronize process, the rest is same.
- Results:
  - 11 GeV forward: 9 MHz (+) 5.4 MHz (-)
  - 8.80 GeV forward: 7.9 MHz, 4.6 MHz (-)
    - Pion are higher for two reasons:
      - Larger acceptance for CLEO vs. CDF
      - The suppression factor from collimator was under-estimated.
  - 11 GeV large @ p_e>3.0: 58 kHz (+) 41 kHz (-)
  - 8.80 GeV large @ p_e>3.0 : 40 kHz (+) 27 kHz (-)
  - Here for large angle, we expect to have a 20 from calorimeter rejection for “electron” trigger.

Forward Angle Pion which can mimic electron.



Top Left: Pip @ 11 GeV
Top Right: Pim @ 11 GeV

Bottom Left Pip @ 8.8 GeV
Bottom Right Pim @ 8.8 GeV

We can add a cut to mimic cut shown in slide 6.
Shown as black lines.

The remaining rates are:
11 GeV pip: 4.8 MHz
11 GeV pim: 2.9 MHz

8.8 GeV pip: 3.1 MHz
8.8 GeV pim: 1.8 MHz

We can add the position cut as well.

Calculate Hadron Rate

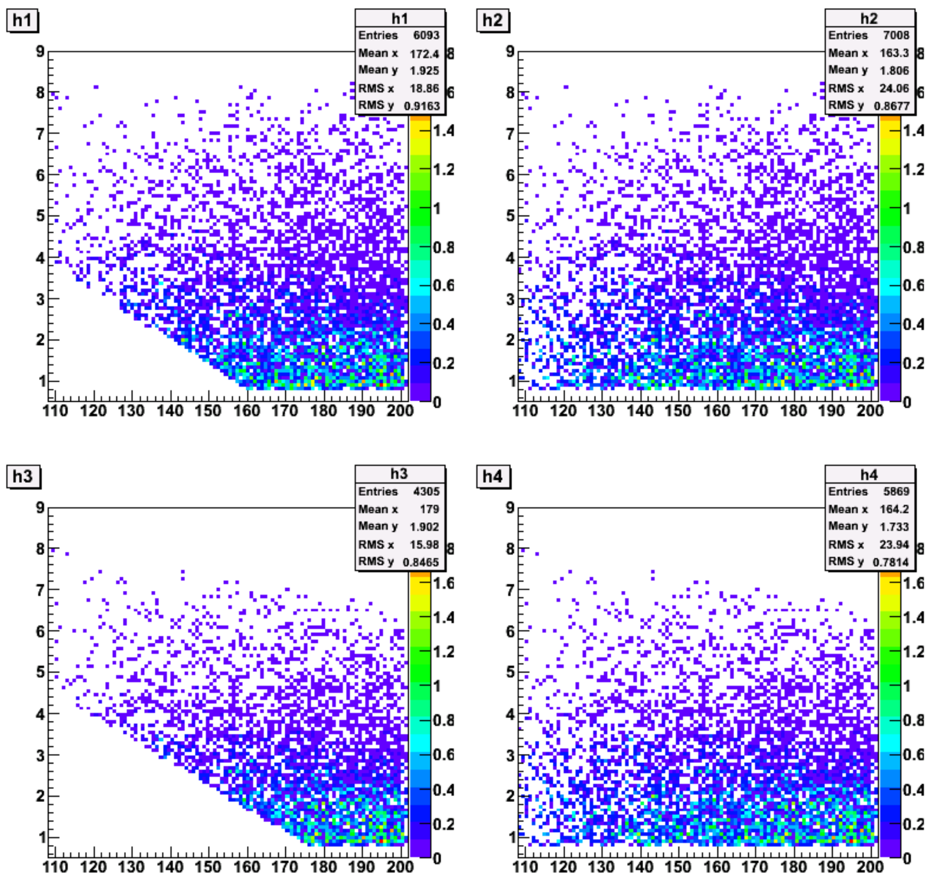
- Same as Pion Case, tread proton as 1/3. of pion case
- Treat Kaons as 5% of Pions.
- Total 40%.

- Then the hadron rate which might mimic electons are:
  - 11 GeV hp: 6.7 MHz
  - 11 GeV hm: 3.0 MHz
  - 8.8 GeV hp: 4.3 MHz
  - 8.8 GeV hm: 1.9 MHz
- The Full hadron rate:
  - 11 GeV hp: 12.6 MHz
  - 11 GeV hm: 5.7 MHz
  - 8.8 GeV hp: 11 MHz
  - 8.80 GeV hp: 4.8 MHz

Calculate Photon Rate

- Calculate Pio, treat collimator as black hole again. Go back to electron situation.
  - Turn on Decay processes.
  - We loop through each decay particles, so the rate can be a double-counted (over estimated).

Pion Rate @ forward angle



- 11 GeV: 462 kHz with cut
- 8.8 GeV: 362 k Hz with cut

- 11 GeV without cut: 605 kHz
- 8.8 GeV without cut 612 kHz

Large Angle Side

- 11 GeV: 31 kHz.
- 8.8 GeV side: 21 kHz.

Following Arguments from Proposal.

- Single electron trigger @ 11 GeV:
  - Forward angle: 41 kHz (electron) + 9.7 MHz (hadron)/ 400 + 462 (photon)/40 ~ 77 kHz.
  - Large angle: 14.3 kHz (electron) + 31 kHz (photon) ~ 44 kHz.
    - Total: 121 kHz.
- Single hadron trigger @ 11 GeV:
  - ~20 MHz
- Coincidence Trigger (35 ns)
  - 121e3*20e6 * 35e-9 ~ 85 kHz

8.8 GeV

- Single electron trigger @ 11 GeV:
  - Forward angle: 61 kHz (electron) + 6.2 MHz (hadron)/ 400 + 362 (photon)/40 ~ 86 kHz.
  - Large angle: 13 kHz (electron) + 21 kHz (photon) ~ 34 kHz.
    - Total: 120 kHz.
- Single hadron trigger @ 11 GeV:
  - ~20 MHz
- Coincidence Trigger (35 ns)
  - 120e3*18e6 * 35e-9 ~ 76 kHz

Thoughts on DAQ

- Idea I: Single-trigger alone:
  - If the GEM pad readout is successful, we can reduce the direct photon at large angle, so that the total rate:
    - 11 GeV: 90 kHz
    - 8.8 GeV: 100 kHz
    - @ SoLID-3He woth CLEO magnet setup with collimator.
  - **Here, we assume a position dependent energy threshold cut.**

Idea II: Coincidence Trigger

- At full luminosity, coincidence trigger is
  - 11 GeV: 63 kHz
  - 8.8 GeV: 63 kHz
- Since Coincidence Trigger Rate goes with 1/L^2 and single trigger rate goes 1/L
- Assume DAQ limit is 40 kHz, then we can
  - Case 1, reduce overall rate by 2-2.5 for single trigger.
  - Case 2, reduce rate by 25% for coincidence trigger.
  - **We assume that GEM read out is good for large angle detection.**

Discussion

- The advantage of coincidence trigger is that it decrease with L^2, so can be more effective if reducing luminosity.
- The advantage of single trigger is that it is Simple, but one may lose more if one have to reduce the luminosity.

Idea III: Threshold Effect

- At low Q2, the momentum is low, so the rates is high for background, also rates of single electron, pion etc are high.
  - SIDIS rate is also much higher at low Q2 region.
- Therefore, we can divide the running into a two period:
  - 1. at high threshold, run full or even higher luminosity to get better data at high Q2.
  - 2. at low threshold, run with less luminosity to get enough data at low Q2.
- Let’s look at this idea with MC.

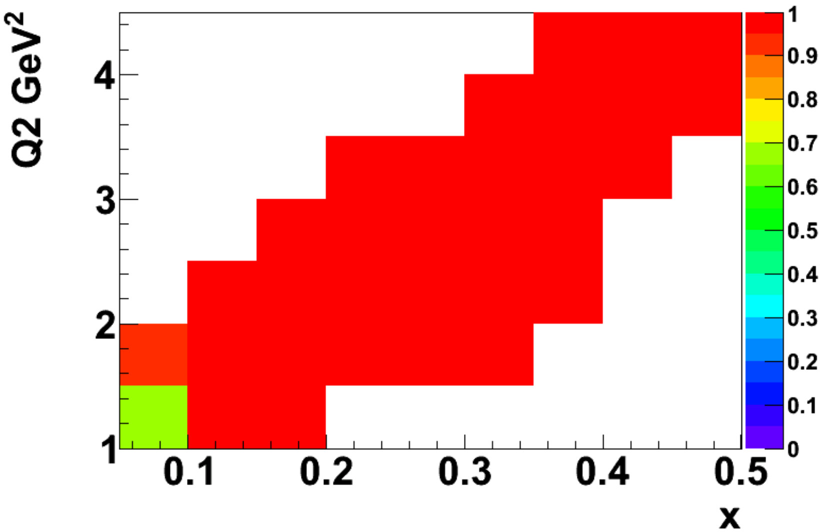
Pi^+ Case (For example)

- Let's assume that we are going to cut at p_e == 2 GeV @ 11 GeV.
  - Then Single electron rate becomes: 40 kHz
  - Single Photon rate: 199 kHz
  - Single Hadron rate: 3.8*1.4 + 2.5 ~ 7.8 MHz
  - Final single electron rate becomes: 64 kHz
- In additional to position dependent energy cut:
  - Single electron: 36 kHz
  - Single Photon: 178 kHz
  - Single Hadron: 4.4 MHz
  - Final single rate: 51 kHz

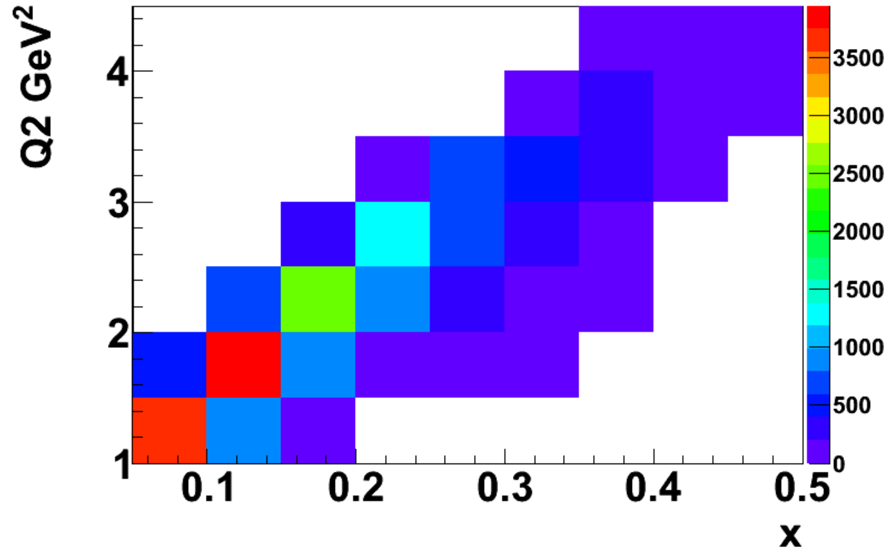
What about the x-Q2 Bin with 2.0 GeV Cut.

Ratio with Cut vs. Without cut

Loss about 30% at low xQ2 bin due to cut



Distribution with Cut directly



Note: this is simplified picture, since the physics is in 4-D (x,Q2, z, Pt)

Combine these two plots, we lose about 1200 events (arbitrary unit)
While the effect at high Q2 is about 100 events.
For example, in total we have 48 days, we can run at ½. Current for the low threshold setting with 8 days → 100 events (similar to the high Q2 case).
At High threshold, we can run at a higher luminosity (etc. 1.5 or twice)
We can optimize the cut vs. rate to balance low and high Q2 (or low x and high x division)

Summary

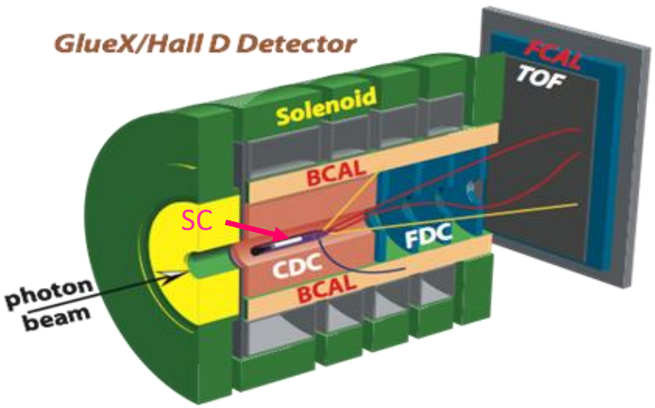
- The considering options are:
  - GEM Pad R&D is important to DAQ
  - ~2 GeV cutoff.
    - Two running period, higher luminosity with high threshold (high x and high Q2) and low luminosity with low threshold (low x, low Q2)
  - Position dependent Shower Cut
  - Coincidence Trigger (more effective if one have to reduce luminosity)
- An example of two runing periods is discussed here (2 GeV cutoff example)

SIDIS channel count

Detector	Module type	Number of channels	Number of modules
Forward Calorimeter	FADC+TDC	1896	119
Large angle calorimeter	FADC+TDC	920	58
Light Gas Cerenkov	FADC+TDC	120	8
Heavy Gas Cerenkov	FADC+TDC	270	17
Scintillator	FADC+TDC	120	8
GEM	VME/SRS	164K	
MRPC	VME	2550	

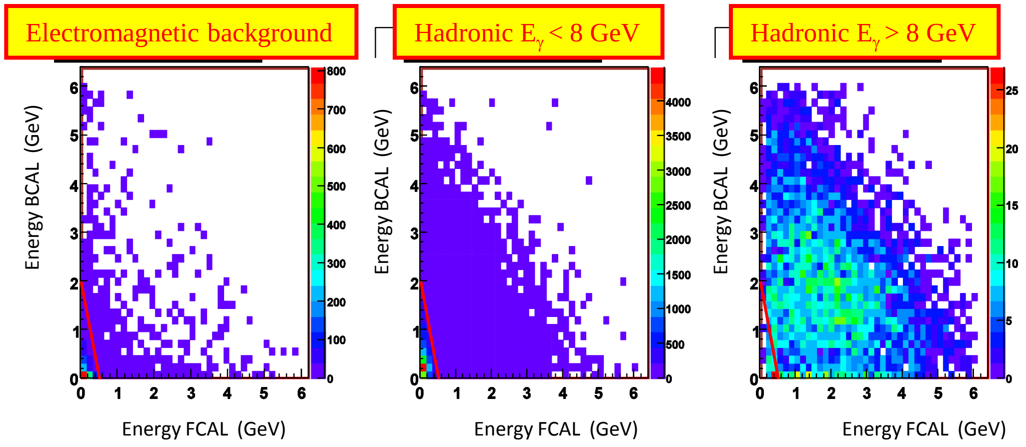
Hall D L1 Trigger-DAQ Rate

- Low luminosity (10^7 γ/s in $8.4 < E_\gamma < 9.0$ GeV)
  - 20 kHz L1
- High luminosity (10^8 γ/s in $8.4 < E_\gamma < 9.0$ GeV)
  - 200 kHz L1
  - Reduced to 20 kHz L3 by online farm
- Event size: 15 kB; Rate to disk: 3 GB/s



Detectors which can be used in the Level-1 trigger:

Forward Calorimeter (FCAL)	Energy
Barrel Calorimeter (BCAL)	Energy
Start Counter (SC)	Hits
Time of Flight (TOF)	Hits
Photon Tagger	Hits

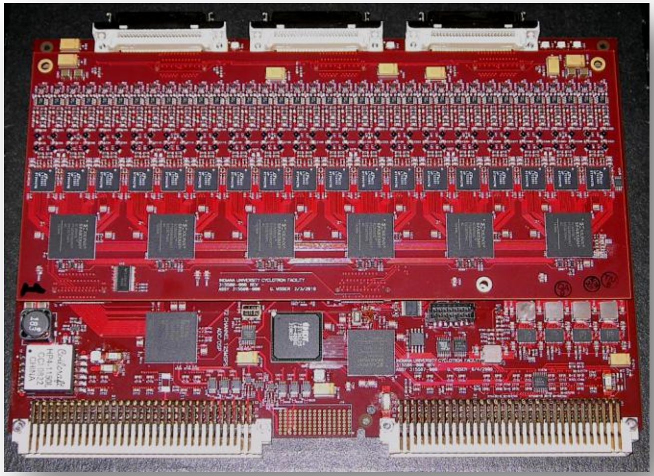


Basic Trigger Requirement:

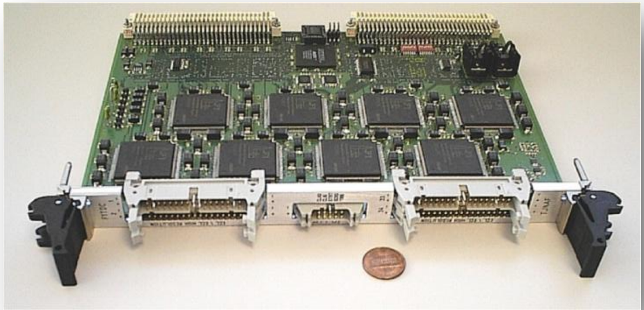
$$E_{BCAL} + 4 \cdot E_{FCAL} > 2 \text{ GeV}$$
and a hit in Start Counter

Custom Electronics for JLab

- VME Switched Serial (VXS) backplate
  - 10 Gbps to switch module (J_0)
  - 320 MB/s VME-2eSST (J_1/J_2)
- All payload modules are fully pipelined
  - **FADC125** (12 bit, 72 ch)
  - **FADC250** (12 bit, 16 ch)
  - **F1-TDC** (60 ps, 32 ch or 115 ps, 48 ch)
- Trigger Related Modules
  - **C**rate **T**rigger **P**rocessor (**CTP**)
  - **S**ub-**S**ystem **P**rocessor (**SSP**)
  - **G**lobal **T**rigger **P**rocessor (**GTP**)
  - **T**rigger **S**upervisor (**TS**)
  - **T**rigger **I**nterface/Distribution(**TI/D**)
  - **S**ignal **D**istribution (**SD**)

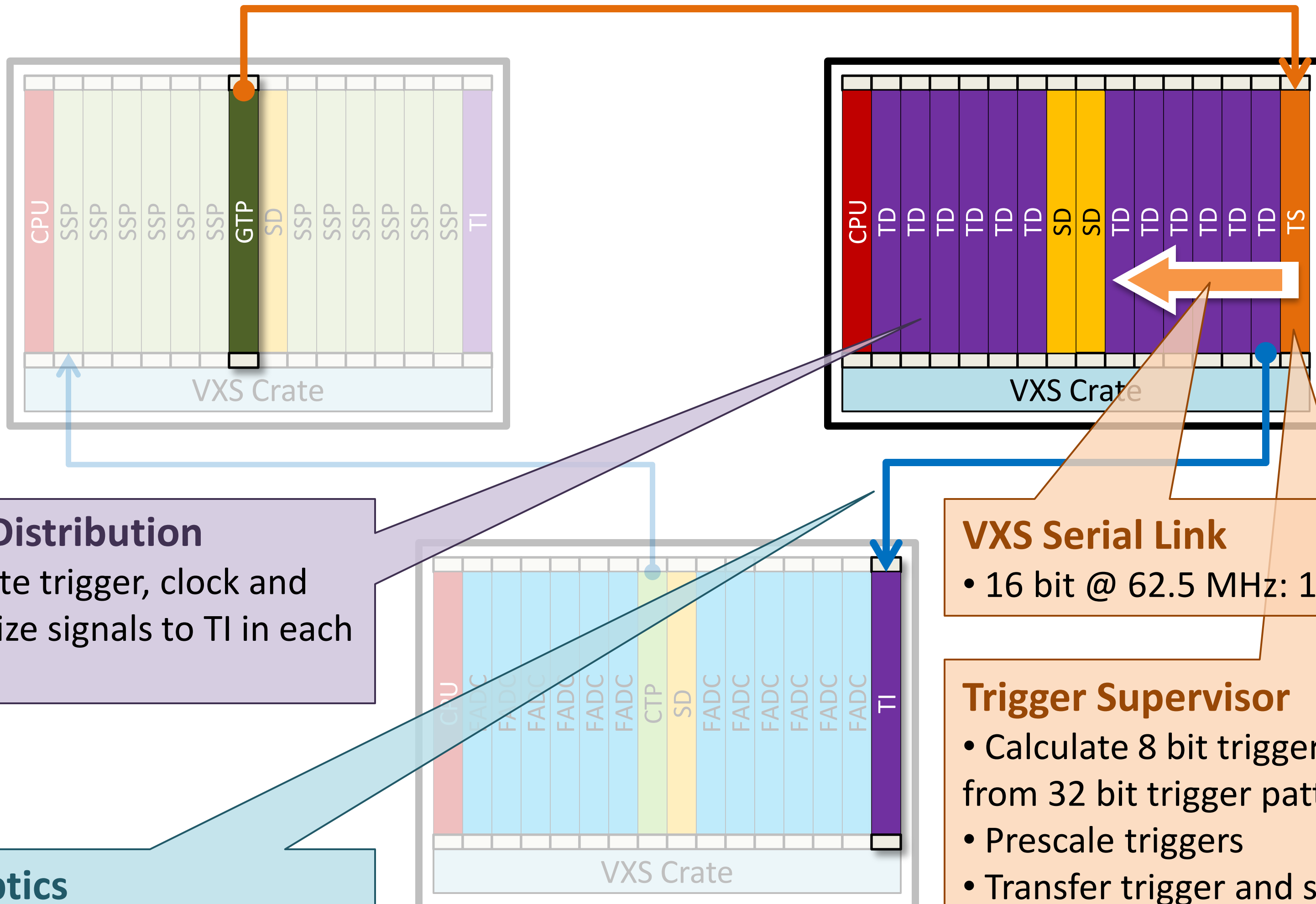


FADC125



F1-TDC

L1 Trigger Diagram



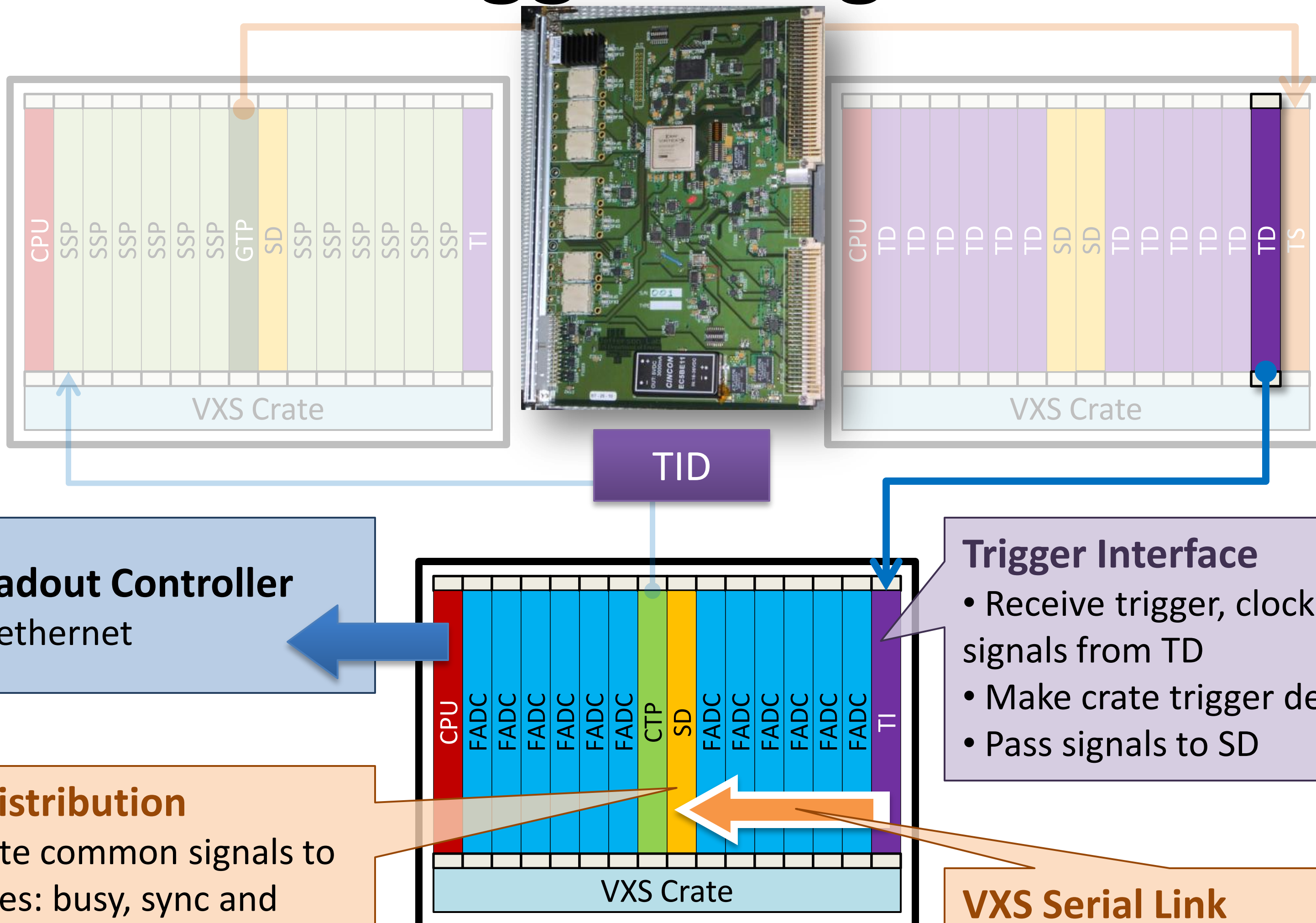
Trigger Distribution
- Distribute trigger, clock and synchronize signals to TI in each Crate

Fiber Optics
- 16 bit @ 62.5 MHz: 1 Gbps

VXS Serial Link
- 16 bit @ 62.5 MHz: 1 Gbps

Trigger Supervisor
- Calculate 8 bit trigger types from 32 bit trigger pattern
- Prescale triggers
- Transfer trigger and sync signal to TD (16 bit total)

L1 Trigger Diagram



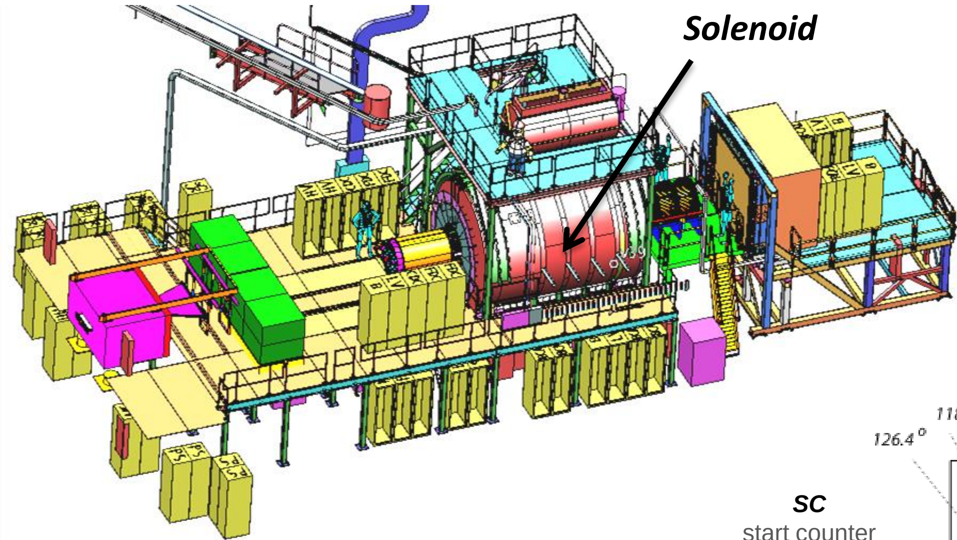
VME Readout Controller
- Gigabit ethernet

Trigger Interface
- Receive trigger, clock and sync signals from TD
- Make crate trigger decision
- Pass signals to SD

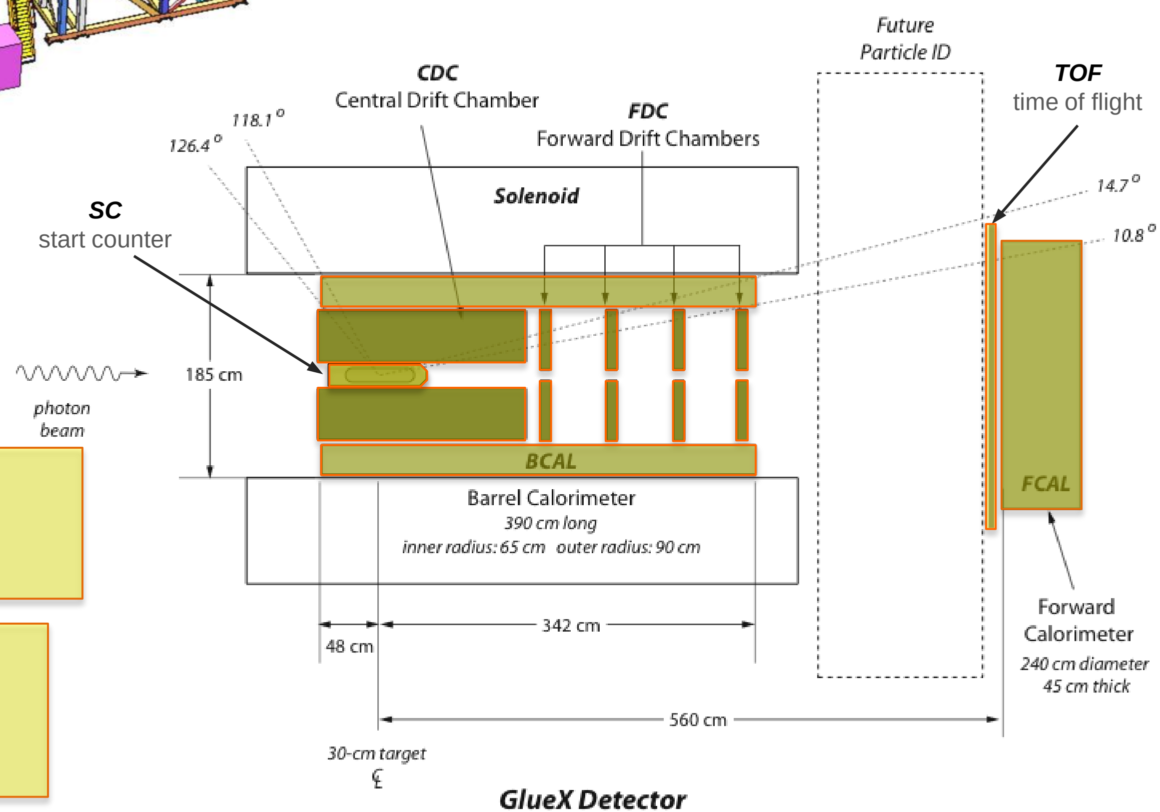
Signal Distribution
- Distribute common signals to all modules: busy, sync and trigger 1/2

VXS Serial Link
- 4 bit @ 250 MHz: 1 Gbps

The GlueX Detector



- 2.2T superconducting solenoidal magnet
- Fixed target (LH_2)
- 10^8 tagged γ/s (8.4-9.0GeV)
- hermetic



Charged particle tracking
- Central drift chamber (straw tube)
- Forward drift chamber (cathode strip)

Calorimetry
- Barrel Calorimeter (lead, fiber sandwich)
- Forward Calorimeter (lead-glass blocks)

PID
- Time of Flight wall (scintillators)
- Start counter
- Barrel Calorimeter

GlueX Data Rate

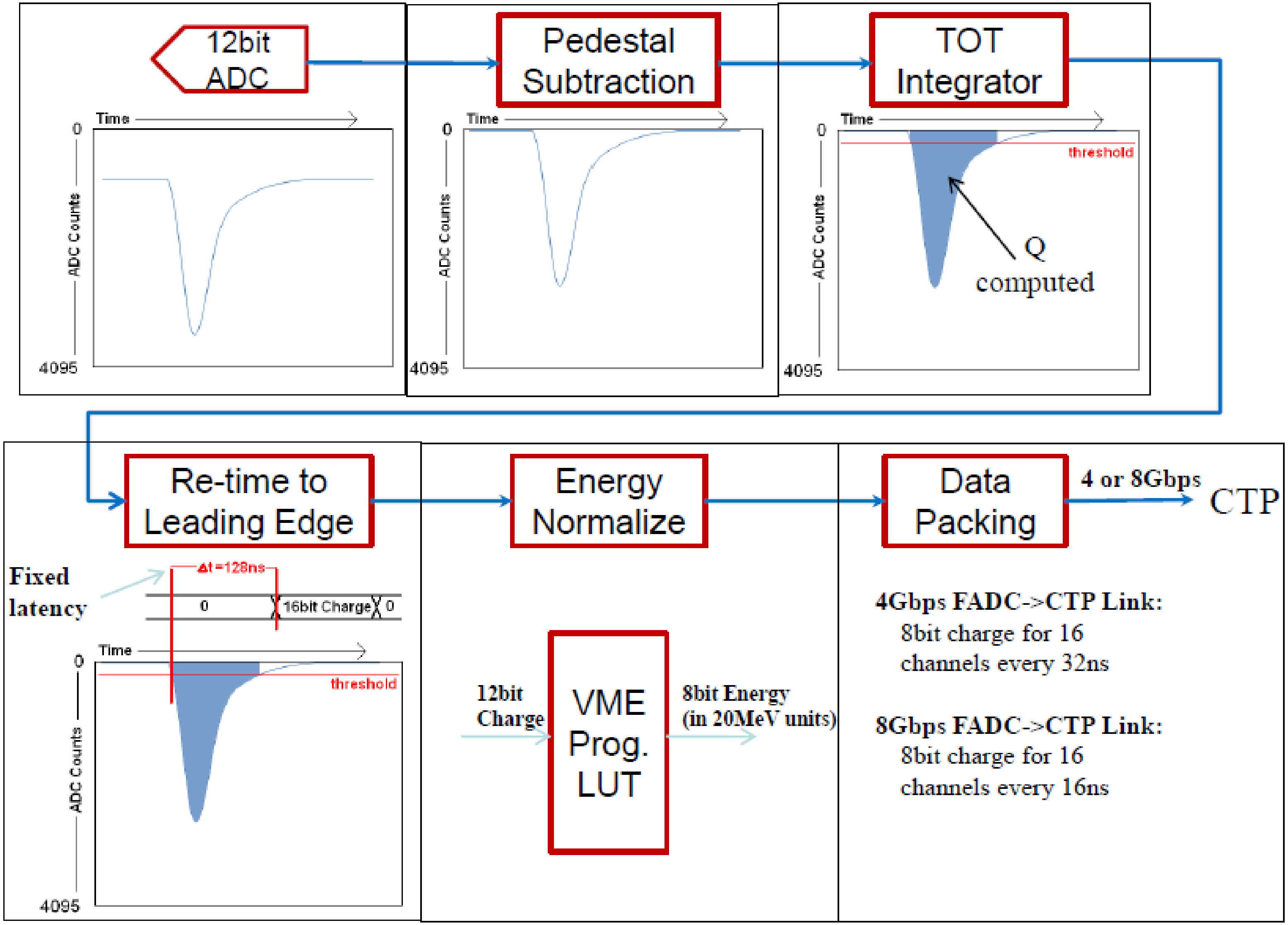
		Front End DAQ Rate	Event Size	L1 Trigger Rate	Bandwidth to mass Storage	
JLab	GlueX	3 GB/s	15 kB	200 kHz	300 MB/s	private comm.
	CLAS12	0.1 GB/s	20 kB	10 kHz	100 MB/s	
LHC	ALICE	500 GB/s	2,500 kB	200 kHz	200 MB/s	CHEP2007 talk Sylvain Chapelin
	ATLAS	113 GB/s	1,500 kB	75 kHz	300 MB/s	
	CMS	200 GB/s	1,000 kB	100 kHz	100 MB/s	
	LHCb	40 GB/s	40 kB	1000 kHz	100 MB/s	
BNL	STAR	50 GB/s	1,000 kB	0.6 kHz	450 MB/s	*
	PHENIX	0.9 GB/s	~60 kB	~ 15 kHz	450 MB/s	**

* Jeff Landgraf Private Comm. 2/11/2010
** CHEP2006 talk MartinL. Purschke

CODA3 – What's different

CODA 2.5	CODA 3
Run Control (X, Motif, C++) (rcServer, runcontrol)	Experiment Control – AFECS (pure JAVA) (rcPlatform, rcgui)
Communication/Database (msql, cdev, dptcl, CMLOG)	cMsg – CODA Publish/Subscribe messaging
Event I/O C-based simple API (open/close read/write)	EVIO – JAVA/C++/C APIs Tools for creating data objects, serializing, etc…
Event Builder / ET System / Event Recorder (single build stream)	EMU (Event Management Unit) Parallel/Staged event building
Front-End – vxWorks ROC (Interrupt driven – event by event readout)	Linux ROC, Multithreaded (polling – event blocking)
Triggering: 32 ROC limit, (12 trigger bits -> 16 types) TS required for buffered mode	128 ROC limit, (32 trigger bits -> 256 types) TI supports TS functionality. Timestamping (4ns)

FADC Encoding Example



GTP Trigger Bit Example