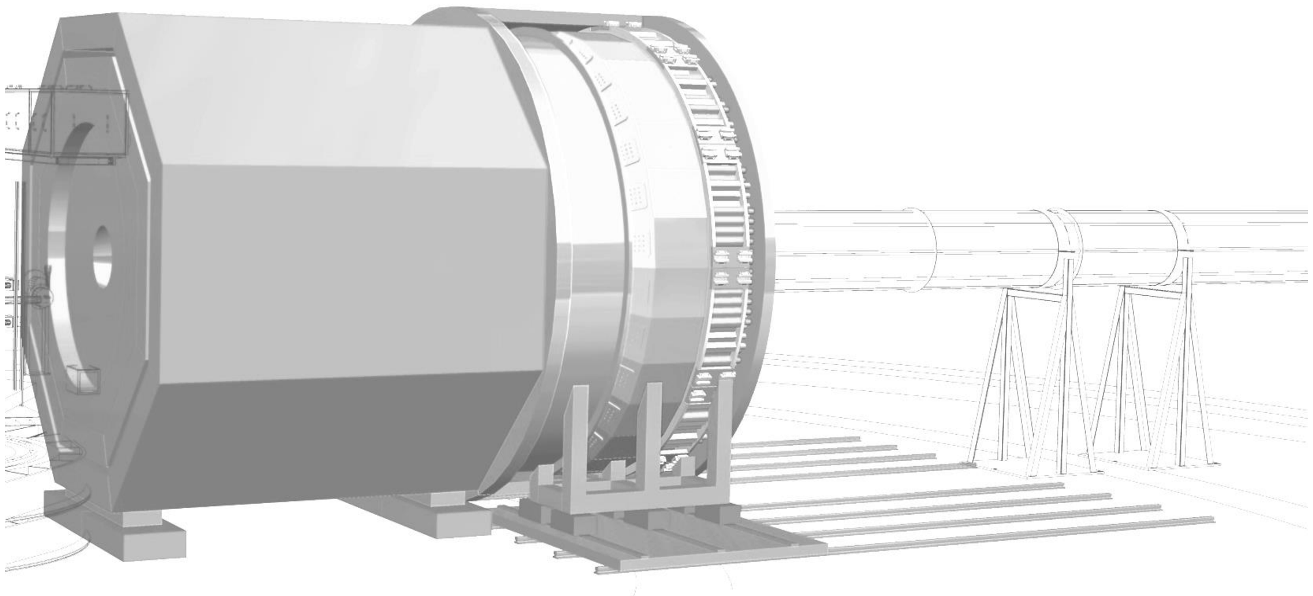

SOLENOIDAL LARGE INTENSITY DEVICE

SoLID GEM Read Out streaming consideration

Streaming Readout Workshop

April 21st 2021

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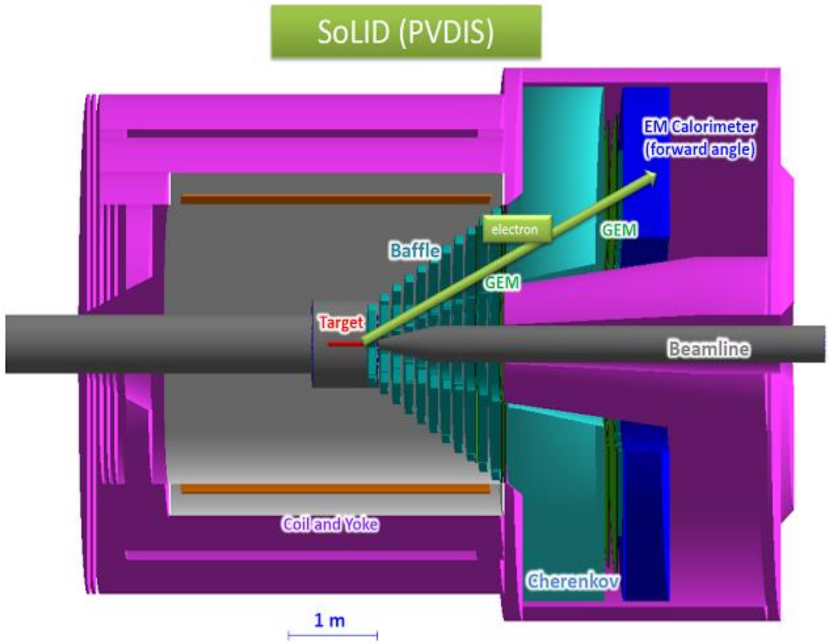
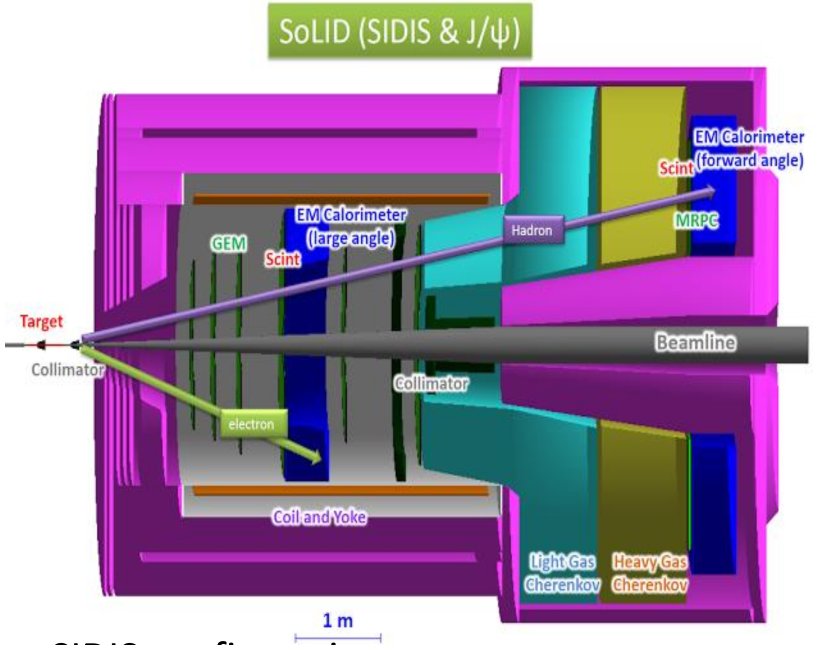
Outline

- SoLID experiments overview
- Requirements
- GEM detectors
- GEM readout(s)
- Trigger and data rates
- Streaming consideration
- Conclusion

SoLID experiments overview



- PVDIS configuration
  - Inclusive DIS electrons
  - Trigger Calorimeter + Cerenkov
  - 30 individual sectors
  - 12 KHz/sector = less 500 KHz total



- SIDIS configuration
- Trigger :
  - Electron trigger : Calorimeter+Light Gas Cerenkov
  - Pion trigger
    - Scintillator + calorimeter
  - Main trigger : coincidence eπ
- 100 KHz of coincidence eπ
- J/ψ 30KHz triple coincidence ee^-e^+

Data Acquisition Requirement and Design

Experiments	PVDIS	SIDIS-^{3}He	SIDIS-Proton	J/ψ
Reaction channel	$p(\vec{e}, e')X$	$(e, e'\pi^{\pm})$	$(e, e'\pi^{\pm})$	$e + p \to e' + J/\Psi(e^-, e^+) + p$
Approved number of days	169	125	120	60
Target	LH_2/LD_2	^{3}He	NH_3	LH_2
Unpolarized luminosity ($cm^{-2}s^{-1}$)	$0.5\times10^{39}/1.3\times10^{39}$	$\sim 10^{37}$	$\sim 10^{36}$	$\sim 10^{37}$
Momentum coverage (GeV/c)	2.3-5.0	1.0-7.0	1.0-7.0	0.6-7.0
Momentum resolution	~2%	~2%	~3%	~2%
Polar angular coverage (degrees)	22-35	8-24	8-24	8-24
Polar angular resolution	1 mr	2 mr	3 mr	2 mr
Azimuthal angular resolution	-	6 mr	6 mr	6 mr
Trigger type	Single e^-	Coincidence $e^- + \pi^{\pm}$	Coincidence $e^- + \pi^{\pm}$	Triple coincidence $e^-e^-e^+$
Expected DAQ rates	<20 kHz × 30	<100 kHz	<100 kHz	<30 kHz
Backgrounds	Negative pions, photons	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	BH process Random coincidence
Major requirements	Radiation hardness 0.4% Polarimetry π^- contamination Q^2 calibration	Radiation hardness Detector resolution Kaon contamination DAQ	Shielding of *sheet-of-flame* Target spin flip Kaon contamination	Radiation hardness Detector resolution

GEM Requirements and Design: PVDIS

- High rate operation up to localized hit rates of approximately 1 MHz/cm^2.
- Instrument 5 locations with GEMs:
  - 30 GEM modules a location: each module with a 12-degree angular width.

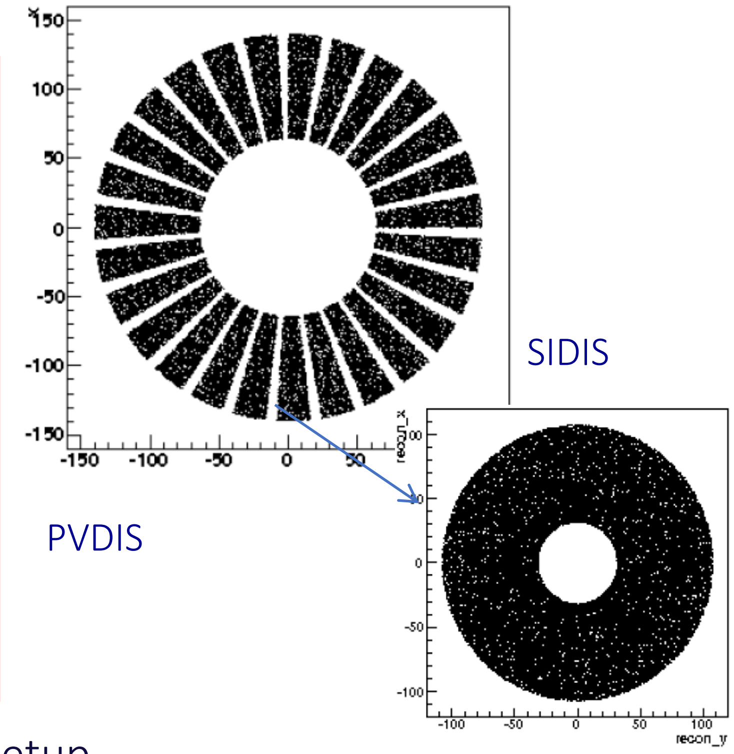
Location	Z (cm)	R_{min} (cm)	R_{max} (cm)	Surface (m^2)	# chan
1	157.5	51	118	3.6	24 k
2	185.5	62	136	4.6	30 k
3	190	65	140	4.8	36 k
4	306	111	221	11.5	35 k
5	315	115	228	12.2	38 k
Total				$\approx$ 36.6	$\approx$ 164 k

- The high occupancy at layer #1: may require splitting each readout strip into two channels: this will add another 12 k channels
- So, total number of channels needed could be : ~ 176 k
- With ~ 15% spares (to account for losses during production etc.) need to plan for 200 k readout channels
- Lot of data at high occupancy; but we can have multiple parallel DAQs

GEM Requirements and Design: SIDIS

- Compared to PVDIS, rates a bit lower: 0.15 MHz/cm^2.
- But need to read the whole layer based on a single trigger: no sectors here: no possibility to have many parallel DAQs.
  - bandwidth could be an issue: but ways to handle it.
- Instrument 6 locations with GEMs:

Plane	Z (cm)	R_I (cm)	R_O (cm)	Active area (m^2)	# of channels
1	-175	36	87	2.0	24 k
2	-150	21	98	2.9	30 k
3	-119	25	112	3.7	33 k
4	-68	32	135	5.4	28 k
5	5	42	100	2.6	20 k
6	92	55	123	3.8	26 k
total:				~20.4	~ 161 k

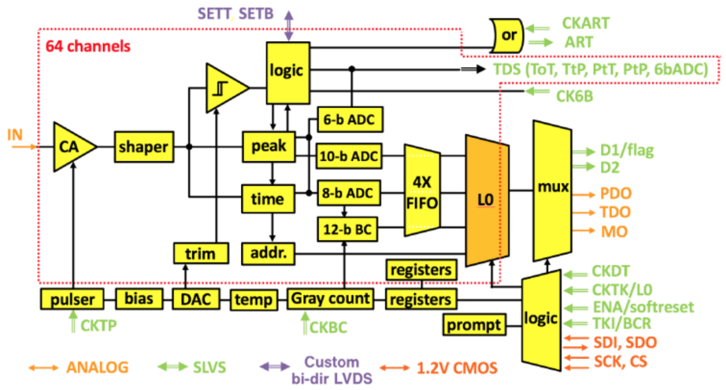


- More than enough electronic channels from PVDIS setup.
- The two configurations will work well with no need for new GEM or electronics fabrication.

GEM readout

- DAQ based on 12 GeV pipelined electronics (Flash ADC) designed for use in Halls B & D. (Supports up to 200 kHz trigger rate and meets PVDIS and reach deadtime systematic of less than 0.1%)

- GEM readout with VMM3

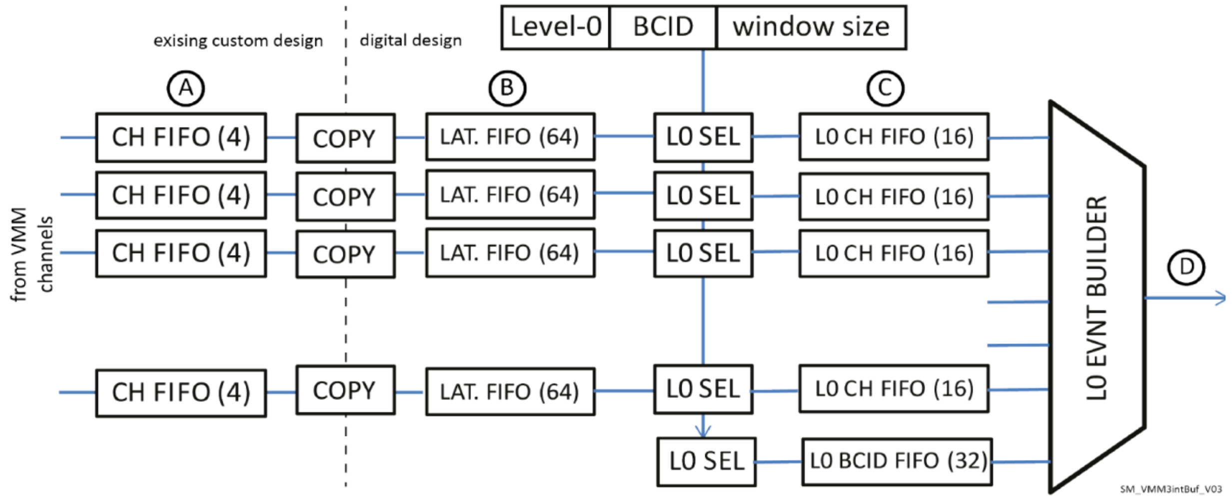


VMM3 block diagram

- ASIC for ATLAS New Small Wheel
- Radiation hard
- 64 channels
- 6 bit and 10 bit ADC, 8 bits TDC, 12 bits Beam Crossing time stamp
- Deadtimeless up to 4 MHz of rate per channel thanks to multilevel FIFO
- Latency up to 16 μs
- Self triggering path
- Data link up to 320 Mbit/s

- SAMPA option studied but concern about radiation hardness

VMM3



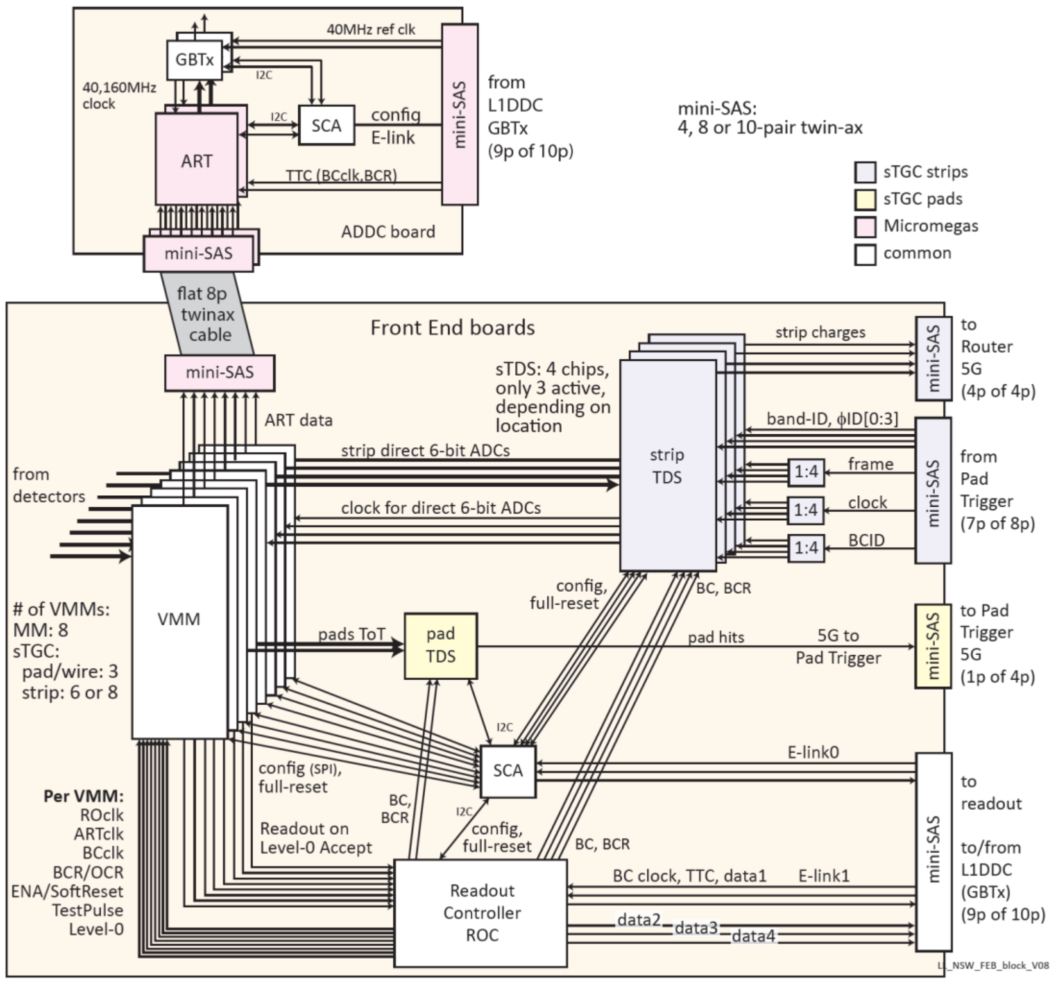


Figure 2: Overall connection diagram of the VMM.

VMM3 prototype board development (Ed)

FPGA for VMM Direct Readout

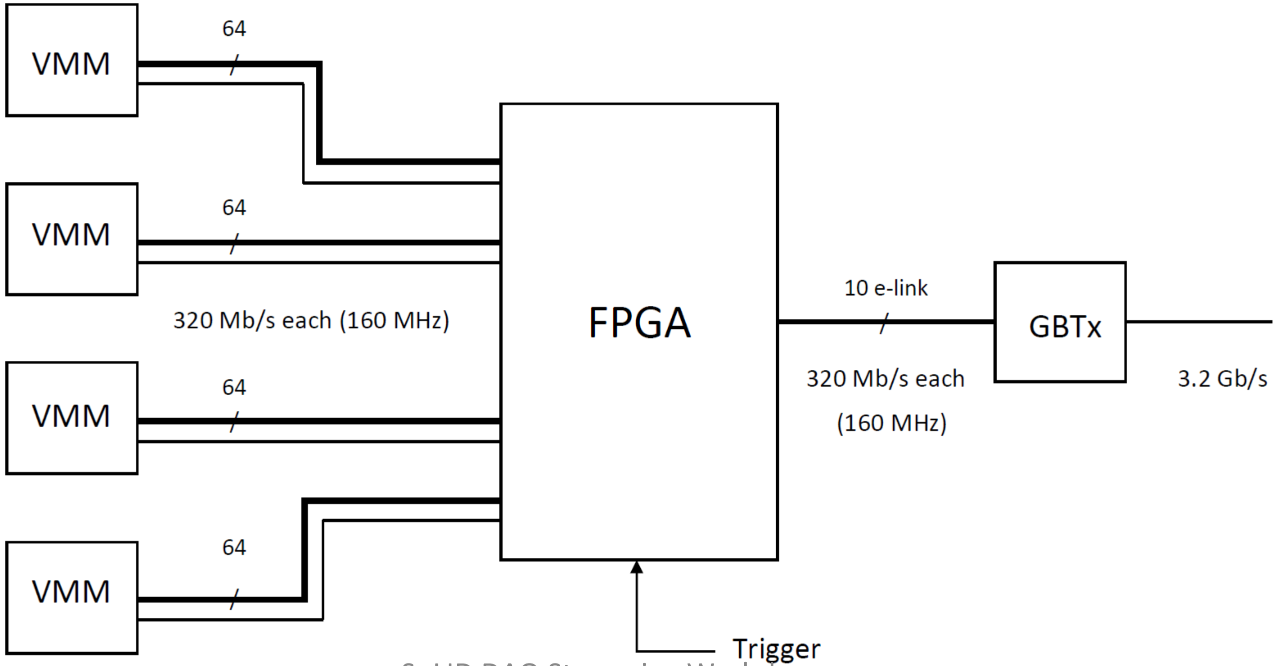
(E.J. 5/28/20)

Proposal

1 FPGA handles direct readout of 4 VMM chips

[64(channels/chip) + 1(clock/chip)] x 2(pins/signal) x 4(chips) = 520 pins (reasonable size, price FPGA)

1 GBTx data link for FPGA output data (10 e-links @ 320 Mb/s = 3.2 Gb/s)



Total = 81.92 Gb/s

1

VMM3 prototype board development (Ed)

Trigger rate (max) = (3200 Mb/s) / (4656 + w*r*3072 b)

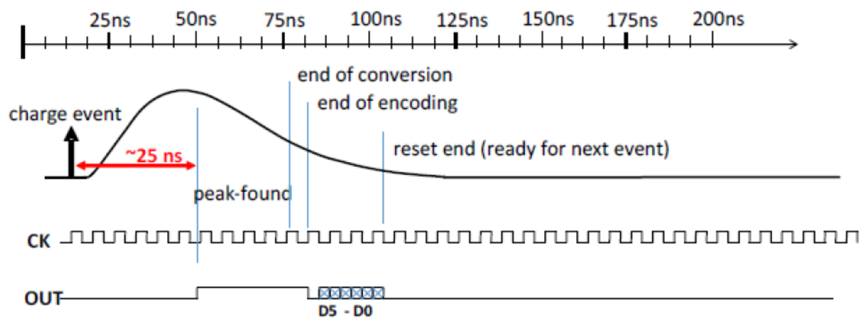
e.g. r = 10 MHz, w = 0.400 μs => Trigger rate (max) = 189 KHz

r = 15 MHz, w = 0.400 μs => Trigger rate (max) = 139 KHz

Or we can solve for the quantity w*r:

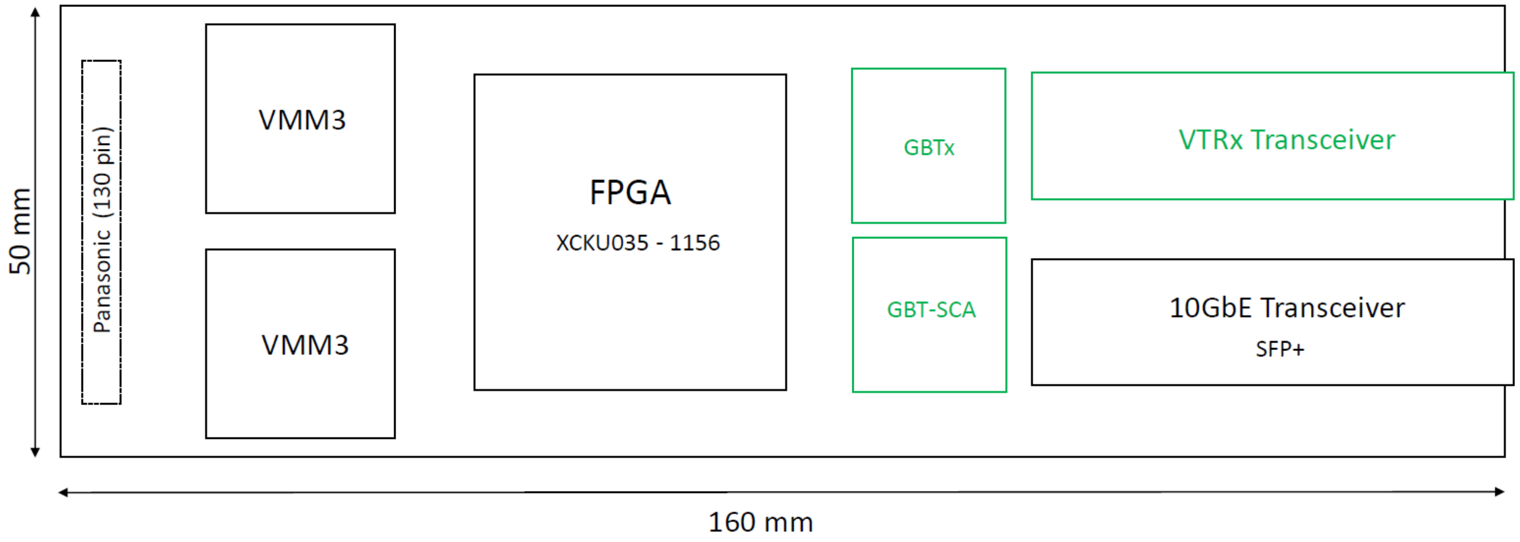
R = trigger rate (MHz)

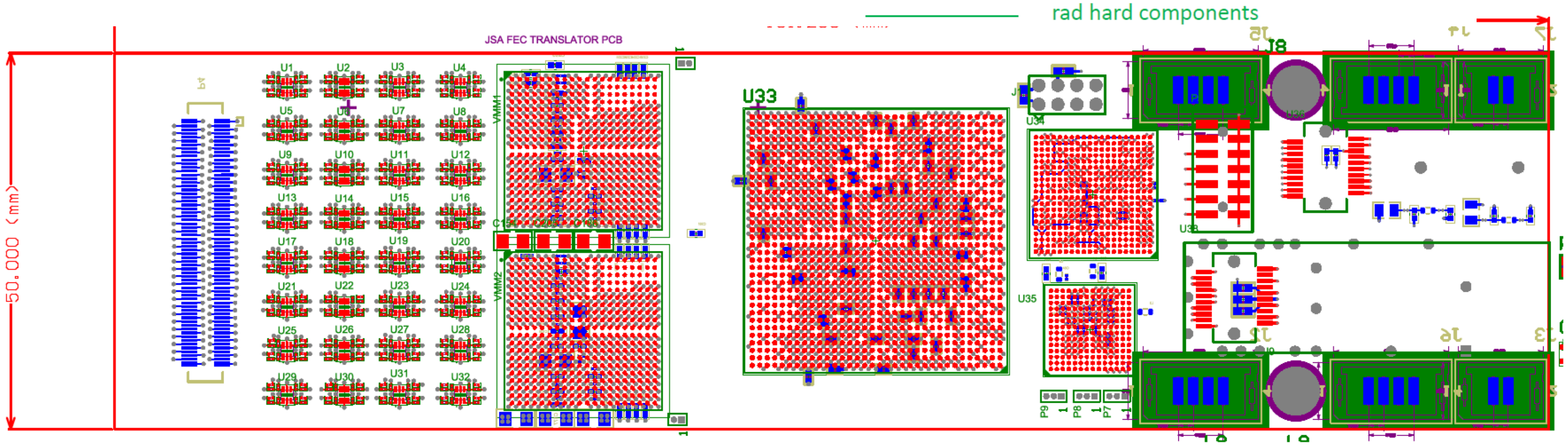
w(μs)*r(MHz) = 1.04166 / R(MHz) - 1.51563



VMM 6-bit ADC Direct Output timing

VMM3 prototype





Trigger rates PVDIS

	PVDIS
Singles ECAL	230 KHz
Singles rates Cerenkov	803 KHz
Accidental 30 ns	4.1 KHz
DIS electron	7.7 KHz
Total rate	**12.1 KHz**

SIDIS Trigger Rates

Rate (kHz) Ecal+LGC(2,2)+SPD(>0.425MeV)	7 modules **3 GeV** trigger threshold for LAEC +Up window+ down widow
FA e-	60+1.1+1.8
FA hadron no e-	29+3.6+5.3
LA e-	4.1+3.6+2.6
LA hadron no e-	7.7+6.5+3.8
hadron trigger	8013+2591+3887
SIDIS coin	31.2
Hadron coin	14.7+2.52+2.61=19.83
Total rate	**<85 kHz** (30ns time window)

Triggered data rates PVDIS

PVDIS	30000 kHz						
		Total strips	Occupancy %	strips fired	event size bytes (time + amplitude)		data rate (MB/s)
1		34740	16.2	5627.88	22513.52		675.4056
2		41280	8.3	3426.24	13706.96		411.2088
3		41280	7.1	2930.88	11725.52		351.7656
4		68400	2.7	1846.8	7389.2		221.676
5		70560	2.7	1905.12	7622.48		228.6744
		256260	37	15736.92	62957.68	GEM rate	1888.7304
						FADC	176
						Total	2064.7304

Triggered data rates SIDIS

SIDIS He3	200000 KHz						
		Total strips	Occupancy %	strips fired	event size bytes (time + amplitude)		data rate (MB/s)
1		27120	1.8	488.16	1954.64		390.928
2		30540	5.5	1679.7	6720.8		1344.16
3		34920	2.5	873	3494		698.8
4		42060	1.6	672.96	2693.84		538.768
5		31140	1.6	498.24	1994.96		398.992
6		38340	1.2	460.08	1842.32		368.464
		204120	14.2	4212.06	16858.24		3371.648
						FADC	300
						Total	3671.648

Trigger data rates J/Psi

JPsi	100000						
		Total strips	Occupancy %	strips fired	event size bytes (time + amplitude)		data rate (MB/s)
1		27120	5.4	1464.48	5859.92		585.992
2		30540	9.7	2962.38	11851.52		1185.152
3		34920	6.1	2130.12	8522.48		852.248
4		42060	4.8	2018.88	8077.52		807.752
5		31140	4.3	1339.02	5358.08		535.808
6		38340	3.3	1265.22	5062.88		506.288
		204120	33.6	9914.88	39669.52		3966.952
						FADC	300
						Total	4266.952

Similar data rates as APV25 for Jpsi, slightly lower rate for PVDIS and SIDIS

Computer resources tracking triggered

- PVDIS
  - Clustering : 0.4 ms
  - Tracking : 2 ms
  - 20 KHz x 2.4 ms= 48
  - 30 sectors = 1440 cores

- SIDIS
  - Clustering : 4.5 ms
  - Tracking : 1.7 ms
  - 100 kHz x 6.2 ms = 620 cores

SoLID GEM Streaming Readout

- L3 farm not included in project, seems tape silo can handle rate, triggered DAQ default solution
- Data dominated by GEM data
- Switch to VMM3 makes the system streaming capable
- PVDIS is a good candidate for streaming since sectors are independents and number of channels reduced
- SIDIS has larger event size but lower occupancy
- If computing resources available, would like to process more the data (tracking) to reduce the data size even in triggered or streaming mode

PVDIS full streaming per sector

GEM
8541 strips
SAMPA
20 MHz

1700 Gbit/s =
170 x 10 gigE

or 17x 100 gigE

Computer farm
clustering
1700 Gbit =
200 GB/s

Assume
1 node can
handle 150 GB/s

2 nodes

reduce to ~1
MHz per channel
max

Tracking
Rate
dominated
by highest
occupancy
channel

1 MHz x 2.4
ms = 2400
cores

= 40 nodes
(64 cores)

For 30 sectors
1300 nodes and 340 100gigE

PVDIS semi-streaming per sector
(activate suppression on board)

GEM
8541 strips
SAMPA or VMM3
20 MHz
Up to 1 MHz per channel

~200 Gbit/s

20 x 10 gigE
Or
2x100 gigE

Tracking
Rate dominated by highest occupancy channel

1 MHz x 2.4 ms = 2400 cores

= 40 nodes
(64 cores)

1200 nodes

and

60x100gigE

for 30 sectors

SIDIS full streaming per sector

GEM
164k strips
SAMPA
20 MHz

32800 Gbit/s = 3280 x 10 gigE

or 328x 100 gigE

Computer farm clustering
32800 Gbit = 4100 GB/s

Assume
1 node can handle 150 GB/s

28 nodes

reduce to ~1 MHz per channel max

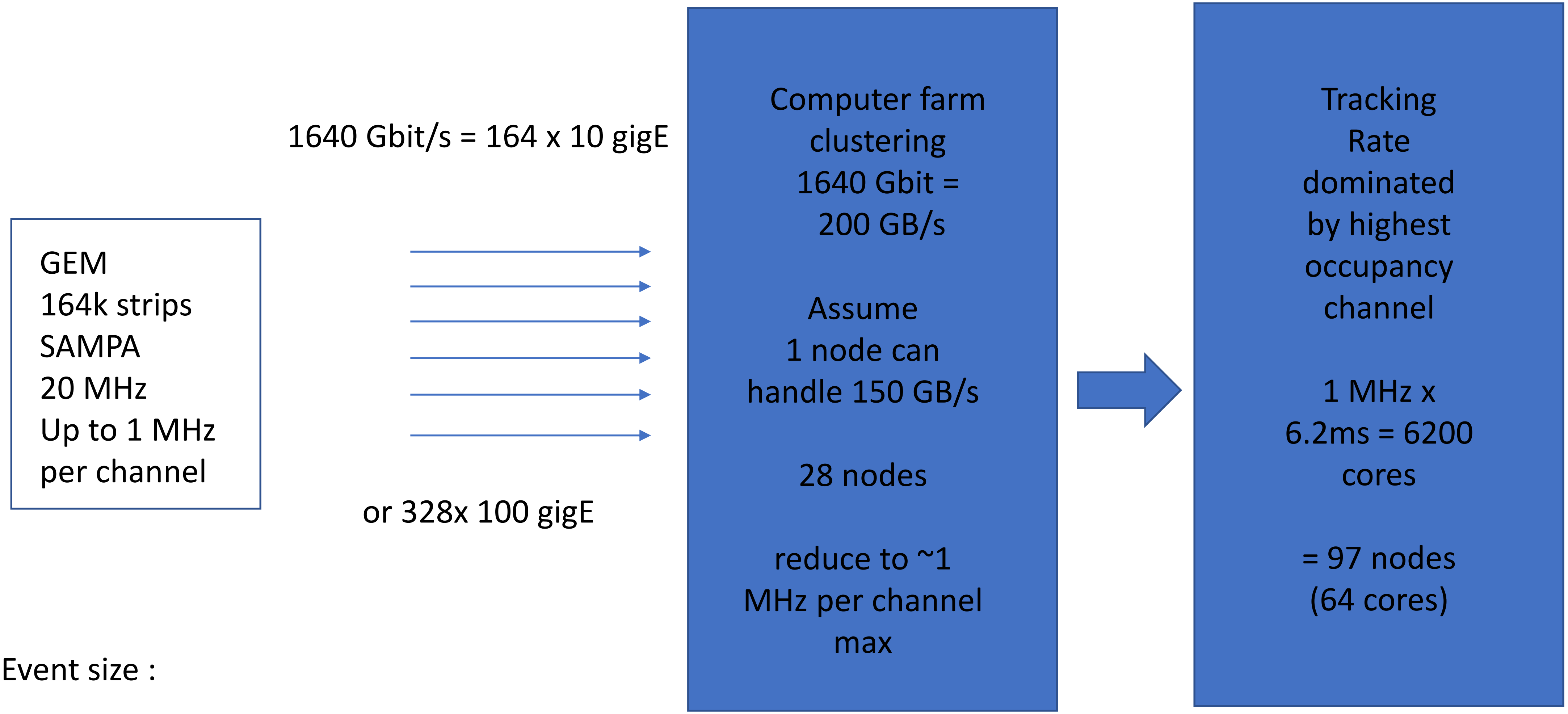
Tracking
Rate dominated by highest occupancy channel

1 MHz x 6.2ms = 6200 cores

= 97 nodes (64 cores)

For 30 sectors ~1300 nodes

SIDIS semi-streaming per sector



Event size :

Modification for streaming

- Assume 1 MHz rate max per channel (roughly 10x more rates than triggered)
- 6 bit adc, 20 bit channel, 38 bit timestamp = 64 bit / channel
- 64 bits x 64 channels at 1 MHz = 4 Gbit/s
- 1 or 2 VMM per board
- 4 x more data links

Conclusion

- SoLID high luminosity experiment 10^39 cm-2.s-1
- Baseline is triggered data without L3
- Rates low enough to be put on tape without tracking
- Online tracking
  - PVDIS : 1440 cores
  - SIDIS : 620 cores
- Streaming option using VMM seems doable
  - Need more data link from high occupancy
  - PVDIS : ~ 72000 cores
  - SIDIS ~6500 cores
- Need testing to refine number and figure out bottle necks