Development of a DAQ system for the DeeMe experiment

Nguyen Minh Truong (D3, Kuno-lab)

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- Monitor after-proton background
- FADC readout board

  + Firmware for DeeMe experiment

  + Test multiple FADC readout board and network switch

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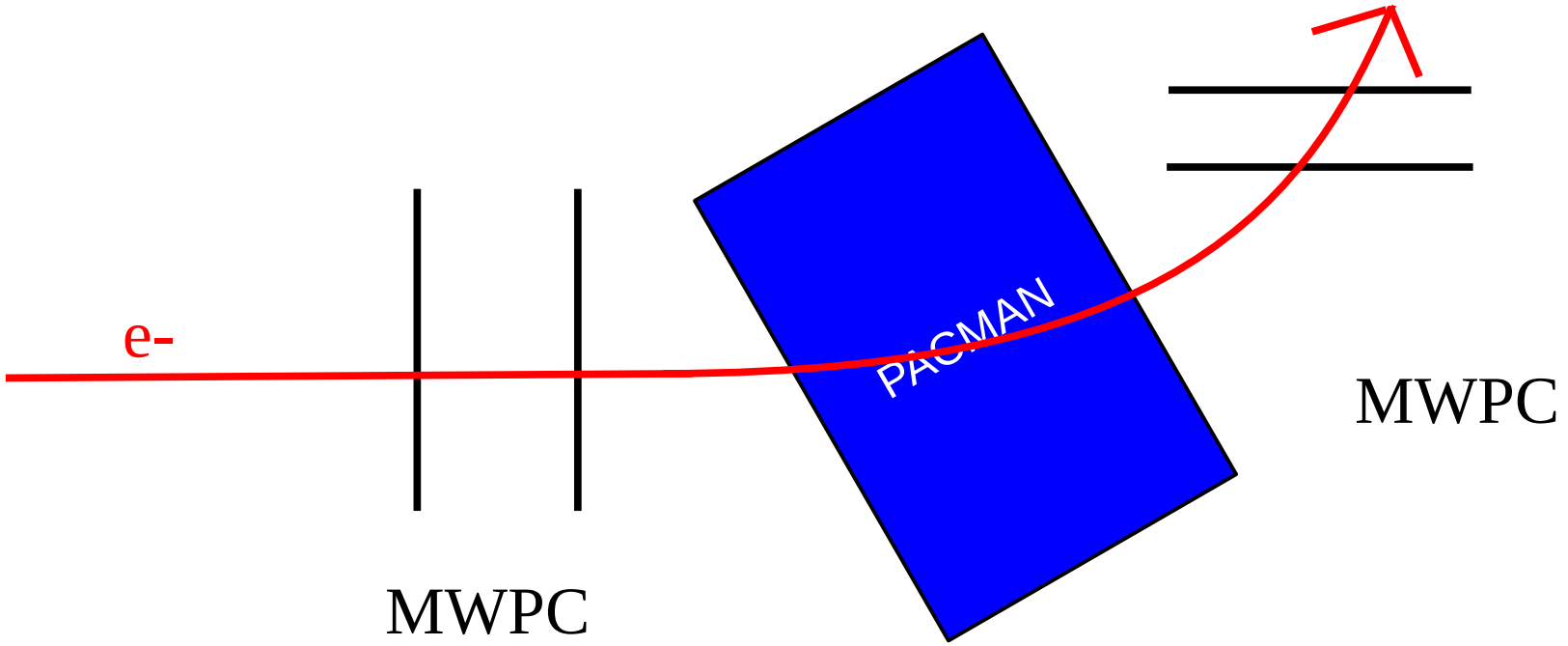
- Summary

Motivation

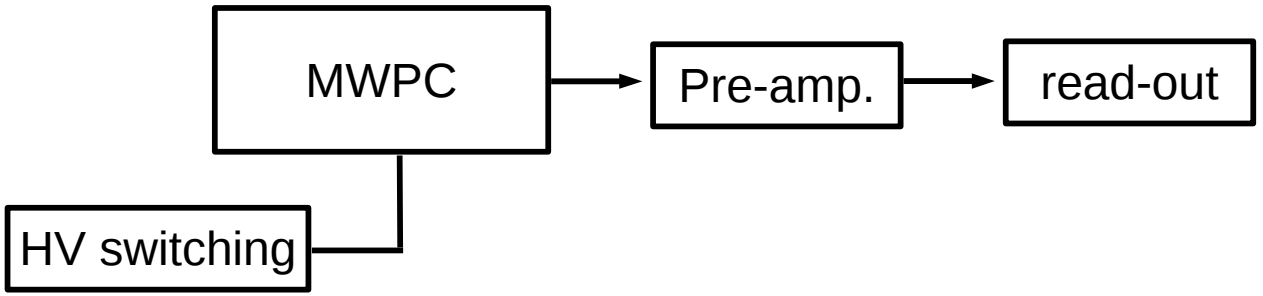
- Readout signal from MWPC, PMTs signal and store data to disk



- Monitor beam off timing background – after proton background
- Monitor cosmic rays background

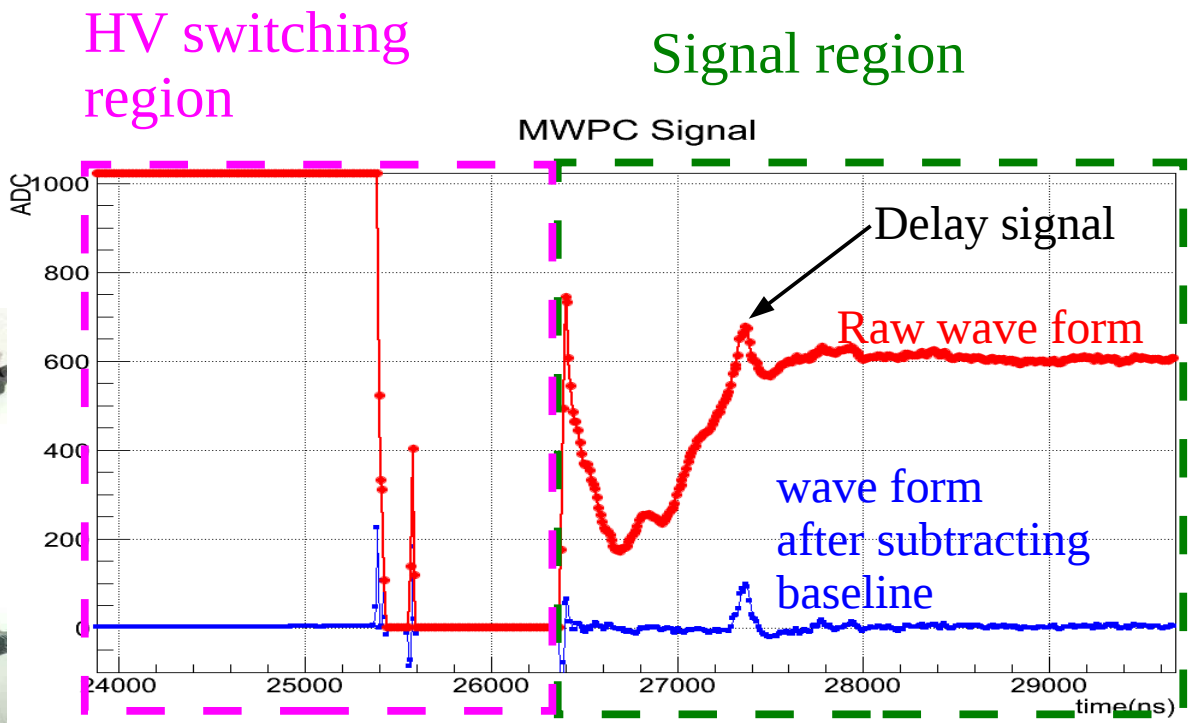
MWPC Signal

- Readout signal from MWPC for DeeMe experiment



MWPC, 96 channels

Pre- amplifier



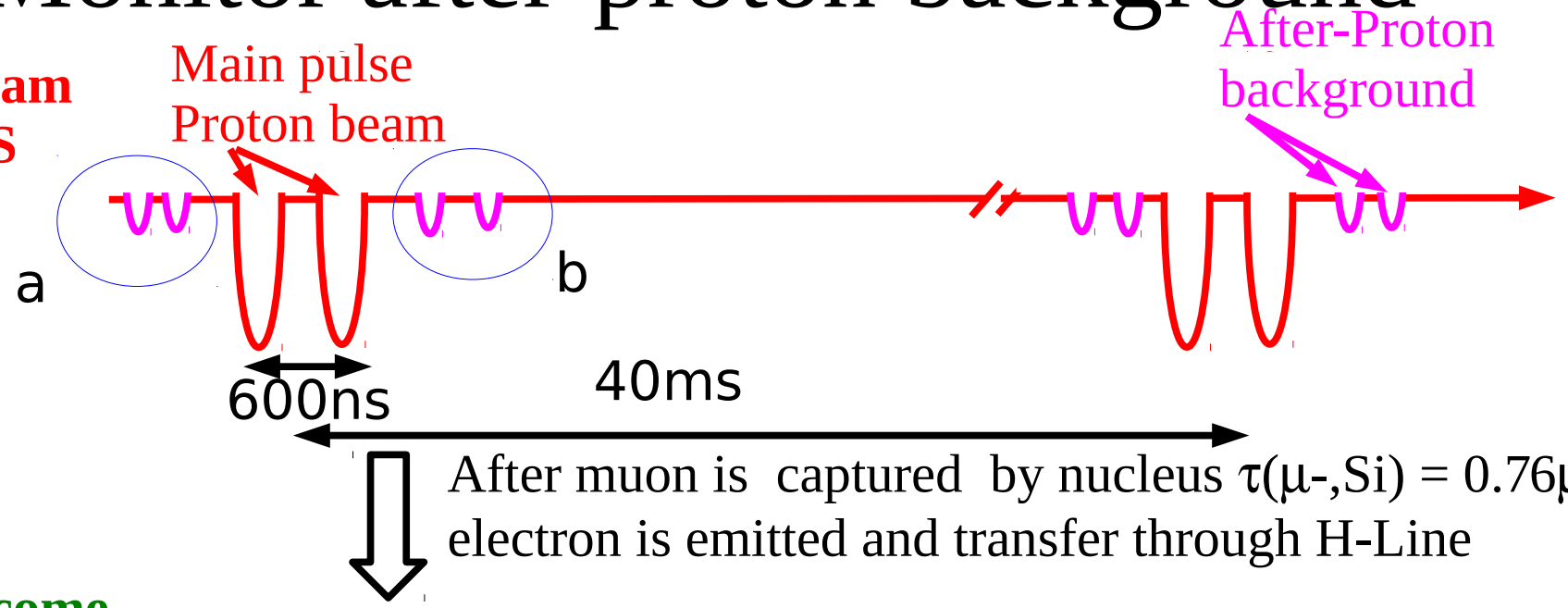
Signal of MWPC in the beam test with e- beam at KURRI, Aug 2014

We want to see delay signal but the base line is not flats

=> should use FADC board to readout signal

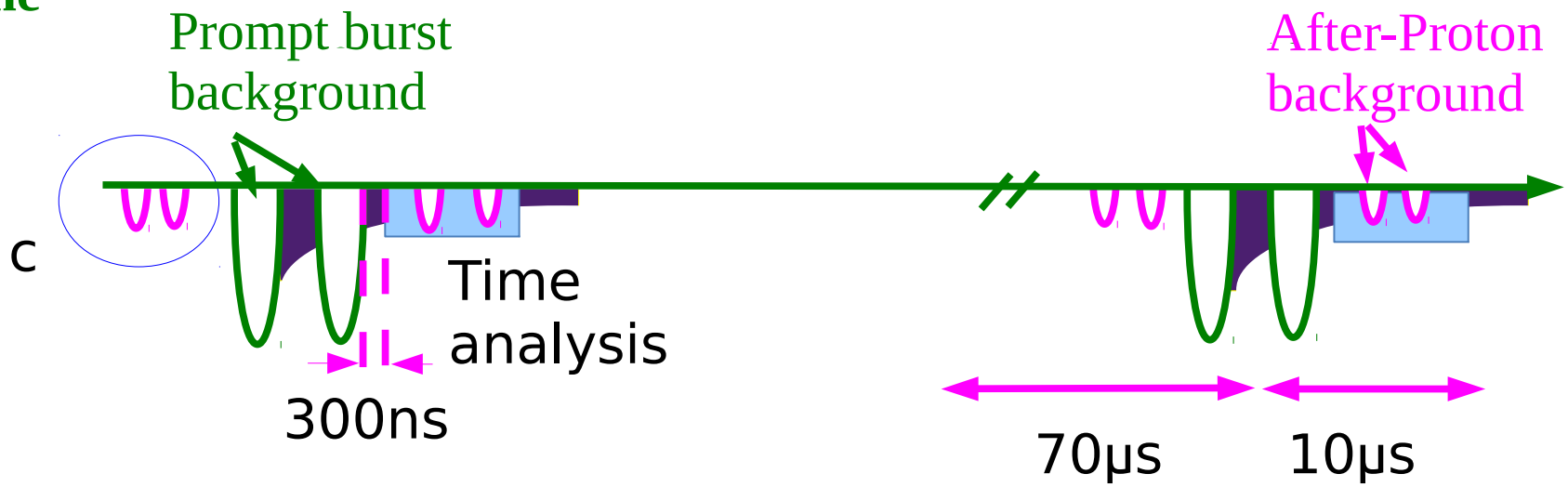
Monitor after-proton background

Proton pulsed beam from RCS



After muon is captured by nucleus $\tau(\mu^-,Si) = 0.76\mu s$, electron is emitted and transfer through H-Line

Electron come to tracker



We can “simply” estimate after proton background affect to our data by:

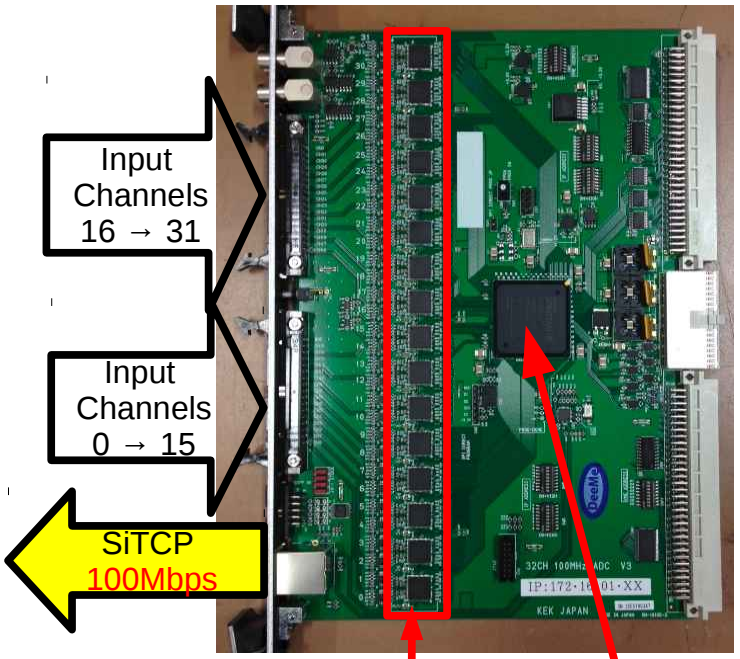
$$APB = \frac{c}{a} \times b$$

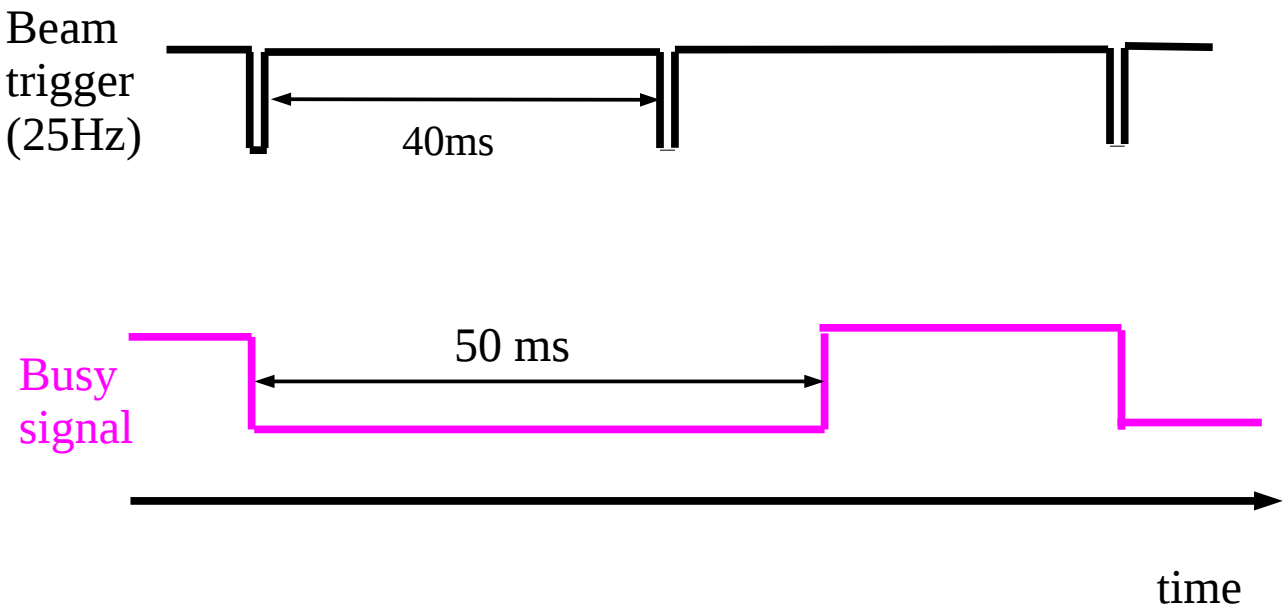
FADC readout board

- 10-bits 100-MHz FADC board, hardware was developed by IGARASHI Youichi for TREK experiment,
  it can record long waveform ~80 μs, useful for after proton background monitoring

  dead time 50 ms

- ✔ Readout signal from MWPC for DeeMe experiment but its dead time too long



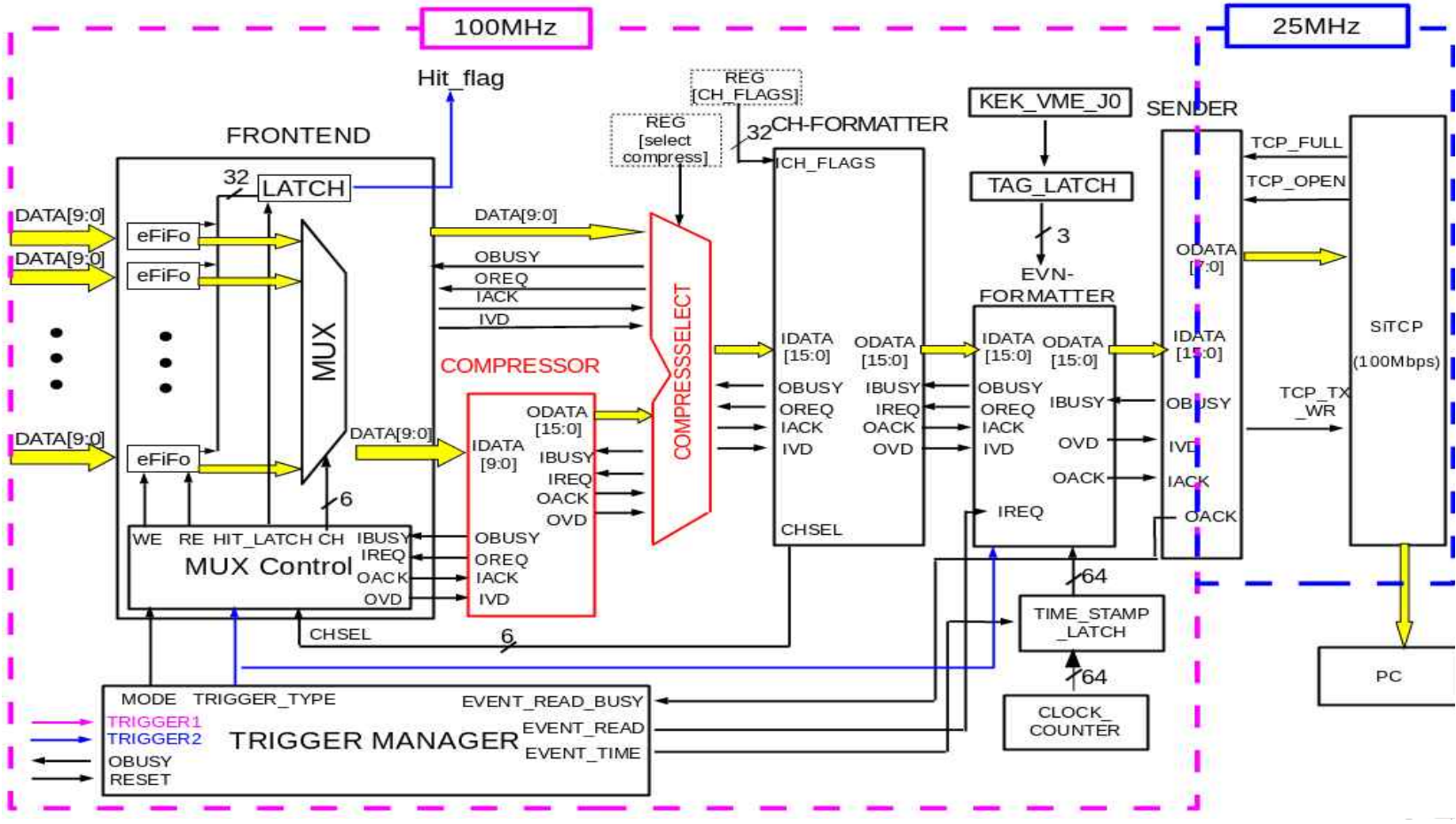


FADC readout board

Rewrite firmware for DeeMe experiment
+ record long waveform 80 μs, data of 1 FADC readout board ~ 4.5Mbyte/s
+ small dead time ~18ms by using compressor module in FPGA

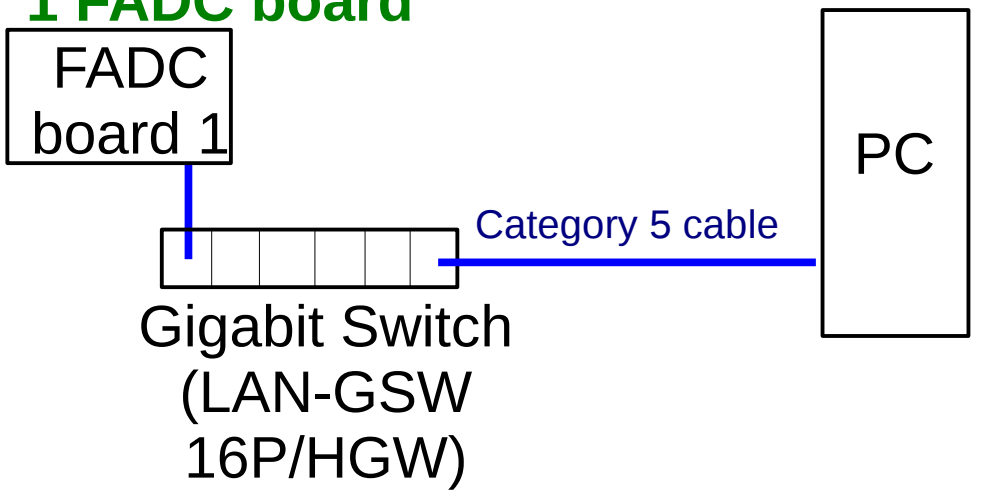
✓ Readout signal and monitoring after proton background
+ implement self trigger

✓ Useful for cosmic rays monitoring



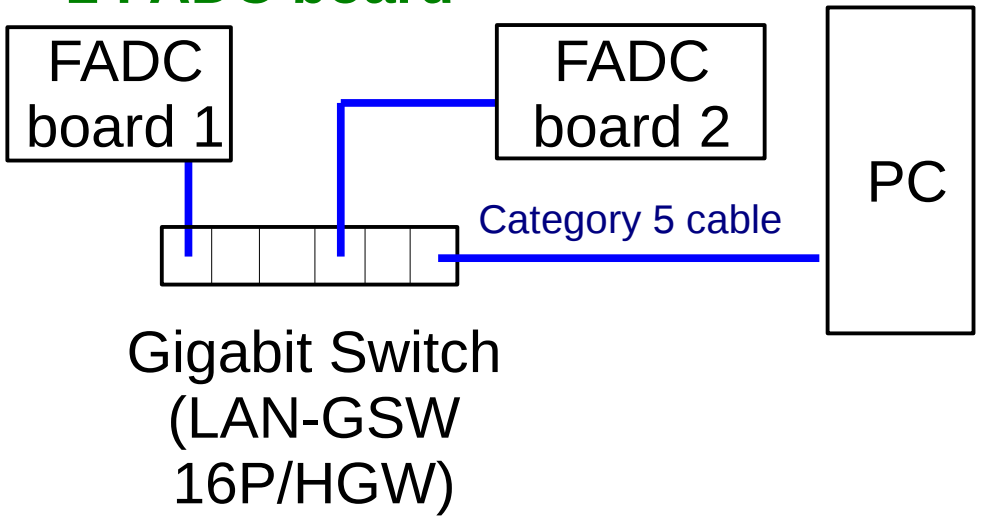
Test FADC boards & data transfer

First setup with 1 FADC board



Trigger rate: 25Hz
Acceptance trigger rate: 25 events /s
Data rate: 4.5 Mbyte/s
Busy signal: ~18 ms

Second setup with 2 FADC board



Trigger rate: 25Hz
Acceptance trigger rate: ~2 events /s
Data rate: ~0.38 MByte/s
Busy signal: ~ 500ms

Gigabit Switch (LAN-GSW 16P/HGW)

Test FADC boards & data transfer

→ Use high performance network switch, Cisco Catalyst WS-C3850-24T-S

14 FADC boards

High performance network switch
Cisco Catalyst WS-C3850-24T-S

DAQ screen base on MIDAS

Run Status

Run 17 Running

Stop

Start: Fri Mar 27 18:22:58 2015 Running time: 0h00m48s

Alarms: On Restart: No Data dir: /home/DeeMe/DAQ/data

Experiment Name: DeeMe_experiment

18:22:58 [mhttpd,INFO] Run #17 started

Equipment

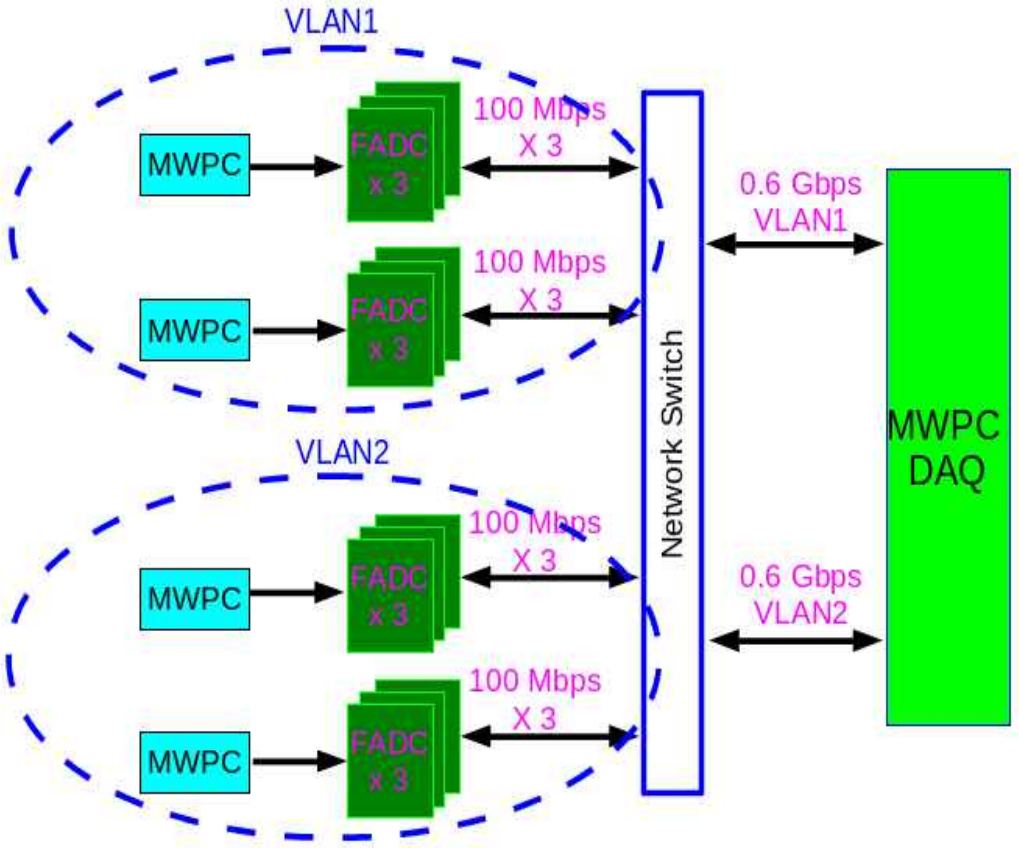
Equipment	Status	Events	Events[/s]	Data[MB/s]
SiTCP_board2	feSiTCP_board2@DeeMe	2249	49.8	5.174
SiTCP_board4	feSiTCP_board4@DeeMe	2302	50.0	5.197
SiTCP_board7	feSiTCP_board7@DeeMe	2385	50.0	5.190
SiTCP_board3	feSiTCP_board3@DeeMe	2247	50.0	5.191
SiTCP_board17	feSiTCP_board17@DeeMe	2305	50.0	5.204
SiTCP_board5	feSiTCP_board5@DeeMe	2264	50.0	5.198
SiTCP_board6	feSiTCP_board6@DeeMe	2299	49.8	5.179
SiTCP_board3_2	feSiTCP_board3_2@DeeMe	2315	50.0	5.303
SiTCP_board3_3	feSiTCP_board3_3@DeeMe	2310	49.9	5.289
SiTCP_board3_4	feSiTCP_board3_4@DeeMe	2267	49.7	5.203
SiTCP_board3_5	feSiTCP_board3_5@DeeMe	2312	50.0	5.205
SiTCP_board3_6	feSiTCP_board3_6@DeeMe	2312	50.0	5.239

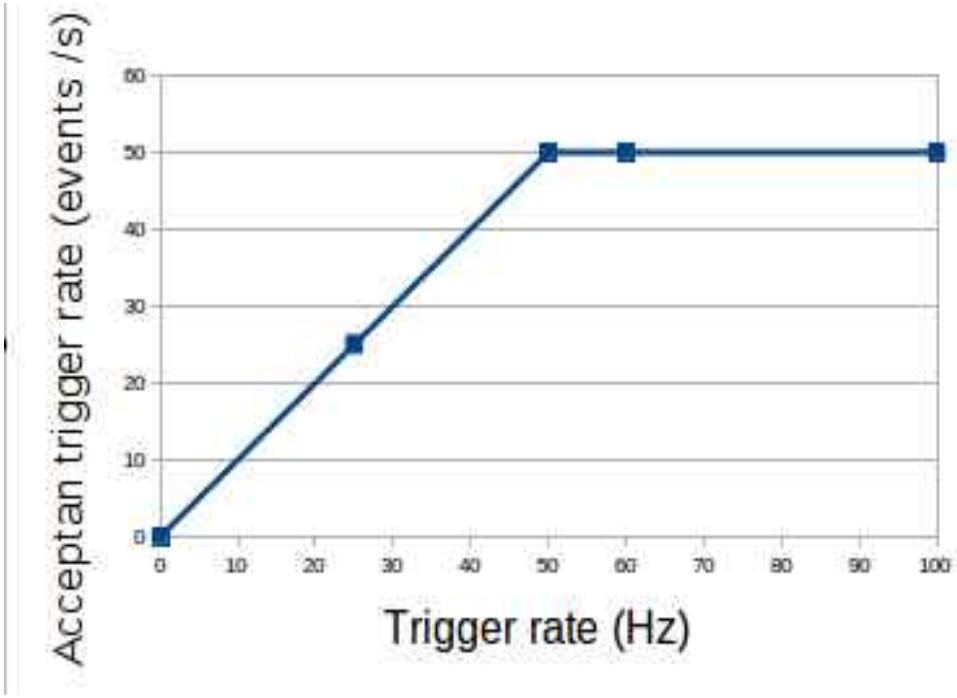
Test FADC boards & data transfer

1 FADC board has 100 Mbps data transfer

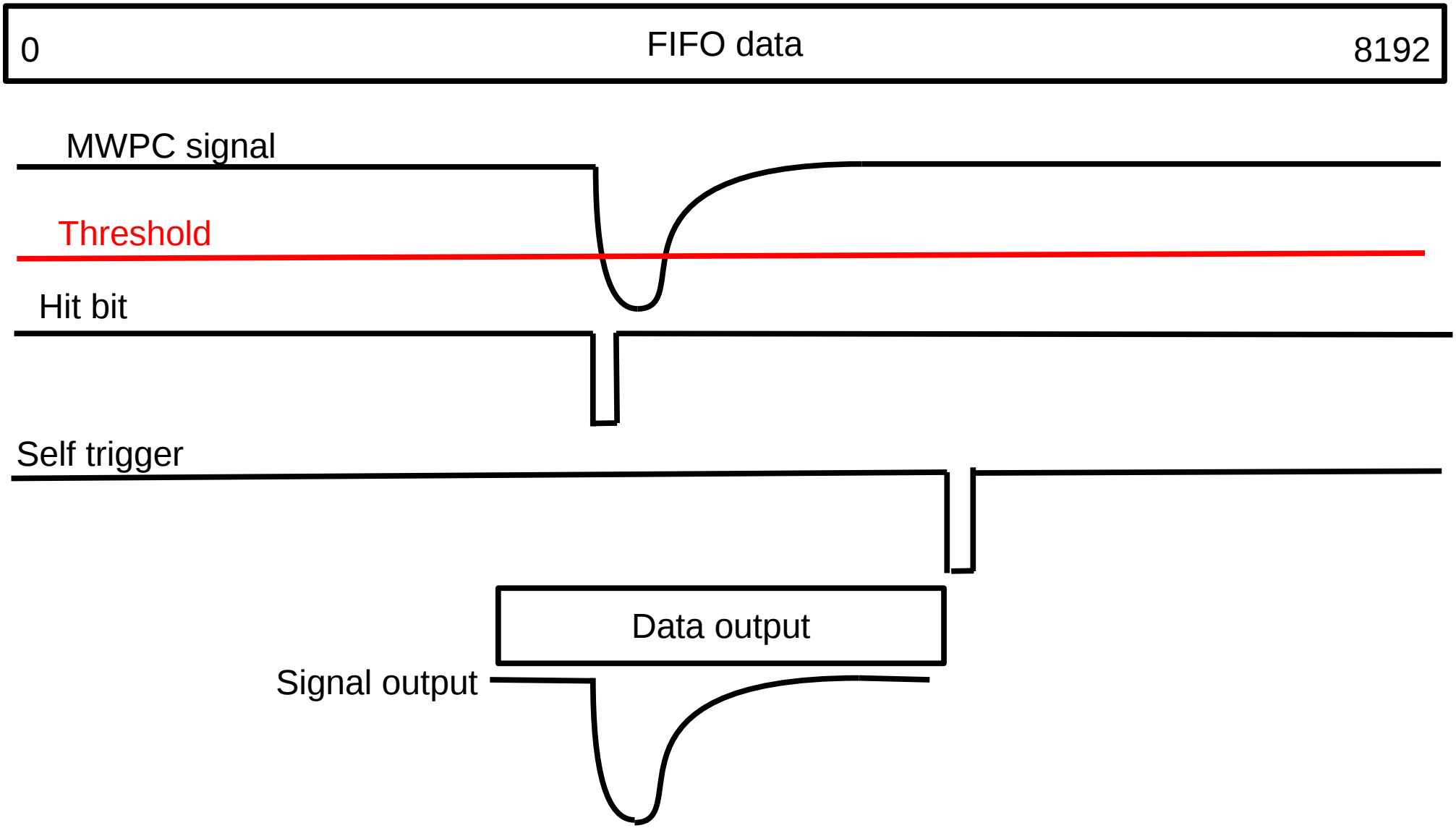
→ 12 FADC boards have 1.2 Gbps data transfer, it will overload the network cable and network switch

=> Use VLAN to divide FADC boards to 2 groups for data transfer better



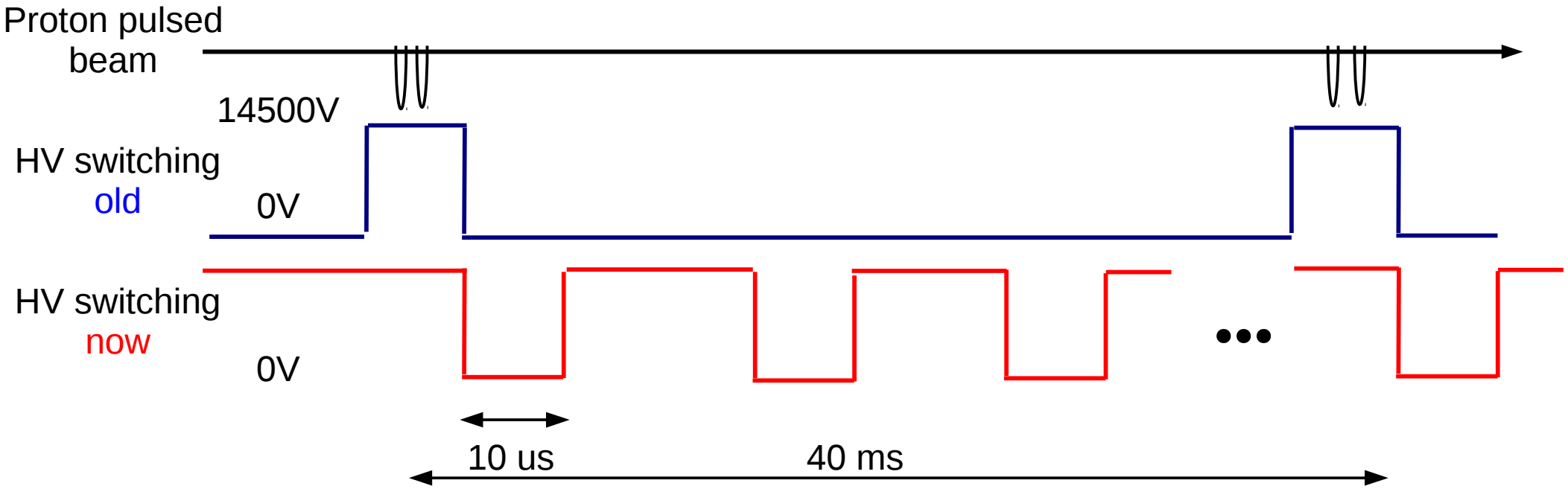


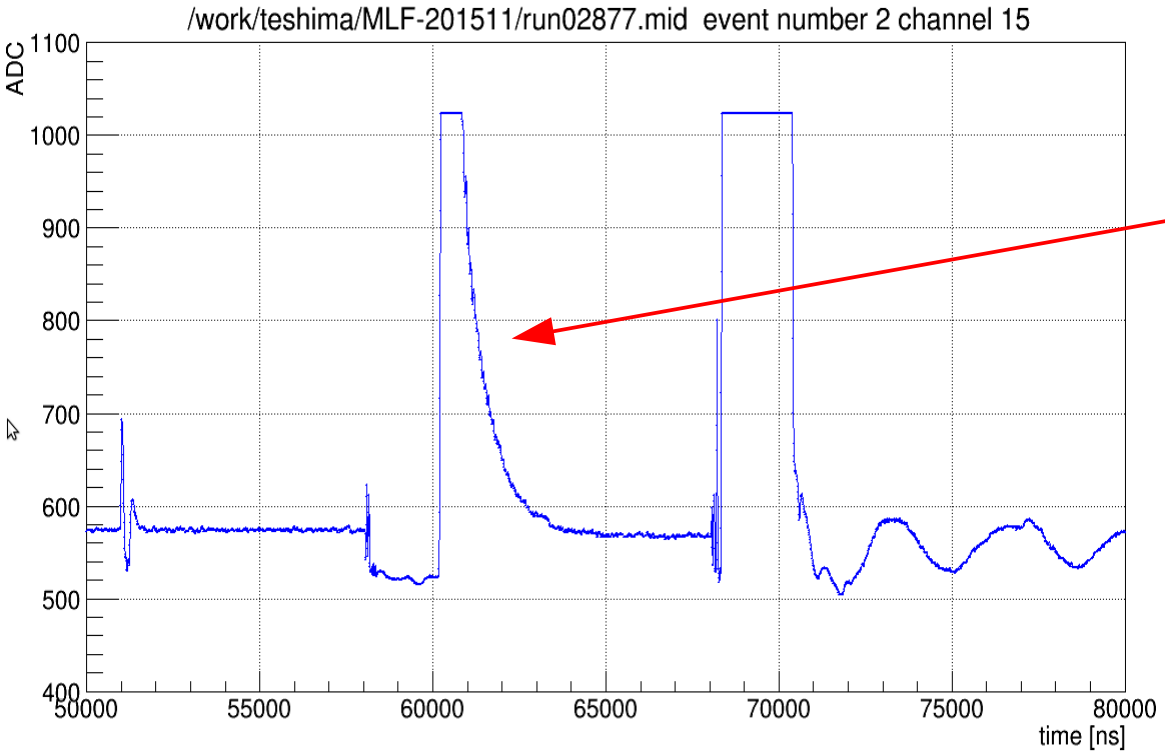
Cosmic rays trigger or self trigger



* This trigger only work when base line is flat

From Oct. 2015, we change condition of HV switching

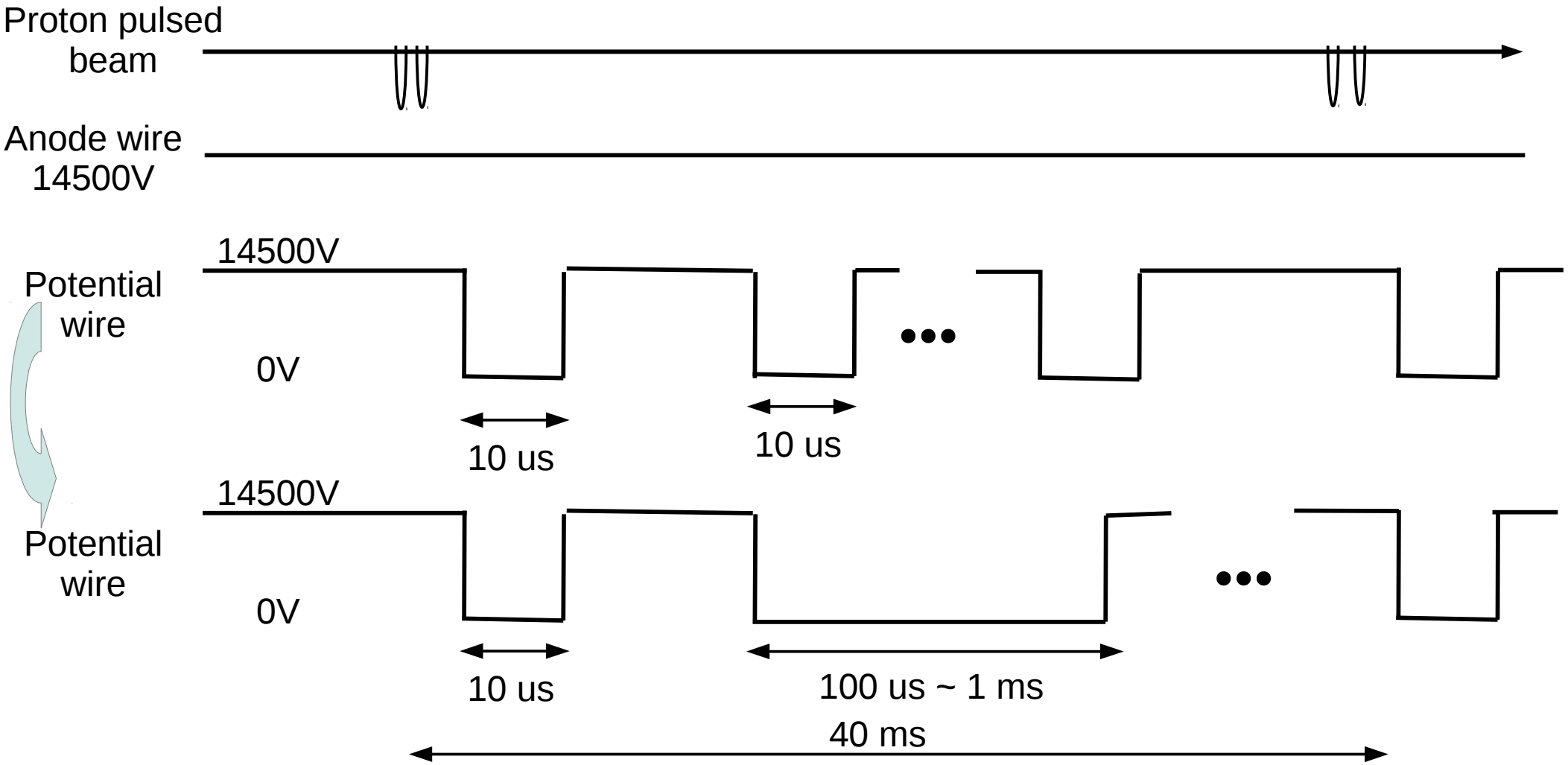




* Base line in 10 us is not flat

Two ways to monitor cosmic rays background

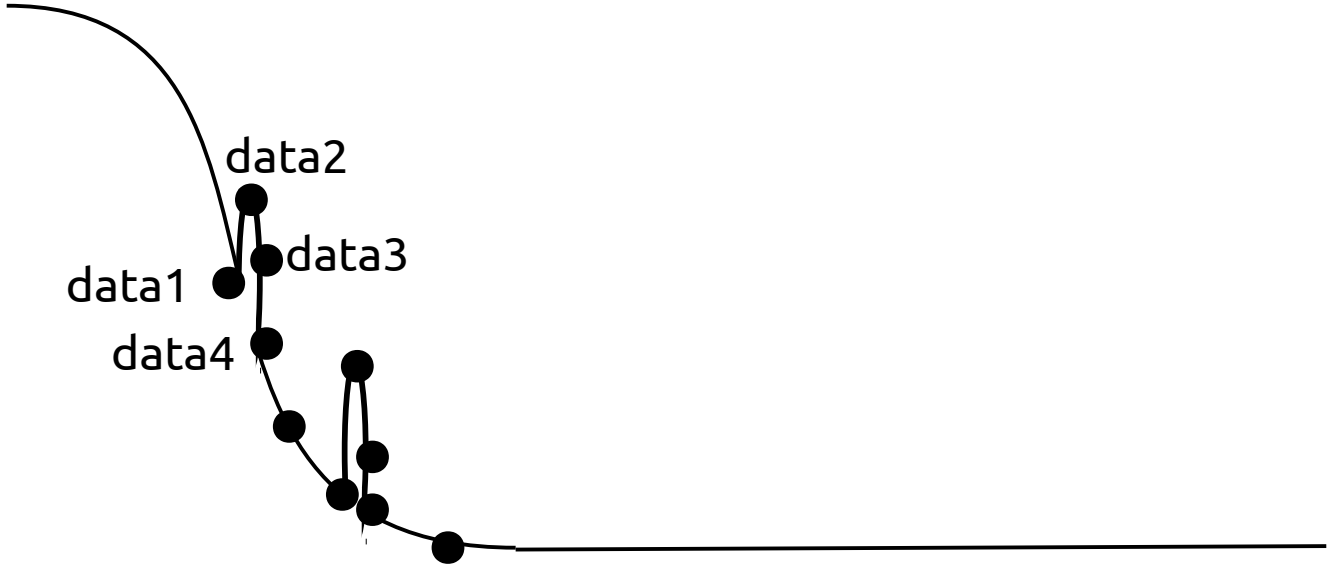
First method: change HV switching condition



In this method, we have long flat base line and we can use old self trigger, which I already install to FADC readout board

Second method:

Keep HV switching status and implement new self trigger



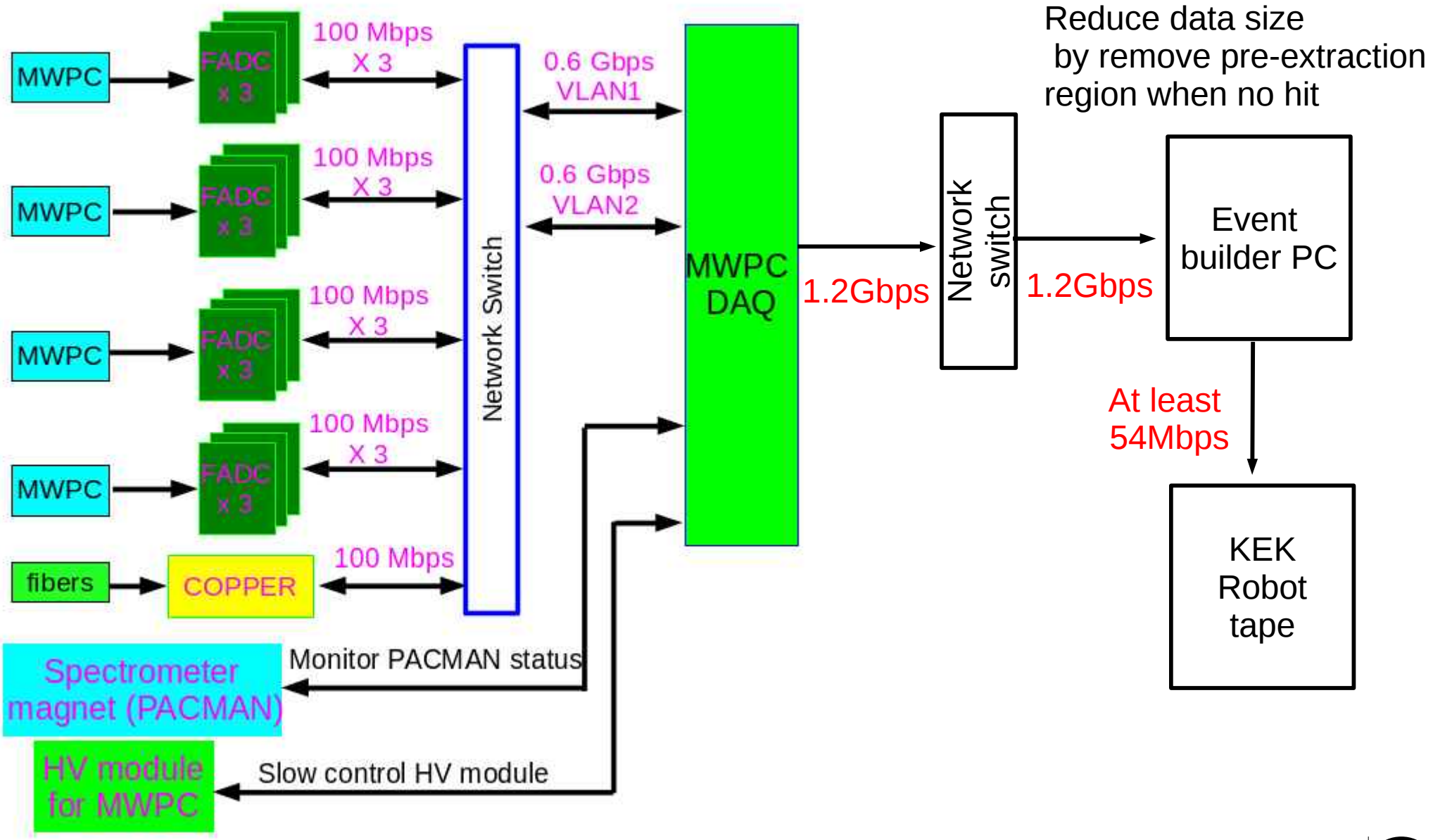
Condition for self trigger: data1 < data 2 > data 3 > data 4

* This is new idea for new self trigger, we have not install to FADC board

Base on simulation and hardware of HV switching and we will select which method is better for us

DAQ Design

The final design for MWPC DAQ



Data size to transfer and store to Robot tape library

- 1 FADC readout board with 80 μs waveform has 0.18 Mbyte/events

  → 4.5 Mbyte/s (since 25 events/s)

- We need 10 μs after extraction to lock at μ – e conversion signal

  →data size need to store of 1 FADC readout board ~ 0.56 Mbyte/s

  →data size need to store of 12 FADC readout board ~ 6.7 Mbyte/s = 54 Mbps

  This data will be transfered to KEK robot tape

- For 1 days run, we need store data:

  (54 x 3600 x 24) : 8 = 0.6 Tbyte/days

Summary

- We design new firmware for FADC readout board which satisfy for DeeMe project

  +New firmware with delta compression algorithm to compress data and achieved busy signal with 8192 sample point and 32 channel ~ 18ms

  + Slow control to readout board

- Make DAQ with multiple FADC boards and test network performance
- DAQ and FADC board are working well now, we already test DAQ and 3 FADC boards in beam test at MLF Nov 2015
- Next step:

  + We will make new self trigger for readout board if it is necessary

  + Build event builder PC to reduce data size

  + Connect to KEK robot tape

Thanks for your attention

Data format of FADC Readout board

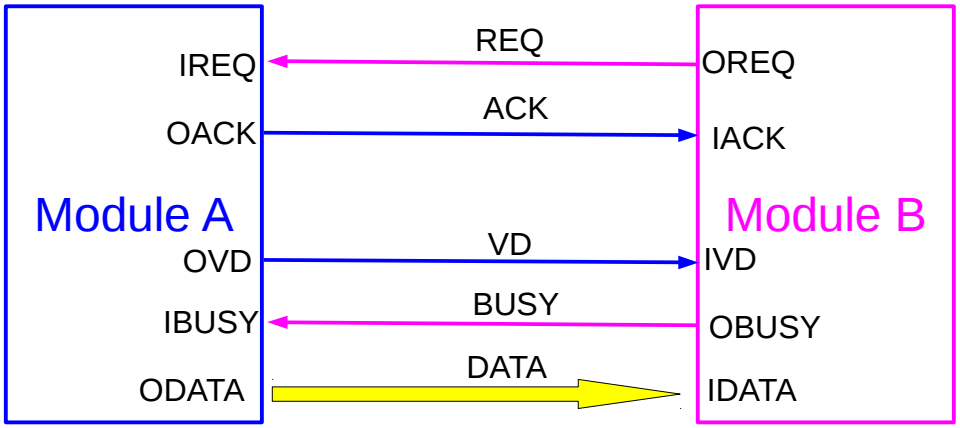
Word	Event Format
0xFAFA	Begin of Event
0xF1F2	Byte oder, 0xF1F2 = Big Endian, 0xF2F1 = Little Endian
0xA1A1 or 0xB1B1	Trigger type: 0xA1A1 = External trigger 0xB1B1 = Self trigger
$10a^7b^7$	a^7 = Header Format Version Code, b^7 = Firmware Version Code
$10c^{14}$	c^{14} = Module ID, lower 14-bits of module's IP address
$10d^{14}$	$d^{14}e^{14}$ = Local Event Number,total 28bits
$10e^{14}$	
$10f^9g^5$	f^9 = reserved, f^9 = Event tag
$10h^{14}$	$h^{14}i^{14}j^{14}k^{14}$ = Local Time stamp, total 56 bits
$10i^{14}$	
$10j^{14}$	
$10k^{14}$	
	Channel data format
0xFBFB	End of Event Data

Word	Channel Format
0xFFFC	Start of Channel Data Block
0xFC01	Module ID
$10l^{14}$	$l^{14}m^{14}n^{14}$ = Bit-Mask of Active channels
$10m^{14}$	
$10n^{14}$	
$0xFFq^8$	Start of channel q^8 = channel number
	Compressor data format
0xFDFD	End of Channel
$0xFFq^8$	Start of channel q^8 = channel number
	Compressor data format
0xFDFD	End of Channel
●●●	●●●
0xFFFD	End of Channel Data Block

Data format of compressor

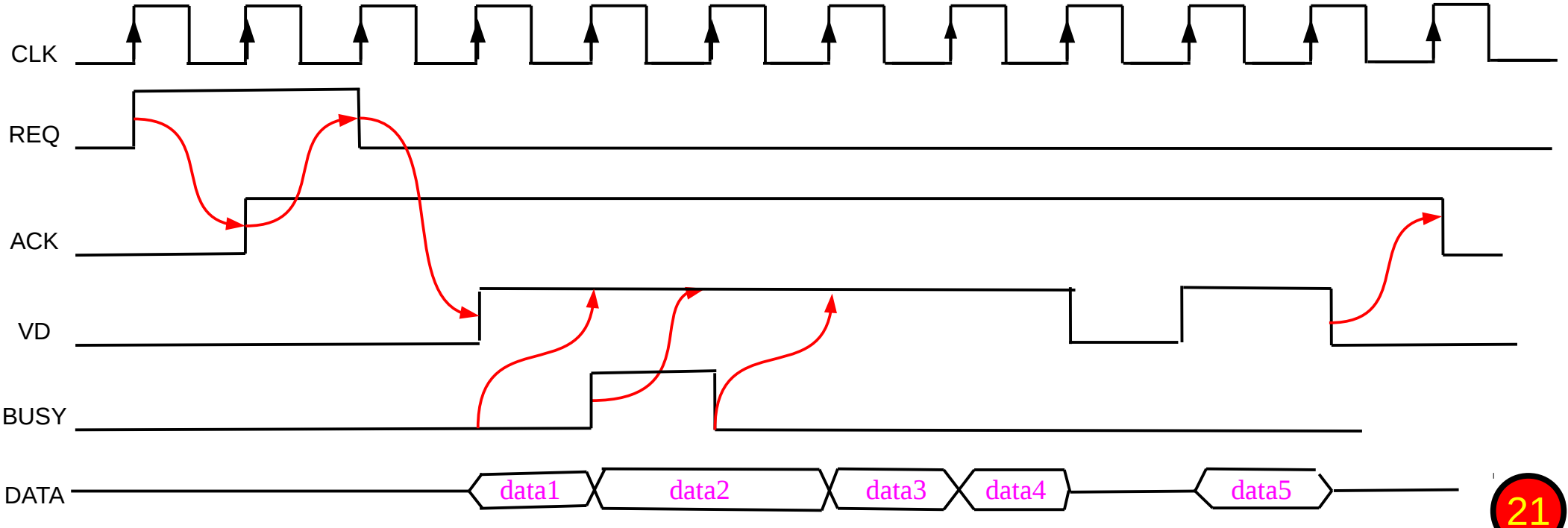
Begin of Compressor	**0xFEFE**									
Field size (raw data)	0	0	0	0						
Raw next	1									
Raw data	x	x	x	x	x	x	x	x	x	x
Raw data next	1									
Raw data	x	x	x	x	x	x	x	x	x	x
End raw data	0									
Field size(3-bits delta)	0	0	1	1						
3-bits delta	x	x	x							
3-bits delta	x	x	x							
●●●	●●●	●●●	●●●							
End of 3-bits delta	1	0	0							
Field size(n-bits delta)	n	n	n	n						
n-bits delta	x	x	x	x	●●●	x				
●●●	x	x	x	x	●●●	x				
End of n bits delta	1	0	0	0	●●●	0				
End of delta compressor stream	1	1	1	1						
End of Compressor	**0xFEFD**									

Handshake protocol between module A and module B



+User can modify their own data processor

+Transfer data in one clock

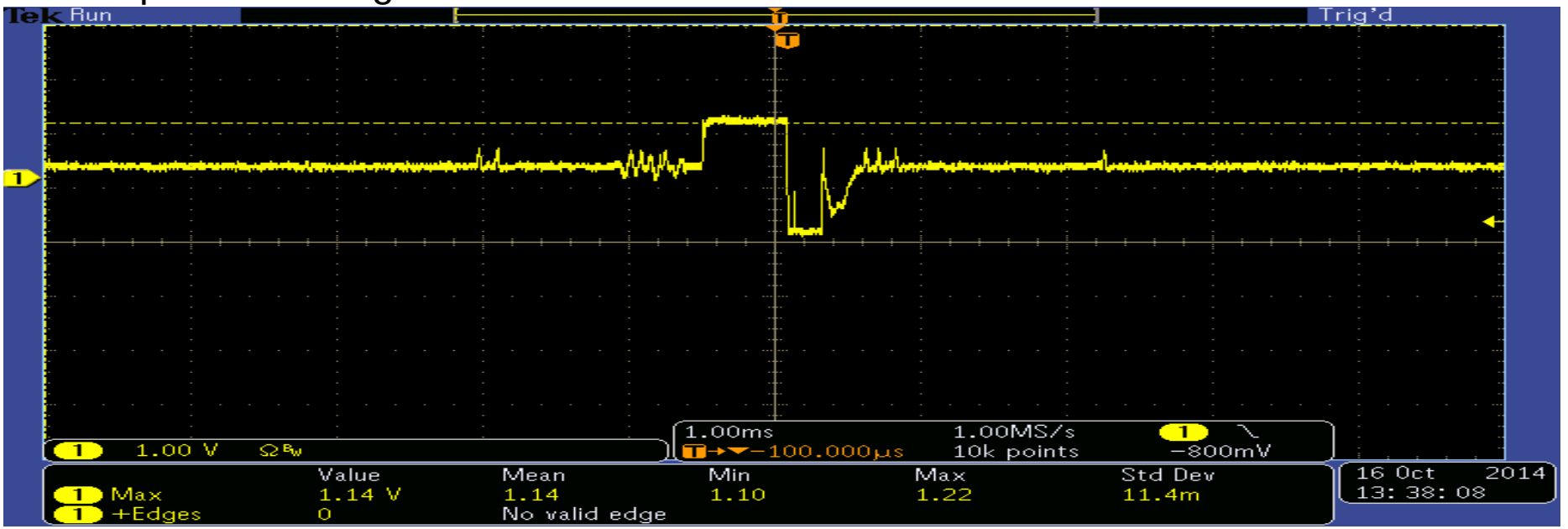


Data output of FADC Readout Board

Beam trigger

FIFO

Example MWPC signal will store in FIFO

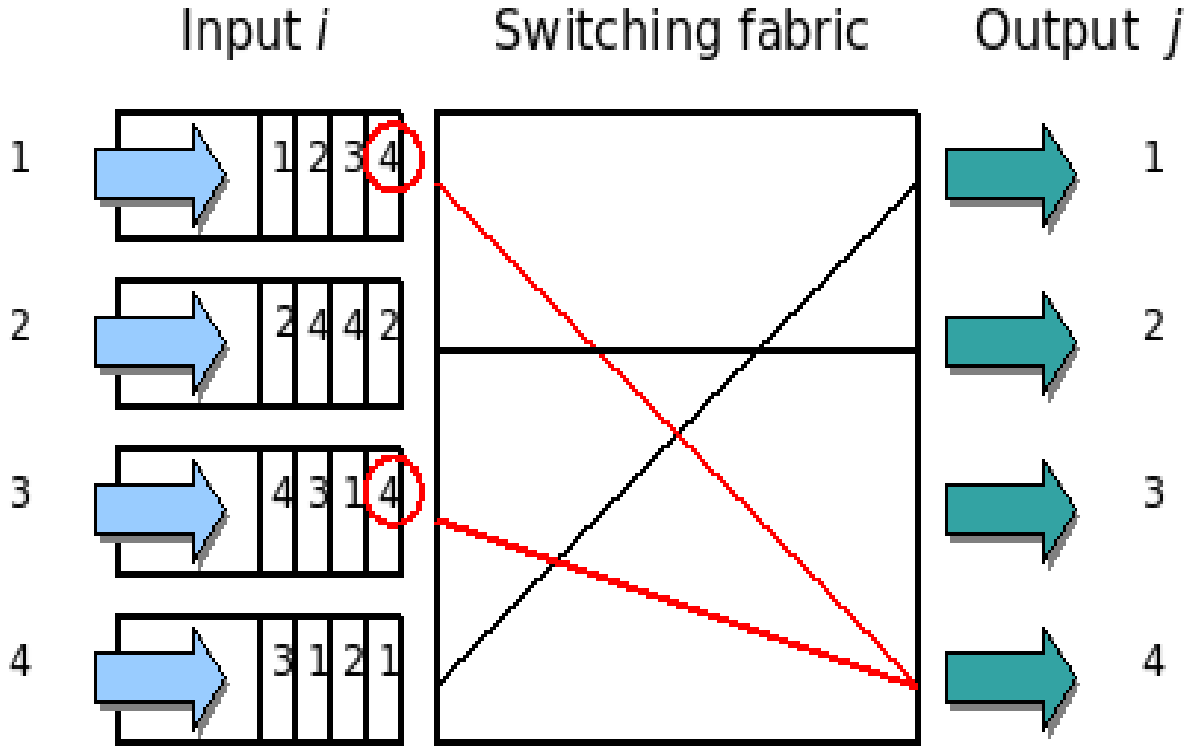


Beam trigger

Data output

HoLB Problem

- Packet buffer size is small 256 kbyte
- Head of Line Block problem (HoLB)



=> Find switch have larger buffer size

=> switch have Virtual Output Queue (VoQ) to solve HoLB