The Development Of DAQ System For J-PARC K^{O}TO Experiment

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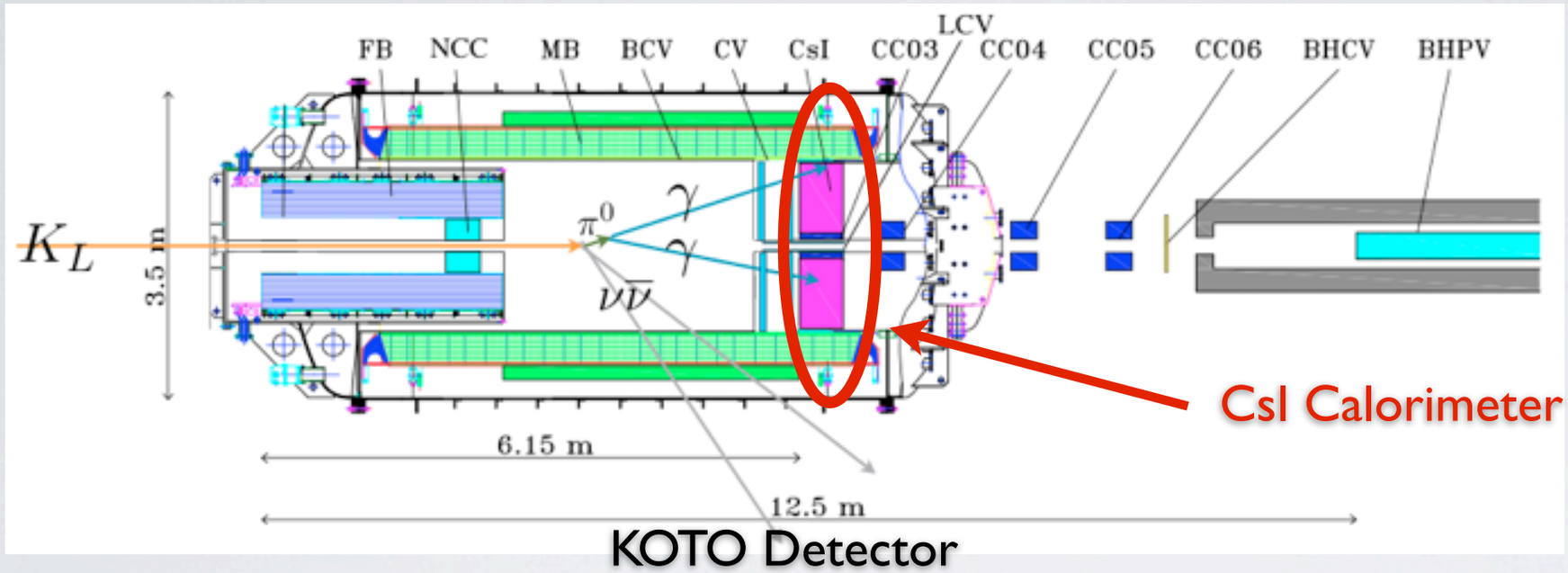
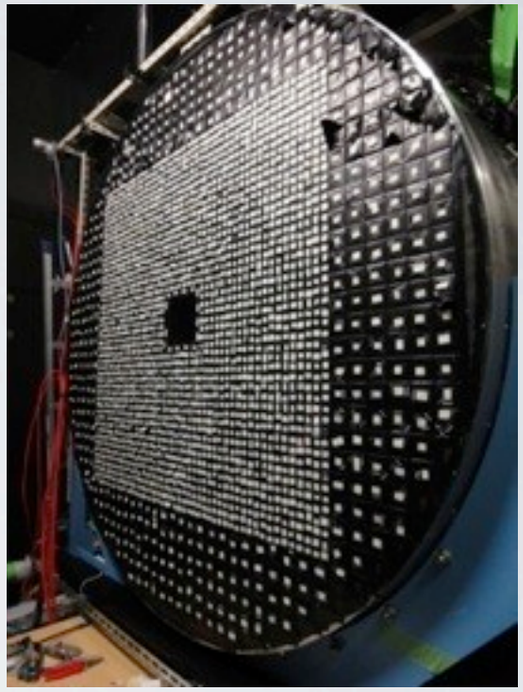
Year End report meeting
2010/12/19(Mon)

Contents

- KOTO Experiment
- Trigger/Data Acquisition(DAQ) system for KOTO experiment
- Current Status

KOTO Experiment

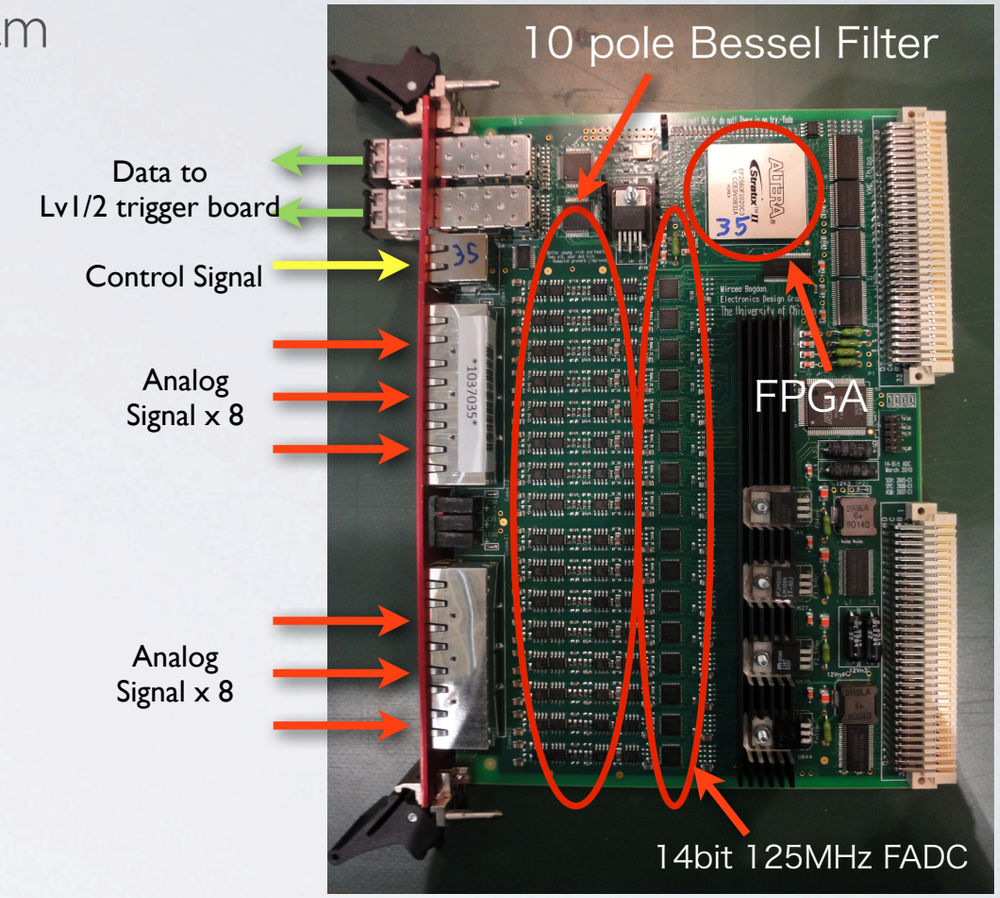


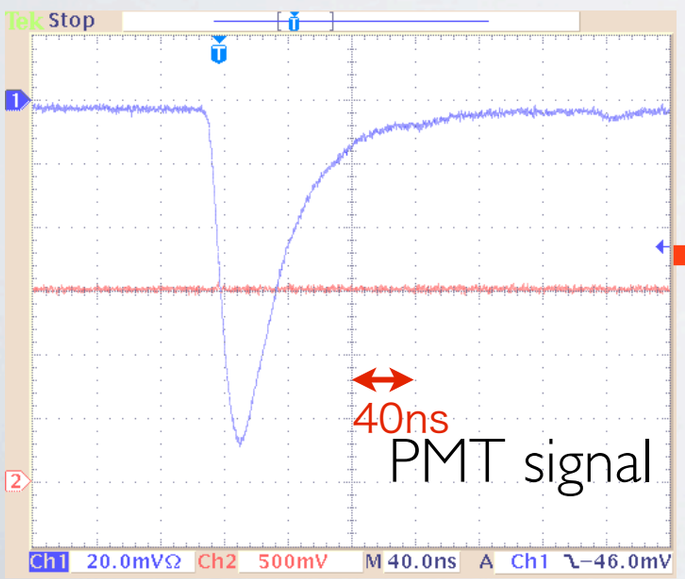


- Experiment for searching K meson rare decay mode: $K_L^0 \to \pi^0 \nu\bar{\nu}$
- Detect **γ** from **π**0 decay by CsI calorimeter.
  →Make trigger by signal from CsI calorimeter.
- Store all waveform information by Flash ADC ~3600 channel
- Can acquire timing and energy information.

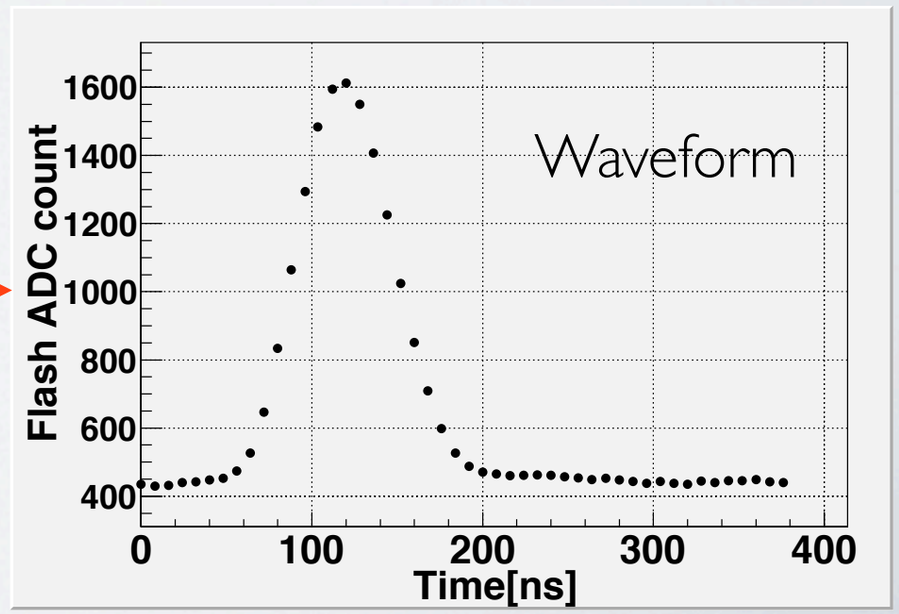
Waveform readout by Flash ADC

- Requirement
  - Deal with High hit rate comes from High Intensity Beam
    - Time resolution <1ns
    - Distinguish overlapped signal.
  - 14bit Energy resolution for1MeV~1GeV
- Digitize the signal from **all detector** and **store waveform** by **Flash ADC**
  - Use**125MHz Flash ADC** by stretching waveform with 10 pole Bessel Filter
  - Use 500MHz FADC for the detector near the beam.
- Use pipeline buffer to reduce dead time.

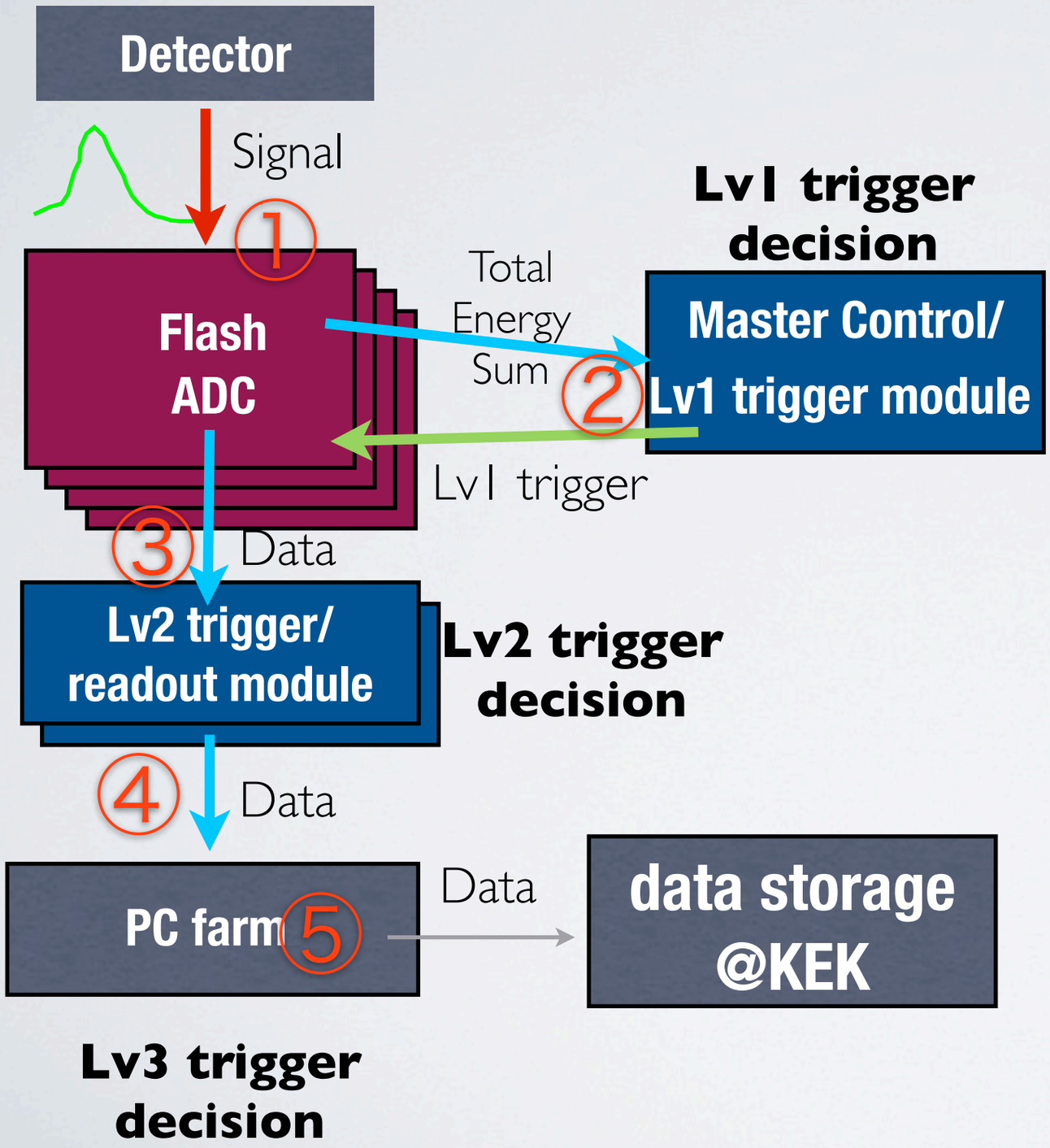




10pole Bessel FIlter → 14bit 125MHz Flash ADC →

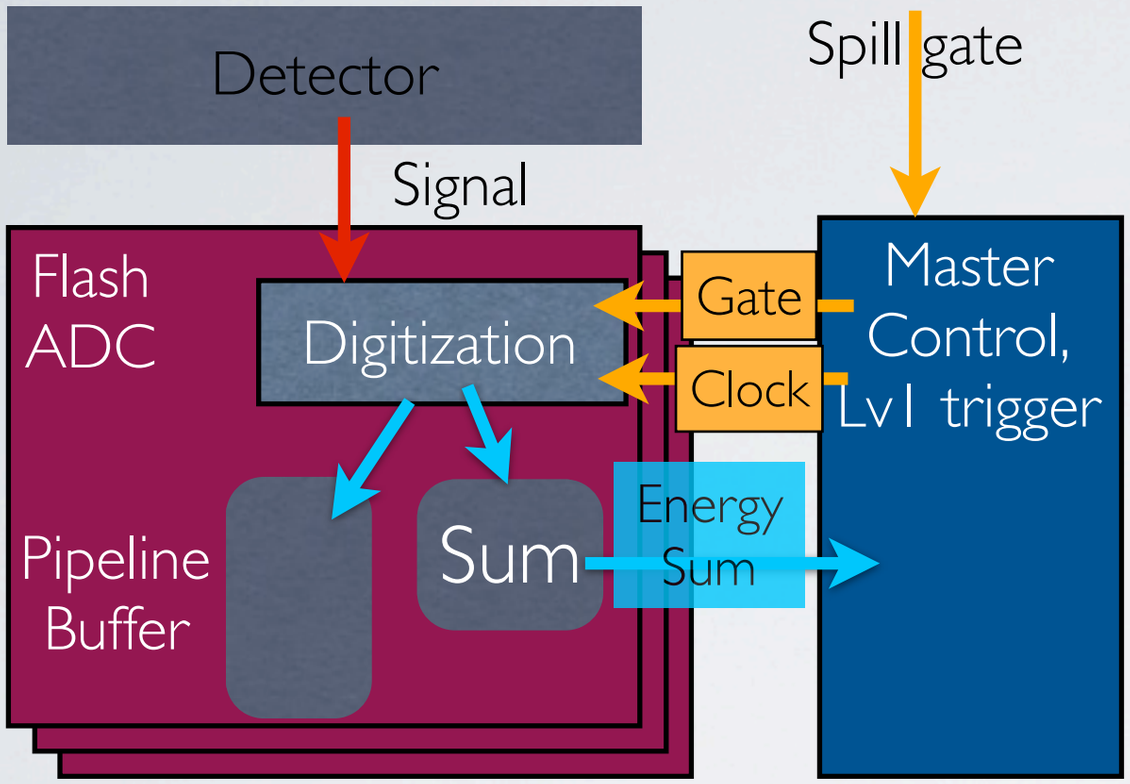


The Data Flow Of KOTO DAQ System

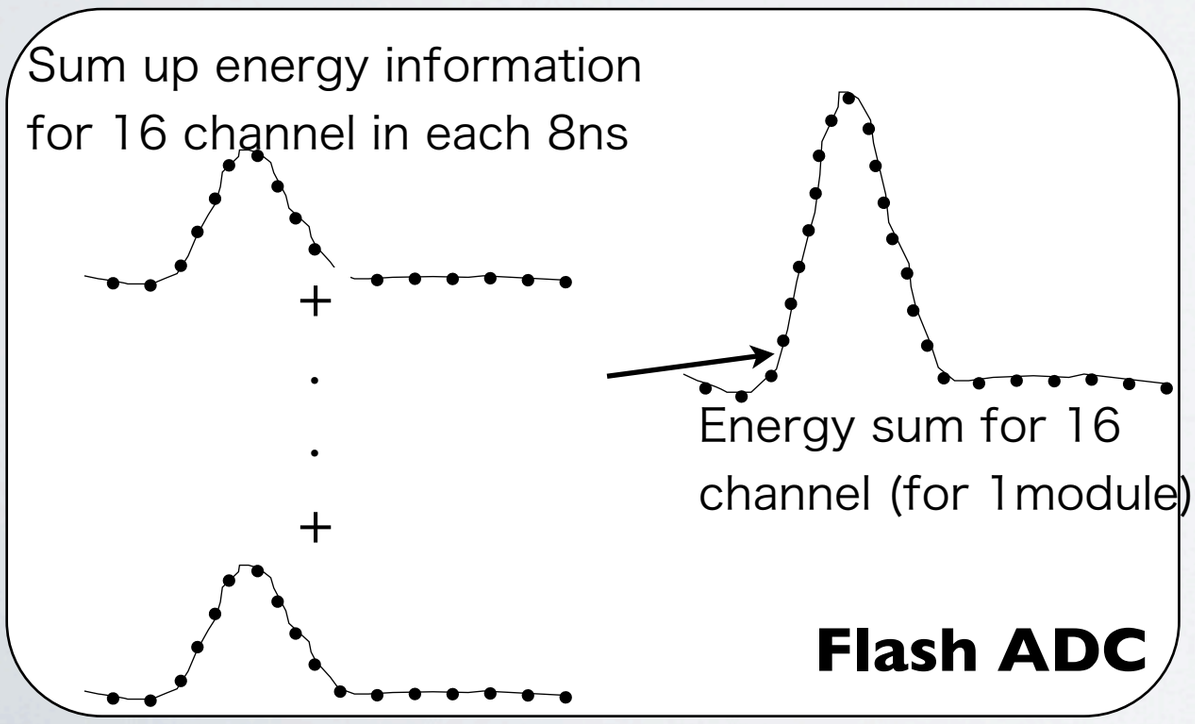


1. Digitization by Flash ADC
2. Online Trigger decision using the energy of CsI Calorimeter. (**Lv1trigger**)
3. Data readout from FlashADC to Lv2 trigger module,**Lv2Trigger decision.** **(Counting γ cluster etc...)**
4. Data transfer using Gigabit Ethernet.
5. Event building, **Lv3 Trigger decision**、Data storing.

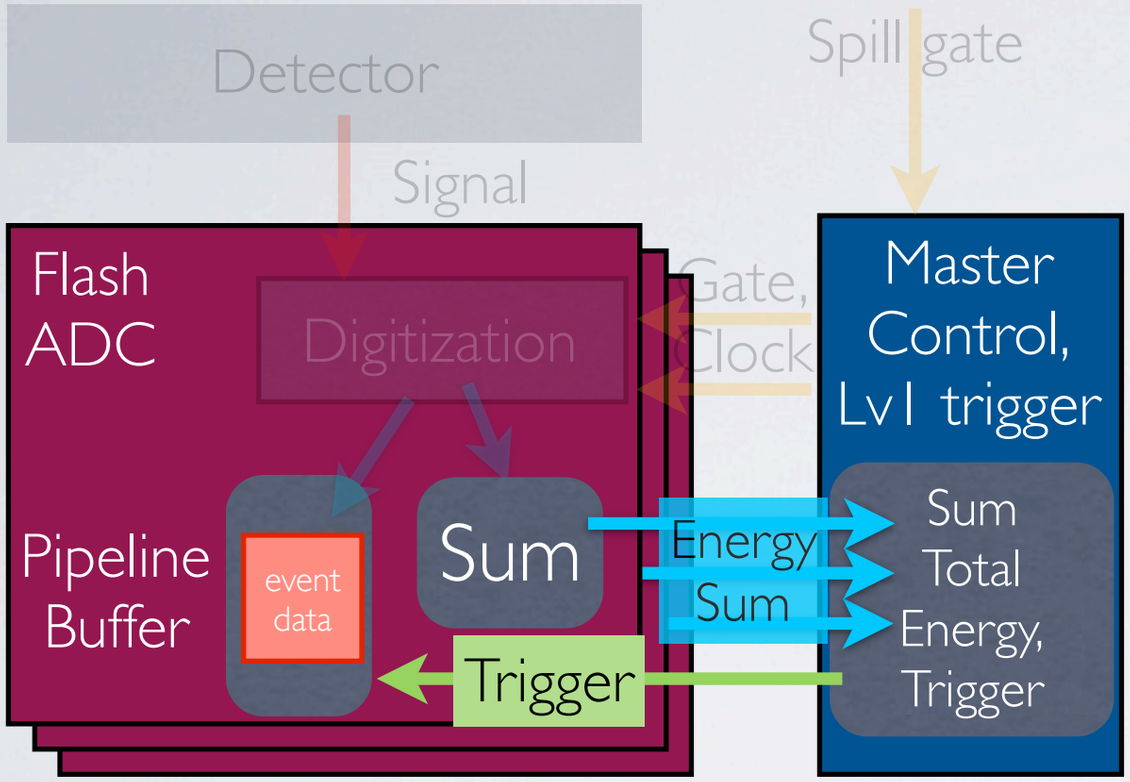
①Waveform Degitization Using FADC



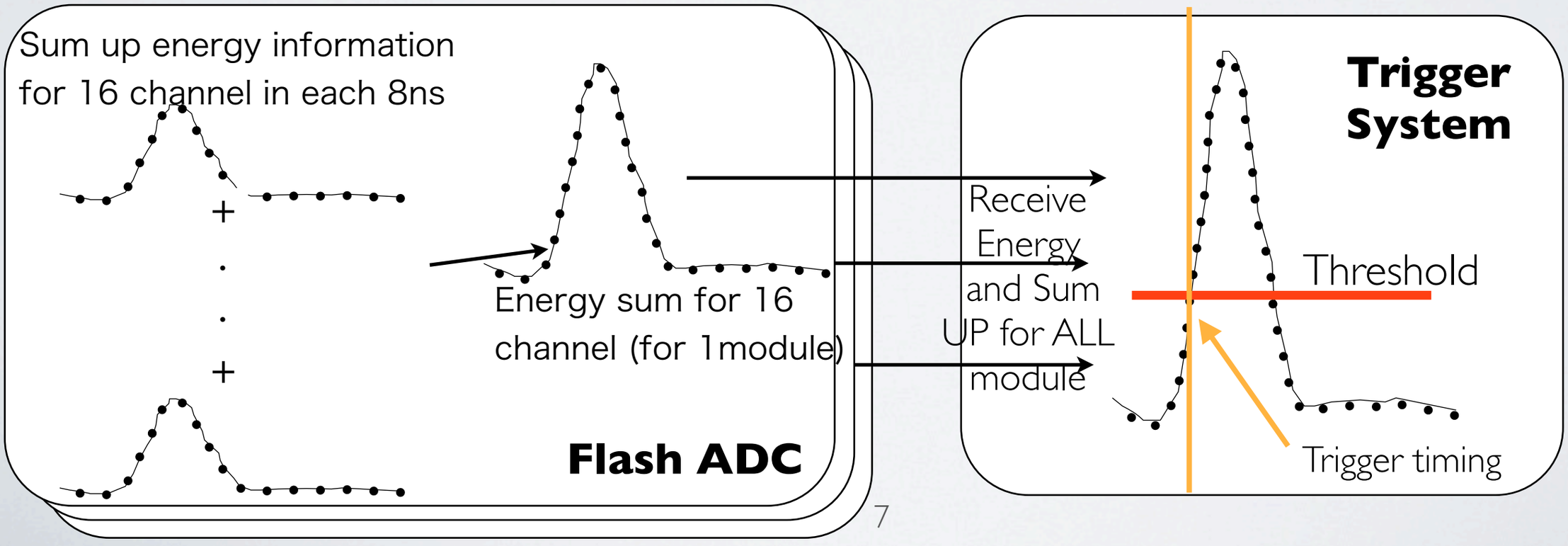
- Digitize the signal from detectors in each 8ns
- Store waveform information for 4μs in pipeline buffer.
- Sum up the energy in each module and send it to Trigger system



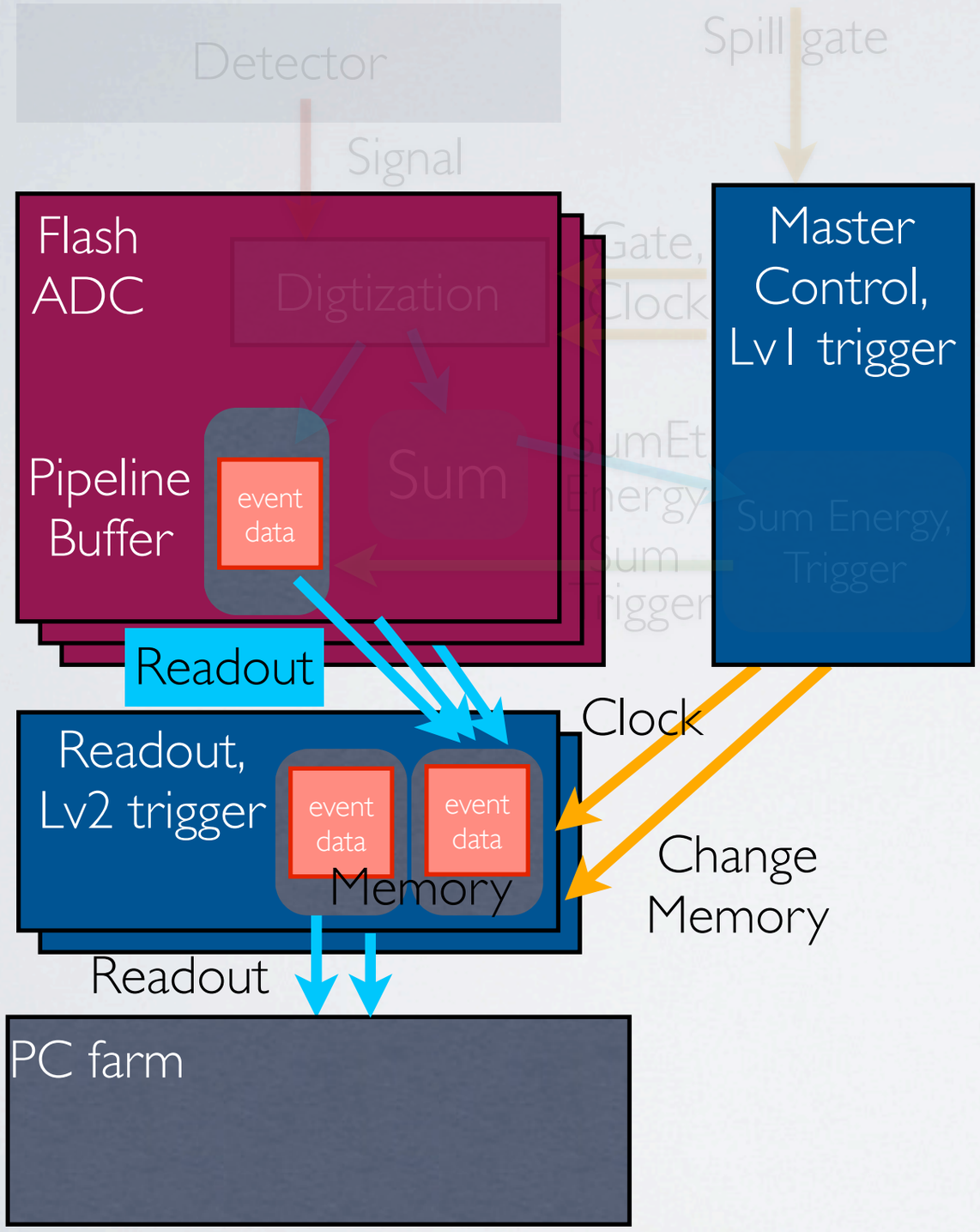
②Lv1 Trigger Decision



- Receive Energy information from All FADC modules using Optical link.
- **Calculate Total energy of CsI Calorimeter and Make Lv1 Trigger decision**
  - Compare Calorimeter energy with threshold
- Take event data from Pipeline buffer.

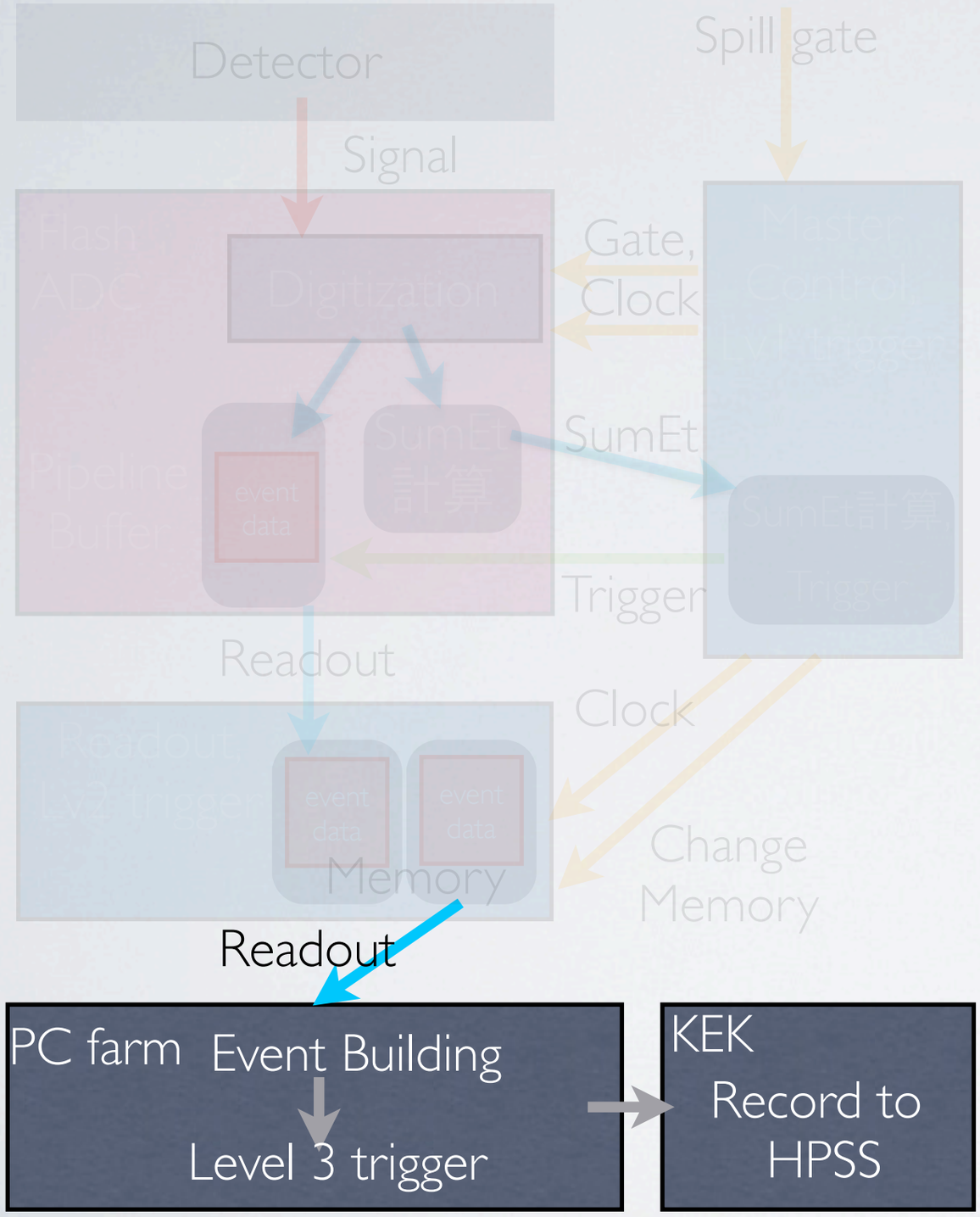


Read Out By Lv2 Trigger Module With③Optical Link ④Ethernet



- Readout event data from Flash ADC using Optical link, and store it into onboard memory in Lv2 trigger module.
- Making **Lv2 Trigger decision** using waveform information.
- Switch two onboard memory in every spill to maximize performance.
- Send event data to PC farm using Gigabit Ethernet.

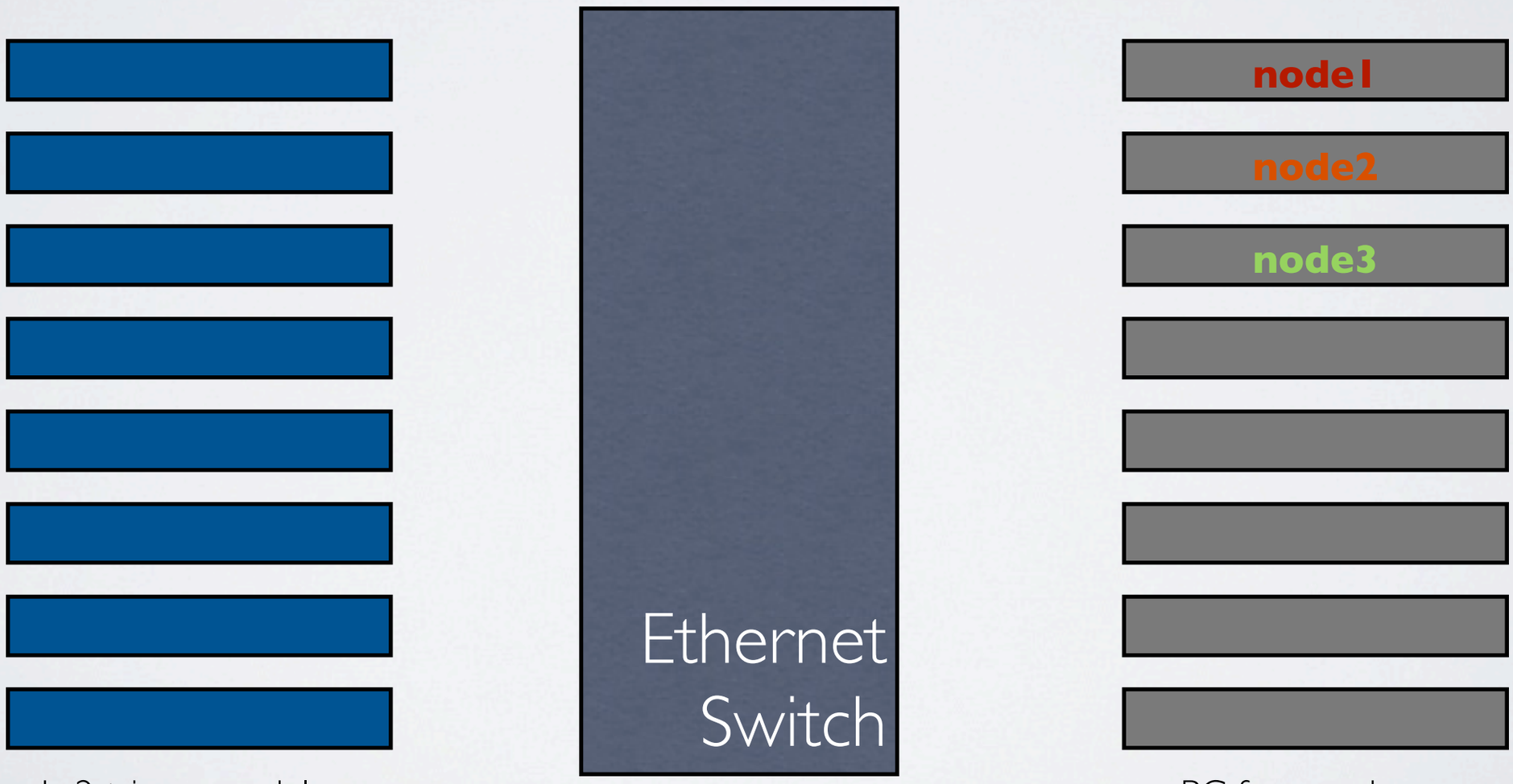
⑤Event Building



- Lv2 trigger module sends its data which is part of event data.
- PC farm build the event with data from all Lv2 trigger modules.
- PC farm process the event data
  - Online monitoring
  - Data compression
  - Lv3 trigger with online event analysis.
- And send event data to Storage at KEK

Event Building

- Use Network Switch and MAC address of PC Farm Nodes for Event building
  - Lv2 trigger board changes the "Destination MAC address of PC nodes" for each event.
  - Network switch sort the ethernet packet of event into one PC nodes



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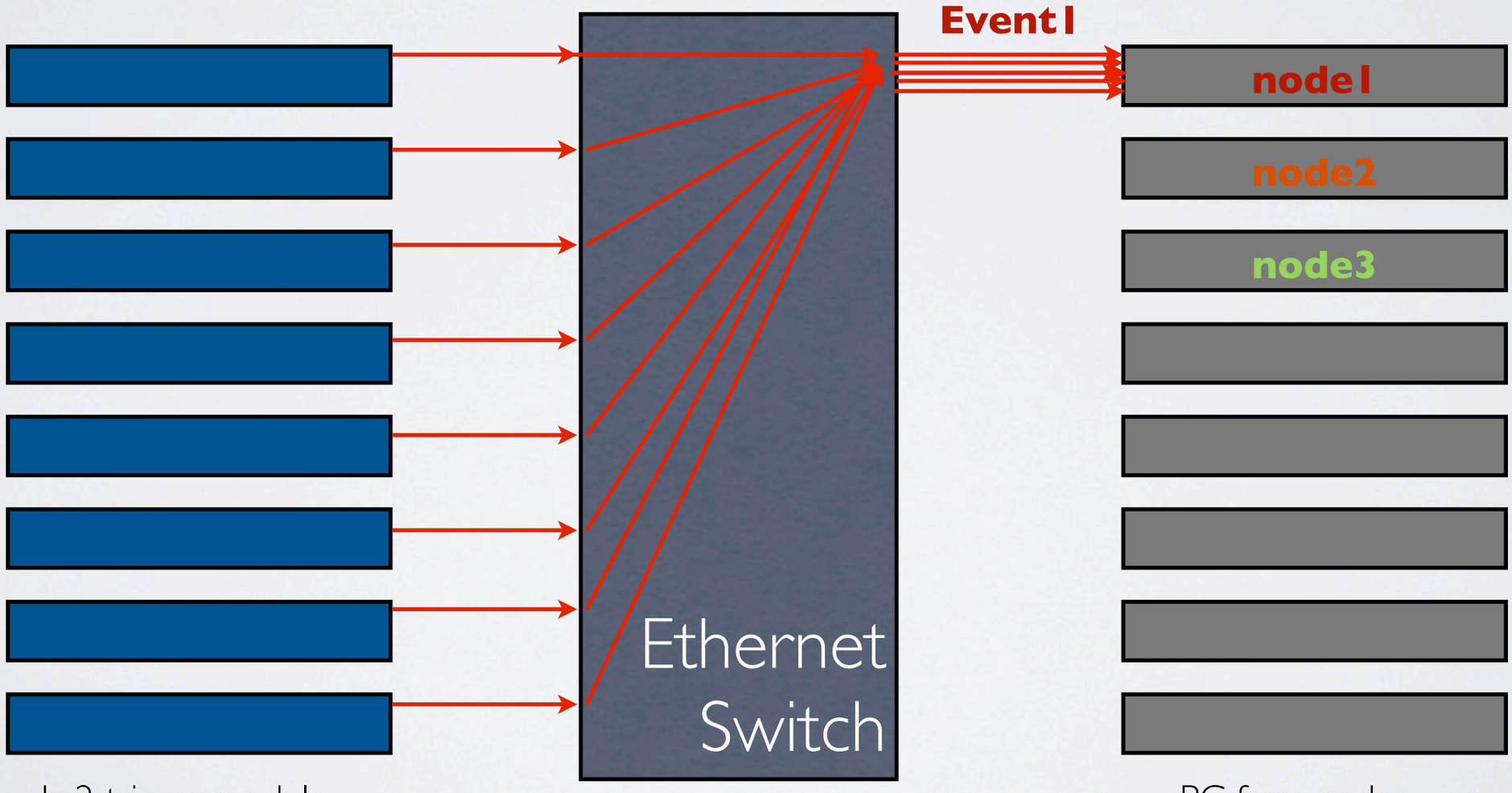

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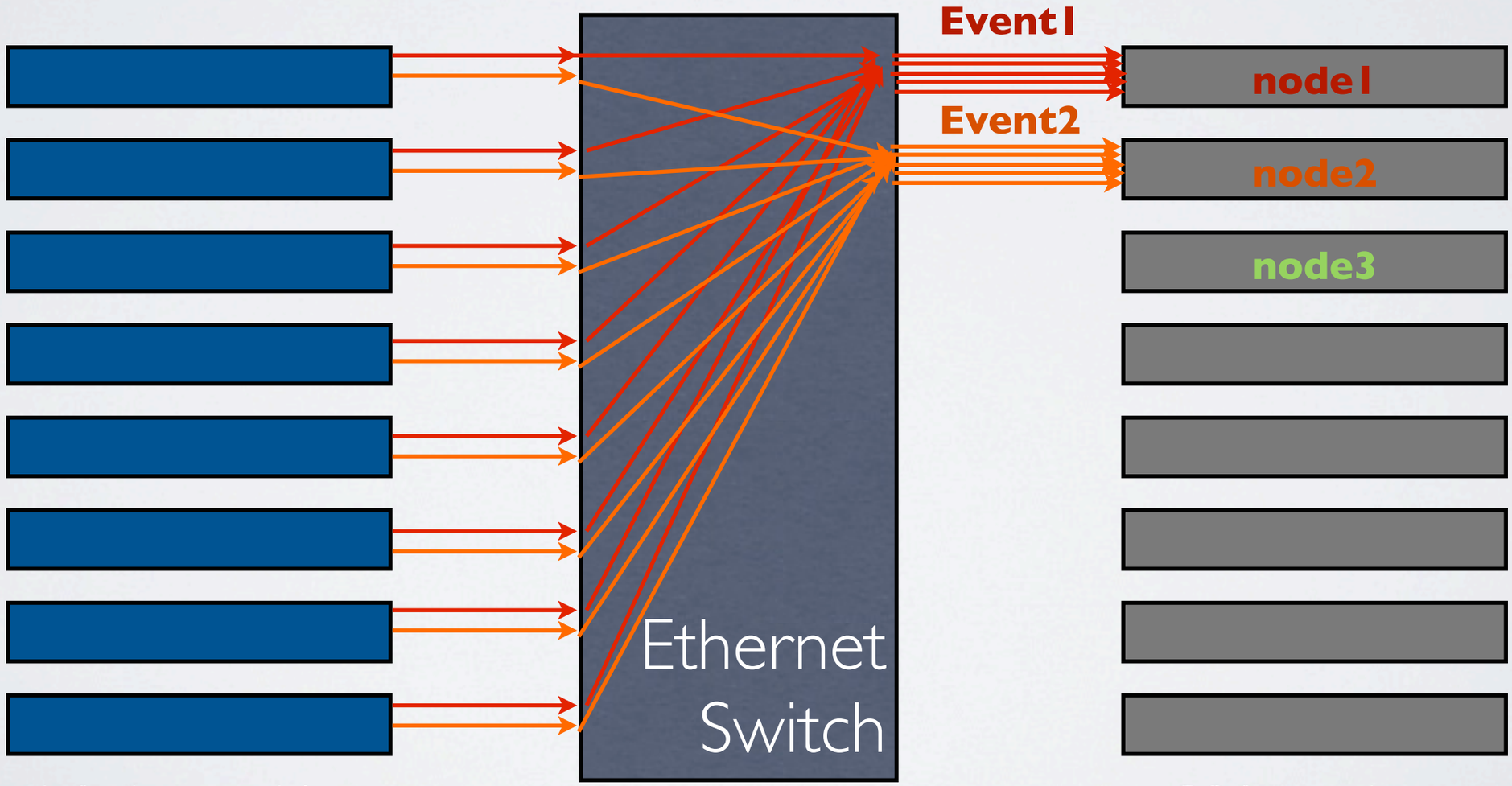

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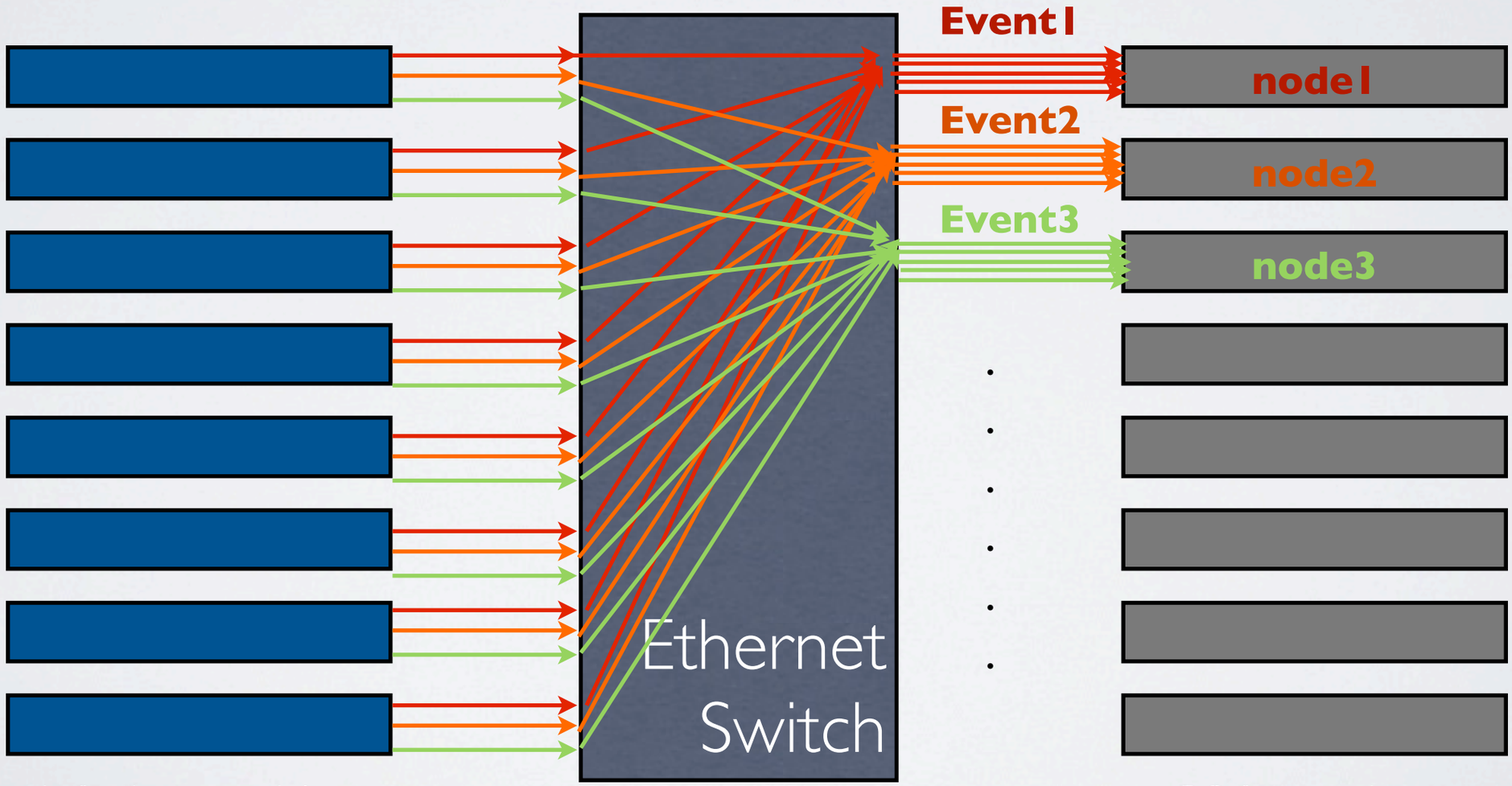
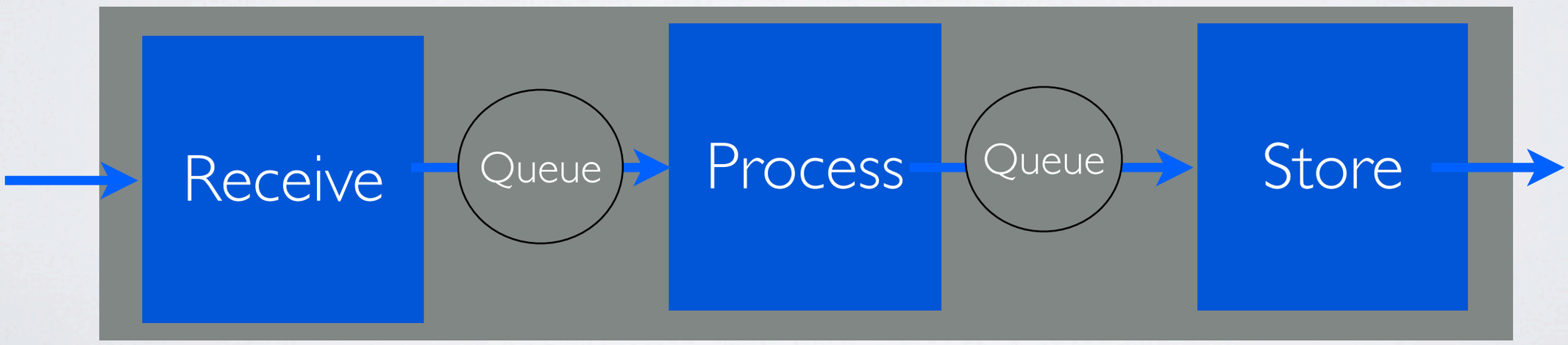


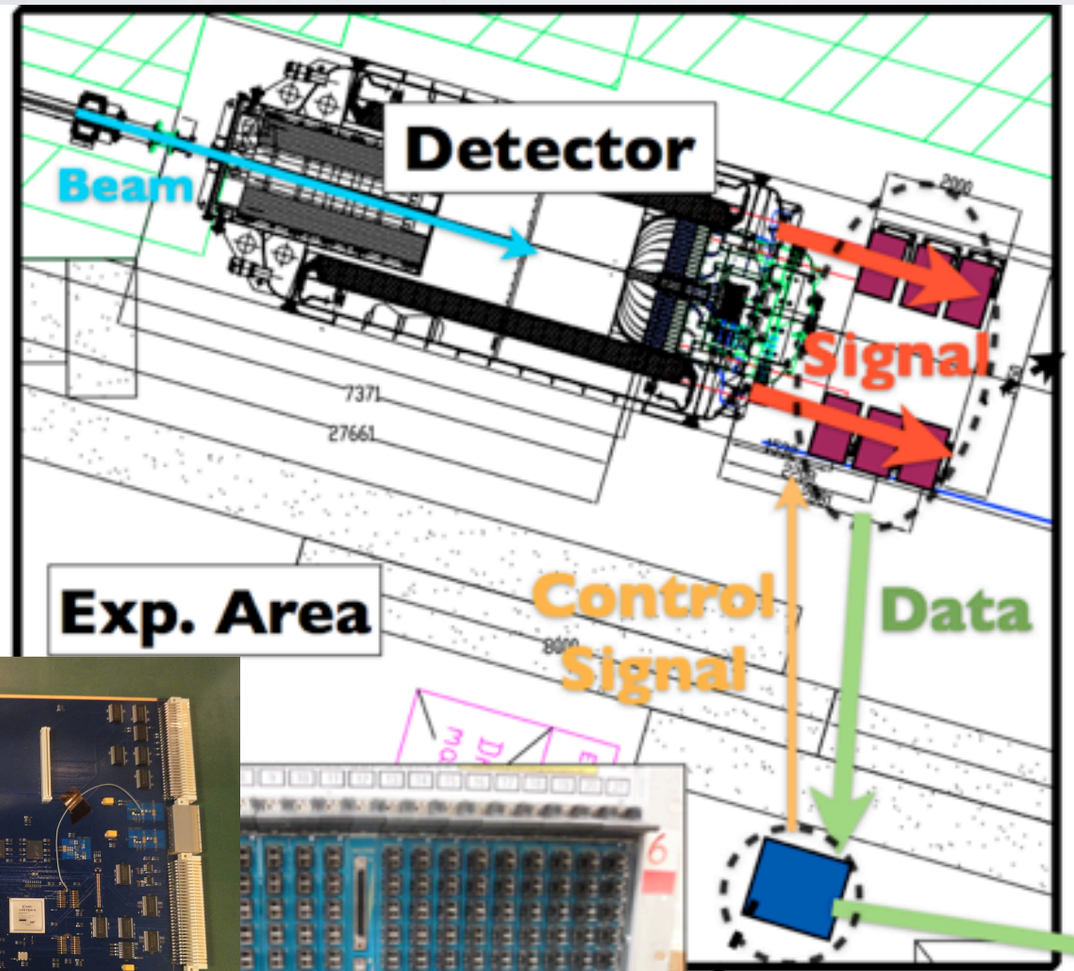
Data Processing In PC Farm

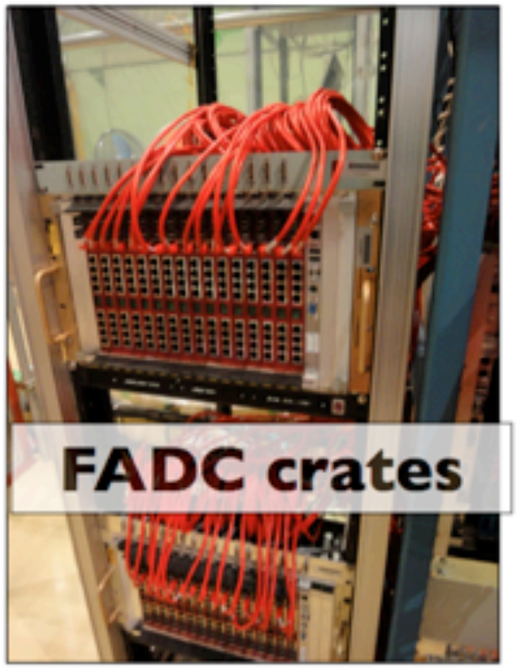
- Lv3 framework consists of 3 software modules in PC.
  - Receiver: Receive network packet from Lv2 trigger module.
  - Processor: Sort packets/Build events/Event Selection(Lv3 trigger)/
    Data compressoion
  - Store: Store data to file.
- Using queue system to manage tasks.
  - Each module send event data to queue after its task.
  - Next module start its task if event queued to its queue.

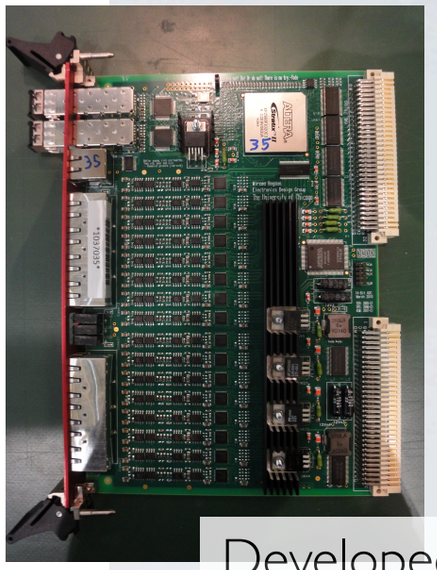


DAQ Location

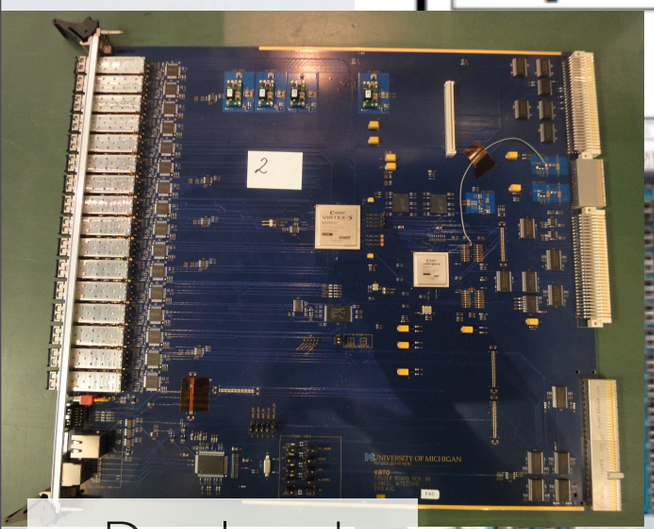
- Put FADCs near detectors. Put Trigger system outside of the shields.
- Put PC farm in the counting room outside the Experiment Hall.
- Use Optical fiber to connect between FADC/Trigger system/PC farm.



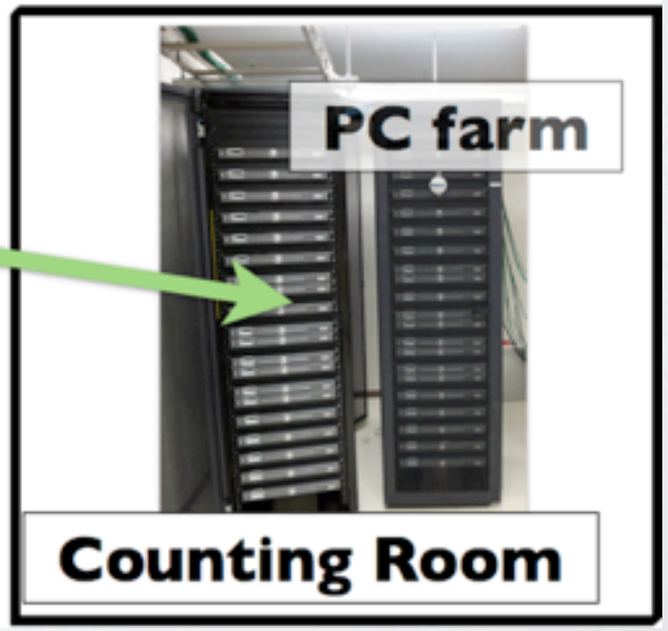




Developed by Univ.Chicago



Developed by Univ.Michigan



In 2010

- Jan/Apr:Beam test @ LNS,Tohoku-Univ.
  - Test FADC/Trigger prototype.
- Beam commissioning in 2010 Autumn
  - Read out ~1200 channel with mass-production FADC module.
  - Use prototype trigger module

	LNS	2010 autumn	Physics run
#of readout channels	144	1200	~3000
#of FADC for trig.	1	8	~200
Readout scheme	Opt/VME	VME	Optical
Network transfer	X	X	○
Event building	X	only monitor	○

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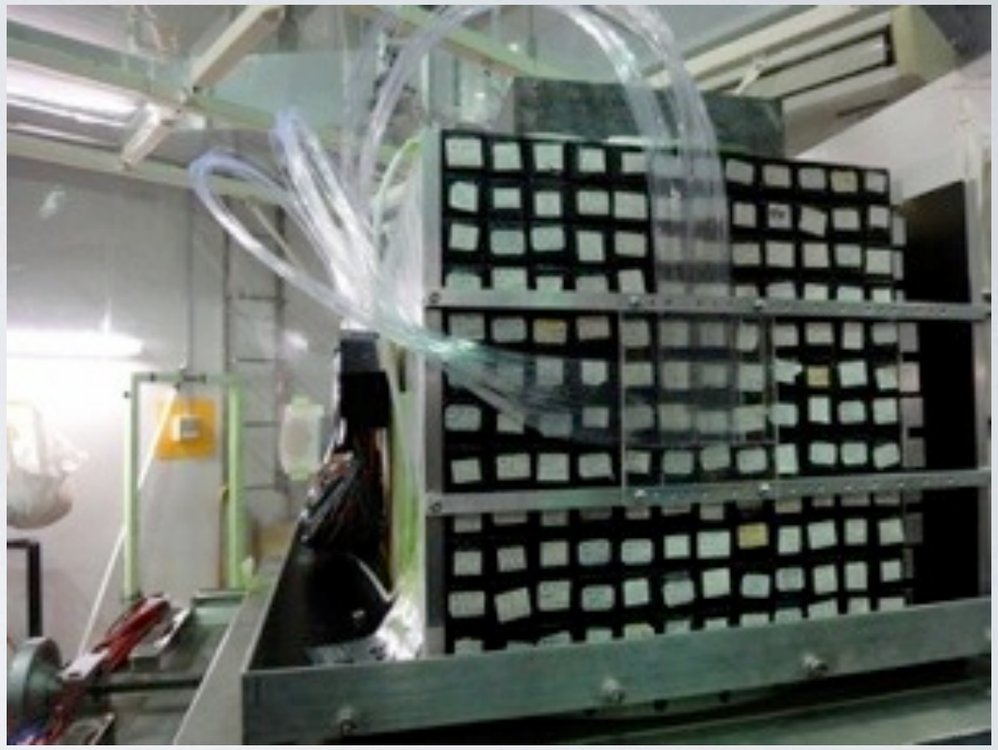

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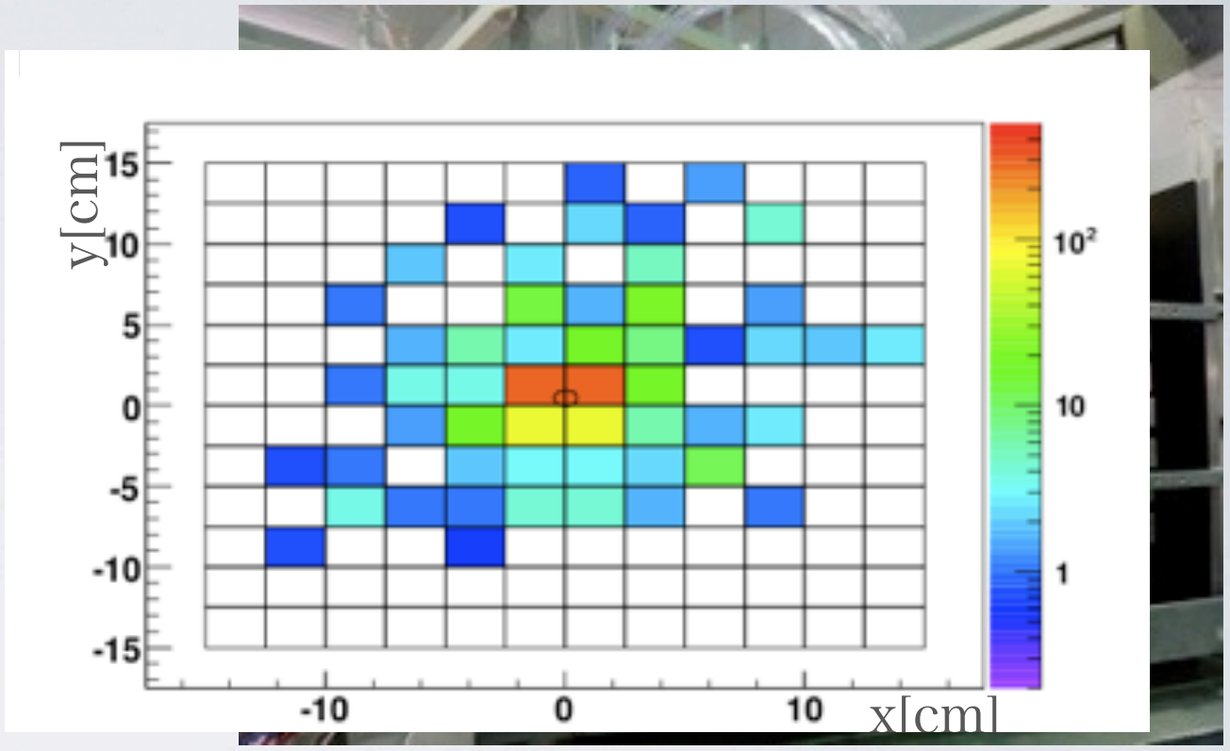

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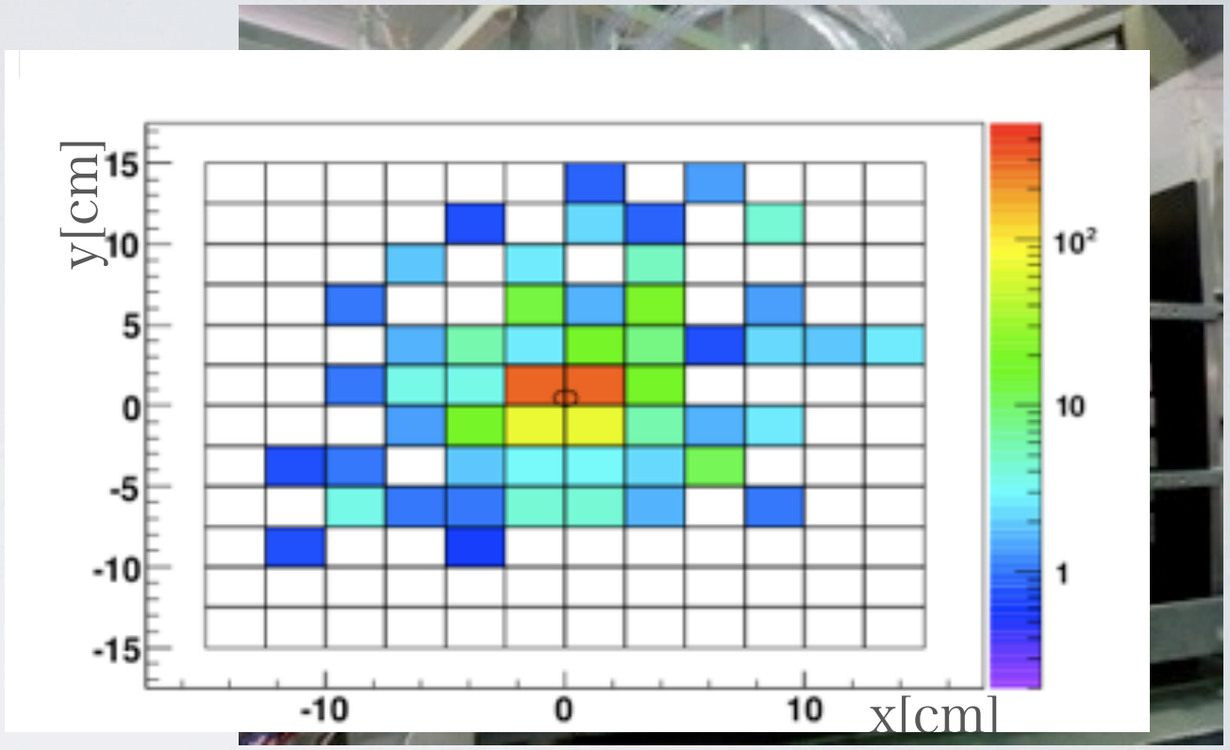

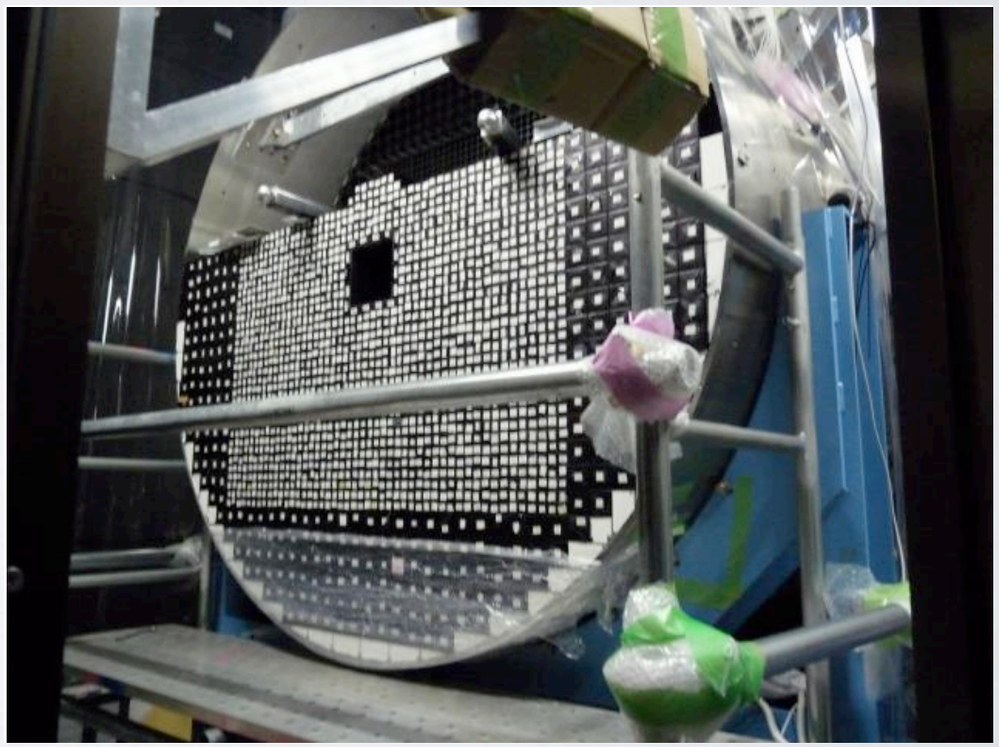

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#of readout channels	144	1200	~3000
#of FADC for trig.	1	8	~200
Readout scheme	Opt/VME	VME	Optical
Network transfer	X	X	○
Event building	X	only monitor	○

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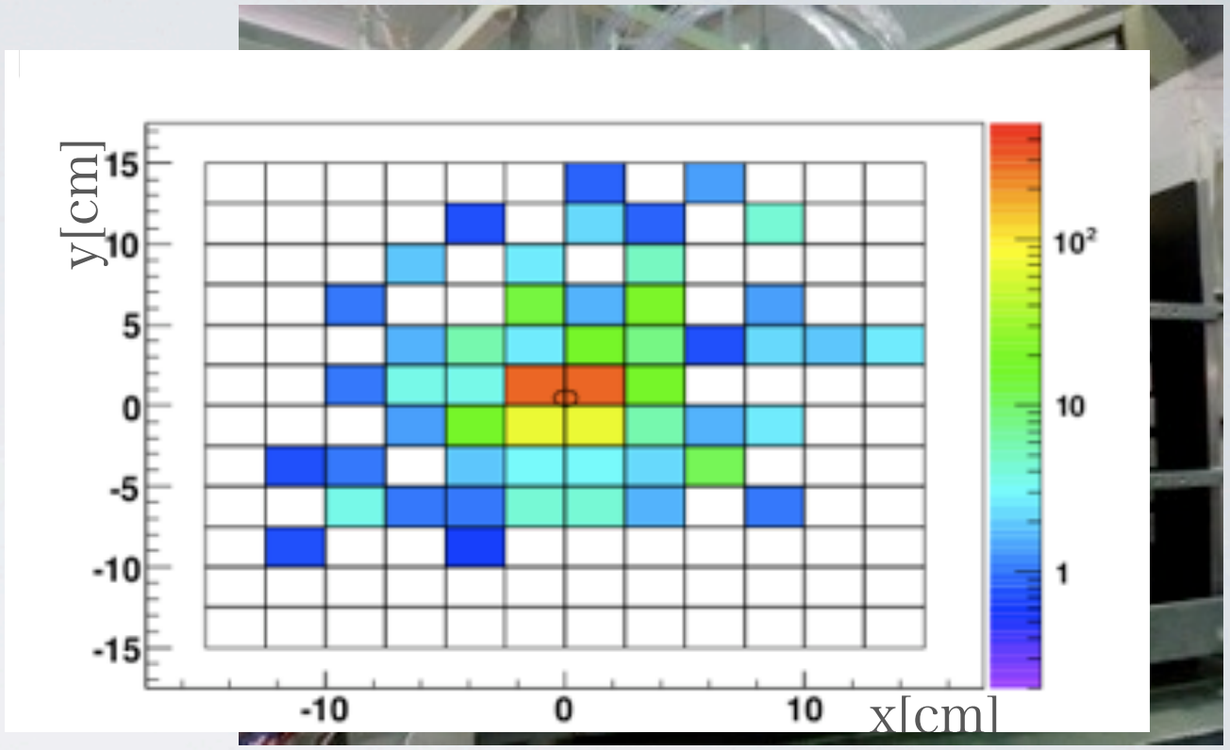
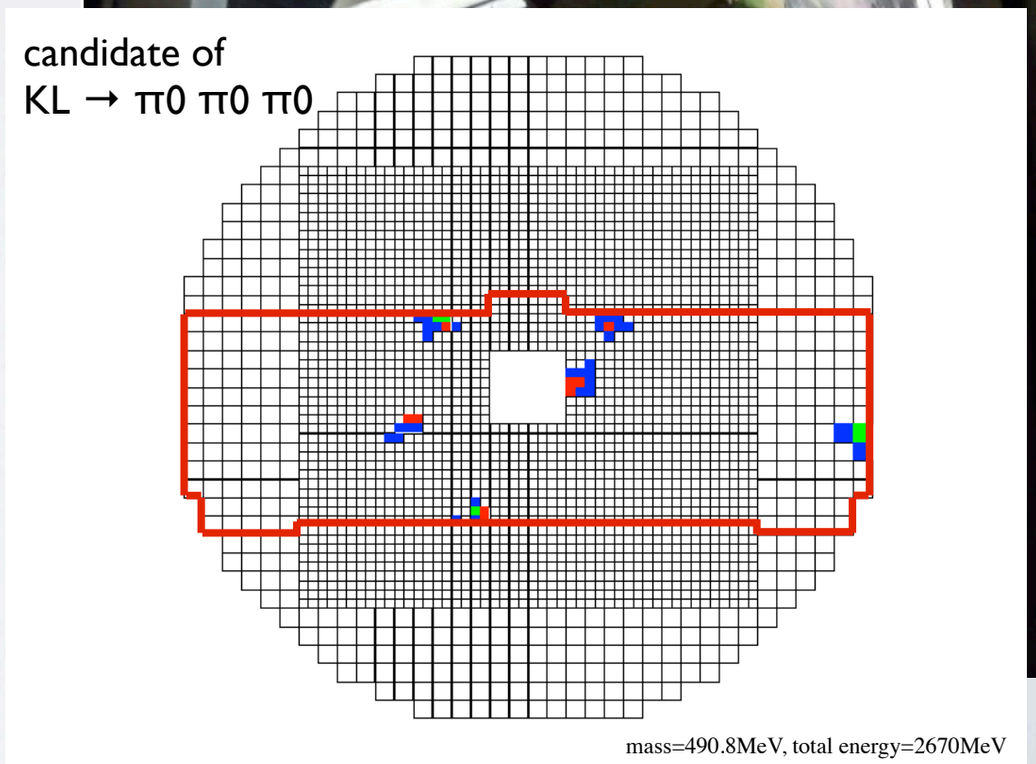
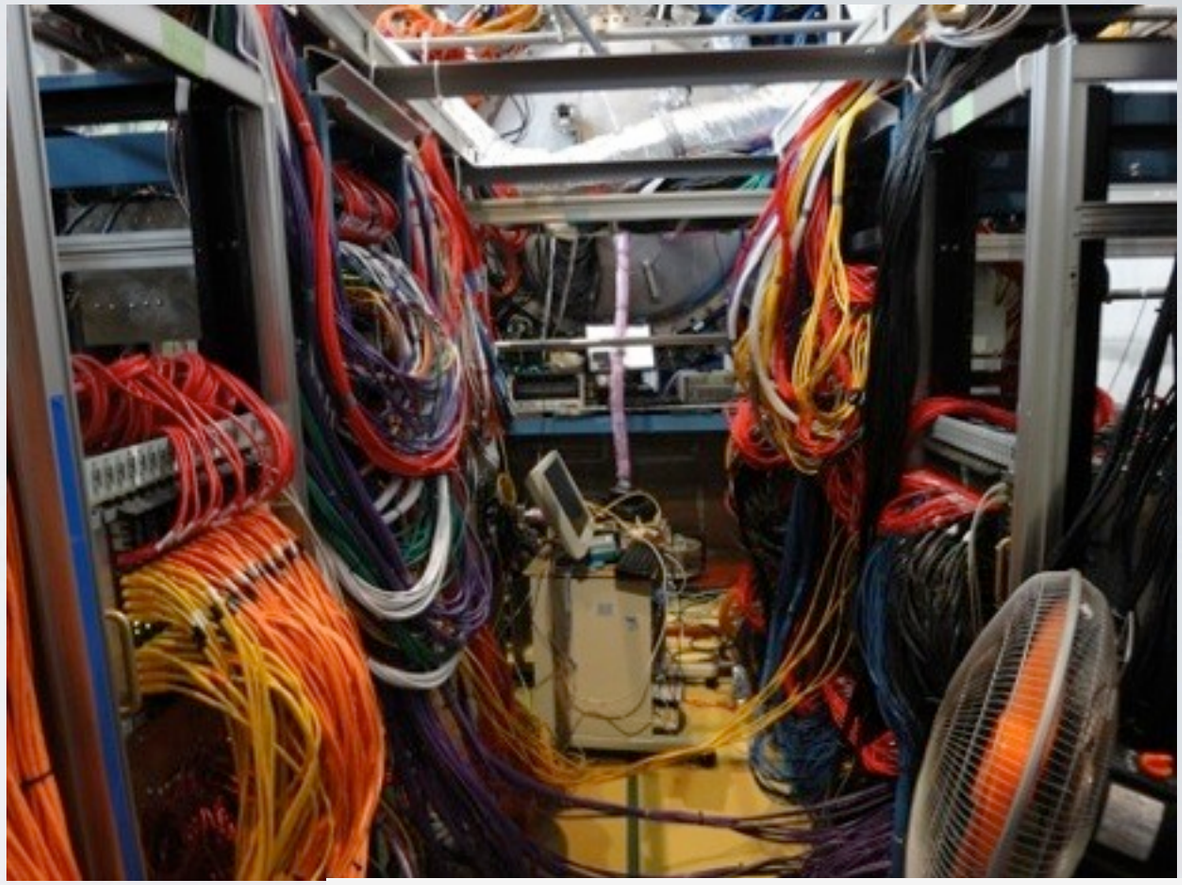


	LNS	2010 autumn	Physics run
#of readout channels	144	1200	~3000
#of FADC for trig.	1	8	~200
Readout scheme	Opt/VME	VME	Optical
Network transfer	X	X	○
Event building	X	only monitor	○

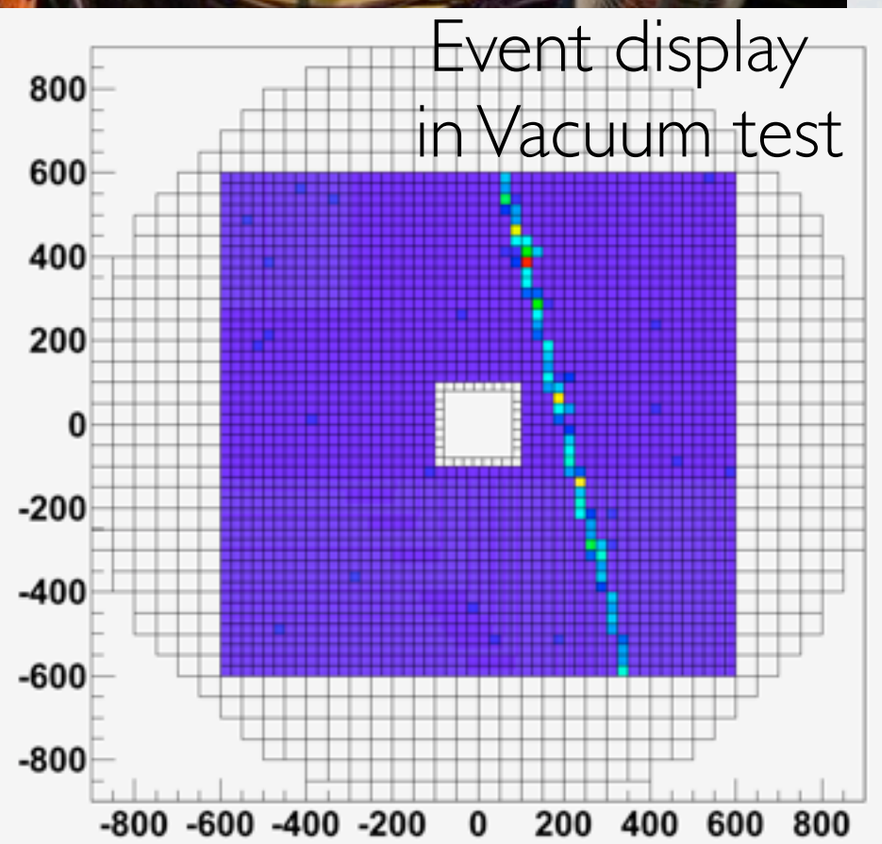


Current Status

- No serious damage from Earthquake to DAQ system
- All FADC module for calorimeter are ready and read in Vacuum test in this summer.
- Trigger system
  - Lv1/2 trigger system is under debug for Optical link and Ethernet transfer.
  - Lv3 trigger system is now under modification in Receiver part.



	LNS	2010 Autumn	Current	Phys.run
#of readout channels	144	1200	2716(CsI)	~3000
#of FADC for trig.	1	8	176	~200
Readout scheme	Opt./VME	VME	VME→Opt.	Optical
Network transfer	X	X	△(debug)	○
Event building	X	only monitor	△(debug)	○



Summary

- Develop DAQ system for J-PARC KOTO experiment.
- No serious damage from Earthquake to DAQ system.
- Read full calorimeter by FADC in Vacuum test.
- Starting DAQ Full Integration (FADC/Lv1~3) test in Next January.
- Prepare DAQ system for Next beam time and incoming Engineering/ Physics Run.

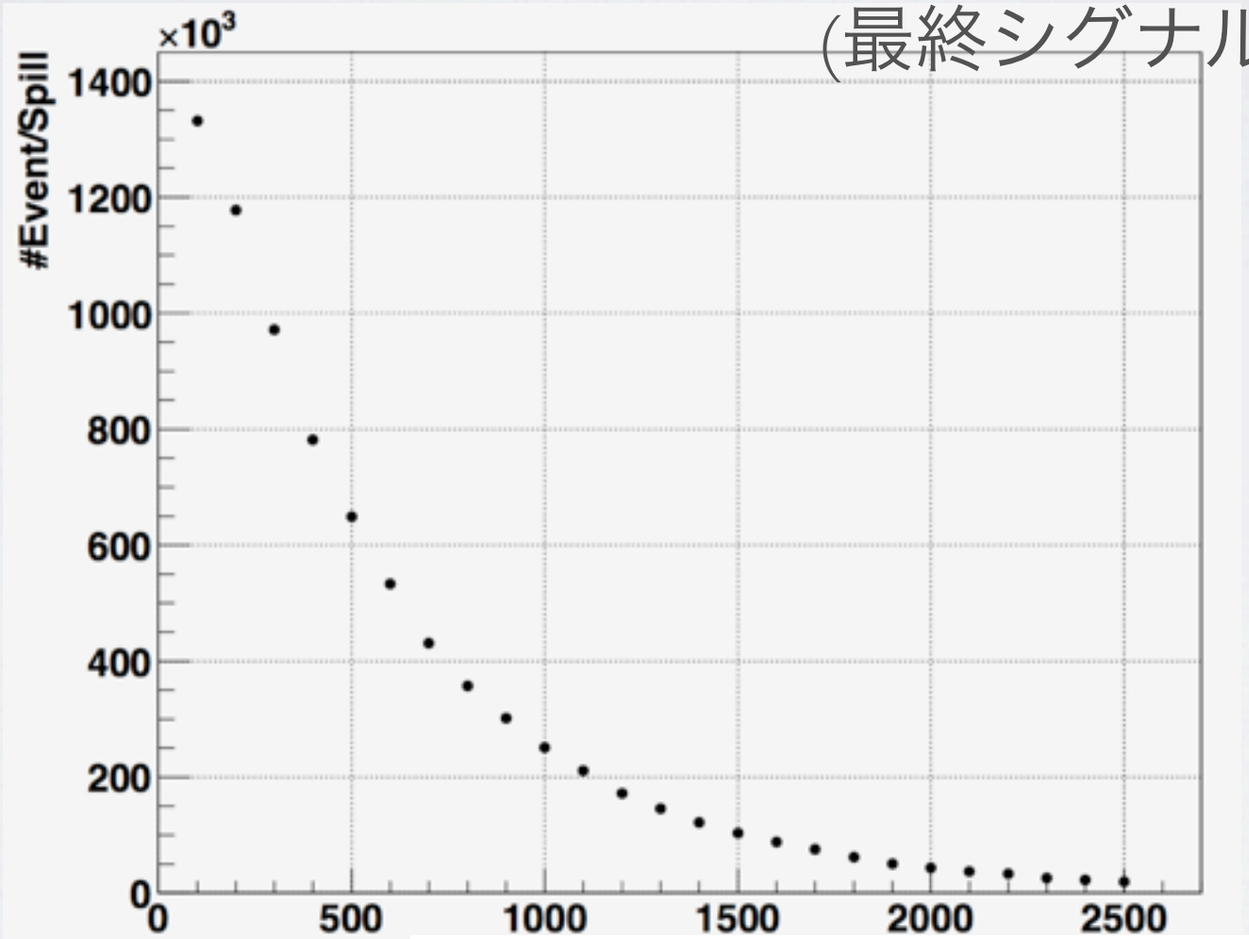
BACKUP SLIDES

トリガーシステムの改良

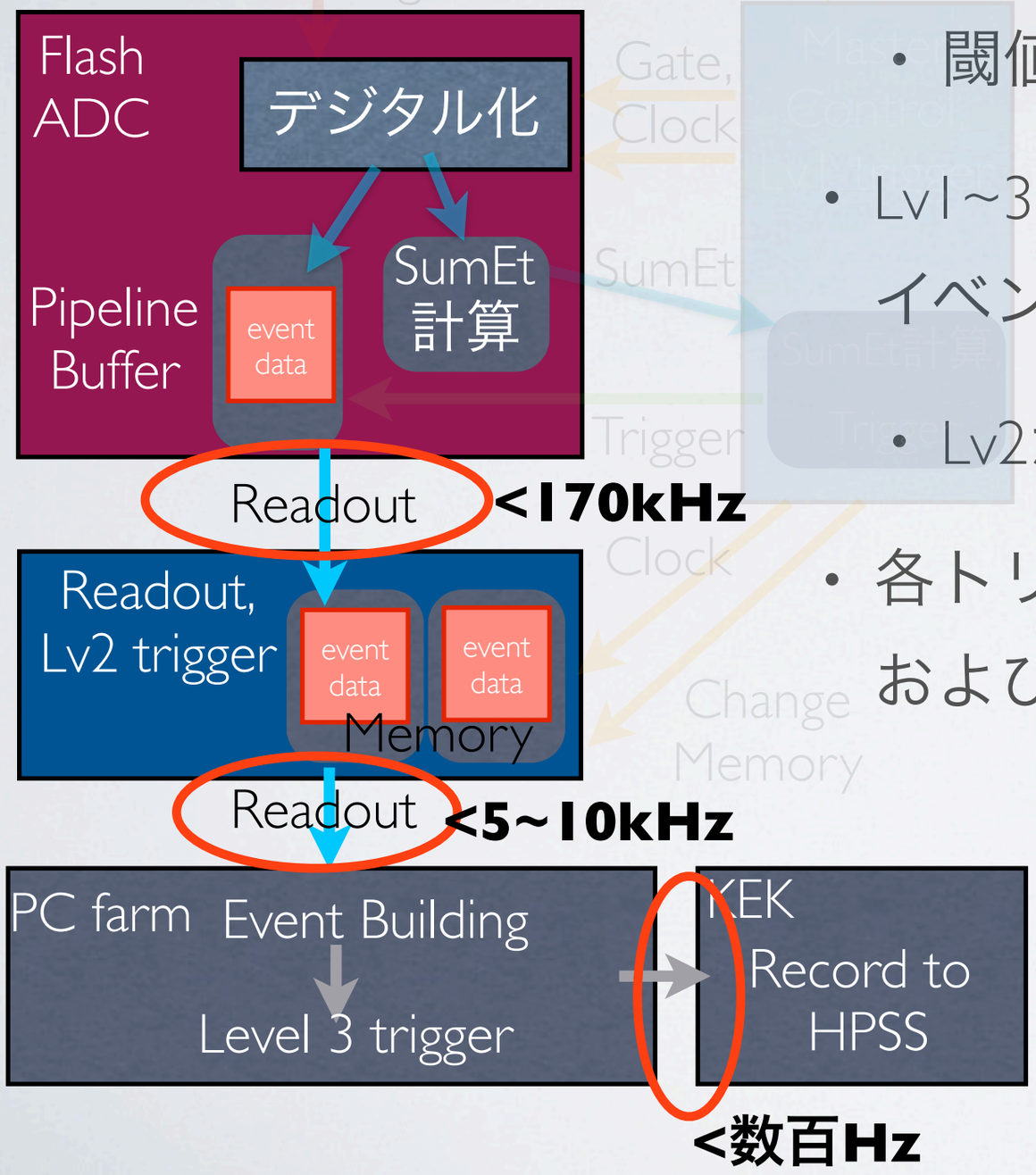
閾値とトリガーレート

- LvIトリガーの判断条件はCsIカロリメータにおける総エネルギー。
- 閾値を300MeVとすると、Simulationでは~1M Event/Spill @330kW。
- x2 in real beam. 1MHz for 2secbeam, 2.8MHz for 0.7sec beam

(最終シグナルカットではEt>500MeV)



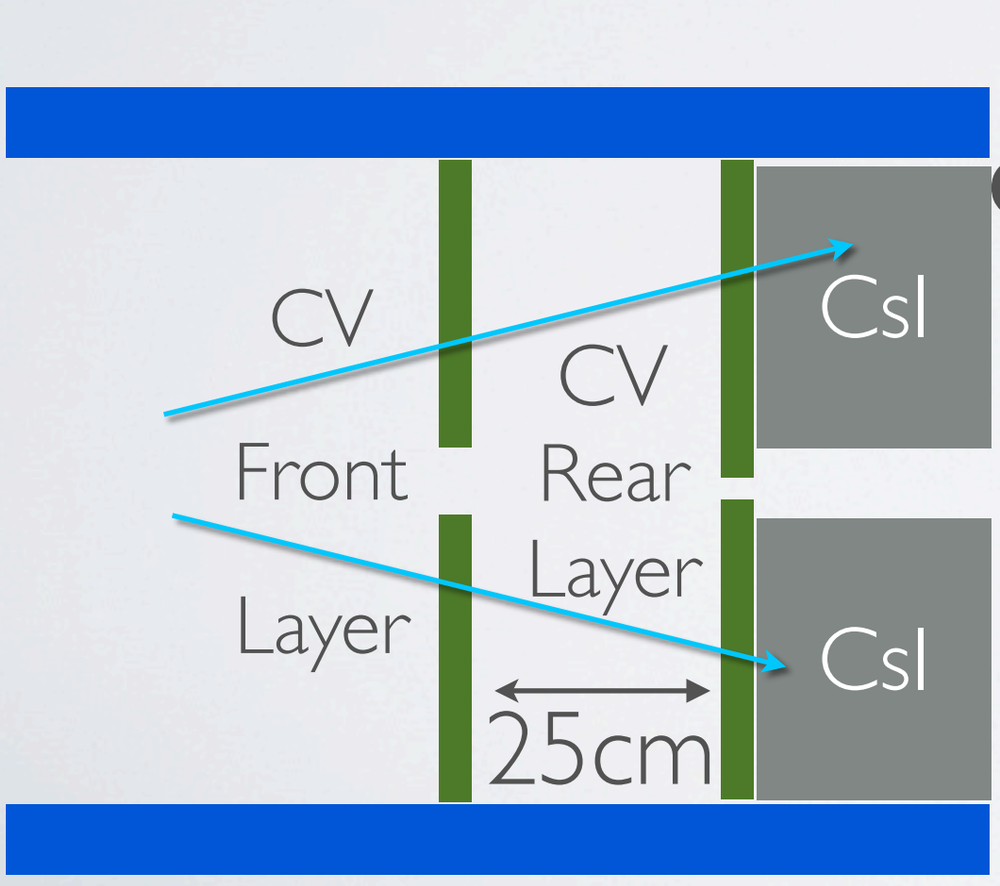
最大トリガーレート



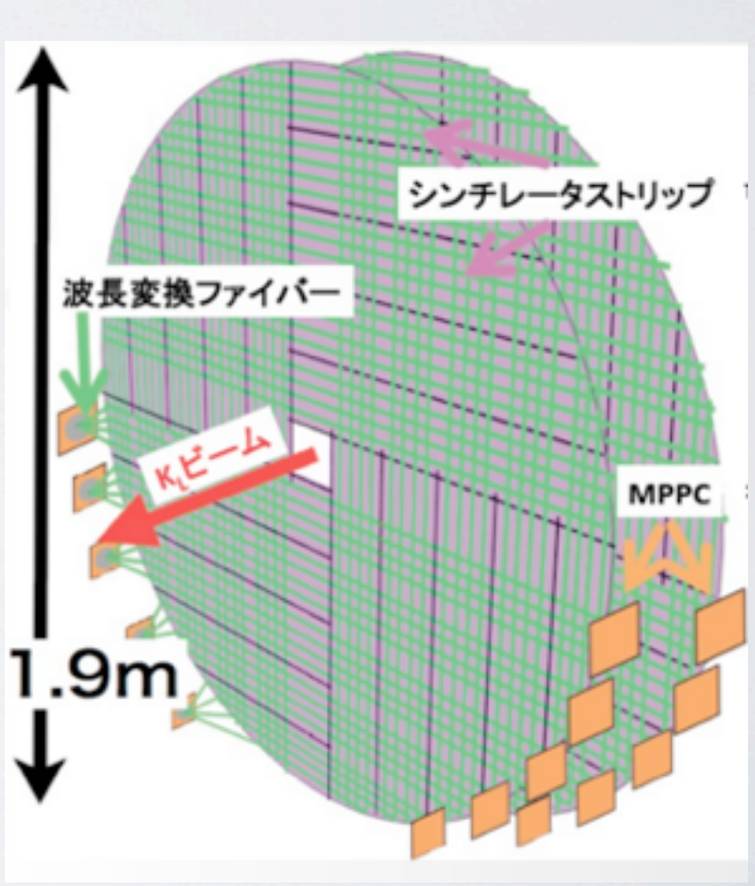
- Lv1 トリガーの判断基準は
  CsIカロリメータでの総エネルギー和。
  - 閾値を300MeVにすると、**1MHz (330kW時)**
- Lv1~3までの各トリガー段階での読出し速度で
  イベント取得レートが制限。
  - Lv2からの読出し段階では**2~3kW**が限界。
- 各トリガー段階でのトリガー抑制、
  およびデータサイズの圧縮が必要。

Charged Vetoを用いたOnlineVeto

- 欲しいイベントは崩壊で出来る粒子が全て中性。
- 荷電粒子検出器**ChargedVeto(CV)**のエネルギー・ヒット情報を用いれば荷電粒子を伴う崩壊をトリガー段階で取り除ける。
  - **$K_L \to \pi e \nu$** (Ke3): 40%、 **$K_L \to \pi \mu \nu$** (Kμ3):27%、 **$K_L \to \pi^+ \pi^- \pi^0$**: 13%
- イベントのロスを抑えつつ、どれだけトリガーレートを抑えられるか？

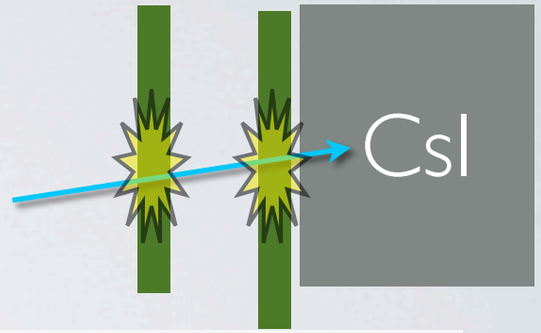


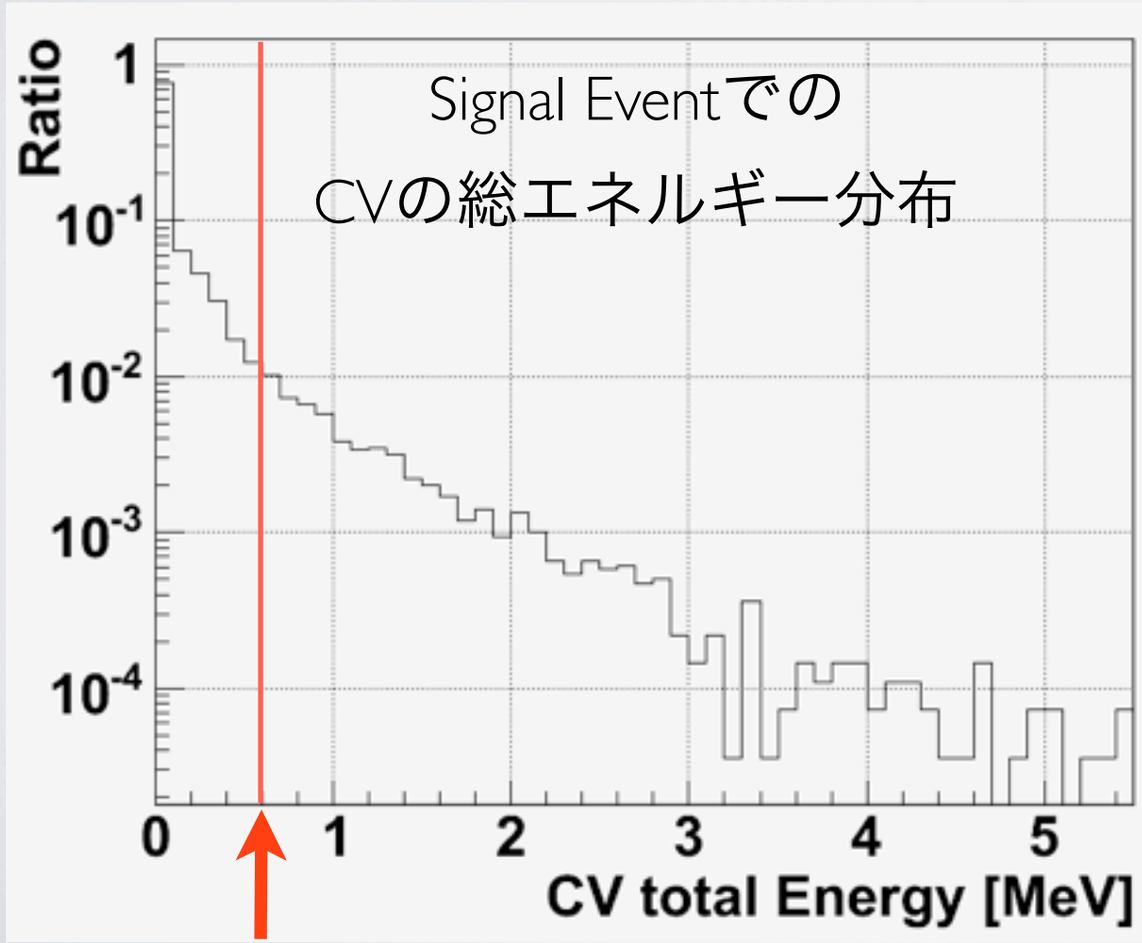
ChargedVeto:
3mm厚の
プラスチック
シンチレータ
2 Layerで構成
(CVに関しては
16pSH4,5,8の講演参照)



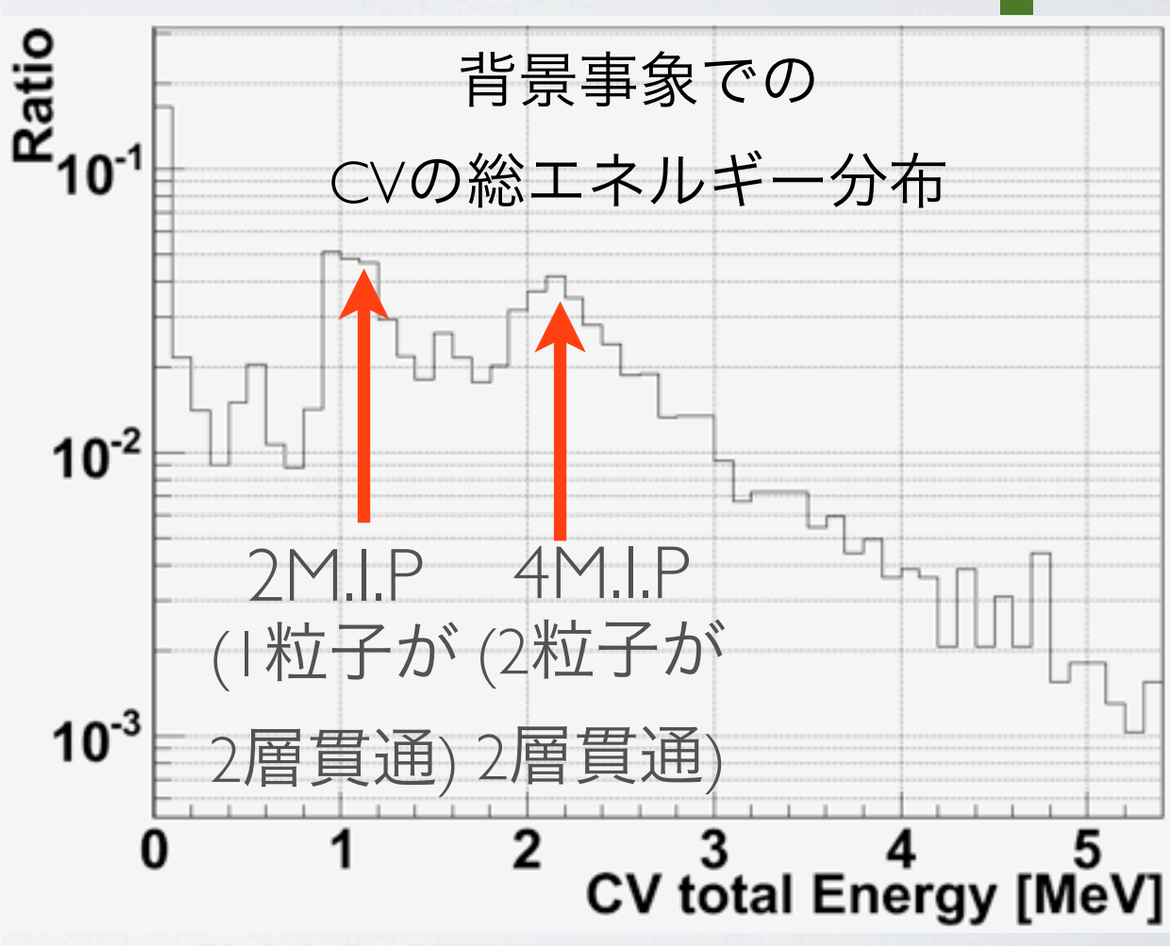
CVの総エネルギー分布

- 1layer 3mm厚のプラスチックシンチ→600 keV for 1M.I.P on 1CV layer
- シグナルと背景事象で、2層の総エネルギーを比べる。(Simulation)
  - シグナルイベントでは、９割以上のイベントが1M.I.P以下
  - 背景事象では、2 層を貫通するものが多く合計2~4 M.I.P





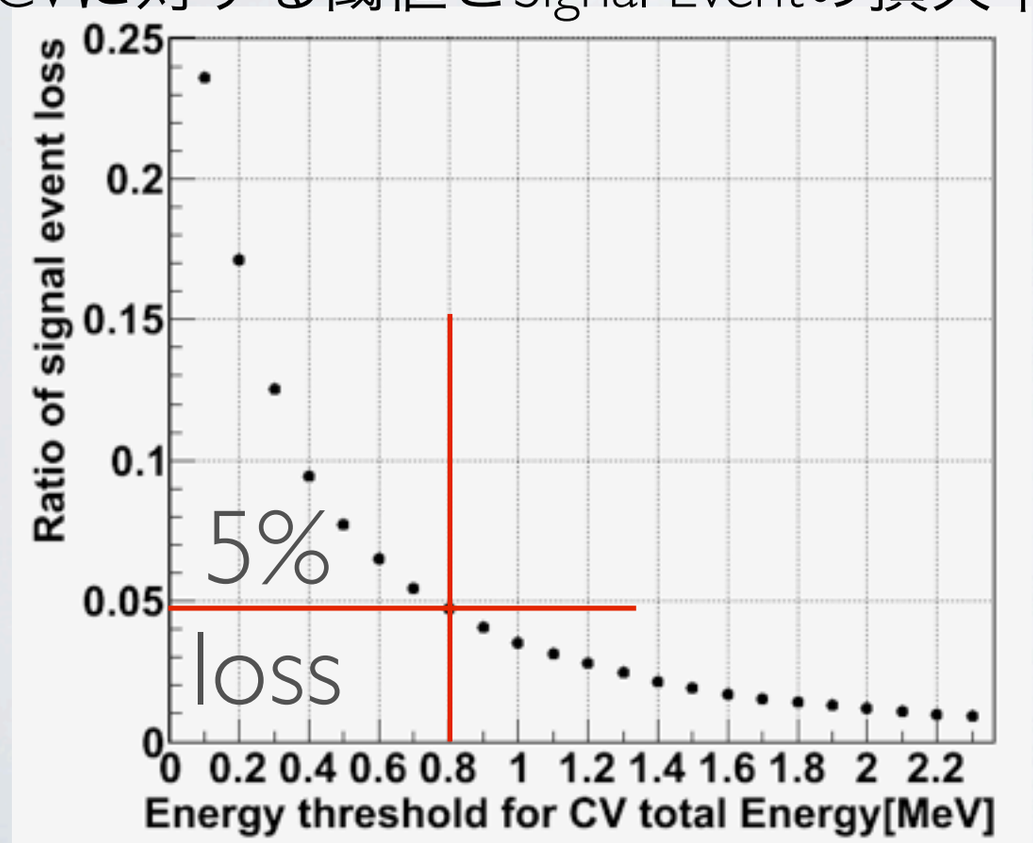
1M.I.P



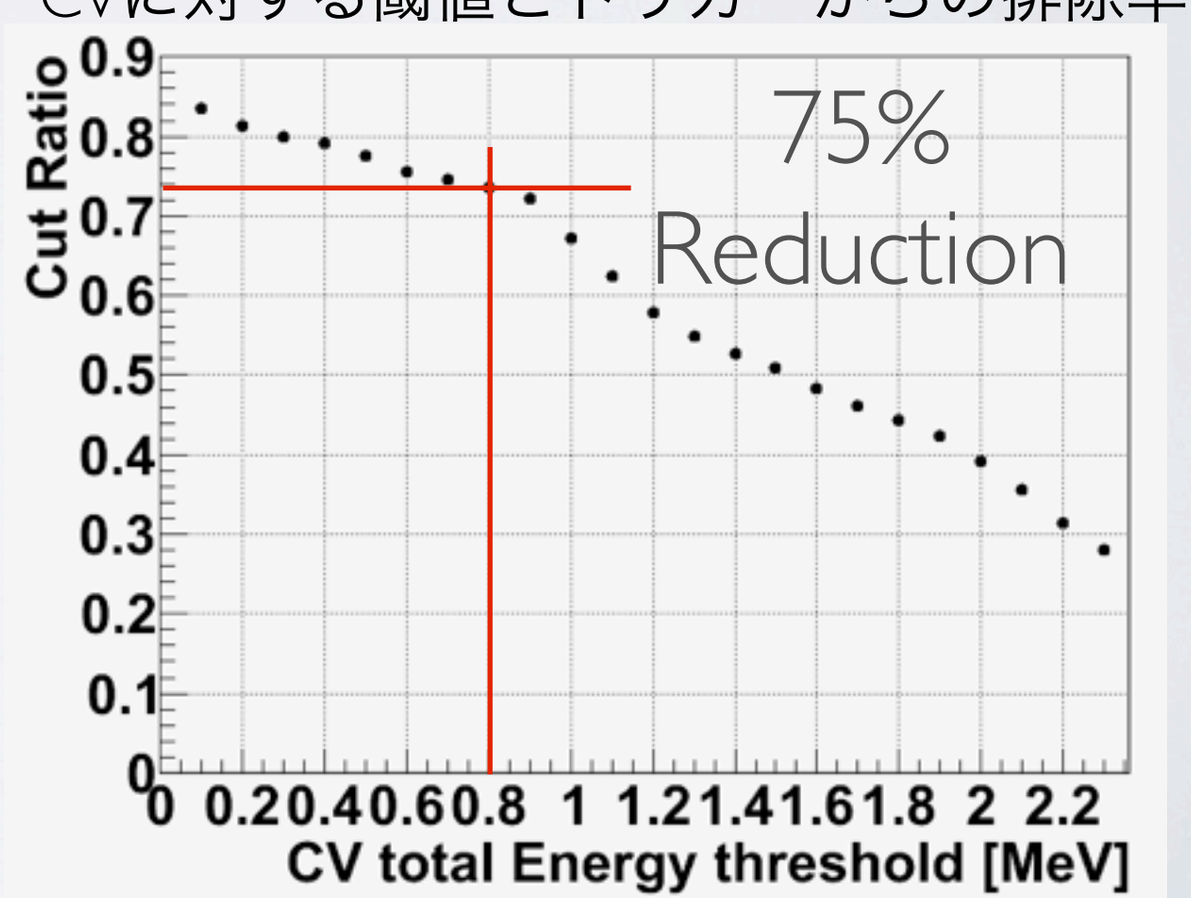
イベントカットとそれによるロス

- CVの総エネルギーに対し閾値を0.8MeVにすると、75%のイベントがカットできる。
  - Lv1トリガーに実装を検討。
  - Lv2モジュールからの読み出し段階で~10kW相当の強度まで対応可能。
- データ圧縮と、γ線クラスター認識によるカットを組合わせれば330kWまで対応可。

CVに対する閾値とSignal Eventの損失率



CVに対する閾値とトリガーからの排除率



Detector

Spill Signal

Signal

Front end system

Master fanout

Control Signal
(clock,gate)

Slave fanout

FlashADC

Digitize

Pipeline
Buffer

Lv1 trigger module

Sum

Energy Sum

Energy
Sum

Master Control Module

Level 1 trigger decision

Compare with
Threshold

Lv1 trigger

Data samples

Lv2 trigger module

Pipeline
Buffer

Waveform

Cluster
counting etc..

Event
Information

Level 2 trigger
decision

Lv2 trigger

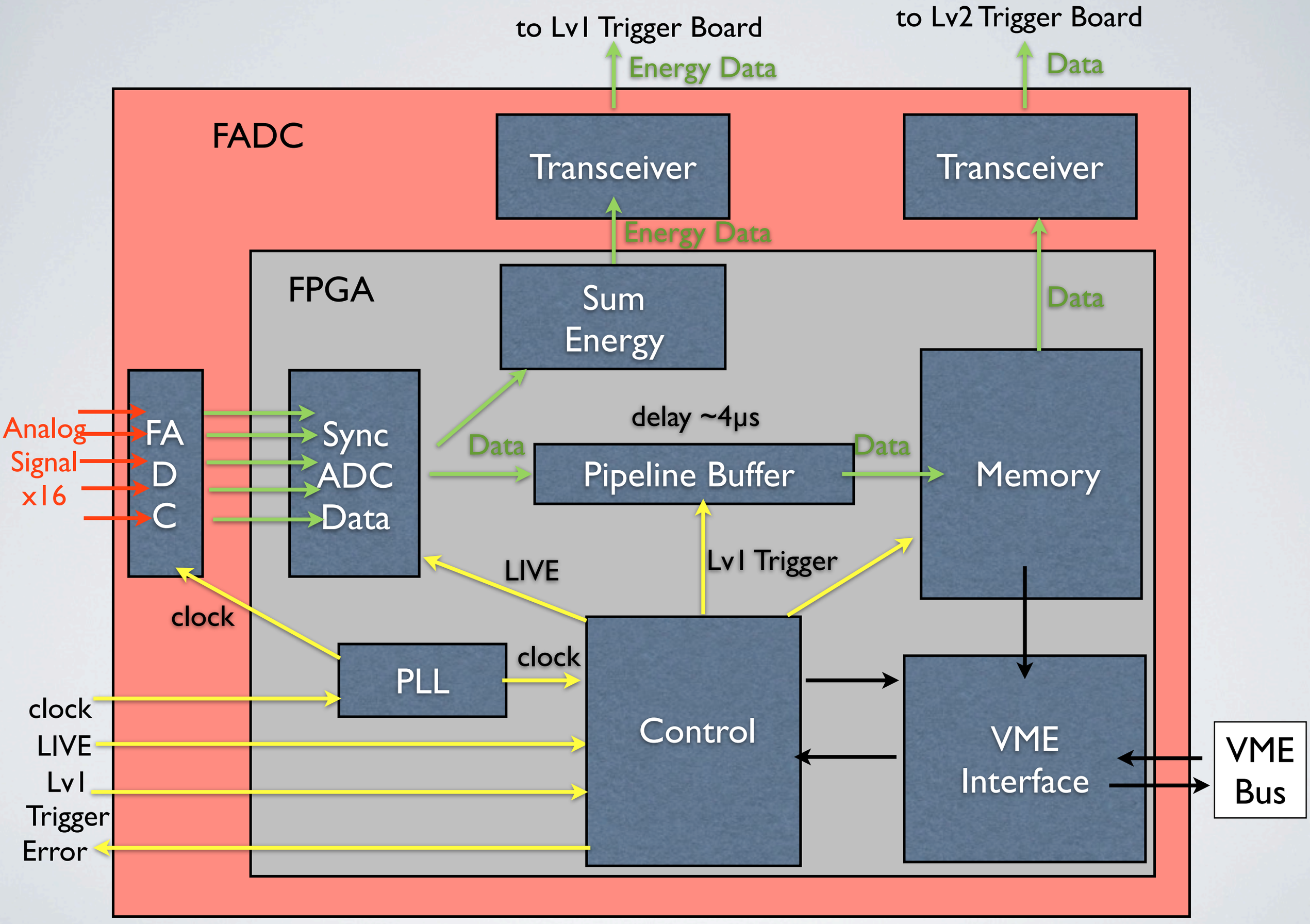
Readout by 1Gbps Ethernet link

Event Building,
Level 3 trigger decision

PC farm

Back end system

to storage @KEK


to Lv1 Trigger Board
Energy Data
to Lv2 Trigger Board
Data
FADC
Transceiver
Transceiver
Energy Data
FPGA
Sum
Energy
Data
Analog
Signal
x16
FA
D
C
Sync
ADC
Data
delay ~4μs
Data
Pipeline Buffer
Data
Memory
LIVE
Lv1 Trigger
clock
PLL
clock
Control
VME
Interface
VME
Bus
clock
LIVE
Lv1
Trigger
Error

最大トリガーレート

- 現在の読み出し方式でのトリガーレートへの制限。

（1イベントあたり、12Kbit/1FADC(16channel), 192Kbit/Lv2board(16FADC) ）

  - Lv1: FADC->Lv2間のデータ転送速度。光通信2Gbps→170k Events/s(Hz)

  - Lv2: Lv2でのデータ蓄積用メモリ容量2Gbit/Board →11k Events/Spill

    PCファームへの転送速度1Gbps/Board。 →5k Events/s(Hz)

    - →Spill長が2secより短い場合はメモリに貯めて次スピル読出が有利

      長い場合は、貯めずにそのまま転送したほうが有利。

  - Lv3: PCファームからKEKへの転送速度で制限。最大2Gbps→数百Hz

- **Lv1/2トリガー段階でのイベント選択と、データ圧縮が必要。**