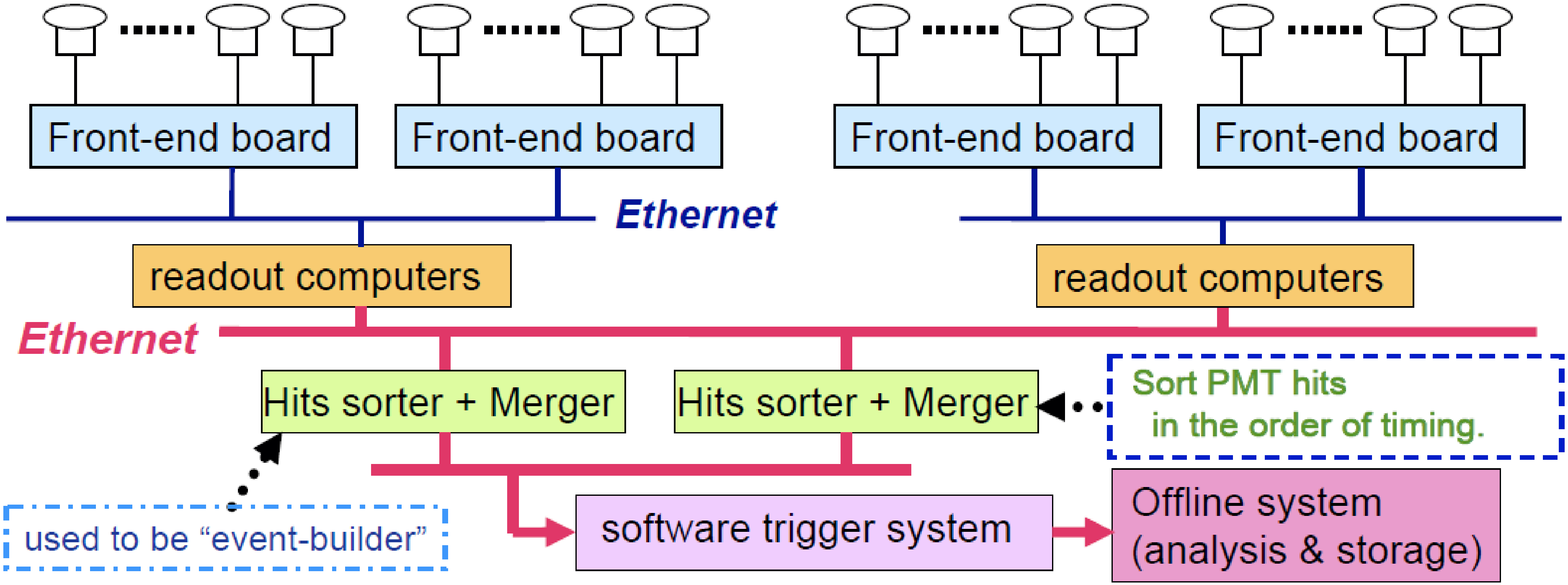
Baseline design of electronics and DAQ system

Yoshinari Hayato (Kamioka / ICRR)
for the electronics /online working group

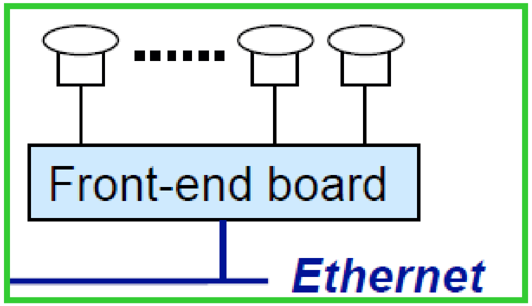
1) Design overview
2) Schematic diagram of the front-end module
3) Arrangements of the modules “in the detector”
4) Expected data rate from the online system
~ effects of the dark rate ~

Current schematic diagram of the HK DAQ system

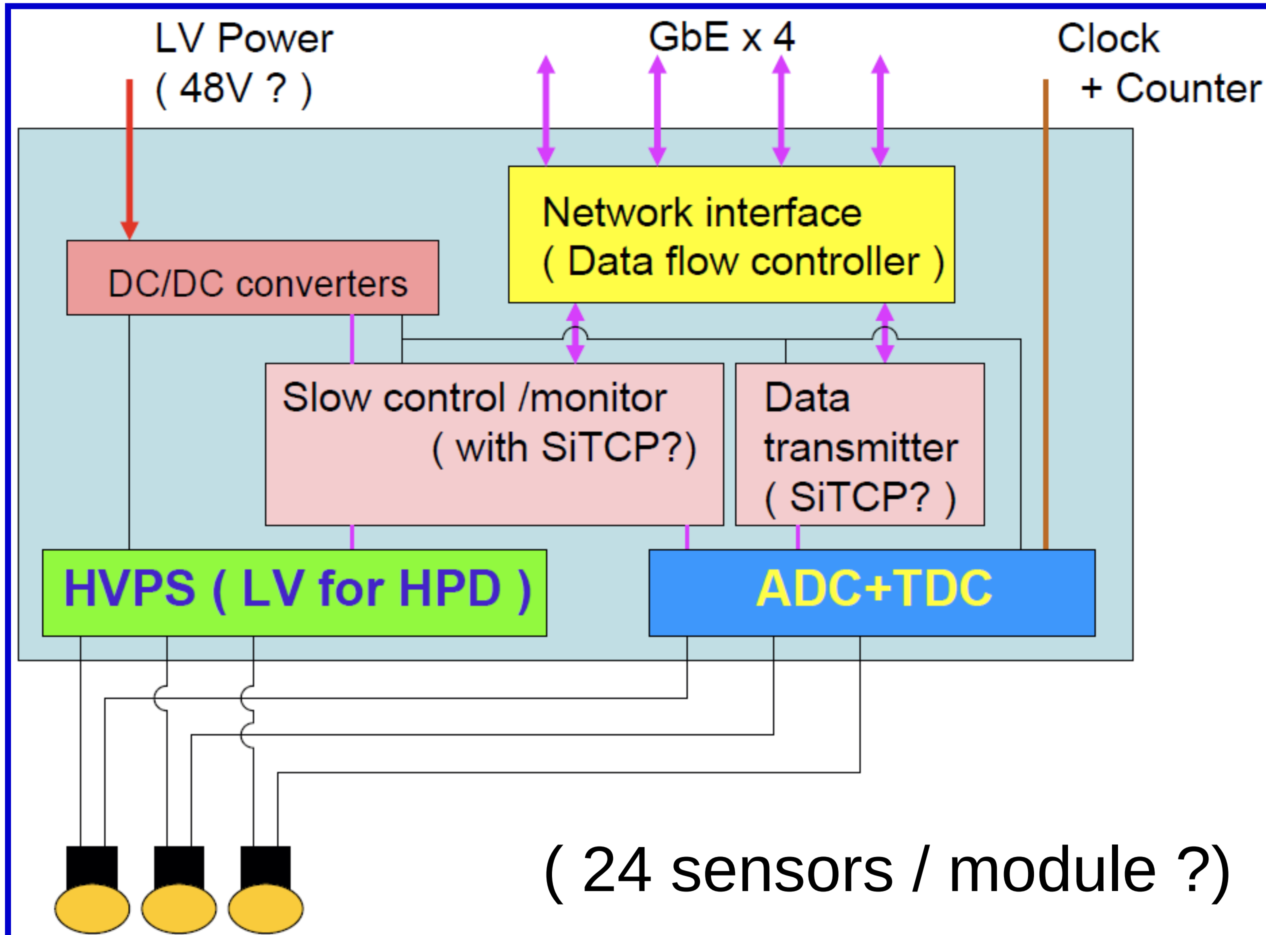


1) Signals from the photo sensor above discriminator threshold are continuously digitized.
2) All the "digitized" hit information including dark noise are sent to the readout computers.
3) Define events using the software trigger and send them to the offline system and also store the events in the disk.

Possible front-end electronics module connections



Schematic diagram of the front-end board



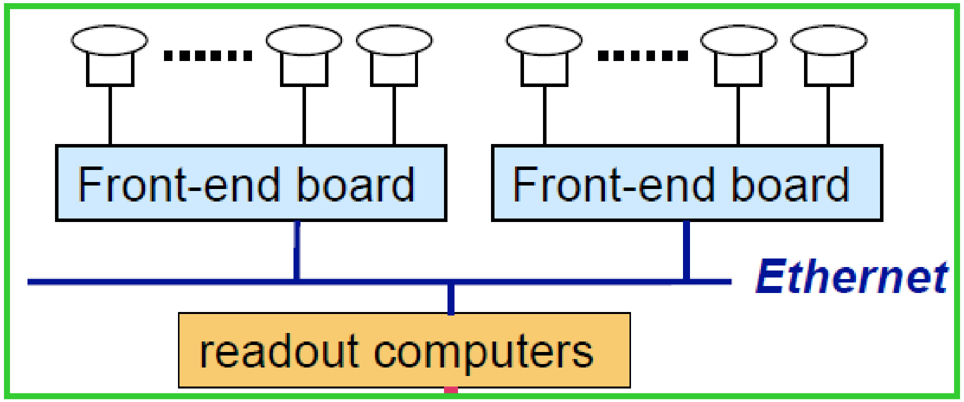
Key components

- Self triggering
  & dead-time free
  ADC + TDC
- HV (LV)
  for photo-sensors
- Intelligent
  network interfaces

In the last meeting, experts strongly recommend to keep the module DRY (not to in the water).

Detector design group want to reduce the weight of the cables….

Possible front-end electronics module connections

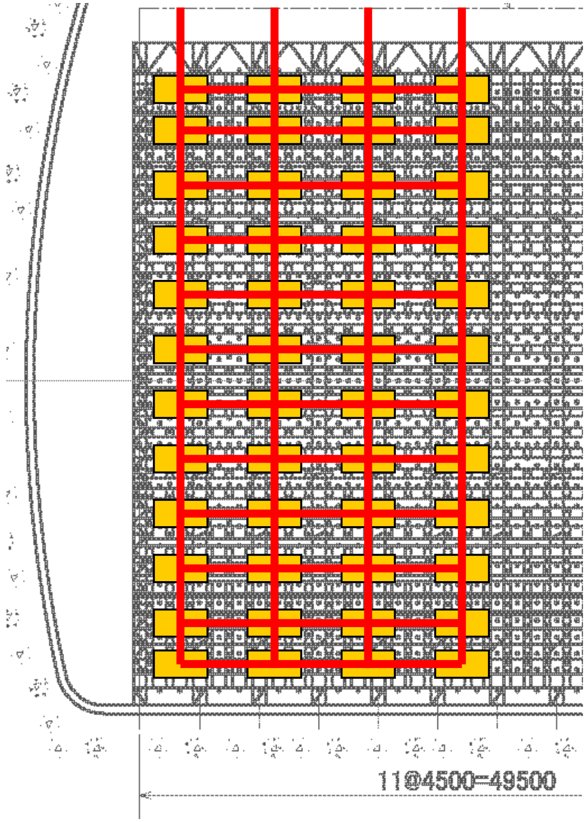


~ Design of the data flow

1) Assuming to use 1GbE

- Robustness
- Power consumption

HK detector Side view



2) Connect neighboring Front-end boards each other

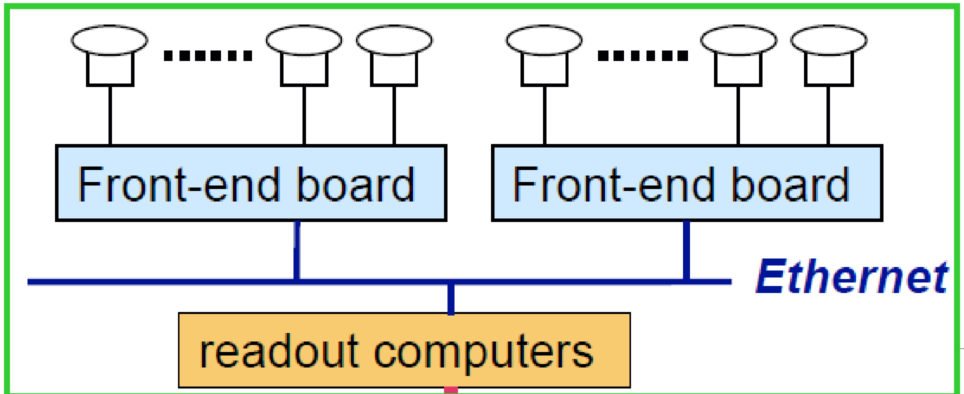
- Reduce total length of the cables
- Avoid single point failure

Usually, data collected by a module are transferred to the upper module (vertically)

If a module failed, transfer data to the other module instead of the failed module (horizontally).

Data rate at the top modules has to be enough smaller than 1Gb/sec.

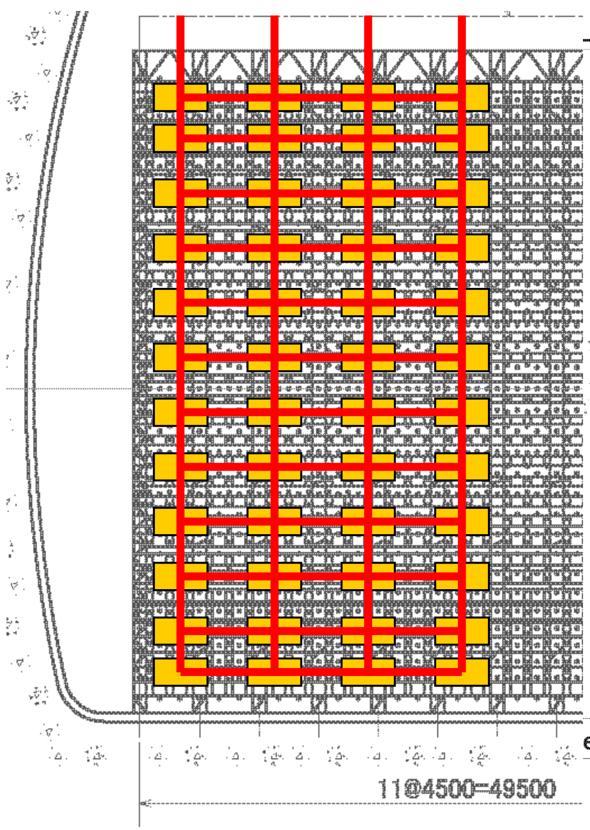
Possible front-end electronics module connections

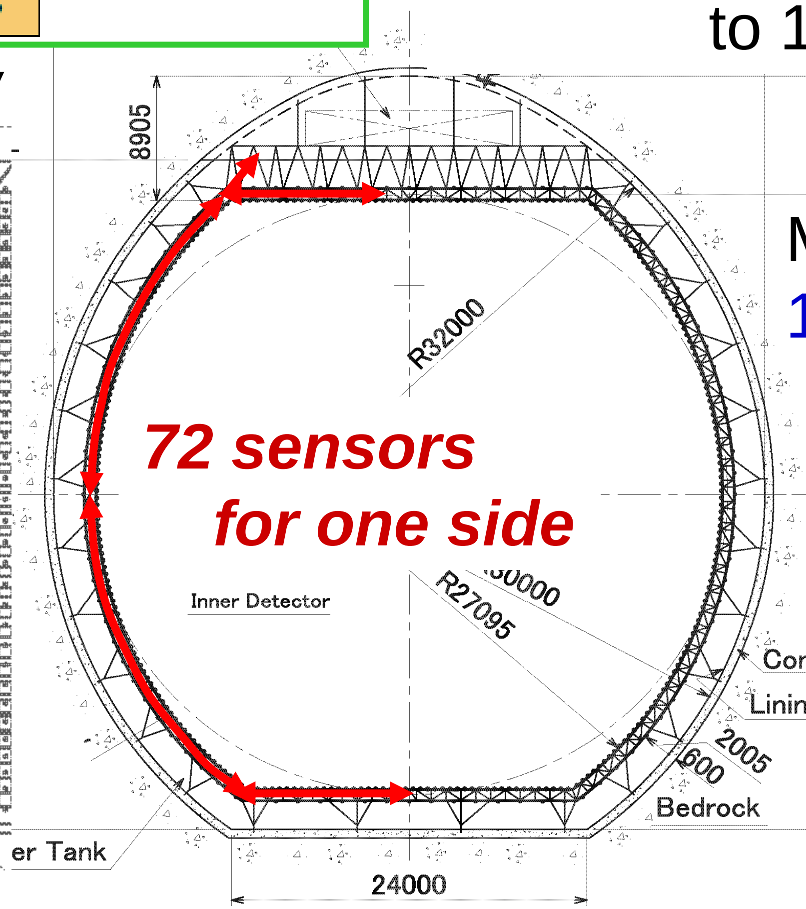


- From top to the bottom
  ~ 72 sensors / side
- Connect 6 x 4 sensors
  (vertical x horizontal)
  to 1 front-end board

Maximum
18 boards / cable

HK detector Side view

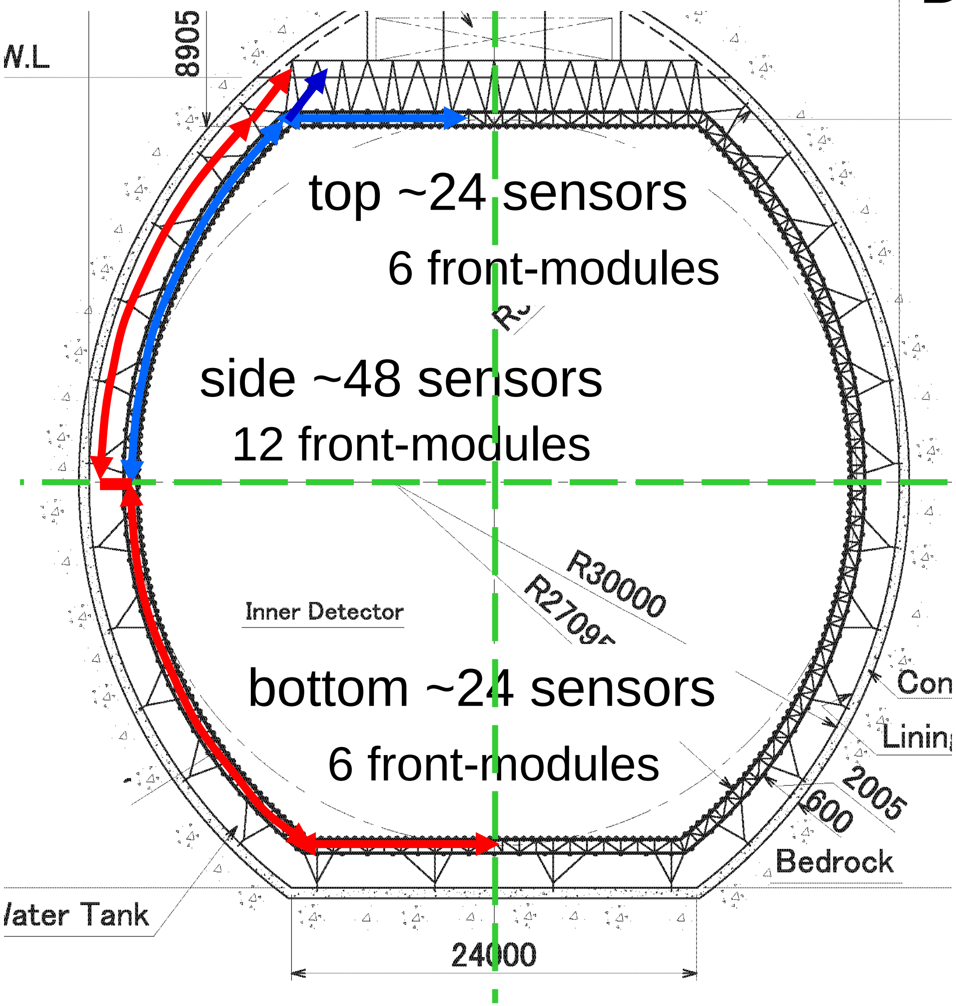




Possible front-end electronics module connections

Data rate from one front-end board ~ 200 x [dark rate] B/sec
(assuming 24 ch / board)

Possible configuration
for 10 kHz dark rate



Dark rate

1) 5kHz

Data rate ~ 1 MB/sec/board
Connect 18 boards / cable
1 cable from each side

In total ~ 120 signal cables are coming out from single tank

2) 10kHz

Data rate ~ 2 MB/sec/board
Connect 9 boards / cable

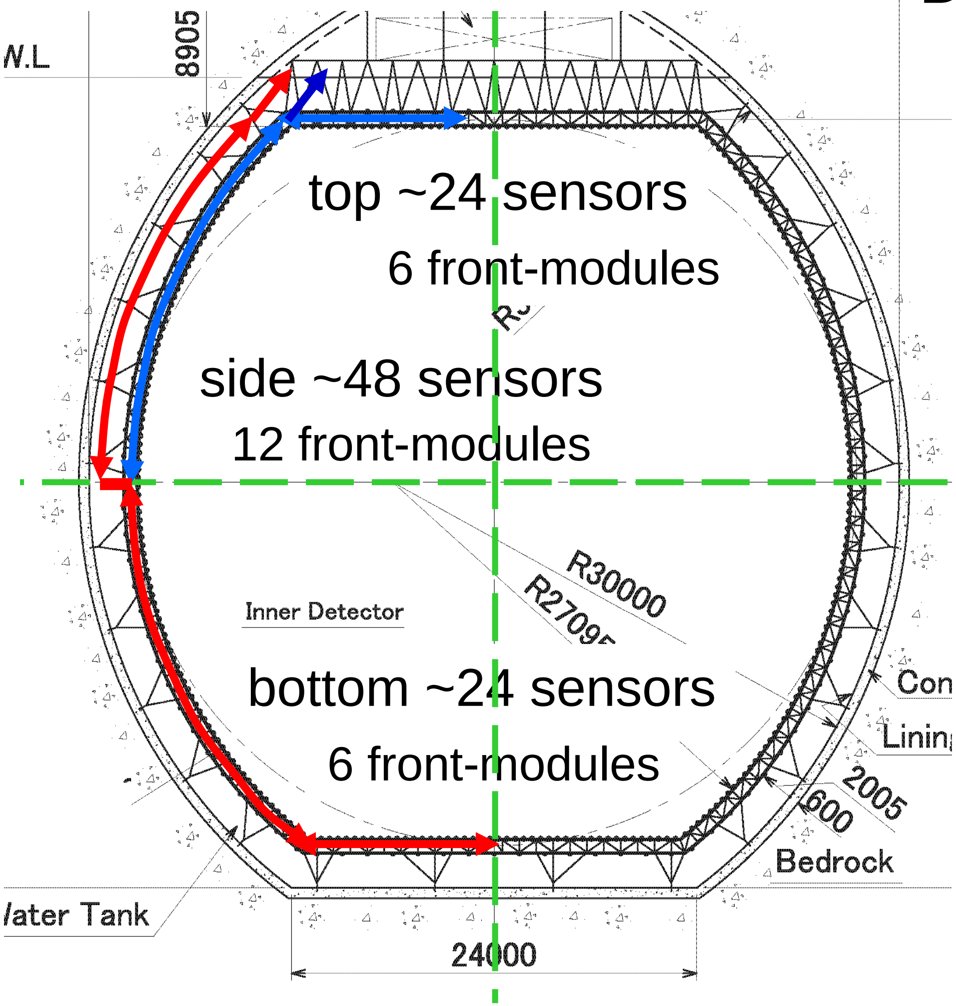
2 cables from each side

In total ~ 240 signal cables are coming out from single tank

Possible front-end electronics module connections

Data rate from one front-end board ~ 200 x [dark rate] B/sec
(assuming 24 ch / board)

Possible configuration
for 10 kHz dark rate



Dark rate

If dark rate is ~ 100kHz
data rate from a board
~ 20 MB/sec!
It might be possible to connect
two modules
and share one 1 GbE cable.

→ ~ 1200 signal cables

Also,
total “raw” data rate
50GB/sec/tank!

of channels per 1 front-end board

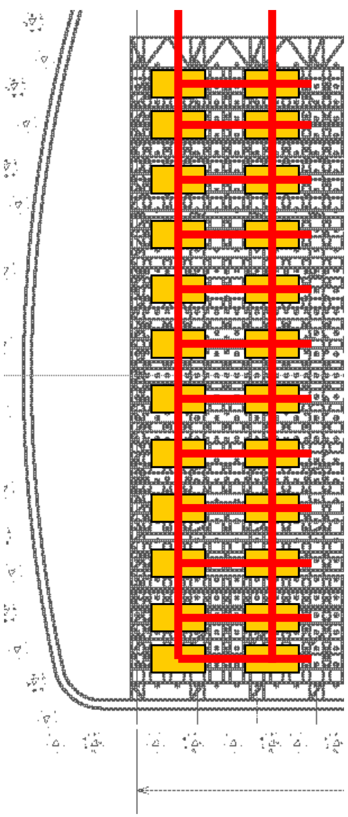
of channels per board

Usually, high density module is favored in terms of cost.

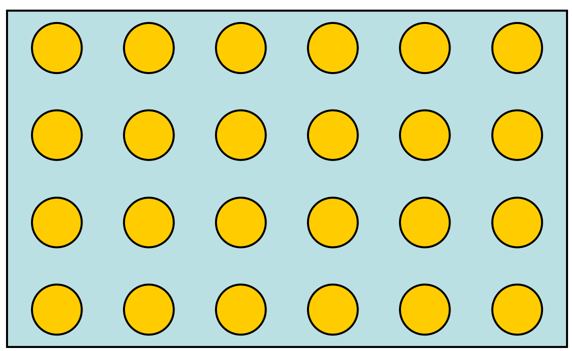
Restrictions
- Data rate per module
- Allowed size of the “dead region”

→ Effects could be reduced with better arrangements?

HK detector Side view

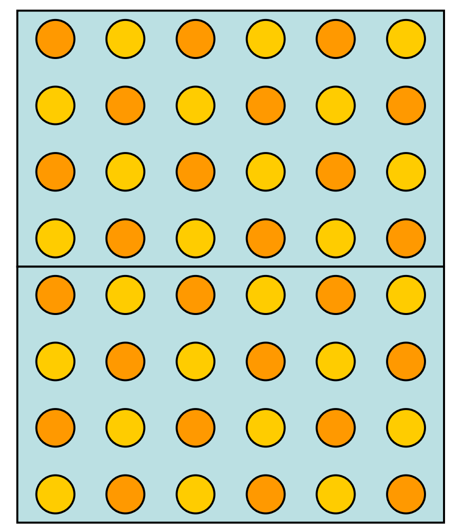


Simple configuration (like SK)



All sensors in a block are connected to one font-end board

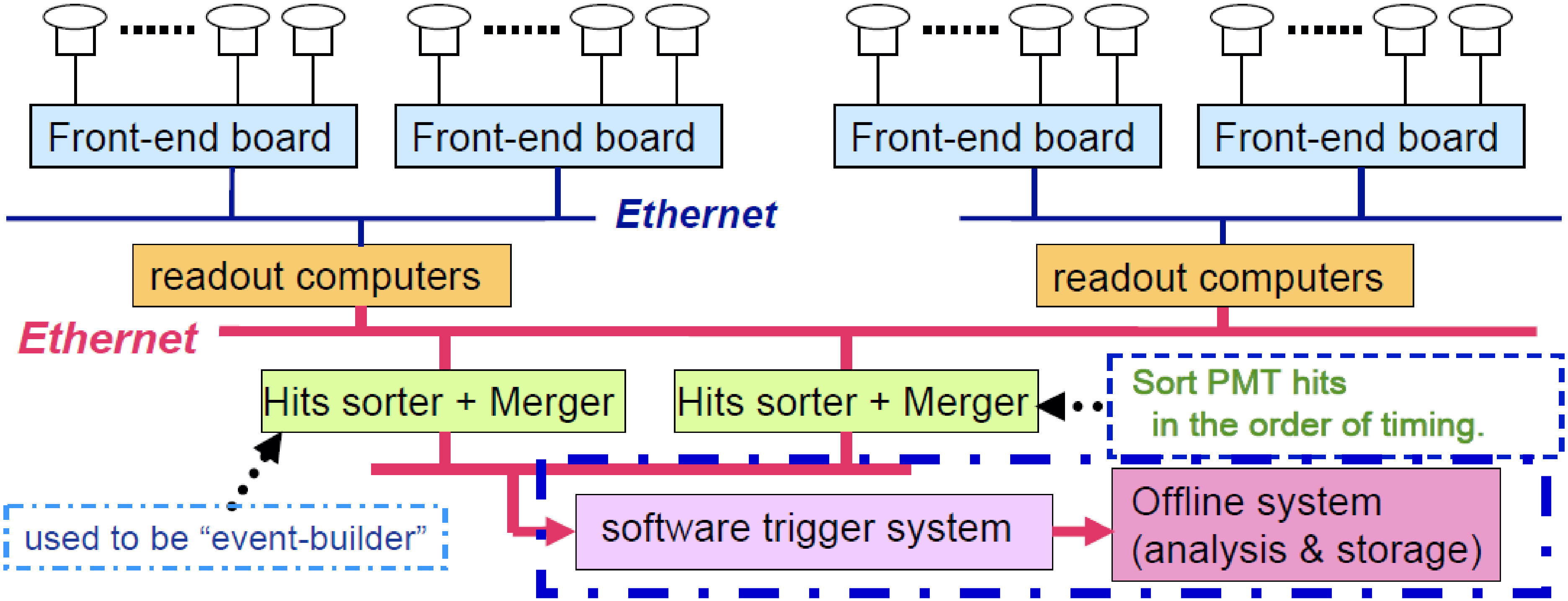
Possible alternative



Connect neighboring sensors to different front-end boards

Data rate after the software trigger

~ real-time data processing ~



Trigger rates and data sizes of "real" events

a) How many photo-sensors have hits from signal photons.

b) How high the trigger rates for each trigger type will be

c) How wide the gate width will be.

d) How high the nominal dark hit rate will be.

(There might be "fake events" from dark hits.)

Data rate after the software trigger

~ real-time data processing ~

1) Trigger rates and data sizes of “real” events

a) How many photo-sensors have hits from signal photons.

assuming 20% photo-coverage and

20 ~ 30% quantum efficiency

3 ~ 4.5 hits / MeV (based on SK experiences)

b) How high the trigger rates for each trigger type will be

c) How wide the gate width will be

Need assumption (here, **N** is the # of compartments)

Trig. type	Trig. rate	Gate	Signal hits
SLE	3,000 Hz	1.3 us	25
LE	35 Hz	40 us	50
Muon	**30 ~ 150 Hz**	40 us	50000 / N
Calibration	1 Hz	40 us	50000 / N
pedestal	2 Hz	17 us	50000 / N * 3

Data rate after the software trigger

~ real-time data processing ~

1) Trigger rates and data sizes of “real” events

d) How high the nominal dark hit rate will be.

Assume ~ 10kHz

(nominal dark rate for SK-PMT = 3 ~ 5 kHz)

Expected data rates after the software trigger

case 1) 3 compartments (N = 3)

10 kHz dark, 17 k sensors / compartment

μ rate = **35 Hz** (muon rate * area ~ 18 times larger)

~ 15 MB/sec/compartment

~ 40 % from SLE & 40% from μ

case 2) single compartment

10 kHz dark, 50 k sensors / compartment

μ rate = **150 Hz** (muon rate * area ~ 60 times larger)

~ 110 MB/sec ***~ 80 % from μ***

(not all the SLE events & μ are necessary to be stored in the disk)

Fake event rate ~ dark rate and majority trigger

Primarily, simple “majority” trigger is assumed.

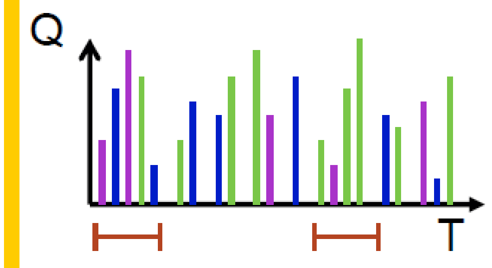
Count # of hit photo-sensors within a few ~ several hundreds of ns

If # of hits exceeds the threshold, hit data are recorded as an event.

Collect all the hits in a detector (compartment) and search for the timing cluster (peak)

1) sort hits in order of time

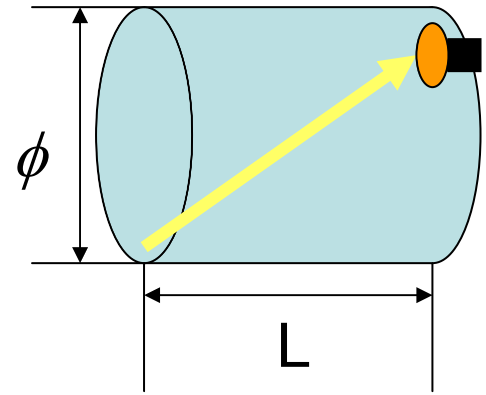
2) search for events by software or hardware



- Need to extend the “trigger gate width” as the detector gets larger.
- Accidental # of hits increases if dark rate gets higher and “trigger gate width” gets wider.

Dark hits may issue trigger ~ fake events.

Fake event rate ~ dark rate and majority trigger



How wide the coincidence gate should be?

~ how far a photons is expected to travel?

Size of the detector **~ 45 m ϕ x 50 m L**

max. photon travel time **~ 200 ns**

Size of the detector **~ 45m ϕ x 250m L**

max. photon travel time **< 1000 ns**

Considering the absorption / scattering length (80 ~ 100m)

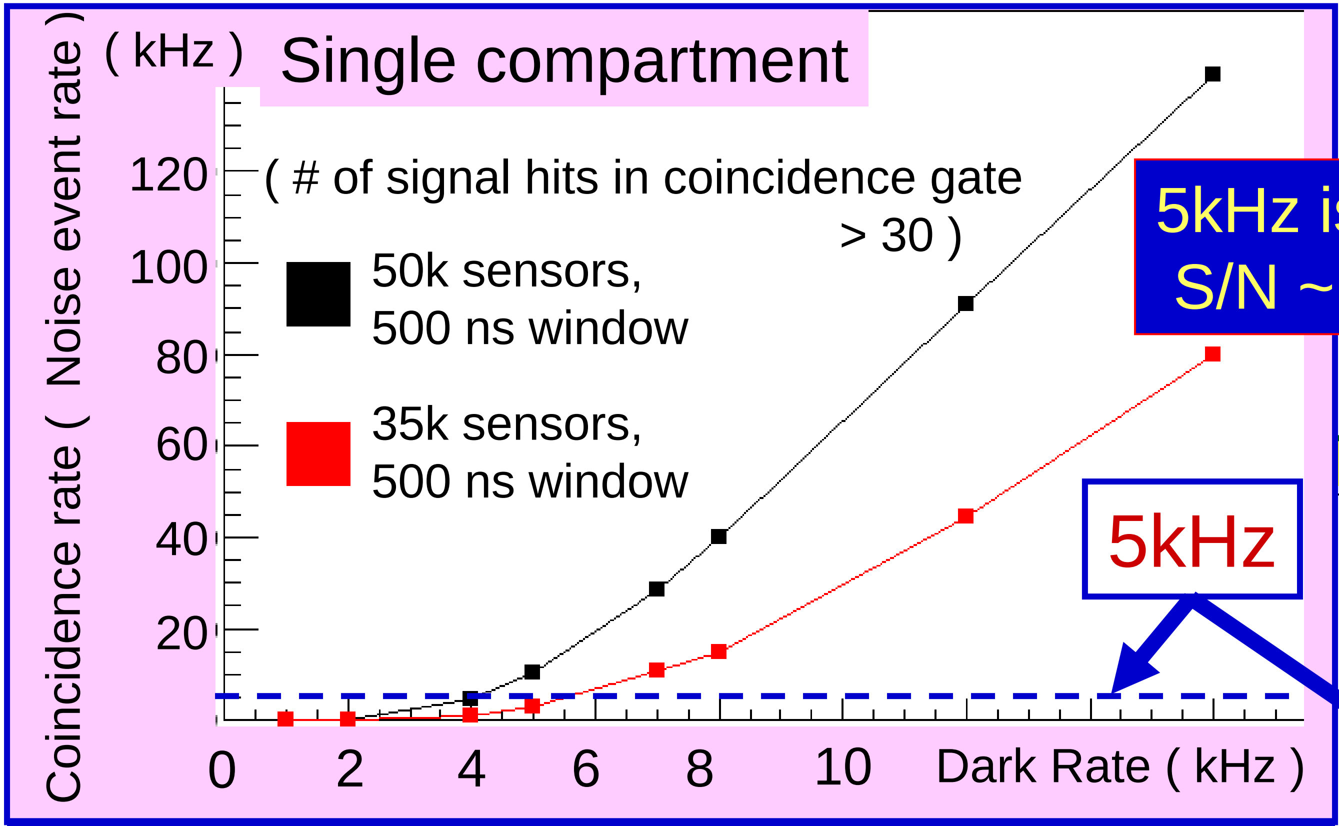
~ 500ns is (expected to be) sufficient

Evaluation of the fake trigger rate (noise event rate)

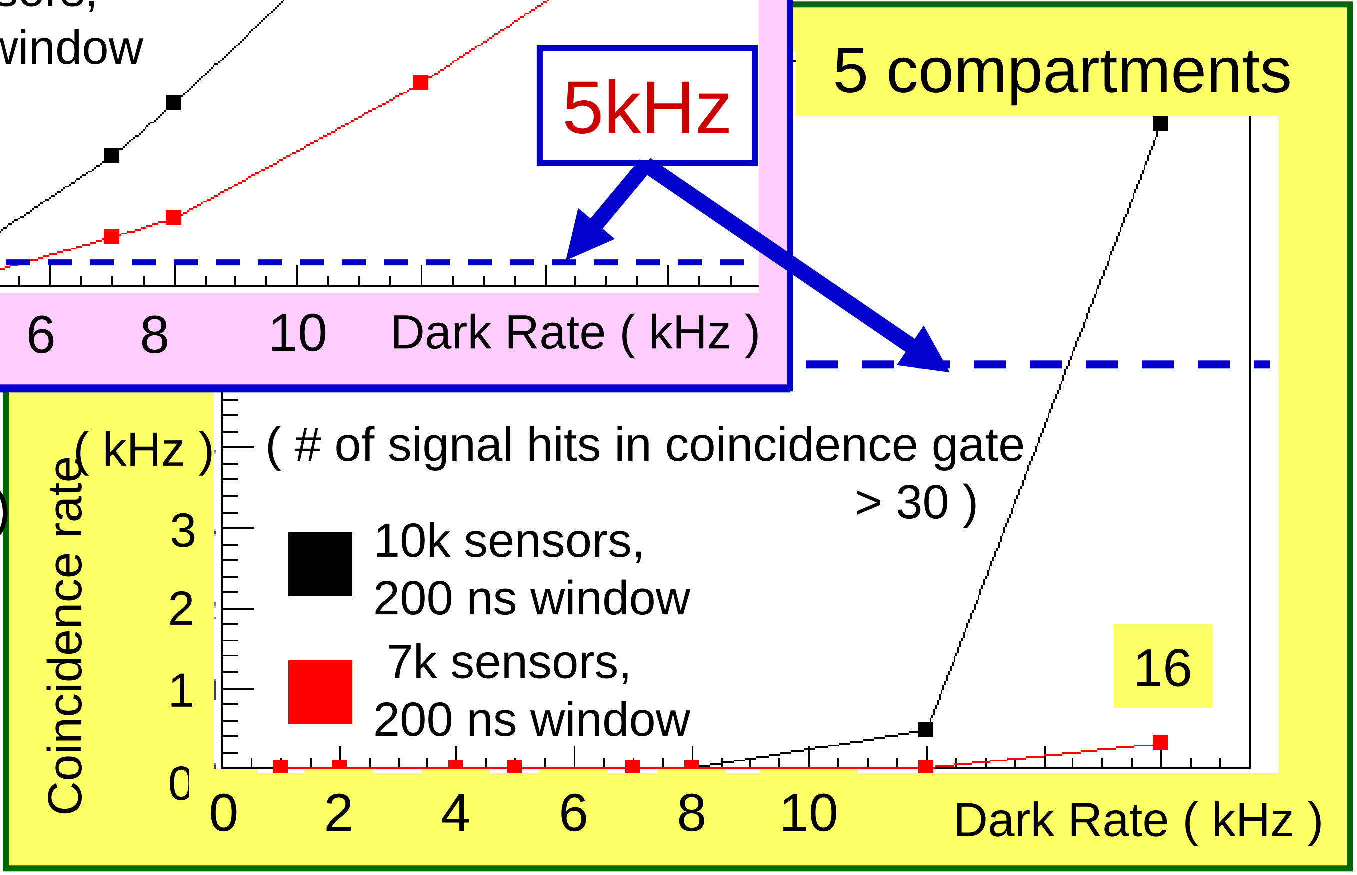
For 5 compartment case (default configuration), assume coincidence gate to be 200 ns.

Single compartment case, assume coincidence gate to be 500 ns.

Fake event rate ~ dark rate and majority trigger



5kHz is not a solid value
S/N ~ 1/1 or much worse



S.Hirota
(Photo sensor group)

Fake event rate ~ dark rate and majority trigger

1) Baseline configuration (5 compartments)

No problem for dark rate ***~ 10 kHz or less***.

2) Another configuration (single compartment)

Must be less than ***a few kHz***

to use "simple" majority trigger.

Single compartment configuration

Careful design and configuration

with new ideas / implementation.

a) Cabling (# of cables) and efficient connections

b) Triggering scheme

c) Handling of the data

both in the online and the offline system.

Also in the analyses.

Extremely rough estimate of the costs

Electronics part		
	ADC/TDC	~ 480k / board (20k * 24 channels)
	Network	~ 50k / board
	Control block	~ 50k / board
LV/HV		
	power supply	~ 240k / board (10k * 24 channels)
Connectors		~ 120k / board (5k * 24 channels)
Case		~ 100k / board
Total		~1040k / board
		(for 100k channels, ~ 4.3×10^9)

Summary ~ R&D starting from this year

Actual design of the analog signal handling part
and LV/HV components

Need to wait for the final decision of the photo-sensor

Start R&D work of the following items:

1) Water-tight case for the electronics modules

2) Connectors and cables
   - Water-tight connectors
   - under-water network cable etc.

3) TDC ~ search for the candidate chips

4) Data handling components (incl. network interface)

fin.

Data rate from front-end electronics modules

Nominal hit data (data rates) are dominated by dark noise

1 hit corresponds to 64 bits

Cable ID (with additional info)	32 bits
Timing	16 bits
Charge (Q)	16 bits

Could be compressed to 48 bits but

“64 bits” block is faster to handle in the software.

Nominal data rate per channel

Dark noise rate : R_D kHz

Data rate = R_D x 1000 x 8 bytes

= 8 x R_D kB/sec/channel

Assuming R_D = 5kHz

~ 40 kB/sec/channel

Data rate from front-end electronics modules

Assuming R_D = 5kHz ~ 40 kB/sec/channel

24 ch / board -> ~ 1MB/sec/board

(current SK)

Assuming to use Gigabit Ethernet

(Limitation of the length of the cable and stability)

Want to limit nominal data rate < 30 ~ 50MB/sec

(1/2 ~ 1/3 compared to the maximum band width)

In order to reduce the # of cables from the tank,

data from multiple modules are transferred

via single GbE cable.

→ *30 ~ 40 modules per cable* is one guide upper limit