DISCUSSION OF CEPC DAQ

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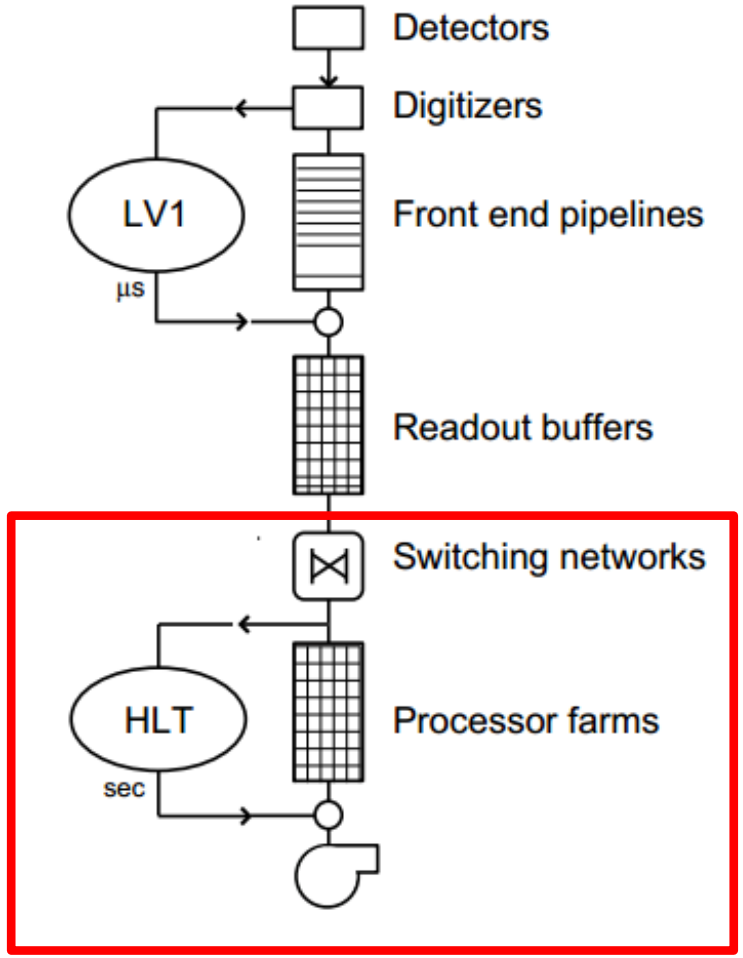
DAQ System Scope



- Link with off-detector electronics.
- Need readout buffers in electronics
  - Protect for readout latency and jitter from backend asynchronous and not enough real time computing system
- Commercial computer and network devices
- Specific distributed cluster computing software

Main Tasks

- Readout data from the electronics
  - With the level-1 trigger decision given by trigger system
  - Hardware trigger-less option is not included in current version
- Build into a full event
  - with data fragments from different sub-detectors
- Process data
  - such as data compression and event filter to reduce data volume
- Save data to permanent storage
- Other functions
  - Run control/configuration/monitoring

Event Rate and Hit Density

- The event rate reaches 32 kHz for Z factory operation
  - from Z boson decays and Bhabha events
  - with the 2 Tesla solenoid option (L= 3.2 x10^{35} cm^2/s).
- Assume a maximum event rate of 100kHz
  - Safety factor for level-1 trigger system

	H(240)	W(160)	Z(91)
Hit density (hits $\cdot$ cm^{-2} $\cdot$ BX^{-1})	2.4	2.3	0.25
Bunching spacing (μs)	0.68	0.21	0.025
Occupancy (%)	0.08	0.25	0.23

Table 4.2: Occupancies of the first vertex detector layer at different machine operation energies: 240 GeV for ZH production, 160 GeV near W-pair threshold and 91 GeV for Z-pole.

Data rate estimation: Tracker

	Total # channels M(10^6)	Occupancy %	Nbit /channel	# Channels readout/evt k(10^3)	Volume /evt MBytes	Data rate @100 kHz GBytes/s
Vertex	690	0.3	32	2070	8.3	830
Silicon Tracker						
Barrel	3238	0.01 ~ 1.6	32	1508	3.15	315
Endcap	1238	0.01 ~ 0.8	32	232	0.4	40
TPC	2	0.1-8	30	1375	5	500
Drift Chamber	0.056	5-10	480	?	3	300

- Collect requirements from each detector systems
  - Readout time of pixel sensors is set as 10 μs for Vertex and SiTracker
  - Same with trigger less mode
- Data rate of tracker <1700GBytes/s

Data rate estimation: Calorimeter

	Total # channels M(10^6)	Occupancy %	Nbit /channel	# Channels readout/evt k(10^3)	Volume /evt MBytes	Data rate @100 kHz GBytes/s
ECAL						
Barrel	17/7.7	0.17	32	28.8/13.1	0.117/0.053	11.7/5.3
Endcap	7.3/3.3	0.31	32	22.4/10.2	0.090/0.041	9.0/4.1
AHCAL						
Barrel	3.6	0.02	32	0.72	0.0029	0.3
Endcap	3.1	0.12	32	3.72	0.015	1.5
DHCAL						
Barrel	32	0.004	2	1.28	0.00032	0.03
Endcap	32	0.01	2	3.2	0.0008	0.08
Dual Readout Calorimeter	22	0.4-1.6	64	88-352	0.704-2.8	70-280

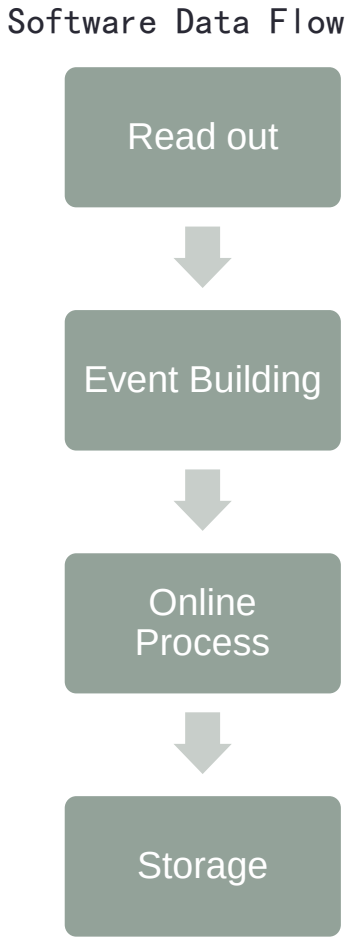
- Data rate of calorimeter < 280GBytes/s
  - Unknown data rate with trigger less mode
- Total data rate of CEPC < 2TBytes/s, with 20MBytes/event

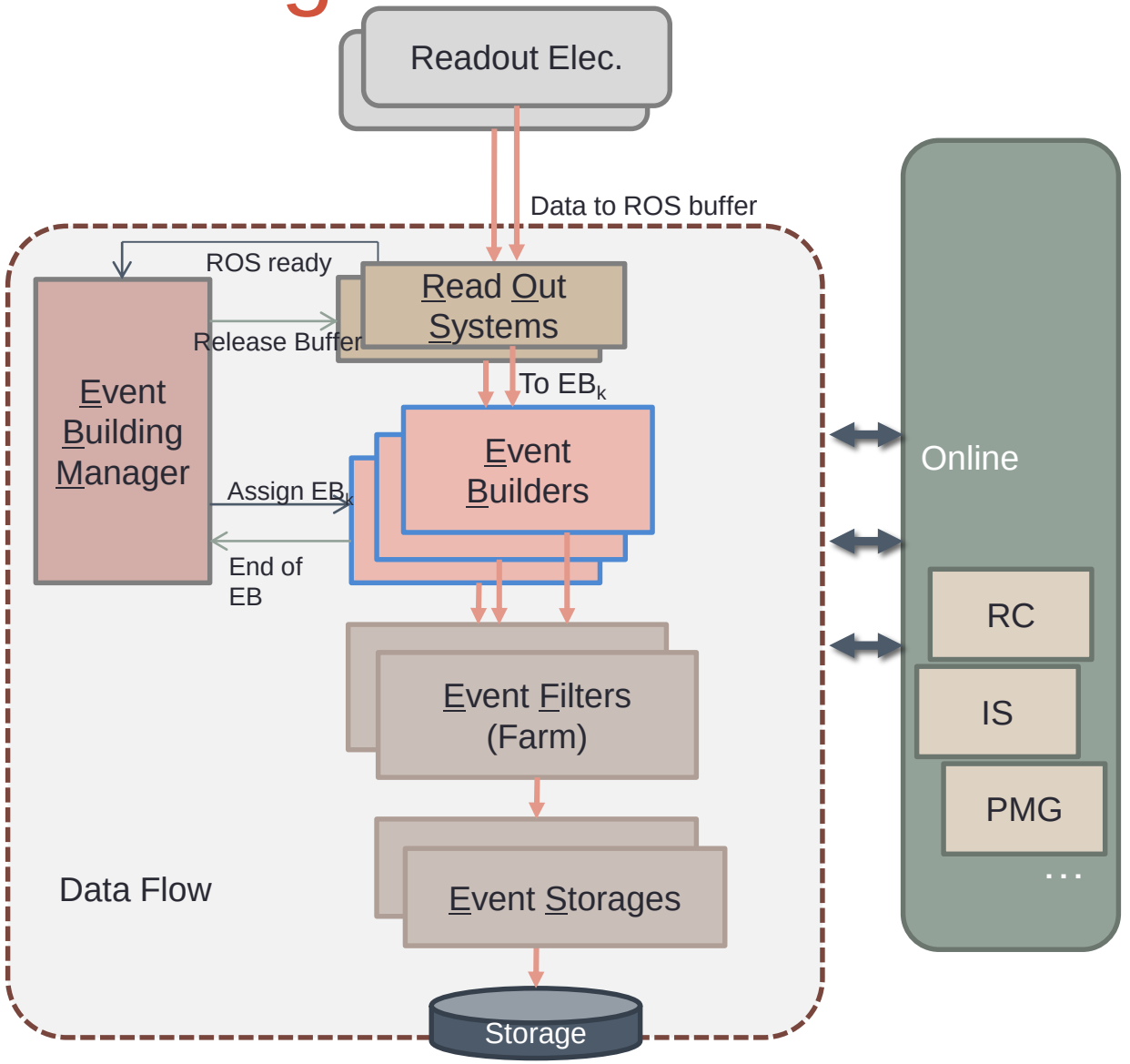
Electronics readout interface

- Physics links: Ethernet should be best option
  - Specific boards reside in xTCA off-detector electronics crates
    - Convert to Ethernet: cable or fiber
  - Easy concentrate links with 1Gb-> 10Gb/25Gb -> 40Gb/100Gb by commercial switches
  - Only arrange network switches at front end with off detector electronics and uplink to backend computing room
- Interface link numbers to counting room for 2TBytes/s data rate
  - 16000~20000 1Gbits/s links
  - 1600~2000 10Gbits/s links
  - 640~800 25Gbits/s links
  - 160~200 100Gbits/ links

DAQ Software Architecture Design

- Big distributed cluster computing
  - Thousands of current computing nodes(32cores)
  - EB throughput ~2GBytes/node
- Similar software architectures design with BESIII and ATLAS DAQs
  - Modular design, easy to expand
  - Event building by L1 trigger number





Summary

- Estimate order of magnitude for total data rate as 2TBytes/s
- Computing requirements for event processing depends on the reconstruction times and trigger algorithms
- Give a compatible baseline solution for DAQ conceptual design
  - No challenge with current technologies
  - But could be updated with developing and newest technologies
- Hardware trigger less option should be discussed later
  - Closely related to electronics designs of each detectors
- Need follow newest computing hardware and software technologies progress
  - High speed and efficiency readout
  - Big scale online distributed computing
    - Data transport, data compression, event filter, software trigger

Thank you for your attention!

Backup

Vertex

- Readout Time: 10 us
- Cell size: 0.016x 0.016 mm^2
- Number of channels: 690 Million
- Cluster 9 cells / hit
- Average occupancy: 0.3%
- Number of bits per hit: 32 bits
- 690M*0.3%*4=8.3MByes * 100kHz=830GBytes/s
- 100kHz vx 10us readout time = trigger less option (100kHz vs 40MHz)
- 690M*0.25*16um*16um*9*4=16kBytes/bunch * 100kHz=1.6GBytes/s

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Silicon tracker

- 1. pixels instead of strips;
  2. pixel size: 50 um x 350 um;
  3. chip size about 20 mm x 20 mm, and one chip for one electronic channel;
  4. others consistent with the VTX.

	Readout Time (us)	cell size (mm2)	number of channels	occupancy	Nbits/hit	data volume (Mbyte)
SIT-L1	20	0.350x0.050	1,784	1.6%	32	2.6
SIT-L2	20	0.350x0.051	6,263	0.4%	32	2.3
SET-L3	20	0.350x0.052	133,634	0.01%	32	1.4
sum			141,681			6.3

TPC

- Time sampling period: 25ns
- Cell size& 1.0 x 6.0 mm2
- Number of channels: 2 Million
- Average to maximum occupancy: 0.1-8%
  (for IBF*Gain<10 in the continuous beam bunches)
- Number of bits per hit: 30 bits
- Data volume: 300 - 500 MB
- 2m*8%*30/4=3.75kBytes * 100kHz = 375MBytes/s