

CDR of CEPC DAQ

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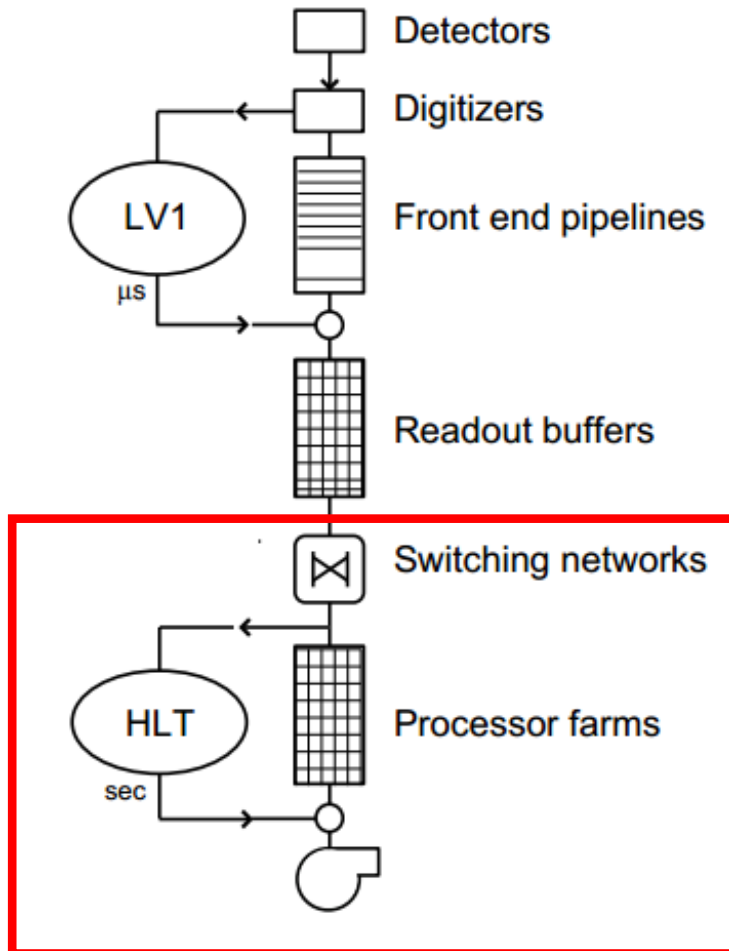
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Content

- Scope and main task
- Data rate estimation
- Conceptual design schema
- Summary

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 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 to storage
- 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 ($L = 3.2 \times 10^{35} \text{ cm}^2/\text{s}$).
- Assume a maximum event rate of 100kHz
 - Safety factor for level-1 trigger system

	H(240)	W(160)	Z(91)
Hit density ($\text{hits} \cdot \text{cm}^{-2} \cdot \text{BX}^{-1}$)	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

- Readout time of pixel sensors is set as 10 μ s for Vertex and SiTracker
- 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 < 280 GBytes/s
- Total data rate of CEPC < 2 TBytes/s, with 20 MBytes/event

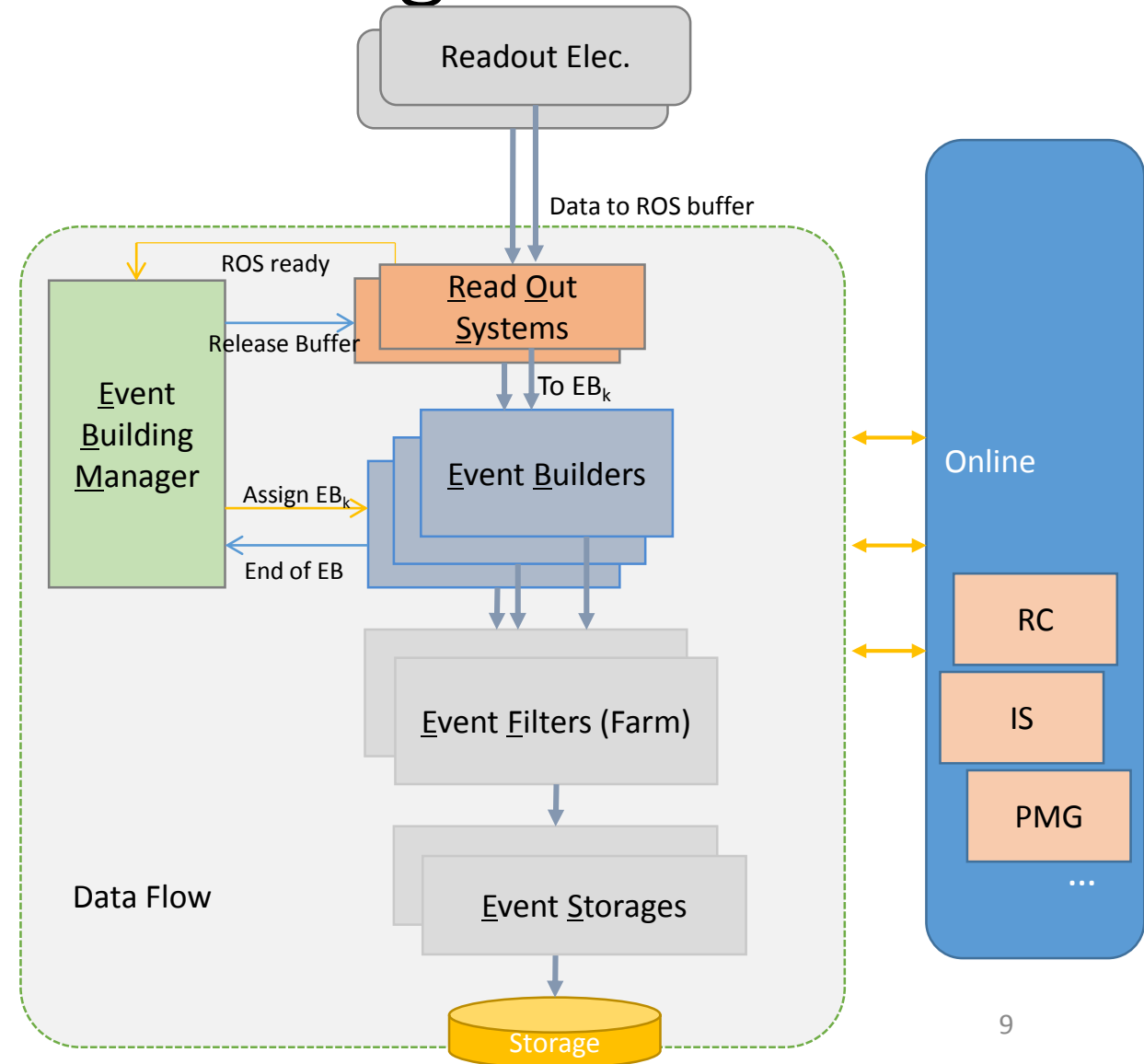
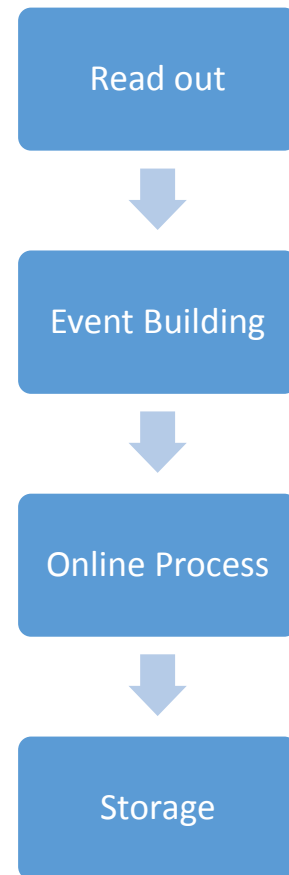
Electronics readout interface

- Interface link numbers for 2TBytes/s data rate
 - 16000~20000 1Gbits/s links
 - 1600~2000 10Gbits/s links
 - 640~800 25Gbits/s links
- Physics links: PCIE/HDMI/DP/Fiber/Ethernet
 - Specific computing boards reside in xTCA off-detector electronics crates
 - Convert to Ethernet: cable or fiber
 - General computer servers with specific fiber adapter
- Ethernet should be best option
 - Whatever any other interface should be convert to Ethernet for latter computer processing
 - Easy concentrate links from 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

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

Software Data Flow



Summary

- Collect requirements from sub detectors and electronics
- 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 conceptual solution for DAQ design
 - No challenge with current technologies
- Hardware trigger less option should be discussed later

Thank you for your attention!

Backup

Vertex

- Readout Time: 10 us
- Cell size: 0.016x 0.016 mm²
- Number of channels: 690 Million
- Cluster 9 cells / hit
- Average occupancy: 0.3%
- Number of bits per hit: 32 bits
- $690\text{M} \cdot 0.3\% \cdot 4 = 8.3\text{MBytes} \cdot 100\text{kHz} = 830\text{GBytes/s}$
- 100kHz vx 10us readout time = trigger less option (100kHz vs 40MHz)
- $690\text{M} \cdot 0.25 \cdot 16\mu\text{m} \cdot 16\mu\text{m} \cdot 9 \cdot 4 = 16\text{kBytes/bunch} \cdot 100\text{kHz} = 1.6\text{GBytes/s}$

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Silicon tracker

- 1. pixels instead of strips;
- 2. pixel size: 50 μm x 350 μm ;
- 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 (mm ²)	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
- $2m * 8\% * 30/4 = 3.75 \text{ kBytes} * 100 \text{ kHz} = 375 \text{ MBytes/s}$