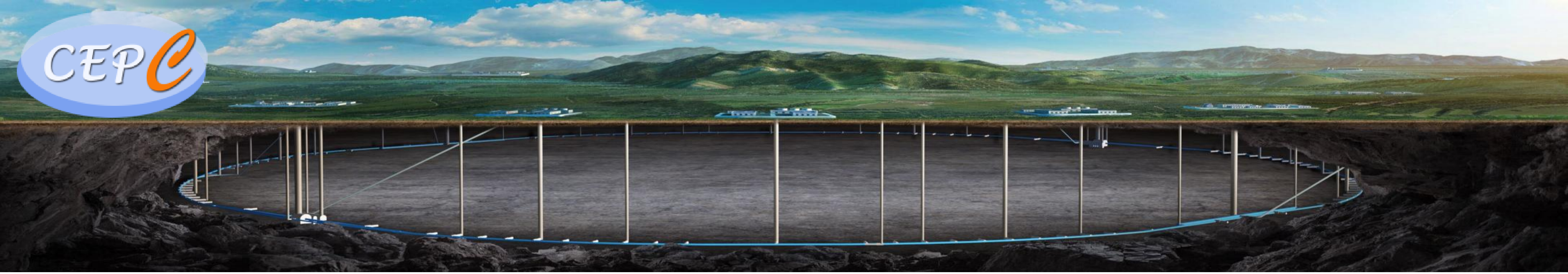

TDAQ Progress of CEPC Detector ref-TDR

Fei Li
On behalf of CEPC TDAQ Group

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Progress of TDAQ

- Revised TDR content
  - Update readout window
- Prepared answer to IDRC review 2

Second IDRC review

Comments

The background event rate and event size are critical inputs to defining the TDAQ system dataflow requirements. Assumptions used should be explicitly stated and consistently referenced across all relevant chapters (some inconsistencies were noted in the current draft).

>>The detail information for the event rate and event size are summarized in table 12.4 and 12.5

Table 12.4: Time windows for each subdetector and the event size calculation for both ZH and Z mode. The "Full Data" is from Figure 11.1. The data size per bunch is derived by dividing the "Full Data" by the collision frequency, with the ZH mode collision frequency being 1.34 MHz and the Z mode 12 MHz. The data size per event is obtained after accounting for the impact of the time windows of each sub-detector on individual events.

	Vextex	ITK	OTK	TPC	ECAL	HCAL	Muon	Total
Time windows (ns)	223	53	53	34023	323	1023	123	
ZH mode Full Data(Gbps)	1983.88	17.36	98.70	56.03	2445.12	751.20	0.72	5353.00
Data size / bunch (kB)	185.06	1.62	9.21	5.23	228.09	70.07	0.07	499.35
Data size / event (kB)	185.06	1.62	9.21	642.86	456.18	280.30	0.07	1575.29
12.1MW Z mode Full Data(Gbps)	7828.95	25.91	170.06	60.97	3470.40	1255.63	0.72	12812.64
Data size / bunch (kB)	81.55	0.27	1.77	0.64	36.15	13.08	0.01	133.47
Data size / event (kB)	326.21	0.27	1.77	311.85	180.75	196.19	0.02	1017.05

Table 12.5: Trigger rate estimation table for different run conditions. The background data rate is calculated by summing the "Full Data rate" of all the subdetectors in Figure 11.1 in the electronics chapter. The background data size/bunch crossing derived from the ratio of the background data rate to bunch crossing rate. The detail calculation for the trigger rate and DAQ readout rate are shown in Table 12.12.

Operation phase		I		II	III
Condition	Higgs	Z (12.1 MW)	W	Z (50 MW)	$t\bar{t}$
Luminosity ($10^{34}/cm^2/s$)	8.3	26	26.7	95.2	0.8
Physical event rate (kHz)	0.5	10	1.1	40	0.057
L1 triger rate (kHz)	50	120	65	400	2
DAQ readout rate (Gbyte/s)	53.6	92.3	-	-	-
High level trigger rate (kHz)	1	20	2	80	1
Raw event size (kbyte)	1575.29	1017.05	1500	1000	1000
DAQ storage rate (Gbyte/s)	1.6	20	1	80	1

The event size is calculated based on the information from the electronic chapter, and the time windows for each sub-detector.

The safety factors applied in system design should be made explicit, clearly motivated, and documented to allow for easy updates and assessment of their impact on different subsystems.

>>A safety factor "1.5" is applied when estimating the event size, mentioned in section 11.2: "It is worth noting that during the calculation, a safety factor of 1.5 was considered for the background rate."

On top of that, another safety factor "10" is applied when estimating the trigger efficiency, as mentioned in section 12.4.1: "For both the ZH and the Z mode, each

Table 12.6: L1 Trigger resource estimation table. The number in parentheses represents the resources required for track trigger additional, in which ITK,TOTK and TPC will be used.

Detector	Area (m^2)	Modules	BEE Num	Area/BE (m^2)	Modules/BE	Hit Rate($10^3Hz/cm^2$) or cluster in BX	TP Bits	Trigger Board	ATCA Crate	DCTD Boards
TPC	–	–	32	–	–	–	–	(2)	(1)	(1)
ITK-Barrel	11.9	–	149	0.086	–	34.8	64 bits	(9)	(0)	(0)
ITK-EndCap	2*9.89	–	78	0.2	–	487	64 bits	(51)	(6)	(6)
OTK-Barrel	65	–	34	1.92	–	4.82	64 bits	(3)	(0)	(0)
OTK-EndCap	2*10	–	45	0.67	–	23.9	64 bits	(4)	(1)	(1)
ECAL-Barrel	–	480	60	–	8	1 cluster/module/BX	48 bits	8	1	1
ECAL-EndCap	–	224	28	–	8	1 cluster/module/BX	48 bits	4	1	1
HCAL-Barrel	–	640	346	–	2	1 cluster/module/BX	48 bits	22	2	2
HCAL-EndCap	–	128	192	–	1	1 cluster/module/BX	48 bits	12	2	2
Muon-Barrel	–	144	18	–	8	1 fiber/trigger/BE	–	1	0	0
Muon-EndCap	–	96	6	–	16	1 fiber/trigger/BE	–	1	1	1
Global Trigger	–	–	–	–	–	–	–	18+(12)	2+(2)	2+(2)
TCDS	–	–	–	–	–	–	–	1	1	1
Sum	–	–	–	–	–	–	–	67+(81)	10+(10)	10+(10)

- Update the design of the common trigger board—particularly the bandwidth and input link capacities from the BEEs—to reflect the information presented. Explain the rationale behind the estimated number of trigger boards required at each of the three L1 levels.

>> These part is added in "resource estimation" section as the last answer.

- Provide a detailed description of how the TPC data stream will be handled, especially considering its long drift times.

>>The TPC reads all raw data, and uses trigger info to integrate 34 μs data segments sent to DAO. Data is packed in blocks by Trigger ID for parallel processing. TPC data is easily located via Trigger ID, enabling joint analysis with other detectors sharing the same trigger. A new paragraph for the TPC data stream detail information is added in section 12.5.2.

- Continue exploring the development of a fast-track trigger, emphasizing its potential to reduce background rates and ease the load on the HLT.

>>The track trigger is being studied, some fast tracking algorithm, including neural network, will be tried in future.

- Demonstrate the necessity for RDMA technology in transferring data from the BEE to the HLT, including a justification based on system performance needs.

>> Currently, CEPC's baseline design is to use the traditional TCP protocol for data transfer from the BEE to the HLT, while RDMA is primarily being considered as a research direction. This consideration is mainly based on the following points:

1. RDMA supports direct memory access, significantly reducing CPU utilization during data transfer. This helps to overcome the performance bottlenecks of traditional protocols and meet the demands of future high-throughput data transmission (e.g., for high-luminosity Z mode).

Raw Event Size and Data Rate

- Beam background with electronics

	Vextex	ITK	OTK	TPC	ECAL	HCAL	Muon	Total
Time windows (ns)	223	53	53	34023	323	1023	123	
ZH mode Full Data(Gbps)	1983.88	17.36	98.70	56.03	2445.12	751.20	0.72	5353.00
Data size / bunch (kB)	185.06	1.62	9.21	5.23	228.09	70.07	0.07	499.35
Data size / event (kB)	185.06	1.62	9.21	642.86	456.18	280.30	0.07	1575.29
12.1MW Z mode Full Data(Gbps)	7828.95	25.91	170.06	60.97	3470.40	1255.63	0.72	12812.64
Data size / bunch (kB)	81.55	0.27	1.77	0.64	36.15	13.08	0.01	133.47
Data size / event (kB)	326.21	0.27	1.77	311.85	180.75	196.19	0.02	1017.05

- Data rate
  - More storage
  - Need event size compression
    - Full Rec. with BX
    - ROI

Operation phase Condition	I Higgs	 Z (12.1 MW)	 W	II Z (50 MW)	III $t\bar{t}$
Luminosity ($10^{34}/cm^2/s$)	8.3	26	26.7	95.2	0.8
Physical event rate (kHz)	0.5	10	1.1	40	0.057
L1 triger rate (kHz)	50	120	65	400	2
DAQ readout rate (Gbyte/s)	53.6	92.3	-	-	-
High level trigger rate (kHz)	1	20	2	80	1
Raw event size (kbyte)	1575.29	1017.05	1500	1000	1000
DAQ storage rate (Gbyte/s)	1.6	20	1	80	1

backup

Raw Event Size and Data Rate

- Confirmed time windows for each subdetector + 1 clock uncertainty
  - VXD 200 ns (not confirmed), ITK/OTK 30 ns, TPC 34 us, Muon 100 ns
  - Ecal 150 ns, Hcal 3000 ns
- Raw event size 1.8/1.3 kB for Higgs/Low Z(readout data rate 67/130 GB/s)

	vextex	itk	otk	tpc	ecal	hcal	muon	total
signal width	200	30	30	34000	150	3000	100	
time window	223	53	53	34023	173	3023	123	
higgs full data(Gbps)	1983.88	17.36	98.70	56.03	2445.12	751.20	0.72	5353.00
kB/bunch	185.06	1.62	9.21	5.23	228.09	70.07	0.07	499.35
kB/event	185.06	1.62	9.21	642.86	228.09	770.82	0.07	1837.72
Readout data rate(Gbps)	74.03	0.65	3.68	257.14	91.24	308.33	0.03	533.97
low Z full data(Gbps)	7828.95	25.91	170.06	60.97	3470.40	1255.63	0.72	12812.64
kB/bunch	81.55	0.27	1.77	0.64	36.15	13.08	0.01	133.47
kB/event	326.21	0.27	1.77	311.85	108.45	575.50	0.02	1324.06
Readout data rate(Gbps)	313.16	0.26	1.70	299.37	104.11	552.48	0.01	1032.70

Comments of IDRC second Review

- ~~The background event rate and event size are the most critical inputs to designing the dataflow requirements for the TDAQ system. The assumptions should be clearly stated and referenced consistently in the different chapters (there are some inconsistencies in the draft document).~~
- ~~The safety factors used in the design of the system should be made explicit and clearly motivated and documented so that they can be updated and their implications for different systems readily understood.~~
- ~~Section 12.4 should be moved to come after section 12.6.~~

Strike-throughs indicate that changes have been made.

Recommendations of IDRC second Review

- ●~~The data bandwidth requirements into the L1 trigger and between trigger system layers and the number of links required should be motivated. The current plans or assumptions for trigger primitives from each of the Back End Electronics types and their volume should be described. Similarly, the output products of the local trigger layers should be described, along with data bandwidth estimates into the next global trigger layer.~~
- ●~~Update the design of the common trigger board, in particular the bandwidth and input links from the BEEs, to match the information shown in the presentations. Explain the factors leading to the estimated number of trigger boards at each of the three levels.~~
- ●~~The handling of the TPC data stream should be explained in detail.~~
- ●~~The possibility of using a fast track trigger should continue to be explored, including the potential savings in the HLT from having a lower background from the L1 level.~~
- ●~~The need for RDMA technology for transferring data from the BEE to the HLT should be demonstrated.~~
- ●~~The handling of data flow in the event of full buffers should be described.~~

Recommendations of IDRC second Review

- ●~~Consider whether the hierarchy of the L1 trigger could be collapsed into a multiplexer layer directly feeding into a layer with full global trigger primitives in each common trigger board.~~
- ●~~We recommend categorising the event rate as e+e- physics signal (e.g. ZH, but also two and four fermions, and Bhabha), gamma-gamma interactions and beam backgrounds. The first category aims at full trigger efficiency, the second one is potentially of some interest with much lower priority and the last one must be reduced as much as possible~~.
- ~~We recommend studying the beam background distribution as a function of energy, multiplicity, polar and azimuthal angle, to develop the most appropriate algorithm to suppress it. The background peaks shown at Fig. 12.10 (i.e. at about 7 GeV for the ECAL Endcap) should be understood~~.