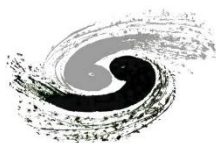




Progress of CEPC ref-TDR TDAQ

Fei Li

On behalf of CEPC TDAQ Group



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Progress of TDAQ

- TDR draft v0.3
 - Update for Trigger/HLT/DAQ
 - DCS/ECS missing
- TDAQ meeting
 - Nov. 28th (Tue. afternoon)
- Trigger and read out window

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TDAQ meeting Nov. 28th (Tue. afternoon)

Cross section of Bhabha need to be updated

- the energy difference between the two particles has to be greater than 10 GeV.

Process	Luminosity[ab^{-1}]	Final states	X-sections(fb)
$e^+e^- \rightarrow e^+e^-$	5.6	e^+e^-	24770.90

HLT algorithm strategy

- 1st fast and rough rec. to reduce event rate
- 2nd full rec. and ROI to compress event size

Discussion of DCS design

Discussion for Cal & Muon detectors

CEPC TDAQ meeting		🔍
📅 Thursday Nov 28, 2024, 2:00 PM → 5:00 PM Asia/Shanghai		
2:00 PM → 2:10 PM	Introduction Speakers: Mr Fei Li (EPC, IHEP, Beijing, China), Jingzhou ZHAO (高能所), Xiaolu Ji (Institute of High Energy Physics, CAS)	🕒 10m 🔍
2:10 PM → 2:20 PM	Simulation Speakers: Boping Chen, dong Liu (中国科学院高能物理研究所) 📎 cepc触发1128.pdf	🕒 10m 🔍
2:20 PM → 3:10 PM	Detector Survey	🔍
2:20 PM	Vertex Speakers: Hongyu ZHANG (EPC, IHEP, CAS, China), 韩 徐 (高能所)	🕒 10m 🔍
2:30 PM	ITK&OTK Speakers: Sheng DONG (IHEP, CAS), Xiangyi Mu (高能物理研究所)	🕒 10m 🔍
2:40 PM	TPC&DC Speakers: Hongyu ZHANG (EPC, IHEP, CAS, China), 叙 张 (高能所)	🕒 10m 🔍
2:50 PM	ECal&HCal Speakers: Boping Chen, dong Liu (中国科学院高能物理研究所) 📎 CAL study.pptx	🕒 10m 🔍
3:00 PM	Muon Speakers: Junhao YIN (南开大学), 灿明 李 (中科院高能物理研究所) 📎 cpec_muon_pre_1... 📎 Design and test for...	🕒 10m 🔍
3:10 PM → 3:20 PM	Trigger Hardware Speakers: Jingzhou ZHAO (高能所), Sheng DONG (IHEP, CAS), dong Liu (中国科学院高能物理研究所)	🕒 10m 🔍
3:20 PM → 3:30 PM	Readout Protocol Speakers: Hongyu ZHANG (EPC, IHEP, CAS, China), Sheng DONG (IHEP, CAS), 韩 徐 (高能所)	🕒 10m 🔍
3:30 PM → 3:40 PM	HLT Speakers: Boping Chen, Junhao YIN (南开大学), Yi LIU (DESY), 启东/Qidong 周/Zhou (山东大学/Shandong university)	🕒 10m 🔍
3:40 PM → 3:50 PM	DAQ software Speakers: Hongyu ZHANG (EPC, IHEP, CAS, China), Xiangyi Mu (高能物理研究所), Xiaolu Ji (Institute of High Energy Physics, CAS), Yi LIU (DESY), 叙 张 (高能所)	🕒 10m 🔍
3:50 PM → 4:00 PM	DCS&ECS Speakers: Sheng DONG (IHEP, CAS), 斯 马 (高能所)	🕒 10m 🔍

Beam Backgrounds

Ave. hit rate Higgs Vs Low Z

- Vertex: 0.49 -> 1.96, 5 times
- ITK: 0.0021 -> 0.08, 40 times
- ECal: 0.011 -> 0.35, 30 times

Higgs Vs Low Z

- BX rate 1.34 -> 12 MHz

Raw data rate @Higgs

- 400GB/s

Raw data size per BX @Higgs

- 300KBytes

	50MW Higgs, 346ns/BX
Pair Production	~1.82GHz in IR
Beam Thermal Photon	~0.30MHz/beam in IR
Beam Gas Bremsstrahlung	~0.04MHz/beam in IR
Beam Gas Coulomb	~0.23MHz/beam in IR
Touschek Scattering	~0.06MHz/beam in IR
Radiative Bhabha	
SR	~630 PHz/beam generated at last bending magnet

	50MW Higgs, 23ns/BX
Pair Production	~25.5GHz in IR
Beam Thermal Photon	~0.26GHz/beam in IR
Beam Gas Bremsstrahlung	~0.01GHz/beam in IR
Beam Gas Coulomb	~2.36GHz/beam in IR
Touschek Scattering	~6.24GHz/beam in IR

	10MW Z, 69ns/BX
Pair Production	~3.2GHz in IR
Beam Thermal Photon	~63MHz/beam in IR
Beam Gas Bremsstrahlung	~2.5MHz/beam in IR
Beam Gas Coulomb	~272MHz/beam in IR
Touschek Scattering	~62MHz/beam in IR

Sub-Detectors	Ave. Hit Rate(MHz/cm2)	Max. Hit Rate(MHz/cm ²)	Max. Occupancy/BX(%)
Vertex	0.49	0.61	0.0022
ITK	0.0021	0.25	0.025(Strip)
TPC	2.7	6.0	0.0045
OTK – Endcap	0.0002	0.0006	0.35(Strip)
ECal – Endcap	0.011/bar	0.3/bar	0.0008
HCal – Endcap	0.002/GS	0.05/GS	0.0005
Muon – Endcap	0.00000001/cell	0.00002/cell	0.006
LumiCal – Crystal	3.37	7.82	9.1

Sub-Detectors	Ave. Hit Rate(MHz/cm2)	Max. Hit Rate(MHz/cm ²)	Max. Occupancy/BX(%)
Vertex	15.64	18.34	3.73e-3
ITK	0.61	57.61	0.0543
TPC	2	3.5	0.0026
OTK – Endcap			
Ecal – Barrel	1.54/bar	22.3/bar	7.03
ECal – Endcap	2.84/bar	43.5/bar	9.29
HCal – Endcap			
Muon – Endcap			1.5

Sub-Detectors	Ave. Hit Rate(MHz/cm2)	Max. Hit Rate(MHz/cm ²)	Max. Occupancy/BX(%)
Vertex	1.96	2.30	3.73e-3
ITK	0.08	7.20	0.0543
TPC	0.25	0.45	0.0026
OTK – Endcap			
ECal – Barrel	0.2	2.79/bar	7.03
ECal – Endcap	0.35	5.44/bar	9.29
HCal – Endcap			
Muon – Endcap			1.5
LumiCal – Crystal			

Trigger & Data Rate

■ L1 trigger rate

- 13 kHz@Higgs, 120 kHz@low. Z

■ Read out window

- TPC 34 us
- CLIC rec. time window
 - ECAL & HCAL Endcaps & Silicon 10 ns
 - HCAL Barrel 100 ns

■ Readout event size

- 620KBytes @ Higgs
 - 100 BX/events and 3.2 KBytes/BX for TPC
- 2 MBytes @Low lum. Z
 - 500 BX/event for TPC(full readout)
 - 2 BX for Hcal (75 KBytes/BX)
- 5.3 MBytes @High lum. Z
 - 1472 BX/event for TPC(full readout)
 - 5 BX for HCal

■ DAQ data rate

- Read out: 8 GB/s @Higgs, 83.4 GB/s @ Low lum. Z (120kHz*375KB + 12MHz*3.2KB)
 - 366 GB/s @ High lum. Z (400kHz*(300+75*4)KB + 39.4MHz*3.2KB)
- Storage: 0.6 GB/s @Higgs, 50 GB/s @Low lum. Z (7.5GB/s after event size compression)
- 1 year(3600h): 8 PB, 100 PB

	Higgs	Z(10MW)	Z(50MW)	W	tt
Luminosity(10E34/cm2/s)	8.3	38	192	26.7	0.8
Bunch space(ns)	346.2	69.3	23.1	253.8	4523.1
Bunch cross rate(MHz)	1.34	12	39.4	6.5	0.18
Raw data rate before trigger (TBytes/s)	0.4	3.6	11.82	1.95	0.048
Physical event rate(kHz)	0.008	13.2	66	0.1	0.002
L1 trigger rate(kHz)	13	120	400	65	2
DAQ readout rate(Gbyte/s)	26	240	800	130	4
High level trigger rate(kHz)	1	25	100	6	1
DAQ storage rate(Gbytes/s)	0.3	7.5	30	1.8	0.3

Event size: readout 2MB, storage 300KB

Backup

Physical Event Rate

■ Higgs 240GeV(30MW/50MW)

- BX rate: 0.8(1.74)/1.34(2.9) MHz
- Physical event rate: 5Hz/8Hz (Higgs: 0.02Hz)

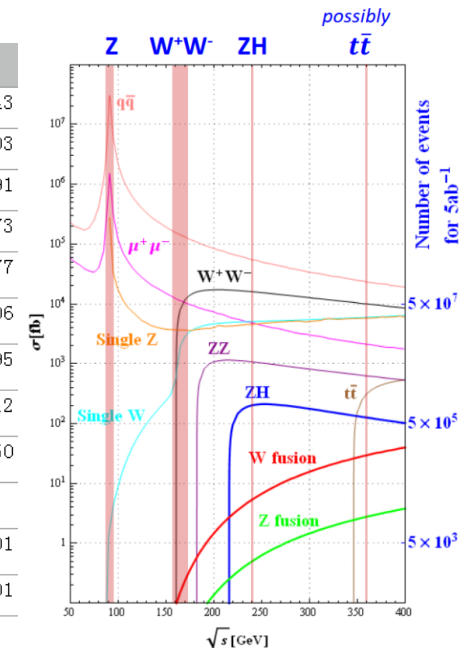
■ Z pole 91GeV(10MW/50MW)

- BX rate: 12(14.5)/39.4(43.3) MHz
- Physical event rate: 13.2kHz/66kHz

	Higgs	Z		W	$t\bar{t}$
SR power per beam (MW)	30	30	10	30	30
Bunch number	268	11934	3978	1297	35
Bunch spacing (ns)	576.9 (×25)	23.1(×1)	69.2(×3)	253.8(×11)	4523.1(×196)
Train gap (%)	54	17	17	1	53
Luminosity per IP ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	5.0	115	38	16	0.5

	Higgs	Z	W	$t\bar{t}$
SR power per beam (MW)	50			
Bunch number	446	13104	2162	58
Bunch spacing (ns)	346.2 (×15)	23.1 (×1)	138.5 (×6)	2700.0 (×117)
Train gap (%)	54	9	10	53
Luminosity per IP ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	8.3	192	26.7	0.8

过程	xsection(nb)	百分比	事例率kHz
Bhabha	0.0586	0.001371951	0.068597543
muon	1.5361	0.035963374	1.798168703
tau	1.5249	0.035701158	1.78505791
电子中微子	2.9607	0.069316296	3.465814777
muon中微子	2.9896	0.069992906	3.499645306
tau中微子	2.9909	0.070023342	3.501167095
中微子总	8.9411	0.209330202	10.46651012
总共	42.7129	1	50
		亮度	
30MW		1.15E+36	4.91E+01
50MW		1.92E+36	8.20E+01



Z pole, ref: MC /cefs/data/stdhep/CEPC91/
2fermions/wi_ISR_20220618_50M/2fermions/

Raw Data Rate

■ Data rate before trigger

- <1 TB/s @ Higgs
- Several TB/s @ Z

■ L1 trigger rate

- O(1k) Hz @ Higgs
- O(100k) Hz @ Z

■ Event size < 2 MB

- Related to occupancy and read out window

■ Storage rate after HLT

- <100 Hz(200 MB/s) @ Higgs
- 100 kHz (200 GB/s) @ Z

	Vertex	Pix(ITKB)	Strip (ITKE)	OTKB	OTKE	TPC	ECAL-B	ECAL-E	HCAL-B	HCAL-E	Muon
Channels per chip	512*1024	512*128	1024	128		128	8~16				
Data Width /hit	32bit	42bit	32bit	48bit		48bit	48bit				
Avg. data rate / chip	0.18Gbps/chip, 1Gbps/chip inner	3.53Mbps/chip	21.5Mbps/chip	2.9Mbps/chip	38.8Mbps/chip	~70Mbps/module Inmost	10kHz/ch	10kHz/ch	5kHz/channel	5kHz/channel	10kHz/channel
Detector Channel/module	1882 chips @Stch &Ladder	30,856 chips 2204 modules	23008 chips 1696 modules	83160 chips 3780 modules	11520 chips 720 modules	492 Module	0.96M chn ~60000 chips 480 modules	0.39 M chn	3.38M chn 5536 aggregation board	2.24M chn 1536 Aggregation board	43,176 chn, 288 modules
Avg Data Vol before trigger	474.2 Gbps	101.7 Gbps	298.8 Gbps	249.1 Gbps	27.9 Gbps	34.4 Gbps	460.8 Gbps	187 Gbps	811.2 Gbps	537.6 Gbps	24 Gbps
Occupancy(%)	0.022	0.025(Strip)		0.35(Strip)		0.0028	0.58		0.002		0.038
Sum	3.2 Tbps = 400GB/s										

Collected from each detectors @Higgs

Trigger & Data Rate

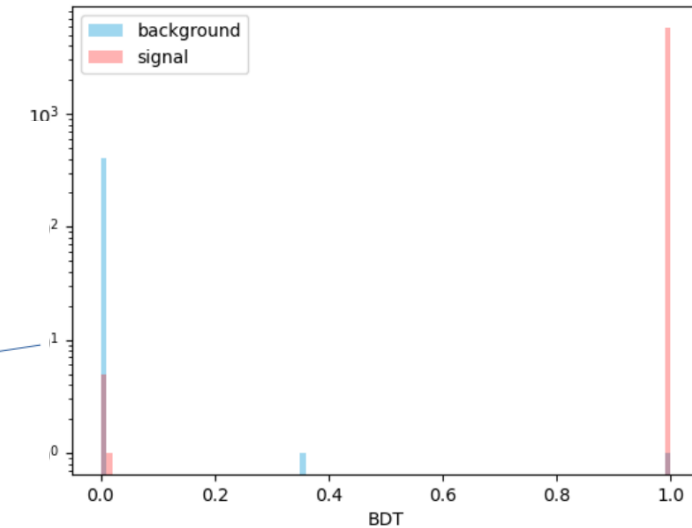
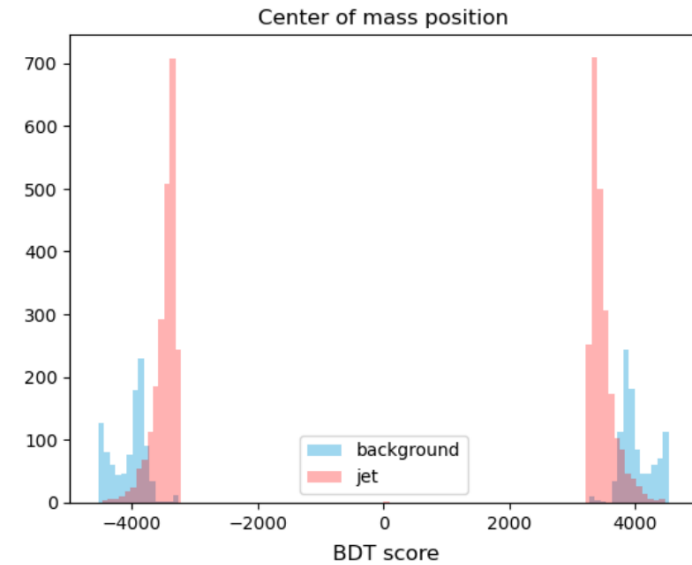
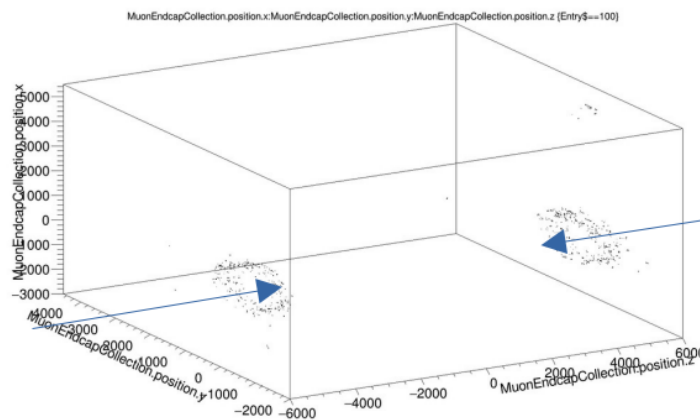
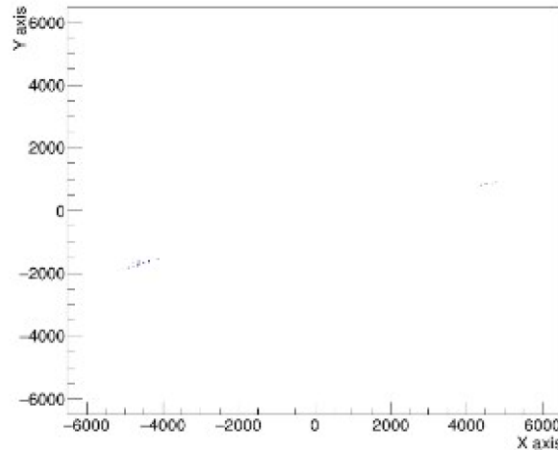
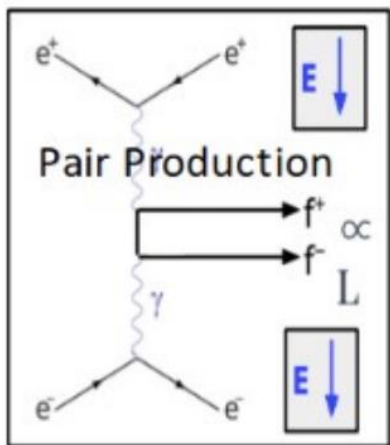
- Compress background -> 1% @ L1
- Compress background -> 0.1% @ HLT
- Data size per bunch cross
 - 300Kbytes @ Higgs
 - Unknown @Z
- Event size < 2 Mbyte
 - Occupancy and read out window
- L1 trigger rate
 - 13 kHz@Higgs, 120 kHz@low. Z
- DAQ data rate
 - Read out: 26~240 GB/s
 - @ Higgs & low lum. Z
 - Storage: 0.3~7.5 GB/s

	Higgs	Z(10MW)	Z(50MW)	W	tt
Luminosity(10E34/cm2/s)	8.3	38	192	26.7	0.8
Bunch space(ns)	346.2	69.3	23.1	253.8	4523.1
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L1 trigger rate(kHz)	13	120	400	65	2
DAQ readout rate(Gbyte/s)	26	240	800	130	4
High level trigger rate(kHz)	1	25	100	6	1
DAQ storage rate(Gbytes/s)	0.3	7.5	30	1.8	0.3

Trigger simulation

■ Trigger simulation study

- BDT: energy + Centre of gravity for Ecal&Hcal
 - Higgs: 1.34MHz- $\rightarrow$ 3.4kHz
 - Trigger efficiency 95%- $\rightarrow$ 99.9%, background 5%- $\rightarrow$ 0.25%
- Tracking @ Muon detector
- gamma-gamma collisions

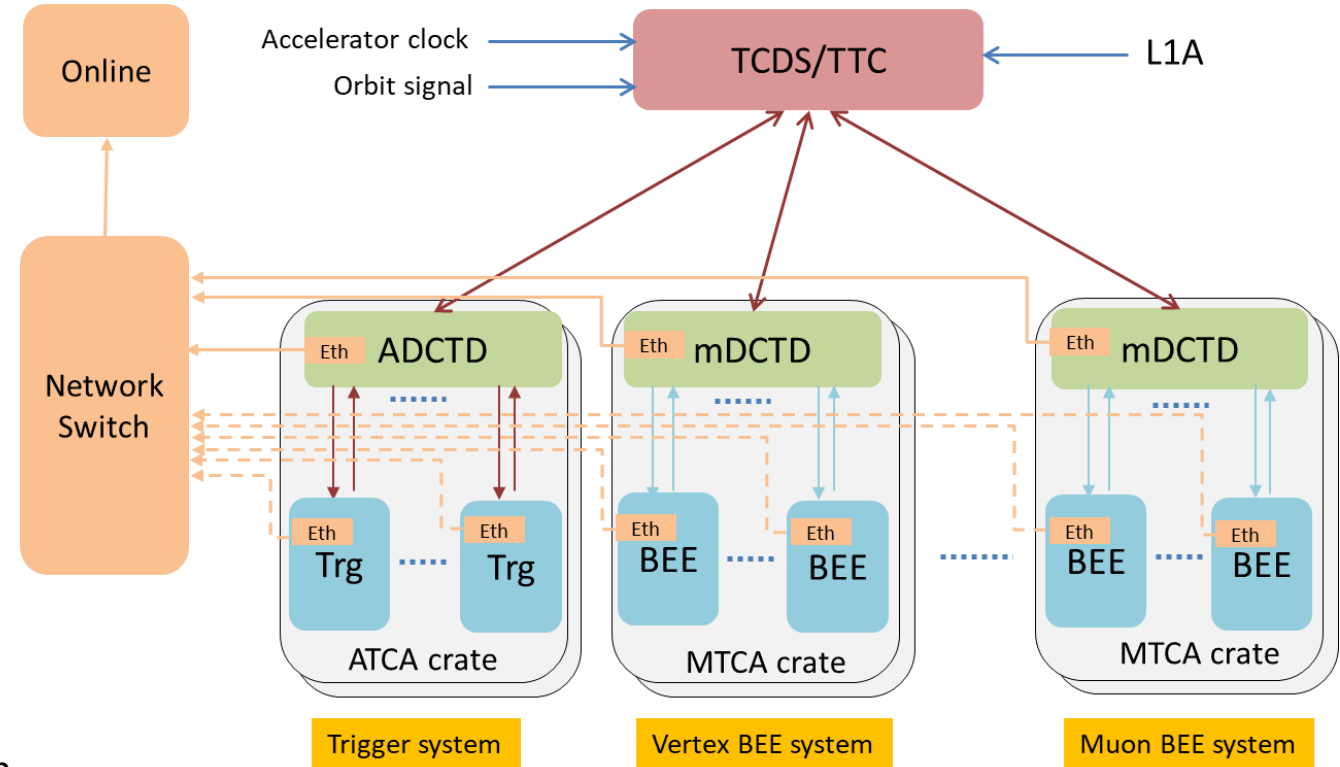


TCDS-Trigger Clock Distribution System

■ TCDS/TTC

- Clock, BC0, Trigger, orbit start signal distribution
- Full, ERR signal feed back to TCDS/TTC and mask or stop L1A

- TCDS-Trigger Clock Distribution System
- TTC- Trigger, Timing and Control
- DCTD-Data Concentrator and Timing Distribution
- BEE-Backend board Electronic



TDAQ are only responsible for system-level distribution, each system is then responsible for its own internal distribution.

DCS&ECS schema discussion

■ Missing requirements of detectors

- <https://jupyter.ihep.ac.cn/CwulQi9ESayf4QLUXqbz8A>
- HV
 - TPC/ SiPM per module
- LV
 - 26116 ch/ 549 crates
- Gas/
 - TPC 8 input/8 output
- Cooling/TH/Others

■ IOT

- Wireless LoRA

■ Software

- WinCC-OA, EPICS

CEPC Detector Control & Monitoring

Underground Requirements

Number Of Detectors Parameters required for control and monitoring

Detectors	HV Crates	HV Channels	Gas Monitoring	Cooling	Temp& Humidity	Other
Eg.	10	160	control:10 flow:10 ?	control:10 flow:10 ?	T:20 H:20 ?	
Vertex	x	x	x	x	x	
TPC	3个9U的SHV机箱	248*2	8 input/ 8output			
ITK-Barrel						