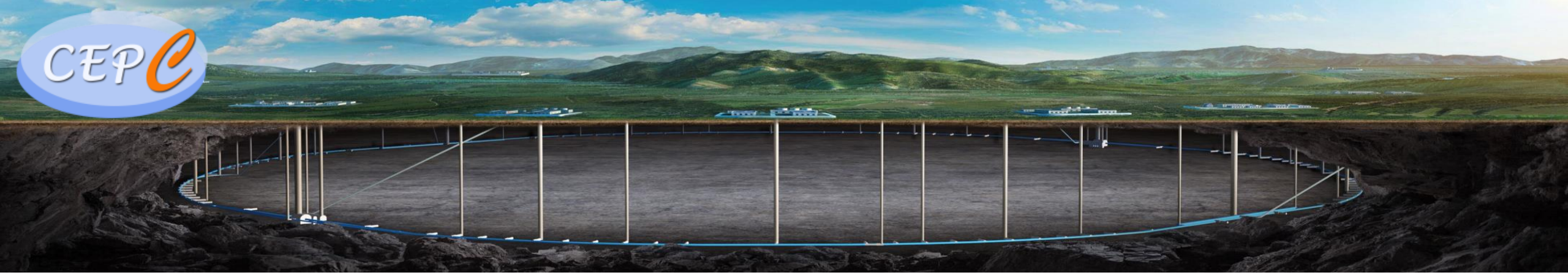

Progress of CEPC ref-TDR TDAQ

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Progress of TDAQ

- TDR draft v0.1
- DAQ/RADAR meeting
  - Nov. 11th (Mon. afternoon)
  - DAQ architecture design
- Trigger rate discussion
- Trigger simulation study

Chapter 12 Trigger and Data Acquisition

12.1 Introduction
12.2 Requirements and Design Considerations
12.2.1 Requirements
12.2.2 Event rate & background rate estimation
12.2.3 TDAQ design consideration
12.3 Trigger Simulation and Algorithms
12.3.1 Physics Signatures and primitives with sub-detectors
12.3.2 Sub-detectors trigger algorithms
12.3.3 Global trigger algorithms
12.4 Hardware Trigger
12.4.1 Previous experience on large facilities
12.4.2 System architecture
12.4.3 Common Trigger Board
12.4.4 Trigger Control and Distribution
12.4.5 Resource cost estimation
12.5 Software and High Level Trigger
12.6 Data Acquisition System
12.6.1 Previous experience on large facilities
12.6.2 Overview of System Functionality
12.6.3 Detector Readout
12.6.4 Dataflow
12.6.5 Online Software
12.6.6 Hardware Deployment
12.7 Detector Control System
12.8 Experiment Control System
12.9 Summary

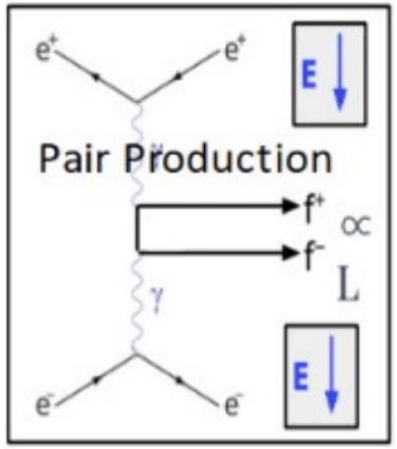
Trigger & Data Rate

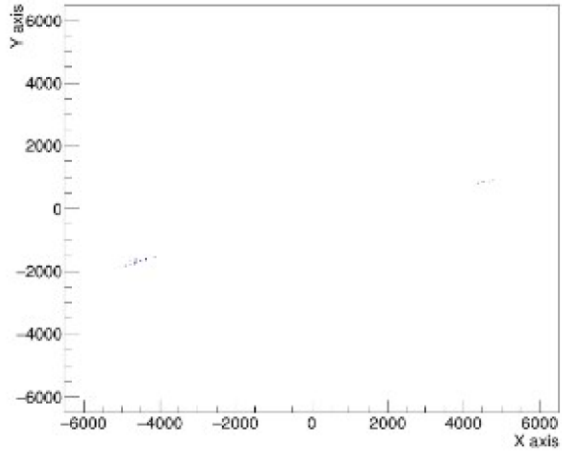
- Compress background -> 1% @ L1
- Compress background -> 0.1% @ HLT
- Data size per BX
  - 300Kbytes @ Higgs
  - Unknown @Z
- Event size < 2 Mbyte
  - Occupancy and read out window
- L1 trigger rate
  - 13~120 kHz @ Higgs & low lum. Z
- DAQ data rate
  - Read out: 26~240 GB/s @ Higgs & low lum. Z
 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

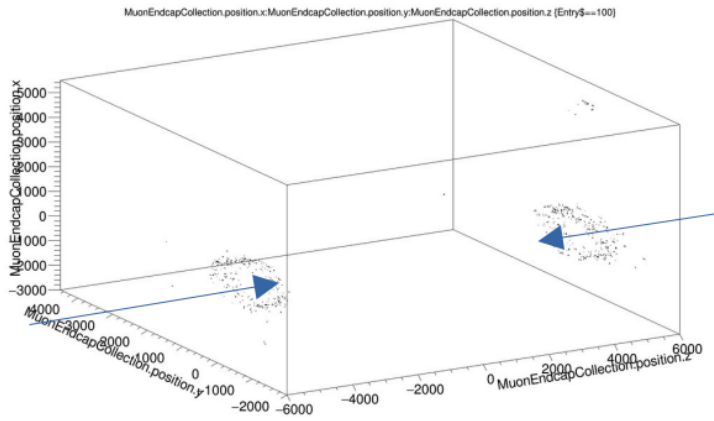
	Higgs	Z(10MW)	Z(50MW)	W	tt
Luminosity(10E34/cm2/s)	8.3	38	192	26.7	0.8
Bunch space(ns)	346.2	69.3	23.1	253.8	4523.1
Bunch cross rate(MHz)	1.34	12	39.4	6.5	0.18
Physical event rate(kHz)	0.008	13.2	66	0.1	0.002
L1 trigger rate(kHz)	13	120	400	65	2
DAQ readout rate(Gbyte/s)	26	240	800	130	4
High level trigger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

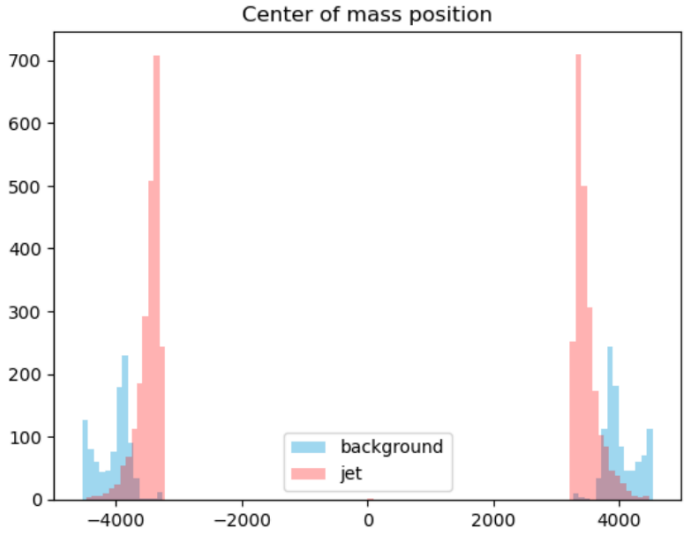
Trigger simulation

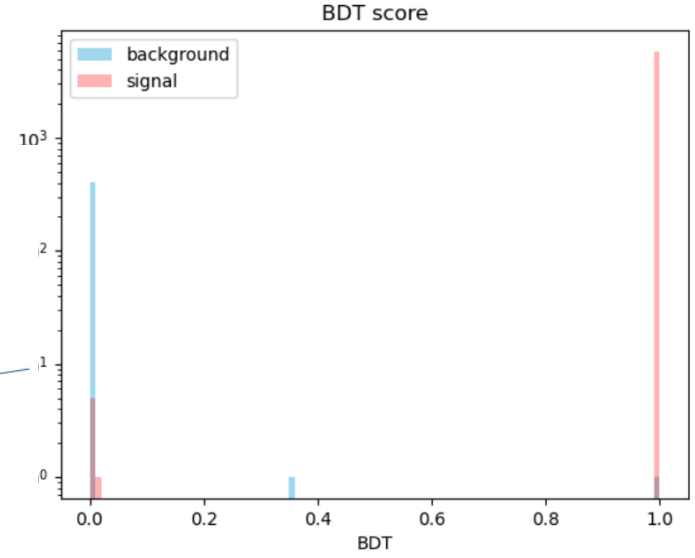
- Trigger simulation study
  - BDT: energy + Centre of gravity for Ecal&Hcal
    - Higgs: 1.34MHz->3.4kHz
    - Trigger efficiency 95%->99.9%, background 5%->0.25%
  - Tracking @ Muon detector
  - gamma-gamma collisions











Backup

Working Plan for TDR

- 先根据河南技术方案修改一个版本，一周。后面三周扩充内容。
- 模拟：
  - 第一周：事例率（Cal+Muon), muon tracking
    - 双gamma光子应对策略
  - 第二周：L1算法(Cal+Muon)算法，TDR editing
  - 第三周：TPC、OTK tracking，low lum. Z background.
  - 第四周：Global trigger start，TDR draft 0.1
  - 12月，TDR draft 1.0
    - HLT algorithm 结果
    - Global trigger
    - trigger efficiency

Chapter 12 TDAQ and online

12.1 Introduction
12.2 Requirements and Design Considerations
12.2.1 Requirements
12.2.2 Event rate & background rate estimation
12.2.3 Technology survey
12.2.4 TDAQ policy consideration
12.2.5 TDAQ Interface with electronics
12.3 Trigger Simulation and Algorithms
12.4 Hardware Trigger
12.4.1 Previous experience on large facilities
12.4.2 System architecture
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12.8 Experiment Control System
12.9 Summary

Working Plan for TDR

- 硬件触发
  - 11月
    - Hardware trigger structure design for TDR
    - trigger board/ TTC detailing
    - BEE interface
    - basic trigger primitives
  - 12月：
    - trigger primitives for each L1 detectors
    - common trigger board structure finalize
    - L1 algorithm deploment design, boards num

Working Plan for TDR

- HLT
  - 11月
    - 编辑一页的FPGA加速
    - GPU，概念性描述
    - 离线软件状况
- DAQ
  - 11月
    - system architecture
    - software layer data flow
    - RDMA/GPU/FPGA/Mem buffer
  - 12月
    - Network/hardware
    - Online software
- DCS
  - 11月
    - DCS requirement from each detectors
    - framework design
- ECS
  - 11月
    - framework design
    - control network
  - 12月
    - IT infrastructure
    - hardware
    - control/computing room
    - monitoring

Findings--revised

- The baseline plan is to transmit the full raw data to the front-end electronics and connect the trigger to the back-end electronics.
  - Transmit the full raw data from front-end electronics(on-detector) to back-end electronics(off-detector)
- A hierarchical trigger scheme is foreseen to bring event data rates down from ~3MHz to ~1kHz in ZH running and ~40MHz to ~100kHz at the Z pole.
  - The bunch cross rate in ZH running is about 1.34 MHz when bunch space is 346.2 ns (2.9 MHz) and there is 54% bunch train gap.

Comments

- The detailed (bottom-up) design of the TDAQ must await further details on the sub detector design.
  - We will closely follow the design of each sub detector. Especially background study and data rate estimation from each sub detectors.
- Work on the trigger primitives is needed to bring the rate down to an acceptable input for the second-level trigger, and to inform further planning for the processing farms in the DAQ design. Should it be needed, a track trigger could provide a powerful additional primitive.
  - More simulation works on trigger primitive and more discussion with physics and detector experts are needed. Track trigger simulation will be next main work.
- High-level triggering will also need to weigh the physics-versus-bandwidth tradeoff for lower-energy events, e.g. from gamma-gamma collisions.
  - We need more study for low-energy events of beam induced background. And few gamma-gamma collisions are included in the available background sample data.

Recommendations

- A simple simulation of sub detector-based trigger inputs using simple, robust algorithms should be prioritized to allow more detailed specification of the requirements for TDAQ hardware and identify areas that need further attention. This should include an appropriate safety factor for beam-related backgrounds.
  - Basic trigger simulation study for each sub detectors are in progress.
  - And the safety factor needs to be discussed carefully.
- Further work should include an evaluation of benefits of implementing a track trigger as a complement to the calorimeter and muon primitives, and to clarify the bandwidth foreseen for gamma-gamma events.
  - We will move forward this after finish simple trigger simulation.

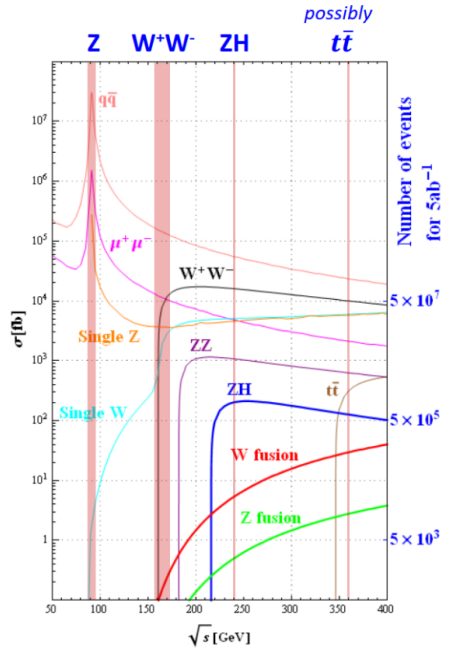
Physical Event Rate

- 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} cm^{-2} 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} cm^{-2} 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
qq	30.6522	0.717633315	35.88166573
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