Welcome and Thanks

- As conveners of this TDAQ session, we warmly welcome your participation to this TDAQ session
- Special thanks to the presenters of talks in this session for their contributions!

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Issues about the Trigger and DAQ of CEPC

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CEPC Workshop, Trigger and DAQ Session

Beijing, Nov. 13 2018

Outline

- Overview of CEPC Machine/Detectors
- Guide lines for CEPC Readout + T/DAQ R&D Activities before TDR
- TDAQ R&D activities
- Summary

Overview of CEPC Machine/Detectors

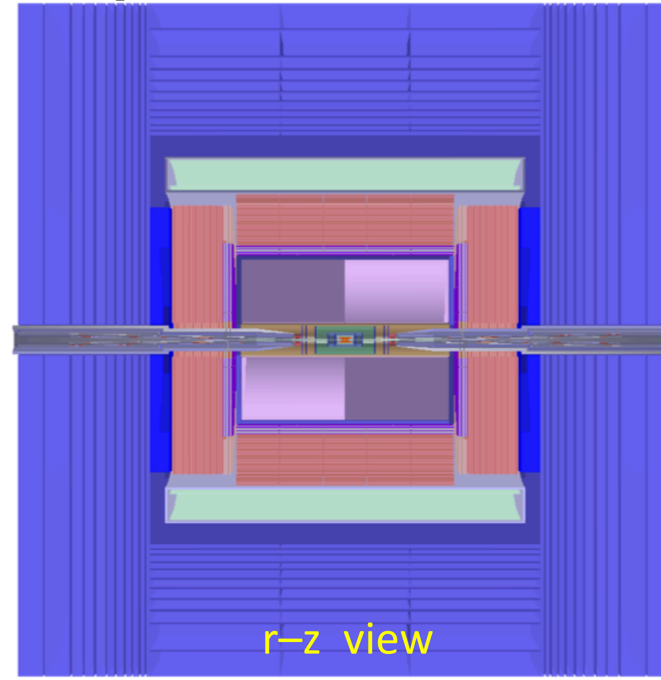
- Machine
  - WW scan and Z/Higgs Factory Modes
  - Bunch Number of 1524,12000 and 242
  - Bunch Spacing of 210, 25 and 680 ns

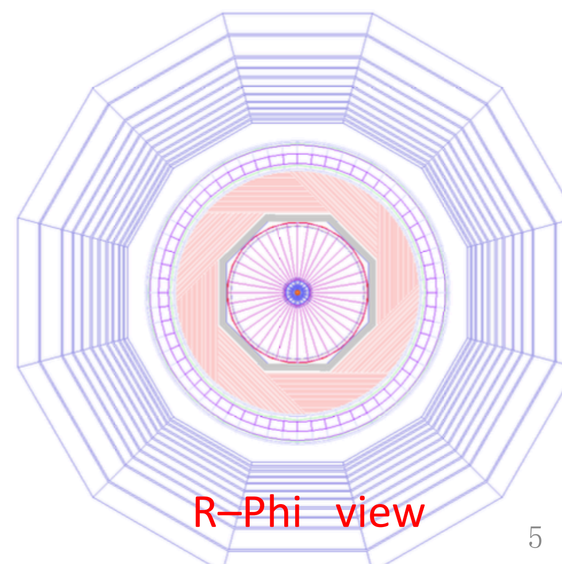
	Higgs	W	Z (3T)	Z (2T)
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	3.48	7	23.8	
Bunch number	242	1524	12000 (10% gap)	
Bunch spacing (ns)	680	210	25	
No. of particles/bunch $N_e (10^{10})$	15	12	8	
Beam current (mA)	17.4	87.9	461	
Synch. radiation power (MW)	30	30	16.5	
Bending radius (km)	10.7			
β function at IP: β_x^* (m)	0.36	0.36	0.2	0.2
β_y^* (m)	0.0015	0.0015	0.0015	0.001
Emittance: x (nm)	1.21	0.54	0.18	0.18
y (nm)	0.0024	0.0016	0.004	0.0016
Beam size at IP: σ_x (µm)	20.9	13.9	6.0	6.0
σ_y (µm)	0.06	0.049	0.078	0.04
Beam-beam parameters: ξ_x	0.018	0.013	0.004	0.004
ξ_y	0.109	0.123	0.06	0.079
RF voltage V_{RF} (GV)	2.17	0.47	0.1	
RF frequency f_{RF} (MHz)	650			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	4.4	5.9	8.5	
Natural energy spread (%)	0.1	0.066	0.038	
Energy spread (%)	0.134	0.098	0.08	
Photon number due to beamstrahlung	0.082	0.05	0.023	
Lifetime (hour)	0.43	1.4	4.6	2.5
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP (10^{34} cm^{-2}s^{-1})	3	10	17	32

Operation mode	Z factory	WW threshold scan	Higgs factory
$\sqrt{s}$ (GeV)	91.2	158 – 172	240
Running time (years)	2	1	7
L (10^{34} cm^{-2}s^{-1})	17 – 32	10	3
Integrated Luminosity (ab^{-1})	8 – 16	2.6	5.6
Higgs yield	–	–	10^6
W yield	–	10^7	10^8
Z yield	10^{11-12}	10^8	10^8

Overview of CEPC Machine/Detectors

- Baseline Detectors
  - In the barrel from inner to outer, the detector is composed of
    - a silicon pixel vertex detector,
    - a silicon inner tracker,
    - a TPC,
    - a silicon external tracker,
    - an ECAL, an HCAL,
    - a solenoid of 3 Tesla and a return yoke with embedded a muon detector.
  - In the forward regions, five pairs of silicon tracking disks are installed to enlarge the tracking acceptance (from | cos(✓)| < 0.99 to | cos(✓)| < 0.996)





Studies in Chapter 3 of CDR

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

Table 3.3: Physics processes and key observables used as benchmarks for setting the requirements and the optimization of the CEPC detector.

- Charged kaon identification
- Photon identification and energy measurement
- Jet and missing energy
- Flavor tagging
- Most of the above-mentioned requirements are driven by the precision Higgs physics program. Some examples are shown in Table above

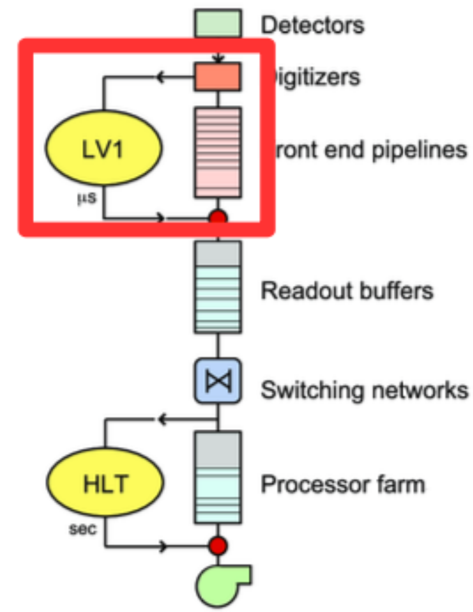
Background study of Chapter 3 of CDR

- Three most important sources of radiation backgrounds are evaluated for the CEPC:
  1. synchrotron radiation photons from the last bending dipole magnet;
  2. e+e pair production following the bremstrahlung process;
  3. off-energy beam particles lost in the interaction region.
- Study Conclusion
  1. The studies using the BDSim software show that the masks can reduce the number of SR photons hitting the central beam pipe effectively, from almost 40,000 to below 80 from one of the two beams per bunch crossing. Further optimization may suppress SR photons even more and make this particular background well controlled
  2. The total ionizing dose (TID) and non-ionizing energy loss (NIEL) are 620 kRad/year and 1.2 x10ˆ(12) 1 MeV neq /cm2 · year, respectively.
  3. After the introduction of two sets of collimators upstream of the IPs, backgrounds due to bremstrahlung and beam-gas interaction become negligible. The residual backgrounds due to radiative Bhabha scattering yields hit den- sities of about 0.22 hits/cm2 per bunch crossing when operating at ps = 240 GeV. The corresponding TID and NIEL are 310 kRad/year and 9.3 -> 10ˆ(11) 1 MeV neq/cm2 · year, respectively
- Direct translation to background rate will be estimated

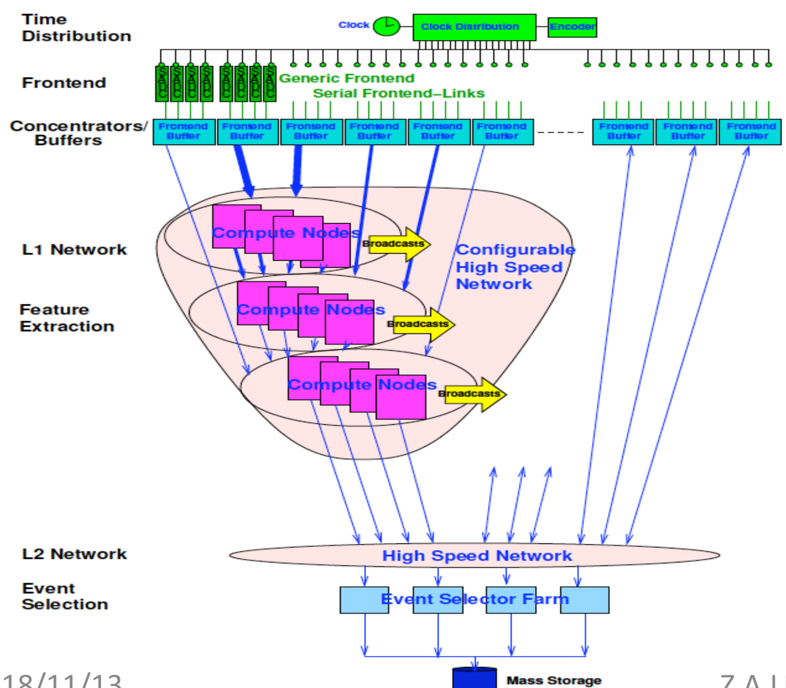
Background Suppression Studies

- The event rate reaches ~32 kHz for Z factory operation
- Trigger rate allowed by DAQ: 100kHz
- Simple background estimation(25ns bunch space)
  - 40 x 10ˆ6 Hz = 40000 x 1kHz
- Background Suppression
  - 70k/40000k, need to be refined

Guide lines for CEPC Readout + T/DAQ



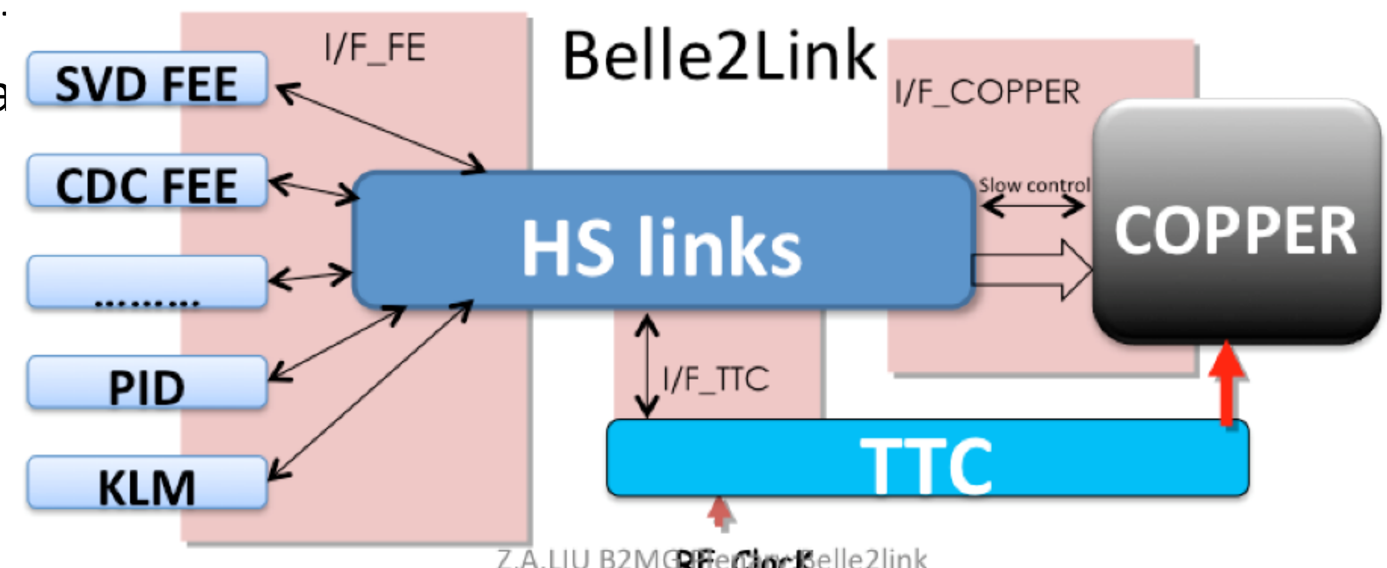
- TRIGGER Baseline: Traditional Hardware Trigger
  - See Talk: Overview of CMS Trigger by Simone Bologna



- Hardware Trigger-less/ Timestamp for backup
  - See Trigger and DAQ of PANDA Experiment by Wolfgang Kuehn

Guide lines for CEPC Readout + T/DAQ(2)

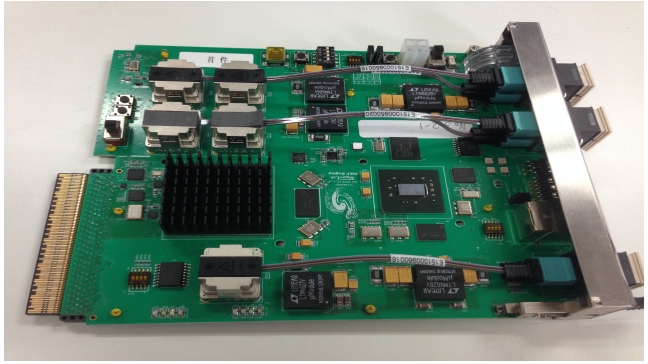
- Readout R&D see talks
  - By Wei Wei on Pixel Detector,
  - By Jia TAO on JadePix,
  - Hui GONG on TPC readout and DAQ
- Common projects to develop unified hardware and firmware module(s) in FEE electronics for each of the detector systems and Backend readout Electronics as in Belle II
  - Serial HS links
  - Fast/Slow Con
  - Fibers for Data and control



Guide lines for CEPC Readout + T/DAQ(3)

See talk Hardware Development for TDAQ by Jingzhou Zhao

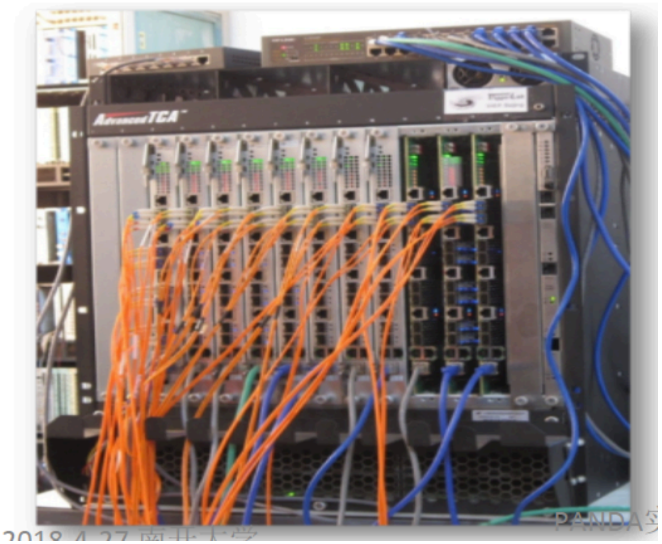
- For Backend readout and Trigger/DAQ hardware with xTCA standards
  - uTCA boards/crate
    - FPGA/DSP based
    - Provide powerful processing
    - High IO Bandwidth(10-26Gbps/ch)
    - General IPMC+MMC for Control

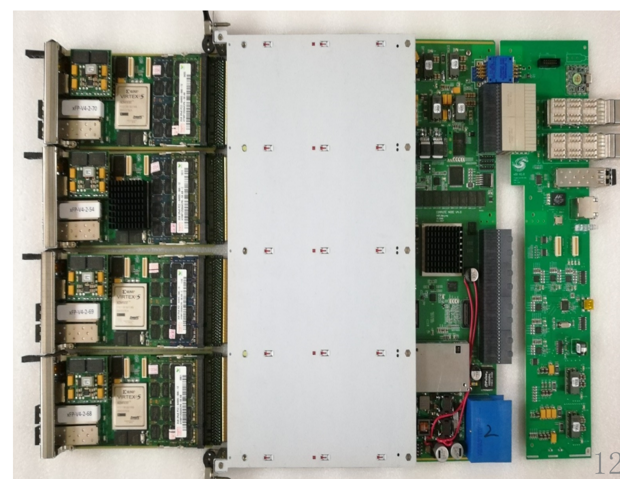


Guide lines for CEPC Readout + T/DAQ(4)

See talk Hardware Development for TDAQ by Jingzhou Zhao

- General Processor board for trigger and DAQ
  - ATCA boards/crate
    - Size advantage over uTCA
      - 50% more area
      - 100% more front panel
    - Power advantage over uTCA
      - 400% more available power
    - Provide powerful processing (V7 or Ultra-scale+ like FPGA)
    - High IO Bandwidth(10-26Gbps interconnections)





Guide lines for CEPC Readout + T/DAQ(5)

- Clock, Trigger Timing and Control(TTC)
  - uTCA
    - AMC MCH module as AMC13 in CMS
      - Standard redundant telecom backplane with port 2 and 3 routed to respective MCH
      - Custom development
      - Compliant to uTCA
      - Resides in redundant MCH slot
      - TCDS interface
      - DAQ links for full crate
  - ATCA
    - Master module with interface to Trigger and Machine
    - Slave switch module
      - TTC++
      - TTS++
      - DAQ interface

Guide lines for CEPC Readout + T/DAQ(6)

- CEPC DAQ data bandwidth estimation
  - Virtex, TPC, Tracker, DC with large data size
  - Assuming a L1 trigger Rate of 100 kHz, the total raw data rate is estimated 2 TBytes/s
- DAQ Structure
  - See Fei LI's talk

	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
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	8	1.28	0.00128	0.13
Endcap	32	0.01	8	3.2	0.0032	0.32
Dual Readout Calorimeter	22	0.4-1.6	64	88-352	0.704-2.8	70-280
Muon						
Barrel	4.9	0.0002	24	0.01	< 0.0001	< 0.01
Endcap	4.6	0.0002	24	0.01	< 0.0001	< 0.01
LumiCal	0.5	0.2	12	0.5	0.0007	0.07

TDAQ R&D activities foreseen

1. Take this workshop as start of the R&D
2. Formation of TDAQ and Control Study Group with Funding
3. Regular meetings/discussions
4. Draft Requirement/Specifications of FEE readout
5. Draft Requirement/Specifications of Backend readout
6. Draft Requirement/Specification of processor
7. Draft Requirement/Specification of TTC/TTS
8. Study of trigger primitives and tracking/cluster finders
9. Prototyping/testing
10. Demonstration

Collaboration

- Collaborations with other experiments are expected and necessary

Summary

- Present idea of readout/trigger/DAQ was presented
- Further R&D activities is foreseen with control/readout/trigger/DAQ subgroups
- Common requirement/specification to be drafted