ISBN: 978-3-95450-216-5 doi:10.18429/JACoW-eeFACT2018-THXBA01

SUMMARY ON ACCELERATOR INFRASTRUCTURES AND COMMISSIONING AND OPERATION

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Abstract

In this paper, summary of the woking group on "Accelerator Infrastructures and Commissioning & Operation" is described.

LIST OF TALKS

The following talks were given in the working group #12 "Accelerator Infrastructures and Commissioning & Operation".

- BEPCII Status: given by Qing Qing (IHEP)
- CEPC Civil Engineering design and Infrastructure: given by Yu Xiao (Yellow River Engineering Consulting Co., Ltd)
- Operation Model, Availability and Performance: given by Frank Zimmermann (CERN)
- CEPC Cryogenic System: given by Jianqin Zhang (IHEP)
- LHC Commissioning The good, the bad the ugly: given by Frank Zimmermann (CERN)
- KEKB/SuperKEKB Cryogenics Operation: given by Kota Nakanishi (KEK)
- Operation of SuperKEKB in Phase 2: given by Yoshihiro Funakoshi (KEK)
- A site-specific ILC-CFS design and the Green ILC: given by Masakazu Yoshioka (Iwate University)
- DAΦNE as Open Accelerator Test Facility: given by Catia Milardi (INFN)

The talks are categorized into 3 groups, *i.e.* civil engineering and infrastructure, cryogenic system and beam operation. In the following, a summary of each group is given.

SUMMARY OF CIVIL ENGINEERING AND INFRASTRUCTURE

Two talks were given for this topic. One was on ILC and the other was on CEPC. The talk on ILC covered the site investigation, conceptual designs of a surface access facility, underground facilities and interaction region facilities and reuse of waste heat from the facilities. Of the topics, the site investigation of ILC was very impressive. The unique ILC candidate site is "Kitakami highland". This site has been decided considering the following aspects, *i.e.* geology, topography, availability of important social infrastructures and small impact on the natural environment. As for geology, the site consists of a large and uniform granite area without active faults. Due to this feature, the risk for the underground construction is low and the ground motion or vibration is expected to be very small. In the Great East Japan earthquake on March 11th 2011, all fragile equipment and long glass tubes were not damaged at all at "Esashi earth tide observatory underground facility" which locates in the same granite zone as ILC. The reasons for this is that the earthquake ground motion in the granite zone is coherent and that the earthquake ground motion in the deep underground is 20 % of the ground surface. The Japanese government will make an decision on approval or disapproval of ILC within this year (2018).

The other talk is on CEPC. In the talk, the site investigation and the layout of the project, conceptual designs of the civil engineering system. The designs include tunnels, shafts, surface buildings, electrical engineering, the cooling water system, the ventilation and air-conditioning system, the fire protection system and the permanent transportation and lifting equipments. As for the the site investigation, 5 candidate sites were investigated. Qinhuangdao site is the best among the five candidate sites based on the terrain and geological conditions. But in general, all the sites are suitable for the underground construction of such a large scale. The main geological problems encountered can be solved by engineering measures. The CDR of the CEPC project was submitted on August 2018.

SUMMARY OF CRYOGENIC SYSTEM

Two talks were given on this subject. One talk was on the KEK cryogenic system. A cryogenic system for the superconductiing cavity system was first constructed for TRISTAN in 1988 at KEK. Basically the same system has been used for 30 years also for KEKB and SuperKEKB, since the heat load for KEKB and SuperKEKB was less than that for TRISTAN. Although all of cryogenic system at KEK are very old, they are working very well. Experiences on the maintenance and troubles with the cryogenic system were given in the talk. The experiences should be referred in the future machines.

The other talk was on the cryogenic system for CEPC. Features of the CEPC cryogenic system is a 2K refrigerator using superfluidity He and a high heat load of 47.5 kW (4.5K equivalent heat load). Aggressive R&D works on the 2K JT heat exchanger and the cold compressor are under way. The cryogenic group at IHEP has manufactured 58 1.3GHz 9-cell cryomodules for EXFEL cooperated with domestic companies. This was very impressive. It will be a

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good foundation for the optimization design for the CEPC cryomodules.

SUMMARY OF BEAM OPERATION

In the session, 5 talks on the beam operation were given. Four of them were on existing machines, *i.e.* DAΦNE, BEPC-II, LHC and SuperKEKB. One of them was a future machine, FCC-ee. As for the 4 existing machines, many experiences were shown in the talks. Among them, several are picked up and listed in Table 1. The experiences are divided into 4 categories, excellent, good, bad and ugly.

DAΦNE came into operation in 2000 and will stop running as a collider in 2020. It is planned to transform it into an accelerator test facility (DAΦNE-TF). The excellent experience at DAΦNE is a beam test of the "crab-waist" scheme. In DAΦNE, it was proved that crab-waist is an effective approach to increase the luminosity in circular colliders even in presence of an experimental solenoid magnet. The crab-waist scheme has become a basic design concept for future new colliders. The longitudinal feedback kicker developed at DAΦNE has been adopted in many machines and become a standard. In DAFΦNE, an optics with negative values of the momentum compaction factor was studied. In the study the beam collision was also tried with negative α and a 25 % higher specific luminosity was observed at a low current. However, the beam collision failed at high beam current due to the microwave instability. The similar instability issue with negative α was also observed at KEKB.

BEPCII came into operation in 2006 and is still in operation now. The excellent achievement at BEPCII is that it reached the design luminosity of $1 \times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ on April 5th in 2016. It seems that the lattice evolution such as the low momentum compaction lattice was important to achieve the design luminosity. When they increased the beam currents, they also experienced a lot of hardware failures just like KEKB.

LHC came into beam operation in 2008 and is in the middle of its whole life. The highest peak luminosity of LHC is $2.2 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and broke the world record which KEKB made. The integrated luminosity in Run 2 (2015-2018) with $\sqrt{s} = 13$GeV was 147fb^{-1} and is 50 % higher than the initial target. The famous quench incident happened on Sep. 19th 2008 and the beam operation restarted on Nov. 20th 2009. The machine optics is reproducible and the beta-beating is corrected down to the % level at 6.5 TeV. The IP beta function β^* has been progressibely reduced down to 30 cm (design 55 cm). In the beam operation of LHC, they encountered peculiar phenomena such as UFOs (Unidentified Falling Objects) . UFOs are believed to be dust events and can quench a superconducting magnet. After a two year long shutdown in 2019-2020, the LHC will be back for Run 3 with upgraded injectors. In Run 3, more than a factor of 2 higher peak luminosity is expected and they need the luminosity llevelled operation.

SuperKEKB came into operation in 2016. The Phase 1 operation was done from Feb. 2016 to June 2016 without the Belle-II detector and IR magnets. The Phase 2 commissioning was done from March 2018 to July 2018. The excellent achievement in Phase 2 was to verify effectiveness of the "Nano beam scheme" to increase the luminosity. At SuperKEKB, they use a large Piwinski angle collision without the crab-waist scheme. In the talk in this session, only an ugly experience of the QCS quench was discussed. The Phase 3 commissioning will start in March 2019.

The talk on the operation of FCC-ee discussed a study on the operation model, availability of the machine and its performance. The purpose of the study was to validate the operation model of FCC-ee based on achieved values at past machines such as PEP-II and KEKB. The integrated luminosity per year is expressed as the following expression;

$$L_{\mathrm{int}}/year \approx T \cdot E \cdot L_{\mathrm{nominal}}.$$

Here, T, E and L_{nominal} is a number of days scheduled for physics per year, efficiency and the nominal (design) luminosity, respectively. The efficiency E was estimated based on experiences of past machines. The conclusion of the study is that the assumed annual physics run time of 185 days, hardware availability of at least 80 %, corresponding physics efficiency of 75 %, and projected annual luminosities of FCC-ee look solid, in view of the experience at several circular lepton colliders over the past 30 years.

SUMMARY OF SUMMARY

In the sessions, both old and future machines were reported. Useful lessons from old (or present) machines should be made the most use of in the future machines. Experiences in SuperKEKB may be useful in future machines. Study on the ILC civil engineering investigation is very impressive. Like this, we should learn from machines in other fields such as SR machines. In the next eeFACT workshop at Frascati in 2020, it is expected to hear excellent progress in future machines such as CEPC, FCC-ee, Super t-c factories, DANFE-TF, BEPC-III, SuperKEKB and VEPP-2000.

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Table 1: Summary of excellent, good, bad and ugly experiences in the beam operation for 4 colliders

	Excellent	Good	Bad	Ugly	Future
DAΦNE	•Crab waist	•Collision with negative α •Low impedance •Longitudinal kicker			DAΦNE-TF
BEPCII	•Achieve design luminosity	•Improved optics and beam-beam parameter	•Hardware failures		BEPCIII
LHC	•Peak luminosity •Integrated luminosity	•Optics corrections •Collimation •Machine protection	•UFOs •16L2	•Quench incident •Dipole detraining	Run 3
SuperKEKB	•Validation of “nano-beam scheme"			•QCS quench	Phase 3