RADIATION SHIELDING CONSIDERATIONS FOR CEPC-SPPC

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Abstract

A planned project CEPC-SPPC is under-researched by IHEP, CAS, China [1]. Due to its big circumference and high energy, the radiation shielding issues should be treated more serious than ever whether for the machine itself or the worker and the public. In this paper, we briefly introduce the configurations and parameters of the machine, the tools and principle used in the radiation shielding design, and discuss the preliminary result for the shielding of main tunnel and the synchrotron radiation. Some radiation protection issues are listed to be resolved next. All the aspects presented should be discussed and verified, any other un-mentioned radiation protection problems will be excavated in the future.

INTRODUCTION

A project named Circular Electron-Positron Collider (CEPC) - Super Proton-Proton Collider (SPPC) is being planned and under researched these years in Institute of High Energy Physics (IHEP), Beijing, China. The CEPC e+ e– collider will bring a major leap in precision with the Higgs boson, and enable electroweak measurements with the Z and the W bosons, while the SPPC proton-proton collider will provide real discovery potential and a laboratory to address many of the major physics issues we face today[1].

From the radiation protection of view, the main parameters and characteristics of the machine can be affirmed now is that the two machines (CEPC-SPPC) will be hold in one tunnel and maintain the possibility that running the two machines at the same time; Circumference of the tunnel is larger than 50km and underground about 50-70m, the exact circumference is according to different physical goals and the expenditure; the major parameters listed in Table 1 is adopted as our preliminary research study inputs.

RADIATION SHIELDING DESIGN

In any accelerator radiation shielding design progress, the design criteria, radiation source analysis and the design methods are the most basic issues to be clarified first.

Dose Limit Standard

CEPC-SPPC is planned to be an international research center because of the comprehensive research, the radiation dose limits should be suitable for the most international laboratories. We comply with the dose limits from the national standards - The national standard of the People's Republic of China, "Basic standards for protection against ionizing radiation and for the safety of radiation sources", GB 18871-2002. In our shielding design, the philosophy ALARA (As Low as Reasonably Achievable) was adopted, one fourth (5mSv/year) of national dose limit for the worker and 0.08mSv/year for the public. This value will be checked by the international advisory committee in the future.

Table 1: Parameters Related to Radiation Shielding

CEPC parameters about radiation shielding	
Energy (GeV)	120
Number of IPs	2
Circumference (km)	54
SR loss/turn (GeV)	3.1
N_e/bunch (10^{11})	3.79
Bunch number	50
Beam current (mA)	16.6
SR power /beam (MW)	51.7
Life time due to beamstrahlung_cal(minute)	47
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04
SPPC parameters about radiation shielding	
Energy(TeV)	35.6
Number of IPs	2
Circumference(km)	54
Injection energy(TeV)	2.1
Number of bunches	5835
Bunch population	2.0E+11
Stored energy per beam (GJ)	6.6
Peak luminosity per IP $cm^{-2}s^{-1}$	1.2E+35

Table 2: Prompt Dose Rate Limits for Different Areas

Area	Design Value	Example
Radiation monitored area	< 2.5 μSv/h	Outside the tunnels, where a worker can stay longer
Radiation controlled area	< 25 μSv/h	Outside the tunnels, where a worker can stay occasionally
Forbidden area	>>1 mSv/h	Inside the tunnels; access forbidden during accelerator operation
Site boundary	0.08 mSv/year	

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Taking into account the occupancy factor and the function of each underground building, the areas are classified into three parts, the derived prompt dose rate limits in each kinds of areas are listed in Table 2.

The residual dose rate limit for the workers entering the tunnel is that after a lone running time and 4h shutdown period, the dose rate of 30cm distance to the maintained equipment surface should be lower than 1mSv/h, especially but not exclusively the collimation section, the positron targets, etc. Dose limit for the outflows should be complied with the national standard above.

Radiation Shielding Methods

All the radiation shielding design is based on Monte-Carlo (MC) simulations using the FLUKA and MCNP codes. After simulation, the results are checked by comparison with results got from empirical formulas. The calculation process of FLUKA in the shielding design is as Fig. 1.

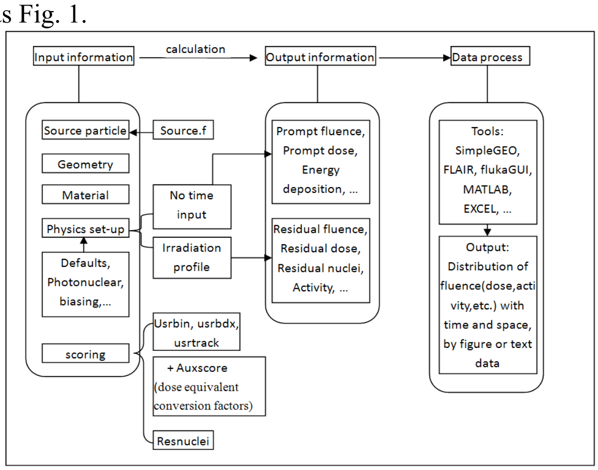

Figure 1: Calculation process of FLUKA in simulation.

The radiation shielding design philosophy applied is that the shielding thickness of the main tunnel is determined by the radiation level caused by the average beam loss along the tunnel; at hot spots, such as the locations for collisions, injection, collimation and beam dump, needs to be locally shielded to reduce the radiation level to be the same as former for the main tunnel.

Radiation Source Analysis

Generally speaking, the running of accelerator will induce the prompt radiation and the residual radiation, the thickness of the tunnel is determined by the prompt radiation and the dose received by the workers is caused by the residual dose.

For the SPPC-CEPC, the two machines are constructed in one tunnel, so the tunnel shielding should take care attention to enclose the radiation induced by the twins. But the fact is that the beam loss mechanism is different, the synchrotron radiation of CEPC in the arc section is severe while the beam loss of SPPC in this section is very small; meanwhile, the active beam loss in the straight section is large for SPPC, where exists many collimations, but for CEPC the loss is very small. This should be considered in the tunnel thickness design.

There are a lot of factors affect the prompt radiation yields, such as the accelerator operation mode, the beam loss control scheme of the machine. In general, the hot spots list above are the main shielding parts for prompt radiation and need locally shielded to reduce the prompt radiation level. In this case, if the sections have to be maintained after shutdown, its residual dose rate should also be considered in the first shielding design stage.

Apart from the local shielding mentioned above, the activation of cooling water, ventilation air, ground water and the environmental samples should be calculated detailed after the main shielding blocks are determined and the scheme of infrastructure system is completed.

RADIATION SHIELDING DESIGN PROGRESS

Synchrotron Radiation Shielding Design

As we know, electrons and positrons pass through dipole and focusing (quadrupole) magnets are always accompanied by the Synchrotron Radiation. For CEPC, the SR spectrum extends from the region of visible light through the energy range of ordinary diagnostic X-rays (hundreds of Kev) up to ten MeV, shown in Figure 2. The SR power per unit length is up to 1 kW/m.

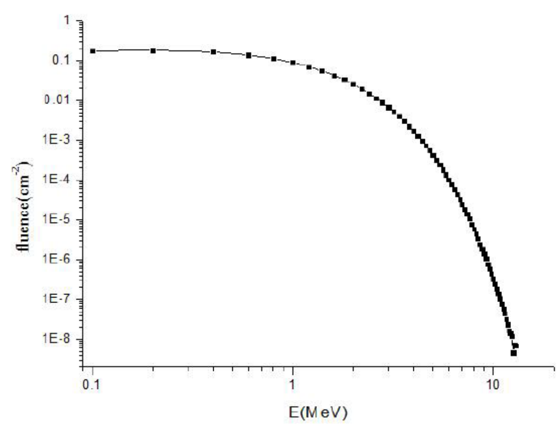

Figure 2: The photon spectrum of synchrotron radiation.

Until now, two vacuum chamber structures are proposed to absorb the heat load: (1) aluminium covered by lead shielding as LEP used[2] and (2) fabricate an elliptical copper beam pipe with thickness of 6mm, the cross section is 100×50 mm, shown in Figure 3.

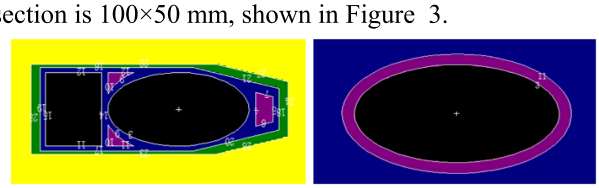

Figure 3: Vacuum chambers proposed

Through the MCNP simulation, the total heat deposited in the vacuum chamber is 80.7% and 65.8% separately. This heat load value of elliptical beam pipe is too small to induce the heavy workload for the air conditioning system, and should be optimized and balanced between the beam pipe design and the tunnel ventilation system.

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The Thickness of the Arc Tunnel

Now the project is in the CDR phase, the exact beam losses for the hot stations are not explicit, so 1W/m beam loss for CEPC and SPPC is assumed to give a prompt radiation dose in the tunnel, simulation result is shown in Figure 4. The dose level for other beam loss parameters can be deduced through appropriate conversion coefficients.

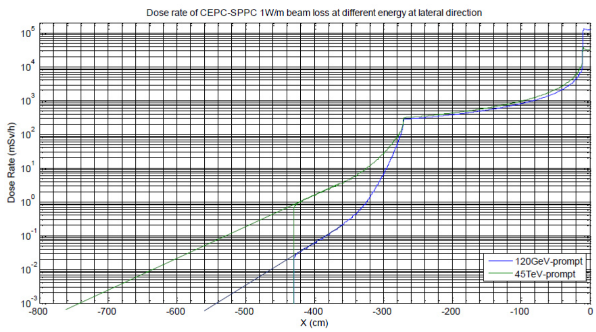

Figure 4: Distribution of the prompt radiation dose rate.

OTHER ISSUES RELATED TO THE RADIATION PROTECTION

Personnel Safety Interlock System

The PSIS consists of a Programmable Logic Controller (PLC) system and Access Control System (ACS), PLC monitor interlocking equipment, while ACS administrative interlocking information. For such a large equipment, the logical control settings, the patrol route and scheme, the cooperative work between the radiation shielding staff and the personnel safety control staff should be the main consideration.

Radiation Dose Monitoring Program

As state above, the equipment is so large and should be an international research complex, so the radiation dose in and around the experimental areas must be well monitored and the data should be conserved for inquiring. There are several sub-systems which should be established, include the data acquisition system, workplace monitoring system, environmental monitoring system, radioactive outflow monitoring system, personnel dose monitoring system and the radioactive waste management system.

Radiation Protection Management

This should include the pre-employment training, health administration, environmental impact assessment and other issues.

CONCLUSION

In this paper, we introduced the radiation protection issues considered until now. This is a new machine for ourselves and one of a few largest machines in research, so there are a lot of things to do and international cooperation is keen to be involved. The things listed in this paper is just preliminary and not full-scale for radiation work. Any suggestion and discussion is welcomed.

REFERENCES

[1] CEPC-SPPC Preliminary Conceptual Design Report, IHEP-AC-2015-001.

[2] Synchrotron Radiation Lead Shielding of the Vacuum Chamber for LEP, IEEE *Transactions on Nuclear Science, Vol. No-30. No. 4, August 1983.*

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