Evaluative Report of Variable Energy Cyclotron Centre

1 Name of the CI

Variable Energy Cyclotron Centre (VECC), Kolkata

2 Year of establishment

Please see para 6 of the 'Profile'.

3 Is the CI part of the university

Yes

4 Names of programmes offered

VECC offers Ph.D. in Physical Sciences. Students, who have completed course work at one of the BARC Training Schools and join VECC as employees, do their project work for M.Tech. at VECC. Please also see Appendix 1 of the profile.

5 Interdisciplinary programmes

Subject of research leading to Ph.D. is inter-disciplinary in many cases. Subject of project work leading to M.Tech. in Engineering Physics is also inter-disciplinary in many cases.

6 Courses in collaboration with other universities, industries, foreign institutions, etc.

Ph. D. students can have two guides with one of them from a collaborating institution with whom HBNI has a formal MoU. For a list of collaborating institutions, please see Para 2.4.10 of 'Criteria-wise Inputs'. Additionally VECC has MoU with Indian Statistical Institute, Kolkata and Jadavpur University, Kolkata.

7 Details of programmes discontinued, if any, with reasons

NIL

8 Examination System

Semester system

9 Participation of the department in the courses offered by other departments

This question is not applicable to VECC. CIs of HBNI have no rigid boundaries. Development of advanced technologies being pursued at VECC involves inter-disciplinary teams.

10 **Number of teaching posts sanctioned, filled and actual (Professors/Associate Professors/ Asst. Professors/ Others)**

Please see para 24 of the Profile.

11. Faculty profile with name, qualification, designation, area of specialization, experience and research under guidance

Please see Appendix 1

12. List of senior Visiting Fellows, adjunct faculty, emeritus professors

Please see para 26 of the 'Profile'.

13. Percentage of classes taken by temporary faculty – programme-wise information :

NIL

14. Programme-wise Student Teacher Ratio

1:4 for delivering lectures to students attending credit courses forming a part of Ph. D programme. For supervision of number of research students per supervisor, guidelines of UGC are strictly followed.

15. Number of academic support staff (technical) and administrative staff: sanctioned, filled and actual

Please see para 24 of the 'Profile'.

16. **Research thrust areas as recognized by major funding agencies**

The **Variable Energy Cyclotron Centre (VECC**), one of the premier nuclear science and accelerator technology centres of India is a Constituent Institution (CI) of Homi Bhabha National Institute (HBNI), Mumbai. In addition to its own programmes of building the latest state of the art accelerators, the Centre provides R & D facilities to various branches of nuclear sciences. VECC posses a room temperature cyclotron (K=130) and a superconducting cyclotron (K=500). A wide spectrum of research programmes on Accelerator Physics, Experimental and Theoretical Low Energy Nuclear Physics, Physics with Rare Ion Beams & Nuclear Astrophysics, Hadronic Physics, Quark Gluon Plasma Physics, Material Science, Radio Chemistry, Nuclear Medicine, Computer Science & Engineering, Electronics etc are carried out at the Centre. VECC is also part of the International Collaboration at ultra-relativistic heavy ion collisions in Relativistic Heavy Ion Collider at Brookhaven National Laboratory & Large Hadron Collider at CERN, Geneva.

Funding in all these areas of R&D activities is provided by the Department of Atomic Energy.

For more details, please see para 3.1 of the 'Criteria-wise Inputs'.

17. Number of faculty with ongoing projects from a) national b) international funding agencies and c) Total grants received. Give the names of the funding agencies, project title and grants received project-wise.

Full funding is received from the Department of Atomic Energy and all the faculties are involved in one or more projects. Details of ongoing projects and grants for VECC put together are given in Appendix 2.

18. Inter-institutional collaborative projects and associated grants received

VECC is associated with several international projects including CERN-Geneva; FAIR-GSI, Germany; TRIUMF, Canada; BNL, USA; Fermilab, USA.

19. **Projects funded by DST-FIST; UGC-SAP/CAS, DPE; DBT, ICSSR, AICTE, etc.; total grants received**.

Nil.

20. Research facility / centre with

- **state recognition**
- **national recognition**
- **international recognition**

VECC has no formal recognition from any agency.

VECC houses Variable Energy Cyclotron, ECR ion source and various kinds of detectors for carrying out experiments in nuclear physics and material sciences which are being used by researchers form Universities and Academic Institutions in India.

21. Special research laboratories sponsored by / created by industry or corporate bodies

HBNI is essentially a research university and research output of its CIs including VECC is deployed in industry, including industrial units and PSUs of the DAE. Many technologies are transferred to outside entities through a well established technology transfer mechanism. All research laboratories in VECC are sponsored by the Government for the purpose of deployment in the industry.

22. Publications:

Please see para 3.3 of the 'Criteria-wise inputs'.

23. Details of patents

None

24. Areas of consultancy and income generated

Not Applicable. Please see para 3.4 of the 'Criteria-wise Inputs'.

25. Faculty selected nationally / internationally to visit other laboratories/ institutions/ industries in India and abroad :

Visits within India rae numerous and are not listed. For visits abroad, please see Appendix 4.

26. Faculty serving in
a) National committees b) International committees c) Editorial Boards d) any other (please specify)

Please see Appendix 3 of the 'Criteria-wise Inputs.

27. Faculty recharging strategies (UGC, ASC, Refresher / orientation programs, workshops, training programs and similar programs).

HBNI encourages faculty to participate in and organise national and international workshop and conferences, go to universities abroad for post doctoral fellowships and short term research assignments, act as consultants for developing countries under programmes sponsored by IAEA, participate in collaborative projects with universities in India funded by BRNS, participate in collaborative projects with laboratories abroad under various MOUs. All this helps to recharge the faculty.

28. Student projects :

- **percentage of students who have done in-house projects:** 100%
- **percentage of students doing projects in collaboration with other universities/ industry/ institute:** 0%**.**

Situation in VECC is actually reverse of what is there in other universities. About 200 UG/PG students from other universities come every year to VECC for carrying out their project works.

29. Awards / recognitions received at the national and international level by

- **Faculty**
- **Doctoral / post doctoral fellows**
- **Students**

Please see Appendix 1 of the 'Criteria-wise Inputs'.

30. Seminars/ Conferences/ Workshops organized and the source of funding (national/ international) with details of outstanding participants, if any.

Please see Appendix 5.

31. Code of ethics for research followed by VECC

In addition to excellence in Science and Engineering, a strict adherence to

high ethical standards is a necessity. The core ethical policy of DAE is to establish a tradition with highest ethical standards, ensuring a harmonious future for the entire humankind, where every individual can live with dignity and self-respect. In accordance with the guidelines of the DAE, adhering to highest ethical standards is one of the guiding values of VECC. Every complaint of malpractice or plagiarism received is investigated and appropriate action is taken.

32. Student profile programme-wise

Please see para 15 and para 28 of the 'Profile.'

33. Diversity of students

Please see Para 2.1 of the 'Criteria-wise Inputs'.

34. How many students have cleared Civil Services and Defense Services examinations, NET, SET, GATE and other competitive examinations? Give details category-wise.

Please see para 1.1.3 of the 'Criteria-wise Inputs. This question is not applicable to HBNI.

35. Student progression

Students joining BARC Training School and posted at VECC pursue their project at VECC, become employees of DAE and at some stage come back to enroll for Ph.D. Students who qualify in JEST and NET also join VECC as JRF after being interviewed by a committee formed by the Director, VECC. After completion of their Ph D, they join various academic institutions/laboratories as Post Doctoral fellow or faculty.

36. Diversity of staff

Please see para 2.4.3 of the 'Criteria-wise Inputs.'

37. Number of faculty who were awarded M.Phil., Ph.D., D.Sc. and D.Litt. during the assessment period

Nil

38. Present details of infrastructural facilities with regard to

a) Library: Please see para 4.2 of the 'Criteria-wise Inputs'. The library has adequate physical facilities such as reading-rooms, internet and is stocked with number of books (7549), journals and other library resources (i.e. CDs/ cassettes, etc.). In addition the Department of Atomic Energy (DAE) has set up a consortium to subscribe 2405 journals through Science Direct and these are available to VECC.

b) Extensive internet and computing facilities are available to staff members and students.

d) Two class rooms, all equipped with ICT facility are also available. ICT available consists of the hardware, software, networks and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images) as well as related services.

e) Students' laboratories Yes

f) Research laboratories Yes

39. List of doctoral, post-doctoral students and Research Associates

Please see Appendix 6.

40. Number of post graduate students getting financial assistance from the university.

All students pursuing Ph. D programme get financial assistance from the university. All students pursuing project work for M.Tech. are employees and get salary.

41. Was any need assessment exercise undertaken before the development of new programme(s)? If so, highlight the methodology.

Please see para 1.1.2 of the 'Criteria-wise Inputs.

42. Does VECC obtain feedback from

a. faculty on curriculum as well as teaching-learning-evaluation? If yes, how does VECC utilize the feedback?

b. students on staff, curriculum and teaching-learning-evaluation and how does VECC utilize the feedback?

c. alumni and employers on the programmes offered and how does VECC utilize the feedback?

Obtaining feedback from faculty, alumni and employees is a continuous process. Feedback from students is obtained once every year at the end of the academic session. All feedbacks received are analysed and courses are modified, instructors are selected on the basis of the feedbacks. Introduction of new programmes and changes in syllabus are decided whenever required.

43. List the distinguished alumni of the CI (maximum 10)

The list below includes those, who received a Ph.D. based on the work done at VECC, or are from the Training School, but prior to the setting up of HBNI.

Sl. No	Name
1.	Dinesh Kumar Srivastava
2.	Alok Chakrabarti
3.	Y P Viyogi
4.	Rakesh Kumar Bhandari
5.	Sailajananda Bhattacharya
6.	Debranjan Sarkar

44. Give details of student enrichment programmes (special lectures/ workshops/ seminars) involving external experts.

VECC regularly hosts international experts to give seminars in their field of specializations. Several interaction meetings/workshops have been organized at VECC during last five years for utilization of the various state-of-the-art facilities.

45. List the teaching methods adopted by the faculty for different programmes.

Besides standard class room teaching, interaction though discussions in laboratories.

46. How does VECC ensure that programme objectives are constantly met and learning outcomes are monitored?

Professional programmes conducted at the Training School prepare students for a lifelong career in DAE. Their successful outcome is demonstrated by the success of setting up of various accelerators and other facilities for R & D

works. These programmes have seen continuous evolution over the years in terms of updating of syllabus and choosing appropriate project work for M.Tech. The expected outcome of M.Tech. programmes consisting of lectures (at BARC Training School) and project work is to equip its graduates to apply fundamental knowledge of nuclear science and engineering in day to day working in units of the DAE.

Quality of theses produced by doctoral students is demonstrated by comprehensive research abilities acquired by students. Invariably number of publications in peer reviewed journals coming out of a thesis varies from one to several as can be seen from previous annual reports. Students after their completion of PhDs are generally selected for employment in national laboratories, universities or post doctoral works in India or abroad.

47. Highlight the participation of students and faculty in extension activities.

Please see para 3.5 of the 'Criteria-wise Inputs'. Further, faculty and students at VECC pursue various extension activities in the form of 'public outreach programme', 'project training programme' and 'young scientists' research programme'. Many of the students do their Ph D in the area related to international collaboration, as a results they get opportunities to visit various overseas laboratories.

48. Give details of "beyond syllabus scholarly activities".

The faculty is continuously engaged in research necessary for meeting the mandate of the DAE. A significant percentage of this engagement is scholarly and results in good publications in peer reviewed journals. The students and faculty give lectures very frequently in various fora like national and international symposia, workshops, awareness programmes and colloquia. They interact on a regular basis with scientist and technologists of repute from the country and from abroad. They organise high level knowledge dissemination activities like organization of advanced schools under the aegis of BRNS/ DST and other similar bodies.

49. State whether the programme/ CI is accredited/ graded by other agencies? If yes, give details.

Yes, by UGC.

50. Briefly highlight the contributions of VECC in generating new

knowledge, basic or applied.

Due to a very large volume of very high quality basic and applied research being carried out by the faculty and the students, the research output is excellent and this gets documented in the form of publications in international journals and reports. The activities of VECC relevant in generating new knowledge in the field of basic and applied sciences are briefly mentioned below:

Accelerator Physics:

VECC is named after the first room temperature Variable Energy Cyclotron built in the 1970s. This was the first big accelerator to be indigenously built in the country and helped to form the backbone of accelerator based research in the country. At the turn of the new century, VECC undertook the project to develop a Superconducting Cyclotron to accelerate light and heavy-ions to higher energies.. From about 2000, the development of Superconducting Cyclotron (SCC) has become another priority area. The SCC has been built successfully and has already been commissioned with internal beams.

Active research on design and development of various types of ion sources has been going on in VECC. Several ECR Ion Sources, all designed and built indigenously for the first time in the country, has been in operation. Altogether six ECR Ion sources are operational at the moment- two 14.4 GHz ones are being used for injecting beams in the two cyclotrons, the two 6.4 GHz are routinely used for experiments in material science and RIB production and the two 2.4 GHz sources are used for production of high current proton beam (7 mA) and for RIB production. Additionally a novel RF ion source working at 13.56 MHz has been developed for a new type of focused ion beam system that has capability of micro milling of materials with a speed that is at least 100 times faster than commercially available liquid metal ion source based FIB systems. Design of cyclotrons with novel features, especially for medical purposes has been another thrust area. Significant contributions have also been made in the design and development of space charge limited high intensity light particle beams.

Experimental Nuclear Physics:

Resonance Particle Spectroscopy: Resonance particle spectroscopy is a quite powerful technique in nuclear physics to study the space-time characteristics of particle emission mechanism in nuclear reactions. This unique tool is used to study the structures and properties of the particle-

unbound resonance states in nuclei by detecting their decay products in coincidence. At VECC a charged particle array (CPDA), consisting of 24 telescopes (with a combination of silicon-silicon-CsI detectors) has been developed and is being used is to carry out systematic resonance spectroscopy studies of (a) the alpha-cluster structure of light alpha-like nuclei using K130 cyclotron and other accelerators in India, and, (b) the structures of exotic particle-unstable resonances of stable nuclei and nuclei away from alpha-stability line, which will be produced in intermediate energy nuclear reactions using K500 superconducting cyclotron. Recently, studies on 2-alpha structure of 8Be, and 3-alpha structure of Hoyle state of ^{12}C, have been carried out. Hoyle state of ^{12}C is specially interesting as it is claimed to be either a 3-alpha-chain structure or a gas-like condensate. These new measurements are expected to throw new light on the structures of these resonances.

Fragments emission studies in light Heavy-ion Collision: Study of fragment emission mechanisms for light heavy-ion (Aproj.+ Atarget < 60) collisions, at energies (<10 MeV /u) is subject of great interest in the recent years. The origin of these fragments extends from quasi-elastic, deep-inelastic transfer and orbiting, to fusion–fission processes; and in some cases the structure of the nuclei has been found to play an important role. Many interesting features, e.g., quasi molecular resonance, super deformed bands, orbiting etc. have been seen for nuclear reactions involving alpha like nuclei. Although, there is no apparent link between these phenomena, they are believed to originate from highly deformed configuration of these systems. The occurrence of such highly deformed configurations and their evolution with excitation energy are studied at VECC through charged particle spectroscopy.

Study of the Fusion-fission and Quasi-fission Dynamics: An active research program is on to explore the role of entrance channel on fusion-fission dynamics. One of the major aspects of today's nuclear physics research is to look for the dynamical effect which inhibits the fusion process. These studies are important since they give a clue for picking up the right kind of target and projectile combination for the formation of super heavy elements (SHE). A comprehensive study of fission fragment mass and angular distribution at near barrier energies was embarked on for heavy ion induced fission reactions experimentally, to have an insight of the dynamics of the fusion-fission reactions. The detectors required for these studies are developed indigenously in the laboratory.

Gamma Ray Spectroscopy: Many of the secrets of an atomic nucleus, a tiny object but a potential source of huge energy, can be understood by putting it under "extreme conditions" and studying how it survives such a stress.

Gamma ray spectroscopy is one of the powerful tools for such study and to "visualize" the shape and shell structure of a nucleus. The "extreme conditions" of large isospin (neutron-proton asymmetry), high excitation and large angular momentum are achieved in a nucleus by producing them in a variety of direct and indirect nuclear reactions using energetic beam of particles from an accelerator. The gamma rays, emitted from the produced nuclei, carry the information of the shape of a nucleus and the quantum states of the protons and the neutrons inside it. These gamma rays are detected using several high resolution, state-of-the-art, Hyper Pure Germanium (HPGe) Detectors. Several ancillary detectors for detecting charged particles, neutrons and to measure gamma multiplicity are also used in conjunction with the HPGe detectors to achieve better sensitivity. Several such experiments have been performed using the experimental facilities at VECC, at BARC-TIFR Pelletron, Mumbai, Inter University Accelerator Centre, New Delhi and also at various facilities abroad. In these experiments, combined with nuclear model calculations, we try to understand the new symmetries in nuclei (manifested in tetrahedral shape, chiral bands, magnetic rotation etc.), the change in shell structure in extremely neutron rich nuclei, shape change and shape coexistence in nuclei, formation of high spin isomers in nuclei, etc.

High Energy Photon Spectroscopy: Hot nuclei are formed in heavy ion fusion reaction where the relative kinetic energy of the colliding nuclei is converted into internal excitation energy and high angular momentum of the compound nuclei. These systems are unstable and decay by emission of particles (neutron, proton, alpha-particle, etc.) and heavier fragments. Apart from particle emission, the system can also decay by emitting gamma-rays. The decay of Giant Dipole Resonance (GDR) is one of the way through which the energy is released from the system in the form of electromagnetic radiation (8-20 MeV). At VECC, a Large Area Modular BaF2 Detector Array (LAMBDA) has been developed to to detect the high energy photons.

Change of Electron Capture Nuclear Decay Rate in Different Environments: Is it possible to change the decay rate of a radioactive substance by external means such as pressure, temperature, chemical environment etc.? The answer given in the text books is **"No".** However the electron capture radioactive decay (meaning the capture of an orbital electron by the nucleus) should be slightly affected by the external environment. The electron capture decays taking place deep inside massive stars are expected to be faster than observed terrestrially. Perhaps such decays taking place deep inside the earth are also faster than we normally see. At VECC, research is being pursued to understand the change of electron capture decay rate of ^{7}Be, ^{109}In, ^{110}Sn etc. under pressure and in different chemical environments

Penning trap development: Penning trap is a device to store charged ions and sub-atomic particles using a strong homogeneous magnetic field and a weak inhomogeneous electrostatic field. The mass of the trapped charged particle can be determined very accurately by measuring the axial and cyclotron frequencies of the trapped ion. A cryogenic Penning trap facility is under development where the trap would be at liquid helium (4 K) temperature and plan to put in radioactive ions in it.

Development of Neutron Detectors - *For Time of Flight and Multiplicity Measurement:* To boost up the experimental nuclear physics research in the country, several detector arrays were planed at VECC under the super conducting cyclotron utilisation project, neutron Time OF Flight (TOF) array is among one of major system. Neutron TOF array has been developed for the precise measurement of neutron energy and angular distribution. The array consists of 50 numbers of neutron detectors, each having 5" diameter and a similar length. Detectors are liquid scintillator based and have been indigenously designed and developed at VECC, after long, involved and careful R & D efforts. The primary motivation of the array is to look for answer of the some of today's frontline nuclear physics problems, understand the fission dynamics at near barrier energies, measurement of nuclear level density parameter, multi-fragmentation, exotic fragment studies, etc.Neutron Multiplicity Detector constitutes a powerful means for the nuclear temperature measurements. It allows to measure, event by event, with high efficiency, the number and total kinetic energy of neutrons emitted in a nuclear reaction. This detector has been developed first time in India.

Research with Rare Ion Beam: The aim of Rare Ion Beam (RIB) Project is to accelerate radioactive, rare isotope beams for using them in frontline research experiments. The main motivation is to understand the properties of exotic nuclei and the mystery behind element synthesis in stars using RIB as a tool. RIB also has numerous applications, namely in material science, radiation biology, R&D on radio-isotope production, etc. to name a few. The facility will have practical applications also, for example in radiotherapy facilities.

Many critical milestones of the RIB project have already been reached. Notably, India’s first heavy-ion Radio Frequency Quadrupole (RFQ) linac has been developed at VECC indigenously. Later a longer RFQ linac that accelerates particle beams to 100 keV/u has been built. In addition to RFQ, fully indigenous development of heavy-ion LINAC (Linear accelerator) modules, also for the first time in the country, has helped to further accelerate

the beam to 415 keV/u. A 6.4 GHz Electron Cyclotron Resonance (ECR) ion-source also have been successfully developed. A new 2.4 GHz ECR ion source has been recently added – this will form the first ion-source in the charge breeder. Presently the facility delivers 415 keV/u (that is 16.6 million electron volt for Argon-40) heavy-ion beams. Several radioactive ion beams such as ^{14}O (half-life 71 sec), ^{42}K (12.4 hr), ^{43}K (22.3 hrs) & ^{41}Ar (109 min) have been produced using primary beam from the K130 cyclotron using a completely novel technique. The centre has also made considerable progress in designing and developing a powerful state of the art superconducting electron linac operating at 2K that can deliver 50 MeV, 2 mA beam (that is, a beam power of 100KW). For the centre's flagship project ANURIB, the RIB group has designed a novel superconducting heavy ion Linac, which can simultaneously accelerate multiple charge states of 1 MeV/u HI beams to about 7 MeV/u.

Study of super-allowed beta decay of nuclei such as ^{14}O along with other experiments provides a test of the unitarity of the CKM matrix which gives an important laboratory test for the Standard Model of particle physics. The RIB of ^{14}O is also important for study of astrophysical reactions crucial in understanding the nucleo-synthesis path from hot CNO cycle to rp-process. Radioactive potassium isotopes ^{42}K and ^{43}K have several bio-medical applications whereas ^{41}Ar is an industrial tracer also used in engineering and environmental science studies. Recently RIB of ^{111}In (half-life 2.8 days) has been accelerated. ^{111}In is used as a radioactive probe in Perturbed Angular Correlation (PAC) spectroscopy. PAC is a widely used technique in several areas of materials research, chemistry and biology. Apart from PAC, ^{111}In is also used as a radiotracer e.g. in wear studies of medical prostheses, and several other medical applications.

Apart from RIB, the facility also delivers stable isotope beams of oxygen, nitrogen, carbon, argon, iron, potassium, zinc, indium, nickel etc. These beams are being extensively used for materials science studies, for example in study of room temperature ferro-magnetism in dilute magnetic semiconductors such as ZnO and TiO_2 and study of nano-pattern formation and coulomb sputtering studies. Recently a set-up for laser spectroscopy has also been installed. Several studies on target R&D, particularly sintering induced grain growth, high power target design and simulation along with on-line experiments using K130 cyclotron beam for new RIB development are on-going.

Experimental Material Science:

Defect Dynamics: Understanding of the basic mechanisms of the plastic instability in Portevin-Le Chatelier effect. Study of the dynamics of

dislocation by molecular dynamics simulation techniques. ***Radiation Damage Studies:*** Characterization of microstructure of deformed and irradiated nuclear structural materials by X-Ray diffraction. Developing irradiation facilities in the Materials Science beam line of the DAE Medical Cyclotron. ***Development, characterization and physical studies of nano-structured multifunctional materials:*** Multiferroic perovskites with ferroelectricity, ferromagnetism and ferroelasticity. Graphene and conducting polymer based super-capacitors with application in energy cells.

Theoretical Nuclear Physics:

Theoretical physicists at VECC are engaged in evaluating the nuclear reaction rates of astrophysical importance, the equation of state of dense nuclear matter and the study of compact astrophysical objects, microscopic calculations of spontaneous fission life time, developing a hybrid model for explaining multi-fragmentation reaction in Fermi energy domain, study of liquid gas phase transition from transport model calculation in intermediate energy heavy ion reactions and the analysis of production cross-section of hyper-nuclei in intermediate energy heavy ion reactions. The group is actively involved in the study of dissipative relativistic hydrodynamics and its application in relativistic heavy ion collisions, evaluation of transport coefficients of hadronic and quark matter, evolution of fluctuations in heavy ion collisions at relativistic energies, calculation of the electromagnetic probes of quark gluon plasma (QGP), study of the interaction of heavy flavors in QGP and hot hadrons, jet quenching in QGP and the applications of thermal field theory in ultra-relativistic heavy ion collisions.

Experimental High Energy Physics:

ALICE Experiment at CERN, Geneva:. Indian scientists have been playing crucial roles in the ALICE experiment, one of the largest collaboration in the world for more than twenty years, since the conception of the experiment.. The India-ALICE Collaboration has made very important contributions to the experiment over the years in terms of detector technologies, electronics, computing and physics. In particular, the Photon Multiplicity Detector (PMD) has been primarily designed and built at VECC, which is one of the major detector systems in the experiment. VECC scientists are involved in the ALICE upgrade projects of building GEM detectors for the TPC and have taken responsibility for the Common Readout Unit (CRU) of the experiment.

STAR Experimet at Brookhaven National Laboratory, New York: At present, the STAR experiment is going through beam energy scan program to locate the QCD Critical Point of the phase diagram. The PMD, installed in the

experiment by VECC scientists, has taken data during 2003 - 2011 beam time. VECC scientists are taking leading roles in the Critical Point search.

CBM Experiment at FAIR, GSI, Darmstadt: VECC hold the responsibility of designing, building and operating a muon detector system to enable muon measurements at the Compressed Baryonic Matter (CBM) experiment at FAIR, the upcoming accelerator facility at Darmstadt, Germany.

Indian Neutrino Observatory (INO): A laboratory for the operation of a prototype of the Iron Calorimeter (ICAL) for proposed INO experiment is fully functional at the centre. A magnet consisting of 13 layers of 2 m x 2m x 6 mm iron plates and 12 RPCs are sandwiched between the iron plates are implemented.

Superconducting Magnetic Energy Storage (SMES) System:
Design, development, fabrication and testing of a novel high current two-quadrant DC-DC chopper for charging the SMES coil to a constant current for energy storage and for discharging it to a constant DC capacitor voltage. A DSP based digital controlled Voltage Source Inverter (VSI) for generating the compensating signal so as to instantaneously mitigate voltage sag at the load terminals at the correct phase. A Quench Protection System for quench detection and protection of superconducting coil of the SMES system.

Development of TCM-AUTOSOLEX (in collaboration with BRIT):

Design, development, fabrication and testing of ^{99}Mo/^{99m}Tc-TCM-AUTOSOLEX, an automated computer operated closed cyclic module for separation, purification and recovery of ^{99m}Tc, using methyl ethyl ketone (MEK) by solvent extraction technique, from low specific activity (n,□)^{99}Mo obtained in BARC research reactor. The TCM-AUTOSOLEX module can provide the most economic ^{99m}Tc-pertechnetate giving enhanced radiological and pharmaceutical safety as well as providing enhanced capacity to handle much larger quantity of Mo-99. Installation of the unit at RRMC, VECC, Thakurpukur. Following physico-chemical quality control and bio-quality control, first human study at RRMC was carried.

Mechanical Engineering: The mechanical engineering activities of VECC comprises design, modeling, prototyping, fabrication, installation and commissioning for different accelerator related systems and components. The latest FEA (Finite Element Analysis) software is used to design accelerator magnets, cavities and accelerator components operating at room temperature and cryogenic temperatures. CAD (Computer Aided Design) software is used to generate computer models and fabrication drawings. CAM (Computer Aided Machining) software is used to generate machine codes for use in

workshops under the group. The mechanical workshop carries out fabrication of precision components with complex geometries. It has a combination of conventional and CNC (Computer Numeric Control) machines, wire cut EDM (Electro Discharge machining) machine, co-ordinate measuring machine, welding equipments, etc. The room temperature cyclotron and superconducting cyclotron operate round the clock.

Data Acquisition & Development: The design and development and system integration and user support of the data acquisition systems for nuclear physics experiments using cyclotrons are actively pursued. This includes software development for multi-parameter data acquisition system for CAMAC and VME platforms and hardware development of various CAMAC and other related utility modules. In recent years embedded system development using micro-controller and FPGA is being pursued. Various embedded hardware like RS232 to Ethernet converter, digital pulse processing (DPP) hardware for radiation detectors have been developed. A heterogeneous data acquisition system to integrate CAMCA, VME, DPP systems based on timestamp correlation is under development.

Accelerator Instrumentation & Control: The design and development of embedded electronic instruments for various subsystems and beam diagnostics equipments of both room temperature and superconducting cyclotrons and development of software for supervisory control of major subsystems of both the cyclotrons are pursued. The electronics systems and software for magnetic field mapping has also been developed. Specialization has been achieved in designing micro-controller based system with embedded linux at the instrument controller level and EPCIS based control software under client-server architecture at the supervisory level. A scinitillator based phase probe to measure beam bunch position with respect to accelerating RF waveform has been developed to detect magnetic field error and assist beam tuning. Apart from the primary design and development activities related to cyclotron and its utilization, this division has carried out research work on neural network applications, image processing, medical expert system for coronary artery diseases, semi-automated parallelizer of FORTRAN programs. At present research and development work is being pursued on high resolution gamma imaging system for detecting mammary gland abnormality, parallel processing on MPI, OpenMP and functional programming paradigm, performance studies of different pulse processing algorithms on digital domain, fault-tolerant FPGA firmware for single event upsets etc.

51. Detail five major Strengths, Weaknesses, Opportunities and Challenges (SWOC) of VECC.

Strengths

1. The quality of students is very good because of very rigorous selection process adopted. Since a vast majority of the students are scientists recruited by a tough selection process, a very high level of research output is ensured. This is contrary to the general trend seen elsewhere where students not finding employment are taking up research.
2. After a tough selection, the initial training imparted to the students is of very high standard.
3. The quality of research and infrastructural facilities available is very good.
4. The funding is very generous.
5. Besides the students, the faculty is also very strong, nationally and internationally known and there is very strong peer pressure on both the sides to do better.

Weaknesses:

1. Ensuring very high quality sometimes leads to very low number of students in some of the disciplines.
2. The number of faculties in engineering sciences at VECC is very low at the moment. Doctoral programme in engineering sciences has started expanding only in recent years. Engineers of VECC were so long, deeply involved in the development activities rather than research and academic activities. However, HBNI has brought about a marked difference in the research and academic activities of the engineers of VECC

Opportunities

1. Opportunity to do high level research having immediate application in national programmes.
2. Opportunity to interact with scientists at national level and international level
3. Opportunity to get various forms of national and international recognitions in the form of fellowships and awards
4. Opportunity to develop various types of skills
5. Opportunity to do interdisciplinary research

Challenges

1. To balance various types of responsibilities for the faculty

2. To balance between various types of responsibilities for the employees enrolled as students
3. To ensure superiority in quality of research while doing doctoral research on large scale set ups.

52. Future plans of the VECC.

Expand the doctoral programme so as to utilise the full potential of the faculties and research infrastructure. Particular emphasis will be given to develop qualified human resources (both scientists and engineers) required for the rapidly developing fields of high energy particle accelerators in the country for energy, medical and industrial applications.

VECC is setting up two new campuses: (i) Rajarhat campus will house the Centre for Nuclear Theory for research in the frontiers of nuclear theory and the forthcoming ANURIB facilities which will add new dimension to research in nuclear physics, material science and biology; (ii) the Chakgaria campus will house the medical cyclotron facility for research in nuclear sciences and related areas and application to detect and cure human diseases.

List of appendices (to be made available to the assessment team during their visit)

1. VECC: Appendix 1: Faculty profile referred to at para 11
2. VECC: Appendix 2: Ongoing projects referred to at para 17
3. VECC: Appendix 3: Not included
4. VECC: Appendix 4: Visits of faculties to International Laboratories/ Institutions referred to at para 25
5. VECC: Appendix 5: Seminar/ Meetings/ Conferences/ Colloquia referred to at para 30
6. VECC: Appendix 6: List of doctoral students referred to at para 39