DOI: https://doi.org/10.36094/sc.v89.2024.A_Tribute_to_Professor_Bikash_Sinha.Srivastava_Mandal.101

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Sci. and Cult. 90 (3–4) : 101-106 (2024)

A TRIBUTE TO PROFESSOR BIKASH SINHA – A CELEBRATED PHYSICIST OF INDIA

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With the passing away of Prof Bikash Sinha, on August 11, 2023,India in general, and Kolkata in particular, lost one of its most loved and respected visionaries, scientists, science administrators, andscience communicators, who led the Variable Energy Cyclotron Centre Kolkata (VECC) and Saha Institute of Nuclear Physics (SINP), Kolkata for decades, till he retired in 2009. Later he was DAE Homi Bhabha Chair Professor at VECC for 5 years, and then Indian National Science Academy, Senior Scientist, at VECC. He founded the Tagore Centre for Natural Science and Philosophy, New Town, Kolkata. He was also Vice Chancellor of the West Bengal University of Technology, Kolkata for some time, and Chairman, or Member of Councils or Boards of Governors of severalnational and international institutes.

Professor Bikash Sinha

A grateful nation had honoured him variously, first as Padma Shree (2001), then as Padma Bhushan (2010). He was elected as a Fellow of - the Indian National Science Academy (1989), the National Academy of Sciences (1993), and the Indian Academy of Science (2004). He was also elected as a Fellow of The World Academy of Sciences (2001) and the Institute of Physics, UK (2009). He received Honoris Causa Doctorates from several universities in India and abroad. He was a recipient of the R. D. Birla Award (2002) from the Indian Physics Association, the Humboldt Research Award from the Alexander von Humboldt Foundation, Germany (2005), Rabindra Purashkar and Bang Bibhushan from the Government of West Bengal (2022), and several other Memorial Lecture Awards and Memorial Awards instituted by various academies and organisations.

Early Years

Prof Sinha was born on 16th June 1945 in Kandi, Murshidabad. He had his early education in Kolkata and after a B.Sc. (Hons.) in Physics from the Presidency College, he moved to the University of Cambridge from where he did his MA (Tripos). He obtained a Ph.D. from the

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University of London, and some years later also a D. Sc. from there.

He was working at King's College London, when he visited Variable Energy Cyclotron Project, then operating as a division of the Bhabha Atomic Research Centre, Mumbai. One of us (DKS) started a lifelong collaboration in nuclear physics with Professor Sinha and studied the energy dependence of optical model potential in nuclear physics. By then his work on the use of medium-modified (density dependent) nucleon-nucleon interaction along with experimentally determined density distributions of nuclei to describe this potential was becoming a powerful and robust theoretical framework to describe the elastic scattering of nuclei, to get density distribution of nuclei, to get details of medium modification of nuclear interactions, and to determine the thickness of neutron skin in neutron-rich nuclei. It continues to be used with excellent efficacy, even today, 5 decades later.

Prof Sinha returned to India in 1976 to join the Nuclear Physics Division of the Bhabha Atomic Research Centre, Mumbai with the initiative of Dr Raja Ramana. His work on the increasing role of two-body nuclear interactions as compared to one-body nuclear interactions in nucleus-nucleus collisions, as the energy of nucleon-nucleon collisions increased and went past the Fermi Energy of nuclei- was to provide a firm footing for the study of nuclear collisions at higher and higher energies, which could be done at a superconducting cyclotron, for example. Along the way, he also provided an elegant description of the energy loss in the deep inelastic collision of nuclei, using the Linear Response Theory. The turning point in his research interest, during this period, was triggered by his pioneering study of the emission of photons and dileptons in relativistic collisions of heavy nuclei as a signature of the formation of quark-gluon plasma, a deconfined strongly interacting matter which filled the nascent universe soon after the Big Bang and which could be created in the relativistic collision of nuclei.

Accelerators and Other Research Facilities

By the late 1980s, the cyclotron at VECC had started operating, and experimentalists from across the country had started using it for studies of nuclear reactions and nuclear structure. Prof Sinha moved to Kolkata in 1983, to take over the Research and Computer Facilities at VECC, as Prof Nripendra Kumar Ganguly- the then head for these was retiring. Prof Sinha became the director of VECC, upon the retirement of Prof Ajay Srinivas Divatia, its first director in 1988, at a very young age of 44. He held this position till 2009. His youthful energy, very positive attitude, deep understanding of the physics issues, and strong determination became visible immediately as he initiated the fabrication and installation of massive research facilities, revamping the ion sources to provide heavy ions from the cyclotron, and initiating a project to revamp the various power supply units which had started showing age-related issues.

For the last more than two decades, the K130 cyclotron has been operating most successfully and providing beams of protons, deuterons, alpha particles, and heavy ions to users from across the country for studies of nuclear reactions, nuclear structures, radiation damage studies for nuclear materials, and isotope productions for medical applications. An Electron Cyclotron Resonance ion source, which had earlier been built to provide heavy ions is now a stand-alone facility for the study of ion implantation, and several others were made as ion sources for the K130 and K500 cyclotron. In parallel, his encouragement and support led to pioneering works in the theory of collision of nuclei at intermediate energies, microscopic studies of fission, neutron stars, proton and heavy ion radioactivity, liquid-to-gas phase transition in nuclear collisions, multifragmentation of nuclei, and nuclear equation of state being done by researchers from VECC and SINP. The young researchers have now taken the microscopic study of nuclear fission to the next level by performing *ab initio* calculations for it, and a quantitative description of emission of neutrons and photons.

Parallelly, he started a forceful campaign to build a K500 superconducting cyclotron at Kolkata and efforts to set up a helium-jet transported online isotope separator facility for the study of short-lived (radioactive) nuclei. Yet, another project- which was very close to his heart was setting up a medical cyclotron facility, to produce radiopharmaceuticals for medical diagnostics and cancer treatment.

The construction of the superconducting cyclotron was one of the most complex and challenging technological tasks, requiring extreme precision at every level and for every equipment, that the country had taken till then. But the spirited determination, unfailing enthusiasm, and firm yet generous management of Prof Sinha, his overall good-will, scientific friendship across the international laboratories, and ability to enthuse and encourage his colleagues and workers in Public Sector Undertakings- which provided many components including the main magnet, saw it commissioned, in August 2009, with the

internal beam accelerated up to the edge. He also saw to it that most of the components were made in the country- including the superconducting coil- for which a special facility was set up at VECC, and the cryostat, the ECR ion sources, as well as the RF system were made in the country to the required precision.

The Radioactive Ion Beam (RIB) facility for producing, separating, transporting using a helium jet, and studying short-lived nuclei evolved to incorporate an ion source, two Radio Frequency Quadrupole accelerators (the first in the country), and several Linear Accelerators (LINACs) to provide low-energy beams, each one of them designed and built indigenously. It also spawned a very vibrant and successful collaboration with the TRIUMF Laboratory in Canada for handling radioactive targets and fabricating superconducting cavities, for the acceleration of electrons up to 50 MeV, to provide a source of neutron-rich rare isotopes using fission of heavy nuclei.

Professor Sinha bought a K30 medical cyclotron to be installed on a 5-acre plot, provided by the Government of West Bengal in Chakagaria. The cyclotron is now operating and providing radiopharmaceuticals to hospitals in and around Kolkata and constantly establishing and perfecting protocols to produce different isotopes for medical use, for the last several years, by now. The cyclotron also provides unique facilities for the study of radiation damage in nuclear materials and eutectic targets for the Accelerator Driven Subcritical Systems being developed by the Department of Atomic Energy.

VECC already had a Memorandum of Understanding with Saroj Gupta Cancer Centre and Research Institute, Thakurpukur, to provide and support several nuclear techniques for diagnostics and cancer treatment using iodine therapy. A very important step in this direction was setting up a 4 MeV electron LINAC for radiation therapy in the late 1990s, which operated for a decade, before being replaced. VECC provided regular maintenance to the accelerator during that period. Prof Sinha spoke extensively, engagingly, and widely, creating awareness for the need for a high-energy proton accelerator (say about 200 MeV) for the treatment of cancer, and prepared the stage for their introduction in the country.

Prof Sinha always thought big, and to set up A National Unstable Rare Isotopes Beams (ANURIB) facility based upon design and fabrication experiences at VECC, he organised to get a 25-acre plot in the neighbouring New Town, which is developing into a wonderful complex for a variety of activities of the Department of Atomic Energy. A Radiation Medicine and Research Centre, to conduct research in nuclear medicine and treatment of cancer using iodine therapy, a regional unit of the Atomic Energy Regulatory Board, a regional unit of the Atomic Minerals Directorate, and Kolkata Centre of UGC-DAE Consortium for Scientific Research, along with the subsystems for ANURIB facility have already started coming up.

Prof Sinha was given the additional charge of the Saha Institute of Nuclear Physics in late 1992. He immediately started to get funding for setting up ultramodern facilities for condensed materials research and bio-sciences- and the institute now boasts of state-of-the-art equipment and laboratories for these and has made valuable contributions in these fields. He also pushed for setting up a modern low-energy high-current 3-MeV tandem accelerator to study nuclear reactions of astrophysical interest. The Facility for Research in Experimental Nuclear Astrophysics (FRENA) has now been ready and operational for over a year.

Research

During all this, Prof Sinha continued his research on the study of quark-gluon plasma. He collected young and old researchers of VECC and SINP and from other institutes and enthused them to form a group of theoreticians who started studying the formation, evolution, and signatures of the quark-gluon plasma which was likely to be produced in relativistic collisions of heavy nuclei.

Some of the most notable outcomes from this work were: the production of photons and dileptons, medium modification of hadron properties, successive equilibration of gluons, light quarks, and heavy quarks in the quark-gluon plasma, propagation of heavy quarks in quark-gluon plasma, transport properties of quark-gluon plasma and hadronic matter, the chemical equilibration of quark-gluon plasma, the hadronization of the quark-gluon plasma, the theory of the relativistic hydrodynamics of strongly interacting matter, dissipative hydrodynamics, the azimuthal flow of the plasma in non-central collisions, the parton cascade model of nucleus-nucleus collisions, and intensity interferometry of thermal photons and hadrons, etc. The results of these investigations published in leading international journals, catapulted the Kolkata Theory group to the international stage, and its members and students are now sought after as post-docs, for teaching, collaborations, invited talks, invited reviews, and for writing textbooks on the field from across the world.

One of the results with a great impact was a calculation performed by DKS and Prof Sinha, which offered the first suggestion that quark-gluon plasma was formed in relativistic heavy-ion collisions. The explanation of the corresponding photon data from lead + lead collisions measured by the CERN experiment at SPS was used by CERN to claim the discovery of the quark-gluon plasma. The same calculations went on to provide a quantitative explanation for the photon measurements performed on gold + gold collisions at Brookhaven National Laboratory (BNL), New York by the PHENIX experiment, and the lead + lead collisions performed at different energies at the ALICE experiment at CERN Large Hadron Collider (LHC), Geneva. Now it has become a standard procedure for this study. These activities, along with the experimental activities, allowed VECC to plead for and start a PhD programme for students- which provides a vibrant atmosphere of internationally competitive research.

Collaborations with CERN, BNL, and FAIR

Along with the theoretical work, Prof Sinha started efforts for collaboration with experiments looking for quark-gluon plasma. His charm, magnetic personality, and intellectual leadership came into full play, as he leveraged his scientific friendship with scientists at CERN and GSI to start a collaboration and build a Photon Multiplicity Detector (PMD) – with funding from the Department of Atomic Energy and the Department of Science and Technology and taking researchers from across the country from different universities and institutes. This was a unique initiative, which held fast and true when the researchers made a larger PMD for use with SPS, and later with a change of design to be used in the STAR experiment at BNL, and ALICE experiment at LHC.

These, along with the contributions of the Raja Ramanna Centre for Advanced Technology in building the LHC, the contributions to the making of the CMS detector by TIFR, BARC, and several universities, and the setting up of the Tier-II Grid computing facilities at VECC and TIFR went on to play a crucial role in India being invited to join CERN- first as an Observer State and then as an Associate Member State. The CMS group went on to discover the elusive Higgs boson, which had been sought for 50 years and which completed the last missing component of the Standard Model.

The collisions at CERN produce the quark-gluon plasma at very low baryonic densities but high temperatures- that mimics the condition during the early universe, while the plasma in the interior of neutron stars is at large baryonic densities and lower temperatures. A Facility for Antiproton and Ion Research (FAIR) was being planned at GSI Darmstadt. The FAIR management went one step further and invited India to be part owner of the Facility – by making part cash and part kind contribution to it. India is now a 3% owner of an ultramodern research facility to serve its high-energy nuclear physics community for several decades.

The necessary Radiation Plate Chamber (RPC) detectors and the muon detectors were designed, developed, and are being fabricated and tested at VECC. The experimentalists of high energy nuclear physics as well as of nuclear structure and nuclear reaction, are enthused at this unique possibility and they are designing extensive preparations for detectors to be used there. This collaboration is remarkable for one other reason- VECC and other institutes of the DAE collaborated in making the power converters and those were then built by the Electronics Corporation of India and supplied to FAIR-matching required precision. Several vacuum chambers and beam lines were also designed, fabricated, and supplied by Indian Industries.

Legacy

Prof Bikash Sinha will be remembered for his monumental contribution towards science, especially in the fields of nuclear and high-energy physics. The CERN collaboration discussed above arose from the (first) International Conference on Physics and Astrophysics of Quark-Gluon Plasma in 1988, which he organised at TIFR Mumbai. Now it has developed into one of the most important series of international conferences in this field and has been extremely valuable in shaping the field. He also helped organise regular schools for in-depth teaching of advanced topics in the field of nuclear physics.

Prof Sinha was a very forceful and enthusiastic speaker and communicator in support of basic research, higher education, and rational thought. Blessed with a clear booming voice, easy laughter, natural grace, and flawless spoken and written English and Bangla, he became one of the best ambassadors of science, science education, and scientific outreach. He wrote extensively in newspapers and spoke on national and regional television frequently to emphasize these points. However, it was his passion for furthering a vibrant research ecosystem in all sciences- that became his defining hallmark.

He was one of the best spokespersons for nuclear energy in the country- whose neglect has exposed the entire world to the excruciatingly devastating and painful

strangulation of Climate Change that we have started experiencing daily across the world.

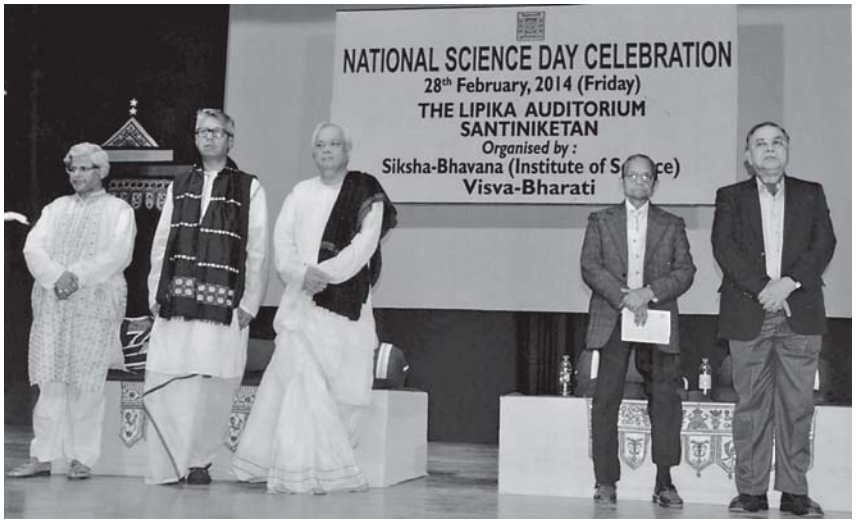
Professor Sinha had a long association with Visva-Bharati and Indian Science News Association (ISNA). He served as Scientific Advisor to Visva-Bharati and full member of the Academic Council and Court and took active part in the development and propagation of Scientific temper in Visva-Bharati Scientific Community.

Professor Bikash Sinha, inaugurated the National Seminar on "Jagadish Chandra, Rabindranath, Prafulla Chandra and National Integration" organized jointly by the Indira Gandhi Centre for National Integration, Visva-Bharati, Indian Science News Association and Bose Institute on 26th February, 2012 in the Lipika Auditorium, Santiniketan. In his inaugural address Professor Sinha highlighted the academic linkage among Acharya Jagadish Chandra Bose, Gurudev Rabindranath Tagore and Acharya Prafulla Chandra Ray. Professor Sinha also highlighted the convergence of three personalities in the arena of science which was very informative for the people and students as well.

Professor Bikash Sinha delivered the inaugural address at the two day National Seminar on "Science and Technology Policy: The Need for State Specific Appraisal" was organized by the ISNA on 26th and 27th February, 2014 at Bose Institute, Kolkata.

Professor Sinha delivered Science Day Lecture at the Lipika Auditorium, Visva-Bharati, Santiniketan on 28th February, 2014 where he highlighted the scenario of nuclear energy in India. He took active part in the inauguration of the new building of the Integrated Science, Education and Research at Visva-Bharati, Santiniketan in April, 2014 along with the Hon'ble Governor of

L to R: Prof. Sudhendu Mandal, Prof. Supriyo Tagore, Prof. Bikash Sinha, Prof. Sibaji Raha, Prof. N.C. Datta and Prof. Susanta Datta Gupta



L to R: Prof. Sudhendu Mandal, Prof. Susanta Datta Gupta, Prof. Bikash Sinha, Prof. Anil K. De and Prof. Samir Bhattacharya

L to R: Dr. K. Kasturirangan, Prof. Sudhendu Mandal, Mr. M.K. Narayanan, Professor Sibaji Raha, Professor Susanta Dattagupta, Prof. Bikas Sinha and Dr. V.K. Thomas

West Bengal, Rector of Visva-Bharati, Dr. M.K. Narayanan, Dr. K. Kasturirangan, Professor Sibaji Raha, Professor Susanta Dattagupta and Professor Sudhendu Mandal.

Prof. Sinha got along extremely well with the young and readily agreed to travel to the remotest parts of the country- happily bearing the hardships of travel to speak at schools and colleges situated in the middle of disturbed areas, forests, and hills. Many researchers from India and elsewhere in the national and international laboratories, will readily tell you of the lasting impression of after they had the inspiring and life-altering talks of Prof Sinha.

He loved world literature and readily lent it to us from his vast collection. His pride in the Bengal Renaissance and the philosophy of Tagore, which pervades the intellectual atmosphere of the country was palpable. His understanding, appreciation, and love for paintings, and Western and Hindustani Classical music- both vocal and instrumental were phenomenal. We were treated to some of the greatest masters of Santoor, Sarod, Piano, Thumri, and Khayal at numerous get-togethers at his house or functions organised by him. He was a very generous host.

His easy charm and friendly nature, his depth of intellect, and his sincerity won him lifelong friends, from across the world, and he shared them generously with us- which helped get our young students placements in the best laboratories in the world.

He was truly loved and revered in Kolkata, and will, forever be remembered as a voice of reason, hope, and faith in India's youth and their capacities. ❒