Annual Review of Nuclear and Particle Science, 2018. Barry R. Holstein, Wick C. Haxton and Abolhassan Jawahery (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, California 94303-0139, USA. Vol. 68. viii + 459 pages. Price: Not mentioned.

The *Annual Review of Nuclear and Particle Science* brings out valuable state-of-the-art review articles every year from experts across the world precisely in this area. It is a valuable addition to all libraries and researchers in the field. The collection of articles deals with the physics of subatomic matter, like nuclei and their components, viz. the nucleons, which is a collective term for protons and neutrons. In turn, the protons and neutrons are made up of the up and down quarks. Their heavier counterparts are the charm, strange, bottom and top quarks. These heavy quarks are produced in high-energy collisions at laboratories across the world and their properties studied in detail using detectors of great sophistication. Quarks are bound inside hadronic matter by the strong interactions, the force carriers of which are called gluons. Heavy quarks are rendered unstable and transform into lighter quarks due to the weak interactions which are mediated by the W and Z bosons, which are very heavy. It is the heaviness of the force carriers which makes the force short range and effectively makes them weak. The gluons, on the other hand, are massless, but due to the so far unproven confinement hypothesis, they as well as the quarks are doomed to be bound inside the hadronic matter. Hadrons come in two varieties – baryons which are a configuration of three quarks, and mesons which are made up of a quark and antiquark pair. The mesons include the well-known pion, which is the effective force carrier of the inter-nucleon force. The weak interactions due to the work of Glashow, Weinberg and Salam have been unified with the electromagnetic, made up of electric and magnetic forces which in turn has been unified by Maxwell, and is today known as the electroweak theory, and this latter along with the strong interactions constitutes the Standard Model (SM). Besides quarks, they also describe the interactions of the leptons, of which the electron and its neutrino are familiar particles. The latter have heavier counterparts which are the muon and its neutrino, and the tau-lepton and its neutrino. The manner in which part of the electro-weak interactions turn short range is due to the Higgs mechanism. The prediction of the latter was the existence of the Higgs boson, which was discovered at the Large Hadron Collider (LHC) some years ago. The SM appears to reign supreme, and controls the interactions not just in the laboratory but also in the cosmos. Today cosmology is also a precision science, with branches of study devoted to the abundance of elements in various astrophysical environments. In the present collection of 17 articles, we are regaled to the spectacle of physics from the largest to the smallest scales by the finest experts in the world. There are significant challenges to turn all the information that arrives into something useful. One also needs the mathematical and computational tools to make sense of all the data that pour in. There are rapid advances in several directions, some of which are reviewed in the present collection. Here we provide a glimpse on what awaits the serious reader in this volume.

It is often the case that there is an article in the *Annual Reviews* which is a 'human interest'. This year is no exception and the first article is on the life and work of the recently departed Guido Altarelli, a well-known theoretical physicist who spent a large fraction of his working life in the theory group at CERN, Geneva, and was a pioneer in the study of the strong interactions and their phenomenology. The tribute to his life and work has been paid by his friends and colleagues Luciano Maiani (former Director-General of CERN) and Guido Martinelli. Altarelli is well known as being one of those who found the DGLAP (Dokshitzer–Gribov–Lipatov–Altarelli–Parisi) equations which describe how quarks and gluons carry momentum fractions inside protons. Without these, one could not make sense out of the physics, for example, the LHC which collides protons on protons. The article captures the romance of doing science in the post-World War II era in Italy, which has been termed as 'the Italian Miracle'. In the later years, Altarelli was also the leader of the Theory Group at CERN, and the authors of the tribute remark on his human qualities. Altarelli has significant contributions also to the resolution of difficult puzzles that faced the weak interactions as the SM was being established. In his later years, Altarelli was interested in looking beyond the SM and in the consistency of extensions of the SM subjecting them to phenomenological tests, and also in the physics of neutrinos. While it was painful to lose a brilliant physicist, the celebration of his life and work will remain a touchstone for future generations.

The Thomas Jefferson National Accelerator Facility in Newport News, Virginia, USA, has been the flagship of physics at the border of nuclear and particle physics. Voklker Burkert in 'Jefferson Lab at 12 GeV: the science program' outlines the science objectives as the 12 GeV gets ready for its run. The aims are to measure the quark and gluon polarized distribution functions of the nucleon, and elucidate the structure of the nucleon and also study the hadronization properties of quarks using the nuclei. Indeed, this work would have been close to Altarelli's heart and therefore would have a special place in this volume.

Even in the era that we presently live in where quantum field theory computations have reached a very high level of sophistication, a class of computations called one-loop computations that prima facie appears simple, requires a lot of sophisticated treatment, especially when they have to be input into simulations of events and Monte-Carlo generators for use at hadron colliders, of which the LHC is an example. In the article entitled 'Automatic computation of one-loop amplitudes' by Degrande *et al.*, a thorough review of the methods and tools of the automation is presented in a readily accessible form.

Returning now to the issue of the composition of hadrons that come as baryons and mesons, the mathematics that describes the strong interactions does not preclude the existence of other configurations such as, for example, two quarks and two anti-quarks, or four quarks and an anti-quark. These are popularly known as tetra-quarks and penta-quarks. Surprisingly, there has been no definitive evidence of such states that involve just the three lightest quarks. Recent experiments, including those at the LHC, have provided near-convincing evidence of the existence of these when heavy quarks such as the charm and b quarks participate in the configurations. The article entitled 'Multiquark states' by Karliner *et al.*, reviews the most important developments in the field. There is a wealth of information in the article on the observations, and the puzzles and the possibility of future discoveries, which is a useful reference for anyone embarking on studying these exotic states.

Whereas today we have all become accustomed to hearing and reading about the LHC and its most recent discoveries and/or about its excluding this or that favourite extension of the SM, it may also be interesting to read about how it actually came to be. What were the challenges in its construction and also in the design of two of its most famous detectors, namely the compact muon solenoid (CMS) and a toroidal LHC apparatus (ATLAS). In this collection, Negra *et al.* (pioneers of the LHC) present a comprehensive and compelling story of the two detectors. Guest *et al.* in the article entitled 'Deep learning and its application to LHC physics' bring to the physicist the subject of deep learning well-known to computer scientists and show its connections to high-energy physics data analysis, and explain with examples the neural works and prove that the future of data handling may well be in the hands of deep learning.

Whereas the LHC has famous discoveries associated with the Higgs boson and its searches for beyond the SM physics in the form of dark matter or supersymmetry or extra-dimensions, all of which occur in the so-called proton on proton collision mode, it is also a collider for heavy ions with proton on lead or lead on lead. The discoveries associated with such collisions are those of the quark gluon plasma, a state of matter at high energy and temperature at which the quarks and gluons behave as if they have been released from their prisons. An important facility to study matter in such conditions is the relativistic heavy ion collider at Brookhaven National Laboratory, USA, which collided a variety of ions, some light on heavy and heavy on heavy to be able to understand the properties of the resulting fireball. Important properties have been established in these experiments of matter, which have been reviewed by Nagle and Zajc in 'Small system collectivity in relativistic hadronic and nuclear collisions'. Such systems probe the description of matter as fluids or as systems that are away from equilibrium. Busza *et al.* in their article entitled 'Heavy ion collisions: the big picture and the big questions' present an in-depth review of the subject, and the aspects of the study of what has been termed as the hottest droplet of liquid made on earth, and indeed the large number of big and open questions in the field. On the other hand, in 'Dark matter searches at colliders', Boveia and Doglioni survey the properties of particles that have not been seen. Namely the famous dark matter which we all know exists in the Universe but do not know anything about it, except that it forms a halo around galaxies. That said, collider searches which do not directly yield fruit do contribute to our knowledge of dark matter indeed as in the LHC, which is reviewed in this article.

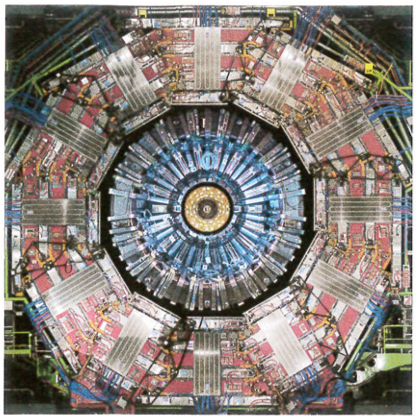
While one celebrates the great physics achievements of particle colliders, nothing would be possible without highly developed detector technology. 'Silicon calorimeters' by Brient *et al.* reviews the development of this field and the challenges for electromagnetic calorimeters based on silicon calorimetry for future e^+e^- machines as well as the end cap for the CMS, when it is upgraded for the high-luminosity run that would follow the long shutdown post Run 3 of the LHC.

For most of the world, CERN is no more than the home of the LHC. Indeed, there are other pioneering experiments that take place which probe the physics of matter at high precision and also help in developing technologies. At CERN, a Penning trap that assists in the measurement of masses of radioactive isotopes called ISOTRAP was first introduced long ago. In the article 'Penning-trap mass measurements in atomic and nuclear physics' by Jens Dilling *et al.*, the reader is brought abreast with the most recent developments in the field. The Penning traps assist in precision science and also in testing the electroweak sector, and tests of fundamental symmetries and conservation laws.

As repeatedly mentioned in the foregoing, hadrons are made up of constituents but do we really have knowledge of the detailed structure of these objects? What are the probes of the structure? Indeed, since these objects are electrically charged and/or have electrically charged constituents (recall that the quarks carry charges in units of 1/3 of electronic charge), the electromagnetic interaction itself can probe these objects. More energetic the real or virtual photon that strikes a hadron, the deeper it penetrates into the hadron past the cloud of virtual photons and other particle and antiparticle pairs that pop in and out of vacuum. Measurements in one kinematic domain can be combined with those from another using mathematical tools known as dispersion relation to reconstruct their structure to the best extent possible. Pasquini and Vanderhaeghen review these developments in 'Dispersion theory in electromagnetic interactions'.

Whereas use of electromagnetic probes is as old as modern physics itself, physics with neutrino beams in considerably more difficult, as neutrinos, the neutral counterparts of the corresponding charged leptons such as electrons, interact only weakly and precision physics using neutrino beams is much harder from an experimental point of view. However, their interactions with nuclei need to be well understood if one has to extract information on neutrino oscillation parameters at high precision. Mahn *et al.* review the status of the field in 'Progress in measurements of 0.1–10 GeV neutrino–nucleus scattering and anticipated results from future experiments'. Baha Balantekin and Boris Kayser in their article entitled 'On the properties of neutrinos' give a comprehensive state-of-the-art review of the properties of neutrinos, their mixing, masses, and possible decays and electromagnetic interactions.

Of the many key principles in quantum mechanics, the Pauli exclusion principle occupies a hallowed place. In the context



Transverse section of the barrel part of CMS, illustrating the successive layers of detection starting from the centre, where the collisions occur: the inner tracker, the crystal calorimeter, the hardon calorimeter, the superconducting coil, and the iron yoke instrumented with the four muon stations. The last muon station is at a radius of 7.4 m.

of nuclear physics, as one populates the various allowed energy levels in nuclei which are themselves composed of protons and neutrons, and generate the potential in which they live, Pauli's principle dictates the structure of the nucleus. Since nature has so kindly provided a third relatively light and long-lived quark, namely the strange quark, one can create a cousin of the proton and neutron, which has a strange quark in place of one of the up or down quarks, leading to a strange baryon (hyperon). This can be used to then break the spell of Pauli's principle and probe energy levels of the nucleus as we now have a distinct particle which would otherwise have been forbidden. This has led to the development of the field of hyper-nuclei. One could then consider the possibility of having two strange quarks and create a doubly strange hyperon, and study the nuclei in an unprecedented manner. Hiyama and Nakazawa review the status of this fascinating field in 'Structure of $S = -2$ hypernuclei and hyperon–hyperon interactions'.

Despite the long history of nuclear physics in terrestrial experiments, the field of nuclear physics in the cosmos, which is now called nuclear astrophysics is a challenging one. While the abundance of light elements can be worked out in big bang nucleosynthesis, we know that heavy elements must be made of instellar interiors, and very heavy elements must have come from supernovae. Very old stars bear the imprint of the stellar cauldrons in which heavy elements must have been produced, and yet there are mysteries as regards some elements which require a neutron-rich environment. Today, with LIGO having definitely observed a neutron-star merger, some puzzles may get resolved. This fascinating subject has been reviewed in Frebel's 'From nuclei to the cosmos: tracing heavy-element production with the oldest stars'. Tatischeff and Gabici in 'Particle acceleration by supernova shocks and spallogenic nucleosynthesis of light elements' describe the puzzles facing the supernova remnant paradigm for the origin of galactic cosmic rays and describe the abundance of light elements in old stars. Thus, in these two articles one sees the delicate interplay between the fields of nuclear physics and astrophysics.

In conclusion, the present volume has a collection of attractive and accessible articles from leading experts on fields ranging from colliders to the cosmos, from particle physics to nuclear physics, and the interplay between these distinguished fields.

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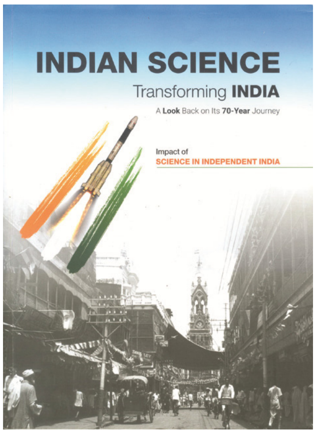


Indian Science: Transforming India – Impact of Science in Independent India. L. S. Shashidhara (ed.). Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi 110 002. 2018. viii + 177 pages. Price: Not mentioned.

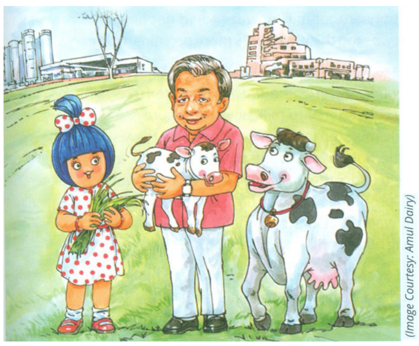
India achieved independence just over 70 years ago. Though the figure is not a specific anniversary, unlike, say, a golden jubilee or a platinum jubilee (which it will be in 2022), it is still a good time to learn about our successes in science. In April 2018, the Indian National Science Academy released a book with some of these success stories.

The selection of topics in this book, for areas that India has made progress in, is eclectic. Thus, we read about our achievements in the production of Samba Mahsuri and Basmati rice, in the shrimp industry, plant tissue culture, the diamond industry, etc. For instance, Basmati rice can be distinguished from adulterated rice using DNA fingerprinting, thus leading to identification of authentic rice, resulting in better exports. Mechanization in the diamond industry has led to over 12,000 laser units in Surat, with a resultant loss of 90% of the diamond-cutting jobs in Antwerp and 70% of those jobs in Israel, to Surat.

I must admit that I knew nothing at all about many of these areas and the book certainly achieves its first aim of showcasing the unsung areas that we have made progress in. Hopefully, it will achieve success in its other aim – that of inspiring more scientists to tell us their stories of research in science.

Not surprisingly, Amul, the Indian dairy company gets a chapter. (Perhaps there should have been a reference to the Amul advertisements too – after all, they are in a class of their own.). Medicine makes it appearance in more than one chapter, and there are essays on Shantha biotechnics and its vaccines as well as one on the blood bags manufactured by Penpol, and a separate chapter on generic drugs in India. I did wonder why atomic energy and space research have been left out – after all, they are easily India's biggest success stories, along with the green revolution. While it is commendable to highlight the lesser known areas, I think it would have been appropriate to have had something on the above topics too.

Any person with a science background who reads this book would no doubt be impressed to learn where the Indian researcher publishes – the rice research papers have been published in *PLOS ONE* (Samba Mahsuri rice) and in *Proceedings of the National Academy of Sciences* (*USA*) (Basmati). The tone is chatty, as it should be, in a book that is meant to popularize the science that is



One of the famous Amul cartoons in honour of Verghese Kurien.