African Strategy for Fundamental and Applied Physics
Interim Report

Edited by: ASFAP Steering Committee **Version 1: 9 Oct 2022**

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The African Strategy for Fundamental and Applied Physics was initiated in late 2020.
This is the first interim report on the following Working Group Activities.

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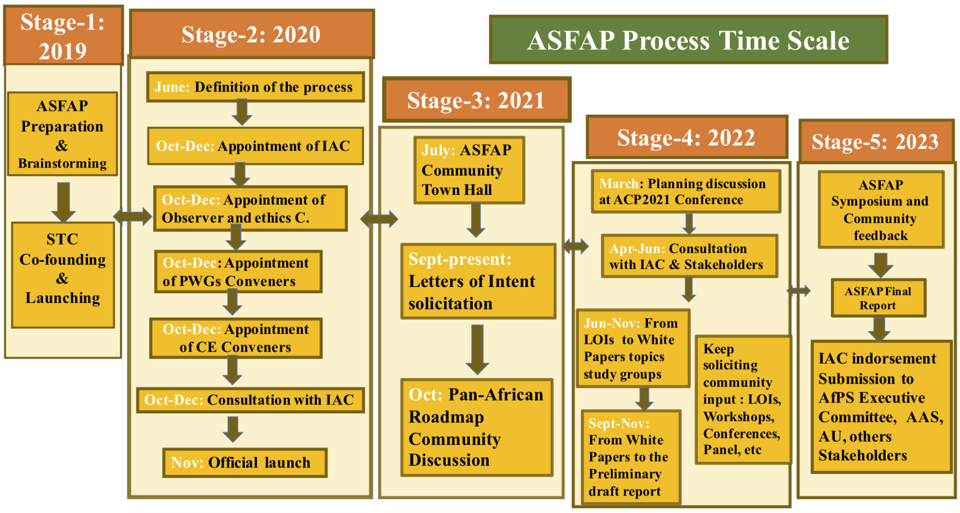

Figure 1: ASFAP Timeline

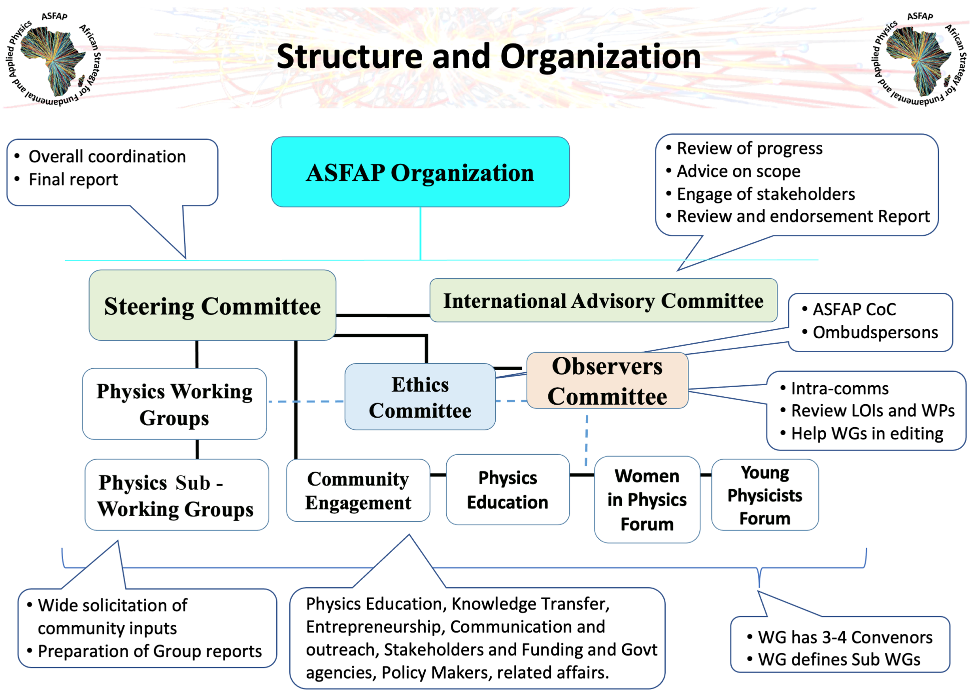

Figure 2: ASFAP Structure

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Introduction to the African Strategy for Fundamental and Applied Physics (ASFAP)

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Abstract:
Generating scientific and technological knowledge and converting them into innovations which are of added value to society are key instruments for a society's economic growth and development. As outstanding as these capabilities are for other regions in the world, Africa's science, innovation, education and research infrastructure, particularly in fundamental and applied physics, have over the years been under-valued and under-resourced. To efficiently address the scientific and technological gaps with the rest of the world, Africa's stance needs radical overhaul. With the big ambition to drive a community-wide effort in Africa, the African Strategy for Fundamental and Applied Physics (ASFAP) was founded. The aspiration is to demonstrate the physics potential benefits for African society and how physics can contribute to the technological infrastructure development and to provide trained personnel needed to take advantage of scientific advances. The vision consists in fostering scientific literacy driven by physics-based technologies and their impact for economic growth, including other sciences that draw heavily on advances in physics. In addition to developing and enhancing collaborations and partnerships among Africans in national, regional, and Pan-African organizations. This should assist to tackle the challenges that Africans struggle and prioritize educational and research resources, innovation and development. The ASFAP initiative could present a unique opportunity of overcoming the complexity of the African social and economic challenges, if Africa needs to have and maintain its position as a co-leader in the global scientific process and reap the consequent socio-economic benefits. ASFAP will take a few years with a final report to notify the African policymakers and broader communities concerning the strategic directions that will have greatest impacts on physics education and research in the next decade.

Keywords: ASFAP, Physic Education, Science, Research, Innovation, Human Capital Building

1. Introduction

Science and technology capabilities are fundamental for social and economic growth and development. Yet Africa's science, innovation and education have been chronically under-funded. Transferring knowledge, building research capacity and developing competencies through training and education are major priorities for Africa in the 21st century. Physics combines these priorities by extending the frontiers of knowledge and inspiring young people. It is therefore essential to make basic knowledge of emerging technologies available and accessible to all African citizens to build a steady supply of trained and competent researchers. In this spirit, ASPAF [1] was founded to foster social transformation and economic competitiveness, through science, technology and innovation

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for effective human capital development as a key means of implementation to drive sustainable development in Africa. ASFAP aims to increase African education and research capabilities, build the foundations and frameworks to attract the participation of African physicists, and establish a culture of awareness of grassroots physics activities contrary to the top-down strategies initiated by governments. To address many of the fundamental issues that African society continue to face, ASFAP will complement African top-down strategies and encourage a broad community participation.

2. Africa Major Challenges in the 21th century

Literacy and education are essential for human development in today's knowledge world as Nelson Mandela said "*Education is the most powerful weapon, which we can use to change the world*". Education allows us to better understand the world in which we live. Nevertheless, literacy in the African continent is affected by a number of key factors, which are: colonial legacy includes the linguistic framework that strongly affect the educational environment, as well as shortage of resources (reliable access to electricity), inadequate infrastructure as shown in Graph-1 (middle and right-hand images), lack of digital literacy, lack of trained teachers and better learning material which include Information and Communication Technologies (ICT). These constraints hinder the process of promoting literacy to Africans, and present the biggest challenges of science knowledge creation and technological innovation in Africa. These led to the continent´s failure to create high quality education, stop brain drain, correct for gender equality, as well as they fail to ensure science-led development on a sustainable basis and unlock the minds for brighter economic prospects.

Because of that, the overwhelming majority of the Africans are falling into poverty and lack of decent jobs. Parallel to this, there is a demographic explosion in Africa (see Graph-1, left-hand) based on the United Nations forecasts [2] [3]. Africa's population is expected to grow by an average of 2.2 % (2.5 % by 2040) every year until the 2060s (and by 2050 a quarter of the world's people will be African). In addition, more than half of Africa's population will be under 25 years old [4]. In the next few decades, Africa will become the youngest and most populous continent. In view of these developments, the difficulty of confronting a population explosion and weak economic growth exacerbated the situation. The situation for female youth, who are even worse off than male youth, is particularly serious. Young women suffer from a deeper lack of insufficient levels of literacy and therefore are largely emarginated and work in the informal and precarious sectors.

Graph-1: The world´s population will rise to 10,9 billion by 2100, with most of the growth driven by Africa [3] (Left-hand). Middle and right-hand images show examples of the educational environment issues in Africa.

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Although, African countries show commitment to invest in science through investment in research and development (R&D), only four out of five countries still spent less than 1% of global investment in R&D of its Gross Domestic Product, which is the closest to the African Union's suggested of 1% [5]. Furthermore, several countries ranked as 0%, while the R&D expenditures for more than 20 African countries are unknown. This chronic underfunding on Africa's R&D is gravely impacting the Africa´s participation in the creation of scientific knowledge, which is extremely poor in comparison with the rest of the world. The Africa's contribution to the global scientific knowledge is roughly 0.74%. On top of this, African publishing research outputs are under-valued and under-cited in the international indexing systems namely, Scopus and the Web of Science. That said, Africa has also an extremely low number of researchers per million people (it is about 198) [6], and in order to achieve the world average concerning the number of researchers per capita, Africa needs another million new PhDs students. This landscape gets worse and worse when Africa is losing roughly 20,000 professionals to the high-income countries every year due to the lack of opportunity. Hence, one must recognise that the aforementioned limitations leave Africa lagging behind and the continent become a peripheral region in the world. Even, the gap is widening exacerbated by the persist underperformance. It is high time, that Africa narrows and closes the scientific and technological gaps with other regions in the world. That it's been massively underfunded over a long time impacting critically the growth of African economies. Thus, African countries are at a critical juncture socioeconomic, and to achieve the commitment of the leadership a deep African engagement is required. It is therefore, imperative that Policymakers and stakeholders appreciate the return on investment in research, innovation and higher education to reverse the trend towards greater science-led development on a sustainable basis for Africans.

3. ASFAP-African Strategy for Fundamental and Applied Physics

In response to the previously mentioned challenges, ASFAP presents an ambitious initiative that seeks to set up the foundation and framework for enhancing the African science community collaboration in defining education, physics priorities and stressing the powerful of physics for African society. The main goal is to address the interests of a wide range of varying needs from the community with the aim to attract enthusiasms of every physics disciplinary group, which is particularly targeted. These perspectives have arisen from and been driven by the science community with its potential to deliver a long-term strategy that would encourage and engage the continent to align its scientific research policy in physics to support national agendas towards higher education development and improve basic physics research by using more robust means of assessment that focus mainly on values of insight, impact and reliability. All these include a strong desire for investment in African science for economic growth driven by physics-based technologies.

ASFAP founding initiative is designed to be a transparent and democratic process, to be owned by Africans for Africa and it is mandated by the African Physical Society. The co-founders who form the Steering Committee (STC) are: Kétévi Assamagan (Brookhaven National laboratory, USA), Simon Connell (University of Johannesburg, South Africa), Farida Fassi (Mohammed V University in Rabat, Morocco), Shaaban Khalil (Center for Fundamental Physics, Zewail City, Egypt) and Fairouz Malek (CNRS and Grenoble University, France).

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The process development requires a few years and in due course will release the strategy report. STC will first explore manners to better adapt the overall ASFAP strategy generated. In particular, the focus will be suggesting a strategic plan with direction that has a positive and significant impact on physics education and research in the next decade, along with actionable items. The report will be communicated to the African and broader communities. With the aim to make well-informed decisions that would contribute to a sustainable development, a collaborative culture must be instilled as a core principal that can bring together policymakers, managers, scientific communities in national, regional and Pan-African organizations. Moreover, to strengthen this collaboration and ensure the implementation of those decisions one needs to do a close follow up.

Just like a strategic plan, in order to be useful it needs to be periodically reviewed and revised to adjust priorities and re-evaluate goals, so that ASFAP process has to be repeated regularly, every 7-10 years for the following decades with a review of the impact of previous strategies. The overall roadmap process is shown in Fig-1, that illustrates a tentative timeline and deliverables, as well as the activities.

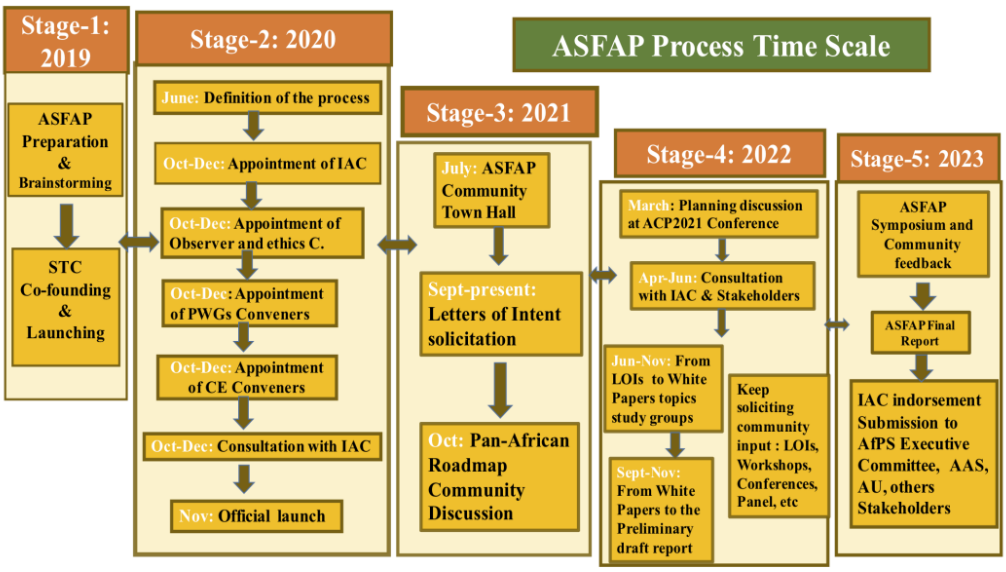

Fig-1: ASFAP roadmap timeline

ASFAP organization structure is shown in Fig-2. The Steering Committee (STC) body manages the process development, ensure the overall coordination and advance the necessary efforts involving all ASFAP bodies. In addition to the final report preparation. The International Advisory Committee (IAC) is formed of international institutes and leading individuals in the field in Africa and beyond. IAC advises on the ASFAP scope, review the progress and engage the international communities and policymakers as well as endorse the final report. ASFAP considers the Observers Committee (OC) who is made up of Seniors and Expects from many research fields in physics. OC is responsible for advising and conveying ideas between STC, Physics Working Groups (PWGs), Fora and Community Engagement groups. OC has also to review the community inputs, in particular Letter Of Intents (LOIs) and White paper, and help PWGs in report editing. ASFAP include also the Ethics

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Committee (EC), who is responsible for dissemination and maintain the Guidelines of ASFAP Code of conduct. A subset of EC might serve as an Ombudspersons as well.

ASFAP has a broad footprint by discipline and fields, it has 16 PWGs and are as follows: Accelerators, Astrophysics & Cosmology, Atomic & Molecular Physics, Biophysics, Computing & 4IR, Earth Science, Energy, Fluid and Plasma, Instrumentation & Detectors, Light Sources, Materials Physics, Medical Physics, Nuclear Physics, Particle Physics, Optics and Photonics and Theoretical & Applied Mechanics. PWGs play a pivotal role in the ASFAP process, by encouraging and soliciting the community inputs, engaging the discussion, reviewing and revising the progress in the relevant groups. Furthermore, PWGs are in charge of the group reports preparation. PWGs provide also the liaisons between the different PWGs to enable that cross-cutting topics receive the proper coverage and consideration in all the relevant groups. In what concern the Engagement Groups & Fora, there are Community Engagement, Physics Education, Women in Physics Forum and Young Physicists Forum. These are convened and working closely with STC and the rest of ASFAP bodies to promote science-led development on a sustainable basis, contribute to the scientific literacy of high schools and universities and revitalize higher education. It is clear that the first step should be the gathering of inputs and evidence from the community to draw upon. This kind of inputs give the full picture and help to address the right questions on how to encourage and engage young people in physics, technology and scientific careers. And a special attention must be paid to the women participation. This widely and deeply consultation can contribute in raising awareness of the necessity to prepare and form qualified young people, to technology and knowledge transfers and can thus stimulate Africa's productivity development.

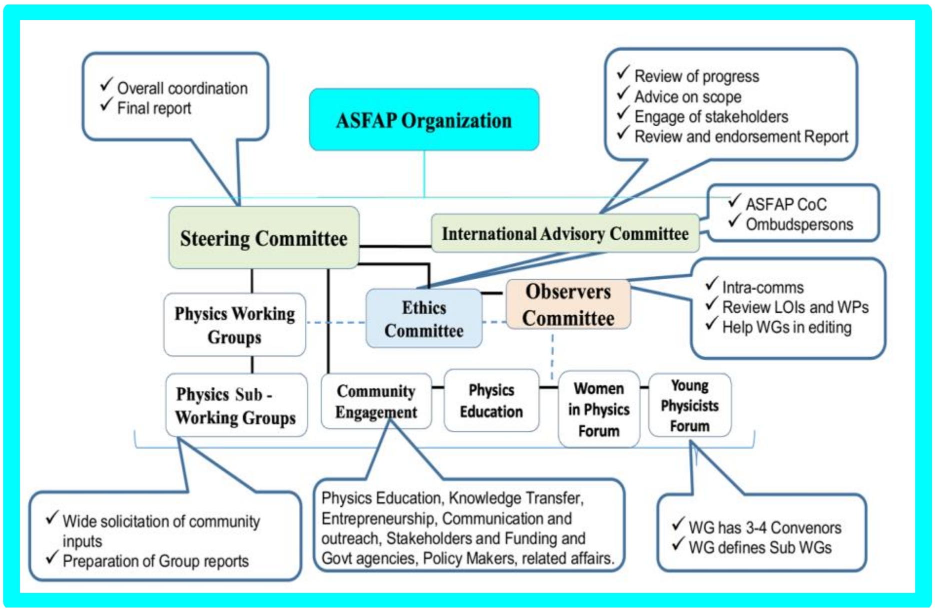

Fig-2: ASFAP Organization structure

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4. African Strategies and ASFAP

Africa has already numerous strategies authored by governments and policymakers, large political bodies and institutions [5] [7] [8]. These include strategies for a green growth model, better education and research, job creation, digital transformation and so on. However, the effective local implementation of these strategies is still missing, and which is evident by the persistent of Africa laggardness. As a result, it is essential for the scientist's community, engineers, technicians, funding agencies and policymakers to come together and create the critical masses needed to address and define a concerted strategy for the continent. Unlike African top-down strategies, ASFAP is based on a large community consultations and large footprints in all the physics and engagement topics of importance to Africa.

Since decades other regions in the world have already been conducting the efforts; this is the case for the European and United States strategies for Particle Physics and other physics fields, and recently Latin America that has been developing its strategy as well. For that, Africa should fight seriously to take its equal place as a co-leader in the global scientific process, along with all the consequent socio-economic benefits. To achieve that, ASFAP is a crucial process, where the central mission would be to help improving higher education in Africa across national borders and in so doing, to contribute in a significant way to the development on the continent. To fulfil this mission several considerations, have to be implemented among them: 1.) the engagement and participation of the African scientist's community, 2.) the establishment of culture awareness for the periodic strategies done by grassroots physicists, 3.) the improvement of the low level of intra-African collaboration in the exchange and sharing of data and in scientific collaboration and 4.) the strengthen of the African education and research capabilities. Since the international cooperation forms the common denominator of today's culture of scientific activities, it is equally important, to increase and sustain networking to extend the existing international scientific ties to Africa, in the development of the strategical visions for fundamental and applied physics. Such as engagement in physics education, communication and outreach, toward developing countries, should be sustained also in targeted programs toward Africa. In order to exploit and overcome a realistic path for development, African countries must adopt a coherent coordinated strategy and implement what it needs to be changed to radically give science and technology their due weight in the development process. This will certainly be a unique opportunity to prosper for a continent of more than a billion people with large unmet needs but vast human potential.

5. Organizations supporting ASFAP

Graph-2 represents the ASFAP support, including the national and international organizations funding agencies and governments organizations, institutions and academies in Africa and beyond. The organizations supporting ASFAP are as follows: African Physical Society, African Union, African Academy of Sciences, Network of African Science Academies (NASAC), South African Department of Science and Innovation, iThemba Labs (South Africa), Hassan II Academy of Science and Technology (Morocco), Ministry of Higher Education and Scientific Research (Tunisia), South African Institute of Physics (SAIP), United Nations Educational, Scientific and Cultural Organization (UNESCO), East African Institute for Fundamental Research (UNESCO-EAIFR), Third world Academy of Sciences (UNESCO-TWAS), International Union of Pure and Applied

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Physics (IUPAP), CERN (European Organization for Nuclear Research), International Centre for Theoretical Physics (ICTP), International Atomic Energy Agency (IAEA), European Physical Society (EPS), German Physical Society (DPG), Institute of Physics (IOP), French Physical Society, European Astronomical Society (EAS), Spanish Royal Physics Society (RSEF), Spanish Astronomical Society (SEA), Netherlands' Physical Society (NNV), Physical Society of Japan (JPS), Association of Asia Pacific Physical Societies (AAPPS) and Islamic World Educational, Scientific and Cultural Organization (ISESCO).

Graph-2

6. Community Inputs

The worldwide expert community has demonstrated the wish to promote better education and research for Africa. However, they do not consider the African conditions due to their ignorance of the African reality. To translate the diversity and complexity of African realities, Africans themselves must develop their own strategy for science and technology to achieve their greatest impact and benefits. This would also help the international partners interested in capacity development and retention in Africa to integrate the Africans inputs, rather than to default to their own views of how they may want to develop Africa. In this spirit, ASFAP process relies on the African community inputs, as well as Pan-African and international communities. The inputs from the communities are collected in several forms of proposals: LOIs, white papers (that aim to be published in a peer-reviewed Journal), including surveys, Panel discussion, networking with stakeholders, conferences and workshops and then discussed and debated in plenary sessions and topical parallel sessions. The engagement of the community inputs would be also the commitment in PWGs meetings, nominations of the PWGs conveners and liaisons, offering constructive opinions and expertise and encouraging institutional credits for those working on ASFAP for people in leadership roles as conveners and liaisons.

7. Conclusion

ASFAP was founded with a big ambition for change and longer-term reforms that should focus on strengthening institutions, improving infrastructure, accelerating technology adoption and enhancing high education, capacity building, scientific research. In addition, the strategy aims to influencing

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directions of strategic science development taken by policymakers and effective implementation. ASFAP would help donors and funding agency in deciding where best to invest limited resources and support the African Physical Society into an outstanding professional body. The initiative also stresses the pivotal role that physics plays as a key part of the educational system and hence an advanced society governments need to be supportive of the science of physics. It is worth emphasizing, furthermore, that the digital revolution, the so-called 4th Industrial Revolution, presents a great opportunity for Africa to benefit from developed ICT capabilities such as automation and digitalisation if Africa succeeds in implementing the technological transformation locally.
In pursuing this vision, the African scientific communities emphasize the importance of building synergy between fundamental physics and practical applications which is crucial for a solid education in Africa.

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ASFAP summary report: Particles and their Applications

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Abstract

The Second Biennal African Conference on Fundamental and Applied Physics (ACP) took place in March 2022. The scientific program included three summary reports on the African Strategy for Fundamental and Applied Physics (ASFAP). Here, the summary report of "Particle Physics and related applications" groups (Particle Physics, Nuclear Physics, Medical Physics, Astrophysics and Cosmology, Fluid and Plasma, and Complex Systems; and the cross-cutting fields: Accelerators, Instrumentation and Detectors, Computing, and Nuclear Energy) is presented. The scope of each of the groups, the events organised so far and their upcoming activities are summarised.

Keywords: The African Conference on Fundamental and Applied Physics, ACP, the African Strategy for Fundamental and Applied Physics, ASFAP, Particle Physics, Nuclear Physics, Medical Physics, Astrophysics and Cosmology, Fluid and Plasma, Complex Systems, Accelerators, Instrumentation and Detectors, Computing, and Nuclear Energy

1. Introduction

The scientific program of the Second Biennal African Conference on Fundamental and Applied Physics (ACP2021), that took place online in March 2022 [1, 2], included three working sessions with three summary reports on the African Strategy for Fundamental and Applied Physics (ASFAP) [3]. ASFAP effort started in 2019, with the objetive to develop a strategy to increase African education and research capabilities; improve collaborations; and inform policymakers, stakeholders and international partners on the strategic directions likely to impact African advancement. For the development of such strategy, input was requested to the whole community (from all career stages and nationalities) as letters of interest (LOI). ASFAP has 16 Physics Working Groups and 6 Engagement Groups. Here, the summary of the report of the "Particle Physics and related applications" groups is presented. At the time of ACP2021, around 25-30 LOIs were submitted by these groups.

2. Particle Physics

The scope of the Particle Physics group is to:

- Contribute to build a network of Particle Physicists in Africa.

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- Push forward the ongoing activities and foster cooperations between African researchers for both Experimental and Theoretical physics.
- Address the possibilities of evolution and expansion of these involvements and drive future endeavors.
- Collect scientific inputs from the African Particle Physics community (in form of written LOIs) from subgroups, to provide a shared roadmap for the field (white paper).

The research experience of the groups in Africa involved in Particle Physics is very broad. On theoretical physics, there are groups working on radiative corrections in the Standard Model and beyond, perturbative unitarity and boundedness from below for scalar potentials and electroweak precision tests, Naturalness and Veltman conditions, Charged Higgs phenomenology and Vector like quarks. On the experimental physics side, there is expertise on physics analysis, beam tests, electronics development and remote operations.

Given the vast amount of topics covered by the group, four subgroups have been proposed (with two conveners for each, an experimentalist and a theorist):

1. "Fundamental constituents and forces" (Higgs physics; electroweak and beyond Standard Model physics; direct searches)
2. "Symmetries and composite structures" (flavour physics, charge-parity violation; strong interaction, hadron physics, heavy ions; indirect searches; neutron electric dipole moment)
3. "Light messengers" (neutrino physics: neutrino parameters, charge-parity violation, beyond Standard Model)
4. "Infrastructures"

The Particle Physics group organised the "First ASFAP Particle Physics Day" in November 2021 with more than ten contributions from different groups around the whole African continent. It was an online event and it included reports from institutes working on the different experiments (ATLAS [4], CMS [5], ALICE [6] and LHCb [7]) of the Large Hadron Collider [8] at CERN, as well as reports from DUNE experiment on neutrino physics and theory groups, as shown in Figure 1. The next event is planned for Spring 2022: "the ASFAP Particle Physics PhD and postdocs day". So far, 7 LOIs have been received.

Figure 1: Covers of some of the presentations of XXX

The presence at CERN of the Particle Physics group is quite relevant, with involvement in experiments either as full members or associate (ATLAS, CMS and ALICE); also training opportunities in LHCb and computing WLCG. During the conference, it was pointed out several times that collaborations at CERN are very open, and the international laboratory is welcoming further participation of African physicists and groups. CERN can offer exciting science and training opportunities in an international context. Such networking also within Africa would also be highly beneficial.

3. Nuclear Physics

The first mini-workshop organised by the Nuclear Physics group took place in March 2022 with four contributions: i) "ASFAP introduction"; ii) "Nuclear Physics Activities at BIUST"; iii) "The Pan African Virtual Nuclear University"; and, iv) report from a student "Tanzania: challenges facing nuclear physics research (lack of suitable and qualified personnel, laboratory equipment for nuclear research, etc.)". It followed with a discussion session in which few relevant aspects were brought-up, such as the need for a training session on Geant4 program (a nuclear and particle physics simulation software). So far, 4 LOIs have been received: three on experimental facilities and one about education and training.

4. Nuclear Energy

The energy situation, which is very worrying in Africa, is evidenced by the absence, in most countries, of energy policies based on energy development master plans in the short, medium and long term. The "Energy" working group includes energy for a broad range of needs in Africa. It covered nine topics, "Nuclear Energy" is one of them. Such subgroup includes nuclear reactors, micro reactors, civil nuclear, synchrotron and fusion physics.
The objectives of the Energy working group are to:

- Strengthen cooperation/relations between African researchers and other actors in energy.
- Identify scientific communities working in the field of energy, energy efficiency and sustainable development.
- Create a dynamic of exchange and sharing of knowledge and know-how between academics and experts.
- Have an overview and mapping on the research and innovation in energy area around Africa.
- Facilitate the collaboration between researchers working in same topics.
- Facilitate and encourage researchers to participate in the ASFAP project in an active manner and submit LOIs.

The first meeting of this working group took place in February 2022 with contributions on the different kind of energies and regions in Africa. A second event is planned and, so far, 16 LOIs have been received.

The concrete scope of the "Nuclear Energy" subgroup is:

- *Nuclear reactors*: Define and locate the African position on research and future of nuclear energy
- *Micro-reactors*: Research on the application of nuclear energy in health and civil fields
- *Civil nuclear*: Training and development in nuclear energy
- *Synchrotron*: Training and development in synchrotron techniques
- *Fusion physics*: Sharing information+results with actors and researchers in the field

5. Medical Physics

The Medical Physics group organised its first mini-workshop in December 2021 with an overview of ASFAP mission and contributions from the International Atomic Energy Agency (IAEA), the Federation of African Medical Physics Organizations (FAMPO), and the platfrom Global Health Catalysts (GHT). Now, the focus is on bringing all Medical Physics Organisations together through FAMPO. One of the next meetings will be devoted for a joint sesion of the Medical Physics, Nuclear Physics, Energy and Instrumentation groups.

6. Astrophysics and Cosmology

The first mini-workshop of the Astrophysics and Cosmology group took place in November 2021, with more than 110 people involved (people from 21 countries in Africa and from 14 countries in Europe, South America and Asia). This working group is subdivided into different subgroups: solar physics; solar system, planetary sciences, astrobiology; stellar astronomy; galactic and extragalactic astronomy; cosmology and gravitational astronomy; transients and pulsars; high-energy astrophysics and astro-particle physics; astronomical instrumentation and infrastructure; astronomical methods and data; ethno-archeoastronomy (cultural astronomy); and astronomy for development. Close to 65% of the participants are men and 35% women.

The conveners of the working group have presented ASFAP initiative at more than 20 international conferences, and also distributed information about it among different networks and e-mail lists such as the African Astronomical Society, the African Network of Women in Astronomy, and Astronomy in Africa.

The plans for the upcoming months are: i) to start with regular meetings under each subgroup; ii) discuss about received LoIs and promote submission of new ones so that all topics are covered; iii) start shaping the White Papers; iv) discuss connections with other ASFAP working groups.

During the ACP2021, the second call for applications (schoolarships) of the Pan African Planetary and Space Science Network (PAPSSN) was advertised.

7. Fluid and Plasma

The Fluid and Plasma Physics group presented its strategy and initiatives in the ASFAP Town Hall meeting from July 2021. The focus on the group is on: i) non-thermal plasma generation (affordable low-cost methods); ii) environmental applications; iii) water purification; iv) disinfection; v) plasma agriculture (plasma-activated water); vi) plasma medicine; and, vii) aerospace applications. The role of plasma science and technology in enabling/augmenting new processes and applications is really broad, but it also faces grand challenges (infrastructure development, local technologies, education, etc.). Additional person power in this working group would be very benefitial.

8. Complex Systems

The Complex Systems includes theoretical groups working on applied mechanics such as biomechanics, solid mechanics, micro- and nano-structures dynamics, dynamical systems, and computer modeling. The work strategy includes these work-packages: WP1) identify the working groups in Africa and African scientists in the field all over the world; WP2) send out invitations and keep advertising to embark more people; WP3) form workgroups, assign tasks and come out with an activity timetable. Person power in the group is quite limited, so additional contributions would be very benefitial.

9. Instrumentation and Detectors

The Instrumentation and Detectors Physics Group aims at promoting physics, development, design, implementation and evolution for a broad range of instrumentation and detectors applications in Africa. It is a transversal and multi-disciplinary group related to all physics groups. The goals of the group are: i) provide a coherent/flexible framework for efforts in instrumentation and detectors across Africa; ii) target groups: laboratories/centers, universities, pre-college; ii) bottom-up approach: individual and/or group collaborations; iv) encourage and help to submit LOIs; v) identify projects in instrumentation across countries, like shared facilities; vi) useful and meaningful efforts with tangible results; vii) cost effective implementation.

The first meeting of this working group took place in November 2021, with the goal to help the submission of LOIs by collecting and structuring information on existing facilities and projects in instrumentation. The main purpose of the meeting was to identify the most important future needs with respect to instrumentation in all fields of physics in Africa.

From a survey and listening to talks at ACP2021 and other meetings, it was concluded that the main problem that experimental researchers are facing is the need for experimental facilities and educational training centres in instrumentation for basic and applied experimental physics.

Starting from existing LOIs and discussions at ACP2021, the conveners of the group have approached the LOI's authors directly and encouraged concretisation on the plans. They also discussed a very interesting proposal for a "International Centre for Experimental Physics in Africa (ICEPA)", common LOI of Instrumental and Physics Education working group. The idea is inspired by African Institute for Mathematical Sciences (AIMS) and other educational centres like Southern African Institute for Nuclear Technology and Sciences (SAINT). It will consist on a master-like curriculum typically one and a half year, including 6-month research project. It will include high-level lectures ($\leq$50%) and hands-on experiences ($\geq$50%), with a final examination and recognised diploma (association to university required in such case). The proposed educational training centre is similar to AIMS, but for experimental physics, strongly oriented towards instrumentation. Experimental installations and/or facilities will be installed at such a centre.

10. Computing and 4^{th} Industrial Revolution

The Computing and 4^{th} Industrial Revolution group is also a transversal one. In order to identify the needs for computing in the science community a survey was opened. The group covers a abroad range of topics: data science, (deep) machine learning, artificial intelligence, quantum science and technology, distributed computing, distributed analysis, computational physics, African infrastructure for networks and cloud services, e-learning, high performance computing, open source software, internet and bandwidth capacities, data centers, governance and policy, etc. This working group is co-organizing "International Conference on Data Science, Machine Learning and Artificial Intelligence" conference, in collaboration with Namibia University of Science and Technology (NUST). The current status of this working group is described in Ref. [9].

11. Accelerators

Accelerators is also a transversal working group, in connection with other groups such as Particle Physics, Nuclear Physics, Medical Physics and Radiation Biophysics, Material Science, Astrophysics and Cosmology, and Instrumentation and Detectors. The conveners started collecting a list of all existing facilities in Africa. This was not that trivial, as some of them cannot be found online, and there is also lack of information about the research that is being done in those facilities. Another challenge is the fact that the Accelerator community in the African continent is very small due to lack of facilities where young people can be trained. Thus, before thinking of building more facilities on the African continent, the African youth needs to be trained with necessary skills. iThemba Laboratory for Accelerator Based Science (LABS) in South Africa has recently been appointed as a collaborating center for IAEA. They are planning to host a training based on Electrostatic Accelerators which will take place in December 2022 at iThemba LABS. The training will target the audience from facilities in Africa to address the lack of skills in operation and maintenance. This initiative is a crucial starting point on this collaboration which will have a huge impact on the field of particle accelerator in African continent.

12. Conclusions

The summary of the report of the Particle Physics group and related applications of ASFAP at ACP2021 is presented here. It would be great to profit from the momentum of the conference and carry on with the planned activities and submit more LOIs. It is essential to establish connections among the different African groups, and also synergies among the different working groups are also very important. Joint meetings/workshops and even liasions among the different groups are encouraged. In case there is no national-level Physics Society, the idea of appointing national contact points could be considered. If any institute or university wants to get involved in the experiments at CERN, please get in touch with the ASFAP Steering Commitee. CERN makes cooperation agreements with governments once there is a solid basis of scientific cooperation.

Acknowledgments

The author would like to thank the ACP2021 Organizing Committee and the ASFAP Steering Committee for their initiative.

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Assessment of Atomic and Molecular Physics in Africa

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We present the status of the research in the field of atomic and molecular physics in Africa as well as some challenges hindering the efforts being made by the African scientists. We further report the discussions and progress of the African Strategy for Fundamental and Applied Physics (ASFAP) working group on Atomic and Molecular physics with the view of providing the continent research direction for next decade.

Keywords: ASFAP, Atomic and Molecular Physics, Physics and Society

Recent advances in experimental and theoretical scanning probing methods at the atomic scale have led to tremendous applications in biology, medicine, electronics, quantum technologies, spintronics or heterogeneous catalysis. For example, insight into the structure of living cells, the single molecule transistor, the minute working of catalytic reactions allowing the rational design of catalysts and improvement of properties, just to cite a few. However, probing matter at the nanoscale on the African continent is still challenging, both theoretically and experimentally. This stems from the various limitations in research facilities.

Despite the population of about 1.3 billion, which are mainly youth, the research and development output of Africa is quite low in virtually all areas of physics. To quantitatively understand this abysmal performance, we analyse the amount of research articles published by African scientists (based in African institutions) from 2000 – 2021, see Figure 1. Over the last two decades, the total research output from Africa stands shy of 70,000 articles with about 6,000 per year in recent times. It will be interesting to know that these are comparable to the Brazil scientific research output over the same period. However, the dramatic rise of India over the same period clearly shows the need for understanding the problem facing African scientists. This graphical illustration could readily be linked to the poor economic performance of the Africa continent, the world's poorest inhabited continent according to the World Bank. This is basically demonstrated by the difficulty to access energy for community services (health, education and so on) as well as the lack/inadequate information and communication technologies among others [1]. Moreover, only Egypt and South Africa made it in the Top 40 of the world's research and development index in 2021 [2]. However, Africa Union Agenda 2063 has identified Physics – fundamental and applied as a key solution to address the developmental problems facing the continent [3].

(a)

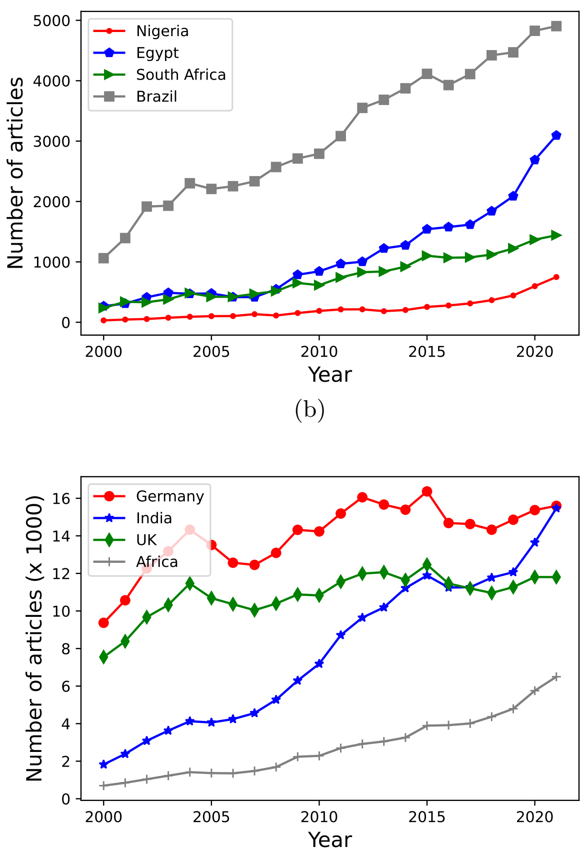

FIG. 1: Research output per year from 2000 – 2021 for search keywords: atoms, atomic, molecular, molecules, or ions. (a) The number of articles published by some African countries (Egypt, Nigeria, South Africa) compared to the Brazil. (b) The total articles published by African scientists (Algeria, Cameroon, Congo, Egypt, Ethiopia, Ghana, Kenya, Morocco, Nigeria, South Africa, Tunisia) compared western countries (Germany and UK) and India. Source: Scopus – accessed October 8, 2022.[6]

Challenges facing African scientists/physicists

On a theoretical point of view, electrical power instability in many countries does not allow sustainable computing and computational facilities are scarce, see Ref.[4] for more discussion. Most sub-saharan countries barely have supercomputers available for

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research. The few available facilities on the continent are concentrated in Northern Africa and South Africa. Researchers rely on the latter and on external partners such as the Abdus Salam International Centre for Theoretical Physics, Italy. A dependence that limits the productivity but also the size of the system to study simple molecules. Experimentally, resources are also scarce. For example, it is only recently that central Africa got its first operational AFM apparatus in what is likely the first nanotechnology laboratory in the Republic of Congo. Besides, the light source community is still to build the first synchrotron on the continent and relies on external sources and networks like the Synchrotron-Light for Experimental Science and Applications in the Middle East (SESAME) and the free and open-source software such as Large-scale Atomic/Molecular Massively Parallel Simulator (LAAMPS). Unfortunately, for Africa, international organizations often support research of their interest and are compounded by the government's ill-advised policies towards education.

Current support towards enhance research output

During the last decades, various research groups and networks have been active on the continent, thanks to some foreign collaborations/donors. These include Physics Department, Marien Ngouabi University (Brazzaville, Congo), CEPAMOQ (Douala, Cameroon), Lasers Atoms Laboratory, Cheikh Anta Diop University (Dakar, Senegal), Atomic Molecular Spectroscopy and Applications Laboratory, University of Tunis El Manar (Tunisia), Medical University of Southern Africa (South Africa), African Laser Atomic Molecular and Optical Science Network. In addition, there is growth in the study of materials sciences in Africa through the African School for Electronic Structure Methods and Applications (ASESMA).

As an extension of these efforts, African physicists from a variety of specializations are developing an African strategy for basic and applied physics, see https://africanphysicsstrategy.org/ [5]. Organized into several working groups, committees, and forums, they are working to produce a report to inform the African and broader community of strategic directions that can positively impact physics education and research over the next decade [7, 8].The report is intended to help African policy makers, educators, researchers, communities, and international partners prioritize resources and activities for physics education and research at the national, regional, and pan-African levels. As part of this group of African physicists, we have the task of coordinating the activities of the Atomic and Molecular Physics working group.

Atomic and molecular physics working group – journey so far and way forward

In the spirit of the ASFAP, the Atomic and Molecular Physics (AMP) working group aims at reporting on the state of research and knowledge transfer of these groups and their derivatives on the continental level but also on the various research carried by African scientists in AMP performed all over the world and that align to sustainable development goals. From the above-mentioned research groups and networks, we have identified and have traced the various African scientists still active in the field, their research interests and compiled their various achievements.

As part of this, we have successfully organised meetings and had an online workshop on Atomic and Molecular Physics in January 2022 during which the discussion is cantered on identifying challenges facing different research groups across the continent among others. These efforts, in conjunction with other ASFAP working group, have resulted in some letter of intents (LOIs) submitted for the strategies. In addition, after deliberation with the ASFAP Steering committee members and the Photonics and Optics working group during the second African Conference of Fundamental and Applied Physics ACP2021, there is a unilateral decision to merge the two working groups – *Atomic, Molecular and Optical Physics*. We believe that this will synergise interdisciplinary activities towards industrial and technological advancements.

To conclude, we advocate for physics-based policies in the various country, region and the continent at large. These will be geared towards development of human capital as well as engaging the private sectors for support. Finally, with the support of international collaborations, qualitative increase in the research output of Atomic, Molecular and Optical Physics in Africa will become a fruition.

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Status of the Computing for Research in Africa

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May 20st, 2022

Introduction

Research in any Science needs nowadays strong computing services to extract results and make discoveries.
What we define as computing service might rank from the underlying structure, namely networks, computers, storage, to applications and software but, as well, new techniques such as Artificial Intelligence to extract the expected results.

In order to estimate the overall needs in this field, we have launched a survey including all the people that we could reach, participants in ASFAP[1] as well as the attendants to the 2nd African Conference of Fundamental and Applied Physics ACP2021 that was held in mars 2022. Results of the survey can be found here[2].
In this paper we summarize the answers that were provided to the different questions of the survey and extract some general observations. Possible guidelines and recommendations to improve the situation are drawn in the conclusion.

1. Panel distribution

175 people filled in the survey out of which 167 were African citizens. 26 countries of the African continent were represented.
82% of the African citizens are based in Africa, the rest is what is defined as the diaspora, i.e., people that are based in other continents.
For the Non-African citizens, the motivation for participation was mainly an already established collaboration with African colleagues or students.
Figure 1 highlights the job situation of the participants: 48% are students and 39.4% hold a position in academia, research, engineering. More than 88% work in Africa, whether it is in their own country or in another African country. 10.9% reside out of Africa.

[1] ASFAP is the African Strategy for Fundamental and Applied physics: https://africanphysicsstrategy.org
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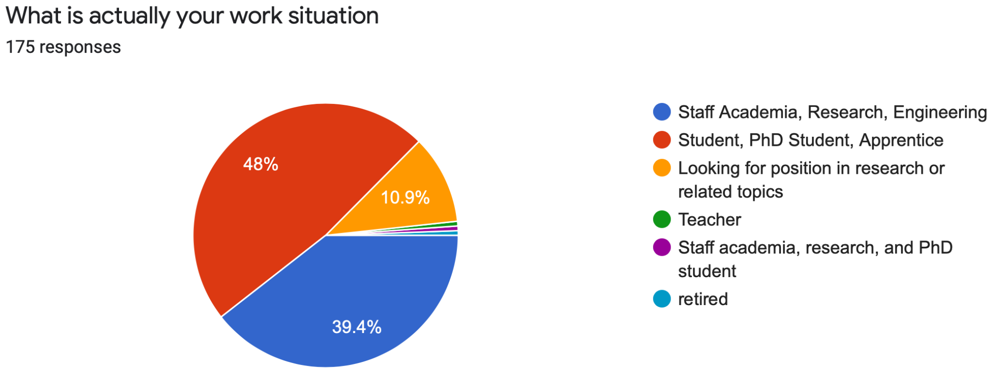
https://twiki.cern.ch/twiki/pub/AfricanStrategy/AfComputing4IR/ASFAP:_Comp4IR_Survey.pdf



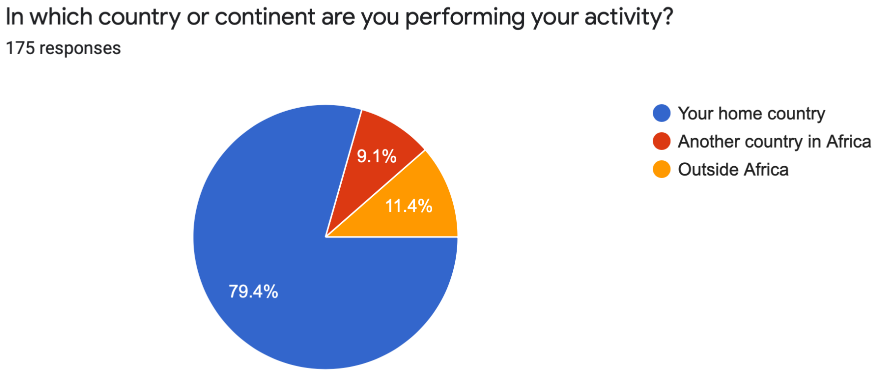


Figure 1: shows the work situation of the participants (top) and the location of the activity (bottom)

2. Field of Research

The field of research in which the participants are working is spread among many disciplines as shown in the figure below. The name of the fields is the name of the various working groups that are represented in the ASFAP. A large number of fields are concerned by the computing, fundamental physics such as Astrophysics and cosmology as well as physics domains such as the energy (biomass, fossil, nuclear and solar, etc.).

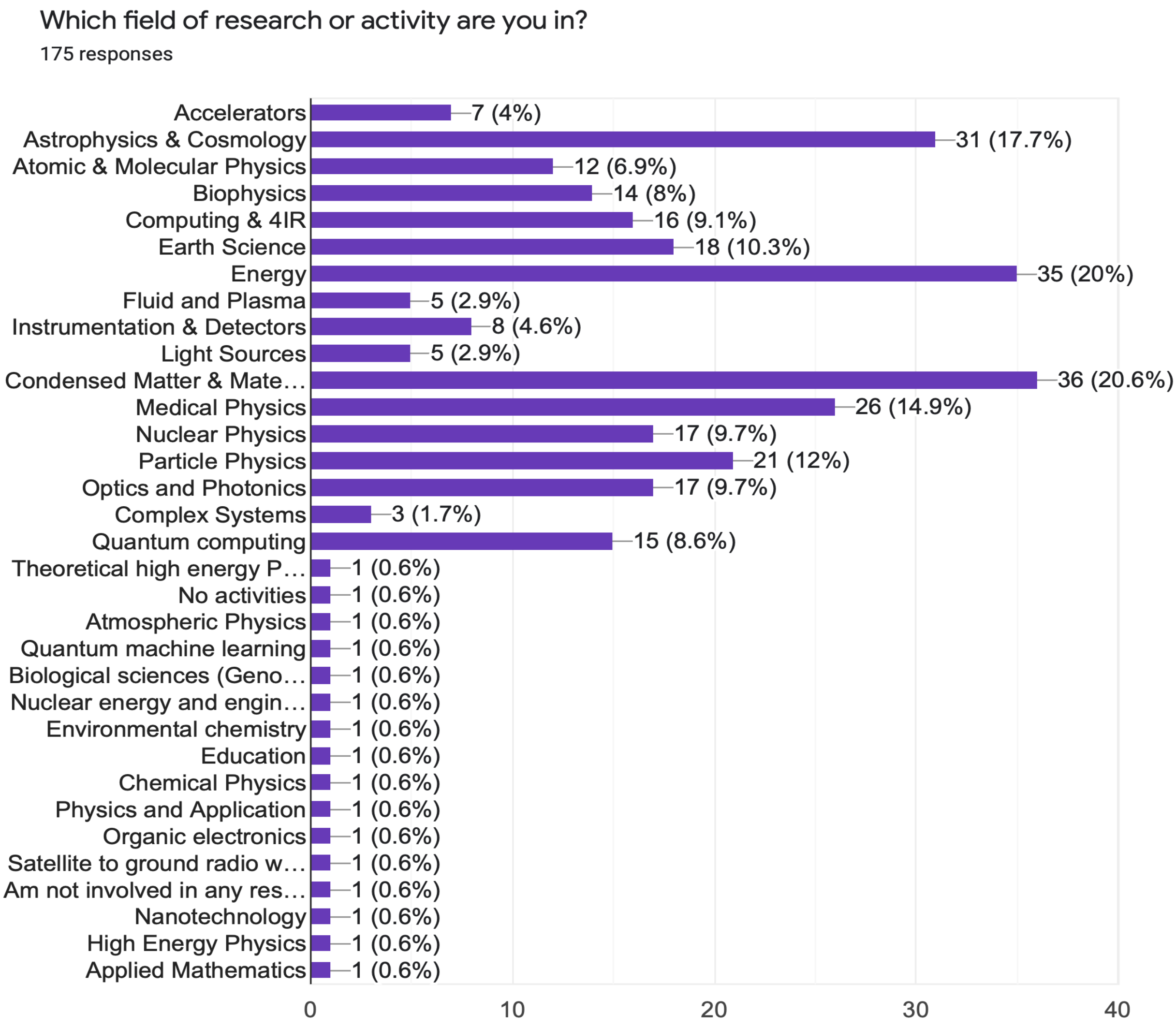


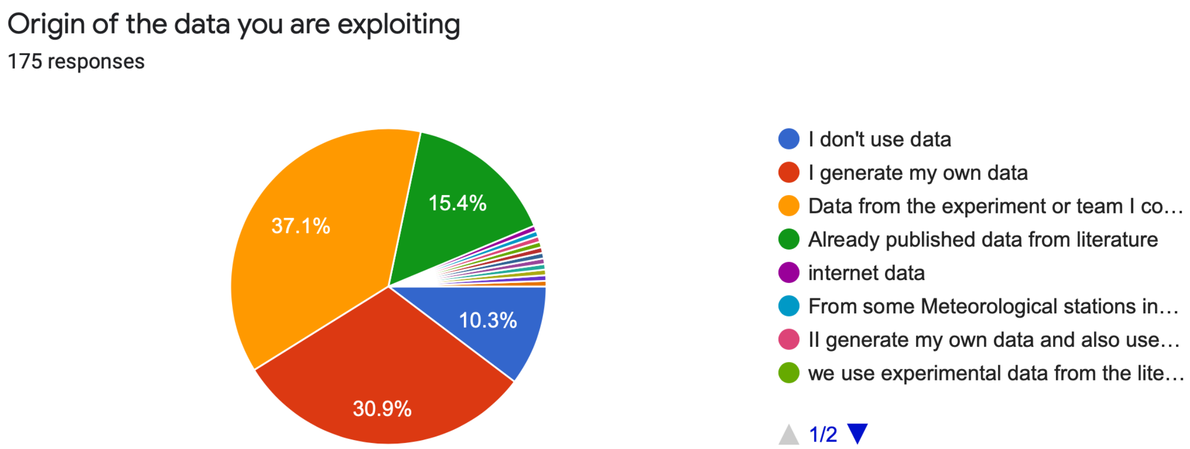
Figure 2: Field of Research covered by the participants

3. Properties of the exploited data sample

Depending on whether the scientist is part of a collaboration or working alone, the storage location and the volume of the data that he is analysing in order to extract results varies a lot. Figure 3 below shows the distribution and the magnitude of the sample.

- About 40% of the participants use data coming from an experiment or a collaboration they belong to, 15% use some open data from literature and about 35% use personal data. The numbers quoted here have been obtained summing up the numbers in the pie of fig 3 that fall in the same category.
- Considering the magnitude of the data samples, the majority of the samples are at the Gigabyte and Megabyte level. It is to be noted that the samples of Terabytes- and Petabytes-level are most of the time stored internationally.

- As to understand where the users are running their job to exploit the data, another graph not shown here shows that 57% of the scientists do it in their own laboratory or in their own country, while 20% do it internationally.



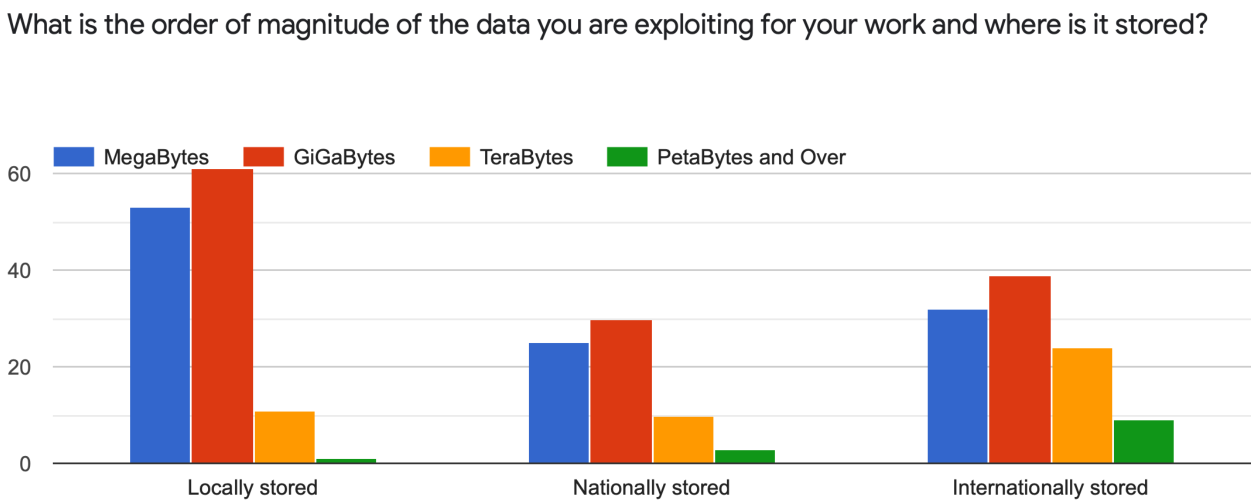


Figure 3: upper graph shows the origin of the data that is exploited. The lower graph the magnitude of the sample as a function of the storage location

4. Software and Tools to exploit data

Figure 4 below illustrate the type of software scientists are using:

- In the top graph of fig 4, we observe that 52.9% of the scientists use collaboration software and 48.4% use commercial software to exploit their data. Only 24.6% of them use exclusively their own software. It is important to note that 11.6% cannot use software because of lack of computing resources. Some comments collected below in this survey point out the fact that sometimes, the need is very modest (1 laptop for example) but even that is not available. Even if it has not been studied in this survey it might be worth investigating why even the modest requests are not satisfied.

- In the pie of the bottom graph of fig 4, usage of Artificial Intelligence (AI) or Deep Learning (DL) is represented. Already 20.9% of the scientists have introduced it in their toolbox. What is striking is that more than 73% of the scientists would like to use it but are prevented to do so either because they cannot find the information and/or training they need, or because they lack computing resources to execute it. This is important to keep in mind because of the growing importance of AI in many fields of sciences.

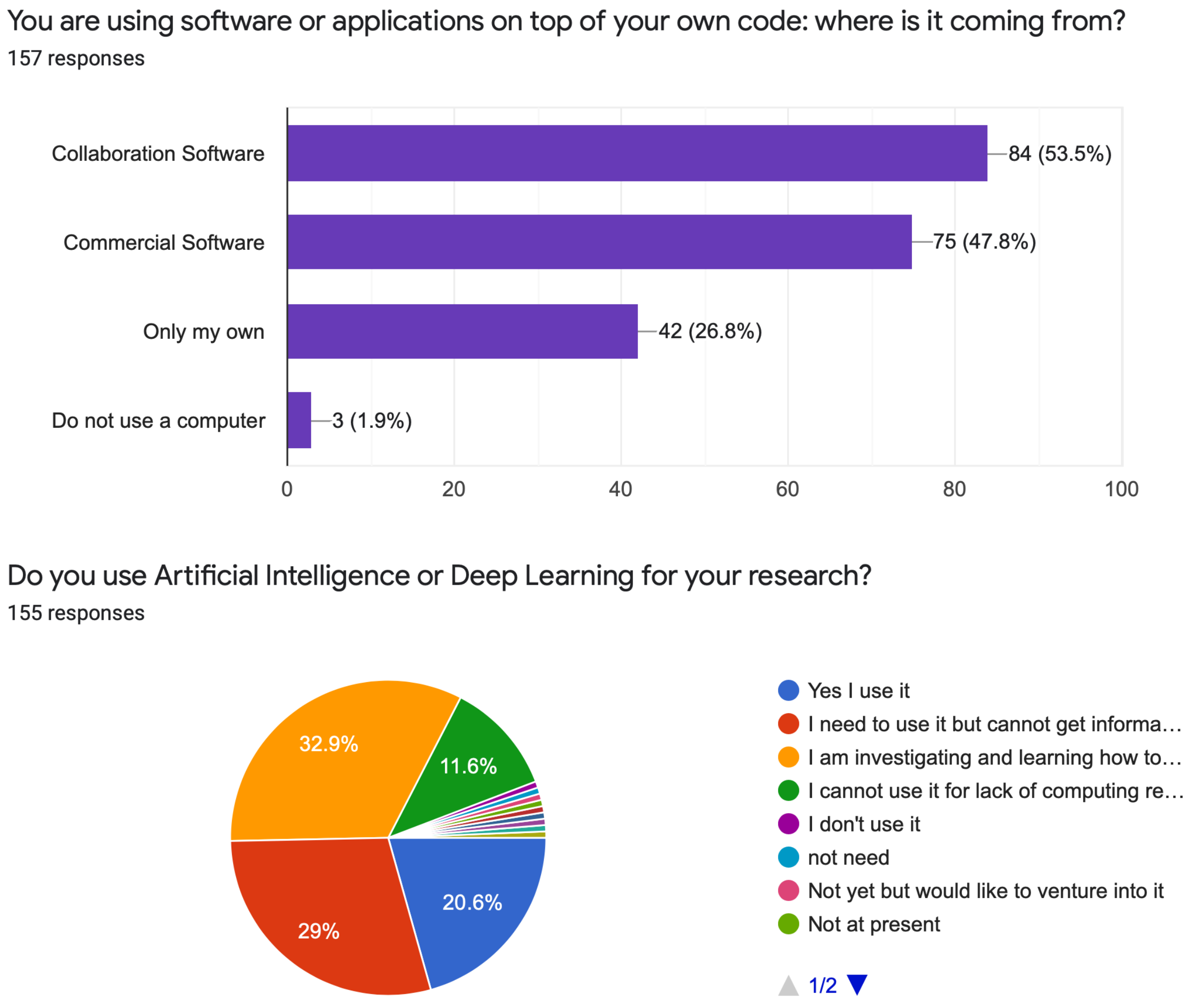


Figure 4: Top is distribution of the type of software that is used by the researchers. Bottom shows the usage of Artificial Intelligence or Deep Learning by the scientists.

5. Status of the infrastructure and tools

We have questioned the participants about the resources or knowledge that need to be provided in order to be able to use the magnifying effect of the computing to extract research results. They rated the different points in the figure 5:

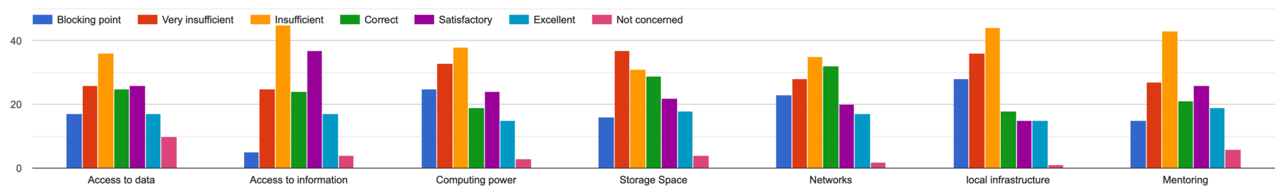


Figure 5: Main blocking or satisfactory points to be able to exploit data:

If we summarize the results they are as follows:

- **Access to data and access to information**: about half of the people experience blocking points leading to insufficient access to the data they need. This could be due to different reasons some of which could be equipment, networks or the fact that scientists feel isolated from the rest of their community.

- **Hardware resources, Computing power, Storage space and Networks**: 55 to 60% of the participant find it insufficient. When it comes specifically to local infrastructure, 66% of the people find it insufficient. The reason of the difference between the 2 percentage above is certainly that some people use international infrastructures that are more efficient: 20% of the people are based outside their home country and about 40% claim that they use resources abroad (see fig.1).
- **Mentoring:** training, guidance, lectures, etc..: 54% of the participants don't find it sufficient. This point will be detailed later.

6. Education and knowledge

Figure 6 below highlights one of the major problems of the education in sciences:

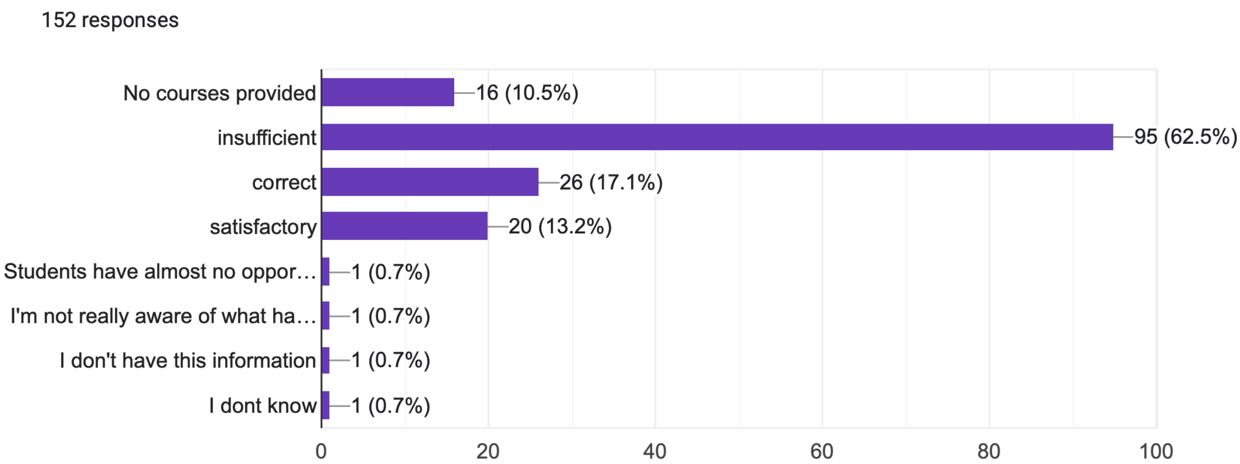


Figure 6: Rating of teaching and training provided to students during their cursus

75% of the participants claim they are provided no or insufficient level of courses or trainings during their cursus. This impacts not only the students themselves but it creates a generation of managers and scientists that are not made aware of the huge potential that computing can provide to their science field.

7. Bottlenecks

In Figure 7, we specifically question the users about the main bottlenecks there are facing when they want to use computing.

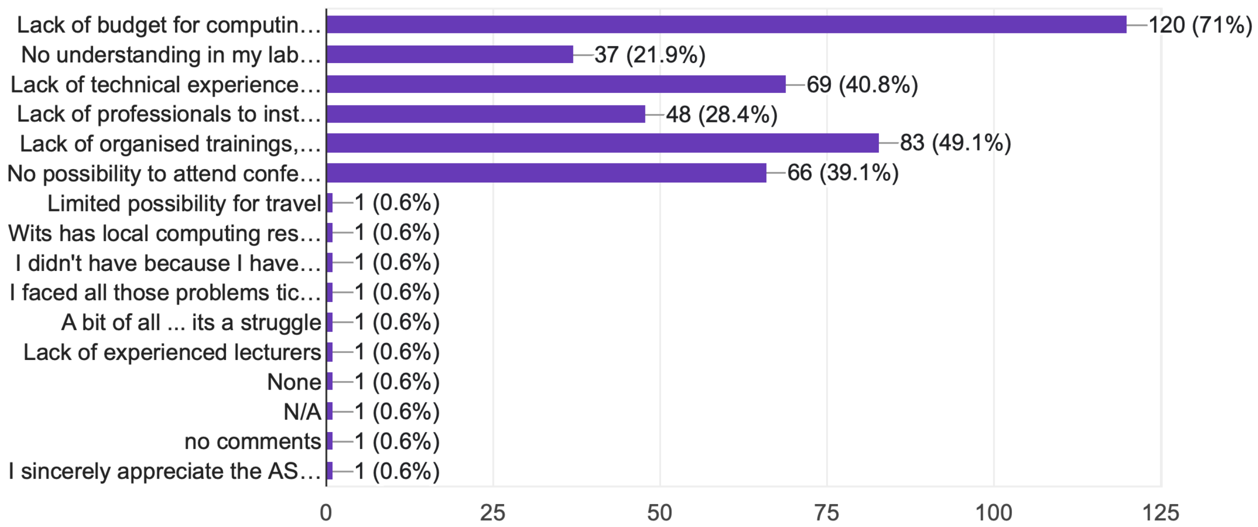


Figure 7: Problems faced by the scientists to perform their job

Two main group of answers:

- **Computing resources**: the largest number of responses stress the lack of budget for computing, the lack of technical support and the fact that the hierarchy and the stakeholders do not understand the need of computing for research: what would a scientist do with a computer when doing crystallography for example?
- **Education, knowledge**: the participants point out the lack of organised trainings and workshops and the difficulty to attend those organised abroad. More detailed information is found in the previous paragraph and fig 6 about the teaching and education in computing: 75% of the scientists are not provided courses and lectures, or at an insufficient level.

8. General comments from the survey

In the free comments asked for after some questions, the participants highlight and give precisions on the points raised above in particular about the resources: sometimes it is one computer that is

needed and not being provided. HPC resources are also cited, certainly due to the needs related to AI and DL.
Many others raise the problematic linked to lack of budget, lack of professionals to install and run data centres and difficulty to find collaborators or join collaborations to work in team.

Being asked what they would consider to improve research productivity in their country, the participants elaborated on isolation: scientists and engineers would gain a lot by working together and by having collaborations within African countries as well as with foreign countries.

9. Conclusion and recommendations

This survey was launched to evaluate the status of computing resources in the field of African physics research. The panel was mainly composed from participants from Africa and residing in Africa. Considering the answers, we draw the following guidelines to improve the situation and boost the scientific research in Africa:

- **Build and improve and the infrastructure**: the infrastructure should be made available and, if already existing, improved at a significant level.
    - **Network**: One essential part of the Computing situation is the access, availability and performance of the **Network**, i.e., Academic and Research Network, in Africa. Networks are vital for the access to data and information. This is not only true at the level of the universities and research centres, but even more at national and international level with connection to other countries. We need to have a global picture of the Network status in order to know the possible problems for the research groups and draw the strategy for improvement. Without filling this gap, there is no possibility of collaboration or share of knowledge. An African coordinated initiative would be a real asset.
    - **Storage and computing power** are necessary to store and process the data, which is the only way to produce results and science. The computing needed is more and more sophisticated now that Artificial Intelligence and Deep Learning have entered the game in all sciences. As suggested by some of the participants, large data centres shared within a country or with other countries within Africa would certainly be a solution that would federate the resources, decrease the costs and the disparities between universities and countries.
    - **Qualified technical staff** are necessary to deploy and run these computing resources and make them available to the physics research scientists that would not be able to deal with Cloud deployment or computer access to storage. Here a collaboration between different African countries and foreign countries could be a fruitful initiative to share IT technicians, setup few test sites, and start having an infrastructure on site.

- **Build Knowledge and include computing in Education**: The poll has highlighted the insufficient level of education in computing. Many solutions should be envisaged simultaneously:
  - Increasing the level of **computing courses** in the cursus of the physics (and other sciences) students.
  - Training **IT professionals** to prepare and operate the infrastructure.
  - Organising regular **workshops and training**. This would be highly beneficial for knowledge sharing and knowledge update to stay in the forefront in computing where evolution is very fast. But this would have an important positive side effect: Researchers have highlighted the fact that they quite often work isolated. These workshops are the best place to meet their peers and initiate collaborations that would only be beneficial to raise the research productivity.
  - Last but not least, **national and international collaboration** with others more advanced in these fields throughout the world would speed up the knowledge transfer and build collaborations that would be mutually beneficial.

> The top priority is raising the awareness of the governing bodies and stakeholders at each level: state, university, research centres, about the importance of the computing in physics research. This is absolutely necessary as this evolution needs strategic planning over years.
> Budget should be expressly dedicated to computing whether it is at the personal computer level as well as to the level of building and running large infrastructure.
> None of the main discoveries of the last decade would have been made possible without the collaborative work and the distributed use of powerful data centres all over the world.

10. Acknowledgments

I would like to thank all the participants that have taken some time to respond to the survey. My thanks go also to the organizers of 2021 ACP conference, to the ASFAP steering committee and to José Salt and Uli Raich for their comments and advice on this paper.
3

ASFAP impact towards the 1st African Light Source

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The concrete vision of having Africa as a leader sharing equivalent responsibilities and deliverables towards the global scientific societies turn out to be more obvious by time. Africa is not an exception when it comes to advanced science and technological grounds. Many challenges do exist and many others are still accumulating such as establishing cutting-edge large scale research infrastructures and institutions, reversing the brain-drain dramatic challenge, addressing local and/or regional concerns (health, environment, water, human heritage), as well as being a vehicle for industrial development and growing economy. In addition to bringing forward the African educational systems, employment status, besides the human capacity building which is alleged to be the backbone of any advanced society. Into the discussion, and besides their strong influence on education and advancing science and technology, as well as, capacity building development, are synchrotron light sources demonstrating the extensive capabilities with numerous techniques supporting a wide range of applications of basic science for instance physics, chemistry and biology, along with applied science aspects including life sciences such as biomedicine, pharmaceuticals and drug design, in addition to agriculture, environment, and air and water pollution, besides materials science and industrial applications, and energy and climate change. Furthermore, comprehensive insights can be identified and documented for cultural heritage and archaeology domains.

Keywords *ASFAP, Light Sources, African synchrotron, Capacity building, economic development*

To address the above multiple challenges and more, a huge demand in the implementation of such infrastructures is evidently viewed. For instance, based on several statistical figures, one of the most important aspects to be also tackled is the gender balance concern. Light sources have also shown to be effective in reducing such a gap as much as possible being an open and flexible environment that is based only on scientific merit and skills. In addition, synchrotron light sources proved to convey a valuable segment of diplomacy — that is based on scientific cooperation ceasing complications across borders. Through them, collaborations were made possible only using the neutral language of science. This in line, can encourage new partnerships on the national and international levels to address mutual demands of scientific and societal challenges, and education and economic development as well. One activity of the African School of Physics (ASP) is the African Conference on Fundamental and Applied Physics (ACP) with its first edition in 2018 at the University of Namibia in Windhoek. In this manuscript, a contribution on the light sources for capacity development and research in Africa that was presented during the second edition of ACP [1], organized on March 7-11, 2022, is reported here.

In an attempt to catch the fast evolving scientific and technical race of light sources around the world, African scientists – through collaborations, agreements and training fellowships – are also in a race with time to set up the first facility ever in the continent. In this contribution, the significant need of such facilities to the African continent – the only continent that is left exclusively without a single synchrotron light source is emphasized (Figure 1). Occasionally, establishing a synchrotron light source goes beyond the financial capacity or even a dedicated initial budget of a single country. Therefore, it represents a real bottleneck for the low economic standing position countries – which is the current case of most African countries. On the other hand, the condition can be also deteriorating as a direct influence by the human capacity deficiency, that yet again, signifies the necessity to reverse the brain-drain issue. Overall, synchrotron light facilities do operate in what can be considered as a democratic mode; that is by facilitating efficacious scientific cooperation to promote peace and understanding between people from different cultures, religions, races, and political systems (Herman Winick).

Figure 1: Distribution of synchrotron light sources around the world.

As a general reflection, diverse motivations do embody the aforementioned case, such as the next:

- establishing a world-class and applied research interdisciplinary research laboratories.
- Addressing the many local and regional concerns (for instance; human health, environment, materials and energy, cultural and human heritage, etc.).
- providing a vigorous environment for successful collaborations and allowing the essential space needed for individual career development.
- attracting African diasporas thus drawing back the brain-drain alarm and in the same time resolving the internal brain-drain to other sectors as well, this is the case as the majority may tend to target other fields rather than natural sciences or engineering where the remuneration for jobs in economy for example are much higher than for scientists and with many excellent young scientists choosing such more profitable careers.
- training and preparing graduate students who will no longer need to go abroad to industrialized countries, which implies a minimum of infrastructure and some interesting projects to take place and to be constantly developed in the home country and/or region.
- promoting development of high-tech industry (capacity building).
- decreasing the gender gap on every occasion proves possible.

The ASFAP (African Strategy for Fundamental and Applied Physics [2] basic objective is to develop capacity building in physics education and research. With no exception and as noteworthy as achievements are growing up for other regions, similar scientific and economic challenges persist to be addressed in African continent with the dream that Africa, too, should take its matching identity as a co-leader in the global scientific arena. With this, the requisite of having the ASFAP has turned out to be indispensable for Africa. One of the ASFAP working groups is dedicated to light sources establishment and development. A recent assessment survey launched by the ASFAP Light Sources Working group was released in February. The survey expected to gather a further considerate input from the African scientific community among others on the case of founding an African light source. The subsequent purpose of this questionnaire is to well prepare and establish collaborative research themes and angles. It also aims at preparing Letter of Intents for the Light Sources Working Group within the ASFAP. Herein, some assembled inspirations out of the survey are listed in the following sections.

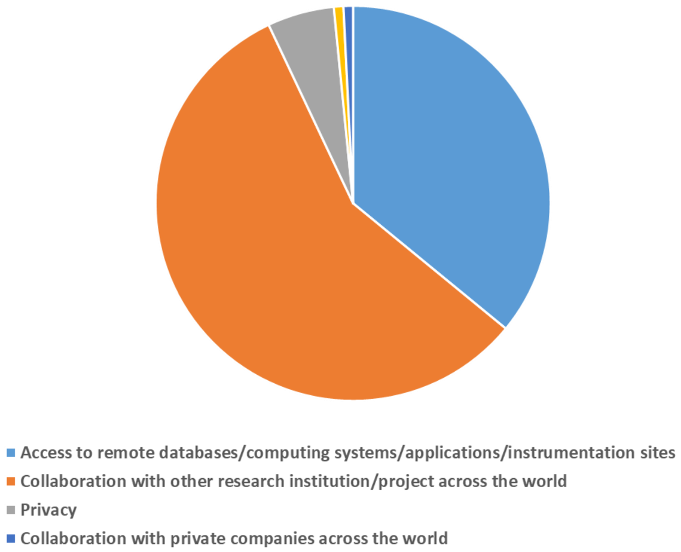


Figure 2: Chief research assisting requirements reported through the ASFAP survey on light sources.

77% of the survey's participants are resident citizens in African countries, while 26% are African diasporas. Participants from nineteen African countries (Nigeria, Morocco, Kenya, Cameron, Senegal, South Africa, Ethiopia, Tunisia, Uganda, Algeria, Ghana, Sudan, Egypt, Ivory Coast, Zambia, Mozambique, Togo, Congo, and Sierra Leon. Participants from 13 non-African countries have also contributed to the survey. Specifically, from USA, India, Pakistan, Italy, Germany, Jordan, UK, France, Malaysia, Peru, Canada, Japan, and Portugal.

Amongst the research interests and scientific activities those were favored by the respondents of the survey came on top the basic and/or applied science, followed by life sciences, materials sciences, cultural heritage and archaeology, accelerators' physics and technology, optical instrumentations, beamlines development, as well as experimental instrumentation and data analysis approaches. A thought-provoking input was also attained by the fact that 76% of the researchers and students opted for current and/or future synchrotron-related interests. Figure 3 shows the required synchrotron techniques, which again, confirms the necessity of establishing such a facility. Moreover, geographical distribution, collaborations with other research institutions, access to remote databases and software, as well as advanced instrumentation, were assigned as higher priorities for research chief requirements. 70% of those who participated showed a previous experience in light sources facilities, while 61% opted for a looked-for employment given the opportunity and depending on qualifications. Besides, 88% opted for their willingness to initiate interactions on different axes of collaboration and assistance with other African groups. 81% marked their need for advanced training regarding the general use of such available infrastructures, with a descending order of financial, technical, and scientific support.

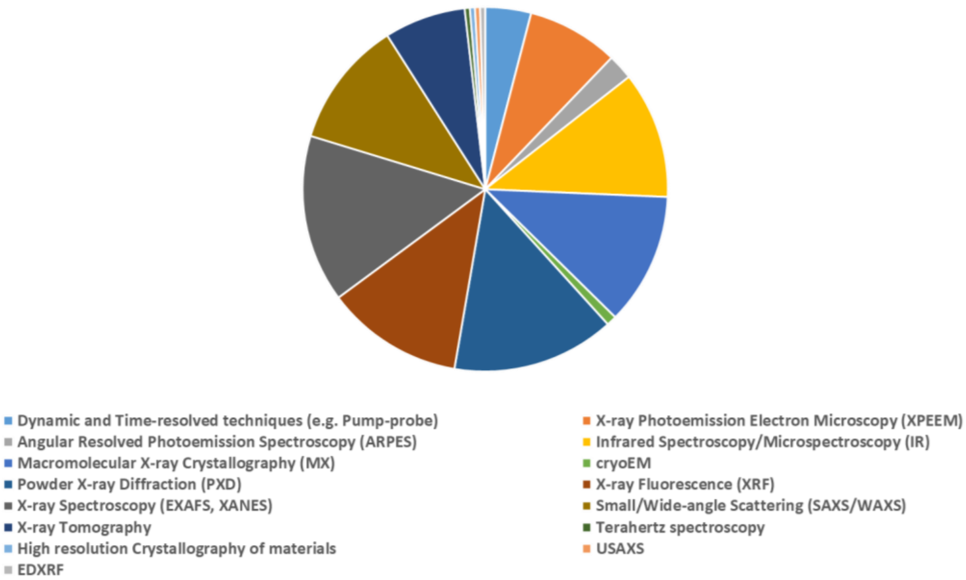


Figure 3: Favorable techniques reported through the ASFAP survey on light sources.

Tackling the expected scientific impacts of light sources have been also brought to the attention of the participants. Some detailed responses are provided subsequently:

- Human health and energy-related materials discovery and development.
- Transfer the know-how among the related counties, and bridging communities through collaborations.
- Profile for African Science, capacity building, local technology, local infrastructure, enhanced networks and participation in international collaborations, more innovation, African wealth.
- A light source facility will support many other research field, providing a framework for research and education centered in Africa. It will also draw the international community and boost the regional economy in providing jobs.
- To make sure that specific problems get attention and not have to depend on exogenous market and policy forces.
- Solving local problems with greater economic output, by means of light sources one can develop solutions and products to raise the balance of trade for Africa.
- Improving major scientific, educational and socio-economic and industrial advances.
- Diversification of the types of research questions posed, particularly in medicine, energy and materials. Escape from European fixation on batteries and fusion.
- With the abundance of mineral resources on the continent of Africa and the huge interest in crystallography, this is a great opportunity to explore our raw materials to create wealth for our people and also education on the interaction of matter with light which will help build the science base of our people.
- To foster scientific and technological excellence; prevent or reverse the brain drain by enabling world-class scientific research; build cultural bridges between diverse societies, as well as education and capacity building.
- Supporting the Pan-African initiative of Africa having its own scientific light source.
- Discovery of novel molecules capable of curing diseases and infections that affect the population.
- Increase number of publications in African countries
- Significant if one would like to keep pace with the global community.

- Light sources technology must be more available and cheaper for all geographical areas in Africa and the world as it provides cutting-edge tools for advancing almost any branch of science.
- Mastering our raw materials and transforming them to get out of poverty.
- Addressing of brain drain and societal issues; Promotion of knowledge base economies

For instance, the status of the human health in Africa represents a huge pillar of scientific research by African scientists and others. Many diseases are there to be investigated and treated. Figure 4 sheds some light on some of the targets to be explored.

There is no doubt that such global research infrastructures do have a strong impact on economy, food security, and disaster management. Moreover, 73% of the participants expected societal impact of light sources in the form of establishing a common culture of knowledge, competitive local industry, entrepreneurship, and capacity building.

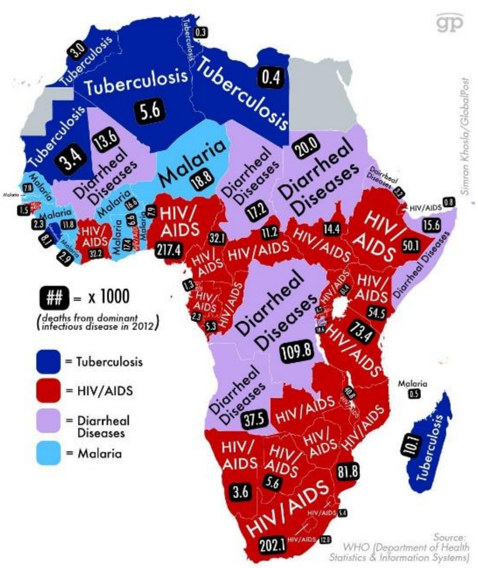


Figure 4: Human health examples of persistent diseases in the African continent.

The participants were also invited to provide their insights on what sort of changes are essential to allow better use of networking facilities. Some collected opinions were as following:

- Prepare short videos highlighting the scientific impact of using synchrotron facilities and addressing what kind of research could be conducted in such facilities. Also, it is important to outreach activities to undergraduate students.
- Scientists everywhere have challenges with stable funding, it is likely more acute in Africa than in the US, EU and Asia.
- Establishment of more local facilities with clustered partnerships (Intra-continental and extra-continental), and sharing equipment available in Africa cross the country and/or within the same through its different institutions.

- Dynamic collaborations to expose the underprivileged institutions.
- Bilateral agreements with African nations by major US and European agencies.

At the same level of importance, and as there is a clear need to have a research infrastructure in Africa specifically and African light source to cope with challenges that Africa is facing, it was also vital to gain some insights from the scientific community on how can African countries join forces to overcome the major challenges to establish its own light source. Below are some of them:

- To start with common infrastructures that can be shared among all communities.
- Cooperation in benchmarking degrees, visas, mobility and exchange funds.
- Involve local industry.
- Develop a concrete strategic vision for a light source facility - Engaging policymakers and the international community to support such a vision.
- In Africa, this might have to be done on region basis via the RECs. Each country, then each REC should develop a major science facility policy in general (as part of STI policies, respectively), and a light source policy in particular. Which can be then developing joint policies given other realities, e.g. transportation routes.
- With the African Union podium and other African institutions in promoting the light source in all African countries and regions.
- By instituting centers of excellence, sharing experiences, equipment and good team work.
- Invest in the science that drives light sources in the rest of the world, e.g. the study of proteins. Plus, showing the necessity of using the light source for research in Africa to solve our local problems such as malaria, famine and technological advancement.
- There must be intense educational system on the research capabilities of light sources and their importance to scientific revolution in Africa.
- Through scientific discoveries and common research activities to tackle preexisting problems and those raised by the side effects of technologies.
- Reach the Critical Mass. Ensure mobility, training, and enrollment of large multi-skilled young scientists through workshops and conferences and funding.
- Collaboration and joint funding to meet the expense of such a huge infrastructure to establish the first African Light Source. African governments can also provide joint funding that involves the private sector. Revenues from minerals and exports should be invested in a light source.
- Establishing better scientific masses within Africa than are groups/projects, much like the commercial and trade blocks that are already existing.
- Top-down and bottom-up organization. Grass roots support is very important. It would be hard to justify "from the top" without strong evidence of current or near-future demand. The multinational aspect of such a project should not be forgotten - it would be a great way for African nations to work closer together. Coming under the umbrella of a Pan-African society such as the AU or perhaps a regional one like SADC, ECOWAS, etc. is another depending on the eventual decisions made. Use the experience gained from SESAME light source on how they are reaching out to new Members to convince them to join.
- Establishment of a regional project, and networking with other light sources.
- Raising awareness among African Heads of State and the African Union on the need to implement their light source for controlled and therefore sustainable development.

Another inquiry of the survey targeted the major obstacles faced when attempting to pursue scientific research in a worldwide light source? Answers were given with the following order.

- Bureaucracy in the facility of destination.
- Lack of funding schemes (travel and mobility, project expenses, etc.).
- Lack of basic and/or preliminary research equipment in own country.
- Lack of mentoring.
- Lack of training opportunities to develop professional skills.
- Scientific merit-related needs.
- Bureaucracy in own country.
- Lack of dedicated manpower.

Based on the above-mentioned information provided within this simple statistical survey, it was also significant to retrieve some informative data on the prospect of the potential cross-disciplinary collaborations and links to light sources user-communities which may be achieved by create multi-folds' links with academia and industrial sectors, as well as, the basic interdisciplinary collaborations. Results showed the following crucial aspects:

- A light source facility can serve communities in various disciplines: materials physics, atomic and molecular physics, biophysics, optics and photonics, Pharmacognosy, etc.
- Materials and Energy systems, biomedical engineering, and plant molecules exploitation.
- Major advances in drug discovery and materials development - crystallographers work with chemists in the extraction and crystallization of potential drug molecules including different vaccine development.
- Agriculture where chemists will synthesize and crystallize fertilizers for crop production, and new techniques to be applied to new fields such as imaging for paleontology, archaeology etc.
- Development of new materials or characterization of newly discovered materials from mines.
- Advancement of society based on communication because it explores wanted field as per the situation.

Light sources are the best example of an open and multidisciplinary research infrastructure. They provide strong opportunities for integration through networking and cost-sharing, and promote multi-disciplinary collaboration with the wider global community, while promoting science diplomacy and peace at large. Moreover, environmental problems, advanced materials, cultural heritage valorization are all complex issue intrinsically involving cross-disciplinary collaboration.

References:

[1] Ketevi A. Assamagan, Obinna Abah, Amare Abebe, Stephen Avery, et al., Activity report of the Second African Conference on Fundamental and Applied Physics, ACP2021, arXiv:2204.01882 (2022). doi:https://doi:org/10:48550/arXiv:2204:01882.

[2] Ketevi A. Assamagan, Simon H. Connell, Farida Fassi, Fairouz Malek, Shaaban I. Khalil, et al., The African Strategy for Fundamental and Applied Physics, https: //africanphysicsstrategy:org/ (2021).

ASFAP (Medical Physics) Report

Key Achievements

- We held the Global Health Catalysts Summit at Johns Hopkins University in July. Part of the summit was dedicated to highlighting ASFAP to encourage LOI. Agenda of the meeting is attached.
- Leaders at FAMPO | Federation of African Medical Physics Organizations (Fampo-africa.org) attended the AAPM meeting this year. We discussed a model for building capacity which included accreditation of sites and certification of medical physicists.
- We have an invited talk at the First FAMPO meeting in November http://www.acmp2022.com/ . We will give (2) talks:
  - Global Oncology University (GO-U): a workforce model to build capacity in Africa
  - FAMPO-AAPM Partnership: ideas and suggestions for a strong collaboration
- African School of Physics will hold the school in person this year ASP2022-Poster-724x1024.png (724×1024) (africanschoolofphysics.org). We are organizing the lectures for the medical physics part of the school.
  - The next African School of Physics, ASP2022, is planned for November 28 – December 9, 2022 at Nelson Mandela University in Gqeberha, South Africa.
  - They expect about 90 students from all over Africa, 50 high school teachers from South Africa and 15-20 international lecturers.
  - We plan to announce the launch of the AAPM Global summer program (GLOBAL REACH) at the ASP2022. Overview of program is attached.
- We received a grant from the American Institute of Physics Venture fund to offer microgrants the LMICs. We awarded (6) microgrants this year.

Anticipated Focus Areas

- Continued development of the Global Oncology University to offer Certificate/Graduate/Residency programs – need to review requirements for accreditation. Discuss procedure for credentialing sites for in-country training.
  - Nigeria will serve as a pilot program for an International Certificate Program in Medical Physics – We plan to launch in February 2023.
- Opportunities to include VR education. We are exploring developing course content for immersive learning https://youtu.be/MyShfrXiu4g in medical physics. This is the future of global education/training.

Areas in progress

- We are exploring academic collaboration with Ghana to develop AI tools for medical physics as well develop a comprehensive cancer center. Overview attached.

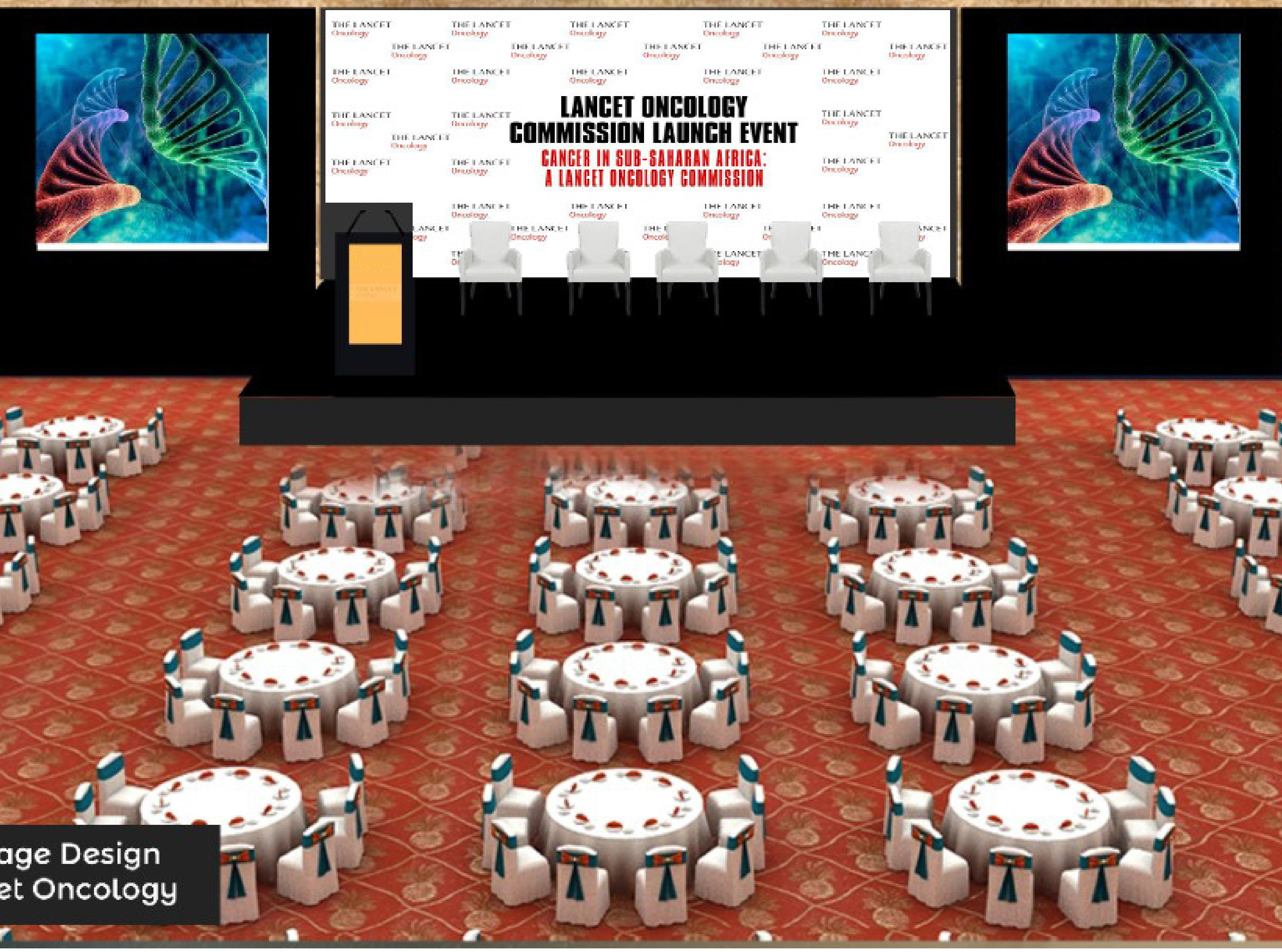
GLOBAL HEALTH CATALYST SUMMIT

GLOBAL HEALTH CATALYST SUMMIT

THE LANCET Oncology

JULY 7-9, 2022 @ JOHNS HOPKINS-SIBLEY MEMORIAL CONFERENCE CENTER 5255 LOUGHBORO RD NW, WASHINGTON, DC 20016 AND ONLINE CLICK HERE

THE CANCER MOONSHOT; COLLABORATING TO ADVANCE GLOBAL HEALTH & DEVELOPMENT



The yearly Global Health Catalyst Summits are focused on catalyzing collaborations to advance global health and development

Learn more at www.globalhealthcatalystsummit.org

PROGRAM OUTLINE

subject to change

JULY 7, 2022 — 8:30 am Est start

WELCOME AND OPENING REMARKS

Welcome by Johns Hopkins Administration:
- Carolyn Carpenter (President, National Capital Region, Johns Hopkins Health System
- Akila Viswanathan (Professor and Department Chair, Johns Hopkins University)

Remarks
- Glen Gaulton (Faculty Director, Center for Global Health, University of Pennsylvania)*
- James Metz (Professor and Chair, UPenn)*

Remarks by Global Health Catalyst Summit Directors:

9:00 AM: LANCET ONCOLOGY COMMISSION LAUNCH EVENT

Moderator: (Prof David Collingridge, Editor of Lancet Oncology)
- 9:00 am: Welcome Remarks (Collingridge)
- 9:15 am: Backdrop and Commission objectives (Ngwa)
- 9:25 am: Registration/Screening (Beatrice W.Addai)
- 9:35 am: Diagnosis/Prevention (Sulma Mohammed)
- 9:45 am: Treatment/Palliative Care (Avery/C Ntizimira)
- 9:55 am: Research (Rebbeck)
- 10:05 am: Workforce/Health Systems (Ngoma/Ndoh)
- 10:15 am: Calls to Action (R Anorlu, Elzawawy, O Brawley)

USA Launch of commission report with government leaders, dignitaries and Commissioners

10:30 AM: LANCET ONCOLOGY COMMISSION LAUNCH RESPONSE

Moderator: Wil Ngwa/Mel Foote
- Intro: Professor Ben Anderson, World Health Organization**
- Key Speaker: Dr Satish Gopal, Director of the NCI Center for Global Health (15 mins)
- Catharine Young, White House OSTP; Cancer Moonshot*
- Ambassador of USA to African Union*
- Ambassador of AU to USA
- Ambassador of Mozambique to USA
- Minister of Health of Ghana
- Minister of Health of Tanzania

12:00 PM: TIME FOR ACTION

Panel Discussion (Gopal, Ministers of Health, AU Ambassador to USA, Ambassador of Mozambique, W.Addai) (Moderated by Prof Tim Rebbeck)

1:00 PM

Lunch and meet the press moderated by Prof David Collingridge: (Ministers of Health, Gopal, W.Addai, Ngwa)

PROGRAM OUTLINE

subject to change

JULY 7, 2022

2:00 PM: CALL TO ACTION INDUSTRY/ORGANIZATIONS

Moderator: (Jennifer Dent, President of BVGH)

- 2:00 pm: Welcome remarks (Jennifer Dent)
- 2:05 pm: Key address: Chris Toth, (CEO of Varian)*
- 2:20 pm: Lacy Hubbard (President of Elekta Foundation)
- 2:30 pm May Abdel-Wahab (IAEA Rays of Hope)
- 2:40 pm Eric Broyles (NanoCan)
- 2:50 PM Josette Gbemudu, Executive Director, Health Equity, (Merck)
- 3:00 pm Dr Pierre R. Theodore, M.D., Vice-President Global Public Health, (Johnson & Johnson)**
- 3:05 pm: Michelle Erwee, Global Head of Access to Medicine (Takeda)**
- 3:10 pm Panel Discussion (Toth, Hubbard, Abdel-Wahab, Broyles, Gbemuda)

3:30 PM: CALL TO ACTION PROFESSIONAL SOCIETIES

Moderator: Prof Eduardo Cazap (President of SLACOM; Editor-in-chief of ecancer)/Prof Saiful Huq (University of Pittsburgh)

- 3:30 pm: Key Speaker: Jeff Michalski (President-elect of ASTRO)
- 3:50 pm: Rose Anorlu (President of AORTIC)
- 4:05 pm: Daniel Bourland (President of AAPM)
- 4:20 pm: Christopher Trauernicht (President of FAMPO)
- 4:35 pm: Julie R. Gralow (President of ASCO)**
- 4:40 pm Panel Discussion

6:00 PM: WELCOME AND AWARDS DINNER

- 6:00 pm Welcome by Akila Viswanathan (Dinner begins)
- 6:05 Pm: During Dinner Speech:
  - Application of Narrative Theory in Cancer by Rebkha Atnafou/Norma Kanarek (Johns Hopkins)
  - Martina Möllers, Project Manager. Global Health
  - Edith Moynihan: Dealing with Diabetes and Cancer (GHC)
- 6:30 pm. Keynote address: First Lady Ghana/Botswana
- 6:40 pm Why the Lancet Oncology commission report really matters?
  - Breast Care International and collaborators model: Beatrice Wiafe (BCI President); Mr George Ntim (Chairman BCI America), Ms Katerina Takovska of Direct Direct Relief)
  - Stories from cancer survivors
- 7:00 pm: Sikhona (Rev Vanessa Wilson)
- 7:10 pm: Awards and recognition/Celebration
  - Rose Anorlu (President of AORTIC)
  - Otis Brawley (Bloomberg Distinguished Professor @ Johns Hopkins)
  - Cures Within Reach (Improving patient quality and length of life by leveraging the speed, safety and cost-effectiveness of repurposing research)
  - Calvin Johnson (NFL Hall of Famer and Health Equity advocate)

PROGRAM OUTLINE

subject to change

JULY 8, 2022

8:30 AM: COLLABORATION INITIATIVES AND FUNDING OPPORTUNITIES

Global Oncology University Collaboration initiative

- 8:30 am: Welcome Remarks (Organizing partners)
- 8:45 am: Remarks: A Viswanathan (Chair/Director of CME @ JHU)
- 9:00 am: The GO-U Collaborative Education Model (Elzawawy, Kerr, Cazap, Ngoma, Avery, Mohammed, Baines)

- 9:30 am: HFRT (Hypofractionated Radiotherapy) Course
  - 9:30 am: Key Lecture: May Abdel-Wahab (IAEA)
  - 10:00 am: HFRT Talk: Mack Roach III (UCSF);
  - 10:30 am: Quality Management solutions: S Huq (UP)
  - 11:00 am: Official launch of HFRT Course and Q & A Panel

- 11:30 am: Launch of Education on Phytomedicines International Collaborative for global health (EPIC-Global) with Faculty from JHU, Upenn, Harvard, Imperial College, Oxford, MUHAS, Elpasso Farms and others)

12:00 PM: LUNCH, AND EXCITING NEW OPPORTUNITIES FOR COLLABORATION TO INCREASE ACCESS TO CARE

(Chairs: Prof Bashkim Ziberi (GHC, Macedonia); Dr Christian Ntizimira (GHC Rwanda), Dr Obeidat Salameh (Beth Israel/Harvard; GHC Jordan); Dr Sayeda Yasmin-Karim (BWH/Harvard; GHC Bangladesh)

- 12:00 PM Democratizing Proton Therapy (Thomas Bortfeld Harvard Medical School)
- 12:30 PM Bangladesh collaboration
  - Zunaid Ahmed Palak; Honorable Minister of State for Information and Communication Technology Division, Bangladesh
  - Dr. Nowreen Haq, Mr Mehdi Shams, Dr. Akhtar Mahmood (Kambaii Health collaboration)
- 1:00 PM Jordan collaboration
  - Laila Faruk Tutunji (Head of the Office of Medical Research School of Medicine - The University of Jordan)
  - Dr Obeidat Salameh (Beth Israel/Harvard)
  - H E Dina Kawar (Ambassador of the Hashemite Kingdom of Jordan to the United States of America)
- 1:30 PM Rwanda Collaboration
  - Remarks by H.E. Mathilde Mukantabana (Ambassador of Rwanda to USA)
  - Panel discussion moderated by Mel Foote (Panelists: Ambassador Mukantabana, Lacy Hubbard (President of Elekta Foundation), Martina Möllers (Project Manager. Global Health in Rwanda), and Dr Christian Ntizimira (Executive Director of ACREOL, Rwanda)

PROGRAM OUTLINE

subject to change

JULY 8, 2022

2:00 PM: GLOBAL RADIATION ONCOLOGY

Global Oncology University and other Education initiatives: Radiation oncology, Medical Physics, Education: (Moderators: Stephen Avery, Jatinder Palter)

- 2:00-2:12 African Strategy for Fundamental and Applied Physics – Ketevi Assamagan
- 2:15-2:27 Federation of African Medical Physics Organization – Chris Trauernicht
- 2:30-2:42 Senegal Project – How to become a IAEA Designated site- Paul Gueye
- 2:45-2:57 Ghana Medical Physics Program – Francis Hansford
- 3:00-3:25 Collaboration Panel Discussion

3:30 PM: GLOBAL RADIATION ONCOLOGY

Global Health in Radiation Oncology (VR and Technology) Moderator: Michael LaRiviere (UPenn)

- 3:30-3:42 HeizenRader Creative – Cory Heizenrader https://heizenrader.com/our-platform/
- 3:45-3:57 Vertual – Andy Beavis andy@vertual.co.uk
- 4:00-4:12 Treatment Planning AI tools – Laurence Court LeCourt@mdanderson.org
- 4:15-4:27 Virtual education tools for Radiotherapy - Taoran Li
- 4:30-4:42 Virtual education tools for Brachytherapy - Neil Taunk
- 4:45-5:30 Collaboration Panel Discussion

6:00 PM: NETWORKING AND COMMUNITY OUTREACH COLLABORATION EVENING

6:00 PM Developing and Expanding Academic-Church Health Models

- 6:00 PM: Dr. Richard Wender (Executive Director of the Center for Public Health Initiatives)
- 6:05 PM: Kevin Mahoney (CEO, UPenn Health System)
- 6:10 PM: Donald Moore (Pastor of Mount Carmel Baptist Church)
- 6:20 PM: Vanessa Wilson (Pastor of Good Shepherd)
- 6:30 PM: Stan Straughter (Chairman, African and Caribbean Business Council of Greater Philadelphia)
- 6:40 PM: Curtiland Deville (Associate Professor, Johns Hopkins)
- 6:50 PM Discussion

- 7:00 PM: Janet Okang (Phd Student, Drew University)
- 7:10 PM Rebkha Atnafou, MPH (Johns Hopkins)
- 7:20 PM Lydell Lettsome, MD (Founder and director of Vanbert Health)
- 7:30 PM Sharon Williams, DLitt (Drew University Caspersen School of Graduate Studies)
- 7:40 PM Discussion

PROGRAM OUTLINE

subject to change

JULY 9, 2022

8:30 AM: COLLABORATION INITIATIVES AND FUNDING OPPORTUNITIES IN RESEARCH

Moderator (Dr Curtiland Deville, Clinical Director of Radiation Oncology at Sibley Memorial Hospital, Associate Professor at the Johns Hopkins University School of Medicine)

- 8;30 am: Africa-Oxford-Harvard-Hopkins Clinical Trials network; (David Kerr (Professor, Oxford University); Ahmed Elzawawy (Professor of Clinical Oncology, Chair of the GHC win-win initiative)

- 9:00 am: HypoAfrica trial: and collaborations to develop an IROC Africa
  - 9:00 am: Prof Twalib Ngoma (MUHAS Tanzania), Dr Adedayo Joseph (NSIA-LUTH Cancer Center Nigeria), Dr Abba Mallum (Albert Inkosi Albert Luthuli Central Hospital. South Africa),
  - 9:30 am: Dr Heng LI (Associate Professor, Johns Hopkins; Jumaa Bin Dachi (Head Medical Physicist, Ocean Road Cancer Institute); Dr. Adeneye Samuel (Head Medical Physicist, NSIA-LUTH Cancer Center); Dr Thokozani Mkhize (Albert Inkosi Albert Luthuli Central Hospital. South Africa)
  - 10:00 am: Growing Collaborations
    - Katy Graef (Vice-President Bioventures for Global Health)
    - Nwamaka Lasebikan (President of ARCON, Nigeria),

- 10:30 am: International Phytomedicines Institute research collaboration and funding initiative speakers/panelists: (Moderator: Dr Brylyne Chitsunge, CEO Elpasso Farms, Pan African Ambassador)
  - 10:30 am: Dr Brylyne Chistsunge)
  - 10:40 am: Hall of Famer Calvin Johnson (Primitiv)
  - 10:50 am Dr Ngeh Tonya (Flavocure Biotech)
  - 11:00 am Prof Gary Strichartz, Harvard Medical School**
  - 11:10 am Dr Simon Erridge (Imperial College London)
  - 11:20 am Dr Sandra Carrillo (University of Panama)
  - 11:30am: Important voices (videos)
  - 11:40 am: Panel discussion (Collaborations on medical cannabis research and funding)

PROGRAM OUTLINE

subject to change

JULY 9, 2022

12:00 PM: LUNCH, AND EXCITING NEW OPPORTUNITIES FOR COLLABORATION

Moderators (Dr L Asana (GHC), Dr Elsy Ngwa (Harvard))

- 12:00 PM: Keynote Address on Health Information Technology and AI by Cupid Chan (PISTEVO) and Harry Quon (Johns Hopkins)
- 12:25– 1pm – GHC – ICTU Collaboration – student project proposals
- 1:00 – 1:30pm – GHC – USF Collaborations – student projects
- 1:30 - 2:00 – GHC Young Catalyst Projects

2:00 PM: YOUNG GLOBAL HEALTH CATALYST SESSION

Moderators (Drs Lindy Davidson, L Asana)

- 2pm – Introduction of session
- 2:05 – 2:30 Youth Engagement Collaborations
- 2:30– 3:10 Nonprofit Collaborations
- 3:10 – 3:55pm Research & Innovation Collaborations
- 4:00 pm: Other Presentations (Chin, Möllers, Ziberi)

4:45 PM: CLOSING CEREMONY AND TOUR

- Closing remarks; announcements on collaborations/funding
- Tour of facilities (limited) and Washington DC Nite Out

Project: AAPM Undergraduate **Global REACH** (Research Education And Career coacHing) Program

Executive Sponsor AAPM Board	**Sponsors** AAPM Education Council AAPM International Council
Lead Stephen Avery (GMPETC) Parminder Basran (SUFP) Ketevi Assamagan (ASP)	**Team** AAPM - Undergraduate Summer Fellowship and Outreach Subcommittee (SUFP) AAPM - Global Medical Physics Education and Training Committee (GMPETC) African School of Physics (ASP)

Project description:
Building on the successes of the SUFP and Dream programs within the AAPM, and the strong interest of the AAPM in expanding its role in global education, training and mentorship by way of the International Council and the Global Medical Physics Education and Training Committee, we propose to provide a new opportunity for undergraduate students in LMICs to participate in a virtual undergraduate medical physics training program – AAPM Undergraduate Global Reach Program.

The goal of this project is to provide an opportunity for promising 2nd and 3rd year undergraduate physics or engineering students in a LMIC to participate in a global summer undergraduate fellowship under the supervision of an AAPM member. Through partnership with the African School of Physics, we aim to pilot this proposal with 4 undergraduate students in an African LMIC. The model for the fellowship will be adopted from the currently successful AAPM SUFP and DREAM programs with provisions for supporting a global fellowship.

Objective:
The objectives of this project are to:

- Provide a 10 week paid undergraduate fellowship for 4 undergraduate students enrolled in a university within a LMIC as defined by the African School of Physics.
    - Students will be mentored by an AAPM mentor in good standing, located in a HIC, ideally close to where the current AAPM ASM will be held.
    - Eligibility criteria for fellows
        - Each student applicant shall have completed at least 2 years of their undergraduate studies, but shall not have graduated, i.e. rank of junior or senior.
        - Students with graduation date in the year they partake in the fellowship are not eligible.
        - Applicants shall have declared a major or be eligible to declare a major in physics, engineering, or other science, which requires mathematics at least through differential equations, modern physics/quantum mechanics, electricity and magnetism or equivalent courses in engineering sciences.
        - Promising students will be identified in partnership with the African School of Physics

        - The AAPM Undergraduate Global REACH Fellows are restricted to those in an LMIC defined by the African School of Physics, and with no direct ties to an existing university that has a medical physics program, and thus provide opportunity for recruiting medical physicists into the profession.
        - Complete application form on AAPM website, similar to form used by SUFP/DREAM
    - Eligibility criteria for mentors
        - Hosting institution must be within driving distance to the current AAPM ASM
        - Complete application form for mentorship on AAPM website, similar to form used by SUFP/DREAM
        - Project must be able to be completed virtually
- Student projects will be virtual in nature using the schema for virtual fellowships established by SUFP, with an opportunity for travel to the hosting institute and the AAPM ASM for up to 3 weeks
    - Students will be matched with a AAPM mentor, who will reside within driving distance of the current AAPM ASM
    - Mentors must assist the fellow in securing
        - VISA and travel visitation documentation and sponsor the fellow
        - Short-term accommodation for the duration of the visit
        - Travel to and from the AAPM ASM, ideally with another student or mentor to reduce costs
        - Accommodations at the AAPM ASM, ideally with another student or mentor to reduce costs
- Fellows will be required to participate in the summer fellowship with additional responsibilities including
    - 1-page written report to the AAPM Undergraduate Global REACH program, African School of Physics, and host institution
    - Participation in post-fellowship research presentations, in combination with the AAPM SUFP and DREAM programs, typically held in late August

Major Deliverables:
Deliverables of this project include:
- 10-week global fellowship opportunity for students from LMICs
- Travel to and from hosting institution and attend AAPM Annual meeting
- Increase knowledge of medical physics profession in LMICs
- Partner with the African School of School to create pipeline program in medical physics
- Contribute to the African Physics Strategy as a long term goal to building capacity

Budget:
- Global REACH Fellowship awards are currently budgeted at $1500 per student, provided by the hosting institution to the fellow. This rate is consistent with the standard of living in African countries. (source Cost of Living (numbeo.com))
- In addition, a travel bursary of $2500 will be awarded to the fellow. Fellows must pay for transportation in advance, provide receipts. Included costs
    - Documentation, travel visas
    - Air travel

    - Per-diem during travel to and from host
    - Local travel to and from AAPM ASM
- Student registration dues for the conference, to be paid by the program: $350
- Total budget
    - Fellowship award: 4 x 1500 = 6000
    - Travel bursary: 4 x 2500 = 10000
    - ASM Registration: 4 x 350 = 1400
    - Certificate of completion 4 x 25 = 100
    - TOTAL Requested: $17,500

High level Timelines:

- December 2022
    - Conference Meeting with African School of Physics
    - Open applications for fellowship & mentors
- February 2023
    - Close applications
    - Select and match fellows and mentors
- May 2023 – August 2023
    - Participate in Fellowship
    - Early July – travel to host institution
    - July 23-27 AAPM ASM (Houston TX)
    - Mid-late July – travel back to LMIC
    - August -complete fellowship
- Late August
    - Presentation with SUFP / DREAM fellows
    - Submit summary report to AAPM and African School of Physics

"One-stop" Comprehensive Cancer Center of Excellence in Ghana

Overall goal: The overall goal of this project is to establish a premier Comprehensive Cancer Center of excellence in Ghana providing world class care with support from leading USA institutions and other partners. The comprehensive cancer center will have four CORE (Care, Outreach, Research, and Education) components. In Care, the Peace & Love Hospital ("PLH") in Ghana which treats nearly 8,000 women each year will be extended to offer top clinical services across the cancer control continuum from prevention through treatment and palliative care bolstered by telehealth and artificial intelligence (AI) with international partners. The Outreach component will support continuous engagement, including with policy makers, communities and other stakeholders for continuous growth and greater impact. Meanwhile, the Research component will support next-generation multicenter clinical trials, and other research and innovation. The Education component will leverage the award-winning collaborative global oncology university platform to provide continuous education, and high-quality capacity building. The Center is envisioned as a real life Wakanda healthcare, providing a state of the art "ONE STOP" facility in the heart of Ghana, with satellite centers creating a well-rounded center of oncological healthcare that will set a new standard for cancer care in West Africa. The mission is to give African cancer patients access to the most advanced forms of cancer treatment, incorporating chemotherapy, radiotherapy, surgery and immunotherapy options in order to create a genuine bastion for cancer care on the African Continent.

Background: In Africa, urgent action is needed to curb a growing emergency in cancer incidence and mortality. Without rapid interventions, a new *Lancet Oncology commission* report[1] and other studies estimate an almost doubling in cancer mortality from 2020 to about 1 million deaths per year by 2030, with prostate, breast, and cervical cancers being the most lethal. Factors limiting access to treatment include a dearth in infrastructure e.g. only 22 countries out of 54 have megavoltage radiotherapy equipment, with most radiotherapy machines concentrated in the southern and northern extremes of the continent. Vast Majority of Cancer Centers have Staff shortages. In Ghana, with a population of 30 million, there are only 3 radiotherapy machines or 1 per 10 million people; only 1 nurse for every 1,500 Ghanaians, 1 doctor for every 20,000 Ghanaians, 24,000 diagnosed cancer cases per year, with cancer being the 4th leading cause of deaths in Ghana. There is urgent need to establish a comprehensive cancer center of excellence in West Africa that can address these needs. Meanwhile, a stunning 2020 report[2] by the American Association for Cancer Research shows that African Americans, who share similarities in genetic profile with Africans, face some of the same barriers limiting access to treatment, resulting in major disparities, e.g., in double prostate cancer death rates compared to every other racial/ethnic group in the USA. The Center of Excellence with links to USA institutions will provide a platform for facilitating high-impact USA-Africa collaborations to address disparities, building on Ghana's 'Year of Return" and diaspora engagement, with services as a top medical tourism hub in Africa.

Approach: Funding is needed to support the 4 cores of the Center beginning with infrastructure and human capacity. PLH is already renowned for surgical oncology services and some chemotherapy services. A major addition will be a new Radiotherapy facility equipped with a state-of-the-art linear accelerators and capacity to delivery high quality radiotherapy services. PLH will also collaborate with industry partners to bring immunotherapy options. PLH already has 52 acres of land to this project.

Funding opportunities (see separate attachment) to consider including in collaboration with leading USA institutions Hopkins, Upenn and Harvard include.

- USAID
- DOD
- NIH
- Foundations
- Funding raising events in the USA

Report of Nuclear Working Group

Meeting to discuss the ASFAP Nuclear Physics Letters of Interest (LOIs) was held on the 6th of July 2022 (Online). Below are the points raised during the meeting:

NUPHAPHA-Nuclear Photonics Accelerated Physics for Africa

Kalambuka Angeyo (University of Nairobi, Kenya) presented the LOI on Nuclear Photonics using pulse lasers and novel sources based on African Union Agenda 2023. He further explained that similar facilities mostly in advanced developmental stage are taking place at ELI-NP in Bucharest Romania, MEGaRay at Lawrence Livermore USA, Nuclotron Based Ion Collider Facility NICA at Dubna Russia. Paving way out on how best African countries can benefited from this technology, suggestion was made that this initiative can be coordinated through African Laser Centre and iThemba LABS in South Africa.

The use of Am-Be neutron source for teaching and applied research

Sunday Jonah (Ahmadu Bello University, Nigeria) presented on the use of Am-Be neutron source for Physics education teaching, training and applied nuclear research purposes. He mentioned that similar set-up have been developed at Ghana Atomic Energy Commission (GAEC) through the financial supports from IAEA. Emphasis was placed that other African countries can benefited from this project through ASFAP education organising committee. There was a question raised by Mark on the actual cost implication and technical requirements for installation of this equipment at other African countries. This will include shielding, safety aspects as well as security of sources. The actual cost implication will be provided by Sunday Jonah and sent to the Nuclear Physics Committee. In terms of running expenses, there will be available training of technician through seminars and workshop to be organised via the IAEA regional training courses. In terms of communication and outreach, there was a suggestion that the committee should develop pamphlets for distribution to other African countries who might be interested in setting up similar training facility in their institutions regionally within the country.

Unique Research Facilities at the SSC Laboratory in South Africa

Iyabo Usman (University of the Witwatersrand, South Africa) presented on the updates about the South African Isotope Facility (SAIF) project taking place at iThemba LABS. New IBA cyclotron has been brought to complement the SSC and dedicate to the medical isotope production at iThemba LABS, Cape Town South Africa. Also, on the nuclear education and training activities, SAINTS program have been implemented whereby several training activities for undergraduate and postgraduate students are been organised. This includes training workshops on radiation protection, accelerators, radiation biophysics, nuclear metrology, detectors and GEANT4 simulations. More information on future workshops will be announced through ASFAP for participation by students from other African countries.

Challenges:

One of the attendee pointed out about challenges in accessing Am-Be training facilities in the northern part of Nigeria, and suggested if regional facility of the same kind can be implemented due to a very large geographical area of the country. Sunday Jonah and Moji Usikalu will prepare a proposal for six regional centres in Nigeria.

Another challenge is the funding to set-up this training facility in African countries. A suggestion about approaching IAEA funding through AFRA technical cooperation research as alternative source of funding can be implemented vi National Liaison Officers of each member states in Africa.

Finally, challenges of getting more members signing up for the ASFAP Nuclear Physics group was mentioned in the discussion. Conveners and committee members should develop a strategic way to get more researchers involved. This can be achieved through nominating country representatives into the ASFAP Nuclear Physics working group.

Present at the meeting are:

Mark Dalton (ASFAP Nuclear Physics Convener)

Moji Usikalu

Kalambuka Angeyo

Sunday Jonah

Ketevi Assamagan

Iyabo Usman

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High Energy Physics activities in Africa: An overview

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Abstract

This document summarises our best knowledge of the ongoing High Energy Physics activities in Africa. The information was primarily extracted from the first ASFAP Particle Physics day organised on November 2021 and on our working group talk presented at ACP 2021 conference on March 2022.

Keywords: High Energy Physics, ASFAP.

1. Introduction

High Energy Physics (HEP) reveals the profound connections underlying all observed phenomena, ranging from the smallest to the largest structures in our Universe. Everything in our universe is found to be made from elementary particles, as a few basic matter blocks, governed by four fundamental interactions. Our best knowledge of how these particles interact is encoded in the Standard Model of particle physics (SM). The SM developed in the seventies has become an established and well tested theory. This document is divided in two section, the first one focuses on theoretical HEP physics while the second one is dedicated to experimental particle physics in Africa. For each field, the activities are reported per country by alphabetical order. If an important activity had been forgotten please contact the authors. To contribute in a significant way to the development of HEP in Africa, we believe that we should focus on maintaining leadership of the organization of HEP education programs in some targeted institutes, with involvement of African governments and policy makers. To this end, ASFAP has dedicated a working group to Particle Physics with the aim to build an African network, support and expand the activities in this field, and ultimately prepare a road map based on collected letter of intents proposed by particle physics community. The list provided in Table 1 is a tentative summary of the current (as of 2022) involvements of African countries in particle physics experiments.

2. Overview on Theoretical physics in Africa

In July 2012, ATLAS and CMS experiments at LHC have announced the discovery of a scalar particle, later identified as a Higgs boson, the last missing piece of the Standard

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Model [1, 2]. However, despite its success, there are still many fundamental questions awaiting a clear answer, which require the construction of new theoretical models, beyond the SM, which is then treated as effective theory of a more fundamental description. Among unsolved problems and experimental data that cannot be explained by the SM , we can cite: the neutrino mass generation, pattern of fermions hierarchy, and dark matter/energy. possible extensions of the SM This means that we have to look at alternatives beyond Standard Model (BSM) that could solve those issues and could be tested at the LHC and future colliders. So far, many theoretical proposals are on the shelves: The most attractive one are BSM Models involving Higgs fields with higher representation: more doublet, more singlet, doublet and triplet,..

Several African groups have strong expertise in phenomenology of the beyond the Standard Model Physics. Theses groups have gained footholds in dealing with multi-Higgs models with an emphasis on the symmetries of the scalar sector and Dark Matter candidates arising from these models.

The Egyptian team, from the Center for Fundamental Physics (CFP) at Zewail City Research areas, is specialist in many high energy theory topics including: Susy phenomenology, early Universe and astro-Particle Physics (selected references [3]).

The Moroccan groups, from Cadi Ayyad and Abdelmalek Saadi Universities, have relevant expertise in phenomenological studies in BSM physics including non-minimal Higgs models and supersymmetric scenarios with a particular focus on Higgs phyics , theoretical and EW precision constraints on scalar sectors in various extensions of the SM, including their implementation in high energy physics tools (selected references [4]).

The East African Institute for Fundamental Research (EAIFR), at the University of Rwanda has research interest in fundamental physics with a focus on collider physics, physics beyond the Standard Model, cosmic inflation, Dark Matter and Dark Energy. EAIFR has produced significant papers on the impact of additional Higgs bosons on signal rates and study of possible deviations from the SM (selected references [5]).

The South African HEP groups are strongly involved in development of BSM phenomenology and analysis of the data collected by the ATLAS experiment at the LHC. They are mainly affiliated to U. Witwaters, Johansburg U. and iThemba LABS (selected references [6]).

At last, a team from Madagascar is specialist of non perturbative methods in strong interactions. More precisely, they use QCD sum rules to predict hadron properties, such as masses and coupling constants(selected references [7]).

3. Experimental physics

The Large Hadron Collider is the largest and most powerful collider in the world. It is located at CERN between Switzerland and France. The first proton beams started to circulate in 2008. Four major experiments, ATLAS, CMS, LHCb and ALICE are located across the ring. A sketch of ATLAS and CMS can be found in Figure 1. Their purpose is complementary and aims at understanding the behaviour of fundamental particles and their interactions. An upgrade of the LHC, HL-LHC, is foreseen in 2025. After a successful period of data taking (Run1/2) the detectors are being upgraded in many phases. A detailed list of the associated institutes can be found in Table 1. The information collected in this

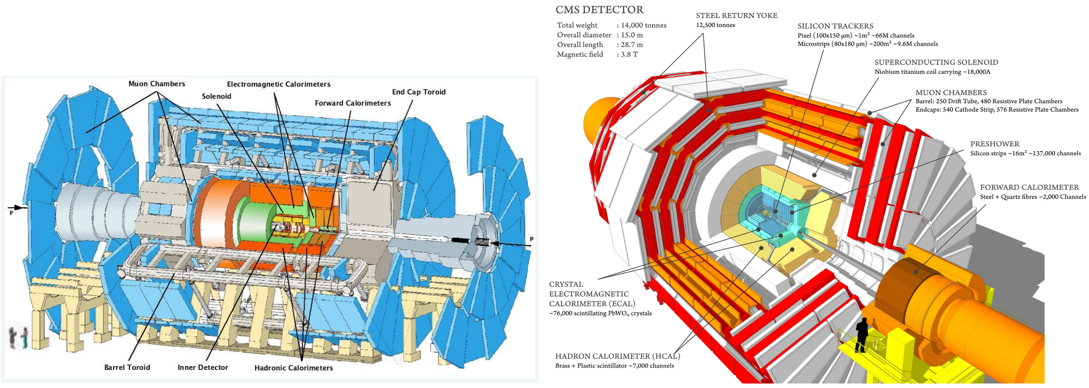

Figure 1: ATLAS (left) and CMS(right) detectors.

document is based on the material that was presented at the First ASFAP Particle Physics Day.

3.1. Algeria

A computing group contributes to ATLAS to face future computing challenges during the HL-LHC upgrade. This body of work consists of two projects porting of ATLAS software to parallel architectures and monitoring of conditions database access.

3.2. Egypt

The cluster of groups contributes to the CMS experiment. On the physics analyses side, Beyond Standard Model searches have been or are being conducted. For instance a Z' search, Kaluza Klien excitation from Extra-dimensions, and also Dark matter searches signatures combined with mono-Z mono-Higgs or mono-Z' topologies. On the detector side the groups are involved in developments of the Resistive Plate Chamber (RPC) as well as Gas Electron Multiplier (GEM).

3.3. Madagascar

DUNE is an international flagship experiment to unlock the mysteries of neutrinos. The group contributed to the Near Detector Conceptual design report and to the SAND-System for on-Axis Neutrino Detection.

3.4. Morocco

ATLAS:. In 1996, Morocco signed an agreement with CERN and became the first African member of the ATLAS collaboration. The RUPHE, a Moroccan cluster of several HEP groups, works currently on HL-LHC, High Granularity Timing Detector (HGTD). Two axes are pursued on the b-tagging and performance optimisation. For the first axis, there are ongoing studies are based on the Generic Boosted Decision Tree and self-tagging. For the latter the aim is improvement the jet energy resolution in the forward region and use of particle-flow reconstruction and HGTD impact. The assembly of HGTD modedules locally coordinated by MAScIR. The groups contributed team beam campaigns to finalise the choice of Low Gain Avalanche Detector (LGAD). On the analyses side the following topics have been investigated: Search for a BSM resonance in the top quark sector, search for Invisible Higgs, Search for Hidden Higgs or dark Sector, search for charged Higgs in $H^+ \to tb$ channel, diboson resonances in semi-leptonic final states Z', Kaluza Klein and Dihiggs HH resonant and non-resonant production : $bb\ell\ell$ and $bbVV$ channels

ANTARES/KM3Net. KM3NeT, the legitimate successor of ANTARES, is a new research nfrastructure consisting of a network of deep-sea neutrino telescopes in the Mediterranean Sea. The main objectives of the KM3NeT1 Collaboration are: i) the discovery and subsequent observation of high- energy neutrino sources in the Universe and ii) the determination of the mass hierarchy of neutrinos (MHN). These objectives are strongly motivated by two recent important discoveries, namely: The high- energy astrophysical neutrino signal reported by IceCube, and the sizeable contribution of electron neutrinos to the third neutrino mass eigenstate as reported by Daya Bay, Reno and others. To meet these objectives, KM3NeT is building two detectors ORCA and ARCA. Morocco has signed an agreement to join KM3NeT collaboration in 2017. So far three universities (Mohammed V U., Cadi Ayyad U., and Mohammed 1 U.), currently full members of the collaboration, are actively participating in the production line of optical modules in a national site located in Rabat. Besides, the Moroccan team is also involved in the physics analysis of many topics, essentially related to search for magnetic monopoles, search for nuclearites, and study of the neutrino mass hierarchy [8].

3.5. South Africa

There are multiple South African experimental HEP research groups active in both the ALICE and ATLAS experiments.

ALICE. The group contributes to upgrade projects towards a common read out unit for the muon identifier, the Low-Voltage System for muon tracking, and online data processing for the Transition Radiation Detector. Given the travel restrictions, the possibility to work operate the systems remotely has been utilised. The ALICE experiment explores the outcomes of heavy ion collision, the group worked on W and Z boson tests of the Standard Model via the study of the cross-sections in lead-lead and proton-lead collisions.

ATLAS. On the hardware side the following activities are ongoing:

- Silicon detector developments on both the SCT and ITk system including, data acquisition electronics development, evaporative cooling systems, material description in simulation, firmware and test QC for EoS redout cards, polymoderator design, procurement, and fabrication.
- Muon New Small Wheel work including, material description in simulation, manufacturing and assembly of components and installation tools as well as commissioning.
- ATLAS Local Trigger Interface boards were installed in the TTC crates of LBA, LBC, EBA, EBC and the Laser crate.
- Assembly, quality checks and installation of the gap scintillator counters on the ATLAS detector

- Phase-II upgrade of the Tile Calorimeter, 50% of the production of the Low Voltage Power Supplies (LVPS), 24% of the production of the Tile Preprocessor (PPr).
- Participation to ATLAS TileCal November 2021 Test-beam.
- CFD simulations for temperature and humidity distributions inside the detector ITk volume.
- Operation of the TDAQ SysAdmin and Network, Muon ConfigDB in the Control Room
- Detector Lab – Micro-Megas NSW.

On the physics analyses side, the following analyses are or have been pursued:

- Top quark mass measurement utilising leptonic J/ψ decays.
- Higgs boson production in association with a W/Z boson, with the Higgs decaying to two bottom quarks.
- New Physics searches via the study of top electro-weak couplings in rare processes (ttW, tWZ)
- Boosted Heavy Neutrino Search.
- Dark and semi-visible jets: unusual signatures emanating from strongly interacting dark sector.
- Anatomy of the multi-lepton anomalies.
- The Higgs Portal to the Dark and or Hidden sector for example $H \to Z_d Z_d \to 4e, 4\mu, 2e2\mu$, $H \to \gamma\gamma_d$

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Experiment	Institution	Country
ANTARES	Faculté des Sciences, Université Mohammed 1, Oujda	Morocco
ANTARES	Faculté des Sciences, Université Mohammed V, Rabat	Morocco
ANTARES	Faculté des Sciences Semlalia, Université Cadi Ayyad, Marrakech	Morocco
KM3Net	Faculté des Sciences Semlalia, Université Cadi Ayyad, Marrakech	Morocco
KM3NeT	Faculté des Sciences, Université Mohammed 1, Oujda	Morocco
KM3Net	Faculté des Sciences, Université Mohammed V, Rabat	Morocco
KM3Net	Universities of Johannesburg/Witwatersrand/North-West	South Africa
DUNE	The University of Antananarivo	Madagascar
ATLAS Morocco Cluster	Faculté des Sciences Ain Chock, Université Hassan II, Casablanca	Morocco
	Faculté des Sciences, Université Ibn-Tofail, Kénitra	Morocco
	LPHEA, Faculté des Sciences Semlalia, Université Cadi Ayyad, Marrakech	Morocco
	LPMR, Faculté des Sciences, Université Mohamed Premier, Oujda	Morocco
	Faculté des sciences, Université Mohammed V, Rabat	Morocco
	Mohammed VI Polytechnic University, Ben Guerir	Morocco
ATLAS South Africa Cluster	Department of Physics, University of Cape Town, Cape Town	South Africa
	Department of Mechanical Engineering Science, University of Johannesburg	South Africa
	University of South Africa, Department of Physics, Pretoria	South Africa
	iThemba Labs, Western Cape	South Africa
	University of South Africa, Department of Physics, Pretoria	South Africa
	University of Zululand, KwaDlangezwa	South Africa
	School of Physics, University of the Witwatersrand, Johannesburg	South Africa
ATLAS Technical Associate Institute	Ecole Nationale Supérieure d'Informatique (ESI)	Algeria
CMS	Academy of Scientific Research and Technology, Cairo	Egypt
CMS	Center for High Energy Physics (CHEP-FU), Fayoum University, El-Fayoum	Egypt
ALICE	iThemba LABS, Universities of Cape Town/Witwatersrand	South Africa

Table 1: Overview of ongoing High Energy Physics activities and institutions in Africa.

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ASFAP Working Group Summary of Societal Engagements

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[b] *University of Johannesburg, South Africa*
[c] *Université Alioune Diop, Senegal*
[d] *Brookhaven National Laboratory, USA*
[e] *University of Rwanda, Rwanda*
[f] *CERN, Switzerland*
[g] *University of Constantine-1 & CERIST, Algeria*
[h] *University of Zambia, Zambia*
[i] *NASRDA, Nigeria*

Abstract

The second African Conference of Fundamental and Applied Physics (ACP2021) took place in the week of March 7–11, 2022. During this conference, all the African Strategy for Fundamental and Applied Physics (ASFAP) working groups had been reserved specials sessions to discuss their scope, activities (past & current) and topics of common interests. The aim of this report is to summarize the discussion of the ASFAP working groups in societal engagements, namely Physics Education, Community Engagement, Young Physicists and Women in Physics. The recommendations for future activities in societal engagements are summarised in the report as well.

Keywords: The African Strategy for Fundamental and Applied Physics, ASFAP, Physics Education, Community Engagement, Young Physicists, Women in Physics

1. Introduction

The ACP2021 [1, 2] was held virtually, with over six hundred and fifty registered participants, five hundred and sixty-three of whom came from thirty-three African countries. The overall program, presentations and recordings are available at [2].

The compilation of the ASFAP working group summary of societal engagements is based on discussions and working meetings from the societal engagements community. All major societal engagement projects in ASFAP have been included in this report and have been categorized as follows:

- Societal Engagements: Status & Plan;

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- Discussion on Societal Engagements.

2. Societal Engagements: Status & Plan

ASFAP contains four working groups devoted to societal engagements. Our task was twofold: to discuss the focus and scope of the working groups in societal engagements; and either identify topics of common interest or topics that are cross-cutting among various societal engagement working groups.

2.1. Physics Education

Research in fundamental and applied physics needs to be supported by a strong and effective physics education to train the next generation of physicists. The objective of the Physics Education (Phys Ed) [3] working group is to identify where improvements are needed and propose improved methods to prepare and deliver physics instructions or lessons.

As part of the ASFAP process, the Phys Ed working group held workshops, carried out discussions regarding participation and attitudes toward physics education and outreach. Targeted workshops include physics education discussion: at the university level [4, 5], with the Francophone countries [6] and with the engagement working groups [7]. The Phys Ed working group received a number of letter of interests (LOIs) [8] that will be used to form white-paper study groups for the ASFAP strategy.

The Phys Ed working group developed its goals, strategies and recommendations from physicists and education input and outreach professionals obtained prior to and during the ACP2021 meeting. The recommendations support a proactive, coordinated Phys Ed working group effort from the entire ASFAP community. The following are recommendations from previous meetings, conferences and workshops:

Recommendation 1: Increase investment in infrastructure and equipment.
For Africa to adequately leverage its potential for developing physics education and outreach, a coordinated effort between African countries is needed to ensure that a sustained stream of investment is directed.

Recommendation 2: Improve the quality of teachings through the training of teachers and a strong focus on applications and technologies.
Less theory oriented curricula and more practicals and experimental physics are needed if we want to train good skilled physicists and engineers in African countries.

Recommendation 3: Pan-African association of physics teachers and lecturers
We propose to establish a Pan-African association of physics teachers and lecturers. Science societies in Africa should be strongly encouraged to commemorate continental scientific events.

2.2. Community Engagement

Community Engagement (CE) [9] working group consists of several sub-groups, namely physics communication and outreach; technology transfer; Internet connectivity/ start-up resources, applications and industry; e-lab & e-learning; business development and entrepreneurism; public education and outreach, diversity, inclusion and equity; government engagement and public policy; and career pipelines & development, retention and capacity development. The objective of CE working group is to draw a broader engagement and participation in the development of the African strategy, address issues of physics education and intra-African—national, regional and pan-African—collaborations on education and research.

The CE working group held five pre-meetings in order to discuss the scope and different topics proposed by the group. February 2021, CE held a workshop with other societal engagement working groups [10]. At this workshop, discussions led to ideas for future collaborations between CE and other societal engagement working groups. The CE working group has proposed a series of topics in conjunction with other societal engagement working groups. Among them:

- Physics and Environmental Pollution:
  How can we use physics to resolve the problem of environmental pollution and raise awareness of the local community on environmental pollution? This would include: recycling methods for plastics, waste burning, special collection programs for pharmaceutical waste, education & awareness campaigns.

- Public Outreach & Education:
  This will create awareness and broaden the community's understanding of physics. It would include a survey on the views of physics teachers in Africa, periodic training of physics teachers, annual fairs to introduce the public and in particular the children to the fun of physics. It would also include virtual physics laboratories sessions and campus visits for high school children. Virtual Physics laboratories: for those schools where there is no access to laboratories (+ internet access): classroom demonstrations for teachers and students and physics Olympiads.

- Astronomy in the service of physics:
  Astronomy is that discipline which can fire up people's imagination, and hook them to science. It may at the same time play the role of an appetizer for the other sciences in addition to being a fundamental science by itself. Indeed, the Cosmos being after all the largest laboratory in the World. Astronomy could be seen as generalized physics, unless physics (the study of the matter) wishes to reclaim it to itself and considers it as part of it! In this case, physicists will have to get their act together as far as their connection to astronomy.

2.3. Young Physicists Forum

Young Physicists Forum (YPF) [11] was established to engage rising-star physicists to gather, study and debate the major issues in their research careers. As a guideline, YPF roughly defines young physicist as students, postdocs, engineers, technicians, faculty, etc., up to ∼10 years post-highest degree. The main objectives of the YPF are among others, to create a diverse continent of next-generation physicists to play an active role in collaborations pertaining to scientific research and educational issues in Africa.

Since launching YPF in 2021, the forum has played an active role in identifying the challenges and remedies for young physicists to flourish in various physics fields. To this effect, the forum has so far conducted several virtual meetings to share the knowledge. January 2022 [12], the forum invited stakeholders to discuss some of the challenges and opportunities for young African physicists. The workshop brought together young physicist researchers and feature panelists, drawing more than one hundred and forty registered participants from all over Africa. During presentations and panel discussion, physicists detailed the challenges facing young African physicists; highlighted existing solutions; and brainstormed new strategies for research and policy.

Physicists Data Collection: ASFAP— Young Physicists Forum Survey

The ASFAP— Young Physicists Forum survey [13] was originally intended to run for five and a half months (from July 15 until December 31, 2021), however, the deadline was extended to December 31, 2022 to allow further feedback from the community. Results from two of the questions are presented below.

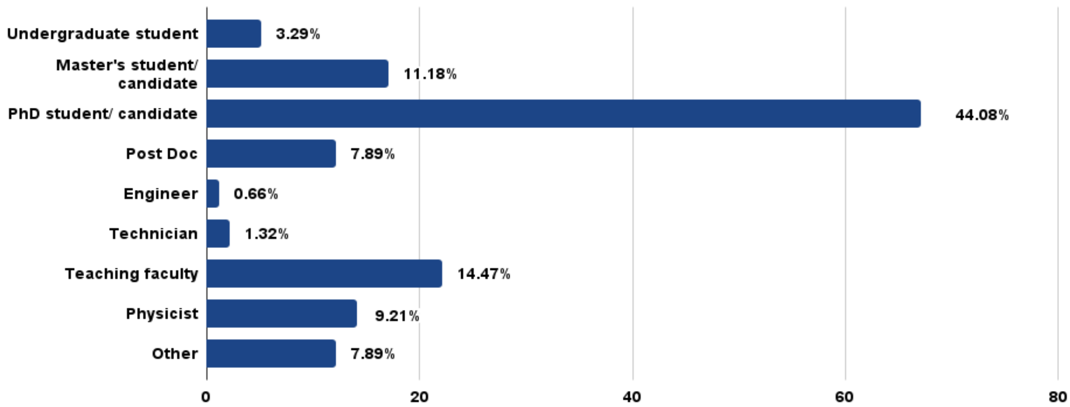

Figure 1: Current position of the respondents.

Figure 1 shows that majority of the survey respondents are PhD students or candidates (44.08%), followed by teaching faculty members (14.47%) and Master's students or candidates (11.18%).

The results in Figure 2 show that general lack of research funding and funding for equipment identified by two-thirds of our respondents as the biggest challenges. Challenges related to human capacity building and professional development (lack of training opportunities; lack of mobility and lack of mentoring and support) were subsequently

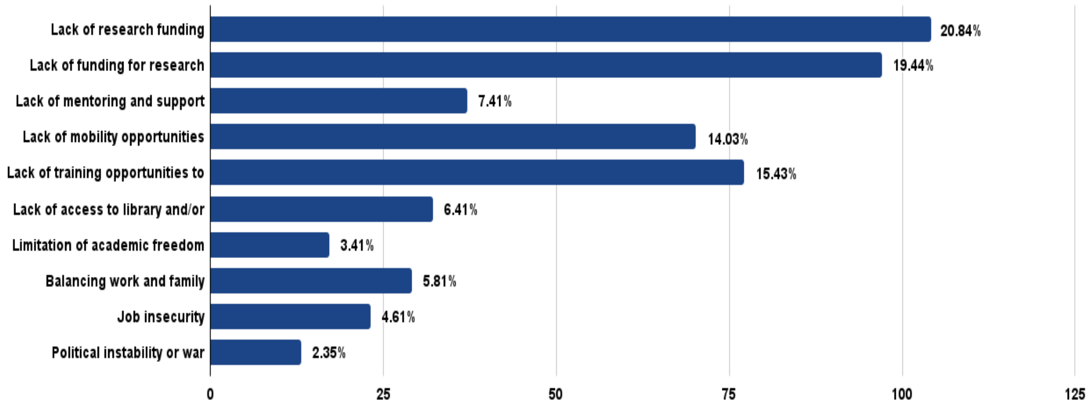

Figure 2: Respondents' perceptions of the impact of 10 challenges on their careers.

listed as the third largest challenges by most of our respondents and, importantly, especially by the young physicists. Therefore the need to develop digit libraries supported by efficient Internet connectivity at low costs to African researchers. The fifth largest challenge (balancing work and family demands) speaks to time demands. Interestingly, 'job insecurity' received the lowest rating. Political and social factors (lack of academic freedom and political instability) was also not listed as a major challenge– probably because most of our respondents are already in permanent academic or research positions.

The YPF has received a number of LOIs so far and are related to the challenges facing young African physicists [8]. In addition to the LOIs, many YPF topics and issues were collected through workshops and the survey results.

2.4. Women in Physics Forum

Despite so many efforts over the past decades to close the gender gap in physics in Africa, women are still largely unrepresented in the physics workforce and even fewer women reach leadership positions. The objective of Women in Physics Forum (WiPF) [14] is to mitigate the lack of the African women participating in Physics.

In the short time since WiPF was launched in 2021, WiPF has started important discussions with ASFAP community regarding women's participation in and attitudes toward physics and raised awareness of the systemic structural barriers that silently push women away from their career track.

WiPF organized their first workshop in February 2022 [15] which was the international Day for Women and Girls in Science. On December 9, 2021, WiPF get a chance to participate in The AERAP Africa-Europe Science Collaboration Platform in a session dedicated for women's movements in the fields of science, technology, and innovation. As a result of these many meetings and discussion sessions, WiPF developed the following strategies and implementation plans to help women community achieve the overarching WiPF goals:

- Initiate mentorship and networking initiatives.
- Establish a system to encourage more girls to study physics.
- Links to external databases or community-generated databases that track important statistics on women participation in physics.
- Emphasize on the gender balance in working place.
- Funding of physics projects for women and removing age limit for women in physics.

3. Discussion on Societal Engagements

Following Societal Engagements: Status & Plan at ACP2021, we had a discussion of a mix of community engagement, physics education, young physicists, and women in physics colleagues. Ideas for future interactions between all societal engagement working groups have been identified.

Implementation ideas

1. Organise join meetings to disseminate new ideas and work to identify common issues.
2. Work to identify and improve the the grassroots level related-issues.
3. Create and foster new opportunities for interaction with fields beyond physics.
4. Develop and increase access to resources, training activities, and opportunities that engage physicists with policy makers, opinion leaders, the general public, educators and students.

The societal engagements will be engaged in a variety of efforts to inform the public and policy makers about fundamental and applied physics research, and to encourage support for that research. The societal engagements should augment and enhance ongoing efforts by providing continental coordination and support, and by developing needed resources to make a compelling case for support of fundamental and applied physics research.

4. Conclusions

We summarized past and current activities of the societal engagements community. These include: (1) conferences, workshops, meetings and panel discussions, (2) survey, and (3) letter of interests. These activities have been useful in terms of interest and participation, and should be encouraged and continued. However, we conclude that more direct engagement from all societal engagement working groups is needed.

Acknowledgments

Special thanks to the ASFAP— societal engagement co-conveners & session organizers for their contributions.

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Physics Masterclasses in Africa and the World

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Abstract

International Masterclasses (IMC) enable high school students and teachers to work with particle physicists to analyze authentic data from contemporary experiments and experience being "physicists for a day". The IMC program has a worldwide reach, including several universities and research institutes in Egypt, Algeria, Morocco, Sao Tomé and Principe, and South Africa. As technical infrastructure in Africa improves, there is a great opportunity for many more African institutes to offer IMC on their premises. The authors will discuss the advantages of IMC to Africa, how institutes may join, and ways to overcome obstacles.

Keywords: The African School of Physics, ASP, The African Conference on Fundamental and Applied Physics, ACP, International Particle Physics Outreach Group, IPPOG, International Masterclasses, IMC, education, outreach, particle physics

1. Introduction

International Masterclasses (IMC) are experimental particle physics education and outreach events for high school students aged 15 to 19 years. In the IMC concept, students become "scientists for a day". They are invited to a research institute or a university, where they attend introductory talks on topics such as the Standard Model, detectors, and accelerators to help them prepare them to make their own measurements. Students analyze authentic data from an actual experiment to be able to answer a research question or to draw conclusions from the measurement. Currently, students at different masterclasses are engaged in measurements from the Large Hadron Collider (LHC) at Conseil Européen pour la Recherche Nucléaire (CERN), Belle II at Kō Enerugī Kasokuki Kenkyū (KEK), neutrino experiments at Fermilab, and particle therapy from Gesellschaft für Schwerionenforschung (GSI). The capstone of the masterclass is an international videoconference with 3-5 other masterclass institutes that have made measurements from the same experiment. [1] [2]

What makes this event a *masterclass* is the interaction of high school students and their teachers with the particle physicists who host and tutor the event. Most important, as students analyze data for their measurements, they interact with physicists to ask questions and clarify the meaning of the data. It is in this interaction that the physicists impart not only specific information but also their approach to understanding both the experiments and the results. One way to express the goal of a masterclass is to help students see data as scientists see data.

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This paper is organized as follows. In Sections 2, we explain details of the masterclass day. In Section 3, we discuss goals, motivations, and requirements. In Section 4, we flesh out the opportunities from different "flavors" of masterclass. We conclude in Section 5 with an invitation to participate.

2. The Moving Parts

The masterclass day varies depending on the institute and time zone but generally follows a plan similar to this Sample Agenda:

Local Time	**Activity**
(prep)	(classroom)
09:00-09:30	registration and welcome
09:30-10:30	introduction to particle physics
10:30-11:30	second talk or tour
11:30-12:00	introduction to measurement
12:00-13:00	lunch (with physicists)
13:00-15:00	data analysis
15:00-16:00	local combination of results and discussion
16:00-17:00	international videoconference

The international videoconference has the following key features:

- 45-60 minute duration
- 3-5 institutes, reflecting international collaboration (where possible)
- Same measurement, different data
- 2-3 moderators (physicists, graduate students)
- moderation centers: CERN, Fermilab, KEK, GSI, TriIniversity Meson Facility (TRIUMF)
- Agenda of videoconference:
  - welcome
  - combination and discussion of results
  - general Q&A
  - quiz (CERN).

[1] [3]

3. Why and What

Why do we facilitate and promote International Masterclasses? Why do physicists invest their time and efforts in them? IMC is a way to help start development of the next generation of scientists and engineers by giving young learners a real experience with cutting-edge science. In the same way, IMC promotes interest in science among all students. Visiting a university or laboratory where they work side-by-side with physicists near their homes as well as international collaborators, high school students have the chance to participate in the excitement of contemporary physics research. Teachers who bring students to masterclasses year after year often develop their own expertise and interest that can enhance their instruction in the classroom.

To host a masterclass, local organizers need to secure space to work with students and computers with high-speed internet (unless the masterclass is local only). All masterclass packages are web browser-based (although some need installation of Java and software, e.g. event display). All masterclass packages are available for educational purposes without cost. The physicist leadership of the masterclass should consist of an organizer, at least one tutor for each ten students, coordination with IMC, some flexibility to deal with local conditions and unforeseen problems, and a welcoming attitude.

4. Opportunities

The masterclasses described so far have been from the IMC "regular season". These are the mostly standard full masterclasses that occur each year from February to April and are coordinated by IMC central. However, there are additional opportunities that arise each year.

World Wide Data Day (W2D2) is a one-day simplified masterclass event held in November or December each year. W2D2 measurements are from the ATLAS and CMS detectors in the LHC and can be completed in about two hours, from introduction to videoconference end. High school teachers organize W2D2 measurements at their own schools and connect their students to physicists in the videoconferences, which occur in a day-long "shift". [4]

IMC also holds special masterclasses for the International Day of Women and Girls in Science on 11th February each year. These are much like standard masterclasses but are designed to especially benefit young women with female scientists as role models and discussions of women in physics. [1]

In addition, any organizers can host masterclasses anytime of the year, in or out of the IMC schedule. IMC gives these initiatives support upon request and many institutions, from universities and laboratories to high schools, have successfully created meaningful particle physics masterclasses opportunities for students.

IMC is open to alternative designs of masterclasses as needed by local organizers. There have been masterclasses for university physics students, masterclasses as outreach activities in conferences, and many more examples.

5. Conclusion and Invitation

International Masterclasses have spread to countries all around the world. Africa is part of IMC but there is great room for mutual growth and enrichment for high school students and teachers between IMC and physicists in Africa. Some of these opportunities include masterclasses already described, adaptations to make the masterclasses more appropriate in the local context, and masterclasses redesigned for African physics experiments, such as HESS or the African Light Source.

The authors invite physicists and graduate students in Africa and the world to think about organizing a masterclass, tutoring in a masterclass, becoming a videoconference moderator, or even creating a new masterclass measurement. The authors, as co-Coordinators of International Masterclasses, are eager to help.

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On making physics relevant to society in general and to scientists in particular: Closing the epistemic gap

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Abstract

Physics has a bad press: it is seen by a majority of people as a boring discipline ever since their High School days. There is no glamour to it, just toil and pain, and for many who engaged in it, the end sight is often unemployment. Could it be that physicists don't know how to communicate what their discipline entails to? I will be tackling the problematic of making physics relevant to society and to the scientists in general. I will also be dealing with the methodological and educational aspects of teaching and practicing physics, and the need to close the epistemic gap between physics teaching and the physicist's understanding ... By the way, do physicists understand physics?

"...that statement made me furious, so I started studying physics." Masotoshi Toshiba in his 1997 Nobel Prize address

Keywords: Physics and society, didactics of physics, epistemic gap

1. Introduction

There is an overall feeling of negativity from the general public towards physics seen as an unyielding and boring discipline, all this feed up by an unfruitful encounter with it during the High School years. This strong feeling goes further to encompass its practitioners as I will argue. This is a hard reality we have to face and correct, and making the general public aware of physics' centrality in science is a vital first step in that direction. One should make people aware not only of its utilitarian aspect through its contributions to the economy, industry and medicine, but it should include its cognitive aspect along with its mind-boggling discoveries and puzzling open questions. Educating people in the methodology of science, in this era of fake news is also of great importance as physics is the archetypal discipline where science in action might be seen in its purest form or at least the simplest one, even as advances may takes meandrous paths.

We will start by arguing that physics is a fundamental discipline, and indeed the most fundamental one, which simply stated is the gateway to understand the material (I was about to say the "physical"...) world. This is not a self-aggrandizing statement uttered by a physicist, but an obvious fact that we physicists don't often want to make out of displaced modesty. This of course doesn't mean that physics is the most important discipline or the

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"noblest" one, whatever it may mean, as the criteria for evaluating the impact of the field is complex and has also to do with the degree to which society and the economy make a beneficial use of it. In fact for this later title, it looks pretty straightforward that computer science and electronics might be the top contenders[1].

2. Physics as Magic

Physics indeed works like magic. We can from our today's physics produce apparatuses which would bluff any back-in-time physicist, activate devices at distance (and soon at the motion of an eyelid, and even at some point from a mere thought), and other feats (See Figure 1).

Figure 1: Science works like magic, nay better than magic, even better than science fiction...

In fact, I would say it may work better than magic as we not only manipulate objects, mass produce them, improve on them, but crucially we understand their mode of operation. We even do often better than science fiction: Science fiction imagines things while science not only conceive them, but it explains and produce them. Quite often, objects manufactured by science couldn't have been thought by science fiction writers.

In the same vein, not to leave anyone unaccounted for, chemists do better than alchemists: They produces wondrous substances with properties "à la carte". They are the magicians of the molecular world.

3. Physics as the Grammar of Nature

Let us ask the rhetorical and somewhat provocative question: What is the most basic science of all? It is certainly the science which deals with the intimate nature of material things at all scales! This is precisely what physics is about and on this I rest my case that it is indeed the most fundamental science and I may even add, by definition! It provides at each scale a description of what is going on, makes quantitative predictions and predicts

[1]Both based on physics: Quantum mechanical properties of semiconductors for the computer chips, Maxwell's equations in a given regime for the other.

correctly outcomes coming out of the experimentally tested domain. Its domain of action covers all the space and time scales albeit with different degrees of completion for some. We can illustrate this in two ways, one through the Glashow's snake or the cosmic Oroboros which not only shows the vast domain of relevancy of physics from the infinitely small (particle physics down to the Planck scale, at least in principle) up to the extra galactic realm, with the additional benefit of portraying the new deal where cosmology "merges" with sub-nuclear physics, achieving the coming together of the two infinities (Figure 2),

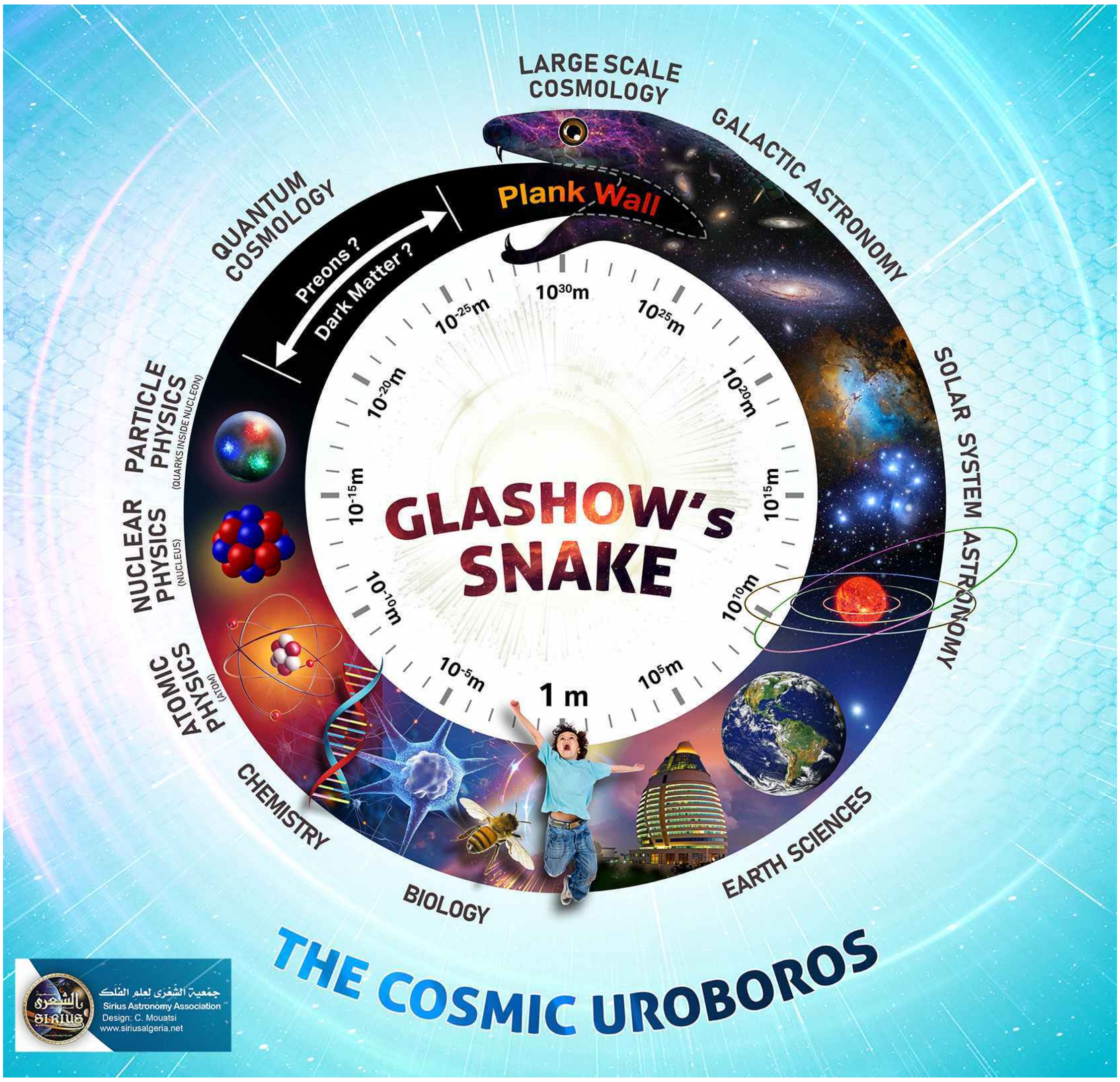

Figure 2: The Cosmic Uroboros showing the two infinities and their merging

Physics is also this fundamental science used by a multitude of disciplines. Sometime we hear a rather similar claim about Mathematics. Well, keeping in the realm of analogies, if Mathematics is the language of Nature, Physics is its syntax and grammar, its underpinnings. Mathematics is not unlike a toolbox, but if using the right tool is crucial for the car mechanic, a toolbox without a motor to apply it to is useless. Physics is in fact so basic that we are not enough conscious of its fundamental character! Let us list some of those disciplines which use it in a fundamental way:

We can also see the efficiency of physics through this wheel of approximations in the diagram below. See Figure 3 By assigning various values to the fundamental constants, we can blithely hopping through the various domains of validity of covering all of the physical world at various regimes. It is the ultimate game of taking the limits that theoretical physicists have brought to a high degree of perfection. It is also the science which strives to synthetize all the knowledge within it in a grand unified explanation scheme, quite a lofty goal for any science. It is in fact the only science which pushes the fullest unification attempt of its domain of investigation as one of its goals (The theorists at least)... even if this objective has been looming farther and farther during the past several decades.

- The Earth Sciences, from geophysics to atmospheric physics, to oceanography, to plate tectonics...

- Life Sciences, from biophysics and medical physics of course, to plant physiology, cardiology... It is used for example in cytology to model the movement of the cell through the beating of cilia, for following the motion of substances across the cytoplasmic membrane...

- The Sciences of the Universe as it is obvious enough: Is not the Universe the ultimate laboratory of matter under diverse physical conditions including the most extreme ones? We may add to the list the various branches of engineering, which behind their facade of utilitarianism, are in fact practicing the art of optimizing cost (with the exigency of availability of ingredients, ergonomics of the product, public taste...) using physics! It may indeed be described as "opportunistic physics" or more politely "constrained physics".

Thus, much like we cannot do without mathematics to analyze and interpret data, it is too not possible to dispense ourselves of physics to do science, almost any science, even if we wanted to. Physics is indeed for the other sciences what the air we breathe is for life.

4. Some of the Physics' success stories

Every scientific discipline which ever appeared has been brought to fruition and has in the process developed a unique practice and understanding that no one not trained within it can compete with. Physicists can rightly be proud of having achieved great successes. I would like to point out to three such broad domains although I won't be able to expand on any of them here. I will choose them at very different scales:

- Subatomic scale: We have been able to map out the particle content of the sub-nuclear world and its modus operandi (interactions, conservation laws...) through mainly the Standard Model.

- Atomic scale: Starting from Schrodinger equation and the orbital configuration business, i.e. the whole chemistry, we can confidently go about predicting properties of any atomic and molecular structure one can think of, at least to some good degree of accuracy. Explaining the stellar atmosphere spectra is also a tribute to the mastery we have reached, and by the way, a success story of statistical mechanics not often acknowledged.

- Stellar world: the physics of the stars and their evolution from their birth to their demise, has matured to the point where we can explain the Hertzsprung - Russell diagram:

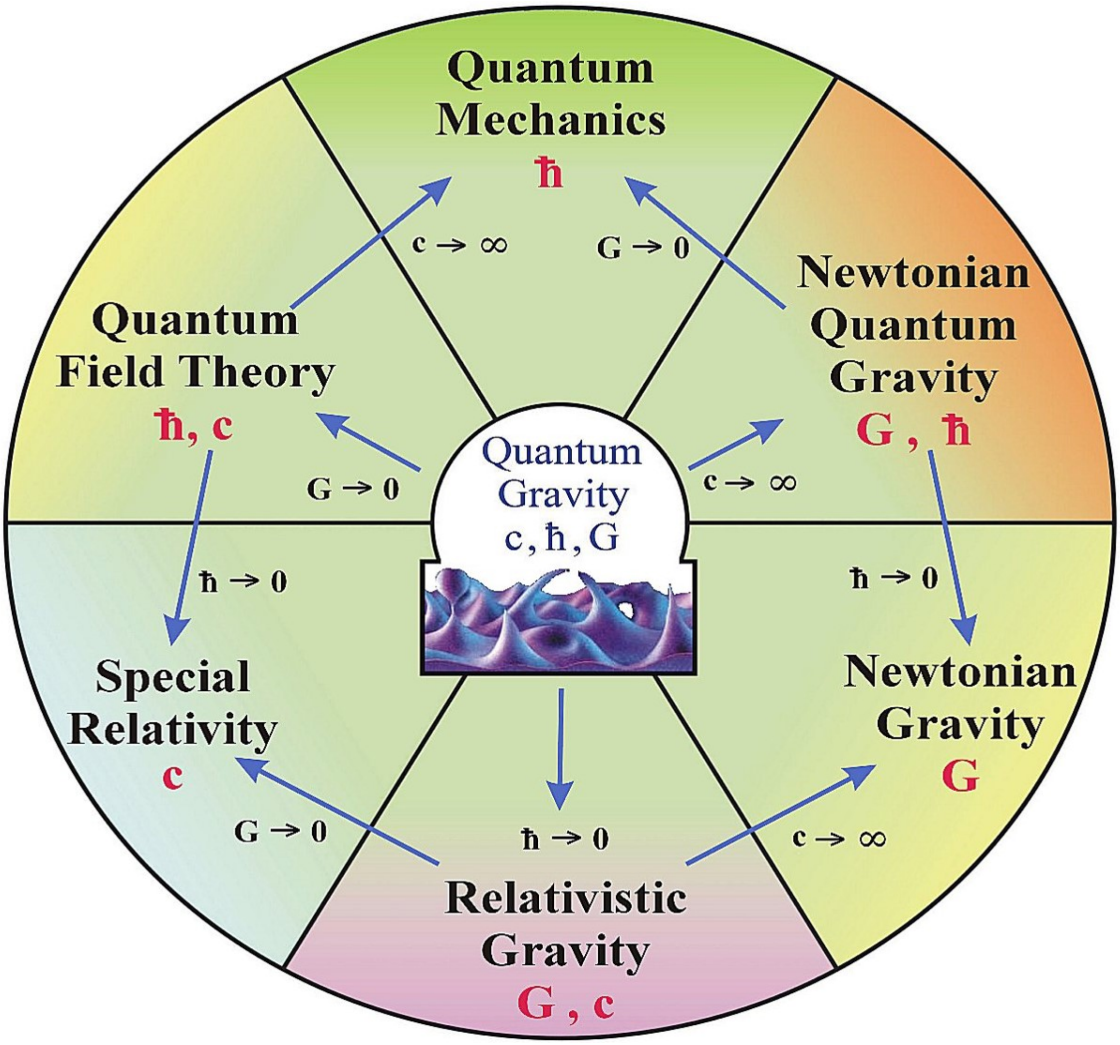

Figure 3: The art of taking the limits

location, density and timeline of the various type of stars represented in the diagram. Yet many surprises still await us with stars of weird constitution not yet discovered.

5. Imperialistic ... but generous

Physics is characterized by a very specific spirit, that of magnanimity and selflessness. In fact, the imperialistic tendency often attributed to it is really an unsubstantiated feeling. Physicists are a race of pioneers who clear up constantly new territories up to the borders of the unknown, then leave to other disciplines the task to exploit them. While it does occupy basically all the domains of the material world as we saw, at all scales, from the microscopic, to the macroscopic, to the cosmic realm, yet the physicist's curiosity is fully disinterested. There is indeed no "occupation de terrain"; it generates cutting-edge knowledge but leaves to others the task of making it flourish and find applications, thus electronics, nuclear energy, laser technology[2] (Figure 4).

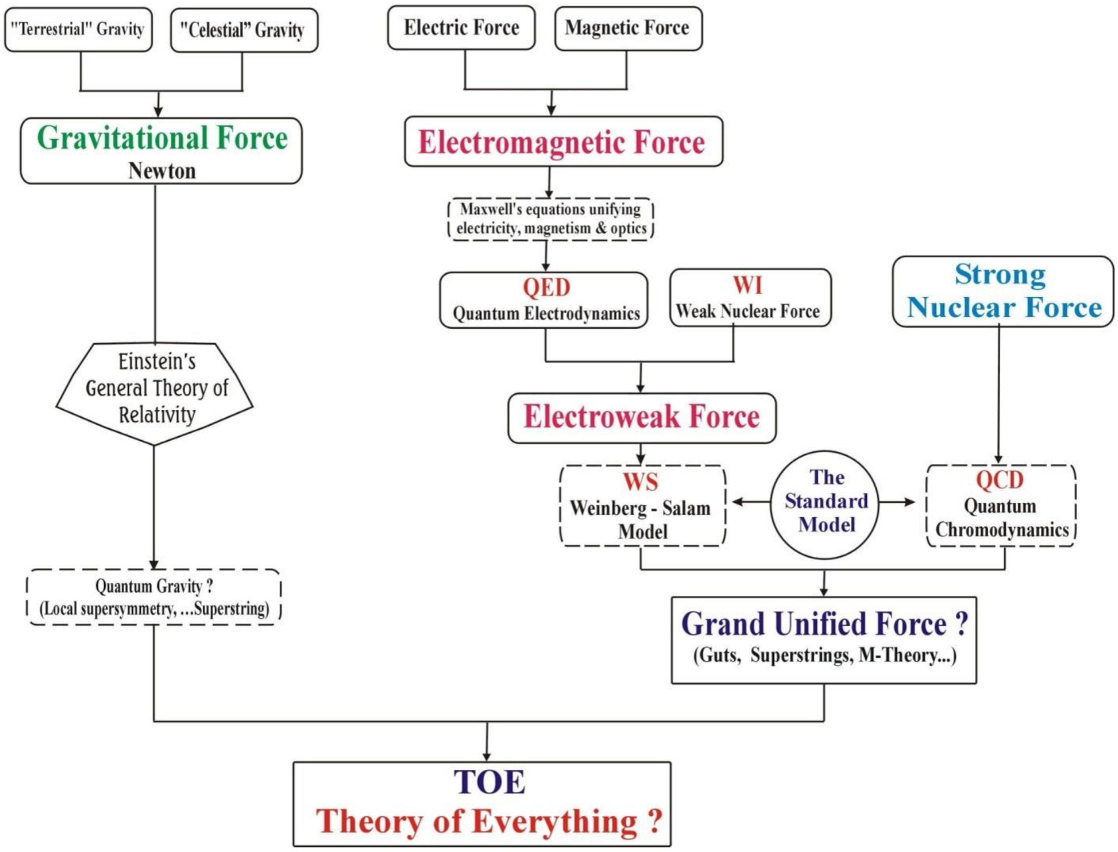

Figure 4: Towards a Theory of Everything ?

Claims have been made that chemistry has been annexed to it becoming a subdomain with a special vested interest[3]. Actually it is true in principle that physics has been tasked to unravel the working of the whole material world, and so the other material branches have been made de facto subsidiary to it, but that's from the hazards of the history of sciences. Yet physics is in compensation generous. It hands over any new branch it opens

[2]It spurred the development of whole branches of mathematics like the theory of distribution (Quantum mechanics), the calculus of variations (Lagrangian mechanics and QFT...), Riemannian and non-Riemannian geometries (General Relativity...) ... and I would dare add the Web, an invention at CERN, a spin-off of accelerator physics meant to improve communications and the exchange of data across collaborating centers all over the world.

[3]Yet we understand that this situation arises from the natural way of classification of sciences which goes back to the meanders of the history of the "physical sciences". If one is to feel better about it, call the chemist an applied molecular physicist, although I doubt that will improve the situation... In any case, the overlapping is there and the rational for it is that physicists and chemists working in this common domain have different agendas.

to technologists to fructify it.

6. Physics in a Nutshell

The magic of physics lays in the utter simplicity it goes about explaining the world. The fundamentals laws are a concentrate of sobriety to the point of simpleness, of coherence, and (mathematical) eloquence, in addition to elegance[4]. Look at mechanics which is set to explain most of the large scale behavior of matter. What used to be the biggest stumbling block to human thinking, namely the nature of motion, now embodied in the first law of Newton, ultimately states according to Galileo that motion is like "nothing". As for the remaining stuff embodied in the other Newton's laws[5] which can explain the trajectories of intercontinental missiles, the stability of bridges, the running of plasma engines, the orbits of planets, the motions of stars in clusters, it just operationally states:

- Search for a deviation from the inertial motion (the uniform linear motion, or "The motion is like nothing "), which would embody the presence of an (external) force!

- Plug in the expression of the force into Newton's second law, and you get the Equations of Motion (EoM)... and then go solve them!

If Newton laws' simplicity didn't impress you, consider electromagnetism where every electrical, magnetic or radiation phenomenon you have ever heard of can be deduced from the four Maxwell differential equations (See the didactic challenges below). The whole of geometric optics is but the eikonal approximation applied to those equations. Or alternatively, look at General Relativity (GR), especially if derived from a least action principle; it is the epitome of aesthetic beauty and simplicity[6]...

Of course in practice, each of those laws have to be seriously unpacked before been made full use of. For example Einstein's equations of GR is a set of highly non-linear set of coupled tensor differential equations... which can't be solved exactly except in the simplest cases (Like Black Holes...).

In order to convey further the idea that simplicity doesn't mean ease of manipulation, here's the ultimate theory of everything (That we know of today...) written in a compact path integral formulation (Figure 5). May we add that a whole (theoretical) life of unpacking may be needed to explore the various terms. This equation indeed contains in a compact way all the known microscopic physics. Yet it by no mean a Theory of Everything. Thus it doesn't explain how the various material entities represented in the various terms above

[4]Some people may argue that laws, and thus a theory built around its equations merely embodies a given set of observations and thus has no "truth" in it. We can over go further in relativizing the meaning of truth to turn into a "human truth" like in Bohr's words: "It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about Nature." In other words, physics is a model of our perception of the world, but not the world itself as much as the map is not the territory. Actually, there are different ways from an epistemological point of view of understanding the core principles of physics, as there are many paths to spirituality...

[5]The second Newton law states that an applied force to a body provides an acceleration impeded only by the "inertia" of its mass, while the third one is just the push–pull like rule that to every action there is a reaction equal and opposite.

[6]Quantum mechanics could also be formulated in a terse axiomatic mode, but the non-traditional aspects of the theory call for some mathematical culture so as to fully comprehend its "abstruseness" and translate it into physically "operational" terms.

$$W = \int_{k<\Lambda} [Dg][DA][D\psi][D\Phi] \exp\left\{ i \int d^4x \sqrt{-g} \left[\frac{m_p^2}{2} R \right.\right.$$
$$\left.\left. -\frac{1}{4} F^a_{\mu\nu} F^{a\mu\nu} + i\bar{\psi}^i \gamma^\mu D_\mu \psi^i + \left(\bar{\psi}^i_L V_{ij} \Phi \psi^j_R + \text{h.c.} \right) - |D_\mu \Phi|^2 - V(\Phi) \right] \right\}$$

Figure 5: The equation of the "World" in a path integral formulation. There is the space-time structure, the material content and all the fundamental interactions

emerge or are related to each other. It is just an equation containing all the basic interactions in a unified way, formulated as a gauge invariant theory and written in the path integral formalism.

Thus physics ultimately embodies the power of simplicity and parsimony applied to slick fundamental objects. At the end of the road, there is an incredible accuracy of its predictions when confronted to experimental data. Explaining a very large set of phenomena with a minimum set of principles is very much like the artistic expression of an esthete pushed to the extreme. Theoretical physics in some strong sense is an art, and Newton, Maxwell, Einstein, Dirac are their emblematic heroes.

Furthermore, the basic laws become even simpler and the description easier when going to smaller scale (thus to higher energy), or back in time. Look as an example at the behavior of the quarks and the asymptotic freedom they gain at high energy originating from the mathematical structure of QCD, or the structure of matter when getting closer to the Big Bang. Even the Black Hole which was thought for a long time to be the simplest object in the Universe as it is characterized with only two numbers namely it's mass and spin speed In addition to those feats, physics has much to claim from a utilitarian point of view, but this is so well known that there should be no need to elaborate further here (Figure 6).

7. The Didactic Challenge and about Closing the epistemic gap

Physics for what it's worth is all in its conceptual part. Without this cognitive dimension which enables one to truly understand the material world around us, it would be an unpretentious phenomenological discipline that is just a degree above the usual explanations in non-fundamental disciplines. It is that cognitive part which can fire up the imagination of aspirant physicists and kindle genuine vocations. Take away this conceptual part and you draw closer to be soldiers of fortune of physics than true physicists. It is all the difference between mercenaries and freedom fighters. Indeed, if all one's skills is to apply equations and crunch numbers, one is not doing physics but is just at best a physics consumer. This is precisely the problem with all those bright young minds who get their baccalaureate (Bac) with flying scores in physics... and then go to medicine. They haven't mastered physics for the least but have just worked out all the possible combinations of problems that may come

Figure 6: Slide taken from a lecture by theoretical physicist Michio Kaku from City College of New York

to the exam according to the chapters covered[7]. Luckily books have appeared, although not much known or used in our countries in Africa, which appeal to the conceptual part of physics [1] [2] [3]. The famous Feynman's lectures in physics [4] have been and still are a goldmine for those who wish to go into the inner working of physics and look for physical insight. Some have adopted the precise approach I am advocating for here like Hassani's one [5] who states in his preface:

"This book goes against the philosophy that the only physics worth learning is that which can be applied to the making of a cell phone, high definition TV, computer, SUV, or movie filled with graphics trickery. It does not glorify the pragmatic aspect of physics. Rather, it talks about some of the great ideas that have defined our era; about the inner workings of that magnificent enterprise of our race, science; about the power of theoretical prediction and the delight of experimental confirmation..."

Nothing better to show the deficiency in physics understanding than to have would-be physicists (even bona fide ones) go through a series of didactic challenges where the skill is not to regurgitate a theory or an equation, but to explain. Here are few of them:

- What is the most fundamental science of all? Luckily, I have already answered that

[7]Yet its description might be a daunting task if not an impossible one. First because lurks at its center a singularity that we don't know how to properly describe physically. Then because the devil of thermodynamics has stepped in and now we are not sure of what is ambushed just behind the Schwarzschild horizon. A "firewall" theory was proposed in 2012, namely a hypothetical phenomenon where an observer falling into a black hole encounters high-energy quanta close or at the event horizon and get fully roasted. Never mind the subsequent spaghettification, if he ever reaches that stage..

Figure 7: Explaining the operation of spinning on oneself: Here's some help from the story of "le Petit Prince" of Saint-Exupery

one.

- Why is there only two electrons in the first layer of atoms?

- By which interaction is the Sun shining?

- Describe braking thermodynamically wise.

- Explain all magnetic phenomena in one sentence ... and all e.m. wave production in another one.

- Why doesn't an inclining spinning top fall over?

- Explain the operation of spinning on oneself, that is of changing your direction of motion when standing on Earth's surface.

For this later one, a Newtonian physicist's explanation would go like that: Go about rotating the Earth in the opposite direction of the one you want to spin, and in reaction, the Earth will make you rotate in the right direction! The Earth is huge so its rotation will be imperceptible while you, tiny creature, will rotate the way you intended. I have no place to explain in more detail here why, but I will display a candid version from an illustration for "Le Petit Prince" of Saint-Exupery which should be self-explanatory (Figure 7).

Some answers to those above questions may look paradoxical if you use your "common sense" logic, which is precisely what a physicist shouldn't go about.

8. Grand connections and inner workings

Let us go back to our original questioning: Why don't people understand physics? The answer I argued about was that because physics has never been made attractive, and in the first place by physicists themselves. It is as if physicists all too often in their own hearts and minds believe that indeed their stuff is boring. So they take solace in going into problem solving and exerting their guts in developing the best bag of tricks to faster find solutions to some normative problems. They are in some way applying subconsciously what Feynman stated: “Nobody understands quantum mechanics”[8], but this time to the whole of physics and in a defeatist mood. Actually if physicists want to save their discipline or to be at least true to its spirit, and not to behave as disembodied soulless physicists, they should become essentialists. Namely go: back to basics! Every discussion on a physics related issue should always point back to its fundamental inner working. Talking about artificial satellites that’s Newton centripetal force in action, or in less abstract term, that’s free fall around a spherical Earth. But don’t obfuscate either: the blueness of the sky should not be explained away by merely uttering the magic answer - “Raleight’s scattering”- or by bringing to bear some quantum theory of light propagation in a medium (Unless you have the proper audience for that), but as resulting from some easily understood soft semi-classical exposition. Like maternal love, you don’t necessary increase the feeling of filial love by rehashing a series of moral rules and duties that the society has set up, but by appealing to the inner sentiments towards your Mom, from which the rules are but a pale copy, not unlike the shadows in Plato’s allegory of the cave.

Or like the beauty of a mathematical theory, it is not the range of its applications whatever extended it might be which counts, nor the elegance of some of the demonstrations, that’s all fioritura; but rather in the purity of its minimalist set of axioms and the richness of developments and connections it allows.

If physicists invoke the grand picture, the mighty connections, the coherence and the simplicity, then utilitarian arguments become quite secondary. That’s at least the proper spirit of physics, and that calls for an extra dose of love for one’s own discipline. In this process of making a case for physics, he might convoke some high ends of physics that he might not master (One needs not know about the quark model or QCD in order to state that nucleons are made of sub-entities called quarks...), while de-emphasizing the utilitarian and problem solving aspects of his discipline.

[8]This statement of Feynman was pronounced in connection with the puzzle of the two-slit experiment. In addition to be a candid acknowledgement of the weirdness of quantum mechanics in comparison to all the other branches of physics, it is more an attitude that when theorizing on a topic, namely that we should submit to rock solid facts no matter how strange they might look, and it is certainly not an attitude of powerlessness if not despair as displayed by some meek physicists.

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Ethics Committee Report

African Strategy on Fundamental and Applied Physics

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Introduction

Ethical behavior within the African Strategy on Fundamental and Applied Physics (ASFAP) is governed by a code of conduct (COC) [1], which is a set of core principles and community guidelines to which members of the ASFAP community must adhere. Registration to any working group implies that the member has read and accepted the ASFAP COC. The COC was drafted by the ASFAP steering committee but it subsequently fell under the responsibilities of a four-member ethics committee, which had been established to review and act as custodians of this document. It is the task of the ethics committee to amend this document whenever necessary, while ensuring that ASFAP remains a community where everyone feels welcome and respected. In addition, members of the ethics committee are mandated to serve as ombudspersons if need arises.
We're pleased to report that, so far, we have not received any reports of conflicts within the ASFAP community requiring our intervention. Therefore, this report only outlines amendments we have made to the COC to date.

Amendments to the code of conduct

Since June 2021, we have had several meetings to review contents of the COC and have made adjustments and addendums in addition to some general textual editing. We have also incorporated a few suggestions received from the steering committee. The current version of the COC was implemented in March 2022. Highlighted below are some of the "major'' edits/addendums to the document.

Authorship

Very often there are ethical questions raised around large authorship papers in terms of each author's contribution to the body of work that has been published. In some cases, names are included as authors 'only because it was always done'. Therefore, the ethics committee decided that this matter needed to be covered in the COC. The following text was thus added to section 3(d) of the COC [1].

Authorship offers credit for an individual's contributions to a study. It also holds the author accountable for the content in a published paper.

All individuals who carried out the work are responsible for the decision on who should be listed as an author when that work is published. Any individual who makes a significant contribution to the work (as agreed by everyone contributing to the paper) should be listed as an author. Any other individual or organization should be acknowledged accordingly.
In case of conflict, working group conveners should be contacted in order to help resolve the conflict. If the conveners and the contributors are unable to reach a consensus, the ethics committee should be contacted.

Email Communication

For a community involving hundreds of people, poor use of email communication could be problematic if not addressed. For example, one member could send a personal email to another member (e.g to congratulate them) but adding a larger email group in cc. This may be an issue if several other members reply to this email with everyone in copy. The ethics committee felt that this borders on the "unethical use of email communication''. Hence, the text below was added to the COC as a bullet point in section 3(c).

Ethical use of email communication: If your email concerns an individual person or a closed group of individuals, do not write to or reply to everyone in a general list. In addition, email communication should be done in a respectable manner, respecting the rest of this document's guidelines. Be also conscious of the fact that members of the ASFAP community are in different time zones. Therefore, prompt responses should not always be expected.

Guidelines on virtual meetings

Given that ASFAP meetings are mostly virtual, the steering committee advised to add a section on guidelines for such meetings to the COC. The text below was thus added to section 3(e).

As members of ASFAP are located in various places across the globe, virtual meetings are inevitable. In addition, due to the ongoing pandemic, virtual or hybrid conferences/workshops may also be inevitable. To facilitate the smooth running of such meetings, members of the ASFAP community and invited guests should adhere to the guidelines listed below:

- *Meeting times should accommodate participants from all time zones. Meeting minutes and/or recordings should also be made available on the meeting web page.*
- *Meeting hosts should ensure that only the speaker's microphone is ON at any given time.*
- *Participants should use the raise hand feature found in online meeting solutions (e.g. Zoom), or type their comments/questions in the chat box. Otherwise, participants should wait for an appropriate opportunity to comment or ask questions without interrupting other participants.*
- *Conveners should ensure that each participant receives an equal opportunity to participate in the discussion.*
- *Given that many individuals are currently working remotely, conveners should ensure that the meeting durations are respected. Virtual meetings tend to go overtime, but participants' time zones and personal lives should be respected.*

General edits

- In section 5(b), we replaced "moderator/host/code of conduct committee" by "convener/host/observer/ethics committee" because we believe that members of the observers committee should also be able to speak up in case of violation.
- Throughout the COC document, we removed parts that mention contacting an individual's institution if the individual violates the COC. We believe this is unnecessary as in many cases, members of ASFAP are by no means representing their institutes

Conclusion

We have highlighted the major addendums and edits that we have made to the COC document since our engagement as its custodians. To date, no violations to the COC that needed our intervention have come to our attention.
We believe that we would have done our job very well if there are zero complaints that come to us. Therefore, rather than being passive about these matters, our plan has been to constantly educate the community about these issues in a smart and non-intrusive way. We have not enforced this in the past year and we hope to find a way to keep these ideas alive and discussed in the public domain from time to time. This could, for example, be a five minute slot at every meeting with conveners to remind them of the COC and its importance.

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Physics Education for Capacity Development and Research in Africa

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Abstract

The acceleration of socio-economic development is intrinsically linked to the level of scientific development. While the existing scientific interventions within Africa played a transformative role in the enhancement of human capital development, adequate investment in research and development is required to make further significant strides going forward. Unlocking Africa's potential requires sustained investment in research and development. However, inadequate expenditure in research and development as a percentage of gross domestic product by African countries does not augur well for the progressive realization of sustainable scientific development. This contribution highlights challenges afflicting physics education in Africa and provides a reflection on key areas for intervention to strengthen capacity building. Critical interrogation of enablers and constraints is required in order to harness the efficacy of capacity building efforts with a view to engender fundamental transformative change in relation to meaningful enhancement of human capital development in Africa. Reconfiguration of the existing scientific interventions some of which yielded remarkable results remains a key strategic imperative in the long to medium term. Progressive realization of this key strategic imperative hinges to a large degree on the establishment of collaborative partnerships involving African key stakeholders. Contextually appropriate recommendations for coherent acceleration of scientific development within the broader African context are advanced.

Keywords: Physics Education, capacity building, scientific development, scientific interventions, transformative change

1. Introduction

Capacity development and sustainable scientific development in Africa are plagued by existing pervasive fundamental challenges. These challenges include lack of requisite facilities to conduct research at many African institutions and universities, inadequate engagement by physicists in research and academia, low doctoral enrolment and graduates, low research publications as well as paucity of research institutes and industry which limits job opportunities for physicists to teaching in secondary schools and universities [1, 2]. There is a critical need to put appropriate scientific interventions in place which are essentially geared towards the improvement of the quality of physics education in Africa. In response to this key strategic imperative, the Association of Commonwealth Universities (ACU) and the Institute of Physics (IOP) created an evidence base for a potential multi-year programme to improve physics training, research, infrastructure and collaboration in nine countries in Sub Saharan Africa [3]. These countries are Ethiopia, Ghana, Kenya, Malawi, Nigeria, Rwanda, South Africa, Tanzania and Uganda. This enormous undertaking represents a significant step towards strengthening physics education for capacity development and research in Africa.

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2. Capacity development and research

Physics education provides a solid basis for progressive realization of capacity development and robust pursuit of scientific research in Africa. However, a range of interventions are required to strengthen human capacity development. Strengthening human capacity development should be predicated on clearly identified key areas for intervention. Key areas for intervention identified by the Association of Commonwealth Universities and Institute of Physics include gender inclusivity, training and education, academic and staff capacity, innovation and commercialization as well as collaboration and networks [3]. The under-representation of women in physics remains a major structural problem in Africa. Physics training and education ought to foster the inclusion of women as an integral part of capacity development. In addition, African universities need to create opportunities for establishing vibrant partnerships that promote collaborative construction of scientific knowledge. The advent of the Fourth Industrial Revolution provides enormous opportunities for African universities to embrace digital transformation with a view to foster innovation and commercialization.

3. Unlocking Africa's potential through physics education

Physics education has the potential to play a pivotal role in unlocking Africa's potential. Sustainable pursuit of scientific research in fundamental and applied physics requires highly skilled physicists. By its very nature, effective physics education can be harnessed as a vital means to train the next generation of physicists required to unlock Africa's potential. Other creative mechanisms identified to unlock Africa's potential include addressing Africa's inability to fill positions in physics fields, critical reflection on future aspirations and the role of physics education, and rethinking the role of teachers and other stakeholders in physics education [4]. Filling positions in physics fields in Africa remains a perennial challenge which stems from existing limited critical mass of available physicists. This perennial challenge stifles Africa's global scientific competitiveness.

4. Existing interventions promoting scientific development in Africa

There is a number of existing interventions promoting scientific development in Africa. The South African Institute of Physics (SAIP) coordinates a Teacher Development Project which is primarily aimed at teacher professional development in South Africa [5]. The project program is accredited by the South African Council for Educators (SACE). SACE is the professional council for educators that aims to enhance the status of the teaching profession through appropriate registration, management of professional development and inculcation of a Code of Ethics for all educators [6]. Teachers' participation in the SAIP Teacher Development Project enables them to accumulate Continuous Professional Development (CPD) Points which are essential for career enhancement. The National Astrophysics and Space Science Programme (NASSP) is another existing intervention that promotes scientific development in Africa. NASSP is a multi-institutional initiative funded by the Department of Science and Innovation through the National Research Foundation to train South African students in

Astrophysics and Space Science at Honours and Master's levels and to provide a pipeline to PhD studies in these and related research areas [7]. At another pragmatic level, the African Union (AU) established Innovating Education in Africa Initiative in 2018. The initiative is aimed at identifying, promoting and supporting the systemic adoption and replication of education innovations in all aspects of education and training in Africa, fostering policy dialogues with policy makers and development stakeholders to make the case for embedding innovation in education systems in Africa and endorsing the implementation of the continental programme [8]. As a dynamic and vibrant scientific intervention, the African School of Fundamental Physics and Applications made significant strides in human capacity development in Africa since its inception [9]. This monumental achievement is evidenced by a substantial number of students from various African countries who benefited immensely through active participation in this scientific intervention. The success achieved through the implementation of the aforementioned scientific interventions underscores the need for more interventions to be put in place across the African continent with a view to unlock Africa's potential.

5. Attraction and retention of students in Physics

Concerted efforts are required to attract and retain students in Physics. Attraction and retention of students in Physics can be realized through adoption of appropriate and sustainable mechanisms. These mechanisms may include:

- Assessing the quality of students entering African universities.
- Rethinking student under-preparedness for higher education.
- Assessing the state of undergraduate physics teaching and learning in African universities.
- Developing a set of standards for Physics training in Africa.
- Assessing levels of commonality and diversity of the physics programmes in Africa.
- Assessing range, scope and effectiveness of current teaching and learning practices in Physics at African universities.
- Developing a set of contextually appropriate recommendations aimed at improving the effectiveness of Physics teaching at African universities.

6. Recommendations

Scientific development remains a key strategic imperative in Africa. Coherent realization of this imperative ought to be informed by contextually appropriate recommendations. The following proposed recommendations are advanced to inform scientific development within the broader African context:

- There is a need for enhanced coordination of existing scientific interventions.
- Regular assessment of the impact and efficacy of existing scientific interventions is imperative.
- There is a need to go beyond capacity building to track and monitor the progress made through coherent implementation of existing scientific interventions.

- Active involvement of African key stakeholders in scientific development is imperative.
- Enhanced coordination of African efforts aimed at acceleration of meaningful scientific development is absolutely essential.
- It is imperative for African universities to embrace evidenced-based physics education research that fosters adequate exposure to plurality of knowledge epistemologies.
- Increased investment in scientific development is crucial for unlocking Africa's potential.
- Better funding of African universities is a timely and necessary strategic intervention.
- There is a need to establish African scientific evaluation and monitoring committee.

7. Conclusion

Physics education is crucial for the acceleration of socio-economic development in Africa. Strengthening physics education remains a key requirement for capacity development and sustainable pursuit of scientific research within the broader African context. Existing scientific interventions ought to be sustained and augmented to ensure skills development through active involvement in physics education activities. African countries face the key imperative to address inadequate expenditure in research and development as a percentage of gross domestic product with a view to facilitate sustainable scientific development in its broadest sense.

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Young Physicists Forum and the Importance for Education and Capacity Development for Africa

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Abstract

Higher education and advanced scientific research lead to social, economic, and political development of any country. All developed societies like the current 2022 G7 countries: Canada, France, Germany, Italy, Japan, the UK, and the US have all not only heavily invested in higher education but also in advanced scientific research in their respective countries. Similarly, for African countries to develop socially, economically, and politically, they must follow suit by massively investing in higher education and local scientific research.

Keywords: Young Physicists Forum, YPF, African Strategy for Fundamental and Applied Physics, ASFAP, Second Edition of the African Conference on Fundamental and Applied Physics, ACP2021, African School of Physics, ASP, Physics Working Groups, YPF-Survey

1. Introduction

In 2009, the United Nations Population Fund announced that the population of Africa had reached the one-billion mark and doubled in size in 27 years [1]. Regardless of the size and large pool of the human resource that the continent is endowed with, most African countries still continue struggling economically. Based on World Bank estimates [2], the proportion of Africans living on less than US$ 1.90 per day fell from 56% in 1990 to 43% in 2012. This indicates a positive improvement of 13% in the living standards of people in Africa though according to the World Bank Report [2], there were still more poor people in Africa in 2012 than in 1990 estimated to be more than 330 million up from about 280 million due to rapid population growth [1] that the continent has been undergoing over the years. Furthermore, despite poverty being a major problem in Africa [2], the continent also experiences deadly diseases such as the Acquired Immune Deficiency Syndrome (AIDS) caused by the Human Immunodeficiency Virus (HIV) believed to have originated from Africa [3, 4]; Ebola virus disease [5] whose fatality rate is around 50% with case fatality rates ranging from 25% to 90% in past outbreaks [5], and the recent outbreak of the COVID-19 pandemic [6], which has impacted negatively on Africa and the rest of the world. The continent also faces challenges of science and technology [7] with many African countries technologically

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depending on other continents for engineering, educational, agricultural, and health services, among others. African countries also face inadequate research-output capability or interest with Africa noted to generate only less than 1% of the world's research output [8] despite its increasing population [1]. Due to all these challenges and other factors, the continent has seen young, talented, skilled, and educated Africans leaving African countries in search for better opportunities overseas, a trend referred to as brain drain [9]. To overcome all these challenges and others, African countries should emulate the scientific, education, health, social, political, and economic policies of developed societies such as the Group of Seven (G7) 2022 countries: Canada, France, Germany, Italy, Japan, the UK, and the US [10], which have all massively invested in higher education, science, and technological advancements. The Young Physicists Forum (YPF) [11] was founded in 2021 by the African Strategy for Fundamental and Applied Physics (ASFAP) [12], amid the COVID-19 pandemic [6], to identify the major challenges that young physicists face and solutions thereof in order to positively contribute to the educational and local-scientific research on the continent, and thus, build capacity for Africa.

2. Young Physicists Forum

The Young Physicists Forum [11] is one of the engagement and physics working groups (PWG) under the African Strategy for Fundamental and Applied Physics (ASFAP) [12]. The forum is driven by three, young, and vibrant physicists who are co-conveners of the group all in possession of a doctor of philosophy in physics [11]. The co-conveners' mandate is, among other things, to ensure that the group remains sharply focused on its aims and objectives. The forum has a total of 65 active and registered members [11], most of whom are in possession of either a master of science degree or doctor of philosophy in physics. There is, however, no discrimination regarding the highest level of education YPF members [11] must meet and, therefore, all interested individuals within and outside the African continent are eligible to join the forum [11] as long as they sign up [11] and get approved by the steering committee of ASFAP [12]. The group also encourages bachelors students in various science disciplines, particularly physics, from various African universities to join the YPF [11] and enjoy the mentoring/scholarship benefits that YPF members share within the group, and thus increase their chance of embarking on postgraduate studies either within Africa or overseas. The Young Physicists Forum [11] reports to the steering committee of ASFAP [12] in a well organized structure as shown in Figure 1.

The aims and objectives of the ASFAP-YPF [11] are, among others, to collect ideas, opinions, and experiences on education, physics outlook, careers, workplace environment, and scientific research in Africa. Furthermore, the forum is mandated to clearly identify and raise awareness of the educational challenges and science career opportunities for young physicists in Africa and advocate for change by informing policymakers for action. Last, but not the least, the forum also aims at collecting preliminary data for future research. Since the group's inception in 2021, the Young Physicists Forum [11] has made tremendous progress in meeting its mandate (i.e., its aims and objectives) with the main modes of information dissemination being through scheduled meetings within the group and regular co-conveners' meetings, which are usually held on a weekly basis on Wednesday at 5:00 PM, Coordinated Universal Time (UTC). The forum has also formulated a survey [13] to

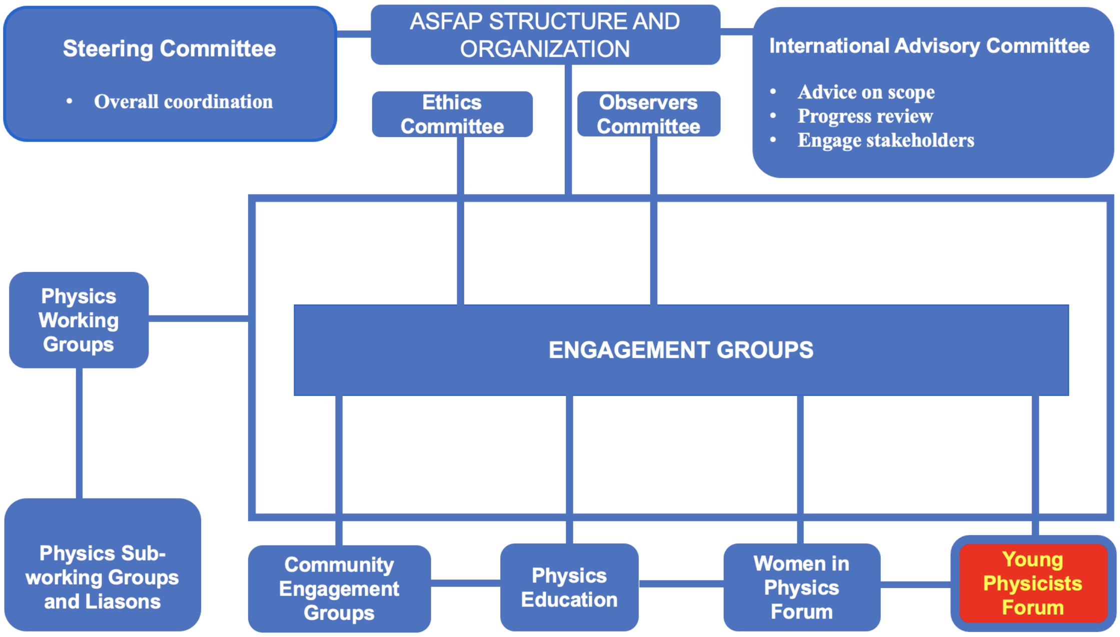


Figure 1: Structure and organization of the African Strategy for Fundamental and Applied Physics.

solicit for a wider community input of ideas. In addition, the group has so far held one successful workshop with stakeholders within and outside ASFAP [12] that was virtually conducted on 26^{th} January, 2022 tagged *ASFAP: YPF-Challenges and Opportunities* [14]. The YPF [11] also actively participated in the second edition of the African Conference on Fundamental and Applied Physics tagged *ACP2021* [15] and contributed three talks under different themes mainly focused on the status and progress the forum has so far made in line with the aims and objectives of the group.

3. Challenges and Opportunities Survey

To solicit for a wider community input, the Young Physicists Forum [11] has opened a survey [13] to sample African respondents within and overseas, main of whom are alumni of the African School of Physics (ASP) [16]. The survey [13] is aimed at gathering information on the education background, research performance, collaboration opportunities, career development, and workplace environment of the respondents. Survey results [13] show that 79.56%, of the respondents pursued their highest level of education within Africa while 20.44% of the respondents attained their highest level of education outside the continent of Africa. The survey [13] has further revealed that of the respondents who attained their highest level of education within Africa normalized to 100%, only 39.42% were satisfied. Factors leading to the educational dissatisfaction rate by respondents are plotted in Figure 2 and outlined in Table 1. From Figure 2 and Table 1, it is evident that good quality education and research in Africa still remain a huge challenge. Other major obstacles of an African educational system include the lack of mentors, skills training, libraries, job insecurity, and to a lesser extent political instability such as wars, among others. Since education, science, and technology are ingredients that contribute massively to good life and development of the global economy, there is need to solicit for remedies that counter the education and research challenges that many African countries have been grappling with for years.

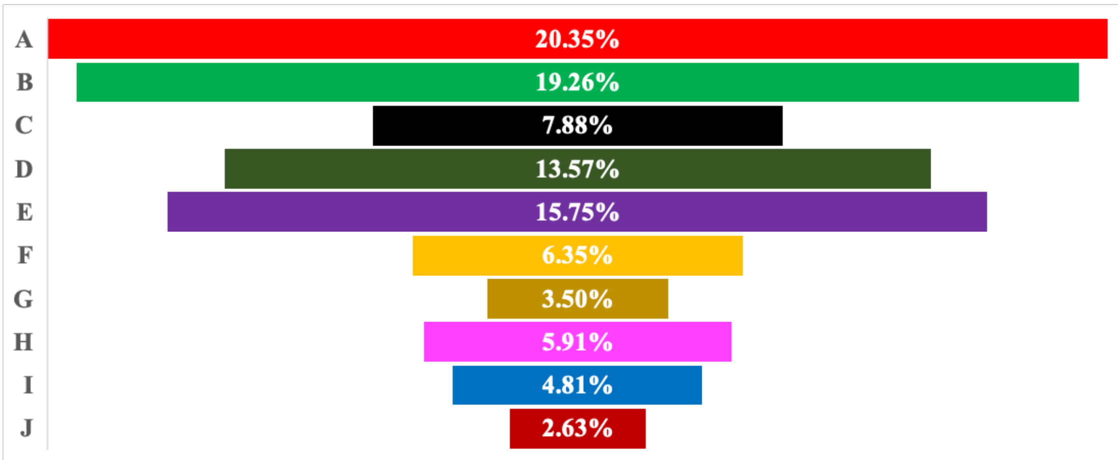


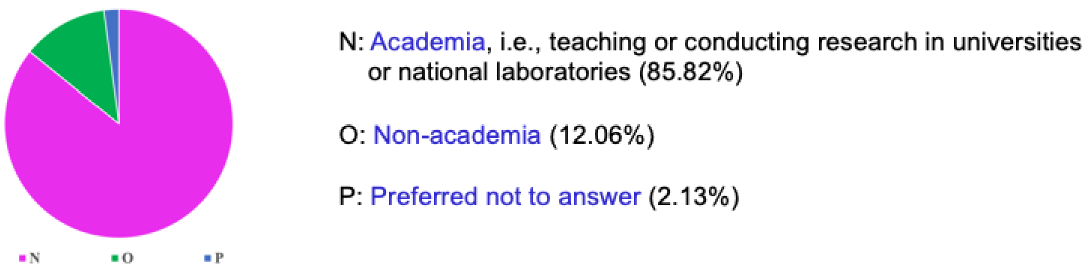
Figure 2: Challenges faced by respondents pursuing their highest level of education in African universities.

Table 1: Educational challenges faced by respondents pursuing higher education in African institutions

Responses	Challenges	Rate (%)
A	Lack of research funding	20.35
B	Lack of research equipment	19.26
C	Lack of mentoring support	7.88
D	Lack of mobility opportunities	13.57
E	Lack of proper skills training	15.75
F	Lack of access to libraries	6.35
G	Limitation of academic freedom	3.50
H	Imbalance between work and family demands	5.91
I	Job insecurity	4.81
J	Political instability and wars	2.63

According to the survey [13] being conducted by the Young Physicists Forum [11], prominent solutions to educational challenges include raising awareness to African policymakers and private enterprises on the need to fund research through provision of grants, which universities in Africa should accountably utilize to buy experimental equipment and conduct meaningful research. African governments should also invest in building higher learning institutions that are well equipped with research facilities such as modern laboratories where academic staff and their students could establish the link between theory and experimental work. This would then help reduce over-dependence on foreign research facilities and contribute to meaningful and solid collaboration relationships with other institutions and research facilities overseas. Public and private universities should work together and help improve the internet network in universities and research facilities across Africa as a good and stable internet connectivity undoubtedly enhances scientific research output and helps improve the quality of learning.

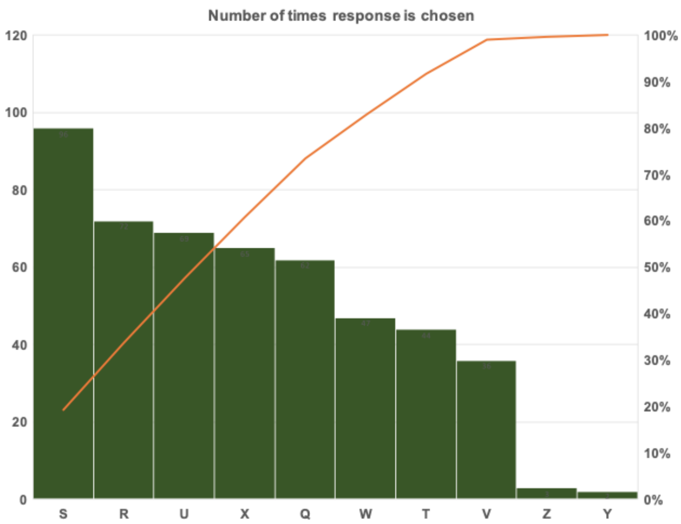
Other measures that may help counter educational challenges in Africa include revision of the school and university curricula by reducing over-dependence on theoretical work [13], building scientific research facilities, and securing laboratory equipment to encourage research skills and knowledge acquisition through experimental work among African students. Furthermore, the lack of mentors in science disciplines like physics in African universities could be resolved by motivating professors to embark on scientific-research projects and closely working with their students [13] once research grants are available to them from governments and private enterprises. Academic staff should also spend more advisory time with their students and try and establish the link between theoretical and experimental work together [13]. Additionally, academic staff members should offer more structured feedback to students and also establish research collaborations within and outside the continent so as to expose their students scientifically [13]. Occupational and career guidance should also be provided to students by their advisors in order to motivate them regarding their future endeavours in academia within Africa [13]. Career with occupational development is another huge challenge being faced by young physicists in Africa [13]. According to the population sampled in the survey [13], it is found that roughly 85.82% of the respondents are in the field of academia where they are teaching and conducting research in national universities and laboratories while those in non-academia fields accounted to about 12.06%, and approximately 2.13% preferred not to reveal there occupation as shown in the pie chart in Figure 3 by N, O, and P, respectively. Those in academia identified themselves as bachelors, masters, and doctoral students, postdocs, engineers, technicians, physicists as well as faculty members.



Occupation and precent representation of sample									
Current position	Bachelors students	Masters students	PhD students	Postdocs	Engineers	Technicians	Faculty	Physicists	other
Percent (%)	3.55	10.64	44.68	8.51	0.71	0.71	14.18	9.93	7.09

Figure 3: Occupation and percent representation of respondents according to the survey conducted by YPF.

Results of the survey [13] have further revealed that securing an academia position in universities and national research facilities within Africa poses a major challenge and is, at the same time, a huge sacrifice owing to the fact that the workplace environment is mostly not conducive due to lack of experimental equipment, among other challenges, more so in the last two years with the breakout of the COVID-19 pandemic [6]. Based on the results of the survey [13], the Young Physicists Forum [11] have learnt that the effects of the nature of an academia-workplace environment in Africa and the impact of the COVID-19 [6] have led to a reduction of academic interactions between academic staff and students, experimental activities, and research funding as highlighted in Figure 4. Other negative effects include less advisor-student interactions, physical and mental-health problems as well as financial hardships, among other challenges, as described in Figure 4. The poor currency-exchange rate of African currencies against major world currencies such as the United States Dollars ($) and British Pound (£), among others, is another major challenge [13] not explicitly stated in Figure 4, but being faced in the academia field in Africa as this significantly and negatively impacts scientific-collaboration work between Africa and other continents as far as international research visits and conferences by students and academic staff are concerned.



	Nature of workplace and COVID-19 impact (Responses)
S	Reduction of academic interactions
R	Reduction of experimental activities
U	Less advisor-student interactions
X	Financial hardship
Q	Reduction of research funding
W	Mental health problems
T	Less productivity of online classes
V	Physical health problems
Z	Not applicable
Y	None

Figure 4: Impact of the nature of the workplace and COVID-19 pandemic on research institutions in Africa.

The lack of good will and minimal interest in education, science, and technology in Africa [7] have led to a huge challenge over the years where the world has witnessed a large number of skilled manpower leaving Africa for other continents in search of a more conducive workplace environment and an attractive income to support their families, a trend known as brain drain [9]. The survey [13] being conducted by the YPF [11] has so far revealed some instances of brain drain [13, 9] that have been taking place in Africa over the years. These include young and skilled African students studying abroad on scholarships opting to stay and work overseas after completion of their studies [13]. Researchers and postdocs also feel more comfortable working overseas than in African universities where they are either not welcomed or because of the nature of an African academia workplace environment and meagre salaries [13]. The lack of academic freedom (i.e., students having no choice of what to study due to financial reasons), inadequate funding, and absence of research equipment disfavor Africa as a good destination for good quality education and research work [13]. Political instability such as wars in some countries in Africa drive away academically qualified personnel to other countries outside the continent where they settle down peacefully and continue to contribute to science and technology there than in their African countries of origin [13]. In spite of all these brain drain challenges [13, 9], the hope for Africa in education, science, and technology [7] is still alive. Through the survey [13], the YPF [11] have come up with measures to counter the effects of brain drain [9] and hence help keep alive the hope of African countries to develop their education and build capacity for Africa. Some of these interventions are summarized and listed in Table 2.

Table 2: Measures that may help counter brain drain according to the survey conducted by the YPF

	Interventions that may help counter brain drain in most African countries
1	Create a school of excellence within Africa for Africans who have obtained their baccalaureate with honors in order to encourage African academic excellence and experience.
2	Policymakers on the continent should partner with private enterprises and work together to improve the research-workplace environment and conditions of service such as salaries to match foreign-based counterparts in academia.
3	Create national research laboratories and more academic positions in African universities and provide research grants to enable academic staff members to embark on a meaningful scientific research experience within the continent.
4	Policymakers should stabilize African currencies to compete favorably with other major world currencies such that the salaries skilled academic staff are earning in Africa are favourably comparable to salaries fellow counterparts earn abroad.
5	Enhance and connect African academic infrastructures with the rest of the world; promote scientific collaborations with international universities, research institutions, and laboratories and allow creative young Africans to present new scientific research projects.
6	Massive investment in African university education is required that will result in an increase in well paying jobs. A marketing campaign should be setup to encourage the youth to stay and work in their respective countries in Africa.

4. Conclusions

The African continent is endowed with abundant natural resources ranging from huge arable land through oil, natural gas, and minerals to floras and faunas. It is amazingly puzzling to note that the continent holds a large proportion of the world's natural resources, both renewable and non-renewable and yet, to a large extent, Africa still remains undeveloped with higher poverty levels [2] than other continents. To restrain or minimize these challenges, Africa should heavily invest in higher education and promote local scientific research [13, 7]. Advanced scientific research carried out within Africa would, for example, help find solutions to diseases such as HIV/AIDS [4, 3] that have been ravaging the continent over the years; produce vaccines of its own to cure pandemics such as COVID-19 [6] without having to entirely depend or solely wait for developed societies [10] to share portions of their vaccines; process its abundant natural resources from raw materials to finished products, and reduce over-dependence on developed countries for finished goods and services [7]. This would, in turn, build an even better relationship between Africa and the rest of the world as far as business is concerned. Since higher education and research are key to social, political, and economic independence of any country, it goes without saying that, education and research should be prioritized across Africa and ensure that educated human resource is enticed to stay and work within the continent by offering an attractive workplace environment and competitive conditions of service and thus, help minimize the brain-drain [13, 9] phenomenon. The YPF [11] is entirely open and solely devoted to identifying the challenges that young physicists face in developing their careers in Africa and finding solutions as well as career opportunities available for young physicists on the continent so as to revamp education and build capacity for Africa. The YPF is also entirely committed to mentor young physicists in Africa and to help promote research collaborations with other young physicists globally [13]. All in all, the YPF [11] is willing to partner with policymakers across the continent and beyond, the private sector, and business enterprises as far as promotion of higher education and advanced, local scientific-research projects in Africa are concerned.

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