Enabling capacity development in physics in Africa through science, technology, and innovation policy and governance

Azwinndini Muronga

Nelson Mandela University, Gqeberha, South Africa

NELSON MANDELA UNIVERSITY

The 7th Biennial African School of Fundamental Physics and Applications

28 November - 9 December 2022

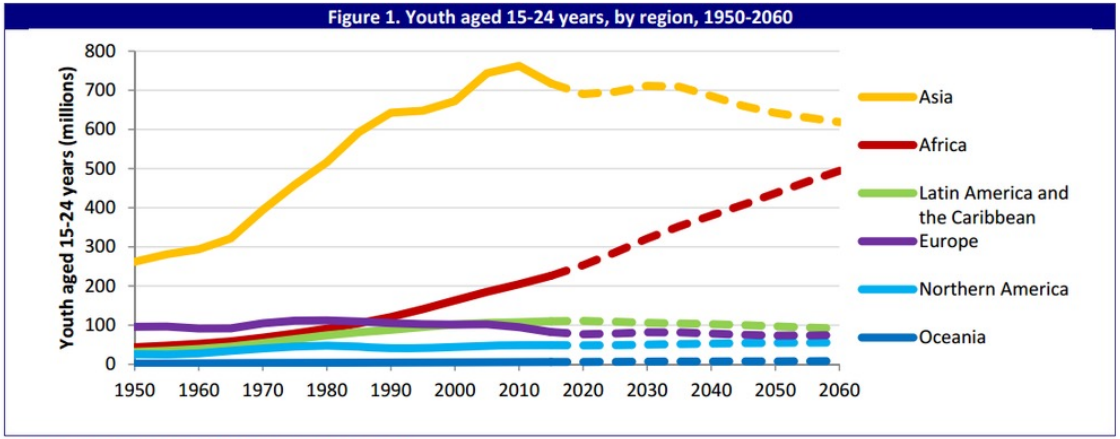
ASP2022

Core messages from this lecture

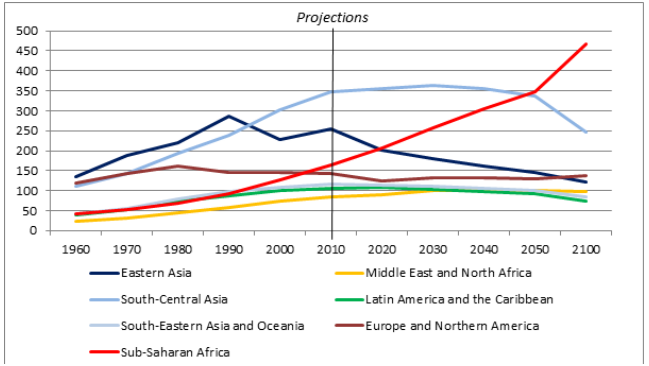
- Why is capacity development in physics in Africa important?
- Do we need policies to build capacity in physics?
- What is our role in shaping the STI policy in our spaces?
- A growing movement of physics capacity building in Africa.

Why capacity building in physics is important for Africa and the international physics community?

The rise of Africa's Youth population



Data source: United Nations (2013) *World Population Prospects: The 2012 Revision.*



UNESCO: Priority Africa Flagship Programmes and Actions

- Strengthening education systems for sustainable development in Africa
- Fostering science for the sustainable management of Africa's natural resources and disaster risk reduction
- Harnessing STI and Knowledge for the Sustainable Socio-Economic Development in Africa

- Africa is positively changing at an extraordinary speed.
- But with change also comes risk.
- Rapid urbanization, growing population, youth unemployment, inequality and social exclusion, new natural resource finds and a changing climate as well as peacebuilding processes, all have the potential to place African societies under considerable strain.

https://en.unesco.org/priorityafrica/flagshipprogrammes

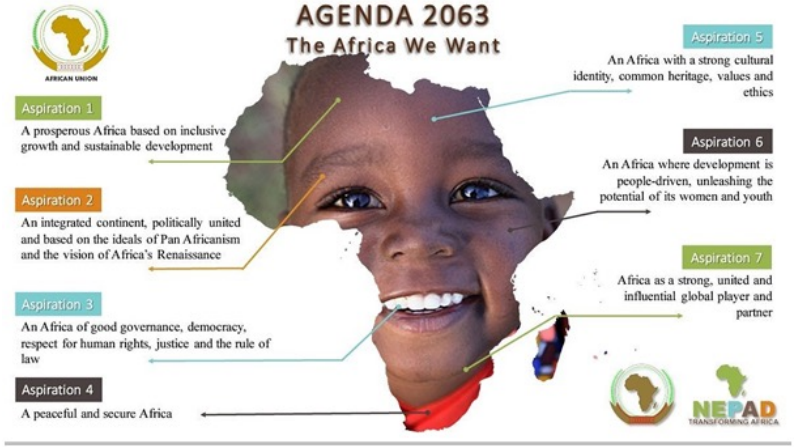
UNESCO: Priority Africa Flagship Programmes and Actions

- Stability and prosperity start in schools, with quality education, to teach skills for jobs, and skills for peace to all African youth. In a continent where more than 60% of the population is under 25 - empowering people means educating youth, especially girls.
- The cradle of humanity is a powerhouse of cultural diversity and the "big origin" story.
- Education should involve teaching the history of Africa that has shaped the world.
- It should be about social networking, teaching and training STI to respond to socio-economic and environmental challenges

https://en.unesco.org/priorityafrica/flagshipprogrammes

Africa and the UN SDGs

Africa is expected to play a significant role in achieving the sustainable development goals.



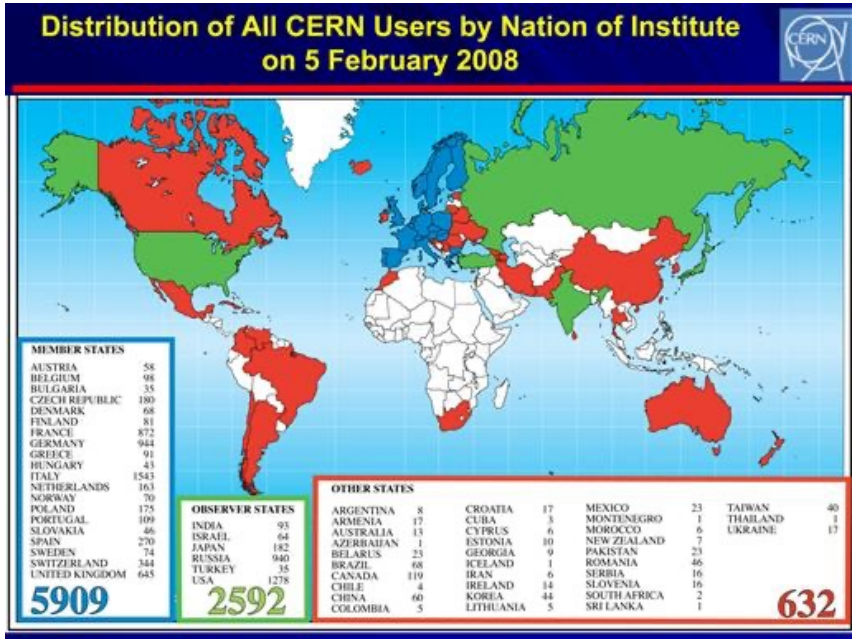
IUPAP Centenary YEARS 1922 - 2022

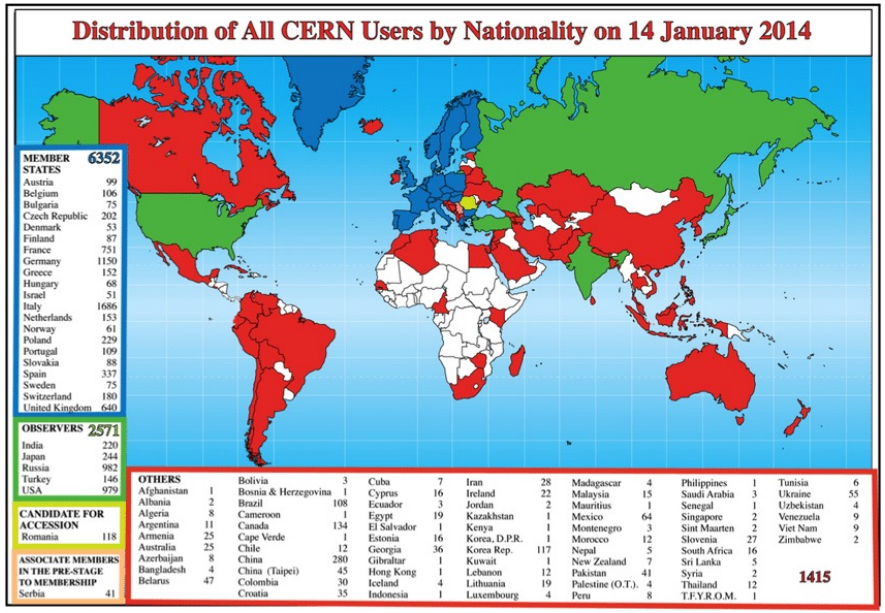
United Nations Educational, Scientific and Cultural Organization

IYBSSD2022
International Year Basic Sciences for Sustainable Development

Africa is participating in IYBSSD and IUPAP Centenary celebrations

High Energy Physics in Africa



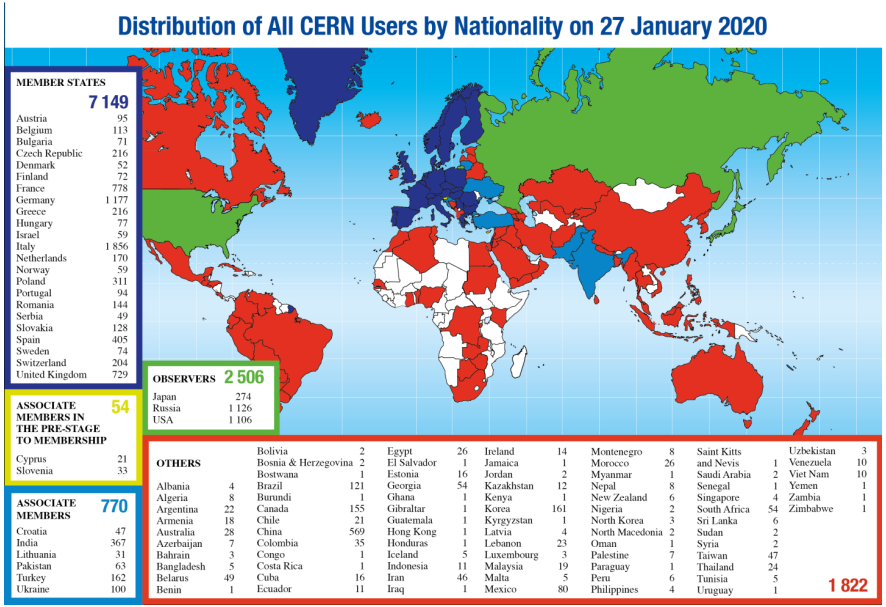


Africa's participation in international HEP

- Africa's participation in international HEP facilities remains extremely low.

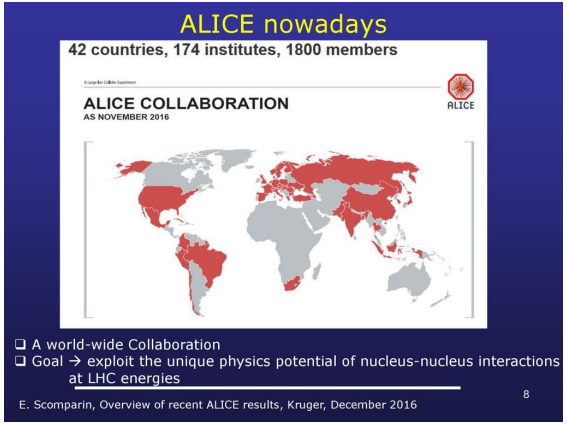
About 1.1% of CERN users are African Nationals

Not limited to CERN, a broader issue



Africa's participation in international HEP

- About 43 countries with one African country
- About 178 institutes of which 2 are from South Africa
- Over 1900 members of which 5 are from South Africa



South Africa
SA-CERN programme
ATLAS, ALICE, ISOLDE, CERN, Theory

science & innovation
Department: Science and Innovation
REPUBLIC OF SOUTH AFRICA

Participating institutions : 1 National Facility (iThemba LABS) and 10 Universities

	ATLAS	ALICE	ISOLDE	Theory	Total
PhD	6	5	6	8	25
MSc	19	2	7	15	43
Accad Staff	7	6	6	7	26
Tech Staff	3				3
Post Docs	5	2	2	2	8

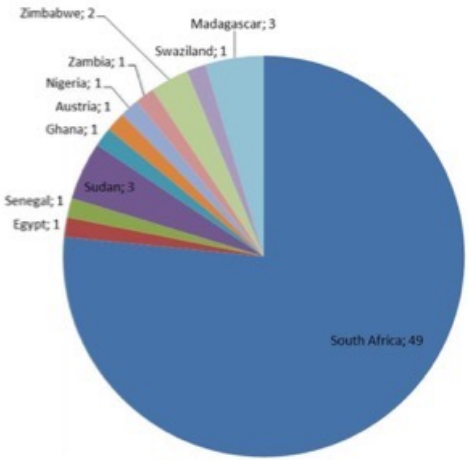
2017 numbers, increasing trajectory

- SA has a long history in High Energy Physics, eg : 1st neutrino discovered and studied in nature 1965
  - Long history at CERN, BNL, JLAB, JINR, others
  - Also a long history of theoretical contributions
- **SA-CERN Co-operation Agreement 1992**
- Now formal participation at CERN and JINR

Most HEP now in the SA-CERN and JINR Programmes

Decades of "ad hoc" participation

- ALICE since 2001
- ATLAS since 2010
- ISOLDE since 2017
- Theory
- JINR since 2005



Courtesy of Simon Connell

Change the World

Africa participation at ICHEP

Summary and Outlook

- Introduction
- Happy 50th birthday Standard Model!
- ICHEP 2018
- Thoughts for the future

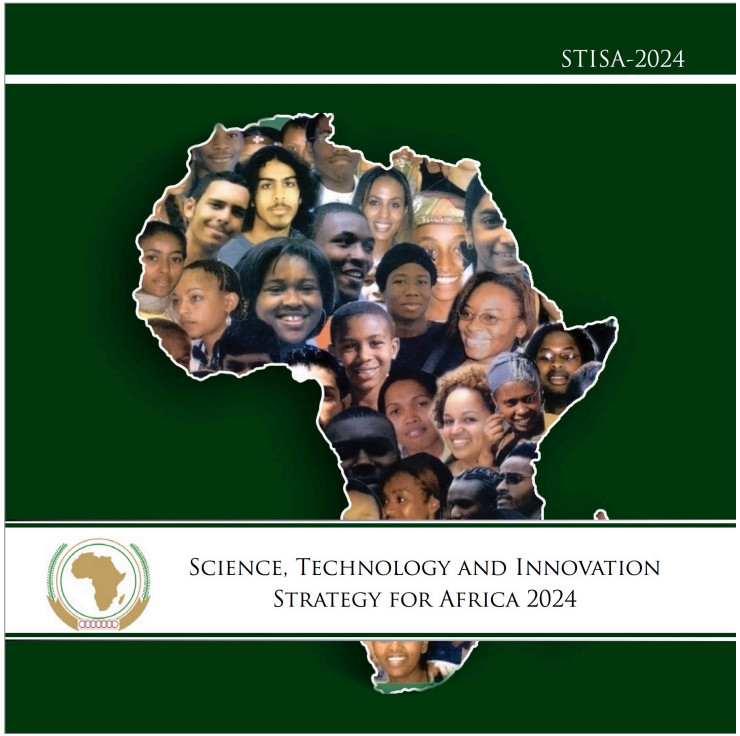
- **Broad and exciting conference**
  - Experiment, phenomenology, theory, astro-particle, accelerator, detector, computing, education, diversity, applications
  - 1119 participants (213 women, 906 men)
  - 835 parallel talks in 16 sections
  - 41 plenary talks
  - 2 award lectures
  - 6 satellite meetings
  - 2 public lectures
  - 226 posters (3 award talks)
  - Director's panel
- *Not* a detailed/complete summary

- Asia/Pacific: 560
- Europe: 414
- N/S America: 137
- Africa: 8
- Antarctica: 0

STI policy in Africa

Policy on STI in Africa

- The African Union's Science Technology and Innovation Strategy for Africa (STISA-2024) calls for knowledge-based economies
- Driven by STI so that we can address and respond to the social, environmental and economic challenges of the 21st century



Policy on STI

- Science, technology and innovation (STI) play a central role in national, regional and global sustainable socio-economic development
- Knowledge-based economic growth requires partnerships between governments (policy makers), science/knowledge producers (universities, research and development institutions), industry, and civil society

Evolution of innovation governance

- First evolution of innovation governance is associated with the work of Vannevar Bush, 'Science: The endless frontier' (1945)
- In this paper, Bush argued that, for universities to engage in R&D, the US government would need to stimulate innovation by increasing research funding while respecting the autonomy of universities
- From the 1960s to the 1980s, universities and industry were government-controlled and regulated. This seems to be the case in most African countries today.
- The 1980s and 1990s the industries and the universities were operating in accordance with their own developmental strategy – with little or no interconnection between one another – and so the governmental influence on engagement between universities and industries was reduced.

Evolution of innovation governance

- In Africa we should consider a system of interconnected subsystems namely:
  - (i) university systems for knowledge generation and dissemination;
  - (ii) industrial systems generating and controlling financial capital;
  - (iii) government or political systems with political, regulatory and legislative capital;
  - (iv) civil society, comprising non-governmental organisations which have social capital to safeguard and engage in promoting and upholding the cultural, social and contextual values of society; and
  - (v) the natural environment encompassing natural capital elements such as 'natural resources, climate, air quality and geological stability'

https://journals.sagepub.com/doi/10.1177/09504222211026218

African countries and STI policy

Table 2. Rwanda and South Africa: Summary of distinctive research and innovation features.

Country settings	Rwanda	South Africa	Features
Population, total (millions)	12.30	57.78	Overview and demographic
Surface area (sq. km) (thousands)	26.3	1,219.1	
Poverty rate (% of population)	38.2	53.2 (2010–2015)	
GDP per capita (current US$)	801.65 (2019)[a]	6001.40 (2019)[b]	
Mobile phone subscriptions (per 100 people)	78.9	159.9	
Individuals using Internet (% of population)	21.8	56.2 (2017)	
Higher education institutions	30	149	Higher education, research and innovation ecosystem
Public higher education institutions	1	26 (2016)	
Total (public and private) higher education institutions per 1 million inhabitants	2.4*	2.5*	
Academic staff with PhD (% of all academics, aka university teaching staff)	20.3	43 (2014)[d]	
Annual HEIs doctoral (PhD) graduates	6 (2016/2017)[c]	3164 (2016)	
R&D expenditure (as % of GDP)	0.66	0.82 (2016)	
Higher education expenditure on R&D (HERD) (as % of GDP)	0.08	0.2	
Innovation rate[e]	–	65.4% (2014)	
STI policy	National STI Policy (2020)	STI White Paper (2019)	STI policy and governance ecosystems
	Based on TH framework	Based on QuadH framework	
Governance: institutional settings and structure	No S&T Ministry	ST&HE[f] ministry	
	A single agency (NCST[g]) coordinates R&I and funding	Multiple agencies (DSI, NRF[h] etc.) coordinate R&I and funding	

Source: AUDA-NEPAD (2014); GoSA (2016); British Council (2018); World Bank (WB, 2018a, 2018b); AU (2019); GoR (2019b).

Table 3. Rwanda and South Africa: Key observations of similarities and contrasts in R&I and STI characteristics.

R&D and STI characteristics	Similarity	Contrast
R&D expenditure as % of GDP and GDP per capita	R&D expenditure as % of GDP of 0.66 and 0.82, respectively, for Rwanda and South Africa exceeds the SSA average (0.5).	South Africa's GDP per capita is over seven times as high as that of Rwanda, which partly demonstrates Rwanda's drastic effort in investing in R&D in relation to its lower economic performance.
Organisational and institutional settings for human capital development	2.4 and 2.5 higher education institutions per million inhabitants in Rwanda and South Africa, respectively.	Universities in South Africa produce significantly more doctoral (PhD) graduates than Rwanda, the ratio being about 527%, which partly explains the divergence in scientific and technological capabilities in the two countries.The number of doctoral academic staff (PhD holders) in South Africa is over twice that in Rwanda, which is reflected in a similar discrepancy between the two nations in respect of R&D intensity in higher education.
HE and R&I	In both countries the higher education sectors (more generally R&I) are dominated by public universities.	Rwanda has only one public research university – the University of Rwanda (UR),[a] while South Africa boasts 26 public higher education institutions operating independently from one another.
STI policy	The two countries have relatively new STI policies.	Rwanda's STI policy (2019) was conceptually designed through the lens of TH while South Africa's STI White Paper (2019) was designed on the basis of a QuadH framework. This partly implies the divergence in actors' engagement in policymaking and governance (this is discussed further in this study).
STI governance	–	With no dedicated national S&T Ministry, Rwanda's R&I programmes, STI policy implementation and other STI-related activities are coordinated and funded through a single semi-autonomous public entity (NCST). In South Africa's context, the DSI under the ST&HE Ministry is responsible for the design of STI policy. It also oversees the implementation and coordination of STI policy. In addition, DSI oversees R&I coordination and/or funding in collaboration with multiple agencies.

Note: [a]The University of Rwanda (UR) is the merger of seven former public universities and higher education institutes in Rwanda.

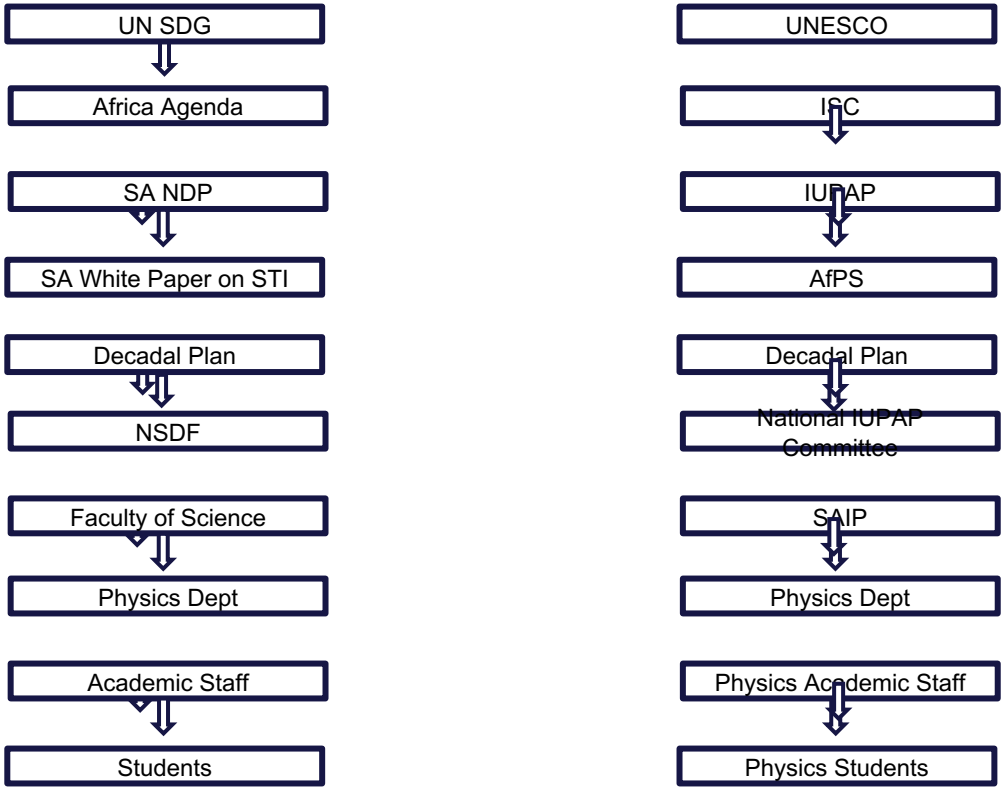
https://journals.sagepub.com/doi/10.1177/09504222211026218

Twiringiyimana, Daniels and Chataway

Change the World

What should you do to influence policy in your spaces?

Physicists are key to influencing STI policies



Lessons from Snowmass 2021

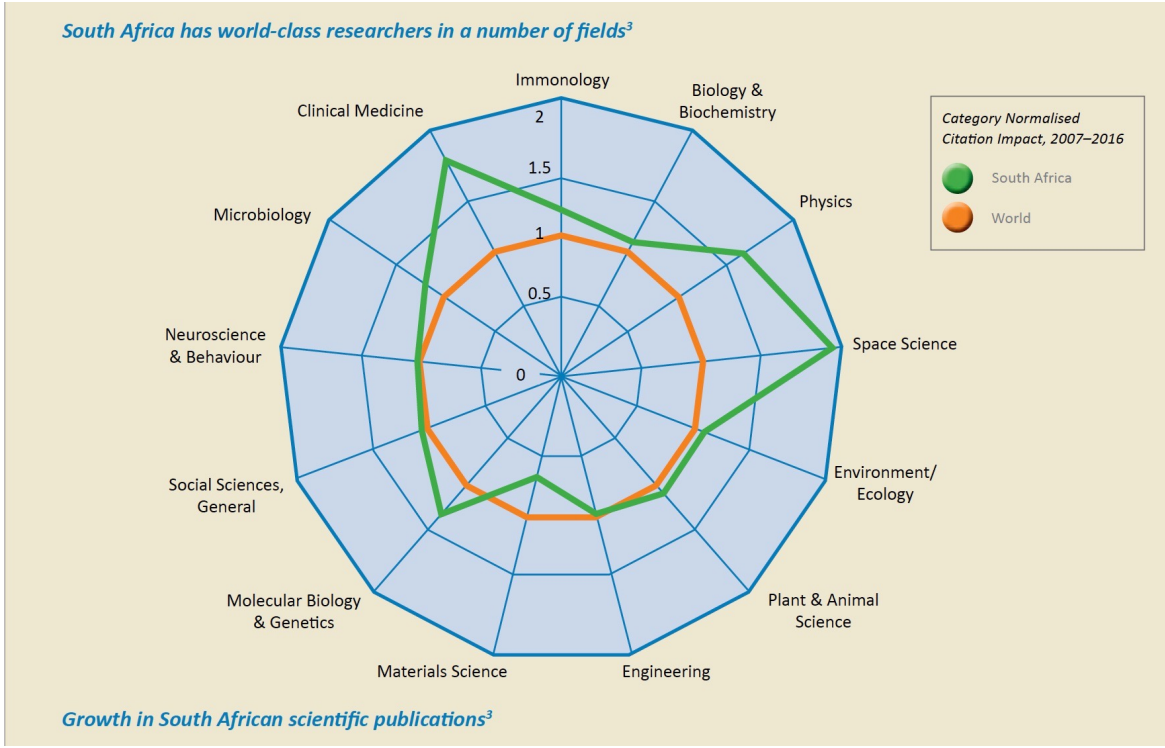
- These Snowmass contributed might be of particular interest to you
- I strongly recommend anyone interested in influencing policies to study these white papers and their recommendations.
-

- Why should the U.S. care about high energy physics in Africa and Latin America? arXiv:2203.10060
- The Necessity of International Particle Physics Opportunities for American Education arXiv:2203.09336
-
- The need for structural changes to create impactful public engagement in US particle physics arXiv:2203.08916
-
- Building a Culture of Equitable Access and Success for Marginalized Members in Today's Particle Physics Community
- arXiv:2206.01849

In Africa, change in STI governance at all levels within the physics community and its stakeholders is necessary for an accelerated capacity development.

We should present what is!

Physicist should present data to influence policy and to support our science case



Diversity & Inclusion @ Nelson Mandela University

Diversity and Inclusion at Mandela University

This starts at leadership level:

Chancellor - Geraldine Fraser-Moleketi,
Vice-Chancellor - Professor Sibongile Muthwa
Chair of Council - Ambassador Nosipho January-Bardill.

- Two of the four Deputy Vice-Chancellor positions are occupied by women
- Five of the seven Executive Deans are women

Building a culture of Diversity & Inclusion starts at home.

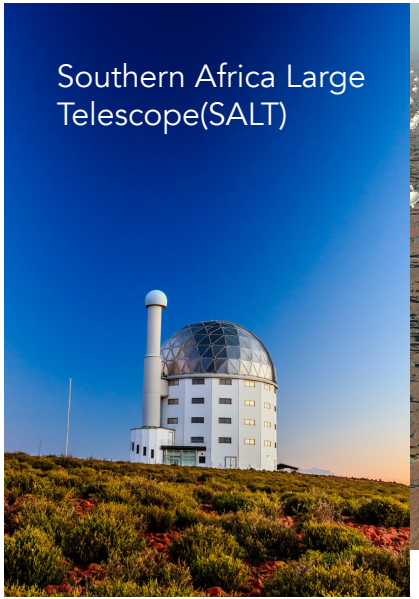
NELSON MANDELA UNIVERSITY

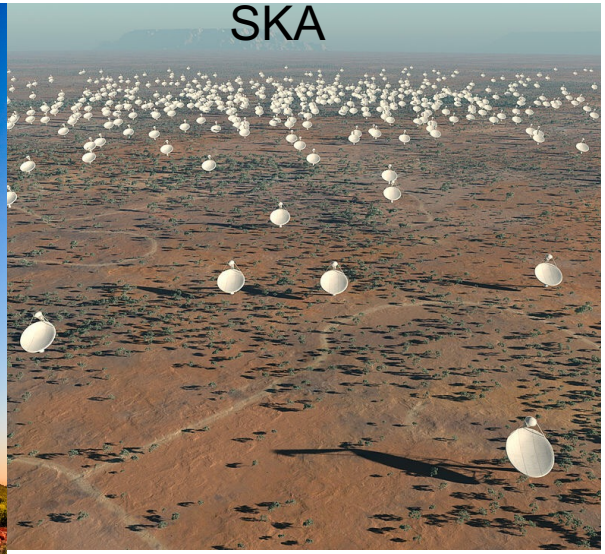
Africa is fertile with possibilities

Why is physics capacity building in Africa important?

- Major research research facilities coming to Africa
- SKA - The largest radio astronomy observatory to be (co-) hosted by South Africa (70%) and Australia (30%) : meaning that two Global/Geographical South nations will be at the heart of managing and driving the project; and this will need a large African STEM workforce
- Africa and in particular Southern Africa has geographic advantage in astronomy research (besides point of human origins)
- In Africa the diversity challenge is both local and global.

Multi-messenger Astronomy





SKA science and the birth of multi-messenger astronomy

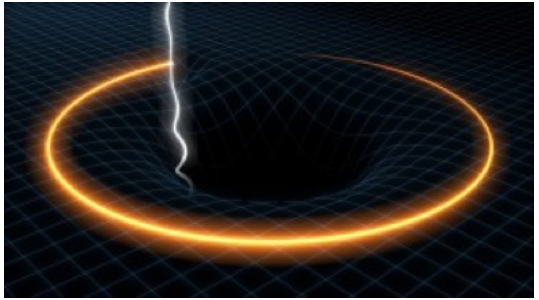
The Astrophysical Journal Letters, 848:L12 (59pp), 2017 October 20
https://doi.org/10.3847/2041-8213/aa91c9

Multi-messenger Observations of a Binary Neutron Star Merger

LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc

A comparison between SALT/SAAO observations and kilonova models for AT 2017gfo: the first electromagnetic counterpart of a gravitational wave transient – GW170817

Buckley et al.
McCully et al.



NELSON MANDELA UNIVERSITY

Rural capacity building

- Science engagement in primary and secondary schooling education system
- Going from province to province visiting schools and HEIs – and beyond borders from one country to the next
- Talking about wonders of nuclear physics, particle physics, astrophysics, and cosmology
- Science Centres in SA have transformed themselves into into training Centres for STEM learners and educators – can credit myself here☺

NELSON MANDELA UNIVERSITY

…has challenges in Africa

- Science engagement in in rural schools, in open spaces and under trees
- These challenges require local solutions that are implemented globally
- No time to wait for luxury infrastructure

Capacity building through educator training

- Programmes for STEM educators
- Training teachers has ripple
- Effects – as evidenced by schools which improved their results
- SAIP has an educators development programme which has been very successful
- The programme is now rolled to the provinces and neighbouring African countries

Capacity building at universities

- Annual Hot and Dense Matter in Heavy Ion Collisions and Astrophysics (HDM) school and workshop
- The school curriculum covers introductory topics including mathematical physics, computational physics, nuclear physics, particle physics, astrophysics and cosmology
- The HEPP Workshop series - The topics to be covered will be high-energy theory and phenomenology (heavy ions, pp, ep, ee collisions), ATLAS physics and ALICE physics.
- National Institute for Theoretical and Computational Sciences (NITheCS) Internship Programme. The NMU-NITheCS internship programme is a 4 weeks+ programme in topics spanning nuclear and particle physics, astrophysics and cosmology as well as mathematical and computational skills

Capacity building in Africa

- The African School of Fundamental Physics and Applications (ASP)
- The African Conference on Fundamental Physics and Applications (ACP)
- The African Strategy on Fundamental & Applied Physics (ASFAP)
- The African Physical Society (AfPS)
- The African Astronomical Society (AfAS)

African School of Fundamental Physics and Applications

- Also known as “The African School of Physics”
- Acronym: ASP; Logo: as above
- https://www.africanschoolofphysics.org
- Organized biennially in different African countries since 2010 by an International Organizing Committee (IOC), ASP-IOC@CERN.CH

ASP	Host Country	Applicants	Students	Mentorship	Teachers	Pupils	Conference
2010	South Africa	125	65	Continuously, even when there is no formal school			
2012	Ghana	138	50				
2014	Senegal	330	70				
2016	Rwanda	429	75	Program formalized in 2016. Runs continuously	20	150	
2018	Namibia	523	85		63	> 1200	+60
2020	Morocco						
2021	Online	N/A	94				+649

The African Conference on Fundamental and Applied Physics (ACP)

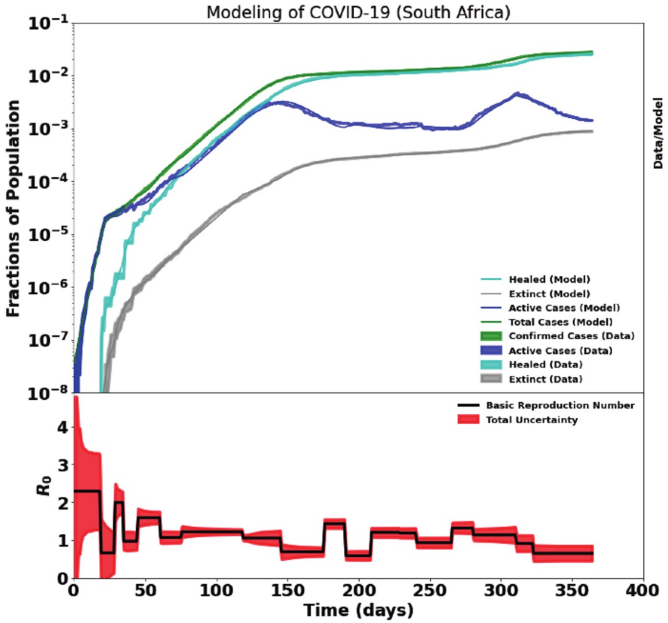
- **One week, integrated in ASP since 2018**
- **The first ACP tool place in Namibia in July 2018**
- **Formalized to promote**
  - Participation of African research faculties
  - Encourage participation of African students not selected for ASP due to budget constraints
  - International conference open to anyone

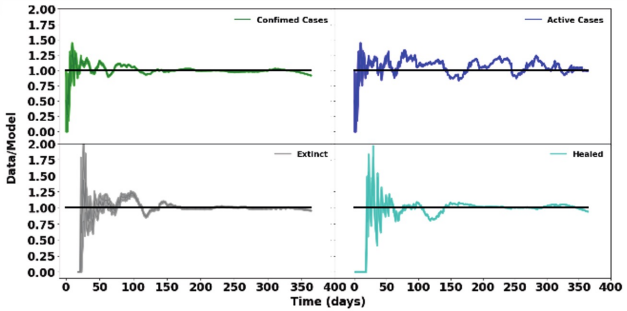
Prof. Lerothodi Leeuw at ACP2018

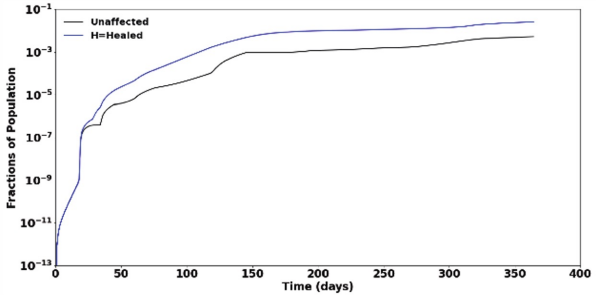
ASP Mentorship during COVID-19 Pandemic

APS alumni learned about

- Analysis tools in C++ and Python
- Understanding their data
- Modeling, goodness of fit
- Statistical analysis
- Uncertainties (statistical, systematic)
- Estimation of basic reproduction number R_0
- Giving scientific talks
- Writing a paper and responding referees comments







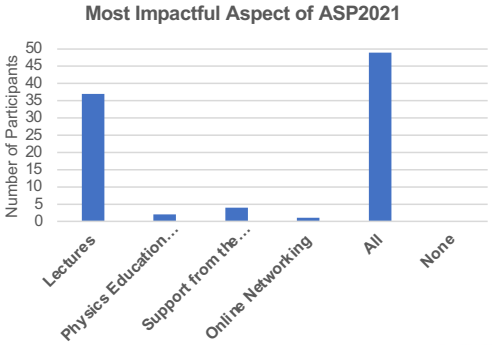
First 12 months of COVID-19 data of 10 countries analyzed
> 50% of all COVID-19 cases in Africa were analyzed by 13 African students

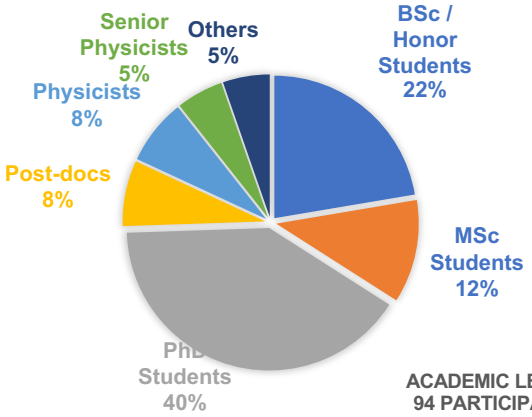
Study published in the Scientific African
https://doi.org/10.1016/j.sciaf.2021.e00987

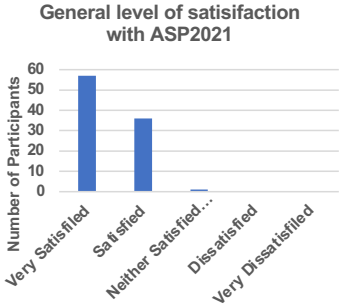
See the talk by Toivo S. Mabote (Mozambique, ASP2020 alumnus)
On Friday, March 11, 2022

ASP2021, July 19-30, 2021; online school

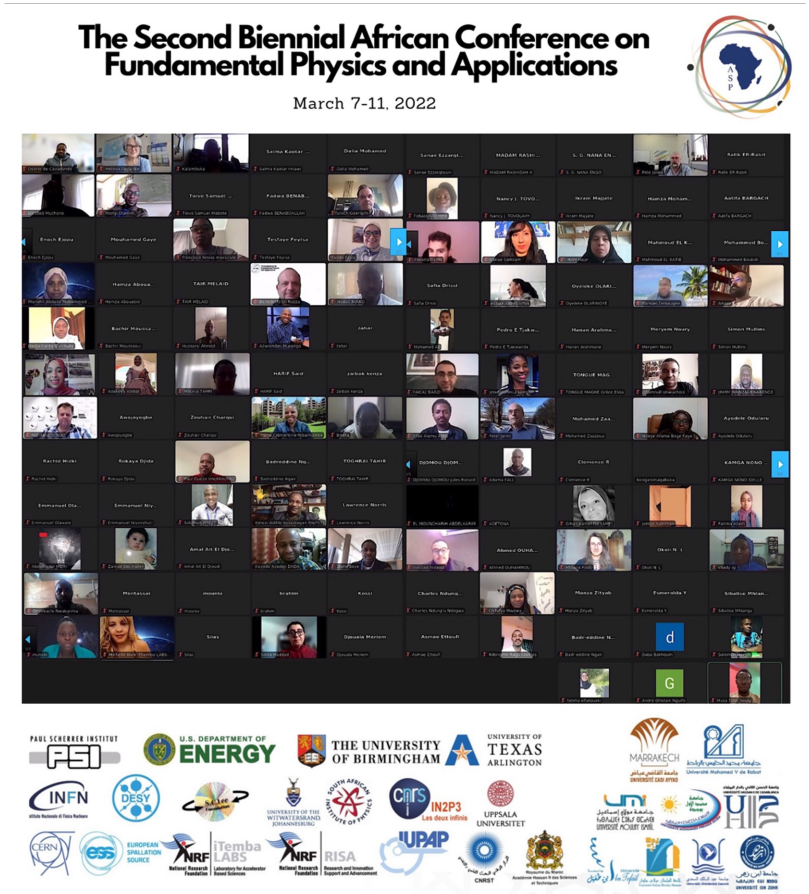
- **ASP2020-Morocco**
  - Cancelled because of COVID-19
  - A 2-week online version organized as ASP2021







Participant group photo, March 11, 2022



African Strategy for Fundamental Physics & Applications (ASFAP)

- ASFAP is an opportunity for African physicists (including particle physicists) to come together, identify and document a scientific vision for the future of physics (including particle physics) in Africa.
- The particle physics community will define the particle physics' direction for the next decade: identify and prioritize the actions/activities in the coming years.
- This initiative will refine Africa's needs and capacities in particle physics in order to present them as Letters of Interest (LoI).
- Subsequent sessions are planned to emerge with a collective strategy of physics (including particle physics).

Your participation in the ASP2022 forms part of a growing *physics capacity development* movement in Africa

International Organising Committee (IOC)

B. Acharya (ICTP and King's College London)
K. Assamagan (BNL)
A. Dabrowski (CERN)
C. Darve (ESS)
J. Ellis (King's College London)
F. Ferroni (GSSI-INFN)
S. Muanza (CNRS-IN2P3)

Local Organising Committee (LOC

V. Bongela (Nelson Mandela Universit
N. Hashe (Nelson Mandela University
A. Muronga (Nelson Mandela Univers
R. Mosia (Nelson Mandela University)
S. Ngesi (Nelson Mandela University)
A. Tabalaza (Nelson Mandela Univers
S. Thwala (Nelson Mandela University
T. Trantaal (Nelson Mandela Universit
EE. van Dyk (Nelson Mandela Univers
A. Venter (Nelson Mandela University
B. Masara (South African Institute of Physics)
N. Mahani (South African Institute of Physics)

Regional Organising Committee

S. Connell (University of Johannesburg)
M. Diale (University of Pretoria)
E. Maluta (University of Venda)
B. Mellado (University of the Witwatersrand) (iThemba LABS)
I. Gledhill (University of the Witwatersrand)
E. Kasai (University of Namibia)
RE. Simon (University of Botswana)
JM. Tshitenge (University of Kinshasa)
TD. Bucher(Cape Peninsula University of Technology)
Z. Katamzi - Joseph (South African National Space Agency)
JB. Habarulema (South African National Space Agency)
R. Maphanga (Council for Scientific and Industrial Research)
S. Mullins (Botswana International University of Science and Technology)