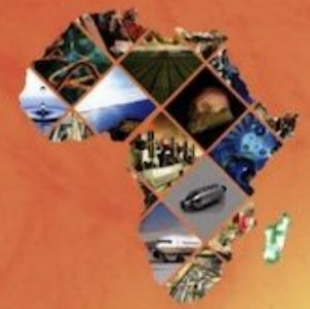
THE AFRICAN LIGHTSOURCE

Towards a Lightsource for the African Continent



African Light Source Conceptual Design Report

Tabbetha A. Dobbins

Professor

Dept. of Physics & Astronomy

Interim VP for Research and Dean of the Graduate School

Rowan University (Glassboro, NJ)

http://users.rowan.edu/~dobbins/

Dorian Bohler

Engineering Physicist

Linac and FEL Division

SLAC National Laboratory (Menlo Park, CA)

https://profiles.stanford.edu/dorian-bohler

AfLS3 Workshop
Nov 19, 2020

What will a light source mean for Africa?

The African Light Source Project

www.AfricanLightSource.org

Cost: ~$1.0 B

(construction– depending on size & capabilities)

Where: Somewhere on the continent of Africa

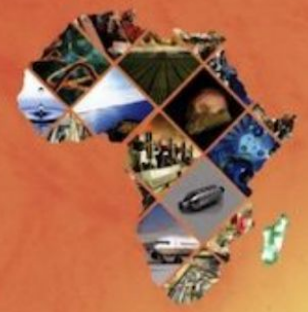
When: Within 20 years (~speculation~)

How: With planning laid out in the AfLS CDR!

"The True Size of Africa"
Generated by Kai Krause (graphic designer)
http://kai.sub.blue/en/africa.html

THE AFRICAN LIGHTSOURCE

Towards a Lightsource for the African Continent



http://www.africanlightsource.org/afls-roadmap-cdr/

Socio-economic benefits

- Boost African Scientific Research, Research Capacity (Continent, regions, Institutes), Capacity-Building – African Science Renaissance
- Global Research Community led by Pan-African Scientists and Professionals
- Tackling Disease (Malaria, TB, AIDS, Ebola, …) from a molecular level
- Unique African Research Opportunities attracting international collaboration: Energy, African Environmental Science, Cradle of Humankind, Cradle of Culture, Mineral Beneficiation, Agriculture
- Mobility, Conference, Schools, International mentoring partnerships in student raining, Regional Centers of Excellence, Local feeder instrumentation
- Building research capacity in Industry and new competitive industries
- Science for Peace (e.g. SESAME)
- Return of the African Science Diaspora – new opportunities for young scientists
- For African countries to take control of their destinies and become major players in the International community
- Regional Facilities offering technological solutions in support of the light source.

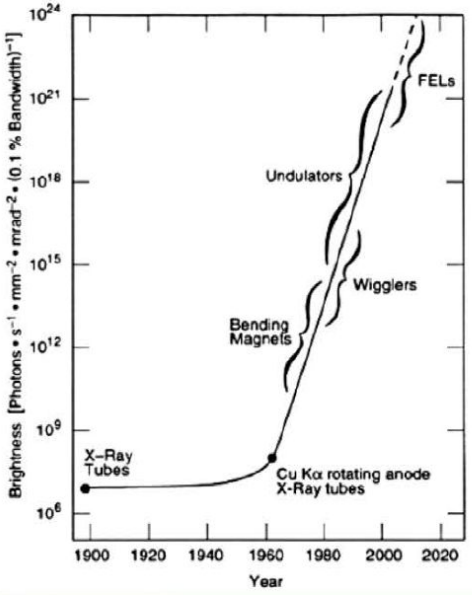
THE AFRICAN LIGHTSOURCE

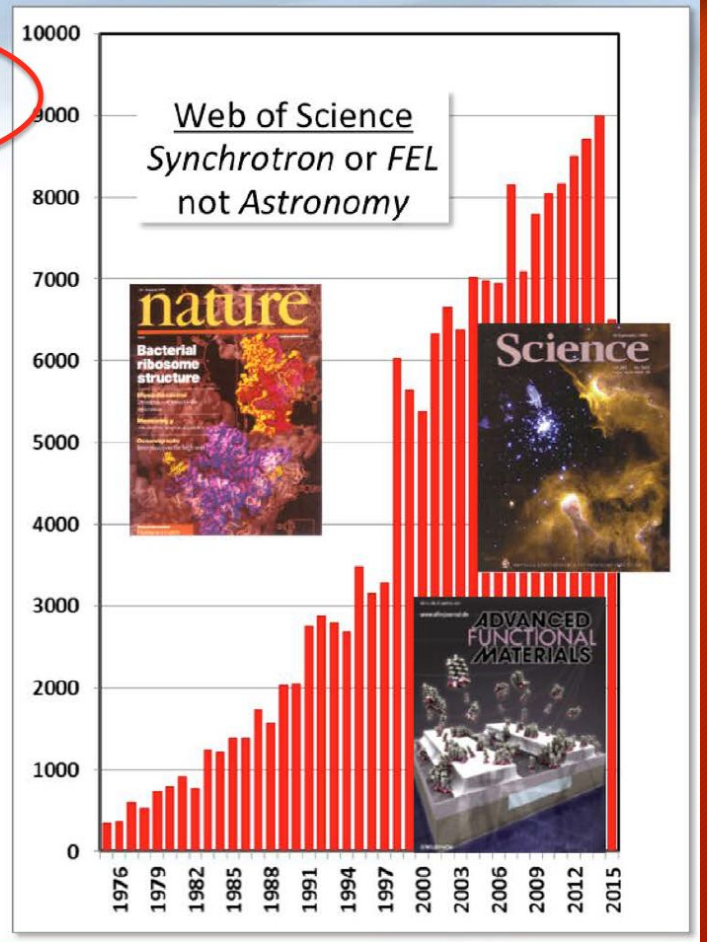
Towards a Lightsource for the African Continent

http://www.africanlightsource.org/afls-roadmap-cdr/

Growth in Synchrotron Science

- Steady growth in past four decades – big jump in late 1990's fueled by 3rd-SRs





THE AFRICAN LIGHTSOURCE

Towards a Lightsource for the African Continent

http://www.africanlightsource.org/afls-roadmap-cdr/

https://worldmapper.org

The AfLS CDR's Historical Perspective

http://www.africanlightsource.org/afls-roadmap-cdr/

November 2015 - Grenoble Resolutions and Roadmap

January 2019 - CDR Whitepaper by Ernest Malamud

Nov 8, 2019 - First meeting of CDR Committee (10 members)

Today - Twenty Member CDR Committee (including two student members) underway with planning for a CDR (estimated completion is November 2021 at AfLS in Kigali, Rwanda)

Grenoble Resolutions towards the African Light Source (http://events.saip.org.za/conferenceDisplay.py/getPic?picId=70&confId=61)

1. Advanced light sources are the most transformative scientific instruments similar to the invention of conventional lasers and computers.

2. Advanced light sources are revolutionizing a myriad of fundamental and applied sciences, including agriculture, biology, biomedicine, chemistry, climate and environmental eco-systems science, energy, engineering, geology, heritage studies, materials science, nanotechnology, paleontology, pharmaceutical discoveries, physics, with an accompanying impact on sustainable industry.

3. The community of researchers around the world are striving collaboratively to construct ever more intense sources of electromagnetic radiation, specifically derived from synchrotron light sources and X-ray free-electron lasers (XFELs), to address the most challenging questions in living and condensed matter sciences.

4. The African Light Source is expected to contribute significantly to the African Science Renaissance, the return of the African Science Diaspora, the enhancement of University Education, the training of a new generation of young researchers, the growth of competitive African industries, and the advancement of research that addresses issues, challenges and concerns relevant to Africa.

5. For African countries to take control of their destinies and become major players in the international community, it is inevitable that a light source must begin construction somewhere on the African continent in the near future, which will promote peace and collaborations among African nations and the wider global community.

The AfLS CDR Committee Members

http://www.africanlightsource.org/CDR-committee/

1	Riccardo	Bartolini	Diamond Light Source
2	Muaaz	Bhamjee	Univ. of Johannesburg
3	Dorian	Bohler	SLAC - Stanford University
4	George	Clerk	-
5	Simon	Connell	Univ. of Johannesburg
6	Joseph	Daafuor	Univ. of Ghana- Legon
7	Christine	Darve	European Spallation Source (ESS)
8	Tabbetha	Dobbins	Rowan University
9	Kenneth	Evans-Lutterodt	Brookhaven National Laboratory
10	Benson	Frimpong	Univ. of Ghana- Legon
11	Nkem	Khumbah	University of Michigan
12	Ernest	Malamud	FermiLab (retired)
13	Genito	Maure	Universidade Eduardo Mondlane
14	Ed	Mitchell	ESRF
15	Sekazi	Mtingwa	TriSEED, LLC
16	Marcus	Newton	Diamond Light Source
17	Prosper	Ngabonziza	MPI-Stuttgart
18	Lawrence	Norris	-
19	Samuel	Sloetjes	Uppsala University
20	Herman	Winick	SLAC - Stanford University (retired)

* Presenting on Machine Design Concepts in this talk

Volumes and Chapters in the CDR

http://www.africanlightsource.org/organizational-chart/afls-executive-committee/

Volume I. Political, Economic Development and Management Concepts
Volume II. Machine Design Concepts
Volume III. Scientific Cases and Technical Capabilities
Volume IV. Integrated Site Design and Construction.

Volumes and Chapters in the CDR

http://www.africanlightsource.org/organizational-chart/afls-executive-committee/

Volume I. Political, Economic Development and Management Concepts
- Chapter 1. The Science Case
- Chapter 2. Economic Benefits Analysis
- Chapter 3. Financial Considerations and Models
- Chapter 4. Light Sources across the world
- Chapter 5. Suggested Roadmap Trajectories and Procedures
- Chapter 6. Roadmap

Volume II. Machine Design Concepts
- Chapter 7. Electron Injector, LINAC
- Chapter 8. Booster
- Chapter 9. Storage Ring
- Chapter 10. XFEL (long-term future options)

Volume III. Scientific Cases and Technical Capabilities
- Chapter 11. Other Technical Capabilities and Innovations

Volume IV. Integrated Site Design and Construction
- Chapter 12. Overall Design Specifications and Building Concepts
- Chapter 13. User Support Laboratories, Feeder Infrastructure, adn Ancillary Technology Labs
- Chapter 14. Computational Infrastructure
- Chapter 15. Zone for Integrated Mega-Science and Innovation Park
- Chapter 16. Site Selection Criteria and Procedures

CDR Volume II: Machine Design Concepts

Members:

- Riccardo Bartolini - Lead Scientist, DESY, Petra IV Accelerator
- Christine Darve - Engineering Scientist, European Spallation Source
- Dorian Bohler - Engineering Physicist, SLAC National Laboratory

Status:

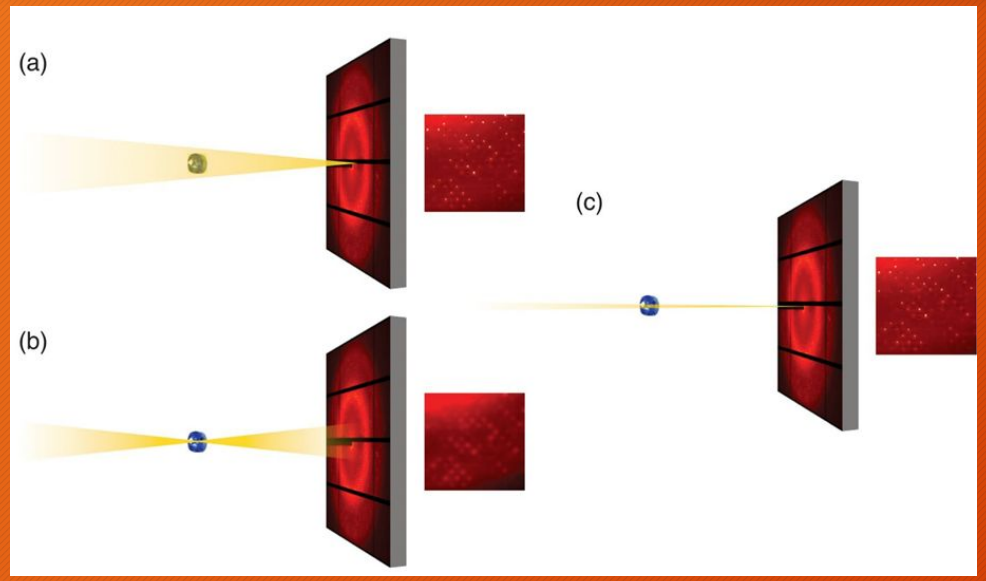
- Reviewing/Building a catalogue of Design Reports
- Drafting whitepaper on machine design considerations for AfLS
- Recruiting other experts to join the effort
- Committed to organizing and contributing to Vol II

Needs:

Establish key parameters to specify AfLS design:

- $$\text{brilliance} = \frac{\text{photons}}{\text{second} \cdot \text{mrad}^2 \cdot \text{mm}^2 \cdot 0.1\%\ \text{BW}}$$
- Emittance $\epsilon_x = \sigma_x \sigma_x'$ $\epsilon_y = \sigma_y \sigma_y'$
- Photon Energy Range
- Number of Beamlines

Tackling Disease Endemic to Africa - from the atomic scale to the whole body



The improved x-ray source at 4th Gen light sources gives crystallographers the ability to determine structures of medicinal drug targets 1 um (or below)

Lightsources.org lists 30+ publications on COVID-19 since march

Published articles

2020.11.10 **Diamond Light Source** (UK), article and video on their website: From nought to sixty in six months... the unmasking of the virus behind COVID-19

2020.10.29 **Canadian Light Source** (Canada) video on their website: Studying how to damage the COVID-19 virus

2020.10.07 **National Synchrotron Light Source II (NSLS-II) at Brookhaven Lab** (NY / USA) article on their website: Steady Progress in the Battle Against C

2020.10.07 **Diamond Light Source** (UK), article on their website: Structural Biology identifies new information to accelerate structure-based drug design

2020.10.06 **MAX IV** (Sweden), article on their website: Tackling SARS CoV-2 viral genome replication machinery using X-rays

2020.08.31 **SLAC** (CA / USA), article also with news about research at **Stanford Synchrotron Radiation Lightsource (SSRL)**: SARS-CoV-2 Spike Protein

2020.08.27 **Diamond Light Source** (UK), article on their website: Structural Biology reveals new target to neutralise COVID-19

2020.08.27 **Canadian Light Source** (Canada) video on their website: Developing more effective drugs

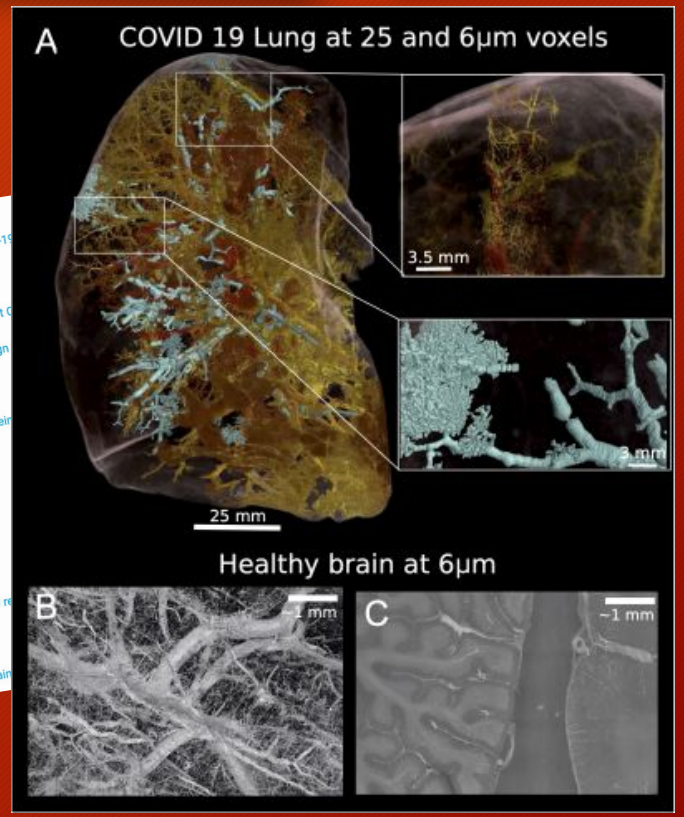
2020.08.25 **Australian Synchrotron (ANSTO)** (Australia) article on their website: More progress on understanding COVID-19

2020.08.24 **DESY** (Germany) article on their website: PETRA III provides new insights into COVID-19 lung tissue

2020.08.11 **Australian Synchrotron (ANSTO)** (Australia) article on their website: Unique immune system of the alpaca being used in COVID-19 re

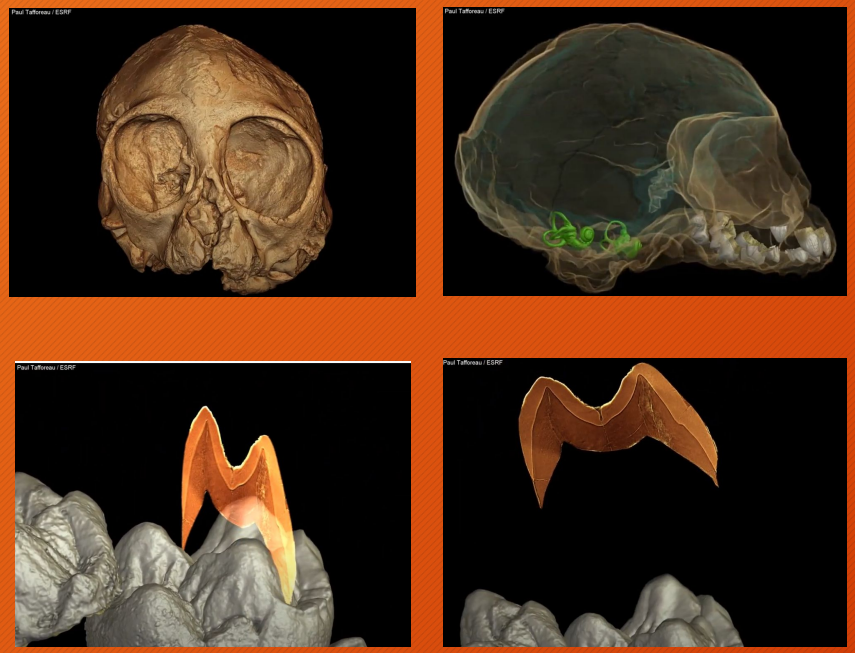
2020.07.30 **Swiss Light Source at PSI** (Switzerland) article on their website: COVID-19 research: Anti-viral strategy with double effect

2020.07.29 **National Synchrotron Light Source II (NSLS-II) at Brookhaven Lab** (NY / USA) article on their website: Ready to join the fight again

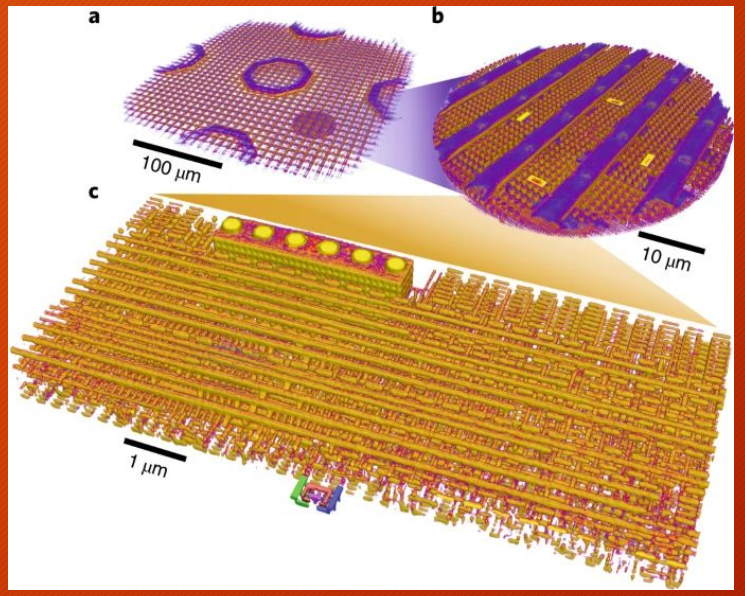


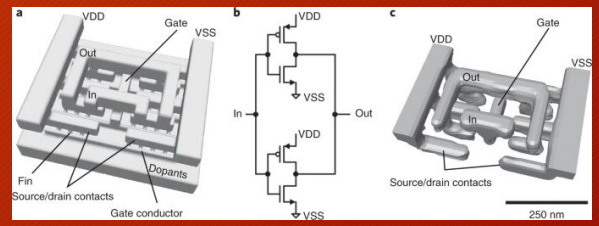
Unpublished results from X-ray tomography studies at ESRF

Research of relevance for Africa - environment, energy, agriculture, clean water, mineral extraction, human origins and the origins of human culture.



13 Million year old fossil Alesi discovered in Kenya and imaged at the ESRF



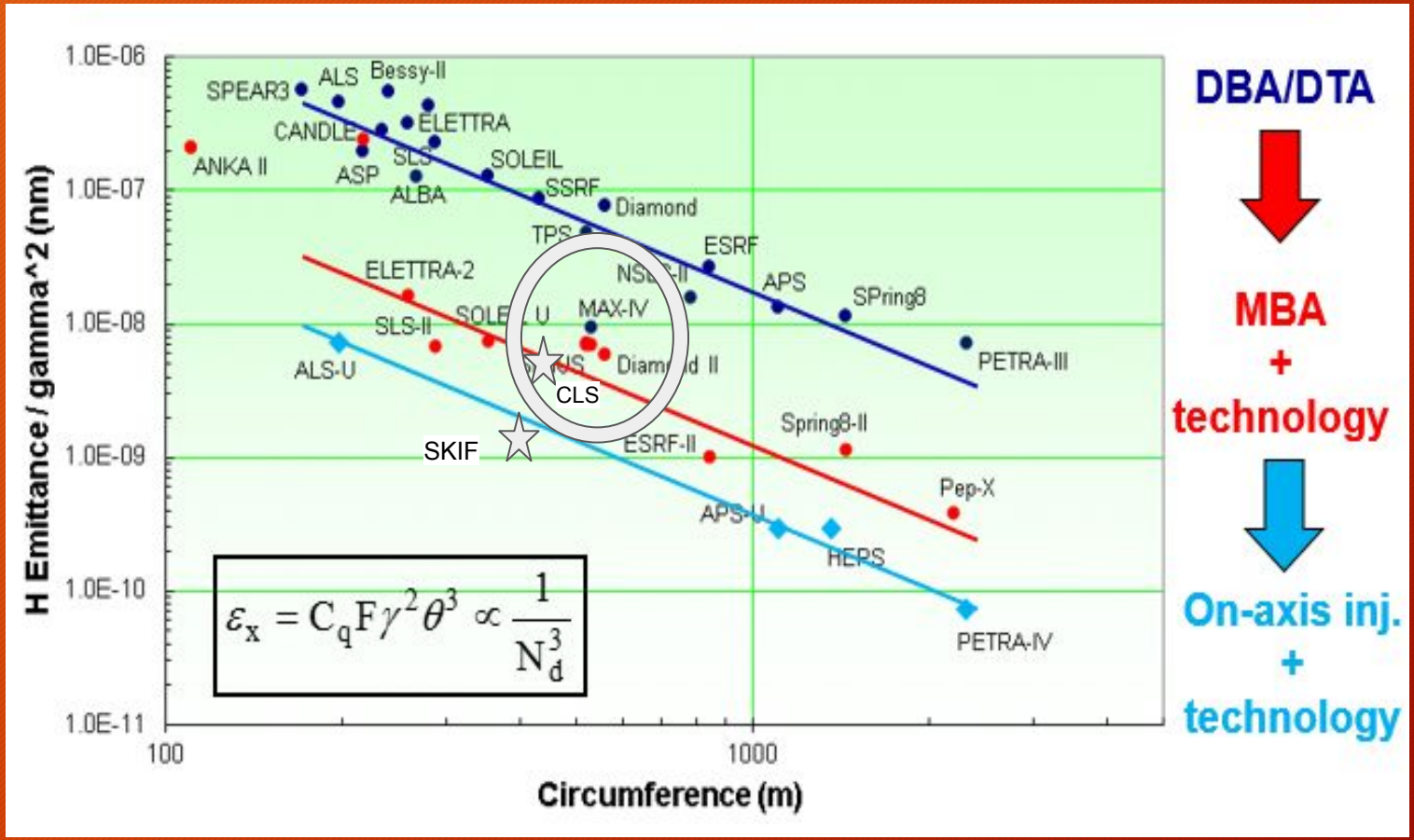


PyXL represents the only non-destructive method for nm res analysis of integrated circuits. Swiss Light Source

State of the Art: 4th Generation Light Sources

Benefits of Smaller emittance:

- Smaller beam (nano vs micro focus)
- Better Angular collimation-cleaner diff patterns
- Better spectral line width / less heat load on optics
- Better coherence
- Higher Flux - more rapid experiments, use of weakly diffracting samples
- Beam more symmetric - easier optics designs



Comments On Cost

Costs:

- **Max IV - 750 MUSD**
- **Canadian Light Source - 750 MUSD**
- **Siberian Circular Photon - 585 MUSD**
- **Sirius - 420 MUSD**
- **Siam Photon Light - II 300 MUSD**
- **Diamond II - 300 MUSD**

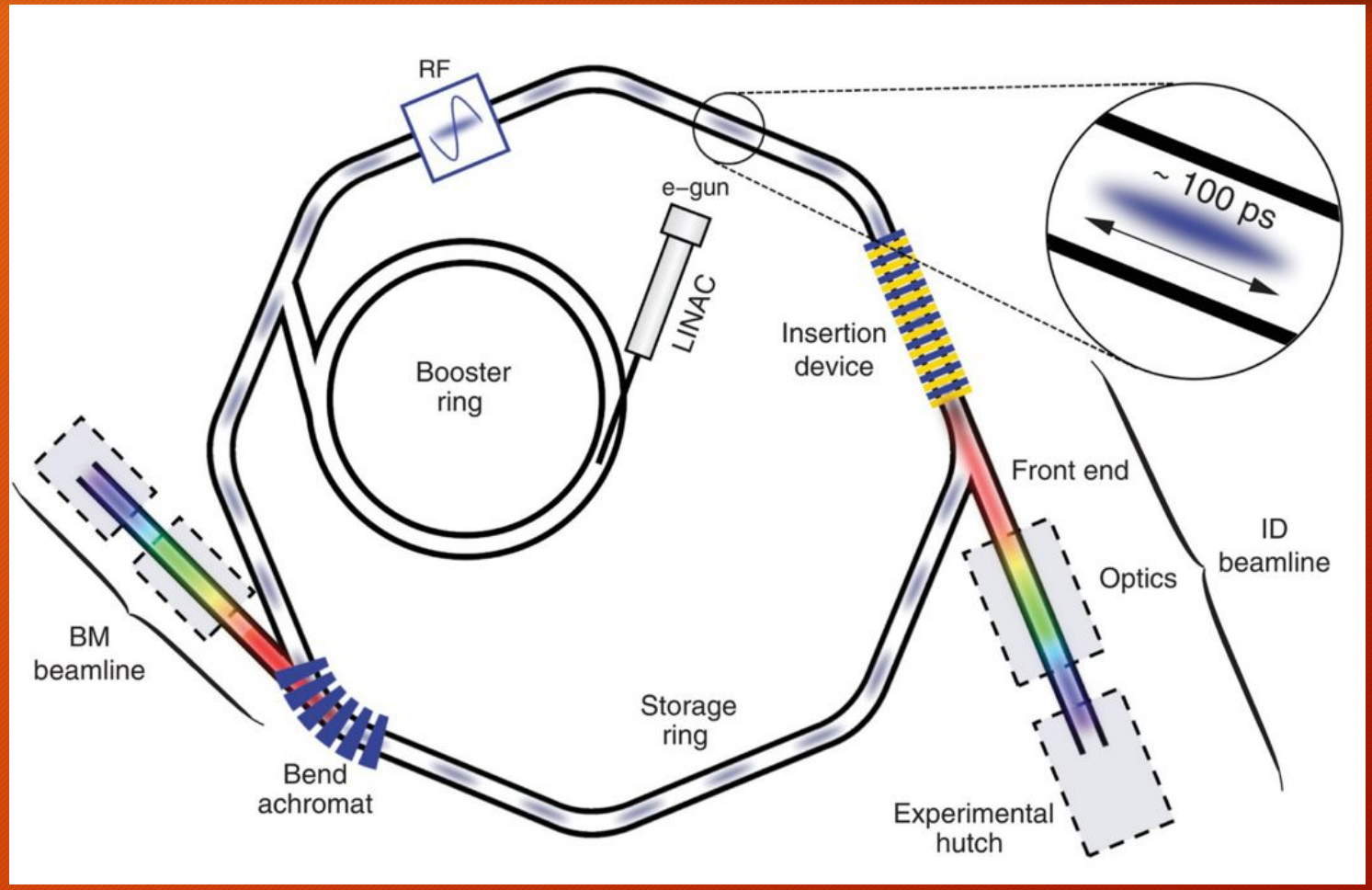
Technological opportunities for Africa:

- **Industrial capacity to support R&D**
- **Facilities to support high standards of machining / quality control**
- **Expertise in many technical fields**
- **Improvement of local infrastructure (power, computing, etc)**
- **Training for technicians, scientists, and engineers**

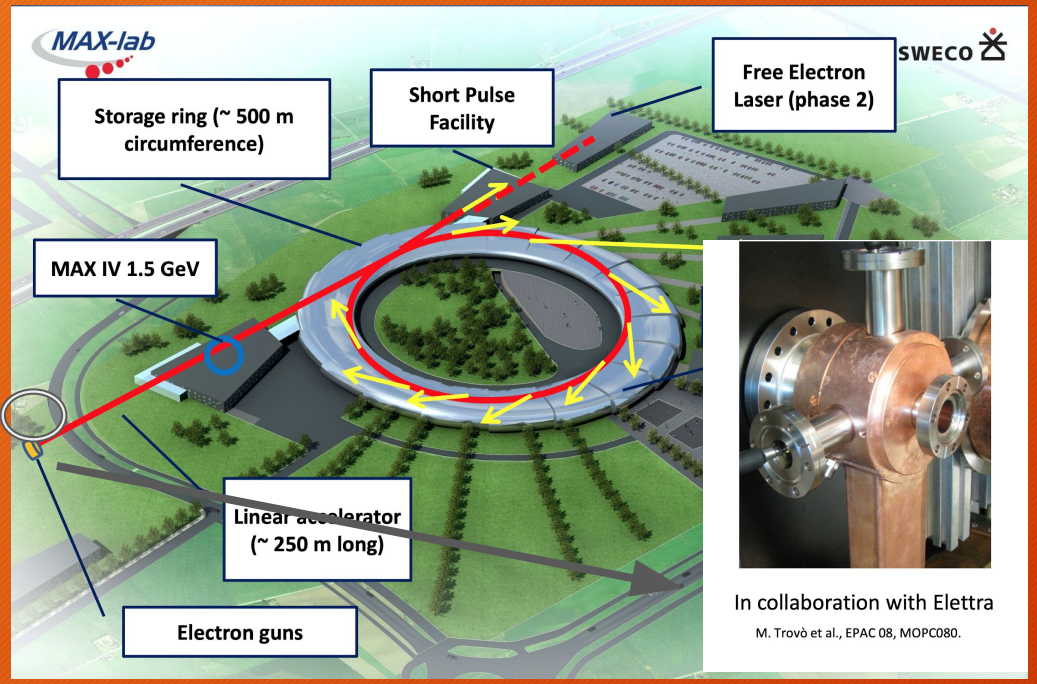
Could add 250M to the budget?

The CDR will place significant efforts towards discussing adequate strategies to ensure opportunities are realized and accounted for

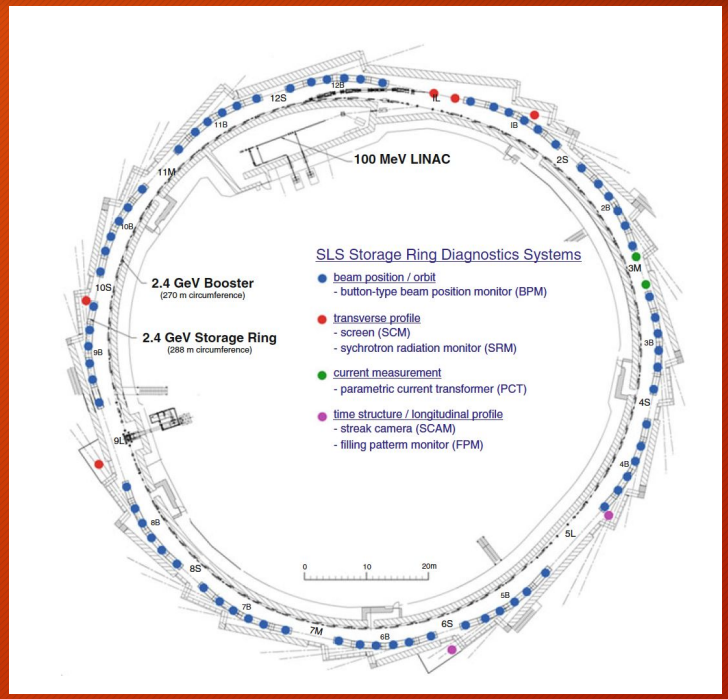
Major Components of Synchrotrons



Injection Technologies



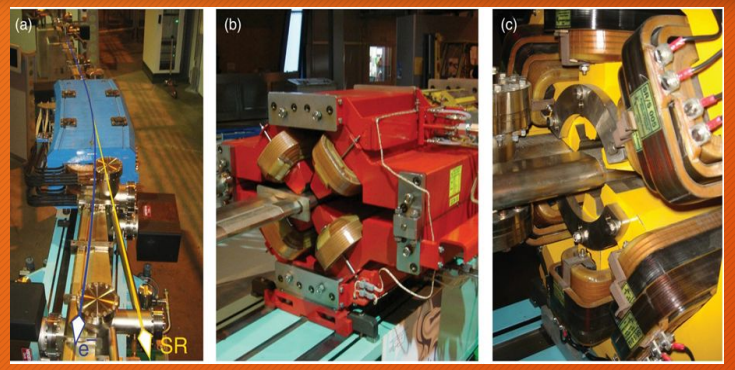
Rendering of MAX-IV Facility



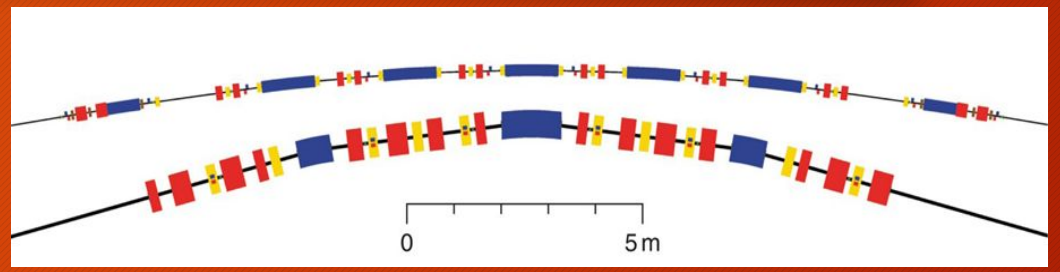
Schematic of SLS which accommodates both the booster ring and the storage ring in the same tunnel

Most modern facilities operate in top-up mode however ‘on-axis’ injection may further increase beam quality

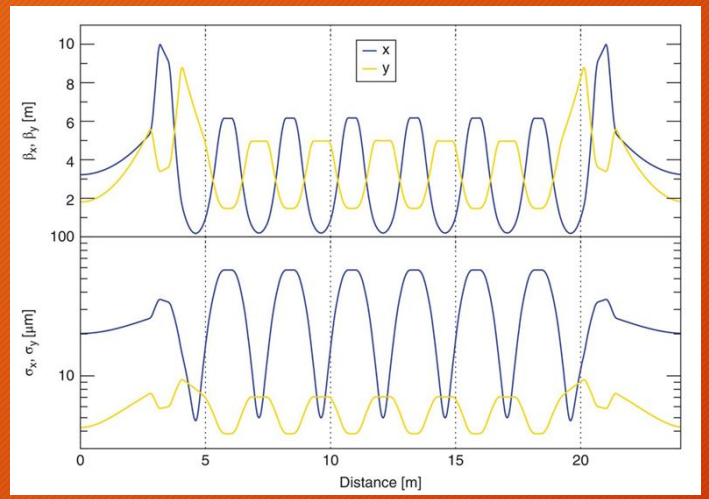
The Magnet Lattice



a) Bending or dipole magnets (b) A focussing quadrupole magnet, and (c) sextupole magnet.

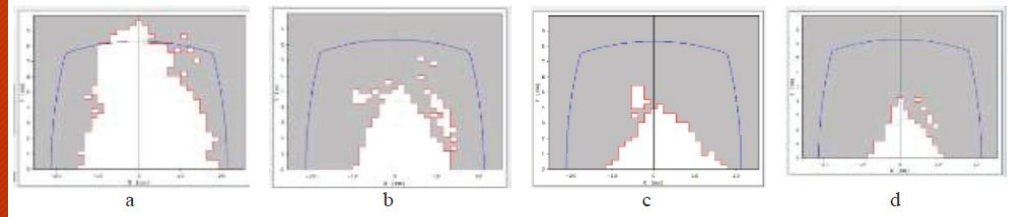


Multibend Achromats Above: the MAX-IV 7-bend achromat; below: the SLS triple-bend achromat.



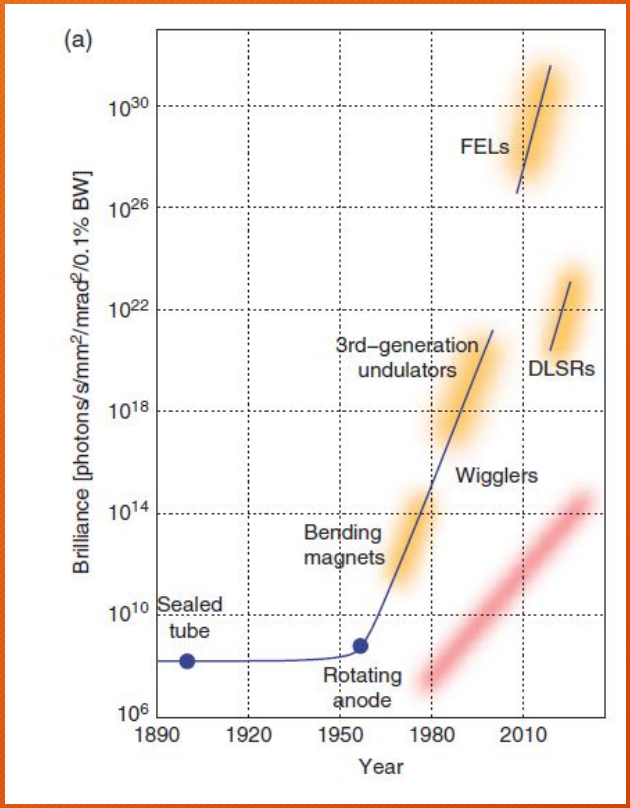
Calculation of the beta function and the e-beam profile around 1 of 12 sectors in SLS-2

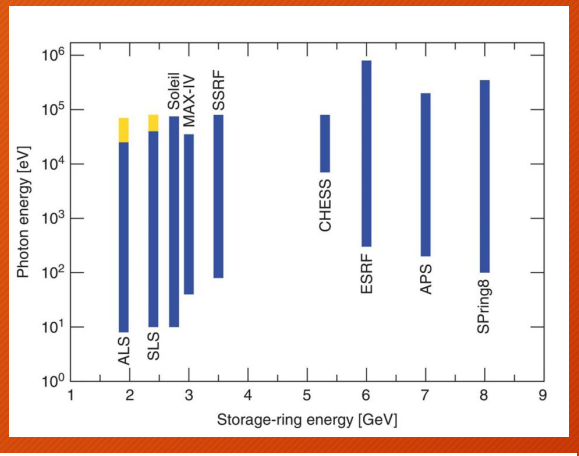
# of achromats		20	24	28	32
Achromat length	m	18.39	18.39	18.39	18.39
Total length	m	367.8	441.4	514.9	588.5
ε (bare lattice emittance)	pm	508	306	184	127
β_x (in center of long straight)	m	9	9	9	9
β_y	m	2	2	2	2
η_x	m	0	0	0	0

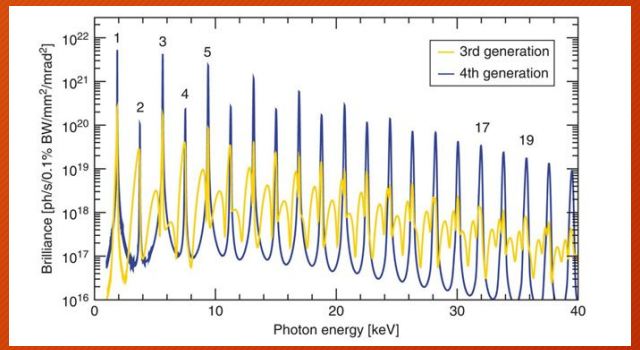


Calculation from CLS A variety of machine sizes are considered from 20 to 32 achromats. The dynamic aperture is shown to decrease with emittance.

Next Steps towards Volume II







- Complete white paper which provides context to this talk
- Receive guidance from the AfLS Executive Committee on key design parameters including
  - Brilliance
  - Photon Energy
  - Emittance
  - Number of Beamlines
  - Target Budget
- Continue to recruit contributors for the CDR

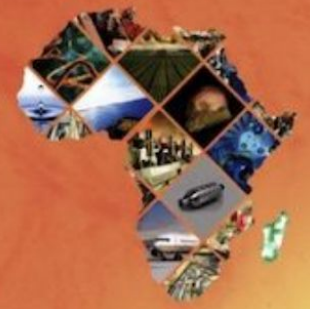
Future Activities

- January 2021– will begin a series of meetings, e.g. topical workshops to assess the different aspects of the project (please answer the call to join a topical group)
- Survey / more LS and w/ African community to identify the specific needs in Africa
- Develop a detailed budget and WBS to support the current road map
- Training African accelerator community, e.g. MOOC (NPAP)
- Motivating the scientific needs for a Light Source, e.g. ASP Online Lecture Series starting on November 24, 2020 by Prof. A. Harrison
- Develop a balanced and sustainable eco-system adapted to Africa in the concept of Ubuntu (“I am because we are”)

Thank You

THE AFRICAN LIGHTSOURCE

Towards a Lightsource for the African Continent



AfLS3 Workshop
Nov 19, 2020