Fundamental physics and accelerator science in developing countries

Christine Darve

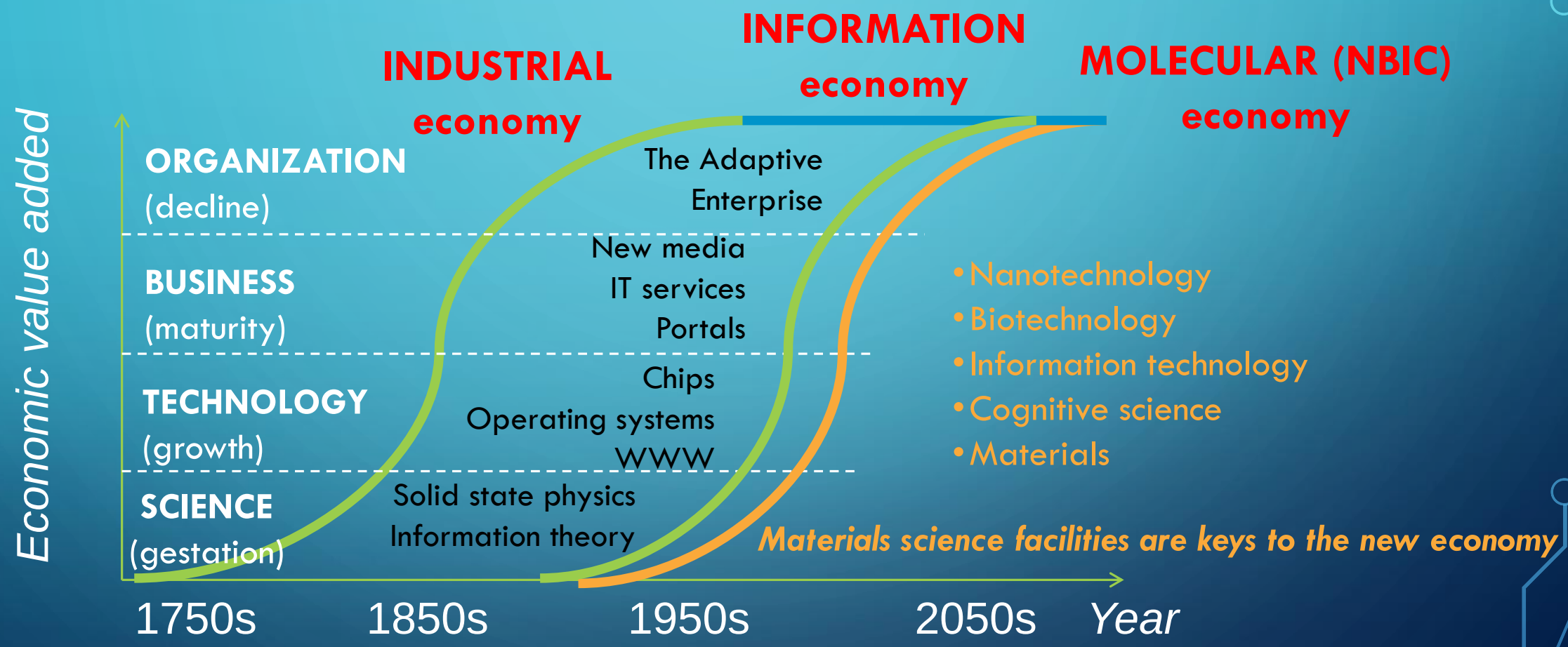
Session M19: Physics for Development

March 4, 2020

OUTLINE

- Scientific and technological paradigms
- Platforms to accelerate developing countries transformation
  - African School of Fundamental Physics and Applications
  - Nordic Particle Accelerator Project
- Particle Accelerators as tools for transformation

TECHNOLOGICAL PARADIGM EVOLUTION



It's Alive - The Coming Convergence of Information, Biology, and Business Christopher Meyer 2003

HOW TO REACH TECHNOLOGICAL PARADIGMS ?

IDEAL: Transform developing countries to reach technological paradigms

→ Support implementation of scientific infrastructures

→ Education as a vector for development !

→ Topics of interest: *Fundamental physics and accelerator science*

→ Platforms: From summer schools to Massive Open On-line Courses (MOOC)

→ Complementary to existing World Wide initiatives and gender balance !

Science Transcending Boundaries !

AFRICAN SCHOOL OF FUNDAMENTAL PHYSICS AND APPLICATIONS (ASP) - AS A START-UP



Already 5 editions completed since 2010 !

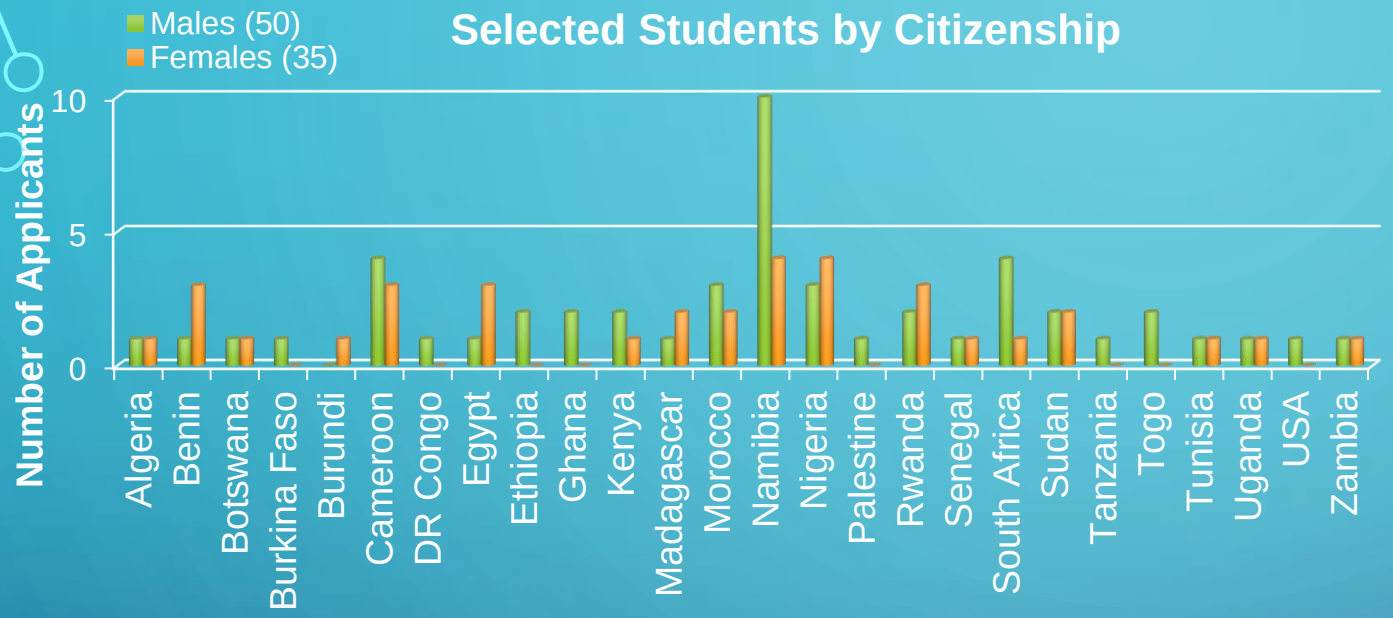
ASP2020 to be conducted in Marrakesh

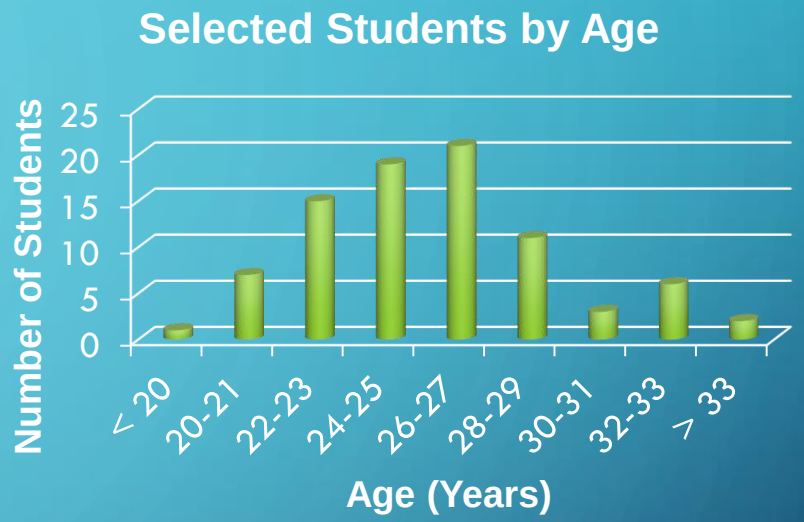

A non-profit organization created by a small group of worldwide scientists to stimulate and include more African talented physics students in the world scientific community

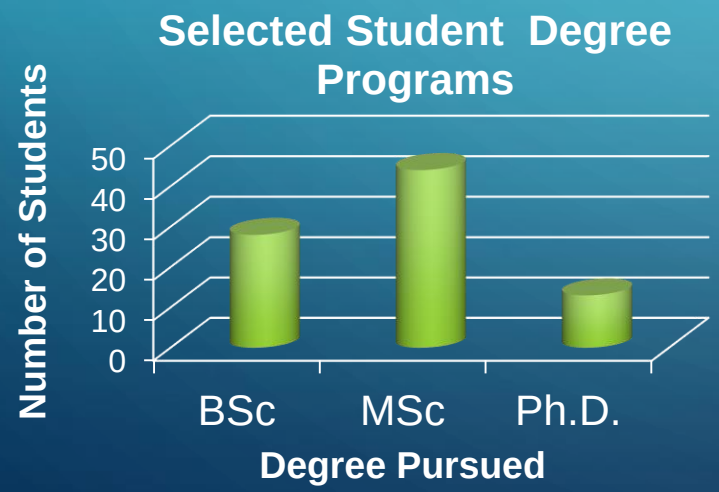
The aim of the school is to build capacity in African countries, to harvest, interpret, and exploit the results from physics experiments with particle accelerators, and to increase proficiency in related applications and technologies.

- → To contribute to a world w/ equal access to knowledge
- → To support financially up to 85 African students for 3-week classes attendance
- → To establish a biennial educative program to be hosted across Africa
- → To provide high quality classes by international re-known Scientists

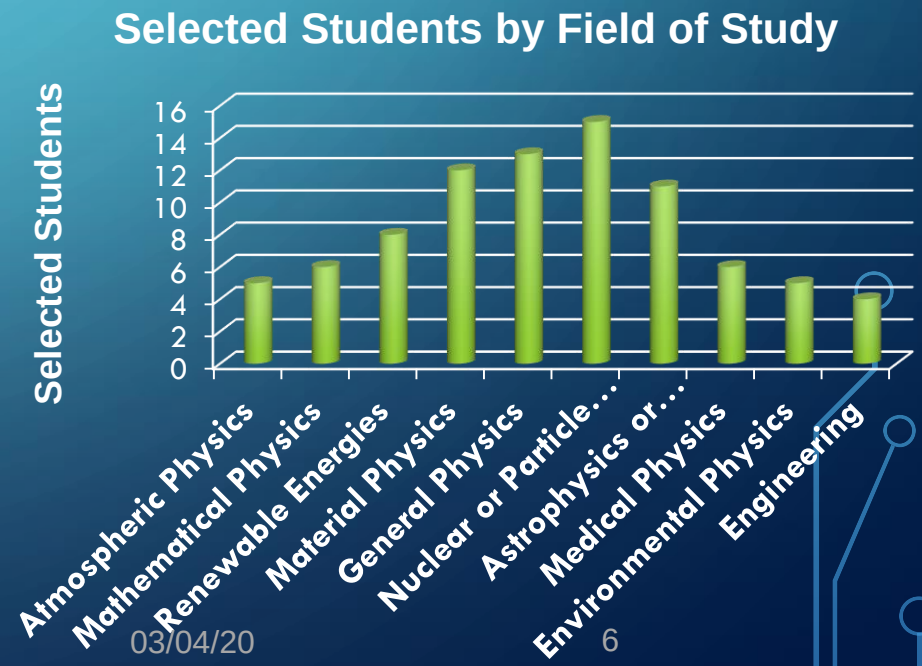
ASP2018 STUDENTS PROFILE







- 523 Applications
- Total selected: 85 (+30 waiting list)
- Selections constrained by budget and logistics



SPONSORSHIP & FINANCIAL SUPPORT

APS MARCH MEETING 2020 MARCH 2-6 DENVER, CO

APS physics

ICTP Support major
- Student participation
- Management of application database
- Arrange student travels

ASP2018 Sponsors in addition to USA DOE Labs (BNL)

African Contributors:
- Namibia
- SA DST/NRF
- IUCEA

Integrated: ~50% of ASP2018 budget

Fund Management
- Funds centralized and managed by the South African Institute of Physics (SAIP)

Host Country Support Significant
- In-kind support
- Direct Financial contributions
- Human Resources toward ASP Organization

IOC
- *Writes Proposals, Requests for Supports*
- *Produces Final Reports of Activities*
- *Seeking permanent financial backing*

Lecturers and Organizers Supported by External Sources - Significant
- Support received then used to maximize student participation

ASP TOPICS OF INTEREST

Theoretical Physics

- Nuclear and Particle Physics
- Beyond the Standard Model
- Astro-particle physics and Cosmology
- Theoretical Heavy-ion physics
- Linux tutorials

Experimental Physics

- Particle Detectors
- Particle Identification and Data Analysis and statistics
- Exp. Particle physics, current status of the field
- Exp. Nuclear Physics
- Exp. Heavy Ion Physics
- Exp. Astro-particle Physics

Accelerators, Applications, HPC

- Accelerator physics and Technology
- Physics of Particle Beams
- Instrumentation
- Medical Applications
- Neutron and Light Sources
- Energetics and solid state
- GRID and High Performance Computing
- Digital Library

ASP PROGRAM EXPANSION

High School Teachers Program

1-week intensive workshop

- Train High School Teachers for improved physics teaching

Student Program

3-week intensive school

- 3rd year of University to Ph.D.
- Mostly African Students
- 70-80 Students; total > 320

ASP Conference

1-week International Conference

- Participation of ASP Alumni
- Part. Research Faculties
- Networking & collaborations

Learners Program

1-week learners Outreach

- 10-12th grade learners
- Encourage learners to develop and maintain interests in Physics and Applications

Forum and Outreach

2 events

- Involve Regional policy makers
- Promote spin-off activities in Africa
- Introduce students to policy

Mentorship/ Coaching Program

- Work with Academic Advisors
- Connect Students w/ Researchers
- Place students at Labs
- Support students & help address their academic needs

ASP STUDENTS

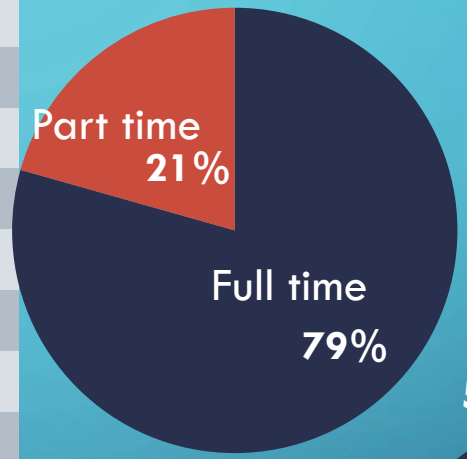
Provide partial or full financial support to students and create a scientific melting pot of cultural diversity

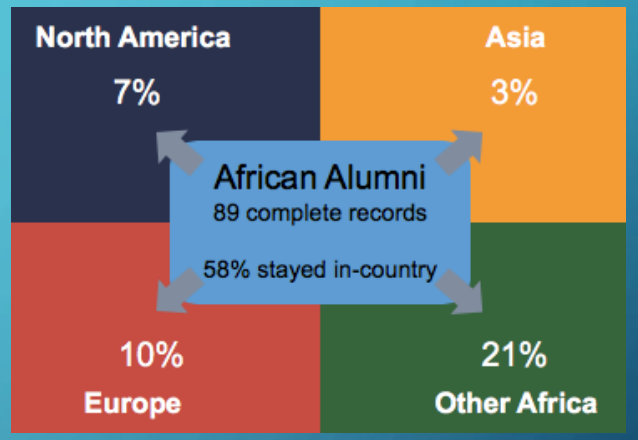
- **Diversity of academic levels**
  - Mainly Master and PhD students
- **Diversity of education background**
  From theoretical physics to engineering sciences
- **Diversity of the countries of origin**
  Priority to Sub-Saharan African students
- **Women/girls participation (~32%)**
  Role of women/girls in LDC.
- **Local Universities**
  Involve students and professors

CURRENT STUDIES AND EMPLOYMENT

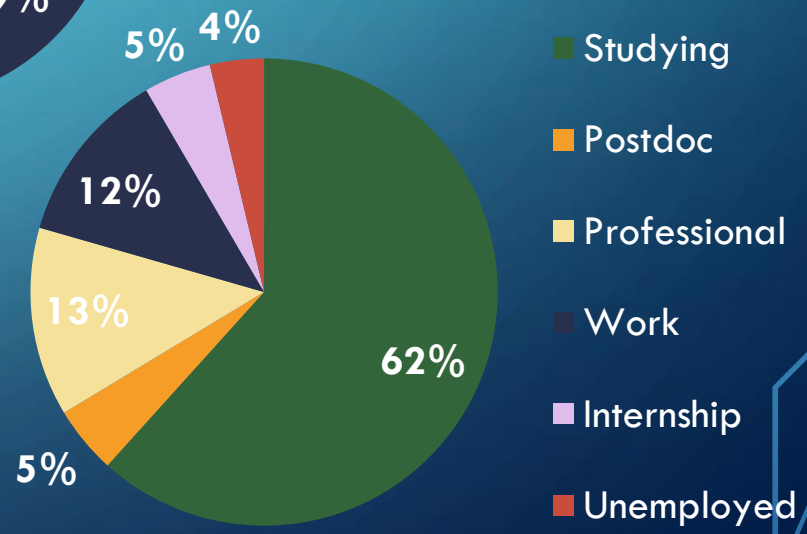
"What do you do now? (you can make multiple selections) "

Studies and employment	# of alumni
Full time undergraduate student	2
Part time undergraduate student	0
Full time masters student	19
Part time master student	1
Full time doctorate student	39
Part time doctorate student	4
Studying at a non-degree granting institution	1
Full time postdoctoral researcher	3
Part time postdoctoral researcher	2
Full time professional work	11
Part time professional work	3
Full time work	3
Part time work	10
Internship	5
Unemployed	4
Looking for higher education opportunities	26





Courtesy Julia Gray



ASP FORUM AND OUTREACH DAY

ASP2010 Stellenboth, South Africa

AfLS and compact acc.
Prof. H. WINICK, Prof. Emeritus, SLAC **and Prof.** L. SERAFINI (INFN, IT)

ASP2012 Kumasi, Ghana
→ Launched the African Light Source steering committee

ASP2014 Dakar, Senegal

UN support
Dr. H. TOURE, UN ITU Secretary General.
Prof. A. WAGUE and O. KA M. NGOM - US Embassy rep.

Dedicated to Knowledge and Transfer of Technology
Dr. D. ADAMS, chief director: Emerging Research areas & Infrastructure, Human Capital and Knowledge Systems.

ASP2016 Kigali, Rwanda

East Afr. Science and New ICTP Center
Rwandan Ministry of Education

Dr T. TJIVIKUA, Vice-Chancellor, Namibia University of Science and Technology (Namibia)
Dr. R. ADAM (SKA, SA)

ASP2018, Windhoek, Namibia,

ASP2014 - FORUM DAY WITH Focus on ITU / ICT SPEECH

” In Africa, in the 21st century, it is not enough to have opportunities; you need to have digital opportunities. It is not enough just to be smart; you need to be **digitally smart**.
The most obvious example of this is the **employment market**, where digital literacy is now an essential prerequisite in all countries for getting a job or starting a business.

Prof. A. WAGUE and Dr. H. TOURE, former ITU Secretary General and Smart Africa CEO

- ”As you are all aware, the ICT sector in Africa has experienced quite extraordinary growth in recent years, especially in terms of mobile cellular communications – with penetration rates in sub-Saharan Africa almost doubling in the past five years, to reach 69.3% by the end of 2014. Here in Senegal, there are almost as many mobile cellular subscriptions as there are inhabitants.”

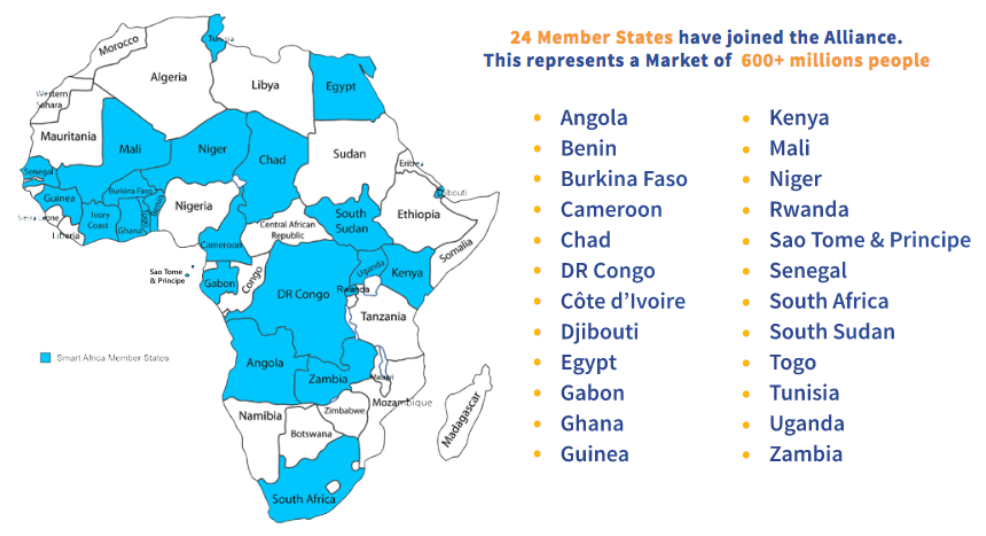
- ”When we talk about youth being critical to Africa’s success, that of course includes **girls, and equal access to ICTs will be an essential part of the solution**.”

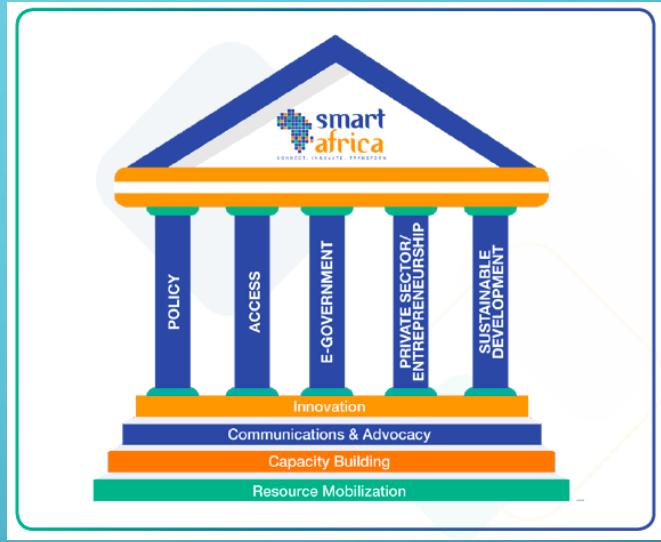
- ” Fortunately, there have never been more or better opportunities for acquiring the necessary digital skills – whether formally, at school, or informally, online – and it is tremendously encouraging to see the proliferation **of MOOCs, Massive Open Online Courses**, as well as open courseware and mobile learning, hackathons, and mobile app competitions.”

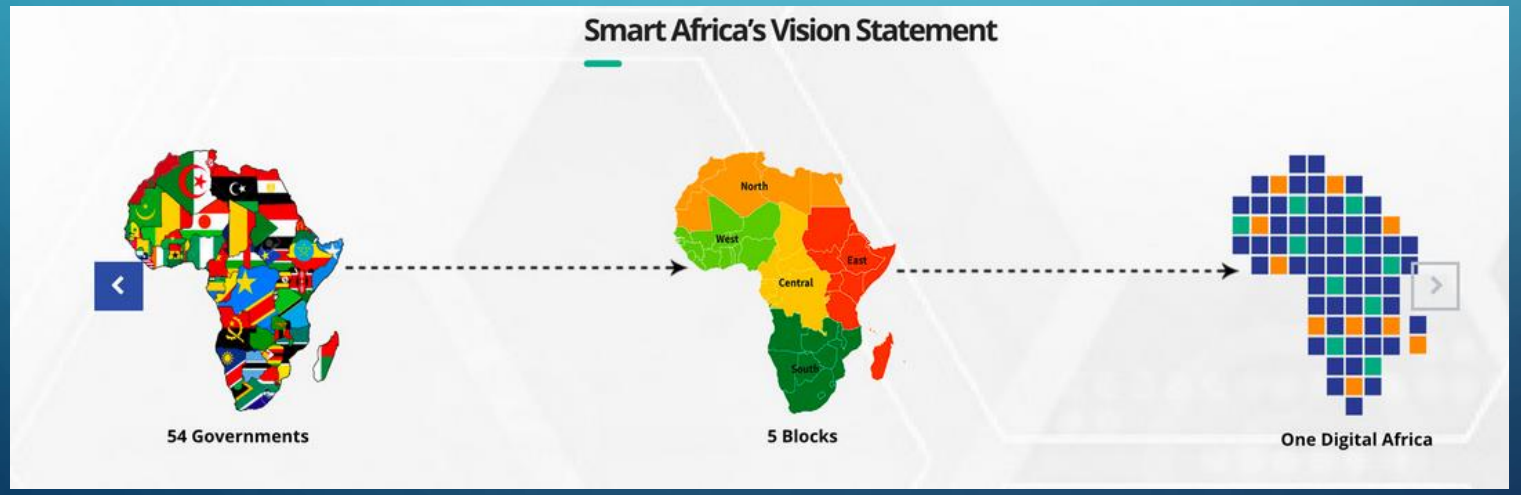
https://indico.cern.ch/event/276481/contributions/1620267/attachments/502040/693352/AT_Speech_ASP_Physics_v8.pdf

SMART AFRICA

www.smartafrica.org







OUTLINE

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  - Nordic Particle Accelerator Project
- Particle Accelerators as tools for transformation

MOOC AND NORDIC PARTICLE ACCELERATOR PROJECT

www.npap.eu

Develop capacity in Northern Europe with emphasize on MAXIV and ESS

➔ Intrinsically use it as tools for distant teaching, hence support developing countries !

Existing educative platforms and programs:

- ✓ Particle Accelerator schools: JUAS, CAS, HASCO, USPAS, ACAS, ASP, etc
- ✓ University Unit (e.g. Aarhus, LU)
- ✓ EU-TIARA and other market surveys
- ✓ EU-ARIES: Accelerator Research & Innovation for European Science and Society

Why do we need new Pedagogical tools for Accelerator science?

- School levels are typically advanced
- Domains/Field complementarity
- To provide sustainable and “users-friendly” tools

NPAP - TEAM BUILDING

A first summer school operated in 2015 has served as a proof of concept to identify the team and the topics to be developed in our MOOC

ESS EUROPEAN SPALLATION SOURCE · MAX IV LABORATORY · JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ · UNIVERSITY OF OSLO · UPPSALA UNIVERSITET · AARHUS UNIVERSITY

Grant for the Nordic Particle Accelerator Program

Main deliverables: 2 summer schools and 3 MOOCs

92/100

Erasmus Plus Project of Excellence & Best Practice

Strategic partnership and building cross-sectoral bridges

Support innovative practices from international to regional to organisational and individual levels

Erasmus+

Application Form
Call: 2015
KA2 - Cooperation for Innovation and the Exchange of Good Practices
Strategic Partnerships for higher education

MOOC1: Particle Accelerators introduction

→ Launched in August '19
More than 505 learners enrolled

Accelerators for Synchrotron Light
Light and Light Sources
Accelerator to make light
The development of accelerators for synchrotron light
Photon light sources and MAXIV
Synchrotron radiation
Bending magnets, wigglers and undulators
Free Electron Lasers
Spallation source and ESS
Introduction and neutron science
European Spallation Source
Particles Colliders
Introduction to Particles Colliders
The LHC and its experiments
Linear Colliders
Future Circular Colliders
Plasma Wakefield (to be completed)

MOOC2: Fundamentals of accelerator technology

→ Launched in March '19
More than 716 learners enrolled

RF-System
Introduction to RF-systems
RF cavities
Waveguides
RF Amplifiers
More about cavities
Magnets technology for accelerators
Magnets part1/2/3
Beam Diagnostics
An overview
Beam intensity and position
Transverse Beam Profile
Longitudinal Beam Profile
Beam Loss Monitoring
Basics of Vacuum techniques
An overview and motivation
Residual gases and vacuum regions
Vacuum equipment
Other vacuum components

MOOC3: Medical App. of Particle Accelerators

→ Launched in Nov. '18
More than 1044 learners enrolled (on 28 Feb 2020)

Introduction to the course and radiotherapy
Introduction
Biological rational for radiotherapy
Intro. to the electron linac for radiation therapy
Electron Linacs for radiation therapy
The multi-energy electron Linac structure
Dose delivery to the patient
Proton therapy 1
Rationale of proton therapy
Accelerators for proton therapy
Treatment delivery of proton therapy
Proton therapy II and production of medical radionuclides
Heavy ion therapy
Challenges in pr. th. and heavy ion th.
Introduction to medical radionuclides
Production of medical radionuclides

MOOC1: INTRODUCTION TO PARTICLE ACCELERATOR

WEEK 1

2 hours to complete

WEEK 2

2 hours to complete

WEEK 3

3 hours to complete

Spallation sources and ESS

WEEK 4

3 hours to complete

Particle Colliders

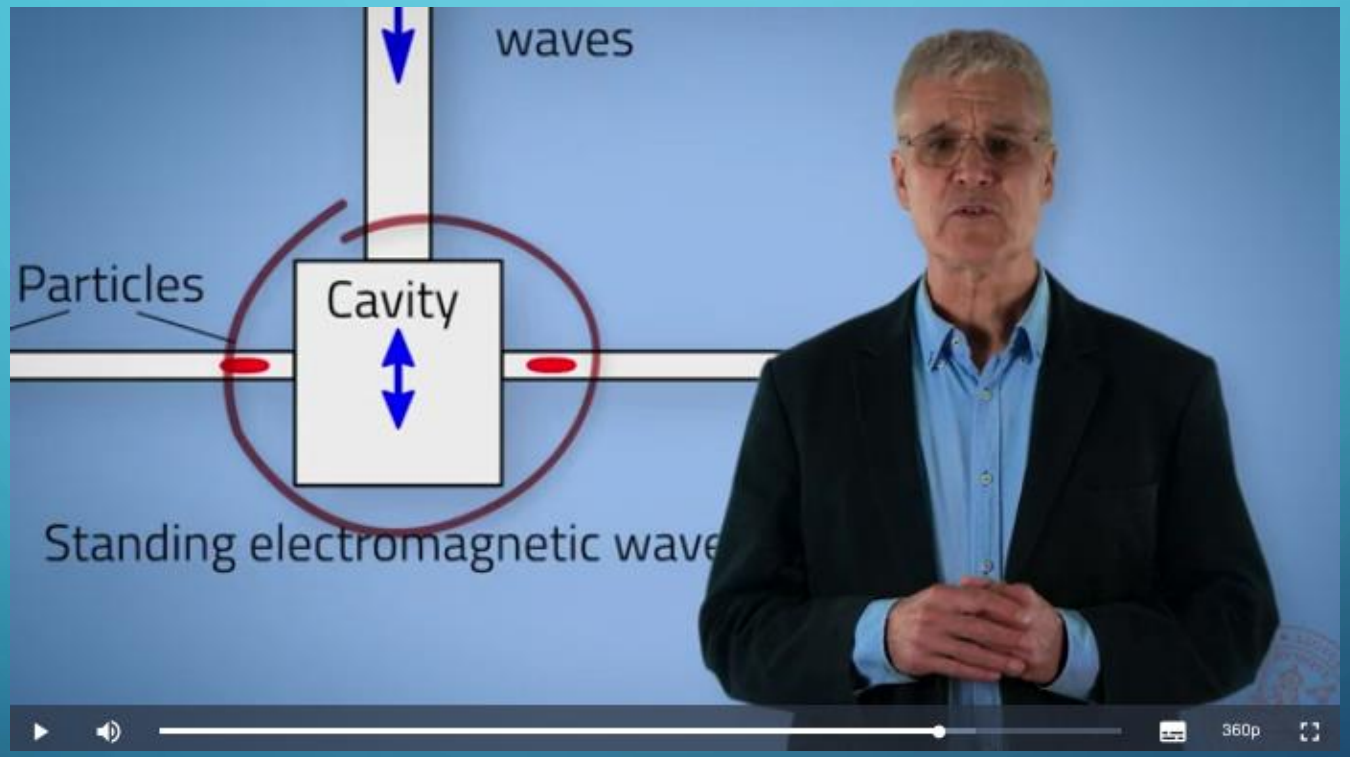
This module describes particle colliders and explains why we need them. After a brief history of colliders it focuses on the Large Hadron Collider (LHC), which is the world's largest collider. This is followed by two lectures on linear colliders, exemplified by two proposed electron-positron colliders, CLIC and ILC. Finally the module discusses different options for the next generation of circular colliders.

SHOW LESS

9 videos (Total 25 min), 6 readings, 5 quizzes SEE ALL

MOOC2: FUNDAMENTALS OF ACCELERATOR TECHNOLOGY

Example of Lecture



https://www.coursera.org/learn/fundamentals-particle-accelerator-technology

https://www.coursera.org/lecture/fundamentals-particle-accelerator-technology/general-introduction-wf3CB

https://drive.google.com/open?id=160EDKsTJiZruNpGNoDuu0hvxLYf0fafW

Medical Applications of Particle Accelerators (NPAP MOOC)

4.7 (36 ratings) | 4.4/5

Lars Hjorth Præstegaard

Included with cou

Learn More

Go To Course

Already enrolled

Financial aid available

About Syllabus Reviews Instructors Enrollment Options FAQ

About this Course

8,102 recent views

Hello and welcome to this course!

The NPAP - Medical Applications of Accelerators is one out of three courses in the Nordic Particle Accelerator Program (NPAP). Here you will be taken on a tour focusing on the medical applications of particle accelerators. You will see that there are two very important, but different, applications of accelerators in hospitals. The first application concerns radiotherapy of tumours and the other concerns the production of medical nuclides for diagnosis and treatment. Both will be included in this course and described through four modules.

The first module offers the basic principles of radiotherapy from a medical and physics point of view. You there learn about the main components of the machines used for radiotherapy and get to know why radiotherapy is important for cancer treatments.

The second module guides you through the different types of linear accelerators used in the machines for radiotherapy. It also describes the design of the treatment head. The design is important because it is the settings of the treatment head that determines the dose and the radiated region. It is also in the treatment head where the dose given to the patient is measured.

In the third module you are introduced to proton therapy. In this type of therapy protons are first accelerated and then guided down to the tumour by magnets. The machines are considerably larger and more expensive than machines used for radio therapy. The module also offers a description and comparison between different types of accelerators, and explains how the protons interact with tissue.

Also ions that are heavier than protons can be used in cancer therapy. This is described in the fourth module, where we also introduce you to the production of medical nuclides. You learn how the nuclides are produces in proton and ion accelerators and how the nuclides come into play at different places in hospitals. Medical nuclides are for instance used in Positron Electron Tomography, PET.

Enjoy!

coursera Explore What do you want to learn? christine.

Viewing: Original Version Live / February 17, 2020 - March 22, 2020 Live Edit Course

Medical Applications of Particle Accelerators (NPAP MOOC)
Lund University

Overview

Course Manager
Staff & Mentors Only

Set a weekly goal

Learners who set a goal are 75% more likely to complete the course. You can always change it.

- Learn 2 days a week
- Learn 3 days a week
- Learn 5 days a week Recommended

Your goal will be tracked Monday - Sunday

Not now Set goal

Introduction to the course and radiotherapy

		REQUIRED	GRADE	DUE
Videos	8 min left	Quiz, Graded Quiz, 15 min		Feb 23, 11:59 PM PST
Readings	1h 4m left			
Practice Exercises	25 min left			

WEEK 2 Estimated Time: 2h

Electron linacs for radiotherapy

		REQUIRED	GRADE	DUE
Videos	20 min left	Quiz, Graded Quiz, 2 min		Mar 1, 11:59 PM PST
Readings	51 min left			
Practice Exercises	47 min left			

WEEK 3 Estimated Time: 1h 40m

33% got a tangible career benefit from this course

33% got a pay increase or promotion

100% online
Start instantly and learn at your own schedule.

Flexible deadlines
Reset deadlines in accordance to your schedule.

Beginner Level

Approx. 10 hours to complete
Suggested: ca. 5-12 h/week

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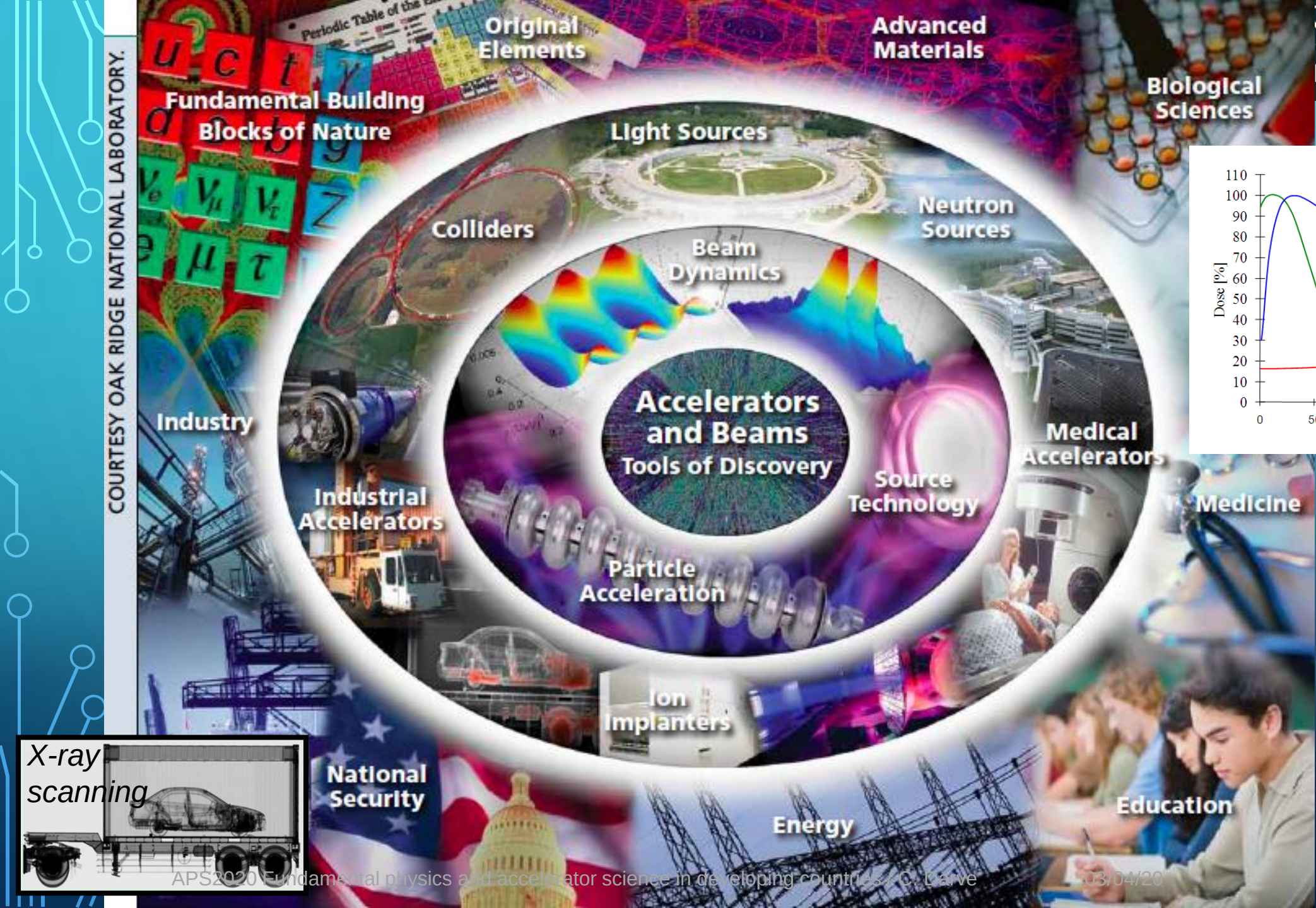
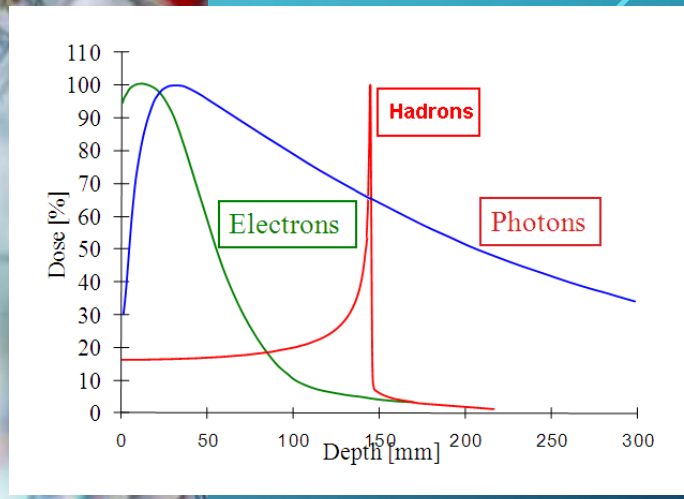

COURTESY OAK RIDGE NATIONAL LABORATORY.
Original Elements
Periodic Table of the Elements
Advanced Materials
Biological Sciences
Fundamental Building Blocks of Nature
Light Sources
Colliders
Neutron Sources
Beam Dynamics
Accelerators and Beams
Tools of Discovery
Source Technology
Particle Acceleration
Industry
Industrial Accelerators
Medical Accelerators
Medicine
Ion Implanters
National Security
Energy
Education

X-ray scanning


Dose [%]
Depth [mm]
Hadrons
Electrons
Photons
0
10
20
30
40
50
60
70
80
90
100
110
0
50
100
150
200
250
300

~ 60 Photon sources

+3 Proton LINAC for Neutron Sources

Nuclear research

Non nuclear research

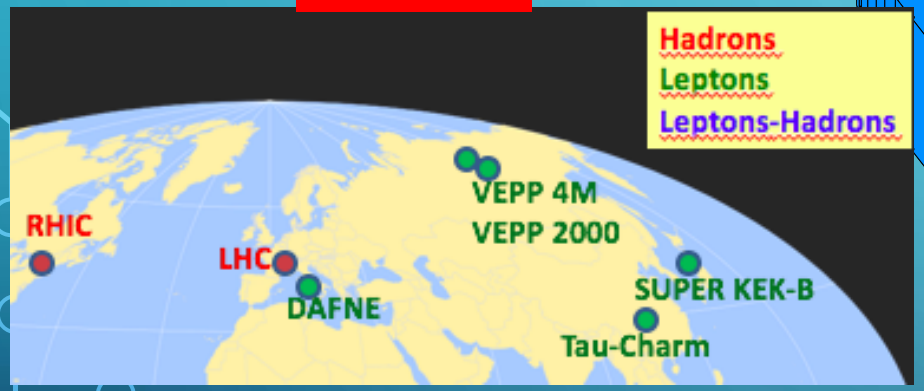
Medical Isotopes

Industry

Radiotherapy

Colliders

Hadrons
Leptons
Leptons-Hadrons



Ion implantation

”Medical Applications” by C. Biscari and L. Falbo CERN–2014–009

Hadrontherapy

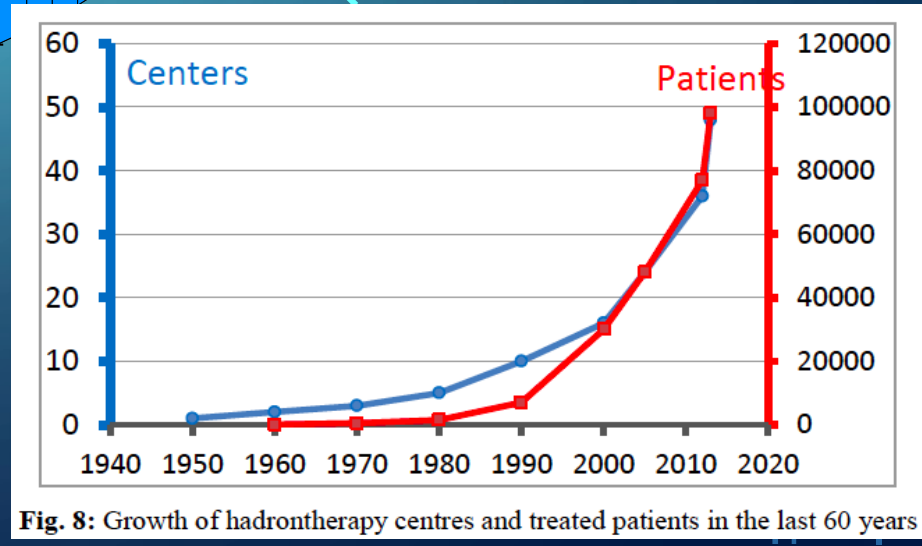


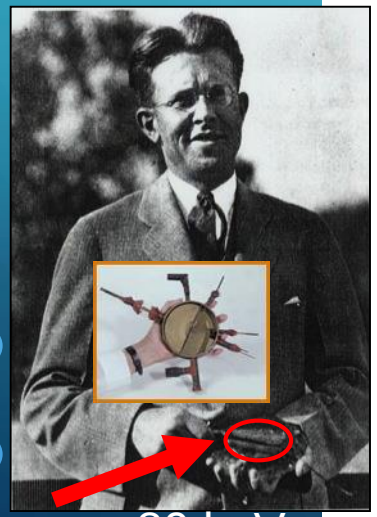
Fig. 8: Growth of hadrontherapy centres and treated patients in the last 60 years

Accelerators in the world: over 35000 (15000 in 2000)

TYPE OF PARTICLE ACCELERATORS

Each generation built on the accomplishments of the previous ones raising the level of technology ever higher

Ernest Lawrence (1901 - 1958)



80 keV

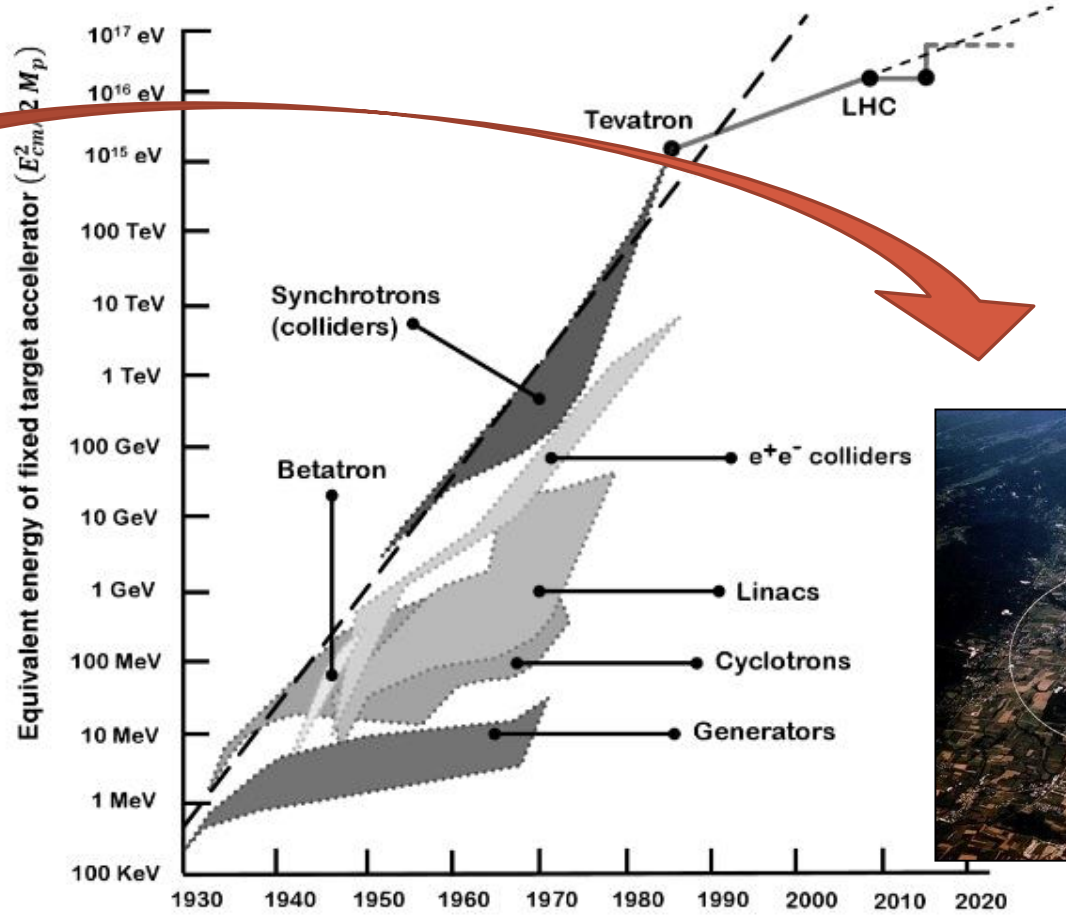


FIGURE 1.6
Livingston plot of evolution of accelerators.

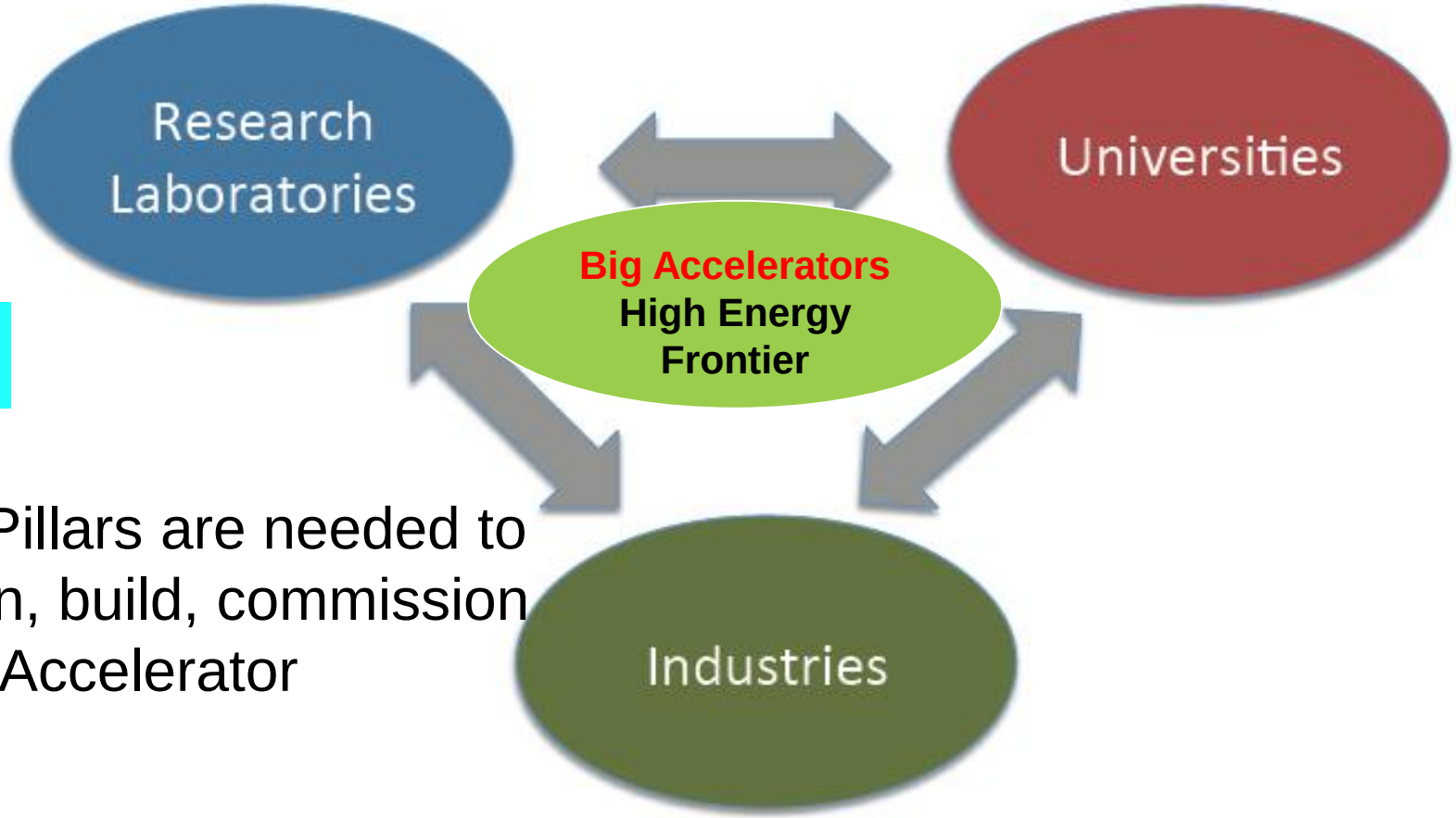
Livingston's diagram

→ 1980 -Tevatron @ Fermilab
980 GeV

→2008 - LHC @ CERN
7-14 TeV

RICH DEVELOPED COUNTRIES / INTERNATIONAL ORGANIZATIONS

TRIANGLE OF KNOWLEDGE – UE "PARADIGM"

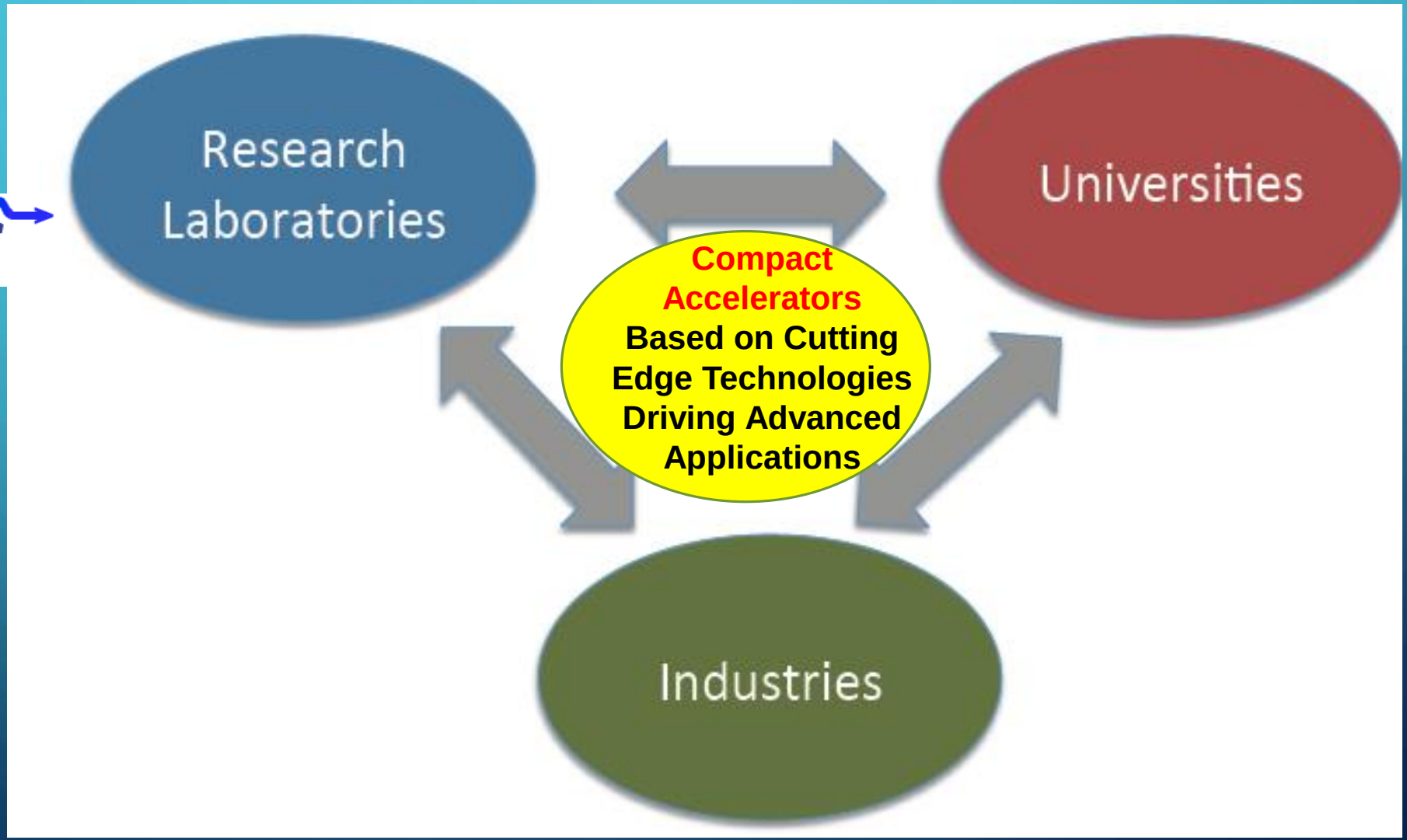


Courtesy
Luca Serafini

ASP-2012 Forum, KNUST, Kumasi (Ghana), 28-07-2012

All 3 Pillars are needed to design, build, commission a Big Accelerator

COUNTRIES UNDER-DEVELOPMENT
triangle of Knowledge and circle of Opportunity

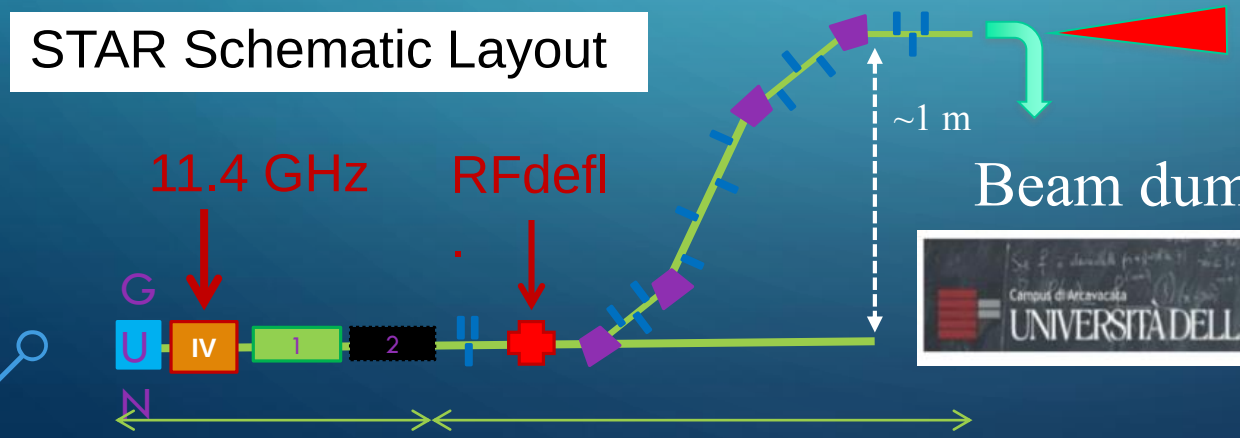


Courtesy
Luca Serafini

EXAMPLE OF SCIENTIFIC INFRASTRUCTURE

All 3 Pillars are interested in designing, building and commissioning a Compact Advanced Accelerator based Systems.

- **Industry** is not capable at the beginning, but will profit from Applications and, eventually, mass production (e.g. cmp. 200 MeV Proton Linacs, Radio-therapy electron linacs, etc)
- **University** wants to contribute in education/training and show a significant social impact of its basic research activity
- **Research** laboratories have the capability to transfer and integrate the expertise in accelerator science and technology generated by the High Energy Frontier challenge



INFN Istituto Nazionale di Fisica Nucleare

elettra Sincrotrone Trieste
Elettra and FERMI lightsources

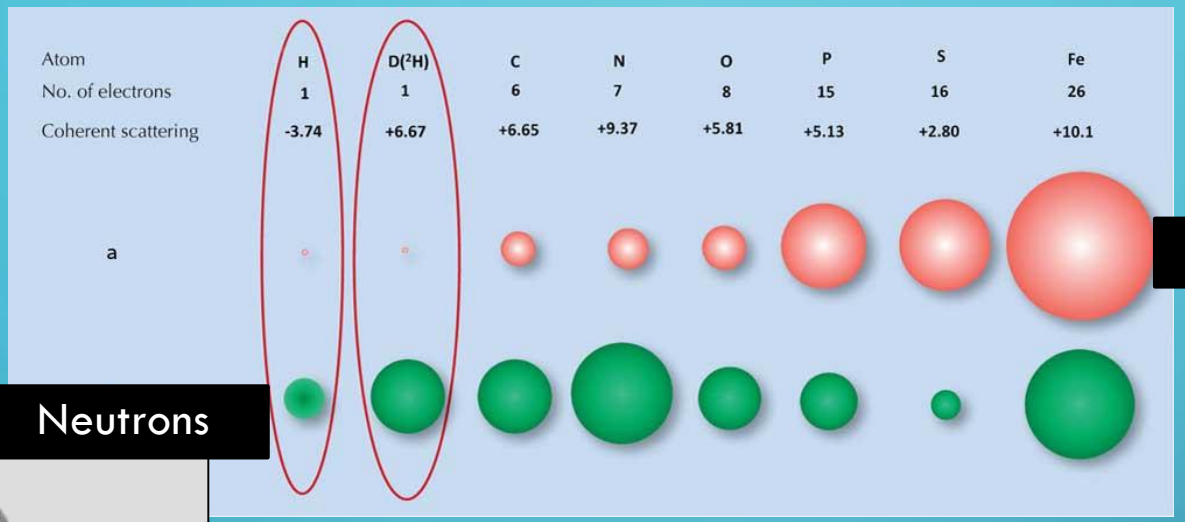
Campus di Arcavacata
UNIVERSITÀ DELLA CALABRIA

CNISM

MaTeRiA
materiali, tecnologie e ricerca avanzata

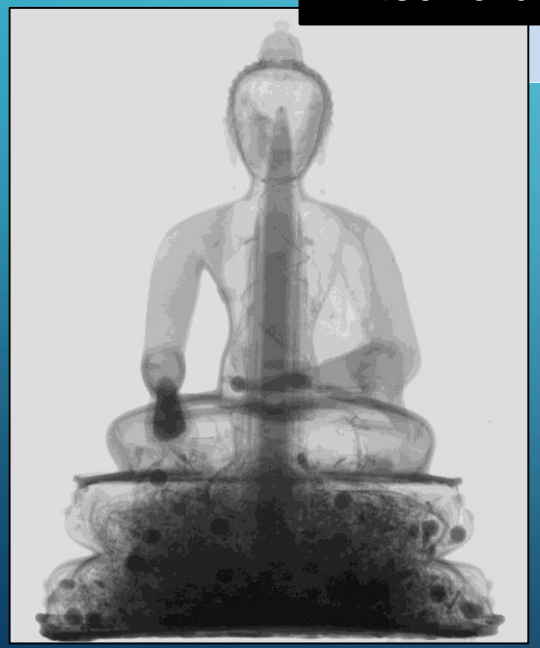
LIGHT SOURCE AND NEUTRON SOURCE

Courtesy Lenny Rivkin

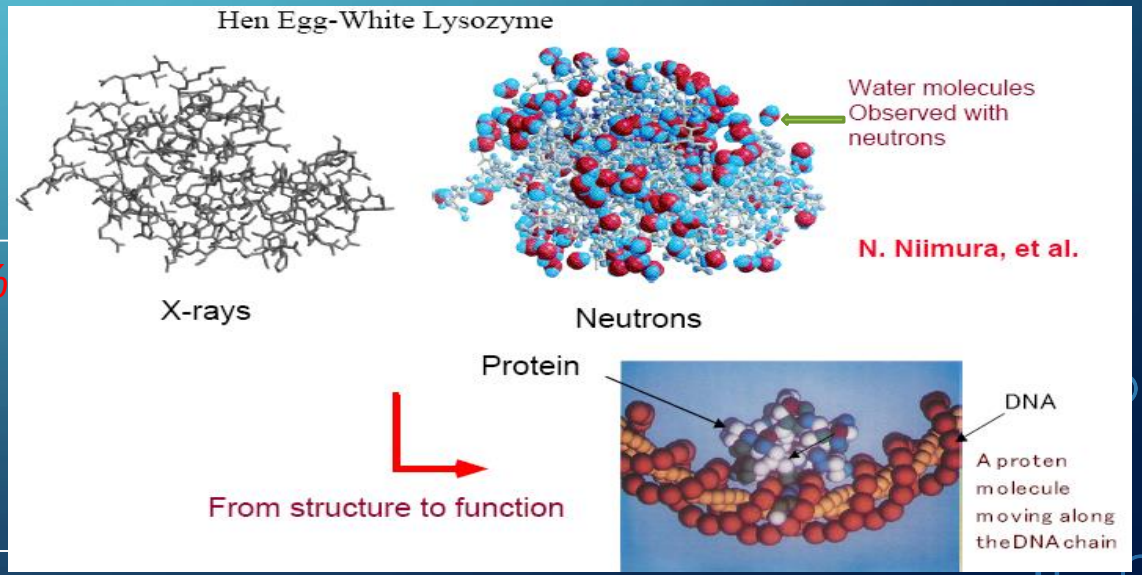


X-Rays

Neutrons



H atoms make up *~50% of atoms of biological macromolecules* (lipids, proteins, nucleic acids, carbohydrates).



LIGHT SOURCES DISTRIBUTION

Courtesy
Caterina
Biscari

https://laamp.iucr.org/__data/assets/pdf_file/0007/135754/brochure-for-web-cover2.pdf

THE AFRICAN LIGHT SOURCE CONFERENCE AND WORKSHOP

16 - 20 NOVEMBER 2015, ESRF GRENOBLE FRANCE

From: African Light Source Conference and Workshop : Grenoble - SH Connell 2015/11/18

AfLS Steering Committee
Regions represented ....
55 members

Courtesy Simon Connell

[See Summary talk at: https://www.dropbox.com/s/inxre3hnpa229gw/AfLS-AAS-ASI.pptx?dl=0](https://www.dropbox.com/s/inxre3hnpa229gw/AfLS-AAS-ASI.pptx?dl=0)

to:

The African Light Source Project

The 2nd African Light Source Conference (AfLS2)

28 Jan – 2 Feb 2019 in Accra, Ghana

[Outcomes: https://docs.google.com/document/d/1dX2NX_FE07gipEWiS-LTUuhn7YkHdbRdRokhfOO_gHQ/edit](https://docs.google.com/document/d/1dX2NX_FE07gipEWiS-LTUuhn7YkHdbRdRokhfOO_gHQ/edit)

3rd African Synchrotron Light Source Conference
AfLS3 : towards a brighter future

Kigali-Rwanda 16-21 November 2020

The African Light Source Project

Courtesy Simon Connell

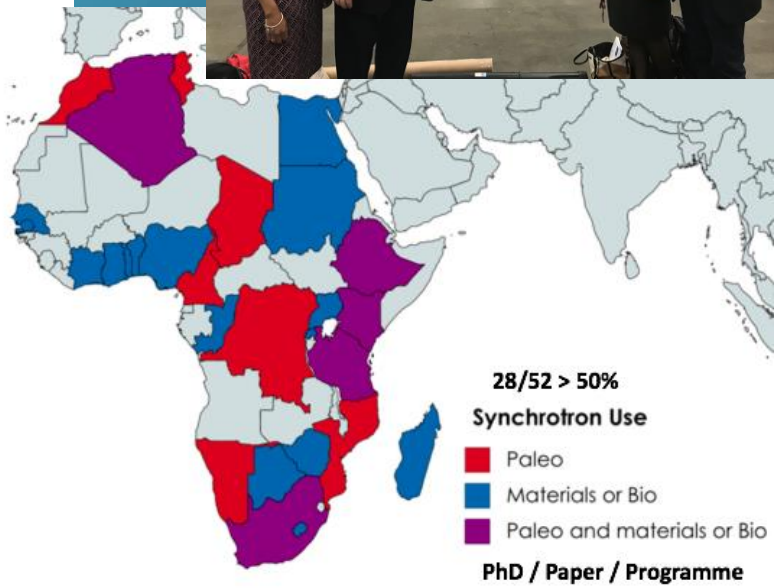
APS physics MARCH MEETING 2020
MARCH 2-6 DENVER, CO

First African Light Source Conference
November 2015

APS March 2018 meeting

Socio-economic benefits

- Boost African Scientific Research, Research Capacity (Continent, regions, Institutes), Capacity Building - African Science Renaissance
- Global Research Community
- Tackling Diseases (Malaria, TB, Aids, Ebola ....)
- Unique African Research Opportunities attracting international collaboration : Energy opportunities, African Environment, Cradle of Humankind, Cradle of Culture, Mineral beneficiation, Agriculture.
- Mobility, Conferences, Schools, International Mentoring partnerships in student training, Regional Centres of Excellence, Local feeder instrumentation
- Build Research capacity in Industry, competitive industry
- **Science for Peace (eg CERN, SESAME)**
- **Return of the African Science Diaspora - new opportunities for young excellent scientists**
- **For African countries to take control of their destinies and become major players in the international community**



The Palestinian-German Science Bridge (PGSB)

SPONSORED BY THE
Federal Ministry of Education and Research

- a program with the aim of establishing
  in science and technology

- BMBF financed program
  2,5 M€in 5 years, 2017-2021
  (Application for 2 years extension and

- Research centre Jülich and its partner

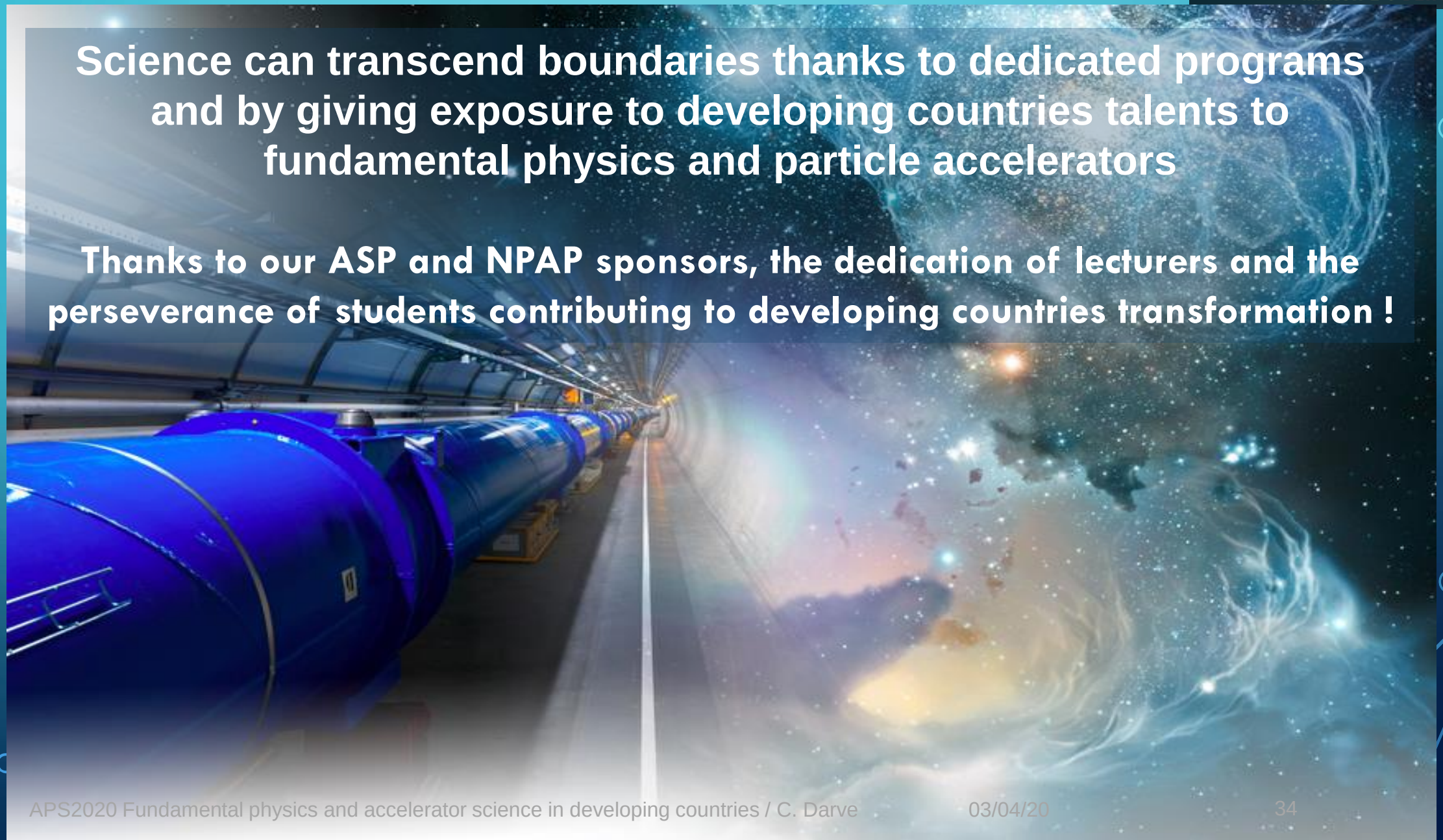
- Palestinian Academy for Science and T
  as an umbrella covering all Palestinian

Courtesy
Ghaleb Natour

Experience so far

SPONSORED BY THE
Federal Ministry of Education and Research

- Students are highly motivated
- Institutes in Jülich are highly satisfied with the Palestinian students (large international competition)
- Short acclimation period
- Good relationship established between scientists
- Exampels of cooperation between several Palestinian universities and Jülich on one topic



Science can transcend boundaries thanks to dedicated programs and by giving exposure to developing countries talents to fundamental physics and particle accelerators

Thanks to our ASP and NPAP sponsors, the dedication of lecturers and the perseverance of students contributing to developing countries transformation !