Royaume du Maroc
Académie Hassan II des Sciences et Techniques


# From Nuclear Physics to Medical Impact: My Journey in Science

## Professor Rajaâ Cherkaoui El Moursli

**L'Oréal-UNESCO L'Oréal-UNESCO For Women in Science Award Laureate 2015**

**Mohammed V University in Rabat**

**Hassan II Academy of Science and Technology**

# Introduction: Gender equality in science - SDGs

**The United Nations Agenda 2030**

Science, technology and innovation (STI) have a have a crucial role in meeting all the Sustainable Sustainable Development Goals (SDGs); so does does gender equality.


**the united nations Global Goals framework aims mainly at reducing inequality in the world,**

Reducing inequality by attracting more women into STEM fields will support the achievement of SDG achievement of SDG targets **4.3, 5.5, 5.c, 9.5 and 17.18.**

# Early Years and Education: Breaking Barriers

**1954**

1

Born in Salé, Morocco with a natural curiosity about how the world works

2

**Early Education**

Earned first degree in mathematics at Lycée Descartes in Rabat, where my passion for science was nurtured

**1974**

3

Convinced my father to allow me to pursue pursue graduate studies in France, overcoming cultural barriers

4

**Doctoral Studies**

Completed PhD in Physics from University University Joseph Fourier in Grenoble, laying laying the foundation for my career

My journey began with inspiration from Neil Armstrong's moon landing, Marie Curie as a role model and role model and the encouragement of a passionate high school teacher. These early influences showed me influences showed me that boundaries could be overcome through dedication and scientific pursuit. pursuit.

# Returning to Morocco: Building a Scientific Legacy Legacy

**1982: Faculty Position**

Joined the Faculty of Sciences at Mohammed V University, beginning my academic journey

1

2

**1996: Laboratory Leadership**

Became Head of Nuclear Physics Laboratory, serving until 2017

3

**2013: University Leadership**

Appointed Vice President of Mohammed V University

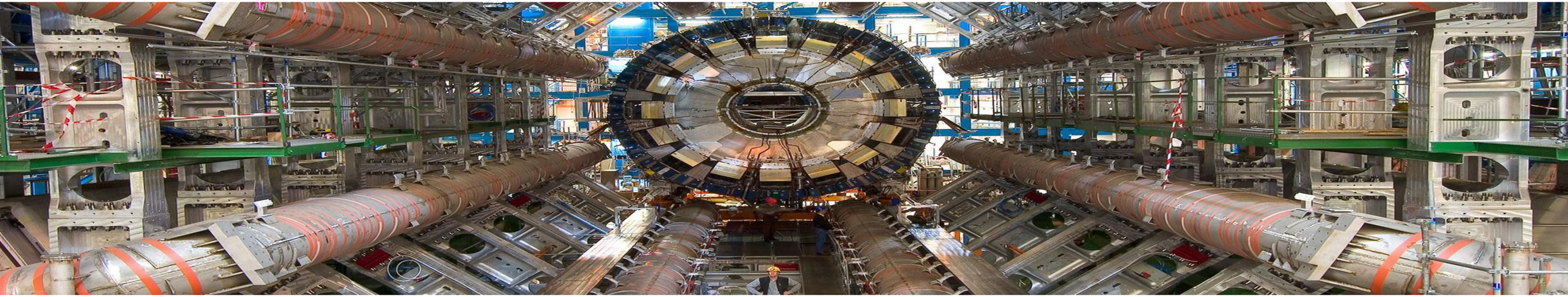
Despite numerous opportunities to build a career abroad, I made the conscious decision to return to return to Morocco. My goal was to develop scientific capabilities and inspire future generations in my generations in my home country.

# Adapting My Research Journey

**PhD Foundations**
• Thesis on **heavy-ion reactions near particle accelerators** (Grenoble)

**Pivot in Morocco**
• Limited accelerator access → shifted to **applied nuclear physics**
• Led projects on **environmental radioactivity & pollution monitoring**

**Back to Fundamental Research**
• Re-established collaboration with the **Grenoble laboratory** to pursue advanced nuclear studies



# Entering the Global Stage – CERN and ATLAS Collaboration

**Morocco Joins CERN (1996**

Led Morocco's participation in ATLAS, making it the first African country in the collaboration

**Scientists**

Collaborated with thousands of researchers from 42 countries and 181 institutes

**African Team**

Pioneered African participation in large-scale international physics research

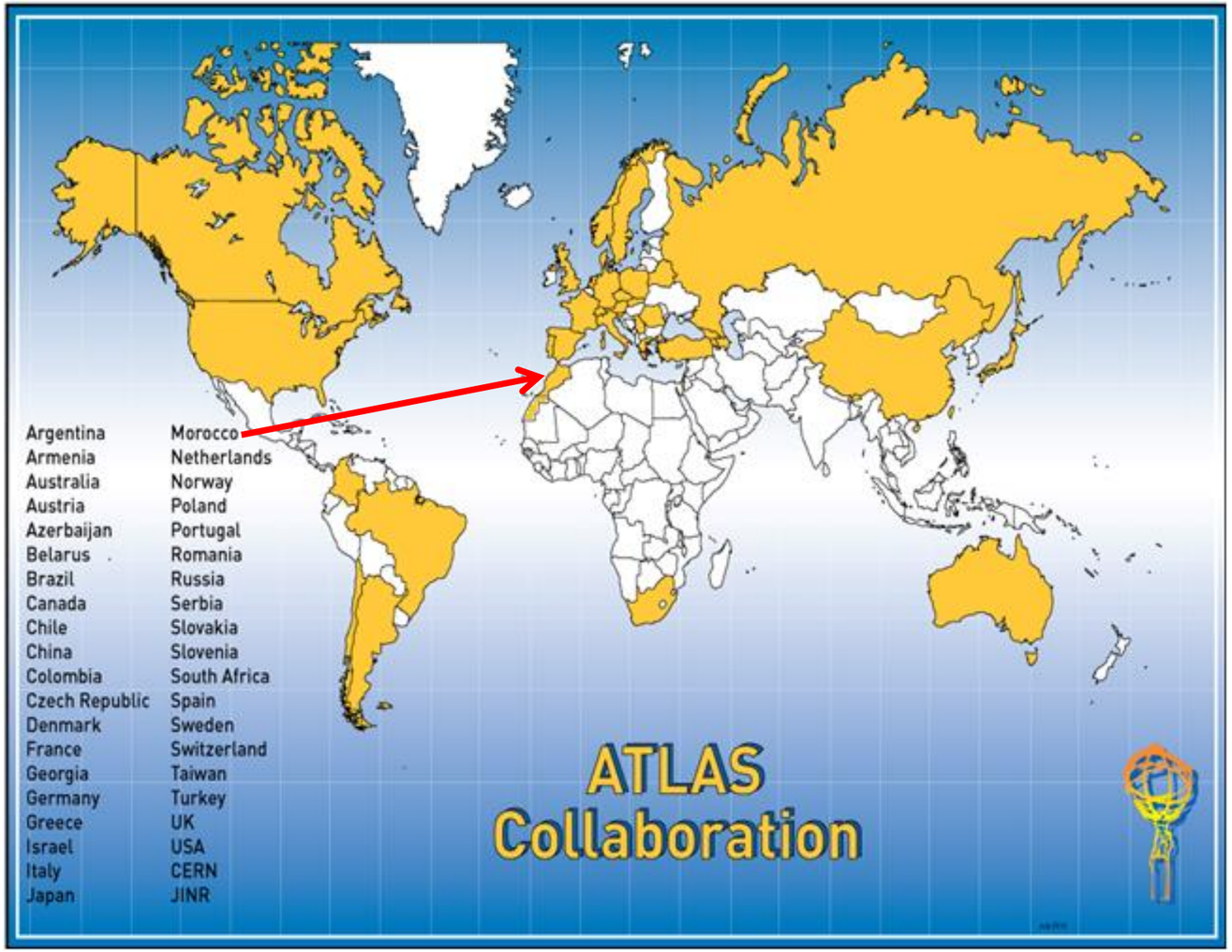
**My role in bringing Morocco into the ATLAS experiment at CERN marked a historic milestone for African milestone for African scientific participation on the global stage.**

# Morocco : member of the International ATLAS collaboration collaboration

42 Countries

- 245 institutes
- **5500 scientists**

**Morocco is the only Arab and African country in 1996 until 2009 .**



# The ATLAS Experiment

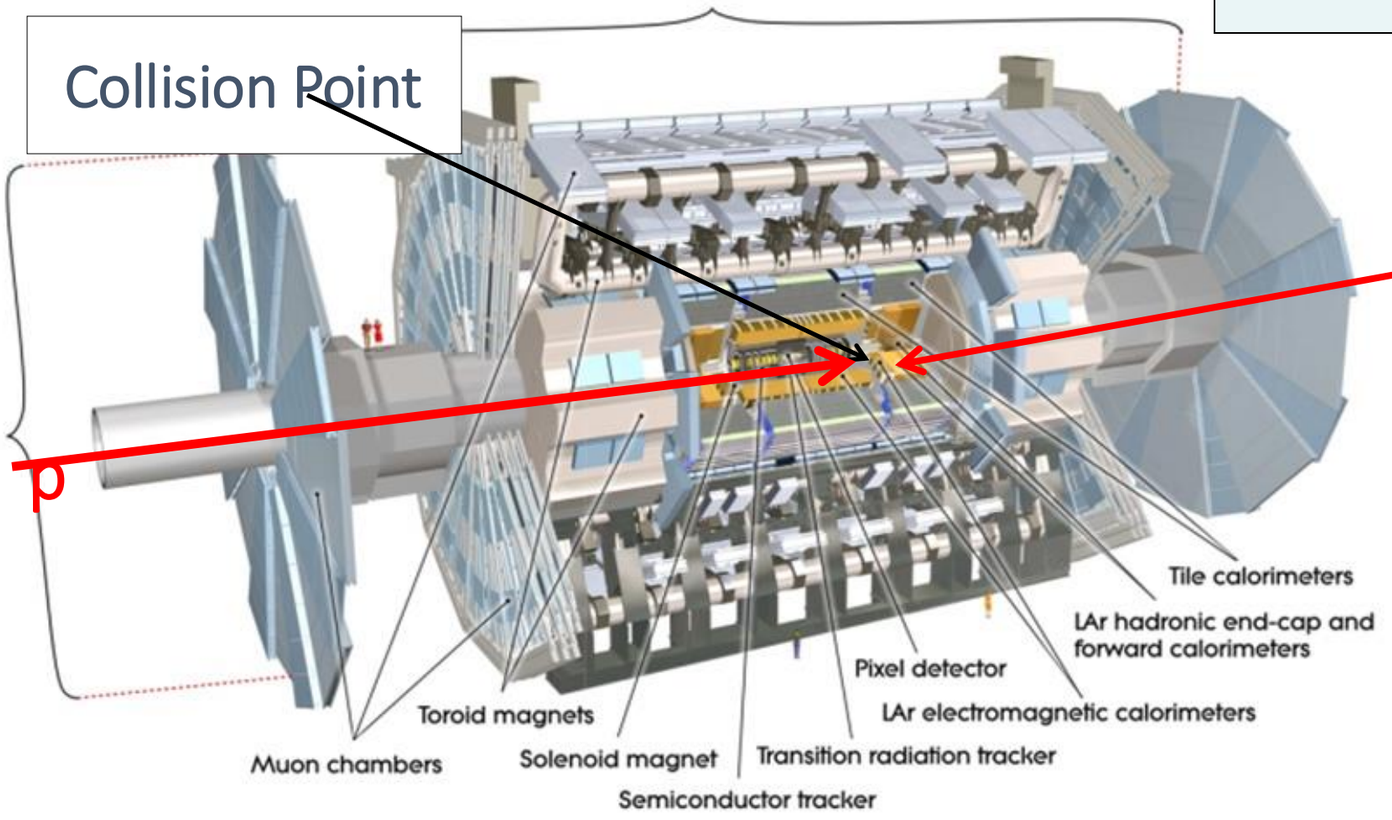
**ATLAS is designed to detect particles created by the proton-proton collisions**

**Overall weight=7000 Tons**

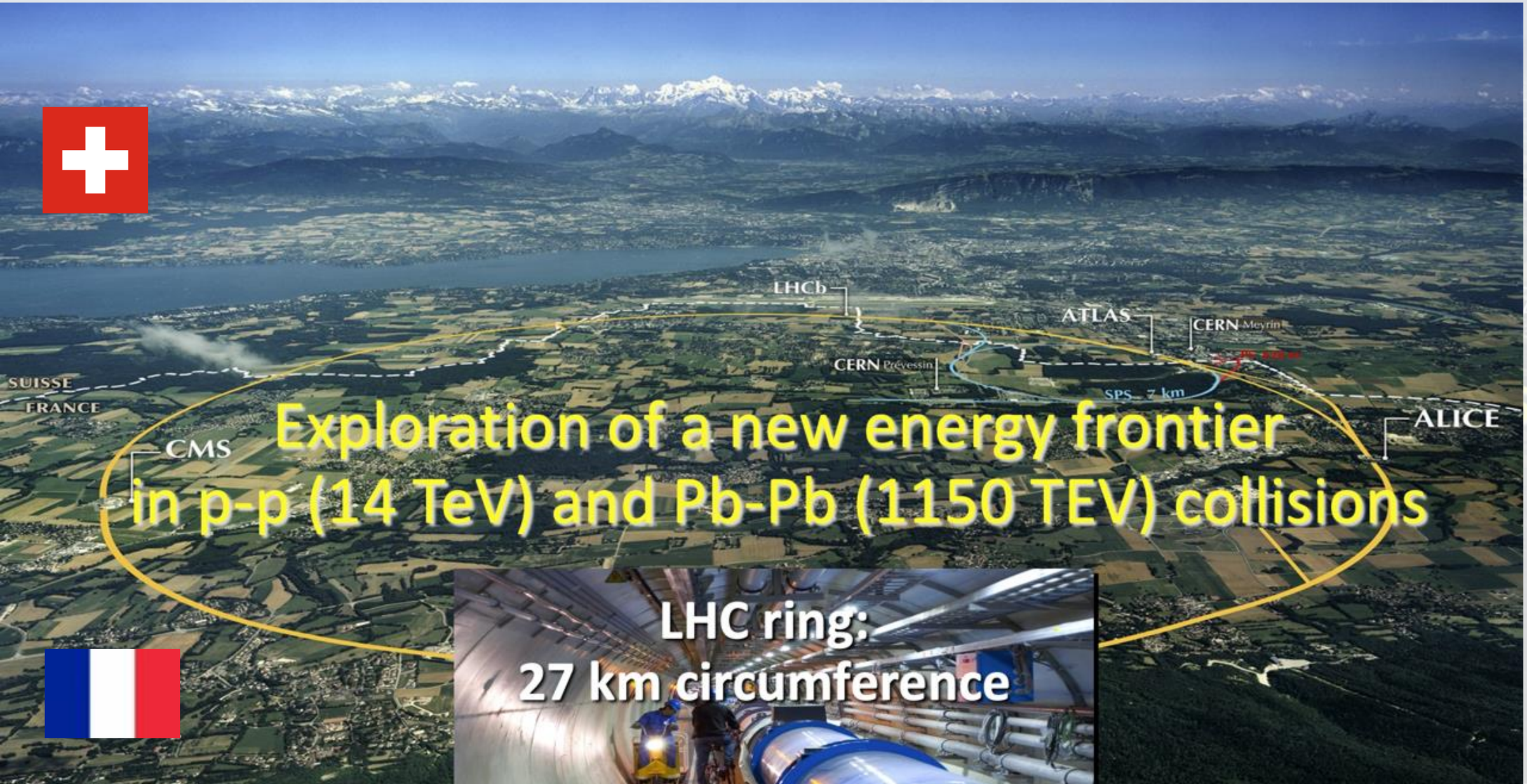
**A Toroidal LHC ApparatuS**

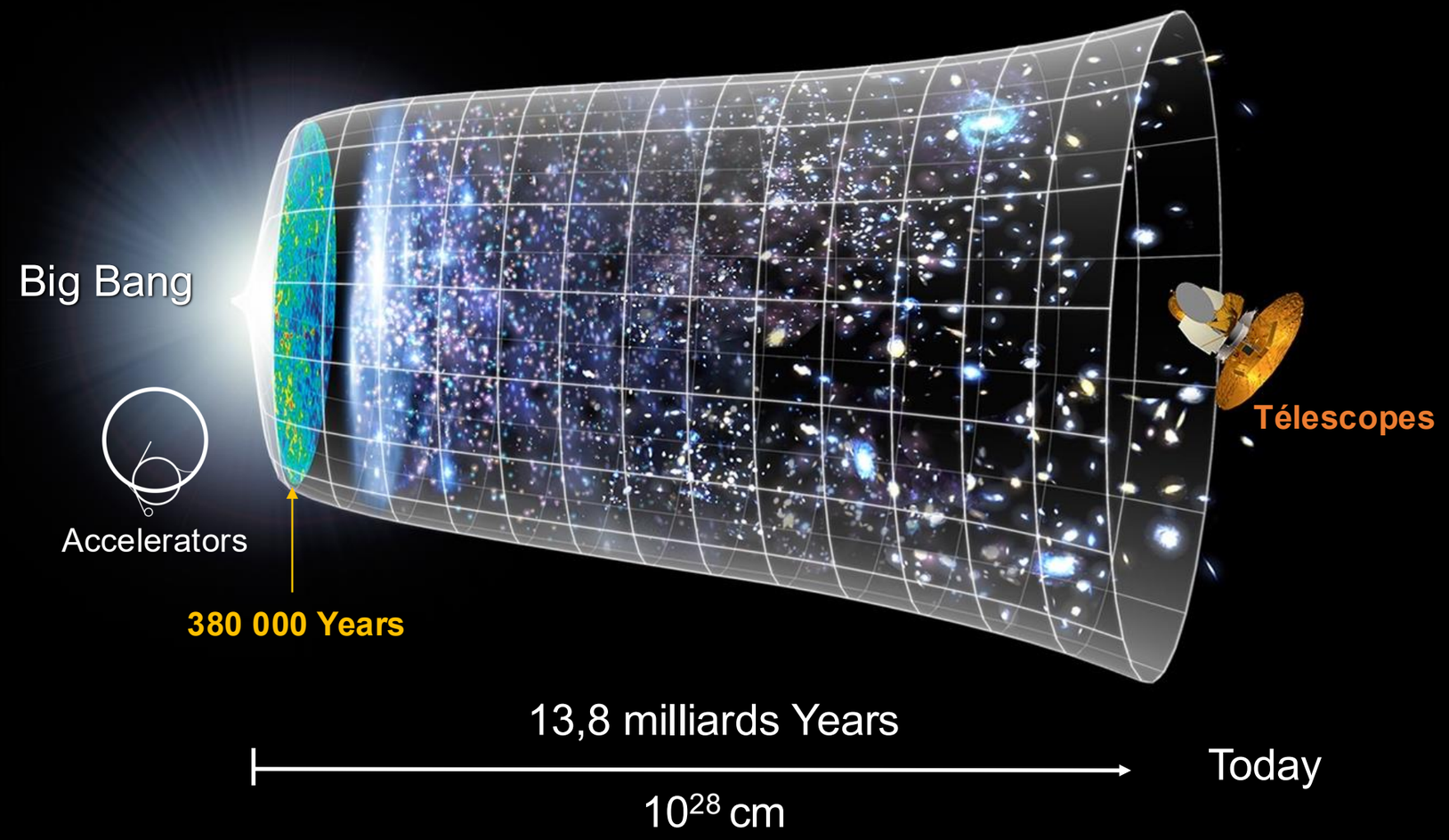
46 m

25 m



# Large Hadron Collider (LHC)



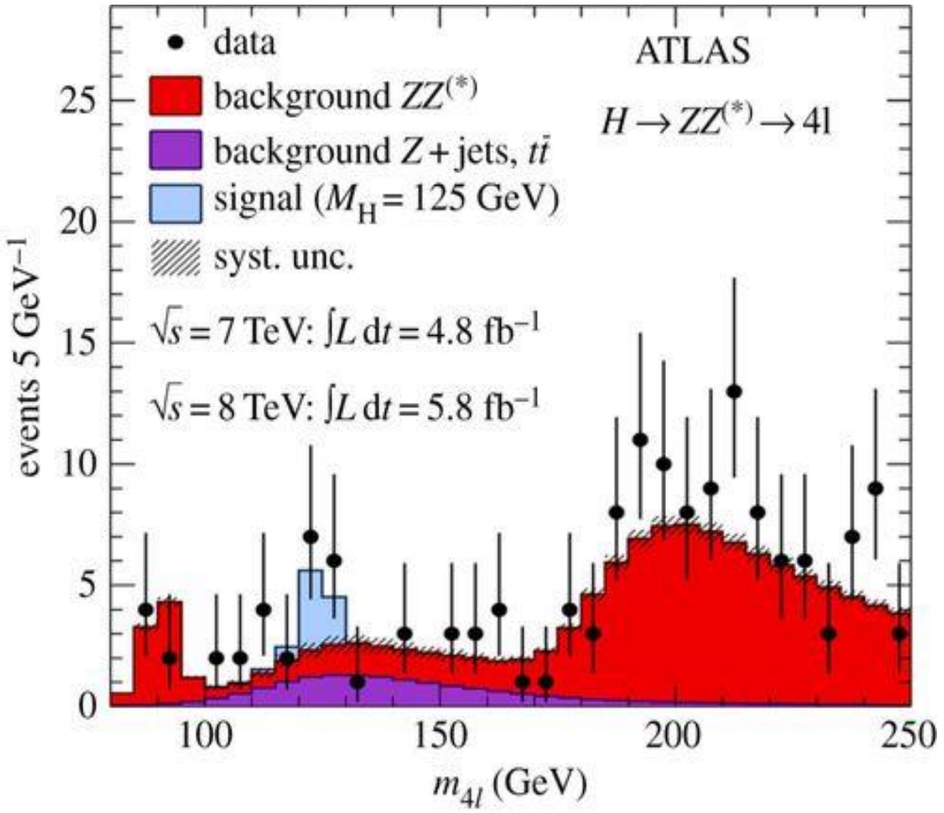



# WHAT WERE THE FIRST MOMENTS OF THE UNIVERSE?

We reproduce the conditions that prevailed a fraction of a second after the Big Bang, to understand the structure and evolution of the Universe

The image shows the expansion of expansion of the universe from from the Big Bang (left) to today today (right), spanning 13.8 billion billion years and 1028 cm. Accelerators help us study the earliest moments, while telescopes observe the later universe.

# DISCOVERY OF HIGGS PARTICLE 2012




**Exciting moment !!**

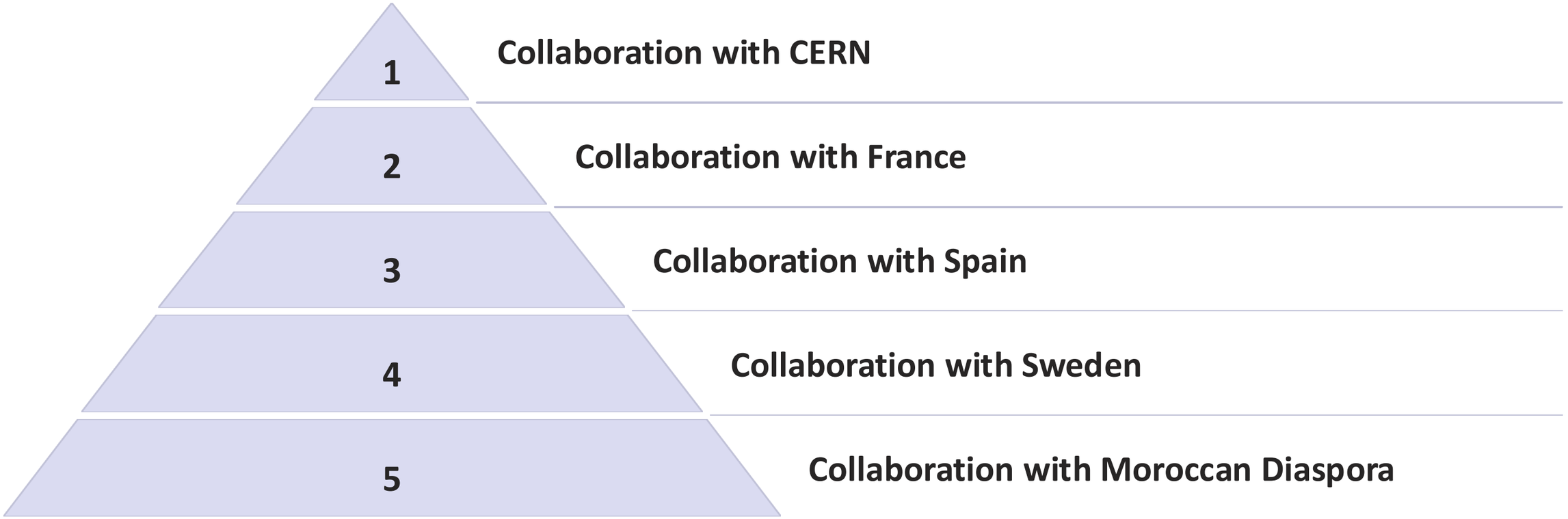
- The **Nobel Prize in Physics 2013** Higgs was awarded jointly to François Englert and Peter W. Higgs
- **WE**, in ATLAS, contributed to an important discovery of this century.
- The contributions of the Moroccan team to the experimental proof of the Higgs boson's existence represented the culmination of years of dedicated research.

**The discovery and measurements of a Higgs boson, Volume: 373, Issue: 2032, DOI: (10.1098/rsta.2014.0384**

# BENEFITS FOR MOROCCO

- Benefits of such participation: PhD students with a high scientific level, innovative training, technology transfer.
- The first master of Medical Physics in Morocco (2007)
- Master's degree in Computer Science and Scientific Instrumentation in High Energy Physics (2007 today)
- A new master in Radioprotection (2022)
- All these concrete results have established complete confidence to this day with Policy makers, despite the changes in government.

# To develop collaborations



# Benefits of fundaqmental research


**Pushes forward our knowledge of the Universe**


**Develop new technologies for accelerators, detectors, computing**

# The 3 technology pillars of particle physic

**Accelerators**

cancer radiotherapy

hadron therapy

production of radioisotopes

**Detectors**

new developments in medical medical imaging detectors detectors

and imaging tools faster and and more sensitive

detectors

**Computing tools & Radiation protection**

Grid computing, Simulation tools

Establishing personalized treatment plans,

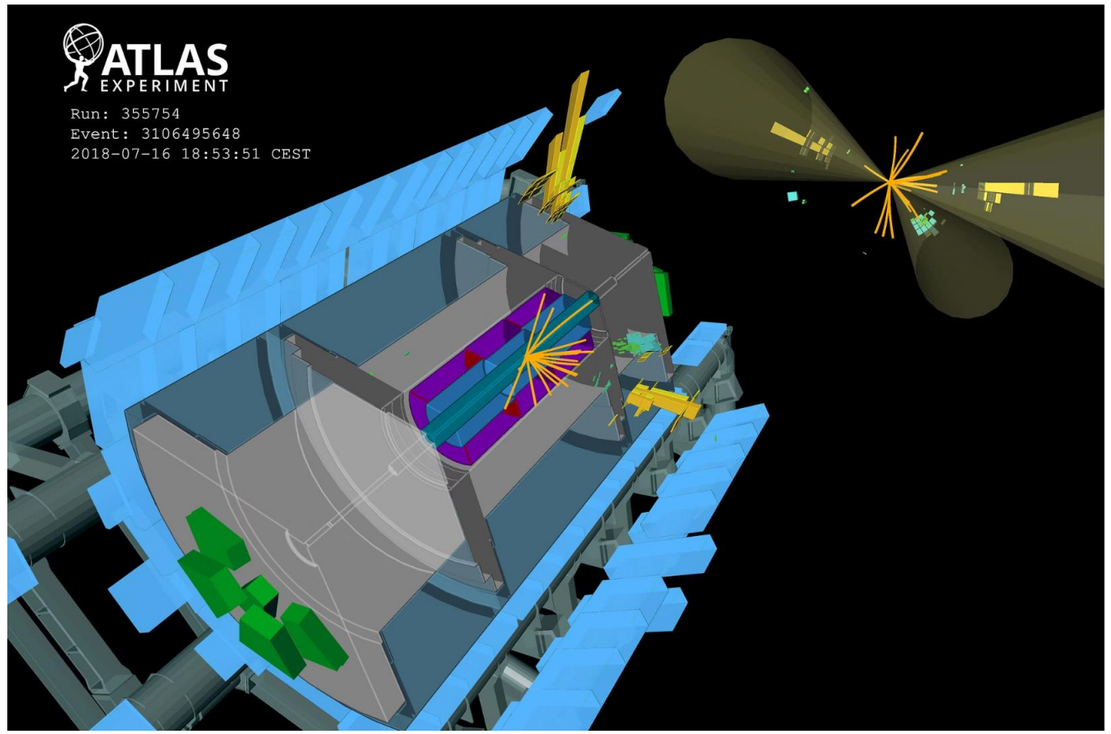
Radiation protection

# Geant4 & ATLAS: Pioneering Particle Physics Simulation

**GEANT4 is a powerful Monte Carlo toolkit toolkit**
**Geant4 stands as the cornerstone simulation simulation toolkit in modern particle physics, supporting groundbreaking research at ATLAS experiment.**

**The toolkit simulates:**

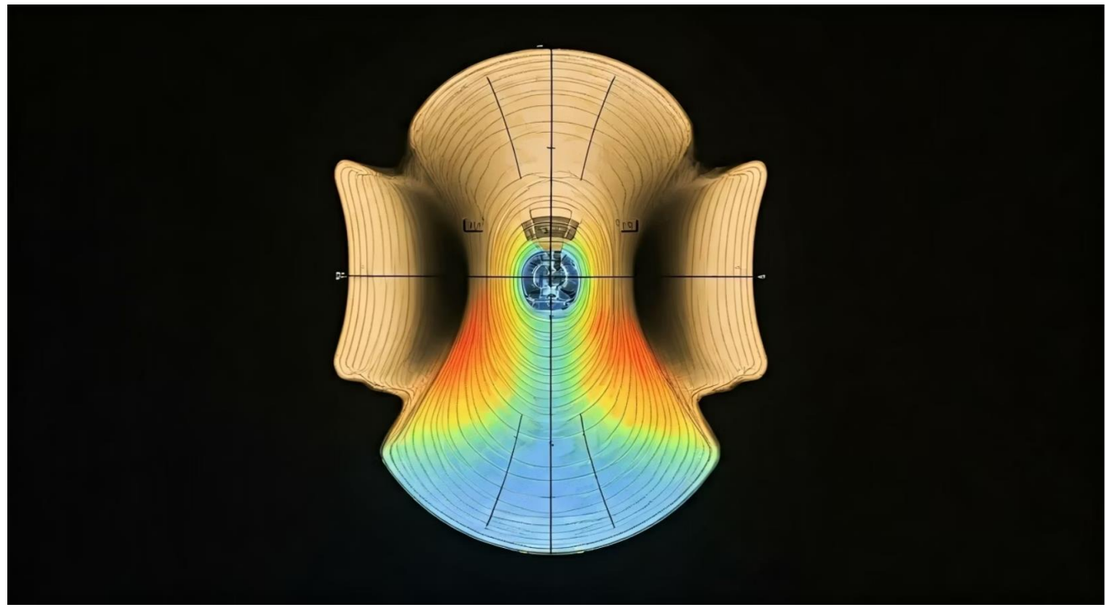
- stochastic processes of particles interacting with matter
- modeling intricate detector geometries, materials
- fundamental particles, and electromagnetic fields



# GEANT4: Transforming Medical Physics Through Simulation

## Radiation Therapy

- Models external beam radiotherapy treatment treatment heads and patient anatomy
- Calculates 3D dose distributions for brachytherapy with superior flexibility
- Simulates complex hadrontherapy beam interactions with tissue



## Advanced Diagnostics

Supports cutting-edge imaging techniques including digital mammography and tomosynthesis with comprehensive physics models.

# **GATE:** Geant4 Application for Tomographic Emission

- GATE (Geant4 Application for Tomographic Emission) is a software platform designed for the simulation of medical imag systems,
- used in nuclear medicine.
- built on the Geant4 toolkit and is widely used for simulating the behavior of particles in medical applications

# GATE: Applications

## Applications in Medical Physics:

- **PET and SPECT Imaging**: GATE is used to simulate the performance of PET and SPECT scanners, enabling researchers to study the design of new scanners or optimize existing ones.
- **Radiation Therapy**: GATE is useful for simulating dose distributions in external beam radiation therapy or particle therapy (e.g., proton therapy). It helps in assessing treatment plans and optimizing radiation delivery.
- **Imaging System Design**: GATE assists in the design and development of novel imaging systems, such as hybrid scanners (e.g., PET/CT, PET/MRI), by simulating their performance in different scenarios.
- **Phantom Studies**: GATE can simulate the behavior of particles in tissue phantoms, which are used to are used to calibrate and validate medical imaging devices and treatment techniques.

## From Particle Physics to Medical Applications

1
**2007-2009: Education Innovation**
Implemented the first Master's program in Medical Physics in Morocco

2
**Research Team Development**
Built specialized team focused on Simulation and Medical Imaging

3
**Healthcare Impact**
Graduates now serve as radiation physicists in hospitals across Morocco

4
**Clinical Applications**
Applied physics knowledge to radiotherapy, radiology, and nuclear medicine

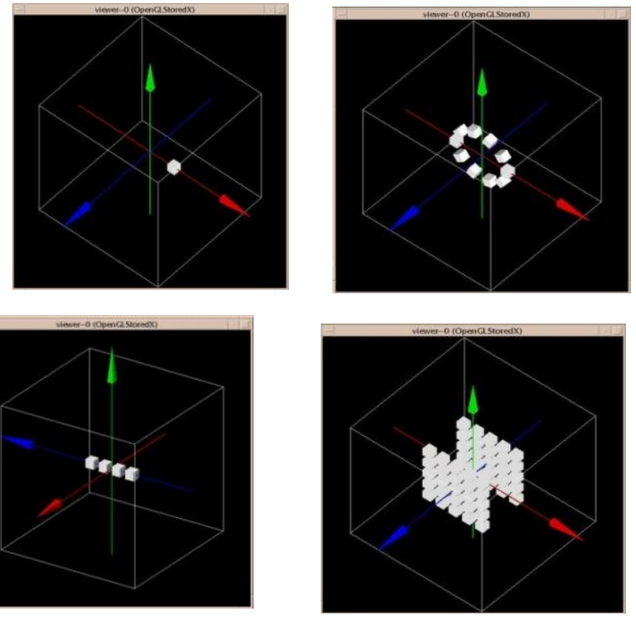
Perhaps the most meaningful aspect of my career has been translating theoretical physics into practical applications that directly benefit patients.

# GATE: Geant4-based Application for Tomographic Emission

**GATE** is a Geant4-based simulation platform for emission tomography

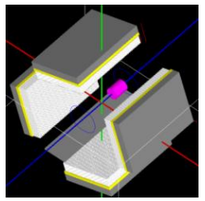
Geant4 is used as the basis layer for Monte Carlo simulations of nuclear medicine acquisition systems in Gate.

Gate allows the user to realistically model experiments using accurate physics models and time synchronization for detector movement trough a script language contained in a macro file.

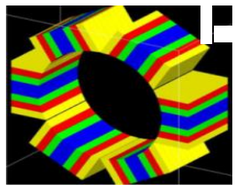


```
# W O R L D
/gate/world/geometry/setXLength 400. cm
/gate/world/geometry/setYLength 400. cm
/gate/world/geometry/setZLength 400. cm
# E C A T E X A C T H R +
/gate/world/daughters/name ecat
/gate/world/daughters/insert cylinder
/gate/ecat/setMaterial Air
# R E P E A T P M T
/gate/PMT/repeaters/insert cubicArray
/gate/PMT/cubicArray/setRepeatNumberX 1
/gate/PMT/cubicArray/setRepeatNumberY 2
/gate/PMT/cubicArray/setRepeatNumberZ 2
```

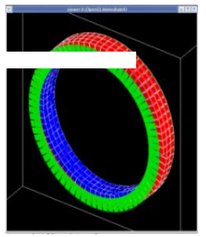
## Simulation of various systems :



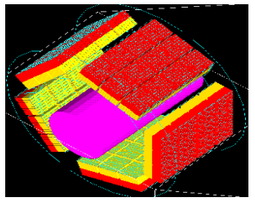
SPECT



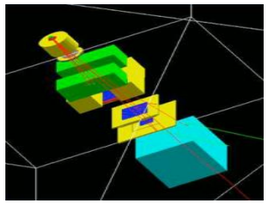
PET scanner



Ecat PET



Cylindrical PET



Radiotherapy

Reduce the overall computing time consumed by a GATE experiment

Use a parallel computing platform for running such heavy simulations on a local cluster of computers - managed by the open- source package TORQUE version 6.1.0 based on the original wrapper portable bash System (PBS)

The local cluster used in our laboratory is managed by the open-source package TORQUE version 6.1.0 based on PBS

made of 12 nodes with dual Intel XEON 3GHz processors, each with 8GB of memory.

performance computing is supported by a robust infrastructure, including a state-of-the-art **computing server cluster**

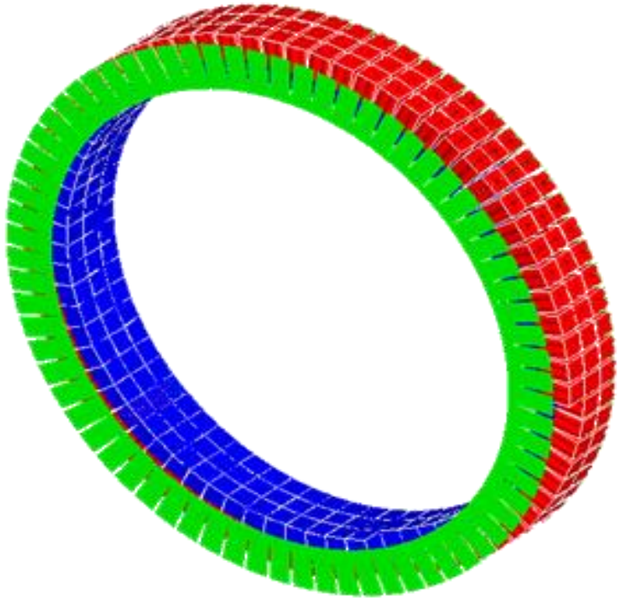
**Toubkal Supercomputer**

Among the **top supercomputers in Africa**.

# Some research projects carried out in our lab

Validation, using GATE according the NEMA NU2-2012 protocol, of:

- the **clinical Positron Emission Tomography PET** scanner,
- **Emission Computed Axial Tomograph** (a brand of PET scanner developed by Siemens/CTI) ECAT
- **High Resolution Plus** – A specific high-resolution PET scanner model used in clinical research, EXACT HR+



NEMA: National Electrical Manufacturers Association

# Some research projects carried out in our lab

- Study the effect of changing the CTW (Coincidence Time Window) and dead time model on the NECR (Noise Equivalent Count Rate) .

- Validation of Siemens Biograph mCT 20 Excel PET/CT System using Gate

- Study the influence of Windows Timing Coincidences on Count Rate Performance

Study the influence of Crystal/block Gap on Count Rate Performance and spatial resolution

Biograph mCT 20

# Ultrasound Image Enhancement Using An Adaptive Anisotropic Diffusion Filter

**Y. Toufique** [1], **R. Cherkaoui El Moursli**[1],**Lh. Masmoudi**[1], **M. Kaci**[2], **A. El Kharrim**[3], **S. Allal** [4]
[1]LPNR, Faculty of Sciences, Mohammed-V-Agdale University, Rabat, Morocco
[2]Instituto de Física Corpuscular, CSIC/Universidad de Valencia, Spain
[3]Mohamed Premier University, Oujda, Morocco
[4] Radiology Department of the Sheikh Zaid Hosp

The main idea of this work
developing an adapted anisotro
diffusion filter based on Perona
Malik method, that can reduce
speckle noise of US image and
the same time preserve the edges

Noisy Ultrasound Image

Filtered Image wit

# Experimental Data

Noisy Ultrasound Image

Filtered Image with AADA

# Monte Carlo study of a replacement flattening filter on a 12 MV photon beam

**A. ZEGHARI*, R. SAAIDI and R. CHERKAOUI EL MOURSLI**
Laboratory of Nuclear Physics, Faculty of Sciences, Mohammed V University

**Objective:**In the last years, many works on the dosimetric properties of free flattening filter photon beams have shown some benefits characteristics of dosimetric for radiotherapy. The purpose of this work is to provide a published theoretical study and basic dosimetric properties analysis for the head of Saturne 43 to implement free flattening filter beams clinically.

**Methods:** This is the first Monte Carlo study for the head of Saturne 43 with replacement flattening filter mode investigating beam dosimetric characteristics, including central axis absorbed doses, beam profiles, and photon energy spectra. The later ones were analyzed for flattening filter beam and replacement flattening filter beam with the BEAMnrc Monte Carlo code.

**Results:** A 3.94-fold increase in the dose rate was obtained with the replacement of the flattening filter beam on a field size of $10 \times 10$ cm$^2$. A decrease was attained with the replacement of the flattening filter beam in the peripheral dose up to 30%, and the time was reduced by 90 %.

**Conclusion:** Our work has shown that a maximum increase in the dose rate, lower out-of-field dose, and reducing the time can be beneficial for the unflattened beam to be used in the radiotherapy with advanced techniques.

**K**

# FLASH Therapy: Revolutionizing Cancer Treatment

A breakthrough approach delivering ultra-fast radiation

High radiation doses delivered in milliseconds

Up to 1000× faster than conventional treatments

RC

Targets tumors precisely

Dramatically reduces damage to surrounding tissue

# Patient Experience

## Shorter Sessions

Minutes vs hours

## Fewer Visits

Reduced treatment schedule

## Faster Recovery

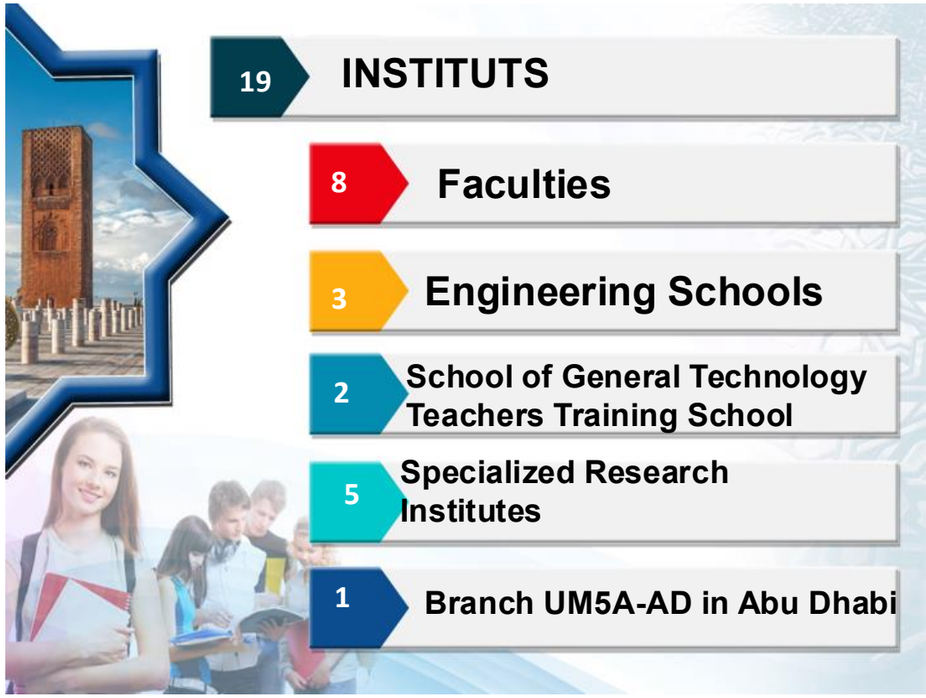
Return to daily life sooner

# REWARDS / NOMINATIONS

## After effort comes comfort

# TO BECOME VICE-PRESIDENT OF UM5R

- Becoming Vice-President of Mohammed V University in Rabat, the first and biggest university in Morocco
- creation of  a university center of entrepreneurship



# NOMINATIONS

- **Resident Member of the Hassan II Academy of Science and Technology**

# NOMINATIONS

- 2015, Elected as a **Fellow of the African Academy of Sciences**. Currently Vice-President
- 2018, Elected as a **Fellow of The Word Academy Science (TWAS)** for the advancement of Sciences in developing countries.

# NOMINATIONS

- 2022, Elected as a **Fellow of the European Academy of Sciences and Arts**.


# L’OREAL-UNESCO AWARD FOR “WOMEN IN SCIENCE” - 2015

**Cultural Change**: Helps shift perceptions and break gender stereotypes in science and technology.



# HONOURED BY THE ORGANIZATION OF ISLAMIC COOPERATION (OIC)


- at the First OIC Summit on Science and Technology in Astana, Kazakhstan on 10-11September, **2017.**
- the OIC has decided to honour four Muslim Scientists in recognition of their valuable contribution in the field of Science and Technology.

# Leadership Roles in Morocco’s Nuclear and Radiological Safety and Research Institutions

**Member of the  board of Trustees**

- Moroccan Agency for Nuclear and Radiological Safety and Security **AMSSNuR**
- National Center for Energy, Sciences and Nuclear Techniques – **CNESTEN**
- National Center for Scientific and Technical Research - **CNRST**

# JURY MEMBER OF THE L'ORÉAL- UNESCO MAGHREB FELLOWSHIPS

- since 2015
- The Maghreb Fellowships L'Oréal-UNESCO For Women in Science aim:
  - at promoting the participation of young women in science.
  - to distinguish young female researchers for the quality of their works and to encourage them to pursue a brilliant career in science.

# MEMBER OF THE INTERNATIONAL JURY “L’ORÉAL-UNESCO FOR WOMEN IN SCIENCE AWARDS”

- Since 2018, Member of the Jury that select the 2019 Laureates of the L’ORÉAL-UNESCO For Women in Science Awards.

# PRESIDENT OF THE NATIONAL ORGANIZING COMMITTEE MT180

- Since 2014, president of the national organizing committee of the French speaking contest in Morocco "My thesis in 180”

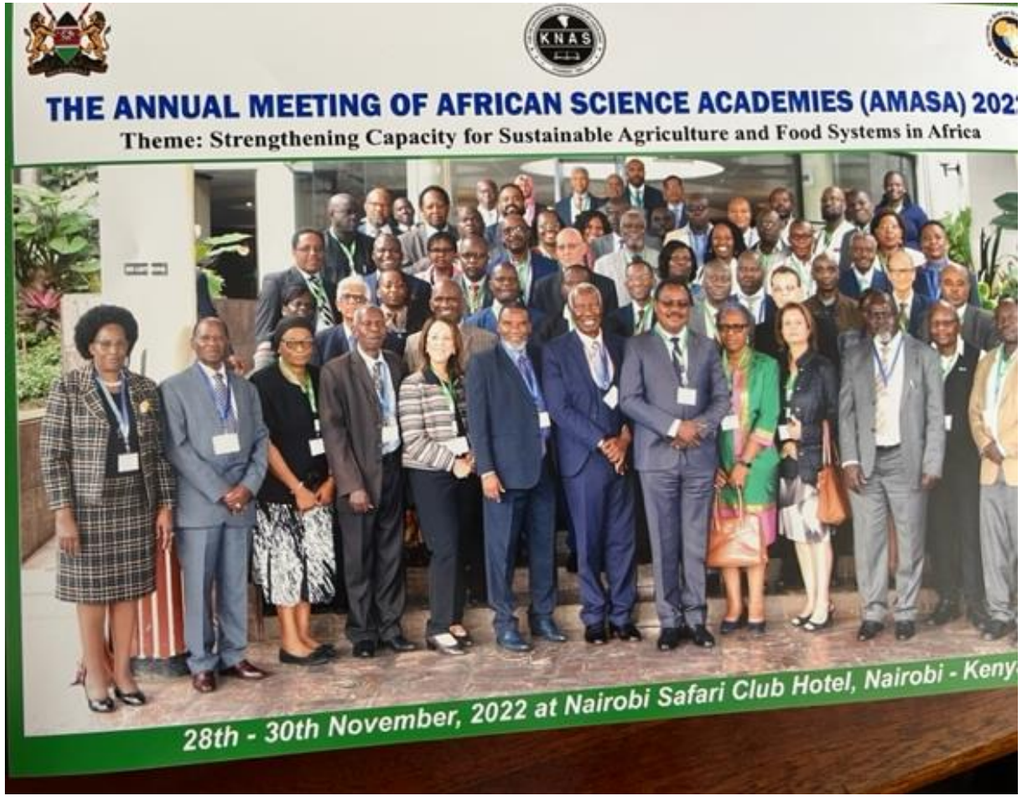
# MEMBER OF THE SCIENTIFIC COMMITTEE OF THE WOMEN'S FOUNDATION FOR AFRICA

- Since 2016, Member of the Scientific Committee of the Spanish Women's Foundation for Africa (Fundacion Mujeres por Africa)


4th edition of science by women program request for applications for visiting senior research fellowships in spanish centers of excellence

# VICE PRESIDENT OF NASAC

2019-2025, Elected Member and Vice-President of The Network of African Science Academies board.



# CONCLUSION

- **A Journey from Discovery to Impact**
- From childhood curiosity to world-class science
- From fundamental research to real-life medical applications
- A collective journey: students, institutions, international collaborations
- The future: Women in STEM, African leadership, and science for society

# *THANK YOU FOR YOUR ATTENTION*

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