Hélène Langevin-Joliot

Marie Curie, les femmes et la science d'hier à aujourd'hui
29.6.2017, Globe of Science and Innovation
Welcome

Summer Students including openlab

to Accelerating Science and Innovation
CERN’s Mission

- Fundamental research in particle physics
- Technology and innovation
  - transfer to society (e.g. the World Wide Web)
- Training and education
- Unite people in their quest for knowledge:
  - > 13000 scientists, > 110 nationalities

CERN staff member T. Berners-Lee, inventor of the WEB, with Kofi Annan

Carlo Rubbia, Nobel Prize, 1984

Samuel Ting, Nobel Prize, 1976

George Charpak, Nobel Prize, 1992
CERN: founded in 1954: 12 European States “Science for Peace”
Today: 22 Member States

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

Associate Member States: India, Lithuania, Pakistan, Turkey, Ukraine

Associate Members in the Pre-Stage to Membership: Cyprus, Serbia

Applications for Membership or Associate Membership: Brazil, Croatia, Russia, Slovenia

Observers to Council: Japan, Russia, United States of America; European Union, JINR and UNESCO

~ 2500 staff
~ 1800 other paid personnel
~ 13000 scientific users
Budget (2017) ~ 1100 MCHF
Science is getting more and more global
They do not all stay: where do they go?

Today:
>3000 PhD students in LHC experiments
CERN’s primary mission is SCIENCE

Study the elementary particles (e.g. the building blocks of matter: electrons and quarks) and the forces that control their behaviour at the most fundamental level

Particle physics at modern accelerators allows us to study the fundamental laws of nature on scales down to smaller than $10^{-18}$ m à insight also into the structure and evolution of the Universe à from the very small to the very big …
Evolution of the Universe

Big Bang

13.7 Billion Years

Today

10^{28} \text{ cm}

Accelerators

380000 years

Telescopes

Hubble

ALMA

VLT

AMS

AMS
2010: a New Era in Fundamental Science

Exploration of a new energy frontier

LHC ring: 27 km circumference

CMS

LHCb

ATLAS

ALICE
Accelerator:

- 1232 high-tech superconducting magnets
- Magnet operation temperature: 1.9 K (-271 °C)
  - LHC is “coldest” place in the universe
- Number of protons per beam: 200000 billions
- Number of turns of the 27 km ring per second: 11000
- Number of beam-beam collisions per second: 40 millions
- Collision “temperature”: $10^{16}$ K
Detectors:
- size of ATLAS: ~ half Notre Dame cathedral
- weight of CMS experiment: 13000 tons (more than Eiffel Tower)
- number of detector sensitive elements: 100 millions
- cables needed to bring signals from detector to control room: 3000 km
- data in 1 year per experiment: ~10 PB (20 million DVD; more than YouTube, Twitter)
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".
With the discovery of the Higgs boson, we have completed the Standard Model (> 50 years of theoretical and experimental efforts !)

However: the SM is not a complete theory of particle physics, as several outstanding questions remain (raised also by precise experimental observations) that cannot be explained within the SM.

These are very exciting times in particle physics!

We have tested the Standard Model with very high precision (wealth of measurements since early ‘60s, in particular at accelerators)
à it works BEAUTIFULLY (puzzling …)
à no significant deviations observed (but difficult to accommodate non-zero neutrino masses)

These questions require NEW PHYSICS
Key questions in today’s particle physics

- Why is the Higgs boson so light (so-called “naturalness” or “hierarchy” problem)?
- What is the origin of the matter-antimatter asymmetry in the Universe?
- Why 3 fermion families? Why do neutral leptons, charged leptons and quarks behave differently?
- What is the origin of neutrino masses and oscillations?
- What is the composition of dark matter (23% of the Universe)?
- What is the cause of the Universe’s accelerated expansion (today: dark energy? primordial: inflation?)
- Why is Gravity so weak?

However, there is no direct evidence for new particles (yet…) from the LHC or other facilities.

- Where is the new physics?
- What is the (energy) scale?
CERN scientific programme

Exploits unique capabilities of CERN’s accelerator complex; complementary to other efforts in the world.

~20 projects other than LHC with > 1200 physicists
The Worldwide LHC Computing Grid

Tier-0 (CERN and Hungary): data recording, reconstruction and distribution

Tier-1: permanent storage, re-processing, analysis

Tier-2: Simulation, end-user analysis

WLCG: An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists

~170 sites, 40 countries

~500k CPU cores

500 PB of storage

> 2 million jobs/day

10-100 Gb links
Medical Application as an Example of Particle Physics Spin-off
Combining Physics, ICT, Biology and Medicine to fight cancer

**Hadron Therapy**

Accelerating particle beams
- ~30'000 accelerators worldwide
- ~17'000 used for medicine

>100’000 patients treated worldwide (45 facilities)
>50’000 patients treated in Europe (14 facilities)

**Imaging**

Detecting particles

Clinical trial in Portugal, France and Italy for new breast imaging system (ClearPEM)

PET Scanner

Leadership in Ion Beam Therapy now in Europe and Japan

Brain Metabolism in Alzheimer's Disease: PET Scan
CERN openlab Summer Student Projects

- Machine Learning for Fast Physics Simulation
- Image Processing for Track Reconstruction
- Biology Development Simulation in the Cloud
- Deep-Learning Algorithms for Image Feature Extraction
- Artificial Intelligence
- Image Analysis
- Code Modernization
- HPC in the Cloud
- Internet of Things for Smart Control Systems in the LHC
- Internet of Things
CERN openlab Research Activities

Accelerated computing platforms for data acquisition and filtering (GPUs, CPU+FPGA)

Specialized platforms for Machine Learning applications

Parallelized Simulation Software (Physics and Medical Research)

Data Centre Architectures and Infrastructure

Computing Platforms and Software Optimization

Data Analytics and Machine Learning

Anomaly Detection (Data Quality and Engineering Systems)

Cloud-based Data Training

Fast Inference for Triggers, Big Data Reduction

Image Processing (Track Reconstruction, Medical Applications, Maps)

Software Defined Networks (SDN), IoT Infrastructures, Sensor Networks, High-Speed Fiber Links

Software Defined Infrastructure (SDI)

Scalable Hybrid Clouds, File Systems as a Service, In-Memory Databases
Enjoy your stay at CERN!