Small particles and large instruments

Accelerating Science and Innovation
CERN was founded 1954: 12 European States
“Science for Peace”
Today: 20 Member States

~ 2300 staff
~ 1050 other paid personnel
> 11000 users
Budget (2012) ~830 MEuro

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

Candidate for Accession: Romania

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

Applicant States: Cyprus, Slovenia, Turkey

Observers to Council: India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO
CERN in Numbers

Distribution of All CERN Users by Nationality on 4 April 2012

MEMBER STATES
Austria 115
Belgium 122
Bulgaria 87
Czech Republic 202
Denmark 73
Finland 90
France 866
Germany 1259
Greece 21
Hungary 71
Italy 1760
Netherlands 169
Norway 71
Poland 264
Portugal 136
Slovakia 92
Spain 380
Sweden 79
Switzerland 225
United Kingdom 685

OBSERVERS 2522
India 215
Japan 254
Russia 982
Turkey 110
USA 961

CANDIDATE FOR ACCESSION
Romania 117

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP
Israel 67
Serbia 39

COUNTRY COVERAGE
Afghanistan 1
Albania 3
Algeria 11
Argentina 16
Armenia 21
Australia 23
Azerbaijan 6
Bangladesh 2
Belarus 41
Bolivia 2
Bosnia & Herzegovina 2
Brazil 98
Cambodia 1
Cameroon 2
Canada 141
Chile 6
China 270
China (Taipei) 48
Colombia 29
Costa Rica 2
Croatia 30
Cuban 6
Cyprus 14
Ecuador 2
Egypt 9
El Salvador 1
Estonia 15
Georgia 31
Hong Kong 1
Iceland 4
Indonesia 2
Iran 21
Ireland 23
Jordan 2
Kenya 1
Korea, D.P.R. 1
Korea Rep. 119
Lebanon 11
Lithuania 17
Luxembourg 3
Madagascar 3
Malaysia 7
Malta 2
Mexico 63
Moldova 1
Mongolia 1
Montenegro 2
Morocco 13
Nepal 3
New Zealand 8
Nigeria 1
Oman 1
Pakistan 44
Palestine (O.T.). 3
T.F.Y.R.O.M. 3
Peru 5
Qatar 1
San Marino 1
Saudi Arabia 3
Senegal 1
Slovenia 43
South Africa 16
Sri Lanka 6
Syria 1
Thailand 7
Tunisia 6
Ukraine 46
Uzbekistan 2
Venezuela 10
Viet Nam 10
Zimbabwe 2

1353
Next challenge: to understand the first moments of our Universe

13.7 Billion Years

Today

$10^{28}$ cm
Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology.
The Standard Model

Quarks
- u, c, t
- d, s, b

Leptons
- e, μ, τ
- ν_e, ν_μ, ν_τ

Forces
- Z
- γ
- W
- g

Forces
- E&M
- Strong
- Weak

Earth

Standard Model

Sun

You
The Higgs Mechanism
4 JULY 2012
CERN Press conference
S/B Weighted Mass Distribution

- Sum of mass distributions for each event class, weighted by S/B
- B is integral of background model over a constant signal fraction interval
Some particles and processes

Hydrogen Atom

More exotic particle observes in accelerators
K- (kaon)

Beta decay
Unification of forces, dark matter

Supersymmetric particles = dark matter?
Unification of forces
Extra dimensions

Gravitation and Quantum Mechanics
Collisions at LHC

Proton/Proton collisions
$10^{11}$ protons per bunch

Event rate in detectors:
$N \approx 1,000,000,000$ interactions/s
Interesting hard events are rare

Selection of 1 in $10,000,000,000,000$

→ very powerful detectors needed
LHC: a New Era in Fundamental Science

LHC ring: 27 km circumference

CMS
ALICE
LHCb
ATLAS
The Large Hadron Collider (LHC) tunnel
Capabilities of particle accelerators

- A modern HEP particle accelerator can accelerate particles, keeping them within millimeters of a defined reference trajectory, and transport them over a distance of several times the size of the solar system.

HOW?
Electric fields accelerate while magnetic fields are used to focus and bend the particle trajectories.

Energy is limited by magnet strength and ring size.

⇒ We use really strong magnets and really big rings.
A collision at LHC
The Data Acquisition

~ 300,000 MB/s from all sub-detectors

~ 300 MB/s Raw Data

Trigger and data acquisition

Event filter computer farm
Tier 0 at CERN: Acquisition, First pass processing, Storage & Distribution

LHCb ~ 50 MB/sec
ATLAS ~ 320 MB/sec
CMS ~ 220 MB/sec
ALICE ~ 100 MB/sec

1.25 GB/sec (ions)
Tier 0 (CERN):
• Data recording
• Initial data reconstruction
• Data distribution

Tier 1 (11 centres):
• Permanent storage
• Re-processing
• Analysis

Tier 2 (~130 centres):
• Simulation
• End-user analysis
Enabling Grids for E-sciencE

~285 sites
48 countries
>350,000 CPU cores
>80 PetaBytes disk, >80PB tape
>13,000 users
>12 Million jobs/month

21:13:50 UTC
Example: medical application

Accelerating particle beams

Detecting particles

Charged hadron beam that loses energy in matter

Large-scale computing (Grid)

Grid computing for medical data management and analysis

CERN Technologies - Innovation

Medical imaging

Tumour Target
CERN, Internet and the WWW
Strong involvement in the ATLAS and ALICE experiments

**ALICE:**
- University of Bergen
- Bergen University College
- University of Oslo

**ATLAS:**
- University of Bergen
- University of Oslo

+ participation in smaller projects (CLIC, ISOLDE, AEGIS, NA61)
The major technology activities at CERN last 15 years:

- Construction of silicon modules for ATLAS (UiB, UiO)
- PHOS detector readout for ALICE (UiB, UiO)
- High Level Trigger development for ALICE (UiB, HiB, UiO)
- Construction of cryogenics tanks for ATLAS (NTNU, UiO, Industry)
- R&D work for future detector systems (UiO, UiB, SINTEF)
- GRID development and deployment (UiO, HiB, UiB, computer centres)
- CLIC accelerator studies (UiO)
High Energy Physics in Norway

Blue: Oslo, Bergen, Trondheim: Universities (offering everything up through PhD)

Red: University Colleges currently involved at CERN (offering up through master level) – some becoming Universities (soon). Some also involved in the ATLAS/ALICE experiments. Supply, with NTNU, all technical students at master level (10-15 yearly)

Today around 140 Norwegian researchers, engineers, postdocs (15-20), PhD students (20-25) and master students (20-25) are involved in the CERN activities:

- At CERN: Around 15-20 technical students at CERN in addition to the Norwegian staff (10-15 at master and ~5 ph.d level)
- Around 90 Norwegian researchers (of all categories above) are registered as users travelling frequently to CERN
- The rest travelling are less frequently or working in Norway within the CERN related research programmes
THANK YOU!
• The two main tasks of an accelerator
  – Increase the particle energy
  – Change the particle direction (follow a given trajectory, focusing)

• Lorentz equation:

\[ \vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) = q\vec{E} + q\vec{v} \times \vec{B} = \vec{F}_E + \vec{F}_B \]

• \( \vec{F}_B \perp \vec{v} \implies \vec{F}_B \) does no work on the particle
  – Only \( \vec{F}_E \) can increase the particle energy

• \( \vec{F}_E \) or \( \vec{F}_B \) for deflection? \( \vec{v} \approx \vec{c} \implies \) Magnetic field of 1 T (feasible) same bending power as en electric field of \( 3 \cdot 10^8 \) V/m (NOT feasible)
  – \( \vec{F}_B \) is by far the most effective in order to change the particle direction