The CERN Physics Department
Your department in 2013-2014

Livio Mapelli

Scientific Program
Organisational Structure
Resources
The CERN Physics Department carries out basic research in the field of experimental and theoretical particle physics. It aims at providing a stimulating scientific atmosphere and remains an important reference centre for the European physics community.

1. LHC experiments
2. Non-LHC experiments
3. Future experiments
4. Theory
5. Support groups
1. Experiments at the LHC
A new era in fundamental science
• General-Purpose Detectors, for energy-frontier physics
  – Studying Higgs boson properties, searching for new physics…

Higgs couplings

ATLAS and CMS

SUSY searches: no signal so far…

<table>
<thead>
<tr>
<th>Model</th>
<th>$E_T^{miss}$</th>
<th>$\lambda (\mu, T, \gamma, \tau)$</th>
<th>ATLAS Preliminary</th>
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</thead>
<tbody>
<tr>
<td>SUSY</td>
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![Graph](image-url)
CERN participates to the ATLAS collaboration

- as an Institute
  - Detectors. Inner: BCM, Pixel, SCT, TRT; Calorimeters: Lar, Tile; Muon spectrometer; Forward detectors (Alfa)
  - Trigger and DAQ, Computing, Offline systems, Physics analysis
  - Upgrade activities
  - 286 papers so far

- as the Host Laboratory
  - Hosting ATLAS Management; Technical Coordination; Tier-0 Operation

Insertion of Pixel detector december 2013

nSW Micromegas sector-sized prototype fully assembled. Study panel deformation and sag, measure elastic & mechanical properties.
• CERN as an Institute:
  – flagship analyses: Higgs-> tau tau, 4 leptons, gamma-gamma and combination of results, top mass, SUSY searches. **328 papers so far**
  – RPC assembly and test in 904, installation half completed
  – Pixel CO2 cooling station
  – DAQ being re-architected

• CERN as the Host Lab:
  – 4th endcap shielding disk
    • 1 installed, 2nd being prepared for installation
    • Push-back system designed and tested
  – Preparation for new beam pipe installation
LHCb

• Dedicated to beauty and charm particles search for new physics in CP violation and rare decays
  • Short term program is based on data sample of ~8 fb\(^{-1}\) collected within ~5 years of LHC running
  • Longer term (with data sample of ~50 fb\(^{-1}\)) \boldsymbol{\rightarrow} study models of new physics (or further constrain it), with upgraded detector
• 167 papers so far, some with high impact

First evidence for the very rare decay \(B_s \rightarrow \mu^+\mu^-\)
ALICE

- Dedicated heavy-ion detector for nucleus-nucleus collisions
  - Physics of strongly-interacting matter at extreme energy densities
  - Formation of new phase of matter: quark-gluon plasma
  - Flagship results: J/psi enhancement, charm flow, collectivity in pA collisions
  - 78 papers so far, 400 conference presentations/year

- CERN as an Institute
  - Detectors (SPD, TPC, HMPID); Online and Offline; Physics Analysis
  - Upgrade: ITS (Inner Tracking System) and O\(^2\) (Online-Offline) projects

- CERN as the Host Lab
  - Hosting technical coordination, major consolidation work in LS1; T0 operations

ITS: 25 G-pixel camera (~10 m\(^2\)) for upgrade

Beam pipe

regeneration

melting
• **Forward experiment at the CMS region, using Roman Pots**

• **Physics in 2013**
  - Luminosity independent pp total cross-section at 8 TeV
  - Double diffraction cross-section at 7 TeV
  - Evidence of hadronic-Coulomb interference in pp elastic scattering at 8 TeV
  - **14 papers so far**

• **Technological developments**
  - RF optimized Roman Pot for high luminosity at LHC
  - Integration of new RP stations in LHC beam line and study of timing detectors in new cylindrical Roman Pot

**Other small experiments at the LHC**
  - **LHCf**: forward experiment at ATLAS region
  - **MoEDAL**: search for magnetic monopoles with plastic sheets around the LHCb region
The Nobel Prize in Physics 2013

@nobelprise.org/nobel_prizes/physics/laureates/2013/

Nobel Prizes and Laureates

Photo: A. Mahmoud

François Englert

Photo: A. Mahmoud

Peter W. Higgs

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".

Photos: Copyright © The Nobel Foundation

To cite this page

The Standard Model

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

Leptons
- e, μ, τ, ν_e, ν_μ, ν_τ

Forces
- Higgs boson
- Z, γ, W, g

Standard Model

The Economist
A giant leap for science
Finding the Higgs boson
Now that we have discovered the BEH scalar boson

- *That explains why particles have different masses and says the final word on the validity of the Standard Model*

- *We remain with fundamental unanswered questions*

Astrophysical measurements indicate that the Universe is made of:
- 5% known matter
- 25% “dark matter”
- 70% “dark energy”

*Today we understand only 5% of the Universe’s composition*

Theories beyond the Standard Model – such as *Supersymmetry* predict new heavy elementary particles
Among them the *neutralino*, our present best candidate for the dark matter which may be light enough to be produced abundantly at the LHC
LHC experiments plans for 2014

- Ongoing physics analysis from Run 1

- Preparation for Run 2
  - Completion of LS1 work
  - Startup early in 2015

- Preparation of upgrades
  - Phase 1 in 2018/19
    - Large upgrades for LHCb and ALICE
    - “Small” for ATLAS and CMS
  - Phase 2 in 2023/24
    - With high-luminosity upgrade of machine (HL-LHC)
    - Large upgrades for ATLAS and CMS
2. Non-LHC experiments

SME – Small and Medium sized Experiments

Hosts the non-LHC experiments
Maintains a diverse programme of physics at CERN

- PS and SPS Fixed-Target experiments
- AD experiments – Antiproton Decelerator
- ISOLDE + nTOF
  - Nuclear physics (Isotope separation, neutron time-of-flight)
- Other experiments
  - CLOUD, DIRAC, CAST
Fixed target at the SPS

Lower energy experiments at PS or SPS allow precision measurements and comparison with theory. 
**Deviations can be sign of new physics at higher energies.**

DIRAC: **pionic atoms** (completed)
COMPASS: **muon spin physics, spectroscopy**
NA61: ion physics, **quark gluon plasma**
NA62: **rare K decays**
NA63: **electromagnetism** in extreme conditions

Successful technical run
*Physics starts in 2014!*

Lead ion collision

Compass in North hall (60 m long)
Antiproton & Antihydrogen Physics

Matter-Antimatter comparison
Very fundamental in the current theory of physics: $m = \bar{m}$, $g = \bar{g}$

ATRAP, ALPHA
Trapping and spectroscopy of Hbar in a "bottle"

ASACUSA
Spectroscopy of exotic atoms and of in-flight Hbars

BASE
Magnetic moment of the antiproton

AEgIS
Hbar free fall, gravity effect on antimatter
Galileo’s experiment for antimatter!

In 2014 commissioning all steps of antihydrogen production:
Positronium formation, laser excitation,
Antihydrogen detection, etc.
**Nuclear Physics: nTOF & ISOLDE**

**nTOF (neutron time-of-flight)**
Measures neutron cross-sections

**Astrophysics**
Burning of nuclear waste

New experimental area EAR-2 in preparation

**ISOLDE: radioactive ion beams**

Nuclear physics
Astrophysics
Solid State Physics
Medical applications

3 papers in Nature in 2013

Upgrade to higher intensity (HIE-ISOLDE) in progress

Octupole deformation in $^{220}$Rn and $^{224}$Ra

**ISOLDE:** radioactive ion beams

Nuclear physics
Astrophysics
Solid State Physics
Medical applications

3 papers in Nature in 2013

Upgrade to higher intensity (HIE-ISOLDE) in progress
Other experiments

CLOUD - Study effect of cosmic rays on cloud formation
Cosmic rays “simulated” by T11 beam, clouds created in a large climatic chamber

CAST - Search for axions from sun
Using a spare LHC dipole, pointing at sun
Study for successor (IAXO) underway

OSQAR - Search for photon regeneration
Using another spare dipole and laser source
3. Future experiments

- **LCD – Linear Collider Detector**
  Studying the detector design for possible future $e^+e^-$ linear colliders (ILC & CLIC)
  Participating in detector and physics studies (CLICdp)

- **FCC – Future Circular Collider study**
  80–100 km circumference machine to study pp collisions at 100 TeV, as well as ee or ep options
  Kick-off meeting 12-15 February,
  PH staff contributing

- **New approved projects and proposals in preparation**
  R&D for future neutrino detectors: WA104 (Icarus), WA105 (Laguna)
  Other proposals under review: beam dump at the SPS, IAXO axion telescope
Linear Collider Detector

**Mandate:**

**Linear Collider Detector**
- Hardware R&D (ILC/CLIC)
- Software development

**CLICdp** (~collaboration, 22 institutes)
- Host lab
- R&D (CLIC-specific) + Physics studies

**Ongoing activities**

**Pixel R&D**
Progress on:
- Electronics
- Pixel assemblies
- Engineering

**Calorimeter R&D**
- Test beam analysis
- Lab test SiPM-scintillator

**Physics studies**

Exploring synergies with other CERN projects:
- Medipix/Timepix, RD53
- HL+LHC, FCC, AIDA-2

**64×64 pixels**

**1.6 mm**

**Higgs couplings at CLIC**
4. Theory

- Excellence and creativity in all vital areas of theoretical physics research
  - Standard Model, collider phenomenology
  - Heavy ion physics
  - Beyond the SM, including neutrinos and non-accelerator experiments
  - Astroparticle physics and cosmology
  - Quantum Field Theory and string theory
  - Lattice field theory

- **Average > one paper per day in 2013!**
  - (including weekends)
Theoretical Physics

- Support the experimental program of CERN
  - and profit from its stimulating environment

- Contribute to training and outreach
  - academic training, high school teachers, summer students, CERN schools, ...

- Reference center for the international theoretical physics community

- Theory Institutes planned in 2014
  - CERN winter school (3-7 Feb)
  - Questioning fundamental physical principles (6-9 May)
  - Numerical holography (2-13 June)
  - Resurgence and trans-series (30 June-4 July)
  - Lattice gauge theory (21 July-1 August)
  - Gauge theories in diverse dimensions (11-22 August)
  - Understanding the early Universe (2 weeks in Autumn)
5. Support groups

AGS  Administration and General Services

DT    Detector Technologies
Development, construction, operation and maintenance of particle detectors
Detector infrastructure for the experiments at CERN
Services for detector R&D

ESE   Electronic Systems for Experiments
Design and maintenance of electronics systems for experiments at CERN
Supply of electronics related services

SFT   SoFTware design for experiments
Development and maintenance of common scientific software for the CERN experimental programme
Administrative General Services

Secretarial support to experiments and groups

USERs' Office

Space management and infrastructure
PH-DT in 2013 and 2014

• Projects
  – Focus on operational and engineering support to LHC experiments during LS1 and to SME (NA62, CAST, AEGIS, CLOUD)
  – Contributions to new detector systems: ATLAS IBL, NA62 Straw Tracker
  – LHC detector upgrades: LHCb SciFi & TORCH, ALICE ITS, ATLAS Micromegas, TK upgrades

• Services
  – Guarantee services and infrastructure for LHC running: Gas, Detector Cooling, Magnet controls and support
  – Facilities for detector R&D: GIF++ and PS facilities

• Strategic R&D projects
  RD50, RD51, LCD hardware effort

• Consolidation of new activities
  – \( \text{CO}_2 \) cooling, micro-fabrication, composite development, effective integration of the former TE PCB workshop in PH
PH-ESE in 2013 and 2014

- **Services**
  - Pool, Power & Crates, IC technologies access (65 nm)

- **White-Paper projects finalization and production**
  - Rad-hard DC-DC converter, Versatile link components and GBT chipset

- **Experiments**
  - Many projects in ALICE, ATLAS, CMS and LHCb
  - ATLAS-CMS-LCD common development of pixel readout ASIC (65 nm)
  - Electronics coordinators of all LHC experiments are in ESE
  - NA62 (Gigatracker (ASIC), Straw detector and LKr RO)

- **Medipix**
  - Development of several ASICs and Through Silicon Vias

- **New R&D or services**
  - High speed low power optical link, Power for extremely high radiation, xTCA (VME replacement), IC technologies and IP blocks, RD53
Three main projects:

- **Geant4.** Released major new version (10) of the simulation toolkit with multi-threaded event parallelism
- **ROOT.** Working towards major version 6 with the full support of all LHC experiments (new C++ interpreter based on open source LLVM/Clang compiler)
- **CernVM.** Virtual Machine approach for Desktop and Cloud Computing. Companion File System is now indispensable for all experiments.

In 2014:

- Prepare for data taking in 2015
- Improve quality, performance and maintainability
- Continue R&D (Concurrent programming, Vectorisation, HEP-wide Software Collaboration)
- New funding opportunities (e.g. Horizon-2020)
Safety in PH

Summary of the CERN Safety Objectives from the DG for 2014

• Improvement of road safety prevention
  – Infrastructure
  – Behaviour

• Incident prevention in view of LS1 and restart

• Emergency preparedness
  – Evacuation exercises
  – Evacuation signalization

• Management of hazardous chemicals

• Safety of activities: work at height
  – Lifelines
  – Personnel Protection Equipment (PPE)

• Environmental Protection
  – Continuous improvement to limit greenhouse gas emissions
  – Optimize consumption of drinking water
  – Limitation of waste products

• Conformity of machine workshops (ongoing from 2012)

Safety concerns each and all of us!
Resources

*PH in numbers:*

*people and money*
In 2013 the budget for exploitation was 26.6 MCHF

**LHC Operation:** operation of ALICE, ATLAS, CMS, LHCb, TOTEM, LPCC, SFT and general LHC.

**SUPPORT:** operation of AGS, DT, ESE, Outreach and TH.

**PROGRAMMES:** budgets for Scientific Associates, Technical Associates and Students.

**NON-LHC:** operation of Aegis, Cast, Cloud, Compass, Isolde, NA62 and other small experimental activities, generic R&D and operation of the LCD group.
In 2013 the budget allocated for projects was **17.5 MCHF**

- **UPGRADE** for LHC detectors.
- **CONSOLIDATION** budget ending in 2014.
- **R&D line** R&D for LHC Upgrade and GETP.
- **OTHER** all non-LHC experiments like Aegis, NA62 and Compass, Isolde building, GIF++ project, LCD R&D, EPLANET and TT.
- **EU** projects financed by the European Commission.
Personnel in PH compared to CERN

CERN / PH - without Users

- PH: 23% (887)
- CERN Total: 77% (2917)

CERN / PH - All categories of personnel

- PH: 22% (3105)
- CERN Total - PH: 78% (11216)

Number of USERs 2004-2014

- Men
- Women
- Total

Number of USERs in 2014 by age groups

- 8443 men
- 1765 women

Nationalities: Users, 99; Staff: 26
Different categories of Personnel in PH

- **Staff Members**: 55% (489)
- **Fellows**: 23% (204)
- **Assoc. with subsistence**: 12% (105)
- **Students + Apprentices**: 10% (89)

**Total**: 100% (908)

*At 30 November 2013*

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Different categories of Personnel in PH (with Users)

- **Staff Members**: 92% (10329)
- **Fellows**: 8% (887)
- **Assoc. with subsistence**: 92% (10329)
- **Students + Apprentices**: 92% (10329)
- **Users + Unp. Assoc.**: 92% (10329)

*At 30 November 2013*
Staff and Fellows in PH (Organic Units)

Staff (487)

- LHC exp: 51% (247)
- Non LHC: 41% (202)
- Future exp: 4% (19)
- TH: 1% (3)
- Support: 1% (3)
- DI: 2% (9)

Fellows (209)

- LHC exp: 56% (117)
- Non LHC: 14% (29)
- Future exp: 19% (40)
- TH: 4% (9)
- Support: 5% (11)
- DI: 1% (3)
Summary by activities (Staff)
In 2013, PH had a material budget of **43.1 MCHF**
for operation and projects includes financial support to students and associates

a personnel budget of **122.5 MCHF**
for salaries of staff members and fellows includes administrative support of ~11000 users

**We have a big responsibility!**
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For the essence of this presentation
the biggest thanks go to you
the people of PH!
To conclude

The CERN Physics Department is your department

Its success is in your hands!

I wish you all a nice and satisfactory 2014