DESY Overview

Welcome Summer Students 2010

Helmut Dosch.
Chair of the Board of Directors of DESY
DESY – Deutsches Elektronen Synchrotron
- founded 1959 -

Mission: Development, construction, operation and scientific exploitation of accelerators

Provide access and services for national and international users

Internationally used, nationally funded Research Institute

<table>
<thead>
<tr>
<th>Base-Budget:</th>
<th>185 MEuro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding source:</td>
<td>90% federal, 10% state</td>
</tr>
<tr>
<td>Staff:</td>
<td>~1600 FTE in Hamburg and Zeuthen</td>
</tr>
<tr>
<td>Users:</td>
<td>~3000 (1500 from abroad) from 45 nations</td>
</tr>
<tr>
<td></td>
<td>920 in particle physics, 2100 in photon science</td>
</tr>
</tbody>
</table>
DESY.

Hamburg.

Zeuthen.

Helmut Dosch  
Summer Students at DESY 2010
DESY. Member of the Helmholtz Association

Research Centres: 17

Employees: ~ 24,000

Budget ~ 2.400 Mio Euro

Research Fields:
- Health
- Energy
- Earth and Environment
- Key Technologies
- Structure of Matter
- Traffic and Space
### Research Landscape Germany

<table>
<thead>
<tr>
<th>Universities</th>
<th>Max-Planck-Gesellschaft</th>
<th>Helmholtz Association</th>
<th>Fraunhofer Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land 100</td>
<td>Federal St. -Land 50:50</td>
<td>Federal St. -Land 90:10</td>
<td>Federal St.-Industry ≈ 65:35</td>
</tr>
<tr>
<td>Excellence Initiative</td>
<td>Fundamental Research</td>
<td>Research Infrastructure</td>
<td>Applied Research</td>
</tr>
<tr>
<td>Research-Education</td>
<td>no research policy requirements</td>
<td>Strategic Research</td>
<td>Knowledge Transfer, TT</td>
</tr>
<tr>
<td>1,4 Bio EUR</td>
<td>1,3 Bio EUR</td>
<td>2,5 Bio EUR</td>
<td>1,3 Bio EUR</td>
</tr>
</tbody>
</table>

- **Universities**: Land 100, Excellence Initiative in Research-Education, 1.4 Bio EUR
- **Max-Planck-Gesellschaft**: Federal St. -Land 50:50, Fundamental Research, no research policy requirements, 1.3 Bio EUR
- **Helmholtz Association**: Federal St. -Land 90:10, Research Infrastructure, Strategic Research, 2.5 Bio EUR
- **Fraunhofer Society**: Federal St.-Industry ≈ 65:35, Applied Research, Knowledge Transfer, TT, 1.3 Bio EUR
DESY Management and Boards.

E. Weckert  
Director  
Photon Science

J. Mnich  
Director  
Particle Physics

R. Brinkmann  
Director  
Accelerators

C. Scherf  
Director  
Administration

H. Dosch  
Director  
General

U. Gensch  
DESY- Zeuthen

Summer Students at DESY 2010
Ahmed Ali, Christian Hambrock (DESY)
Analysis of BaBar and BELLE Data:
evidences for tetraquark states
Scientific Highlights.
Unusual collective Phenomena: 2/ QED Lamb-Shift in Nanostructures

Ensemble of identical atoms behave differently than a single atom under irradiation of light. DESY provides evidence of effect predicted 35 years ago.

The Lamb Shift—Yesterday, Today, and Tomorrow

The study of the emission and absorption of radiation is the royal road that led Planck to quantum mechanics and Einstein to the concept of the photon. The experiment of Röhlberger et al. atom jumps to an excited state and a virtual photon is emitted, followed quickly by the reverse process in which the atom jumps back to the ground state and absorbs a photon (see the first figure, panel A). These $2S_{1/2}$ states were directed onto a detector (see the first figure, panel B). When an atom in the excited state struck the surface, an electron was emitted. The beam was then investigated by means of microwaves, which

Quantum field effects are magnified by collective interactions between many atoms.
DESY Accelerators

- LINAC/Pre-accelerators
- DESY II
- DORIS
- HERA until 2007
- FLASH
- PETRA III
- XFEL under construction
The heart of the accelerator

Niobium
1.9 K
DESY: SCRF Technology
Superconducting RF-structures were developed in many countries

TESLA Collaboration (55 Institutes from 12 countries), centered at DESY, bundled ~ worldwide know-how and achieved significant progress:

>30-fold improvement of acceleration/cost performance over 10 years

Of large relevance for future accelerators such as XFELs and others
DESY Research.

∞ small

elementary particles
unification of forces

∞ large

cosmology
astrophysics

∞ complex

nanoscience, biology
Synchrotron radiation

∞ condensed
matter

Particles, fields
universe

Helmut Dosch

Summer Students at DESY 2010
Particle physics at highest energies, at the „Energy Frontier“ (LHC, ILC)

Expect breakthrough in understanding of mikrocosmos and of early universe
(Physics at the Terascale)
The physical world is composed of Quarks and Leptons interacting via force carriers (Gauge Bosons)

- The “Standard Model” has been tested to permille level in many experiments

- Precise and quantitative description of subatomic physics
Three Generations

Measurement of the number of generations of quarks and leptons (LEP)

\[ N = 2.994 \pm 0.012 \]
Towards the Unification of Forces

Neutral current  \[ e^+ p \rightarrow e^+ X \]

Charged current  \[ e^+ p \rightarrow \bar{\nu} X \]

\[ \sigma_{cc} \approx \sigma_{NC} \quad \text{for} \quad Q > M_W^2, M_Z^2 \]
The biggest mystery of this century

Science 2003

Galaxies rotate wrong!

Expansion of universe accelerates!

The search for nonrelativistic nonbaryonic matter beyond SM

$G + \Lambda = kT$

"The biggest mystery of this century"

Science 2003
Particle Physics – open questions

What generates Mass?  
Search for the "Higgs".

Do we understand the Universe?

Is the world made out of "Strings"?

Is there a "shadow world" of new particles?

In how many dimensions do we live?
Large Hadron Collider LHC

- Large Hadron Collider LHC at CERN/Geneva
- Circular machine
  - 27 km circumference
- Proton-proton collisions at
  - 7 TeV (later at 14 TeV) energy
    - 800 million quark/gluon collisions per second
    - 15 Petabyte of data/year (GRID)
- LHC re-start spring 2010 and is our essential tool to explore the Terascale

HERA results are vital for LHC predictions
the largest and most complex detectors
Successfull Restart LHC

Proton collisions at 7 TeV at 13:06 MEZ
Alfred, look!
The LHC Black Hole
is now at Wall Street
DESY participation at LHC

ATLAS Collaboration:
11 Scientists, 15 Postdocs, 12 PhD-Students, 2 Helmholtz YIG
Computing HH and Zeuthen, ATLAS remote Control room
TIER-2: Worldwide LHC Comp Grid, NAF

Arbeitsschwerpunkte:
„High Level Trigger“, Lumi-Detector ALFA (Teststrahl CERN Ltg. DESY)
ATLAS Data management Core-Activities

CMS Collaboration:
16 Scientists, 9 Postdocs, 8 PhD-Students
2 Helmholtz-YIG Higgs SUSY
TIER-2 (DESY-Aachen)

Focus:
Coordination, CMS-Management Board, Calibration, Alignment (Tracking detector)
Castor Calorimeter, presently CMS tests mit cosmics

Participation in LHC detector upgrade projects
GRID Computing at DESY

LHC Collisions at 40 MHz, recorded at ~100 Hz
Total RAW data by all LHC experiments:
15 PB/year

- DESY (in HH and Zeuthen) provides GRID services & Resources for numerous communities (virtual Organizations)
- NAF provides (interactive, grid, batch) services for entire german particle physics community
HEP in Germany – Future Challenges

- End of HERA: -> turning point for HEP in Germany
- Particle physics at the energy frontier is becoming global in all its areas
- Stay competitive with high impact → restructure HEP in D

Join all forces of complementary excellence in all areas (analysis, computing, detector, accelerator) in a long-lasting structure and strong sustained infrastructures:

**Alliance**: a Network of complementary excellence between

| 2 Helmholtz Centres | 17 Universities | 1 Max Planck Institute |

**Key Elements**

- Physics Analysis
- Detector Development
- GRID Computing
- Accelerator Science
Strategy for Astroparticle Physics

Mission: Understanding Structure and Evolution of matter in the early phase of the universe, origin of high energy cosmic rays, ...

messengers from the early universe: neutrinos and gammas

• Neutrino telescopes:
  – Baikal (pioneering) and Amanda – both finished, analysis on-going
  – IceCube (southpole), deployment until 2011

• Gamma telescope
  – In future large area Cherenkov telescope (CTA)

Combination of neutrino and high energy photon signals (multi-messenger principle)

Close collaboration with German universities

Experimental astroparticle activities are presently mainly located in Zeuthen
Neutrino Astrophysics

• high energy neutrinos from most violent astrophysical sources („cosmic accelerators“)
  – Supernovae remnants, Active galactic nuclei, gamma ray bursts ...
• neutrinos travel cosmic distances and point back to source
• detect Cherenkov light in ice emitted by charged particles (i.e. up-going muons) produced by neutrino interactions using earth as filter
• Search for cosmic neutrino point sources
Neutrino Astrophysics

ICECUBE will have an active volume of 1km$^3$ antarctic ice by 2011 to detect neutrinos from cosmic sources.
Cherenkov Telescope Array

- TeV gamma rays propagate straight and are easy to detect – ideal tracer for cosmic processes
- detect Cherenkov light from air showers produced by interactions of TeV gamma’s in the atmosphere
- Array of imaging telescopes for large field of view and to enhance pointing resolution
- DESY work on 12m prototype telescope
- start construction by 2012
TRENDS in MODERN PHYSICS

∞ small
- elementary particles
- unification of forces

∞ complex
- nanoscience & technology
- biology

∞ large
- cosmology
- astrophysics

∞ universe
- nano cosmos
- condensed matter
Order from Disorder in Nature

Nano Space
Liquids

Energy/Entropy

Order

Tera Space
Quark-Gluon Plasma

cognitivedistortion.com
1895

X-Rays
Gateway to Nanospace
1900-2000 Era of Ordered Matter

„LAUE I“ Structure of Crystals

1912

X-ray tube

Crystal

W.C. Röntgen

M. Von Laue

2000
Some Applications:

Die “Proteinfabrik”

Knee of a Spider
Examples for Research at DORIS

8 keV at BW2

Volume rendering of the head and thorax of the sawfly Tenthredo vespa.


Painting: van Gogh
Boerin, Janssens et al. (s...
DESY. Chemistry Nobel laureate 2009
Ada Yonath

1986-2004 Head of MPG Research Group – Structure of the Ribosome

Pioneering work at DORIS III /DESY
On a typical day in Europe
TRENDS in MODERN PHYSICS

nature

man made

Microtech

Nanotech

„Size matters“
GRAND CHALLENGES II

Sustainable Energy & Water Technology

Reduction of Environmental Pollution
Stopping Climate Change

Fighting Vexing Diseases

IT beyond CMOS

Safety
TRENDS in MODERN PHYSICS

Ordered Structures
Equilibrium Phenomena

Disordered Structures
Nonequilibrium Phenomena
Transient States

Era of Crystalline Matter | Era of Disordered Matter

1900 2000 future
Advanced Analysis in Nanospace
Synchrotron Radiation

X-ray Lasers

ESRF

X-ray tubes

European Megafacility
ESRF, Grenoble

ESRF, 6 GeV

Photonen / mrad² mm² sec 10⁻³ Bandbreite

1900 1950 2000
PETRA III
the most brilliant x-ray source ever built

1 nmrad

1st stored positron beam
April 16, 2009

1st monochromatic light
July 17, 2009
20 µm pinholes
parallel X-ray light
SR beam

Nano transistor
10nm Prototype

„LAUE II“ 3d image of nanostructure

2000 + Era of Disordered Matter
Dream of Mankind
Realtime holograms of the motion of atoms, molecules and electrons

Nano length
L = 1 nm

Nano time
t = L \sqrt{\frac{u_p}{2k_B}} \sqrt{\frac{A}{300K}} \approx 100 \text{ fsec}

Molecular holographic snapshots:
NEED: x-ray Laser fsec pulses!
X-ray Laser with free electrons

The SASE principle

Electron Bunch with 10 GeV

\[ I_{\text{X-Rays}} = \begin{cases} 
N \cdot \text{chaotic} \\
N^2 \cdot \text{coherent}
\end{cases} \]

Self-Organized Micro Bunching

10^{10} \text{ e}^{-} (1 \text{ nC})

200 m
FREE ELECTRON LASER

Peak Brilliance [Phot./(sec·mm²·mm·0.1% bandw.)]

Energy [eV]

10^1 10^2 10^3 10^4 10^5 10^6

10^19 10^21 10^23 10^25 10^27 10^29 10^31 10^33 10^35

TTF-FEL (M)

XFEL spontan. 50 GeV, helical

TESLA spontan. 20 GeV, planar

TTF-FEL

10 Billions!!

10 Billions!!

SLAC LCLS

BESSY-II U-49

PETRA

ESRF Undulator

SPring8 Undulator

APS Undulator

ALS U5.0

Energy [eV]

Time

< 50 fs

< 100 fs

Femtosecond x-ray laser pulses
Life reports from Nanospace

cognitive-distortion.com
FLASH . DESY
1,2 GeV Elektronen
60-4.4 nm Röntgenlaser
20 fsec flashes
Erste Demo von Single-Shot Coherent Diffraction Imaging

FLASH

Henry Chapman
CFEL-DESY
Janos Hajdu
Uppsala
Image reconstruction from an ultrafast FEL diffraction pattern
7.6.2010 ... sFLASH ... lasing at 4.4nm with 150µJ

X-Ray flashes in water window
FLASH II Upgrade
The European XFEL Project

3.4 km
Accelerator

XFEL Construction

1. Construction Phase
European XFEL
„Baptizing“ the tunnel boring machine
30.6.2010
Coherent snapshot diffraction from liquid

Local coordination?
Local bond angle?
Many-body effects?
Novel statistics beyond pair correlation!

substrate
Future Vision in Bio-Nano-Technology

Coulomb Explosion
10-50 fs

LAUE III" Single Molecule Diffraction

50 fs X-ray laser

Laue pictures of tomorrow?
Grand Challenges for Megafacilities

Thanks to the new Mega-microscopes: A brilliant future!
50 Years of DESY

in 2009: we celebrated 50 years of DESY

First operation of DESY in 1964

Minister Balke    Max Brauer
18.12.1959
Finally ...

Enjoy your stay at DESY and in Hamburg ...