Introduction to DESY

Welcome Summer Students 2008

Frank Lehner
DESY

Deutsches Elektronen-Synchrotron

DESY – Deutsches Elektronen Synchrotron
- founded 1959 -

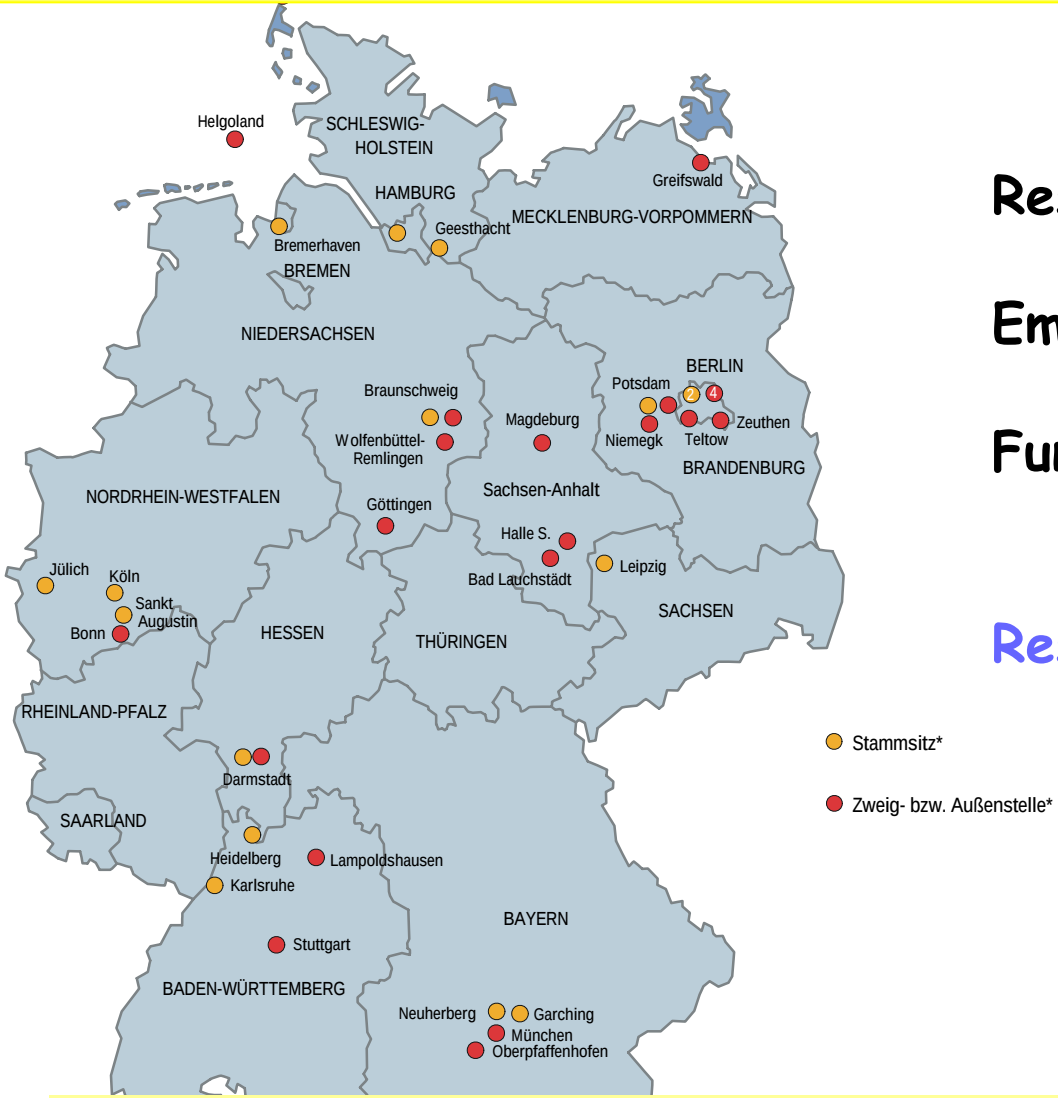
Mission: Development, construction, operation and scientific exploitation of accelerators

Provide access and services for national and international users

Internationally used, nationally funded Research Institute

Base-Budget:	183 MEuro (2007)
Funding source:	90% federal, 10% state
Staff:	~1600 FTE in Hamburg and Zeuthen
Users:	~3000 (1500 from abroad) from 45 nations
	920 in particle physics, 2100 in photon science

DESY - Member of the Helmholtz Association



Research Centers: 15

Employees: ~ 24 000

Funding (Bill. Euro) ~ 2,2

Research Areas:

- Health
- Environment and Earth
- Energy
- Traffic and Space
- Structure of Matter
- Key Technology

Programme oriented funding:
Five year program planning, strategic review -> funding

DESY in Hamburg und Zeuthen

DESY -Hamburg

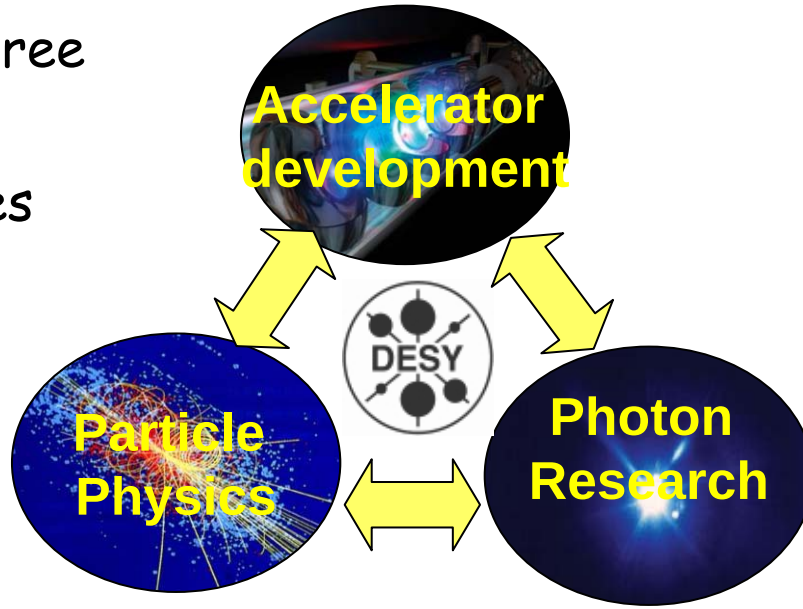
DESY -Zeuthen

Frank Lehner, July 2008

DESY

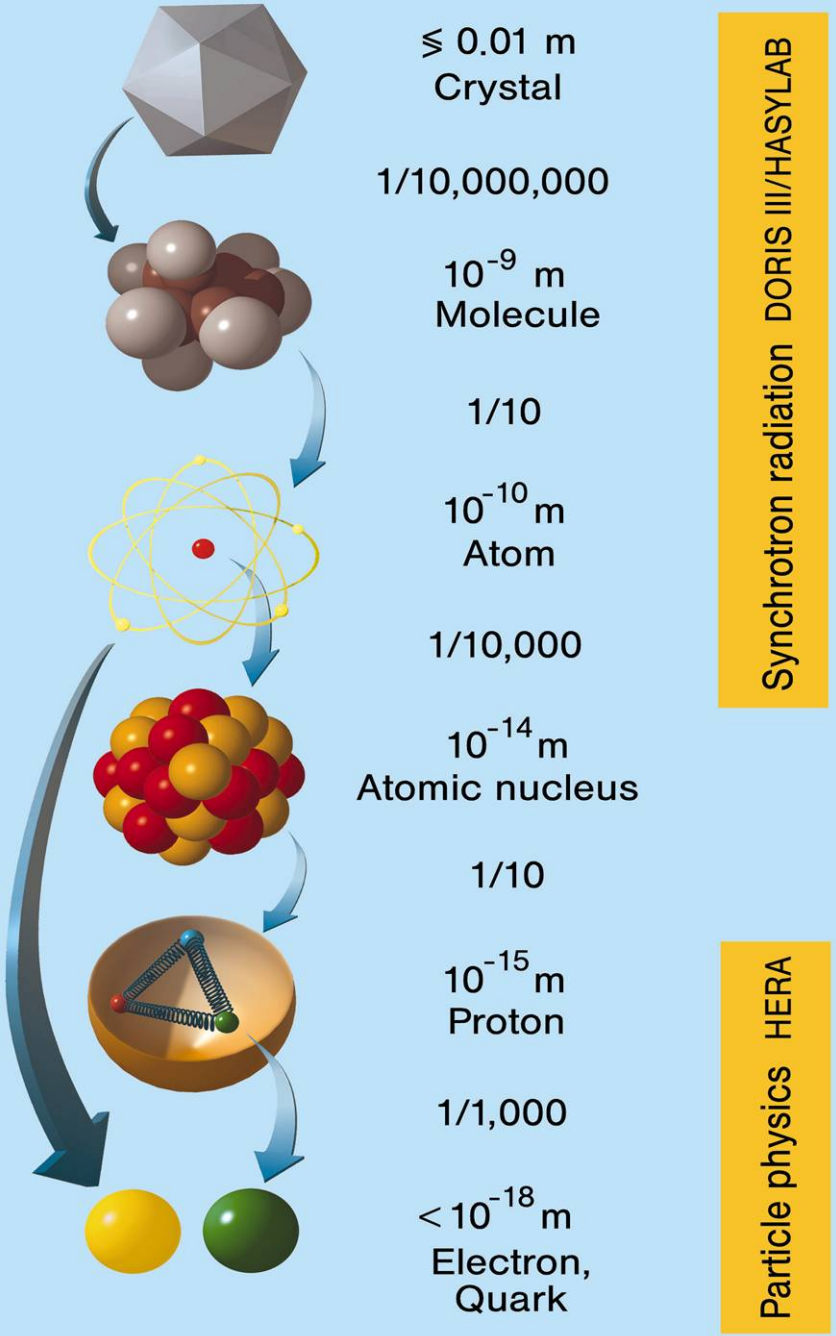
DESY.
Wir machen Erkenntnis möglich

- DESY has a long successful history in three areas of basic science and high tech :
  - Particle physics (one of 5 laboratories world wide),
  - Research with Photons (synchrotron radiation sources and Free-Electron Lasers) and
  - Accelerator development.



- These topics stimulate each other, are unique in their combination in Europe and constitute the basis for the future of the laboratory.
- DESY develops, builds and operates accelerators for research
  - about 70% of budget for operation of accelerators and to provide services for 3000 external users/year

DESY - Research



- Research at DESY spans many orders of magnitude in scale
- Investigate the structure of matter from macroscopic to atomic scales with photons
- Investigate the building blocks of matter and their forces (discovering the quantum universe)
- theory of particle physics & cosmology
- astroparticle physics with neutrinos (experiments at Southpole)
- Accelerator & Detector R&D

DESY Management Structure and Advisory Boards

Scientific Council

Directorate
GD, FH, FS, M, V

Admin. Council

PRC: Particle Physics Research Committee

Exp. & Theor. Particle Physics

MAC: Machine Advisory Committee

Accelerators + Development

PSC: Photon Science Committee

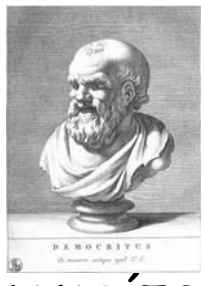
Research with Photons SR, FEL

PRC, PSC, and MAC review the respective fields, advise the Directorate and inform the ESC

DESY RESEARCH

ΔΕΣΥ

Particle and Astro-particle physics	Accelerator R&D and operation	Research w/ Photons
HERA	DESY+Pre-Inj.	DORIS
LHC	DORIS	FLASH
ILC	FLASH	PETRA III
Theory	PETRA III	CFEL (XFEL)
Detectors	PITZ	Detectors
Icecube	XFEL	
	ILC (SCRF)	

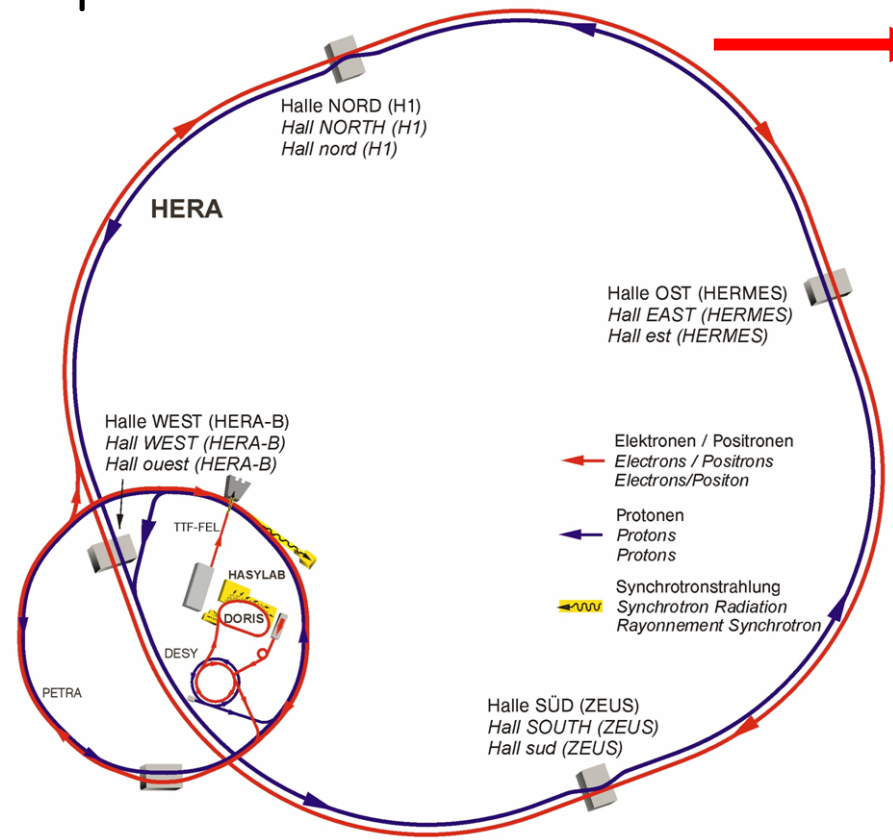


Δημοκρίτειο

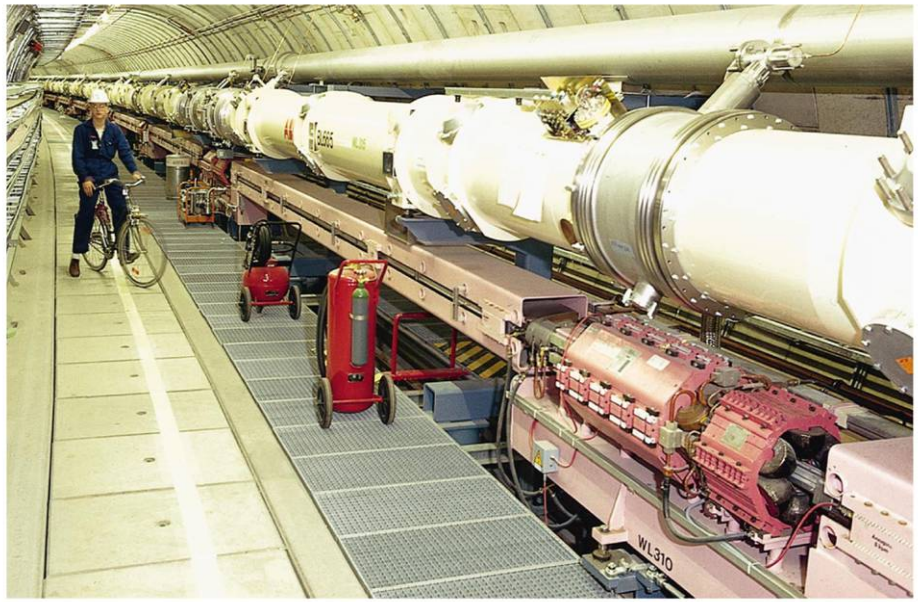
DESY's Accelerators - today

DESY operated until recently 16 km of accelerators for:

- Particle physics
- photon science



HERA



PETRA

Accelerator Development

Strategy:

- Further strengthening of know-how in accelerators, driven by science needs:
  - Accelerator technology development (superconducting RF, electron sources)
  - Operation of synchrotron light sources
  - Development and operation of Linac driven Light sources (FLASH, XFEL)
  - International Linear Collider development
- Exploiting the synergy between projects and technologies

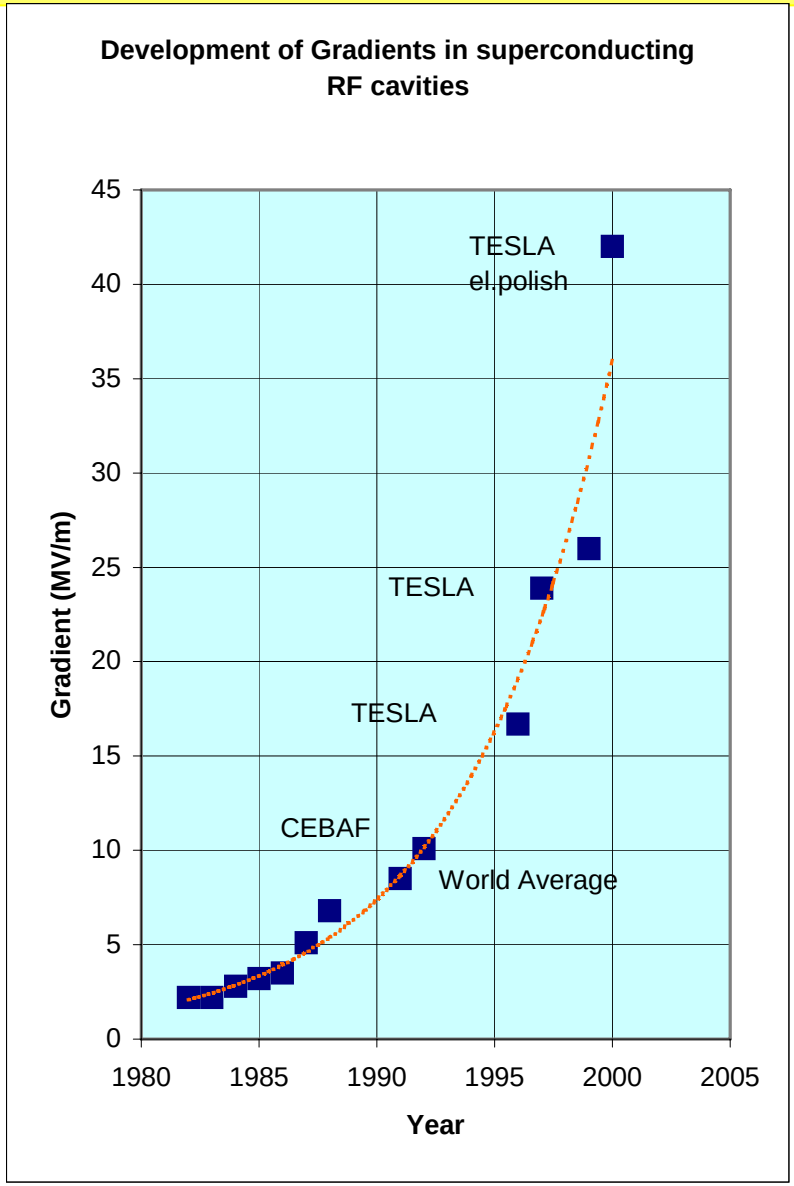
Development of superconducting Resonators

Superconducting RF-structures were developed in many countries

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

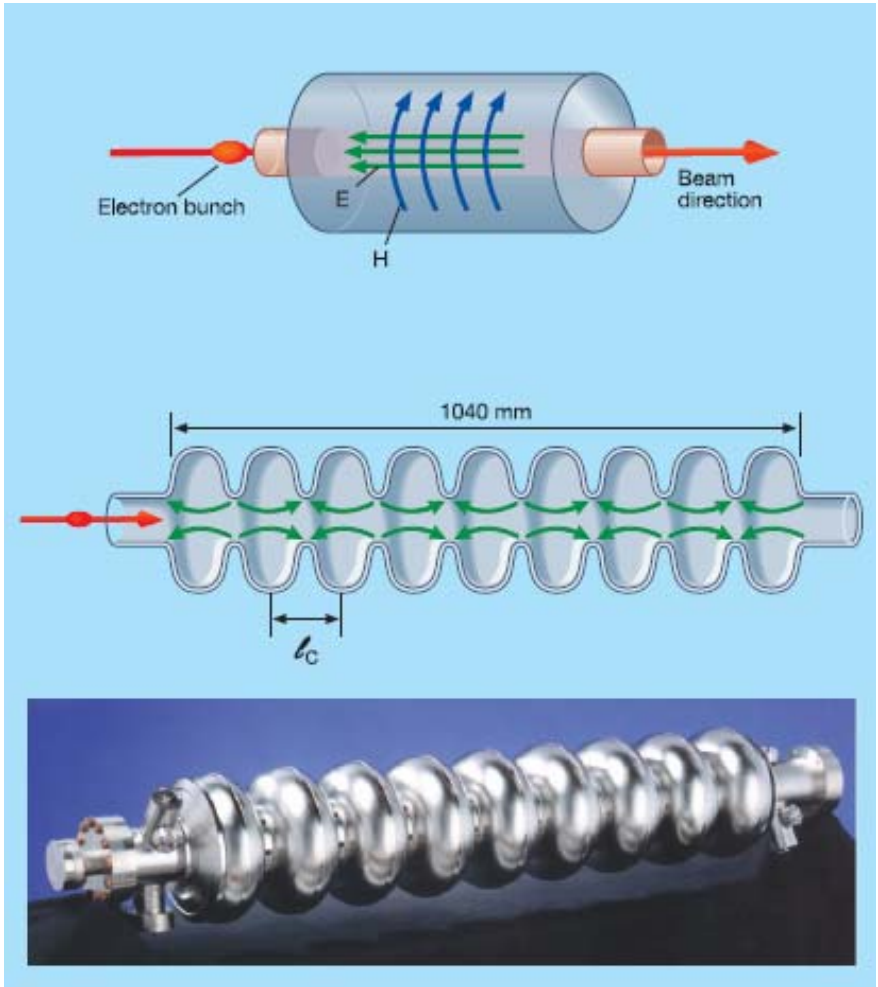
>30-fold improvement of acceleration/cost performance over 10 years

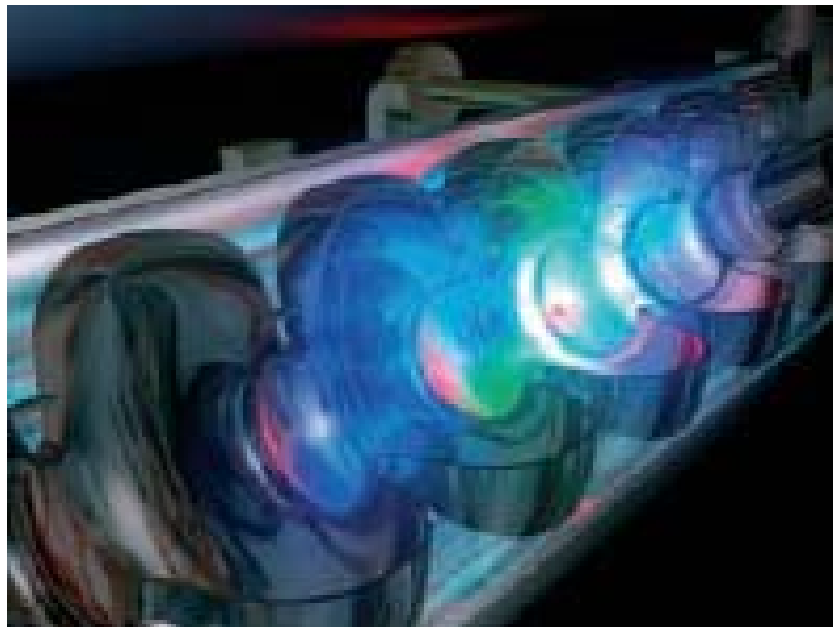
Of large relevance for future accelerators such as XFELs and others



TESLA Technologie

The heart of the accelerator





Niobium

1.9 K

Developed for applications in particle physics

TESLA Collaboration

TESLA

TESLA collaboration

Members of the TESLA Technology Collaboration, TTC

Status: 24.05.07

- CANDLE, Yerevan
- Yerevan Physics Institute, YerPhI, Yerevan

- TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics

- Institute for High Energy Physics, IHEP, Academia Sinica, Beijing
- Tsinghua University, Beijing
- Peking University

- CEA/DSM DAPNIA, CE-Saclay, Gif-sur-Yvette
- Laboratoire de l'Accélérateur Linéaire, LAL, IN2P3-CNRS

- Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung, BESSY, Berlin
- Hahn-Meitner Institut, HMI, Berlin
- Technische Universität Darmstadt
- Universität Frankfurt am Main
- GKSS-Forschungszentrum Geesthacht
- Deutsches Elektronen-Synchrotron DESY in der Helmholtz-Gemeinschaft, Hamburg und Zeuthen
- Universität Hamburg
- Forschungszentrum Rossendorf
- Universität Rostock
- Bergische Universität-GH Wuppertal

- CCLRC-Daresbury Laboratory / ASTeC Department*
- Royal Holloway, University of London, RHUL / JAI
- University College London, UCL
- University of Oxford / JAI

- Raja Ramanna Centre of Advanced Technology RRCAT, Indore
- Bhabha Atomic Research Centre BARC, Mumbai
- Inter-University Accelerator Centre, IUAC & Delhi University, DU

- Laboratori Nazionali di Frascati, INFN, Frascati
- Istituto Nazionale di Fisica Nucleare, INFN, Legnaro
- Istituto Nazionale di Fisica Nucleare, INFN, Milan
- Istituto Nazionale di Fisica Nucleare, INFN, Rome II
- Sincrotrone Trieste

- High Energy Accelerator Research Organisation, KEK

- The Henryk Niewodniczanski Inst. of Nuclear Physics, Polish Academy of Sciences, Krakow
- AGH - University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow
- The Andrzej Soltan Institute for Nuclear Studies – IPJ, Otwock-Swierk
- Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw
- Warsaw University, Department of Physics
- TU Lodz, Department of Microelectronics and Computer Science
- Warsaw University of Technology, WUT, IBE

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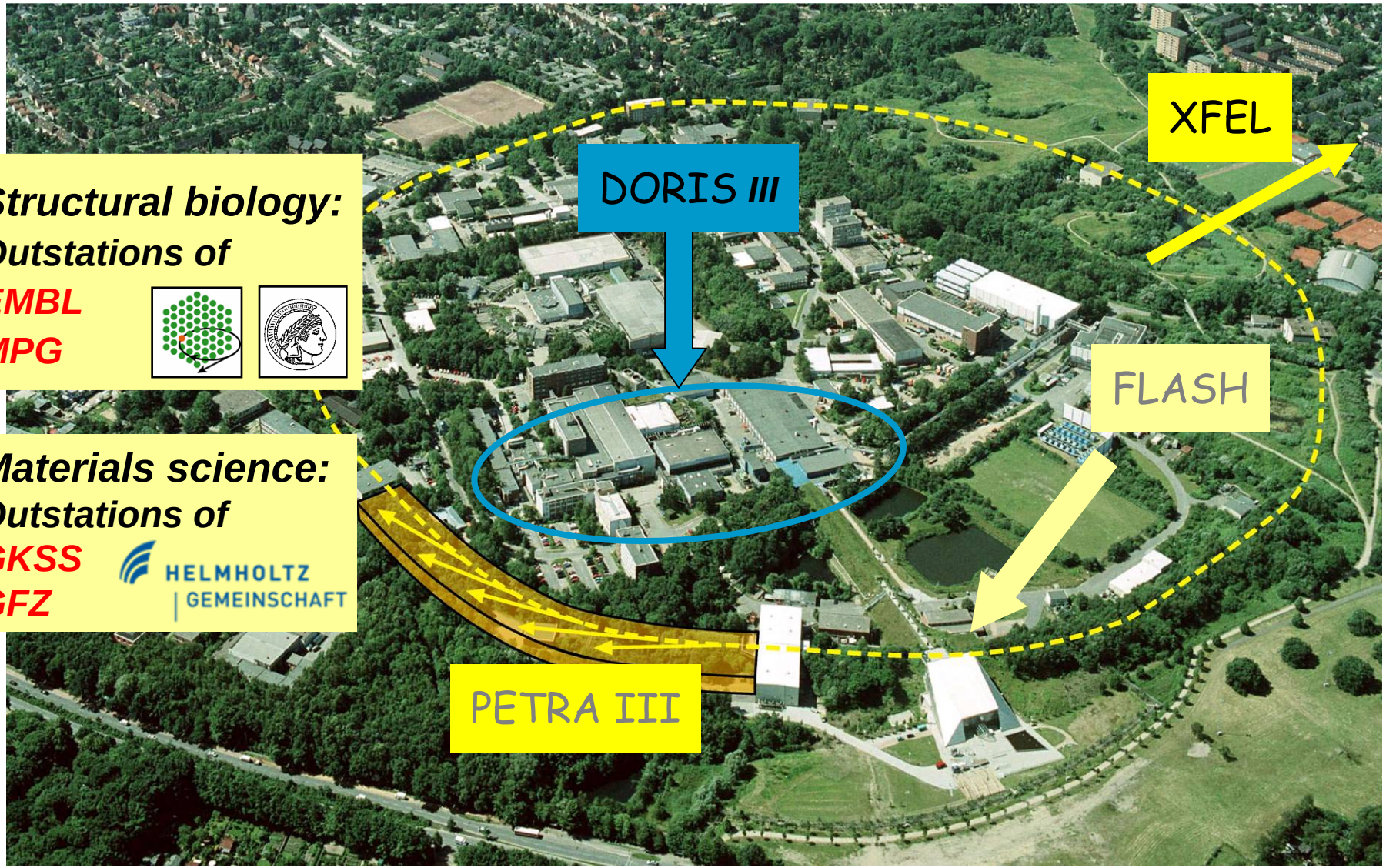
- Moscow Engineering and Physics Institute, MEPhI, Moscow
- Budker Institute for Nuclear Physics BINP, Novosibirsk
- Institute for High Energy Physics IHEP, Protvino
- Institute for Nuclear Research, INR, Russian Academy of Sciences, Moscow

- Argonne National Laboratory, ANL, Argonne IL
- Brookhaven National Laboratory, BNL
- Fermi National Accelerator Laboratory, FNAL, Batavia IL
- Cornell University, Ithaca NY
- Jefferson Lab, Newport News VA
- SLAC, ILC Division
- Lawrence Berkeley National Laboratory, LBNL, Berkeley CA
- Michigan State University (MSU)
- Spallation Neutron Source (SNS)

Research with Photons at DESY



Structural biology:
Outstations of
EMBL
MPG

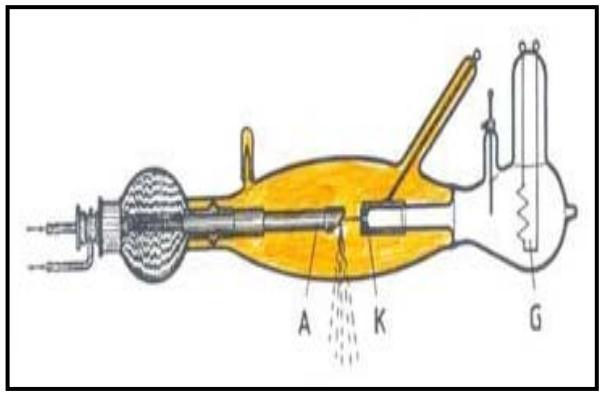
Materials science:
Outstations of
GKSS
GFZ

HELMHOLTZ GEMEINSCHAFT

Research with X-Rays

1895 Discovery of X-Rays (W.C. Röntgen)
X-Rays can penetrate matter

Applications in medicine, life science, natural science and in engineering sciences

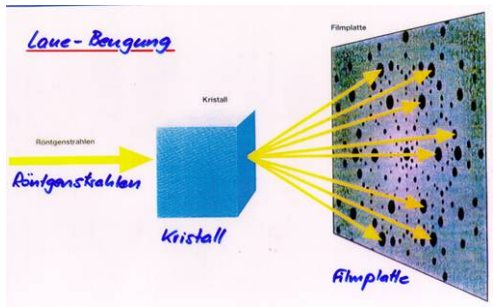


accelerated electrons
generate radiation
(Bremsstrahlung)

The Wavelength of X-Rays
fits to the distance of atoms in Matter

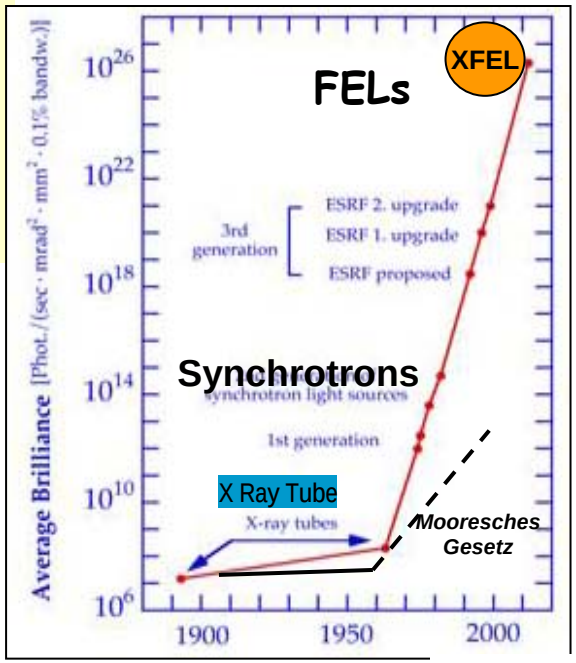
"Position of atoms"

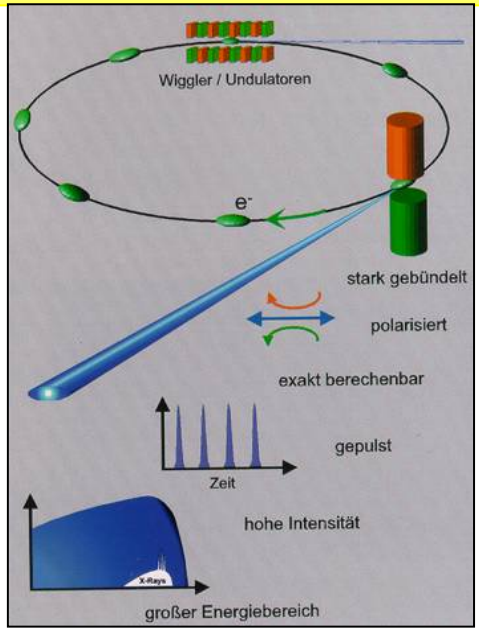
Applications in basic applied science



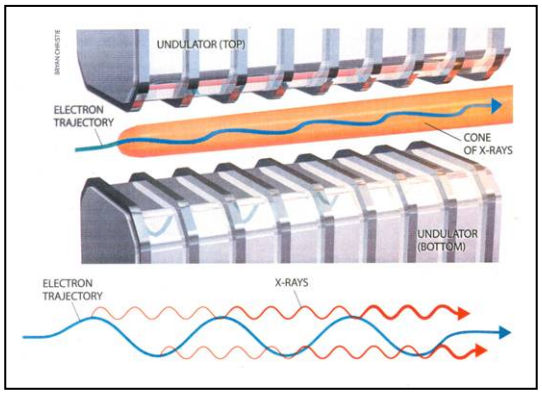
Synchrotron Radiation

Since 1960 sources became stronger by factor 1000 every 10 years -> substantial progress in science





Undulators:
Line spectrum
Higher intensity
Focused in narrow cone

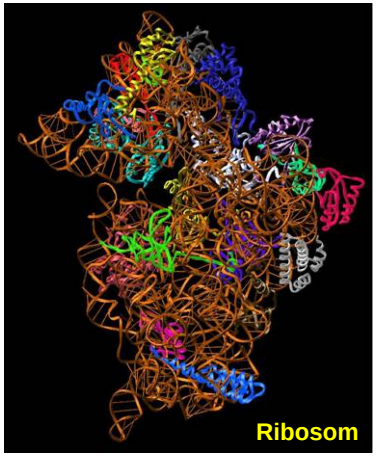


Frank Lehner, July 2008

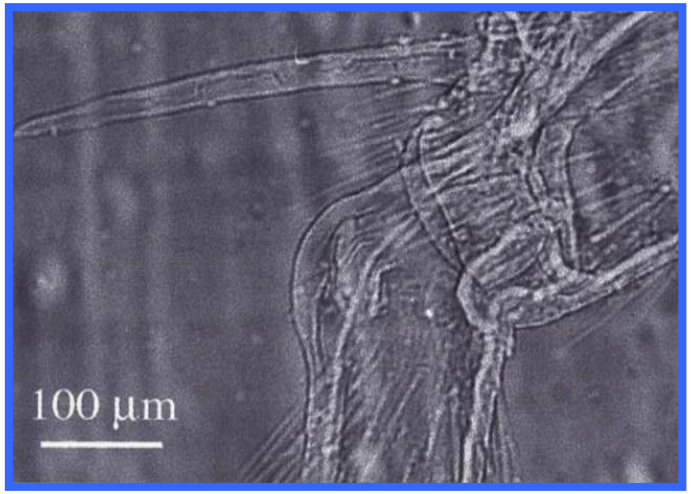
SRSs worldwide

- 16 in USA
- 23 in Europe
- 25 in Asia
- 1 in Australia
- 1 in South America

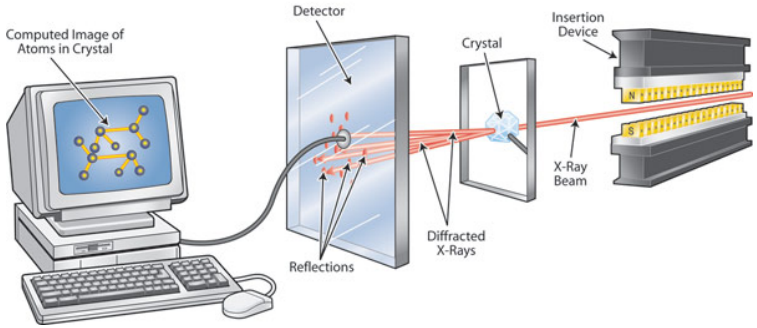
Some Applications:



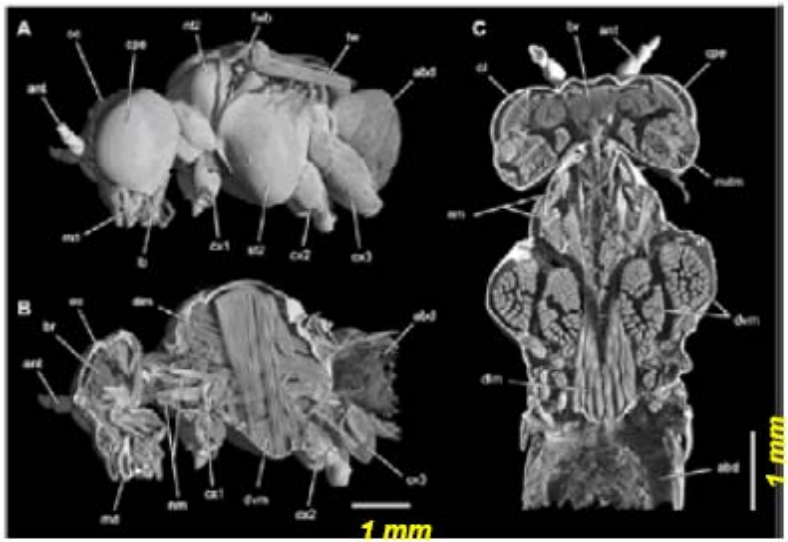
Die “Proteinfabrik”



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.

F. Friedrich, H.W. Pohl, F. Hünefeld, F. Beckmann, J. Herzen and R.G. Beutel (HASYLAB Ann. Rep. 2007)

Painting: van Gogh

Boerin, Janssens et al. (submitted, 2008)

Strategy for Research with Photons

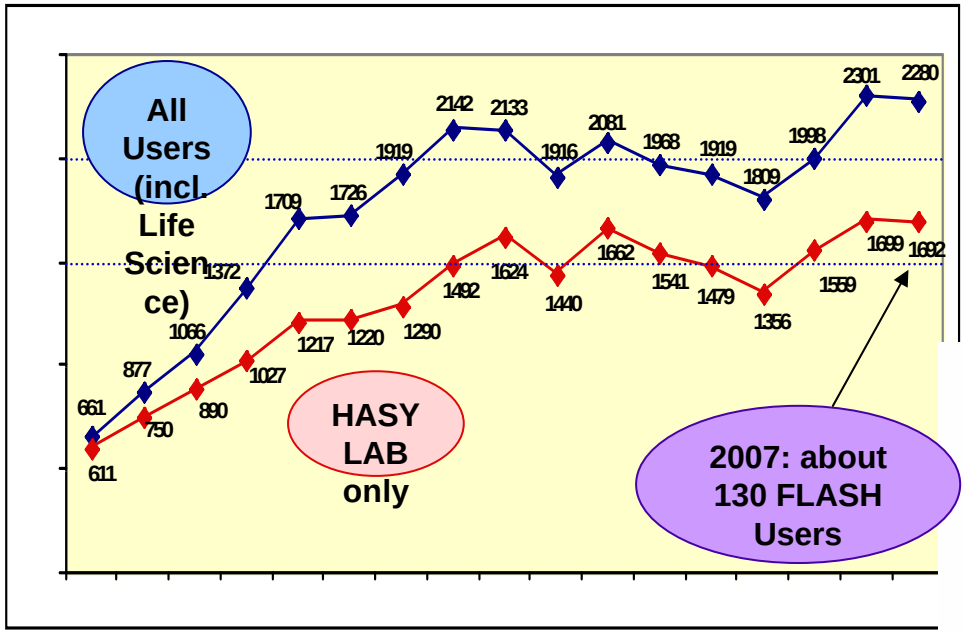
Strategy:

- Make leading edge research possible in physics, chemistry, material science, biology etc. through unique light sources:

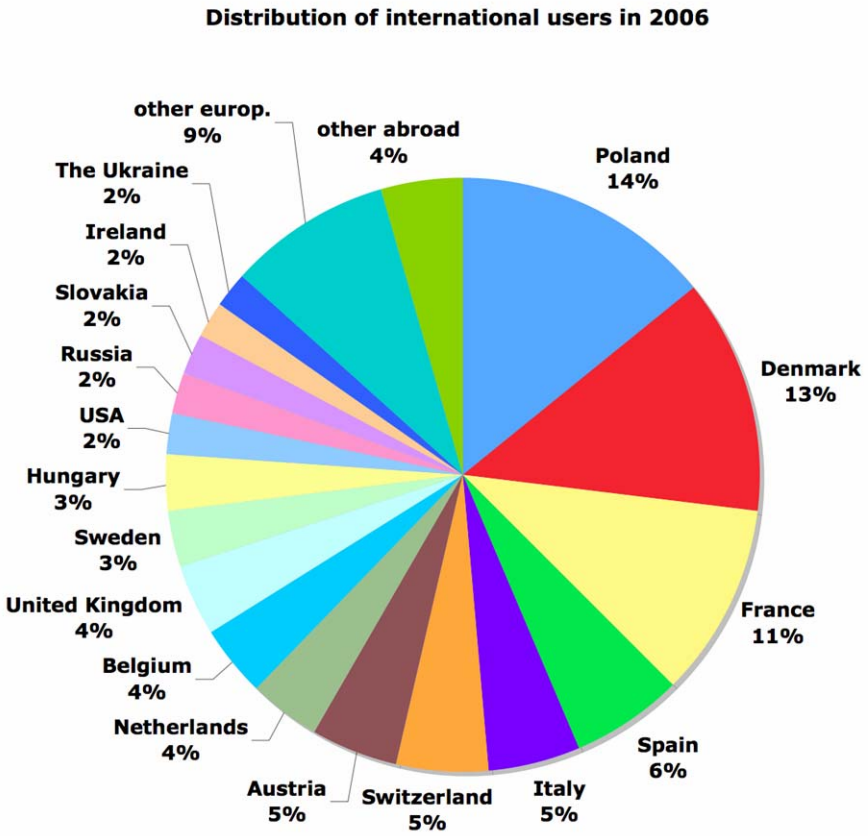
- Synchrotron light sources
  - DORIS
  - PETRA III
- Linac driven light sources
  - VUV-FEL - FLASH
  - Participation in European XFEL

- FLASH, PETRA and the XFEL are or will be unique facilities on a world scale

Photon Science User



Distribution of international Users (2006)



In 2006 at Hasylab:

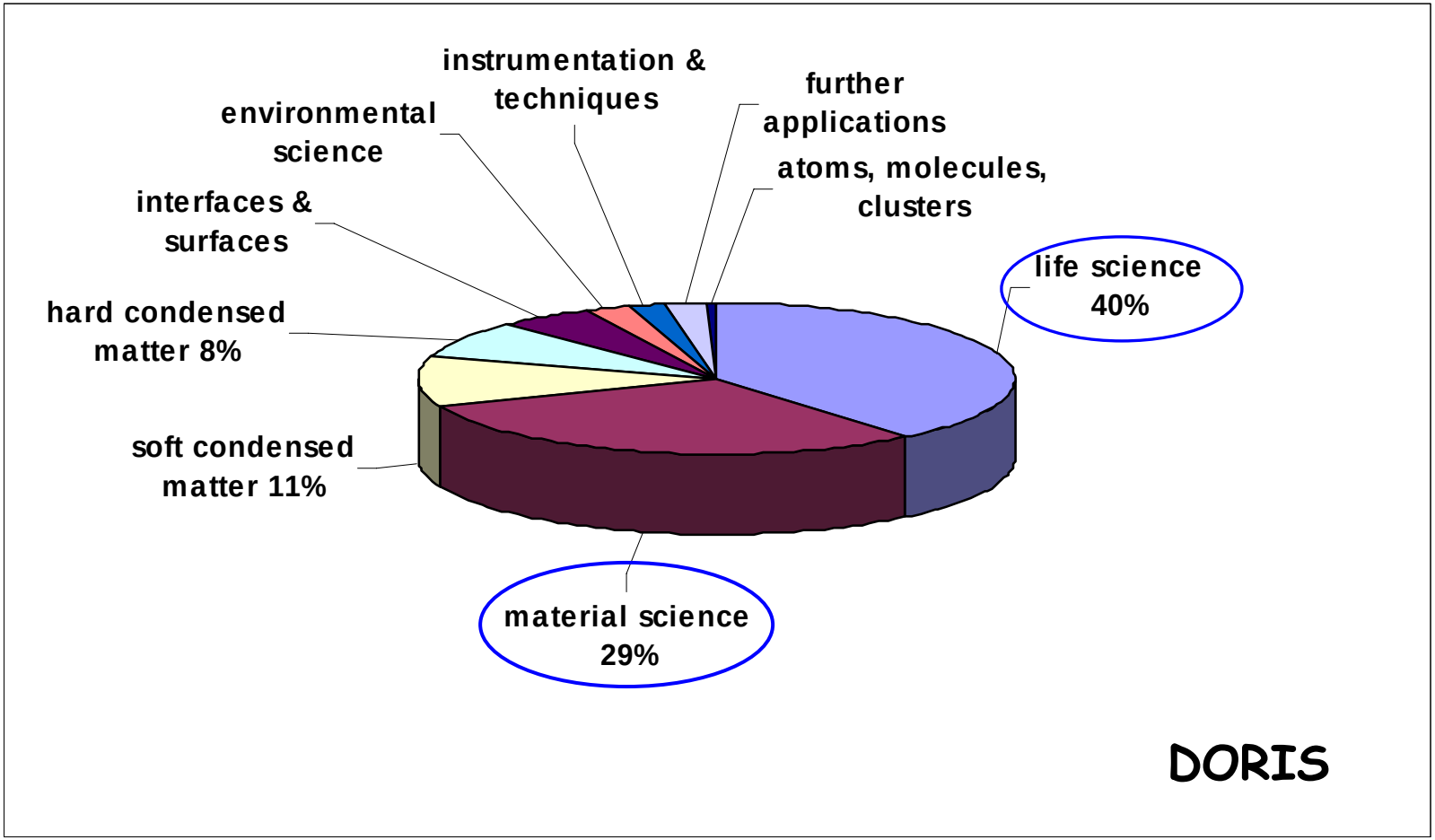
German Users: 928

Internat. Users: 771

No. of Nations: 40

Frank Lehner, July 2008

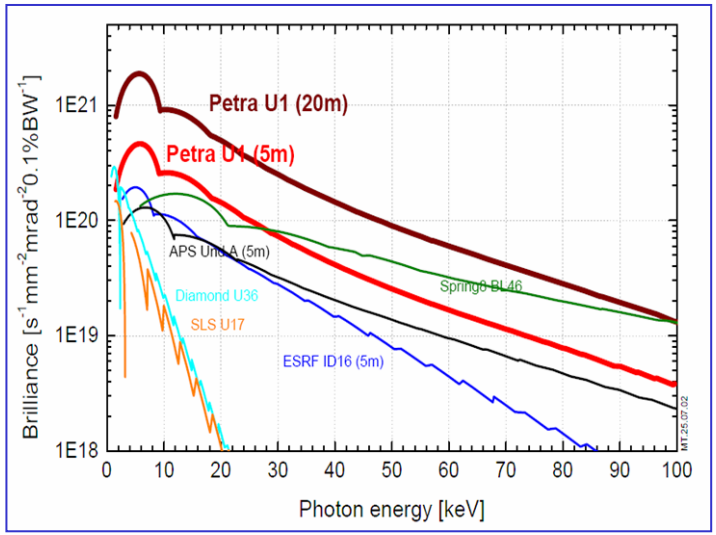
Distribution among Research Fields (biology included)

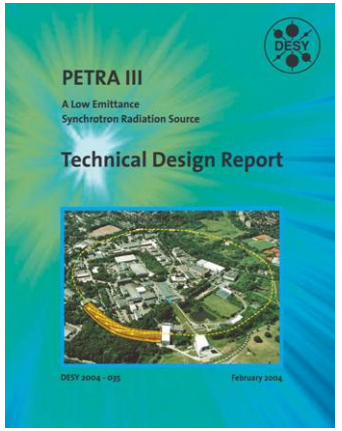


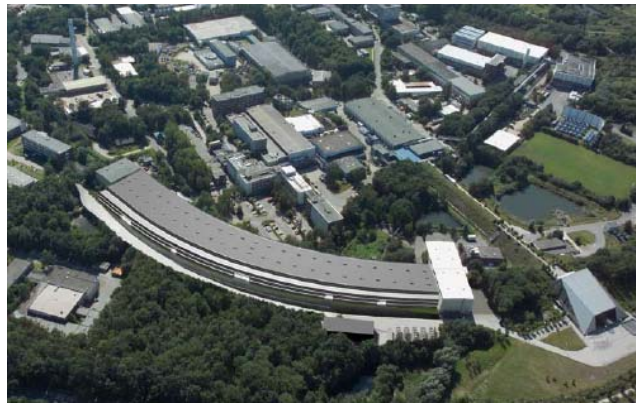
distribution corresponds roughly to "number of experiments performed", it does not scale to allocated beam time

PETRA III

- Originally built for particle physics end of 1970ies
  - Discovery of gluon
  - Later, injector für HERA
- now being refurbished to worldbest source for hard X-ray – PETRA III
  - very high brilliance
  - very low emittance
- a new high performance light source for European users, nationally financed



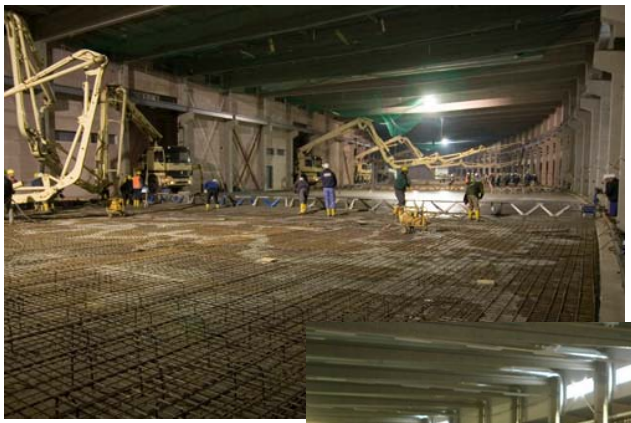




1/8 of ring completely new assembled
7/8 of ring refurbished
14 beamlines (some of them together w/ other institutes, e.g. EMBL)

PETRA III

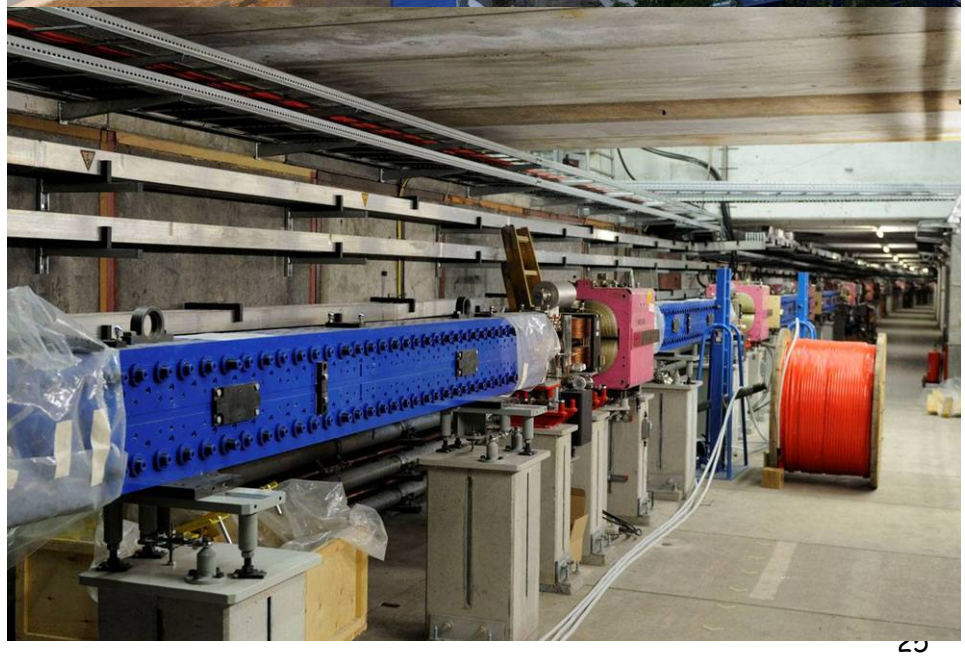
- begin construction: July 2007
- laying of founding stone: September 2007
- roof construction: November 2007
- monolithic concrete slab (280 m long, 24 m wide) poured: December 2007
- Expect user operation mid 2009



PETRA III

Status July 2008:

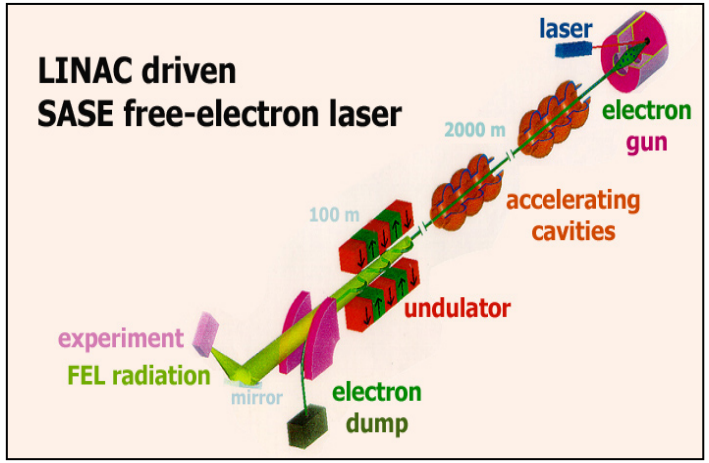
- PETRA III-Hall
  - Outside finished
  - Installation of equipment/beam line in hall has started

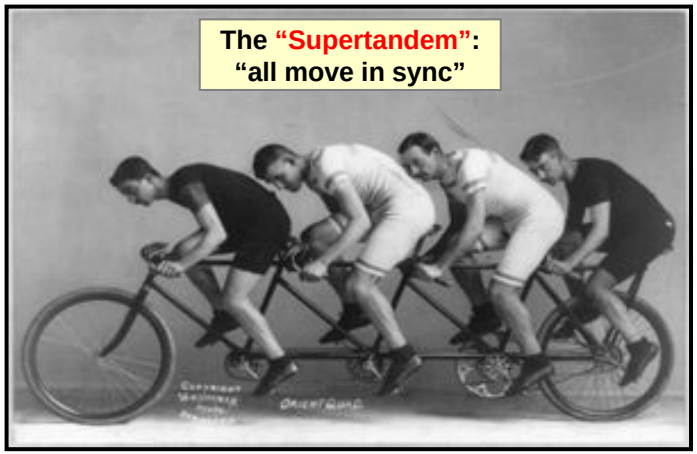


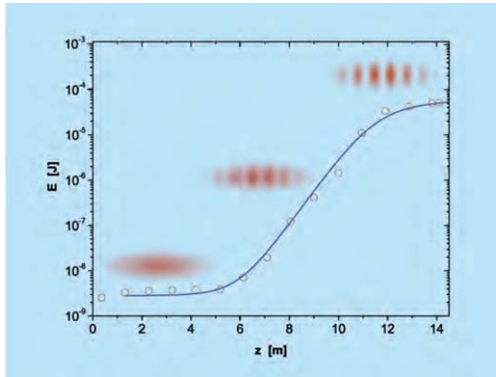
- Refurbishment of PETRA ring finished
- Expect user operation mid 2009

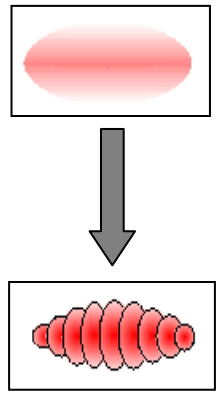
Principle of a Free-Electron laser

- Free-Electron Laser FEL is very long undulator so radiation field is strong enough to introduce periodic microbunches inside bunch and hence a resonance with undulator.



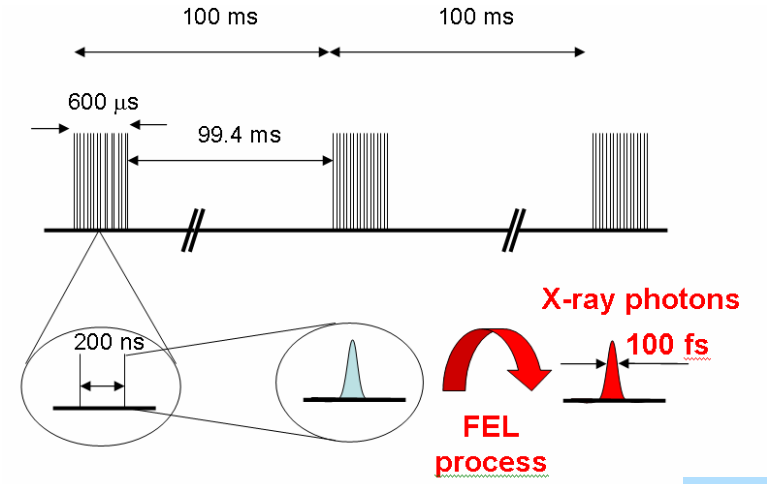


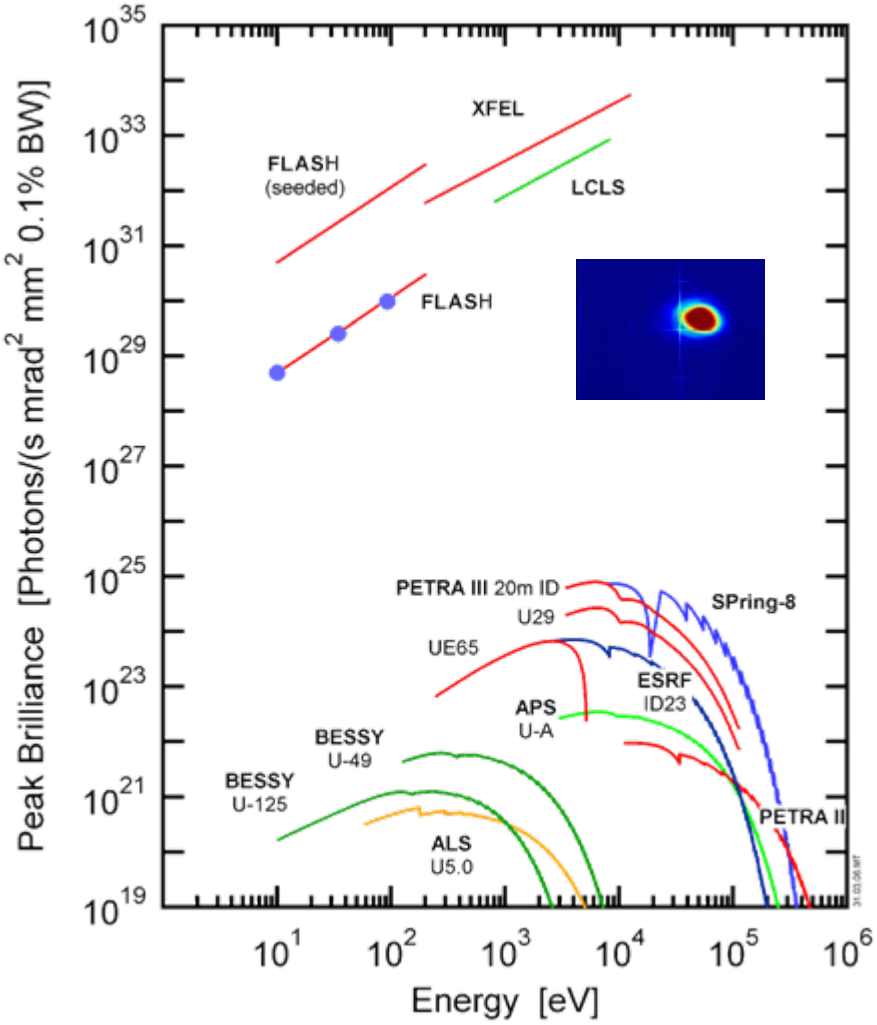




Properties of FEL radiation

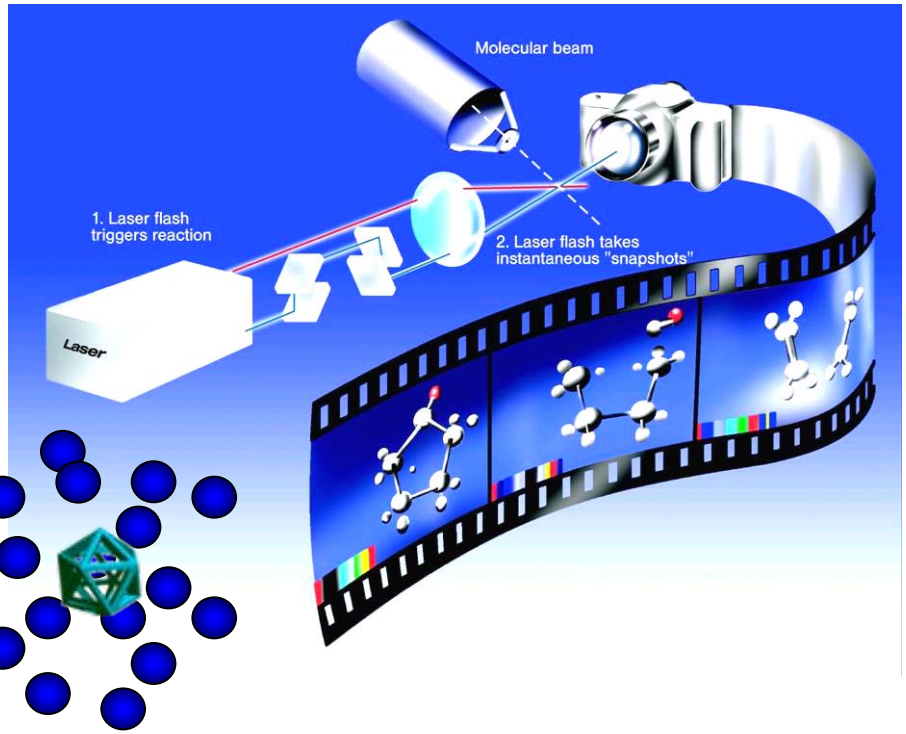
- X-ray FEL radiation (0.2 - 14.4 keV)
  - ultrashort pulse duration <100 fs (rms)
  - extreme pulse intensities 10^{12}-10^{14} ph
  - coherent radiation x10^{9}
  - average brilliance x10^{4}
- Spontaneous radiation (20-100 keV)
  - ultrashort pulse duration <100 fs (rms)
  - high brilliance





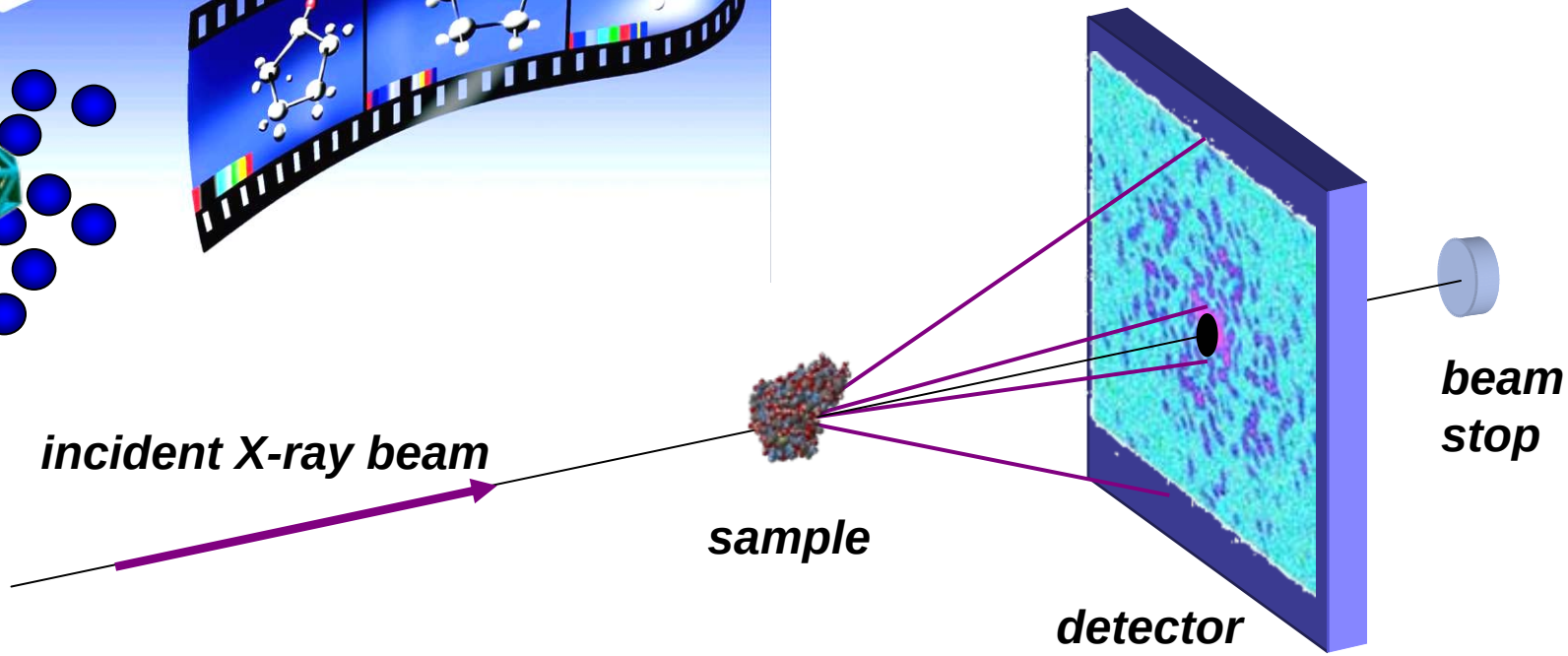
FELs deliver in 10 Femtoseconds so much light as today's best X-ray sources in 1 second.

Diffraction: From Static to Dynamics

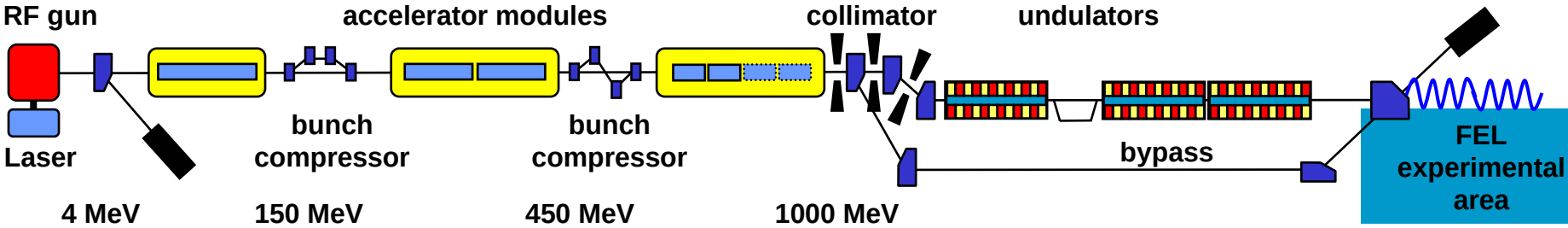


Realtime holograms of motion of atoms, molecules and electrons

on nature's time scale



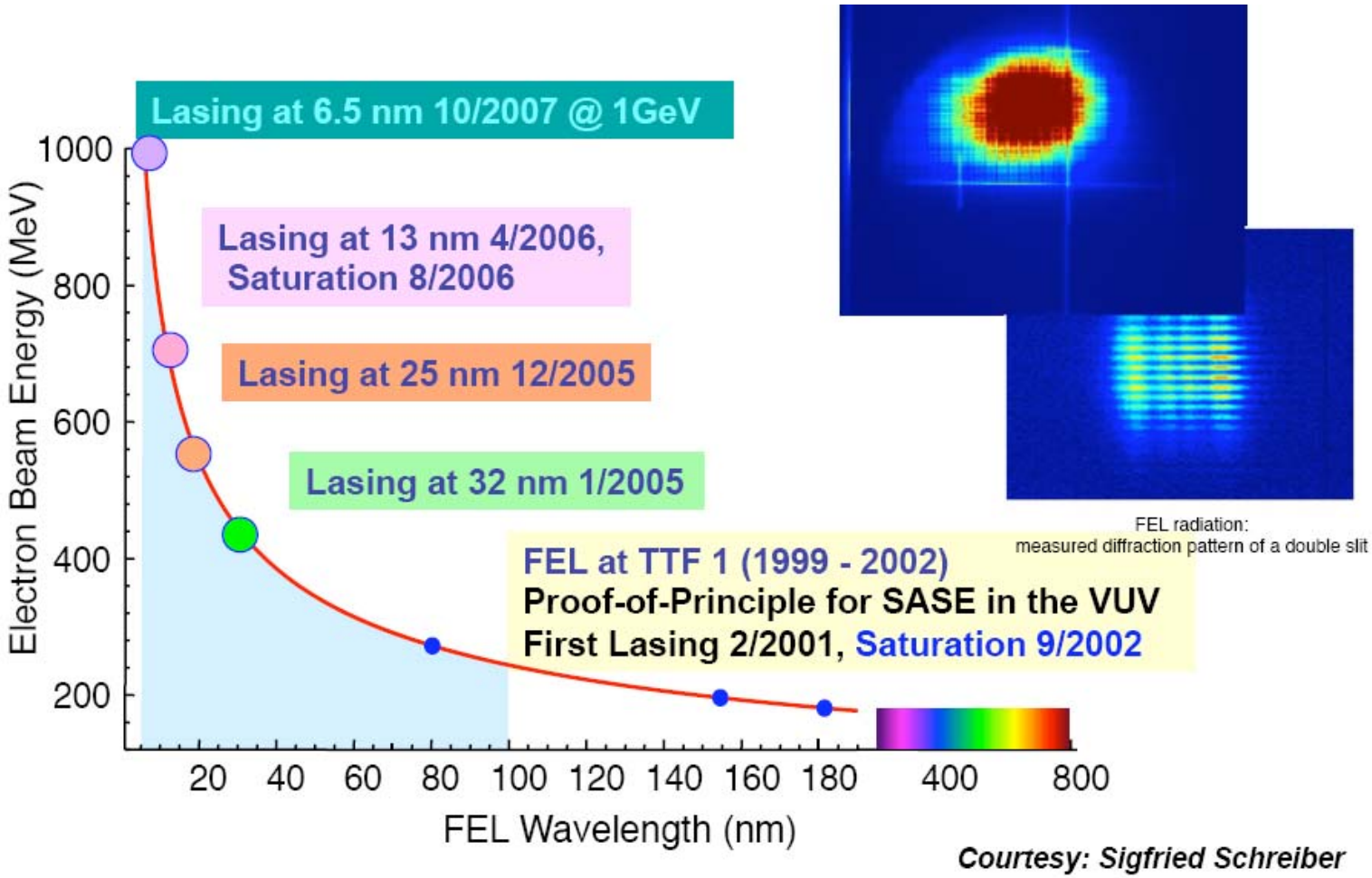
The FLASH FEL as Prototype for the XFEL



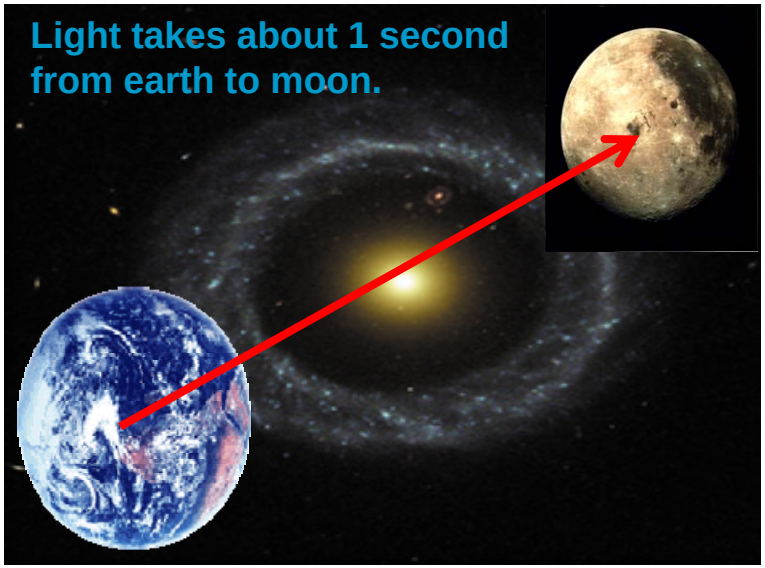
FLASH:
VUV free electron laser

electron energy:	1 GeV
wavelength:	6.5-47 nm
average pulse energy:	2-70 µJ
peak pulse energy:	170 µJ
pulse duration:	10-25 fs
average power (700 pulses / s):	20 mW
peak power:	3-10 GW
peak brilliance	1-10 • 10^{29}
divergence (@13nm):	90 µrad
spectral width:	0.7-1%

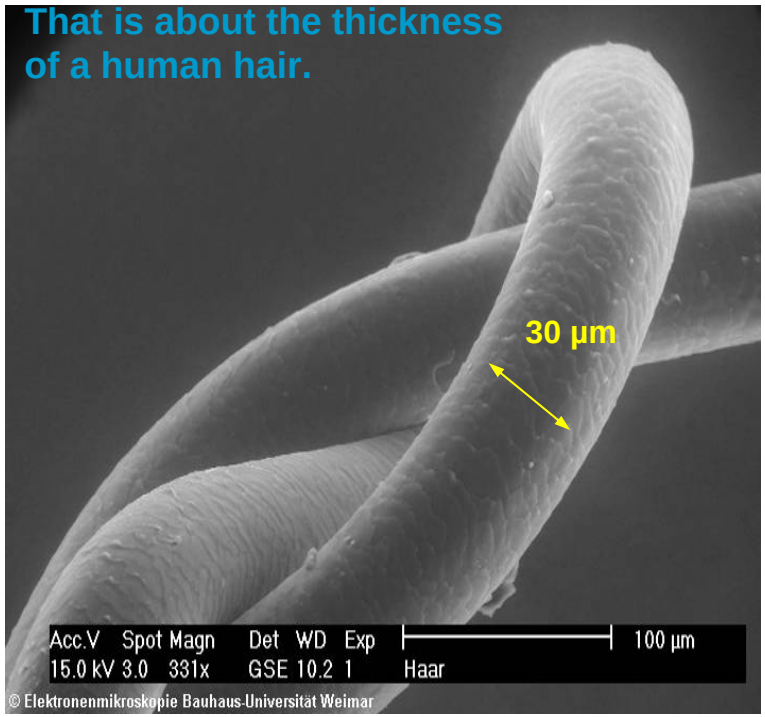
FLASH – lasing towards shorter wavelength



Ultrashort times



Light travels a distance of 30 micrometers in 100 femtoseconds.



Key processes in nature proceed on such ultra-short time scales

First X-ray imaging of biological cells (free fall)

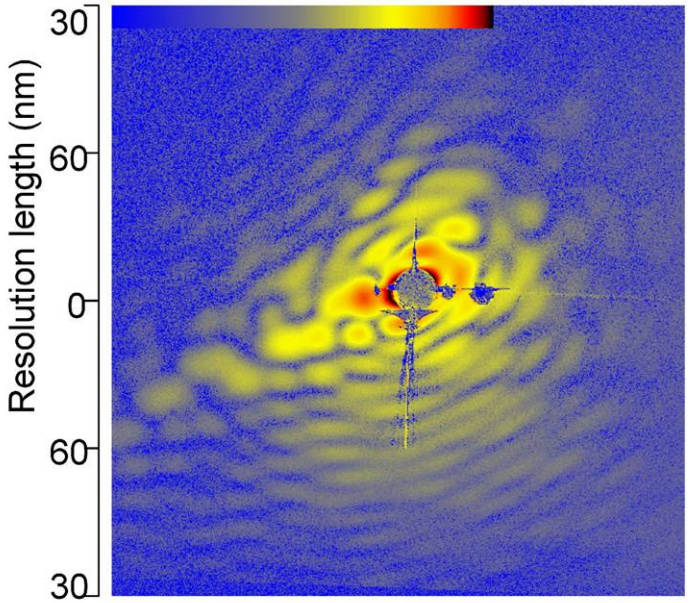
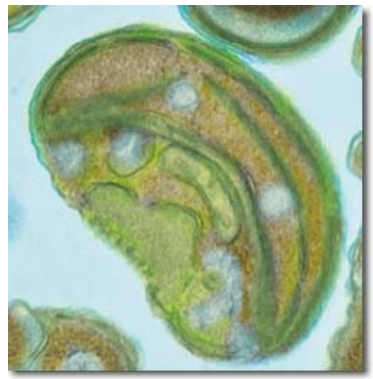


Image of Picoplankton (most abundant photosynthetic cells) recorded with ~10 fs light pulse at FLASH, wave length 13.5 nm.

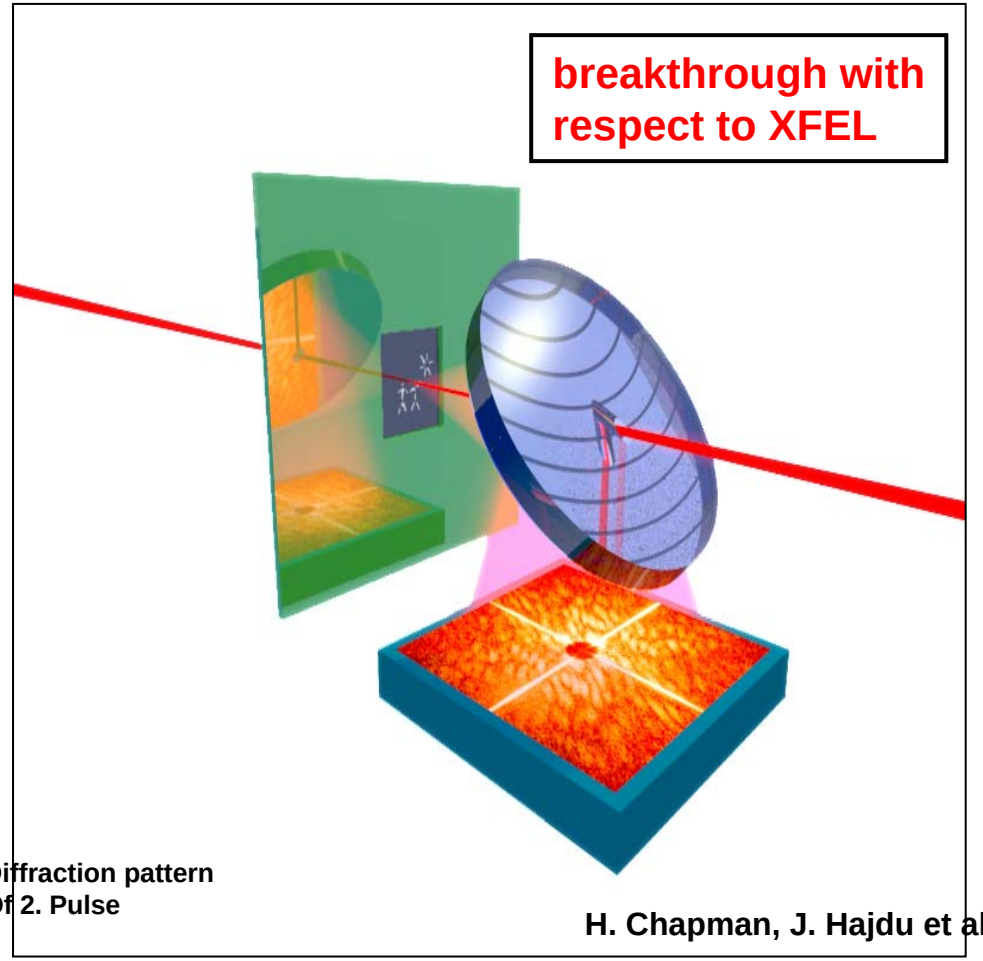


Ostreococcus TEM section
(Wenche Eikrem and Jahn Throndsen, University of Oslo)

J. Hajdu, I. Andersson, M. Svenda, M. Seibert (Uppsala)
S. Boutet (SLAC)
M. Bogan, H. Benner, U. Rohner, H. Chapman (LLNL)

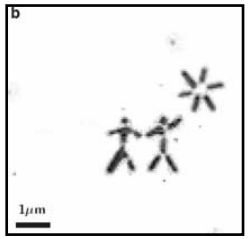
Ultrafast coherent diffraction at 32 nm

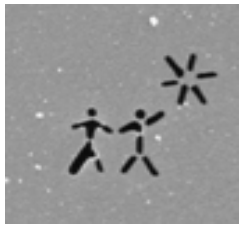
FEL-Pulse at FLASH:
30 fs, 32 nm, 3 x 10^{13} W/cm^2
10^{12} photons/s in one pulse
Probe heats up to 60'000C and evaporates
Take single shot image before probe gets destroyed



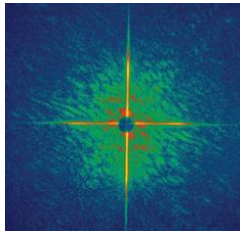
H. Chapman, J. Hajdu et al.

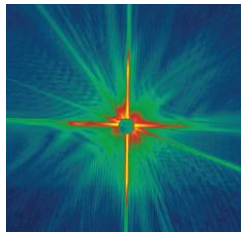
Reconstructed Image





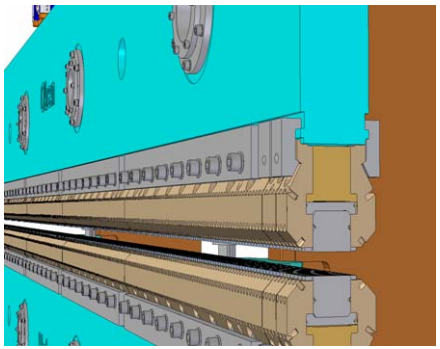
Diffraction pattern of 1. Pulse

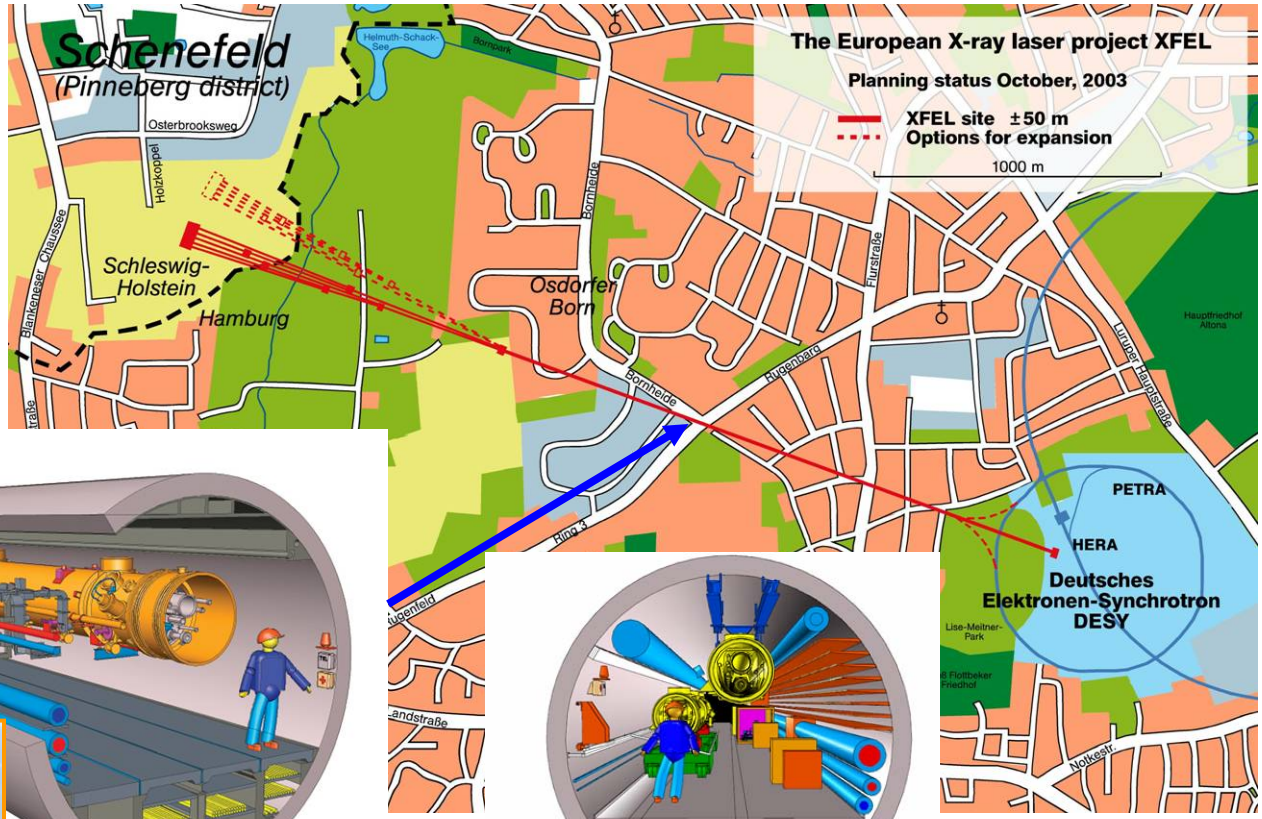


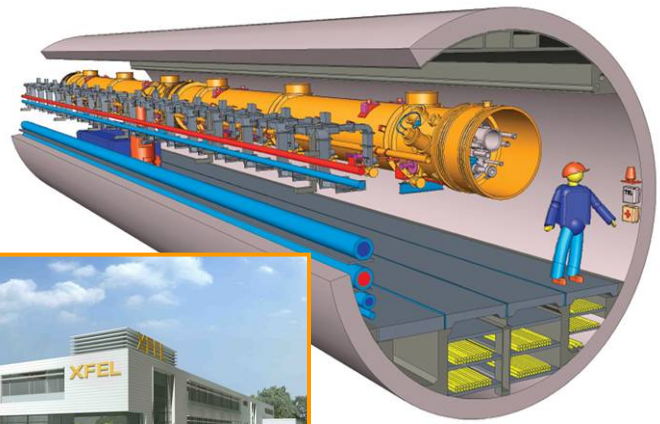


Diffraction pattern Of 2. Pulse

The European XFEL Project

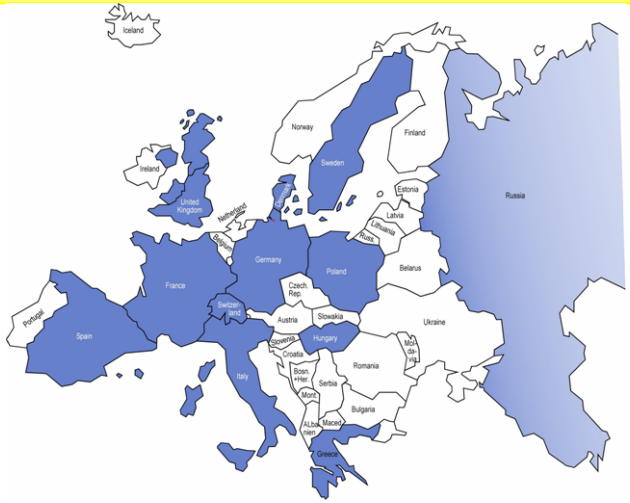






Status of the European XFEL Project

- 14 countries have signed Memorandum of Understanding for the preparatory phase
- Construction Phase officially launched on 5 June 2007



- Prep. Phase support by European Funds
- 12 countries ready to sign convention
- Funding of phase 1 assured

Civil construction tenders out

First Beam: 2013
Complete Operation with up to 10 Exp. Stations: 2015

CH CN DE DK ES FR GB GR HU IT PL RU SE SK

XFEL – Official Launch

- XFEL Launch on 5 June 2007

First beam in 2013,
all beamlines operational in 2015

Approach to FEL science in Germany

Center for Free-Electron Laser Science (CFEL)

MPG, DESY, and University of Hamburg

MPG	***MPG/Uni***	***MPG/Uni***	***DESY***	***DESY***	***DESY***	***Univ. HH***
Advanced Study Group I	***Core Group I Experim.***	***Core Group II Experim.***	***Core Group III Theory***	***Core Group IV Experim.***	***Core Group V Experim.***	***Advanced Study Group II***
Ullrich	*Junior Research Group I*	*Junior Research Group II*	*Junior Research Group III*			***Wurth*** *Johnson*
Rost						*Drescher*
Strüder						*Klanner*
Schlichting						*Rübhausen*
Techert						*Roßbach Khan*

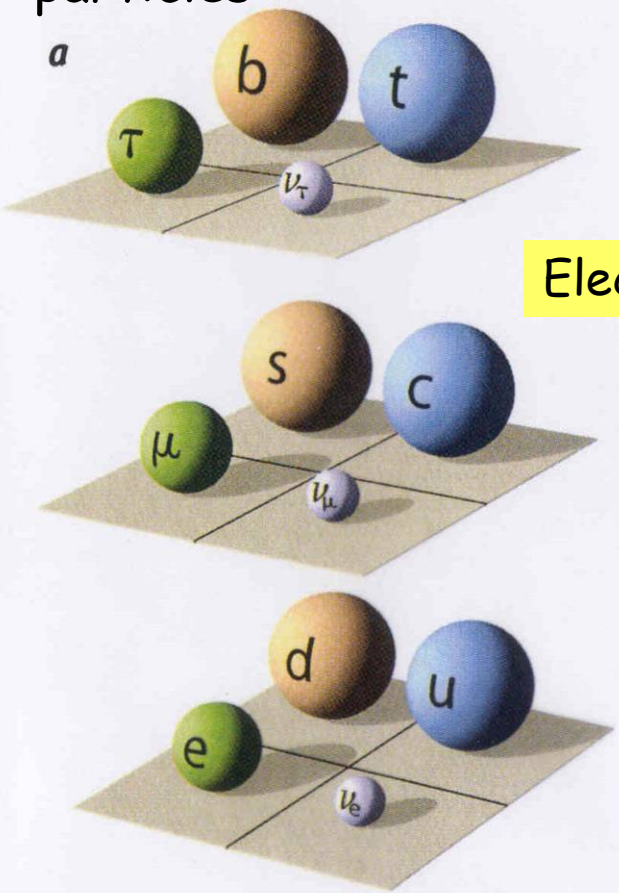
Max-Planck "Forschungsgruppe" of HH University

In 2010 a new building available for ~300 people, annual budget ~15 M€

What do we know about Particle Physics?

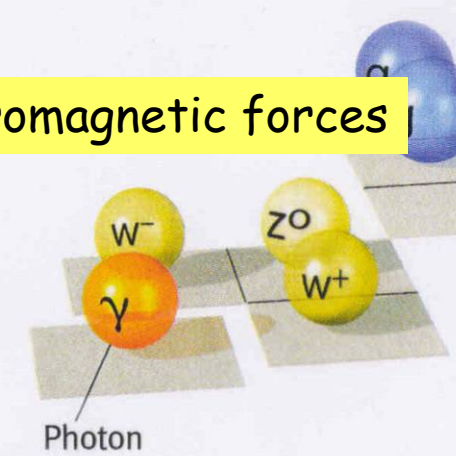
Understanding of the elementary particles and interactions

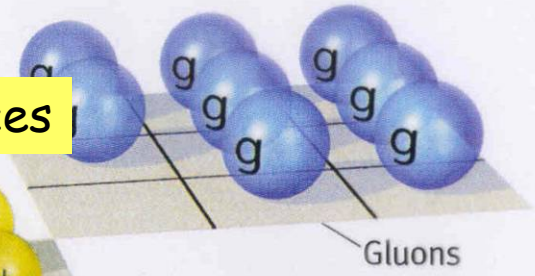
The elementary particles:



The forces:

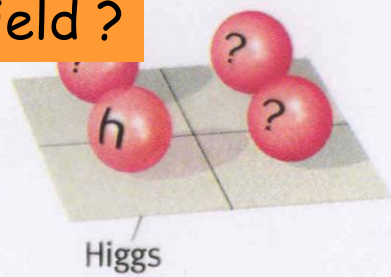
Electromagnetic forces





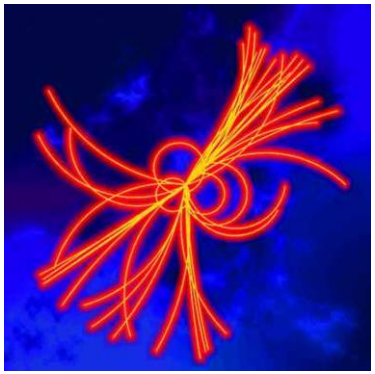
strong forces

Higgs field ?

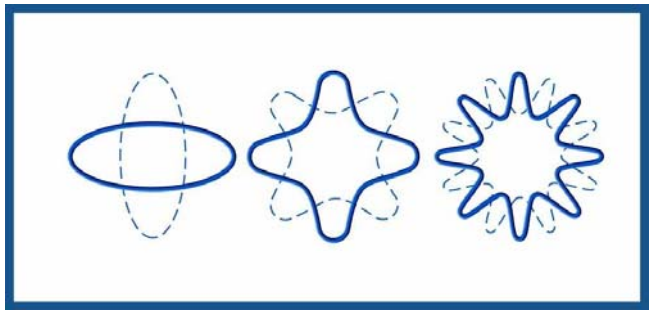


Particle Physics – open questions?

What generates Mass?
Search for the "Higgs".

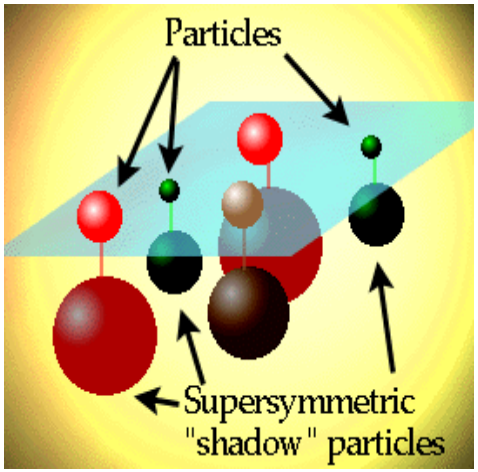


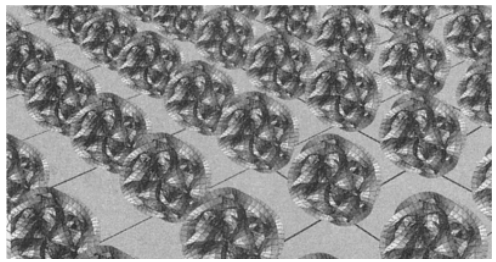
Is the world made out of "Strings"?



Do we understand the Universe?

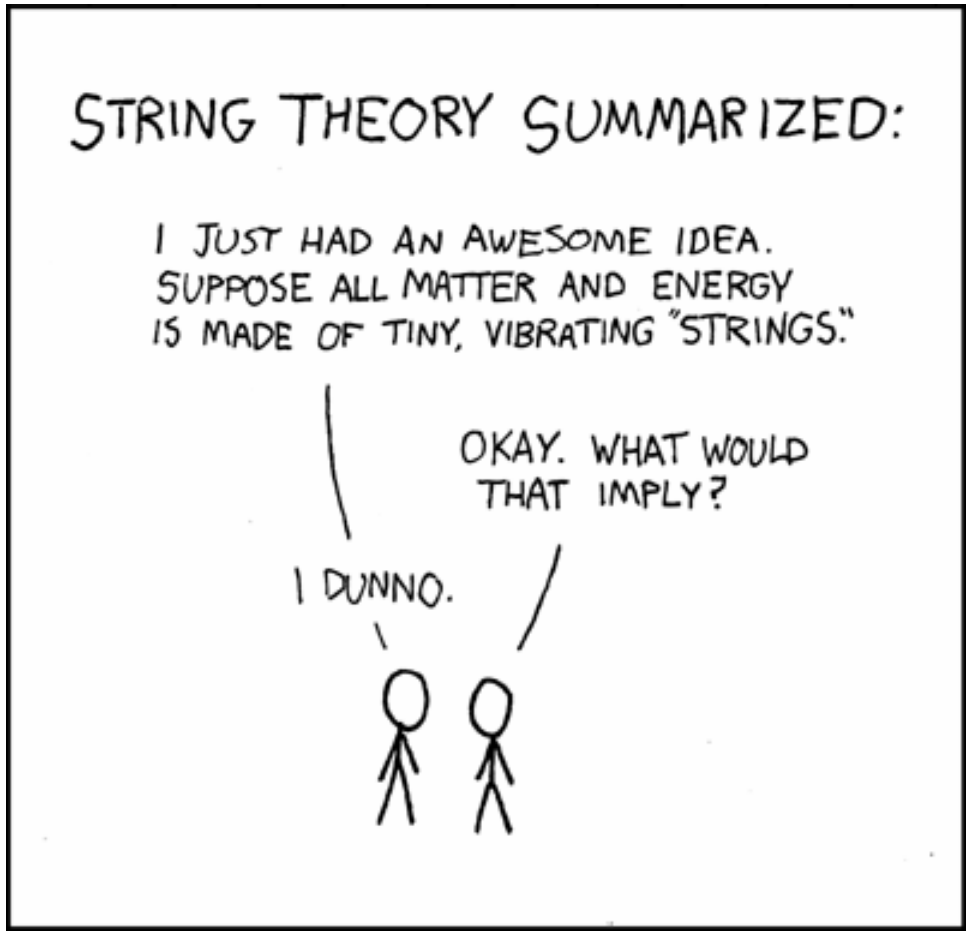
Is there a „shadow world" of new particles?



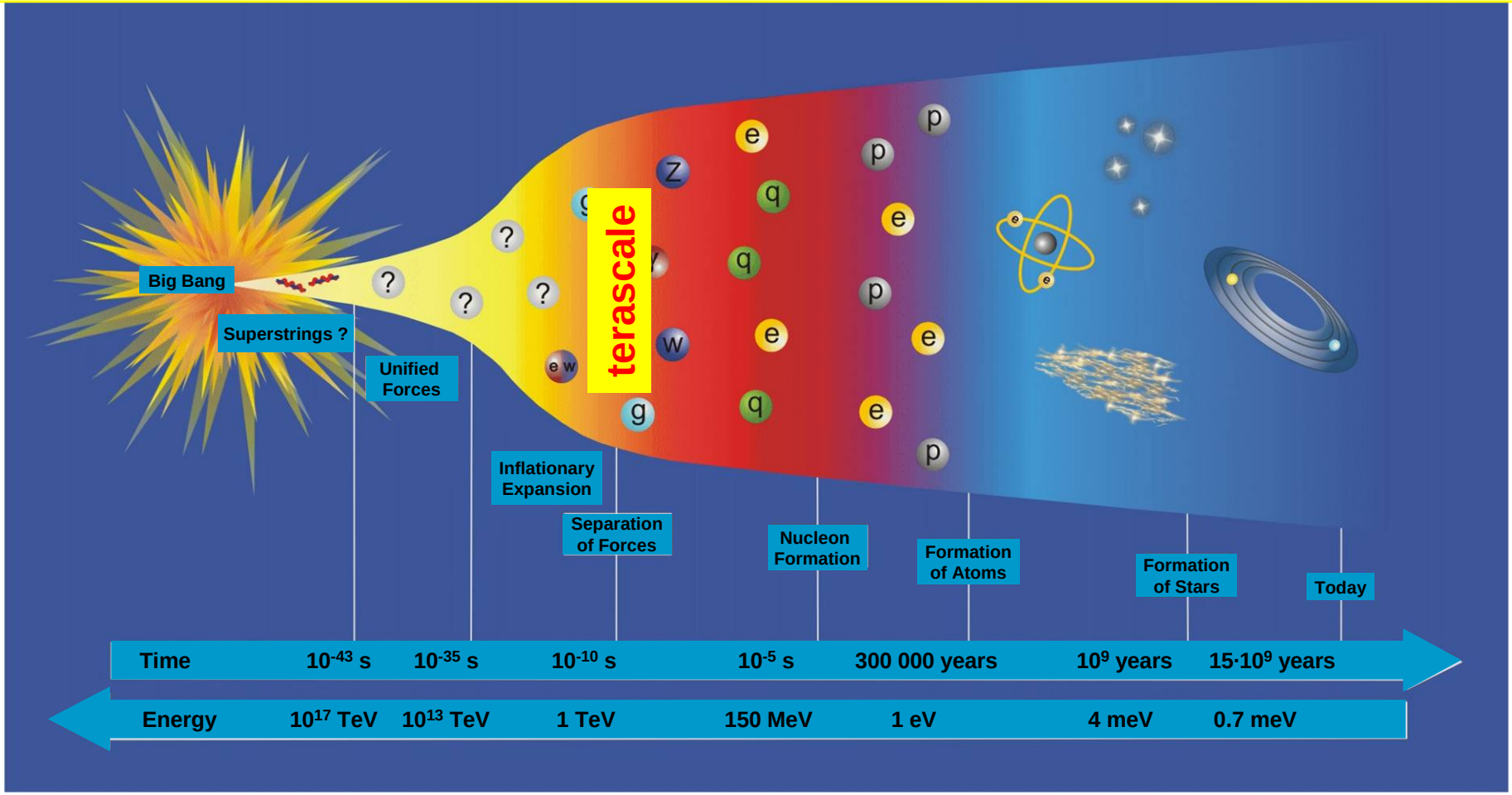


In how many dimensions do we live?

String theory



Particle Physics as telescope to the early universe



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)

Particle/Astroparticle Physics

- rich program pursued at DESY -

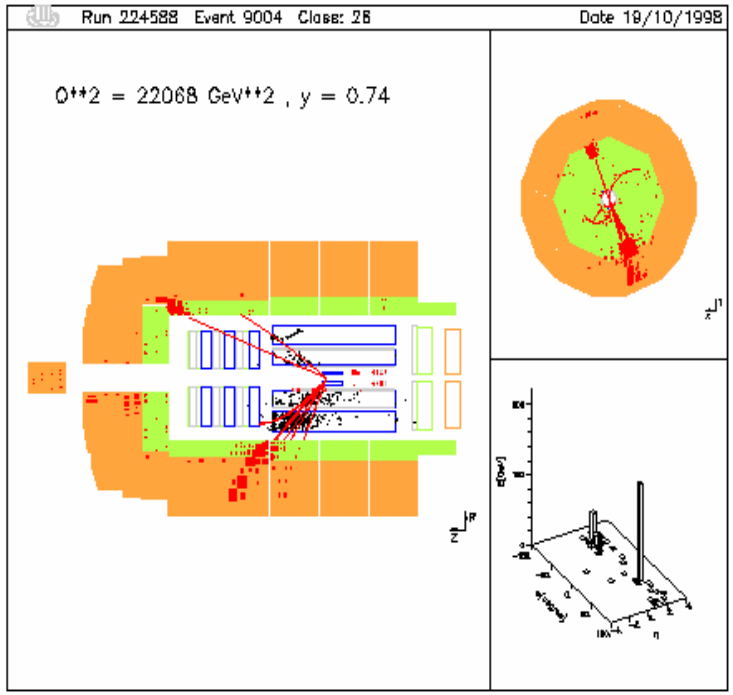
HERA	unique ep-facility, leading physics analyses, combined results, HERA -> LHC HERA Analysis centre at DESY
LHC	involvement in ATLAS and CMS, commissioning and physics, detector R&D towards possible upgrade (sLHC)
Linear Collider	central role in all aspects and through all phases towards Technical Design Phase in 2012
IceCube	complete installation, R&D on acoustic detectors, leading analysis contributions (-> multimessenger), prepare for the future (CTA)
Theory	keep balanced excellence in phenomenology, string theory, cosmology and astroparticle physics, lattice gauge theory (incl. hardware)

HERA

HERA: Microscope - unique world-wide - with a resolution of 1/1000 of proton radius (10^{-18} m)

Questions:

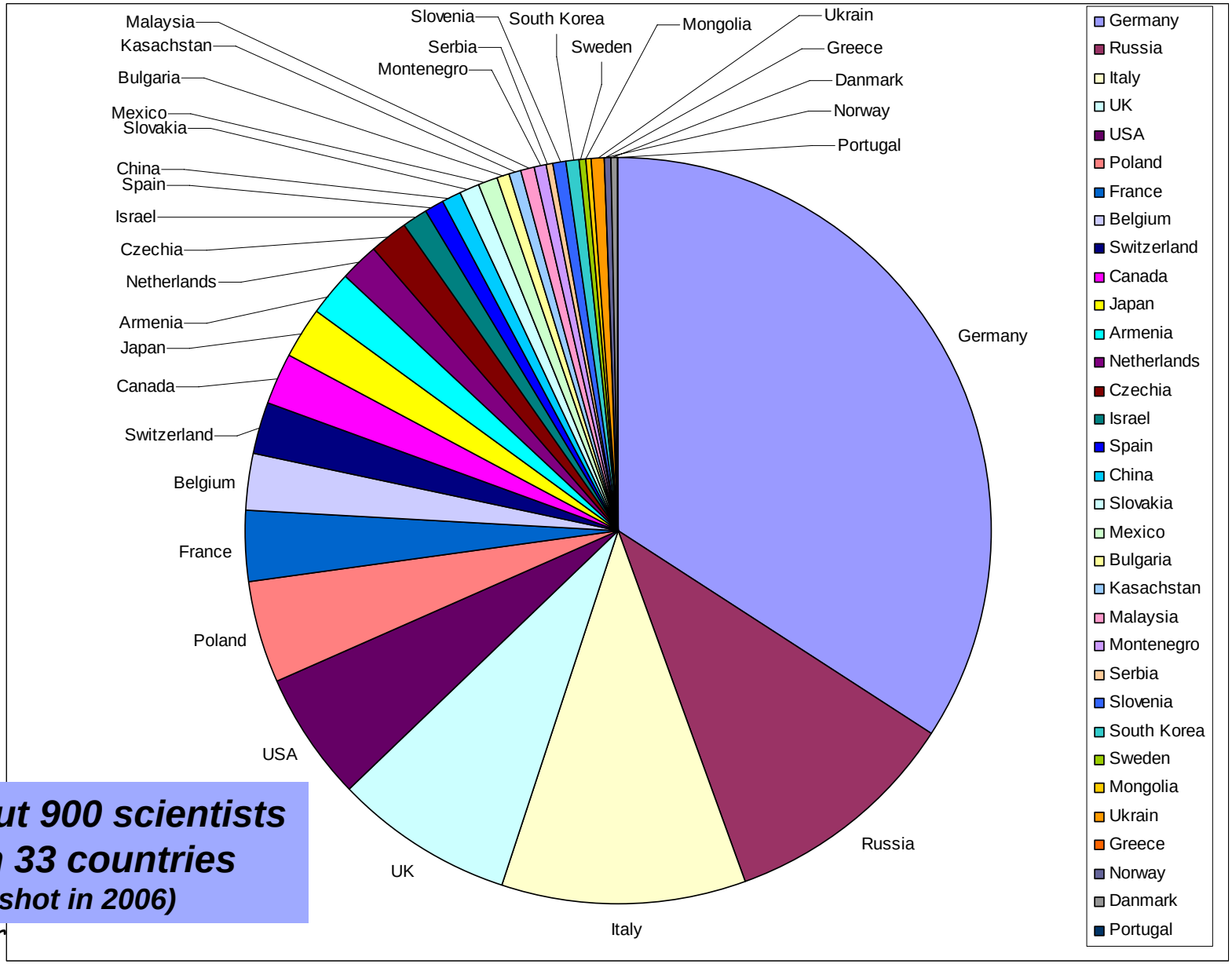
- How big are electron and quark
- What is the proton made of
- Which properties do the fundamental forces have
- What is the origin of spin
- Are there new phenomena



First collisions in 1992

End of Operation 30 June 2007

Particle Physics Users



About 900 scientists from 33 countries
(snapshot in 2006)

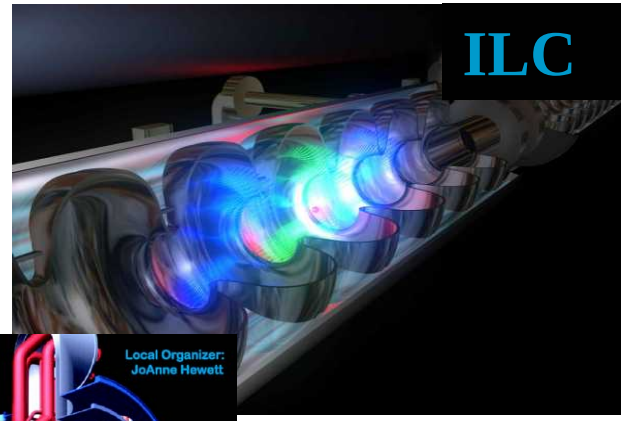
HERA Fest

DESY has ended HERA Programme to make room for new projects

More than 1,000 Physiker
~ 1,000 Ph.D.'s
~ 400 publications

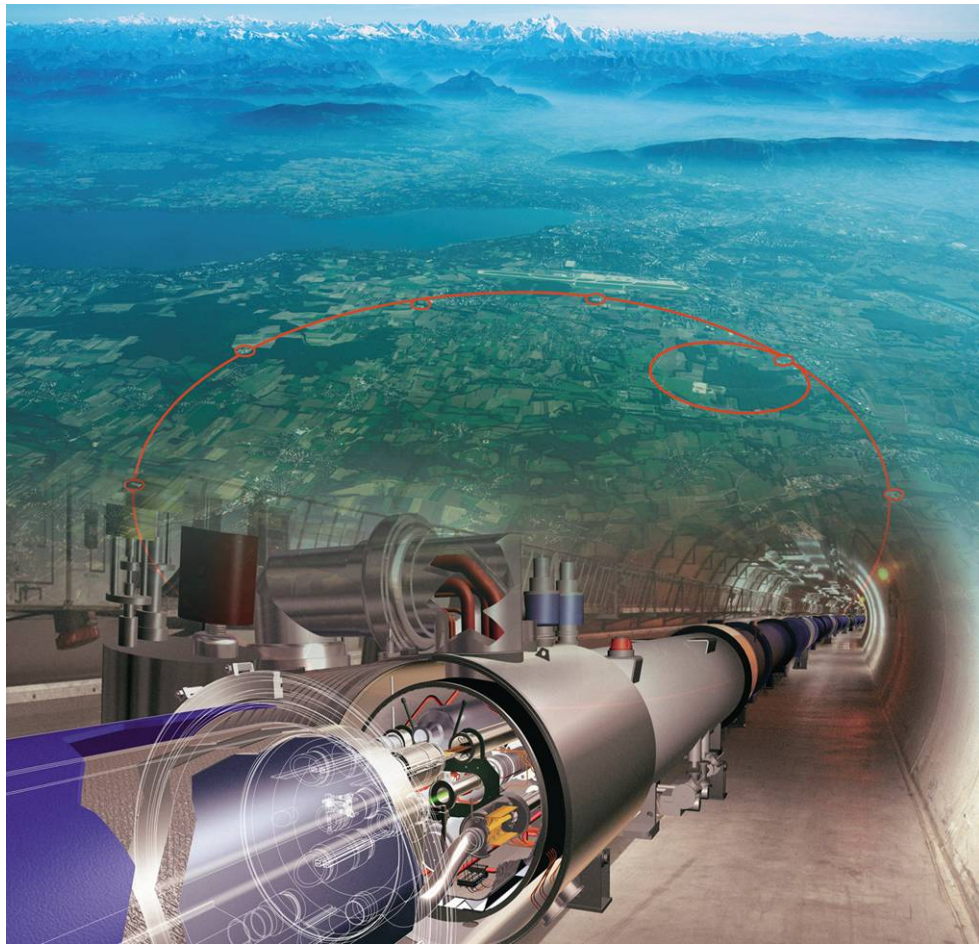
DESY in post-HERA era – participation at LHC

- expect scientific breakthroughs
- strong link to HERA program
- preparation of ILC



Large Hadron Collider LHC

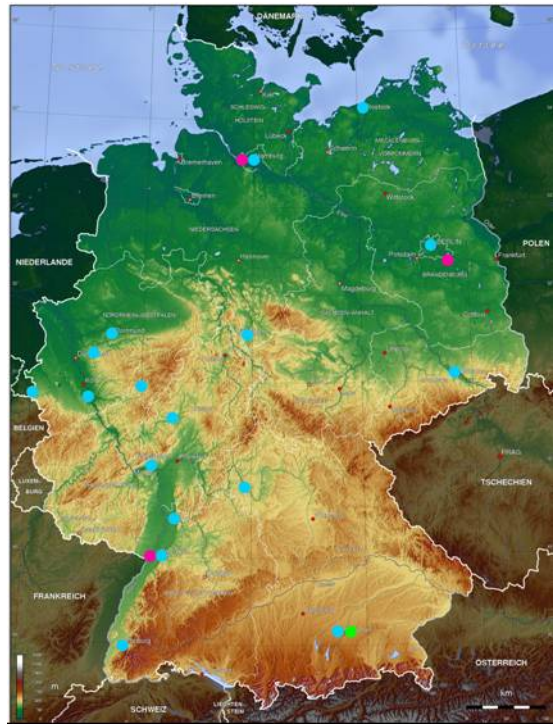
- Large Hadron Collider LHC at CERN/Geneva
- circular machine
  27 km circumference
- proton-proton collisions at
  14 TeV energy
  - 800 million quark/gluon collisions per second
  - 15 Petabyte of data/year (GRID)
- LHC will start by mid 2008 and is our essential tool to explore the Terascale



HERA results are vital for LHC predictions

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

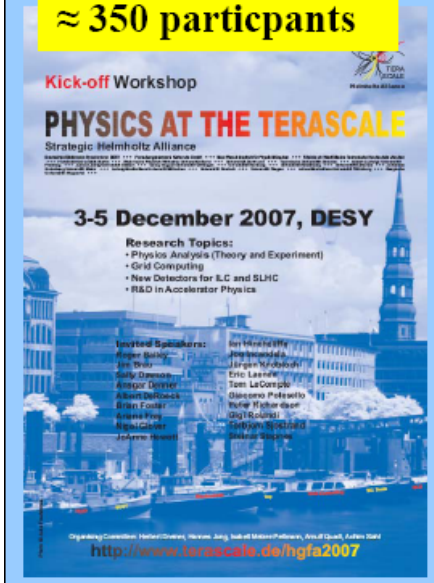
Key Elements

- **Physics Analysis**
- **Detector Development**
- **GRID Computing**
- **Accelerator Science**

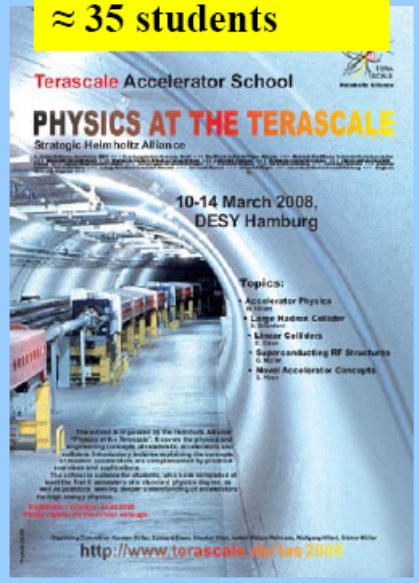
Physics at the Terascale

- Start July 2007 for 5 years duration
  - all structures set up and most positions filled
  - Analysis Centre and Virtual Theory Institute constituted
  - NAF prototype operational
  - lecture and school programme in full swing, e.g.:

Kick-off workshop
≈ 350 particpants

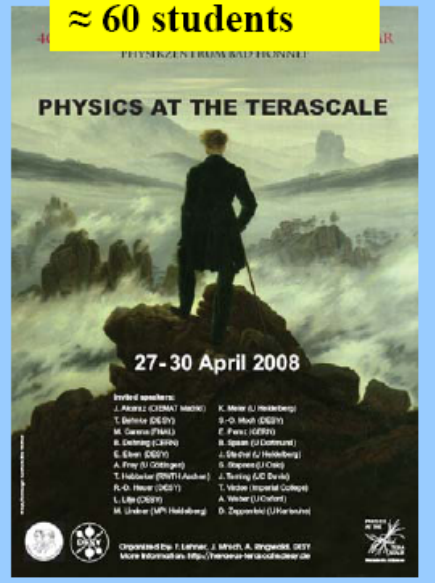


Accelerator school
≈ 35 students



Monte Carlo school
≈ 85 students

Heraeus seminar
≈ 60 students



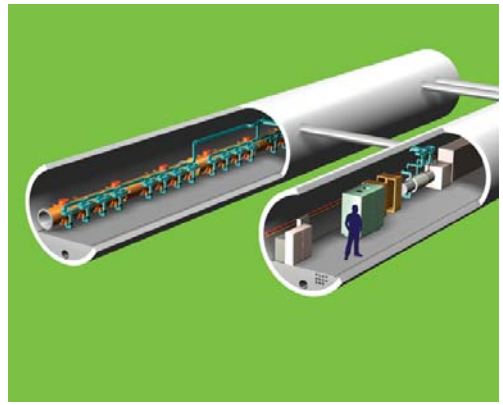
+ university lectures on accelerator physics
+ teaching buy out

- Planned:
  - Sep 2008 Statistical Methods
  - Nov 2008 Parton Density
  - Dec 2009 Annual Workshop (Aachen)

International Linear Collider

- International consensus: Linear Collider as next large-scale facility in particle physics
- Worldwide technology decision in 2004: TESLA (SCRF) Technology
- „Baseline" Design Configuration
  - Many elements of the Main Linac correspond to the XFEL design (except gradient)
  - FLASH and XFEL experience and future work (industrialization)

- DESY actively involved in ILC Global Design Effort
- Reference Design Report including costs were presented in February 2007
- Now strong international effort towards engineering design to be completed by 2012



Which ILC questions are answered by XFEL?

- how to build a 100 accelerator module linac using superconducting RF (SCRF) Technology
- how to industrialize the SCRF on a 5% ILC scale
- how to extrapolate from FLASH by a factor of 20
  Remark: ILC ~ 20 × XFEL
- how to start and organize an international project based on in-kind contributions

Strategy for Astroparticle Physics

Strategy:

Experimental Scientific Focus: Origin of high energy cosmic rays, through neutrino messengers

- Analysis of data from Baikal and Amanda
- deployment of Icecube until 2011

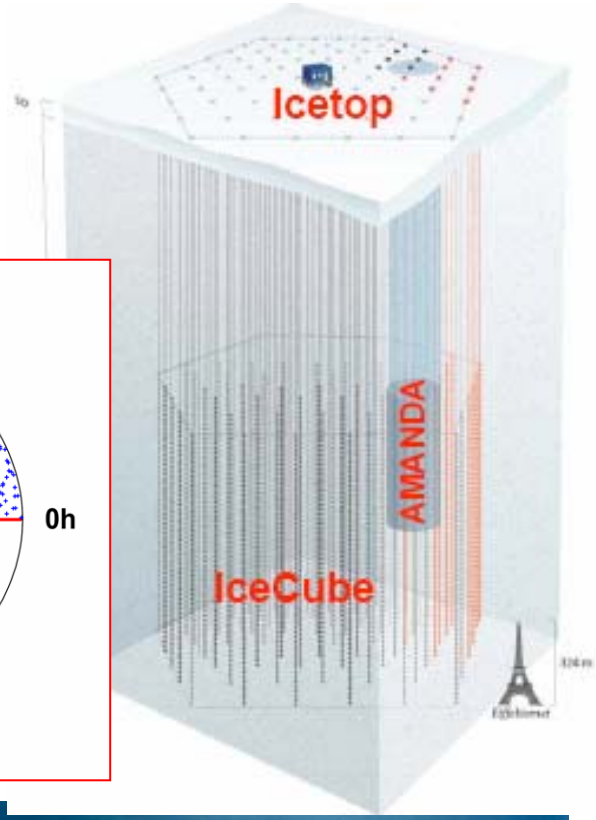
New: Combination of neutrino and high energy photon signals (multi-messenger principle)

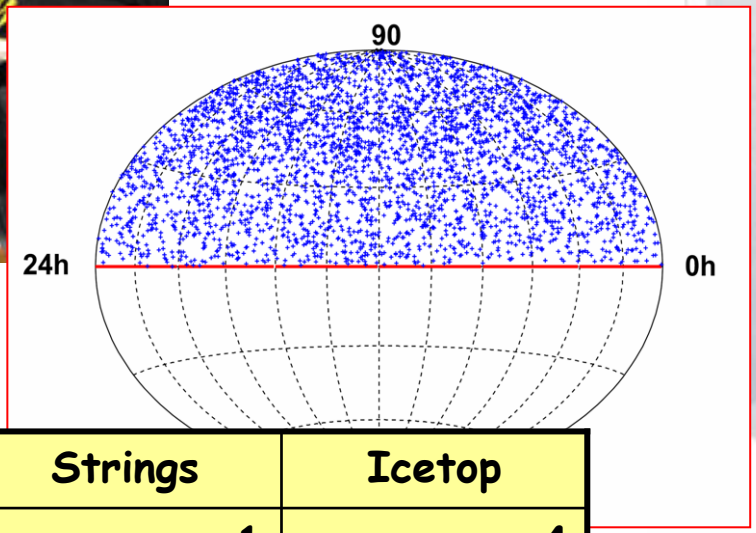
Close collaboration with German universities

Experimental astroparticle activities are presently mainly located in Zeuthen

Neutrino Astrophysics

Icecube





Year	Strings	Icetop
2005	1	4
2006	8	12
2007	12-14	10
2011 Sum	70-80	70-80

ICECUBE will i
antarctic ice t

ALPS – „Axion like particle search"

Elementary particle physics at very low energies :

- Search for particles which are 1.000.000 times lighter than electrons. Hints from:
  - Masses of neutrinos,
  - Dark energy

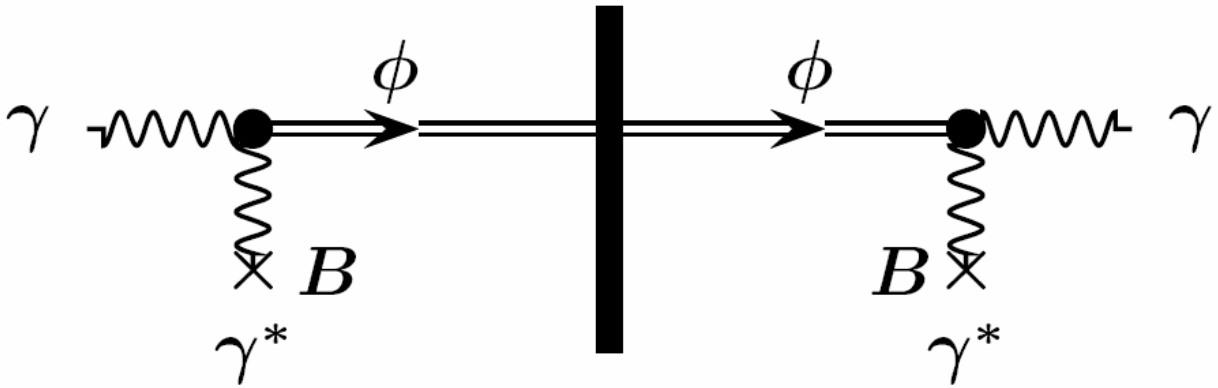
- New very light particles can be easily integrated in extensions of the SM

- Experimental searches for light particles would
  - test String-Theories,
  - Provide indirect access to extremely high energies
  - Complement experiments at LHC and ILC.

The ALPS-Experiment at DESY

DESY, Hamburger Sternwarte, Laser Zentrum Hannover,
MPI für Gravitationsphysik (Albert Einstein Institut)

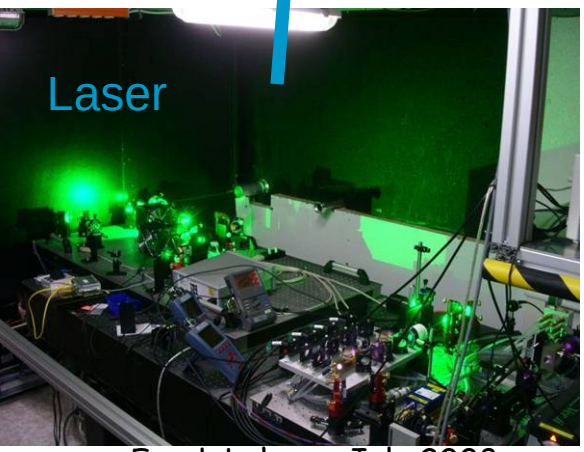
search for „Light shining through the wall".

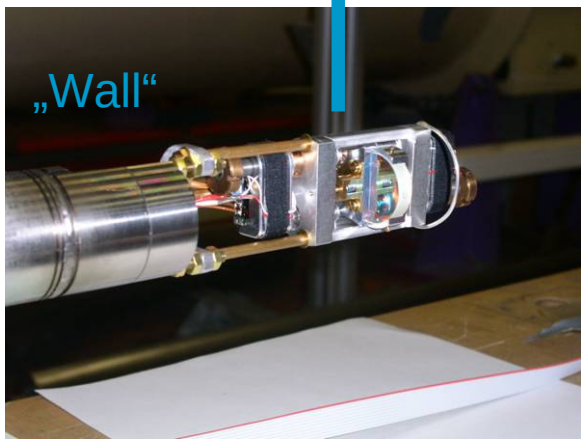


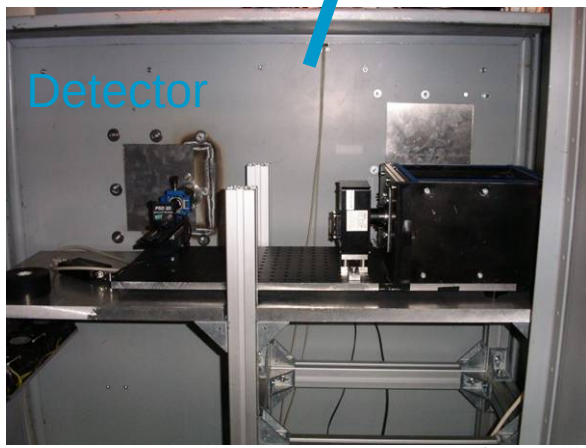
Skivie 1983, Ansel'm 1985, Van Bibber et al. 1987

The ALPS-Experiment

Measurement using old HERA-Dipole magnet







50 Years of DESY

in 2009:
we celebrate 50 years of DESY

start planning for
a series of events, from spring 2009 onwards

First operation of DESY in 1964

Minister Balke Max Brauer

18.12.1959

Summary

Particle- and Astropart.-physics	Accelerators Develop./Operation	Research with Photons

The scientific focus of the research at DESY is the understanding of the structure of matter at different length and time scales

In its three areas of key competence DESY is a world leading institution

Science driven technology developments have led to a major new research possibilities for photon science and particle physics, such as FLASH, XFEL and ILC

Finally …

Enjoy your stay at DESY
and in Hamburg …