Welcome to DESY.

What is DESY and what kind of research is done here?

Michael Grefe
DESY Press and Public Relations (PR)

HELMHOLTZ ASSOCIATION

What is DESY?

- **D**eutsches **E**lektronen-**Sy**nchrotron (German electron synchrotron) DESY
- A national research centre of the

HELMHOLTZ | ASSOCIATION

- Established: 18 December 1959 in Hamburg
- Two locations: Hamburg and Zeuthen
- Annual budget: 192 million euros
  - 90% Federal Ministry of Education and Research
  - 10% city of Hamburg and federal state of Brandenburg

Helmholtz association of german research centres

- Germany's largest scientific organisation
  - 16 research centres
  - 30 000 employees
  - 3 billion euros annual budget
- *Fundamental research* to solve major challenges facing society, science and industry
- Pursuit of long-term research objectives of the state

HELMHOLTZ ASSOCIATION

AWI

DESY

dkfz. DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

DZNE Deutsches Zentrum für Neurodegenerative Erkrankungen in der Helmholtz-Gemeinschaft

GFZ Helmholtz-Zentrum Potsdam

GKSS FORSCHUNGSZENTRUM in der HELMHOLTZ-GEMEINSCHAFT

GSI

HZB Helmholtz Zentrum Berlin

HELMHOLTZ ZENTRUM FÜR INFEKTIONSFORSCHUNG

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

HelmholtzZentrum münchen Deutsches Forschungszentrum für Gesundheit und Umwelt

JÜLICH FORSCHUNGSZENTRUM

KIT Karlsruher Institut für Technologie

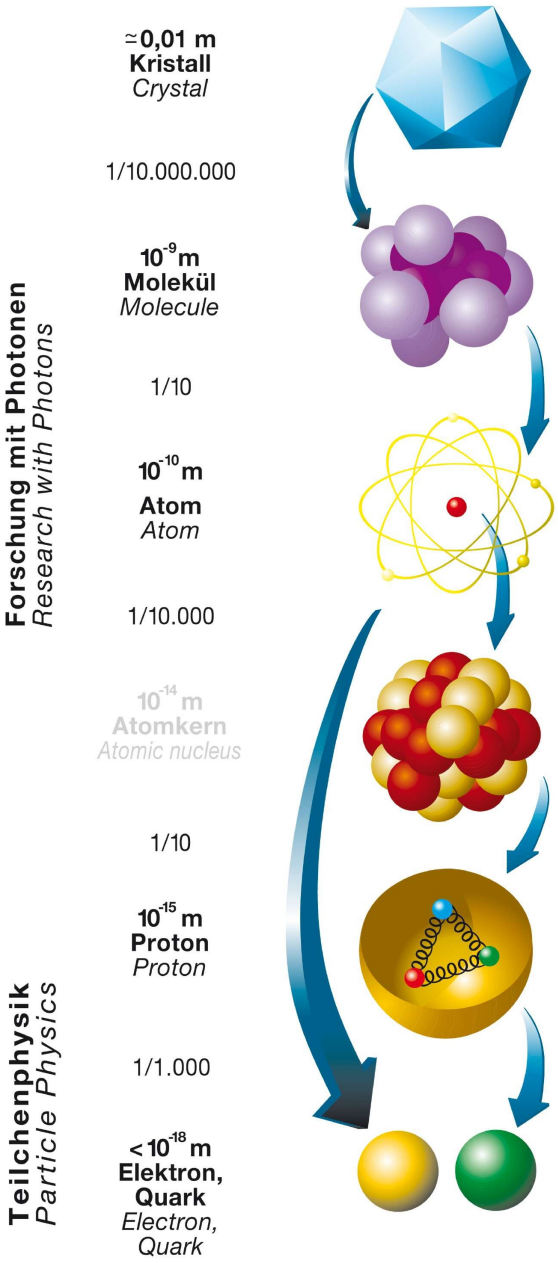
MDC MAX-DELBRÜCK-CENTRUM FÜR MOLEKULARE MEDIZIN BERLIN-BUCH IN DER HELMHOLTZ-GEMEINSCHAFT e.V.

IPP Max-Planck-Institut für Plasmaphysik

Who works at DESY?

- Approximately 2000 employees
  - Including some 650 scientists
- Training programmes
  - More than 100 young people are being trained in commercial and technical vocations
- Young scientists
  - Around 700 graduate students, PhD students and postdocs
- Guest researchers
  - More than 3000 from 40 countries annually

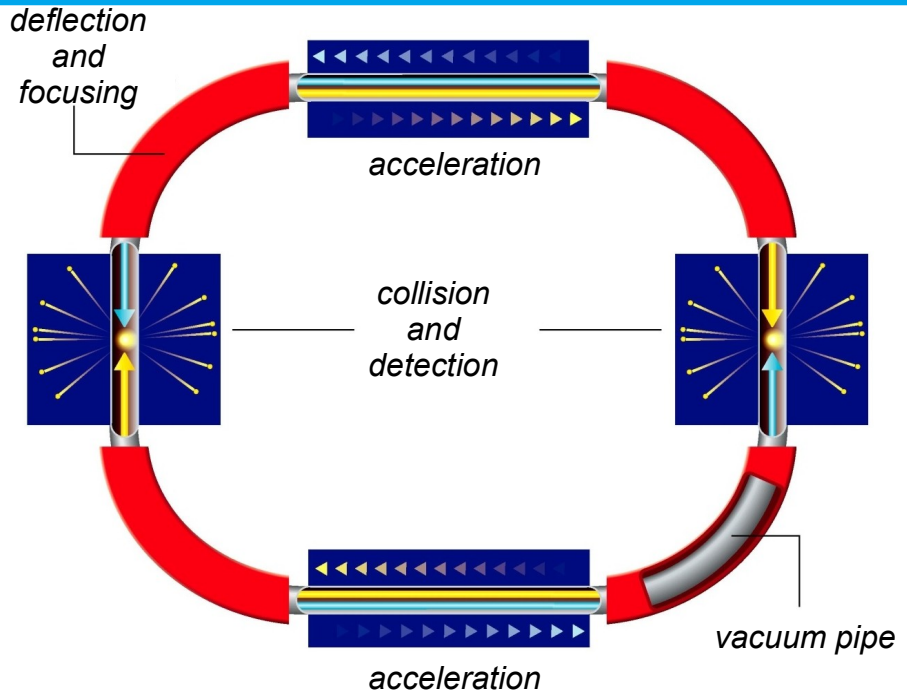
What kind of research is done at DESY?

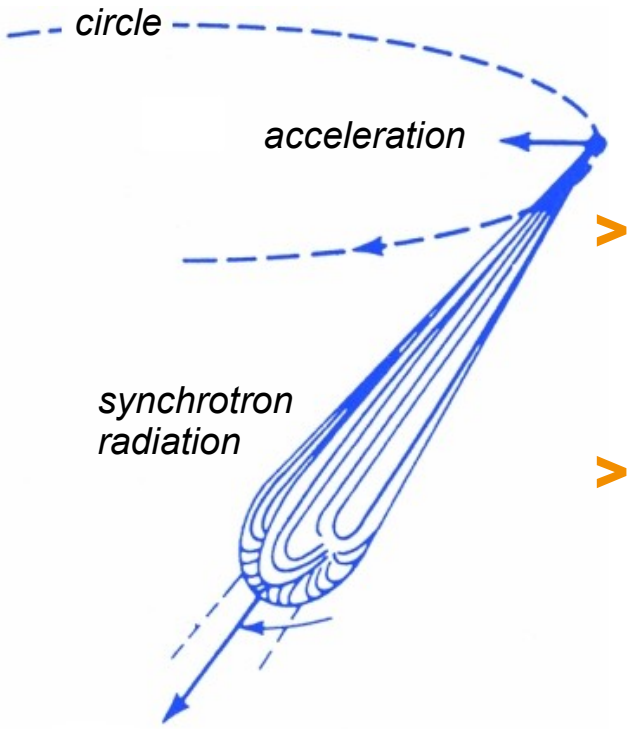


- We do fundamental research in natural sciences
- Research with photons
  - Investigation of molecular and atomic structures from all natural sciences using a special kind of light originating from particle accelerators
- Accelerators
  - Development, construction and operation of particle accelerators
  - Common basis for particle physics and research with photons
- Particle physics
  - Investigation of the fundamental building blocks and forces that make up our universe

What is a particle accelerator/collider?

- Charged particles (electrons, protons, ...)
  - Are accelerated using electric fields
  - Are deflected using magnetic fields



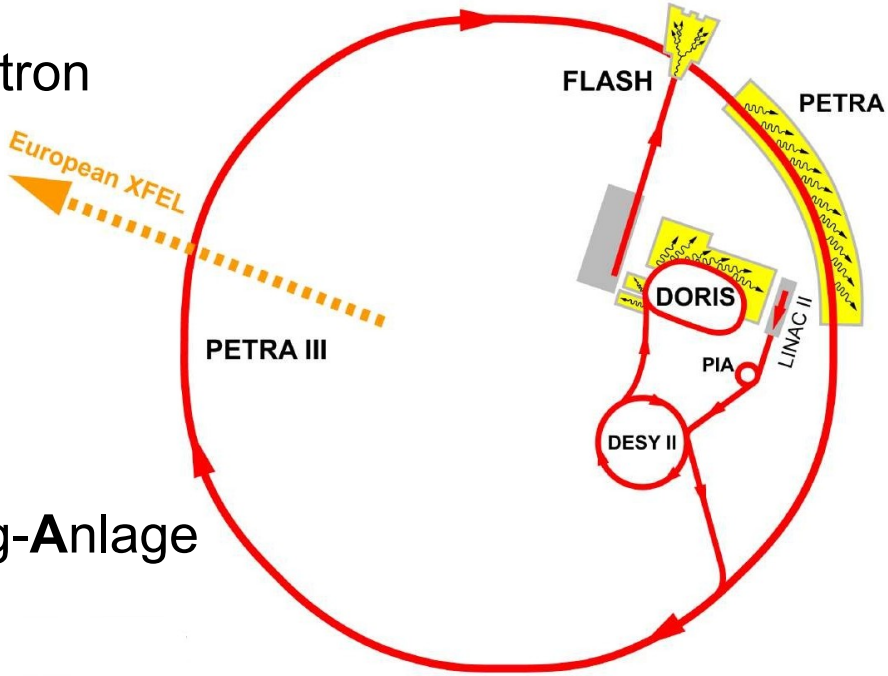


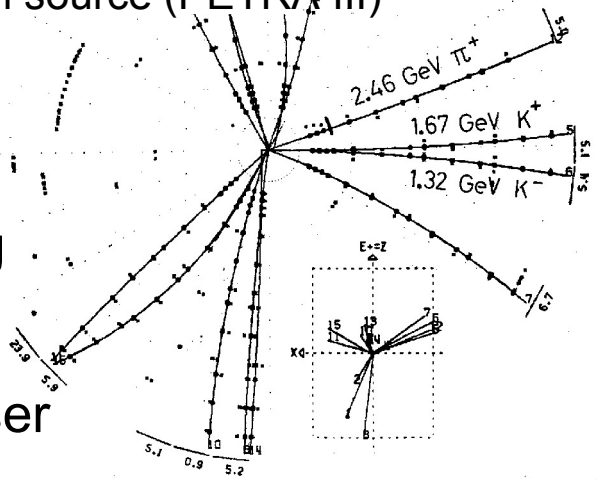
- What limits the achievable energy?
  - The magnetic field strength cannot be increased arbitrarily
  - Energy loss due to synchrotron radiation in the curves
- Solutions:
  - Storage rings with a larger circumference
  - Accelerators without curves → linear colliders

Which accelerators are there at DESY?

The history of accelerators at DESY

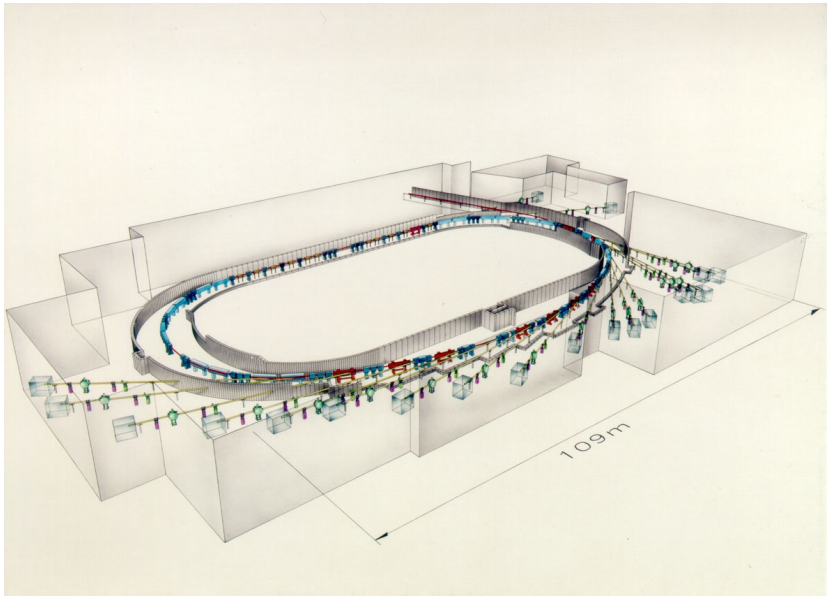
- 1964: **D**eutsches **E**lektronen-**Sy**nchrotron
  - Confirmation of quantum electrodynamics
- 1974: **Do**ppel-**Ri**ng-**S**peicher
  - Heavy quarks and b-mesons
  - Since 1981: **Ha**mburg **sy**nchrotron radiation **lab**oratory (HASYLAB)
- 1978: **P**ositron-**E**lektron-**T**andem-**R**ing-**A**nlage
  - Discovery of the gluon (1979)
  - Since 2009: Utilization as a synchrotron radiation source (PETRA III)
- 1992: **H**adron-**E**lektron-**R**ing-**A**nlage
  - Investigation of the proton
- 2005: **F**reie-**E**lektronen-**Las**er in **H**amburg
  - First FEL in the soft X-ray range
- 2014: European **X**-Ray **F**ree-**E**lectron-**Laser**
  - Most intensive X-ray Laser in the world

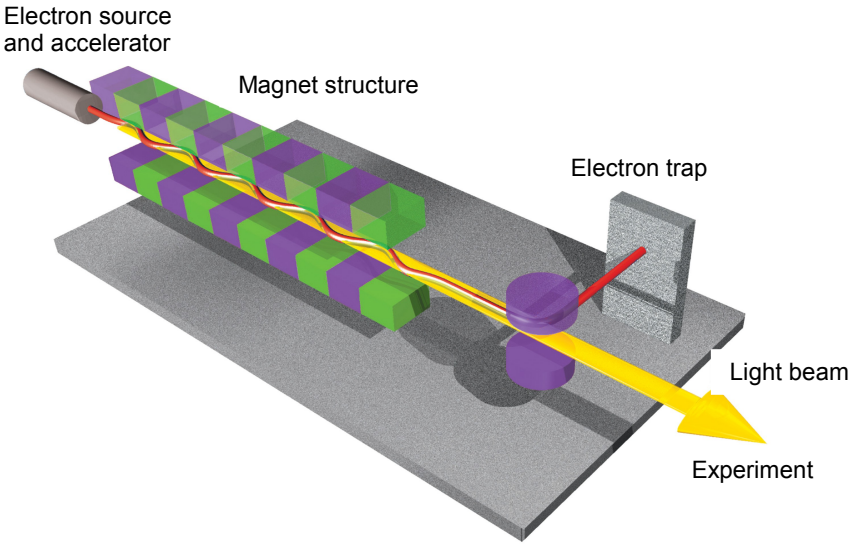




Research with photons

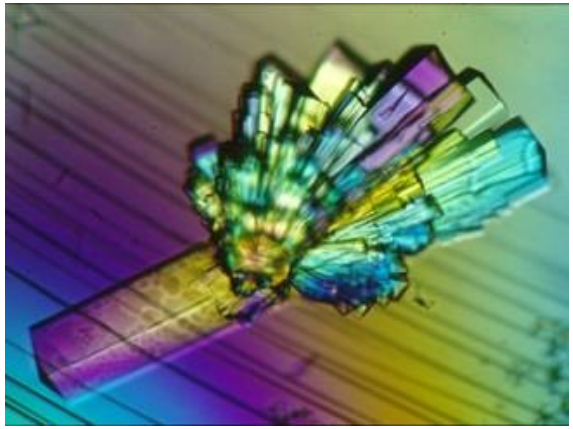
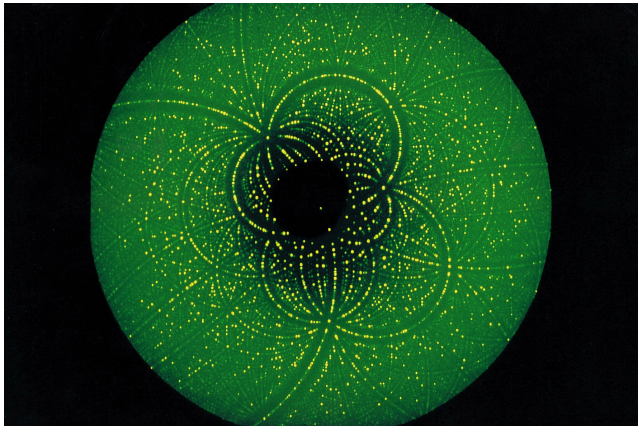
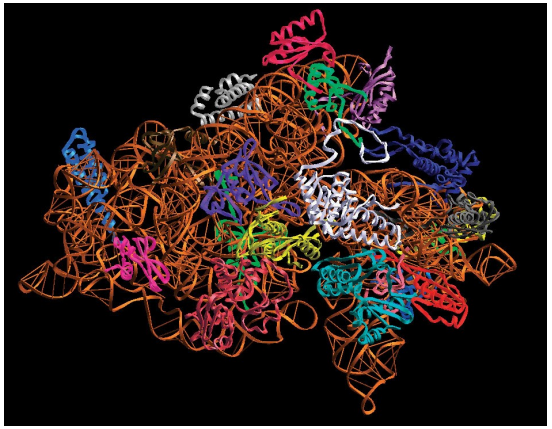
- Synchrotron radiation is light with special characteristics
  - Very intensive
  - Very strongly focused
  - Very broad spectrum (wavelength can be chosen according to the needs of the experiment)
- Particle accelerators are used as synchrotron radiation sources
  - Storage rings: DORIS III (HASYLAB) and PETRA III
  - Free-electron lasers: FLASH and the European XFEL





Applications of synchrotron radiation

- Structural analysis, e.g. of biomolecules

  - From protein crystals ... via diffraction images ... to the 3D structure of ribosomes

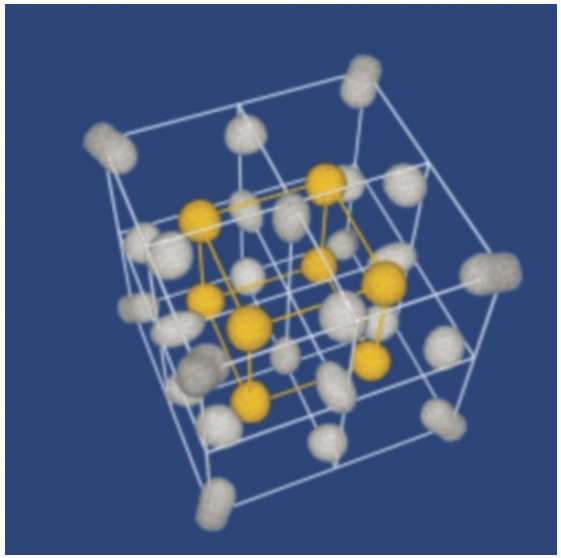
- Structure of ribosomes: Nobel Prize in Chemistry 2009 (*Ada Yonath*)

- Material science
- Investigation of plasmas
- Reconstruction of a hidden portrait in Van Gogh's painting *Grasgrond*

PETRA III & FEL: The capabilities of our facilities

> PETRA III

- Incoherent light beam can only probe materials with a crystalline structure



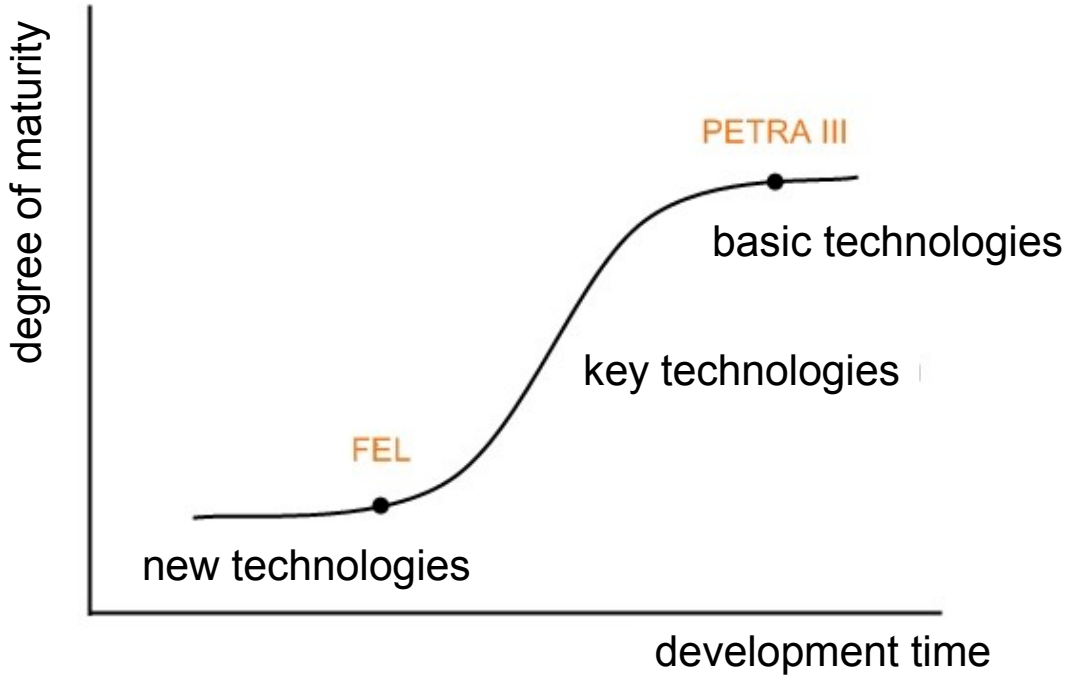
- Crystals

> Free-electron laser

- Coherent light beam can also probe materials with an irregular structure

- Noncrystalline solids
- Biological substances

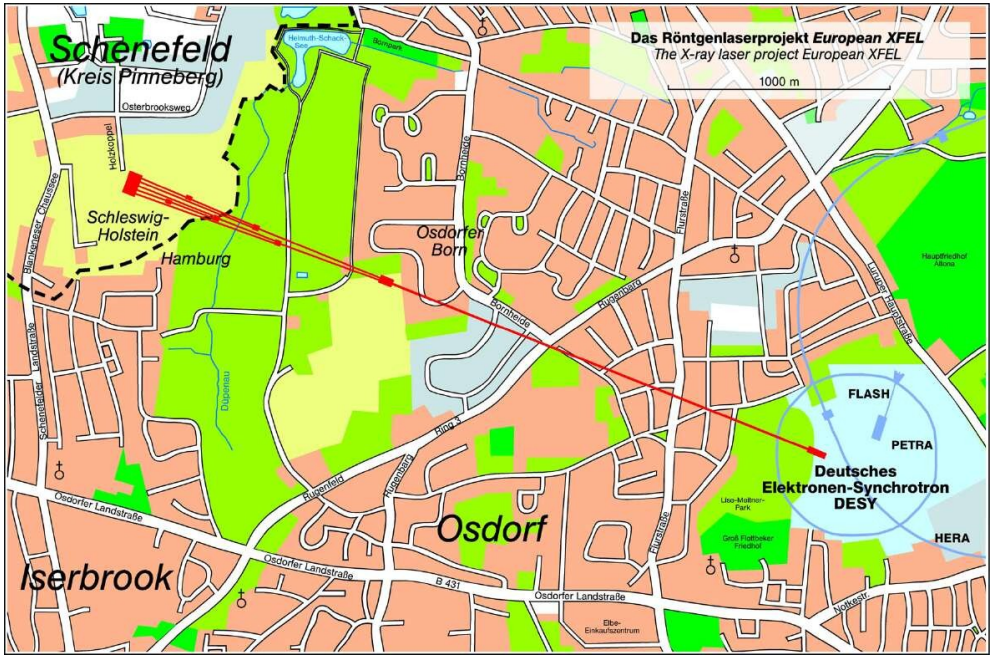
Light sources at DESY: Today, tomorrow and beyond



- PETRA III – Best light source using today's technology
  - Mature technology
  - High application potential:
    Use for industry, medical sciences, ...
  - Freeze images of the nanocosm
- Free-electron laser – Technology of tomorrow
  - Revolutionary technology
  - Live observations of the nanocosm

The future: European X-ray Free-Electron Laser (XFEL)

- Revolutionary light source for fundamental research with ultra-short X-ray flashes
  - Length: 3,4 km
  - Completion: 2014
- Applications:
  - Observation of single molecules
  - Filming of chemical reactions



- Acceleration technology developed at DESY
  - Successfully tested at the prototype FLASH

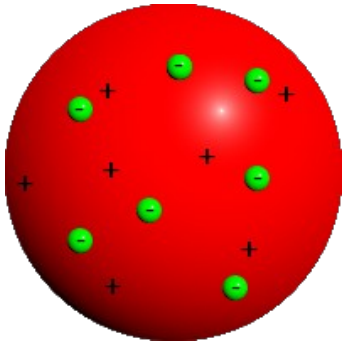
European XFEL

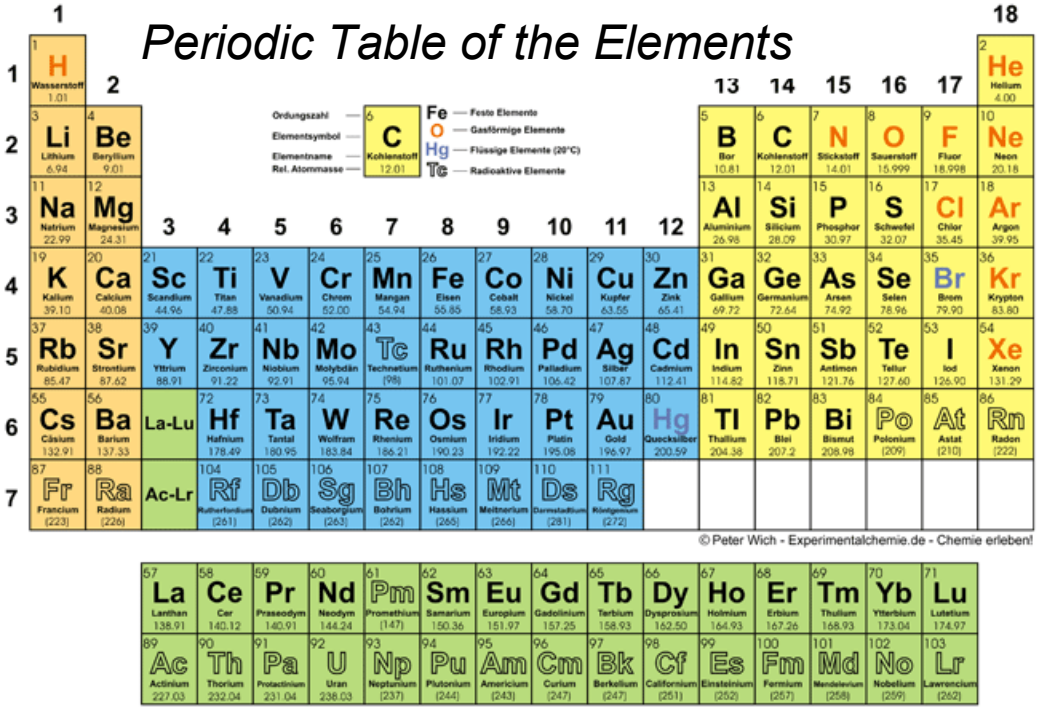
DESY

The beginnings of particle physics

- Around 400 BCE – „By convention sweet, by convention bitter, by convention hot, by convention cold, by convention color: but in reality atoms and void.“ (*Democritus*)

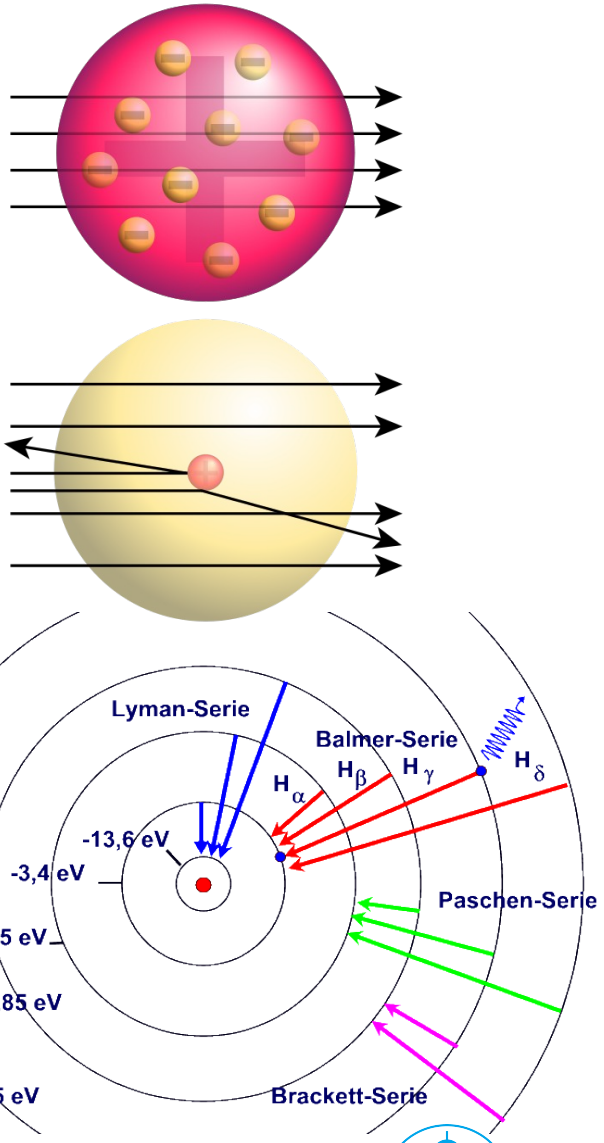
- 19th century – Periodic table of the elements (*Mendelejew*, *Meyer*)
- 1897 – Discovery of the electron (*Thomson*)
- 1903 – Thomson atomic model (Plum pudding model)





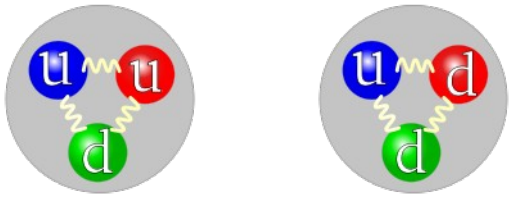
The beginnings of particle physics

- 1909 – Rutherford experiment
  - Scattering of alpha particles off a gold foil
  - In contrast to the expectations based on the plum pudding model a small fraction of the particles is deflected by a large angle or even reflected
- 1911 – Rutherford model
  - The mass and the positive charge of the atoms is concentrated in a tiny, compact nucleus
- 1913 – Bohr model
  - The electrons move on *quantised* circular orbits around the nucleus
  - This model explains the atomic spectral lines
- Around 1950 until today – Discovery of new elementary particles at particle accelerators

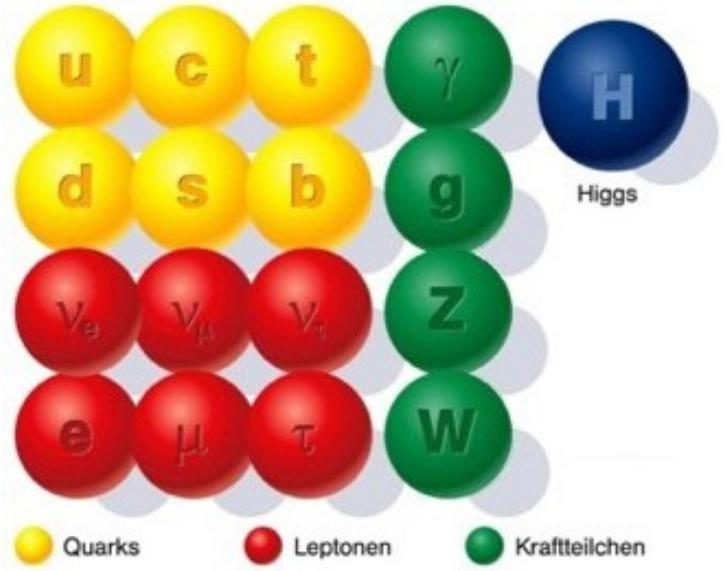


The standard model of particle physics

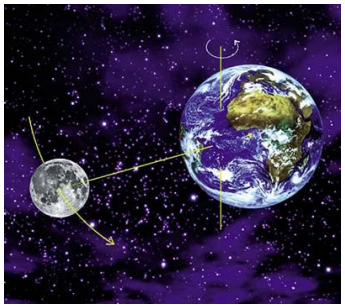
- All matter consists of point-like, indivisible elementary particles
  - Protons and neutrons consist of quarks



  - Quarks: up up down up down down
  - Charge: $+\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=+1$ $+\frac{2}{3}-\frac{1}{3}-\frac{1}{3}=0$

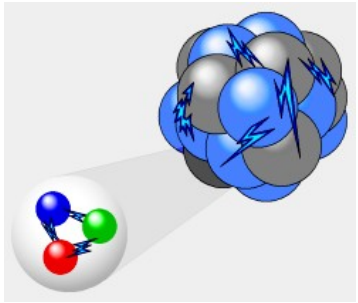


- Forces between matter particles are mediated by the exchange of other particles

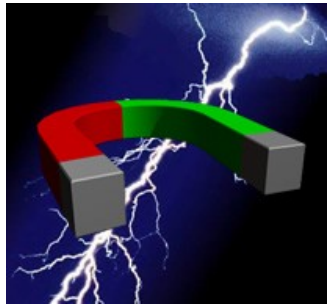


- Gravity (*Graviton?*)

- Weak force (*W and Z bosons*)



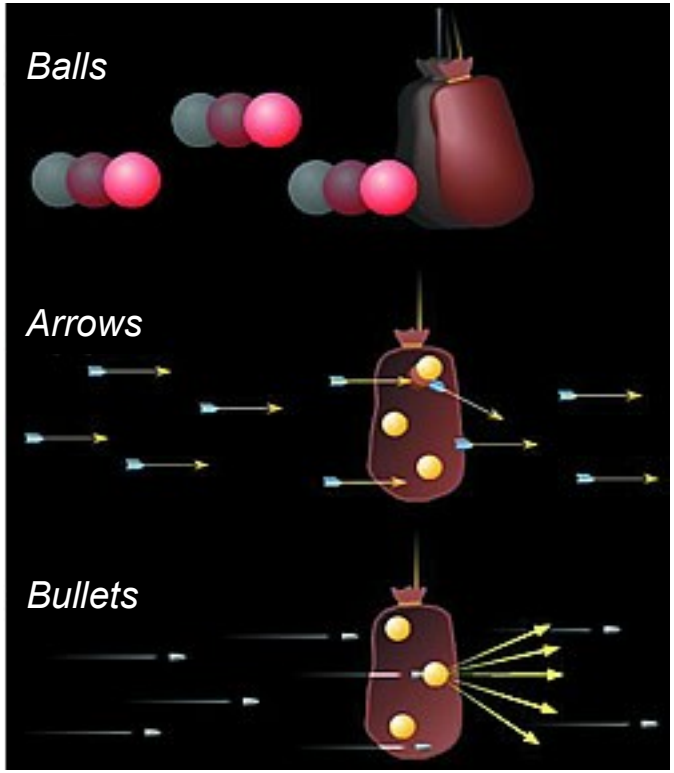
- Strong force (*Gluons*) discovered at DESY

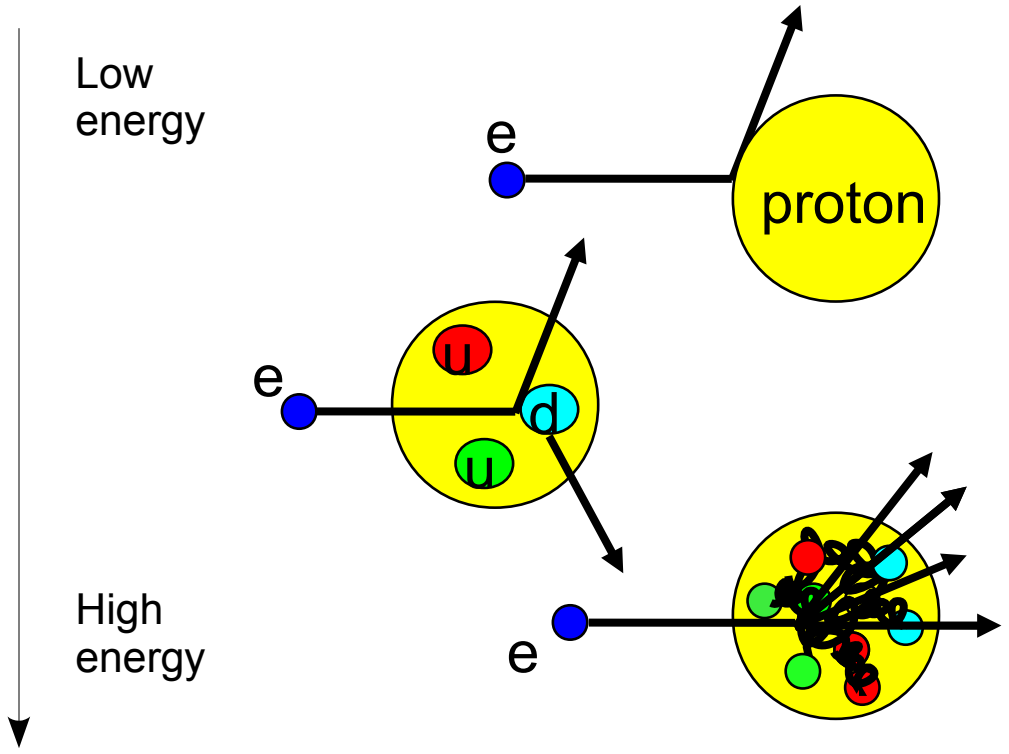


- Electromagnetism (*Photon*)

How do we know all this?

- Investigation of the structure of known particles in scattering experiments
  - High energy = High resolution

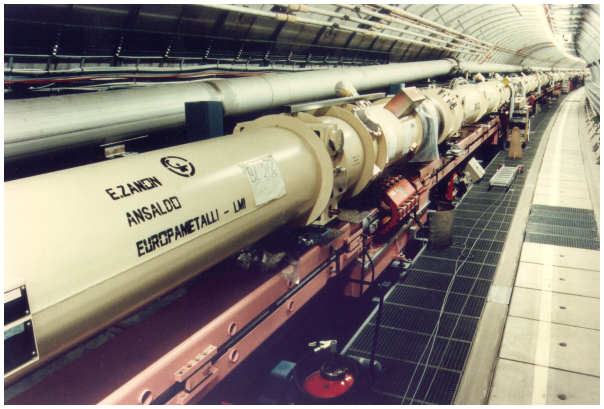


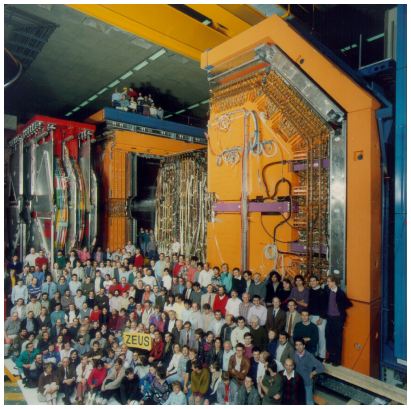


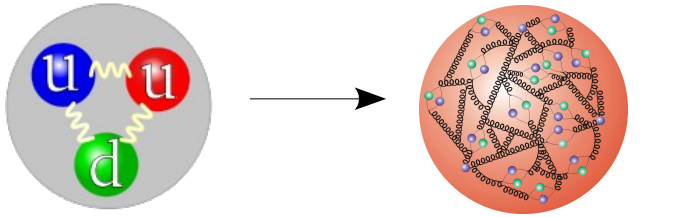
- Creation of new, heavy particles according to $E=mc^2$
  - Light, known particles with a large kinetic energy ⟶ new, heavier particles

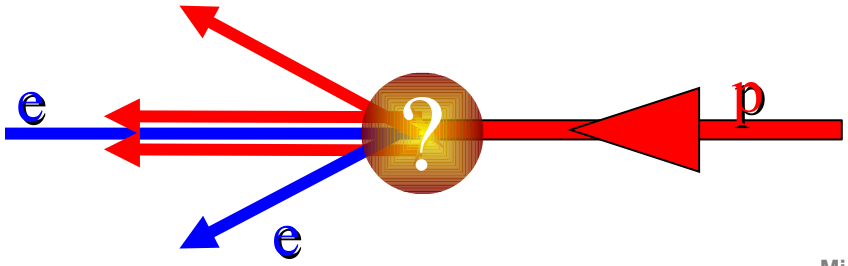
Hadron-Elektron-Ring-Anlage (HERA)

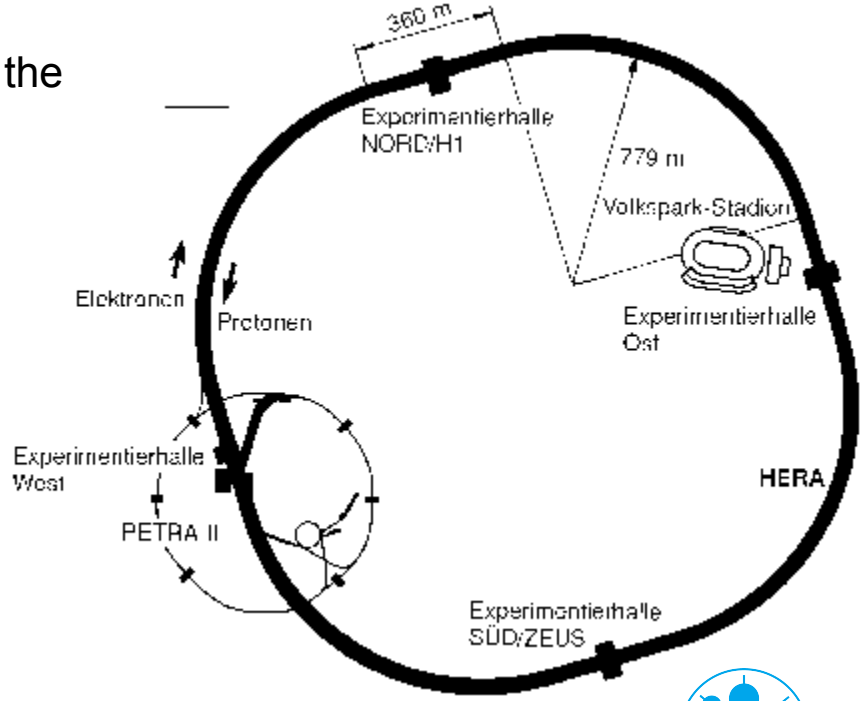
- Electron-proton storage ring
  - Start of construction: 1984
  - Circumference: 6,3 km
  - Running period: 1992 – 2007
  - Data analysis until 2014
  - Unique particle accelerator of this kind
  - Essential contribution to the investigation of the proton structure





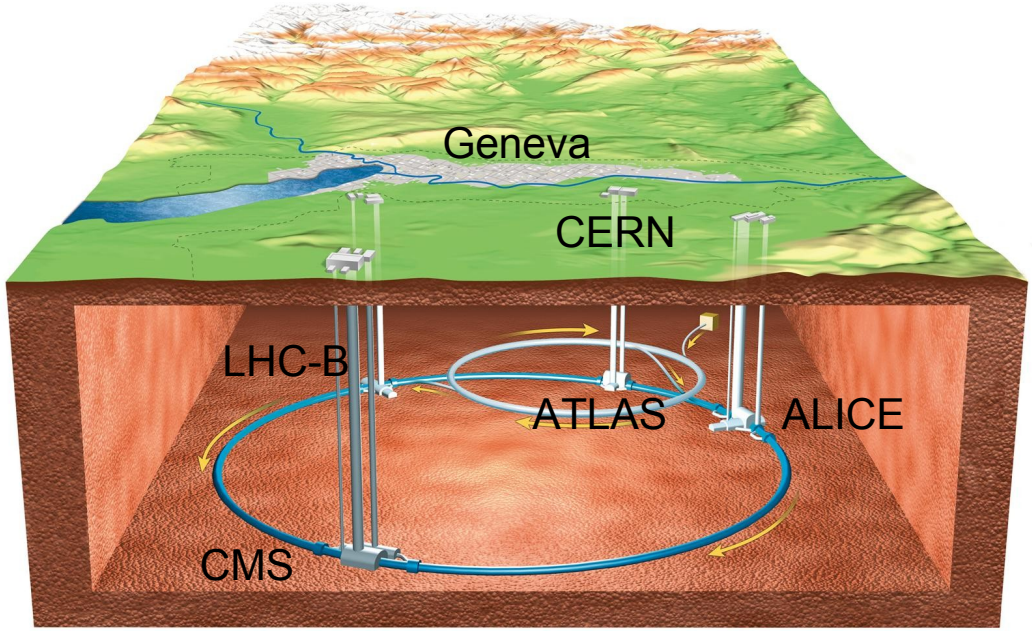




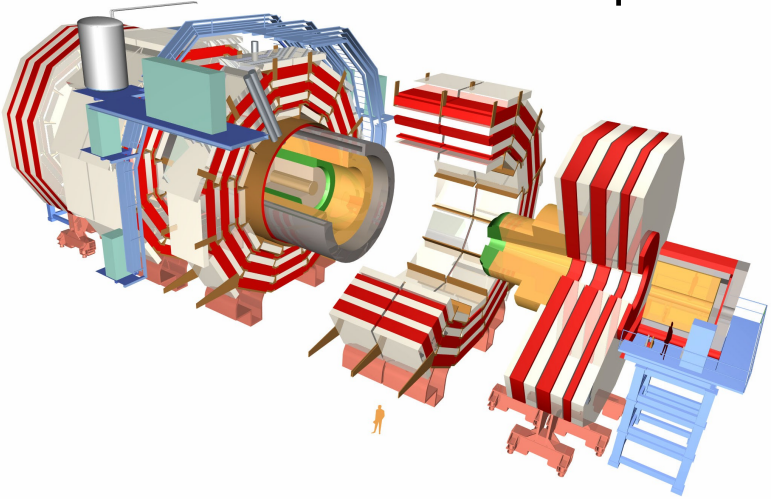


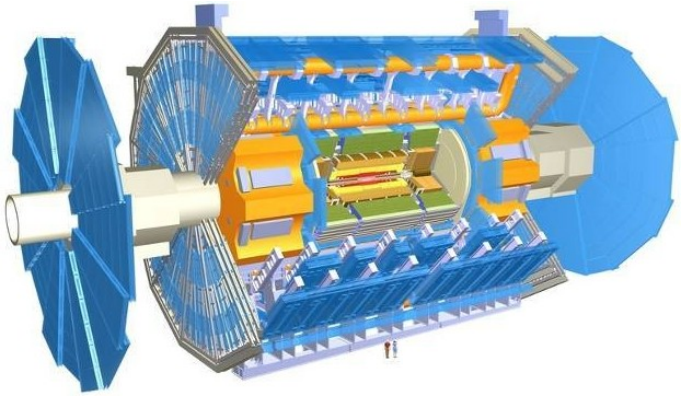
Large Hadron Collider (LHC)

- Proton-proton storage ring
  - Location: CERN close to Geneva
  - Circumference: 27 km
  - Highest energetic accelerator in the world
  - Start of the measurements: 2009



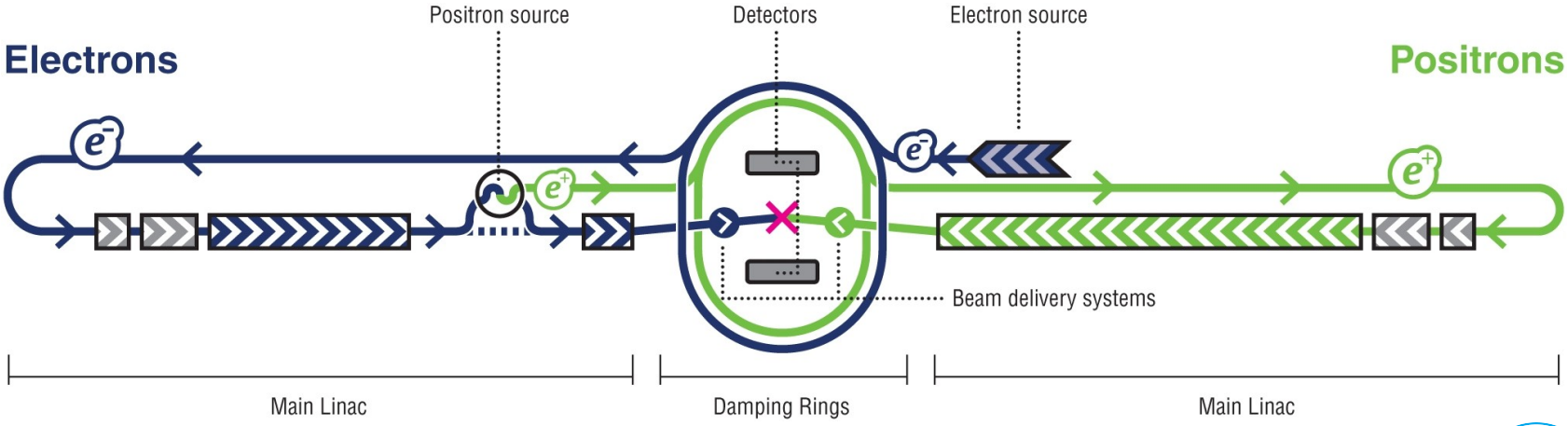
- Objectives:
  - Discovery of the Higgs particle
  - Discovery of additional new particles beyond the standard model of particle physics
- DESY is involved in the particle detectors CMS and ATLAS





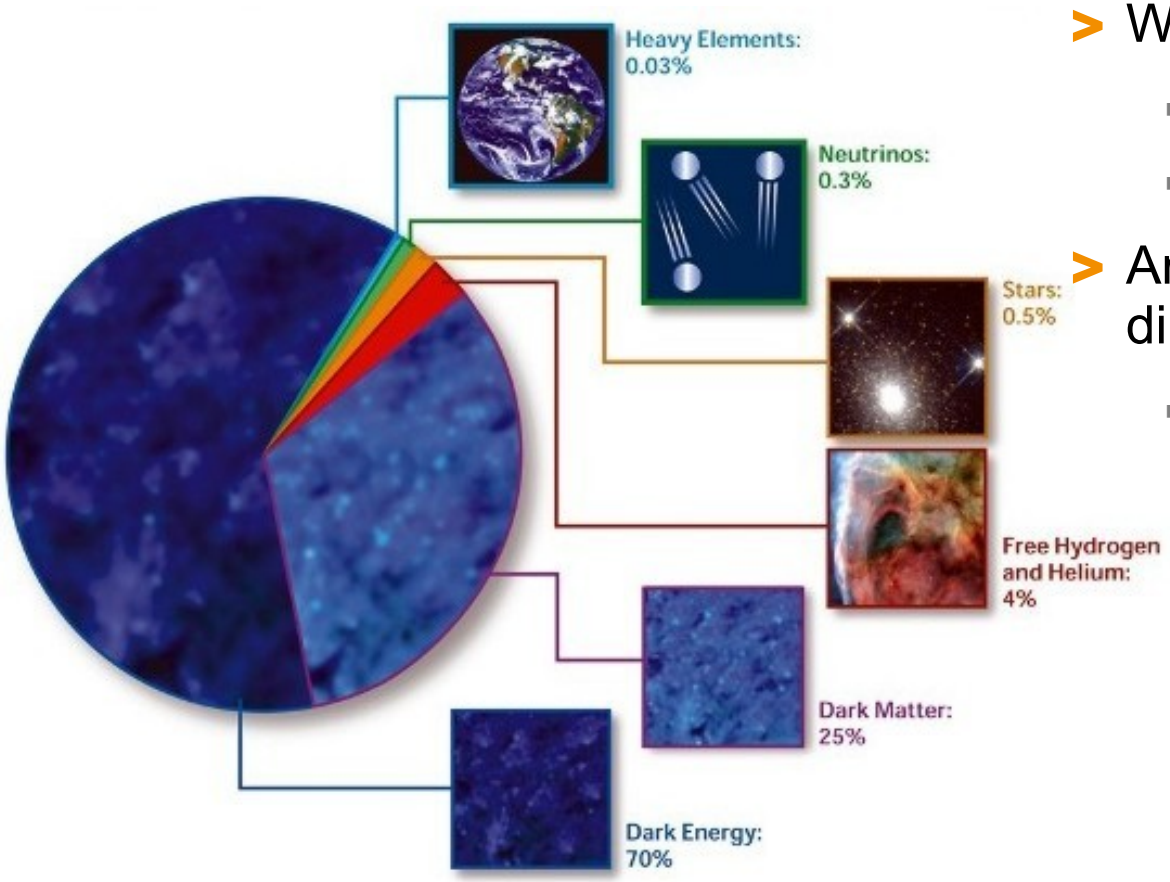
The Future: International Linear Collider (ILC)

- Electron-positron linear accelerator
  - In planning stage, decision on construction and location by 2012
  - Length: More than 30 km
- Objectives:
  - Precision measurements of the new physics discovered at the LHC
- Acceleration technology developed at DESY (FLASH, European XFEL)
- DESY is also involved in the development of the particle detectors

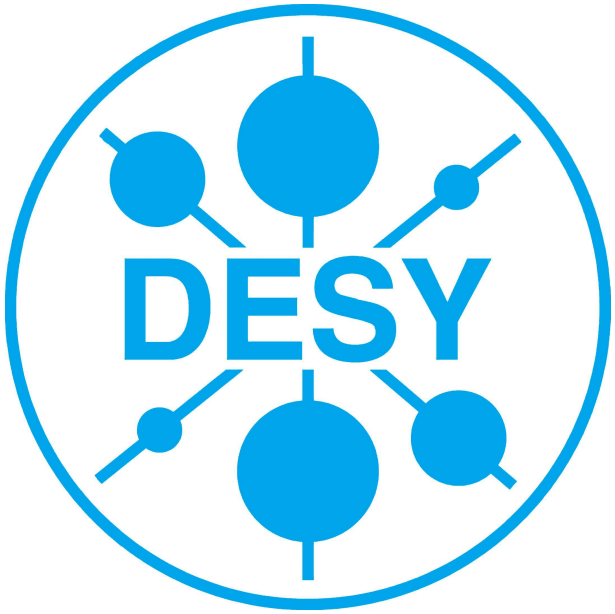


Further Open Questions ...

- What is the origin and the fate of the universe?
  - Why is the universe made of matter and not of antimatter?
  - What is the dark energy?



- What is the dark matter?
  - A new elementary particle?
  - Or several?
- Are there additional dimensions of space-time?
  - String theory?



Have fun at the guided tour!