Elementary particle physics tries to unravel the smallest structures in the universe

micro world

Roses

10^9 m
0.001 km
1 m
Particle physics and cosmology

Understanding of elementary particle physics is a key prerequisite for understanding of the very early universe.

The higher the energy, the nearer we approach big bang.

Now we are at about 0, 000 000 000 001 seconds.
Particle physics experiments world-wide – but concentrated

- Fermilab
- Cornell
- DESY
- KEK
- Brookhaven
- SLAC
- CERN

Deutsches Elektronen-Synchrotron
Hadron-Elektron Ring-Anlage
LEP / LHC – Collider at CERN
LHC:
Huge energies .... huge detectors....
Progress in particle physics
Smaller structures $\leftrightarrow$ higher energies (Heisenberg)
larger experimental setups
extremely demanding technology
high costs / long lasting projects
large groups (LHC expts.: >2000 physicists)

international collaboration
no hierarchical structures
communication in huge groups
(may become a problem)
efficiency due to extreme motivation and enthousiasm

Spin-offs: more than just the Teflon pan

CERN Technology Transfer
ACCELERATORS
ADMINISTRATIVE DATABASE
CONTROLS
CRYOGENICS
DATABASES
ELECTRICAL ENGINEERING
ELECTRONICS - ELECTRONIC SYSTEMS
ELECTRONICS - MICROELECTRONICS
ELECTRONICS - OPTOELECTRONICS
INFORMATION TECHNOLOGY
INSTRUMENTATION - MACHINE
INSTRUMENTATION - PARTICLE DETECTORS
MAGNETS
MATERIALS TECHNOLOGY
MEchanical engineering
POWER SUPPLIES
VACUUM TECHNOLOGY
Some spin-offs.....

Hadron therapy for otherwise untreatable tumors

Positron-Emission-Tomography (PET)

Medical Imaging

Free Electron Laser

The World Wide Web

Grid-Computing

NeuroBayes - Neuronal Bayesian statistics for economy

Accelerators

<table>
<thead>
<tr>
<th>Area</th>
<th>Accelerator type</th>
<th>number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear and particle physics</td>
<td>High energy accelerators</td>
<td>112</td>
</tr>
<tr>
<td>Biomedical applications</td>
<td>Radio therapy</td>
<td>&gt; 4000</td>
</tr>
<tr>
<td></td>
<td>Biomedical research</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Radio-isotope production</td>
<td>400</td>
</tr>
<tr>
<td>Industrial accelerators</td>
<td>Electron accelerators</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Ion implantation</td>
<td>&gt; 2000</td>
</tr>
<tr>
<td></td>
<td>Surface treatment</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Synchrotron sources</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>~10000</td>
</tr>
</tbody>
</table>

(numbers from 2004)
**Hadron Therapy**

initiated at CERN by Prof. Ugo Amaldi

Normal radiation therapy destroys not only the tumor but also tissue in front and behind.

Low energy hadron therapy can also localise destroying energy in depth (Bragg peak).

---

**Tumor therapy by protons and light ions**

With light ions radiation dose can be steered such that only tumor is destroyed without hurting healthy tissue.
Positron-Emission-Tomography (PET)

\[ p^+ \rightarrow n + e^+ + \nu_e \]

Positron emitters (tracers) are created at particle accelerators.

PET principle
Silicon pixel detectors can be used for Medical imaging. Radiation can be reduced by a factor 10.
From synchrotron radiation to Free Electron Laser

- TESLA, Free-Elektronen-Laser
- Synchrotronstrahlungsquellen der
  - 1. Generation
  - 2. Generation
  - 3. Generation

FEL for Biology

- X-ray-FEL: 0.1 nm laser
- Movies of chemical reactions
- Structural analysis with atomic resolution

Diffraction at single molecules
Spin-Offs in Information Technology

Grid Computing commercial: IBM, SUN, Gridsystems, ...

The World Wide Web

Development at CERN 1989/90 (http protocol) by Tim Barners-Lee

Technical problem:
Efficient communication in large international collaborations

Within 10 years:
spread world wide...
Today almost every household is "online"
The World Wide Web

Hyperlinks:
Context sensitive addressing

Lessons:
- Excellent research requires new methods and products which can be applied to other areas.
- Universities and research centers are important developers and multiplicators of new technology.
Das Internet
Das Internet
Das Internet
The future of the internet – the Grid

Future project LHC at CERN
Start 2007
4 huge detectors
about 2000 physicists per detector

An LHC event (simulation)
Data rates

40 MHz x 25 MB = 1 PB/sec = 1000 TB/sec equivalent)

Level 1 - Special Hardware
75 KHz (75 GB/sec)

Level 2 - Embedded Processors
5 KHz (5 GB/sec)

Level 3 - PC Farm (Linux)
100 Hz (100 MB/sec)

Data storage & offline analysis

1 PB per year have to be stored and made available for thousands of physicists worldwide

1 PetaByte = $10^{15}$ Byte

If 1 bit corresponds to 1 leaf,

1 PByte corresponds to all leaves on earth
1 PetaByte = $10^{15}$ Byte

1 PByte: about 1.5 million CDs
( = tower of 1.5 kilometer height)

More data than produced by total telecommunication worldwide

Online: per second
Offline: per year

Europe: 267 institutes, 4603 users
Rest of the world: 208 institutes, 1632 users
(numbers from 2004)
Grid Computing: Vision

Data storage and computing capacity...

...like electric power from the plug or water from the tap....

Grid Computing: Global Sharing of storage and CPU
1 PB per year and experiment

10100101011010
01101011101010
10100010101010
10010101100101
01110101001111

Reconstruct new quantities from raw data.

Don't throw away relevant information!
1 PB pro Jahr
und Experiment

highly optimised
algorithms

1 PB per year
and experiment

~ Mio.
CPU h

highly optimised
algorithms
1 PB per year and experiment

Highly optimised algorithms

10010100101000
01000101001100
10111111100101
00100011000000
Summer University Univ. Strasbourg Prof. Dr. Michael Feindt                       July 11, 2006

1 PB per year and experiment

highly optimised algorithms

highly optimised algorithms

Iterated reconstruction and selections, bases for many analyses

several TB
Tier 1 Computing Centre Karlsruhe

10% der Resourcen für den LHC

- PIII 1GHz procs
- 100 GB disks
- 100 GB tapes
Running a Job....

PC

JDL

Logging & Book-keeping

Resource Broker

Storage Element

Replica Location Service

Information Service

Job Submission Service

Compute Element

Input Sandbox

programme
data set

CPU, storage

Running a Job....
Running a Job....

Logging & Book-keeping

Job Submission Service

Resource Broker

Storage Element

Compute Element

Information Service

Compute Element

Replica Location Service

Running a Job....
Running a Job...

PC

JDL

Logging & Book-keeping

Resource Broker

Job Submission Service

Compute Element

Storage Element

Input Sandbox

Replica

Location

Service

Information

Service

Running a Job....
Running a Job....

- PC
- JDL
- Logging & Book-keeping
- Resource Broker
- Job Submission Service
- Compute Element
- Storage Element
- Information Service
- Replica Location Service
- Output Sandbox

Running a Job....

- PC
- JDL
- Logging & Book-keeping
- Resource Broker
- Job Submission Service
- Compute Element
- Storage Element
- Information Service
- Replica Location Service
- Output Sandbox
Running a Job...

Finding needles in the hay stack...

(+30 minimum bias events)

Reconstructed tracks with pt > 25 GeV

All charged tracks with pt > 2 GeV
Data analysis and statistical methods

- Optimised by world wide competition to extract as much as possible new insight from limited and expensive exp. data

Neural networks

Neural networks:
Self learning procedures, copied from nature

- Motor Cortex
- Parietal Cortex
- Frontal Lobe
- Temporal Lobe
- Brain Stem
- Occipital Lobe
- Cerebellum
Neural networks

The information (the knowledge, the expertise) is coded in the connections between the neurons.

Each neuron performs fuzzy decisions.

A neural network can learn from examples.

NeuroBayes® principle

**NeuroBayes® Teacher:**
Learning of complex relationships from existing data bases (often Monte Carlo simulations).

**NeuroBayes® Expert:**
Prognosis for unknown data.
How it works: training and application

- Historic or simulated data
  - Data set
  - a = ...
  - b = ...
  - c = ...
  - ... 
  - t = ...

- NeuroBayes® Teacher

- Expert system

- Expertise

- Actual (new real) data
  - Data set
  - a = ...
  - b = ...
  - c = ...
  - ... 
  - t = ?

- NeuroBayes® Expert

- Probability that hypothesis is correct (classification) or probability density for variable \( t \)

- \( f(t) \)

Some applications in high energy physics

**DELPHI (mainly predecessors of NeuroBayes)**
- Kaon, proton, electron id
- Optimisation of resolutions inclusive B– E, \( \phi \), \( \theta \), Q–value
- \( B^{**}, B_s^{**} \) enrichment
- B fragmentation function
- Limit on \( B_s \)-mixing
- \( B^0 \)-mixing
- B– F/B–asymmetry
- B–\( \rightarrow \) wrong sign charm

**CDF II: (work in Progress)**
- Electron ID, muon ID, kaon/proton ID
- Optimisation of resonance reconstruction (X, Y, \( B_s \), \( B_s^{**} \))
- Spin parity analysis, likelihood analyses
- B–Tagging for top, Higgs, etc.
- B–Flavour Tagging for mixing analyses (new combined tagging)
Physics Research Examples I

\[ \Phi \rightarrow K^+K^- \]

**Classification:**

Hadron Identification (DELPHI at CERN):

- Doubled signal strength at constant background level by neural network classification

- Original method: several 10 millions CHF cost
- NeuroBayes predecessor: Additional factor of 2 with very limited additional effort

---

Physics Research Examples III (DELPHI, CERN)

**Optimised reconstruction of real valued quantities:**

Extended regression

- Much improved resolution
- (narrow peak around \( \pm 0 \))
- By NeuroBayes-technology
**X(3872) analysis:**

- **Hard NeuroBayes cut:**
  Very clean $X(3872)$ signal

- **Soft NeuroBayes selection**

  background-like
  hardly loose any signal

  signal-like
History of NeuroBayes transfer

2000-2002 NeuroBayes®-specialisation for economy at the University of Karlsruhe, funded by German ministry for Education and Research
Oct. 2002: private company founded, first industrial projects
June 2003: removal into new office
199 qm IT-portal Karlsruhe
Exclusive rights for NeuroBayes®
Staff all physicists (almost all from HEP)

Customers (among others):
- BGV and VKB car insurances
- AXA health insurance
- Lupus Alpha Capital Management
- dm drogerie markt (drugstore chain)
- Otto Versand (mail order business)
- Thyssen Krupp (steel industry)

Direct competition I

Data-Mining-Cup 2005: Fraud recognition in internet trading

531 participants from 176 universities from 41 countries.

6 Karlsruhe students got Phi-T NeuroBayes® and support in lecture and computer lab:
They achieved the top positions 2, 3, 4, 5, 6, 7!

www.data-mining-cup.de
Direct competition II

Data-Mining-Cup 2006: Award ceremony just 2 weeks ago. Predict whether eBay auctions will result in higher than average prices.

579 participants from 177 universities from 42 countries.

11 Karlsruhe students got Phi-T NeuroBayes® and support in lecture and computer lab: They achieved the top positions 1, 2, 3, 4, 6, 7, 9, 10, 12, 16, 22!

www.data-mining-cup.de

Applications of NeuroBayes in Economy

> Medicine and Pharma research (not yet...)  
  e.g. effects and undesirable effects of drugs  
  early tumor recognition

> Banks  
  e.g. credit-scoring (Basel II), finance time series prediction, valuation of derivates, risk minimised trading strategies, client valuation

> Insurances  
  e.g. risk and cost prediction for individual clients, probability of contract cancellation, fraud recognition, justice in tariffs

> Trading chain stores:  
  turnover prognosis for individual articles/stores

Necessary prerequisite:  
Historic or simulated data must be available!
Near Future Turnaround Predictions for Chain Stores

1. Time series modelling
2. Correction and error estimate using NeuroBayes

Turnover prognosis for mail order business

Test at Germany's largest mail order business:
Predict season's turnover of all articles/colours/sizes/catalogues:
4 seasons for training, test on 2 following seasons

Surprise for customer (and also us):
Phi-T- prognoses mostly significantly better than estimates of (experienced) disponents. Optimal prognosis: NeuroBayes-prognosis which also takes into account the (unbiased) disponents' estimates as one input. (Subjective measures like fashionable, good-looking... not in database.)

Huge optimisation potential of many processes in the request/supply chain! Individual determination of uncertainty allows optimisation by NewsBoy-model (relation to Black Scholes)
The "unjustice" of insurance premiums

Ratio of the accident risk calculated using NeuroBayes® to premium paid (normalised to same total premium sum):

The majority of customers (with low risk) are paying too much.

Less than half of the customers (with larger risk) do not pay enough, some by far not enough. These are currently subsidised by the more careful customers.
Prediction of contract cancellation for an insurance

The prediction really holds:

Test on a new statistic year

Contract cancellations in a large financial institute

Real cancellation rate as function of cancellation rate predicted by NeuroBayes®

Very good performance within statistical errors
The <phi-t> mouse game:

or:

even your "free will" is predictable

//www.phi-t.de/mousegame

Particle Physics is an exciting field of basic research. Fundamental questions of space, time, matter and forces in the universe can only be answered with ambitious experiments which push technology to new limits.

There have been many spin-offs which have an impact on the general public. Also in the future methods and techniques of particle physics will find applications in other areas.
Only about 11 – 20% of physicists stay long term in physics research at universities and public research centers.

Other possibilities:
Industry Government
Insurances Finance
Software Business Consulting

But you stay a physicist for your whole life. And industry has noticed: Physicists are good! Analytic thinking, pragmatic problem solving, team work

Chances are good. More and more physicists make very good careers outside physics.

Hidden Physicists

Computing

Biology
Francis Crick, co-discoverer of the structure of DNA, was a physicist. Walter Gilbert invented gene-sequencing, shared the 1980 Nobel Prize in Chemistry. Rosalyn Yalow, Ph.D. in nuclear physics, shared the 1977 Nobel Prize in Physiology.

Invention
Physicist Chester F. Carlson invented the photocopier. In 1947 physicist Edwin Herbert Land invented Polaroid photography. Robert Noyce invented the integrated chip and was cofounder of Intel.

Music
Rock star Brian May of Queen graduated from Imperial College in physics and math. Physicist Robert Moog invented the synthesizer.

Government
Angela Merkel, Germany’s first woman chancellor, has a a doctorate in physics. Jimmy Carter, 39th US President, studied graduate physics at Union College.
Hidden Physicists

**Space Exploration**
Physicist **Sally Ride** was America's first woman astronaut.

**Acting/Directing**
Actress **Jane Mansfield** started out as a physics major, but switched to drama. Director **Brian De Palma** (*Mission Impossible, The Untouchables*) studied physics. Director **James Cameron** (*The Terminator, Alien, Titanic*) studied physics.

**Business**

**Writing**