Particle Physics at MPI Munich

ALEPH

STAR

Cresst

Magic

ATLAS

Muon-Cooling

Werner-Heisenberg-Institut
$\Delta x \Delta p_x \geq \hbar$
Theoretical Physics Division

Munich, August 17, 2004

Richard Nisius

http://mppmu.mpg.de/˜nisius

The organisation of the Max Planck Society

MAX-PLANCK-GESELLSCHAFT

- The Max Planck Society (MPG) is an independent, non-profit research organisation. The MPG supports research mainly at their own institutes, the MPIs.
- At present, the MPG has 80 research institutes, with more than 12.000 employees, together with about 9.100 doctoral students, post-doctoral students, research visitors and student trainees.
- The research topics are divided into three sections: These comprise the sections for Biology and Medicine, for Chemistry, Physics and Technics, and for Humanities.
- Five institutes of the CPT section are located in the Munich area. Namely the MPIs for Astrophysics, Extraterrestrial Physics, Plasma Physics, and Quantum Optics at Garching, und at Munich the MPI for Physics the (Werner-Heisenberg-Institute).

MPI Munich - mission and history

The mission

— At MPI we do basic research in elementrary particle and astroparticle physics, both from a theoretical as well as an experimental perspective.

The history

1917 Founded as Kaiser-Wilhelm Institute for Physics at Berlin.
The head of the directorate was Albert Einstein.

1946 Re-founded as MPI for Physics at Göttingen.
The director was Werner Heisenberg.

1958 Move from Göttingen to the present location at Munich.

1960 Spin-off of the intitute for Plasma Physics (IPP) at Garching.

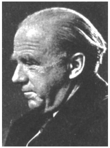
1991 Spin-off of the intitutes for Extraterrestrial Physics (MPE) and for Astrophysics (MPA) at Garching.

Some former colleagues

— Peter Debeye, Albert Einstein, Werner Heisenberg, Max von Laue, Gerhart Lüders, Carl Friedrich von Weizsäcker, . . .

MPI Munich - personnel and research

Todays colleagues



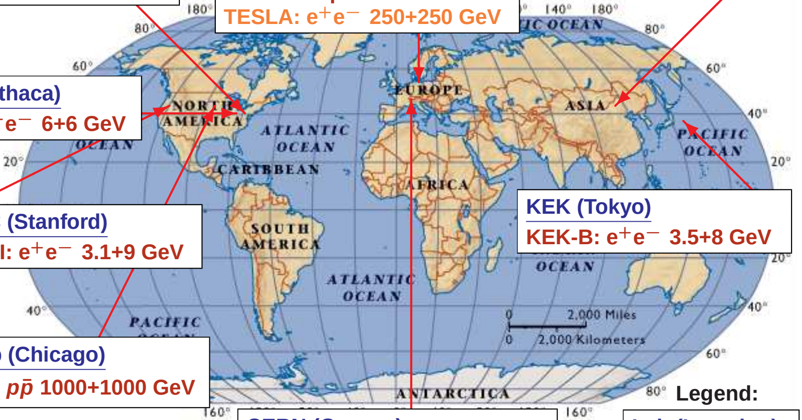
- The MPI has about 210 staff, comprising 65 researchers, 115 people for technical services and 30 people for administration.
- In addition the MPI has about 30 visiting scientist.
- At present there are 35 doctoral students, 10 diploma students and 12 workshop trainees.

The main research topics

- The research topics comprise theoretical work in particle- and astroparticle physics. Experiments are conducted at various accelerators, i.e. at LEP (ALEPH, OPAL), at HERA (H1, ZEUS), at LHC (ATLAS) and at RHIC (STAR). The MPI also has major involvements in the non-accelerator experiments MAGIC and CREST.
- In addition, together with the MPE, the MPI runs a semiconductor laboratory for development of novel detector techniques at Munich-Neuperlach.

The MPI has as a broad spectrum of research in theoretical and experimental physics.

Excerpt of the map of accelerators



BNL (Brookhaven)
RHIC: AA 100+100 GeV/N

DESY (Hamburg)
HERA: ep 30+920 GeV
TESLA: e^+e^- 250+250 GeV

IHEP (Peking)
BEBC: e^+e^- 6+6 GeV

Cornell (Ithaca)
CESR: e^+e^- 6+6 GeV

SLAC (Stanford)
PEP-II: e^+e^- 3.1+9 GeV

KEK (Tokyo)
KEK-B: e^+e^- 3.5+8 GeV

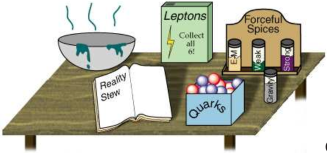
FermiLab (Chicago)
Tevatron: $p\bar{p}$ 1000+1000 GeV

CERN (Geneva)
LEP: e^+e^- 104.5+104.5 GeV
LHC: pp 7000+7000 GeV

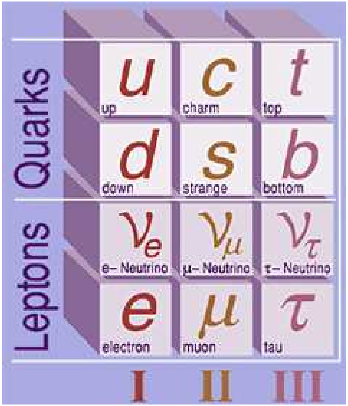
Legend:
Lab (Location)
Realised
Planned

The present picture

Our present understanding



of Natur's recipe is:



— There are three families of leptons and quarks.

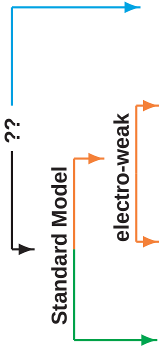
— They are fermions (Spin = 1/2), and stable matter is made only from the first family, $p = uud$ und $n = udd$.

— Each particle has its anti-particle with opposite charges, but otherwise identical features.

— The masses are extremely different and nobody knows why. The fermion masses reach from less than 1 eV for the ν_e up to 175 GeV (mass of a Gold atom) for the heaviest quark, the top quark.

— The interactions of fermions are mediated by the exchange of bosons (Spin = 1,2).

The fundamental interactions



Inter-action	Example	Boson	mass [GeV]	electric charge [e]	strength (range)
gravity	earth's gravi-tational force	graviton G ?	0	0	10^{-38} (∞)
weak	nucleus decay	Z $W^{\pm}$	91.2 80.4	0 $\pm$1	10^{-5} (10^{-3} fm)
electro-magnetic	Coulomb-force	Photon γ	0	0	10^{-2} (∞)
strong	quark con-finement	gluon g	0	0	1 (1 fm)

The proton and its constituents

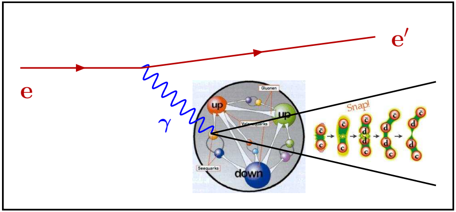
— The 

is made from quasi-free *uud* valence quarks and the see quarks.

— The quarks are bound by 

This bindung results in the  confinement.

— In total this gives a complex structure from valence- und see quarks.



— By scattering of high energetic electrons off protons the quarks can be freed.

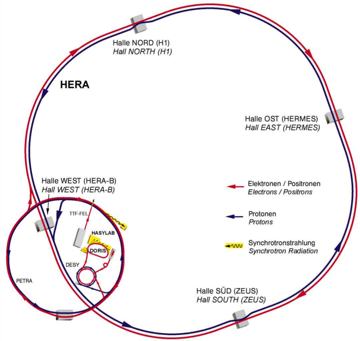
— The rate and kinematical properties of the events reveal the information about the distribution of quarks in the proton.

The complex structure of the proton is investigated in electron-proton scattering.

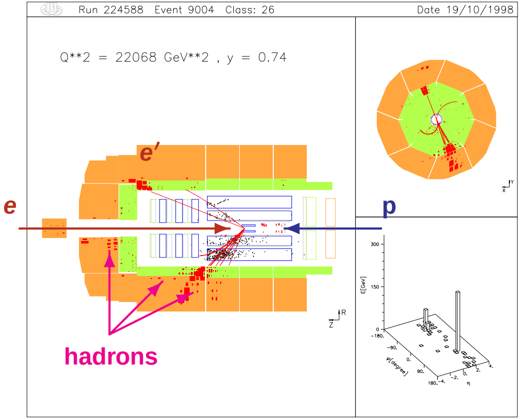
HERA and an H1 event

The HERA accelerator

— $E(e^+/e^-) = 27.6$ GeV
— $E(p) = 920$ GeV
— $\sqrt{s_{ep}} \approx 320$ GeV



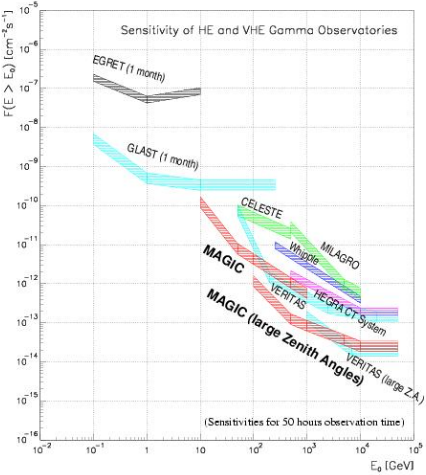
A deep-inelastic scattering event from H1



The H1 and Zeus experiments take data since 1989.

MAGIC - what are we looking at

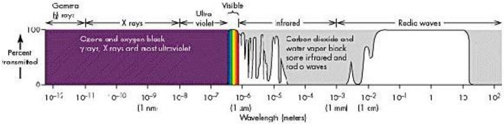
— The **M**ajor **A**tmospheric **G**amma-ray **I**maging **C**herenkov telescope investigates showers in the earth's atmosphere by making use of the Cherenkov radiation.



— The showers are caused by high energetic particles of the cosmic radiation, mainly by light hadrons and by photons.

— Cherenkov radiation occurs when particles in matter move with velocities larger than the local speed of light.

— The effect is analogous to the sonic boom.

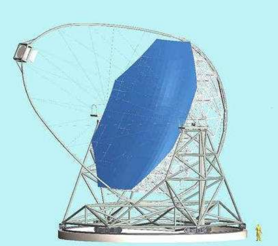


— The earth's atmosphere is very transparent to Cherenkov radiation.

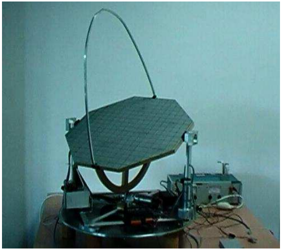
One needs dark nights and large mirrors.

MAGIC - the telescope at the Roque de los Muchachos (La Palma)

From the technical drawing . . .



. . . via the small scale model . . .



. . . and the final telescope . . .

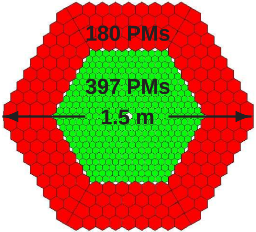
$\varnothing = 17$ m, $A = 240\ m^2$

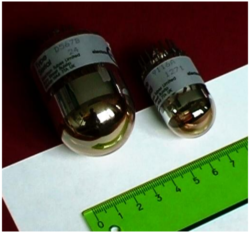
. . . to the inauguration.

MAGIC takes data since summer 2003.

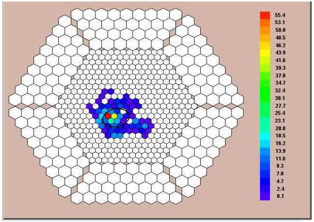
Magic - the camera and first events

— the camera layout, the photomultiplier (PM), and the final camera in its support frame.

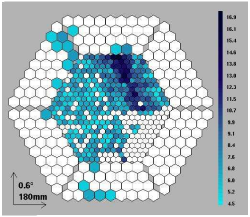




— A simulated event,



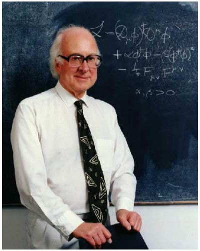
and the first cosmic muon.



Magic already provided the first physics results.

A solution - the Higgs-Boson

The father of the thought



Peter Higgs

The speculation (1965)

- Fundamental particles, fermions as well as bosons, are massless per se.
- Masses are generated by interaction with a background field, the Higgs field. The stronger the Higgs coupling, the larger the particle mass.

The consequence

- There has to be a scalar Higgs-Boson as an excitation of the Higgs field.

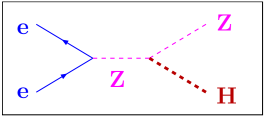
The predictions of the Standard Model

- The couplings of the Higgs-Boson to all elementary particles are fixed.
- Given a Higgs mass, the decay channels and decay rates of the Higgs-Boson are fixed.

The Higgs-Boson mass is not predicted and has to be measured by experiments.

Search for Higgs-Boson at LEP

— The main production mechanism is the Higgs-Strahlung:

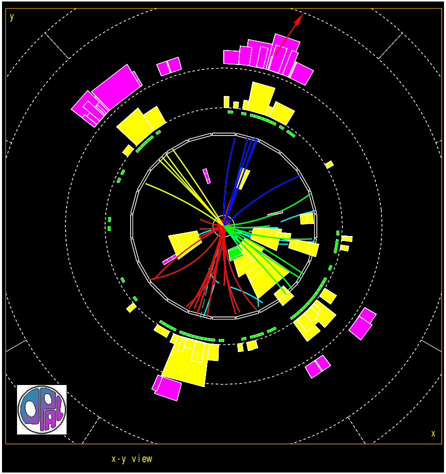


— The discovery potential of LEP2 is about $M_H < 115$ GeV.

— In total, one expects about 8 signal- and 16 background events, when combining the 4 LEP experiments.

— Only 17 candidates have been found, with: A / D / L / O = 8 / 3 / 4 / 2.

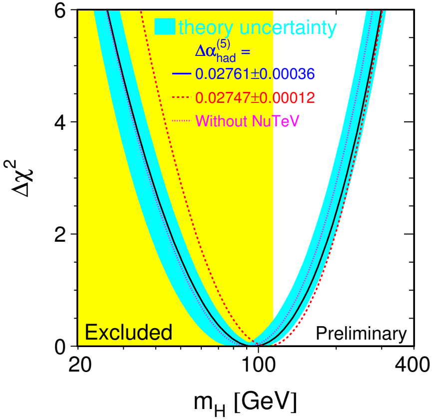
$Z \to \bar{q}\, q, \quad H \to b\, \bar{b}$



The final result is negative and we need to continue the search for the Higgs-Boson.

The Higgs-Boson within the Standard Model

The Standard Model Fit

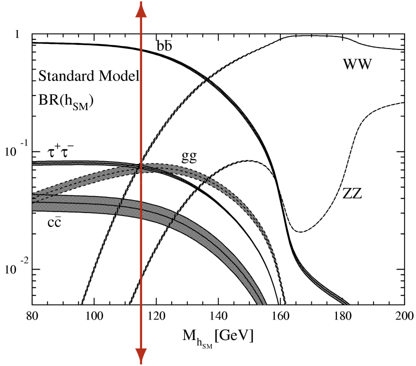


The best value: $M_H = 96^{+60}_{-38}$ GeV.

The limit: $M_H < 219$ GeV with 95% CL.

The branching ratios

$M_H = 115$ GeV

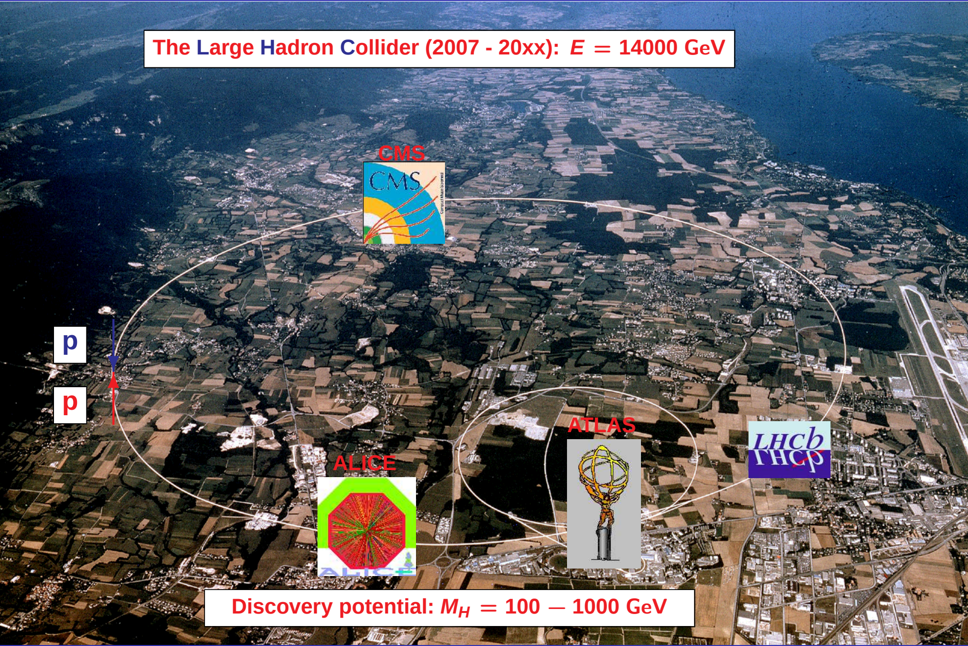


$74\%(H \rightarrow b\bar{b})$

$7\%(H \rightarrow \tau^+\tau^-, W^+W^-, gg)$

$4\%(H \rightarrow c\bar{c})$

The Large Hadron Collider (2007 - 20xx): $E = 14000$ GeV



Discovery potential: $M_H = 100 - 1000$ GeV

The LHC - a proton-proton accelerator (2007^{++})

Alice

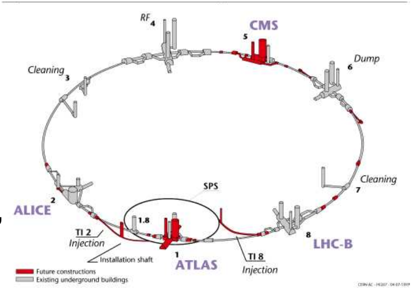
Heavy Ions, ...

LHC-B

Matter $\leftrightarrow$ Antimatter, ...

ATLAS / CMS

Higgs production, ...



Technical details

$L = 26.7$ km

$E_p = 7$ TeV

$N_p = 1.1 \cdot 10^{11}$/ beam

$t_{BC} = 25$ ns

$N_{ev} = 25/BC$

Lumi expectations

10 fb^{-1}/ y at start

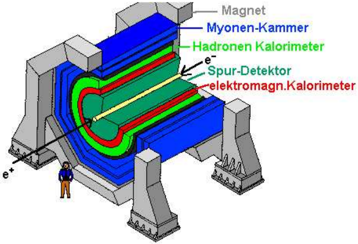
100 fb^{-1}/ y nominal

The Heart of the LHC - the superconducting magnets

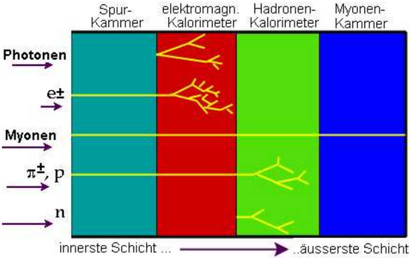
length	15 m
weight	23.8 t
B-field	8.3 T
temperature	1.9 K
current	12000 A
energy	7.1 MJ

A generic detector - general layout

With the onion-skin-principle...



...we get them (almost) all



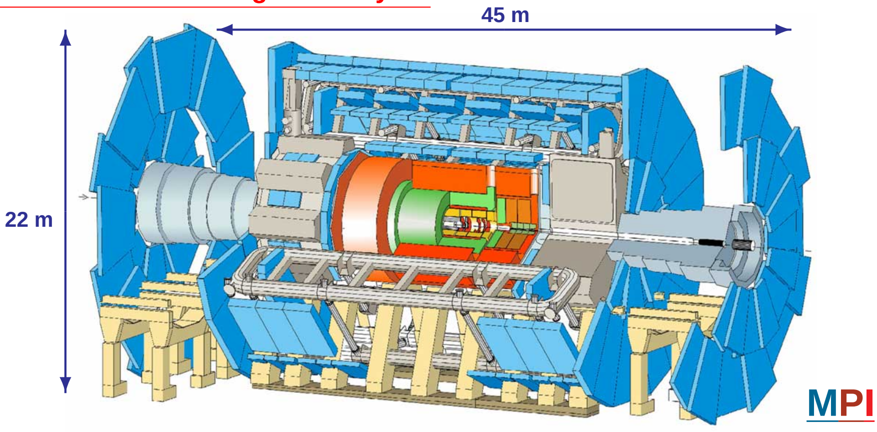
$\vec{x}, \vec{v}, \vec{p}$ $\vec{x}, E$ $\vec{x}, E$ $\vec{x}, \vec{p}$

Some basic decisions to be made

- Where to put the coil for the central magnetic field.
- How to minimise the dead material in front of the electromagnetic calorimeter

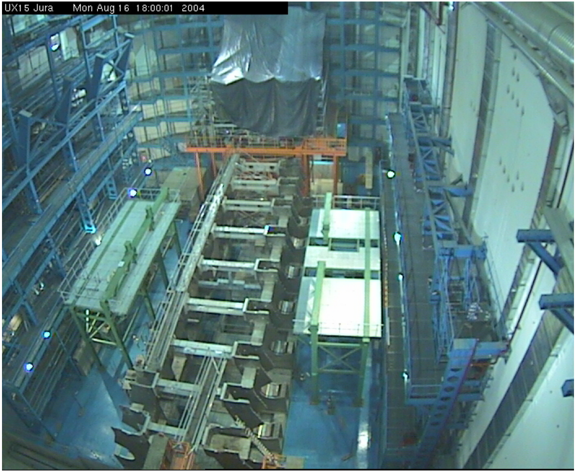
The answers to these questions result in different detectors.

The ATLAS detector - general layout



- Silicon tracker (Pixel, SCT)
- Transition radiation tracker (Xe)
- Central solenoid ($B = 2$ T)
- Electromagnetic calorimeter (Pb, LAr, 25 X_0)
- Hadronic tile calorimeter (Fe, Szi, 11 λ)
- Hadronic end cap (Cu, LAr, 11 λ)
- Forward calorimeter (Cu/W, LAr, 11 λ)
- Air toroid magnet ($B = 4$ T)
- Muon spectrometer (MDT/CSC, RPC/TGC)

Installation work for ATLAS



29.05.2003

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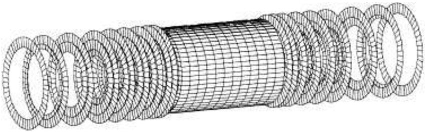
17.08.2004

Please come back, and visit this page occasionally until spring 2007.

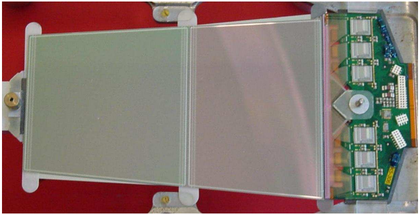
The ATLAS SemiConductor Tracker SCT

The general layout



— The barrel has 4 layers.
— The end caps have 9 discs each.
— In total there are 4088 modules, 2112 in the barrel and 1976 in the end caps.
— The spacial resolution is 16 μm ($\perp$) and 580 μm ($||$) to the strips.

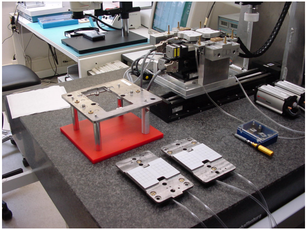
An SCT module



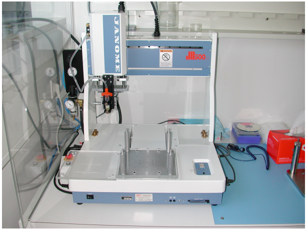
— A wafer has 768 single-sided p-in-n strips with 50-90 μm strip pitch.
— SCT uses binary read-out on a double-sided hybrid with 6 chips per side.
— Precise mounting is a achieved with location pads with 20 μm tolerance.

The equipment for module production

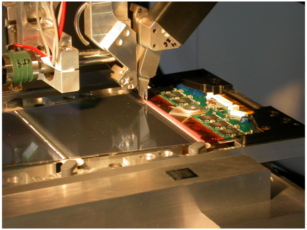
The robot for alignment



The robot for glue dispensing



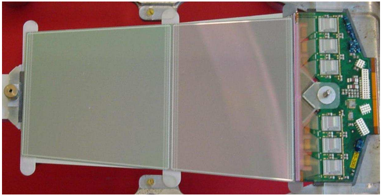
The bonding machine



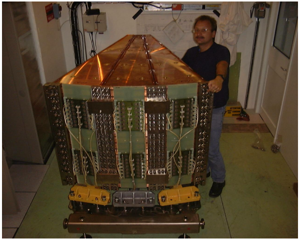
A final module built at MPI

16 cm

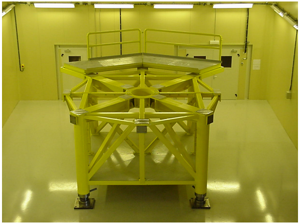
8 cm

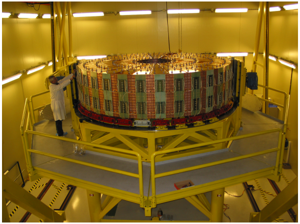


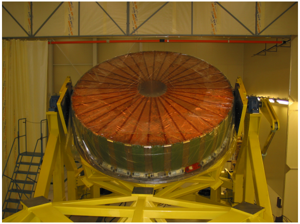
The hadronic endcap calorimeter HEC



- The absorption of the hadronic showers is achieved by copper plates with 25 mm thickness. The sensitive material is liquid Argon.
- AT MPI 27 modules have been build and tested.
- A wheel is made from 32 modules.
- In total there are 4 wheels. Each wheel has a radius of 2.1 m and a total weight of 67 t.

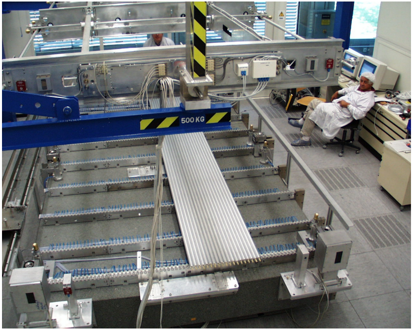






The mounting of modules to wheels is very delicate work.

Construction of an MDT chamber



Many things have to be done

— Mount 432 tubes of 3.8 m length, with a precision of 20 μm (thickness of a hair).

— Mount 1728 (tight!) gas connection.

— The weight of a chamber is about 350 kg.

Very precise tools are needed to properly do the job.

Mass production of chambers

There are very many chambers

- For ATLAS one needs 1200 MDT chambers produced at 13 institutes.
- At MPI 88 chambers are being build.
- This means 38016 tubes and 152064 gas-tight connections.

A complex logistics is needed

- The chambers are being tested with cosmic muons.
- They are stored for several years.
- The transport has to be secure.

The production time is about 6 years.

Conclusions

1. The MPG is one of the main columns in the field of basic research in Germany. The research of the MPG is conducted by the MPIs.
2. The MPI Munich has a broad spectrum of basic research in experimental as well as theoretical particle and astroparticle physics. Some examples of which have been presented.
3. The MAGIC telescope will accumulate data on high energetic photons of the cosmic radiation with unprecedented statistics.
4. The MPI makes large contributions to the construction and commissioning of three subdetector components of ATLAS.
5. It is very likely that we will uncover the mechanism for the generation of particle masses, by exploring the rich potential of the ATLAS experiment at the upcoming LHC accelerator at CERN.

I thank you for your attention and wish you a nice Sommer-Akademie.