Fixed Target Experiments

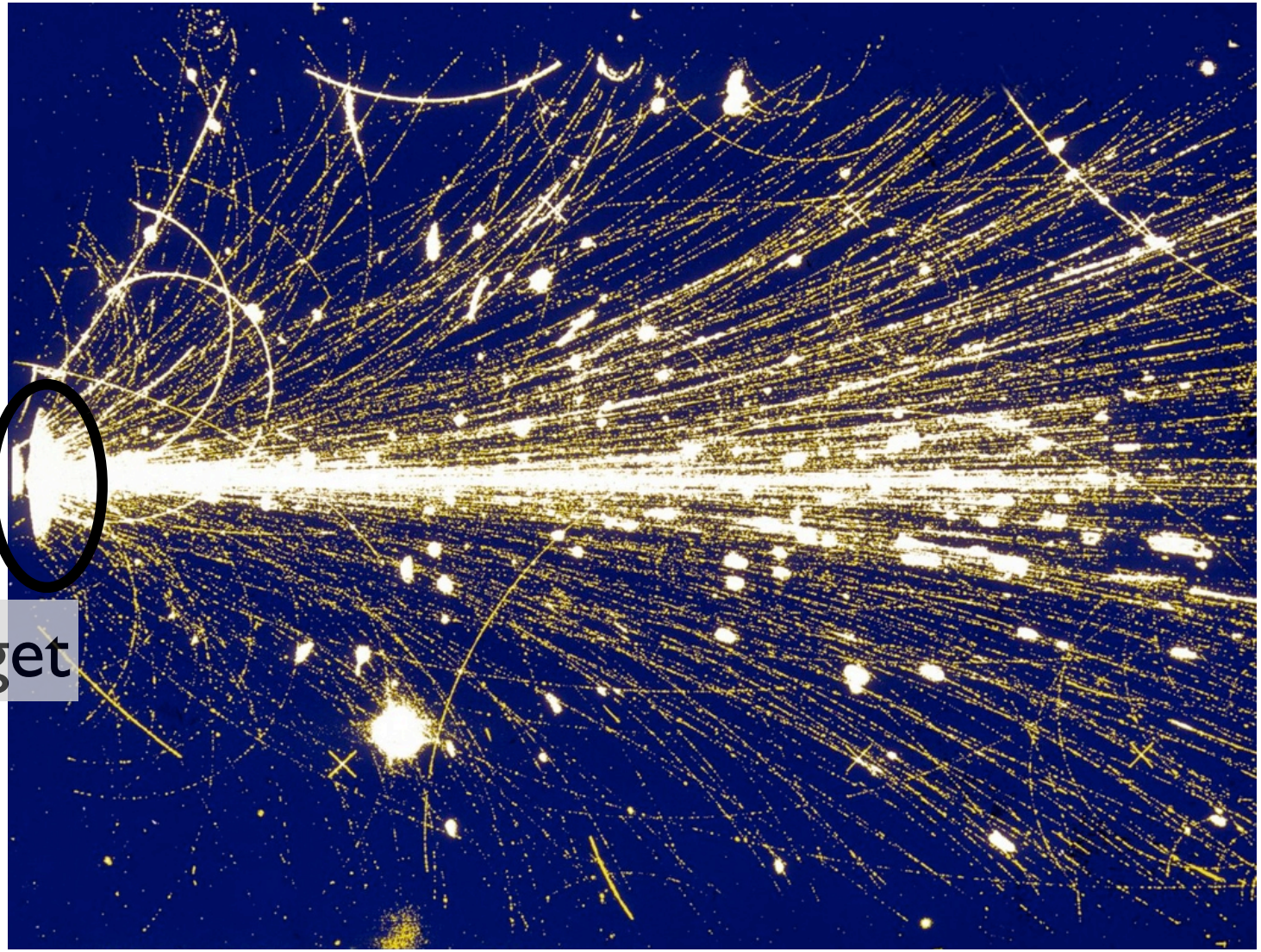
KET Jahrestreffen Bad Honnef, 23.11.2013

Christoph Rembser

Fixed target Experiments:
Physics experiments which use a secondary beams

primary beam e.g. protons

target



electrons, muons, pions, antiprotons, kaons, neutrinos...

Picture: a collision of a sulphur ion onto a gold target, recorded by the NA35 experiment at the SPS in 1991

Non-collider experiments vital part of physics landscape

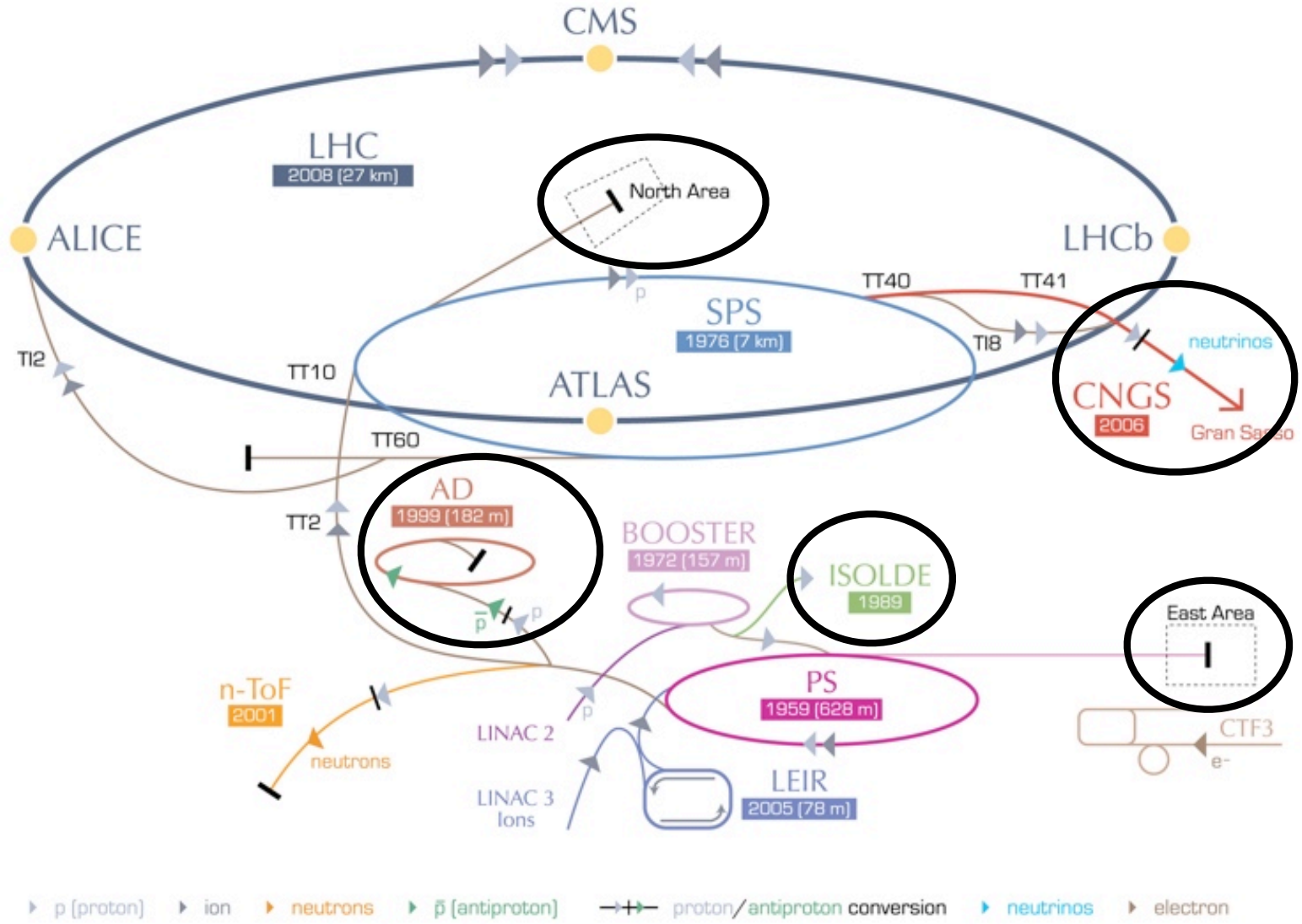
- Exploration and understanding of
  - ➡ of novel phenomena
  - ➡ using high statistics
  - ➡ and investigating rare processes
- Active option in front-line physics: factories for e.g.
  - ➡ τ/Charm, K, antiproton, anti-Hydrogen, different neutrino species

Covered in this talk:

The European Strategy for Particle Physics - Update 2013:

h. Experiments studying quark flavour physics, investigating dipole moments, searching for charged-lepton flavour violation and performing other precision measurements at lower energies, such as those with neutrons, muons and antiprotons, may give access to higher energy scales than direct particle production or put fundamental symmetries to the test. They can be based in national laboratories, with a moderate cost and smaller collaborations. Experiments in Europe with unique reach should be supported, as well as participation in experiments in other regions of the world.

Fixed target experiments at the CERN accelerators

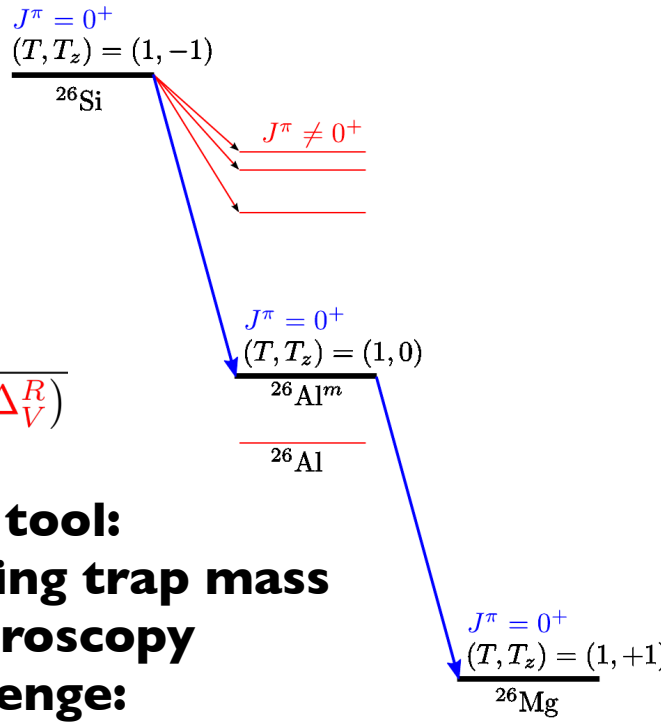


...there are more opportunities for FT experiments in the world.

Testing the SM at ISOLDE, an example

ISOLDE (Isotope mass Separator On-Line facility): radioactive nuclides are produced via spallation, fission, fragmentation reactions in a target, irradiated with a proton beam from the PSB at an energy of 1.4 GeV and an intensity >2 microA. Energy of 3.5MeV/ nucleon. Currently upgraded to HIE-ISOLDE, reaching energies up to 5.5 MeV/nucleon, start 2015.

- Example: Test of the unitarity of the CKM quark mixing matrix via **Measurements of Q values of Superallowed beta emitters**
  (Decays of nuclear $0^+ \rightarrow 0^+$ states)
  - ➡ Q_{EC} value: m_{parent} - $m_{daughter}$
  - ➡ Characterised with an ft value
    (f stat. rate function; (f Q_{EC}^5), t partial half-life $t_{1/2}$/b)
  - ➡ corrected value: $\mathcal{F}t = ft\,(1+\delta'_R)\,(1+\delta_{NS}-\delta_C) = \dfrac{K}{2G_V^2\,(1+\Delta_V^R)}$



$$V_{ud} = \frac{K}{2G_F^2\,(1+\Delta_R^V)\,\overline{\mathcal{F}t}}$$

currently 13 transitions contribute

Main tool:
Penning trap mass spectroscopy
Challenge:
need Q-values at 100 eV level

Tests of CKM unitarity; SUSY

Check unitarity via first row elements:

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1 + \Delta$$

V_{us} and V_{ub} from particle physics data (K and B meson decays)

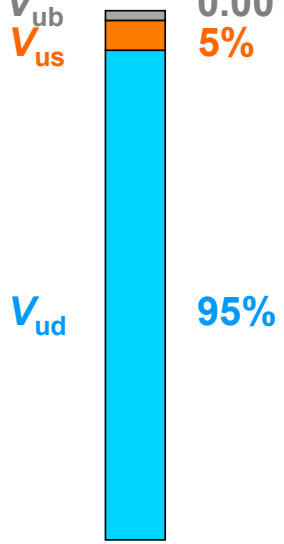
Present status:

V_{ud} (nuclear β-decay) = 0.97425(22)
V_{us} (kaon-decay) = 0.22521(94)
V_{ub} (B meson decay) = 0.0037(5)

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9999(6)$$

Towner&Hardy, Rep. Prog. Phys. 73 (2010) 046301

Unitarity contribution:



Significant progress in the precision of the unitarity test of the Cabibbo-Kobayashi- Maskawa quark-mixing matrix.

Info taken from and for details see:
Tommi Eronen (MPI für Kernphysik, Heidelberg, Germany): Precision mass measurements for fundamental studies and Klaus Blaum (MPI für Kernphysik, Heidelberg, Germany) privat communications

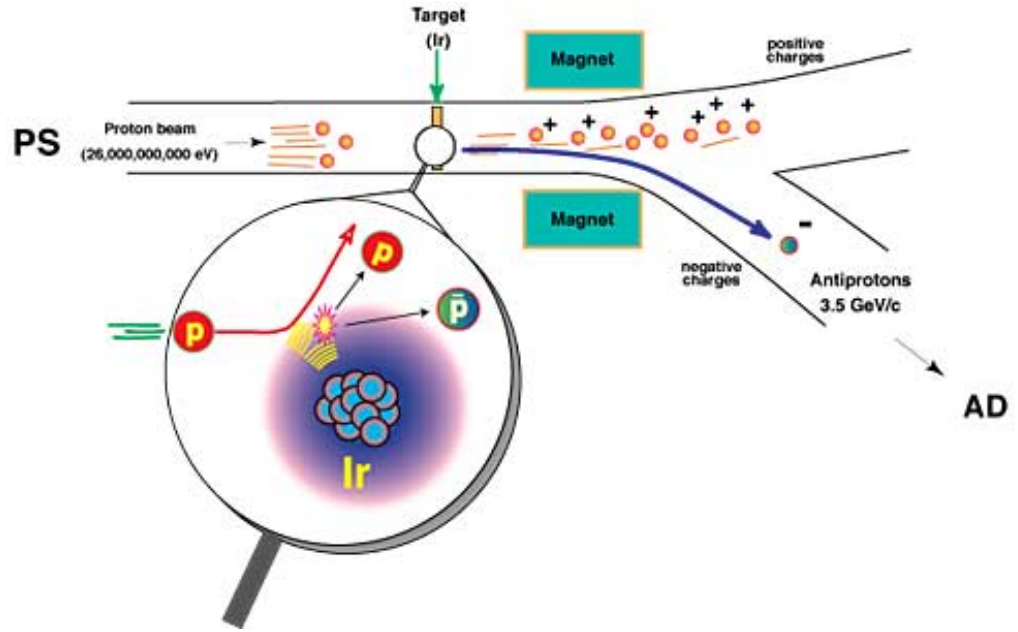
- Also at ISOLDE - Example for measuring electromagnetic dipole moment, expect strong contributions if there is SUSY:
  ^{225}Ra EDM to the 10^{-27} e . cm level (HIE-ISOLDE project)
  (see L.Willman, K. Jungmann, H.W.Wilshut, CERN-INTC-2010-049; J. Pakarinen et al, CERN-INTC-2010-022)
  Current experimental limits e.g. $|d_{Tl}| < 9\times10^{-25}$ e · cm or $|d_n| < 3\times10^{-26}$ e · cm

Significant german contributions to "low energy precision experiments".

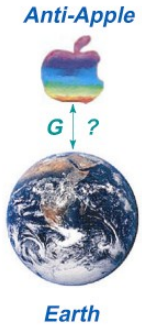
Contact person: **Klaus Blau** (Max-Planck-Institut für Kernphysik, Heidelberg)

Antimatter experiments at the PS

- Over the last few years experiments with antimatter at the AD facility at CERN have provided important new physics results. These allow for different new tests of the symmetry of the Standard Model under the combined CPT operation (Charge conjugation, Parity and Time reversal) through comparisons of properties of particles and corresponding antiparticles.



AEGIS, Gbar experiments:
Comparing the behaviour of hydrogen
and anti-hydrogen in the earths **gravitational field**

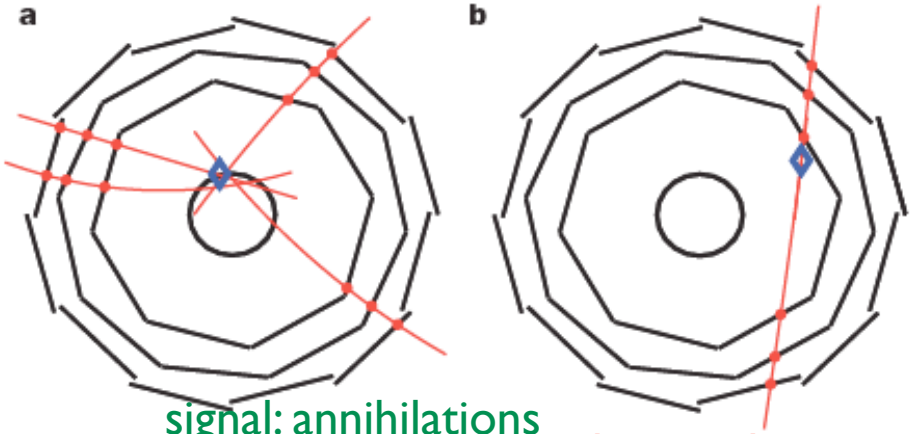


Very recent BASE experiment:
Comparison of anti-proton / proton magnetic moment aiming to 10^{-9} precision (current limit $4.4 \cdot 10^{-6}$ by ATRAP) by use of double Penning trap

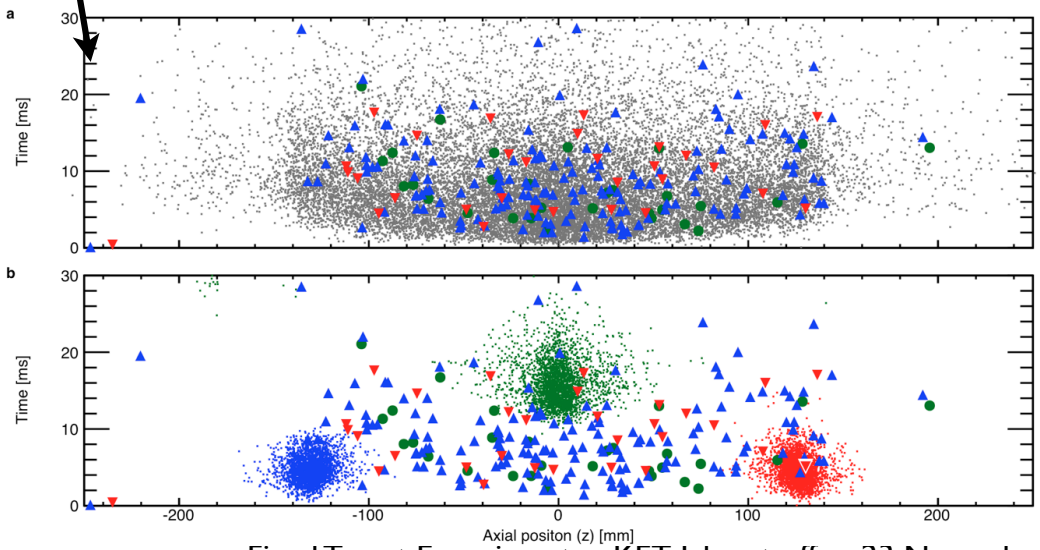
ALPHA, ATRAP, ASACUSA experiments:
Looking for differences between hydrogen and anti-hydrogen using **spectroscopy**

An example: the ALPHA experiment - trapping and detecting antihydrogen

Key Measurements: location of the annihilations using silicon strip detector.



ALPHA demonstrated that anti-hydrogen can be stored >>2000 sec.
Next steps, starting 2014: spectroscopy

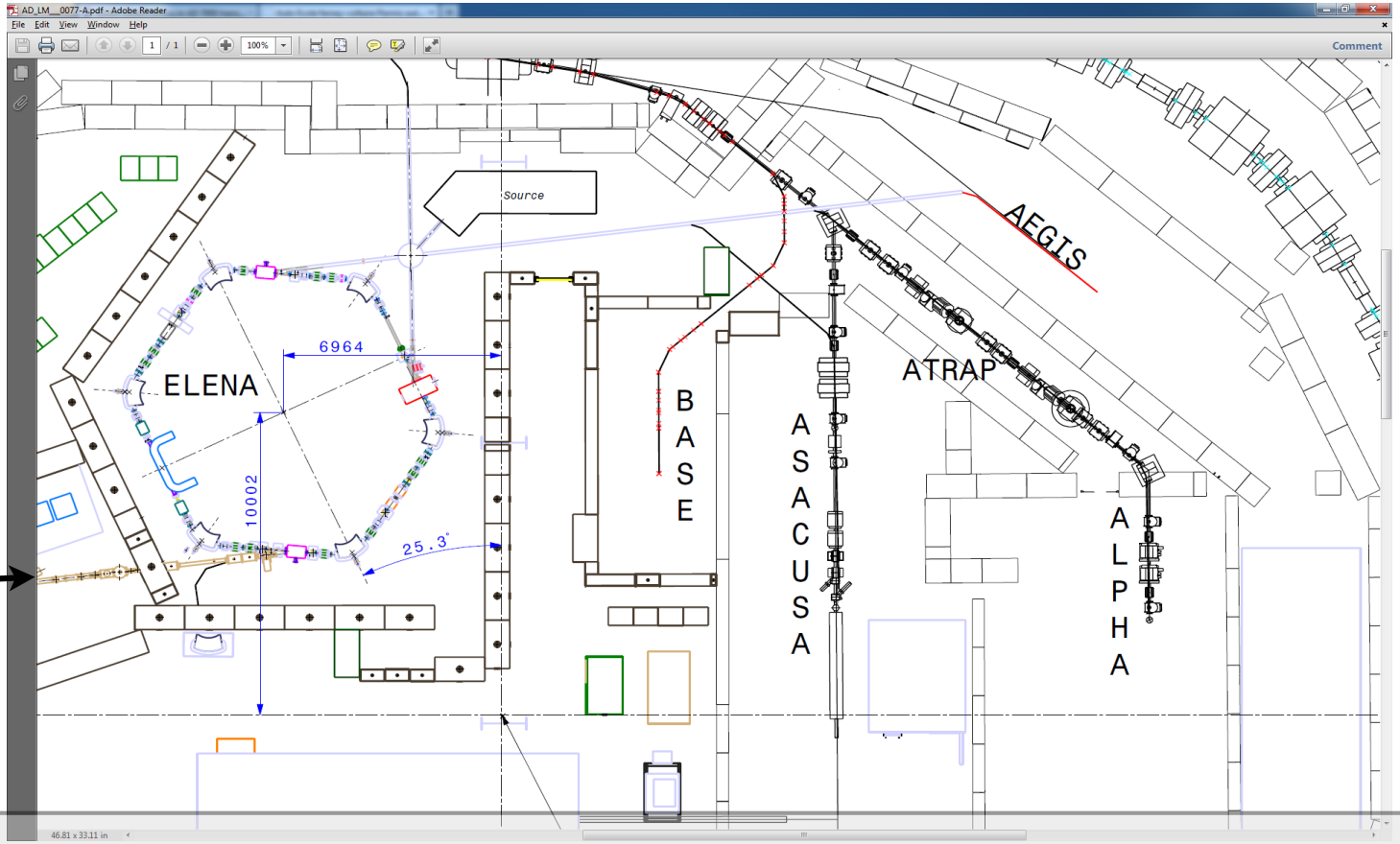


As for many "smaller" experiments, state-of-the-art particle detectors are used.
Experiments need expertise, technical support and collaboration.
Example: the ALPHA strip detector build in collaboration with University of Liverpool, e.g. also in ATLAS strip detector community.

Small dots: simulation
Triangles, big dots: data

Very active programme at the CERN's AD

- To provide sufficient number of antiprotons, the "antiproton accumulator" ELENA (10-100 times more antiprotons for experiments), commissioning 2016, operation 2017.



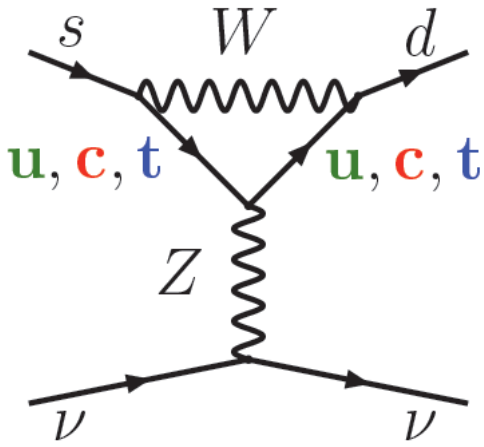
Also to the AD facility and experiments significant german contribution

Contact person: **Walter Oelert** (Johannes-Gutenberg-University Mainz

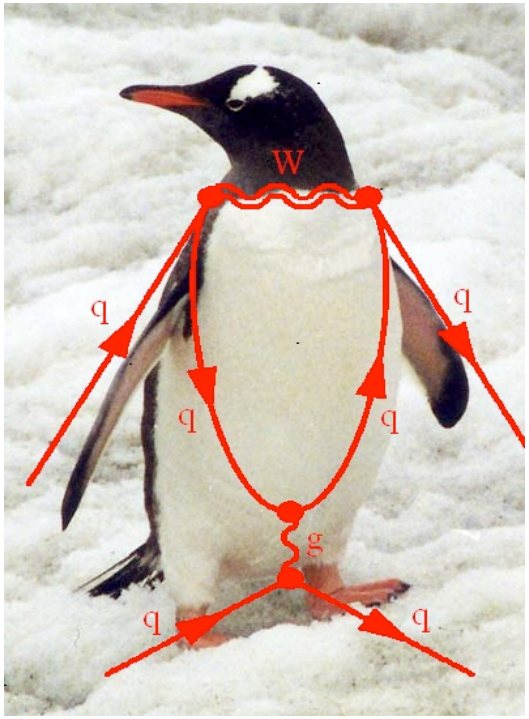
Flavour Physics: Probing the Standard Model

- flavour physics programme in the world covering B physics (LHCb), charm physics (CLEO-c) and kaon physics (NA62.)

$$K \to \pi \nu \bar{\nu}$$

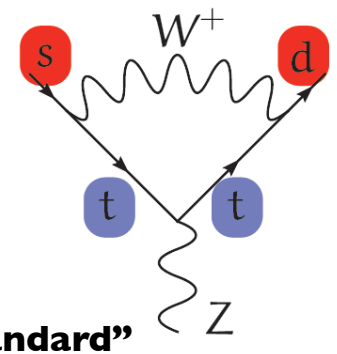


...so-called "penguin graph"

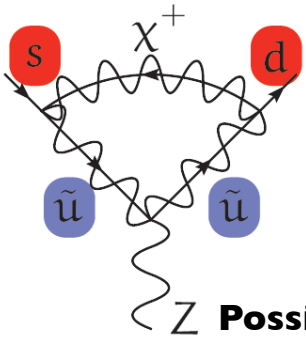


The contribution to these processes due to the Standard Model is **strongly suppressed (<10^{-10})** and **calculable with excellent precision (~%)**

They are very sensitive to possible contributions from **New Physics**



"Standard" Penguin

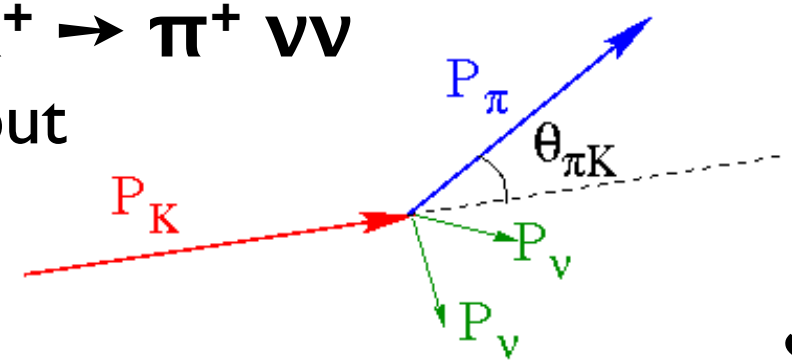


Possible "Super-Symmetric" Penguin

N62 at the CERN SPS: measuring rare kaon decays

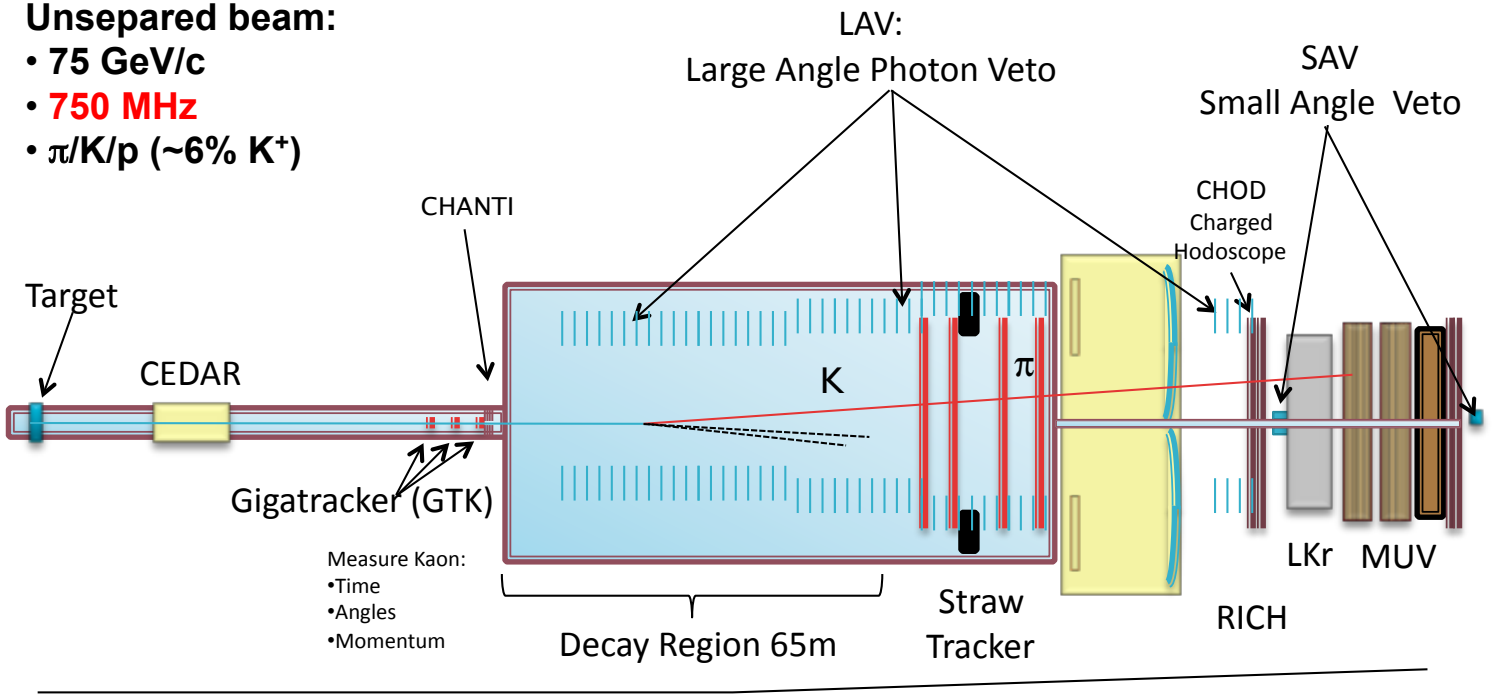
Goal of the experiment:
Measure rate of rare kaon decay $K^+ \to \pi^+ \nu\nu$
Rate in Standard Model: ~O(10^{-6}) but much enhanced when there is physics beyond the SM

Main background
$K^+ \to \pi^+ \pi^0$



Start of data taking in 2014

SPS primary p: 400 GeV/c
Unsepared beam:
- **75 GeV/c**
- **750 MHz**
- **π/K/p (~6% K^+)**



Beam line:
- CEDAR: K ID
- Gigatracker: beam particle ID
- CHANTI: Charged particle veto

Detector region:
- pion tracks: straws
- particle ID: LKr, RICH
- muon rejection: MUV
- photon rejection: LKr, LAV, SAV

- K+ rate: 11 kHz

NA62 high intensity will allow searches for lepton flavour violation

- 4.5x1012 K decays/year will allow improvements in many possible processes:

Mode	UL at 90% CL	Experiment	Reference
$K^+ \to \pi^+\mu^+e^-$	1.3×10^{-11}	E777/E865	PRD 72 (2005) 012005
$K^+ \to \pi^+\mu^-e^+$	5.2×10^{-10}	E865	PRL 85 (2000) 2877
$K^+ \to \pi^-\mu^+e^+$	5.0×10^{-10}		
$K^+ \to \pi^-e^+e^+$	6.4×10^{-10}		
$K^+ \to \pi^-\mu^+\mu^+$	1.1×10^{-9}	NA48/2	PLB 697 (2011) 107
$K^+ \to \mu^-\nu e^+e^+$	2.0×10^{-8}	Geneva-Saclay	PL 62B (1976) 485
$K^+ \to e^-\nu\mu^+\mu^+$	no data		
$\pi^0 \to \mu^+e^-$	3.6×10^{-10}	KTeV	PRL 100 (2008) 131803
$\pi^0 \to \mu^-e^+$	3.6×10^{-10}		

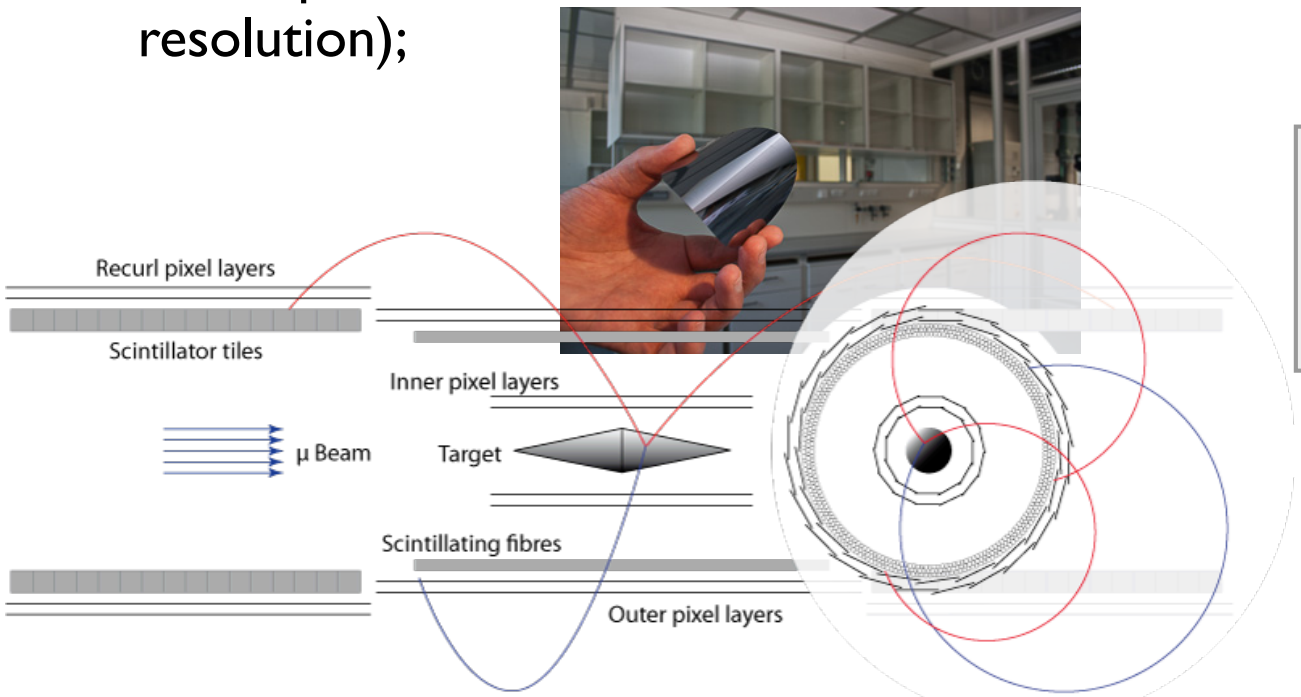
from T. Spadaro, talk at BLV2013 in Heidelberg

- First studies indicate that sensitivities down to 10^{-12} are possible.
- Also option to measure decays from π^0 are currently studied as e.g. decays into eμ are forbidden by SM.
- More studies for future measurements at NA62: study of very rare $K^0_L \to \pi^+ \nu\nu$

German participation in NA62, Johannes-Gutenberg-Universität Mainz, contact **Rainer Wanke**
or contact NA62 spokesperson **Augusto Ceccucci (CERN)**

Mu3e - searching for lepton flavour violation

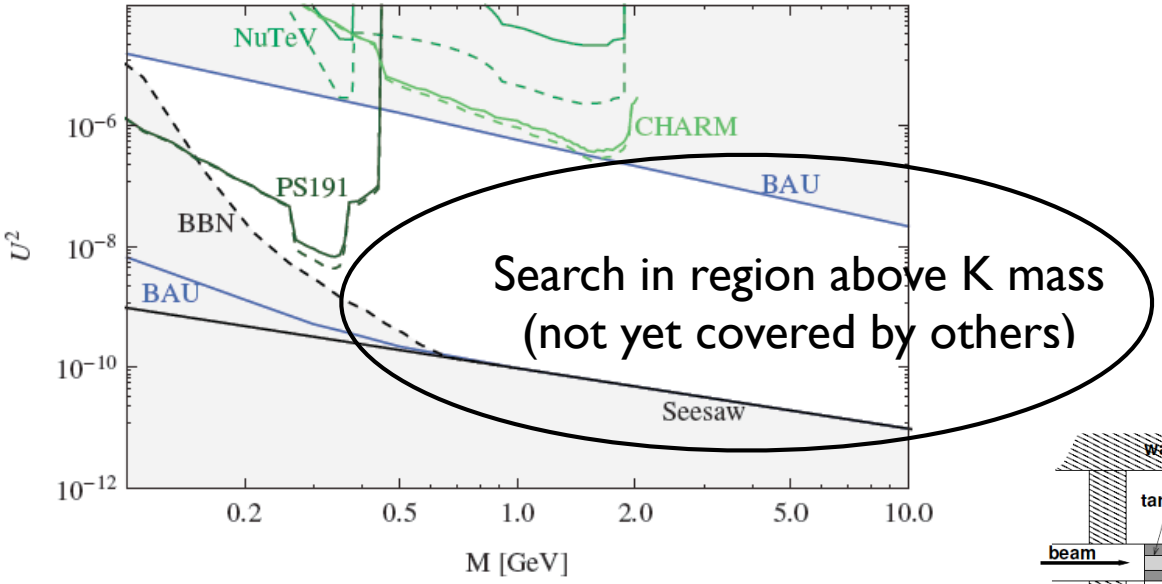
- Search for the lepton flavour violating decay of the muon to three electrons with a branching ratio sensitivity of 10^{-16};
  - ➡ muons from a beam at the PSI; supply of low-energy surface muons (from stopped pion decay at rest, at the surface of the production target);
- Innovative technologies (large scale HV-MAPS, tracker cooling with gaseous helium), data taking 2015/16 (Phase1)
  - ➡ HV-MAPS important technology also for ATLAS, CLIC (commercial CMOS technique allows low-cost, thin, radiation hard detectors with very good timing resolution);



German participation, University of Heidelberg, contact **Andre Schoening**

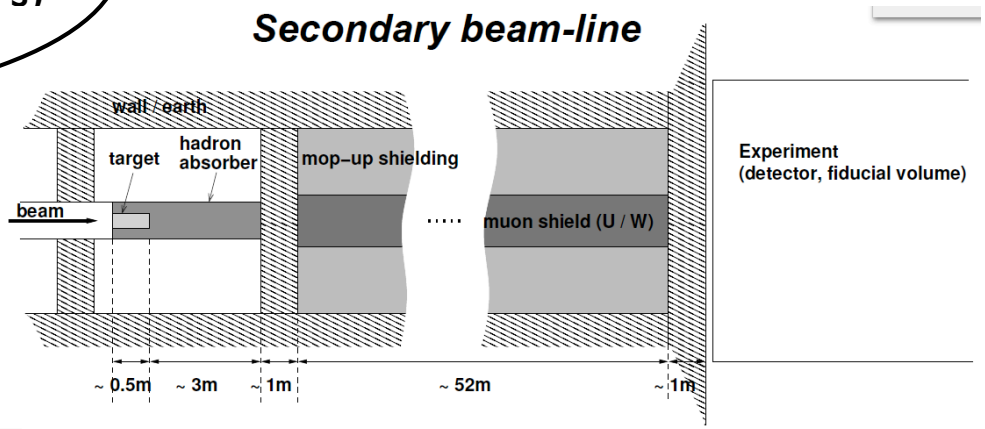
More ideas for future experiments

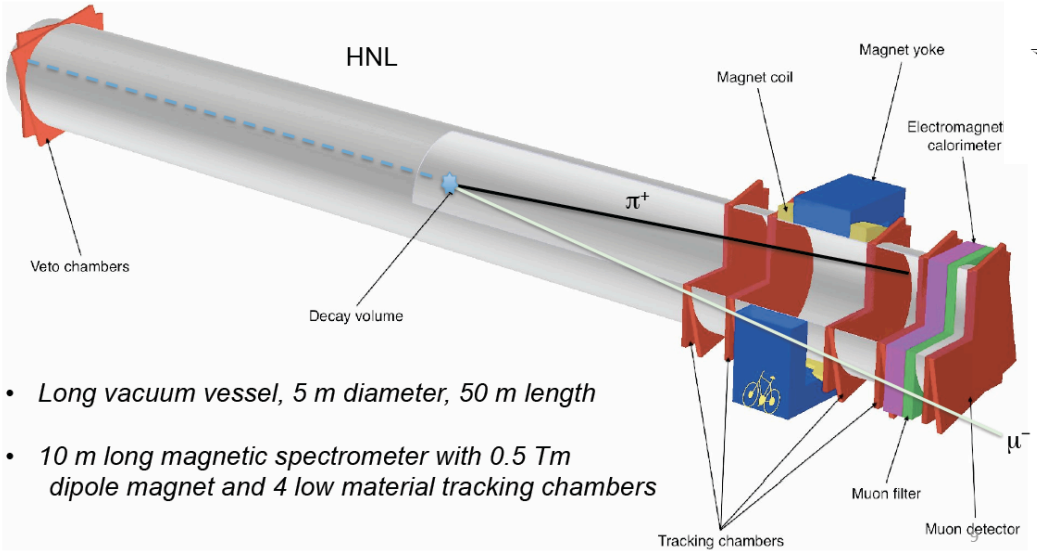
- Expression of interest to search for heavy neutral leptons (νMSM: T.Asaka, M.Shaposhnikov PL B620 (2005) 17)



Search in region above K mass (not yet covered by others)

Experimentally challenging:



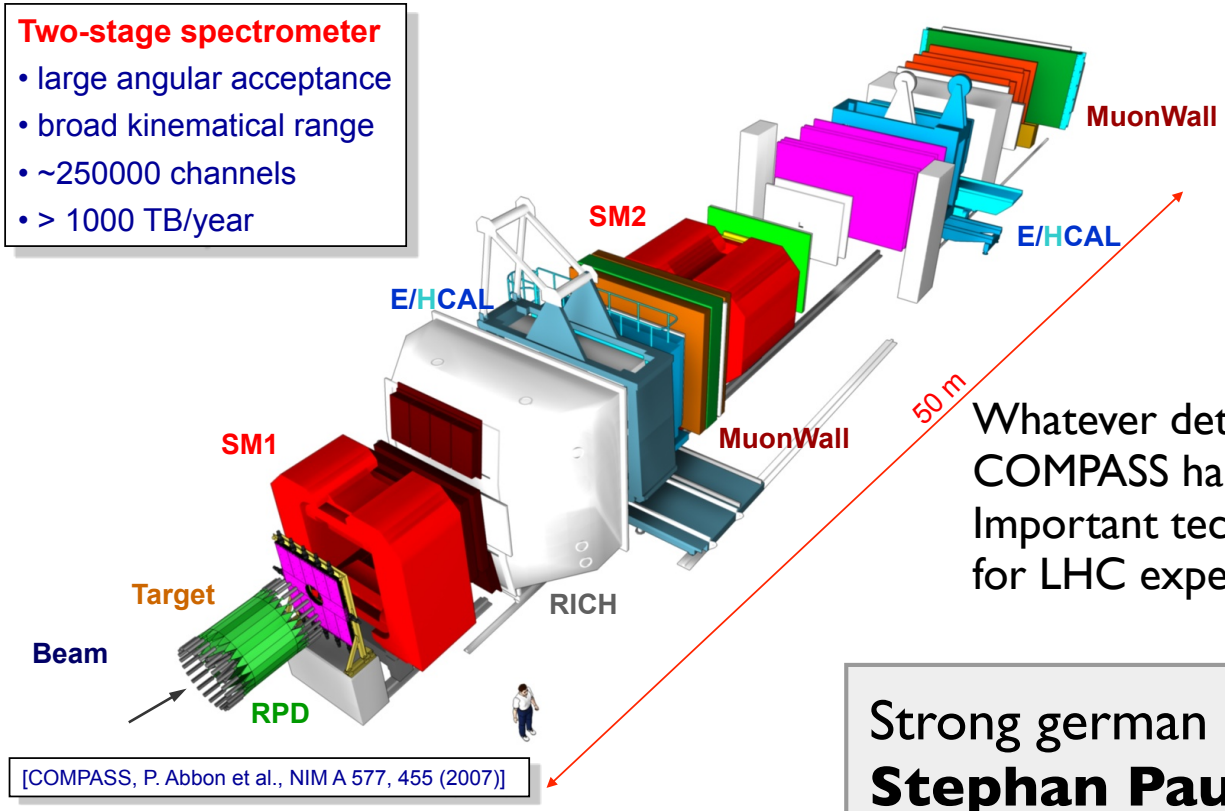


- *Long vacuum vessel, 5 m diameter, 50 m length*
- *10 m long magnetic spectrometer with 0.5 Tm dipole magnet and 4 low material tracking chambers*

EoI at CERN SPSC (October 2013), no german participation, experiment contact **Andrey Golutvin**

The COMPASS experiment

Two-stage spectrometer
- large angular acceptance
- broad kinematical range
- ~250000 channels
- > 1000 TB/year



[COMPASS, P. Abbon et al., NIM A 577, 455 (2007)]

Whatever detector technology you can imagine: COMPASS has it!!!
Important technologies and techniques e.g. also for LHC experiments.

Strong german participation, contact
Stephan Paul
(Technische Universität München)

Two major experiment programmes:
1) Investigating nucleon structure
2) Hadron spectroscopy:
QCD describes the interaction between colored quarks by the exchange of gluons which carry color themselves. In contrast to QED, therefore, the gluons can also interact among themselves, generating a rich and complex excitation spectrum of bound quarks and gluons. High-statistics measurements will lead to a more complete understanding of the spectrum of mesons and baryons up to masses of 2.5 GeV.

More on fixed target experiments

- Not covered in this talk: accelerator-based neutrino experiments

  ➡ main programmes: search for sterile neutrinos and determination of neutrino mass hierarchy;

  ➡ The European Strategy for Particle Physics - Update 2013:
  f. Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. *Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.*

- Note: also non-accelerator based experiments address fundamental questions beyond the Standard Model of particle physics, e.g. axion search experiments as CAST, ALPS.

Summary

- Fixed target experiments play a very important role in exploring novel phenomena in particle physics and/or to understand the SM physics processes;
  - ➡ Vital part of particle physics community;
  - ➡ very often innovative technologies, methodes - a lot can be learned;
  - ➡ provide excellent opportunities for education/training of young colleagues;

What can KET do to support these experiments?

German participation in particle physics experiments (LHC experiments not included)

LIST OF PARTICLE PHYSICS EXPERIMENTS/R&D ACTIVITIES WITH CONTRIBUTIONS FROM GERMAN UNIVERSITIES AND INSTITUTES

The final list should include all experiments with the participating institutes including contact persons as well as sources of funding.
It should also be indicated to which of the German committees (KET, KHuK, KAT, KfB) the experiment is linked to.

This preliminary and not complete list does not include:

- LHC experiments and many test beam activities / detector tests related to LHC;
- Irradiation tests or test beam users from Germany or with German participation;
- Neutrino experiments, experiments at the GSI and PSI@PSI, PANDA.

Information/sources used for the list:

- CERN Database of experiments (Grey Book), see http://greybook.cern.ch/, status 12.2.2013
- SPSC documents, see http://cds.cern.ch/collection/SPSC%20Public%20Documents?ln=en, status 12.2.2013
- private communications (PS/SPS/AD users meetings, SPS Committee, Hanna Mahlke/ DESY PT, Jochen Dingfelder/ Uni Bonn, Axel Lindner / DESY, Uwe Schneekloth/DESY ...)

EXPERIMENTS AT THE CERN PROTON SYNCHROTRON (PS)

DIRAC (PS212)
(Lifetime measurements of $\pi^+\pi^-$ and $\pi^+ - K^+$ atoms to test low-energy QCD predictions. Plans for a proposal of a DIRAC II experiment at the SPS are around.)

- no participation from German institute

CLOUD (PS215)
(Studies the influence of galactic cosmic rays on the earth's climate through the media of aerosols and clouds.)

- Johann Wolfgang Goethe-University of Frankfurt, Institute for Atmospheric and Environmental Sciences(Joachim CURTIUS (Joachim.Curtius@cern.ch))
- Leibniz Institute for Tropospheric Research (IFT), Leipzig (Frank STRATMANN (stradk@tropos.de))

- Karlsruhe Institute of Technology (KIT) (Contact: Thomas LEISNER (thomas.leisner@kit.edu))

The neutron time-of-flight facility (n-TOF)
(pulsed neutron source coupled to a 200 m flight path designed to study neutron-nucleus interactions for neutron kinetic energies ranging from a few meV to several GeV.
Research fields are ranging from stellar nucleosynthesis, symmetry breaking effects in compound nuclei, and the investigation of nuclear level densities, to applications of nuclear technology, including the transmutation of nuclear waste, accelerator driven systems and nuclear fuel cycle investigations.)

- GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (Alberto MENGONI (Alberto.Mengoni@cern.ch))
- Johann-Wolfgang-Goethe Universität, Frankfurt (Rene REIFARTH (rene.reifarth@cern.ch))
- Karlsruhe Institute of Technology, Institut für Kernphysik, Karlsruhe (Franz KAEPPELER (franz.kaeppeler@kit.edu))

EXPERIMENTS AT THE CERN ANTIPROTON DECELERATOR

ATRAP (AD2)
(cold Antihydrogen for Precise Laser Spectroscopy)

- Forschungszentrum Julich GmbH (KFA) (Walter OELERT (walter.oelert@cern.ch))
- Johannes-Gutenberg-Universitat Mainz Institut für Physik (WALZ (jochen.walz@cern.ch))

ASACUSA (AD3)
(Atomic spectroscopy and collisions using slow antiprotons)

- Max-Planck-Institut für Quantenoptik (Masaki HORI (mhori@nucl.phys.s.u-tokyo.ac.jp))
- Johannes-Gutenberg-Universitat Mainz, Institut für Physik (Stefan ULMER (stefan.ulmer@cern.ch))

ACE (AD4)
(Relative biological effectiveness and peripheral damage of antiproton annihilation. Stopped data taking in 2012, data analysis in progress. Maybe new proposal?)

- German Cancer Research Center (DKFZ) (Niels Bassler (bassler@physics.au.dk))
- Max-Planck-Institut für Kernphysik (MPI) (Michael Holzscheiter (Michael.Holzscheiter@cern.ch))

- no participation from German institutes

R&D PROJECTS AT CERN

RD42
(Development of diamond tracking detectors for high luminosity experiments at the LHC.)

- GSI - Helmholtzzentrum fur Schwerionenforschung GmbH
- Georg-August-Universität Göttingen, Fakultat für Physik, II Physikalisches Institut

RD50
(Development of radiation hard semiconductor devices for very high luminosity colliders.)

- Technische Universitaet Dortmund
- Albert-Ludwigs-Universität Freiburg
- Universität Hamburg, Institut fur Experimentalphysik (UHH)
- Karlsruher Institut fur Technologie (KIT), Universität Karlsruhe, Institut für Experimentelle Kernphysik
- Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut)

RD51
(Development of micro-pattern gas detectors technologies)

- Rheinisch-Friedrich-Wilhelms-Universitat Bonn, Physikalisches Institut
- Physikalisch-Techni. Bundesanstalt
- GSI - Helmholtzzentrum fur Schwerionenforschung GmbH
- Albert-Ludwigs-Universität Freiburg
- Technische Universitat München
- Deutsches Elektronen-Synchrotron (DESY)
- Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut)

RD52
(Dual- Readout Calorimetry for high-quality energy measurements)

- no participation from German institute

CRYSTAL (UA9)
(feasibility of crystal-assisted collimation in hadron colliders)

- no participation from German institutes

CERN: PROPOSAL, EXPRESSION OF INTEREST, ETC

P347 (ICARUS&NESSI)
Search for "anomalies" from neutrino and anti-neutrino oscillations at $\Delta 2m=1eV2$ with muon spectrometers and large LAr-TPC imaging detectors, see http://cds.cern.ch/record/1432214?ln=en)

- no participation from German institute

TDR002 (BASE)
(direct high-precision measurement of the magnetic moment, or g-factor, of a single antiproton, see http://cds.cern.ch/record/1503514?ln=en)

- Johannes Gutenberg University, Mainz
- Max Planck Institute for Nuclear Physics, Heidelberg

EOI007 (LBNO)
(very long baseline neutrino oscillation experiment, see http://cds.cern.ch/record/1457543?ln=en)

- III. Physikalisches Institut, RWTH Aachen, Aachen

EOI008 (CHIC)
(experiment to study charm production with proton and heavy ion beams, see http://cds.cern.ch/record/1488986?ln=en)

- no participation from German institute

LOI240 (AWAKE)
(experiment on proton-driven plasma wakefield acceleration (PDPWA), see http://cds.cern.ch/record/1537313?ln=en)

- DESY, Hamburg
- Universität Heidelberg, Heidelberg
- Heinrich Heine University, Düsseldorf
- Karlsruher Institute of Technology KIT, Karlsruhe
- Ludwig Maximilian University, Munich
- Max Planck Institute for Physics, Munich
- Max Planck Institute for Plasma Physics, Greifswald

ALPHA (AD5)
(Antihydrogen Spectroscopy)

- no participation from German institute

AEGIS (AD6)
(test of weak equivalence principle at high precession of antimatter)

- Ruprecht-Karls- Universität Heidelberg, Kirchhoff Institute of Physics (Alban KELLERBAUER (Alban.Kellerbauer@cern.ch))
- Max-Planck- Institut für Kernphysik, Heidelberg (Markus OBERTHALER (Markus.Oberthaler@cern.ch))

GBAR (AD7)
(test of weak equivalence principle at high precession of antimatter)

- Johannes-Gutenberg-Universitat Mainz (Jochen WALZ (jochen.walz@cern.ch))

EXPERIMENTS AT THE CERN SUPER PROTON SYNCHROTRON (SPS)

COMPASS (NA58)
(study of hadron structure and hadron spectroscopy)

- Rheinisch-Westfälische Technische Hochschule (RWTH), III. Physikalisches Institut (B) (Jorg PRETZ (Jorg.Pretz@cern.ch))
- Universitat Bielefeld (Gunter BAUM (baum@physik.uni-bielefeld.de))
- Ruhr-Universität Bochum (Werner MEYER (werner.meyer@cern.ch))
- Rheinisch-Friedrich-Wilhelms-Universitat Bonn, Physikalisches Institut (Friedrich KLEIN (Klein@physik.uni-bonn.de))
- Rheinisch-Friedrich-Wilhelms-Universitat Bonn, Helmholtz-Institut für Strahlen- und Kernphysik (Jens-Ulrich BISPLINGHOFF (jens@hiskp.uni-bonn.de))
- Friedrich-Alexander-Universität Erlangen (Albert LEHMANN (Albert.Lehmann@cern.ch))
- Albert-Ludwigs-Universität Freiburg (Kay KONIGSMANN (Kay.Konigsmann@physik.uni-freiburg.de))
- Technische Universität München (Stephan PAUL (Stephan.Paul@cern.ch))
- Johannes-Gutenberg-Universitat Mainz (Dietrich GRAF VON HARRACH (dvh@kph.uni-mainz.de))
- Ludwig-Maximilians-Universität München (Martin FAESSLER (Martin.Faessler@cern.ch))

SHINE (NA61)
(Study of hadron production in hadron-nucleus and nucleus-nucleus collisions)

- Johann-Wolfgang-Goethe Universität Frankfurt (Marek GAZDZICKI (Marek.Gazdzicki@cern.ch))
- Fachhochschule Frankfurt am Main Fachbereich 2 (Wolfgang RAUCH (Wolfgang.Rauch@cern.ch))
- Karlsruher Institut fur Technologie (KIT), Forschungszentrum Karlsruhe GmbH (FZK) (Ralph ENGEL(Ralph.Engel@cern.ch))

NA62
(measurement of the rare decay $K^+ \to \pi^+ \nu\bar{\nu}$)

- Johannes-Gutenberg-Universitaet Mainz

NA63
(studies of electromagnetic processes in strong crystalline fields. Interesting e.g. to understand positron production in bend crystals, useful e.g. for LC)

- no participation from German institute

OPERA (CNGS1)
(appearance experiment to search for $\nu_\mu \leftrightarrow \nu_\tau$ oscillations. End of data taking in 2012, data analysis ongoing.)

- Universität Hamburg, Institut fur Experimentalphysik (UHH)
- Westfälische Wilhelms-Universität Münster

ICARUS (CNGS2)
(search programme of explicit ν-oscillations. End of data taking in 2012, data analysis ongoing.)

- no participation from German institute

CERN: NON-ACCELERATOR BASED EXPERIMENTS

CAST
(Solar Axion Searches)

- Technische Universitat Darmstadt, Institut für Kernphysik
- Johann-Wolfgang-Goethe Universitat Frankfurt
- Max-Planck- Institut für Extraterrestrische Physik
- Max-Planck-Institut fur Sonnensystemforschung, Katlenburg-Lindau
- Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut)
- (but also interest from the University of Bonn to test new gaseous micro-pattern detectors INGRIDs)

OSQAR
(Optical search for QED vacuum magnetic birefringence, Axions and photon regeneration)

CERN: RECOGNISED EXPERIMENTS

- AMS (Alpha Magnetic Spectrometer)
- AUGER PROJECT (The Pierre Auger Observatory Project)
- EXPLORER (Gravitational Wave Detector)
- ANTARES (An Undersea Neutrino telescope)
- FERMI
- LISA
- NESTOR (Neutrino Extended Submarine Telescope with Oceanographic Research)
- ICECUBE Neutrino telescope at the South Pole
- RE11 (MICE) Muon Ionization Cooling Experiment
- RE12 (MEG) MEG: search for the mu e decay at PSI
- RE13 (TEK) Neutrino Oscillation Experiment at JHF
- RE14 (KATRIN) Tritium beta-decay experiment for direct measurement of the electron neutrino mass
- RE15 (WARP) Search for cold dark matter using a cryogenic noble liquid detector
- RE16 (HESS) High Energy Stereoscopic System
- RE17 (MAGIC) MAGIC Major Atmospheric Gamma Imaging Cherenkov Telescope
- RE18 (ArDM) ArDM: Search for Dark Matter in the Universe with Liquid Argon
- RE19 (CREAM) Cosmic Ray Energetics and Mass
- RE20 (Belle II) Belle II
- RE21 (CBM) Compressed Baryonic Matter
- RE22 (PANDA) Proton Antiproton DArmstadt
- CTA-PP Cherenkov Telescope Array
- Planck
- **CALET** (Calorimetric Electron Telescope), see http://calet.phys.lsu.edu/instrumentation.php
  - no participation from German institute
- **Borexino**, see http://borex.lngs.infn.it/
  - Technische Universität München
  - Max-Planck-Institut für Kernphysik
- **PAMELA** (Search for Antimatter in Space), see http://pamela.roma2.infn.it/index.php
  - Physics Department of Siegen University

EXPERIMENTS AND R&D PROJECTS AT OTHER LABORATORIES AND ACCELLERATORS

BELLE II
(flavor physics and *CP* violation measurements)

- Bonn (J. Dingfelder, H. Kruger, N. Wermes)
- DESY (C. Niebuhr)
- Giessen (W. Kuehn, S. Lange)
- Goettingen (A. Frey)
- Heidelberg (P. Fischer, I. Peric)
- KIT Karlsruhe (T. Mueller, Michael Feindt)
- TU Muenchen (S. Paul)
- LMU Muenchen (J. Schieck)
- MPI Muenchen (C. Kiesling, H.G. Moser)

ALPS (ALPS II approved)
(Search for very Weakly Interacting Sub-eV Particles (WISPS) as Axions, Chameleons...)

- DESY (Axel LINDNER)
- Uni Hamburg (Dieter Horns)
- AEI Hannover (Benno Willke)
- more institutes/universities interested after approval of ALPS II

OLYMPUS
(Study of Nucleon elastic form factors: electric G_E and magnetic G_M)

- DESY
- Universitaet Bonn
- Universitaet Mainz

CALICE
(A high granularity calorimeter system optimised for the particle flow measurement of multi-jet final states at the ILC running, with centre-of-mass energy between 90 GeV and ~1 TeV)

• DESY	F. Sefkow
• CERN	L.Linssen
• Uni Hamburg	E. Garutti
• Uni Heidelberg	H-C Schultz-Coulon
• Uni Mainz	V. Buescher
• MPI München	F. Simon
• Uni Wuppertal	C. Zeitnitz

Mu3e
(Search for the lepton flavour violating decay of the mu

- Universitaet Heidelberg (Andre Schoening)

Missing / in progress:

- Neutrino Experiments, help from Caren Hagner
- PSI Experiments, help from Andre Schoening
- GSI Experiments (PANDA....)
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