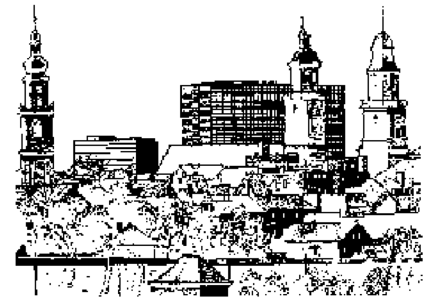
Spinning Protons in Bottles



Erhard Steffens

Physikalisches Institut, Univ. Erlangen-Nürnberg

steffens@physik.uni-erlangen.de

- Willy's idea of the storage vessel (bottel, cell)
- Initial feasibility studies by Willy and others
- Successful applications at various places
- Some personal remarks

The starting idea

Proceedings
of the 2nd International Symposium
on Polarization Phenomena
of Nucleons

Karlsruhe, September 6–10, 1965

Editors: P. Huber and H. Schopper

Sources of Polarized Negative Ions for Tandem Accelerators

By W. HAEBERLI, University of Wisconsin, Madison, Wisconsin, USA

The construction of sources of polarized positive ions was discussed at this conference by Prof. FLEISCHMANN [1][1]). It has been demonstrated repeatedly over the last three years that such positive ions (i.e., protons and deuterons) can be accelerated in low voltage *dc* accelerators, in cyclotrons and in linear accelerators. While the electrostatic accelerator is the most widely used device for nuclear reaction studies in the energy region of a few MeV, the use of polarized sources in the high voltage terminal of these machines is made very difficult because of the complexity and large size of the present sources.

70 W. Haeberli

The process, in principle, should have a high efficiency because at the energies considered most protons would be converted into neutral atoms in the first foil. However, there are obvious difficulties because of heating of the foil, unpolarized surface contaminants, scattering of the beam etc. Also, the expected polarization is not high. Most of the objections are removed if one replaces the iron foil with a vessel containing ! a polarized paramagnetic gas. In practice this might consist of a storage container of polarized hydrogen atoms like RAMSEY's group [25] uses for the hydrogen maser, or ! an optically pumped alkali vapour. The charge transfer cross section $H^+ + H^\circ$ (1 S) $\to H^\circ$ (1 S) $+ H^+$ to the ground state of hydrogen is quite large [26] (about ten times the geometric cross section at 10 keV). With an atomic beam source producing $3 \cdot 10^{15}$ atoms/sec the intensity of polarized fast neutral atoms is estimated to be 10^{-4} of the incident proton beam.

In summary, it has been shown that under suitable conditions polarized negative ions can be produced and accelerated without loss in polarization. Only one method of producing negative ions has been used so far. There are good reasons to believe that much more intense beams will be obtained in the near future.

a polarized paramagnetic gas. In practice this might consist of a storage container of polarized hydrogen atoms like RAMSEY's group [25] uses for the hydrogen maser, or an optically pumped alkali vapour. The charge transfer cross section $H^+ + H^\circ$ (1 S)

1980: Experimental demonstration of storage vessel idea by Wisconsin group

Polarization Phenomena in Nuclear Physics-1980
(Fifth International Symposium, Santa Fe)

Editors
G.G. Ohlsen, Ronald E. Brown, Nelson Jarmie, W.W. McNaughton and G.M. Hale
Los Alamos Scientific Laboratory

Conclusion: The hydrogen atoms keep their polarization during many wall collisions!

A TARGET OF POLARIZED HYDROGEN
BY STORAGE OF ATOMS IN
A COATED PYREX VESSEL

M.D. Barker, G. Caskey, C.A. Gossett, W. Haeberli
D.G. Mavis, P.A. Quin, S. Riedhauser, J. Sowinski
and J. Ulbricht
University of Wisconsin, Madison, WI. 53706†

A test was conducted to study the feasibility of producing a target of polarized hydrogen for nuclear scattering experiments by accumulating atoms from a Stern-Gerlach atomic beam source in a coated pyrex vessel similar to that used in the hydrogen MASER.[1] The idea has been proposed by Haeberli[2] and more recently by Hanna.[3] As shown schematically in figure 1, the atomic beam entered

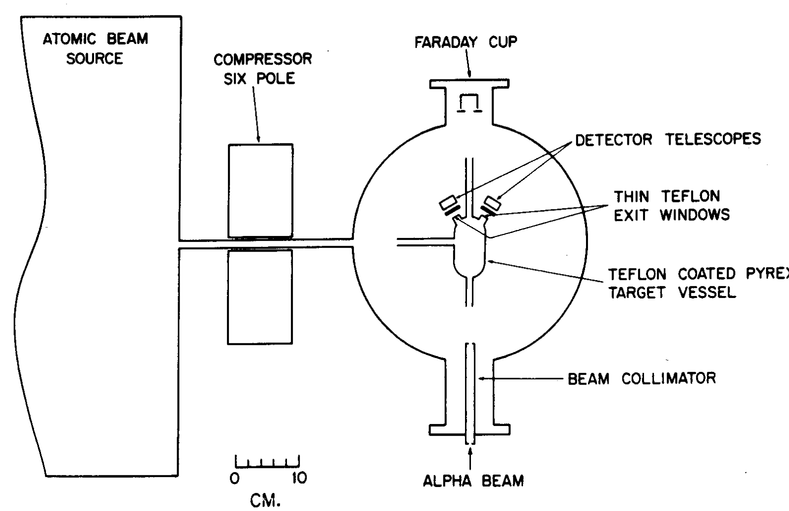


Figure 1. The apparatus shown was used to produce a polarized target by accumulating atoms in a coated pyrex vessel.

Int. Workshop on

Nuclear Physics with Stored, Cooled Beams

Indiana 1984 (Schwandt & Meyer)

Willy Haeberli: Free and Stored Atomic Beams as Internal Polarized Targets

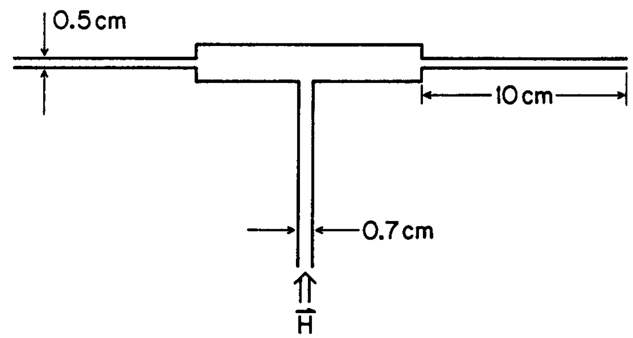


Fig. 5. Schematic of storage cell.

ES: Storing and Cooling of Polarized Ions

Principle of Storage Cells

Storage Cell proposed
by Willy Haeberli

•Proc. Karlsruhe 1965, p. 64

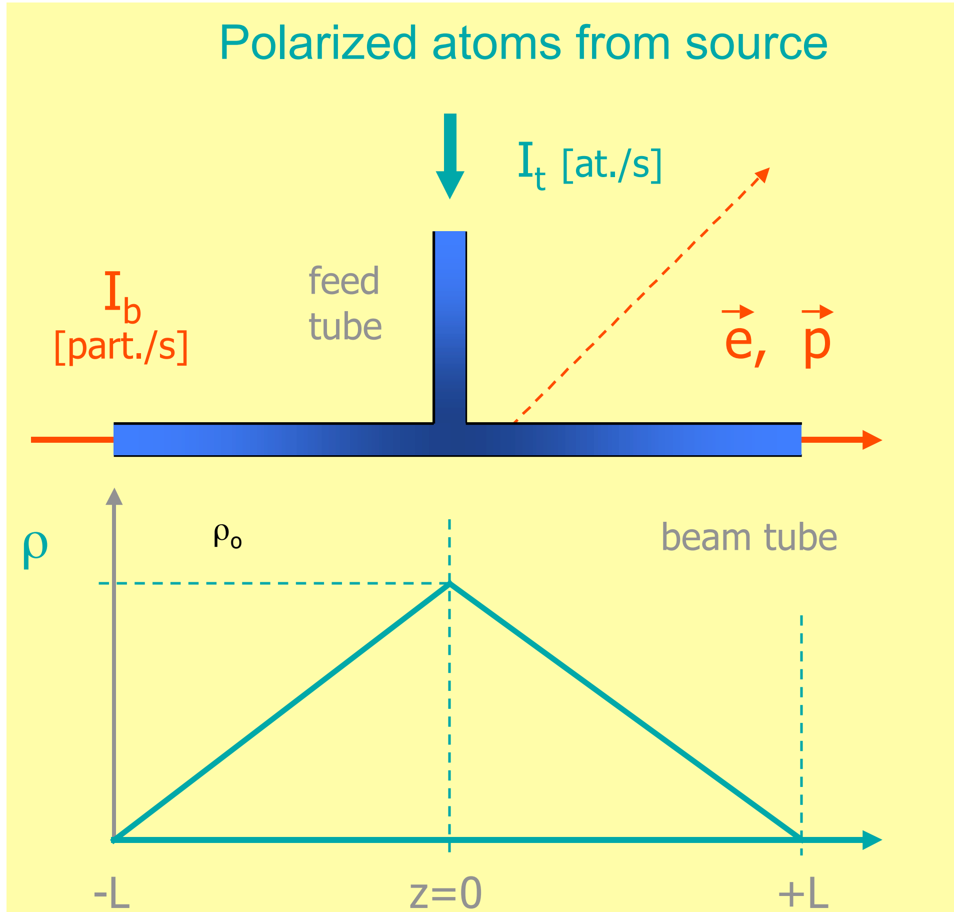
•Proc. Workshop IUCF 1984,
AIP Conf. Proc.#128, p.251

Target density $\mathbf{t = L\,\rho_o}$

with $\rho_o = I_t / C_{tot}$ and $C_{tot} = \Sigma\, C_i$

Note: $\mathbf{C_{tube} \propto r^3/L}$

$\mathbf{t \propto L^2 / r^3}$



Density gain compared to Jet of same intensity can be up to several hundred!

Filtex Proposal 1985

CERN/PSCC/85-80
PSCC/P 92
November 5, 1985

MEASUREMENT OF SPIN-DEPENDENCE IN $\bar{p}p$ INTERACTION
AT LOW MOMENTA

H. Döbbeling, K. Dworschak, H. Jänsch, E. Jaeschke, D. Krämer,
M. Nomachi, S. Paul, B. Povh, R. Repnow, T.-A. Shibata, E. Steffens
Max-Planck-Institut für Kernphysik and Physikalisches Institut
der Universität, Heidelberg, F.R. Germany

L.S. Pinsky, B.W. Mayes
University of Houston, Houston, Texas, USA

G.S. Mutchler, J. Kruk
Rice University, Houston, Texas, USA

H. Poth, A. Wolf
Kernforschungszentrum Karlsruhe, F.R. Germany

W. Haeberli, T. Wise
University of Wisconsin, Madison, Wisconsin, USA

D. Fick, W. Korsch
FB Physik, Phillips-Universität Marburg, F.R. Germany

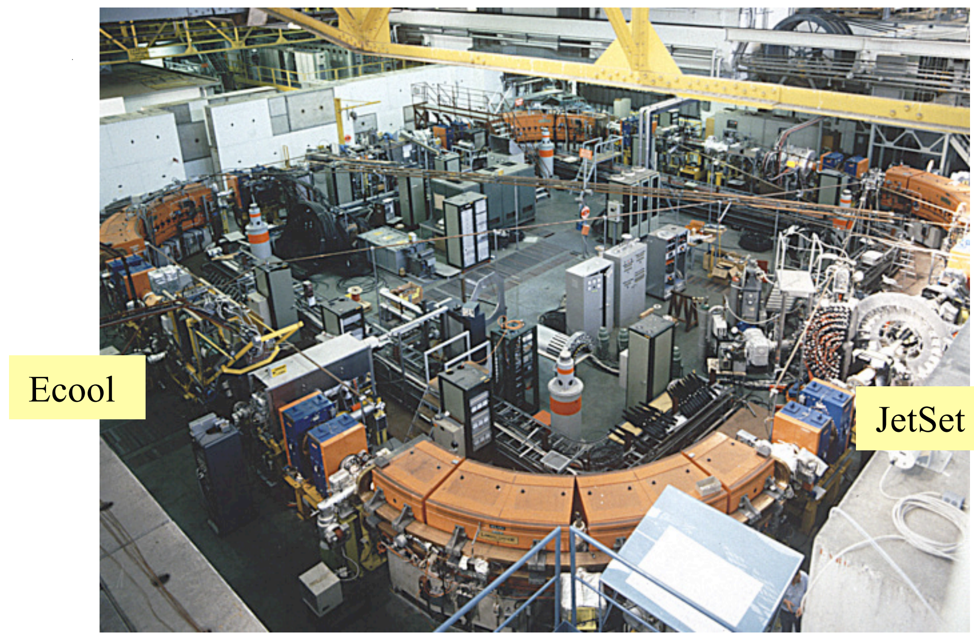
Th. Walcher
Institut für Kernphysik, Universität Mainz, F.R. Germany

G. Graw, P. Schiemenz
Sektion Physik, Universität München, F.R. Germany

R. Ransome
Rutgers University, Piscataway, New Jersey, USA

Basic idea: to polarize antiprotons by spin-filtering on a dense internal polarized hydrogen gas target based on a storage cell → 10^{14} atoms/cm^2 required!

Proposed for LEAR/CERN



Low Energy Antiproton Ring (LEAR)/CERN

8th International Symposium
on High Energy Spin Physics

September 12-17, 1988

University of Minnesota

- Workshop on ‚Polarized Gas Targets for Storage Rings' organized by Willy and ES
- First positive results on Argonne-Novosibirsk test of a storage cell in an electron storage ring reported
- Practical realization of storage cell targets for experiments envisaged

SUMMARY REPORT: POLARIZED GAS TARGETS FOR STORAGE RINGS

W. Haeberli
University of Wisconsin-Madison, Madison, WI 53706

ABSTRACT

A two day workshop was held prior to the High Energy Spin Physics Conference to discuss progress and open problems in the development of polarized internal gas targets for storage rings. The talks and discussions addressed the production of polarized targets of hydrogen, deuterium, ^{3}He and alkali atoms, depolarization mechanisms, and problems arising from the interaction between target and storage ring.

INTRODUCTION

The workshop was attended by 50 participants. The two days of the workshop activities were divided into four sessions, with four or five short technical talks presented in each session. A program of the workshop is attached at the end of this report. Each of the four sessions was followed by a discussion session on one of the following four topics:

1. Performance and limits of jet targets
2. Wall depolarization in storage cells
3. Beam-target and machine-target interaction
4. Target polarization measurements in situ

Several presentations at the workshop partially overlapped sessions of SPIN-88. Thus, for some of the workshop material we refer to papers and session summaries on Targets, Hadron Sources, Electron Accelerators and High Energy Hadron Interactions.

Experiments based on polarized Storage cells

- **Filter Target Experiment (FILTEX) for LEAR/CERN**

  - target and test experiment: Heidelberg-Marburg-München-Wisconsin

- **Polarized Internal Target Experiment (PINTEX) for IUCF Cooler ring**

  - target: Wisconsin

- **HERA Measurement of Spin…. (HERMES) at HERA electron ring (DESY)**

  - target: based on FILTEX target, with Liverpool (now: Beijing-Erlangen-Ferrara-Yerevan)

- **Internal target experiment DEUTERON for VEPP-3 at BINP/Novosibirsk**

  - source and detector: BINP, target cell: ANL (LDS-upgrade: ANL)

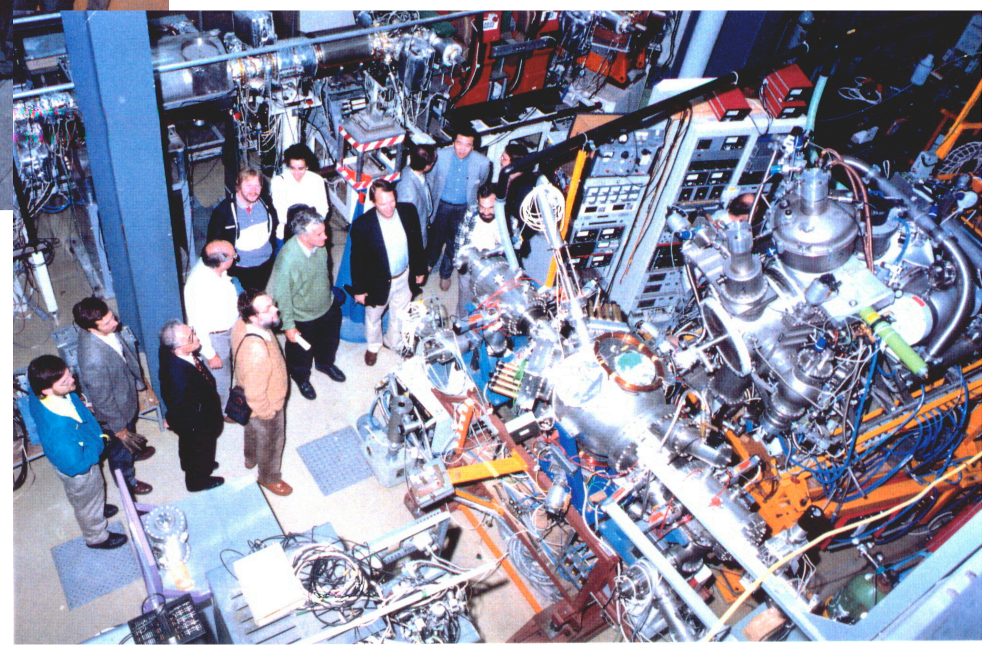
- **Internal target experiment for Amsterdam Pulse Stretcher facility (AmPS)**
- **Internal target experiment (BLAST) for MIT-Bates South Hall Ring**

NEW: Super-FILTEX (PAX) at HESR-FAIR (Darmstadt) → Frank

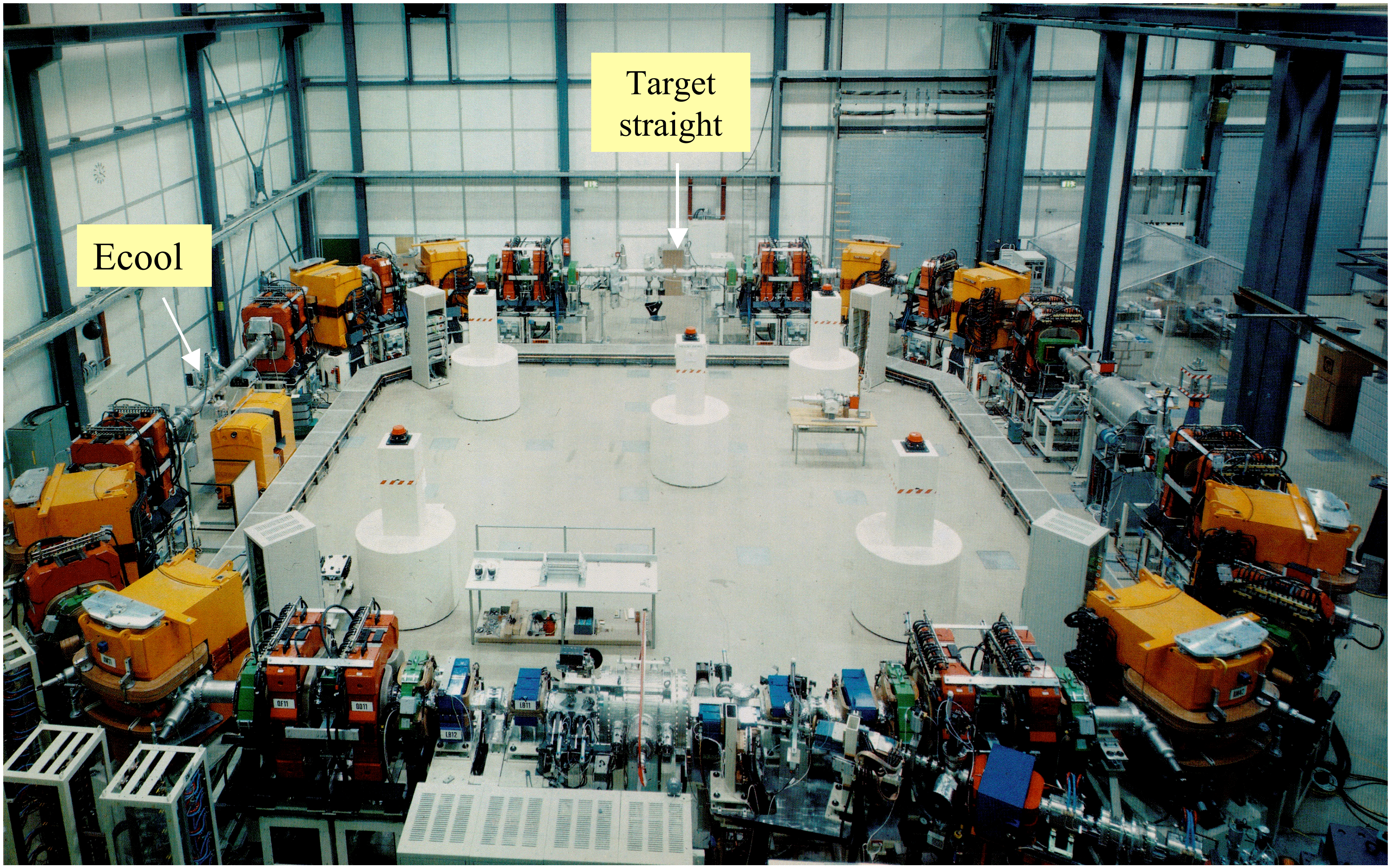
Workshop on Polarized Gas Targets 1991 (Heidelberg)

Willy

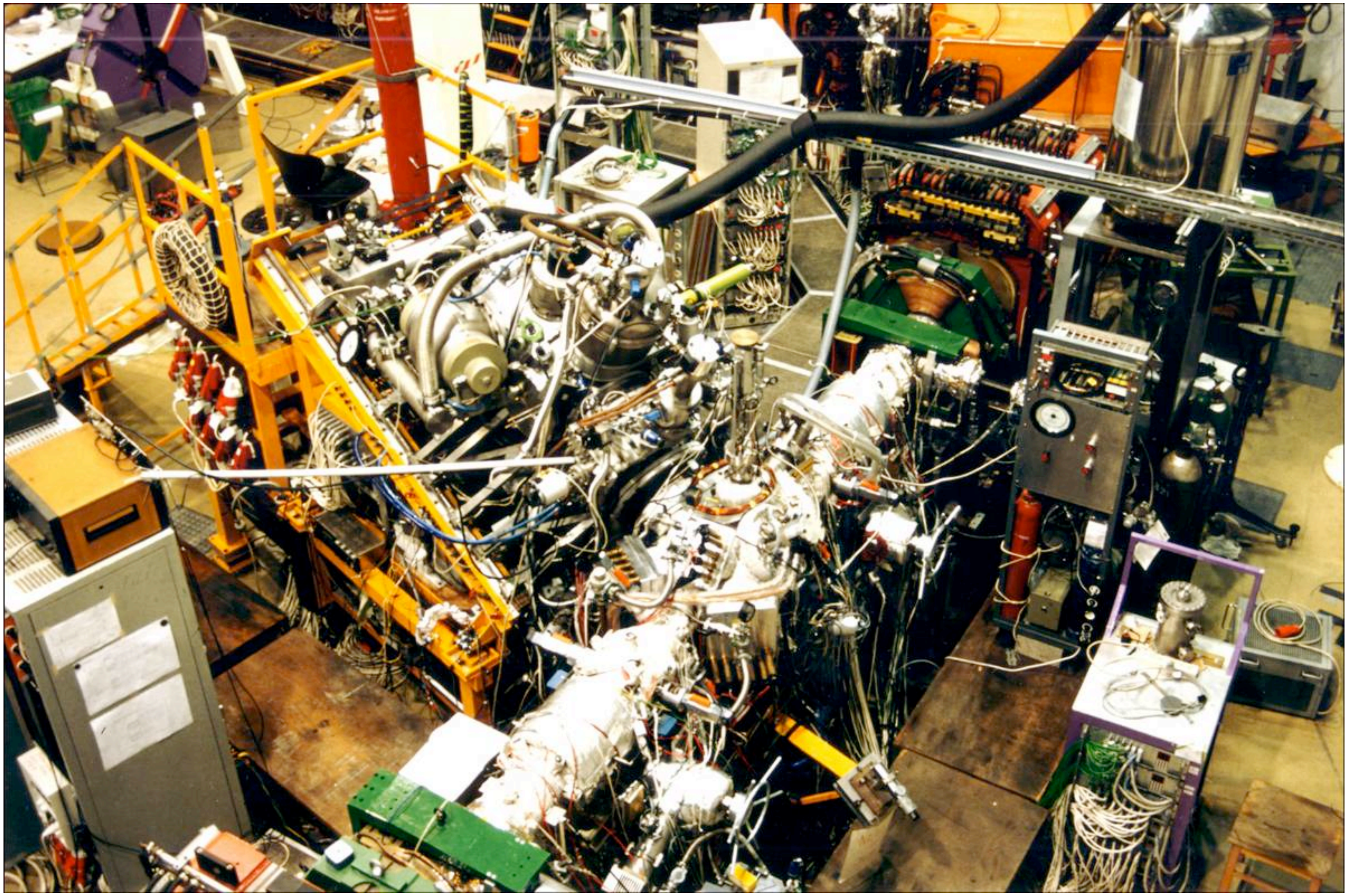
FILTEX Target and TSR (background)



Test Storage Ring (TSR) Heidelberg

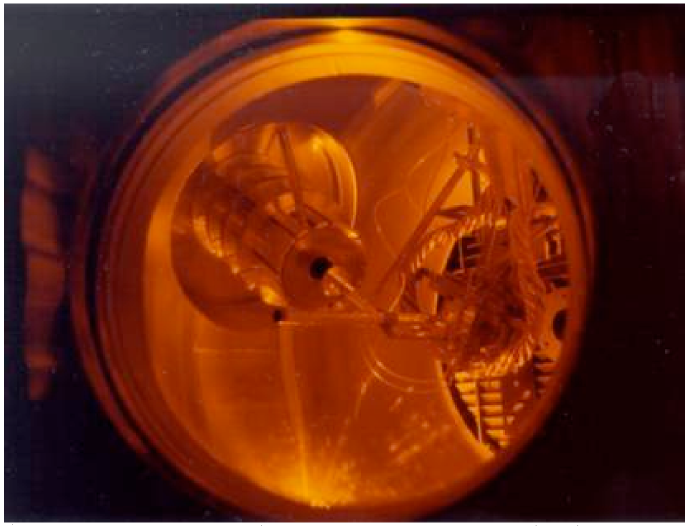


FILEX test experiment at TSR (Heidelberg)

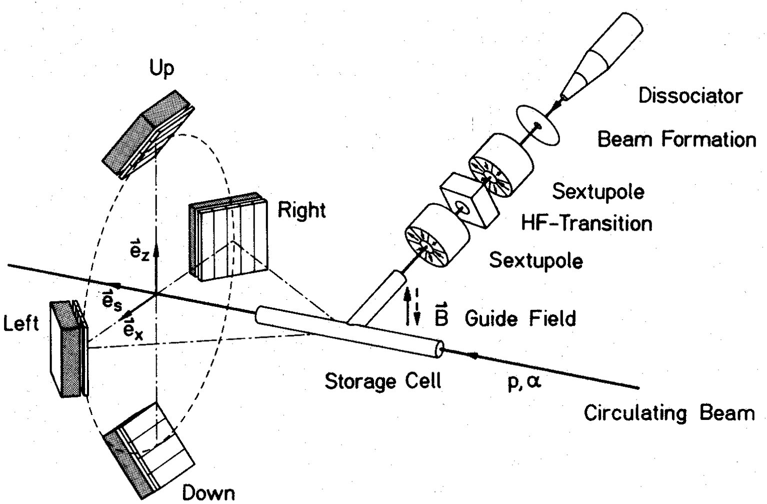


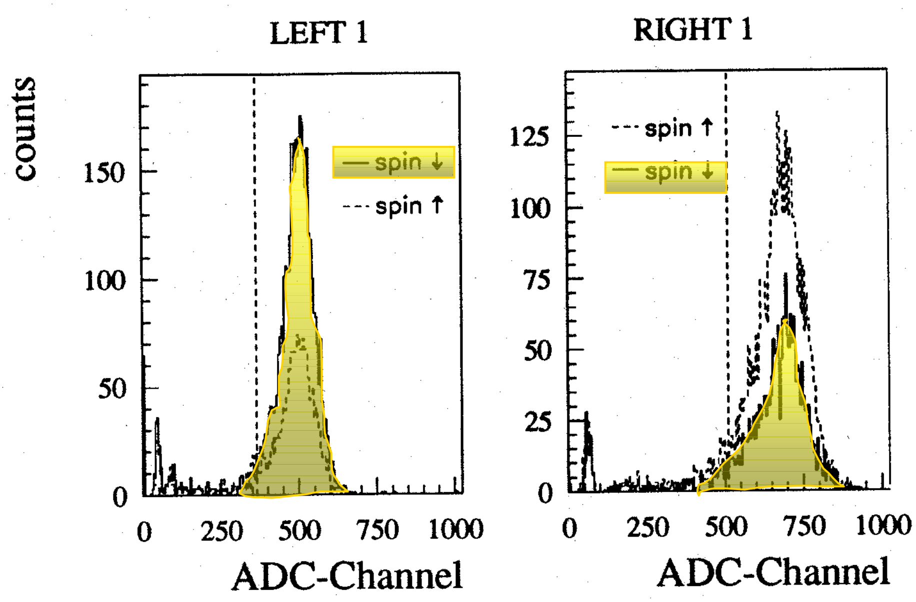
(1992)

FILTEX test: results



- -Target cell (100K) in a weak guide field
- - Areal density of $10^{14}/cm^2$ with two substates
- - P = 0.8 with single substate |_, _>





Highlight # 1

Successful test of PINTEX target using the tandem beam at Wisconsin

POLARIZED ION SOURCES AND POLARIZED GAS TARGETS

MADISON, WI 1993

EDITORS:

L.W. ANDERSON

WILLY HAEBERLI

UNIVERSITY OF WISCONSIN–MADISON

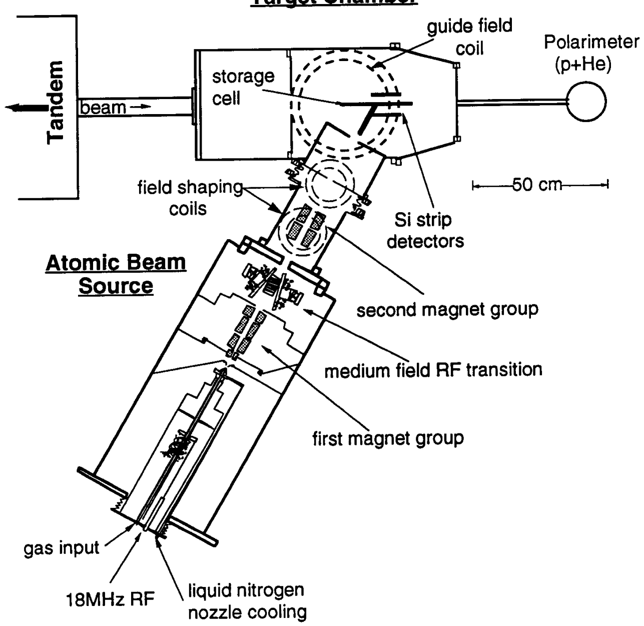


Fig.1. Layout of the Atomic Beam Source at the UW Tandem accelerator.

Table 1. Polarization Results

Medium Field	$p_t(\uparrow)$	$p_t(\downarrow)$	$\lvert p_t \rvert$(ave)	p_{calc}
OFF	0.415±0.032	-0.457±0.031	0.436±0.022	0.485
ON	0.701±0.029	-0.743±0.030	0.722±0.021	0.871

The results indicate that when the medium field transition is on we obtain a polarization that is 83% of the expected maximum. The reason for the 17% loss is not known at the present time. Inefficiency in the medium field unit or polarization losses in the cell are two possibilities. However, the polarization is large enough for experiments at the IUCF Cooler to begin later this year.

K. Zapfe 5

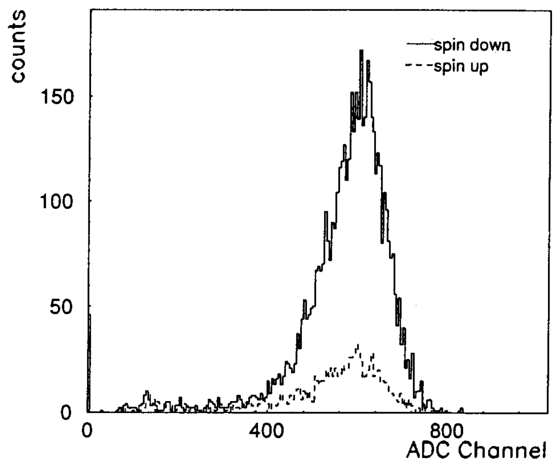


FIG. 1. Pulse height spectrum produced by recoil protons at $\theta_{lab} = 21°$ for target spin up (- - -) and down (——) in the bombardment of the polarized hydrogen target by 27 MeV α-particles circulating in the storage ring. The spectra shown were obtained by selecting a single spin state. The results indicate a target polarization of $P_T = 0.826 \pm 0.004$ (statistical error). The run time was 6 min.

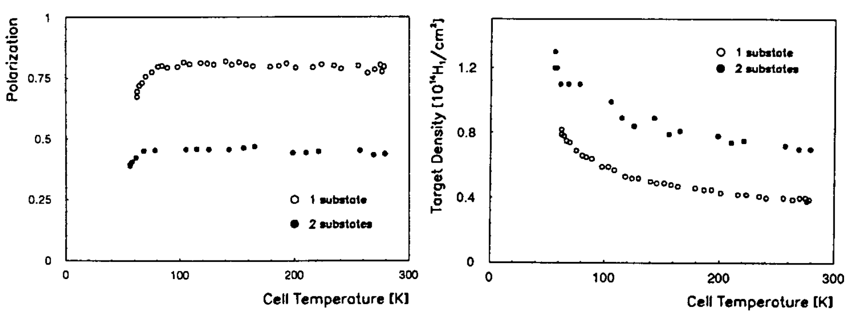


FIG. 2. Measured target polarization (left) and target thickness (right) as a function of the cell wall temperature. Open and closed circles refer to measurements with the RF-transition in the atomic beam source turned off and on, respectively.

POLARIZED ION SOURCES AND POLARIZED GAS TARGETS

MADISON, WI 1993

EDITORS:

L.W. ANDERSON
WILLY HAEBERLI
UNIVERSITY OF WISCONSIN–MADISON

Highlight # 2

Report about the successful tests of the FILTEX target: high density confirmed experimentally!

Highlight # 3

First results by ‚extracted ion polarimeter' about performance of wall coatings (Scott Price and Willy)

similar results obtained at Heidelberg by B. Braun and H.-G. Gaul

POLARIZED ION SOURCES AND POLARIZED GAS TARGETS

MADISON, WI 1993

EDITORS:

L.W. ANDERSON
WILLY HAEBERLI
UNIVERSITY OF WISCONSIN–MADISON

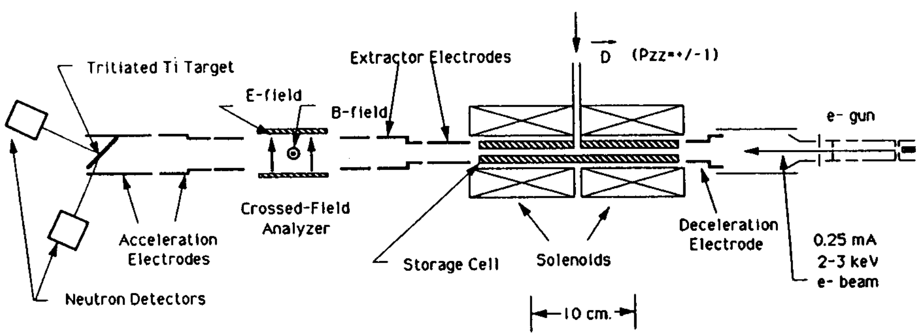
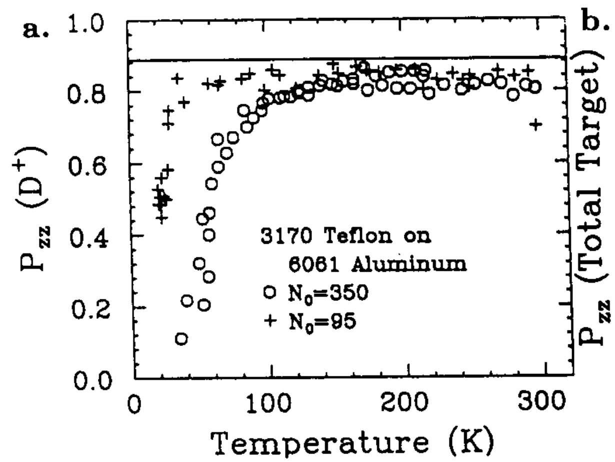
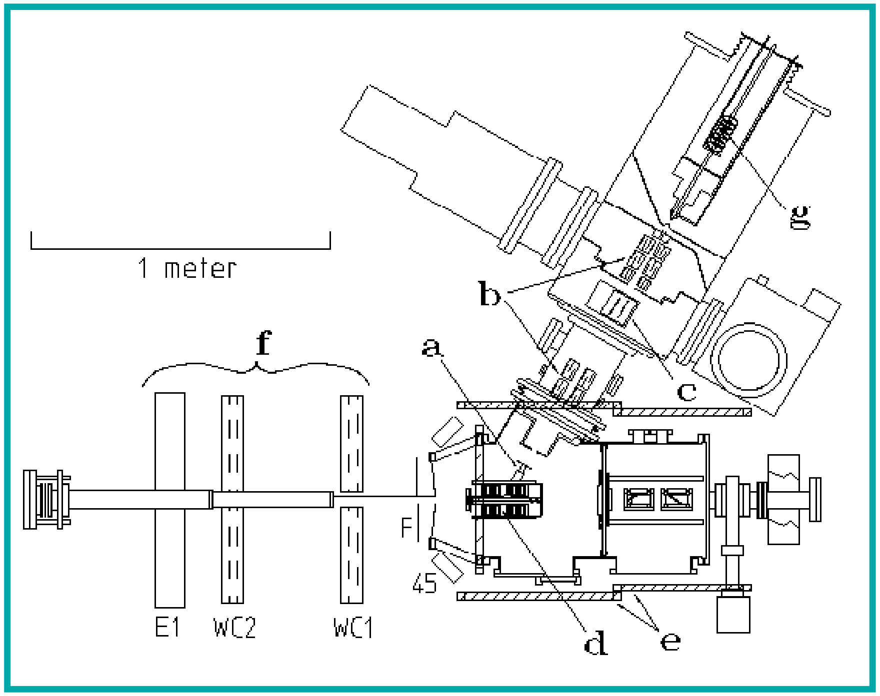


Fig. 1 Diagram of polarimeter used in strong field tests.



PINTEX Target at the IUCF-Cooler

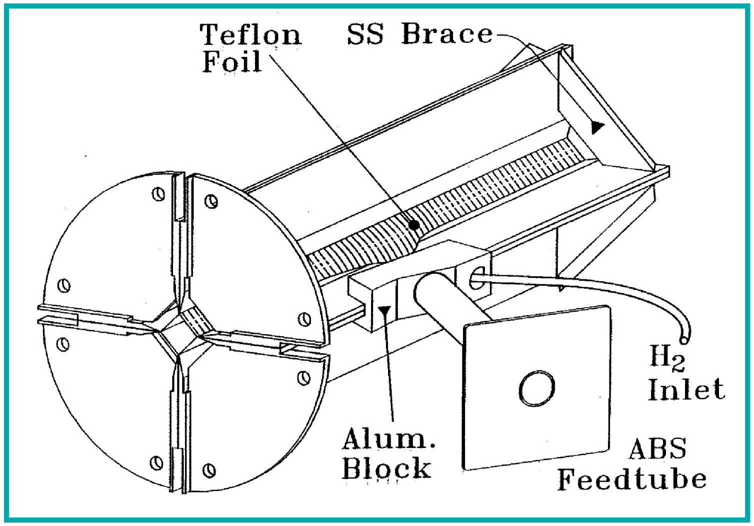
- Operational 1993-2002, first for H, and later also for D atoms
- For H the upper state |1> is injected. By a variable weak B-field (x,y,z) the polarization can be rapidly switched without disturbing the circulating beam
- Room temperature cell with walls from thin Teflon foil
- Surrounded by Si strip detector
- PINTEX has, in conjunction with the flexible IUCF Cooler (polarized protons with T_p = 130 - 450 MeV) produced a wealth of new data

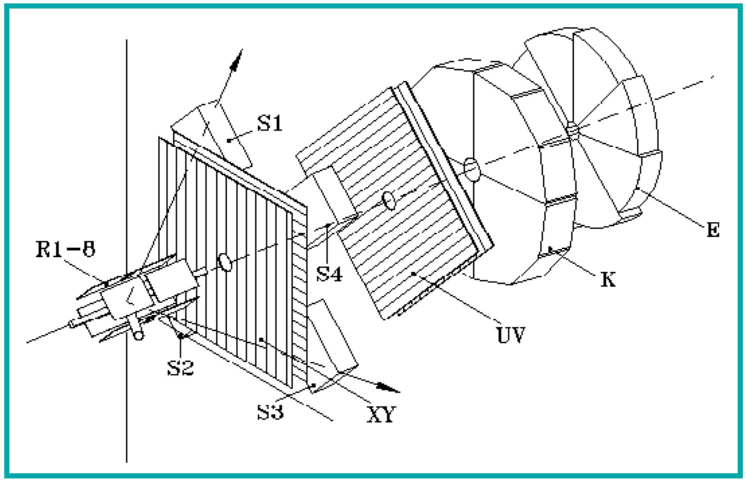


a = feed tube with cell, b = 6-poles, c = rf transition, d = recoil detector, e = flip and correction coils, f = detector, g = dissociator

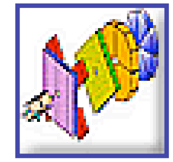
Design of PINTEX Storage Cell

- Optimized for detection of low energy recoil particles - Si strip detectors close to cell
- Walls consist of ~ 450mg/cm^2 Teflon foil suspended by 4 fins and forming a quadratic channel of 10x10mm^2, 250mm long
- Cell at room temperature in weak magnetic guide field. The direction of the B-field can be rapidly switched between x, y, z in order to vary the target polarization





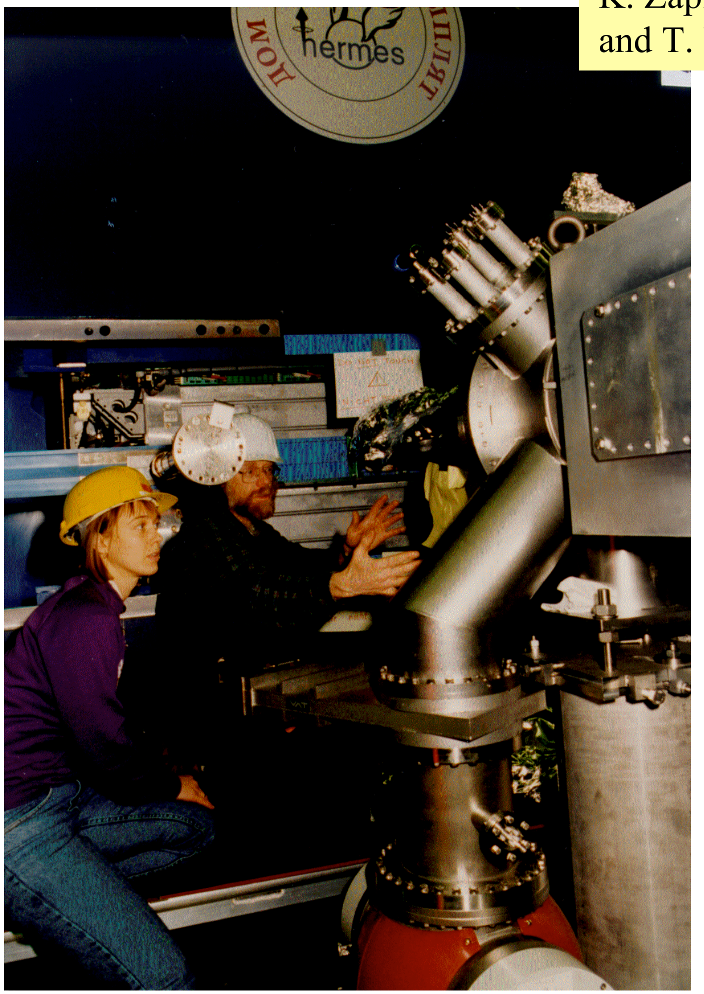
PINTEX Target at the IUCF-Cooler



- Target had been upgraded in 2000 to produce vector and tensor polarized deuterium targets
- Source provided P_z and P_{zz} of both signs by a system of two medium field transitions (MFTs)
- Direction of the polarization (and sign for P_z) provided by the set of Helmholtz coils previously used
- Operation terminated in 2002 after ten years

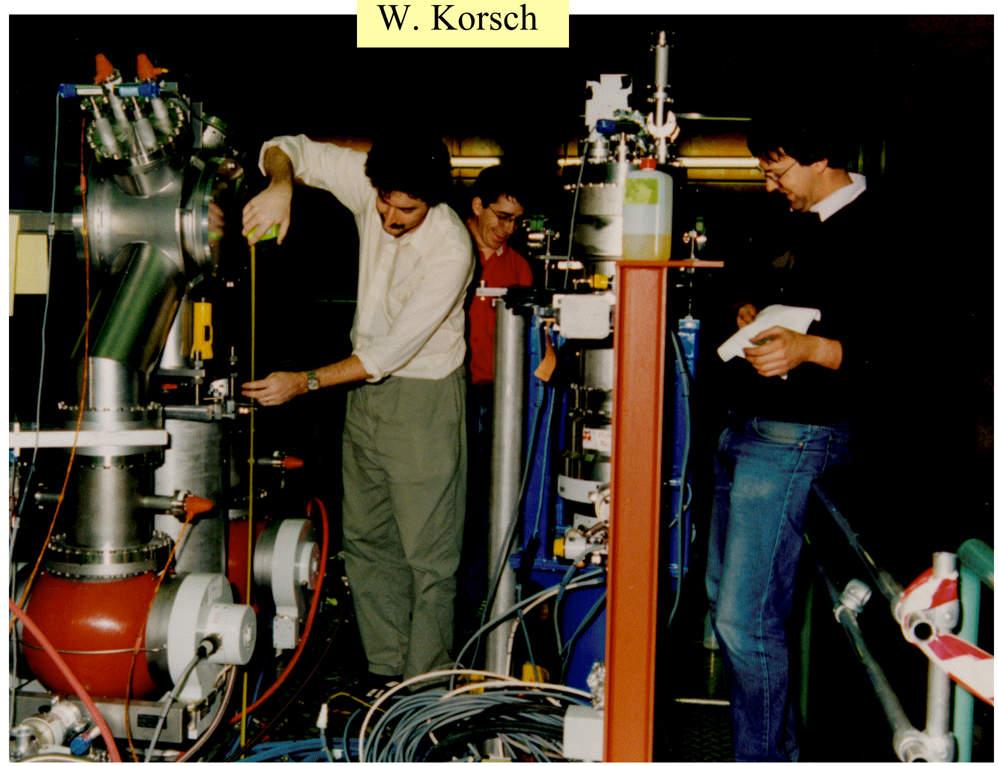
1993: HERMES approved

K. Zapfe
and T. Wise



1994: Work on target installation (^{3}He)

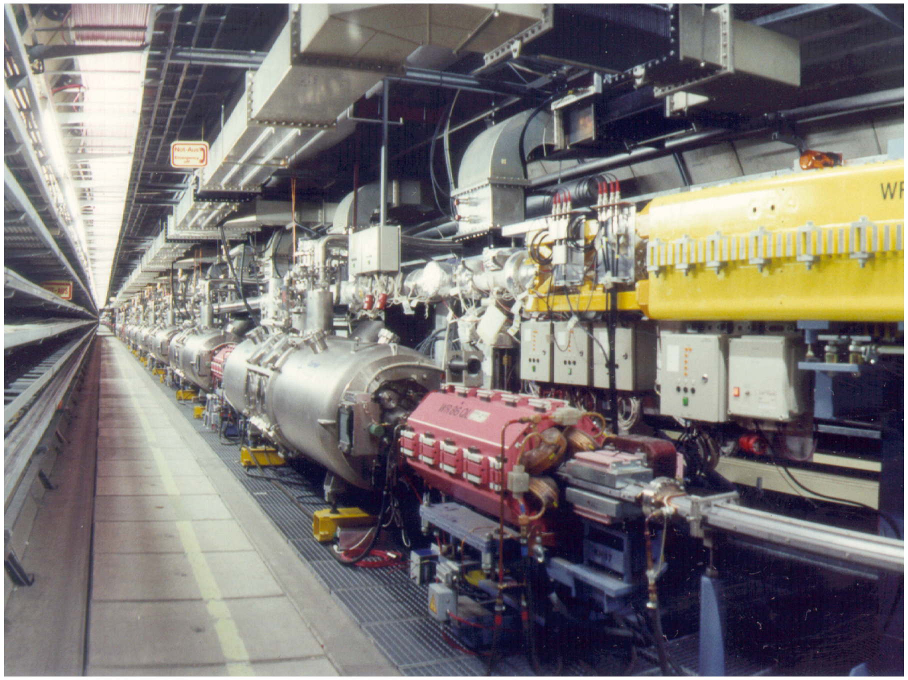
S. Pate and
W. Korsch



HERMES Collaboration 1994/95

HERMES experiment at HERA-e

HERMES experiment (HERA east)

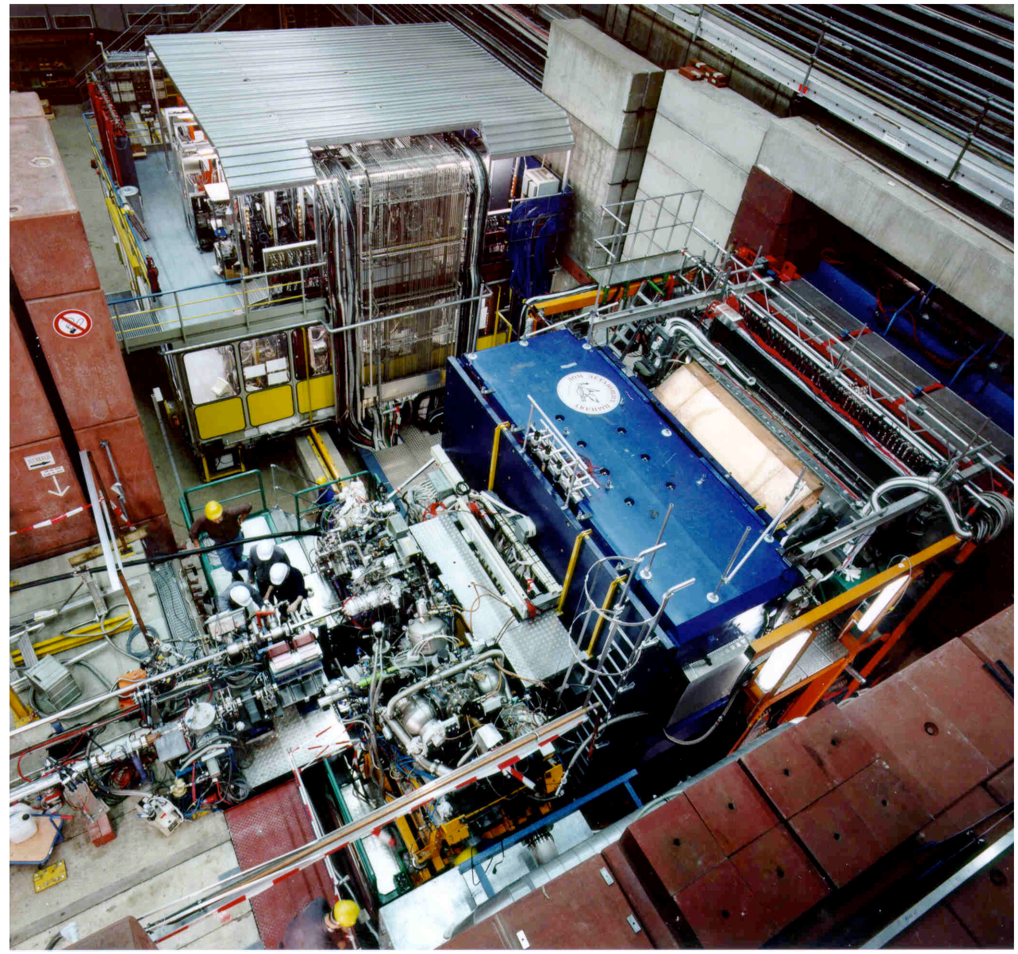


HERA Collider (DESY – Hamburg)

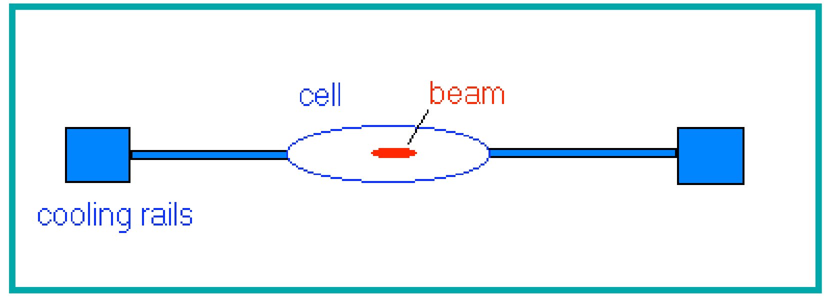
C = 6.3km, E_p = 920GeV, E_e = 27.5GeV

Electrons self-polarized

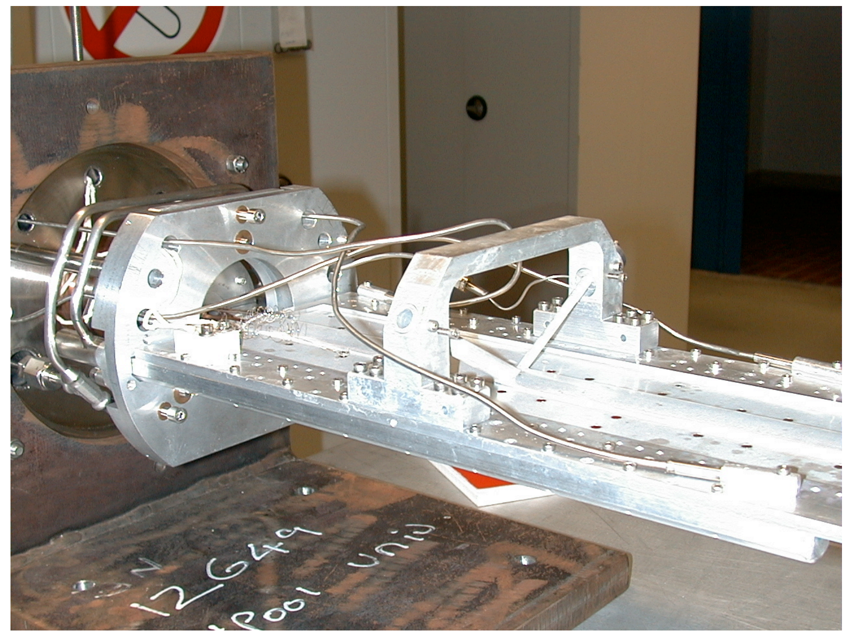
Shown: SC cavities in HERA west straight



Storage Cell Design: HERMES Target



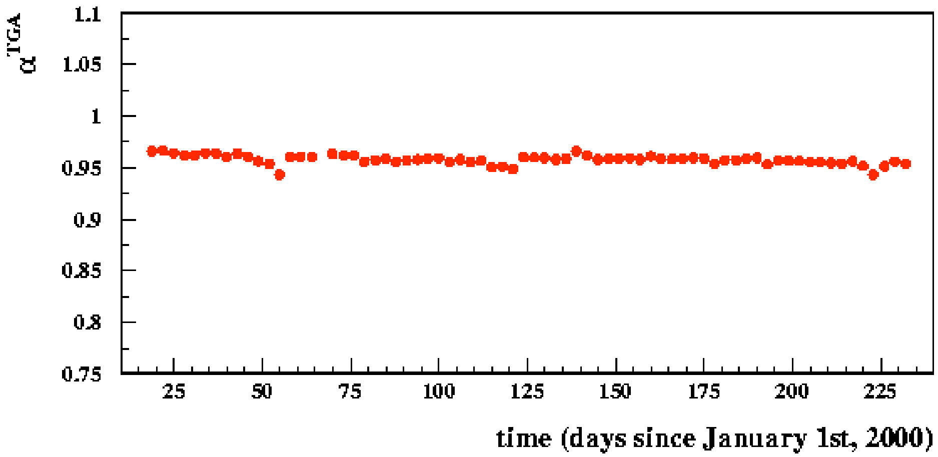
- Cell optimized for operation in an electron storage ring
- System of W collimators for protection against beam and SR
- Cooled via cooling rails by cold He gas to 60-100K
- 75mm Al walls with Drifilm coating - radiation damage visible!
- But: Very effective wall coating due to ice layer maintained by small fraction of water in the atomic beam



Cell design and fabrication: Tom Wise (with Geoff Court)

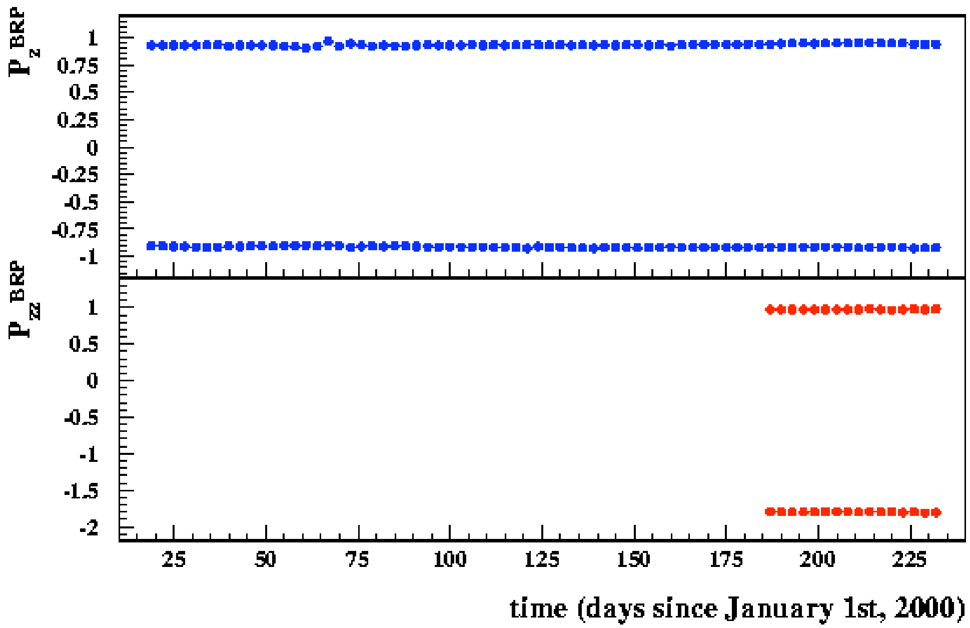
Now: Ferrara group

HERMES Target at HERA-DESY



Atomic fraction α for deuterium run 2000

$\alpha = N_{atom} / (N_{atom} + N_{mol.})$



Polarization P_z, P_{zz} for deuterium run 2000

vector: $P_z = N_+ - N_- / (N_+ + N_-)$

tensor: $P_{zz} = 1 - 3N_o$

Workshop PST99 at Erlangen (1999)

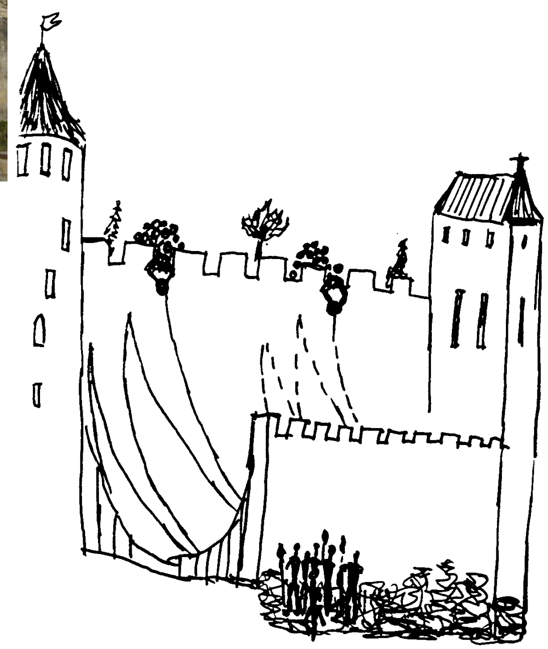
Willy and
R. Fleischmann

About 110
participants

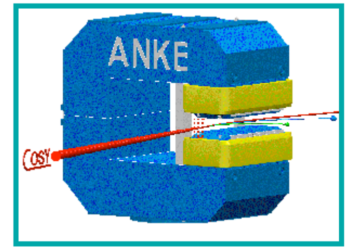
PST99 Opening Talk: **Polarized Gas Targets and Medieval Warfare**

Carcasonne - France

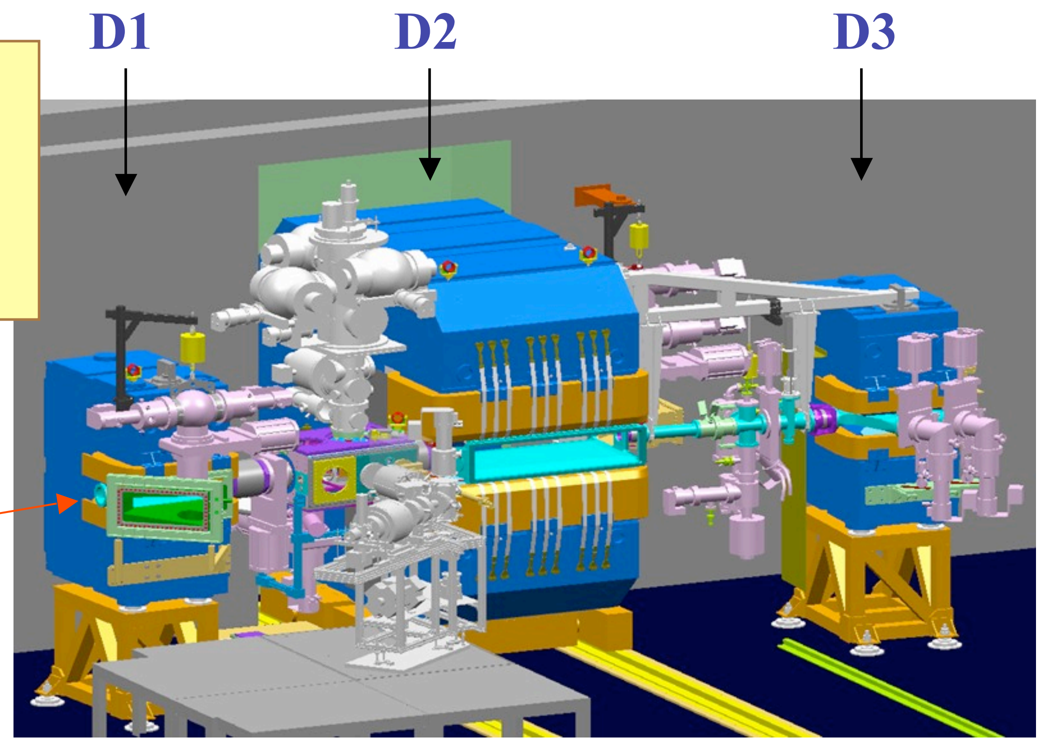
multiple use of each projectile -
back and forth oscillation
in potential well...



Target of the ANKE-Spectrometer



Target arrangement with ABS, target chamber and polarimeter, and the differential pumping system. The detector system is not shown.

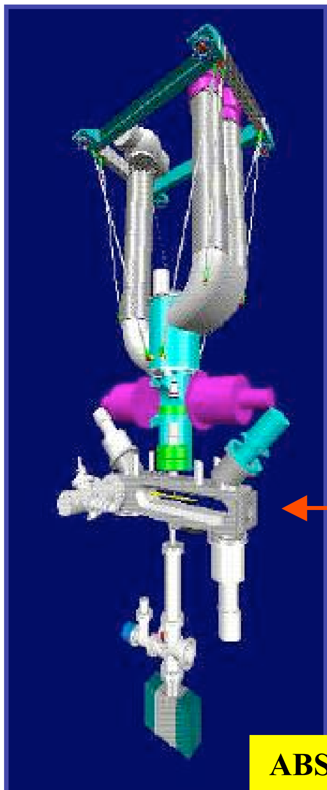


ABS, LS polarimeter and target chamber have been commissioned. The cell cross section has been determined by scraper studies.

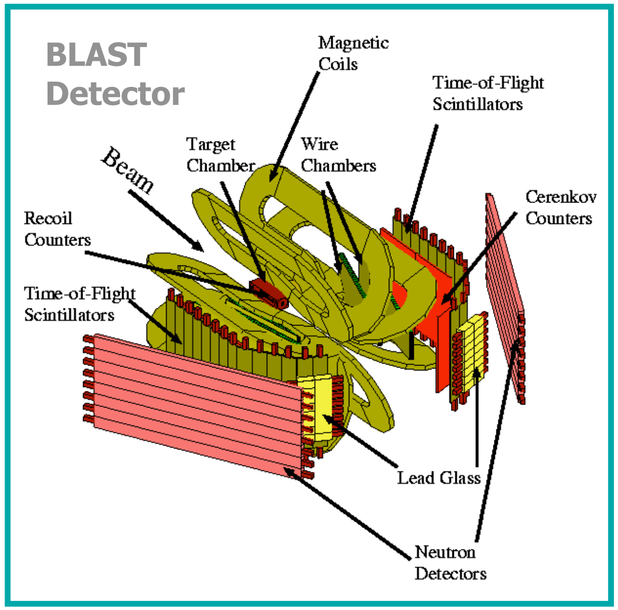
The polarized target has been recently moved into COSY. Spin program approved for 2005-2008

ABS Target for BLAST/MIT-Bates

- Target based on former AmPS target(NIKHEF)
- Toroid spectrometer field has been shielded carefully



ABS, target chamber and polarimeter



BLAST experiment at the SHR (MIT-Bates)

- Magnetic spectrometer with toroidal field and internal polarized storage cell target (deuterium)
- Over 200mA of polarized electrons stored with P ≈ 0.7
- Siberian snake for long. polarization at IP

Operation terminated in June 2005 ☹

Final paper work

INSTITUTE OF PHYSICS PUBLISHING — REPORTS ON PROGRESS IN PHYSICS

Rep. Prog. Phys. **66** (2003) 1887–1935 — PII: S0034-4885(03)18688-5

Polarized gas targets

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[2] Department of Physics, University of Wisconsin, 1150 University Avenue, Madison, WI 53706-1390, USA

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Abstract

This review describes the development and present performance of nuclear polarized gas targets in nuclear or particle physics experiments. After a brief account of the various development steps, the design principles for the relevant light nucleon targets, hydrogen, deuterium and ^{3}He, for storage rings, are discussed. Most of these targets make use of so-called storage cells in order to enhance the target thickness. The performance of targets used in medium and high-energy ion and electron storage rings is reviewed. Finally, future trends and possible improvements are discussed.

First encounter with Willy

Polarization Nuclear Physics

On the occasion of the 70th birthday of Rudolf Fleischmann (Erlangen)

Proceedings of a Meeting held at Ebermannstadt October 1–5, 1973

Edited by D. Fick
Max-Planck-Institut für Kernphysik, Heidelberg/BRD

DIRECT INTERACTION

W. Haeberli
Department of Physics, University of Wisconsin, Madison, Wisconsin

1. INTRODUCTION

In this section we will be discussing so called direct reactions which take place on a very fast time scale, a time given roughly by the nuclear diameter divided by the velocity of the incident particle, or ~ 10^{-22} sec. Whatever fine structure there may be in the cross section from individual resonances is supposed to be averaged out by the experiment, i.e. we are interested in the energy-averaged S-matrix. Experimentally one tests whether the reaction or scattering is "direct" by measuring the cross section at a number of angles as a function of bombarding energy and by noting the absence of pronounced fluctuations with energy. Correspondingly the cross section angular distributions for direct reactions show only slow, systematic changes when the energy is varied over a range of several MeV. In practice the averaging over the fine structure is often accomplished painlessly in the experiment by the finite thickness of the target and by the energy spread of the beam.

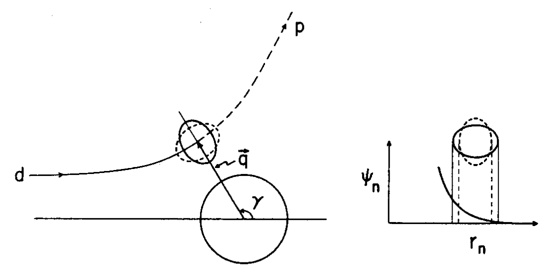


Fig. 29. Semi-classical explanation of the tensor analyzing power in (d,p) reactions in terms of the deuteron D-state [ref. 59)].

Willy in Heidelberg (1983)

Picking cherries

‚Wandern' in the Neckar valley

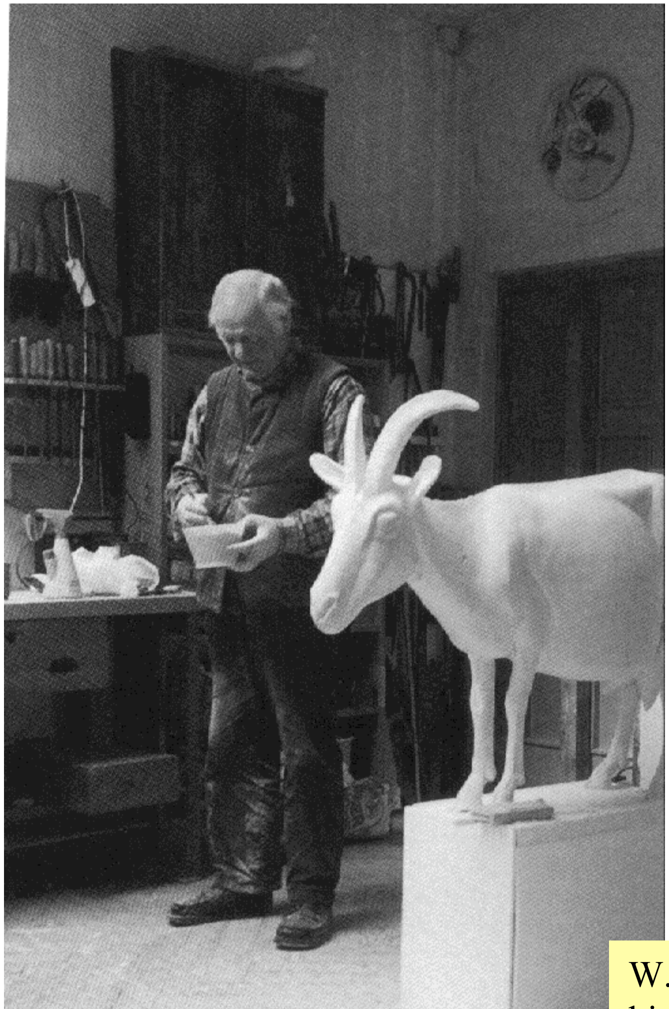
Meeting with Prof.Willy Uhlig (Nürnberg)

His studio at the Nürnberg city wall

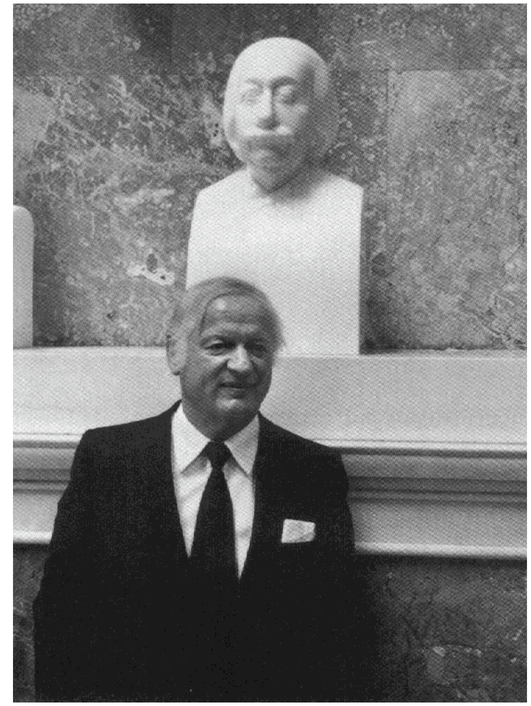
Exhibition in the Fembo House (Nürnberg)

W I L H E L M   U H L I G

Prof. Willy Uhlig

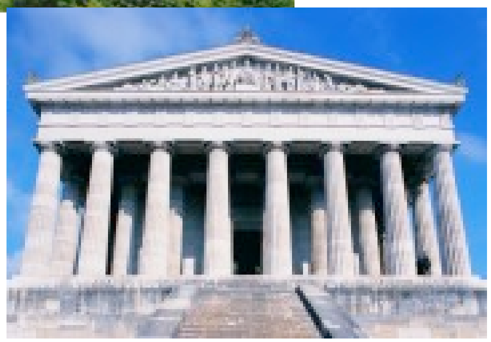


W. Uhlig in his Studio



Presentation of the Einstein bust in 1990 at the Walhalla Memorial

Walhalla near Regensburg (Bavaria)



- a memorial of famous Germans, Austrians and Swiss (!)
- founded by Ludwig II, King of Bavaria
- in 1990 the bust of A. Einstein has been added, created by W. Uhlig
- still some space left…

His favourite castle Neuschwanstein

Best wishes from all of us!

Physikalisches Institut Erlangen

HERMES Collaboration

[redacted]

Searching for a present for Willy

ABC

ABC