Polarized Internal Targets

Frank Rathmann
Institut für Kernphysik
Forschungszentrum Jülich

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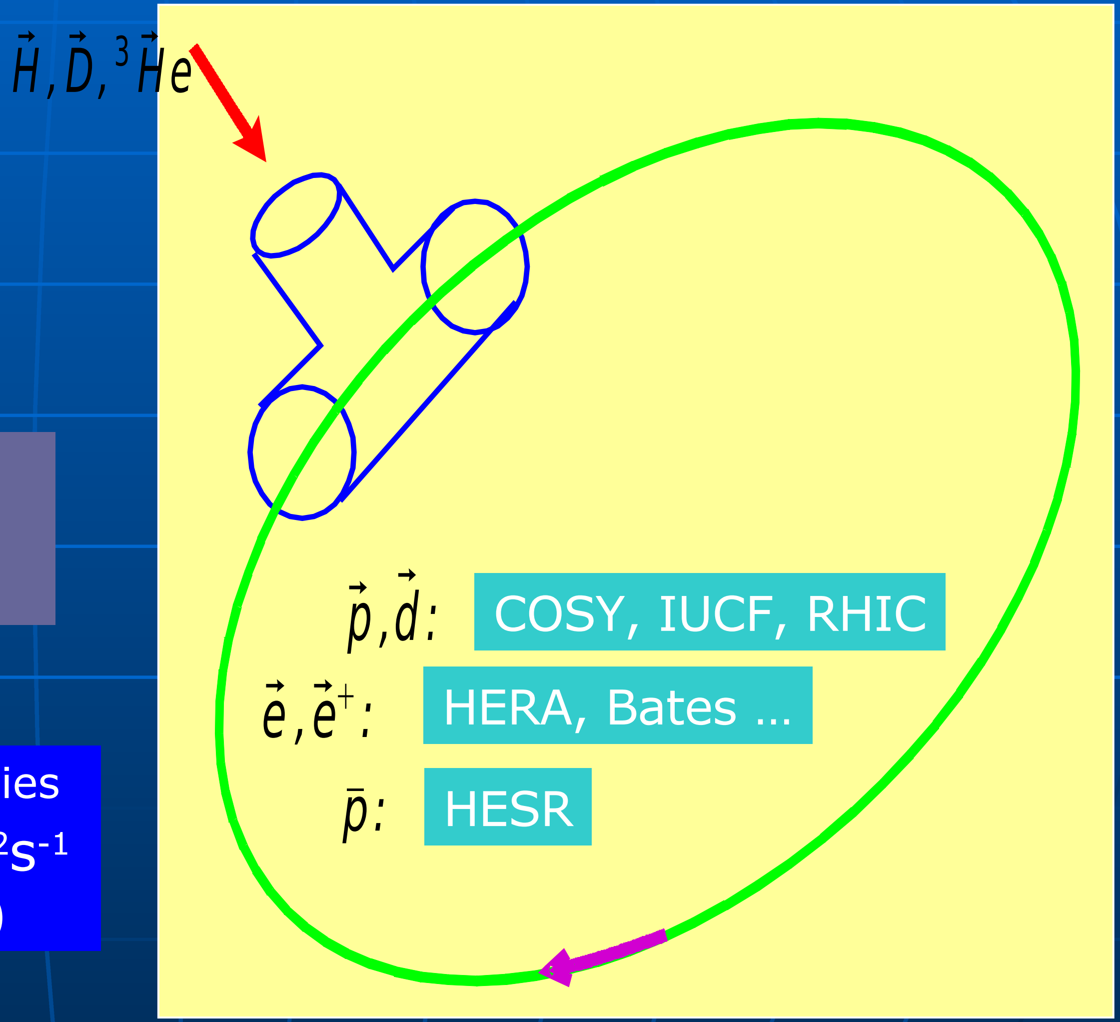
Gas Targets in Storage Rings

Gas Targets:
- Thin
- isotopically pure
- polarized

Storage Rings:
- high stored currents
- low background

Presently achievable Luminosities

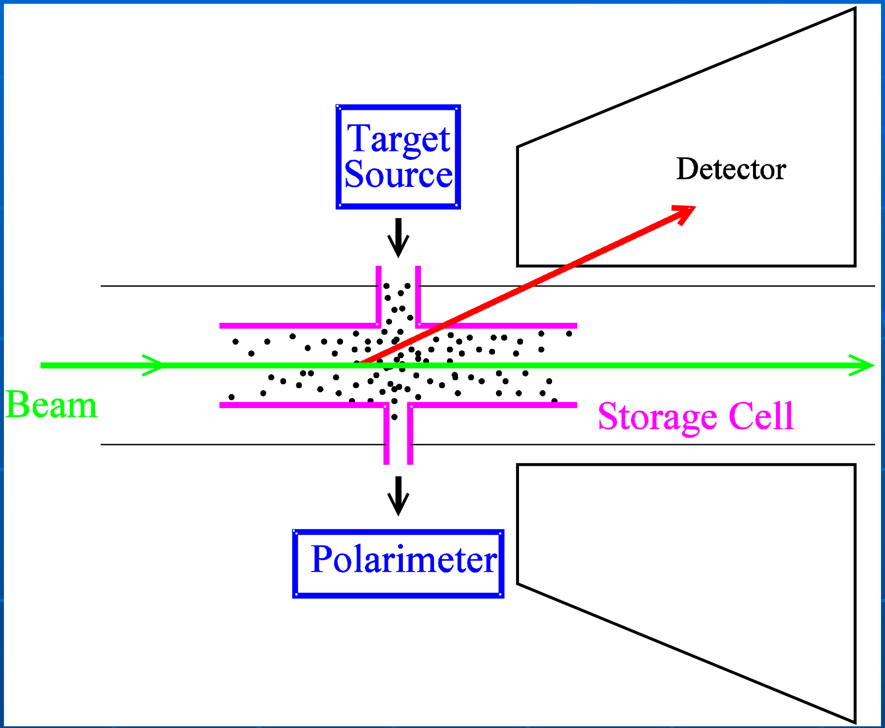
L ~ 10^{29} – 10^{31} $cm^{-2}s^{-1}$
(protons) (electrons)



Outline

- Introduction
  - Principle of a PIT
  - Main types of sources for targets
- Storage Cells
  - Spin Relaxation
  - Examples
- Polarimetry of PIT's
  - hadronic reactions
  - Ion-extraction
  - extraction of neutral gas samples

Principle of a polarized internal target



Polarized gas targets internal to storage rings provide **distinct advantages** over solid or high pressure targets:

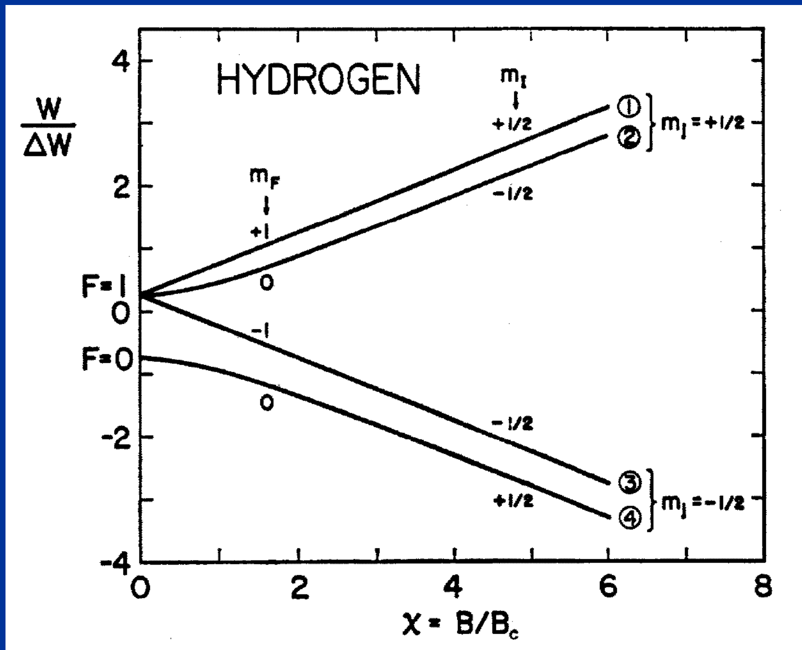
- rapid reversal of target spin (x,y,z): In H/D up to 100 Hz achieved
- isotopically pure, no contamination by unpolarized components in the target
- low background due to absence of container walls
- no radiation damage, target gas replenished every few ms

Interaction Region				
point-like	5-10 mm	free jet	**low density**	10^{12} cm^{-2}
extended	200-500 mm	storage cell	**high density**	10^{14} cm^{-2}

⇒ PIT's are ideally suited for high precision experiments

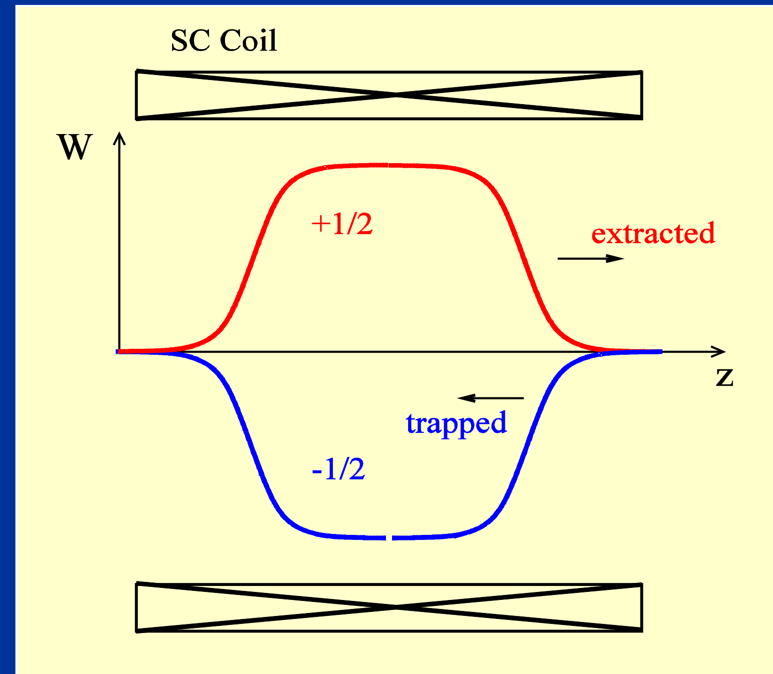
Four main types of sources for PIT's

① Atomic beam source



Atoms with m_j=+½ focused in sextupole magnets. RF transitions select HFS.

Ultra-cold source

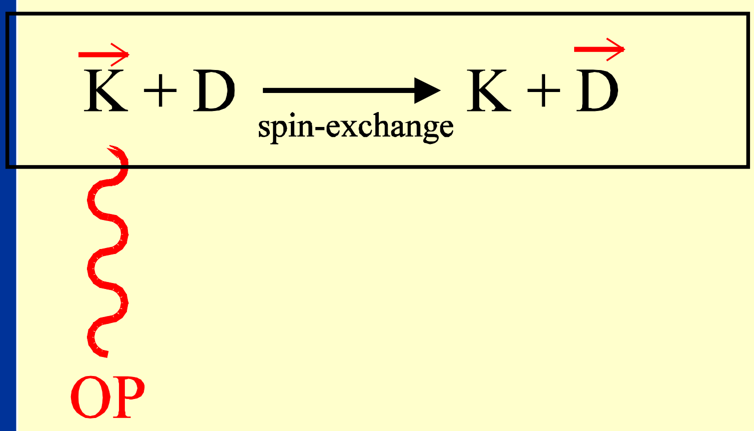


$W_{thermal} \ll W_{magnetic}$

One electron spin state m_j=½ extracted from strong solenoid field and focused

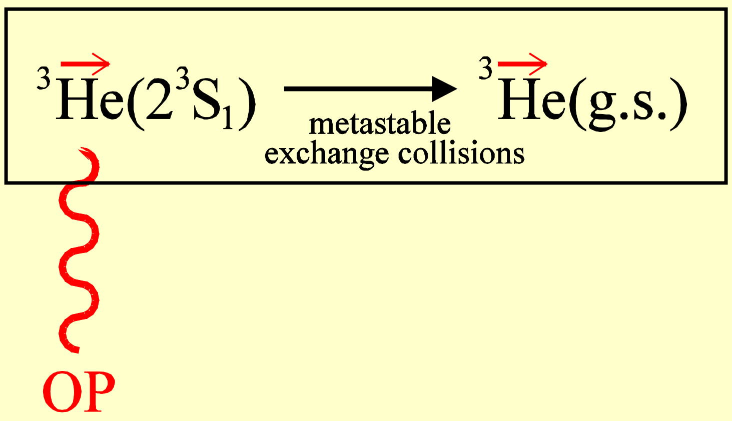
Main types of sources (cont'd)

Spin-Exchange source



Deuterium or Hydrogen atoms polarized by spin-exchange with optically pumped potassium vapor

^{3}He source

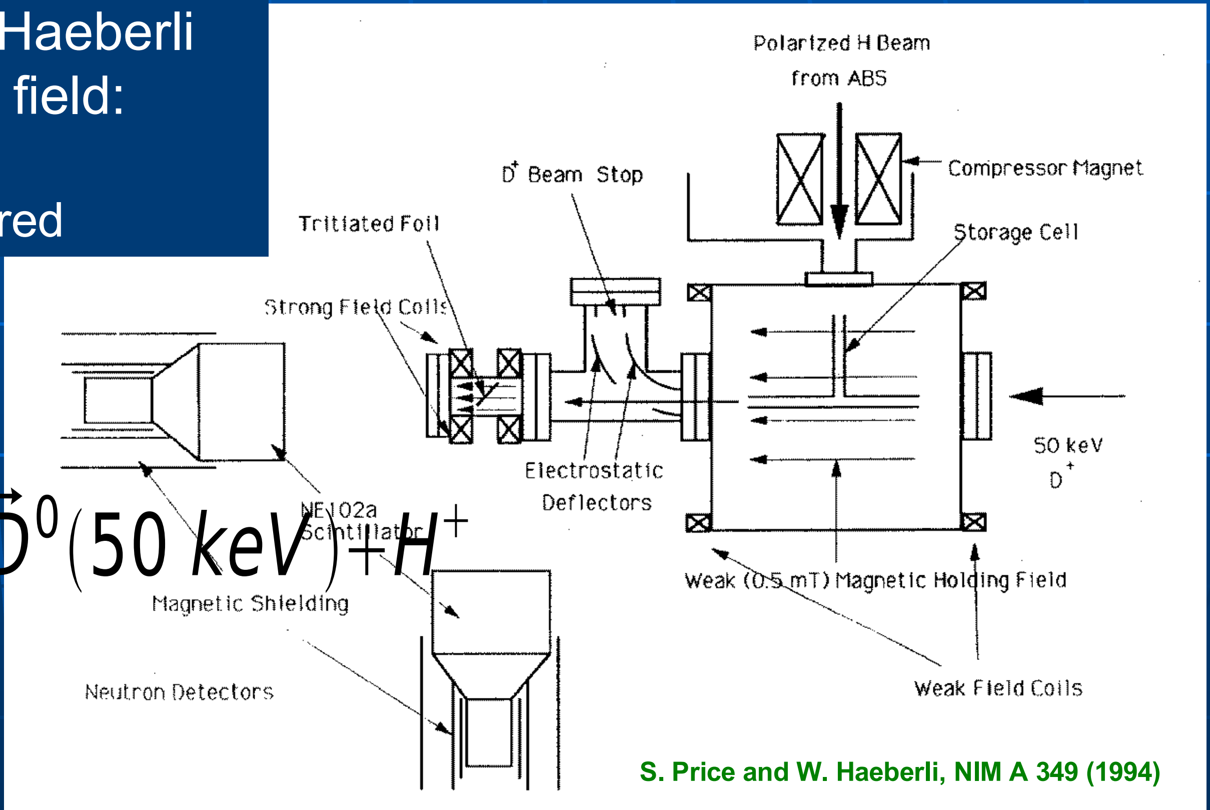


Small fraction of metastable ^{3}He (2^3S_1) atoms pumped with laser optical pumping. Ground state atoms polarized via exchange collisions

Storage cells

- **Main task:** Identification of suitable cell wall materials that
  - suppress depolarization in wall collisions
  - are compatible with storage ring operation

Investigations by Price & Haeberli in a weak magnetic guide field:
- Electron Pickup
- Tensor Polarization measured

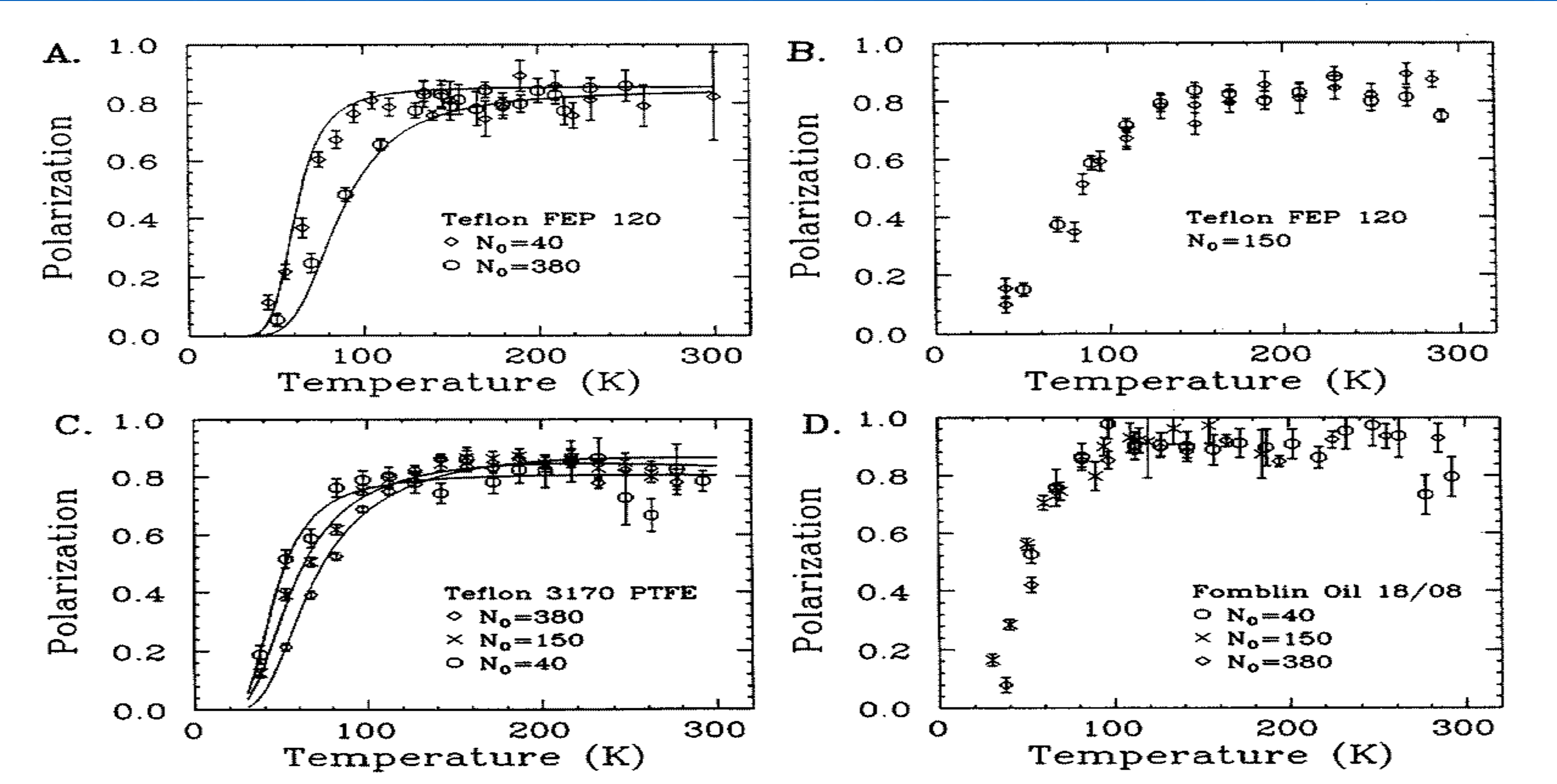


S. Price and W. Haeberli, NIM A 349 (1994)

$$D^+(50\,keV)+\vec{H}^0\rightarrow\vec{D}^0(50\,keV)+H^+$$

$$^3H(\vec{d},n)^4He$$

Results



Target thickness $d_t \sim \frac{1}{\sqrt{T}}$

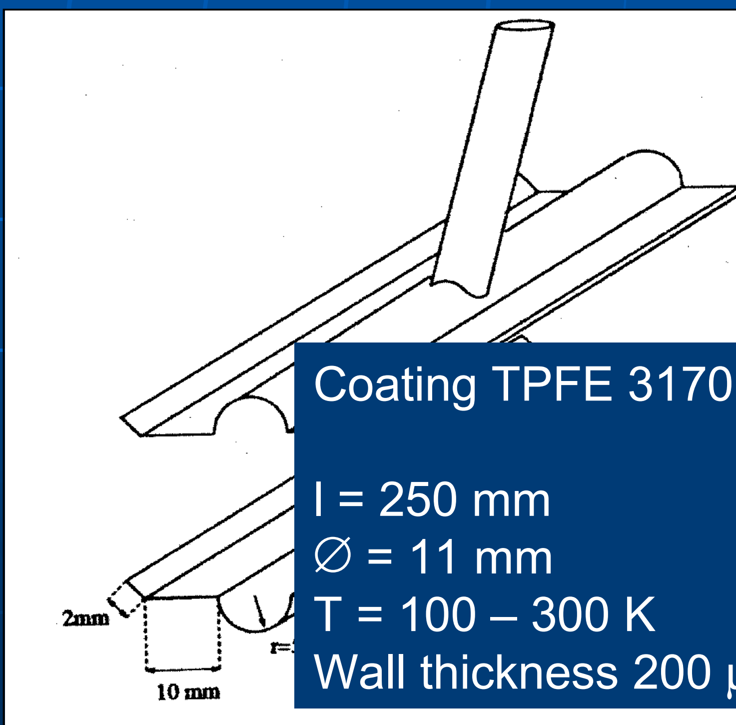
Figure of Merit $FOM \sim P^2 \cdot d_t$

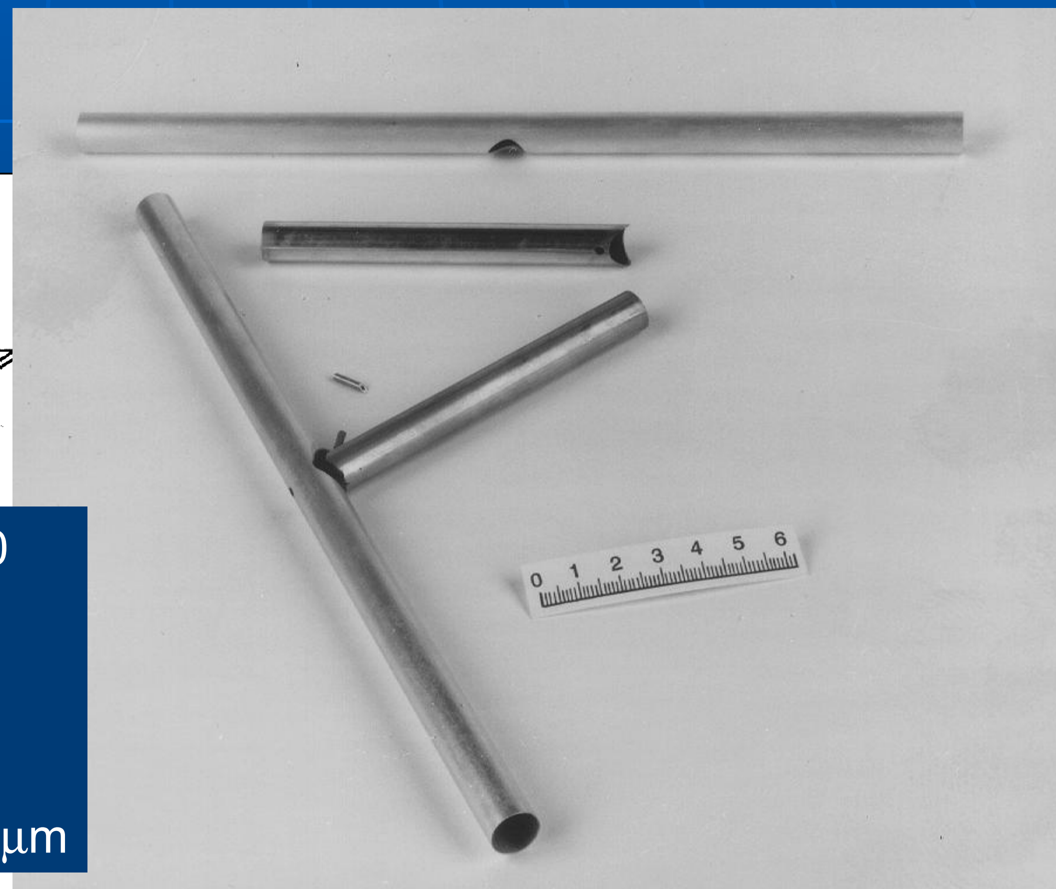
Storage cells for storage rings

1992

Filtex Test Experiment at Test Storage Ring Heidelberg

3. Clam shall mechanism
   - No limitation of machine acceptance during injection
4. Spot-welded structure
   - Test of a closed cell
5. Cylindrical tube



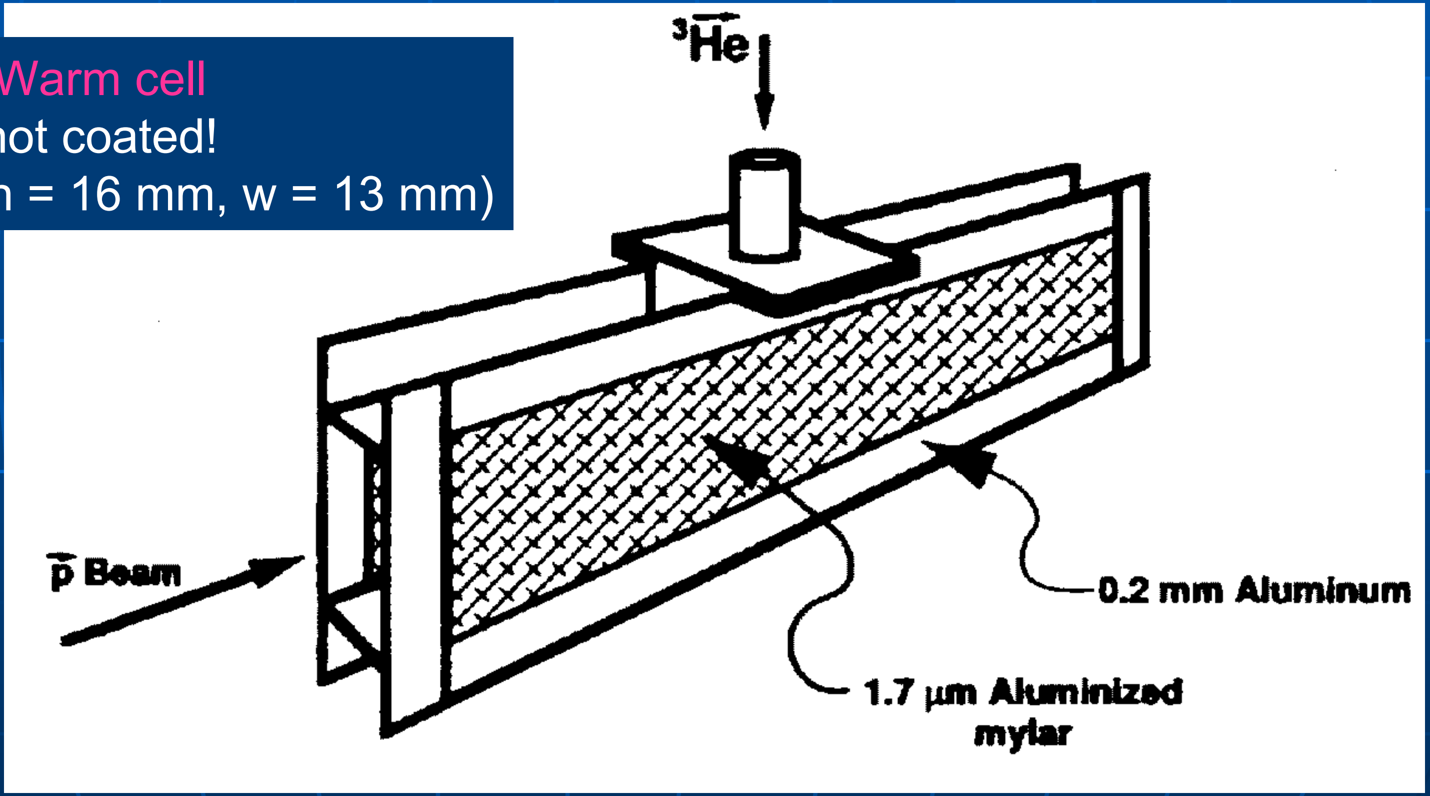


Coating TPFE 3170

l = 250 mm
∅ = 11 mm
T = 100 – 300 K
Wall thickness 200 μm

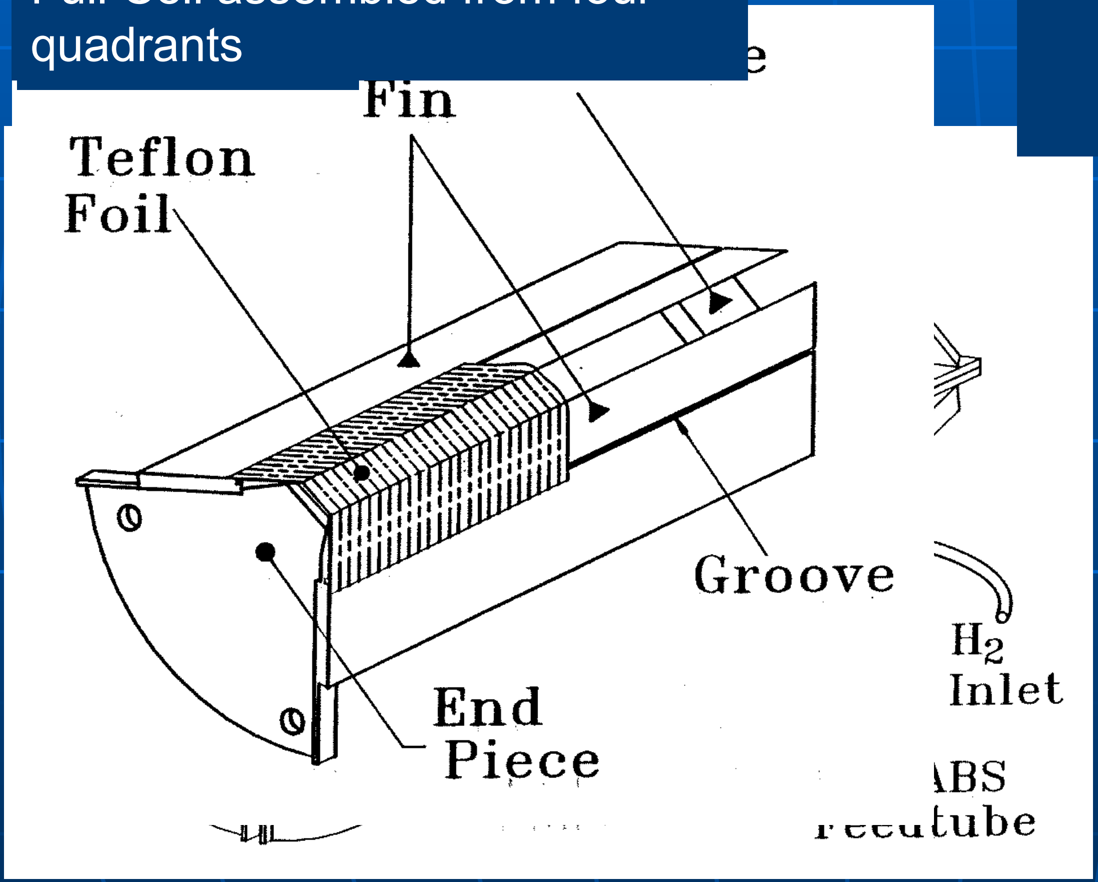
1992 ^{3}He target at IUCF

Warm cell
not coated!
(l = 400 mm, h = 16 mm, w = 13 mm)



1994 PINTEX cells for pp elastic experiments

Full Cell assembled from four quadrants

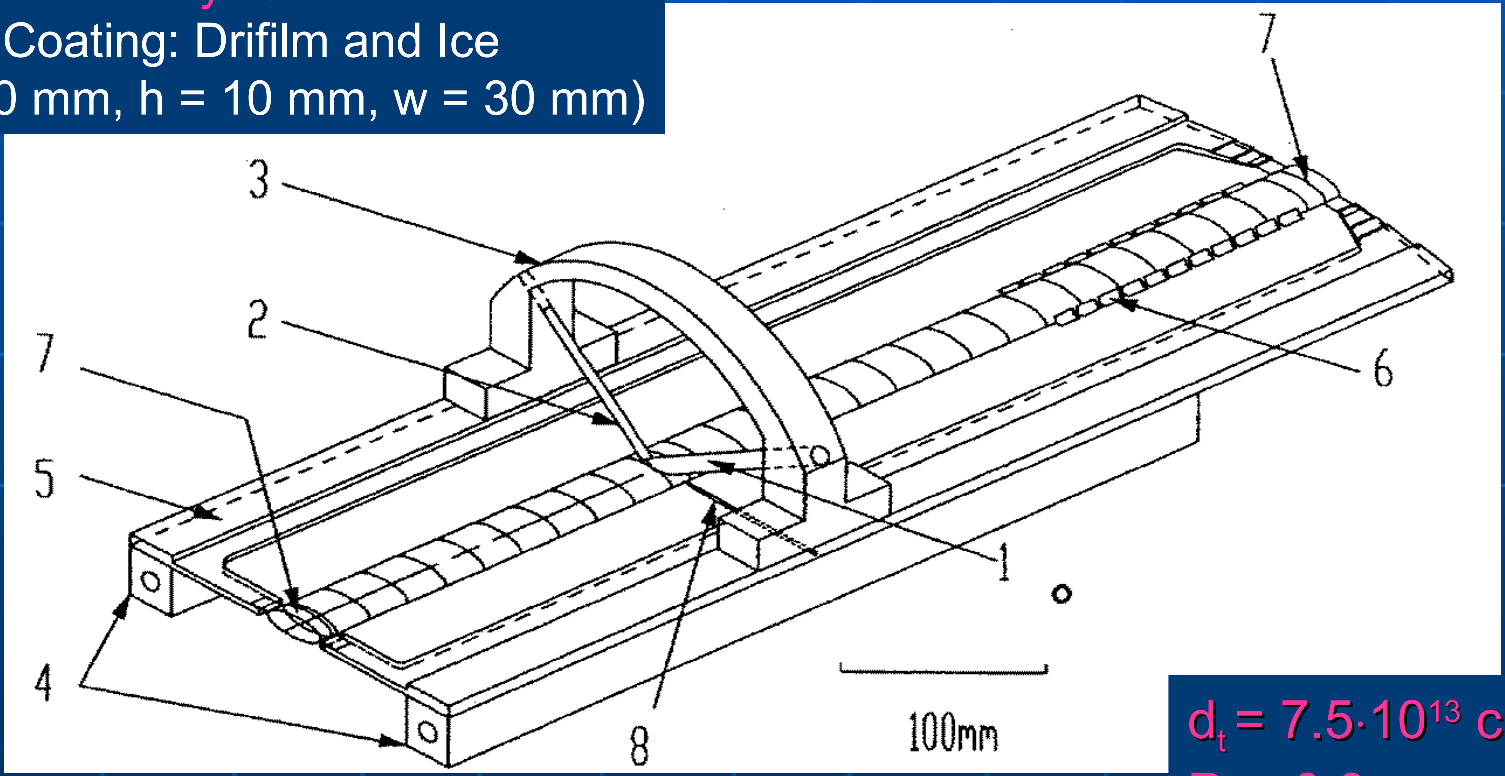


- Thin walls from teflon foil
  - 450 µg/cm² (1 µm)
- warm cell

This type of cell ideally suited for **quasi-free pn scattering** on deuteron target with detection of low energy spectator protons

1996 HERMES H and D target cell at HERA-e

High luminosity ⇒ T = 35 - 260 K
Coating: Drifilm and Ice
(l = 400 mm, h = 10 mm, w = 30 mm)

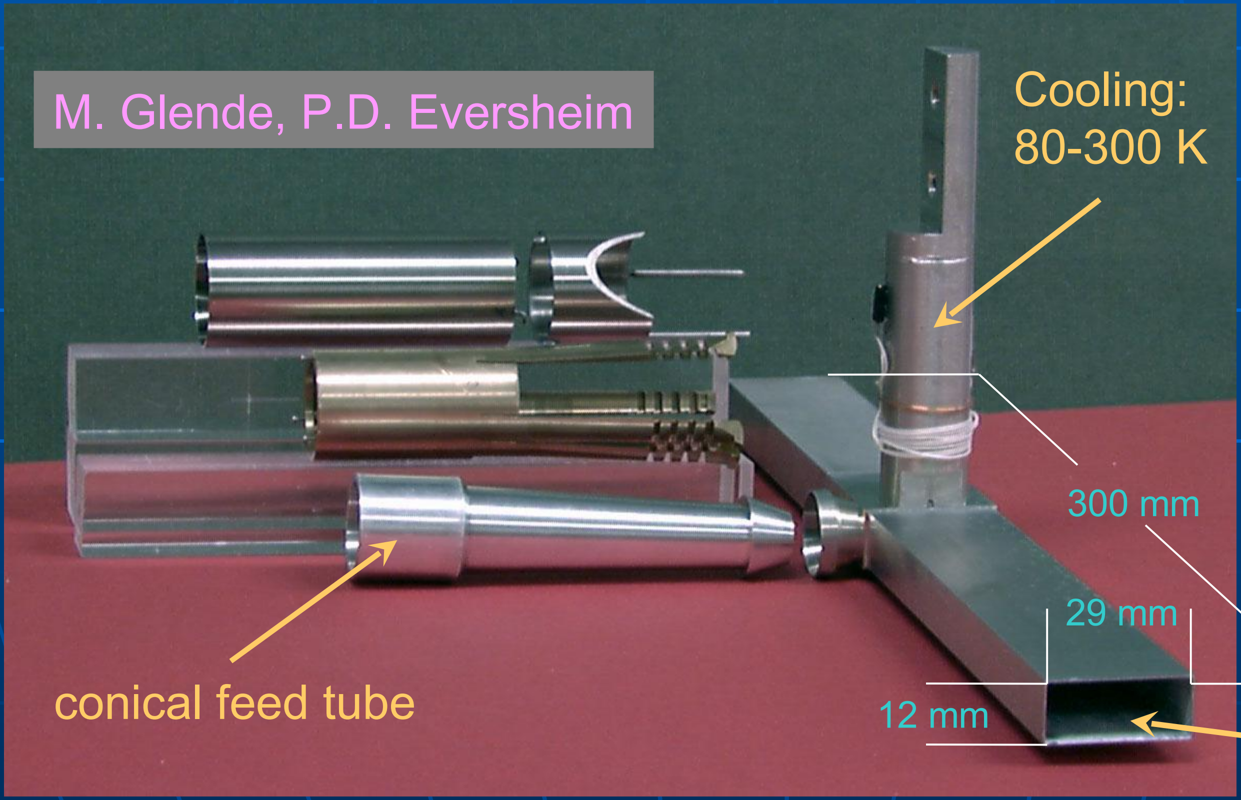


$d_t = 7.5 \cdot 10^{13}$ cm^{-2}
$P_z = 0.9$

1999 EDDA cell for test at COSY

Polarized EDDA target primarily used as an atomic jet

- spin correlation, analyzing powers in pp elastic scattering
- Time-Reversal invariance exp't needs a storage cell

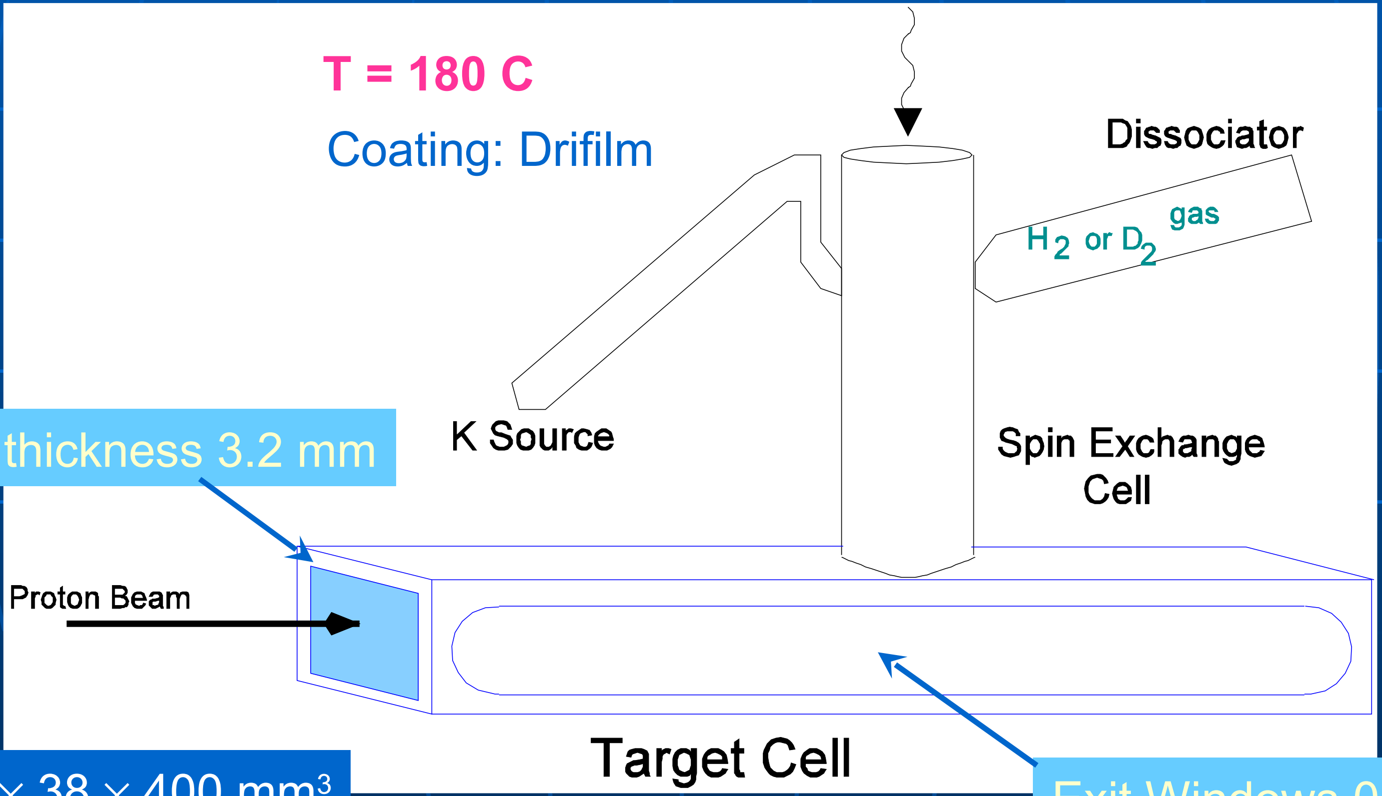


possible to remove cell while in vacuum

Teflon coated

1999 pd elastic at IUCF (CE66)

Cell body has to be kept at high temperature in order to maintain K-vapor.

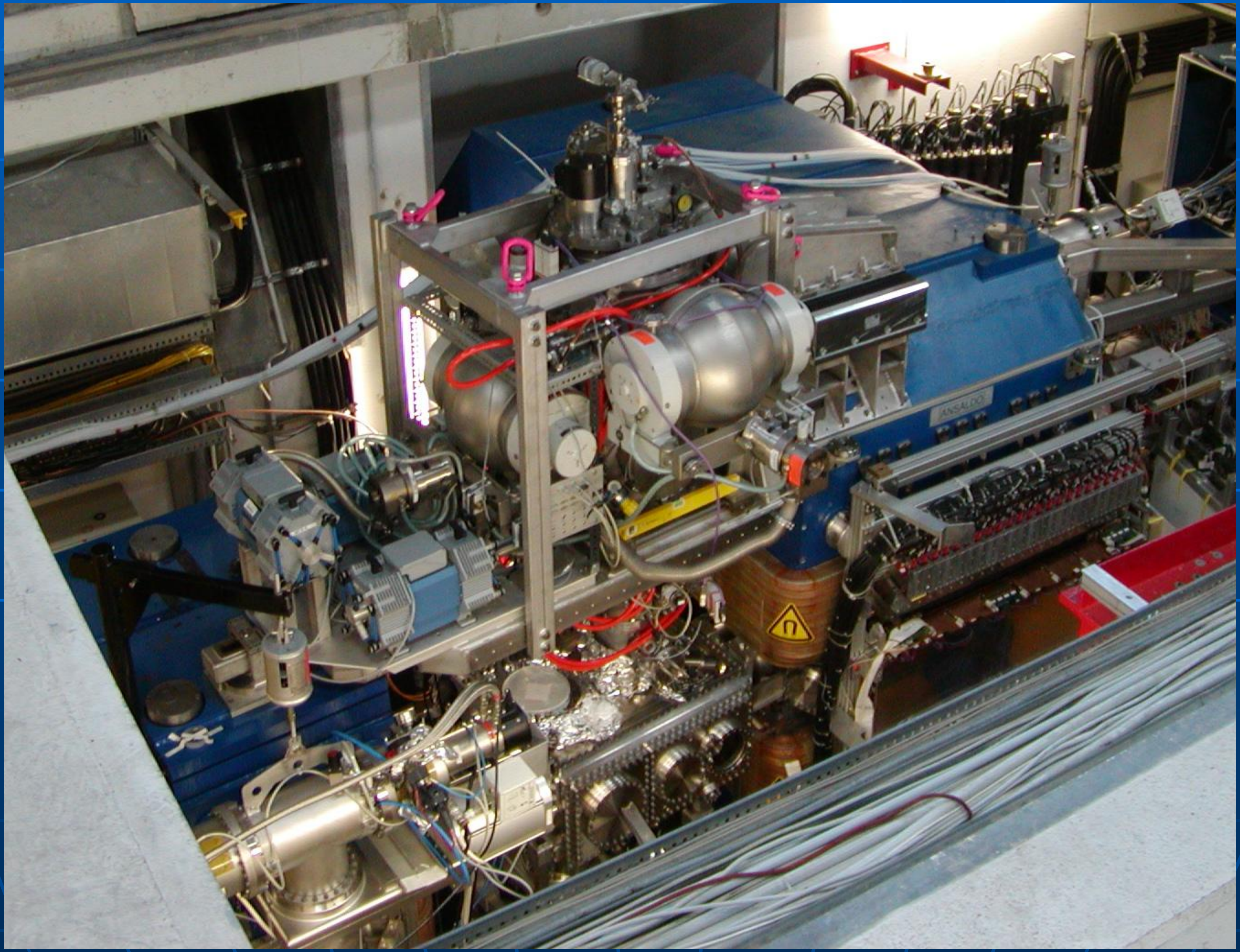


Wall thickness 3.2 mm

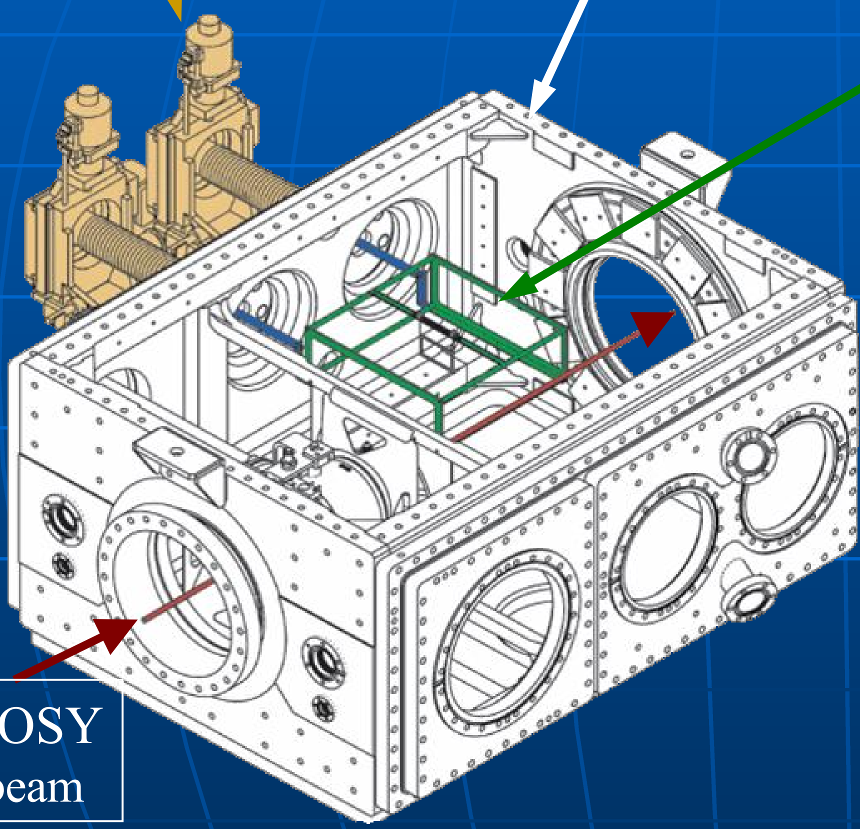
$19 \times 38 \times 400$ mm^3

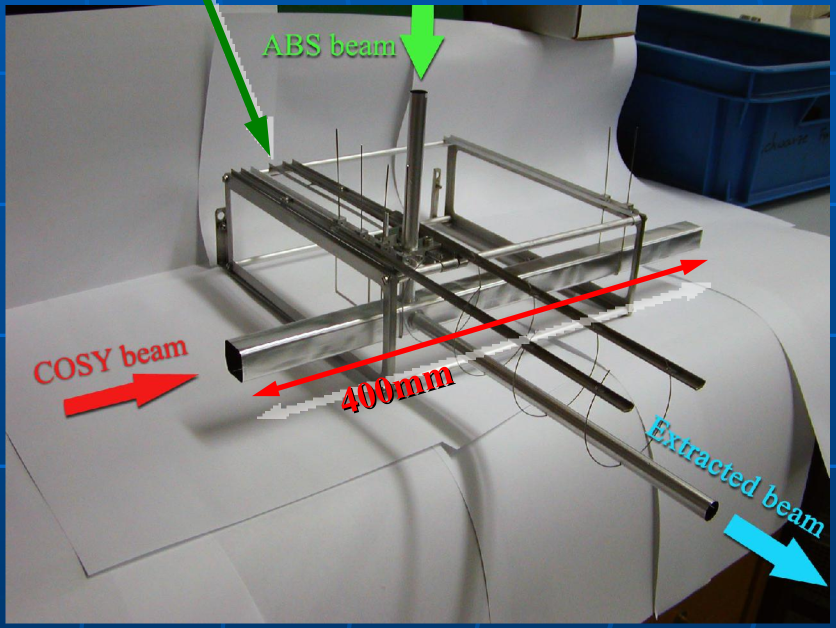
Exit Windows 0.3 mm

2005 ANKE PIT



Storage cell setup





Feeding tube:	**l = 120 mm, Ø = 10 mm**
Extraction tube:	**l = 230 mm, Ø = 10 mm**
Beam tube :	**l = 400 mm, 20x20 mm^2**
Coating:	**Teflon**

Polarimetry of PIT's

Three different approaches are distinguished:

II. Calibration by a known reaction

1. αp scattering (FILTEX at TSR)
2. pp elastic scattering (PINTEX at IUCF)
3. dp $\rightarrow$ $p_{sp} d \pi^0$

III. Ion extraction

1. NIKHEF Ion extraction polarimeter

IV. Neutral gas extraction

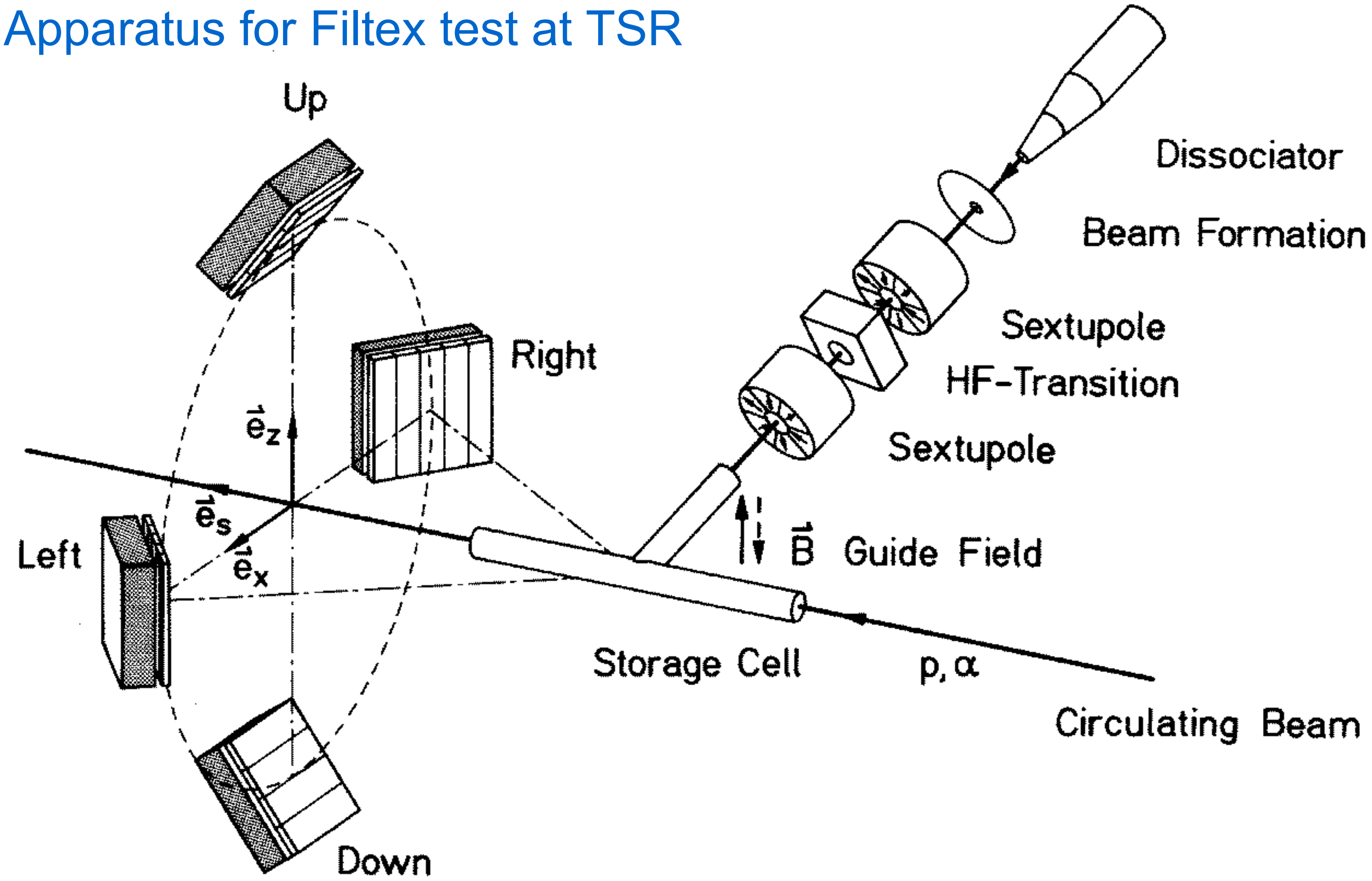
1. Breit-Rabi Polarimeter for HERMES
2. Lamb-shift Polarimeter for ANKE

Method I does not distinguish atoms from molecules or any other material in the target ⇒ **1st choice** whereever applicable

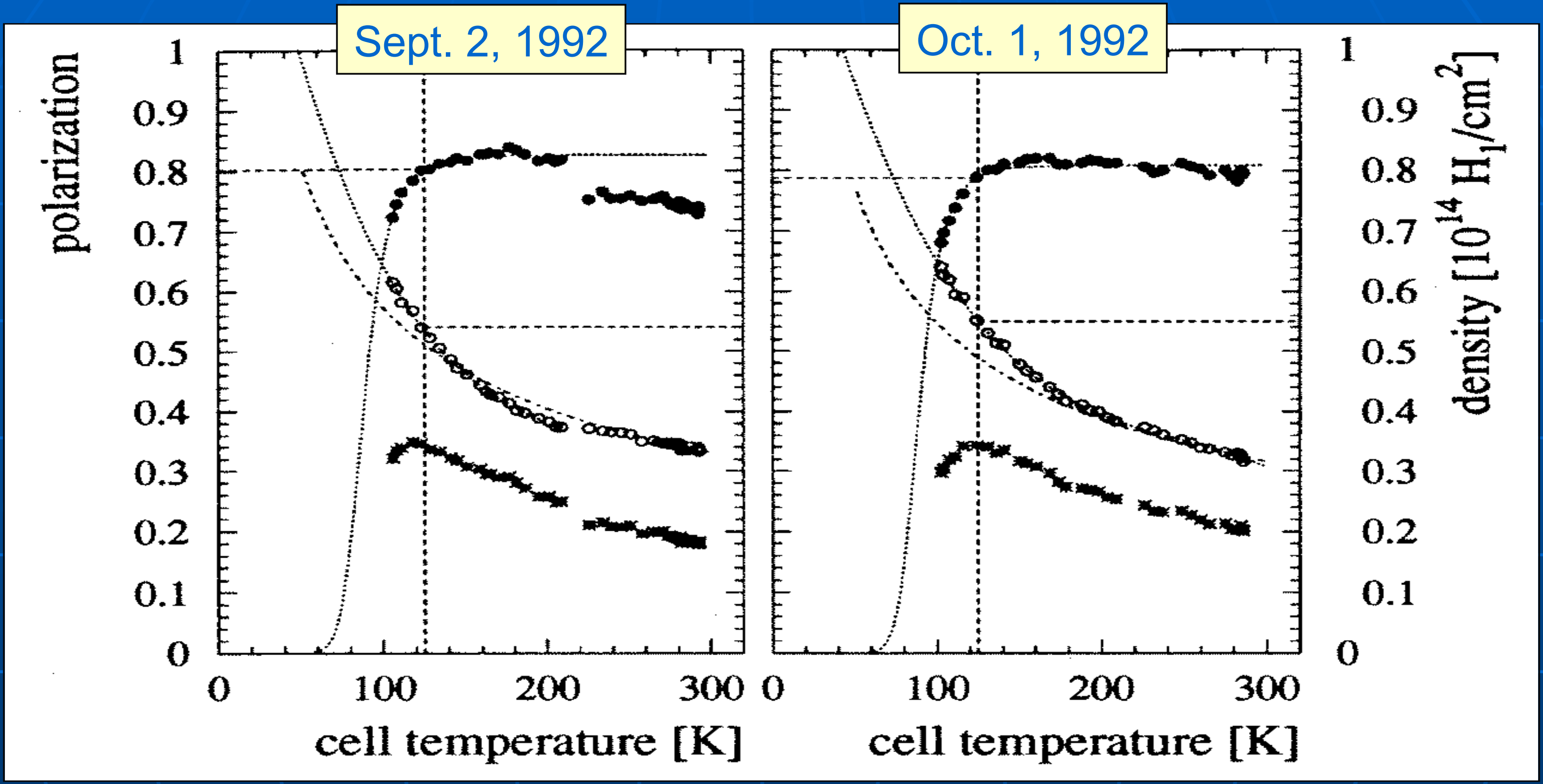
Methods II and III measure the polarization of atoms in the target, with additional instrumentation also the degree of dissociation in the target
but: Molecules dilute the polarization!
and: What is the polarization of the molecules?

Ex. 1: *αp scattering at* 27 MeV

Apparatus for Filtex test at TSR



Results



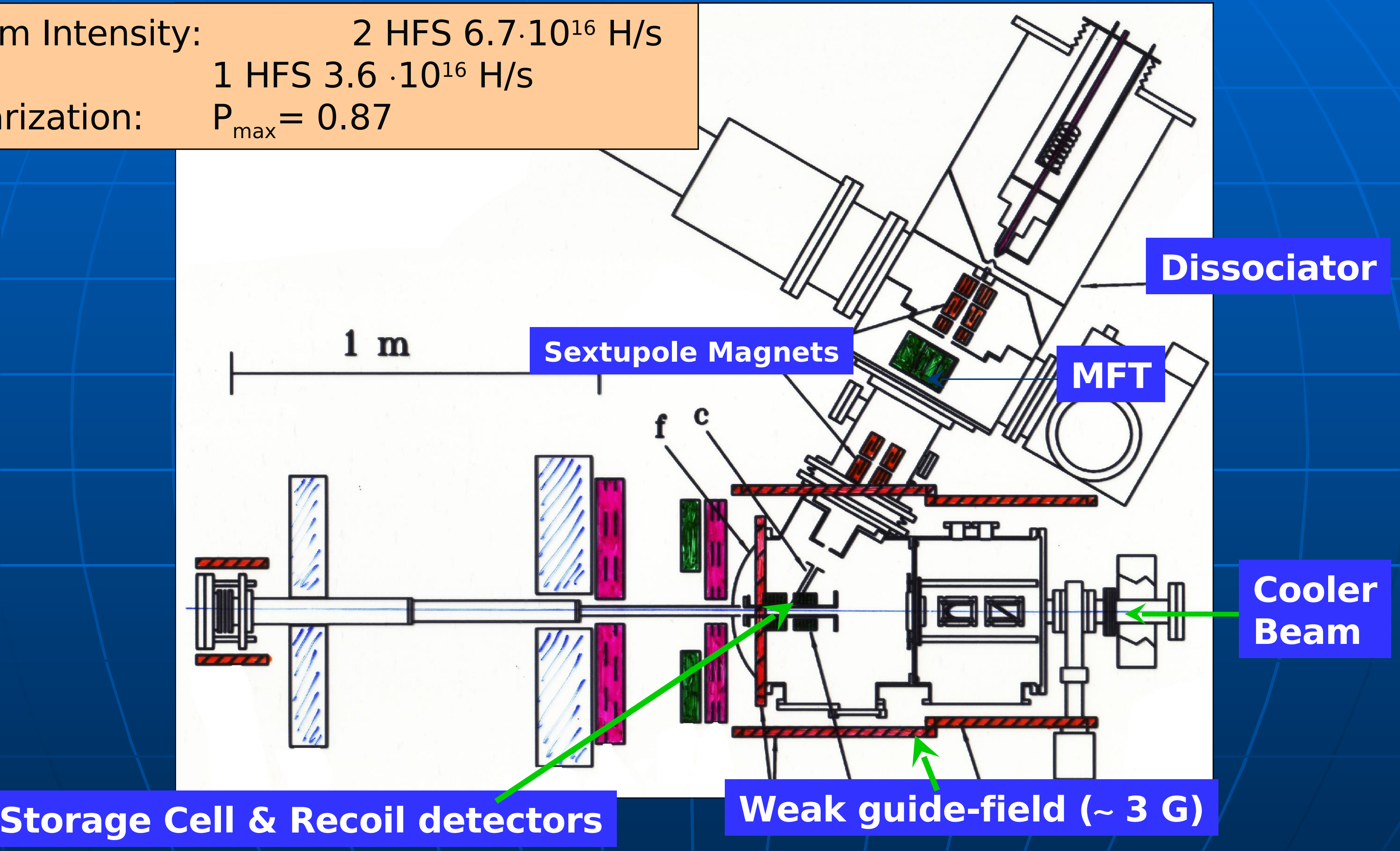
T_{opt} = 125 K

Sept. 2, 1992	Oct. 1, 1992
$P = 0.80 \pm 0.02$	$P = 0.79 \pm 0.02$
$d_t = (5.4 \pm 0.3) \cdot 10^{13}$ 1/cm^2	$d_t = (5.4 \pm 0.3) \cdot 10^{13}$ 1/cm^2

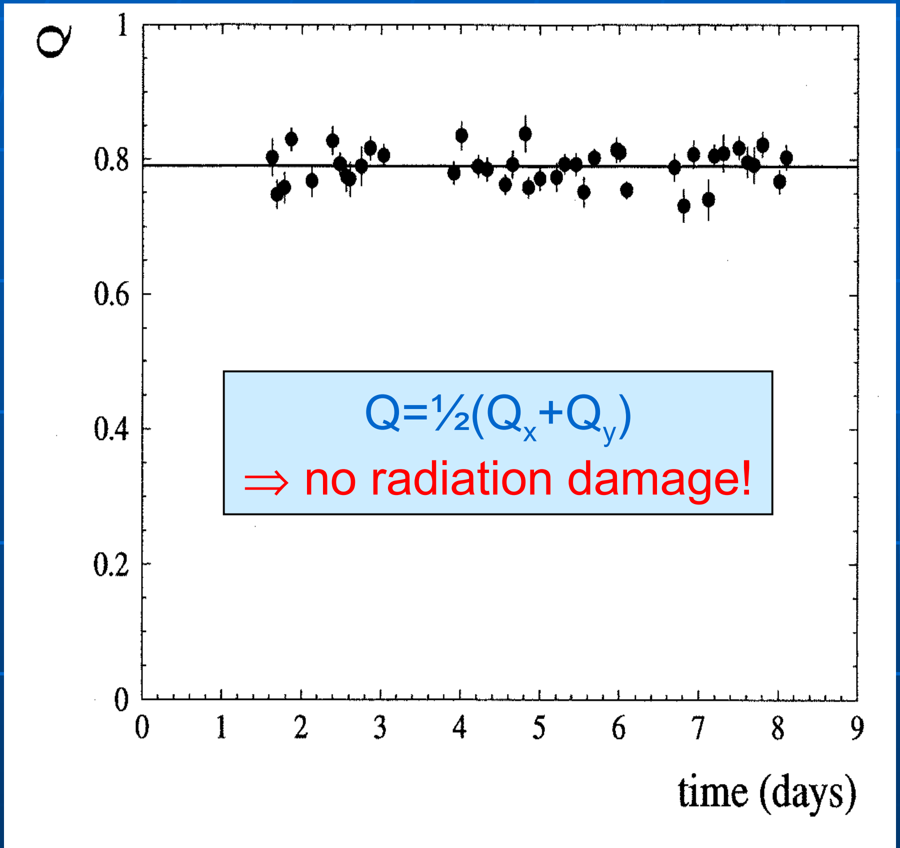
No radiation of the wall coating

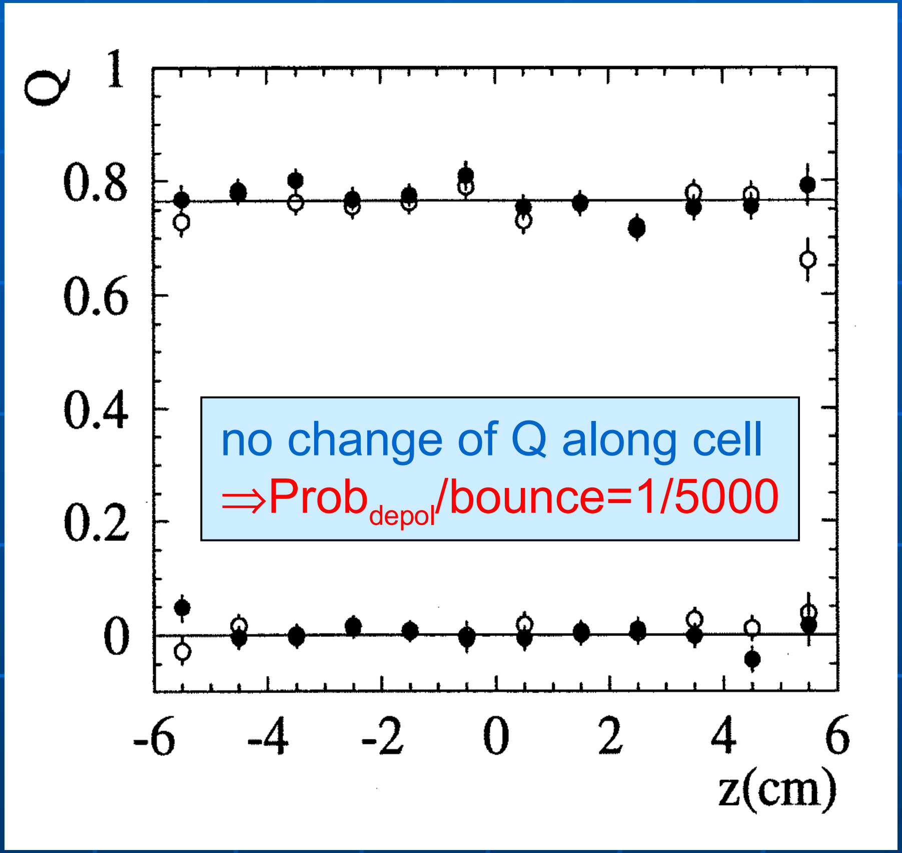
Ex. 2: PINTEX pp *elastic scattering*

m Intensity: 2 HFS $6.7 \cdot 10^{16}$ H/s
1 HFS $3.6 \cdot 10^{16}$ H/s
rization: $P_{max} = 0.87$



Polarization vs time and vs z



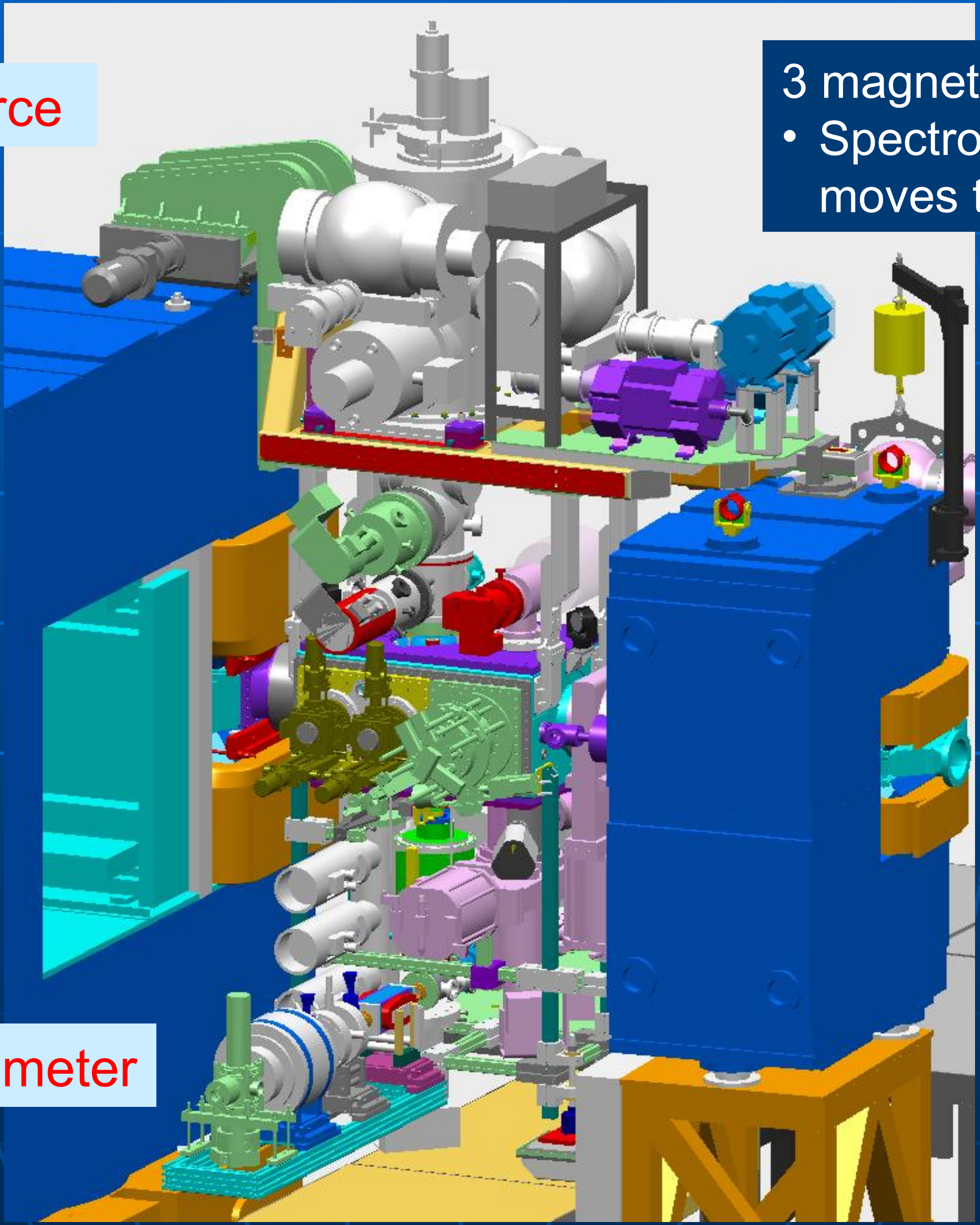


with I_{beam} = 100 – 400 μA ⇒ $L = 5{\cdot}10^{28}$ $1/cm^{-2}s^{-1}$

Ex. 3: Polarized Target for ANKE with Lamb-shift Polarimeter

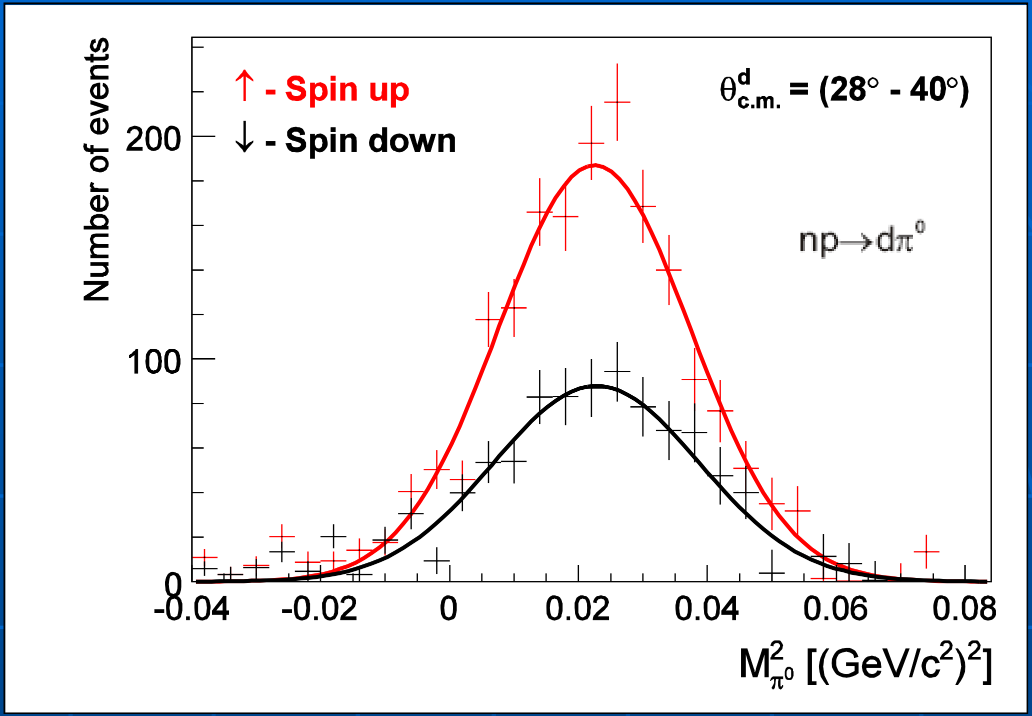
Atomic Beam Source

3 magnets form a chikane
- Spectrometer magnet D2 moves transversly



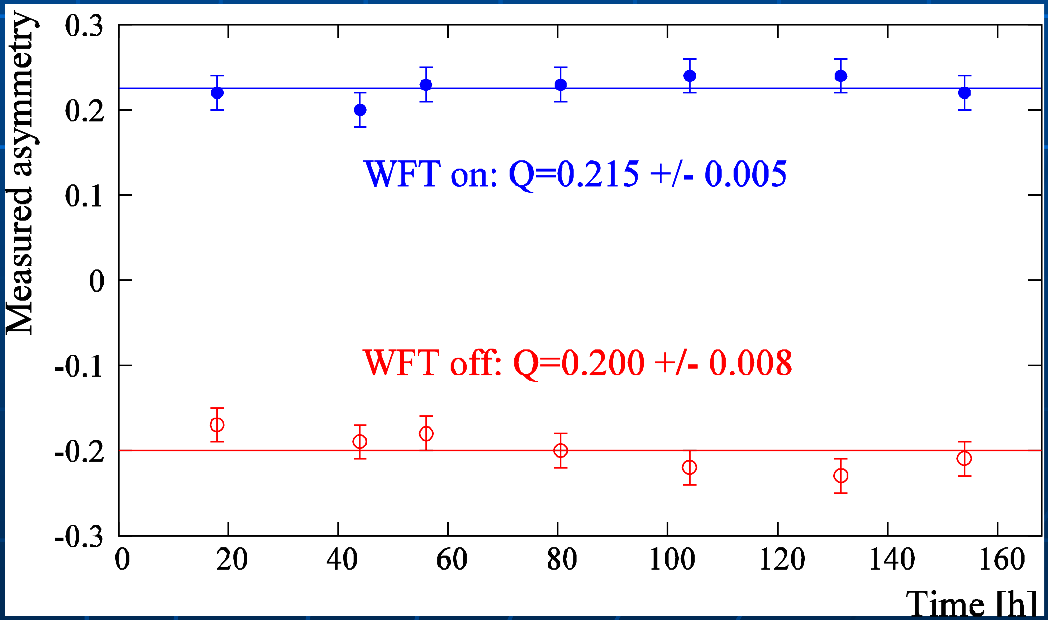
Lamb-Shift Polarimeter

$dp \rightarrow p_{sp} d\pi^0$



Target polarization
Qy=0.79 ± 0.06

Online monitoring of ABS polarization via LSP

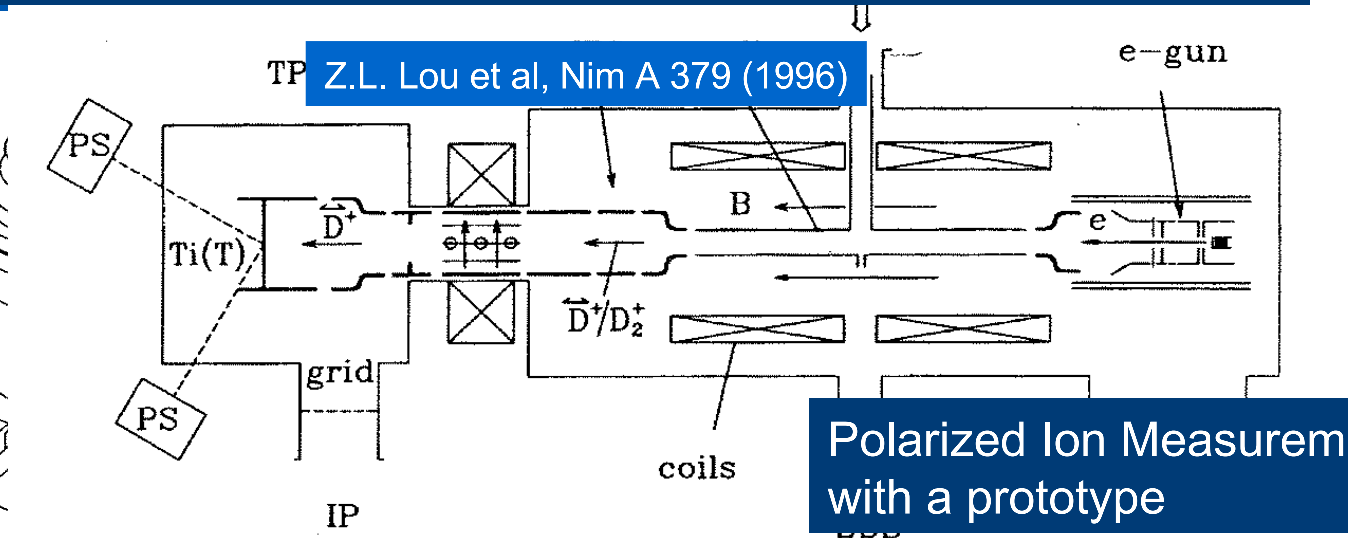


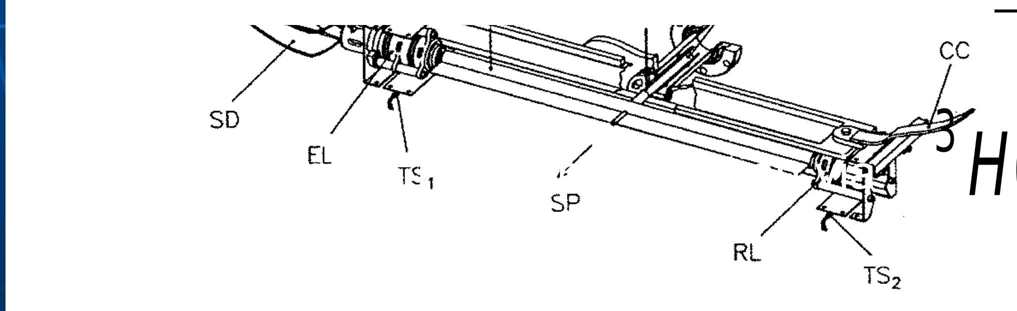
Ex. 4: NIKHEF Ion-extraction polarimeter

Princi

Ionization in AmPS via stored e⁻: σ(1 keV)/ σ(565 keV) ~1/50

Z.L. Lou et al, Nim A 379 (1996)





Polarized Ion Measurement with a prototype

$-0.89^{\pm 0.03\ stat.}_{\pm 0.05\ syst.}$ $\langle P_{zz} \rangle$ $0.49^{\pm 0.01\ stat.}_{\pm 0.03\ syst.}$ Nim A 326 (1993)

$^3H(\vec{d},n)^4He$

Ex. 5: HERMES Breit-Rabi Polarimeter

Determination of Hyperfine state population numbers by
- RF transitions
- sextupole magnet system