JÜLICH FORSCHUNGSZENTRUM

Coating Test at FZ Jülich

19.02.2021

by Ralf Engels

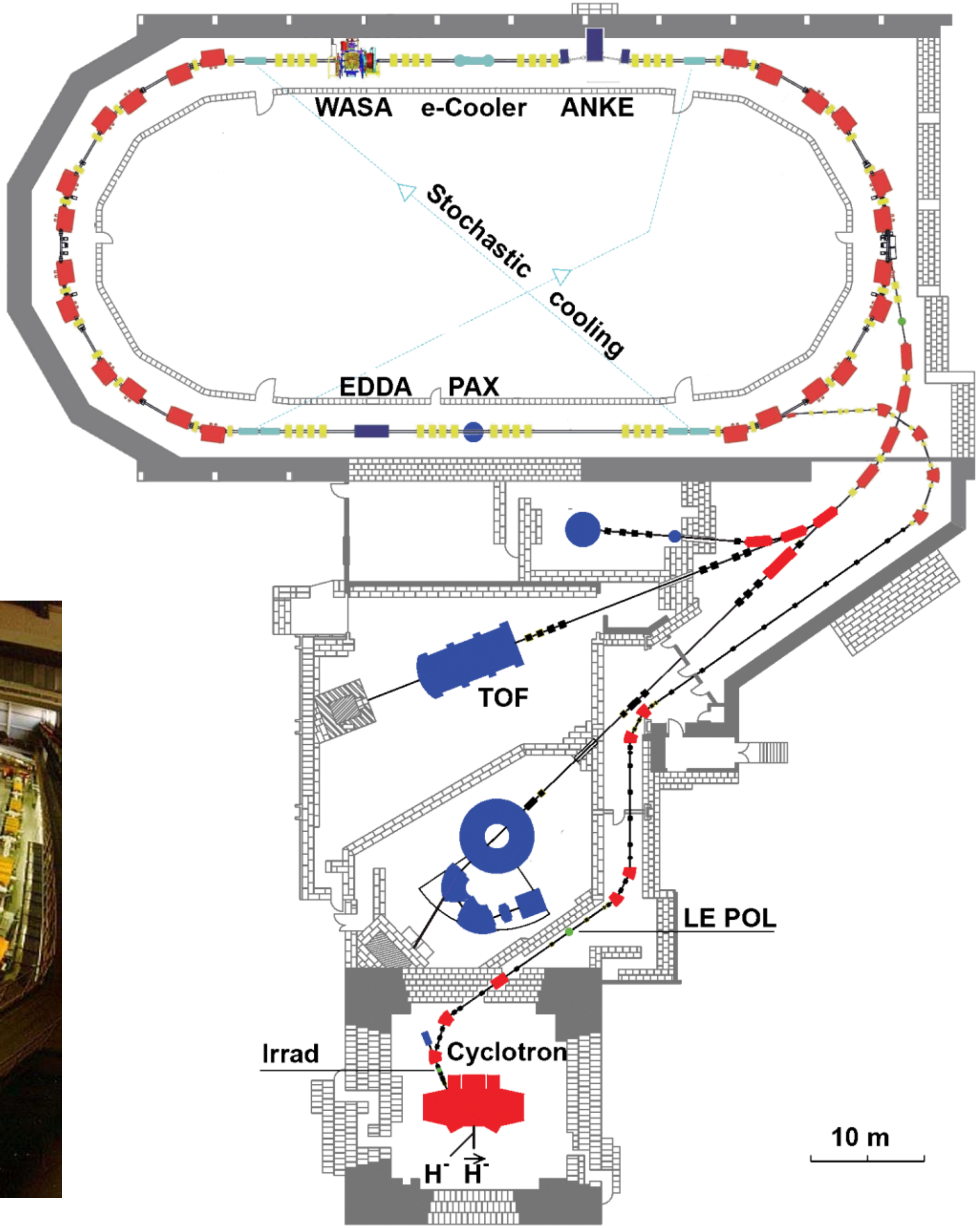
JCHP / Institut für Kernphysik, FZ Jülich

PIT@ANKE

$p, \vec{p}, d, \vec{d}$

with momenta up to 3.7 GeV/c

- **internal experiments** – with the circulating beam
- **external experiments** – with the extracted beam

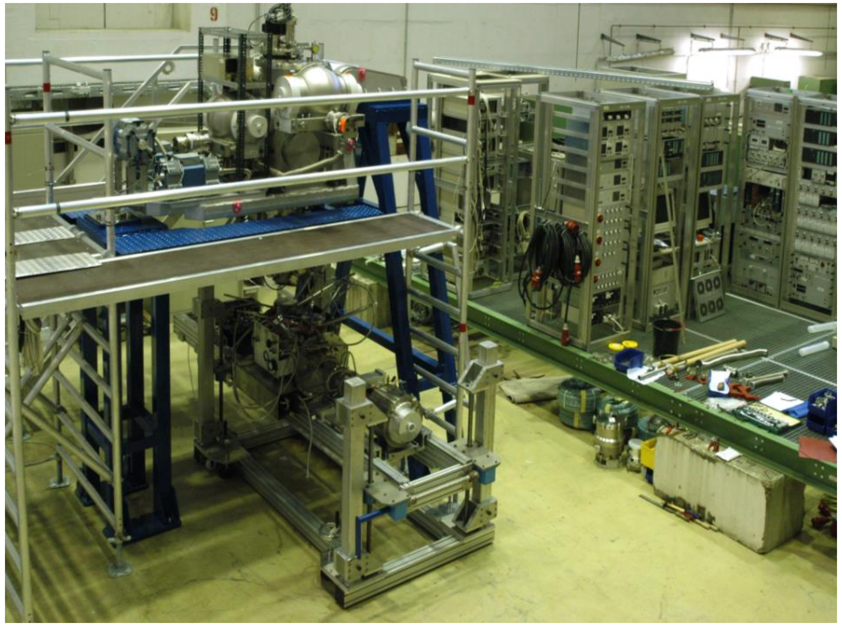


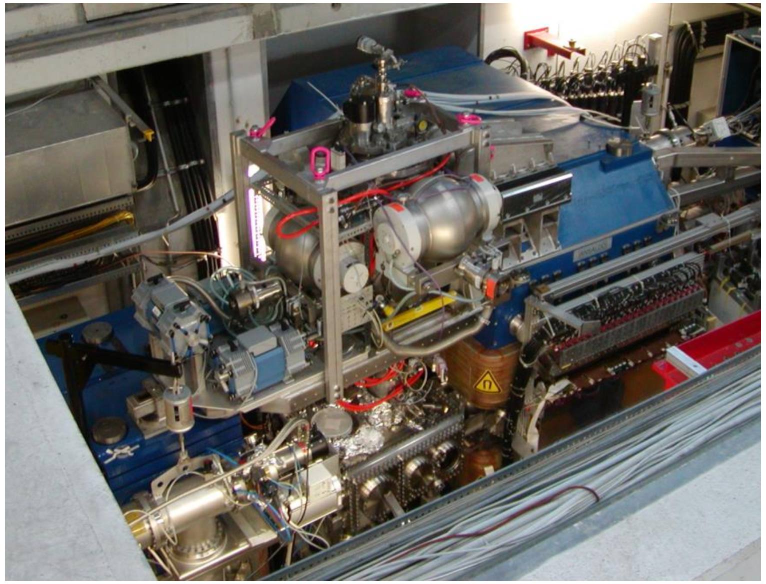
PIT @ ANKE/COSY

Main parts of a PIT:

- Atomic Beam Source
  - Target gas
    hydrogen or **deuterium**
  - H beam intensity (2 hyperfine states)
    $8.2 \cdot 10^{16}$ atoms / s
  - Beam size at the interaction point
    $\sigma = 2.85 \pm 0.42$ mm
  - Polarization for hydrogen atoms
    $P_Z = 0.89 \pm 0.01$ (HFS 1)
    $P_Z = -0.96 \pm 0.01$ (HFS 3)

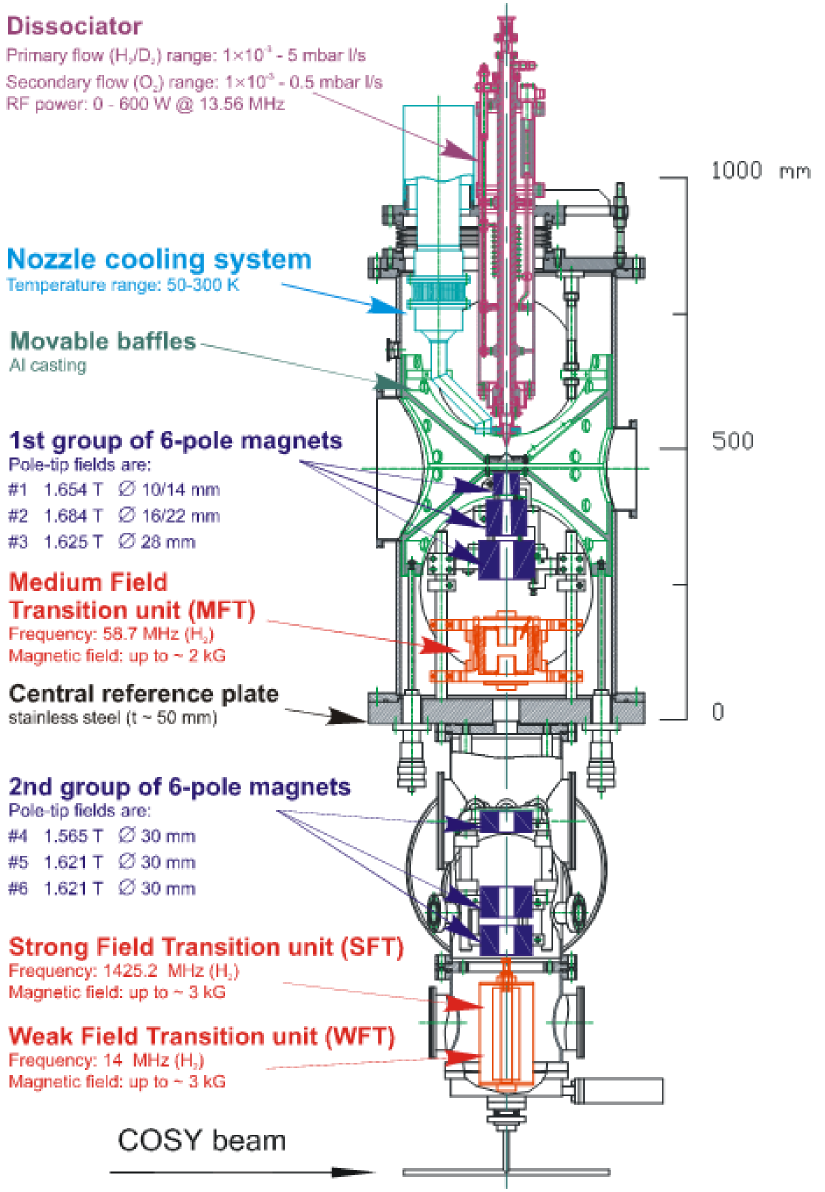
- Lamb-Shift Polarimeter
- Storage Cell





M. Mikirtychyants et al.; NIM A **721** (0) 83 (2013)

Polarized Storage-Cell Targets



Polarized atomic beam sources seem to reach a limit of ~ 10^{17} atoms/s and P ~ ± 0.9
-> Density of the polarized jet ~ 10^{12} atoms/cm^2

Storage Cells:

Density: ~ 10^{14} atoms/cm^2

Polarization: P ≤ 0.9

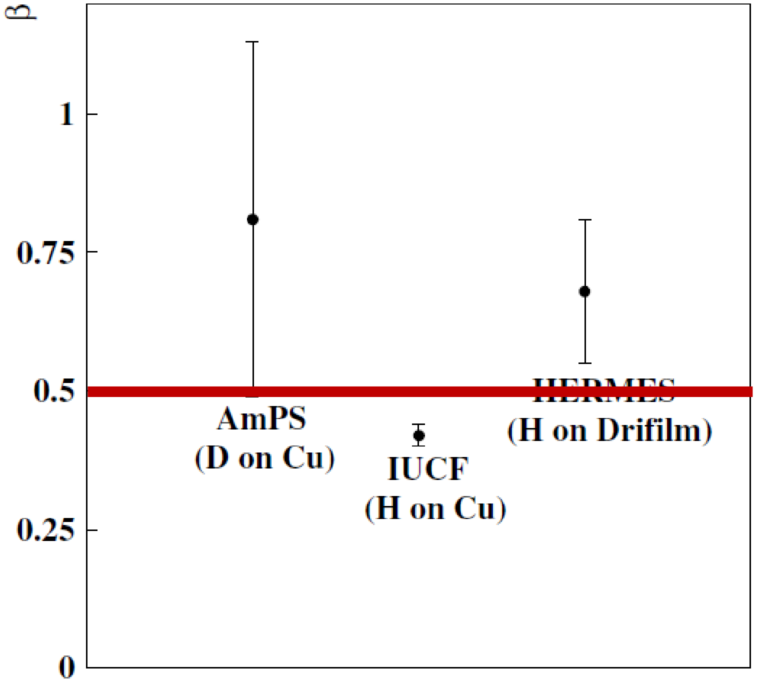
Problems:

- Beam focussing more complicated
- Dedicated magnetic fields are needed
- Depolarization inside the cell
  -> Magnetic inpurities on the cell wall
  -> Recombination into molecules

Polarized H_2 Molecules

Measurements from NIKHEF, IUCF, HERMES show that recombined molecules retain fraction of initial nuclear polarization of atoms!

$$\beta = \frac{P_m}{P_a}$$



$$P_m = \tfrac{1}{2} P_a$$

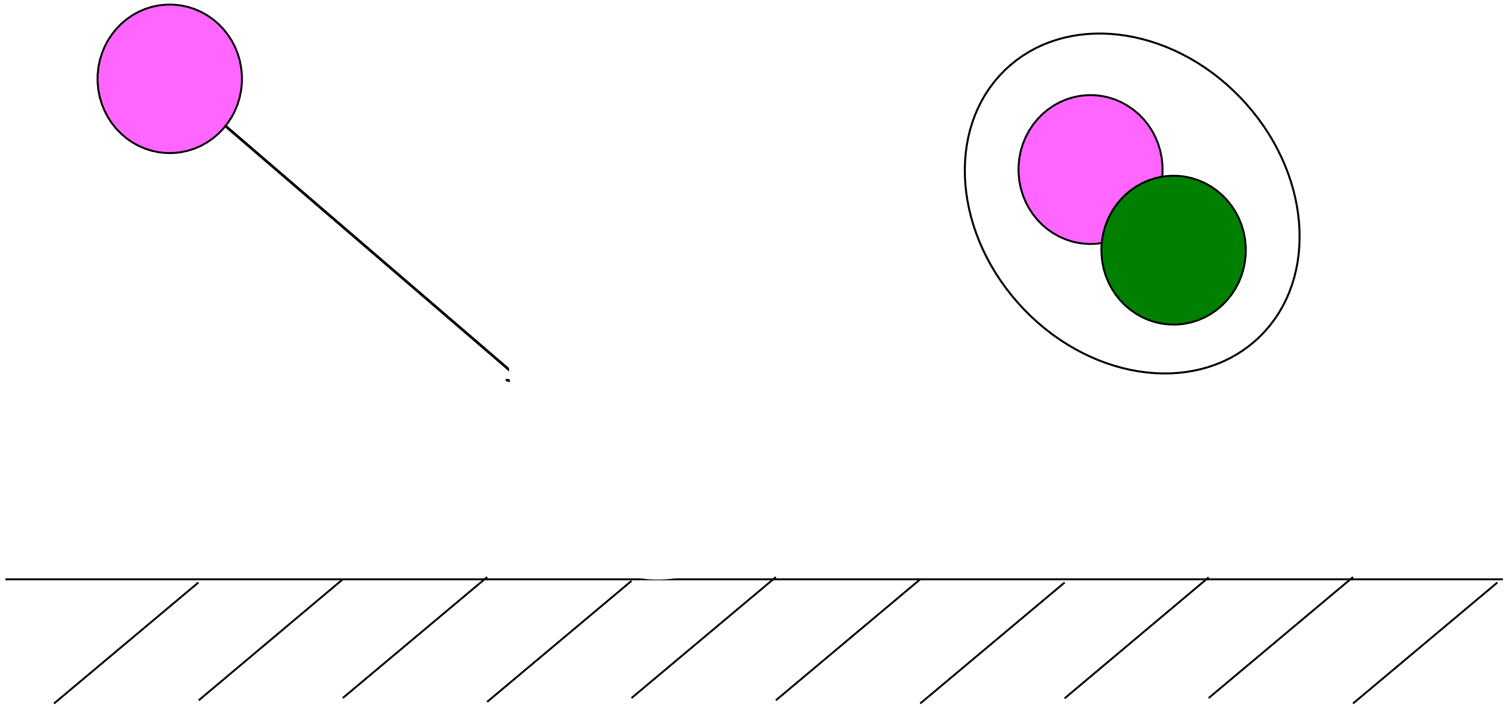
Fig. 2. Summary of the existing measurements of the nuclear polarization of recombined molecules. The newly obtained HERMES measurement at 260 K with a holding field of 330 mT is compared to the measurement by AmPS and IUCF obtained at room temperature and magnetic holding fields of 28 mT and 440 mT respectively.

The HERMES Collaboration; Eur. Phys. J. D **29**, 21–26 (2004)
DOI: 10.1140/epjd/e2004-00023-5

Polarized H_2 Molecules

Eley-Rideal Mechanism

$P_m = 0.5\ P_a$

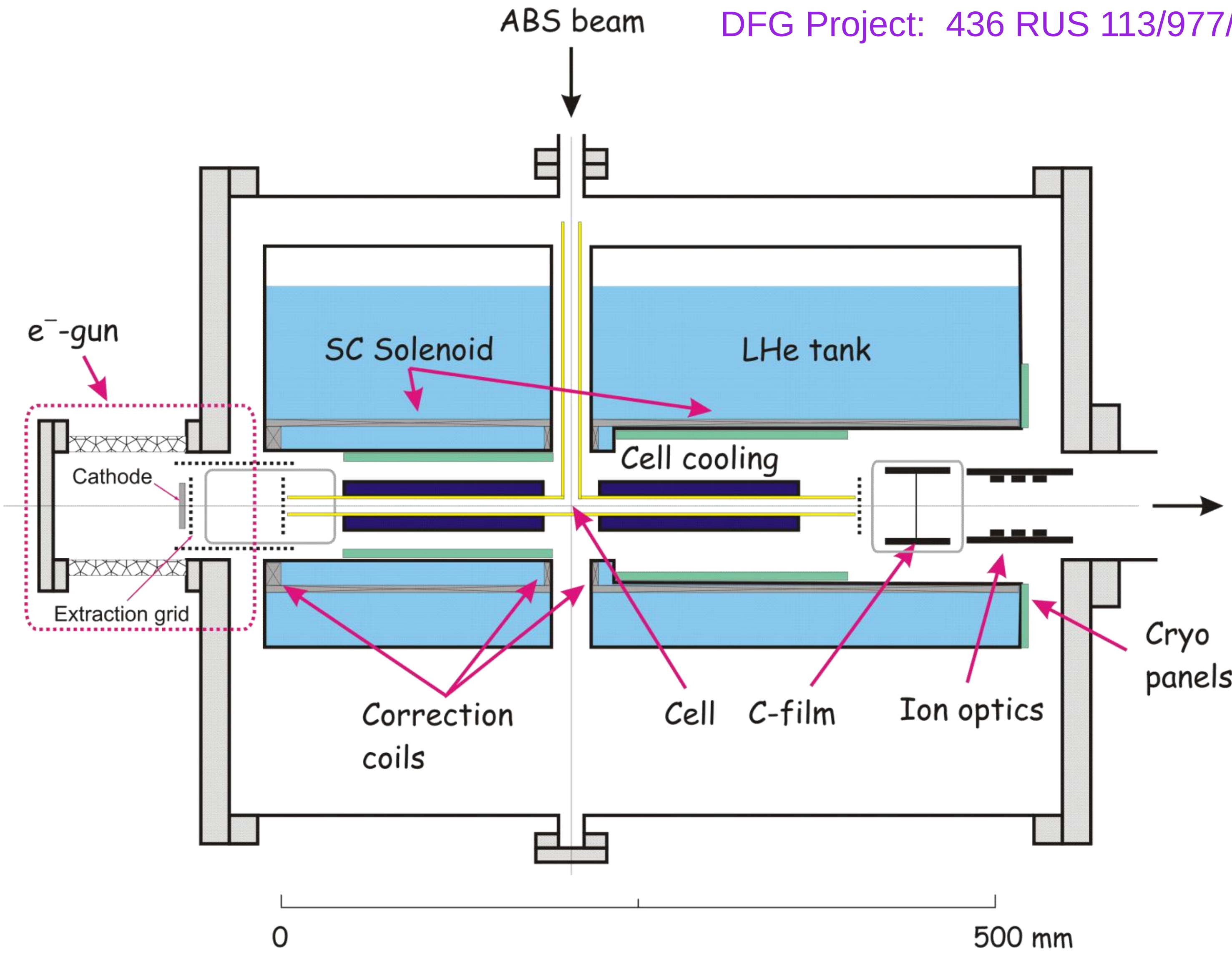


Is there a way to increase P_m

(surface material, T, B etc)?

Storage Cell Tests: The Experimental Setup

ISTC Project # 1861 PNPI, FZJ, Uni. Cologne
DFG Project: 436 RUS 113/977/0-1

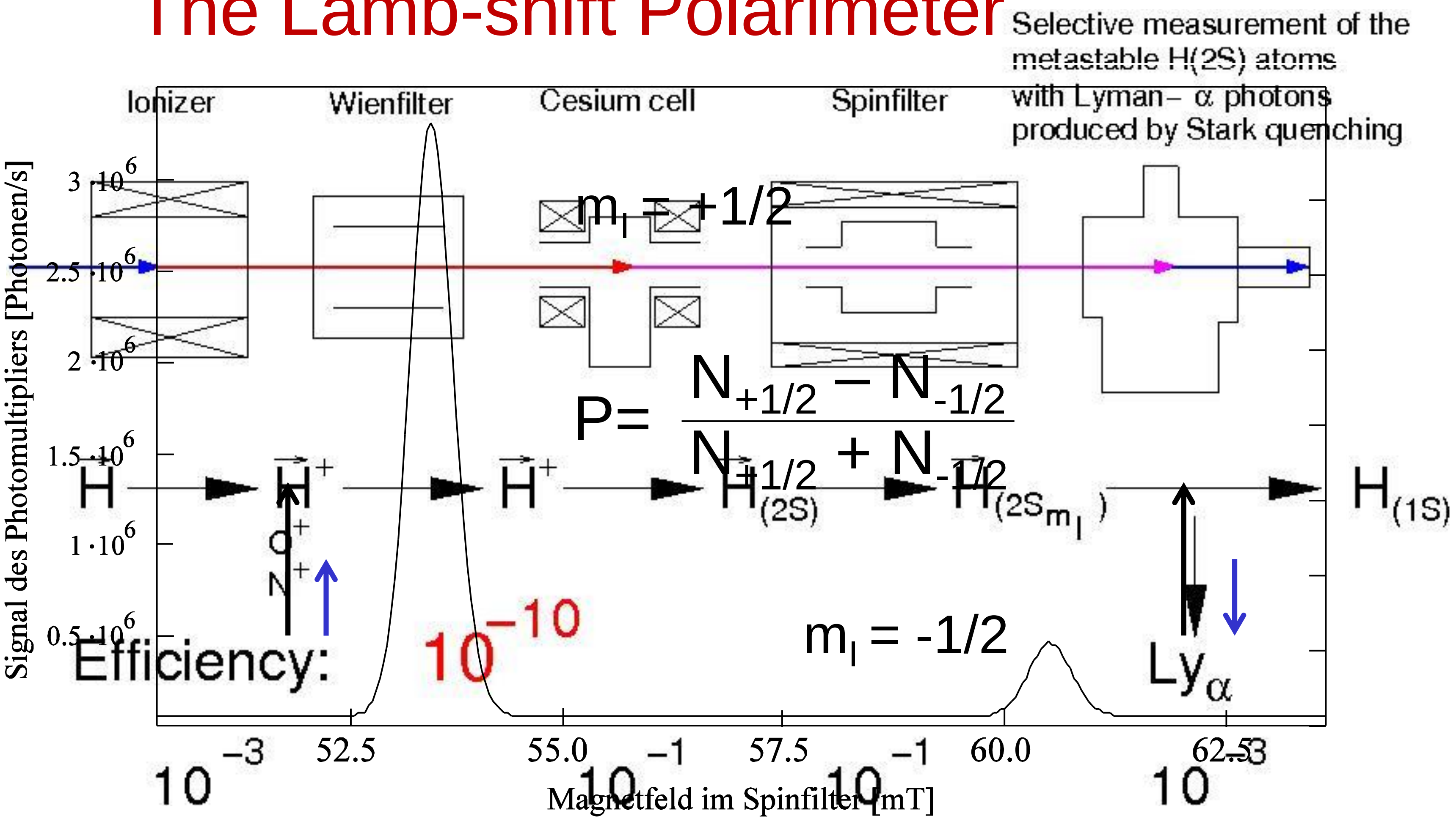


H_2^+, D_2^+
HD^+, H_3^+

p, d

The experimental Setup

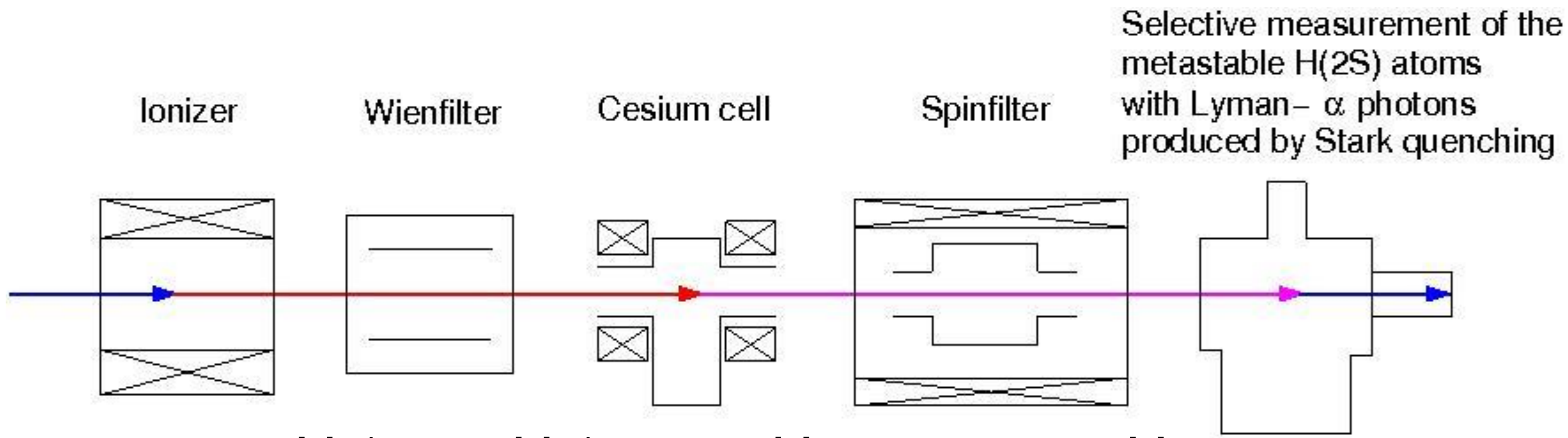
The Lamb-shift Polarimeter



R. Engels et al., Rev. Sci. Instr. **74** 4607 (2003)
R. Engels et al., Rev. Sci. Instr. **85** 103505 (2014)

The experimental setup

The Lamb-shift Polarimeter



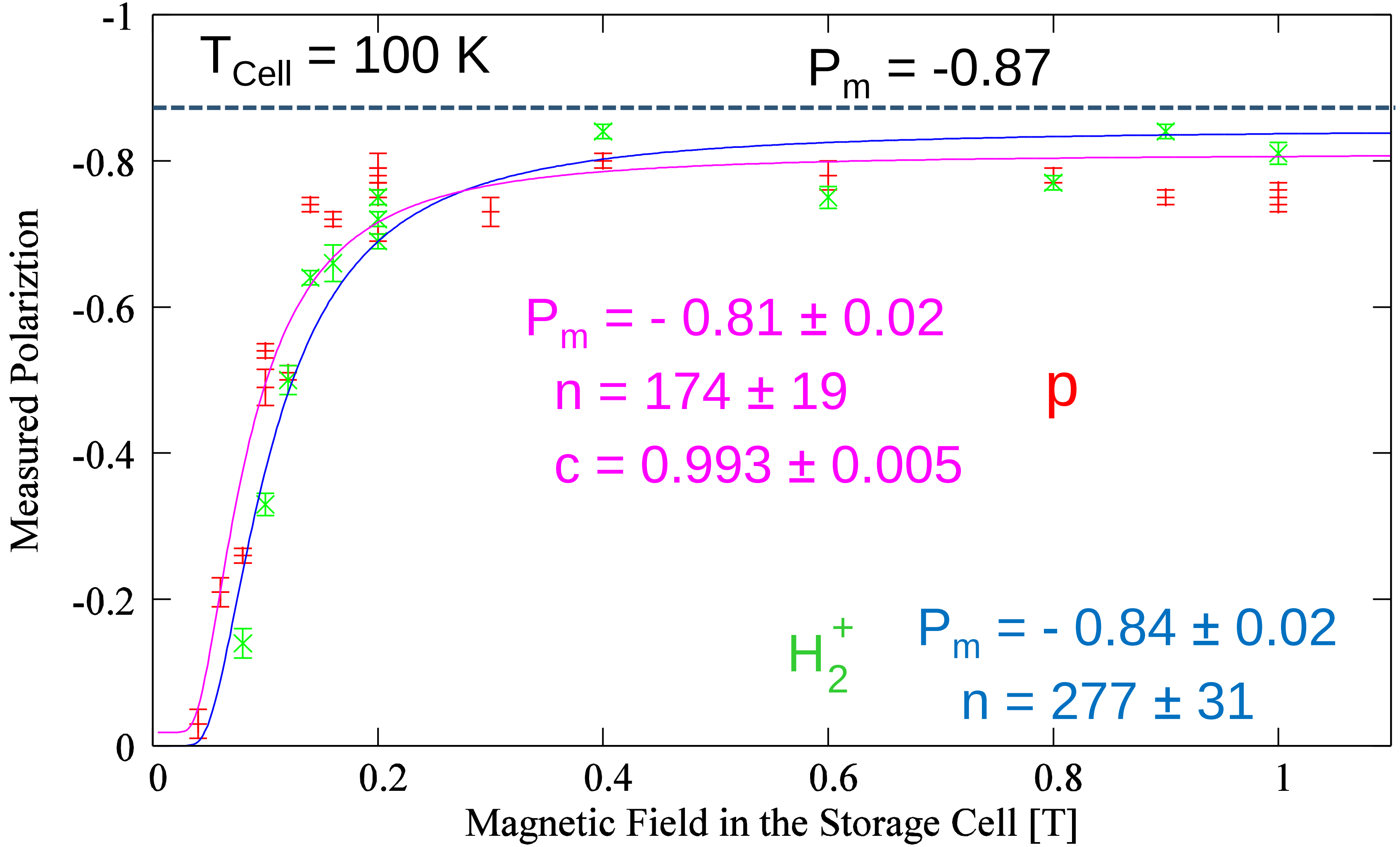
$$H_2 \rightarrow \begin{cases} H_2^+ \longrightarrow H_2^+ \longrightarrow H_{2S} \longrightarrow H_{2S\,(\alpha 1)} \\ H^+ \longrightarrow H^+ \longrightarrow H_{2S} \longrightarrow H_{2S\,(\alpha 1)} \end{cases}$$

Experimental Results: Polarized H_2 Molecules

JÜLICH FORSCHUNGSZENTRUM

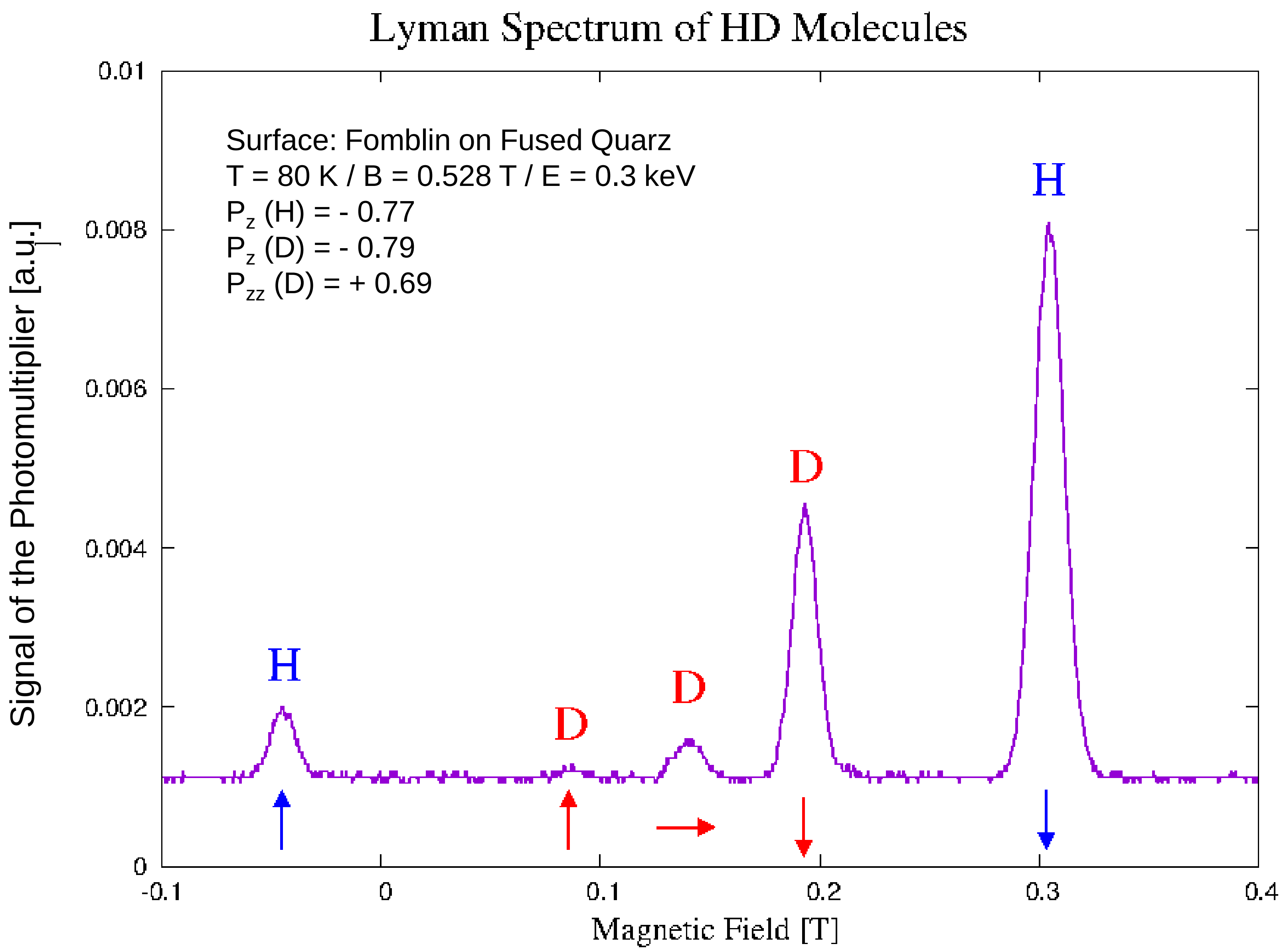
Measurements on Fomblin Oil (Perfluoropolyether PFPE)

HFS 3



R. Engels et al., Phys. Rev. Lett. **115** 113007 (2015)

Experimental Results: HD Molecules

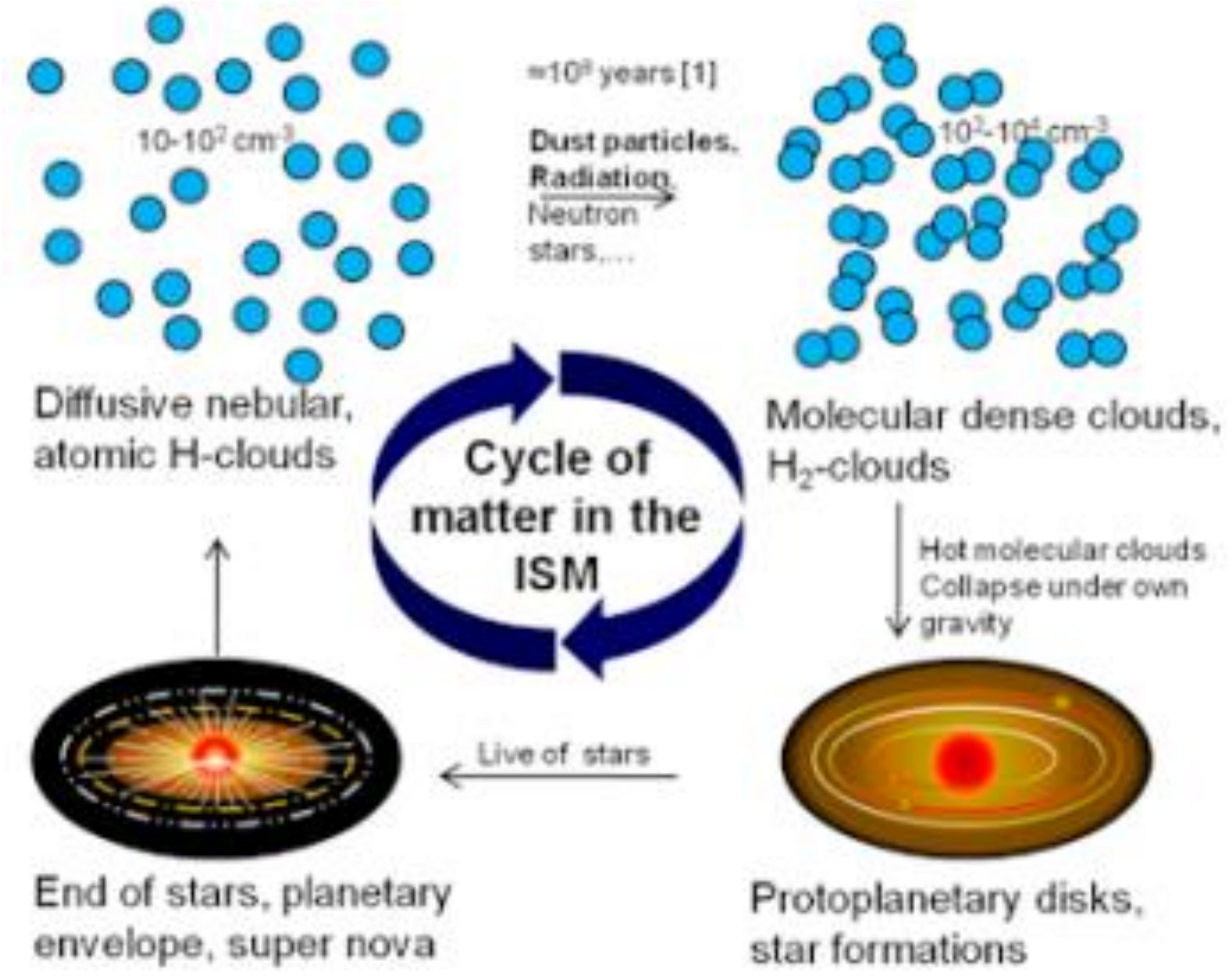


R. Engels et al., Phys. Rev. Lett. **124**(11) 113003 (2020)

The LHCb Polarized Target: Carbon Coating

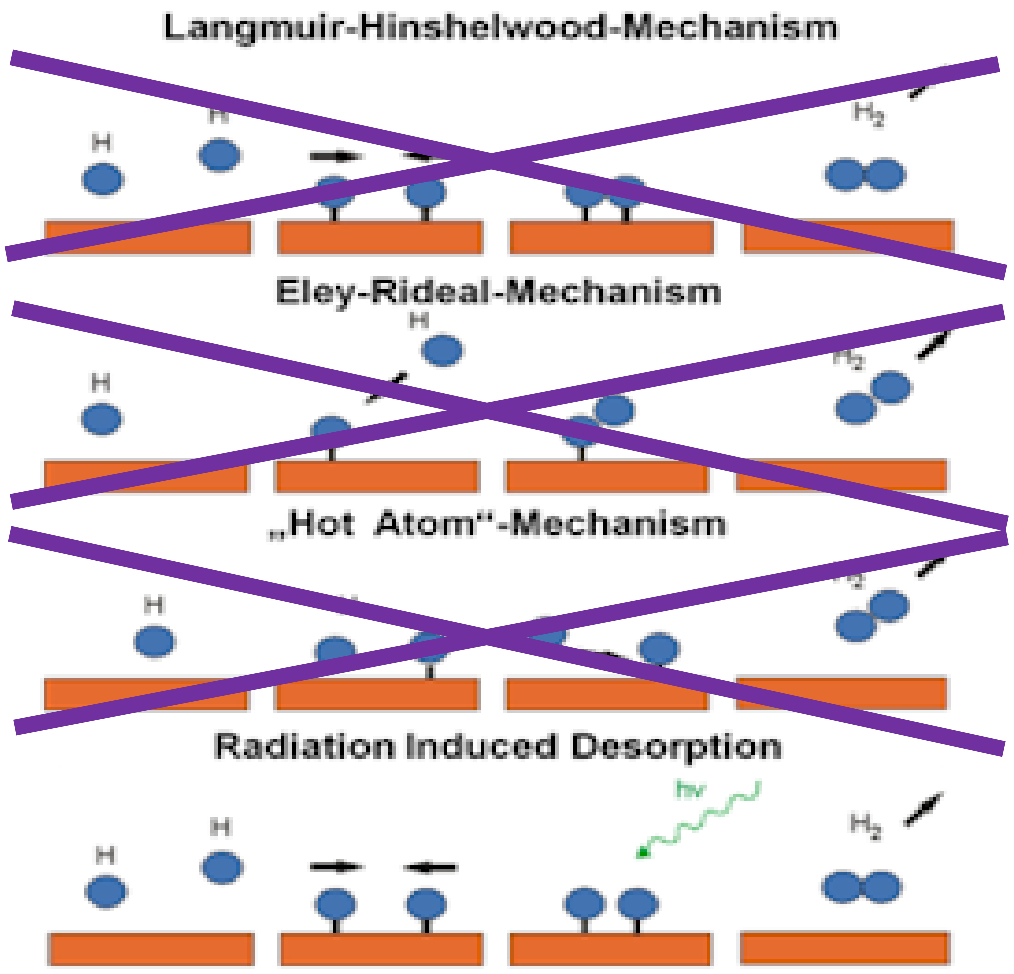
CERN allows Carbon coating ⟶ What will happen with the polarized atoms?

Recombination of H Atoms in the Universe



Hydrogen Recombination in the Universe

Possible Recombination Mechanism



WWU Münster; Phys. Institute, Prof. H. Zacharias

-> **C-H** Bond (~ 4.3 eV) is so strong that it will not allow the recombination

-> **H-H** Bond: ~ 4.5 eV

Radiation induced Desorption

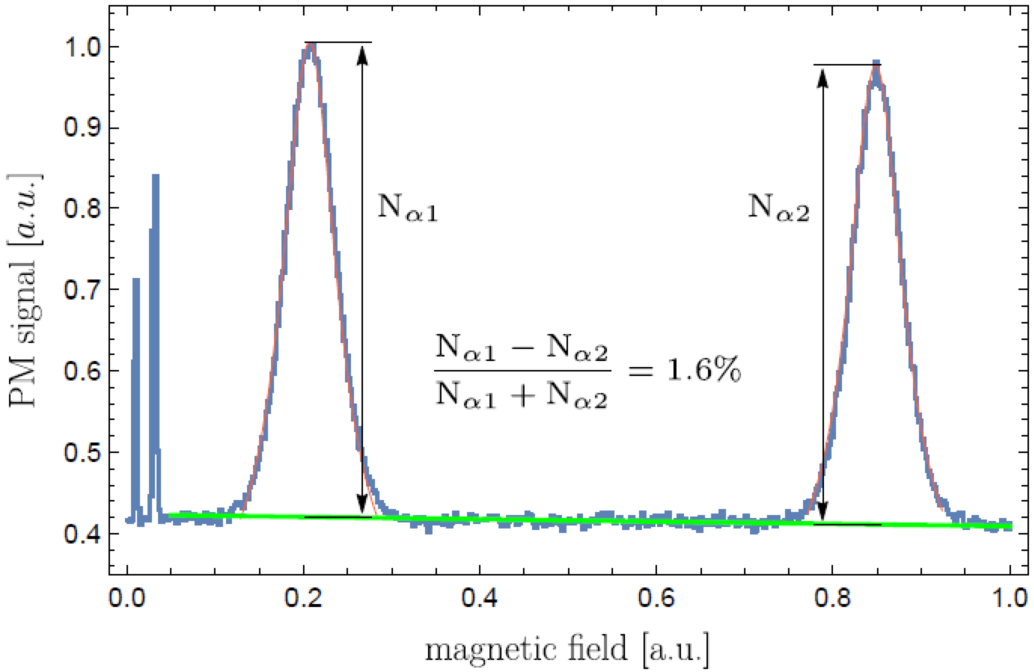
New Observation at BINP in Novosibirsk

ABS / MBS

D. Toporkov et al.

→ **LSP**

DFG Project
BU 2227/1-1



Huge Lyman-α background
(n=2 -> n=1 : 10.2 eV)

Source**: Plasma in Dissociator**
Balmer (n=3 -> n=2) light is very bright !

Estimate amount: ~ 10^{18} Ph/s

Storage Cell Coating

Why have other materials worked for coating ?

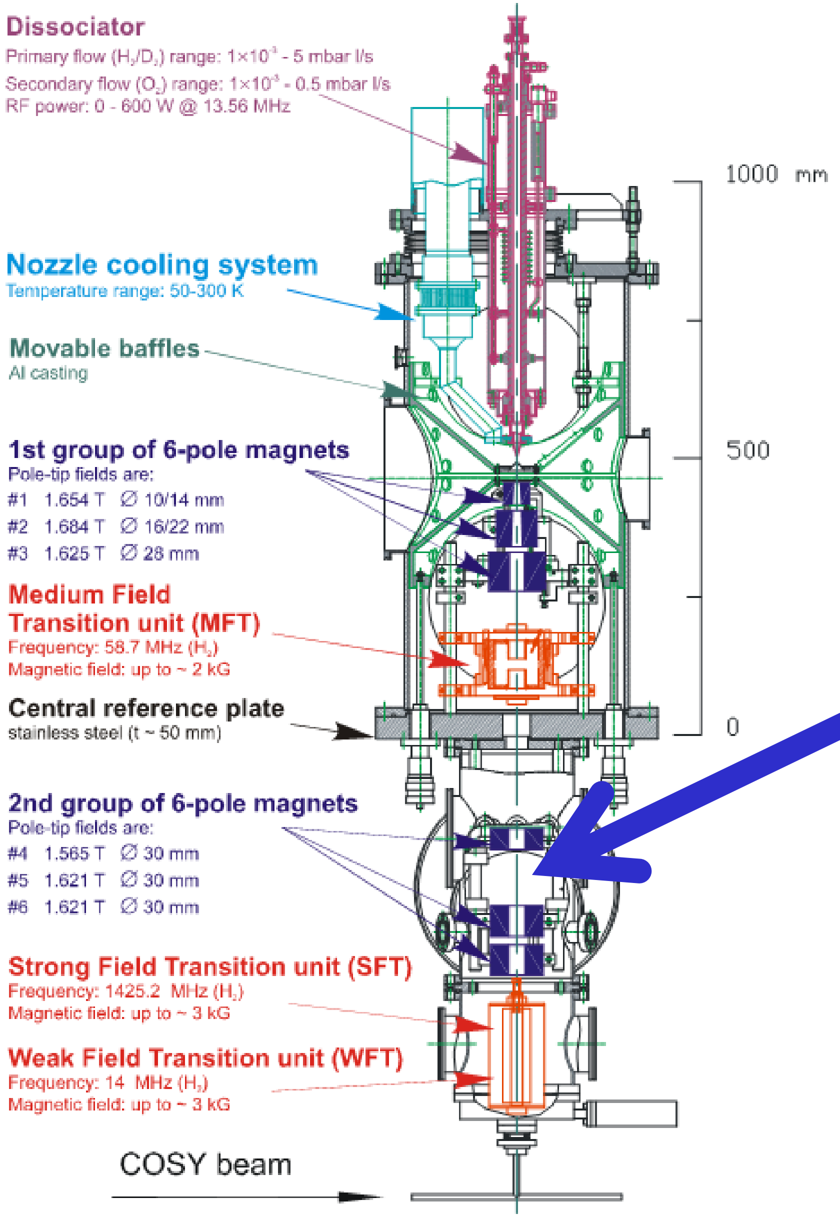
1.) Aluminium cells -> reflects Lyman-α photons

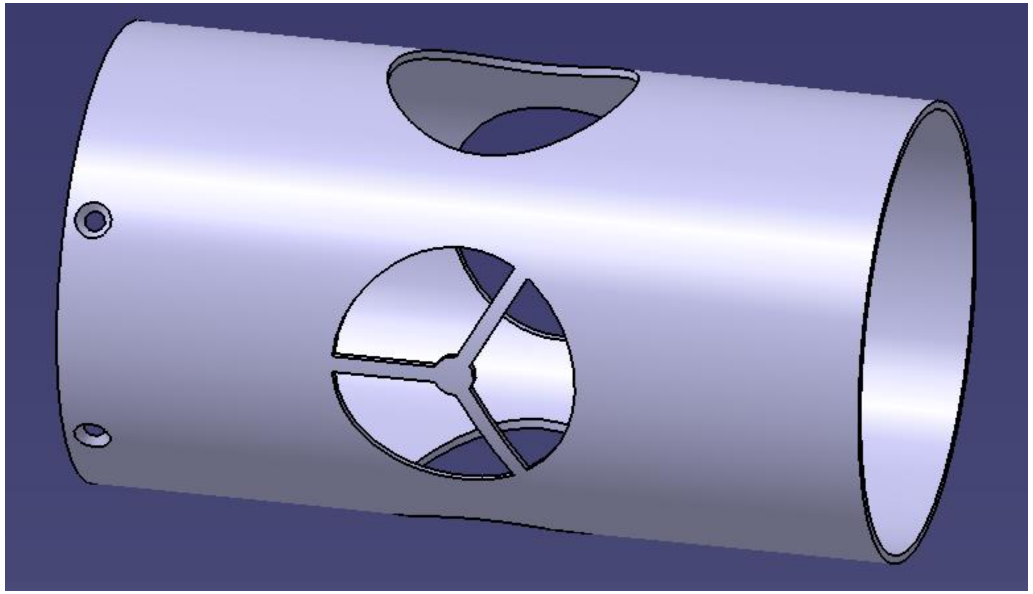
2.) Teflon cells -> transmission through the surface ?

3.) Water ice -> reflects Lyman-α photons / transmission through the surface ? (O-H: ~ 4.8 eV)

Expectation for Carbon: -> Large Recombination in Combination with Lyman-α radiation !

Possible Solution for the LHCb pol. Target





New Chopper with 3 Options:

- Beam can pass
- Beam is blocked
- Ballistic trajectories are blocked only

First Test of Carbon Coating with new Chopper

Measure the recombination/polarization with and without the Lyman-α photons

Be aware: Intensity of the atomic hydrogen beam might influence the recombination rate in the cell
-> Intensity losses due to beam stopper can be compensated

Measurements under preparation in Jülich:

- Master Thesis of Hendrik Smitmanns
- new chopper is mounted
- most components are ready to use:
  -> carbon coated cells are missing

-> New options for future storage cell targets: Carbon !!!!

-> Some more insights in hydrogen recombination for Astro-Physics