Polarized ^{3}He targets at MAMI

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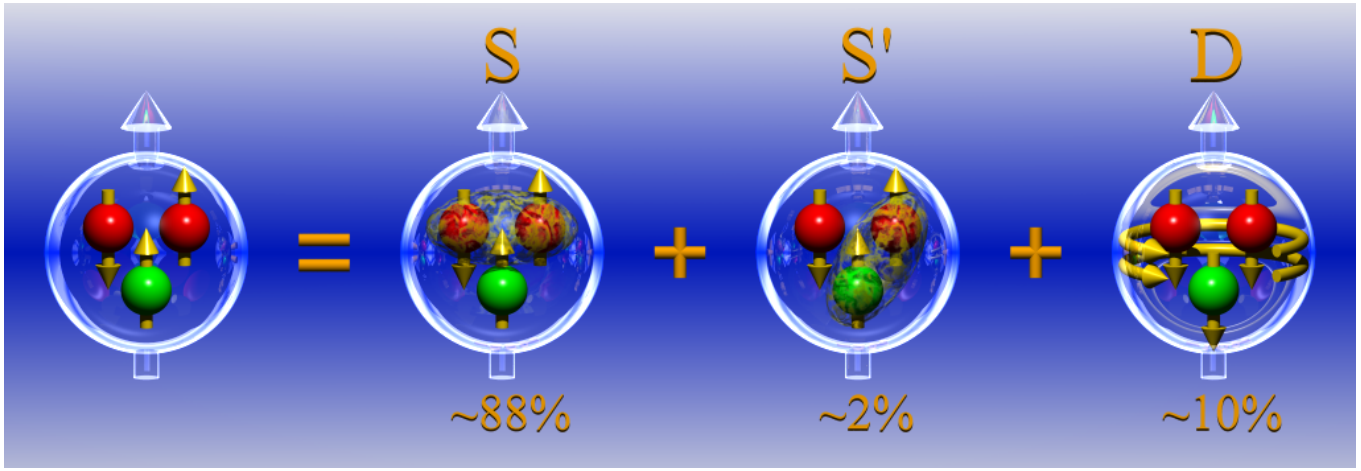
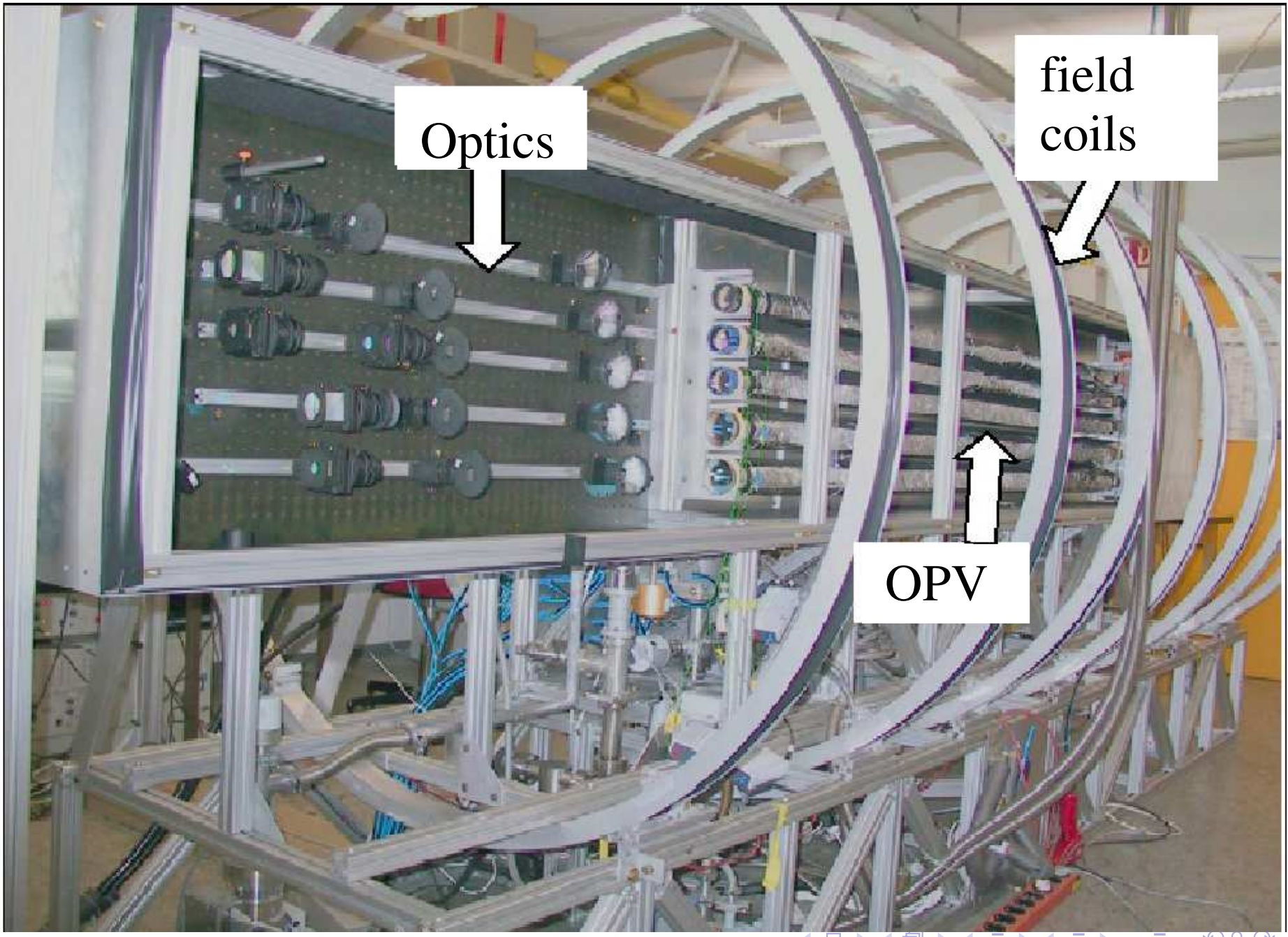
Polarized ^{3}He

- Effective polarized neutron target

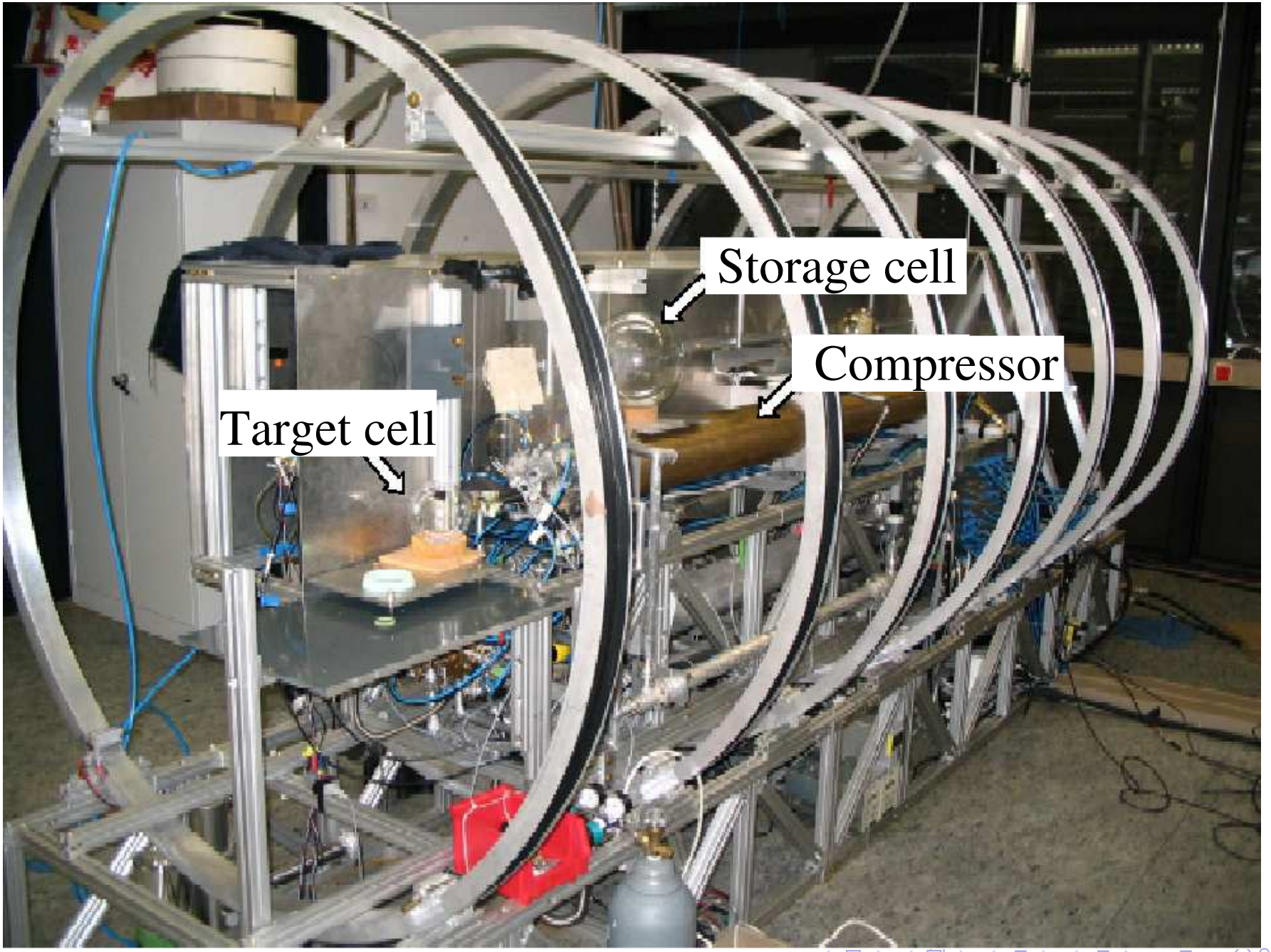


- Demands for the target
  - Polarization 70-75 %
  - Gas pressure 5 bar
- Metastability Exchange Optical Pumping (MEOP)
  - Metastable 1st excited state via gas discharge
  - Circularly polarized laser light for optical pumping (2*15 W fibre lasers, 1083 nm)
  - Transfer of polarization to the nucleus via hyperfine coupling
- Optical pumping at 1 mb, required pressure 5 bar
  $\Rightarrow$ Compression without loss of polarization.

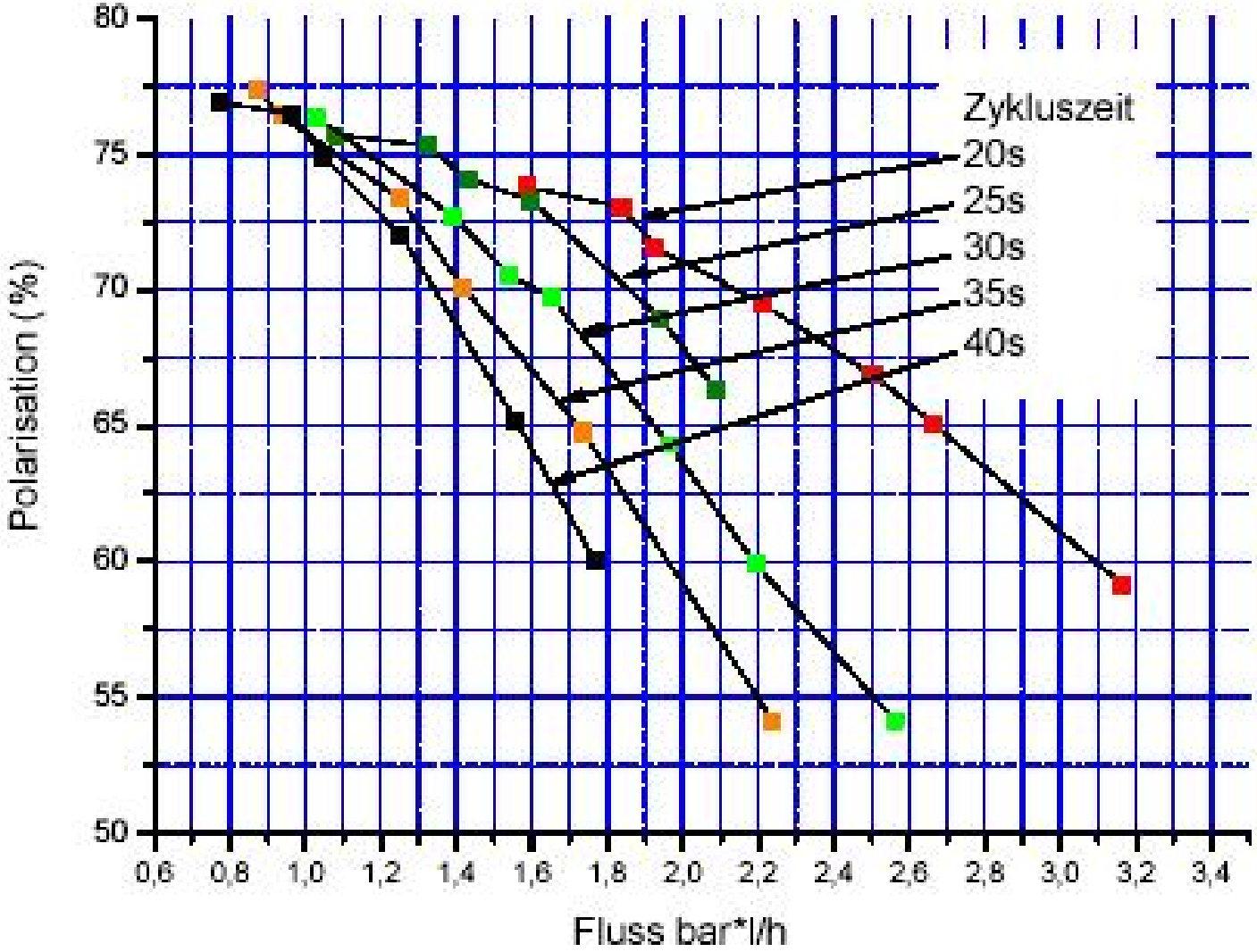
The Polarizer



The Polarizer



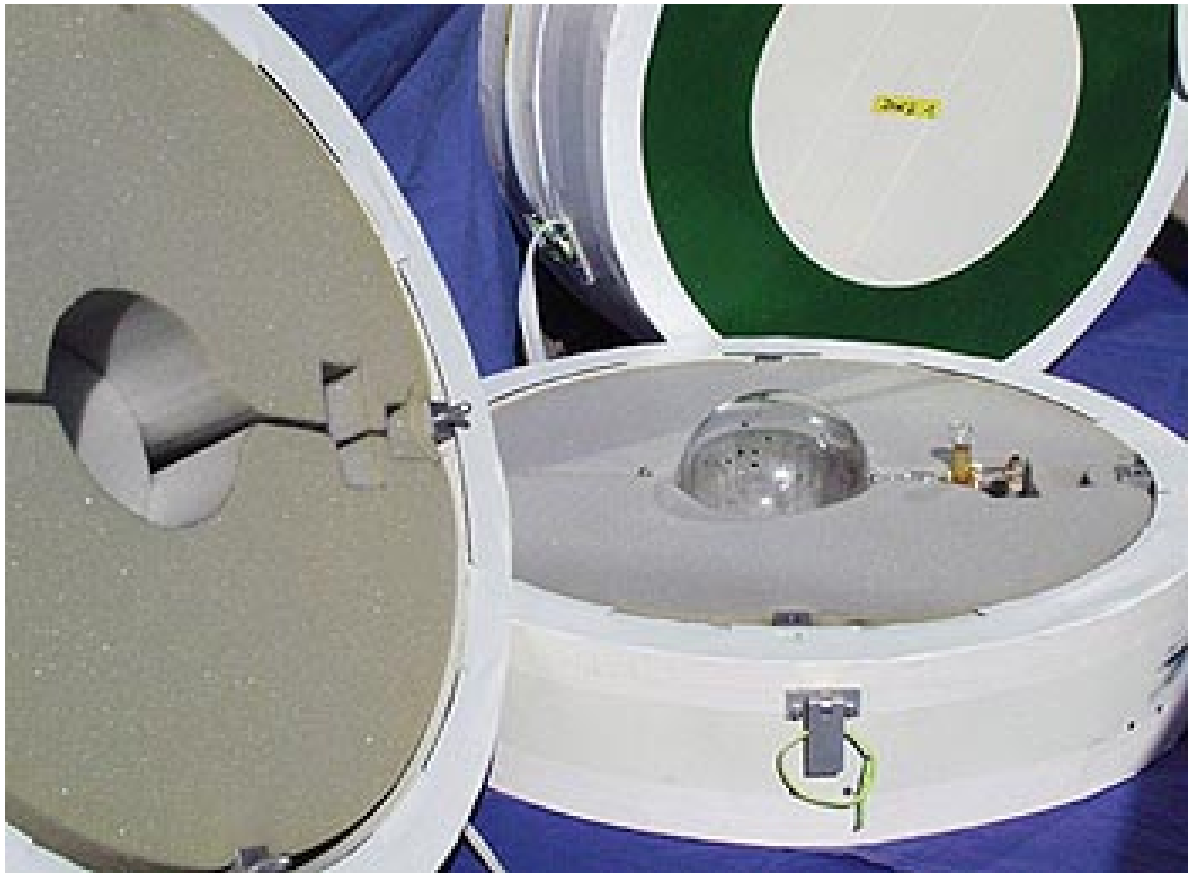
Performance of the Polarizer



- Ph.D. thesis J. Schmiedeskamp, Mainz, 2005

Transport of polarized ^{3}He

- Filling of the target cells at the polarizer
- Transport to the experiment in special transport boxes
  - μ-metal to shield external fields
  - Permanent magnets to provide homogeneous holding field



Relaxation mechanisms

- $$\frac{1}{T_1^{total}} = \frac{1}{T_1^{grad}} + \frac{1}{T_1^{dipole}} + \frac{1}{T_1^{beam}} + \frac{1}{T_1^{wall}}$$
- Field gradients
  - $$T_1^{grad} \sim \left(\frac{B_0}{dB/dr}\right)^2 \cdot p > 1000\ \text{h}$$

    (p = 5 bar and gradient $< 5 \cdot 10^{-4}\text{cm}^{-1}$)
- Dipole-dipole interaction
  - $$T_1^{dipole} \approx \frac{817\text{h} \cdot \text{bar}}{p[\text{bar}]} = 163\ \text{h} \quad (\text{p} = 5\ \text{bar})$$

electron beam	photon beam
Production of $^3He^+$ ions	Target + holding field inside Crystal Ball
$T_1^{beam} = \frac{E_{ion} \cdot V_T}{\frac{dE}{dx} \cdot z_T} \cdot \frac{e}{I} \cdot \frac{1}{P_T}$	
z_T = Target length, I = electron current	Ph.D. thesis of P. Aguar Bartolome
$\Rightarrow T_1^{beam} \approx 150\text{h}$ at 10 μA	

Target design: Entry Windows

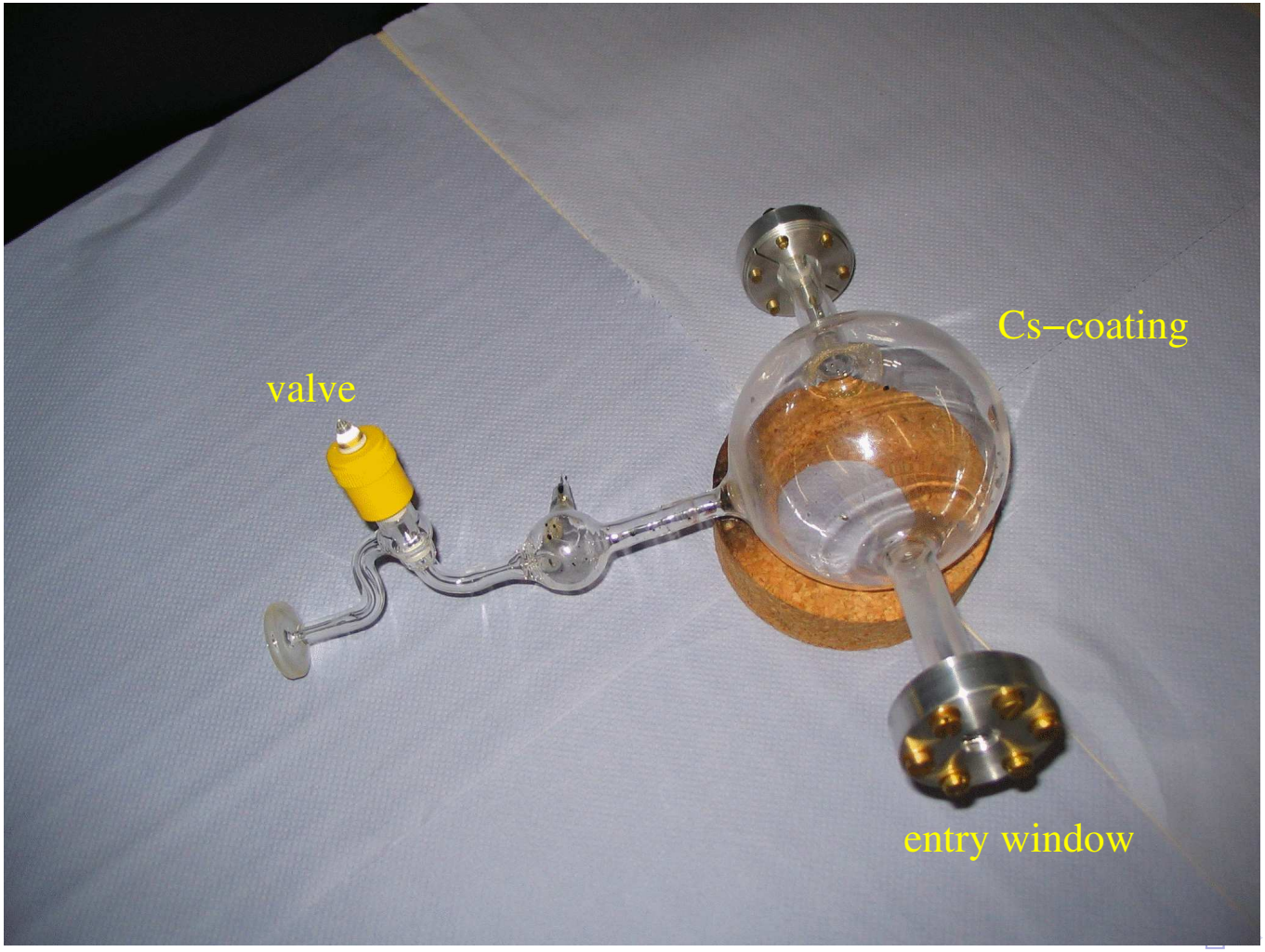
- Demands:
  - Stand pressure of 5 bar
  - Low atomic number to reduce background
  - Minimal effect on wall relaxation
- Tests with an uncoated aluminosilicate cell

window material	T_1^{wall}
Diamond (30 μm)	70 h
Titanium (25 μm)	70 h
Beryllium (50 μm)	20 h
Beryllium (50 μm) + Ti (25 μm)	70 h
Copper (25 μm)	50 h
Beryllium (50 μm) + Al (10 μm)	50 h

- T_1^{total} in the beam: $\frac{1}{T_1^{total}} = \frac{1}{1000\ \mathrm{h}} + \frac{1}{163\ \mathrm{h}} + \frac{1}{150\ \mathrm{h}} + \frac{1}{T_1^{wall}}$
- $T_1^{total} > 40\ \mathrm{h} \Rightarrow T_1^{wall} > 85\ \mathrm{h}$
- Cs coated quartz cells

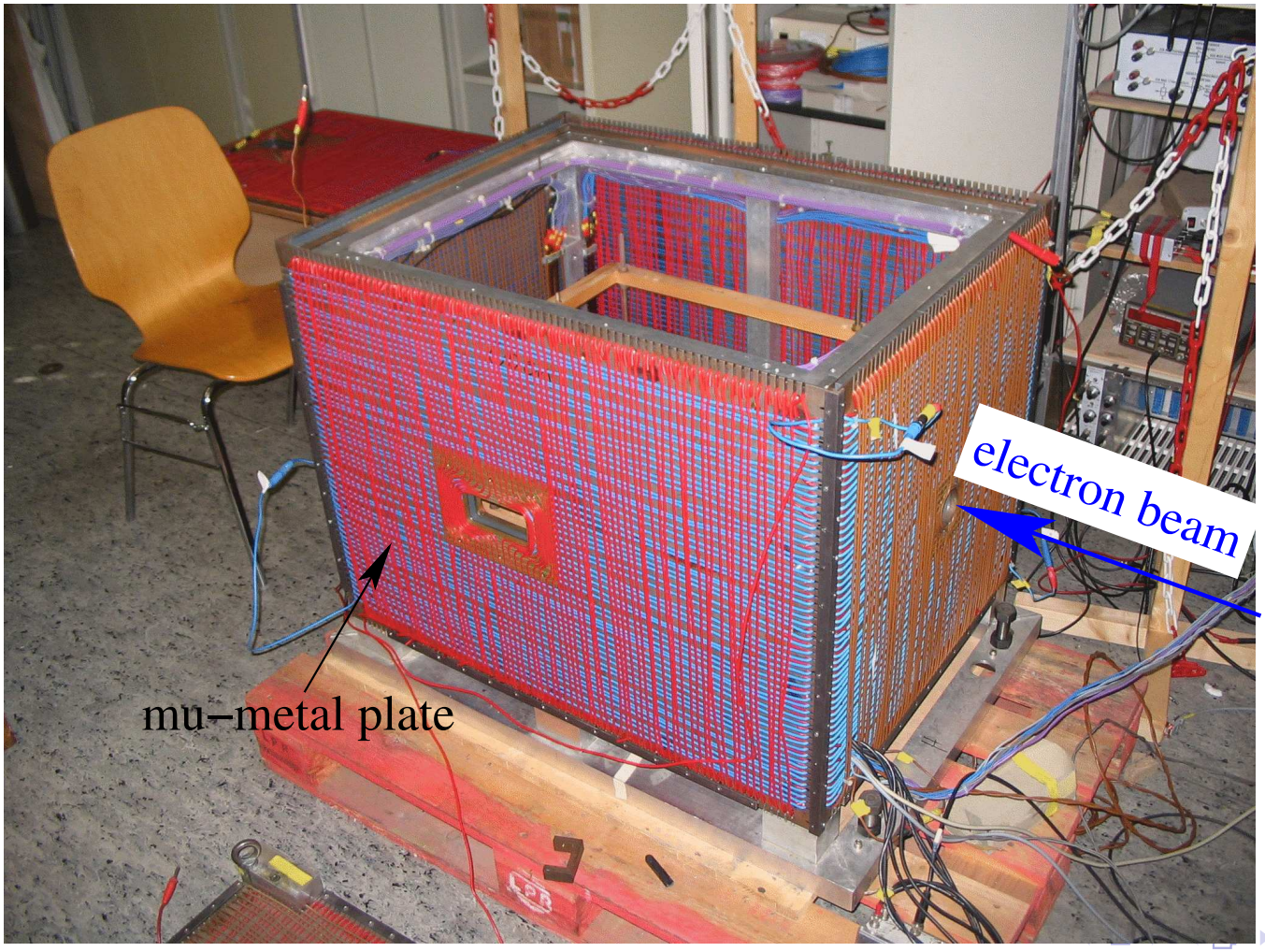
Target cell

- Quartz glass with cesium coating
- Greaseless valve, can stand pressures up to 8 bar
- Windows: Aluminum (0.4 μm) + Beryllium (50 μm)
- T_1^{wall} = 80 h



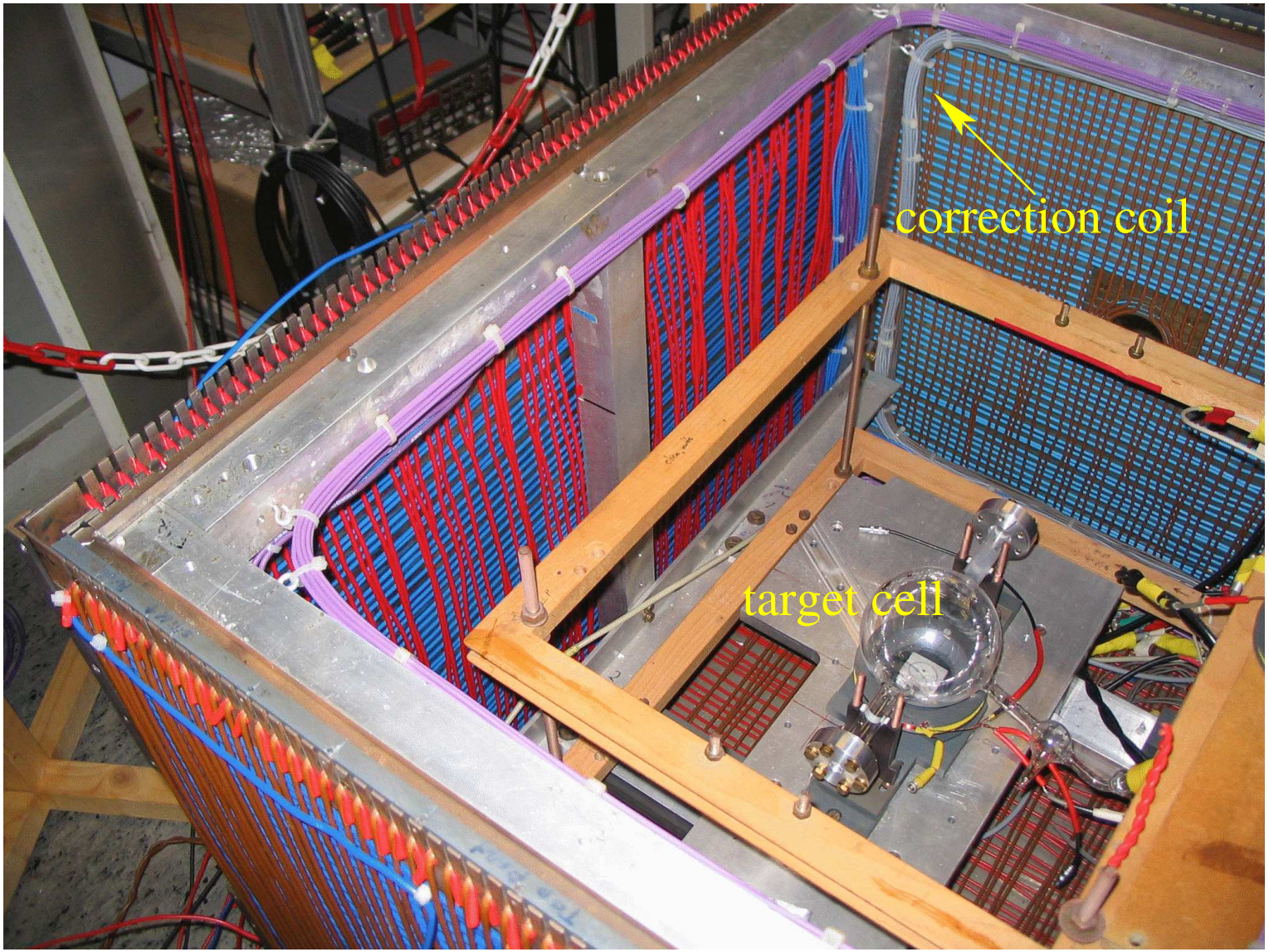
Holding field

- Relative gradient $\left|\frac{dB/dr}{B_0}\right| < 5 \cdot 10^{-4}$ cm^{-1}
- Shield and compensate for fields in A1-hall
- Rotate ^{3}He-spin in scattering plane



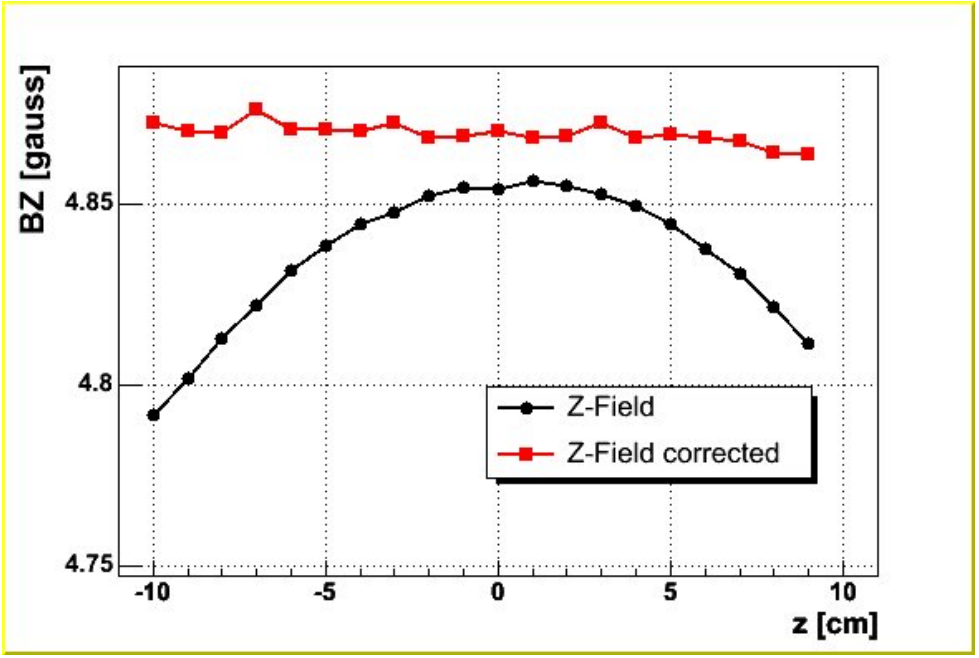
Holding field

- Correction coils to optimize the fields

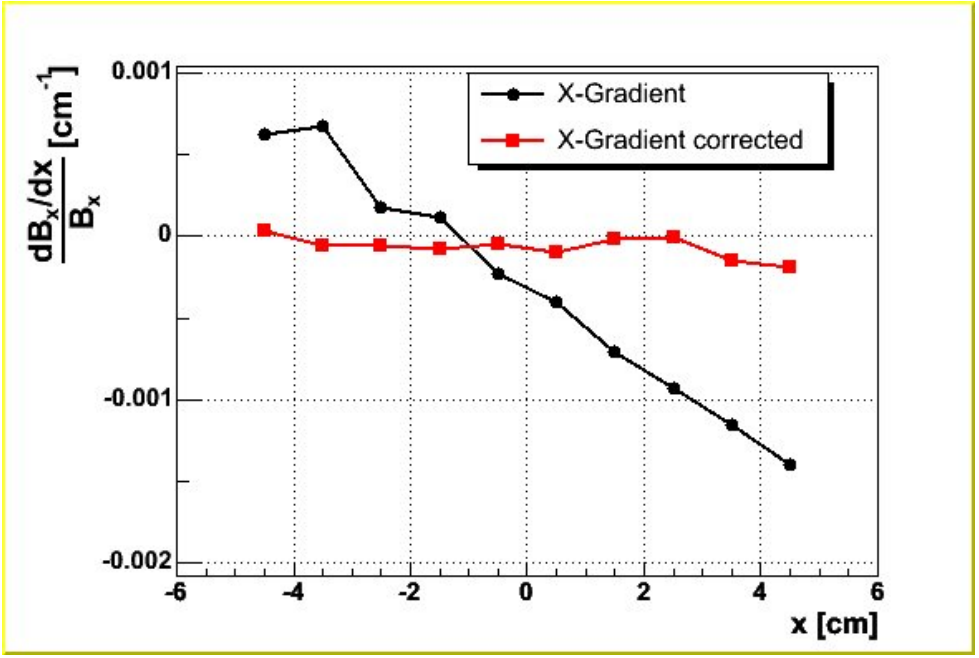


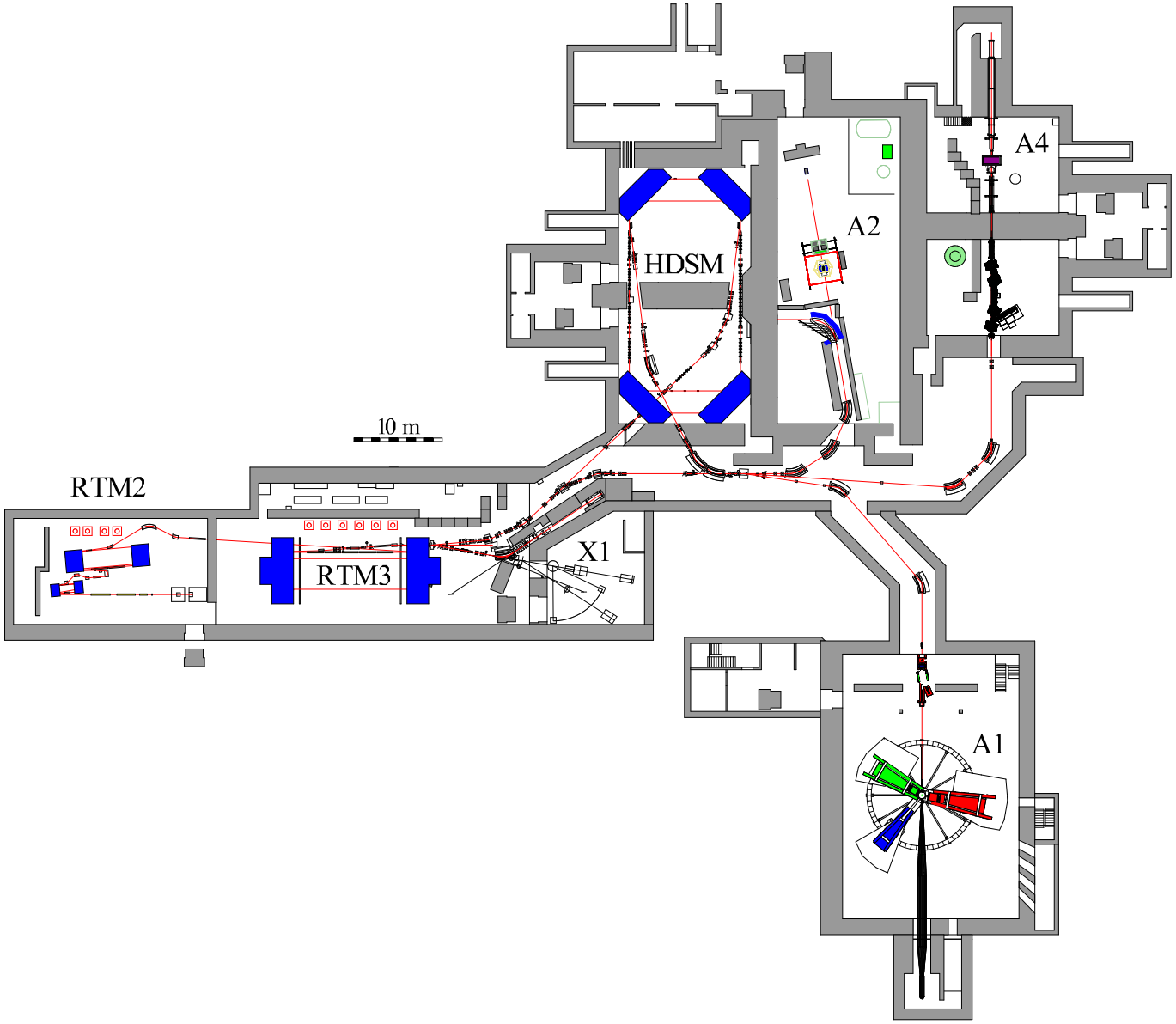
Field measurements

- Z-field, influence of correction coils



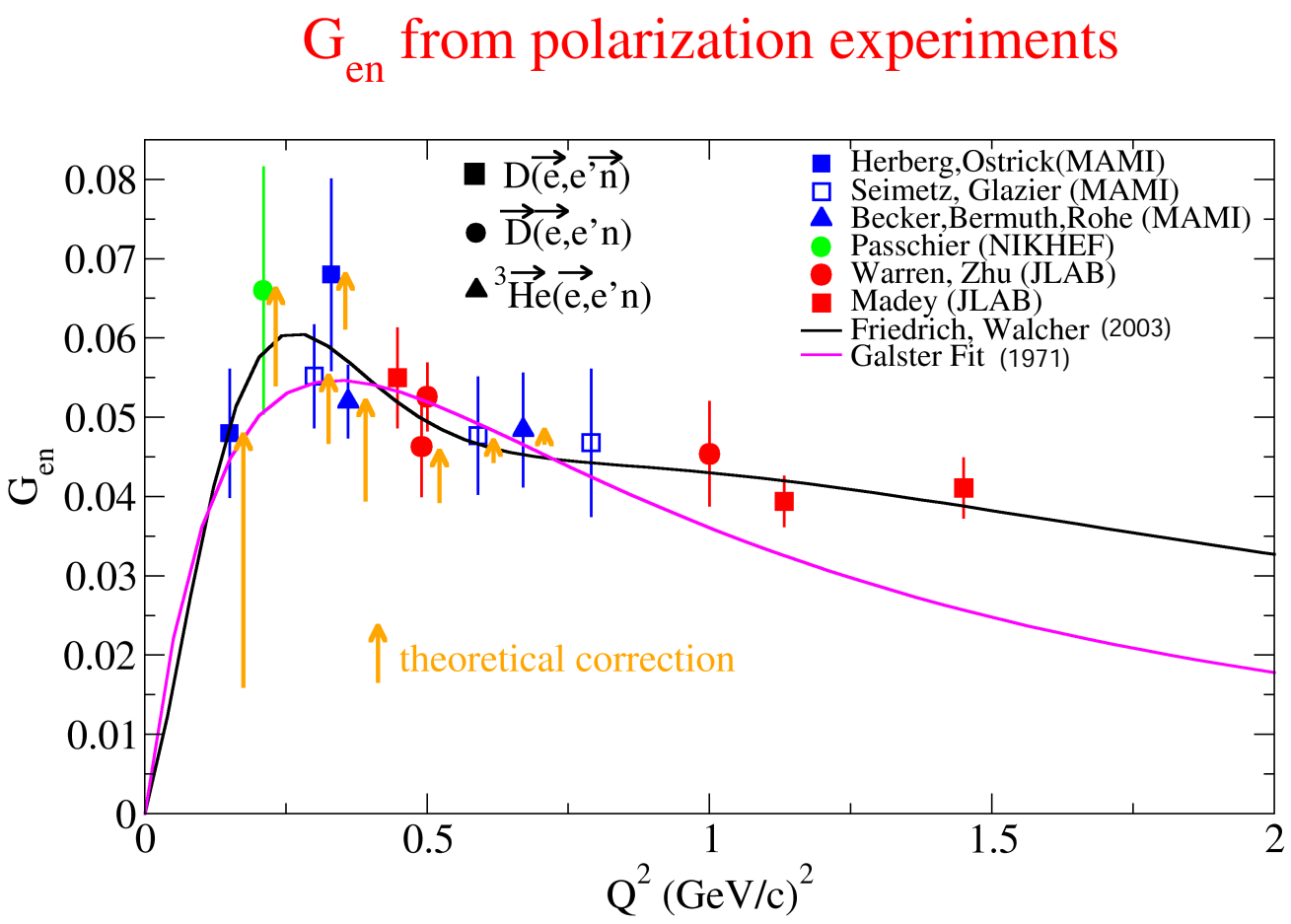
- Relative Gradient $< 5 \cdot 10^{-4}$ cm^{-1}





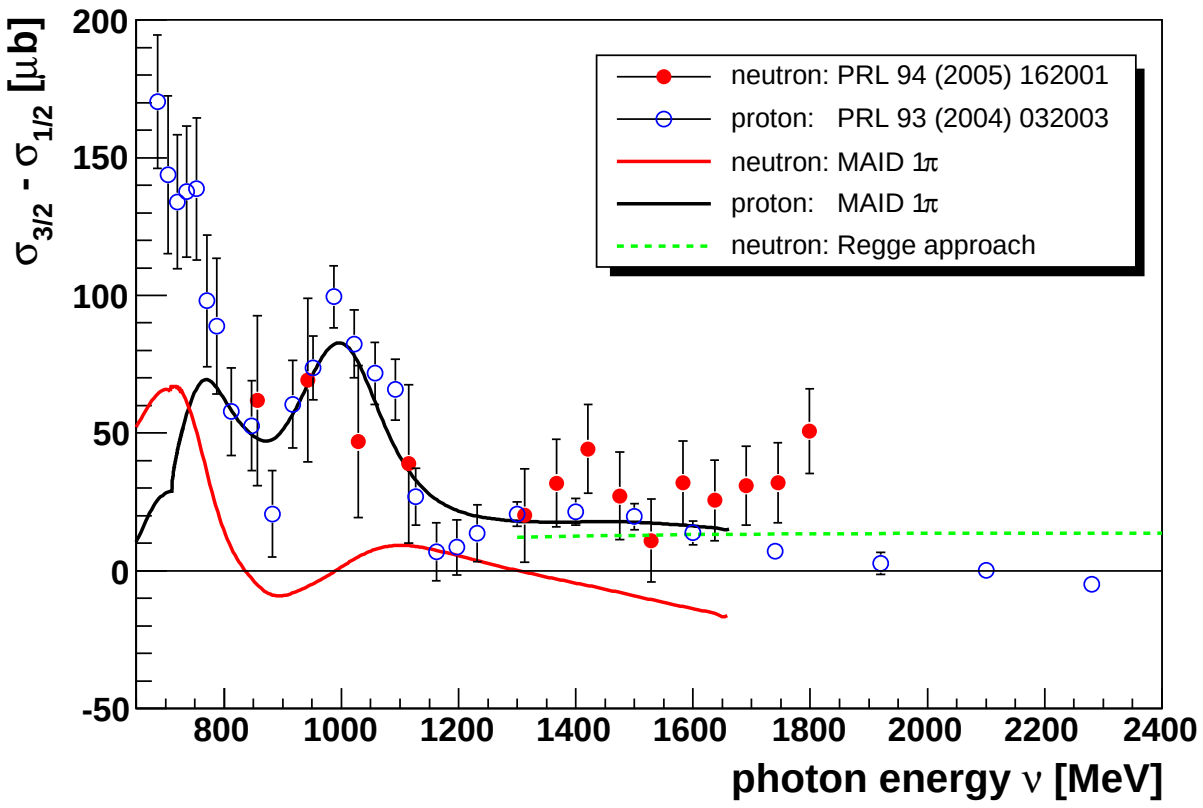
- MAMI-C: Maximum electron energy 1.5 GeV
- Beam for experiments: Beginning of 2007

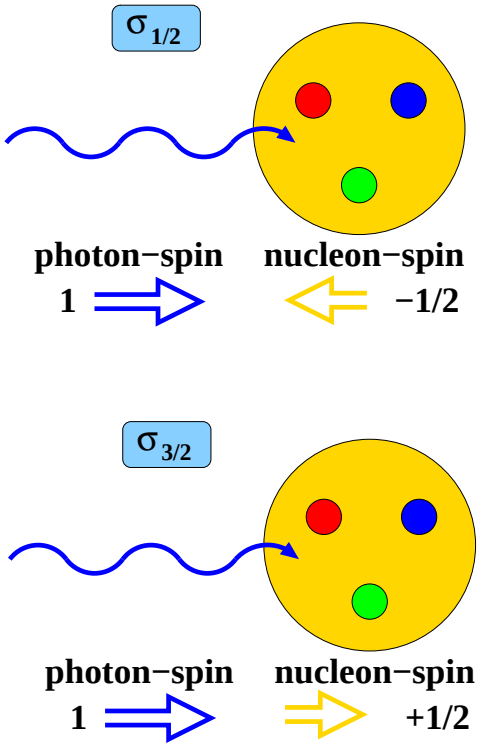
Upcoming experiments: Virtual photons



- Approved proposal to measure G_{en} with polarized ^{3}He at $Q^2 = 1.5\ (\mathrm{GeV/c})^2$

Upcoming experiments: Real photons, GDH



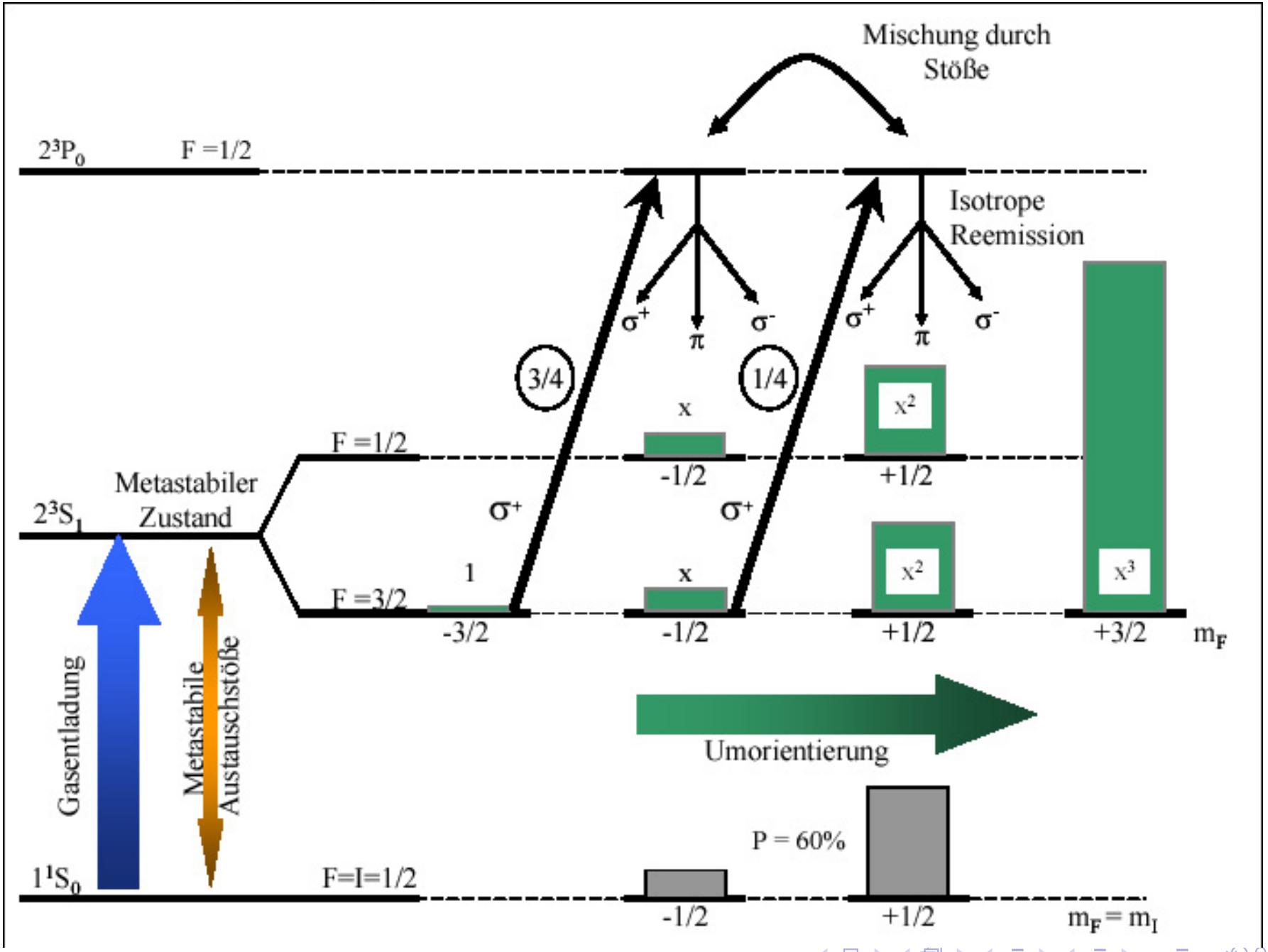


- Neutron: Significant contribution in the 3rd resonance region
  - Modification of the helicity amplitudes ?
  - Double pion contribution ?
  - ⇒ Crystal Ball detector at MAMI-C

Summary

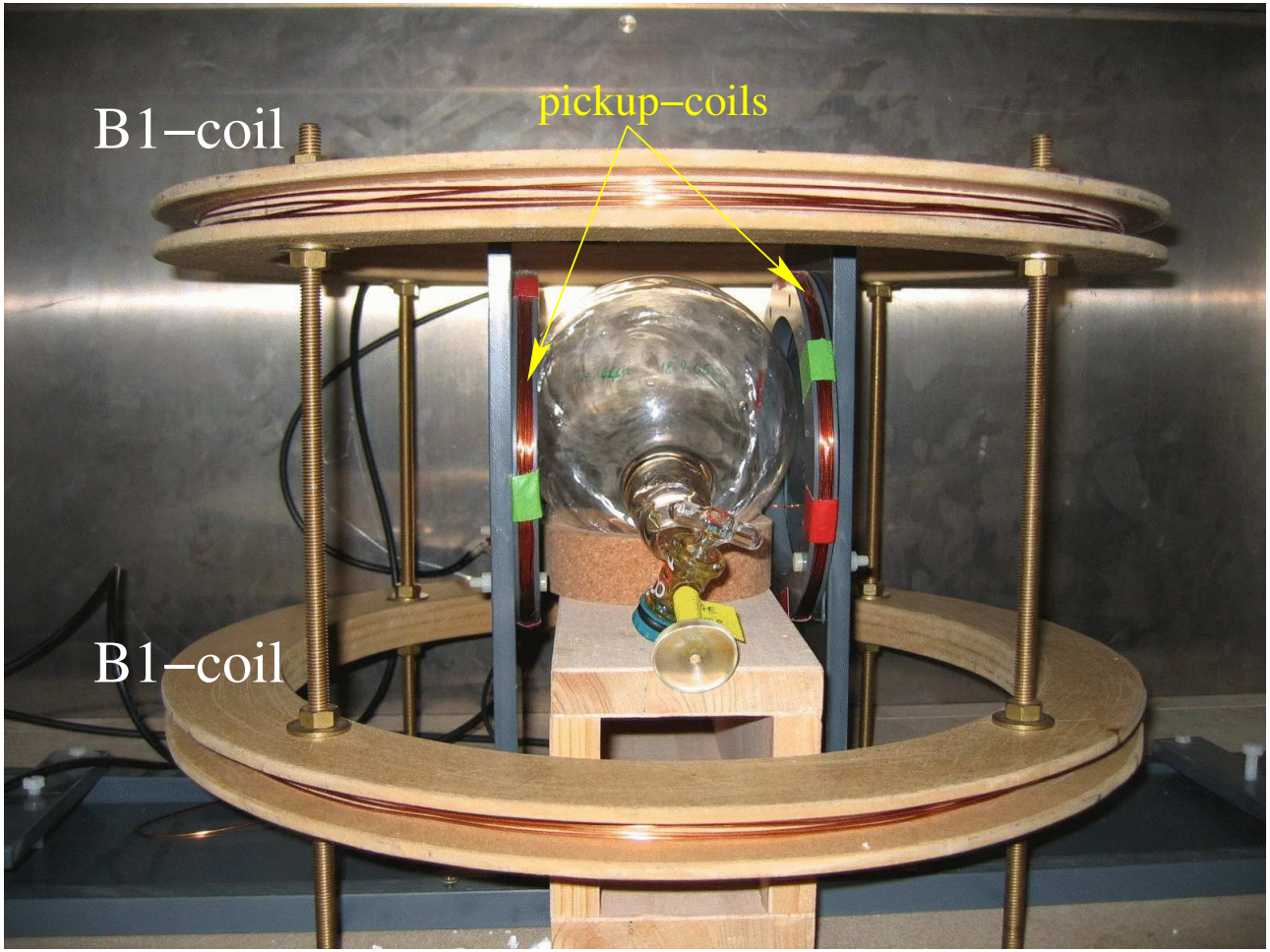
- Polarizer
  - Polarization 70-75 %
  - Flux: 2 bar·l/h
- Target cells
  - Test of different window materials
  - T_1^{wall} = 80 h with Cs-coated quartz cells
- Holding field
  - Relative gradient $< 5 \cdot 10^{-4}$ cm^{-1}
- $T_1^{total} \approx 40$ h (in beam)
- Exchange of target cells twice per day
- Mean target polarization 60-65 %

Polarization principle (MEOP)



T_1 measurement

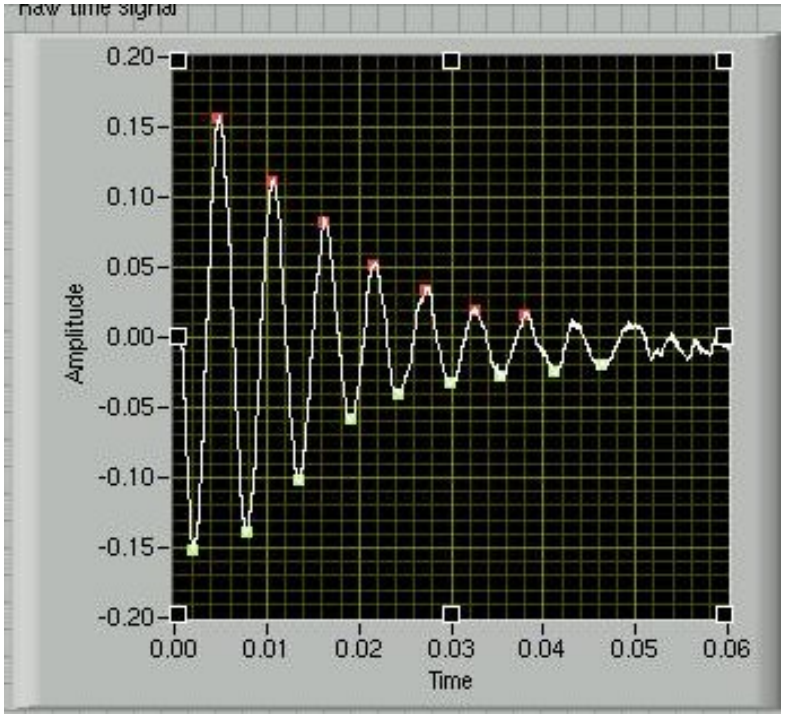
- Additional static field B1 for flipping the magnetization
  $\Rightarrow$ induced voltage in pickup coils
- Flipping angle $< 2^\circ$
- Polarization loss per measurement $\approx 0.02\%$

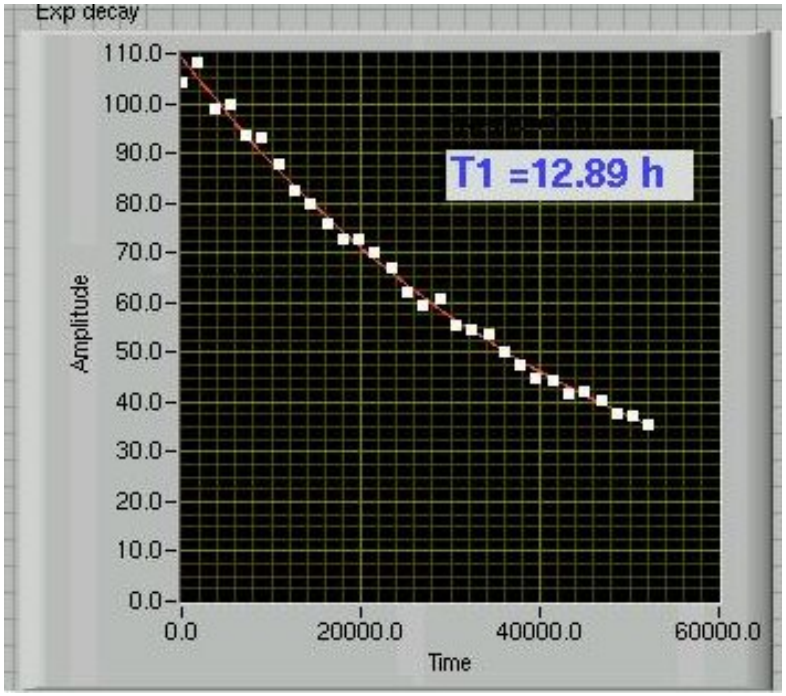


T_1 measurement

Induced voltage in pickup coils
Amplitude $\sim$ polarization

Exponential decay of the signal
$\Rightarrow$ Relaxation time T_1

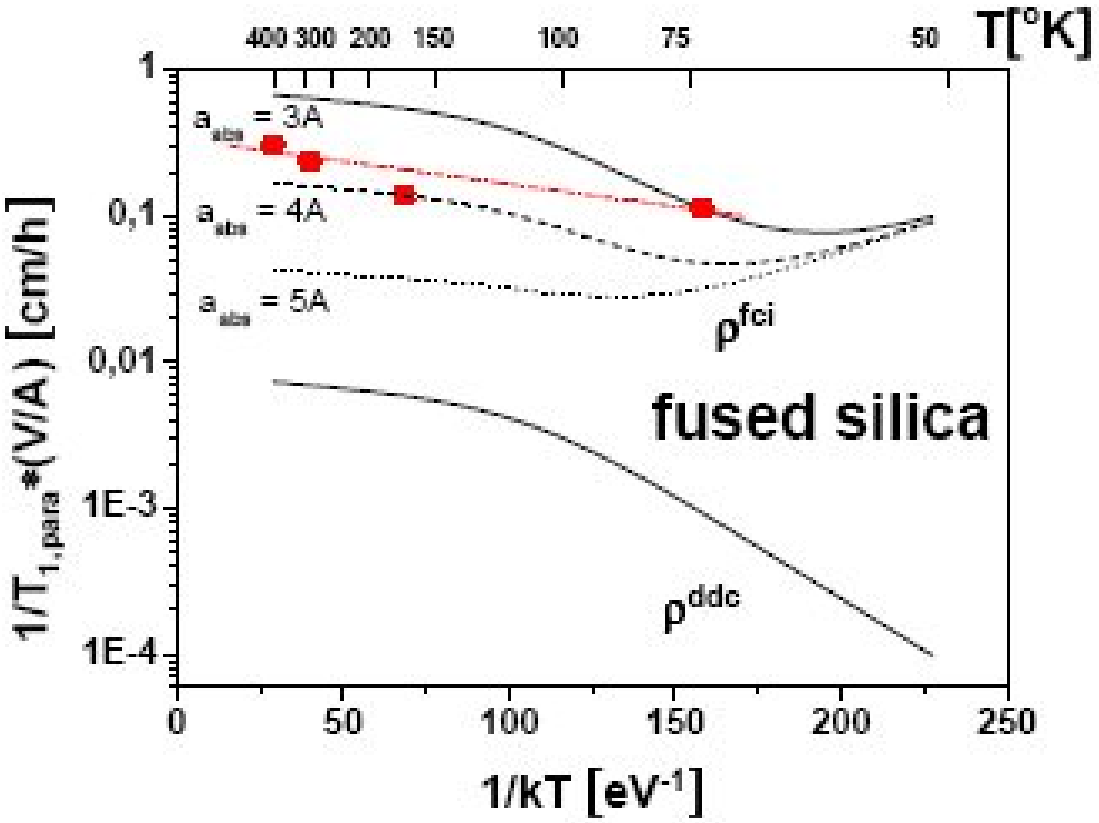




Understanding Wall Relaxation

- "Historical" model:
  Dipolar coupling to paramagnetic impurities, e.g. iron
- Experimental observation:
  "Iron-free" and normal Supremax cells have similar T_1 times

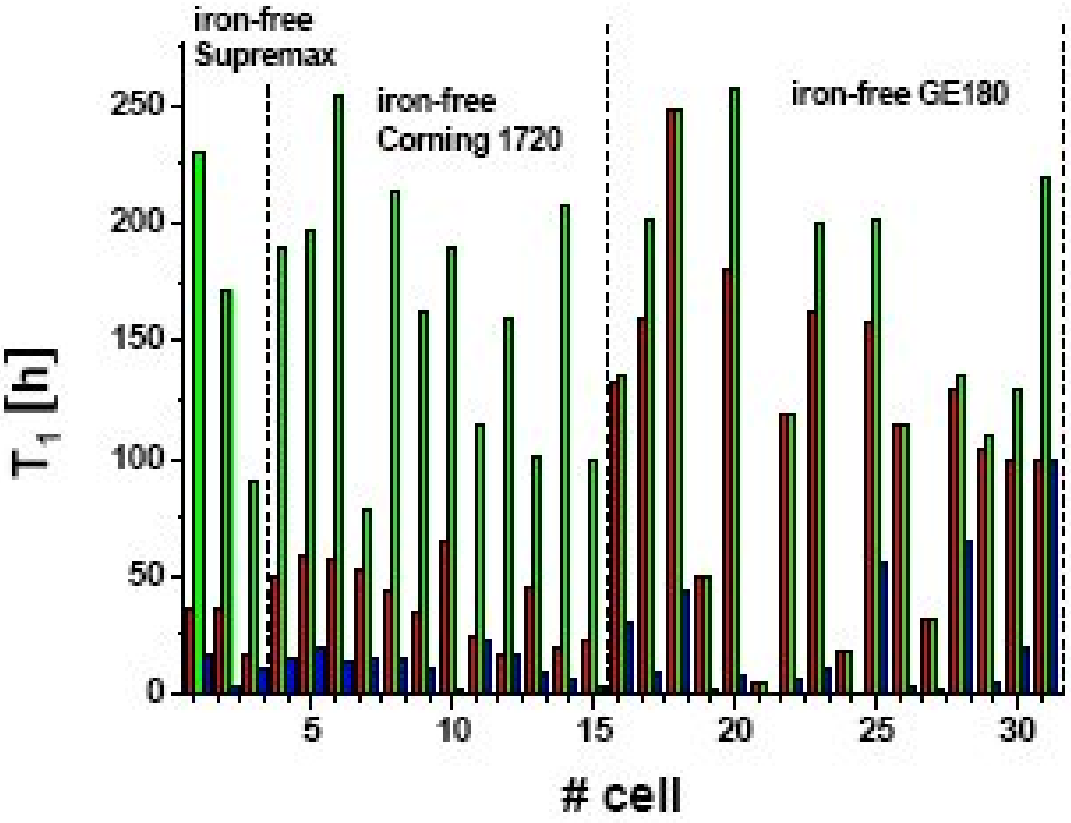
- New model:
  Including Fermi-contact interaction with dangling bonds.



- J. Schmiedeskamp *et.al.* Eur. Phys. J. D 38, 445-454 (2006)

Wall relaxation

- Ferromagnetic impurities
  ⇒ proper de-magnetization



- Adsorption
  ⇒ coating e.g. with Cs to reduce sticking time
- Dissolution
  ⇒ use of dense glasses (aluminosilicates)
  ⇒ pores closed by Cs coating

Demagnetization device