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Prestudy for the use of the polarized ^{3}He target at the photon beam of MAMI

- Motivation
- Polarized ^{3}He gas target
- Solenoid design and test
- ^{3}He feasibility test
- Summary and outlook

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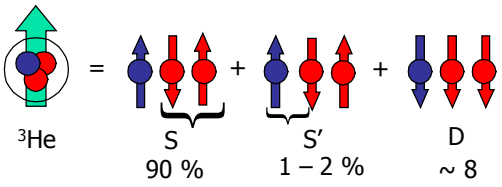
Motivation

- Test of the GDH sum rule on the neutron
- Double polarization experiments
- ^{3}He gas as neutron target for real photon beams
  - Number of neutrons
    2 cm D-butanol target $\longrightarrow$ $4.97 \cdot 10^{22} / cm^2$
    20 cm ^{3}He gas target (p = 6 bar) $\longrightarrow$ $1.2 \cdot 10^{21} / cm^2$
  - Polarization methods
    Spin-exchange optical pumping
    Metastability exchange optical pumping
  - Magnetic holding field
  - Target cell fits into the Crystal Ball detector

Polarized ^{3}He gas target

- ^{3}He is made of two protons and one neutron
- In the ground state the two protons couple together and cancel their spin contribution to the nuclear magnetic moment
- ^{3}He spin is carried by the unpaired neutron

➡ Polarized ^{3}He target used as polarized neutron target.



^{3}He polarization relaxation

The polarization decays with a time constant T_1^{tot}

$$P(t) \propto \exp\left(-\frac{1}{T_1^{tot}}\right)$$

The overall relaxation time T_1^{tot} is given by

$$\frac{1}{T_1^{tot}} = \frac{1}{T_1^{dipol}} + \frac{1}{T_1^{wall}} + \frac{1}{T_1^{grad}} + \frac{1}{T_1^{imp}} + \frac{1}{T_1^{beam}}$$

The relaxation is caused by

- Magnetic dipole-dipole interactions between ^{3}He atoms (T_1^{dipol})

  ➡ $T_1^{dipol}[h] \approx \frac{817}{p}$

- Wall relaxation due to paramagnetic centers on the inner surface of the cell (T_1^{wall}) ➡ Gas stored in special ironfree glass vessels.

^{3}He polarization relaxation (cont.)

- Magnetic field gradients (T_1^{grad}) ⇒

$$T_1^{grad}[h] = \alpha \left(\frac{B_0}{\Delta B / \Delta r} \right)^2 p \qquad \alpha = 17500 \left[cm^2\ bar\ h^{-1} \right]$$

The required relative field gradient is

$$\left(\frac{\Delta B / \Delta z}{B_0} \right) \leq 10^{-3} cm^{-1} \Rightarrow T_1^{grad}[h] \geq 300\ h \quad (p = 6\ bar\ ;\ B_0 = 7\ G)$$

- Interactions with gas impurities (T_1^{imp}) ⇒ The cell and gasses must be very clean.
- Ionization due to the experimental photon beam (T_1^{beam}).

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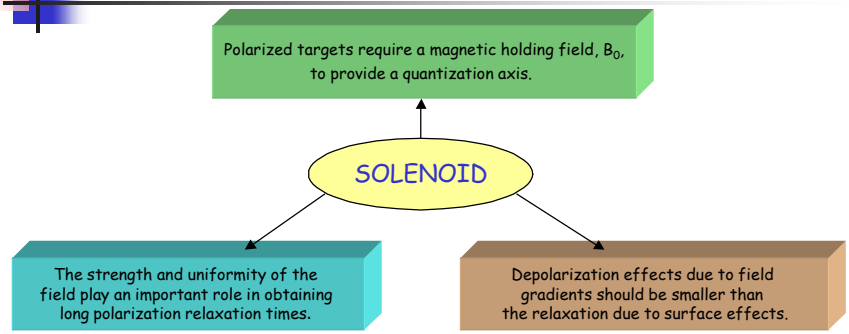
Solenoid design



- Main constraints
  - Produce magnetic holding field of 7G with a relative field gradient of 10^{-3} cm^{-1} for 6 bars in the target cell area.
  - Appropriate outer radius to fit inside the Crystal Ball detector.
  - Target cell dimensions determine the inner radius.
  - The outgoing particles have to pass the coil ⇒ minimization of the wire thickness.

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Magnetic field calculation

- Analytical calculation of the field and gradients (Mathematica)
- Numerical calculation of the field and gradients with a finite element code (FEMM)
- Geometric parameters for the solenoid

Parameter	Value
Solenoid length	80 cm
Nº windings	1975
Current	0.225 A
Inner coil diameter	82.0 mm
Outer coil diameter	82.848 mm
Copper wire diameter	0.424 mm

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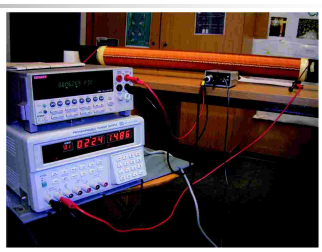
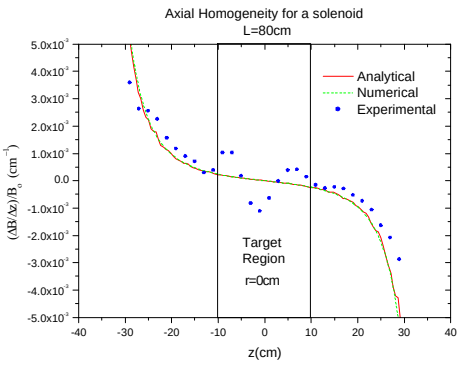
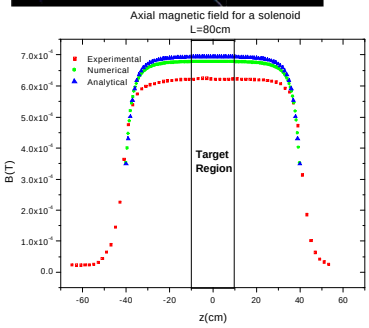
Solenoid test

- Coil wound on a CFK-tube with cross section of 82 x 1 mm^2 and 120 cm length.
- B magnitude determined using the three axis magnetometer MAG-03 MS (Bartington Instruments Ltd.)







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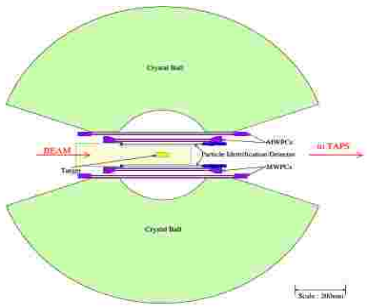
^{3}He feasibility test

- Goal: Study the ratio of nuclear scattering events produced on the windows of the target cell compared to that produced on the gas.
- Detectors



- Scattering experiment performed with the 855 MeV polarized photon beam at MAMI.
- Main detector was CB.
- Vertex detector consisting of two coaxial MWPCs with cathode readout.
- PID coaxial with the MWPCs used to identify charged particles.

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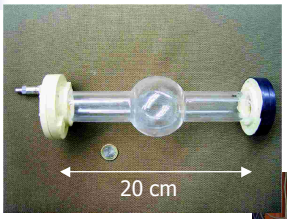
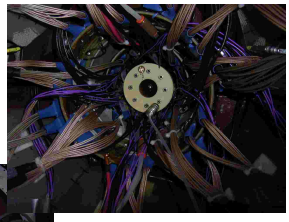
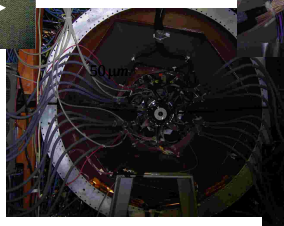
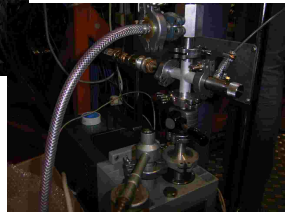
Experimental setup









- Quartz
- 100 cm^3
- 0.3 cm wall
- Pressure up 10 bar
- 50 μm kapton windows

- Entrance cell window placed 2 cm downstream from CB center
- Leak test performed in the whole system

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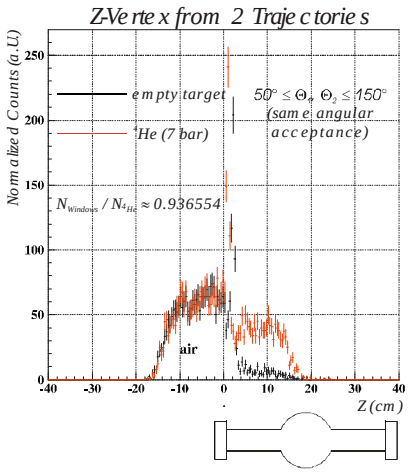
Data analysis and results

Analysis focused on identifying hadronic events from the particles scattered in the target cell.



$N_w / N_g = 0.93$ ➡

Experiment is possible!!!

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Summary and outlook

- Conclusions
  - ✓ A solenoid produced to provide the holding field for the ^{3}He target was designed and tested
  - ✓ First measurement of the relaxation time gave values of 10 hours ➡ $\left(\frac{\Delta B/\Delta Z}{B_0}\right) = 3 \cdot 10^{-3} cm^{-1}$
  - ✓ ^{3}He feasibility test was successfully performed giving a 0.93 ratio which is in good agreement with the 0.89 theoretical prediction ➡ EXPERIMENT IS POSSIBLE!!!
- Future
  - ➢ Improvement of the solenoid in order to achieve better homogeneity
  - ➢ New measurements of the solenoid magnetic field and homogeneity
  - ➢ Production of a new cylindrical target cell ➡ aluminosilicate materials present better relaxation times
  - ➢ New measurements for the relaxation time in a polarized cell placed inside the solenoid

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