Depolarization experiments at COSY:

Do unpolarized electrons affect the polarization of a stored proton beam?

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Outline

- Physics Motivation
- Beam Depolarization study using unpolarized Electron Targets: „The Deuterium Case“
- Plan for the Beam Lifetime Optimization (June 2007)
- Optimization of Polarization Lifetime

  (October 2007)

How to Polarize Antiprotons?

Only one experimentally tested method to make a beam:

Spin-dependent attenuation of a stored beam

(any spin-dependent loss filters spin of the stored beam)

contributing effects (qualitatively)

Nucleon-Nucleon: scattering outside ring acceptance
spin flip

Nucleon-Electron: scattering outside ring acceptance
spin flip

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$$\Theta_{max} = \frac{m_e}{m_p} \approx 0.5\,\mathrm{mrad}$$

Nucleon-Electron: ~~scattering outside ring acceptance~~
spin flip

FILTEX at TSR (1992)

Polarized Antiproton EXperiments

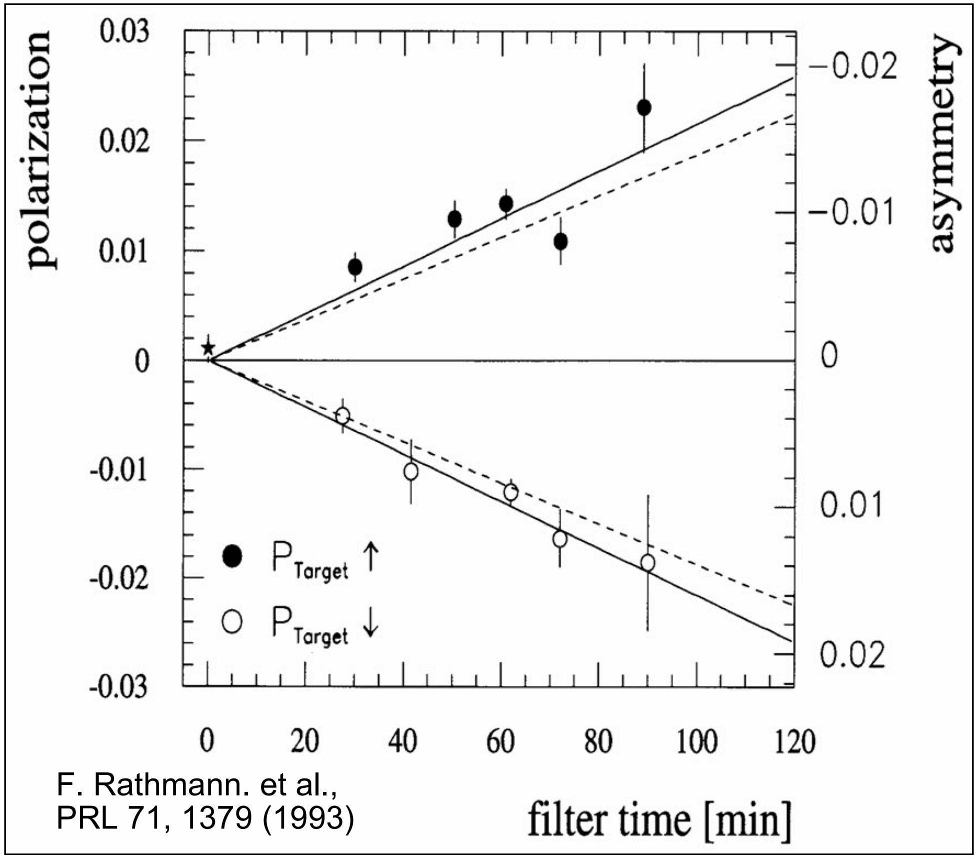
Observed polarization build-up:

$$dP/dt = \pm (1.24 \pm 0.06) \times 10^{-2}\ h^{-1}$$

$$P(t) = \tanh(t/\tau_1)$$

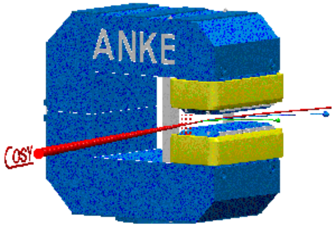
$$1/\tau_1 = \sigma_1 \cdot Q \cdot d_t \cdot f_{rev}$$

$$\sigma_1 = 72.5 \pm 5.8 \text{ mb}$$



F. Rathmann. et al., PRL 71, 1379 (1993)

Spin filtering works! But how?



Two Interpretations

1994 Meyer and Horowitz: three distinct effects

1. Selective removal through scattering beyond θ_{acc}=4.4 mrad ($\sigma_{R\perp}$=83 mb)
2. Small angle scattering into ring acceptance ($\sigma_{S\perp}$=52 mb)
3. Spin-transfer from polarized electrons of target atoms to stored protons ($\sigma_{E\perp}$=-70 mb)

$$\sigma_1 = \sigma_{R\perp} + \sigma_{S\perp} + \sigma_{E\perp} = 65 \text{ mb}$$

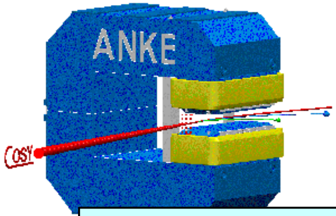
2005 Milstein & Strakhovenko + Nikolaev & Pavlov:

only pp scattering contributes to polarization buildup

$$\sigma_1 = 85.6 \text{ mb}$$

Goal: Distinguish between this two interpretations

→ Do polarized electrons contribute to the polarization build-up of a stored proton beam?



Basic Idea

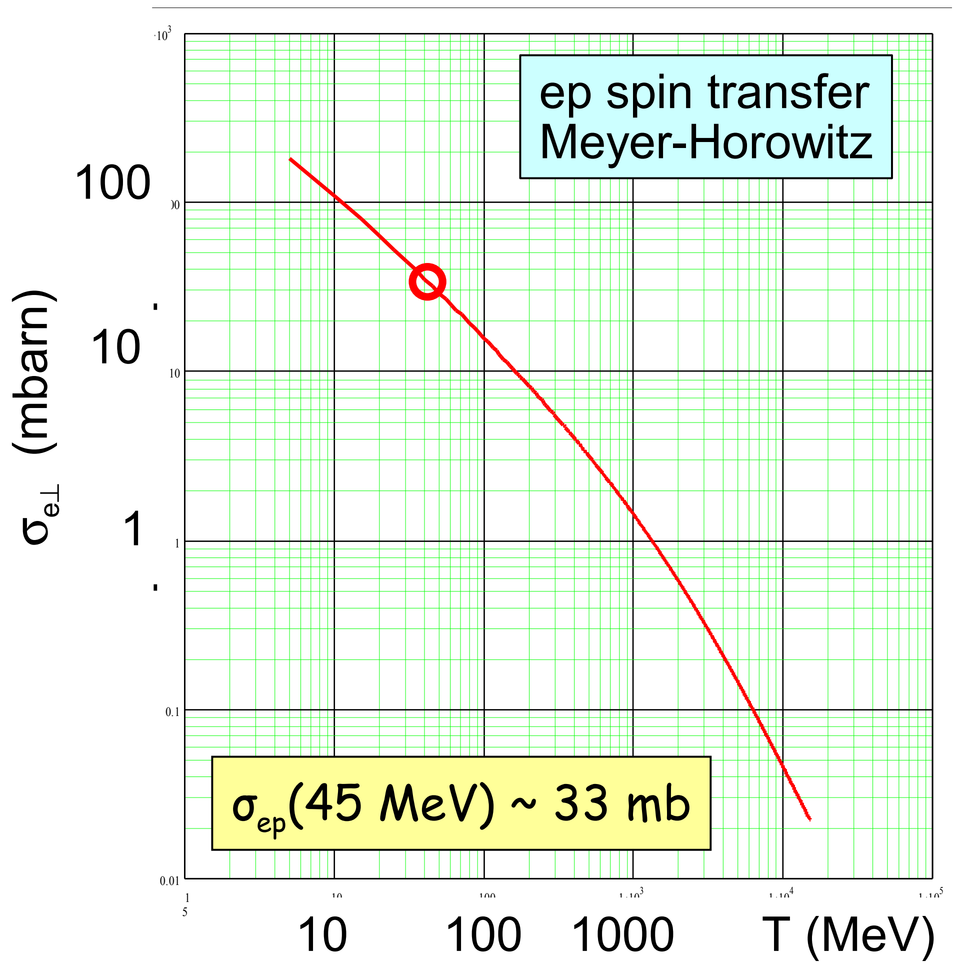
Polarized Antiproton EXperiments

If polarized electrons polarize an unpolarized proton beam
then
unpolarized electrons depolarize a polarized proton beam (H.O.Meyer)

Depolarization Experiment at T_p=45 MeV:
→ Deuterium or Helium as unpolarized electron target
($d_t^e \approx 2 - 4 \cdot 10^{14}$ cm^{-2})

$$P(t) = P_0\, e^{-\frac{t}{\tau_p}}$$

$$\tau_p = \frac{1}{\sigma_{ep} \cdot f \cdot d_t \cdot Q^e}$$



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- Beam Depolarization study using unpolarized Electron Targets:
  1. The Helium Case --> PAC32
  2. The Deuterium Case --> now
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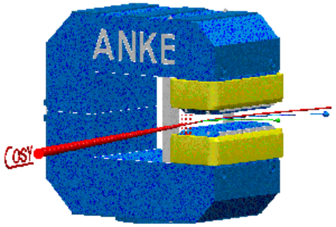
Unpolarized Electron Targets

Dense electron target can be provided at ANKE by:

1. Storage cell (H_2, D_2, or any other gas: ^4He)
2. Cluster Target for H_2 and D_2



Beam Polarization from pd elastic scattering

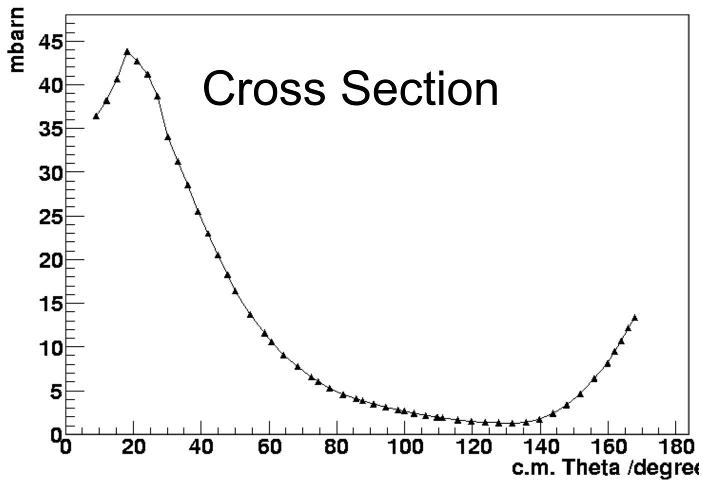
Polarized Antiproton EXperiments

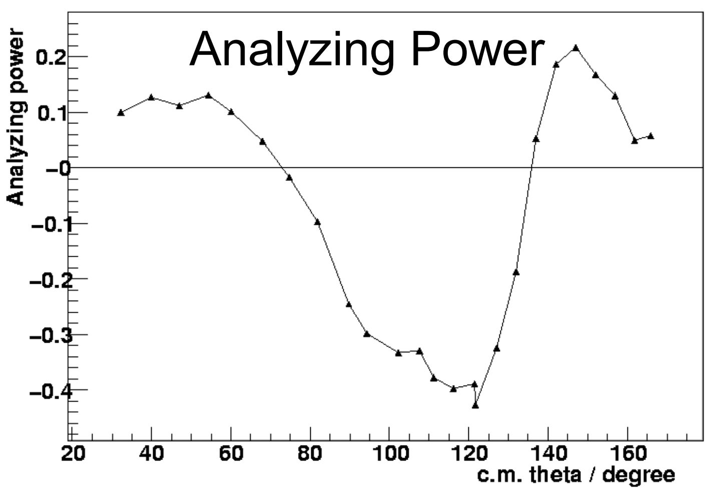
Efficient Analyzer required:

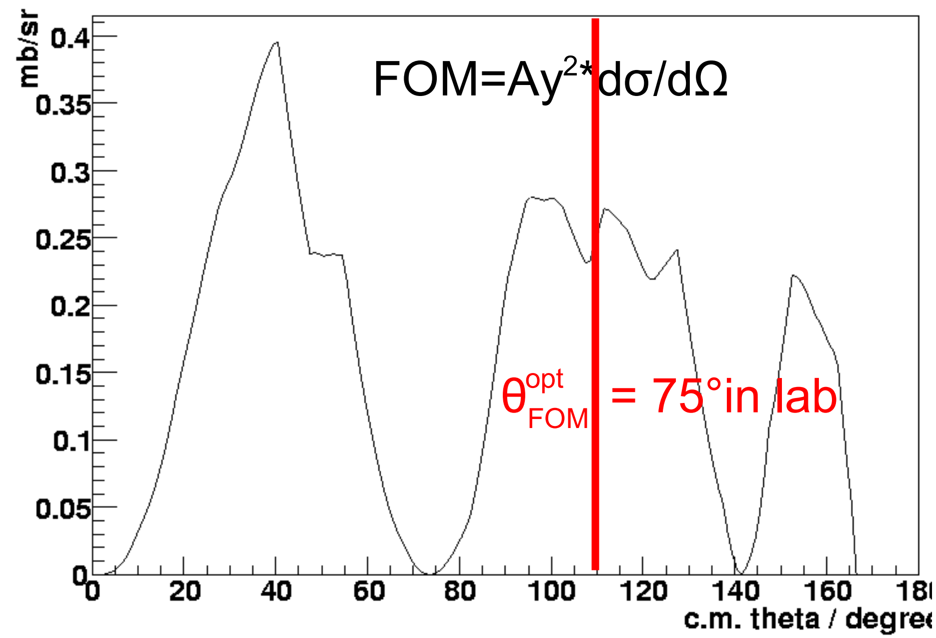
p-d elastic scattering

- **Moderate analyzing power (~0.4)**
- **Dense cluster target**

p-d at 45MeV







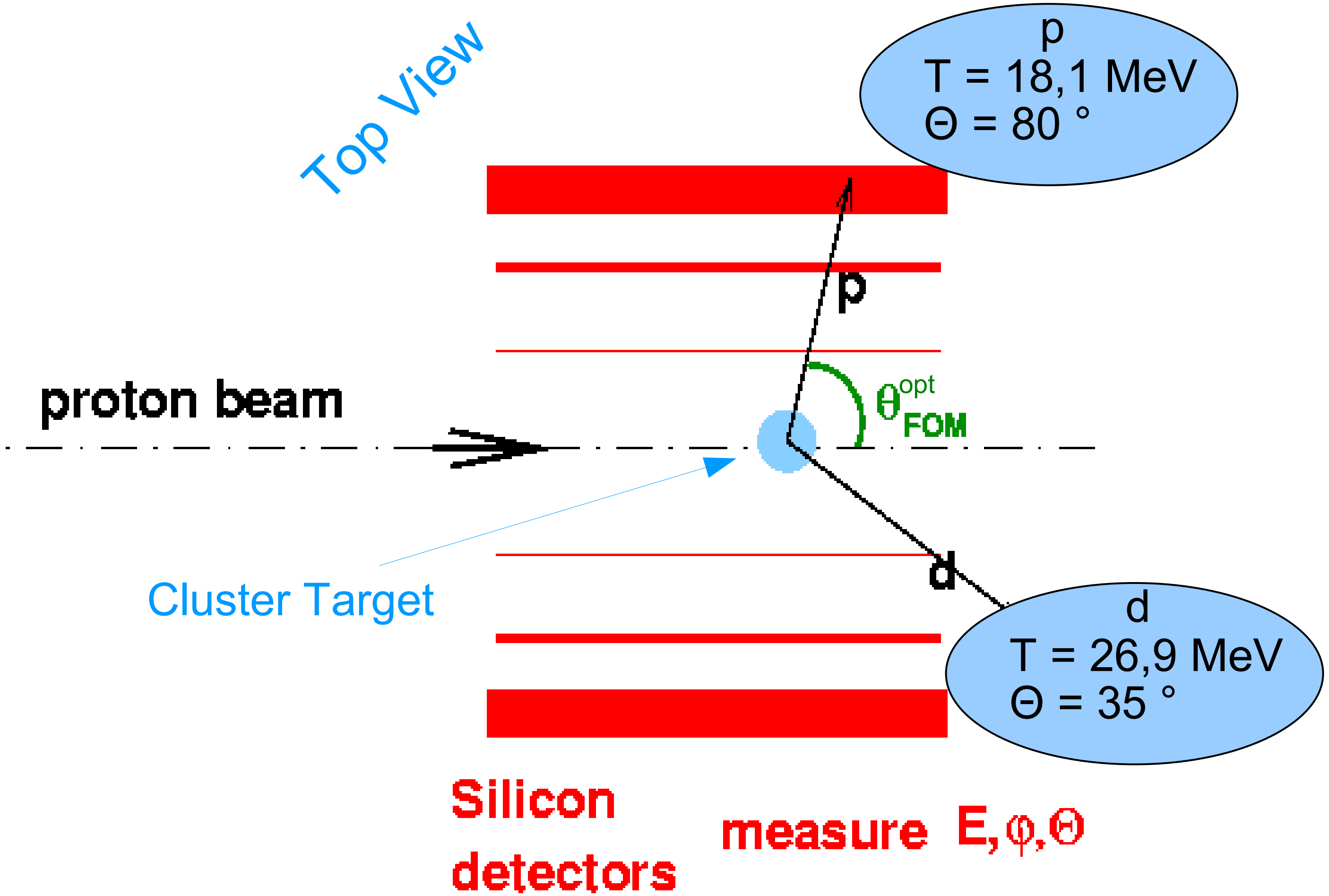
S.N.Bunker et. al. Nuclear Physics **A113** (1968) 461-480

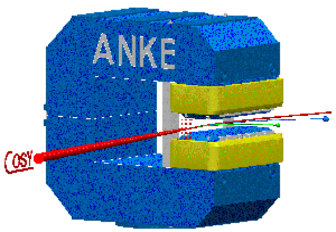
Deuterium Case

Experimental Setup for D_2 - Cluster Target

Polarized Antiproton EXperiments

2 Silicon Tracking Telescopes
left and right side of COSY beam





Polarization Lifetimes

$$P(t) = P_0 \, e^{-\frac{t}{\tau_p^{total}}}$$

$$\frac{1}{\tau_p^{total}} = \frac{1}{\tau_p^{COSY}} + \frac{1}{\tau_p^{MH}}$$

1. Polarization Lifetime of COSY is finite → τ_p^{COSY} > 45000s
2. Depolarizing target effect is about 100 times larger than residual gas effect → τ_p^{MH} > 340000s

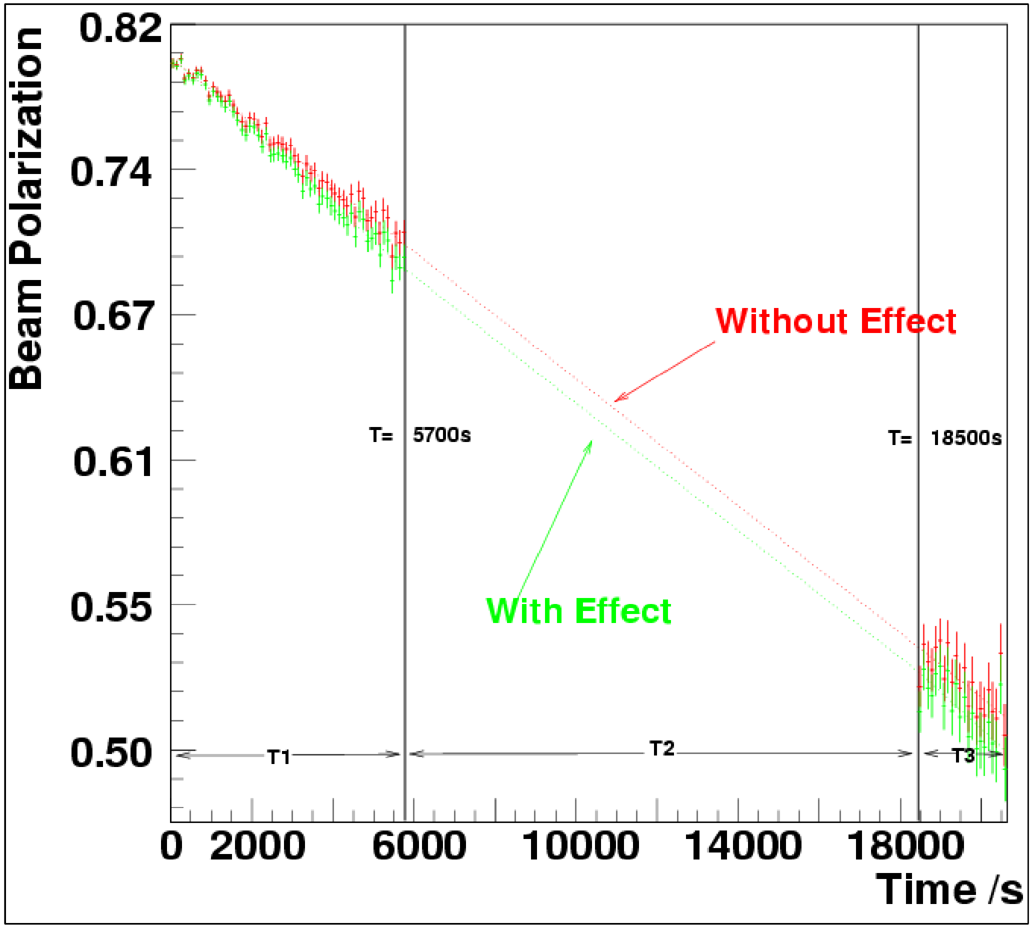
Special COSY cycle needed to obtain individual polarization lifetimes

Optimum COSY Cycle for D_2–Cluster Depolarization Measurement

Polarized Antiproton EXperiments

- Target-On time: T_1 and T_3 → τ_p^{total}
- Target-Off time: T_2 → τ_p^{COSY}

Significance: $\sigma = \frac{\tau_p^{MH}}{\Delta\tau_p^{Target}}$

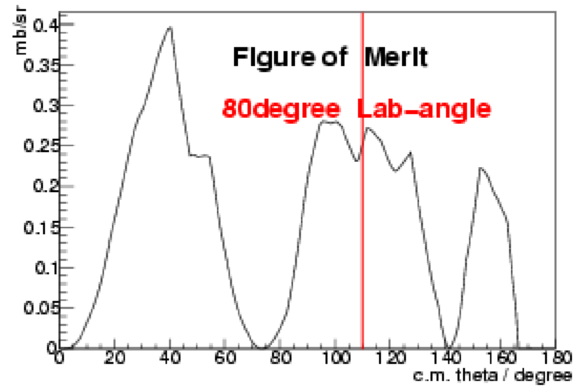


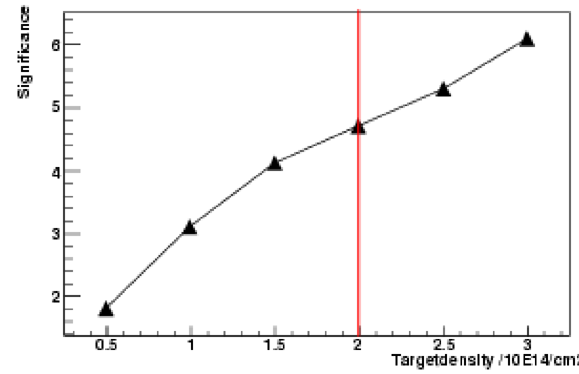
Expected Significance:
4 – 5 σ of target effect in 4 weeks of data taking

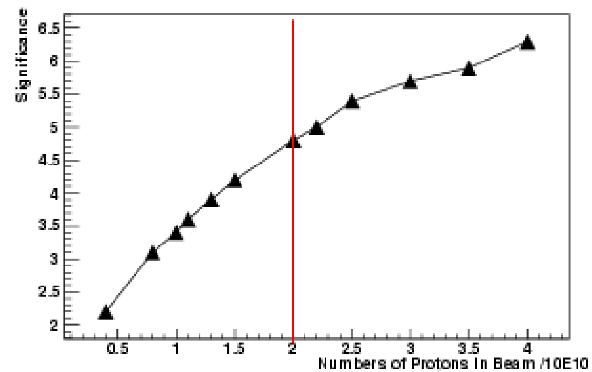
Parameters for D_2-Cluster Target Measurement

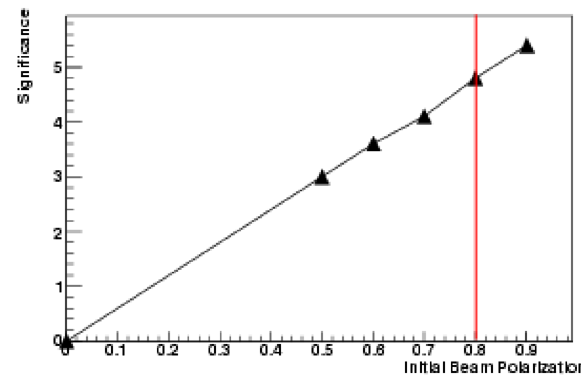
significance:

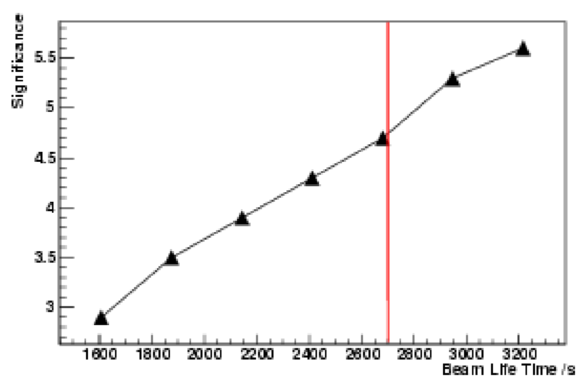
$$\sigma = \frac{\tau_p^{MH}}{\Delta\tau_p^{Target}}$$

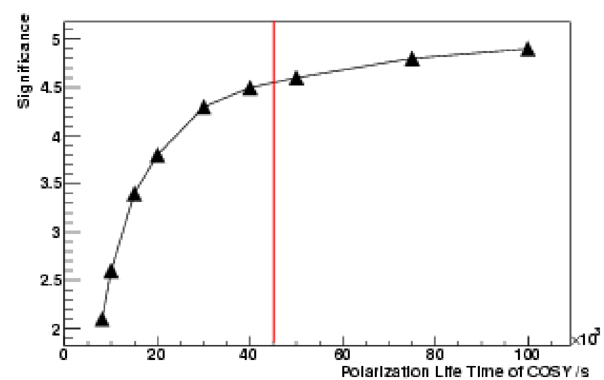


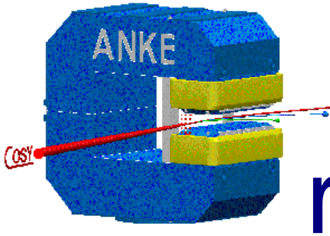












Comparison of requirements with D_2- and ^{4}He-Target

Polarized Antiproton EXperiments

Deuterium

- number of protons in beam > $2 \cdot 10^{10}$
- initial beam polarization P > 0.8
- τ_{beam}^{target} > 2700 s
- $\tau_{beam}^{notarget}$ > 10000 s
- τ_{P}^{COSY} > 45000 s $\tau_{P}^{MH} = 340000$ s
- $d_t \sim 2 \cdot 10^{14}$ D/cm^2
- significance: 4 - 5 σ

Helium

- number of protons in beam > $2 \cdot 10^{10}$
- initial beam polarization P > 0.8
- τ_{beam}^{target} > 670 s
- $\tau_{beam}^{notarget}$ > 10000 s
- τ_{P}^{COSY} > 45000 s $\tau_{P}^{MH} = 170000$ s
- $d_t \sim 2 \cdot 10^{14}$ ^{4}He/cm^2
- significance: 4 - 5 σ

Advantages of Deuterium Cluster Target:

1. Cluster target with small target dimensions of about 1x1x1cm^3
=> high geometrical acceptance of detection system

2. Setup of detectors is identical to setup of existing ANKE STT's (available)

3. much less residual gas in COSY ring

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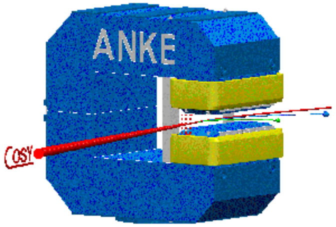

Polarized Antiproton EXperiments

Optimization of Beam Lifetime at Injection (June 2007)

1. Produce a closed orbit (BPM as diagnosis tool)
2. Orbit corrections: horizontal and vertical.
3. Local Bumbs at each quadrupole: make lokal bumbs in the beam trajectory
   measure the beam position and put the beam to the centre position
   do so at „all“ points vertically and horizontally
4. Use the Electron-Cooler
5. Search of an optimal position for the storage cell
6. Try different tunes. Stay near $Q_x = Q_y = 3.62$.

   One should have an eye on good locations for the depolarizing resonances
7. Chromaticity corrections: use Sextupoles in archs
8. Use a ^{4}He and/or a deuterium target (storage cell)
   One has to learn,
   1. up to which density the E-Cooler is capable to reach stable beam conditions (limited emittance growth)
   2. to keep the beam parameters stable at different target densities
   3. whether a burrier bucket cavity could help

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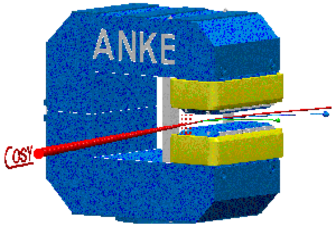

Requirements

- Polarized Proton Beam
  with long Beam Lifetime
  (COSY)
- Efficient Analyzing Reaction
  (D_2-Cluster Target)
- Detector Setup
  with high geometrical acceptance
  and good Energy- and Spatial Resolution
  (2 Silicon Tracking Telescopes)

Optimization of the Polarization Lifetime of COSY

- STT Setup as shown for the Depolarization Experiment with the D_2-Cluster Target