Møller (Iron Foils) Existing Techniques

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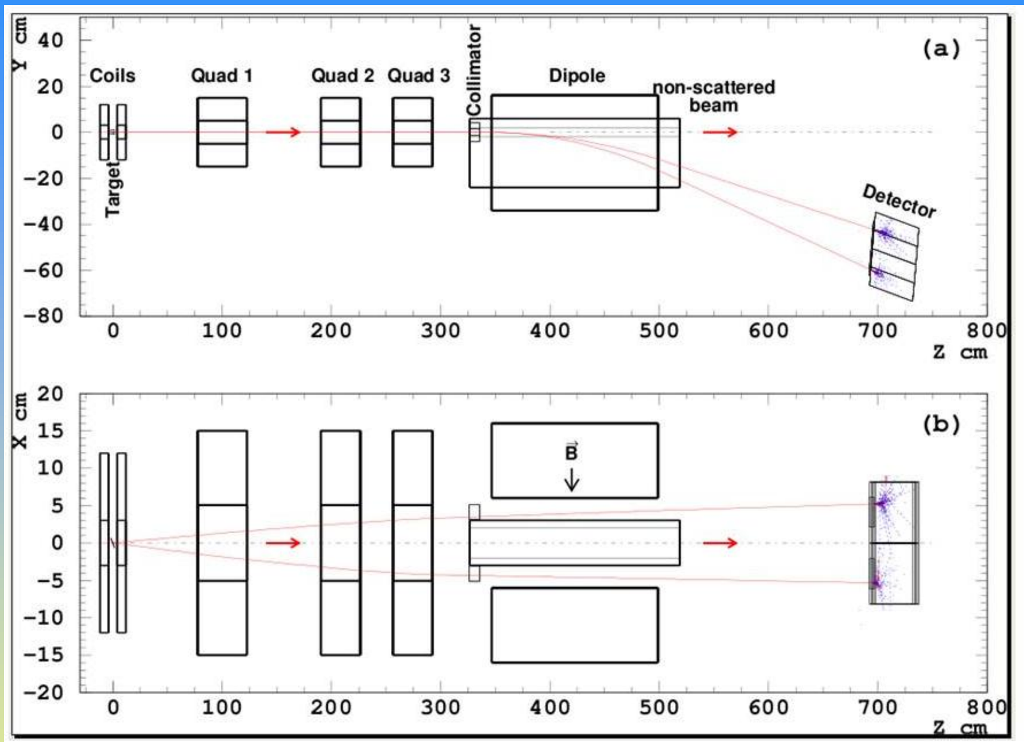
Møller Polarimetry



$$\overrightarrow{e^-} + \overrightarrow{e^-} \rightarrow e^{-\prime} + e^{-\prime}$$ QED

$$d\sigma^{Moll} / d\Omega^* =$$

$$d\sigma_0^{Moll} / d\Omega^* \times (1 + A_{Moll} \times P^b \times P^t)$$

$$A_{meas} = \frac{N^{\uparrow\uparrow} - N^{\uparrow\downarrow}}{N^{\uparrow\uparrow} + N^{\uparrow\downarrow}} =$$

$$A_{Moll} \times P^b \times P^t \times \cos\alpha^{foil}$$

$$P^b = A_{meas} / A_{Moll} \times P^t \times \cos\alpha^{foil}$$

Advantages:

1) Large cross-section
2) High analyzing power at Θ_{CM}=90°
   A_{zz}=7/9
3) Particles in the final state with $E \sim E_0/2$ -> coincidence eliminates background

Disadvantages:

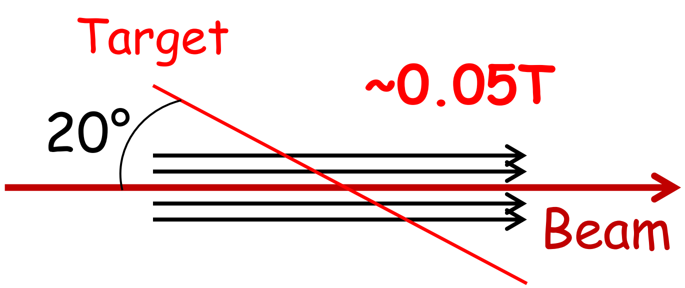
1) Invasive with solid targets
2) Low target polarization ~8%
3) Beam current limit ~3μA (heating)
4) Systematic errors on the target polarization
5) "Levchuk-effect"

Polarized Electron Targets and Techniques

Polarized Solid Targets
- Pure Iron (99.85%-99.99%)
- Supermendur (49%Fe, 49%Co, 2%V)

Polarized Atomic Hydrogen Target

In "weak" field
"classic"



Target polarization has to be measured before using

In "strong" field
"brute force"

Target polarization is taking from literature

Hall A Moller polarimeter (Jlab) has both "classic" and "brute force" targets

Target Polarization In "Weak" Field

$$P^t = \frac{(g'-1)}{g'} \times \frac{g_e}{(g_e-1)} \times \frac{M}{N_e \mu_B}$$

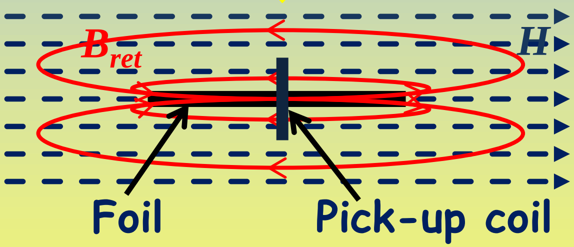
$$B = \mu_0 (H + M)$$

Classic method: Foil unmovable, 2 measurements:
1) With foil: -B→+B→-B, 2) Empty coil -B→+B→-B

$$\Delta\Phi = \int e(t)dt = \mu_0 \Delta M \times S_{foil} + \mu_0 \Delta H \times S_{coil} + \Delta B_{ret} \times S_{coil}$$

μ_{iron}~21500
foil~μm

μ_{air}=1
coil~mm

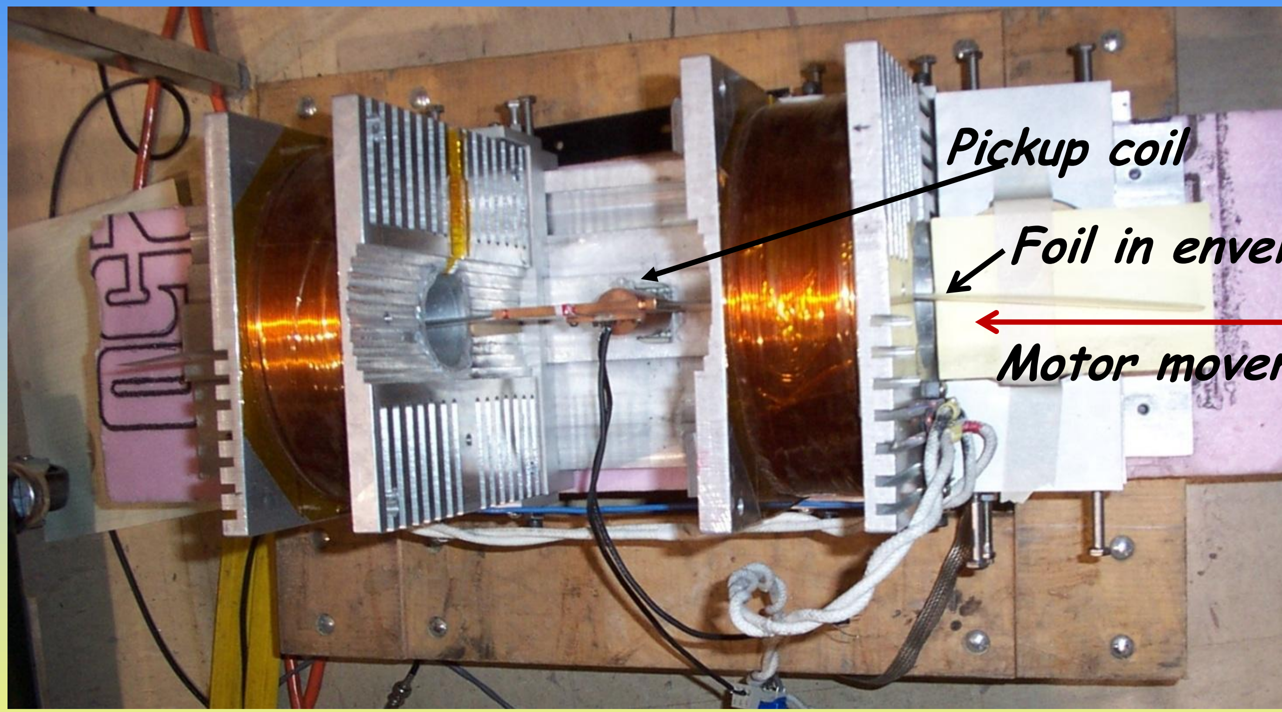


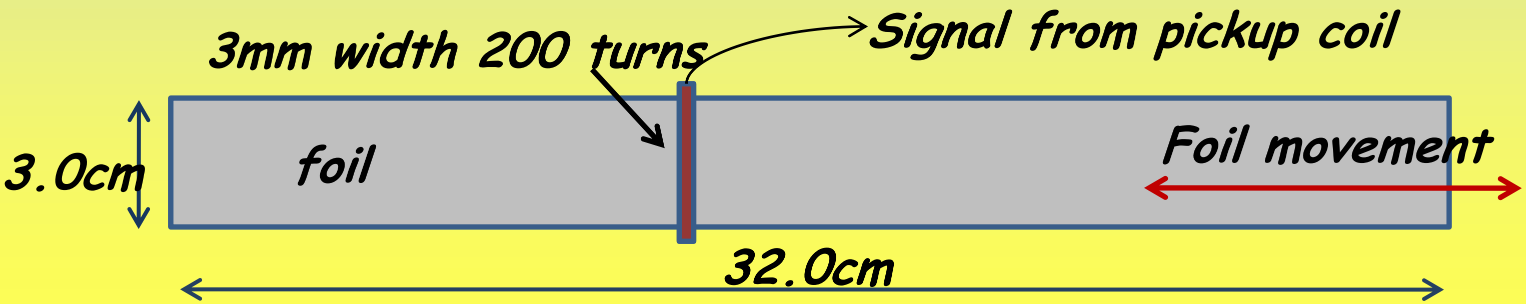
"Kharkov's" method: constant field, movable foil

$$\Delta\Phi = \int e(t)dt = \mu_0 \Delta M \times S_{foil} + \mu_0 \Delta H \times S_{coil} + \Delta B_{ret} \times S_{coil}$$

Const. ->0 ->0

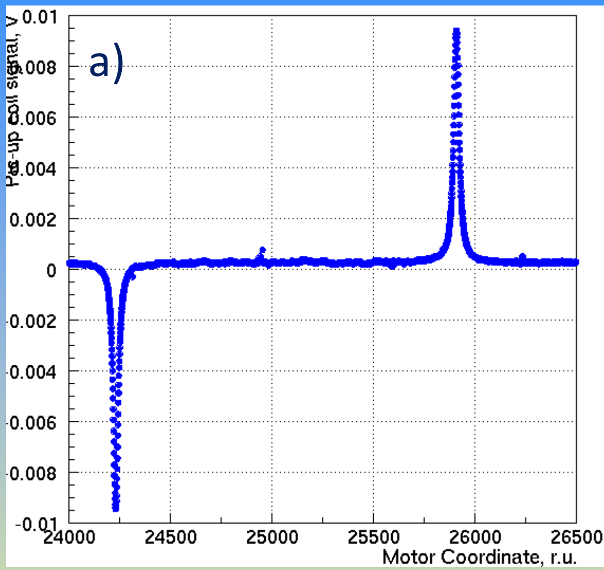
Magnetic Stand for Foil Polarization Measurements

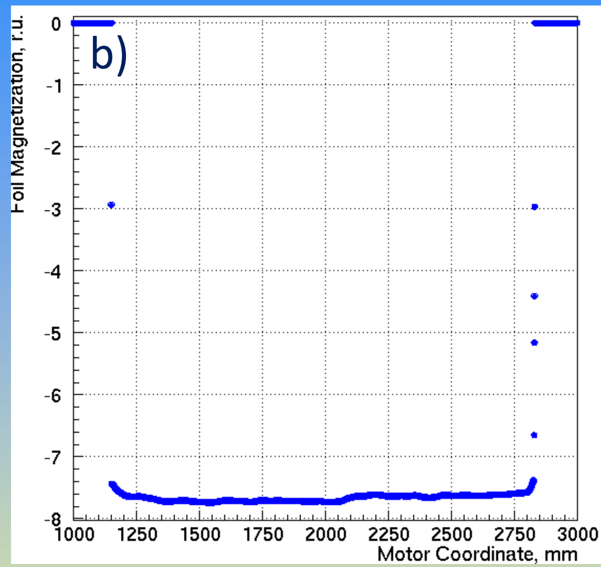


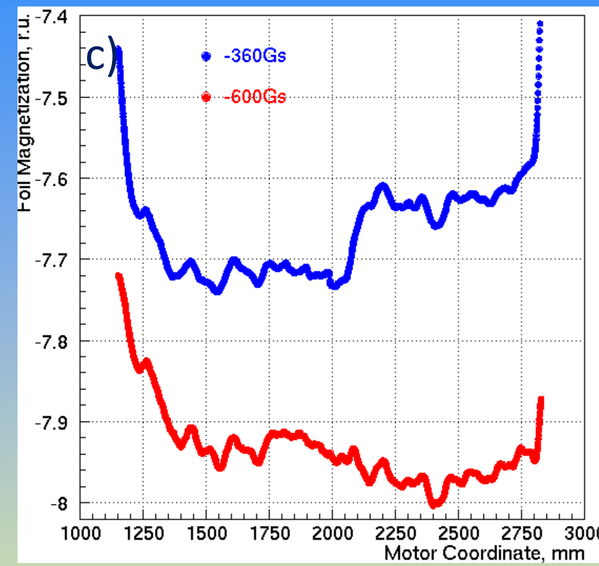


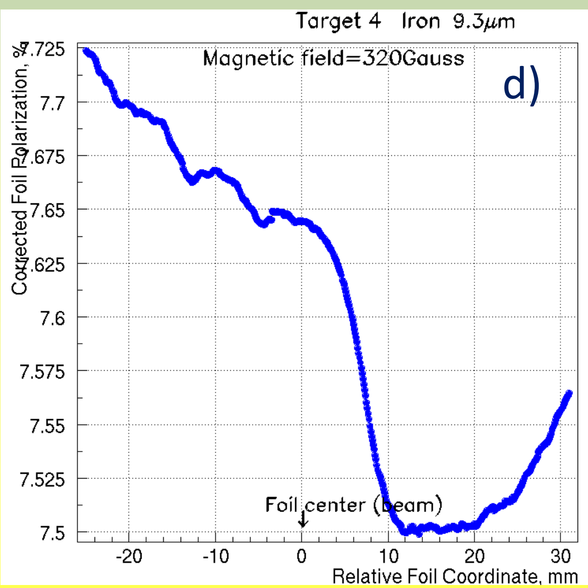
Constant magnetic field, two field geometries, movable foil

Foil Polarization Measurement









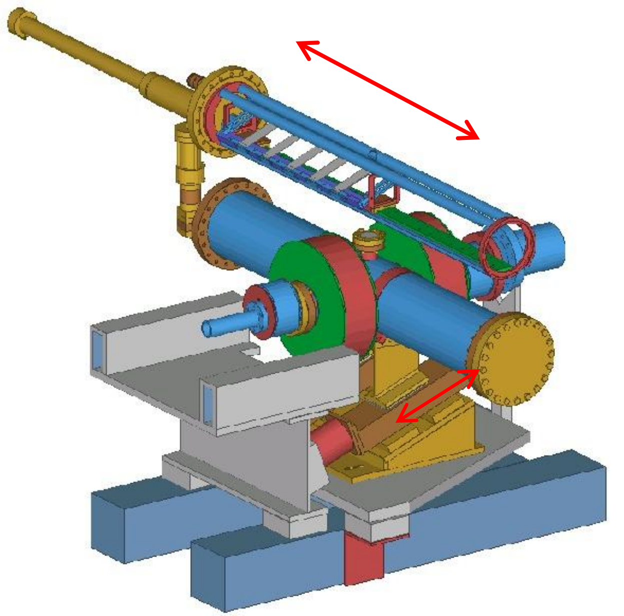
a) raw signal from pickup coil

b) integrated signal, subtracted background
corrections on return field
averaged 10 measurements

c) maximal and Hall A geometry fields

d) corrections on foil thickness, target angle
and magnetic field geometry,
foil coordinate relative to beam

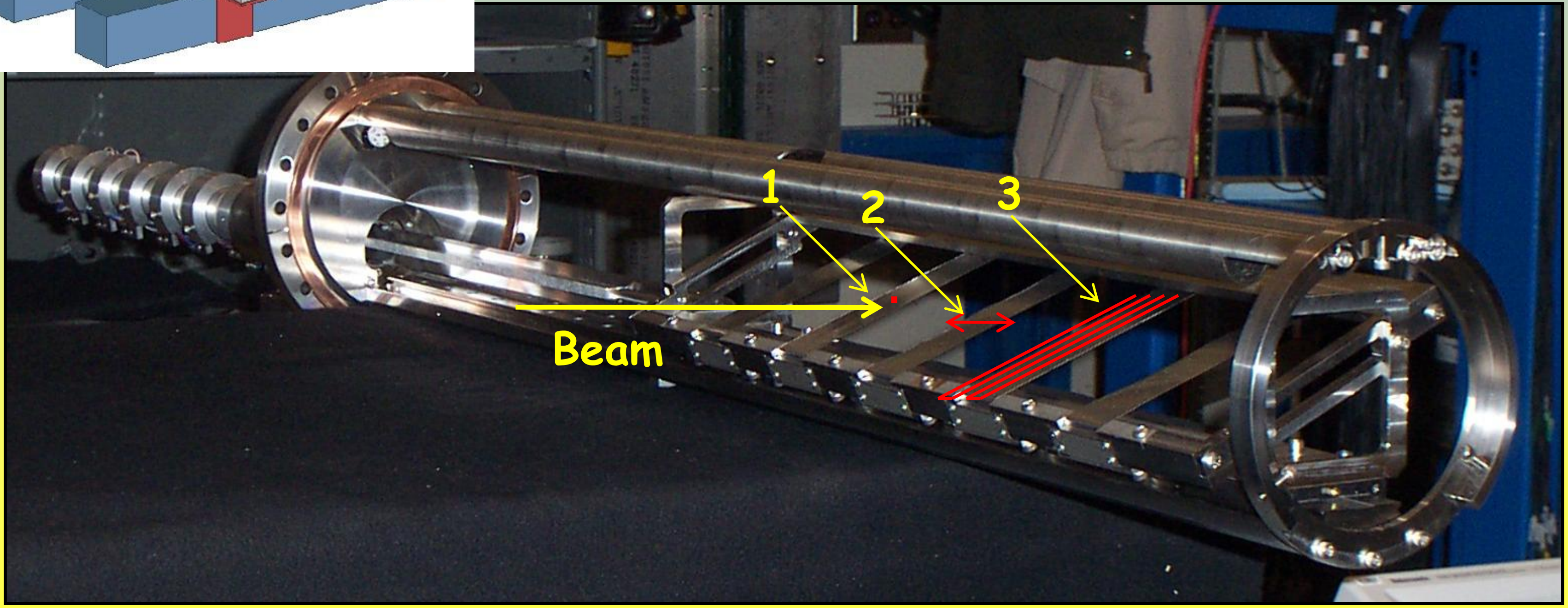
Types of Beam Polarization Measurement



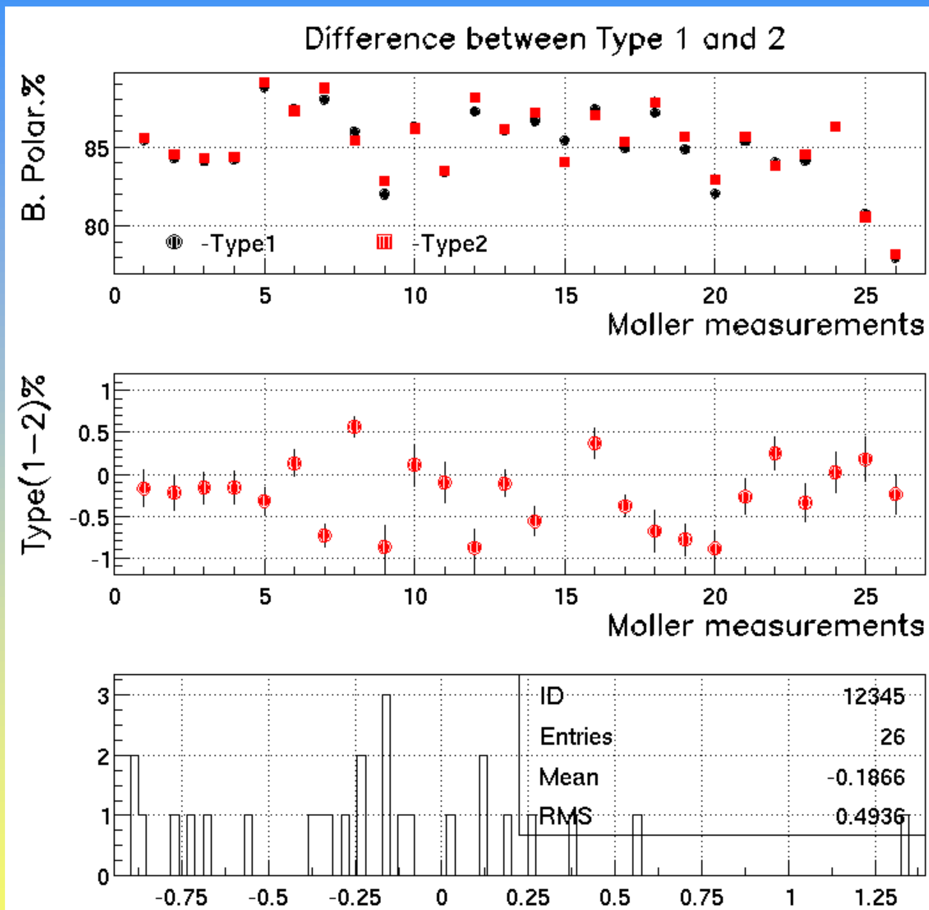
Position	6	5	4	3	2	1	0
Material	park	SM*	Fe	Fe	SM	SM	Al
Thickness, μm	-	6.8	9.3	14.3	29.4	13.0	16.5

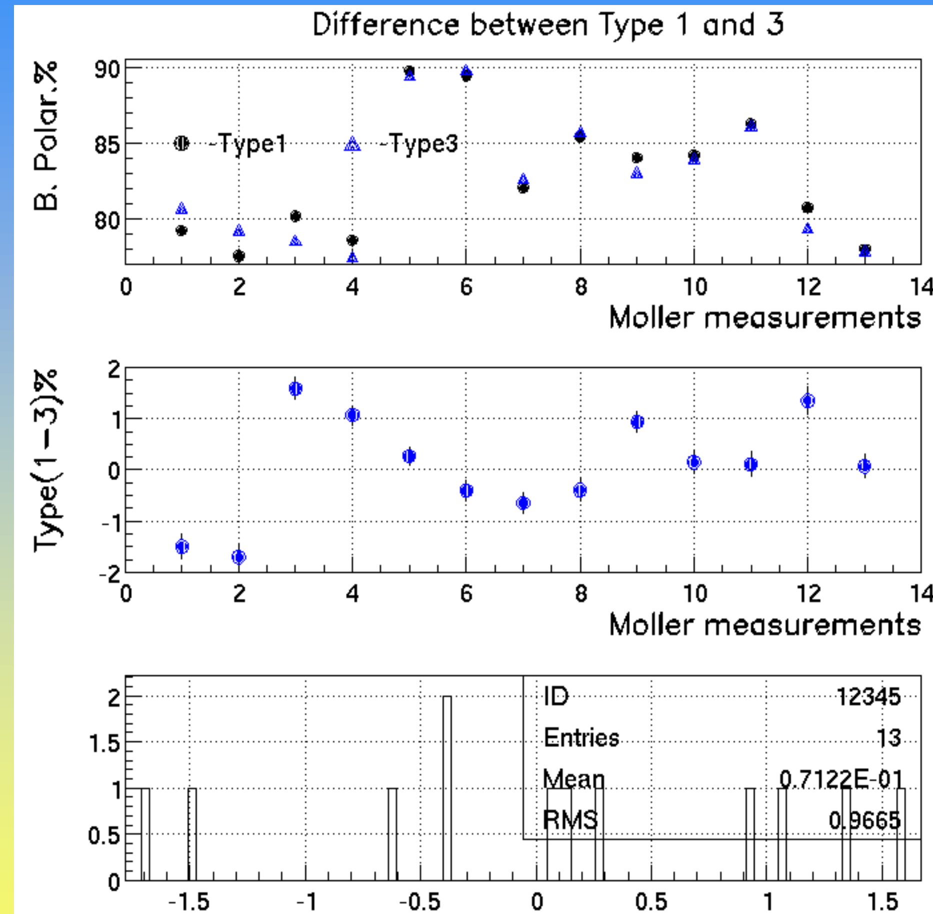
* - Supermendur

Type 1 - measurement in point
Type 2 - foil scan in transverse direction
Type 3 – double direction foil scan (like snake)



Difference Between Types of Measurements

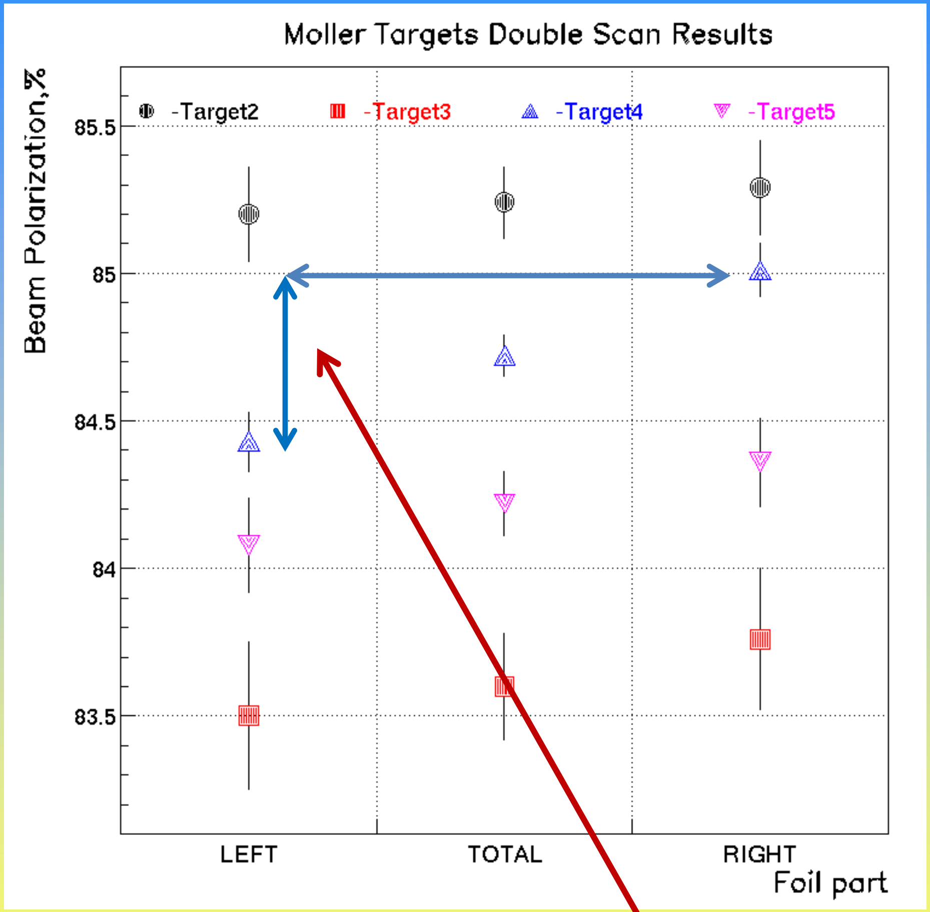




Systematic error Type(1-2): (0.2+0.5)=±0.7%

Systematic error Type(1-3): ±1.0%

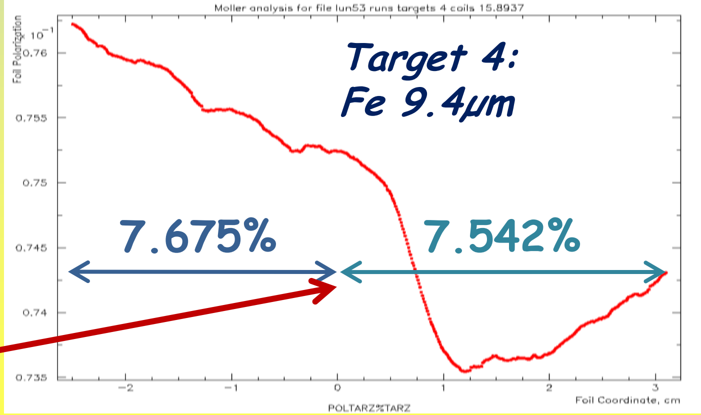
Double Scan (Type 3) Results



LEFT – integral polarization
-2.4cm←→ 0.1cm
RIGHT – integral polarization
-0.1cm←→ 2.9cm
TOTAL – integral polarization
-2.4 cm←→ 2.9cm

Available foil scan along the beam direction is:
-2.5 cm←→3.0cm

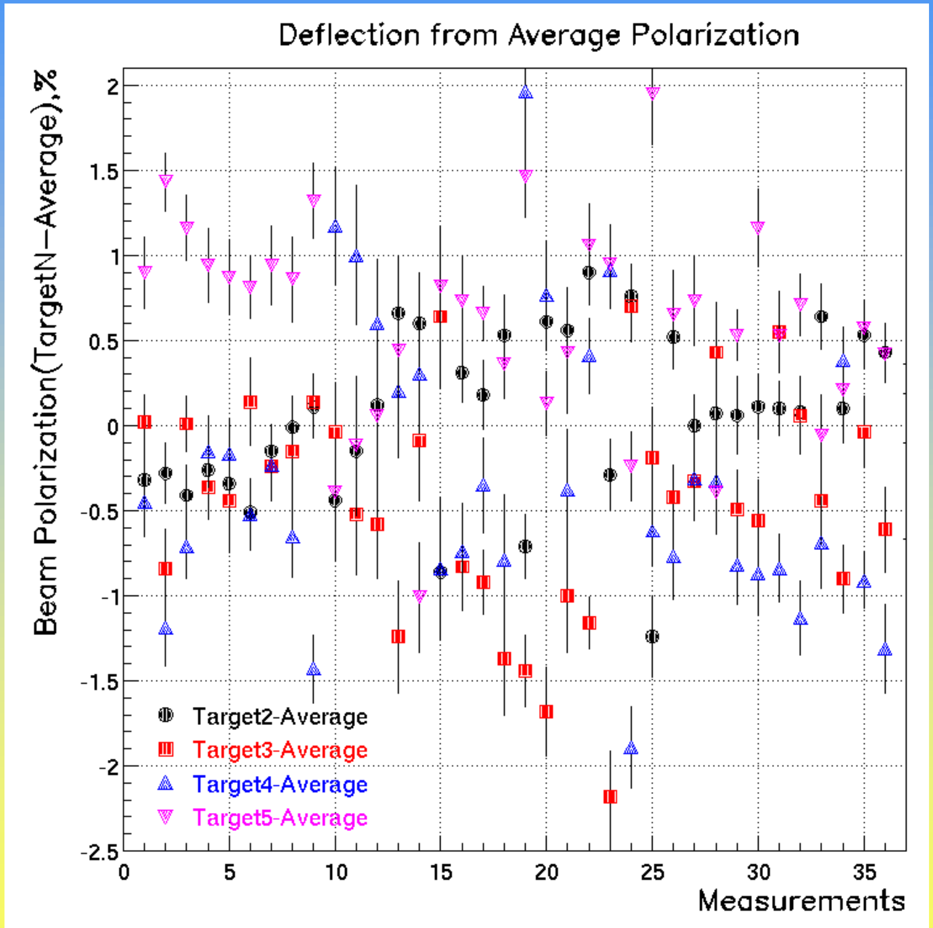
Systematic Error for target 4: +/-0.3%

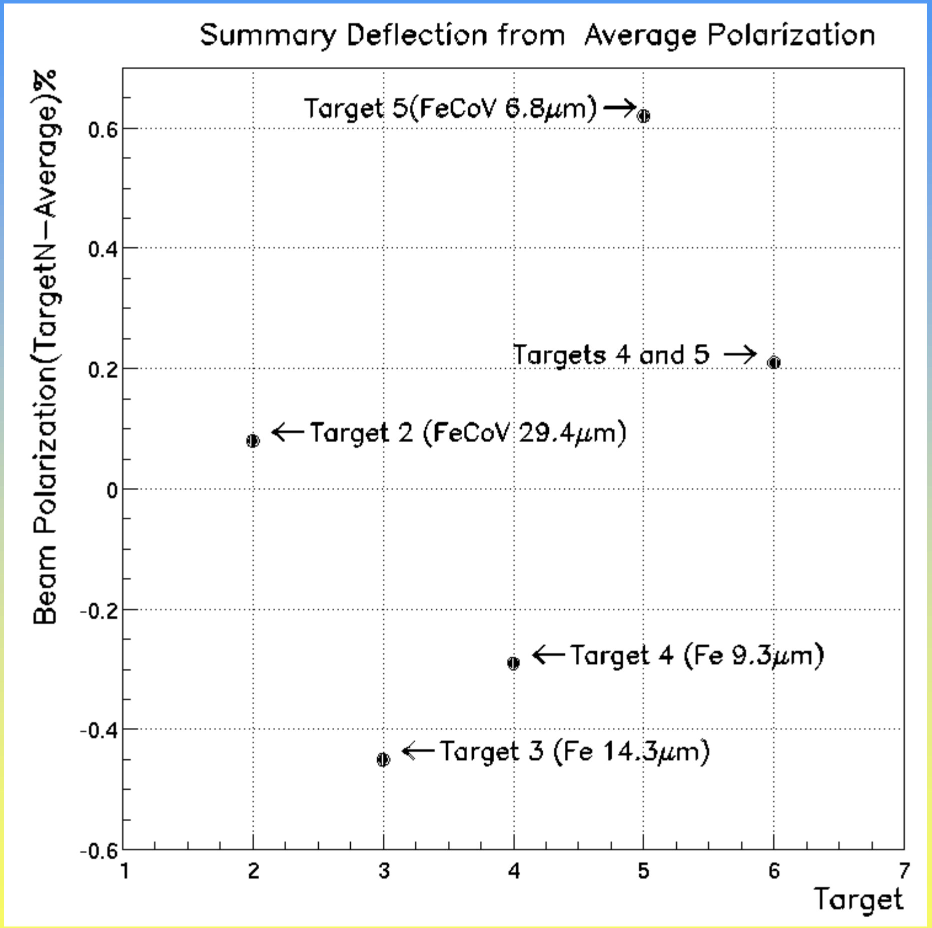


85.01/84.46=0.65%

7.675/7.542=1.76%
if polarization is
constant along the half of the foil

Beam Polarization Measurement with all four Targets



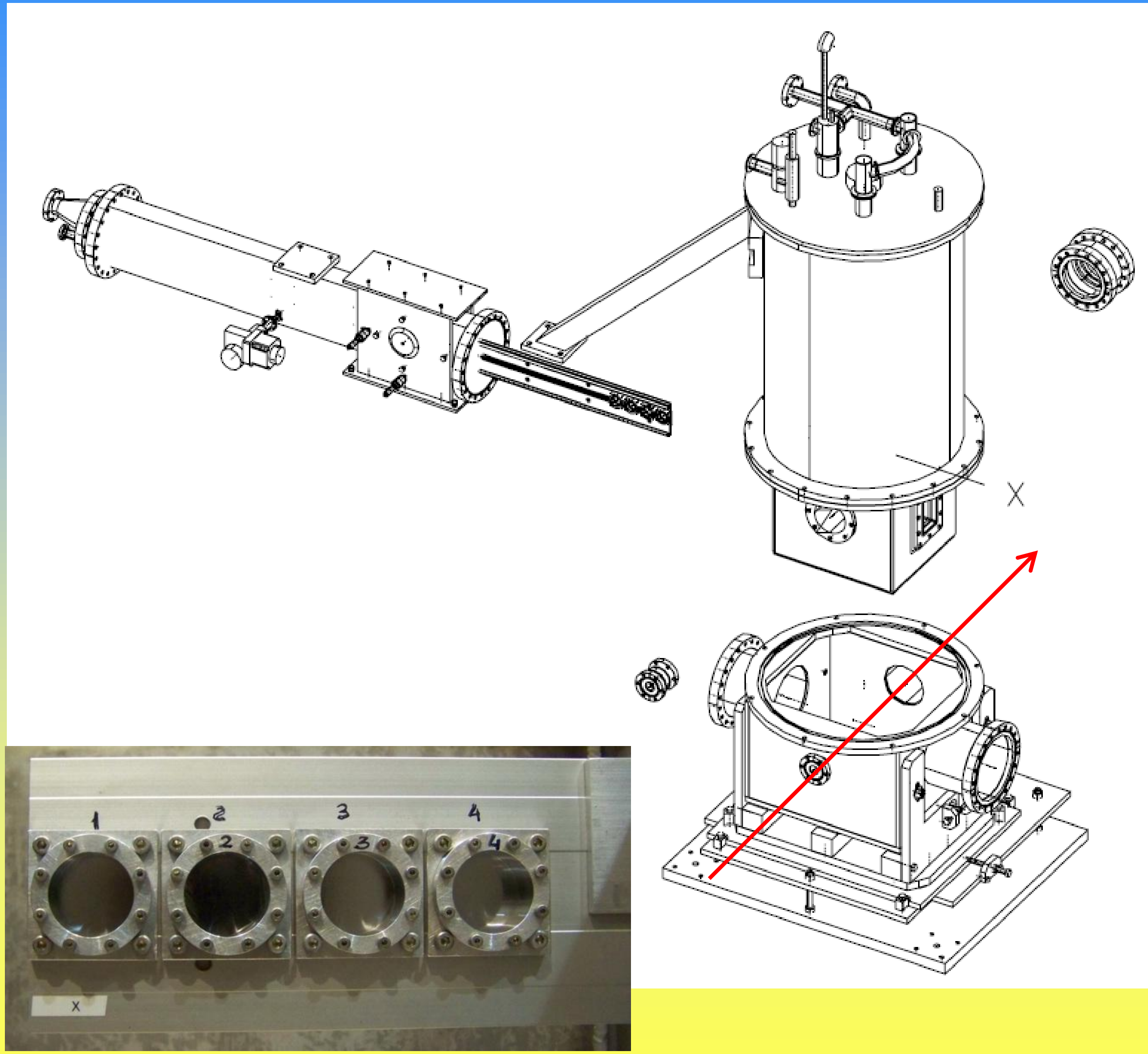


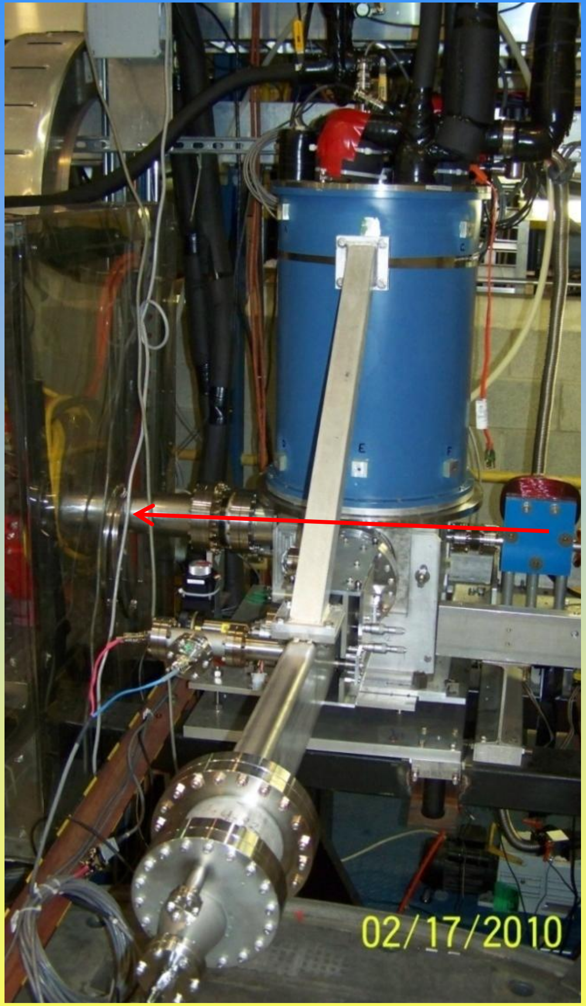
Systematic error (all targets): (0.6+0.4)/2=±0.5%

Target Systematic Error ("Weak" Field)

Variable	Error, %
Stand measurements	0.25
Double Scan (Left vs. Right)	0.3
Type 1 vs. Type 2	0.7
Type 1 vs. Type 3	1.0
All Four Targets Discrepancy	0.5
Target angle	0.3
Others	0.5
Total	**1.5**

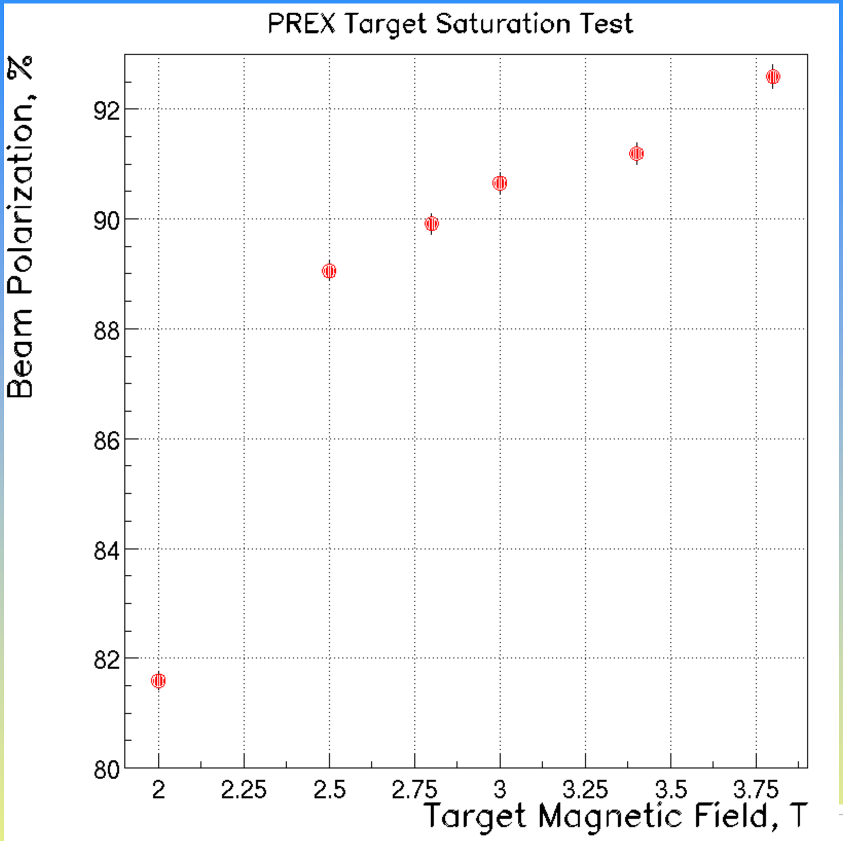
Target Polarization in "Strong" Field

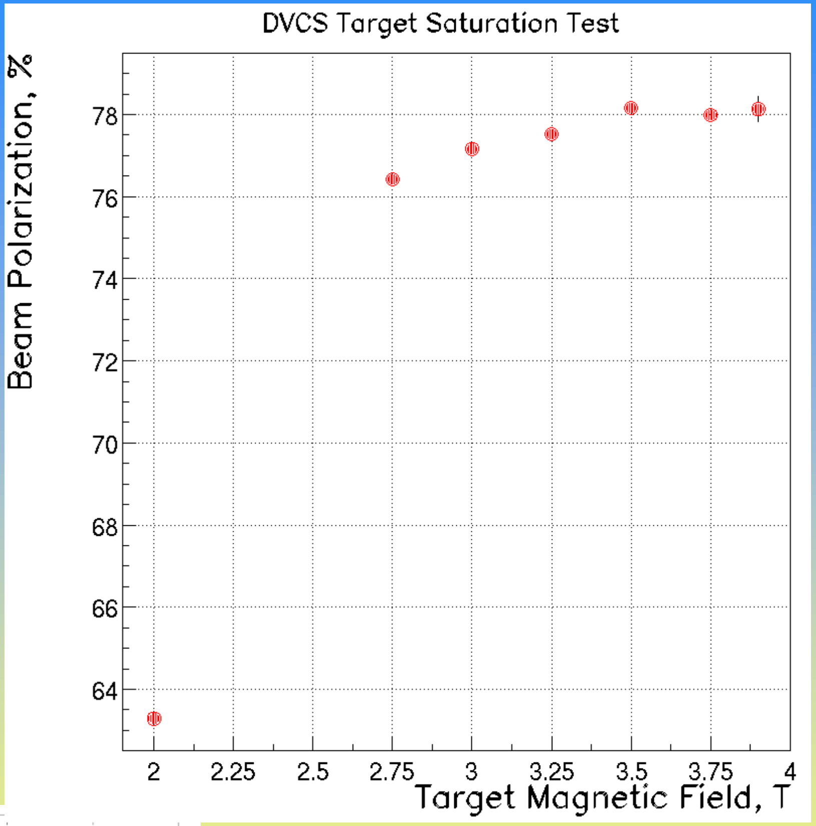


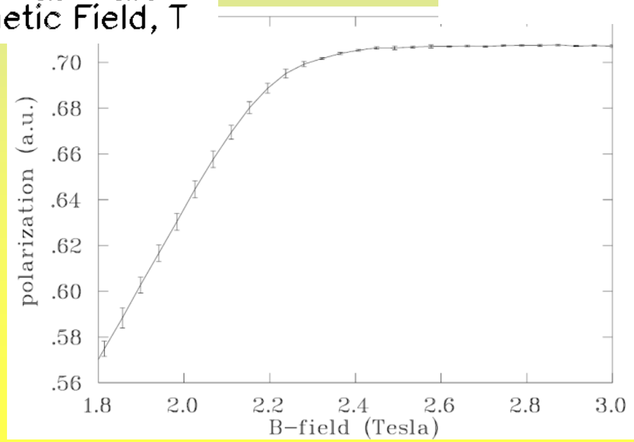


Targets: pure Fe foils 1-1μm, 2-1μm, 3-4μm, 4-12μm

Target Saturation Test



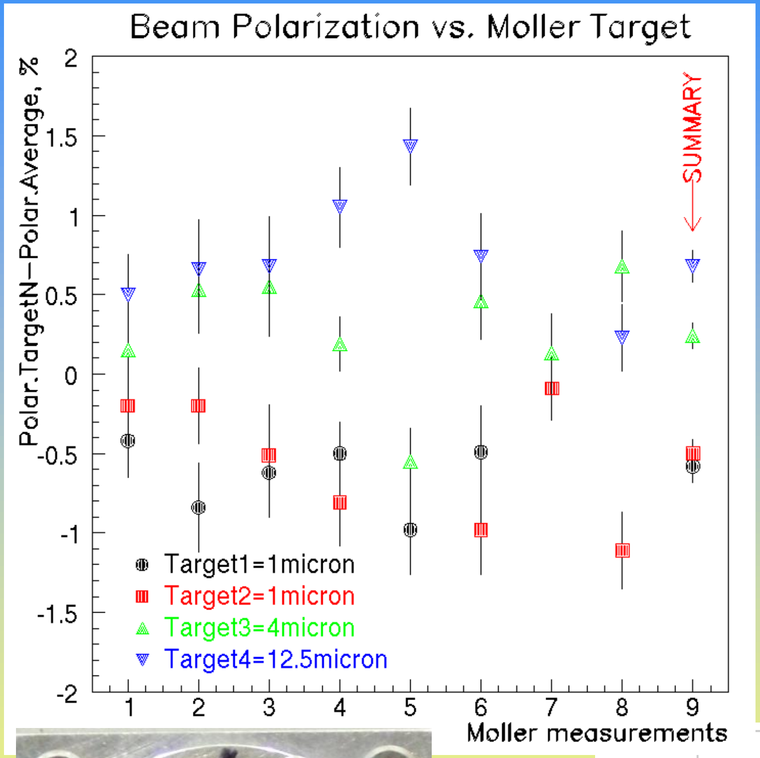


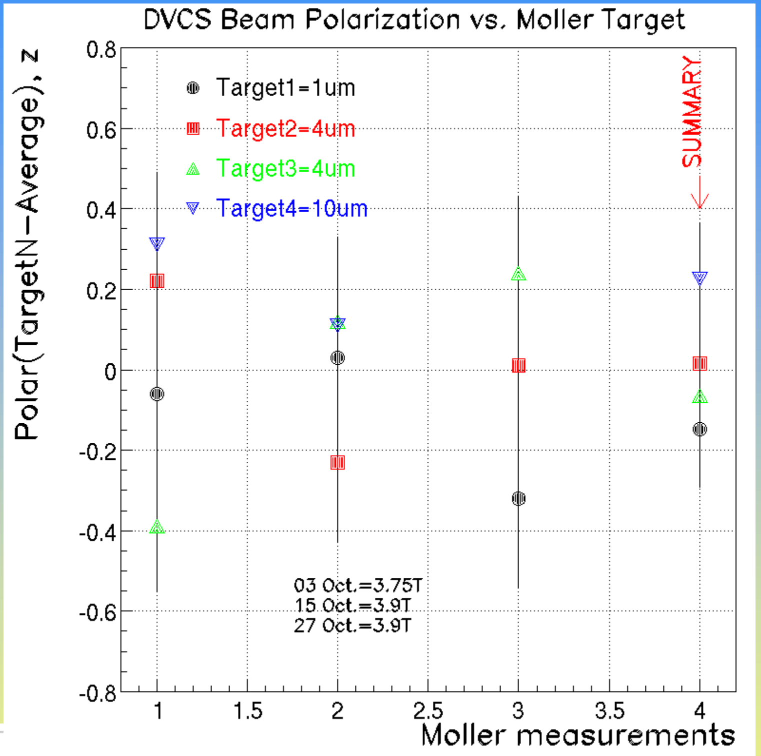


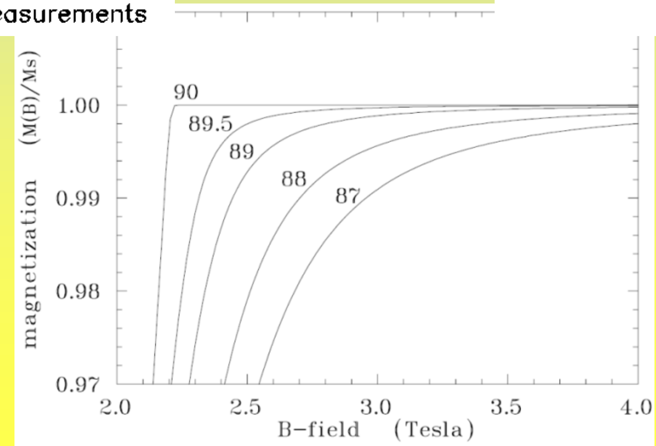
M. Loppacher
"Møller Polarimetry for CEBAF Hall C"
PhD thesis, Basel 1996

Beam Polarization Measurements

PREX (3T) *Warping+Misalignment* **DVCS (3.75-3.9T)**







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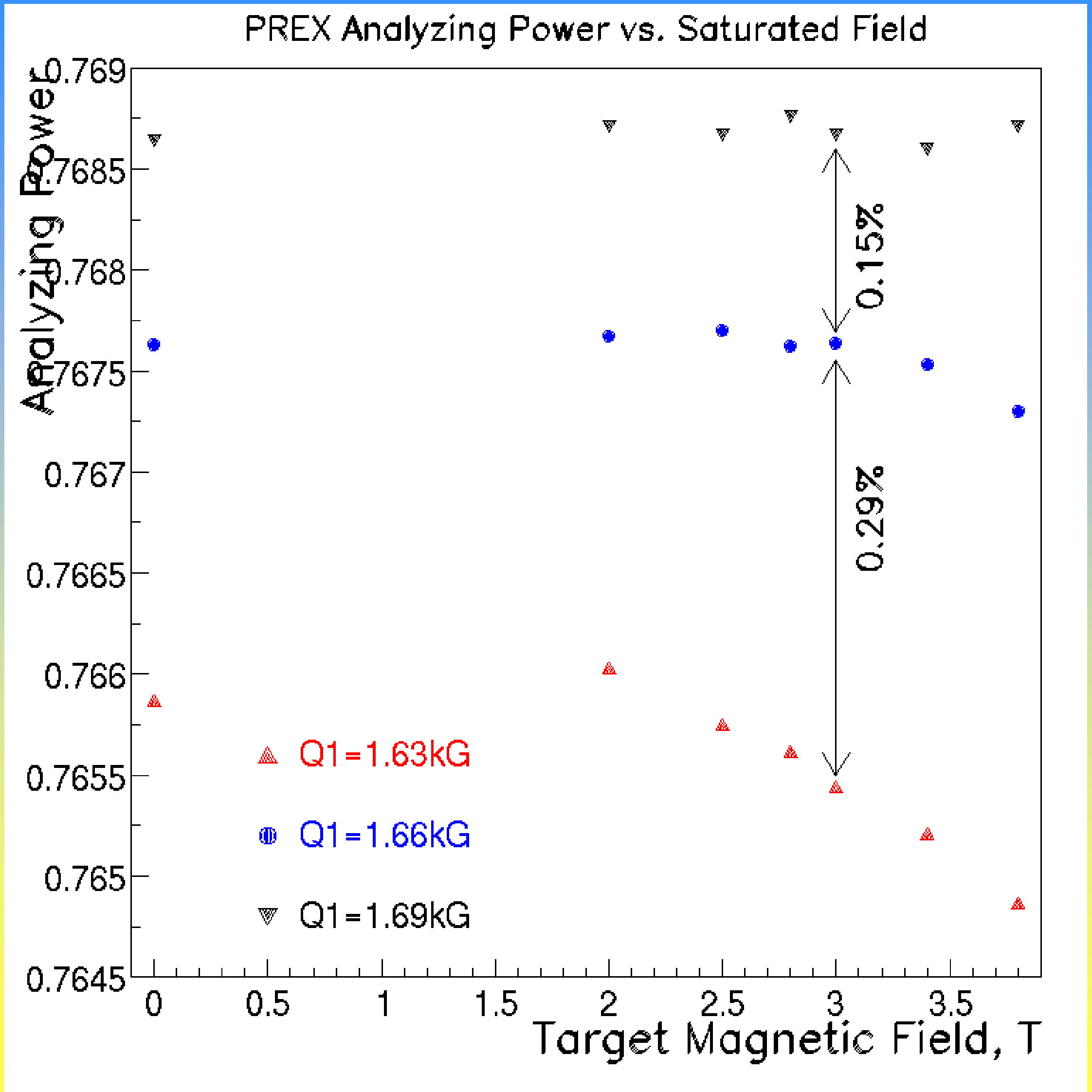
Target Systematic Error ("Strong" Field)

Variable	Error*
Iron Foil Polarization	0.25%
Targets Discrepancy (warping + misalignment)	0.2%
Targets Saturation (magnet alignment)	0.1%
Total	**0.35%**

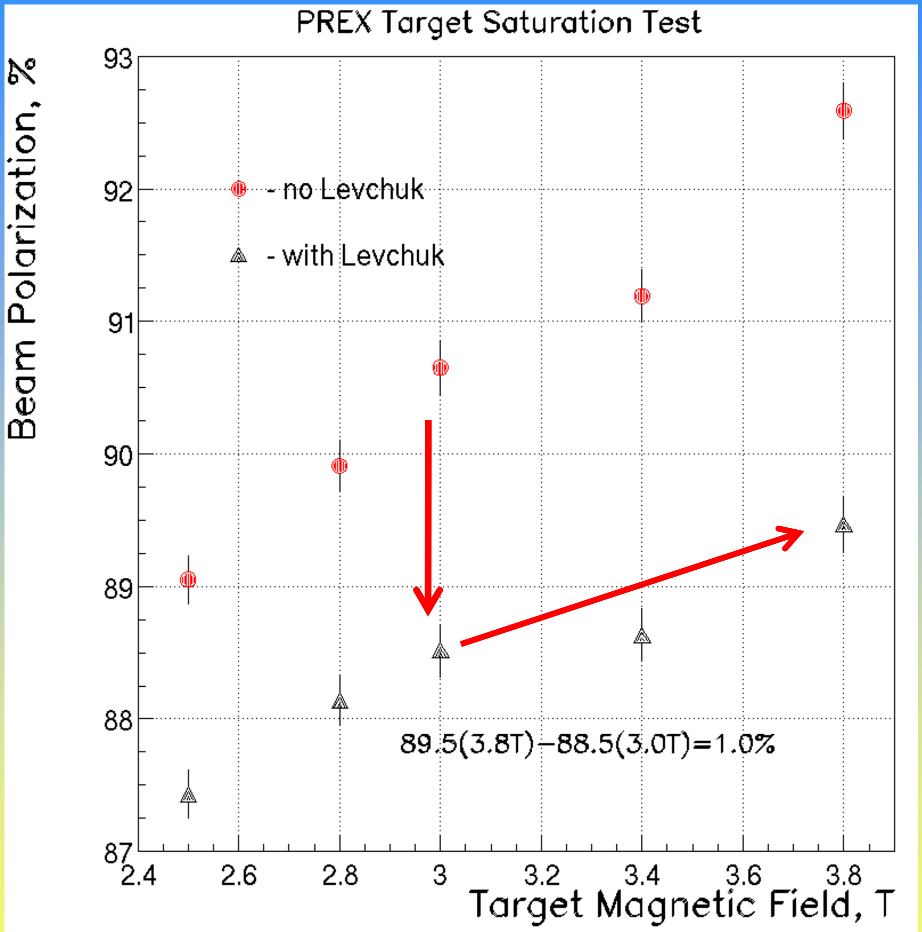
* - 3.9T

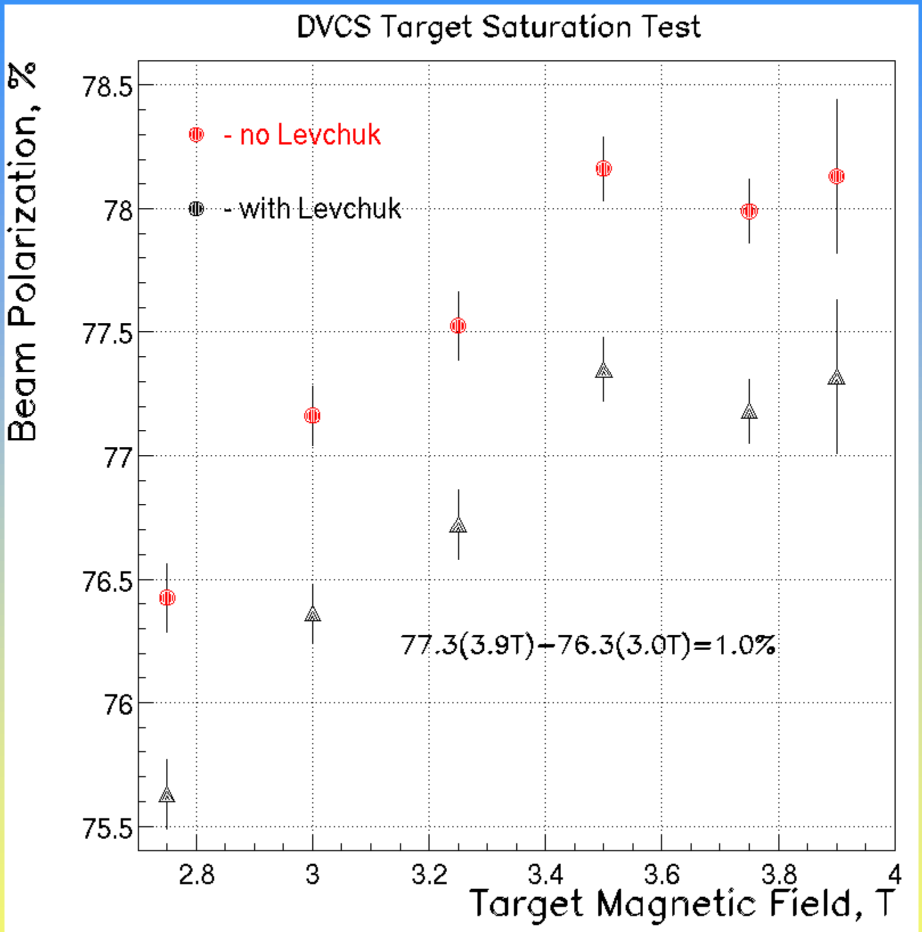
Analyzing Power



Systematic error ±0.3%

Levchuk-Effect





Acceptance of electrons, scattered on K-shell (unpolarized) and D-shell (polarized) is different (K<D)

Measured polarization usually larger than real one (acceptance dependence)

Error can be large

Systematic Errors for Different Target Polarization Techniques

Variable	"Weak" field	"Strong" field 3.9T
Target polarization	1.5%	0.35%
Analyzing power	0.3%	0.3%
Levchuk effect	0.2%	0.3%
Target temperature	0.02%	0.02%
Dead time	0.3%	0.3%
Background	0.3%	0.3%
*High beam current**	0.2%	0.2%
Others	0.5%	0.5%
Total	1.7%	0.88%

* M. Poelker et al. Phys.Rev.ST Accel.Beams 10 (2007) 053502

Hall C Moller polarimeter with "brute force" target: **0.47%**

Comparison of Techniques

"Weak" Field

Advantages

- Small BdL: no influence on the beam optics, analyzing power, Levchuk eff.
- Cheaper equipment

Disadvantages

- Invasive
- Low beam current
- Systematic error ~1.5%
- Have to measure target polarization
- Magnetic stand and time/manpower for target polarization measurements are needed
- Annealing and mechanical treatment!

"Strong" Field

Advantages

- Systematic error <1%
- Faster to build polarimeter (don't need target study on Magnetic Stand)

Disadvantages

- Invasive
- Low beam current
- Target and field alignment
- More expensive (SC magnet + cryoline)
- Large BdL: smaller beam energy – stronger influence on the beam optics
- Can't measure target polarization (have to trust to world published data for bulk materials)

Conclusion

“Weak” field is preferable for experiments with:
- beam polarization accuracy ≥1.5%
- with beam energy < 1GeV
- no cryogenics

“Strong” field is preferable for experiments with:
- beam polarization accuracy ≤1%
- with beam energy > 2GeV
- cryogenics available

For beam polarization accuracy <0.5% non-solid target is needed