Levchuk Effect

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Precision Polarimetry Workshop

November 21, 2016

Levchuk Effect

Target polarization in iron foil comes primarily from electrons in unfilled M-shells
→ Electrons from more deeply bound K/L shells do not contribute

More deeply bound electrons experience more atomic Fermi motion – smears out correlation between scattered electron momentum and angle

→ For 100% acceptance detector, not a big problem
→ Finite acceptance means contribution from polarized and unpolarized scattering not the same

Table 1
Binding energies $|E_n|$ [eV] (ref. [9])

	K	LI	LII	LIII	MI	MII	MIII
Fe	7126	847	726	713	97	57	57
Co	7725	933	802	786	105	64	64

L. G. Levhcuk, NIM A345 (1994) 496-499

Levchuk Effect – bound electrons

Møller lab scattering angle for stationary target electron:

$$\theta^2 = \frac{1}{p_b p'} \frac{s_0}{2} (1 - \cos\theta^*) = 2m_e \left(\frac{1}{p'} - \frac{1}{p_b} \right) \qquad s_0 = 2 p_b m_e$$

(Center of mass energy)^2

Møller lab scattering angle for moving electron:

$$\theta^2 = \frac{1}{p_b p'} \frac{s_1}{2} (1 - \cos\theta^*) = 2m_e \left(\frac{1}{p'} - \frac{1}{p_b} \right) \left(1 - \frac{\boldsymbol{p_t} \cdot \boldsymbol{\hat{n}}}{m_e} \right)$$

$$s_1 = s_0 \left(1 - \frac{\boldsymbol{p_t} \cdot \boldsymbol{\hat{n}}}{m_e} \right)$$

Simulation of Levchuk Effect for SLAC Møller Polarimeter

SLAC simulation: electron distributions based on screened hydrogen atom wave functions

K and L shells compare well with calculations (1993)

Large change in measured polarization from Levchuk effect was found for this device/geometry → 8%

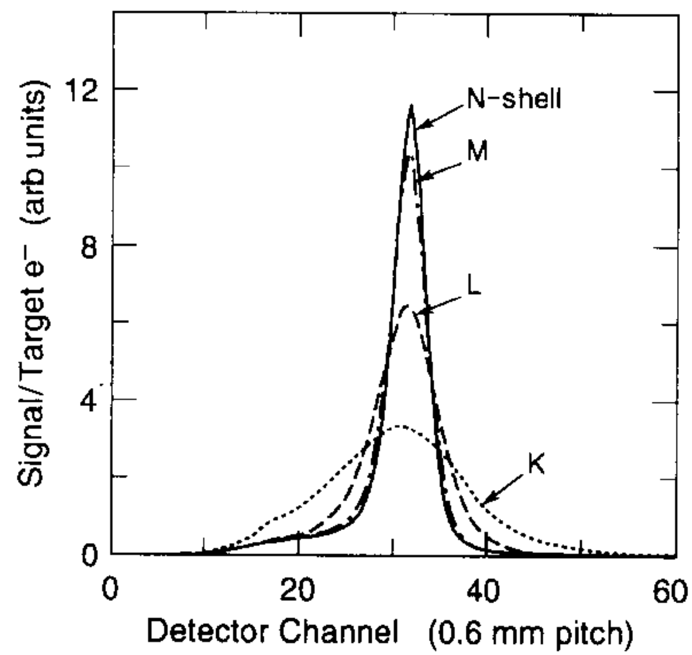

Fig. 2. The simulated signal observed at the SLC linac Møller detector per target electron for each of the atomic iron shells.

M. Swartz, NIM A363 (1995) 526-537

Q-Weak Møller Systematics

Source	Uncertainty	dA/A (%)
Beam position x	0.5 mm	0.17
Beam position y	0.5 mm	0.28
Beam direction x	0.5 mr	0.10
Beam direction y	0.5 mr	0.10
Q1 current	2% (1.9 A)	0.07
Q3 current	2.5% (3.25 A)	0.05
Q3 position	1 mm	0.10
Multiple scattering	10%	0.01
Levchuk effect	10%	0.33
Collimator positions	0.5 mm	0.03
Target temperature	100%	0.14
B-field direction	2^o	0.14
B-field strength	5%	0.03
Spin polarization in Fe		0.25
Electronic D.T.	100%	0.04
Solenoid focusing	100%	0.21
Solenoid position (x,y)	0.5 mm	0.23
Additional point–to–point		0.0
High current extrapolation		0.5
Monte Carlo statistics		0.14
Total		0.85

Hall C Møller designed to mitigate uncertainty due to Levchuk effect by having relatively large acceptance

→ Estimated 3% impact on analyzing

→ Uncertainty = 10% of correction

What is the source of this uncertainty?

"..potential uncertainties in the atomic wave functions employed in the calculation"

M. Hauger et al., NIM A462 (2001) 382-392

Reducing Uncertainty due to Levchuk Effect

- Empirical tests
  - Change spectrometer optics to increase/decrease sensitivity to Levchuk effect (see Sasha's talk)
- Improve simulations
  - Use real wave functions for atomic electrons in iron → with modern computational techniques, should be able to do this with high precision
  - Improve model of "polarization carrying" electrons → perhaps not a large correction, but present simulation ignores the fact that the valence electrons are in bands
  - At present, binding is ignored. Should be "small" effect, but why not check?