Impressions and Thoughts about Polarimetry at the ILC

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DESY (Zeuthen)

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ILC Objectives

- e^{-} - e^{+} collisions
- c.m. energies: 45.6 - 500 GeV
- Longitudinal polarization at (IP)
  – $P(e^{-}) > 80\%$
  – $P(e^{+}) > 50\%$
- Needed accuracy
  – Ε P/P = 0.25% (0.1%)

→ **new territory**

Electron Polarimetry

Many polarimeters are, *have been* in use, or a **planned**:

- Compton Polarimeters:

EIC	***3 – 20 GeV***
LEP	*mainly used as machine tool for resonant depolarization*
SLAC	*SLD 46 GeV*
DESY	*HERA, storage ring 27.5 GeV (three polarimeters)*
JLab	Hall A < 8 GeV / **Hall C < 12 GeV**
Bates	*South Hall Ring < 1 GeV*
Nikhef	*AmPS, storage ring < 1 GeV*

- Møller / Bhabha Polarimeters:

Bates	*linear accelerator < 1 GeV*
Mainz	Mainz Microtron MAMI < 1 GeV
Jlab	Hall A, B, C

Polarimeter Roundup

Laboratory	**Polarimeter**	**Relative precision**	**Dominant systematic uncertainty**
JLab	5 MeV Mott	~1%	Sherman function
	Hall A Møller	~2-3%	target polarization
	Hall B Møller	1.6% (?) 2-3% (realistic ?)	target polarization, Levchuk effect
	Hall C Møller	1.3% (best quoted) 0.5% (possible ?)	target polarization, Levchuk effect, high current extrapolation
	Hall A Compton	1% (@ > 3 GeV)	detector acceptance + response
HERA	LPol Compton	1.6%	analyzing power
	TPol Compton	3.1%	focus correction + analyzing power
	Cavity LPol Compton	?	still unknown
MIT-Bates	Mott	~3%	Sherman function + detector response
	Transmission	>4%	analyzing power
	Compton	~4%	analyzing power
SLAC	**Compton**	**0.5%**	**analyzing power**

The "Spin Dance" Experiment (2000)

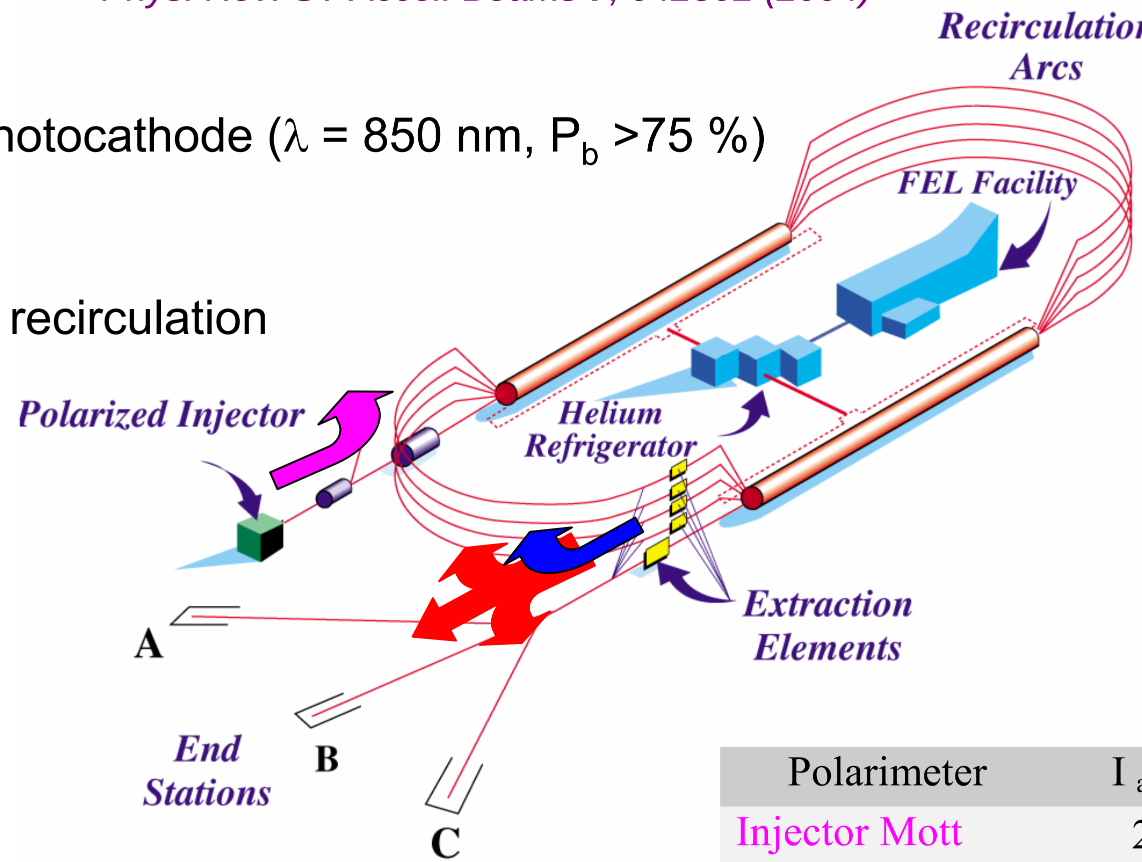
*Phys. Rev. ST Accel. Beams **7**, 042802 (2004)*

Source

Strained GaAs photocathode (λ = 850 nm, P_b >75 %)

Accelerator

5.7 GeV, 5 pass recirculation

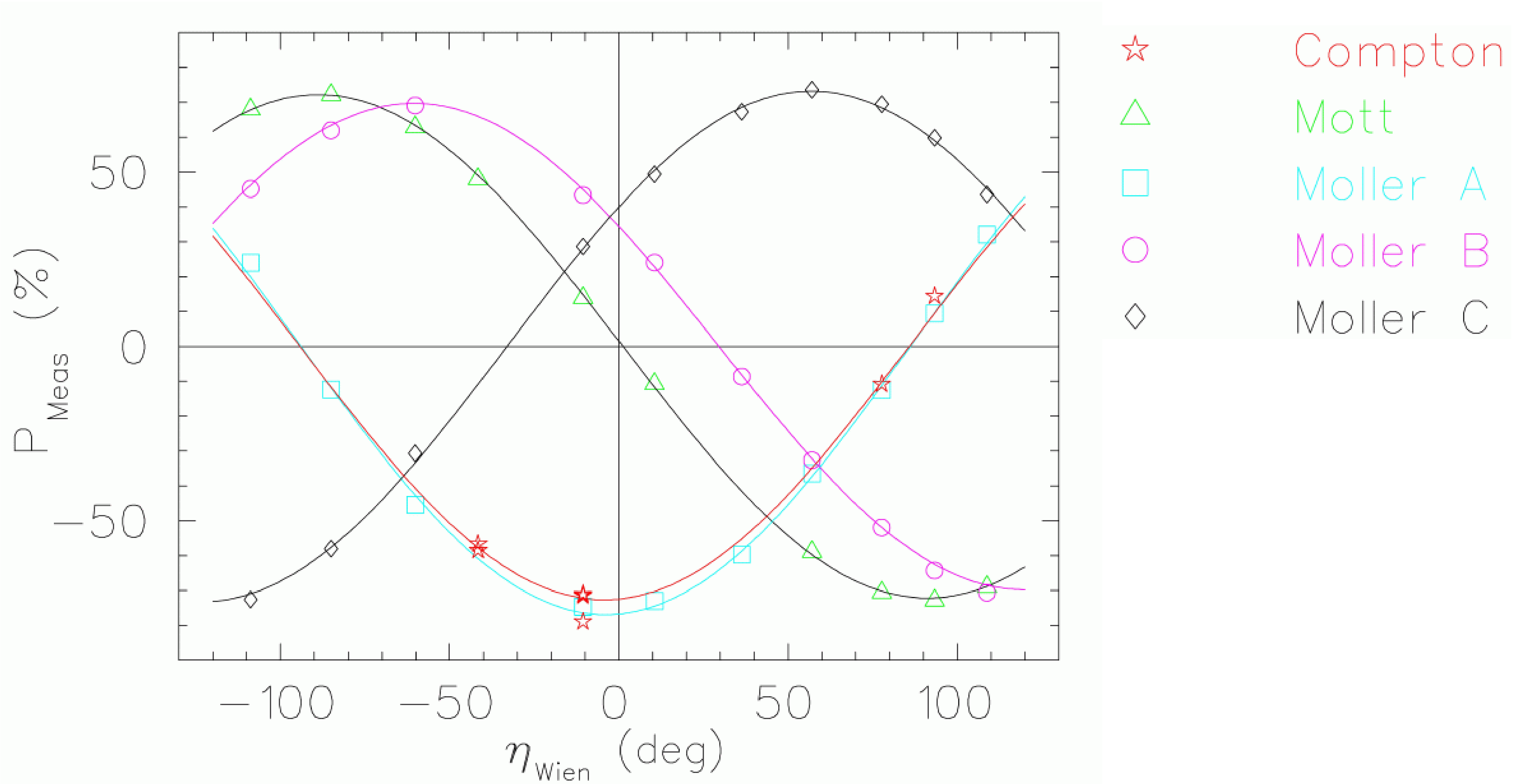


Polarimeter	I_{ave}	P_x	P_y	P_z
Injector Mott	2 μA	x	x	
Hall A Compton	70 μA			x
Hall A Moller	1 μA	x		x
Hall B Moller	10 nA		x	x
Hall C Moller	1 μA			x

Wien filter in injector was varied from -110° to 110° to vary degree of longitudinal polarization in each hall
→ precise cross-comparison of JLab polarimeters

"Spin Dance" 2000 Data

$$P_{meas} \cos(\eta_{Wien} + \phi)$$



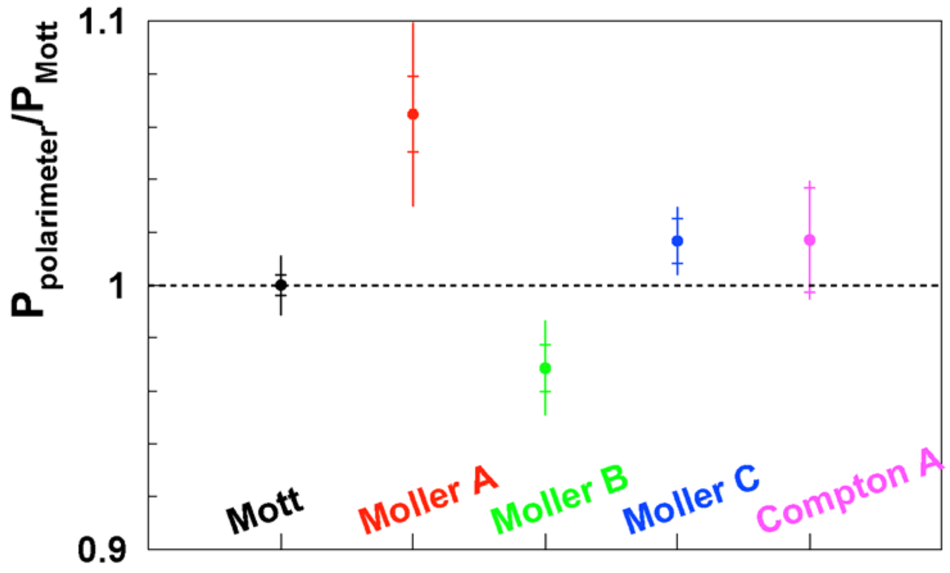
Polarization Results

Results shown include statistical errors only
→ some amplification to account for non-sinusoidal behavior

Statistically significant disagreement

Systematics shown:

Mott	1%
Møller C	1%
Compton	1%
Møller B	1.6%
Møller A	3%

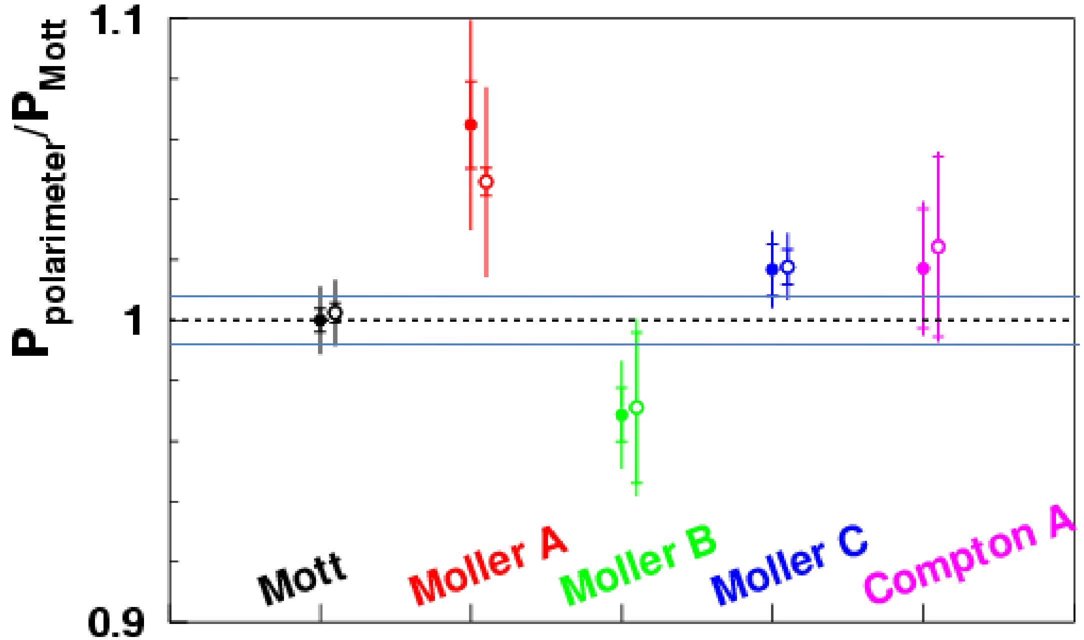


Even including systematic errors, discrepancy still significant

Polarization Results- Reduced Data Set

Hall A, B Møllers sensitive to transverse components of beam polarization

Normally – these components eliminated via measurements with foil tilt reversed, but some systematic effects may remain



closed circles = full data set
open circles = reduced data set

Agreement improves, but still statistically significant deviations
→ when systematics included, discrepancy less significant

Lessons Learned

- Providing/proving precision at 1% level challenging
- Including polarization diagnostics and monitoring in beam lattice design is crucial
- Measure polarization at (or close to) IP
- Measure beam polarization continuously
  - protects against drifts or systematic current-dependence to polarization
- Flip electron and laser polarization
  - fast enough to protect against drifts
- Multiple devices/techniques to measure polarization
  - cross-comparisons of individual polarimeters are crucial for testing systematics of each device
  - at least one polarimeter needs to measure absolute polarization, others might do relative measurements
  - absolute measurement does not have to be fast

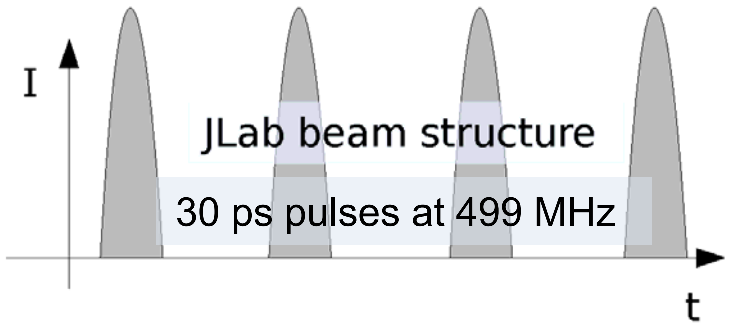
Polarimetry at ILC

- Three ways to measure polarization at the ILC
  - upstream Compton polarimeter
  - downstream Compton polarimeter
  - e^+e^- physics
- Complication
  - polarization at IP = lumi-weighted polarization ≠ polarization at polarimeter
  - depolarization and spin transport effects estimated at 0.1%-0.4% levels!
    - same level as required accuracy
    - keep errors in these effects small
- Need upstream, downstream & e^+e^- physics measurements
  - determine best values for each polarimeter separately (hide from each other)
  - convince yourself that all depolarization and spin transport effects are understood
  - compare and see whether you agree
  - final calibration with $e^+e^- \rightarrow W^+W^-$
- Optimize up & downstream polarimeters separately
  - treat as independent (scattering) experiments
  - different requirements, backgrounds
- Measure beam polarization continuously
- Avoid any distraction from this goal
  - laser wire emmittance diagnostics
  - MPS collimator
- New ideas

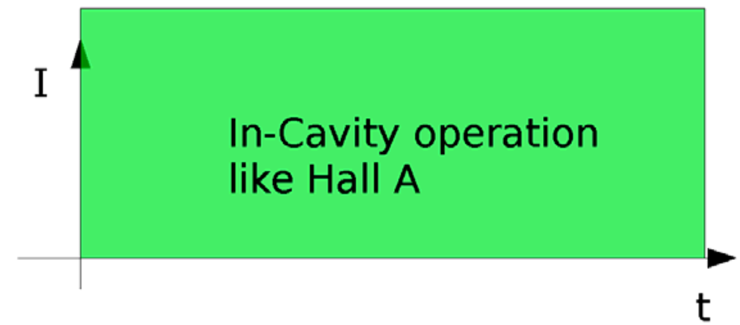
New Fiber Laser Technology (Hall C)

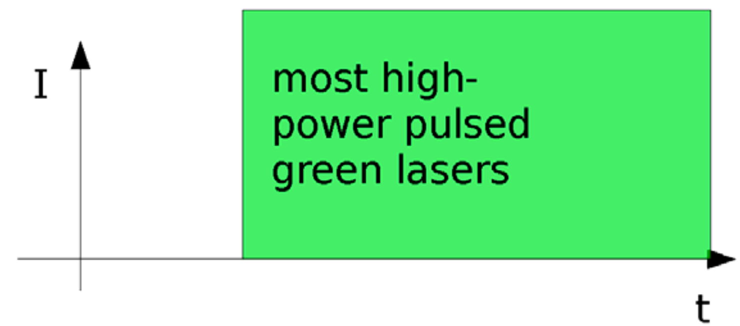
Jeff Martin (Winnipeg)

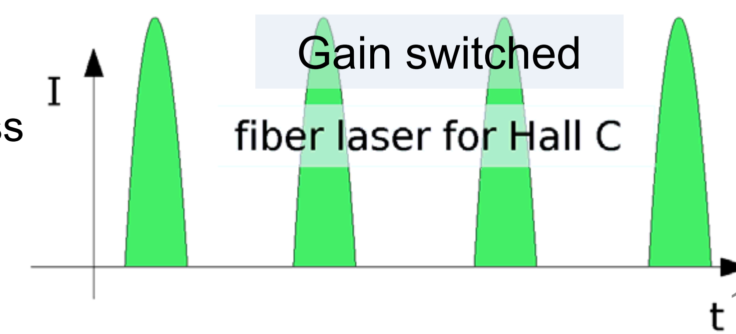
Electron Beam



LaserBeam







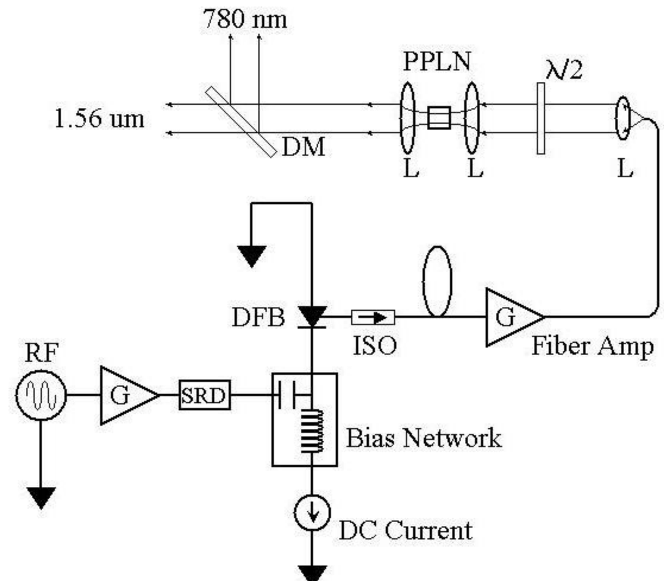
Despite lower average power, fiber laser would achieve higher luminosity than higher power pulsed green lasers on the market.

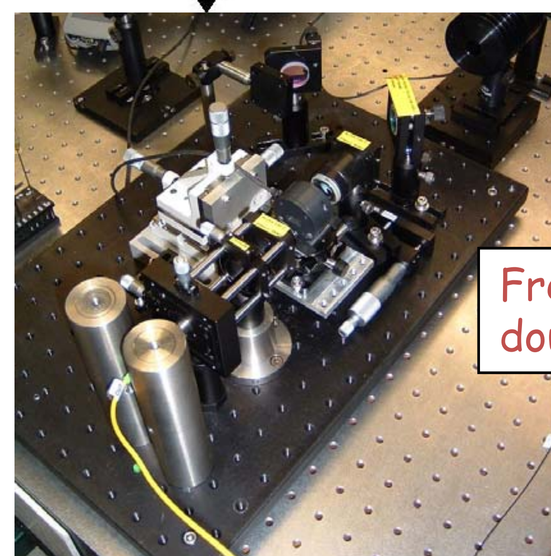
Other advantages:
- lower instantaneous rates for counting
- external to beamline vacuum → easy access
- huge lumi boost when phase locked
- excellent stability, low maintenance

Compact, Off-The Shelf, Rack Mountable…

RF locked low-power
1560 nm fiber diode

ErYb-doped fiber
amplifier





Frequency
doubler

Fiber Laser for Hall C Compton

- Seed laser at 1064 nm
- Fiber amplifier (50 W output at 1064 nm)
- Frequency doubling cavity
- Result: 25 W, 532 nm, 30 ps pulses at 499 MHz
- JLab Polarized source group is willing to build laser (J. Grames)

Dominant Challenge: determine A_z

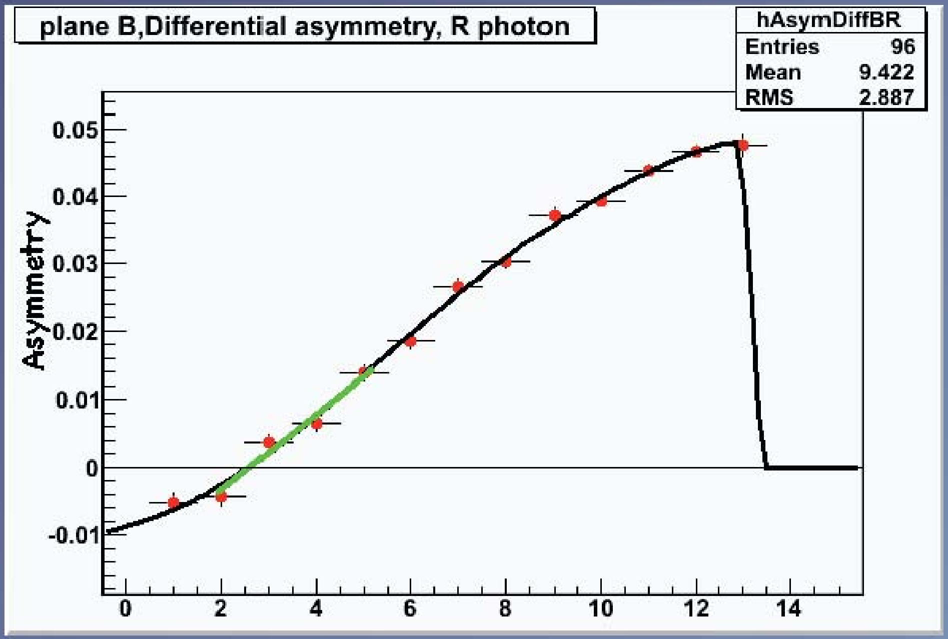
- Best tool to measure e^- polarization

$\rightarrow$ Compton e^- (integrating mode)

- Challenge
  - accurate knowledge of $\int Bdl$
  - must calibrate the electron detector
  - fit the asymmetry shape or use Compton Edge

Zero-Crossing e⁻ Analysis

Kent Paschke



Two Points of well-defined energy:

- Asymmetry zero crossing
- Compton Edge

Linear fit of the zero crossing of the Compton asymmetry

Integrate from the asymmetry from that point

Absolute calibration, the only « input » is QED (with very small corrections for finite strip size and energy resolution).

Weak dependence on energy resolution, no assumption on dispersion characteristics, variation in Y_{Det}, etc... no need to calibrate the spectrometer!

Summary

- Impressive group of people (lots of experience)
  - lots of good ideas / progress
- Big challenge to reach Ε E/E = 0.25%
  - no fundamental show stoppers
- Use multiple devices/techniques to control systematics
  - all three ways to measure polarization needed
- build on experience, but we open to new developments
- extensive modeling needed (A_Z, depol, BMT, etc.)
- much work done, much still ahead to optimize design