Toward 0.5% Electron Beam Polarimetry

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Needs for 0.5%

The proposed PV-DIS experiments may be systematics limited, with fractional errors approaching 0.5%. No <1% polarimetry for an experiment has been *demonstrated* at JLab.

5 polarimeters which can be compared:

Stat error only

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- **Continuous monitoring during production (protects against drifts or systematic current-dependence to polarization)**
- **Statistical power to facilitate cross-normalization (systematics limited on order of 1 hour)**

Moller Polarimetry

$$\vec{e}^{\,-} + \vec{e}^{\,-} \rightarrow \vec{e}^{\,-} + \vec{e}^{\,-}$$

- Analyzing power ~7/9 at $\theta_{CM} = 90^o$
- High cross-section
- Ferromagnetic target
  $P_T \sim 8\%$
- Invasive
- Levchuck Effect

Hall C Moller Polarimeter

- Iron foil in 4T field (saturated, low uncertainty in e^- polarization)
- Large acceptance controls Levchuk effect

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Hall C Moller Polarimeter

Approaches δP_B ~0.5%

Samples (<2hr / measurement) can control drifts of polarization

^{1}**H** target would remove dominant systematics

Some accounted errors?
(no showstoppers)
+ dead-time?
+ radiative corrections?
? Fe polarization could be measured via Kerr effect (not done)

LOW CURRENT ONLY

"Pulsed" Moller might sample from high current beam, but
- larger systematics
- not full current
- less time-efficient and not continuous

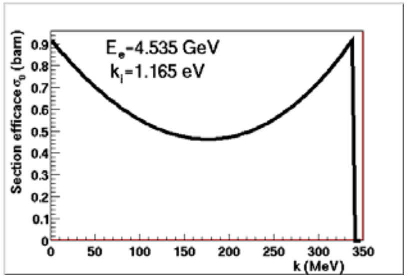
Ingo Sick,

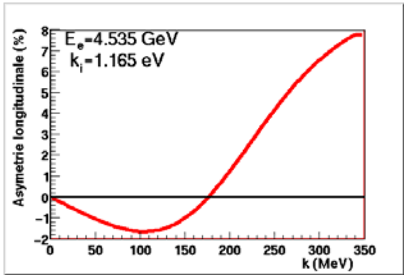
JLab Workshop on Precision Electron Beam Polarimetry

Jefferson Lab, June 9-10, 2003

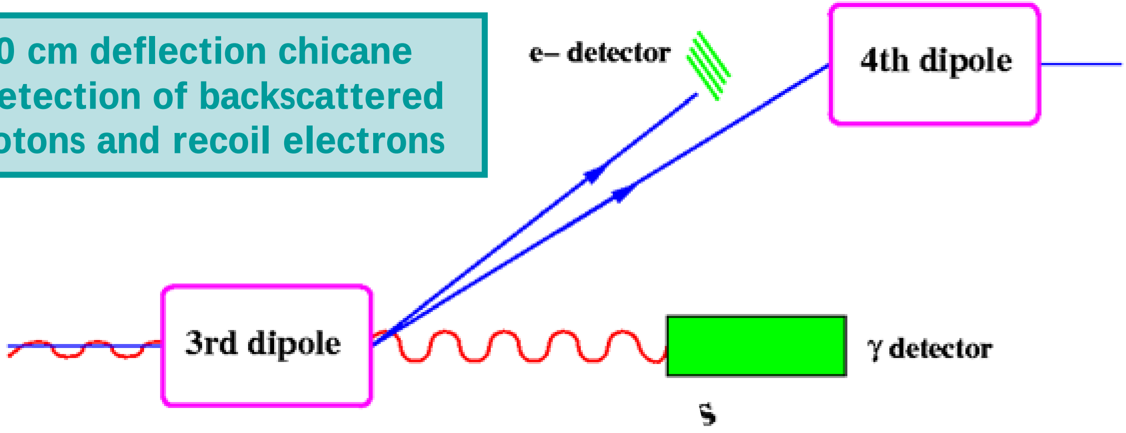
Hall A Compton Polarimeter

$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_\gamma \times P_e \times < A_{th} >$$

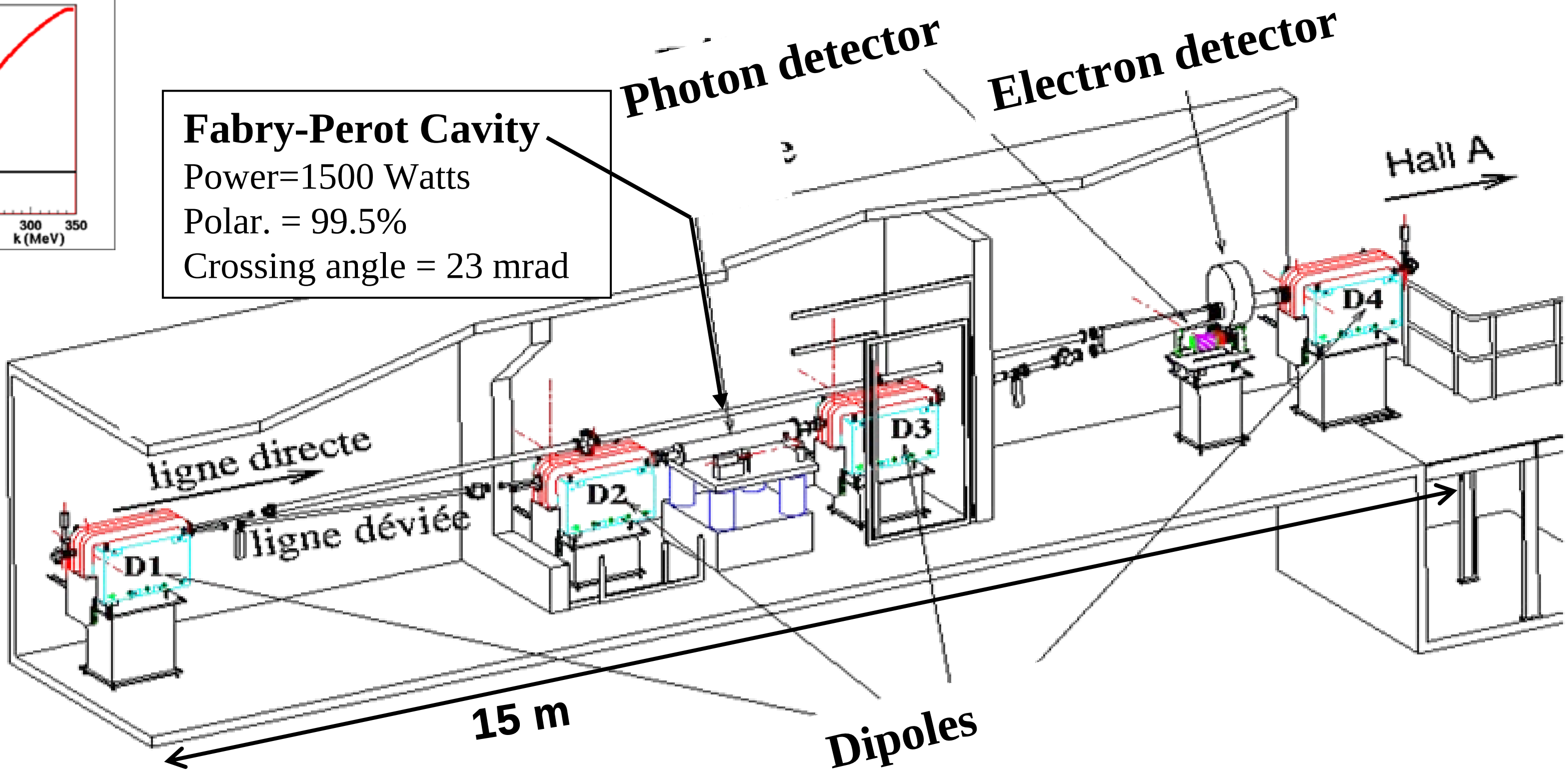




- 30 cm deflection chicane
- Detection of backscattered photons and recoil electrons



Fabry-Perot Cavity
Power=1500 Watts
Polar. = 99.5%
Crossing angle = 23 mrad



Hall A Compton Polarimetry Analysis

$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_\gamma \times P_e \times \langle A_{th} \rangle$$

requires energy calibration

Photon Detector Analysis

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Energy resolution prevents self-calibration:

- Use electron detector to calibrate absolute energy.
- Skip energy calibration with integration technique

Electron Detector Analysis

Rate

Two Points of well-defined energy:

Zero crossing

Compton edge

Asymmetry

Integrate between two known energy points, only sensitive to E_{beam}

Systematic Error Goals

Electron Method:

- $\delta(A_{exp})$
  dead time ~ 0.1%
- $\delta(<A_{th}>)$
  Calibration
  (Strip Efficiency /
  Resolution /
  Spot Size) ~ 0.25%

Photon Analysis Method:

- $\delta(A_{exp})$
  dead time ~ 0.1%
- $\delta(<A_{th}>)$
  Calibration ~ 0.25%
  Response Function ~ 0.40%
  Pile up ~ 0.20%

Common-Mode errors

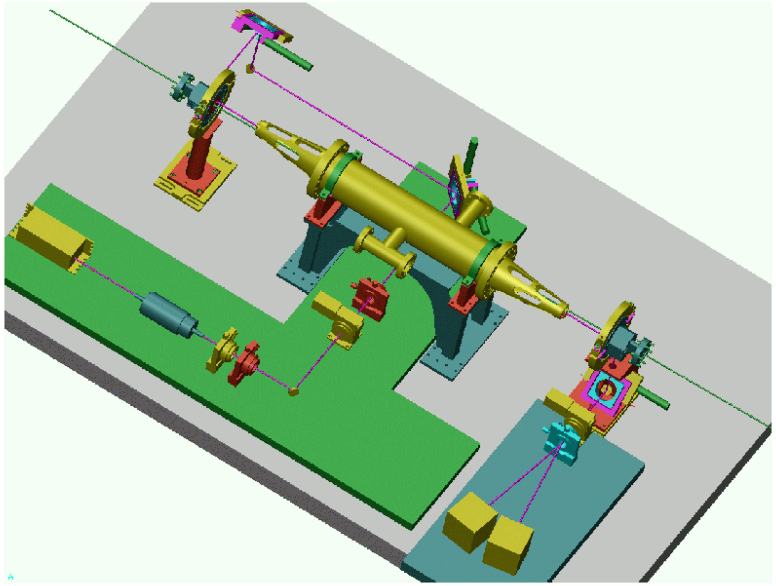
- P_{laser} ~ 0.30%

Other uncertainties :

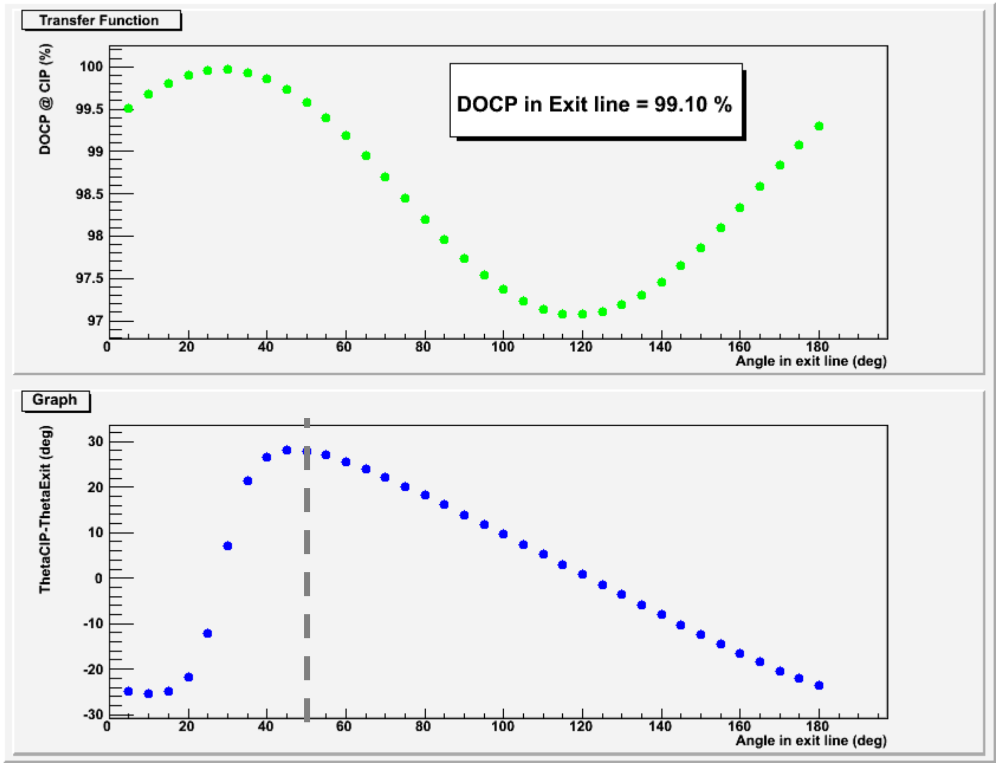
Backgrounds, Beam Asymmetries,
Radiative corrections (<0.05% each)☐

Acheivable: <0.5% polarimetry from electron detection,
<0.7% cross-check from photon detection

Photon Target



Transfer function translates measured transmitted polarization to CIP



Do we know the polarization in the ***cavity*** by monitoring the transmitted light?

Another option: single shot laser. Lower power, but could be pulsed to reduce backgrounds.

An alternate approach for Compton

"The scanning Compton polarimeter for the SLD experiment"
(SLAC-PUB-7319)

- Pulsed mode laser
- Integrating electron and photon detectors, insenstive to low-energy junk
- Published results $\delta P_e \sim 0.5\%$ ($\delta P/P \sim 0.64\%$)
- More forgiving of beam profile, synchrotron radiation, backgrounds
- More difficult to understand, careful and regular study of response functions and Compton asymmetry are necessary

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Atomic Hydrogen For Moller Target

Moller polarimetry from polarized atomic hydrogen gas, stored in an unltra-cold magnetic trap

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TIFF (Uncompressed) decompressor
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- 100% electron polarization
- tiny error on polarization
- thin target (sufficient rates but no dead time)
- Non-invasive
- high beam currents allowed
- no Levchuk effect

10 cm, $\rho = 3\text{x}10^{15}/\text{cm}^3$
in B = 7 T at T=300 mK

Brute force polarization

$$\frac{n_+}{n_-} = e^{-2\mu B/kT} \approx 10^{-14}$$

E. Chudakov and V. Luppov, IEEE Transactions on Nuclear Science, v 51, n 4, Aug. 2004, 1533-40

Atomic Hydrogen Trap Operation

H + H ⌫ H^2 recombination

- suppressed for polarized gas
- surface must be coated (~50nm of superfluid ^{4}He)
- H_2 freezes to walls

Gas lifetime > 1 hour

Beam + RF ⮙ 10^{-4}/sec ionizations (~20%/sec in beam)

- Ions purged by transverse electric field ~1 V/cm
- Cleaning (~20 μs) + diffusion ⮙ <10^{-5} contamination

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$$v = \vec{E} \times \vec{B} / B^2$$

Polarimeter with Atomic Hydrogen

Replace existing Hall A Moller Target (keep spectrometer)

Expected depolarization → <2e-4

Expected contamination (residual gas + He, H_2, excited states, hyperfine states) → < 1%

Dominant systematic errors **total <0.5%**

- Analyzing power → <0.2%
- Background → <0.3%
- He dilution → <0.1%

Statistical error 1% in ~30 min (30 μA)

Summary

Need major effort to establish unimpeachable credibility for 0.5% polarimetry ➢ two separate measurements, with separate techniques, which can be cross-checked.

Methods from 6 GeV CEBAF may be applicable at 12 GeV

- High-Field Moller (Question: beam current extrapolation)
- Counting Compton (Question: 12 GeV e^- beam characteristics)

New methods may provide ultimate results

- Integrating Compton
  Major challenge: fully test simulated response functions/analyzing power
- Atomic Hydrogen Moller
  Least systematic uncertainty, but entirely novel application

HAPPEX-II Systematic Errors

Electron detector analysis

Hardware problem

Relative Error (%)	Diff_^{4}He	0Xing_^{4}He	Diff_LH_2	0Xing_LH_2
Bdl, Y_{det}, D, … (±1.4%)	0.79	0.03	0.69	0.03
E_{beam} (3 MeV)	0.10	0.10	0.10	0.10
ε	0.10	1.00?	0.10	1.50?
$A_{background}$	0.04	0.04	0.02	0.02
RadCorr	0.25	0.25	0.25	0.25
P_{laser}	0.35	0.35	0.35	0.35
Cuts, beam spot size	0.5	0.5	0.5	0.5
TOTAL	**1.04**	**1.20**	**0.93**	**1.64**

Sub-leading, not pursued