Compton Polarimetry for RCS

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EIC Polarimetry WG meeting
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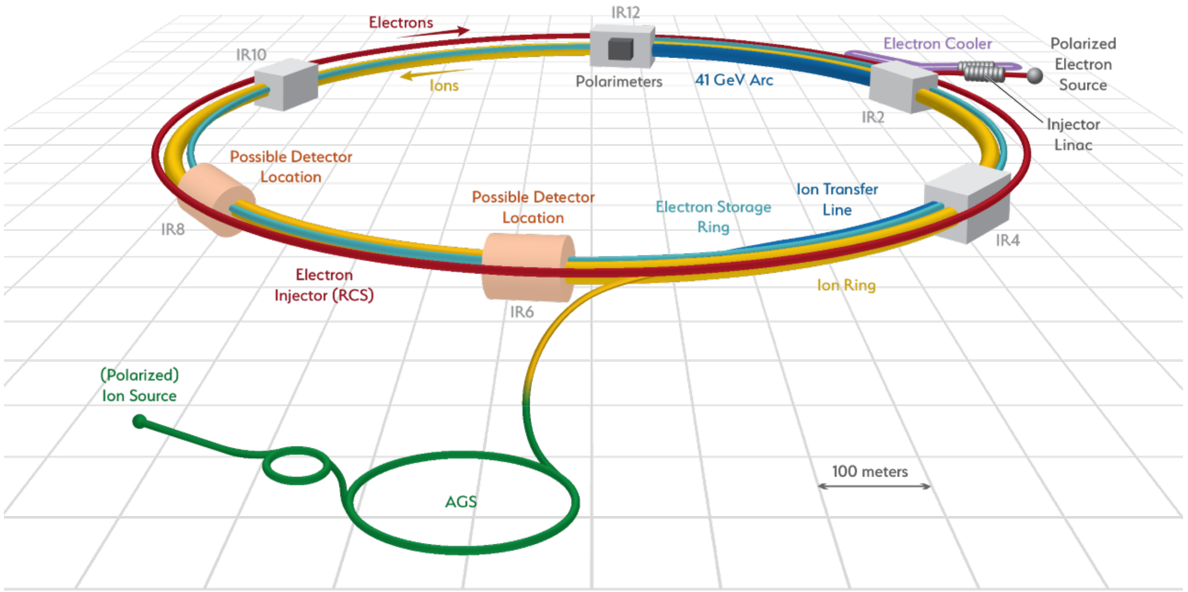
Polarimetry for RCS



<u>RCS properties</u>

- RCS accelerates electron bunches from 0.4 to full beam energy (5-18 GeV)
- Bunch frequency → 2 Hz
- Bunch charge → up to 28 nA
- Ramping time = 100 ms

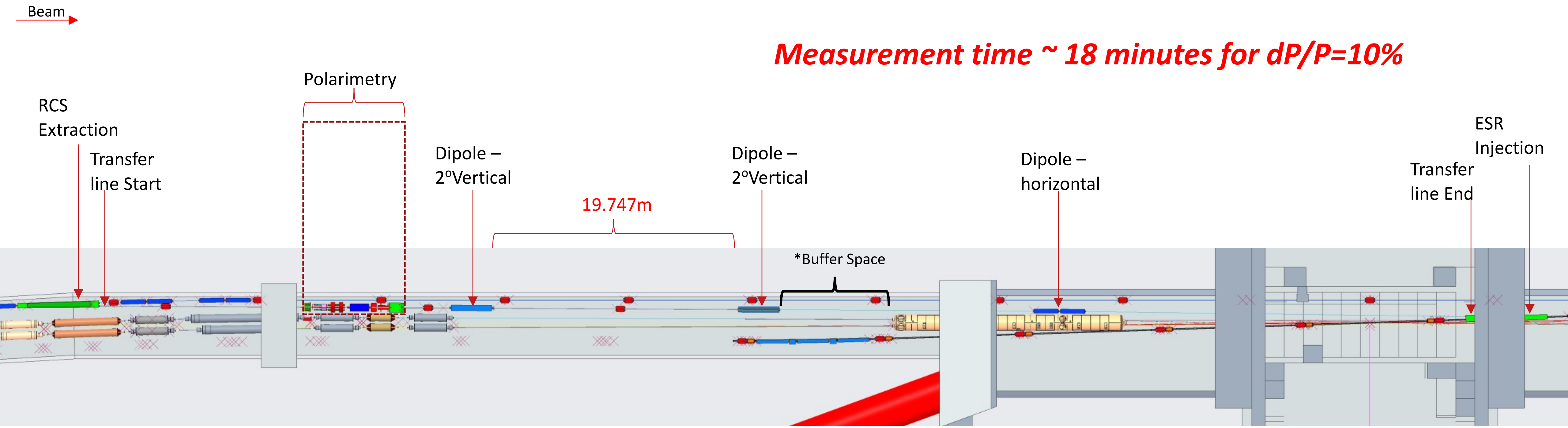
<u>Options</u>

- Compton polarimeter in/after RCS
  - Analyzing power depends on energy – difficult to implement in RCS – could place after RCS in transfer line
  - Initial time estimates assumed same laser as ESR → measurement times much too long
- Møller just after RCS RCS
  - Analyzing power nearly constant
  - Requires spectrometer
  - Destructive – difficult to fit in transfer line
  - Measurement times not short

Hall A Møller in Transfer Line

First look at integrating Møller polarimeter starting with Hall A/JLab design
RCS extraction region very crowded
→ Extraction beam line shares tunnel with several beam lines
→ RCS starts at lower height, beam is kicked up to same elevation as ESR in the extraction line
→ Would like to avoid placing the polarimeter between height-adjusting dipoles (spin precession)
Looking at placing the polarimeter before first dipole, or after last dipole

Measurement time ~ 18 minutes for dP/P=10%



Polarimeter before vertical bend

Picture courtesy Bijan Bhandari

RCS Compton Rate Estimates

$$\mathcal{L} = f_{coll} N_\gamma N_e \frac{\cos(\alpha_c/2)}{2\pi} \frac{1}{\sqrt{\sigma^2_{x,\gamma} + \sigma^2_{x,e}}} \frac{1}{\sqrt{(\sigma^2_{y,\gamma} + \sigma^2_{y,e})\cos^2(\alpha_c/2) + (\sigma^2_{z,\gamma} + \sigma^2_{z,e})\sin^2(\alpha_c/2)}}$$

1-2 Hz

$N_\gamma = \langle P \rangle / (f_{laser}\, E_{laser})$

Original rate estimates for RCS Compton (done for Yellow Report/CDR) assumed **same laser** as used for ESR:

<P> = 5 W, f_{laser} = 25, 100 MHz → 5.4E11, 1.3E11 photons/pulse

Assuming 28 nC electron bunches at 2 Hz, this gives about 2.9 Hz of backscattered photons (by design)
Measurement time on the order of days for $(dP/P)_{stat}$ = 1%

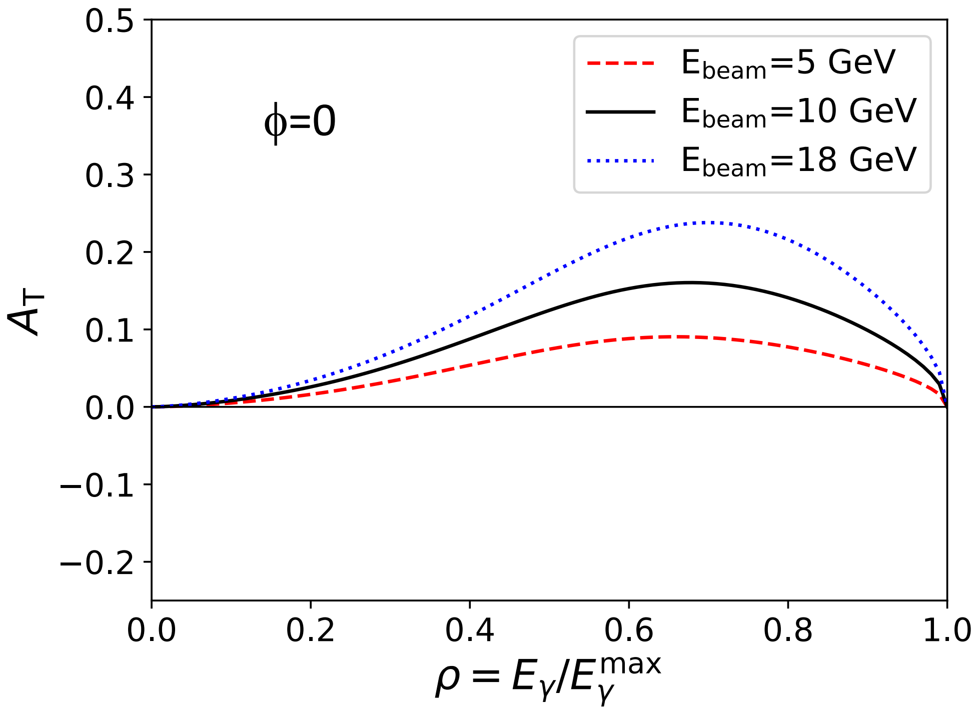
Should have assumed low duty cycle, higher peak power laser (similar to HERMES LPOL)
→ Example system from RPMC lasers: Pulse energy = 30 mJ @ 2 Hz (<P>=60 mW) → 8.0E16 photons/pulse

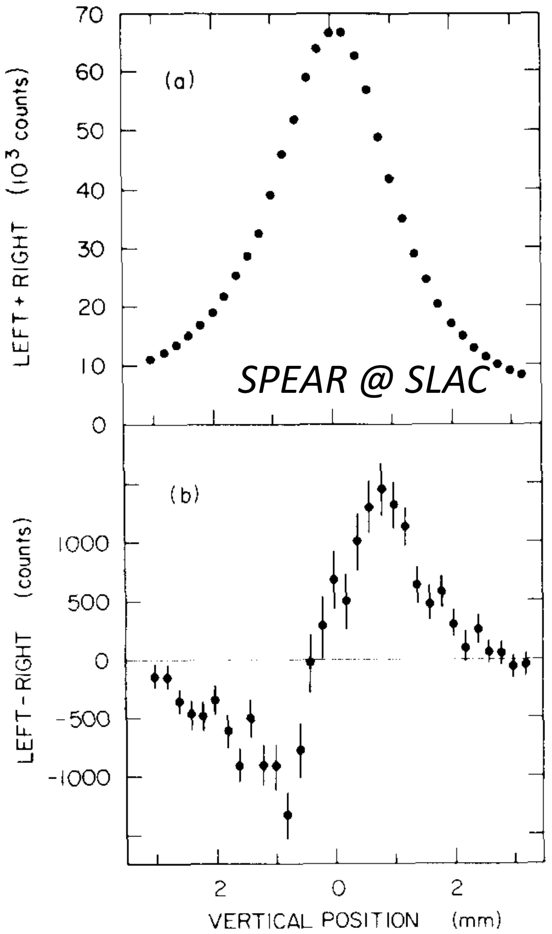
For 15 ns pulses, backscattered photon rate is 240 kHz, "ideal" measurement times on the order of a few seconds

Transverse Analyzing Power and Measurement

$$A_{\mathrm{T}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right]$$

I contrast to longitudinal measurement, measurement of transverse polarization requires sensitivity to spatial dependence of asymmetry





Simple rate, measurement time estimates

$$t^{-1} = \mathcal{L}\sigma \left(\frac{\Delta P}{P}\right)^2 P^2 A^2_{method}$$

Average analyzing power: $A^2_{method} = \langle A \rangle^2$ → Average value of asymmetry over acceptance

Energy-weighted: $A^2_{method} = \left(\frac{\langle EA \rangle}{\langle E \rangle}\right)^2$ → Energy deposited in detector for each helicity state

Differential: $A^2_{method} = \langle A^2 \rangle$ → Measurement of asymmetry bin-by-bin vs. energy, etc.

Assuming 80% polarization, <P_{laser}>= 6mW, 300 μm beam spot size…, → time for 1% measurement

E_{beam}	A_{avg}	T_{avg}	A_{energy}	T_{energy}	A_{diff}	T_{diff}
5	4.51%	243 s	5.78%	148 s	5.48%	164 s
10	7.79%	92 s	10.15%	54 s	9.56%	61 s
18	11.29%	51 s	14.91%	29 s	13.96%	33 s

Toy Monte Carlo

- Used toy Monte Carlo to look at asymmetries, energy/per bunch etc.
- Generated events for 240 bunches (i.e., 2 minutes of running)
  - For each bunch/crossing, generated number of backscattered photons based on simple luminosity estimates
  - Assumed luminosity 10x smaller than previous slide → 6 mW average laser power
  - 12,000-15,800 backscattered photons/bunch crossing
- Assumed detector 25 m away from laser-beam collision point
  - No realistic simulation of detector – just a point in space to look at distributions
- Event generator ignores hourglass effect, assumes all events generated at (0,0) → does incorporated finite beam sizes, but only at that point

Detector Distributions

LEP polarimeter measured difference in vertical position for h+ and h- induce by transverse analyzing power

At 5 GeV, average position difference for h+ and h- is

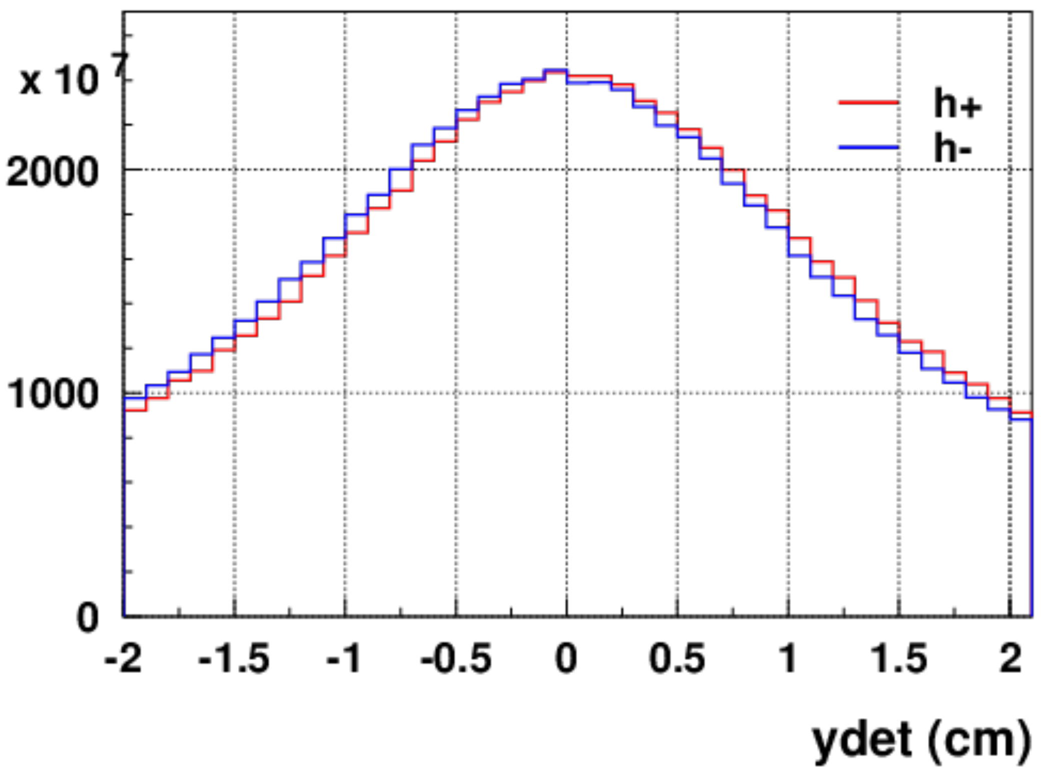
$Y_{h+} - Y_{h-} = 0.49$ mm

At 18 GeV, difference is similar magnitude:

$Y_{h+} - Y_{h-} = 0.38$ mm

While measurable, this quantity extremely sensitive to knowledge of absolute detector position and laser-beam collision point

5 GeV



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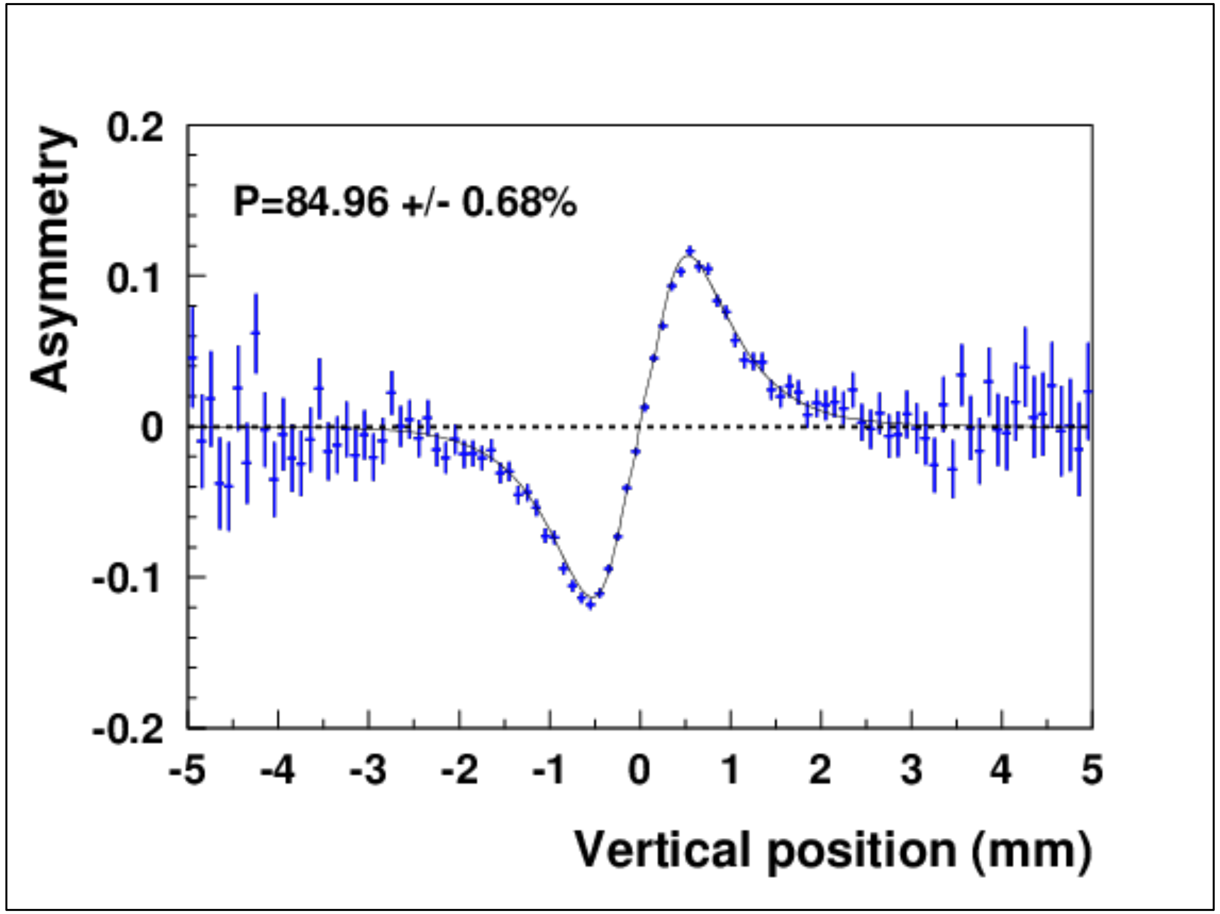
Differential Asymmetry measurement

Differential measurement of asymmetry vs. position at detector allows us to incorporate offsets in the fit

Example using Toy MC for counting-mode asymmetry vs. y assuming 0.1 mm segmentation (240 bunches)

→ Requires detector operated in integrating mode (~10,000 photons/bunch) with signal proportional to number of photons in each channel



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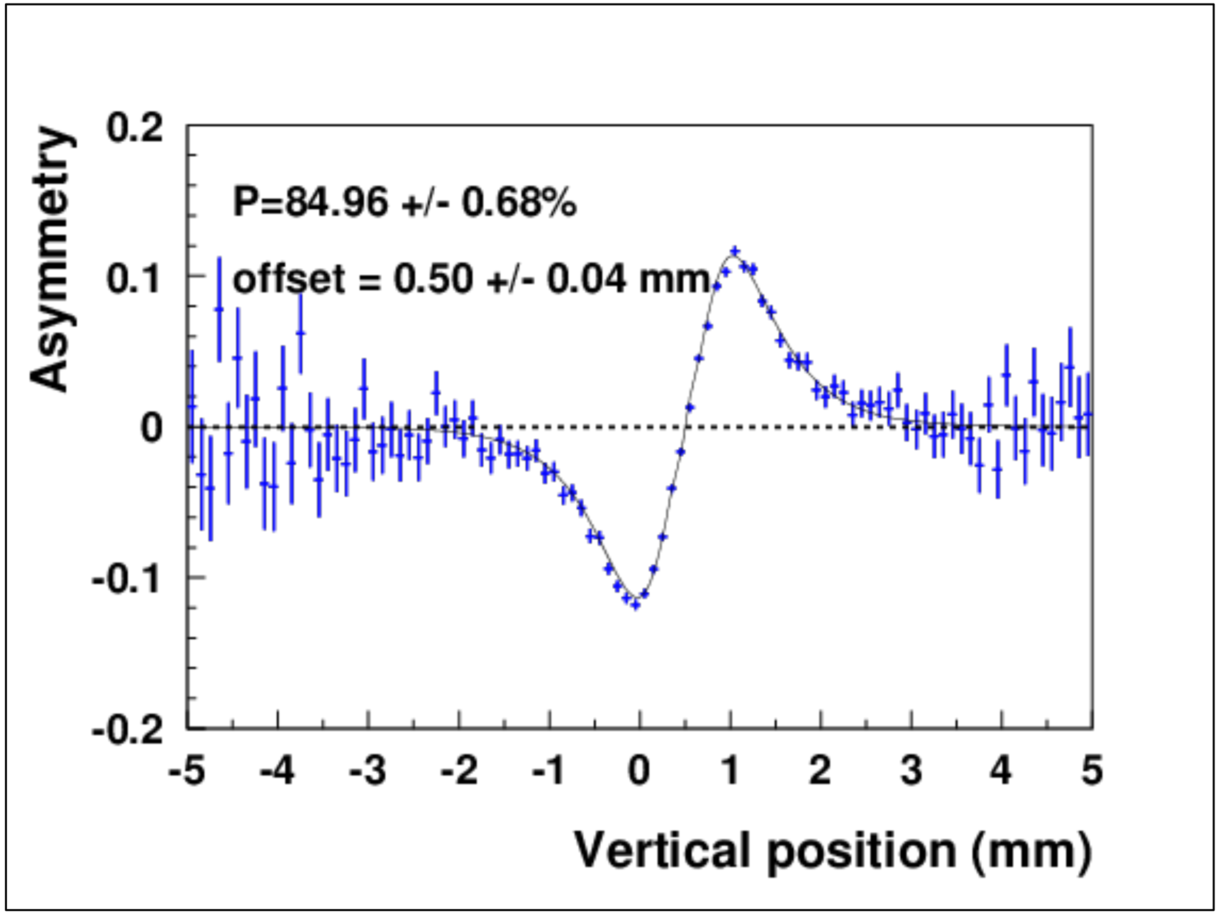

Summary

- Compton polarimeter looks like a viable solution for RCS polarimetry
  - Significantly shorter measurement times
  - Requires less space along beamline
- Issues
  - Can only operate in integrating mode – requires additional characterization of detector response compared to counting mode
  - Integrating mode requires more attention to detector noise, pedestal
  - No bunch-by-bunch measurement – will need to average over several bunches
  - Large total energy/bunch when integrated over all backscattered photons → @ 18 GeV, avg. $\langle E_\gamma \rangle$=3.41 GeV * 12,000 photons = 42,000 GeV! Is this an issue?
- To-do:
  - Identify possible locations in ESR transfer line – main challenge will likely be finding space for long drift to photon detector
  - Investigate detectors for integrating mode operation (diamond? silicon?)
  - More detailed simulations incorporating detector response, noise

Analyzing Power and Measurement Times

Measurement time depends on luminosity, analyzing power, and measurement technique

$$t^{-1} = \mathcal{L}\sigma \left(\frac{\Delta P}{P}\right)^2 A^2_{method}$$

Average analyzing power: $A^2_{method} = \langle A \rangle^2$ → Average value of asymmetry over acceptance

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$$\langle A \rangle^2 < \left(\frac{\langle EA \rangle}{\langle E \rangle}\right)^2 < \langle A^2 \rangle$$