Meeting the HAPPEX Beam Requirements

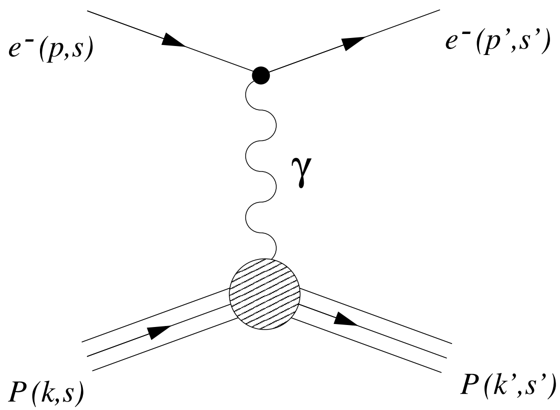
Kent Paschke

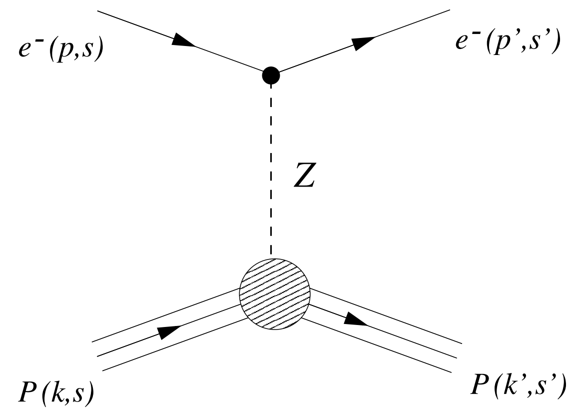
University of Massachusetts

Overview

- Intro to Hall A Parity
- Beam Requirements
- Improving the Source
- Injector Transmission
- Adiabatic Damping
- Phase Trombone
- Possible Schedule
- Necessary Test Plans
- Systematics check: Transverse Asymmetry
- Various Additional Requests

Parity-Violation as a Probe of Nucleon Structure





$$\left\{ A_0 = \frac{-G_F Q^2}{\sqrt{2}\pi\alpha} \right\}$$

$$\begin{aligned} A^{PV} &= \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \\ &= A_0 \frac{\epsilon G_E^{p\gamma} G_E^{pZ} + \tau G_M^{p\gamma} G_M^{pZ} - \frac{1}{2}\left(1 - 4\sin^2\theta_W\right)\epsilon' G_M^{p\gamma} G_A^{pZ}}{\epsilon (G_E^{p\gamma})^2 + \tau (G_M^{p\gamma})^2} \end{aligned}$$

Assuming Isospin Symmetry

$$G_{E,M}^{pZ} = \frac{1}{4}\left(G_{E,M}^{p\gamma} - G_{E,M}^{n\gamma}\right) - \sin^2\theta_W G_{E,M}^{p\gamma} - \frac{1}{4} G_{E,M}^{s}$$

HAPPEX Precision

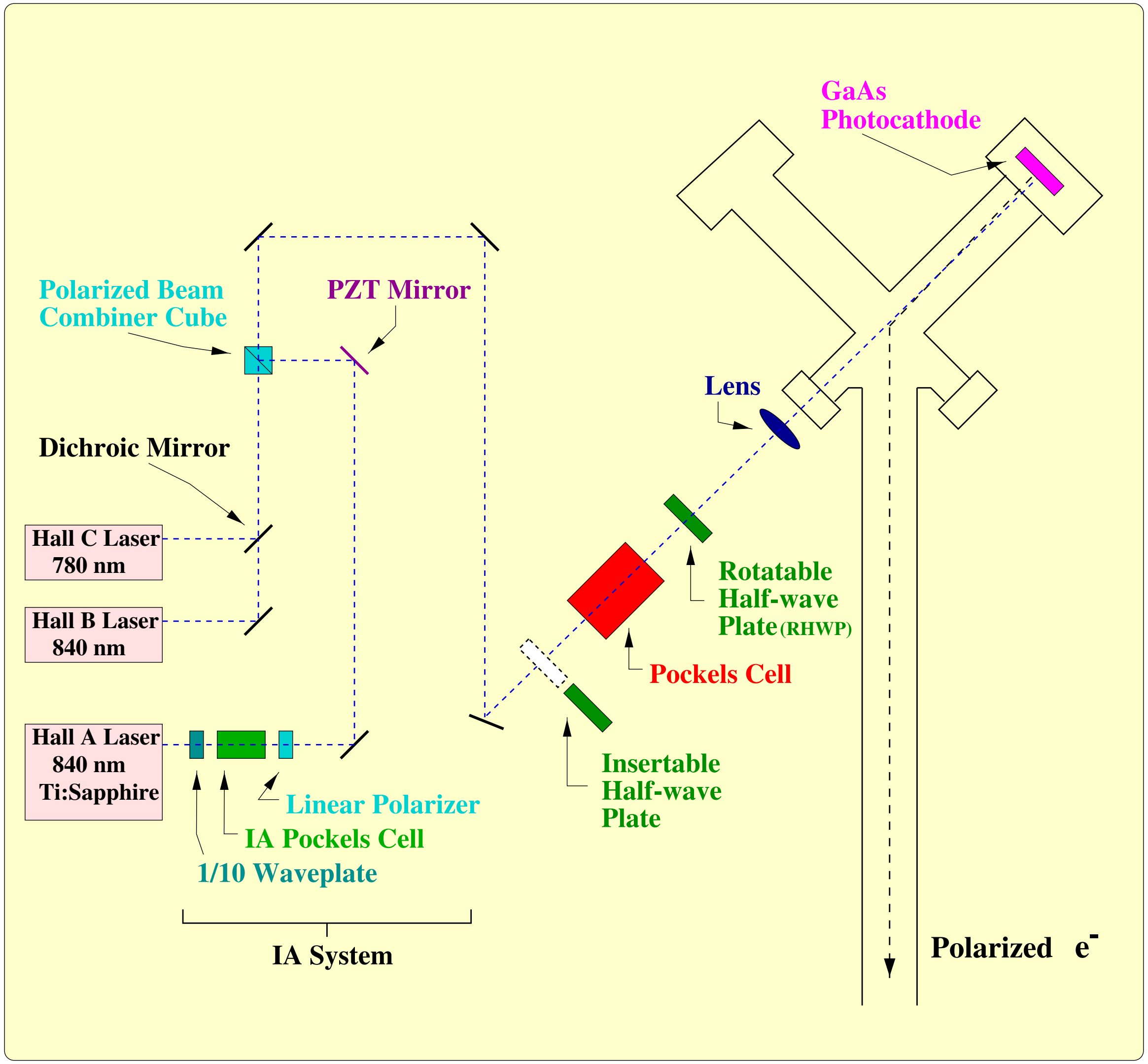
	Asymmetry	Relative Error	Precision
HAPPEX II	1.2×10^{-6}	5%	60 ppb
HAPPEX ^{4}He	8×10^{-6}	3%	240 ppb
P-REx	5×10^{-7}	3%	15 ppb

HAPPEX Beam Requirements

	Nominal Value	Max 30Hz Non-HC Noise	Maximum HC Run-averaged	HC 1-day Average
Average Current $\langle Q \rangle$	100 μA	1000 ppm (>200 ppm)	600 ppb	< 4.5 ppm
Position at target	0	12 μm	$\langle \Delta x \rangle = 2$ nm	< 15 nm
Angle at target	0	12 μrad	$\langle \Delta x\prime \rangle = 2$ nrad	< 15 nrad
Energy	3.2 GeV	$\frac{\Delta E}{E} \leq 80$ ppm	$\langle \frac{\Delta E}{E} \rangle \leq 13$ ppb	100 ppb
Halo	100 Hz/μA @ 3mm †	-	-	-
Beam Size	$> 100\mu$m $< 1000\mu$m	3%* (area)	5 ppm* (area)	40 ppm* (area)

http://hallaweb.jlab.org/experiment/HAPPEX/docs/HAPPEX_Beam_Requirements.ps

Source



- Pockels cell "steering"
- Pockels cell birefringence gradient
- Vacuum Window
- Cathode Gradients
- IA system

Source Configuration

- Superlattice (SVT) cathode
- Imaging to reduce steering
  - (Very difficult in present configuration)
- Pockels cell alignment/centering
- Careful configuration / re-tuning
  - Pockels cell voltages
  - Rotating waveplate

Active Feedback

Feedback Loop Controls Charge Asymmetry

- "PITA" voltage: tunes Pockels cell voltage to reduce asymmetry. (A_Q is primarily caused by laser polarization interaction with cathode.)
- IA system: "brute force" laser intensity attenuation.
- Position feedback is not desirable.
  - No correction mechanism for position differences has yet been shown to be suitable (options lack stability, independence)
  - "Brute-force" approach ignores higher-order effects
  - Systems are available as last resort

Source Configuration

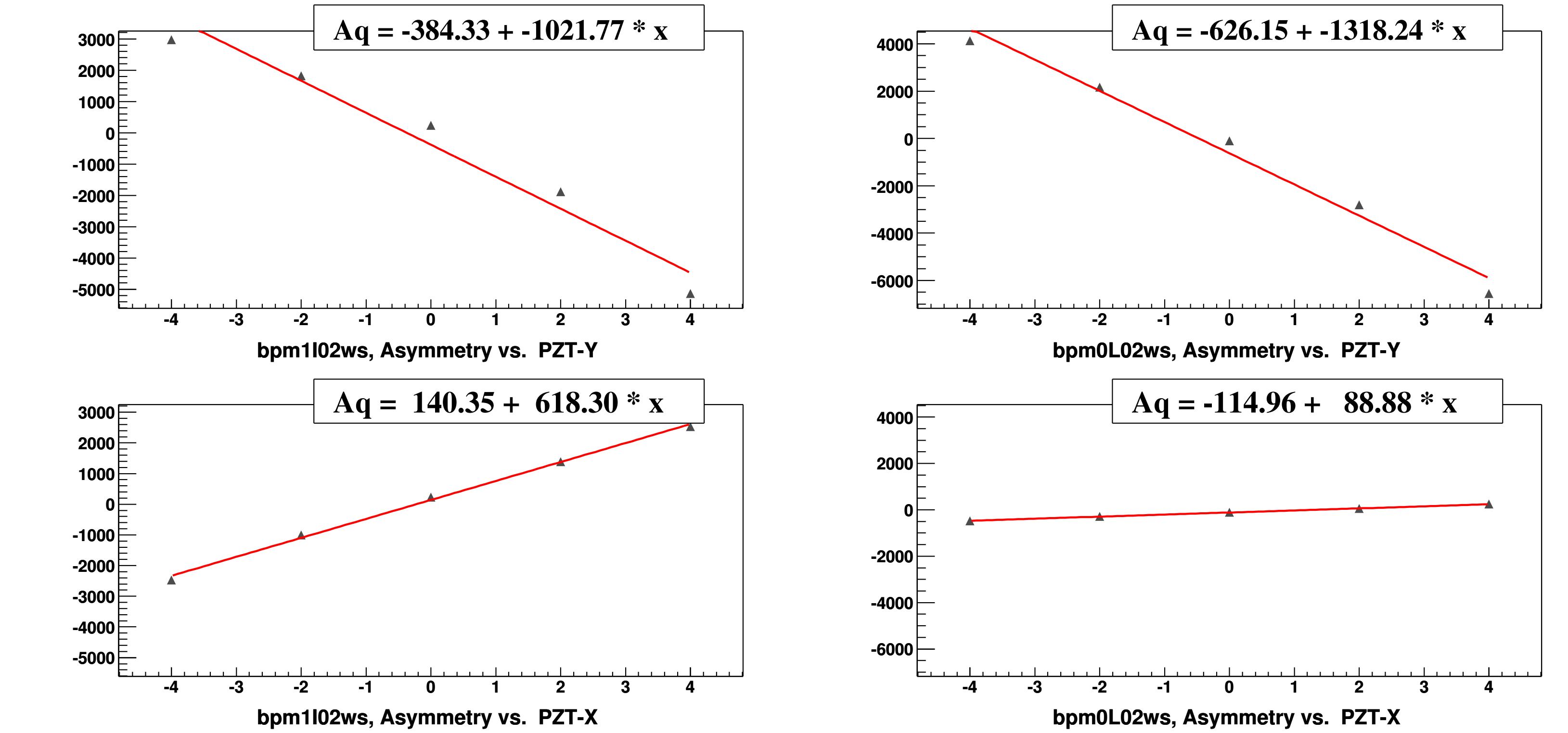
We are developing a plan for start of HAPPEX:

- 1-2 shifts in the tunnel
- 1-2 shifts Injector studies
- Re-tuning based on results of commissioning

Expectations at 100 keV
(before Insertable Waveplate cancellation)

- Best case: 300 nm
- Worst case: 800 nm

Injector Transmission



- Position differences and charge asymmetry can be modified by clipping in the injector (mostly near slits)
- This will lead to “mis-tuning” of source to compensate

Adiabatic Damping

- Improved accelerator matching will lead to more benefit from adiabatic damping.
- New understanding: any two points in phase space don't necessarily reduce their distance during acceleration
- Maximal benefit from damping when beta function is tuned so that angle differences are maximized (and position differences minimized) entering an acceleration cavity.

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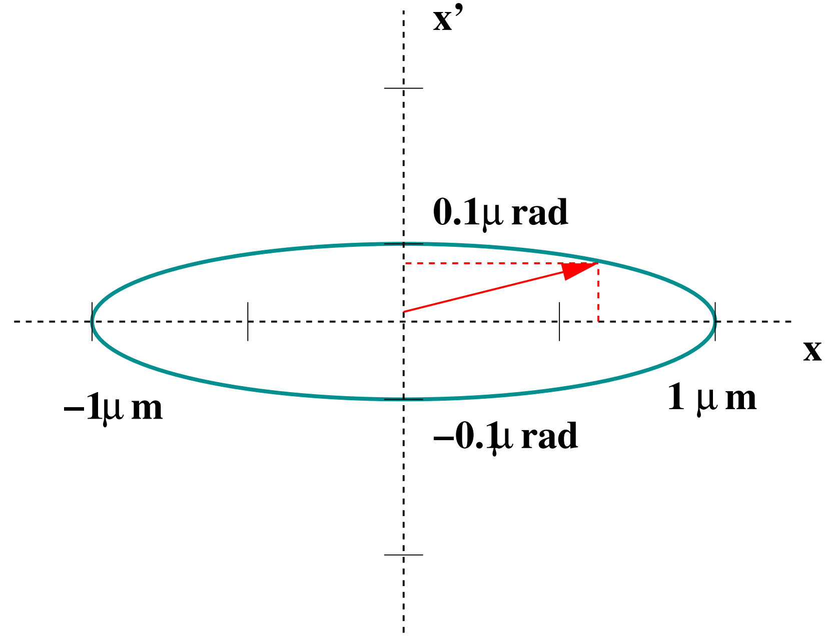
Additional Development Required for
- Matching
- Shifting β phase at acceleration cavities

Phase Trombone

- HAPPEX sensitivity same
  1 μrad $\rightarrow$ 1 μm
- Beamline equates
  1 μrad $\rightarrow$ 10 μm.



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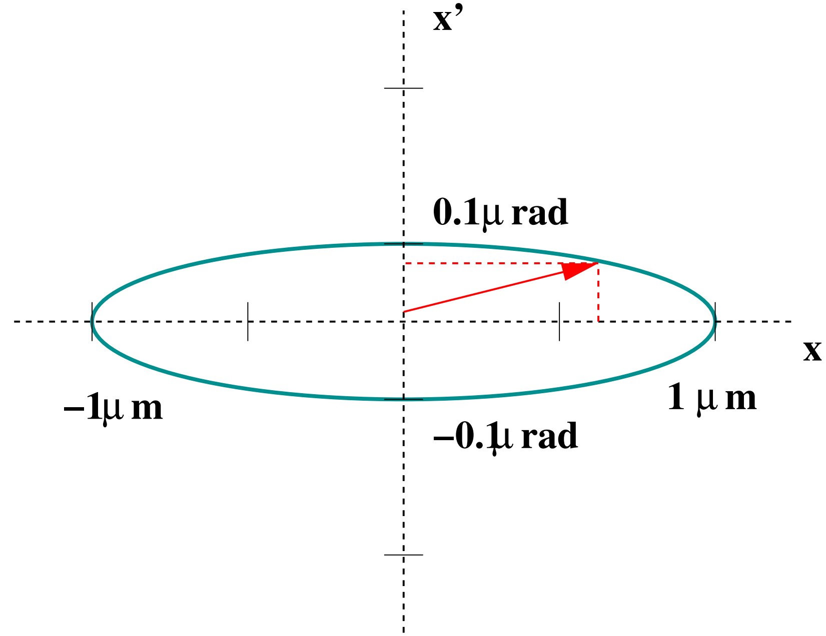

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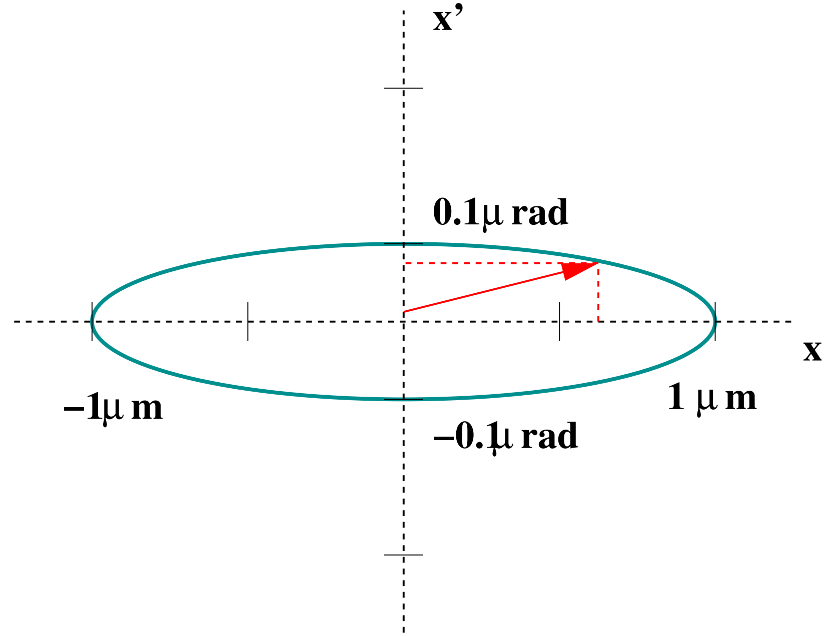

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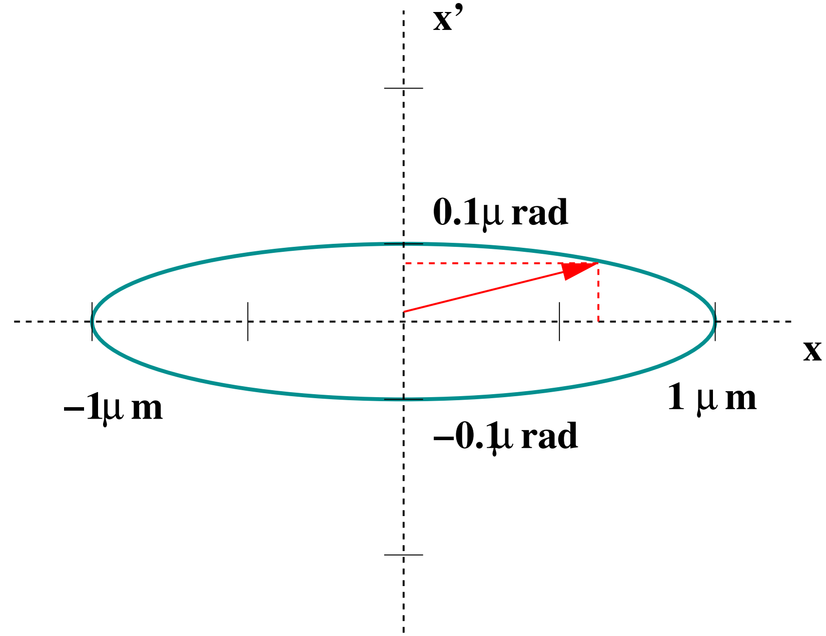

Two potential uses:

- Control over the β function in the Hall A beam line can provide reduction in sensitivity to position differences.
- Additional benefits can be found through changing β shift setpoints to randomize or cancel remaining position differences.

Phase Trombone

- Alex Bogacz has shown (via design calculation) that 5 existing quads can be used to advance the β_x and β_y functions in Hall A while preserving the transfer matrices
- Constraints
  - spot size at Compton Polarimeter
  - Independent control of spot size at Target
  - BPM 12 position dominated by dispersion
- Existing quads provide slightly more than $\pm\frac{\pi}{2}$ advance for β_x, β_y independently
  - Enough for minimizing
  - Probably enough for cancelling/randomizing
- Multi-knob software development and testing required

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Development and commissioning of this tool is seen as a priority for HAPPEX-II

Beam Modulation

A Beam Modulation system is used in order to measure sensitivities to helicity-correlated position and energy differences. The hardware has been re-implementated after years of disuse.

Compatibility with Fast Feedback (target position lock) is a crucial issue.

- Fast Feedback is required for HAPPEX
- Step-wise corrector changes will be fought by FFB
- Solution: FFB data collection disabled using an EPICS switch, which will be enabled by the modulation script during the modulation period (Richard Dickson)

We will seek to test this system, and compatibility with Fast Feedback, as soon as possible when beam returns to Hall A.

Various Requests

- Precision of the Compton polarimeter is crucial for both HAPPEX-H and HAPPEX-He. The polarimeter will require a 10^{-10} supression of rate at 3mm from the beam.
  - Measured only by the Compton polarimeter electron detector
  - 2nd Ocelot (Ti-Saph) laser for Hall C
- Cavity Monitors - Electronics group is completing readout boards.
- Control of Charge Asymmetry in Hall C
- Monitoring of site-boundary radiation rate
  - HAPPEX-He estimated to exceed annual JLab site-boundary limits
  - Short run will be useful for measuring rate at site-boundary to check estimates

Transverse Polarization

It is not possible to rule out a small component of <u>vertical</u> transverse beam polarization ($\sim 2\%$). Recent results have suggested that the left-right asymmetry from transverse polarization may be as large as 20 ppm at HAPPEX kinematics.

Each detector is insensitive to in-plane transverse polarization, but is maximally sensitive to vertical transverse polarization.

Assume:

- 20 ppm scattering asymmetry on transverse polarization.
- 2% vertical transverse polarization.
- Factor 10 cancellation right vs. left

Systematic error: (20 ppm) $\times$ (0.02) $\times$ (1/10) = 40 ppb

Transverse Polarization Study

Vertical polarization can be created by solenoids in injector. Hardware modification + recovery approximately 1 shift.

Sufficient moment is available to rotate transverse polarization fully vertical (Joe Grames, thesis).

There is no method for measuring vertical polarization in Hall A. Mott polarimeter can be used to measure vertical polarization in injector.

Approximately 1 shift of data taking will be required (for each target)

Summary

Tight beam requirements will only be met through the combined efforts of the HAPPEX collaboration and accelerator physicists. HAPPEX collaboration priorities are listed below

- Continued support from Source group
- Continued efforts to improve accelerator matching
- Attempts to exploit new understanding of adiabatic damping in injector.
- Multi-knob Phase Trombone software implementation, commissioning
- Tests of Beam Modulation compatibility with FFB
- Improvements in injector configuration to assist with control of injector transmission, Compton halo?
- Transverse vertical polarization