<table>
<thead>
<tr>
<th>Experiment</th>
<th>Energy (GeV)</th>
<th>Pol (%)</th>
<th>I (µA)</th>
<th>Target</th>
<th>(A_{pv}) (ppb)</th>
<th>Maximum Charge Asym (ppb)</th>
<th>Maximum Position Diff (nm)</th>
<th>Maximum Angle Diff (nrad)</th>
<th>Maximum Size Diff ((\delta \sigma /\sigma))</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAPPEx-I (Achieved)</td>
<td>3.3</td>
<td>38.8</td>
<td>40</td>
<td>(^1\text{H}) (15 cm)</td>
<td>15,050</td>
<td>200</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>G0-Forward (Achieved)</td>
<td>3.0</td>
<td>73.7</td>
<td>40</td>
<td>(^1\text{H}) (20 cm)</td>
<td>3,000-40,000</td>
<td>300±300</td>
<td>7±4</td>
<td>3±1</td>
<td></td>
</tr>
<tr>
<td>HAPPEx-II (Achieved)</td>
<td>3.0</td>
<td>87.1</td>
<td>55</td>
<td>(^1\text{H}) (20 cm)</td>
<td>1400</td>
<td>400</td>
<td>1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>HAPPEx-III (Achieved)</td>
<td>3.484</td>
<td>89.4</td>
<td>100</td>
<td>(^1\text{H}) (25 cm)</td>
<td>16900</td>
<td>200±100</td>
<td>3±3</td>
<td>0.5±0.1</td>
<td>10^{-3}</td>
</tr>
<tr>
<td>PREx-I (Achieved)</td>
<td>1.056</td>
<td>89.2</td>
<td>100</td>
<td>(^{208}\text{Pb}) (0.5 mm)</td>
<td>657±60</td>
<td>100±130</td>
<td>2±3</td>
<td>1</td>
<td>10^{-4}</td>
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<tr>
<td>QWeak-I Run 2 (Achieved)</td>
<td>1.155</td>
<td>89.0</td>
<td>180</td>
<td>(^1\text{H}) (35 cm)</td>
<td>281±46</td>
<td>8±15</td>
<td>1±1</td>
<td>0.1±0.02</td>
<td>?</td>
</tr>
<tr>
<td>PREx-II</td>
<td>1.0</td>
<td>90</td>
<td>70</td>
<td>(^{208}\text{Pb}) (0.5mm)</td>
<td>500±15</td>
<td>100±10</td>
<td>1±1</td>
<td>0.3±0.1</td>
<td>10^{-4}</td>
</tr>
<tr>
<td>Møller</td>
<td>11.0</td>
<td>90</td>
<td>85</td>
<td>(^1\text{H}) (150 cm)</td>
<td>35.6±0.74</td>
<td>10±10</td>
<td>0.5±0.5</td>
<td>0.05±0.05</td>
<td>10^{-4}</td>
</tr>
</tbody>
</table>
Always Tweaking the Design

Endless quest for perfection

Use this gun for PReX
130 kV Inverted Gun

Higher Voltage = Better Transmission = Better Beam Quality (and maybe longer lifetime)

Prebuncher operating at modest power takes care of the rest
The MOLLER Injector: 200kV gun + New \( \frac{1}{4} \) CM with SRF capture section

- Replace 130kV gun with 200kV gun
- Replace \( \frac{1}{4} \) CM with an improved \( \frac{1}{4} \) CM having an SRF capture section
- No prebuncher
- Improve the two-Wien spin flipper layout
- More attention paid to beamline vacuum

Our new “\( \frac{1}{4} \) cryomodule”:
2 cell capture section + 7 cell cavity, should provide 10 MeV beam and introduce no x/y coupling, allow better matching, more adiabatic damping
• Harder to flip spin than we imagined, more “things” change than just spin direction
• Beam orbit downstream of HWien sensitive to laser/prebuncher (mis-)phasing
• Don’t know what to do about this….
Electron Spin Reversal for PV

From Gun
- LEFT
- RIGHT

“Spin Reversal”
Vertical Wien = 90 deg
Two Solenoids = ±90 deg

“Longitudinal Polarization”
Horizontal Wien = {-90…+90}

Pondering a new beamline, but will it behave differently?
Reluctant to move prebuncher for Prex. Would rather wait until we upgrade injector, and simply remove it.
Two Wien Improvements

- Do a better job characterizing optics, and compensate asymmetric focusing using quads, to achieve “perfect” spin flip
- Mis-matched E and B fields create mini-chicane, with e-beam displaced from zero potential, which introduces a time delay…

Fig. 4. Computed E- and B-field variations on the z-axis.
All of the same knobs exist today....
Stewart Platform: complete RC of PC alignment

LINUX-based software/freeware from hobbyists who build flight simulators

X, Y, pitch, roll and yaw
Initial attempts and problems encountered

Two commercial high-speed / high-voltage transistor (\(~$8000\))

This approach needed big capacitors…. lots of current

Exaggeration of voltage droop on cell and subsequent re-charge after a helicity flip. Droop causes a serious problem when helicity flip rate was changed from a toggle to a pseudo-random pattern: pockels cell “memory”

high-voltage switch (\(~$10,000\)) All-in-one commercial bipolar

Charge droop was greatly improved, but high speed ringing of the cell was a problem for the settling time. In addition, the large high-speed switching currents created a noise induced helicity pickup on sensitive helicity DAQ components.

Work of John Hansknecht
Solution: Opto-diode

Encapsulated Opto-diode  $67 each

- $I = \frac{C \Delta V}{\text{Charge time}}$
- +/- quarter wave voltage = 5120V
- Cell capacitance = 6pf
- Desired charge time = 100us
- Calculated current is only 307uA !!
Pockels cell $\lambda/2$ transition optical result. $\sim$70us with no ringing.

Pockels cell $\lambda/2$ flipping at 1kHz. Perfect symmetry and no voltage droop over time.

Reversal at 2kHz is possible, but with increased dead time.

Rise time of $\sim$60-70usec appears limited by $KDP$.

RTP is option (no piezo effect), but polarization quality suffers.

Work of John Hansknecht
Mott Polarimeter at CEBAF
Tests of Mott accuracy in 2015

- M. Steigerwald reported MeV Mott Polarimeter at SPIN 2000, with total accuracy 1.1% dominated by theory (~0.8%)

- Still that accurate? Can we test theory ??? => motivates a new “campaign” to study 5 MeV Mott
Accurate Mott Polarimetry

List of improvements and tasks:

• Reduce background using time of flight analysis, laser at 31 MHz
• Reduce background using Be dump plate
• Upgrade DAQ to operate at higher data rates, higher beam currents (i.e., measure polarization at your current)
• Exhaustive studies of systematic errors
• GEANT modeling and assistance from theorists to help pin down the Sherman function at zero foil thickness
• Different Zs, different energies
• Two run periods planned: Jan 2015 and Summer 2015

Gay, Grames, Horowitz, Mamun, McHugh, Opper, Poelker, Roca-Maza, Sinclair, Stutzman, Suleiman
Role of Beam Dump Background

12 ns round trip time

499 MHz (2ns)

Gold 0.1 um

Gold 1.0 um

Gold 10 um

M. McHugh
Joe Grames
Riad Suleiman
Time Of Flight Separation

\[ f_{\text{beam}} = 31.1875 \text{ MHz} \Leftrightarrow 16 \text{ ns repetition rate} > 12 \text{ ns “clearing time”} \]
Be Dump Design

Kalrez™ high temp (240°C) o-ring

Dump should work fine to 1 kW (200μA @ 5MeV) so limitation will be deadtime.

M. McHugh, Joe Grames, Riad Suleiman
This “200kV gun” is identical to our “130kV gun”, except for a niobium cathode electrode.…

Load-locked photogun and baked beamline:
Pressure ~ 4 e-12Torr
New Injector Test Cave
Might be a good place to develop PV-related upgrades
350kV Inverted Gun

- Longer insulator
- Spherical electrode
- Thin NEG sheet to move ground plane further away

What’s in a name? We will likely use our “350kV gun” for injector upgrade, plenty of voltage headroom means less likely to fail at 200kV.....
PRex To–Do List

Must
• Install Stewart Platform for remote optimization of PC using e-beam
• Prepare for beam matching to maximize damping
• Test of Mott polarimeter absolute precision and systematics

Should
• Optimize 2-Wien spin flipper optics, characterize limitations
• Improve diagnostics to measure/compare “dc” vs. HC beam quality
• Complete the upgrade of the helicity magnets controls

Like
• Augment helicity steering dipoles with helicity size quads
• Model E-field to maximize PC uniformity, buy a properly engineered pockel cell, one with the correct cell-diameter-to-laser-beam-diameter aspect ratio, with thoughtfully engineered electrodes to provide the most uniform electric field across laser beam profile
MOLLER to do list

- Upgrade the injector, 200kV gun, new ¼ cryomodule
- 2 kHz Pockels cell switch, stable voltage and minimum transition time between helicity states
- Improve 2-Wien Spin Flipper optics, one that can accommodate feedback to keep transverse polarization minimized….
- Consider liquid crystal modulator array to control polarization over laser profile?
- Helicity correlated beam size monitor?
- Propose to meet every couple of months, to benefit PRex and MOLLER
  - Arne, Matt, Joe, Yves, Jay, Reza, Alicia, KK, Kent, Paul, Dave Armstrong, others welcome
- We discussed the change in Moller proposal to lower beam current and higher polarization: now 60uA / 90%
- Issues raised regarding running at high energy
  - Depolarization at higher passes?
  - Energy-stability -> precession to the Hall? How large an effect might this be?
  - synchrotron radiation – added noise and beam width/clipping might be spin-state dependent?
  - Feedback to minimize transverse polarization
- Issues regarding injector
  - 2kHz flip rates not yet demonstrated
  - 4-hall operation and/or multiple A/B/C 5th pass requires 249.5 MHz bunch rep rate, and 2x charge density. Approaches Qweak levels at injector
  - New injector expected by 2019: 200 keV Gun, new 1/4 Cryo, new Wiens and different configuration, expect the prebuncher to be superfluous
  - More complete tests to learn limitations of present 2-wien system will be performed soon
  - Matching and optics: "phase trombone" is setup in Hall A line for 12 GeV (might also be possible for PREX)
  - Polarization and Polarimetry issues: Spin dance? Feedback on Horizontal Wien? Complete remote control of pockel cell alignment