Determining the CEBAF Beam Energy

by

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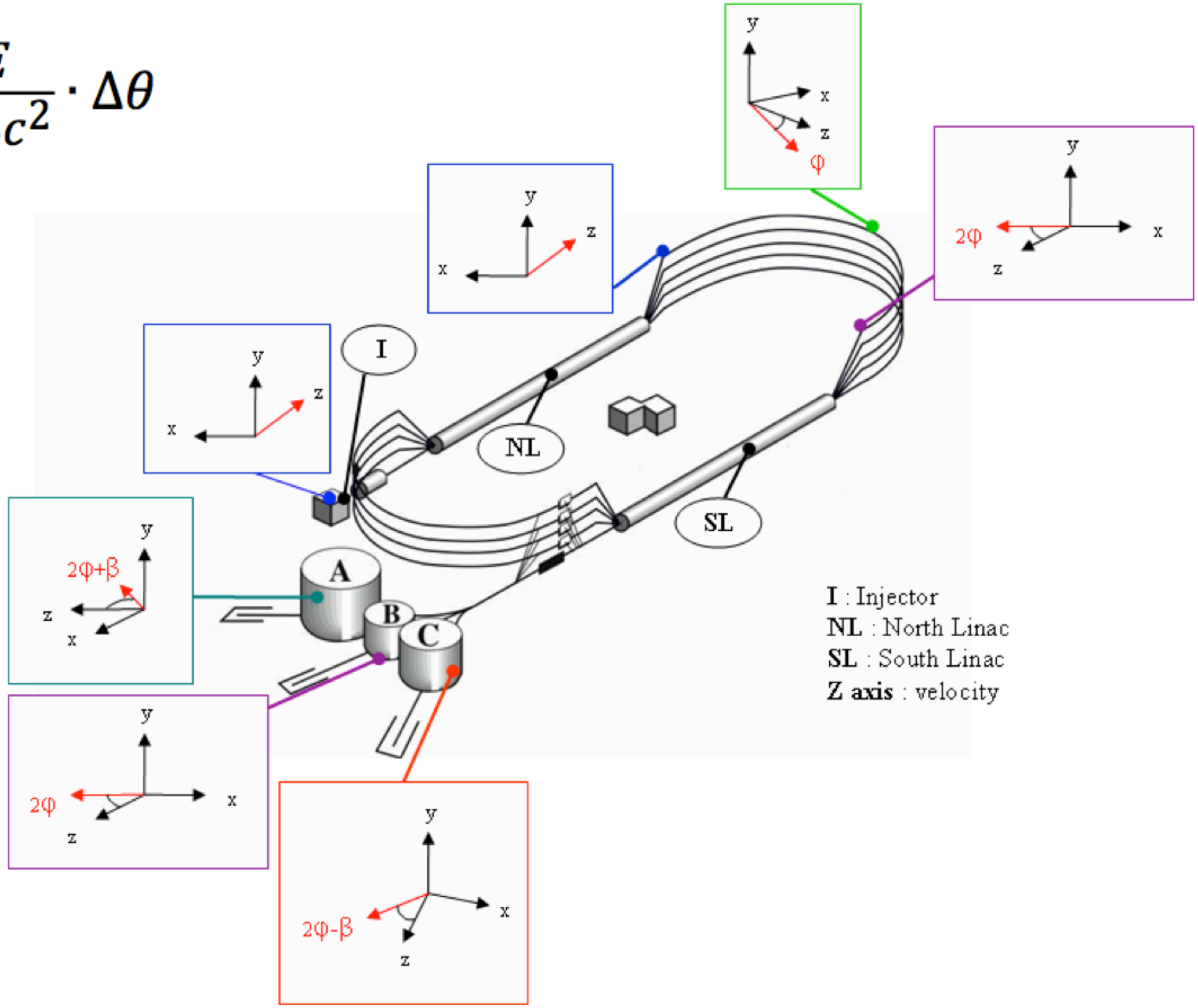
Beam Energy for 6 GeV CEBAF

- ARC Energy Method
  - Use dipole nine magnets connected in series
    - Eight magnets bend the beam into the hall
    - Ninth magnets can be mapped with NMR
  - Measure angle of beam at start and end of bend
  - Use dispersive optics for best precision (~2E-4 dE/E)
- Elastic Scattering
  - Dedicated elastic setup, eP, measure electron proton scattering angles (~2E-4 dE/E)
  - Use spectrometers to measures angles and/or momentum
- Spin Precession
  - Using the polarized source and the many Jefferson Lab polarimeters to determine the energy (also ~2E-4 dE/E)

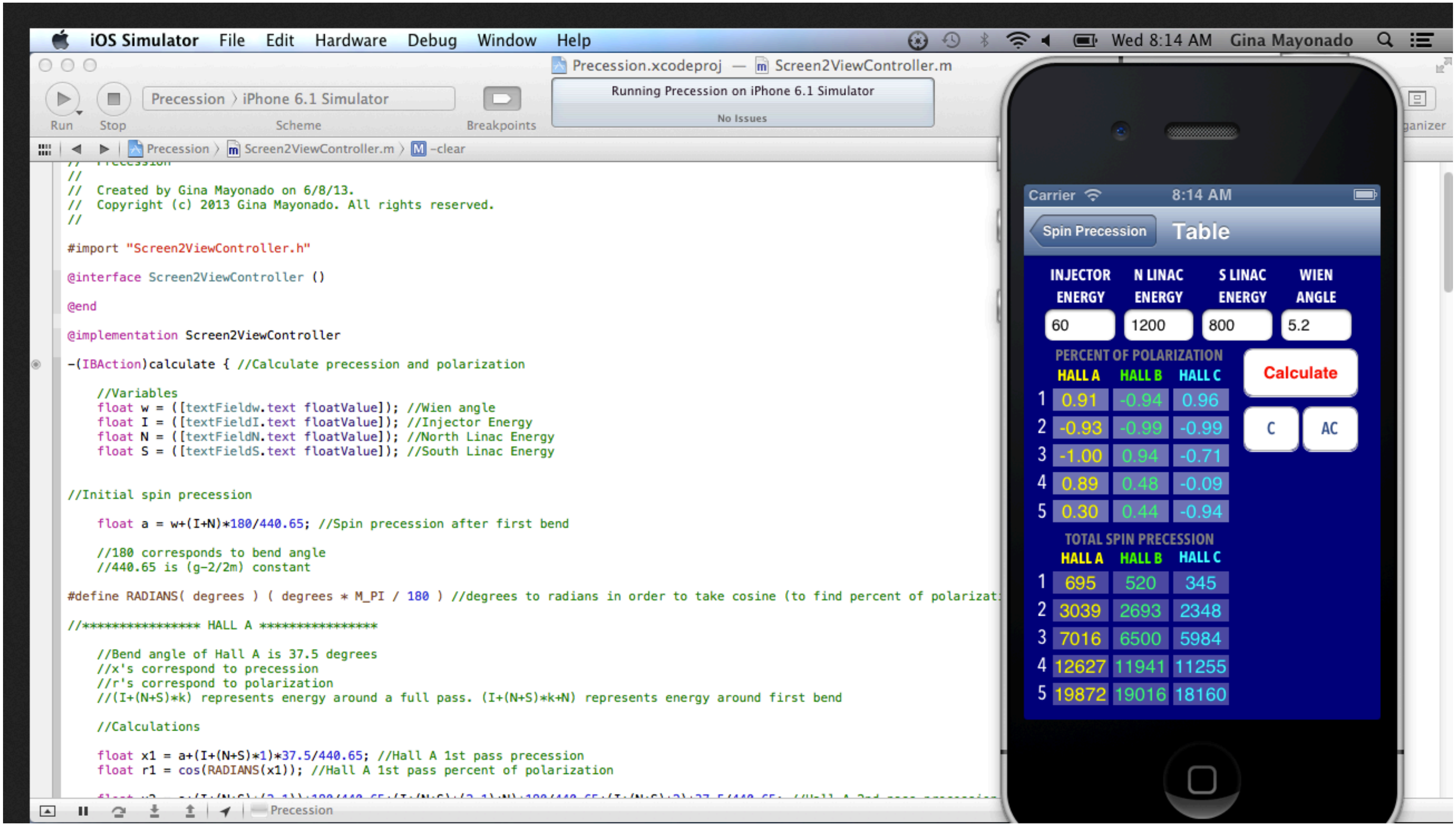
Spin Precession At CEBAF

$$\Delta\varphi = \frac{g-2}{2} \cdot \frac{E}{m_e c^2} \cdot \Delta\theta$$



New Spin Calculator App

Thanks to Department of Energy SULI Student Gina Mayonado



Beam Energy From Total Precession

J. M. Grames et al., Phys. Rev. ST Accel. Beams 7 (2004) 042802.

Polarimeters	Ψ (deg)	E (MeV)
Mott-Compton	10 985.94 ± 1.37	5649.21 ± 0.89
Mott-Møller A	10 984.96 ± 0.71	5648.70 ± 0.65
Mott-Møller B	10 501.60 ± 0.64	5647.20 ± 0.66
Mott-Møller C	10 024.51 ± 0.69	5649.03 ± 0.71

NOTE: The Hall A and C polarimeters receive more attention to systematics then the Hall B polarimeter due to the requirements of the experiments (e.g. G0, HAPPEX, Qweak, etc.).

Even so, full spread these results is only 2 MeV (5648 +/- 1 MeV) so already 2E-4 level.

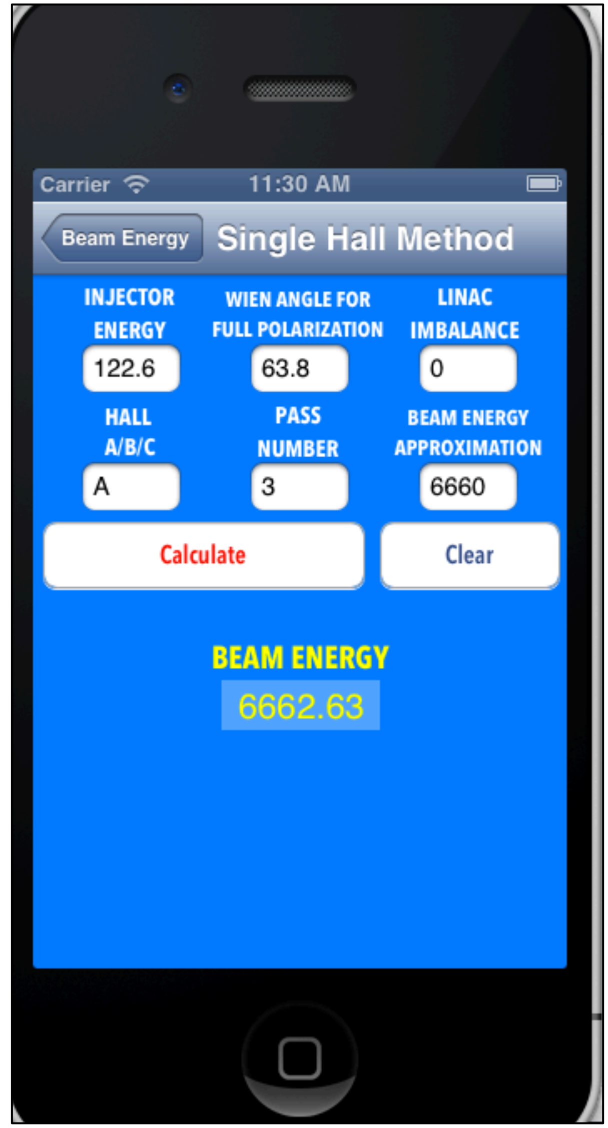
Using Spin At 12 GeV

- At 11 GeV, the beam processes >20k degrees before arriving in Hall A.
- 2 MeV of beam energy change (balanced) is a 5 degree change in the precession.
- Phase can be determined to the degree level with Compton (~8 hrs)
- That would be 9E-5 !! dE/E with just a single hall
- BUT accelerator systematics have to be under control
  - Injector Energy
  - Linac Balance (relative difference in energy)
  - Calibration of Wien angle

Beam Energy – Single Hall

- Known parameters needed:
  - Injector energy
  - Linac imbalance
  - Wien angle that gives full polarization
- Outputs multiple solutions

Energy Output
3489.95
4547.51
5605.07
6662.63
7720.19
8777.75



Energy By Precession Differences

J. M. Grames et al., Phys. Rev. ST Accel. Beams 7 (2004) 042802.

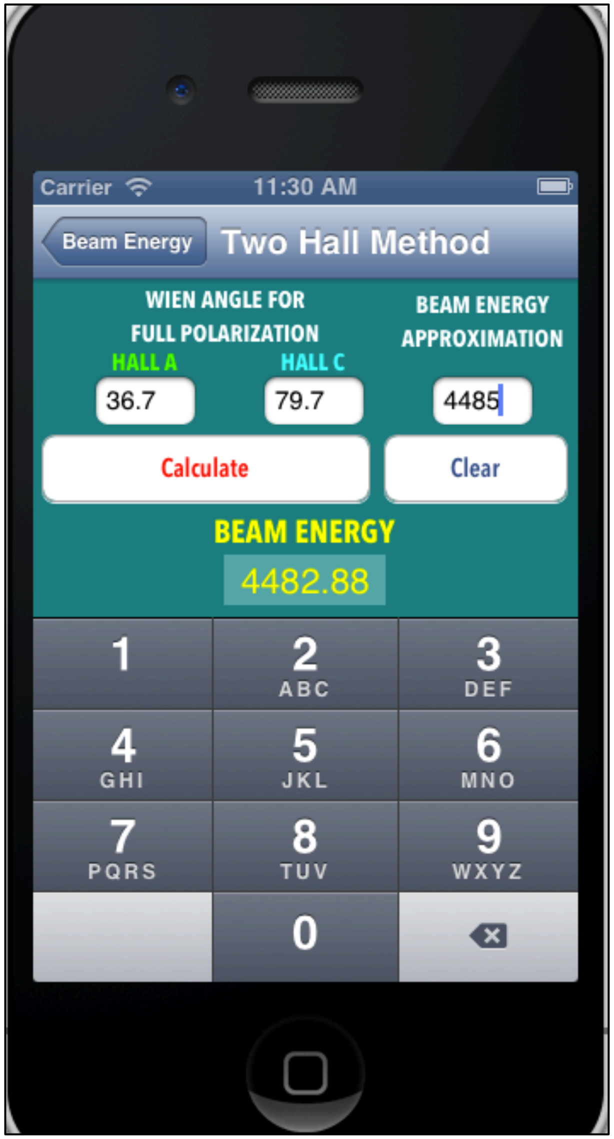
Polarimeters	$\Delta\Psi$ (deg)	$\Delta\Theta$ (deg)	E (MeV)	$\frac{\sigma_E}{E}$ (%)
Møller A-Møller B	483.36 ± 0.84	37.4913 ± 0.0102	5681.10 ± 10.03	0.176
Møller A-Møller C	960.45 ± 0.88	74.9687 ± 0.0060	5645.30 ± 5.17	0.092
Compton A-Møller B	484.34 ± 1.44	37.4913 ± 0.0102	5692.62 ± 17.03	0.299
Compton A-Møller C	961.43 ± 1.46	74.9687 ± 0.0060	5651.07 ± 8.61	0.152
Møller B-Møller C	477.09 ± 0.83	37.4774 ± 0.0115	5609.49 ± 9.89	0.176

Hall A and C give smallest errors since the opening angle between them is twice as large as A and B or B and C.

Repeating this same measurement at 11 GeV has a factor of two better sensitivity; so can be provide a ~5E-4 level absolute measurement with almost no systematic error.

Beam Energy – Two Hall

- Known parameters needed:
  - Wien angles for full polarization in both Halls
- Less systematic errors
  - No accelerator setting dependence.
  - Only uses spin precession from beam switchyard into the halls.



Synchrotron Radiation

- Radiation from charged particles accelerated in a curved path

$$\delta E(in\ MeV) = 0.0885 \times \frac{[E(in\ GeV)]^4}{R\ (in\ m)}$$

Beam Energy (MeV)	Energy Loss (MeV)	Change in Spin Precession (deg)
2302.632	0.01	-0.01
4482.686	0.29	-0.04
6662.604	1.88	-0.16
8842.629	7.32	-0.48
11022.643	21.32	-1.16

At 11 GeV this is a 2E-3 correction that we need to control to the 10% level.

Working on adding this correction into the spin calculator code.

Beam Energy from Integral Field and Angle

Deviations from the average for the eight down in the ARC

Avg (5-12)	1,607,581	2,355,398	2,796,953 [G-cm]
BA1C05	0.02%	0.00%	-0.03%
BA1C06	0.00%	-0.01%	0.03%
BA1C07	-0.02%	0.02%	0.04%
BA1C08	-0.01%	0.04%	0.03%
-			
BA1C09	0.00%	-0.04%	-0.04%
BA1C10	0.00%	0.00%	-0.01%
BA1C11	0.03%	0.01%	-0.02%
BA1C12	-0.01%	-0.01%	-0.01%
BA1C11	0.02%	-0.01%	-0.03% (a repeat measurement)

NOTE: The 9th dipole is systematically different then the other eight at the 1E-3 level.
Need to figure out if that was always true.

Current Man Power

- Luke Myers (review/analysis of Bdl data)
- Seare Farhat (continuing spin dance coding)
  - will shift to Bdl codes in coming months
- David Gaskel (long term for two hall spin dance)
- Vernin Pascal (consulting/original designer)
- Rick Gonzales (technical help)
  - Was able to get the mapper to run during g2p
  - Requested new multiplexer and telsameter which have arrived but not yet installed

Magic CEBAF Energy (2.12 GeV/pass)

At 2.12 GeV per pass, the passes give full polarization the all three of the current halls.

1st	2.12 GeV
2nd	4.23 GeV
3rd	6.35 GeV
4th	8.46 GeV
5th	10.6 GeV