U.S. DEPARTMENT OF ENERGY JSA

Determination of the CEBAF Beam Energy

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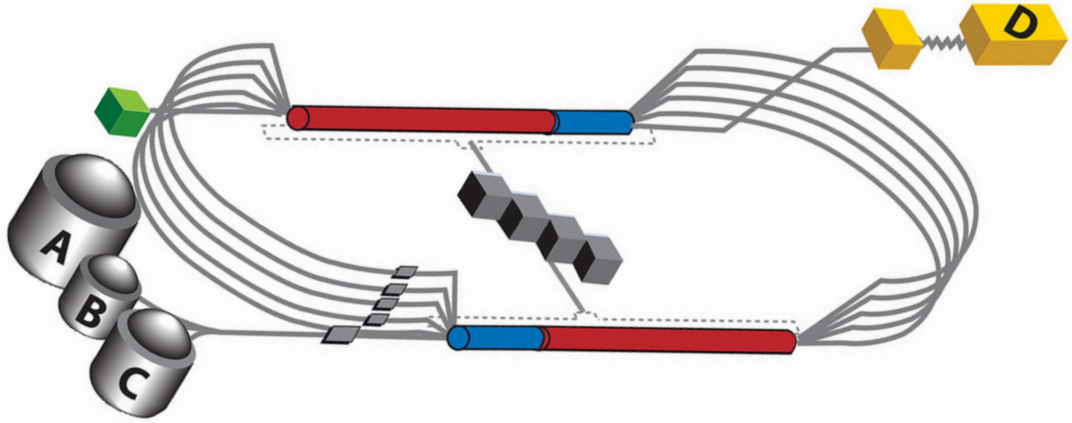
Arial & Schematic View of CEBAF



ARC Energy Measurements

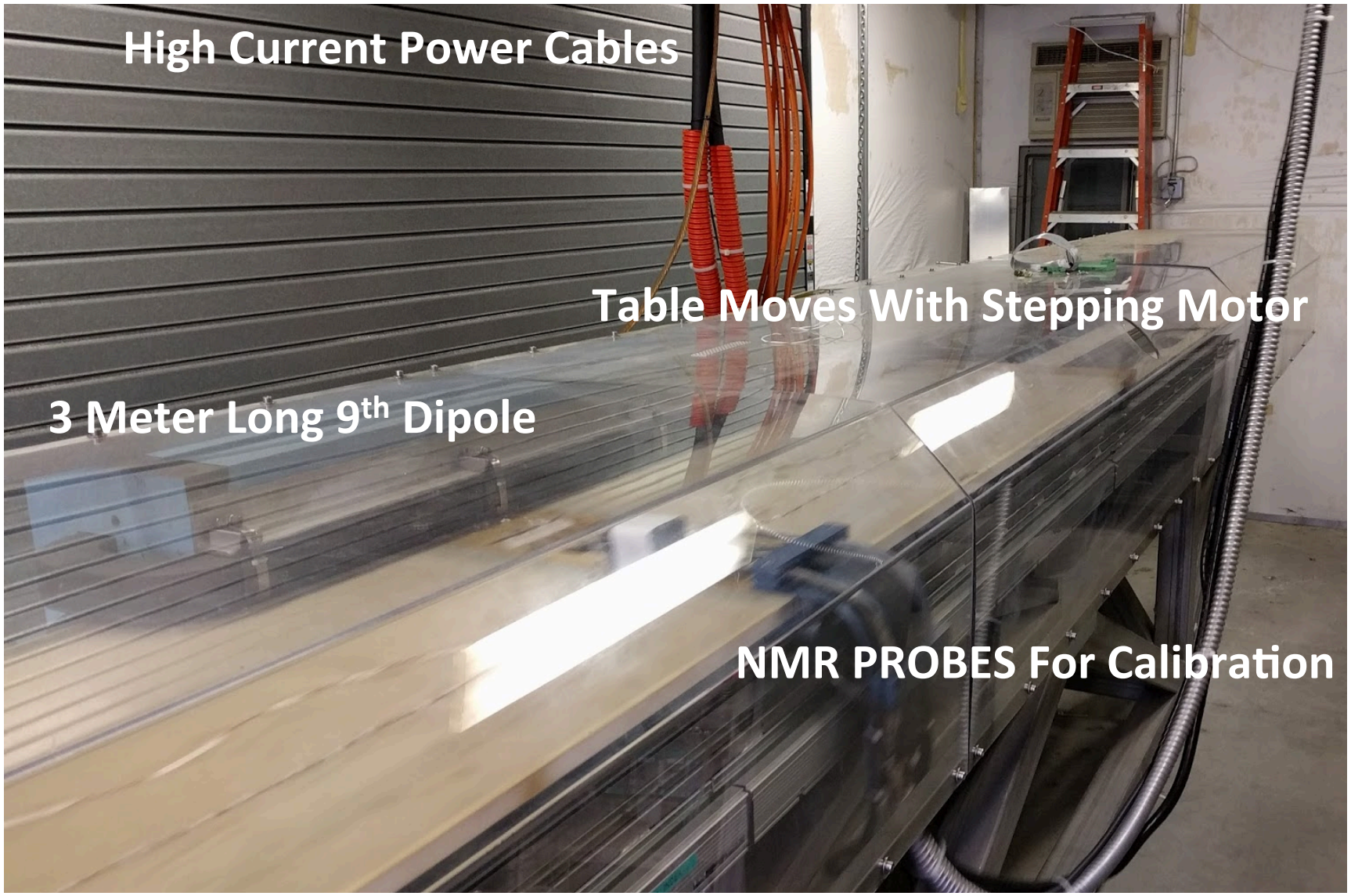
- **Makes Use of The Eight Dipoles That Bend Beam From Acc. Into Hall A**
  - **And a 9th sister dipole that is connect in series with the other eight**
- Angle Measurements
  - HARPS (we can now do HARP scan with pulse beam!)
  - Beam Position Monitors (BPM)
- Quadrupole Centering
  - Checked by turning on and off the magnets
  - Makes Orbit Corrects Negligible
- Bdl Measurements
  - Map the 9th dipole to make best estimate of the other 8 dipoles (located in the tunnel).
  - Use NMR to get an absolute field calibration
- To leading order (with beam quad. centered) *p* of the beam given by:

$$p = k\frac{\int \vec{B}\cdot\vec{dl}}{\theta}$$

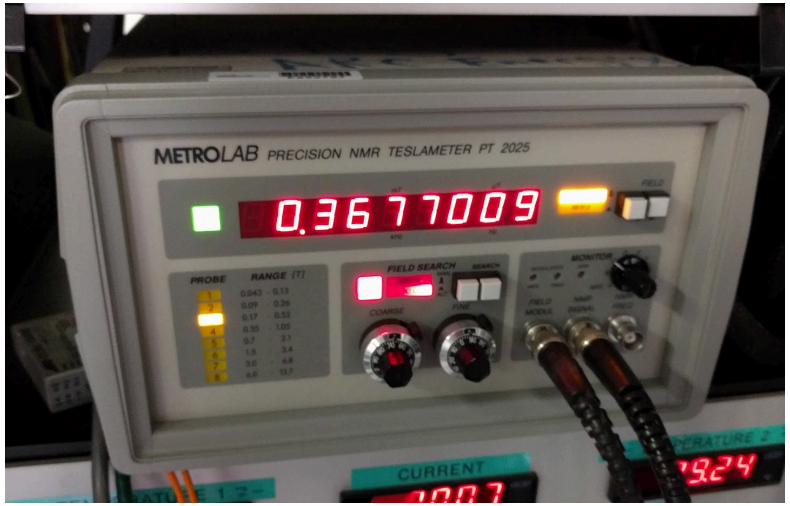
$$\text{where } k = 0.299792 \text{ GeV rad T}^{-1} \text{ m}^{-1}/c.$$

- Higher order corrections (such as sync. radiation) added in full calculations.

Electromagnetic Induction & NMR to get Bdl



NMR Measurements



NMR can stay locked while the probe is moving through the dipole.

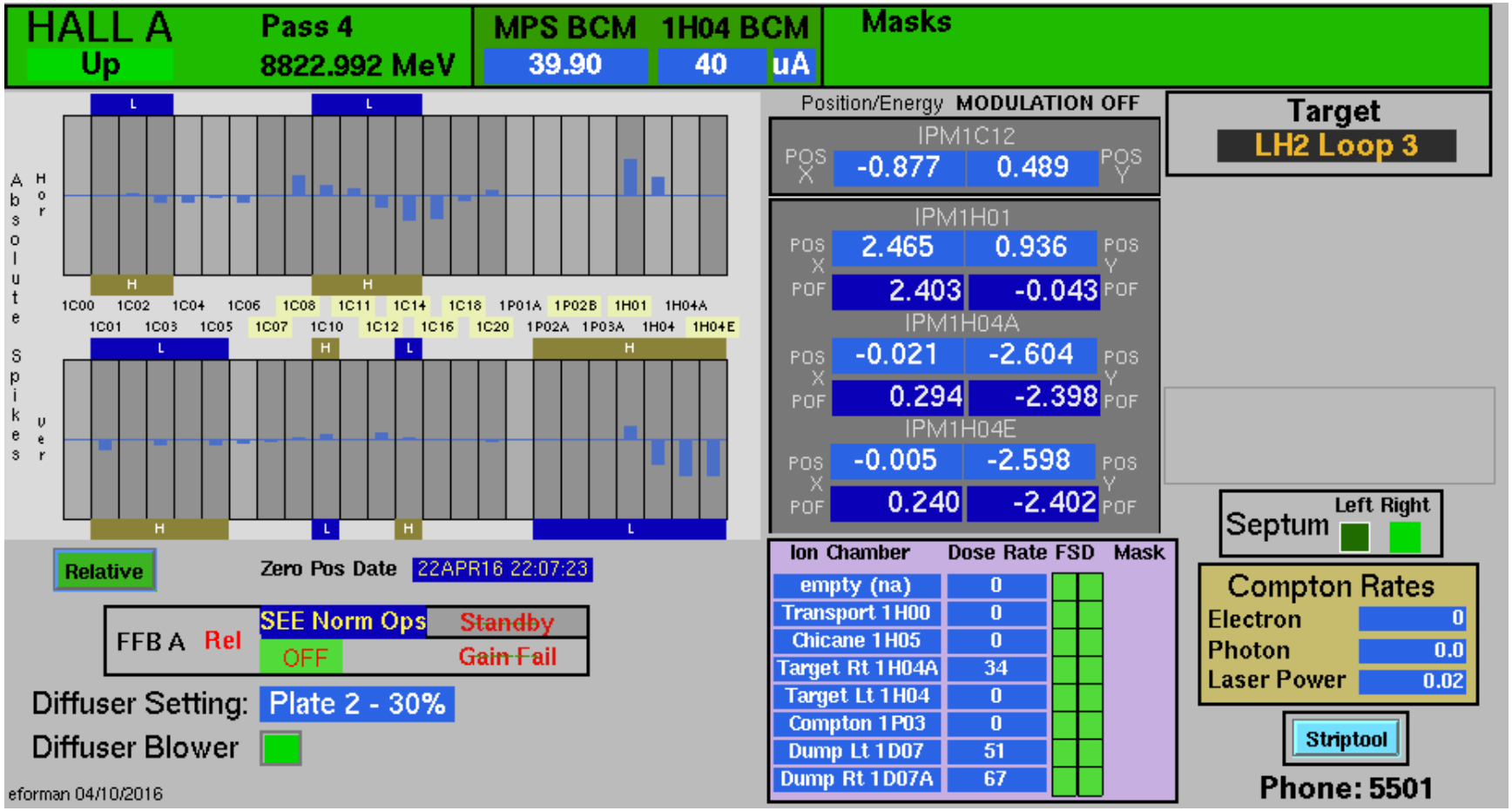
This is only possible due to the very homogenous field of the magnet.

The trickiest part is the fringe field.

Calibrated Magnet Current Measurement

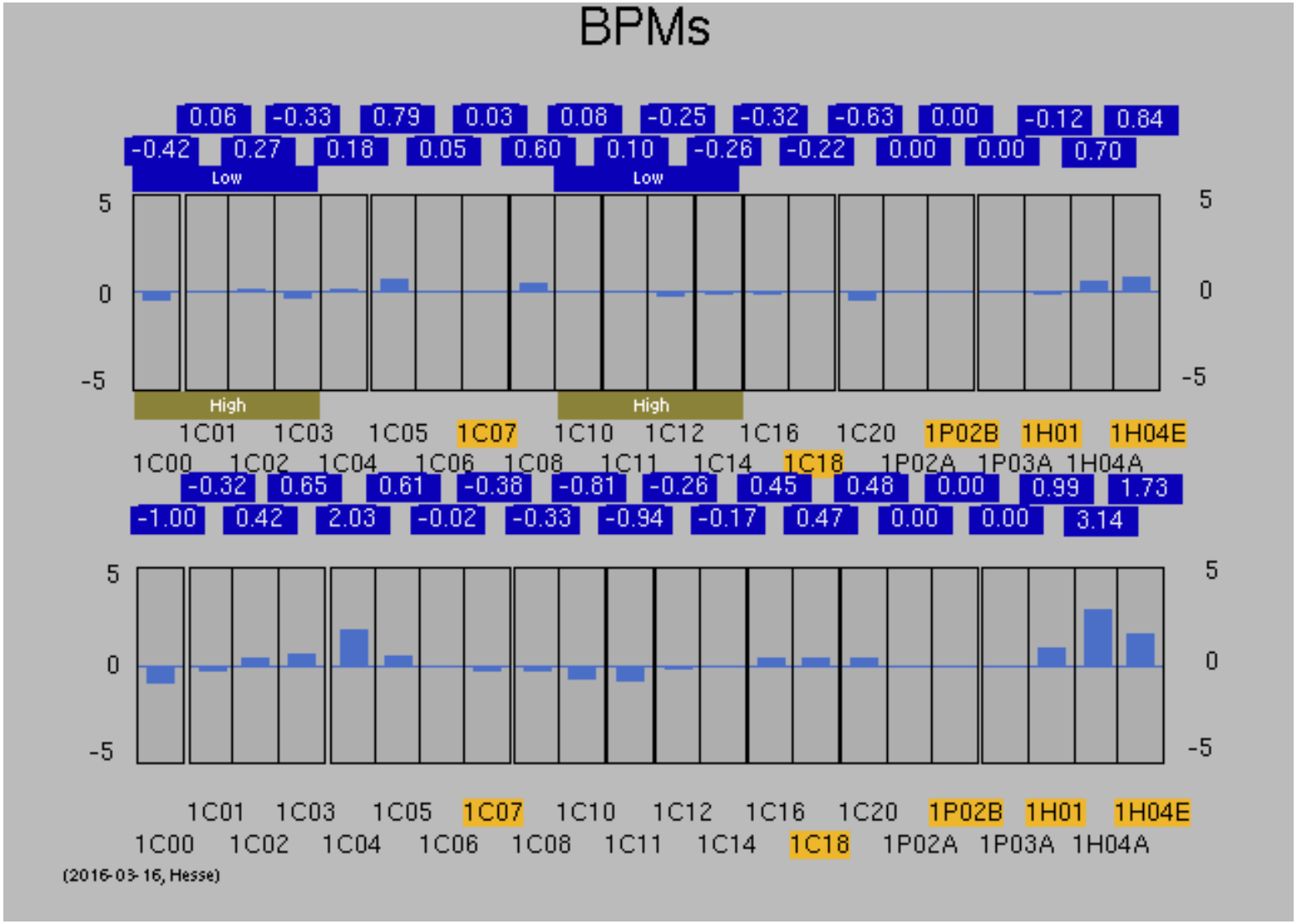
Ultrastab Saturn Unit

A Bad Orbit with Quadrupole Steering



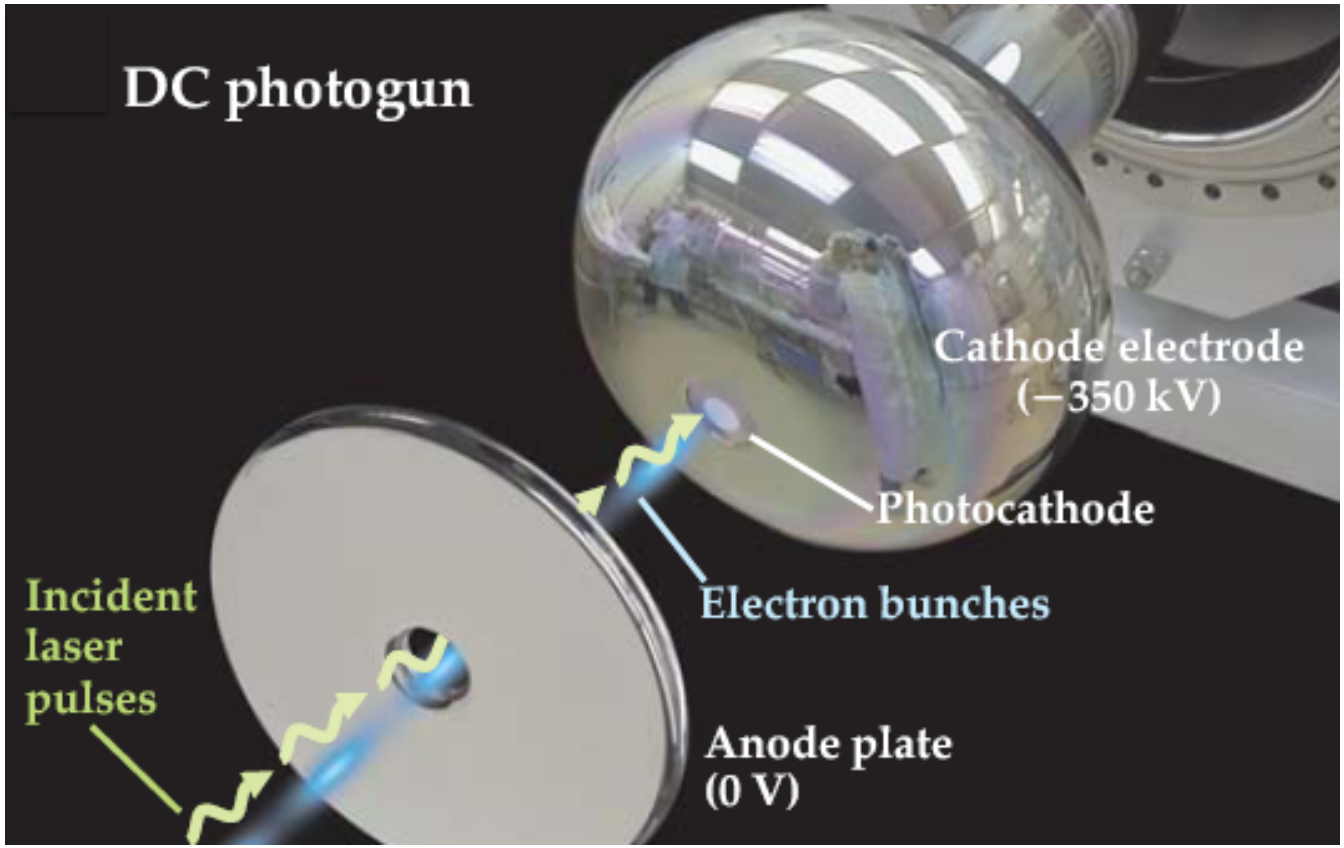
Note the 8823 MeV was used initially to set the Wien for 4th pass.
The Hall A ARC measurement found the energy to be 8842 MeV.

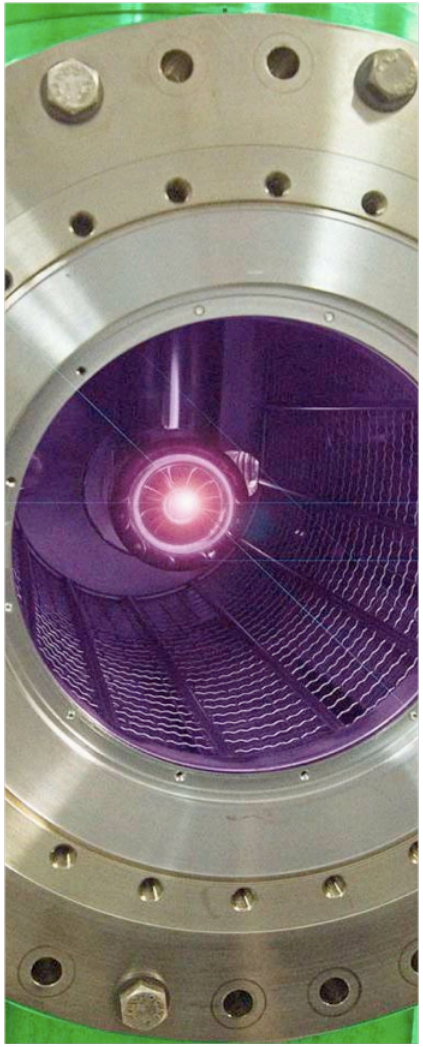
Near Ideal Orbit With Quads Off



Photoelectric Effect Produces CEBAF Beam

C. Hernandez-Garcia, P. G. O'Shea and M. L. Stutzman, Physics Today **61N2** (2008) 44.

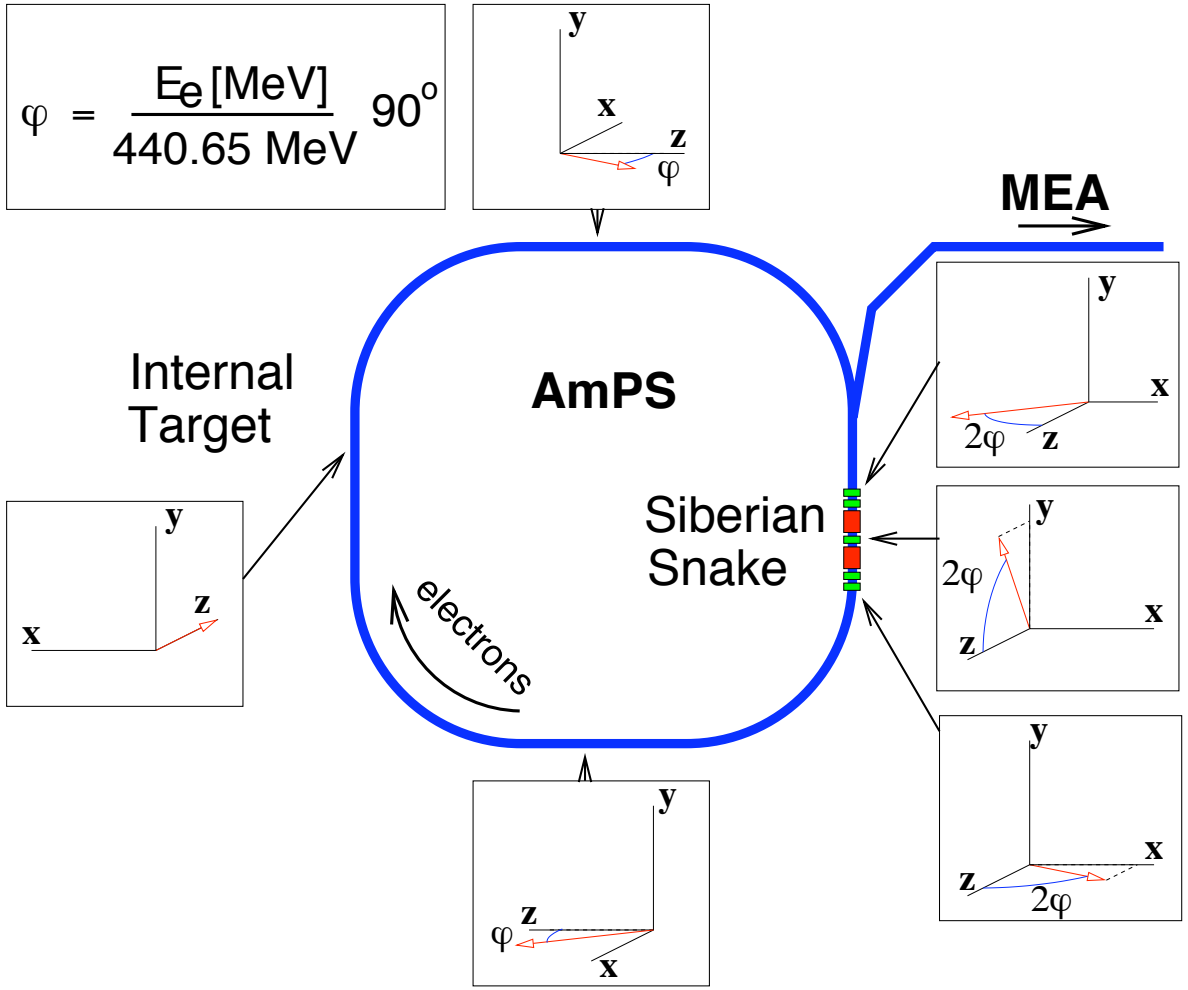




- Strained GaAs Photocathode
- Ultra-High Vacuum (Ions Destroy Cathodes)

Spin Precession In Storage Ring

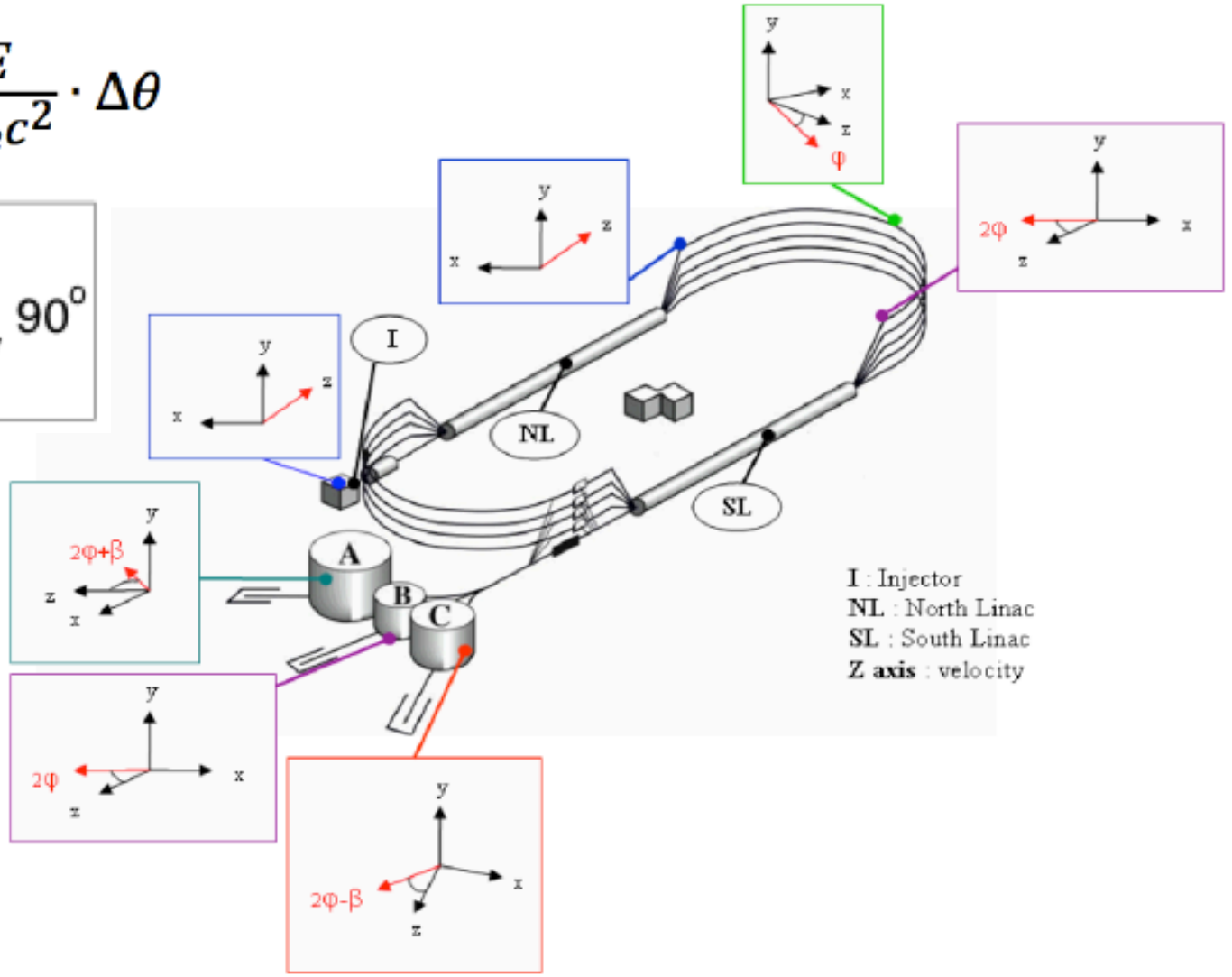
Beautiful demonstration of the electron's anomalous magnetic moment and QED.



Spin Precession in CEBAF

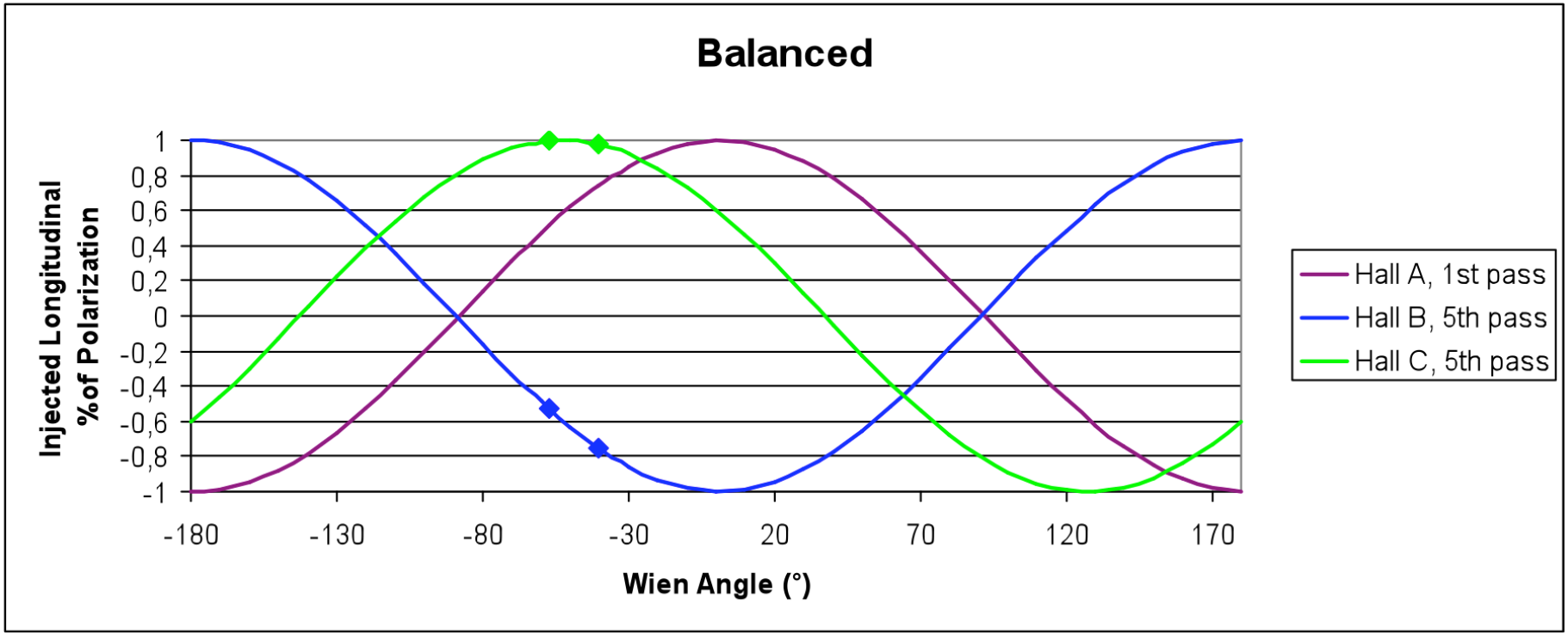
$$\Delta\varphi = \frac{g-2}{2} \cdot \frac{E}{m_e c^2} \cdot \Delta\theta$$

$$\varphi = \frac{E_e\,[\mathrm{MeV}]}{440.65\ \mathrm{MeV}}\ 90^{\circ}$$



Example CEBAF Setup

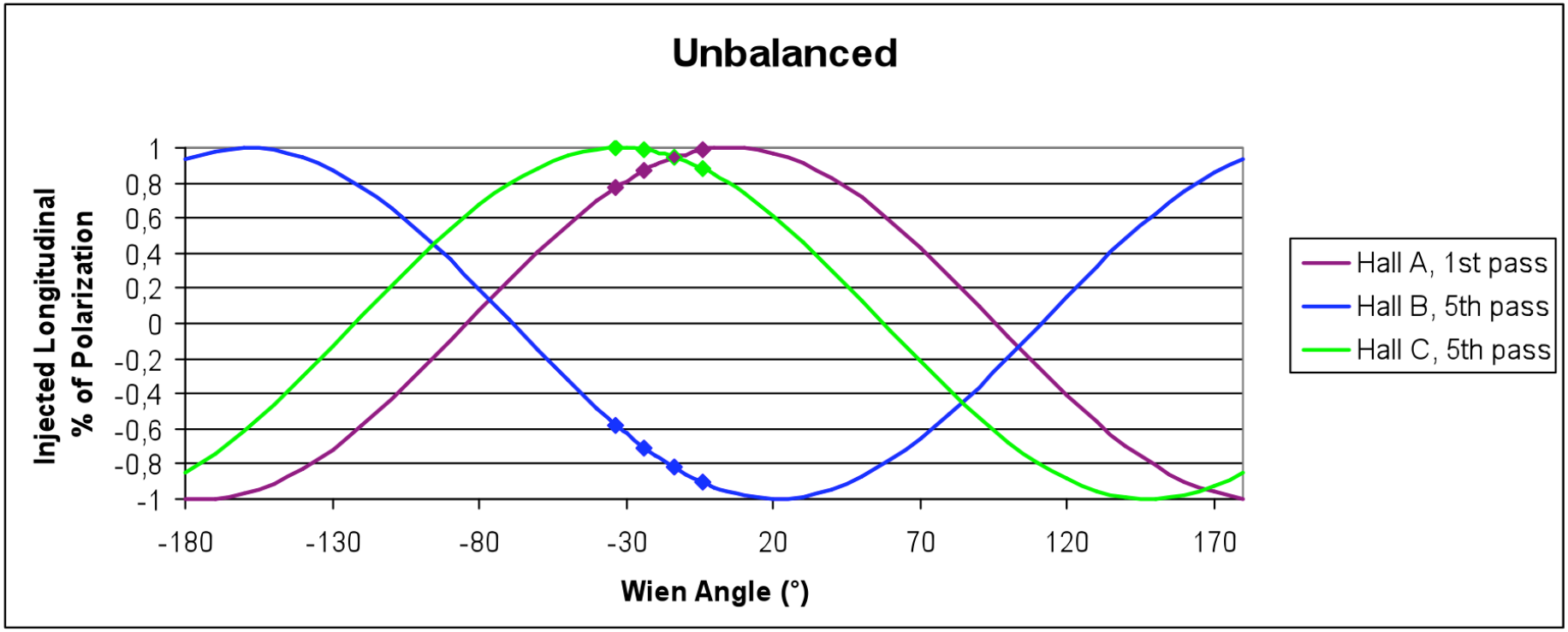
Select a beam energy and Wien angle based on physics requirements of the Halls
(63.5 MeV Injector Energy and 565 MeV Per Linac Per Pass)



- Machine setup with balanced or energy match linacs.
- Hall C required polarization (GEP-III) and Hall's A & B requested polarization.

Imbalanced Linacs

Needed to give Hall A & C high polarization without changing the beam energy for Hall B.
(63.5 MeV Injector Energy and 555 MeV & 575 MeV Per Linacs)

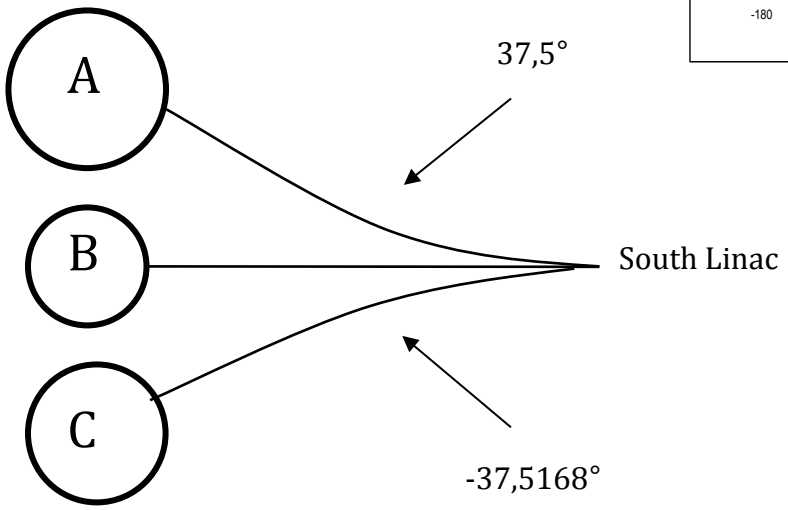


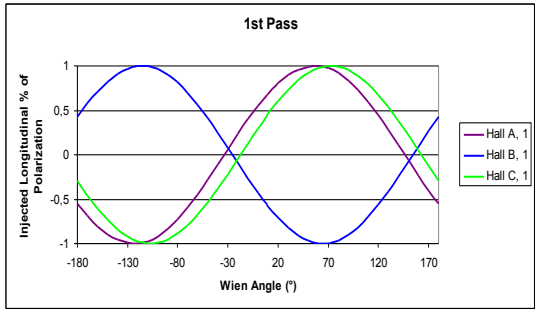
- With imbalanced the linacs, we were able to boost the polarization.
- 10 MeV was removed from the North linac and 10 MeV was added to the South linac.

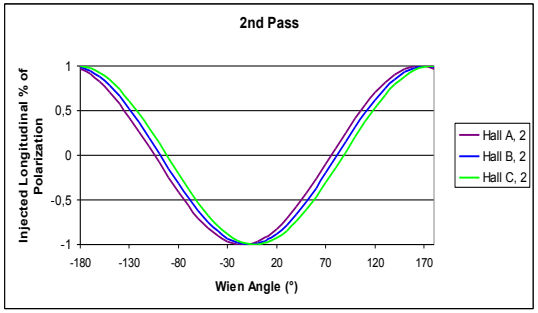
Magic CEBAF Energy (2.12 GeV/pass)

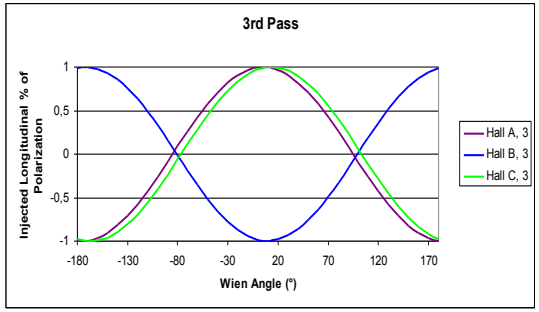
With the 12 GeV upgrade, these energies become available.

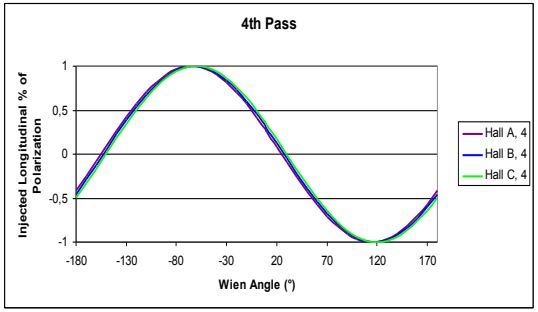
1st	2.12 GeV
2nd	4.23 GeV
3rd	6.35 GeV
4th	8.46 GeV
5th	10.6 GeV

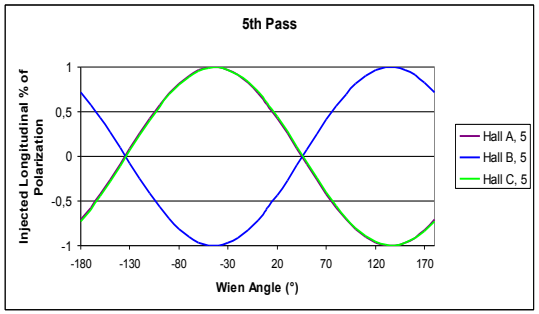








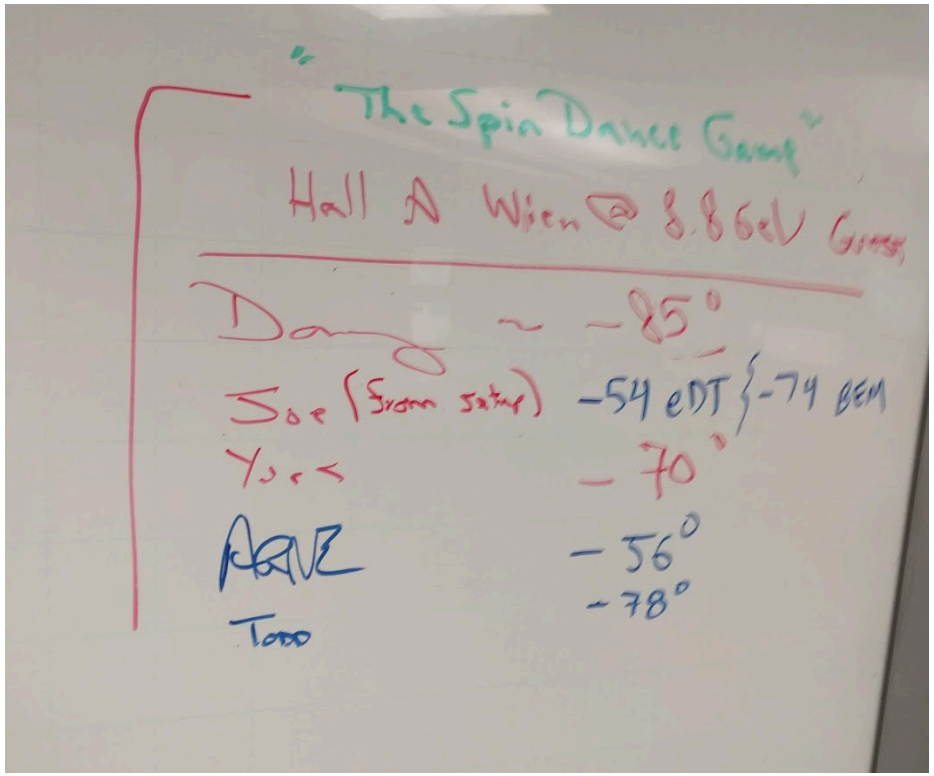




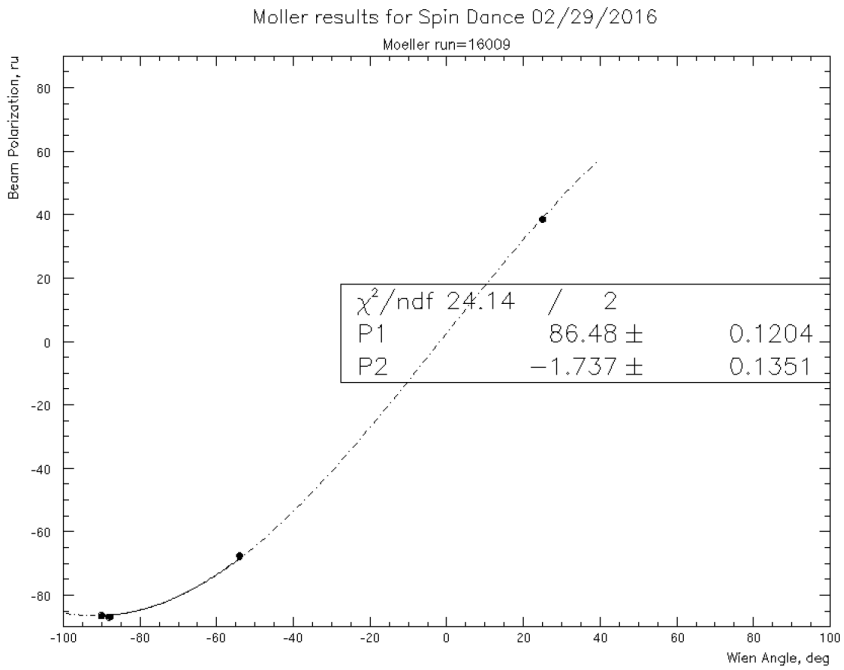
8.8 & 11 GeV Beam Energy from Spin Dance

A way to check the ARC energy measurements is to use them to make Wien angle predictions.

Prediction Based on ARC Energy



SPIN DANCE



Fit of Moller data gave 86.5 degrees

For 11 GeV we just used the ARC energy results & Joe's full model (including sync. Radiation) and we transported full long. polarization the first try. (with >20k degrees of total precession!)

Current Status

- Working on getting all the new results (ARC and Spin Dance) together in a technote.
- It is clear we already know dp/p to better then 10^{-3} and should achieve 5×10^{-4}
- Energy results should be completely tabulated and checked in couple months.
- From those results, we can check the ARC1/2 calibrations that we will need to reply on for the PRad beam energies.