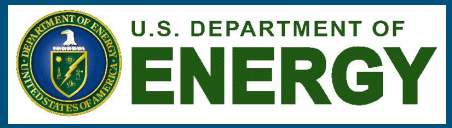
Moller Polarimetry Simulation at Jefferson Lab Hall-A

Eric King

2019 International Workshop on
Polarized Sources,Targets, and Polarimetry



Jefferson Lab
Exploring the Nature of Matter

Syracuse University

Hall-A Moller Polarimeter Simulation [MolPol]

Brief introduction to the MolPol simulation software.

MolPol

- Geant4 based application
- Moller Generator
  - Pre-moller scatter msc in target.
  - Moller scattering radiative corrections
  - Levchuk correction (scattering angle correction)

$$\left(1 - \frac{p_{t,orbital} \cdot \hat{n}}{m_e}\right)$$

- Elastic scattering generator*
- Can utilize ideal fields or mapped fields for quadrupoles
- Solenoid field exclusively map based.
  - Fringe effects which act in direction opposite that of the rotation too significant to be waved away.

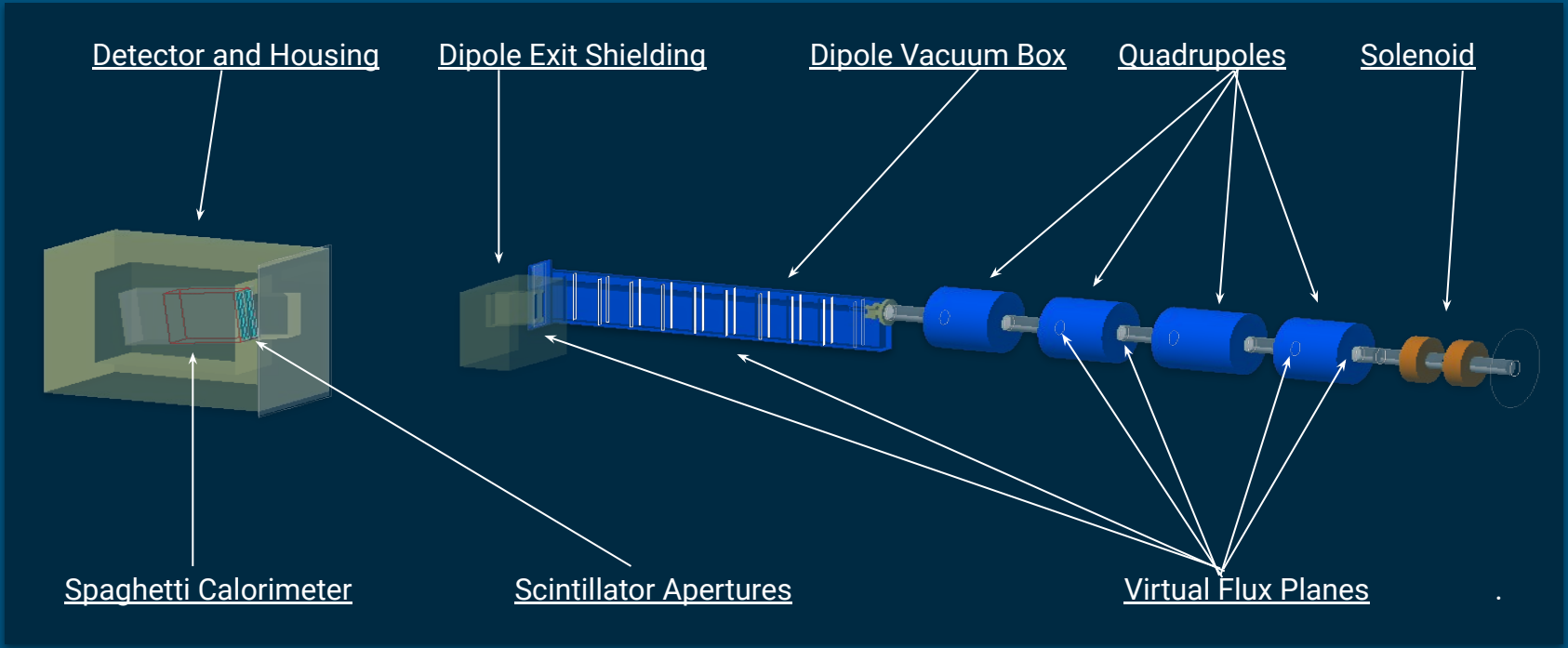
Controllable parameters via macro:

- Beam & target positions.
- Beam smear
- Beam angle
  - Small angle X/Y
- Quadrupole position offsets
  - In X/Y positions for idealized fields
  - In X/Y/Z for mapped fields
- Solenoid position offset
- Solenoid angle offset
- Magnet fields

Optional (sometimes preferable and highly helpful for comparison studies):

- A Geant4 “kryptonite” effect macro
  - Forces fStopAndKill command when intersecting with aperture materials.
- Disallow radiative corrections and pre-scatter msc.
- Turn off the Levchuk Effect.

Polarimeter Geometry Setup

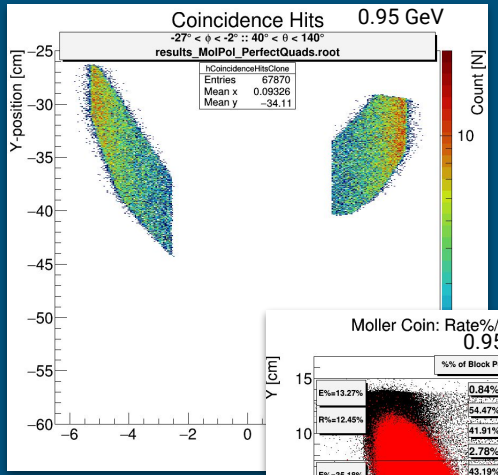


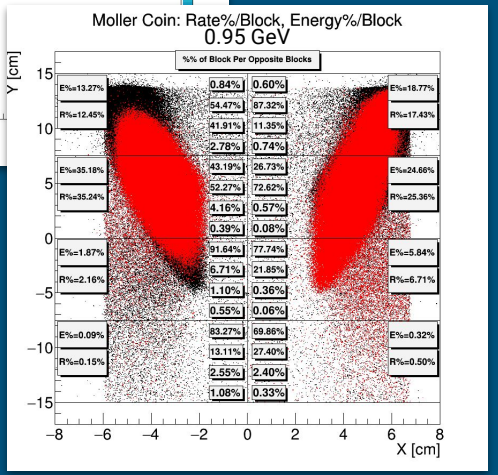
Analysis

Analysis

There are any number of basic analyses that can be made from the simulation that yield useful information.

- Was there a coincidence?

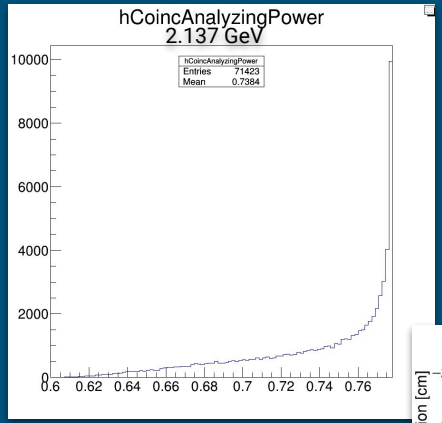


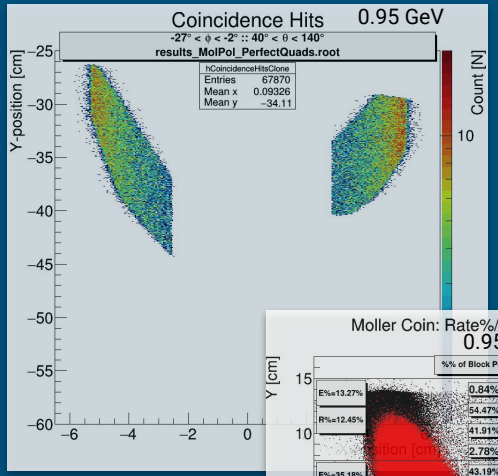


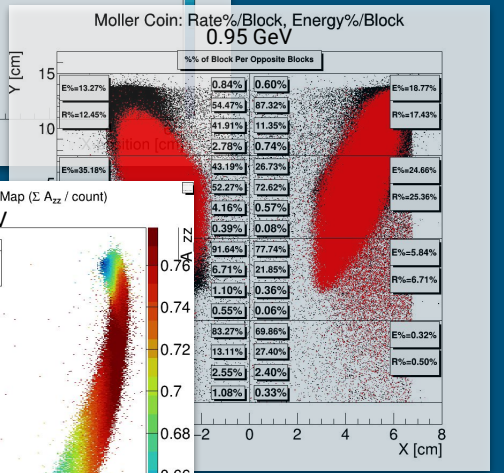
Analysis

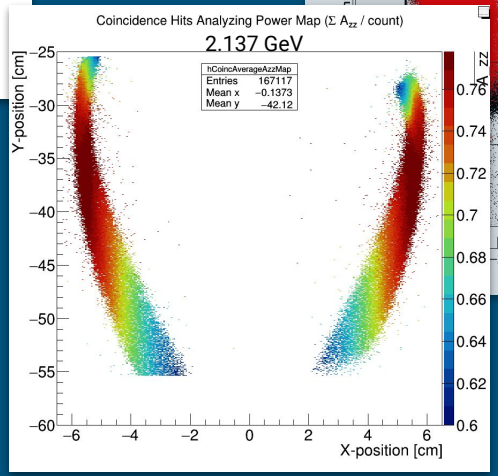
There are any number of basic analyses that can be made from the simulation that yield useful information.

- Was there a coincidence?
- What was the A_{zz} of the scatter?









Analysis

There are any number of basic analyses that can be made from the simulation that yield useful information.

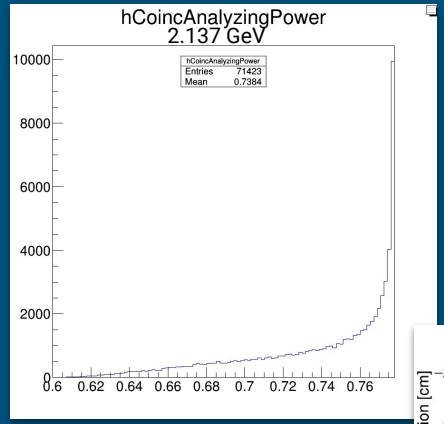
- Was there a coincidence?
- What was the A_{zz} of the scatter?

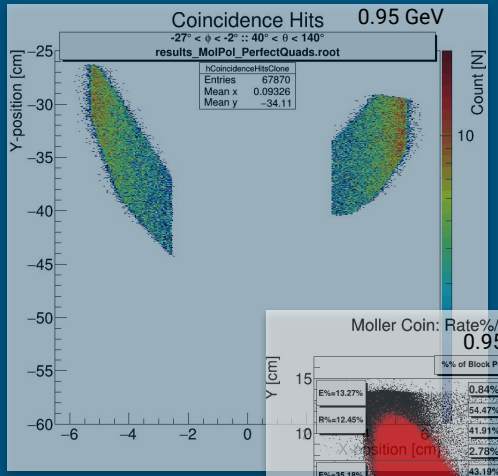
Calculate the average analyzing power of the tune.

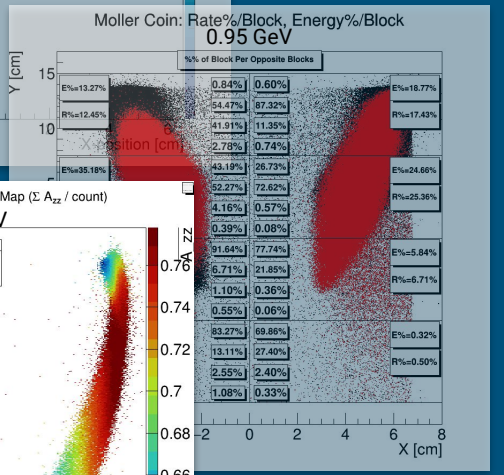
$$< A_{zz} >= \frac{\sum_{unpol} w_i A_{zz,i} + \sum_{pol} w_i A_{zz,i}}{\sum_{all} w_i}$$

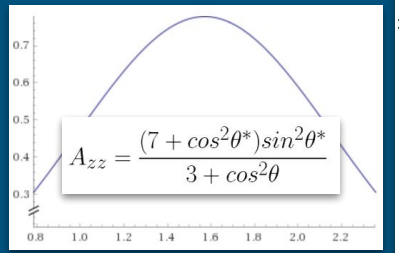
Related to the asymmetry by:

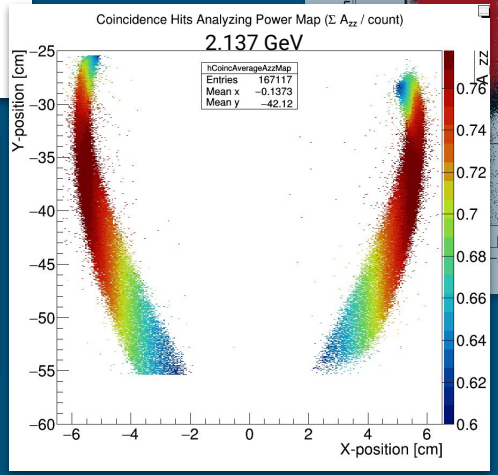
$$A = P_b P_t < A_{zz} >$$









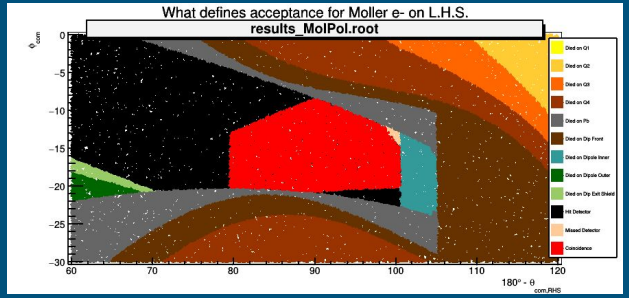


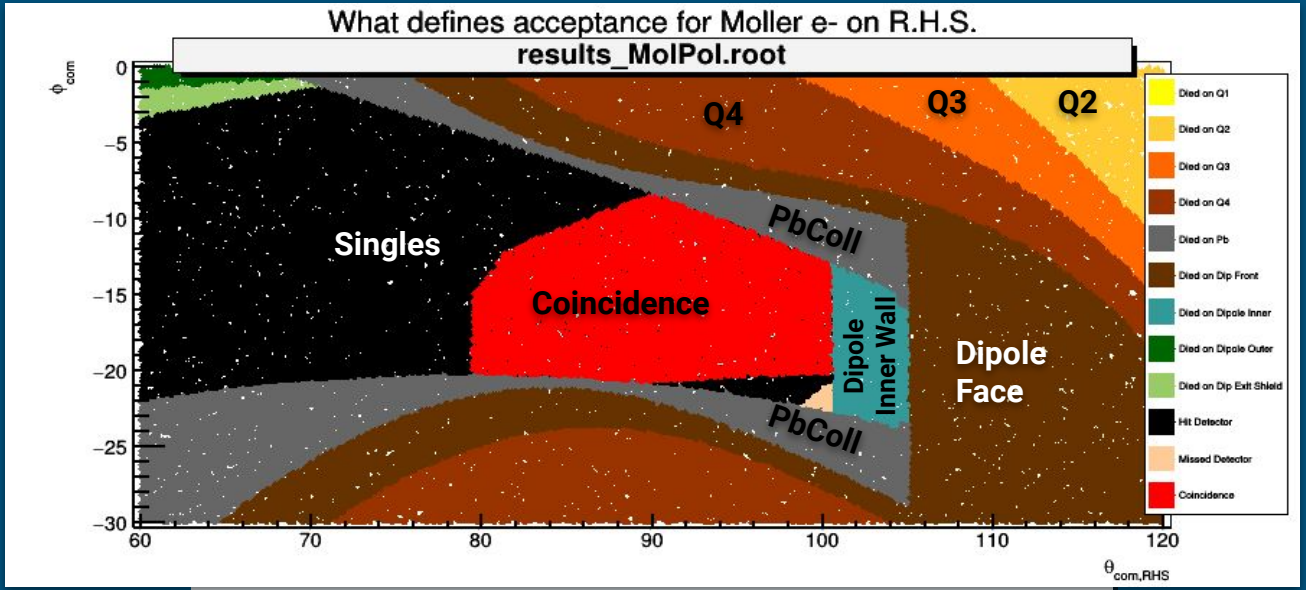
Cemetery Plots

Mapping out where the moller electrons died.

Useful information picked from the flux planes to determine where the moller electron met its demise.

Assists with a greater understanding of the polarimeter and how changes impact the acceptance.





These particular simulations run with no effects on to highlight apertures.

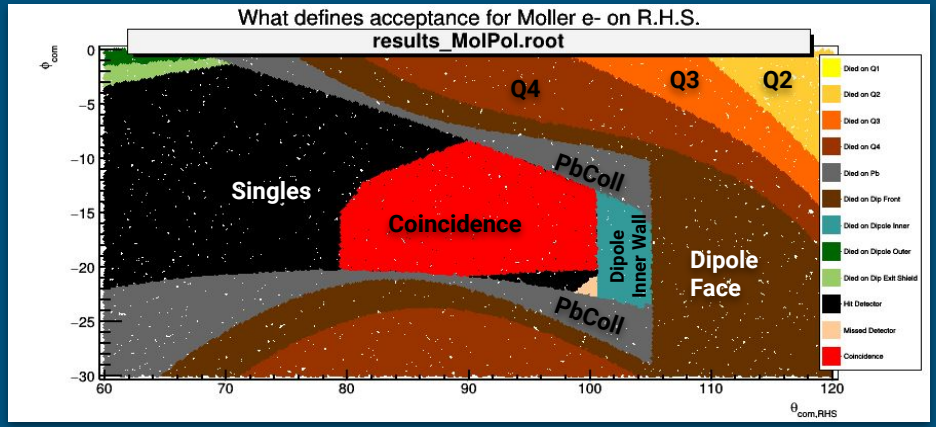
Cemetery Plots

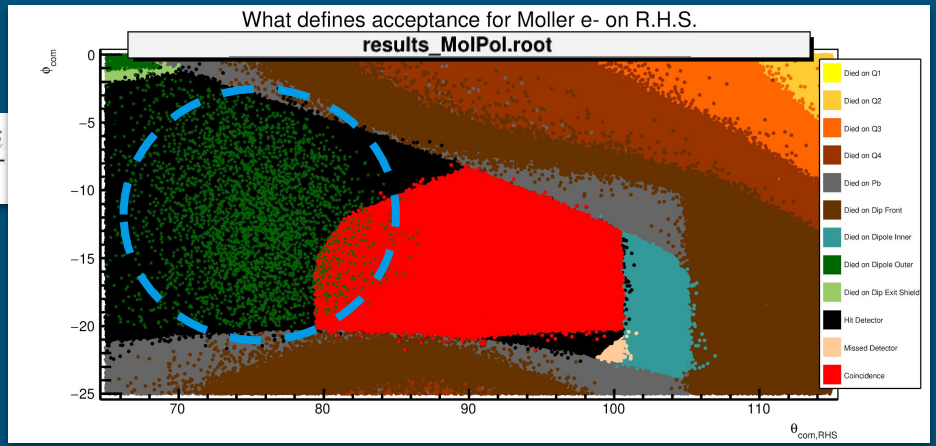
Keeping all other generator effects off and turning on the Levchuk effect we see the following:

Levchuk lights up one area of the scatterplot. This is a Levchuk problem. Green dots circled by the light blue ring.

All of these events are K-shell kicked mollers who clipped the outer dipole wall.

$$< A_{zz} >= \frac{\sum_{unpol} w_i A_{zz,i} + \sum_{pol} w_i A_{zz,i}}{\sum_{all} w_i}$$





Optics Tunes

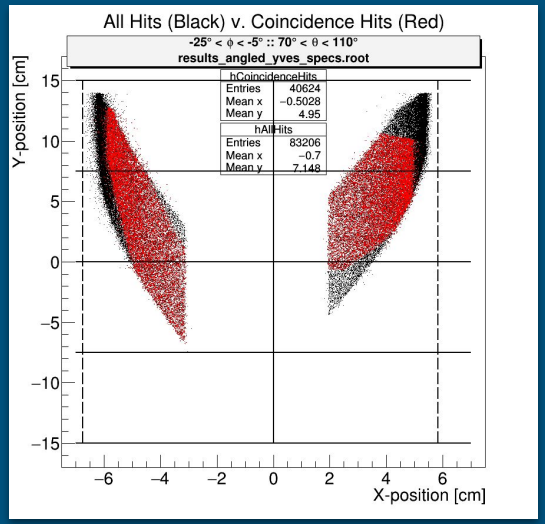
All Detector PMT Optics Solution

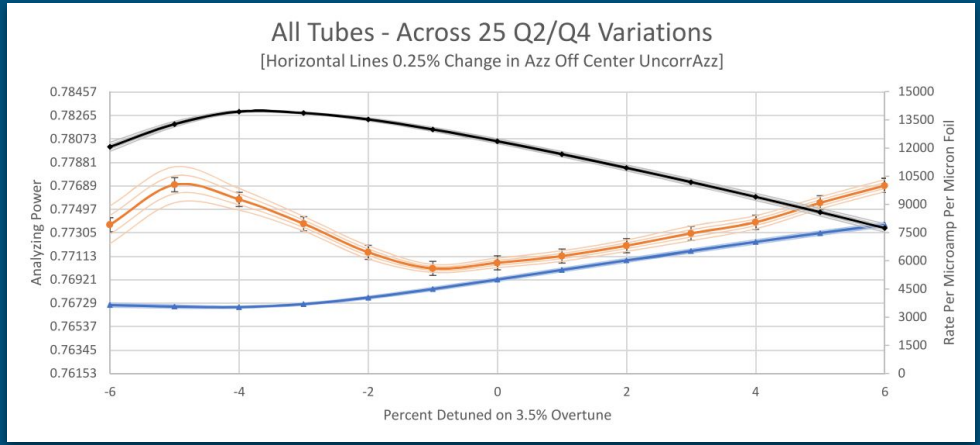
2-PMT Optics Solution

Optics for Hall-A Summer Run

We started off with a optics tune which used the entire detector.

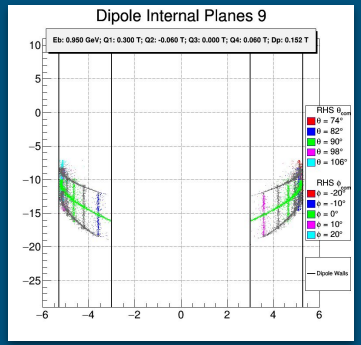
Maximize rate, keep motts low… Done

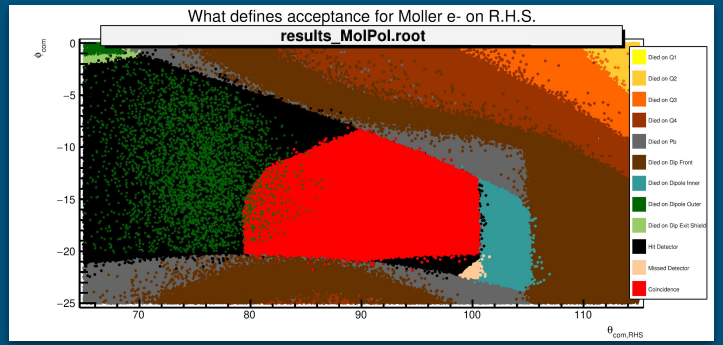




Maximized rate ⇒ Levchuk correction near maximum size ⇒ Highly undesirable

Maximization of the rate necessitates increasing the flux of electrons passing through the dipole box to its maximum. In this design, maximizing the rate is equivalent to maximizing the e- flow through the dipole which means bringing the envelope edge close to the dipole outer wall.





Optics for Hall-A Summer Run

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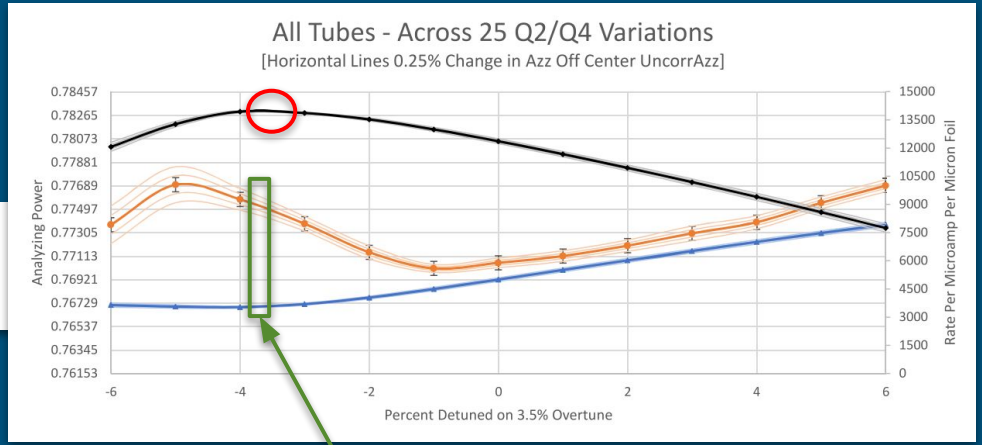
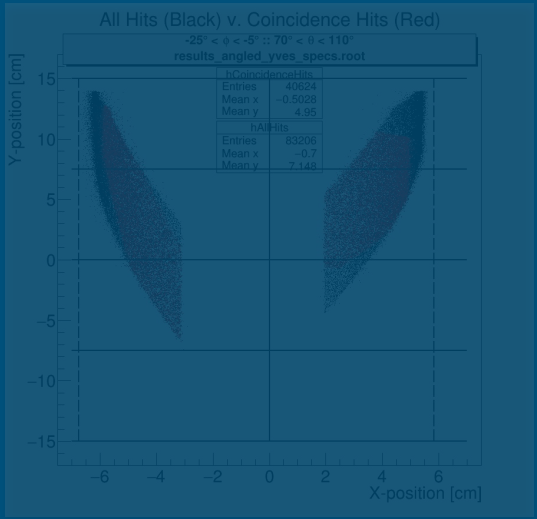
Maximize rate, keep motts low… Done

(1) Find rate peak.





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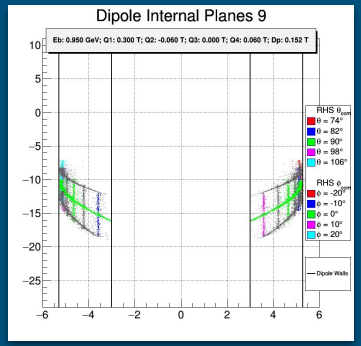

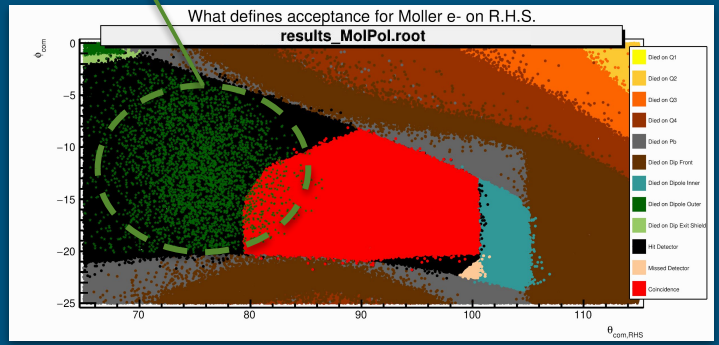

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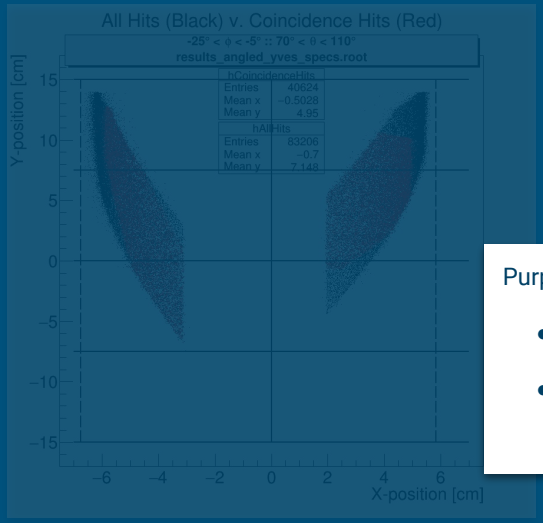
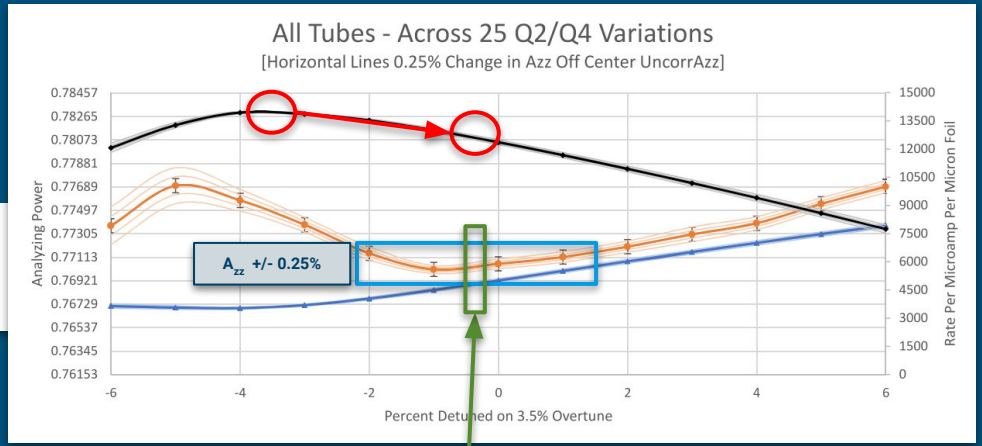


(1) Find rate peak.

(2) Overtune 3.5%.



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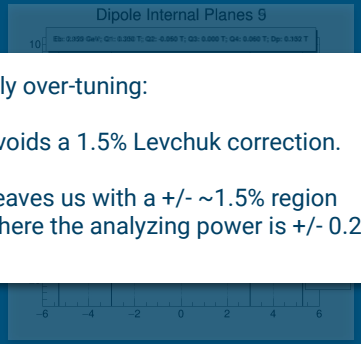
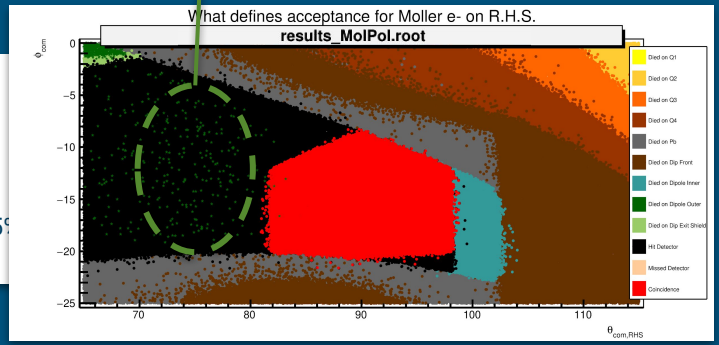


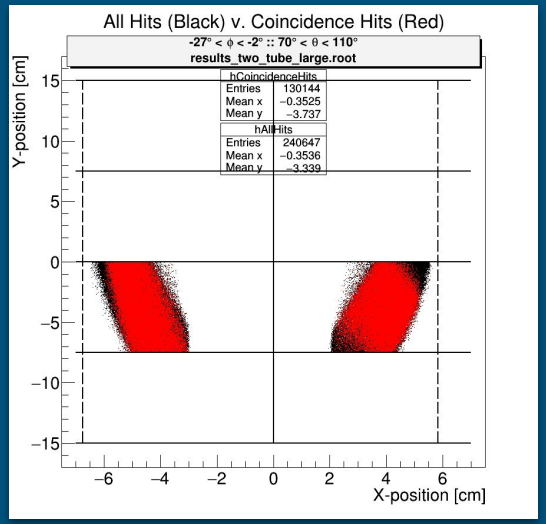
Purposefully over-tuning:

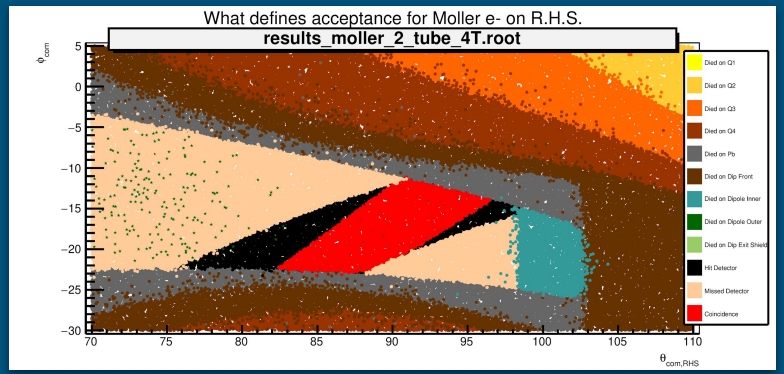
- Avoids a 1.5% Levchuk correction.
- Leaves us with a +/- ~1.5% region where the analyzing power is +/- 0.25%

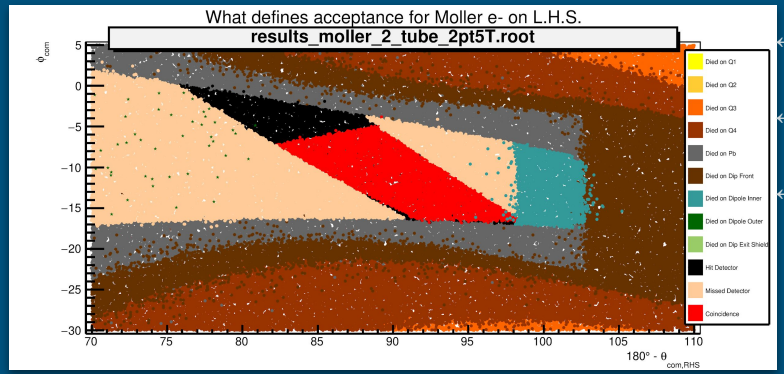


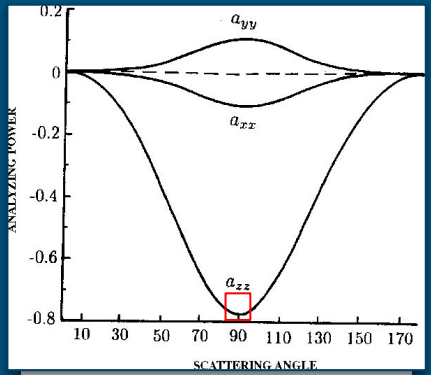
Optics Plan #2 (The 2-Tube Plan)

Restricting the acceptance by only using two (2) PMTs rather than all eight (8).









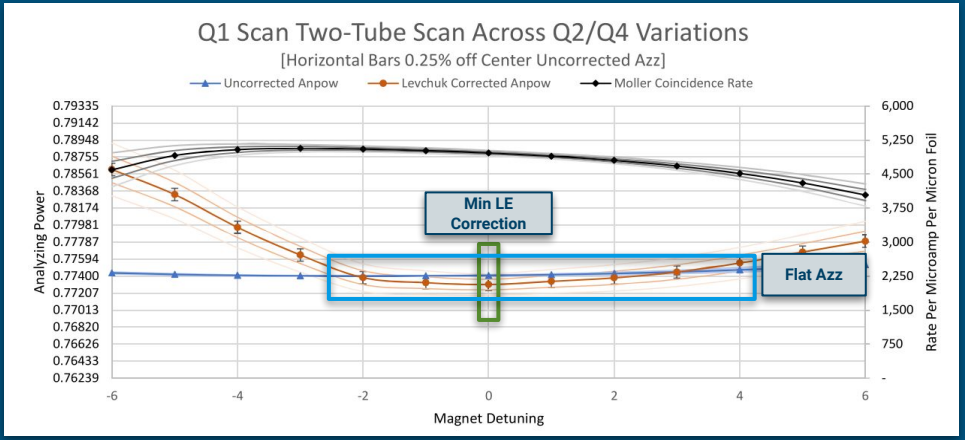
*Cutting the acceptance to a tight region around 90*deg will greatly constrain the analyzing power A_{zz}*

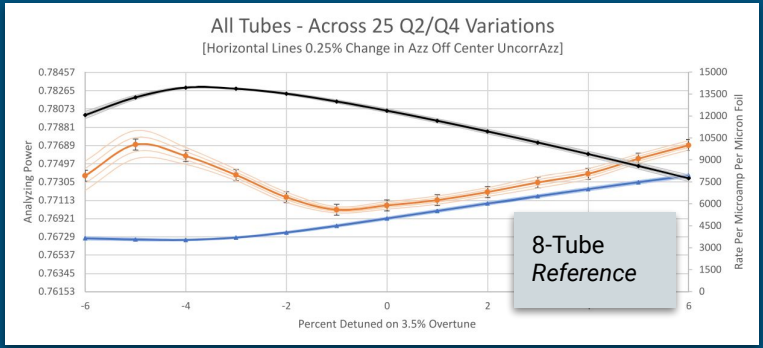
- *Detector cuts are nice and clean.*
- *Now largely avoids levchuk correction from overfocused e-.*
- *Acceptance is constrained tightly around the central ray (90*).*

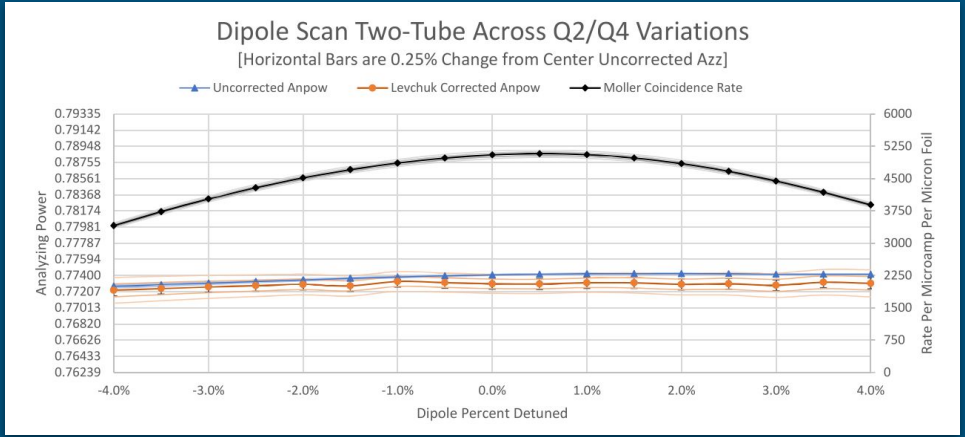
MolPol 0.95 GeV Optics 2-Tube

- Same quad optics tune
- Flat A_{zz} (over a ~7% tuning region)
- Levchuk correction minimization < 0.25%
- 1 GeV moller rates sufficiently high to cut acceptance rate down.

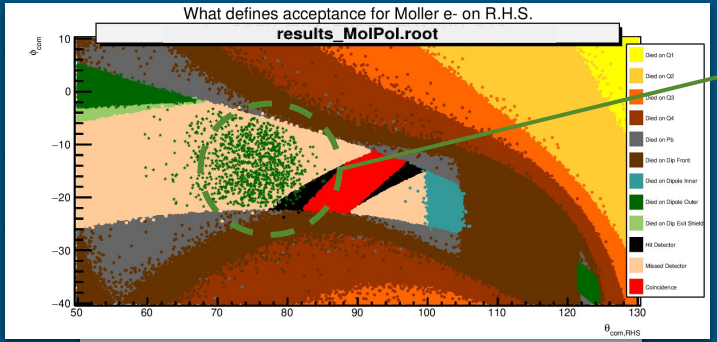
  $\propto 1 / E^2$
- Ability to increase current and target thickness



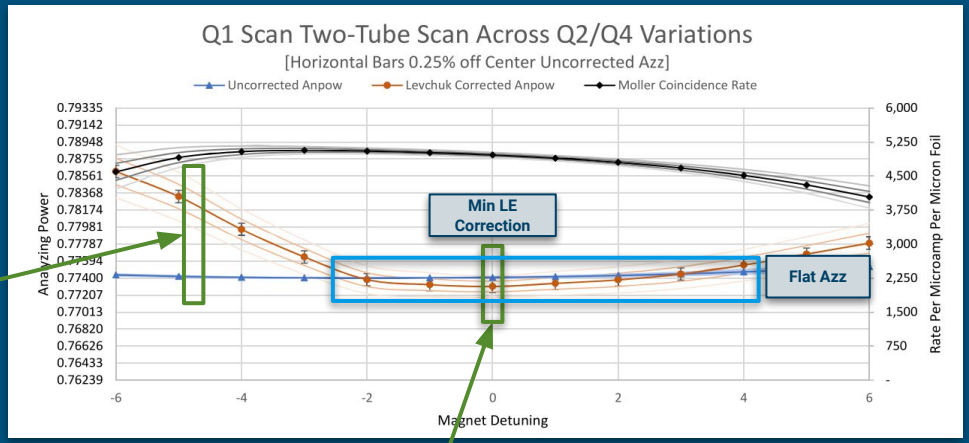




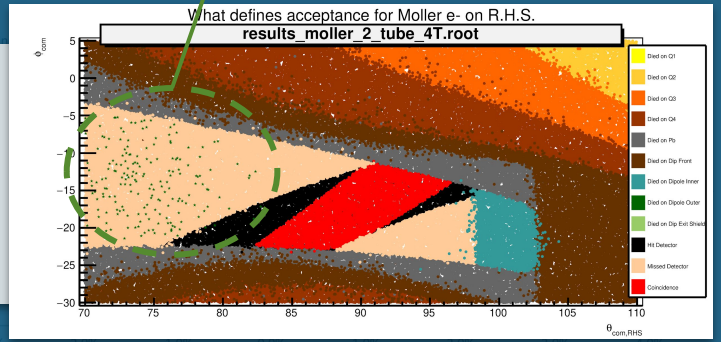
MolPol 0.95 GeV Optics 2-Tube



Again, as the rate is maximized we see that there's a problem with mollers which have been K-shell Levchuk kicked.



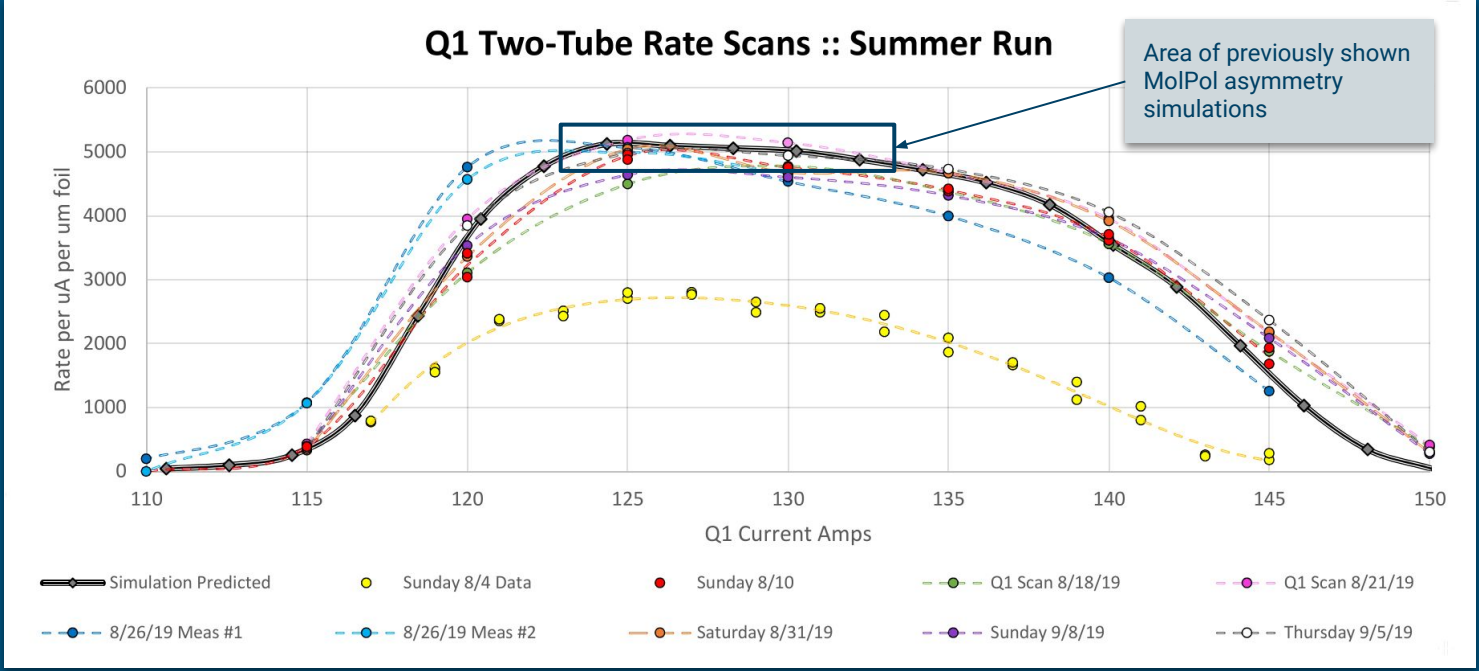
This is remediated by over-tuning from the moller rate peak.



Polarimetry Rate Scan Data

Quadrupole rate scans and dipole rate scans.

Quad 1 Scans over Summer Run - 2 PMT Tube

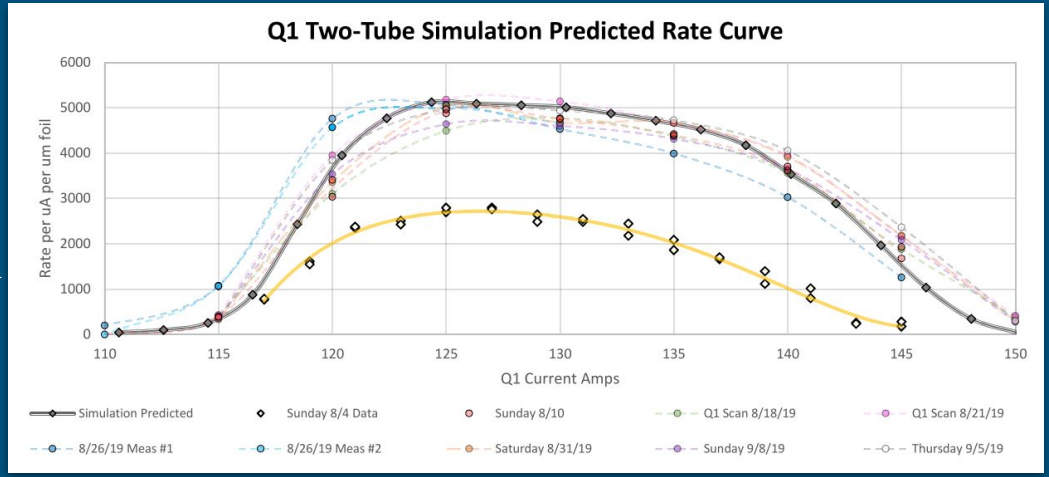


2-PMT Outliers

There exist two outliers in the scan data.

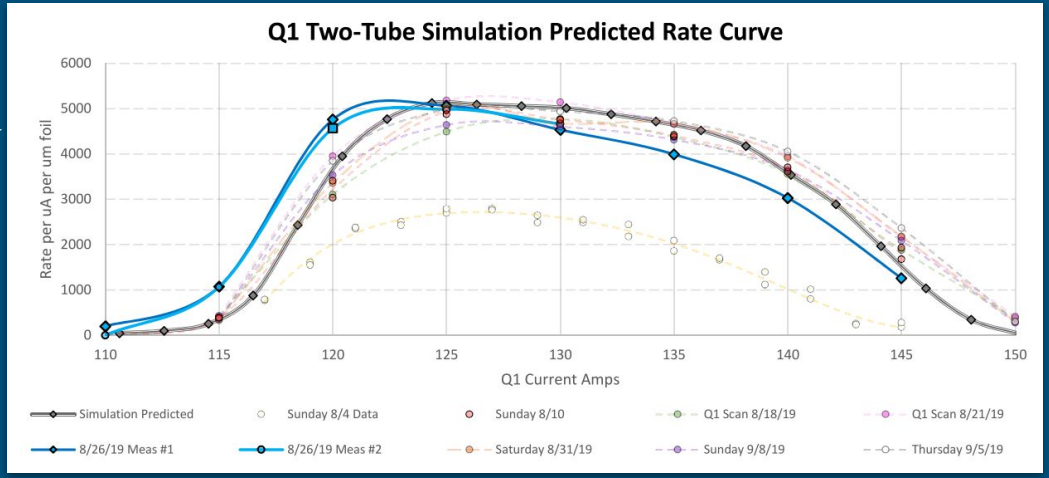
(1) Most easily recognizable is the data from 8/4/19.

This was the result of bad beam orbit. The issue was identified and worked out and a procedure developed to avoid the problem again.



(2) Additionally we have an unexpected deviation on 8/26/19.

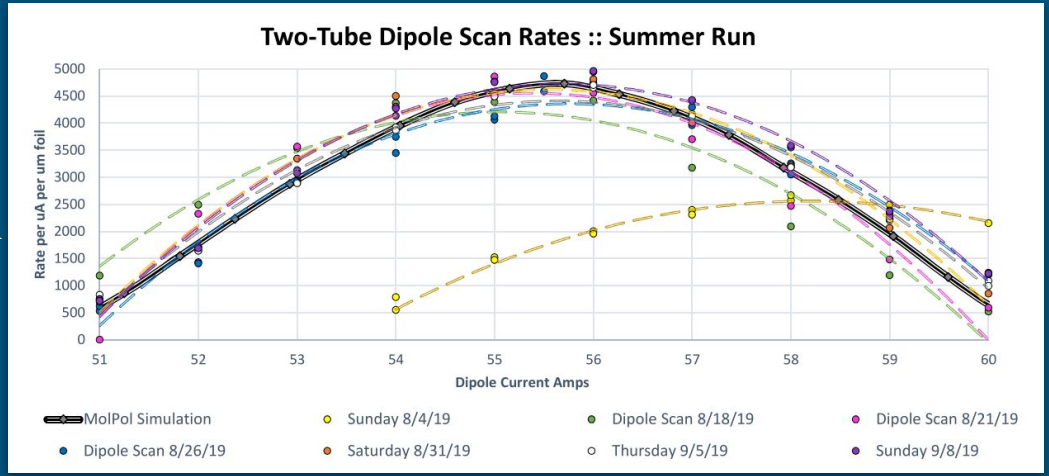
We're still seeking to identify the issue that caused the curve deviation. This deviation will have had no effect on our polarization measurement as we adjusted the quadrupole setting to reflect this observed deviation.



2 PMT Dipole Rates

We began each polarimetry measurement by calibrating the dipole scan.

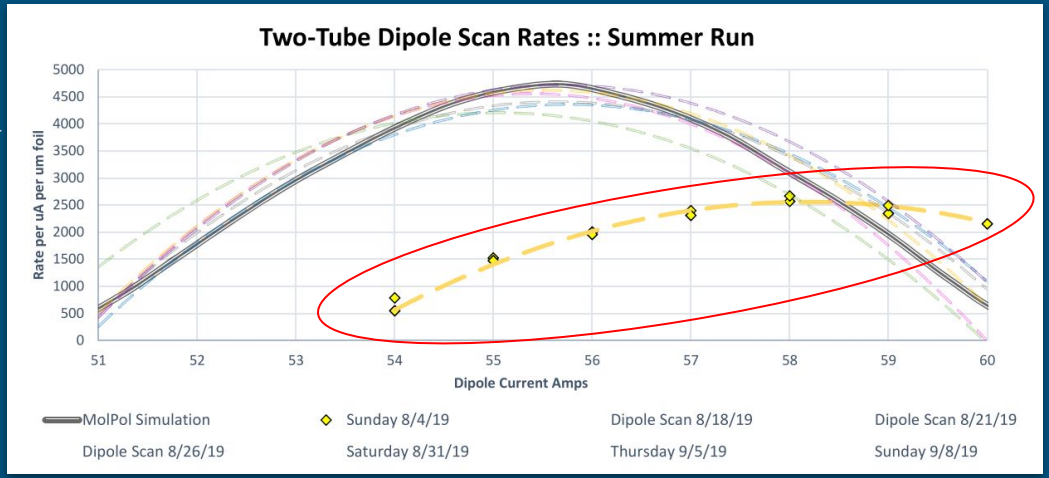
(On top) An overlay of all rate scans taken during the Hall-A summer run.



The Sunday 8/4 problem was identified through the rate scans.

- Peak rate occurred around 58+ amps, a ~4% difference which is anomalous.
- Peak moller coincidence rate was only 50% of expected rate.

We had a problem that wasn't immediately evident to us.



2-Tube Asymmetry Scan

Asymmetry data taken on 8/10		
Detune	Asym	Error
-5%	0.05585	0.00017
-2%	0.05489	0.00016
0%	0.05501	0.00017
2%	0.05487	0.00018