Analysis Progress

for the d_2^n analysis meeting

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1. Raster Calibration
   - P_{diff}
   - BPM Stability

2. Compton
   - Systematic Error from Cavity State Identification
   - Sign Checks

3. What's Next?

Defining P_{diff}

- During our H_2 elastics runs, the LHRS was set up to detect protons
- For a given scattering angle, we can compute the momentum that an elastically-scattered proton should have picked up:

$$p_p c = \frac{2M_p c^2 E(E + M_p c^2)\cos\theta_p}{(E + M_p c^2)^2 - E^2 \cos^2\theta_p} \tag{1}$$

where M_p is the proton mass, E is the energy of the incident electron, θ_p is the proton scattering angle, and we neglect the electron mass. Then:

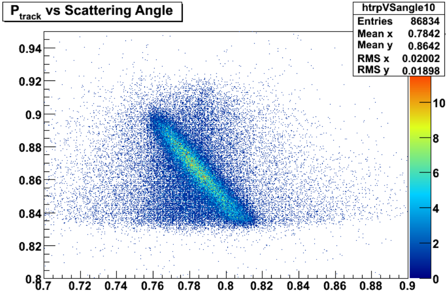
$$p_{diff} = p_p^{track} - p_p^{calculated} \tag{2}$$

- From survey reports, we know that the LHRS angle was 44.985°
- EPICS readback for this period gives $E \simeq 1.23095$ GeV
- We're looking for relatively gross effects here, so we neglect energy loss in target for now

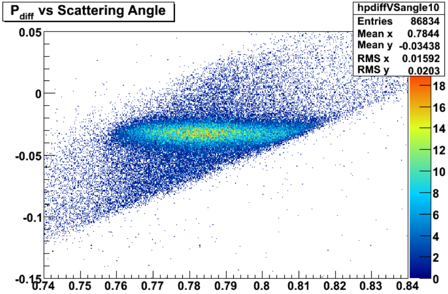
Momentum and Scattering Angle

- We can test our calculation of P_{diff} by plotting it against the proton scattering angle

Reconstructed proton momentum P_{track} will depend on θ_p

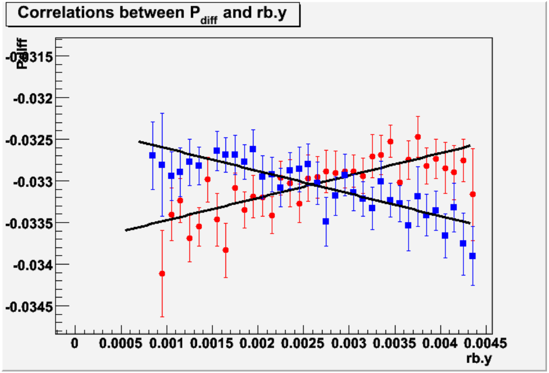


P_{diff} should be flat with respect to θ_p



Size of Raster-Y Correction

- How much do raster corrections affect the reconstructed momentum?
- We can get a quick sense by plotting p_{diff} (**NOT** raster-corrected) versus rb.y (vertical beam position from raster)
  - $\kappa_y = +1 \rightarrow$ blue
  - $\kappa_y = -1 \rightarrow$ red



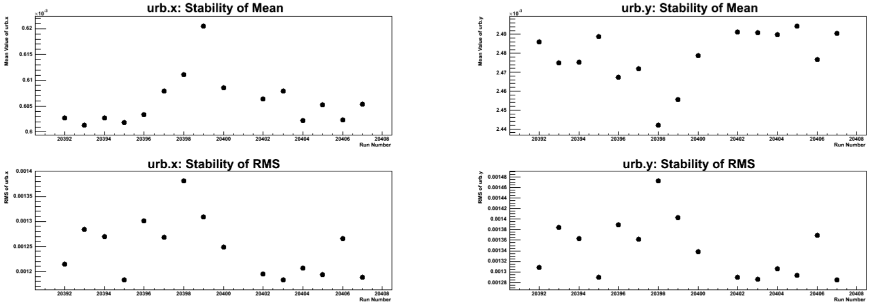
- Over whole rb.y range, the difference in p_{diff} is about 1 MeV/c

BPM Stability and Raster Calibration

- Raster calibration is sensitive to the beam tune
  - Coefficients are based on mean, rms of BPM readings
- Bodo Reitz recommends doing a separate raster calibration for each run (!)
- Kalyan recommends finding periods of stable BPM readings, doing a raster calibration for each region
  - Ten such regions during Transversity's 3 months of running

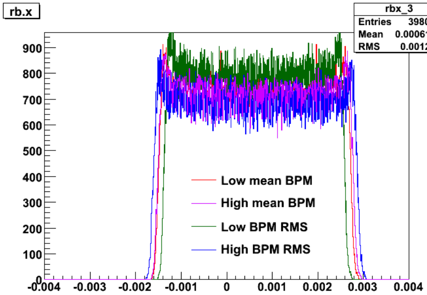
BPM Stability Over One Day

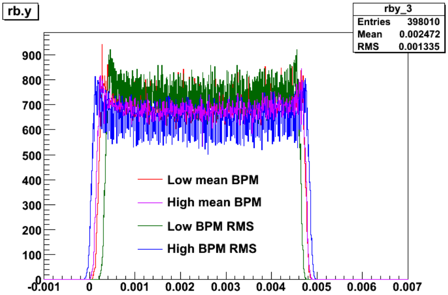
- To begin studying these effects, I looked at the stability of the BPM readings over a single day: February 25, 2009



Effects of Instability on Raster Calibration (i)

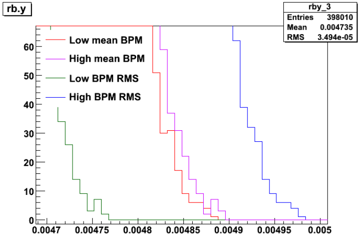
- I derived raster coefficients for each of the four “extreme” (in urb.x) runs in our set:
  - Highest and lowest mean values (20393, 20399)
  - Highest and lowest RMS values (20395, 20398)
- Then, I analyzed Run 20395 with all four sets of coefficients to check the difference in reconstructed beam positions





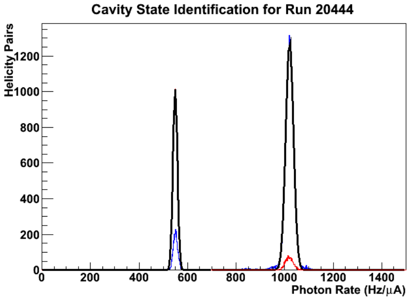
Effects of Instability on Raster Calibration (ii)

- Each change in the raster coefficients resulted in a change in the width of rb.x/rb.y (rather than a translation)
- I looked at the zero crossings of rb.x/rb.y to quantify width changes over the urb.x extremes
- Change ($\Delta \sim 0.02$ mm) in the **mean value** did not have much of an effect
  - ~ 0.1 mm for rb.x and ~ 0.05 mm for rb.y
- Change ($\Delta \sim 0.2$ mm) in the **rms value** had a much larger effect
  - ~ 0.56 mm for rb.x and ~ 0.53 mm for rb.y
- *How much position instability can we tolerate?*



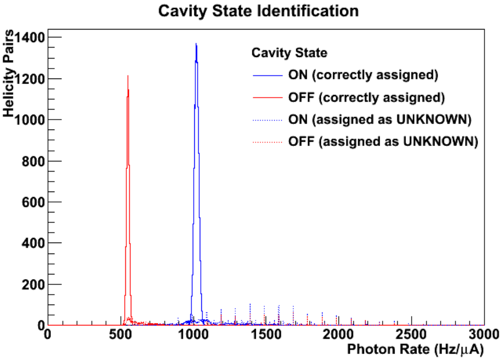
Compton Cavity State ID During d_2^n

- Computing a Compton asymmetry relies on knowledge of whether the laser cavity is in resonance (**ON**) or not (**OFF**)
- Real-time signal cavity-power signal was unreliable during d_2^n
- Our workaround:
  1. Use EPICS data to do a quick pre-sort
  2. Fit two Gaussians to the current-normalized photon rates
  3. Associate rates within 2.5σ of a μ with that state
  4. Classify each pair based on the rates of the two neighboring pairs



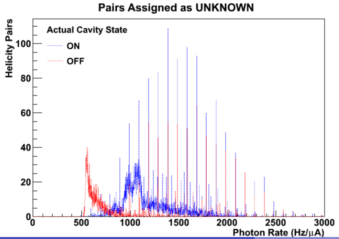
Checking Our Cavity State ID Method

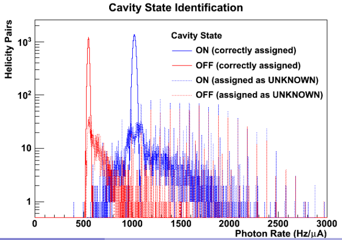
- To investigate the systematics of this approach, we looked at a Compton run (20444) from last fall
  - These runs had a reliable real-time cavity power signal
- We can run the cavity state ID method on these data, then compare our results against the actual cavity states from the real-time signal



Failure Modes for Cavity State ID

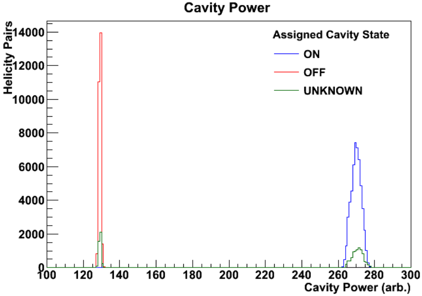
1. Misidentification of ON pairs as OFF, or vice versa
   - Worst effect – dilutes asymmetry
   - Luckily, this only affects 6 pairs out of 92,220 (all OFF states misidentified as ON)
   - May be worse for d_2^n runs with worse beam tune
2. Removal of ON or OFF pairs from data set (via classification as UNKNOWN)
   - *If this mistake is random*, this will only affect our statistics
   - 12.8% of all cavity-OFF pairs were assigned an UNKNOWN state
   - 14.2% of all cavity-ON pairs were assigned an UNKNOWN state
   - Only 1.2% of pairs should be excluded by a 2.5σ cut on a Gaussian

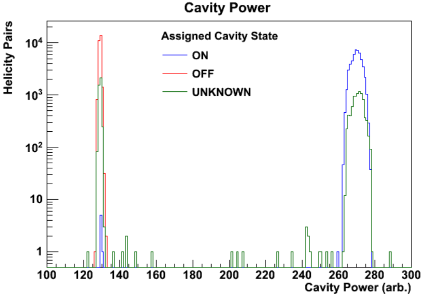




Failure Correlation with Cavity Power

- Could this issue be a reflection of variation in the cavity power?
- Plotting the distributions of assigned cavity states as functions of the real-time cavity power should tell us ...





- Cavity power variation doesn't look like the culprit
- Perhaps the problem is beam tune?

Investigating the Compton Helicity Sign

- Jin has been trying to pin down the sign of the helicity bit in the LHRS DAQ
- One possible line of attack: measure the beam charge asymmetry in both the Compton and the LHRS
- This requires calibrating the helicity sign in the new (CMU) Compton DAQ with that in the old (Saclay) Compton DAQ (which was calibrated to the Møller in 2008)

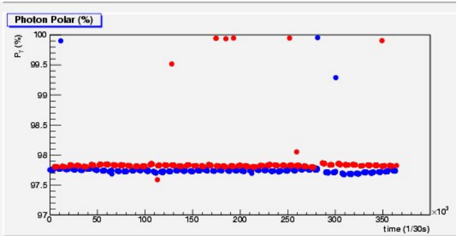
$$A_{Compton} = \frac{A^{\rightarrow\uparrow} - A^{\rightarrow\downarrow}}{A^{\rightarrow\uparrow} + A^{\rightarrow\downarrow}} = -\frac{A^{\leftarrow\uparrow} - A^{\leftarrow\downarrow}}{A^{\leftarrow\uparrow} + A^{\leftarrow\downarrow}} \tag{3}$$

- There are **three** possible sources of a sign flip in $A_{Compton}$:
  1. A flip in the definition of the photon polarization direction ($\rightarrow$ becomes $\leftarrow$)
  2. A flip in the definition of the asymmetry ($A^{\rightarrow\uparrow} - A^{\rightarrow\downarrow}$ becomes $A^{\rightarrow\downarrow} - A^{\rightarrow\uparrow}$)
  3. A flip in the definition of the beam helicity ($\uparrow$ becomes $\downarrow$)

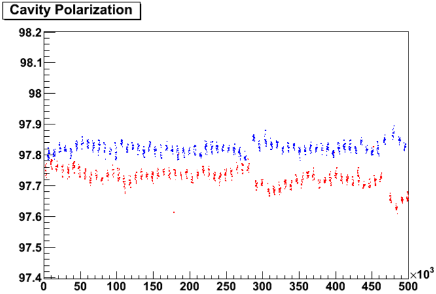
Potential Sign Flip 1: Laser Polarization Direction

- The two laser polarization directions (left- and right-circular) had markedly different polarizations P_γ
- This gives us an easy way to compare the direction definitions
- Both analysis packages use the color convention right and left

Saclay DAQ



CMU DAQ



There ***is*** *a sign flip from the definitions of the laser polarization directions!*

Potential Sign Flip 2: Asymmetry Definition

- In the CMU analysis, we define a Compton asymmetry by taking data for positive helicity (`hel==1`) and subtracting data for negative helicity (`hel==0`)
- Does the Saclay DAQ compute the asymmetry the same way?

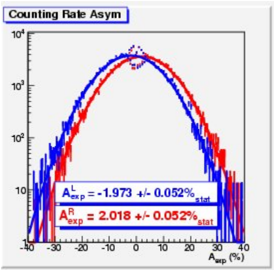
```
AsymRate_i = 100.*(crbinr[i-1]/gLiveTimer/Bcmupr -
          crbinl[i-1]/gLiveTimel/Bcmupl)/
         (crbinr[i-1]/gLiveTimer/Bcmupr +
          crbinl[i-1]/gLiveTimel/Bcmupl);
```

- What this rather arcane code signifies is the asymmetry takes "right" (+/1) events and subtracts "left" (-/0) events
- Here, *right* and *left* refer to electron beam helicity, not photon polarization
- The asymmetry definitions between the two DAQs are therefore broadly the same

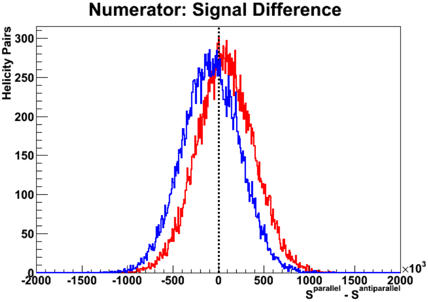
Potential Sign Flip 3: Helicity Bit

- We can't (easily) make a direct comparison of the helicity bits in the two DAQs
- However, we know that – despite a sign flip in the laser polarization definition – our similarly defined asymmetries have the same sign
- Thus, there **must** be a sign flip in the definition of the helicity bit between the two Compton DAQs!

Saclay DAQ



CMU DAQ



What's Next?

- Raster Calibration
  - Implement extended-target corrections (which incorporate rastered-beam info)
  - Confirm sign of raster y
- BB Optics
  - Start on vertex corrections with magnet-on runs
- Compton
  - Analyzing power work continues in background
  - Is cavity state ID failure random?
  - Photon detector resolution
- Cross-section calculation