Re-running the physics asymmetry analysis:

- Up-Down physics asymmetry analysis for four different ways to form the asymmetry

From Kabir's thesis:

1. Single wire asymmetry (normalized by chamber integral yield):

   \[
   A^n_k = \frac{Y_k^\uparrow - Y_k^\downarrow}{Y_k^\uparrow + Y_k^\downarrow},
   \]

   \[
   = PG_k A_p
   \]

2. Wire pair asymmetry

   \[
   A^r_{kk^*} = \frac{R^\uparrow_{kk^*} - R^\downarrow_{kk^*}}{R^\uparrow_{kk^*} + R^\downarrow_{kk^*}}
   \]

   \[
   = \frac{4PG_k A_p}{2 + 2(PG_k A_p)^2}
   \]

   \[
   y_k^\uparrow = \frac{Y_k^\uparrow - b_k}{I^\uparrow}, \quad y_k^\downarrow = \frac{Y_k^\downarrow - b_k}{I^\downarrow},
   \]

   \[
   I^\uparrow = \sum_k (Y_k^\uparrow - b_k), \quad I^\downarrow = \sum_k (Y_k^\downarrow - b_k).
   \]

   \[
   R^\uparrow_{kk^*} = \frac{y_k^\uparrow}{y_k^*}, \quad \text{and} \quad R^\downarrow_{kk^*} = \frac{y_k^\downarrow}{y_k^*},
   \]

   \[
   y_k^\uparrow = Y_k^\uparrow - b_k, \quad y_k^\downarrow = Y_k^\downarrow - b_k.
   \]
Beam On Physics Asymmetry

What was done:

- Up-Down physics asymmetry analysis for four different ways to form the asymmetry

From Kabir’s thesis:

3. Wire pair asymmetry

\[ A_k - A_k^* = \frac{y_k^\uparrow - y_k^\downarrow}{y_k^\uparrow + y_k^\downarrow} - \frac{y_k^* - y_k^\downarrow}{y_k^* + y_k^\downarrow} \]

\[ y_k^\uparrow = Y_k^\uparrow - b_k \quad y_k^\downarrow = Y_k^\downarrow - b_k \]

\[ \approx PG_k A_p + \frac{I_0^\uparrow - I_0^\downarrow}{I_0^\uparrow + I_0^\downarrow} - \frac{I_0^\uparrow - I_0^\downarrow}{I_0^\uparrow + I_0^\downarrow} + PG_k A_p \approx 2PG_k A_p. \]

4. Wire pair beam asymmetry

\[ A_k + A_k^* \approx 2 \frac{I_0^\uparrow - I_0^\downarrow}{I_0^\uparrow - I_0^\downarrow} \]
Beam On Physics Asymmetry

What was done:

- Single asymmetries were calculated from pulse pairs (quartet and null to follow later)

- Asymmetries were grouped by batches (same as in Kabir’s thesis) and calculated from error weighted averages / separated into complete 600 pulse sequences with spin up or down as starting pulse.

- Same cuts as implemented by Kabir were used (1 before and 19 after a dropped pulse)

- Beam fluctuation cut was implemented based on monitor data (> ± 1% variation between pulses in a pair)

- Wire/pair asymmetries were combined with error weighted averages, taking correlations into account.

- Separate asymmetries were obtained for 600 pulse sequence starting spin up and down, as well as the combined asymmetry.
Beam On Physics Asymmetry

Some results:

- Asymmetry results:
  \[ A_{UD}^{SW} = 10 \pm 8 \text{ ppb} \]
  \[ A_{UD}^{WP,1} = 11 \pm 9 \text{ ppb} \]
  \[ A_{UD}^{WP,2} = 11 \pm 9 \text{ ppb} \]
  \[ A_{Beam}^{WP,2} = -101 \pm 20 \text{ ppb} \]

- Kabir’s Result:
  \[ A_{UD} = (0.9528 \pm 0.9527) \times 10^{-8} \]

Program output:

- Final Single Wire Asymmetry = 0.0989248 +/- 0.0768935
- Final Single Wire Asymmetry (pseq. spin -1) = 0.117238 +/- 0.108775
- Final Single Wire Asymmetry (pseq. spin 1) = 0.0806264 +/- 0.108712

- Final Wire Pair Asymmetry = 0.111824 +/- 0.0910967
- Final Wire Pair Asymmetry (pseq. spin -1) = 0.154746 +/- 0.123973
- Final Wire Pair Asymmetry (pseq. spin 1) = 0.0524535 +/- 0.1239

- Final Wire Pair Asymmetry 2 = 0.111824 +/- 0.0910967
- Final Wire Pair Asymmetry 2 (pseq. spin -1) = 0.154745 +/- 0.123973
- Final Wire Pair Asymmetry 2 (pseq. spin 1) = 0.0524552 +/- 0.1239

- Final Wire Beam Asymmetry = -1.0105 +/- 0.197509
- Final Wire Beam Asymmetry (pseq. spin -1) = -0.421591 +/- 0.187672
- Final Wire Beam Asymmetry (pseq. spin 1) = -1.42804 +/- 0.187362
Some results cont.:  

Asymmetry results:

\[ A_{LR}^{SW} = -363 \pm 40 \text{ ppb} \]
\[ A_{LR}^{WP,1} = -393 \pm 50 \text{ ppb} \]
\[ A_{LR}^{WP,2} = -393 \pm 50 \text{ ppb} \]
\[ A_{Beam}^{WP,2} = -158 \pm 103 \text{ ppb} \]

Kabir’s Result:

\[ A_{LR} = (-4.12 \pm 0.52) \times 10^{-7}. \]
Some results cont.: 

- **Issues with the present analysis:**

  1. *We only subtract an average pedestal and this can mix the beam asymmetry back into the measured asymmetry due to beam normalization.*

  2. *We have an annoying, non-statistical variation of all asymmetries with batch number that appears to be somewhat correlated with large beam asymmetries.*
Beam On Physics Asymmetry

Is this be a result of incomplete pedestal subtraction?

- Pedestal subtraction using dropped pulse signal:

  The “pedestal subtracted” yield for wire (i) is

  \[ Y_i^\pm = Y_i^o \pm (1 \pm PC_i A_{PV}) + \tilde{p}_i^\pm \]

  So the beam normalized yield is

  \[ Y_i^\pm = \frac{g_i}{G} (1 \pm PC_i A_{PV}) + \frac{\tilde{p}_i^\pm}{I^\pm G} \]

  And the corresponding single wire asymmetry is

  \[ A_{i,raw} = PC_i A_{PV} + \frac{1}{2} \left( \frac{\tilde{p}_i^+}{Y_i^{o+}} - \frac{\tilde{p}_i^-}{Y_i^{o-}} \right) \]

  Which ignores components in the denominator that are \( \ll 1 \)

  This expression depends on the beam asymmetry (see next page).
Removing False Asymmetries

Corrections to the previous analysis:

- Pedestal subtraction using dropped pulse signal:

  If we define the (measureable) pedestal and beam asymmetries respectively as

  \[
  A_{i,\text{ped}} = \frac{p_i^+ - p_i^-}{Y_i^o^+ + Y_i^o^-} \quad \text{pulse-pair beam off asymmetry}
  \]
  
  \[
  A_{\text{Beam}} = \frac{Y_i^o^+ - Y_i^o^-}{Y_i^o^+ + Y_i^o^-} = \frac{I^+ - I^-}{I^+ + I^-} \quad \text{neutron beam intensity asymmetry}
  \]

  We can write the raw asymmetry as

  \[
  A_{i,\text{raw}} = PC_i A_{PV} + \frac{\tilde{p}_i^+}{2Y_i^o^+} \left(1 - \frac{1 + A_{\text{Beam}}}{1 - A_{\text{Beam}}} \right) + \frac{A_{i,\text{ped}}}{1 - A_{\text{Beam}}}
  \]

  This expression neglects products between the physics asymmetries and any other asymmetry (gain, pedestal, beam), in the asymmetry denominators and assumes that the wire pair gain factors are equal in magnitude and opposite in sign, but is otherwise exact.
Removing False Asymmetries

 Corrections to the previous analysis:

- Using linear regression:

  Expansion in $A_{\text{Beam}}$ leads to:

  $$ A_{i,\text{raw}} = PC_i A_{PV} - \frac{p_i^+}{Y_i^{o+}} A_{\text{Beam}} + A_{i,\text{ped}} + A_{i,\text{ped}} A_{\text{Beam}} + O(A_{\text{Beam}}^2) + \ldots $$

  If we can ignore everything of order $A^2$ then

  $$ A_{i,\text{raw}} = PC_i A_{PV} - \frac{p_i^+}{Y_i^{o+}} A_{\text{Beam}} + A_{i,\text{ped}} $$

  This means that we should see a non-zero slope when we plot $A_{i,\text{raw}}$ vs. $A_{\text{Beam}}$

  Ideally, the slopes $\left| \frac{p_i^+}{Y_i^{o+}} \right|$ should be small ($\lesssim O(10^{-3})$) and should be randomly distributed around zero.

  We can tests this ... and use linear regression to try and remove the effect.
Removing False Asymmetries

Corrections to the previous analysis:

- Using linear regression:

We can test this ... and use linear regression to try and remove the effect.

\[ A_{i,\text{raw}} = P C_i A_{PV} - \frac{\tilde{p}_i^+}{Y_i} A_{\text{Beam}} \equiv a + b A_{\text{Beam}} \]

\[ b = -0.026 \pm 0.015 \]

\[ b = 1.09 \pm 0.021 \]
Removing False Asymmetries

Corrections to the previous analysis:

- Using linear regression:
  - Calculate slope for each wire (i) from $\chi^2$ minimization over a run
    
    \[
    b_i = \frac{N \sum_n A_{n,beam} A_{n,raw}^i - \sum_n A_{n,beam} \sum_n A_{n,raw}^i}{N \sum_n A_{n,beam}^2 - (\sum_n A_{n,beam})^2}
    \]
  
  - Go back over the same run and subtract the asymmetry at the pulse pair level
    
    \[A_{i,reg} = A_{i,raw} - b A_{Beam} = PC_i A_{PV}\]

- Average/combine corrected asymmetries as before

- Check to see if this resolves the strange batch dependence

- Would have been done with this by now, but the analysis server crashed several times due to power outage over last week …

- … will hopefully have results before end of next week.
Previous slides / backup
Beam On Physics Asymmetry

Single wire correlation coefficients, covariance and inverse covariance:
Beam On Physics Asymmetry

Wire pair correlation coefficients, covariance and inverse covariance:
Beam On Physics Asymmetry

UD Asymmetry by batch for starting pulse spin up (zoomed on the UD asymmetries):

![Graph showing UD Asymmetry by batch for starting pulse spin up](image-url)
Beam On Physics Asymmetry

UD Asymmetry by batch for starting pulse spin down:

600 pulse sequence start spin down

Asymmetry (10^{-7})

Single wire
Wire pair
Beam asym
Beam On Physics Asymmetry

UD Asymmetry by batch for both starting spins:

Single Wire UD Asymmetry

600 pulse sequence start spin down
600 pulse sequence start spin up
Beam On Physics Asymmetry

UD Asymmetry by batch for both starting spins:

Wire pair (1) Asymmetry

600 pulse seq. spin start up
600 pulse seq. spin start down
Beam On Physics Asymmetry

UD Asymmetry vs wire for both starting spins:
Beam asymmetry vs wire for both starting spins (from wire pair analysis):