Beam On Physics Asymmetry

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):

$$A_k^n = \frac{\mathcal{Y}_k^\uparrow - \mathcal{Y}_k^\downarrow}{\mathcal{Y}_k^\uparrow + \mathcal{Y}_k^\downarrow},$$

$$= PG_kA_p$$

$$\mathcal{Y}_k^\uparrow = \frac{Y_k^\uparrow - b_k}{I^\uparrow}, \qquad I^\uparrow = \sum_k (Y_k^\uparrow - b_k),$$

$$\mathcal{Y}_k^\downarrow = \frac{Y_k^\downarrow - b_k}{I^\downarrow}, \qquad I^\downarrow = \sum_k (Y_k^\downarrow - b_k).$$

  2. Wire pair asymmetry

$$A_{kk^*}^r = \frac{R_{kk^*}^\uparrow - R_{kk^*}^\downarrow}{R_{kk^*}^\uparrow + R_{kk^*}^\downarrow}$$

$$= \frac{4PG_kA_p}{2 + 2(PG_kA_p)^2}$$

$$R_{kk^*}^\uparrow = \frac{y_k^\uparrow}{y_{k^*}^\uparrow} \text{ and } R_{kk^*}^\downarrow = \frac{y_k^\downarrow}{y_{k^*}^\downarrow},$$

$$y_k^\uparrow = Y_k^\uparrow - b_k \qquad y_k^\downarrow = Y_k^\downarrow - b_k$$

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

$$A_k - A_{k^*} = \frac{y_k^{\uparrow} - y_k^{\downarrow}}{y_k^{\uparrow} + y_k^{\downarrow}} - \frac{y_{k^*}^{\uparrow} - y_{k^*}^{\downarrow}}{y_{k^*}^{\uparrow} + y_{k^*}^{\downarrow}} \qquad y_k^{\uparrow} = Y_k^{\uparrow} - b_k \qquad y_k^{\downarrow} = Y_k^{\downarrow} - b_k$$

$$\approx PG_kA_p + \frac{I_0^{\uparrow} - I_0^{\downarrow}}{I_0^{\uparrow} + I_0^{\downarrow}} - \frac{I_0^{\uparrow} - I_0^{\downarrow}}{I_0^{\uparrow} + I_0^{\downarrow}} + PG_kA_p \quad \approx 2PG_kA_p.$$

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:

$$A_{\mathrm{UD}} = (0.9528 \pm 0.9527) \times 10^{-8}$$

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

Beam On Physics Asymmetry

Some results cont.:

- Asymmetry results: $A_{LR}^{SW} = -363 \pm 40$ 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:

$$A_{\mathrm{LR}} = (-4.12 \pm 0.52) \times 10^{-7},$$

Program Output:

Final Single Wire Asymmetry = -3.63355 +- 0.421451
Final Single Wire Asymmetry (pseq. spin -1) = -4.9835 +- 0.593782
Final Single Wire Asymmetry (pseq. spin 1) = -2.26422 +- 0.598288

Final Wire Pair Asymmetry = -3.93433 +- 0.507592
Final Wire Pair Asymmetry (pseq. spin -1) = -4.56257 +- 0.686844
Final Wire Pair Asymmetry (pseq. spin 1) = -2.89759 +- 0.692067

Final Wire Pair Asymmetry 2 = -3.93433 +- 0.507593
Final Wire Pair Asymmetry 2 (pseq. spin -1) = -4.56258 +- 0.686844
Final Wire Pair Asymmetry 2 (pseq. spin 1) = -2.89758 +- 0.692068

Final Wire Beam Asymmetry = 1.58046 +- 1.03768
Final Wire Beam Asymmetry (pseq. spin -1) = 8.81618 +- 0.979183
Final Wire Beam Asymmetry (pseq. spin 1) = -6.86157 +- 0.981181

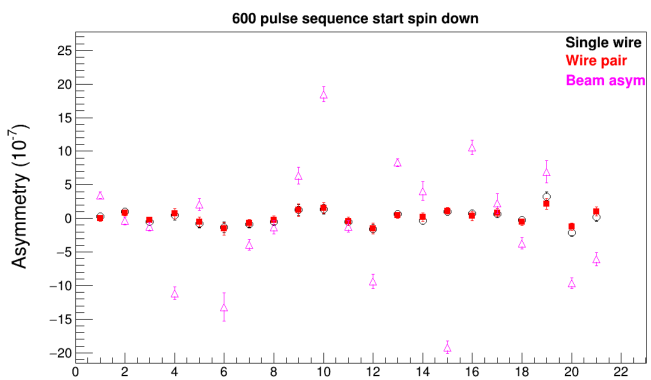
Beam On Physics Asymmetry

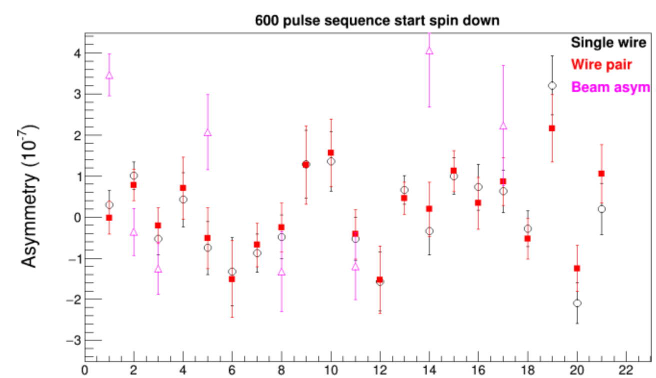
Some results cont.:

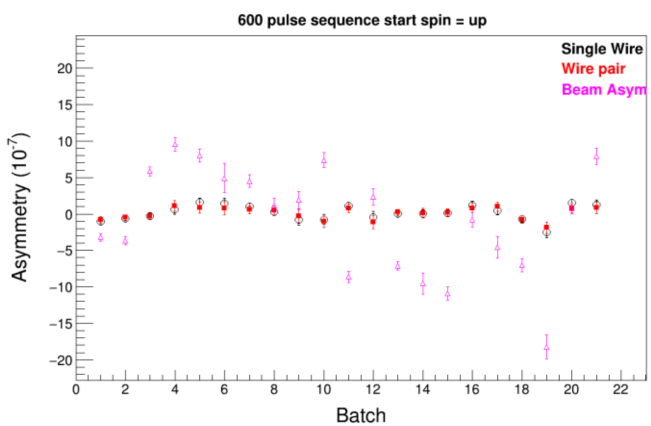
❑ Issues with the present analysis:

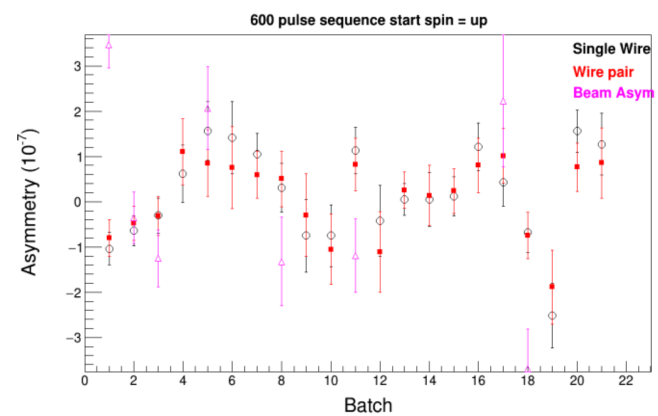
1. We only subtract an average pedestal and this can mix the beam asymmetry back into the measured asymmetry due to beam normalization

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).

Note the notation change:

Spin: $\pm = \uparrow\downarrow$

Wire pair: u, d

Wire "gain": g_i

Chamber "gain": G

Beam intensity: $I^{\pm}$

Reference pedestal: p'_i

$$\tilde{p}_i^{\pm} \equiv p_i^{\pm} - p'_i$$

$$Y_i^{o\pm} \equiv I^{\pm} g_i$$

$$G \equiv \sum_i (g_i^u + g_i^d)$$

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

$$A_{i,ped} = \frac{p_i^+ - p_i^-}{Y_i^{o+} + Y_i^{o-}}$$

pulse-pair beam off asymmetry
(estimate this from our measured pedestal asymmetry)

$$A_{Beam} = \frac{Y_i^{o+} - Y_i^{o-}}{Y_i^{o+} + Y_i^{o-}} = \frac{I^+ - I^-}{I^+ + I^-}$$

neutron beam intensity asymmetry
(use beam monitor asymmetry)

We can write the raw asymmetry as

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

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_{Beam} leads to:

$$A_{i,raw} = PC_i A_{PV} - \frac{\tilde{p}_i^+}{Y_i^{o+}} A_{Beam} + A_{i,ped} + A_{i,ped} A_{Beam} + \mathcal{O}\left(A_{Beam}^2\right) + \ldots$$

If we can ignore everything of order A^2 then

$$A_{i,raw} = PC_i A_{PV} - \frac{\tilde{p}_i^+}{Y_i^{o+}} A_{Beam} + A_{i,ped}$$

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

Ideally, the slopes $\left|\frac{\tilde{p}_i^+}{Y_i^{o+}}\right|$ 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.

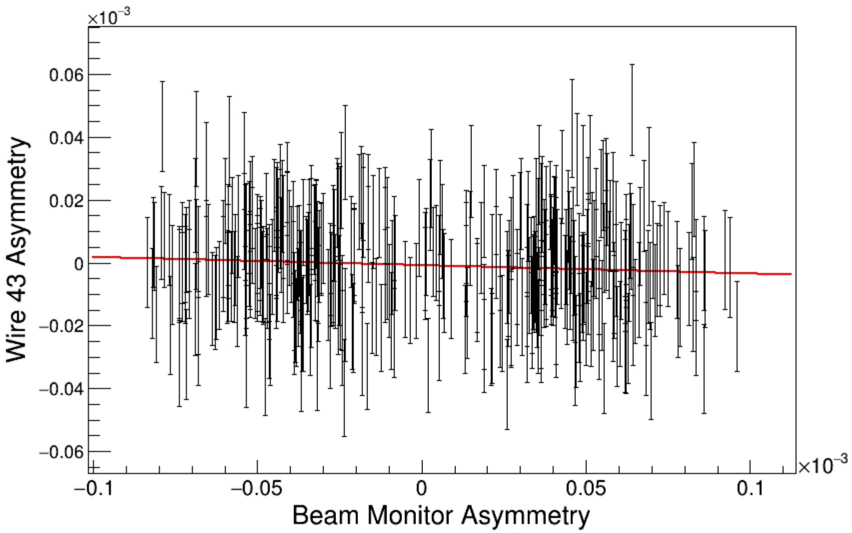
Removing False Asymmetries

Corrections to the previous analysis:

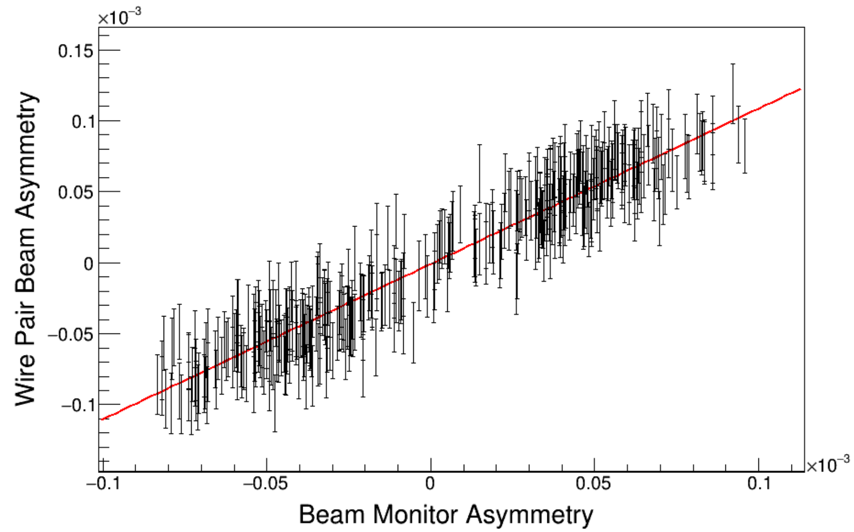
- ❑ **Using linear regression:**

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

$$A_{i,raw} = PC_i A_{PV} - \frac{\tilde{p}_i^+}{Y_i^{o+}} A_{Beam} \equiv a + bA_{Beam}$$



$b = -0.026 \ \pm 0.015$



$b = 1.09 \ \pm 0.021$

Removing False Asymmetries

Corrections to the previous analysis:

- ❑ Using linear regression:

  - Calculate slope for each wire (i) from χ^2 minimization over a run

$$b_i = \frac{N \sum_n A_{n,beam} A^i_{n,raw} - \sum_n A_{n,beam} \sum_n A^i_{n,raw}}{N \sum_n A^2_{n,beam} - \left(\sum_n A_{n,beam}\right)^2}$$

  - Go back over the same run and subtract the asymmetry at the pulse pair level

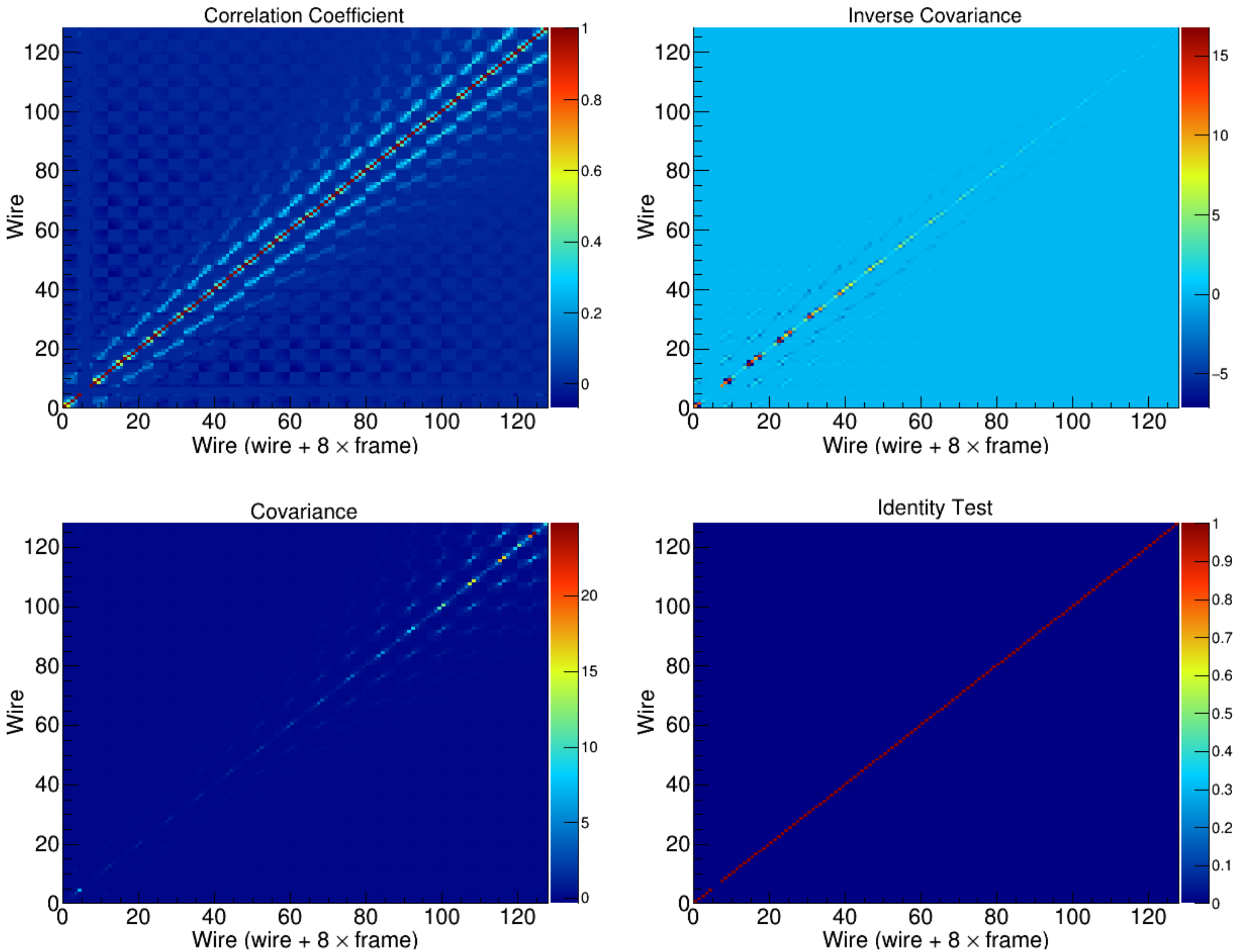
$$A_{i,reg} = A_{i,raw} - bA_{Beam} = PC_i A_{PV}$$

  - 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

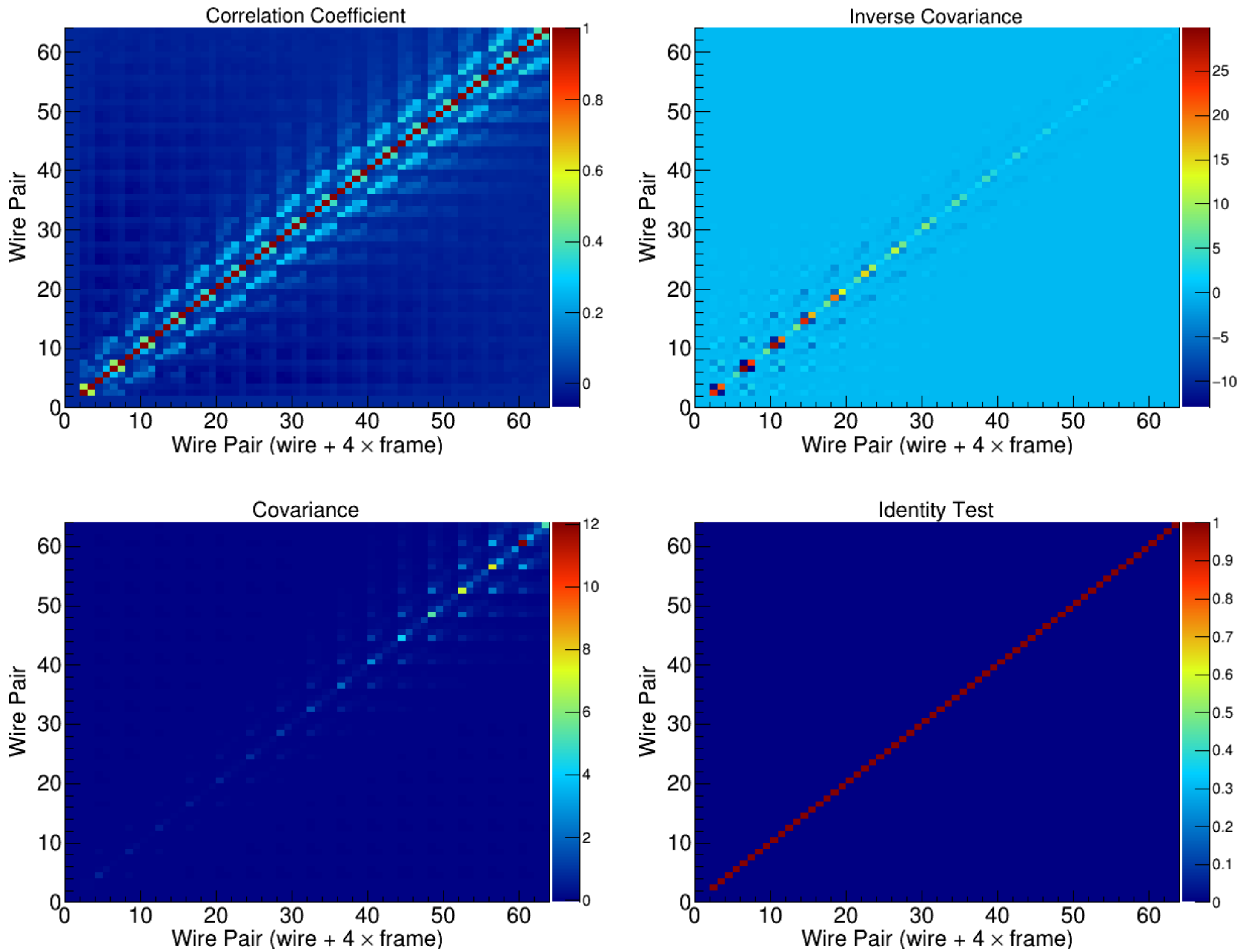
Beam On Physics Asymmetry

Single wire correlation coefficients, covariance and inverse covariance:



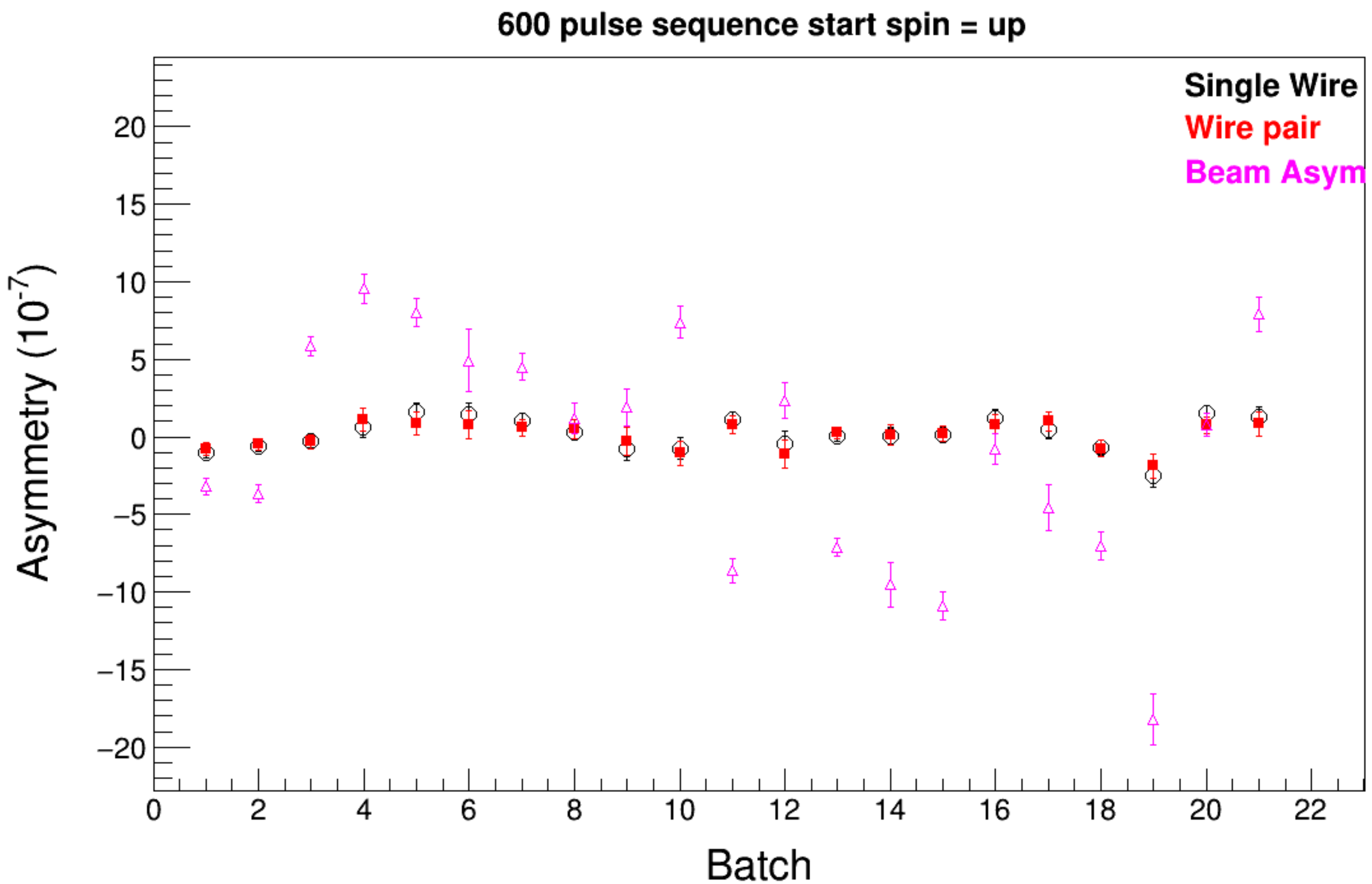
Beam On Physics Asymmetry

Wire pair correlation coefficients, covariance and inverse covariance:



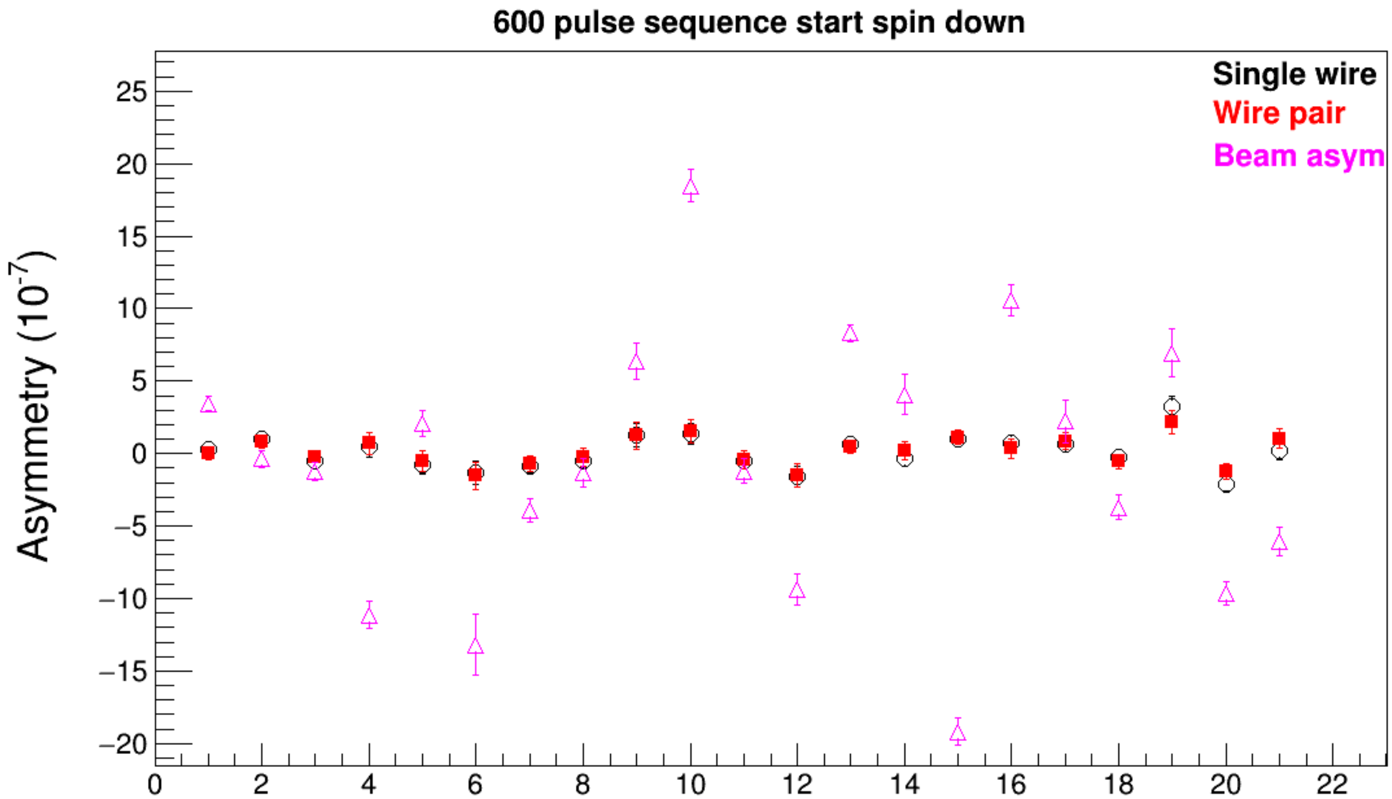
Beam On Physics Asymmetry

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



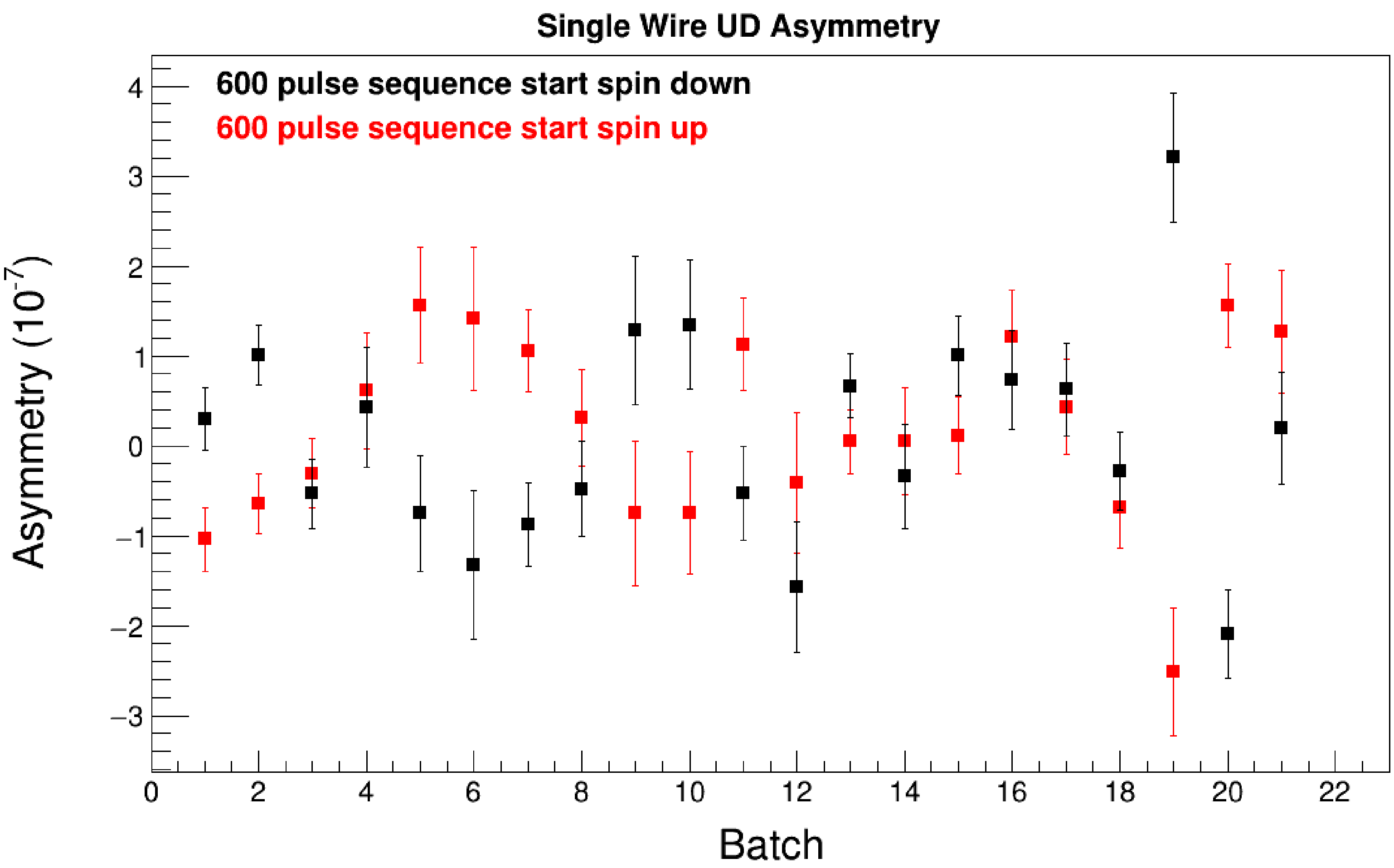
Beam On Physics Asymmetry

UD Asymmetry by batch for starting pulse spin down:



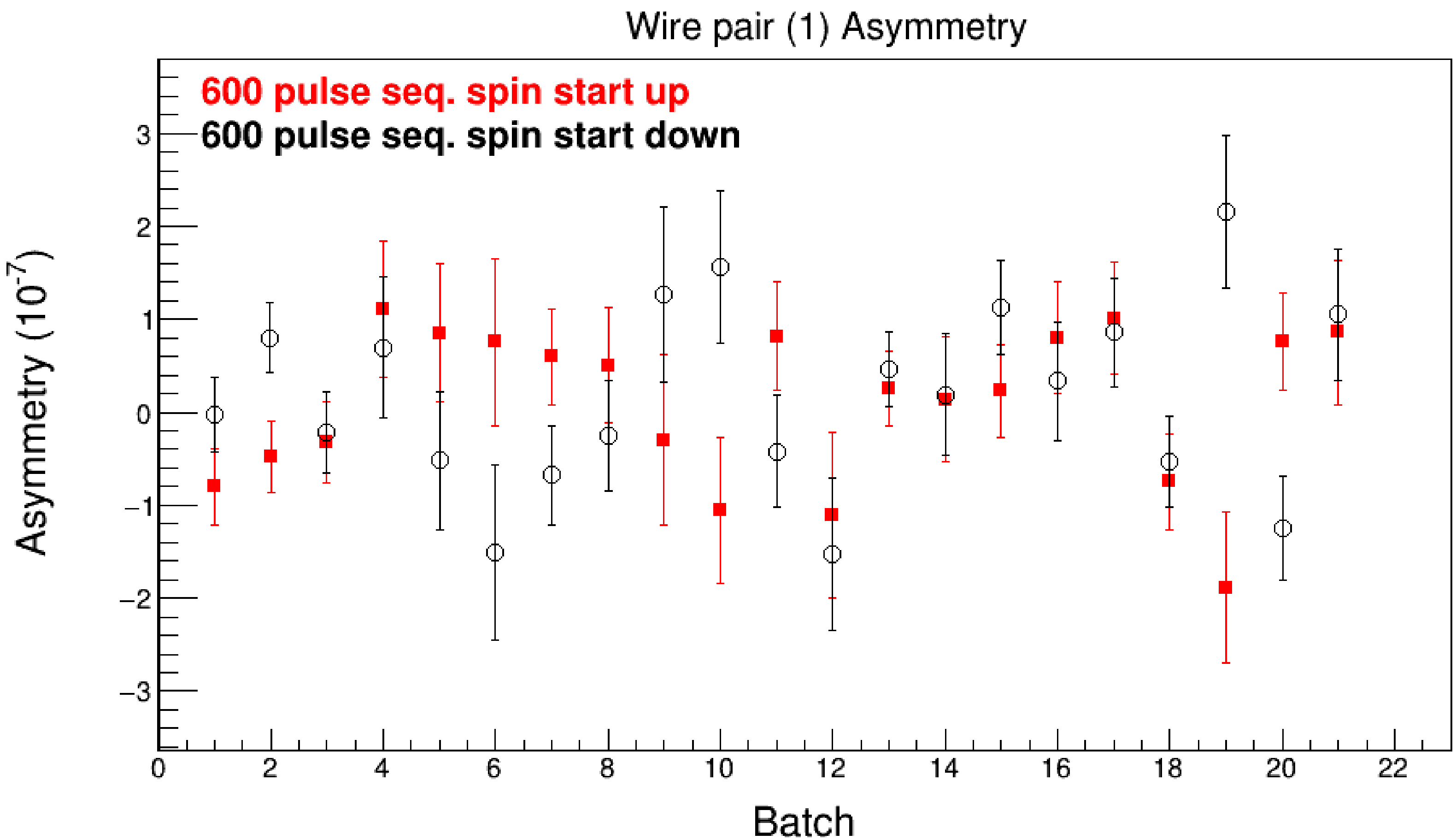
Beam On Physics Asymmetry

UD Asymmetry by batch for both starting spins:



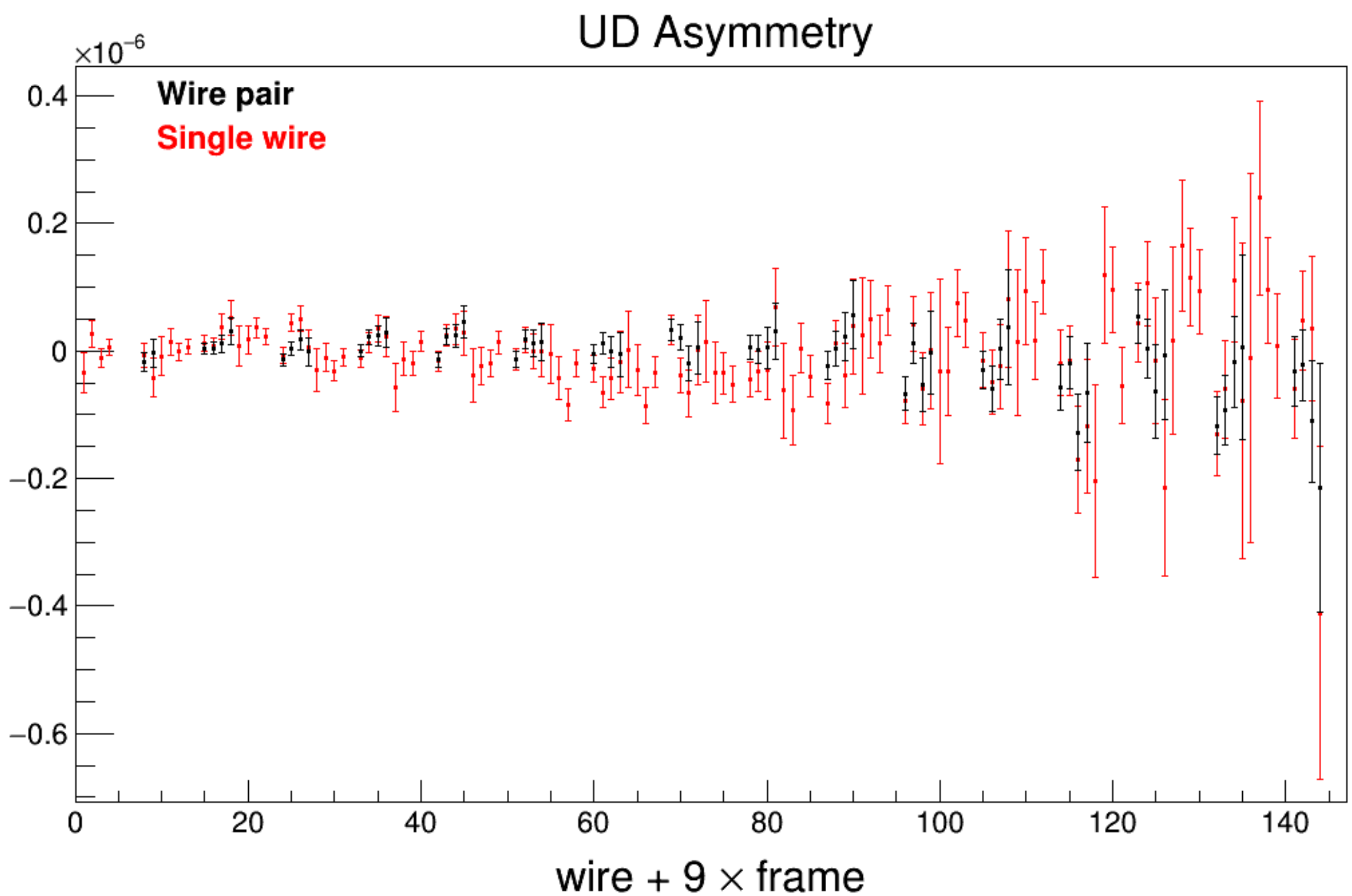
Beam On Physics Asymmetry

UD Asymmetry by batch for both starting spins:



Beam On Physics Asymmetry

UD Asymmetry vs wire for both starting spins:



Beam On Physics Asymmetry

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