Beam Off Asymmetry Analysis - Overall Instrumental Asymmetry Calculations

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rev. 3: - various corrections to asymmetry calculation methods

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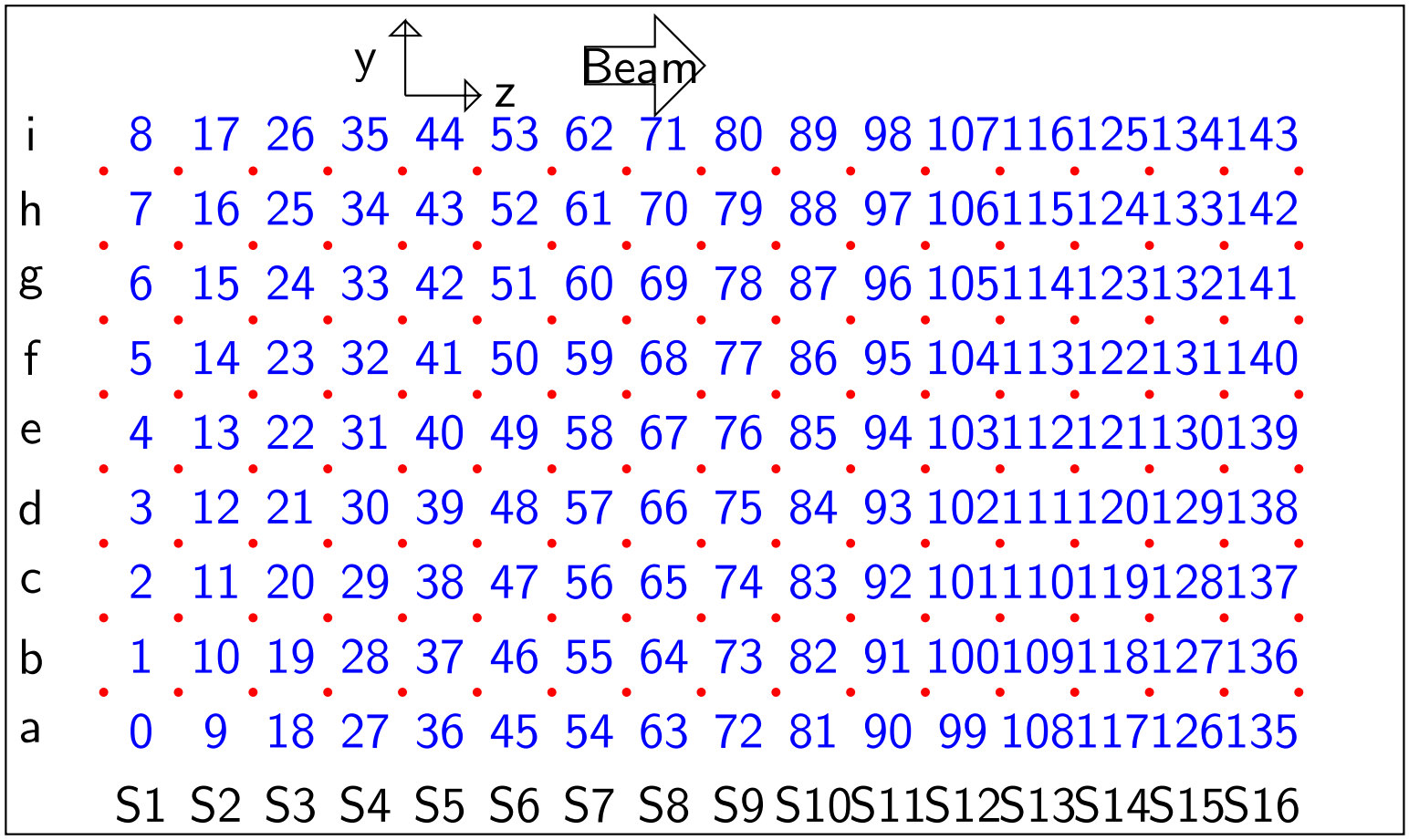
Wire Numbering



- HV 17 HV Frames with 8 wires each
- Signal 16 signal Frames with 9 wires each

Beam Off Asymmetry Calculation

The single wire instrumental asymmetries, $A_{w,j,q,t}$, were calculated using a simple difference formula normalized by one volt to render it unitless.

$$A_{i,j,q} = \frac{Y_{i,j,t,k=\text{even}} - Y_{i,j,t,k=\text{odd}}}{1V} \tag{1}$$

where i is the wire number, j is the run number, t is the time bin number, k is the pulse number, and q is the asymmetry number. Pulse and asymmetry numbers are indexed starting at zero.
Note: Beam on physics asymmetries were calculated over time bins $5 - 44$, and that time bin range was used for all parts of the following analysis.

List of Runs

A list of good beam off runs has been provided by Kabir, and are now on the n3He wiki Instrumental Asym. webpage for reference by the group.

Summer Run List

Date Range	Initial Run	Final Run
2015-06-25	38081	38124
2015-06-26	38125	38215
2015-08-03	38216	38301
2015-08-04	38302	38416
2015-08-10	38417	38493
2015-08-11	38494	38657
2015-08-12	38658	38769

Tuesday Run List

Tuesday Run List

Date Range	Initial Run	Final Run			
T1	17784	17834	T9	32503	32535
T2	19114	19158	T10	45032	45054
T3	20444	20493	T11	46416	46466
T4	21869	21919	T12	49663	49697
T5	24011	24061	T13	51076	51127
T6	26461	26503	T14	52467	52517
T7	27729	27755	T15	56073	56076
T8	30058	30074			

Runs were taken between 9:00am and 4:00pm while beam was off for maintenance, and the total time each Tuesday the beam was off was variable.

Run Statistics

- Run Durations:
  - Standard run length is 24996 pulses long
  - 6.94 minutes per run (8.6 runs per hour)
  - 4.8 days per 1000 runs
- Number of Runs:
  - Total Beam Off Runs: 4035
  - Total Good Beam Off Runs: 3837
  - Better Beam Off Runs : 3437
  - Summer Runs All: 676
  - Summer Runs Period 1: 128
  - Summer Runs Period 2: 198
  - Summer Runs Period 3: 350
  - Tuesday Runs: 565
  - Other Beam Off Runs: 2794

Good Beam Off Runs exclude summer days period 2 where the asymmetry was the worst. Better Beam Off Runs exclude an additional 400 runs that covers a 5000 run range in the time period immediately after the summer running period.

Time Bin and Wire Choices

The time bins and wires that are analyzed for the instrumental asymmetry were chosen to match those used in the physics asymmetry analysis.

- Time bins 5-44 inclusive were analyzed for the chamber wires
- The central row of wires was not analyzed
- Wires 5 and 6 were not analyzed as they did not provide a good signal.
- A total of 126 wires and with 40 times bins were analyzed.

Scaling the Instrumental Asymmetry

The physics asymmetry is calculated as:

$$A_{phys} = \frac{1}{G_i}\frac{Y_i^{\uparrow} - Y_i^{\downarrow}}{Y_i^{\uparrow} + Y_i^{\downarrow}} = \frac{1}{G_i}\frac{S_i^{\uparrow} + b_i^{\uparrow} - S_i^{\downarrow} + b_i^{\downarrow}}{S_i^{\uparrow} + b_i^{\uparrow} + S_i^{\downarrow} + b_i^{\downarrow}} \tag{2}$$

$$\approx \frac{1}{G_i}\frac{S_i^{\uparrow} - S_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} + \frac{1}{G_i}\frac{b_i^{\uparrow} - b_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} \tag{3}$$

assuming $b_i << S_i$, where b is the beam on pedestal.

So to compare the instrumental asymmetry to the physics asymmetry:

$$A_{i,j,q,t} = \frac{Y_{i,j,t,k=\text{even}} - Y_{i,j,t,k=\text{odd}}}{1V} \tag{4}$$

$$\rightarrow A_{j,q,t,scaled} = \frac{1}{G_i}\frac{Y_{i,j,t,k=\text{even}} - Y_{i,j,t,k=\text{odd}}}{2\bar{S}_i} \tag{5}$$

where G_i is the geometry factor for wire i, and $\bar{S}_i$ is the average beam on signal over all beam on runs for wire i.

Averaging Method

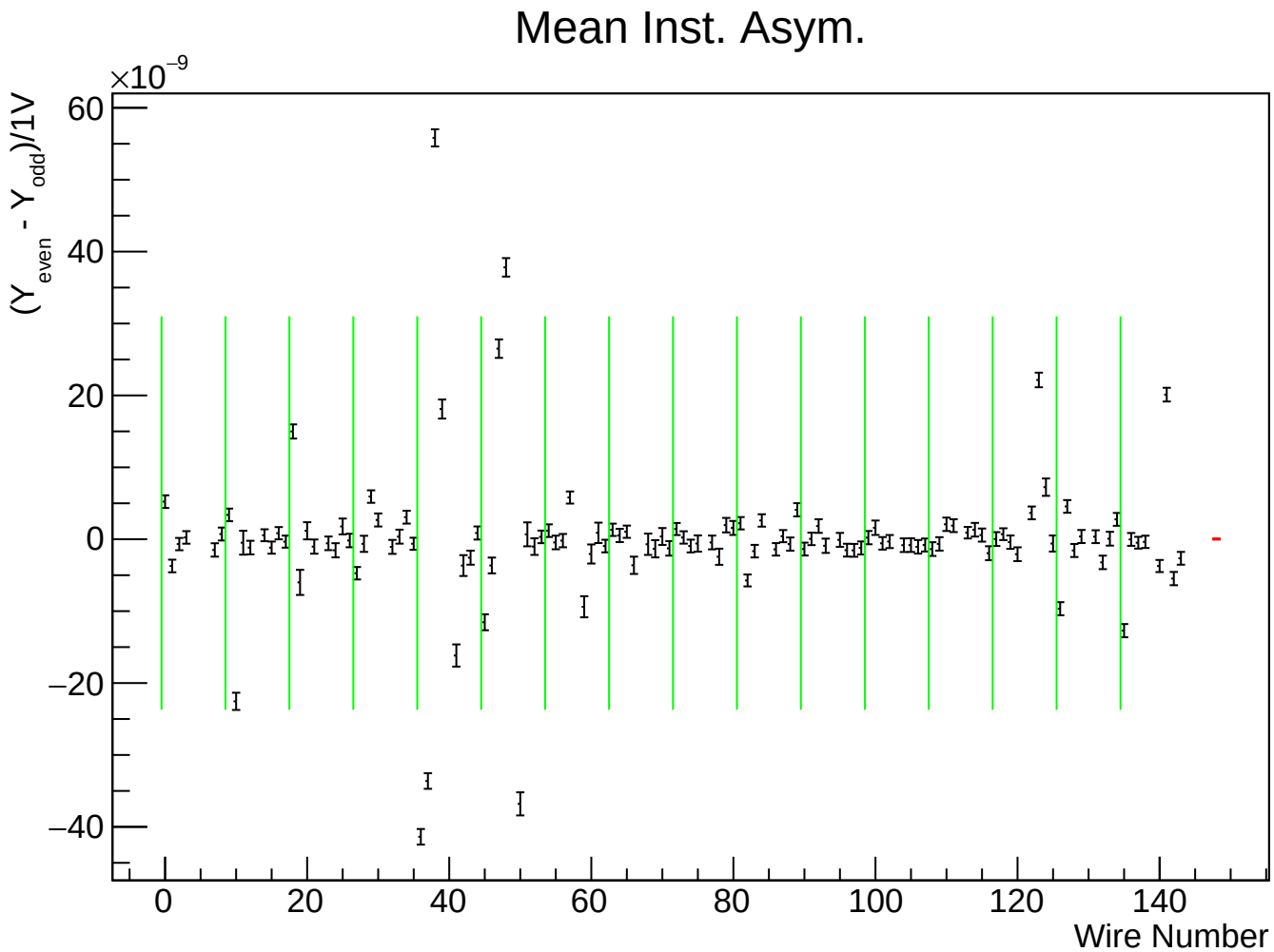
The standard error weighted average is:

$$\bar{x} = \frac{\sum_r x_r/\sigma_r^2}{\sum_r \frac{1}{\sigma_r^2}} \tag{6}$$

$$\sigma_{\bar{x}} = \sqrt{\frac{1}{\sum_r \frac{1}{\sigma_r^2}}} \tag{7}$$

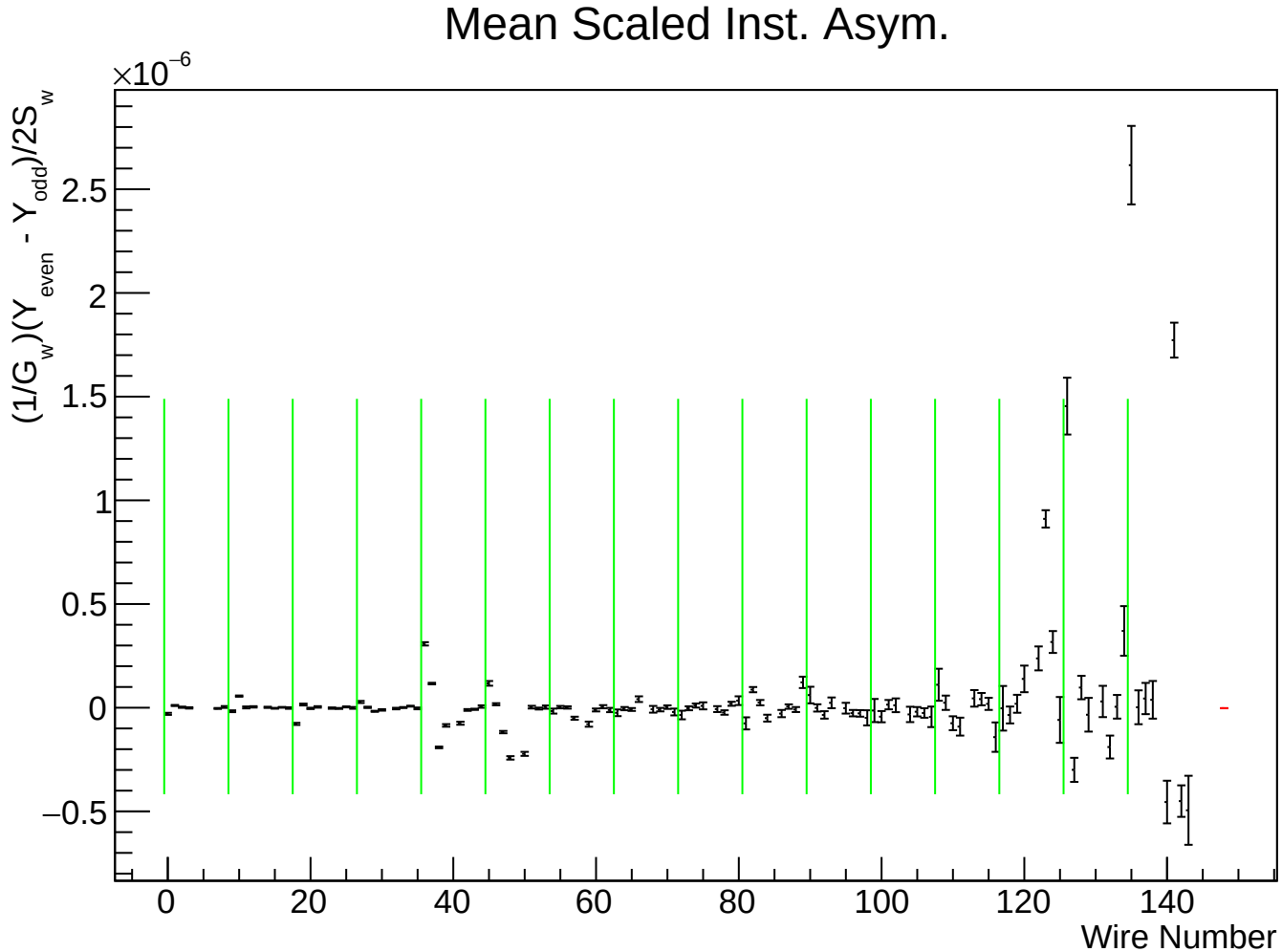
where $\bar{x}$ is the average of x, and σ the uncertainty in x. The standard error was used as the uncertainty for all error weighted averages used in this presentation.
For each run the average instrumental asymmetry, $A_{i,j} = (1/N_q N_t)\sum_q \sum_t A_{i,j,q,t}$, was calculated per wire with a standard error that will be used as the uncertainty σ in the error weighted average. N is the number of items, $N_q = 12498$ and $N_t = 40$.

Error Weighted Average of the Wire Inst. Asyms.



Run Range is for all summer runs, and error bars are standard error. Green lines separate planes.

Error Weighted Average of the Scaled Wire Inst. Asyms.



Run Range is for all summer runs, and error bars are standard error. Green lines separate planes.

Scaled asymmetries have been scaled by the mean wire signal and the geometry factors.

Instrumental Asymmetry Error Weighted Average

Error Weighted Avg. Inst. Asym.		
	Scaled($\times 10^{-10}$)	Un-Scaled($\times 10^{-10}$)
All Beam Off	2.2 ± 1.9	-0.95 ± 0.34
Good Beam Off	2.1 ± 2	-0.83 ± 0.35
Summer All	-23 ± 5	0.31 ± 0.85
Tuesdays	0.18 ± 5	0.74 ± 0.9
Other	8.3 ± 2	-1.2 ± 0.4

Note: These error weighted averages are calculated using the instrumental asymmetry's standard errors per wire rather than the uncertainty on the physics asymmetry which would be the proper weighting as shown on the next slide.

Kabir's Instrumental Asymmetry Method

Instrumental Asymmetry

$$A_i = \frac{Y_i^{\uparrow} - Y_i^{\downarrow}}{Y_i^{\uparrow} + Y_i^{\downarrow}} = \frac{(S_i^{\uparrow} + b_i^{\uparrow}) - (S_i^{\downarrow} + b_i^{\downarrow})}{(S_i^{\uparrow} + b_i^{\uparrow}) + (S_i^{\downarrow} + b_i^{\downarrow})} \approx \frac{S_i^{\uparrow} - S_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} + \frac{b_i^{\uparrow} - b_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} \tag{5}$$

where $b_i^{\uparrow\downarrow}$ is the contribution from pedestal.

$$A_{inst}^i = \frac{1}{G_i} \frac{b_i^{\uparrow} - b_i^{\downarrow}}{2S^i} \tag{6}$$

$$A_{inst} = \frac{\sum_i w_i A_{inst}^i}{\sum_i w_i} \tag{7}$$

$$(\delta A_{inst})^2 = \frac{\sum_i w_i^2 (\delta A_{inst}^i)^2}{(\sum_i w_i)^2} \tag{8}$$

where,

$$w_i = \delta^{-2} A_{phy}^i \tag{9}$$

From meeting on 2017/04/28, Systematics 7, by Kabir.
Note: Geometry factors and averages signals are used for Kabir's asymmetries, and most of those values are less than 1.

Kabir's Run Counting

Instrumental Asymmetry: Tuesday runs vs Summer runs vs all runs

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Summer runs(Total 677 runs):

$$A_{inst} = (13.12 \pm 1.14) \times 10^{-9}. \tag{11}$$

Tuesday runs (Total 620 runs):

$$A_{inst} = (6.918 \pm 1.15) \times 10^{-9}. \tag{12}$$

All runs (Total 4383 runs):

$$A_{inst} = (3.14 \pm 0.60) \times 10^{-9}. \tag{13}$$

From meeting on 2017/05/12, Systematics 9, by Kabir.