n-^{3}He Analysis Outcome

Asymmetry Extraction From n-^{3}He Data: Part 2

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Outline

Data Analysis Algorithm

1. Divide the entire data set into several (contiguous) batches based on beam power stability.
2. Within each batch, separate the runs as A and B groups based on RFSF state on dropped pulses.
3. Within each group, calculate raw asymmetry by considering two consecutive pulses. The yield is background subtracted and normalized by sum over all the detector signals.
4. Cut: Skip dropped pulse and pulses around it. Consider only 600 sequences with no dropped pulse within the sequence.
5. Fill in the histogram per wire for raw asymmetry over all the runs within each group. Get the mean of raw asymmetry from the histogram.
6. Within each batch combine A and B result using simple averaging. Divide by the geometry factor to get physics asymmetry for each wire.
7. Within each batch, considering either A or B group runs($\leftarrow$), calculate correlations and apply that to get correlation corrected physics asymmetry and its uncertainty for group A and B dataset.
$\rightarrow$ Using covariance of A and B, construct covariance for $\frac{1}{2}$(A+B)
8. Combine physics asymmetry from all the batches to get global physics asymmetry for the entire data set.

Combining Group $\mathcal{A}$ & $\mathcal{B}$ data

$$\bar{A}_{\mathcal{A}+\mathcal{B}} = \frac{\bar{A}_{\mathcal{A}} + \bar{A}_{\mathcal{B}}}{2}$$

$$\Delta\bar{A}_{\mathcal{A}+\mathcal{B}} = \frac{\sqrt{\left(\Delta\bar{A}_{\mathcal{A}}\right)^2 + \left(\Delta\bar{A}_{\mathcal{B}}\right)^2}}{2}$$

$$Cov(\bar{A}_{\mathcal{A}+\mathcal{B}}) = \frac{1}{4}\left[\frac{1}{N_{\mathcal{A}}}Cov(A_{\mathcal{A}}) + \frac{1}{N_{\mathcal{B}}}Cov(A_{\mathcal{B}})\right]$$

Correction for correlation : 1.Direct Inversion of Covariance Matrix

$$w_i = \frac{1}{(\delta A_i)^2} = \frac{1}{\sigma_i^2} \longrightarrow w_i = \sum_j Cov(A_p)_{ij}^{-1}$$

$$A_p = \frac{\sum_i w_i A_i^p}{\sum_i w_i} \longrightarrow A_p = \frac{\sum_{ij} Cov(A_p)_{ij}^{-1} A_i^p}{\sum_{ij} Cov(A_p)_{ij}^{-1}}$$

$$\chi^2 = \sum_i \frac{(A_i^p - A_p^{tot})^2}{\sigma_i^2} \longrightarrow \chi^2 = \sum_{ij} (A_i^p - A_p^{tot}) Cov(A_p)_{ij}^{-1} (A_j^p - A_p^{tot})$$

Correction for correlation : 2. Diagonalizing Covariance Matrix

In matrix representation,

$$\bar{A} = bX$$

Where, X is a column matrix filled with all 1 and b is the fit parameter (physics asymmetry).

$$b = (X^T W X)^{-1} X^T W \bar{A}$$

$$(\Delta b)^2 = (X^T W X)^{-1}$$

$$\chi^2 = (\bar{A} - Xb)^T W (\bar{A} - Xb)$$

Where, Weight $W = Cov(A_p)^{-1}$ i.e. inverse of covariance matrix.
Now, let's rotate to a basis where they are uncorrelated,

$$S^T C S = D$$

Where D is a diagonal matrix with diagonal elements

$$D = \text{diag}(\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2, ..., \sigma_{144}^2)$$

Correction for correlation : 2. Diagonalizing Covariance Matrix

In the rotated frame,

$$\bar{A}' = bX' \longrightarrow \text{is our fit in rotated frame}$$

$$b = (X'^T W' X')^{-1} X'^T W' \bar{A}'$$

$$(\Delta b)^2 = (X'^T W' X')^{-1}$$

$$\chi^2 = (\bar{A}' - bX')^T W' (\bar{A}' - bX')$$

Where,

$$A' = S^T \bar{A}$$

$$X' = S^T X$$

$$W' = D^{-1}$$

Do The Fit With Graphical Representation :
If we plot $\bar{A}' X'^{-1}$ vs index i (mode#) $\longrightarrow$ we get linear fit (flat line)
If we plot $\bar{A}'$ vs index i (mode#) $\longrightarrow$ we get a fit which is not flat

Why make A and B separation?

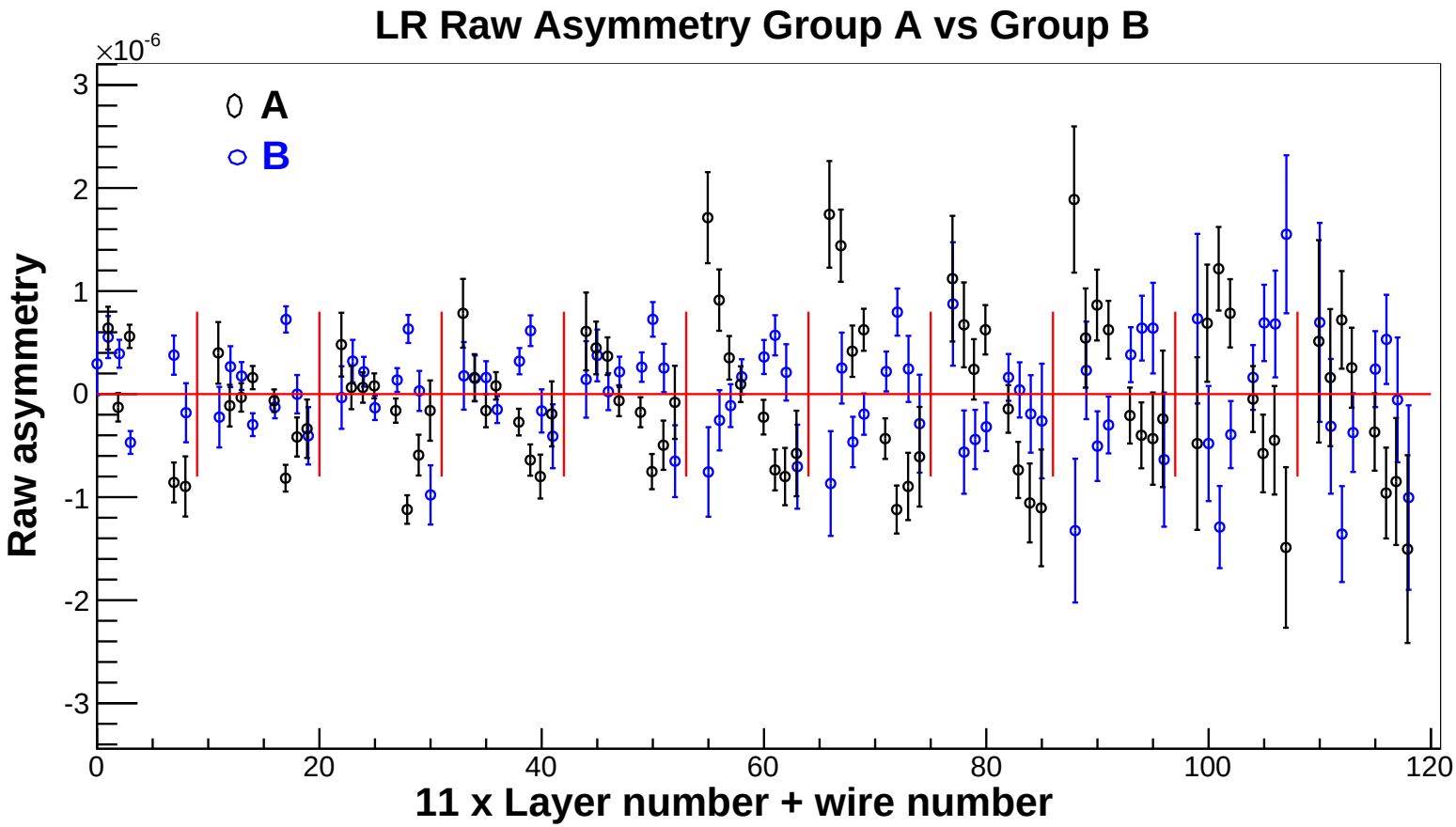


Figure: Raw asymmetry for entire LR data set : Group A vs Group B

Why make A and B separation?

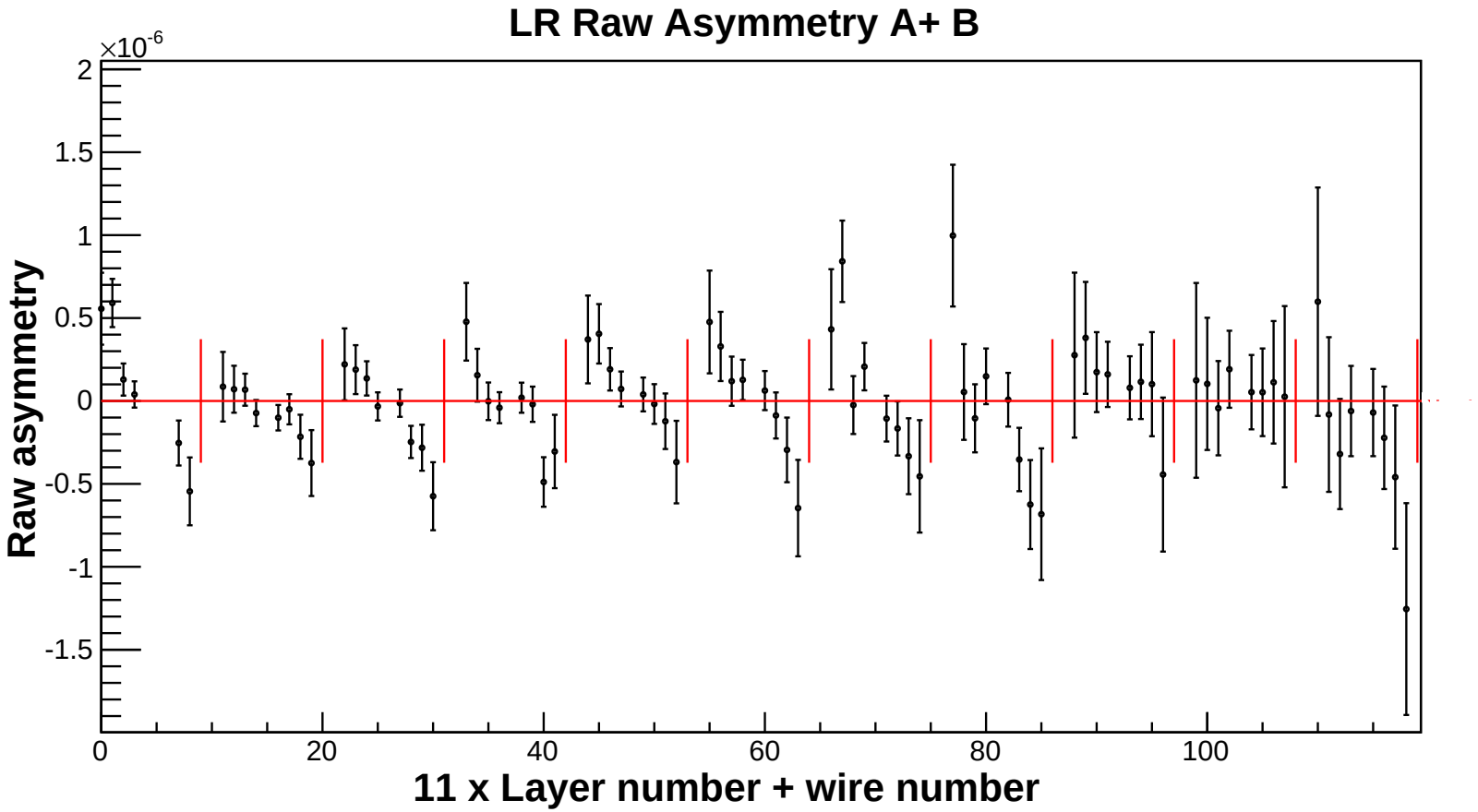
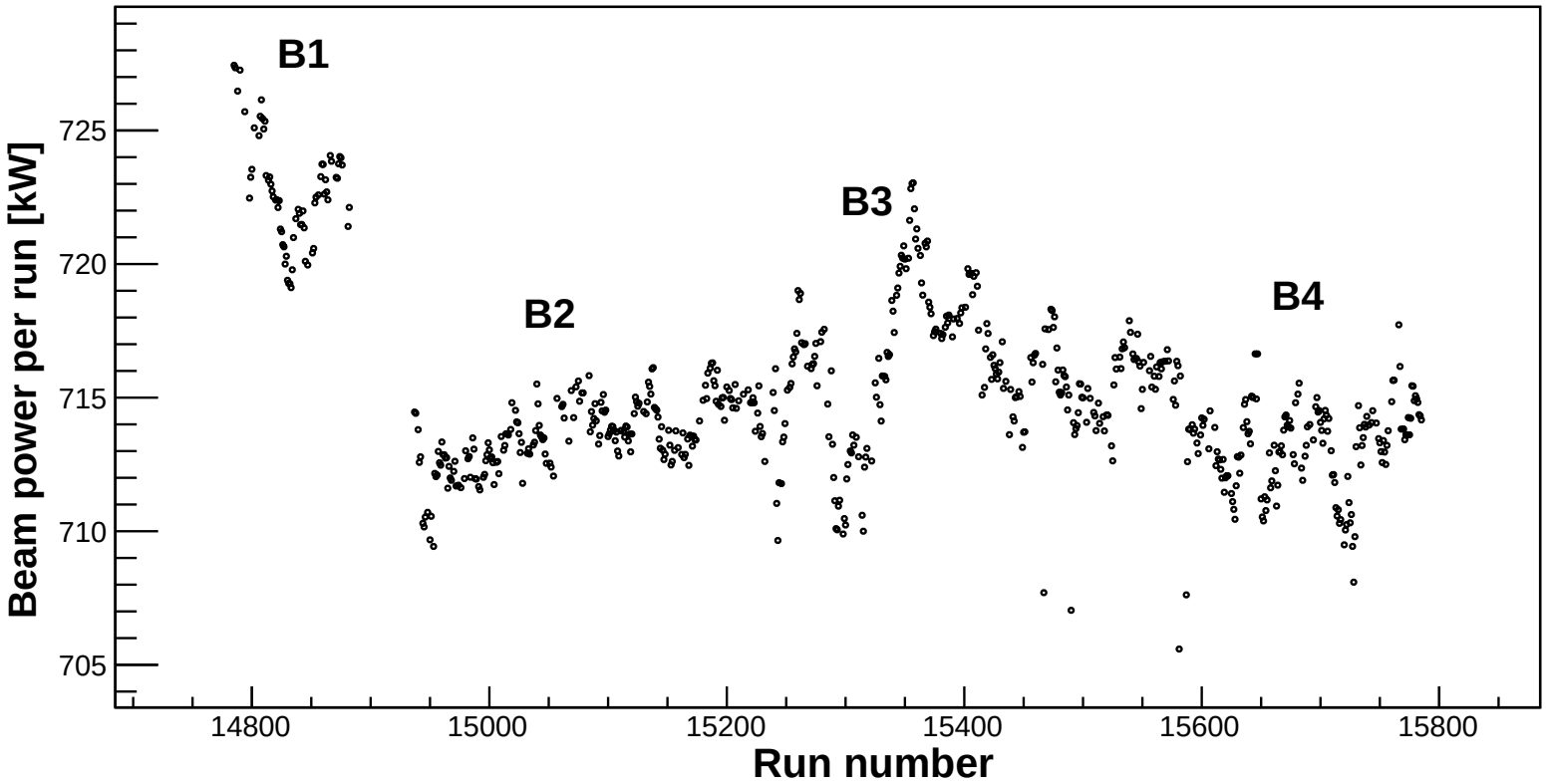


Figure: Raw asymmetry for entire LR data set : Group A + Group B

LR Asymmetry: Data Summary

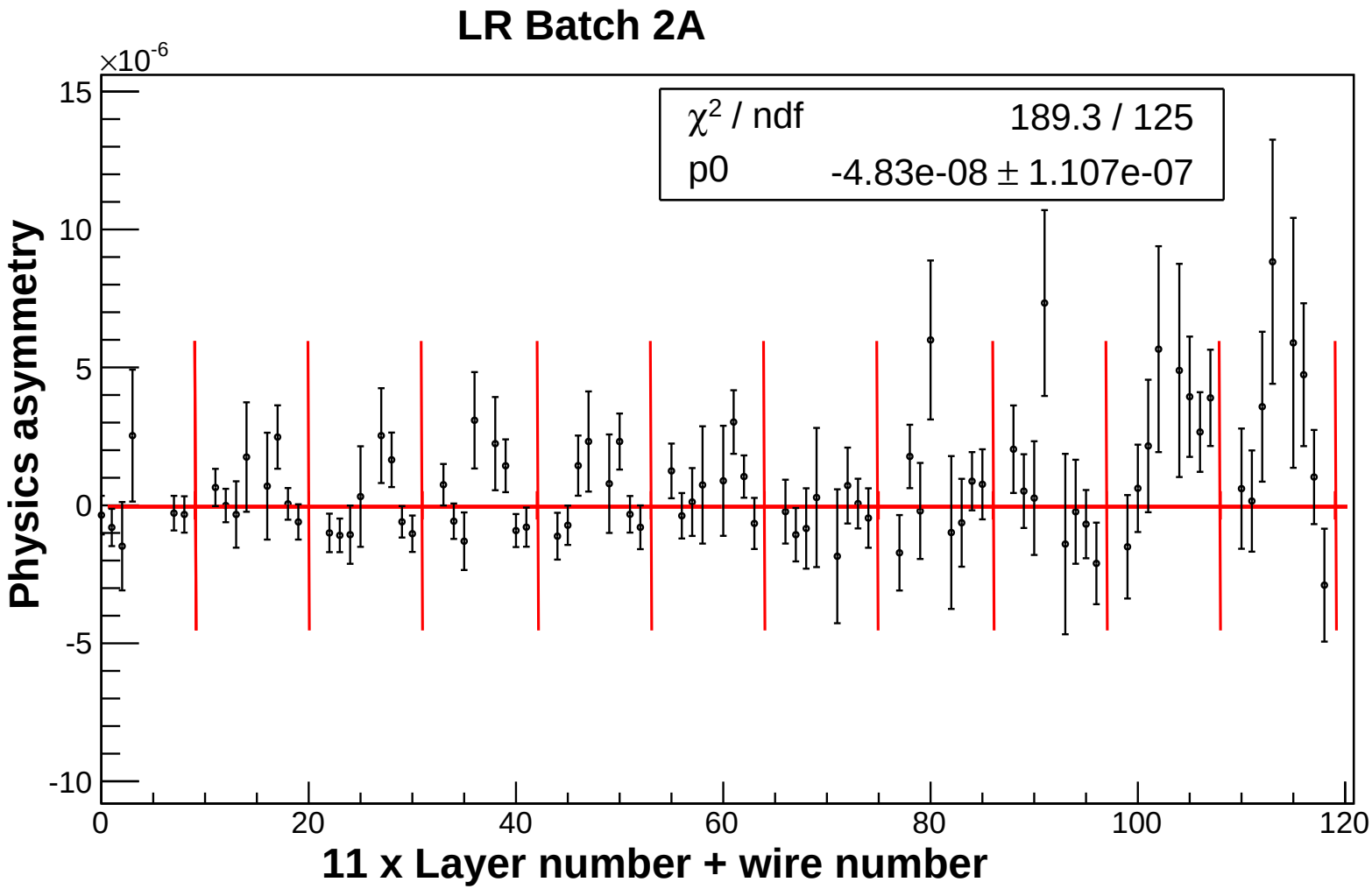
– Run ranges : 14785 - 15860 and 57403 - 57796
– Number of runs analyzed : 718 + 329
– Batches :
Batch-1 : 14785 - 14880
Batch-2 : 14881 - 15235
Batch-3 : 15236 - 15520
Batch-4 : 15521 - 15785
Batch-5 : 15786 - 15860
Batch-6 : 57403 - 57600
Batch-7 : 57601 - 57796

Beam power distribution for LR data

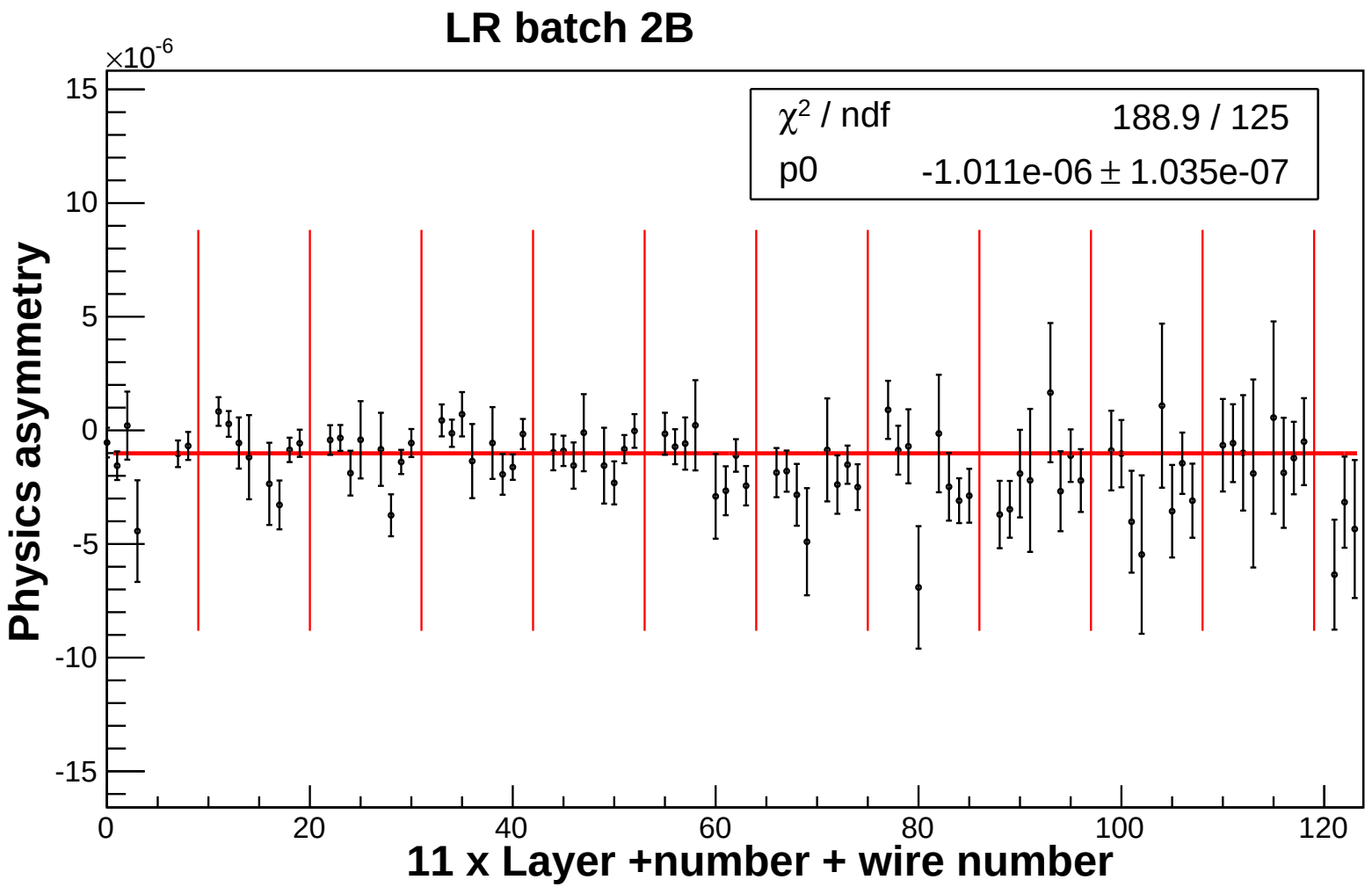


Note : Dropped pulses have been excluded while calculating beam power.

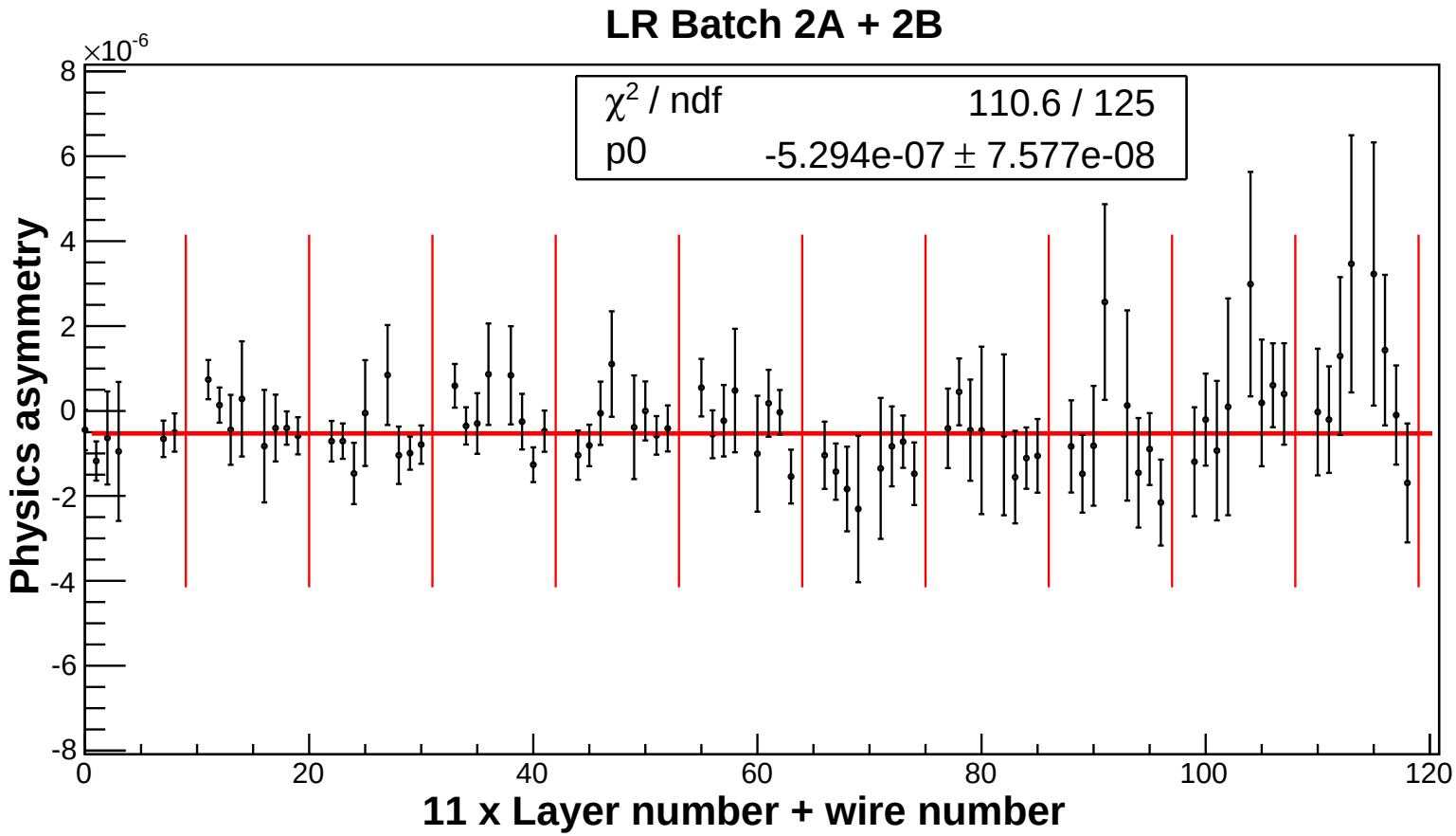
LR Physics Asymmetry from Batch 2A



LR Physics Asymmetry from Batch 2B



LR Physics Asymmetry from Batch 2A+2B (Uncorrected)



LR Physics Asymmetry from Batch 2A+2B (Corrected)

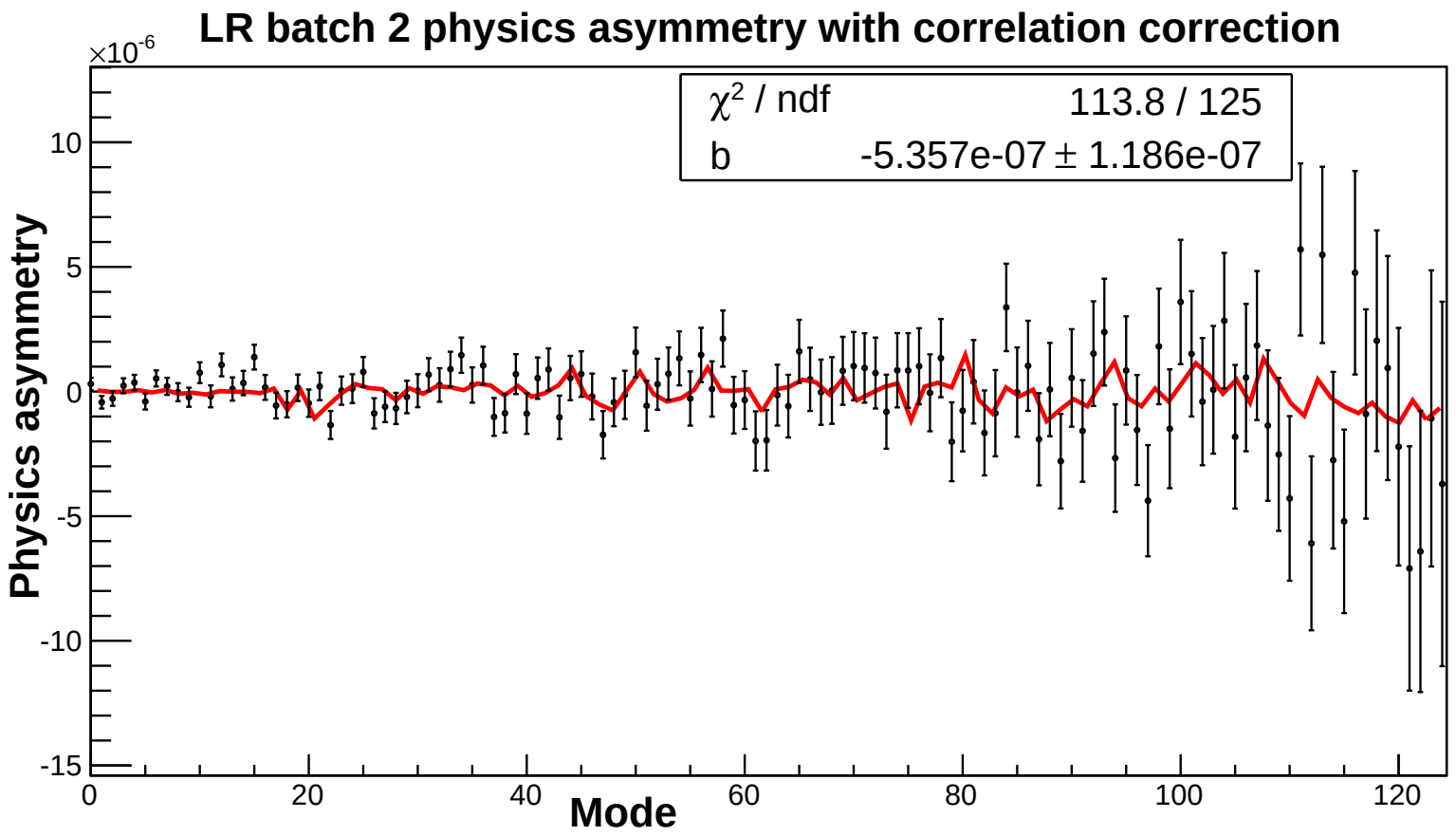


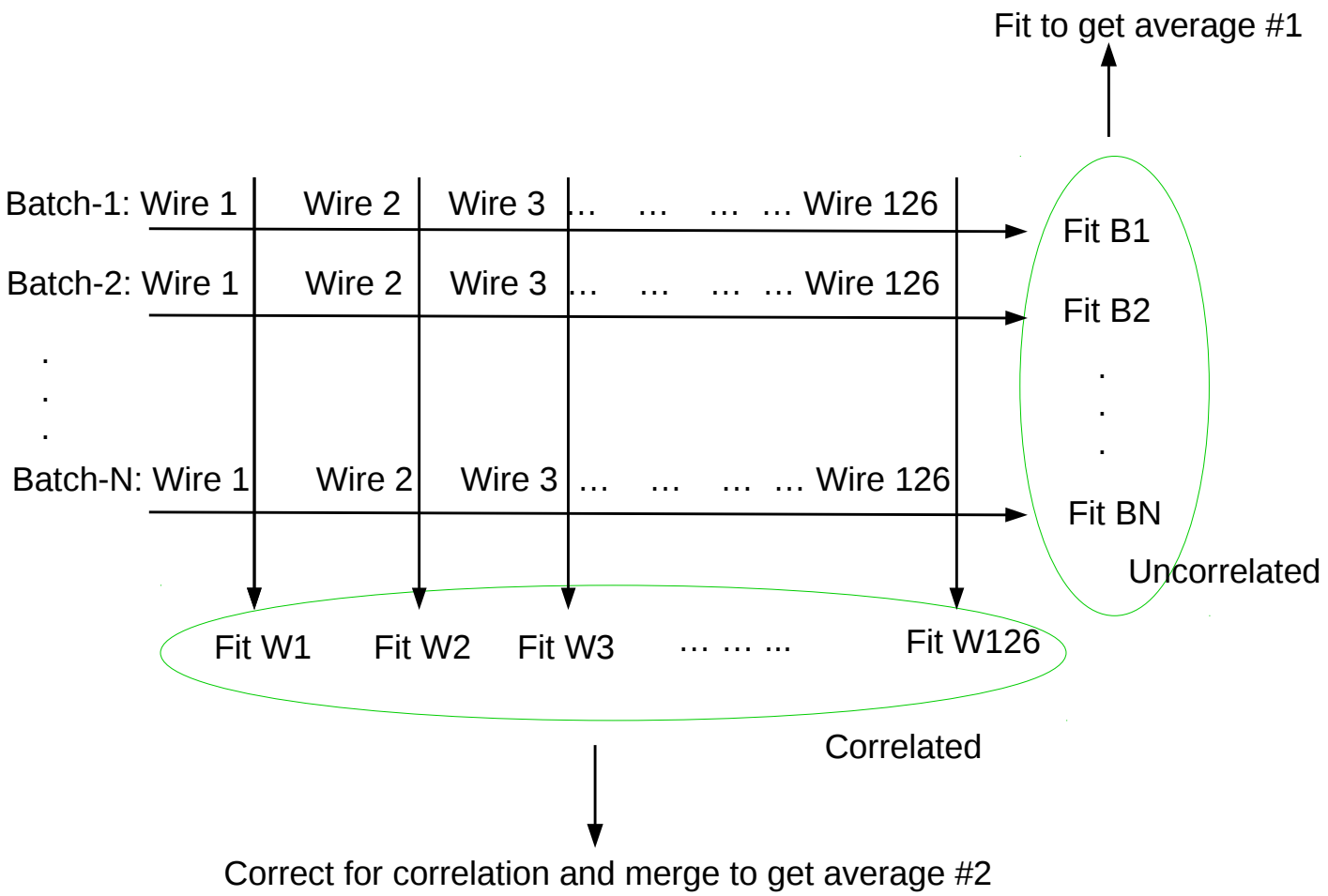
Figure: Fit with covariance for LR batch-2 data

LR asymmetry from different batches

Batch#	Physics Asymmetry		Physics Asymmetry $\mathcal{A}+\mathcal{B}$		Physics Asymmetry (Correlation Corrected)	
	Group: $\mathcal{A}$	Group : $\mathcal{B}$	A $\pm\Delta A$	χ^2/ndf	A $\pm\Delta A$	χ^2/ndf
#1 (64)	-0.56 $\pm$ 1.78	-7.89 $\pm$ 2.09	-4.23 $\pm$ 1.37	113.58/125	-3.81 $\pm$ 2.15	113.96/125
#2 (208)	-0.48 $\pm$ 1.1	-10.11 $\pm$ 1.03	-5.29 $\pm$ 0.76	110.64/125	-5.35 $\pm$ 1.19	113.77/125
#3 (197)	0.91 $\pm$ 1.07	-10.60 $\pm$ 1.12	-4.85 $\pm$ 0.78	141.08/125	-5.09 $\pm$ 1.22	150.37/125
#4 (195)	3.93 $\pm$ 1.09	-8.63 $\pm$ 1.12	-2.35 $\pm$ 0.78	132.35/125	-2.72 $\pm$ 1.22	130.19/125
#5 (57)	4.81 $\pm$ 2.08	-9.92 $\pm$ 2.27	-2.55 $\pm$ 1.54	131.04/125	-3.69 $\pm$ 2.42	147.85/125
#6 (166)	-1.46 $\pm$ 1.30	-4.28 $\pm$ 1.26	-2.87 $\pm$ 0.90	109.46/125	-3.44 $\pm$ 1.39	117.17/125
#7 (163)	-13.00 $\pm$ 1.10	4.61 $\pm$ 1.05	-4.20 $\pm$ 0.76	115.51/125	-3.97 $\pm$ 1.17	106.85/125

Note : Asymmetries and their errors are presented in 10^{-7}.

Data Reduction



Fit Along Batches

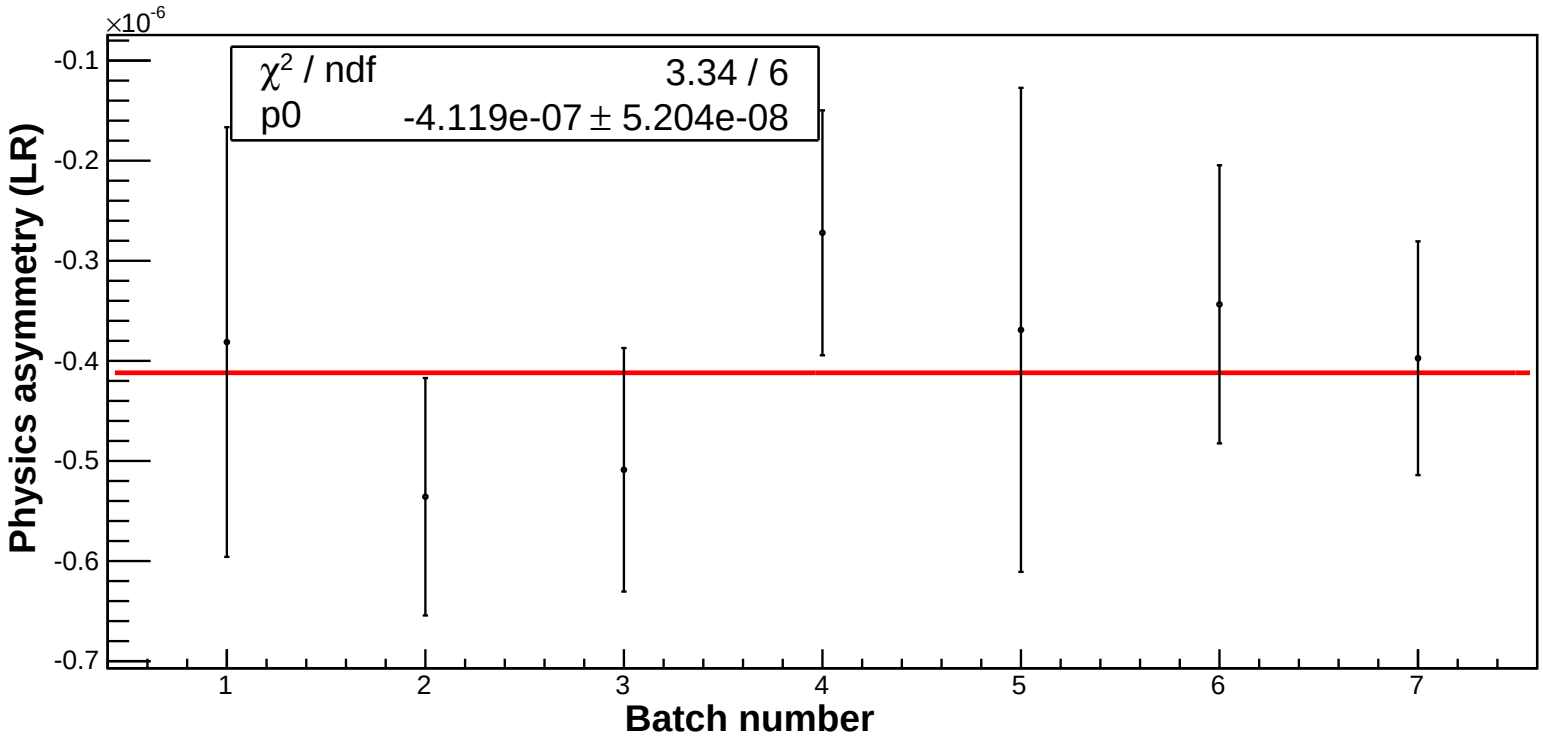


Figure: Average LR physics asymmetry over all batches

Distribution of chi square

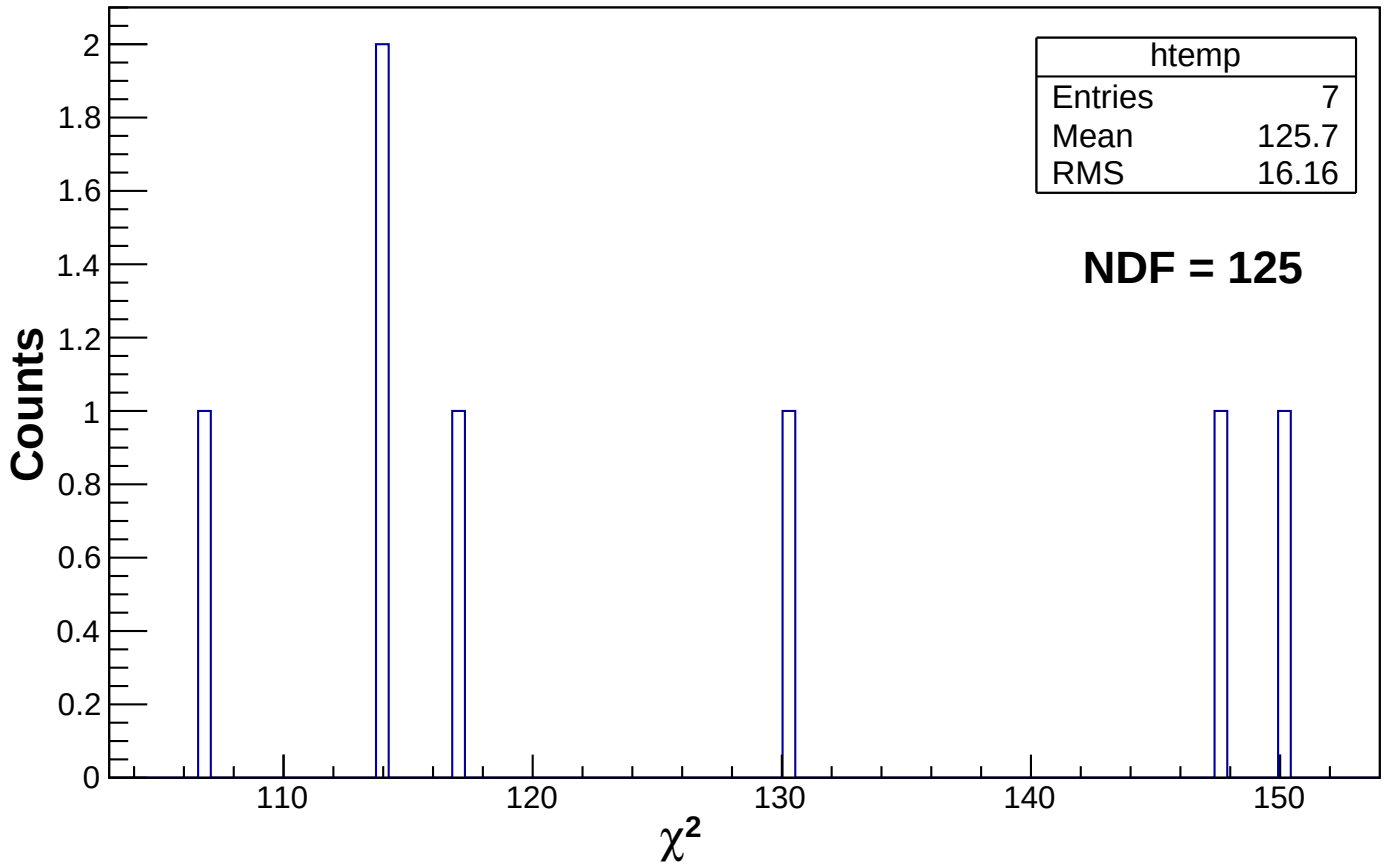


Figure: Chi squares from the LR batches

Fit Along Wires

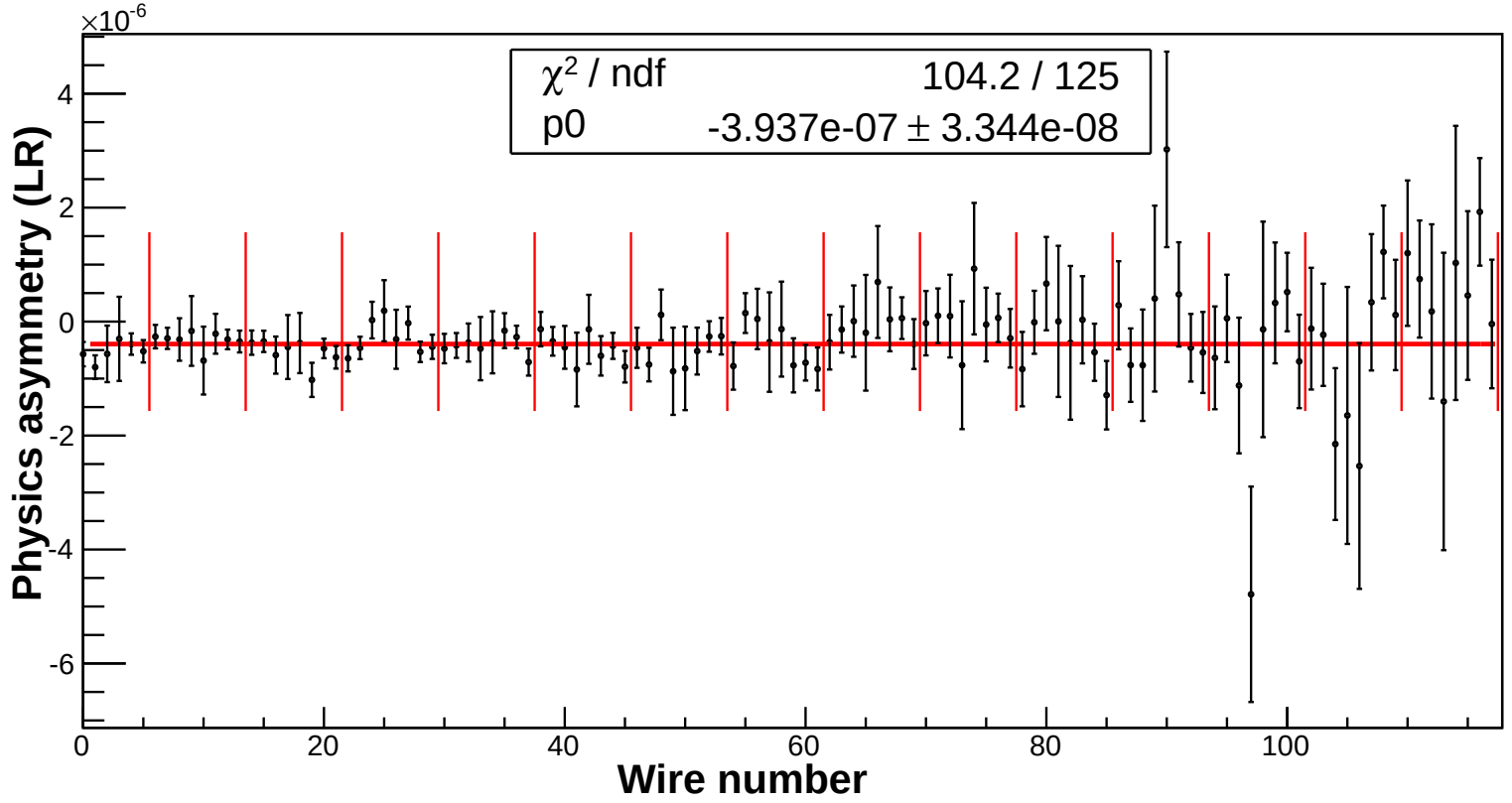


Figure: Physics asymmetry for each wire after fit

Fit Along Wires

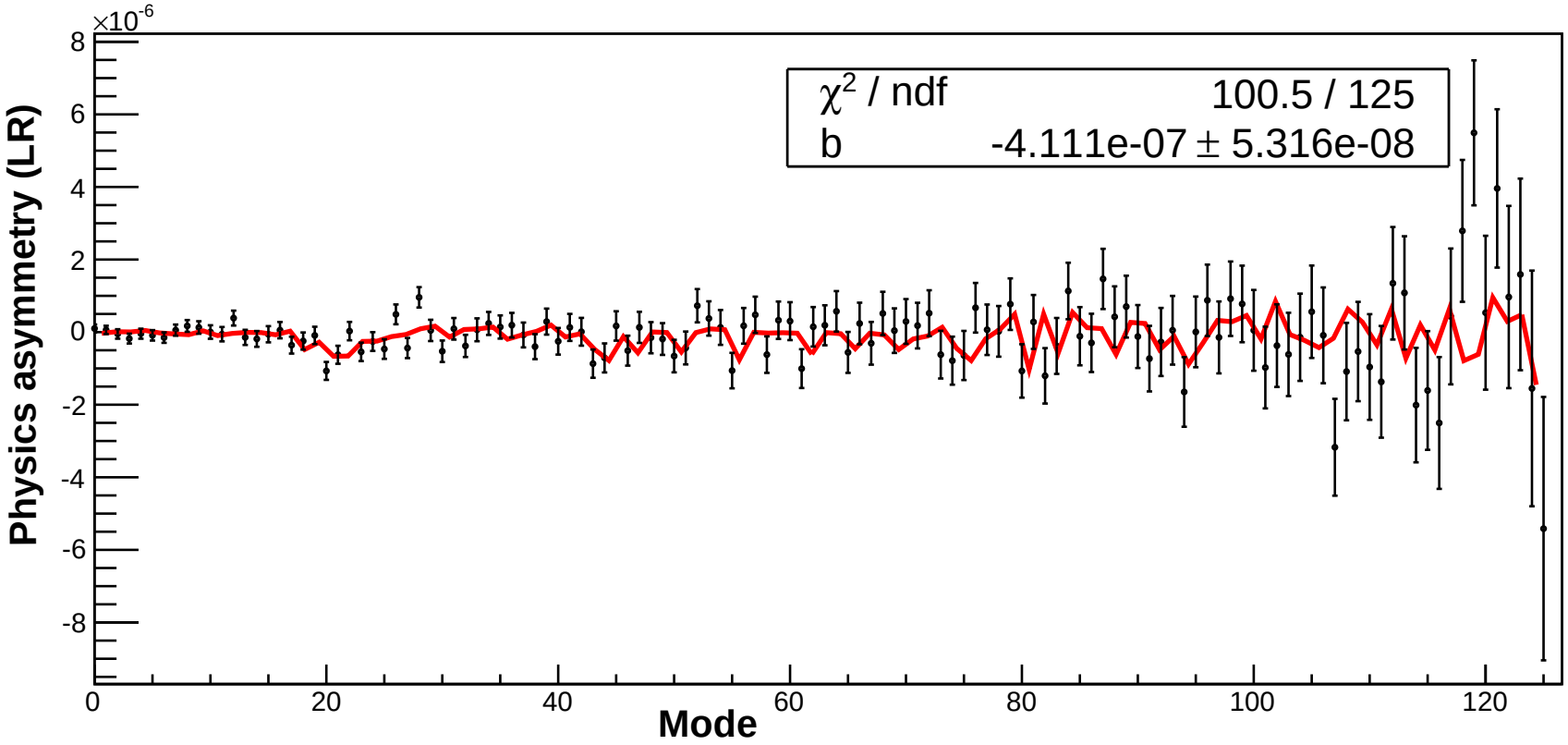
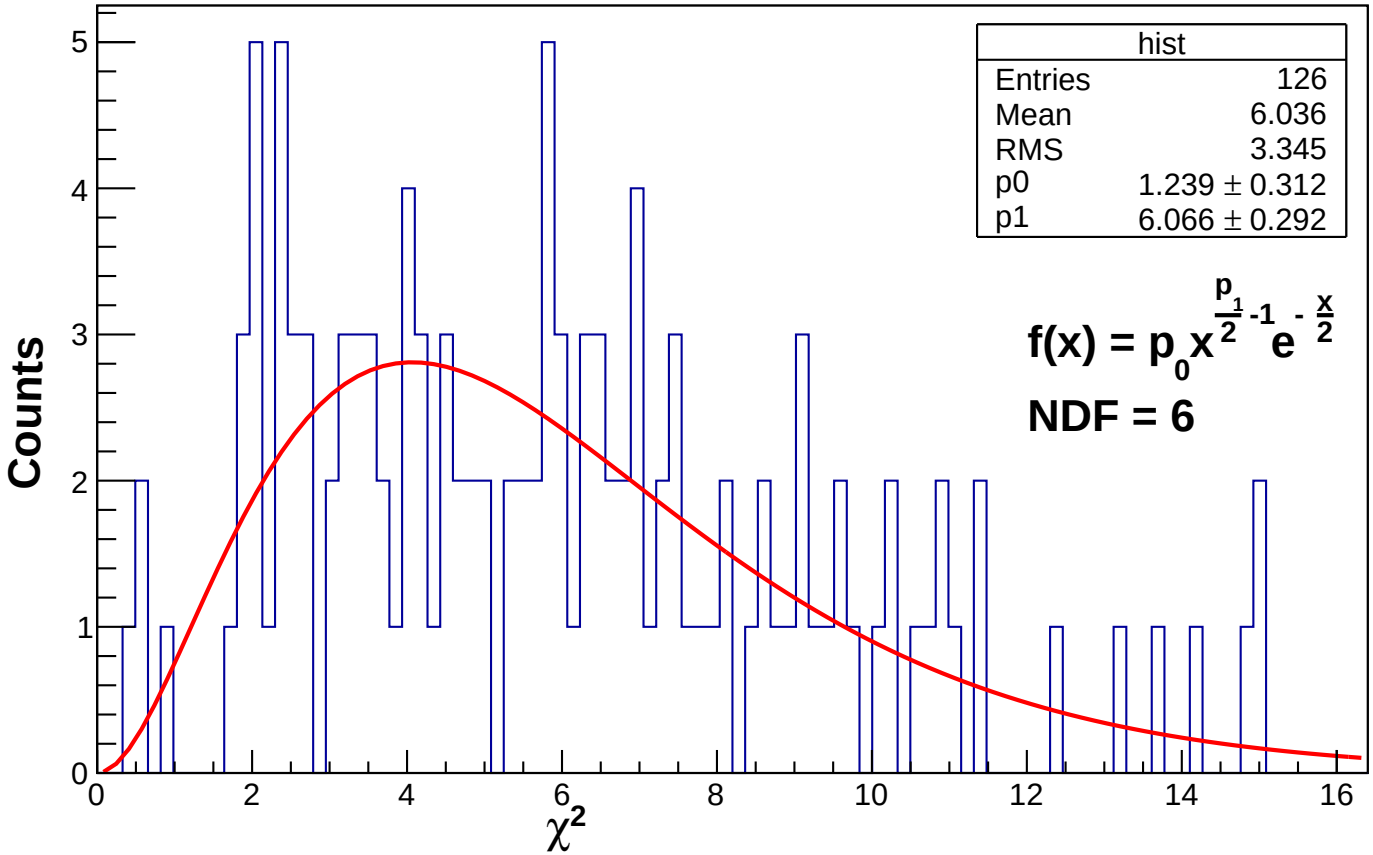


Figure: LR physics asymmetry (corrected) using fit for each wire

Fit Along Wires



Note : Log likelihood fit method is used for the fit

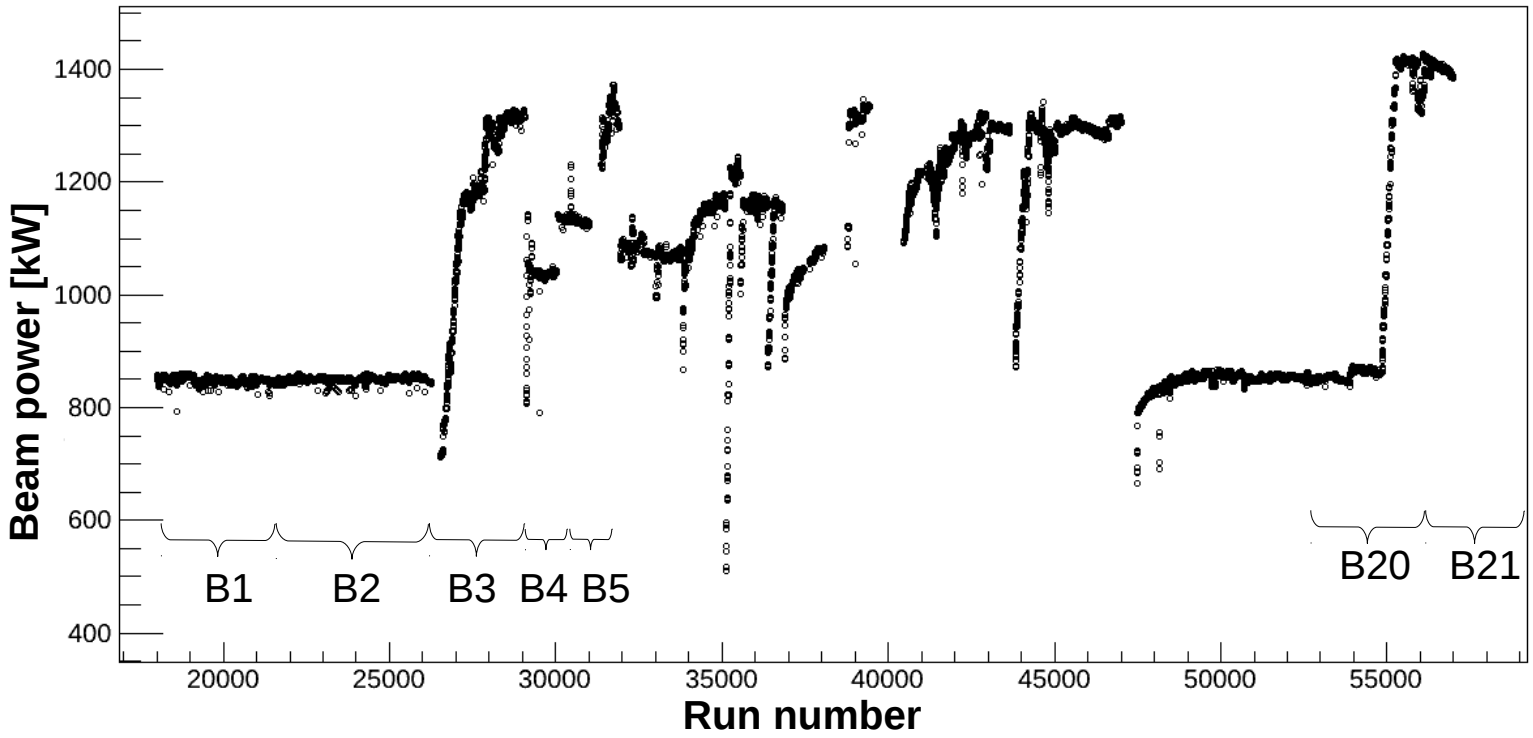
UD Asymmetry

Run summary:
Run ranges : 18000 - 57000
Batch -1 : 18000 - 22000
Batch -2 : 22001 - 26500
Batch -3 : 26501 - 29100
Batch -4 : 29101 - 30050
Batch -5 : 30051 - 31250
Batch -6 : 31251 - 31930
Batch -7 : 31931 - 33800
Batch -8 : 33801 - 35100
Batch -9 : 35101 - 35660
Batch -10 : 35661 - 36380
Batch -11 : 36381 - 38100

UD Asymmetry

Run summary:
Batch -12 : 38101 - 40000
Batch -13 : 40001 - 43700
Batch -14 : 43701 - 45200
Batch -15 : 45201 - 47200
Batch -16 : 47201 - 49200
Batch -17 : 49201 - 51200
Batch -18 : 51201 - 53800
Batch -19 : 53801 - 54800
Batch -20 : 54801 - 56340
Batch -21 : 56341 - 57000

Beam power distribution for UD dataset



Note : Dropped pulses have been excluded while calculating beam power.

UD physics asymmetry for batch 2 (Uncorrected)

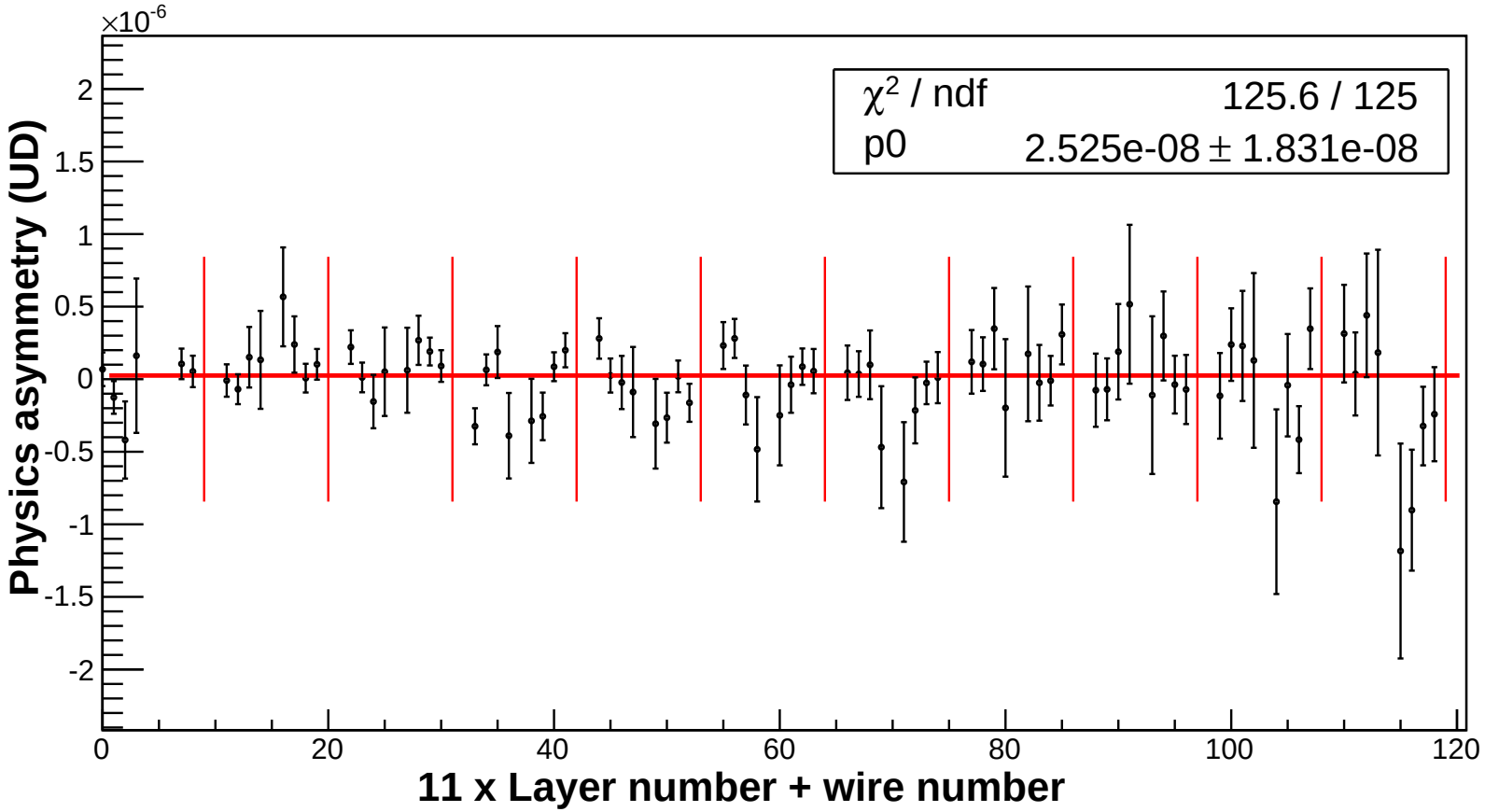


Figure: UD physics asymmetry (uncorrected) for batch 2 after combining group A and B

UD physics asymmetry for batch 2 (Corrected)

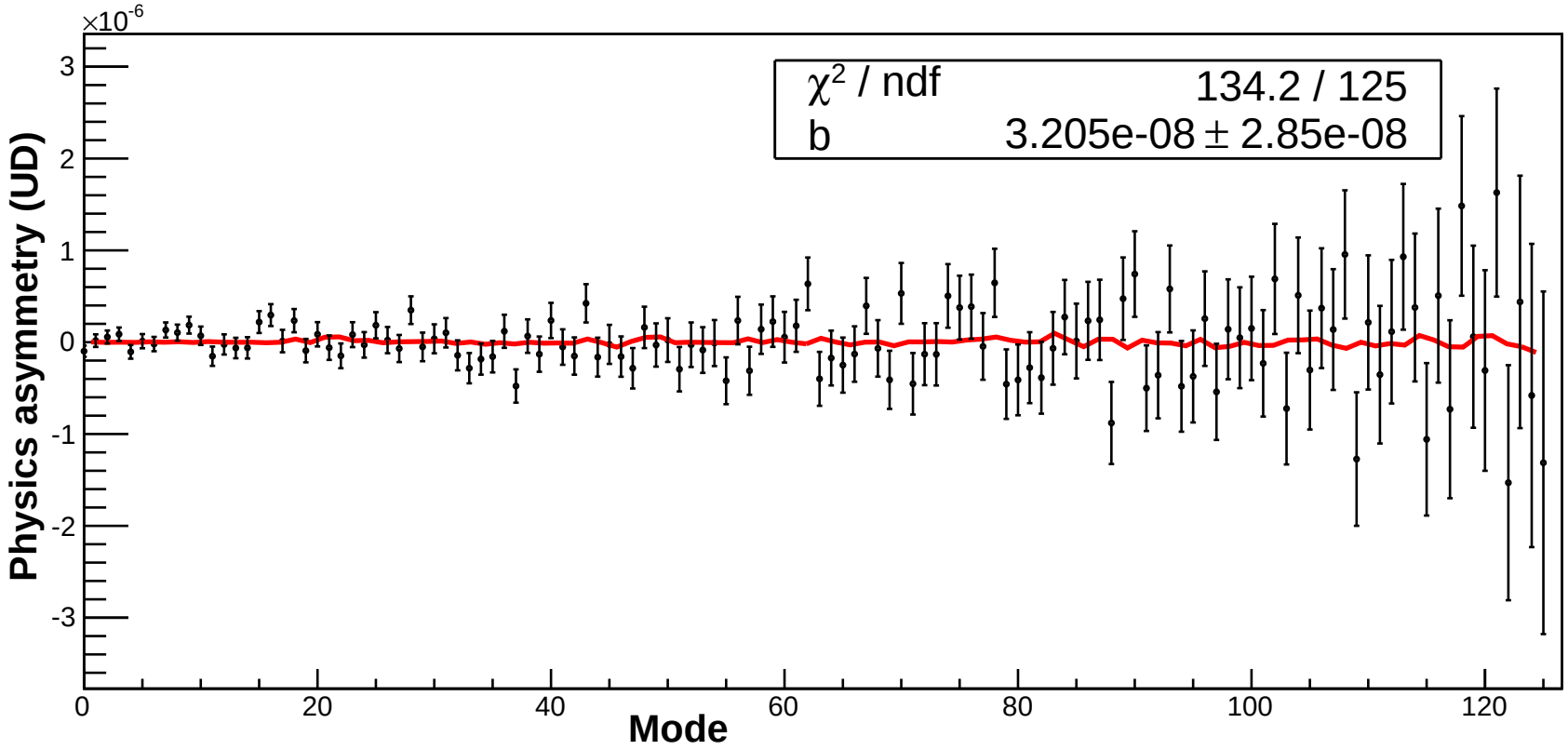


Figure: UD physics asymmetry (corrected) for batch 2

Batch#	Physics Asymmetry		Physics Asymmetry A + B		Physics Asymmetry (Correlation Corrected)	
	Group:A	Group : B	A $\pm\Delta A$	χ^2/ndf	A $\pm\Delta A$	χ^2/ndf
#1 (3242)	-13.16 $\pm$ 2.75	6.25 $\pm$ 2.73	-3.45 $\pm$ 1.94	142.25/125	-4.61 $\pm$ 3.04	142.07/125
#2 (3679)	-6.57 $\pm$ 2.60	11.61 $\pm$ 2.58	2.52 $\pm$ 1.83	125.56/125	3.20 $\pm$ 2.85	134.22/125
#3 (1954)	-1.69 $\pm$ 3.09	-7.09 $\pm$ 3.09	-4.39 $\pm$ 2.18	146.96/125	-5.13 $\pm$ 3.40	136.34/125
#4 (782)	8.11 $\pm$ 5.08	1.77 $\pm$ 5.20	4.95 $\pm$ 3.64	142.68/125	5.81 $\pm$ 5.69	133.15/125
#5 (729)	14.64 $\pm$ 5.07	-4.66 $\pm$ 5.13	4.99 $\pm$ 3.61	146.91/125	2.91 $\pm$ 5.62	158.73/125
#6 (397)	15.53 $\pm$ 6.33	-18.76 $\pm$ 6.77	-1.62 $\pm$ 4.63	105.16/125	-2.82 $\pm$ 7.17	110.00/125
#7 (1483)	14.58 $\pm$ 3.66	-13.72 $\pm$ 3.69	0.43 $\pm$ 2.60	142.05/125	-0.96 $\pm$ 4.06	145.58/125
#8 (1072)	9.78 $\pm$ 4.30	-8.57 $\pm$ 4.18	0.60 $\pm$ 3.00	152.35/125	1.36 $\pm$ 4.68	125.17/125
#9 (467)	-16.97 $\pm$ 6.61	14.69 $\pm$ 6.71	-1.13 $\pm$ 4.71	134.70/125	0.73 $\pm$ 7.37	142.04/125
#10 (609)	-10.24 $\pm$ 5.37	7.54 $\pm$ 5.74	-1.35 $\pm$ 3.93	153.14/125	0.25 $\pm$ 6.13	154.30/125
#11 (1270)	10.17 $\pm$ 3.97	-2.06 $\pm$ 4.12	4.06 $\pm$ 2.86	201.82/125	3.37 $\pm$ 4.48	182.78/125
#12 (503)	-12.46 $\pm$ 6.18	-9.33 $\pm$ 5.66	-10.90 $\pm$ 4.19	158.10/125	-8.32 $\pm$ 6.50	152.74/125
#13 (2464)	1.15 $\pm$ 2.82	2.56 $\pm$ 2.77	1.85 $\pm$ 1.98	171.64/125	2.02 $\pm$ 3.07	148.87/125
#14 (1045)	0.26 $\pm$ 4.68	-5.80 $\pm$ 4.56	-2.77 $\pm$ 3.26	103.27/125	-1.23 $\pm$ 5.08	102.23/125
#15 (1553)	-0.06 $\pm$ 3.33	9.80 $\pm$ 3.46	4.87 $\pm$ 2.40	188.27/125	5.86 $\pm$ 3.73	185.47/125
#16 (1498)	11.96 $\pm$ 4.16	3.32 $\pm$ 4.42	7.64 $\pm$ 3.04	106.6/125	5.78 $\pm$ 4.77	110.42/125
#17 (1559)	4.57 $\pm$ 4.14	6.39 $\pm$ 4.00	5.48 $\pm$ 2.88	133.80/125	8.20 $\pm$ 4.52	148.30/125
#18 (2280)	-4.37 $\pm$ 3.81	-4.46 $\pm$ 3.70	-4.41 $\pm$ 2.65	161.43/125	-4.31 $\pm$ 4.11	163.19/125
#19 (891)	-34.02 $\pm$ 6.01	44.32 $\pm$ 6.05	5.15 $\pm$ 4.26	146.76/125	4.58 $\pm$ 6.59	128.37/125
#20 (1111)	18.33 $\pm$ 3.78	-23.47 $\pm$ 4.06	-2.57 $\pm$ 2.77	131.20/125	-0.42 $\pm$ 4.31	144.69/125
#21 (614)	14.52 $\pm$ 5.33	5.21 $\pm$ 4.85	9.86 $\pm$ 3.60	161.43/125	9.87 $\pm$ 5.60	114.66/125

Note : Asymmetries and their errors are presented in 10^{-8} in this table.

Distribution for chi square

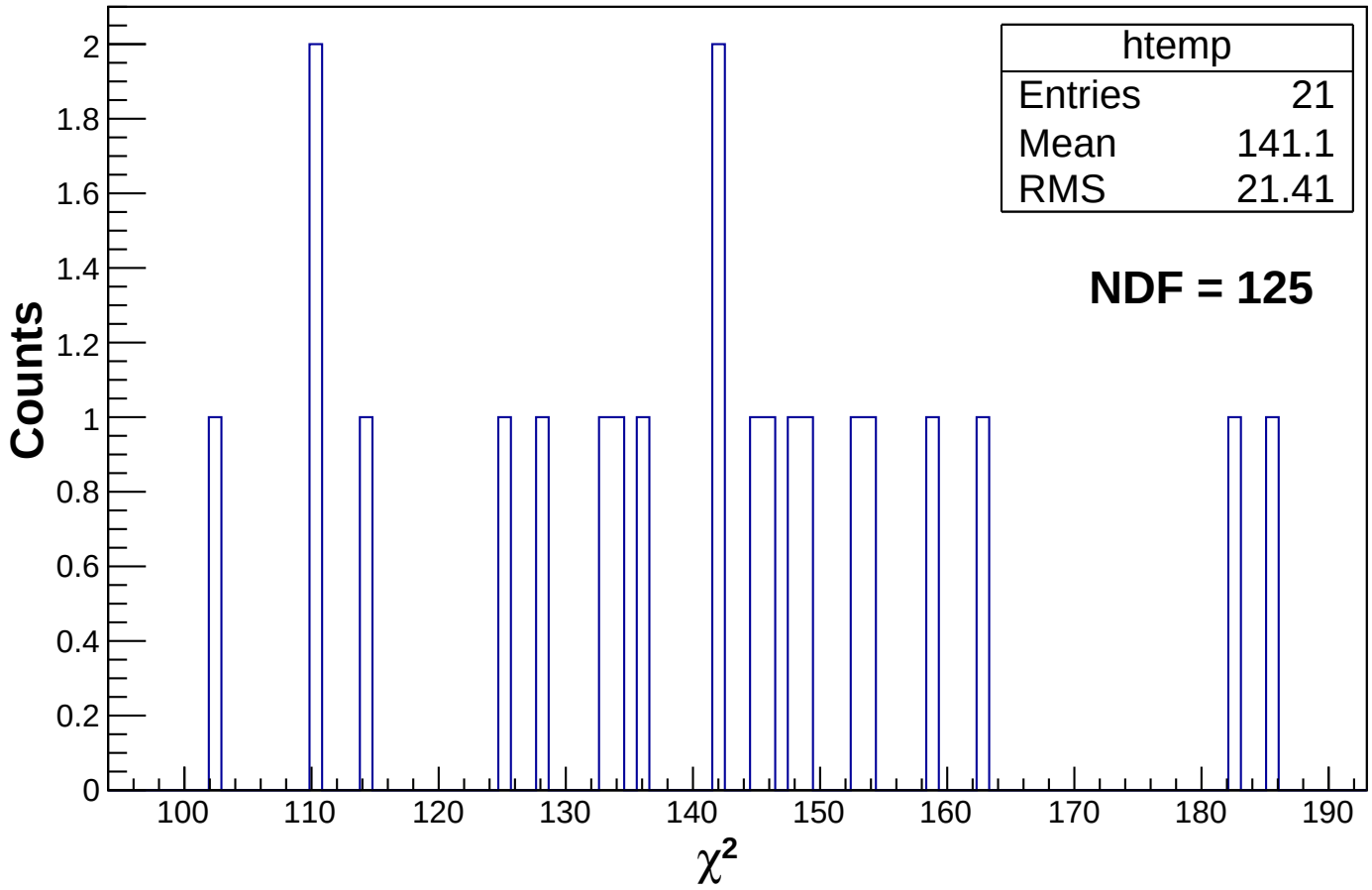
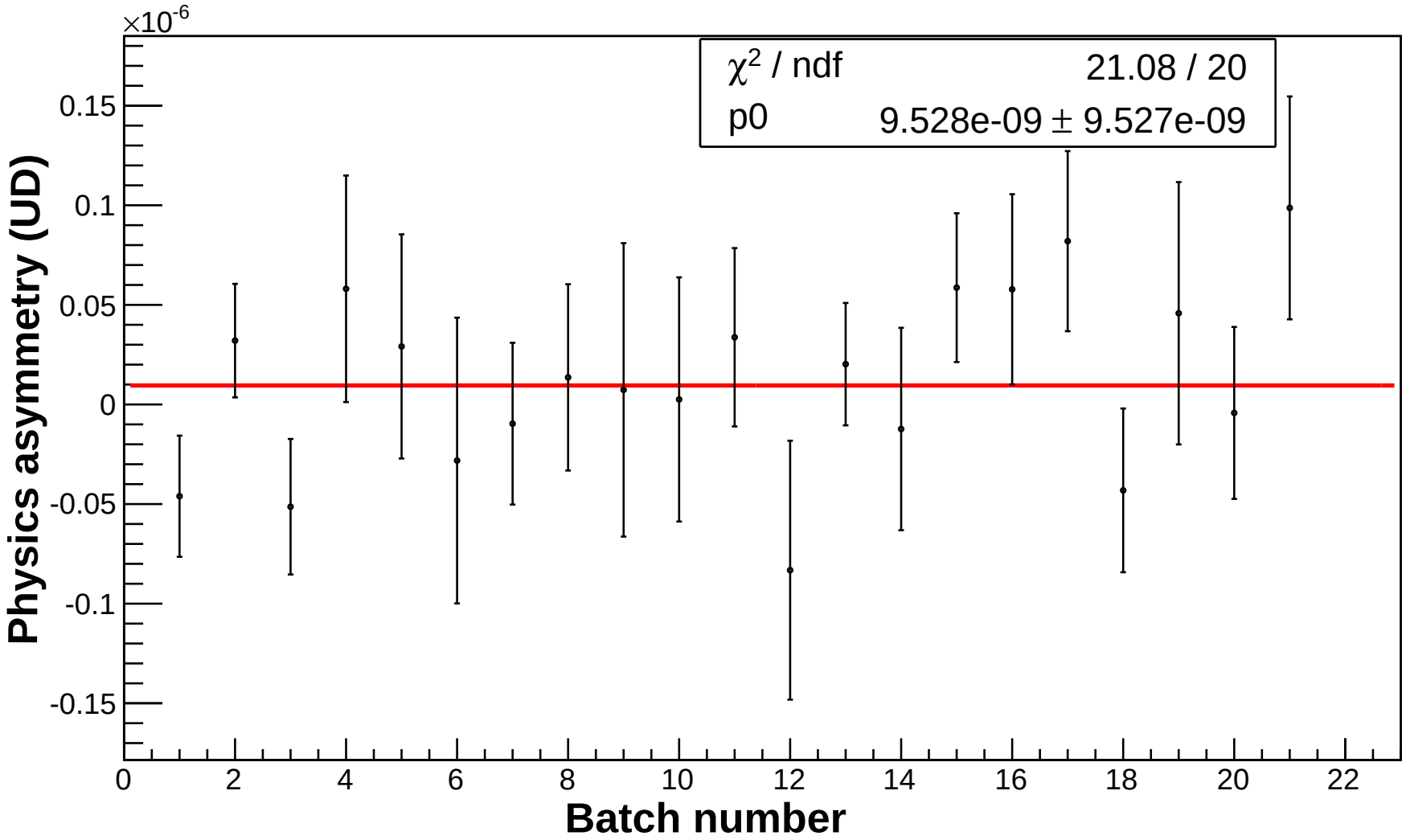


Figure: Distribution of chi square from all UD batches

UD physics asymmetry from all the batches



UD fit along wires

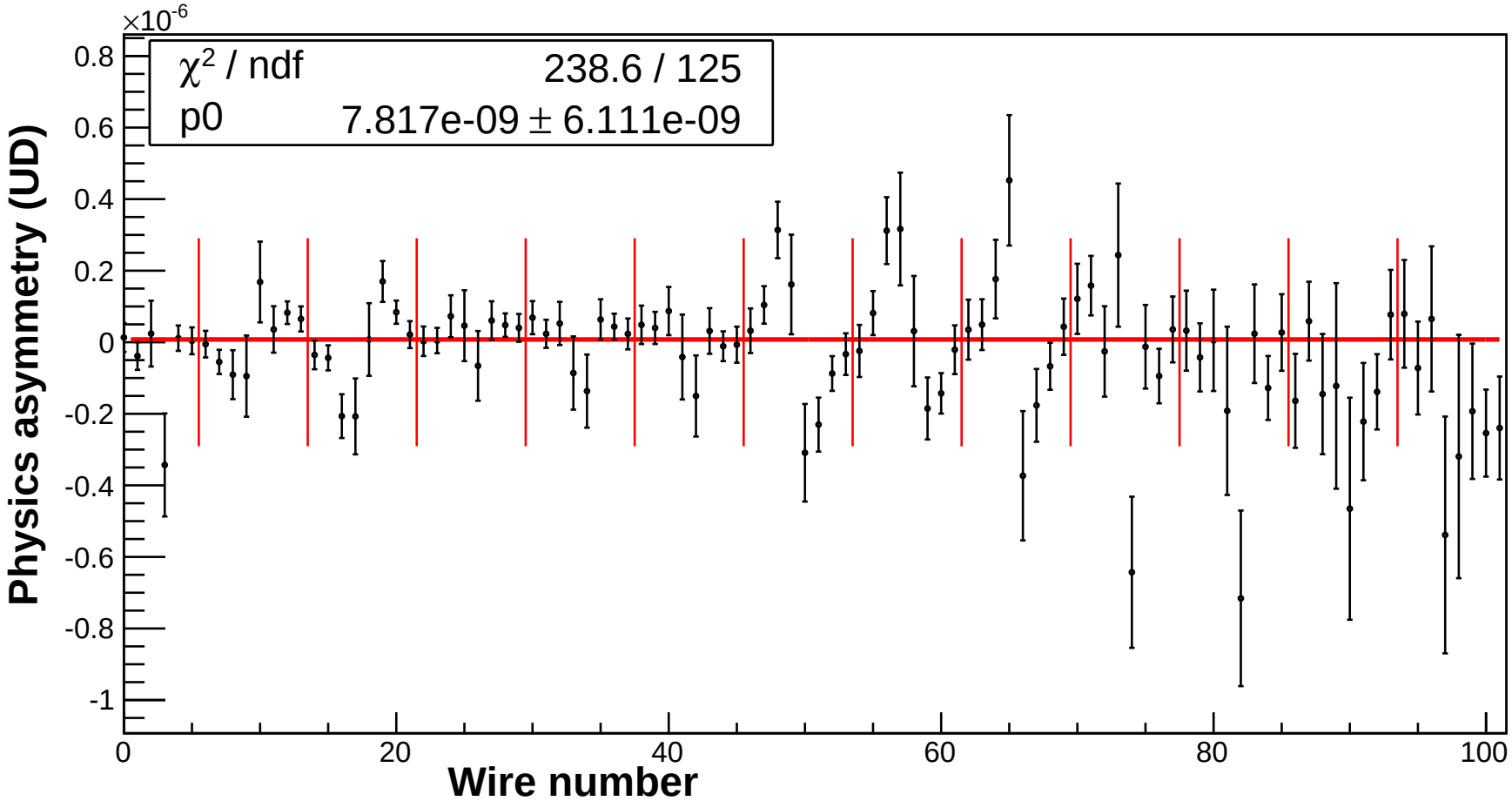


Figure: Average physics asymmetry of each wire (uncorrected) from the fit

UD physics asymmetry (corrected)

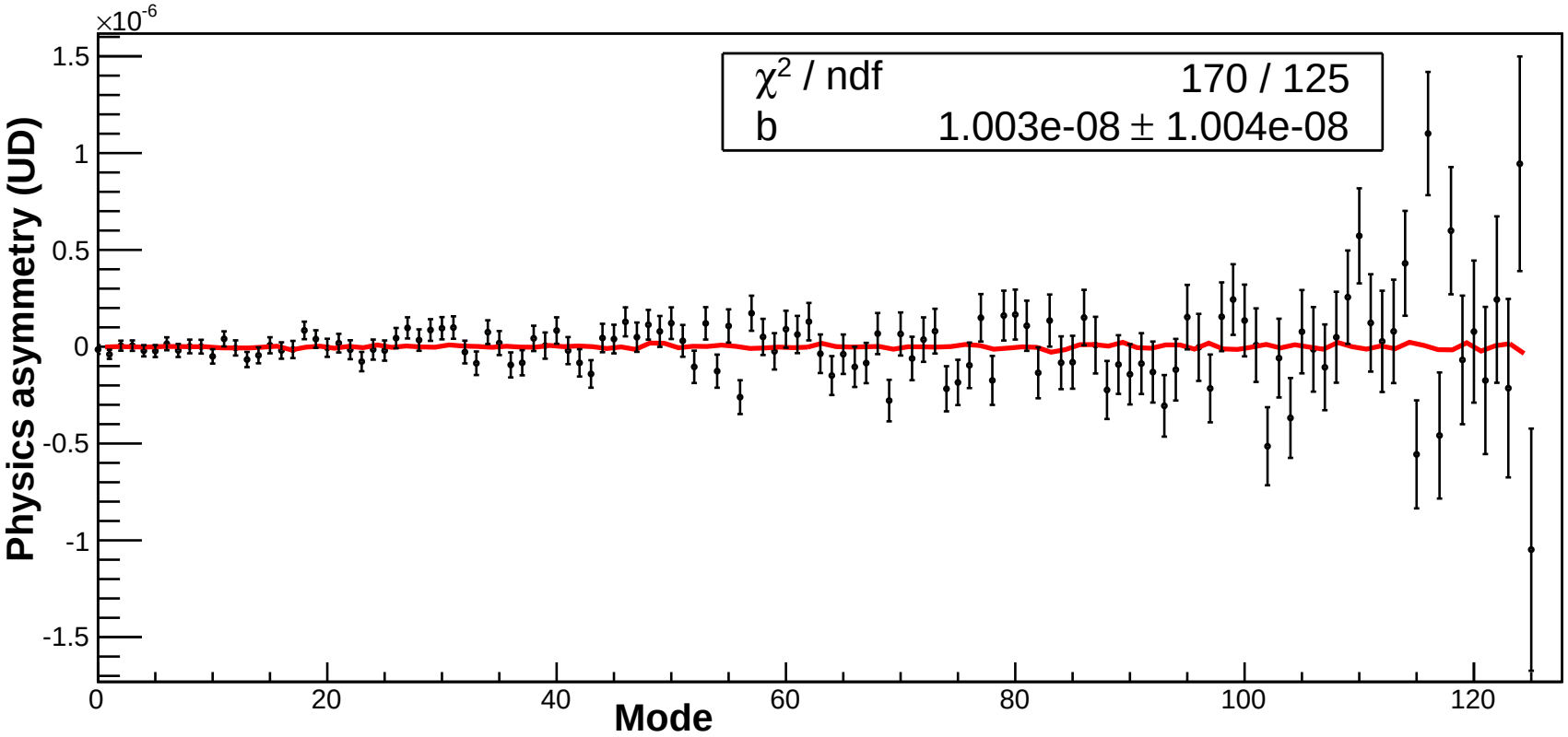
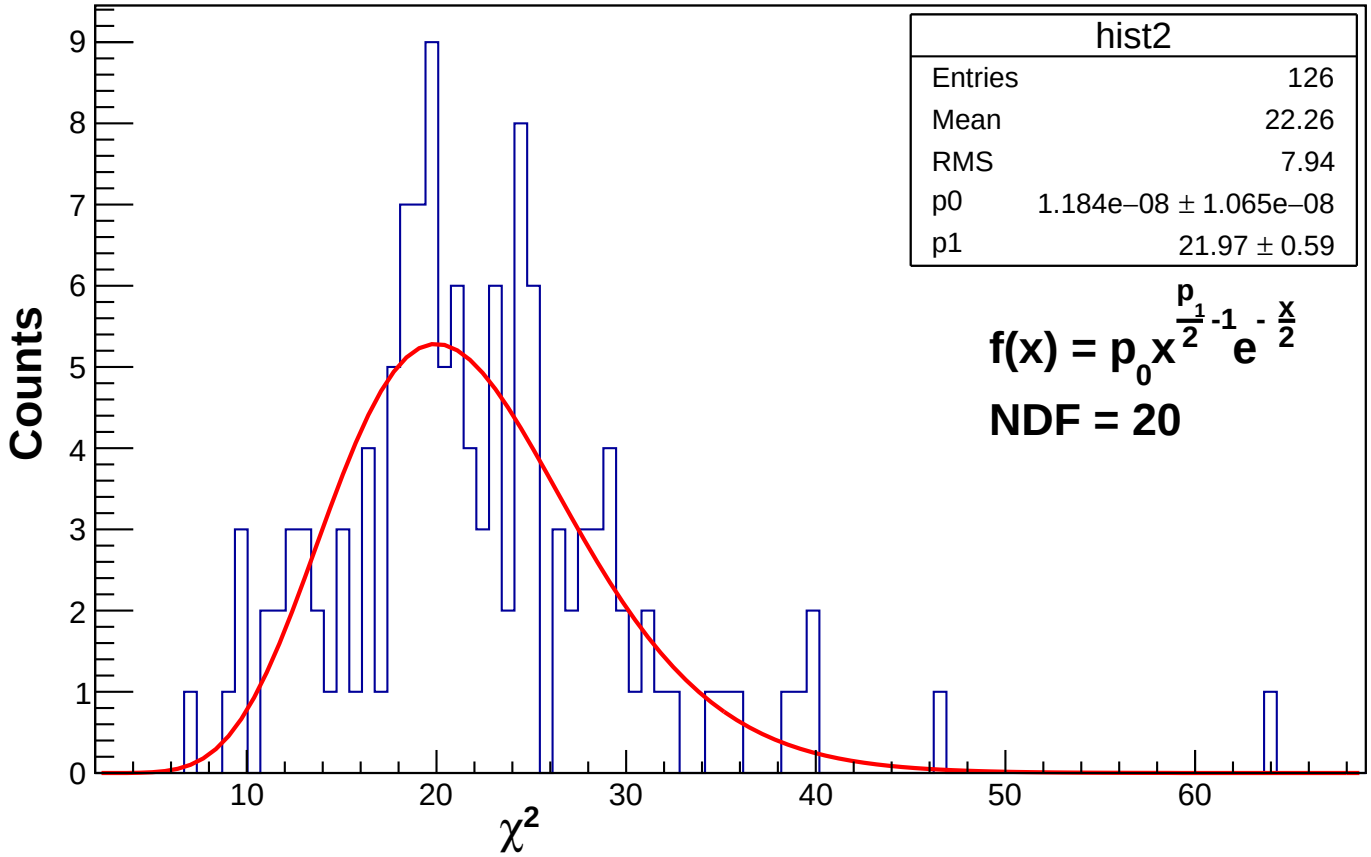


Figure: UD physics asymmetry (corrected) using fit values for all the wires

Distribution of chi square



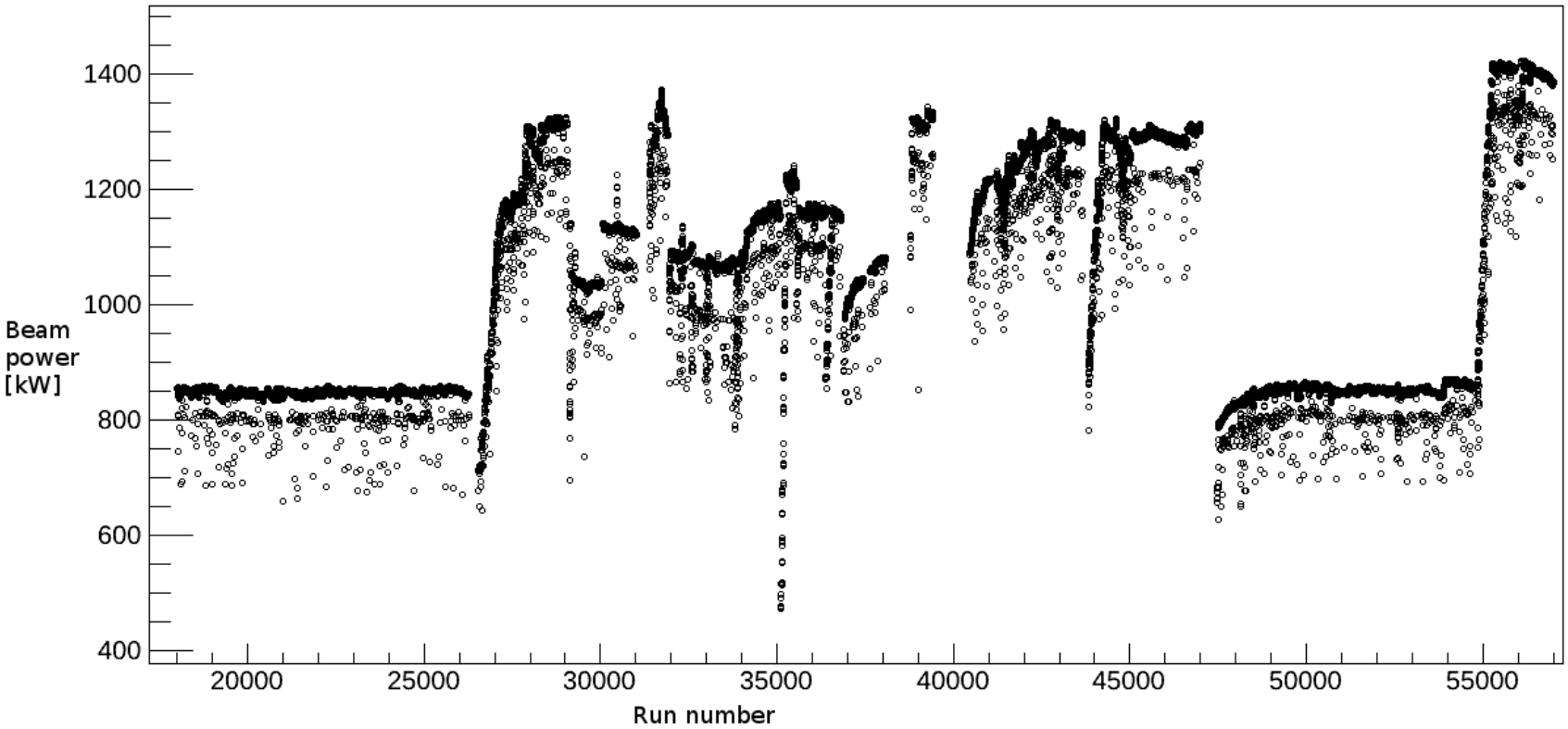
Note : Log likelihood fit method is used for the fit.

Results

PC	$A_{LR} = (-4.12 \pm 0.52) \times 10^{-7}$
PV	$A_{UD} = (0.9528 \pm 0.9527) \times 10^{-8}$

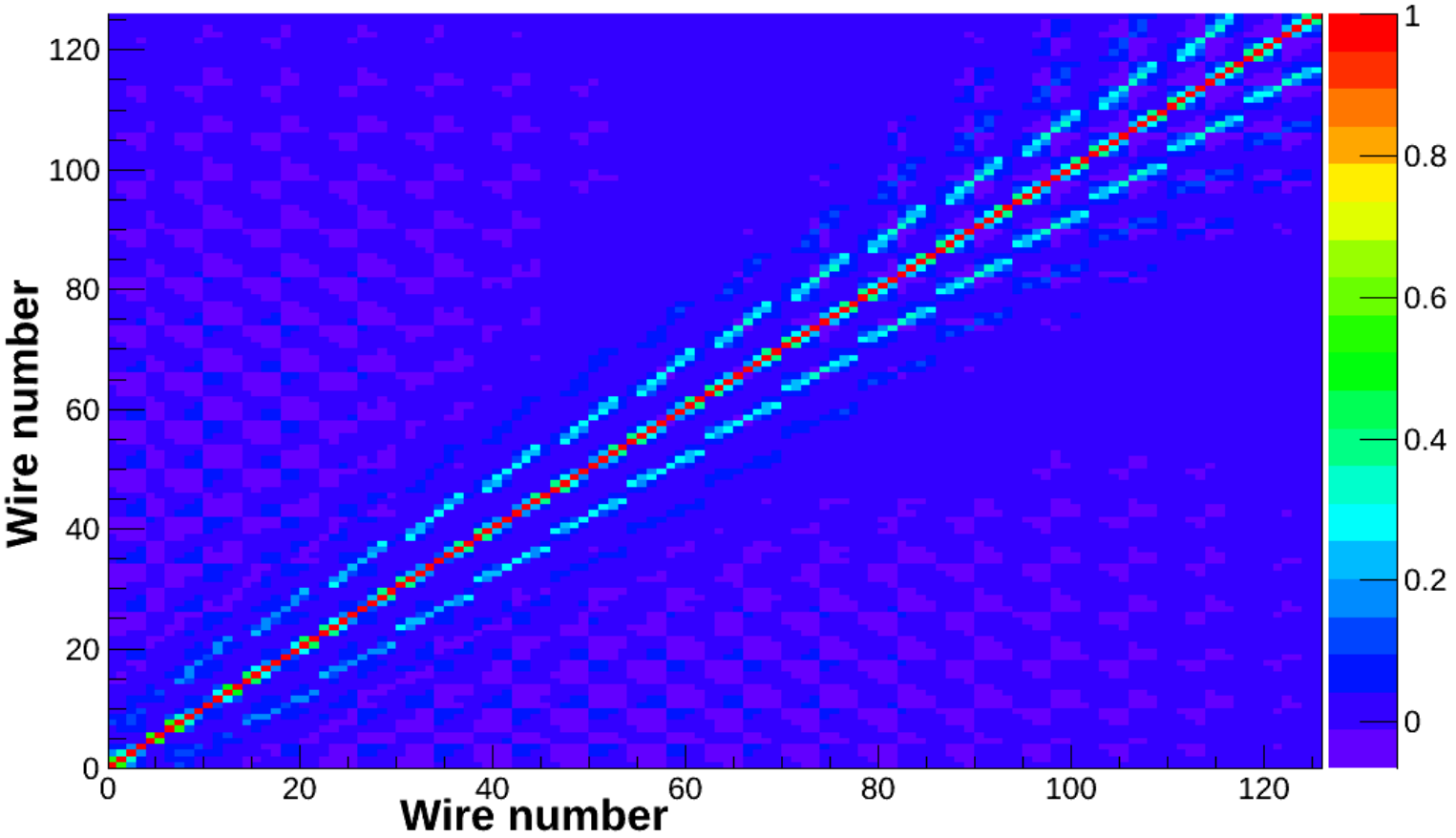
Backup Slides

Beam power distribution for UD dataset



Note : Beam power calculation includes all pulses (including dropped).

Correlation between wires: LR batch 2A correlation for physics asymmetry



The transformation matrix S

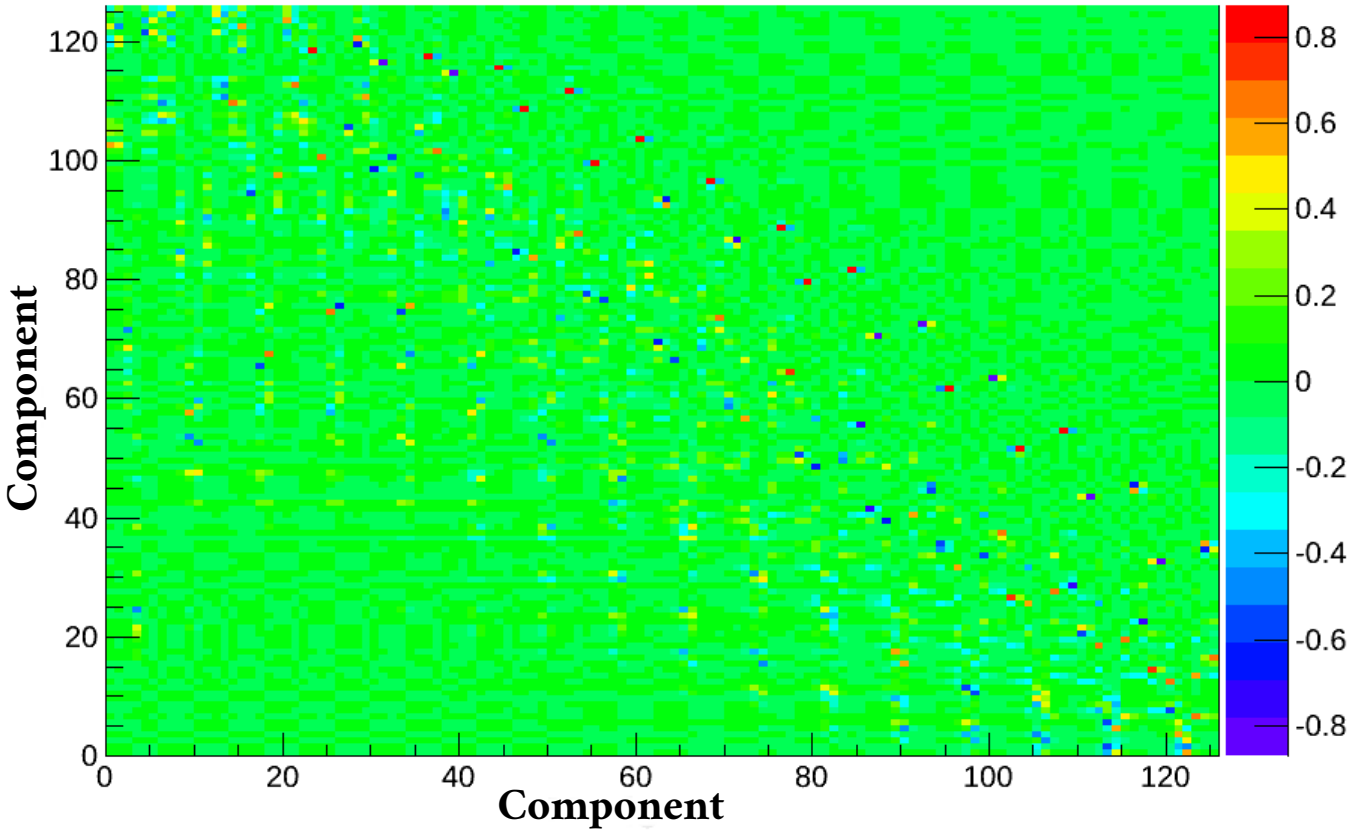


Figure: The transformation matrix S for UD batch-2 data

The eigen values

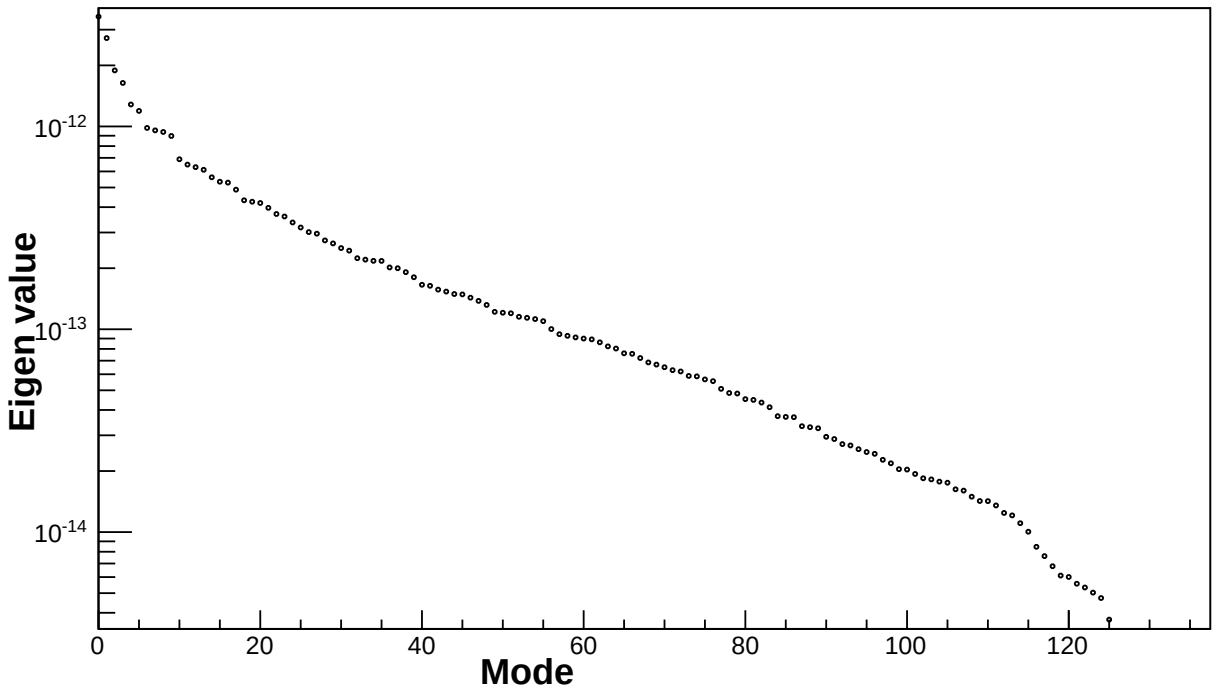


Figure: The eigen values from UD batch-2 data