Beam paper update

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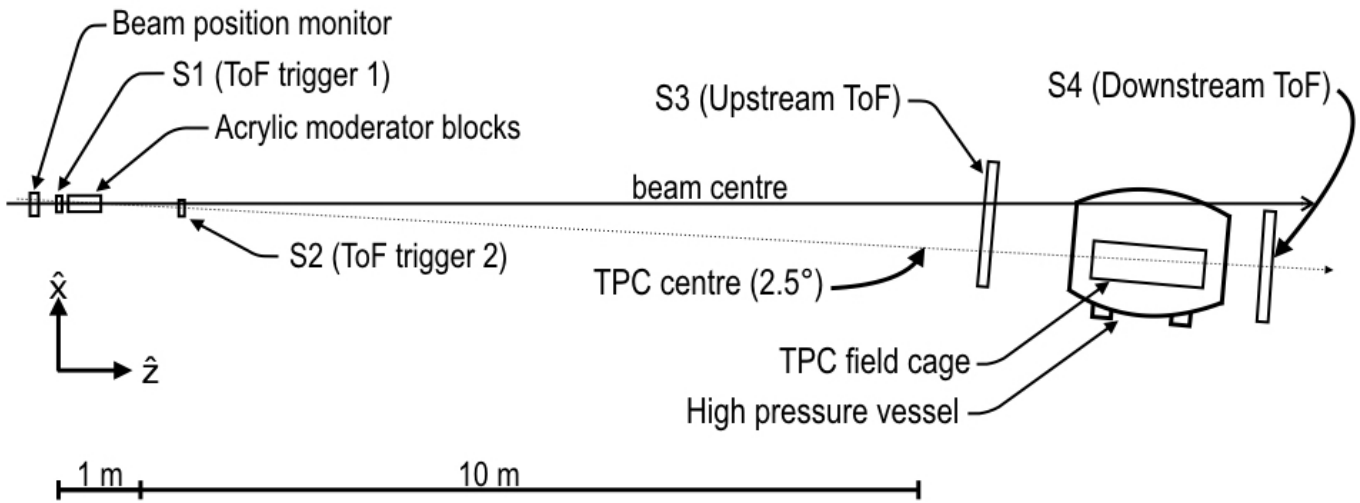
Beam flux MC studies: Background

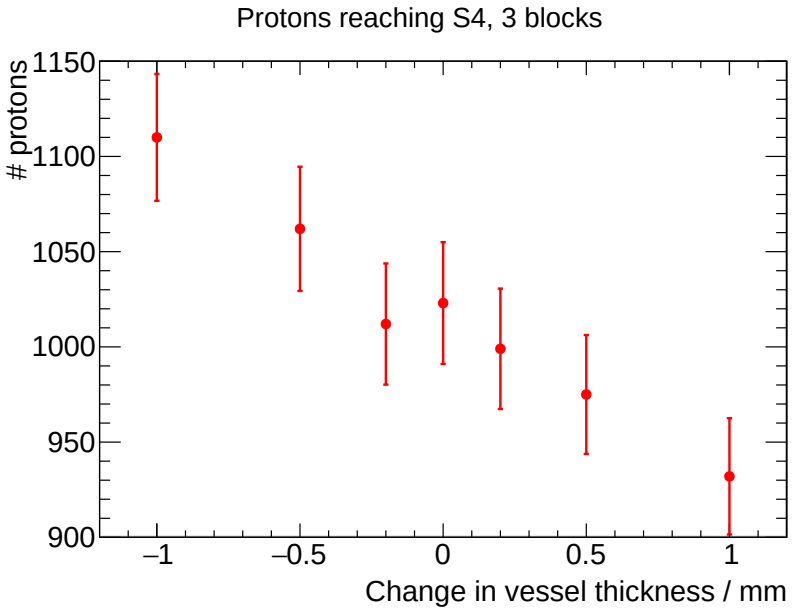
- In our MC simulations we propagate protons from *S3* through the TPC to *S4*
- The positions, direction and momenta are drawn from the information recorded in the *S3* data
- In the beam flux paper the number we compare in data and MC is the ratio of protons in *S3* to those detected in *S4*

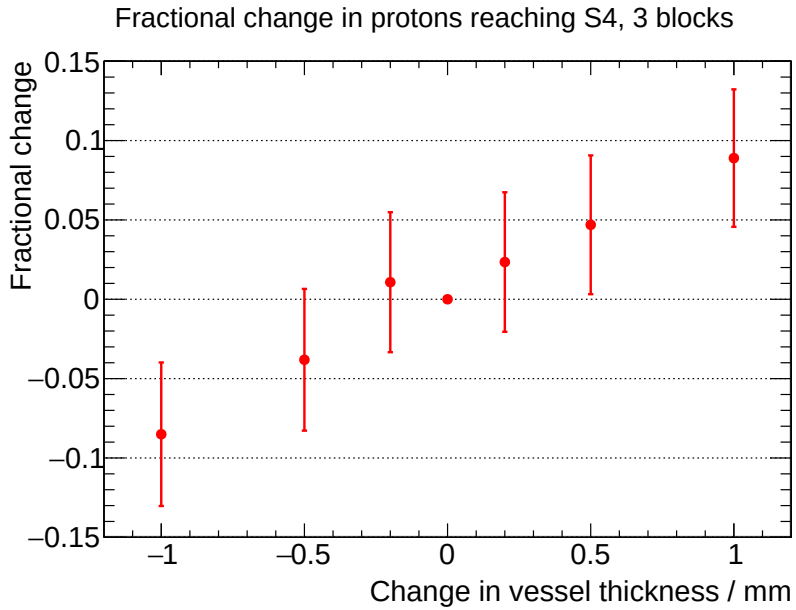


Remaining systematics studies

- There were a couple of additional MC studies that were brought up to be completed
  - For 3 block sample, vary vessel wall thickness by ± 1 mm
  - Rotation of vessel by $\pm 2^{\circ}$ about vertical axis

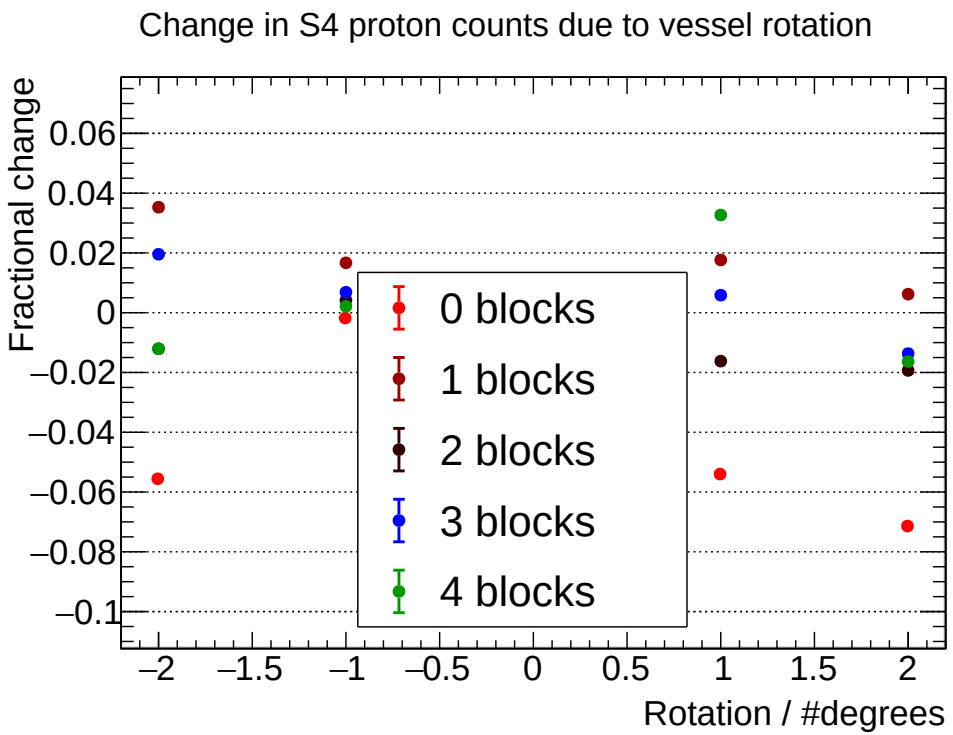
Vessel wall thickness study





- Varied vessel wall thickness for the 3 block sample up to 1 mm
- 1 mm of steel is roughly equivalent to 1 cm of acrylic
- Left shows the change in number of protons reaching *S4*
- Right shows fractional change in this number
- Fractional change is about 10% compared with 16% for the same acrylic study

Vessel rotation study



- Look at effect of rotating the vessel by up to 2°
- Shown here is the fractional change in *S4* proton counts for the various rotations and samples
- Individual plots with errors are in backup slides
- Changes up to 7% for some samples

Summary of MC systematics

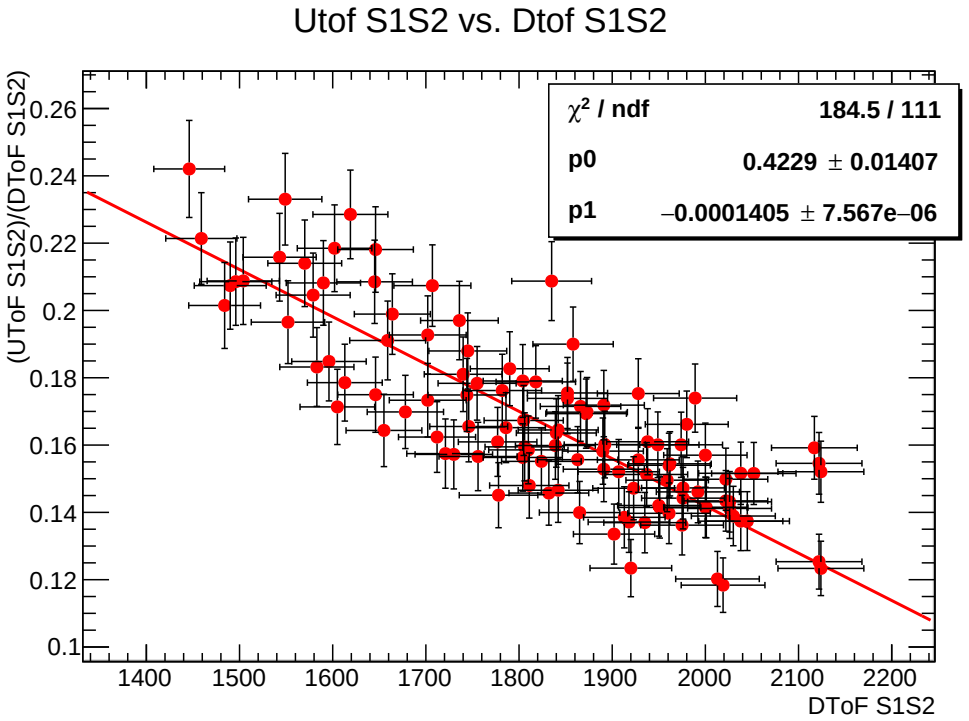
- Express these systematics in terms of the fractional change in the *S4* proton count
- Total systematic errors vary between 8% and 17%

Blocks	0	1	2	3	4
S1 position	0.04	0.04	0.04	0.04	0.04
S2 position	0.04	0.04	0.04	0.04	0.04
1 cm acrylic	0.03	0.04	0.06	0.16	0.04
Vessel rotation	0.07	0.04	0.02	0.02	0.04
Total	0.095	0.080	0.085	0.171	0.080

Dead time correction: recap

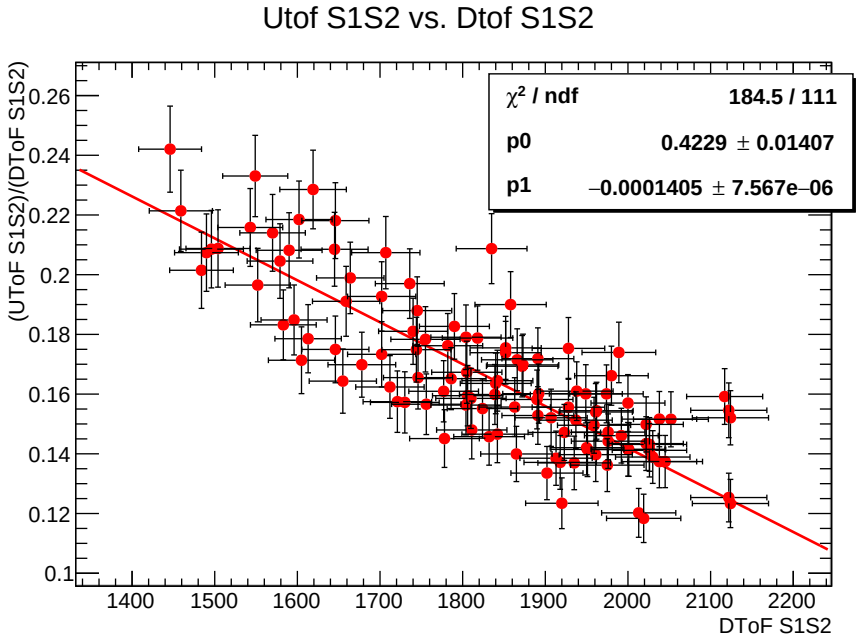
- **The problem:** The UToF (*S1*, *S2* and *S3*) DAQ had an unknown deadtime + would stop recording most hits after a certain time in a spill
- We want to be able to correct for this so we can present things like absolute number of protons and MIPs measured in *S3*
- Fortunately, there is a signal that was inputted into both the UToF and DToF DAQ (which did not have the same issue) $\rightarrow$ the $S1 \times S2$ coincidence signal

Dead time correction: recap



- In theory we have the same quantity measured in both DAQs
- Therefore, should be able to scale events such that the same number of $S1 \times S2$ hits in each DAQ
- This correction is currently used in the beam paper analysis
- Each point on this plot is a spill

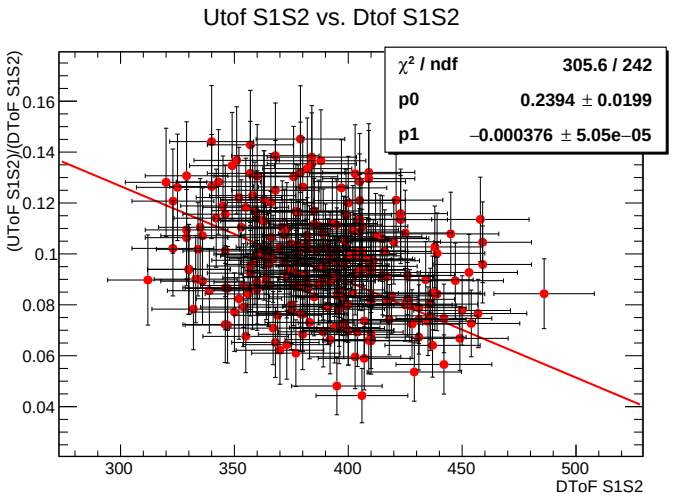
Dead time correction: recap

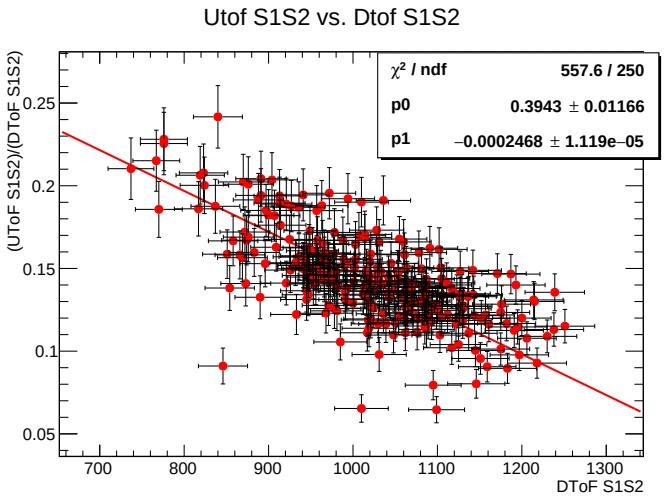


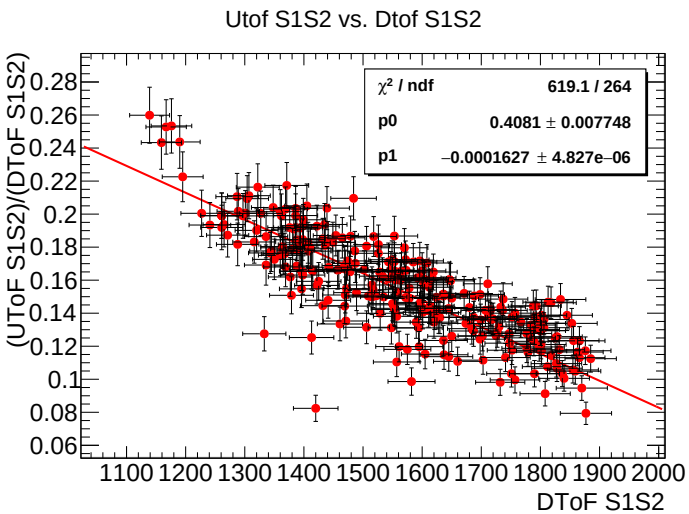
- For each spill in the analysis, count the number of $S1 \times S2$ hits measured in the DToF
- Use fitted line for that sample to determine 1/weight

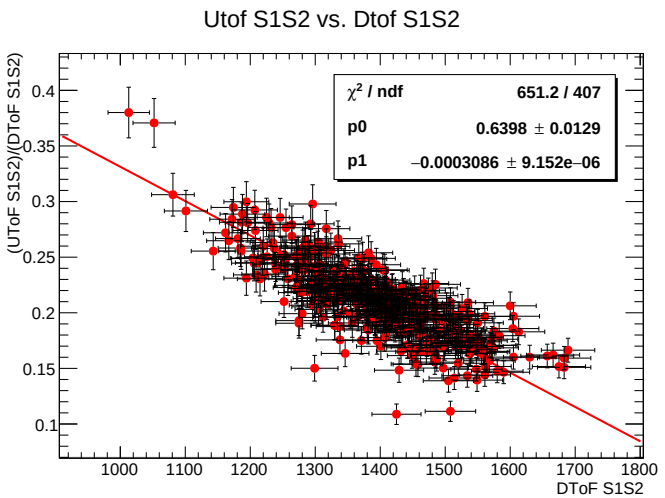
$$\frac{1}{w} = \frac{n_{S1S2}^{UToF}}{n_{S1S2}^{DToF}} = p_1 * n_{S1S2}^{DToF} + p_0$$

Dead time correction: Distributions for other blocks







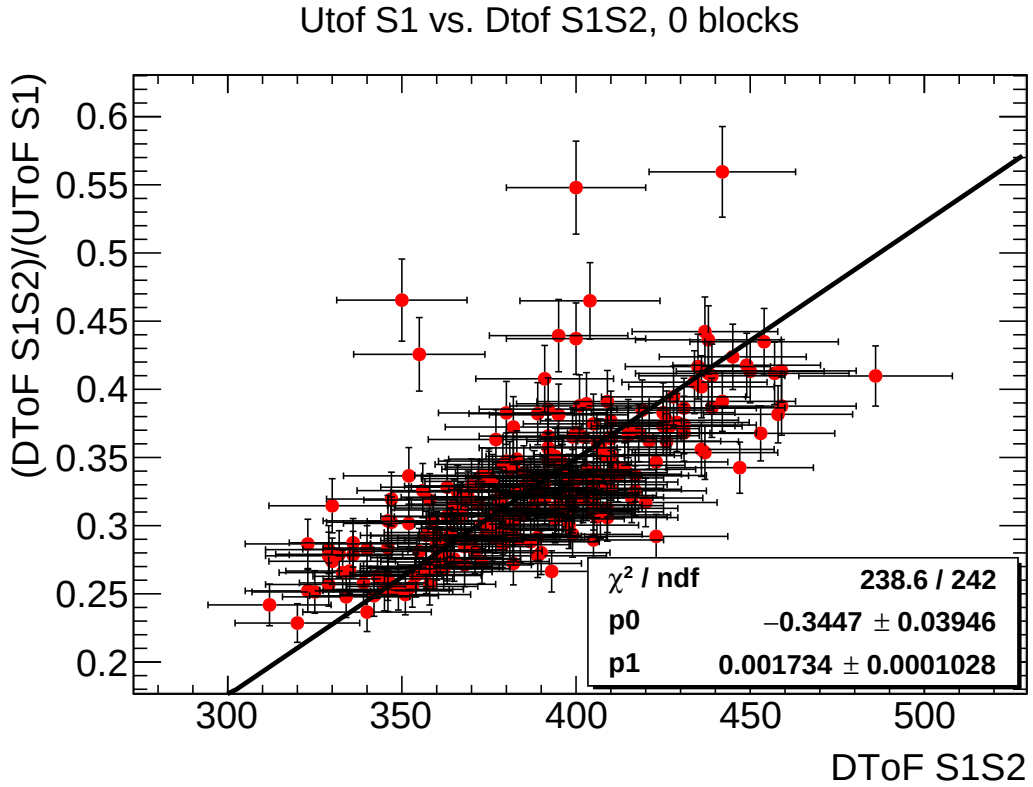


- $0.05 \lessapprox 1/w \lessapprox 0.4$

Problems with this correction

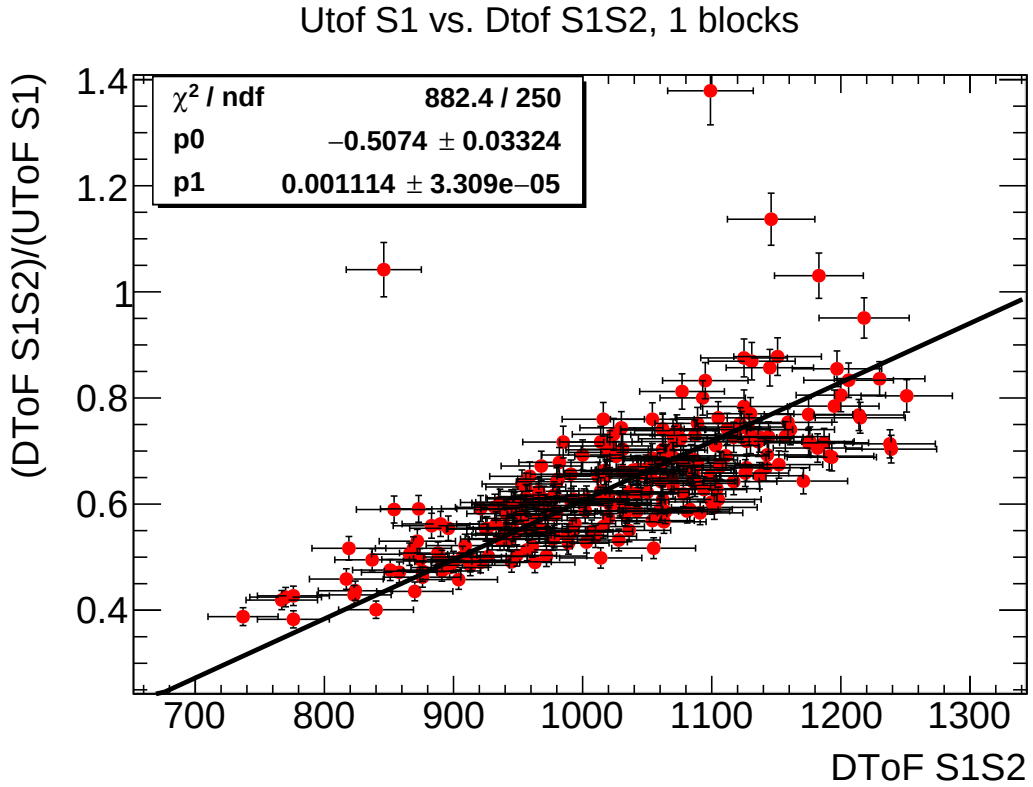
- As has been shown previously, we have an issue with data-MC agreement. In some places, we are a factor of 2 out (hard to imagine uncertainties covering this).
- The dead time is one possible place we could be going wrong
- In particular, we require an error which would affect different samples a different amount to reach agreement across the board
- **Idea:** This current correction is all based around the idea that the only dead time that matters is measured by $S1 \times S2$ hits
  - What if there is some additional factor for $S1$ only hits that is not taken in to account?

S1 dead time correction - 0 blocks



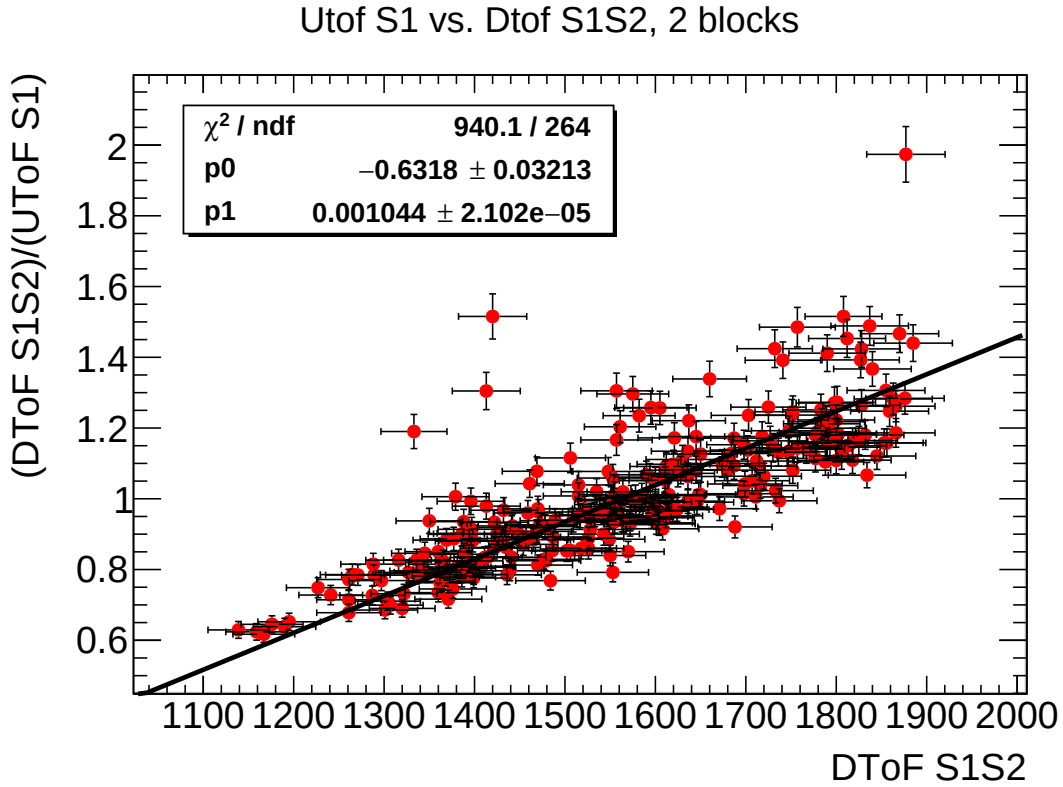
- Want a way to relate n_{S1S2}^{DToF} to correct n_{S1}^{UToF}
- Can plot n_{S1S2}^{DToF} vs. $n_{S1S2}^{DToF}/n_{S1}^{UToF}$
- Multiply by existing weight to get required weight for $S1$ only hits
- For 0 block, additional factor of ~ 3 for $S1$ only hits

S1 dead time correction - 1 block



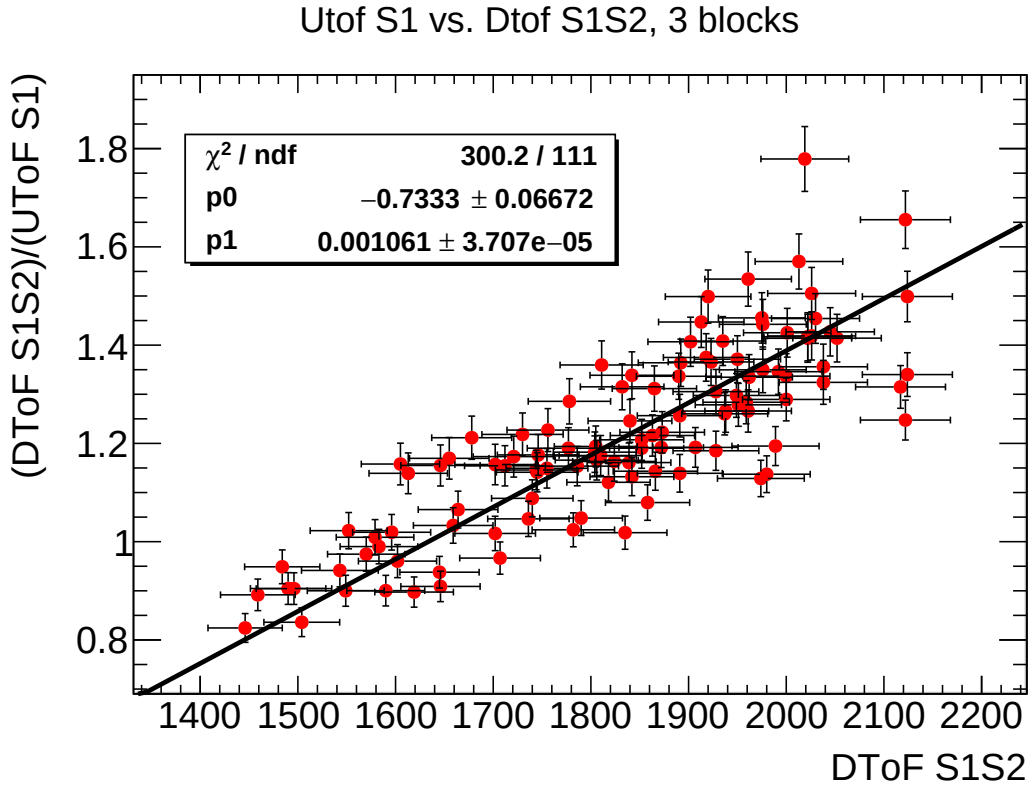
- Want a way to relate n_{S1S2}^{DToF} to correct n_{S1}^{UToF}
- Can plot n_{S1S2}^{DToF} vs. $n_{S1S2}^{DToF}/n_{S1}^{UToF}$
- Multiply by existing weight to get required weight for $S1$ only hits
- For 1 block, additional factor of ~ 2 for $S1$ only hits

S1 dead time correction - 2 blocks



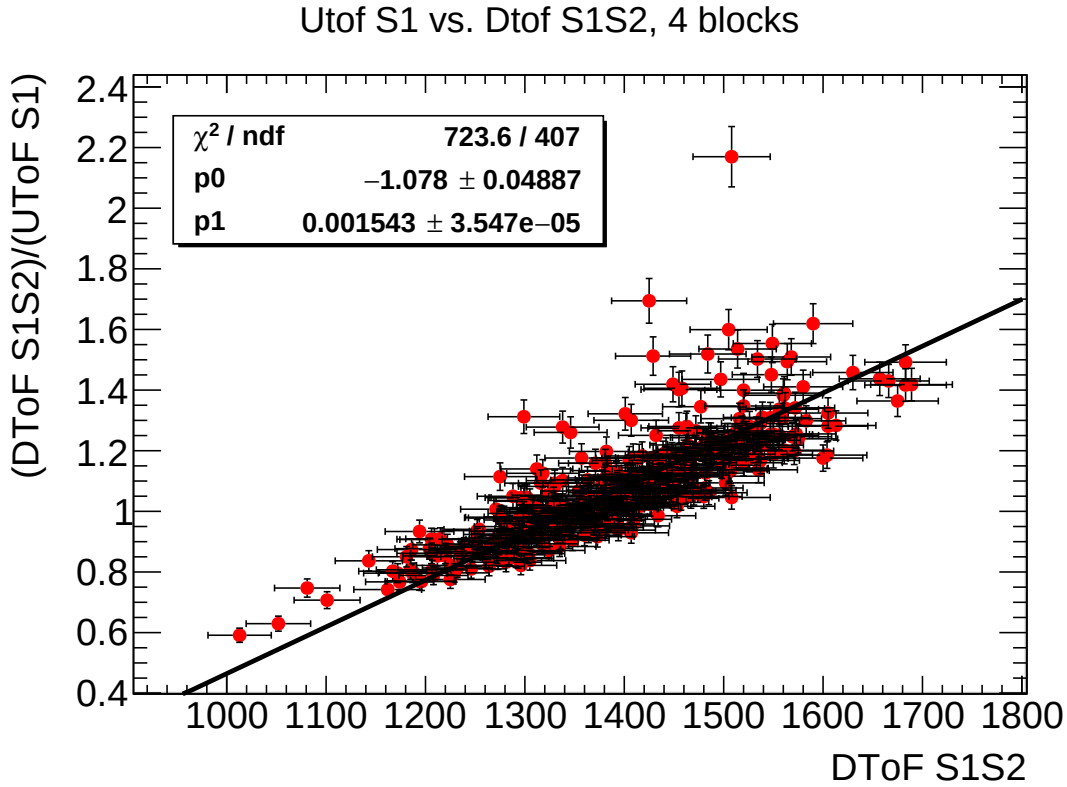
- Want a way to relate n_{S1S2}^{DToF} to correct n_{S1}^{UToF}
- Can plot n_{S1S2}^{DToF} vs. $n_{S1S2}^{DToF}/n_{S1}^{UToF}$
- Multiply by existing weight to get required weight for $S1$ only hits
- For 2 block, additional factor of ~ 1 for $S1$ only hits

S1 dead time correction - 3 blocks



- Want a way to relate n_{S1S2}^{DToF} to correct n_{S1}^{UToF}
- Can plot n_{S1S2}^{DToF} vs. $n_{S1S2}^{DToF}/n_{S1}^{UToF}$
- Multiply by existing weight to get required weight for $S1$ only hits
- For 3 block, additional factor of ~ 0.8 for $S1$ only hits

S1 dead time correction - 4 blocks

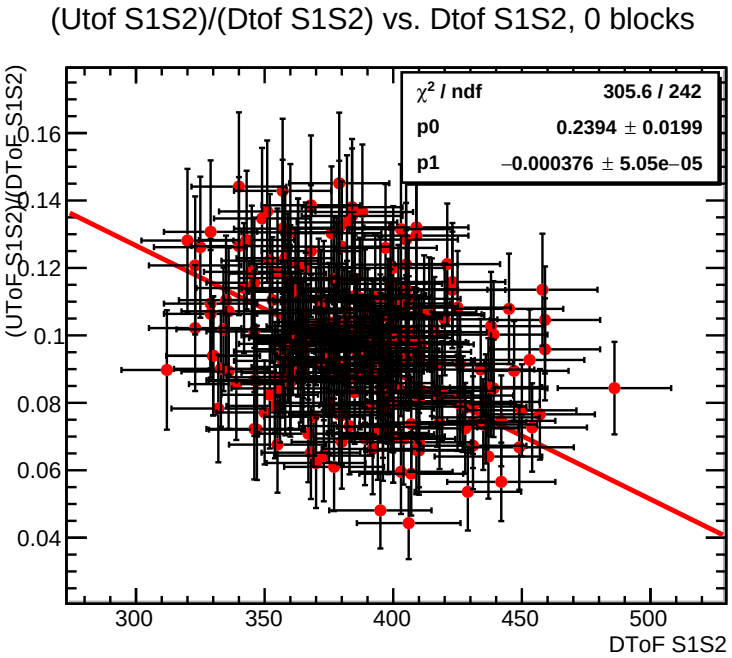


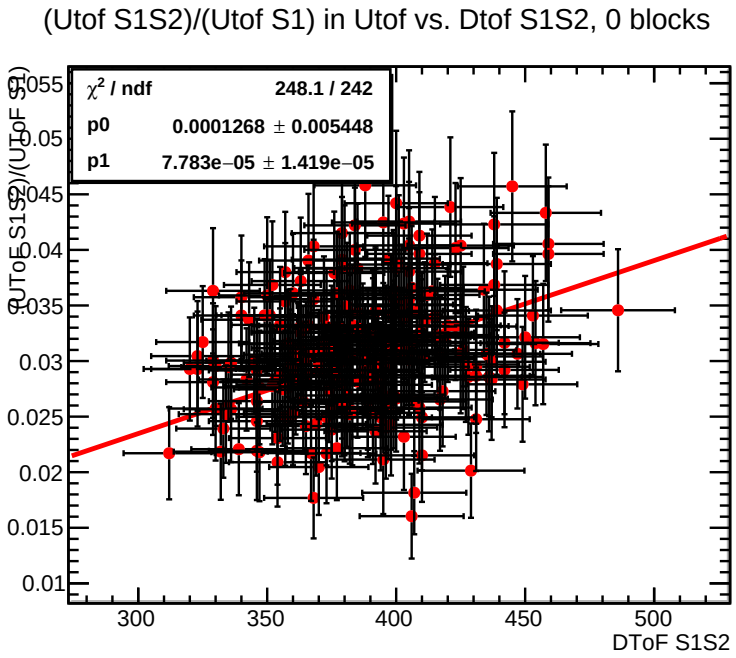
- Want a way to relate n_{S1S2}^{DToF} to correct n_{S1}^{UToF}
- Can plot n_{S1S2}^{DToF} vs. $n_{S1S2}^{DToF}/n_{S1}^{UToF}$
- Multiply by existing weight to get required weight for $S1$ only hits
- For 4 block, additional factor of ~ 0.8 for $S1$ only hits

Comparison of $S1 \times S2$ and $S1$ weights

- For each spill, count up the number of n_{S1S2}^{DToF} hits
- For $S1 \times S2$ hits, $1/w = n_{S1S2}^{UToF} / n_{S1S2}^{DToF}$
- For $S1$ hits, $\frac{1}{w_n} = \frac{n_{S1S2}^{UToF}}{n_{S1S2}^{DToF}} * \frac{n_{S1S2}^{DToF}}{n_{S1}^{UToF}} = \frac{n_{S1S2}^{UToF}}{n_{S1}^{UToF}}$

Comparison of *S1* × *S2* and *S1* weights - 0 blocks

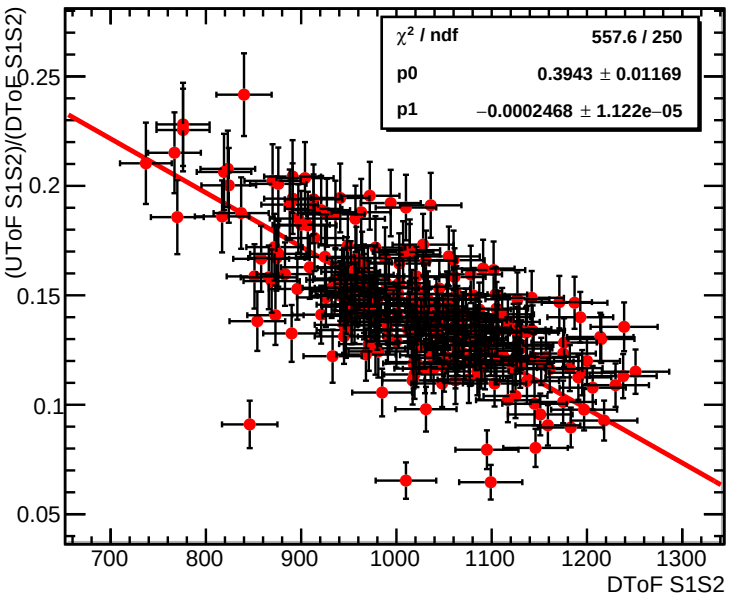




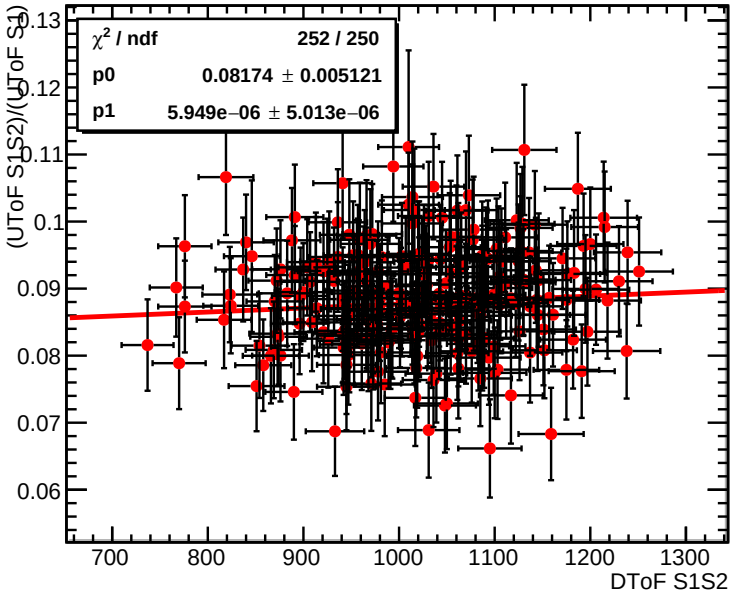
- Left is $1/w_{S1S2}$, right is $1/w_{S1}$

Comparison of *S1* × *S2* and *S1* weights - 1 block

(Utof S1S2)/(Dtof S1S2) vs. Dtof S1S2, 1 blocks



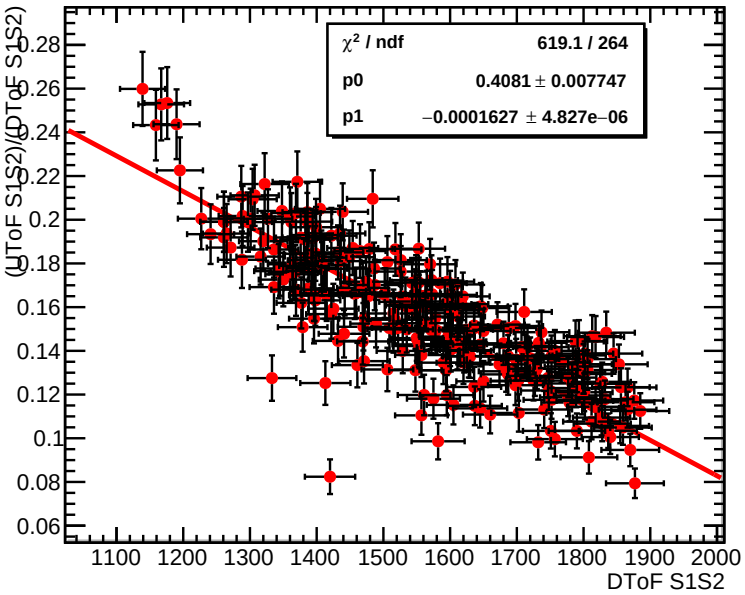
(Utof S1S2)/(Utof S1) in Utof vs. Dtof S1S2, 1 blocks



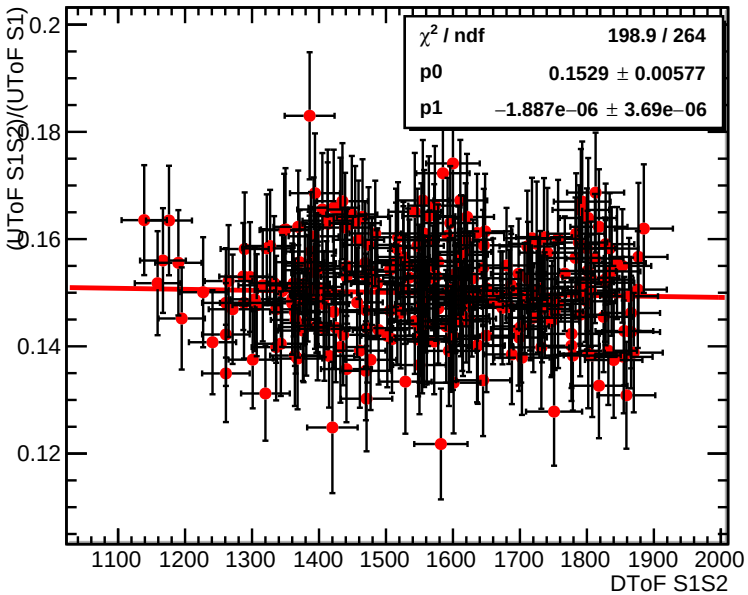
- Left is $1/w_{S1S2}$, right is $1/w_{S1}$

Comparison of *S1* × *S2* and *S1* weights - 2 blocks

(Utof S1S2)/(Dtof S1S2) vs. Dtof S1S2, 2 blocks



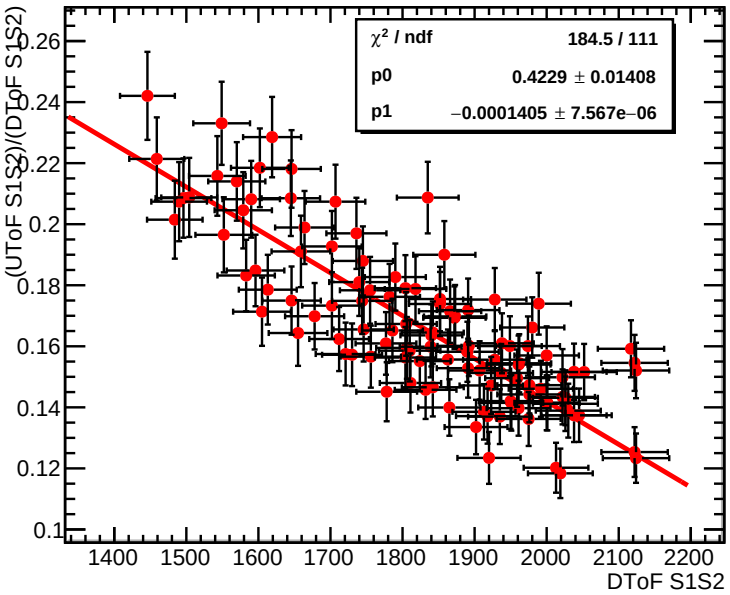
(Utof S1S2)/(Utof S1) in Utof vs. Dtof S1S2, 2 blocks



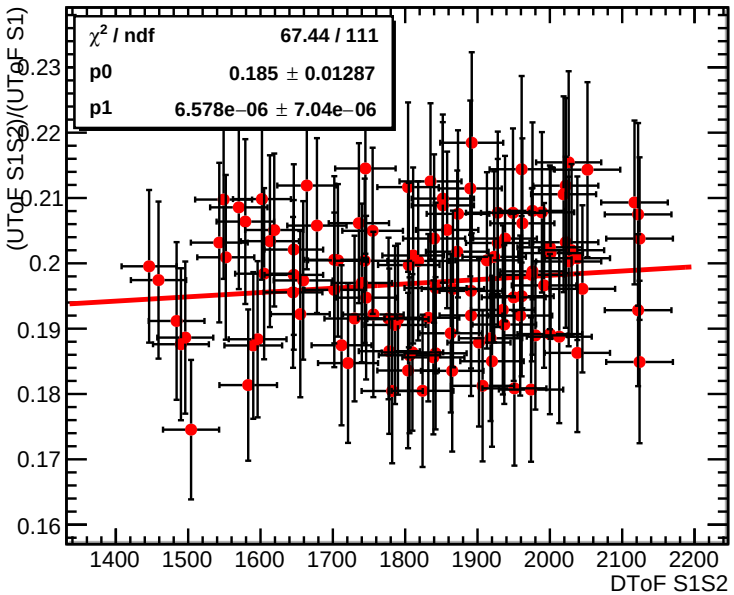
- Left is $1/w_{S1S2}$, right is $1/w_{S1}$
- Weights are fairly similar

Comparison of *S1* × *S2* and *S1* weights - 3 blocks

(Utof S1S2)/(Dtof S1S2) vs. Dtof S1S2, 3 blocks



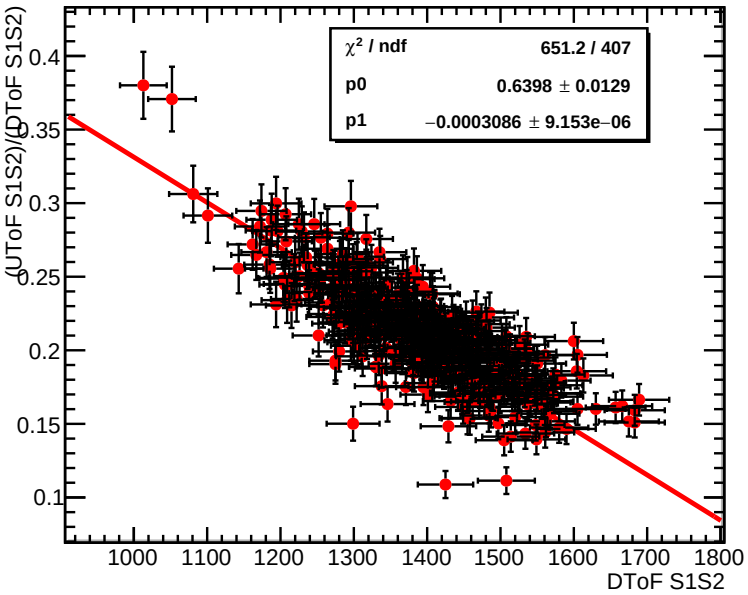
(Utof S1S2)/(Utof S1) in Utof vs. Dtof S1S2, 3 blocks



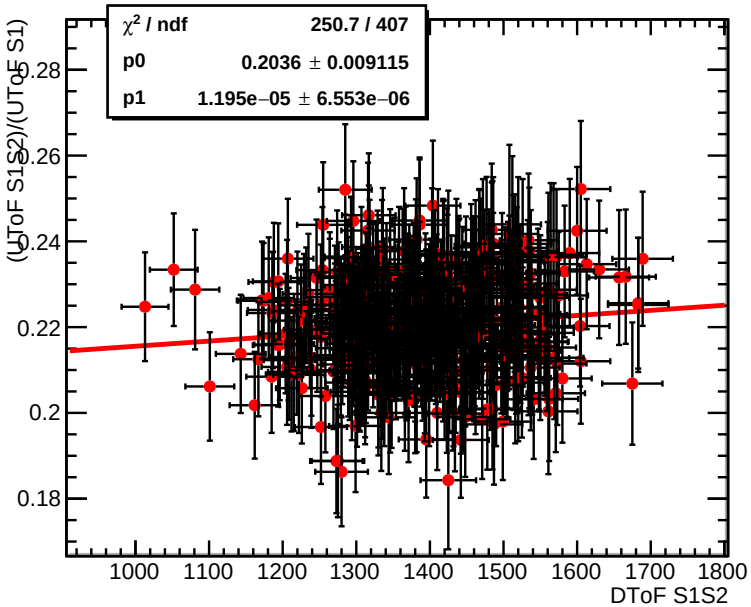
- Left is $1/w_{S1S2}$, right is $1/w_{S1}$
- Mean weights fairly similar

Comparison of *S1* × *S2* and *S1* weights - 4 blocks

(Utof S1S2)/(Dtof S1S2) vs. Dtof S1S2, 4 blocks



(Utof S1S2)/(Utof S1) in Utof vs. Dtof S1S2, 4 blocks



- Left is $1/w_{S1S2}$, right is $1/w_{S1}$
- Mean weights fairly similar

How does this affect our data-MC comparisons?

- Shown here are the old numbers
- Where shown, errors are statistical

N. blocks	$S3_{Data}$ / spill	$(S4/S3)_{Data}$	$(S4/S3)_{MC}$	Data/MC
0	2227 ± 10	0.0548	0.0281	1.95
1	1881 ± 7	0.0984	0.0680	1.45
2	1473 ± 6	0.1134	0.0861	1.32
3	982 ± 7	0.0499	0.0582	0.86
4	148 ± 0.5	0.0392	0.0149	2.63

How does this affect our data-MC comparisons?

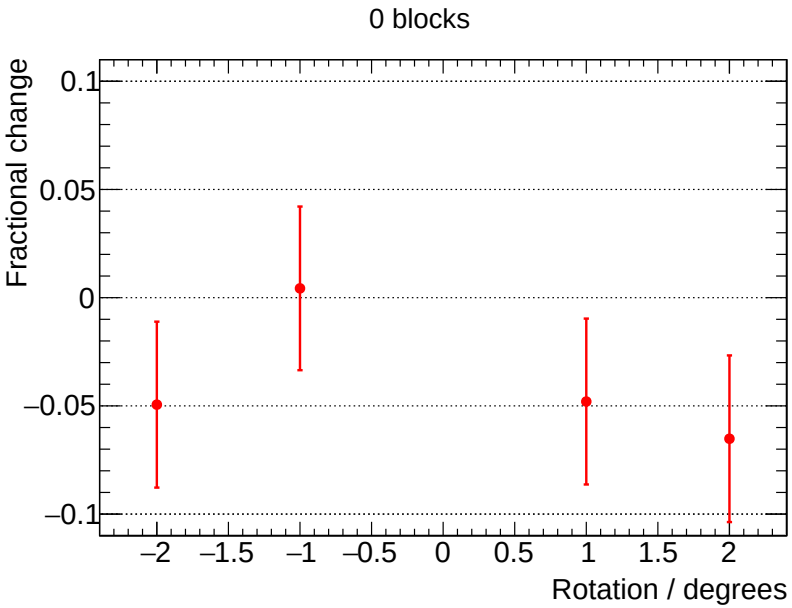
- Shown here are the numbers with the new dead time correction
- Where shown, errors are statistical
- Minor changes also made to MC selection - most ratios very similar

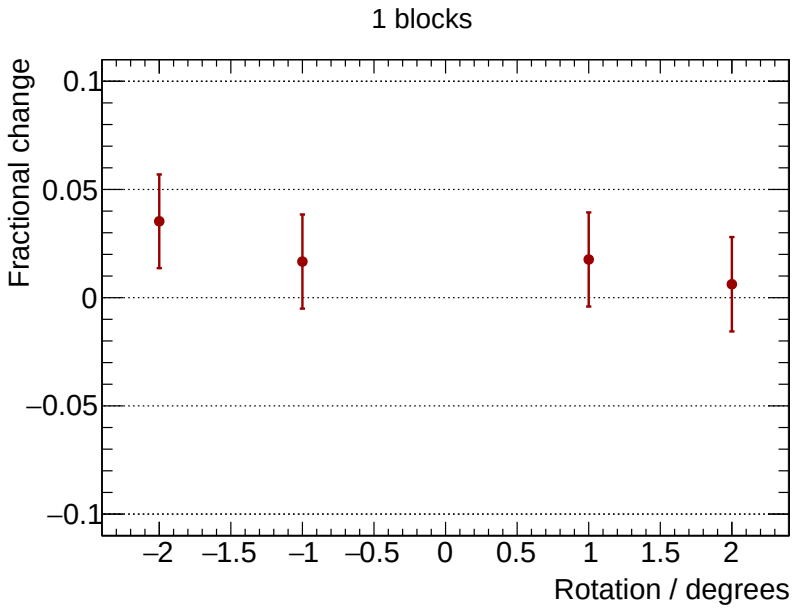
N. blocks	$S3_{Data}$ / spill	$(S4/S3)_{Data}$	$(S4/S3)_{MC}$	Data/MC
0	6608 ± 31	0.0185	0.0275 ± 0.0008	0.67
1	2694 ± 10	0.0687	0.0667 ± 0.0011	1.03
2	1409 ± 6	0.1185	0.0836 ± 0.0012	1.42
3	828 ± 6	0.0592	0.0553 ± 0.0018	1.07
4	164 ± 0.6	0.0354	0.0115 ± 0.0004	3.08

- We see our $S4/S3$ ratios looking more consistent (i.e. no longer our by any factors of 2)
- Four block is still inconsistent. As discussed previously we are very sensitive to mis-modelling at low energies

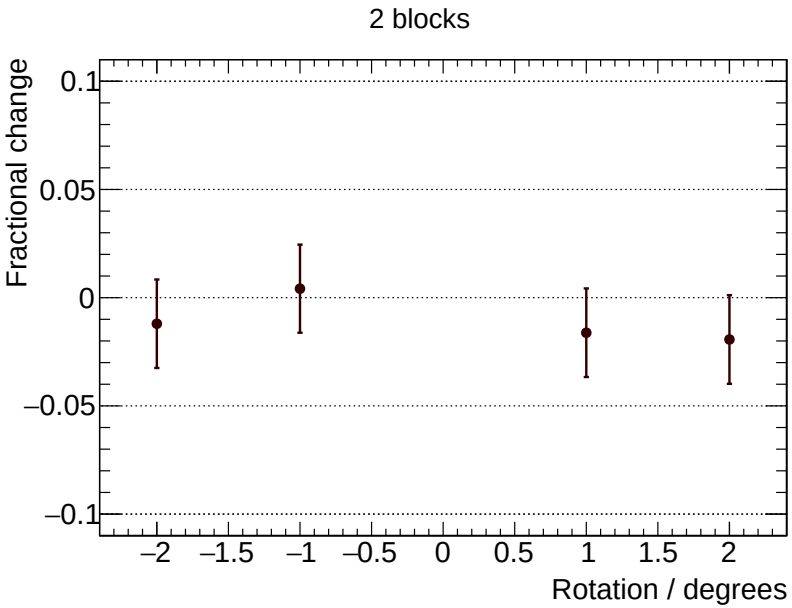
Backup

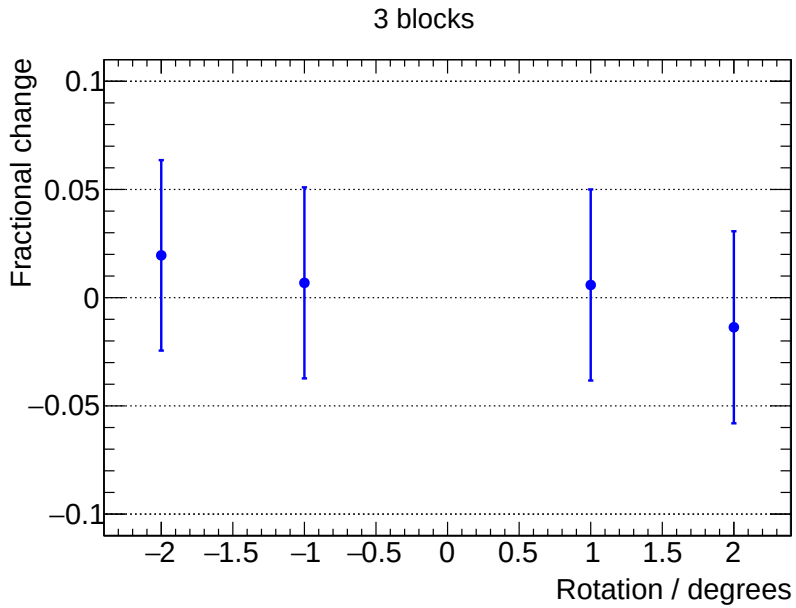
Additional vessel rotation plots





Additional vessel rotation plots





Additional vessel rotation plots