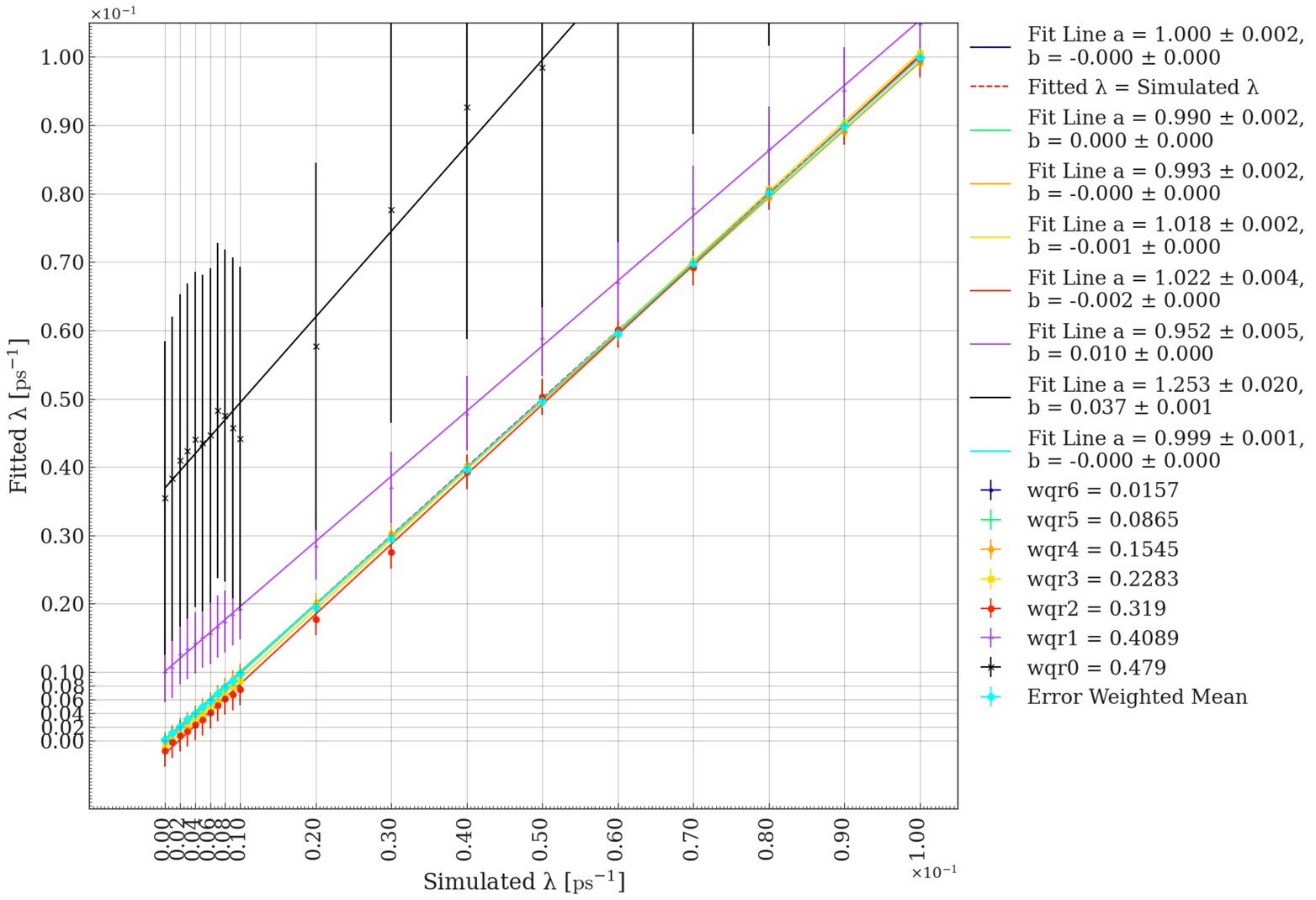
Search for decoherence of $B\bar{B}$ quantum entanglement at Belle II

Update: Unbinned decoherence fitter using individual decay times

Last time: Bias in unbinned decoherence fit



- Observe large “bias” for the two worst wrong tag bins
- Observe small “bias” for the middle wrong tag bins
- What causes this???

- Additional point: Why do my fit points not fluctuate more according to their error bars?

  ➡ Expect 1σ spread

The Problem: Random generation of pseudo experiments

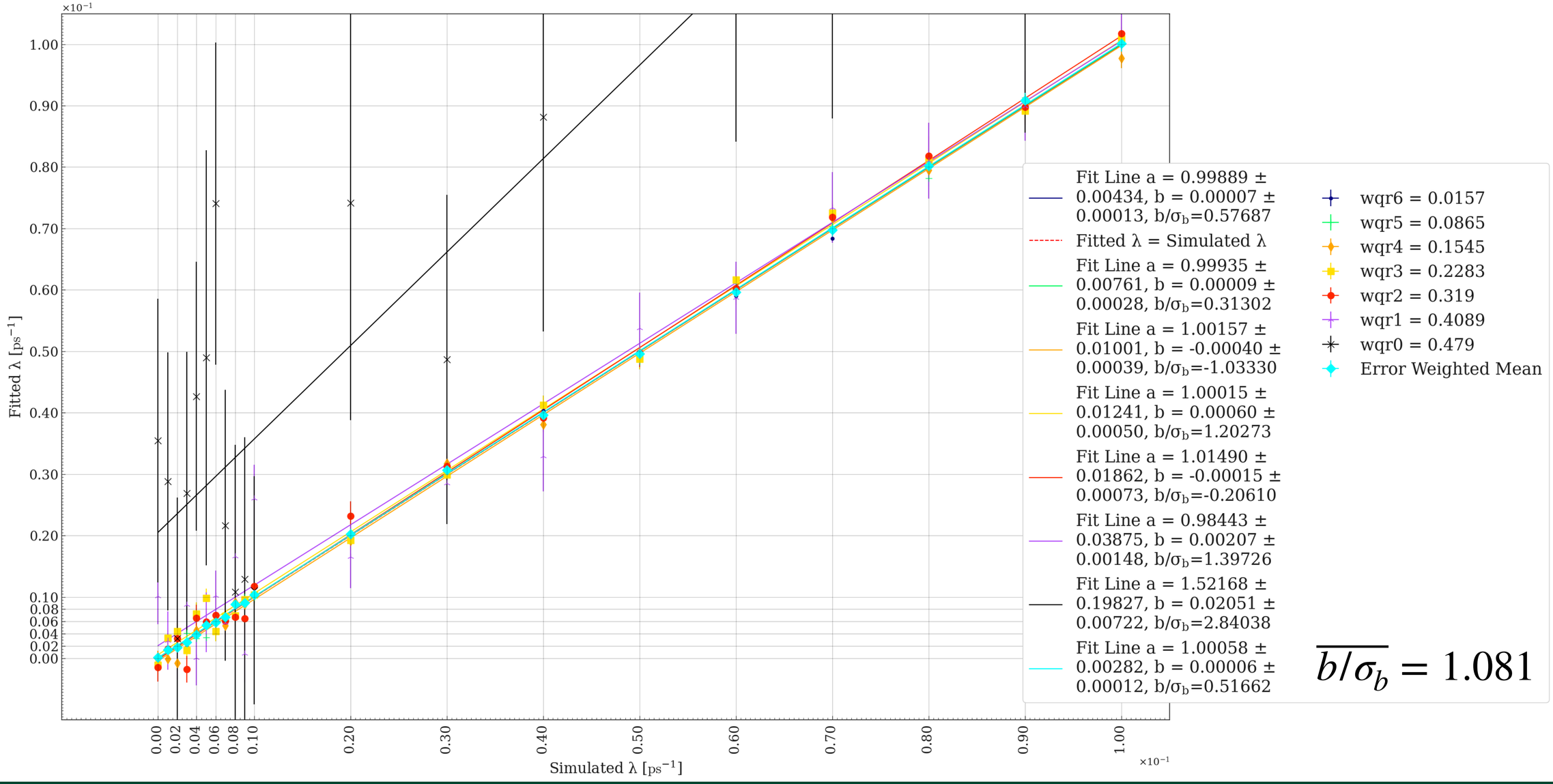
- Generate toy MC for 19 different λ values
- For each λ generate 100 pseudo experiments of random t_1 and t_2 pairs
  - ➡ Problem: I used the same 100 random seeds over and over again
  - ➡ Each experiment number is correlated

	Exp1	**Exp2**	**Exp3**	**…**	**Exp100**
Lam=0.0	1	2	3	…	100
Lam=0.001	1	2	3	…	100
…	…	…	…	…	…
Lam=0.1	1	2	3	…	100

  - ➡ Solution: Use unique random seeds for each experiment for each λ value

	Exp1	**Exp2**	**Exp3**	**…**	**Exp100**
Lam=0.0	1	2	3	…	100
Lam=0.001	101	102	103	…	200
…	…	…	…	…	…
Lam=0.1	1901	1902	1903	…	2000

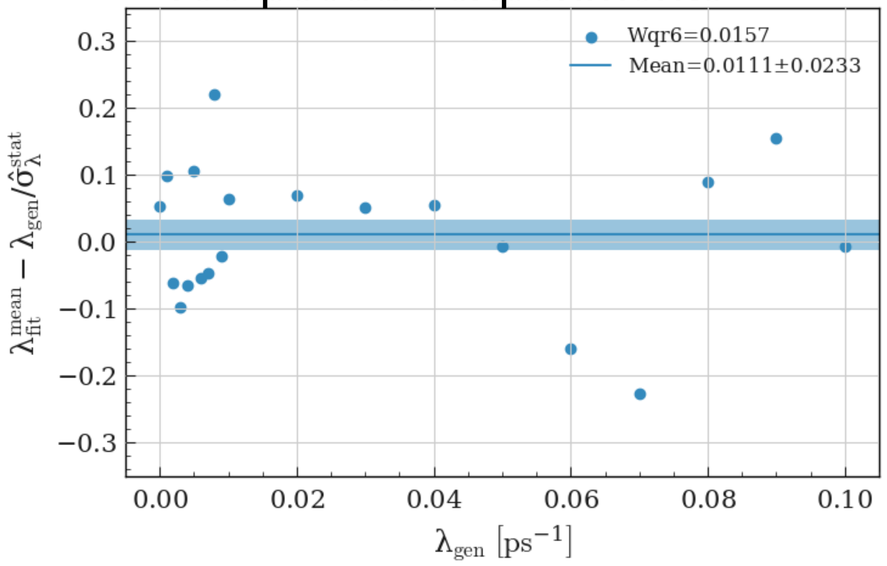
Fixing the pseudo experiment generation



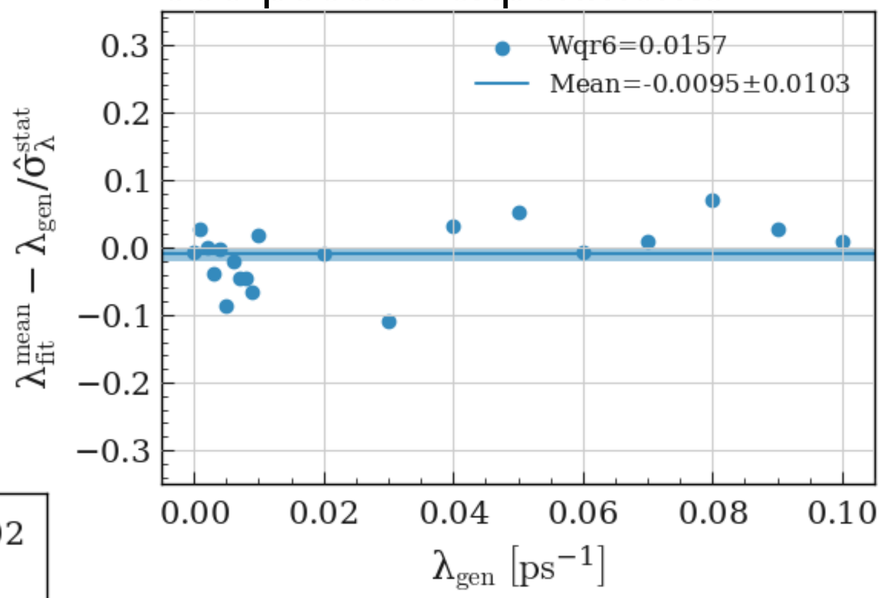
$$\overline{b/\sigma_b} = 1.081$$

Significance of “bias” in good wrong tag bins

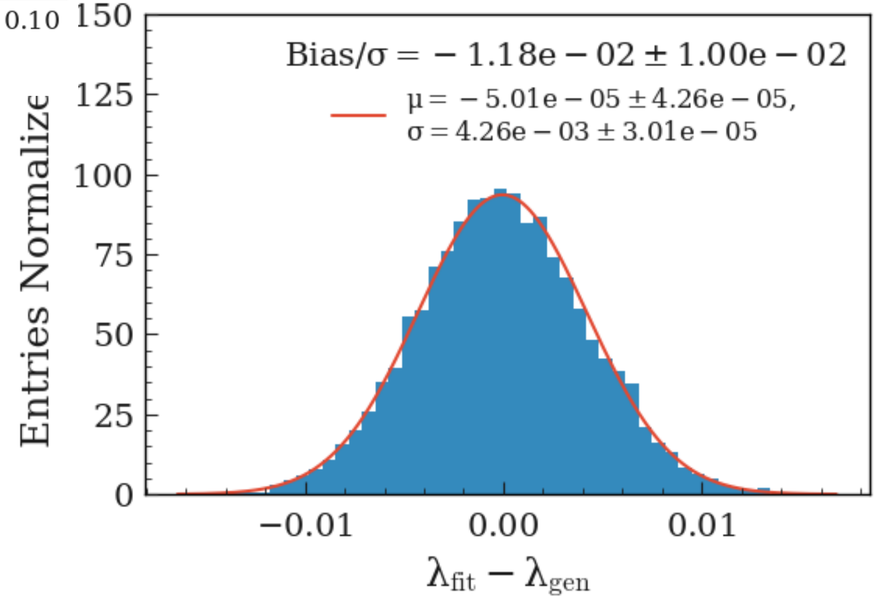
100 pseudo experiments



500 pseudo experiments

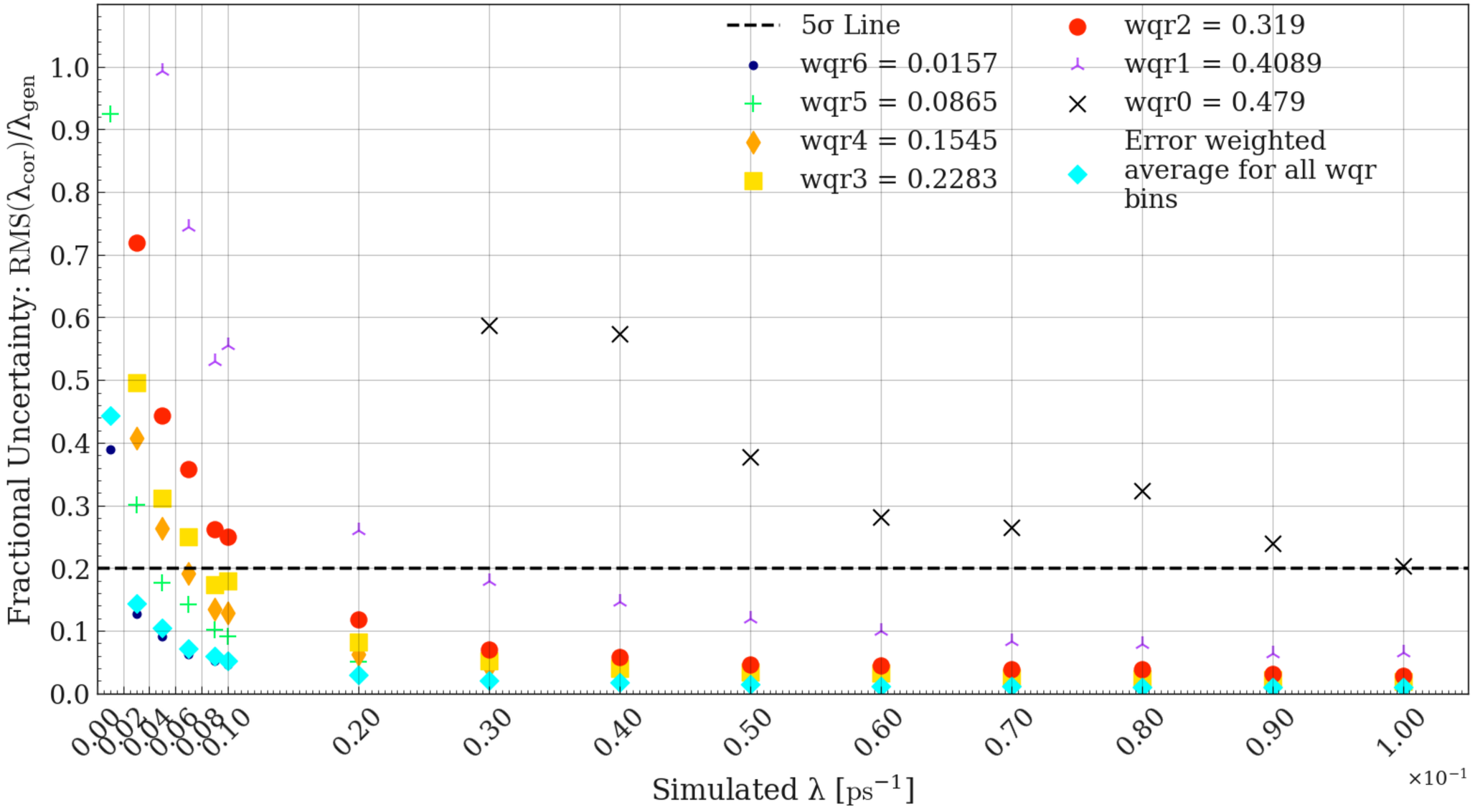


10k pseudo experiments



- No evidence for significant bias
- Bias is statistical dominated and on the order of $\leq 1\,\%$

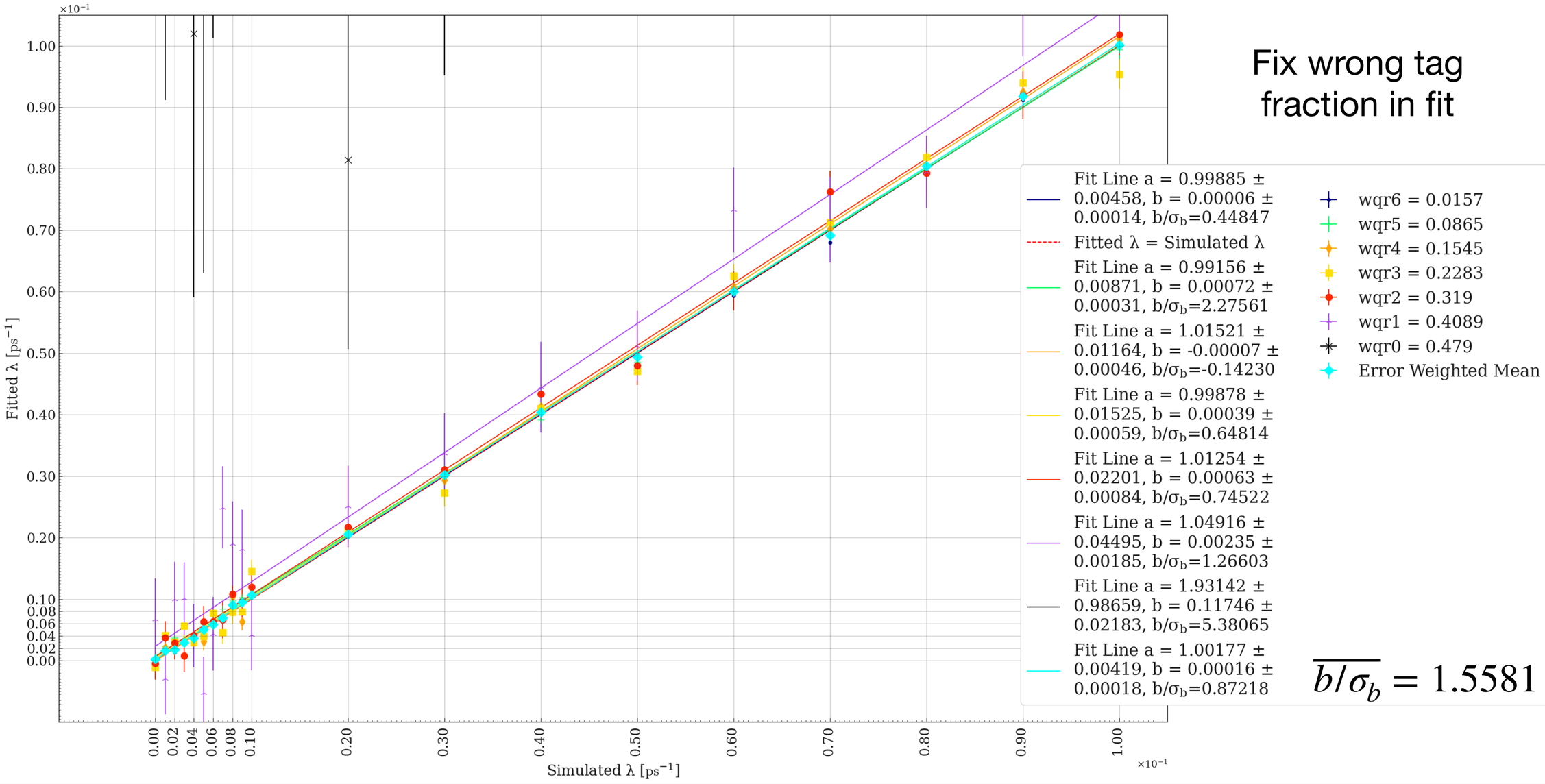
Fixed Sensitivity



Make simulation of Wrong tagging realistic

- So far: For example in best wrong tag bin we have $16.2\,\%$ of the data $\left(72k * 0.162 = 11664\right)$ with a wrong tag ration of $1.57\,\%$
  - ➡ Of these 11664 I flipped the sign (SF to OF or vice versa) of exactly $1.57\,\%$ events $\left(11664 * 0.0157 \approx 183\right)$, randomly
- The Problem: This is not correct as can be seen on coin tosses, each toss has a prob of $50\,\%$ but after 50 tosses we do not necessarily get 25 Heads-25 Tails
- Solution: Treat each event like a coin toss! Each event in the best wrong tag bin has a $1.57\,\%$ chance to flip its sign!

New wrong tag simulation

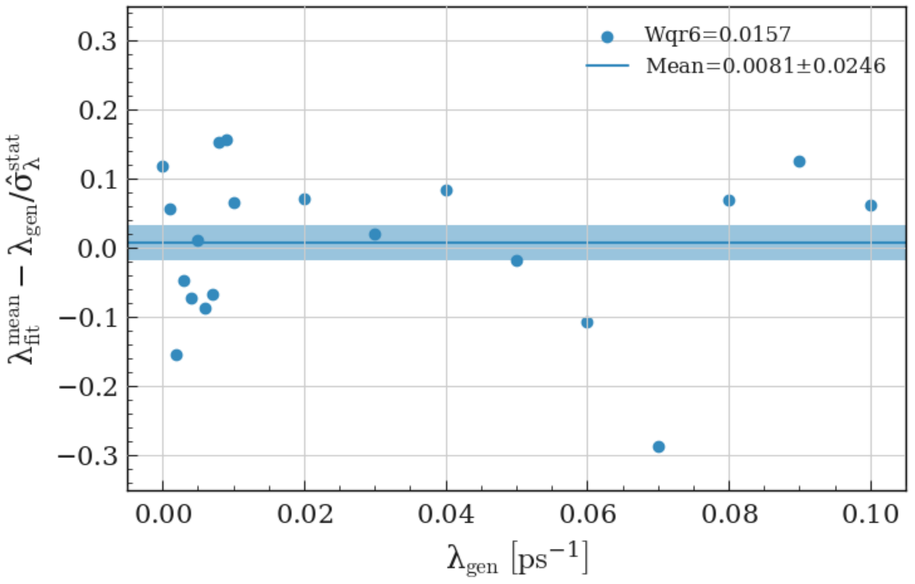


Fix wrong tag fraction in fit

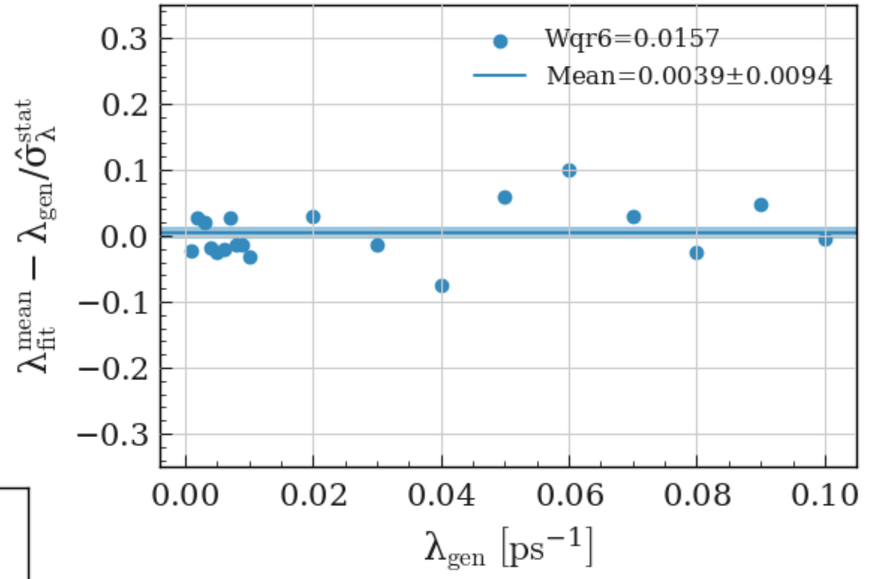
$\overline{b/\sigma_b} = 1.5581$

Significance of “bias” in good wrong tag bins

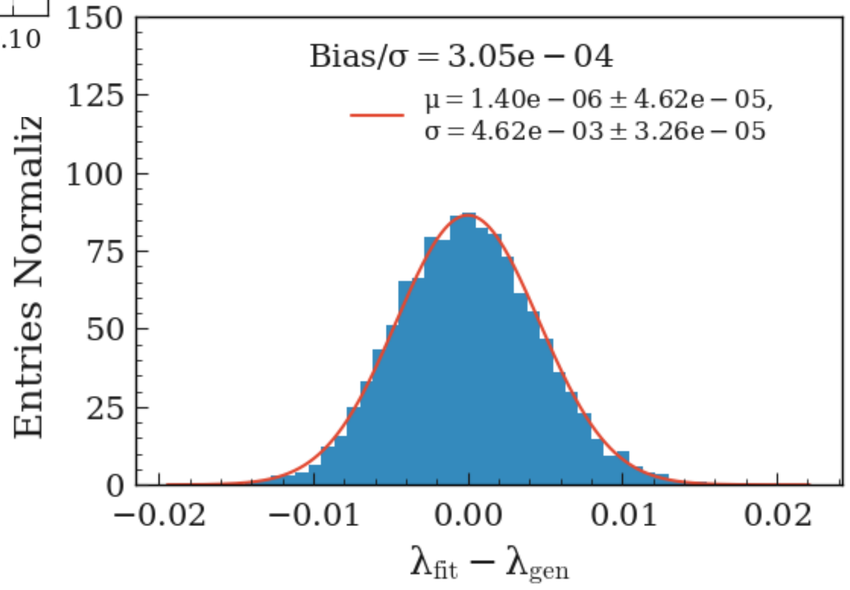
100 pseudo experiments



500 pseudo experiments

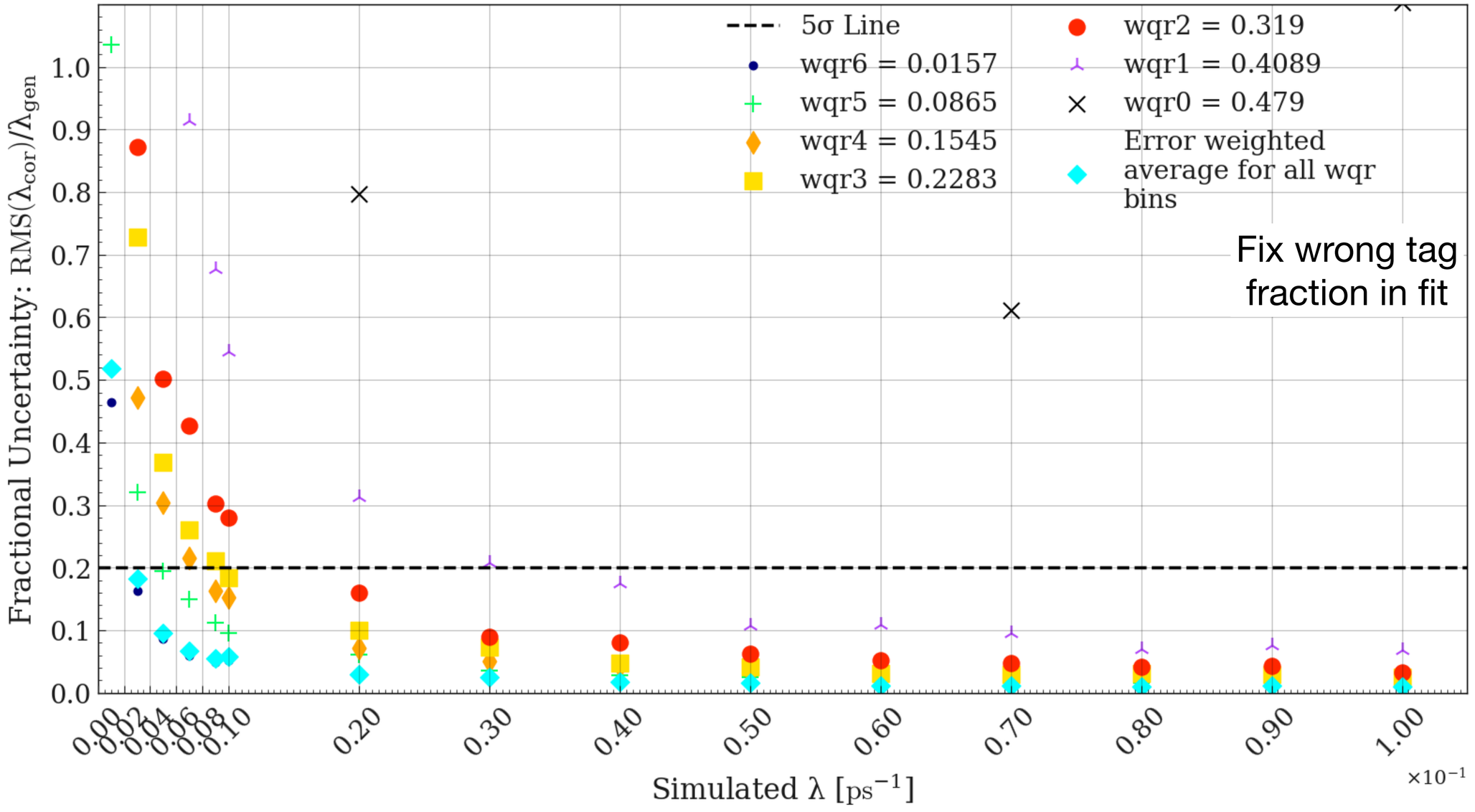


10k pseudo experiments

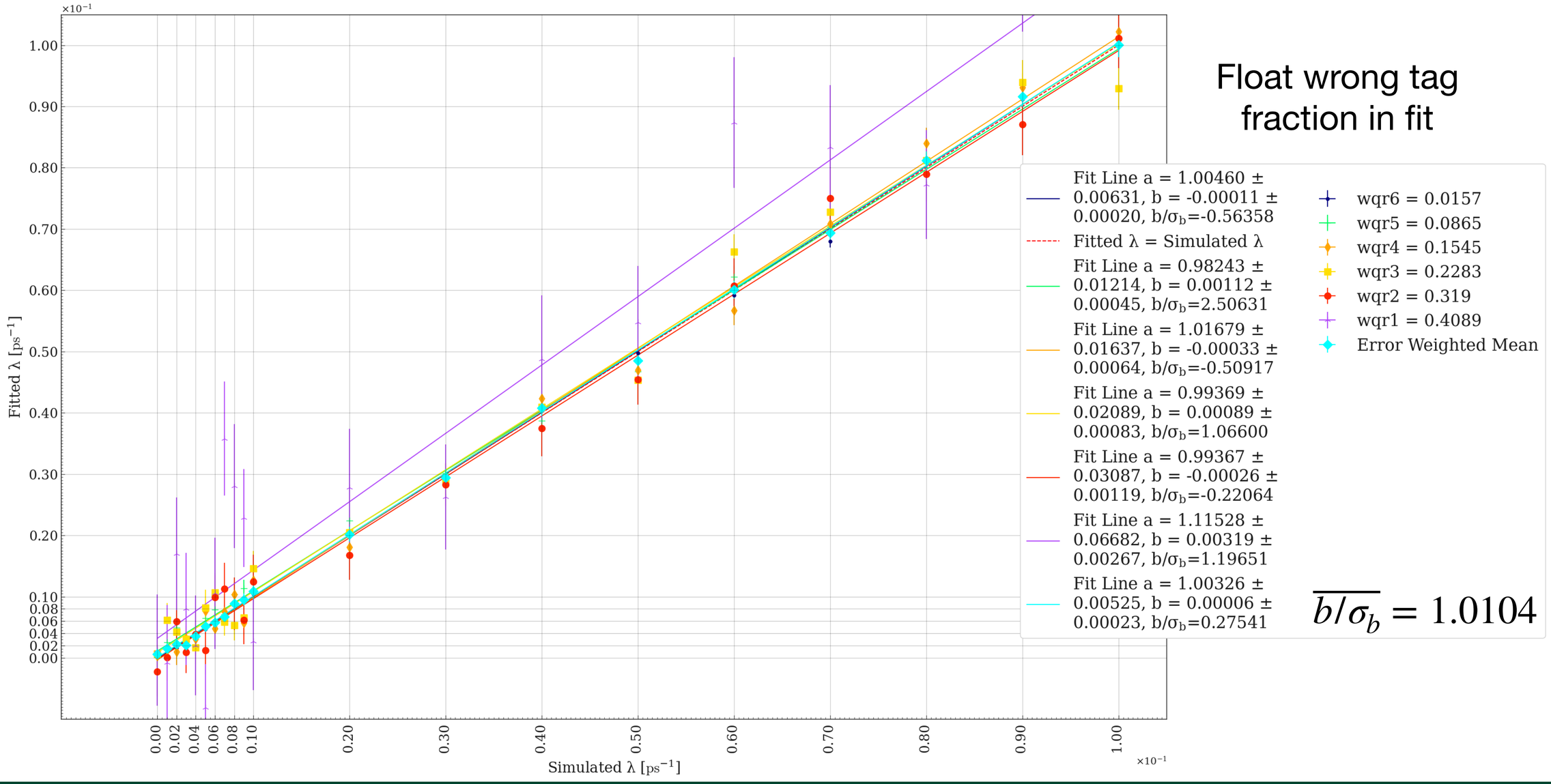


- No evidence for significant bias
- Bias is statistical dominated and on the order of $\leq 1\,\%$

Sensitivity for new wrong tag simulation



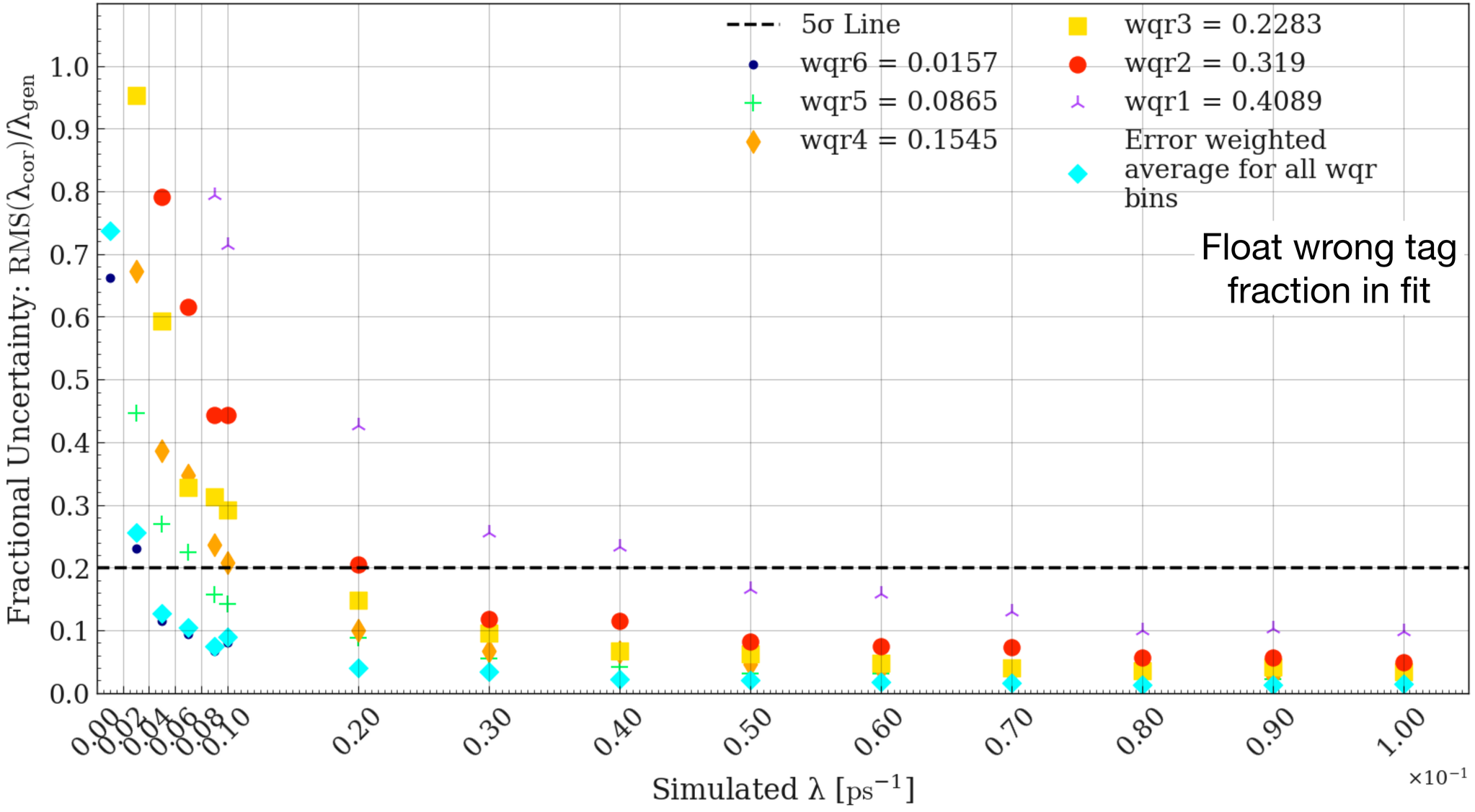
Repeat fit but let wrong tag fraction float



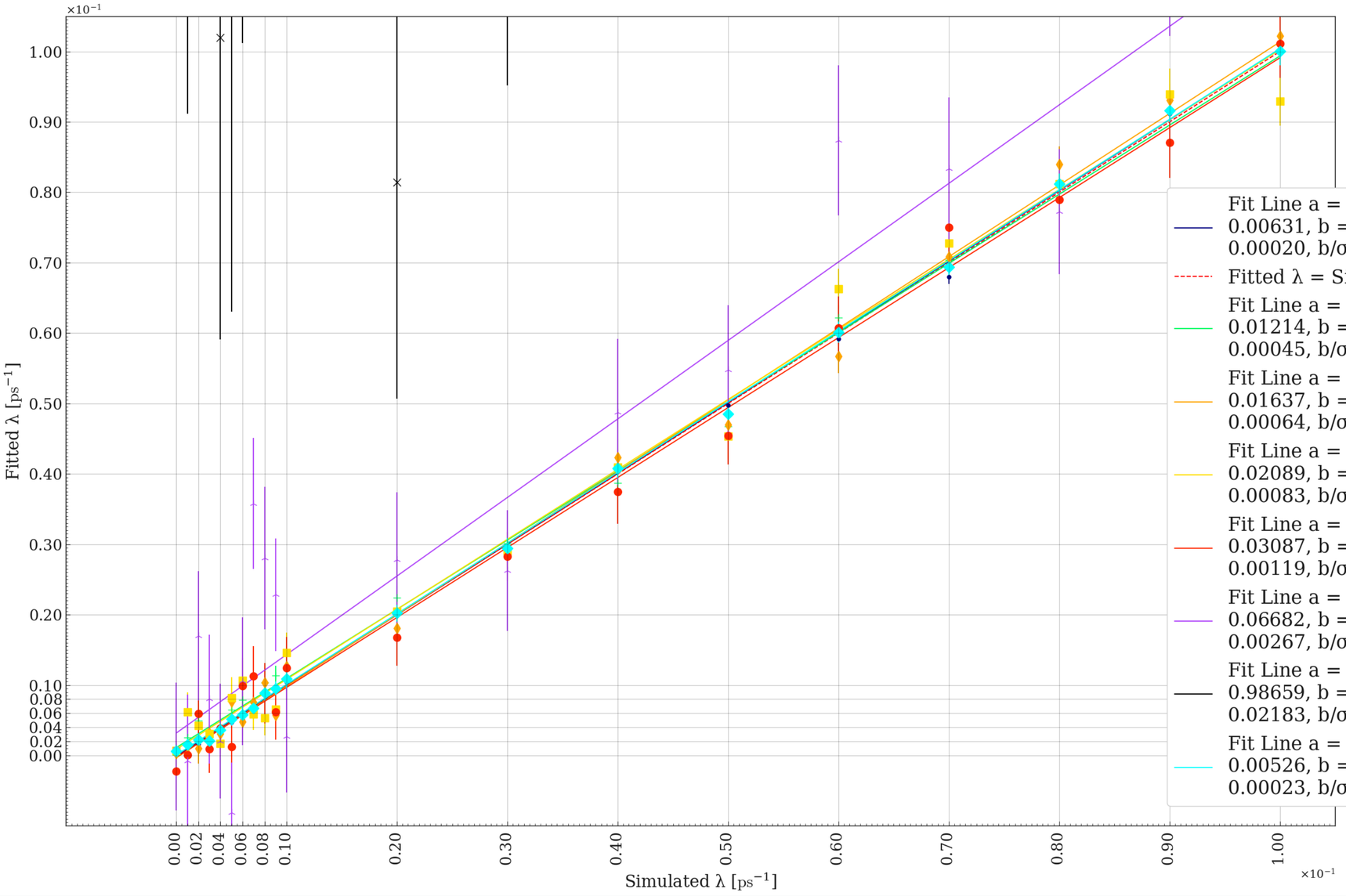
Float wrong tag fraction in fit

$$\overline{b/\sigma_b} = 1.0104$$

Sensitivity for letting wrong tag fraction float



Let every thing float and only fix w_{qr0}



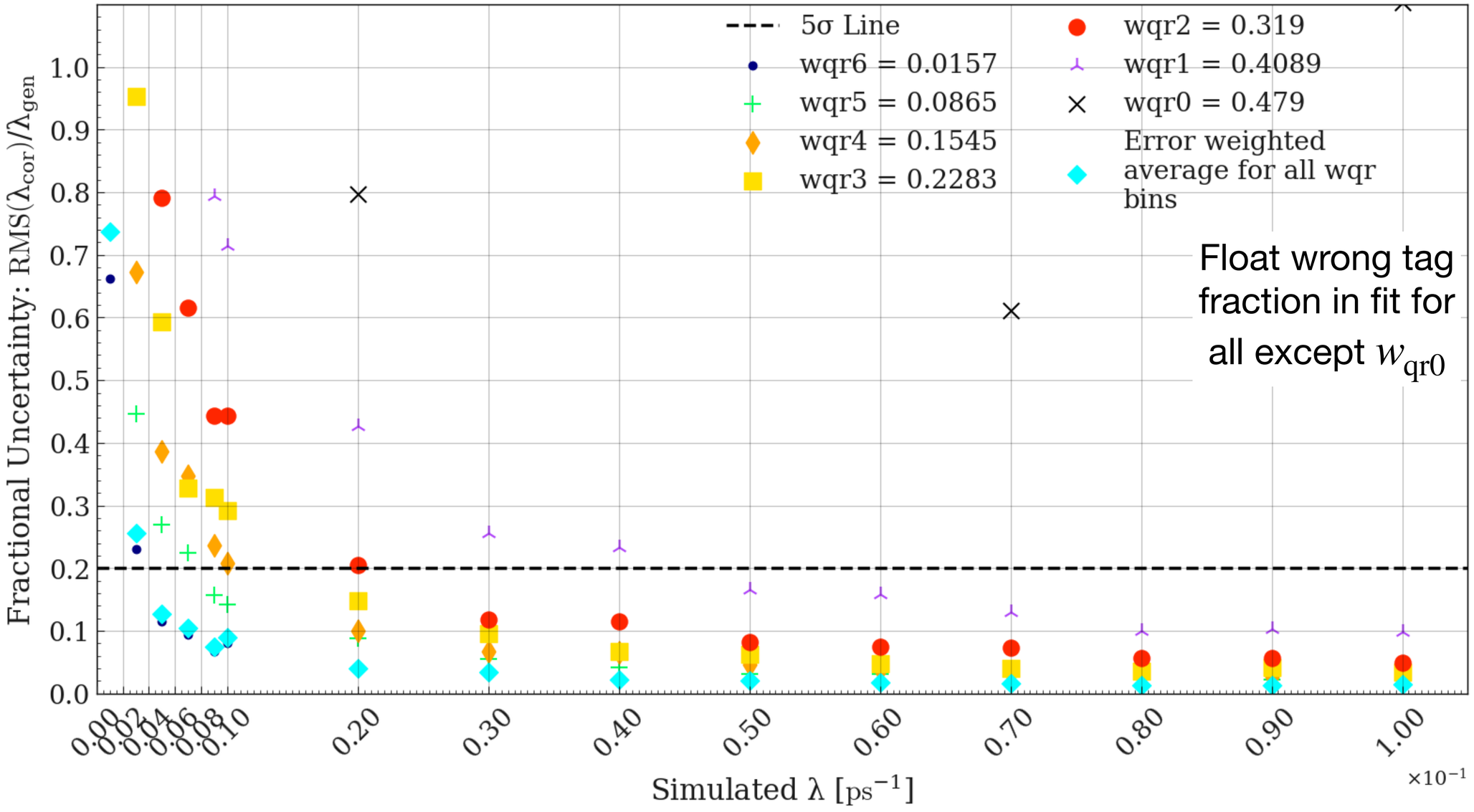
Float wrong tag fraction in fit for all except w_{qr0}

Fit Line a = 1.00460 ± 0.00631, b = -0.00011 ± 0.00020, b/σ_b=-0.56358
Fitted λ = Simulated λ
Fit Line a = 0.98243 ± 0.01214, b = 0.00112 ± 0.00045, b/σ_b=2.50631
Fit Line a = 1.01679 ± 0.01637, b = -0.00033 ± 0.00064, b/σ_b=-0.50917
Fit Line a = 0.99369 ± 0.02089, b = 0.00089 ± 0.00083, b/σ_b=1.06600
Fit Line a = 0.99367 ± 0.03087, b = -0.00026 ± 0.00119, b/σ_b=-0.22064
Fit Line a = 1.11528 ± 0.06682, b = 0.00319 ± 0.00267, b/σ_b=1.19651
Fit Line a = 1.93142 ± 0.98659, b = 0.11746 ± 0.02183, b/σ_b=5.38065
Fit Line a = 1.00320 ± 0.00526, b = 0.00007 ± 0.00023, b/σ_b=0.32105

wqr6 = 0.0157
wqr5 = 0.0865
wqr4 = 0.1545
wqr3 = 0.2283
wqr2 = 0.319
wqr1 = 0.4089
wqr0 = 0.479
Error Weighted Mean

$\overline{b/\sigma_b} = 1.6347$

Sensitivity



Summary

- Creating individual random numbers for the pseudo experiment generation fixed the “bias” problem
- Bias is of the order of $\leq 1\,\%$

  ➡ Therefore, no evidence for significant bias
- Incorporated more realistic wrong tag simulation, where every event has a percent chance to flip sign
- Observe good sensitivity for letting λ and wrong tag fraction float (except w_{qr0})

  $\Rightarrow$ Reach 5σ for $\lambda > 0.003\ \mathrm{ps}^{-1}$