Profile likelihood ratio limits in quadratic dominated fits

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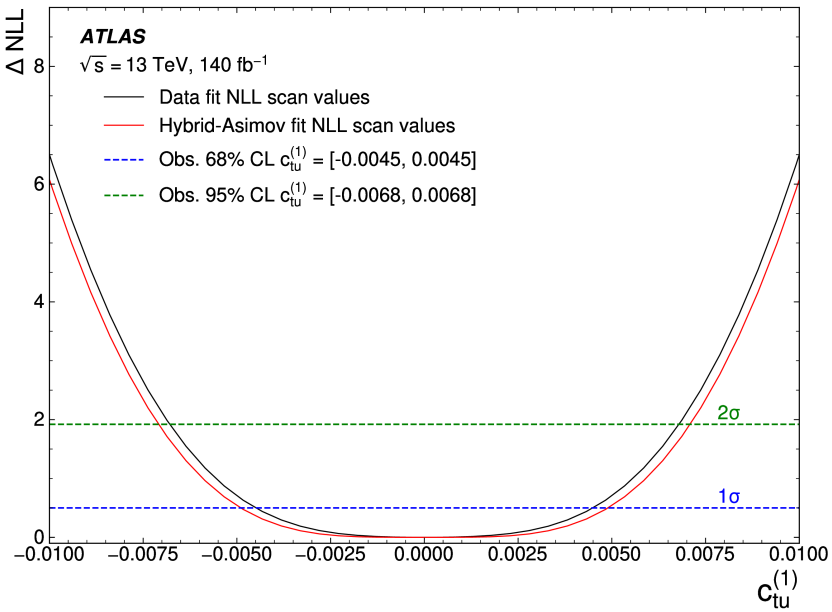
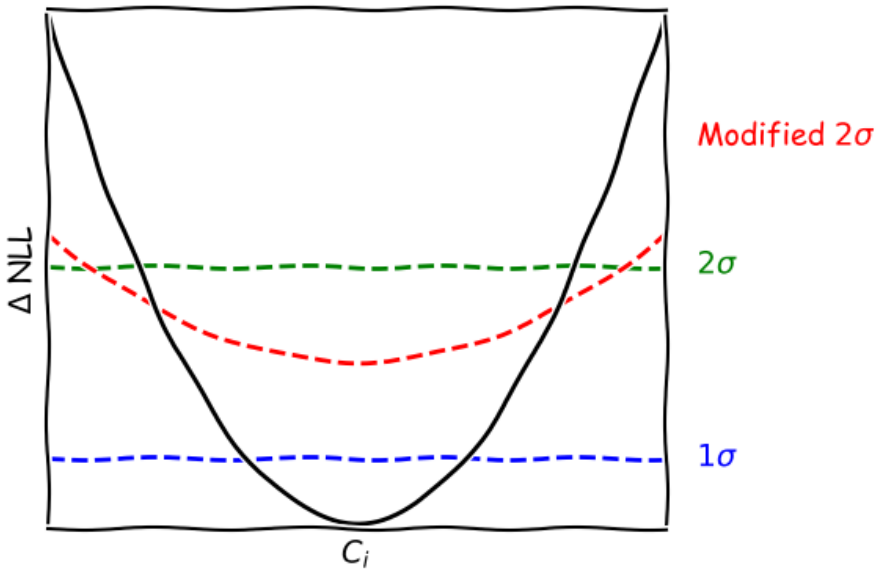
Likelihood fits with quadratic contributions

- In EFT fits: consider interference terms with SM (linear) and pure BSM terms (quadratic)
- Same-sign top analysis ▸ arXiv:2409.14982: no SM contribution → only quadratic contribution
- Checked computed likelihood limits with toys:
  - no undercoverage
  - slight overcoverage (at most 9 %) when Wilson coefficient is close to 0



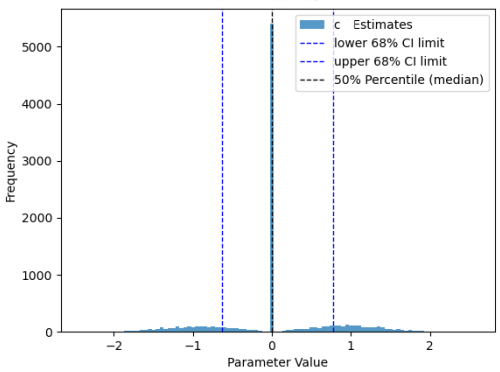


- Performed further studies with a linear+quadratic case

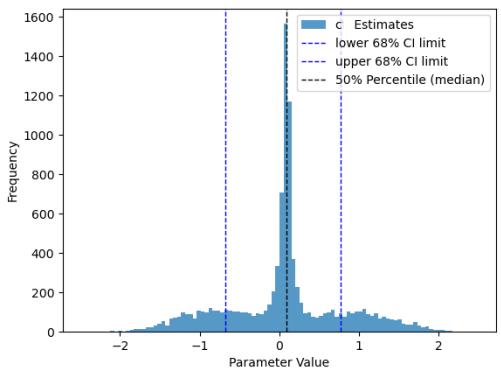
Toy distributions

- All following studies are performed in the context of an ongoing analysis
- Look at toy distributions for different contributions of quadratic and linear EFT terms
- Generate 10k toys

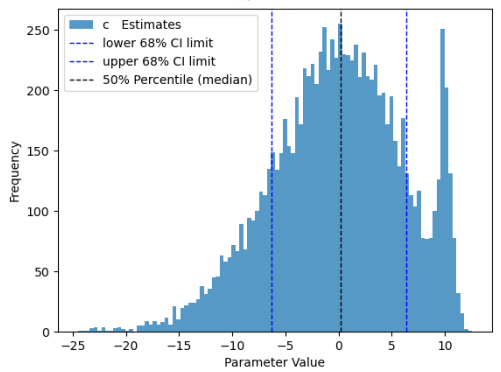
Quadratic only EFT dependence



Quadratic and linear EFT dependence



Linear only EFT dependence



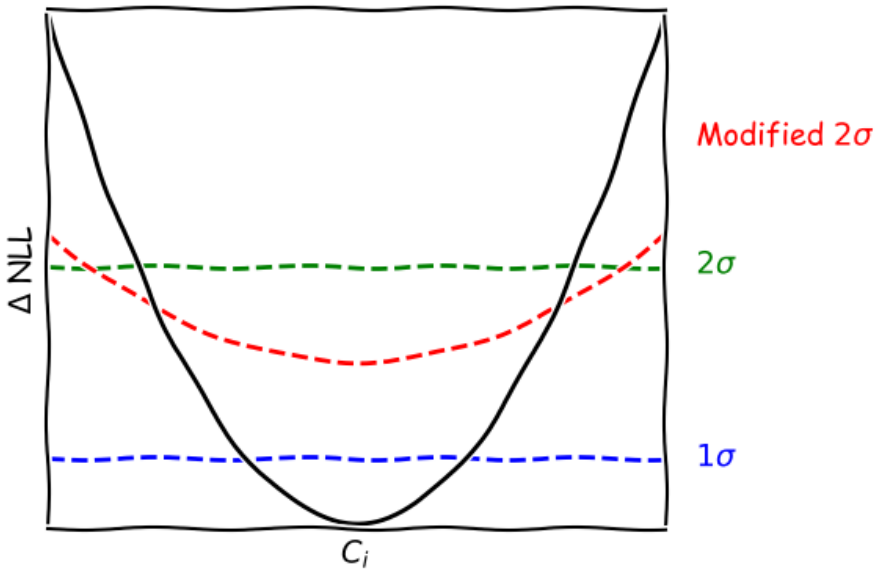
- Fit with quadratic contribution: additional peaks introduced by additional LH minima whith injected signal
- Fit with linear only contribution: recover Gaussian shape (peak at 10 comes from negative bin yields for high WC values)

Limits from toys

- Try to determine impact of violation of Wilk's theorem on LH limits
- If possible, compute corrected LH limits with toys

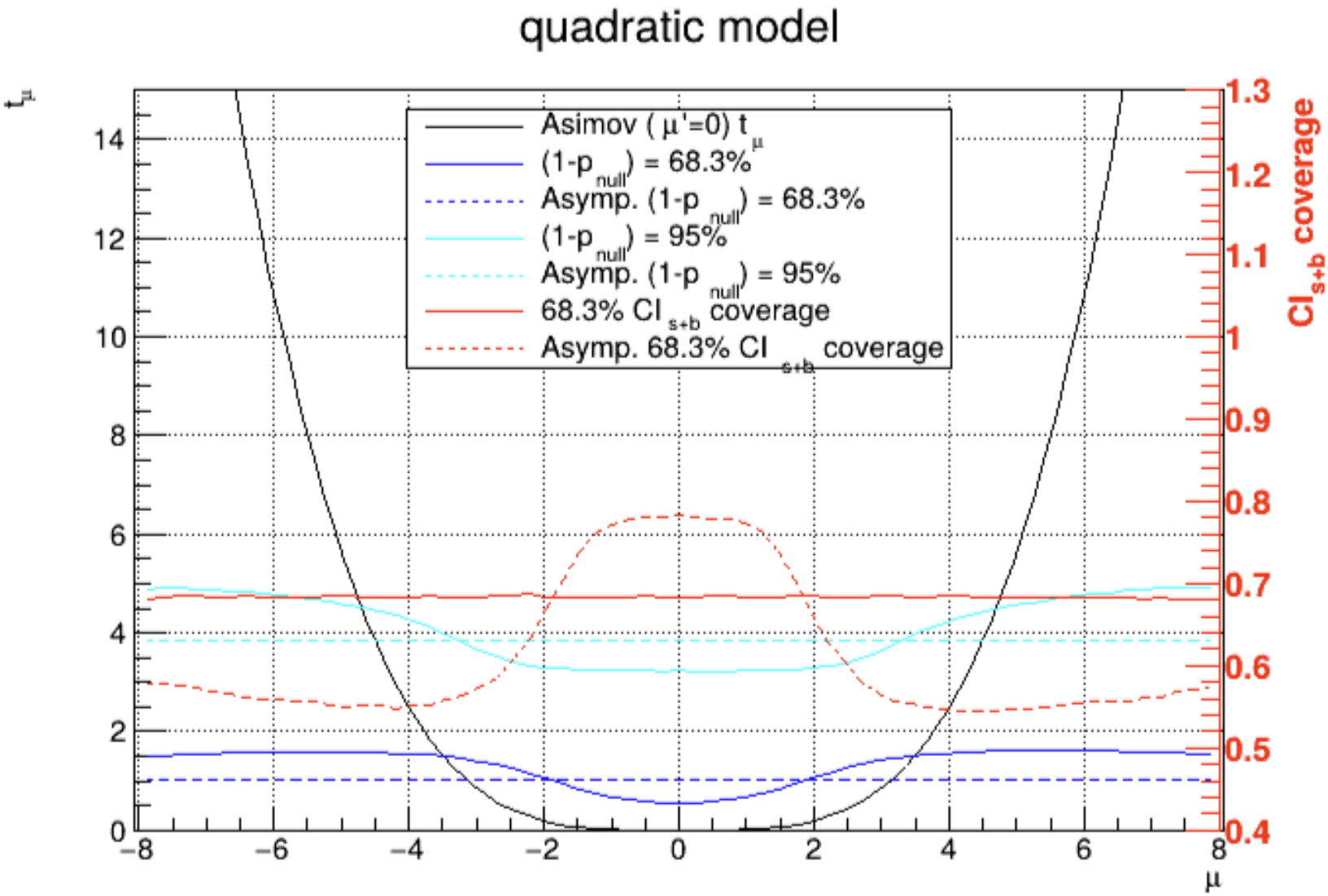
Method to compute these new limits:

- Compute toys around POIAsimov $= \mu_{test}$
- Get likelihood ratio at μ_{test} for each toy
- Determine at which value of the LH ratios, 68 % of the toy LH ratios are below this value
- This LH ratio value corresponds to the 1σ contour at this μ_{test} value



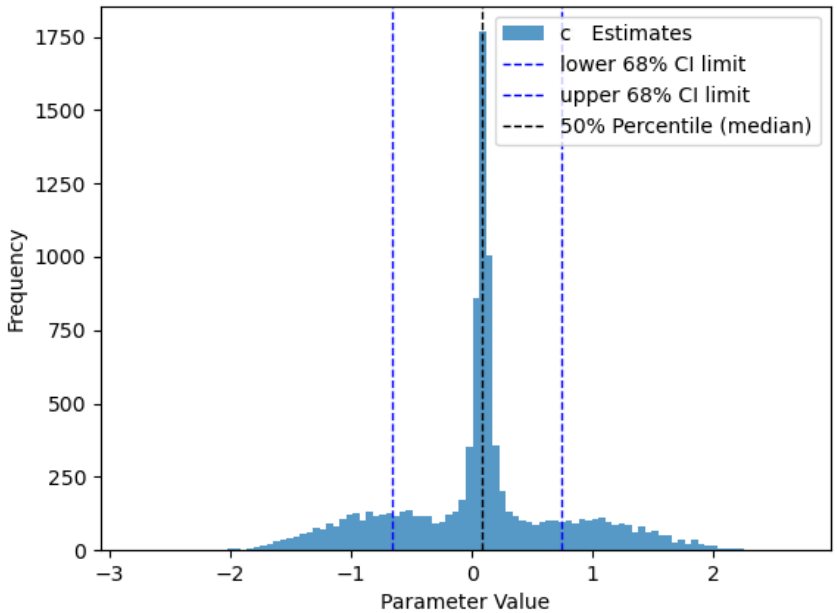
Test of this method

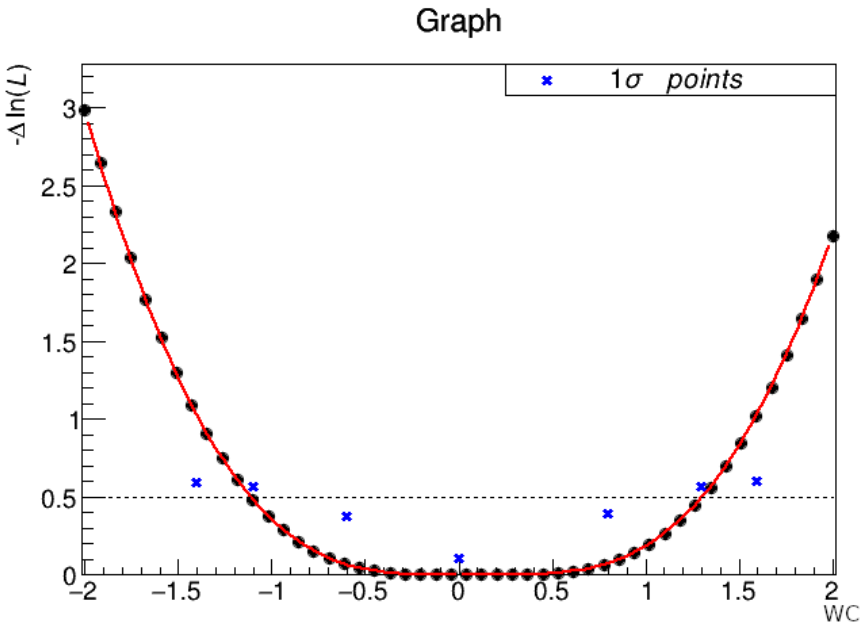
- Test of this method with pedagogical example including linear and quadratic terms



Toy results in fit with one WC

- Perform fit with one WC (linear and quadratic dependence)





- Limit with default contour (0.5): $[-1.11, 1.30]$
- Limits with toy contour: $[-1.16, 1.35]$

Limits from toys

$1d$ case:

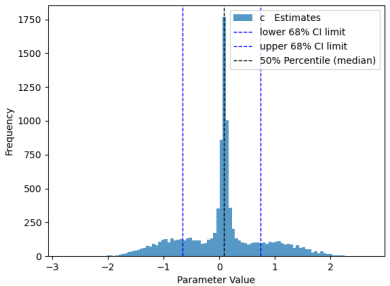
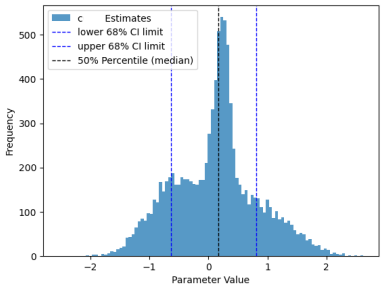
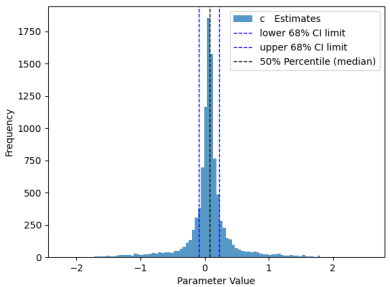
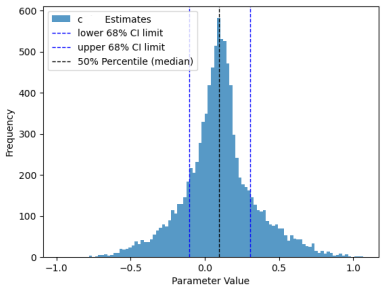
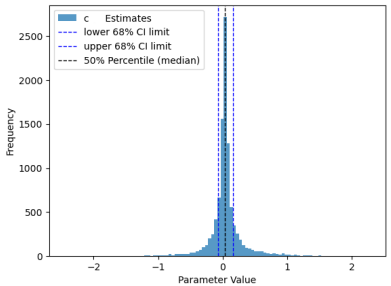
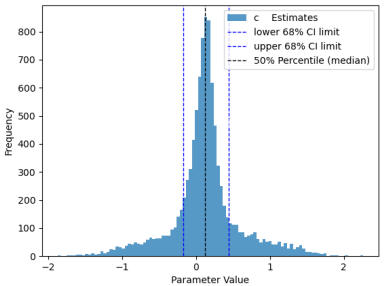
- Have working method
- Method can be computationally expensive when providing full 1σ line $\rightarrow$ only show around crossing points?
- Not clear how to determine systematics ranking

More dimensional case:

- In many analyses several WCs fit at the same time
- Method does not scale for multiple dimensions
- Tried so far to look at 1d limits in multi-EFT fits

Toy distribution in multi-EFT vs. single EFT

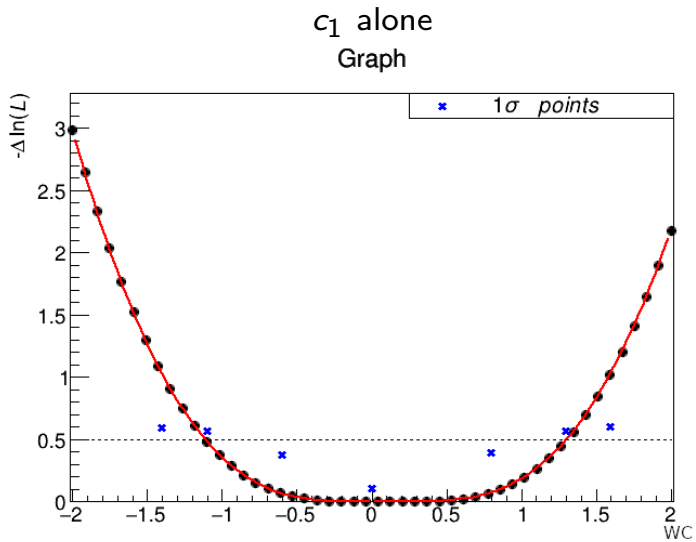
- Compare toy distributions in fit with 1 WC versus in fit with 4 WCs

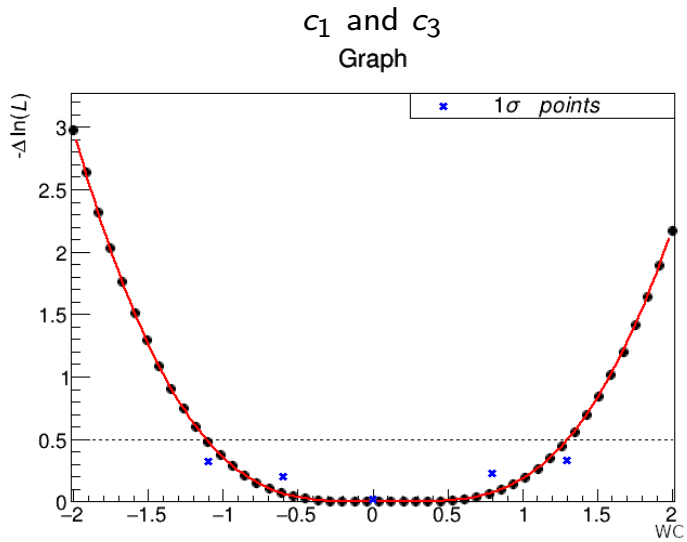
	c_1	c_2	c_3	c_4
1 WC				
4 WCs				

- Constraining several WCs at the same time seems to remove the additional peaks

Toy results in fit with 2 WCs

- Consider c_1 results in fit with 2 WCs (c_1 and c_3)
- Correlation between c_1 and c_3: 12 %



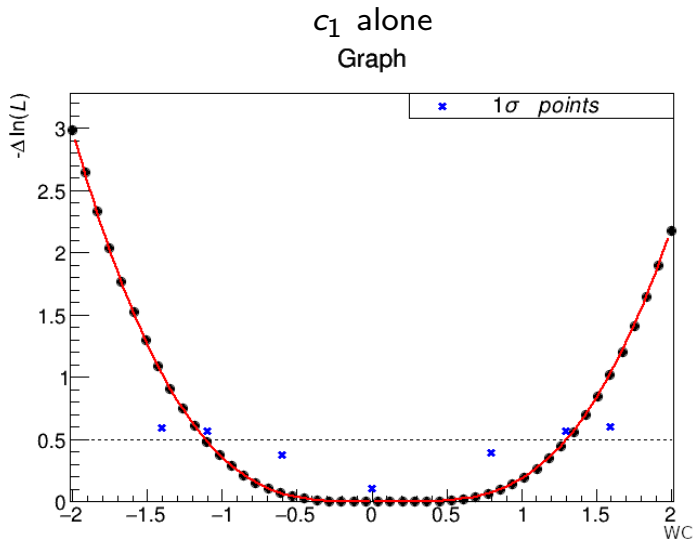


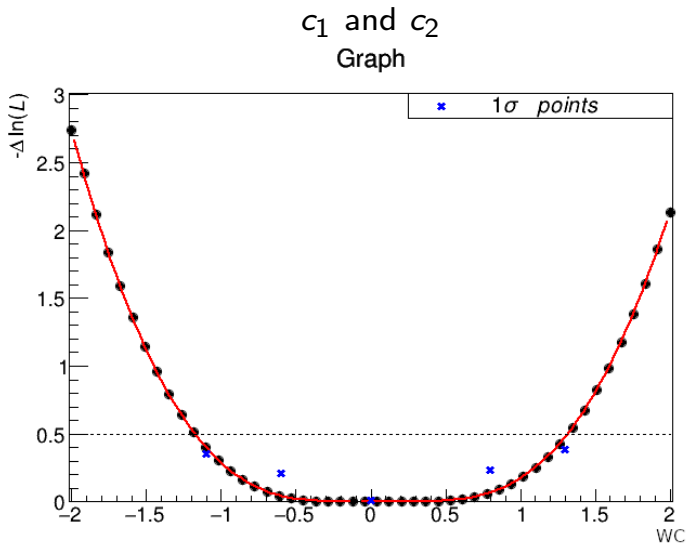
- Limit with default contour (0.5): $[-1.11, 1.30]$
- Limits with toy contour: $[-1.16, 1.35]$

- Limit with default contour (0.5): $[-1.12, 1.31]$
- Limits with toy contour: $[-0.98, 1.17]$

Toy results in fit with 2 WCs

- Consider c_1 results in fit with 2 WCs (c_1 and c_2)
- Correlation between c_1 and c_2: $-2\,\%$





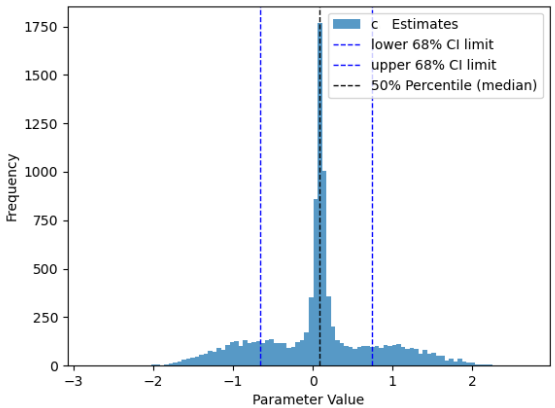
- Limit with default contour (0.5): $[-1.11, 1.30]$
- Limits with toy contour: $[-1.16, 1.35]$

- Limit with default contour (0.5): $[-1.18, 1.32]$
- Limits with toy contour: $[-1.06, 1.23]$

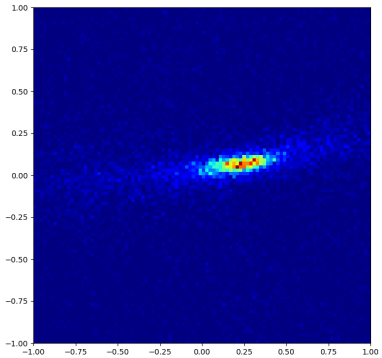
Toy distribution in fit with different correlations

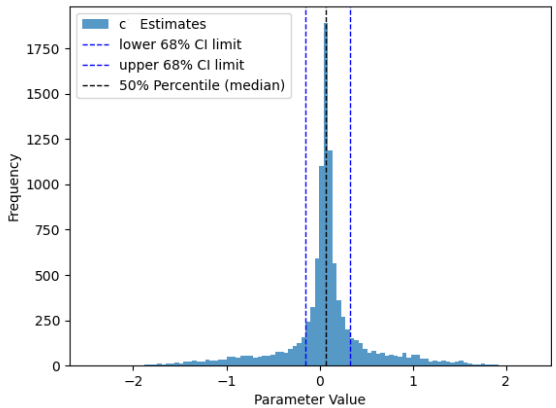
- Fit different combinations of WCs which have different correlations

c_1

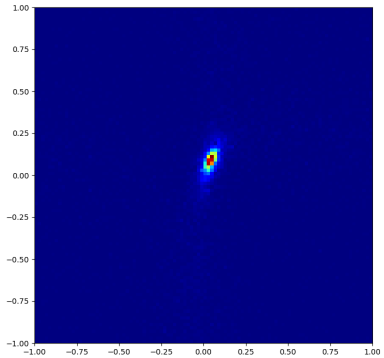


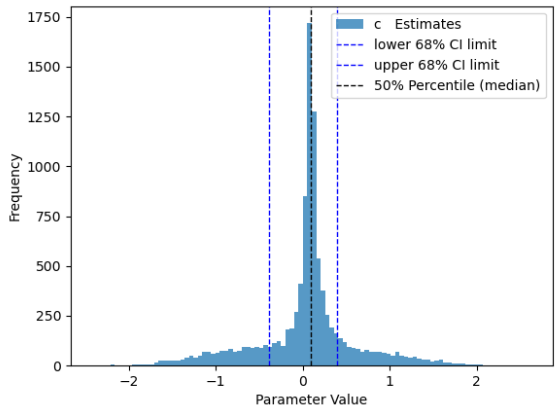
c_1 and c_2





c_1 and c_3

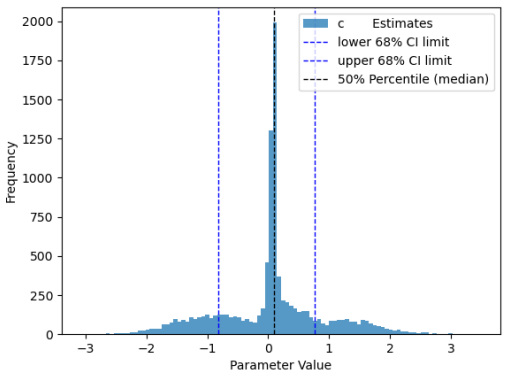




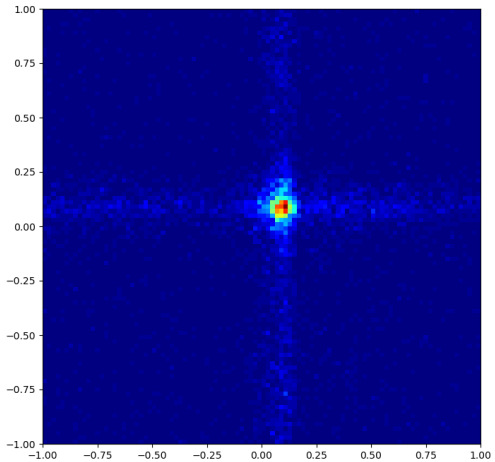
Toy distribution in fit with low correlations

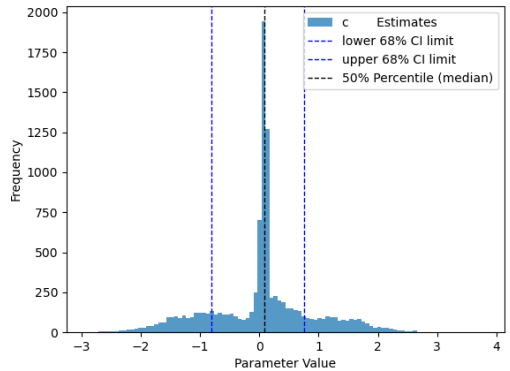
- Consider two operators c_5 and c_6
- Correlation between c_5 and c_6: 0 %

c_5



c_5 and c_6



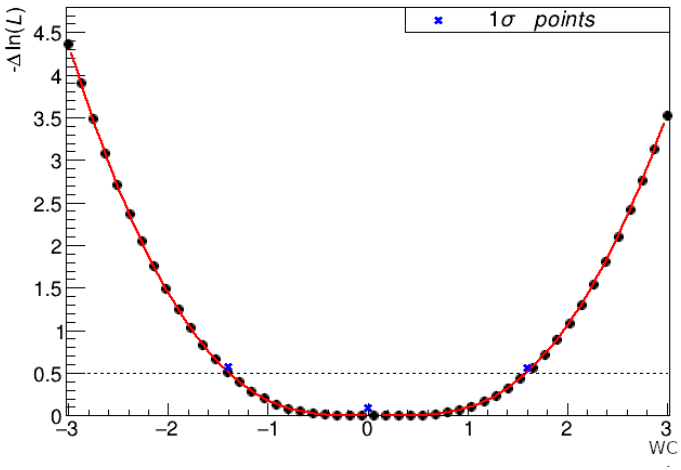


- adding c_6 in fit does not have major impact on c_5 distribution

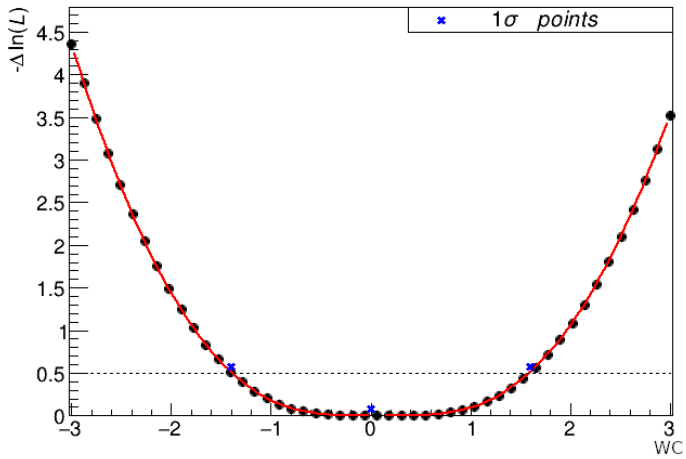
Toy results in fit with 2 WCs

- Consider c_5 results in fit with 2 WCs

c_5 alone



c_5 and c_6



- Limit with default contour (0.5): $[-1.39, 1.59]$
- Limits with toy contour: $[-1.46, 1.67]$

- Limit with default contour (0.5): $[-1.39, 1.59]$
- Limits with toy contour: $[-1.46, 1.66]$

Summary

- For 1d fits: toy results seem sensible
- Some remaining issues/open questions:
  - How many points to compute for modified 1σ or 2σ line?
  - How to compute systematics ranking?
- What to do for multi-dimensional fits?
  - Method does not scale to more dimensions (computationaly expensive, how to report multi-dimensional results)
  - $1d$ limits in multi-EFT fits behave counter-intuitively