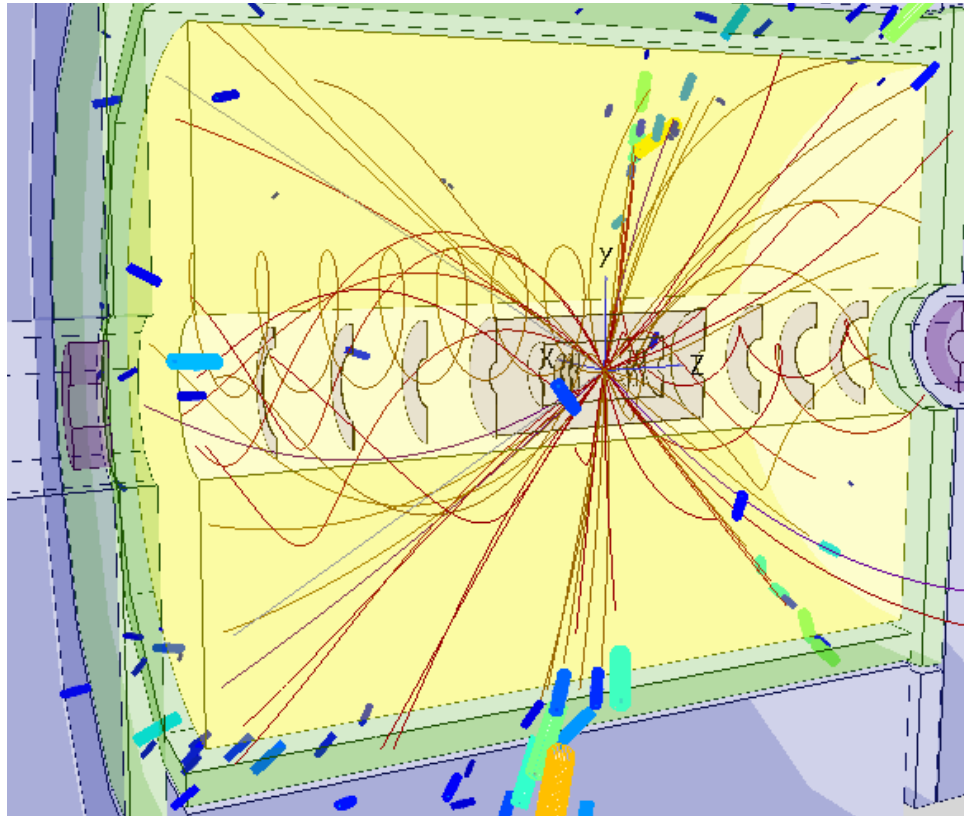


Extracting top-quark mass and Yukawa coupling from the threshold scan



Kacper Nowak, Aleksander Filip Żarnecki

Faculty of Physics, University of Warsaw

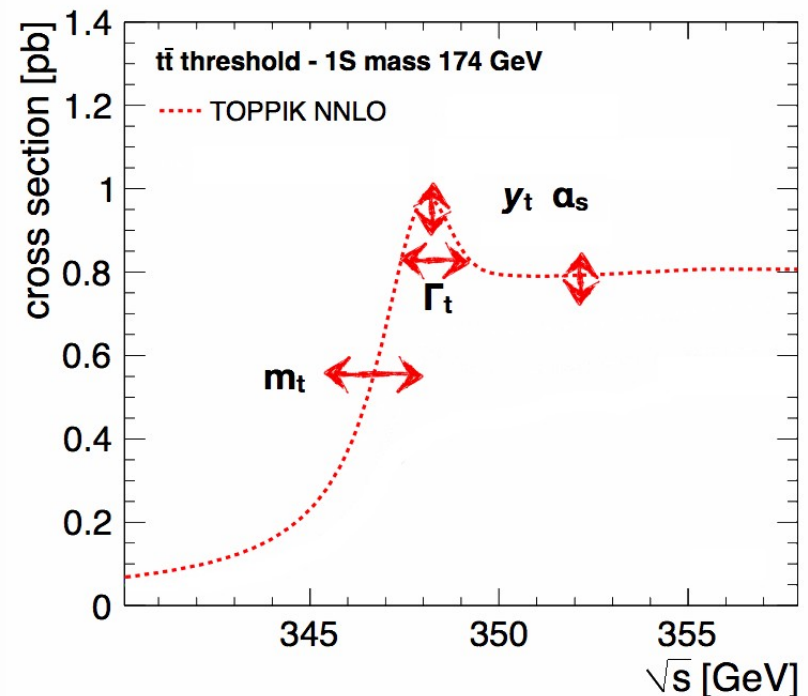
CLICdp WG analysis meeting 05-04-2019

Motivation

Shape of the threshold cross section depends not only on the **top-quark mass**, but also on other parameters: top-quark width, strong coupling constant and **top Yukawa coupling**.

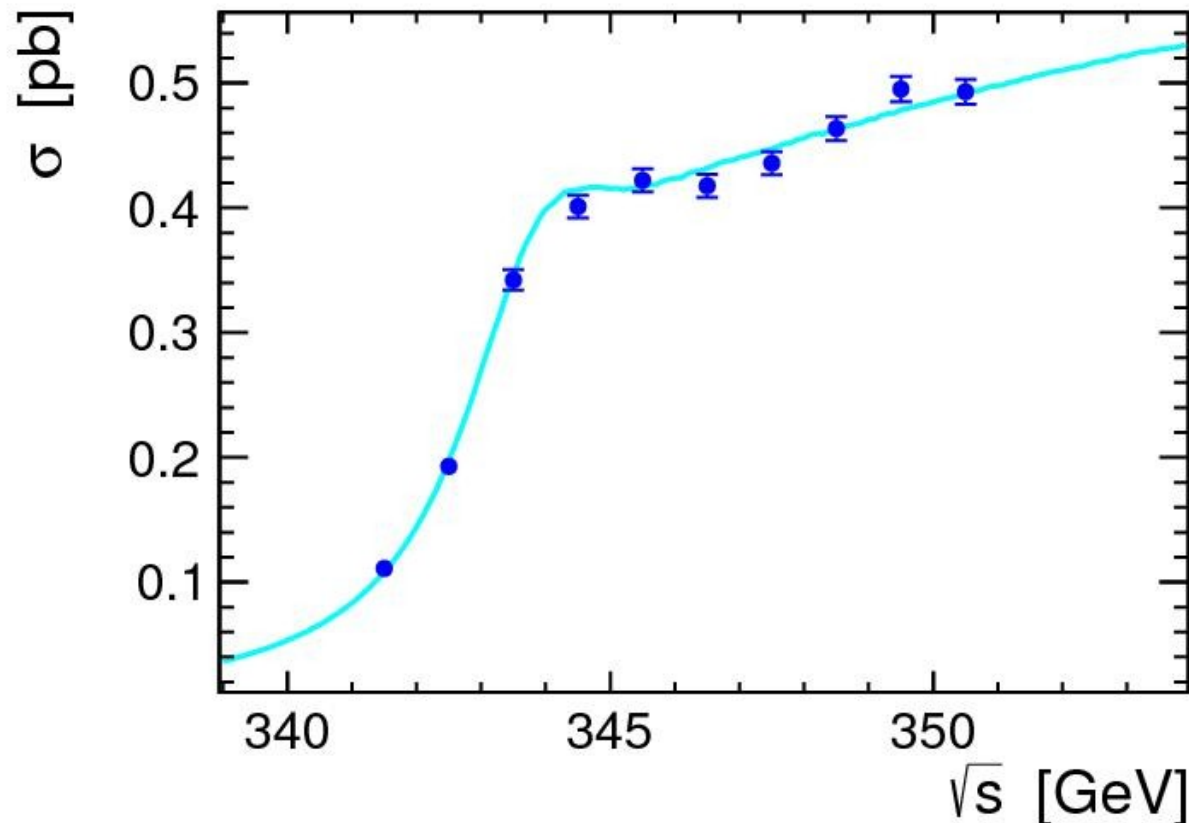
How well can we measure the top-quark mass taking uncertainties on all other parameters into account?

Is it possible to extract y_t from the threshold scan?



Benchmark scenario

Assume 10 measurements at the threshold, with 1 GeV step in energy, with 10 fb^{-1} taken at each energy point (100 fb^{-1} total).



New:

Generate statistical fluctuation assuming 70.2% event reconstruction efficiency and background level (remaining after cuts) corresponding to the 73 fb

[K. Seidel et al., Eur. Phys. J. C 73 \(2013\) 2530 \[arXiv:1303.3758\]](#)

Fit procedure

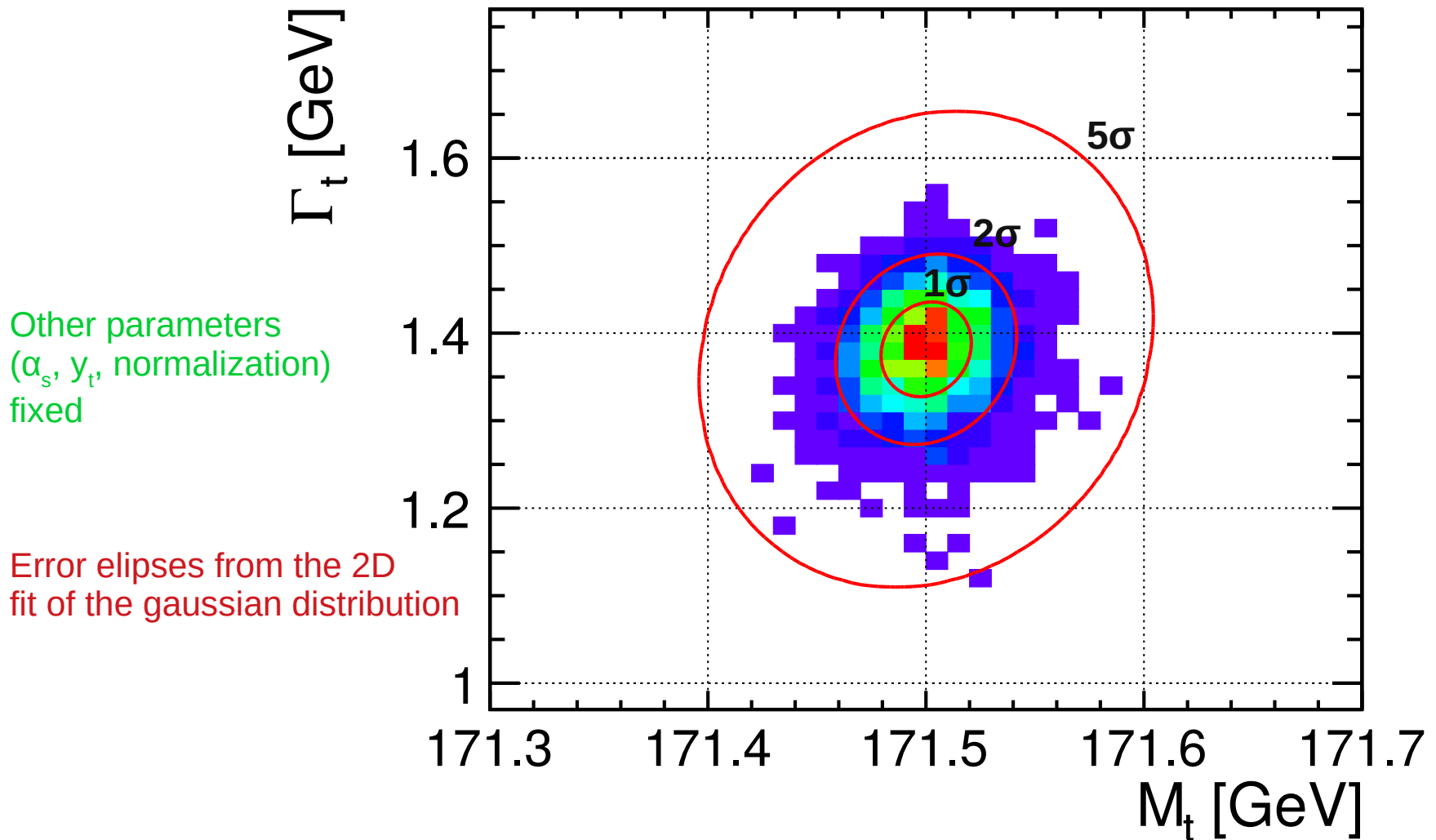
For each generated data set (pseudo-experiment) χ^2 value is calculated for different parameter values (different templates)

Quadratic dependence of the χ^2 value on the model parameters is fitted to find the best fit parameter values and the estimated uncertainty (corresponding to $\Delta\chi=1$)

Fits resulting in the parameter values outside the range used to generate templates are ignored.

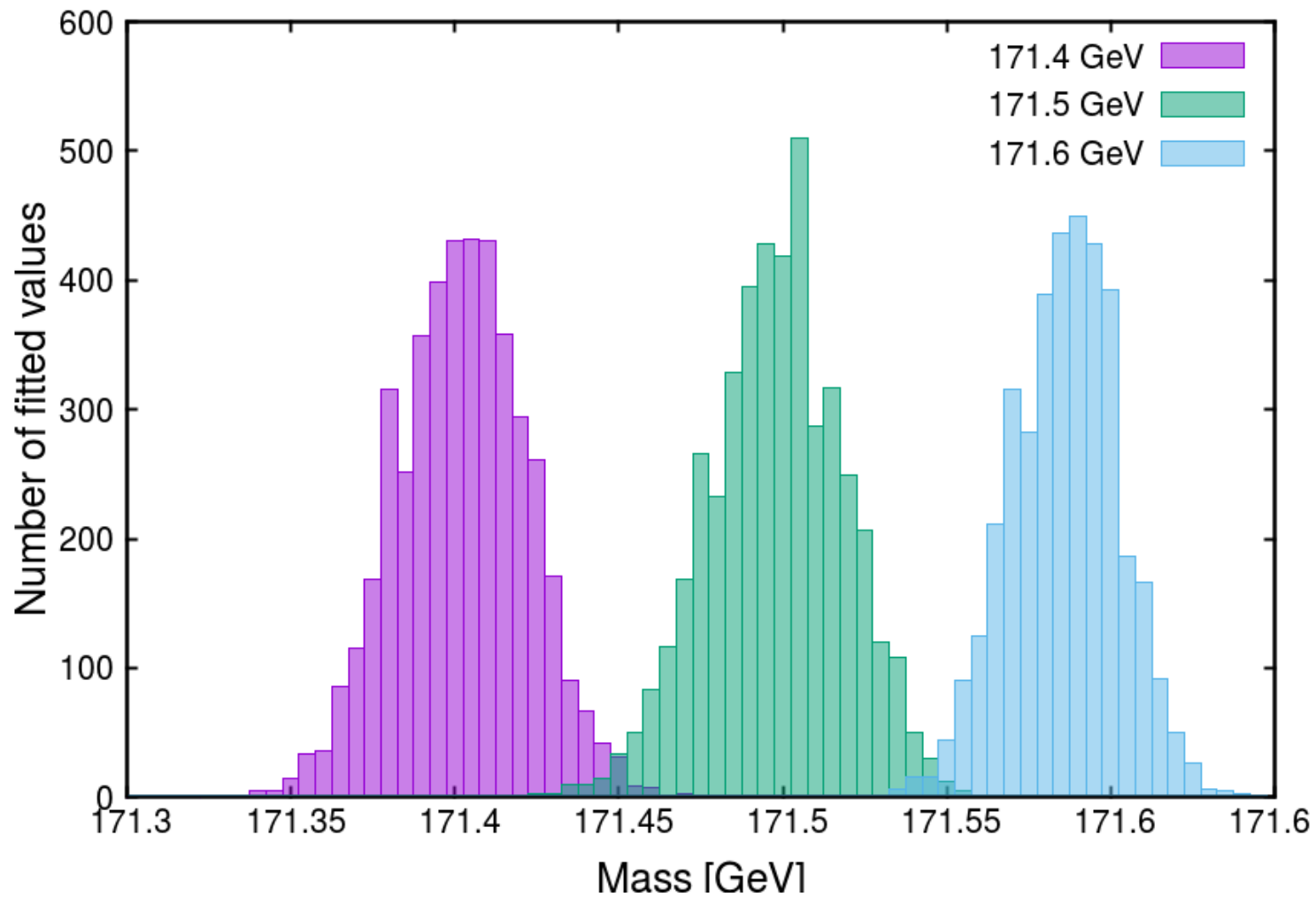
Example of fit results

Fit with two free parameters (**2D**): mass vs width



Validation

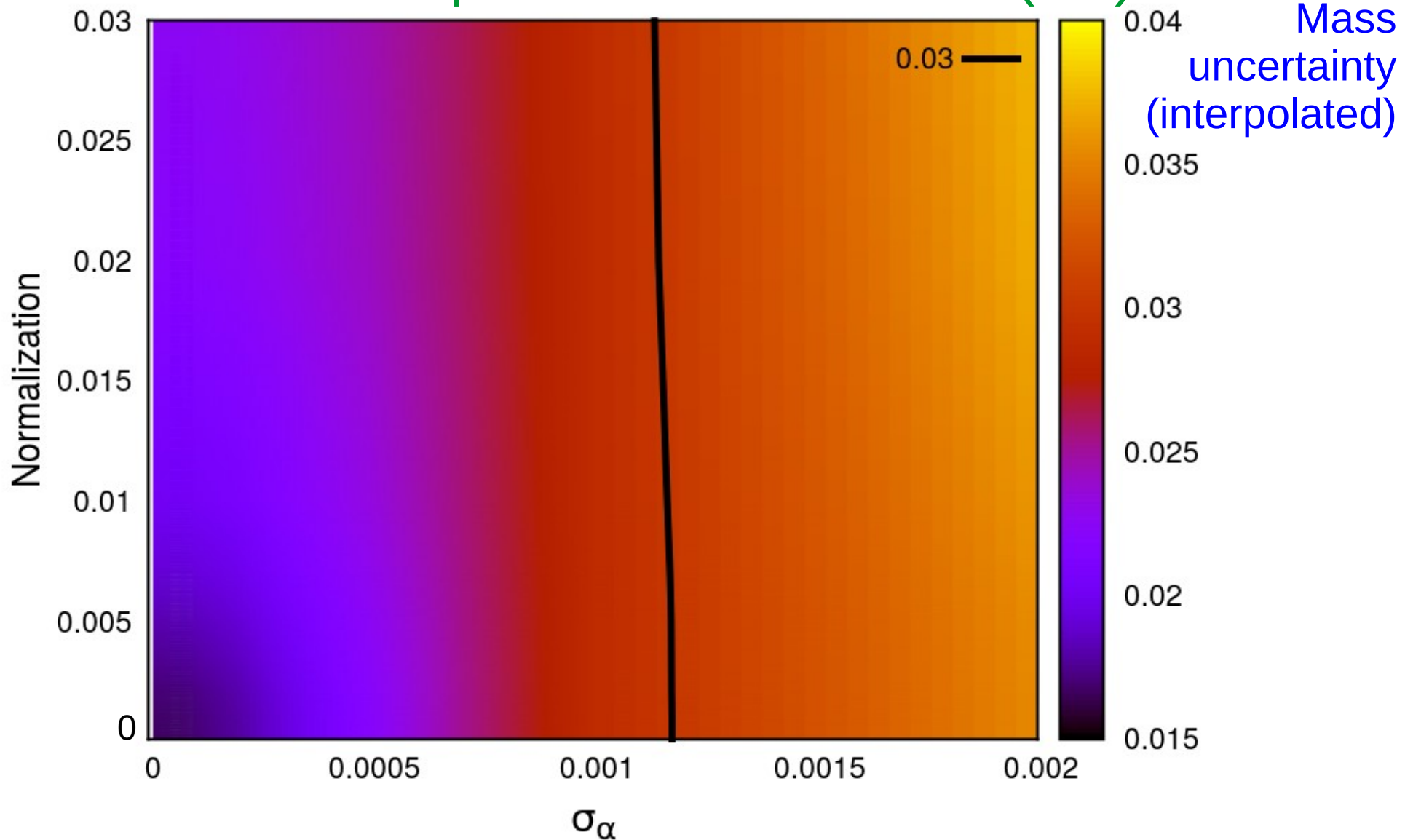
Fit results for different choices of template for pseudo-experiment generation



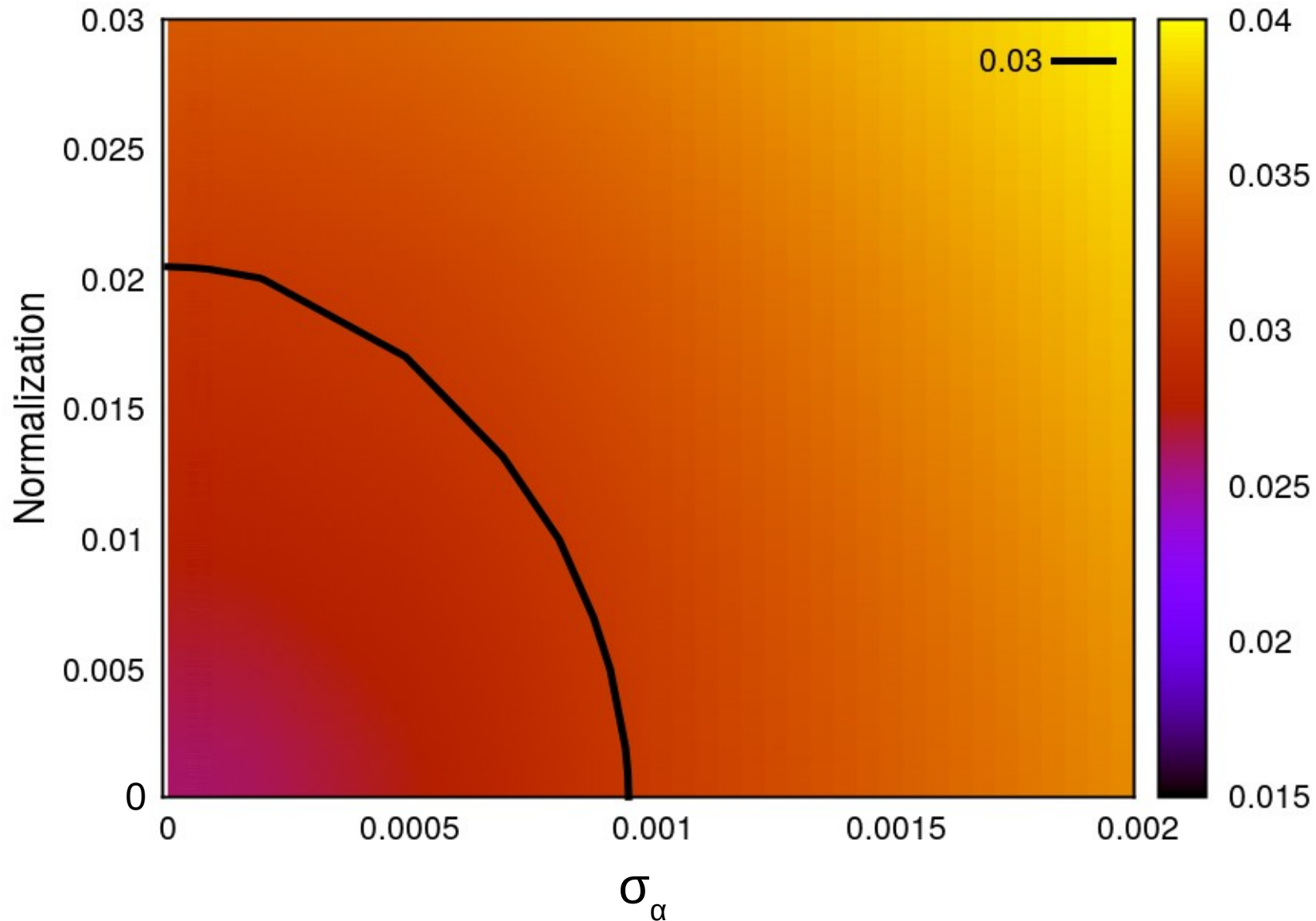
Recent progress

Consider overall normalization uncertainty and uncertainty of strong coupling constant

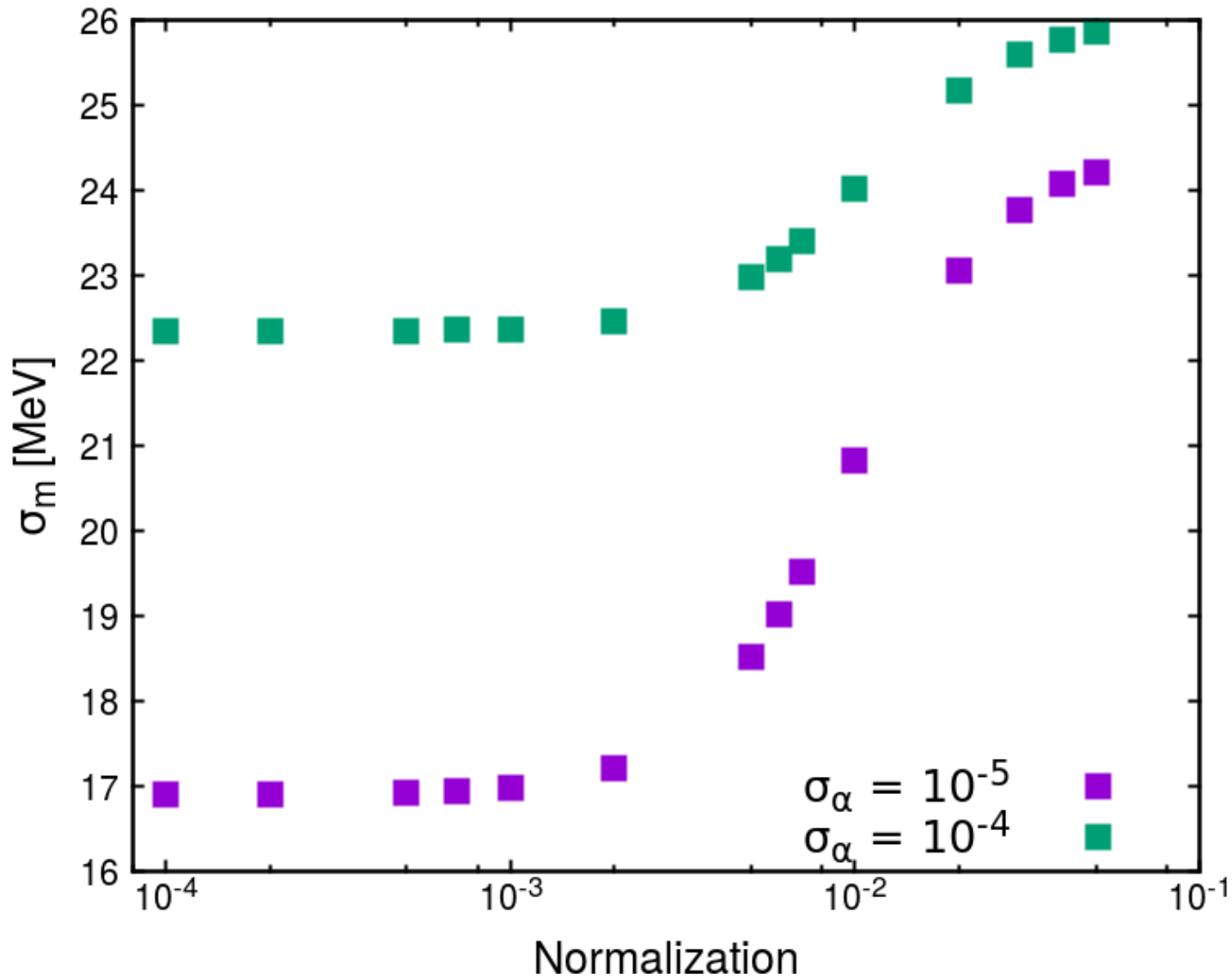
two more parameters in the fit (4D)



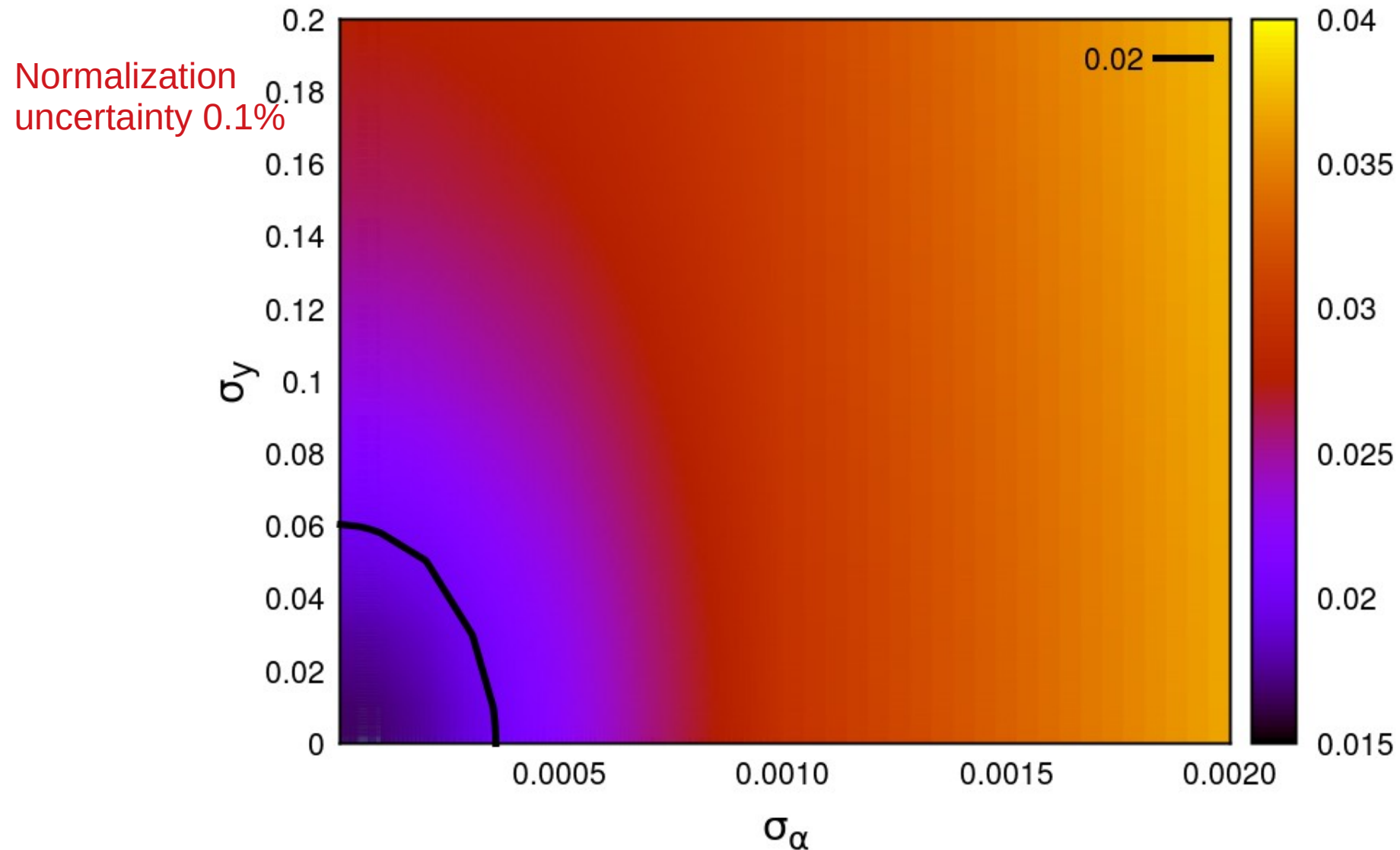
Consider top Yukawa coupling as additional **free** fit parameter (5D fit)



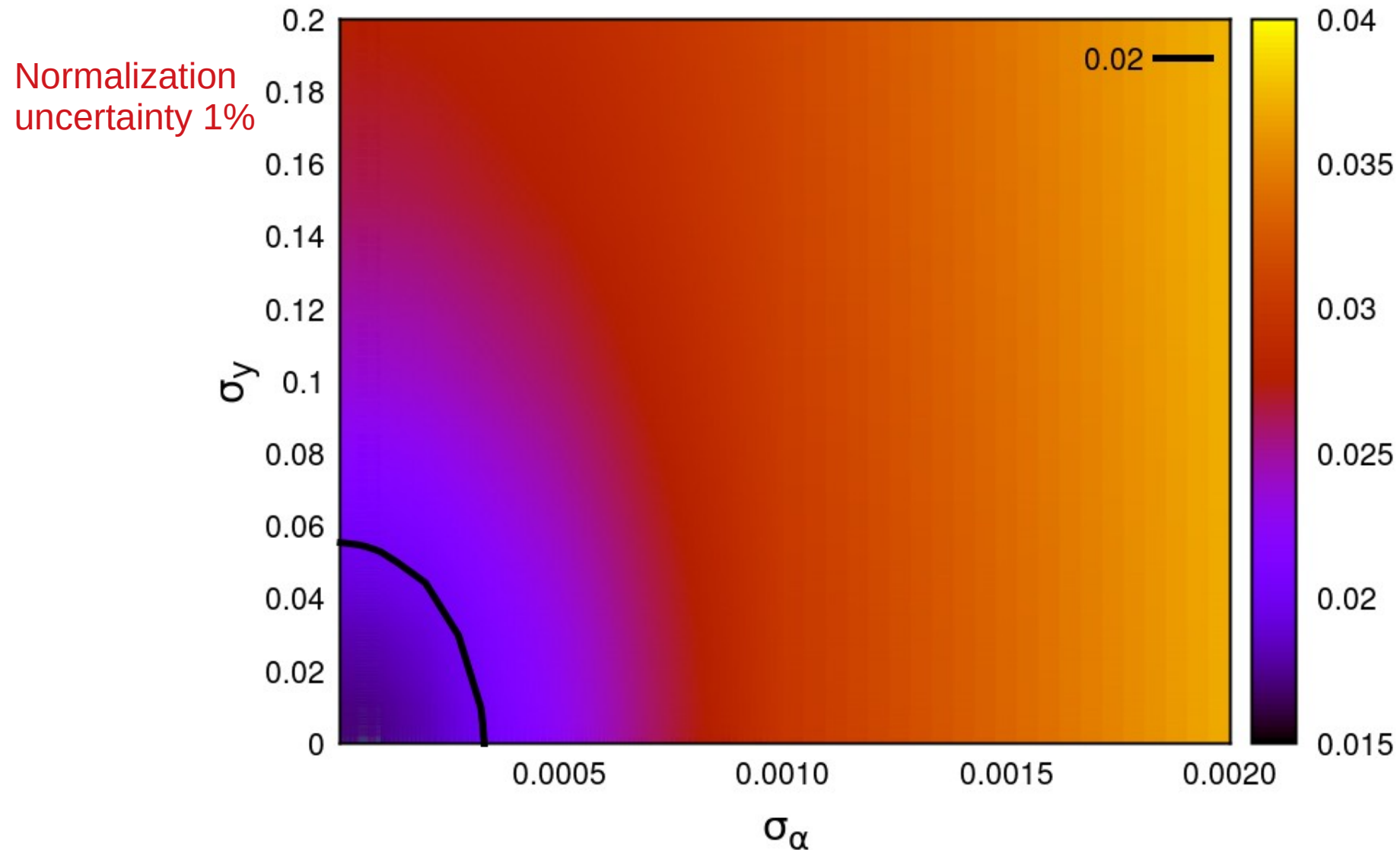
Closer look at the normalization



Statistical uncertainty on top-quark mass vs Yukawa and strong coupling uncertainties from earlier measurements

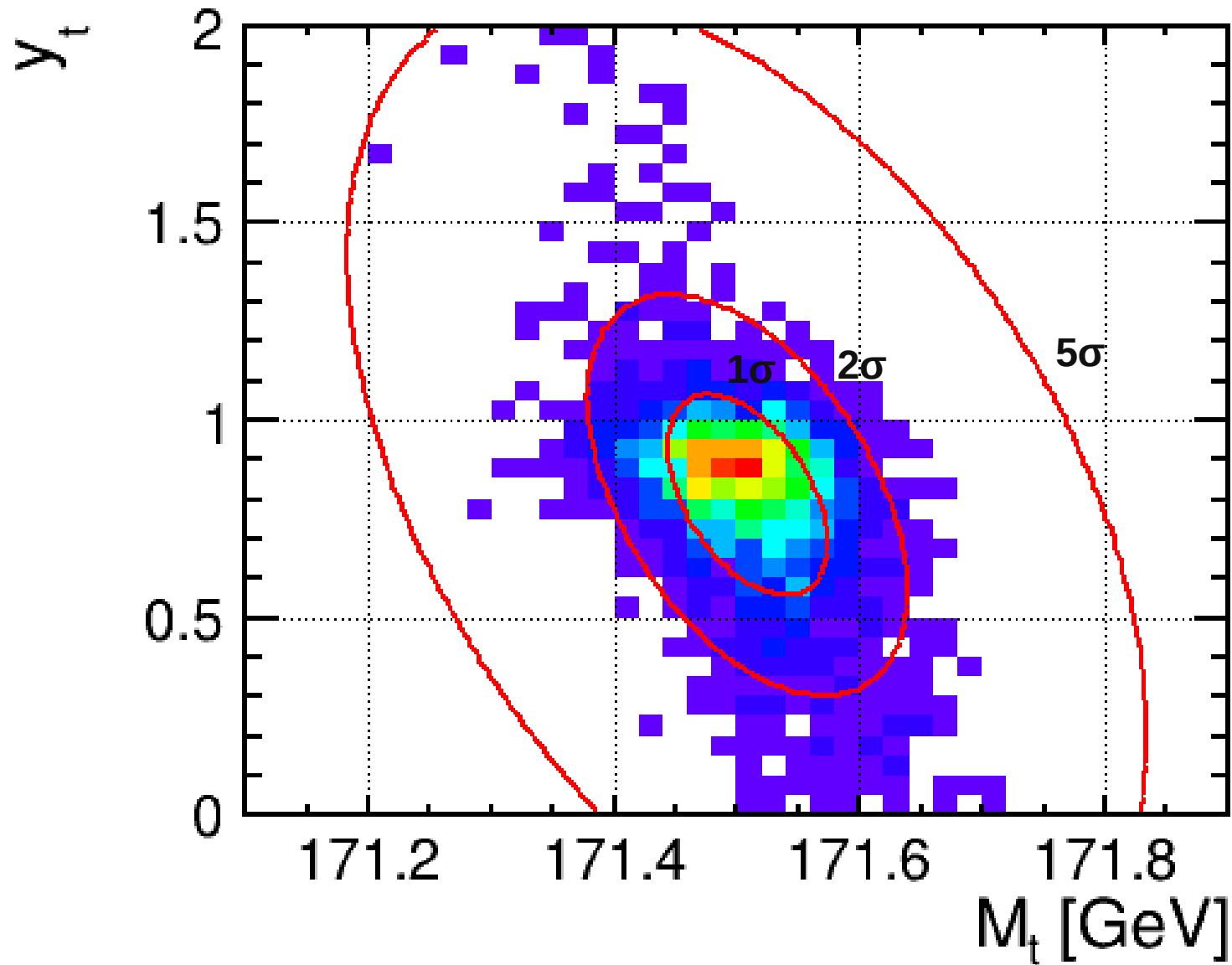


Statistical uncertainty on top-quark mass vs Yukawa and strong coupling uncertainties from earlier measurements

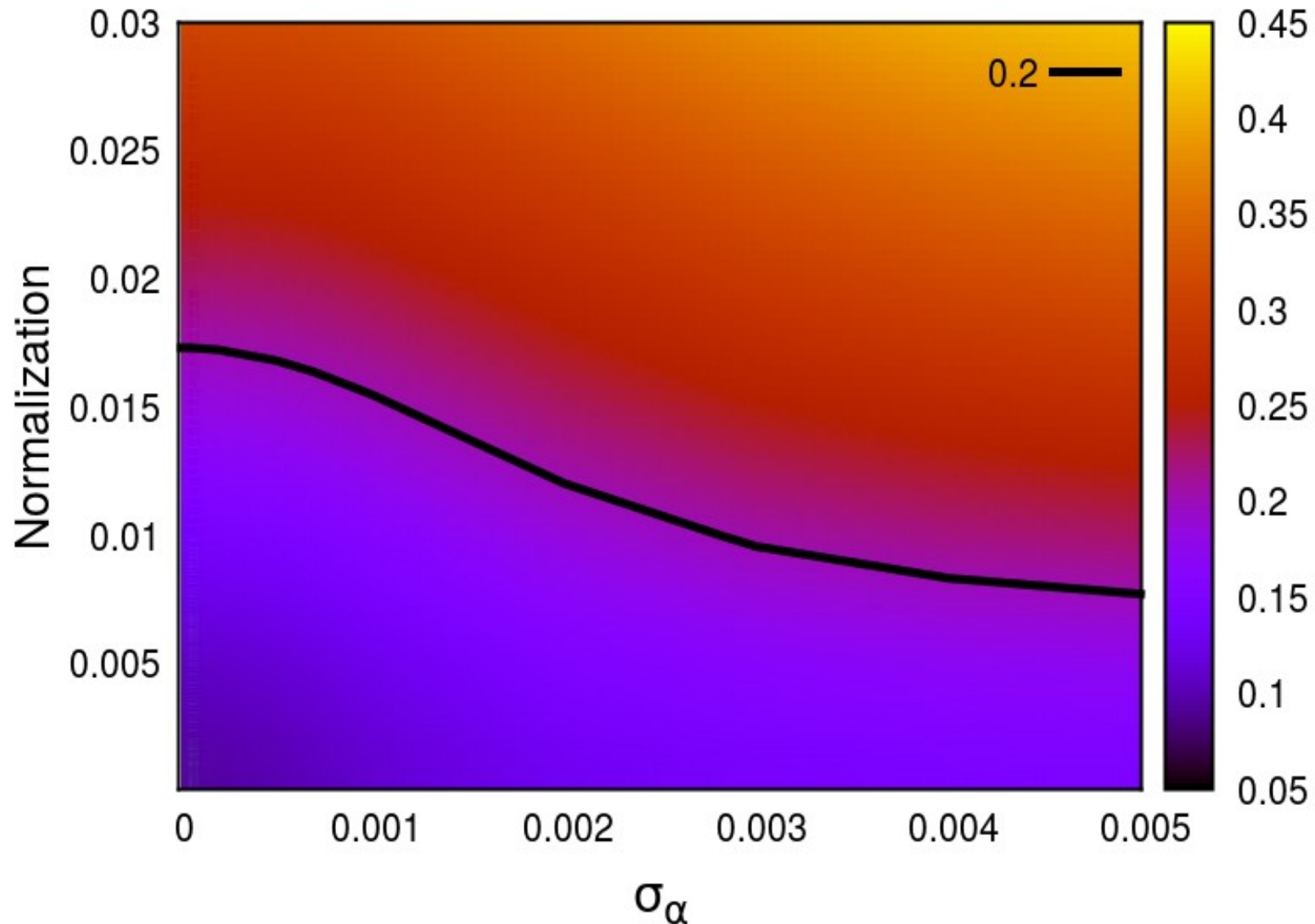


How well can we
constrain y_t ?

Yukawa vs mass



Yukawa uncertainty from 5D fit

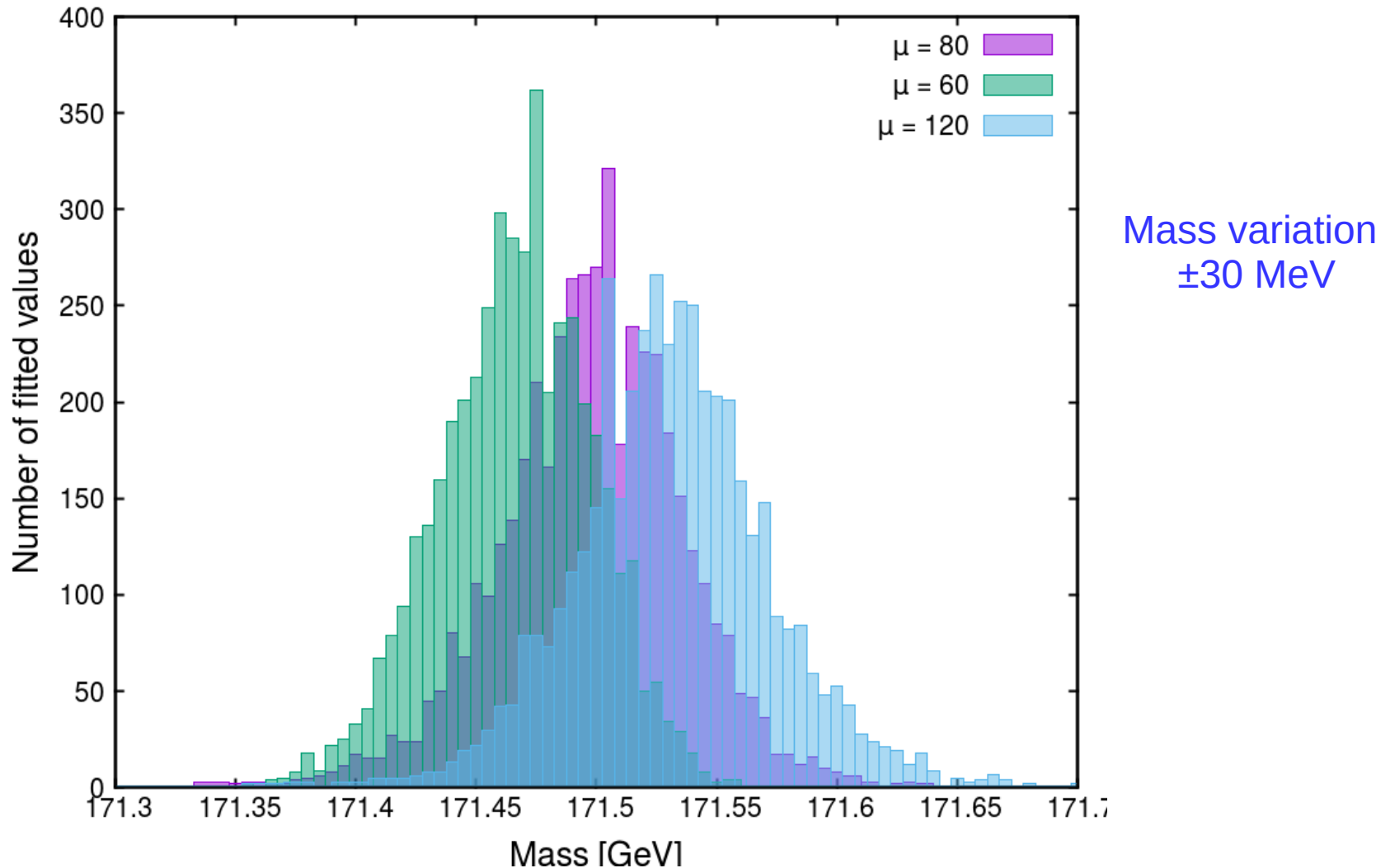


First look at systematic uncertainties

Estimate of theoretical error

Vary scale $\mu = 60 - 120$ GeV in pseudo-experiment generation.

Templates generated with nominal value ($\mu = 80$ GeV) used in the fitting procedure.

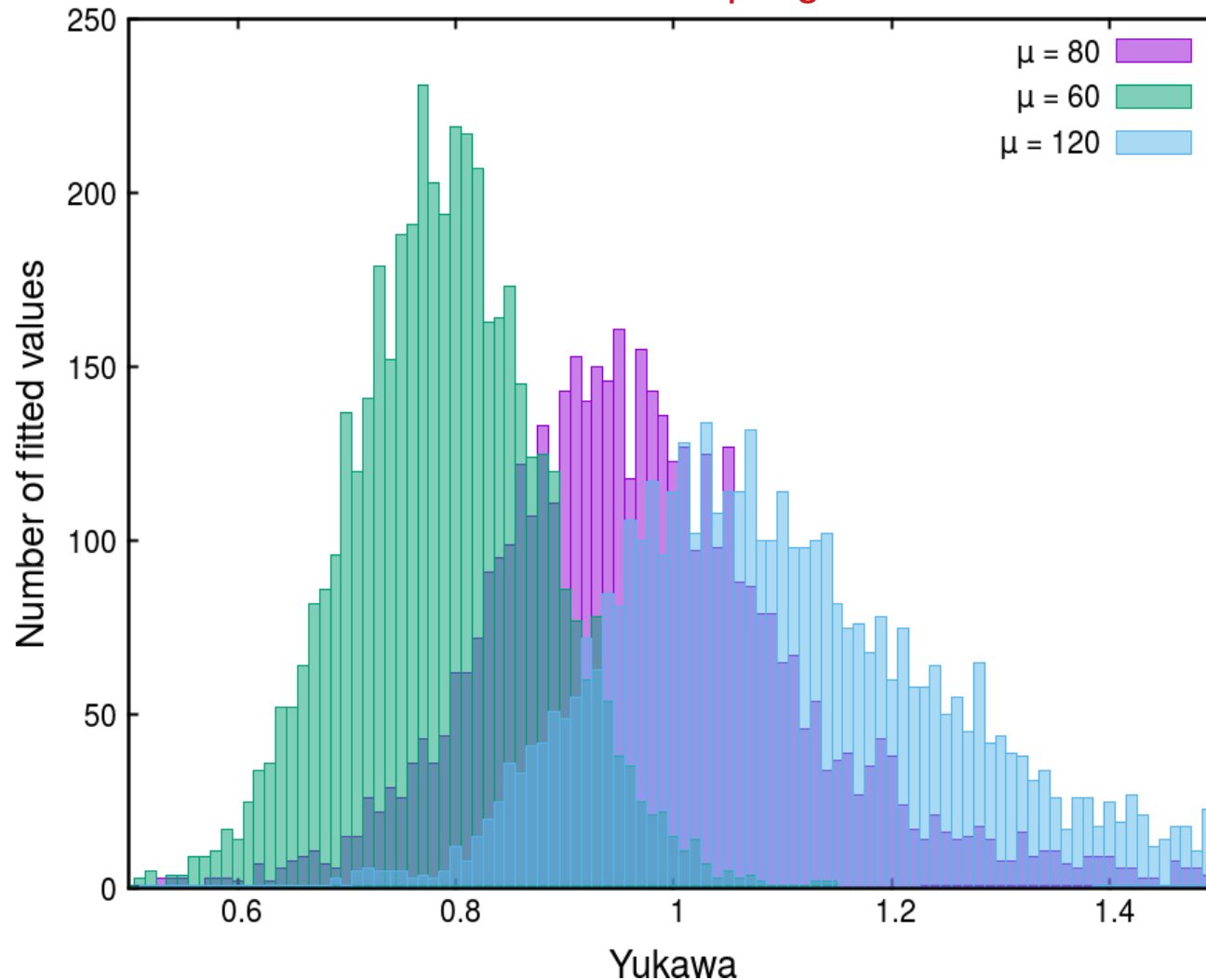


Estimate of theoretical error

Vary scale $\mu = 60 - 120$ GeV in pseudo-experiment generation.

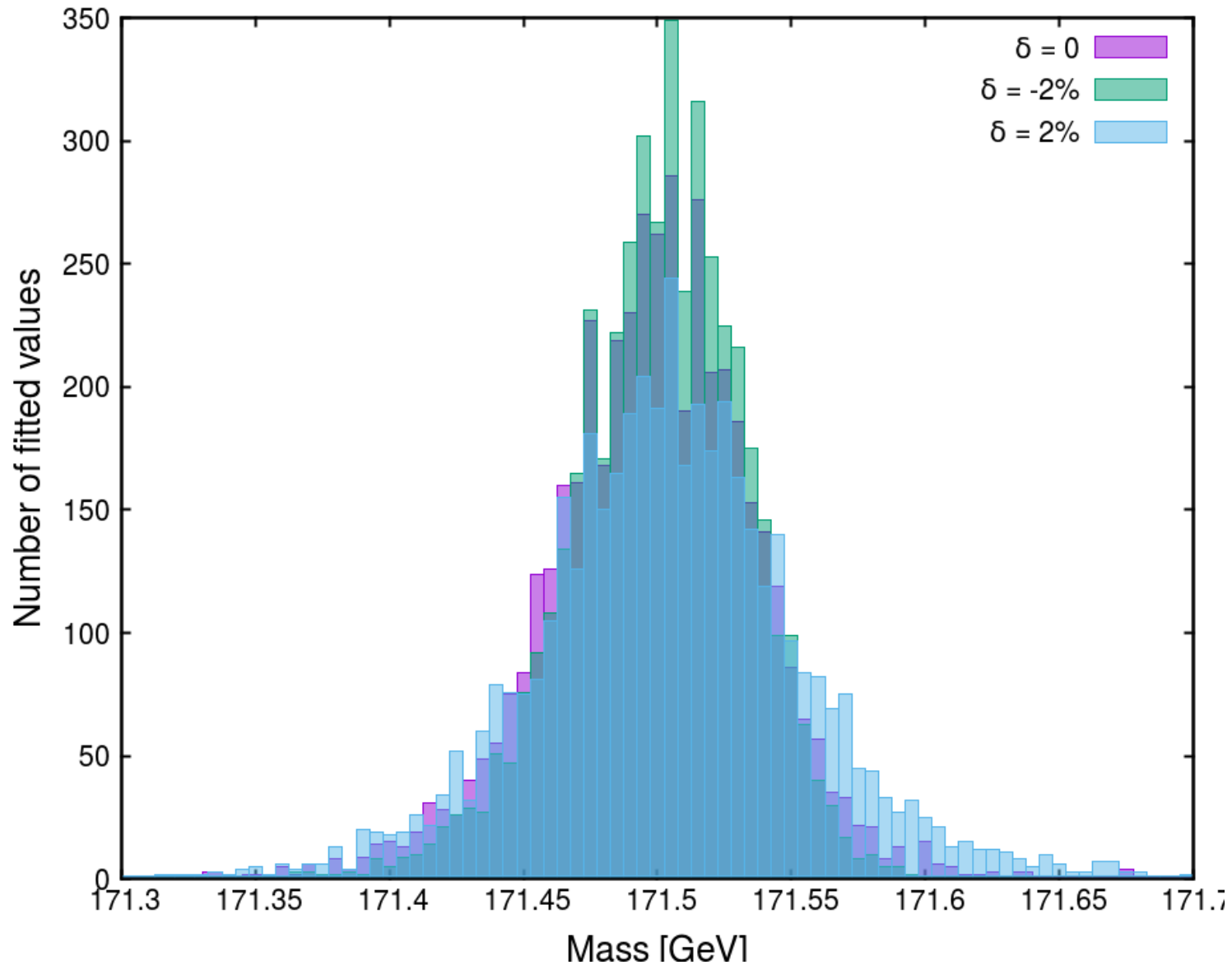
Templates generated with nominal value ($\mu = 80$ GeV) used in the fitting procedure.

Influence on Yukawa coupling determination



Background level uncertainty

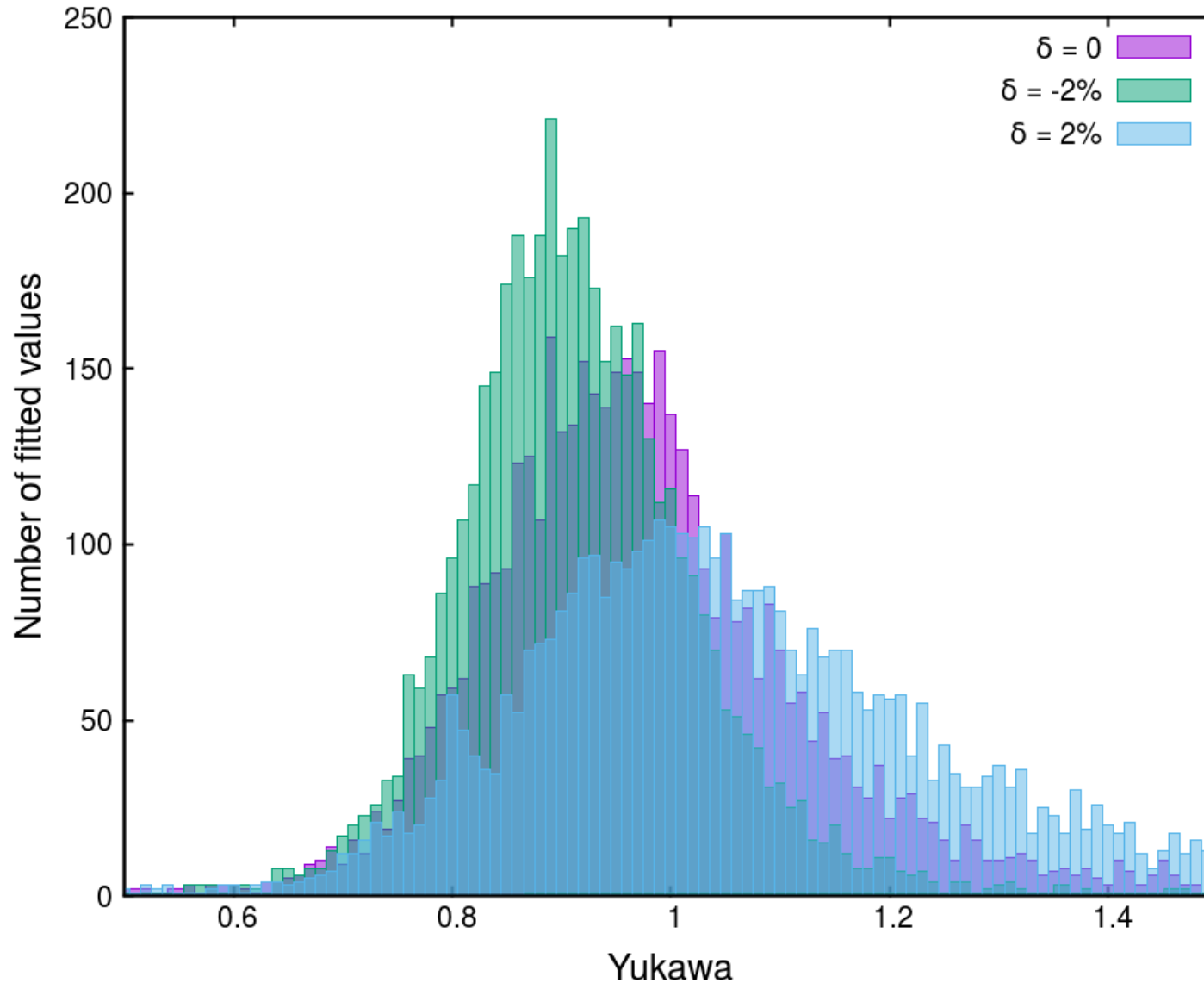
Change background normalization in pseudo-experiment generation by $\pm 2\%$



Background level uncertainty

Change background normalization in pseudo-experiment generation by $\pm 2\%$

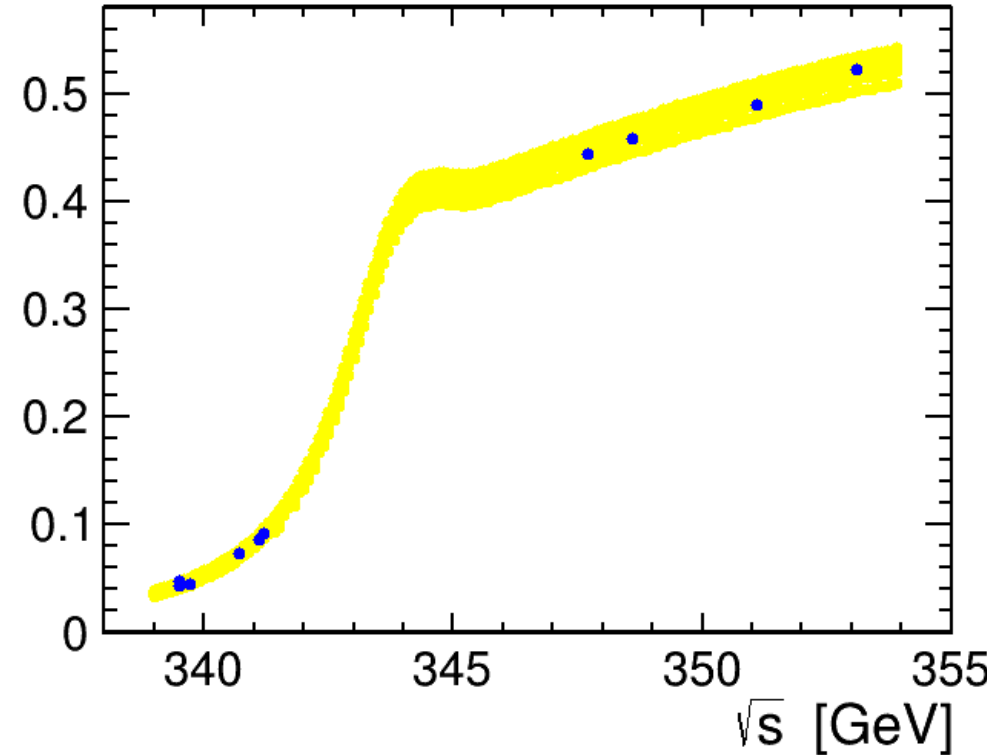
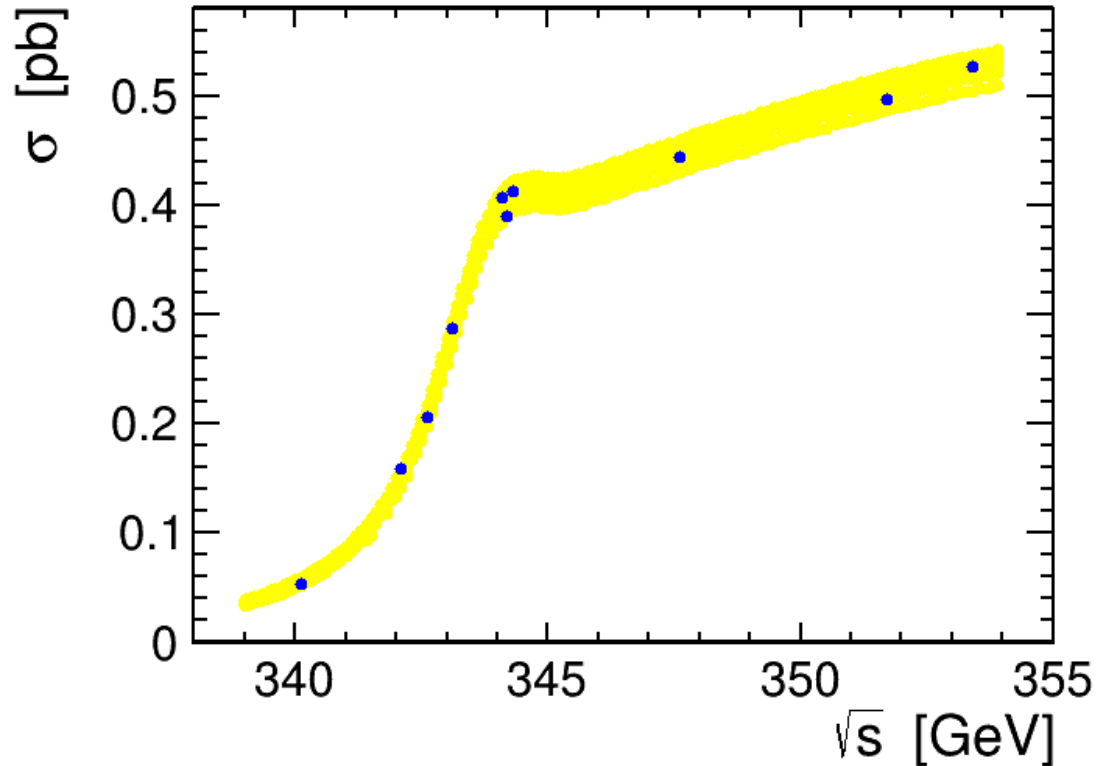
Influence on Yukawa coupling determination



Plans for the future

Optimize measurement scenario

Try to optimise threshold scan point selection to get the smallest uncertainty



Next steps

- Try to improve parameter fitting procedure by taking into account χ^2 uncertainties
- Understand sources of bias in Yukawa coupling
- Submit results as a contribution to
Summer XLIV-th IEEE-SPIE Joint Symposium on
Photonics, Web Engineering, Electronics for Astronomy
and High Energy Physics Experiments, Wilga 2019
(begining of June'2019)

Conclusions

Top-quark mass

can be extracted with ~ 20 MeV statistical uncertainty, provided $\sigma_\alpha < 0.0004$, $\sigma_y < 0.06$ and normalization $\sim 1\%$.

Theoretical uncertainty estimated to about 30 MeV.

Systematic uncertainty from background normalization negligible.

Top-quark Yukawa coupling

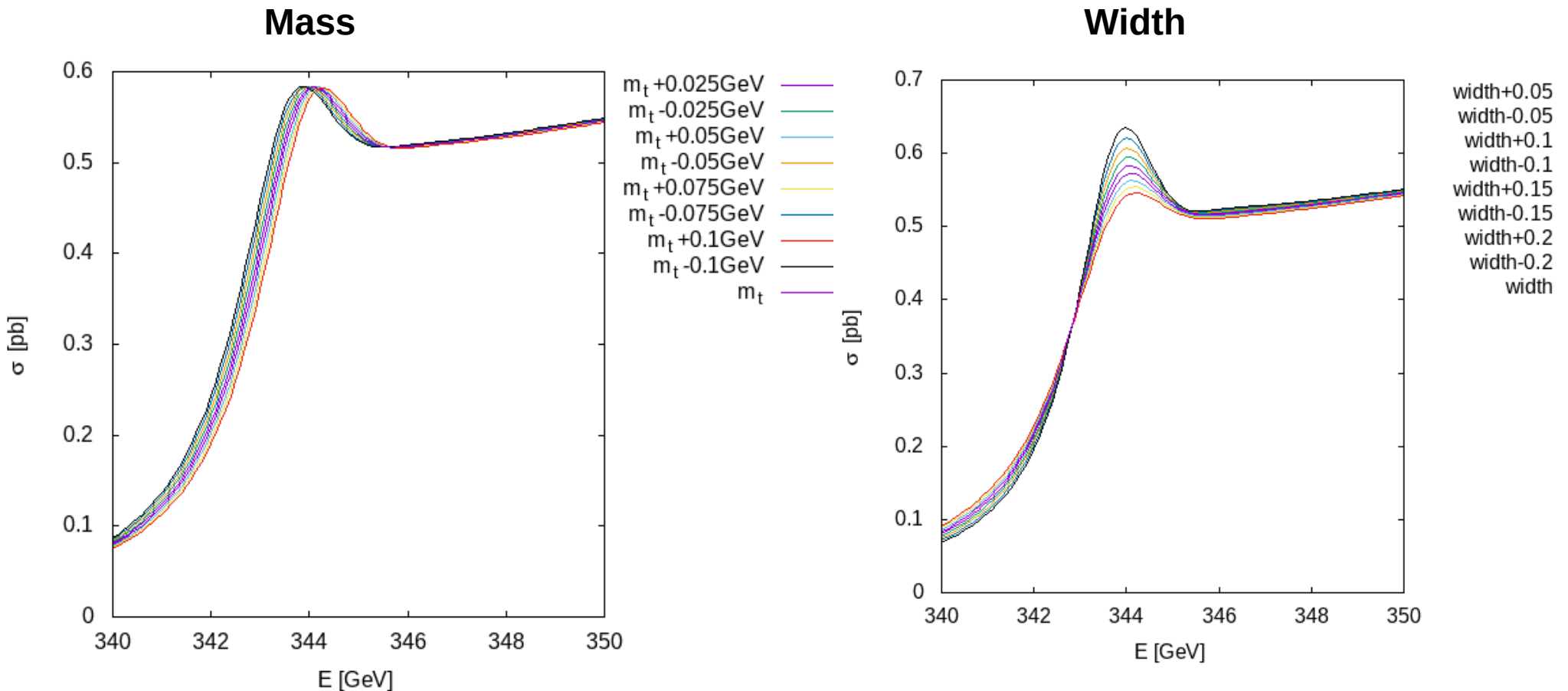
Contribution to the top pair-production cross section can be observed with significance $> 5 \sigma$

Systematic uncertainties due from theoretical perditions and background normalization important for Yukawa coupling determination.

Thank you !

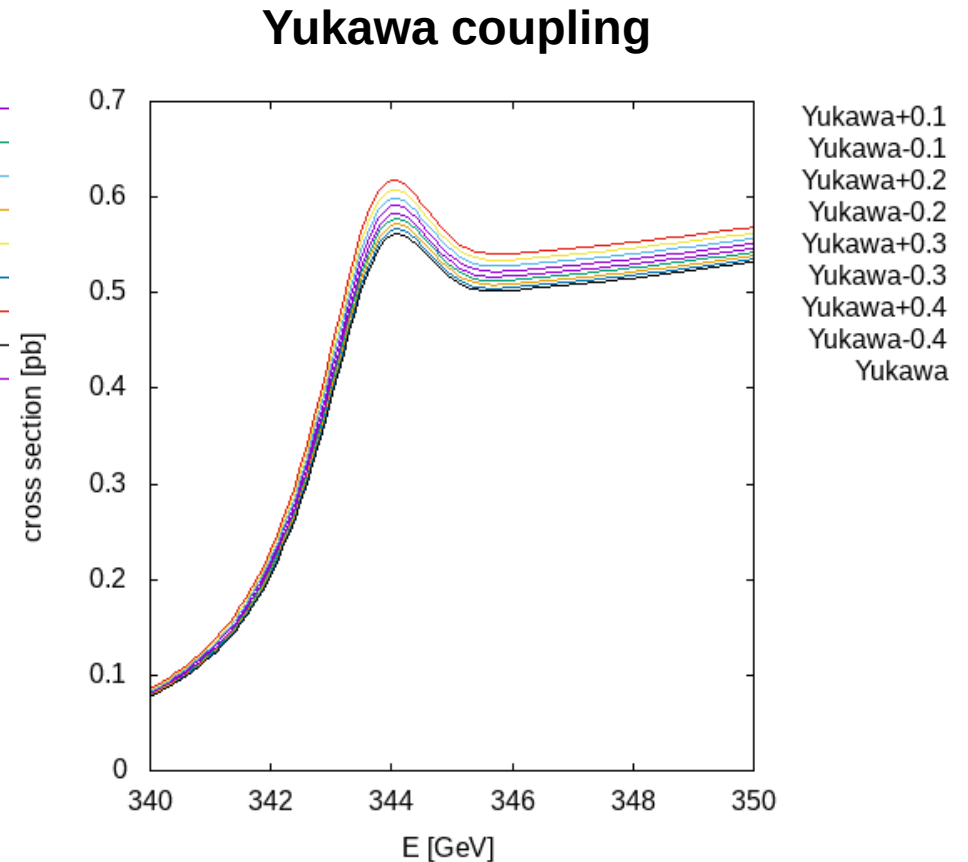
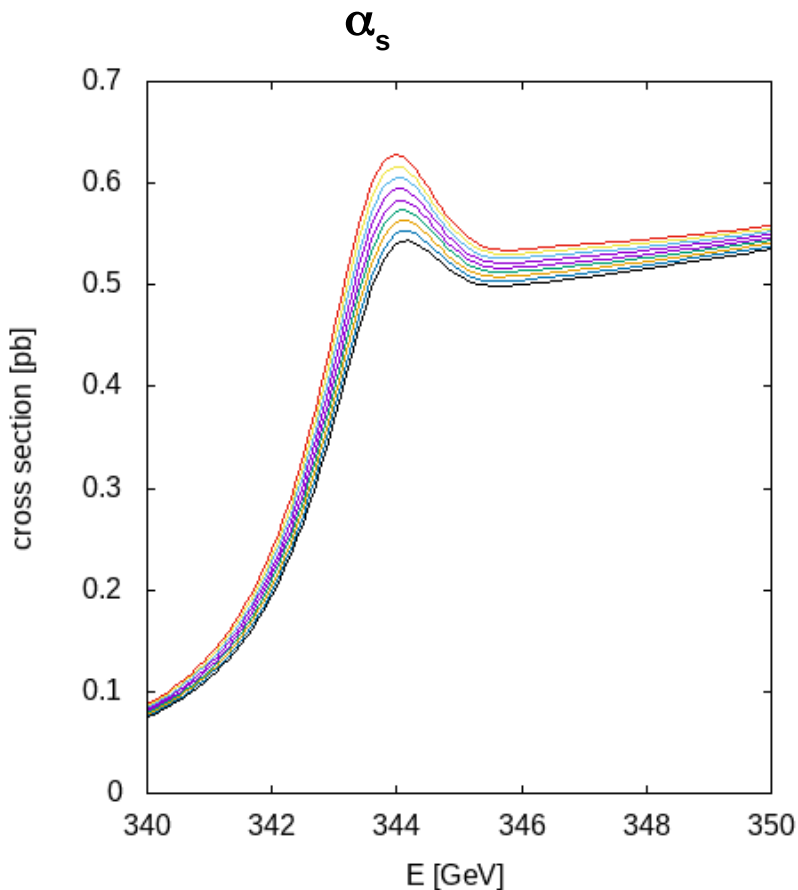
Cross-section calculation

We used `Qqbar_threshold` code (<https://qqbarthreshold.hepforge.org/>) to generate **cross section templates** for different parameter values

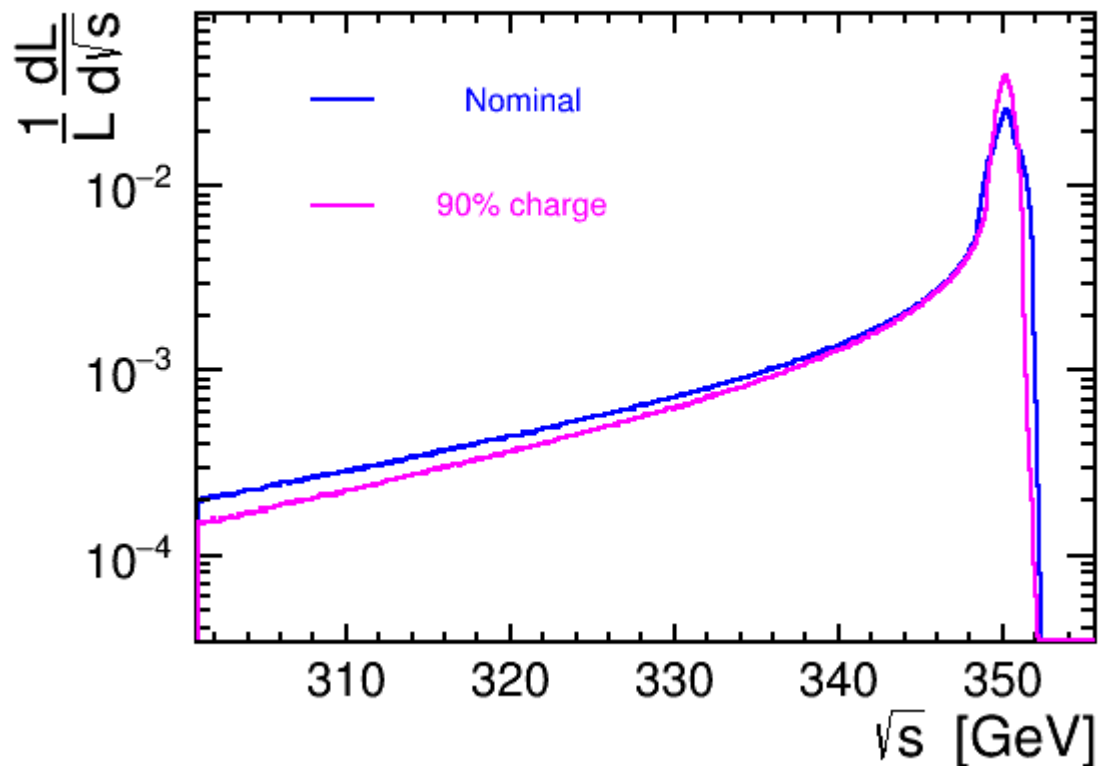


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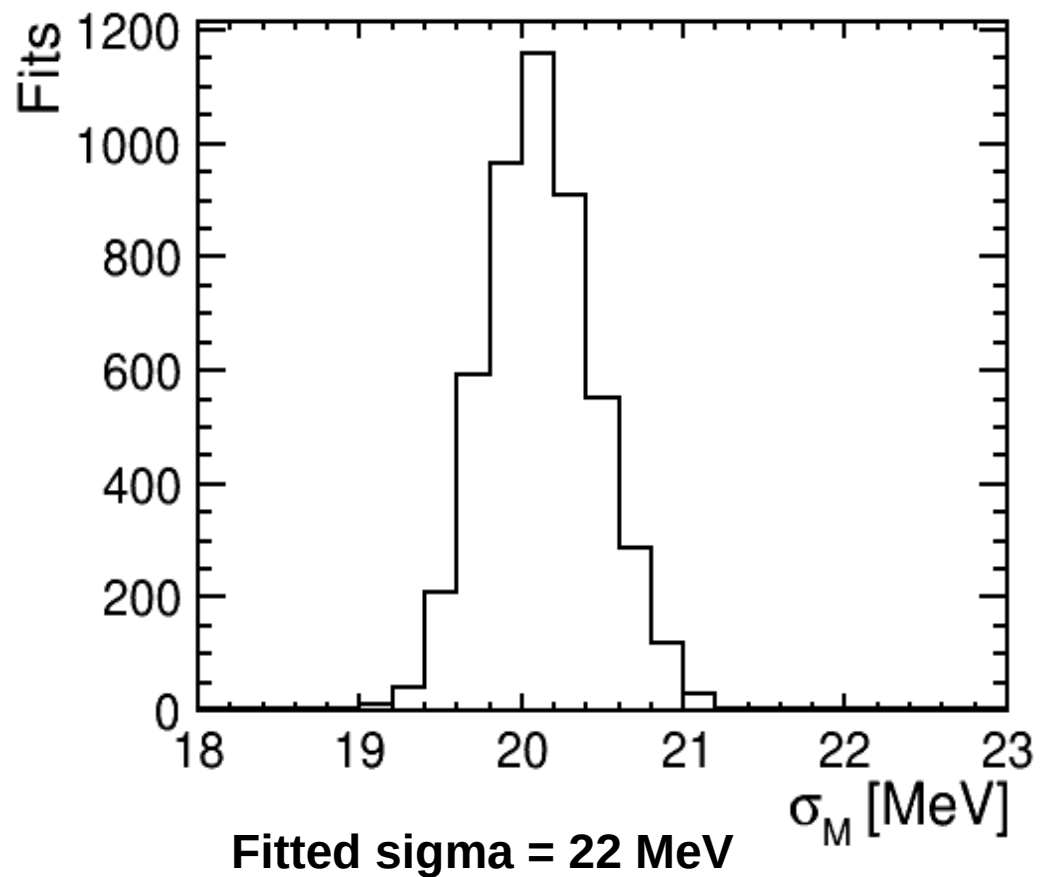
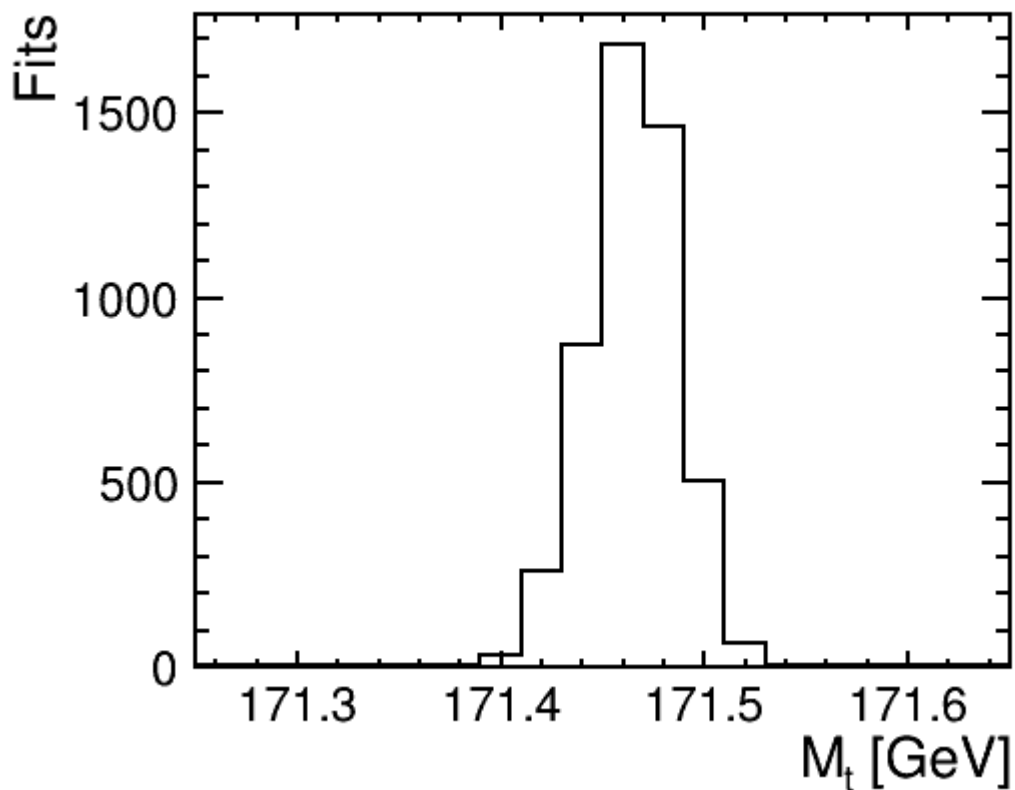
Luminosity spectra



Theoretical cross section templates are convoluted with luminosity spectra
New CLIC spectra for 350 GeV is scaled for different values of \sqrt{s}
90% charge spectra used for presented results

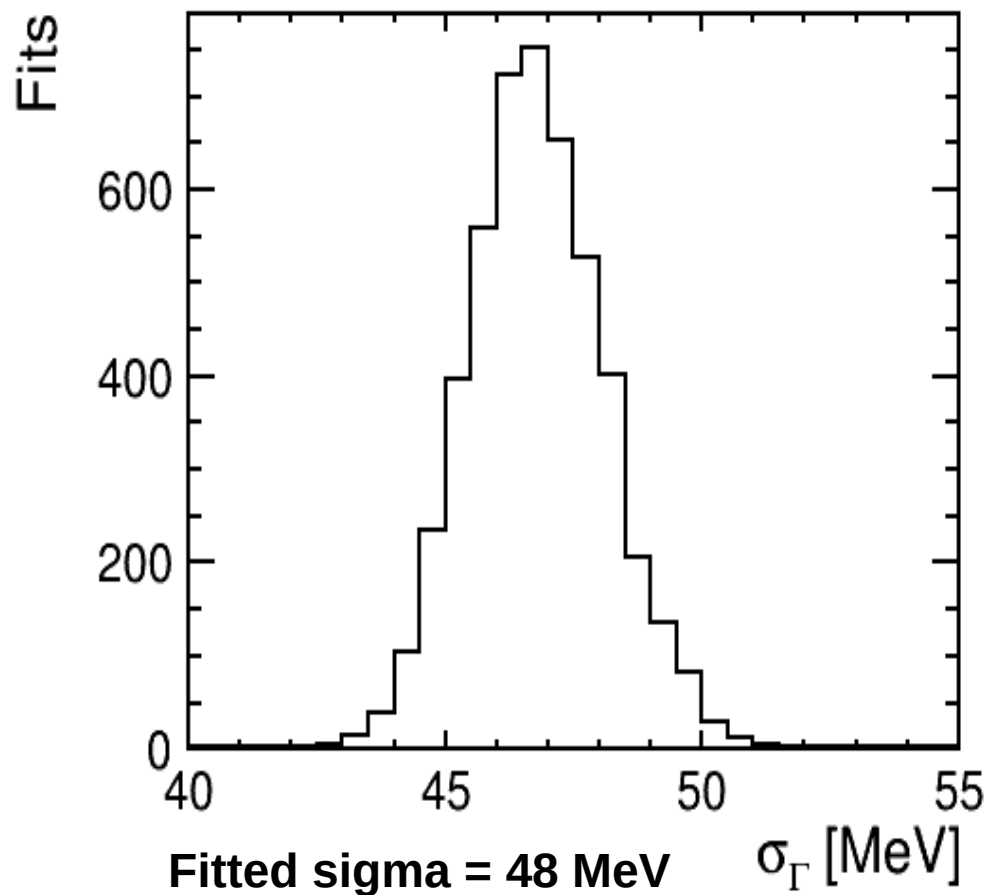
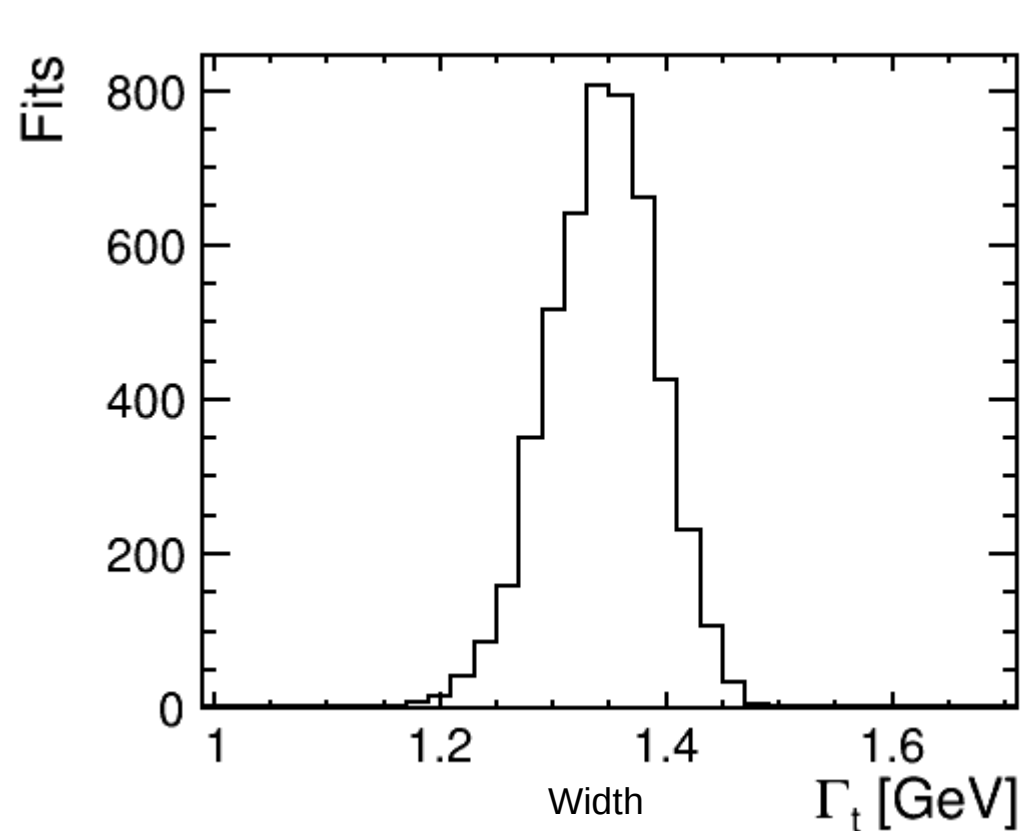
Validation

2D fit: mass vs with (other parameters fixed)



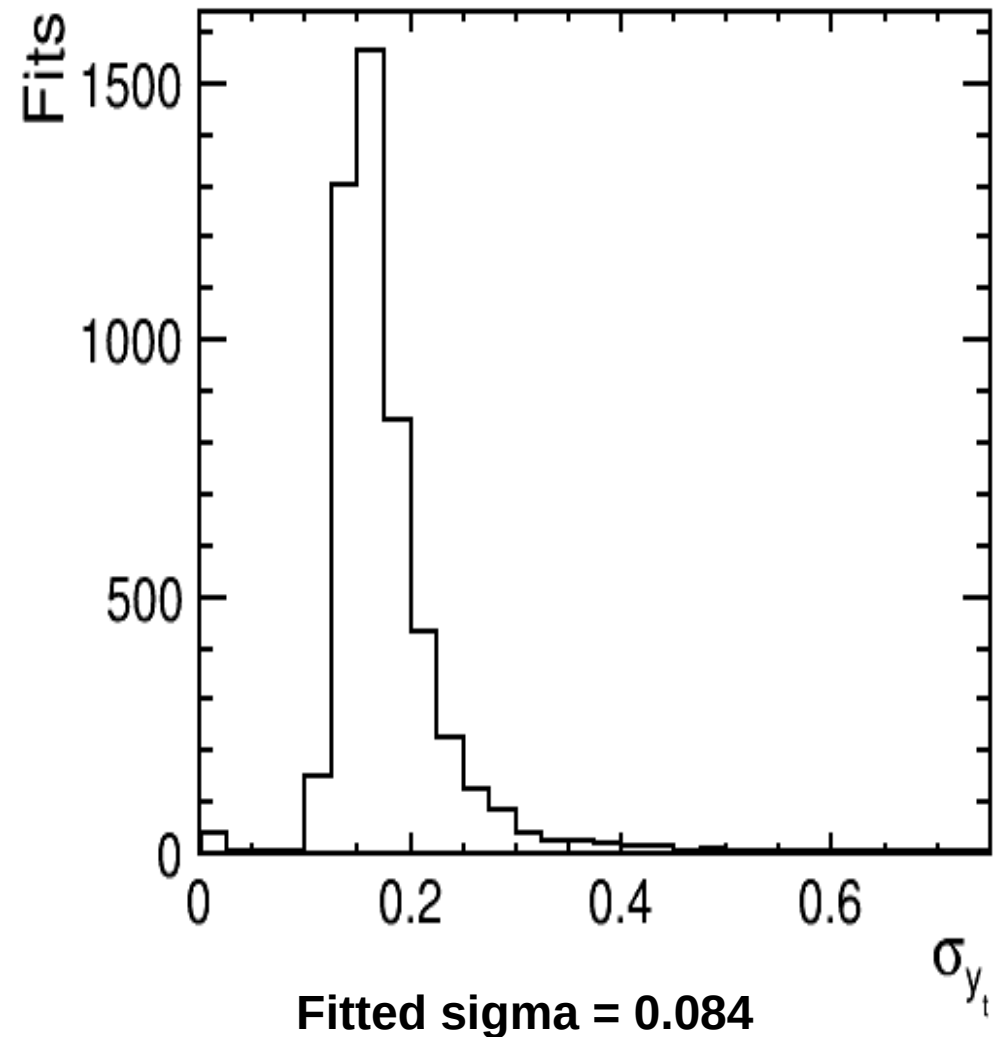
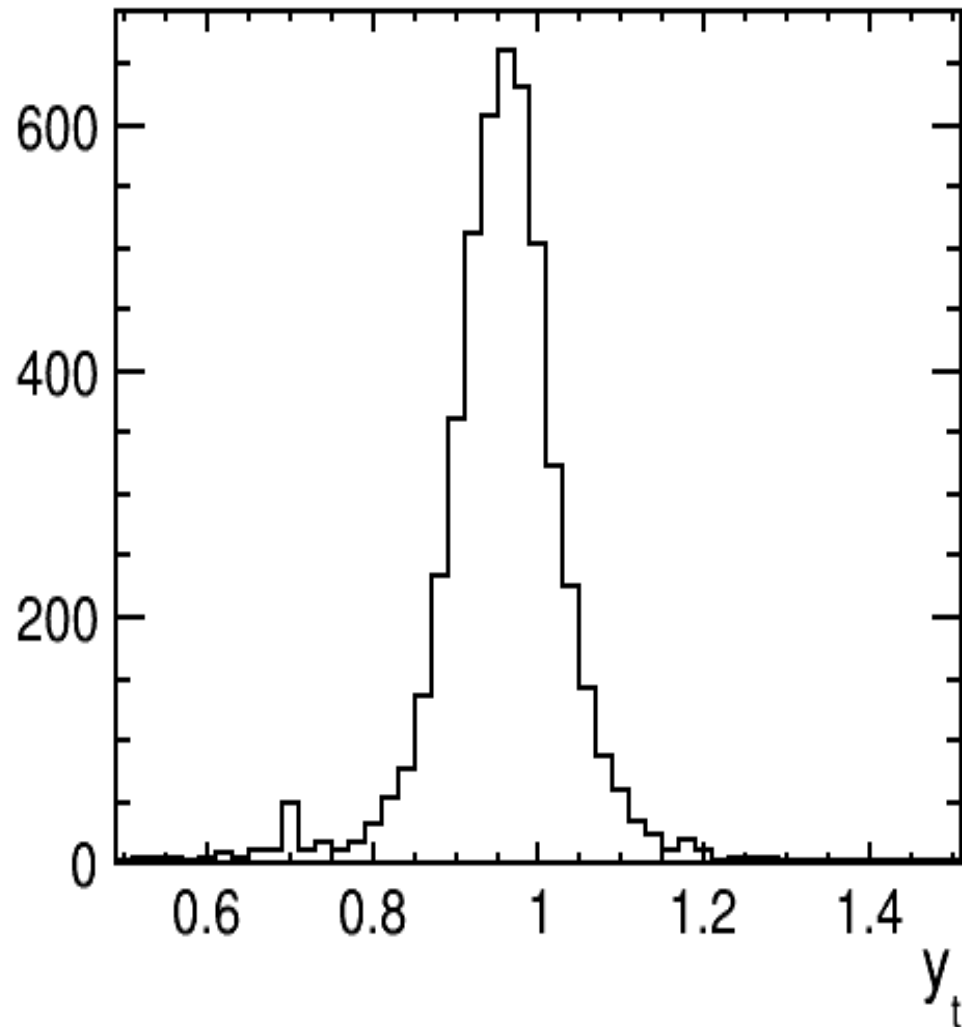
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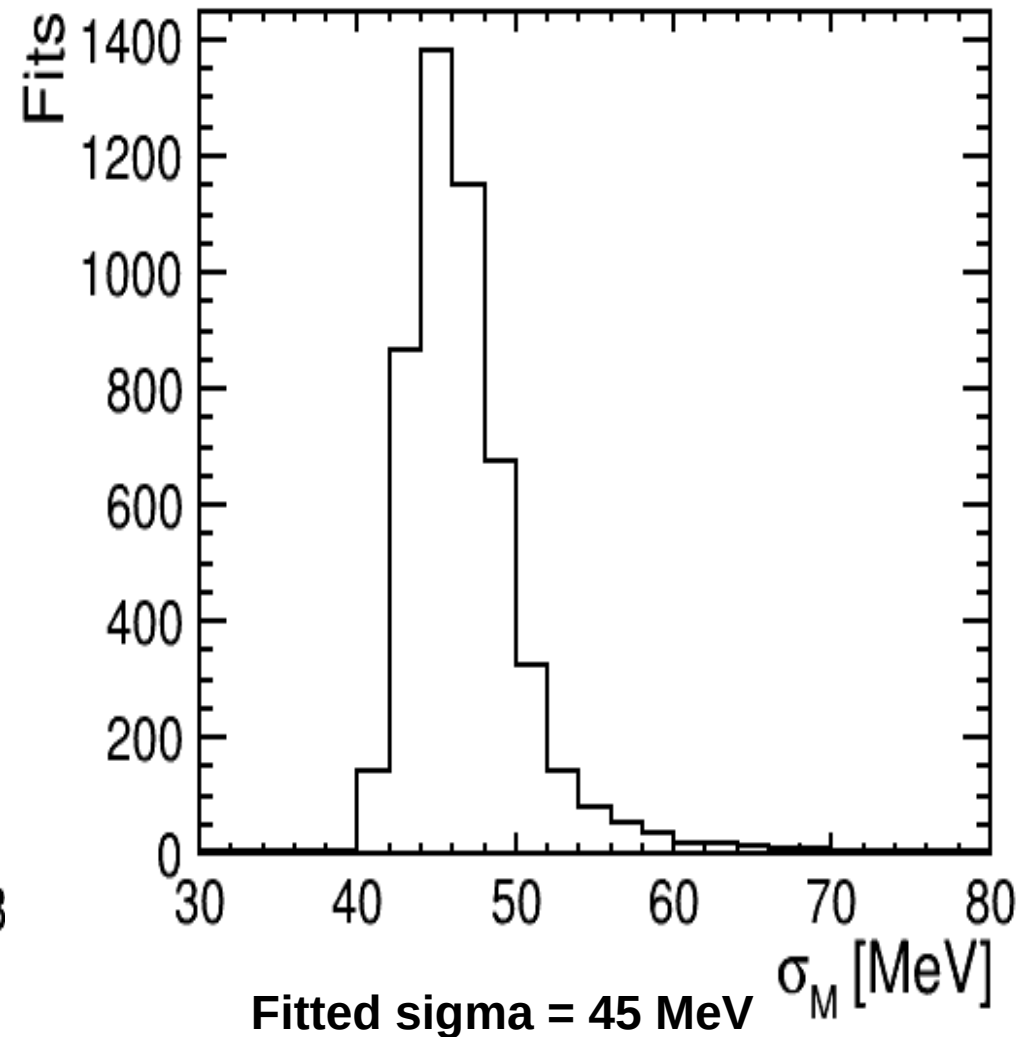
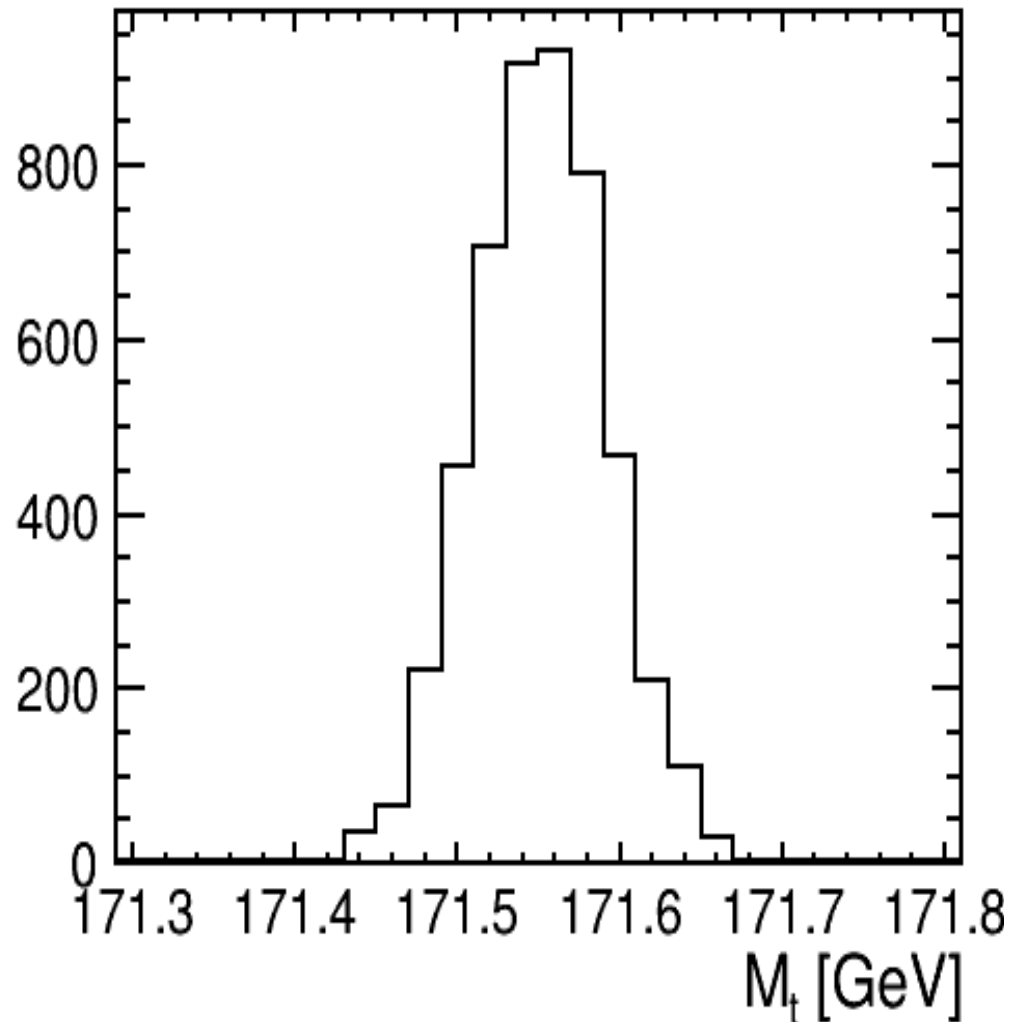
Add Yukawa coupling to the fit

5D fit: mass + width + Yukawa + strong coupling + normalization

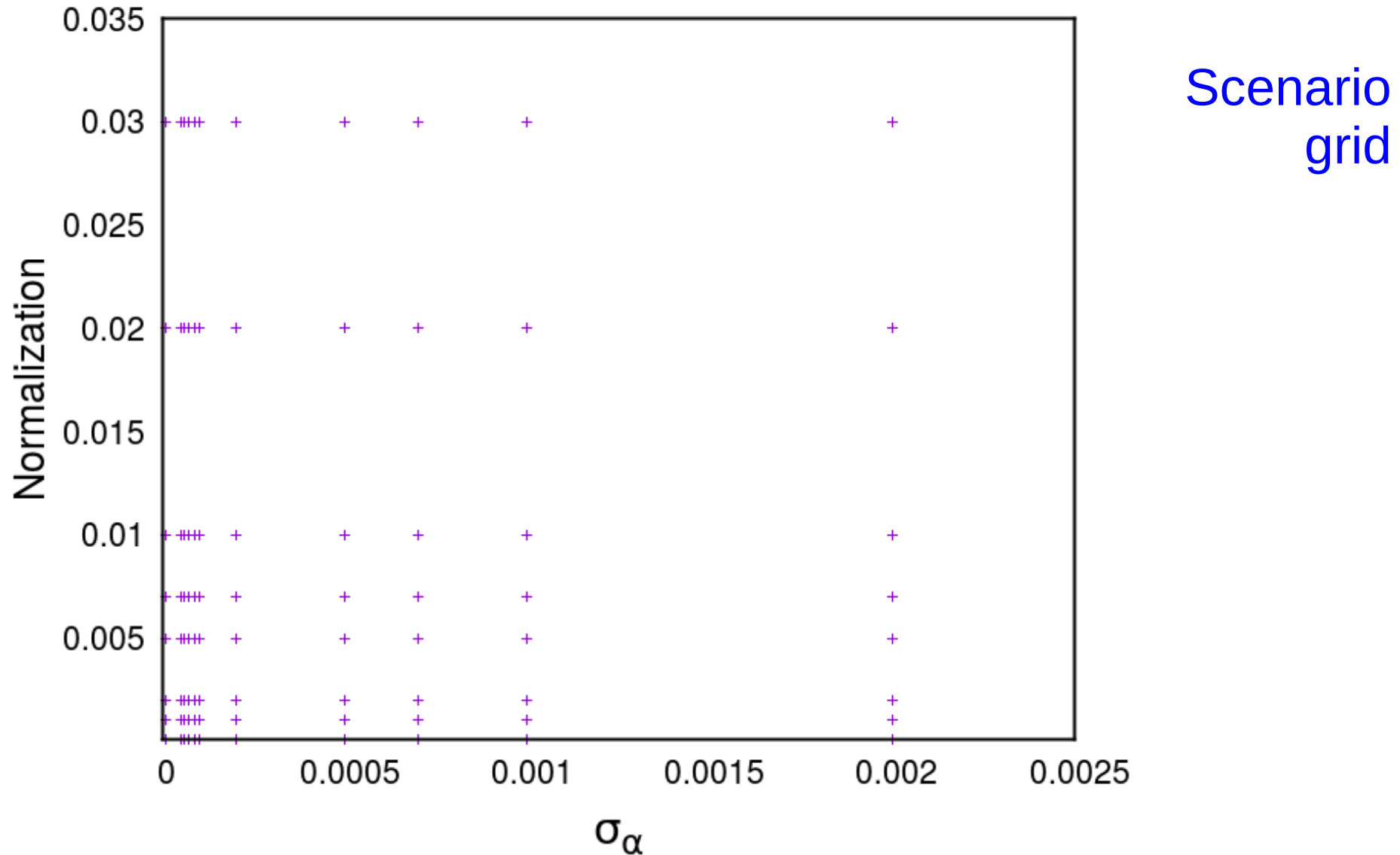


Add Yukawa coupling to the fit

5D fit: mass + width + Yukawa + strong coupling + normalization

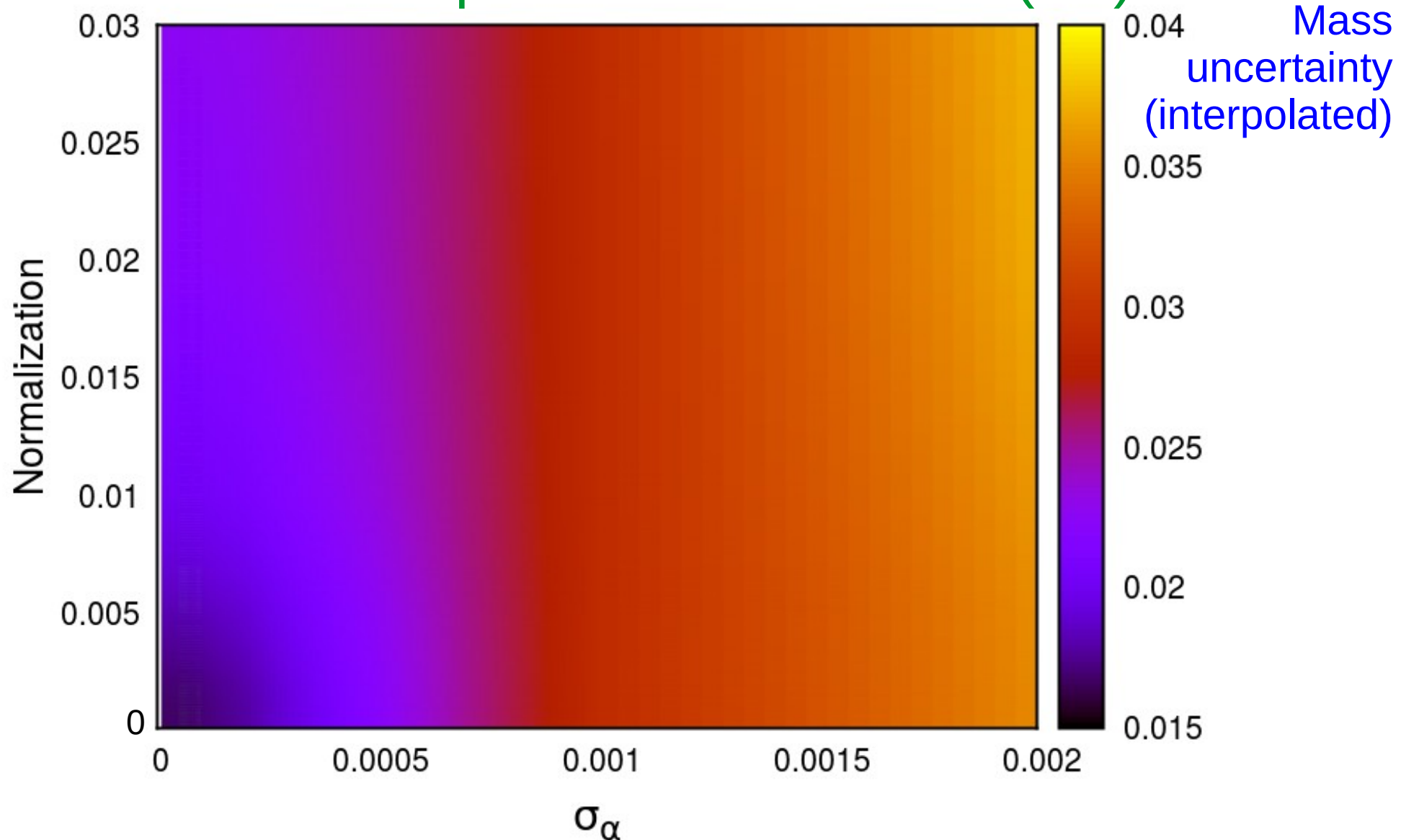


Consider overall normalization uncertainty and uncertainty of strong coupling two more parameters in the fit (4D)



Consider overall normalization uncertainty and uncertainty of strong coupling constant

two more parameters in the fit (4D)



Consider top Yukawa coupling
as additional free fit parameter (5D fit)

