



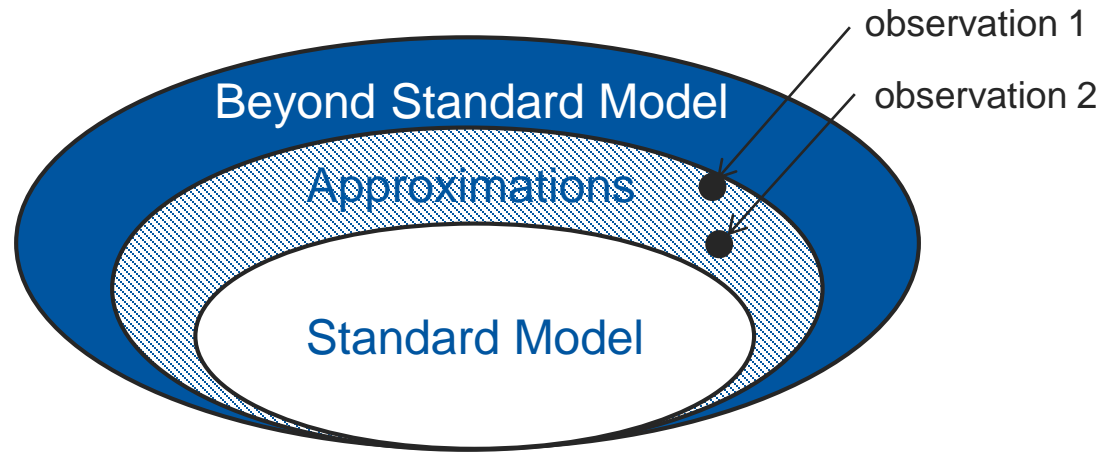
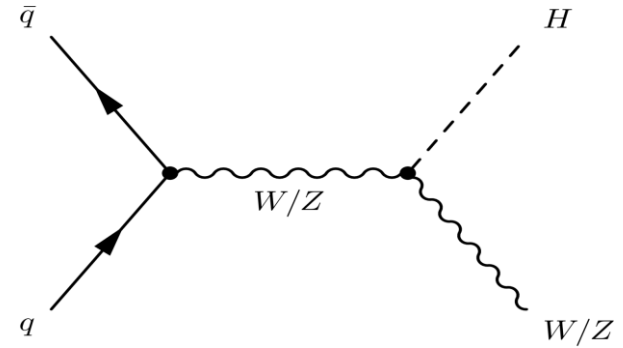
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Electroweak Calibration of the Higgs Characterization Model

Sam Greydanus

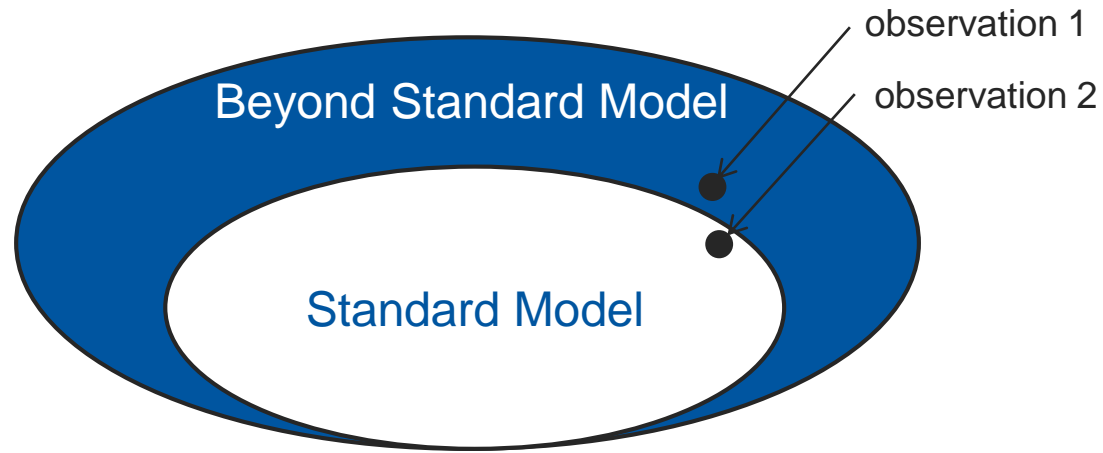
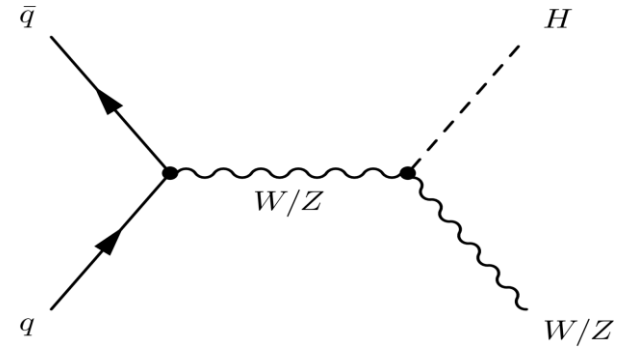
Motivation

- Precision measurements of Higgs
 - More precise Standard Model
- What is new physics?
- Likelihoods



Motivation

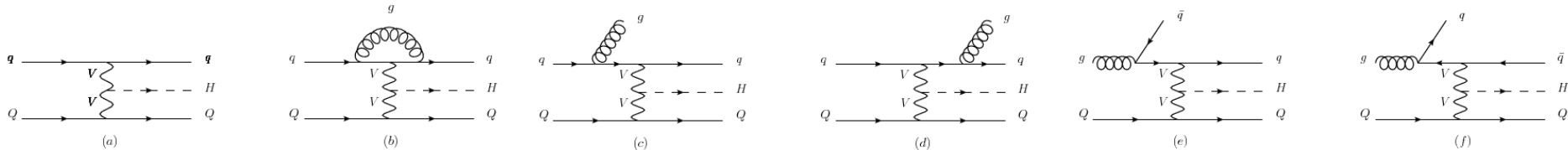
- Precision measurements of Higgs
 - More precise Standard Model
- What is new physics?
- Likelihoods



Procedure

- HAWK full NLO (EWK+QCD)
- MadGraph NLO (QCD)
 - Higgs Characterization Model (BSM)
- Calibrate HC model for EWK corrections

LO / NLO



Results

$$\begin{aligned}
 \mathcal{L}_0^V = & \left\{ c_\alpha \kappa_{\text{SM}} \left[\frac{1}{2} g_{HZZ} Z_\mu Z^\mu + g_{HWW} W_\mu^+ W^{-\mu} \right] \leftarrow \text{Standard Model} \right. \\
 & - \frac{1}{4} [c_\alpha \kappa_{H\gamma\gamma} g_{H\gamma\gamma} A_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{A\gamma\gamma} g_{A\gamma\gamma} A_{\mu\nu} \tilde{A}^{\mu\nu}] \\
 & - \frac{1}{2} [c_\alpha \kappa_{HZ\gamma} g_{HZ\gamma} Z_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{AZ\gamma} g_{AZ\gamma} Z_{\mu\nu} \tilde{A}^{\mu\nu}] \\
 & - \frac{1}{4} [c_\alpha \kappa_{Hgg} g_{Hgg} G_{\mu\nu}^a G^{a,\mu\nu} + s_\alpha \kappa_{Agg} g_{Agg} G_{\mu\nu}^a \tilde{G}^{a,\mu\nu}] \\
 & - \frac{1}{4} \frac{1}{\Lambda} [c_\alpha \kappa_{HZZ} Z_{\mu\nu} Z^{\mu\nu} + s_\alpha \kappa_{AZZ} Z_{\mu\nu} \tilde{Z}^{\mu\nu}] \\
 & - \frac{1}{2} \frac{1}{\Lambda} [c_\alpha \kappa_{HWW} W_{\mu\nu}^+ W^{-\mu\nu} + s_\alpha \kappa_{AWW} W_{\mu\nu}^+ \tilde{W}^{-\mu\nu}] \\
 & - \frac{1}{\Lambda} c_\alpha [\kappa_{H\partial\gamma} A_\nu \partial_\mu A^{\mu\nu} + \kappa_{H\partial Z} Z_\nu \partial_\mu Z^{\mu\nu} \\
 & \quad \left. + (\kappa_{H\partial W} W_\nu^+ \partial_\mu W^{-\mu\nu} + h.c.) \right\} X_0, \quad (1)
 \end{aligned}$$

BSM couplings

Procedure

Physics

Monte Carlo

Templates

N-D Fitting

Conclusions

Procedure

Physics

Monte Carlo

Templates

N-D Fitting

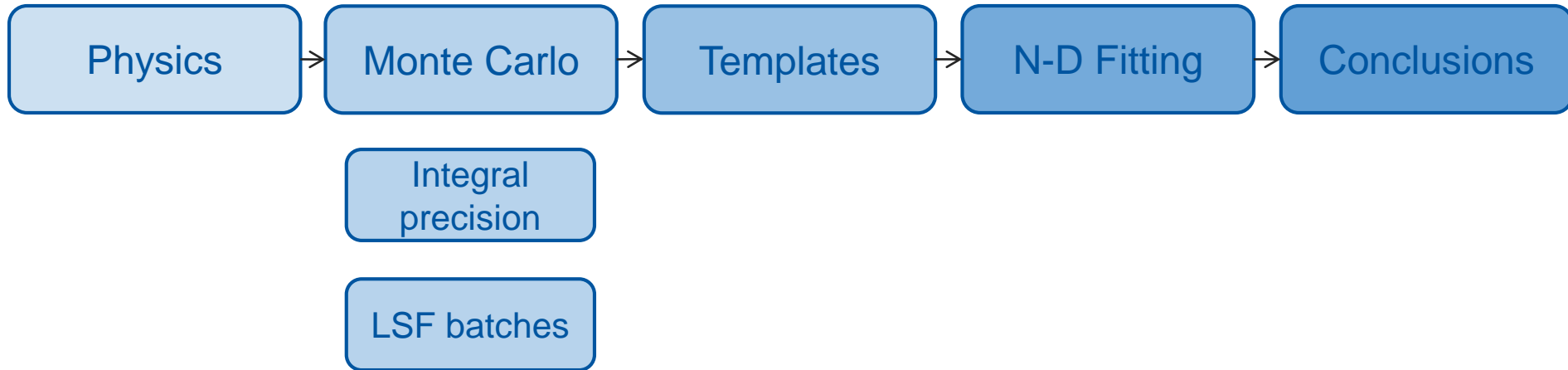
Conclusions

HC
parameters

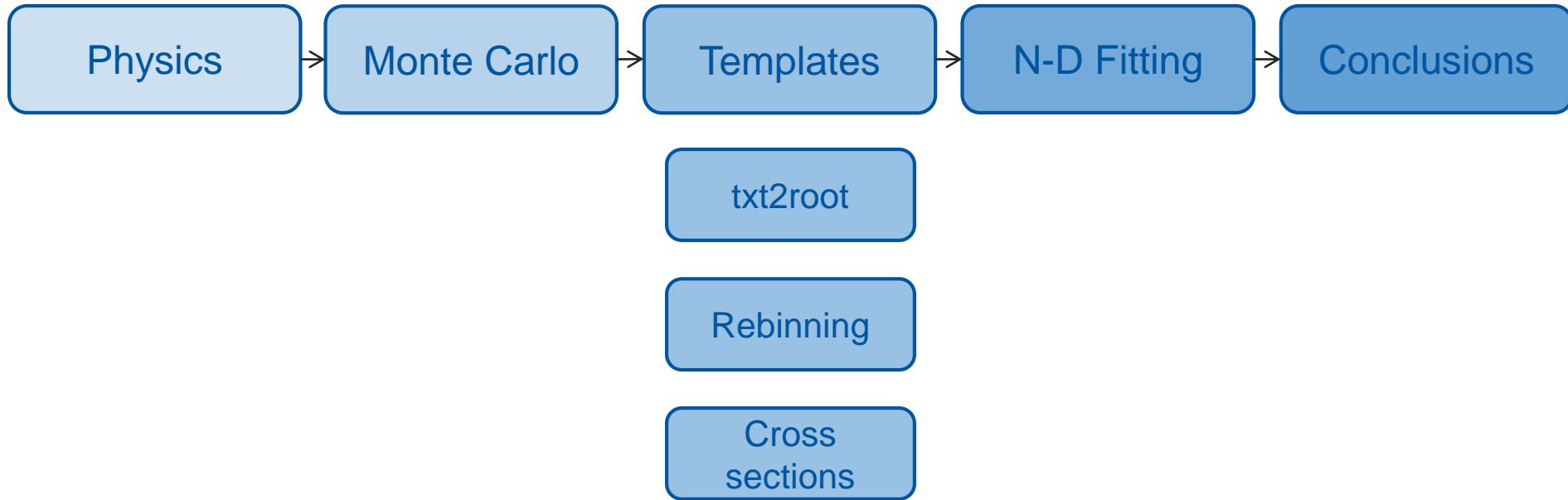
SM
parameters

Luminosity

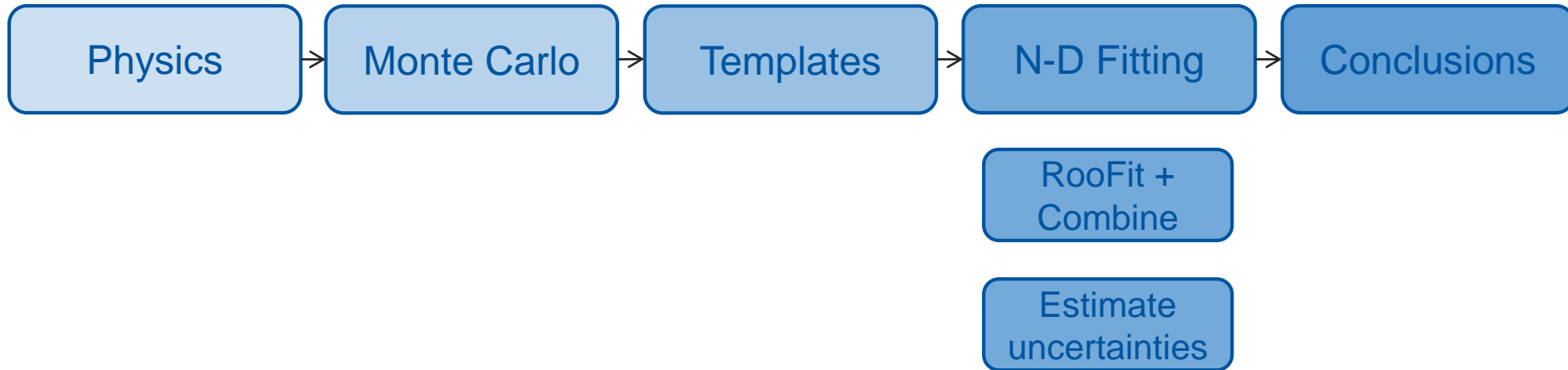
Procedure



Procedure



Procedure



Procedure

Physics

Monte Carlo

Templates

N-D Fitting

Conclusions

Deformed
how?

Does it
matter?

Templates

```
INFO: Computing cross-section
INFO: Idle: 8, Running: 8, Completed: 0 [ current time:
INFO: Idle: 7, Running: 8, Completed: 1 [ 18m 35s ]
INFO: Idle: 6, Running: 8, Completed: 2 [ 18m 55s ]
INFO: Idle: 5, Running: 8, Completed: 3 [ 44m 26s ]
INFO: Idle: 4, Running: 8, Completed: 4 [ 6h 20m ]
INFO: Idle: 3, Running: 8, Completed: 5 [ 6h 51m ] ←
```

Templates

Issues

- Time
 - 1-5 hrs/run
- Shape
 - Varied sensitivity
- Precision
 - Need uncertainties below 1%

Solutions

- Time
 - LSF
- Shape
 - “lite” batches
- Precision
 - New run parameters

Results

$$\mathcal{L}_0^V = \left\{ c_\alpha \kappa_{\text{SM}} \left[\frac{1}{2} g_{HZZ} Z_\mu Z^\mu + g_{HWW} W_\mu^+ W^{-\mu} \right] \right. \leftarrow \text{Standard Model}$$

Haa

$$- \frac{1}{4} [c_\alpha \kappa_{H\gamma\gamma} g_{H\gamma\gamma} A_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{A\gamma\gamma} g_{A\gamma\gamma} A_{\mu\nu} \tilde{A}^{\mu\nu}]$$

Hza

$$- \frac{1}{2} [c_\alpha \kappa_{HZ\gamma} g_{HZ\gamma} Z_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{AZ\gamma} g_{AZ\gamma} Z_{\mu\nu} \tilde{A}^{\mu\nu}]$$

$$- \frac{1}{4} [c_\alpha \kappa_{Hgg} g_{Hgg} G_{\mu\nu}^a G^{a,\mu\nu} + s_\alpha \kappa_{Agg} g_{Agg} G_{\mu\nu}^a \tilde{G}^{a,\mu\nu}]$$

Hzz

$$- \frac{1}{4} \frac{1}{\Lambda} [c_\alpha \kappa_{HZZ} Z_{\mu\nu} Z^{\mu\nu} + s_\alpha \kappa_{AZZ} Z_{\mu\nu} \tilde{Z}^{\mu\nu}]$$

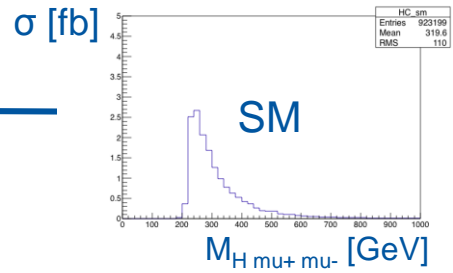
$$- \frac{1}{2} \frac{1}{\Lambda} [c_\alpha \kappa_{HWW} W_{\mu\nu}^+ W^{-\mu\nu} + s_\alpha \kappa_{AWW} W_{\mu\nu}^+ \tilde{W}^{-\mu\nu}]$$

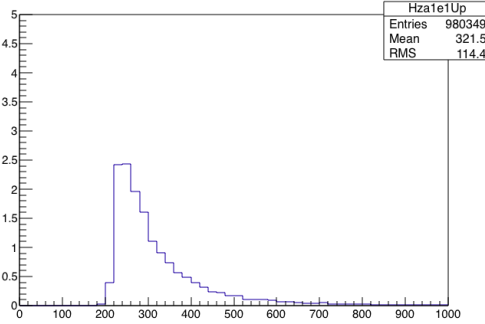
$$- \frac{1}{\Lambda} c_\alpha [\kappa_{H\partial\gamma} A_\nu \partial_\mu A^{\mu\nu} + \kappa_{H\partial Z} Z_\nu \partial_\mu Z^{\mu\nu}$$

Hdw

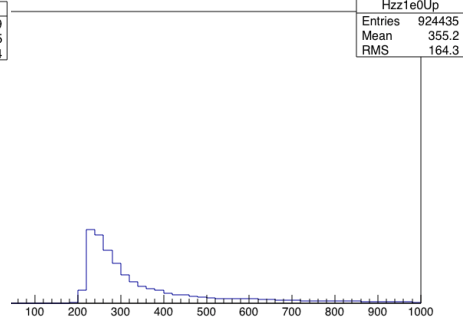
$$+ (\kappa_{H\partial W} W_\nu^+ \partial_\mu W^{-\mu\nu} + h.c.)] \left. \right\} X_0, \quad (1)$$

BSM couplings

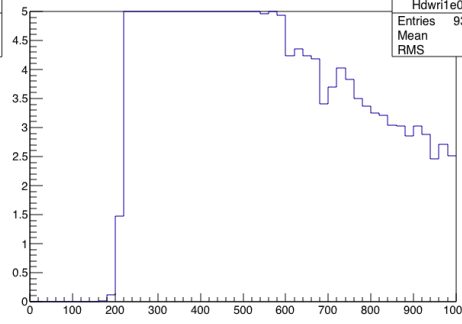




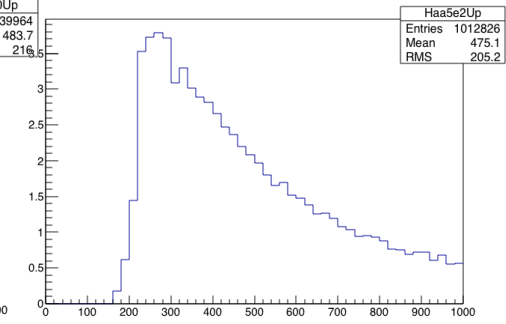
$K_{za} = +10$



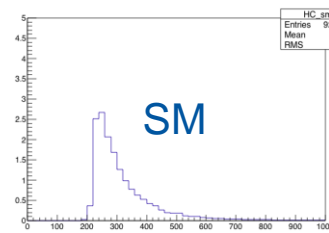
$K_{zz} = +1$



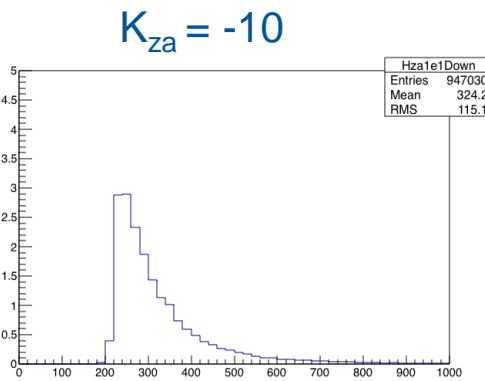
$K_{dw} = +1$



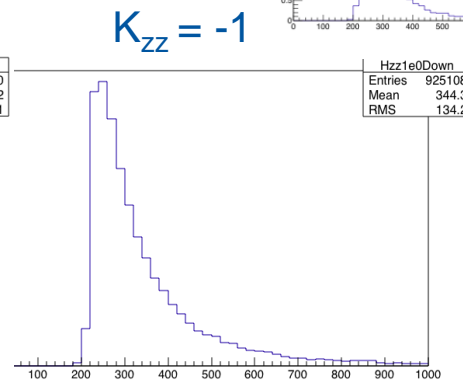
$K_{aa} = +500$



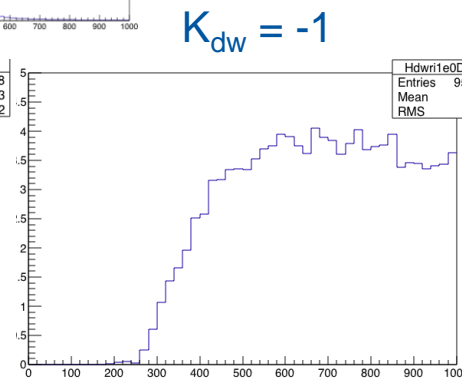
SM



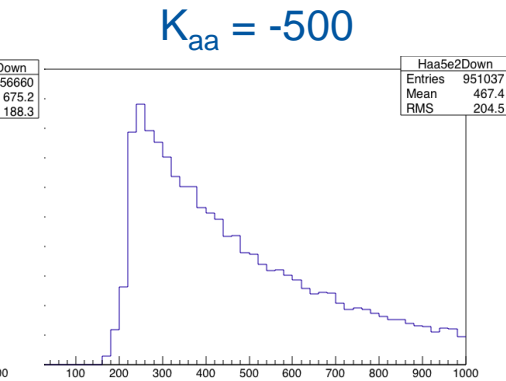
$K_{za} = -10$



$K_{zz} = -1$



$K_{dw} = -1$



$K_{aa} = -500$

Results

Fit of the model to HAWK (NLO EWK+QCD)
(assuming 1/fb of 13 TeV pp collisions)

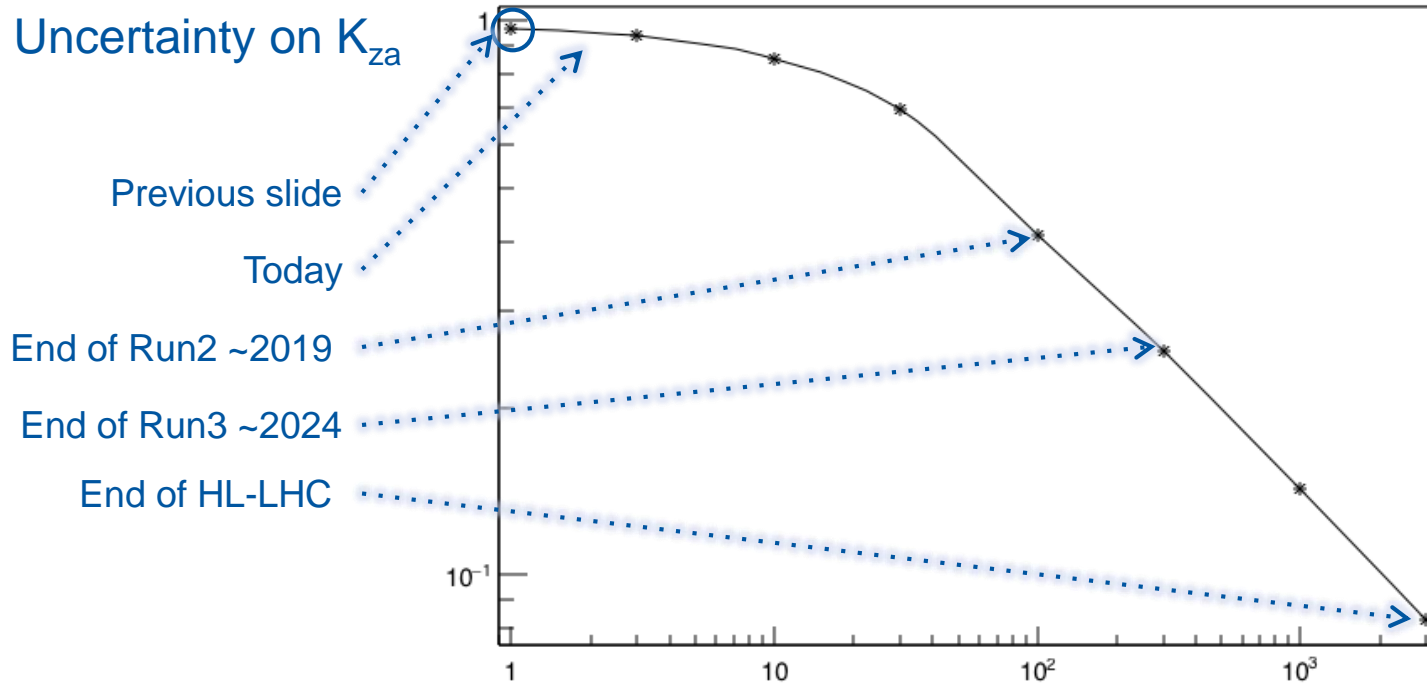
| Floating Parameter | InitialValue | FinalValue (+HiError,-LoError) | GblCorr. |
|--------------------|--------------|----------------------------------|----------|
| Haa5e2 | 0.0000e+00 | 6.9231e-06 +/- 1.26e-01 | <none> |
| Hdwri1e0 | 0.0000e+00 | 2.6292e-07 +/- 1.05e-02 | <none> |
| Hza1e1 | 0.0000e+00 | 2.9707e-02 +/- 9.72e-01 | <none> |
| Hzz1e0 | 0.0000e+00 | 1.5601e-02 +/- 5.72e-01 | <none> |
| r | 1.0000e+00 | 9.8192e-01 (+6.35e-01,-4.62e-01) | <none> |

Results

Poisson error $\sim \sqrt{(N)}$

Hza1e1 luminosity vs fit uncertainty

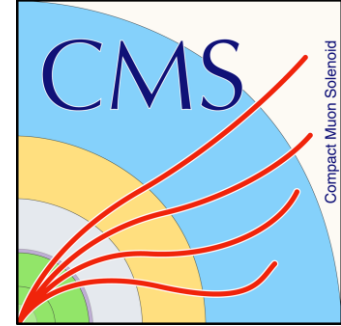
Uncertainty on K_{za}



Luminosity [1/fb]

Significance (practical)

- Where is new physics?
 - LHC
 - HL-LHC
- Future work
 - e^+/e^- colliders



Significance (personal)

- Physics in theory
 - QFT, SUSY, String
- Physics in practice
 - Control room, collaboration
- Computer science
 - FORTRAN, ROOT, MadGraph
 - C++, bash, cluster computing, Python







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