Optimal Input to Global Analyses

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Global LHC analyses

Goal of LHC

- not: testing BSM models
- search for (off-shell) new particles
  in terms of precision-QFT
- exploit many kinematic analyses
  enable re-interpretation for models

$\rightarrow$ Path to understanding all LHC data

SFitter topics [one year per paper]

- independent uncertainty analysis [0904.3866]
- Higgs-gauge sectors in SMEFT [1604.03105]
- di-boson resonance kinematics [1812.07587]
- top sector to NLO [1910.03606]
- loop-matching for full models [2108.01094]
- profile likelihood vs marginalization [2208.08454]

$\rightarrow$ Which experimental results?

Optimal measurements

Madminer from score from Fisher information from likelihood ratio [Brehmer, Cranmer, Kling...]

- likelihood ratio at detector level

$$\log \frac{p(x|\theta)}{p(x|0)} = \log \frac{\int dx_p \, T(x|x_p) \; p(x_p|\theta)}{\int dx_p \, T(x|x_p) \; p(x_p|0)}$$

- Fisher information over events, expanded around SM

$$-2 \, \mathbb{E} \left[\log \frac{p(x|\theta)}{p(x|0)} \right] = -\mathbb{E} \left[\frac{\partial^2 \log p(x|\theta)}{\partial\theta_i \, \partial\theta_j} \right] \; \theta_i \; \theta_j + \mathcal{O}(\theta^3) \, ,$$

- Score and optimal limits [$\text{Cov}[\theta_i, \theta_j] \geq (I^{-1})_{ij}$]

$$I_{ij} \equiv -\mathbb{E} \left[\frac{\partial^2 \log p(x|\theta)}{\partial\theta_i \, \partial\theta_j} \right] = \frac{\mathcal{L}}{\sigma} \frac{\partial\sigma}{\partial\theta_i} \frac{\partial\sigma}{\partial\theta_j} + \frac{\mathcal{L}\sigma}{N} \sum_{x \sim p(x|0)} t_i(x) \; t_j(x)$$

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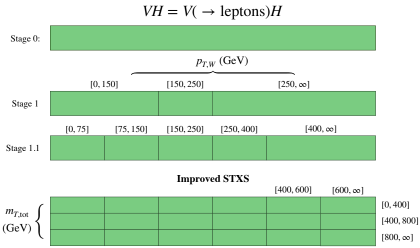
Compared to STXS



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Reach with background

Simple process $pp \to W_\ell H_{bb}$ [Brehmer, Dawson, Homiller, Kling, TP, long time ago]

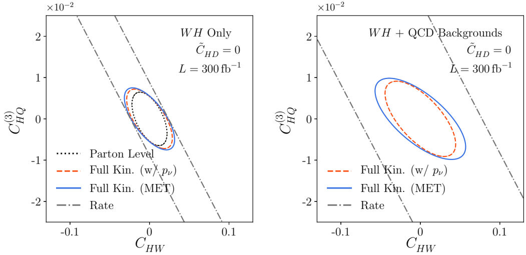
- example operators [wf vs vertex structure vs 4-point]

$$\widetilde{\mathcal{O}}_{HD} = (\phi^\dagger \phi)\Box(\phi^\dagger \phi) - \frac{1}{4}(\phi^\dagger D^\mu \phi)^*(\phi^\dagger D_\mu \phi)$$

$$\mathcal{O}_{HW} = \phi^\dagger \phi W^a_{\mu\nu} W^{\mu\nu a} \qquad \mathcal{O}^{(3)}_{Hq} = (\phi^\dagger i\overleftrightarrow{D}^a_\mu \phi)(\overline{Q}_L \sigma^a \gamma^\mu Q_L)$$

- simplified detector and backgrounds

$\to$ Detector not our problem



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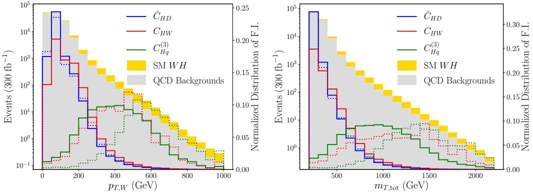
$\to$ Detector not our problem

- signal observables $p_{T,W} - m_{T,\text{tot}}$



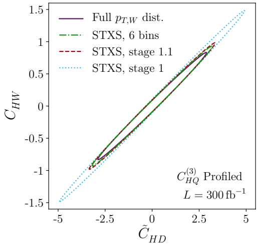
- $\widetilde{\mathcal{O}}_{HD}$ and $\mathcal{O}_{HW}$ from bulk
  $\mathcal{O}^{(3)}_{Hq}$ from high-mass tail

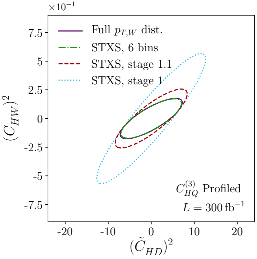
$\to$ Kinematics key

Single distributions

$p_{T,W}$ linear vs squared in D6

- bulk operators

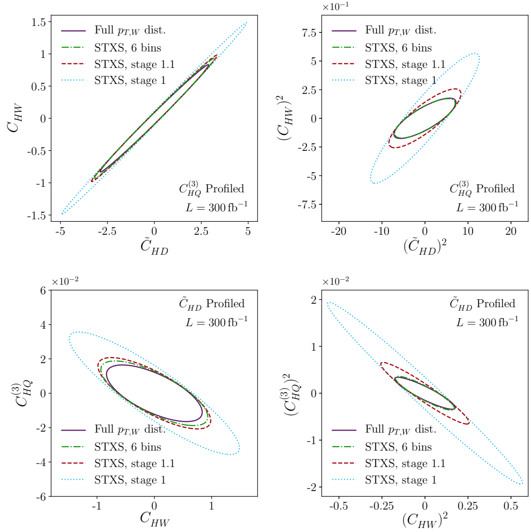




Single distributions

$p_{T,W}$ linear vs squared in D6

- bulk operators
- tail operator

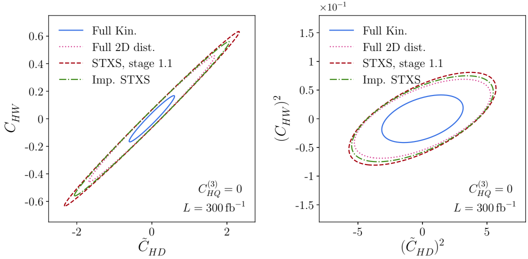


$\rightarrow$ Full range and enough bins needed

Full kinematics

Full kinematics $p_{T,W}$

- bulk operators



Full kinematics

Full kinematics $p_{T,W}$

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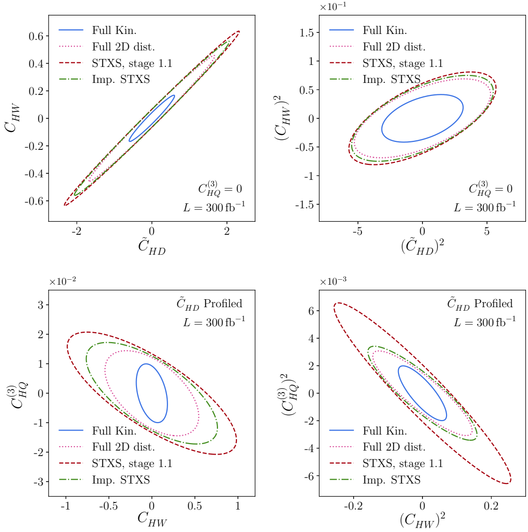

$\rightarrow$ 2D-kinematics not enough

Outlook

SMEFT analyses

- show that global LHC analyses are possible
  result predictable, limits not worth the time...
- interesting theory questions
  interesting pheno questions
  interesting statistics questions
- pre-digested data boring and sub-optimal
  ask top groups: unfolded kinematics
- future:
  likelihoods for uncertainties [Elmer, Madigan, TP, Schmal]
  multi-dimensional unfolding

→ Who do ATLAS and CMS write papers for?