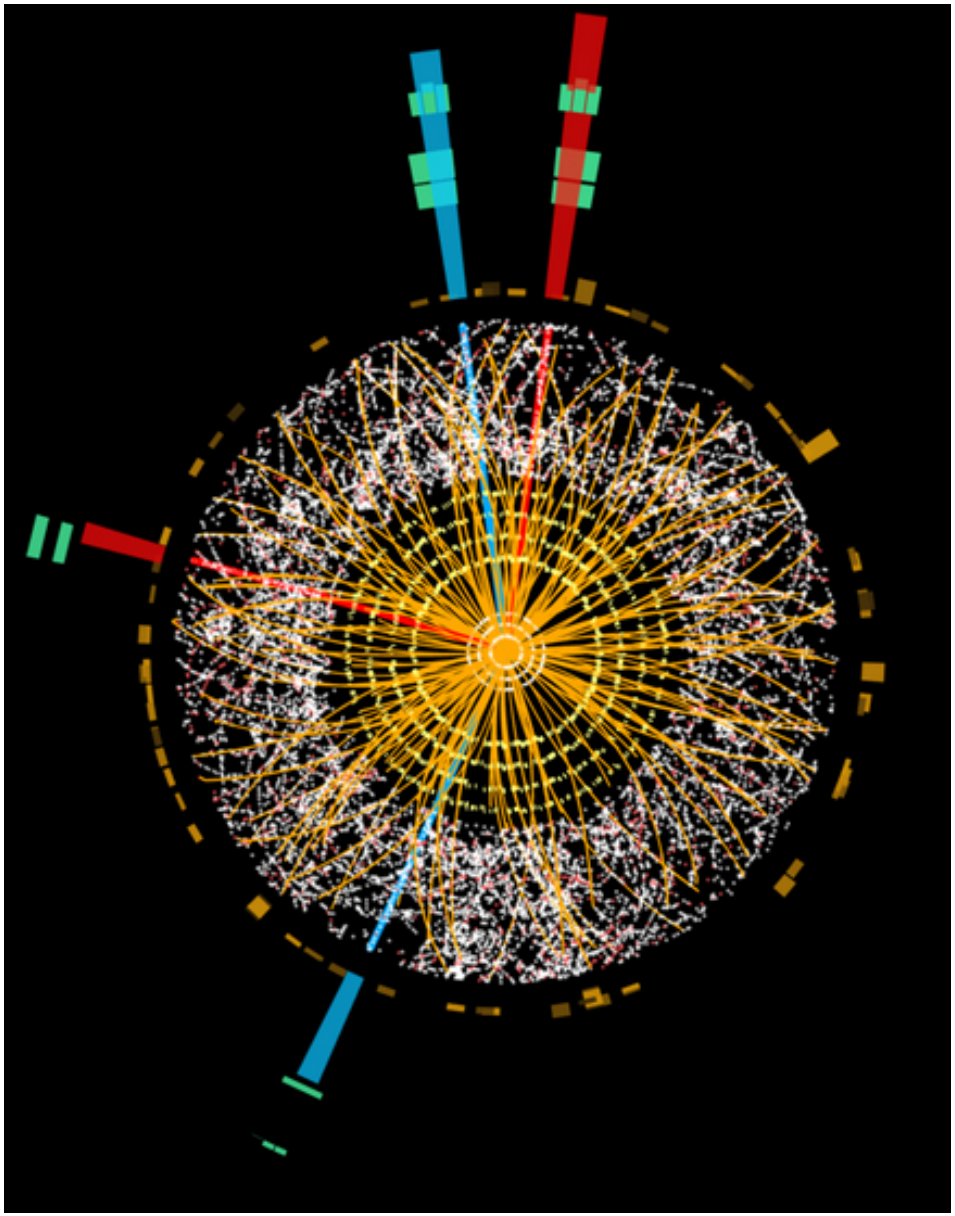

Higgs Report 2
– STXS –

Les Houches Workshop Series
"Physics at TeV Colliders" 2017

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European Research Council
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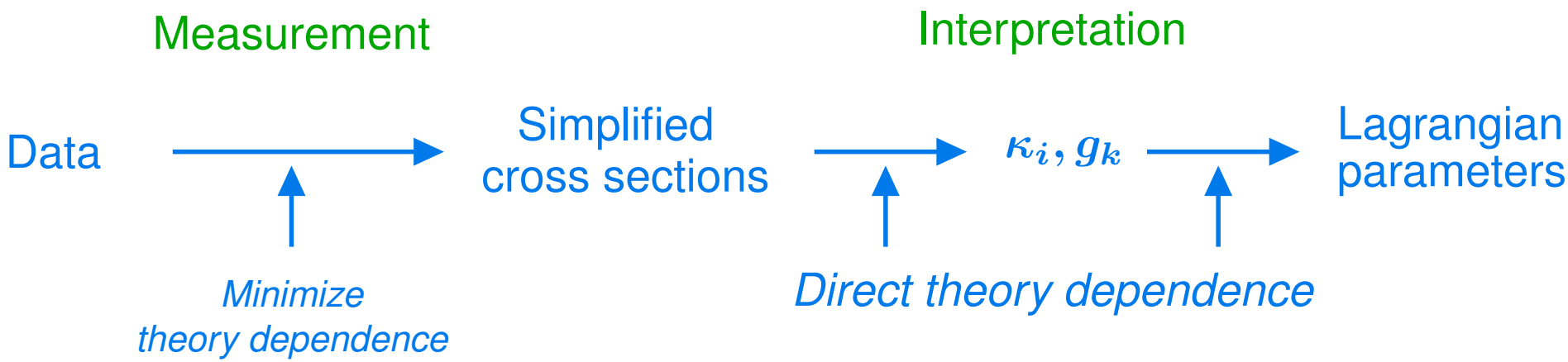
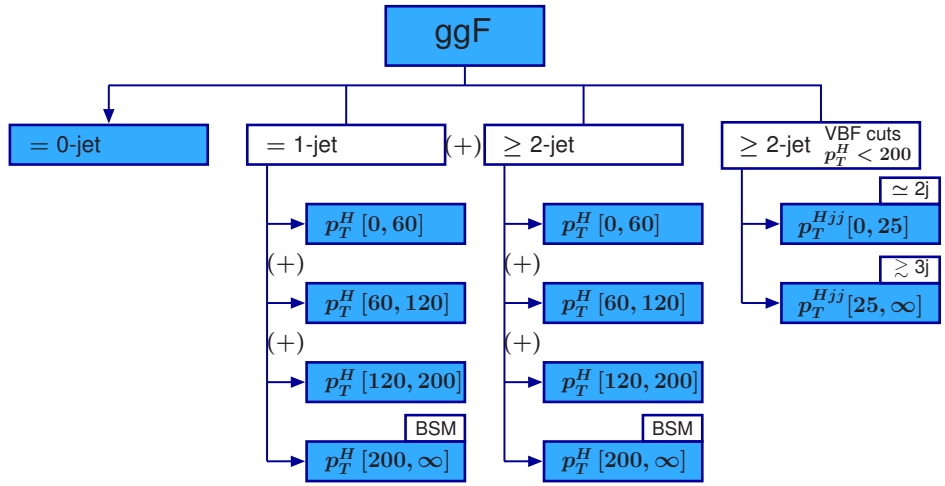
Introduction: simplified template cross sections.

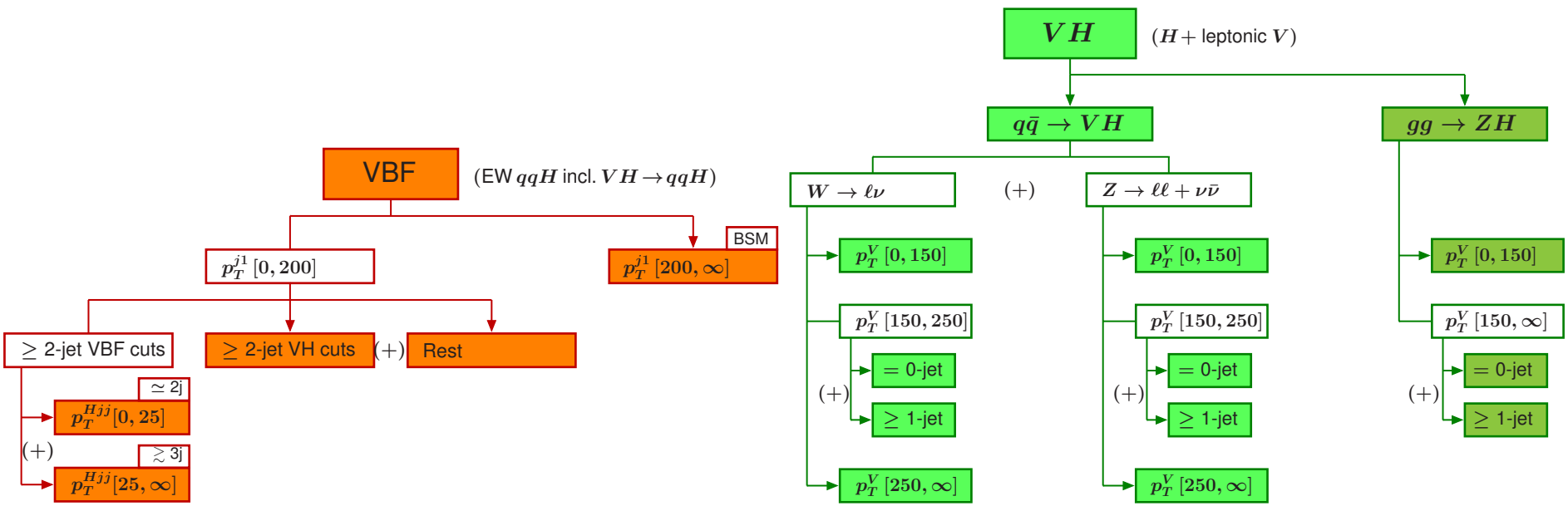


Goals

- Decouple the measurements and the interpretation
  - ⋆ Run1 μ measurements fold theory predictions and uncertainties directly into the measurements
- Minimize the theoretical uncertainties in the measurements
- Allow for interpretation with more/different model assumptions/BSM scenarios than provided by the experiments

Introduction: simplified template cross sections.





Presentation of results.

- Which information should be provided by the experiments so that the results can be used for interpretations?
  - ⋆ EFT fits, specific BSM models, ... as long as the acceptance used in the measurements is not too different
- For all cases: STXS central values

First case (simplest)

- Assumes Gaussian behavior is a good approximation
- Covariance matrices separated by
  - ⋆ statistical uncertainties
  - ⋆ total experimental systematic uncertainties
  - ⋆ combined* theoretical uncertainties
  - ⋆ *but separately specific theoretical uncertainties that might have to be correlated between the measurement and the interpretation
- Size of the uncertainty (variation) that might have to be correlated between the measurement and the interpretation

Presentation of results.

Second case (next simplest)

- Still assumes Gaussian behavior is a good approximation
- Keep the nuisance parameters that might have to be correlated between measurement and interpretation unprofiled
  - ⋆ Report extended covariance matrix or Hessian
  - ⋆ Requires some studies on numerical stability to decide

$$\left(\begin{array}{c|c} C_B + \Delta\Delta^T & \Delta \\ \hline \Delta & 1 \end{array}\right)$$

C_B covariance matrix of measured bins

$\boldsymbol{\Delta}$ impact of unprofiled uncertainty on measured bins

Third case

- In case Gaussian approximation is not good enough for single STXS, provide (parametrized) likelihood for these STXS
- Experiments will have to test if interpretations with these inputs possible (compare to using full likelihoods)

Parametrization of VH uncertainties: sources.

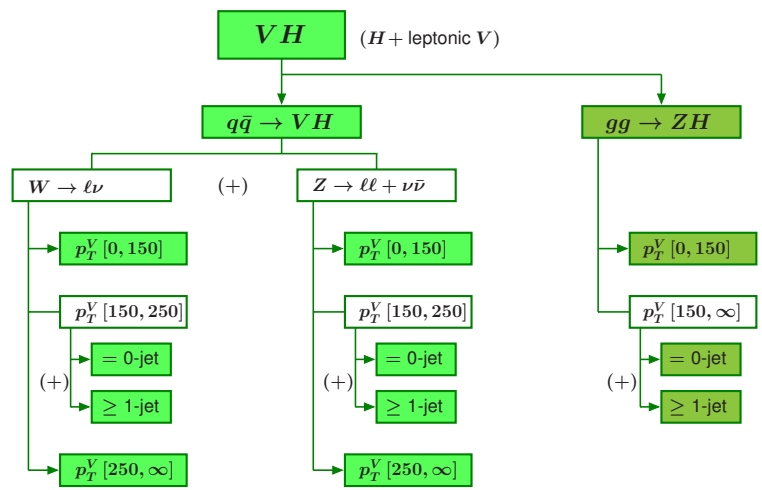
QCD uncertainties (same for W and Z)

- Δ_{μ}, Δ_{150}, Δ_{250}
  - ⋆ Option 1: overall correlated uncertainty plus two uncertainties related to p_T^V shape
  - ⋆ Option 2: one uncorrelated uncertainty per p_T^V region
- $\Delta_{0/1}$: jet bin migration uncertainty

EW uncertainties

- Δ_{Sud}: EW Sudakov effects (correlated between W and Z)
- Δ_W, Δ_Z, Δ_{γ}
  - ⋆ Separate uncertainties for non-Sudakov contributions

- Uncorrelated uncertainties (separate sources) between $q\bar{q} \to VH$ and $gg \to ZH$
  - ⋆ Study which sources for $gg \to ZH$ are correlated with $gg \to H$



Parametrization of VH uncertainties: correlation model.

	QCD uncertainties				EW uncertainties			
Bin	Δ_μ	Δ_{150}	Δ_{250}	$\Delta_{0/1}$	Δ_{Sud}	Δ_W	Δ_Z	Δ_γ
W [0,150]	x_1	$-c$	0		y_1	$*$		$*$
W [150,250]	x_2	$+c$	$+d$		y_2	$*$		$*$
$=$0j [150,250]	$x_2 z$	$+cz$	$+dz$	$+1$	$\cdots$	$*$		$*$
$\geq$1j [150,250]	$x_2(1-z)$	$+c(1-z)$	$+d(1-z)$	-1	$\cdots$	$*$		$*$
W [250,∞]	x_3	0	$-d$		y_3	$*$		$*$
Z [0,150]	x_1	$-c$	0		y_1		$*$	
Z [150,250]	x_2	$+c$	$+d$		y_2		$*$	
$=$0j [150,250]	$x_2 z$	$+cz$	$+dz$	$+1$	$\cdots$		$*$	
$\geq$1j [150,250]	$x_2(1-z)$	$+c(1-z)$	$+d(1-z)$	-1	$\cdots$		$*$	
Z [250,∞]	x_3	0	$-d$		y_3		$*$	

+Uncorrelated sources for $gg \to ZH$

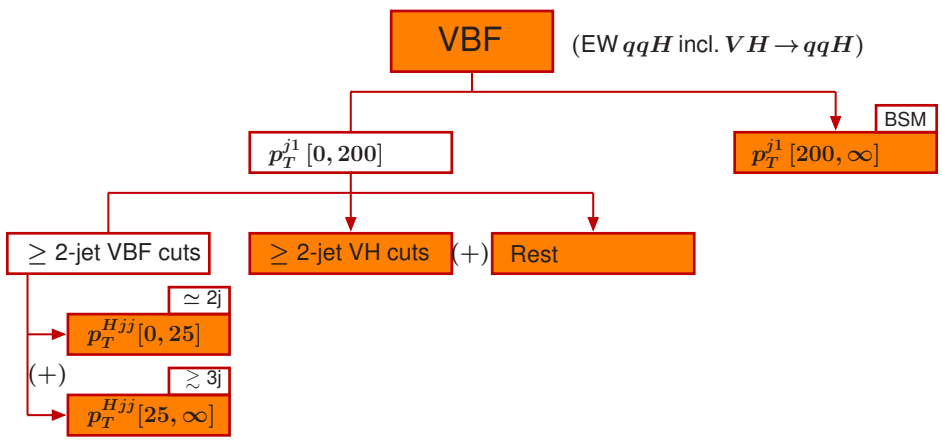
Parametrization of VBF uncertainties: sources.

QCD uncertainties

- Δ_{μ}
  - ⋆ Correlation between bins still to be discussed
- Δ_{μ}^{VH} uncertainty for the VH bin induced by hadronic VH process
  - ⋆ Correlated with leptonic VH
- Δ_{200} migration uncertainty related to p_T^{j1} cut
- Δ_{25} migration uncertainty related to third-jet veto

EW uncertainties

- Δ_{Sud}: EW Sudakov effects
  - ⋆ correlate with $q\bar{q} \to VH$
- Δ_{hard}



Parametrization of VBF uncertainties: correlation model.

	QCD uncertainties				EW uncertainties		
Bin	Δ_μ	Δ_μ^{VH}	Δ_{200}	Δ_{25}	Δ_{Sud}	Δ_{hard}	$\Delta_{W,Z,\gamma}^{\mathrm{VH}}$
p_T^j [0,200]	?	$1-\epsilon$	-1		y_1	$*$	
VBF cuts	?		$-x_1$		y_2	$*$	
p_T^{Hjj} $[0,25]$	?		$-x_1 z$	$+1$	$\cdots$	$*$	
p_T^{Hjj} $[25,\infty]$	?		$-x_1(1-z)$	-1	$\cdots$	$*$	
VH cuts	?	$1-\epsilon$	$-x_2$		y_3	$*$	1
Rest	?		$-x_3$		y_4	$*$	
p_T^j $[200,\infty]$	?	ϵ	$+1$		$1-y$	$*$	

Other topics discussed: binning.

Future binning for gluon fusion

- Consider to split the highest p_T^H bins into [200, 500] and [500, ∞] to have a dedicated bin for boosted analyses

Treatment of $gg \to Z(\to q\bar{q})H$

- Currently considered as part of the gluon fusion bins
- Conclusion of discussion is to keep it like this
- Consider to introduce a split of the gluon fusion 2-jet bins ([60, 120], [120, 200], [200,∞]) to have dedicated bins with 60 GeV $< m_{jj} <$ 120 GeV

Future binning for $t\bar{t}H$

- Currently one inclusive bin for $t\bar{t}H$
- Consider to introduce a split by p_T^H: [0,200] and [200, ∞] (separating non-boosted and boosted analyses)
  - ⋆ Consider to split [0, 200] into =0j and $\geq$1j (in addition to $t\bar{t}H$ signal jets)

Other topics discussed.

Including final state observables

- Angular information from $H \to ZZ^*$ and $H \to WW^*$ currently not available in STXS measurements by construction
- In the measurements, can measure sensitive quantities (e.g. decay angles) in (some) STXS bins
- Extend STXS framework to include final state observables (e.g. angular coefficients/POs)

How to treat out-of-fiducial corrections (for differential measurements)

- To apply corrections for experimentally inaccessible phase space regions
  - ⋆ Essentially one can fix the cross section to the SM or fix the relative cross section between the fiducial and out-of-fiducial cross section to the SM
- To be followed up in the ATLAS–CMS combination group

Summary.

- STXS developed from discussions at Les Houches 2015
- After first experience with the measurements, discussions on specific topics
  - ⋆ Presentation of results
  - ⋆ Parametrization of VBF and VH uncertainties
  - ⋆ STXS bin definitions
  - ⋆ Inclusion of final state observables
- To be continued in the context of the LHC Higgs XS WG and for the Les Houches proceedings