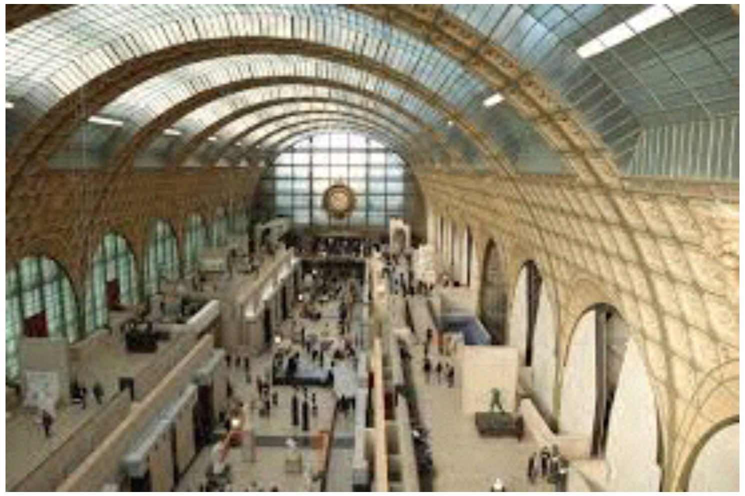


Higgs Boson Properties

now and soon

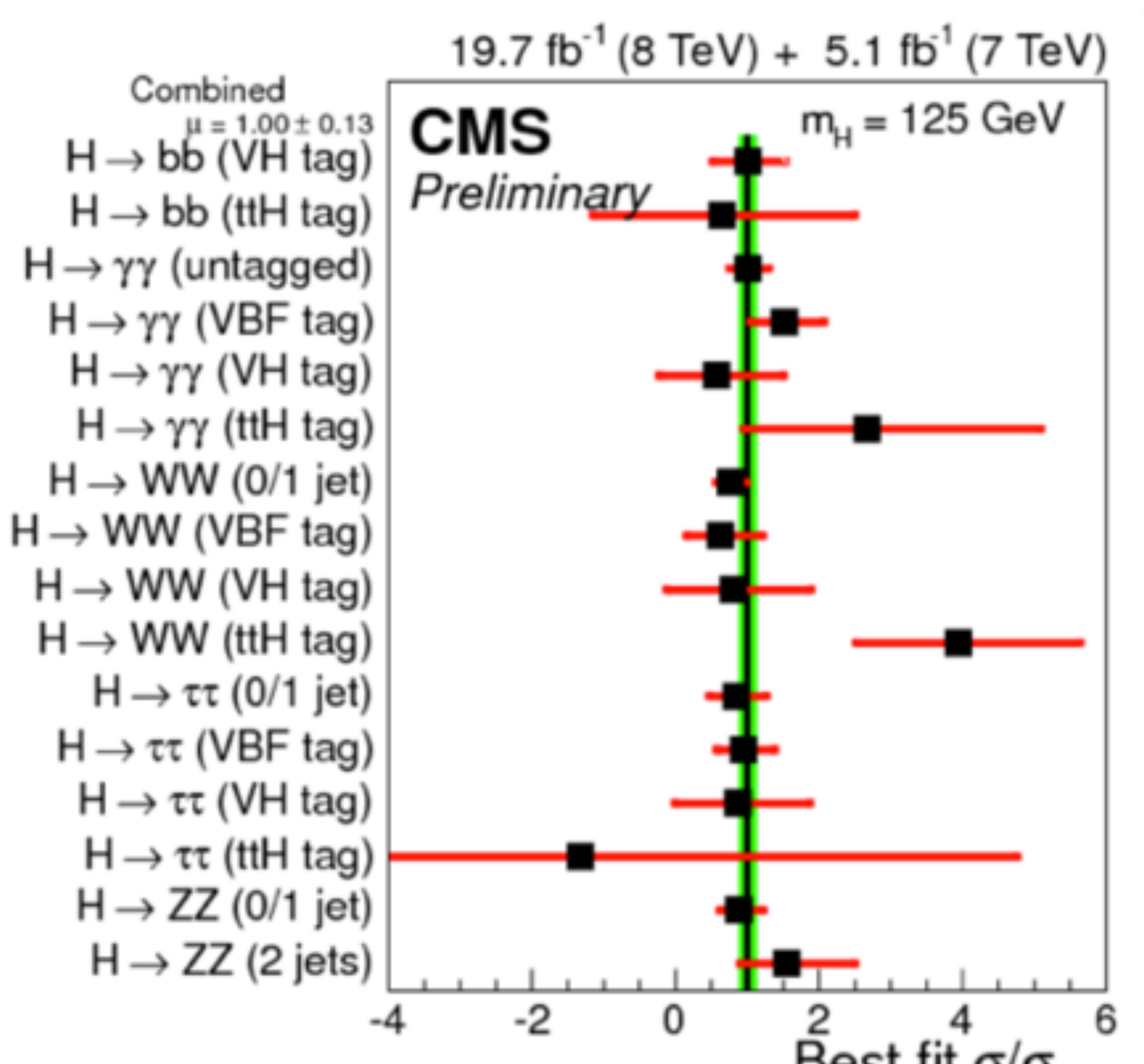
Michael Spannowsky

IPPP, Durham University

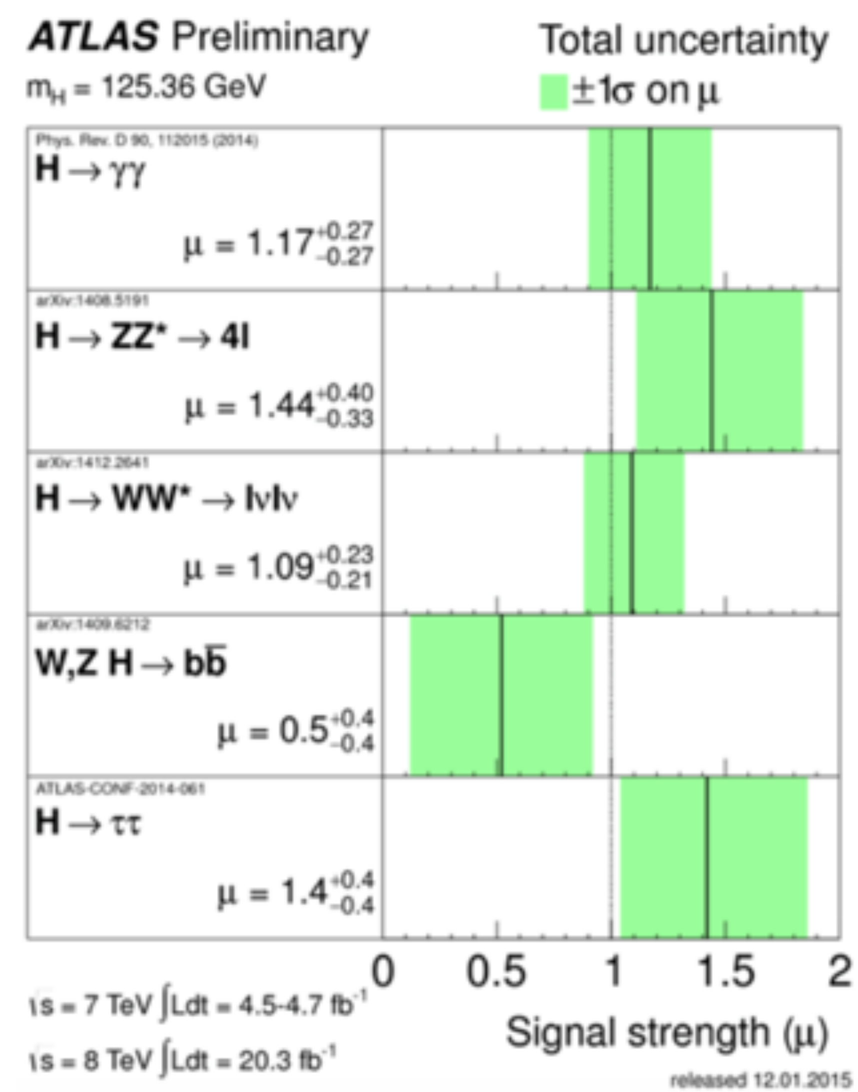
At the dawn of Run 2

Current Higgs property results

- Charge and Mass already well determined
- Higgs Parity-even and Spin-0
- Width for a class of models indirectly constrained to $\Gamma_H \leq 4.2\ \Gamma_{\mathrm{H,SM}}$
- Couplings in agreement with SM



[CMS HIG-14-009-PAS]



Ongoing preparations for coming results:

Improved/Unified way of interpretation of measurements

- only measurement model-independent
- interpretation of measurement model dependent
- interpretation requires communication between different scales as well as theorists and experimentalists

Connecting measurements with UV physics

Kappa Framework

- NP models simple rescaling of couplings
- No new Lorentz -structures or kinematics

EFT

- SM degrees of freedom and symmetries
- New kinematics/ Lorentz structures

Simplified Models

- New low-energy degrees of freedom
- Subset of states of full models, reflective at scale of measurement

Full (UV) Model

- Very complex and often high-dimensional parameter space
- Allows to correlate high-scale and low-scale physics

Complexity/Flexibility

Example 'width-measurement'

Measure coupling off-shell -> limit denominator on-shell

$$\sigma^{\text{on-peak}}_{gg\to H\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{\Gamma_H} \quad \longleftrightarrow \quad \sigma^{\text{off-peak}}_{gg\to H\to ZZ} \sim g^2_{ggH} g^2_{HZZ}$$

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Kappa Framework	EFT	Simplified Models	Full (UV) Model

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Kappa Framework

- Assuming global coupling rescaling

EFT

Simplified Models

Full (UV) Model

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Simplified Models

- Eg. **Higgs portal**, NP can contribute on-shell but not off-shell [Englert, MS '14]
- Eg. **Higgs triplet**, new scalar below measurement range cancels on-shell enhancement [Logan '15]

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Full (UV) Model

- Breaks as Simplified Model breaks

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Kappa Framework

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EFT

- Assuming valid, i.e. NP-scale outside kinematic edge

Coupling assumptions strong LEP limits stronger than LHC

$$0.73 \lesssim \Gamma_h \lesssim 1.87$$

[Englert, McCullough, MS '15]

Simplified Models

- Eg. **Higgs portal**, NP can contribute on-shell but not off-shell [Englert, MS '14]
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Full (UV) Model

- Breaks as Simplified Model breaks

Coupling measurement during Run 1 using kappa-framework:

kappa is ratio of couplings:

$$\kappa_i = \frac{g_i}{g_{i,SM}}$$

so-called

$\sigma(g_p) \times \mathrm{BR}(g_d)$ physics

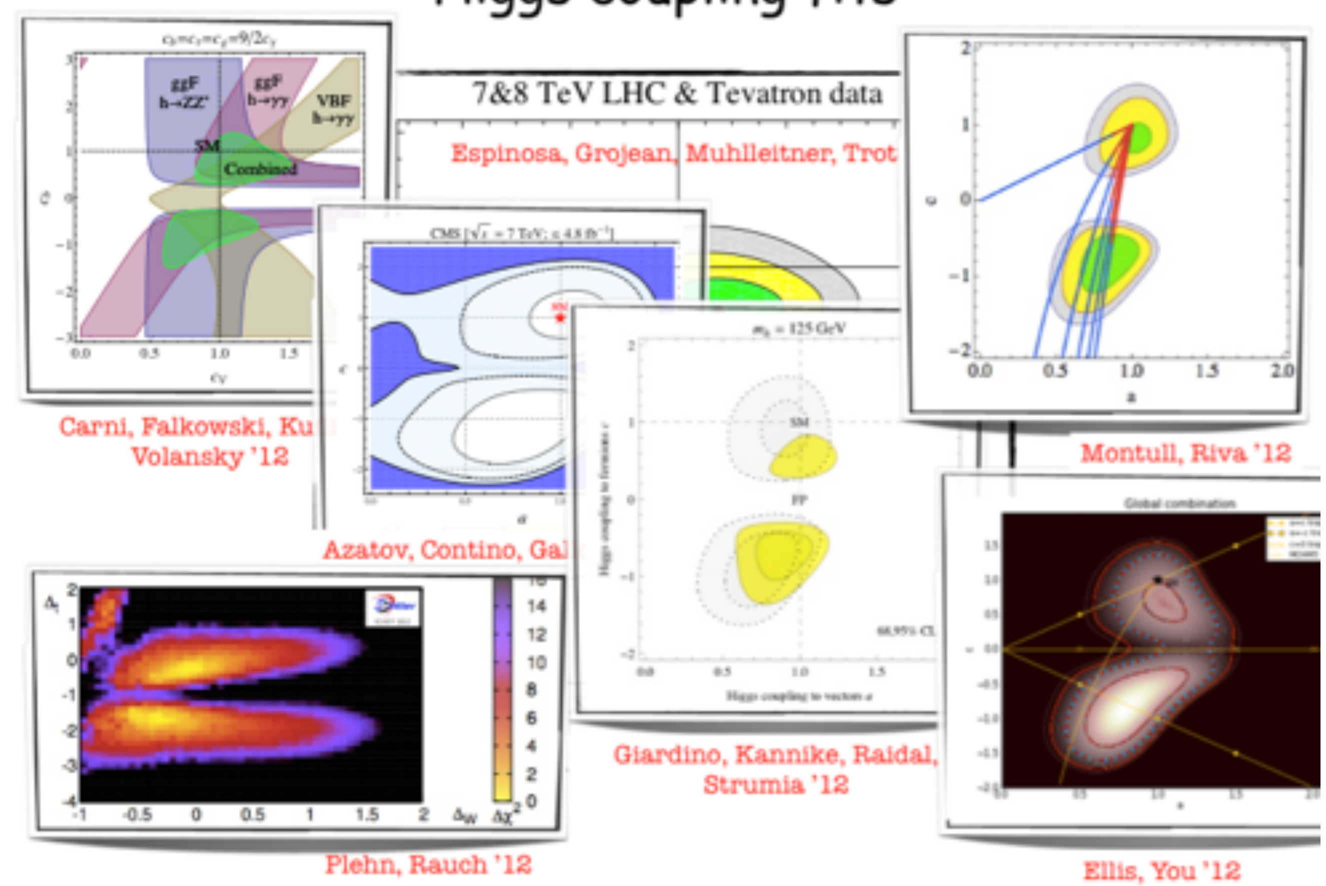
Decay into spec. channel

Production

$$\sigma \cdot BR \propto g_p^2 \frac{g_d^2}{\Gamma_H}$$

Sum of all possible decays

Higgs coupling fits



- try to over-constrain couplings basis
- Higgs width of particular importance

Higgs coupling fits based on total rates... no dynamics

No new Lorentz structures, limited applicability for new physics

The Effective Field Theory approach

All operators respecting gauge invariance, the SM gauge group and particle content

Agnostic operator basis complex: 2499 non-redundant parameters at dim-6

76 flavor-diagonal operators at dim-6

Highly complex: 59 operators (flavor blind and CP-even)

$$\mathcal{O}_H = \frac{1}{2}(\partial^\mu |H|^2)^2$$
$$\mathcal{O}_T = \frac{1}{2}\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$$
$$\mathcal{O}_6 = \lambda |H|^6$$

$$\mathcal{O}_W = \frac{ig}{2}\left(H^\dagger \sigma^a \overleftrightarrow{D}^\mu H\right) D^\nu W^a_{\mu\nu}$$
$$\mathcal{O}_B = \frac{ig'}{2}\left(H^\dagger \overleftrightarrow{D}^\mu H\right) \partial^\nu B_{\mu\nu}$$
$$\mathcal{O}_{2W} = -\frac{1}{2}(D^\mu W^a_{\mu\nu})^2$$
$$\mathcal{O}_{2B} = -\frac{1}{2}(\partial^\mu B_{\mu\nu})^2$$
$$\mathcal{O}_{2G} = -\frac{1}{2}(D^\mu G^A_{\mu\nu})^2$$

$$\mathcal{O}_{BB} = g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu}$$
$$\mathcal{O}_{GG} = g_s^2 |H|^2 G^A_{\mu\nu} G^{A\mu\nu}$$
$$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$$
$$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$
$$\mathcal{O}_{3W} = \frac{1}{3!} g \epsilon_{abc} W^{a\,\nu}_\mu W^b_{\nu\rho} W^{c\,\rho\mu}$$
$$\mathcal{O}_{3G} = \frac{1}{3!} g_s f_{ABC} G^{A\,\nu}_\mu G^B_{\nu\rho} G^{C\,\rho\mu}$$

$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \widetilde{H} u_R$	$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R$	$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R$
$\mathcal{O}_R^u = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R)$	$\mathcal{O}_R^d = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{d}_R \gamma^\mu d_R)$	$\mathcal{O}_R^e = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_L^q = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu Q_L)$		$\mathcal{O}_L^l = (iH^\dagger \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_L^{(3)\,q} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{Q}_L \gamma^\mu \sigma^a Q_L)$		$\mathcal{O}_L^{(3)\,l} = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\bar{L}_L \gamma^\mu \sigma^a L_L)$
$\mathcal{O}_{LR}^u = (\bar{Q}_L \gamma^\mu Q_L)(\bar{u}_R \gamma^\mu u_R)$	$\mathcal{O}_{LR}^d = (\bar{Q}_L \gamma^\mu Q_L)(\bar{d}_R \gamma^\mu d_R)$	$\mathcal{O}_{LR}^e = (\bar{L}_L \gamma^\mu L_L)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_{LR}^{(8)\,u} = (\bar{Q}_L \gamma^\mu T^A Q_L)(\bar{u}_R \gamma^\mu T^A u_R)$	$\mathcal{O}_{LR}^{(8)\,d} = (\bar{Q}_L \gamma^\mu T^A Q_L)(\bar{d}_R \gamma^\mu T^A d_R)$	
$\mathcal{O}_{RR}^u = (\bar{u}_R \gamma^\mu u_R)(\bar{u}_R \gamma^\mu u_R)$	$\mathcal{O}_{RR}^d = (\bar{d}_R \gamma^\mu d_R)(\bar{d}_R \gamma^\mu d_R)$	$\mathcal{O}_{RR}^e = (\bar{e}_R \gamma^\mu e_R)(\bar{e}_R \gamma^\mu e_R)$
$\mathcal{O}_{LL}^q = (\bar{Q}_L \gamma^\mu Q_L)(\bar{Q}_L \gamma^\mu Q_L)$		$\mathcal{O}_{LL}^l = (\bar{L}_L \gamma^\mu L_L)(\bar{L}_L \gamma^\mu L_L)$
$\mathcal{O}_{LL}^{(8)\,q} = (\bar{Q}_L \gamma^\mu T^A Q_L)(\bar{Q}_L \gamma^\mu T^A Q_L)$		
$\mathcal{O}_{LL}^{ql} = (\bar{Q}_L \gamma^\mu Q_L)(\bar{L}_L \gamma^\mu L_L)$		
$\mathcal{O}_{LL}^{(3)\,ql} = (\bar{Q}_L \gamma^\mu \sigma^a Q_L)(\bar{L}_L \gamma^\mu \sigma^a L_L)$		
$\mathcal{O}_{LR}^{qe} = (\bar{Q}_L \gamma^\mu Q_L)(\bar{e}_R \gamma^\mu e_R)$		
$\mathcal{O}_{LR}^{lu} = (\bar{L}_L \gamma^\mu L_L)(\bar{u}_R \gamma^\mu u_R)$	$\mathcal{O}_{LR}^{ld} = (\bar{L}_L \gamma^\mu L_L)(\bar{d}_R \gamma^\mu d_R)$	
$\mathcal{O}_{RR}^{ud} = (\bar{u}_R \gamma^\mu u_R)(\bar{d}_R \gamma^\mu d_R)$		
$\mathcal{O}_{RR}^{(8)\,ud} = (\bar{u}_R \gamma^\mu T^A u_R)(\bar{d}_R \gamma^\mu T^A d_R)$		
$\mathcal{O}_{RR}^{ue} = (\bar{u}_R \gamma^\mu u_R)(\bar{e}_R \gamma^\mu e_R)$	$\mathcal{O}_{RR}^{de} = (\bar{d}_R \gamma^\mu d_R)(\bar{e}_R \gamma^\mu e_R)$	
$\mathcal{O}_R^{ud} = y_u^\dagger y_d (i\widetilde{H}^\dagger \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu d_R)$		
$\mathcal{O}_{y_u y_d} = y_u y_d (\bar{Q}_L^r u_R)\epsilon_{rs}(\bar{Q}_L^s d_R)$		
$\mathcal{O}_{y_u y_d}^{(8)} = y_u y_d (\bar{Q}_L^r T^A u_R)\epsilon_{rs}(\bar{Q}_L^s T^A d_R)$		
$\mathcal{O}_{y_u y_e} = y_u y_e (\bar{Q}_L^r u_R)\epsilon_{rs}(\bar{L}_L^s e_R)$		
$\mathcal{O}'_{y_u y_e} = y_u y_e (\bar{Q}_L^{r\alpha} e_R)\epsilon_{rs}(\bar{L}_L^s u_R^\alpha)$		
$\mathcal{O}_{y_e y_d} = y_e y_d^\dagger (\bar{L}_L e_R)(\bar{d}_R Q_L)$		
$\mathcal{O}_{DB}^u = y_u \bar{Q}_L \sigma^{\mu\nu} u_R \widetilde{H} g' B_{\mu\nu}$	$\mathcal{O}_{DB}^d = y_d \bar{Q}_L \sigma^{\mu\nu} d_R H g' B_{\mu\nu}$	$\mathcal{O}_{DB}^e = y_e \bar{L}_L \sigma^{\mu\nu} e_R H g' B_{\mu\nu}$
$\mathcal{O}_{DW}^u = y_u \bar{Q}_L \sigma^{\mu\nu} u_R \sigma^a \widetilde{H} g W^a_{\mu\nu}$	$\mathcal{O}_{DW}^d = y_d \bar{Q}_L \sigma^{\mu\nu} d_R \sigma^a H g W^a_{\mu\nu}$	$\mathcal{O}_{DW}^e = y_e \bar{L}_L \sigma^{\mu\nu} e_R \sigma^a H g W^a_{\mu\nu}$
$\mathcal{O}_{DG}^u = y_u \bar{Q}_L \sigma^{\mu\nu} T^A u_R \widetilde{H} g_s G^A_{\mu\nu}$	$\mathcal{O}_{DG}^d = y_d \bar{Q}_L \sigma^{\mu\nu} T^A d_R H g_s G^A_{\mu\nu}$	

Struggle for a unified language (basis) for Higgs EFT

Basis

- Complete
- Inspired by UV physics?

Several available:

Warsaw Basis	[1008.4884]
SILH Basis	[hep-ph/070164]
Primary/Higgs Basis	[1405.0181]

Practicality

- Manageable number of operators for fit

Validity

- Validity range of EFT set by kinematic of measurement

Precision

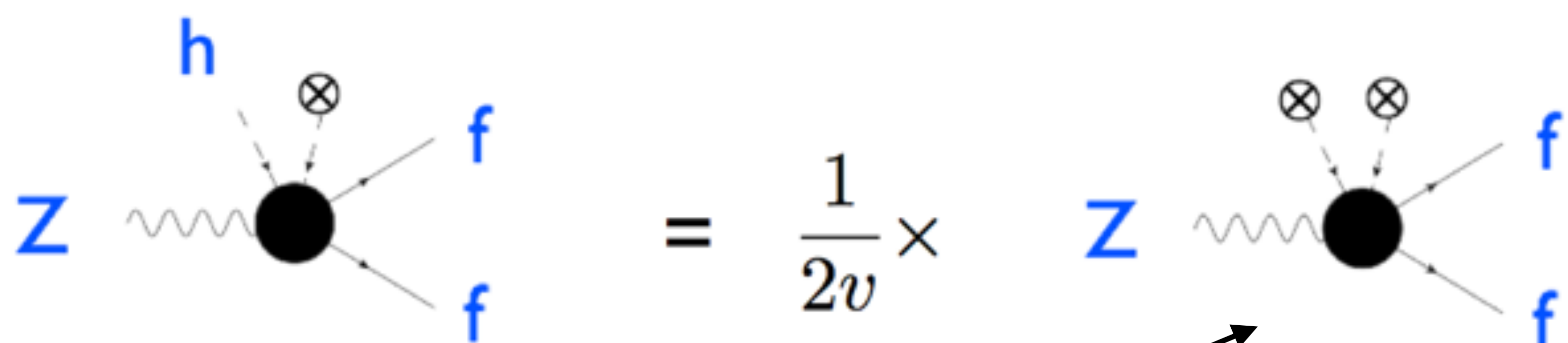
- Resummation of large log (RGE improved pert. theory)
- Full NLO

Practicality

- Focus on operators with Higgs involvement (new kid on the block)

Observation:

Many Higgs operator indirectly constrained by EWP measurements



constrained by LEP at permille level

- Focus on operators that are probed predominantly at LHC

→ In the end ~8 operators including Higgs of interest

As a result of existing bounds, basis of interesting operators can be simplified for collider pheno, e.g. SILH basis: [Giudice, Grojean, Pomarol, Rattazzi '07]

$$\mathcal{L}_{\rm SILH} = \frac{c_H}{2f^2}\partial^\mu\left(H^\dagger H\right)\partial_\mu\left(H^\dagger H\right) + \frac{c_T}{2f^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) - \frac{c_6\lambda}{f^2}\left(H^\dagger H\right)^3 + \left(\frac{c_y y_f}{f^2} H^\dagger H \bar{f}_L H f_R + \text{h.c.}\right)$$
$$+ \frac{ic_W g}{2m_\rho^2}\left(H^\dagger \sigma^i \overleftrightarrow{D^\mu} H\right)\left(D^\nu W_{\mu\nu}\right)^i + \frac{ic_B g'}{2m_\rho^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)\left(\partial^\nu B_{\mu\nu}\right) + \frac{ic_{HW} g}{16\pi^2 f^2}(D^\mu H)^\dagger \sigma^i (D^\nu H) W^i_{\mu\nu}$$
$$+ \frac{ic_{HB} g'}{16\pi^2 f^2}(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu} + \frac{c_\gamma g'^2}{16\pi^2 f^2}\frac{g^2}{g_\rho^2} H^\dagger H B_{\mu\nu} B^{\mu\nu} + \frac{c_g g_S^2}{16\pi^2 f^2}\frac{y_t^2}{g_\rho^2} H^\dagger H G^a_{\mu\nu} G^{a\mu\nu},$$

here $c_T \sim T$ and $c_B + c_W \sim S$ [Peskin, Takeuchi '91]

Wilson coefficients can be (over) constraint in many decay and production processes:

Decays: $H \to f\bar{f}$ $H \to \gamma\gamma$ $H \to \gamma Z$

$H \to ZZ^*$ $H \to WW^*$

Production: $pp \to H$ $pp \to Hj$ $pp \to Hjj$

$pp \to HV$ $pp \to ttH$

Validity and Relevance of EFT

EFT used to set limits on UV models from non-observation of new physics

Lagrangian dim-6: $\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{g_i^2}{\Lambda_{\mathrm{NP}}^2} \mathcal{O}_i$

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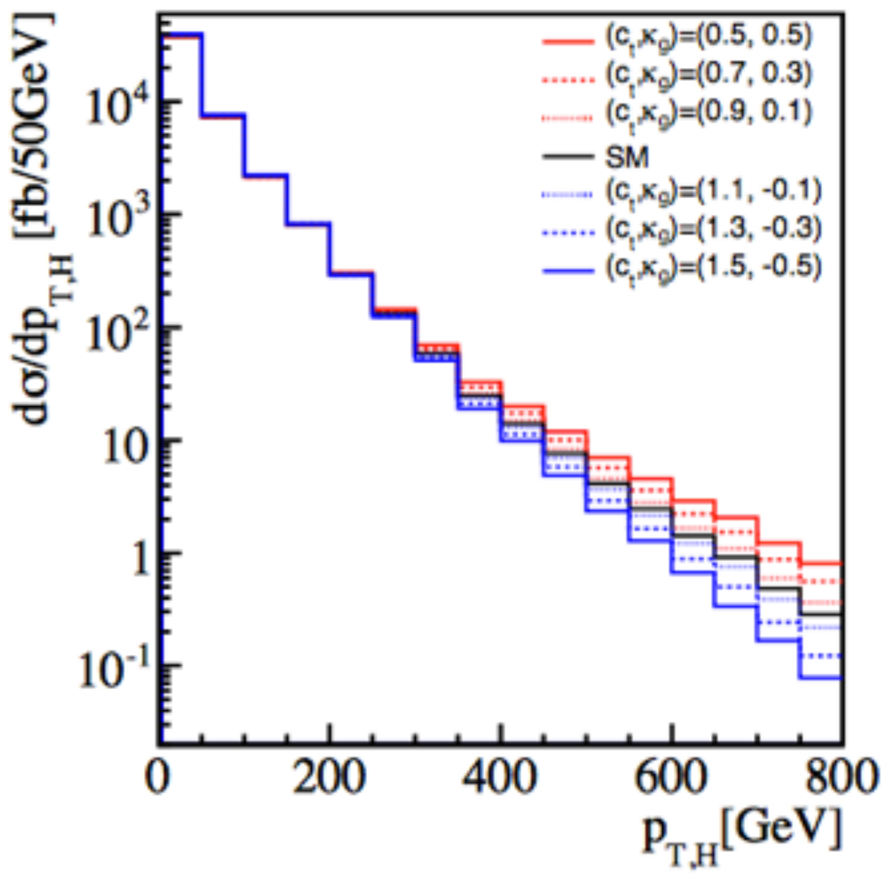
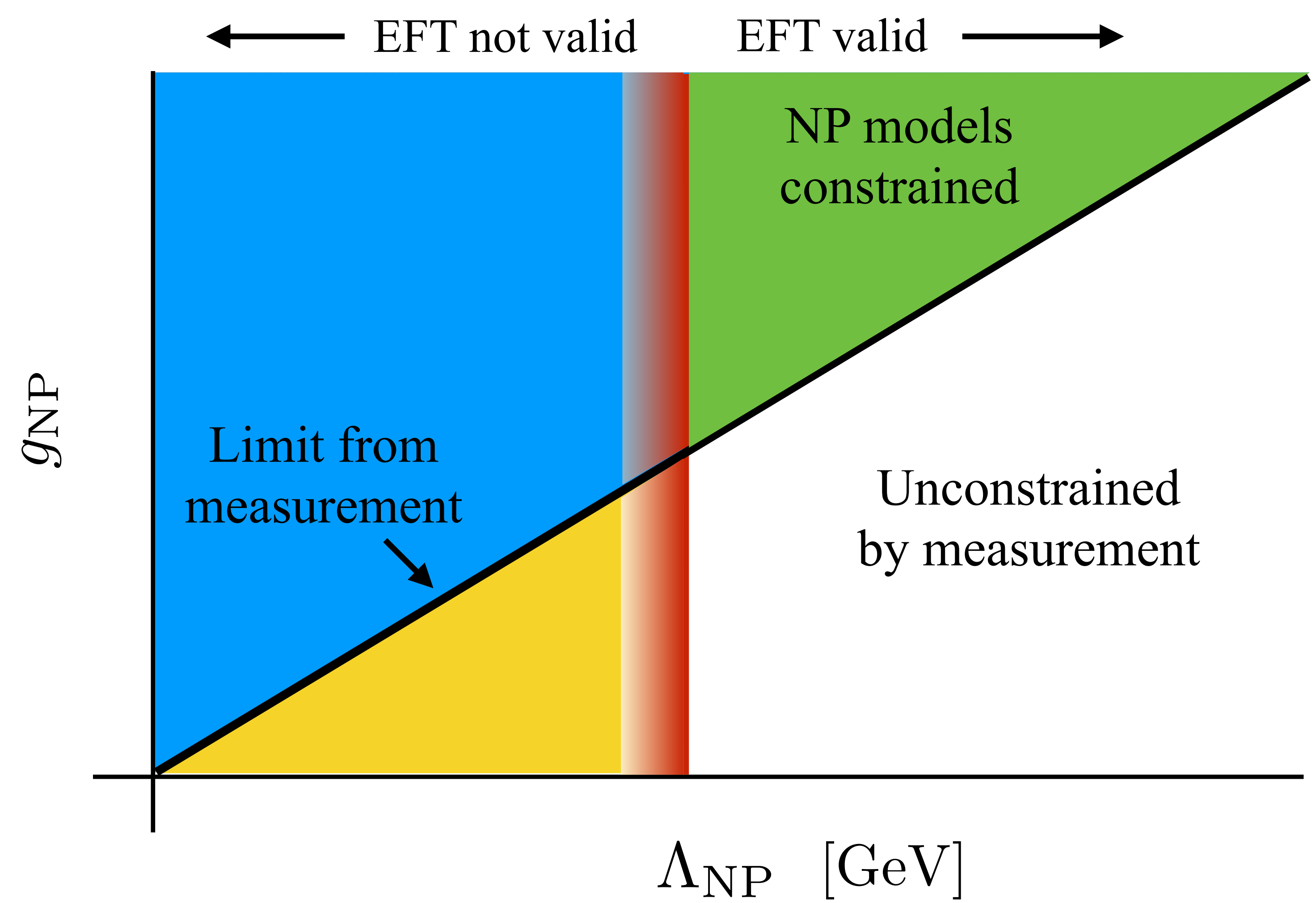
[Englert, MS '14]





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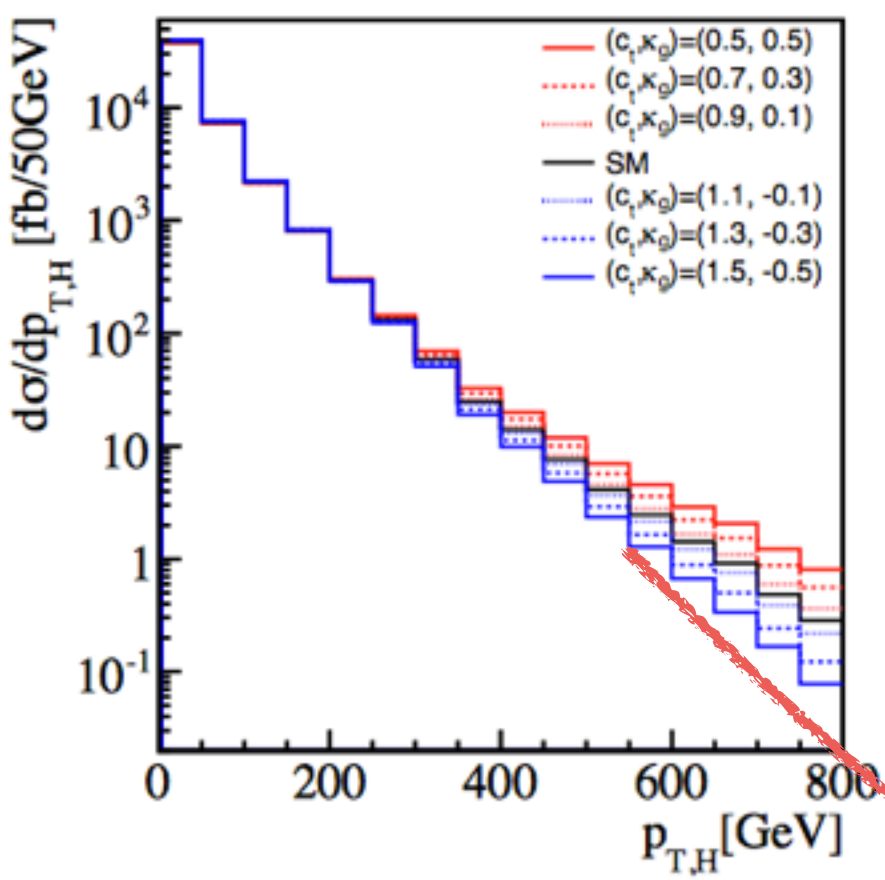

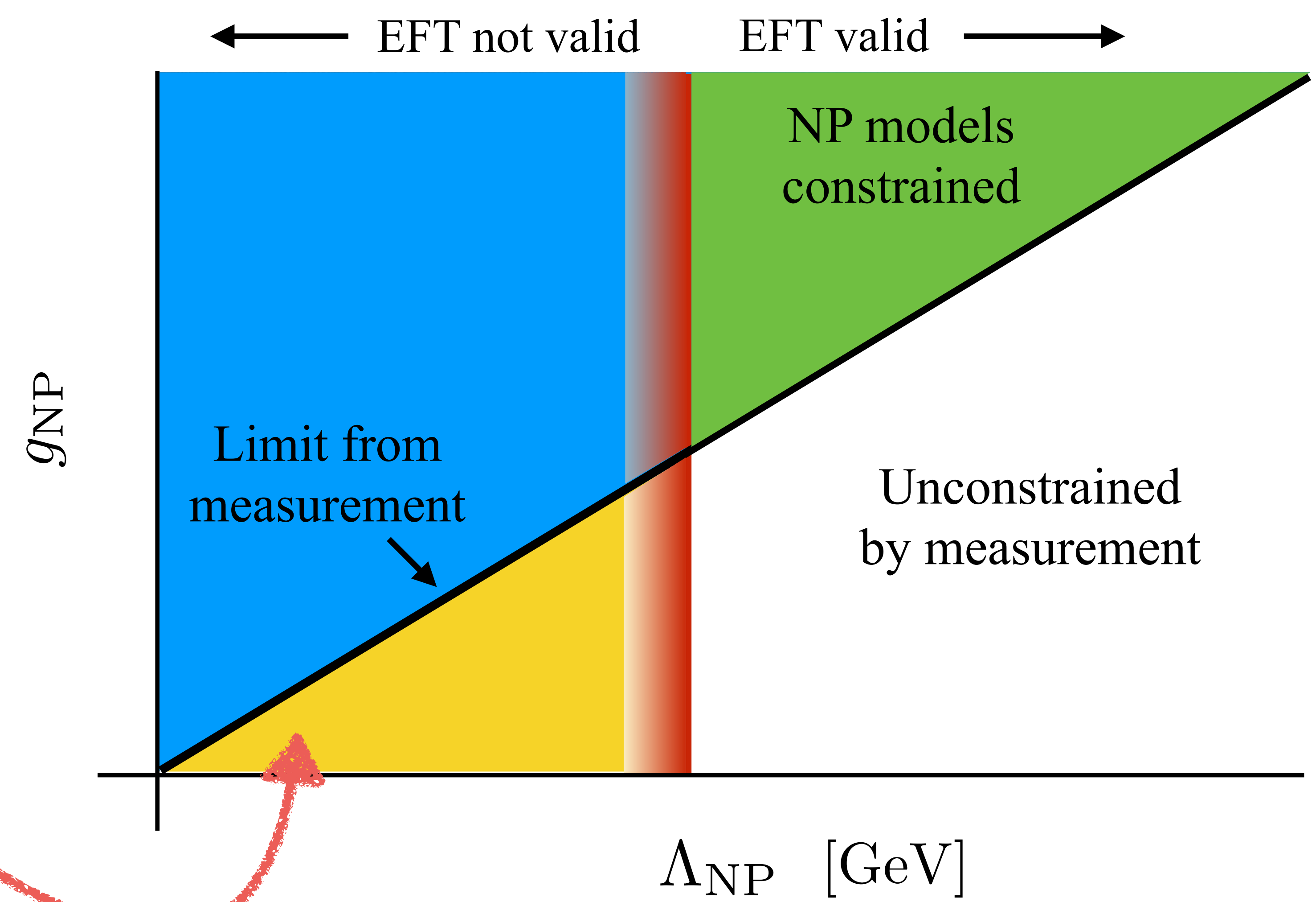

shape sets limit on Wilson coefficient (black line)

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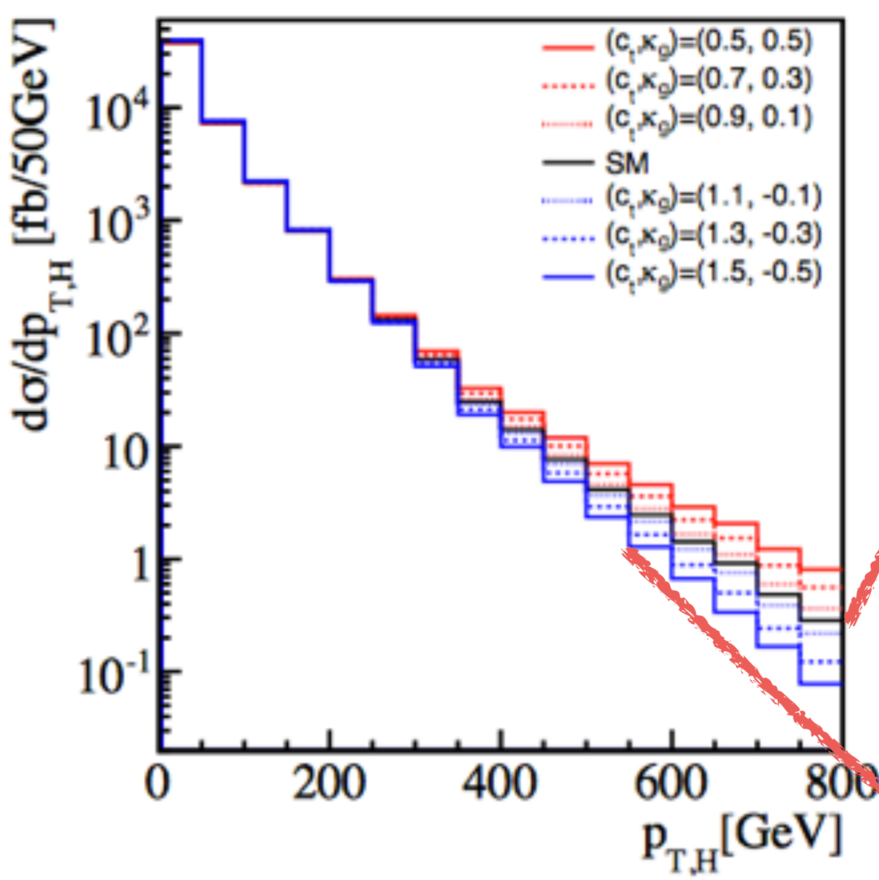
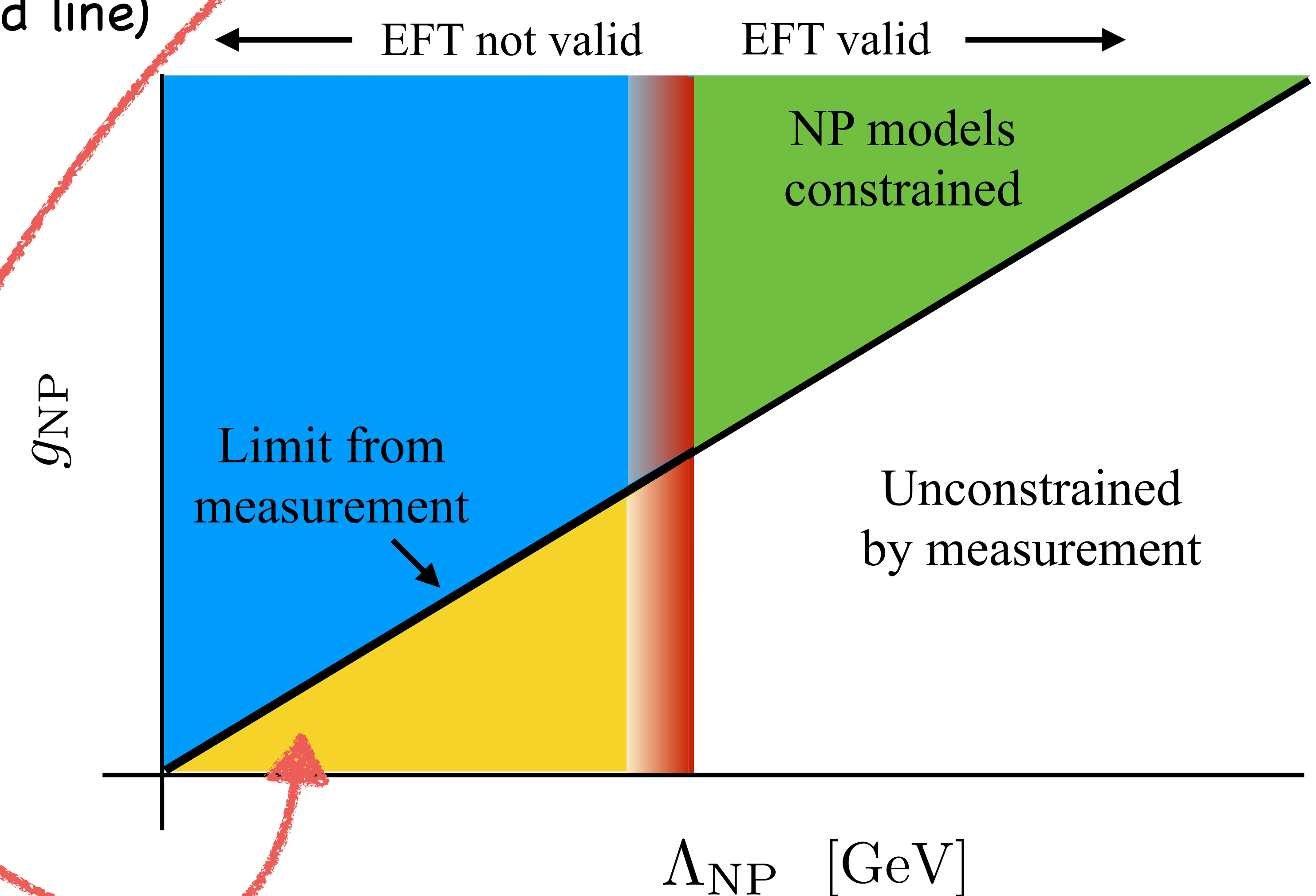
Endpoint of kinematic distribution sets lower cut-off for NP (red line)

[Englert, MS '14]





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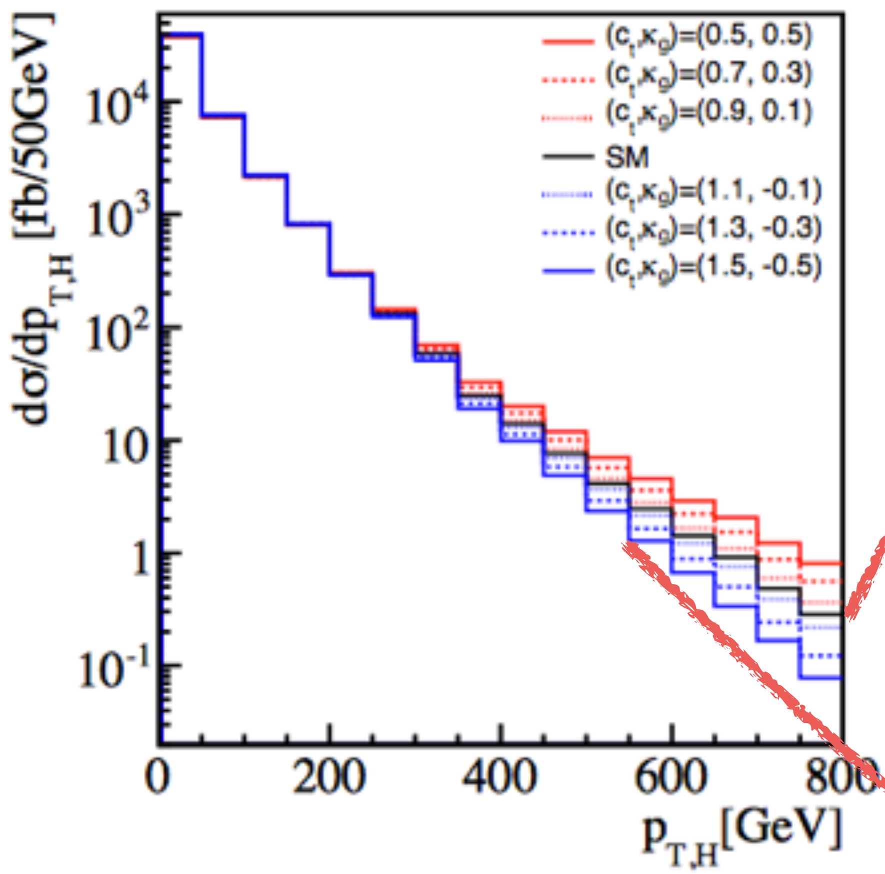
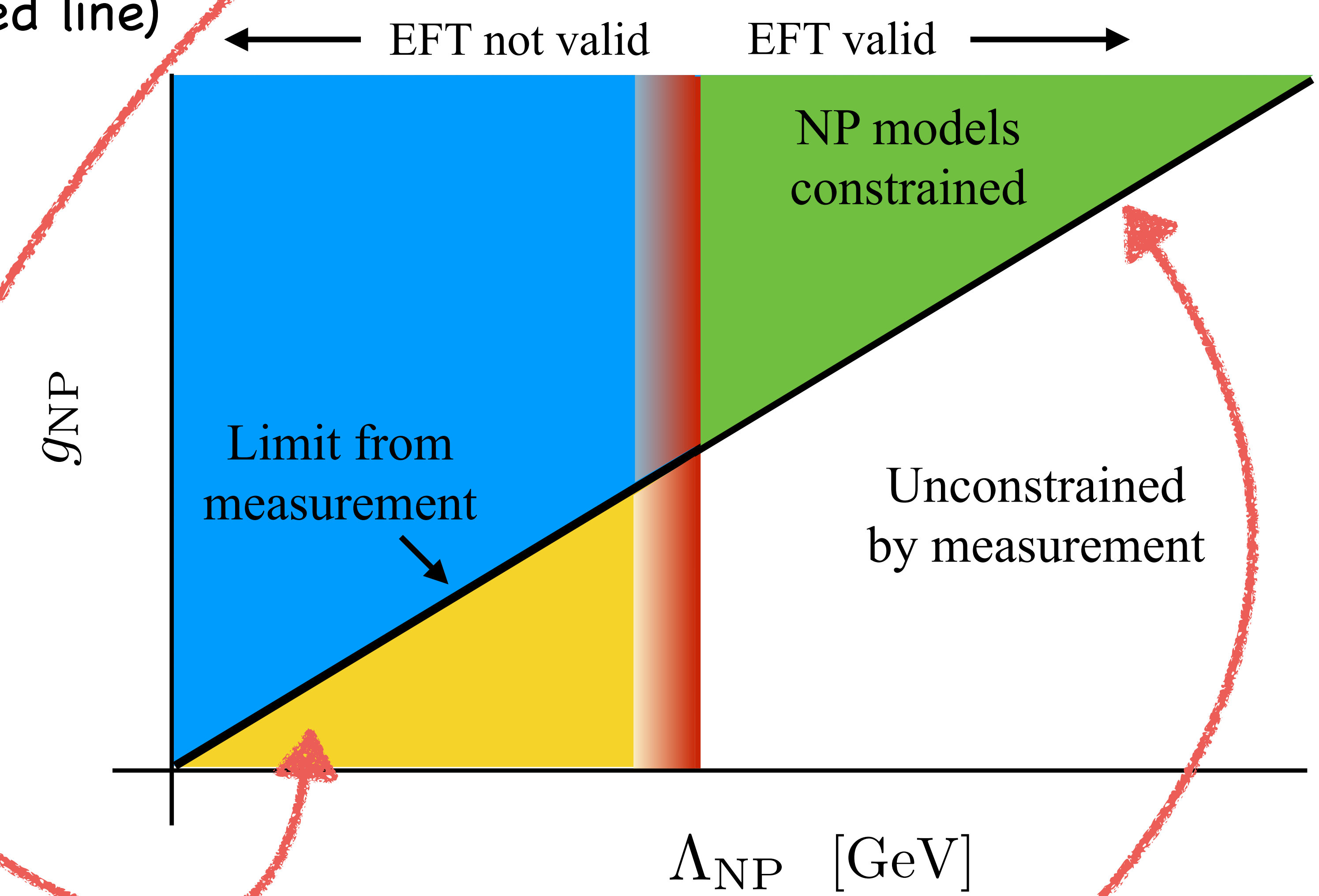
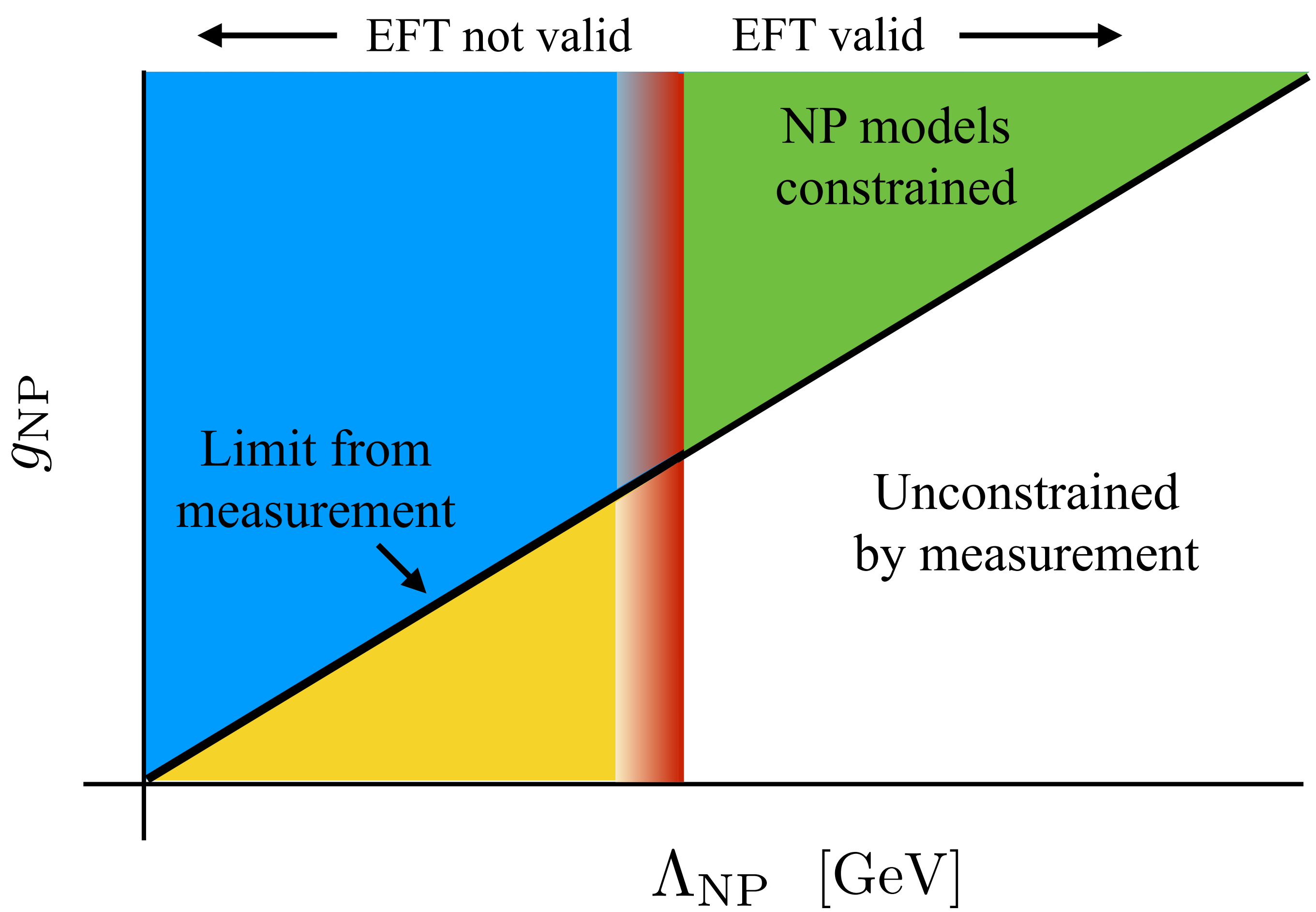




shape sets limit on Wilson coefficient (black line)

Any UV (weakly coupled) models left?

Validity and Relevance of EFT



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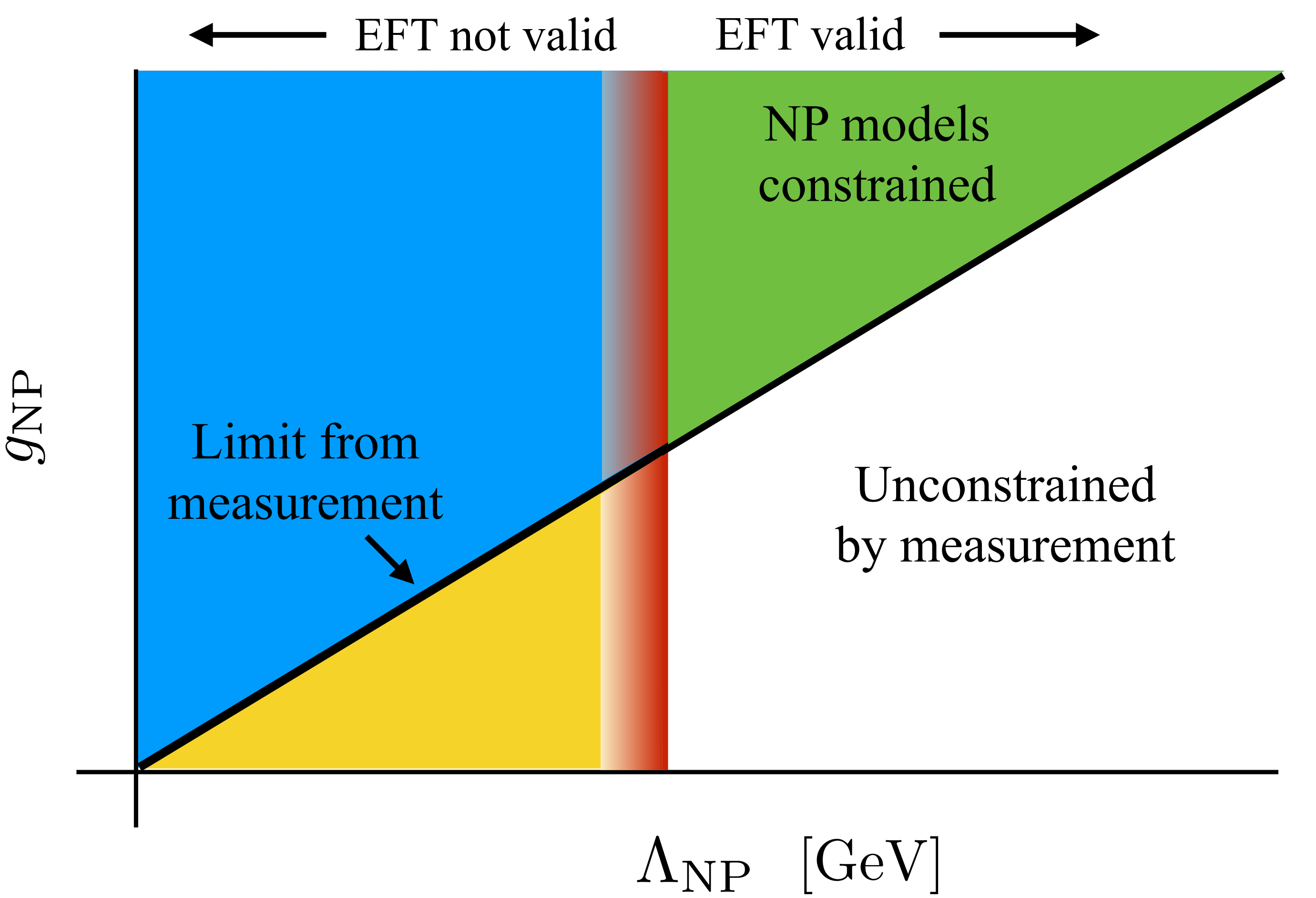
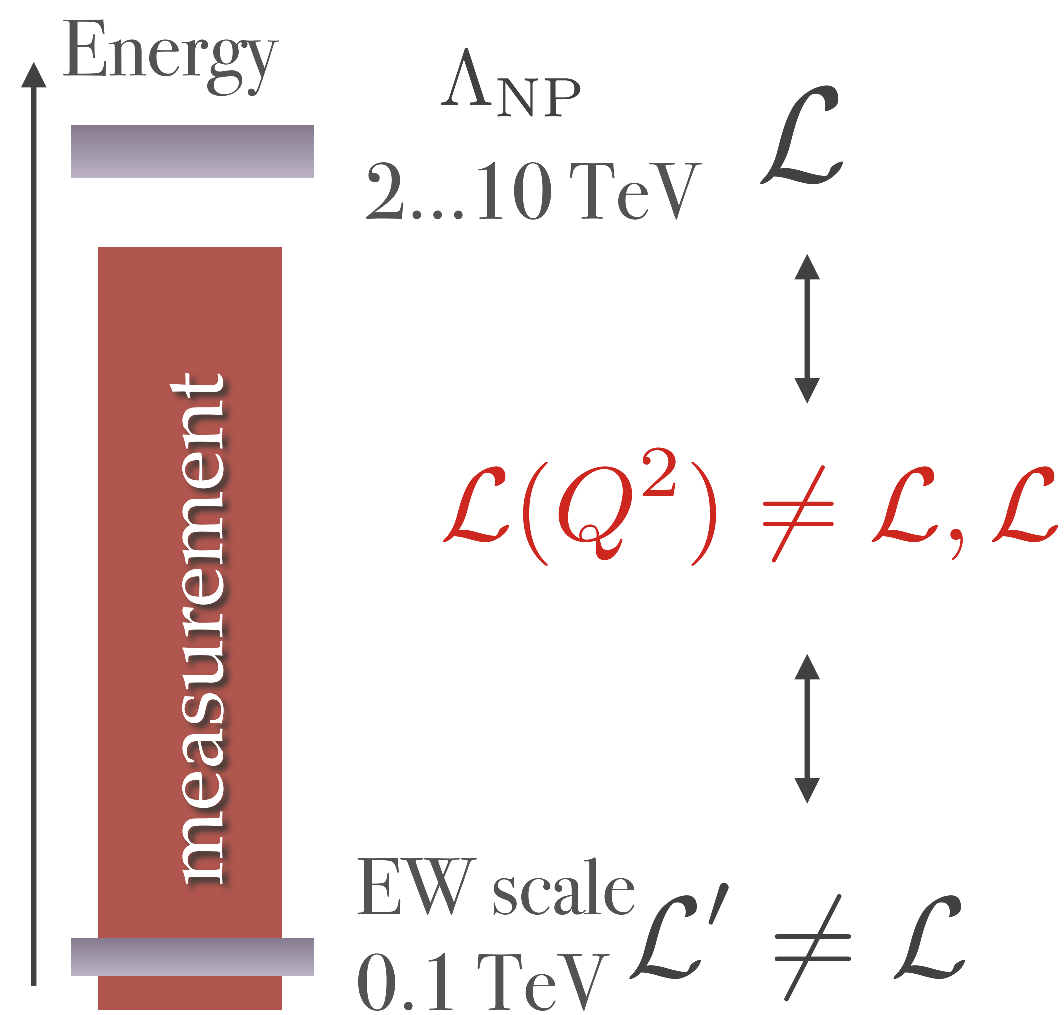


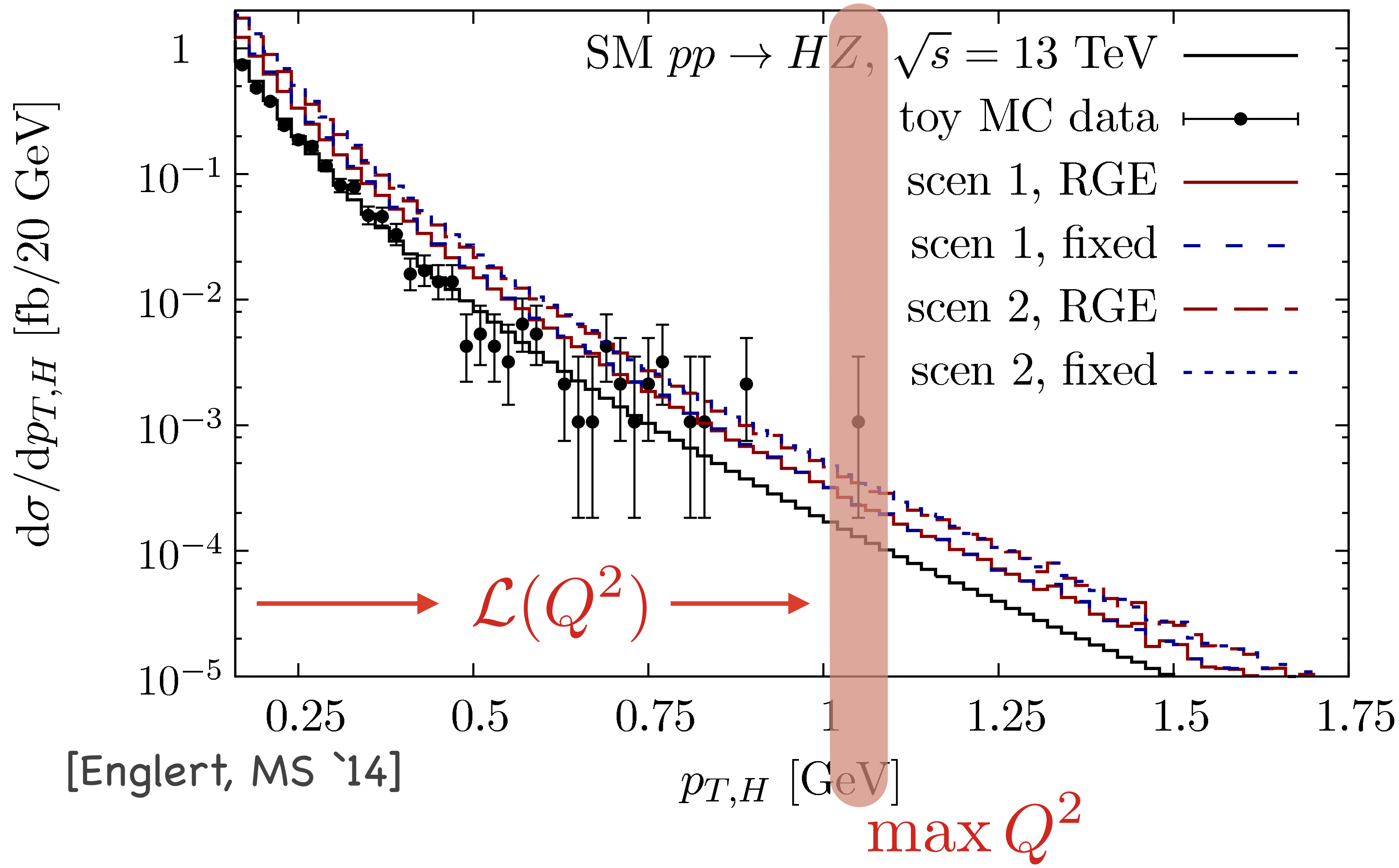


Lagrangian dim-6: $\mathcal{L} = \mathcal{L}_{\rm SM} + \sum_i \frac{g_i^2}{\Lambda_{\rm NP}^2} \mathcal{O}_i$

- scale hierarchies similar to flavor physics mW/mb~20
- evolution from renormalization group equations

  [Grojean, Jenkins, Manohar, Trott '13] [Jenkins, Manohar, Trott '13] [Elias-Miro et al '13]
- consistent interpretation requires **communication of resolved scales**

  [Isidori, Trott '13] [Englert, MS '14]



[Englert, MS `14]

$$\hat{O}_W = \frac{g^2}{2\Lambda_{\rm NP}^2} \hat{H}^\dagger \hat{H} \hat{W}^a_{\mu\nu} \hat{W}^{a\,\mu\nu}\,,$$

$$\hat{O}_B = \frac{g'^2}{2\Lambda_{\rm NP}^2} \hat{H}^\dagger \hat{H} \hat{B}_{\mu\nu} \hat{B}^{\mu\nu}\,,$$

$$\hat{O}_{WB} = \frac{gg'}{\Lambda_{\rm NP}^2} \hat{H}^\dagger t^a \hat{H} \hat{W}^a_{\mu\nu} \hat{B}^{\mu\nu}\,,$$

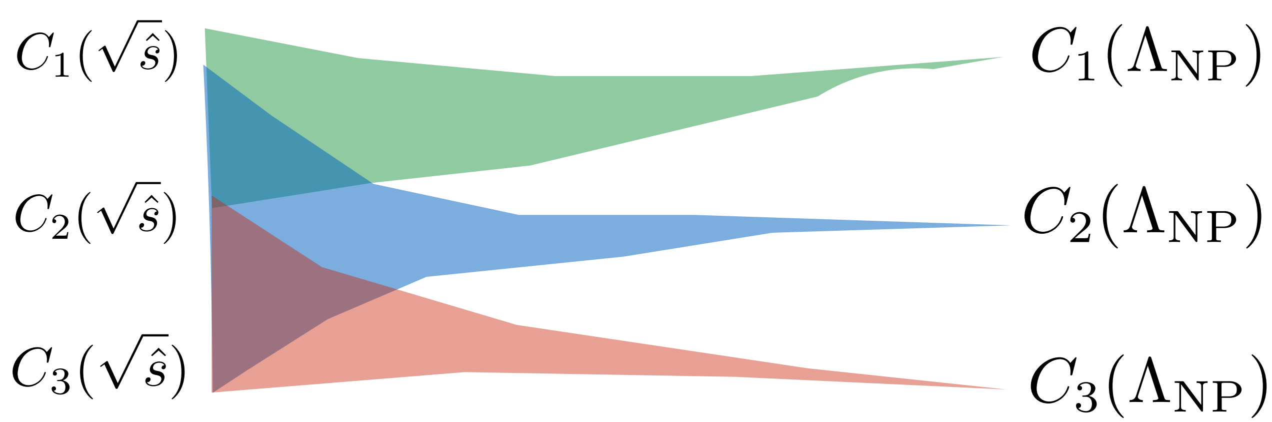
See talk by G. Passarino

In general higher-order corrections induce scale dependence and mixing of operators

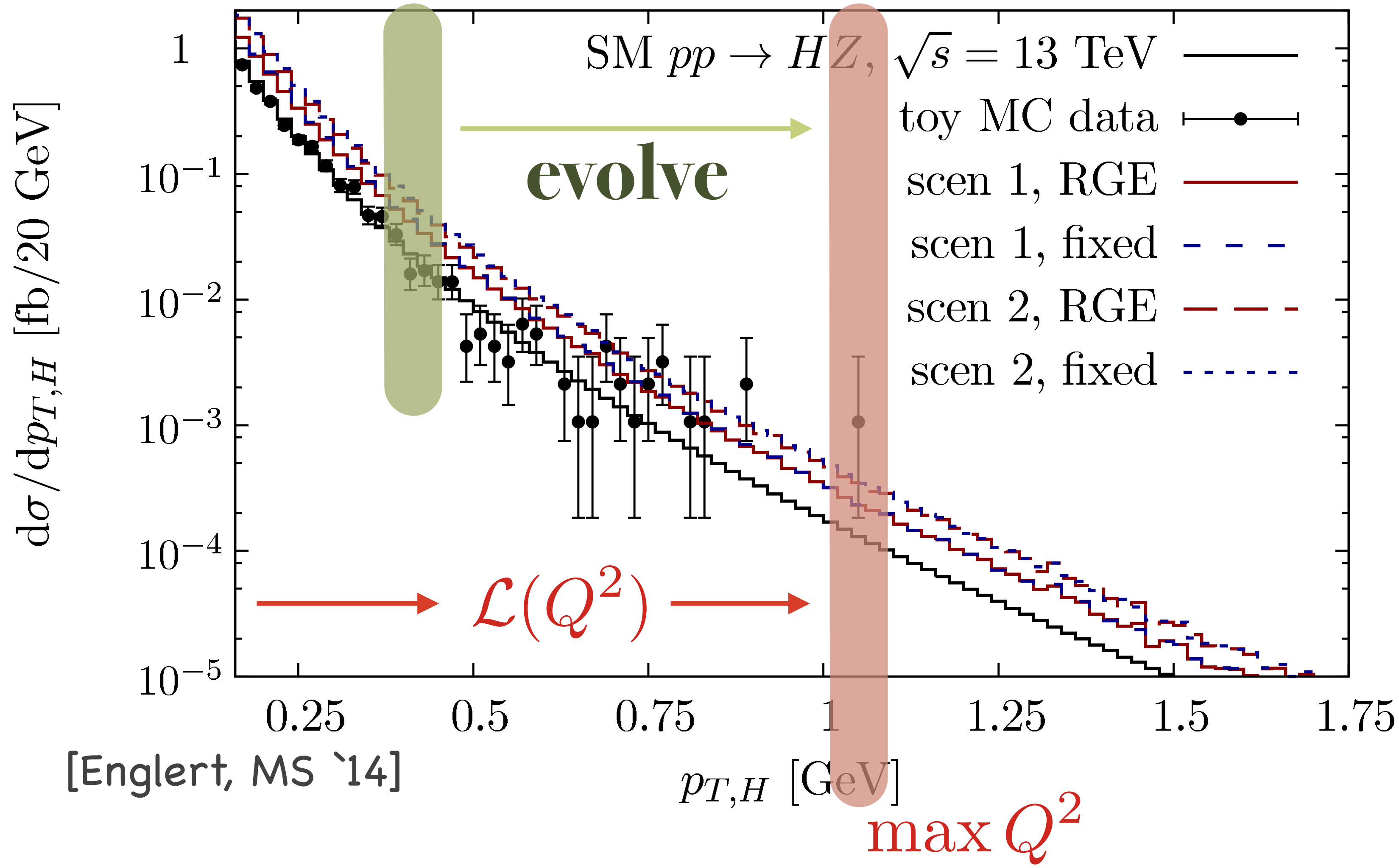
$$C_i(\sqrt{\hat{s}}) \simeq \left(\delta_{ij} + \gamma_{ij}(\sqrt{\hat{s}}) \log \frac{\sqrt{\hat{s}}}{\mu} \right) C_j(\mu)$$

As a result, each measured **event** probes a different combination of operators

measurement at characteristic scale of event



Coefficients of operators at New Physics scale



[Englert, MS `14]

$$\hat{O}_W = \frac{g^2}{2\Lambda_{\rm NP}^2} \hat{H}^\dagger \hat{H} \hat{W}^a_{\mu\nu} \hat{W}^{a\,\mu\nu} ,$$

$$\hat{O}_B = \frac{g'^2}{2\Lambda_{\rm NP}^2} \hat{H}^\dagger \hat{H} \hat{B}_{\mu\nu} \hat{B}^{\mu\nu} ,$$

$$\hat{O}_{WB} = \frac{gg'}{\Lambda_{\rm NP}^2} \hat{H}^\dagger t^a \hat{H} \hat{W}^a_{\mu\nu} \hat{B}^{\mu\nu} ,$$

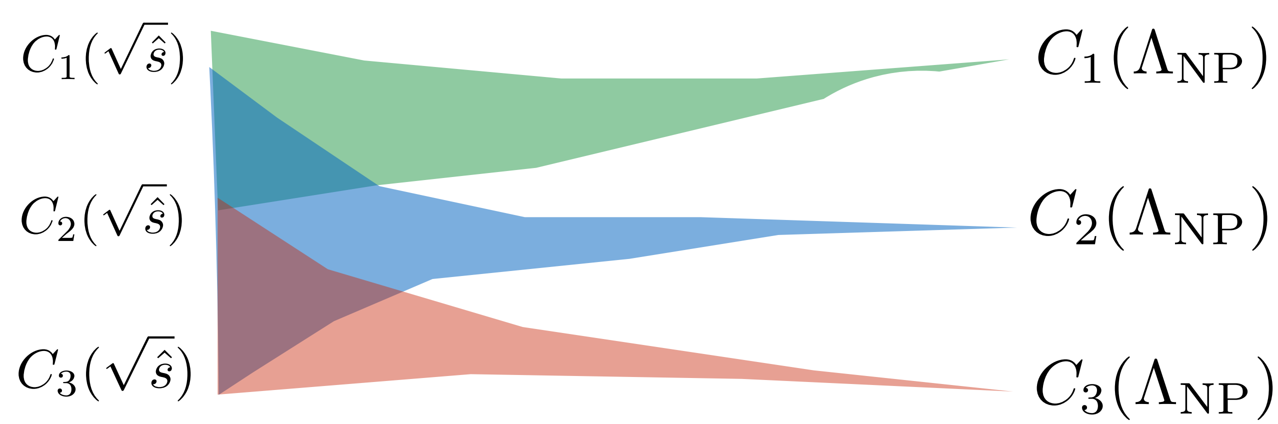
See talk by G. Passarino

In general higher-order corrections induce scale dependence and mixing of operators

$$C_i(\sqrt{\hat{s}}) \simeq \left(\delta_{ij} + \gamma_{ij}(\sqrt{\hat{s}}) \log \frac{\sqrt{\hat{s}}}{\mu} \right) C_j(\mu)$$

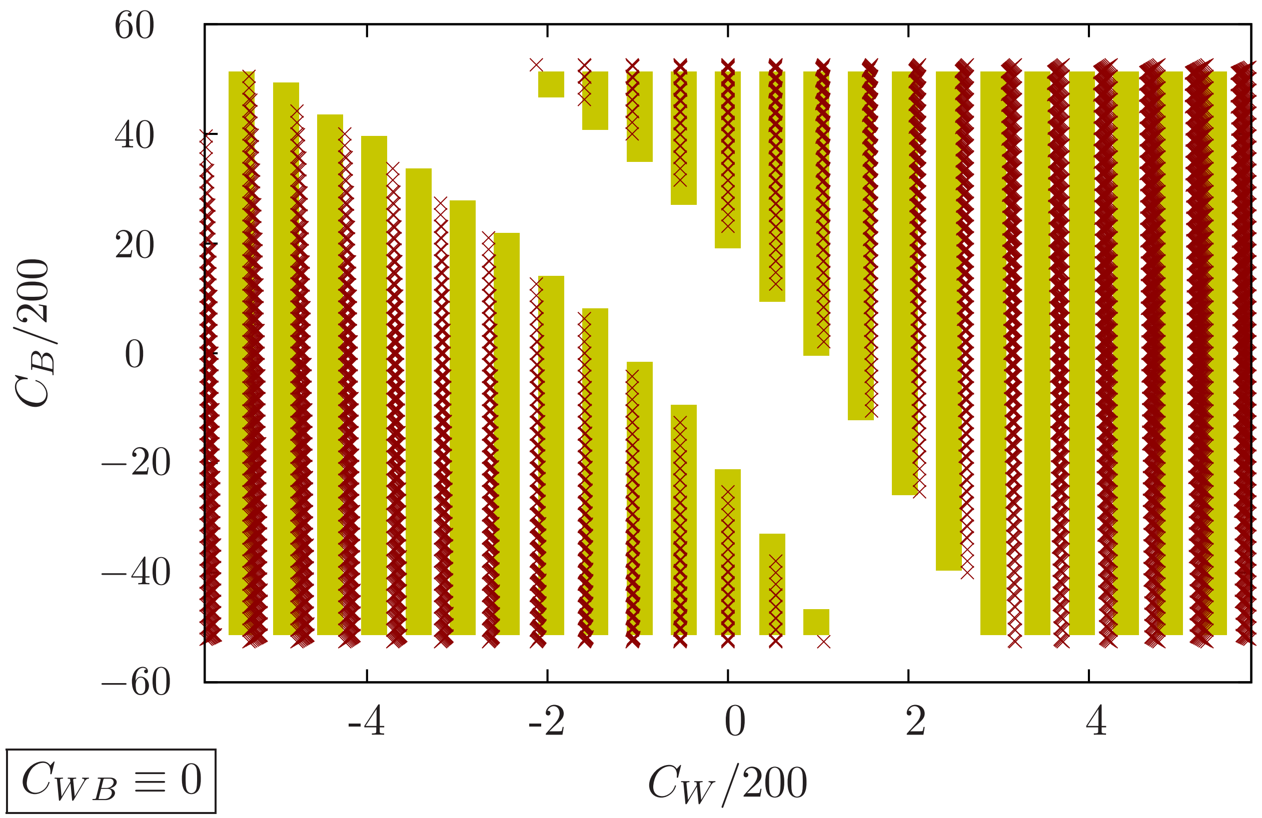
As a result, each measured **event** probes a different combination of operators

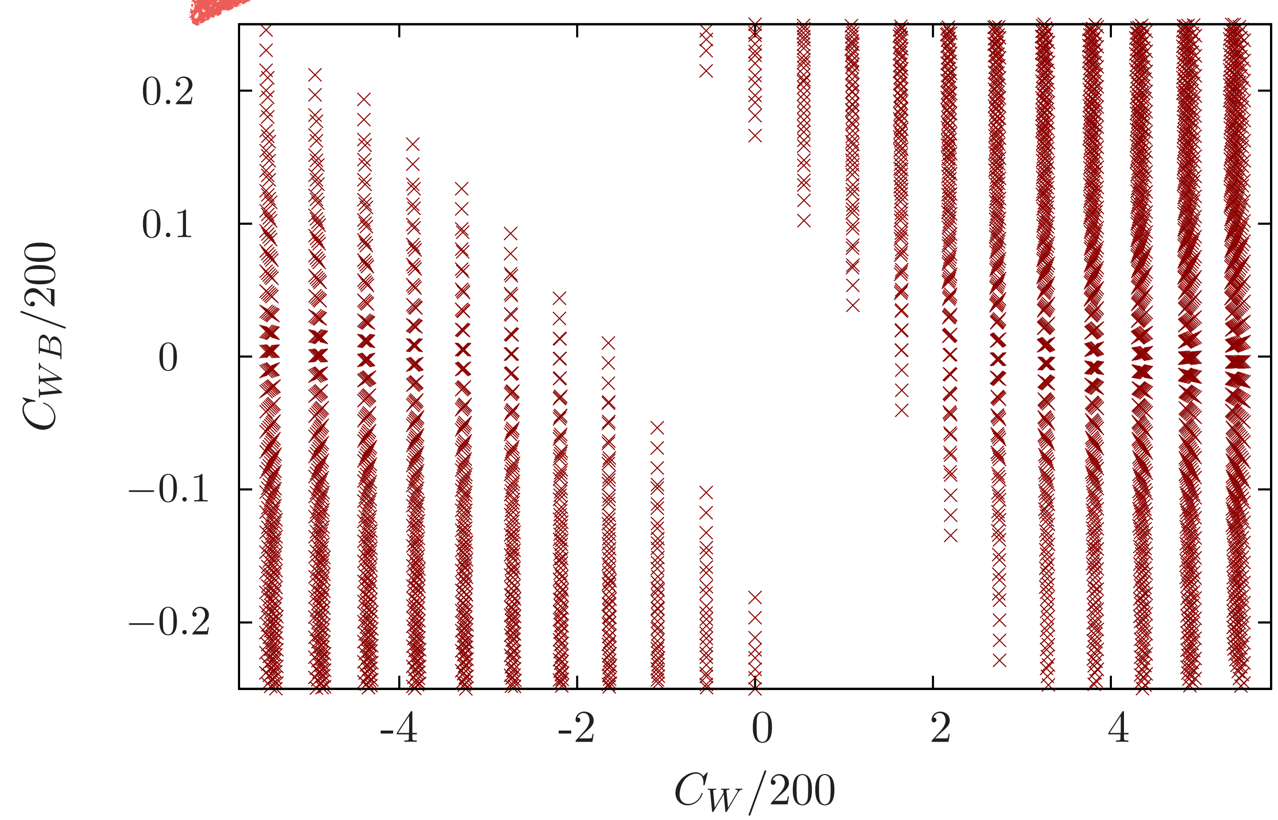
measurement at characteristic scale of event



Coefficients of operators at New Physics scale

T= C_{WB}= 0 at low scale but induced and allowed at high scale





$$\max Q^2 = 2.4\ \text{TeV} \implies \mathcal{L}^{\text{BSM}}(2.4\ \text{TeV})$$

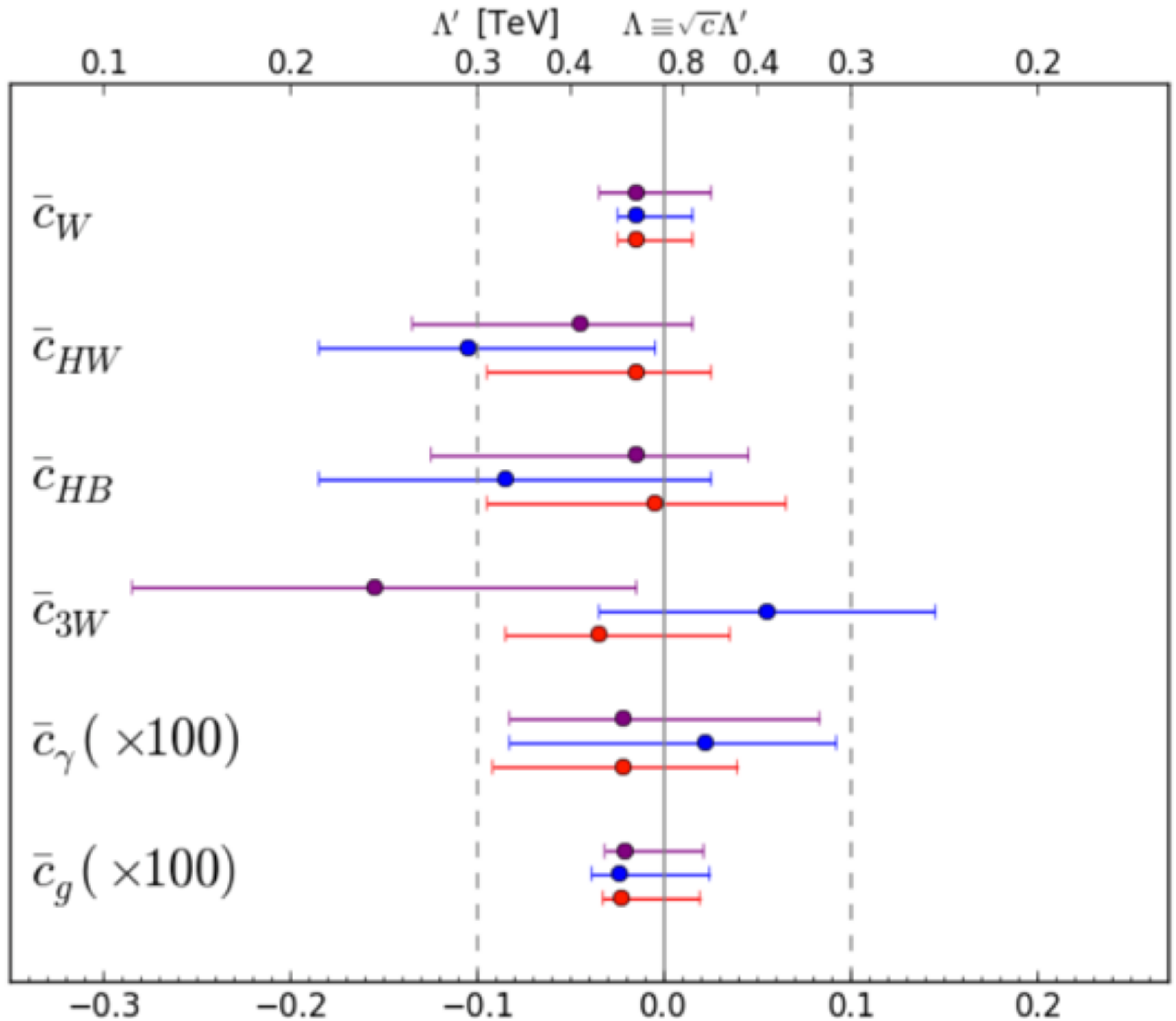
Here maxQ=14 TeV

High-dim operators often momentum dependent

Sensitivity of measurement in tail of distribution

Running less important as scale separation potentially small

EFT results from 7/8 TeV data



[Ellis, Sanz, You '14]

[Corbet, et al. '15]

New physics scale for some of the limits low
EFT could be invalidated

Simplified Models

Choose custodial symmetry as guiding principle for extensions (Practicality):

$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = 1$ indicates that an approximate global symmetry exits, broken by the vev to the diagonal 'custodial' symmetry group $SU(2)_L \times SU(2)_R \to SU(2)_{L+R}$

Thus the Higgs field transforms $SU(2)_L \times SU(2)_R$: $\Phi \to L\Phi R^\dagger$

A. Singlet extension (Higgs portals):

$$\mathcal{V} \supset \eta_\chi |\phi_s|^2 |\phi_h|^2 \quad \longrightarrow \quad (2,2)\otimes(1,1) \simeq 3 \oplus 1 \oplus 1$$

new scalar

observed Higgs 125 GeV

eaten would-be Goldstones

B. Higgs doublet extension:

$$\Phi = \begin{pmatrix} \phi_2^* & \phi_1 \\ -\phi_1^* & \phi_2 \end{pmatrix} \quad U_L \quad U_R^\dagger \quad \longrightarrow \quad (2,2)\otimes(2,2) \simeq 3 \oplus 3 \oplus 1 \oplus 1$$

observed Higgs 125 GeV

H^+ and A

H

C. Higgs triplet extension:

$$\Xi = \begin{pmatrix} \chi_3^* & \xi_1 & \chi_1 \\ -\chi_2^* & \xi_2 & \chi_2 \\ \chi_1^* & -\xi_1^* & \chi_3 \end{pmatrix} \quad U_L \quad U_R^\dagger \quad \longrightarrow \quad (3,3)\otimes(2,2) \simeq 5 \oplus 3 \oplus 3 \oplus 1 \oplus 1$$

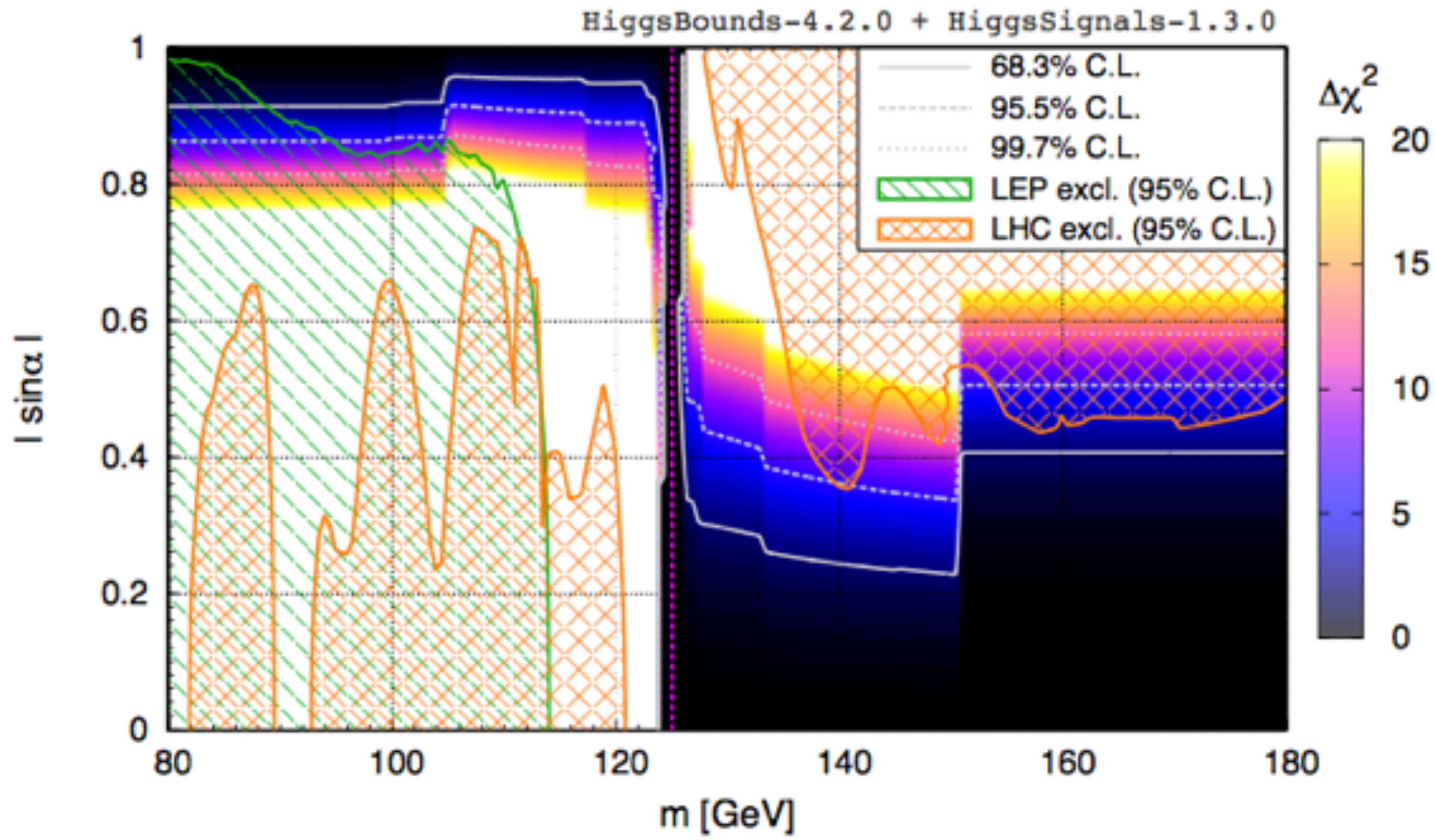
gaugephobic

fermiophobic

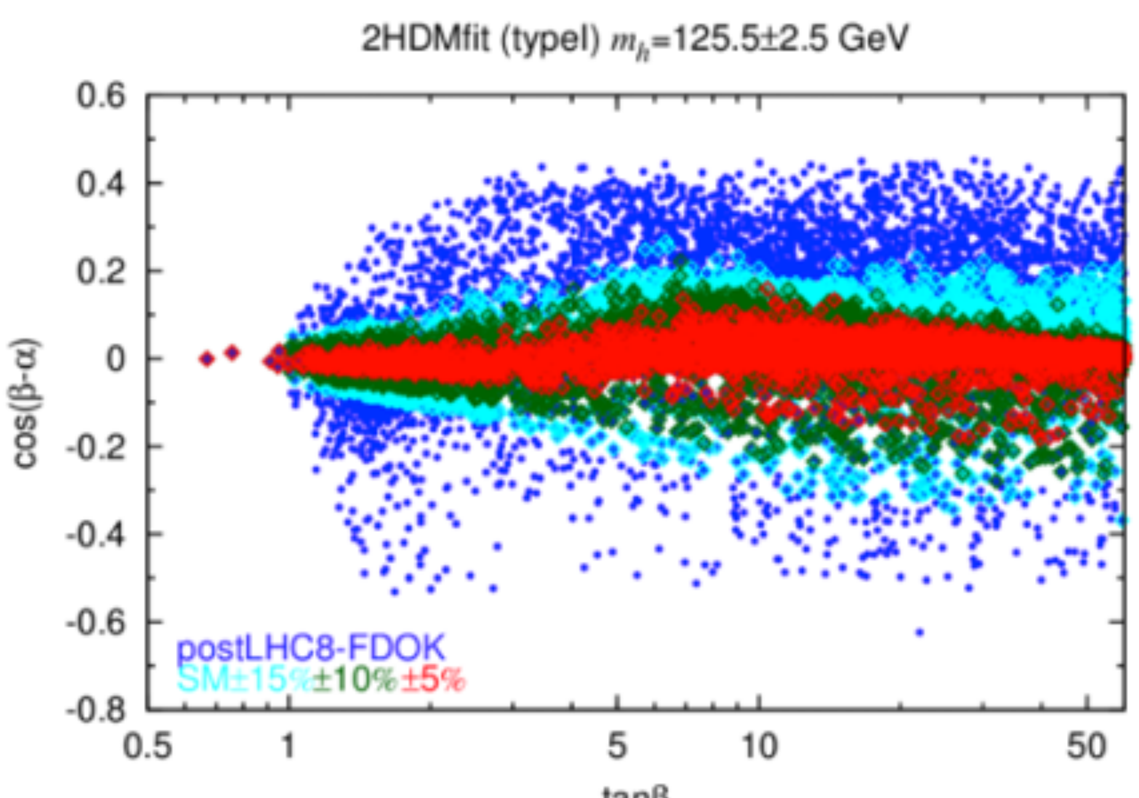
$H^{\pm\pm}$

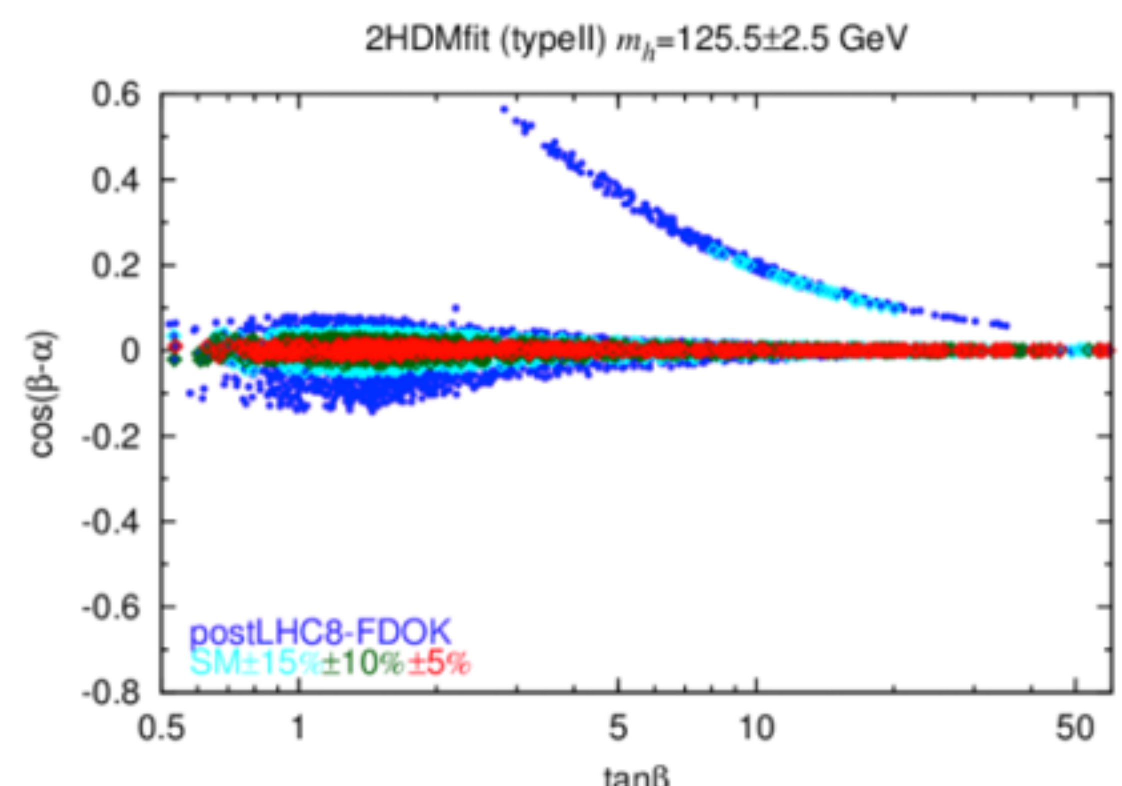
[Georgi, Machacek '85]

Singlet extension: [Robens, Stefaniak '15]



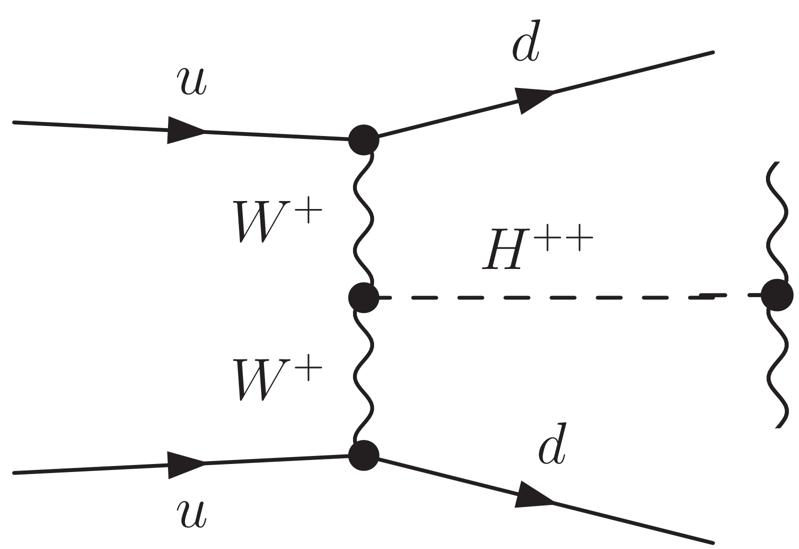
Doublet extension: [Dumont, Gunion, Jiang, Kraml '14]

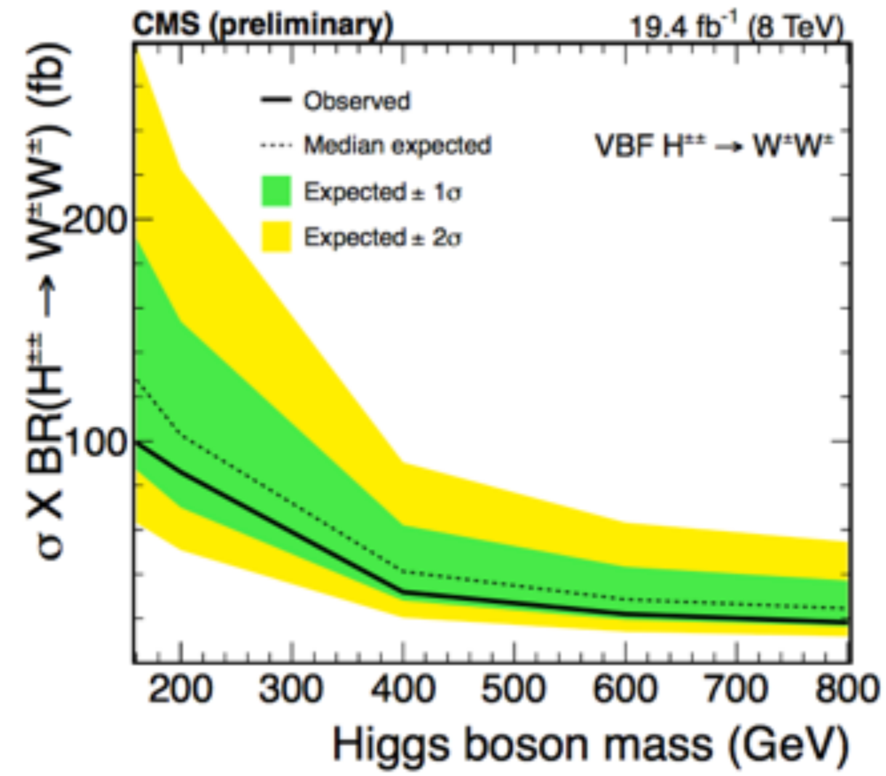




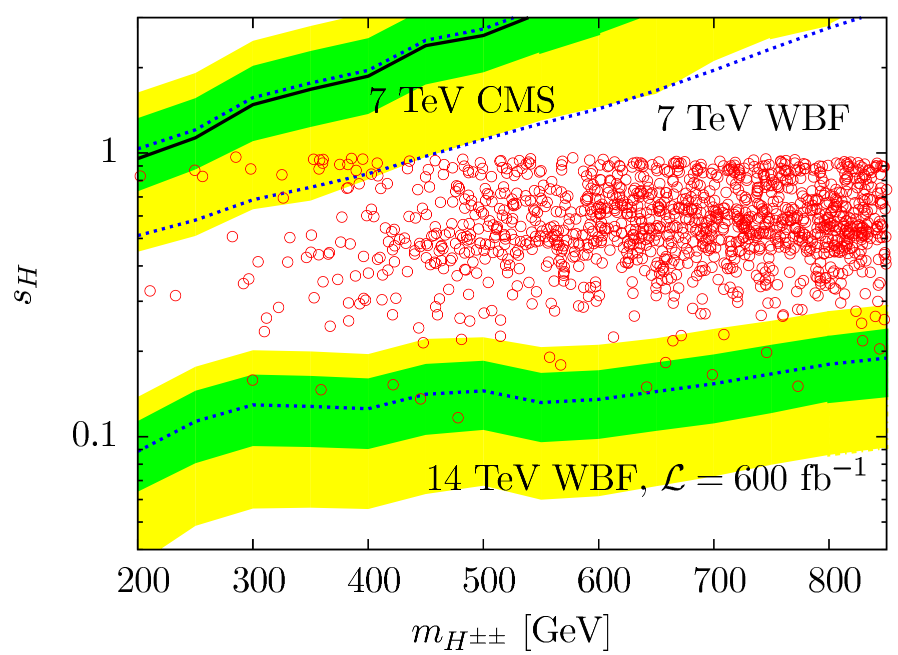
Triplet extension

[CMS-PAS-SMP-13-015]

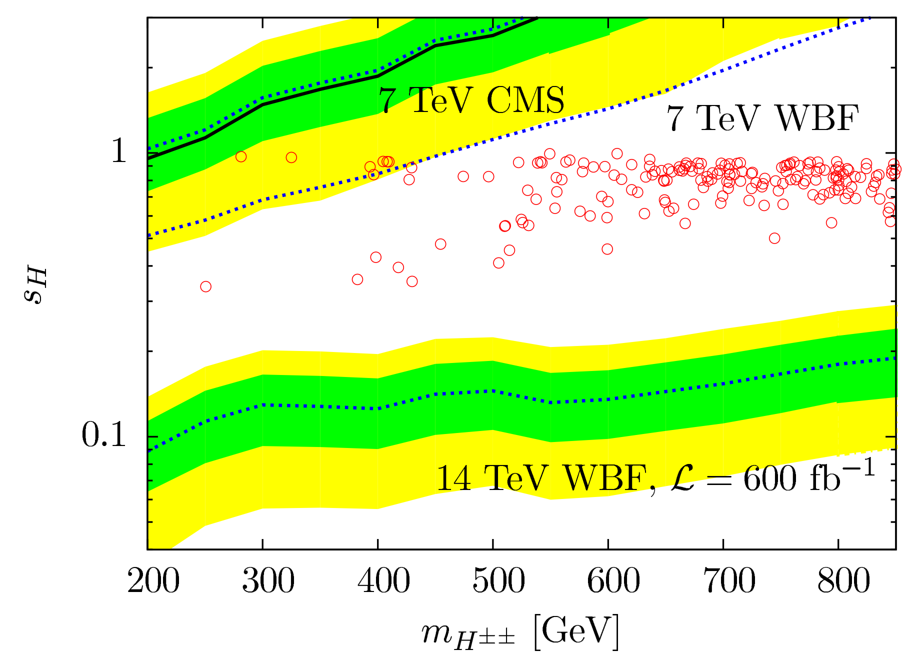




Georgi-Machacek doubly charged Higgs can be entirely excluded at LHC



(a) Higgs to diphoton branching ratio enhanced: $1.3 \leq \xi_{H\to\gamma\gamma} \leq 2.3$



(b) Higgs to diphoton branching ratio SM-like: $0.8 \leq \xi_{H\to\gamma\gamma} \leq 1.2$

[Englert, Re, MS '13]

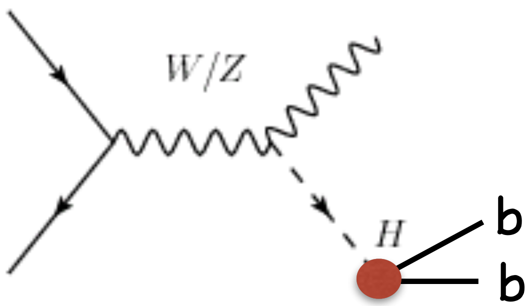
Finally

ATLAS EXPERIMENT and CMS

are taking data at unprecedented energies

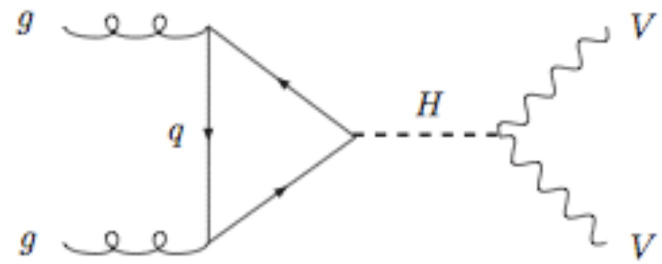
Energetic final states not only important for effective couplings

Higgs-bottom coupling



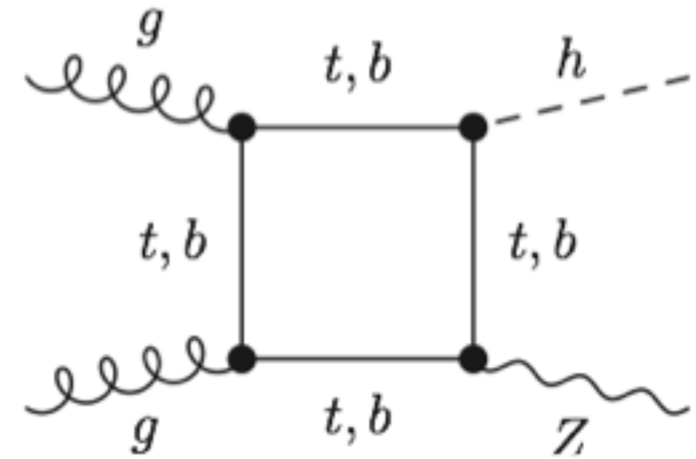
[Butterworth, Davison, Rubin, Salam '08]

Off-shell Higgs (Width)



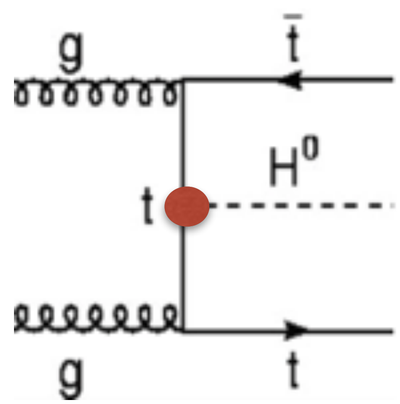
[Kauer, Passarino '12]
[Caola, Melnikov '14]

HZ final state



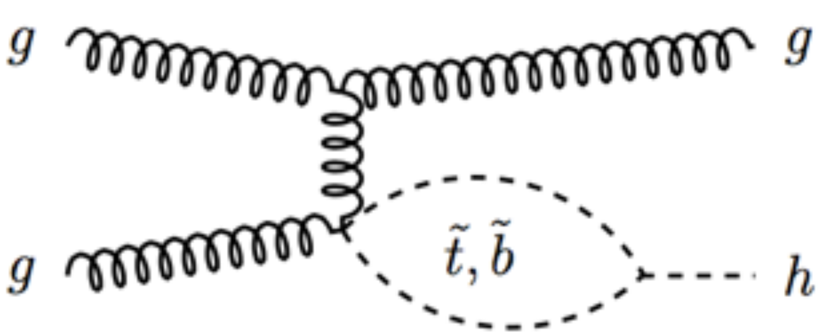
[Englert, McCullough, MS '13]

Higgs-top coupling



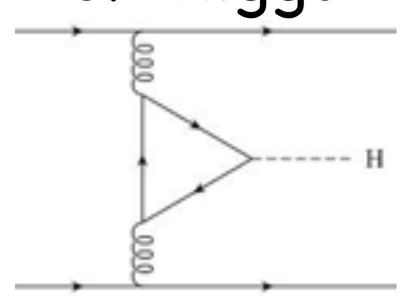
[Plehn, Salam, MS '09]

Boosted Higgs in H+jet



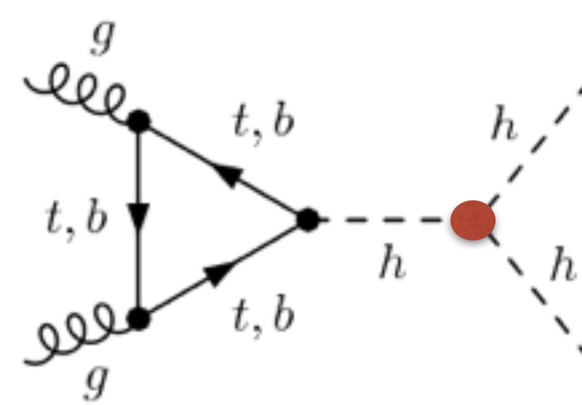
[Harlander, Neumann '13]
[Banfi, Martin, Sanz '13]
[Grojean, Salvioni, Schlaffer Weiler '14]

CP Higgs



[Plehn, Rainwater, Zeppenfeld '01]
[Klamke, Zeppenfeld '07]

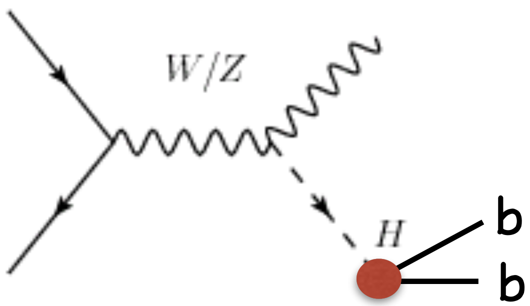
Higgs selfcoupling



[Baur, Plehn, Rainwater '02 '03]
[Dolan, Englert, MS '12 '12]
[Baglio et al '13]

Energetic final states not only important for effective couplings

Higgs-bottom coupling



[Butterworth, Davison, Rubin, Salam '08]

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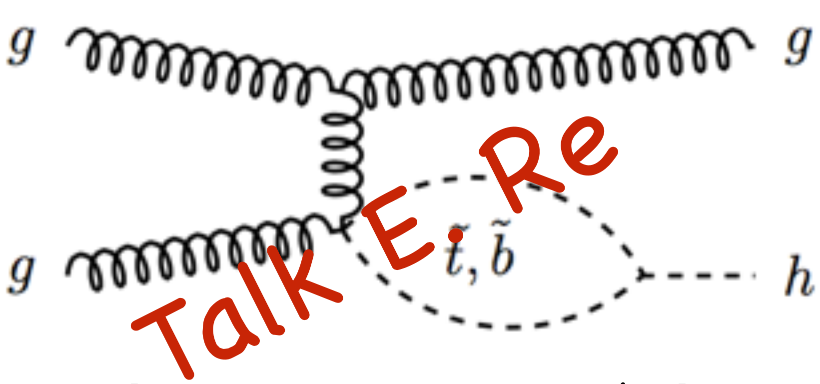

[Harlander, Neumann '13]

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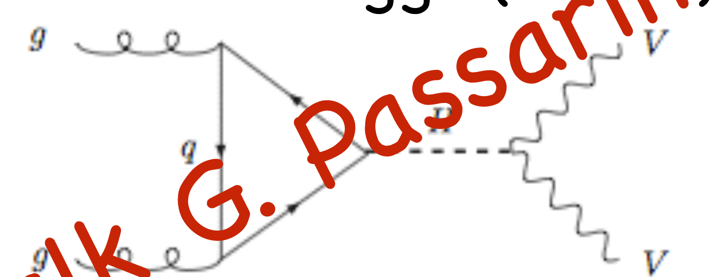
Off-shell Higgs (Width)

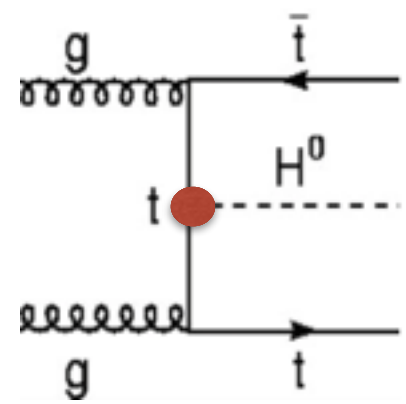
Talk G. Passarino



[Kauer, Passarino '12]

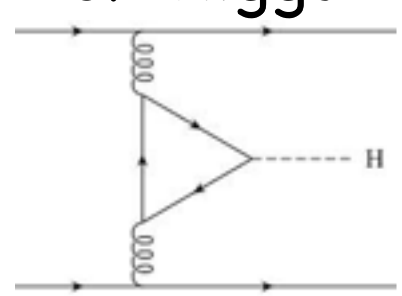
[Caola, Melnikov '14]

Higgs-top coupling



[Plehn, Salam, MS '09]

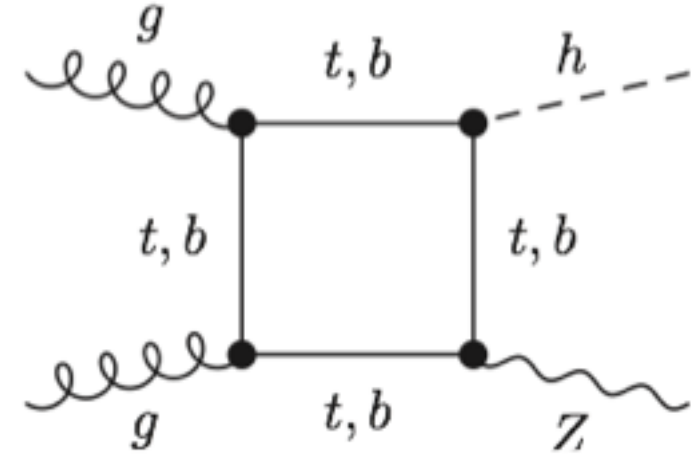
CP Higgs



[Plehn, Rainwater, Zeppenfeld '01]

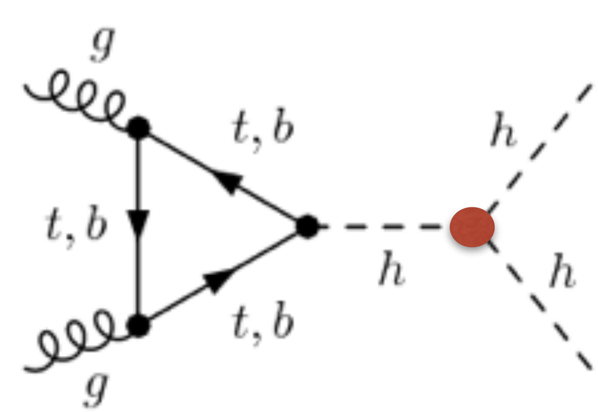
[Klamke, Zeppenfeld '07]

HZ final state



[Englert, McCullough, MS '13]

Higgs selfcoupling



[Baur, Plehn, Rainwater '02 '03]

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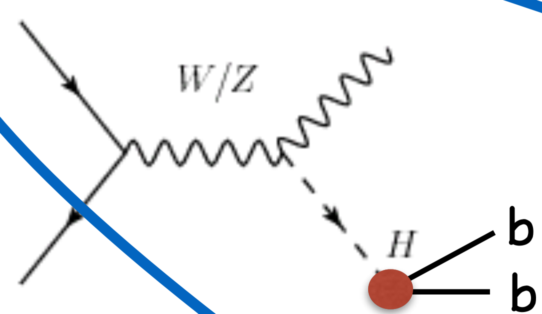
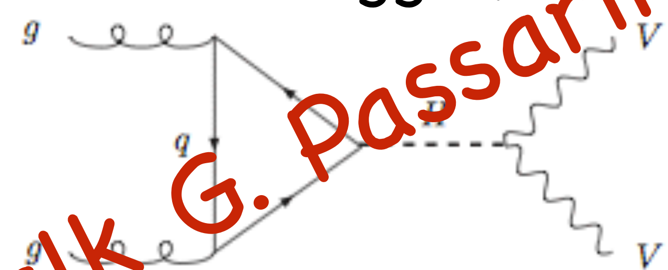


[Butterworth, Davison, Rubin, Salam '08]

Off-shell Higgs (Width)

Talk G. Passarino



[Kauer, Passarino '12]
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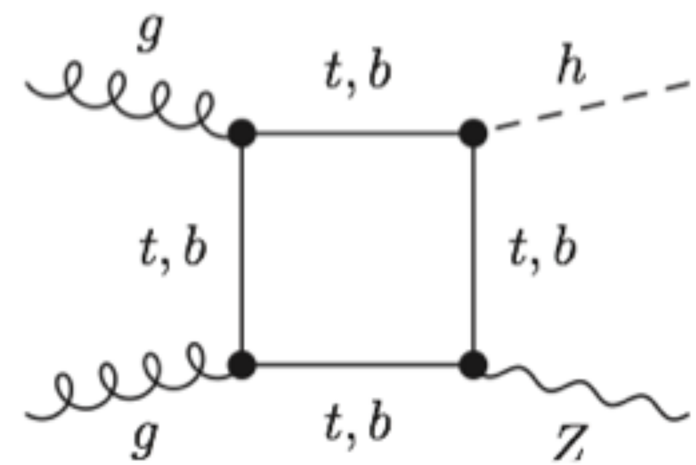
HZ final state



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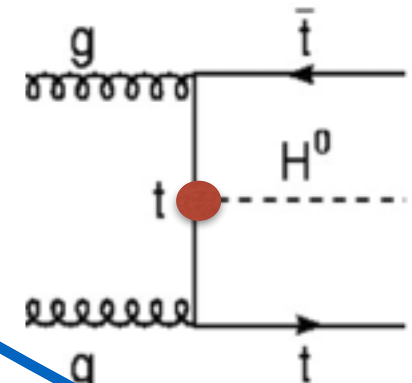
Higgs-top coupling



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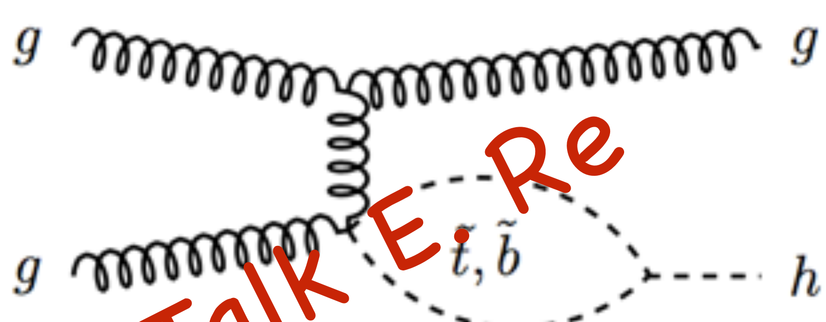
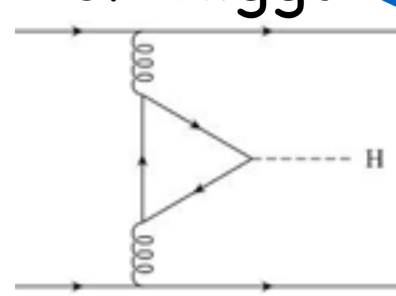
Boosted Higgs in H+jet



Talk E. Re

[Harlander, Neumann '13]
[Banfi, Martin, Sanz '13]
[Grojean, Salvioni, Schlaffer Weiler '14]

CP Higgs



[Plehn, Rainwater, Zeppenfeld '01]
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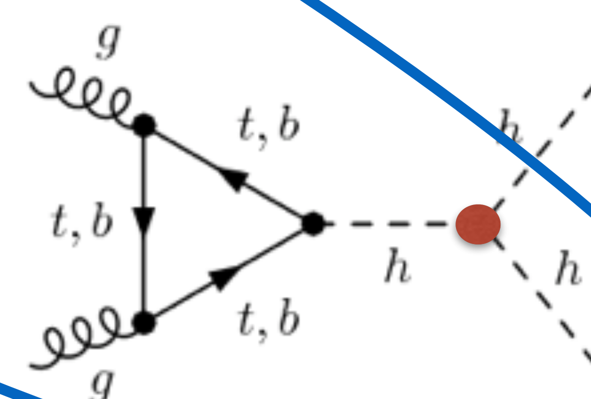
Higgs selfcoupling



[Baur, Plehn, Rainwater '02 '03]
[Dolan, Englert, MS '12 '12]
[Baglio et al '13]

Measuring Hbb at LHC

Decay into spec. channel

Production

$$\sigma \cdot BR \propto g_p^2 \frac{g_d^2}{\Gamma_H}$$

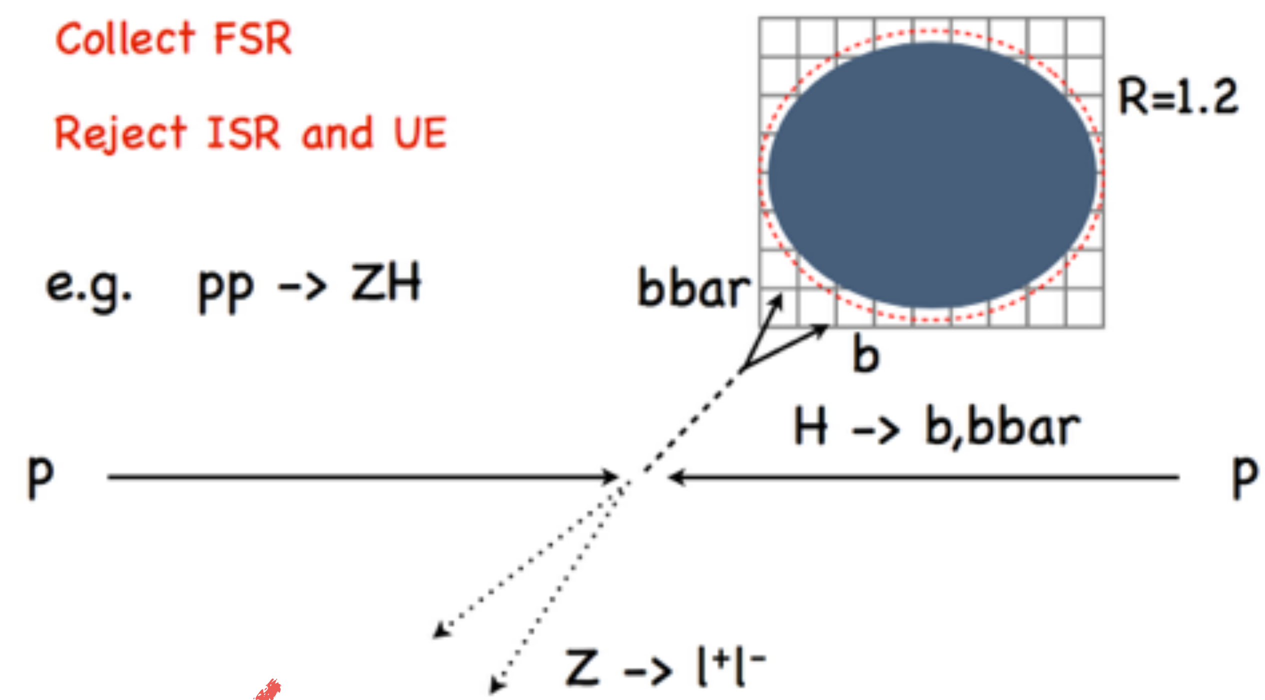
Sum of all possible decays

[Butterworth, Davison, Rubin, Salam '09]

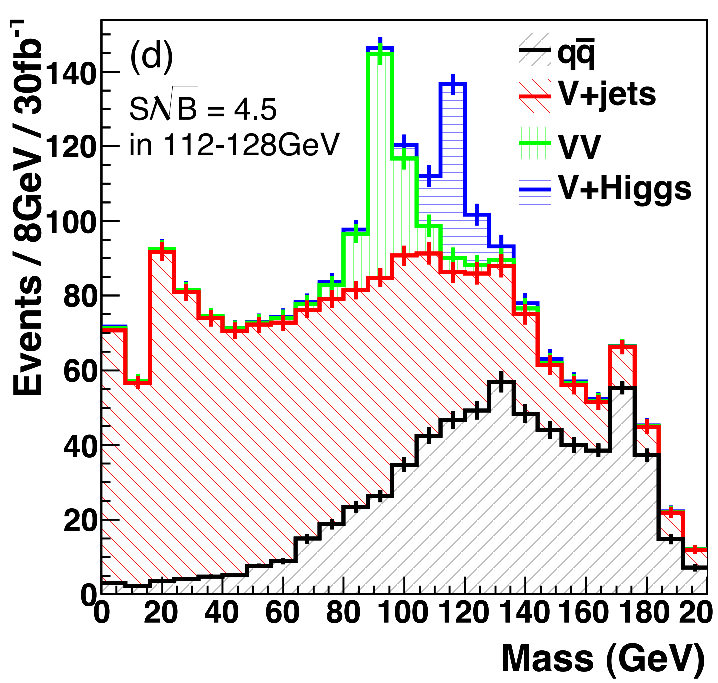
hbb measurement in HV possible

Collect FSR

Reject ISR and UE



Uncertainty of ALL coupling measurements driven by total width, i.e. H-> bb



Δ_{bbH}

Some improvements possible [Soper, MS '10 '11]

Measuring the Higgs-top coupling

Motivation:
- Direct access to top and bottom Yukawa
  -> is Higgs potential stable?
- Potential window to New Physics
- Part of global coupling fit

Possible channels:
- H->bb
- H->gamma gamma
- H->tau tau / WW

$\otimes$ hadronic, semileptonic, di-leptonic tops

Striking signatures, e.g. same-sign leptons

Already now can recast SUSY searches and set limit

$\mu < 3.8$ [Craig et al '13] [Curtin et al '13]

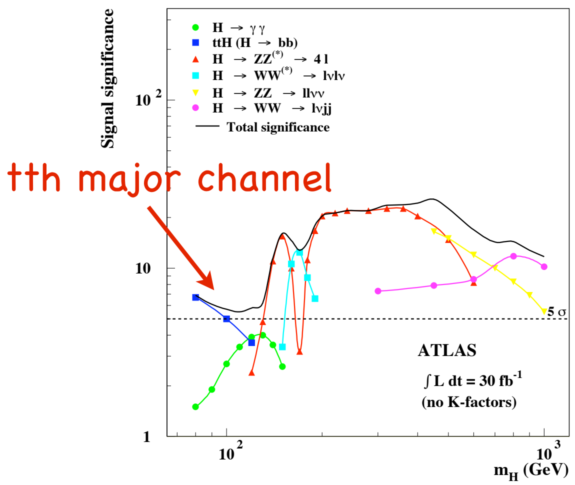
See talk by O. Nackenhorst

Strongest limit currently observed H->bb: $\mu < 3.4$ [ATLAS]

Still, channel systematics limited! S/B small after selection O(0.1)

semileptonic tops in H->bb:

High expectations:



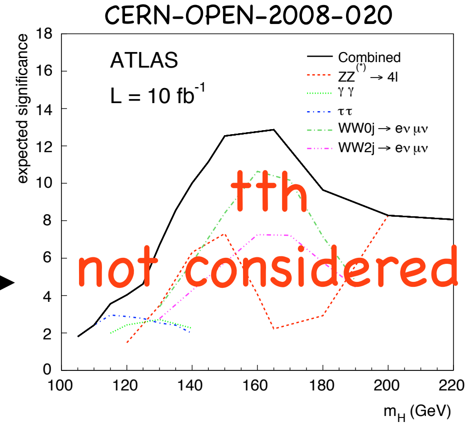
[ATLAS TDR 1999]

Cammin and Schumacher (ATLAS)

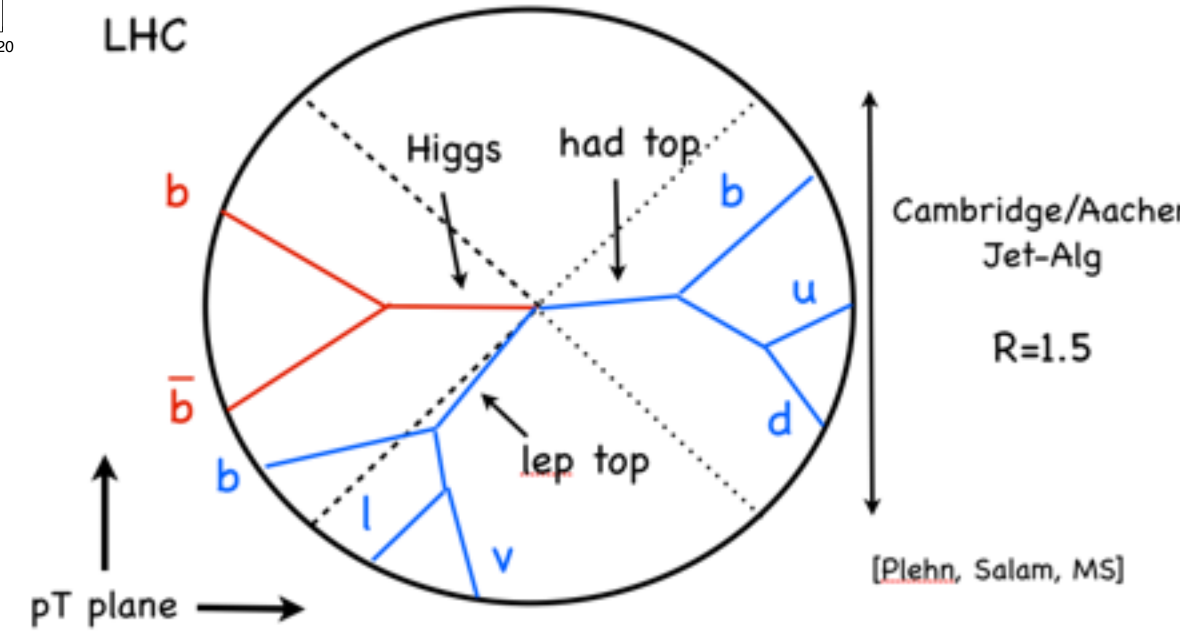
$S/B \simeq 1/9$

$S/\sqrt{B} \simeq 2.2$

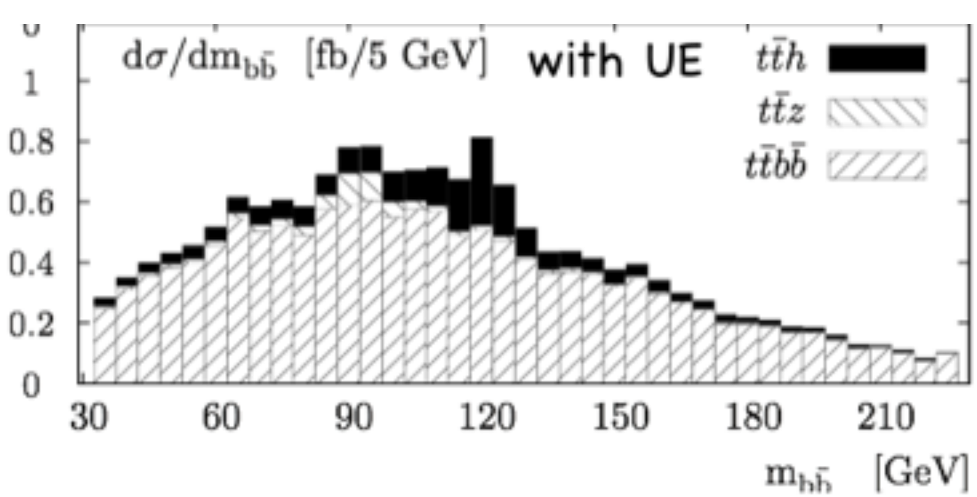
Expected Performance of the ATLAS Experiment, CERN-OPEN-2008-020



For di-leptonic tops see [Artoisenet et al '14]



[Plehn, Salam, MS '09]



- Use boost and jet substructure to ameliorate combinatorics

- Improvement of S/B from 1/9 to 1/2
- 5 sigma significance with 100 1/fb

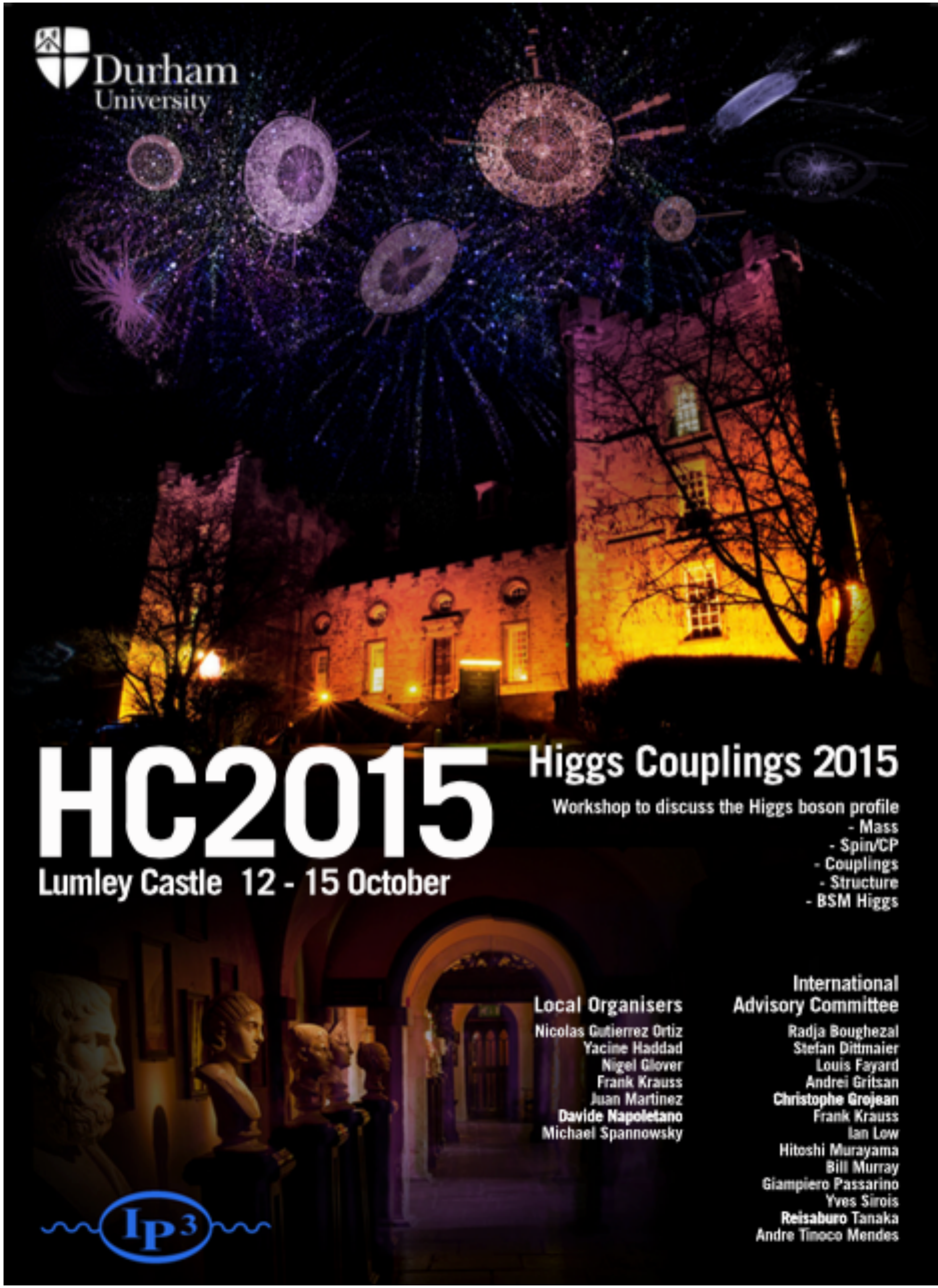
Summary

- Measurements have to be given meaning in terms of hypothesis test

- EFT useful generalisation of kappa framework, however Simplified Models and full theories not obsolete

- Upcoming runs, using energy increase, allow to access most important Higgs couplings

- Whole HEP community is awaiting new data **CALMLY** but with **HIGH HOPES**



You are cordially invited to join Higgs Couplings 2015 in Durham, UK

Oct. 12-15, 2015

http://conference.ippp.dur.ac.uk/event/457/

(HC2016@SLAC)