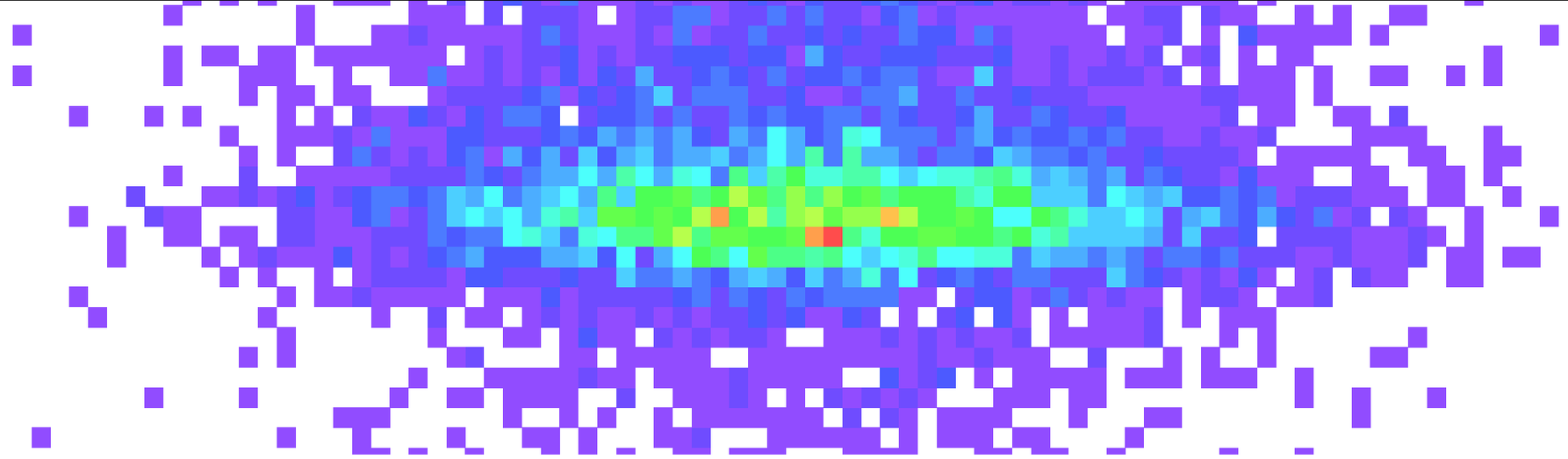


NEW PHYSICS IN TOP-QUARK OBSERVABLES

Project B2b

Susanne Westhoff
Heidelberg University

Kickoff meeting CRC-TRR 257 — March 18-19, 2019 — KIT, Karlsruhe

Project B2b

goal: a global analysis of new physics with top-quarks
in LHC and flavor observables
in the framework of an effective theory

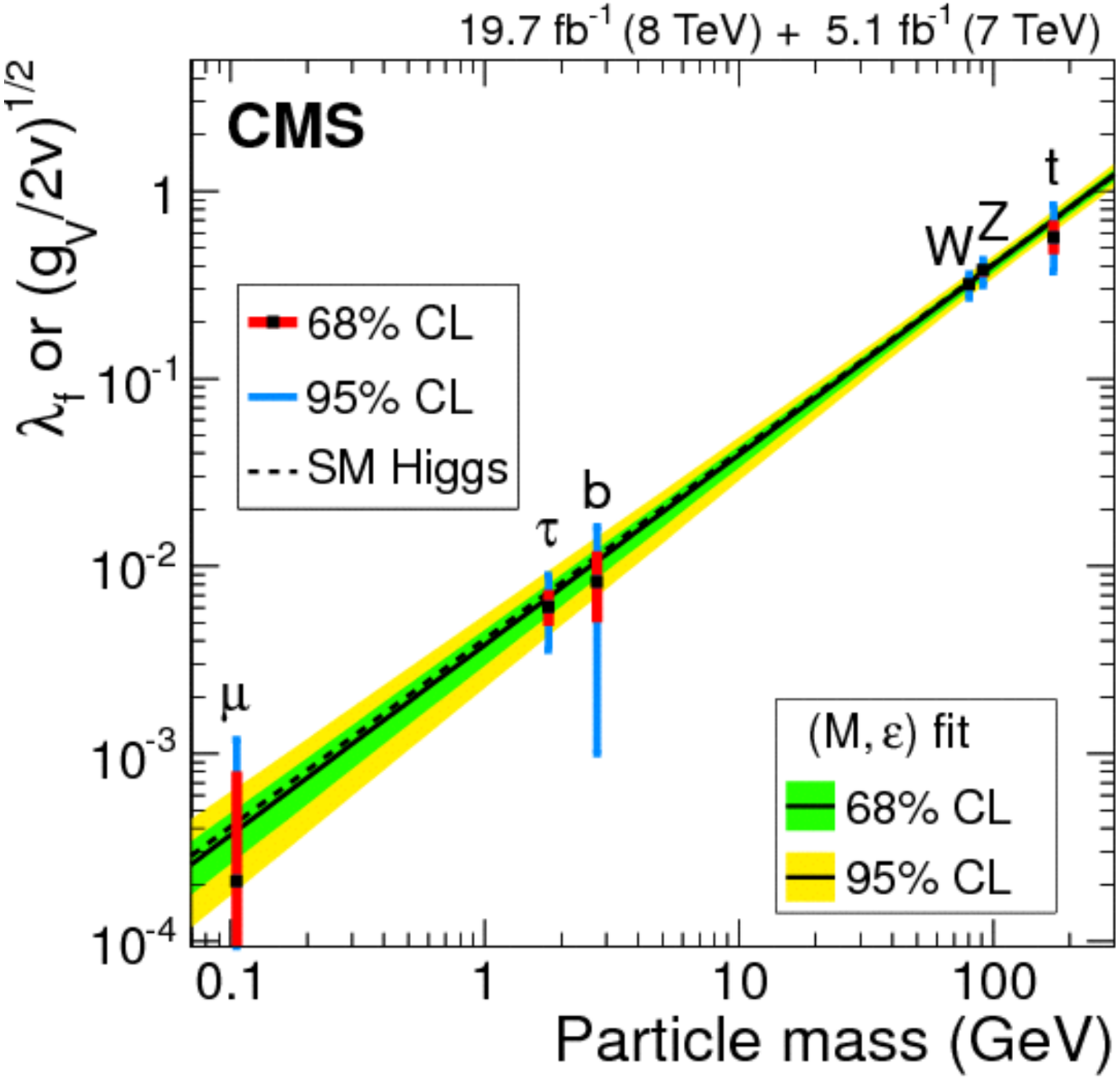
principal investigator: Susanne Westhoff (HD)

participating scientists: Oscar Cata (SI)
Thorsten Feldmann (SI)
Thomas Mannel (SI)
Tilman Plehn (HD)

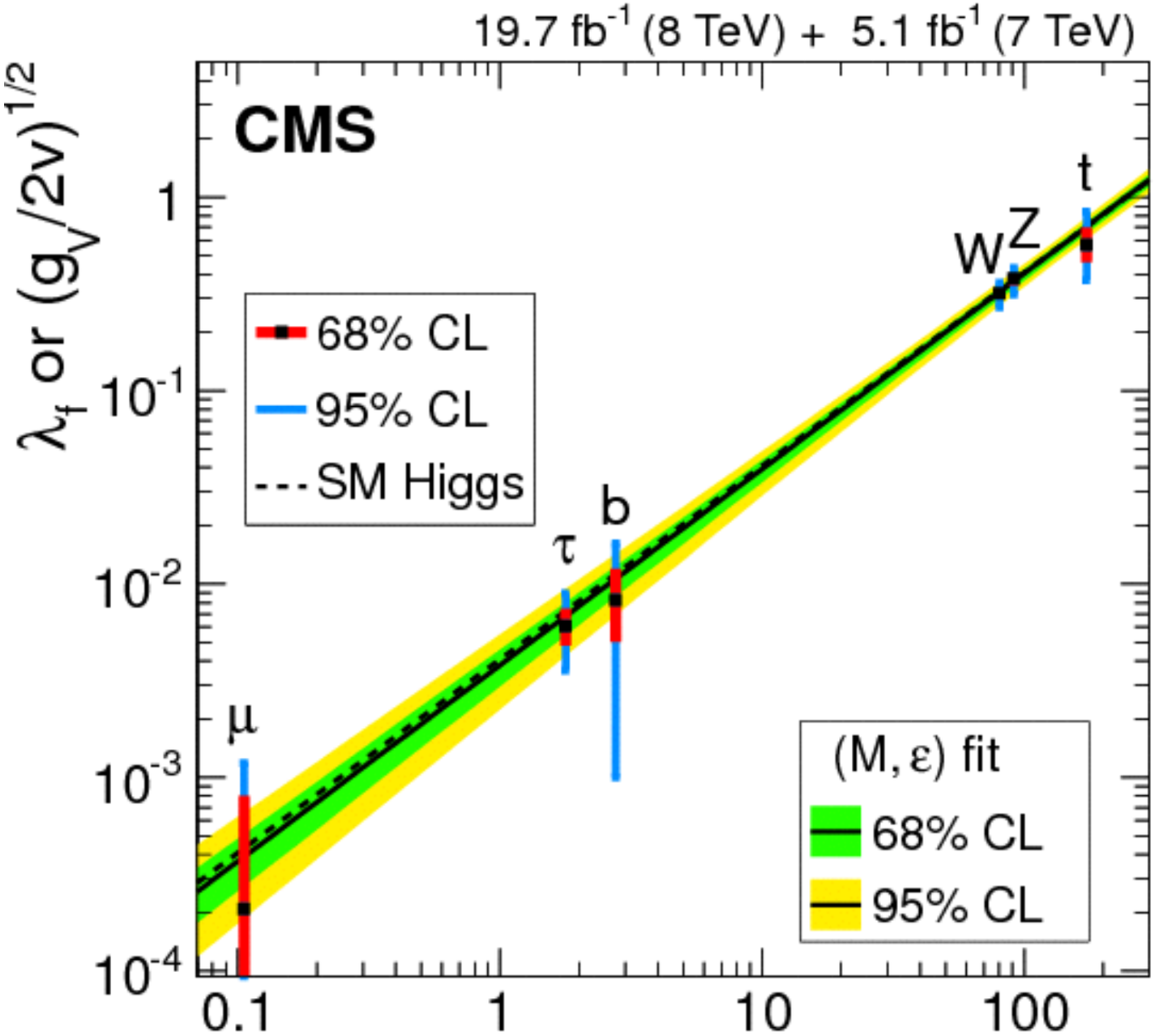
CRC-funded postdoc: Sebastian Bruggisser (HD)

and several CRC-internal and -external contributors

Physics At Different Scales



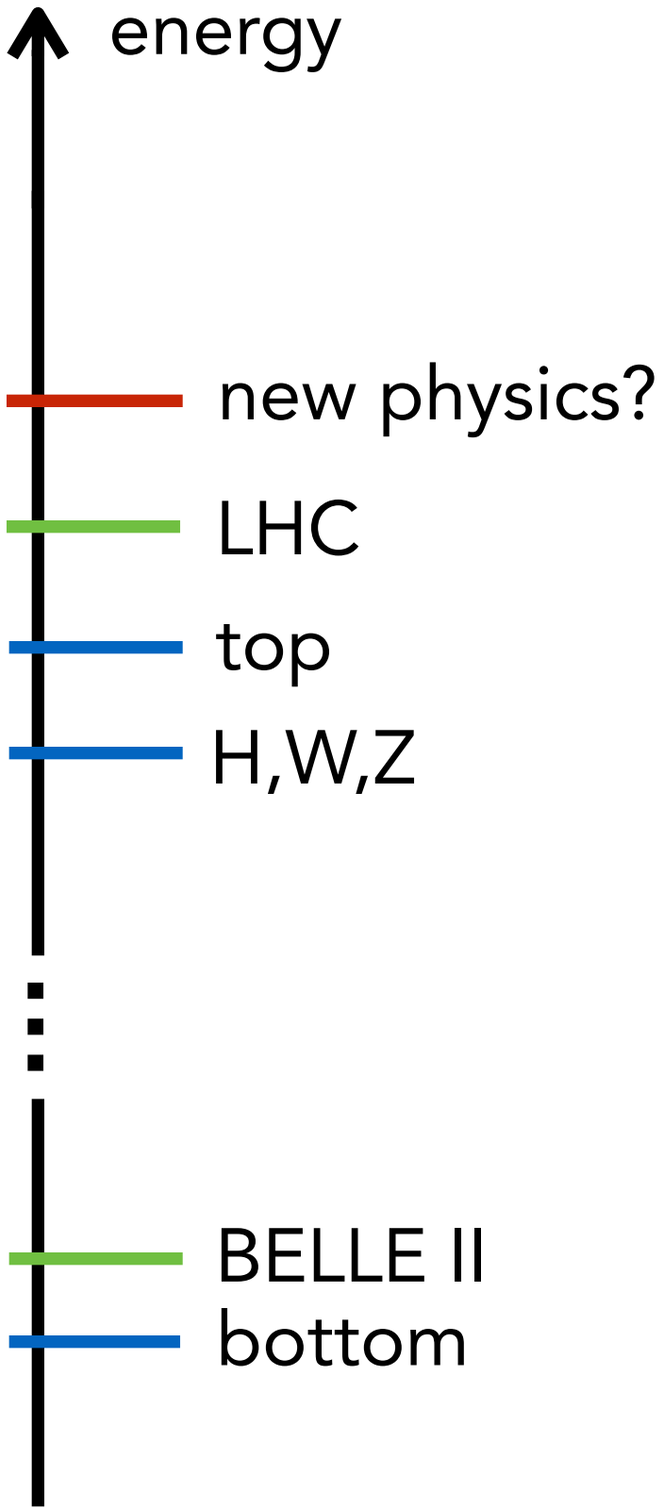
Physics At Different Scales



BELLE II

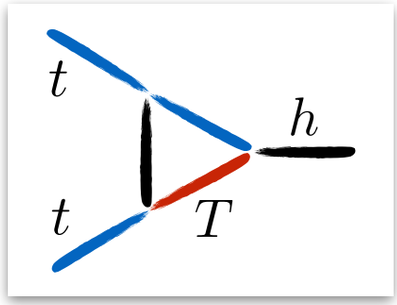
LHC

Beyond The Weak Scale

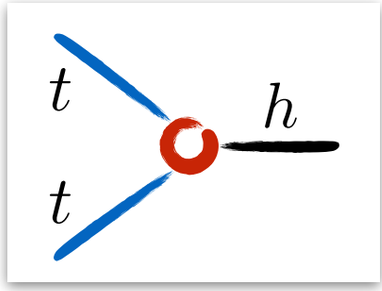


Data suggests that new physics is

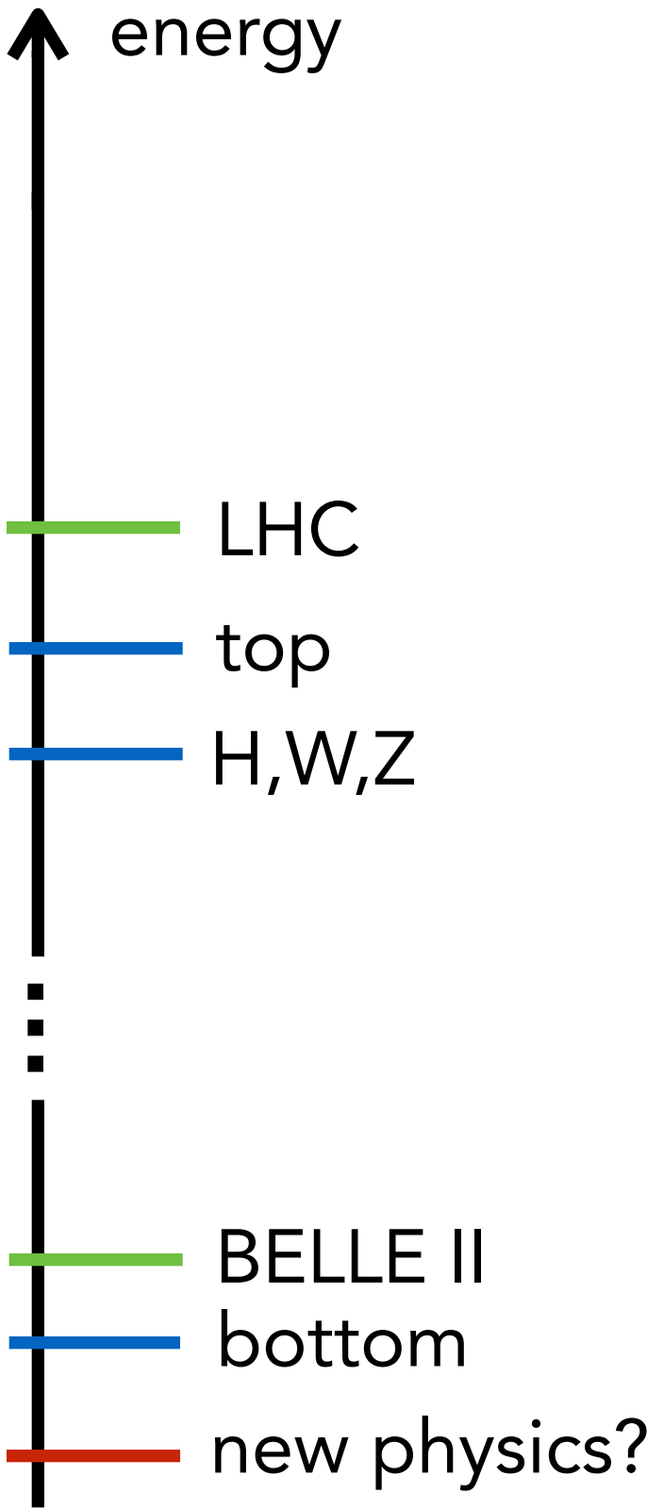
a) very heavy



$m_t \ll m_T$



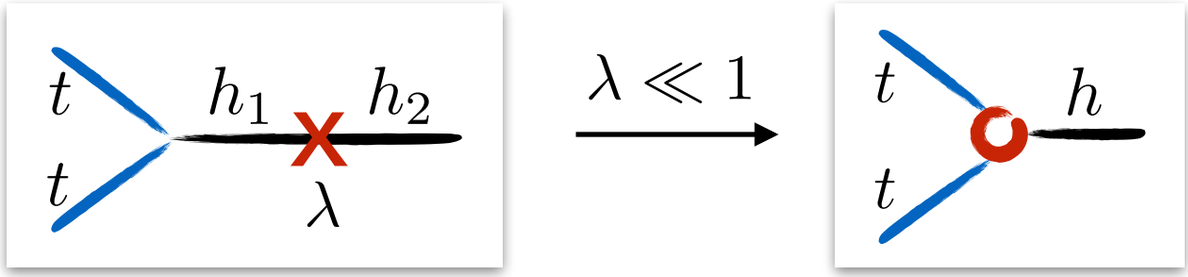
Beyond The Weak Scale



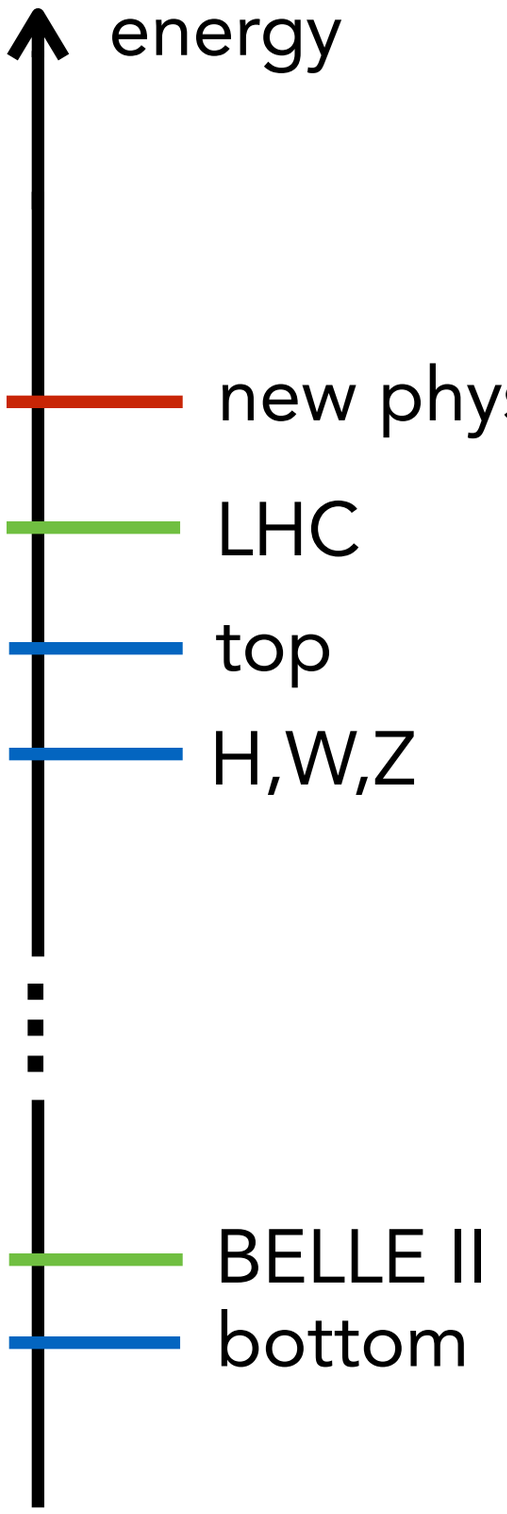
Data suggests that new physics is

a) very heavy

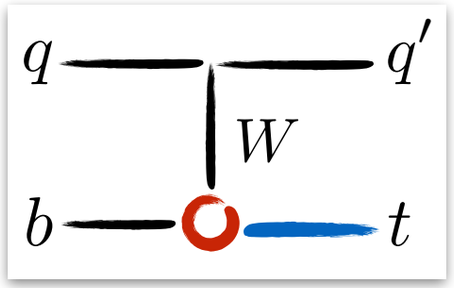
b) well secluded

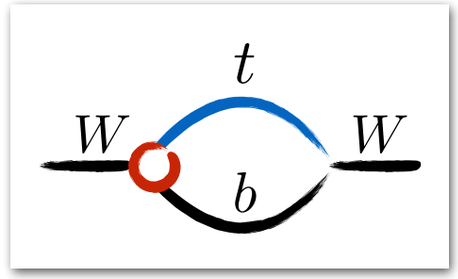


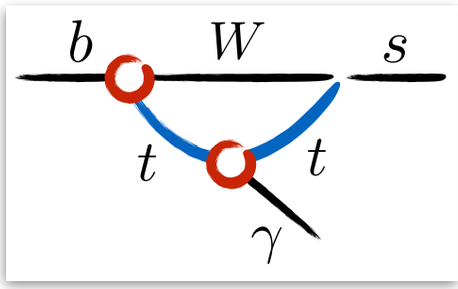
The Top Link



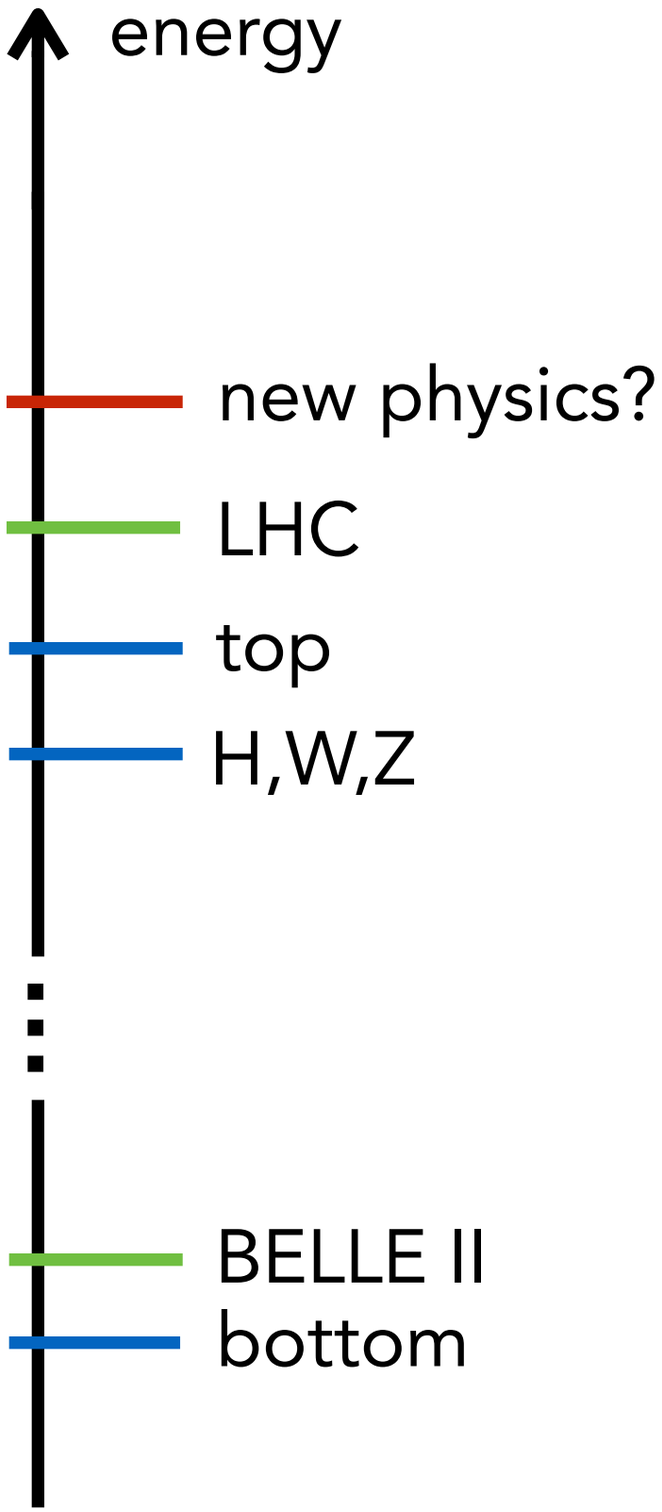
example: weak charged current







Effective Field Theory



- gauge-invariant
- model-independent
- comprehensive

$$\mathcal{L}_f = ???$$

fundamental theory

$$\mathcal{L}_t = \sum_i \frac{C_i}{\Lambda^2} O_i + \dots$$

top effective theory

matching
and
RG evolution

$$\mathcal{L}_w = \sum_j \frac{\mathcal{C}_j}{\Lambda^2} \mathcal{O}_j + \dots$$

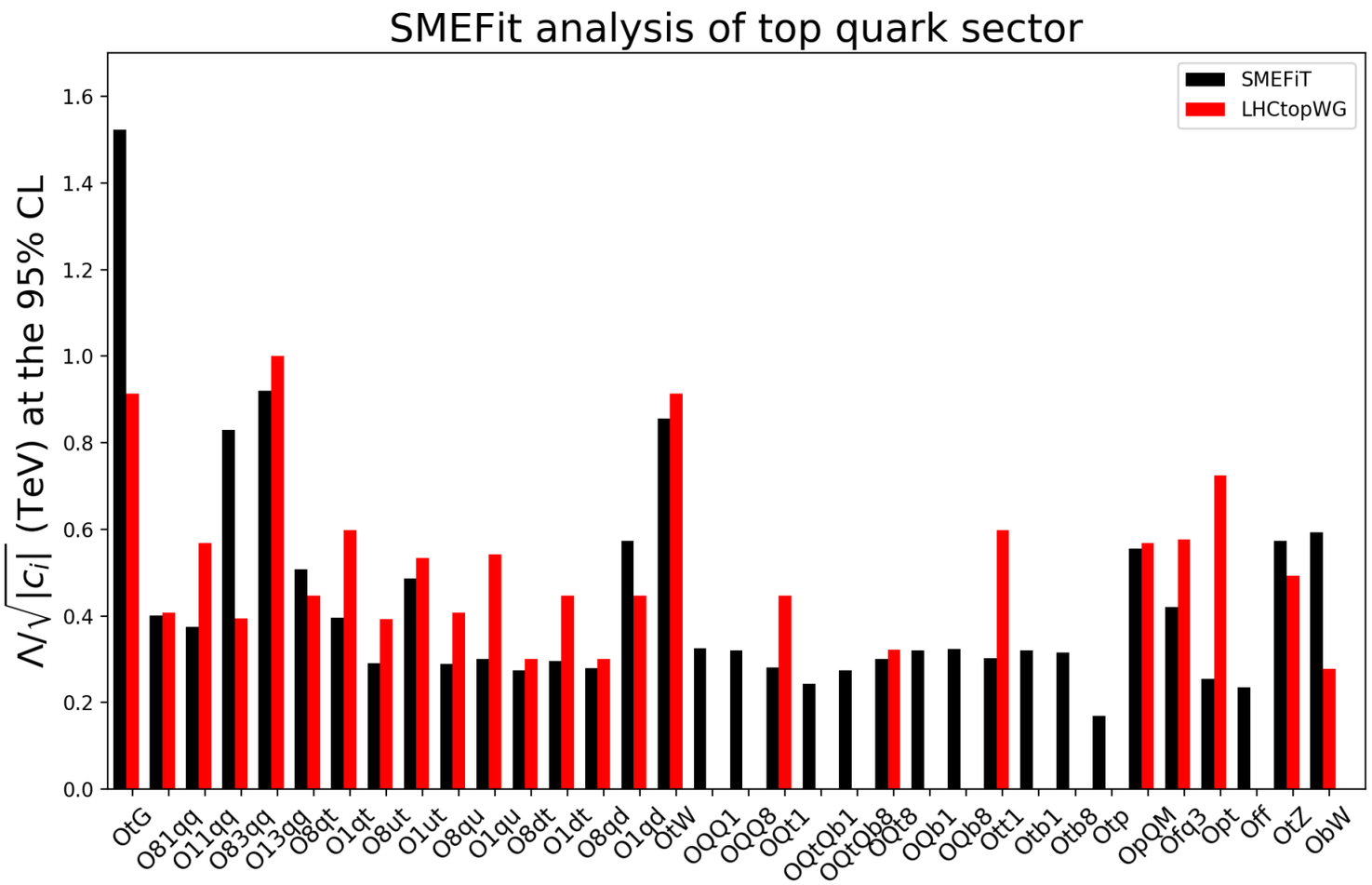
weak effective theory

Global Top Data Analysis

Theory guidelines

Durieux, **Plehn, Westhoff** et al. 2018

- dim-6 operators with tops at NLO QCD (Warsaw basis)
- flavor symmetry $U(2)_q \times U(2)_u \times U(2)_d$



Hartland et al. 2019

Top fits today probe scales comparable with direct LHC reach.

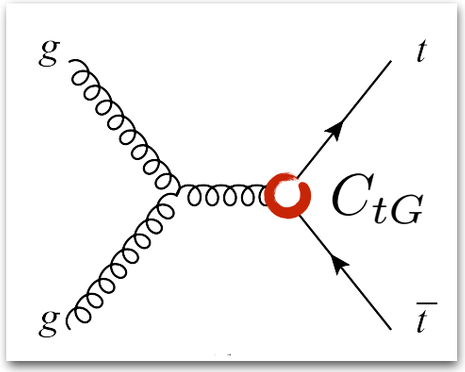
see also: Englert et al. 2016+

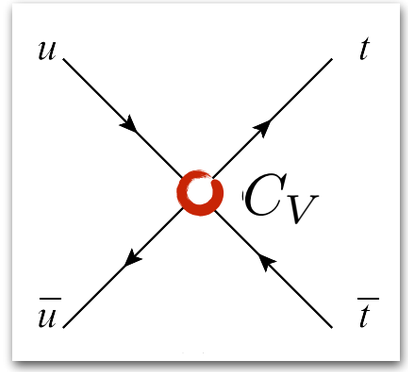
Sensitive Top Observables

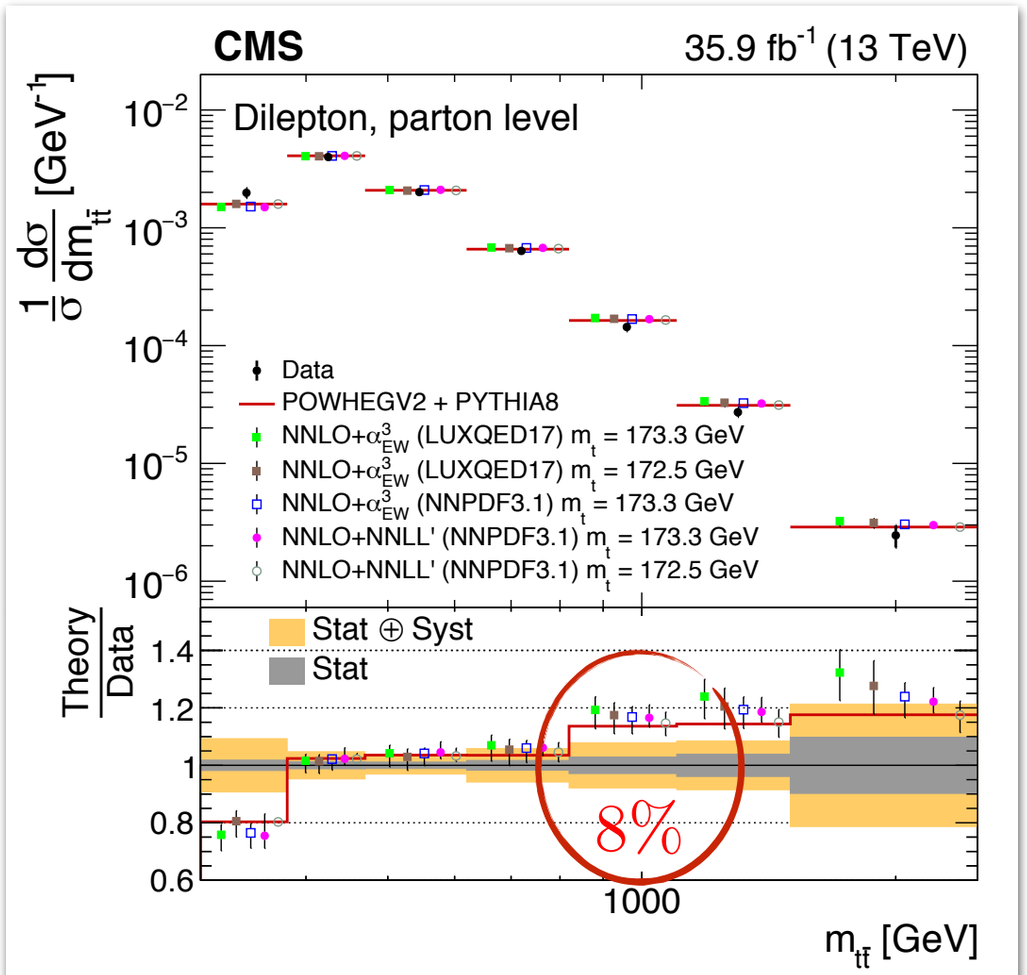
Top-antitop production: high precision in prediction and observation.

$$O_{tG} = (\overline{Q}\sigma^{\mu\nu}T^A t)\widetilde{H}G^A_{\mu\nu}$$

$$O_V = (\bar{q}\gamma_\mu q)(\bar{t}\gamma^\mu t)$$







sensitivity grows with energy

$$\sigma_{t\bar{t}} \overset{s\gg m_t^2}{\longrightarrow} \frac{a}{s} + b\frac{C_{tG}}{\Lambda^2}\frac{v}{\sqrt{s}} + c\frac{C_V}{\Lambda^2}$$

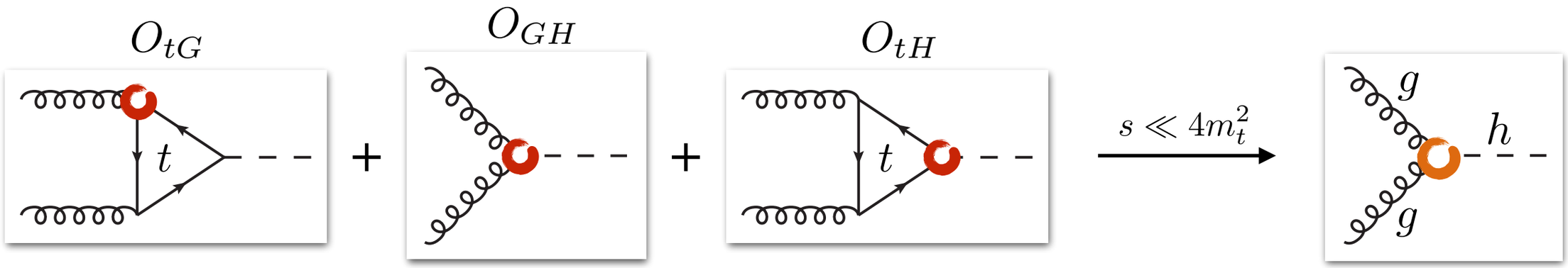
→ Look at tails of distributions

B1b: Precise top observables

and high-pT searches for NP.

Biekoetter, Plehn

Top and Higgs



Higgs inclusive: NLO QCD: Deutschmann et al. 2017

$$\mu_{ggh} - 1 \sim 2.28\, C_{tG} + 114\, C_{GH} - 0.128\, C_{tH}$$

$$O_{tG} = (\overline{Q}\sigma^{\mu\nu}T^A t)\tilde{H}G^A_{\mu\nu}$$

$$O_{GH} = (H^\dagger H)(G_{\mu\nu}G^{\mu\nu})$$

$$O_{tH} = (H^\dagger H)(\overline{Q}\tilde{H}t)$$

strong mixing under RGE

Higgs transverse momentum:

$$C_{tG} \longleftrightarrow \{C_{GH}, C_{tH}\}$$

A1b: Higgs EFT

global analysis Higgs & EW: **Biekoetter**, Corbett, **Plehn** 2018

A2a: Higgs & EW global

top-antitop inclusive: $\sigma_{t\bar{t}} \sim C_{tG} + ...$

top-antitop-Higgs: $\sigma_{t\bar{t}h} \sim C_{tH} + C_{tG}$

Bramante, Delgado, Martin 2014

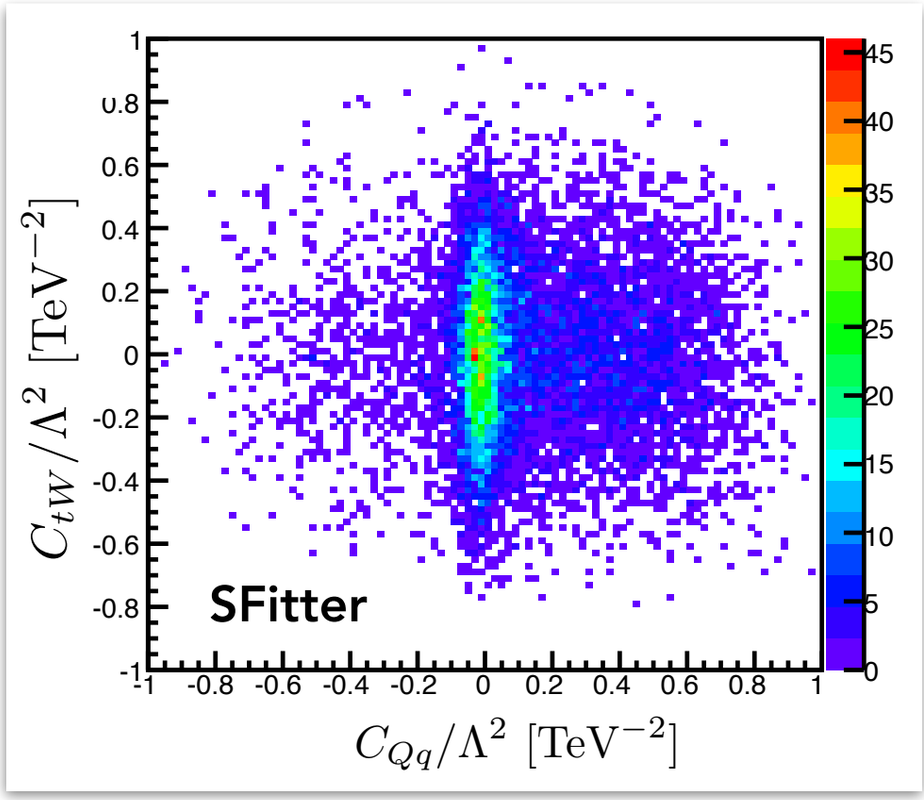
NLO QCD: Maltoni, Vryonidou, Zhang 2016

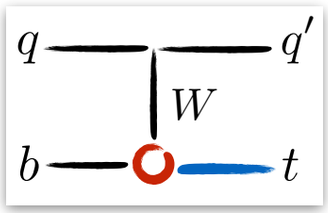
Towards A Precise Top Fit

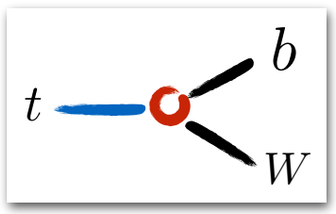
using SFitter: Lafaye, **Plehn**, Rauch, Zerwas 2004+

single top production and decay

process	experiment	energy [TeV]	observable	N_{dat}
single t s-channel	CMS	7	$\sigma_{\text{tot}}(t+\bar{t})$	1
	CMS	8	$\sigma_{\text{tot}}(t+\bar{t})$	1
single t t-channel	ATLAS	7	$\mathrm{d}\sigma_{\text{tot}}(t)/\mathrm{d}p_T^t$	5
			$\mathrm{d}\sigma_{\text{tot}}(\bar{t})/\mathrm{d}p_T^{\bar{t}}$	5
	ATLAS	8	$\mathrm{d}\sigma_{\text{tot}}(t)/\mathrm{d}y_t$	4
			$\mathrm{d}\sigma_{\text{tot}}(\bar{t})/\mathrm{d}y_t$	4
	CMS	13	$\mathrm{d}\sigma/\mathrm{d}p_T^{t+\bar{t}}$	4
tW	CMS	7	$\sigma_{\text{tot}}(tW)$	1
	ATLAS	8	$\sigma_{\text{tot}}(tW)$	1
	CMS	13	$\sigma_{\text{fid}}(Wbl^+l^-q)$	1
t decay	ATLAS	7	F_L	1
			F_R	1
	ATLAS	8	F_L	1
			F_R	1



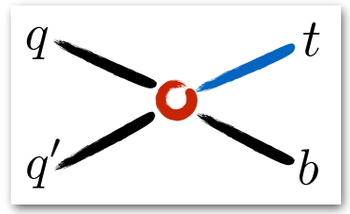




$$O_{tW} = (\overline{Q}\sigma^{\mu\nu}\tau^a t)\widetilde{H}W^a_{\mu\nu}$$

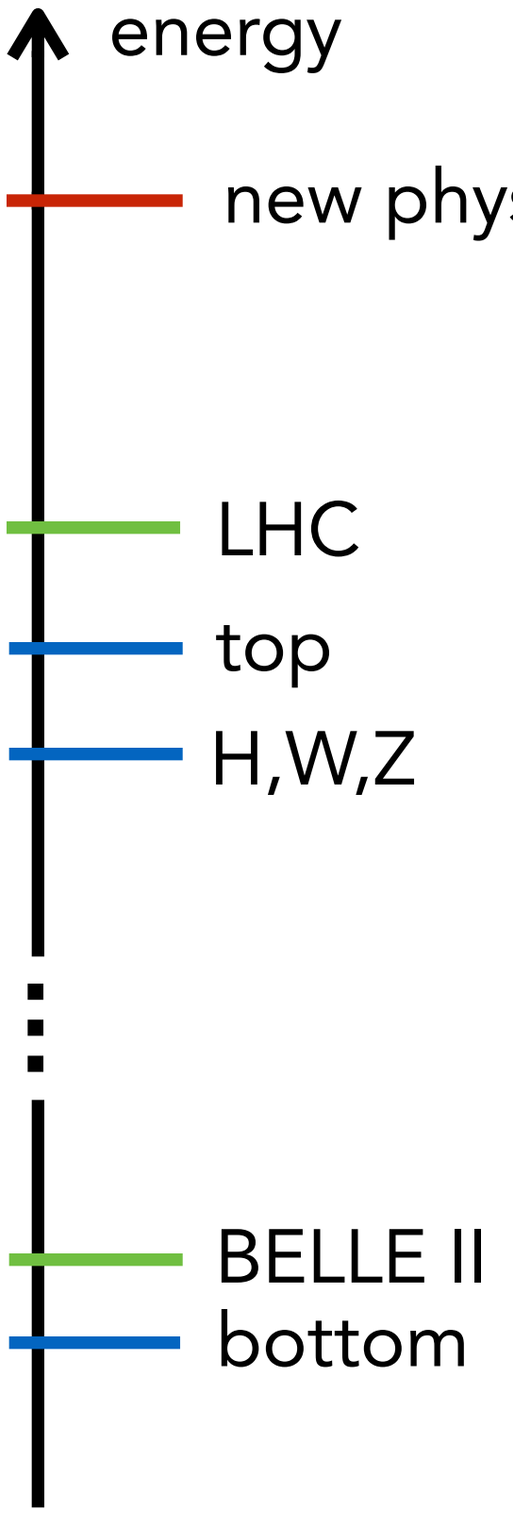
$$O_{Qq} = (\bar{q}\gamma^\mu Q)(\overline{Q}\gamma_\mu q) - (\bar{q}\gamma^\mu \tau^a Q)(\overline{Q}\gamma_\mu \tau^a q)$$

(NLO only)

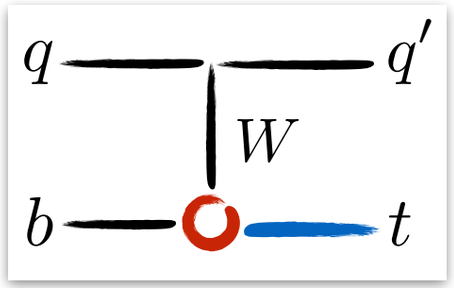


Biekoetter, **Bruggisser**, Maltoni, **Moutafis**, **Plehn**, Vryonidou, **Westhoff**, Zerwas, Zhang

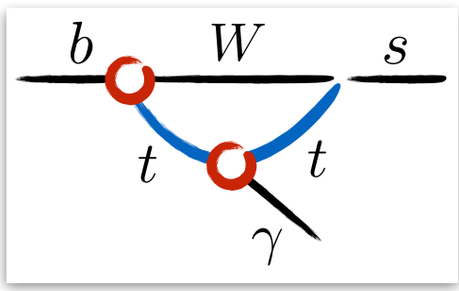
Top And Flavor



flavor structure?



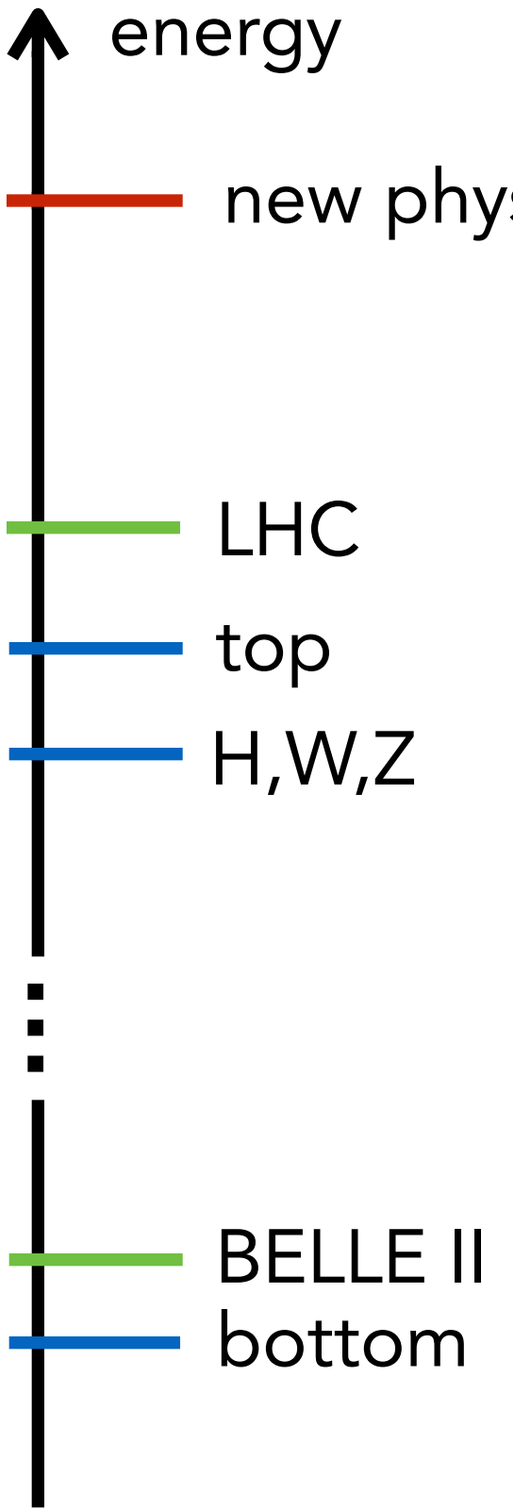
flavor-dependent



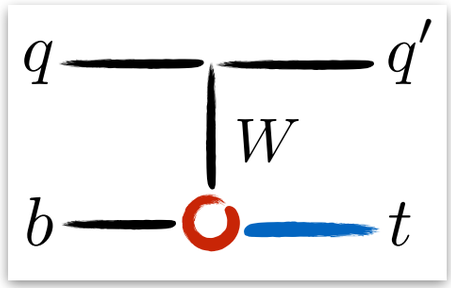
C3a: Flavor at high pT

C3b: New physics in flavor observables

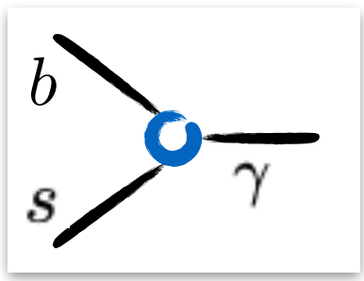
Top And Flavor



flavor structure?



flavor-dependent

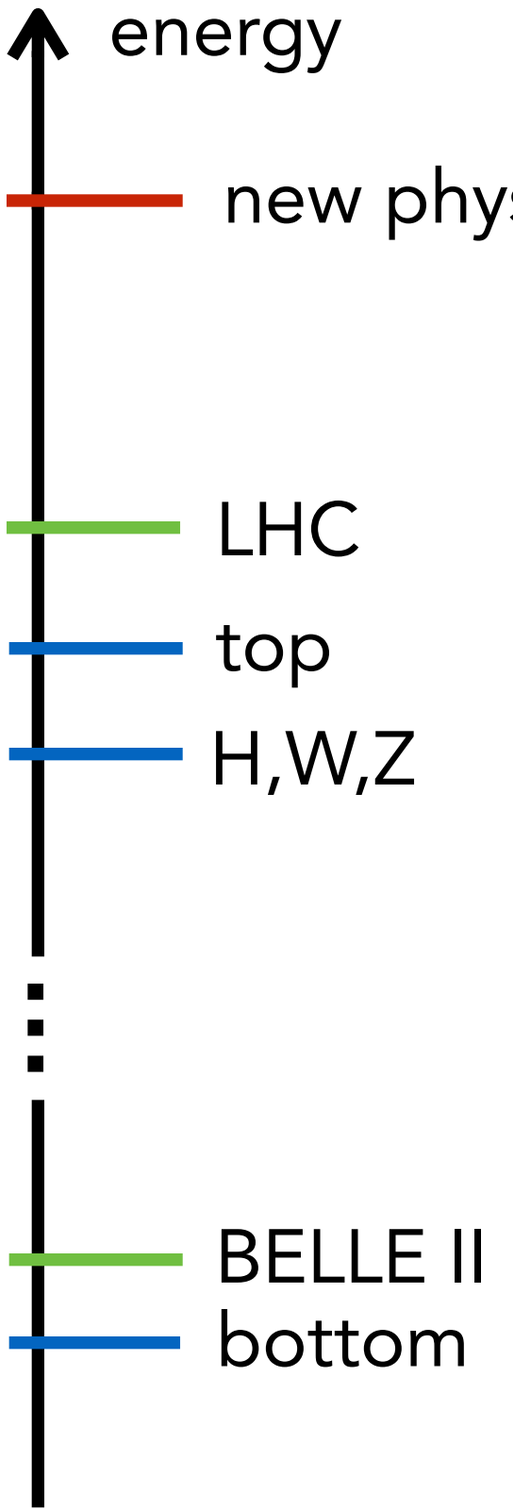


global analysis top EFT

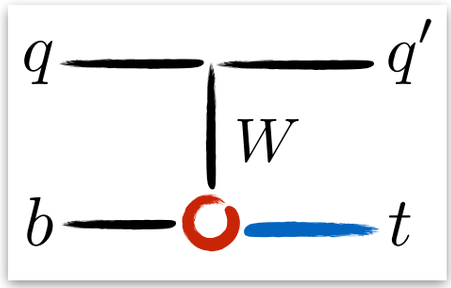
global analysis weak EFT

EOS (van Dyk et al.)
Flavio (Straub et al.)

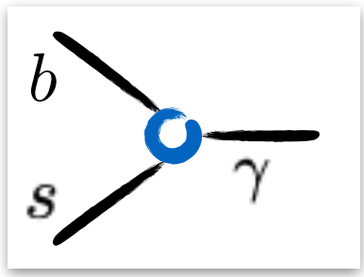
Top And Flavor



flavor structure?



flavor-dependent



global analysis top EFT

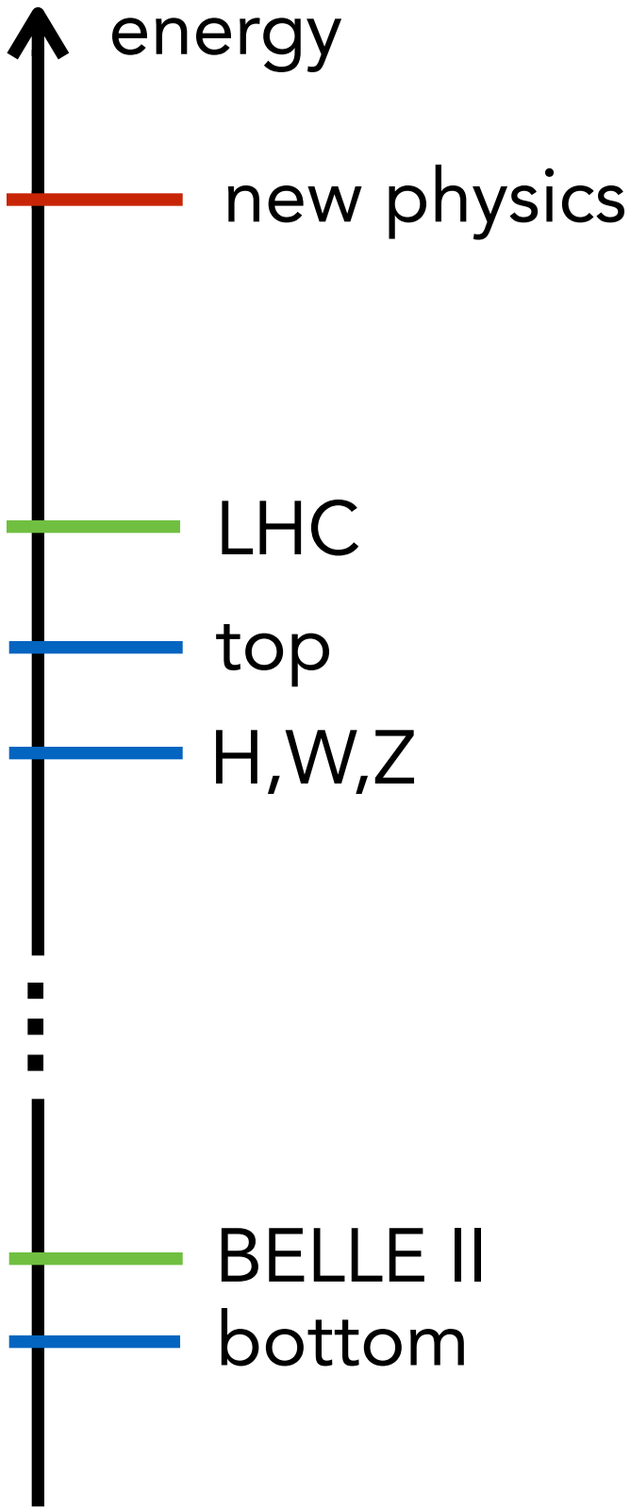
matching (NLO QCD)

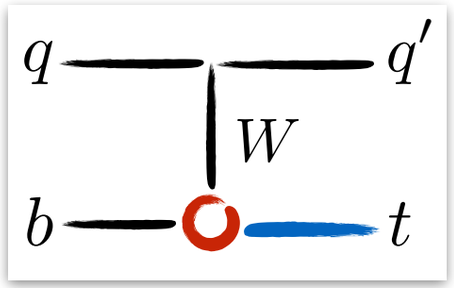
Aebischer, **Fael**

global analysis weak EFT

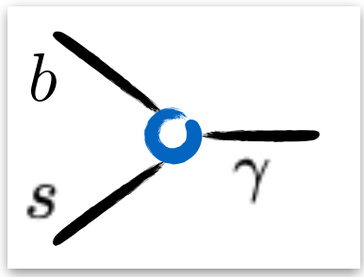
EOS (van Dyk et al.)
Flavio (Straub et al.)

Top And Flavor





flavor-dependent



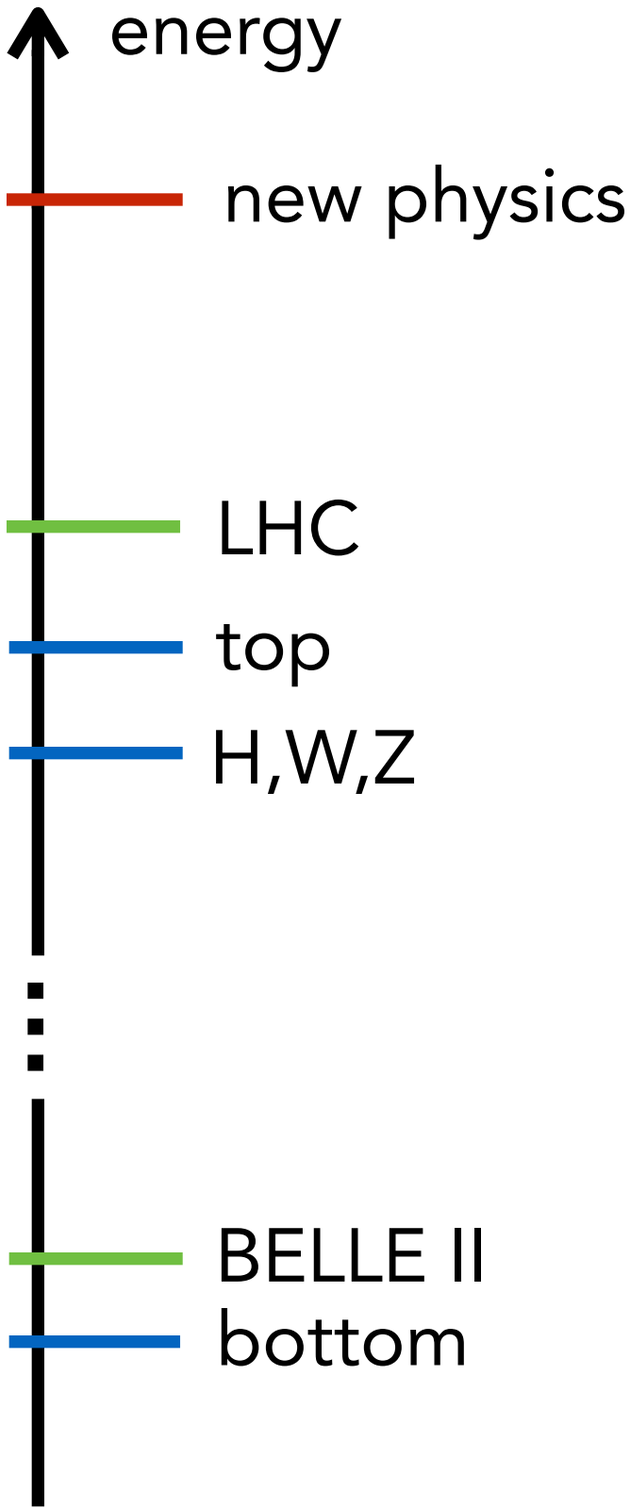
flavor structure

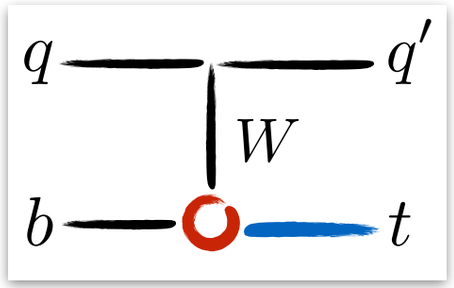
consistent?

consistent?

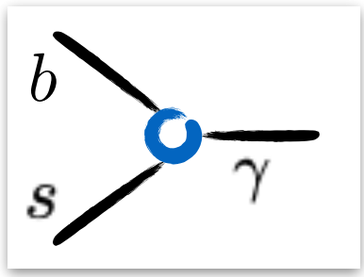
Bordone, Cata, Feldmann, Mannel, Vos, Westhoff

Top And Flavor





flavor-dependent



flavor structure

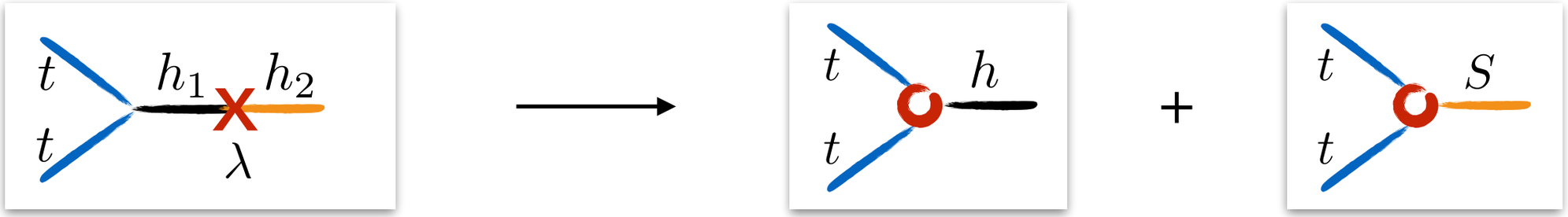
consistent?

flavor anomaly

Bordone, Cata, Feldmann, Mannel, Vos, Westhoff

Top And Hidden New Physics

Higgs-scalar mixing

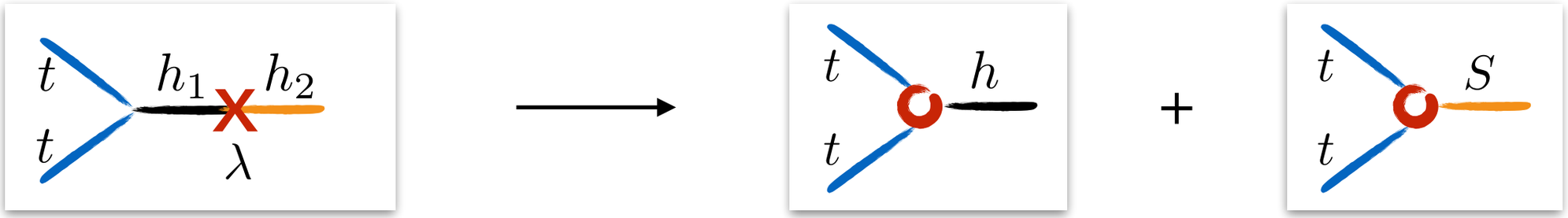


A3a: Extended Higgs sectors

B3a: Dark sectors

Top And Hidden New Physics

Higgs-scalar mixing



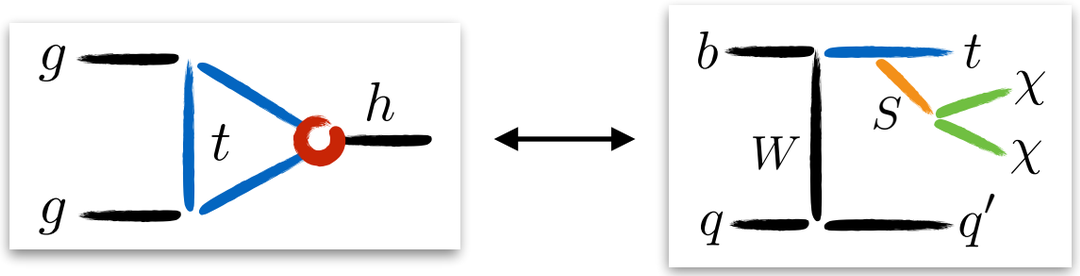
A3a: Extended Higgs sectors

B3a: Dark sectors

Plehn, Thompson, Westhoff 2017

LHC:

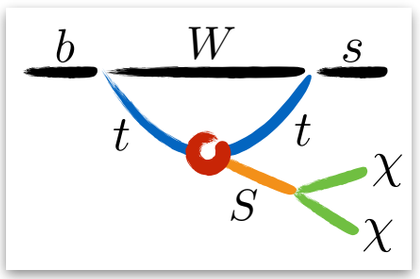
top and missing energy



C3a: Flavor at high pT

BELLE II:

B to K and missing energy



C3b: New physics in flavor observables

Schaefer, Westhoff

Ready To Discuss

- **Top observables**: High sensitivity / precision — where and how?

- **Top and Higgs**: Consistent combination of fits?

- **Top and Flavor**: Useful flavor patterns?

- **Beyond effective theory**: Combine indirect and direct searches?