

# SMEFT as a probe of New Physics at the LHC

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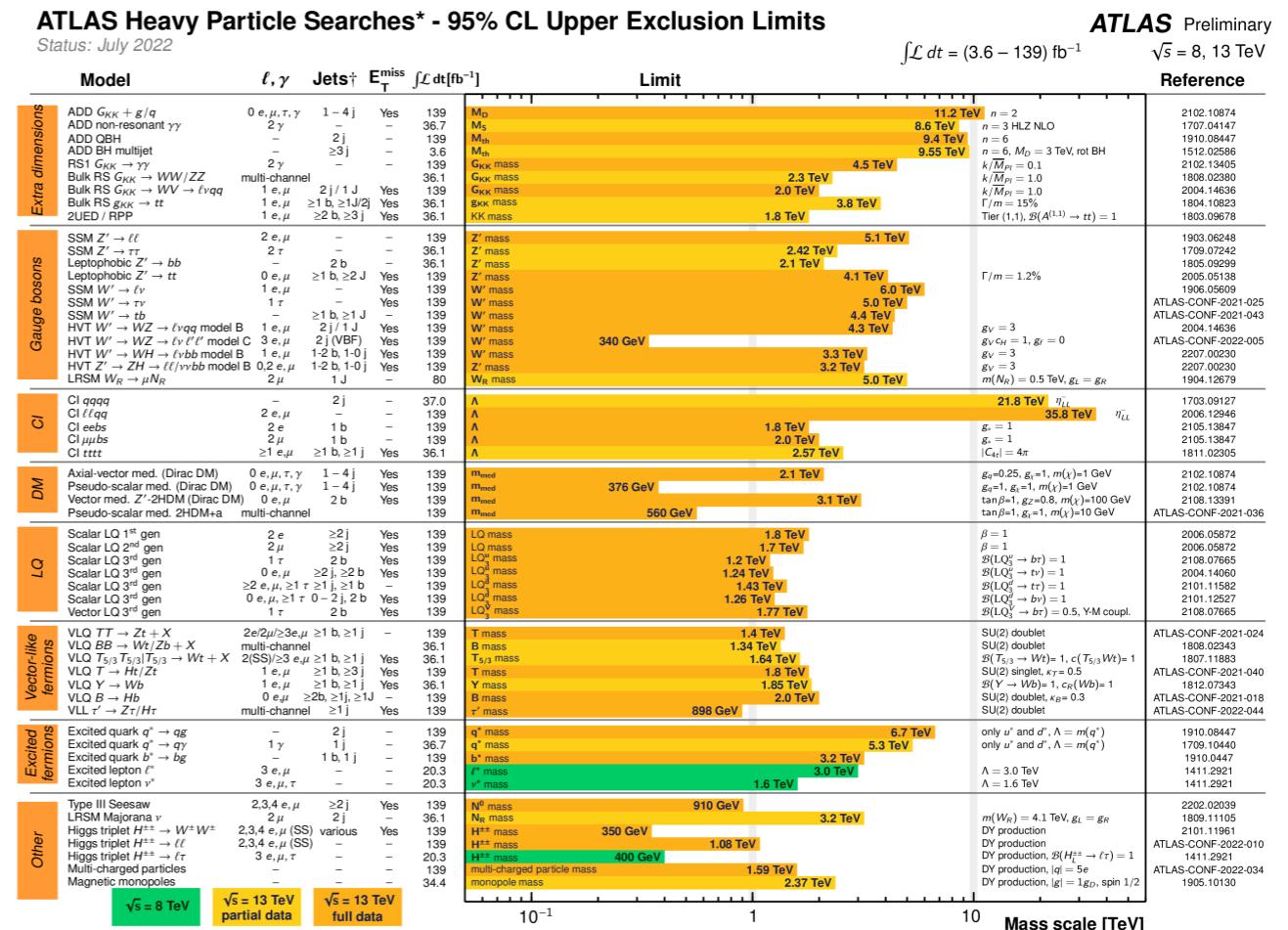
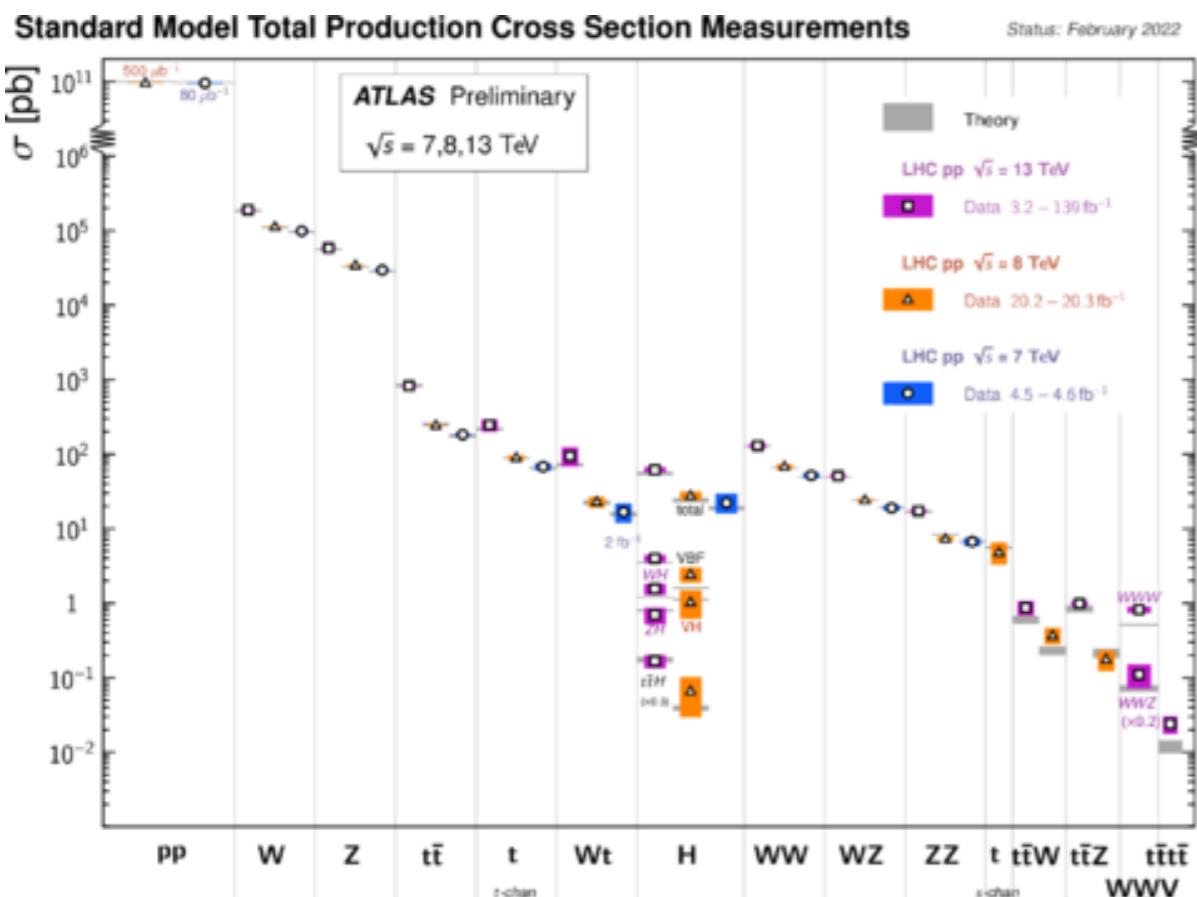


HEP2023  
Ioannina, 05/04/23

# LHC: the story so far

Rediscovering the SM

Searching for the unknown



Good agreement with the SM predictions  
No evidence of new light particles

# Where is New Physics?

**There is a good chance that New Physics is Heavy**



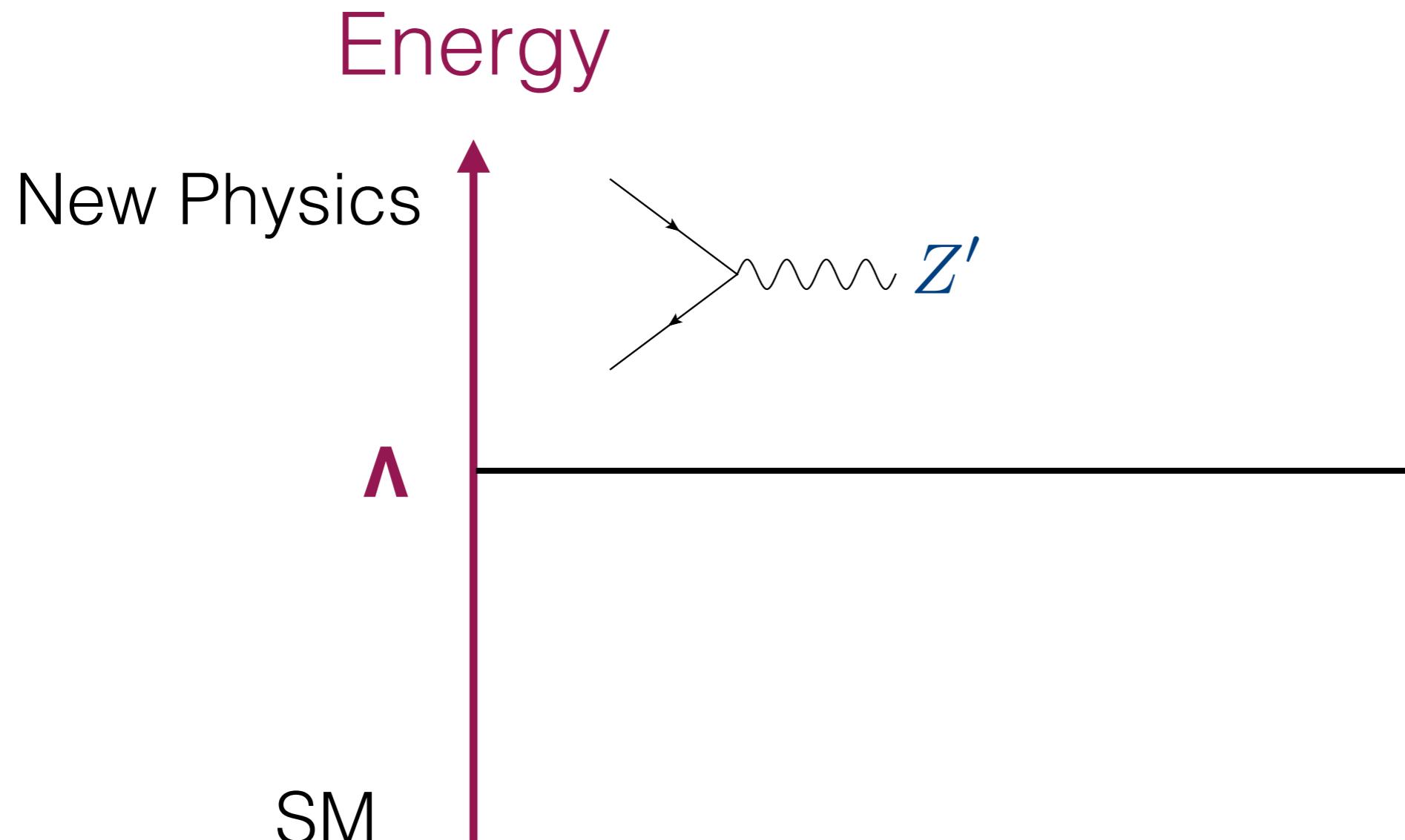
Not enough energy to produce it

Indirect searches are needed

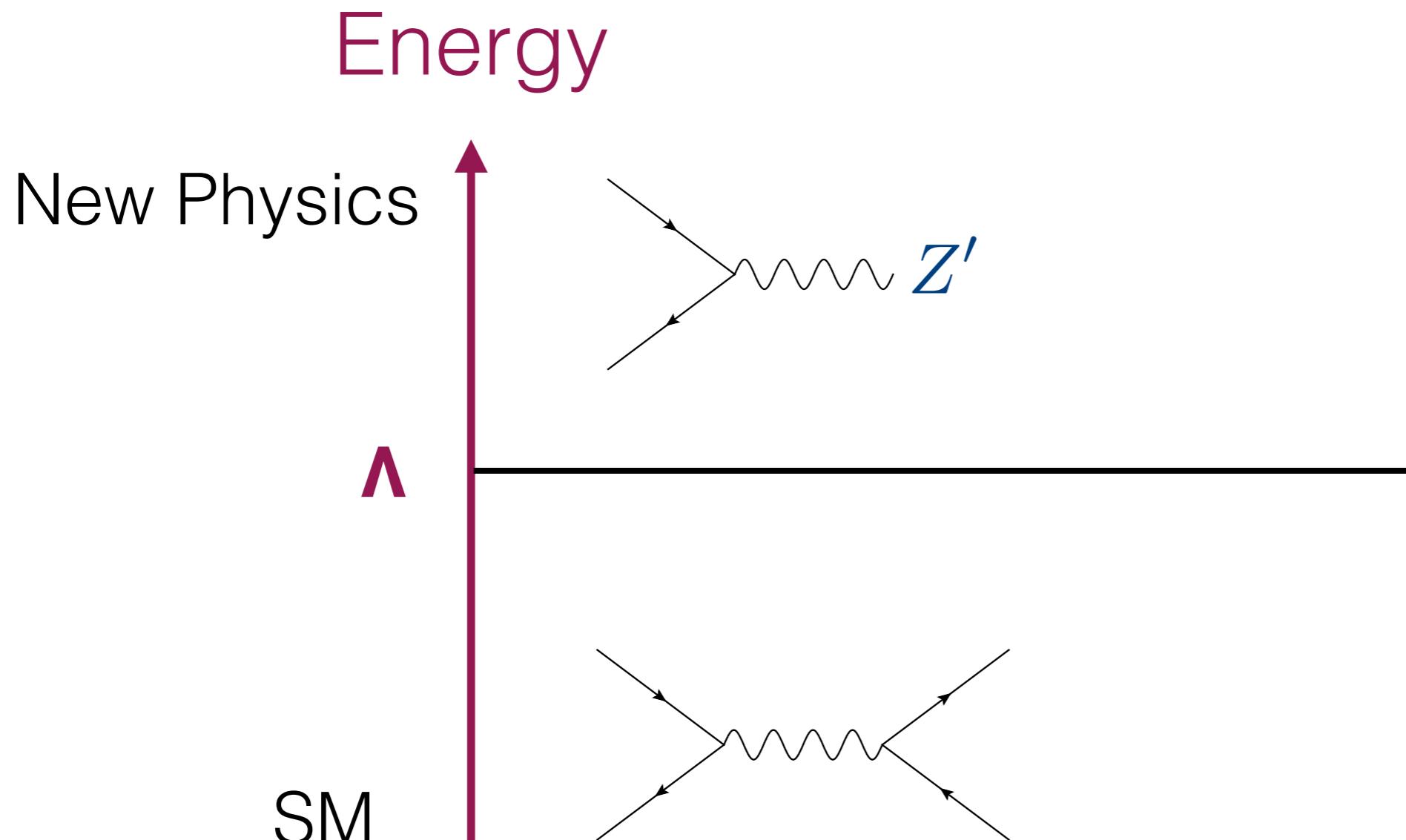


**SMEFT opens new directions**

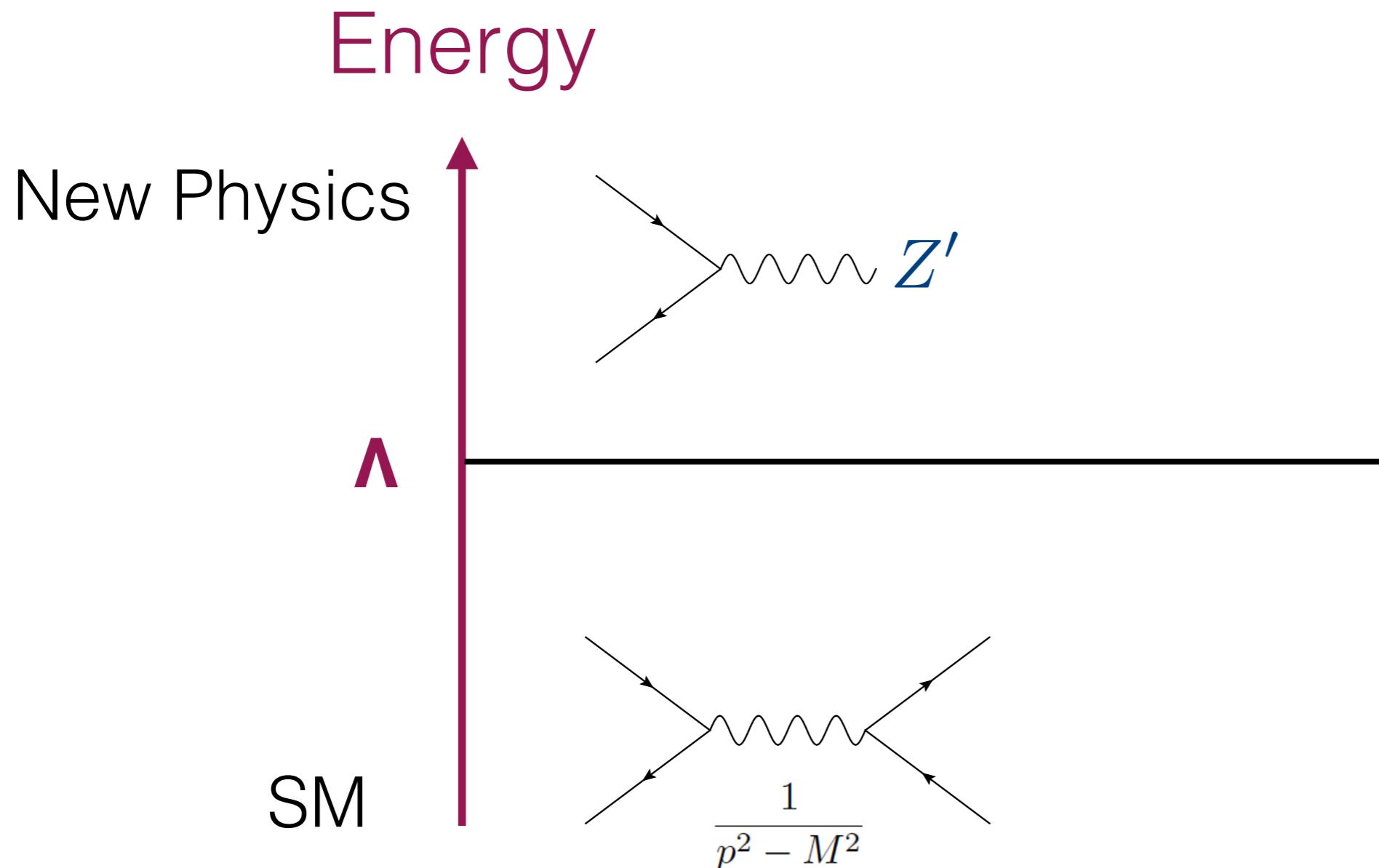
# SMEFT: What is it all about?



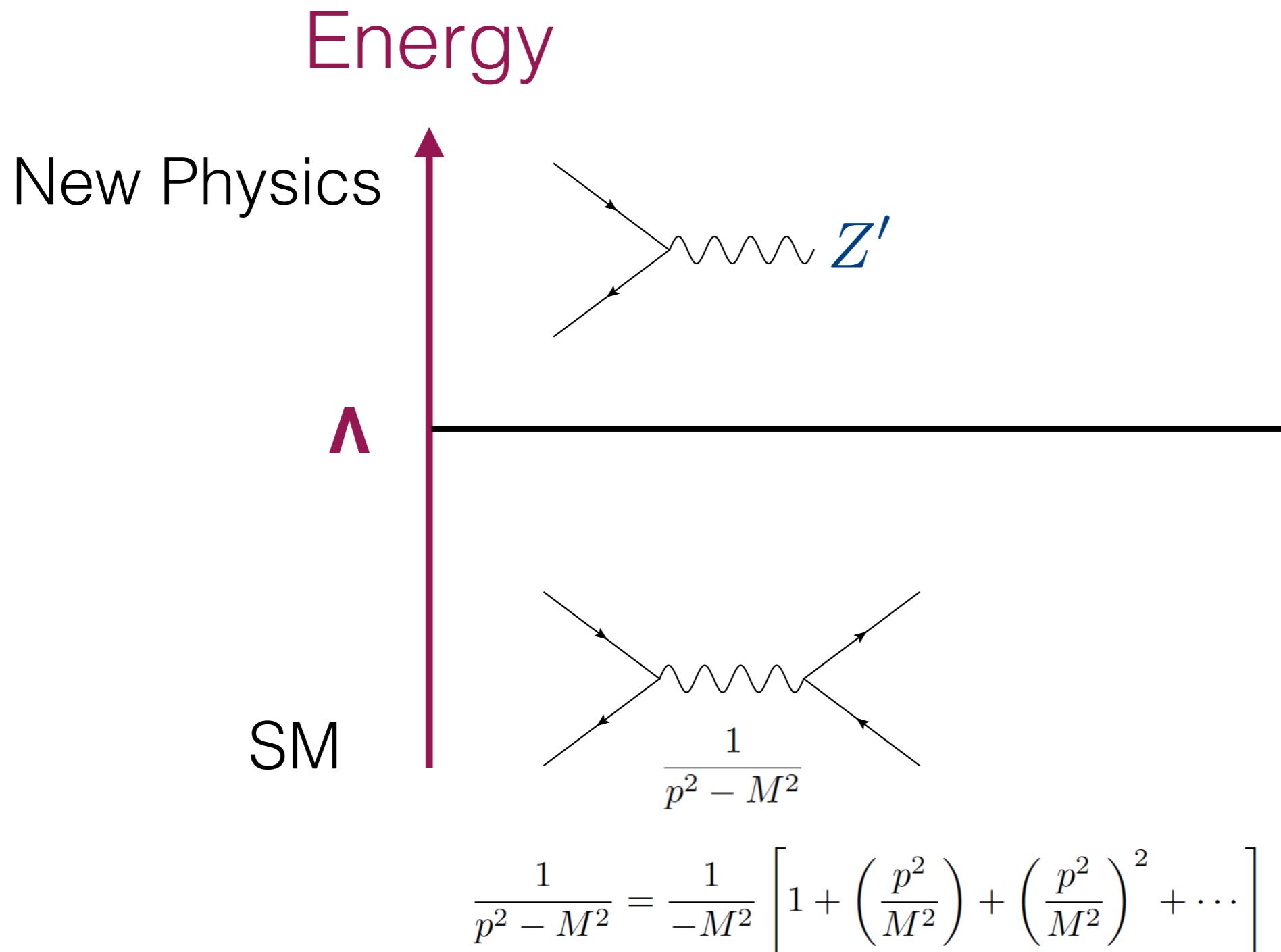
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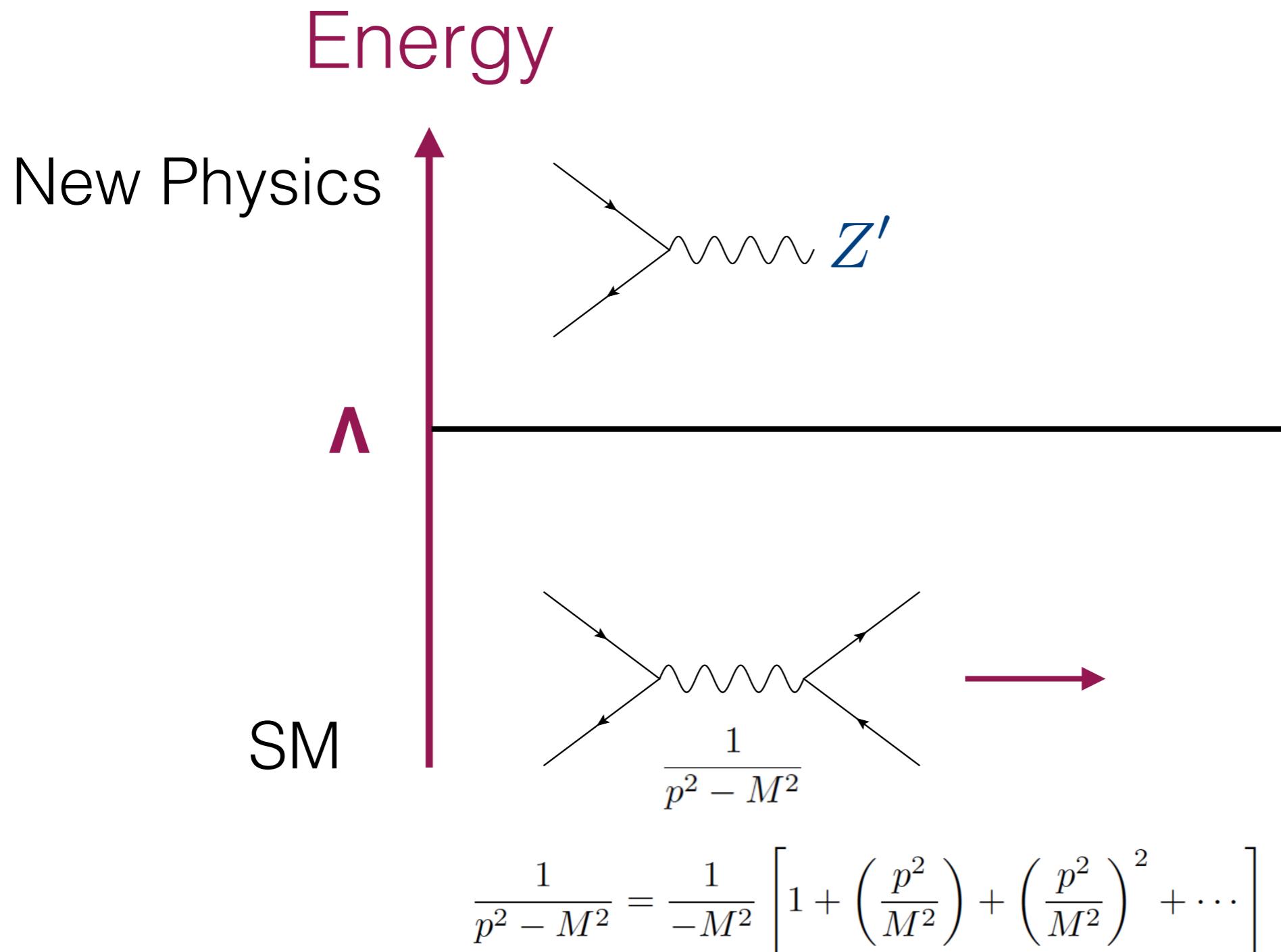
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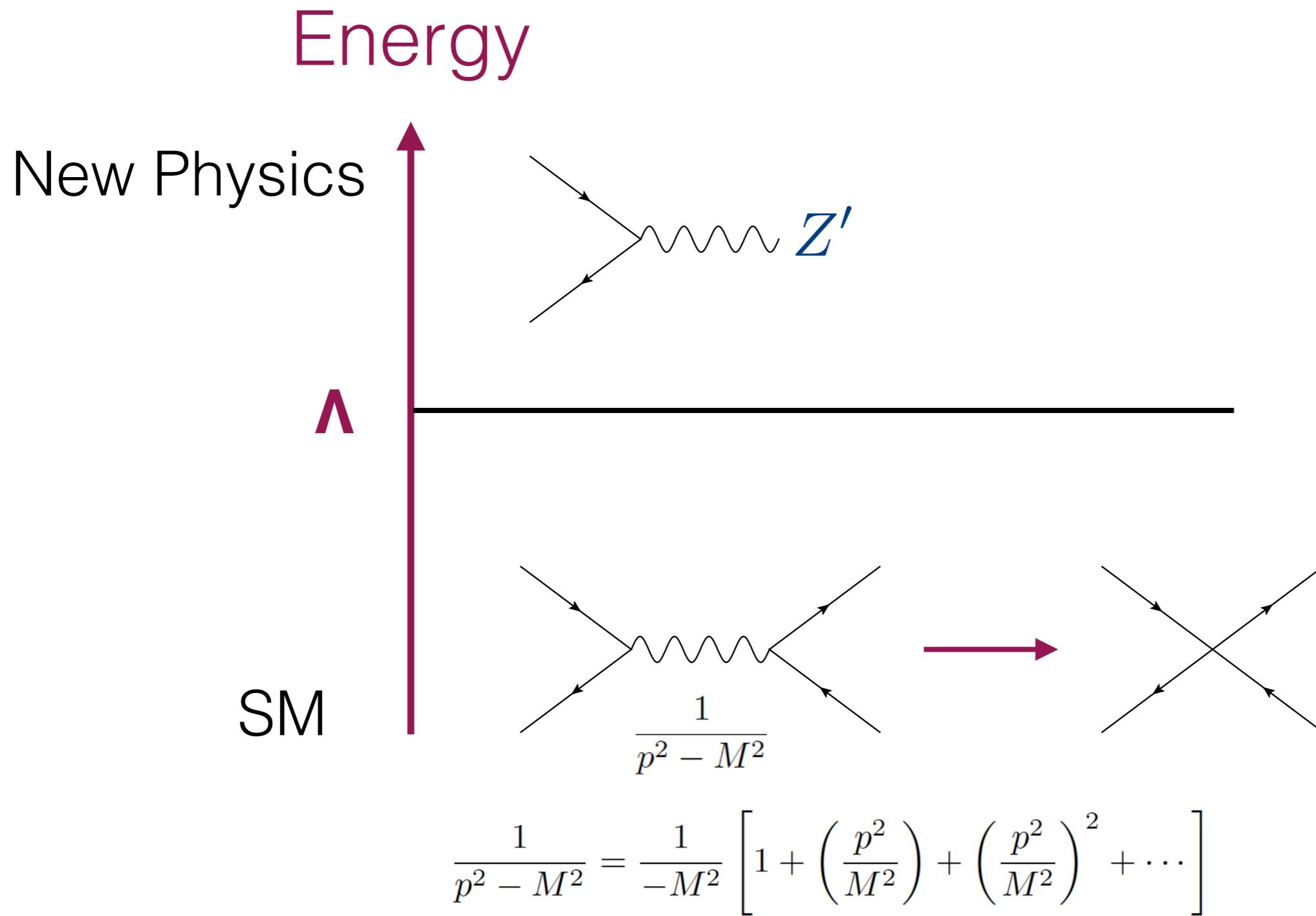
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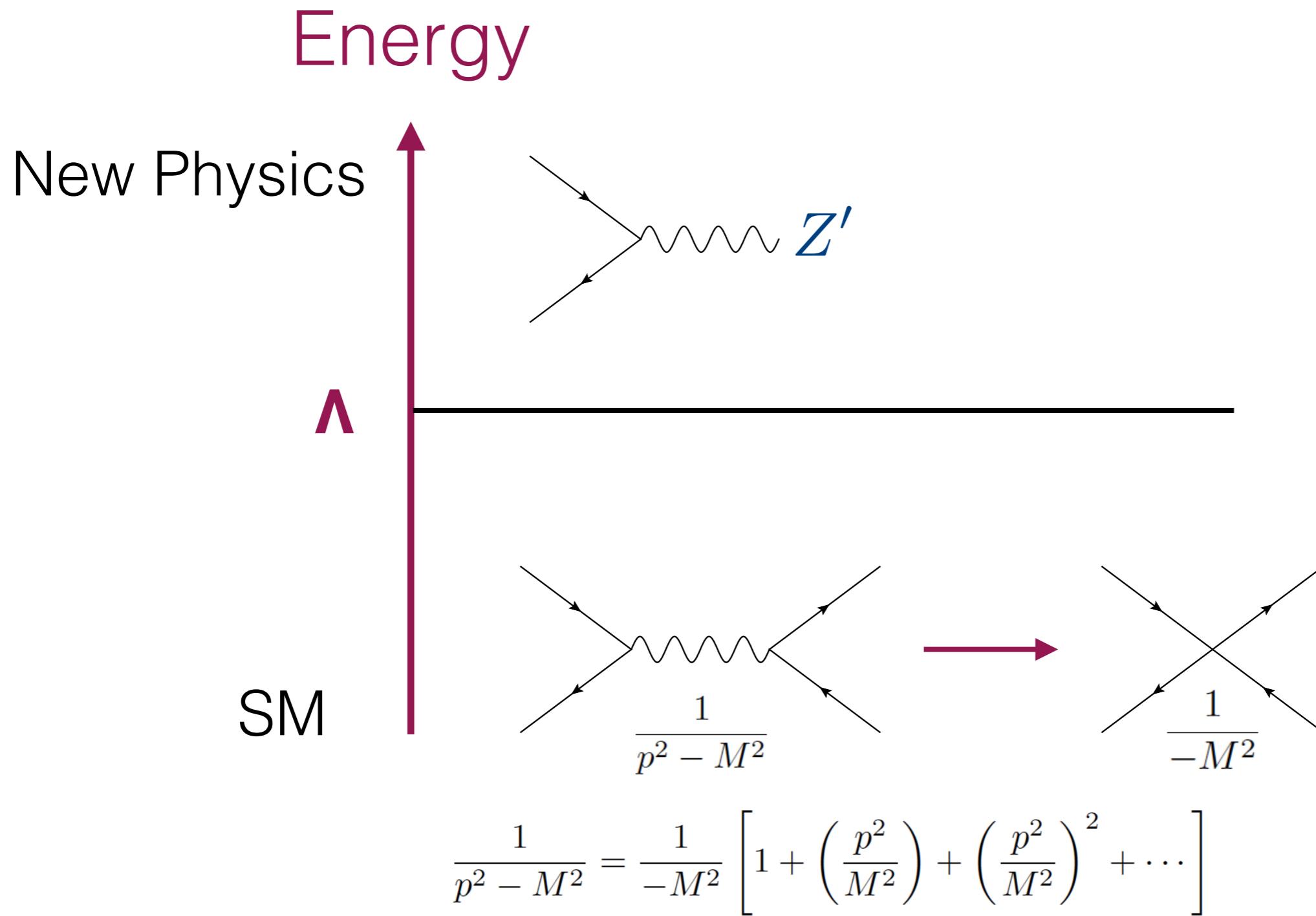
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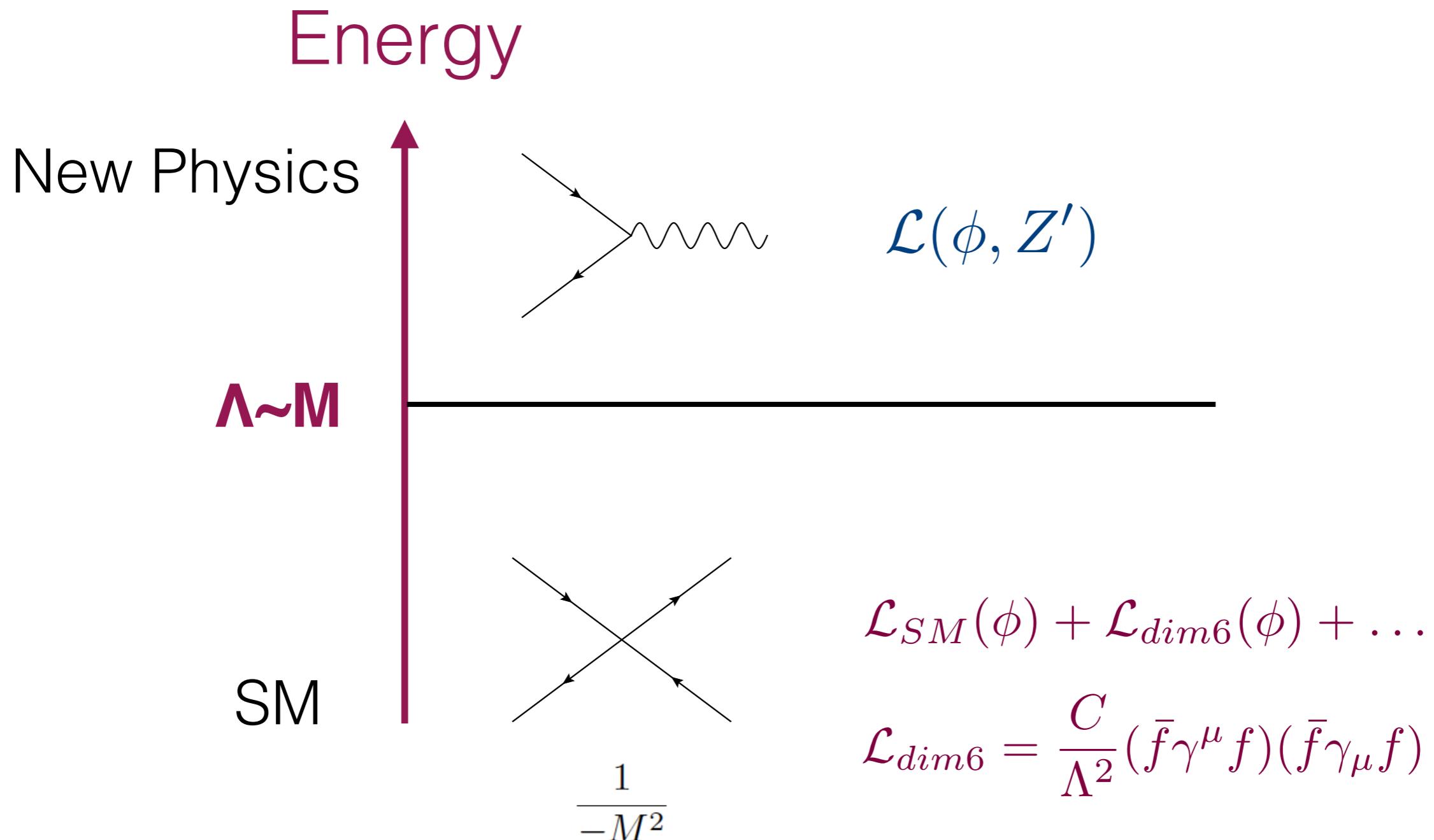
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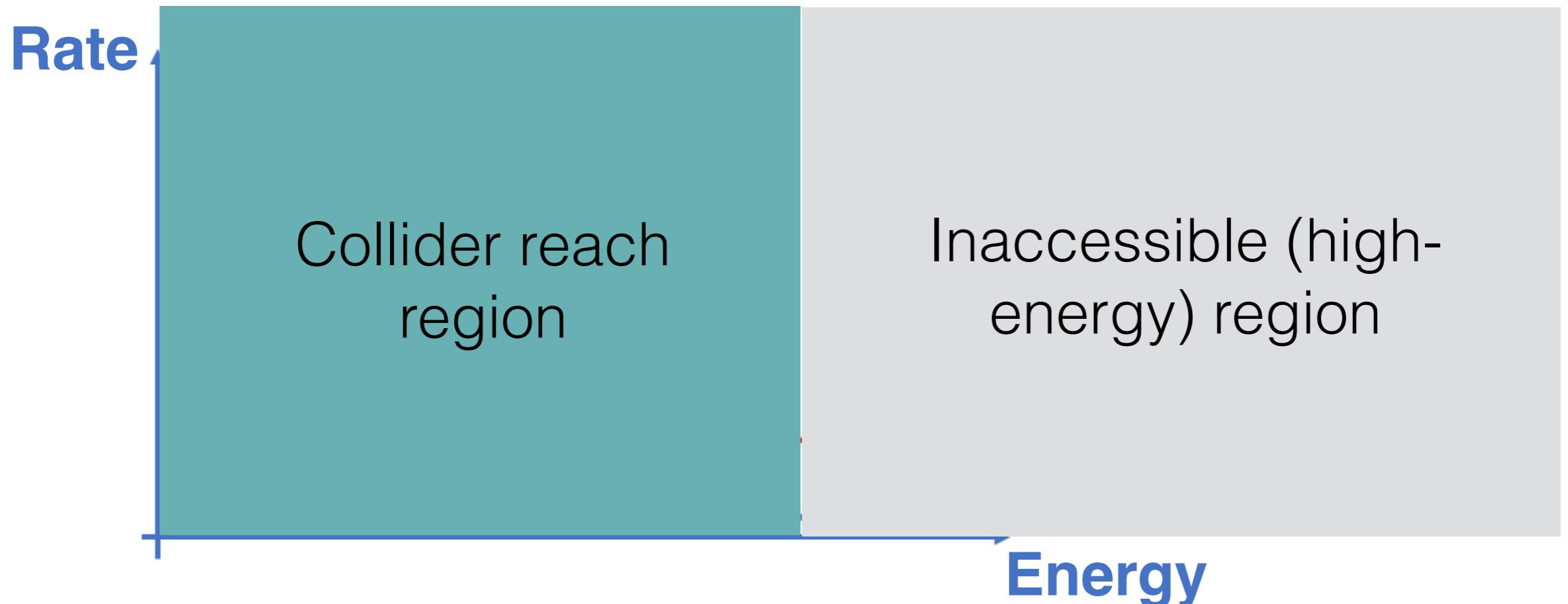
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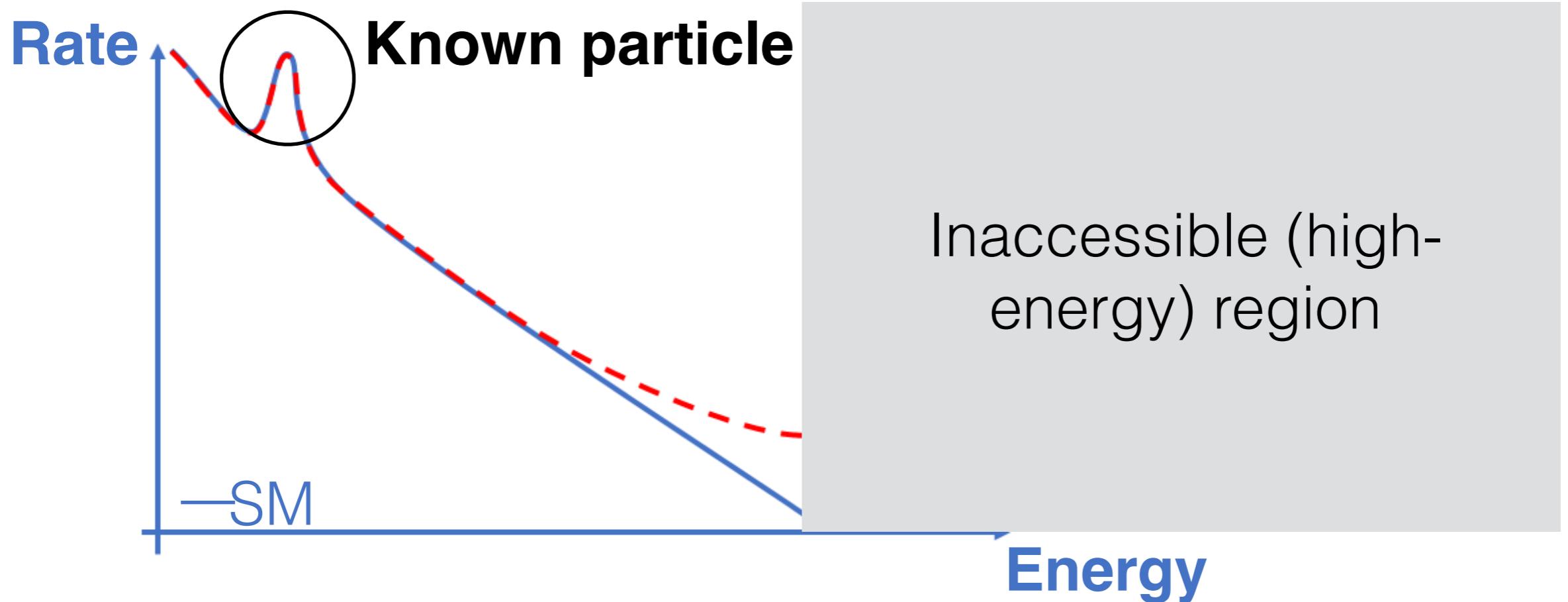


# How to find new physics with EFT?



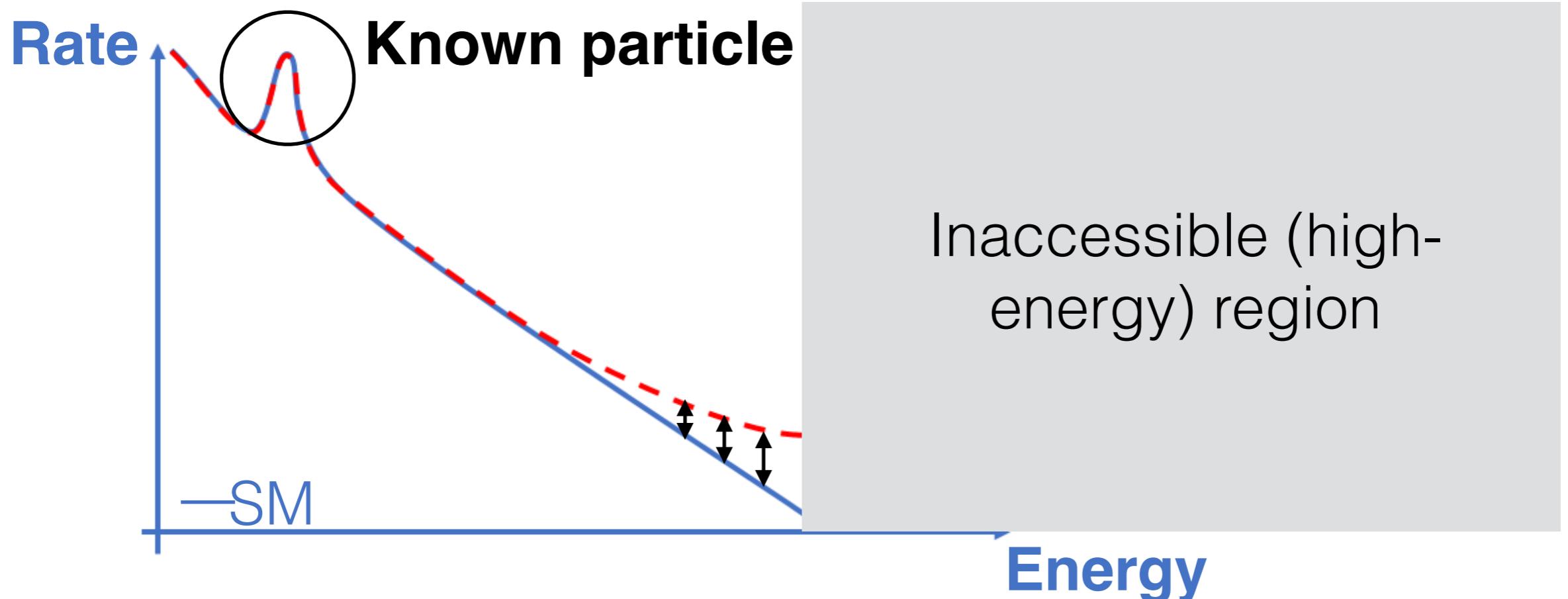
**Effective Field Theory (EFT): The way to probe New Physics beyond the direct collider energy reach**

# How to find new physics with EFT?



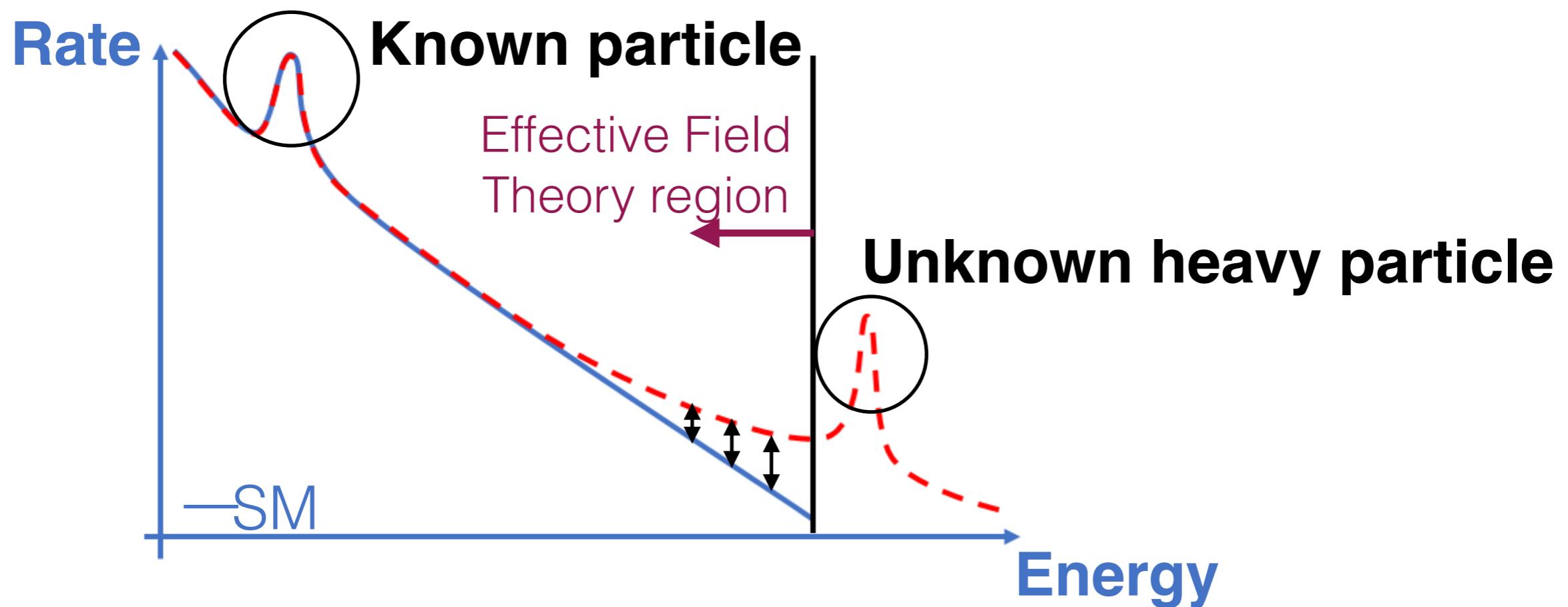
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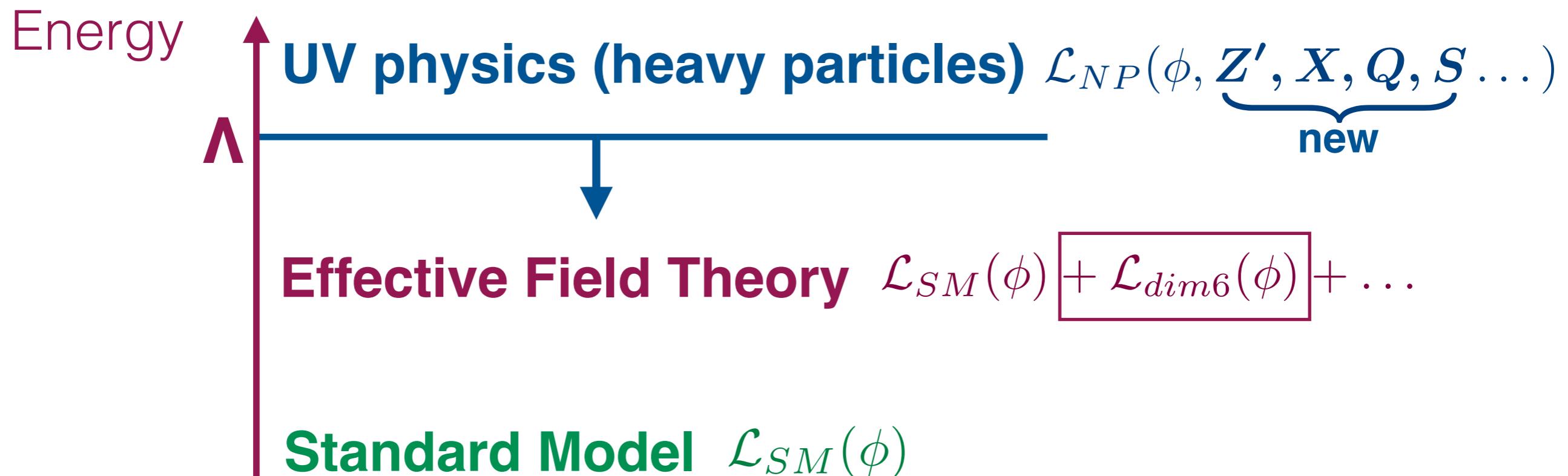
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# How to find new physics with EFT?



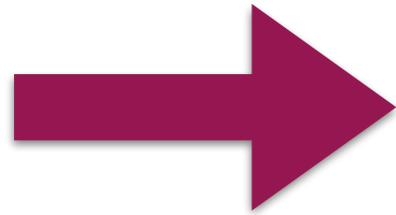
**Effective Field Theory (EFT): The way to probe New Physics beyond the direct collider energy reach**

# Effective Field Theory



Effective Field Theory reveals high energy physics through precise measurements at low energy.

# SMEFT basics



New Interactions of SM particles

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_i \frac{C_i^{(6)} O_i^{(6)}}{\Lambda^2} + \mathcal{O}(\Lambda^{-4})$$

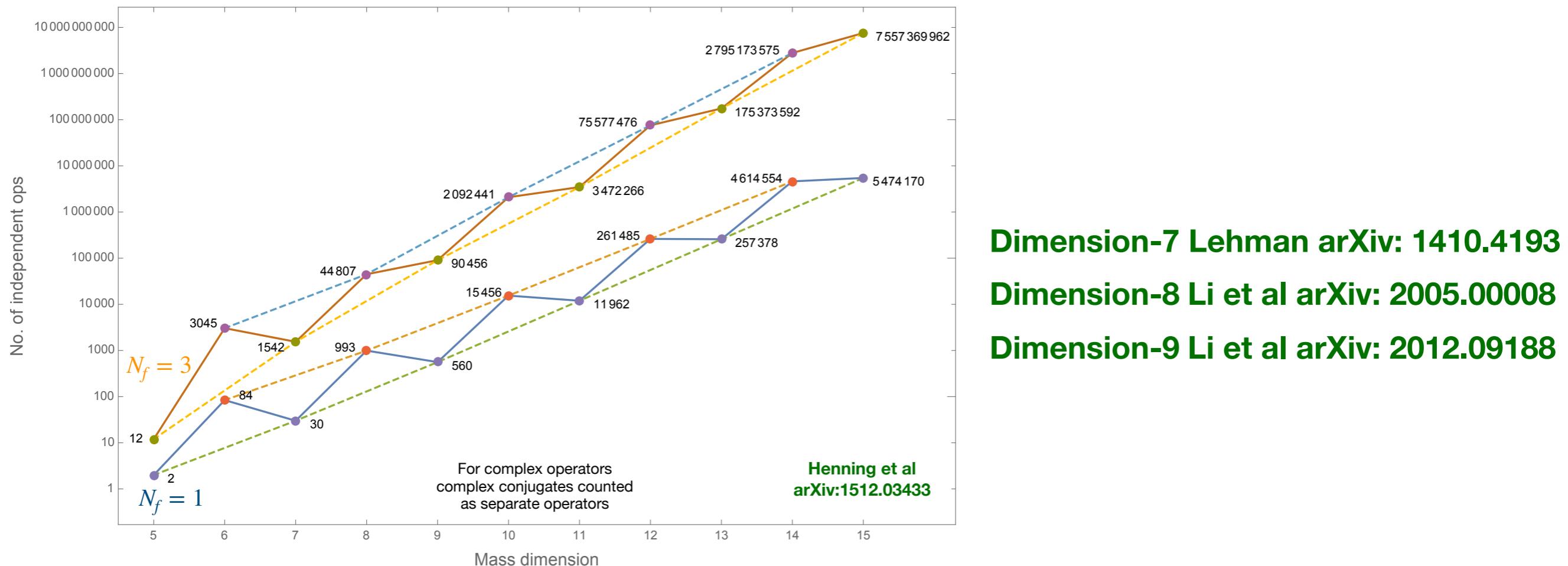
dim-6: 59 operators

Buchmuller, Wyler Nucl.Phys. B268 (1986) 621-653  
Grzadkowski et al arXiv:1008.4884

X <sup>3</sup>		$\varphi^6$ and $\varphi^4 D^2$		$\psi^2 \varphi^3$	
$Q_G$	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_\varphi$	$(\varphi^\dagger \varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger \varphi)(\bar{l}_p e_r \varphi)$
$Q_{\tilde{G}}$	$f^{ABC} \tilde{G}_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\square}$	$(\varphi^\dagger \varphi) \square (\varphi^\dagger \varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger \varphi)(\bar{q}_p u_r \tilde{\varphi})$
$Q_W$	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$(\varphi^\dagger D^\mu \varphi)^*$ $(\varphi^\dagger D_\mu \varphi)$	$Q_{d\varphi}$	$(\varphi^\dagger \varphi)(\bar{q}_p d_r \varphi)$
$Q_{\widetilde{W}}$	$\varepsilon^{IJK} \tilde{W}_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				
X <sup>2</sup> $\varphi^2$		$\psi^2 X \varphi$		$\psi^2 \varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger \varphi G_{\mu\nu}^A G^{A\mu\nu}$	$Q_{eW}$	$(\bar{l}_p \sigma^{\mu\nu} e_r) \tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{l}_p \gamma^\mu l_r)$
$Q_{\varphi \tilde{G}}$	$\varphi^\dagger \varphi \tilde{G}_{\mu\nu}^A G^{A\mu\nu}$	$Q_{eB}$	$(\bar{l}_p \sigma^{\mu\nu} e_r) \varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar{l}_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger \varphi W_{\mu\nu}^I W^{I\mu\nu}$	$Q_{uG}$	$(\bar{q}_p \sigma^{\mu\nu} T^A u_r) \tilde{\varphi} G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{e}_p \gamma^\mu e_r)$
$Q_{\varphi \widetilde{W}}$	$\varphi^\dagger \varphi \tilde{W}_{\mu\nu}^I W^{I\mu\nu}$	$Q_{uW}$	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tau^I \tilde{\varphi} W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{q}_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger \varphi B_{\mu\nu} B^{\mu\nu}$	$Q_{uB}$	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tilde{\varphi} B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar{q}_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi \tilde{B}}$	$\varphi^\dagger \varphi \tilde{B}_{\mu\nu} B^{\mu\nu}$	$Q_{dG}$	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) \varphi G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{u}_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger \tau^I \varphi W_{\mu\nu}^I B^{\mu\nu}$	$Q_{dW}$	$(\bar{q}_p \sigma^{\mu\nu} d_r) \tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{d}_p \gamma^\mu d_r)$
$Q_{\varphi \widetilde{W}B}$	$\varphi^\dagger \tau^I \varphi \tilde{W}_{\mu\nu}^I B^{\mu\nu}$	$Q_{dB}$	$(\bar{q}_p \sigma^{\mu\nu} d_r) \varphi B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\tilde{\varphi}^\dagger D_\mu \varphi)(\bar{u}_p \gamma^\mu d_r)$

$(\bar{L}L)(\bar{L}L)$		$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$	
$Q_{ll}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	$Q_{ee}$	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t)$	$Q_{le}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	$Q_{uu}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t)$	$Q_{lu}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	$Q_{dd}$	$(\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t)$	$Q_{ld}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	$Q_{eu}$	$(\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t)$	$Q_{qe}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar{l}_p \gamma_\mu \tau^I l_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	$Q_{ed}$	$(\bar{e}_p \gamma_\mu e_r)(\bar{d}_s \gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{u}_s \gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{d}_s \gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{u}_s \gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar{u}_p \gamma_\mu T^A u_r)(\bar{d}_s \gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{d}_s \gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{d}_s \gamma^\mu T^A d_t)$
$(\bar{L}R)(\bar{R}L)$ and $(\bar{L}R)(\bar{L}R)$		B-violating			
$Q_{ledq}$	$(\bar{l}_p^j e_r)(\bar{d}_s q_t^j)$	$Q_{duq}$	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jk} [(d_p^\alpha)^T C u_r^\beta] [(q_s^\gamma)^T C l_t^k]$		
$Q_{quqd}^{(1)}$	$(\bar{q}_p^j u_r) \varepsilon_{jk} (\bar{q}_s^k d_t)$	$Q_{qqu}$	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jk} [(q_p^\alpha)^T C q_r^{\beta k}] [(u_s^\gamma)^T C e_t]$		
$Q_{quqd}^{(8)}$	$(\bar{q}_p^j T^A u_r) \varepsilon_{jk} (\bar{q}_s^k T^A d_t)$	$Q_{qqq}^{(1)}$	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jk} \varepsilon_{mn} [(q_p^\alpha)^T C q_r^{\beta k}] [(q_s^\gamma)^T C l_t^n]$		
$Q_{lequ}^{(1)}$	$(\bar{l}_p^j e_r) \varepsilon_{jk} (\bar{q}_s^k u_t)$	$Q_{qqq}^{(3)}$	$\varepsilon^{\alpha\beta\gamma} (\tau^I \varepsilon)_{jk} (\tau^I \varepsilon)_{mn} [(q_p^\alpha)^T C q_r^{\beta k}] [(q_s^\gamma)^T C l_t^n]$		
$Q_{lequ}^{(3)}$	$(\bar{l}_p^j \sigma_{\mu\nu} e_r) \varepsilon_{jk} (\bar{q}_s^k \sigma^{\mu\nu} u_t)$	$Q_{duu}$	$\varepsilon^{\alpha\beta\gamma} [(d_p^\alpha)^T C u_r^\beta] [(u_s^\gamma)^T C e_t]$		

# SMEFT@higher dimensions



**Code to generate a basis (non-redundant set) at arbitrary dimension in SMEFT:**

**Li et al arXiv:2201.04639**

# SMEFT@dim6

59 operators in flavour universal scenario

**2499** if fully general

# SMEFT@dim6

59 operators in flavour universal scenario

**2499** if fully general 

59 operators in flavour universal scenario

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In practice:

- Not all operators enter in all observables
- Many observables available
- We can make “reasonable” assumptions

59 operators in flavour universal scenario

2499 if fully general 

In practice:

- Not all operators enter in all observables
- Many observables available
- We can make “reasonable” assumptions
  - no B,L violation
  - Flavour symmetries (universality, MFV)
  - CP conservation

**<100 operators for the LHC**

59 operators in flavour universal scenario

2499 if fully general 

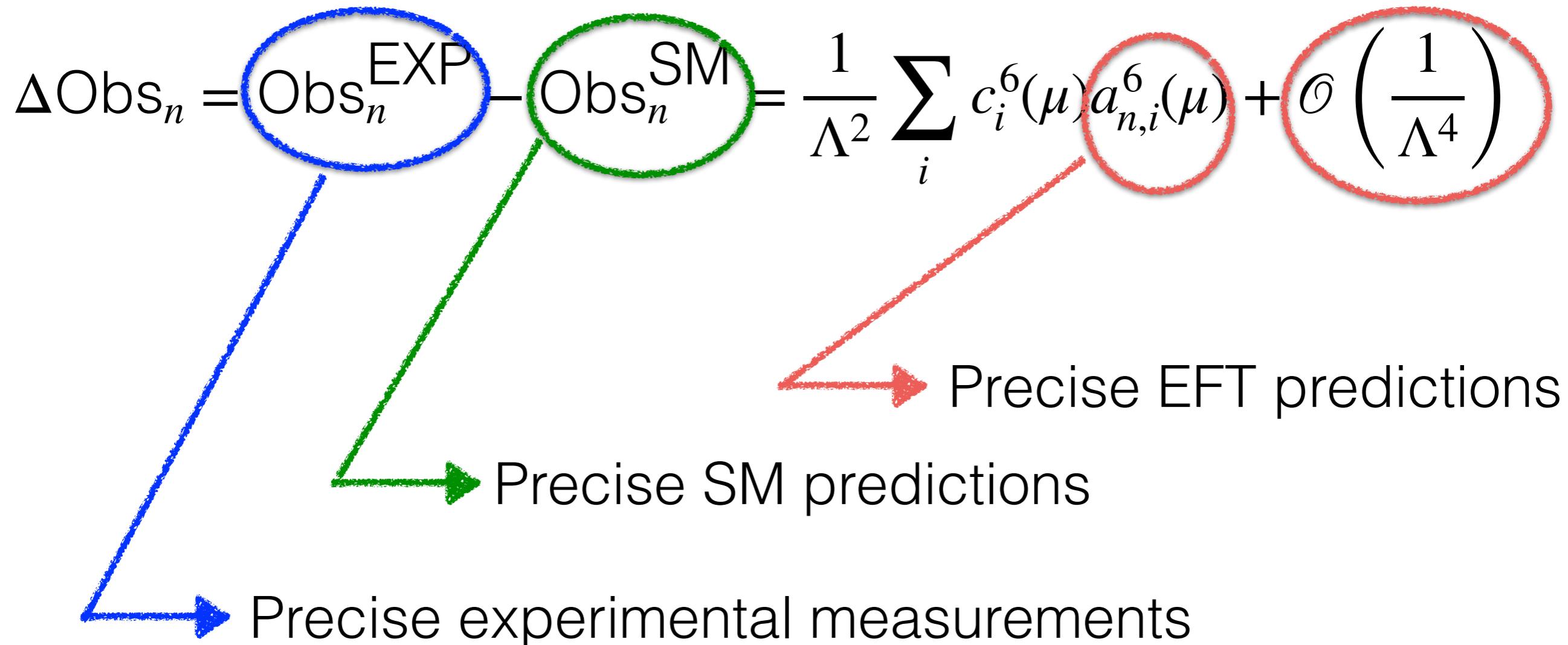
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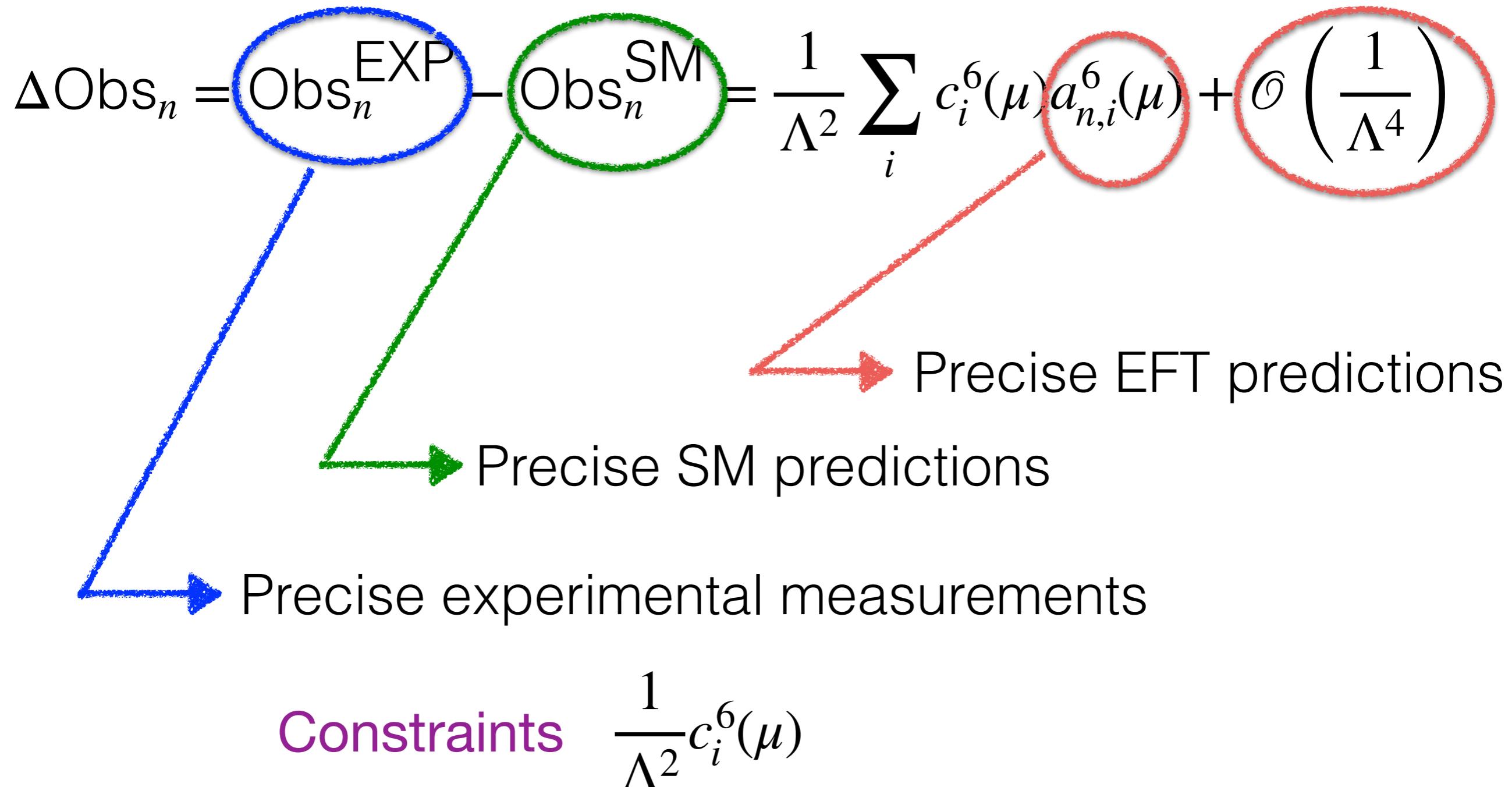
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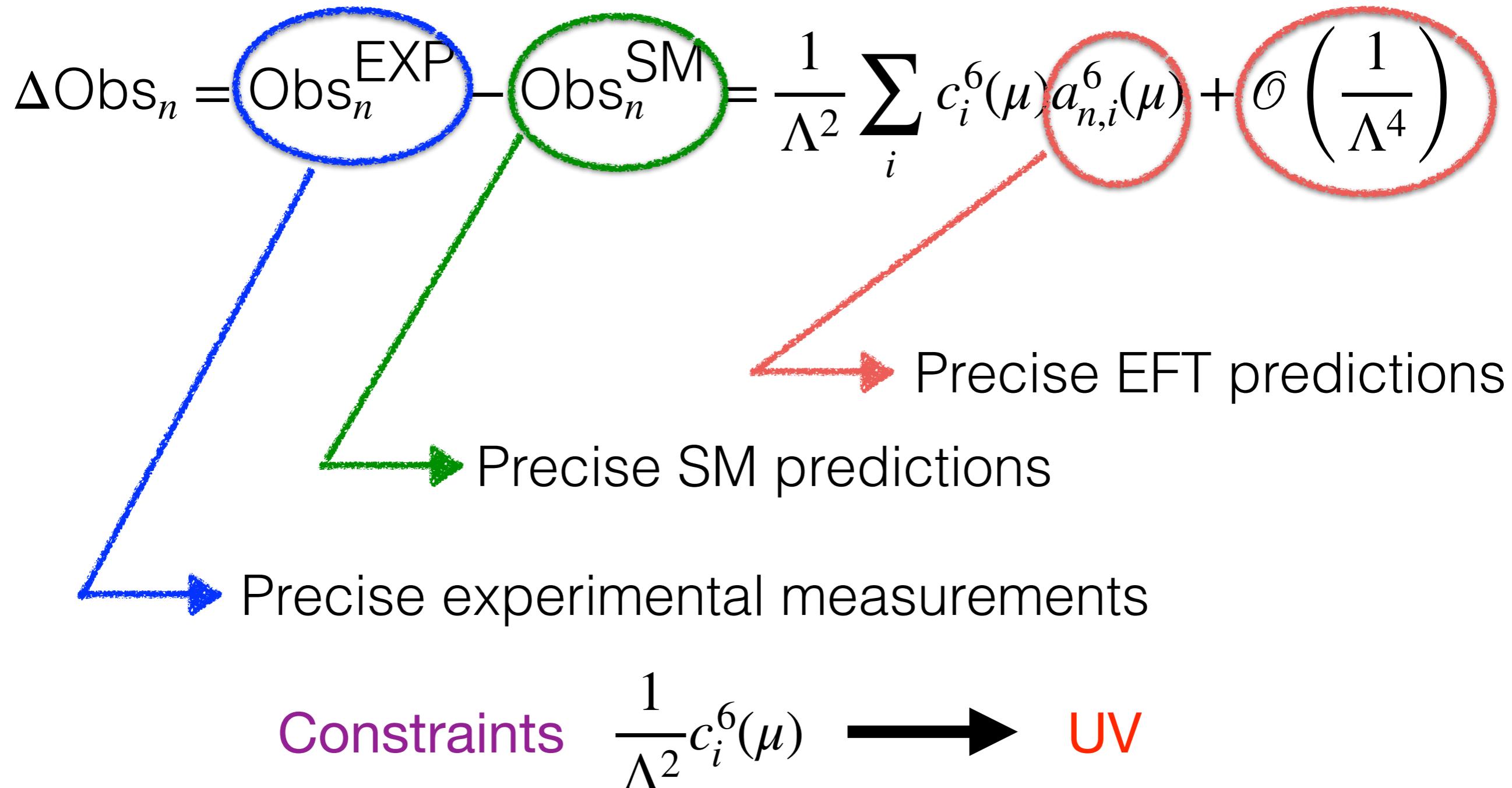
# EFT pathway to New Physics



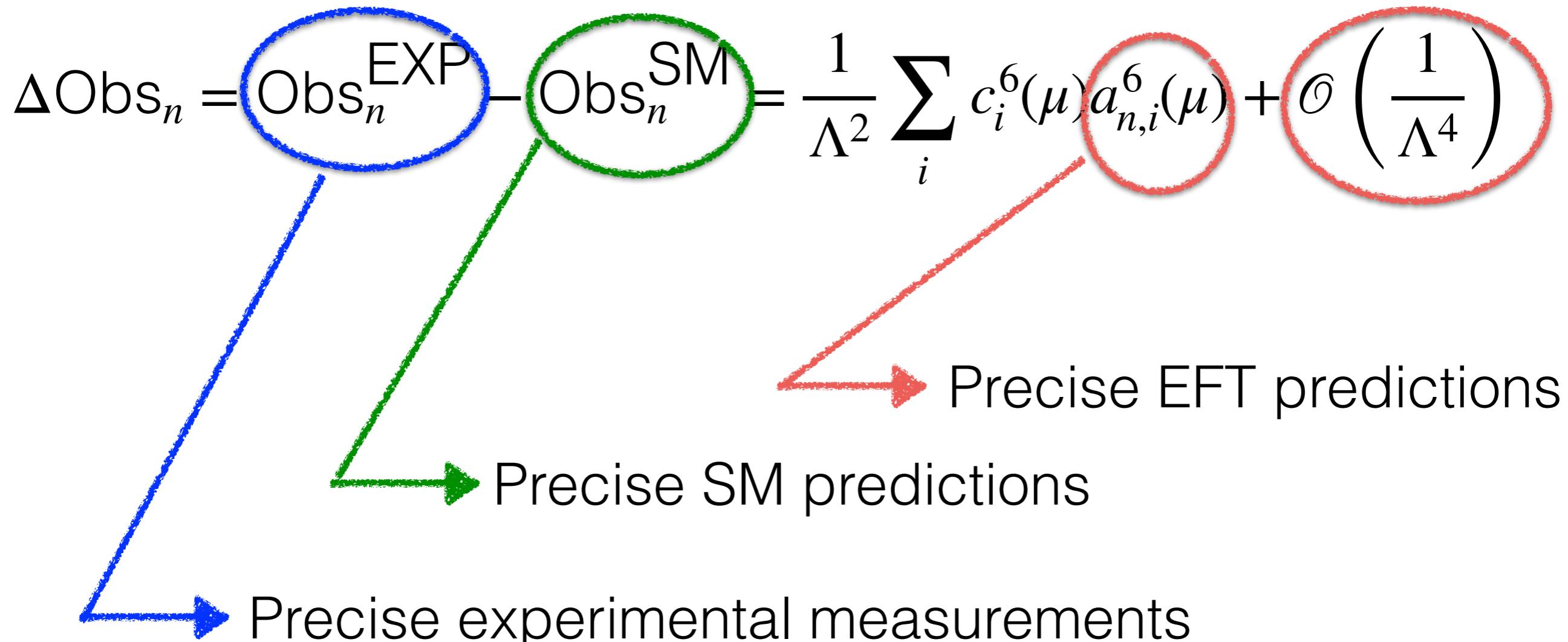
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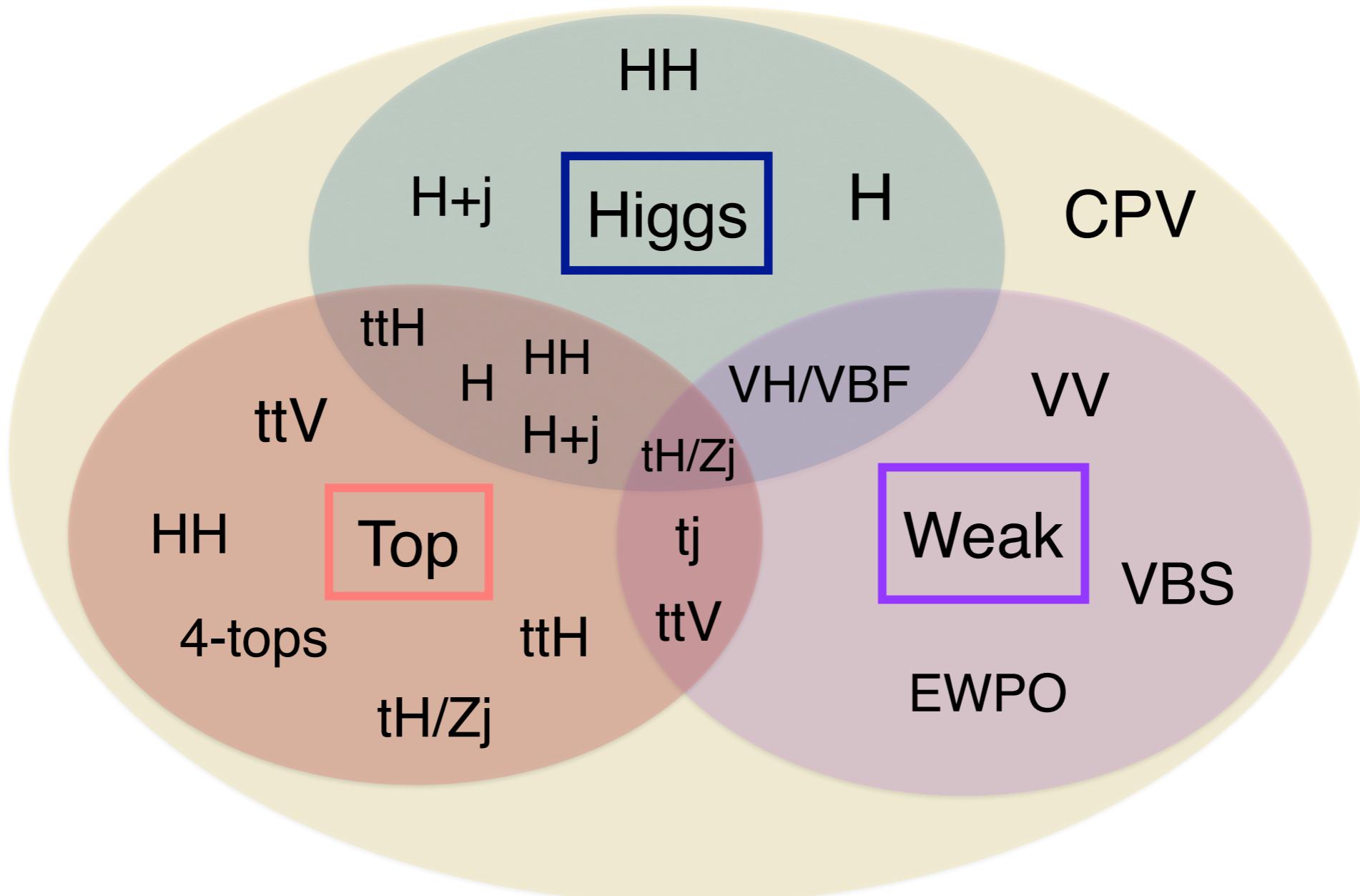
# EFT pathway to New Physics



Constraints     $\frac{1}{\Lambda^2} c_i^6(\mu) \longrightarrow \text{UV}$

Huge effort to improve each one of these steps!

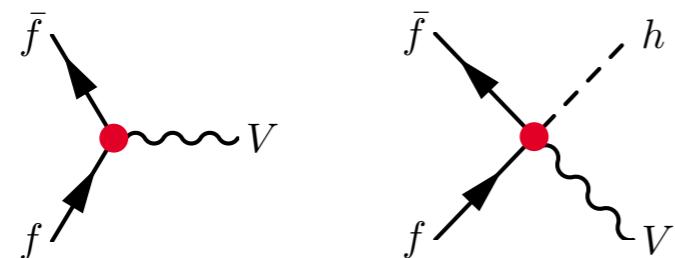
# Global nature of EFT



Adapted from K. Mimasu

# Operator examples

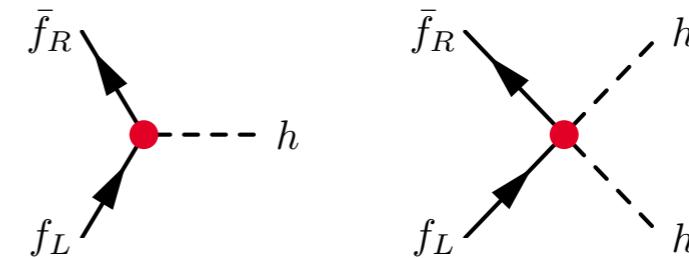
currents  $i(\phi^\dagger \overleftrightarrow{D}^\mu \phi)(\bar{Q}\gamma^\mu Q)$



- Shift SM  $f\bar{f}V$  couplings
- $f\bar{f}Vh$  contact interactions

$C_{\phi f}$

Yukawa  $(\bar{q} t \tilde{\phi})(\phi^\dagger \phi)$

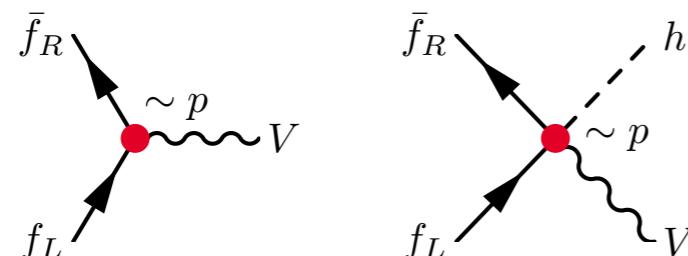


- Decouple  $m_t$  &  $y_t$
- $t\bar{t}hh(h)$  contact interactions

$C_{t\phi}$

dipole

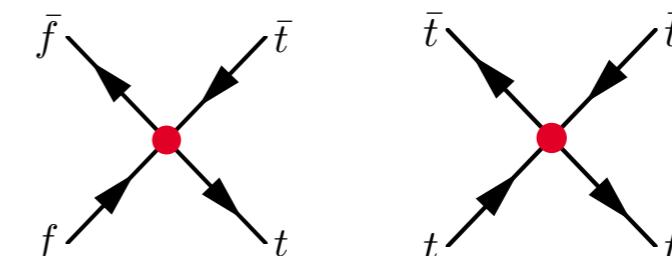
$(\bar{q} \sigma_{\mu\nu} t \tilde{\phi})V^{\mu\nu}$



- Chirality flipping  $f\bar{f}V$  couplings
- $f\bar{f}V(V)h$  contact interactions
- $W, B$  &  $G$  fields

$C_{tV}$

4 fermion  $(\bar{q}\gamma_\mu q)(\bar{Q}\gamma^\mu Q)$



$C_{ft}$

- Contact interactions
- 2-heavy-2-light or 4-heavy
- Numerous ( $\sim O(20)$  w/ top)

+Purely bosonic operators

From K. Mimasu

# EFT in top pair production

4-fermion operators

$$O_{Qq}^{1,8} = (\bar{Q}\gamma_\mu T^A Q)(\bar{q}_i \gamma^\mu T^A q_i)$$

$$O_{Qq}^{3,8} = (\bar{Q}\gamma_\mu T^A \tau^I Q)(\bar{q}_i \gamma^\mu T^A \tau^I q_i)$$

$$O_{tu}^8 = (\bar{t}\gamma_\mu T^A t)(\bar{u}_i \gamma^\mu T^A u_i)$$

$$O_{td}^8 = (\bar{t}\gamma^\mu T^A t)(\bar{d}_i \gamma_\mu T^A d_i)$$

$$O_{Qu}^8 = (\bar{Q}\gamma^\mu T^A Q)(\bar{u}_i \gamma_\mu T^A u_i)$$

$$O_{Qd}^8 = (\bar{Q}\gamma^\mu T^A Q)(\bar{d}_i \gamma_\mu T^A d_i)$$

$$O_{tq}^8 = (\bar{q}_i \gamma^\mu T^A q_i)(\bar{t}\gamma_\mu T^A t)$$

$$O_{Qq}^{1,1} = (\bar{Q}\gamma_\mu Q)(\bar{q}_i \gamma^\mu q_i)$$

$$O_{Qq}^{3,1} = (\bar{Q}\gamma_\mu \tau^I Q)(\bar{q}_i \gamma^\mu \tau^I q_i)$$

$$O_{tu}^1 = (\bar{t}\gamma_\mu t)(\bar{u}_i \gamma^\mu u_i)$$

$$O_{td}^1 = (\bar{t}\gamma^\mu t)(\bar{d}_i \gamma_\mu d_i) ;$$

$$O_{Qu}^1 = (\bar{Q}\gamma^\mu Q)(\bar{u}_i \gamma_\mu u_i)$$

$$O_{Qd}^1 = (\bar{Q}\gamma^\mu Q)(\bar{d}_i \gamma_\mu d_i)$$

$$O_{tq}^1 = (\bar{q}_i \gamma^\mu q_i)(\bar{t}\gamma_\mu t) ;$$

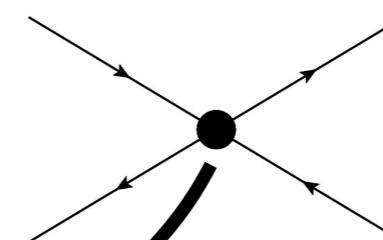
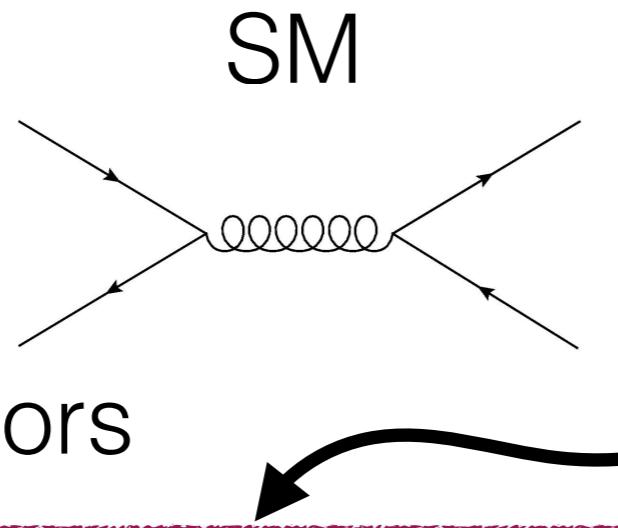
Octets

Singlets

Different chiralities and colour structures

EFT

Cross-section



$c_t$	$\mathcal{O}(\Lambda^{-2})$	
	LO	NLO
$c_{tu}^8$	$4.27^{+11\%}_{-9\%}$	$4.06^{+1\%}_{-3\%}$
$c_{td}^8$	$2.79^{+11\%}_{-9\%}$	$2.77^{+1\%}_{-3\%}$
$c_{tq}^8$	$6.99^{+11\%}_{-9\%}$	$6.67^{+1\%}_{-3\%}$
$c_{Qu}^8$	$4.26^{+11\%}_{-9\%}$	$3.93^{+1\%}_{-4\%}$
$c_{Qd}^8$	$2.79^{+11\%}_{-9\%}$	$2.93^{+0\%}_{-1\%}$
$c_{Qq}^{8,1}$	$6.99^{+11\%}_{-9\%}$	$6.82^{+1\%}_{-3\%}$
$c_{Qq}^{8,3}$	$1.50^{+10\%}_{-9\%}$	$1.32^{+1\%}_{-3\%}$

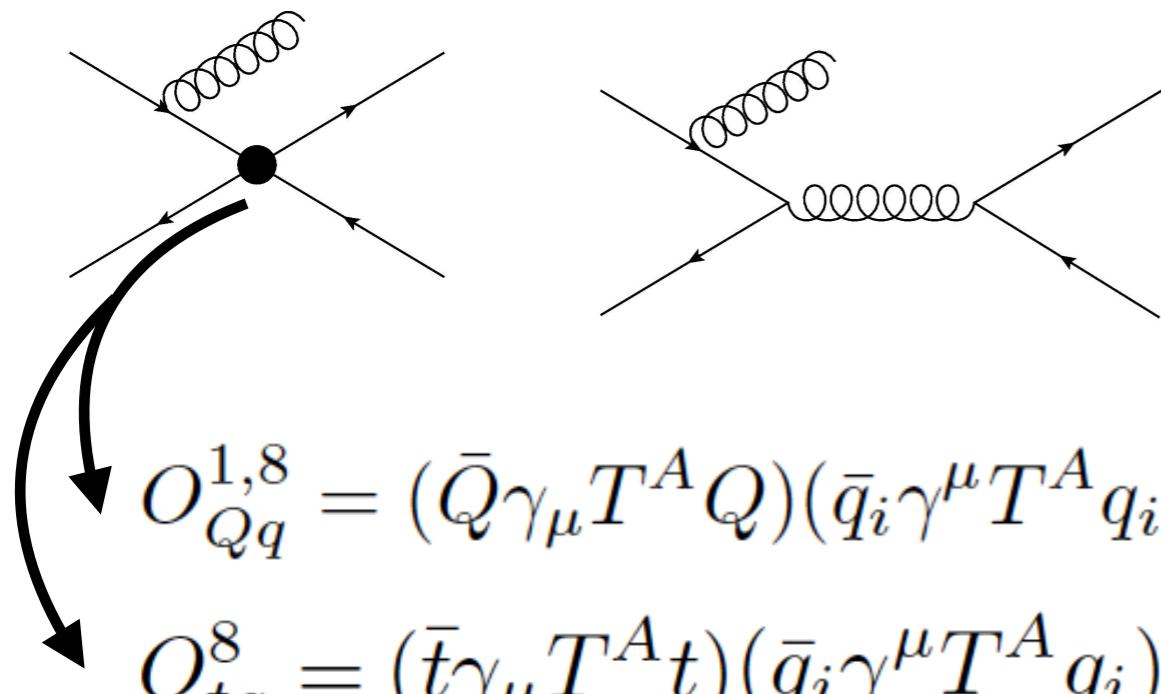
$c_{tu}^1$	$[0.67^{+1\%}_{-1\%}]$	$-0.078(7)^{+31\%}_{-23\%}$	$[0.41^{+13\%}_{-17\%}]$
$c_{td}^1$	$[-0.21^{+1\%}_{-2\%}]$	$-0.306^{+30\%}_{-22\%}$	$[-0.15^{+10\%}_{-13\%}]$
$c_{tq}^1$	$[0.39^{+0\%}_{-1\%}]$	$-0.47^{+24\%}_{-18\%}$	$[0.50^{+3\%}_{-2\%}]$
$c_{Qu}^1$	$[0.33^{+0\%}_{-0\%}]$	$-0.359^{+23\%}_{-17\%}$	$[0.57^{+6\%}_{-5\%}]$
$c_{Qd}^1$	$[-0.11^{+0\%}_{-1\%}]$	$0.023(6)^{+114\%}_{-75\%}$	$[-0.19^{+6\%}_{-5\%}]$
$c_{Qq}^{1,1}$	$[0.57^{+0\%}_{-1\%}]$	$-0.24^{+30\%}_{-22\%}$	$[0.39^{+9\%}_{-12\%}]$
$c_{Qq}^{1,3}$	$[1.92^{+1\%}_{-1\%}]$	$0.088(7)^{+28\%}_{-20\%}$	$[1.05^{+17\%}_{-22\%}]$

Interesting interference patterns

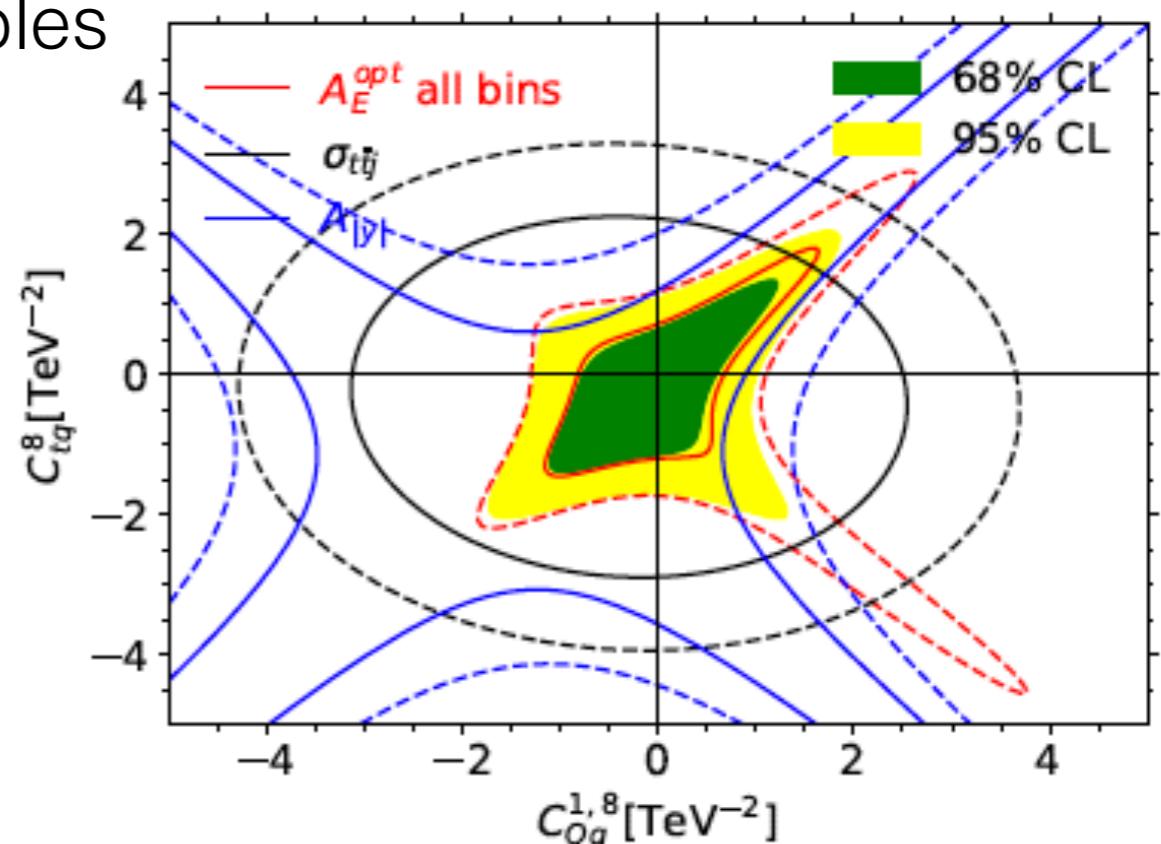
Degrade, Durieux, Maltoni, Mimasu, EV, Zhang arXiv:2008.11743

# Breaking degeneracies

LHC can probe more sensitive observables



Different top chiralities



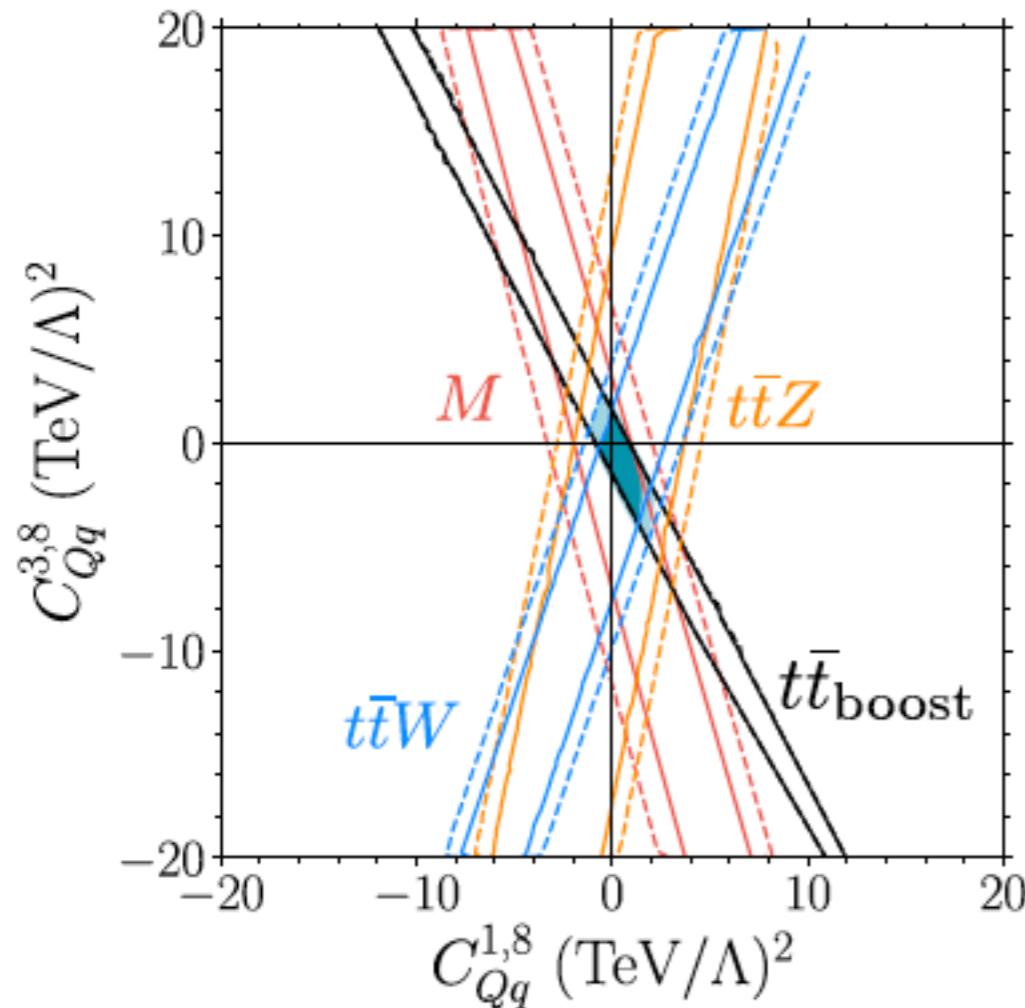
Basan, Berta, Masetti, EV, Westhoff arXiv:2001.07225

An asymmetry observable

$$A_E(\theta_j) = \frac{\sigma_{t\bar{t}j}(\theta_j, \Delta E > 0) - \sigma_{t\bar{t}j}(\theta_j, \Delta E < 0)}{\sigma_{t\bar{t}j}(\theta_j, \Delta E > 0) + \sigma_{t\bar{t}j}(\theta_j, \Delta E < 0)}$$

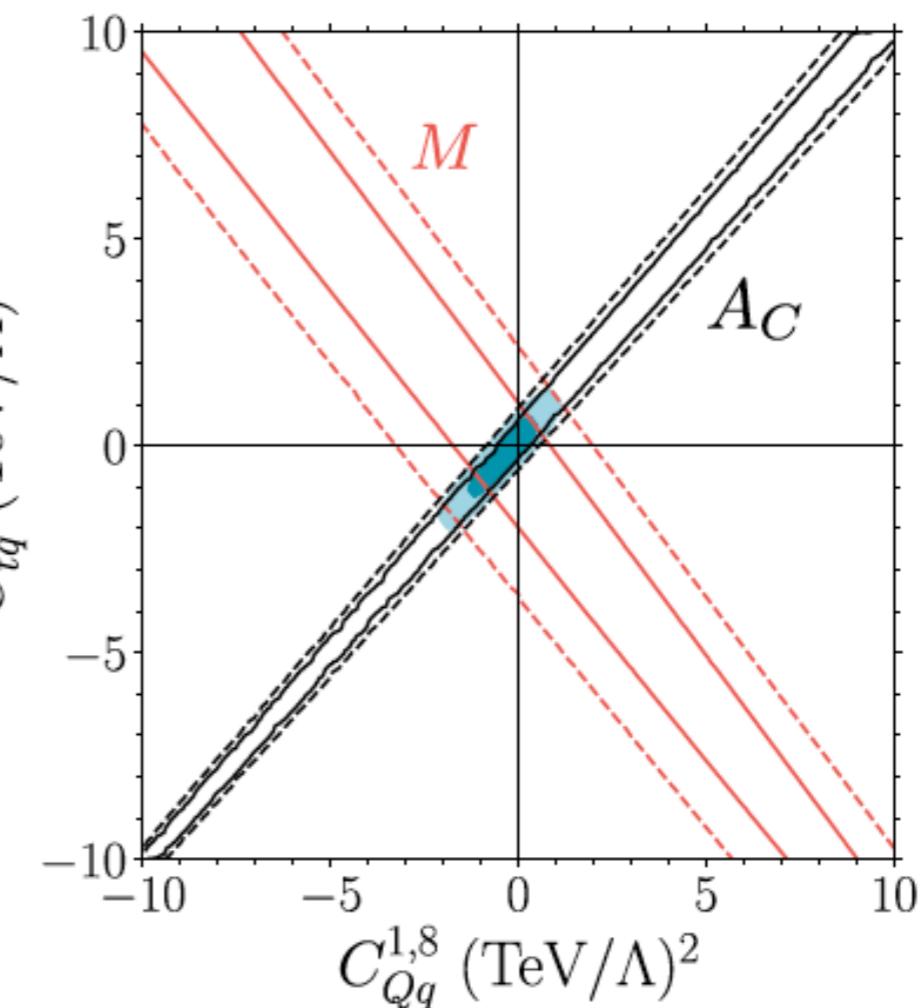
Optimised sensitivity  
Broken degeneracies

# The impact of multiple measurements



$$O_{Qq}^{1,8} = (\bar{Q}\gamma_\mu T^A Q)(\bar{q}_i \gamma^\mu T^A q_i)$$

$$O_{Qq}^{3,8} = (\bar{Q}\gamma_\mu T^A \tau^I Q)(\bar{q}_i \gamma^\mu T^A \tau^I q_i)$$



$$O_{tq}^8 = (\bar{q}_i \gamma^\mu T^A q_i)(\bar{t} \gamma_\mu T^A t)$$

$$O_{Qq}^{1,8} = (\bar{Q}\gamma_\mu T^A Q)(\bar{q}_i \gamma^\mu T^A q_i)$$

Brivio, Bruggisser, Maltoni, Moutafis, Plehn, EV, Westhoff, Zhang arXiv:1910.03606

# Global fit observables

Top

Higgs

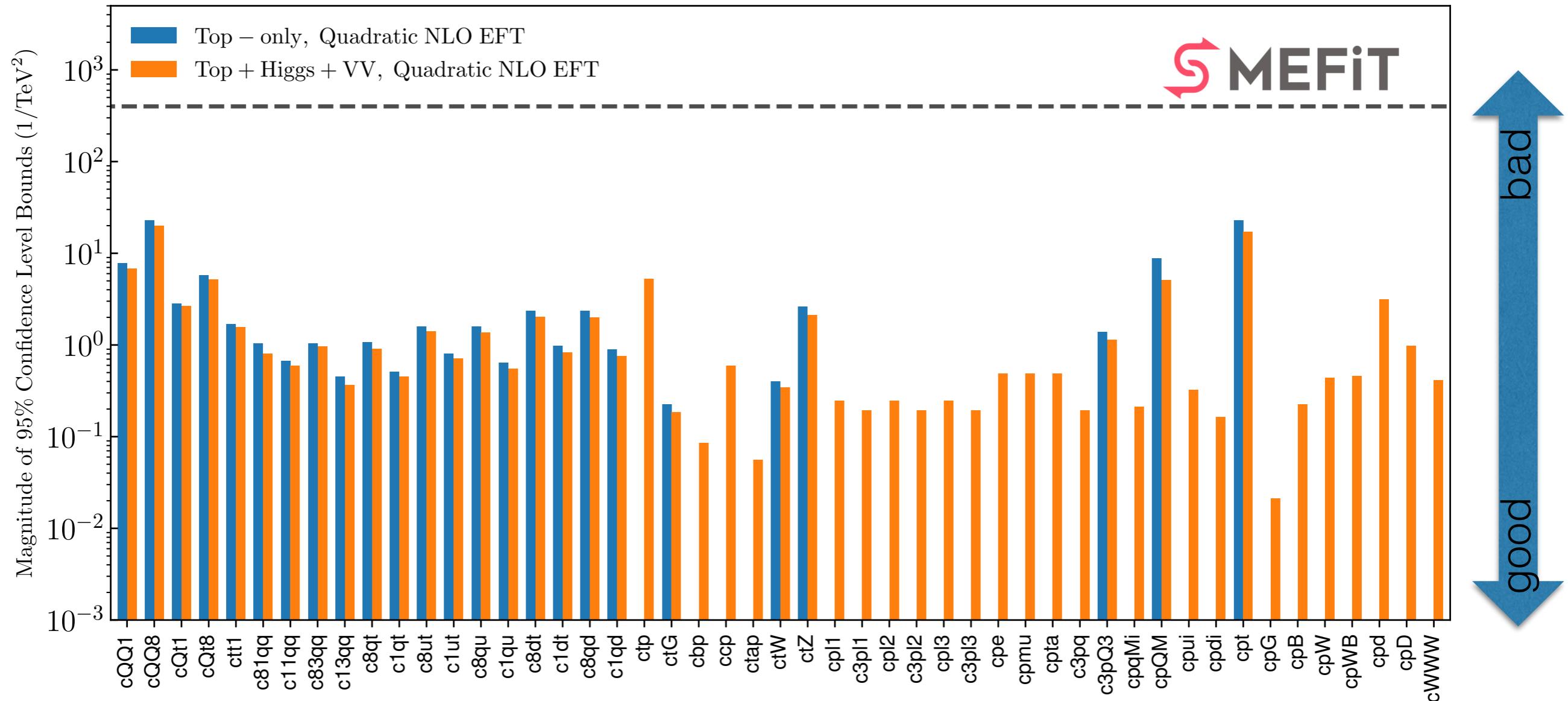
EW

Category	Processes	$n_{\text{dat}}$
Top quark production	$t\bar{t}$ (inclusive)	94
	$t\bar{t}Z, t\bar{t}W$	14
	single top (inclusive)	27
	$tZ, tW$	9
	$t\bar{t}t\bar{t}, t\bar{t}b\bar{b}$	6
	<b>Total</b>	<b>150</b>
Higgs production and decay	Run I signal strengths	22
	Run II signal strengths	40
	Run II, differential distributions & STXS	35
	<b>Total</b>	<b>97</b>
Diboson production	LEP-2	40
	LHC	30
	<b>Total</b>	<b>70</b>
Baseline dataset	<b>Total</b>	<b>317</b>



Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

# Global fit results



Bounds vary from operator to operator! Lots of information

Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

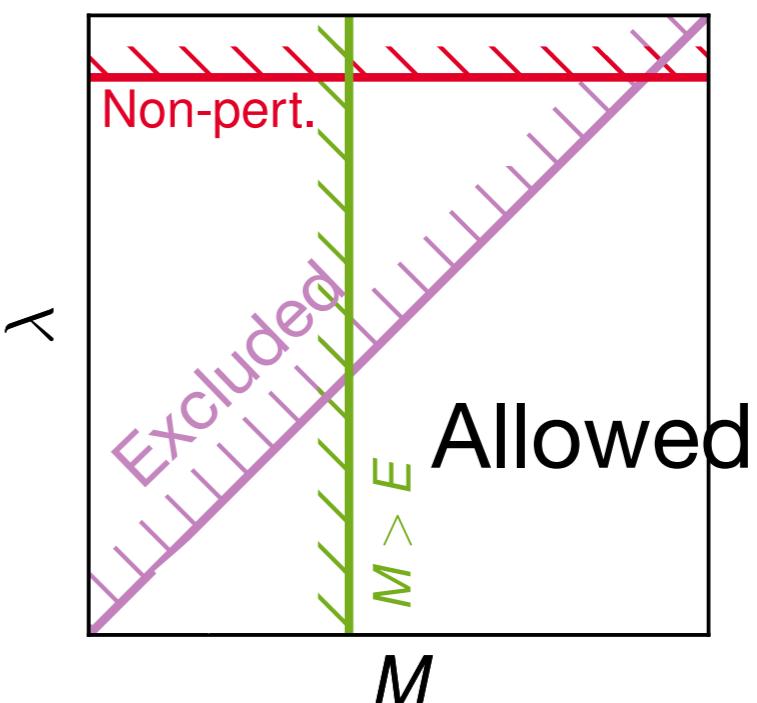
# What do we learn from global fits?

Bounds on new physics scale vary from 0.1 TeV (unconstrained) to 10s of TeV.

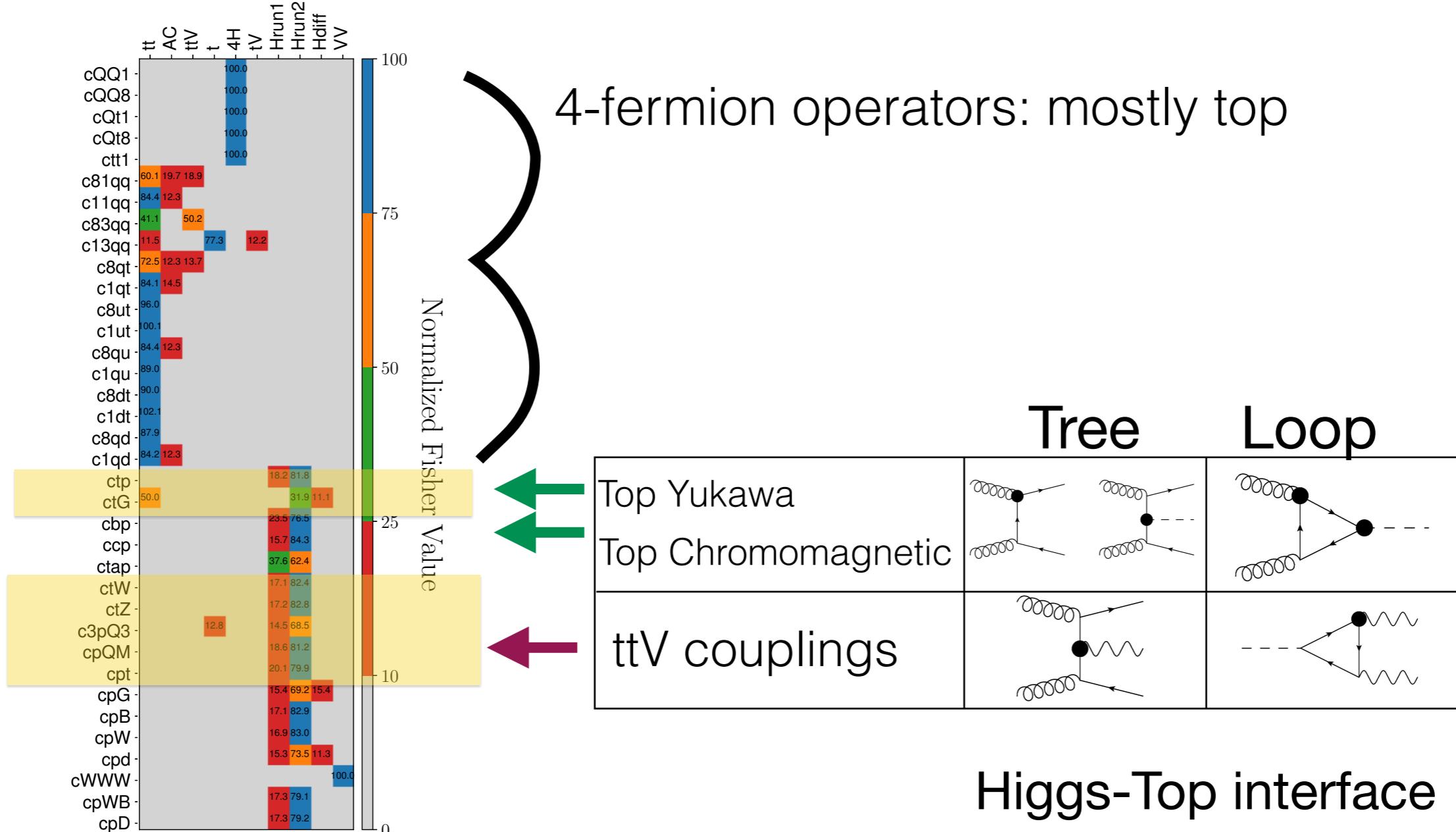
Bounds depend on:

- the operator
- assumption of a strongly or weakly coupled theory
- individual or marginalised bounds (reality is somewhere in-between)
- linear or quadratic bounds

$$\frac{c_i^6(\mu)}{\Lambda^2} = \frac{\lambda^2}{M^2} < X$$



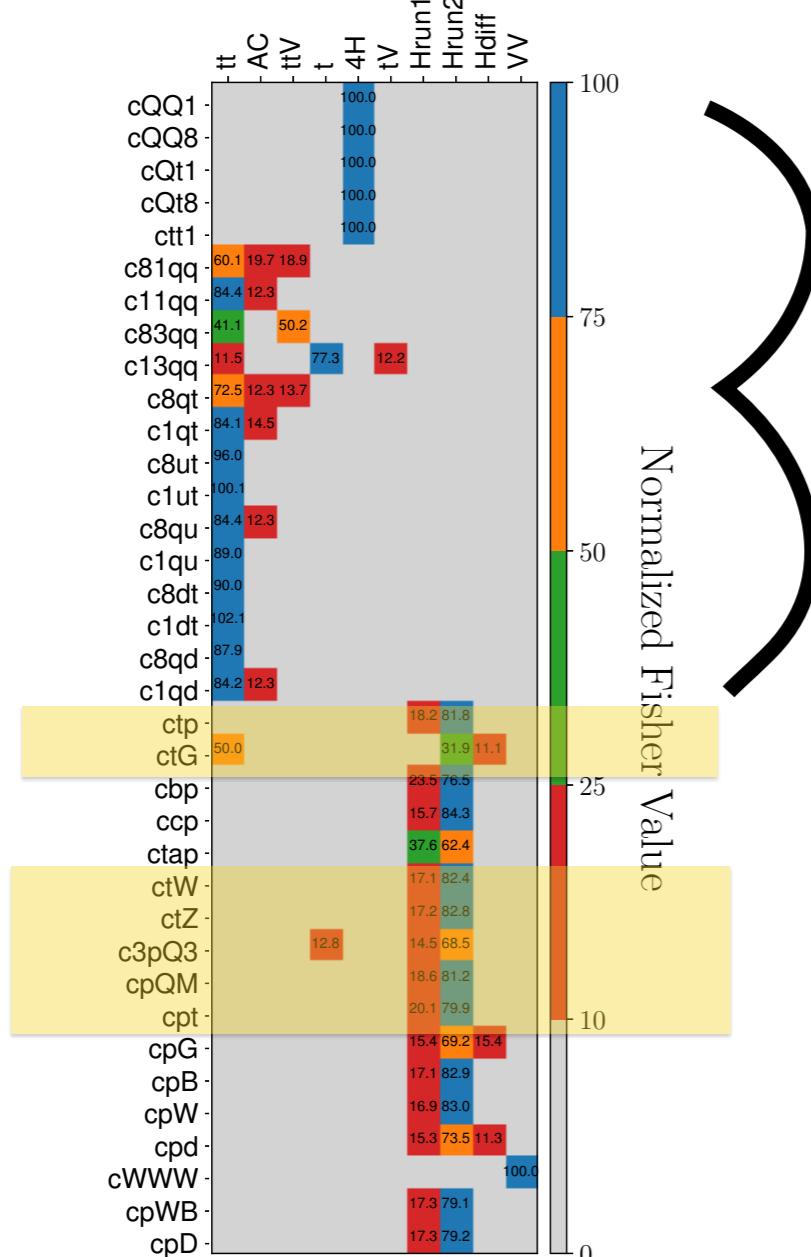
# Where is most information from?



Fisher information table

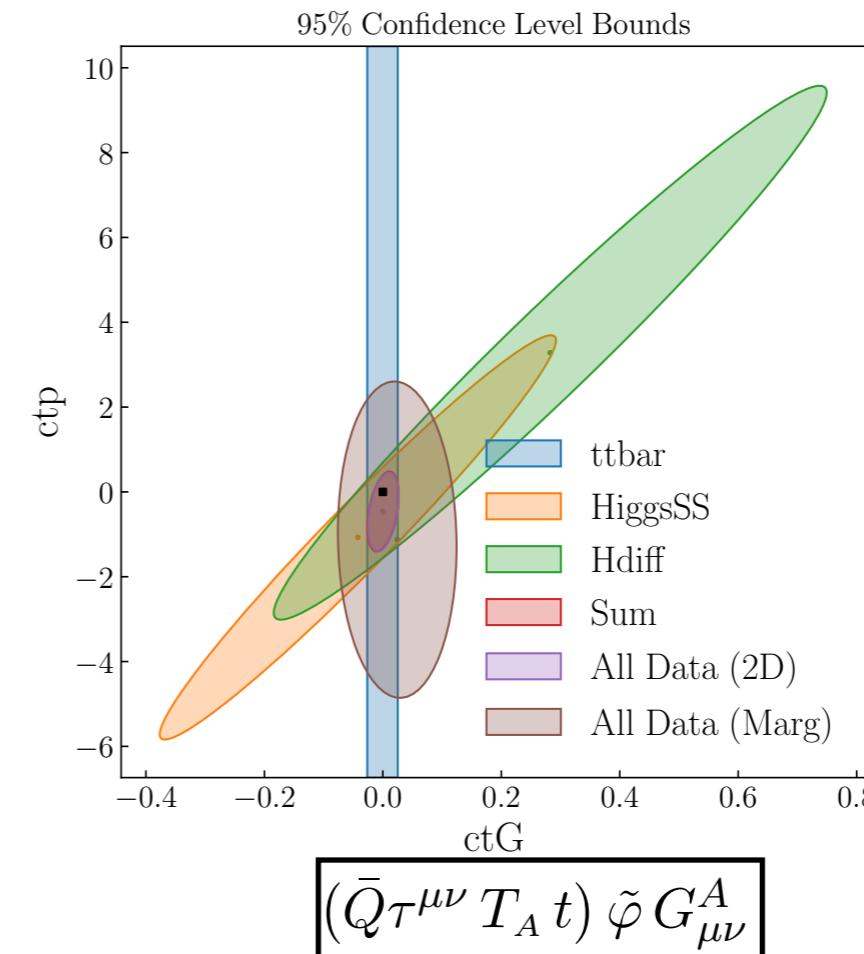
Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

# Where is most information from?



4-fermion operators: mostly top

$$(\varphi^\dagger \varphi) \bar{Q} t \tilde{\varphi}$$



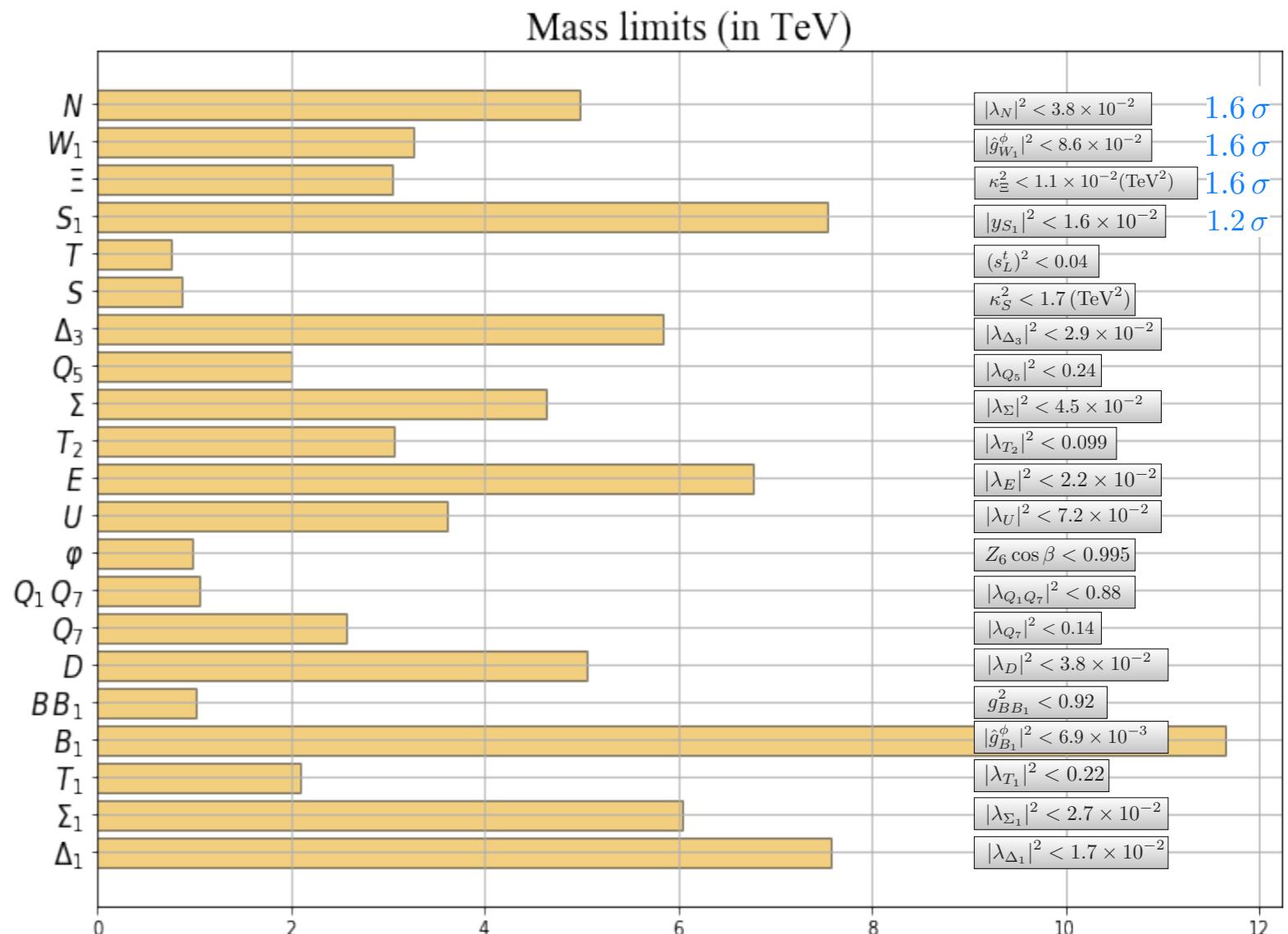
$$(\bar{Q} \tau^{\mu\nu} T_A t) \tilde{\varphi} G_{\mu\nu}^A$$

Fisher information table

Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

# What can we learn from these fits?

- EFT bounds translate to constraints on parameters of UV models
- Simplest case: single-field extensions of the SM



Ellis, Madigan, Mimasu, Sanz, You arXiv:2012.02779

# Future of global fits

## More observables:

- particle level observables
- spin correlations
- new final states

## More/different operators:

- different flavour assumptions
- dimension-8 operators

## Better EFT predictions

Higher Orders in  $1/\Lambda^4$

- squared dim-6 contributions
- double insertions of dim-6
- dim-8 contributions

Higher Orders in QCD and EW

EFT is a QFT, renormalisable order-by order in  $1/\Lambda^2$

$$\mathcal{O}(\alpha_s, \alpha_{ew}) + \mathcal{O}\left(\frac{1}{\Lambda^2}\right) + \mathcal{O}\left(\frac{\alpha_s}{\Lambda^2}\right) + \mathcal{O}\left(\frac{\alpha_{ew}}{\Lambda^2}\right)$$

# SMEFT of computations at dimension-6

$$\Delta \text{Obs}_n = \text{Obs}_n^{\text{EXP}} - \text{Obs}_n^{\text{SM}} = \sum_i \frac{c_i^6(\mu)}{\Lambda^2} \boxed{a_{n,i}^6(\mu)} + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$$

Tree level: Done (SMEFTsim)

<https://smeftsim.github.io/> Brivio, arXiv: 2012.11343

NLO QCD: ~Done (SMEFT@NLO)

<http://feynrules.irmp.ucl.ac.be/wiki/SMEFTatNLO>  
Degrande, Durieux, Maltoni, Mimasu, EV, Zhang arXiv:2008.11743

NLO EW: Some examples available, needed to probe unconstrained operators.

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How about this  $\mu$ ?

# Running and mixing in SMEFT

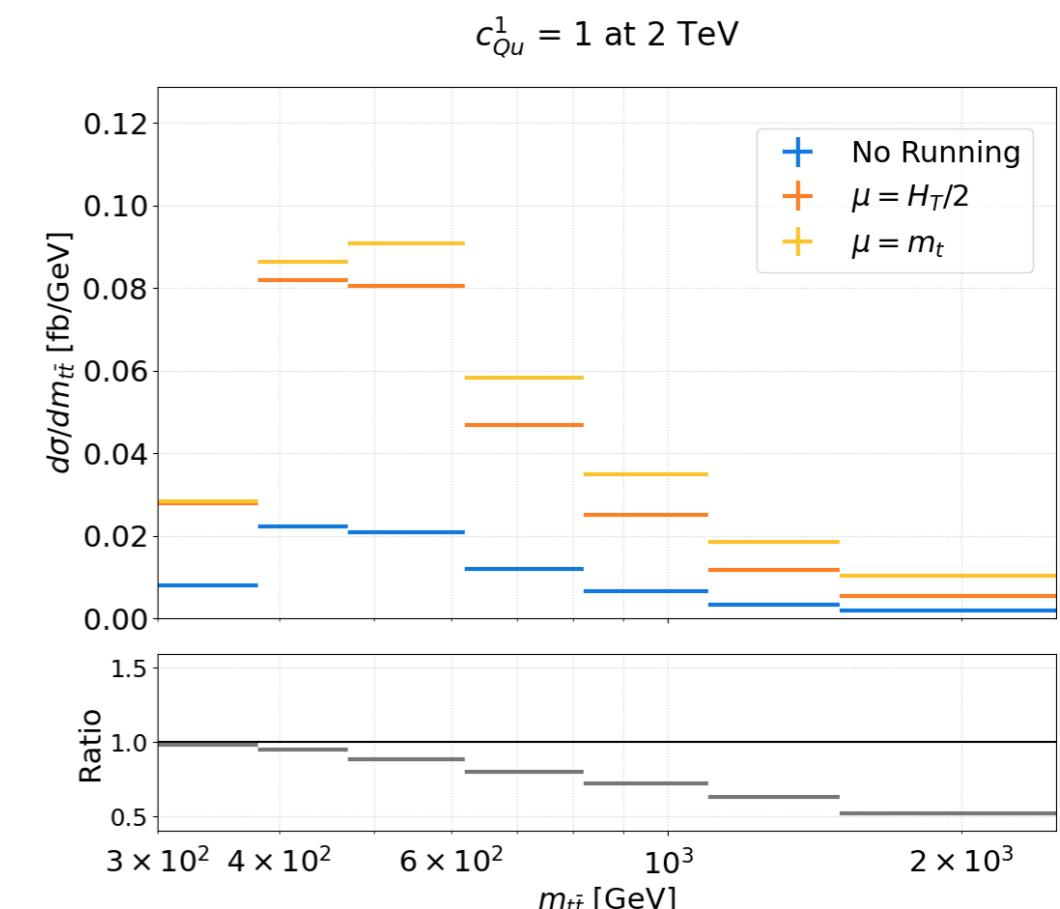
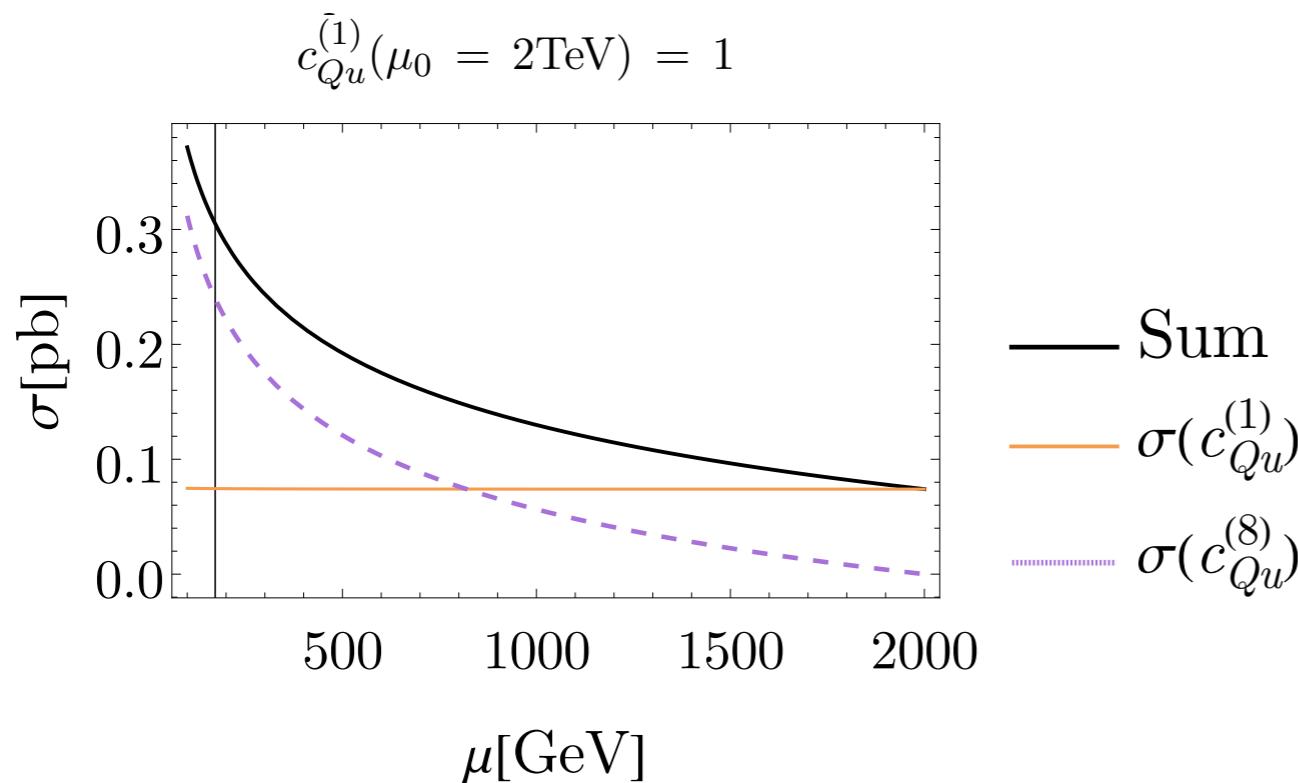
$$\frac{dc_i(\mu)}{d \log \mu} = \gamma_{ij} c_j(\mu)$$

One loop anomalous dimension known:

(Alonso) Jenkins et al arXiv:1308.2627, 1310.4838, 1312.2014

Example: Turn one 1 operator at high-scale

Compute effect on top pair cross-section

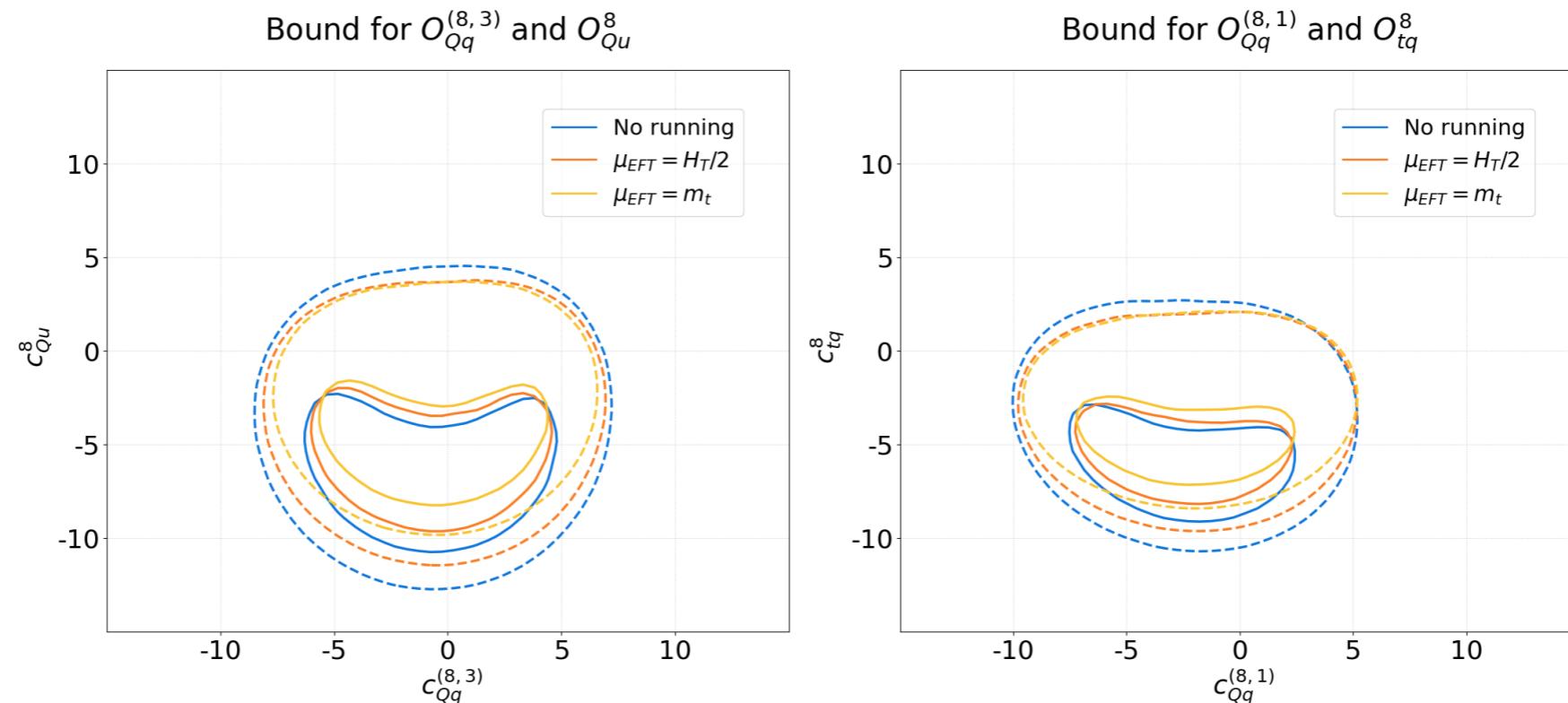


Aoude, Maltoni, Mattelaer, Severi, EV arXiv:2212.05067

# Impact of RGE on constraints

How does running and mixing impacts the constraints?

Top sector fit:



Aoude, Maltoni, Mattelaer, Severi, EV arXiv:2212.05067

Effect becomes more important for differential distributions & measurements with very different scales

# Conclusions

- SMEFT is a consistent way to look for new interactions
- The LHC gives a lot of opportunities to explore SMEFT through a lot of new measurements
- First global fits results already available: important to combine as many processes as possible
- Strong link between Higgs and top sectors
- Precise EFT predictions (NLO, RGE-improved) maximise the potential of EFT probes
- Eventually global fit results give us a clear indication of the scale of potential new physics

Thank you for your attention