UCLouvain
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Top quark physics and EFT

Celine Degrande

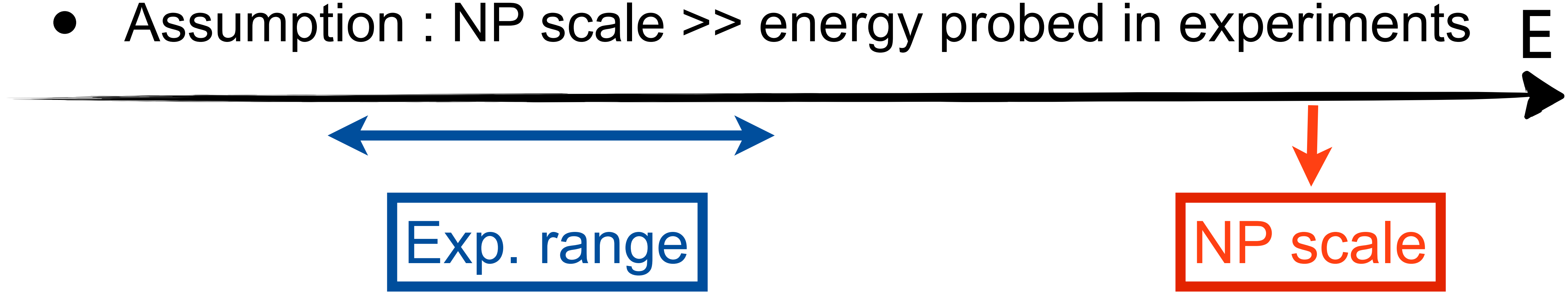
Plan

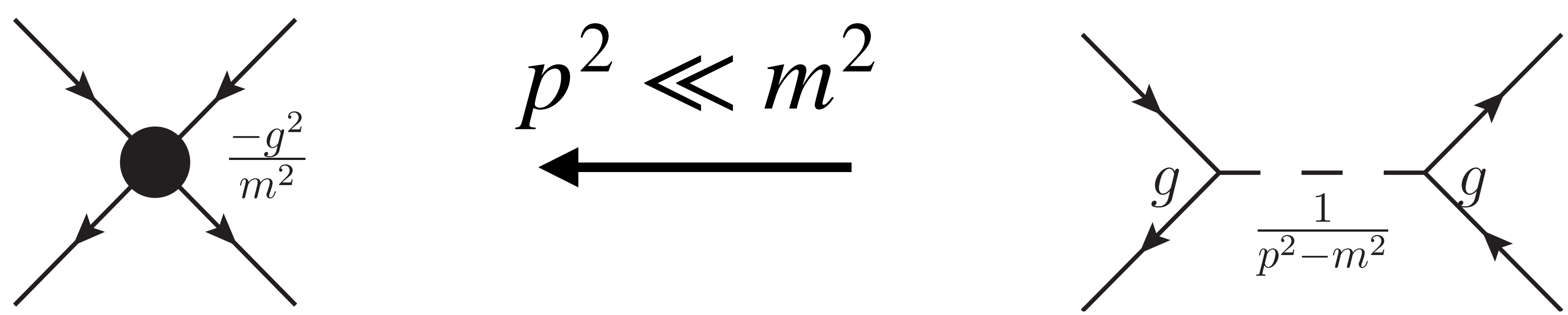
- EFT introduction
- Top examples (with EFT)
- Top fit
- PDF and EFT
- Summary

EFT introduction

Indirect detection of NP

- Assumption : NP scale >> energy probed in experiments





One assumption : $p^2 \ll m^2$

Ex : Fermi theory $-\frac{G_F}{Sqrt[2]} J^\mu J_\mu, \quad J_\mu = J^l_\mu + J^h_\mu, \quad J^l_\mu = \nu_l \gamma_\mu (1-\gamma_5) l$

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Expansion of the Lagrangian

$$L^{NP} = -\frac{1}{4}V^{\mu\nu}V_{\mu\nu} + M^2 V^{\mu}V_{\mu} + \sum_i g_i V_{\mu} J_i^{\mu} + h.c.$$

- if V is very heavy $$-\frac{1}{4}V^{\mu\nu}V_{\mu\nu} \sim 0$$
- and the EOM is $$V^{\mu} = -\frac{1}{M^2}\sum_i g_i J_i^{\mu} + h.c.$$

$$L_{EFT}^{NP} = -\frac{\left(\sum_i g_i J_i^{\mu}\right)\left(\sum_i g_i J_{\mu_i}\right)^{\dagger}}{M^2}$$

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EFT

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{d>4} \sum_{i} \frac{C_i}{\Lambda^{d-4}} \mathcal{O}_i^d$$ ← SM fields & sym.

EFT

Parametrize any NP but an ∞ number of coefficients

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{d>4} \sum_i \frac{C_i}{\Lambda^{d-4}} \mathcal{O}_i^d$$

SM fields & sym.

- Assumption : $E_{exp} << \Lambda$

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{C_i}{\Lambda^2} \mathcal{O}_i^6$$

a finite number of coefficients =>Predictive!

- Model independent (i.e. parametrize a large class of models) : any HEAVY NP
- SM is the leading term : EFT for precision physics

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EFT

Parametrize any NP but an ∞ number of coefficients

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{d>4} \sum_i \frac{C_i}{\Lambda^{d-4}} \mathcal{O}_i^d$$

← SM fields & sym.

- Assumption : $E_{exp} << \Lambda$

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{C_i}{\Lambda^2} \mathcal{O}_i^6$$

measure only C_i/Λ^2

a finite number of coefficients =>Predictive!

- Model independent (i.e. parametrize a large class of models) : any HEAVY NP
- SM is the leading term : EFT for precision physics

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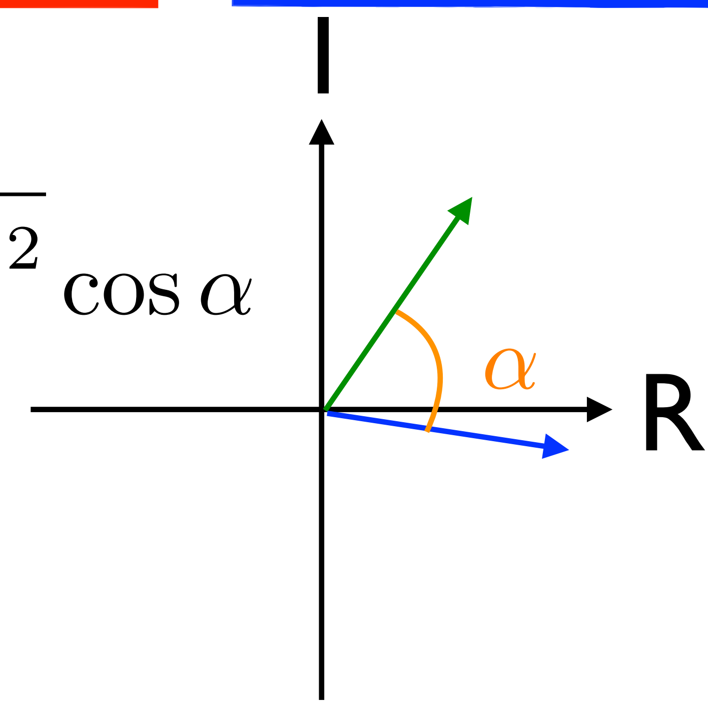
Interference

$$|M(x)|^2 = \underbrace{|M_{SM}(x)|^2}_{\Lambda^0} + \underbrace{2\Re\left(M_{SM}(x)M^*_{d6}(x)\right)}_{\Lambda^{-2}} + \underbrace{|M_{d6}(x)|^2 + \ldots}_{\mathcal{O}\left(\Lambda^{-4}\right)}$$

$$\Re\left(M_{SM}(x)M^*_{d6}(x)\right) = \sqrt{|M_{SM}(x)|^2\,|M_{d6}(x)|^2}\cos\alpha$$



Not always positive

Can be suppressed

$$\sigma \propto \sum_x |M(x)|^2$$

if

$$M_{SM}(x_1) = 1,\ M_{SM}(x_2) = 0$$

$$M_{d6}(x_1) = 0,\ M_{d6}(x_2) = 1$$

$$\sigma_{int} = 0$$

Observable dependent

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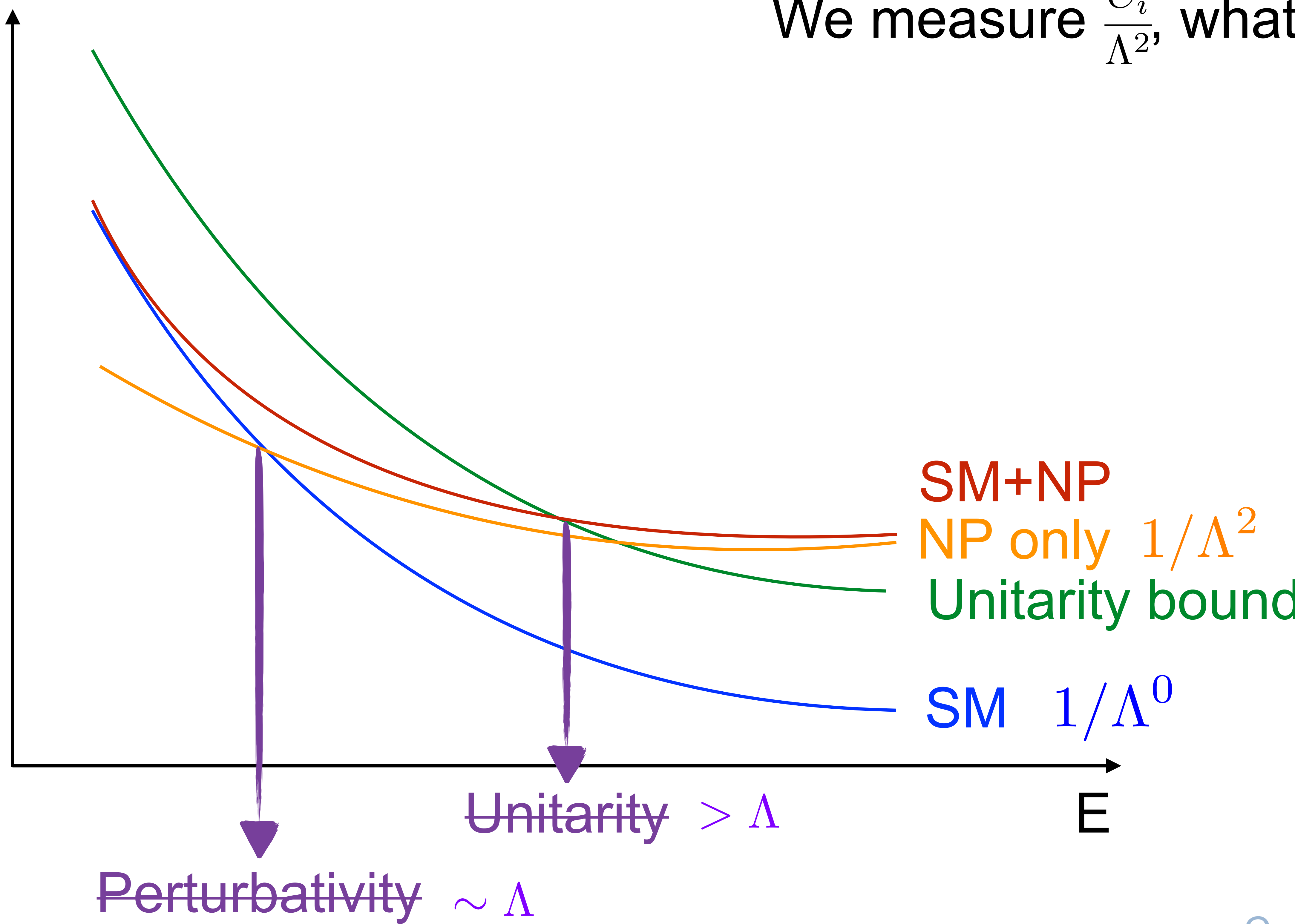
EFT & scales

We measure $\frac{C_i}{\Lambda^2}$, what is Λ?



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EFT & scales

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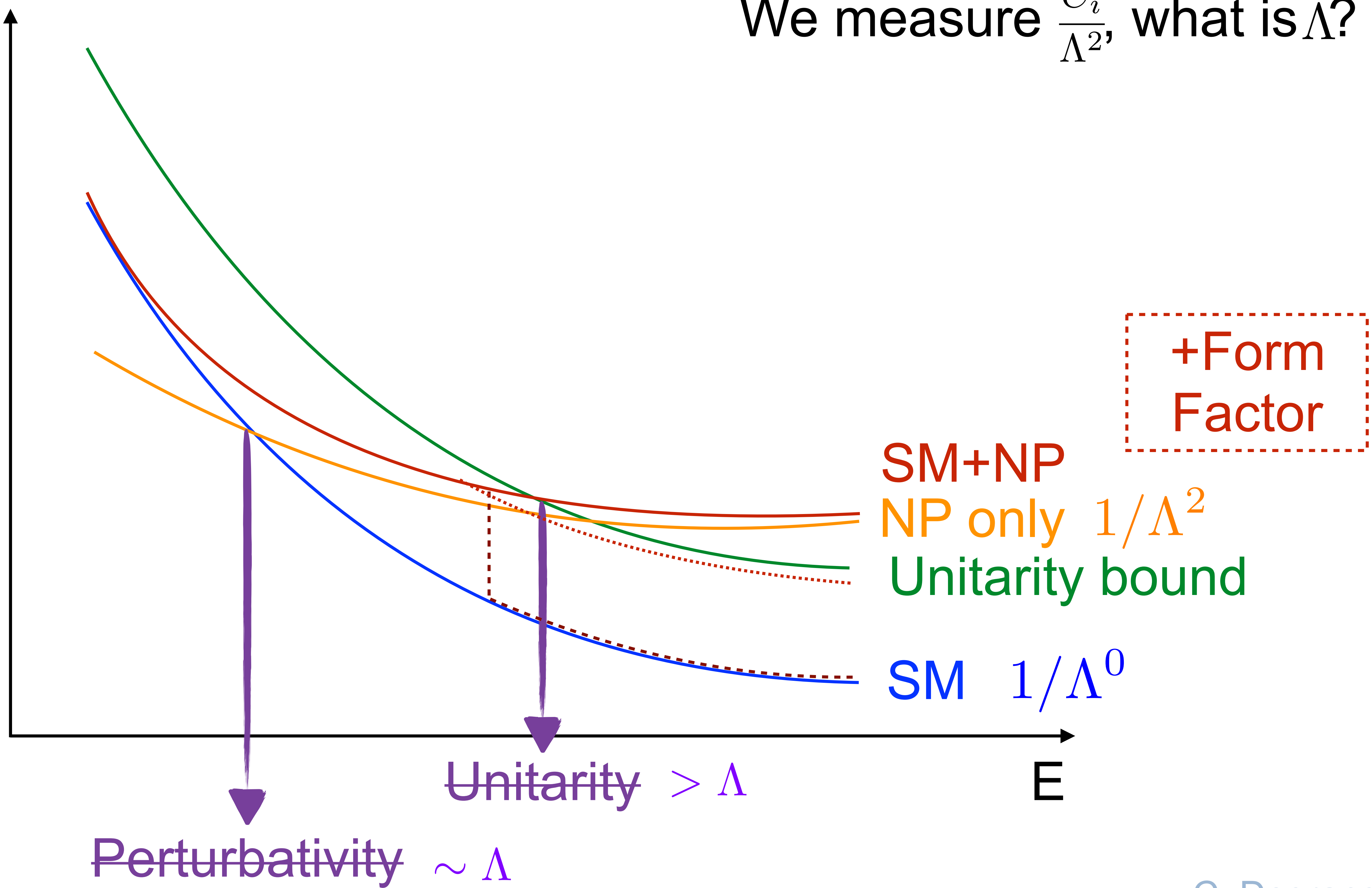

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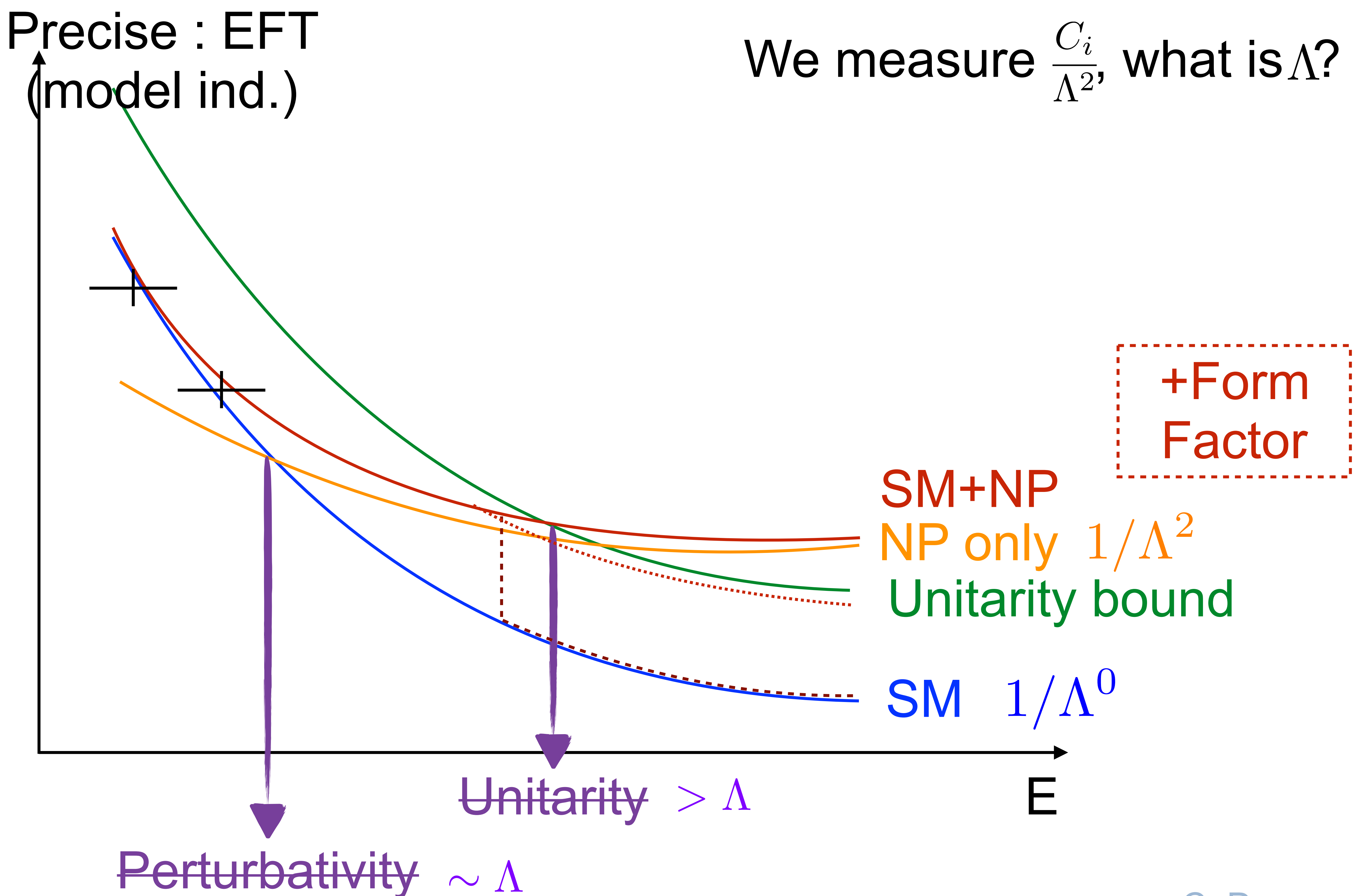
EFT & scales



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EFT & scales

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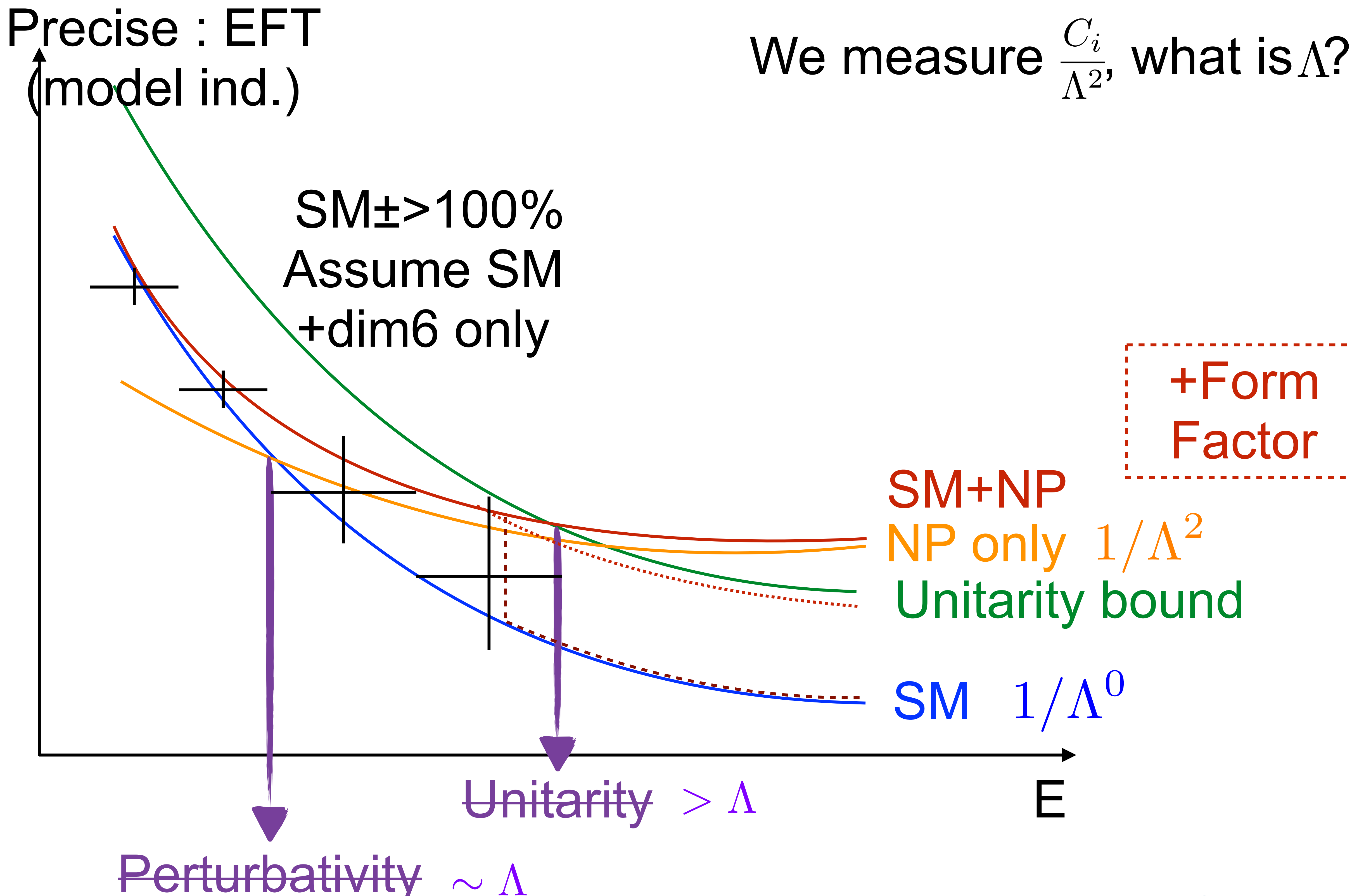

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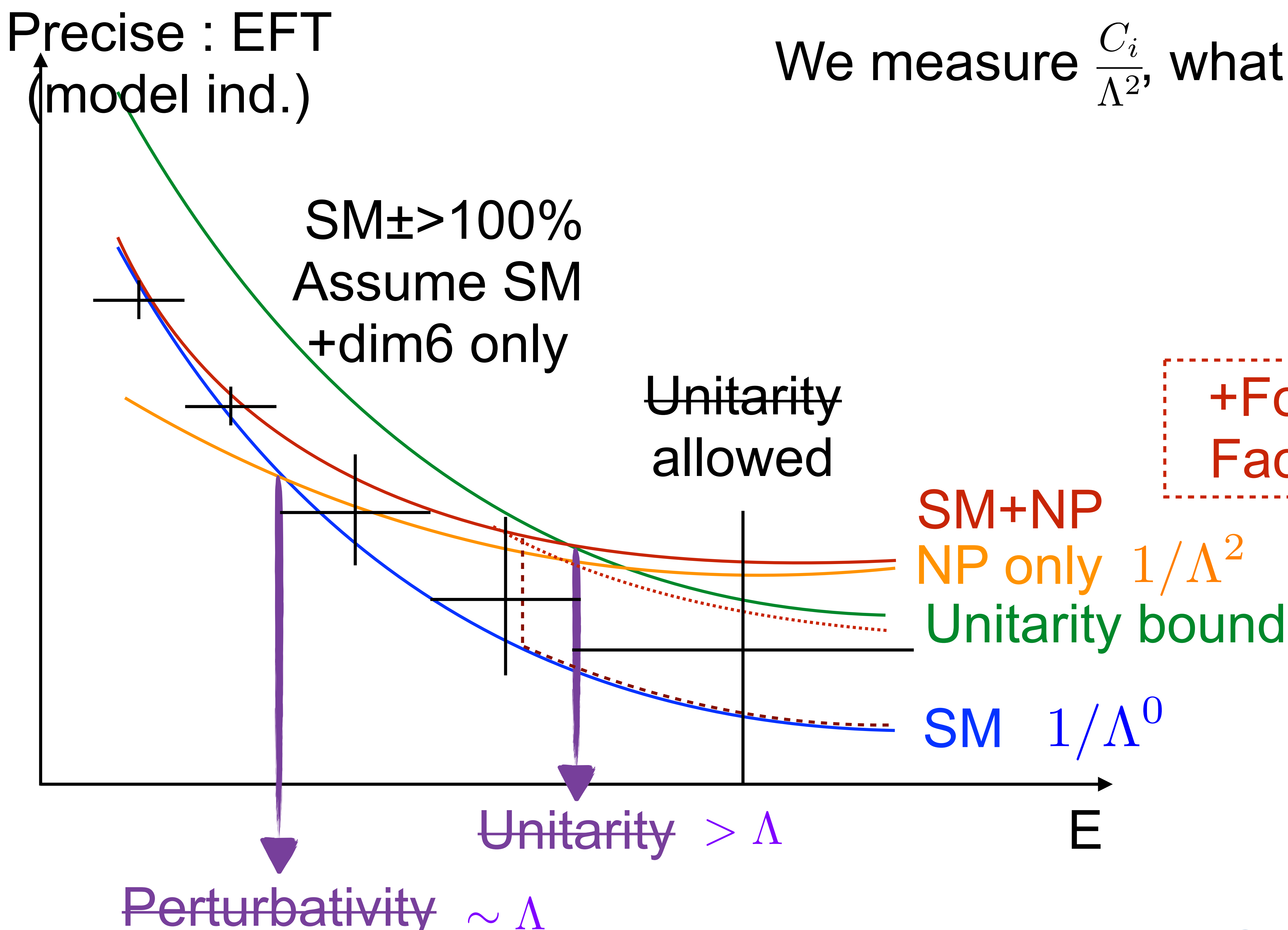
EFT & scales

We measure $\frac{C_i}{\Lambda^2}$, what is Λ?



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Top example

Top operators

Assume (To be checked) that all the **operators without top** are better **constrained** by other processes (i.e. not involving the top)

$U(2)_q \times U(2)_u \times U(2)_d$ flavour symmetry

=MFV with all F massless but t,b

four heavy quarks	$11 + 2$ CPV
two light and two heavy quarks	14
two heavy quarks and bosons	$9 + 6$ CPV
two heavy quarks and two leptons	$(8 + 3\ \text{CPV}) \times 3$ lepton flavours

1802.07237

top pair production

From the Warsaw basis

Two-light-two-heavy (14 d.o.f.)

$$
\begin{aligned}
c^{3,1}_{Qq} &\equiv C^{3(ii33)}_{qq} + \tfrac{1}{6}(C^{1(i33i)}_{qq} - C^{3(i33i)}_{qq}) \\
c^{3,8}_{Qq} &\equiv C^{1(i33i)}_{qq} - C^{3(i33i)}_{qq} \\
c^{1,1}_{Qq} &\equiv C^{1(ii33)}_{qq} + \tfrac{1}{6}C^{1(i33i)}_{qq} + \tfrac{1}{2}C^{3(i33i)}_{qq} \\
c^{1,8}_{Qq} &\equiv C^{1(i33i)}_{qq} + 3C^{3(i33i)}_{qq} \\
c^{1}_{Qu} &\equiv C^{1(33ii)}_{qu} \\
c^{8}_{Qu} &\equiv C^{8(33ii)}_{qu} \\
c^{1}_{Qd} &\equiv C^{1(33ii)}_{qd} \\
c^{8}_{Qd} &\equiv C^{8(33ii)}_{qd} \\
c^{1}_{tq} &\equiv C^{1(ii33)}_{qu} \\
c^{8}_{tq} &\equiv C^{8(ii33)}_{qu} \\
c^{1}_{tu} &\equiv C^{(ii33)}_{uu} + \tfrac{1}{3}C^{(i33i)}_{uu} \\
c^{8}_{tu} &\equiv 2C^{(i33i)}_{uu} \quad \leftarrow \\
c^{1}_{td} &\equiv C^{1(33ii)}_{ud} \\
c^{8}_{td} &\equiv C^{8(33ii)}_{ud}
\end{aligned}
$$

Two-heavy

$$
c^{[I]}_{tG} \equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C^{(33)}_{uG}\} \quad \leftarrow
$$

$$
\begin{aligned}
O^{1(ijkl)}_{qq} &= (\bar{q}_i\gamma^\mu q_j)(\bar{q}_k\gamma_\mu q_l), \\
O^{3(ijkl)}_{qq} &= (\bar{q}_i\gamma^\mu\tau^I q_j)(\bar{q}_k\gamma_\mu\tau^I q_l), \\
O^{1(ijkl)}_{qu} &= (\bar{q}_i\gamma^\mu q_j)(\bar{u}_k\gamma_\mu u_l), \\
O^{8(ijkl)}_{qu} &= (\bar{q}_i\gamma^\mu T^A q_j)(\bar{u}_k\gamma_\mu T^A u_l), \\
O^{1(ijkl)}_{qd} &= (\bar{q}_i\gamma^\mu q_j)(\bar{d}_k\gamma_\mu d_l), \\
O^{8(ijkl)}_{qd} &= (\bar{q}_i\gamma^\mu T^A q_j)(\bar{d}_k\gamma_\mu T^A d_l), \\
O^{(ijkl)}_{uu} &= (\bar{u}_i\gamma^\mu u_j)(\bar{u}_k\gamma_\mu u_l), \\
O^{1(ijkl)}_{ud} &= (\bar{u}_i\gamma^\mu u_j)(\bar{d}_k\gamma_\mu d_l), \\
O^{8(ijkl)}_{ud} &= (\bar{u}_i\gamma^\mu T^A u_j)(\bar{d}_k\gamma_\mu T^A d_l),
\end{aligned}
$$

$$
{}^{\ddagger}O^{(ij)}_{uG} = (\bar{q}_i\sigma^{\mu\nu}T^A u_j)\,\tilde{\varphi}G^A_{\mu\nu},
$$

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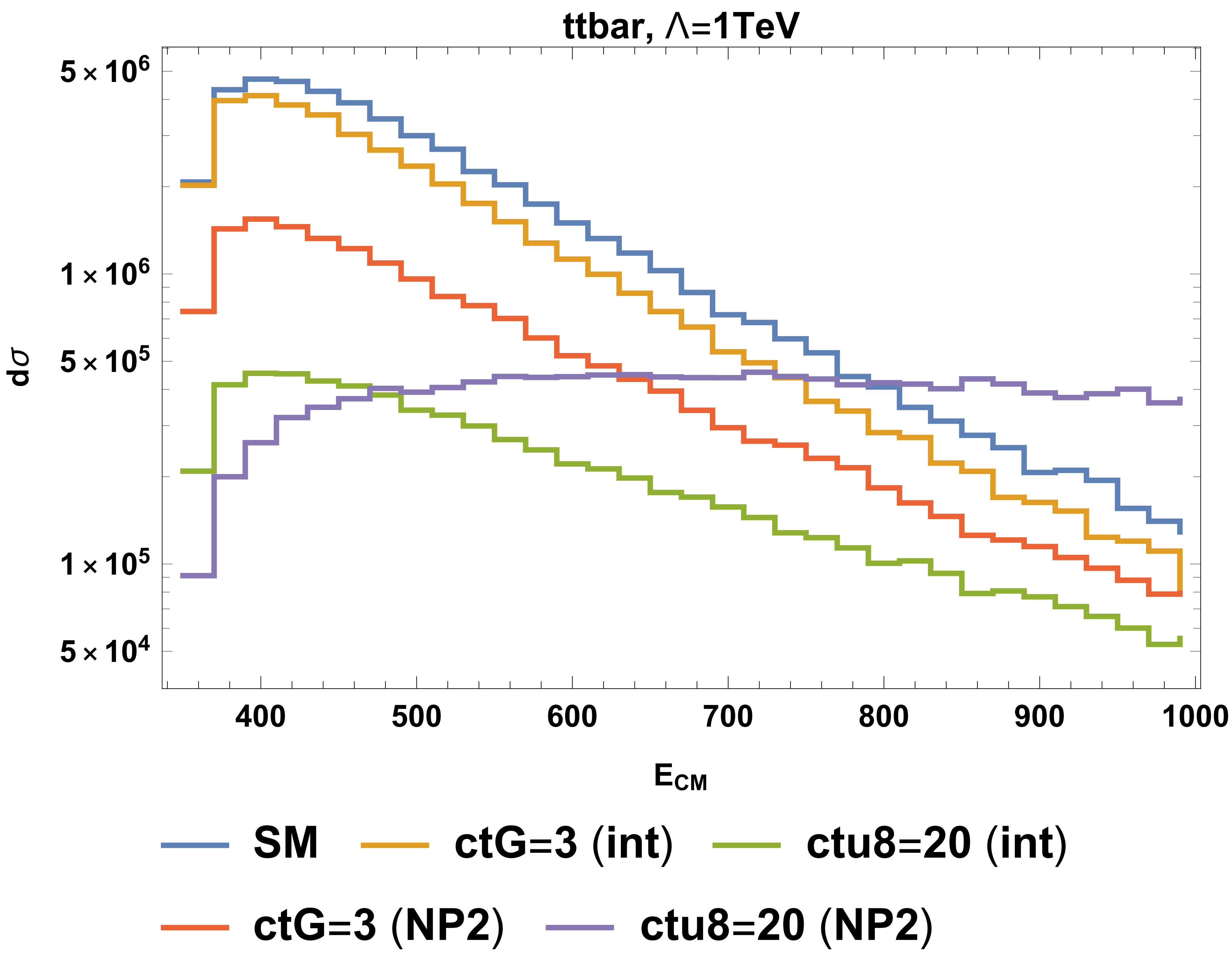
top pair production

4F interfere only with qq



$\sim \frac{s^2}{\Lambda^4}$

$\sim \frac{m_t v}{\Lambda^2}$

$\sim \frac{v^2 s}{\Lambda^4}$

$\sim \frac{s}{\Lambda^2}$

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Top operators

Two-heavy $(9+6 \text{ CPV d.o.f.})$

$$
\begin{aligned}
c_{t\varphi}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{u\varphi}^{(33)}\}\\
c_{\varphi q}^{-} &\equiv C_{\varphi q}^{1(33)} - C_{\varphi q}^{3(33)}\\
c_{\varphi Q}^{3} &\equiv C_{\varphi q}^{3(33)}\\
c_{\varphi t} &\equiv C_{\varphi u}^{(33)}\\
c_{\varphi tb}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{\varphi ud}^{(33)}\}\\
c_{tW}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{uW}^{(33)}\}\\
c_{tZ}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{-s_W C_{uB}^{(33)} + c_W C_{uW}^{(33)}\}\\
c_{bW}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{dW}^{(33)}\}\\
c_{tG}^{[I]} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{uG}^{(33)}\}
\end{aligned}
$$

Two-heavy-two-lepton $(8+3 \text{ CPV})$

$$
\begin{aligned}
c_{Ql}^{3(\ell)} &\equiv C_{lq}^{3(\ell\ell 33)}\\
c_{Ql}^{-(\ell)} &\equiv C_{lq}^{1(\ell\ell 33)} - C_{lq}^{3(\ell\ell 33)}\\
c_{Qe}^{(\ell)} &\equiv C_{eq}^{(\ell\ell 33)}\\
c_{tl}^{(\ell)} &\equiv C_{lu}^{(\ell\ell 33)}\\
c_{te}^{(\ell)} &\equiv C_{eu}^{(\ell\ell 33)}\\
c_{t}^{S[I](\ell)} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{lequ}^{1(\ell\ell 33)}\}\\
c_{t}^{T[I](\ell)} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{lequ}^{3(\ell\ell 33)}\}\\
c_{b}^{S[I](\ell)} &\equiv {}^{[\mathrm{Im}]}_{\mathrm{Re}}\{C_{ledq}^{(\ell\ell 33)}\}
\end{aligned}
$$

Top leptonic decay

0 if $m_b=0$

From the Warsaw basis

$$
\begin{aligned}
{}^{\ddagger}O_{u\varphi}^{(ij)} &= \bar q_i u_j \tilde\varphi\,(\varphi^\dagger\varphi),\\
O_{\varphi q}^{1(ij)} &= (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar q_i\gamma^\mu q_j),\\
O_{\varphi q}^{3(ij)} &= (\varphi^\dagger i\overleftrightarrow{D}^I_\mu\varphi)(\bar q_i\gamma^\mu\tau^I q_j),\\
O_{\varphi u}^{(ij)} &= (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar u_i\gamma^\mu u_j),\\
{}^{\ddagger}O_{\varphi ud}^{(ij)} &= (\tilde\varphi^\dagger iD_\mu\varphi)(\bar u_i\gamma^\mu d_j),\\
{}^{\ddagger}O_{uW}^{(ij)} &= (\bar q_i\sigma^{\mu\nu}\tau^I u_j)\;\tilde\varphi W^I_{\mu\nu},\\
{}^{\ddagger}O_{dW}^{(ij)} &= (\bar q_i\sigma^{\mu\nu}\tau^I d_j)\;\varphi W^I_{\mu\nu},\\
{}^{\ddagger}O_{uB}^{(ij)} &= (\bar q_i\sigma^{\mu\nu} u_j)\quad\tilde\varphi B_{\mu\nu},\\
{}^{\ddagger}O_{uG}^{(ij)} &= (\bar q_i\sigma^{\mu\nu}T^A u_j)\;\tilde\varphi G^A_{\mu\nu},
\end{aligned}
$$

$$
\begin{aligned}
O_{lq}^{1(ijkl)} &= (\bar l_i\gamma^\mu l_j)(\bar q_k\gamma^\mu q_l),\\
O_{lq}^{3(ijkl)} &= (\bar l_i\gamma^\mu\tau^I l_j)(\bar q_k\gamma^\mu\tau^I q_l),\\
O_{lu}^{(ijkl)} &= (\bar l_i\gamma^\mu l_j)(\bar u_k\gamma^\mu u_l),\\
O_{eq}^{(ijkl)} &= (\bar e_i\gamma^\mu e_j)(\bar q_k\gamma^\mu q_l),\\
O_{eu}^{(ijkl)} &= (\bar e_i\gamma^\mu e_j)(\bar u_k\gamma^\mu u_l),\\
{}^{\ddagger}O_{lequ}^{1(ijkl)} &= (\bar l_i e_j)\;\varepsilon\;(\bar q_k u_l),\\
{}^{\ddagger}O_{lequ}^{3(ijkl)} &= (\bar l_i\sigma^{\mu\nu} e_j)\;\varepsilon\;(\bar q_k\sigma_{\mu\nu} u_l),\\
{}^{\ddagger}O_{ledq}^{(ijkl)} &= (\bar l_i e_j)(\bar d_k q_l),
\end{aligned}
$$

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(SM-like) Top decay

$t \to bW$

$$\mathcal{O}_{\phi q}^{(3)} = i\left(\phi^\dagger \tau^i D_\mu \phi\right)\left(\bar{Q}\gamma^\mu \tau^i Q\right) + h.c.$$

$$\mathcal{O}_{tW} = \bar{Q}\sigma_{\mu\nu}\tau^i t\tilde{\phi}W_i^{\mu\nu}.$$

C. Zhang, S Willenbrock, PRD83, 034008

$t \to bl\nu_l$

$$\mathcal{O}_{ql}^{(3)} = \left(\bar{Q}\gamma^\mu \tau^i Q\right)\left(\bar{l}\gamma_\mu \tau^i l\right)$$

J.A. Aguilar-Saavedra, NPB843, 683

+ one four-fermion operator for the hadronic decay

$$\frac{1}{2}\Sigma|M|^2 = \frac{V_{tb}^2 g^4 u(m_t^2 - u)}{2(s - m_W^2)^2}\left(1 + 2\frac{C_{\phi q}^{(3)} v^2}{V_{tb}\Lambda^2}\right) + \frac{4\sqrt{2}\mathrm{Re}C_{tW} V_{tb} m_t m_W}{\Lambda^2}\frac{g^2 su}{(s - m_W^2)^2}$$
$$+ \frac{4C_{ql}^{(3)}}{\Lambda^2}\frac{g^2 u(m_t^2 - u)}{s - m_W^2} + \mathcal{O}\left(\Lambda^{-4}\right)$$

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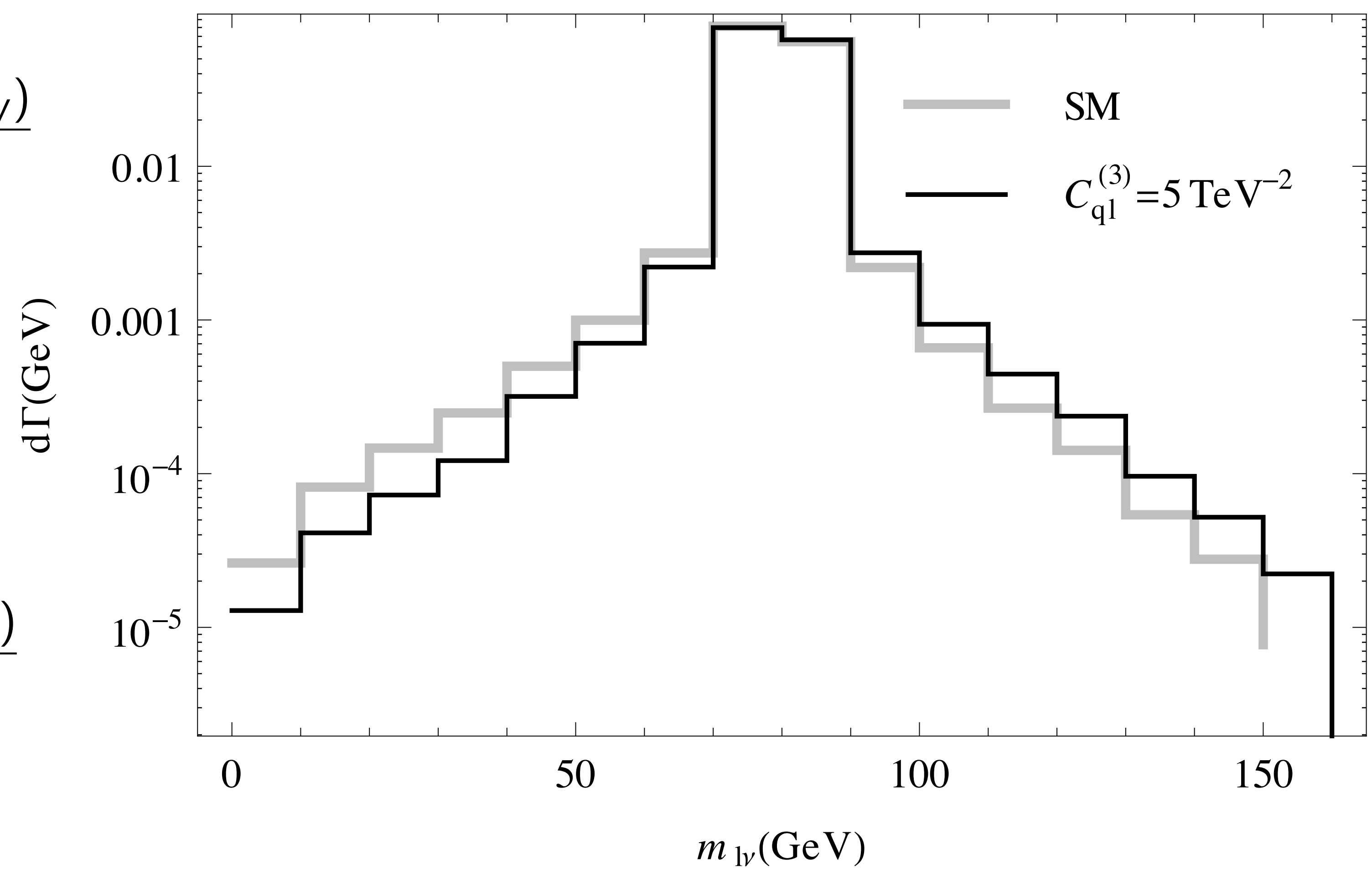
Width, W helicities and …

$$\frac{\Gamma\left(t \to b e^{+}\nu_e\right)}{GeV} = 0.1541 + \left[0.019\frac{C_{\phi q}^{(3)}}{\Lambda^2} + 0.026\frac{C_{tW}}{\Lambda^2} + 0\frac{C_{ql}^{(3)}}{\Lambda^2}\right] \text{TeV}^2$$

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta} = \frac{3}{8}(1+\cos\theta)^2 F_R + \frac{3}{8}(1-\cos\theta)^2 F_L + \frac{3}{4}\sin^2\theta F_0$$

$$\begin{aligned} F_0 &= \frac{m_t^2}{m_t^2+2m_W^2} - \frac{4\sqrt{2}\mathrm{Re}C_{tW}v^2}{\Lambda^2 V_{tb}}\frac{m_t m_W(m_t^2-m_W^2)}{(m_t^2+2m_W^2)^2} \\ F_L &= \frac{2m_W^2}{m_t^2+2m_W^2} + \frac{4\sqrt{2}\mathrm{Re}C_{tW}v^2}{\Lambda^2 V_{tb}}\frac{m_t m_W(m_t^2-m_W^2)}{(m_t^2+2m_W^2)^2} \\ F_R &= 0 \end{aligned}$$

$$\frac{1}{2}\Sigma|M|^2 = \frac{V_{tb}^2 g^4 u(m_t^2-u)}{2(s-m_W^2)^2} + \frac{4C_{ql}^{(3)}}{\Lambda^2}\frac{g^2 u(m_t^2-u)}{s-m_W^2}$$



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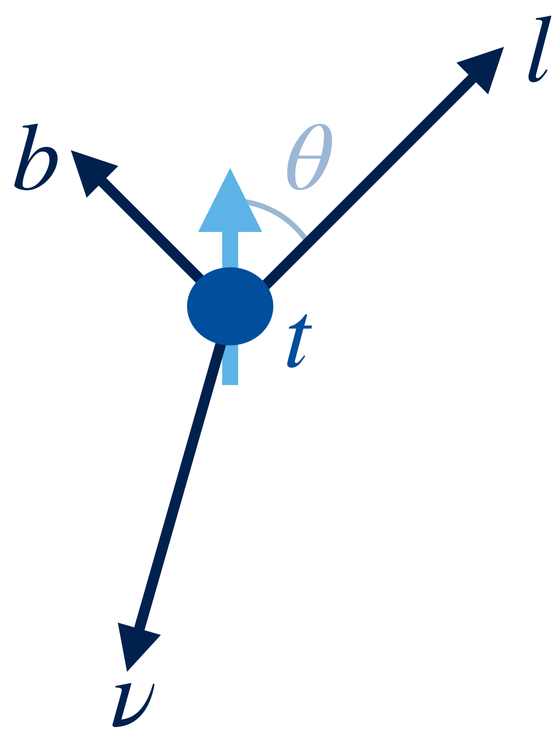
Single top

The top quark is

- one of the least known particle
- more sensitive to many dim-6 operators due to its mass



$$\frac{\Gamma_{\uparrow}}{\Gamma} = \frac{1 + A_i \cos\theta}{2}$$

$$\frac{\Gamma_{\downarrow}}{\Gamma} = \frac{1 - A_i \cos\theta}{2}$$

$$A_l = A_d = 1, A_u = A_\nu = -0.31$$

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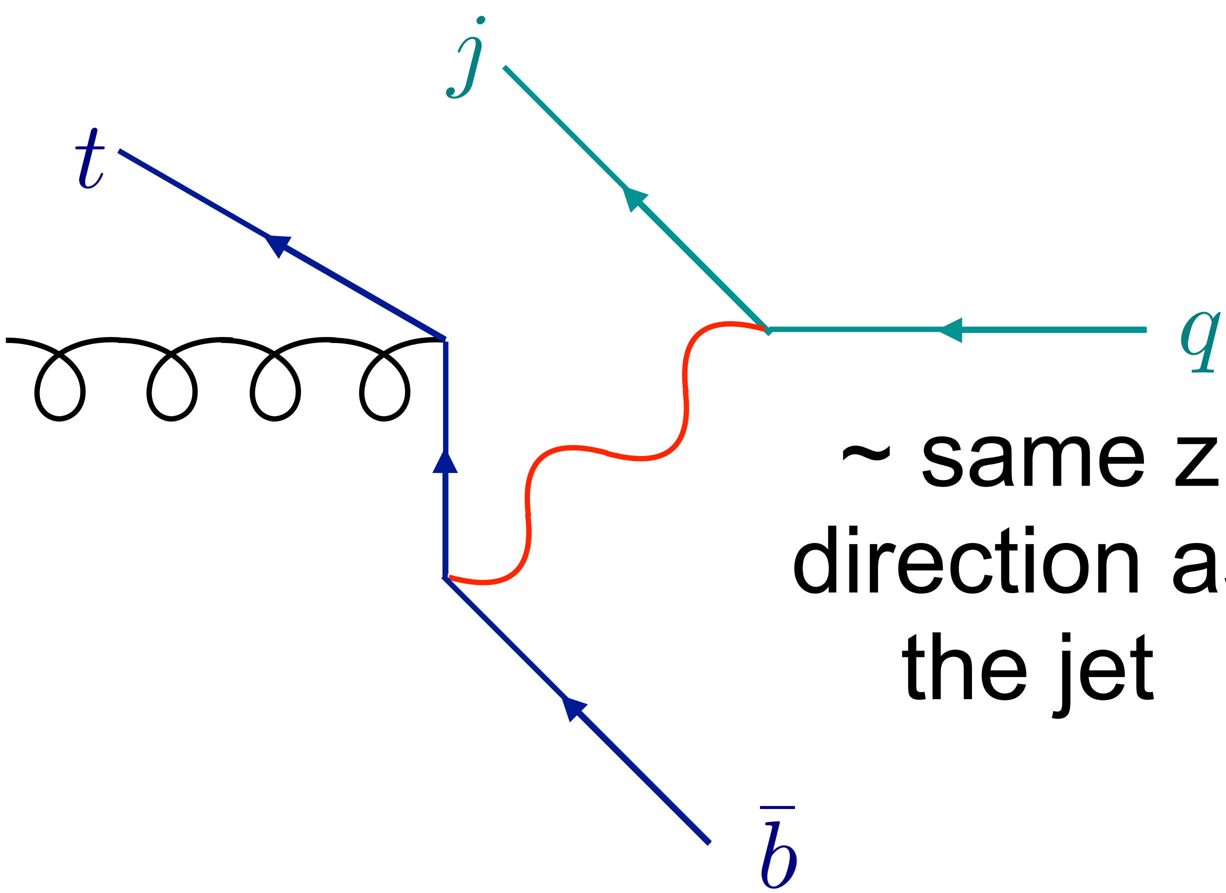
Single top

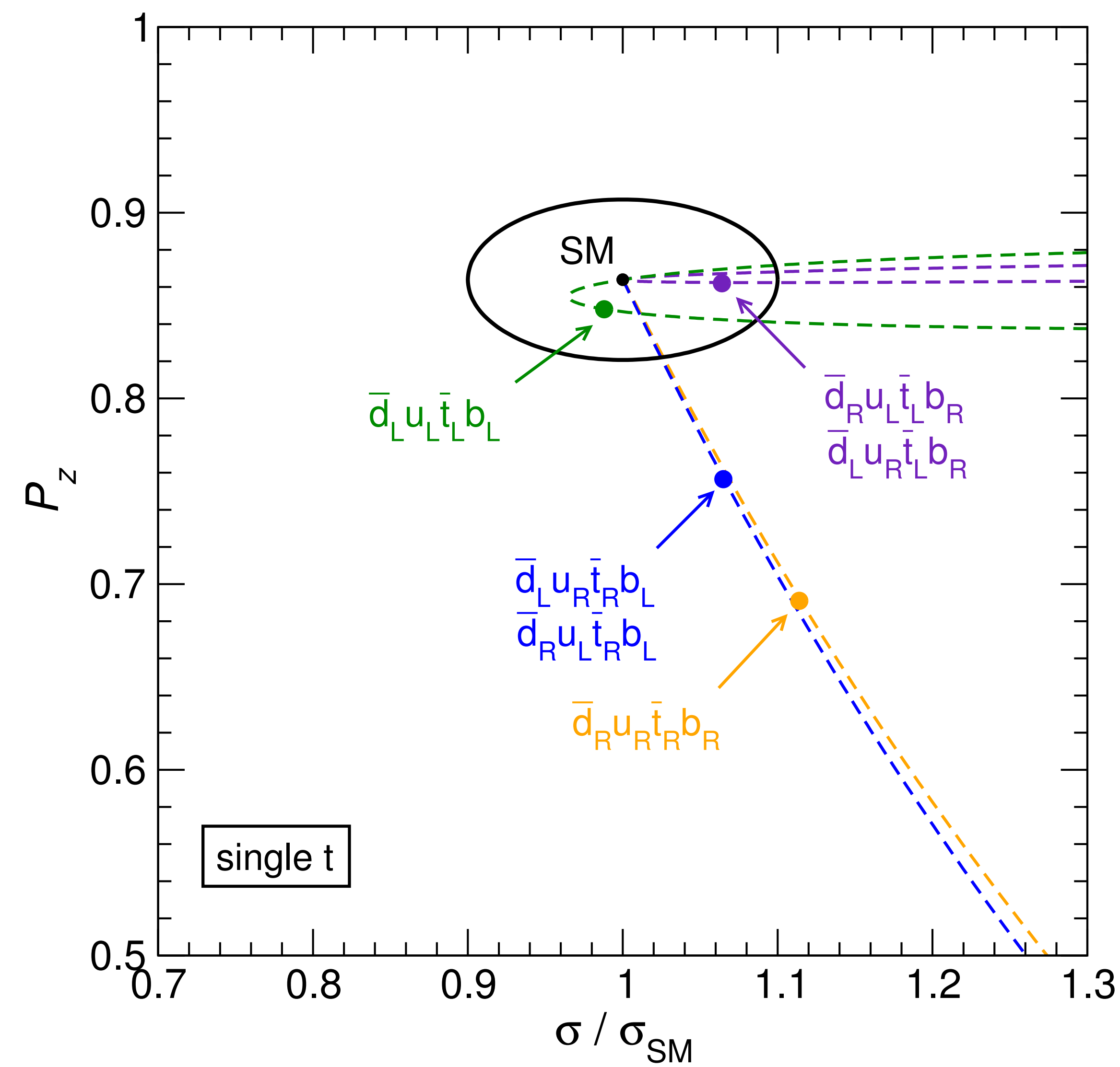
$$\mathcal{L}_{\rm eff} = \frac{1}{\Lambda^2}\left[C_{qq}\,(\bar t_L\gamma^\mu b_L)(\bar d_L\gamma_\mu u_L) + C_{du}(\bar t_R\gamma^\mu b_R)(\bar d_R\gamma_\mu u_R) + C_{qu}(\bar t_R b_L)(\bar d_L u_R)\right.$$
$$\left. + C_{qd}(\bar t_L b_R)(\bar d_R u_L) - C_{qud_R}(\bar t_R b_L)(\bar d_R u_L) - C_{qud_L}(\bar t_L b_R)(\bar d_L u_R)\right] + \text{h.c.}$$

<u>In the top rest frame</u>

$$\hat z = \frac{\vec p_j}{|\vec p_j|}\,, \quad \hat y = \frac{\vec p_j \times \vec p_q}{|\vec p_j \times \vec p_q|}\,, \quad \hat x = \hat y \times \hat z$$



~ same z direction as the jet



J.A. Aguilar-Saavedra, C. D. and S. Khatibi, PLB769 (2017) 498-502

Interference

$$|M(x)|^2 = |M_{SM}(x)|^2 + 2\Re\left(M_{SM}(x)M^*_{d6}(x)\right) + |M_{d6}(x)|^2 + \ldots$$

Λ^0 Λ^{-2} $\mathcal{O}\left(\Lambda^{-4}\right)$

$\approx / = 0$ $\approx / = 0$ $\approx / = 0$

Ex : FCNC such as tt

JHEP 1510 (2015) 146

SM $4.045 \pm 0.007 \cdot 10^{-15}\ {}^{+0.2\%}_{-0.8\%}\ {}^{+0.9\%}_{-1.0\%}$ pb at 13 TeV

$\mathcal{O}_{RR} = [\bar{t}_R\gamma^\mu u_R]\,[\bar{t}_R\gamma_\mu u_R]$ up to 0.5 pb

Phys.Lett. B703 (2011) 306-309

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Top FCNC

	LO		NLO	
Coefficient	σ[fb]	Scale uncertainty	σ[fb]	Scale uncertainty
$C_{u\varphi}^{(13)}=3.5$	2603	+13.0% -11.0%	3858	+7.4% -6.7%
$C_{uG}^{(13)}=0.04$	40.1	+16.5% -13.2%	50.7	+4.0% -5.2%
$C_{u\varphi}^{(23)}=3.5$	171	+9.7% -8.7%	310	+7.3% -6.3%
$C_{uG}^{(23)}=0.09$	9.53	+11.0% -9.7%	16.6	+5.5% -5.1%

$$qg\to tB$$

$$B=\gamma,Z,h$$

$$\mathcal{L}_{\rm EFT}=\mathcal{L}_{\rm SM}+\sum_i\frac{C_i}{\Lambda^2}O_i+H.c.$$

Small when constraints from $ug\to t$ are taken into account

$$O_{\varphi q}^{(3,i+3)}=i\left(\varphi^\dagger\overleftrightarrow{D}^I_\mu\varphi\right)(\bar{q}_i\gamma^\mu\tau^IQ)$$

$$O_{\varphi q}^{(1,i+3)}=i\left(\varphi^\dagger\overleftrightarrow{D}_\mu\varphi\right)(\bar{q}_i\gamma^\mu Q)$$

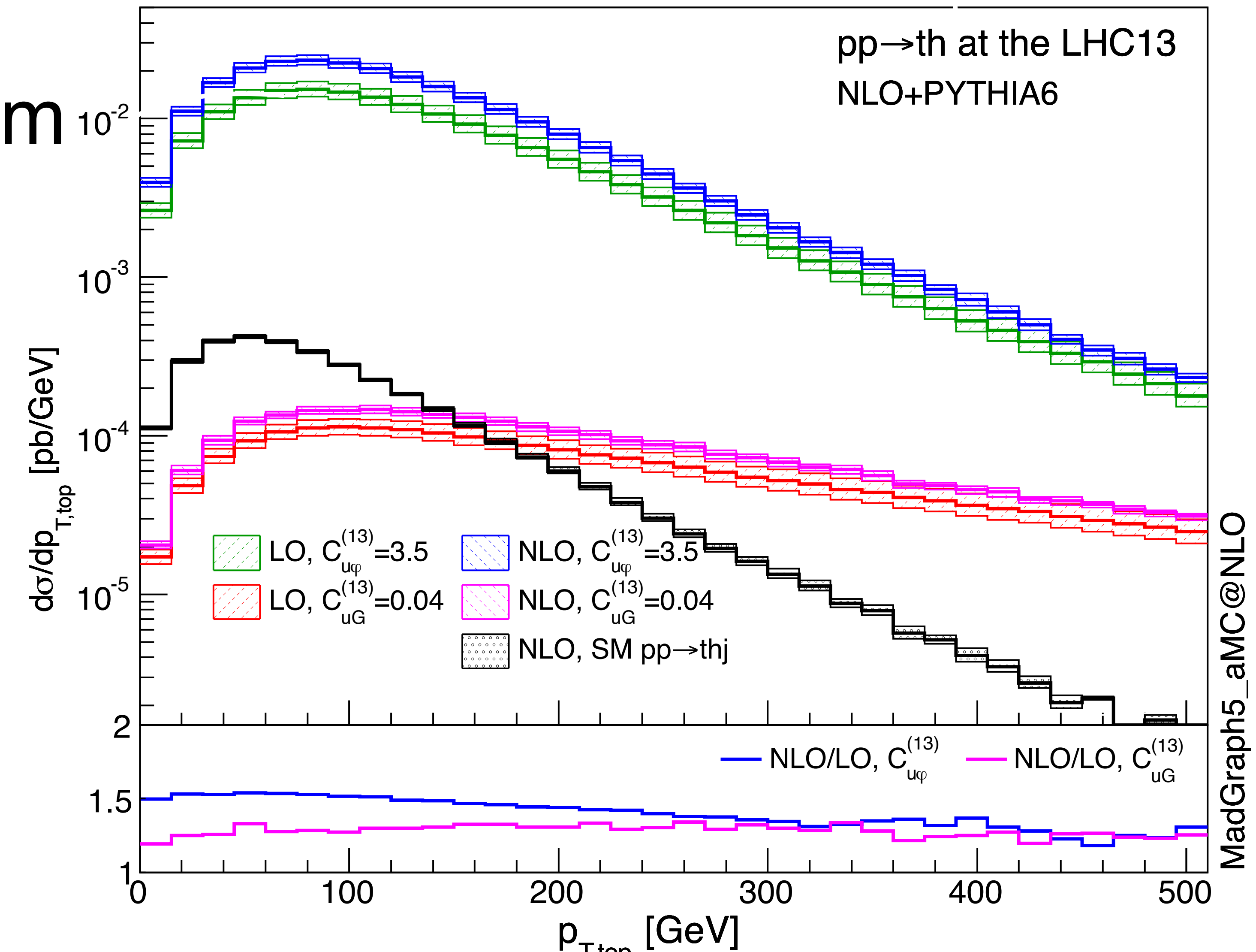
$$O_{\varphi u}^{(i+3)}=i\left(\varphi^\dagger\overleftrightarrow{D}_\mu\varphi\right)(\bar{u}_i\gamma^\mu t)$$

$$O_{uB}^{(i3)}=g_Y(\bar{q}_i\sigma^{\mu\nu}t)\tilde{\varphi}B_{\mu\nu},$$

$$O_{uG}^{(i3)}=g_s(\bar{q}_i\sigma^{\mu\nu}T^At)\tilde{\varphi}G^A_{\mu\nu},$$

$$O_{uW}^{(i3)}=g_W(\bar{q}_i\sigma^{\mu\nu}\tau^It)\tilde{\varphi}W^I_{\mu\nu}$$

$$O_{u\varphi}^{(i3)}=(\varphi^\dagger\varphi)(\bar{q}_it)\tilde{\varphi}$$



CD, F. Maltoni, J. Wang, C. Zhang, PRD91 (2015) 034024

Top fit

Data

Process	Dataset	$\sqrt{s}$	Info	Observables	$N_{\rm dat}$	Ref
$t\bar{t}$	ATLAS_tt_8TeV_ljets	**8 TeV**	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	5, 8, 7, 5	[92]
$t\bar{t}$	CMS_tt_8TeV_ljets	**8 TeV**	lepton+jets	$d\sigma/dy_t$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/dy_{t\bar{t}}$	10, 8, 7, 10	[93]
$t\bar{t}$	CMS_tt2D_8TeV_dilep	**8 TeV**	dileptons	$d^2\sigma/dy_t dp_t^T$, $d^2\sigma/dy_t dm_{t\bar{t}}$, $d^2\sigma/dp_{t\bar{t}}^T dm_{t\bar{t}}$, $d^2\sigma/dy_{t\bar{t}} dm_{t\bar{t}}$	16, 16, 16, 16	[94]
$t\bar{t}$	CMS_tt_13TeV_ljets	**13 TeV**	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	7, 9, 8, 6	[97]
$t\bar{t}$	CMS_tt_13TeV_ljets2	**13 TeV**	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	11, 12, 10, 10	[99]
$t\bar{t}$	CMS_tt_13TeV_dilep	**13 TeV**	dileptons	$d\sigma/dy_t$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/dy_{t\bar{t}}$	8, 6, 6, 8	[100]
$t\bar{t}$	ATLAS_WhelF_8TeV	**8 TeV**	W helicity fract	F_0, F_L, F_R	3	[95]
$t\bar{t}$	CMS_WhelF_8TeV	**8 TeV**	W helicity fract	F_0, F_L, F_R	3	[96]

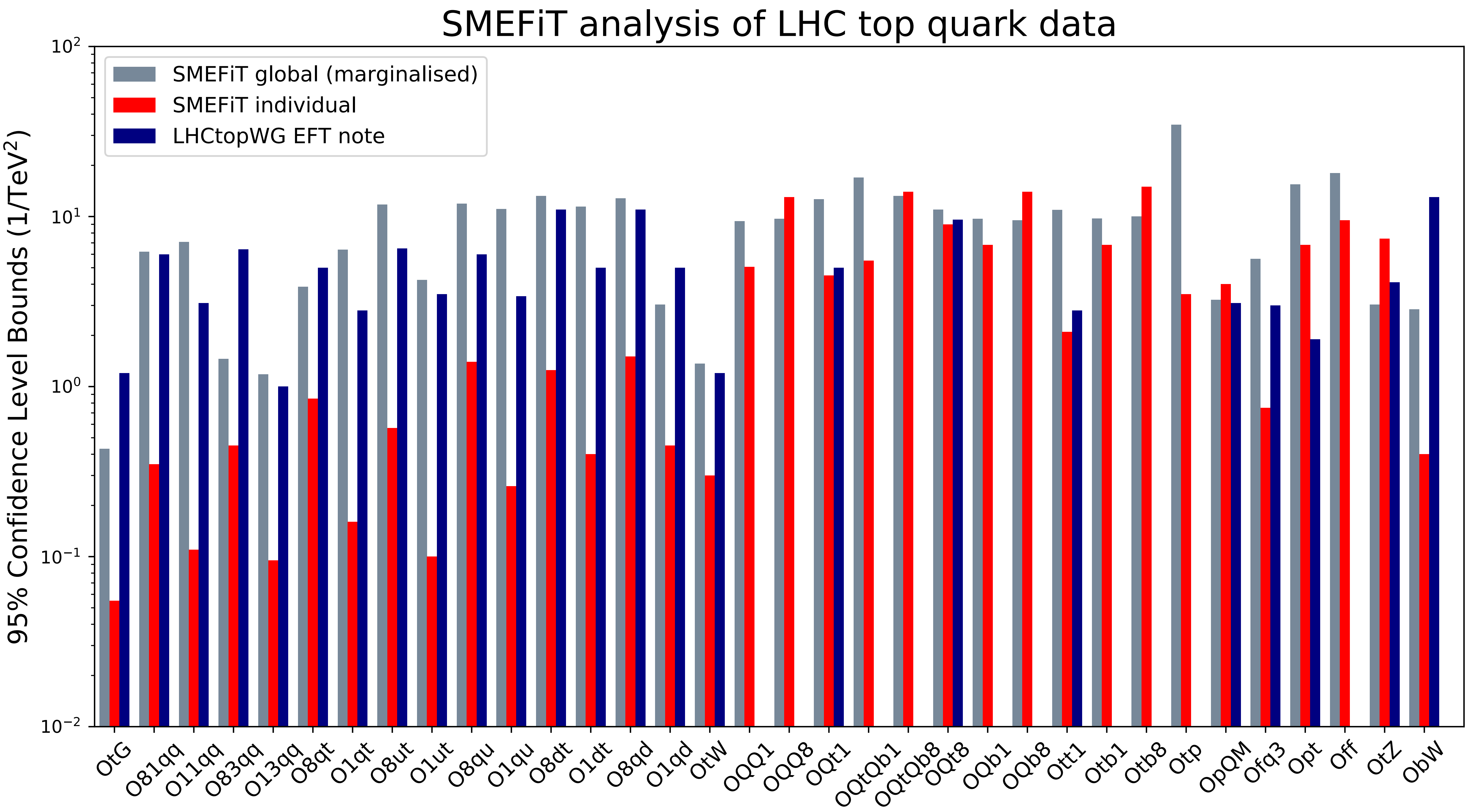
Only one distribution per measurement (correlation)

N.P. Hartland, F.Maltoni, E. R. Nocera, J. Rojo, E. Slade, E. Vryonidou and C.~Zhang,JHEP 1904 (2019) 100

Data

Process	Dataset	$\sqrt{s}$	Info	Observables	N_{dat}	Ref
$t\bar{t}b\bar{b}$	CMS_ttbb_13TeV	**13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}b\bar{b})$	1	[101]
$t\bar{t}t\bar{t}$	CMS_tttt_13TeV	**13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}t\bar{t})$	1	[102]
$t\bar{t}Z$	CMS_ttZ_8_13TeV	**8+13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}Z)$	2	[103, 104]
$t\bar{t}Z$	ATLAS_ttZ_8_13TeV	**8+13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}Z)$	2	[105, 106]
$t\bar{t}W$	CMS_ttW_8_13TeV	**8+13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}W)$	2	[103, 104]
$t\bar{t}W$	ATLAS_ttW_8_13TeV	**8+13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}W)$	2	[105, 106]
$t\bar{t}H$	CMS_tth_13TeV	**13 TeV**	signal strength	$\mu_{t\bar{t}H}$	1	[107]
$t\bar{t}H$	ATLAS_tth_13TeV	**13 TeV**	total xsec	$\sigma_{\mathrm{tot}}(t\bar{t}H)$	1	[108]

Global top Fit



Marg. less constrained than ind.

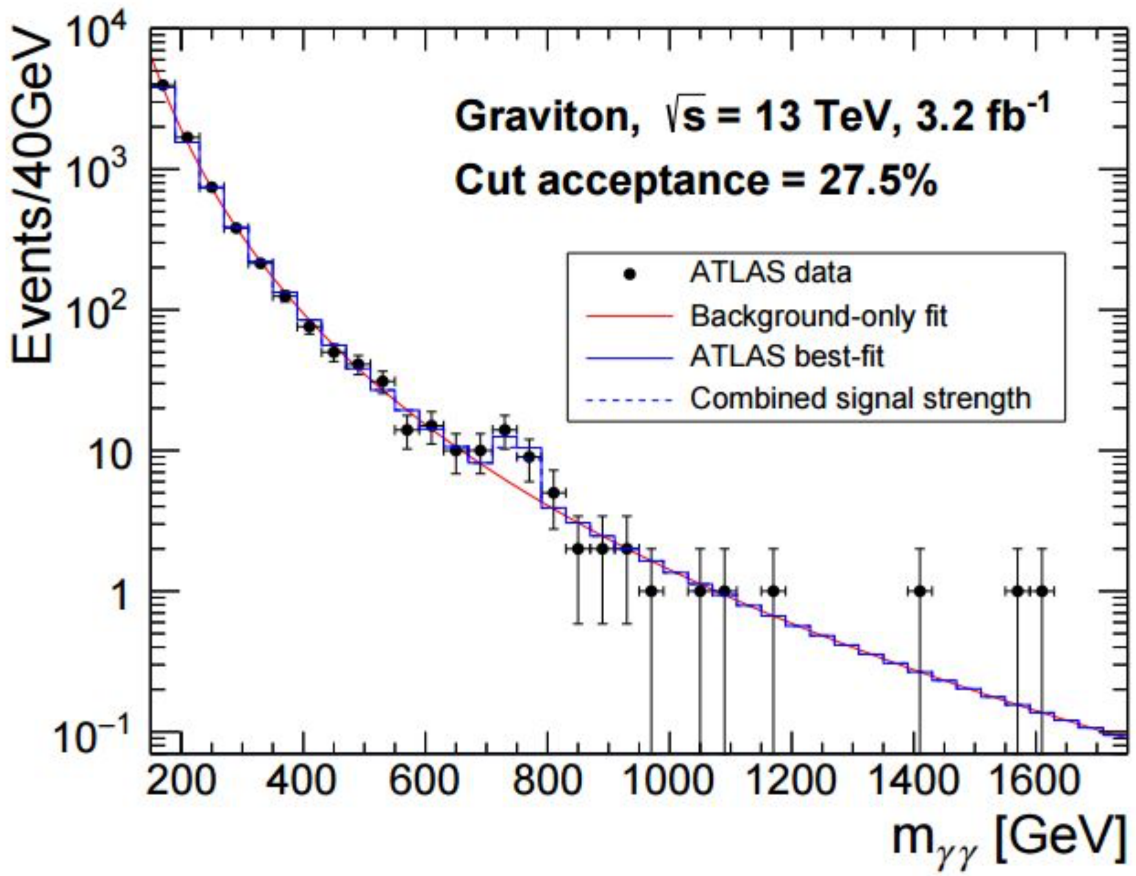
C. Degrande

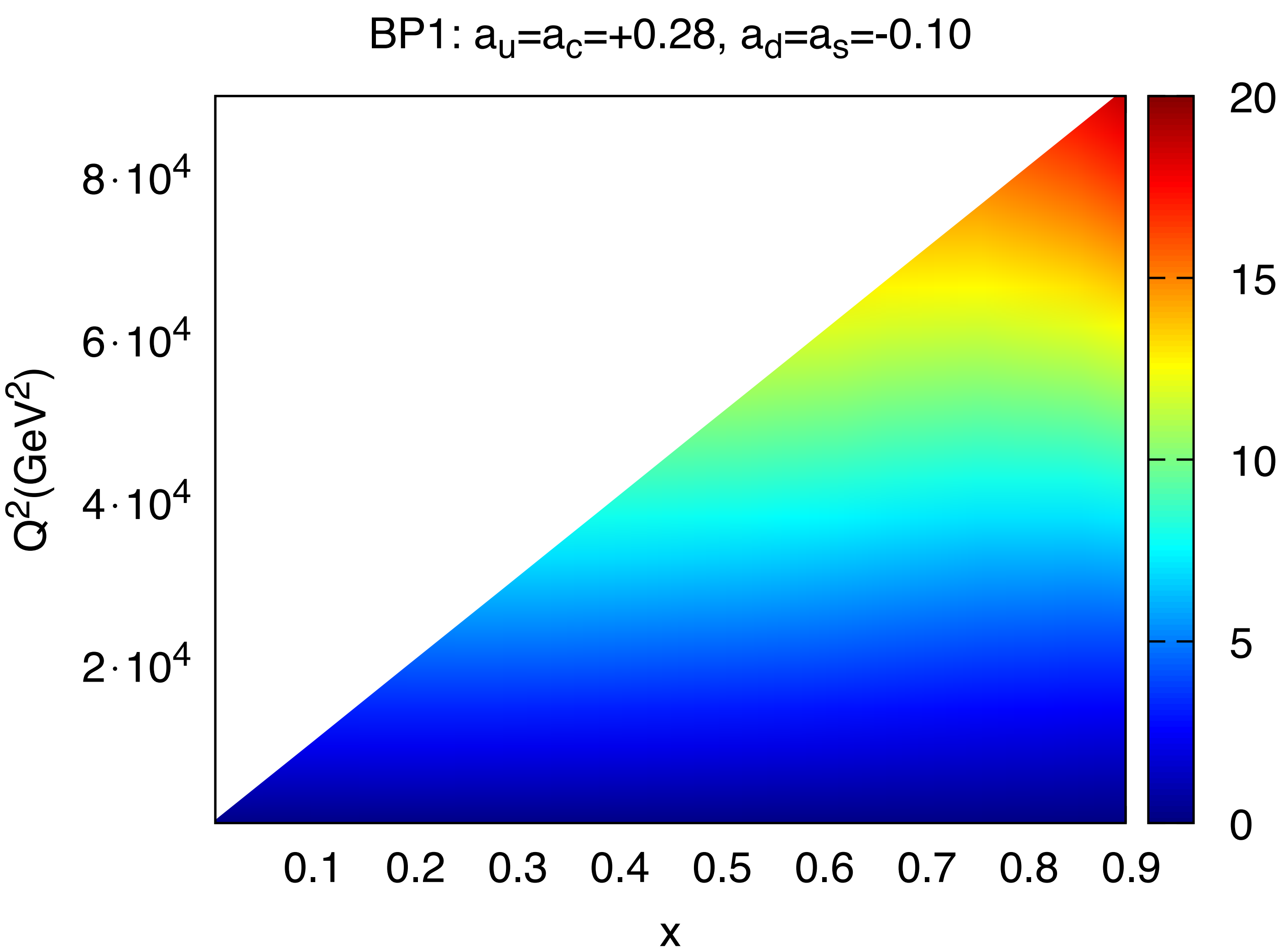
EFT and PDF

EFT and PDF

1905.05215 with S. Carrazza, S. Iranipour, J. Rojo and M. Ubiali

$$\mathcal{O}_{lq} = \left(\bar{l}_R \gamma^\mu l_R\right)\left(\bar{q}_R \gamma_\mu q_R\right)\ ,\ \ q = u, d, s, c\,,$$





$$\Delta F_2^{\rm smeft} \supset \frac{x}{12e^4}\left(4a_u e^2 \frac{Q^2}{\Lambda^2}(1+4K_Z s_W^4) + 3a_u^2 \frac{Q^4}{\Lambda^4}\right) \times \left(u(x,Q^2)+\bar{u}(x,Q^2)\right)$$

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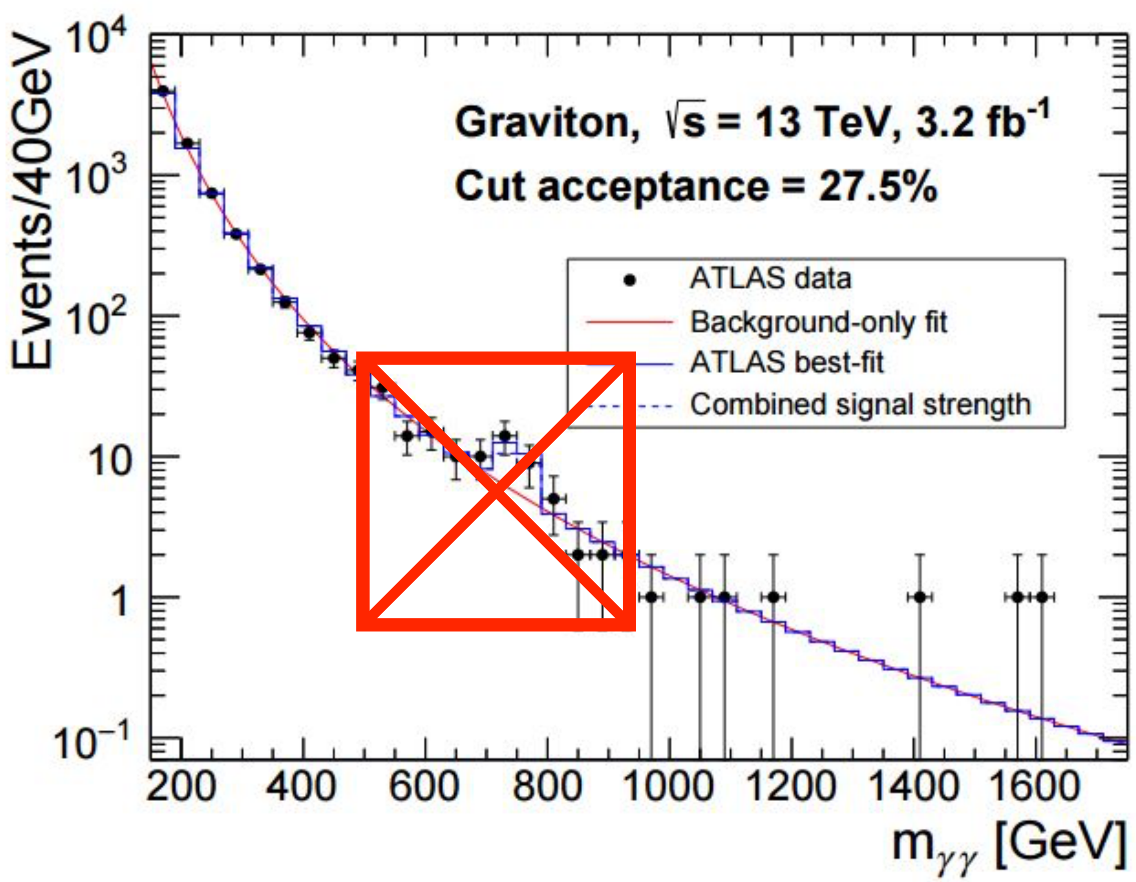
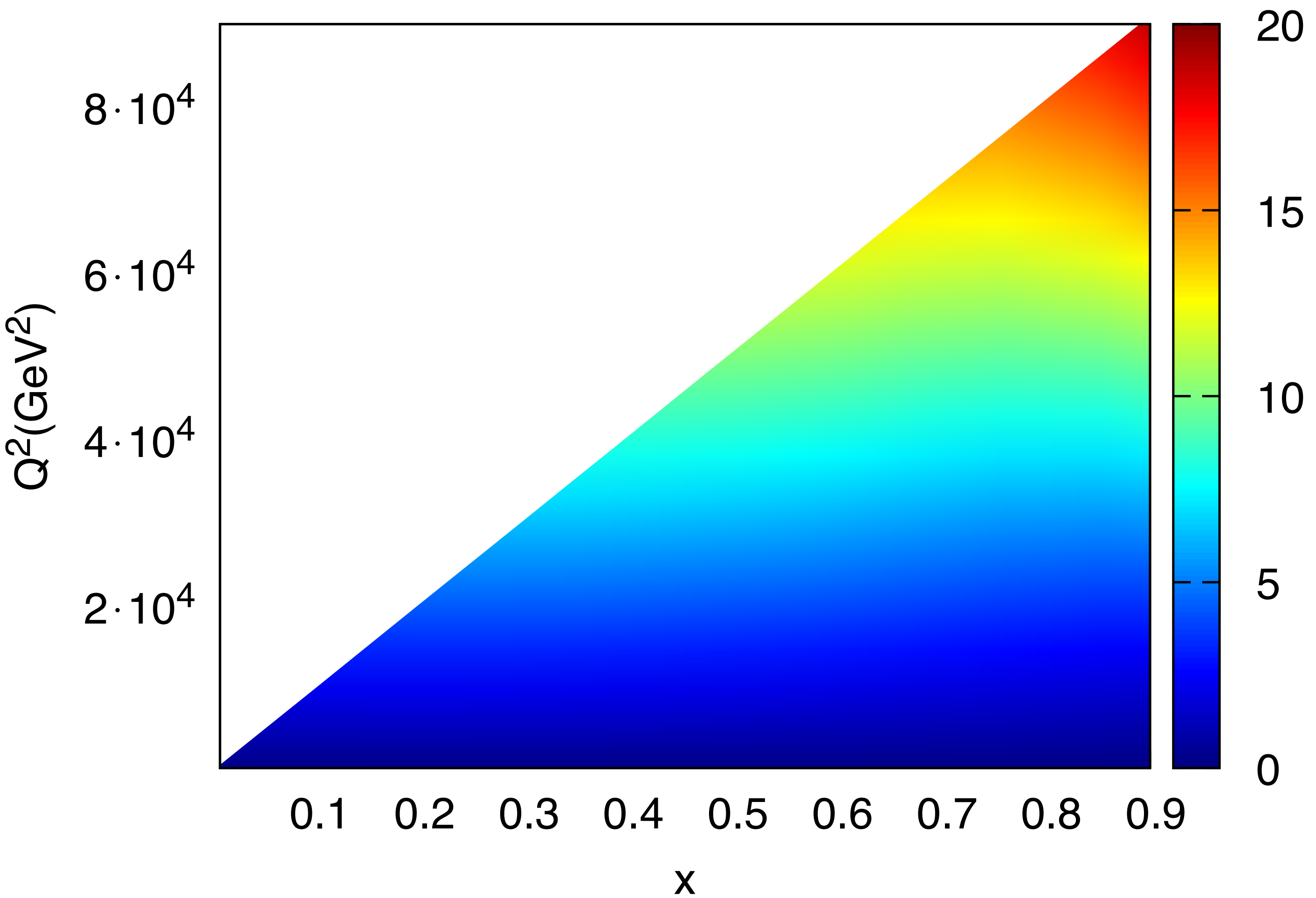
EFT and PDF

1905.05215 with S. Carrazza, S. Iranipour, J. Rojo and M. Ubiali

$$\mathcal{O}_{lq} = \left(\bar{l}_R \gamma^\mu l_R\right)\left(\bar{q}_R \gamma_\mu q_R\right)\ ,\ \ q = u, d, s, c\,,$$





$$\Delta F_2^{\rm smeft} \supset \frac{x}{12e^4}\left(4a_u e^2 \frac{Q^2}{\Lambda^2}(1+4K_Z s_W^4) + 3a_u^2 \frac{Q^4}{\Lambda^4}\right)$$
$$\times\left(u(x,Q^2) + \bar{u}(x,Q^2)\right)$$

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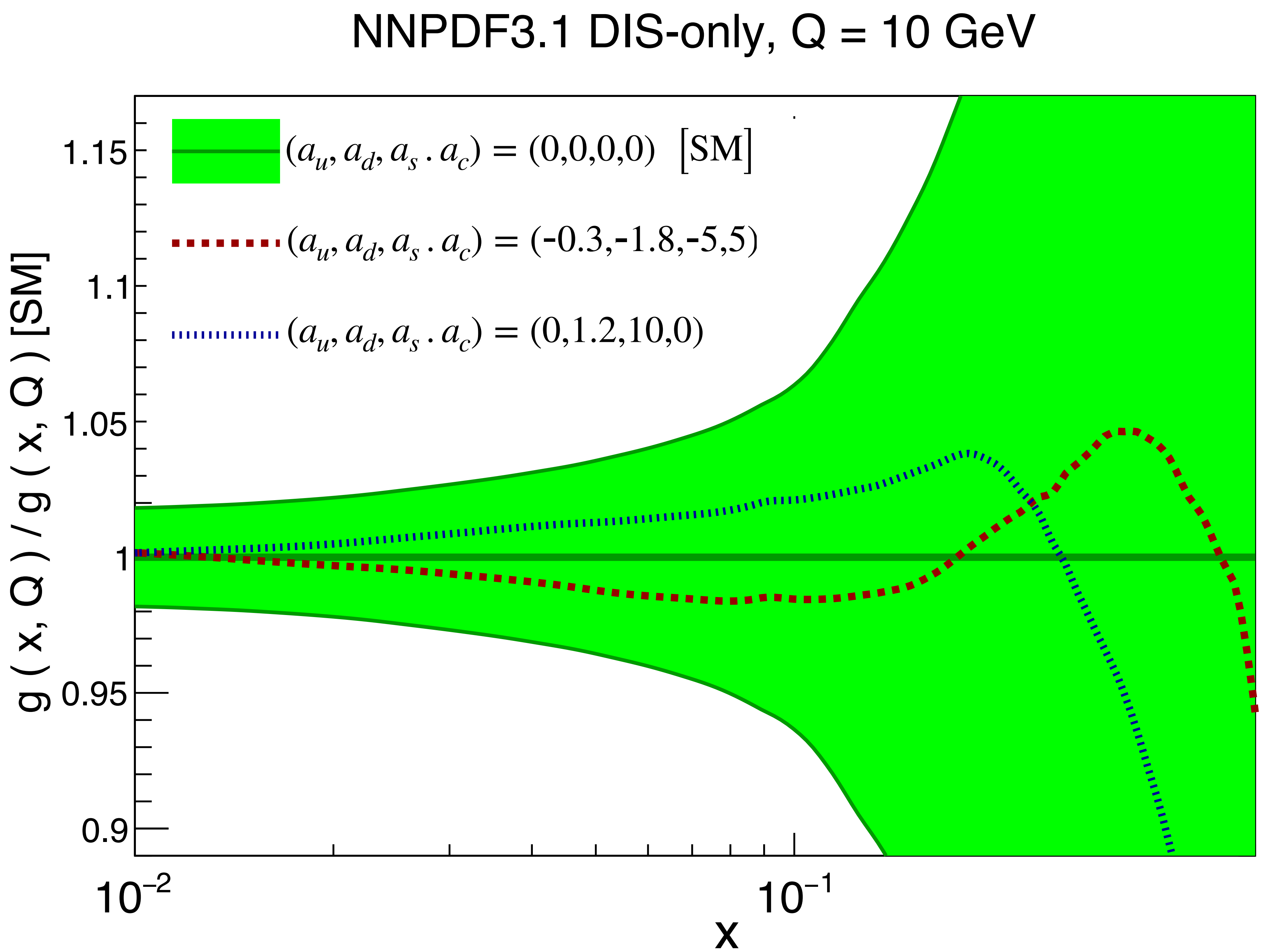
EFT and PDF



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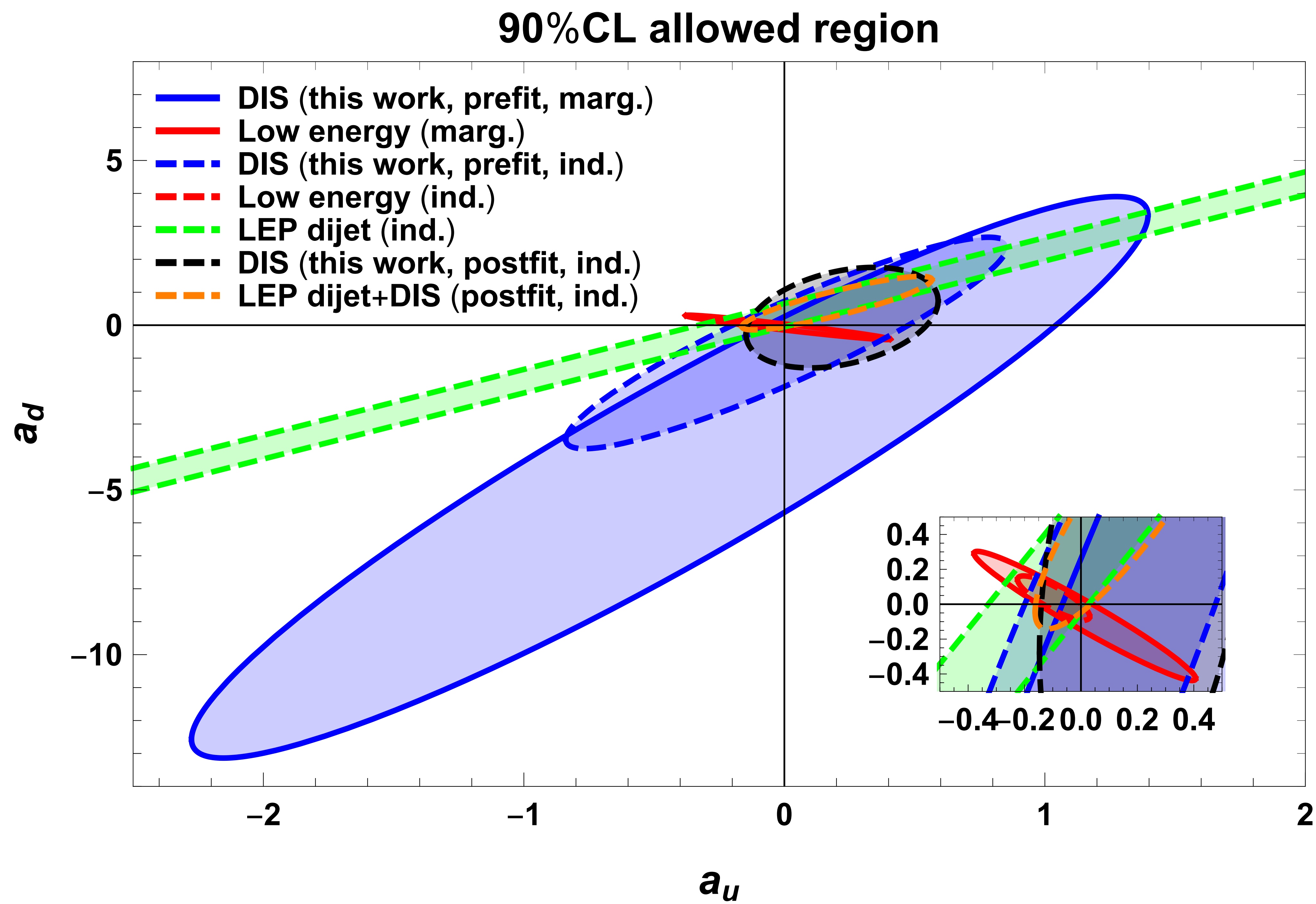
EFT and PDF



90%CL allowed region
DIS (this work, prefit, marg.)
Low energy (marg.)
DIS (this work, prefit, ind.)
Low energy (ind.)
LEP dijet (ind.)
DIS (this work, postfit, ind.)
LEP dijet+DIS (postfit, ind.)
5
0
−5
−10
−2
−1
0
1
2
a_d
a_u
0.4
0.2
0.0
−0.2
−0.4
−0.4 −0.2 0.0 0.2 0.4

Summary

Looking for new physics

C. Degrande

Summary

- EFT provide guidance (which observable)
- Check the validity of the single EFT assumption
- EFT is multi-channel/observable : correlation
- Global fit with a large number of parameters
- Distinguish PDF and EFT

Summary

Thank you

C. Degrande