Different approaches to constrain possible BSM contribution of the top quark interactions

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Effective Lagrangian approach

Effective Lagrangian strategy is widely used in experimental searches of the Beyond the Standart Model (BSM) physics on the colliders. It is based on:

1) constructing of model-independent effective Lagrangian, in a general form, for the considered possible BSM process (signal),

2) prepare all necessary signal and relevant SM backgrounds samples with Monte-Carlo event generators, and then

3) compare the model with experimental data to search the presence of the signal.

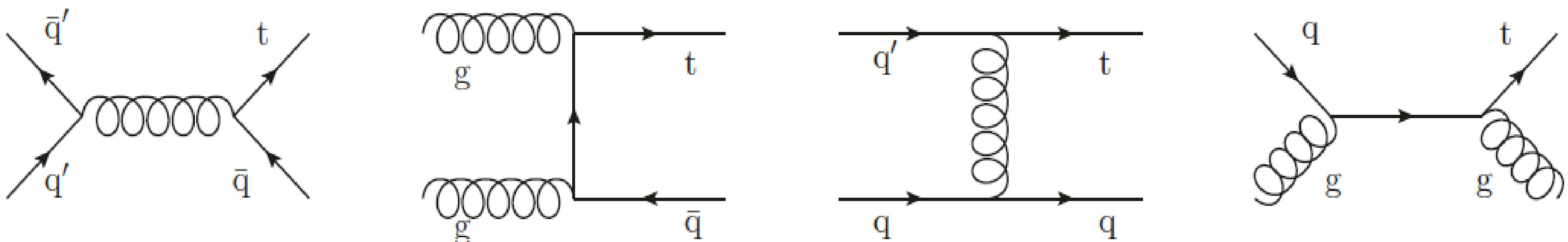
It is relatively simple and effective strategy, widely used on LHC

Example of Effective Lagrangian approach

Effective Lagrangian of gluon mediated FCNC top quark production:

$$g_s \frac{\kappa_{tug}}{\Lambda}\ \bar{u}\ \sigma^{\mu\nu}\frac{\lambda^a}{2} t\ G^a_{\mu\nu} + g_s \frac{\kappa_{tcg}}{\Lambda}\ \bar{c}\ \sigma^{\mu\nu}\frac{\lambda^a}{2} t\ G^a_{\mu\nu} + \ h.c.$$

Representative diagrams of pp->tq->Wbj channel:



Generation of the signal samples:

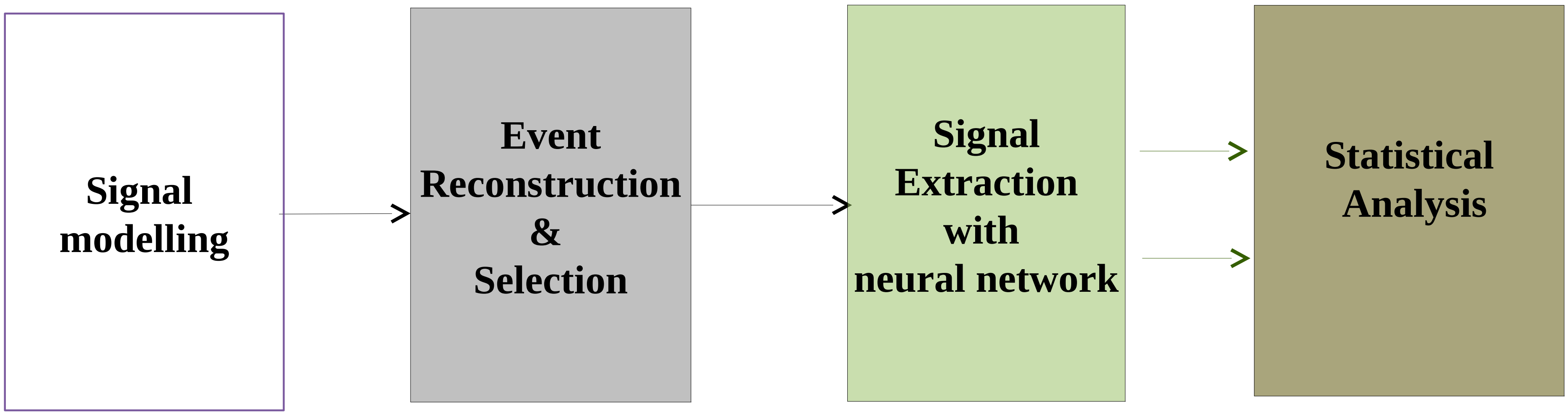
Energy, TeV	FCNC “tug” CompHEP LO CS [pb]	FCNC “tcg” CompHEP LO CS [pb]
7	33.2	4.9
8	41.7	6.7
13	91.6	18.5
14	102.8	21.4
27	268.6	71.1
100	1720	575

κ/Λ=0.03 TeV^{-1}

NLO CS = K* LO CS
K (tgu) = 1.52
K (tgc) = 1.4
(Phys.Rev. D72 (2005) 074018)

Analysis details are described in JHEP02(2017)028

Example of Effective Lagrangian approach



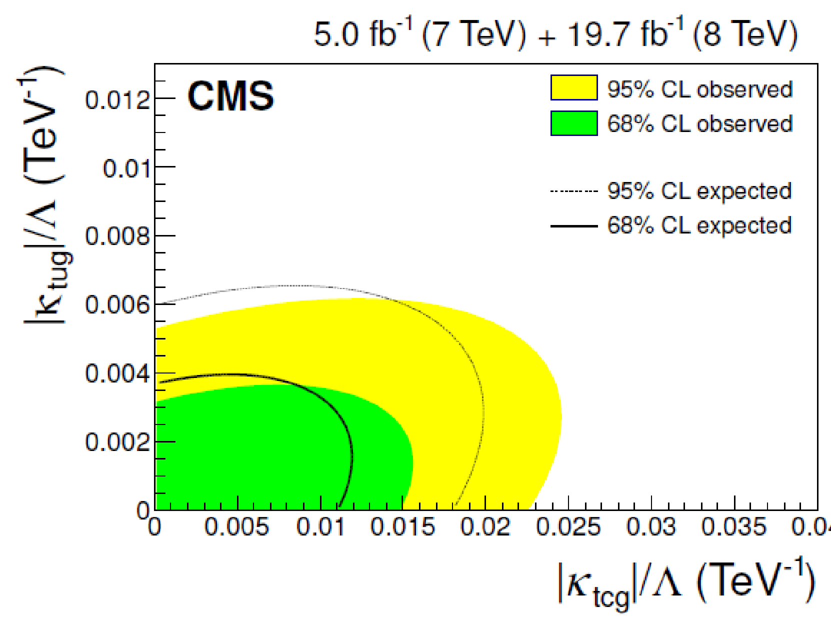
CMS combined 7+8 TeV observed (expected) 95% CL upper limits:

$\kappa^{u} / \Lambda <$ 4.1 (4.8) * 10^{-3} TeV^{-1}

$\kappa^{c} / \Lambda <$ 18.4 (15.2) * 10^{-3} TeV^{-1}

$Br(t \rightarrow ug) <$ 2.0 (2.8) * 10^{-5}

$Br(t \rightarrow cg) <$ 40.5 (27.6) * 10^{-5}



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Effective Field Theory approach

A new strategy is offered by LHC Top Working Group for top-quark measurements, using so-called Standard Model Effective Field Theory (SMEFT) approach. It is based on top-related gauge-invariant dimension-six operators of the Warsaw basis at tree-level. While operator-based approach for top quark was known for a long time ago*, LHC TWG introduce a particular strategy for interpreting the results of the measurements:

1) Define the number of observables O^k, which could be unfolded to a particle-level

2) For each observable compute linear S^k_i and quadratic S^k_{ij} contribution of Dim-6 operators

$$O^k = B^k_l + \frac{C_i}{\Lambda^2} S^k_i + \frac{C_i C_j}{\Lambda^4} S^k_{ij} + \cdots$$

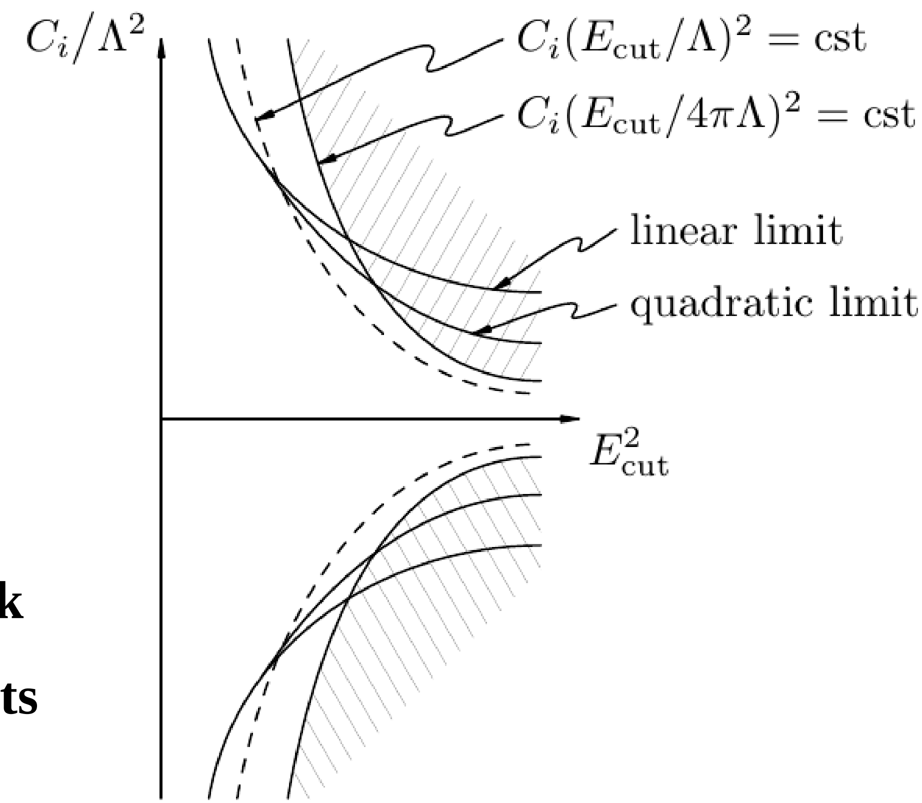
3) Use a statistical framework to find global and individual constraints for each coefficient C_i with their statistic and systematic uncertainties. Do it twice, with and without quadratic S^k_{ij} contribution

*** see, for example W. Buchmuller and D. Wyler, Nucl. Phys. B 268, 621 (1986).**

Effective Field Theory approach

4) The obtained constraints should be validated with a matching procedure: the coefficients of operators are depend on E, the characteristic energy scale (for example, one could use s^ or H_t). The point on this dependence, where linear and quadratic approaches are consistent within uncertainties, could be considered as a real constraint on the C_i, as it show energy limit of applicability of the model.

$$O^k = B_l^k + \frac{C_i}{\Lambda^2} S_i^k + \frac{C_i C_j}{\Lambda^4} S_{ij}^k + \cdots$$



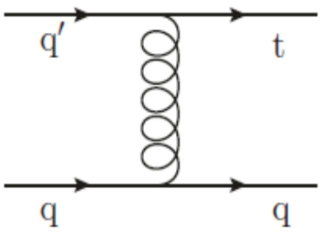
The main goals of the EFT approach is to check applicability of the model and provide a basis for comparison between different measurements and constraints

EL and EFT adjustment

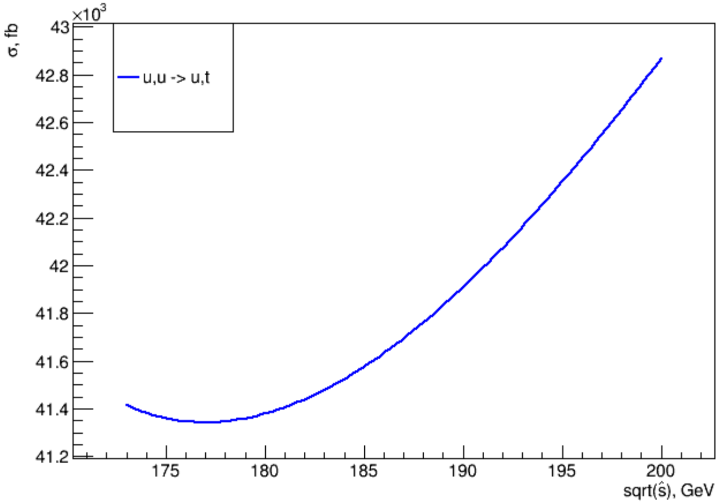
While offered EFT approach could provide good rationale to constrain possible BSM contributions, practical using of this approach is not clear.

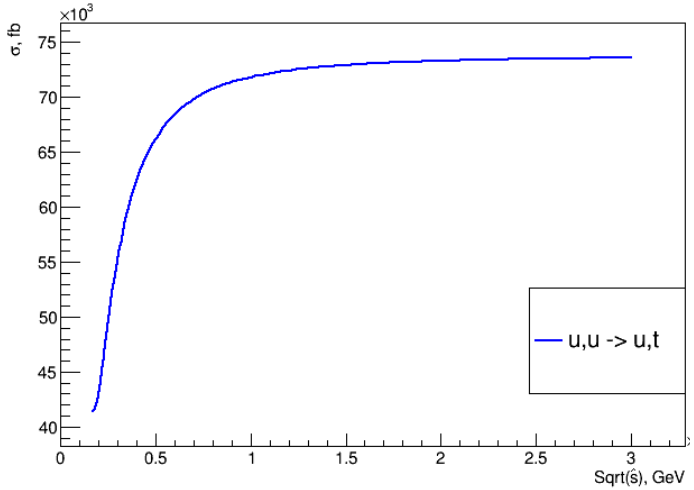
For the particular example of top gluon-mediated FCNC,

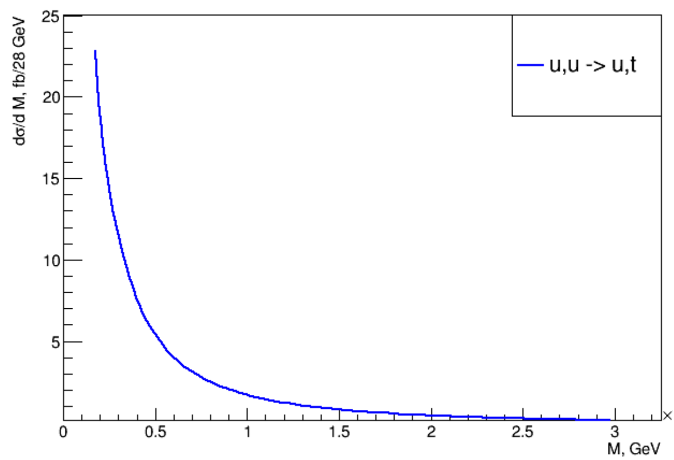
$$g_s \frac{\kappa_{tug}}{\Lambda} \bar{u}\, \sigma^{\mu\nu} \frac{\lambda^a}{2} t\, G^a_{\mu\nu} + g_s \frac{\kappa_{tcg}}{\Lambda} \bar{c}\, \sigma^{\mu\nu} \frac{\lambda^a}{2} t\, G^a_{\mu\nu} + h.c.$$



unitarity violation is shown with the dependence of cross section of u,u→t,u subprocess as function of s^.







Summary

1) Effective Lagrangian approach is relatively simple and effective strategy, but need an additional verification for obtained BSM constraints.

2) Effective Field Theory approach could provide such proofs.

3) However, the EFT approach is a complicated, and practical strategy for real experimental analysis (gluon mediated FCNC top quark production process) is yet to be invented.