Top Physics at FCC-eh

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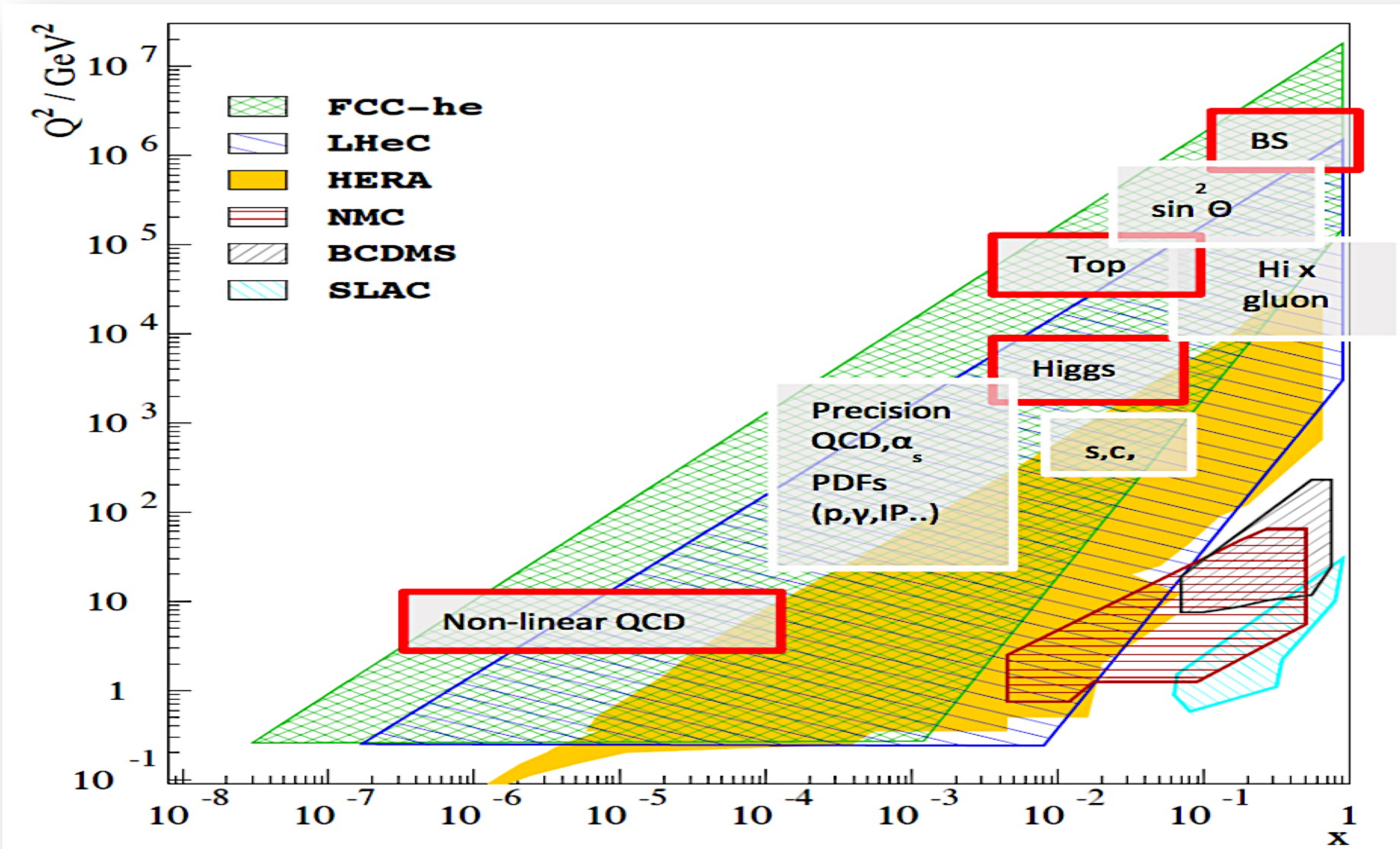
FCC Week 2017, 29 May-02 June 2017, Berlin

PROSPECTS AT FUTURE EP COLLIDERS

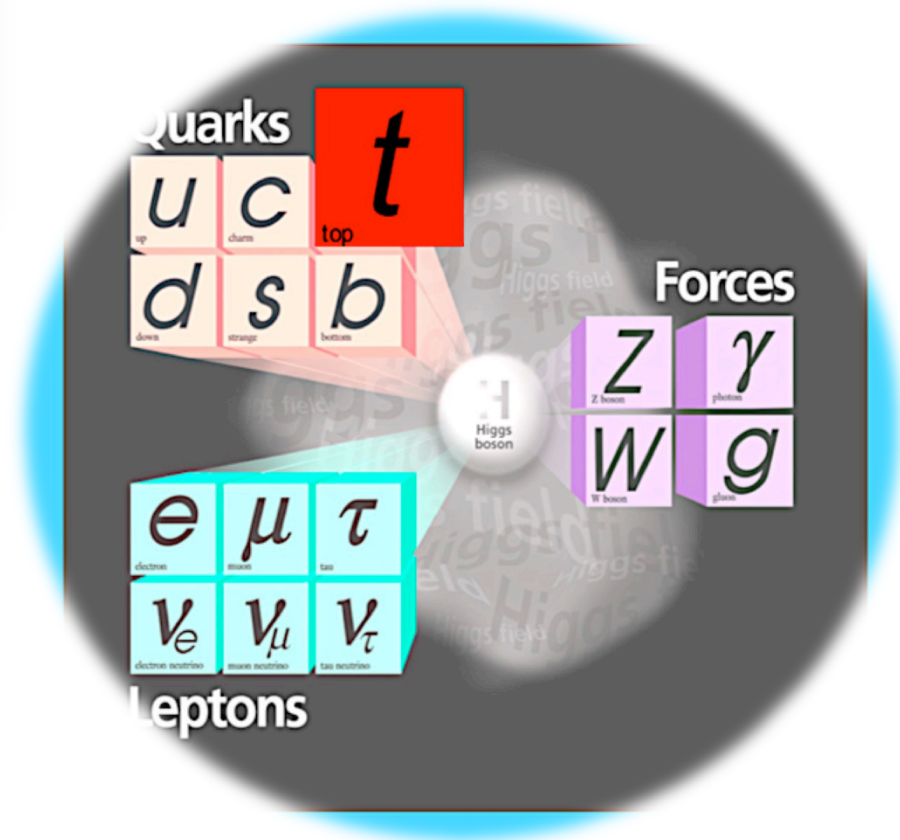


O. Bruning *et al.*, PoS EPS-HEP2015 (2015) 520

The FCC-he and LHeC compared to previous DIS experiments. The plot indicates the placement of key physics subjects in the kinematics plane of x and Q^2.

Precise measurements of couplings between SM gauge bosons and quarks and leptons are sensitive test of new physics (search for deviations), due to its large mass the top quark is expected to be the most sensitive to BSM physics.

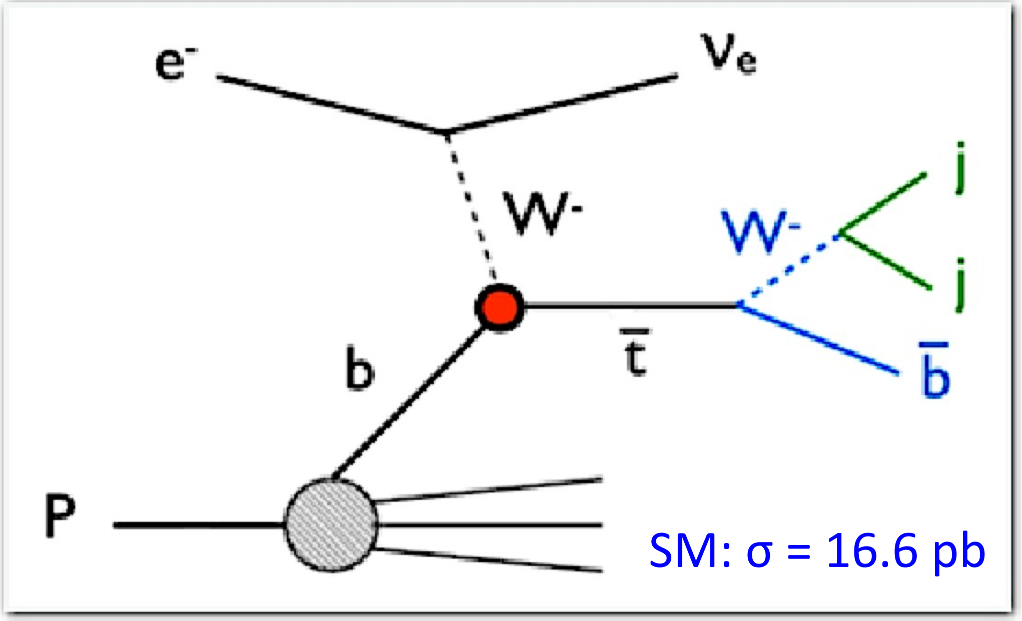
The future ep colliders offers excellent prospects for top physics.



TOP QUARK ANOMALOUS CC/NC INTERACTIONS

1)

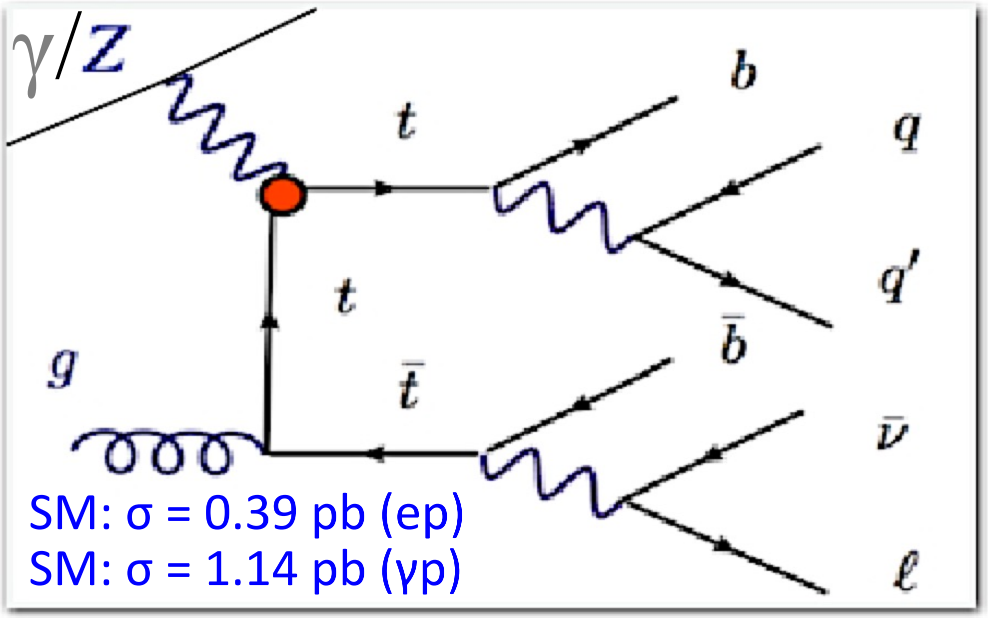
CC



High precision measurements of V_{tb} and search for anomalous Wtb couplings

2)

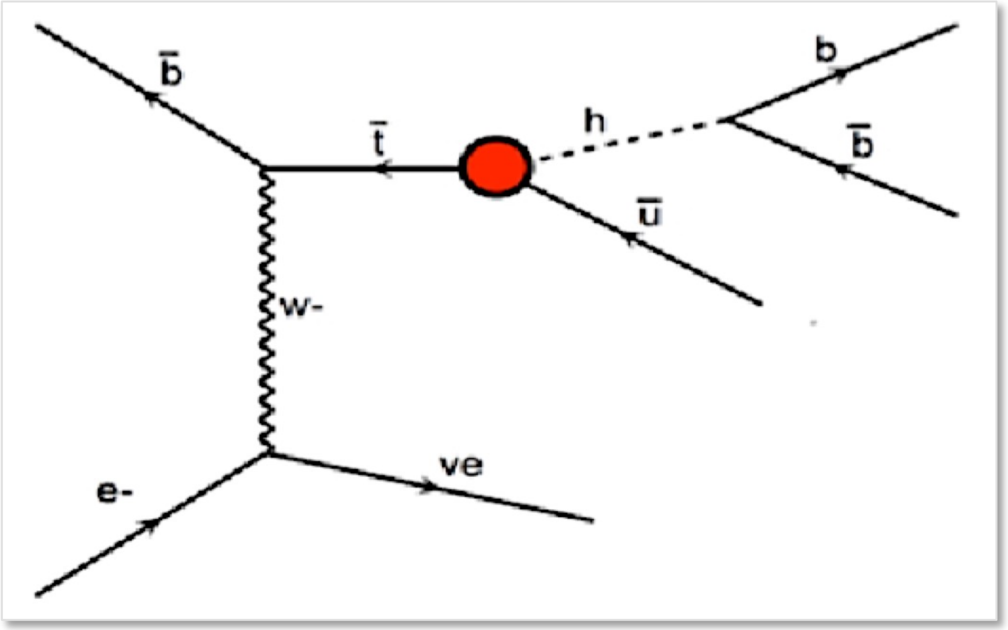
NC



Measurement of top charge/isospin and anomalous ttγ/ttZ (EDM,MDM)

3)

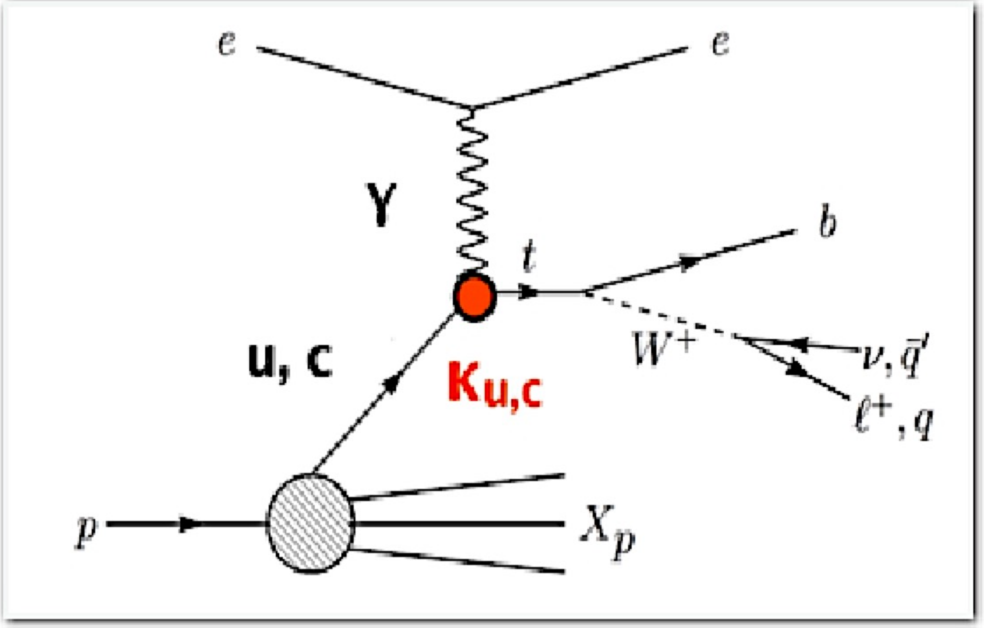
CC



Search for anomalous top-Higgs couplings

4)

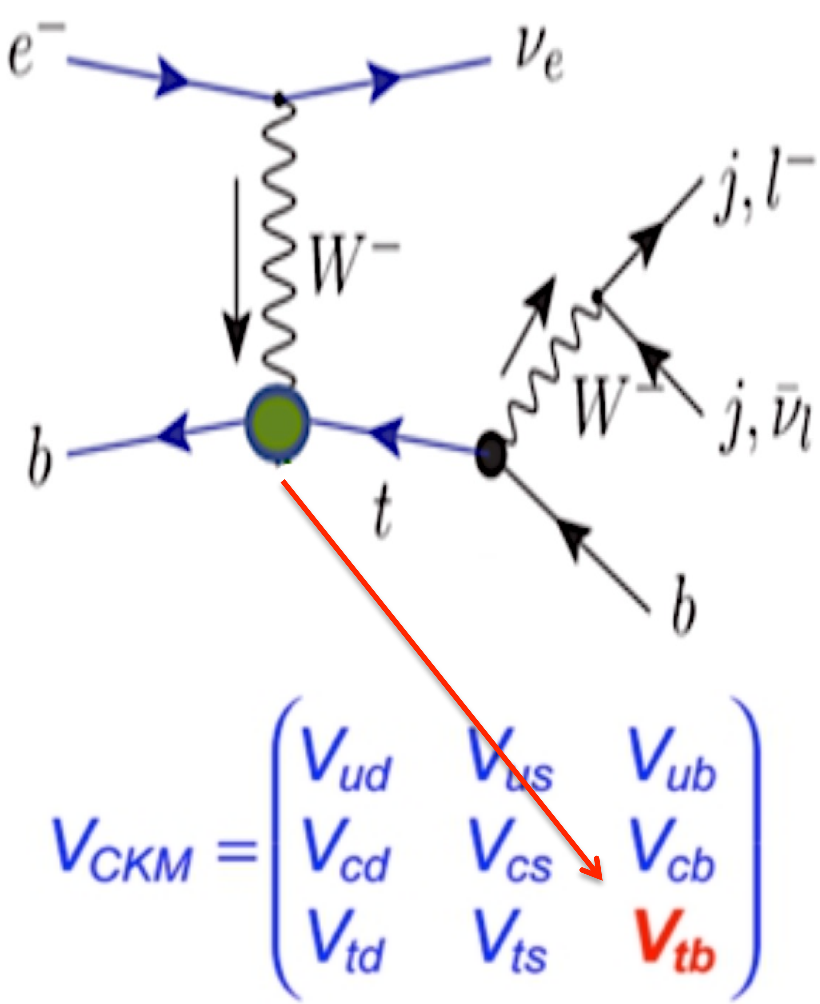
NC

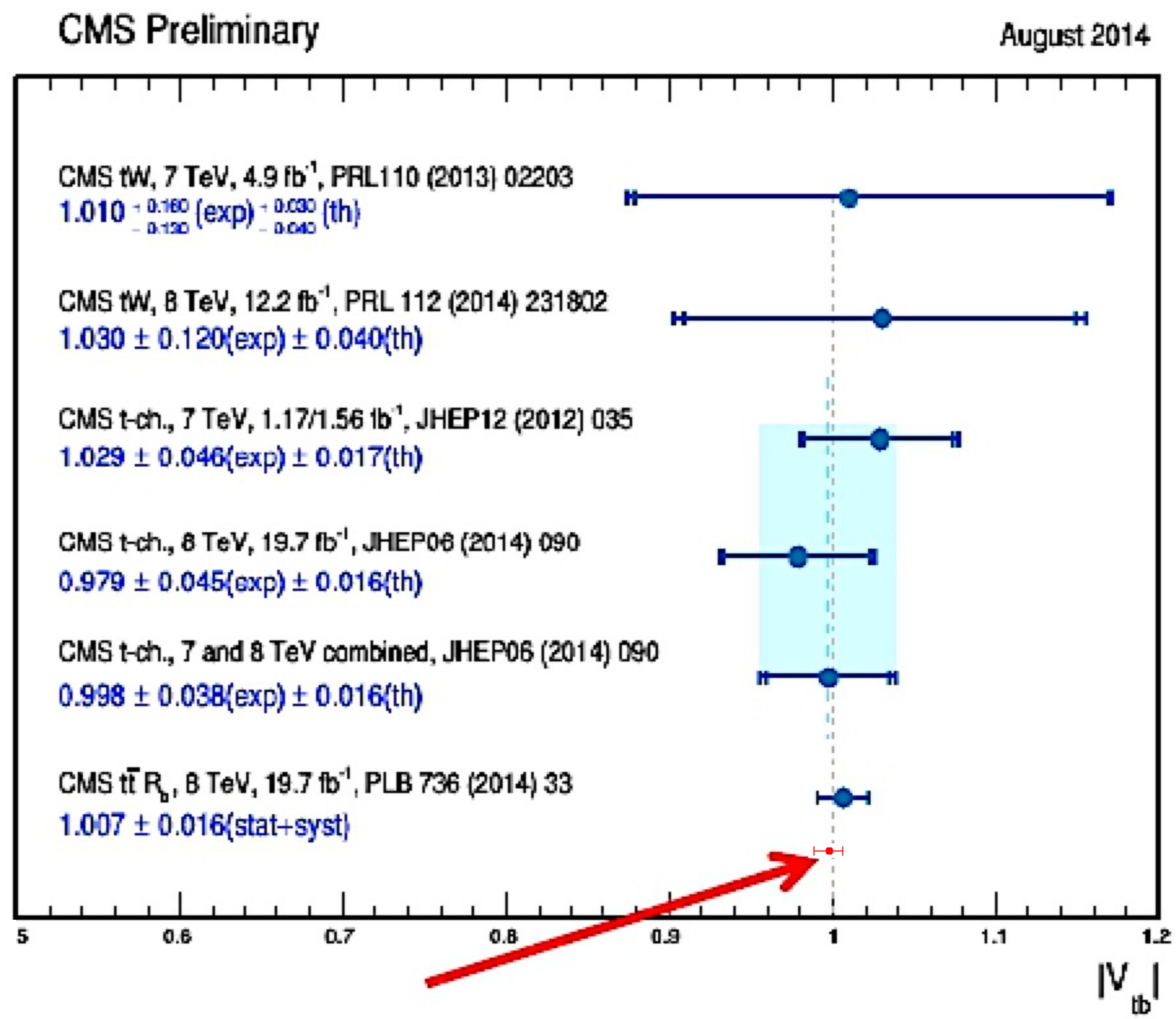


Sensitive search for FCNC couplings will constrain BSM models

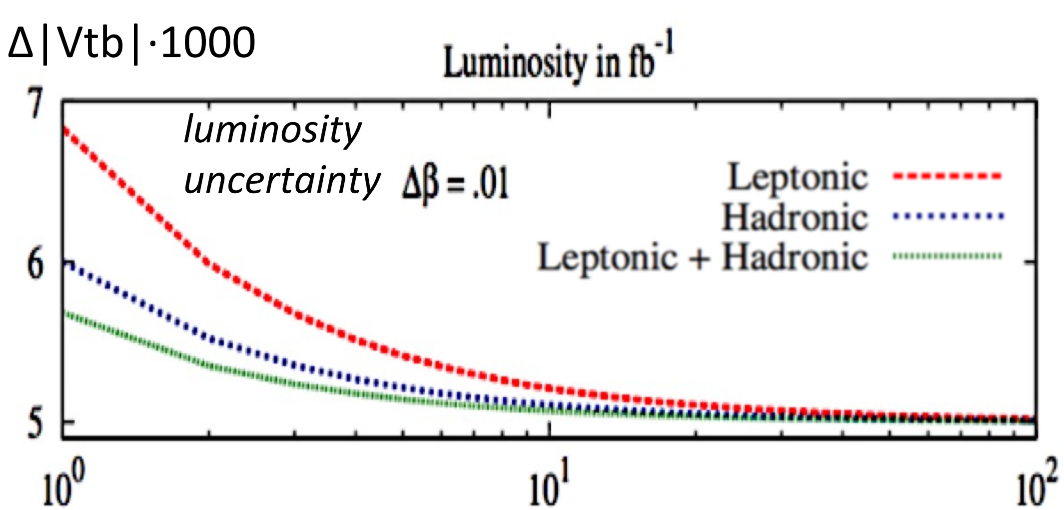
MEASUREMENT OF Vtb

- the results can also be applied conservatively to the FCC-ep





LHeC, 100 fb-1
1.000 ± 0.005 (expected)



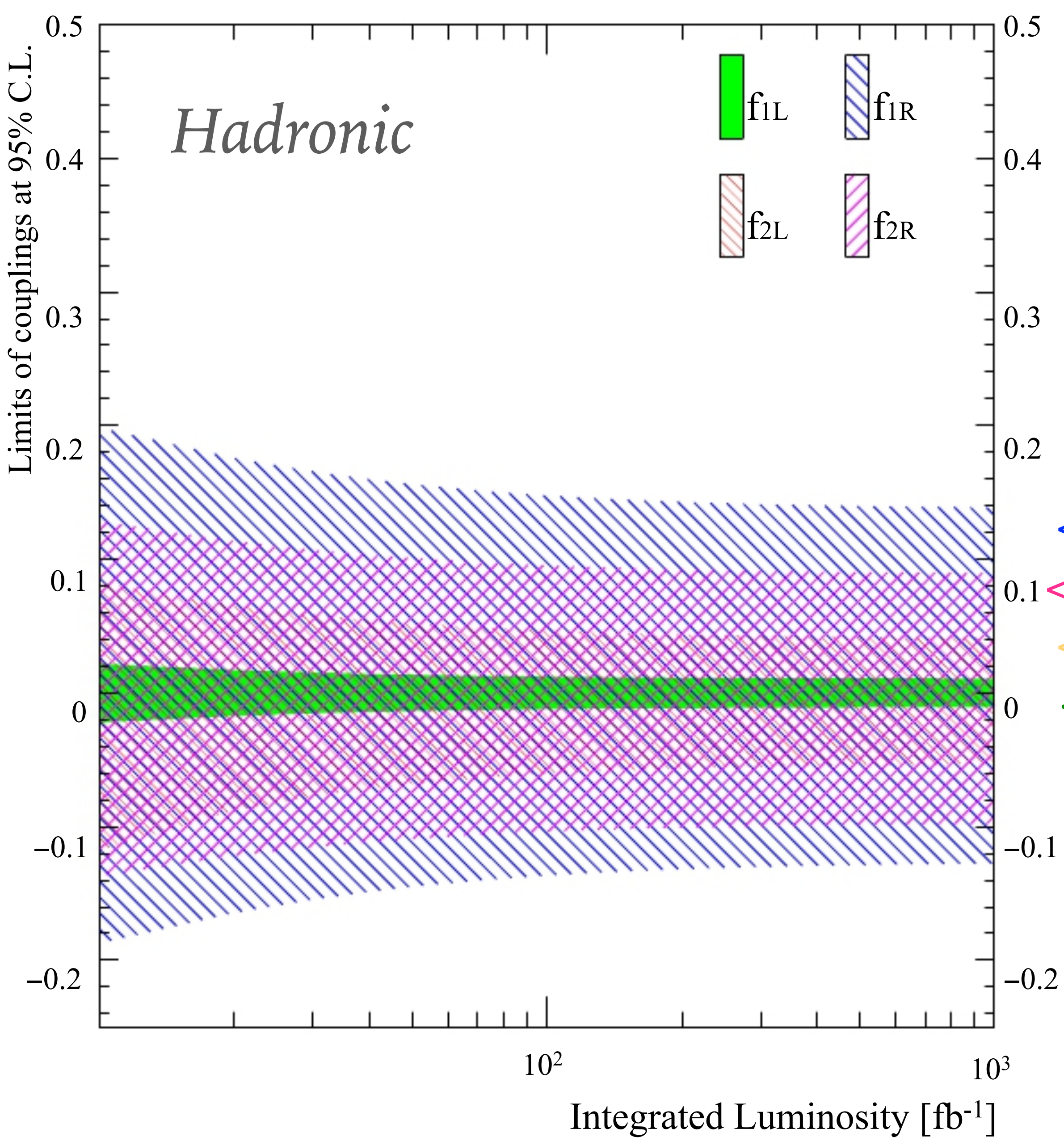
The CKM matrix element Vtb
can be measured with a precision of 0.5%

arXiv:1307.1688

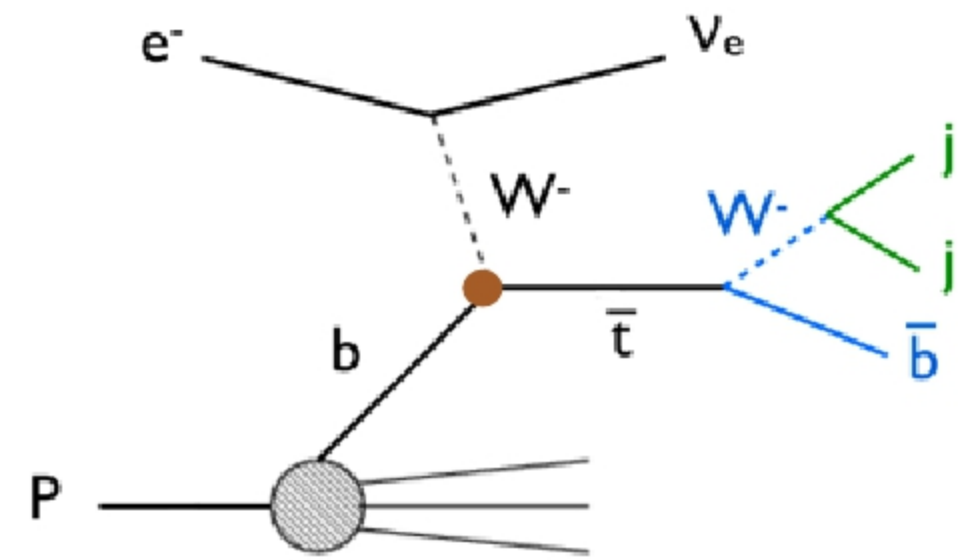
TOP QUARK CC ANOMALOUS INTERACTIONS

Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688
Kumar, Ruan, to be publ.

The updated plots for FCC-eh (a conservative estimate). The errors are systematically limited (assumed to be similar for LHeC and FCC-eh). A better sensitivity to the hadronic channel.



< 0.14
< 0.09
< 0.04
< 0.01



vector/right coupling = 0 in SM

$$\mathscr{L}_{Wtb} = \frac{g}{\sqrt{2}}\left[W_\mu \bar{t}\gamma^\mu (V_{tb} f_1^L P_L + f_1^R P_R) b - \frac{1}{2\, m_W} W_{\mu\nu}\bar{t}\sigma^{\mu\nu}(f_2^L P_L + f_2^R P_R) b\right] + h.c.$$

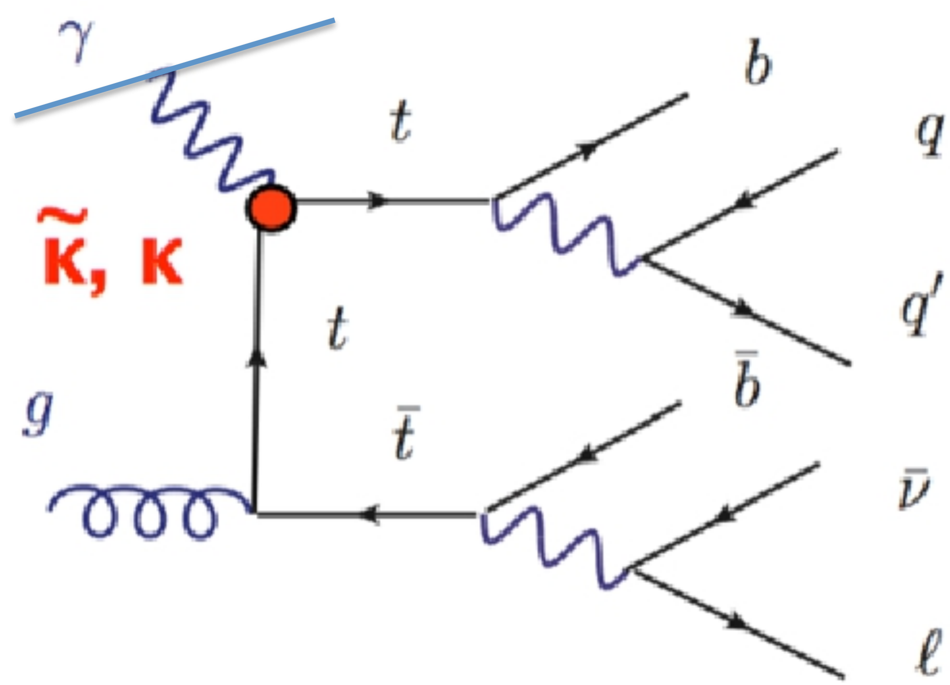
vector/left coupling = 1 in SM

Tensor/left/right couplings

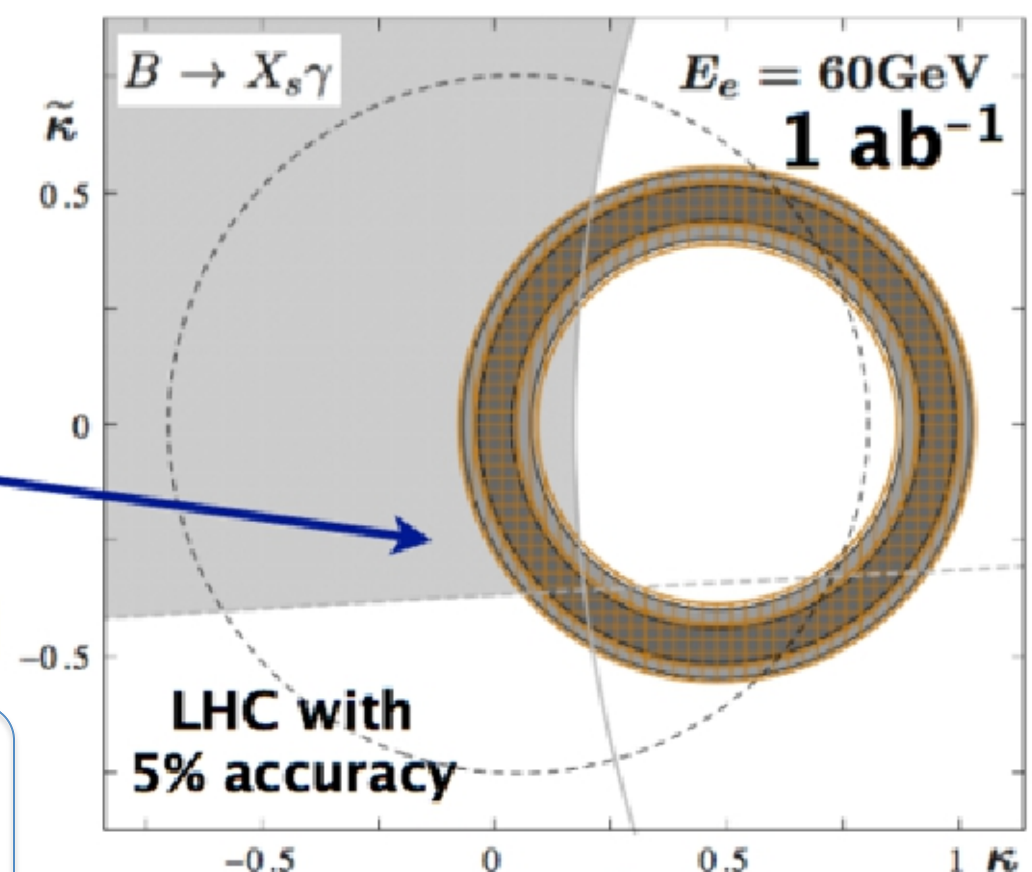
TOP NC EDM AND MDM

- the results can also be applied conservatively to the FCC-ep.

$$\mathcal{L}_{t\bar{t}\gamma} = e\bar{t}\left(Q_t\gamma^\mu A_\mu + \frac{1}{4m_t}\sigma^{\mu\nu}F_{\mu\nu}(\kappa + i\tilde{\kappa}\gamma_5)\right)t$$



electric dipole moment: $\tilde{\kappa}$



magnetic dipole moment: κ

LHeC:
8% and 16% accuracy
10% 18%
→ systematically limited

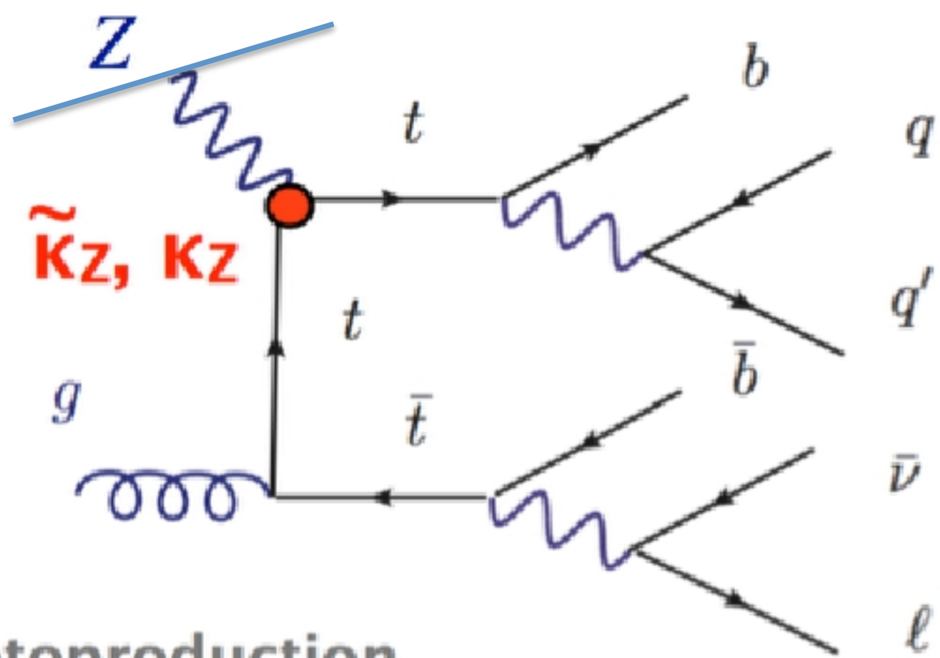
27% accuracy
(4.59fb^{-1}, 7 TeV)

Bouzas, Larios,
Physical Review D 88, 094007 (2013)

TOP NC EDM AND MDM

- the results can also be applied conservatively to the FCC-ep.

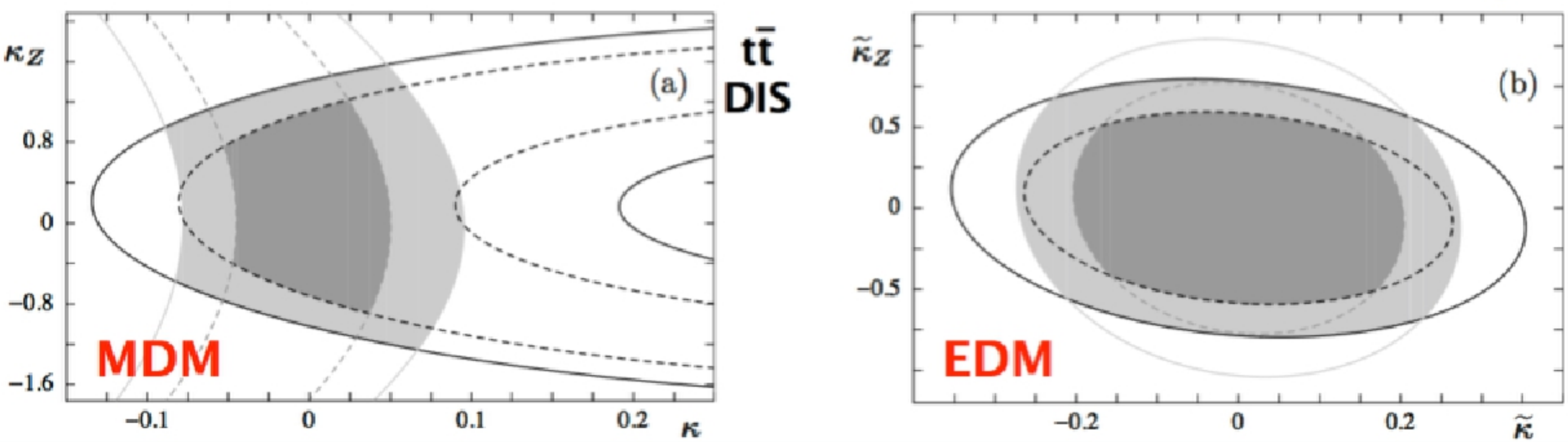
Bouzas, Larios,
Physical Review D 88, 094007 (2013)



property	precision
EDM: $\tilde{\kappa}$ / $\tilde{\kappa}_Z$	0.20-0.28/0.6-0.8
MDM: κ / κ_Z	0.05-0.09/0.9-1.3

LHeC:
10% and 18% accuracy

$t\bar{t}$ photoproduction

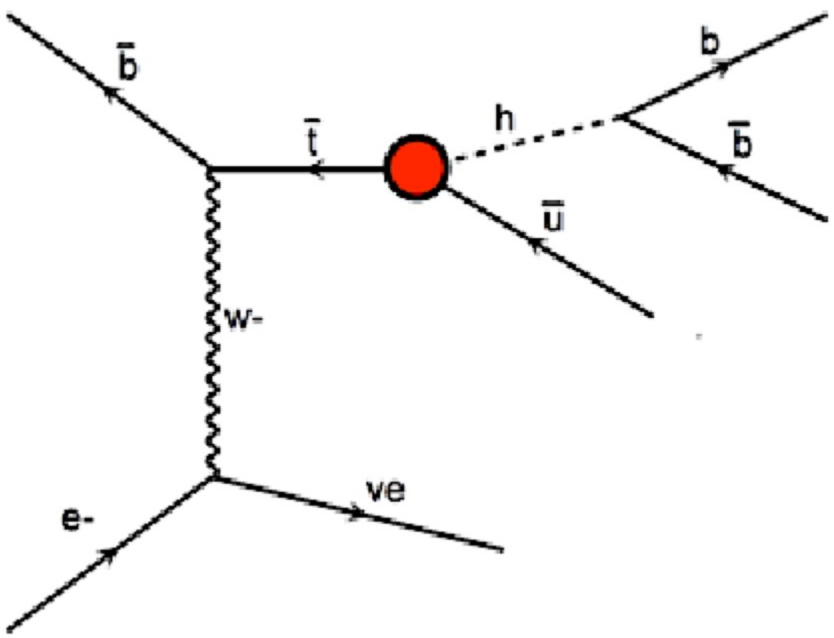


ANOMALOUS FCNC TOP-HIGGS COUPLINGS

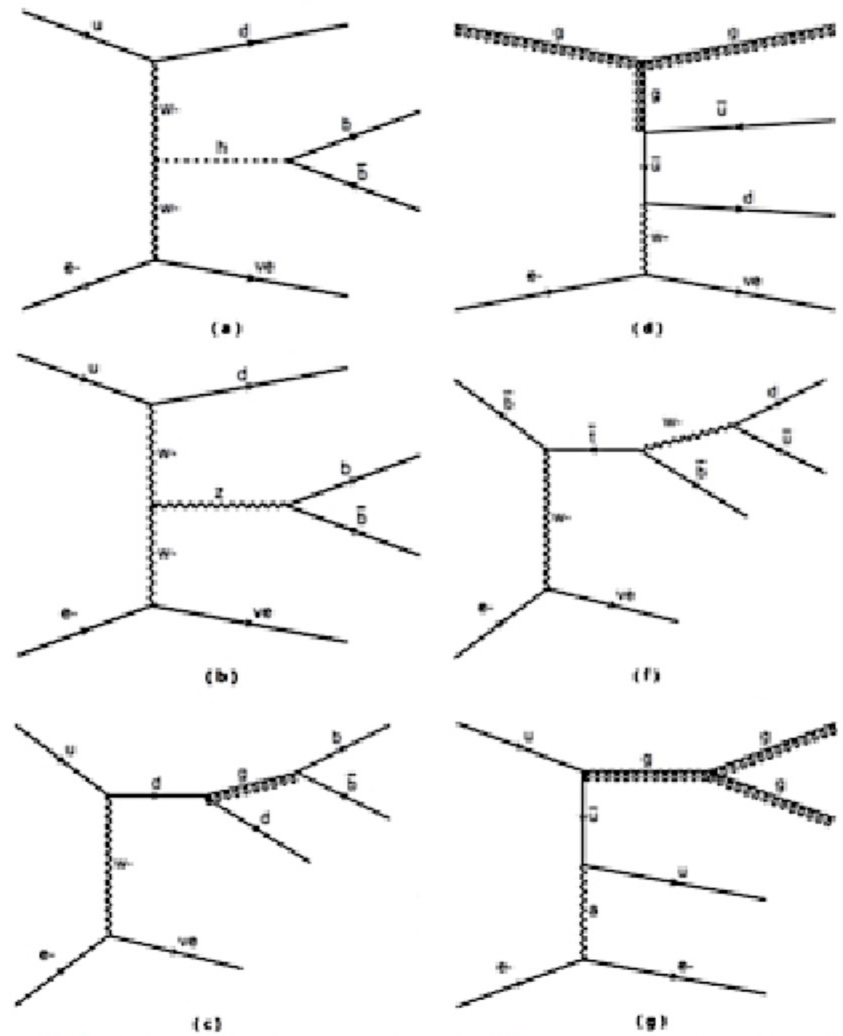
H. Sun
@DIS17

signal

background



$$e^-p \to \nu_e\bar{t} \to \nu_e h\bar{q} \to \nu_e b\bar{b}\bar{q}, \quad q = u, c$$



irreducible backgrounds:

$$e^-p \to \nu_e(h \to b\bar{b})j$$
$$e^-p \to \nu_e(z \to b\bar{b})j$$
$$e^-p \to \nu_e(g \to b\bar{b})j$$

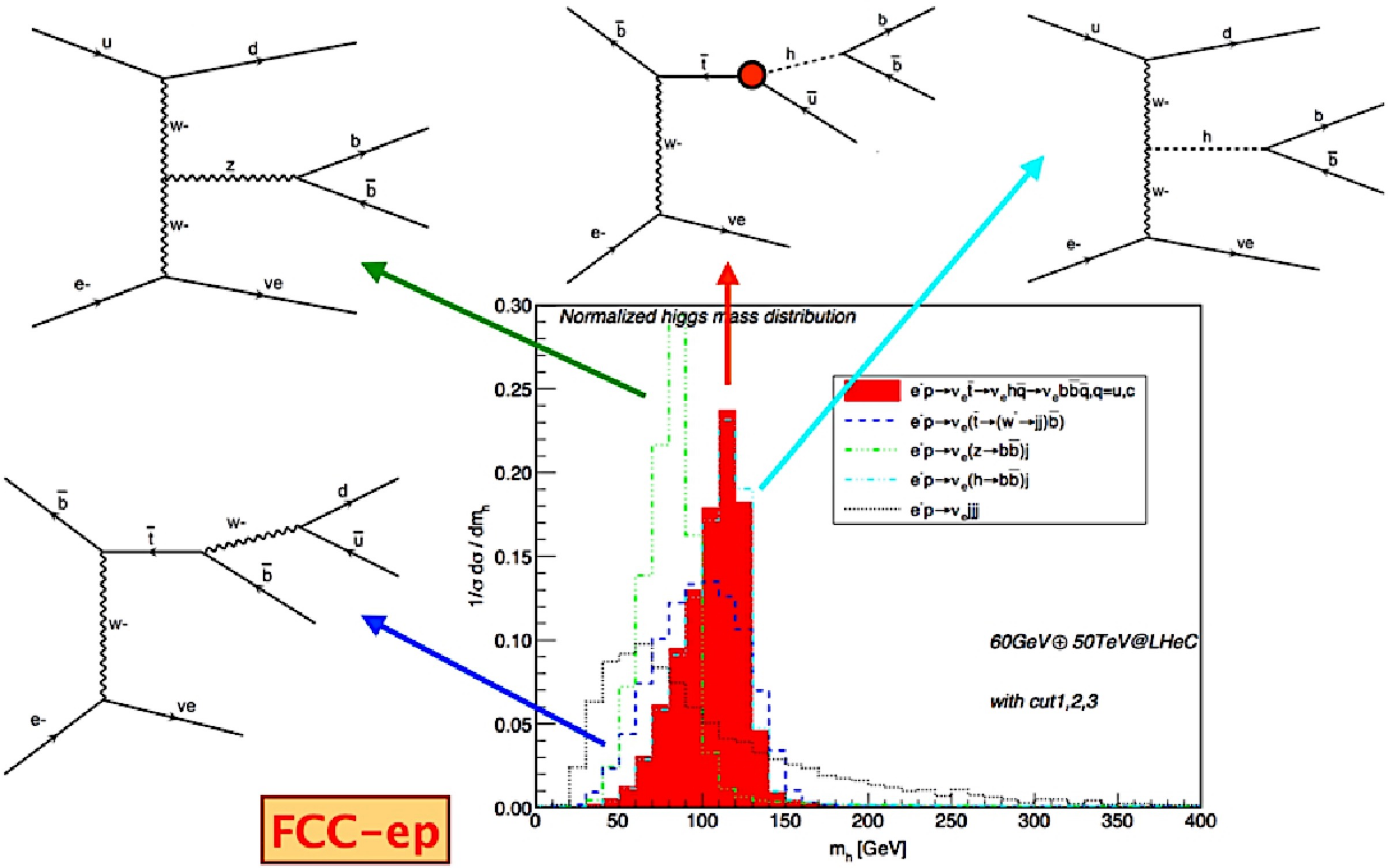
reducible backgrounds:

$$e^-p \to \nu_e jjj$$
$$e^-p \to \nu_e jjb/\bar{b}$$
$$e^-p \to \nu_e\bar{t}$$
$$e^-p \to e^- jjj$$
$$e^-p \to e^- jjb/\bar{b}$$
$$e^-p \to e^-(g \to b\bar{b})j$$

- parametrised assumed resolutions for elecrons/photons, muons, jets and unclustered energy using ATLAS values
- b-tag rate of 60%, c-jet fake rate of 10%, light-jet fake rate of 1%
- selections optimized for LHeC and FCC-ep scenarios (s/√(S+B))
- cut-based and MVA-based analyses

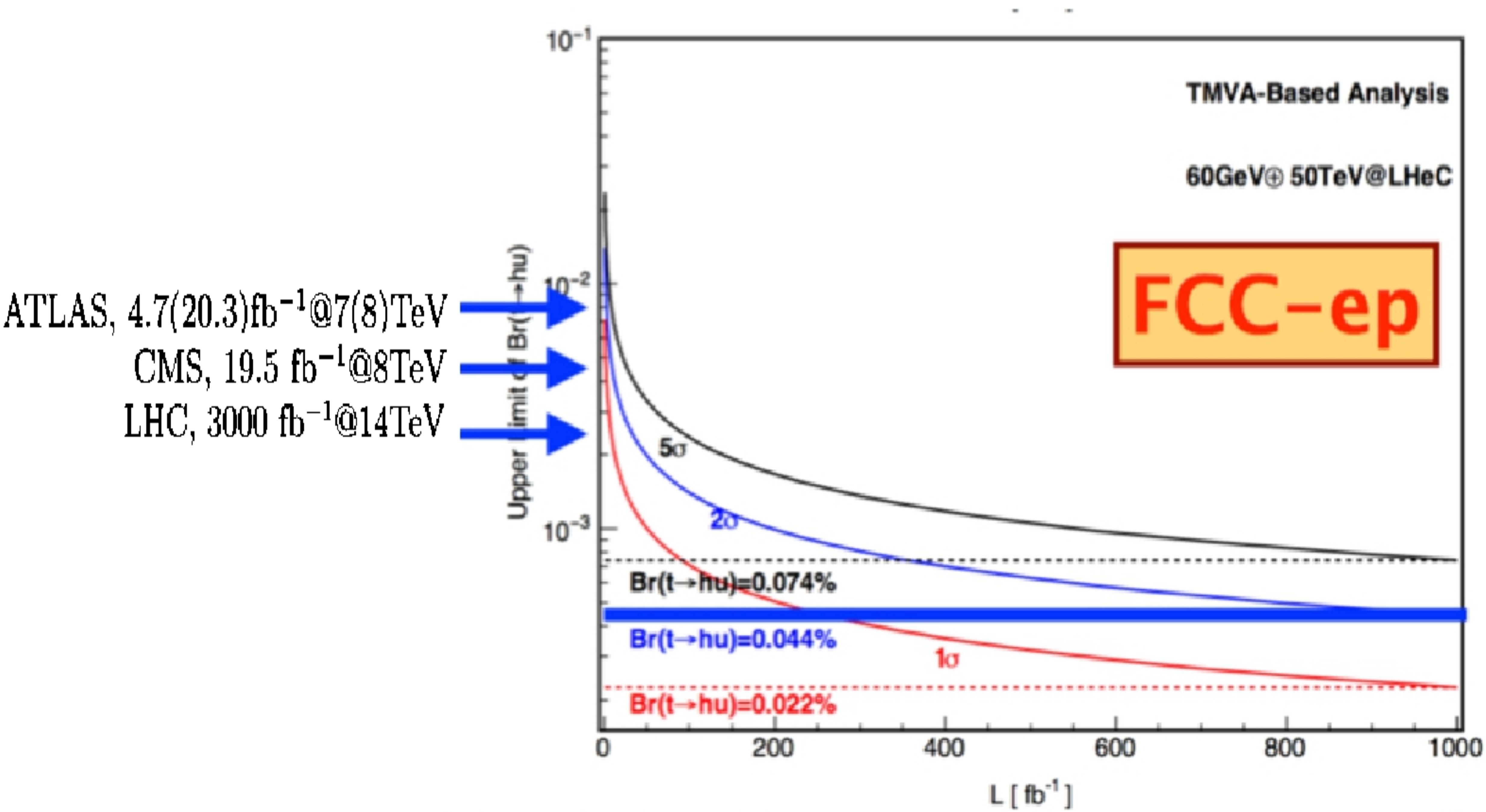
ANOMALOUS FCNC TOP-HIGGS COUPLINGS

H.Sun, [arXiv:1602.04670]



UPPER LIMITS ON BRANCHINGS

H. Sun @DIS17



→ improves sensitivity of HL-LHC

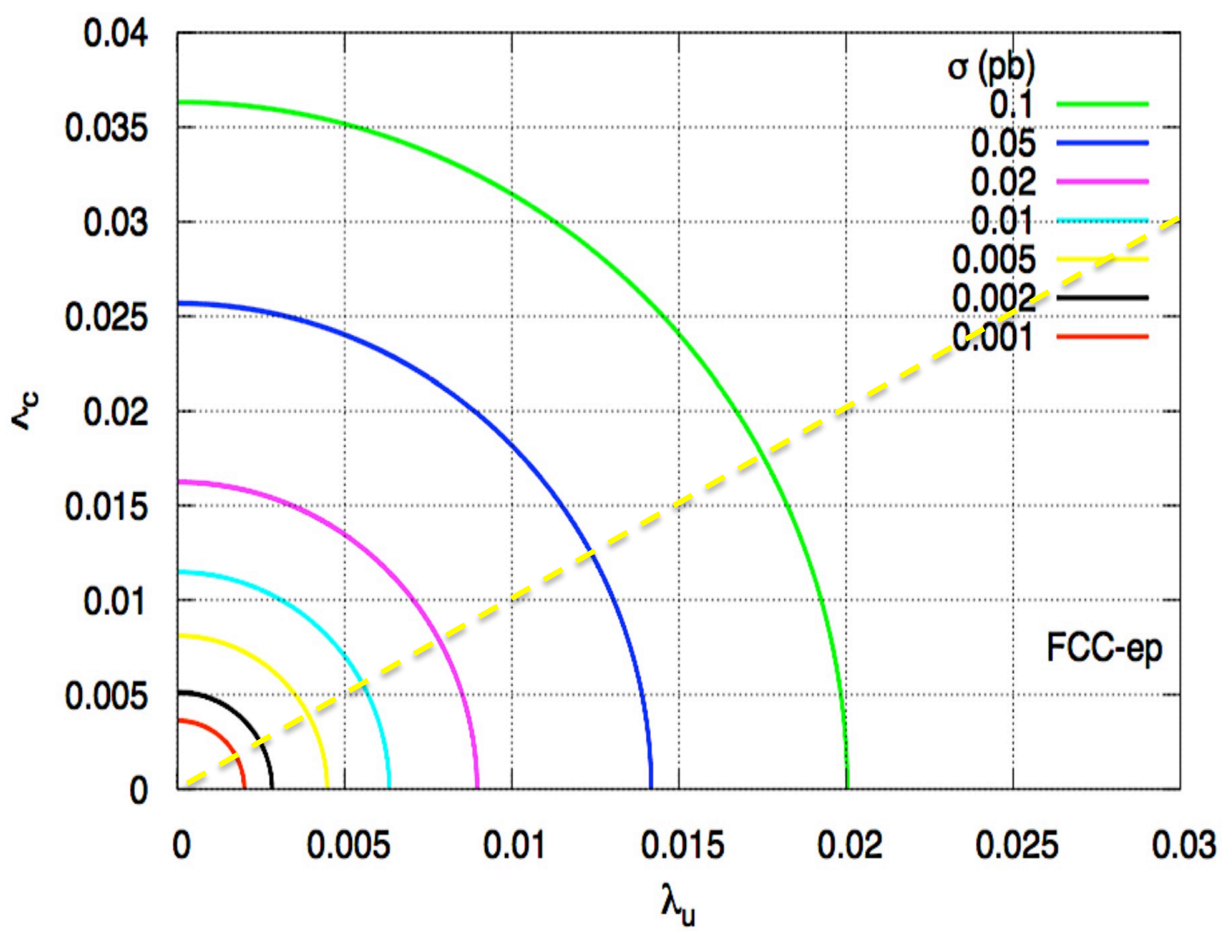
TOP QUARK FCNC PRODUCTION

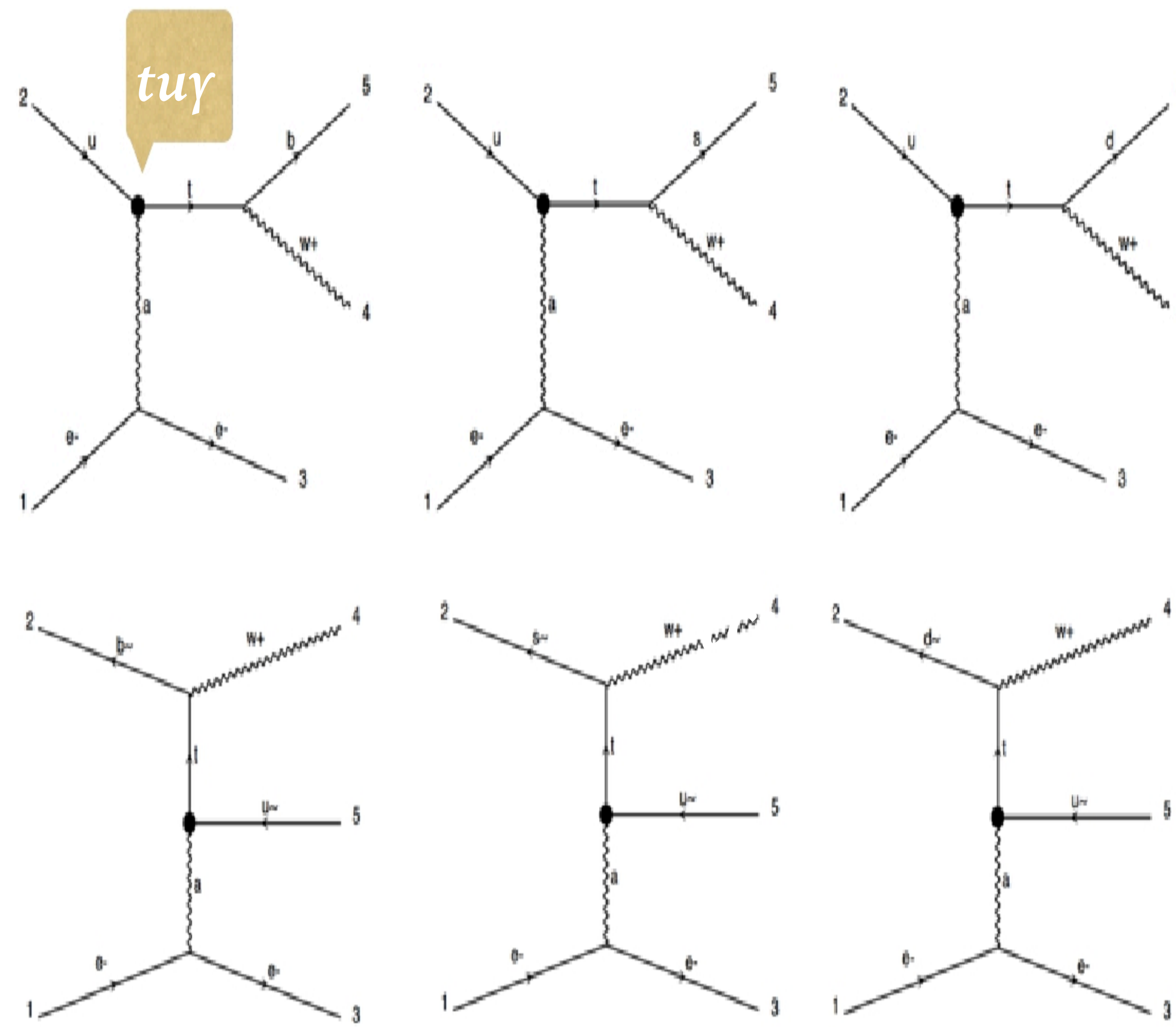
O.Cakir, H.Denizli, I.Turk Cakir, A. Senol, A. Yilmaz, An update since 1st FCC Physics Workshop 2017

Process: e-p->e-Wq+X.

Signal cross sections at FCC-ep collider depending on FCNC tqγ couplings λ_u and λ_c within the interested range.

PDF: NNPDF2.3

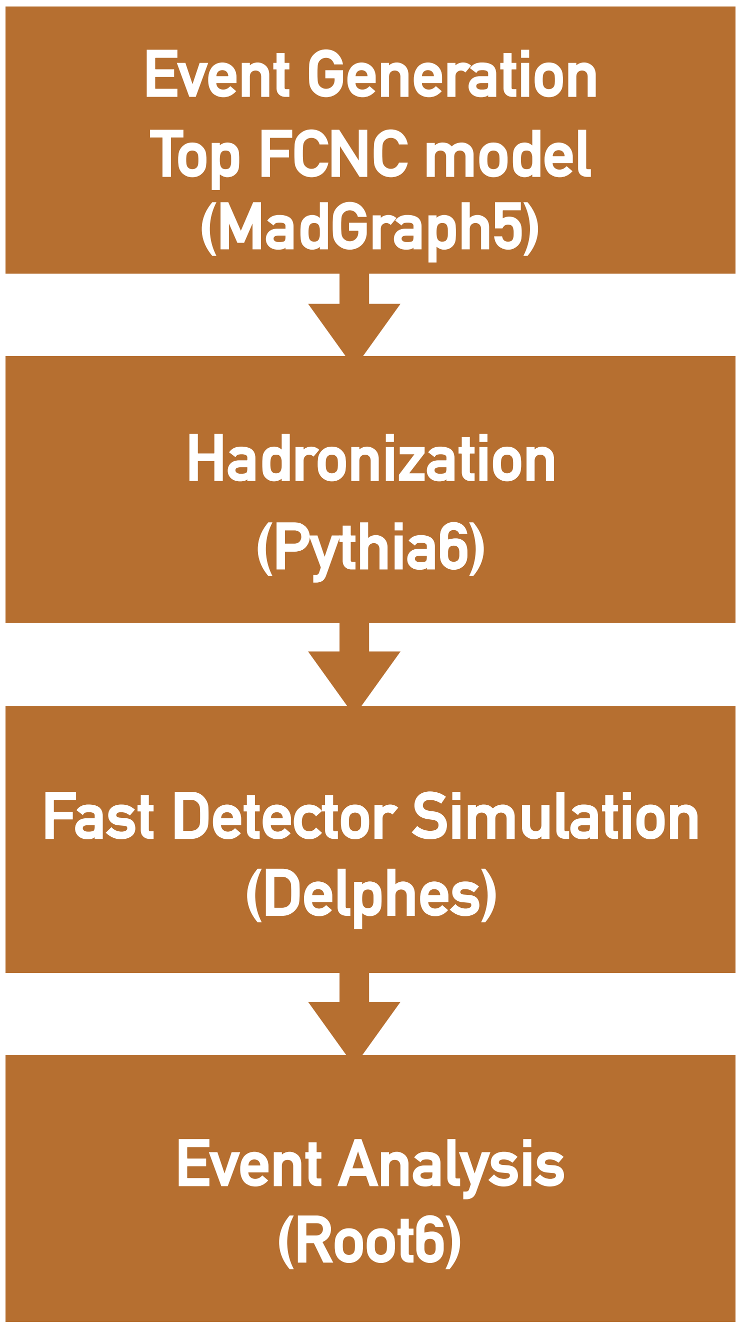




+ similar diagrams for tcγ

(further diagrams for process $e^-p \to e^-W^-q+X$ with the interchange q<—>q~)

ANALYSIS FRAMEWORK

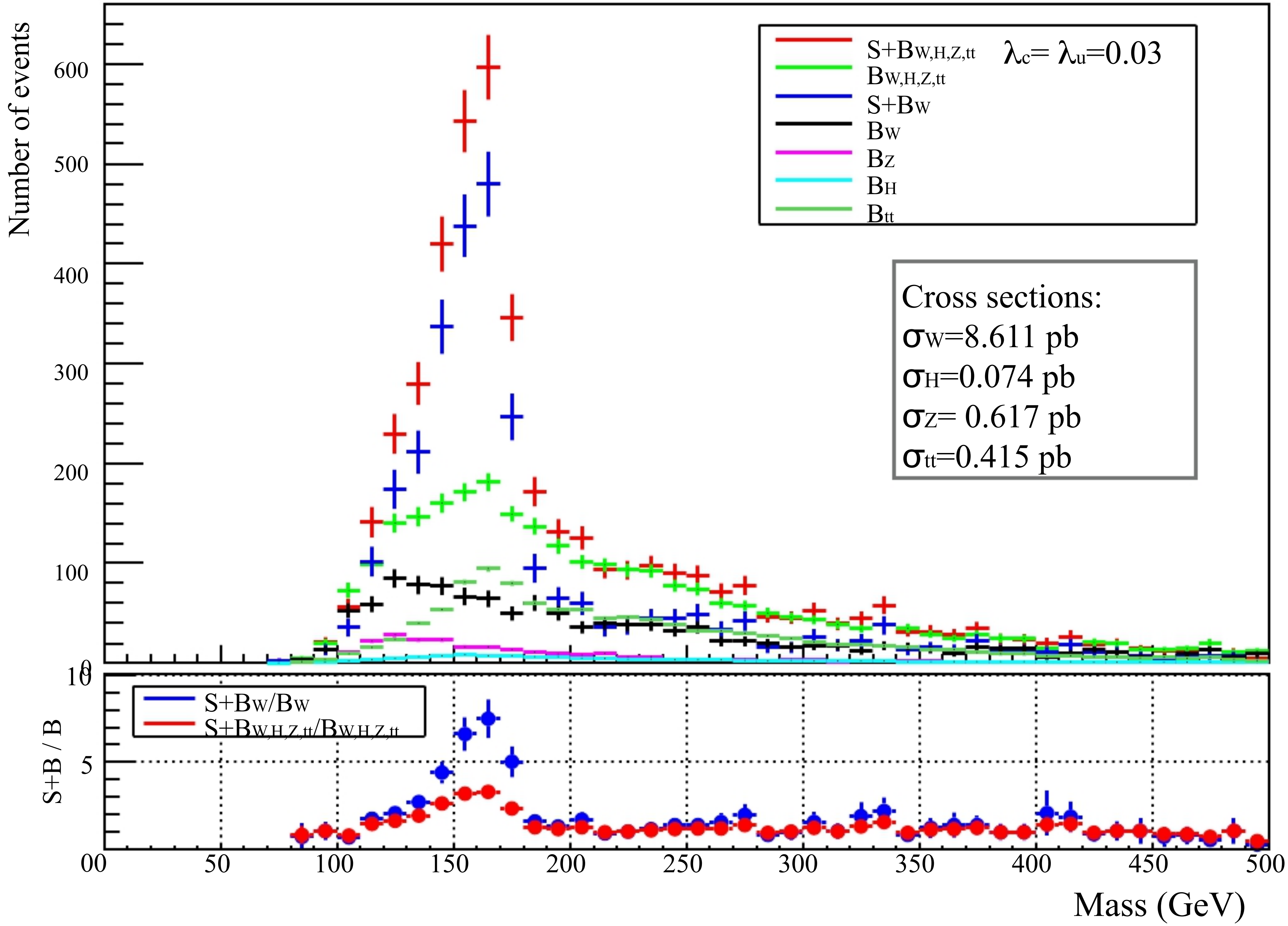


For the analysis, after pre-selection cuts, we use the analysis cuts for further background suppression

Cut flow

Cut-0 :	**at least one electron and three jets (pre-selection with default MG5 cuts)**
Cut-1 :	require one of three jets as being b-tag
Cut-2 :	b-tagged jet has transverse momentum p_T>35 GeV and other jets have p_T>25 GeV, and electron has p_T>20 GeV
Cut-3 :	all jets have pseudo-rapidity -5.0<η<0 ; and electron has -2.5<η<2.5
Cut-4 :	invariant mass of two jets within $50<m_{jj}<90$ GeV (for W- boson)
Cut-5 :	invariant mass of three jets (for top) between $130<m_{bjj}<200$ GeV

FCC-EP: (S+B)/B AND RELEVANT BACKGROUNDS



S: ep→eWj

BW: ep→eWj

BZ: ep→eZj

BH: ep→eHj

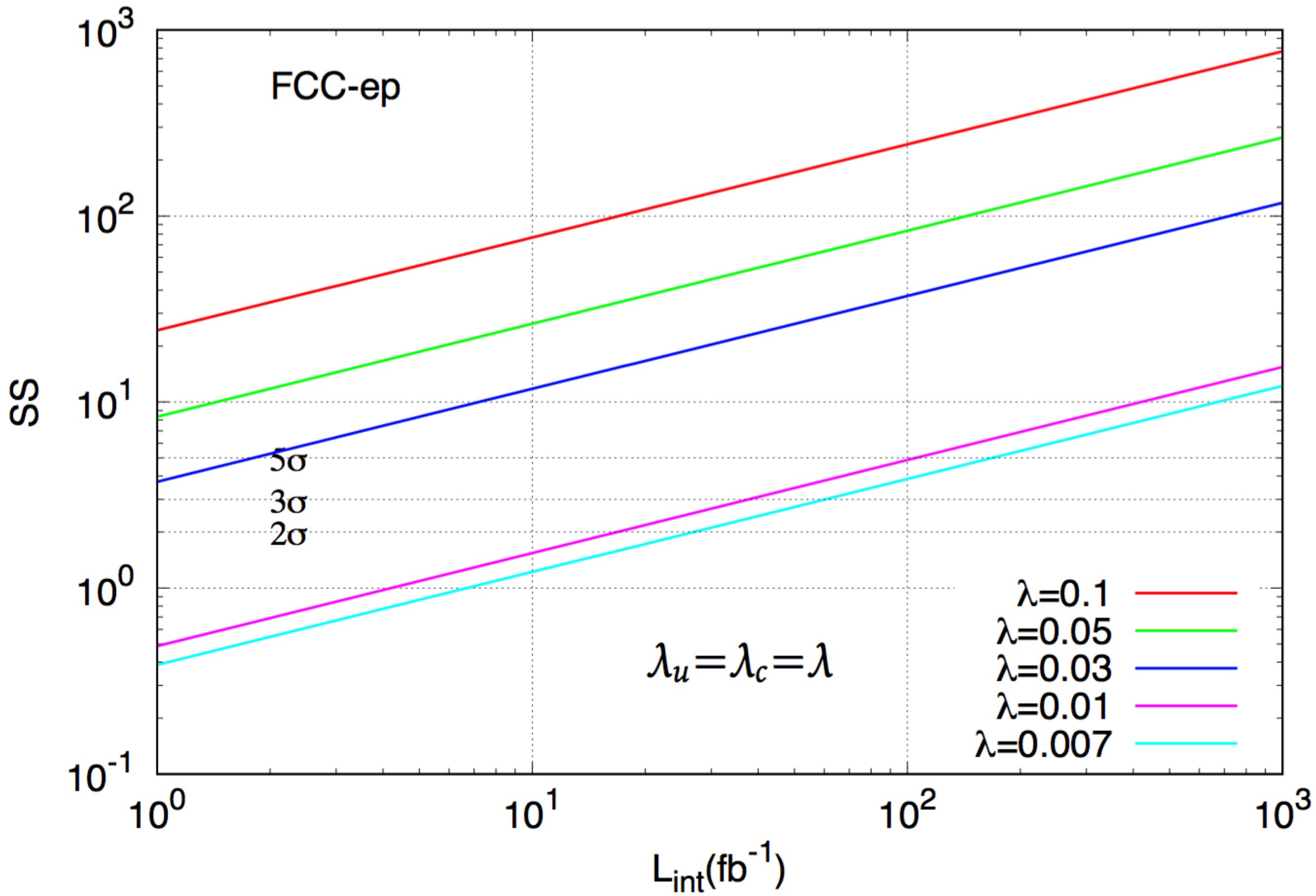
Btt: ep→et$\bar{t}$

➤ *With the relevant backgrounds ($B_T=B_W+B_Z+B_H+B_{tt}$), the ratio (S+B)/B are shown in figure.*

arXiv:1701.06932

FCC-EP: SS PLOT

Statistical significance $SS=\sqrt{2[(S+B_T)\ln(1+S/B_T)-S]}$ for $e^-p \to e^- + bjet + 2j$ with *tqγ* FCNC interactions. Here, we assume equal coupling scenario $\lambda_u = \lambda_c = \lambda$.



All relevant backgrounds (B_T) are included,

<u>3σ significance:</u>

at $\lambda=0.01$ for $L_{int}=40$/fb.

* **Compare with LHeC when $\lambda_q=0.01$ for $L_{int}=80$/fb.**

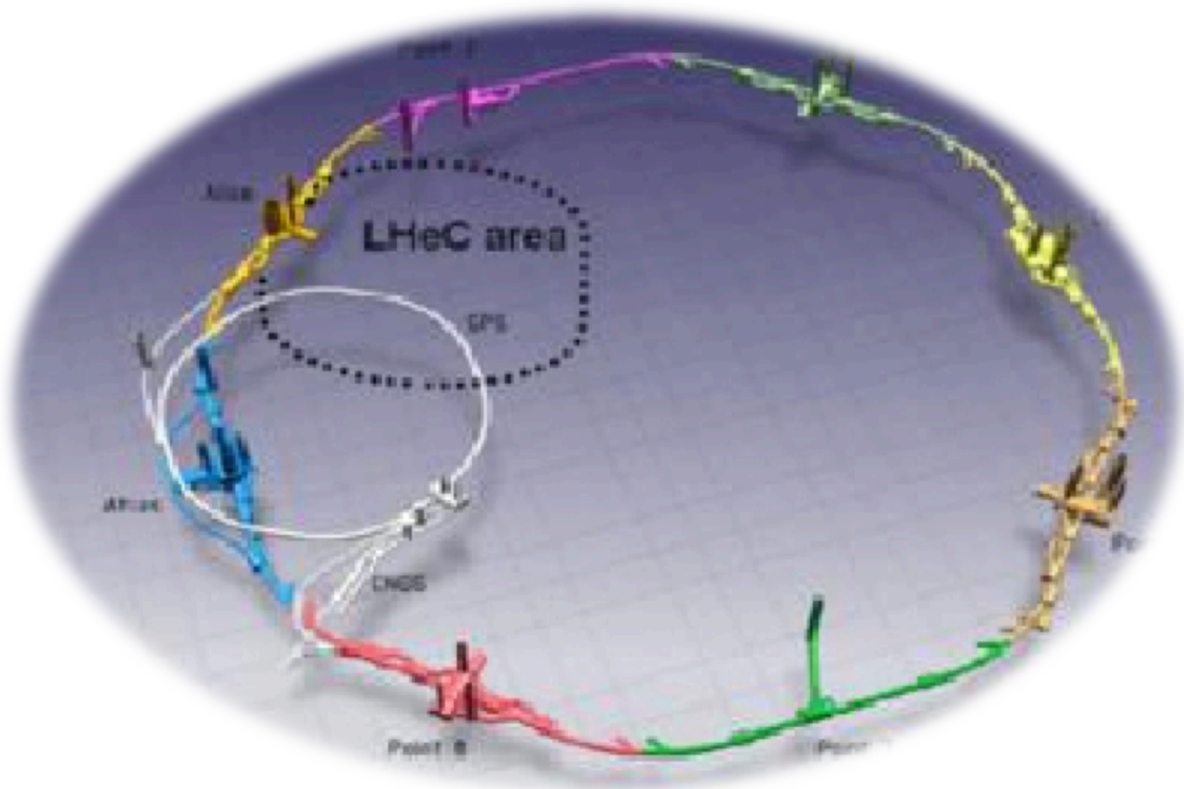
arXiv:1705.05419

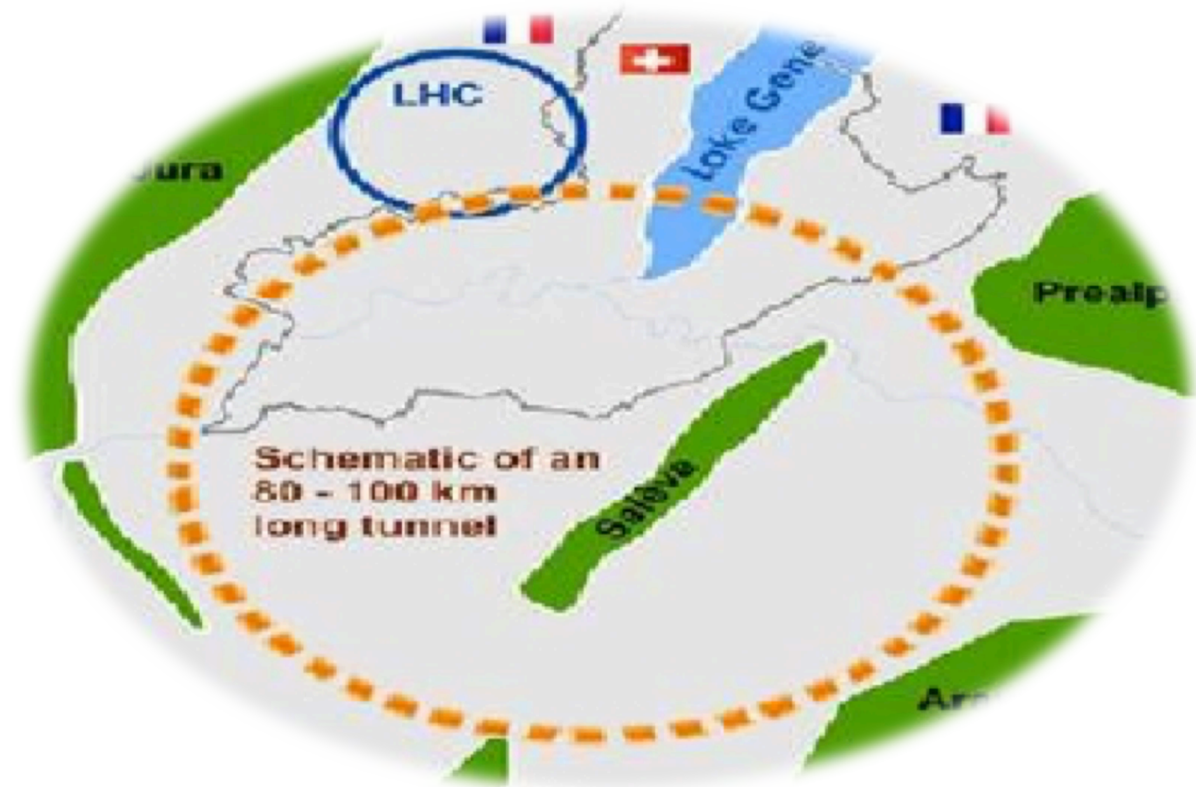
We find 3σ signal significance result to reach an upper limit λ=0.01, with integrated luminosity of 40/fb at FCC-ep and 80/fb at LHeC. This limit on the coupling can also be translated to the branching ratio $BR(t \to q\gamma)=2\times10^{-5}$.

CONCLUSION

- In this talk we present a short overview of the top physics at the ep colliders, which has a rich top physics programme. The selected results include, but not limited to:
  - ✓ *Sensitivity to Wtb vertex with $f_V^L \sim 10^{-3}$ and $f_T^L \sim 10^{-2}$*
  - ✓ *The CKM matrix element Vtb with a precision of 0.5%*
  - ✓ *Anomalous ttγ / ttZ couplings with precision 0.20/0.6 (EDM) and 0.05/0.9 (MDM)*
  - ✓ *Improvement in probing top-Higgs FCNC couplings to have BR($t \rightarrow qh$)~10^{-3} comparing to current LHC experiments*
  - ✓ *CP nature of ttH couplings can be tested to $\zeta_t \sim \pi/5$ (at LHeC)*
  - ✓ *Top FCNC tqγ couplings can be measured down to $\lambda_q \sim 10^{-2}$ and it can be translated into branching ratio BR($t \rightarrow q\gamma$) ~2×10^{-5} at the FCC-eh*
- Some of these topics are being studied with the updated LHeC and FCC-eh Delphes detector simulation.

FUTURE PROSPECTS OF EP COLLIDERS





LHeC

7 TeV proton of LHC

and 60 GeV electron

($\sqrt{s}$ ~1.3 TeV)

FCC-he

50 TeV proton of FCC

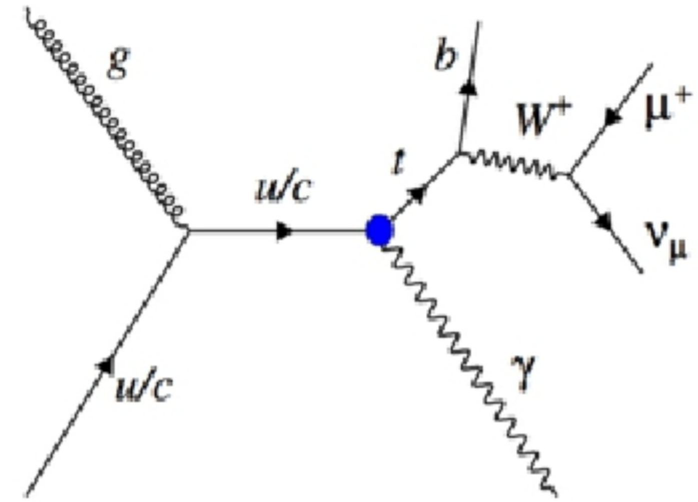
and 60 GeV electron

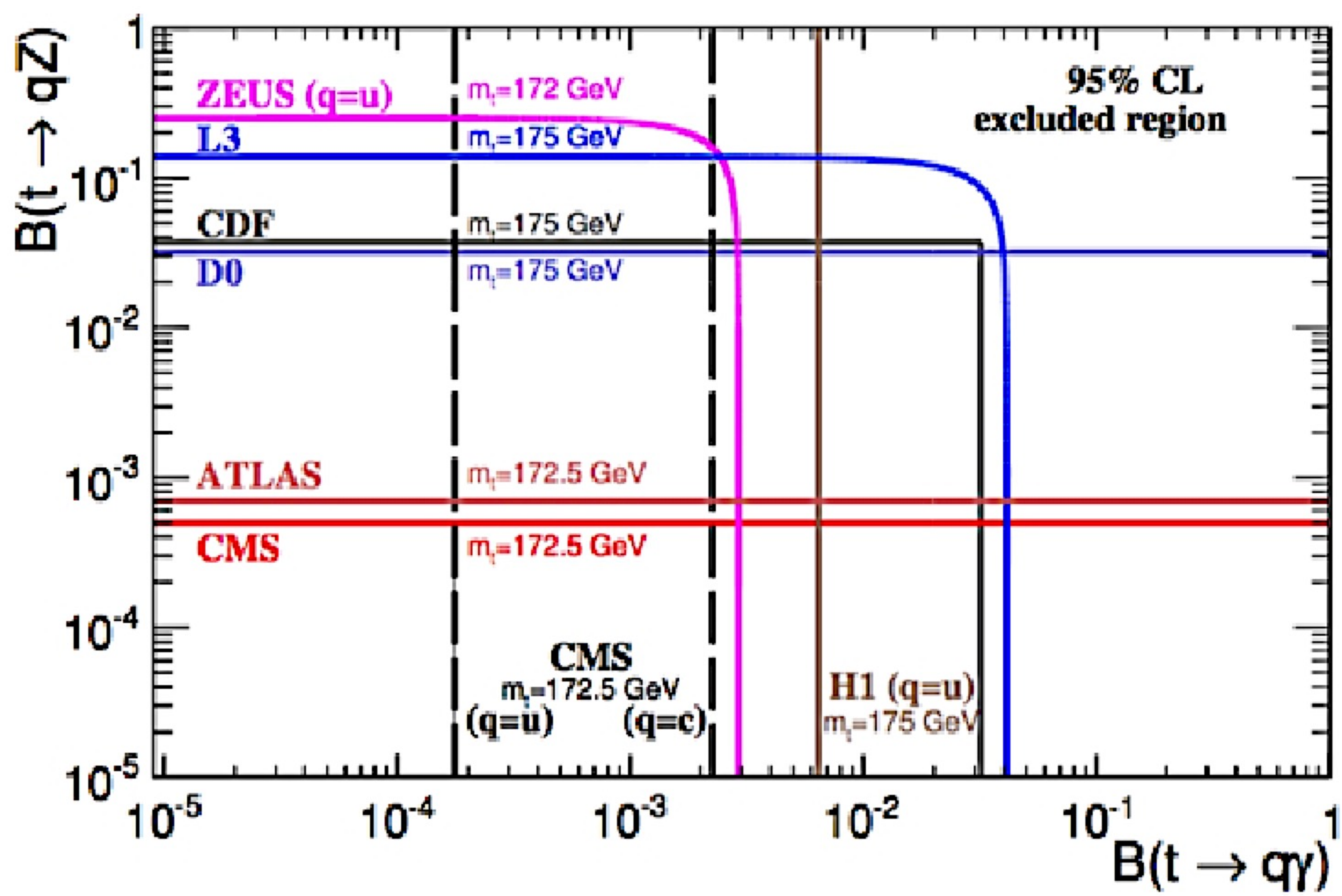
($\sqrt{s}$ ~ 3.5 TeV)

COMPARISON: TOP FCNC AT LHC

Based on proton-proton collisions at 8 TeV within the CMS detector at the LHC at an integrated luminosity of 19.8 fb^{-1}, the limits (95% CL) on the top quark FCNC couplings

$$\mathcal{L}_{\mathrm{eff}} = -eQ_{\mathrm{t}} \sum_{\mathrm{q=u,c}} \bar{\mathrm{q}} \frac{i\sigma^{\mu\nu} q_{\nu}}{\Lambda} (\kappa^{\mathrm{L}}_{\mathrm{tq}\gamma} P_{\mathrm{L}} + \kappa^{\mathrm{R}}_{\mathrm{tq}\gamma} P_{\mathrm{R}}) \mathrm{t} A_{\mu} + \mathrm{h.c.},$$





BR(t→uγ)=1.7x10^{-4}

BR(t→cγ)=2.2x10^{-3}

CMS Collab.JHEP04(2016)035