EWK, Top and BSM Physics at the LHeC and FCC-he

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Deutsches Elektronensynchrotron (DESY)

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High Energy Physics

Chicago

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Outline

Introduction
Electroweak Physics
Top Quark Physics
New Phenomena Searches
Conclusions

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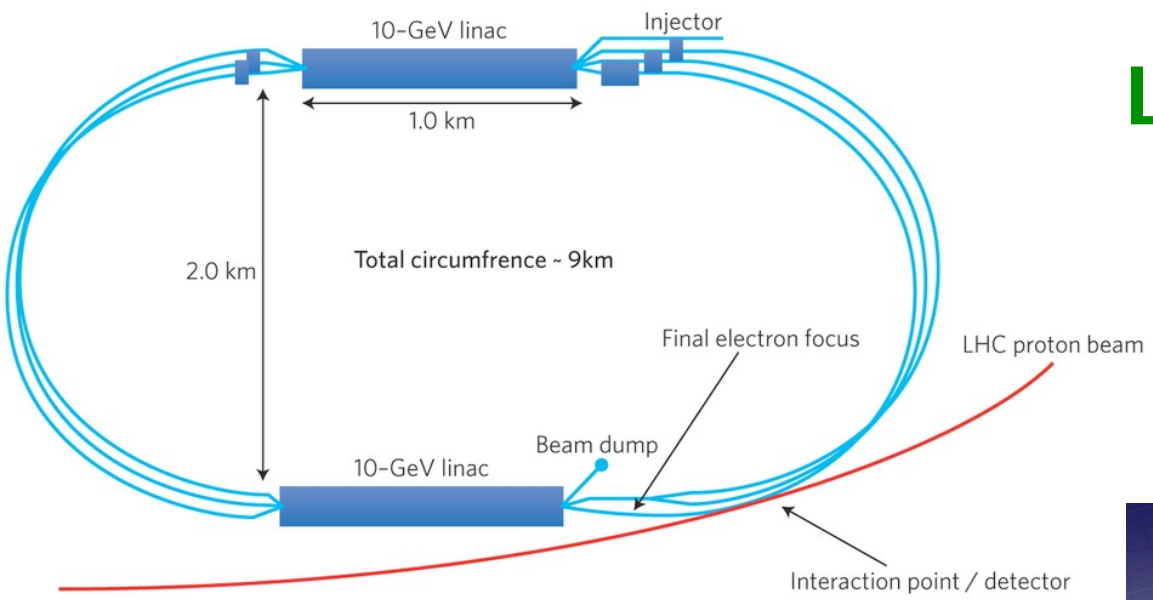
Top Quark Physics
New Phenomena Searches
Conclusions

Linac-Ring Collider, LHeC and FCC-eh

Energy Recovering Linac

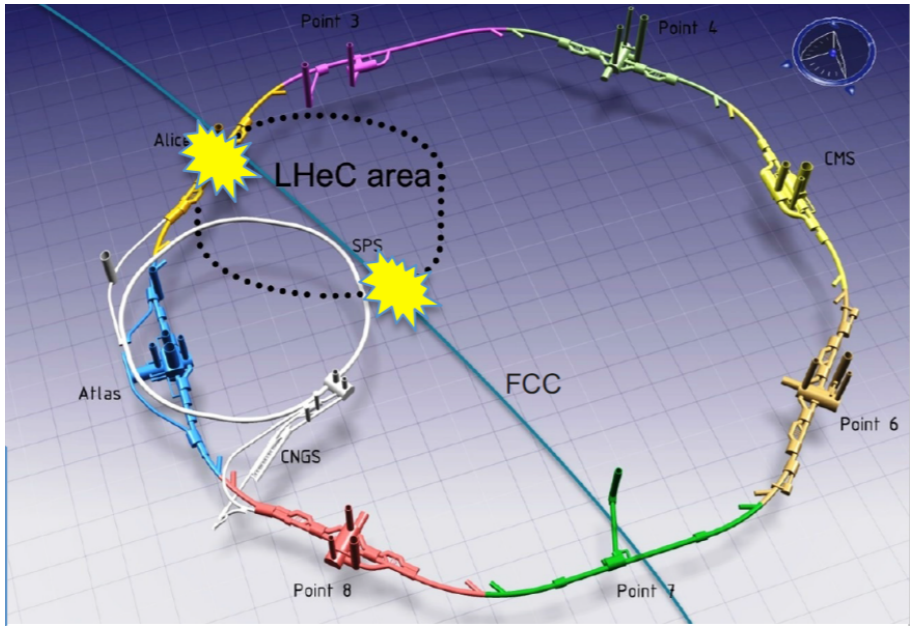
$e^{\pm}$ beam: 60 GeV

L_{int}=1 fb^{-1}–1 ab^{-1}



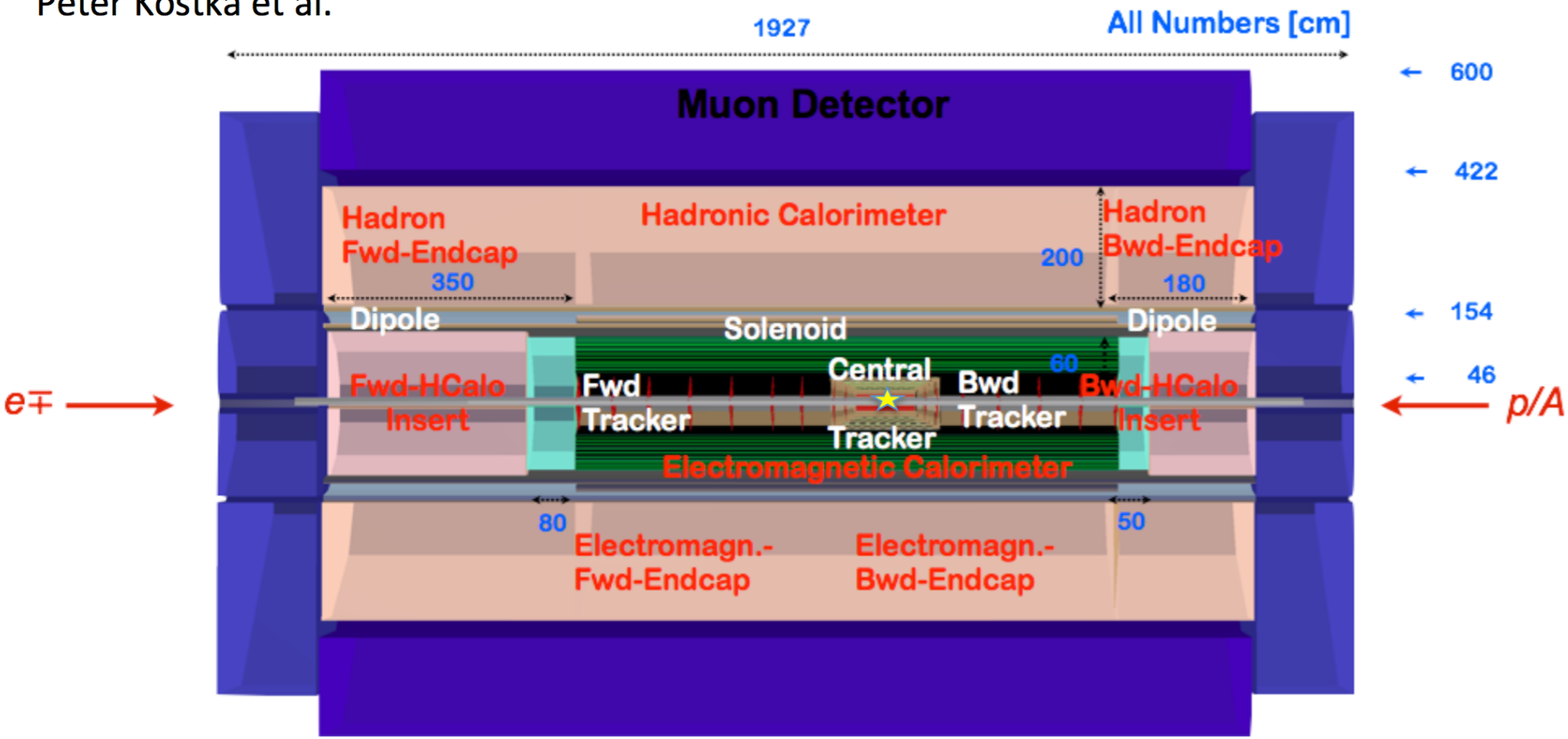
operated synchronously

- with HL-LHC:
  p beam: 7 TeV, √s=1.3 TeV
- or later with FCC-hh:
  p beam: 50 TeV, √s=3.5 TeV



LHeC and FCC-eh Detector Studies

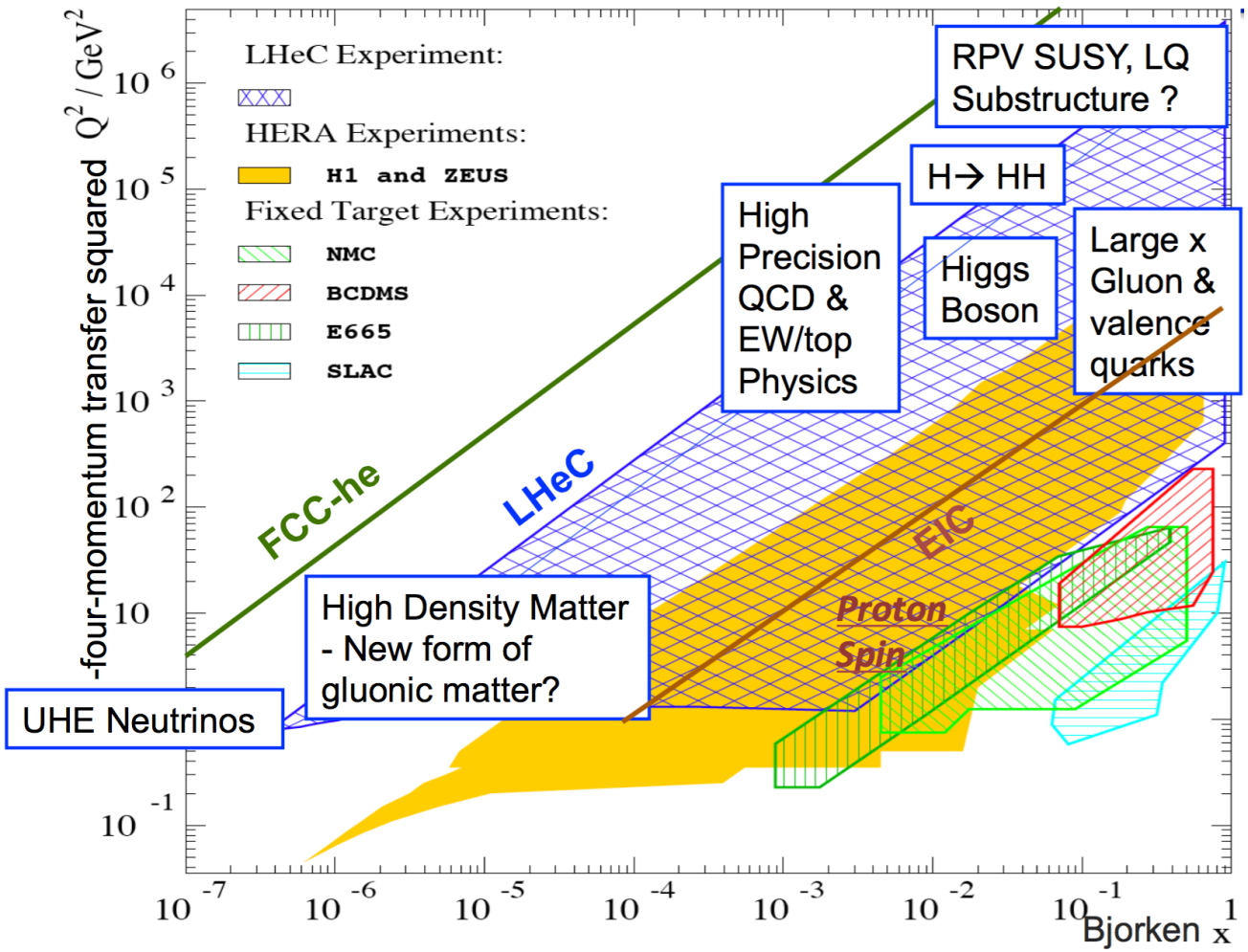
Peter Kostka et al.



- Very preliminary FCC detector design: extension of LHeC baseline detector
- Dimensions 20 x 12 m, transverse and longitudinal (fwd) sizes scaled w.r.t. LHeC
- Assumption of similar electron beam steering dipoles as in LHeC baseline design

Note added: LHeC→HE-LHC→FCC-he: 1→1.4→2 scaling the fwd dimension

High energy frontier eh physics



EW symmetry breaking:

- **precision EW measurements**
- **role of the top quark: study EW interactions with top quarks**
- **search for new physics**

→ **eh collider excellent to explore EW theory**

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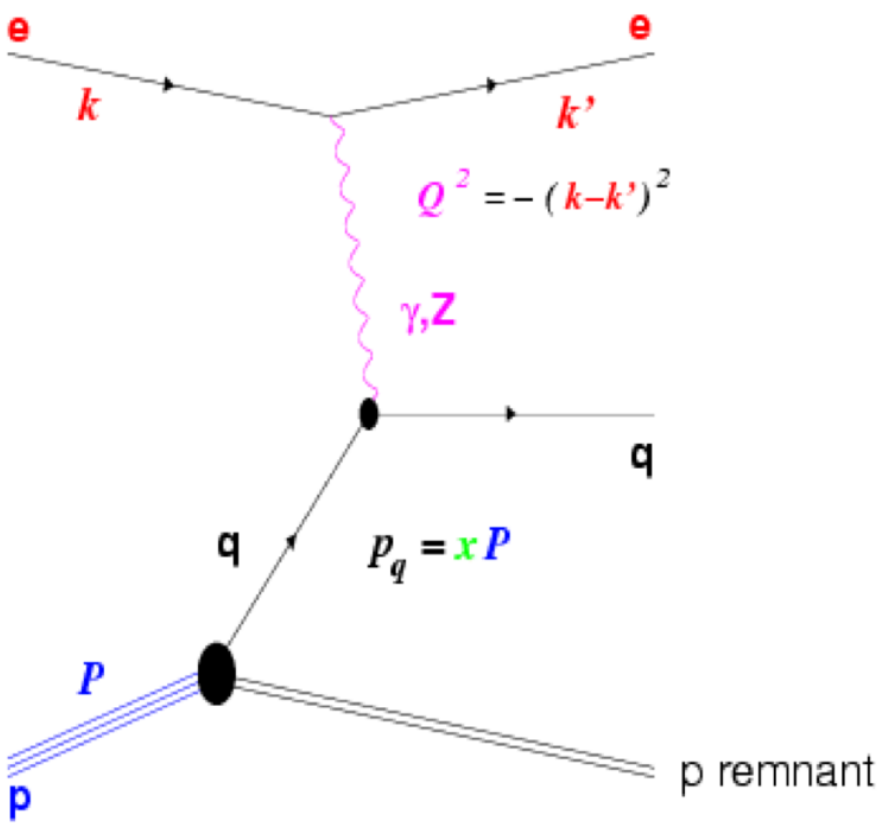
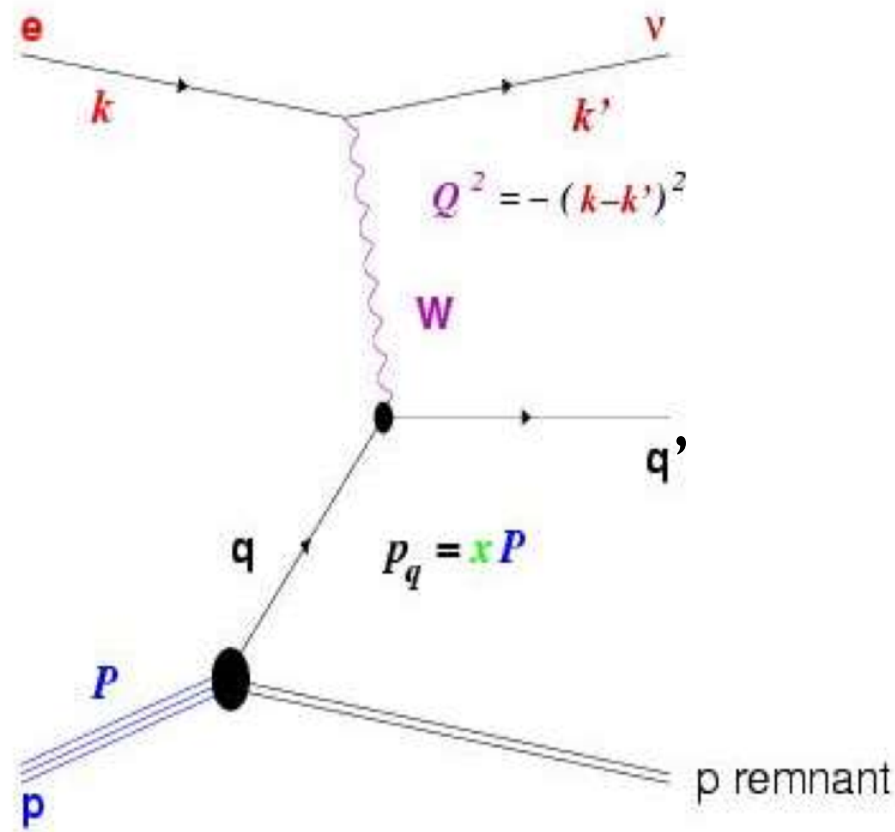
Deep Inelastic Scattering

Neutral Current (NC)



Charged Current (CC)



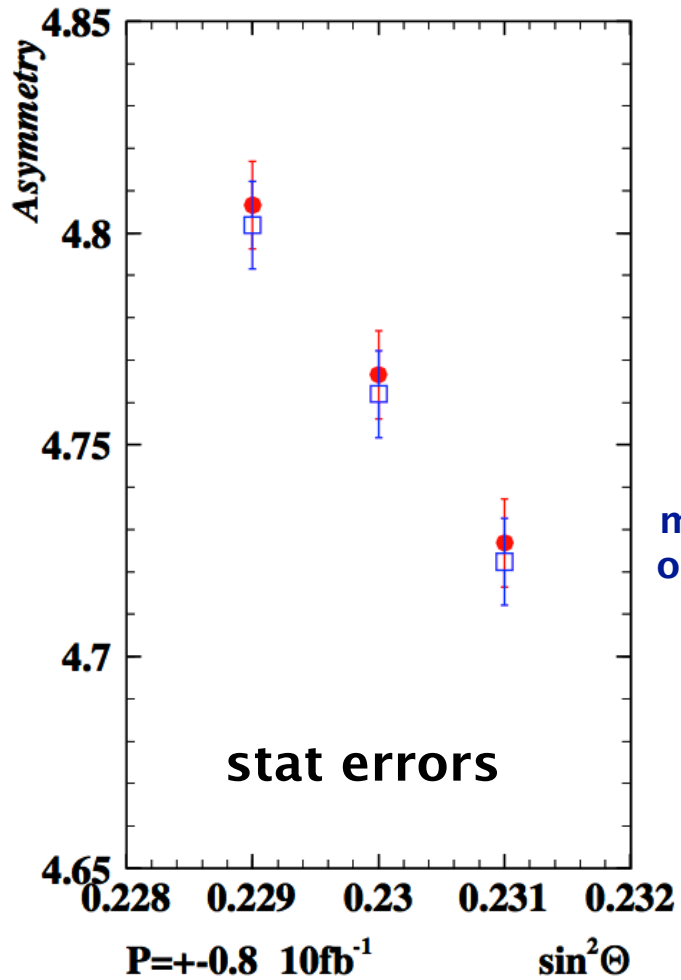
→ **LHeC is unique facility for testing EW theory: two beam charge and polarisation states, NC+CC, p or isoscalar targets**

Asymmetry Measurements

$$A^{\pm} = \frac{\sigma^{\pm}_{NC}(P_R) - \sigma^{\pm}_{NC}(P_L)}{\sigma^{\pm}_{NC}(P_R) + \sigma^{\pm}_{NC}(P_L)}$$

$$R^{\pm} = \frac{\sigma^{\pm}_{NC}}{\sigma^{\pm}_{CC}}$$

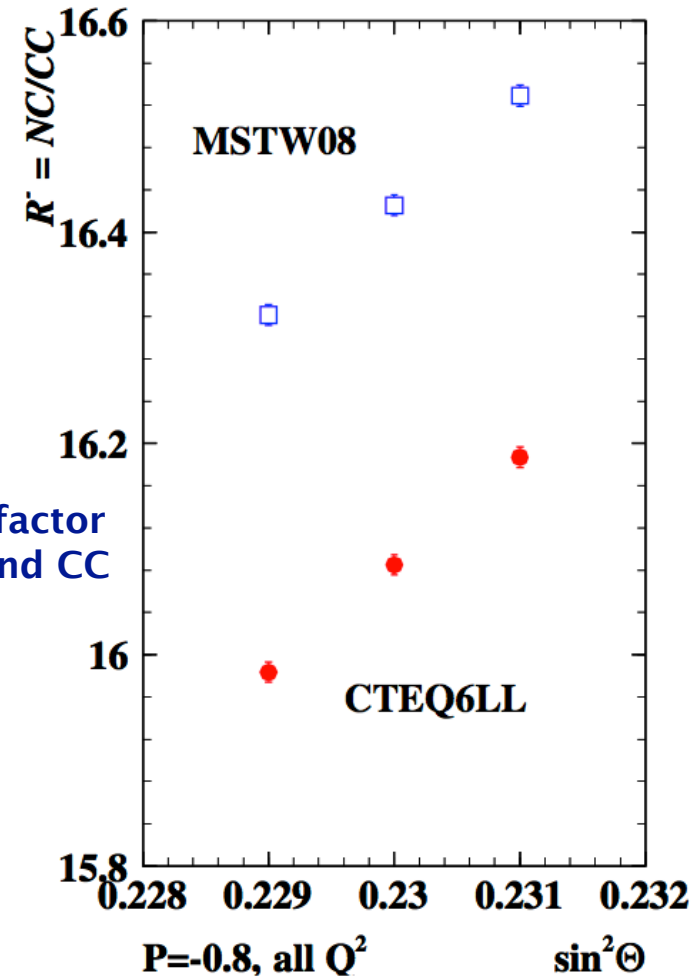
A^-



10 fb^{-1}

e beam: 60 GeV

mean x differs by factor of 6 between NC and CC



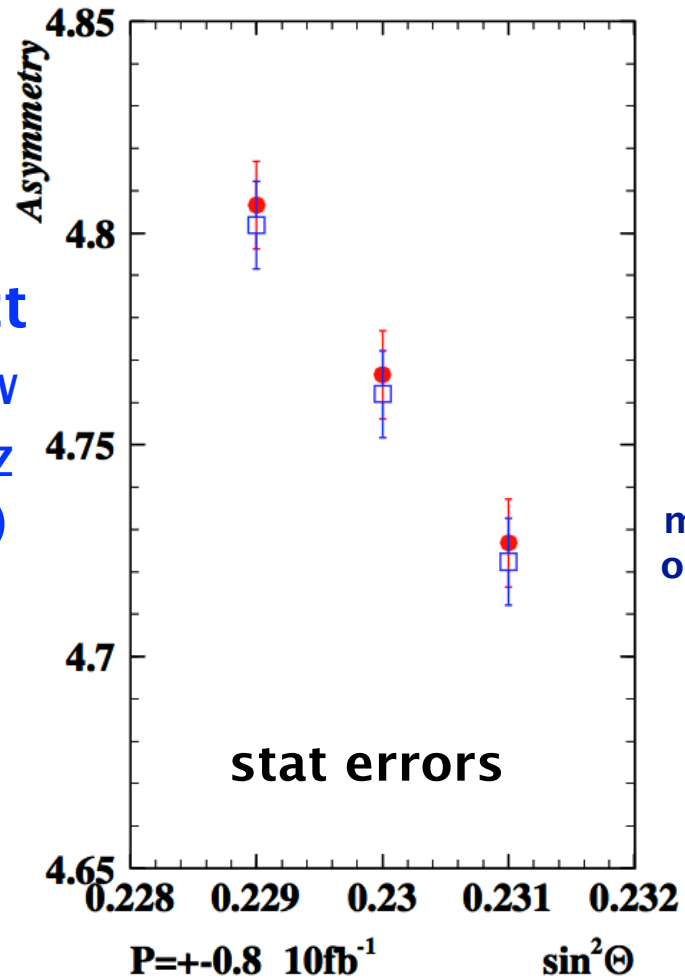
Asymmetry Measurements

$$A^{\pm} = \frac{\sigma^{\pm}_{NC}(P_R) - \sigma^{\pm}_{NC}(P_L)}{\sigma^{\pm}_{NC}(P_R) + \sigma^{\pm}_{NC}(P_L)}$$

$$R^{\pm} = \frac{\sigma^{\pm}_{NC}}{\sigma^{\pm}_{CC}}$$

A^-

extract $\sin^2\theta_W$ (α, m_Z fixed)



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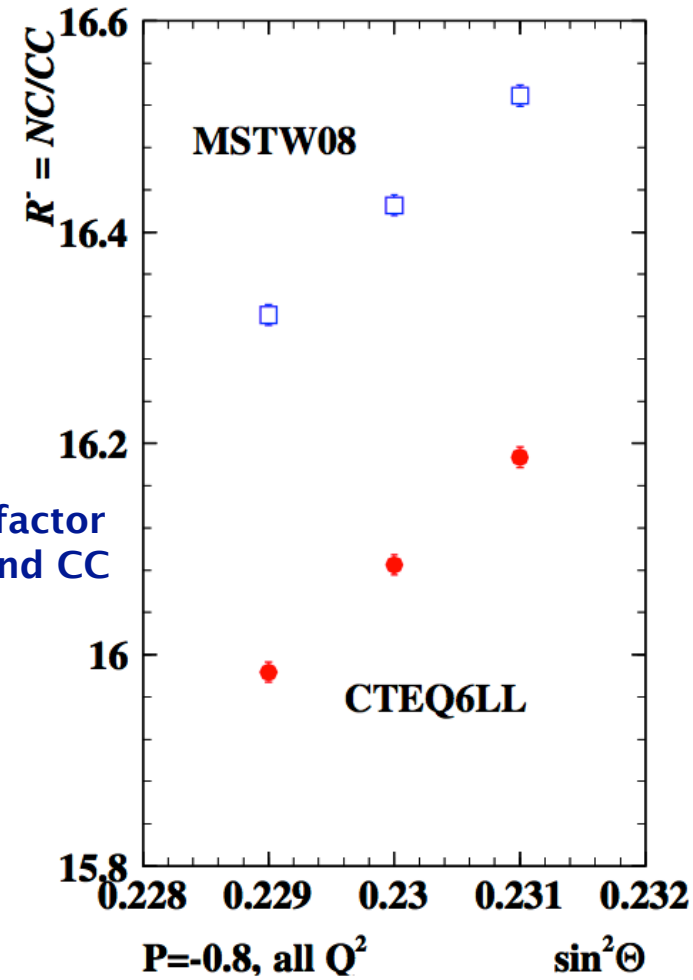
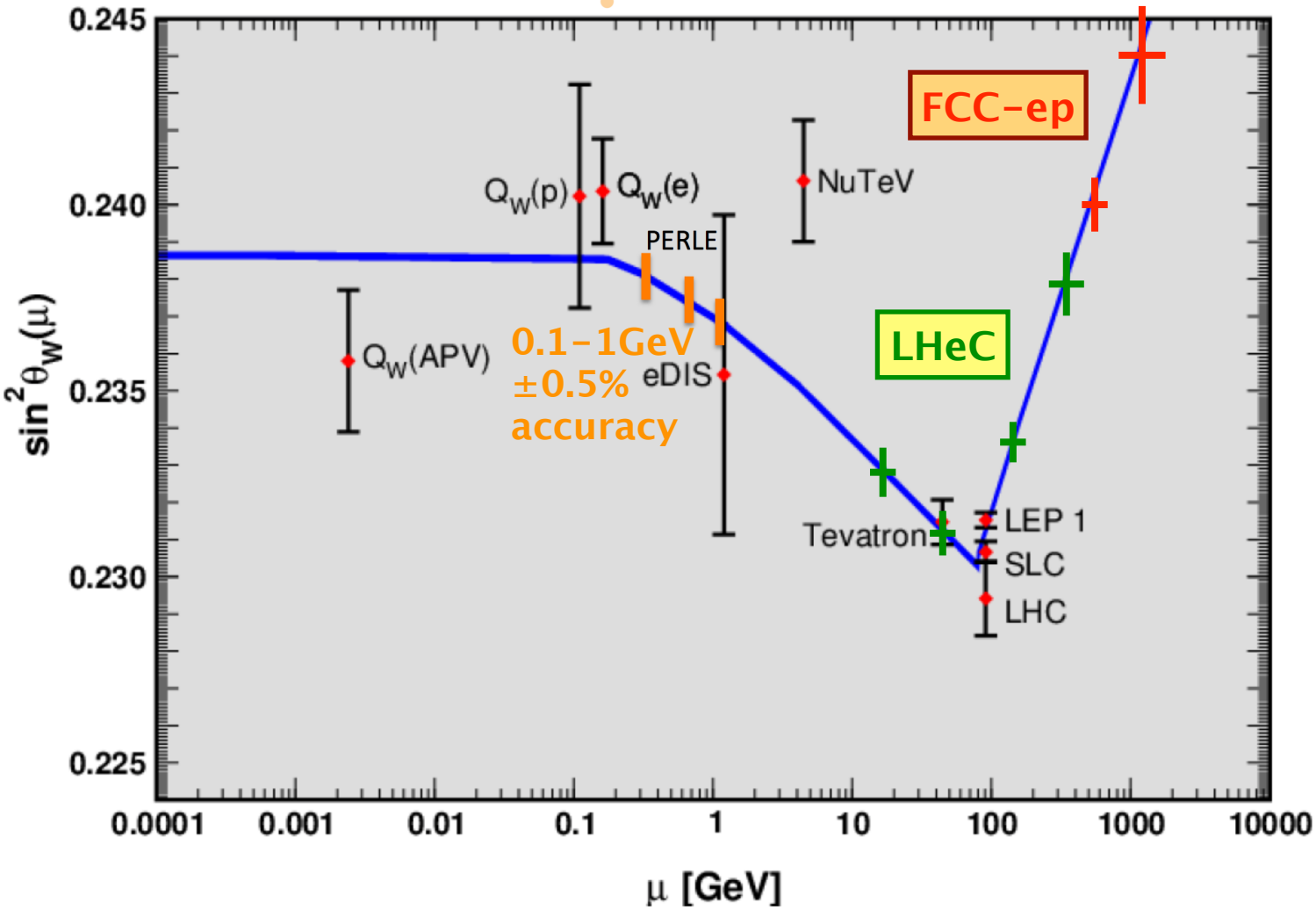


Scale Dependence of $\sin^2\theta_W$

PERLE CDR, Arduini et al, to be published
ICFA BeamNewsletter 68 (January 2016)

LHeC CDR,
J.Phys. G39,
075001 (2012)



→ probe large range of scale dependence

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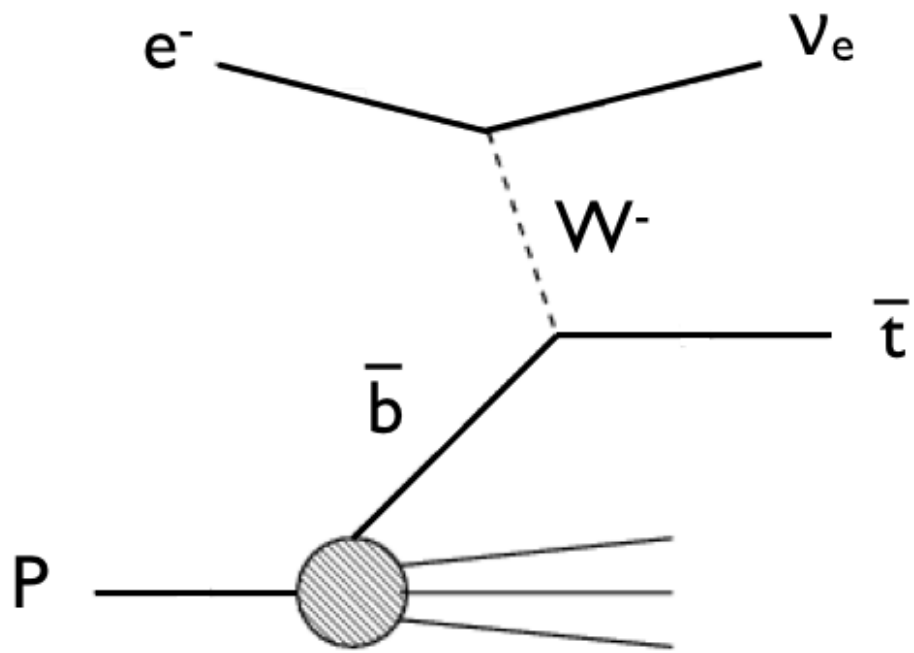
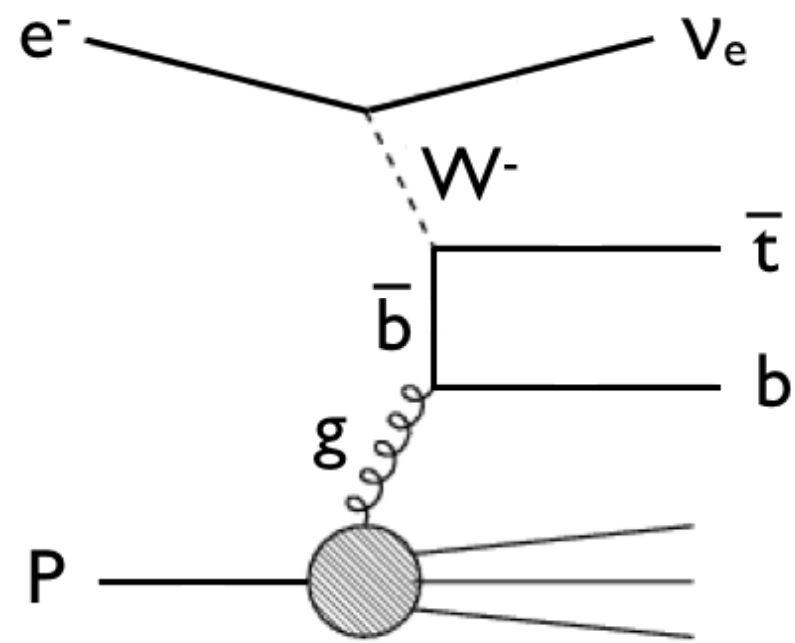
CC Single Top Quark Production





→ future ep collider is ideal to study EWK interactions of the top quark

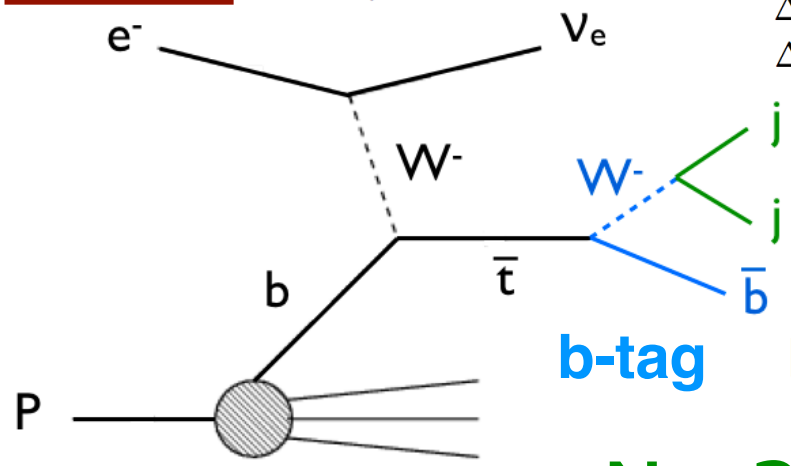
Signal and Backgrounds

signal

$\not{E}_T \geq 25\,\mathrm{GeV}$

Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688 [hep-ph]

background



$\Delta\Phi_{\not{E},j} \geq 0.4$

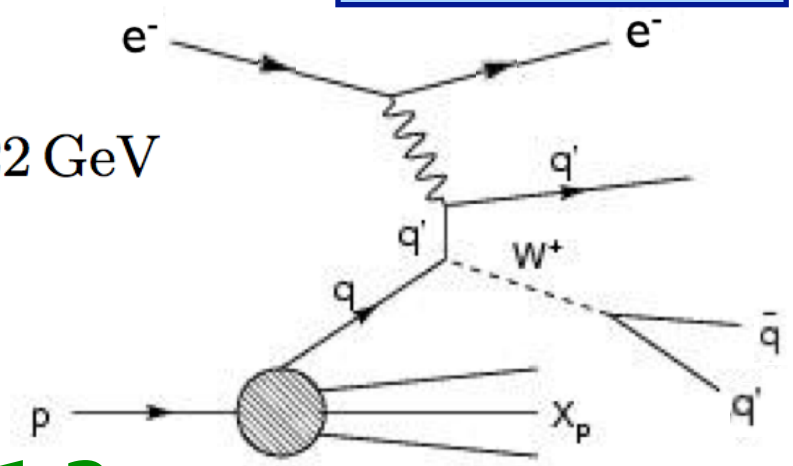
$\Delta\Phi_{\not{E},b} \geq 0.4$

$|m_{j_1 j_2} - m_W| \leq 22\,\mathrm{GeV}$

$p_{T\,j,b} \geq 20\ \mathrm{GeV}$

$|\eta_j| \leq 5, |\eta_b| \leq 2.5$

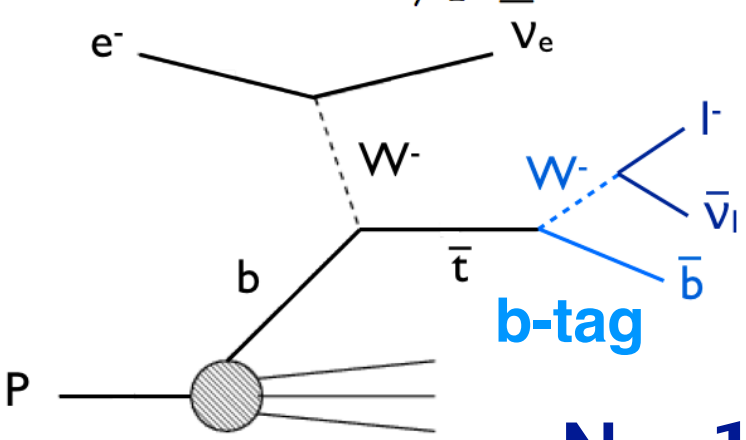
$\Delta R_{j,b/j} \geq 0.4$



N_t=22000, s/b=1.2

e beam: 60 GeV
100 fb^{-1}

$\not{E}_T \geq 25\,\mathrm{GeV}$



$\Delta\Phi_{\not{E},j} \geq 0.4$

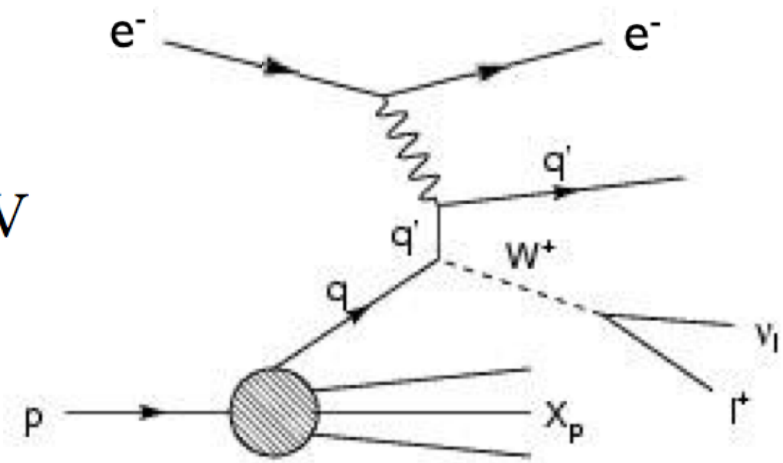
$\Delta\Phi_{\not{E},b} \geq 0.4$

$\Delta\Phi_{\not{E},l} \geq 0.4$

$p_{T\,j,b,l} \geq 20\ \mathrm{GeV}$

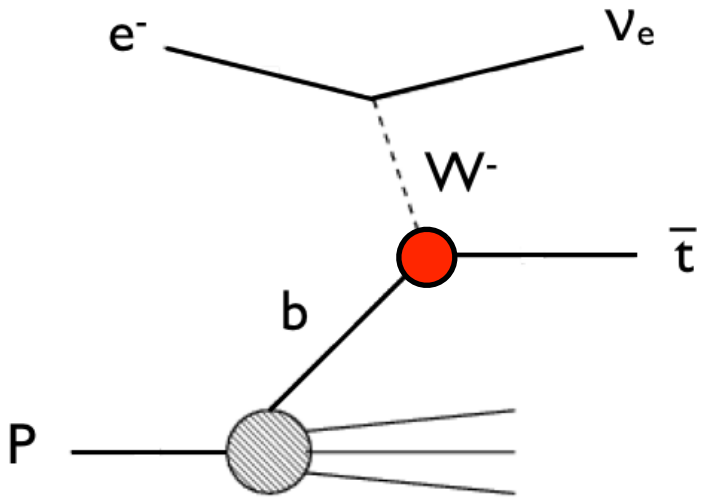
$|\eta_j| \leq 5,\ |\eta_{b,l}| \leq 2.5$

$\Delta R_{j,b/j} \geq 0.4$



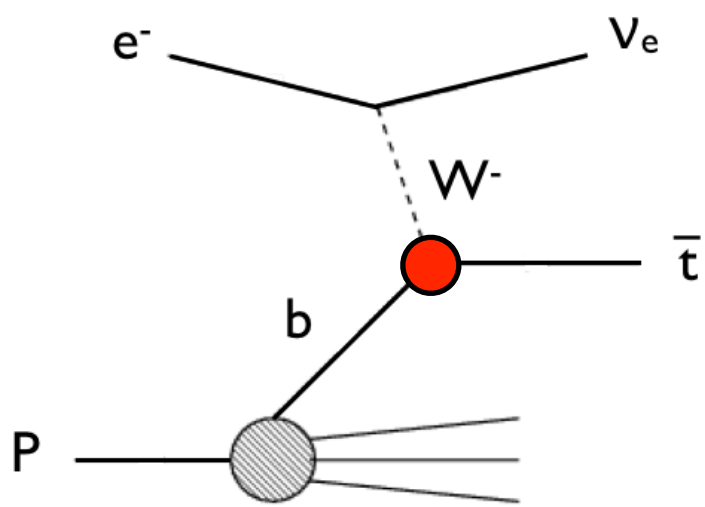
N_t=11000, s/b=11

Direct Measurement of $|V_{tb}|$



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

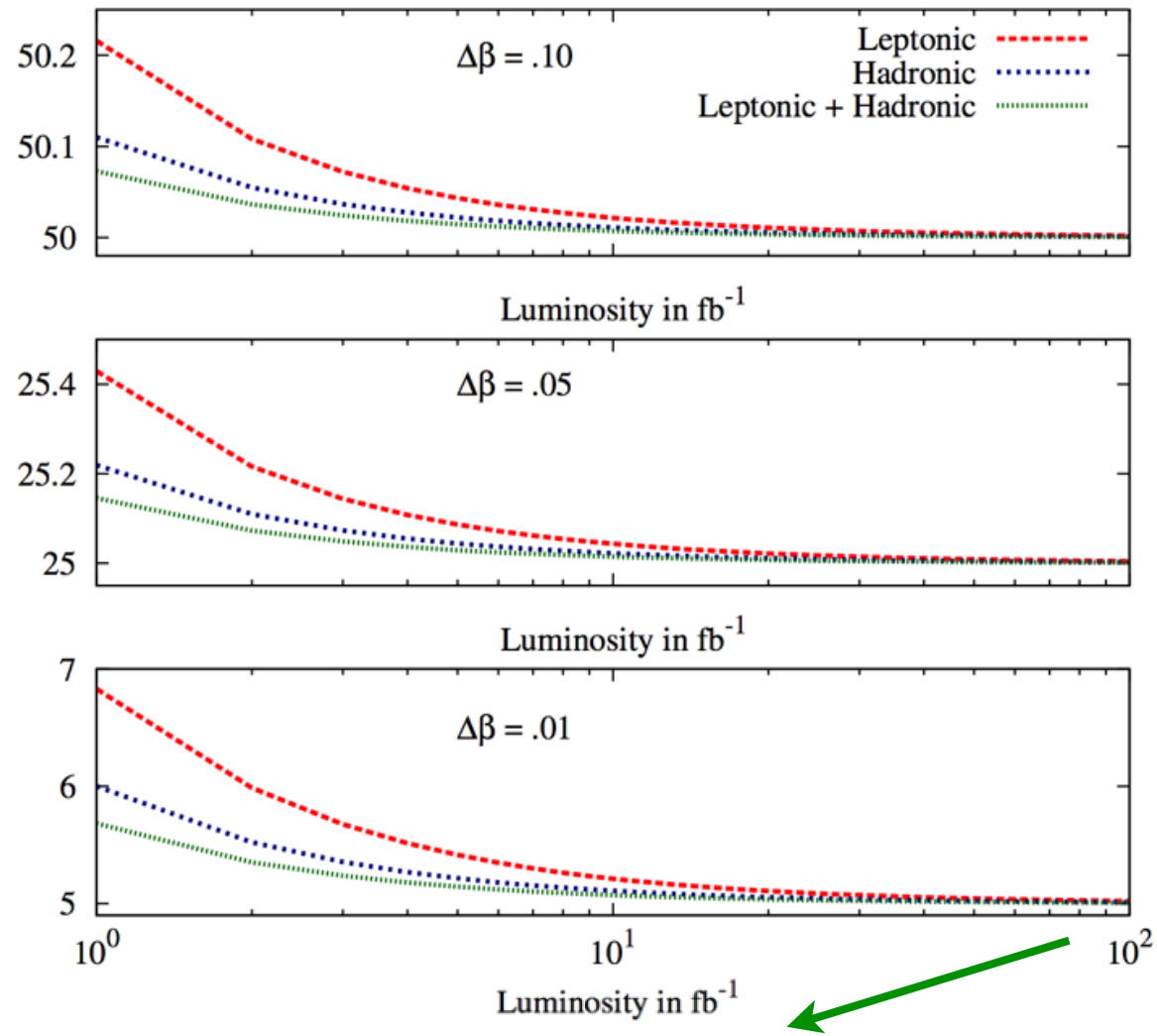
Direct Measurement of $|V_{tb}|$



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$\Delta|V_{tb}| \cdot 1000$

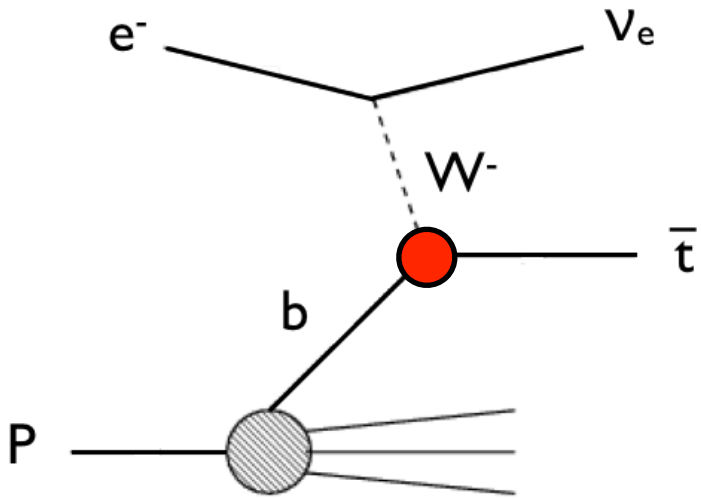
$\Delta\beta$: luminosity uncertainty



100 fb^{-1}: $\Delta|V_{tb}|$=0.005

Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688 [hep-ph]

Direct Measurement of $|V_{tb}|$



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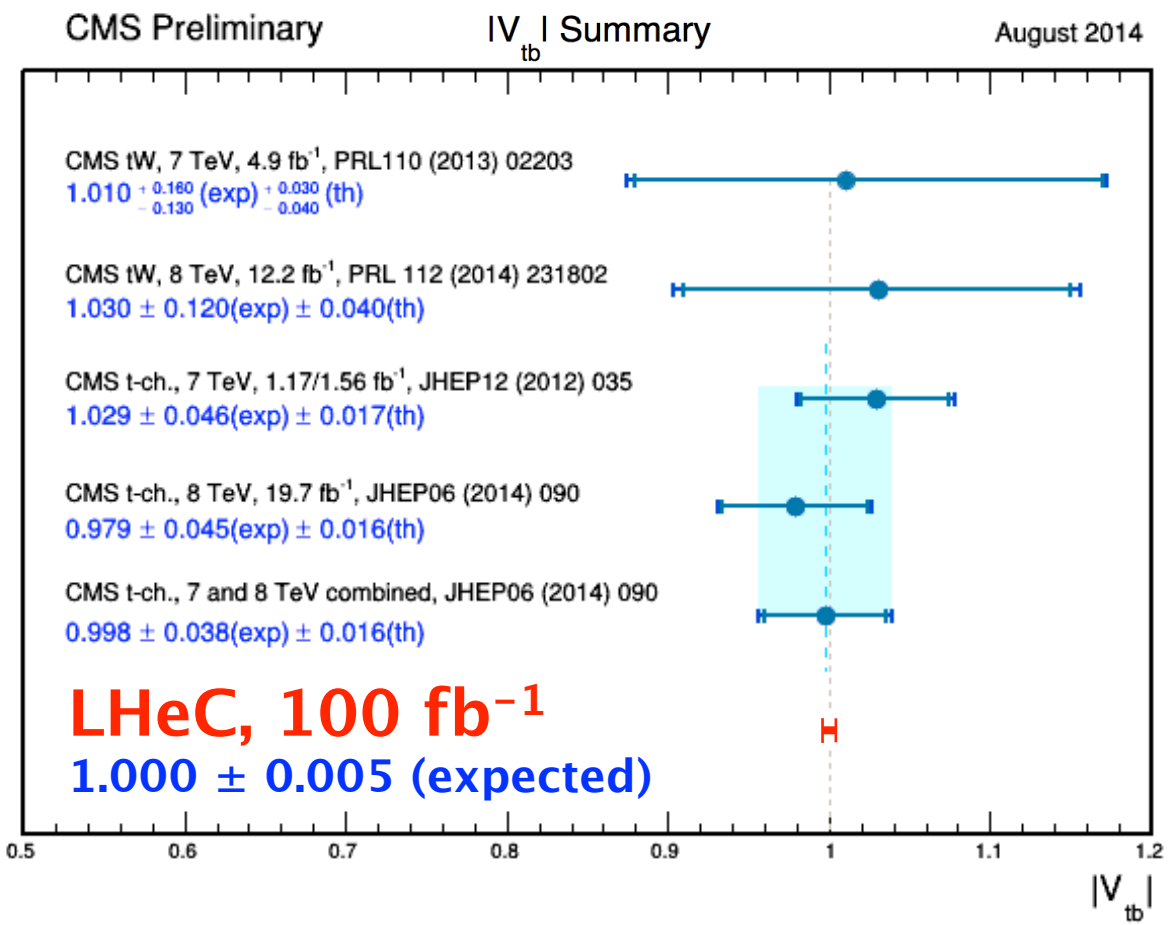

→ **high precision measurement**

Limits on Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

= 1 in SM

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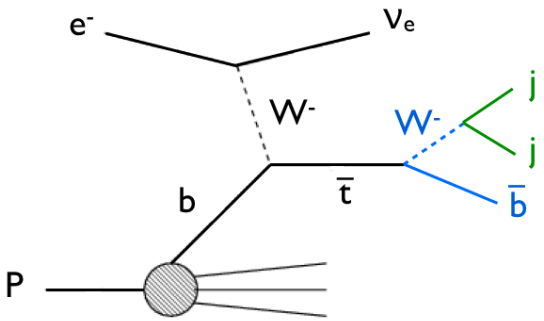
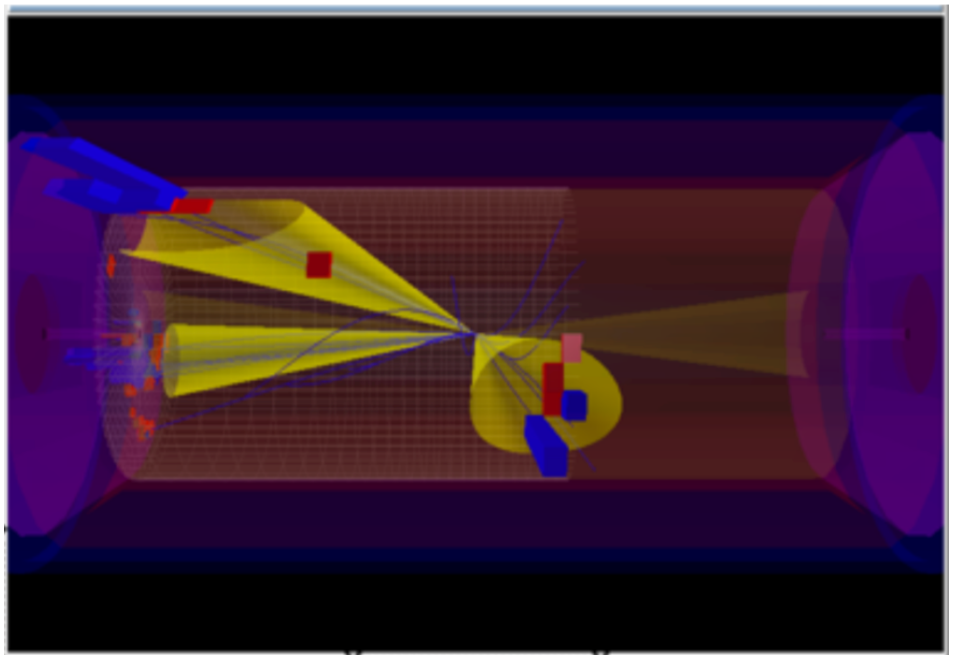
= 1 in SM

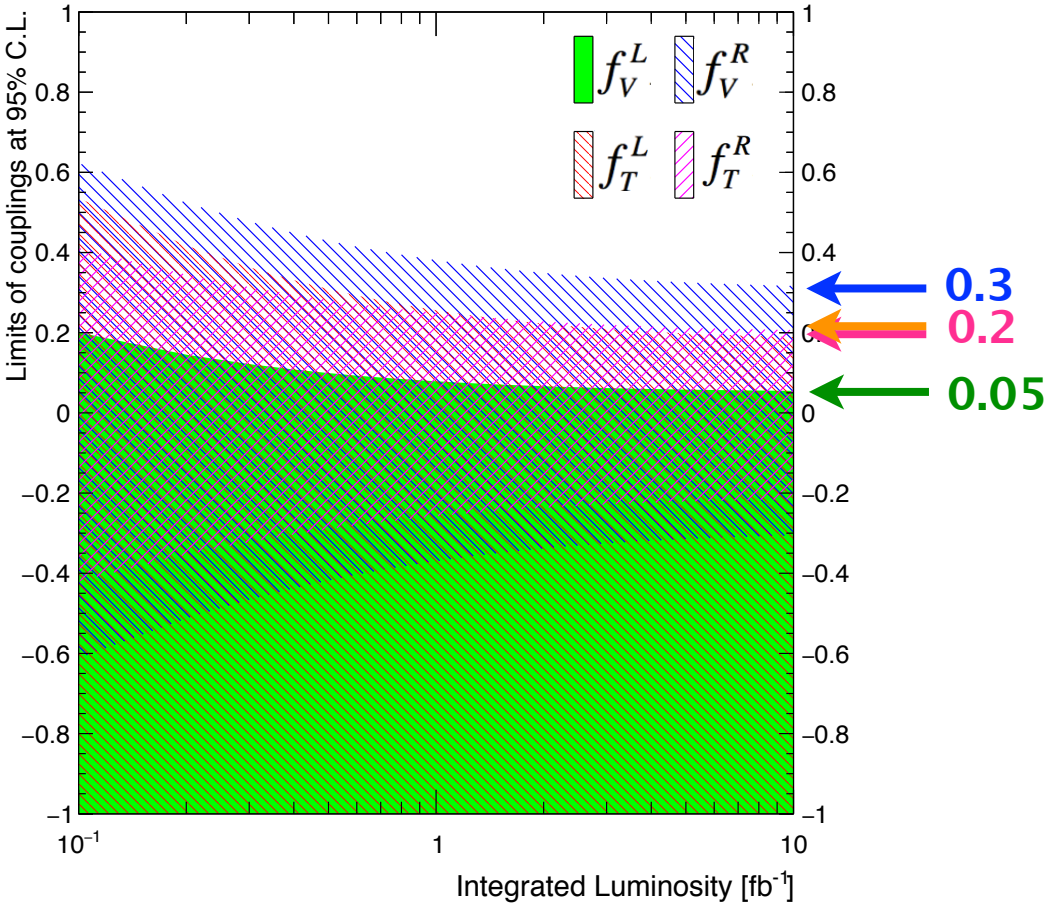
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688
Kumar, Ruan, to be publ.

95% C.L.

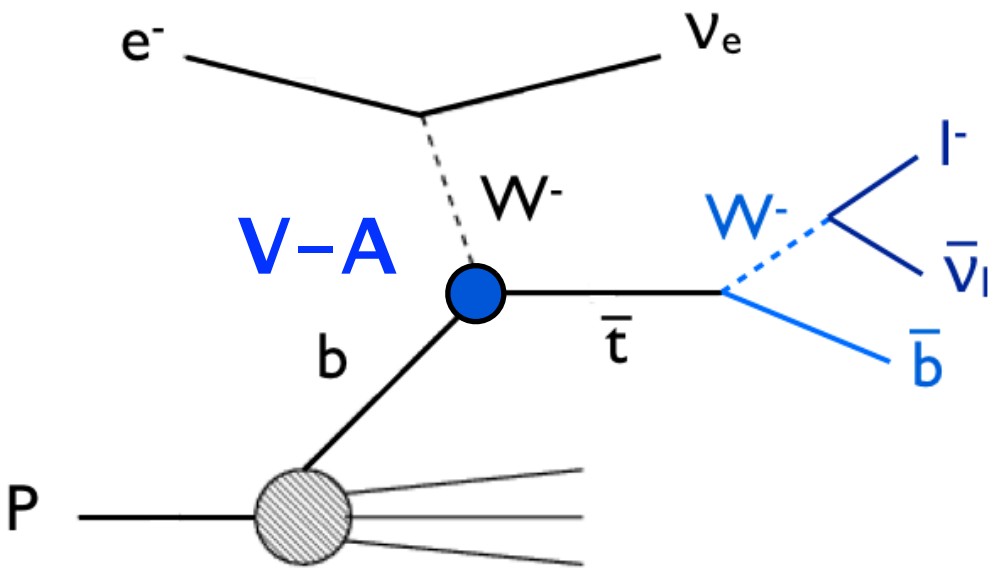




including detector simulation (Delphes)



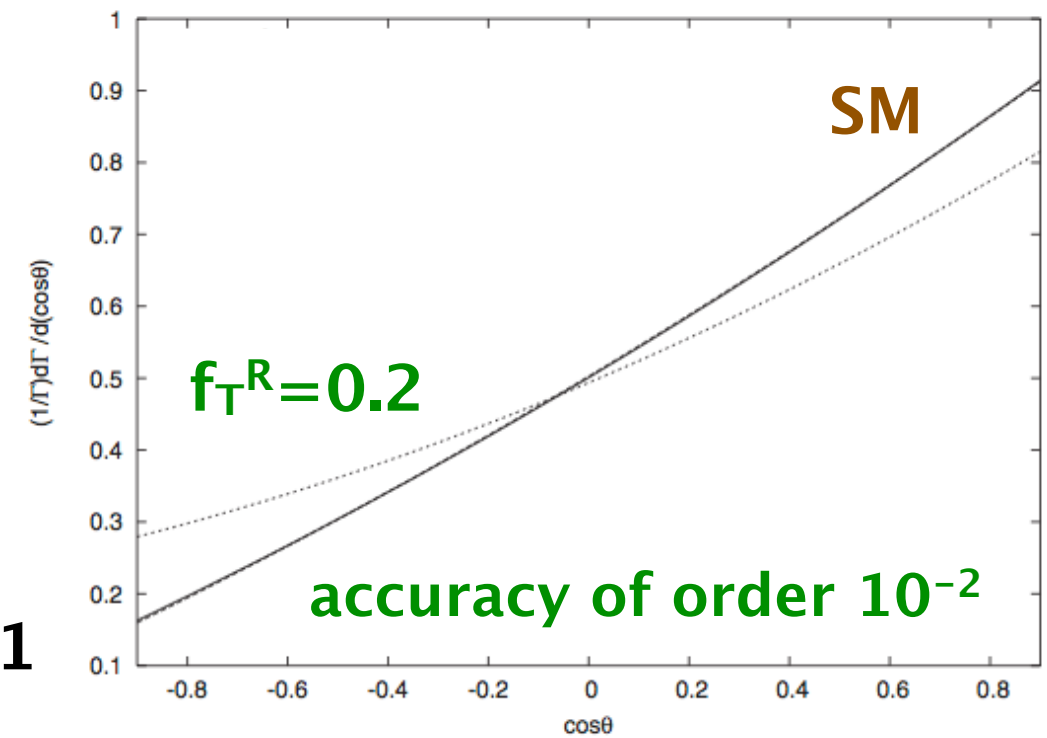
Top Quark Polarisation



Atag, Sahin,
PRD 73, 074001 (2006)

cosθ: angle between charged lepton and spin quantisation axis in top rest frame

$$\frac{1}{\Gamma_T}\frac{d\Gamma}{d\cos\theta} = \frac{1}{2}(1 + A_{\uparrow\downarrow}\alpha\cos\theta) \qquad A_{\uparrow\downarrow} = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$$



using simply e-beam axis: polarisation: P_t = 96%

TESLA+HERAp:

$\sqrt{s}$=1.6 TeV
L_{int}=20 fb^{-1}

19.7 fb^{-1}: $A_{\uparrow\downarrow}$ = 0.26±0.11

JHEP 04 (2016) 073

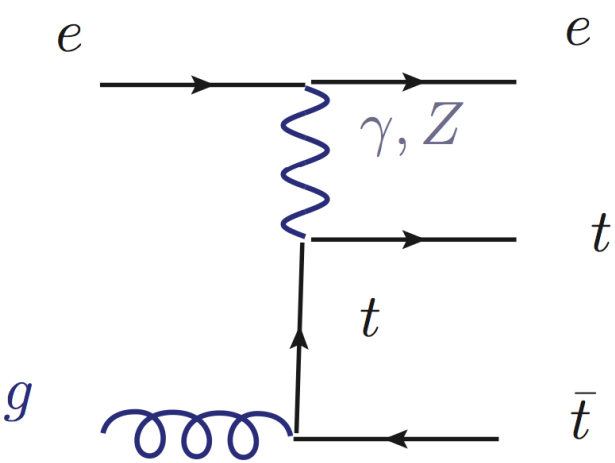
NC Top Quark Production

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

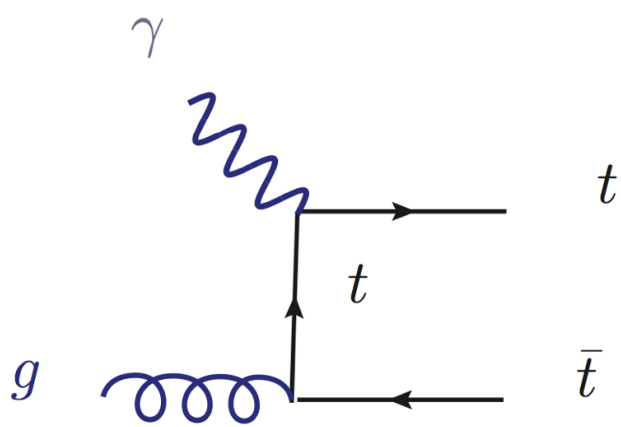
top pair production

single top production

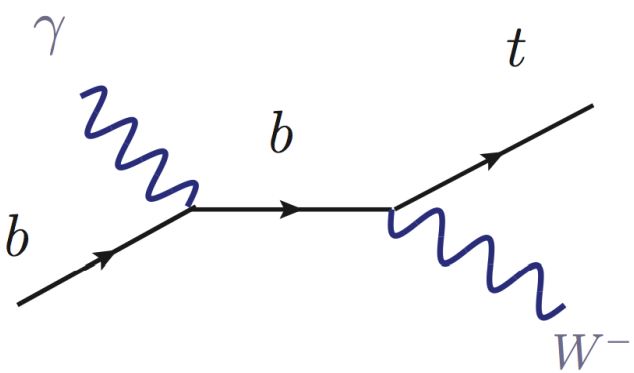
DIS



photoproduction



photoproduction



e-beam 60 GeV, 100 fb^{-1}:

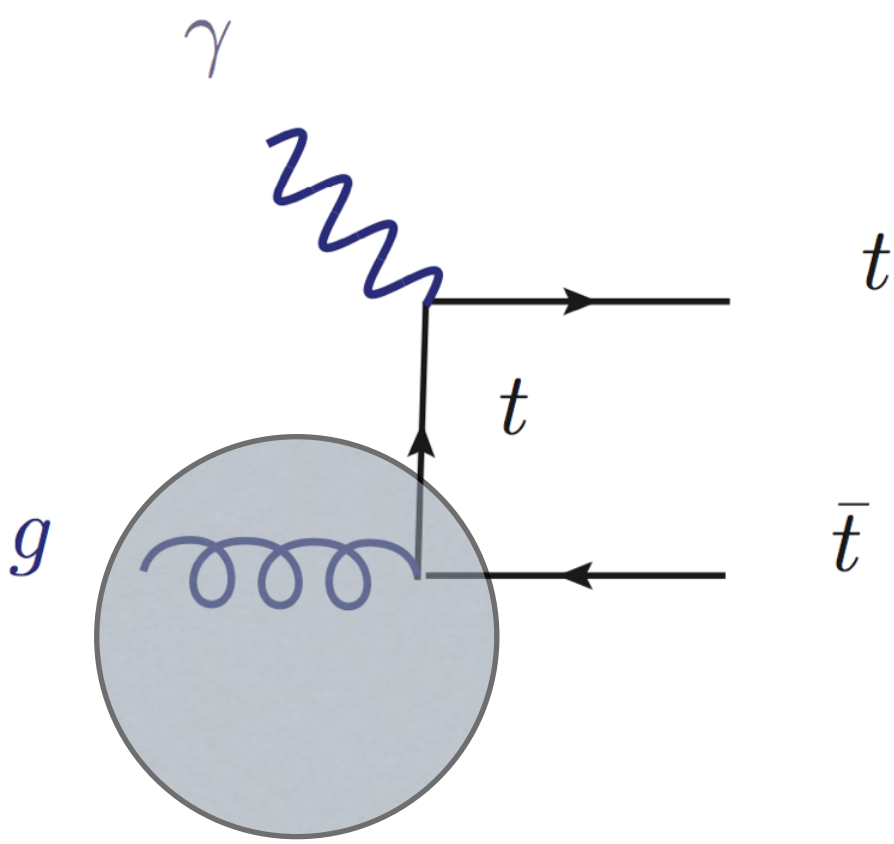
DIS	photoproduction	photoproduction
0.023 pb	0.70 pb	0.031 pb
$N_{t\bar{t}}$=2,300	$N_{t\bar{t}}$=70,000	N_t=3,100

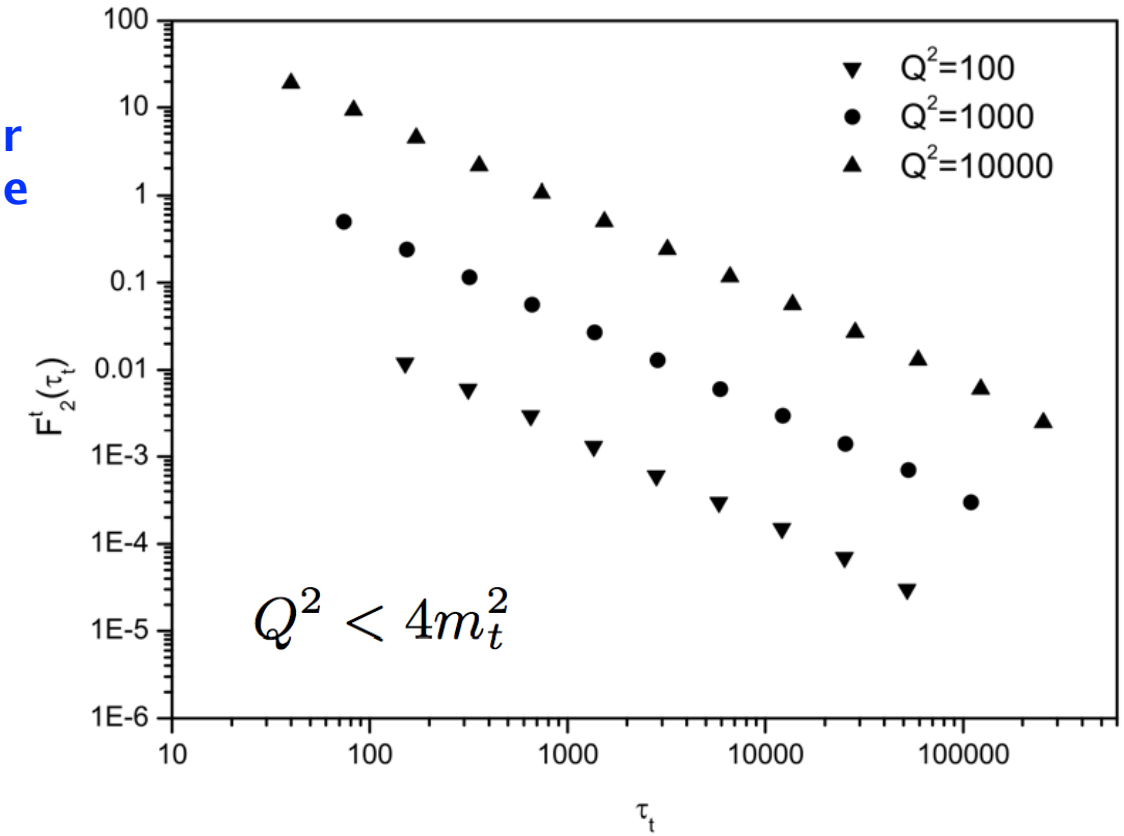
Top Quark Structure Function

Boroun, Phys. Lett. B744, 142 (2015)

L_{int}=10 fb^{-1}

variable flavour number scheme for top quark





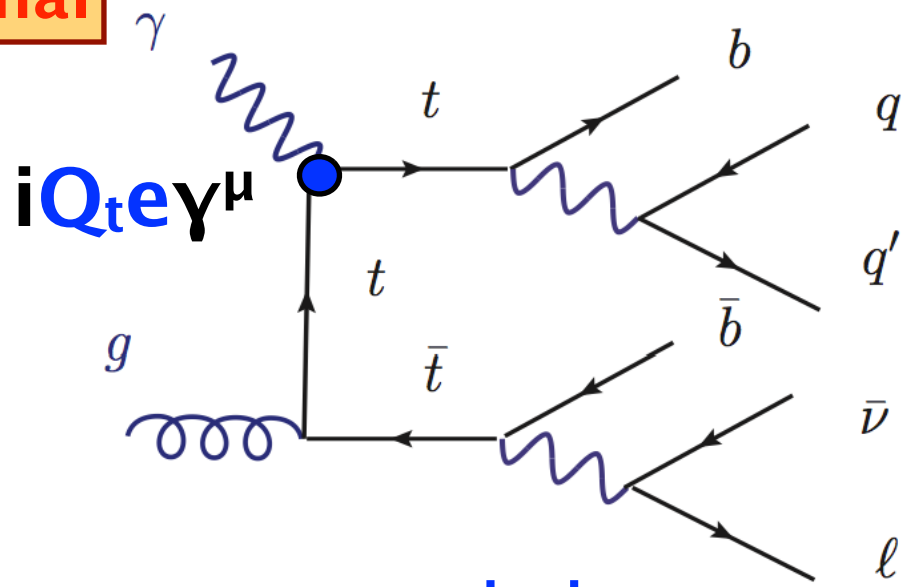
$$\tau_t = (1 + \frac{4m_t^2}{Q^2})^{1+\lambda} \frac{Q^2}{Q_0^2} (\frac{x_B}{x_0})^{\lambda}$$

$$x = x_B (1 + \frac{4m_t^2}{Q^2})$$

→ **LHeC opens up a new field of top quark PDFs**

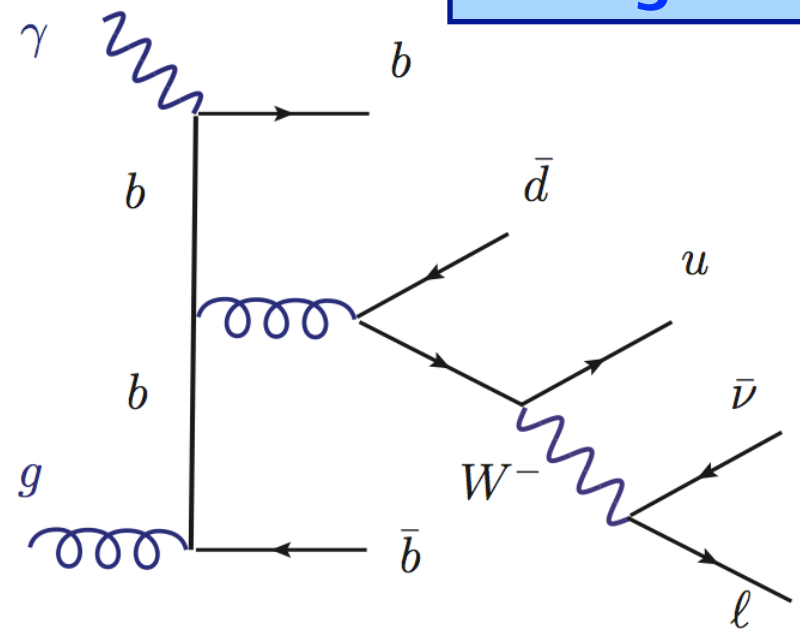
Analysis of the $t\bar{t}\gamma$ Vertex

signal

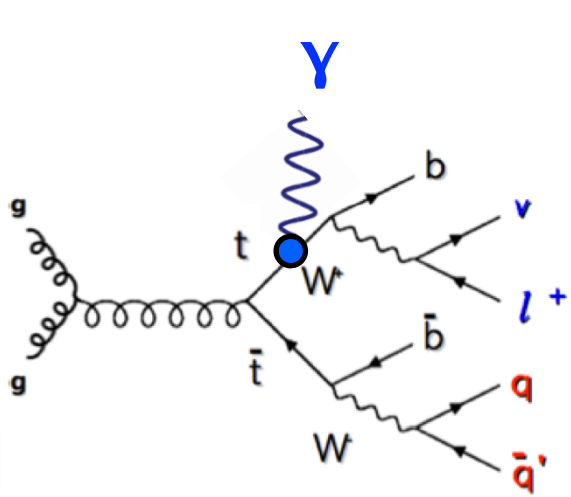


→ measure top quark charge

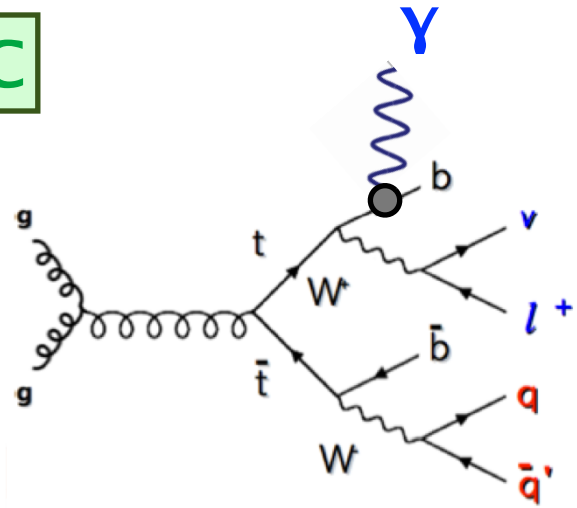
background



LHC



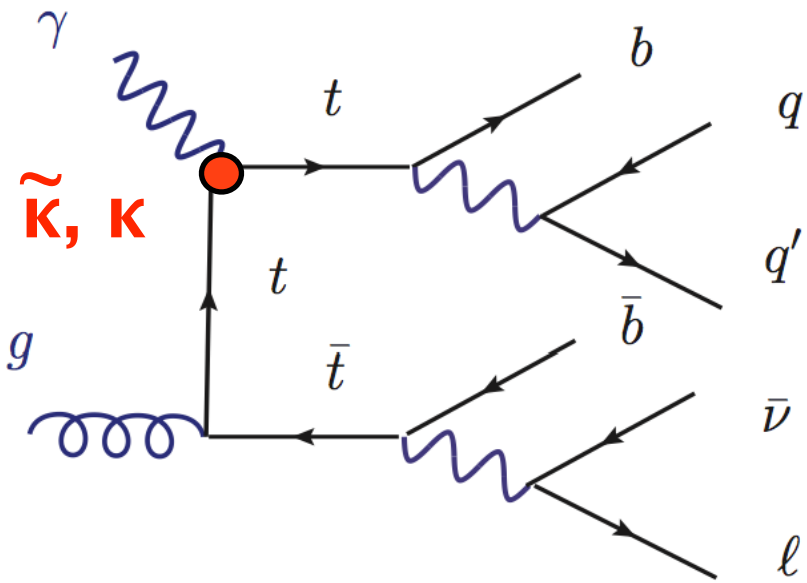
OR



?

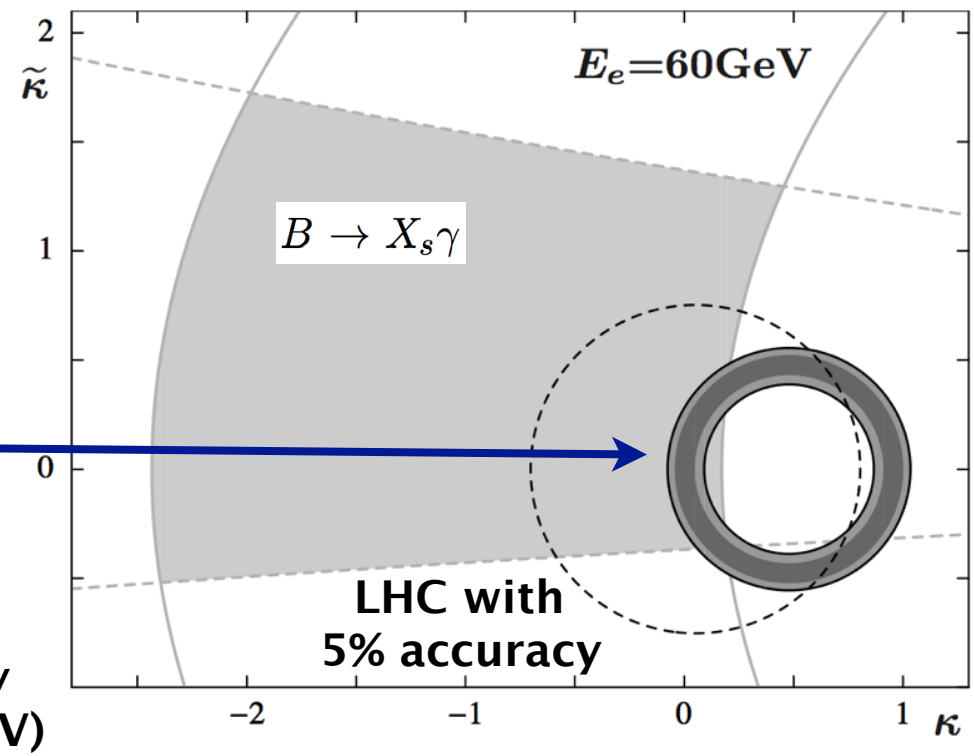
→ difficult at the LHC

Search for Anomalous $t\bar{t}\gamma$ Couplings



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

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



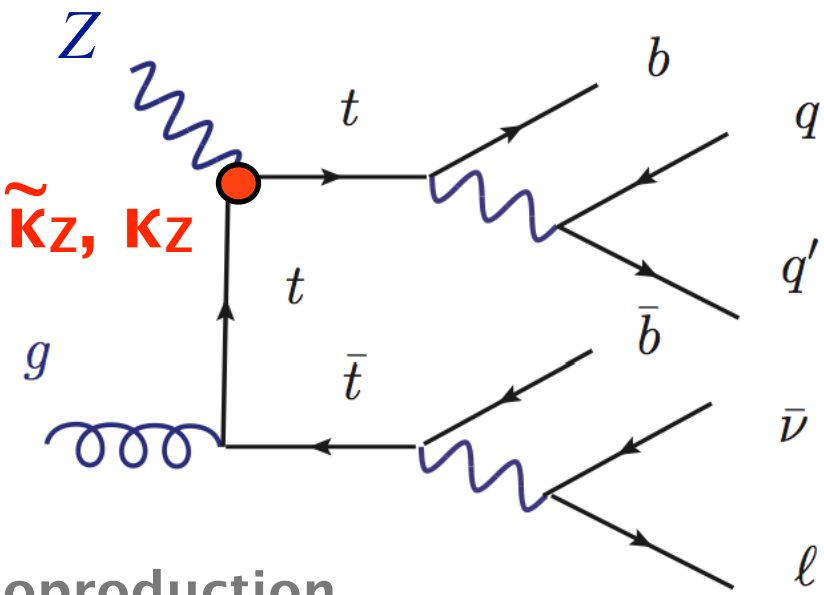
LHeC:
10% and 18% accuracy

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

magnetic dipole moment: κ

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

Search for Anomalous $t\bar{t}Z$ Couplings

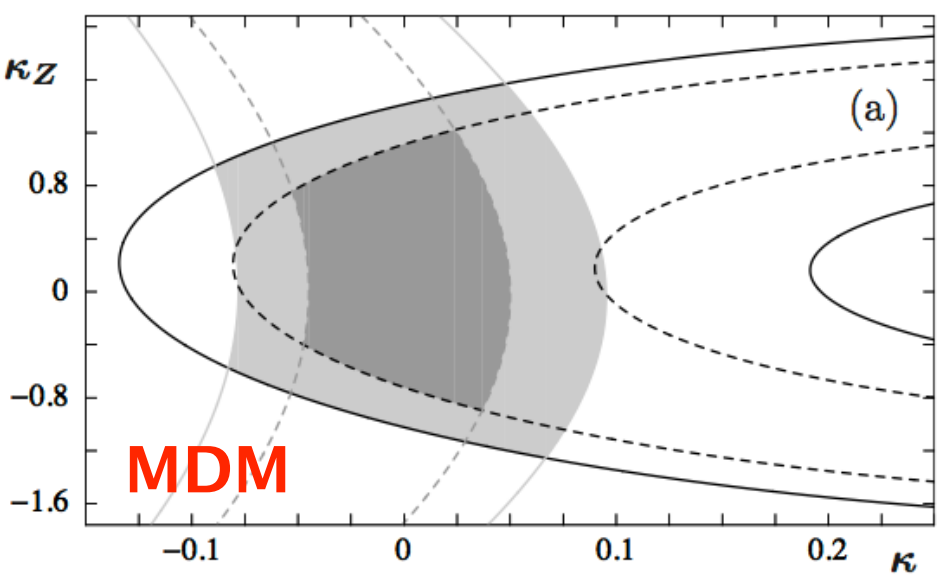


$t\bar{t}$ photoproduction

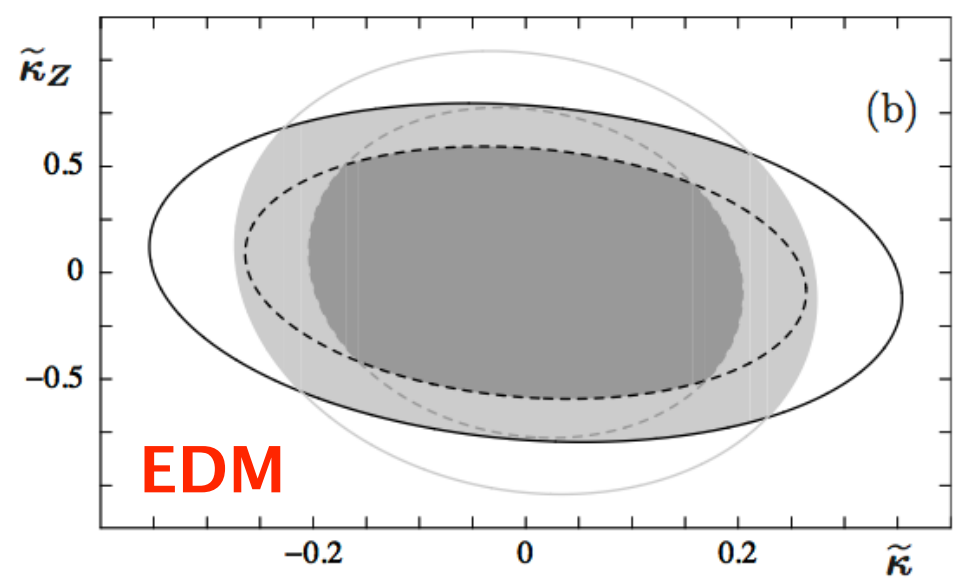
Bouzas, Larios,
Physical Review D 88, 094007 (2013)

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



$t\bar{t}$
DIS



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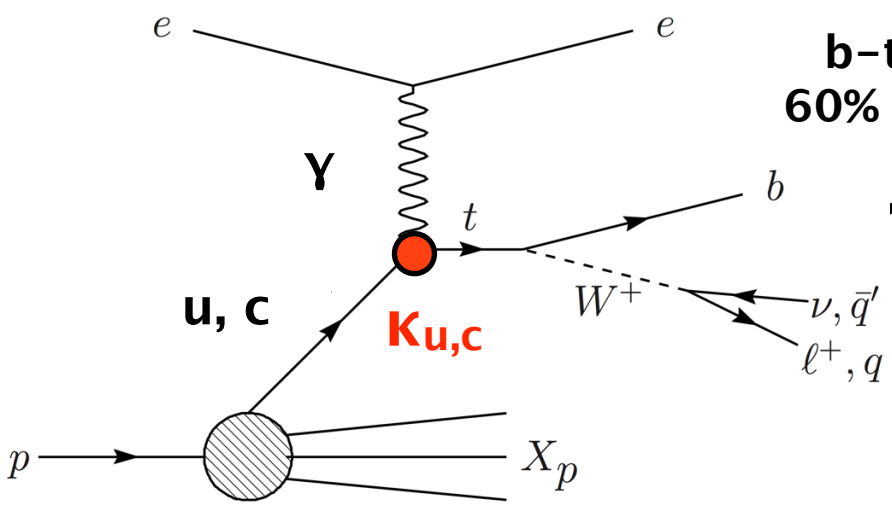
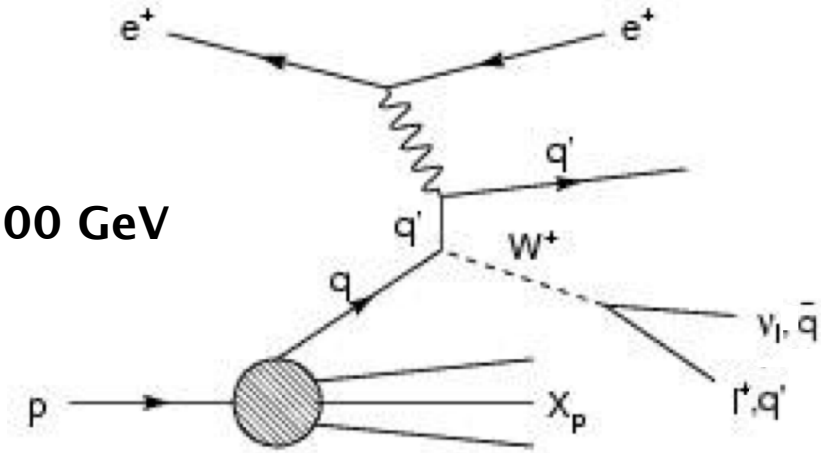
Conclusions

Single Top Quark Production: FCNC



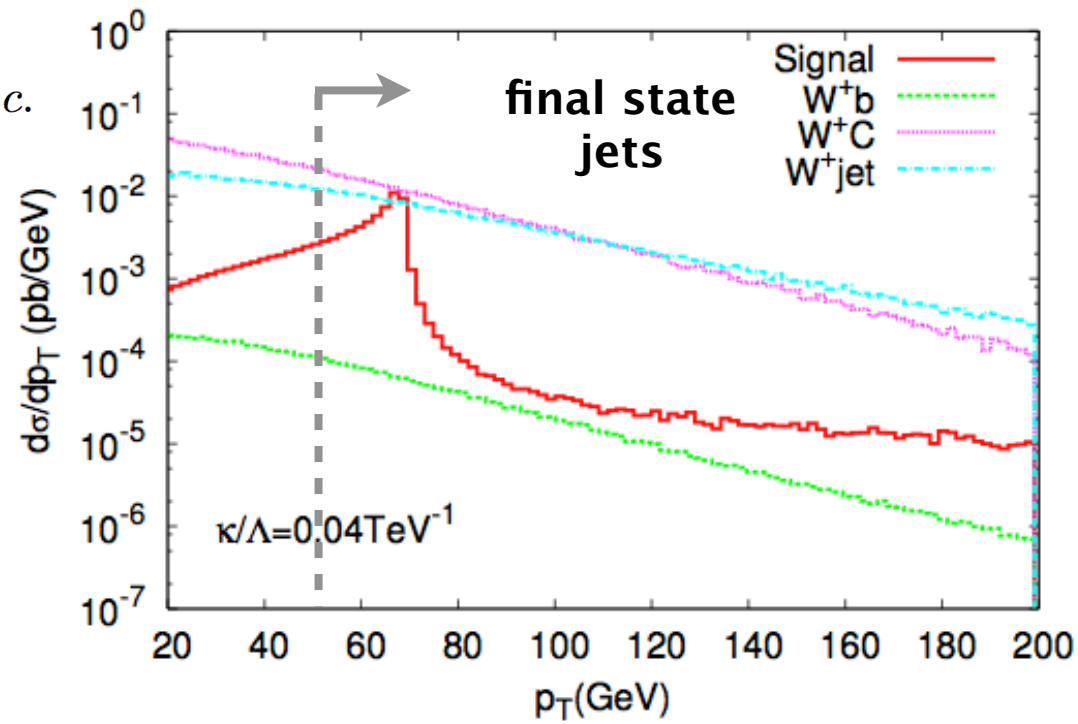
b-tagging:
60% efficiency

150<M_{Wb}<200 GeV



$$L = -g_e \sum_{q=u,c} Q_q \frac{\kappa_q}{\Lambda} \bar{t}\sigma^{\mu\nu}(f_q + h_q\gamma_5) q A_{\mu\nu} + h.c.$$

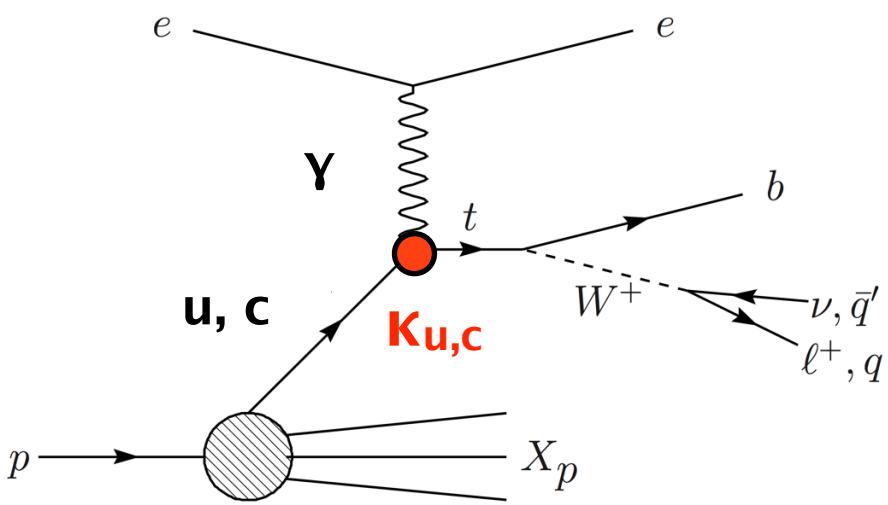
LHeC TDR,
J.Phys. G39,
075001 (2012)



γp collider:

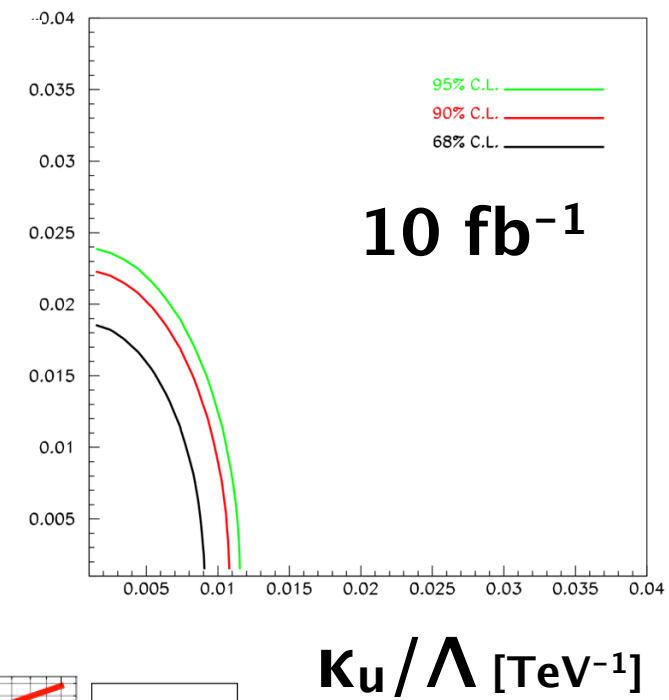
e-beam 70 GeV
γ: 80% of e-energy
L_{int}=10 fb^{-1}

Single Top Quark Production: NC

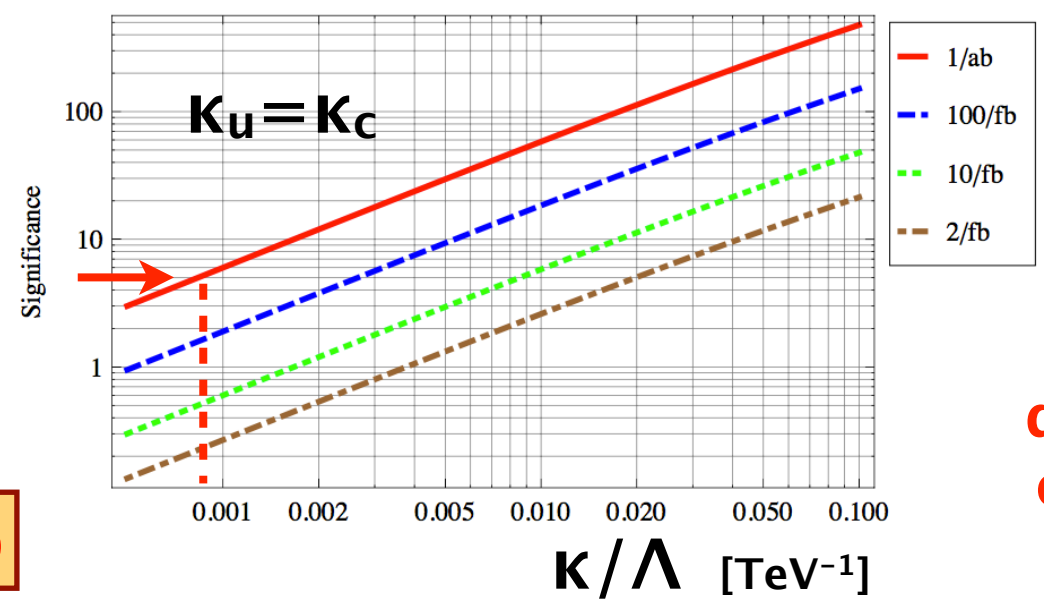


$$L = -g_e \sum_{q=u,c} Q_q \frac{\kappa_q}{\Lambda} \bar{t}\sigma^{\mu\nu}(f_q + h_q\gamma_5) q A_{\mu\nu} + h.c.$$

LHeC CDR, J.Phys. G39, 075001 (2012)



LHeC

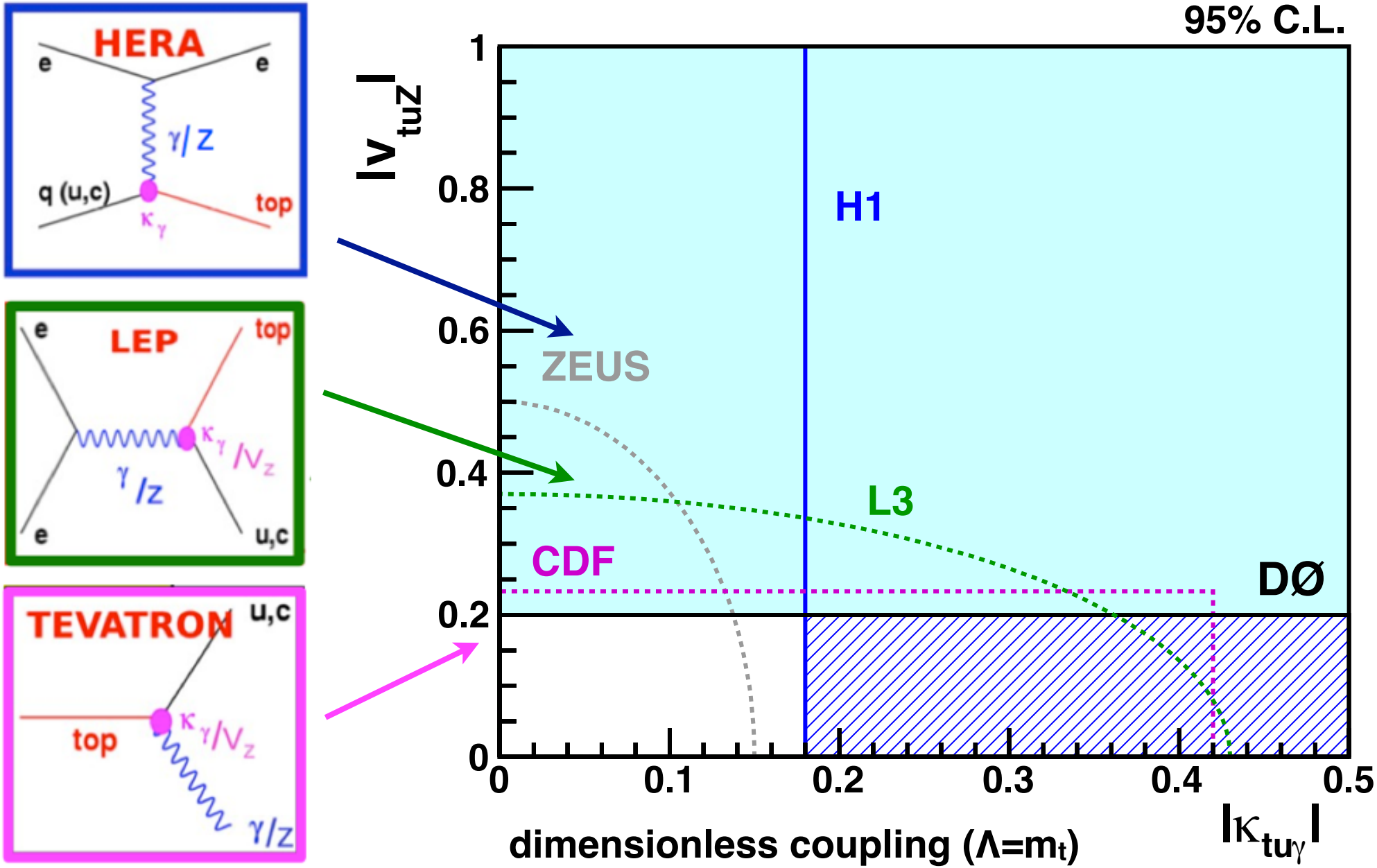


analysis needs to be optimised for FCC-ep conditions

FCC-ep

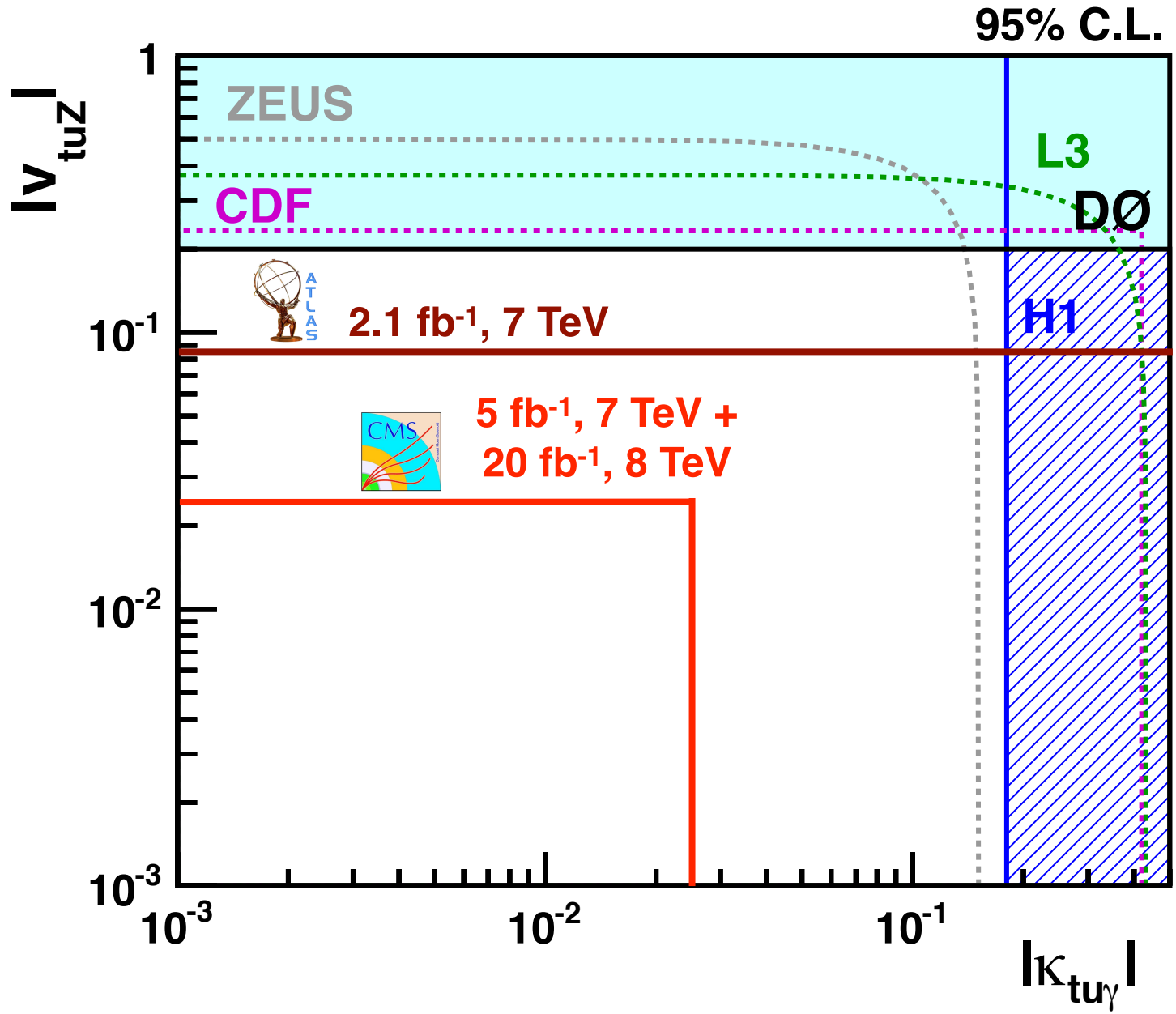
1 ab⁻¹: discovery for couplings of order 10^{-3}

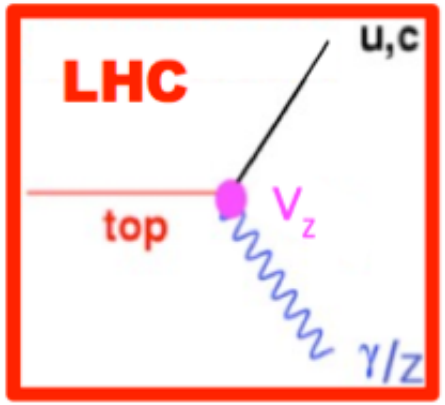
FCNC Top Couplings at Colliders



FCNC Top Couplings at Colliders

Top Quark Working Group Collaboration, arXiv:1311.2028 [hep-ph]





FCNC Top Couplings at Colliders

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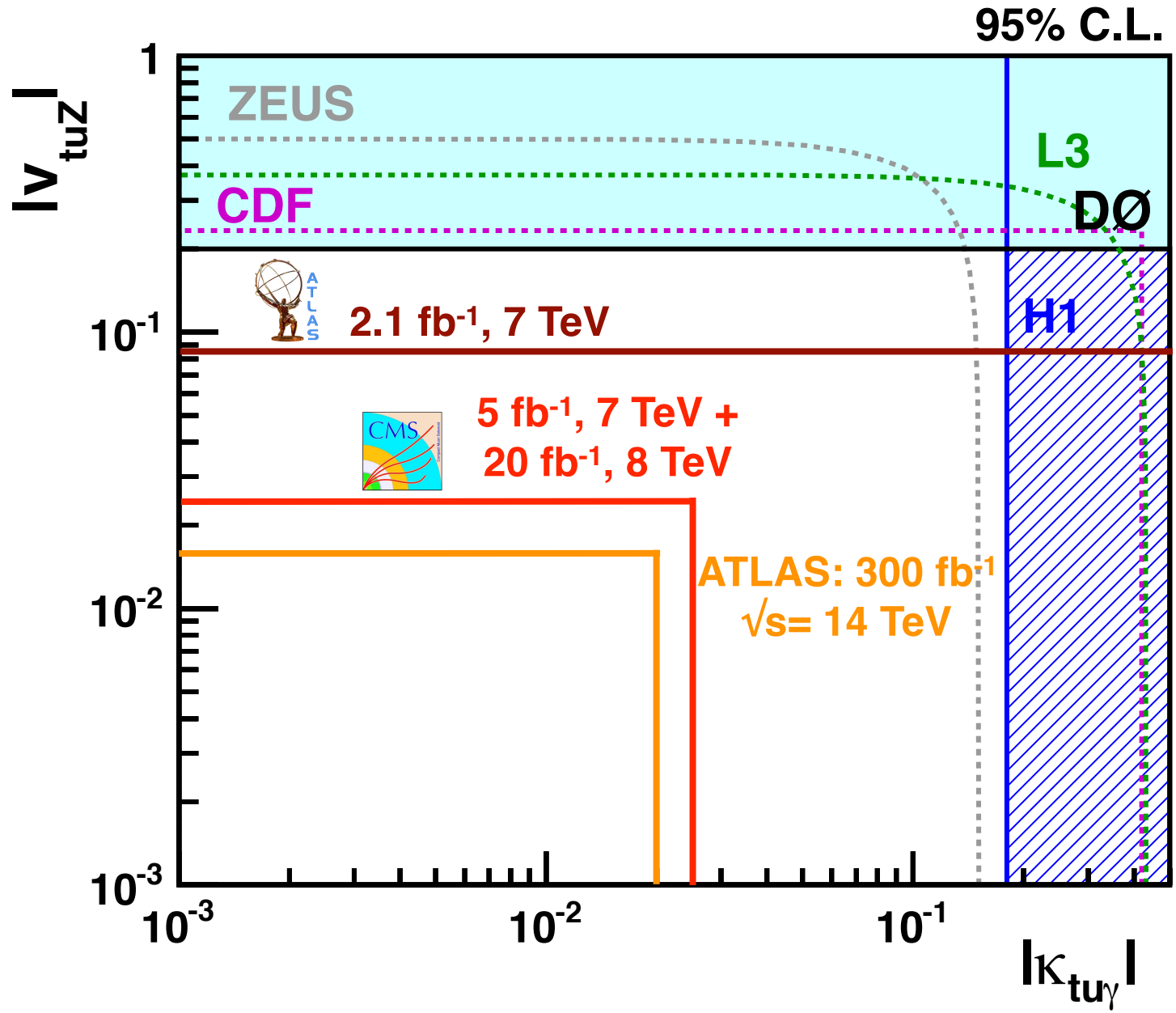

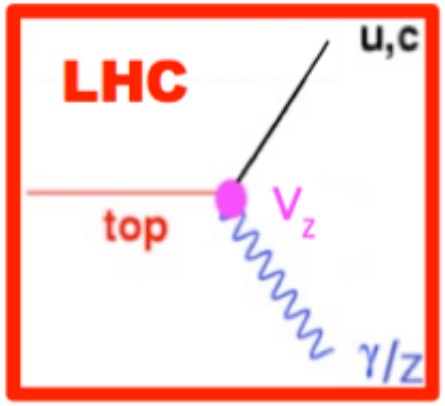

FCNC Top Couplings at Colliders

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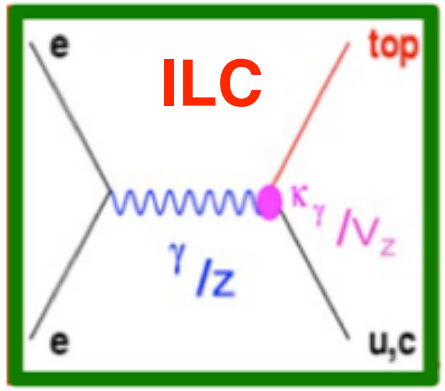
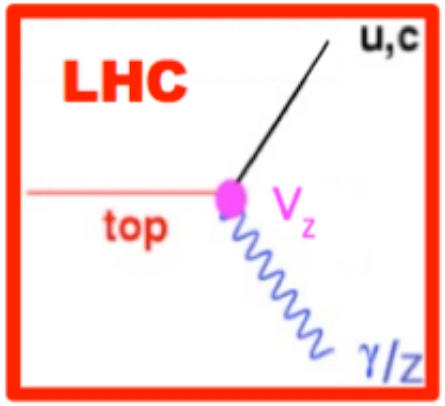
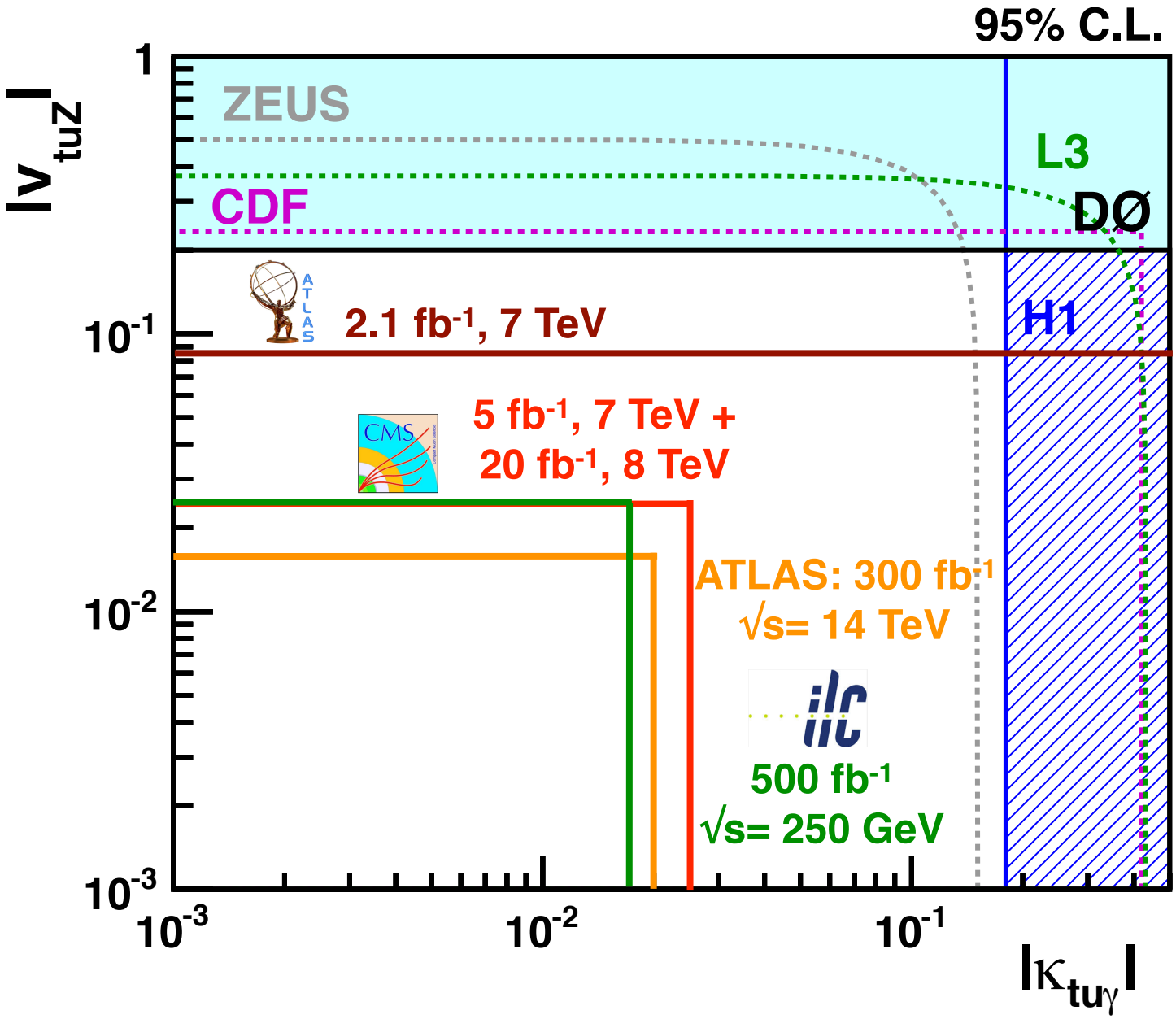
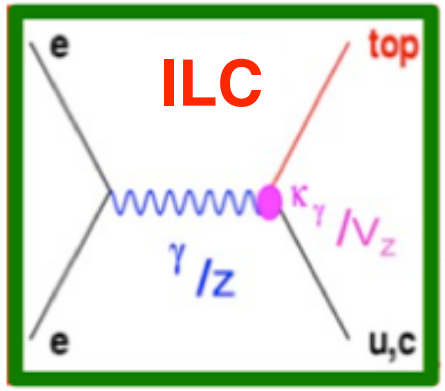
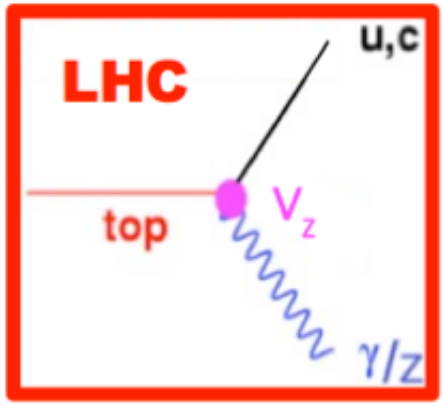


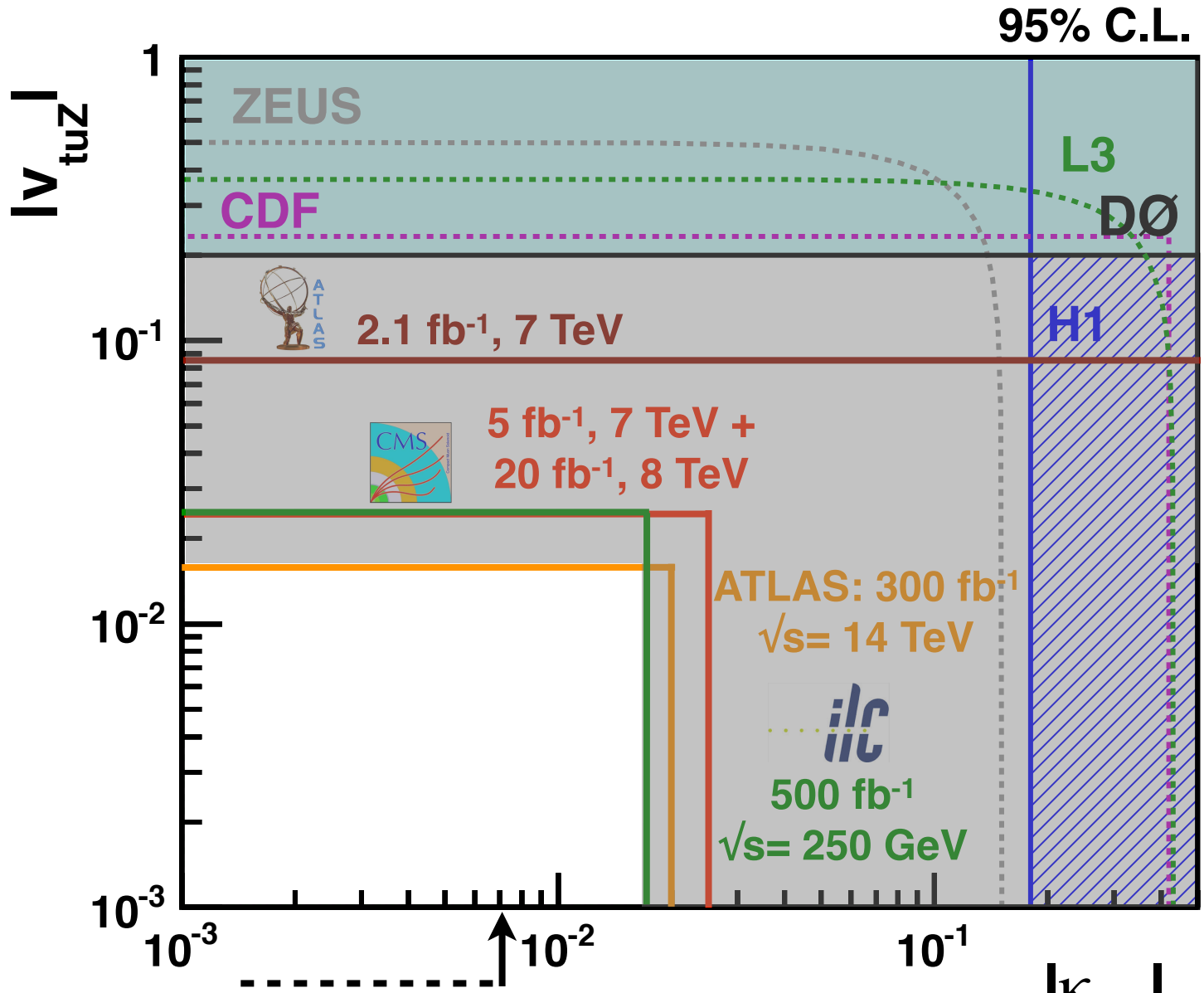




FCNC Top Couplings at Colliders

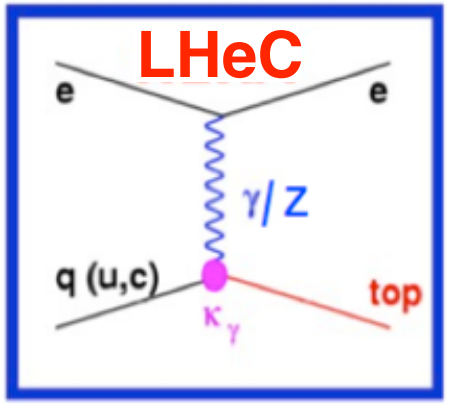


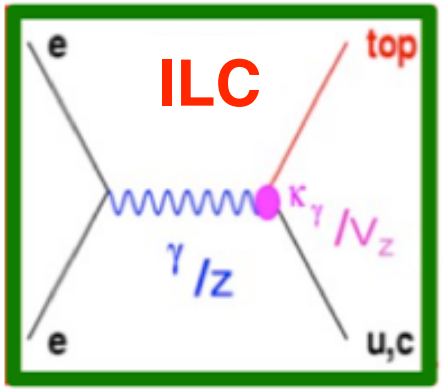


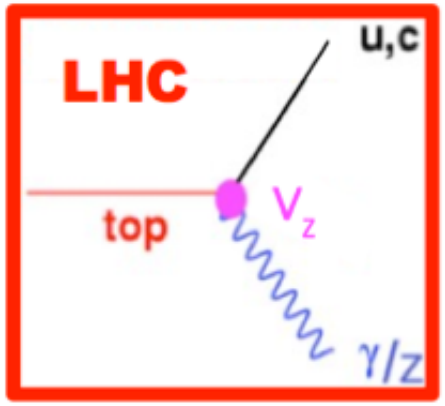


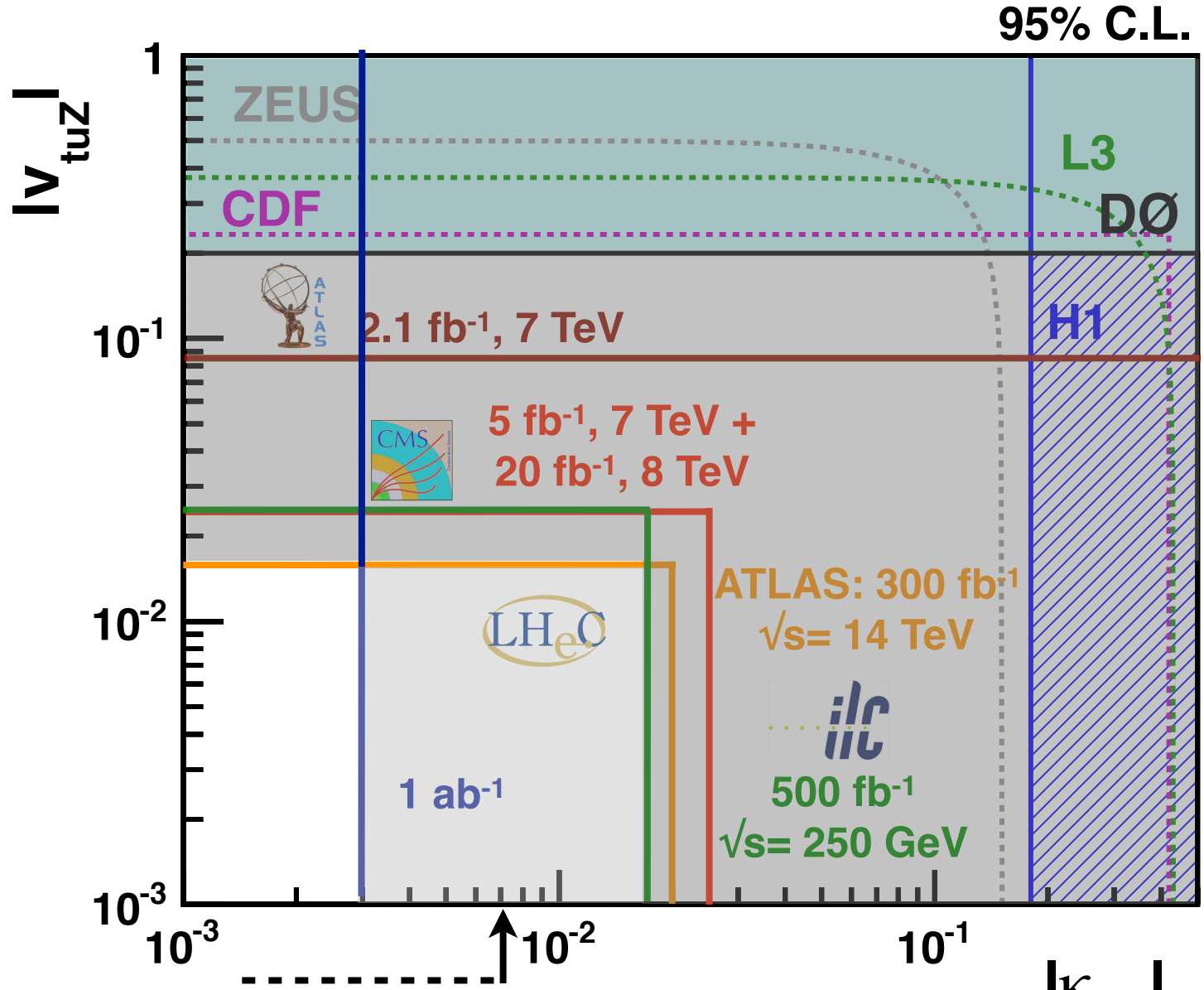
→ test SUSY, little Higgs, technicolor...

FCNC Top Couplings at Colliders



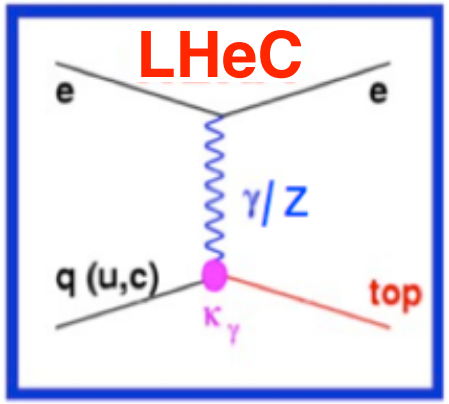


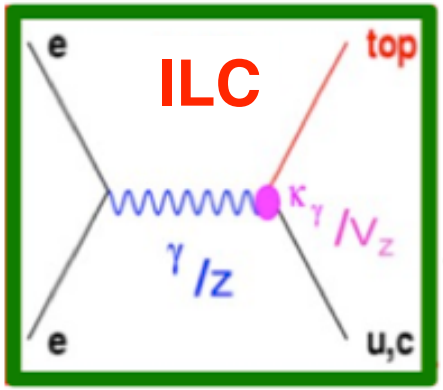


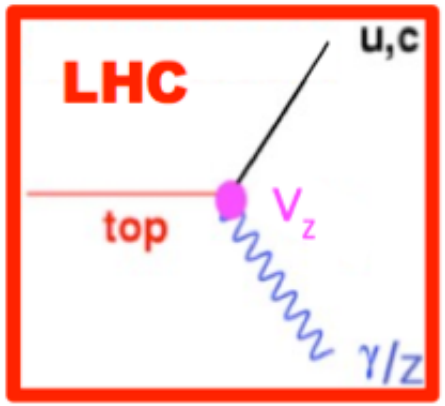


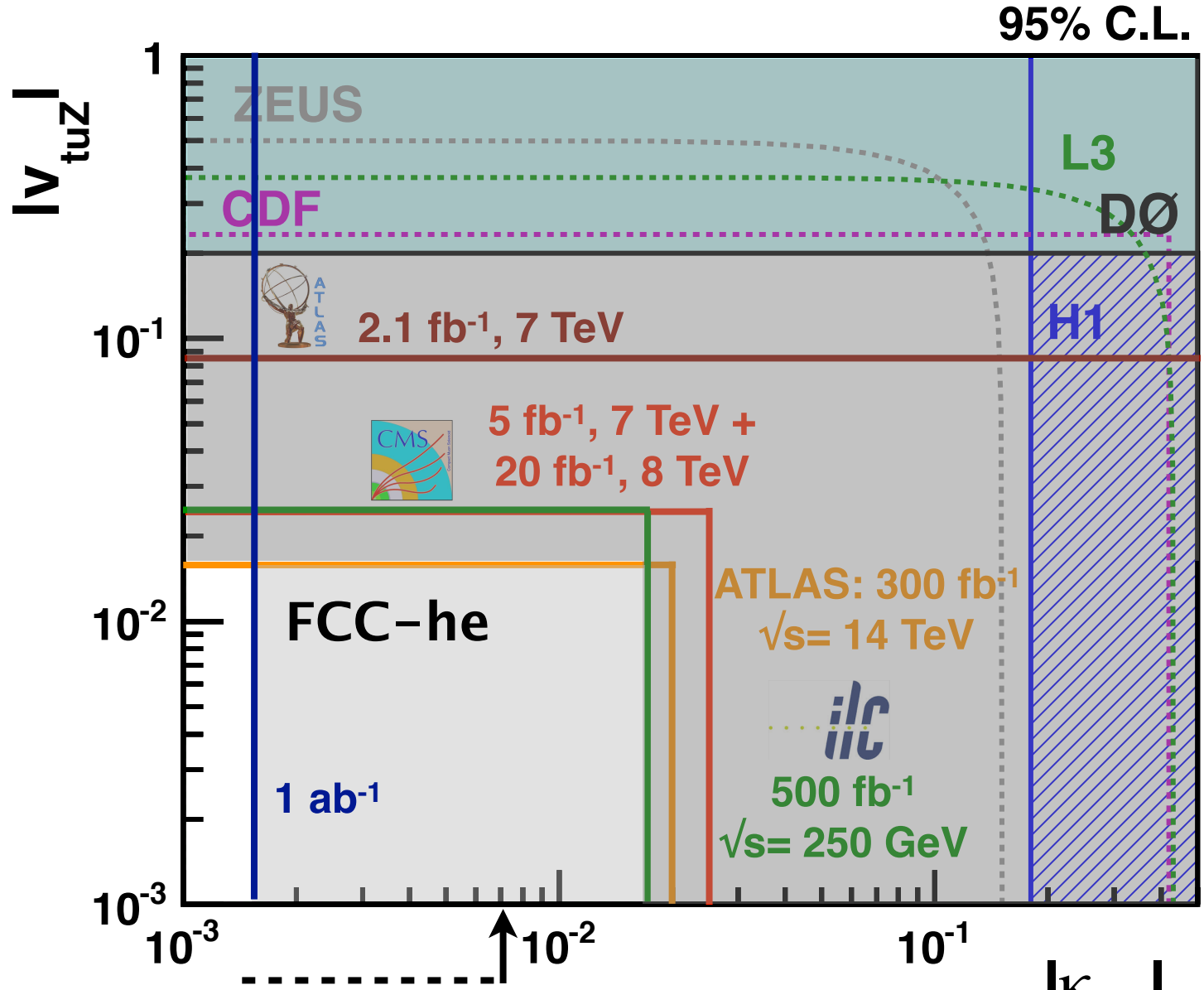
→ test SUSY, little Higgs, technicolor...

FCNC Top Couplings at Colliders





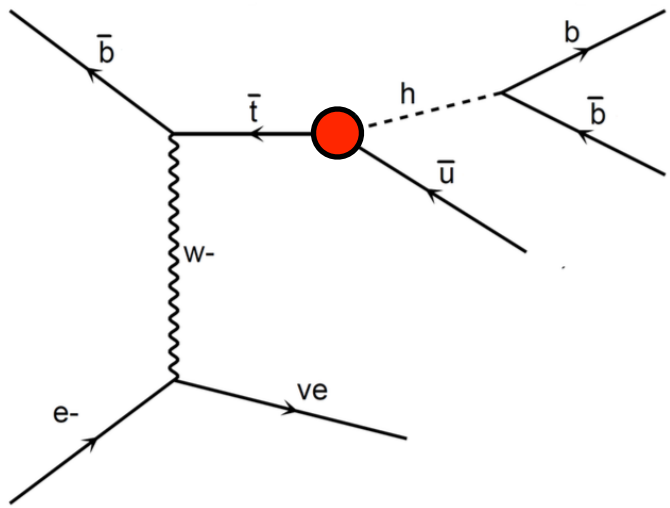




→ test SUSY, little Higgs, technicolor...

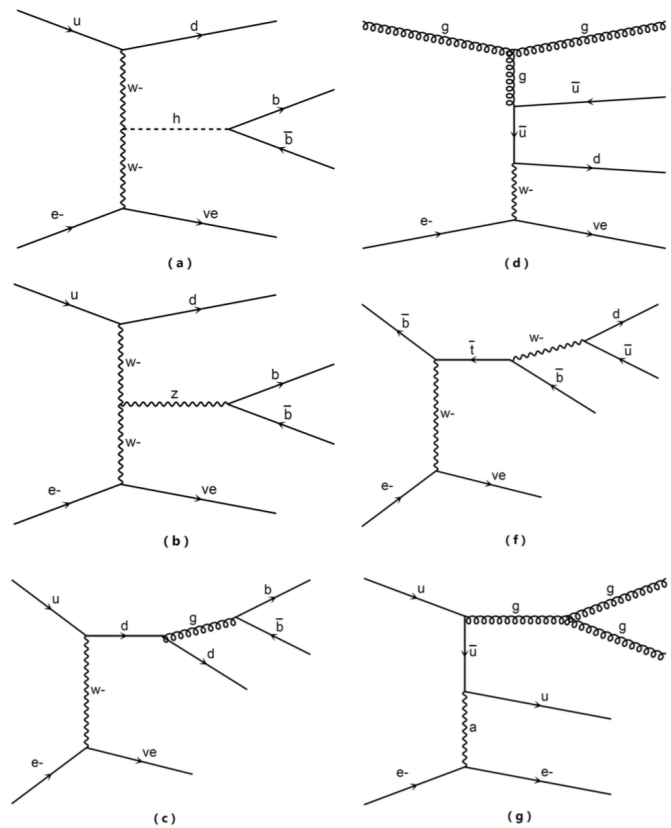
Search for Anomalous FCNC tHu Coupling

signal



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

background



irreducible backgrounds:

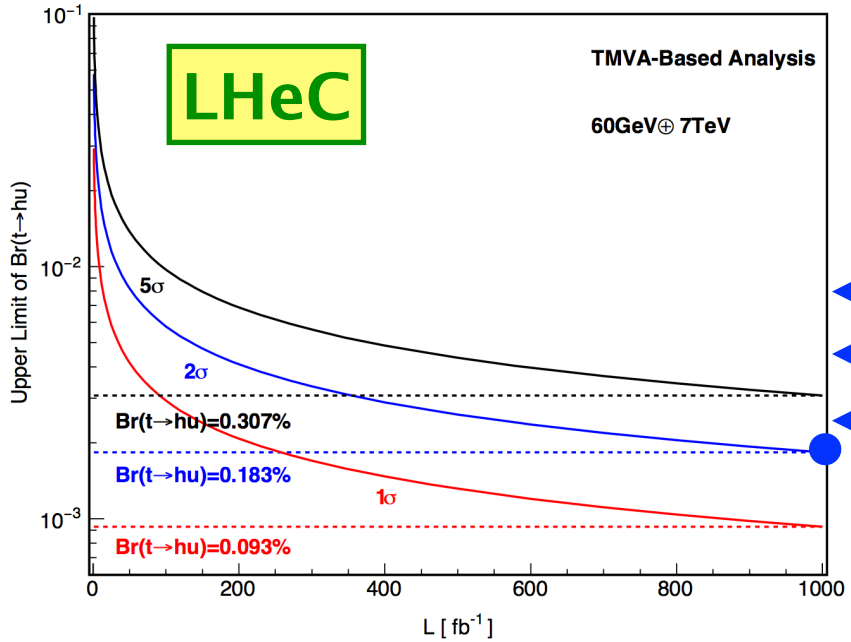
$$e^-p \to \nu_e(h \to b\bar{b})j$$
$$e^-p \to \nu_e(z \to b\bar{b})j$$
$$e^-p \to \nu_e(g \to b\bar{b})j$$

reducible backgrounds:

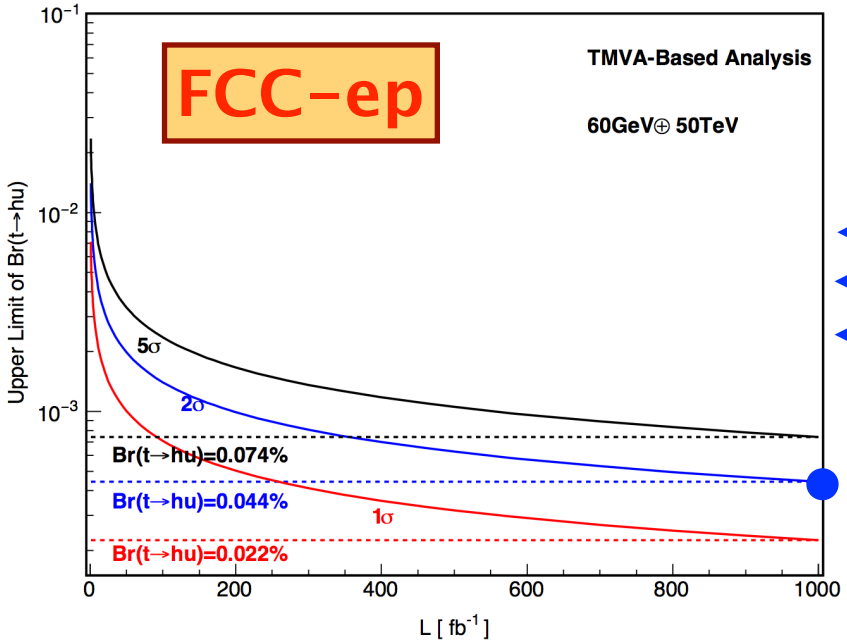
$$e^-p \to \nu_e jjj$$
$$e^-p \to \nu_e jjb/\bar{b}$$
$$e^-p \to \nu_e \bar{t}$$
$$e^-p \to e^- jjj$$
$$e^-p \to e^- jjb/\bar{b}$$
$$e^-p \to e^-(g \to b\bar{b})j$$

- **parametrised assumed resolutions for electrons/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**

Upper Limit on Br(t→uH) in MVA analysis



ATLAS, 4.7(20.3)fb^{-1}@7(8)TeV
CMS, 19.5 fb^{-1}@8TeV
LHC, 3000 fb^{-1}@14TeV



ATLAS, 4.7(20.3)fb^{-1}@7(8)TeV
CMS, 19.5 fb^{-1}@8TeV
LHC, 3000 fb^{-1}@14TeV

→ **improves sensitivity of HL-LHC**

Outline

Introduction
Electroweak Physics
Top Quark Physics
New Phenomena Searches
Conclusions

Summary

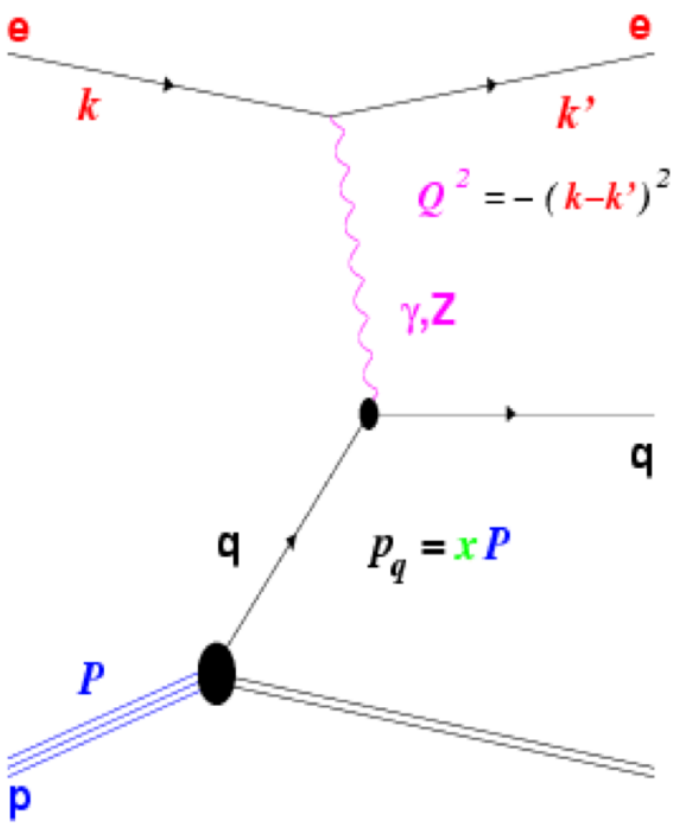
- future ep collider has a rich analysis programme for electroweak interactions of light and heavy quarks
- high precision EW measurements: $\sin^2\theta$, light quark couplings to bosons (v_u, a_u, v_d, a_d)
- top quark couplings to bosons ($|V_{tb}|$, Wtb, ttγ, ttZ, tH)
- analyse top quark properties: polarisation, charge, PDFs of tops, ...
- many stringent searches for new physics:
  anomalous couplings, FCNC, H^+ bosons, heavy top, SUSY, technicolor, ultra heavy/majorana neutrinos, leptoquarks, stops, sbottoms, BSM VB scattering…

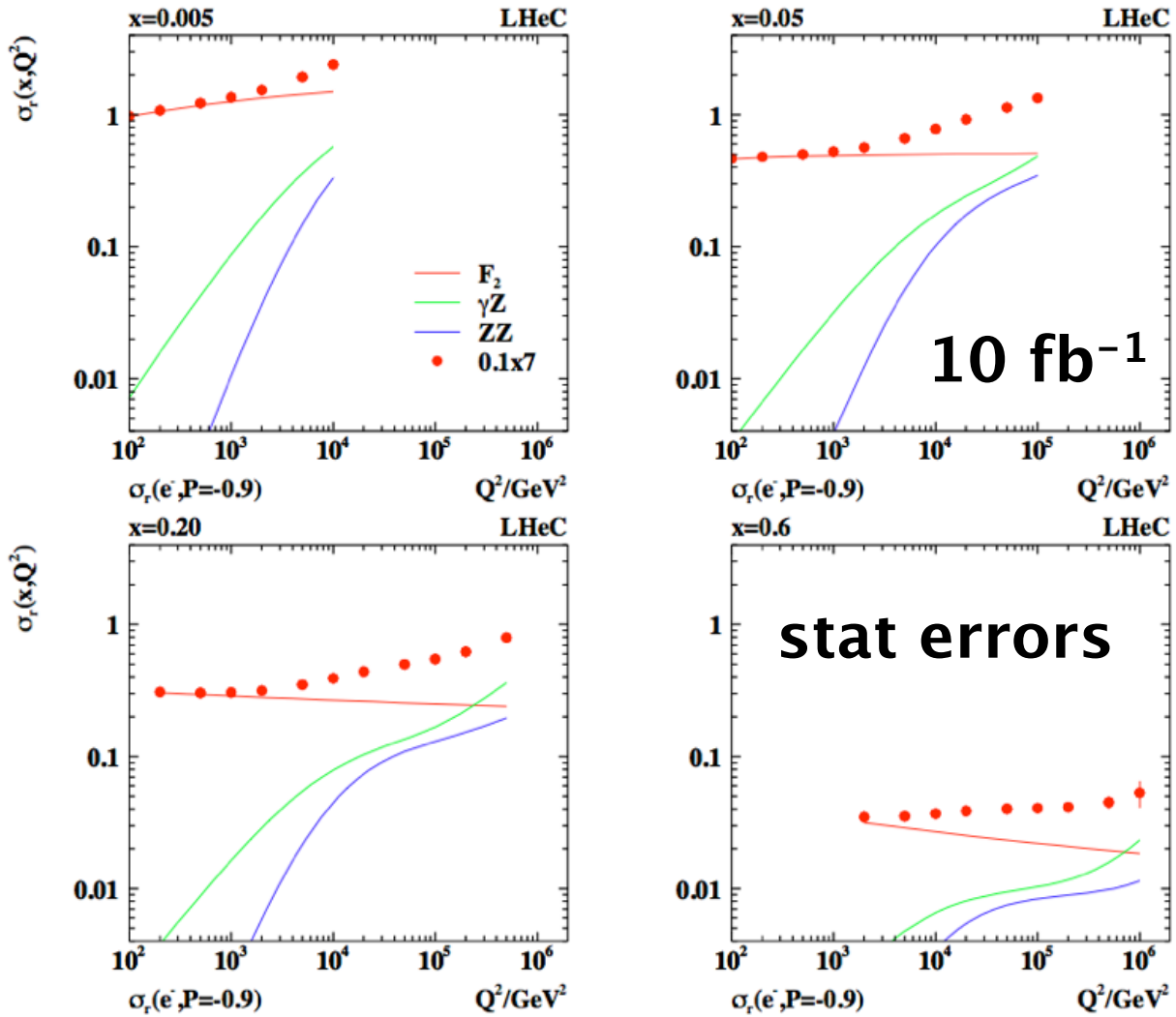
→ more exciting studies to come for

Backup

NC Cross Section Measurement

Neutral Current (NC)



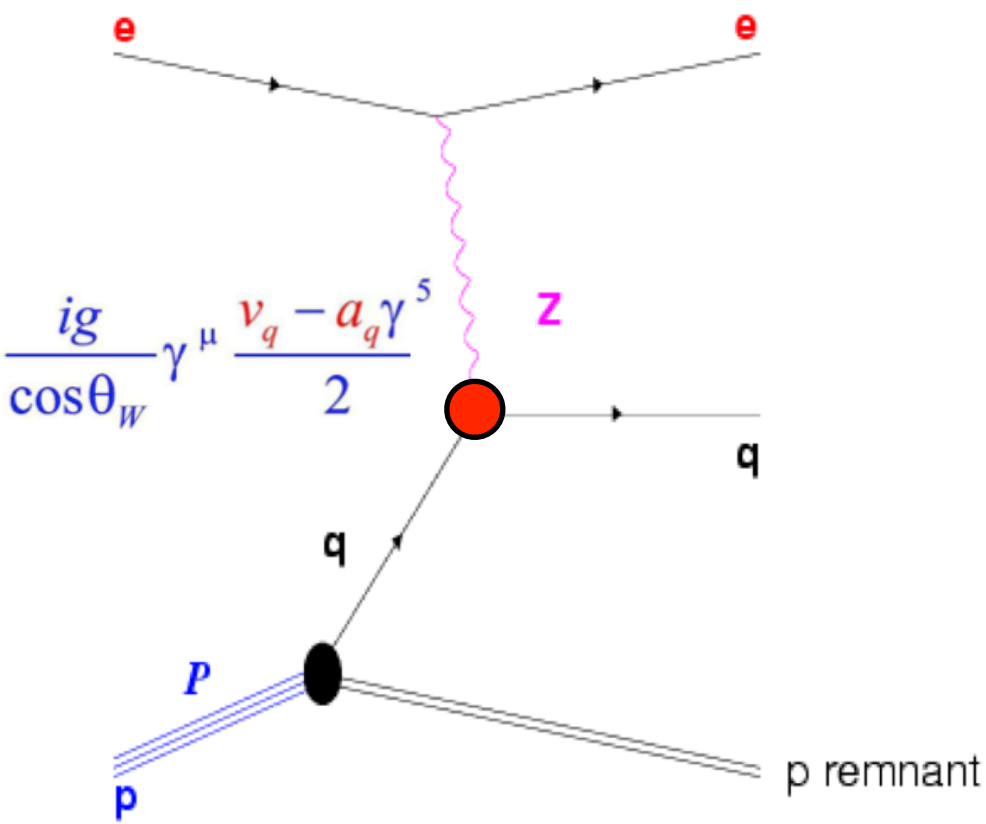


→ **high precision in large range of Bjørken x and Q^2**

LHeC TDR, J.Phys. G39, 075001 (2012)

Quark Couplings to the Z boson

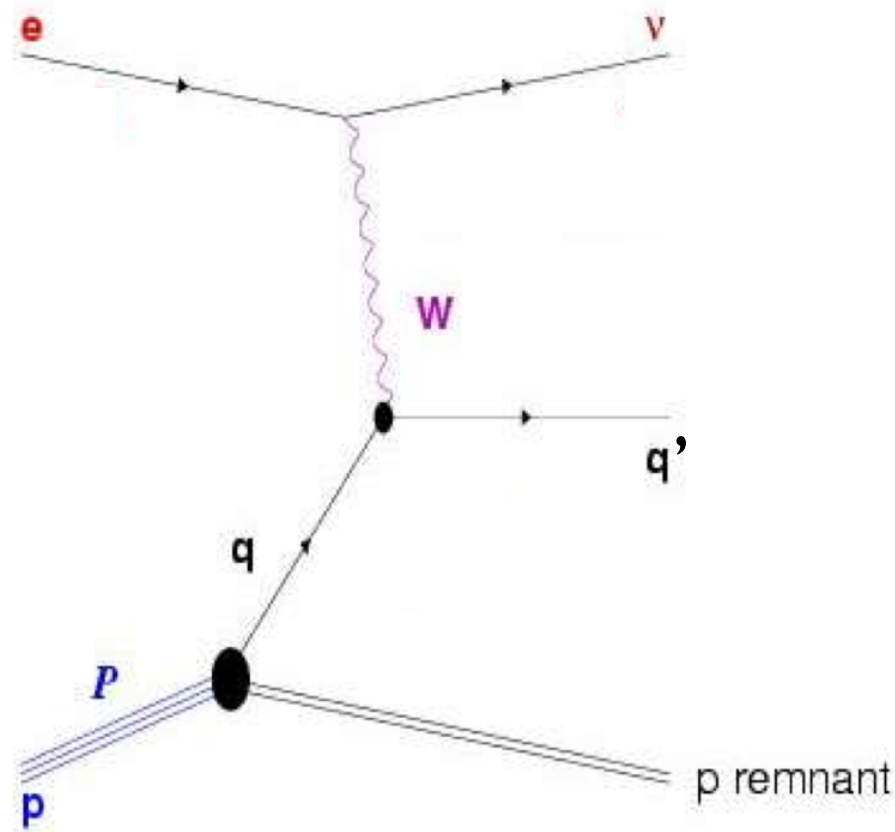
Neutral Current (NC)



$a_q = I_3^L$ Axial coupling, I^3=+1/2 for u, -1/2 for d

$v_q = I_3^L - 2e_q \sin^2\theta_W$ Vector coupling

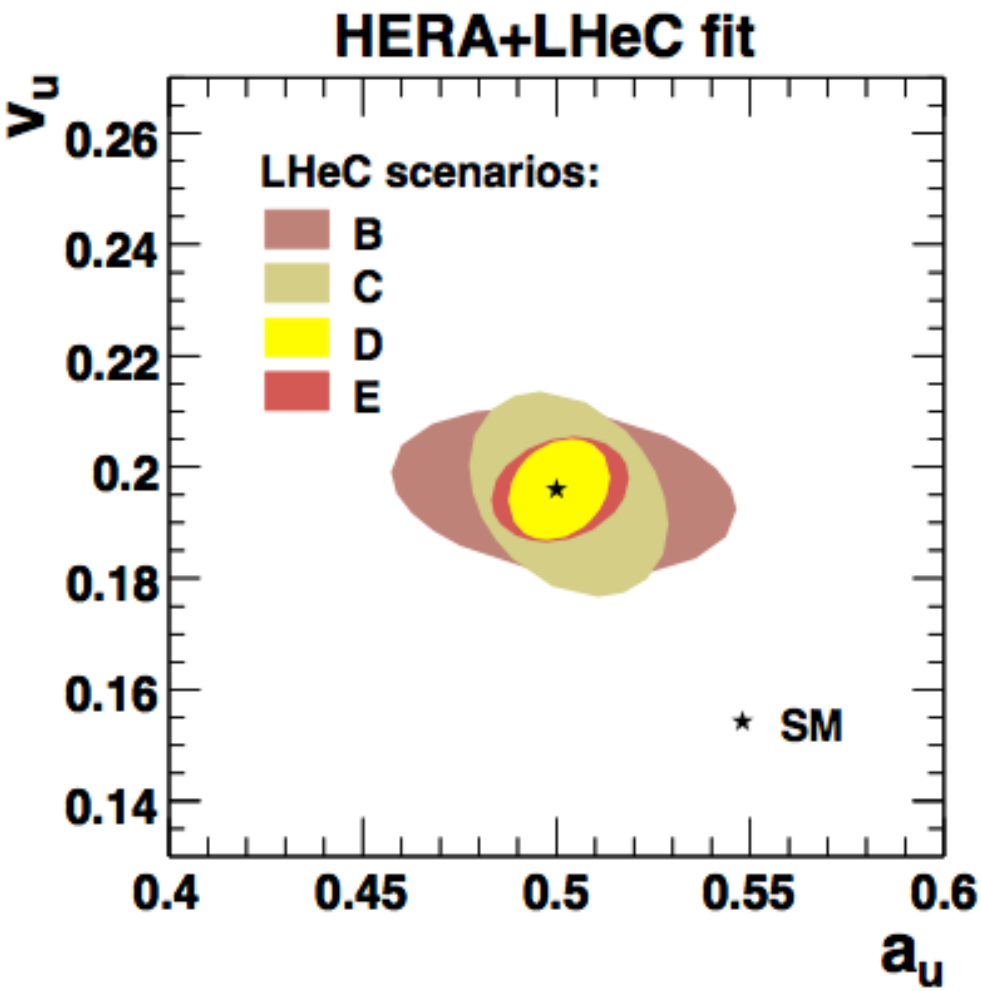
Charged Current (CC)

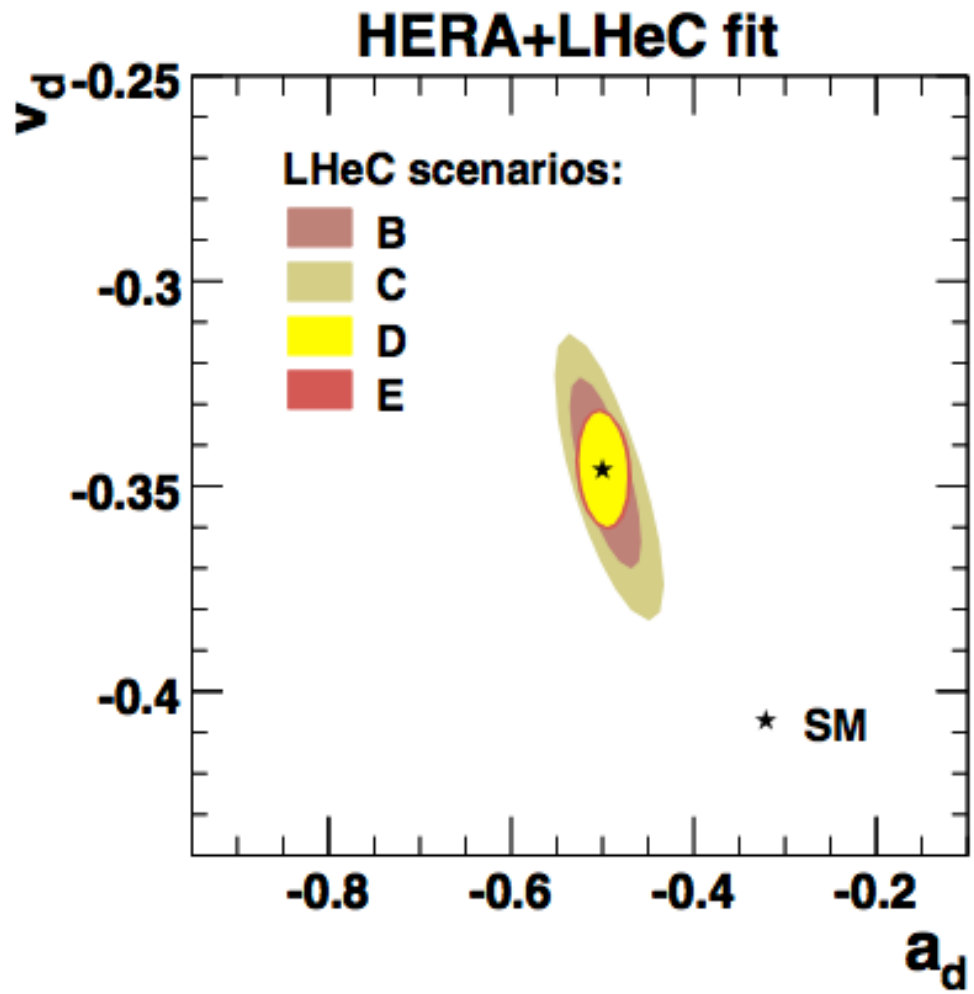


fit to simulated NC and CC data to extract a_u, a_d, v_u, v_d and PDFs simultaneously

Vector and Axial Vector NC Couplings

C: e beam: 50 GeV, 1 fb^{-1} e$^-$p, 1 fb^{-1} e$^+$p, polarisation: 40%



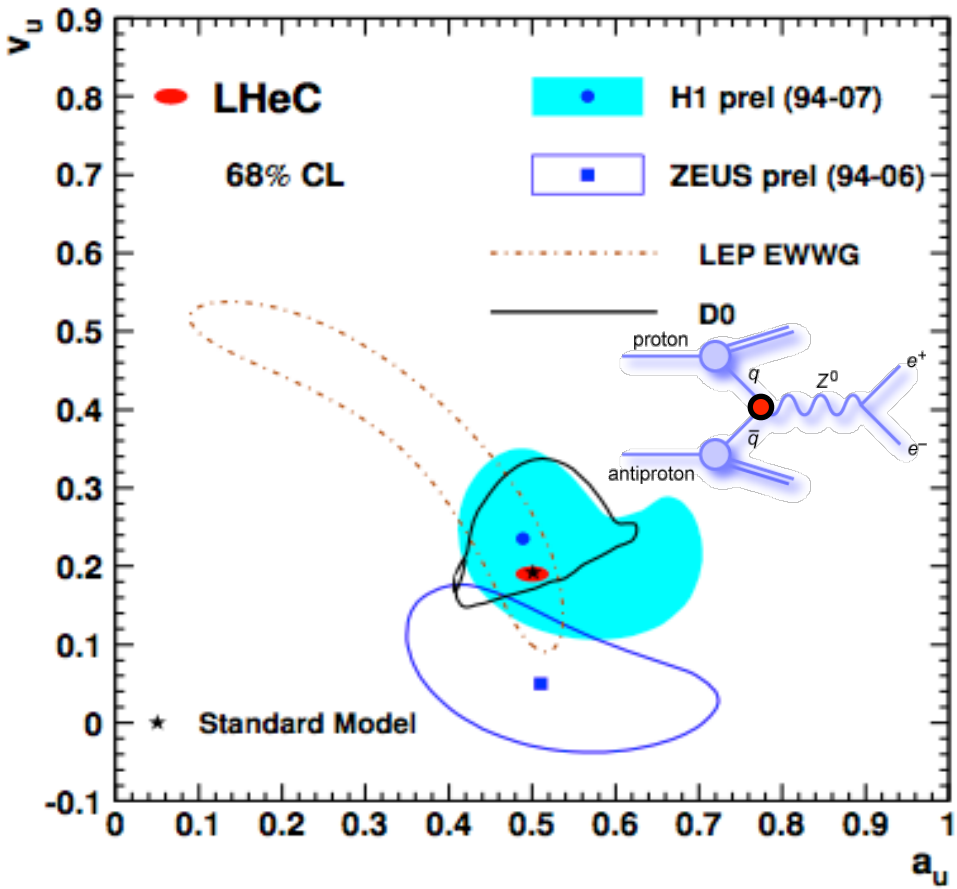


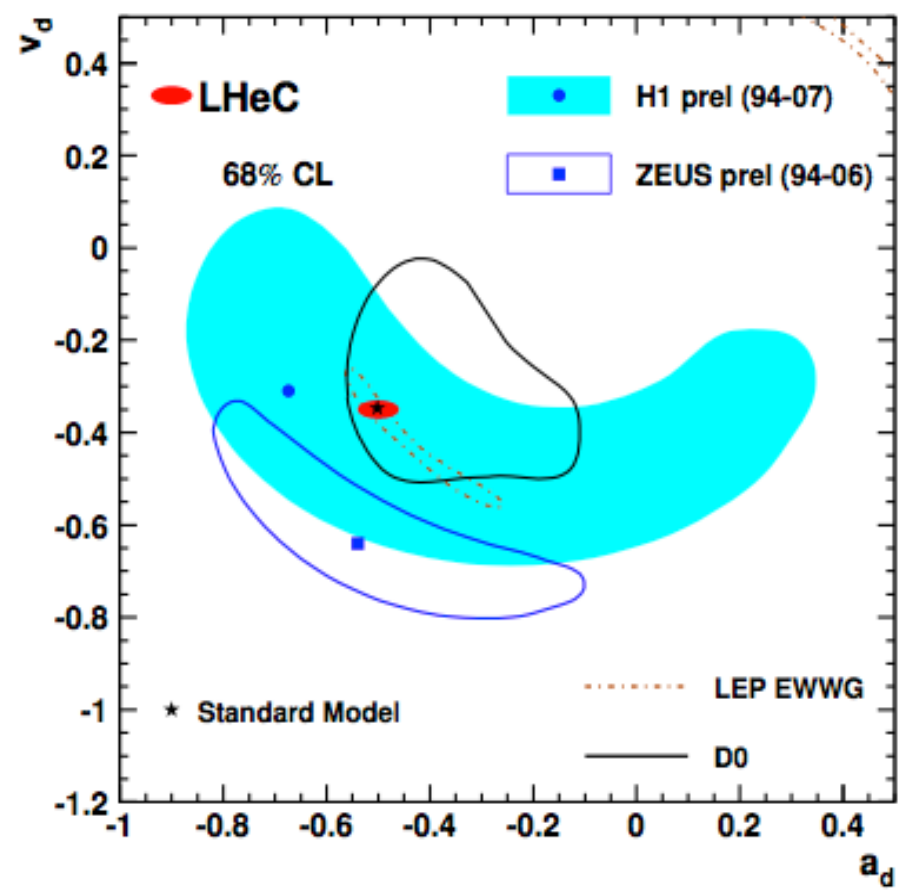
LHeC TDR, J.Phys. G39, 075001 (2012)

Vector and Axial Vector NC Couplings

C: e beam: 50 GeV, 1 fb^{-1} e^-p, 1 fb^{-1} e^+p, polarisation: 40%

significant improvements for higher luminosity and FCC-HE

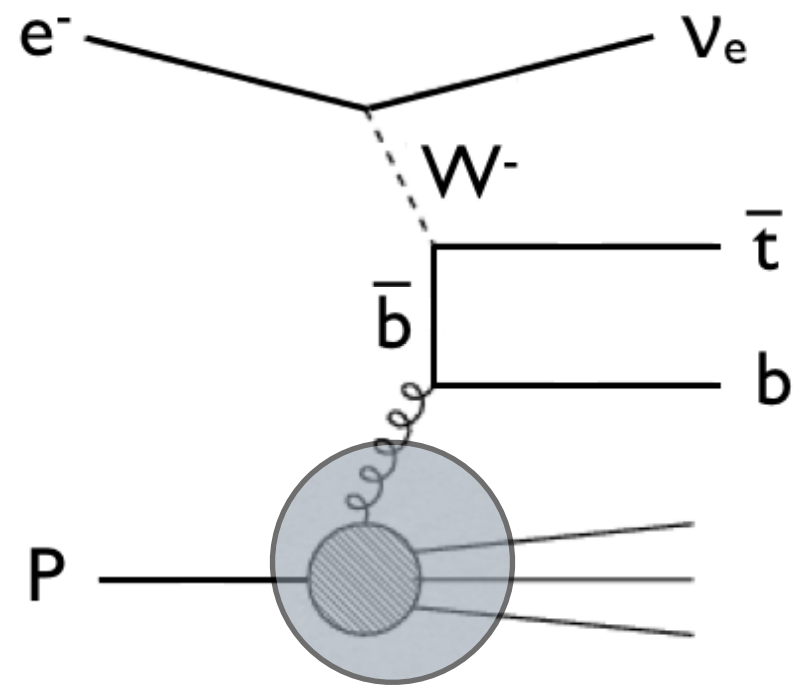




→ **high precision measurement**

→ **test new physics: Z' boson, R-parity violating SUSY, leptoquarks**

Gluon Parton Density Function

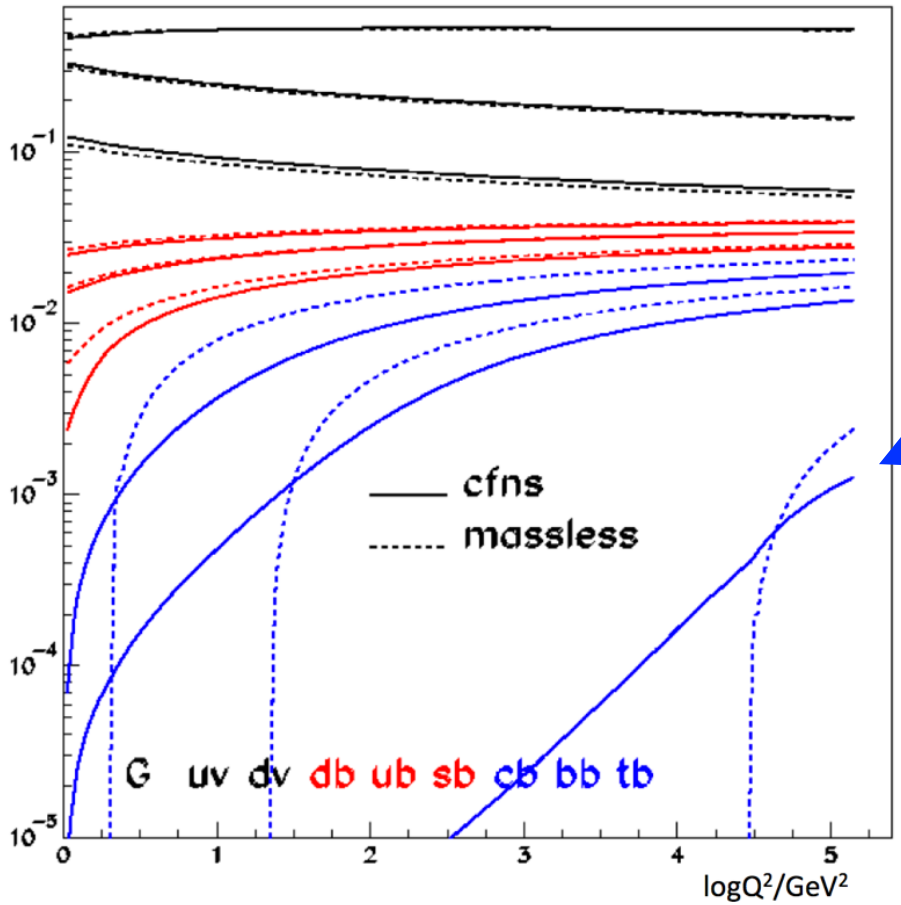


→ **measure gluon density at high x**

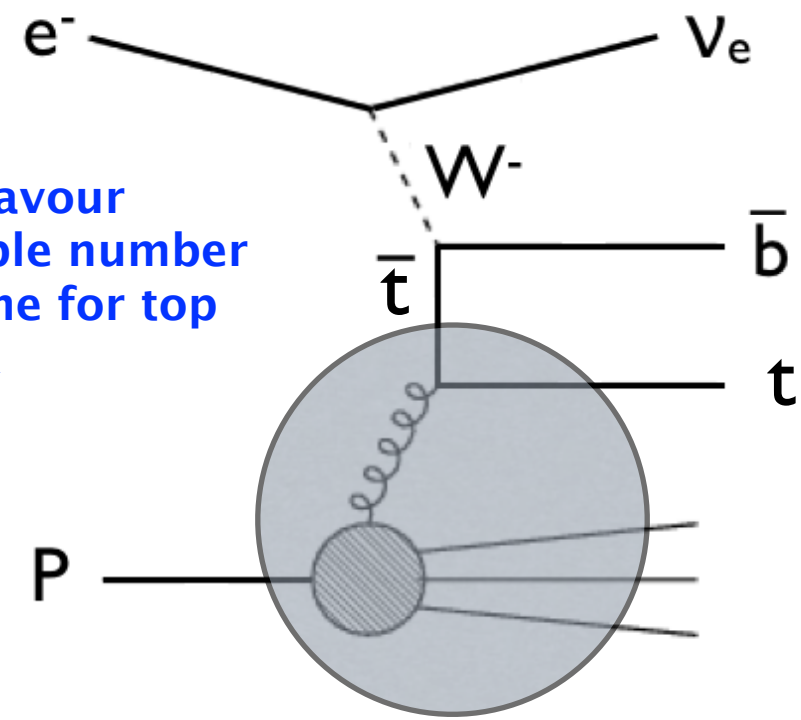
Top Quark Parton Density Function

LHeC CDR, J.Phys. G39, 075001 (2012)

parton momentum fraction



six-flavour variable number scheme for top quark

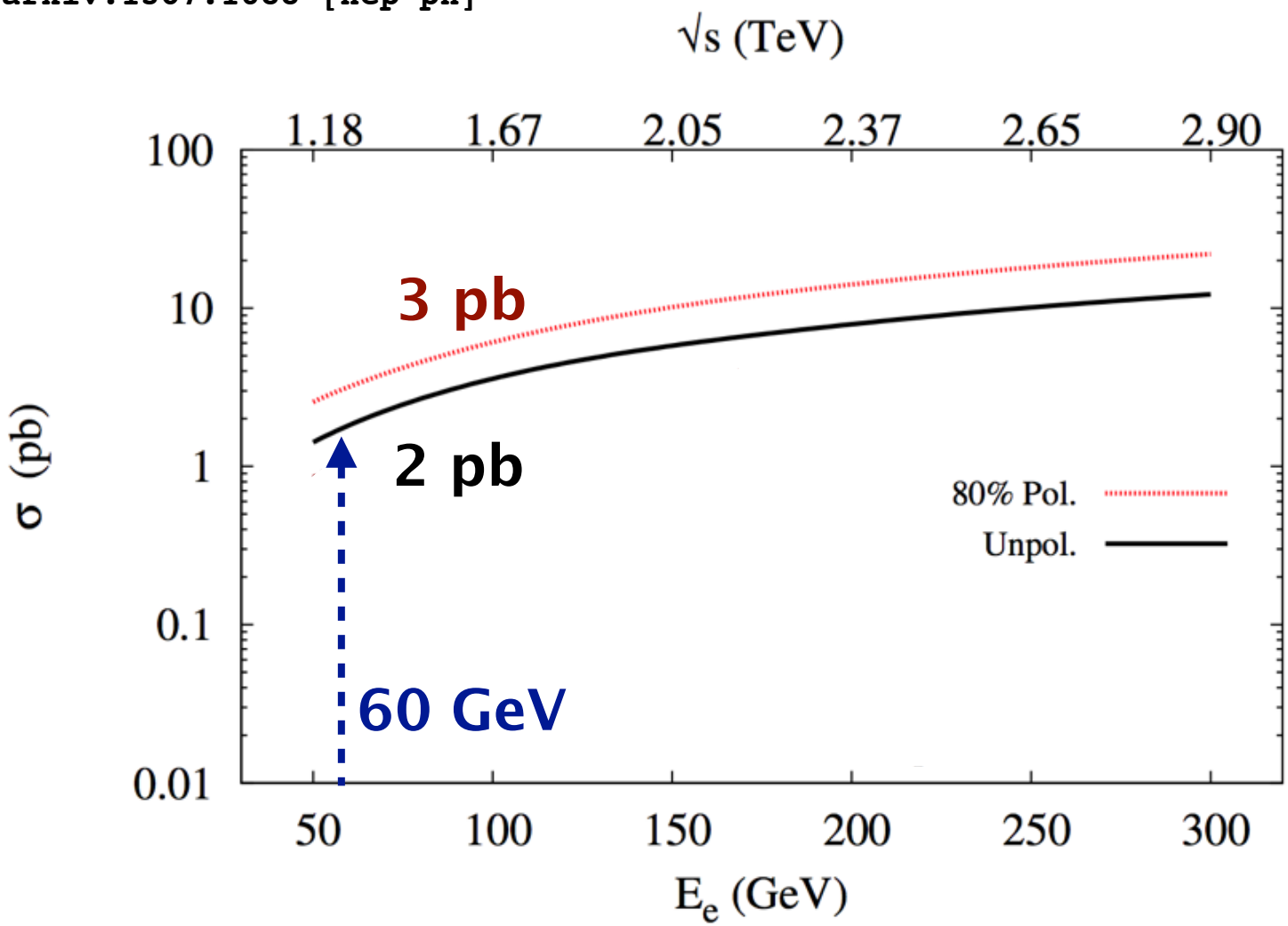


→ LHeC offers new field of research for top quark PDF

CC Single Top Quark Cross Section

Dutta, Goyal, Kumar, Mellado,
arXiv:1307.1688 [hep-ph]

100 fb^{-1}:
$2 \cdot 10^5$ events
$3 \cdot 10^5$ events

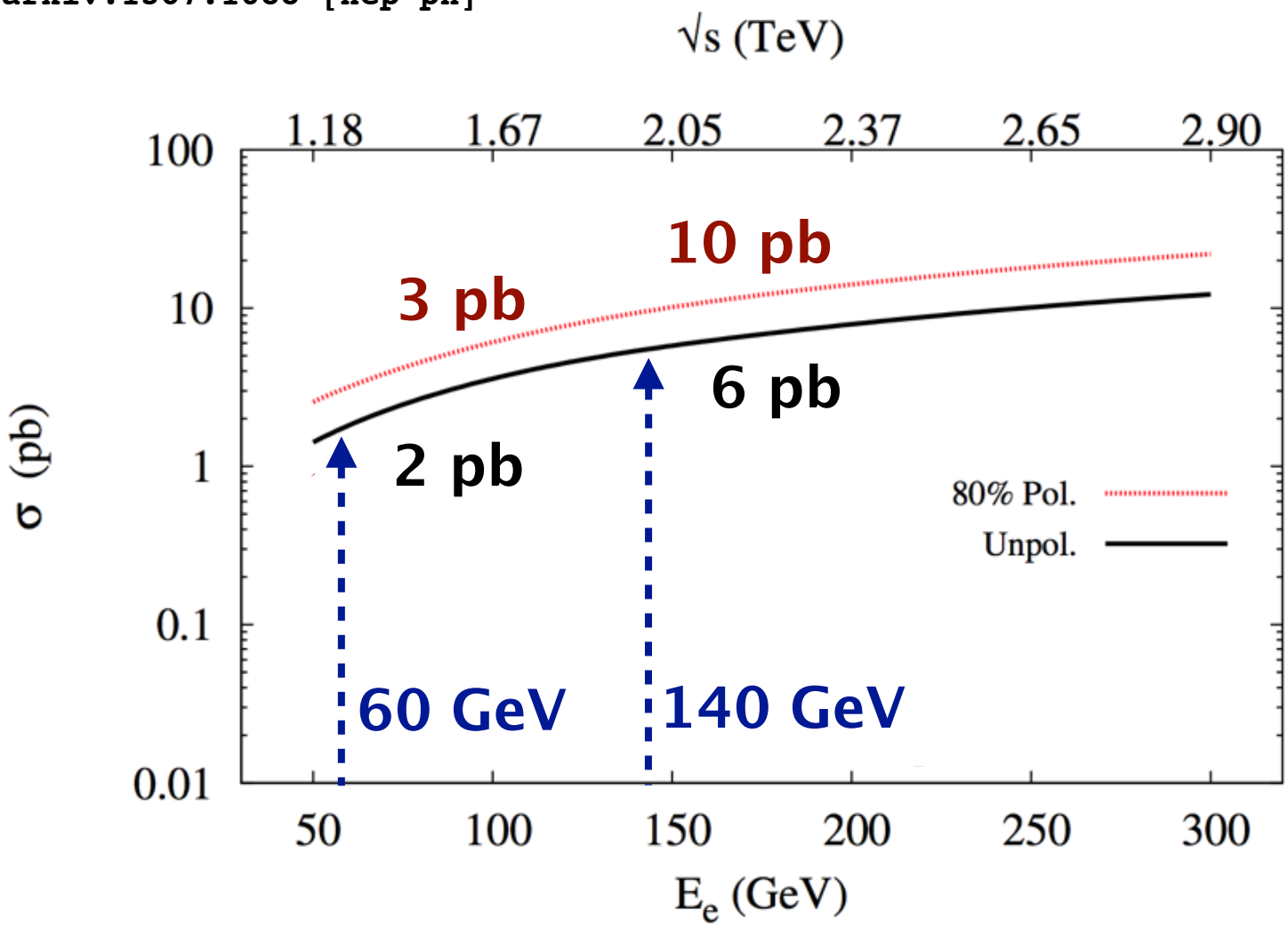


→ **LHeC offers excellent prospects for top quark physics**

CC Single Top Quark Cross Section

Dutta, Goyal, Kumar, Mellado,
arXiv:1307.1688 [hep-ph]

100 fb^{-1}:
2–6 · 10^5 events
3–10 · 10^5 events



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Dutta, Goyal, Kumar, Mellado,
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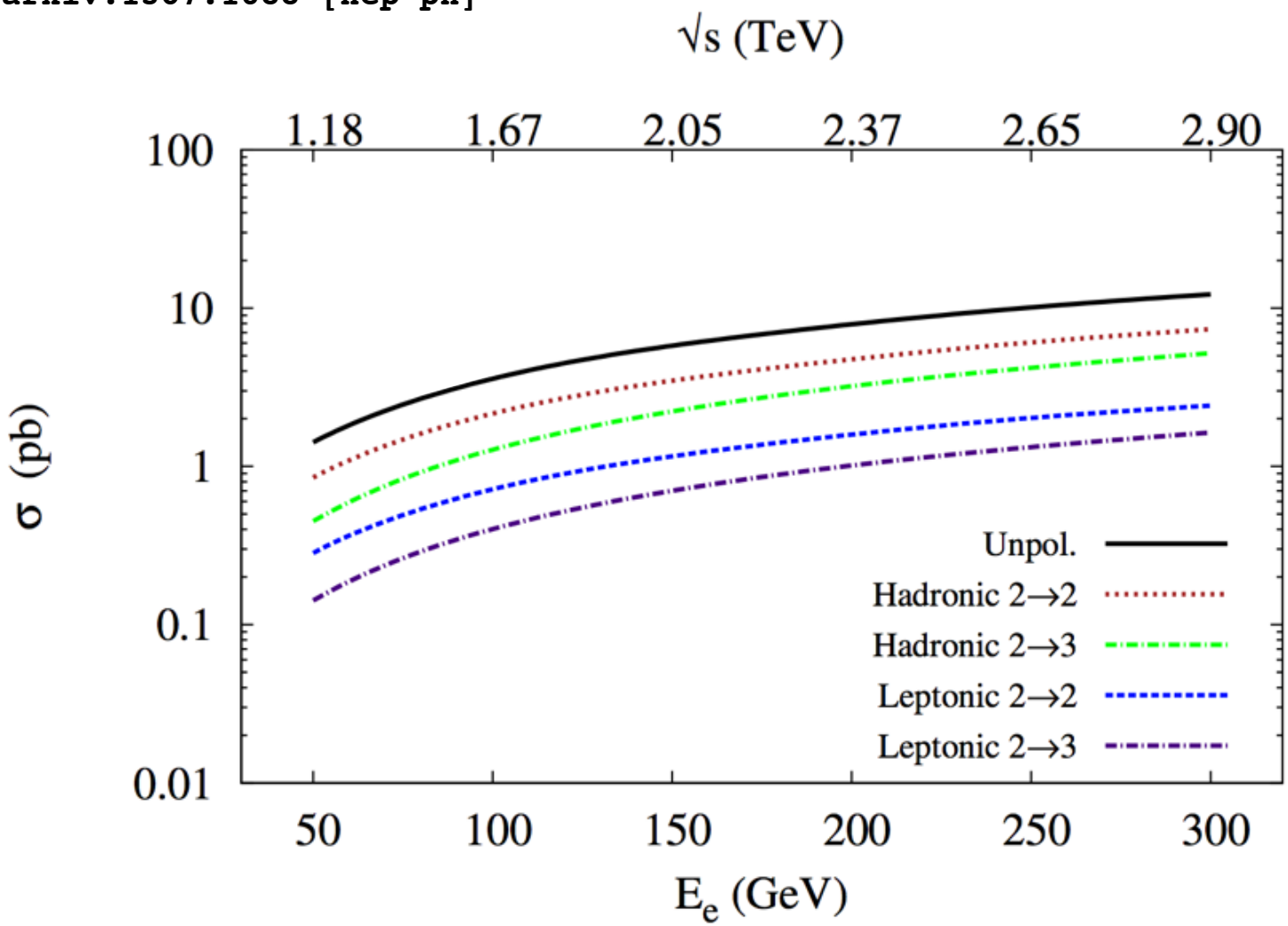

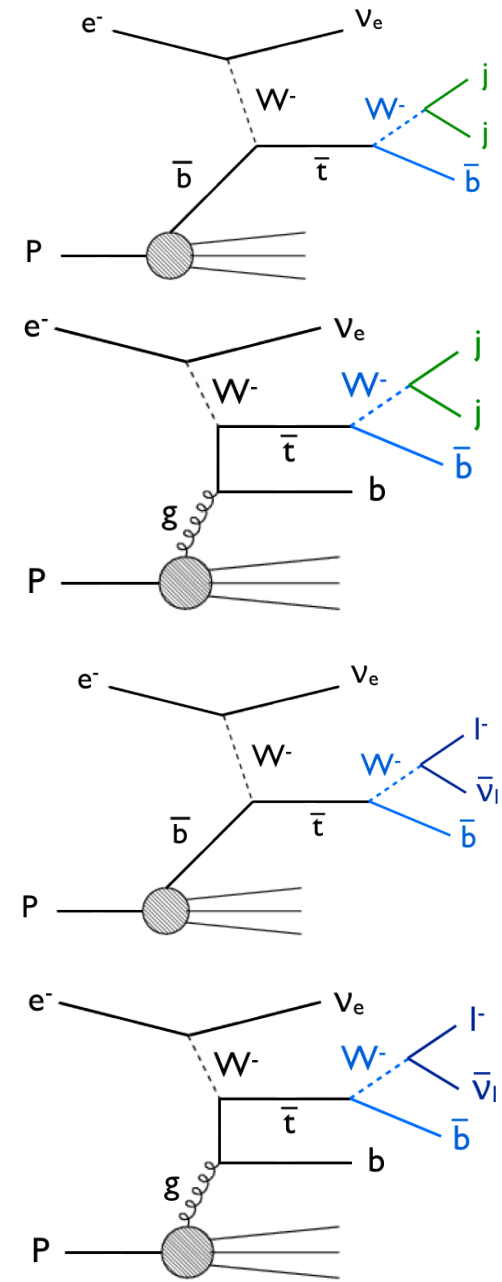

Backgrounds: Hadronic Channel

No.	Background Process	$p_{T\,j,b} \geq 20$ GeV $\lvert\eta_j\rvert \leq 5, \lvert\eta_b\rvert \leq 2.5$ $\Delta R_{j,b/j} \geq 0.4$ $\not{E}_T \geq 25$	$\Delta\Phi_{\not{E},j} \geq 0.4$ $\Delta\Phi_{\not{E},b} \geq 0.4$	$\lvert m_{j_1 j_2} - m_W\rvert \leq 22$ GeV	$\sigma_{\text{eff.}}$
1	$e^- p \to \nu_e W^- \bar{b}$ without anti-top line	7.5×10^{-3}	6.8×10^{-3}	4.5×10^{-3}	2.7×10^{-3}
2	$e^- p \to \nu_e jjj$	4.2×10^{0}	3.6×10^{0}	2.4×10^{0}	7.2×10^{-2}
3	$e^- p \to \nu_e cjj$ & $e^- p \to \nu_e \bar{c} jj$	1.5×10^{0}	1.2×10^{0}	8.6×10^{-1}	8.6×10^{-2}
4	$e^- p \to \nu_e c\bar{c} j$	5.8×10^{-2}	5.0×10^{-2}	3.2×10^{-2}	6.7×10^{-3}
5	$e^- p \to \nu_e b\bar{b} j$	2.5×10^{-2}	2.2×10^{-2}	5.6×10^{-3}	1.3×10^{-3}
6	$e^- p \to \bar{c}\nu_e$ $(\bar{c} \to W^- \bar{s})$	2.5×10^{-2}	2.2×10^{-2}	1.5×10^{-2}	1.5×10^{-4}

Event Selection	$p_{T\,j,b} \geq 20$ GeV $\lvert\eta_j\rvert \leq 5, \lvert\eta_b\rvert \leq 2.5$ $\Delta R_{j,b/j} \geq 0.4$ $\not{E}_T \geq 25$	$\Delta\Phi_{\not{E},j} \geq 0.4$ $\Delta\Phi_{\not{E},b} \geq 0.4$	$\lvert m_{j_1 j_2} - m_W\rvert \leq 22$ GeV	Fiducial Efficiency	$S/\sqrt{S+B}$
SM	3.2×10^4	2.3×10^4	2.2×10^4	66.7 %	–
SM+$\sum_i$ Bkg$_i$	6.5×10^4	5.0×10^4	4.0×10^4	61.5 %	
$\lvert V_{tb}\rvert\, \Delta f_1^L = .5$	7.3×10^4	5.0×10^4	5.0×10^4	68.0 %	1.92
$f_1^R = .5$	4.6×10^4	3.2×10^4	3.2×10^4	69.7 %	1.43
$f_2^L = .5$	4.9×10^4	3.6×10^4	3.6×10^4	73.2 %	1.55
$f_2^L = -.5$	3.4×10^4	2.3×10^4	2.3×10^4	69.6 %	1.40
$f_2^R = .5$	5.7×10^4	4.1×10^4	4.1×10^4	72.3 %	1.69

Backgrounds: Leptonic Channel

No.	Background Process	$p_{T\,j,b,l} \geq 20$ GeV, $\Delta R_{j,b/j} \geq 0.4$, $\not{E}_T \geq 25$ $\lvert\eta_j\rvert \geq 5$, $\lvert\eta_{b,l}\rvert \geq 2.5$	$\Delta\Phi_{\not{E},j} \geq 0.4$ $\Delta\Phi_{\not{E},b} \geq 0.4$ $\Delta\Phi_{\not{E},l} \geq 0.4$	$\sigma_{\text{eff.}}$
1	$e^-p \to l^-\bar{\nu}_l\nu_e j$	1.5×10^{-1}	1.4×10^{-1}	1.4×10^{-3}
2	$e^-p \to l^-\bar{\nu}_l\nu_e c$ & $e^-p \to l^-\bar{\nu}_l\nu_e \bar{c}$	6.6×10^{-3}	6.1×10^{-3}	6.1×10^{-4}
3	$e^-p \to l^-\bar{\nu}_l\nu_e b$ & $e^-p \to l^-\bar{\nu}_l\nu_e \bar{b}$ Without top line	3.6×10^{-3}	3.2×10^{-3}	1.9×10^{-3}
4	$e^-p \to e^-l^-\bar{\nu}_l c$	1.5×10^{-2}	6.9×10^{-3}	6.9×10^{-4}
5	$e^-p \to e^-l^-\bar{\nu}_l j$	1.2×10^{-1}	5.5×10^{-2}	5.5×10^{-4}

Event Selection	$p_{T\,j,b} \geq 20$ GeV $\lvert\eta_j\rvert \leq 5, \lvert\eta_b\rvert \leq 2.5$ $\Delta R_{j,b/j} \geq 0.4$ $\not{E}_T \geq 25$	$\Delta\Phi_{\not{E},j} \geq 0.4$ $\Delta\Phi_{\not{E},b} \geq 0.4$ $\Delta\Phi_{\not{E},l} \geq 0.4$	Fiducial Efficiency	$S/\sqrt{S+B}$
SM	1.2×10^4	1.1×10^4	92.0 %	–
SM+$\sum_i$ Bkg$_i$	1.3×10^4	1.2×10^4	92.0 %	–
$\lvert V_{tb}\rvert\,\Delta f_1^L = .5$	4.5×10^4	2.5×10^4	92.6 %	1.55
$f_1^R = .5$	2.8×10^4	1.6×10^4	94.1 %	1.23
$f_2^L = .5$	3.1×10^4	1.7×10^4	89.5 %	1.27
$f_2^L = -.5$	1.8×10^4	1.0×10^4	90.9 %	0.95
$f_2^R = .5$	3.6×10^4	2.0×10^4	90.9 %	1.38

Search for Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

= 1 in SM

Search for Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
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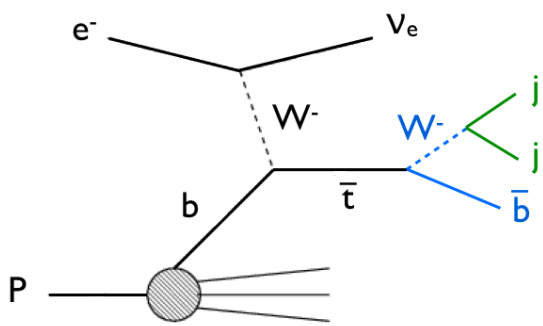
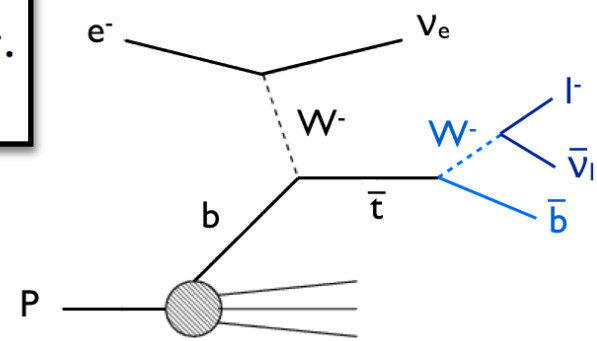
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

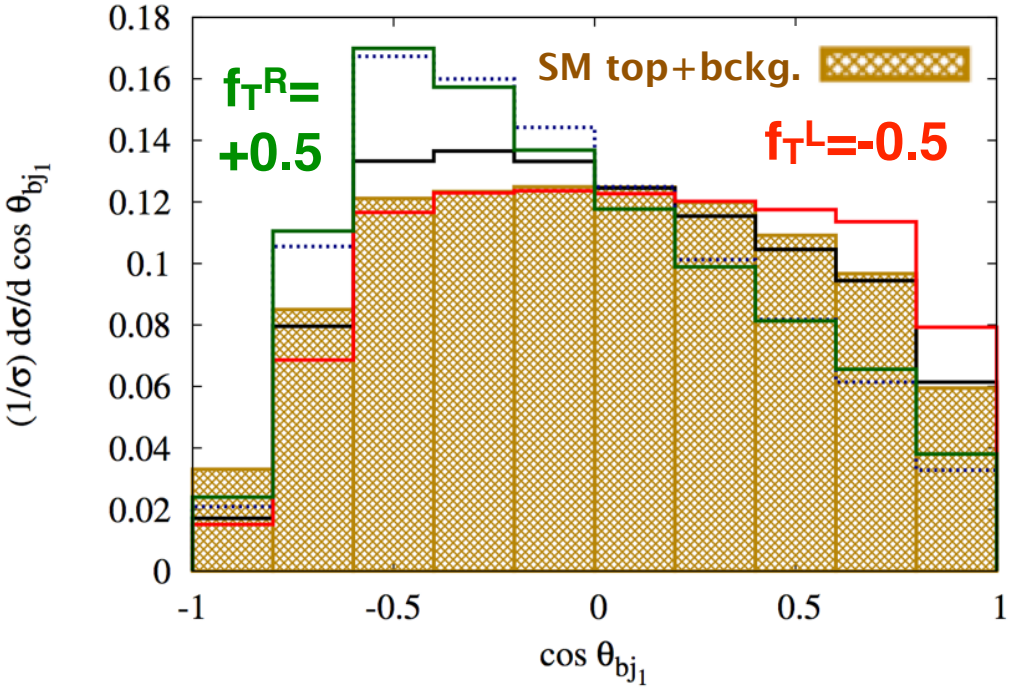
= 1 in SM

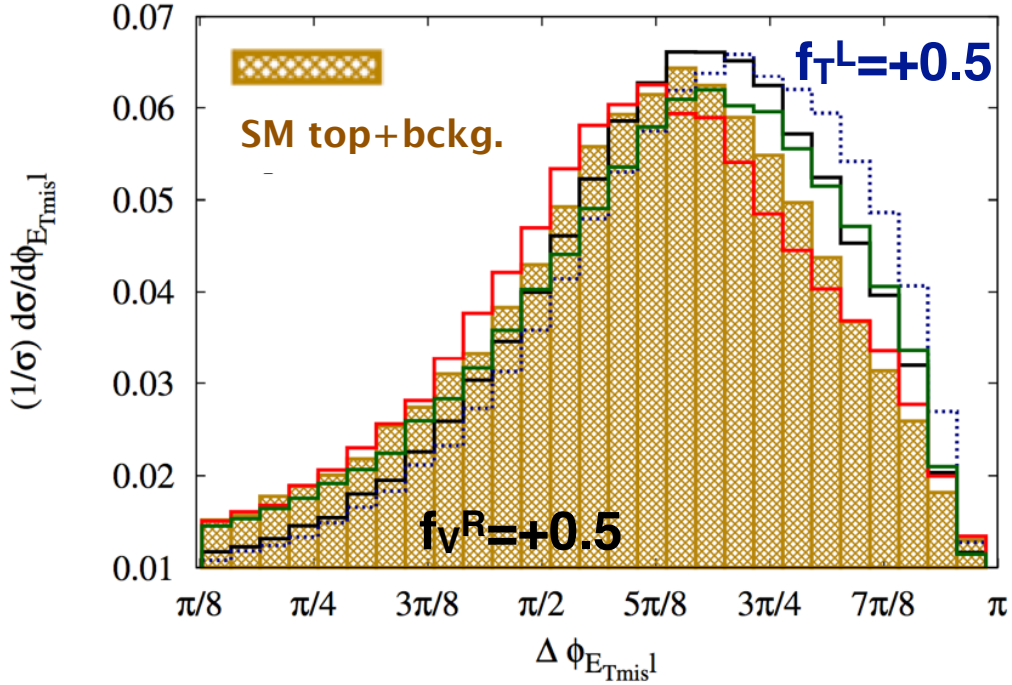
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688



$L_{int} = 100\ fb^{-1}$







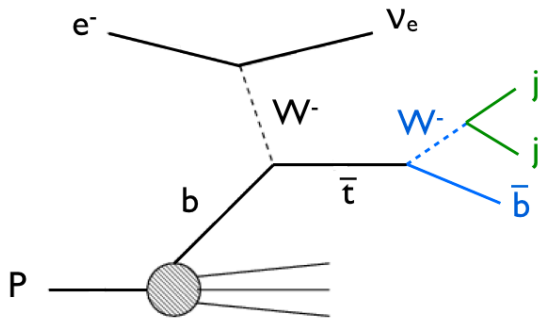
+ other variables sensitive on W helicity

Search for Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

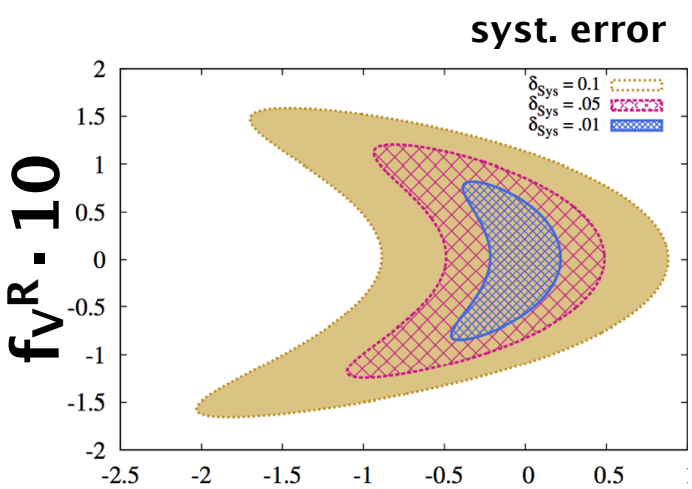
= 1 in SM

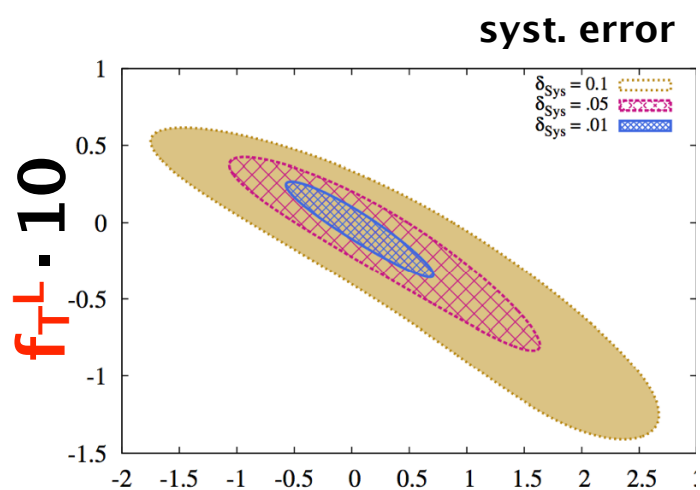
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688

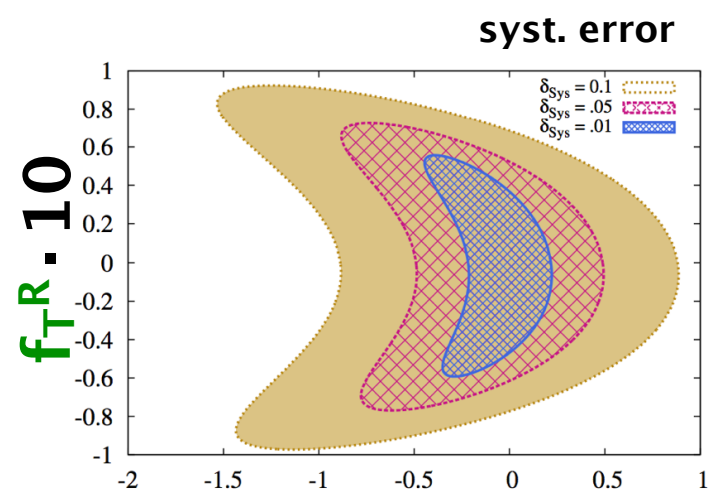


68% C.L.

property	precision
f_V^L	0.001–0.01
f_V^R, f_T^L, f_T^R	0.01–0.1





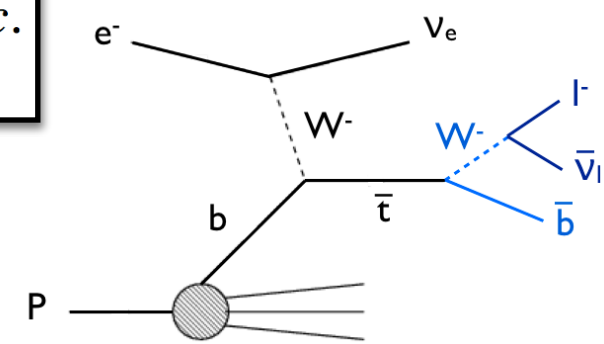


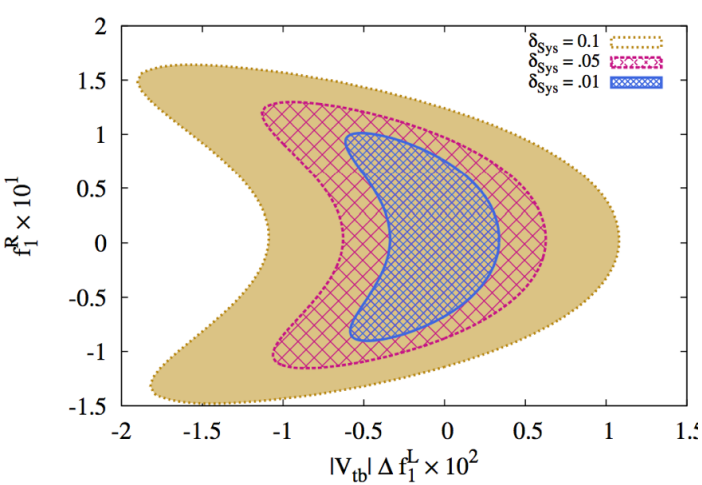
Search for Anomalous Wtb Couplings

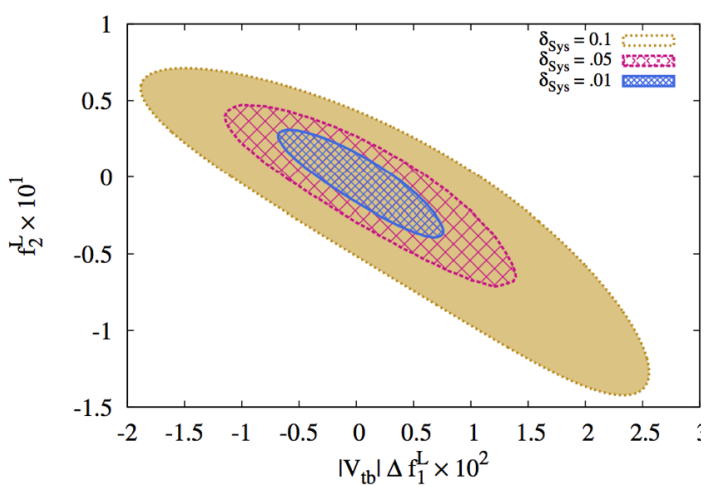
$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

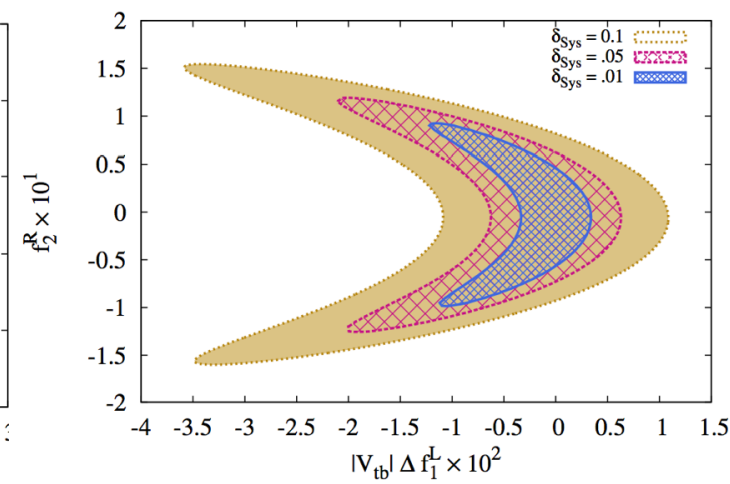
= 1 in SM

68% C.L.





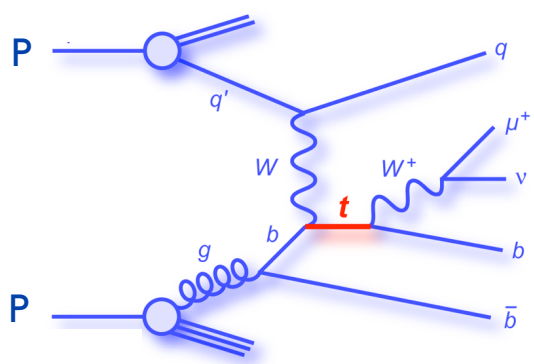


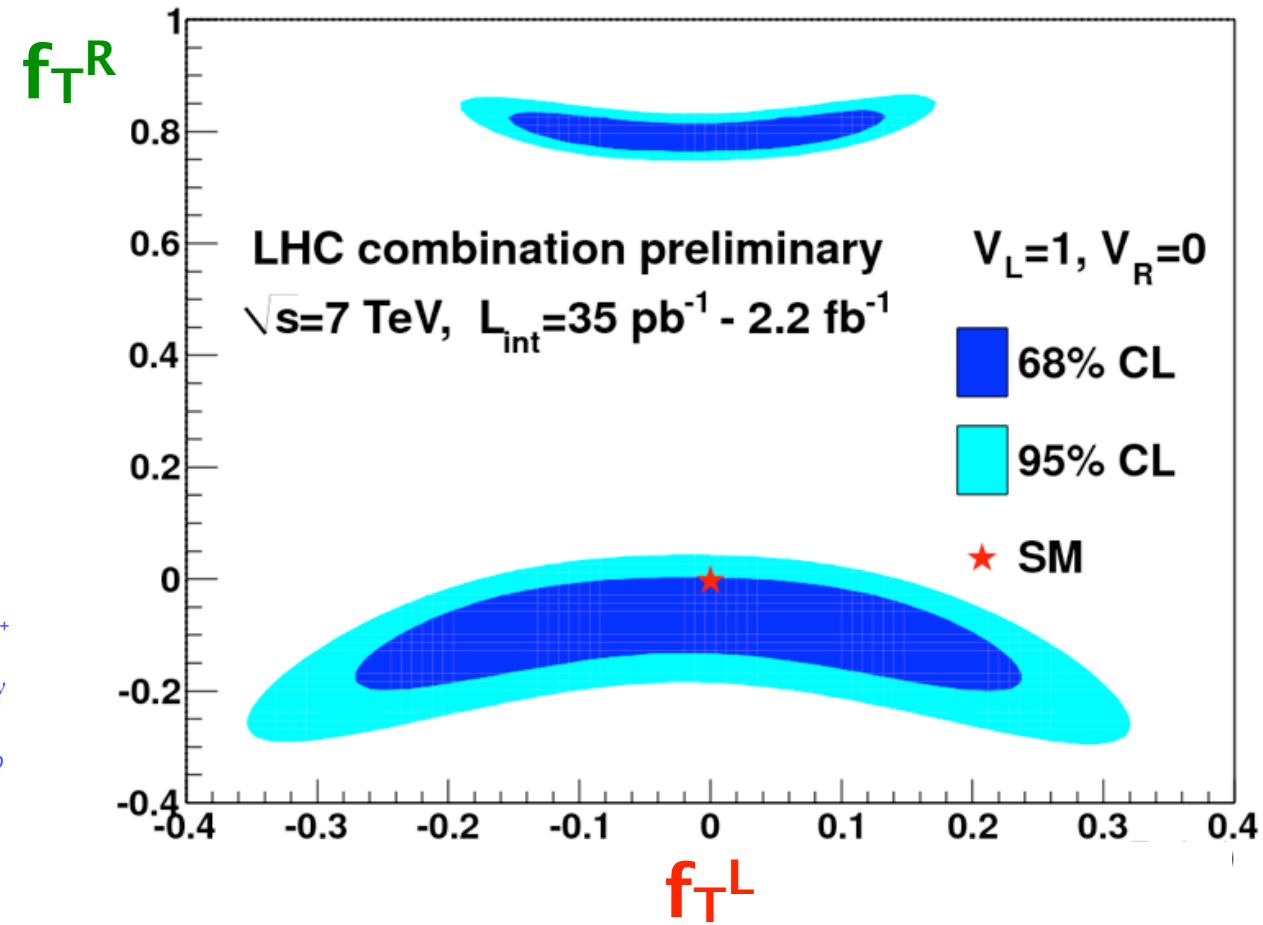


Search for Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

= 1 in SM

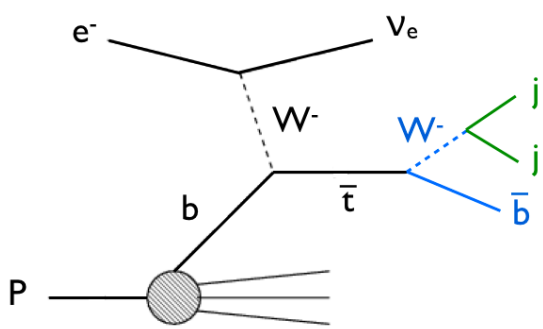


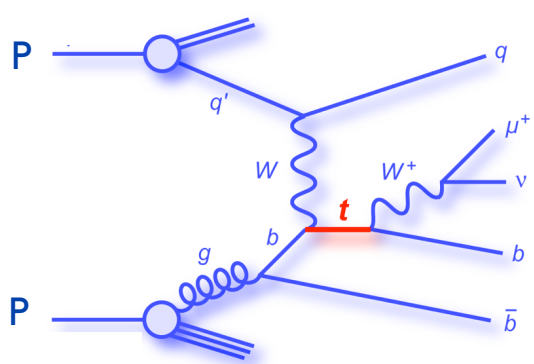


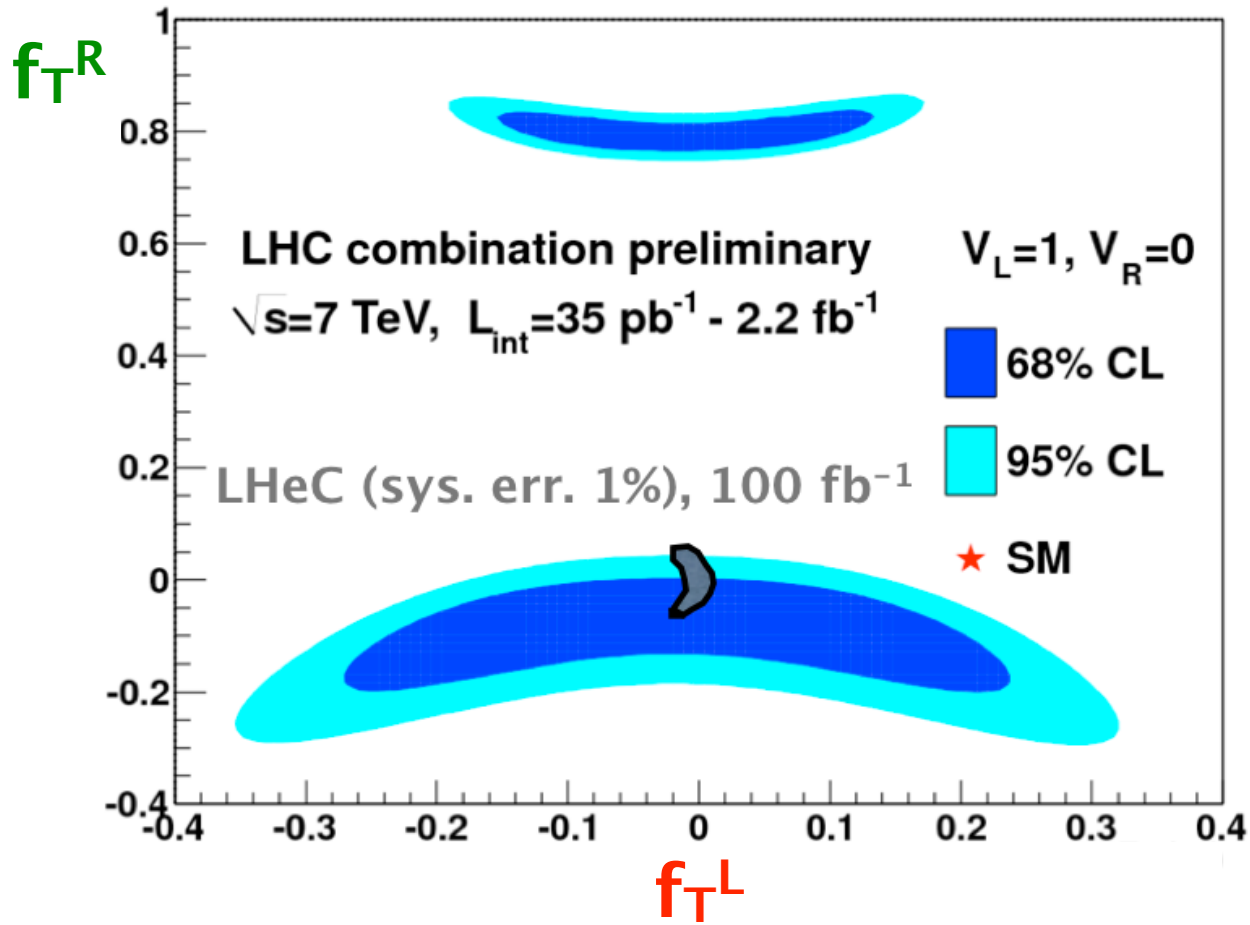
Search for Anomalous Wtb Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

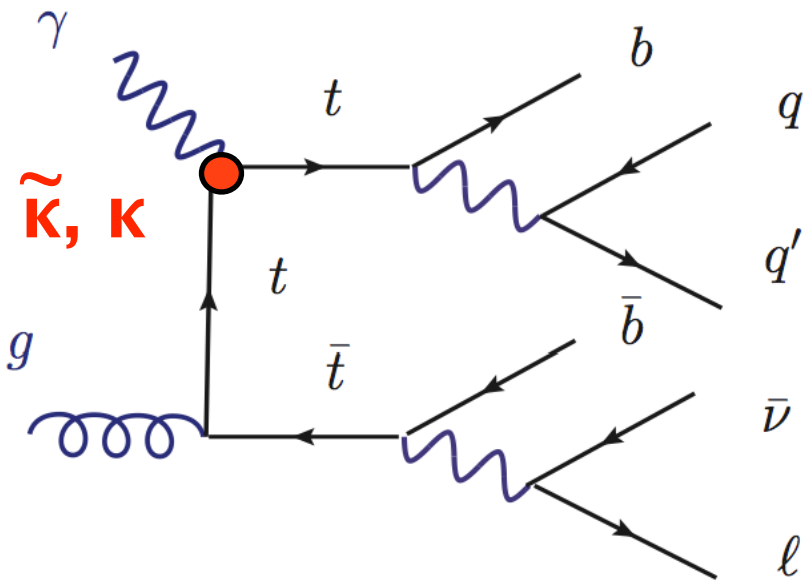
= 1 in SM





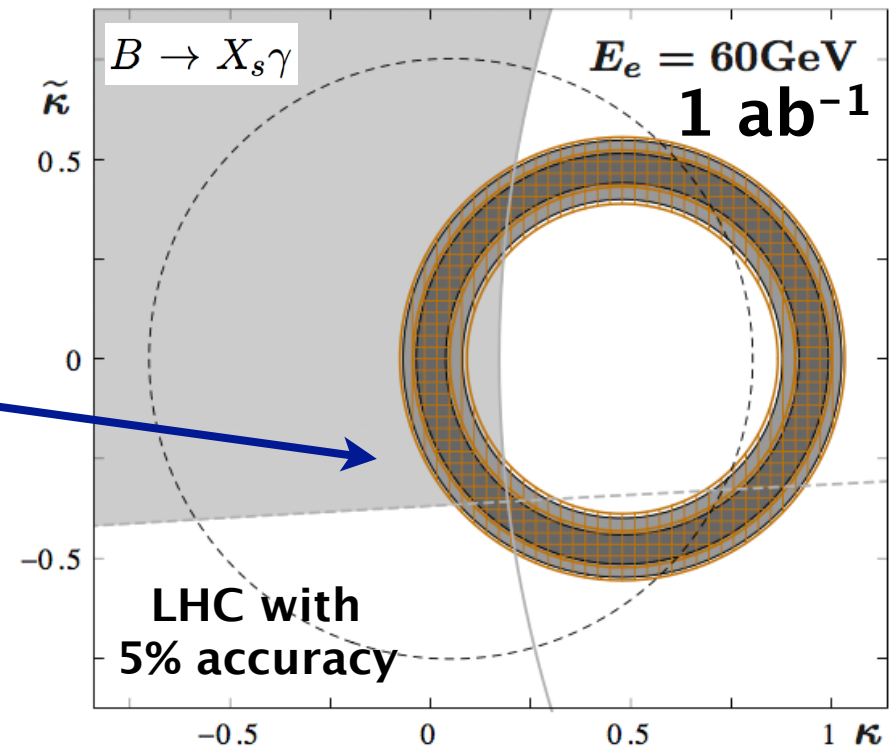


Search for Anomalous $t\bar{t}\gamma$ Couplings



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

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



magnetic dipole moment: κ

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

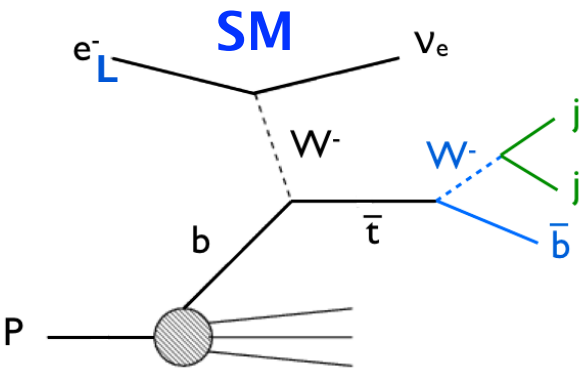
27% accuracy
(4.59fb^{-1}, 7 TeV)

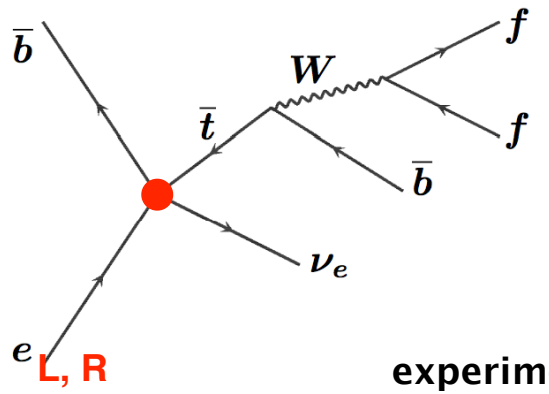
Bouzas, Larios,
Physical Review D 88, 094007 (2013)

Top Quark Dimension 6 Operators

$$\Lambda^2 \mathcal{L}_{4f} = C_1(\bar{\nu}_L \gamma^\mu t_L \bar{b}_L \gamma_\mu e_L + h.c.) + [C_2 \bar{\nu}_L e_R \bar{b}_R t_L + C_3 \bar{b}_L e_R \bar{\nu}_L t_R + C_4 \bar{\nu}_L e_R \bar{b}_L t_R + h.c.]$$

Λ=1TeV





property	precision
C_1	0.50–0.85
C_2^r	2.2–5.0
C_3^r	1.4–2.9
C_4^r	2.2–4.9

Sarmiento-Alvarado, Bouzas, Larios, arXiv:1412.6679

experimental error

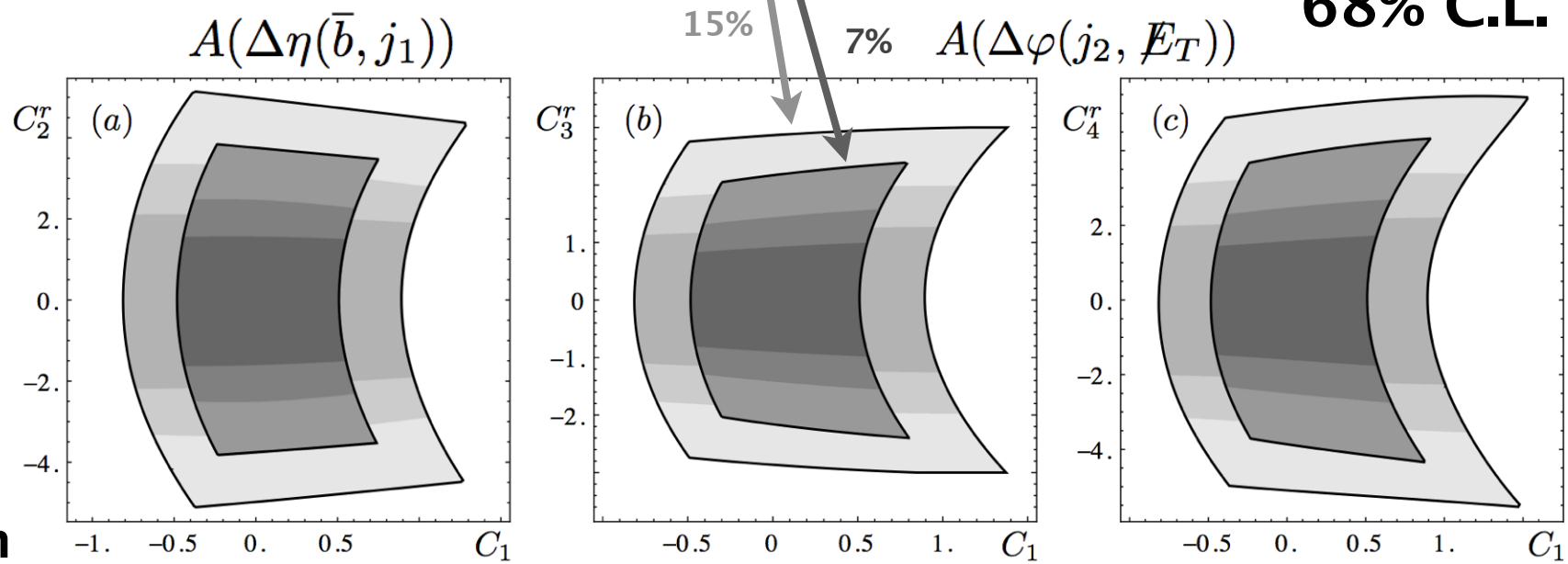
15% 7%

68% C.L.

$\mathcal{P}_e = 0$

$\mathcal{P}_e = 0.4$

$\mathcal{P}_e = 0.7$



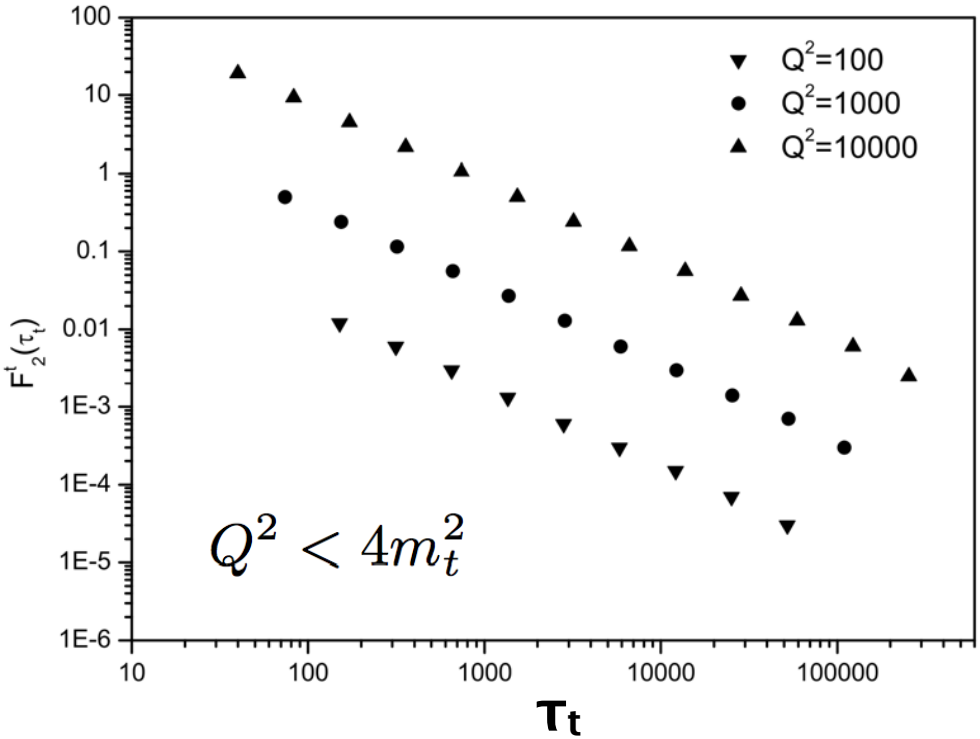
cross section

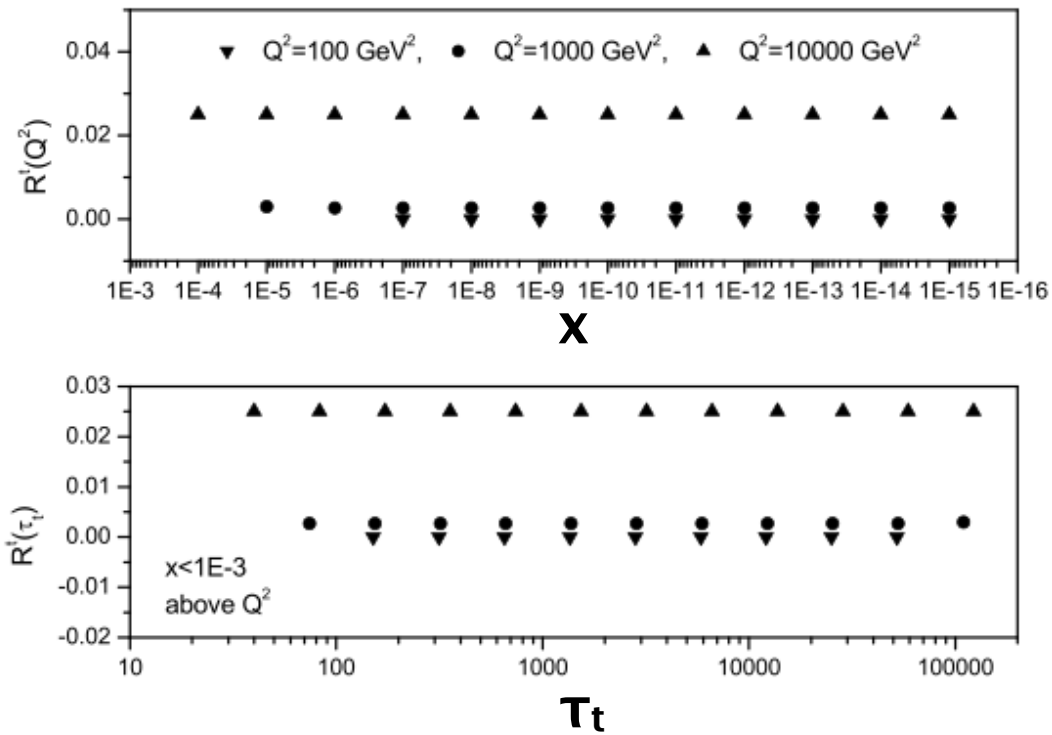
Top Quark Structure Function

Boroun, Phys. Lett. B744, 142 (2015)

$$\tilde{\sigma}^{t\bar{t}}(\tau_t) \rightarrow F_2^t(\tau_t)[1 - R^t(\tau_t)]$$

variable flavour number scheme for top quark



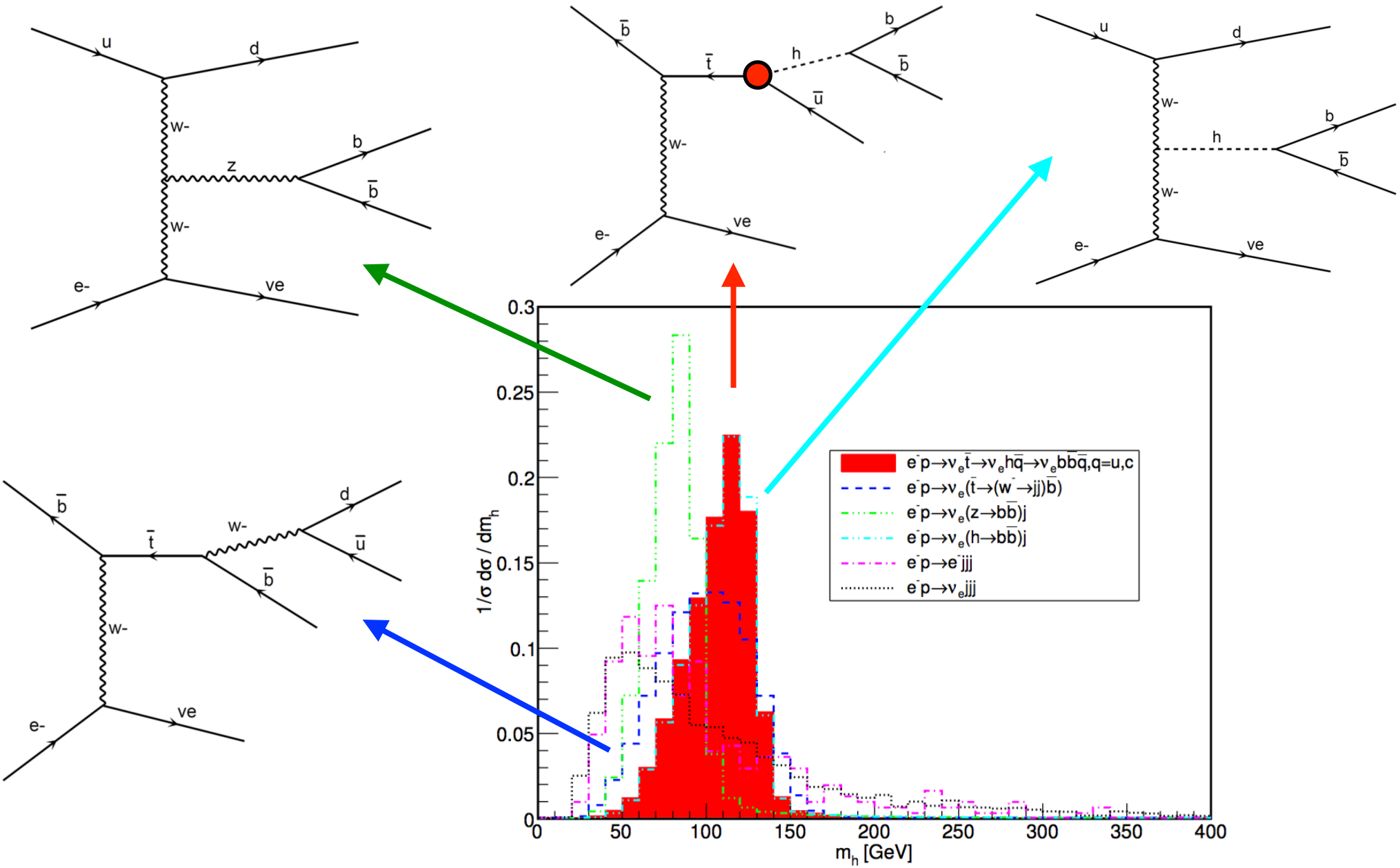


→ approximately: $1/\tau_t$

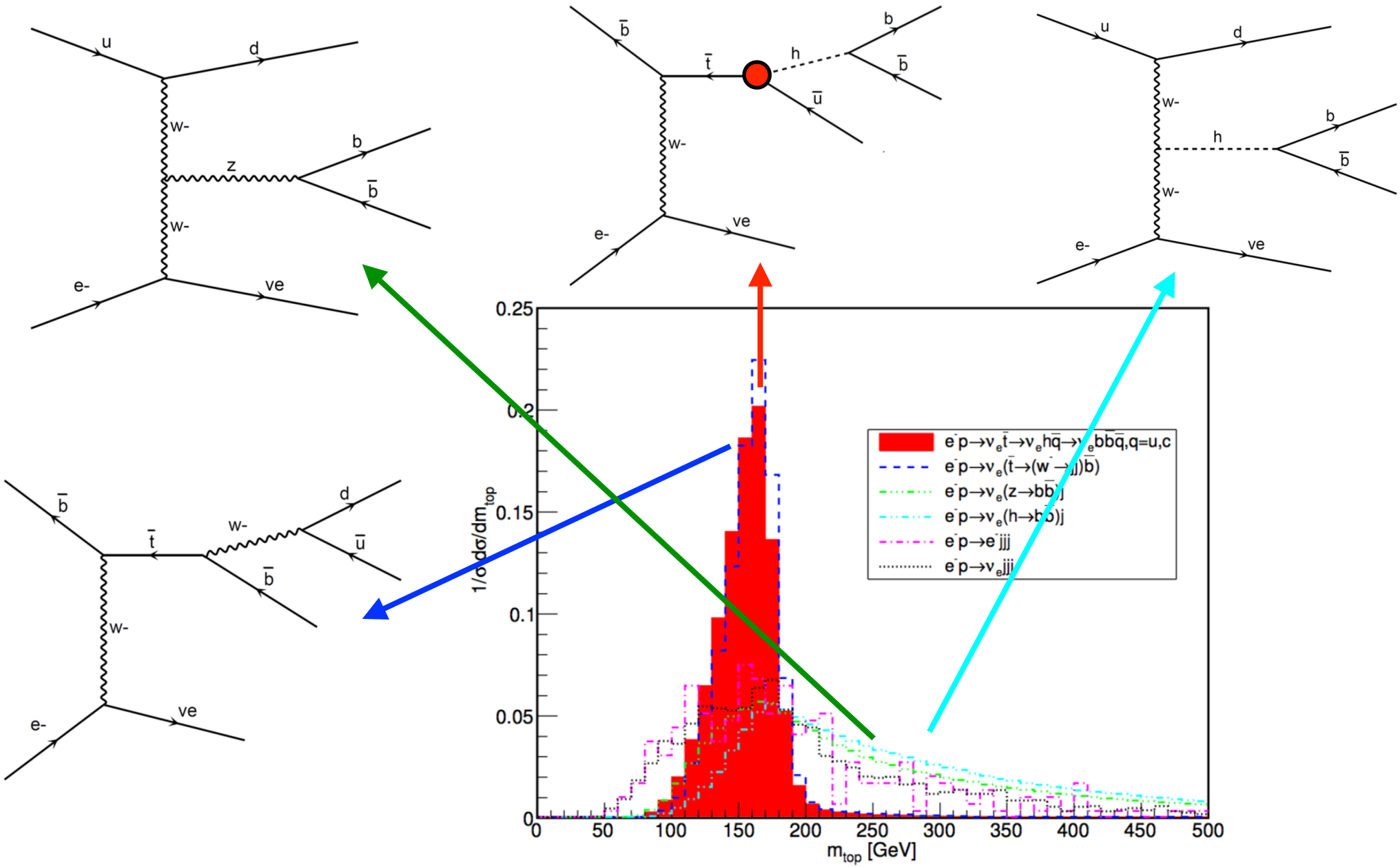
→ independent of x and τ_t

→ longitudinal top structure function component could be good to probe top quark density in proton at $Q^2 \simeq 4m_t^2$

Reconstructed Higgs mass



Reconstructed top quark mass



Searches for RPV SUSY and stops

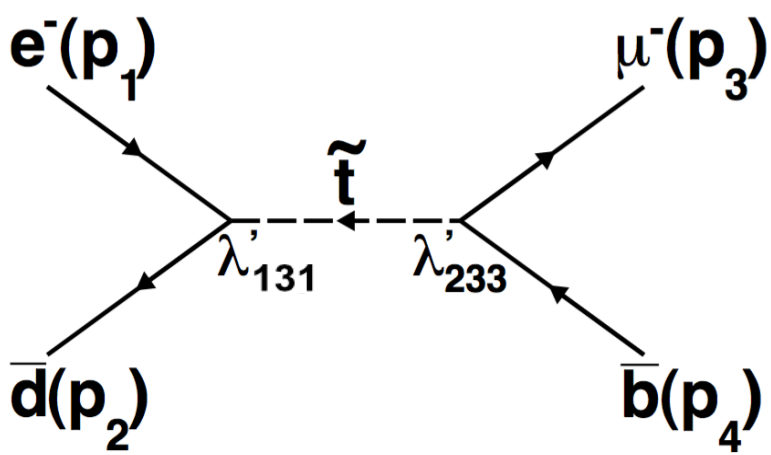
L-number violating terms

$$W_{\not{R}p} = \lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u + \lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k$$

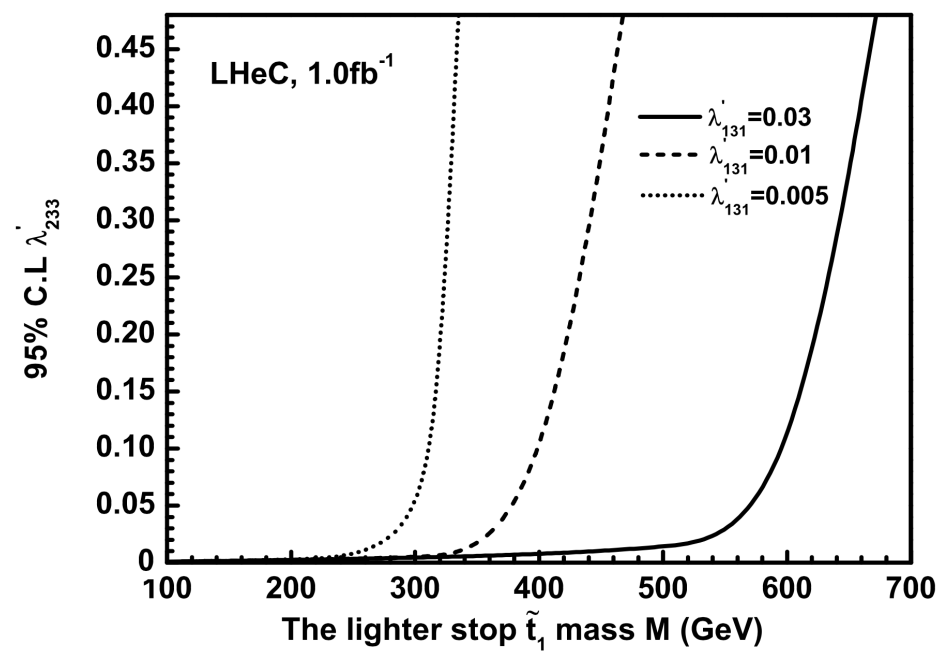
bilinear terms

B-number violating terms

ΔL =1, 9 λ couplings, 27 λ' couplings



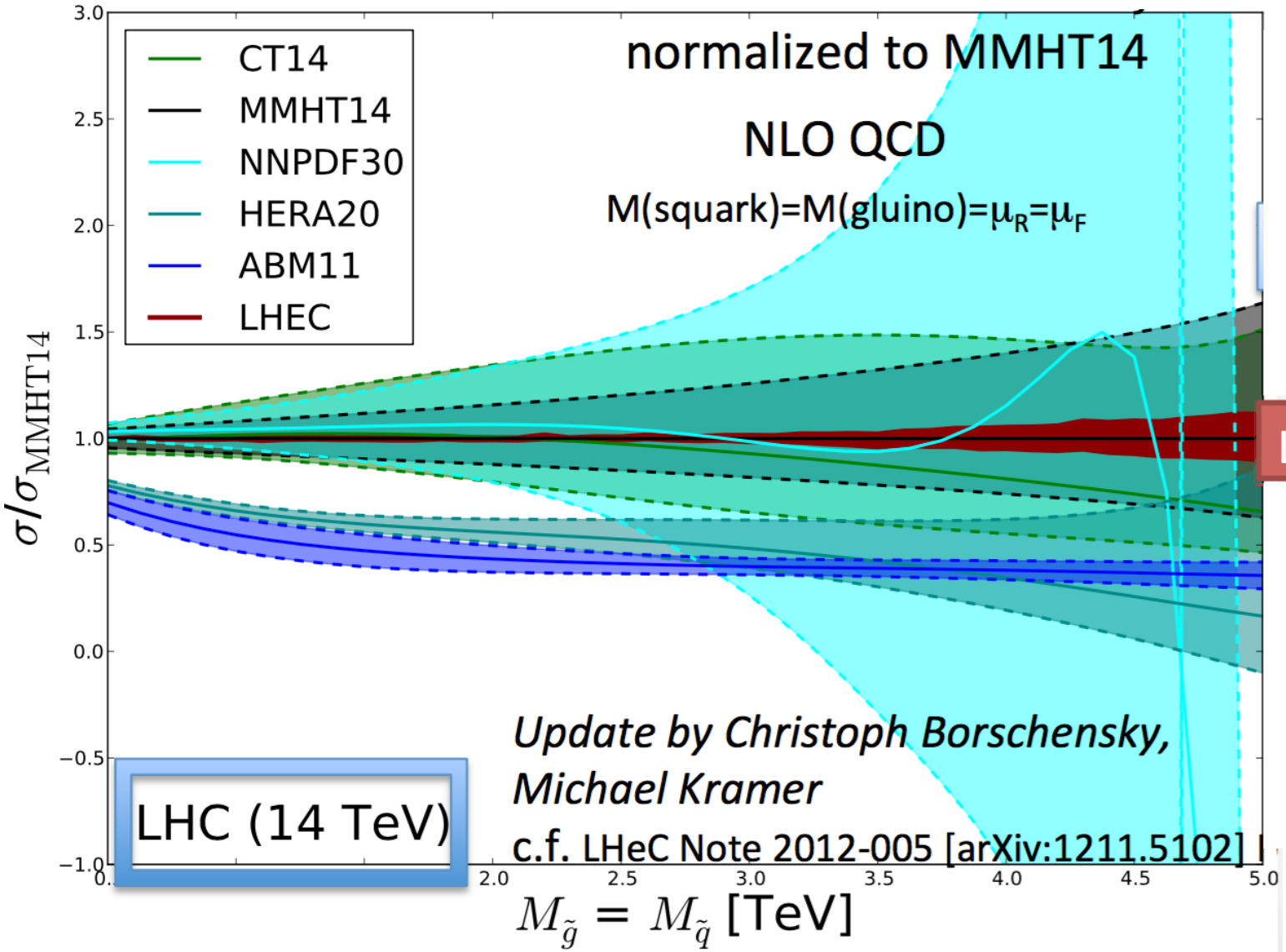
similar to leptoquark searches with generation mixing

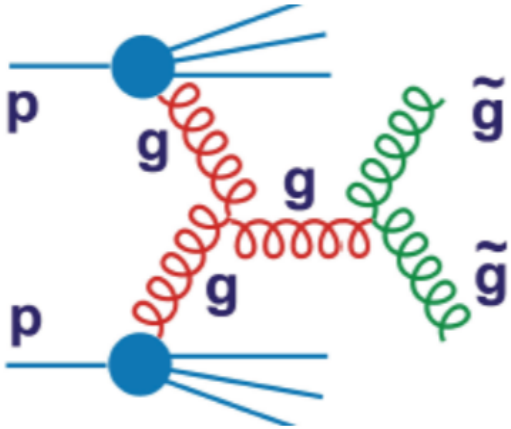


→ very promising with high luminosity

→ **RPV can be probed at unprecedented levels**

Gluino pair production PDF uncertainty





→ **improves sensitivity for HL-LHC**