Highlights in Top Physics

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MANCHESTER 1824

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LHeC Physics Meeting
CERN
4 November 2014

Outline

Introduction
Charged Current
Neutral Current
Summary

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Neutral Current

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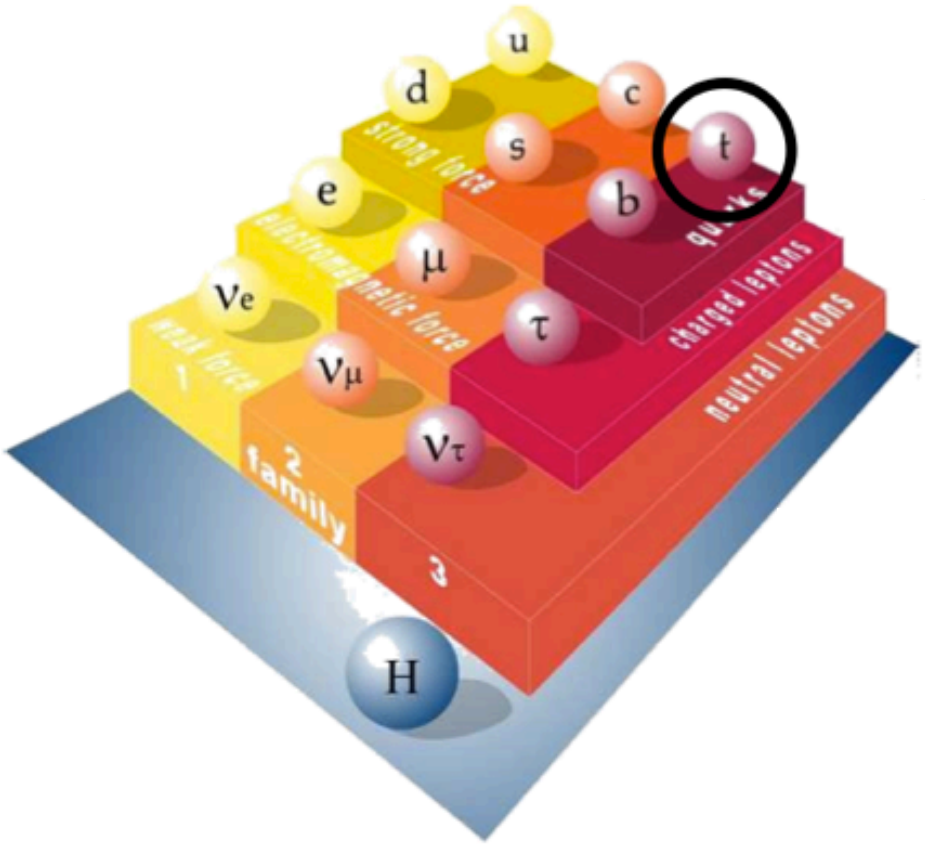
The Top Quark



is the top quark the particle as predicted in the SM?

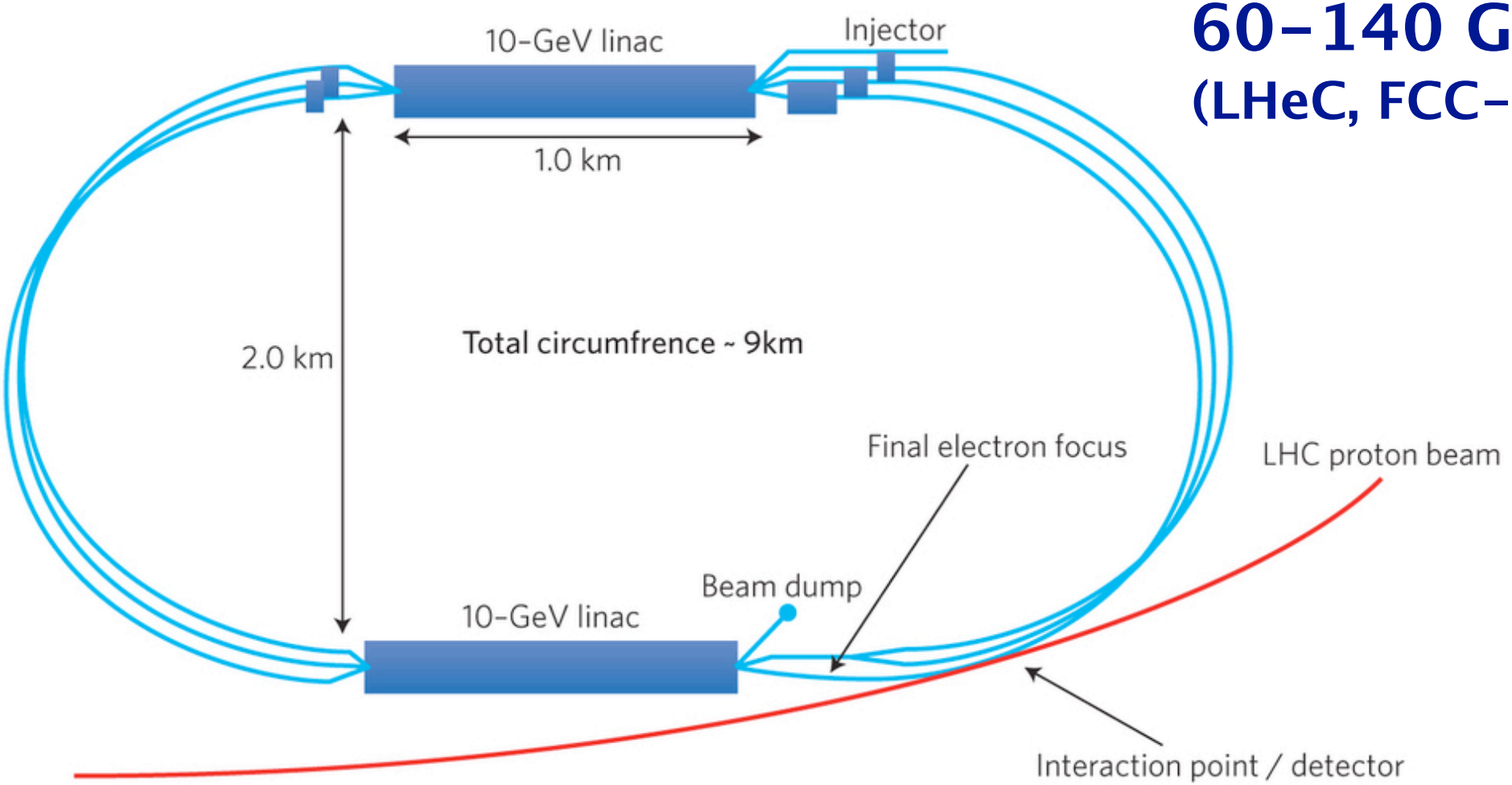
- **EWK interactions of top quarks**
- **top quark properties**
- **search for new physics**

→ **ep collider excellent to explore top quark**

LHeC, Linac-Ring Collider

Energy Recovering Linac

$e^{\pm}$ beam:
60-140 GeV
(LHeC, FCC-HE)



L_{int} = 10, 20, 100 fb^{-1}

p beam: 7 TeV

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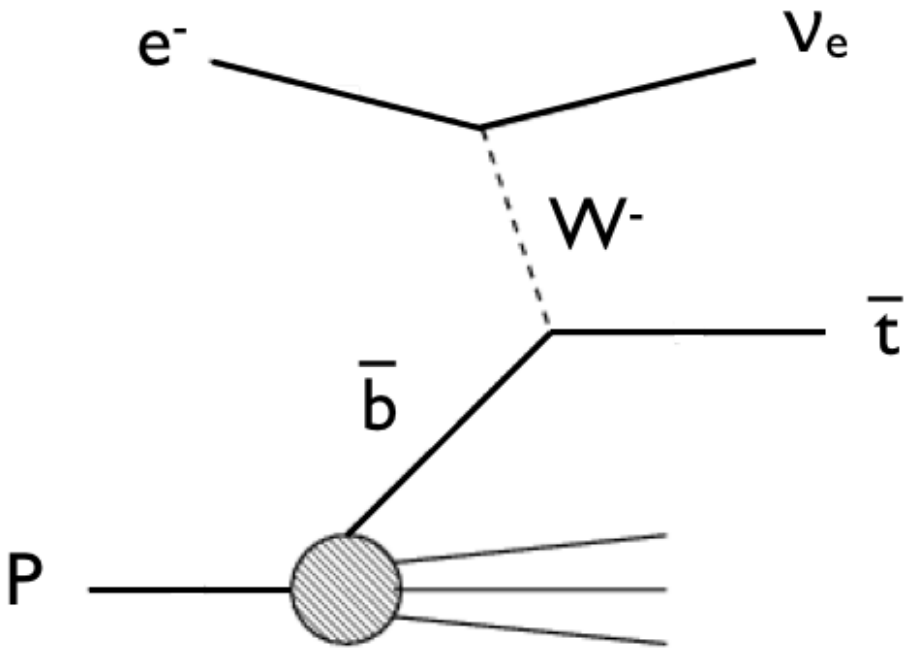
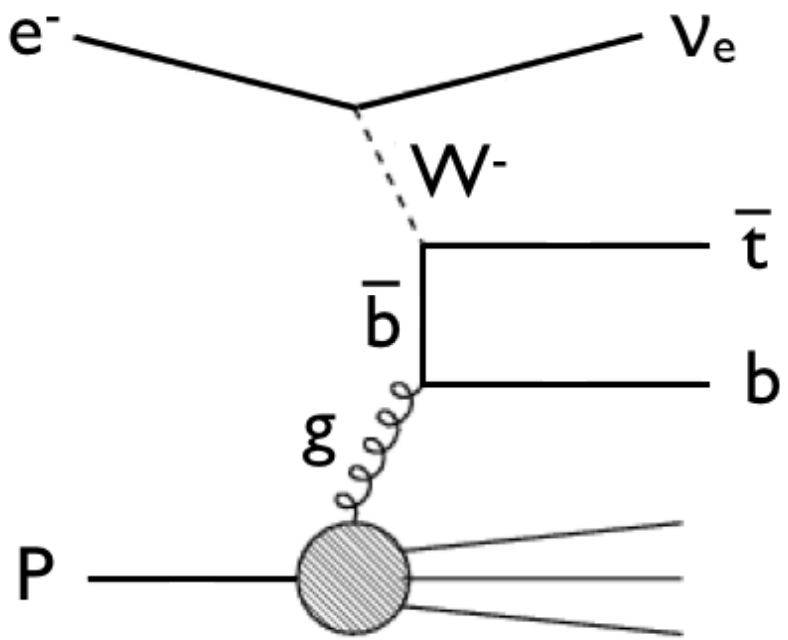
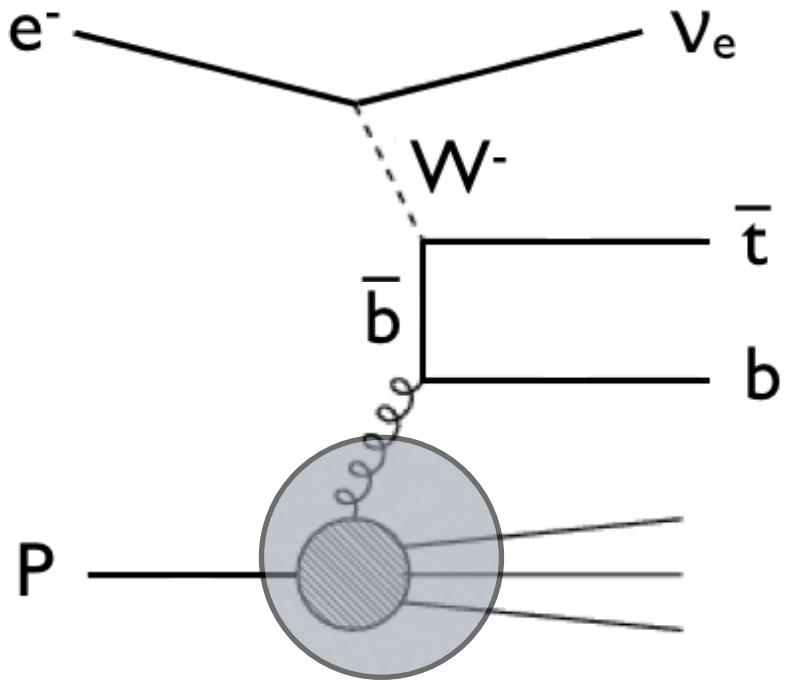
CC Single Top Quark Production





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

Gluon Parton Density Function

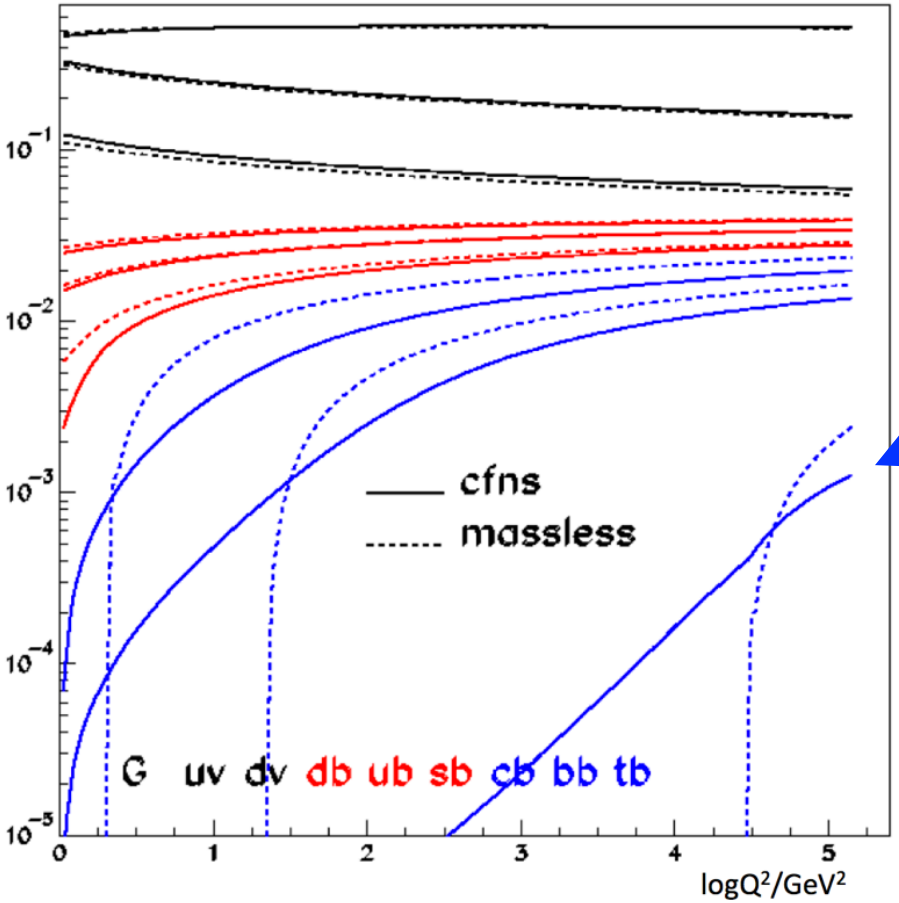


→ **measure gluon density at high x**

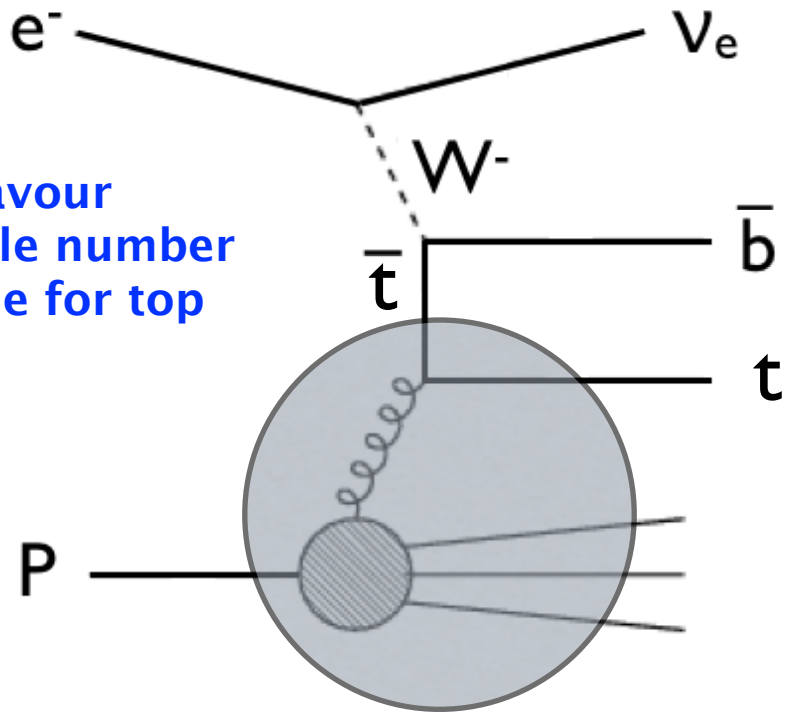
Top Quark Parton Density Function

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

parton momentum fraction



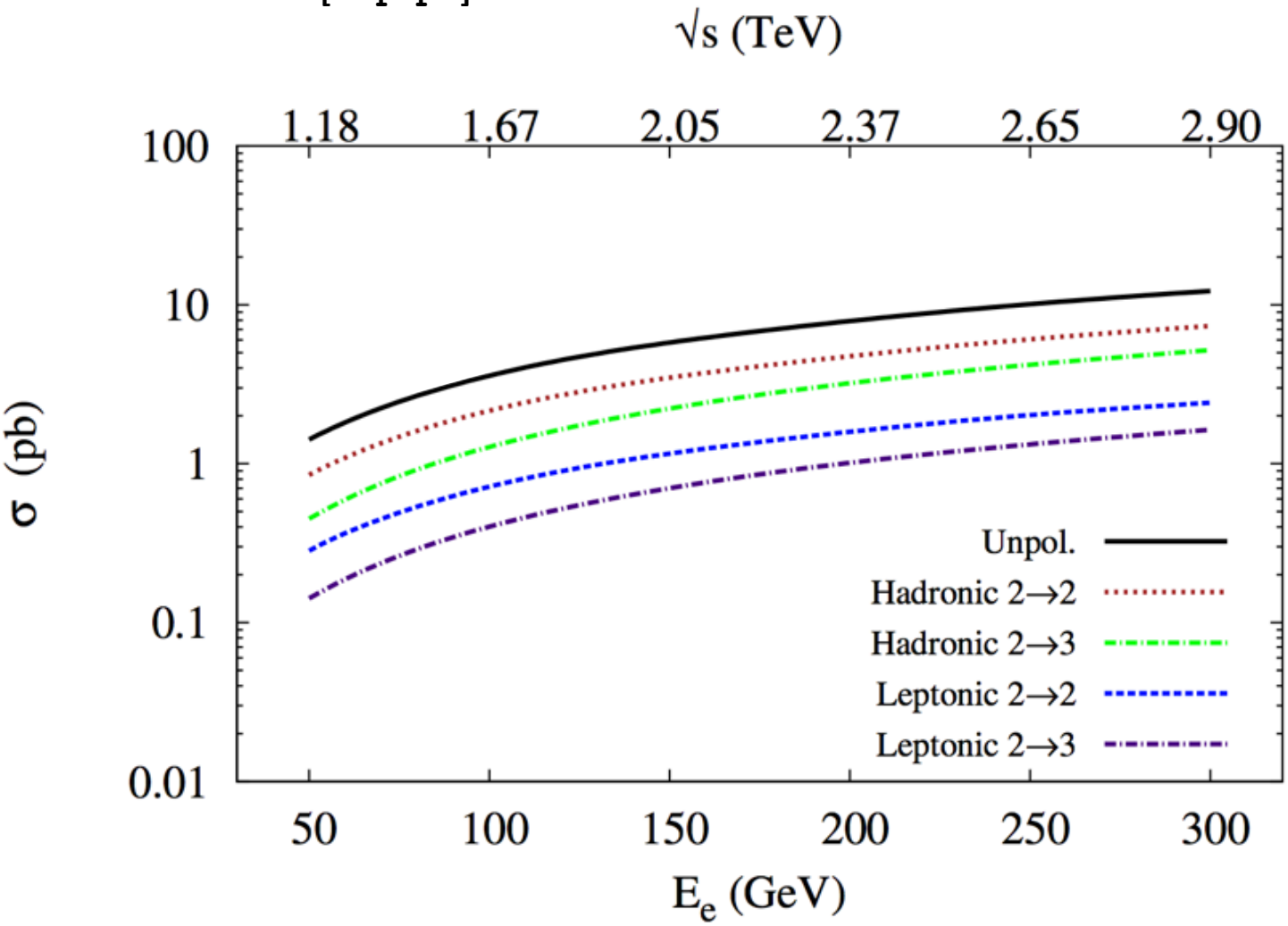
six-flavour variable number scheme for top quark

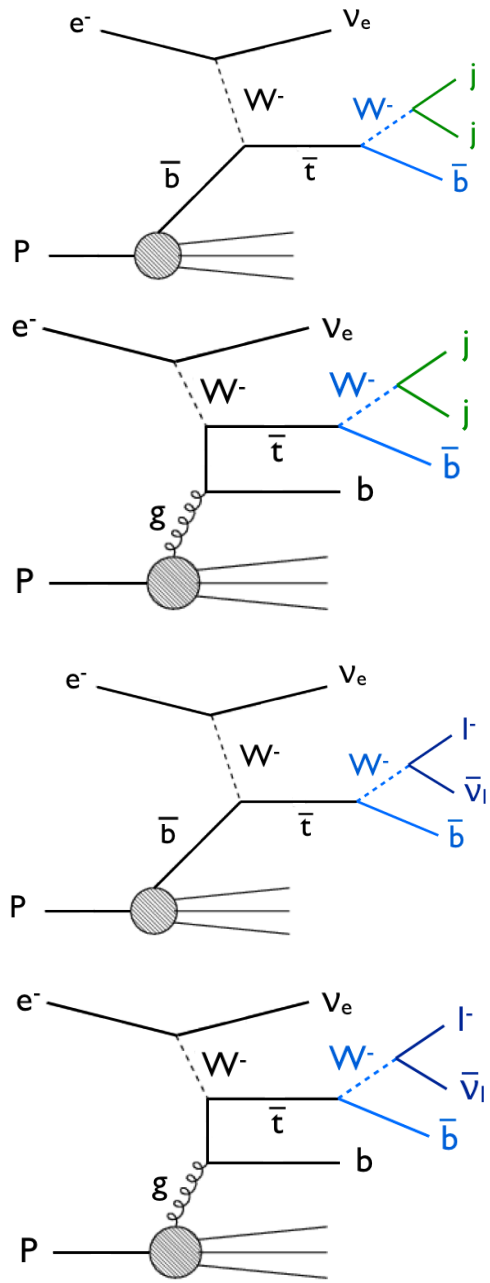


→ LHeC offers new field of research for top quark PDF

CC Single Top Quark Cross Section

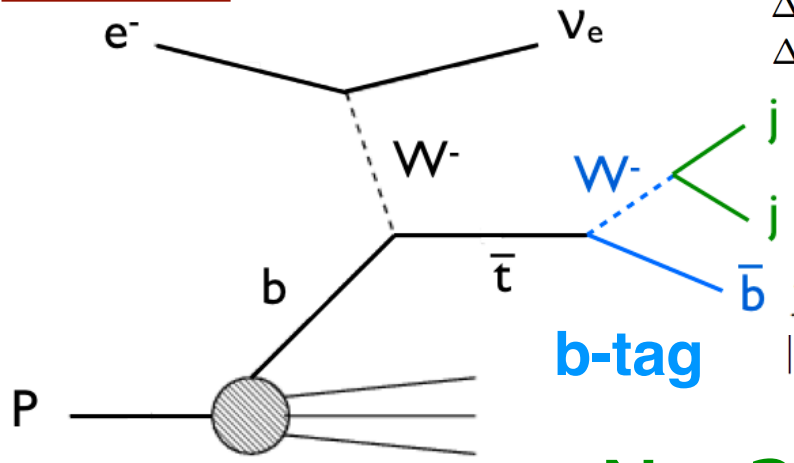
Dutta, Goyal, Kumar, Mellado,
arXiv:1307.1688 [hep-ph]





Signal and Backgrounds

signal



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

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

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

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

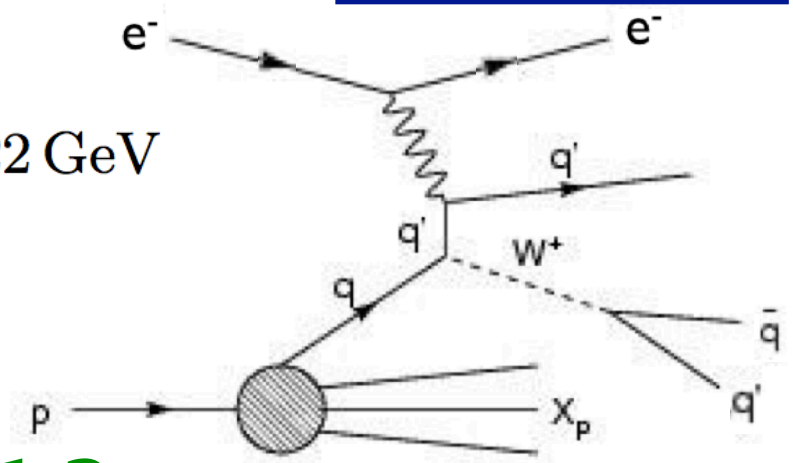
$p_{T\,j,b} \geq 20\ \text{GeV}$

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

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

b-tag

background



N_t=22000, s/b=1.2

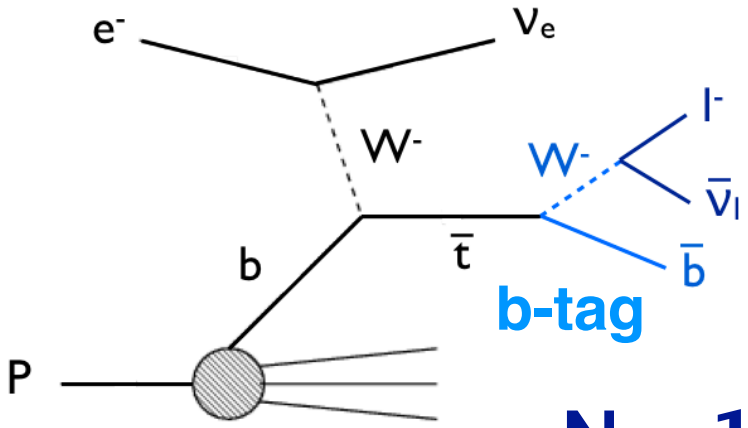
e beam: 60 GeV
100 fb^{-1}

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

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

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

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

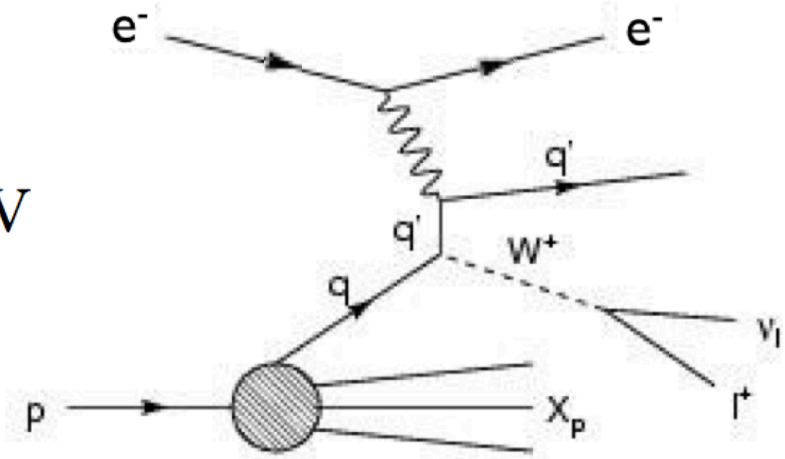


$p_{T\,j,b,l} \geq 20\ \text{GeV}$

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

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

b-tag



N_t=11000, s/b=11

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

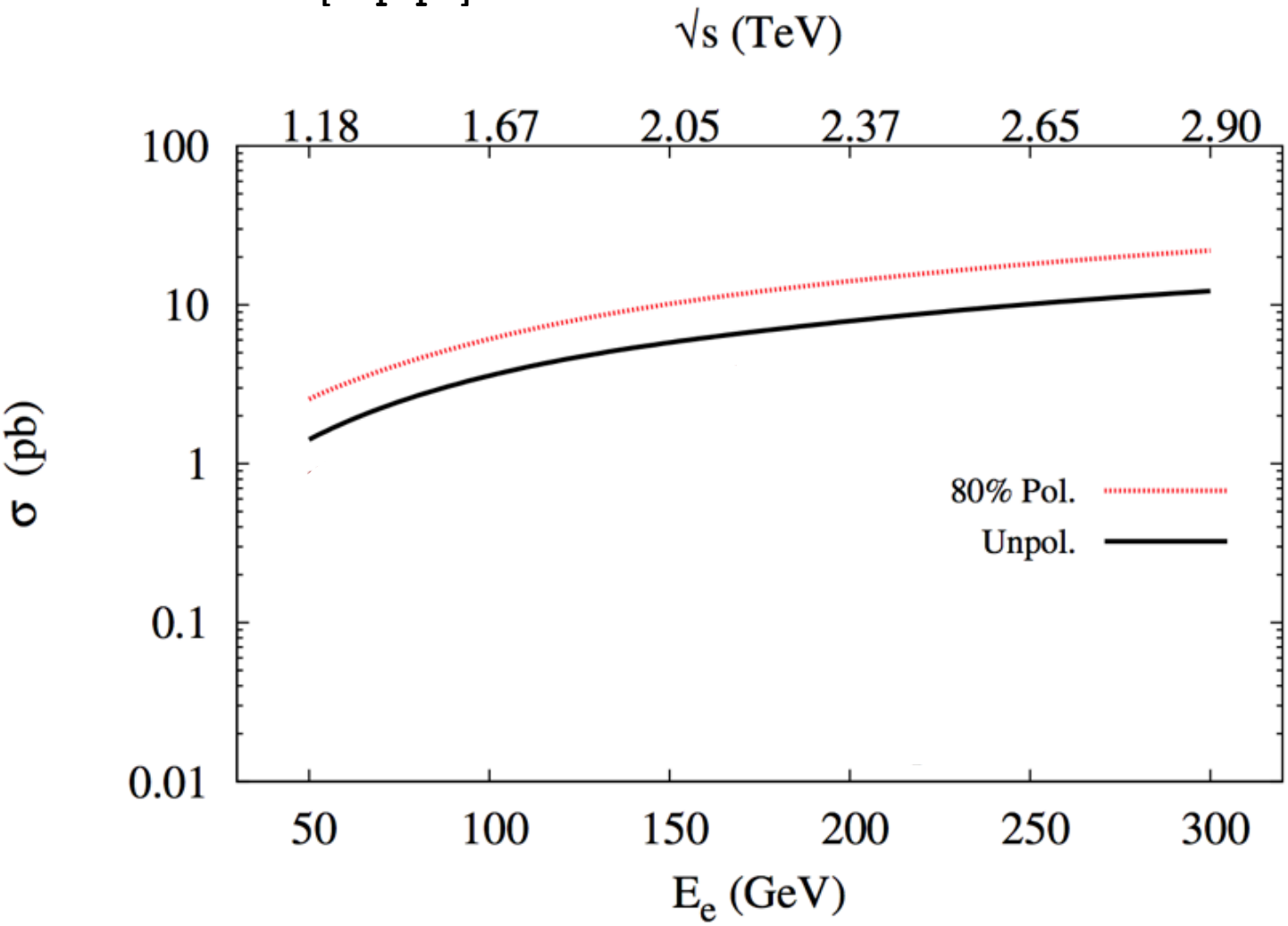
Backgrounds: Leptonic Channel

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

CC Single Top Quark Cross Section

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



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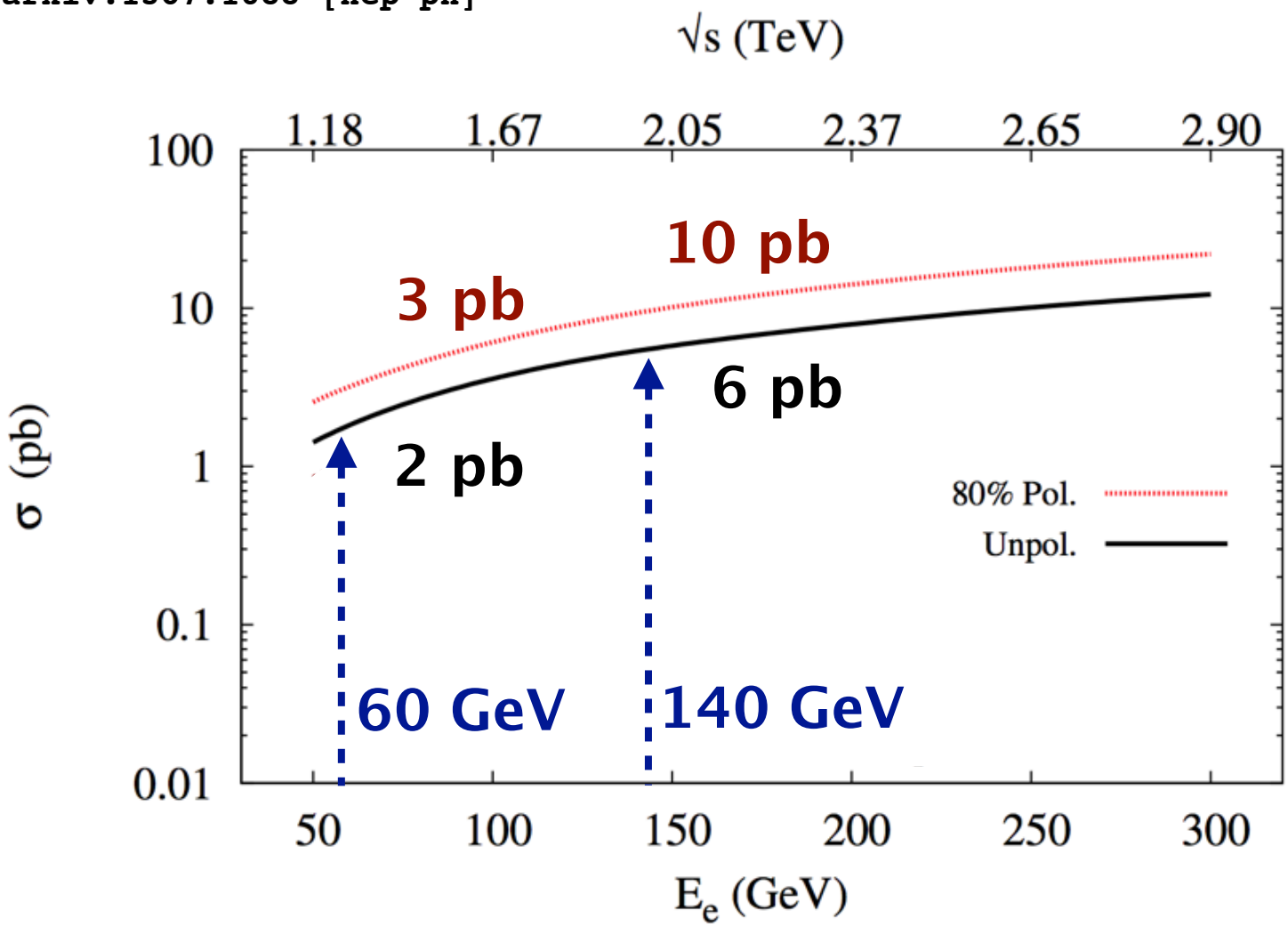
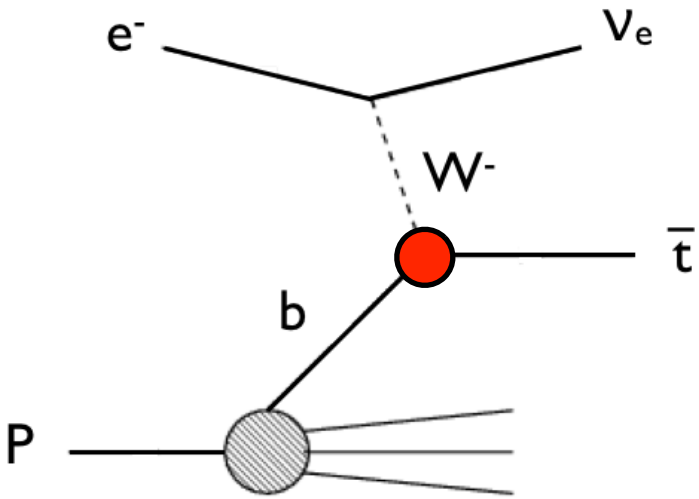


100 fb^{-1}:
2–6 · 10^5 events
3–10 · 10^5 events

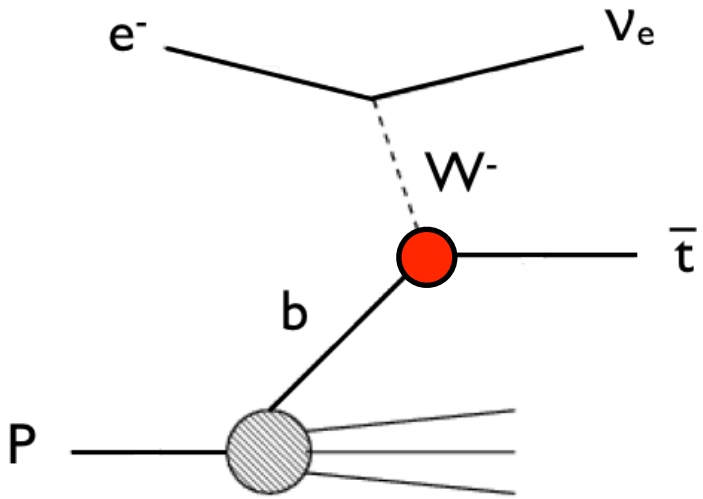
→ **LHeC offers excellent prospects for top quark physics**

Direct Measurement of $|V_{tb}|$



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

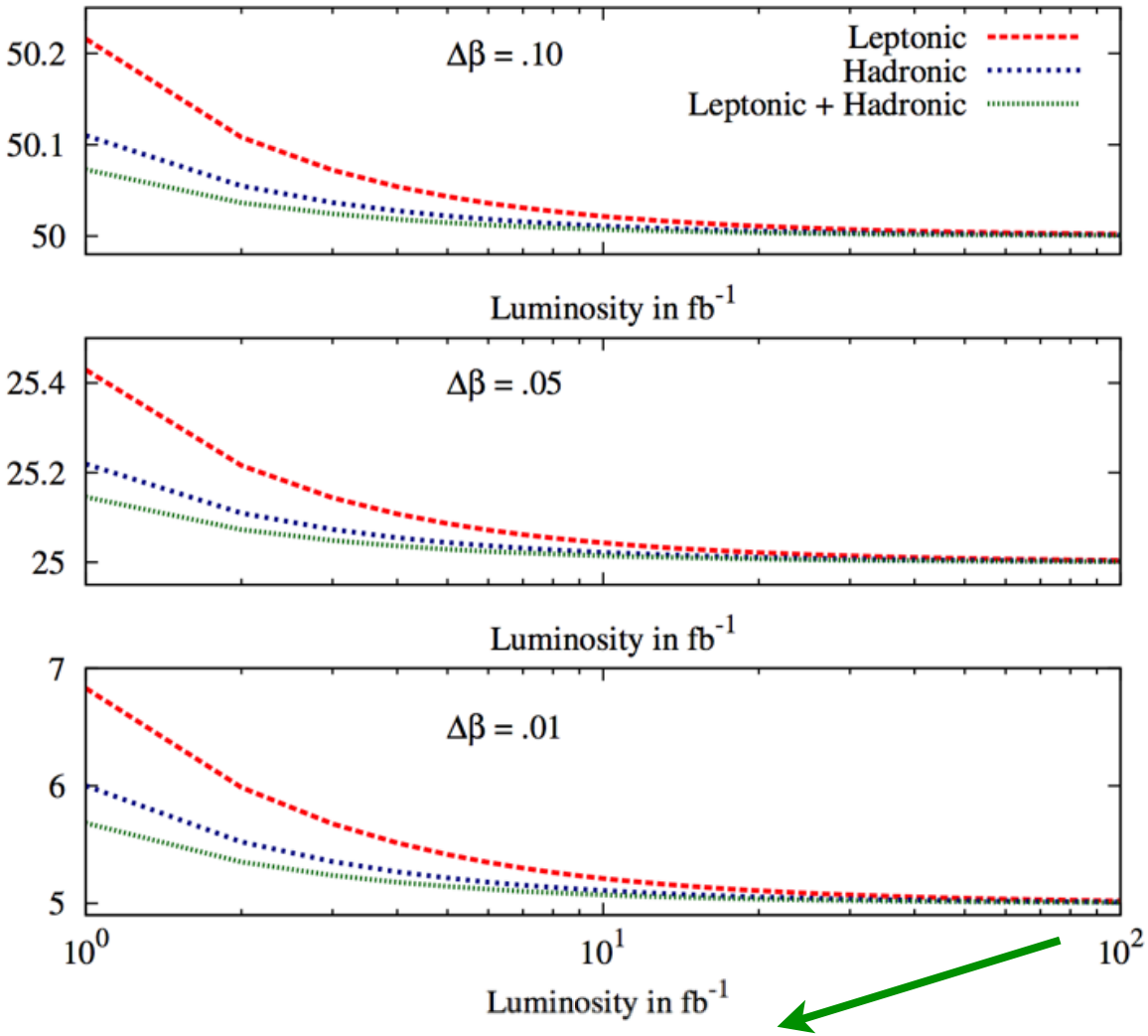
Direct Measurement of $|V_{tb}|$



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

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

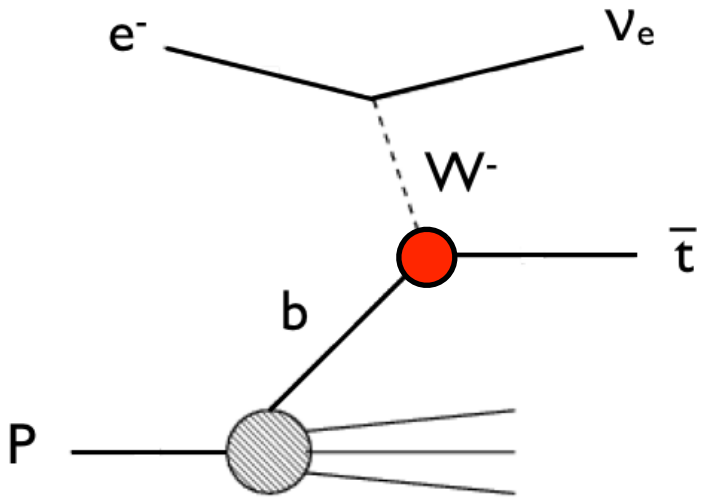
Δβ: luminosity uncertainty



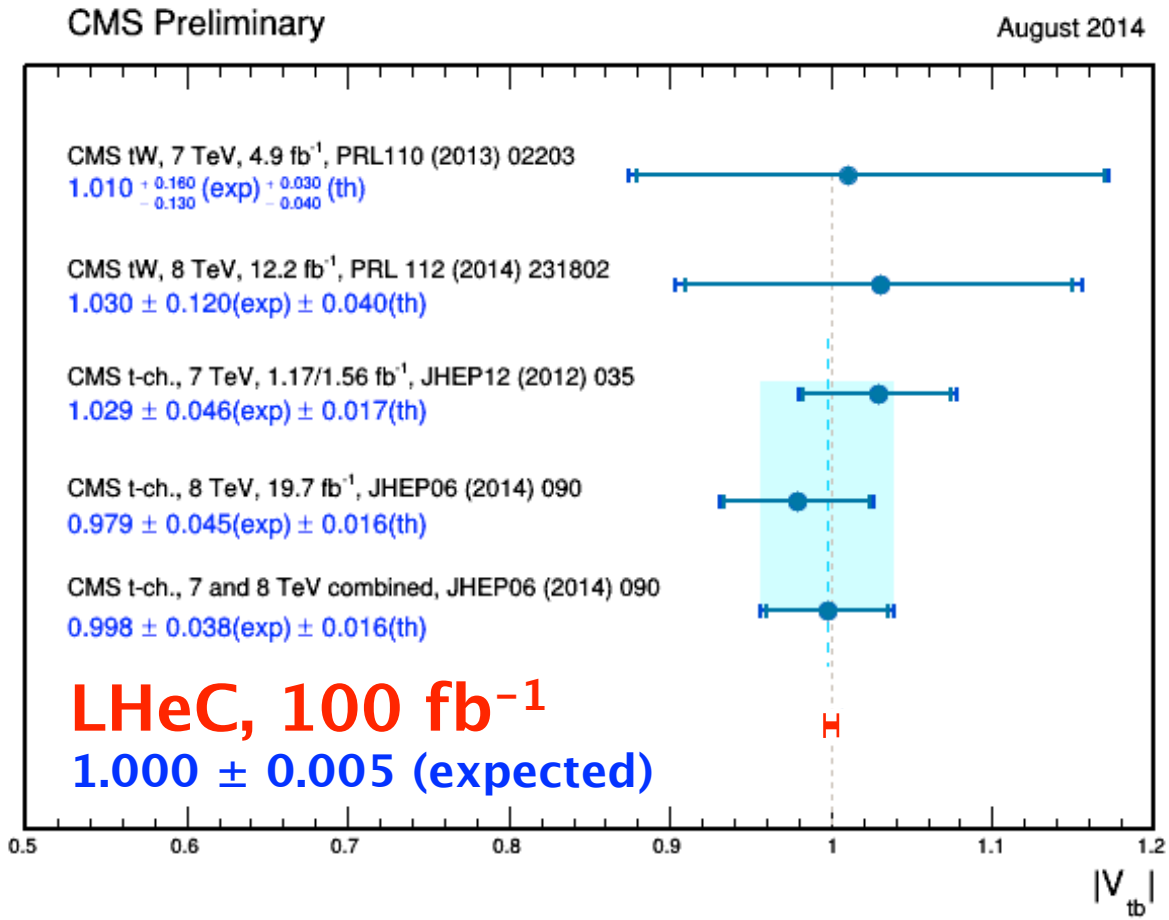
100 fb^{-1}: $\Delta|V_{tb}|$=0.005

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

Direct Measurement of $|V_{tb}|$



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



→ **high precision measurement**

Search for Anomalous Wtb Couplings

= 1 in SM

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

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

Search for Anomalous Wtb Couplings

= 1 in SM

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

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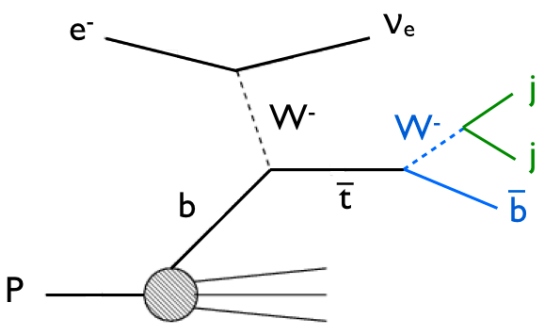
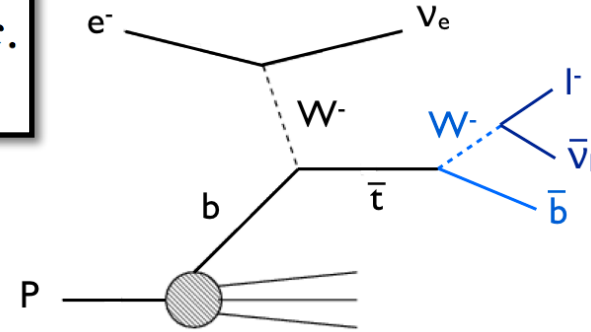
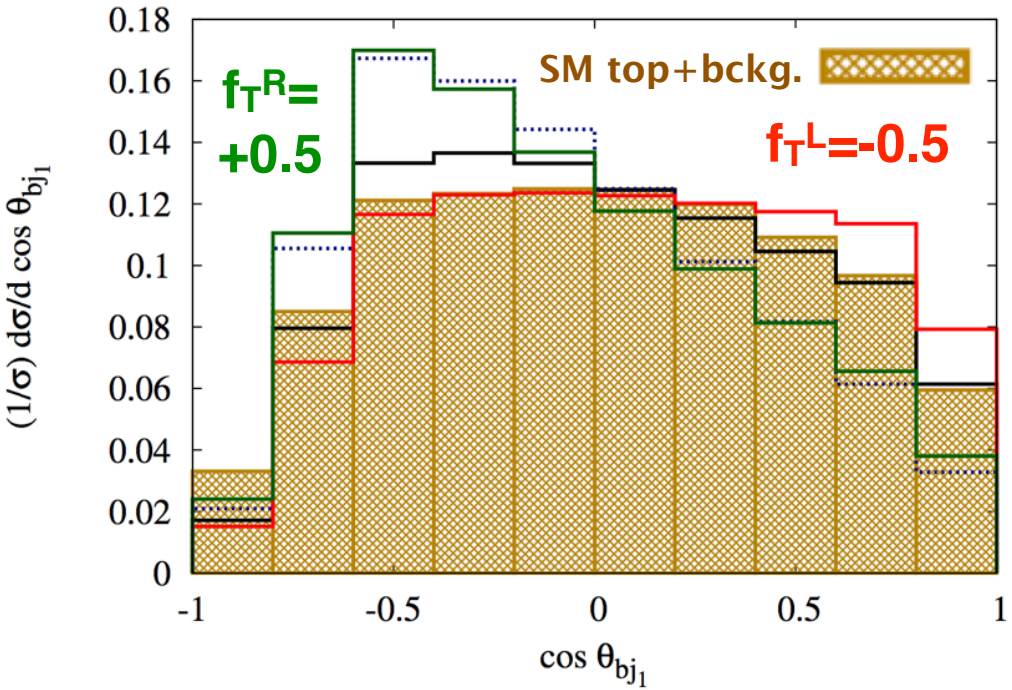
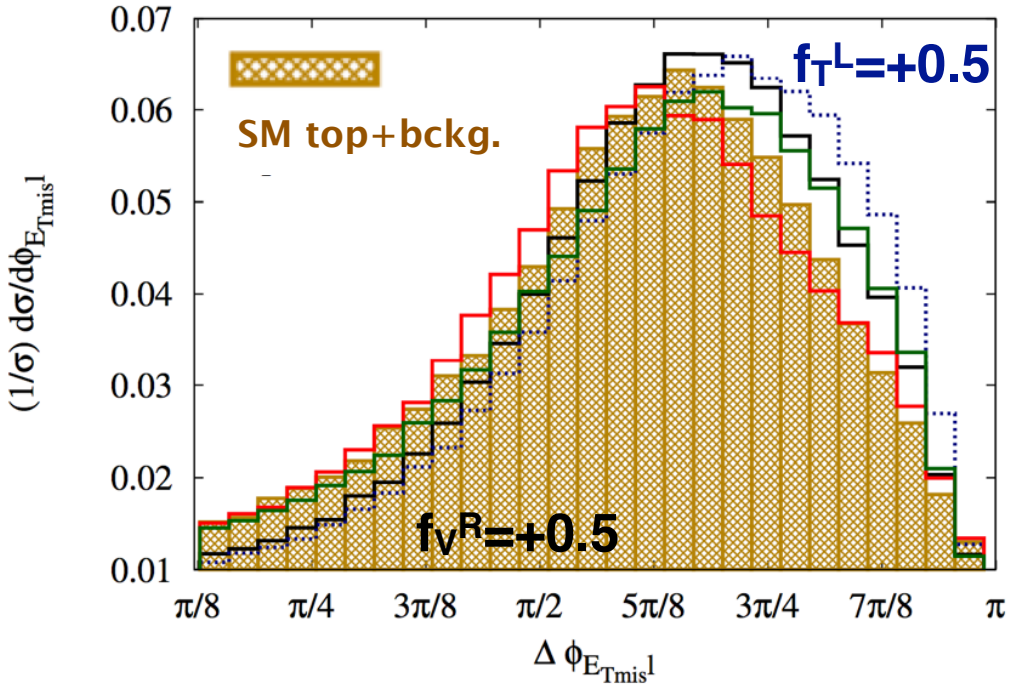
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688









+ other variables sensitive on W helicity

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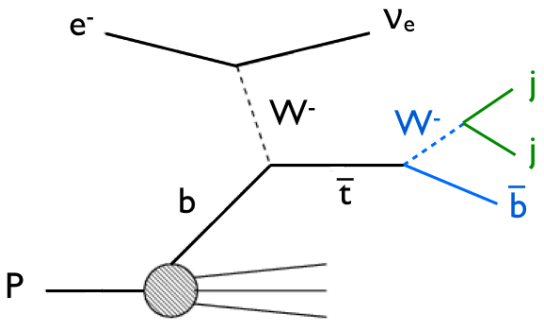
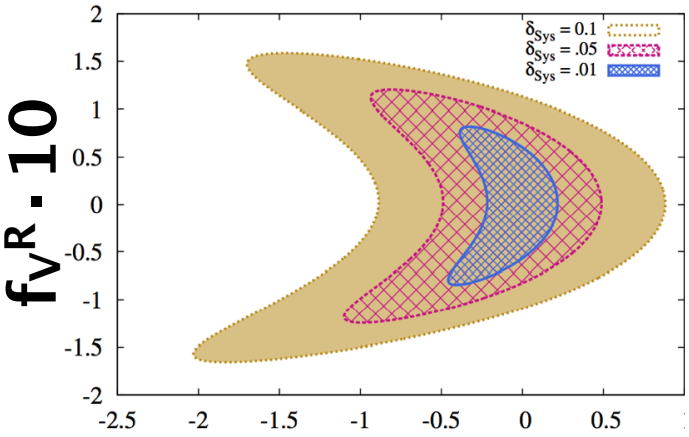
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688



68% C.L.

syst. error



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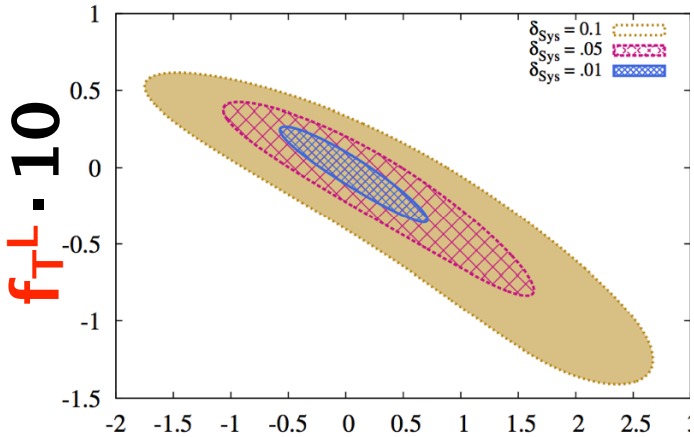

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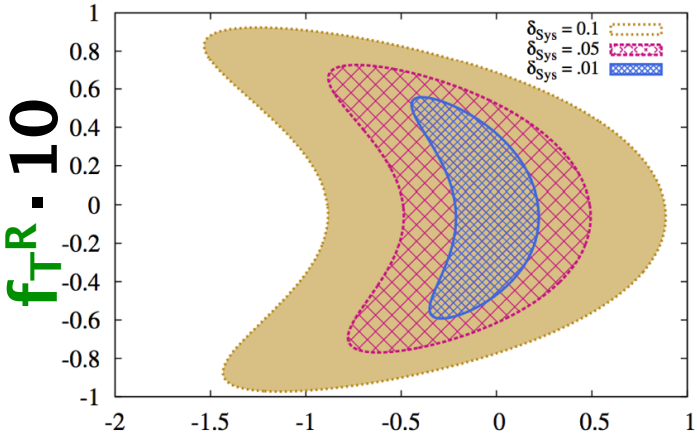

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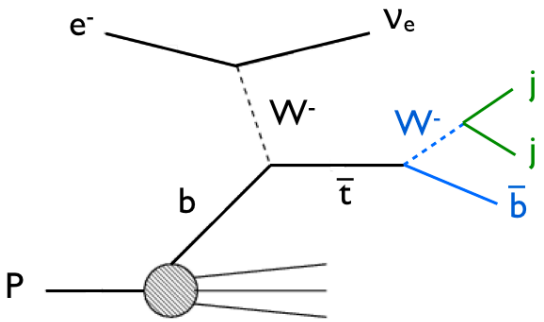
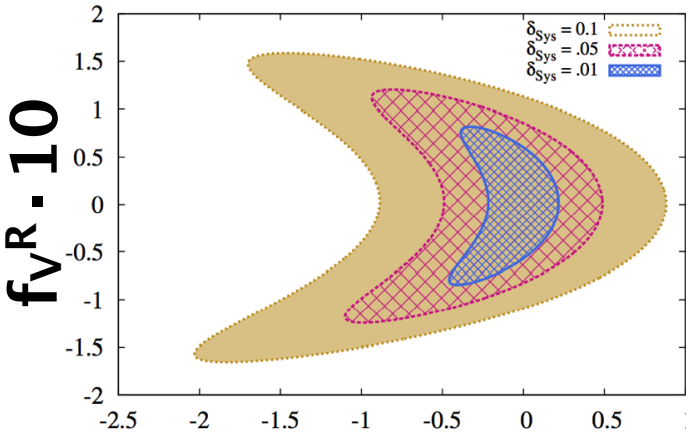
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688



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

syst. error



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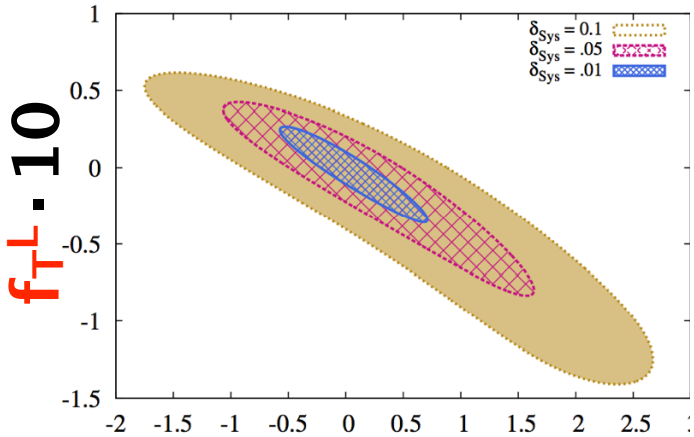

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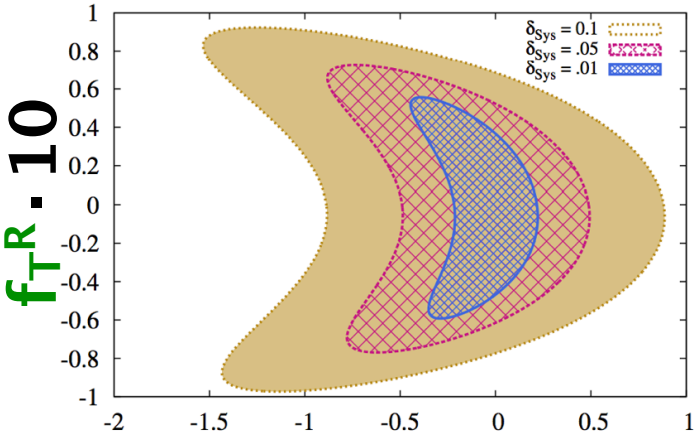

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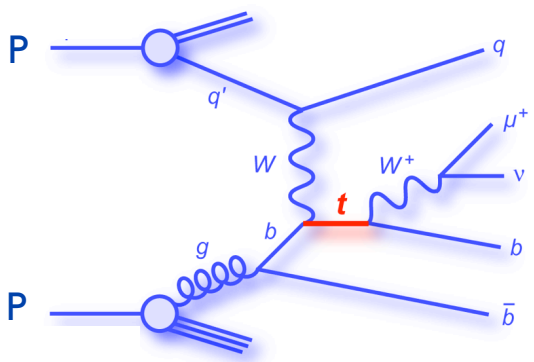
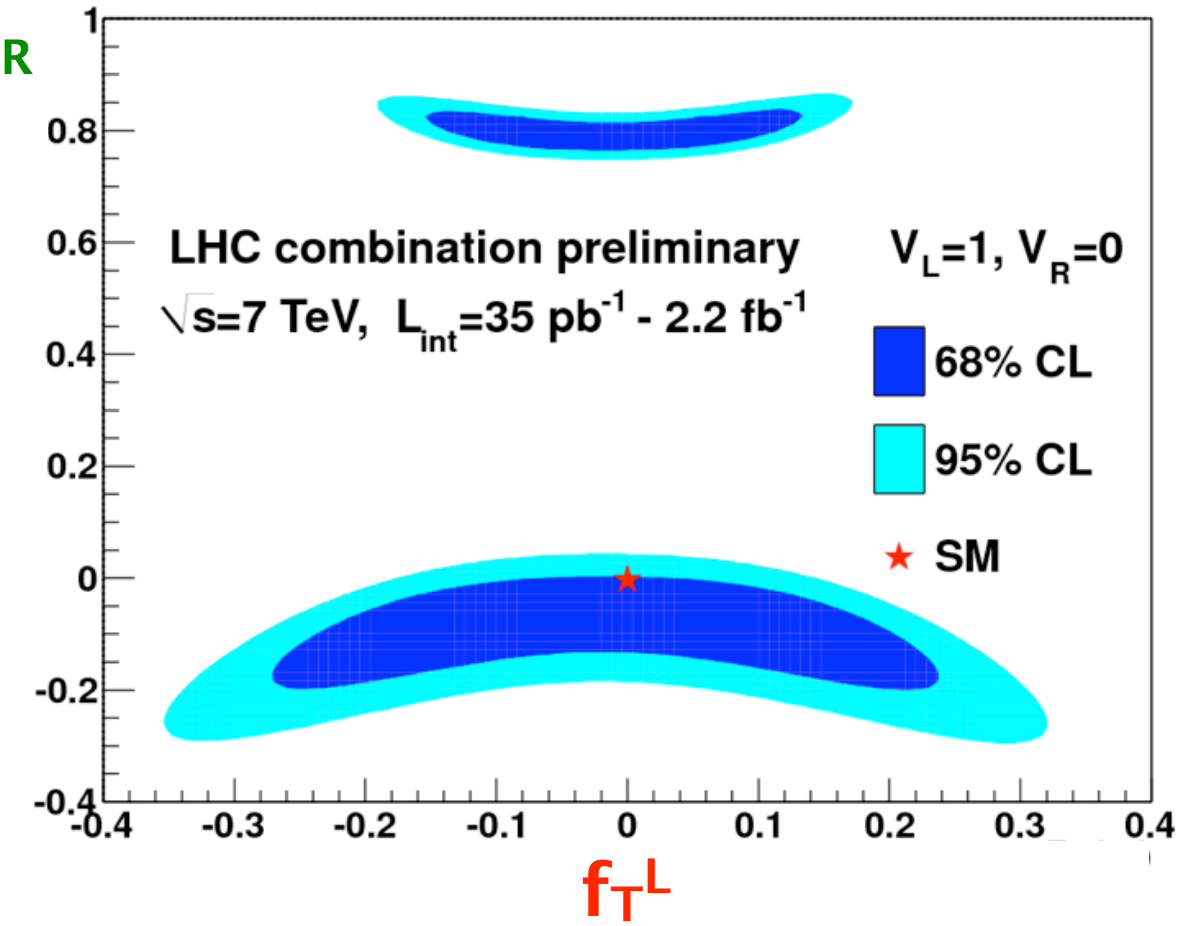
$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

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



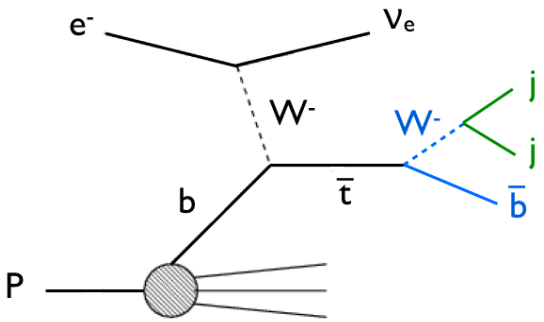


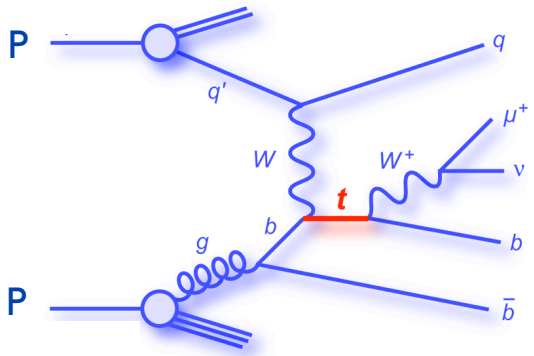
Search for Anomalous Wtb Couplings

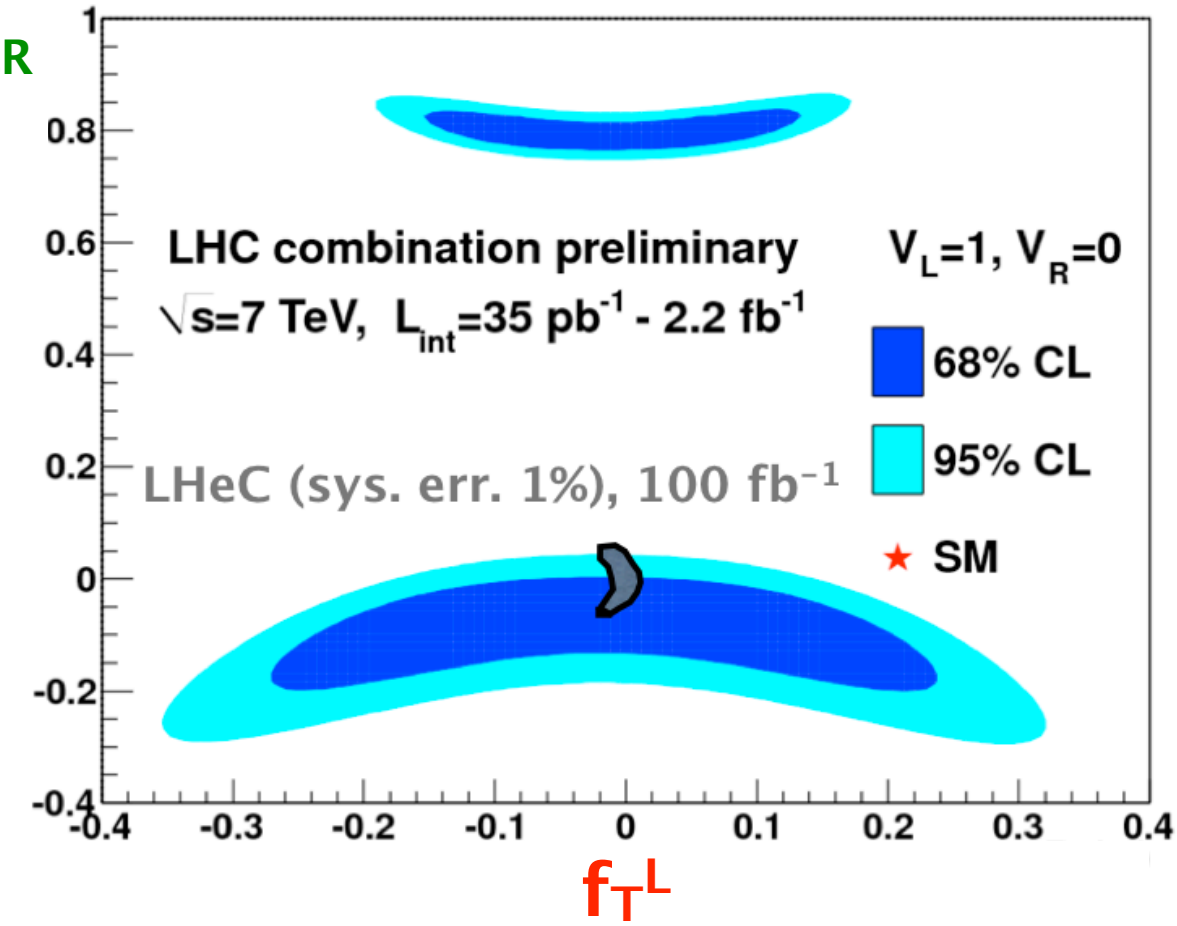
= 1 in SM

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

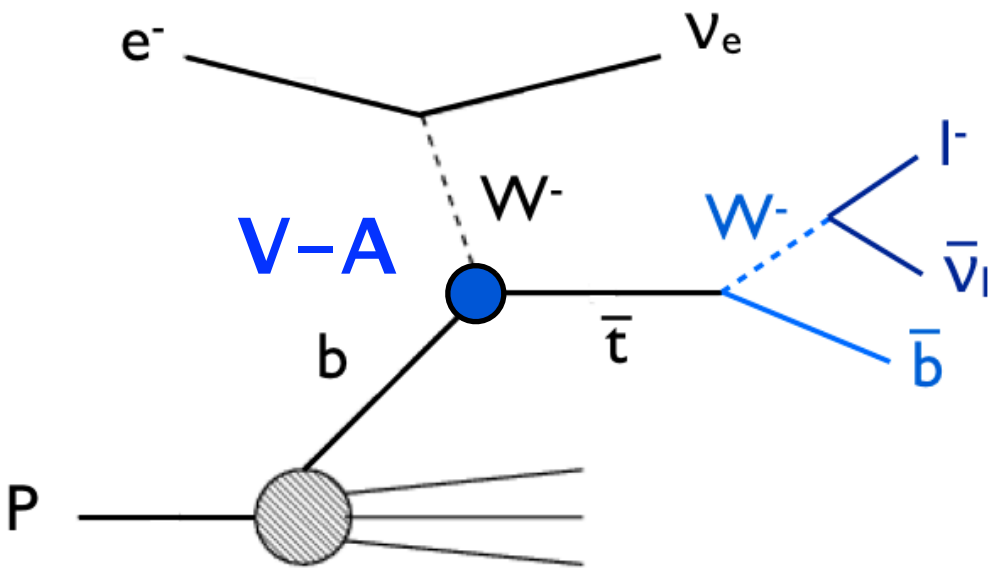
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$







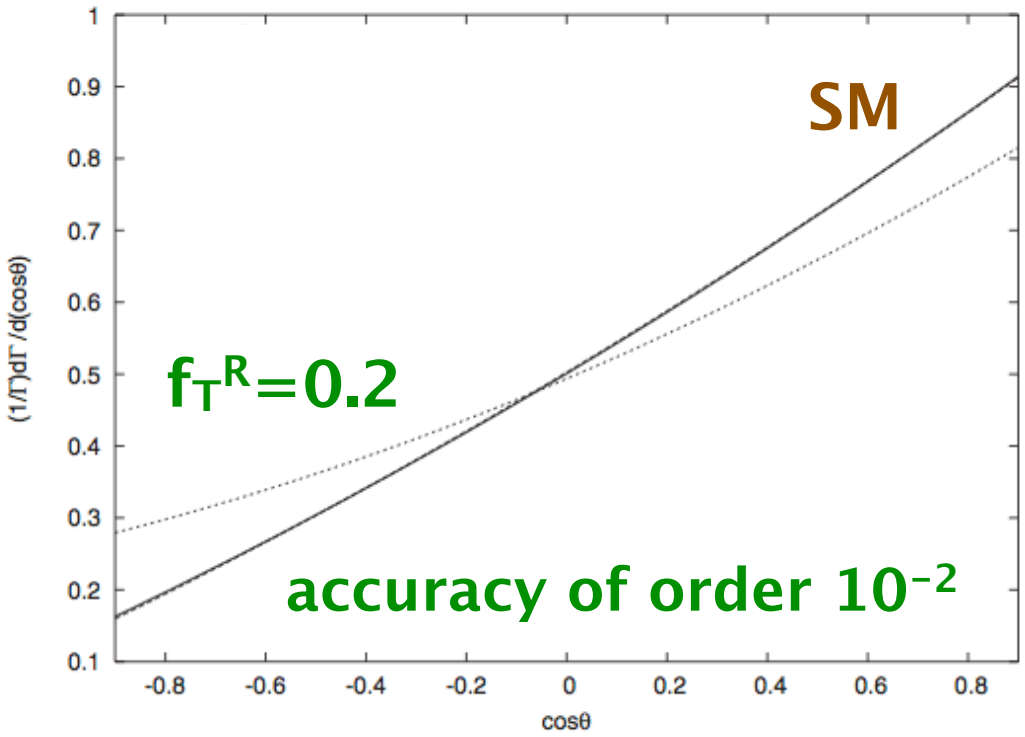
Top Quark Polarisation



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%

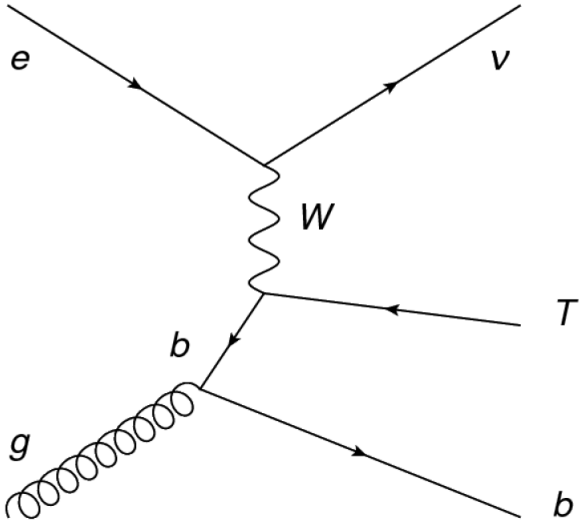
TESLA+HERAp:

$\sqrt{s}$=1.6 TeV
L_{int}=20 fb^{-1} (update for 100 fb^{-1}?)

20 fb^{-1}: P_t = 0.82±0.34

CMS-PAS-TOP-13-001

Search for Heavy Top Partners



J. Ferrando

Madgraph 5

Mass (GeV)	Cross-section (fb)	BR(T->Wb)	BR(T->tZ)	BR(T->tH)
400	13.3	0.64	0.13	0.23
500	1.85	0.58	0.17	0.25
600	0.277	0.56	0.20	0.24
700	3.91e-02	0.55	0.21	0.24
800	4.7e-03	0.54	0.22	0.23

e-beam 60 GeV

→ would need more than 100 fb^{-1}

Outline

Introduction
Charged Current
Neutral Current
Summary

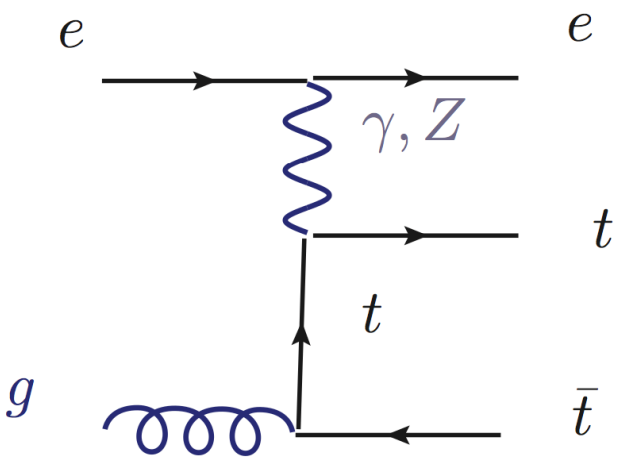
NC Top Quark Production

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

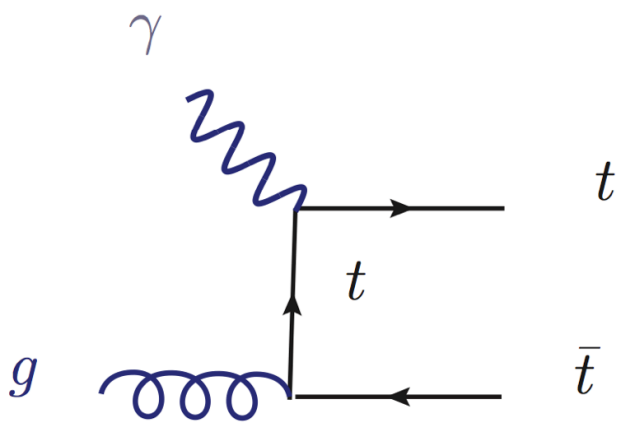
top pair production

single top production

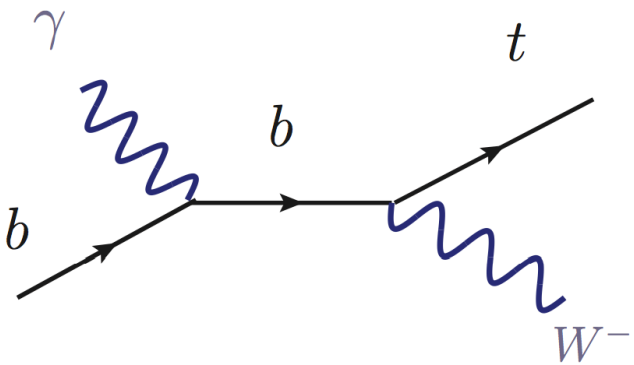
DIS



photoproduction



photoproduction

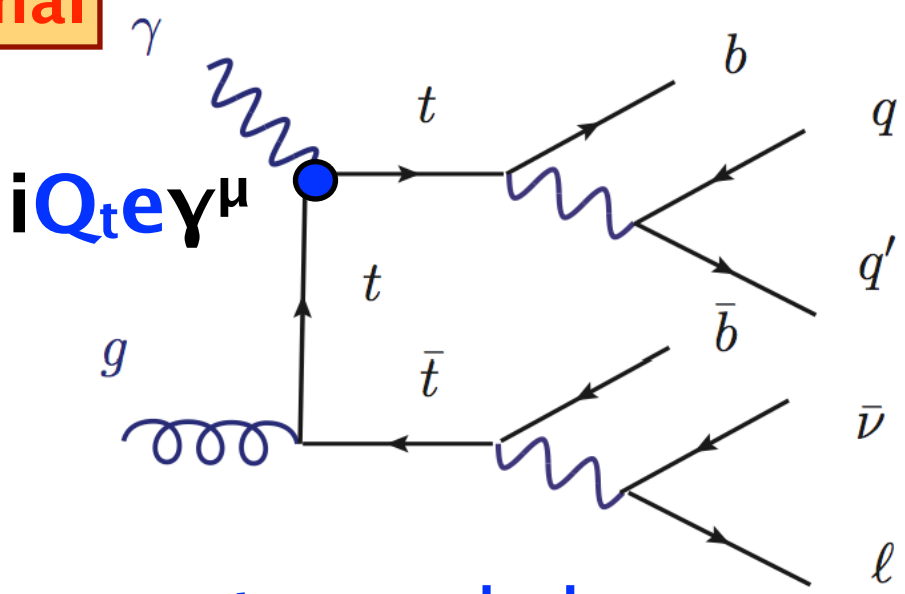


e-beam 140 GeV, 100 fb^{-1}:

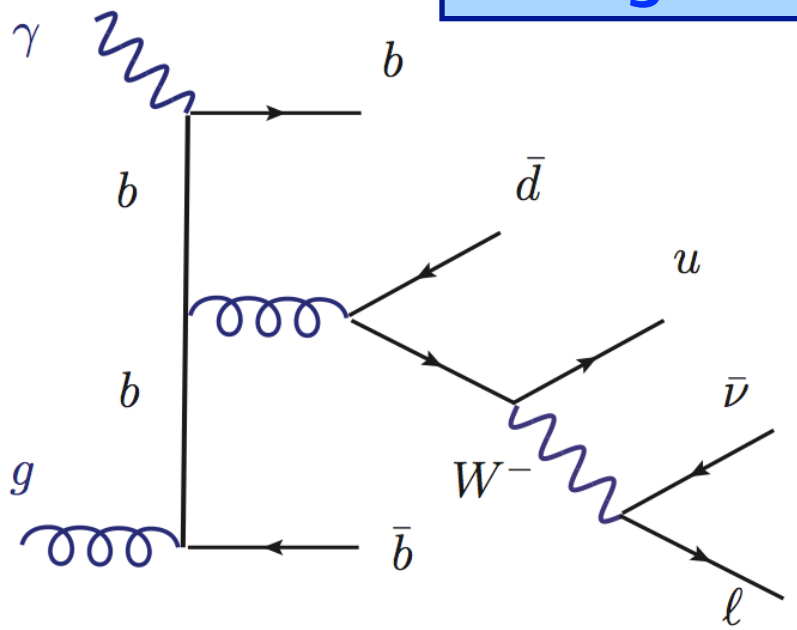
0.12 pb	3.2 pb	0.143 pb
$N_{t\bar{t}}$=12,000	$N_{t\bar{t}}$=320,000	N_t=14,300

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

signal



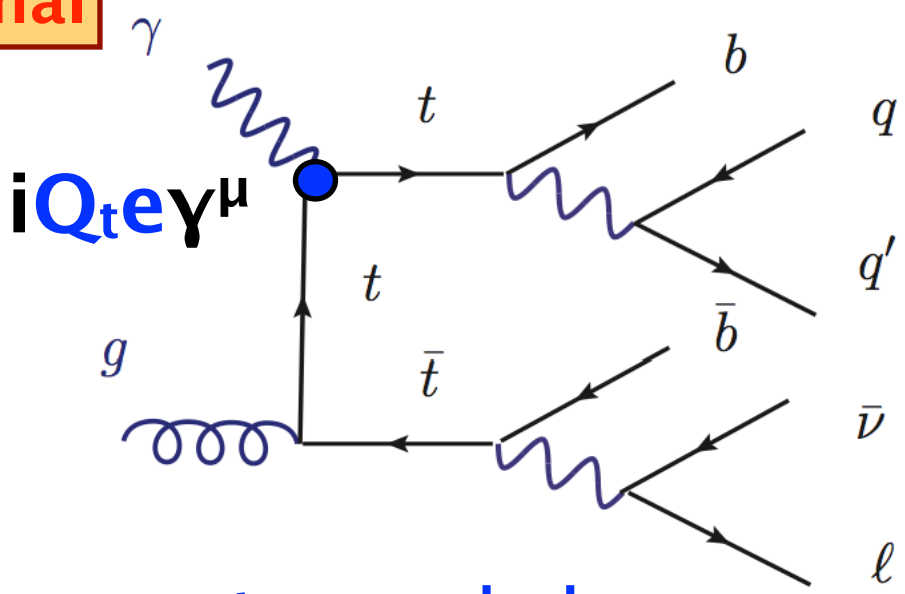
background



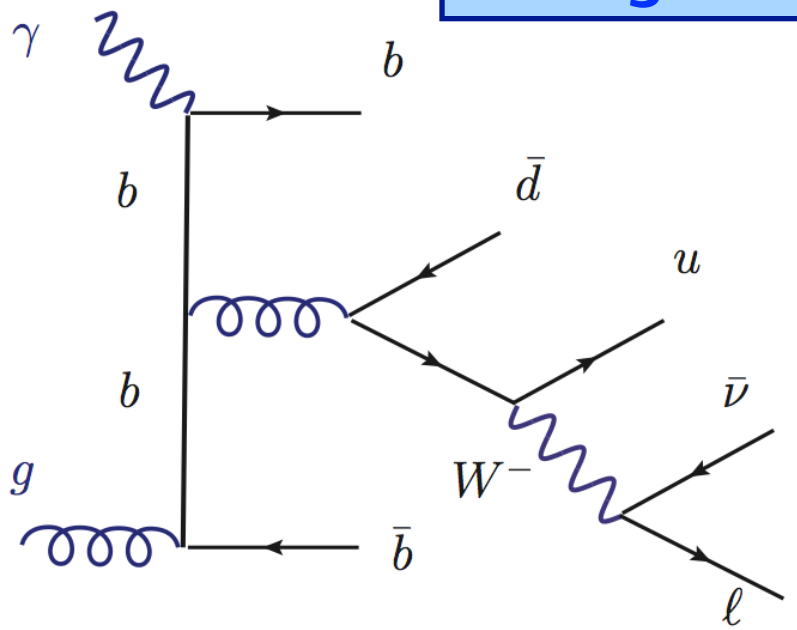
→ measure top quark charge

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

signal

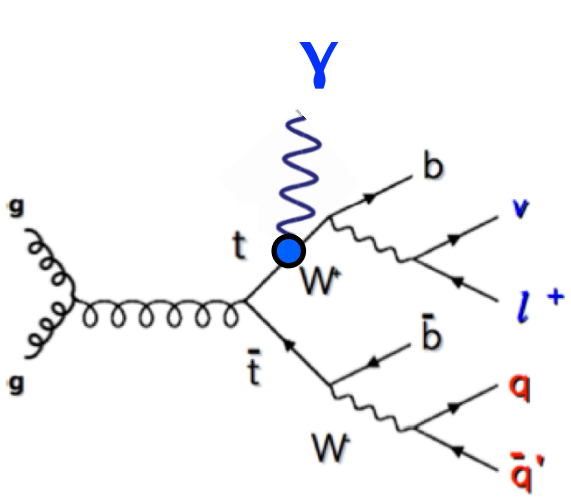


background

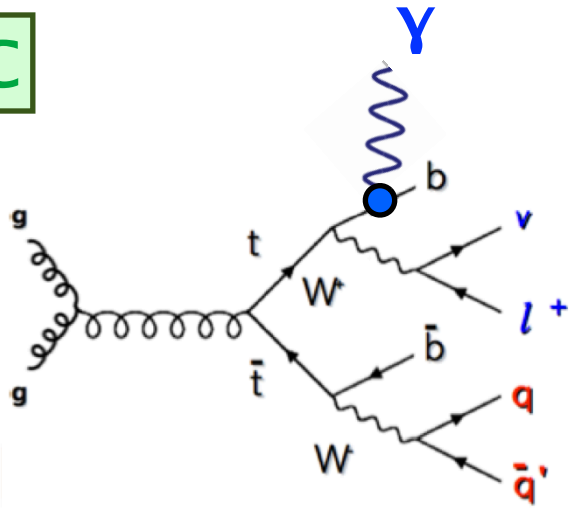


→ measure top quark charge

LHC



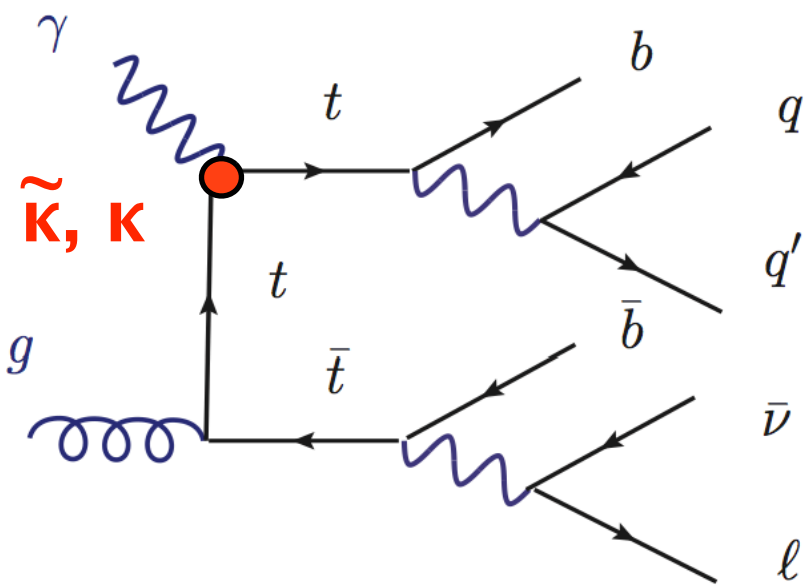
OR



?

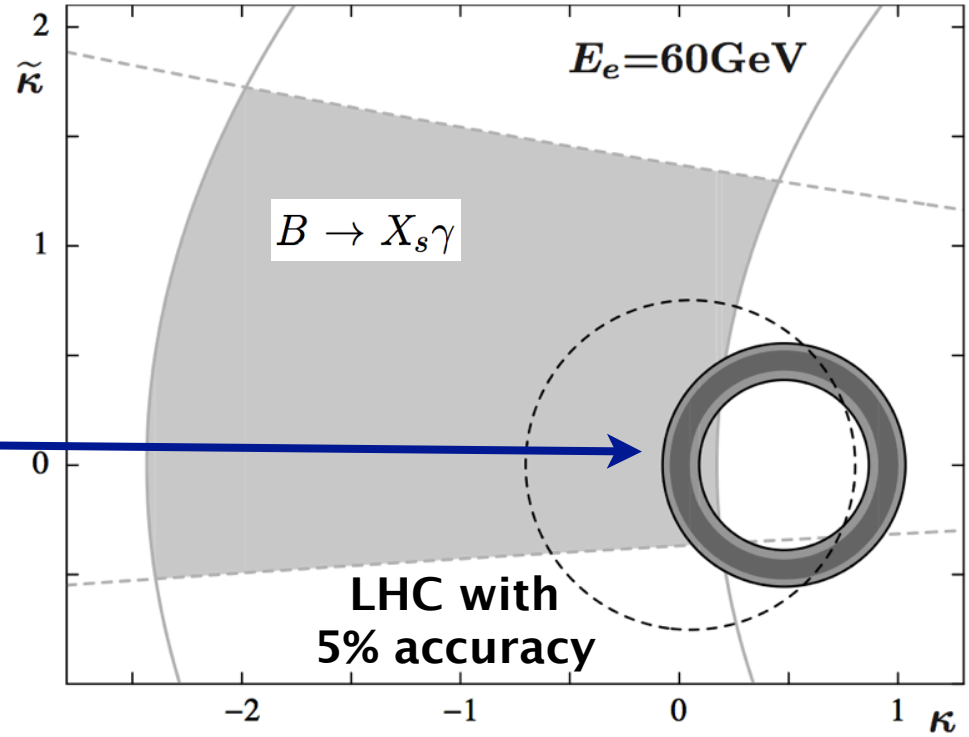
→ difficult at the LHC

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: $\tilde{\kappa}$

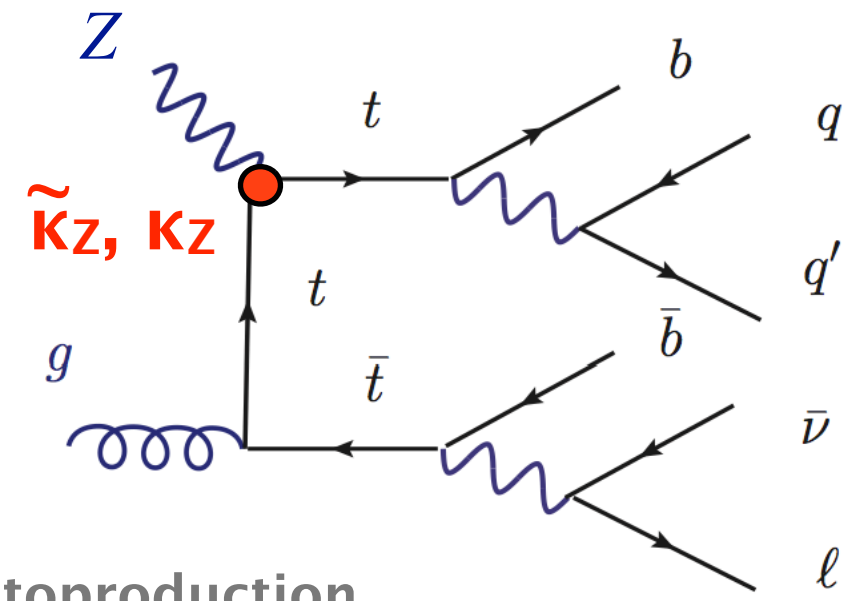


LHeC:
10% and 18% accuracy

magnetic dipole moment: κ

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

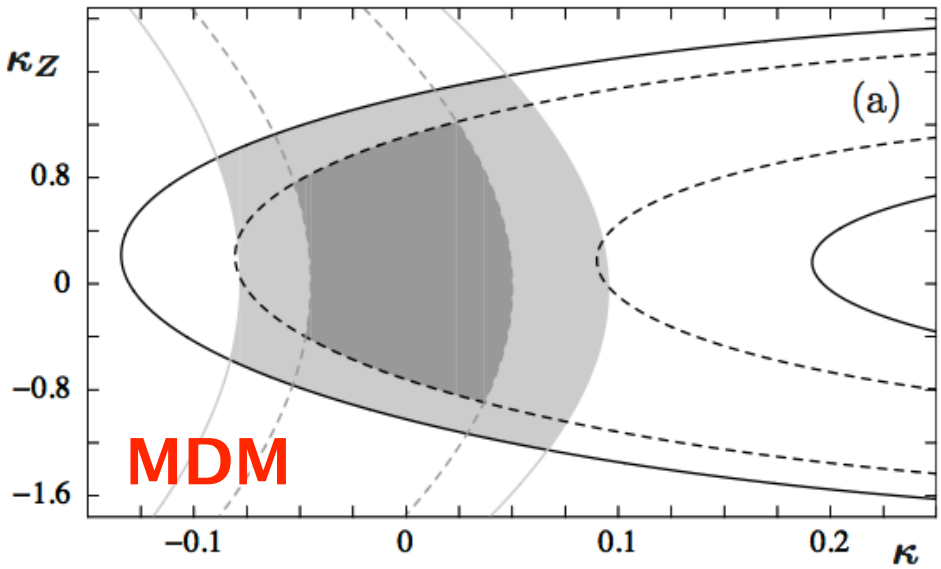
Search for Anomalous $t\bar{t}Z$ Couplings



$\tilde{\kappa}_Z$, κ_Z

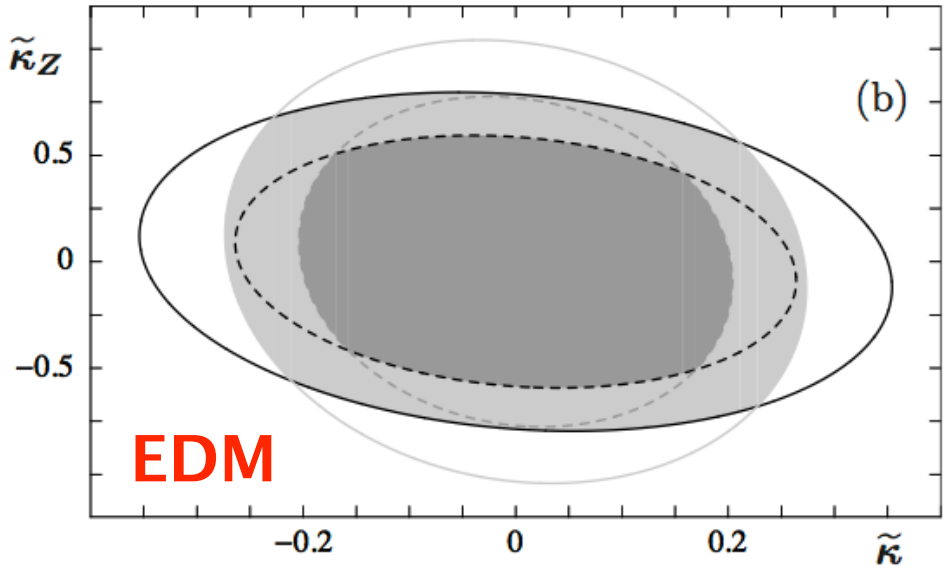
Bouzas, Larios,
Physical Review D 88, 094007 (2013)

$t\bar{t}$ photoproduction

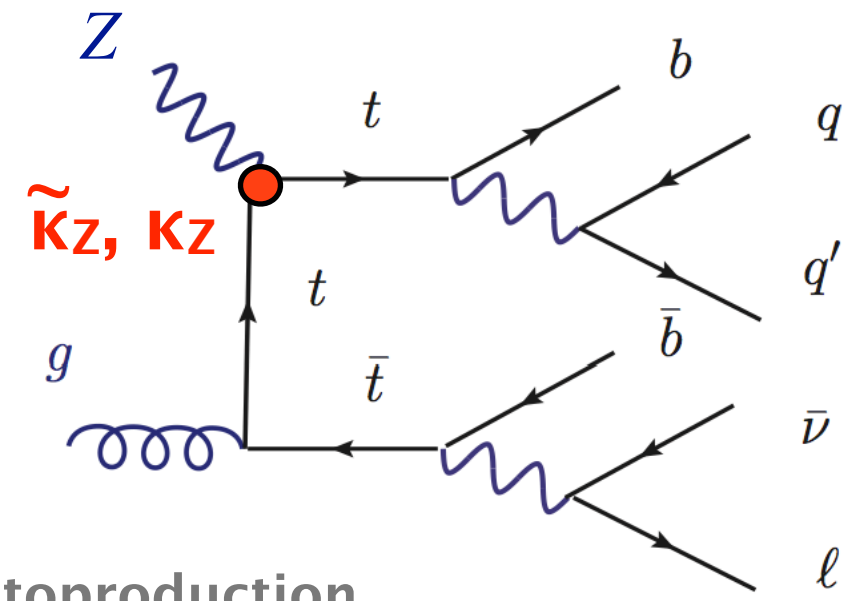


$t\bar{t}$ DIS

LHeC:
10% and 18% accuracy



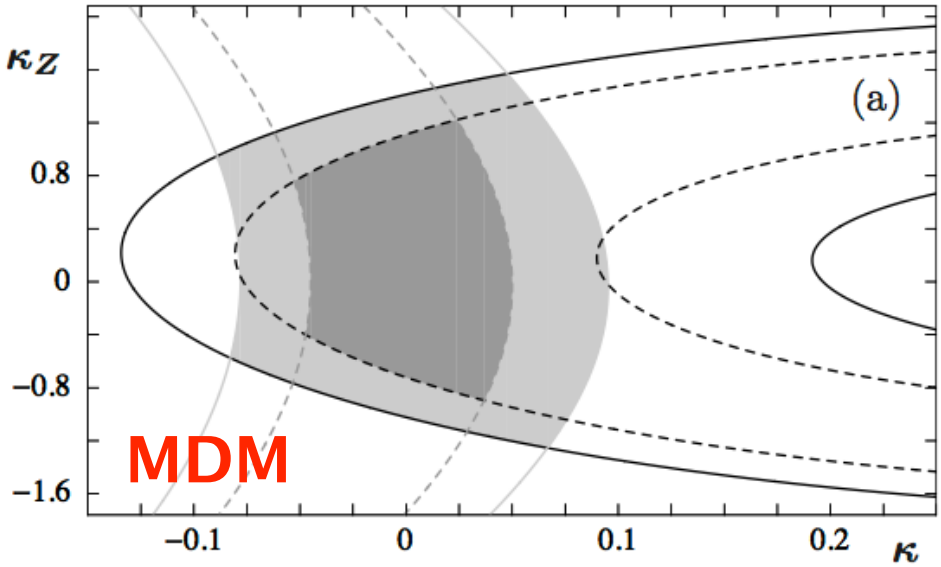
Search for Anomalous $t\bar{t}Z$ Couplings



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

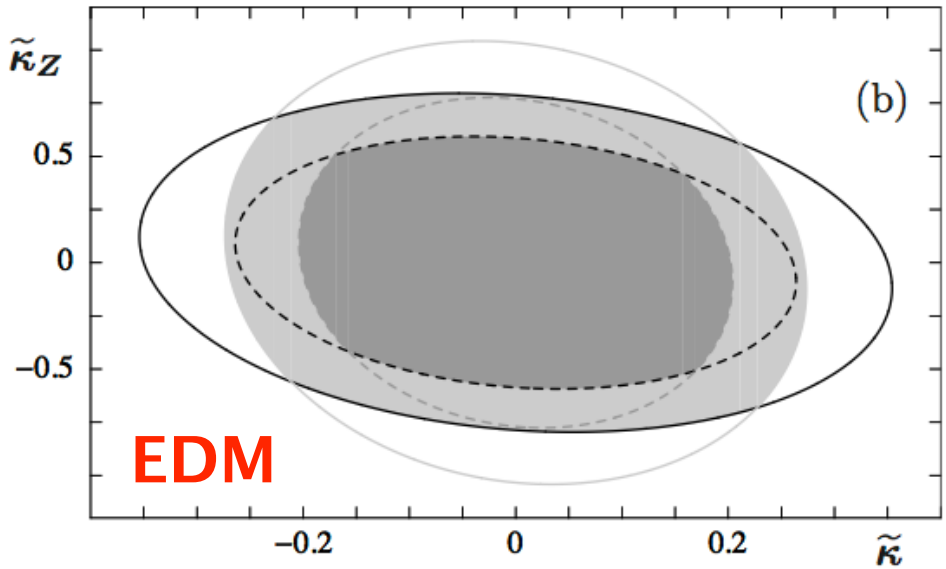
property	precision
EDM: $\tilde{\kappa}$ / $\tilde{\kappa}_Z$	0.20–0.28/0.6–0.8
MDM: κ / κ_Z	0.05–0.09/0.9–1.3

$t\bar{t}$ photoproduction

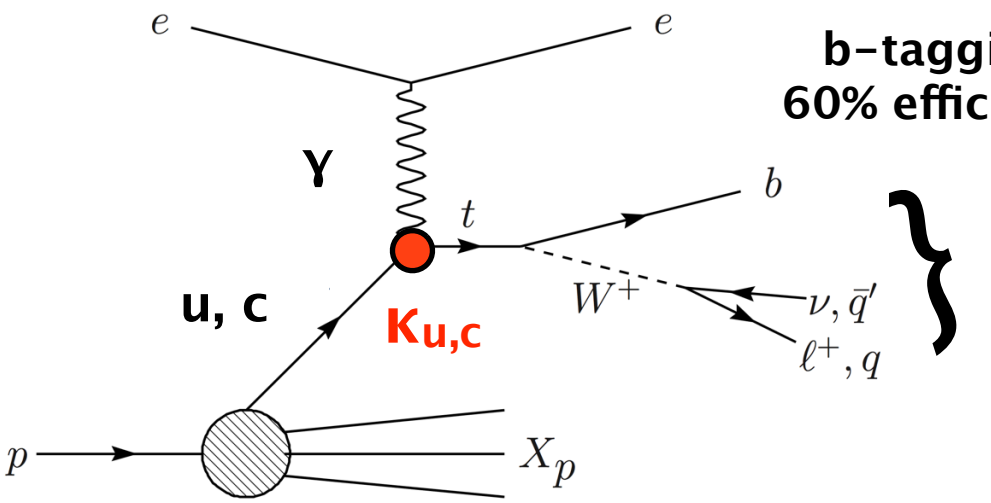


$t\bar{t}$ DIS

LHeC:
10% and 18% accuracy

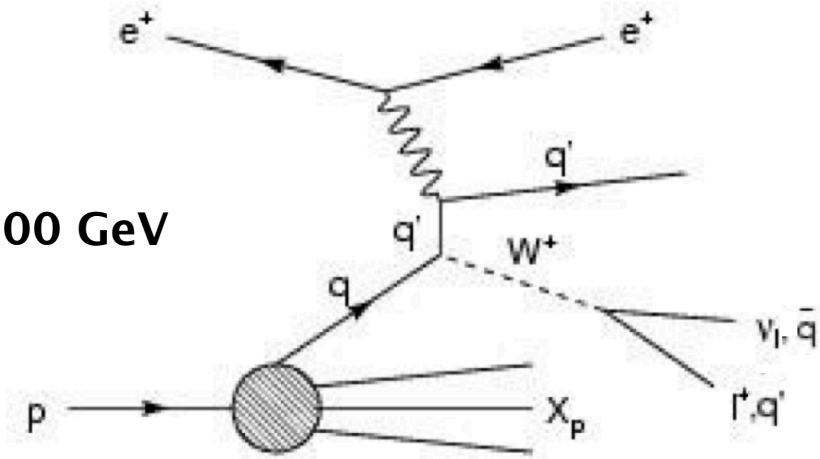


Single Top Quark Production: FCNC



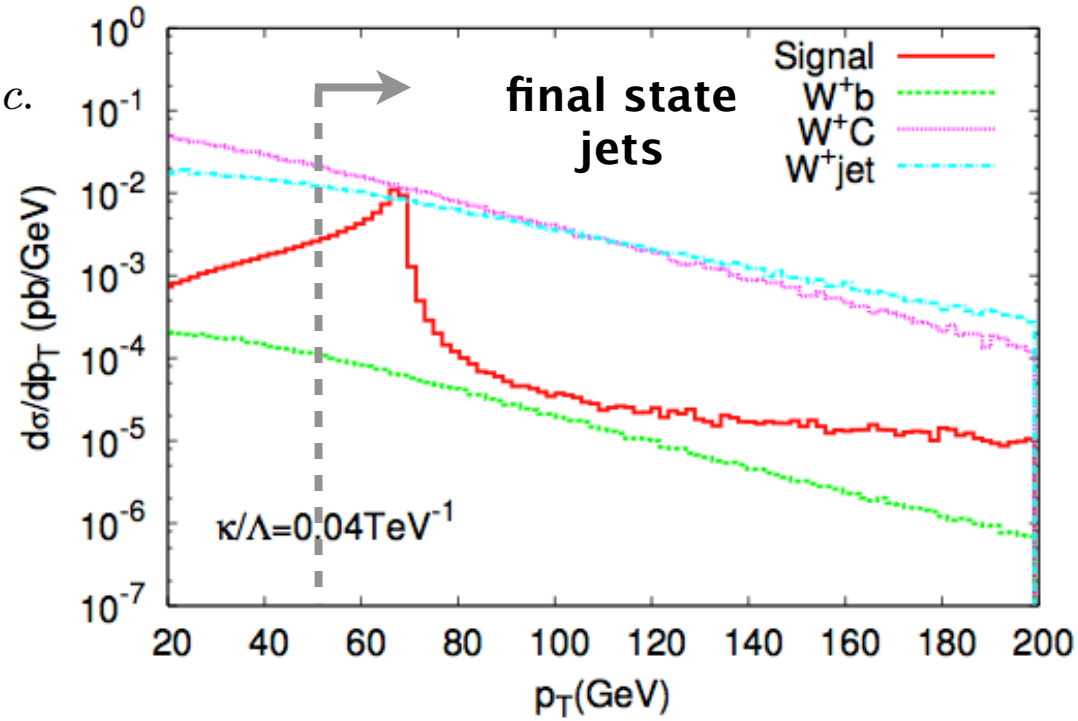
b-tagging:
60% efficiency

150<M_{Wb}<200 GeV



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

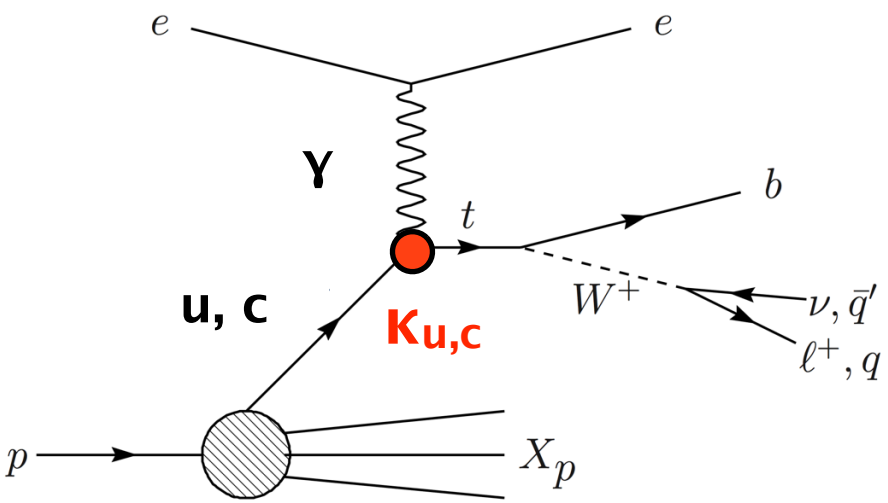
LHeC TDR,
J.Phys. G39,
075001 (2012)



γp collider:

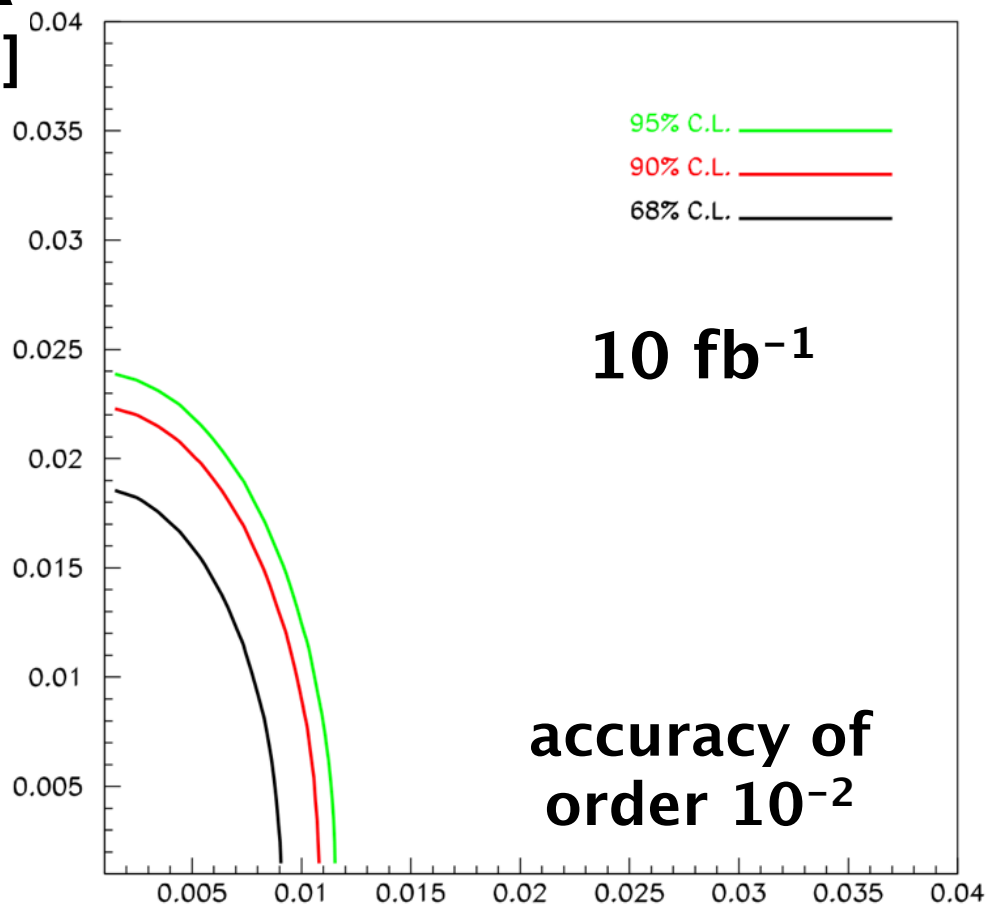
e-beam 70 GeV
γ: 80% of e-energy
L_{int}=10 fb^{-1} (update for 100 fb^{-1}?)

Single Top Quark Production: NC

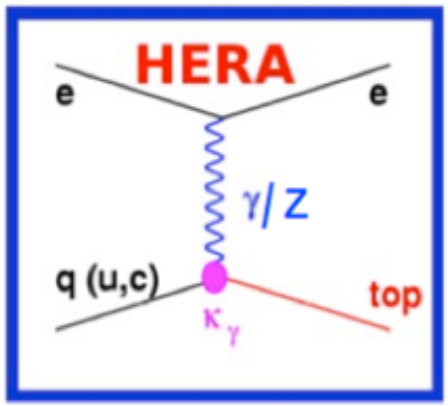


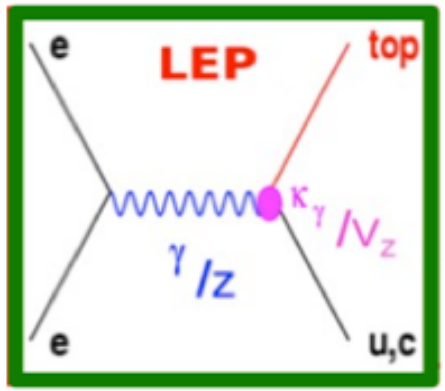
$$L = -g_e \sum_{q=u,c} Q_q \frac{\kappa_q}{\Lambda} \bar{t}\sigma^{\mu\nu}(f_q + h_q\gamma_5)qA_{\mu\nu} + h.c.$$

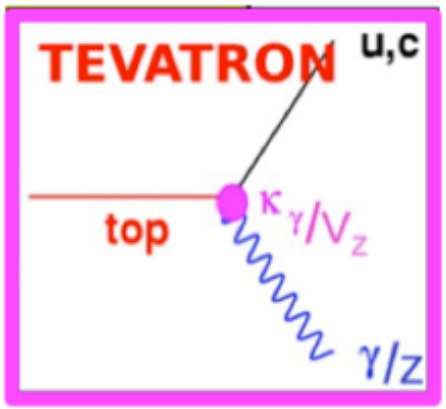
LHeC CDR, J.Phys. G39, 075001 (2012)

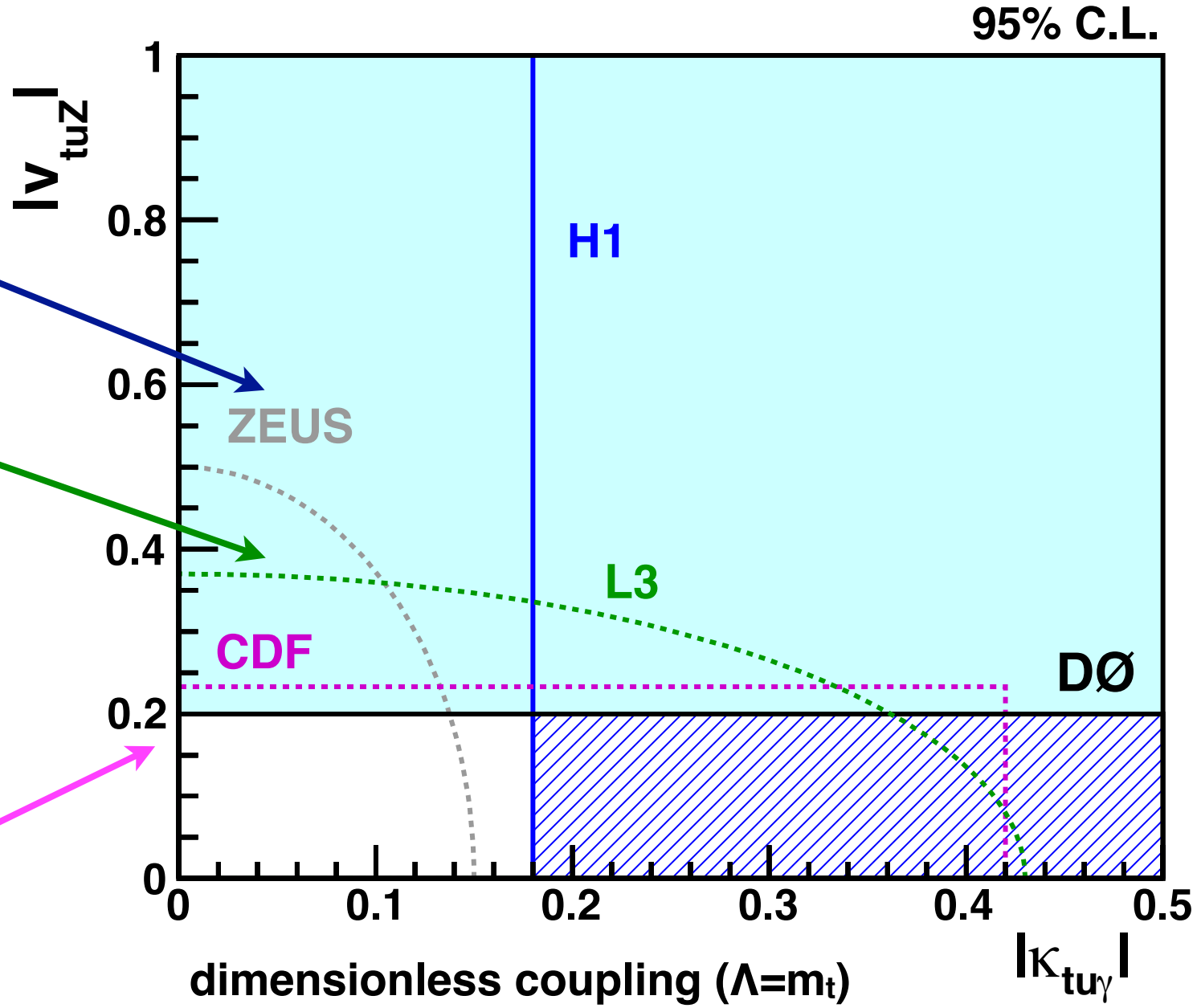


FCNC Top Couplings at Colliders

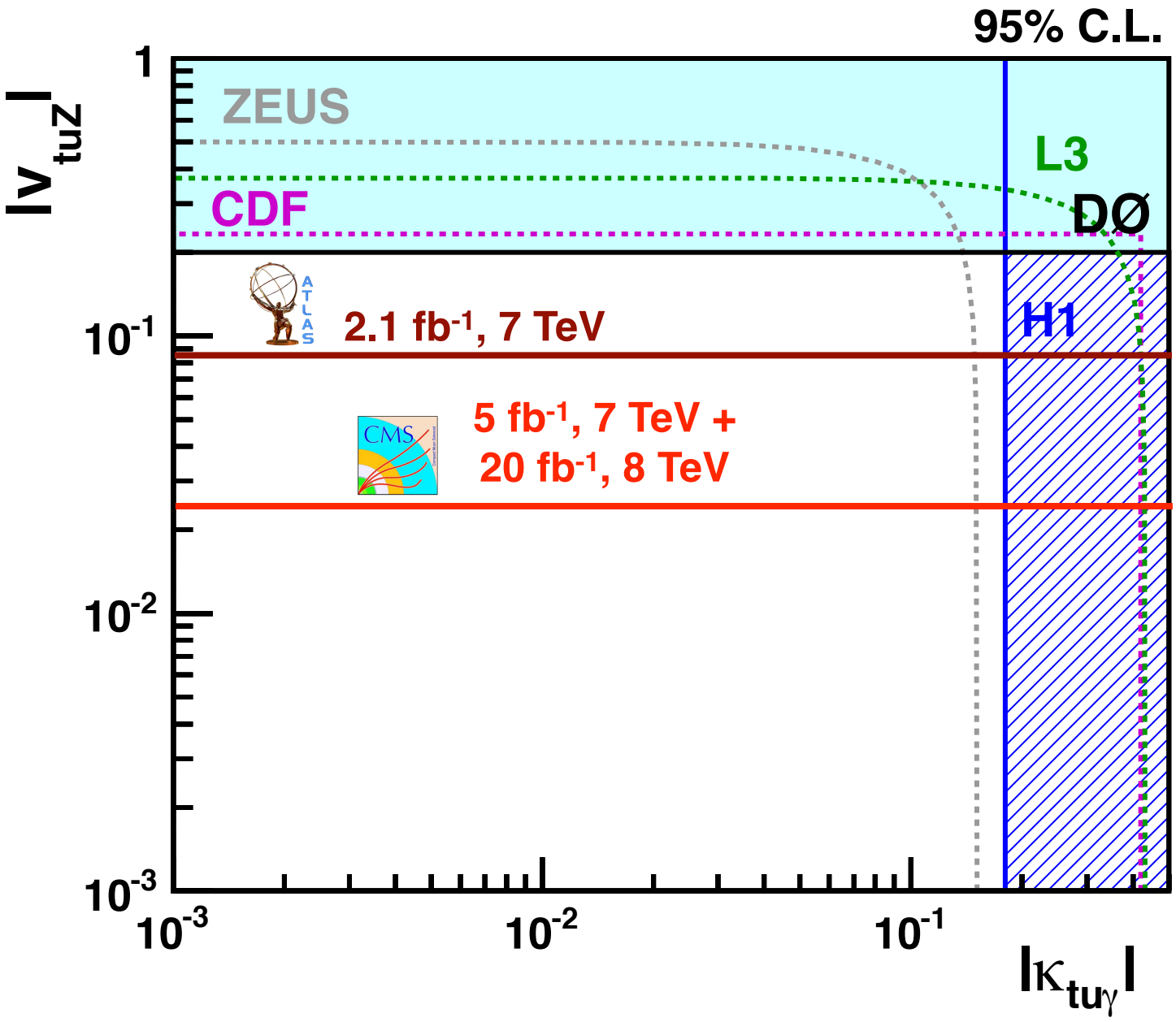


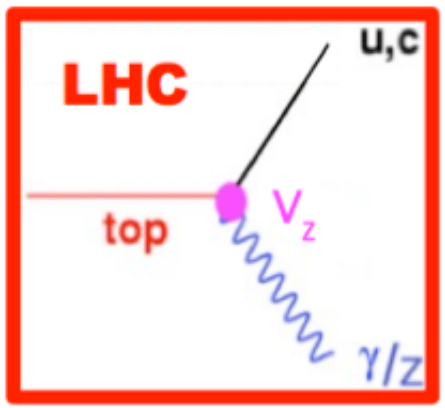






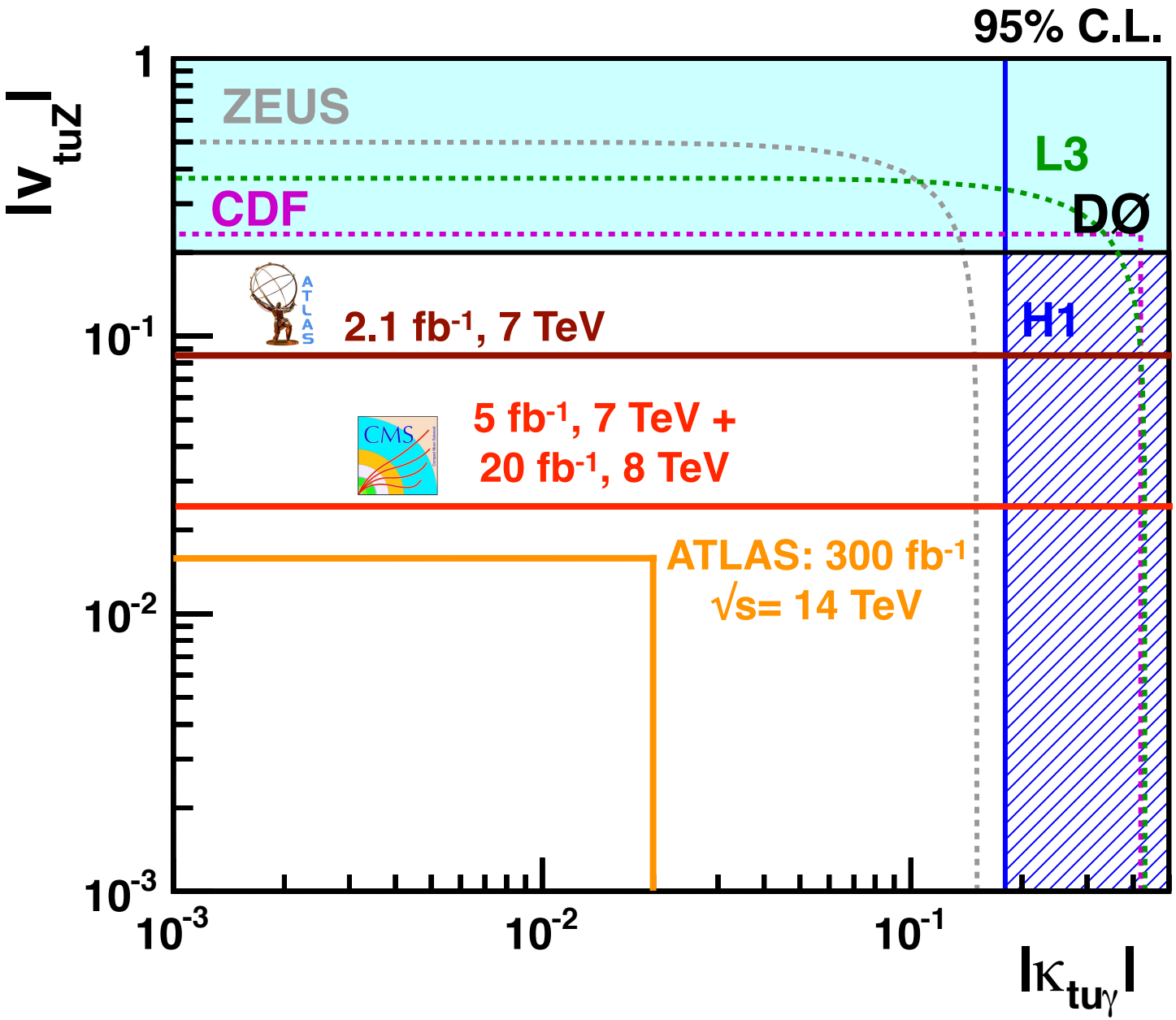
FCNC Top Couplings at Colliders

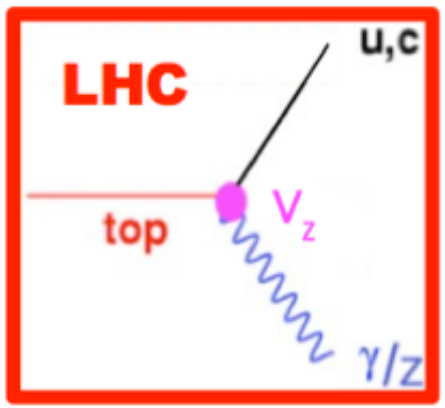




FCNC Top Couplings at Colliders

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





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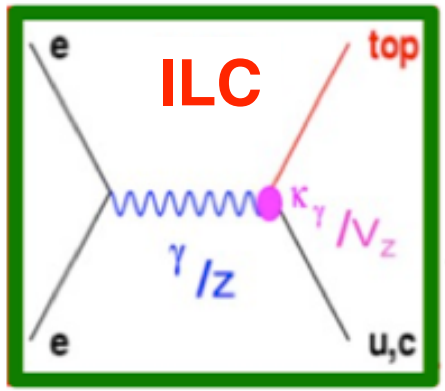
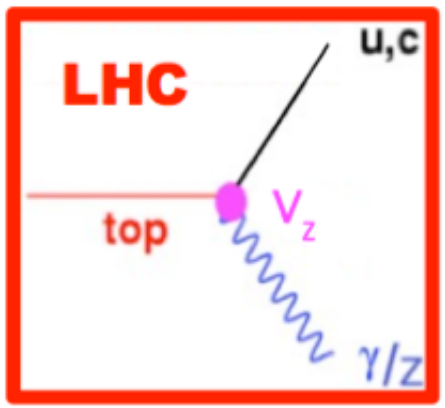
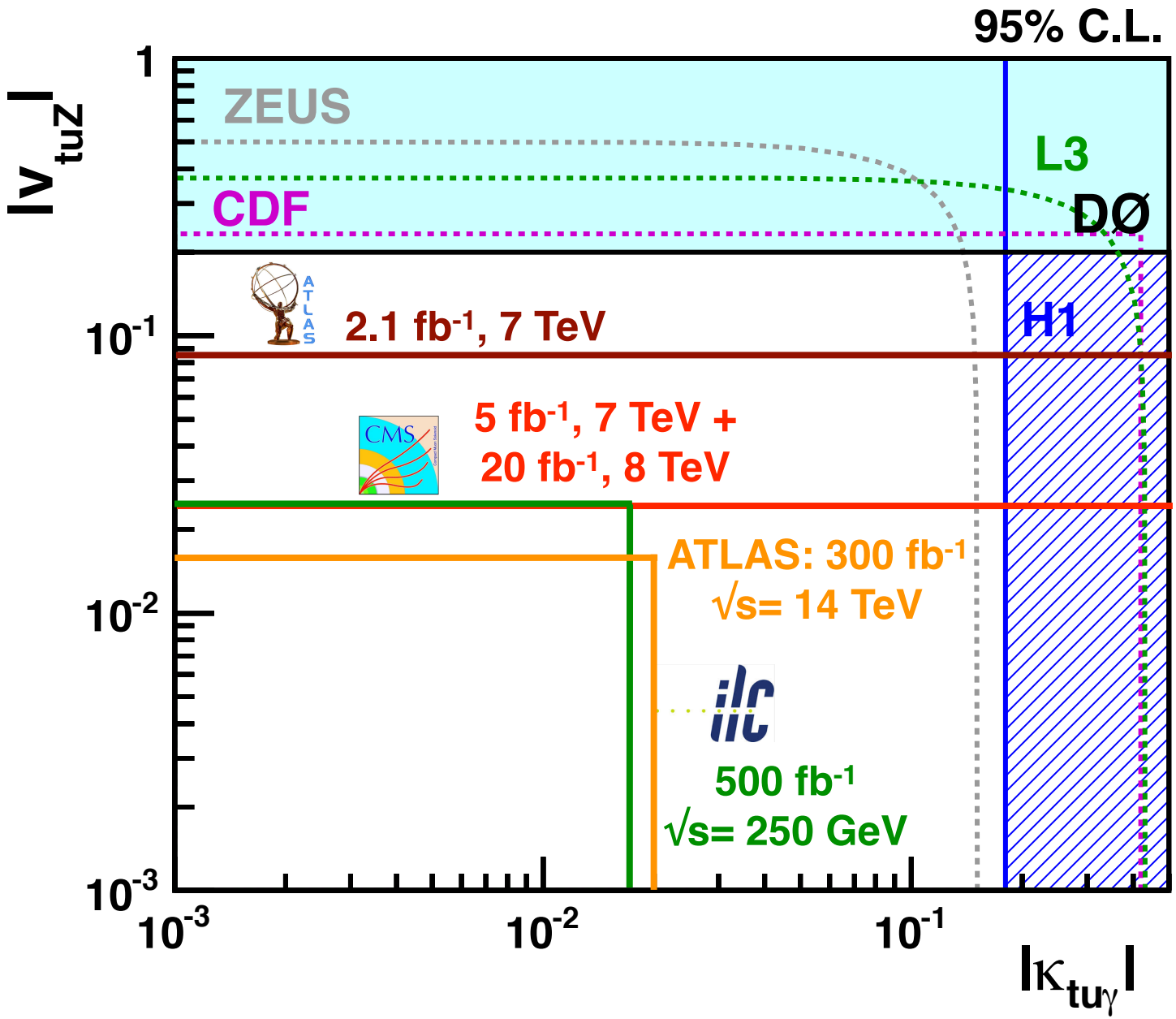
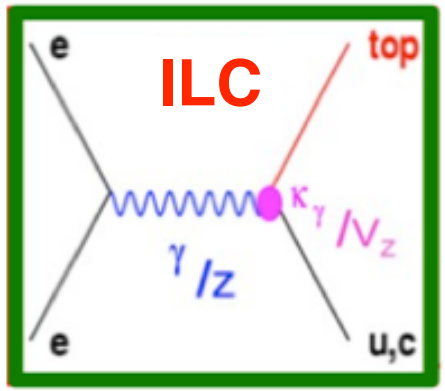
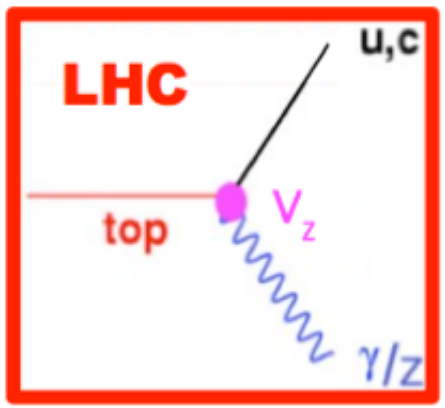


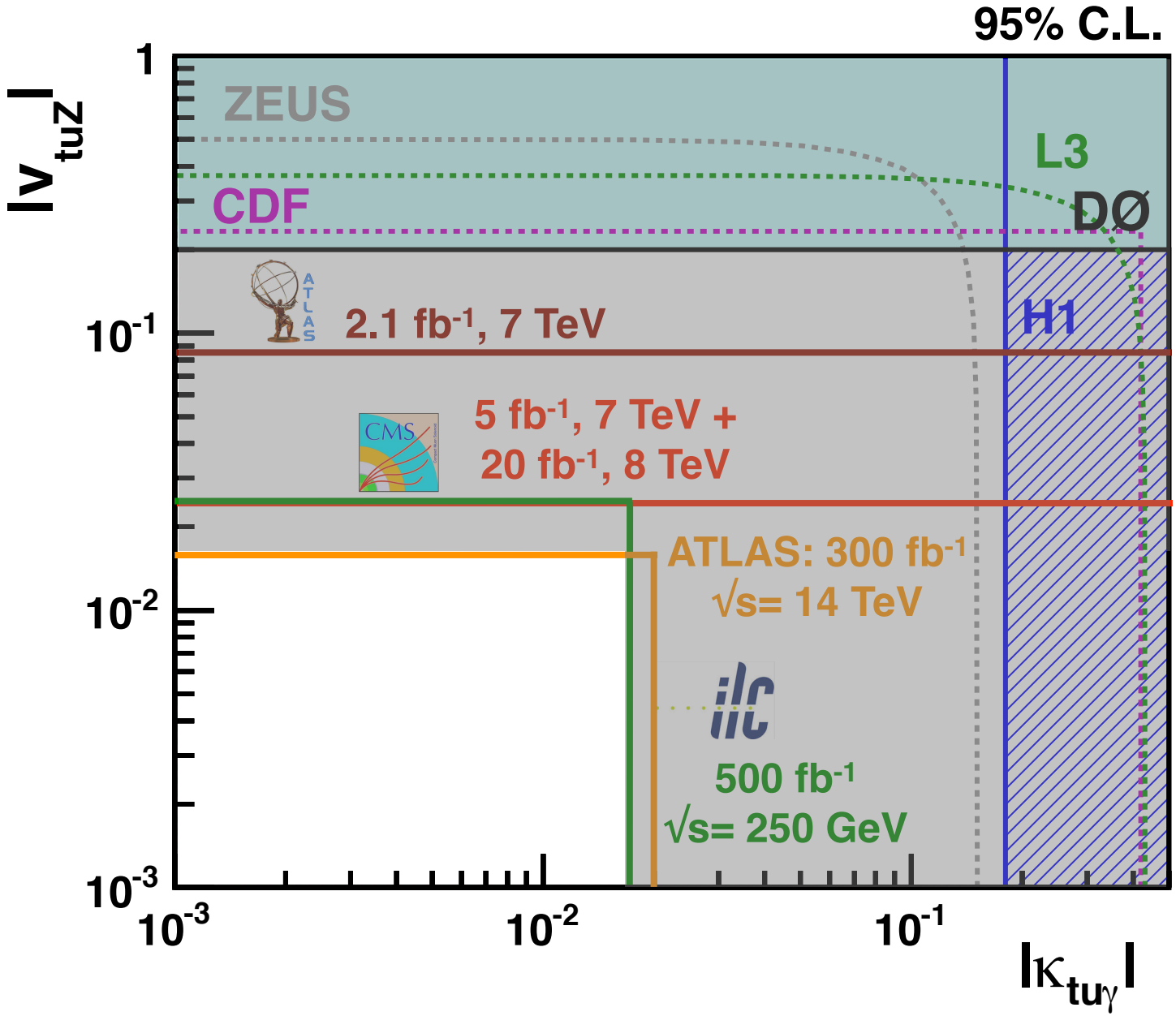




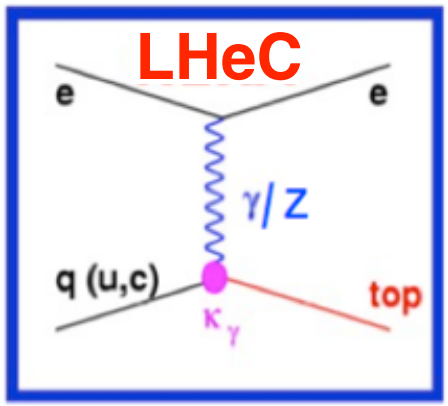
FCNC Top Couplings at Colliders

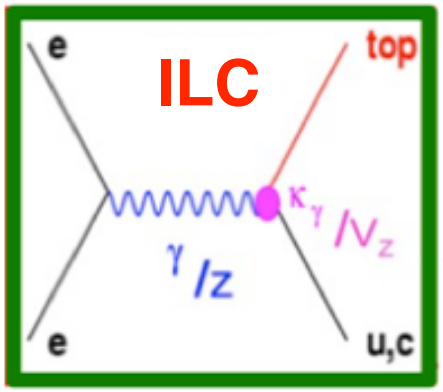


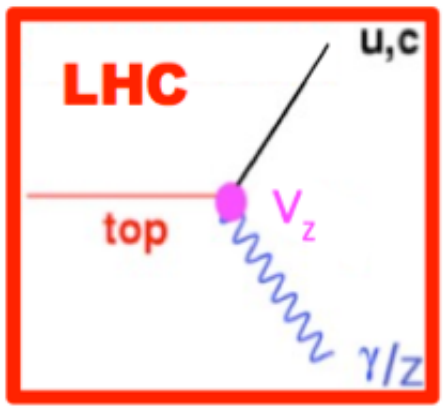


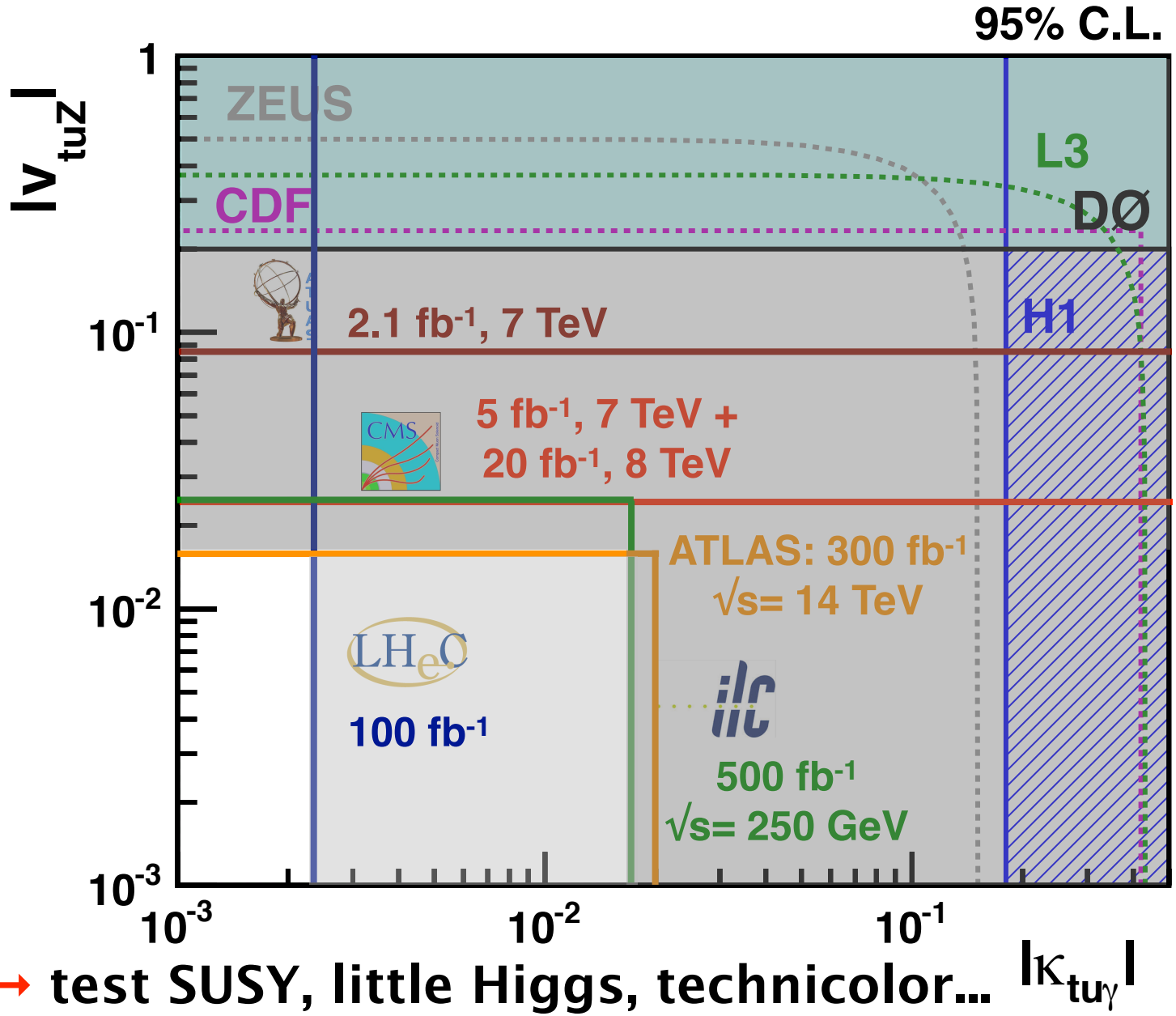


FCNC Top Couplings at Colliders









→ test SUSY, little Higgs, technicolor...

Outline

Introduction
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Summary of Top Quark Properties

property	E_e (GeV)	L_{int} (fb^{-1})	SM value	precision
t: CC unpol.	140	100	6 pb	N_t=600,000
t: CC 80% pol.	140	100	10 pb	N_t=1,000,000
t: NC photoprod.	140	100	0.143 pb	N_t=14,300
$t\bar{t}$: NC DIS	140	100	0.12 pb	N_{tt}=12,000
$t\bar{t}$: NC photoprod.	140	100	3.2 pb	N_{tt}=320,000
top PDF	60	10		measurable
$\|V_{tb}\|$	60	100	1	0.005
f_V^L	60	100	1	0.001–0.01
f_V^R, f_T^L, f_T^R	60	100	0	0.01–0.1
polarisation P_t	$\sqrt{s}$=1.6 TeV	20	0.96	O(10%)
f_T^L, f_T^R from pol.	$\sqrt{s}$=1.6 TeV	20	0	0.01–0.09
EDM: $\tilde{\kappa}$ / $\tilde{\kappa}_Z$	60	100	0 / 0	0.20–0.28/0.6–0.8
MDM: κ / κ_Z	60	100	0 / 0	0.05–0.09/0.9–1.3
FCNC: κ_u / κ_c	70 (γp)	10	0 / 0	O(0.002)/O(0.004)
heavy T(400 GeV)	60	100	BSM: 13.3 fb	$N_{T\to Wb}$=9
heavy T(800 GeV)	60	100	BSM: 0.0047 fb	$N_{T\to Wb}$=0.3

Conclusions

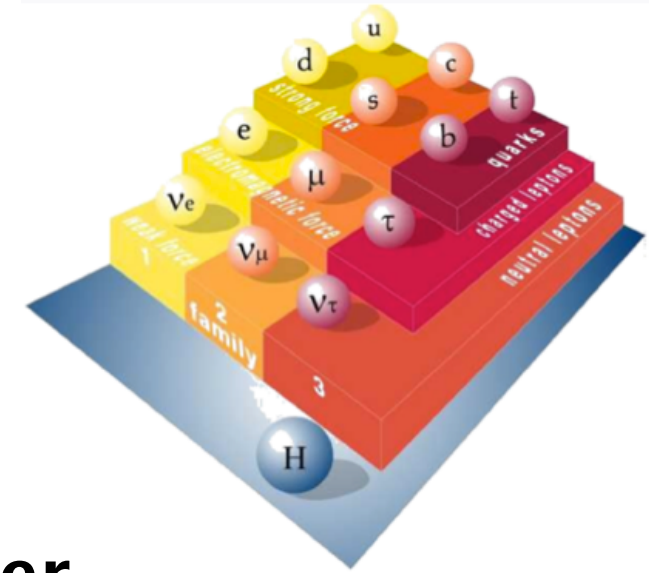
- **future ep collider has a rich analysis programme for top quarks**
- **study top at ep collider for the first time**
- **high precision measurements top quark couplings to gauge bosons (mainly $|V_{tb}|$, Wtb, $t\bar{t}\gamma$, $t\bar{t}Z$)**
- **analyse top quark properties: polarisation, charge, PDFs of tops, ...**
- **many stringent searches for new physics: anomalous couplings, FCNC, heavy top, H^+ bosons, SUSY, technicolor, ...**

→ **all studies worth for yellow paper**

(update to same lumi and beam energies?)

→ **add more studies for long term paper**

→ **detector simulation for long term paper**



Backup

Search for Anomalous Wtb Couplings

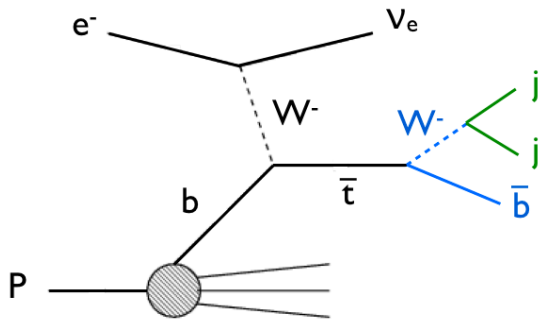
= 1 in SM

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

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

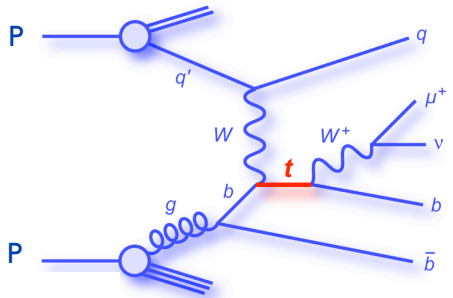
Dutta, Goyal, Kumar, Mellado, arXiv:1307.1688

68% C.L.

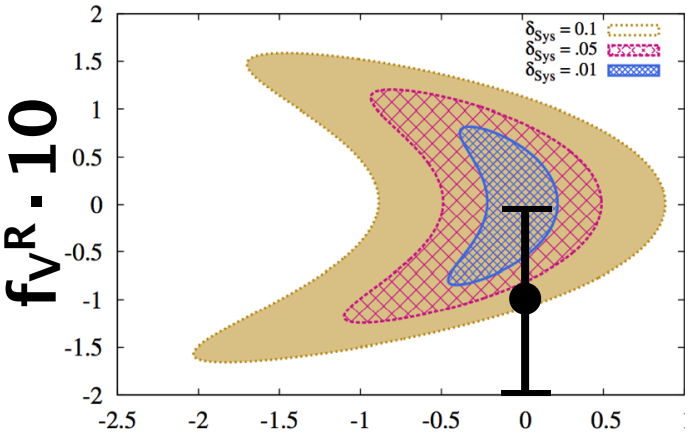


LHC combination preliminary

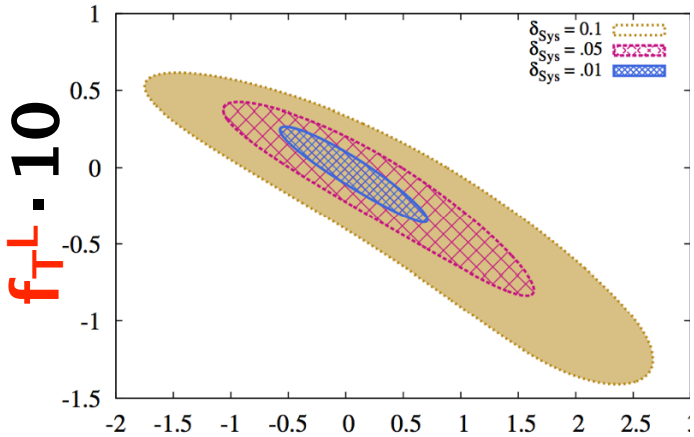
$\sqrt{s}$=7 TeV, L_{int}=35 pb^{-1} - 2.2 fb^{-1}



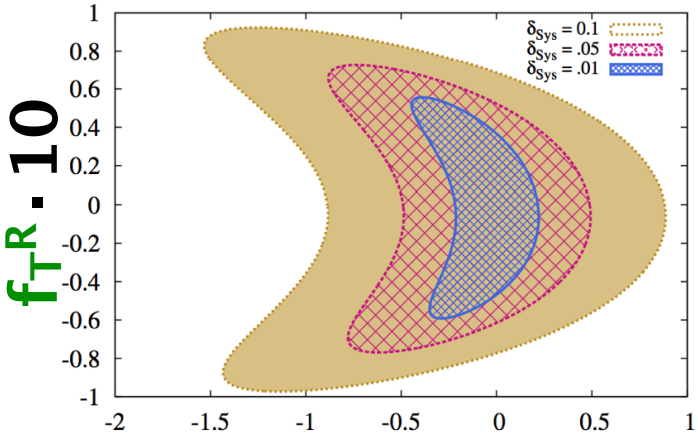
syst. error



syst. error



syst. error



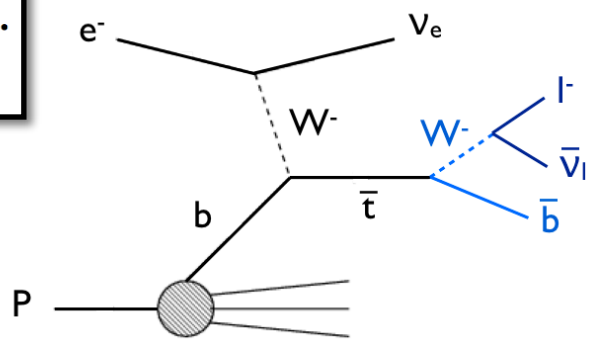
Search for Anomalous Wtb Couplings

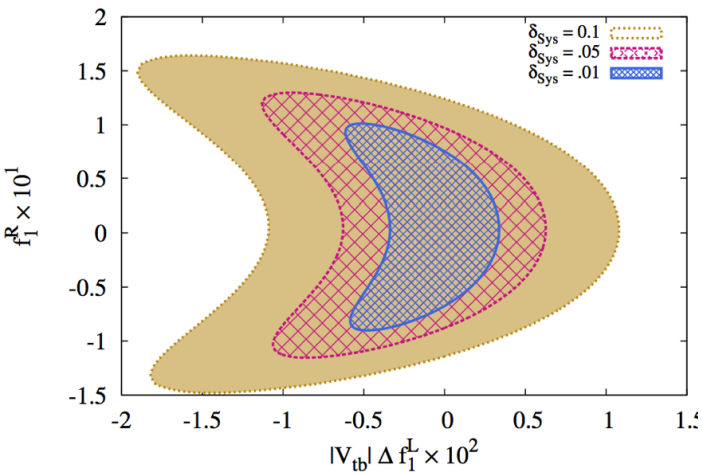
= 1 in SM

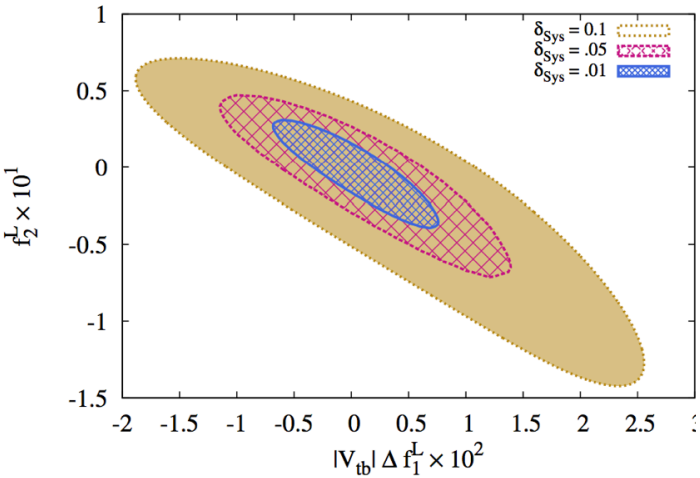
$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}\left(f_V^L P_L + f_V^R P_R\right)tW_{\mu}^{-}$$

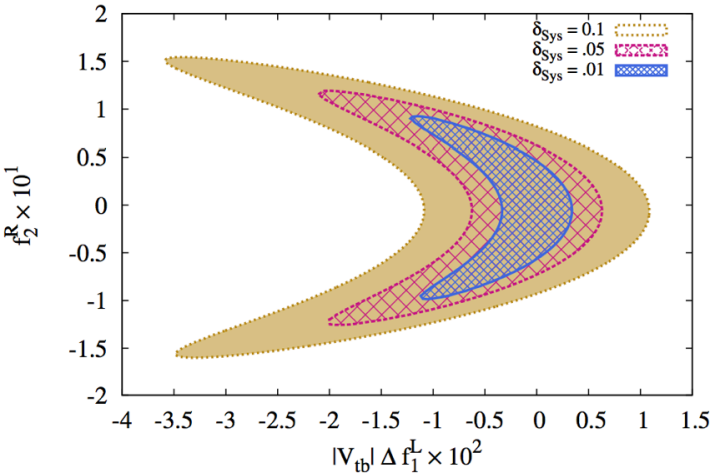
$$-\frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(f_T^L P_L + f_T^R P_R\right)tW_{\mu}^{-} + h.c.$$

68% C.L.

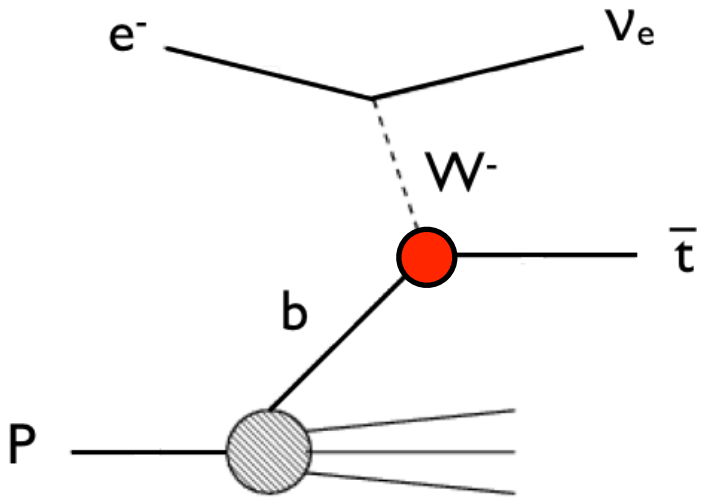




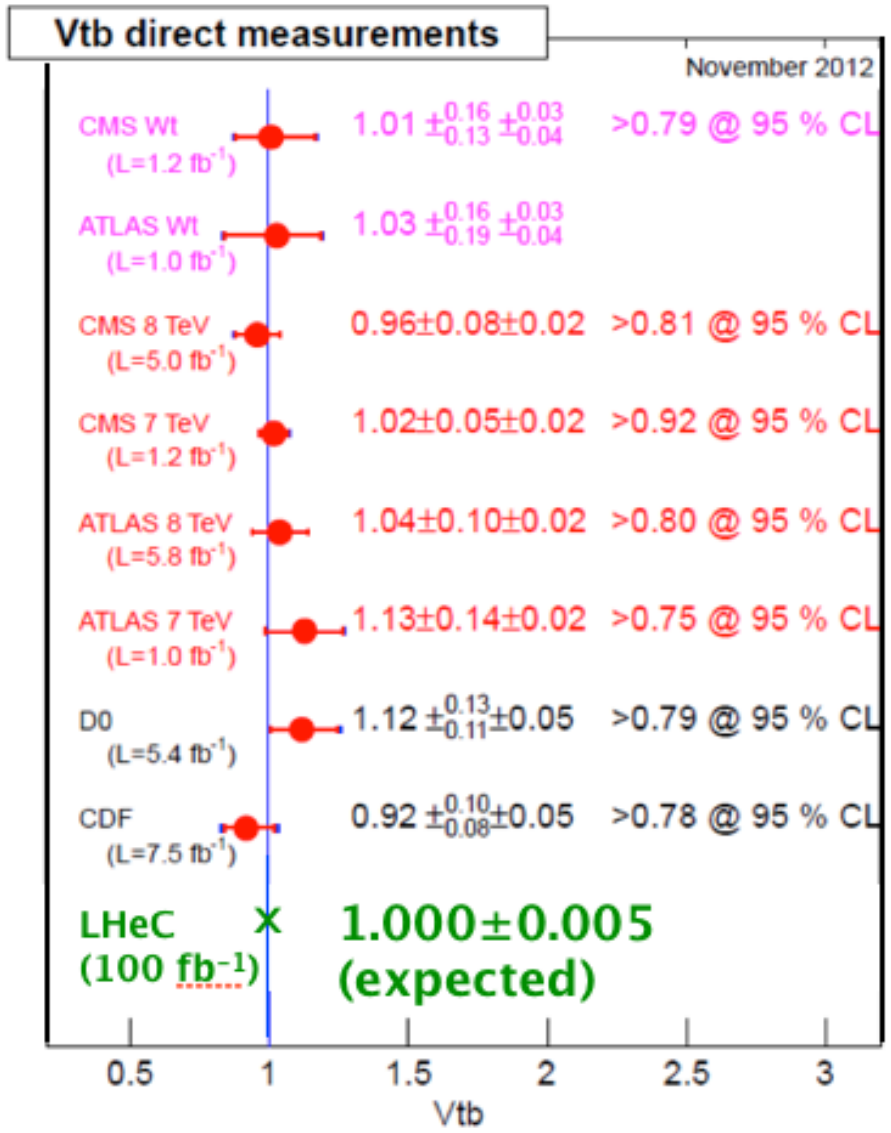




Direct Measurement of $|V_{tb}|$

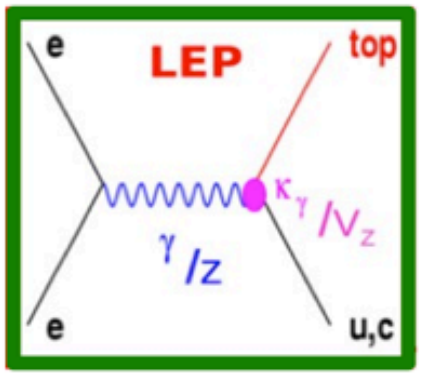


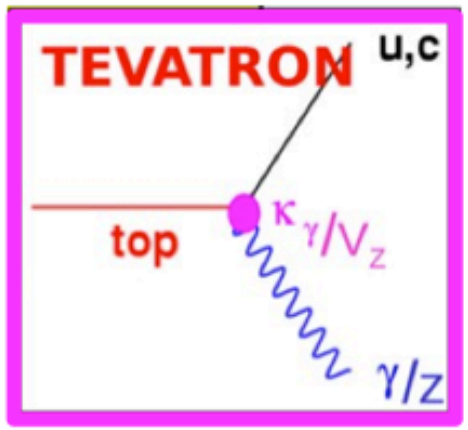
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & \mathbf{V_{tb}} \end{pmatrix}$$

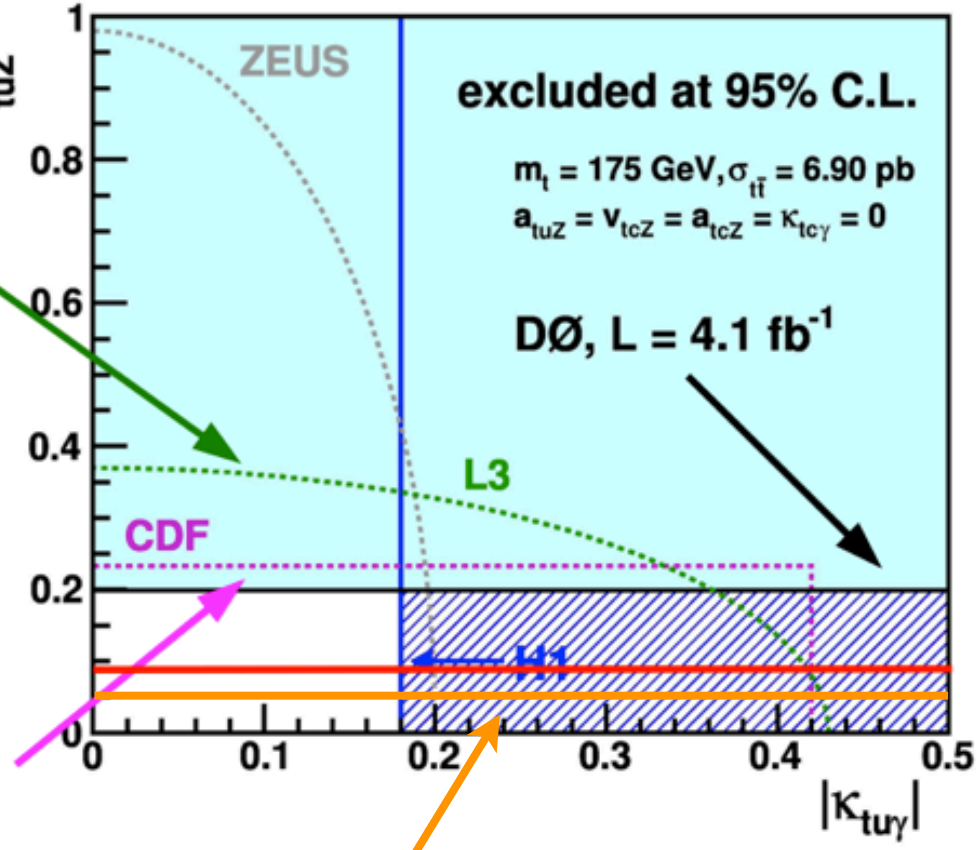


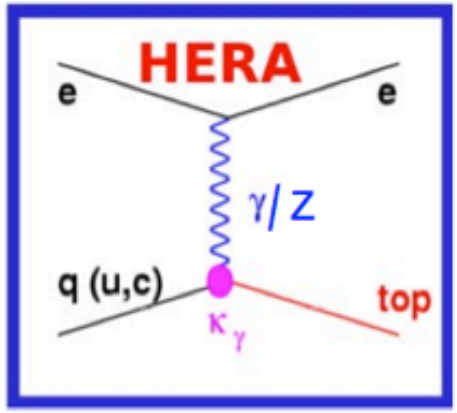
→ **high precision measurement**

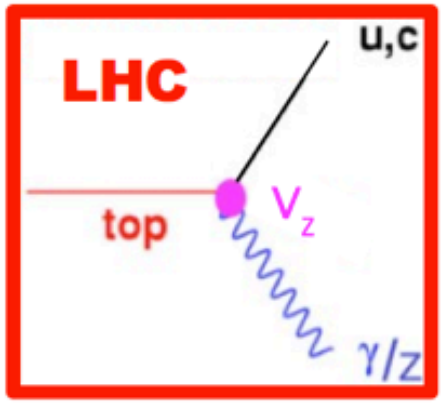
Search for FCNC in Top Quark Decays







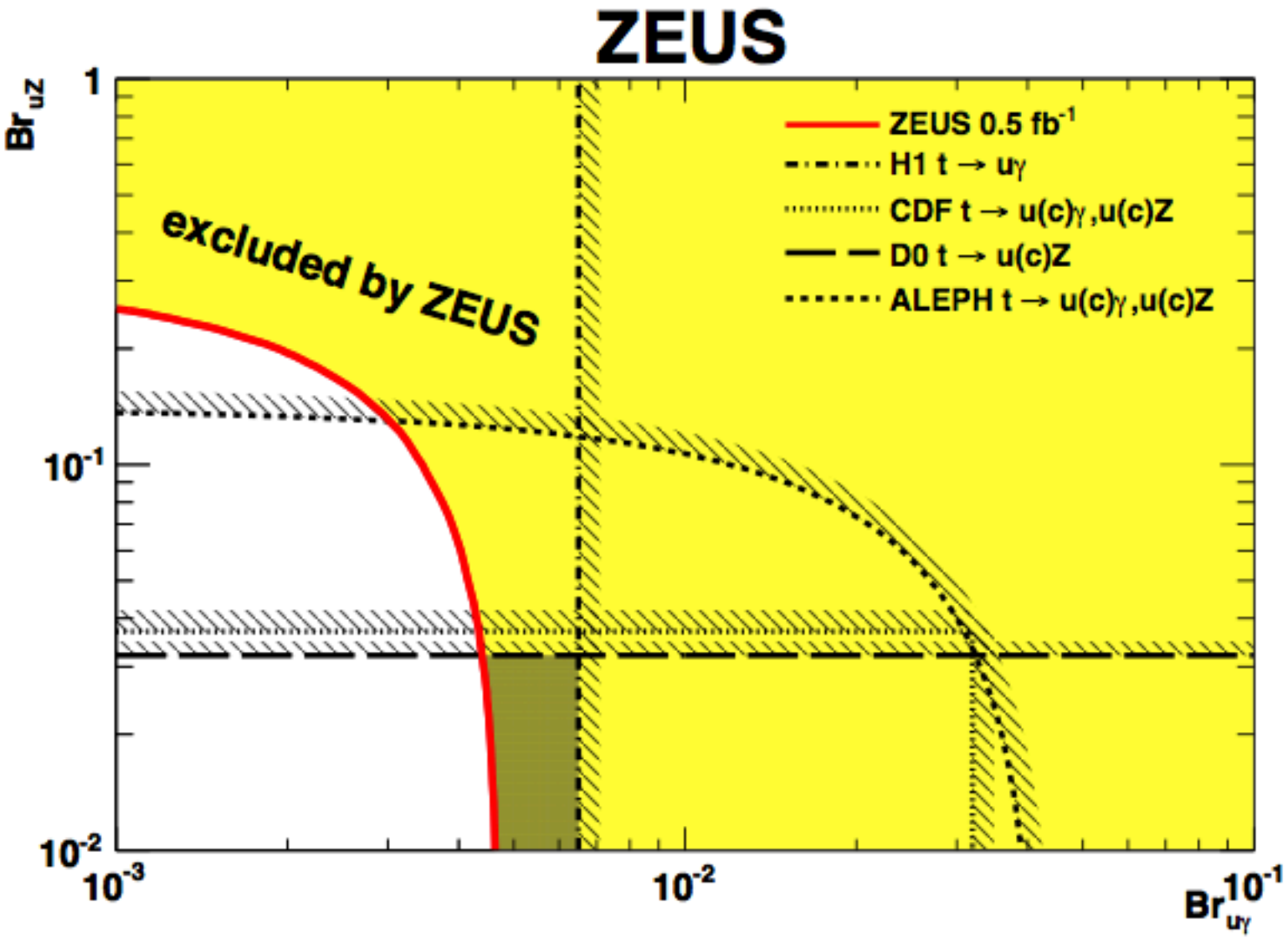




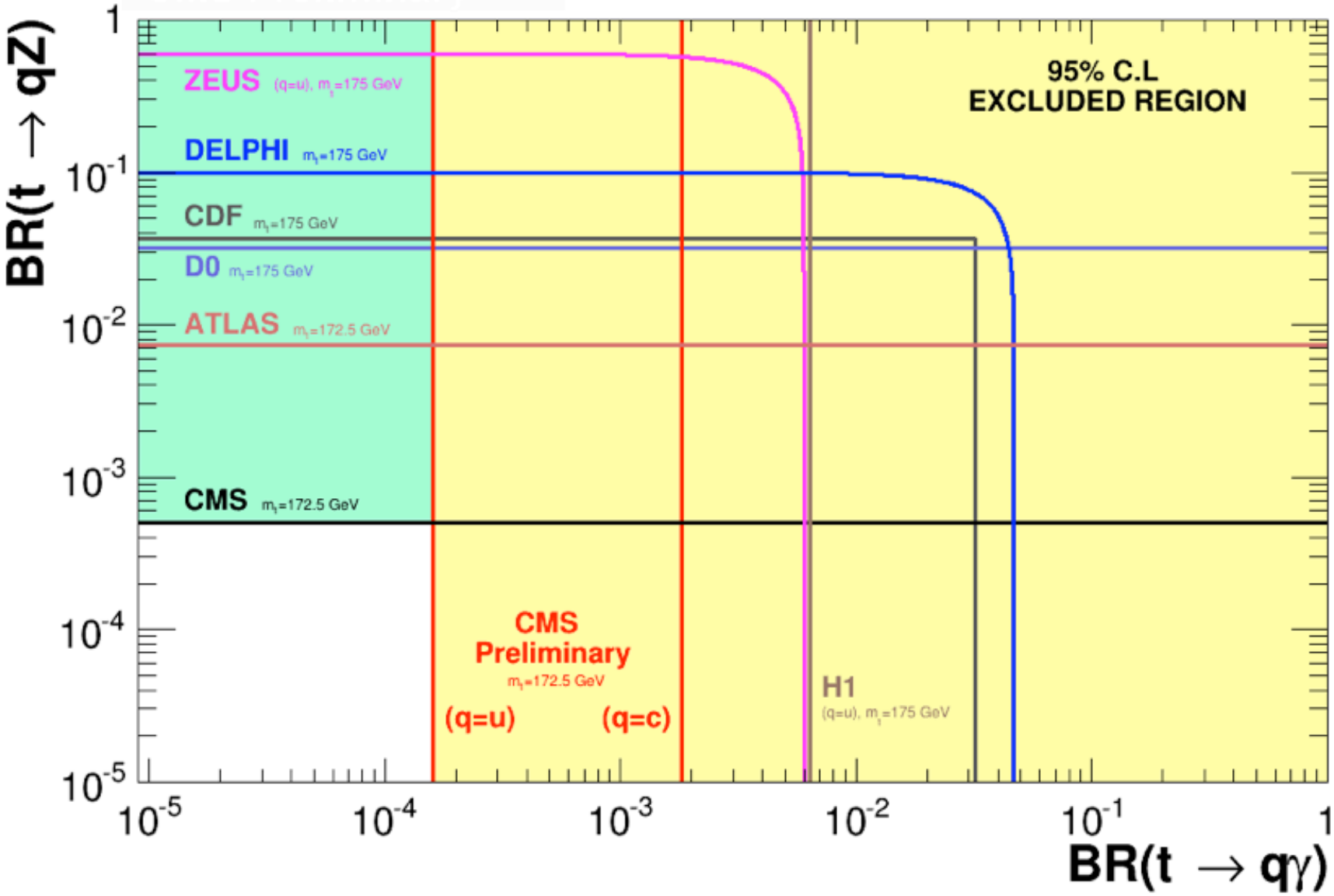
world's best limit
(5.0 fb^{-1})

arXiv:1208.0957 [hep-ex]

Search for FCNC in Top Quark Decays



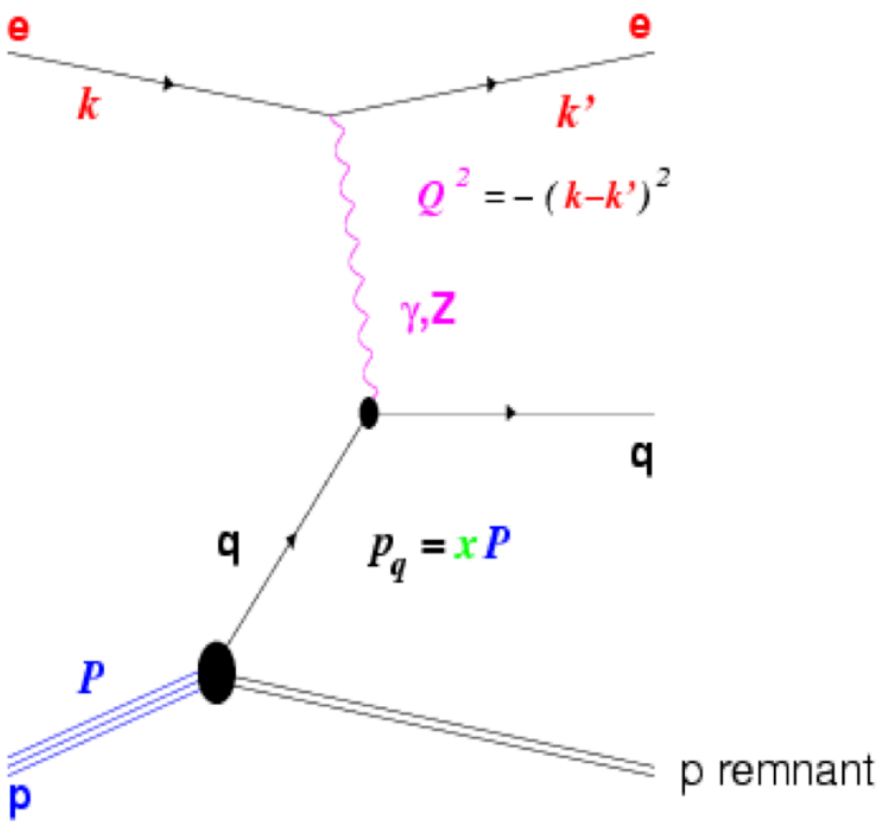
Search for FCNC in Top Quark Decays



Backup EWK

Deep Inelastic Scattering

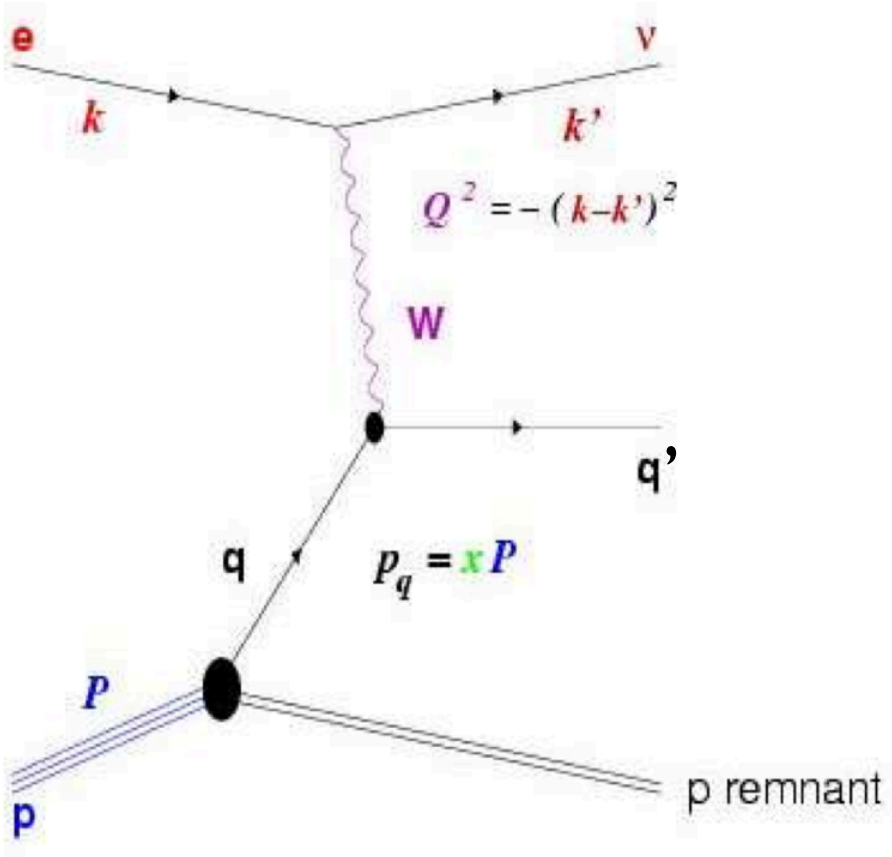
Neutral Current (NC)



Q^2: four-momentum transfer

spatial resolution $\sim 1/Q$

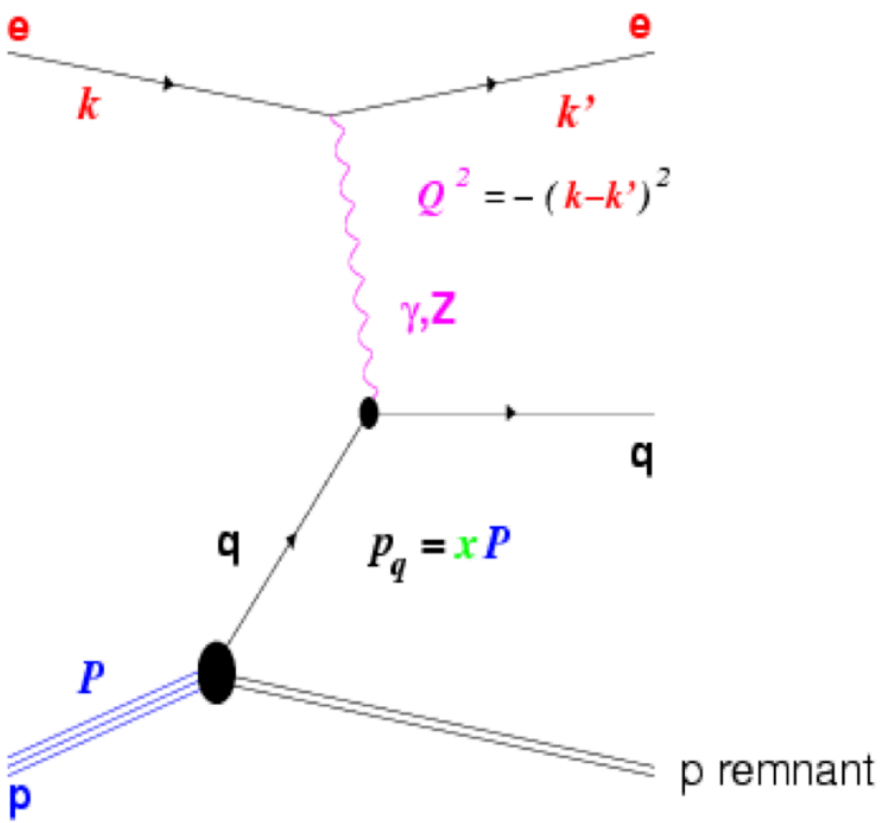
Charged Current (CC)



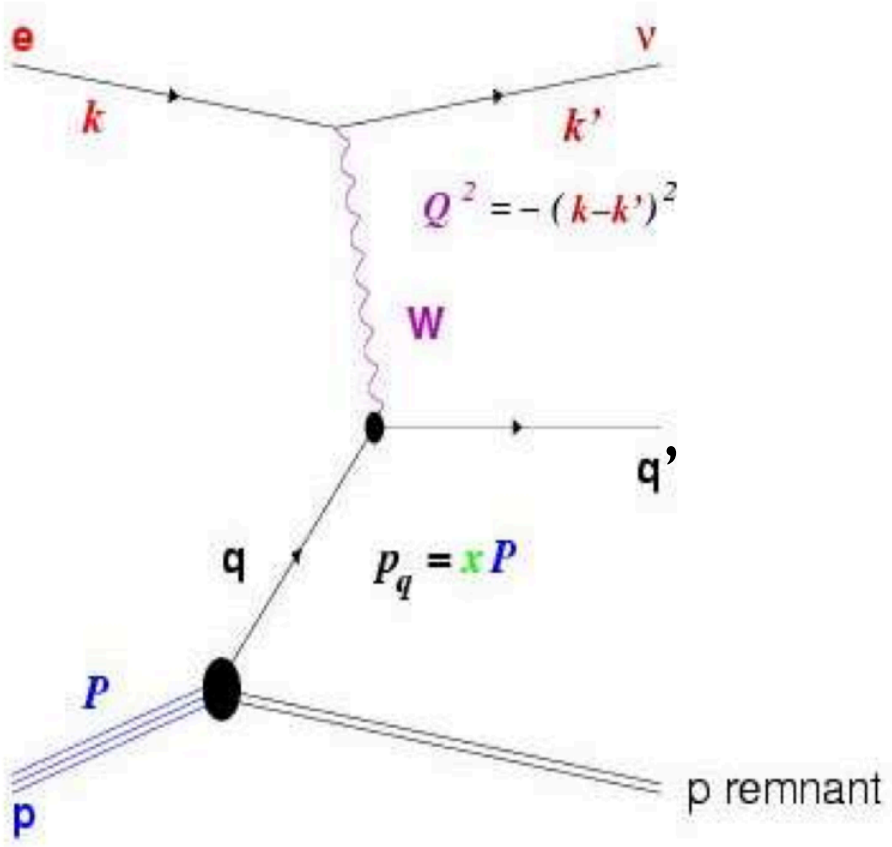
x: fractional momentum of the struck quark

Deep Inelastic Scattering

Neutral Current (NC)



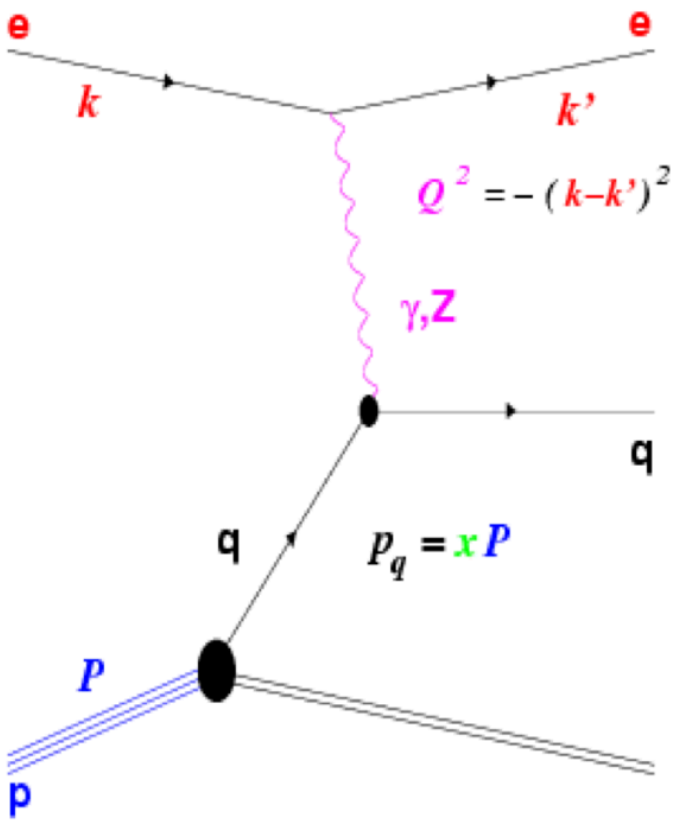
Charged Current (CC)

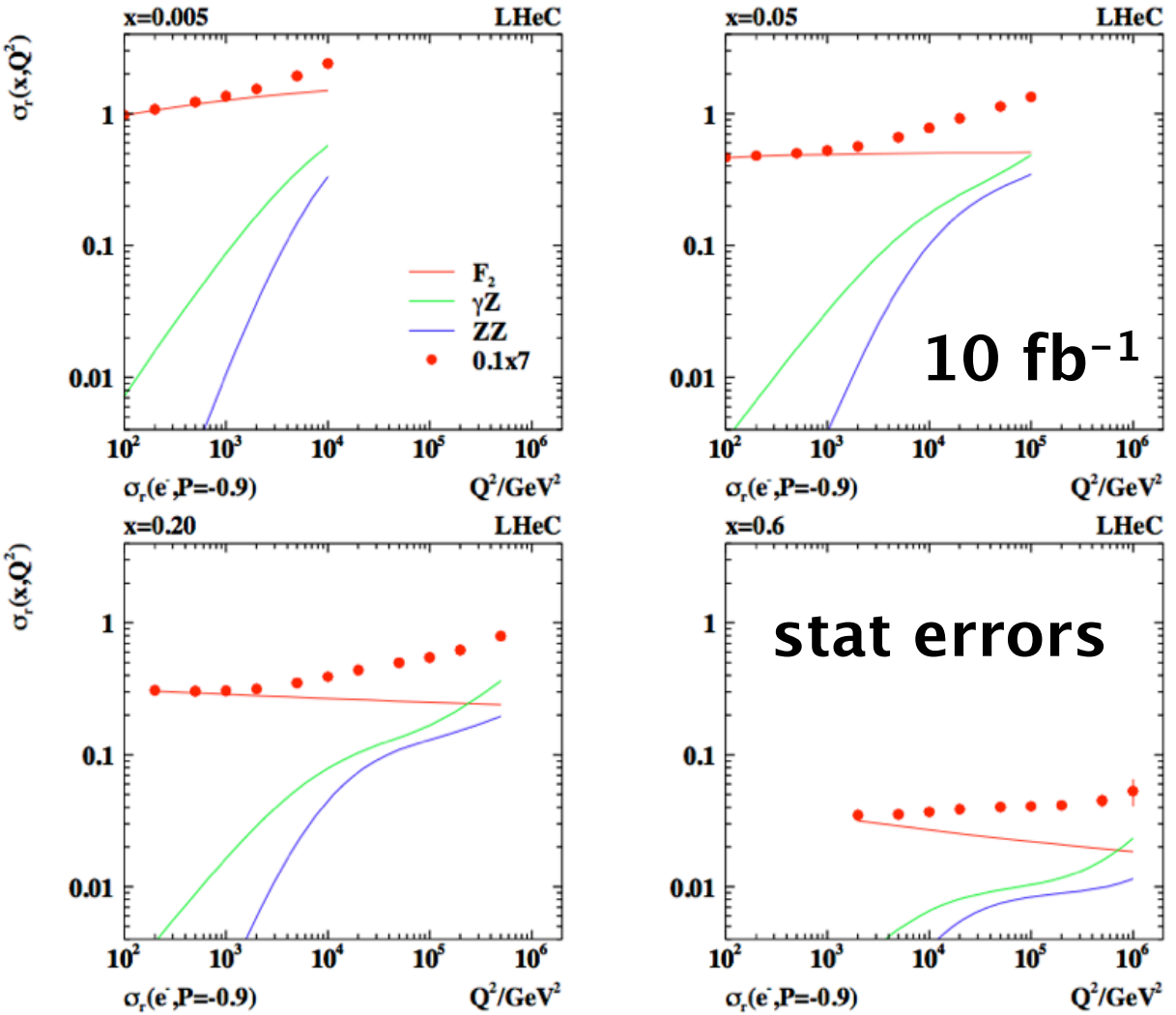


→ LHeC is unique facility for testing EW theory: two charge states, different polarisation states, NC+CC, p or isoscalar targets

NC Cross Section Measurement

Neutral Current (NC)



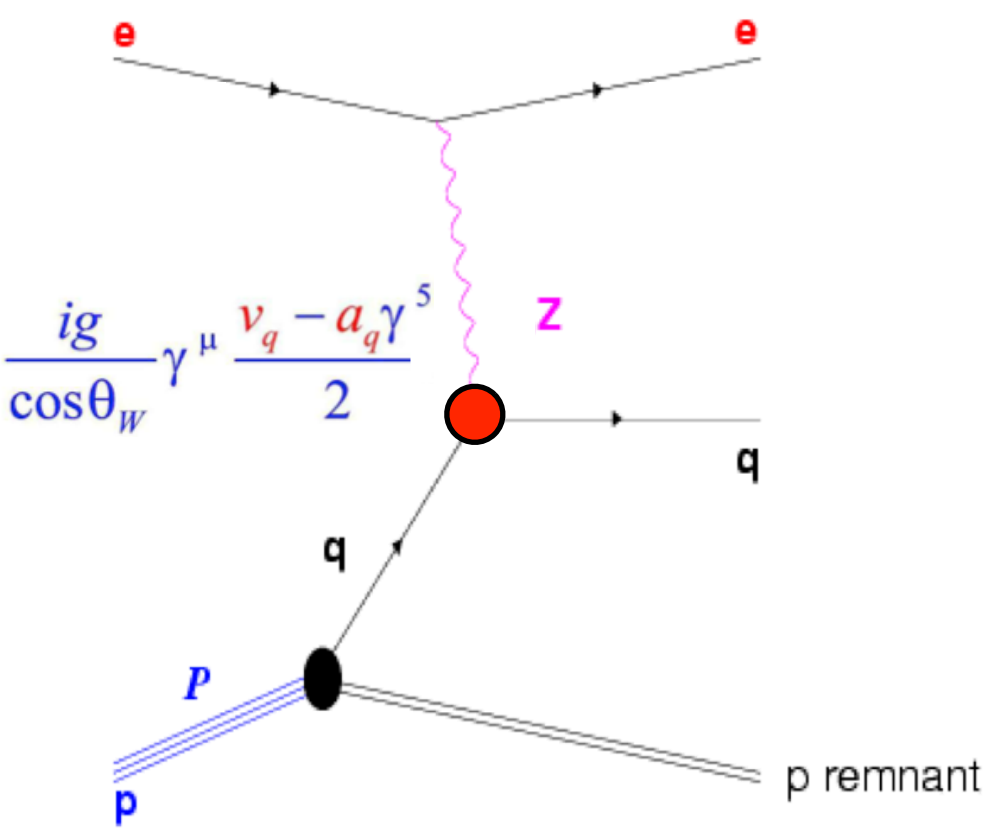


→ high precision in large range of Bjørken x and Q^2

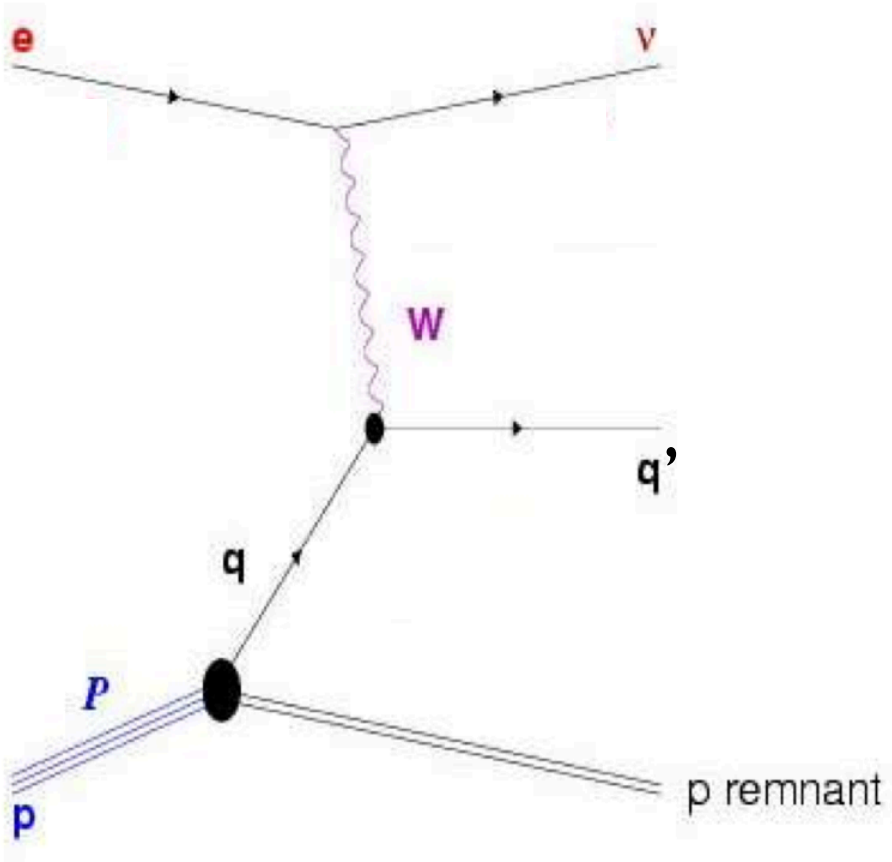
LHeC TDR, J.Phys. G39, 075001 (2012)

Quark Couplings to the Z boson

Neutral Current (NC)



Charged Current (CC)



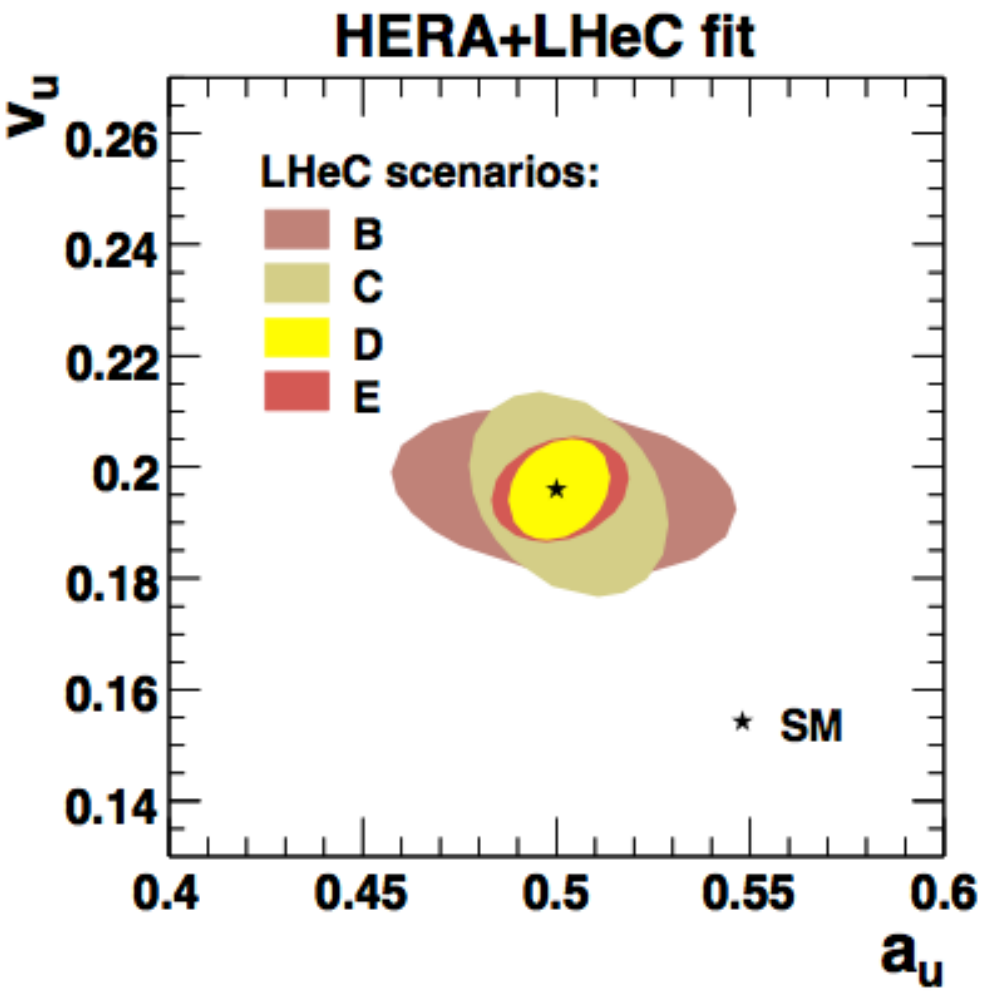
$a_q = I_3^L$ Axial coupling, I^3=+1/2 for u, -1/2 for d

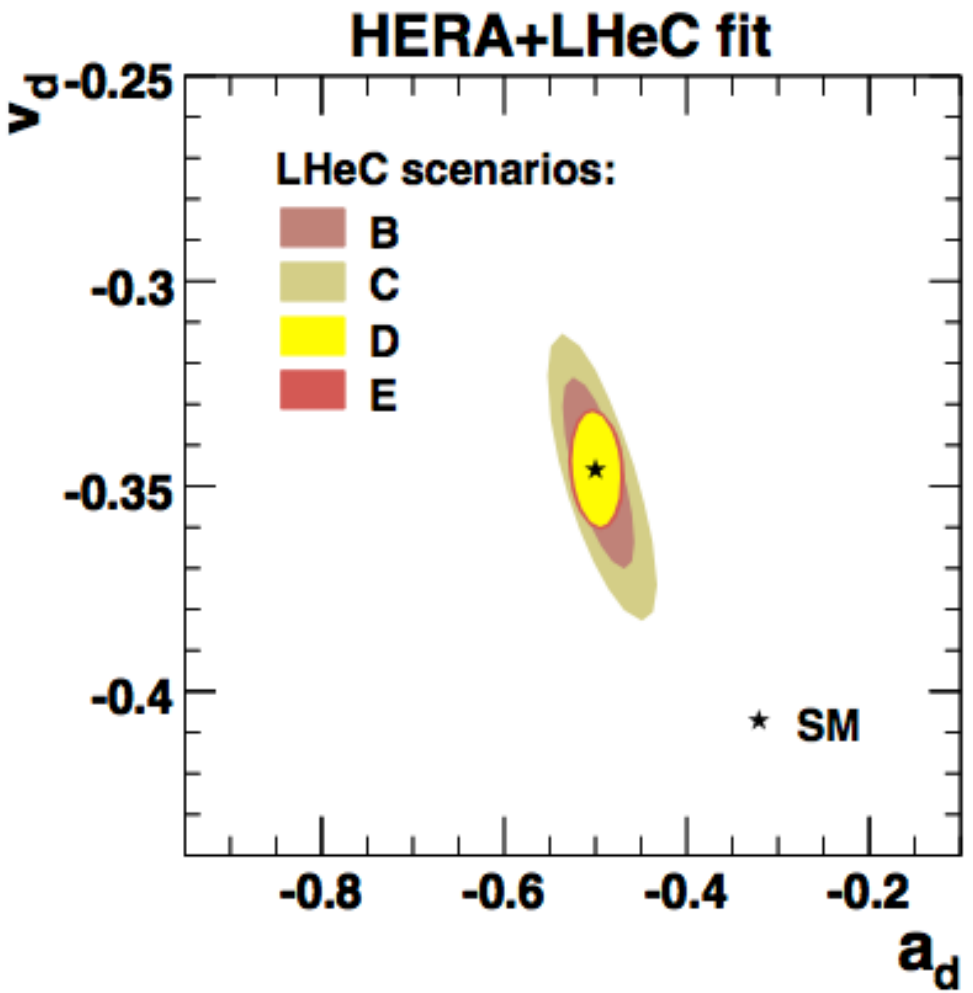
$v_q = I_3^L - 2e_q \sin^2\theta_W$ Vector coupling

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%



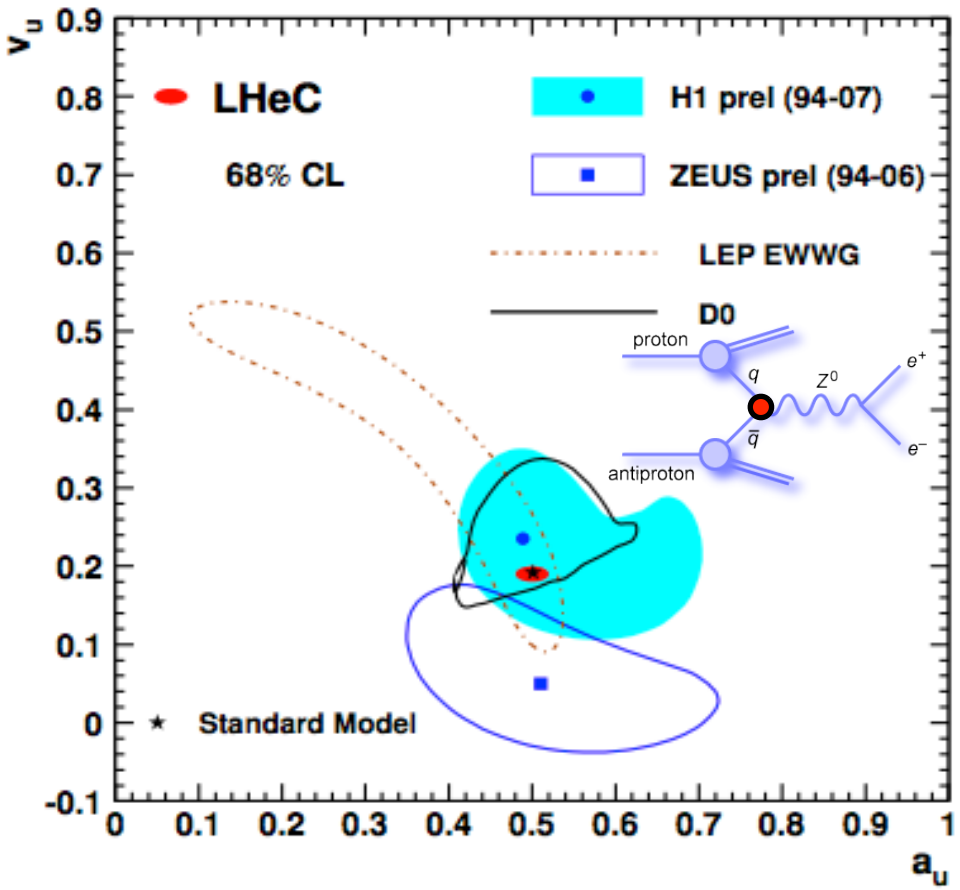


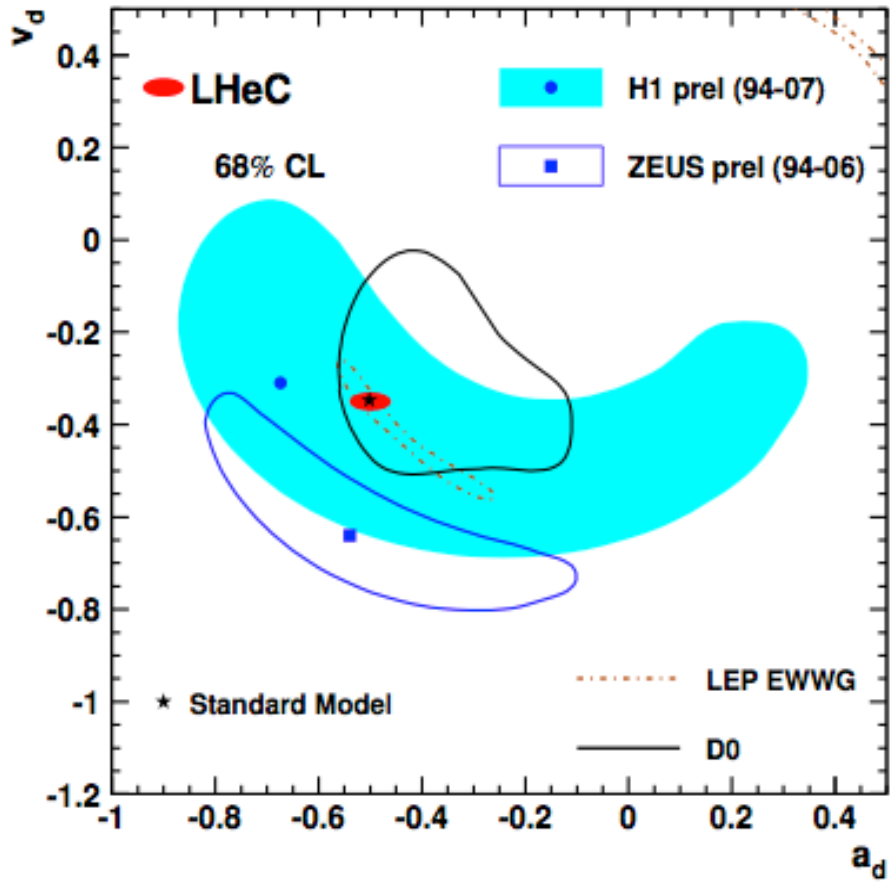
LHeC TDR, J.Phys. G39, 075001 (2012)

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

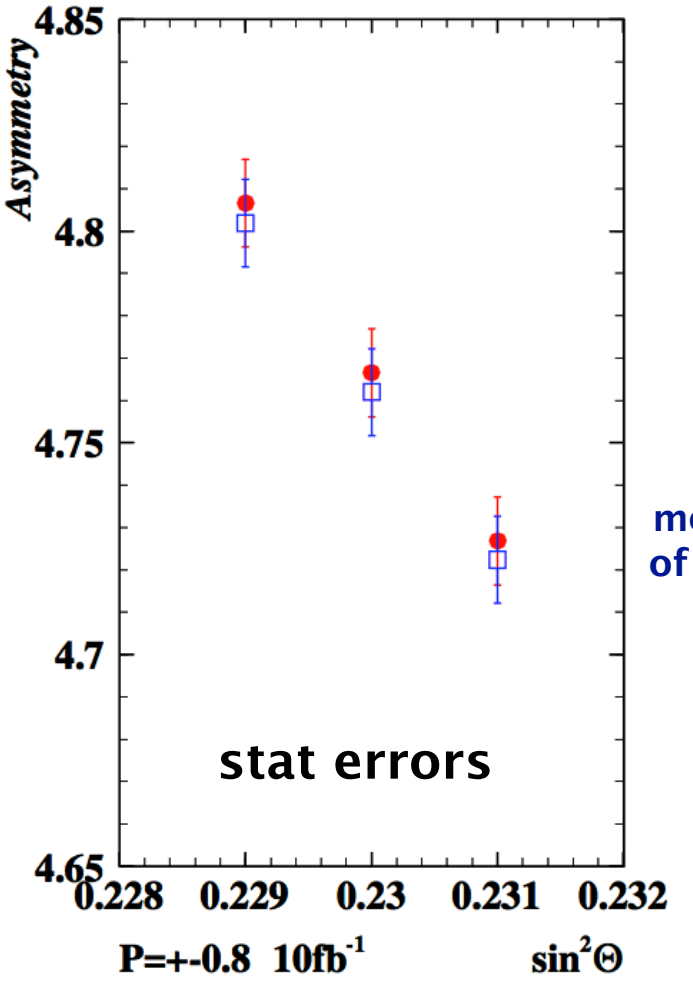
→ test new physics: Z' boson, R-parity violating SUSY, leptoquarks

Asymmetry Measurements

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

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

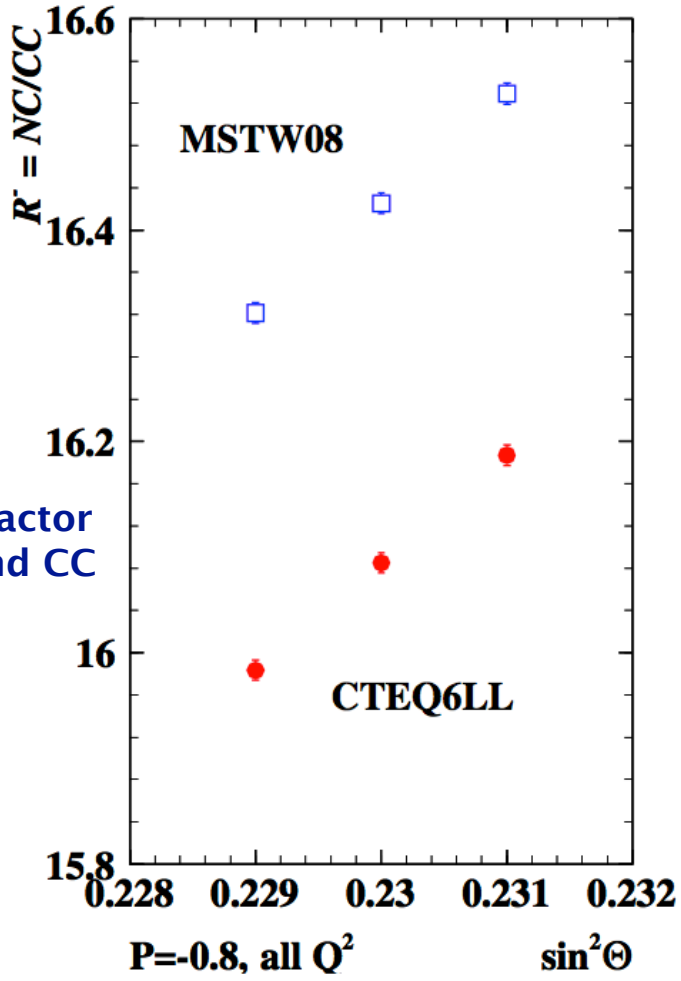
A^-



10 fb^{-1}

e beam: 60 GeV

mean x differs by factor of 6 between NC and CC



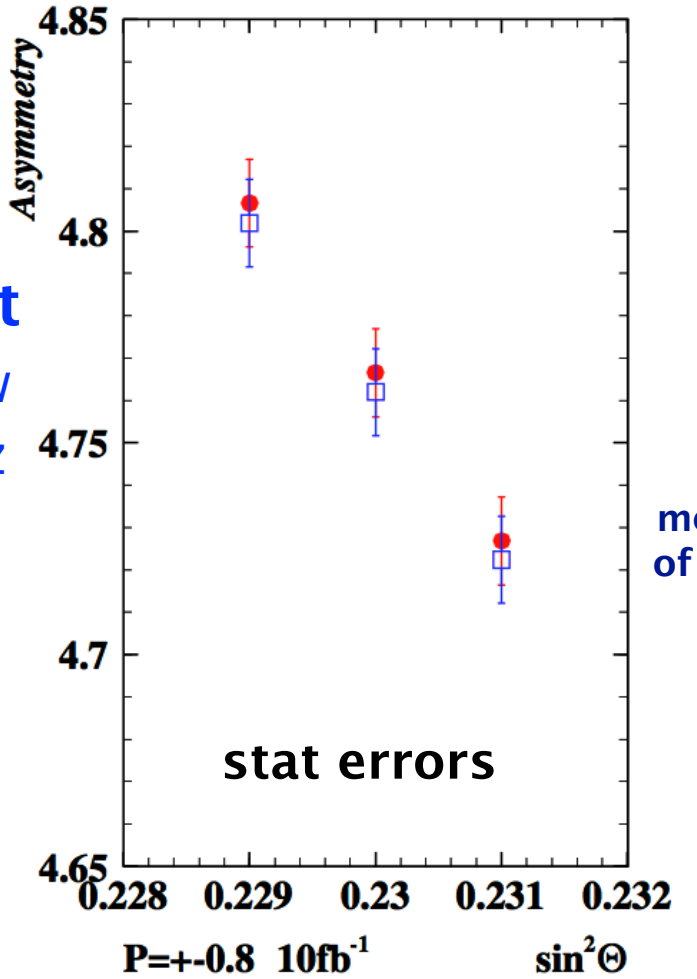
Asymmetry Measurements

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

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

A^-

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



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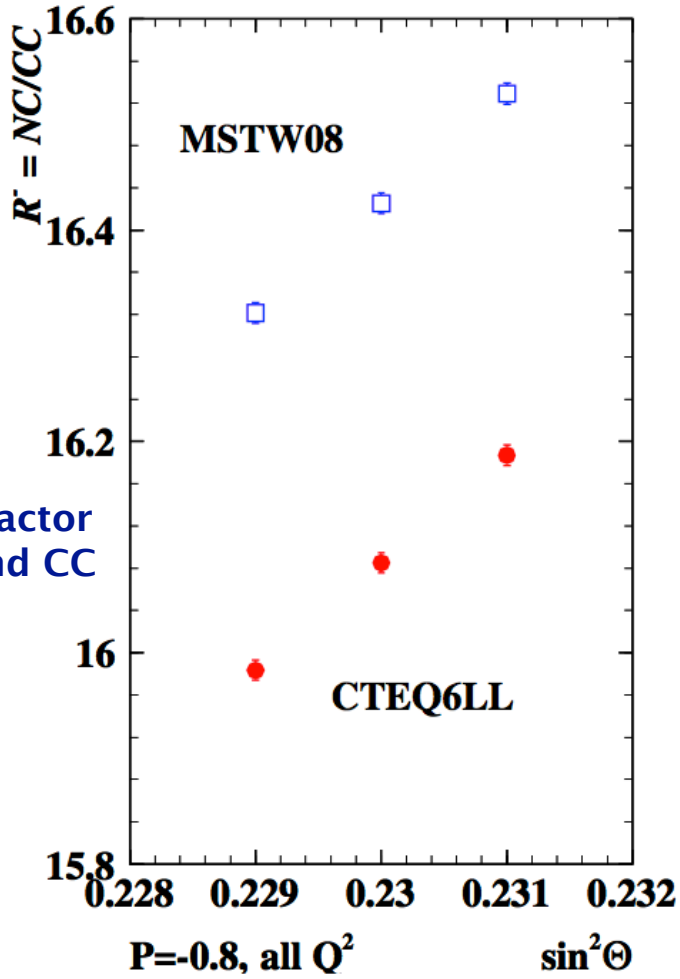
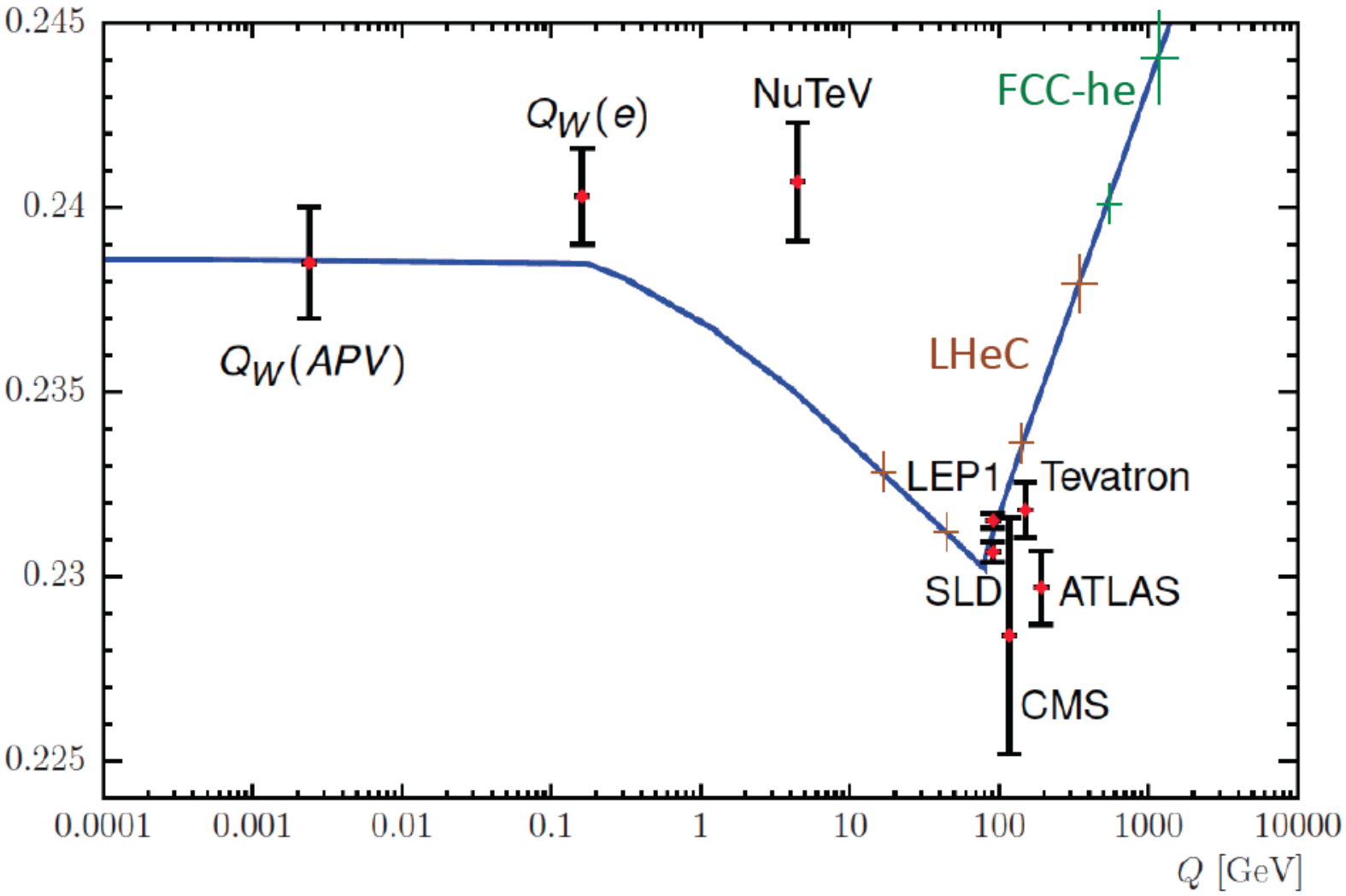
e beam: 60 GeV

mean x differs by factor of 6 between NC and CC



Scale Dependence of $\sin^2\theta_W$



→ **probe large range of scale dependence**