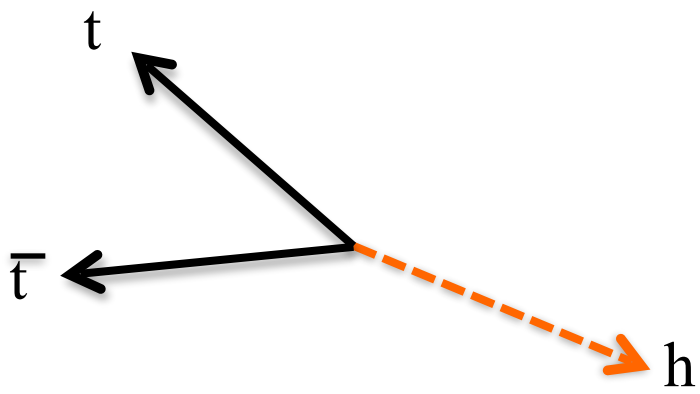
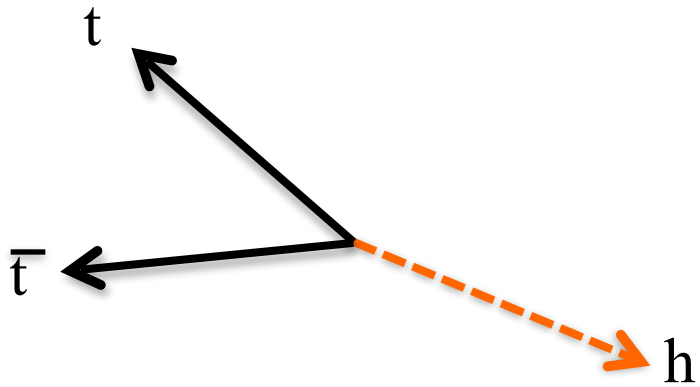


Finding a Bouncing Higgs with Top Quarks at the LHC

1402.5985

Joseph Bramante
with Antonio Delgado, Adam Martin
University of Notre Dame



Finding a Bouncing Higgs with Top Quarks at the LHC

(also Bounding Inflaton Field Ranges, Higgs inflation for particle theorists, and visiting Beijing)

1402.5985

Joseph Bramante
with Antonio Delgado, Adam Martin
University of Notre Dame

What to do after Higgs

A. BUILD MODELS TO SOLVE OLD PROBLEMS, I.E., STRONG CP, BARYOGENESIS, DARK MATTER, CC

What to do after Higgs

A. BUILD MODELS TO SOLVE OLD PROBLEMS, I.E., STRONG CP, BARYOGENESIS, DARK MATTER, CC
B. AMBULANCE CHASE

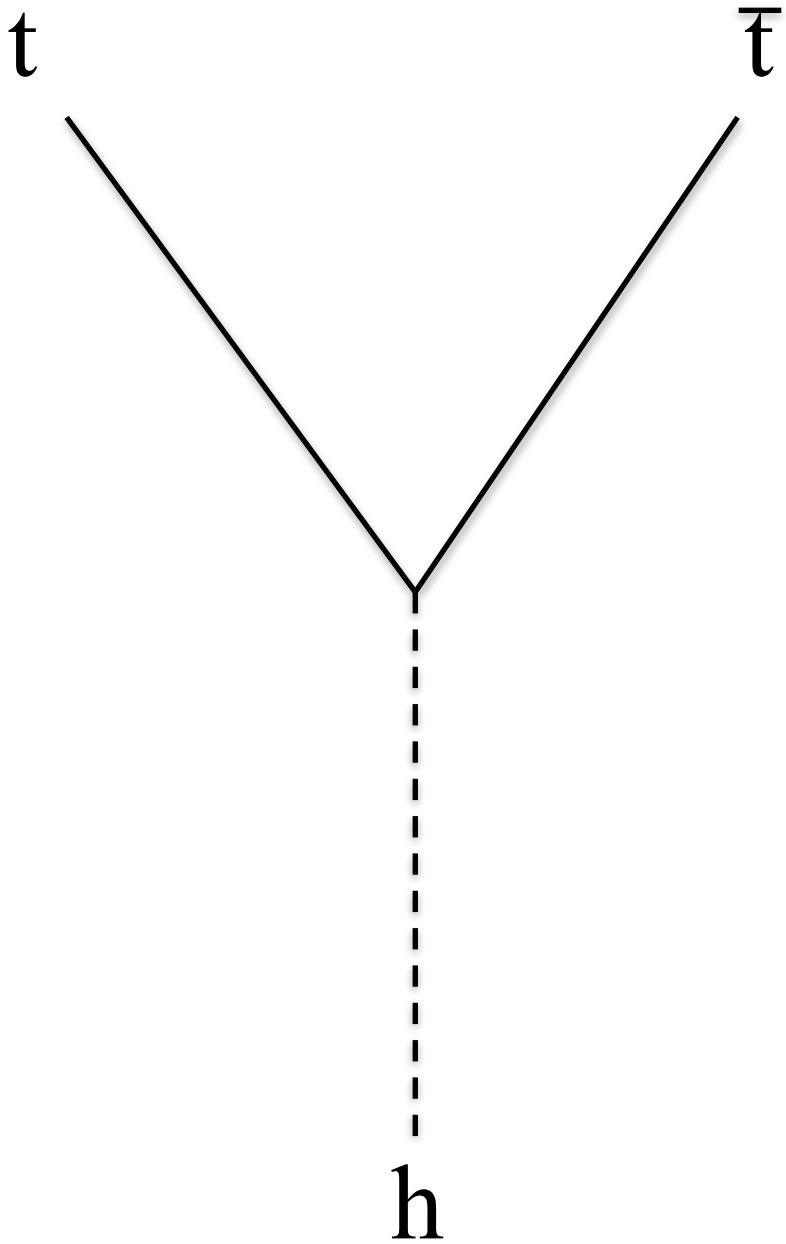
What to do after Higgs

A. BUILD MODELS TO SOLVE OLD PROBLEMS, I.E., STRONG CP, BARYOGENESIS, DARK MATTER, CC
B. AMBULANCE CHASE
C. BOUND MODELS WITH DATA [NEW AND OLD]

What to do after Higgs

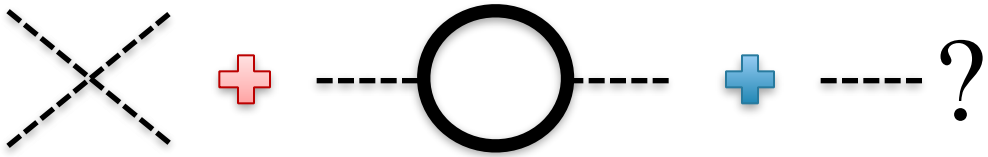
A. BUILD MODELS TO SOLVE OLD PROBLEMS, I.E., STRONG CP, BARYOGENESIS, DARK MATTER, CC
B. AMBULANCE CHASE
C. BOUND MODELS WITH DATA [NEW AND OLD]
D. DEFINE AND MOTIVATE NEW OBSERVABLES
    A. BLEEDING EDGE DISCOVERY POTENTIAL
    B. WE GET TO TALK TO EXPERIMENTALISTS

The ttH Coupling

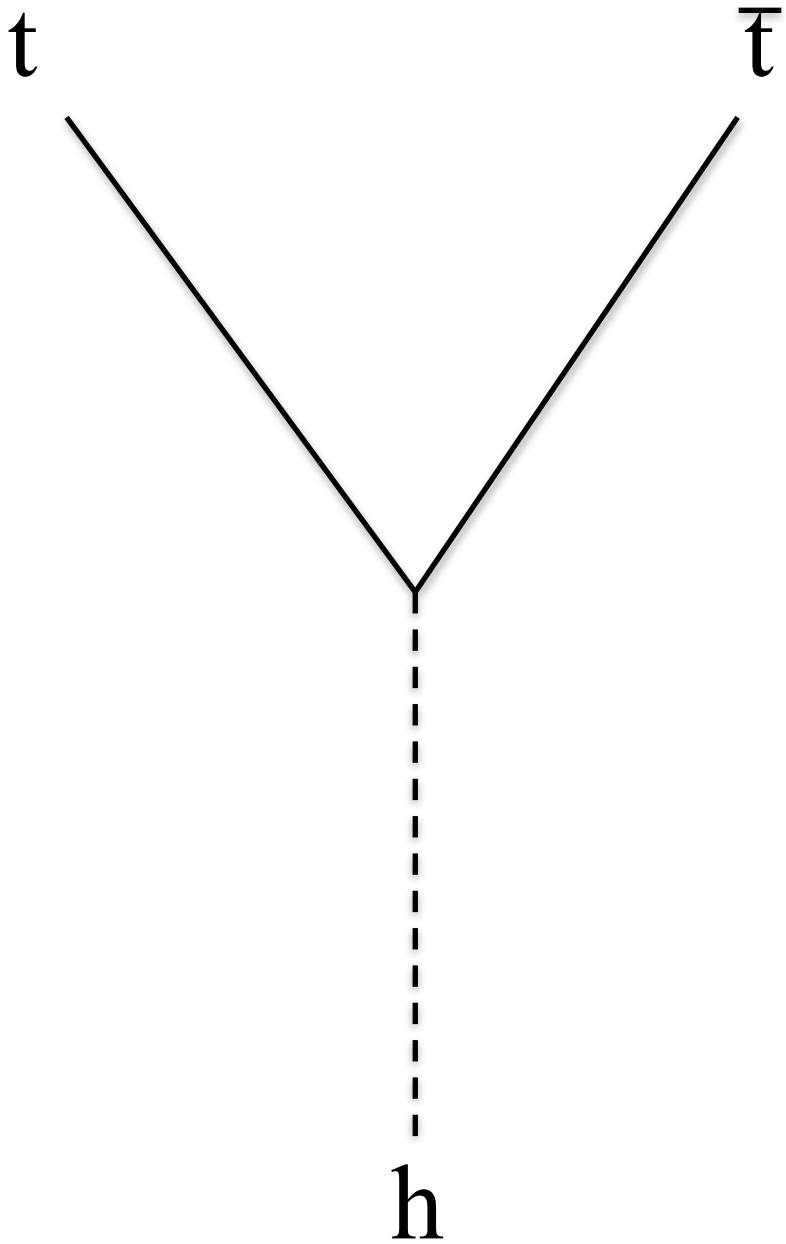


Naturalness

$$m_h^2 \approx m_{h0}^2 - \frac{\lambda_f^2}{8\pi^2} N_c^f \int^{\Lambda} \frac{d^4p}{p^2} \approx m_{h0}^2 + \frac{\lambda_f^2}{8\pi^2} N_c^f \Lambda^2$$

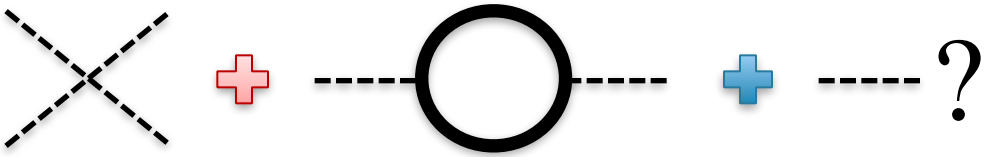


The ttH Coupling



Naturalness

$$m_h^2 \approx m_{h0}^2 - \frac{\lambda_f^2}{8\pi^2} N_c^f \int^{\Lambda} \frac{d^4p}{p^2} \approx m_{h0}^2 + \frac{\lambda_f^2}{8\pi^2} N_c^f \Lambda^2$$



Top Yukawa is unity and tth measurements can be made.

$$\frac{\sigma^{NP}(pp \to tth)}{\sigma^{SM}(pp \to tth)} = \mu_{tth} < 6.6(2\sigma)$$

CMS Higgs 13-020

We can parameterize UV physics with up to Dimension 6 couplings to the Higgs boson.

$$\Big[-\frac{2g'\,\bar{c}_{uB}}{m_W^2} y_u\, \Phi^\dagger \cdot \bar{Q}_L \gamma^{\mu\nu} u_R\, B_{\mu\nu} - \frac{4g\,\bar{c}_{uW}}{m_W^2} y_u\, \Phi^\dagger \cdot (\bar{Q}_L T_{2k}) \gamma^{\mu\nu} u_R\, W^k_{\mu\nu}$$
$$- \frac{4g_s\,\bar{c}_{uG}}{m_W^2} y_u\, \Phi^\dagger \cdot \bar{Q}_L \gamma^{\mu\nu} T_a u_R G^a_{\mu\nu} + \frac{2g'\,\bar{c}_{dB}}{m_W^2} y_d\, \Phi \bar{Q}_L \gamma^{\mu\nu} d_R\, B_{\mu\nu}$$
$$+ \frac{4g\,\bar{c}_{dW}}{m_W^2} y_d\, \Phi (\bar{Q}_L T_{2k}) \gamma^{\mu\nu} d_R\, W^k_{\mu\nu} + \frac{4g_s\,\bar{c}_{dG}}{m_W^2} y_d\, \Phi \bar{Q}_L \gamma^{\mu\nu} T_a d_R G^a_{\mu\nu}$$
$$+ \frac{2g'\,\bar{c}_{eB}}{m_W^2} y_\ell\, \Phi \bar{L}_L \gamma^{\mu\nu} e_R\, B_{\mu\nu} + \frac{4g\,\bar{c}_{eW}}{m_W^2} y_\ell\, \Phi (\bar{L}_L T_{2k}) \gamma^{\mu\nu} e_R\, W^k_{\mu\nu} + \text{h.c.} \Big]$$

$$\frac{\bar{c}_H}{2v^2} \partial^\mu [\Phi^\dagger \Phi] \partial_\mu [\Phi^\dagger \Phi] + \frac{\bar{c}_T}{2v^2} [\Phi^\dagger \overleftrightarrow{D}^\mu \Phi] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi] - \frac{\bar{c}_6 \lambda}{v^2} [H^\dagger H]^3$$
$$- \Big[\frac{\bar{c}_u}{v^2} y_u \Phi^\dagger \Phi\, \Phi^\dagger \cdot \bar{Q}_L u_R + \frac{\bar{c}_d}{v^2} y_d \Phi^\dagger \Phi\, \Phi \bar{Q}_L d_R + \frac{\bar{c}_l}{v^2} y_\ell\, \Phi^\dagger \Phi\, \Phi \bar{L}_L e_R + \text{h.c.} \Big]$$
$$+ \frac{ig\,\bar{c}_W}{m_W^2} [\Phi^\dagger T_{2k} \overleftrightarrow{D}^\mu \Phi] D^\nu W^k_{\mu\nu} + \frac{ig'\,\bar{c}_B}{2m_W^2} [\Phi^\dagger \overleftrightarrow{D}^\mu \Phi] \partial^\nu B_{\mu\nu}$$
$$+ \frac{2ig\,\bar{c}_{HW}}{m_W^2} [D^\mu \Phi^\dagger T_{2k} D^\nu \Phi] W^k_{\mu\nu} + \frac{ig'\,\bar{c}_{HB}}{m_W^2} [D^\mu \Phi^\dagger D^\nu \Phi] B_{\mu\nu}$$
$$+ \frac{g'^2\,\bar{c}_\gamma}{m_W^2} \Phi^\dagger \Phi B_{\mu\nu} B^{\mu\nu} + \frac{g_s^2\,\bar{c}_g}{m_W^2} \Phi^\dagger \Phi G^a_{\mu\nu} G^{\mu\nu}_a \,,$$

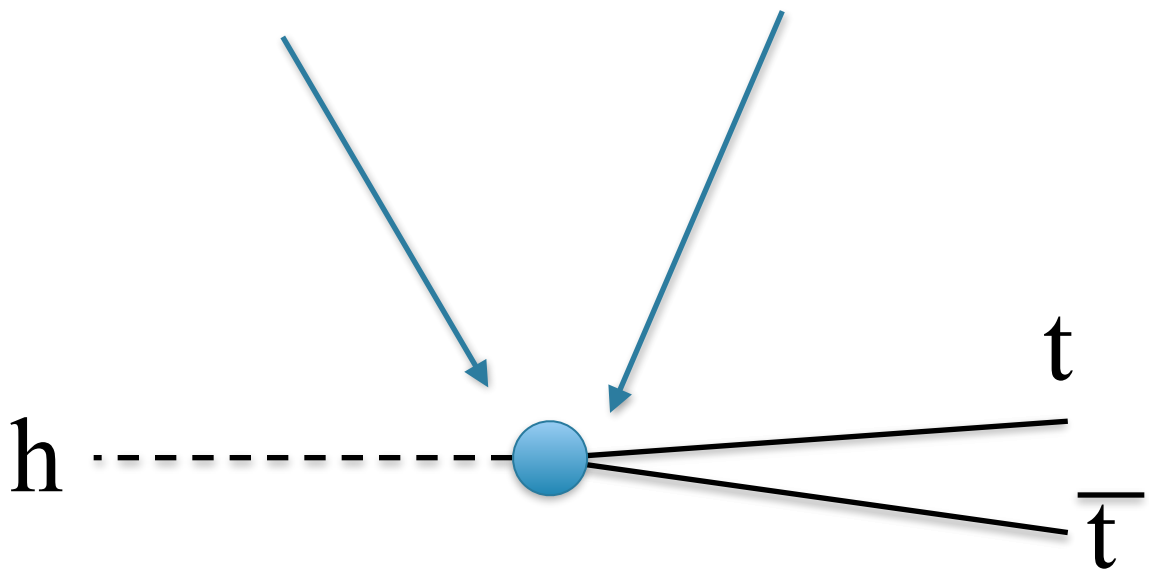
$$\frac{i\bar{c}_{HQ}}{v^2} [\bar{Q}_L \gamma^\mu Q_L] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi] + \frac{4i\bar{c}'_{HQ}}{v^2} [\bar{Q}_L \gamma^\mu T_{2k} Q_L] [\Phi^\dagger T_2^k \overleftrightarrow{D}_\mu \Phi]$$
$$+ \frac{i\bar{c}_{Hu}}{v^2} [\bar{u}_R \gamma^\mu u_R] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi] + \frac{i\bar{c}_{Hd}}{v^2} [\bar{d}_R \gamma^\mu d_R] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi]$$
$$- \Big[\frac{i\bar{c}_{Hud}}{v^2} [\bar{u}_R \gamma^\mu d_R] [\Phi \cdot \overleftrightarrow{D}_\mu \Phi] + \text{h.c.} \Big]$$
$$+ \frac{i\bar{c}_{HL}}{v^2} [\bar{L}_L \gamma^\mu L_L] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi] + \frac{4i\bar{c}'_{HL}}{v^2} [\bar{L}_L \gamma^\mu T_{2k} L_L] [\Phi^\dagger T_2^k \overleftrightarrow{D}_\mu \Phi]$$
$$+ \frac{i\bar{c}_{He}}{v^2} [\bar{e}_R \gamma^\mu e_R] [\Phi^\dagger \overleftrightarrow{D}_\mu \Phi] \,,$$

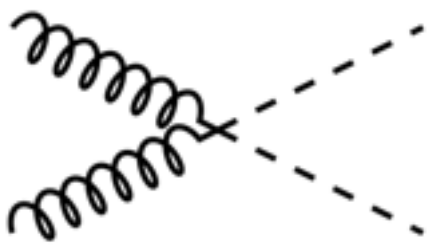
Restrict attention to strongly-coupled and top quark operators. LHC is, after all, a hadron machine.

$$\mathcal{O}_{HG} = \frac{c_{HG}}{\Lambda^2}\left(H^\dagger H\right) G_a^{\mu\nu} G^a_{\mu\nu}$$

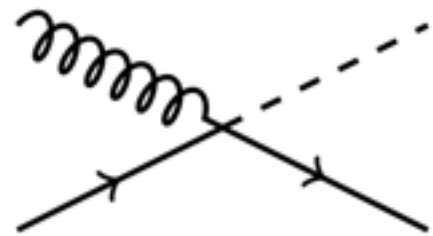
$$\mathcal{O}_{hgt} = \frac{c_{hgt}}{\Lambda^2}\left(\bar{Q}_L H\right) \sigma^{\mu\nu} T^a t_R G^a_{\mu\nu}$$

$$\mathcal{O}_{cHq} = (\bar{Q}_{3L}\gamma^\mu Q_{3L})(H^\dagger \overleftrightarrow{D}_\mu H), \quad \mathcal{O}_{c'Hu} = (\bar{Q}_{3L}\sigma_i\gamma^\mu Q_{3L})(H^\dagger \sigma^i \overleftrightarrow{D}_\mu H), \quad \mathcal{O}_{cHu} = (\bar{t}_R\gamma^\mu t_R)(H^\dagger \overleftrightarrow{D}_\mu H)$$
$$\text{and} \quad \mathcal{O}_{y_u} = H^\dagger H\, \bar{Q}_{3L} H^c t_R.$$



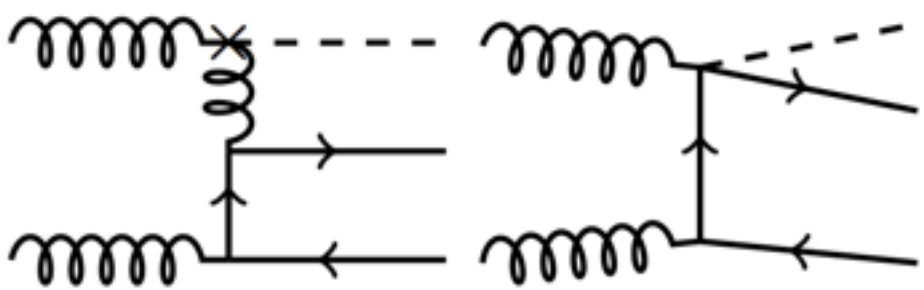


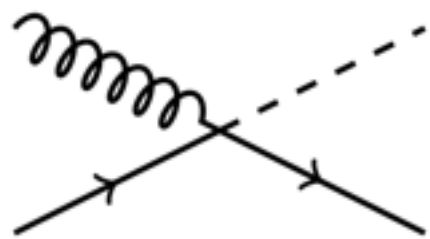
$$\mathcal{O}_{HG} = \frac{c_{HG}}{\Lambda^2}\left(H^\dagger H\right) G_a^{\mu\nu} G^a_{\mu\nu}$$



$$\mathcal{O}_{hgt} = \frac{c_{hgt}}{\Lambda^2}\left(\bar{Q}_L H\right) \sigma^{\mu\nu} T^a t_R G^a_{\mu\nu}$$

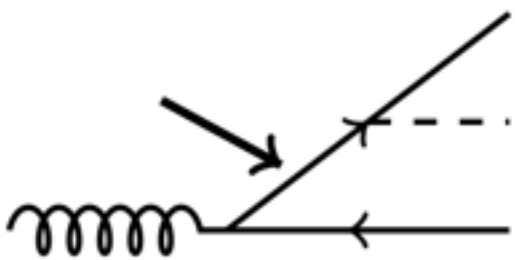
Only two operators contribute to tth at leading order in the strong coupling, and have a different momentum (Lorentz) structure than the Standard Model.

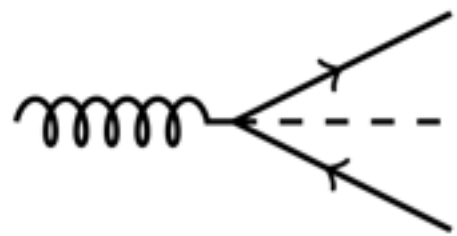




$$\mathcal{O}_{hgt} = \frac{c_{hgt}}{\Lambda^2} \left(\bar{Q}_L H\right) \sigma^{\mu\nu} T^a t_R G^a_{\mu\nu}$$

Different kinematic dependence, for example there is a new gluon s-channel. The SM process has an amplitude with an off-shell top, so it goes as ~1/P(top).



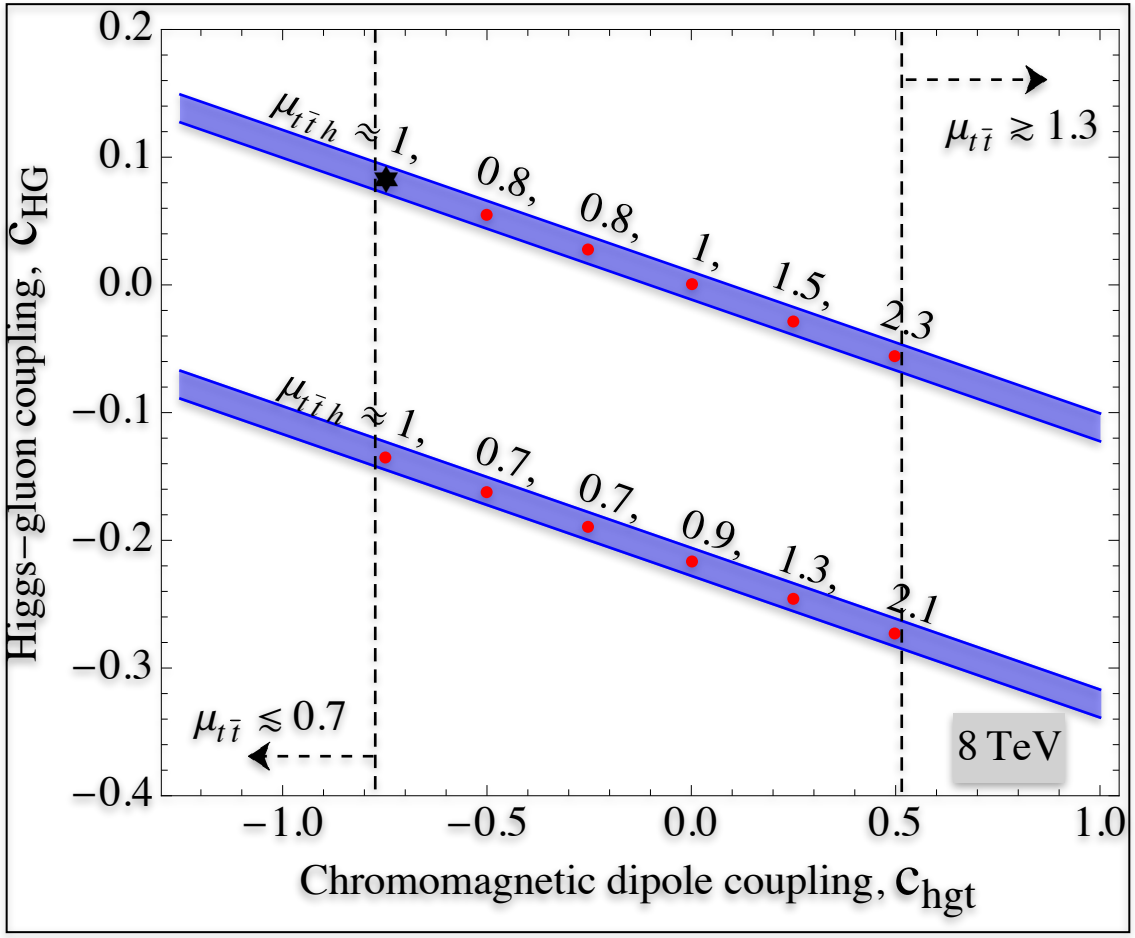


SM .....vs.....Chromomagnetic dipole

Bounds on Dim-6 tth Kinematic Operators

Higgs Production

$0.8 < \mu_h < 1.2$

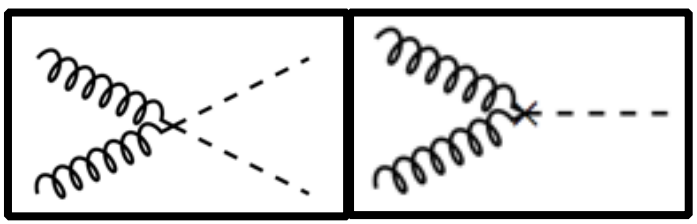


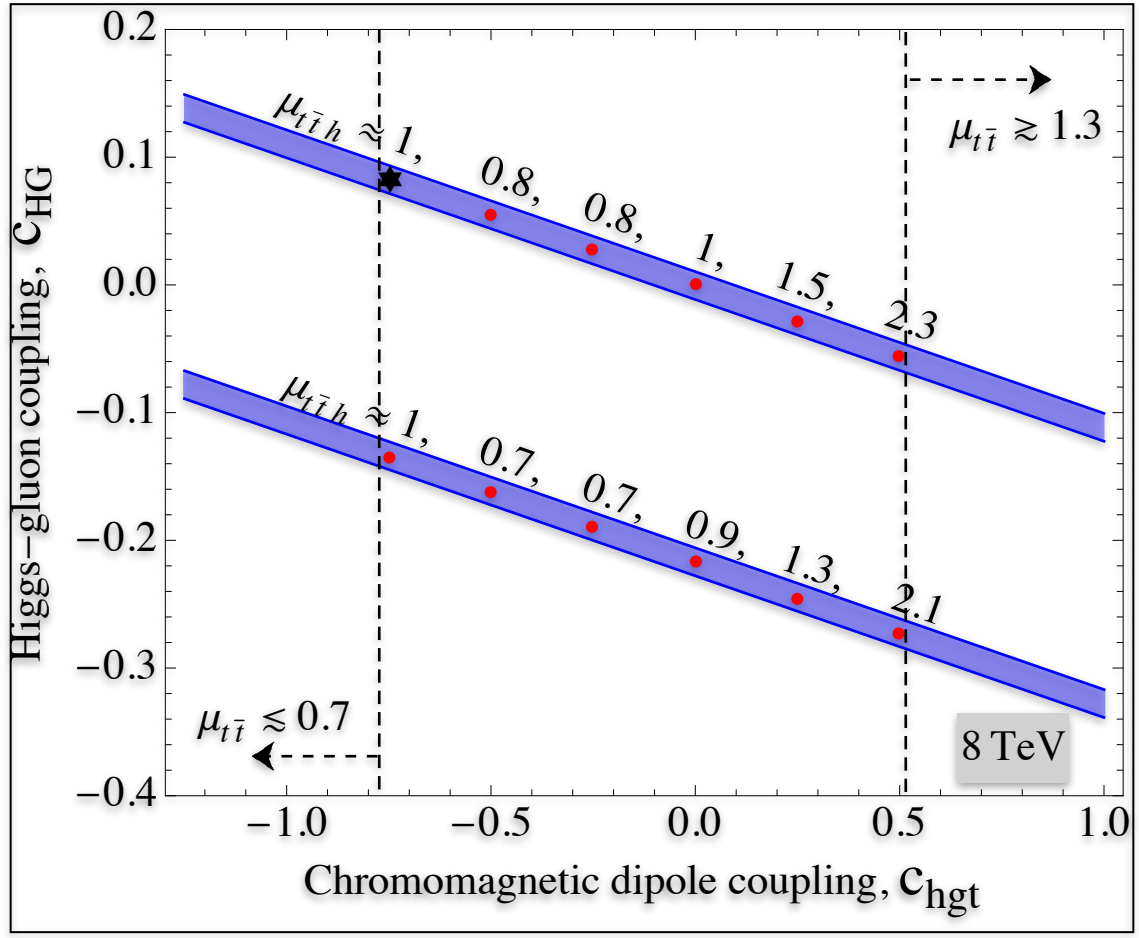
Bounds on Dim-6 tth Kinematic Operators

Higgs Production

$0.8 < \mu_h < 1.2$

c_{HG}



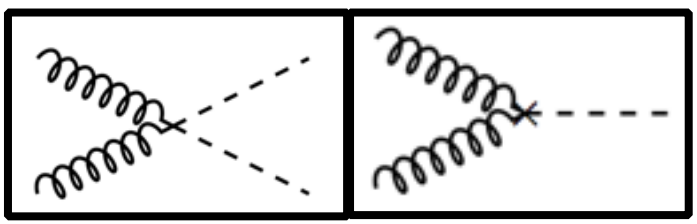


Bounds on Dim-6 tth Kinematic Operators

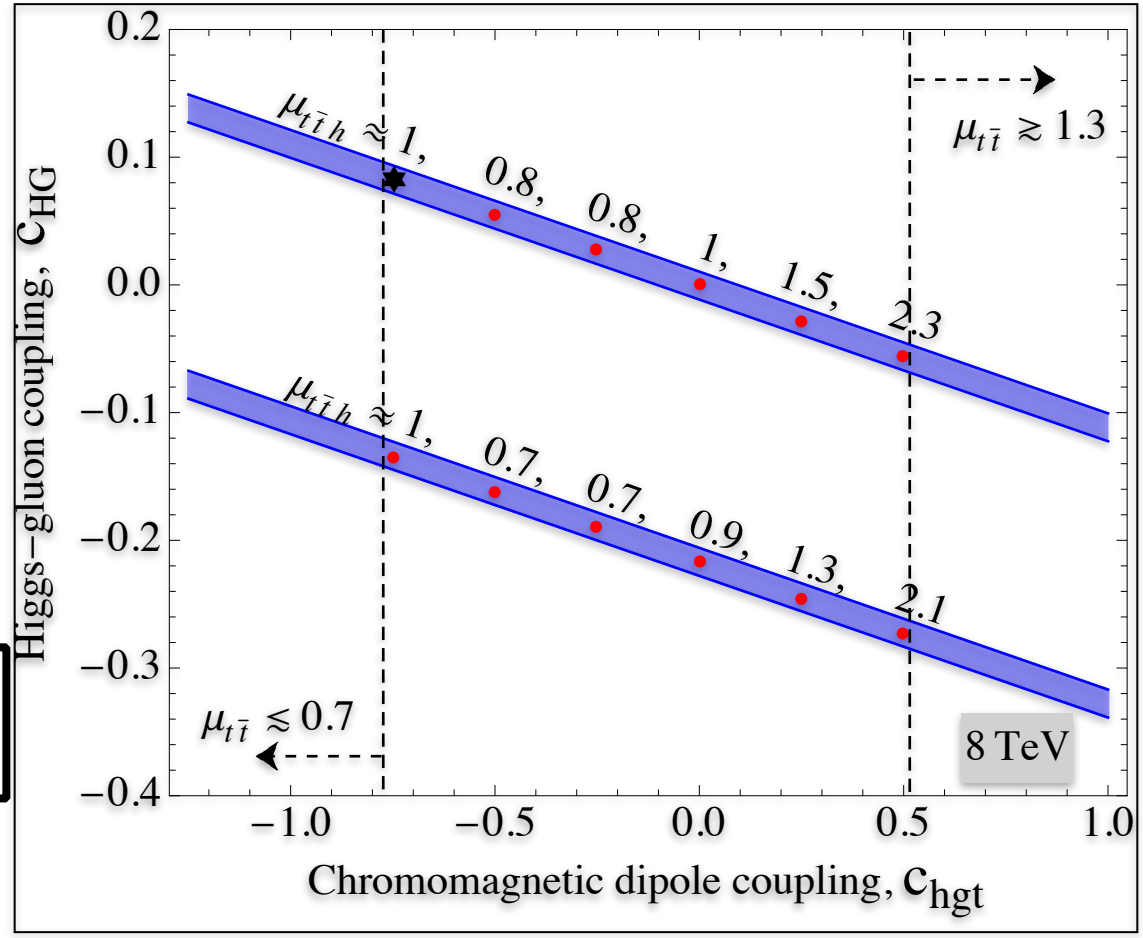
Higgs Production

$0.8 < \mu_h < 1.2$

c_{HG}



$$\frac{\sigma(pp \to h)}{\sigma(pp \to h)_{SM}} \equiv \mu_h \simeq \left(1 + c_{HG}\frac{24\pi^2 v^2}{\Lambda^2 g_s^2}\right)^2$$

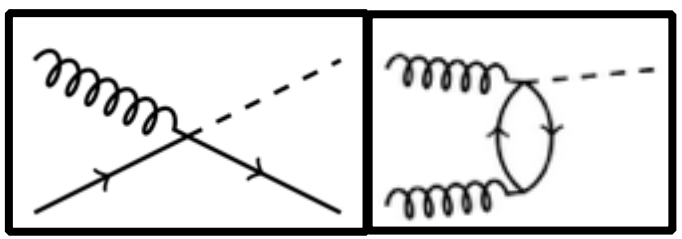


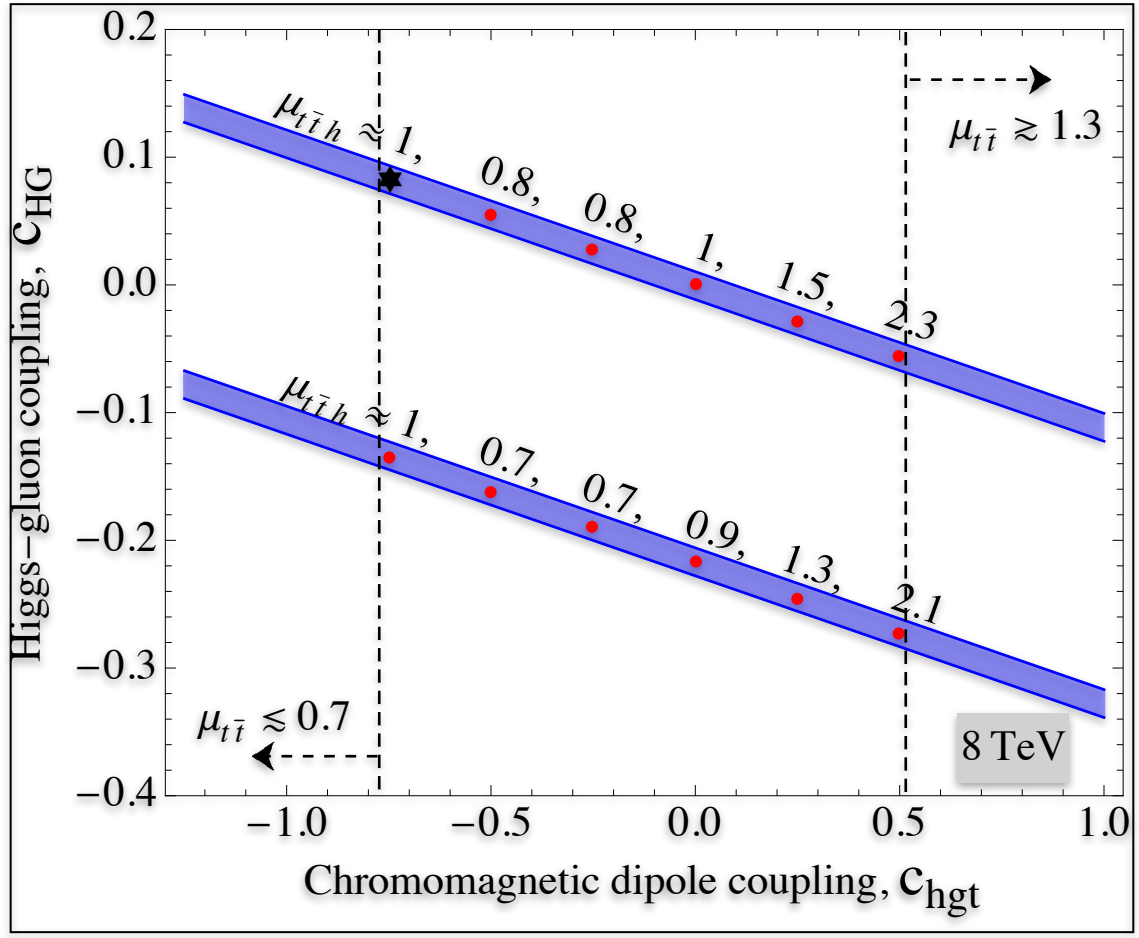
Bounds on Dim-6 tth Kinematic Operators

Higgs Production

$0.8 < \mu_h < 1.2$

c_{hgt}



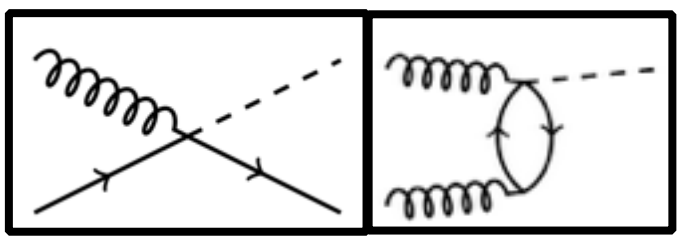


Bounds on Dim-6 tth Kinematic Operators

Higgs Production

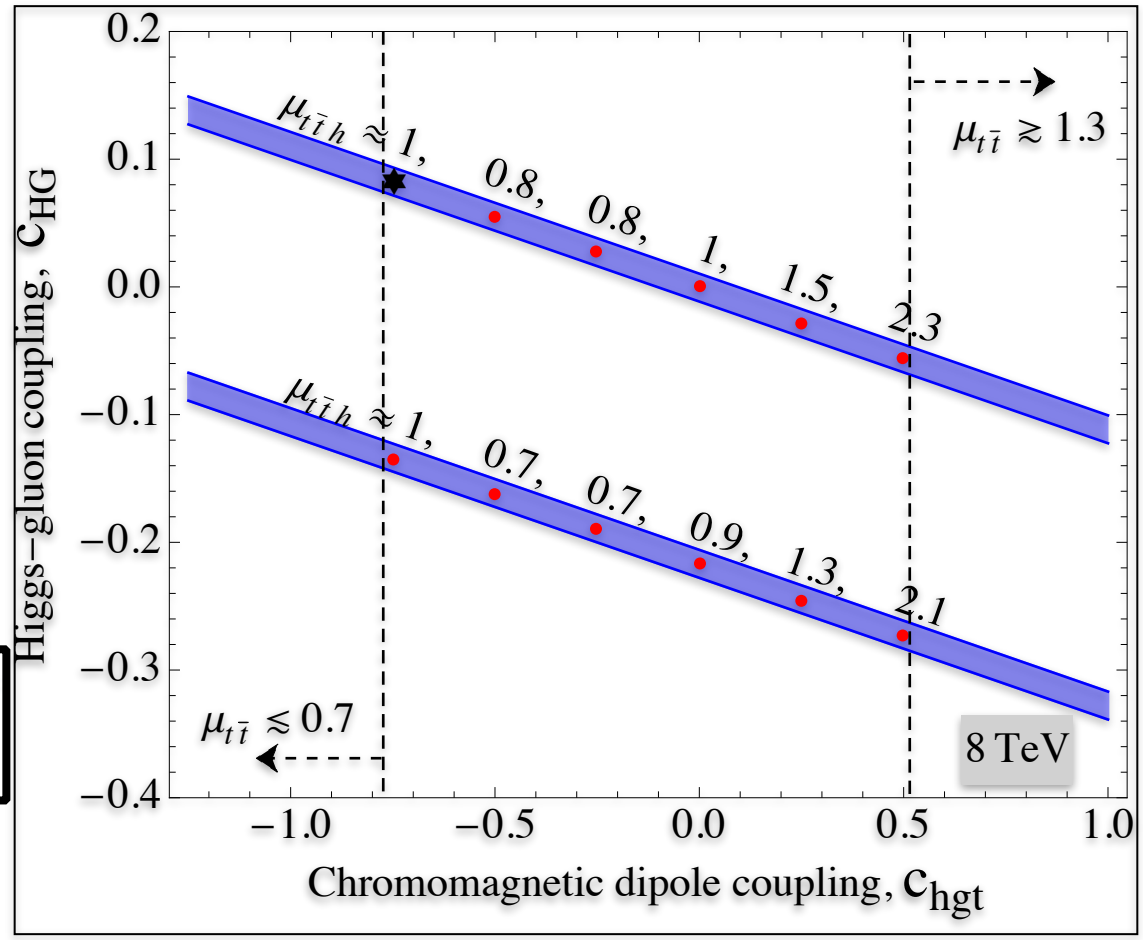
$0.8 < \mu_h < 1.2$

c_{hgt}



$$\frac{\sigma(pp \to h)}{\sigma(pp \to h)_{SM}} \equiv \mu_h \simeq \left(1 + c_{HG}\frac{24\pi^2 v^2}{\Lambda^2 g_s^2}\right)^2$$

$$\delta c_{HG} = c_{hgt}\frac{g_s y_t \log\left(\frac{\Lambda^2}{m_t^2}\right)}{4\pi^2}$$

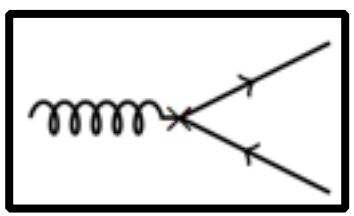


Bounds on Dim-6 tth Kinematic Operators

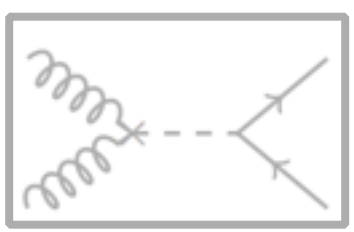
$t\bar{t}$ Production

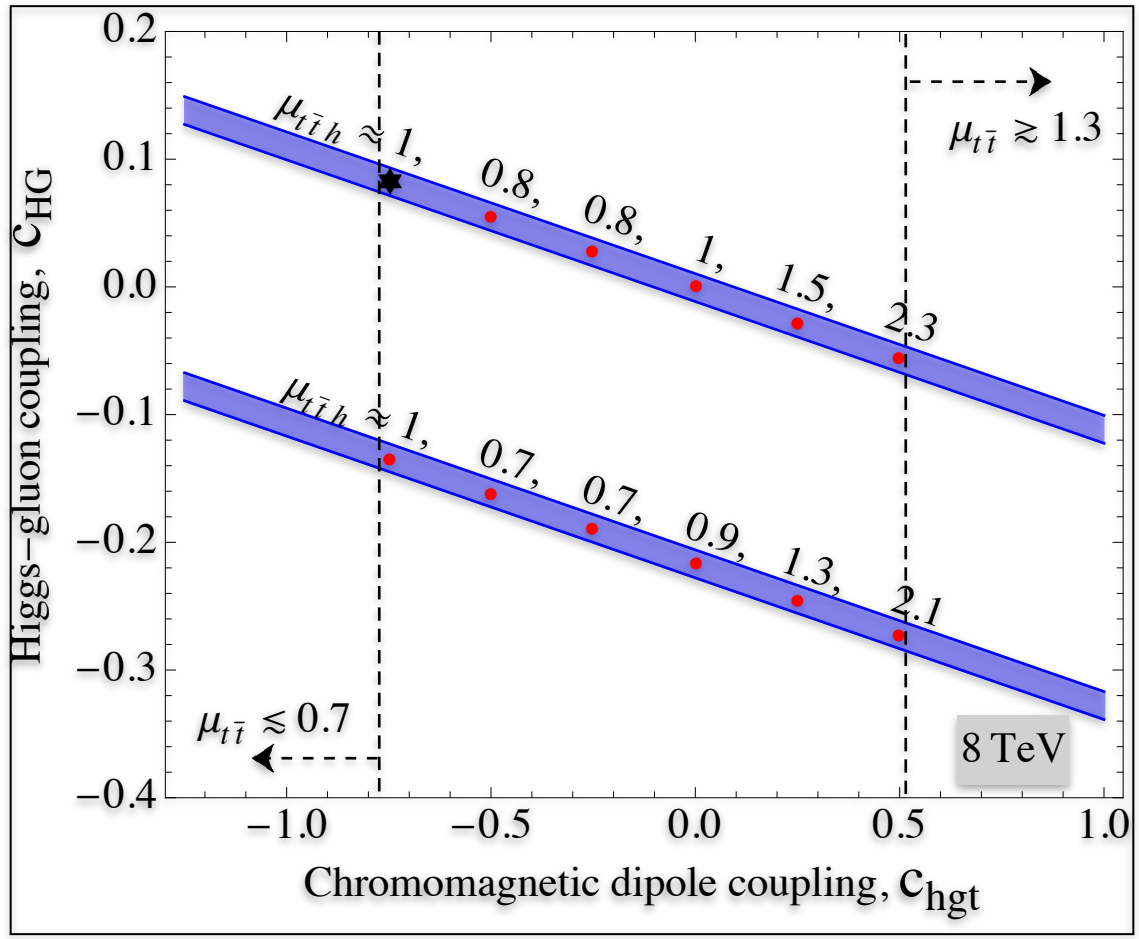
$0.7 < \mu_{tt} < 1.3$

c_{hgt}



c_{HG}

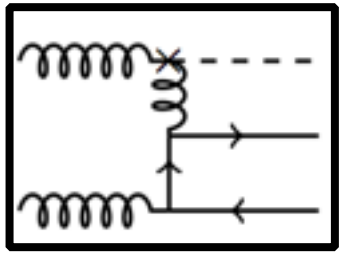




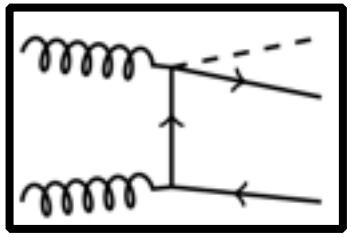
Bounds on Dim-6 tth Kinematic Operators

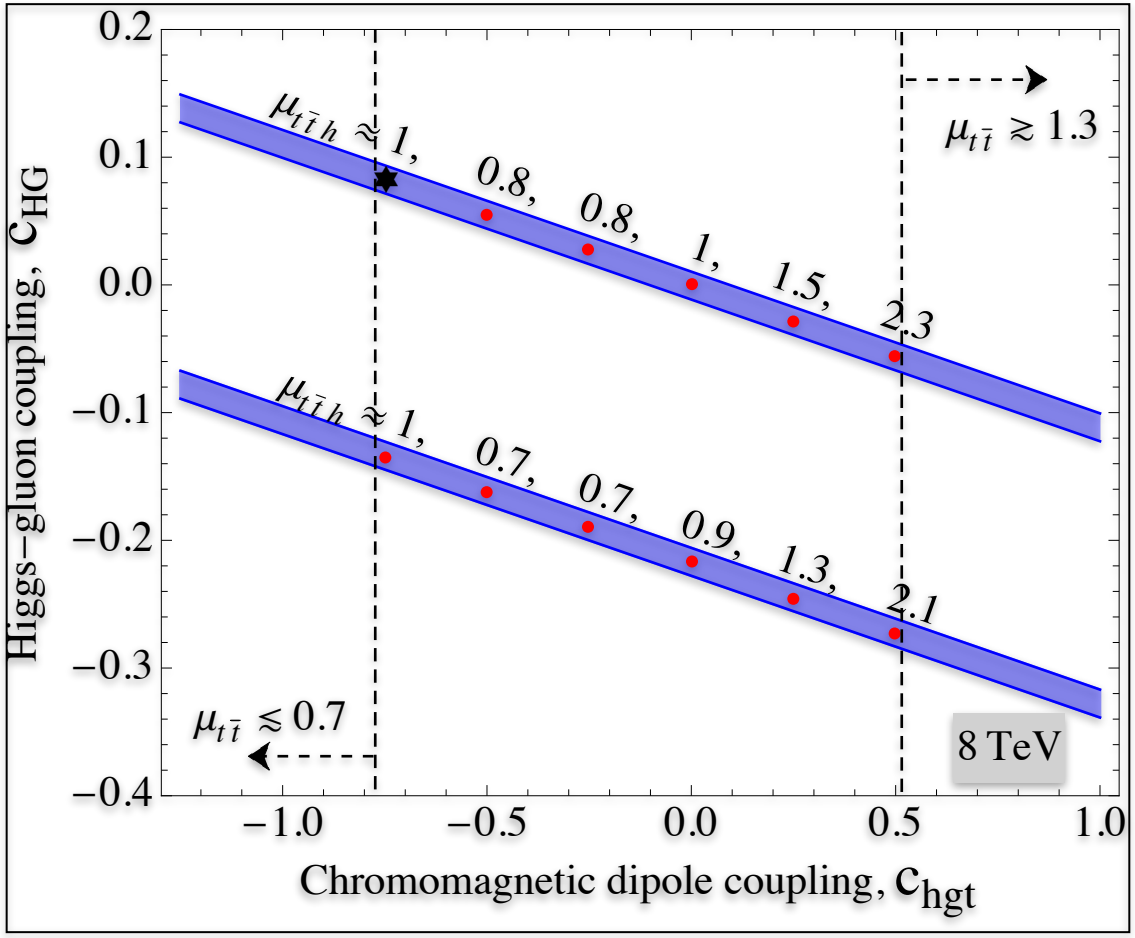
- $t\bar{t}h$ Production

c_{HG}



c_{hgt}

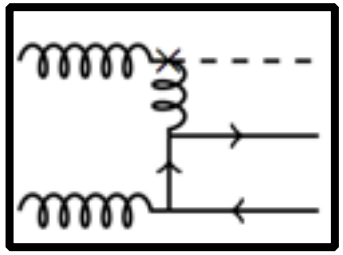




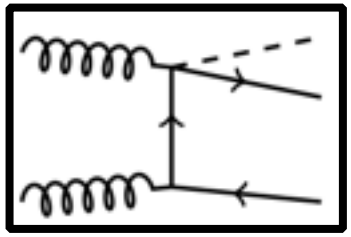
Bounds on Dim-6 tth Kinematic Operators

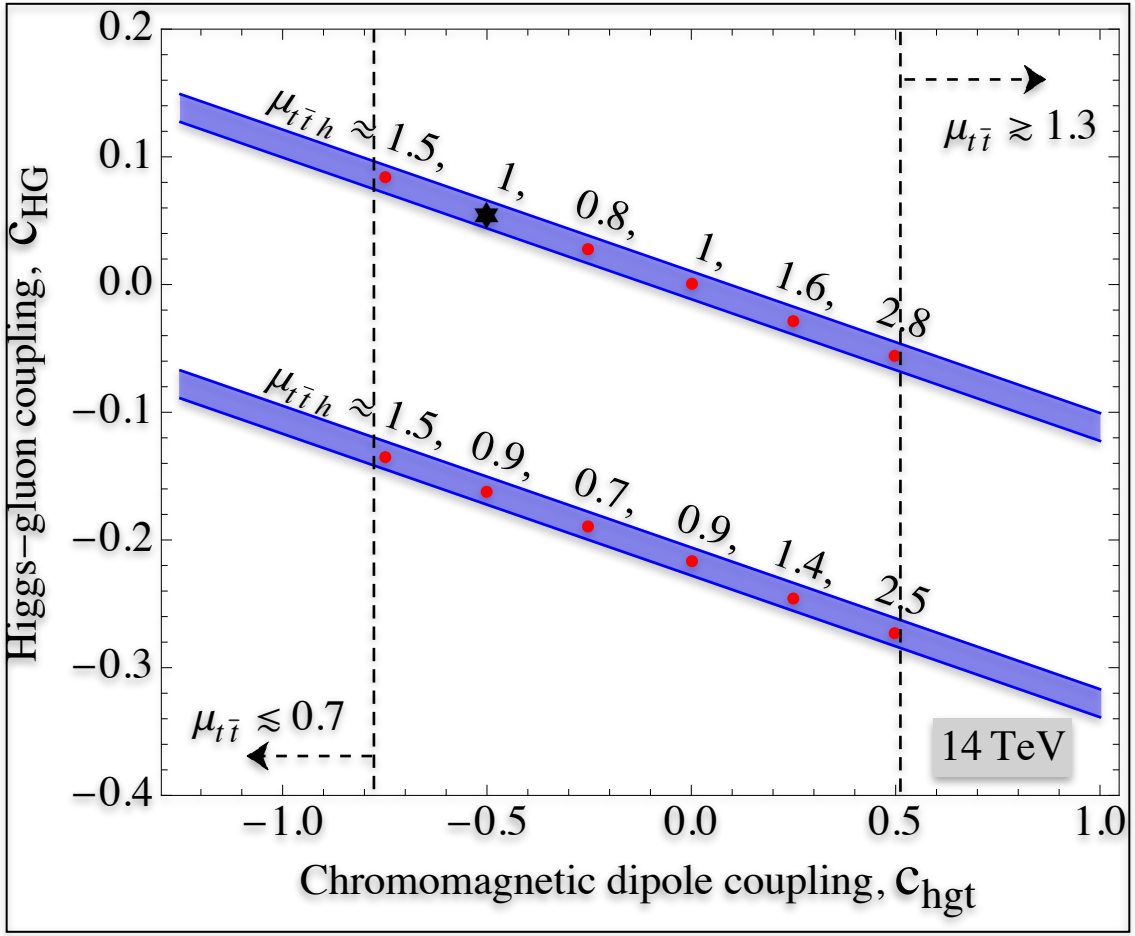
- $t\bar{t}h$ Production

c_{HG}

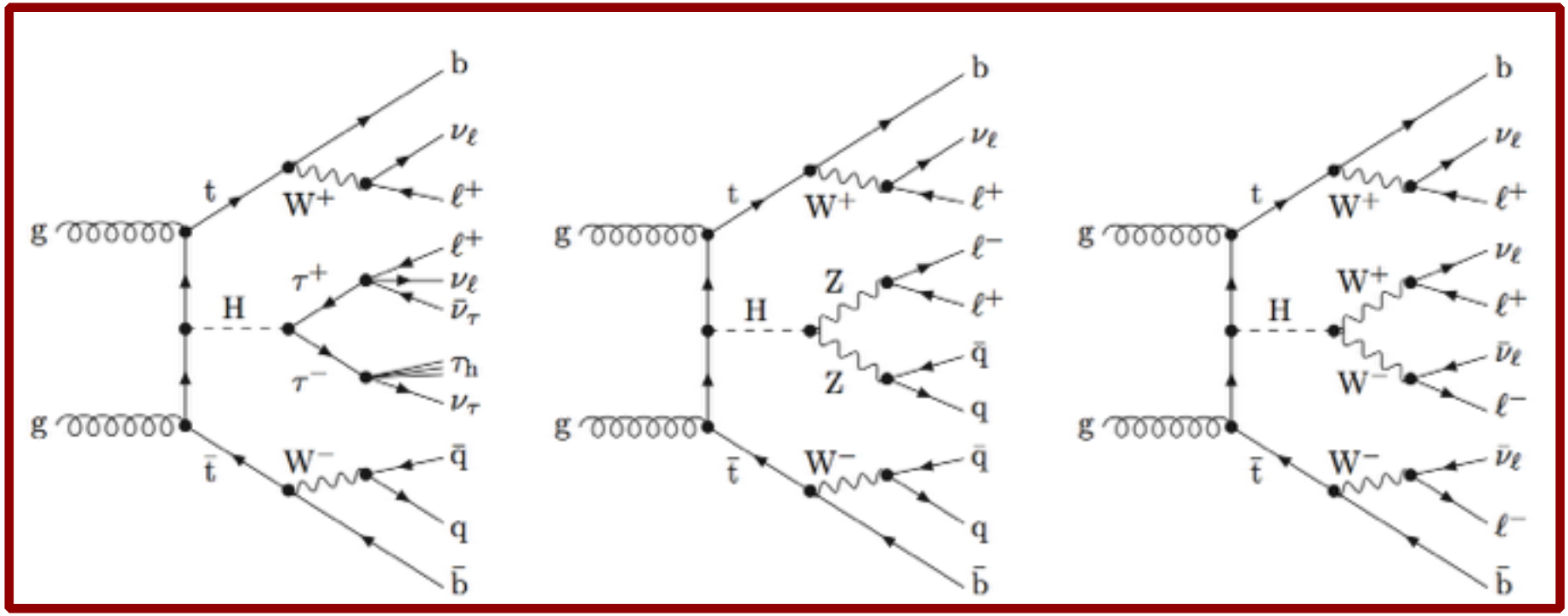


c_{hgt}



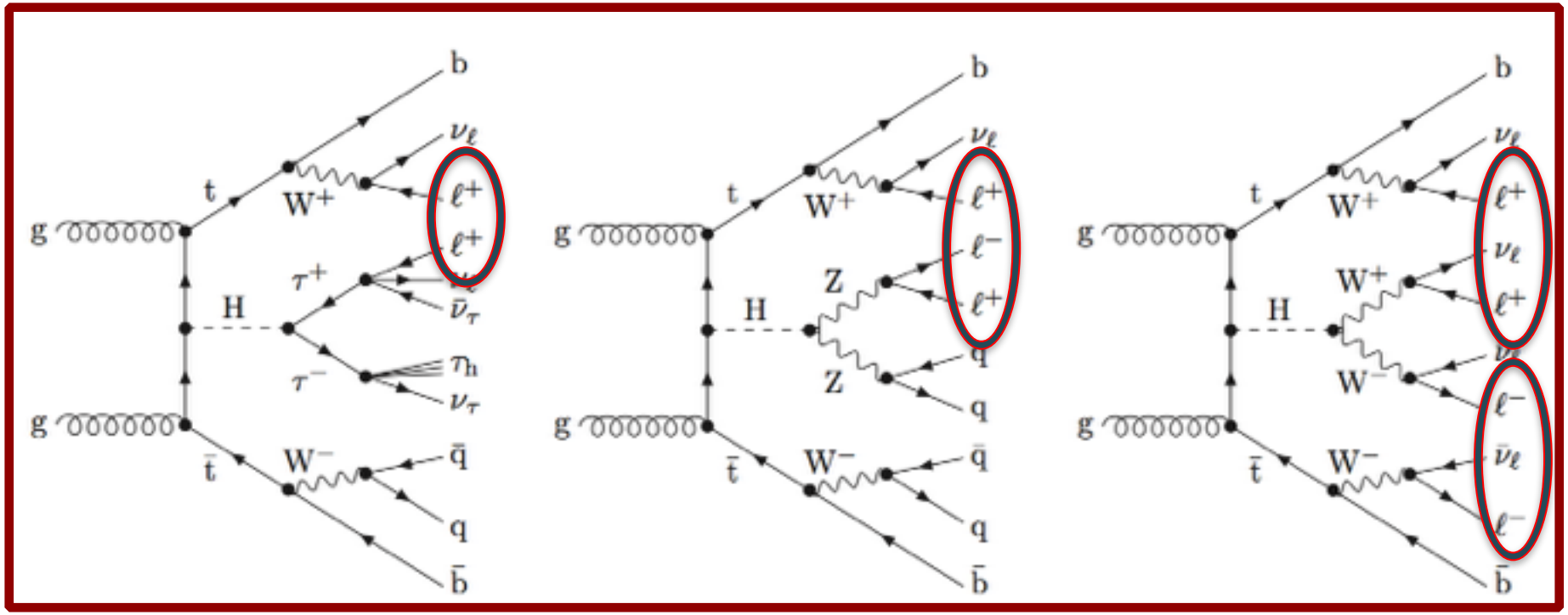


LHC tth to same sign dilepton



CMS search for pp →tth in the isolated same sign dilepton channel

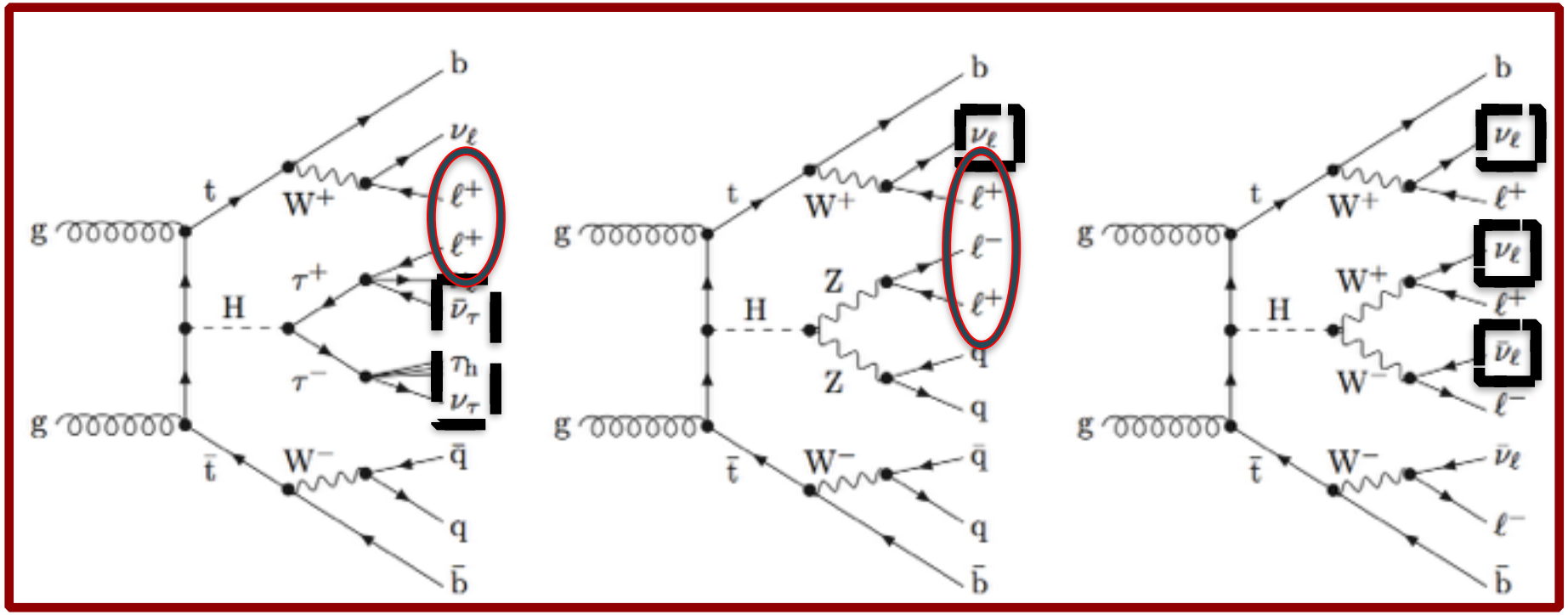
LHC tth to same sign dilepton



CMS search for pp →tth in the isolated same sign dilepton channel

- Cut on isolated same charge dileptons

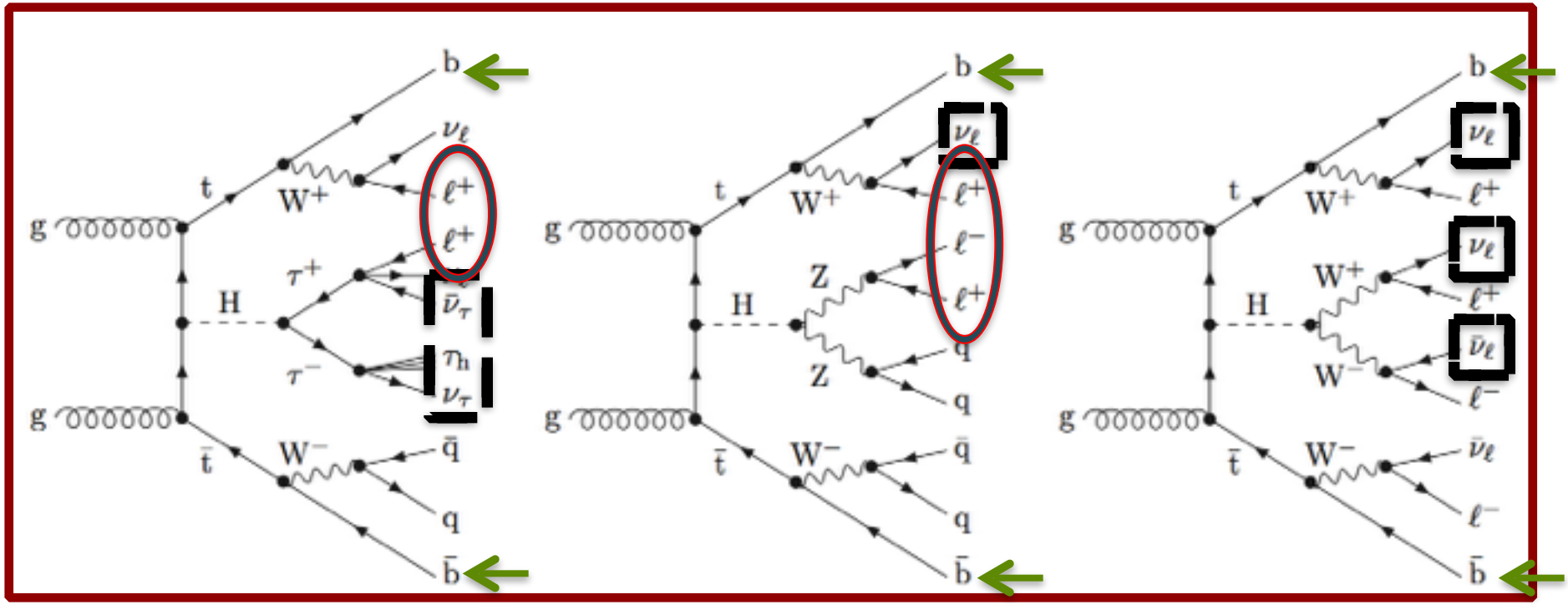
LHC tth to same sign dilepton



CMS search for pp →tth in the isolated same sign dilepton channel

- Cut on isolated same charge dileptons
- Require ~20 GeV missing transverse energy

LHC tth to same sign dilepton



CMS search for pp →tth in the isolated same sign dilepton channel

- Cut on isolated same charge dileptons
- Require ~20 GeV missing transverse energy
- Require 4 jets, with 2 Light Working Point CSV b-tags or 1 Medium Working Point CSV b-tag

Numbers (CMS Higgs 13-020)

tth cross-section - 120 fb || ttW cross-section - 161+71 fb
tt cross-section - 245 pb || tt lep-fake ~ 1/1000 events

Numbers (CMS Higgs 13-020)

tth cross-section - 120 fb || ttW cross-section - 161+71 fb
tt cross-section - 245 pb || tt lep-fake ~ 1/1000 events

	$\mu\mu$	ee	$e\mu$	3ℓ	4ℓ
$t\bar{t}H, H \to WW$	2.0 ± 0.3	0.9 ± 0.1	2.7 ± 0.4	3.2 ± 0.6	0.28 ± 0.05
$t\bar{t}H, H \to ZZ$	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.09 ± 0.02
$t\bar{t}H, H \to \tau\tau$	0.6 ± 0.1	0.3 ± 0.0	0.9 ± 0.1	1.0 ± 0.2	0.15 ± 0.02
$t\bar{t}W$	8.2 ± 1.5	3.4 ± 0.6	13.0 ± 2.2	9.2 ± 1.9	-
$t\bar{t}Z/\gamma^*$	2.5 ± 0.5	1.6 ± 0.3	4.2 ± 0.9	7.9 ± 1.7	1.25 ± 0.88
$t\bar{t}WW$	0.2 ± 0.0	0.1 ± 0.0	0.3 ± 0.1	0.4 ± 0.1	0.04 ± 0.02
$t\bar{t}\gamma$	-	1.3 ± 0.3	1.9 ± 0.5	2.9 ± 0.8	-
WZ	0.8 ± 0.9	0.5 ± 0.5	1.2 ± 1.3	4.2 ± 0.9	-
ZZ	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.4 ± 0.1	0.45 ± 0.09
rare SM bkg.	1.1 ± 0.0	0.4 ± 0.0	1.5 ± 0.0	0.8 ± 0.0	0.01 ± 0.00
non-prompt	10.8 ± 4.8	8.9 ± 4.5	21.2 ± 8.1	33.2 ± 12.3	0.53 ± 0.32
charge flip	-	1.9 ± 0.6	2.4 ± 0.8	-	-
all signals	2.7 ± 0.4	1.2 ± 0.2	3.7 ± 0.6	4.4 ± 0.8	0.52 ± 0.09
all backgrounds	23.7 ± 5.2	18.0 ± 4.7	45.9 ± 8.6	58.9 ± 12.7	2.28 ± 0.94
data	41	19	51	68	1

Numbers (CMS Higgs 13-020)

tth cross-section - 120 fb || ttW cross-section - 161+71 fb
tt cross-section - 245 pb || tt lep-fake ~ 1/1000 events

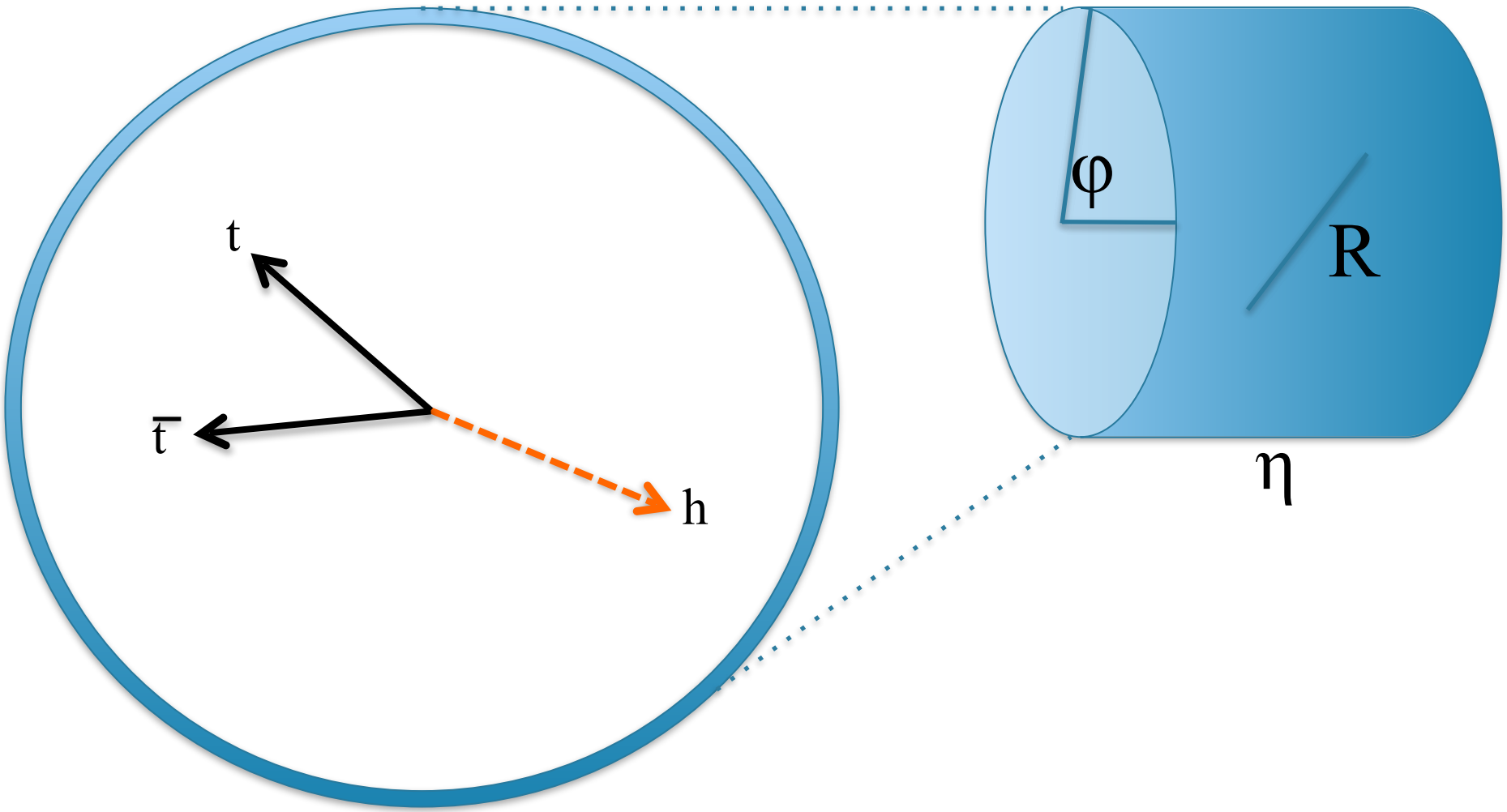
	$\mu\mu$	ee	$e\mu$	3ℓ	4ℓ
$t\bar{t}H, H \to WW$	2.0 ± 0.3	0.9 ± 0.1	2.7 ± 0.4	3.2 ± 0.6	0.28 ± 0.05
$t\bar{t}H, H \to ZZ$	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.09 ± 0.02
$t\bar{t}H, H \to \tau\tau$	0.6 ± 0.1	0.3 ± 0.0	0.9 ± 0.1	1.0 ± 0.2	0.15 ± 0.02
$t\bar{t}W$	8.2 ± 1.5	3.4 ± 0.6	13.0 ± 2.2	9.2 ± 1.9	-
$t\bar{t}Z/\gamma^*$	2.5 ± 0.5	1.6 ± 0.3	4.2 ± 0.9	7.9 ± 1.7	1.25 ± 0.88
$t\bar{t}WW$	0.2 ± 0.0	0.1 ± 0.0	0.3 ± 0.1	0.4 ± 0.1	0.04 ± 0.02
$t\bar{t}\gamma$	-	1.3 ± 0.3	1.9 ± 0.5	2.9 ± 0.8	-
WZ	0.8 ± 0.9	0.5 ± 0.5	1.2 ± 1.3	4.2 ± 0.9	-
ZZ	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.4 ± 0.1	0.45 ± 0.09
rare SM bkg.	1.1 ± 0.0	0.4 ± 0.0	1.5 ± 0.0	0.8 ± 0.0	0.01 ± 0.00
non-prompt	10.8 ± 4.8	8.9 ± 4.5	21.2 ± 8.1	33.2 ± 12.3	0.53 ± 0.32
charge flip	-	1.9 ± 0.6	2.4 ± 0.8	-	-
all signals	2.7 ± 0.4	1.2 ± 0.2	3.7 ± 0.6	4.4 ± 0.8	0.52 ± 0.09
all backgrounds	23.7 ± 5.2	18.0 ± 4.7	45.9 ± 8.6	58.9 ± 12.7	2.28 ± 0.94
data	41	19	51	68	1

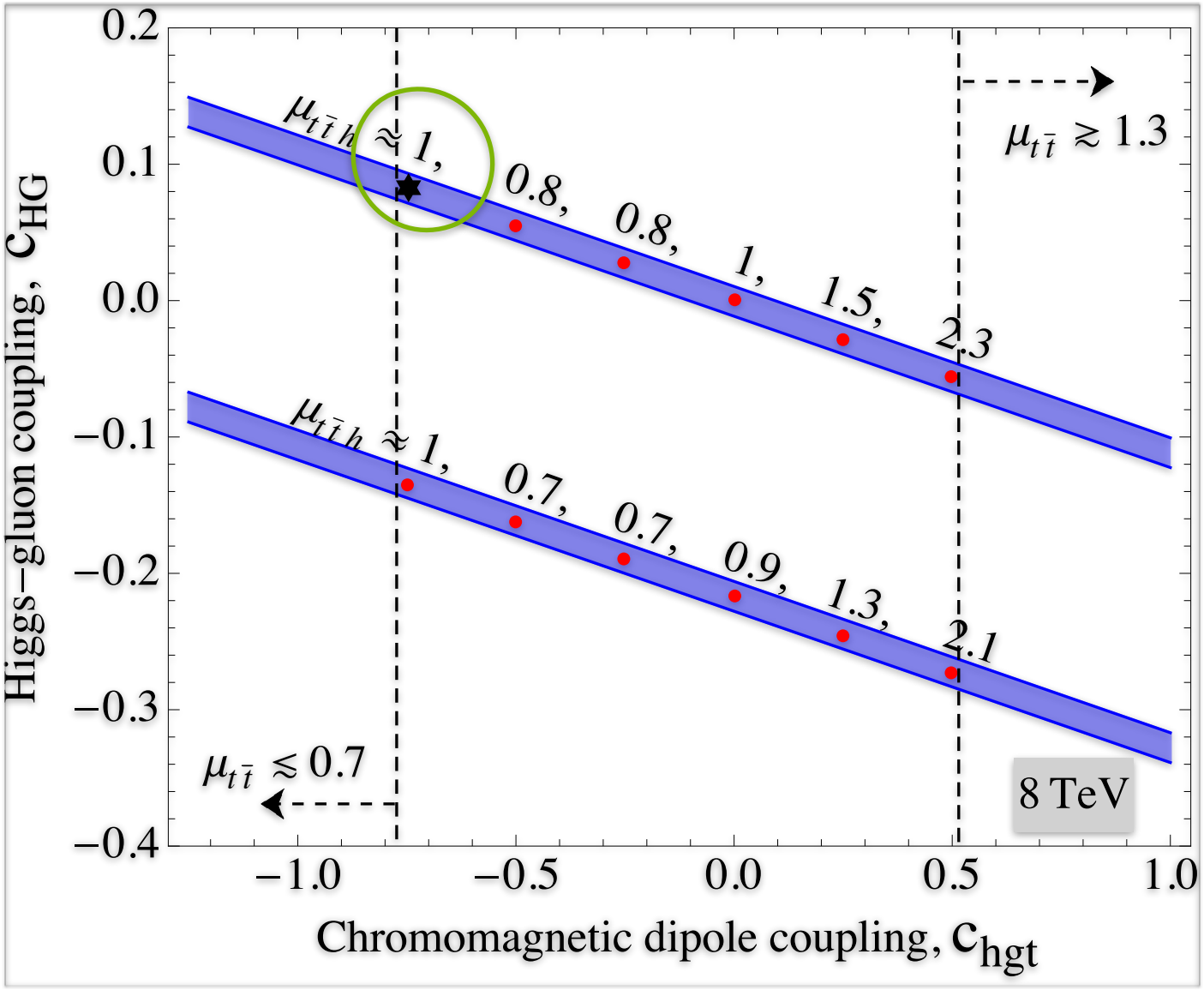
Numbers (CMS Higgs 13-020)

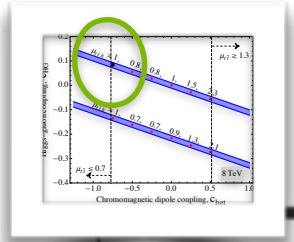
tth cross-section - 120 fb || ttW cross-section - 161+71 fb
tt cross-section - 245 pb || tt lep-fake ~ 1/1000 events

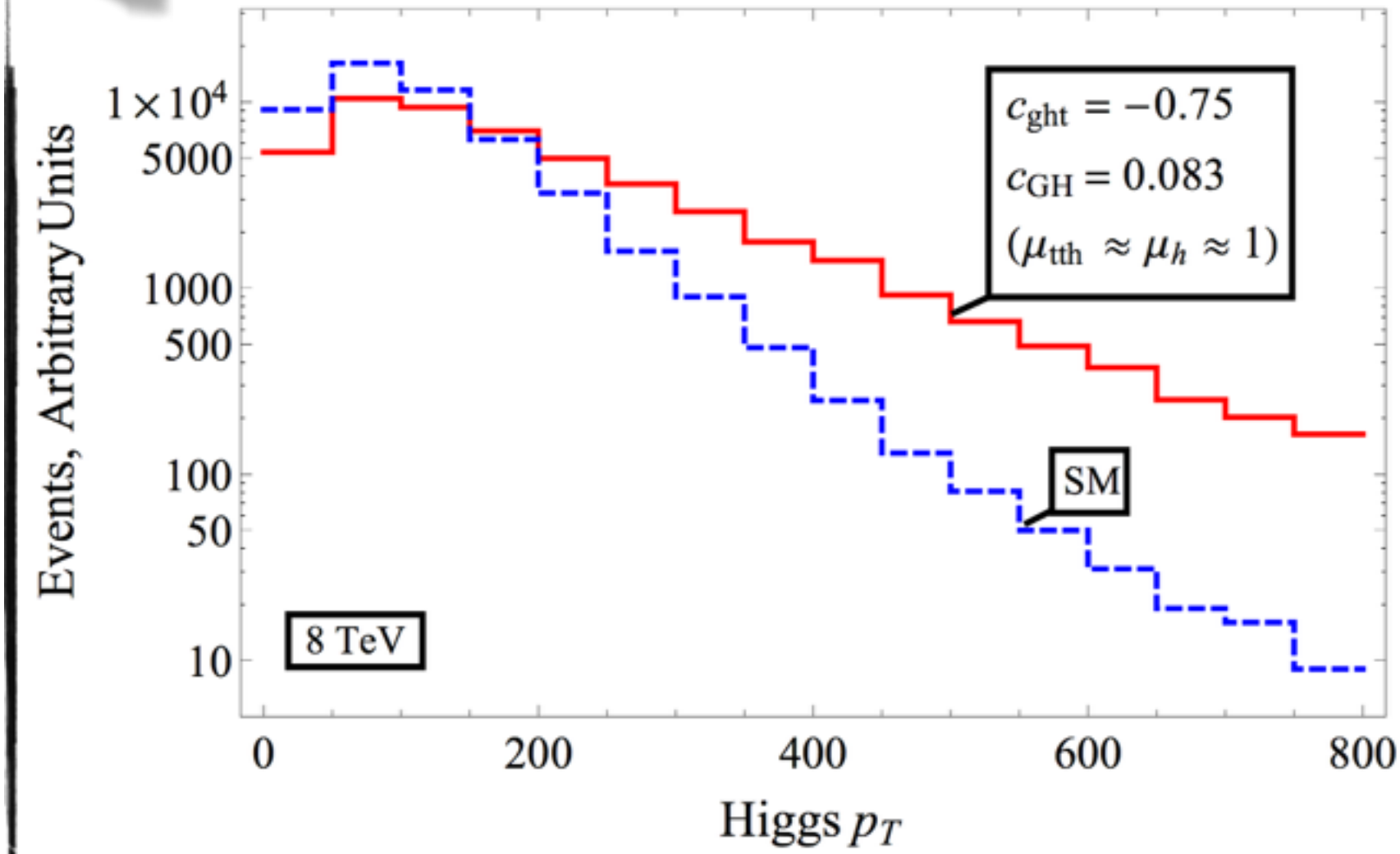
	$\mu\mu$	ee	$e\mu$	3ℓ	4ℓ
$t\bar{t}H, H \to WW$	2.0 ± 0.3	0.9 ± 0.1	2.7 ± 0.4	3.2 ± 0.6	0.28 ± 0.05
$t\bar{t}H, H \to ZZ$	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.09 ± 0.02
$t\bar{t}H, H \to \tau\tau$	0.6 ± 0.1	0.3 ± 0.0	0.9 ± 0.1	1.0 ± 0.2	0.15 ± 0.02
$t\bar{t}W$	8.2 ± 1.5	3.4 ± 0.6	13.0 ± 2.2	9.2 ± 1.9	-
$t\bar{t}Z/\gamma^*$	2.5 ± 0.5	1.6 ± 0.3	4.2 ± 0.9	7.9 ± 1.7	1.25 ± 0.88
$t\bar{t}WW$	0.2 ± 0.0	0.1 ± 0.0	0.3 ± 0.1	0.4 ± 0.1	0.04 ± 0.02
$t\bar{t}\gamma$	-	1.3 ± 0.3	1.9 ± 0.5	2.9 ± 0.8	-
WZ	0.8 ± 0.9	0.5 ± 0.5	1.2 ± 1.3	4.2 ± 0.9	-
ZZ	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.4 ± 0.1	0.45 ± 0.09
rare SM bkg.	1.1 ± 0.0	0.4 ± 0.0	1.5 ± 0.0	0.8 ± 0.0	0.01 ± 0.00
non-prompt	10.8 ± 4.8	8.9 ± 4.5	21.2 ± 8.1	33.2 ± 12.3	0.53 ± 0.32
charge flip	-	1.9 ± 0.6	2.4 ± 0.8	-	-
all signals	2.7 ± 0.4	1.2 ± 0.2	3.7 ± 0.6	4.4 ± 0.8	0.52 ± 0.09
all backgrounds	23.7 ± 5.2	18.0 ± 4.7	45.9 ± 8.6	58.9 ± 12.7	2.28 ± 0.94
data	41	19	51	68	1

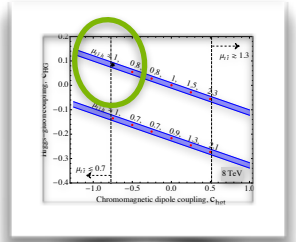
The distribution of tops and Higgs in the detector shift for boosted Higgs events.

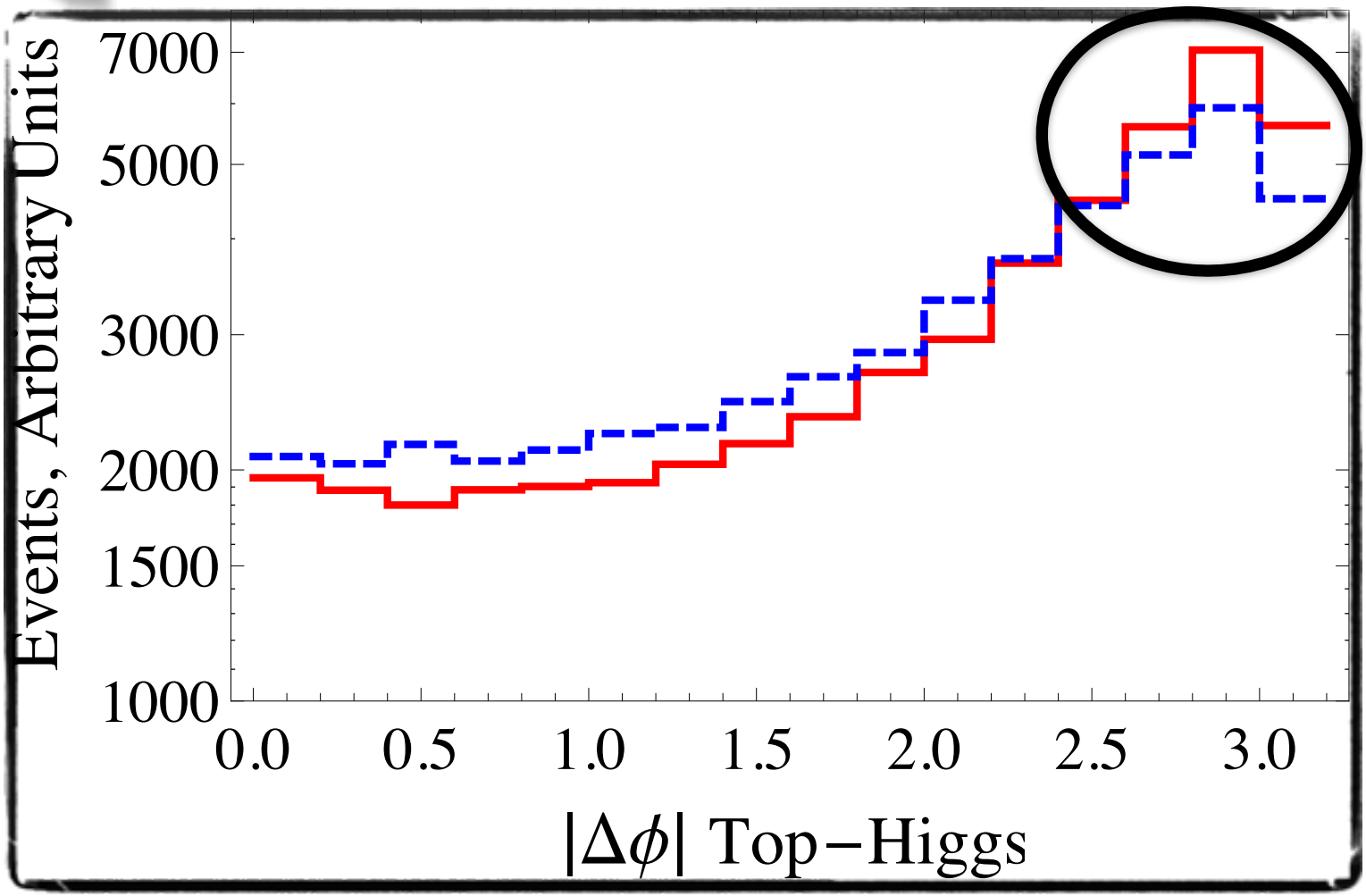


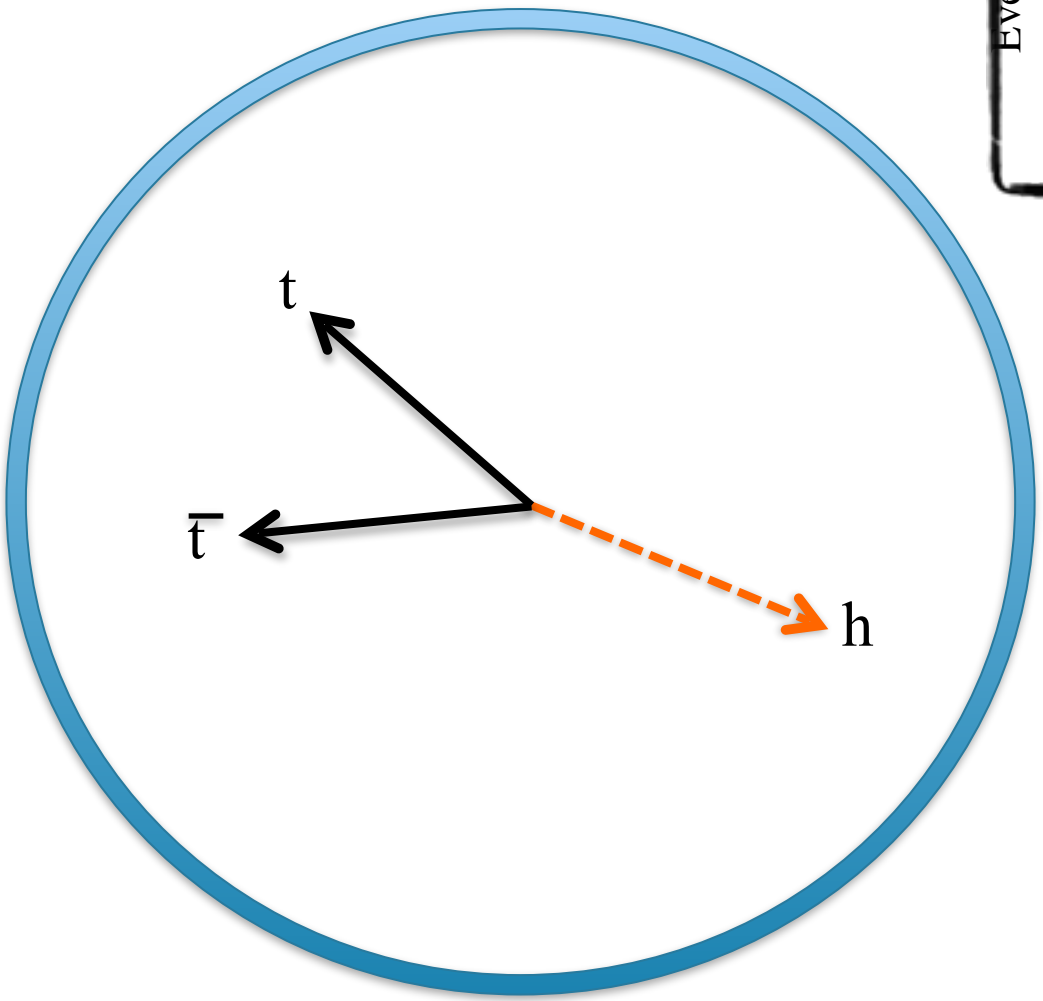

0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−1.0
−0.5
0.0
0.5
1.0
Higgs−gluon coupling, c_{HG}
Chromomagnetic dipole coupling, c_{hgt}
$\mu_{t\bar{t}h} \approx 1$,
0.8,
0.8,
1,
1.5,
2.3
$\mu_{t\bar{t}h} \approx 1$,
0.7,
0.7,
0.9,
1.3,
2.1
$\mu_{t\bar{t}} \gtrsim 1.3$
$\mu_{t\bar{t}} \lesssim 0.7$
8 TeV

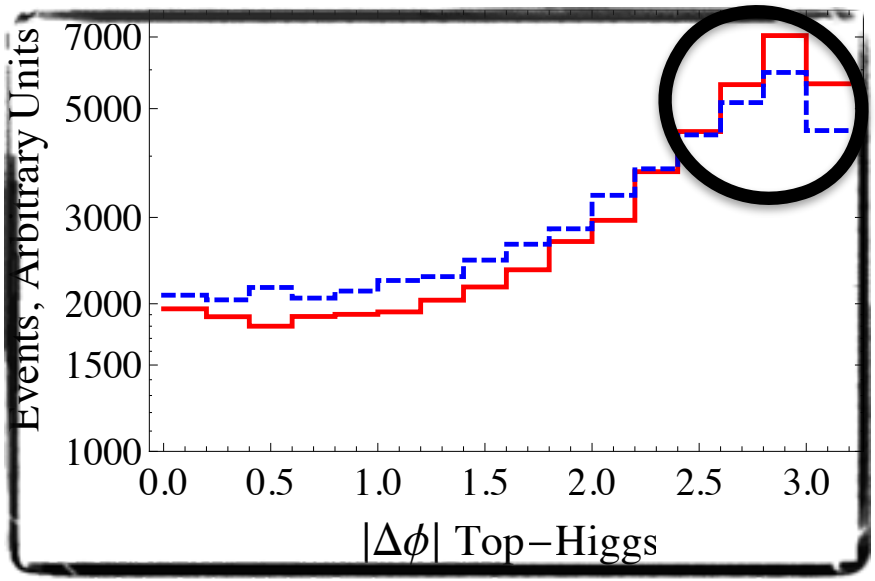

8 TeV
Chromomagnetic dipole coupling, c_{hrt}


$c_{ght} = -0.75$
$c_{GH} = 0.083$
$(\mu_{tth} \approx \mu_h \approx 1)$
SM
8 TeV
Events, Arbitrary Units
1×10^4
5000
1000
500
100
50
10
0
200
400
600
800
Higgs p_T


8 TeV
Chromomagnetic dipole coupling, c_{hgt}


Events, Arbitrary Units
7000
5000
3000
2000
1500
1000
0.0
0.5
1.0
1.5
2.0
2.5
3.0
$|\Delta\phi|$ Top−Higgs



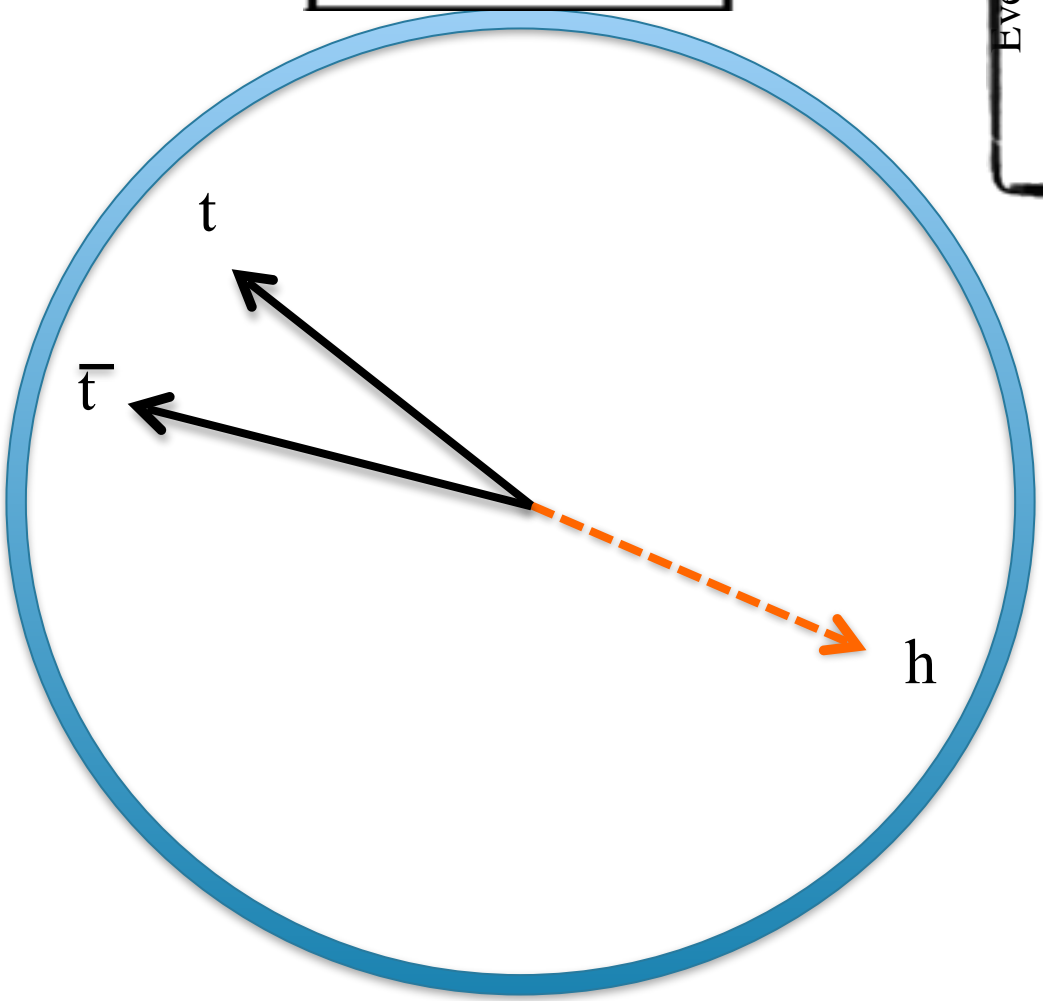


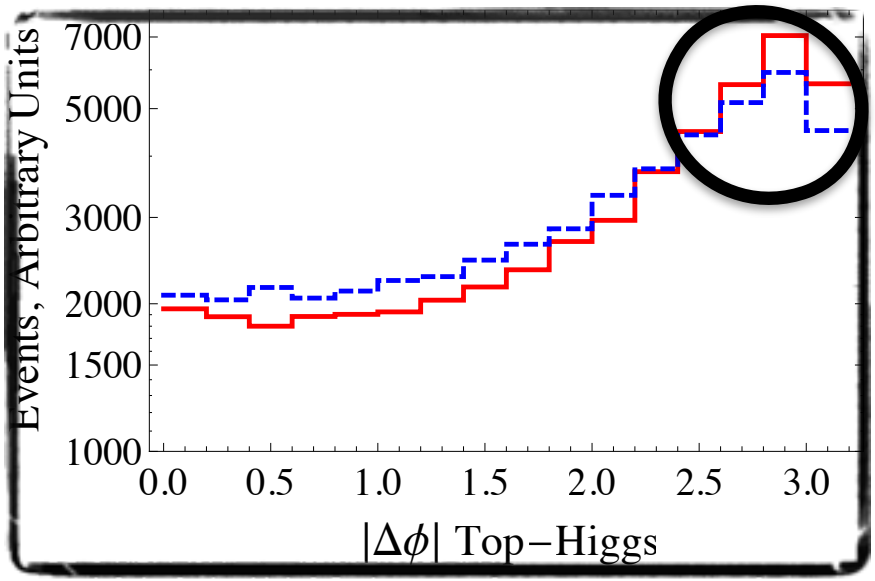
A typical event with Standard Model couplings.

$c_{\mathrm{ght}} = -0.75$

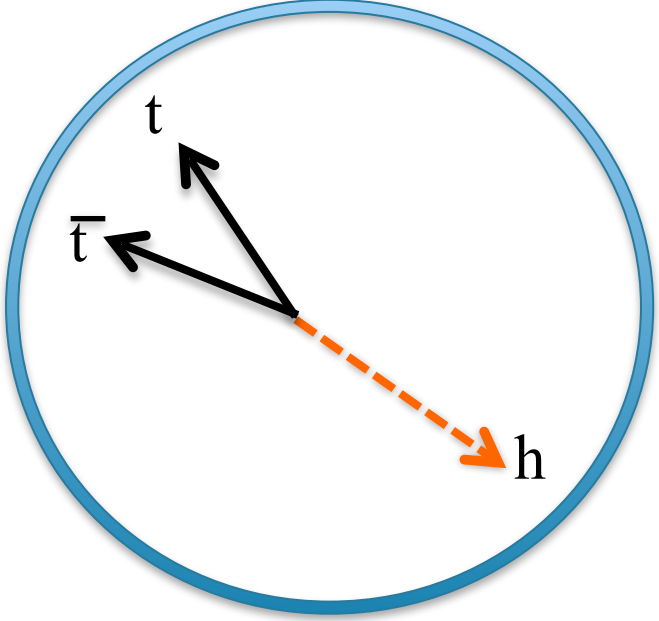
$c_{\mathrm{GH}} = 0.083$

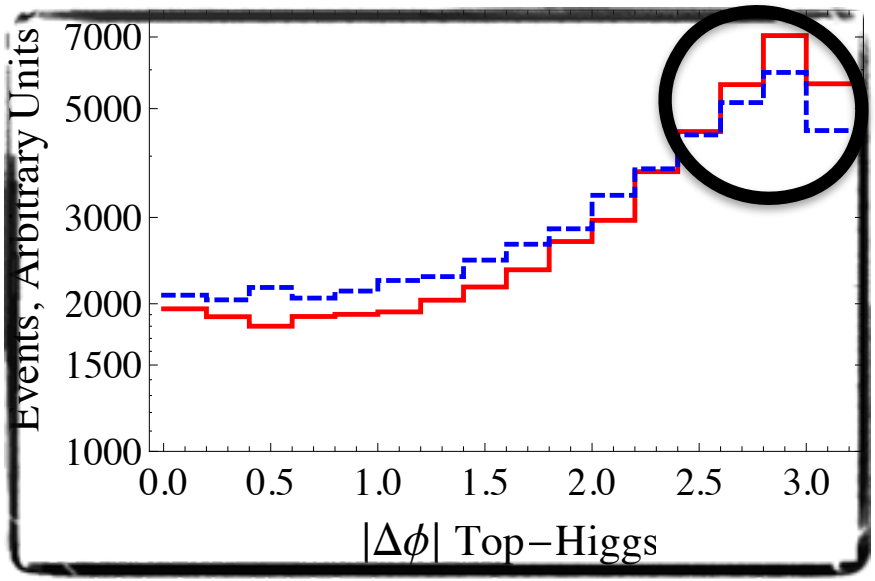
$(\mu_{\mathrm{tth}} \approx \mu_h \approx 1)$





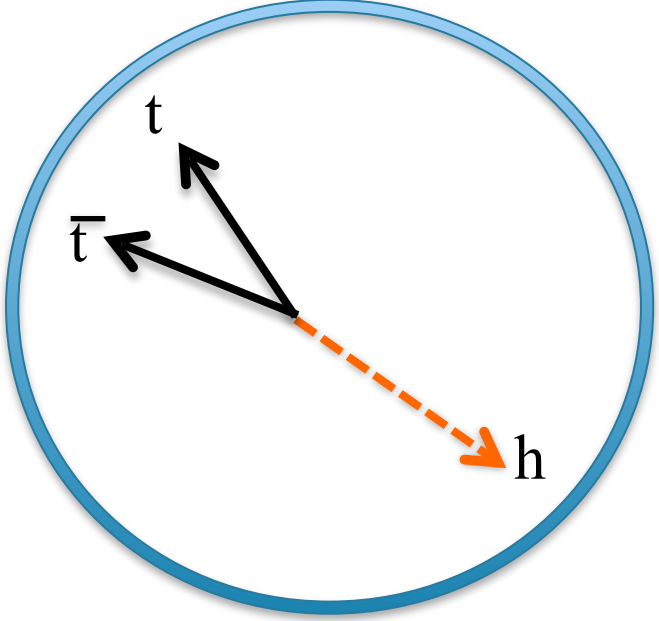
A typical event with NP boosted dim-6 couplings.

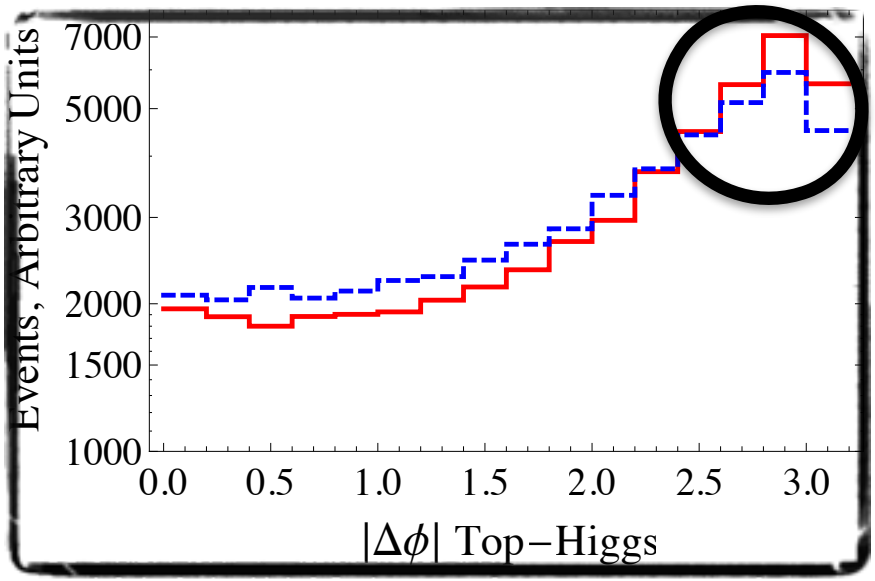




Typically we think about the following simple kinematic variables: m_T, m_{T2}.

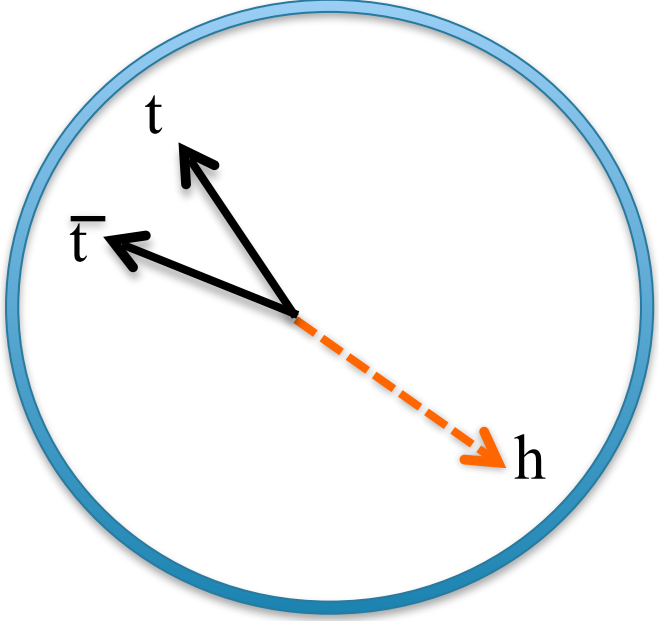
- $$m_T=[2E_{T1}E_{T2}(1-\cos\varphi)]^{1/2}$$

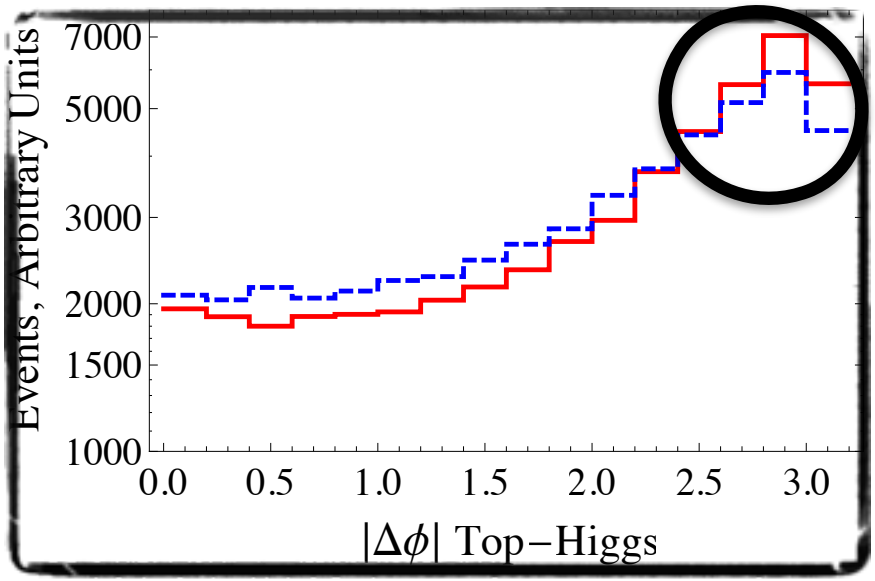




Typically we think about the following simple kinematic variables: m_T, m_{T2}.

- $$m_T=[2E_{T1}E_{T2}(1-\cos\varphi)]^{1/2}$$
- $$m_{T2}$$

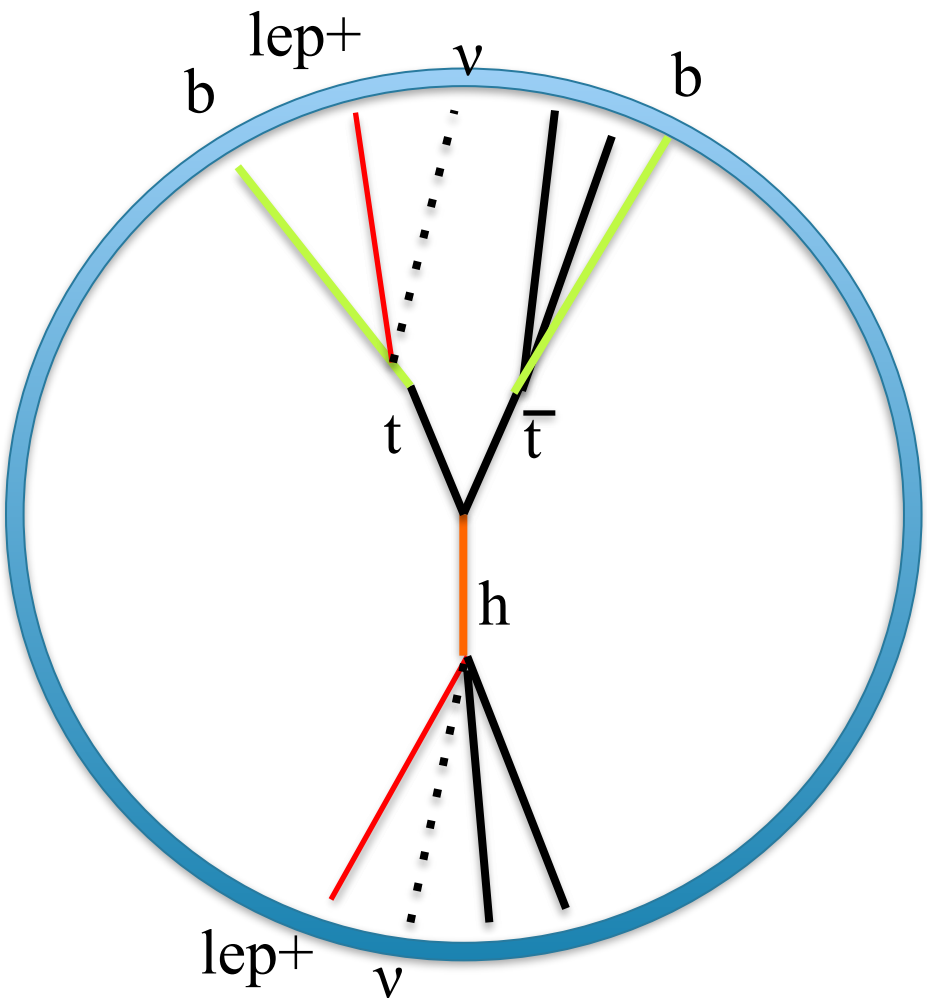




Typically we think about the following simple kinematic variables: m_T, m_{T2}.

- $m_T = [2E_{T1}E_{T2}(1-\cos\varphi)]^{1/2}$
- m_{T2}
- $m_{T,(stupid)}$

To find new physics in the kinematic effective field theory, define new collider observables using the angles between collider objects.
In pp→tth→same sign dilepton, these will be angles between three objects.

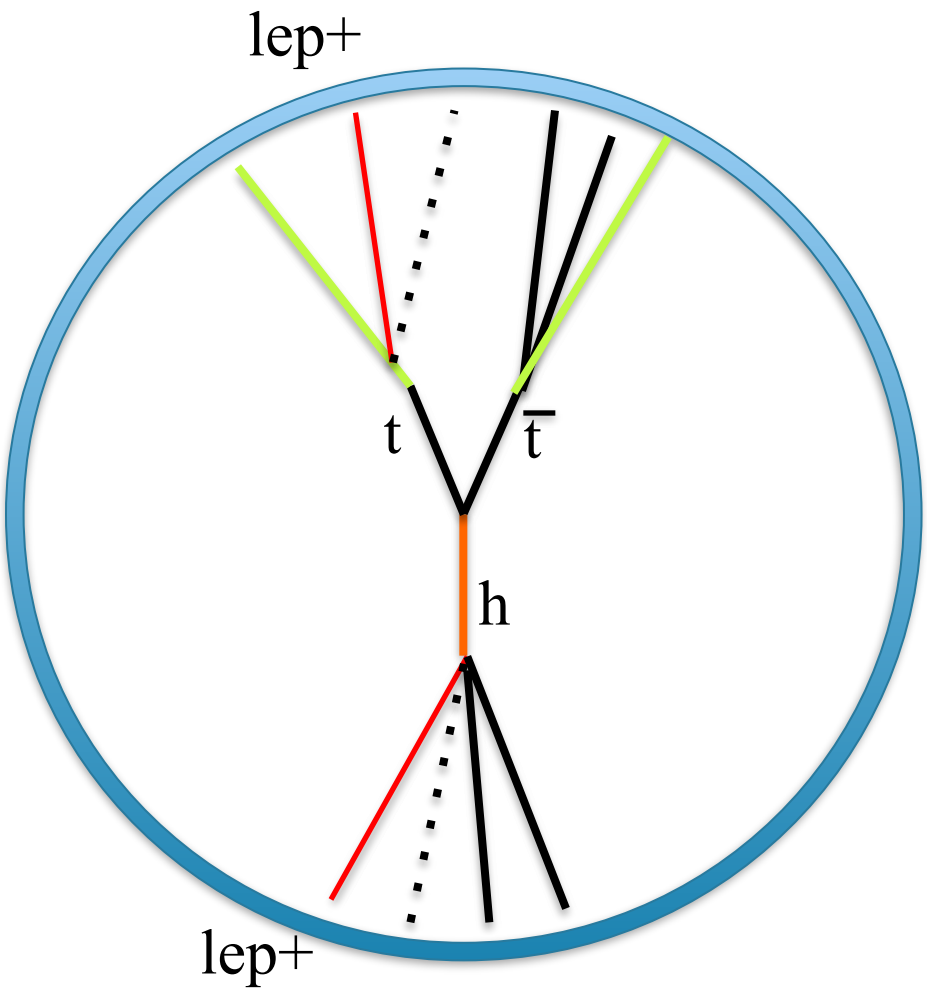


Missing transverse energy (MET) is energy lost in the detector, mostly to neutrinos.

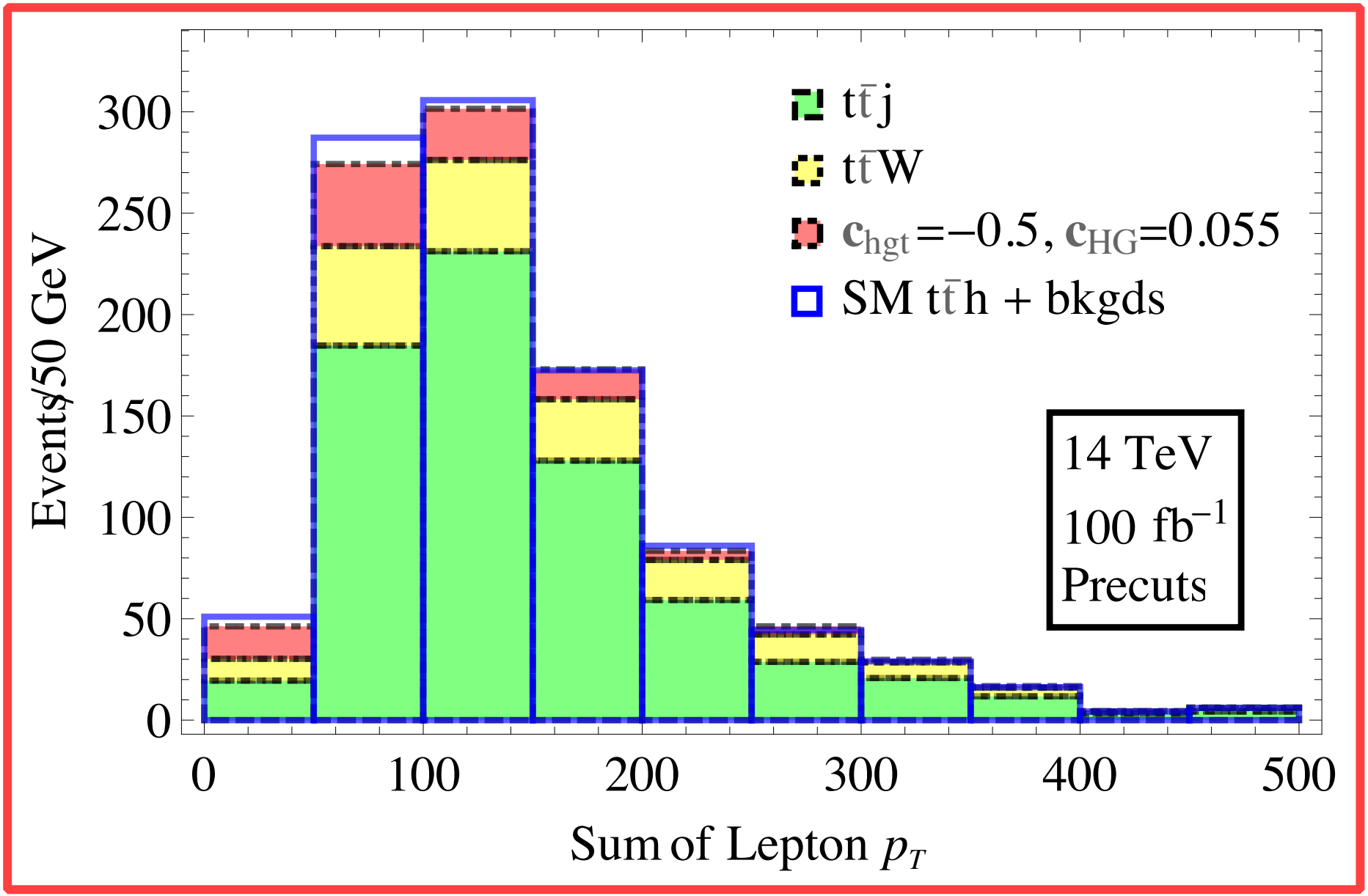
Same charge dileptons.

B-tagged jet(s) (Medium, or 2 Light b-tags).

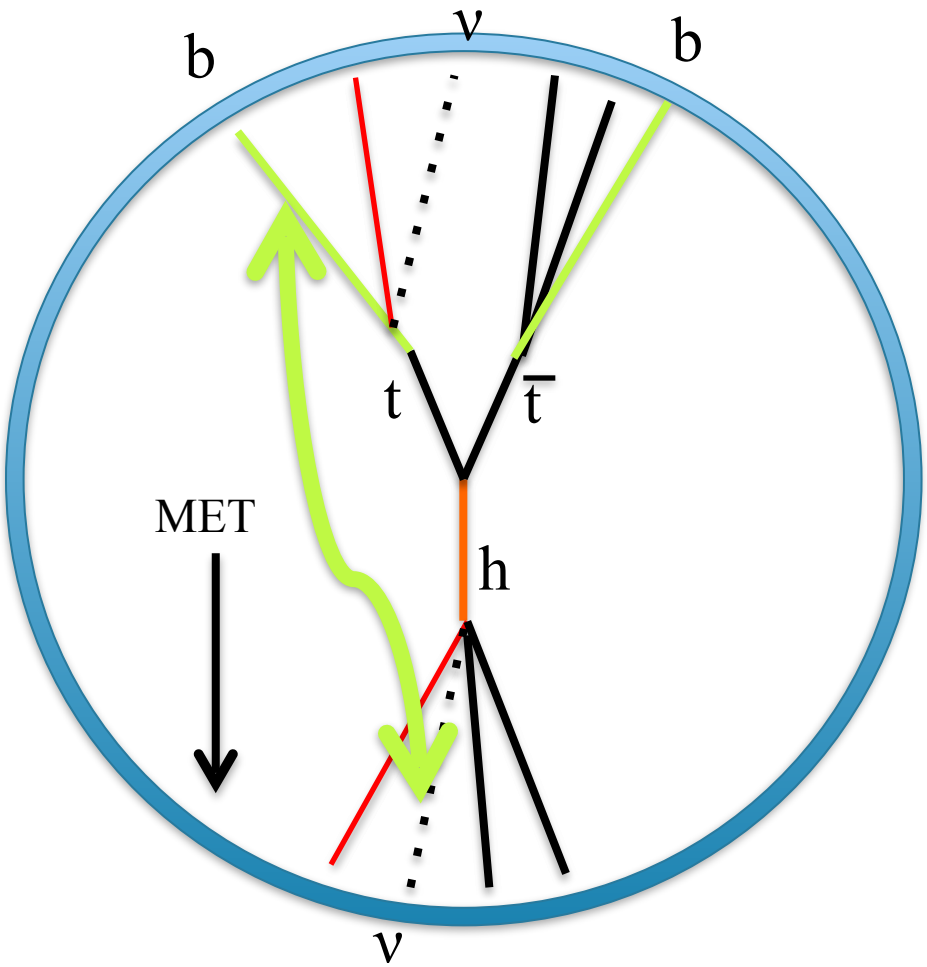
$$L_{p_T} = \sum_{\text{isolated leptons}} p_T^{\ell}$$



Same charge dileptons.

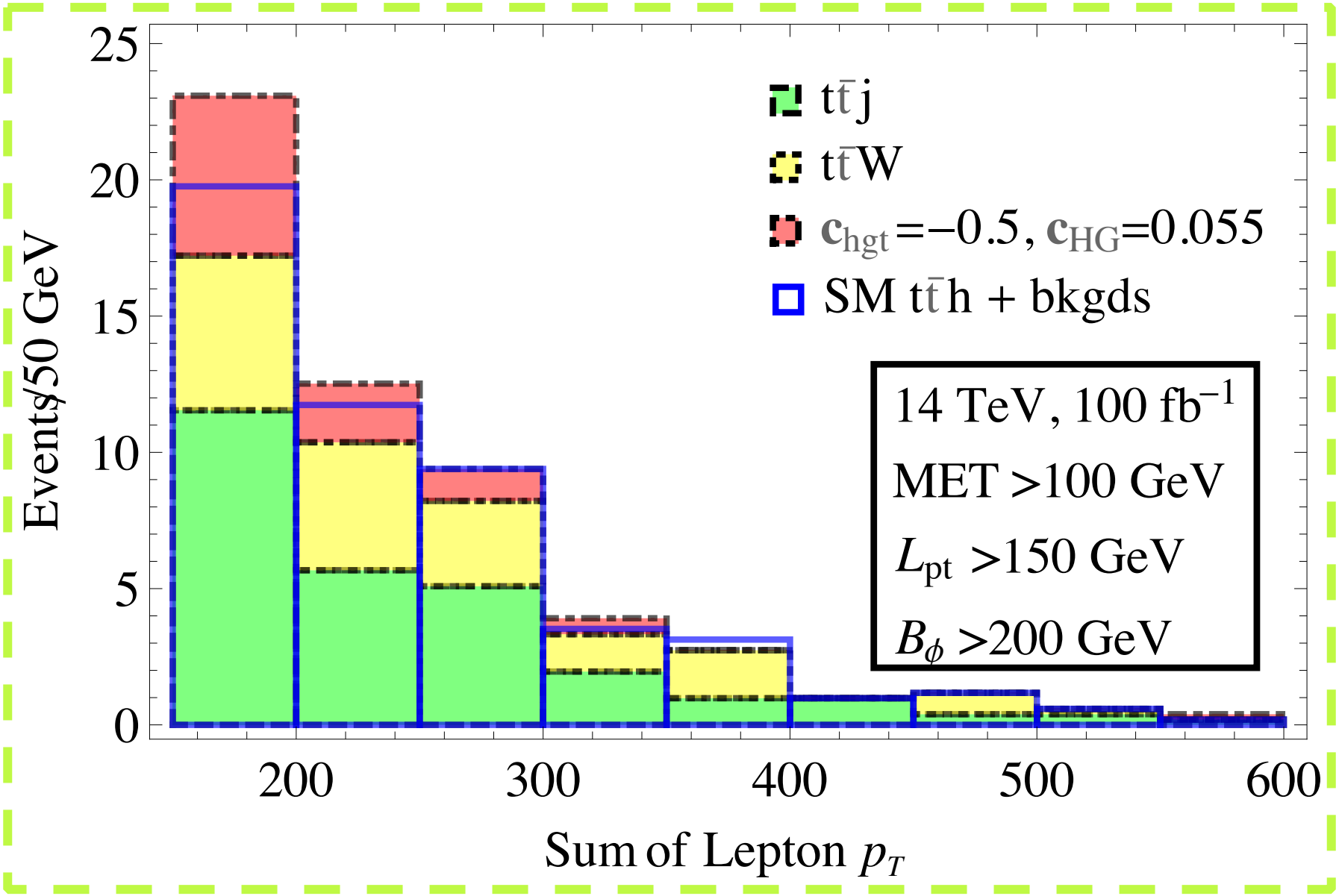

$t\bar{t}j$
$t\bar{t}W$
$c_{hgt}=-0.5$, $c_{HG}=0.055$
SM $t\bar{t}h$ + bkgds
14 TeV
100 fb^{-1}
Precuts
Events/50 GeV
0
50
100
150
200
250
300
0
100
200
300
400
500
Sum of Lepton p_T

$$B_\phi = \sum_{\text{b-tagged jets}} p_T^b \times |\Delta\phi_{\not{E}_T,b}|$$

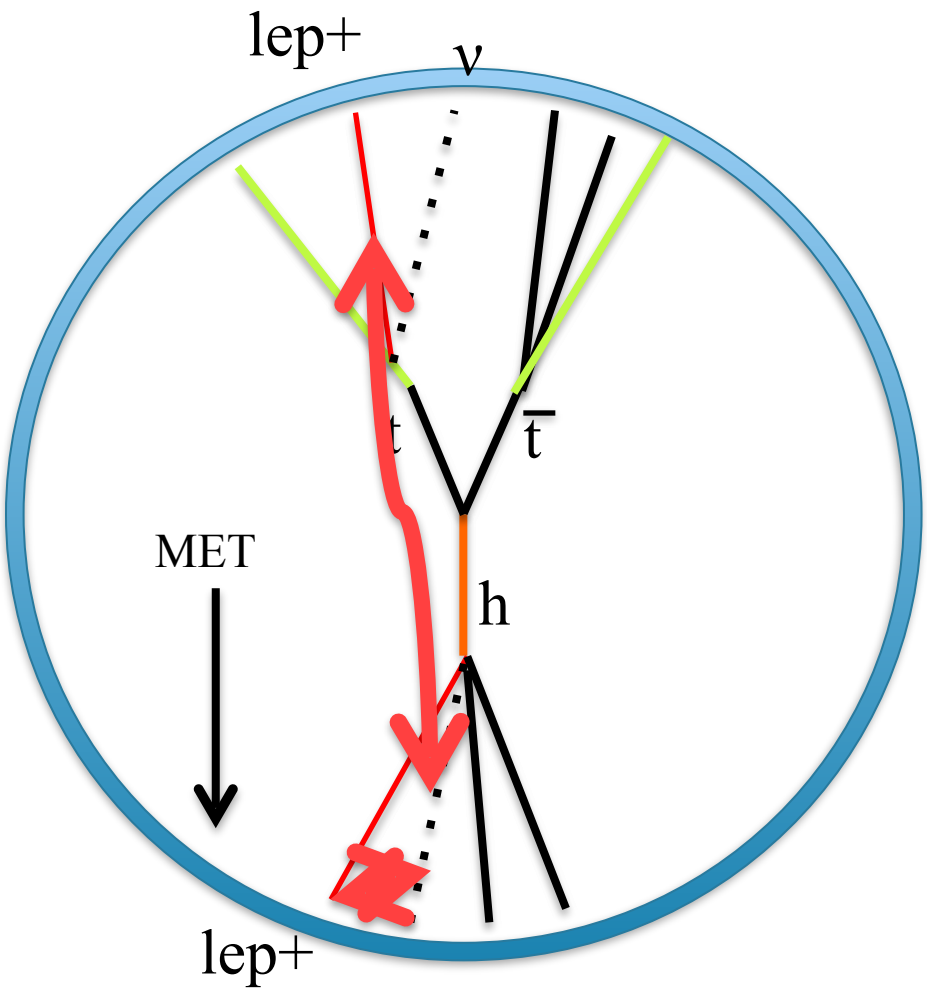


Missing transverse energy (MET) is energy lost in the detector, mostly to neutrinos.

B-tagged jet(s) (Medium, or 2 Light b-tags).


25
20
15
10
5
0
Events/50 GeV
200
300
400
500
600
Sum of Lepton p_T
$t\bar{t}j$
$t\bar{t}W$
$c_{hgt}=-0.5$, $c_{HG}=0.055$
SM $t\bar{t}h$ + bkgds
14 TeV, 100 fb^{-1}
MET >100 GeV
L_{pt} >150 GeV
B_ϕ >200 GeV

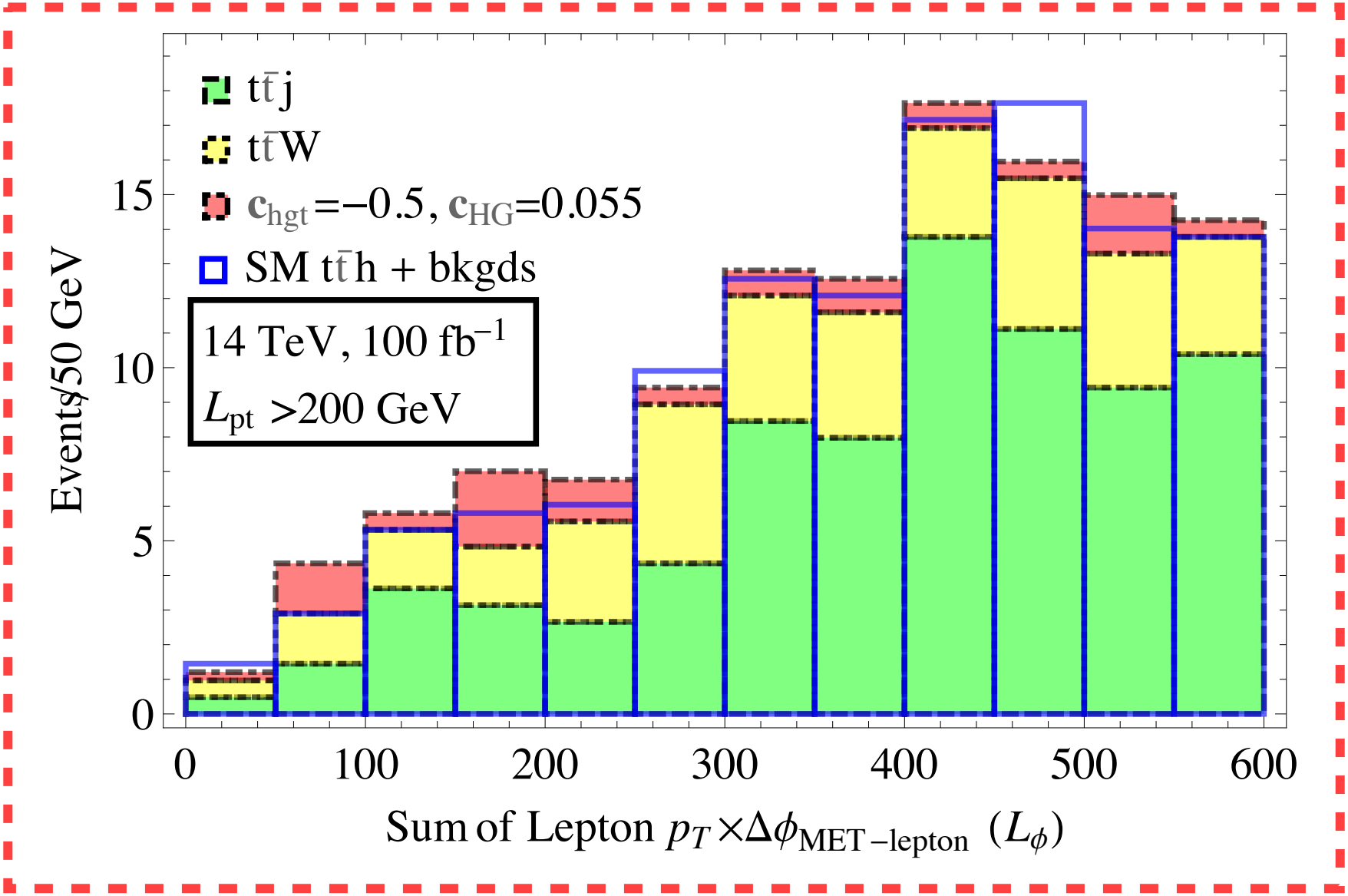
$$L_\phi = \sum_{\text{isolated leptons}} p_T^\ell \times |\Delta\phi_{\not{E}_T,\ell}|$$



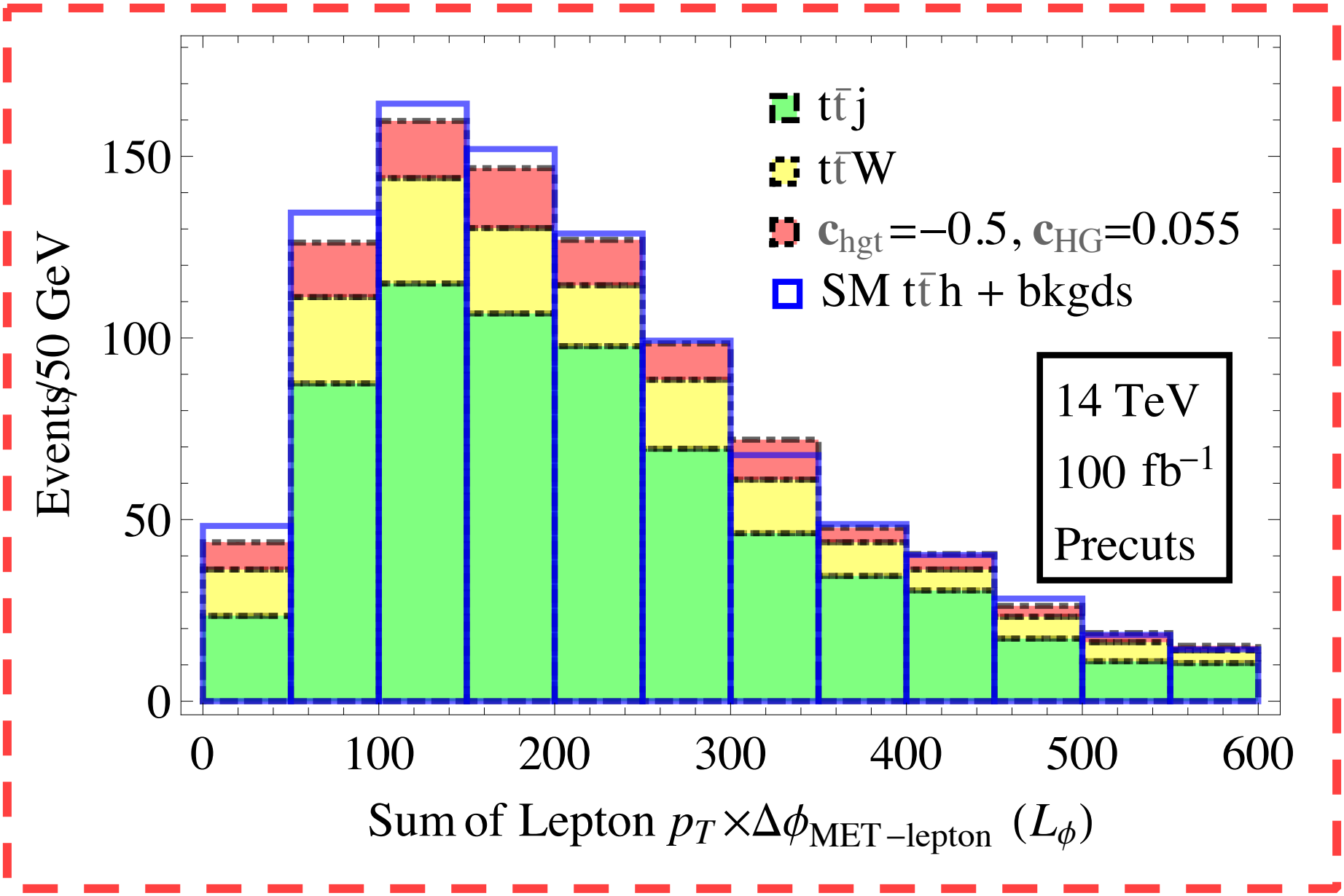
Missing transverse energy (MET) is energy lost in the detector, mostly to neutrinos.

Same charge dileptons.

Can be combined with cut on sum over lepton pt.



Good at backgrounds cuts for SM tth searches



Kinematic Reach for 8 TeV LHC

$\sqrt{s}$ =8 TeV, 19.6 fb^{-1}, $c_{hgt} = -0.75$, $c_{HG} = 0.083$	$t\bar{t} + jets$	$t\bar{t}W^{\pm} + jets$	SM Signal	NP Signal
SSDL preliminary cuts only	34	16	5.8	5.6
$L_\phi < 250$	21	10	4.9	4.4
$L_{p_T} > 200$	5.0	3.7	0.40	0.73
$L_\phi < 150$, $B_\phi > 150$, $\Delta R_{\ell b} > 150$	2.1	1.3	0.45	0.69
$\not{E}_T > 100$, $L_{p_T} > 100$, $L_\phi < 150$	0.59	0.89	0.25	0.46

$\sqrt{s}$ =8 TeV, 20 fb^{-1}, parameter points listed	$\mu_{t\bar{t}h}$	events after $L_\phi < 150$, $B_\phi > 150$, $\Delta R_{\ell b} > 150$
Standard Model	1	0.45
$c_{hgt} = 0.5$, $c_{HG} = -0.27$	2.1	4.1
$c_{hgt} = -1.75$, $c_{HG} = -0.023$	3.3	4
$c_{hgt} = 1$, $c_{HG} = -0.32$	4.6	8.2

Kinematic Reach for 8 TeV LHC

$\sqrt{s}$ =8 TeV, 19.6 fb^{-1}, $c_{hgt} = -0.75$, $c_{HG} = 0.083$	$t\bar{t} + jets$	$t\bar{t}W^{\pm} + jets$	SM Signal	NP Signal
SSDL preliminary cuts only	34	16	5.8	5.6
$L_\phi < 250$	21	10	4.9	4.4
$L_{p_T} > 200$	5.0	3.7	0.40	0.73
$L_\phi < 150$, $B_\phi > 150$, $\Delta R_{\ell b} > 150$	2.1	1.3	0.45	0.69
$\not{E}_T > 100$, $L_{p_T} > 100$, $L_\phi < 150$	0.59	0.89	0.25	0.46

$\sqrt{s}$ =8 TeV, 20 fb^{-1}, parameter points listed	$\mu_{t\bar{t}h}$	events after $L_\phi < 150$, $B_\phi > 150$, $\Delta R_{\ell b} > 150$
Standard Model	1	0.45
$c_{hgt} = 0.5$, $c_{HG} = -0.27$	2.1	4.1
$c_{hgt} = -1.75$, $c_{HG} = -0.023$	3.3	4
$c_{hgt} = 1$, $c_{HG} = -0.32$	4.6	8.2

Kinematic Reach for 14 TeV LHC

$\sqrt{s}$ =14 TeV, 100 fb^{-1}, $c_{hgt} = -0.5$, $c_{HG} = 0.055$	$t\bar{t} + jets$	$t\bar{t}W^{\pm} + jets$	SM Signal	NP Signal
SSDL preliminary cuts only	697	185	128	114
$L_{\phi} < 250$	428	107	106	91
$L_{p_T} > 200$	124	51	8	13
$L_{p_T} > 200$, $L_{\phi} < 250$	10.9	8.1	2.3	4.1
$\not{E}_T > 80$, $L_{\phi} < 100$, $B_{\phi} > 150$, $\Delta R_{\ell b} > 150$	8.1	5.9	4.5	6.0
$\not{E}_T > 100$, $L_{p_T} > 150$, $B_{\phi} > 200$	28	18	4.8	10

$\sqrt{s}$ =14 TeV, 100 fb^{-1}, parameter points listed	$\mu_{t\bar{t}h}$	events after $\not{E}_T > 100$, $L_{p_T} > 150$, $B_{\phi} > 200$
Standard Model	1	4.8
$c_{hgt} = -0.75$, $c_{HG} = 0.083$	1.5	24
$c_{hgt} = -0.75$, $c_{HG} = -0.13$	1.4	15
$c_{hgt} = -0.5$, $c_{HG} = 0.055$	0.99	10
$c_{hgt} = -0.5$, $c_{HG} = -0.16$	0.95	8.2
$c_{hgt} = 0.25$, $c_{HG} = -0.028$	1.2	12

Kinematic Reach for 14 TeV LHC

$\sqrt{s}$ =14 TeV, 100 fb^{-1}, $c_{hgt} = -0.5$, $c_{HG} = 0.055$	$t\bar{t} + jets$	$t\bar{t}W^{\pm} + jets$	SM Signal	NP Signal
SSDL preliminary cuts only	697	185	128	114
$L_\phi < 250$	428	107	106	91
$L_{p_T} > 200$	124	51	8	13
$L_{p_T} > 200$, $L_\phi < 250$	10.9	8.1	2.3	4.1
$\not{E}_T > 80$, $L_\phi < 100$, $B_\phi > 150$, $\Delta R_{\ell b} > 150$	8.1	5.9	4.5	6.0
$\not{E}_T > 100$, $L_{p_T} > 150$, $B_\phi > 200$	28	18	4.8	10

$\sqrt{s}$ =14 TeV, 100 fb^{-1}, parameter points listed	$\mu_{t\bar{t}h}$	events after $\not{E}_T > 100$, $L_{p_T} > 150$, $B_\phi > 200$
Standard Model	1	4.8
$c_{hgt} = -0.75$, $c_{HG} = 0.083$	1.5	24
$c_{hgt} = -0.75$, $c_{HG} = -0.13$	1.4	15
$c_{hgt} = -0.5$, $c_{HG} = 0.055$	0.99	10
$c_{hgt} = -0.5$, $c_{HG} = -0.16$	0.95	8.2
$c_{hgt} = 0.25$, $c_{HG} = -0.028$	1.2	12

Conclusions part one:

IN ORDER TO WRING THE 8-14 TEV LHC DRY OF TOP YUKAWA PHYSICS,

ONE VIABLE APPROACH IS KINEMATIC EFT AND ANGULAR VARIABLES!

NewScientist Physics & Math

Home News In-Depth Articles Opinion CultureLab Galleries Topic G

SPACE TECH ENVIRONMENT HEALTH LIFE PHYSICS&

LHC to probe early universe in best detail yet

For similar stories, visit the Quantum World and The Large Hadron Collider T

The Large Hadron Collider will spend four weeks probing the conditions of the early universe in better detail than ever before, as it takes a break from the hunt for the Higgs boson.

The LHC's main activity for 2011, colliding pairs of protons, came to an end as scheduled on 30 October. The experiment has now produced about 6 inverse femtobarns of collision data, about three times the total used in the last major analysis searching for the Higgs boson, thought to endow other particles with mass, which was reported in August.

As researchers start analysing the new data, the LHC is switching to colliding lead ions for four weeks, starting on 5 November. These collisions produce pockets of very dense and hot matter, recreating the conditions in the first moments after the big bang.

This statement was only a hope.

NewScientist Physics & Math

Home News In-Depth Articles Opinion CultureLab Galleries Topic G

SPACE TECH ENVIRONMENT HEALTH LIFE PHYSICS&

LHC to probe early universe in best detail yet

The Large Hadron Collider will spend four weeks probing the conditions of the early universe in better detail than ever before, as it takes a break from the hunt for the Higgs boson.

The LHC's main activity for 2011, colliding pairs of protons, came to an end as scheduled on 30 October. The experiment has now produced about 6 inverse femtobarns of collision data, about three times the total used in the last major analysis searching for the Higgs boson, thought to endow other particles with mass, which was reported in August.

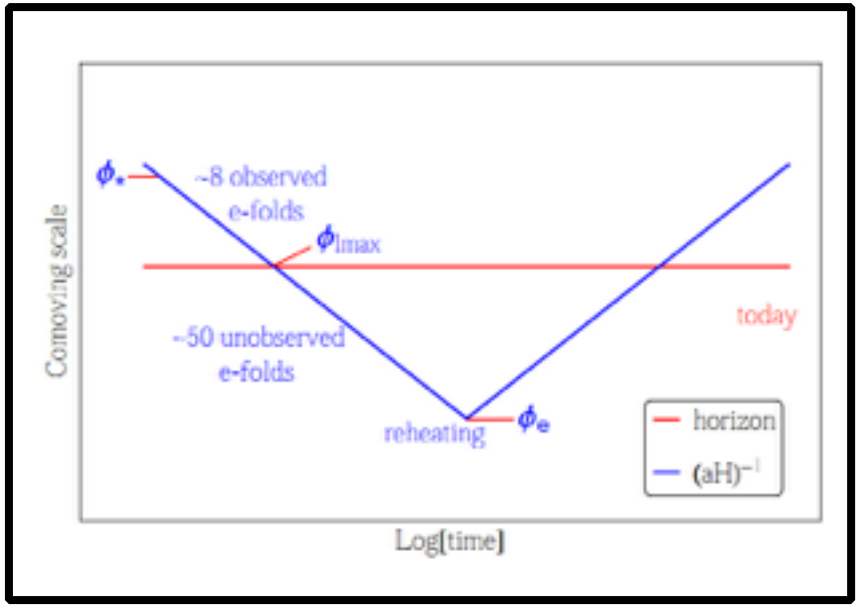
As researchers start analysing the new data, the LHC is switching to colliding lead ions for four weeks, starting on 5 November. These collisions produce pockets of very dense and hot matter, recreating the conditions in the first moments after the big bang.

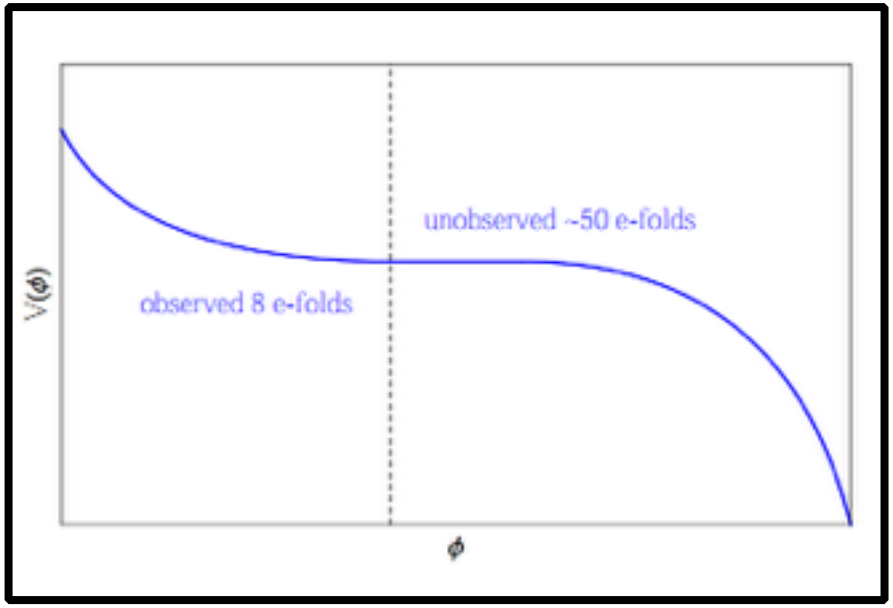
Until BICEP2 (maybe!) It is incredible we (could have!) found r! (or could find it at SPIDER, POLARBEAR, KECK, the BICEP2/Planck joint collaboration announced yesterday!)

In upcoming clarifications of BICEP2, even a small r value would imply access to Planck scale symmetries.

1405.7563 Bramante, Downes, Lehman, Martin

In upcoming clarifications of BICEP2, even a small r value would imply access to Planck scale symmetries.





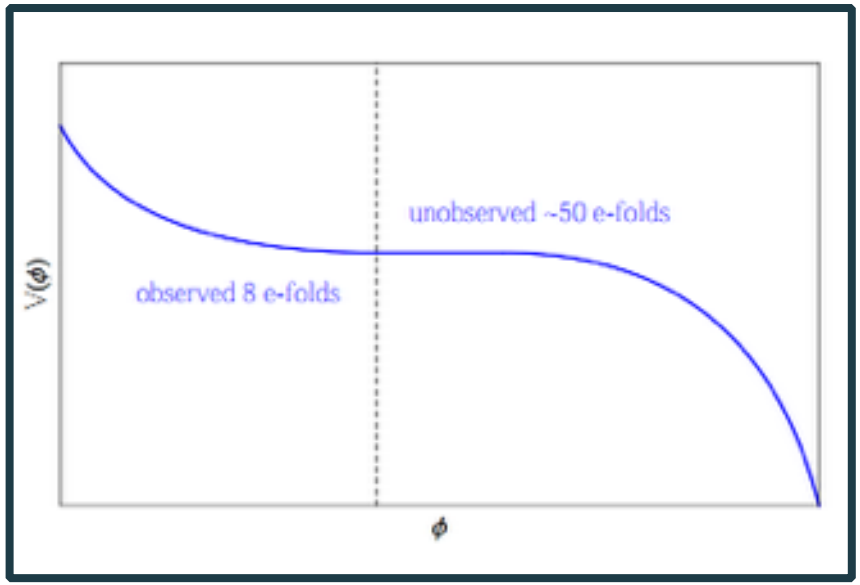
1405.7563 Bramante, Downes, Lehman, Martin

In upcoming clarifications of BICEP2, even a small r value would imply access to Planck scale symmetries.

Planck fat vs. Planck flat.

$$\frac{m_{\rm Pl}^2 V_\phi^2}{2V^2} \equiv \epsilon_V \ll 1$$

$$V_\phi \equiv dV/d\phi$$



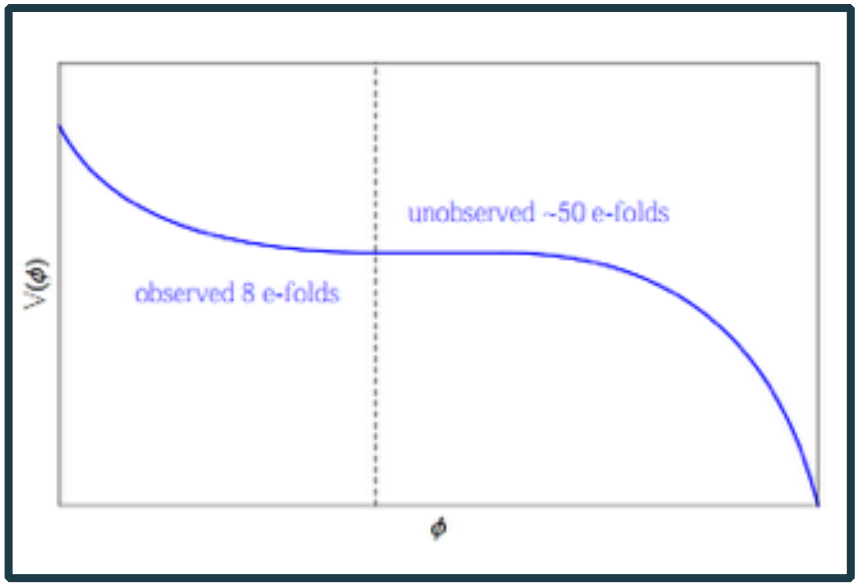
1405.7563 Bramante, Downes, Lehman, Martin

In upcoming clarifications of BICEP2, even a small r value would imply access to Planck scale symmetries.

Planck fat vs. Planck flat.

$$\frac{m_{\rm Pl}^2 V_\phi^2}{2V^2} \equiv \epsilon_V \ll 1$$

$$V_\phi \equiv dV/d\phi$$



Field range bound with n_s.

$$\frac{\Delta\phi}{m_{\rm Pl}} \geq \frac{\sqrt{\frac{r}{8}}}{\frac{1}{3}(n_s - 1) + \frac{1}{N_{\rm total}}}$$

$$\frac{\Delta\phi}{m_{\rm Pl}} \geq 1.00\sqrt{\frac{r}{0.1}}$$

1405.7563 Bramante, Downes, Lehman, Martin

Emergency procedure for particle theorists:

In Case of BICEP2(II), Break out Burgess, Patil, Trott [1402.1476].

Emergency procedure for particle theorists:

In Case of BICEP2(II), Break out Burgess, Patil, Trott [1402.1476].

STEP 1

One extra Higgs term.

$$\mathcal{L}_{HI} = \mathcal{L}_{SM} - \sqrt{-\hat{g}}\left[\frac{M_p^2}{2} + \xi\left(H^\dagger H\right)\right]\hat{R}$$

Emergency procedure for particle theorists:

In Case of BICEP2(II), Break out Burgess, Patil, Trott [1402.1476].

STEP 2

One extra Higgs term.
Weyl Transform.

$$\mathcal{L}_{HI} = \mathcal{L}_{SM} - \sqrt{-\hat{g}}\left[\frac{M_p^2}{2} + \xi\,(H^\dagger H)\right]\hat{R}$$

$$\hat{g}_{\mu\nu} = f\, g_{\mu\nu} \qquad \text{with} \qquad f = \left[1 + 2\,\xi(H^\dagger H)/M_p^2\right]^{-1}$$

Emergency procedure for particle theorists:

In Case of BICEP2(II), Break out Burgess, Patil, Trott [1402.1476].

STEP 3

One extra Higgs term.

$$\mathcal{L}_{HI} = \mathcal{L}_{SM} - \sqrt{-\hat{g}}\left[\frac{M_p^2}{2} + \xi\left(H^\dagger H\right)\right]\hat{R}$$

$$V(h) = \frac{\lambda h^4}{4\left(1 + \frac{\xi h^2}{M_P^2}\right)^2}$$

Planck flat for $\xi h^2 >> M_P$.

Emergency procedure for particle theorists:

In Case of BICEP2(II), Break out Burgess, Patil, Trott [1402.1476].

STEP 4

λ RG Flow from Dim-6 EFT terms.

$$V(h) = \frac{\lambda h^4}{4\left(1 + \frac{\xi h^2}{M_P^2}\right)^2}$$

$$\delta\left(\mu \frac{d\lambda}{d\mu}\right) \supset \frac{m_h^2}{16\pi^2}\left[9\, g_2^2\, C_{HW} + 3\, g_1^2\, C_{HB} + 3 g_1\, g_2\, C_{HWB}\right]$$

arXiv:1403.4971 (cross-list from astro-ph.CO) [pdf, other]

Is Higgs Inflation Dead?

Jessica L. Cook, Lawrence M. Krauss, Andrew J. Long, Subir Sabharwal

Comments: 6 pages, 2 figures

Subjects: **Cosmology and Nongalactic Astrophysics (astro-ph.CO)**; High Energy F

We consider the status of Higgs Inflation in light of the recently announced d
collaboration. In order for the primordial B-mode signal to be observable by
Higgs Inflation generally predicts a small amplitude of tensor perturbations, a
find the answer is essentially no, unless one considers either extreme fine tu
attractive features of the original idea. We also explore the possible importan
the effective potential used in calculating inflationary observables, e.g. n_S
effects of Higgs mass uncertainties and other observables already considerec
small to remove the apparent incompatibility between the BICEP2 observatior

arXiv:1403.5009 (cross-list from gr-qc) [pdf, ps, other]

Two scalar field cosmology from coupled one-field models

P. H. R. S. Moraes, J. R. L. Santos

Comments: 8 pages, 6 figures. Version to appear in Physical Review D

Subjects: **General Relativity and Quantum Cosmology (gr-qc)**; High Energy Physi

One possible description for the current accelerated expansion of the univers
scenarios driven by scalar fields. In this work we present some interesting fea
in a flat space-time. This effective model was constructed by coupling two si
fields allowed us to compute analytical cosmological parameters. The behavic

arXiv:1403.5043 (cross-list from hep-ph) [pdf, other]

Higgs inflation still alive

Yuta Hamada, Hikaru Kawai, Kin-ya Oda, Seong Chan Park

Comments: 7 pages, 3 figures

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; Cosmology and Nong

The observed value of the Higgs mass indicates that the Higgs potential becc
Higgs inflation scenario proposed by Bezrukov and Shaposhnikov. It turns ou
ten. For example, $\xi=7$ corresponds to the tensor-to-scalar ratio $r\sime

arXiv:1403.4971 (cross-list from astro-ph.CO) [pdf, other]

Is Higgs Inflation Dead?

Jessica L. Cook, Lawrence M. Krauss, Andrew J. Long, Subir Sabharwal

Comments: 6 pages, 2 figures

Subjects: **Cosmology and Nongalactic Astrophysics (astro-ph.CO)**; High Energy F

We consider the status of Higgs Inflation in light of the recently announced d
collaboration. In order for the primordial B-mode signal to be observable by
Higgs Inflation generally predicts a small amplitude of tensor perturbations, a
find the answer is essentially no, unless one considers either extreme fine tu
attractive features of the original idea. We also explore the possible importan
the effective potential used in calculating inflationary observables, e.g. n_S
effects of Higgs mass uncertainties and other observables already considerec
small to remove the apparent incompatibility between the BICEP2 observatior

arXiv:1403.5009 (cross-list from gr-qc) [pdf, ps, other]

Two scalar field cosmology from coupled one-field models

P. H. R. S. Moraes, J. R. L. Santos

Comments: 8 pages, 6 figures. Version to appear in Physical Review D

Subjects: **General Relativity and Quantum Cosmology (gr-qc)**; High Energy Physi

One possible description for the current accelerated expansion of the univers
scenarios driven by scalar fields. In this work we present some interesting fea
in a flat space-time. This effective model was constructed by coupling two si
fields allowed us to compute analytical cosmological parameters. The behavi

arXiv:1403.5043 (cross-list from hep-ph) [pdf, other]

Higgs inflation still alive

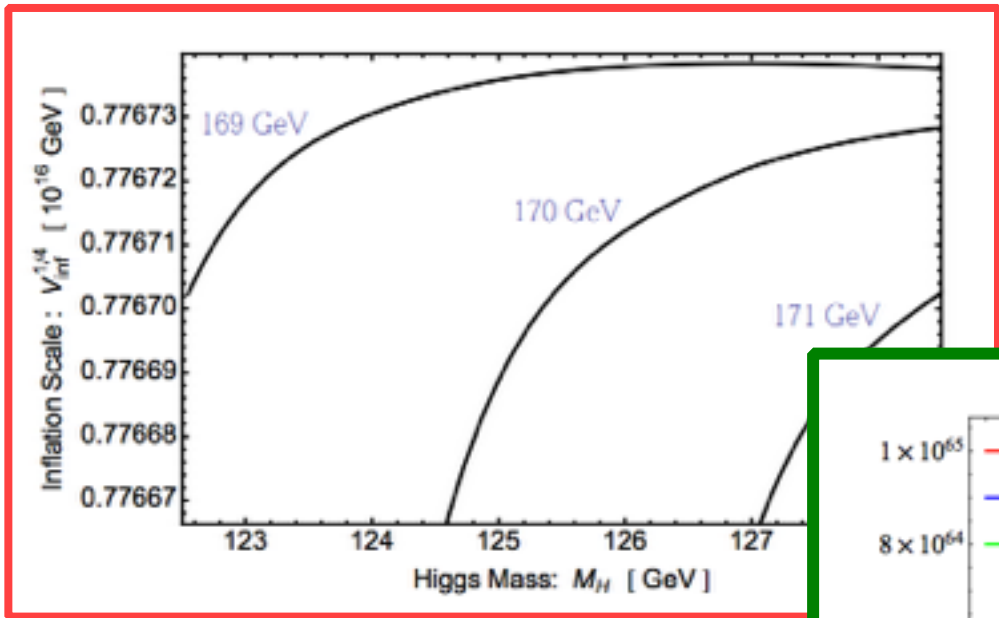
Yuta Hamada, Hikaru Kawai, Kin-ya Oda, Seong Chan Park

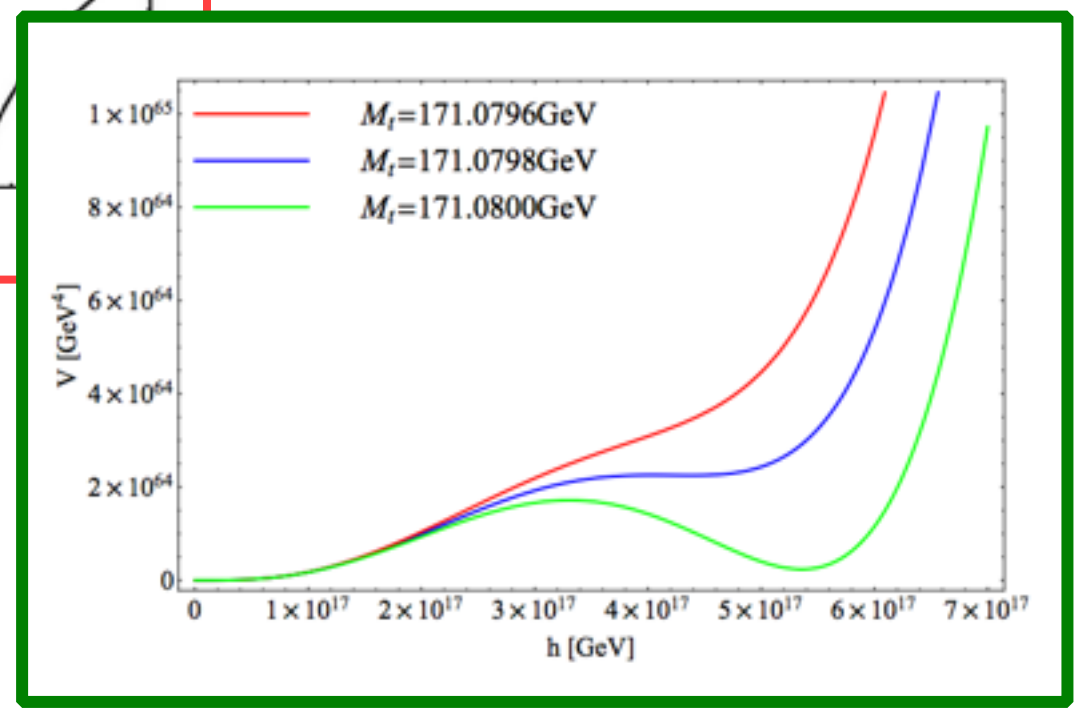
Comments: 7 pages, 3 figures

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; Cosmology and Nong

The observed value of the Higgs mass indicates that the Higgs potential becc
Higgs inflation scenario proposed by Bezrukov and Shaposhnikov. It turns ou
ten. For example, $\xi=7$ corresponds to the tensor-to-scalar ratio $r\sime

Dead.....Alive


169 GeV
170 GeV
171 GeV
0.77673
0.77672
0.77671
0.77670
0.77669
0.77668
0.77667
Inflation Scale : $V_{inf}^{1/4}$ [10^{16} GeV]
123
124
125
126
127
Higgs Mass: M_H [GeV]


M_t=171.0796GeV
M_t=171.0798GeV
M_t=171.0800GeV
1×10^{65}
8×10^{64}
6×10^{64}
4×10^{64}
2×10^{64}
0
V [GeV^4]
0
1×10^{17}
2×10^{17}
3×10^{17}
4×10^{17}
5×10^{17}
6×10^{17}
7×10^{17}
h [GeV]

Center for Future High Energy Physics

高能物理前沿研究中心

http://cfhep.ihep.ac.cn/

Oshkosh
Michigan
Manistee National Forest
Toronto
Mississauga
Watertown
Madison
Milwaukee
Grand Rapids
Sarnia
London
Hamilton
Rochester
Lansing
Kenosha
Buffalo
New York
Albany
Rockford
Detroit
Chatham-Kent
Erie
Ann Arbor
Chicago
Naperville
South Bend
Toledo
Cleveland
Joliet
Gary
Fort Wayne
Akron
Youngstown
Bridgeport
Peoria
Mansfield
Pennsylvania
Allentown
New York
Pittsburgh
Altoona
Harrisburg
Champaign
Indiana
Ohio
Wheeling
Philadelphia
Decatur
Dayton
Columbus
Morgantown
Indianapolis
Terre Haute
Bloomington
Cincinnati
Parkersburg
Maryland
New Jersey
Washington
Delaware
Ironville
West Virginia
Louisville
Huntington
Evansville
Charlottesville
Lexington
George Washington National Forest
Richmond
Owensboro
Kentucky
Paducah
Roanoke
Virginia
Newport News
Bowling Green
Norfolk
Virginia Beach
Kingsport
Nashville
Knoxville
Johnson City
Winston-Salem
Jackson
Tennessee
Asheville
North Carolina
Rocky Mount
Wilson
Charlotte
Greenville
Chattanooga
Fayetteville
Florence
Huntsville
Greenville
Jacksonville
Rock Hill
Tupelo
Decatur
Sumter National Forest
Wilmington
Athens
Atlanta
South

HEP

5/4/2014 at 9:05 PM | 12 Comments

Jim Parsons on What Makes *The Big Bang Theory* So Big

By Amanda Dobbins

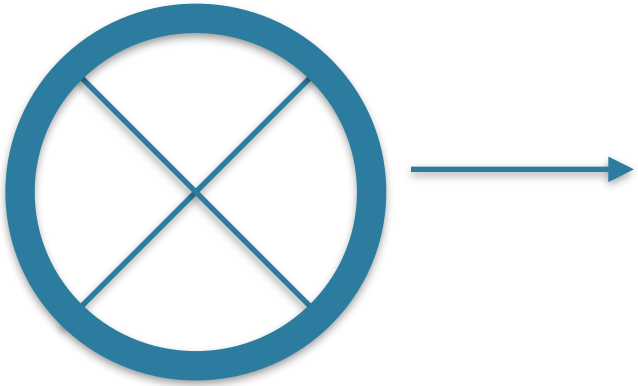
wanted anyway, because he's won three Emmys and beca
The Big Bang Theory, is watched by 23.4 million people
se when you're that successful, why not?—was a white

10^{16} GeV

SU(3) ✖ SU(2) ✖ U(1)

10^{16} GeV

SU(3) ✖ SU(2) ✖ U(1)



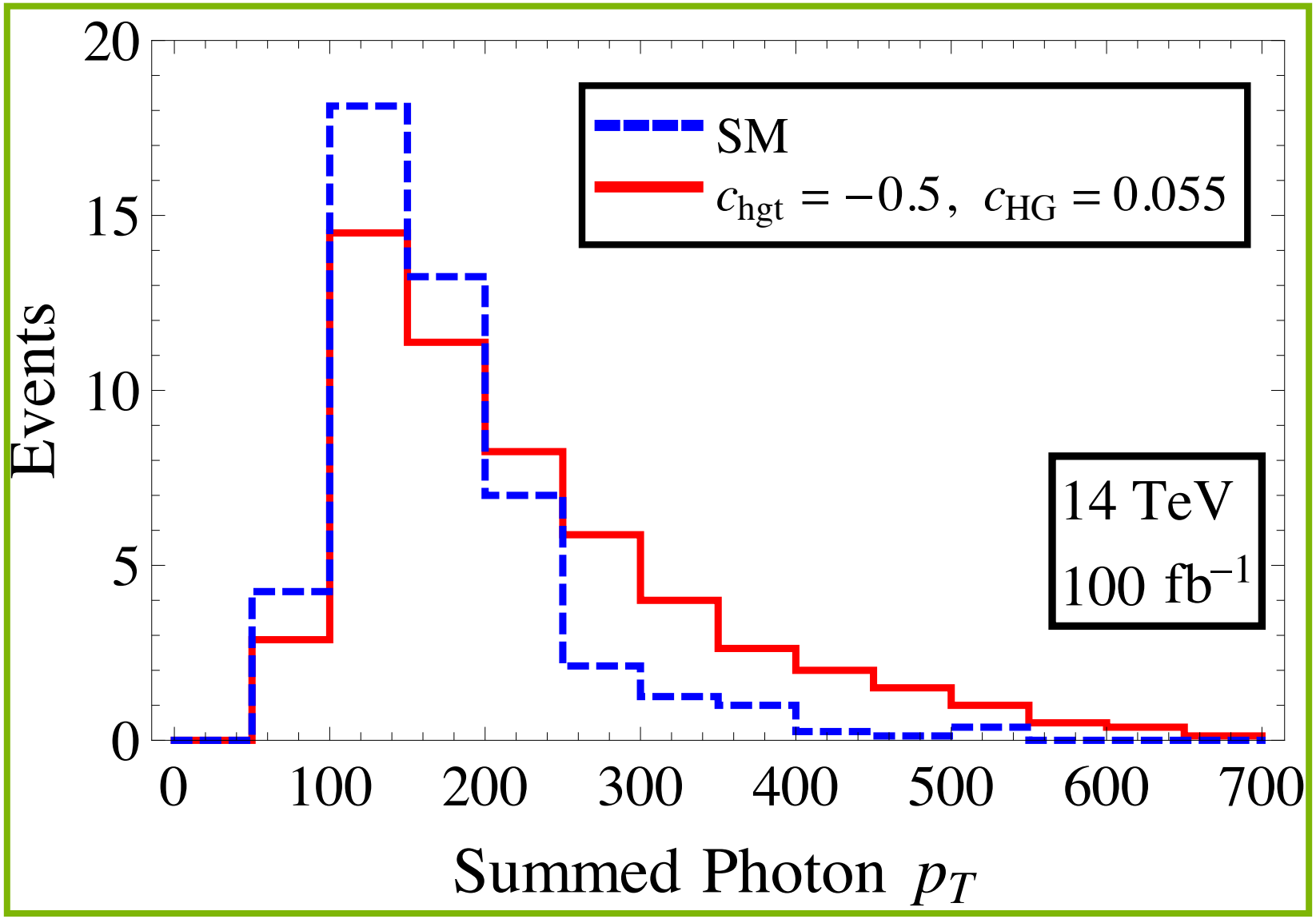
Conclusions part two:

10^{16} GeV

IN ORDER TO WRING THE 8-14 TEV LHC DRY OF TOP YUKAWA PHYSICS —

ONE VIABLE APPROACH IS KINEMATIC EFT AND ANGULAR VARIABLES!

10^{5} GeV

IN THE BICEP2 ERA (REALLY THE ERA OF TENSOR MODES), CONSIDER APPLYING PARTICLE THEORY METHODS IN THE IR TO INFLATION SIGNALS IN THE UV.

Difficult to see boosted top-Higgs in digamma