Strong Dynamics in Electroweak Physics ... in light of LHC

Elizabeth H. Simmons
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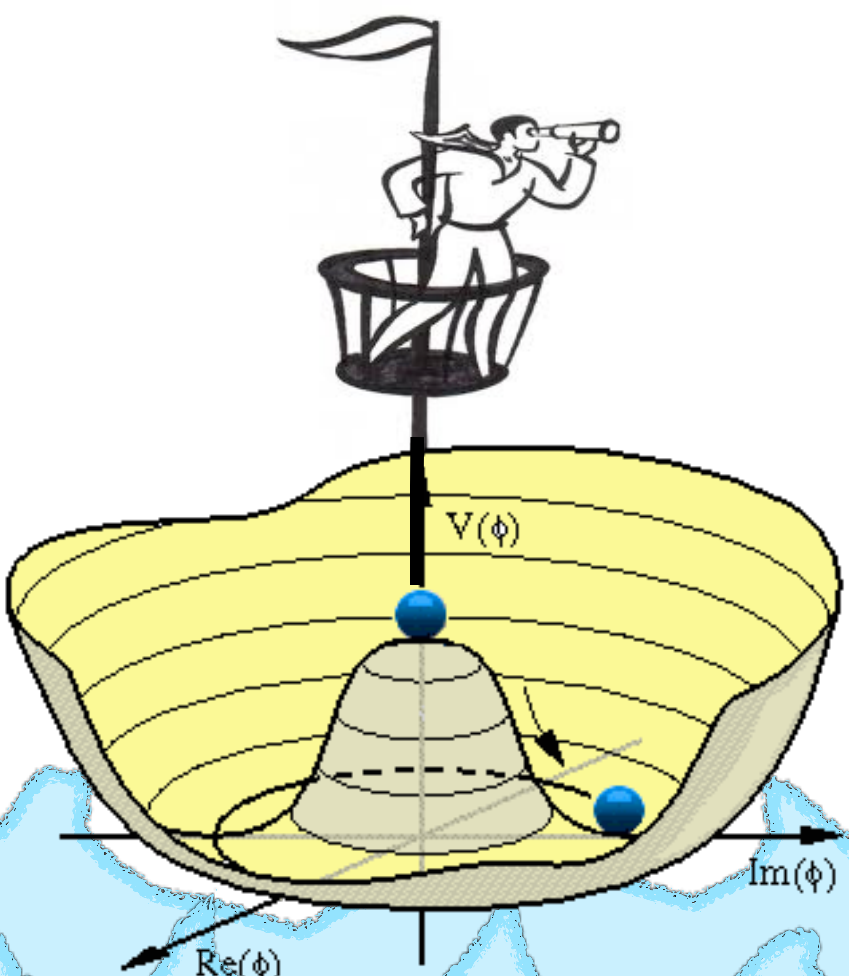
- EWSB and Fermion Masses (including t)
- Models
- New States Related to Strong Dynamics
- LHC Prospects
- Conclusions

PHENO 7 May 2012

Looking Beyond the Standard Model



Fundamental scalars observed?

Hierarchy/Naturalness?

Triviality?

Dynamics causing EWSB?

Strong EWSB and Fermion Masses

Chivukula, Ittisamai, Ren, Simmons

arXiv:1110.3688 [hep-ph] updated 3-2012

Dynamical EWSB:

Classic Technicolor: (inspired by QCD)

Introduce $SU(N)_{TC}$ with

technigluons, inspired by QCD gluons

techniquarks carrying $SU(N)_{TC}$ charge:

- e.g. weak doublet $T_L = (U_L, D_L)$; weak singlet U_R, D_R
- Lagrangian has $SU(2)_L \times SU(2)_R$ chiral symmetry

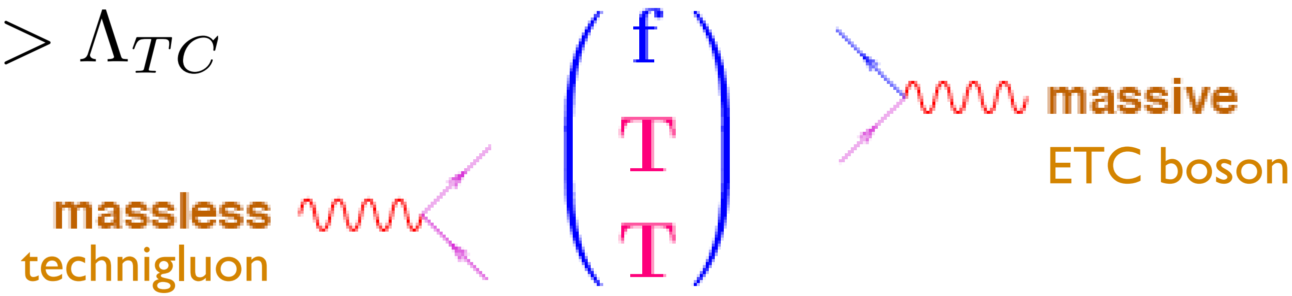
$SU(N)_{TC}$ gauge coupling becomes large at $\Lambda_{TC} \approx 1\mathrm{TeV}$

- $\langle T_L T_R \rangle \approx 250\,\mathrm{GeV}$ causes EWSB
- `**techni**pions' Π_{TC} become the W_L, Z_L
- **techni**rho state unitarizes $W_L W_L$ scattering

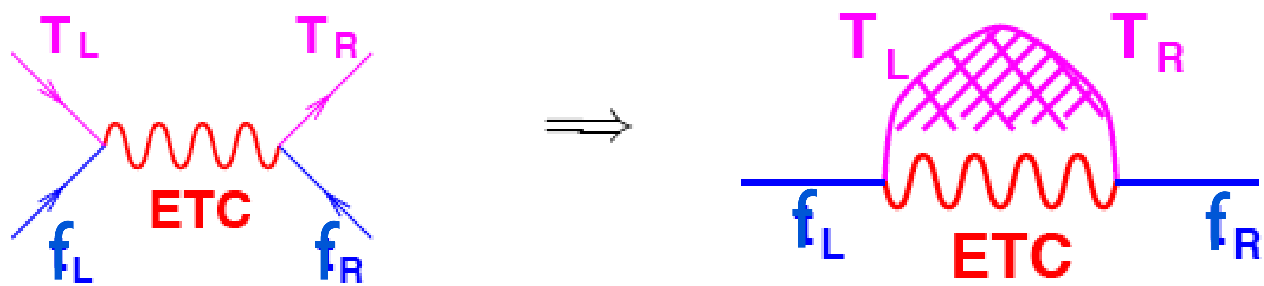
Susskind, Weinberg

Dynamical Fermion Masses: ETC*

$$M_{ETC} > \Lambda_{TC}$$



E.g. the mass of fermion f arises from:



and its size is $\left(\frac{g_{ETC}}{M_{ETC}}\right)^2 \langle \bar{T}T \rangle$ x (flavor-dependent factor)

Challenge I: ETC must violate flavor to provide quark masses and mixings. But how to avoid large FCNC?

*Dimpoulos & Susskind; Eichten & Lane

A Model Builders Dream...

$$\langle \overline{U}U \rangle_{ETC} = \langle \overline{U}U \rangle_{TC} \exp\left(\int_{\Lambda_{TC}}^{M_{ETC}} \frac{d\mu}{\mu} \gamma_m(\mu) \right)$$

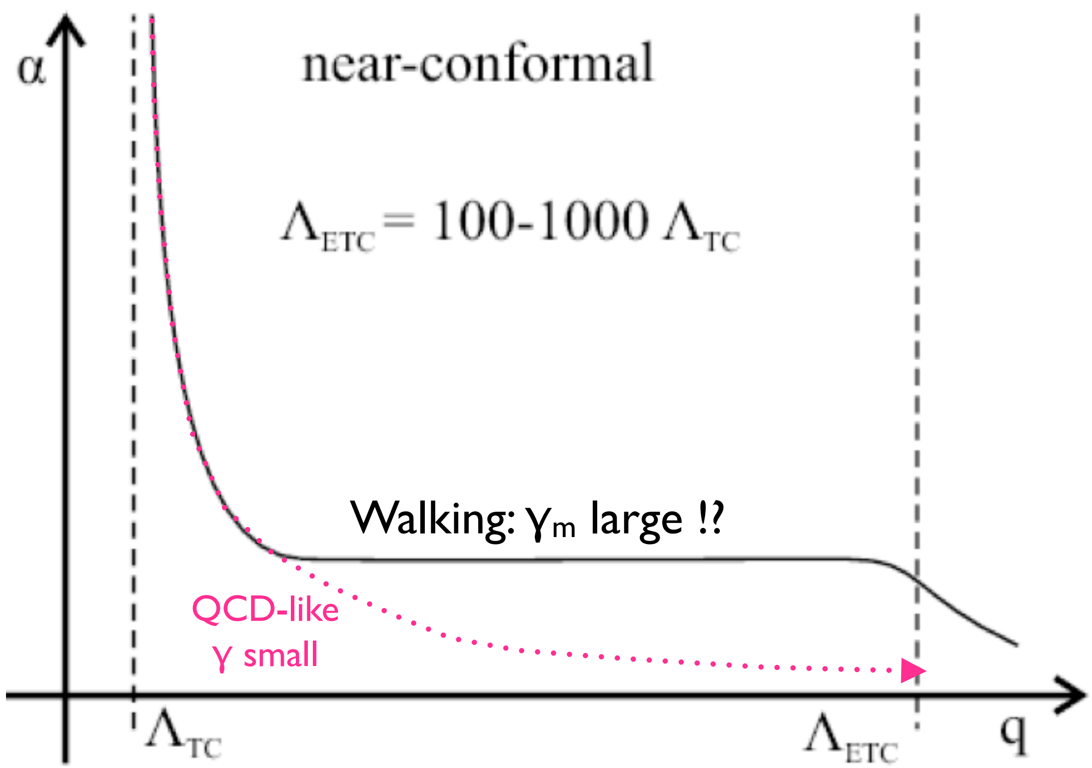


Figure:
K. Holland XQCD 2008

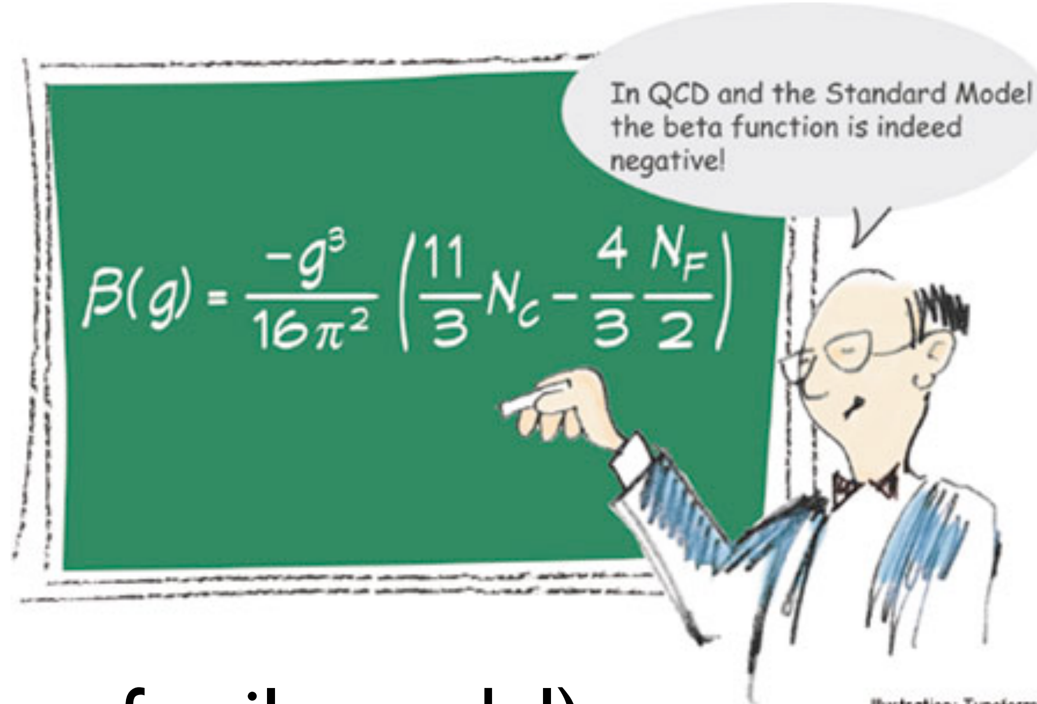
If β_{TC}~0, we expect γ_m~1

- enhancing fermion masses.
- flavor symmetry breaking pushed to higher scale, suppressing FCNCs
- Precision electroweak corrections S,T no longer calculable by analogy with QCD ... smaller?

Holdom, Yamawaki et. al., Appelquist and Wijewardana

Whence The Walking?

$$\beta(g_{TC}) \approx 0$$

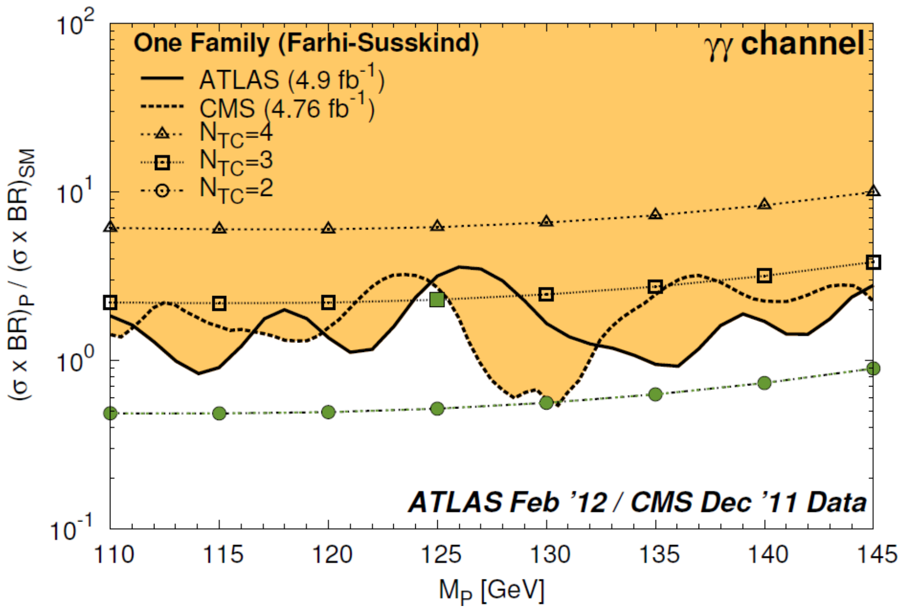


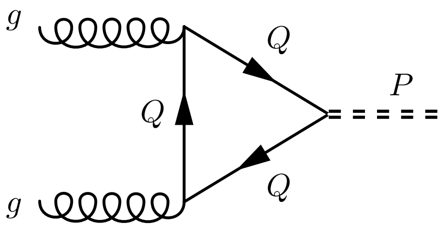
- many technifermions
  - possibly colored (e.g. one-family model)
  - varied TC representations
- larger chiral symmetry than $SU(2)_L \times SU(2)_R$)
- extra technipions beyond those needed for W_L, Z_L

Prediction: Technipions (Π_{TC}) visible at LHC

Eichten, Lane, Womersley; Lane and Mrenna

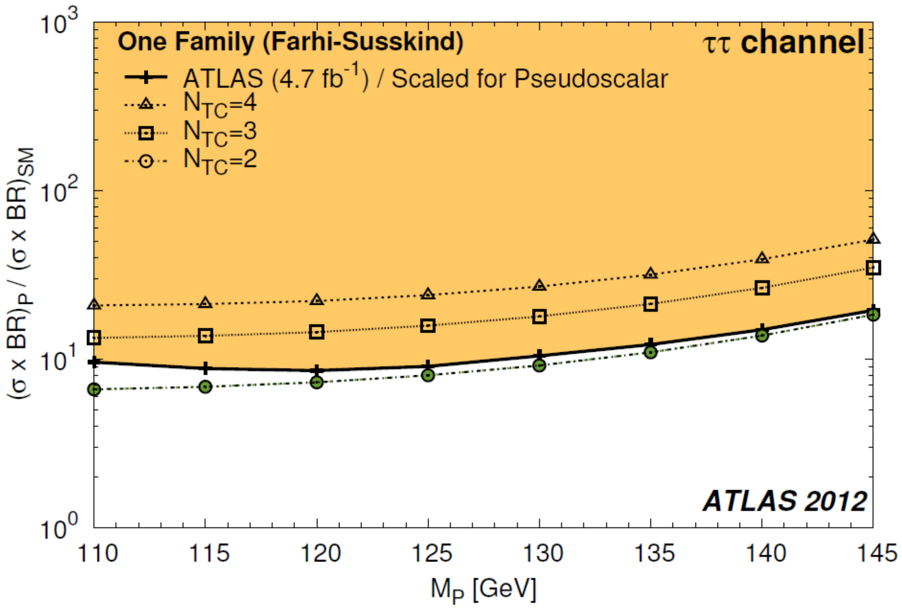
LHC limits on light technipions

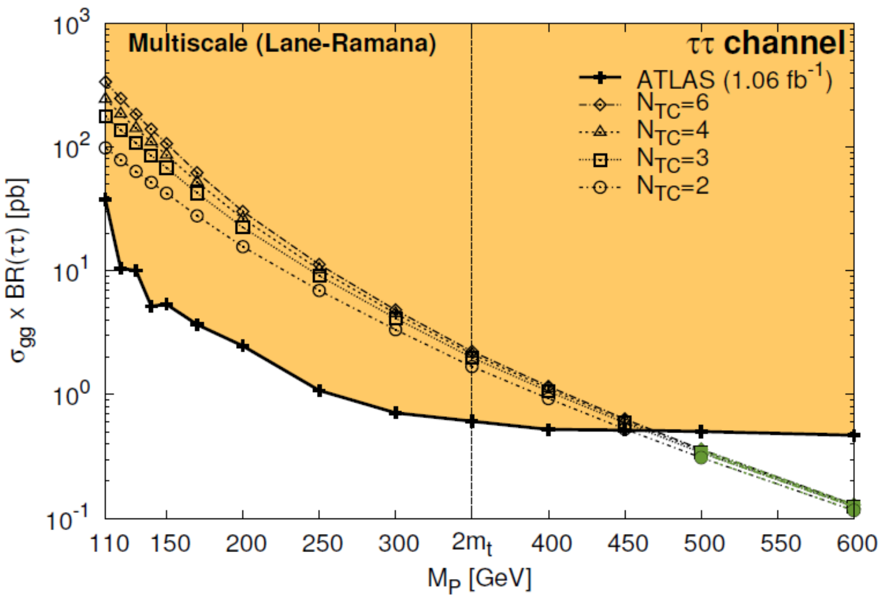




LHC Higgs searches
exclude orange regions

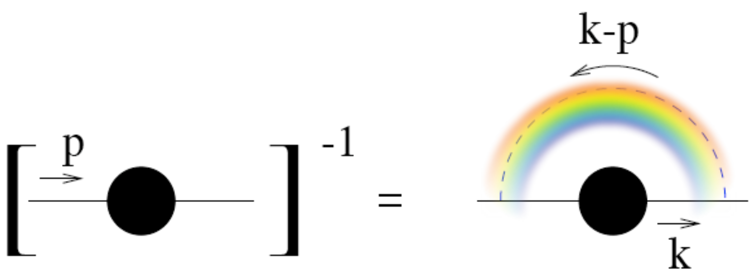
Model curves are for N_{TC} = 2, 3, 4
Minimum value is 2 ...



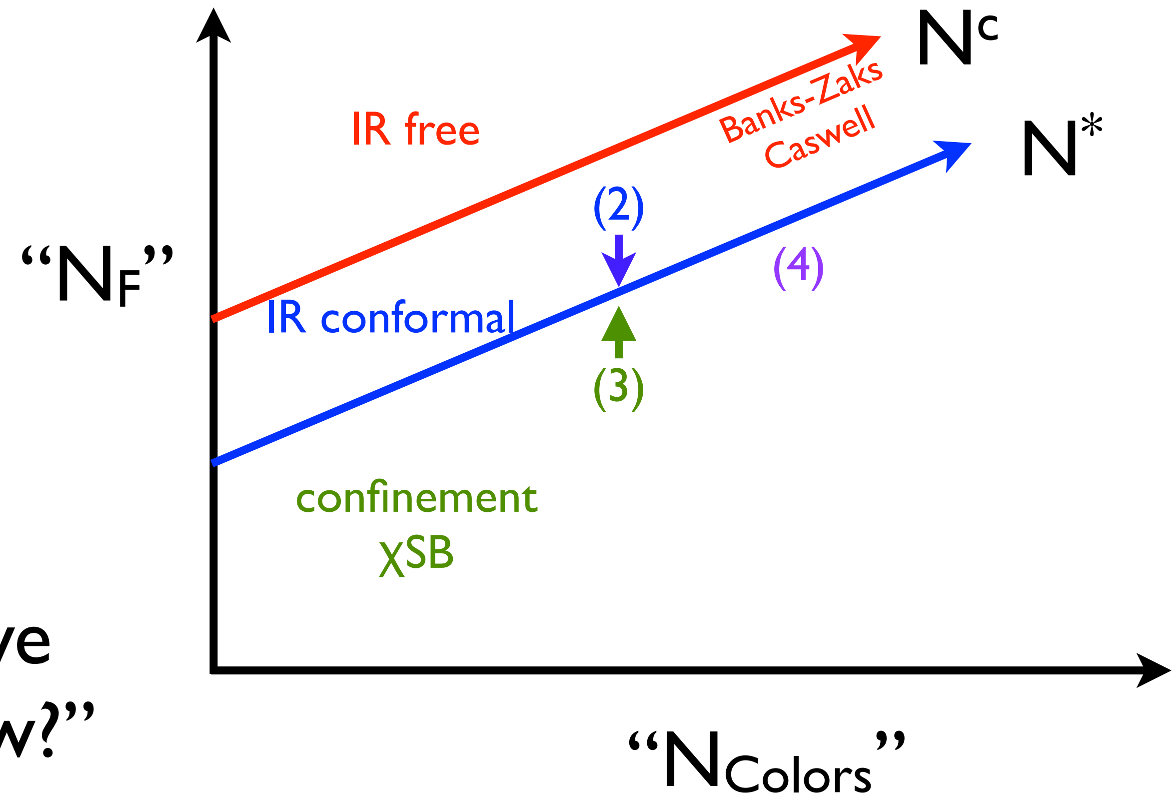


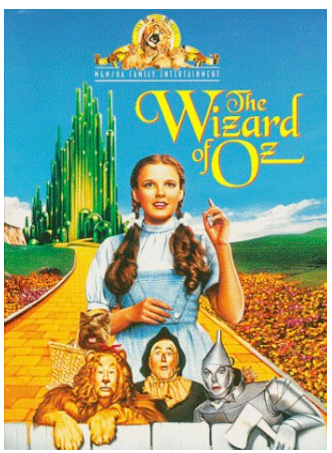
For details, see parallel talk by Jing Ren

Questions for Lattice Gauge Theory



Current Understanding from the "Gap Equation" in "Rainbow Approximation"





How can we move "Over the Rainbow?"

(1) What is the Phase Diagram?

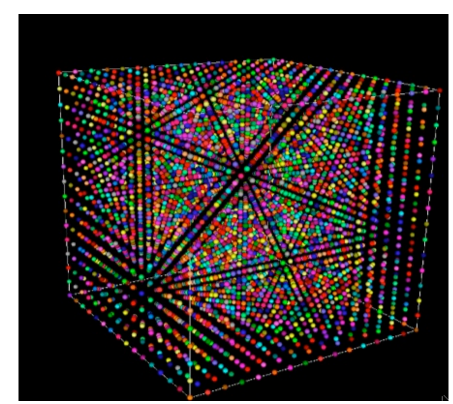
(2) What is γ_m? Near 1? 2? (0.3-0.6!?)

(3) What is S? The spectrum?

Is there a 0^{++} (Higgs-like) state?

(4) Other marginal/relevant operators?

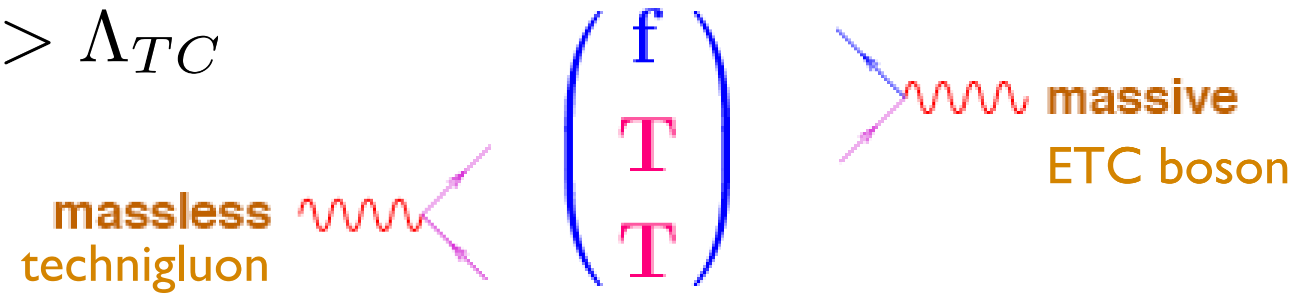
E.g. as suggested by Strong-ETC and "Gauged-NJL" models



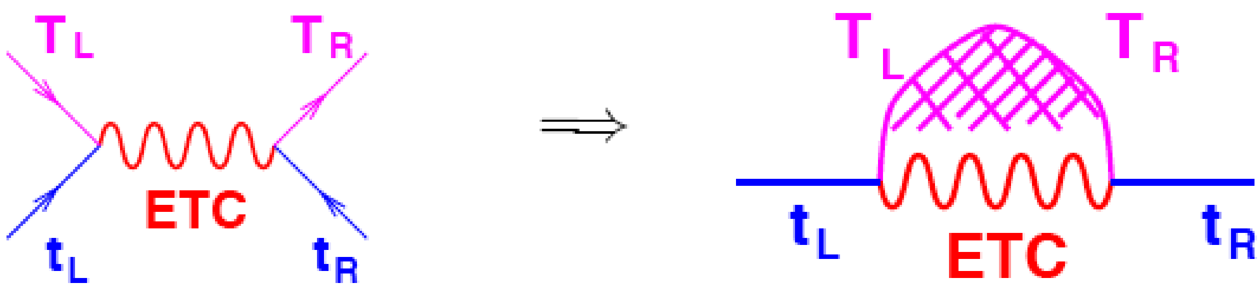
Strong EWSB and the Top Quark Mass

Dynamical Fermion Masses: ETC*

$M_{ETC} > \Lambda_{TC}$



E.g. the top quark mass arises from:



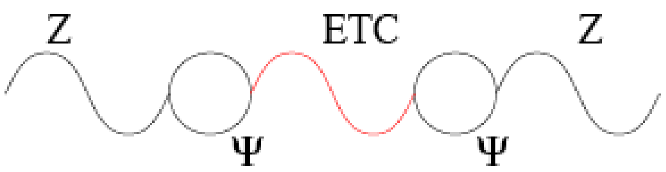
and its size is $\left(\frac{g_{ETC}}{M_{ETC}}\right)^2 \langle \bar{T}T \rangle$ x (flavor-dependent factor)

Challenge II: ETC must break custodial symmetry so $m_t >> m_b$. But how to avoid large changes to $\Delta\rho$?

*Dimpoulos & Susskind; Eichten & Lane

Isospin Violation (I)

ETC *must* violate weak-isospin to make $\mathrm{m_t} \gg \mathrm{m_b}$.
ETC boson mixing with Z through technifermion loops induces dangerous contributions to $\Delta\rho$



$$\Delta\rho \approx 12\% \cdot \left(\frac{\sqrt{N_D}F_{TC}}{250\ \text{GeV}}\right)^2 \cdot \left(\frac{1\ \text{TeV}}{M_{ETC}/g_{ETC}}\right)^2$$

How to satisfy experimental constraint: $\Delta\rho \leq 0.4\%$?

- make ETC boson heavy ?

$$\frac{M_{ETC}}{g_{ETC}} > 5.5\ \text{TeV} \cdot \left(\frac{\sqrt{N_D}F_{TC}}{250\ \text{GeV}}\right)^2$$

too heavy to provide $m_t = 172\,\text{GeV}$

- arrange for $N_D F_{TC}^2 \ll (250GeV)^2$?

e.g. separate sectors for m_t and EW symmetry breaking

Top Condensation and EWSB

If the top quark feels a new strong interaction, a top-quark condensate $\langle \bar{t}t \rangle \neq 0$ can provide some or even all of electroweak symmetry breaking

$$v^2 = f_{TC}^2 + f_t^2 \qquad \sin\omega \equiv f_t/v$$

some (topcolor*, topcolor-assisted technicolor*)

in these models the top quark feels an additional gauge interaction that causes top condensation

all (top mode^, top seesaw^^)

in top seesaw models, a heavy partner quark T forms the condensate; the top quark mass eigenstate that we observe is a seesaw mixture between T and the standard model's top quark gauge eigenstate

* Hill ^Bardeen,Hill &Lindner; Yamawaki; Miranski; Nambu ^^Chivukula, Dobrescu, Georgi & Hill

Physical Realization: Topcolor

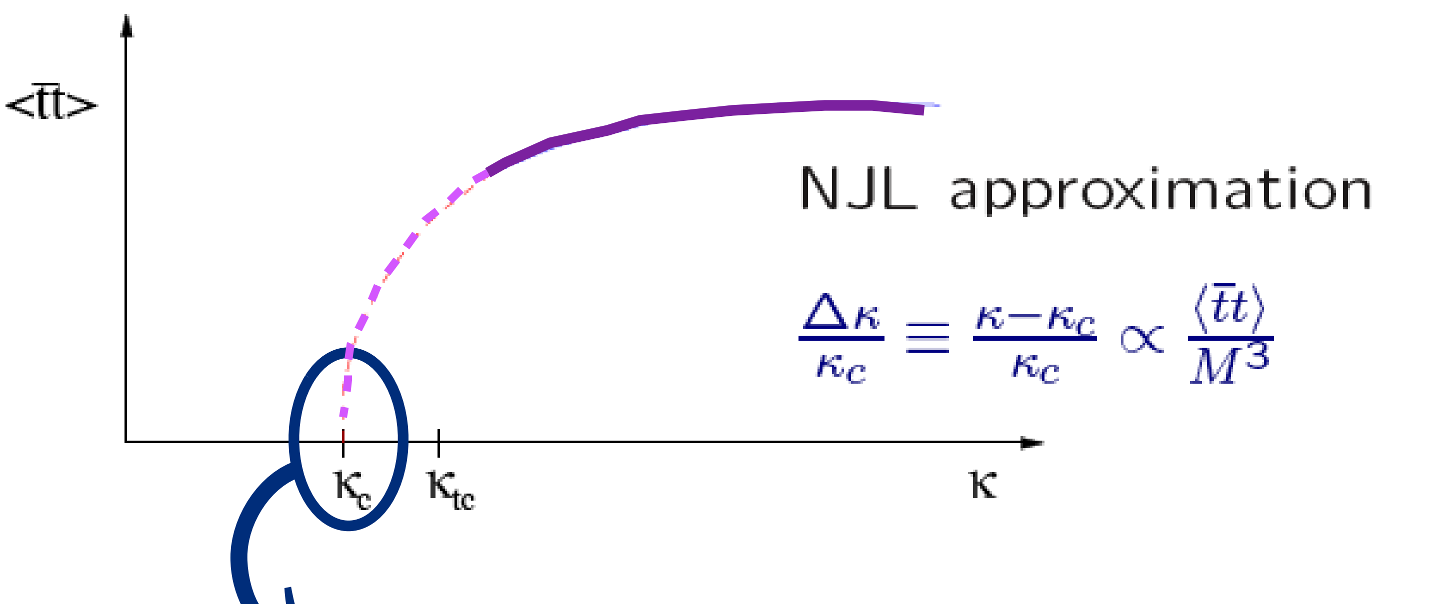
One physical realization of a new interaction for top is a (spontaneously broken) extended color gauge group: topcolor

$$SU(3)_h \times SU(3)_\ell \xrightarrow{M} SU(3)_{QCD}$$

where (t,b) feel $SU(3)_h$ and (u,c,d,s) feel $SU(3)_l$

Below the scale M, exchange of massive topgluons yields four-fermion interactions among top quarks

$$-\frac{4\pi\kappa}{M^2}\left(\bar{t}\gamma_\mu \frac{\lambda^a}{2} t\right)^2$$



Note:
M >> 1 TeV
implies fine
tuning

Prediction: Light Composite H_t at LHC

Models

Hill hep-ph/9411426
Dobrescu & Hill hep-ph/9712319

Chivukula, Christensen, Coleppa, Simmons
arXiv:0906.5667
Chivukula, Coleppa, Logan, Martin, Simmons
arXiv:1101.6023

Topcolor-Assisted Technicolor (TC2)

$$\underset{}{G_{TC}} \times \overset{(g_h > g_\ell)}{SU(3)_h \times SU(3)_\ell} \times SU(2)_W \times \overset{(g_h > g_\ell)}{U(1)_h \times U(1)_\ell}$$

$$\downarrow \quad M \gtrsim 1 \text{ TeV}$$

$$G_{TC} \times SU(3)_{QCD} \times SU(2)_W \times U(1)_Y$$

$$\downarrow \quad \Lambda_{TC} \sim 1 \text{ TeV}$$

$$G_{TC} \times SU(3)_{QCD} \times U(1)_{EM}$$

technicolor: provides most of EWSB

topcolor: provides most of m_t

hypercharge: keeps m_b small

C.T. Hill

Pure Top Condensation?

The relationship between v, M, and m_t when strong topcolor dynamics causes top condensation and EWSB

$$v^2 \approx \frac{N_c}{8\pi^2} m_t^2 \left(\log \frac{M^2}{m_t^2} + k\right)$$

Pagels-Stokar formula (1979) in NJL approximation

yields a dilemma

- To produce $v = 246$ GeV from dynamics at $M \sim 1$TeV, one is forced to generate $m_t \sim 600$ GeV.
- If we pin $m_t \sim 175$ GeV ($v = 246$ GeV), we require $M \sim 10^{15}$ GeV.

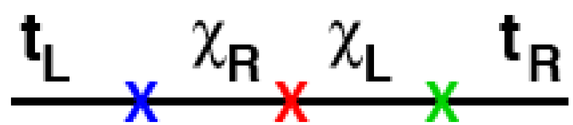
Pure top condensation will not suffice for EWSB.

But what if top is a bit less "standard"?

Top Seesaw

Seesaw: If top mixes with (e.g. weak-singlet) partner fermion "χ", the top we see is a mass (not gauge) eigenstate. Seesaw mixing pattern

$$\begin{pmatrix} \bar{t}_L & \bar{\chi}_L \end{pmatrix} \begin{pmatrix} 0 & \mu \\ m_o & M_\chi \end{pmatrix} \begin{pmatrix} t_R \\ \chi_R \end{pmatrix}$$



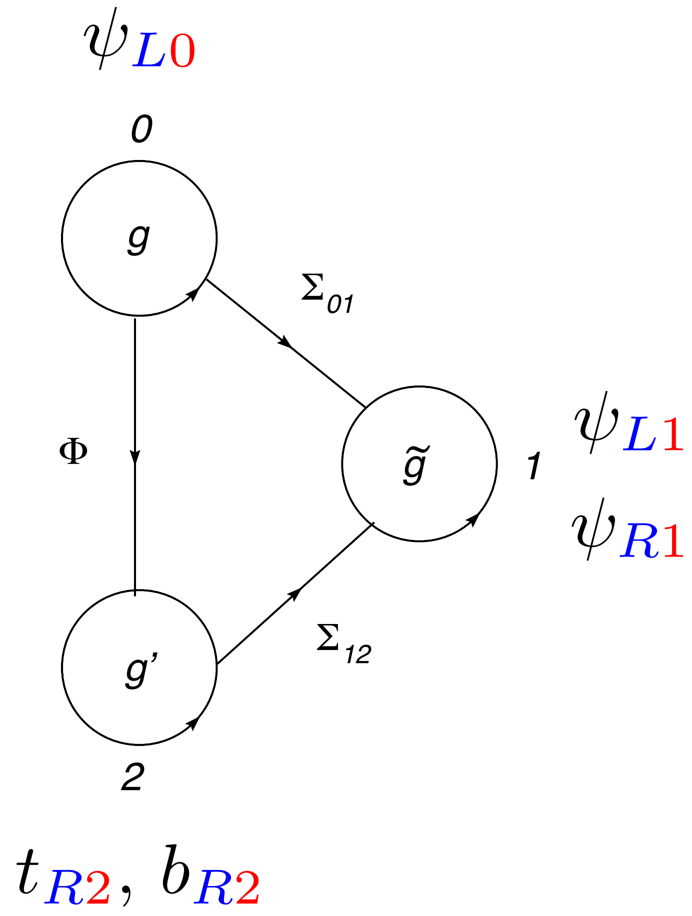
yields two mass eigenstates;

- one is mostly top (LH weak doublet):
  $$m_t^{expt} \approx \frac{m_o \mu}{M_\chi} \approx 175\,\text{GeV}$$
- complementary state (mostly χ) is heavy, with mass $\sim M_\chi$.
- As $\mu \approx 600$ GeV appears in Pagels-Stokar, seesaw makes top-generated EWSB viable.

Dobrescu & Hill hep-ph/9712319; Chivukula et al. 9809470; Collins, Grant, Georgi 9908330; He, Hill, Tait 0108041

Triangle Moose and Topcolor-Assisted TC

Topcolor sector



(E)TC sector

This effective theory can interpolate between the TC2 and top seesaw models

Effective Theory: "Top Triangle Moose"

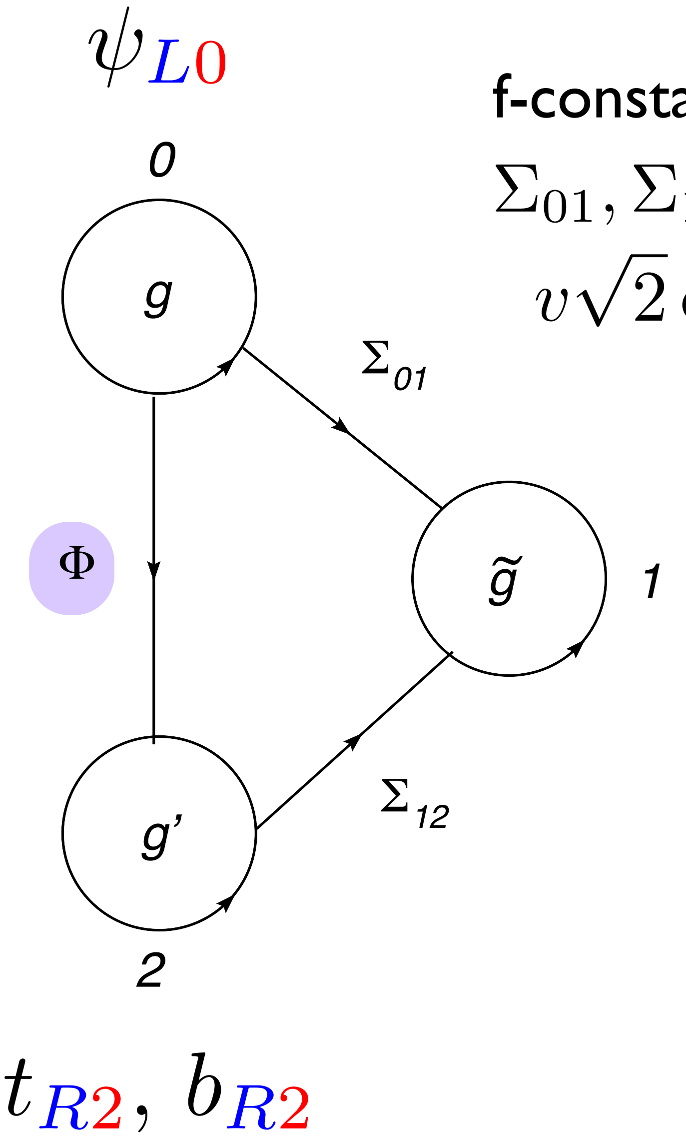
Gauge structure:

$SU(2) \times SU(2) \times U(1)$

$g_0,\ g_2 \ll g_1$

Top-Higgs

$\langle \Phi \rangle = v\ \sin\omega$



f-constants of Σ_{01}, Σ_{12} are $v\sqrt{2}\cos\omega$

Gauge boson spectrum:

photon, Z, Z', W, W'
(as in 3-site, BESS or HLS)

Fermion spectrum:

t, T, b, B; similar for light quarks & leptons
only top couples to Φ

New States Connected to Top Dynamics

topgluon / coloron: C^a

- can be flavor (non)universal

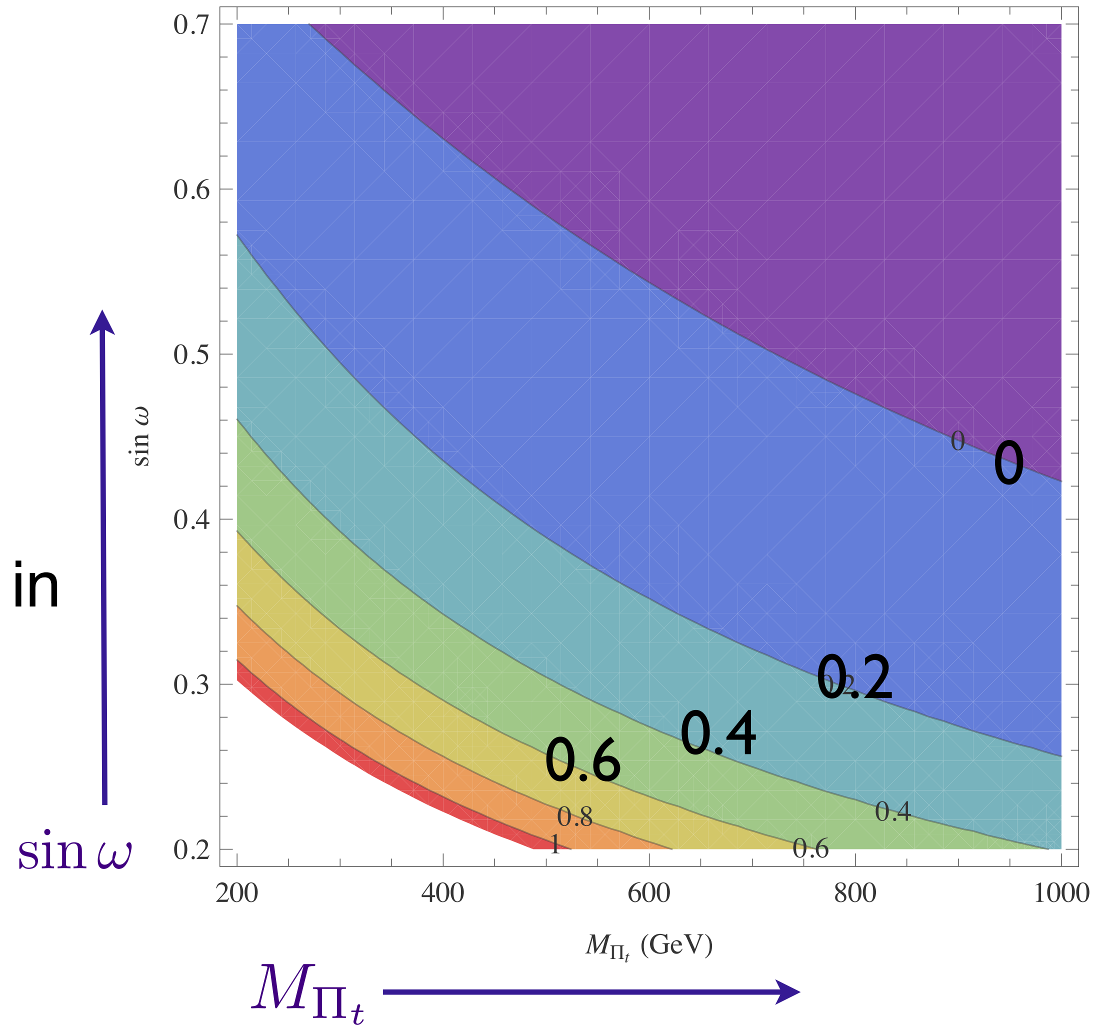
top-Higgs state: H_t

- production in gg → H_t higher than in SM by factor $[\sin\omega]^{-1}$

top-Pion states: $\Pi_t^{\pm},\ \Pi_t^0$

- one-loop R_b contributions minimized by (tree) non-ideal delocalization of t_L as indicated in <u>plot at right</u>:

fractional shift in ϵ_{tL}
to help R_b agree with data



top's seesaw partner: T

- can be produced at LHC

LHC vs. Colorons

ATLAS: CERN-PH-EP-2011-127
CMS: CERN-PH-EP/2011-119

Han, Lewis, Liu arXiv:1010.4309

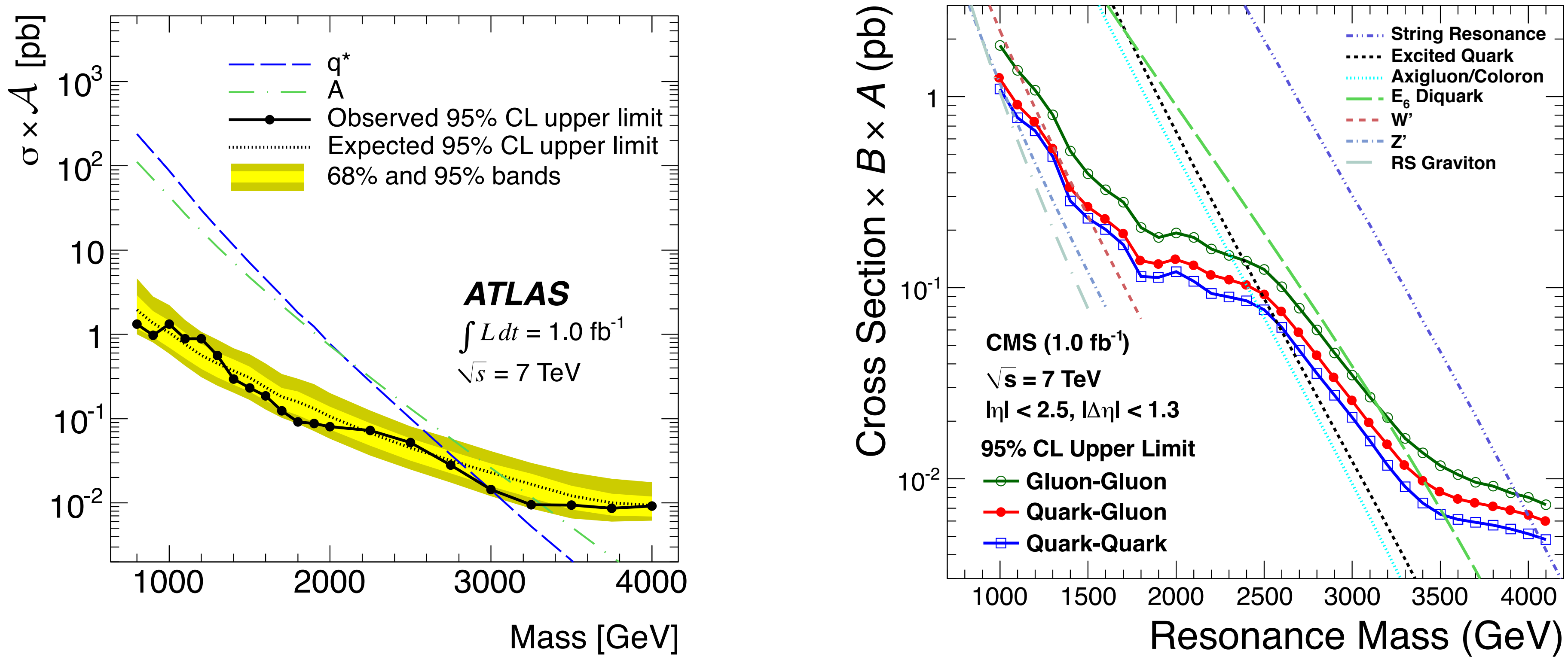
Chivukula, Farzinnia, Foadi, Simmons arXiv:1111.7261

Atre, Chivukula, Ittisamai, Simmons, Yu 2012 (in preparation)

Limits on Topgluons / Colorons

Flavor-universal colorons:

- LHC searches for colorons in dijet constrain $M_C > 2.5$ TeV

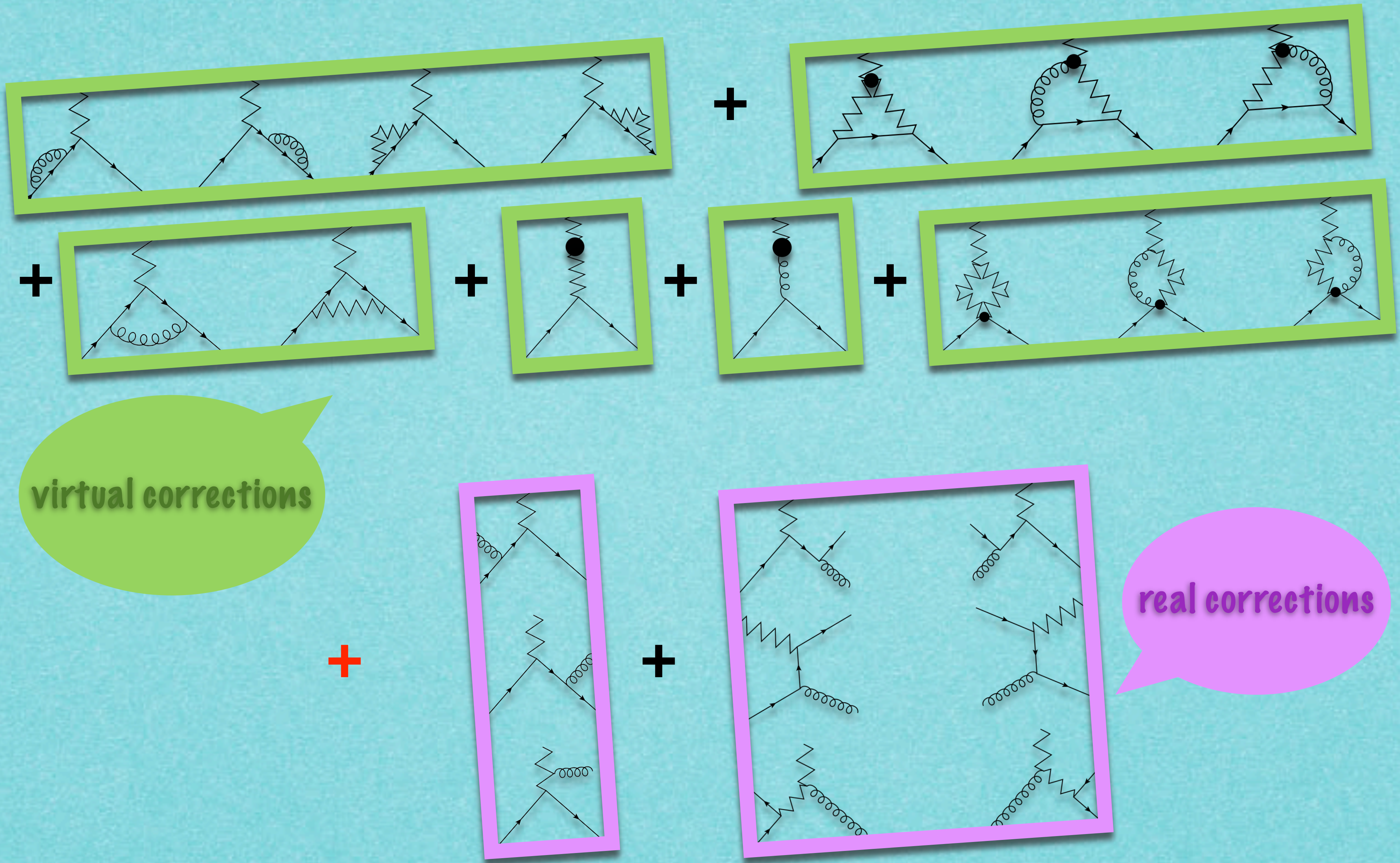


Topgluons coupled preferentially to 3rd generation**:

- FCNC bounds from B-meson mixing: $M_C > 6$ TeV
- Fits of TC2 to precision electroweak data: $M_C \sim 18$ TeV

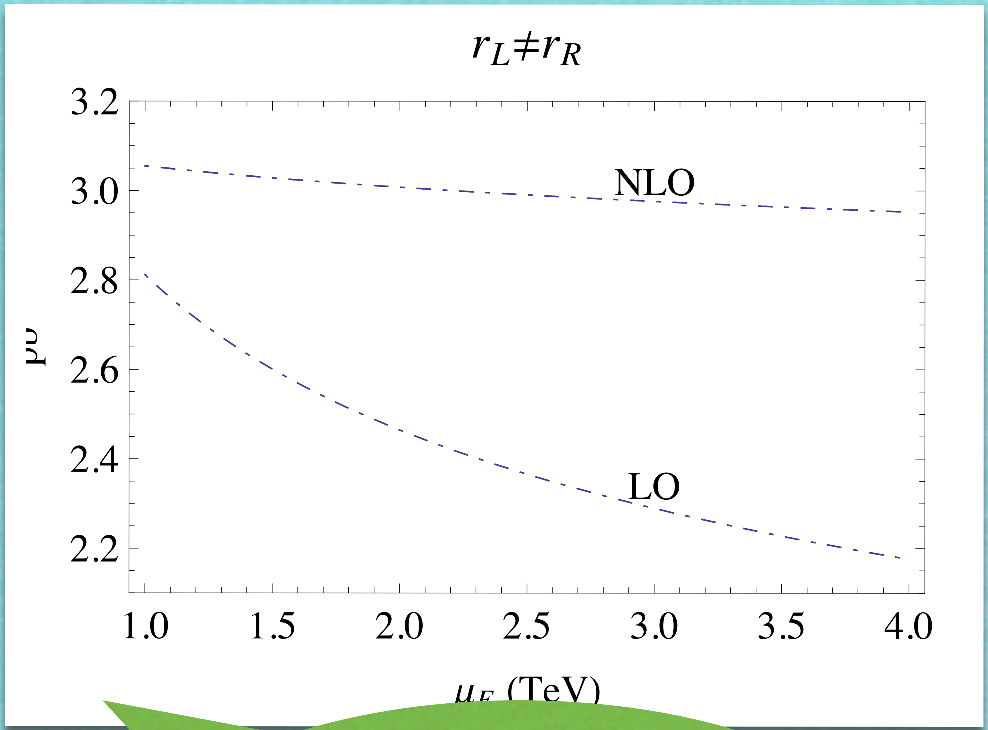
**Braam, Chivukula, DiChiara, Flossdorf, Simmons arXiv:0711.1127

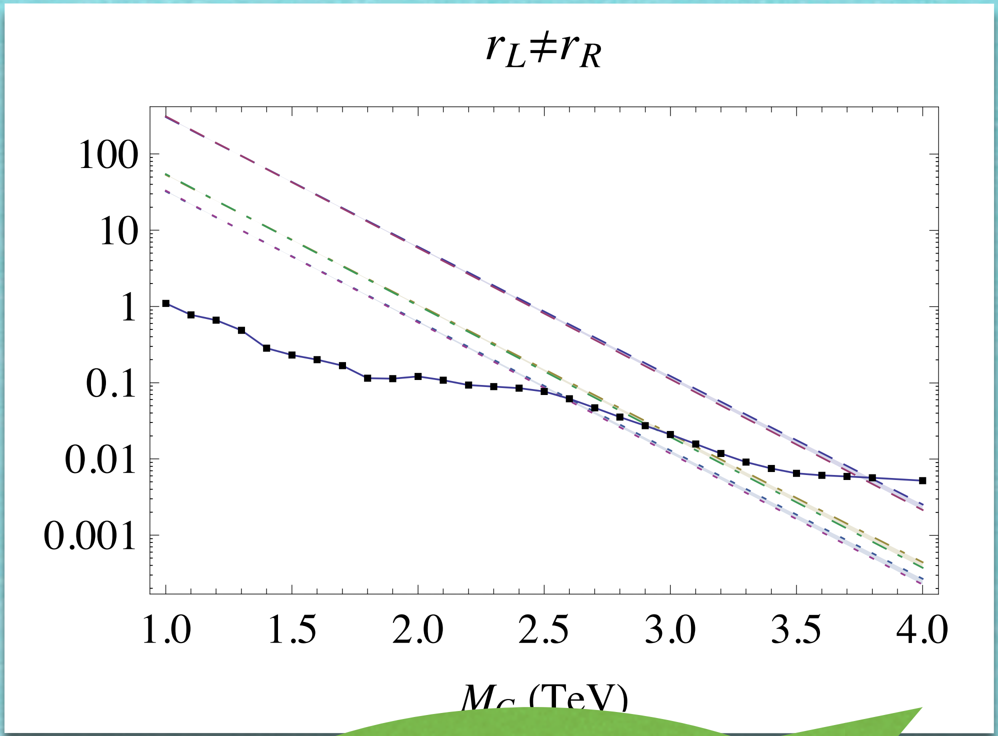
Colorons at NLO



RSC, Farzinnia, Foadi, EHS arXiv:1111.7261

Impact of NLO Corrections





scale dependence at LO: 30% at NLO: 2%

Axigluon mass limit from CMS Data rises to 2.6 TeV

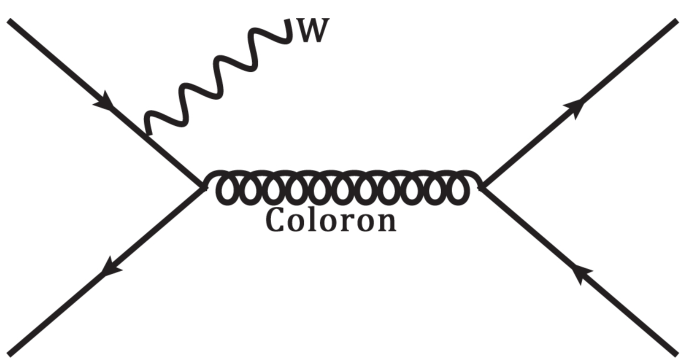
- K-factor: $\sigma_{NLO}/\sigma_{LO} \sim 30\%$
- 30% of produced colorons have p_T > 200 GeV!

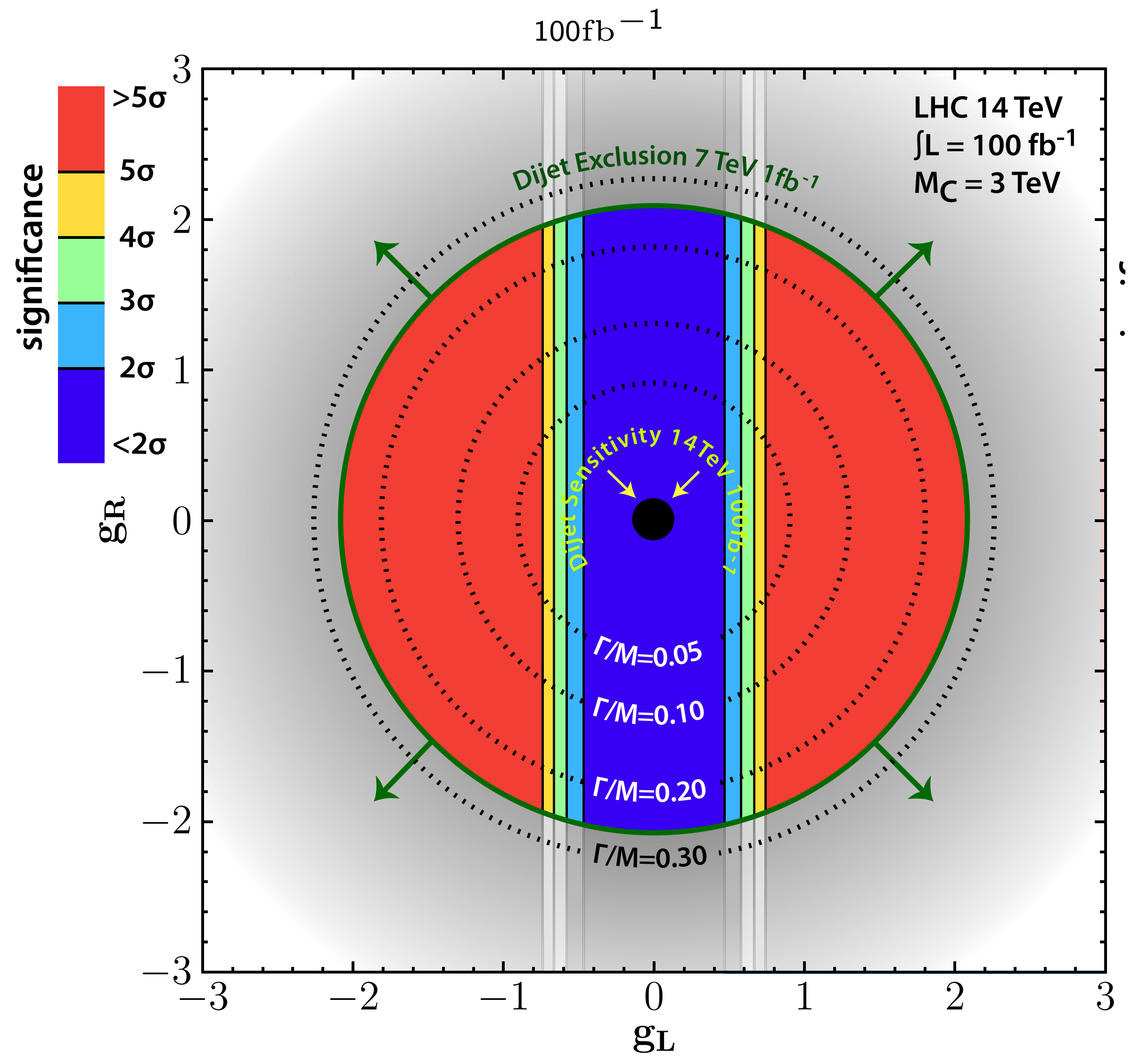
RSC, Farzinnia, Foadi, EHS arXiv:1111.7261

W+C^A production probes Couplings

coloron-W associated production at LHC can reveal chiral couplings of coloron to fermions

heat map shows significance the measurements can reach for varied coupling strengths





For details, see parallel talk by Pawin Ittisamai

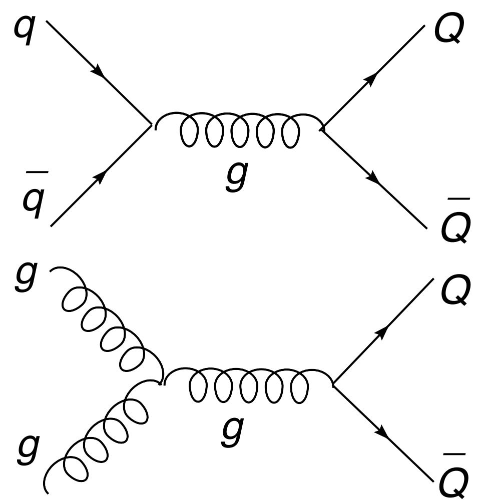
LHC vs. Top Partner (T)

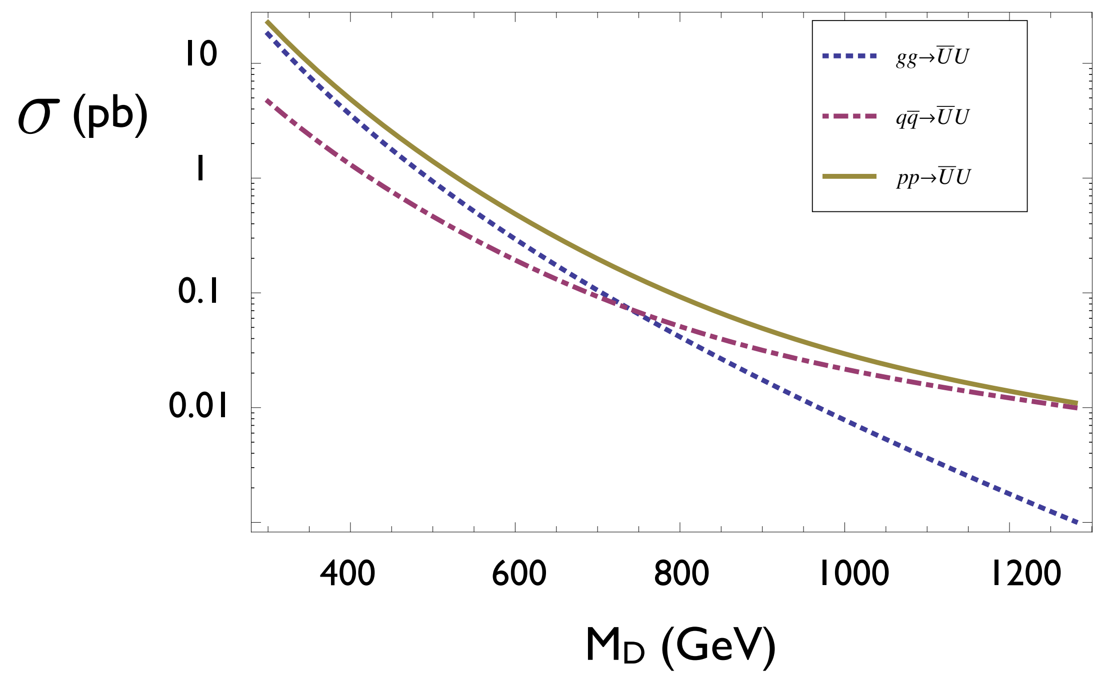
Chivukula, Christensen, Coleppa, Simmons
arXiv:0906:5567 [hep-ph]
Chivukula, Coleppa, Logan, Martin, Simmons
arXiv:1101.6023 [hep-ph]

KK Quark Production at LHC

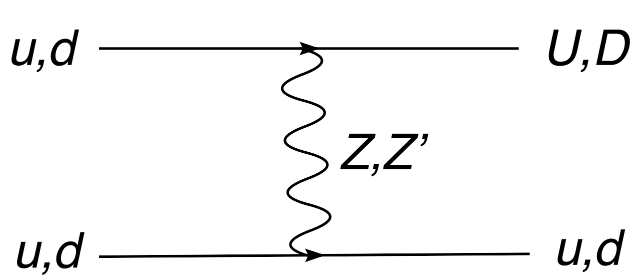
(triangle moose model)

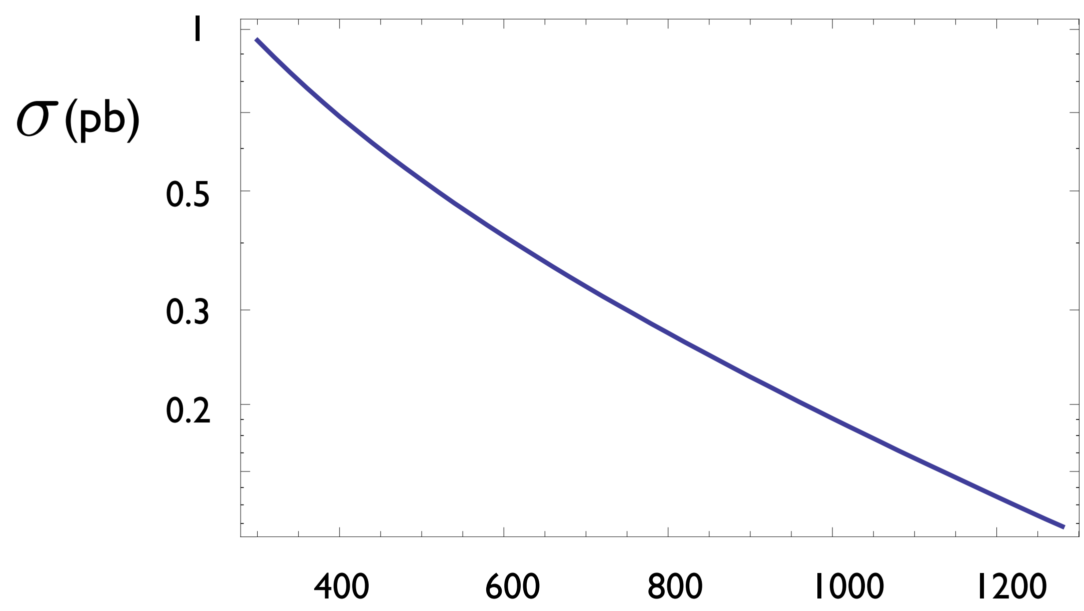
Pair Production





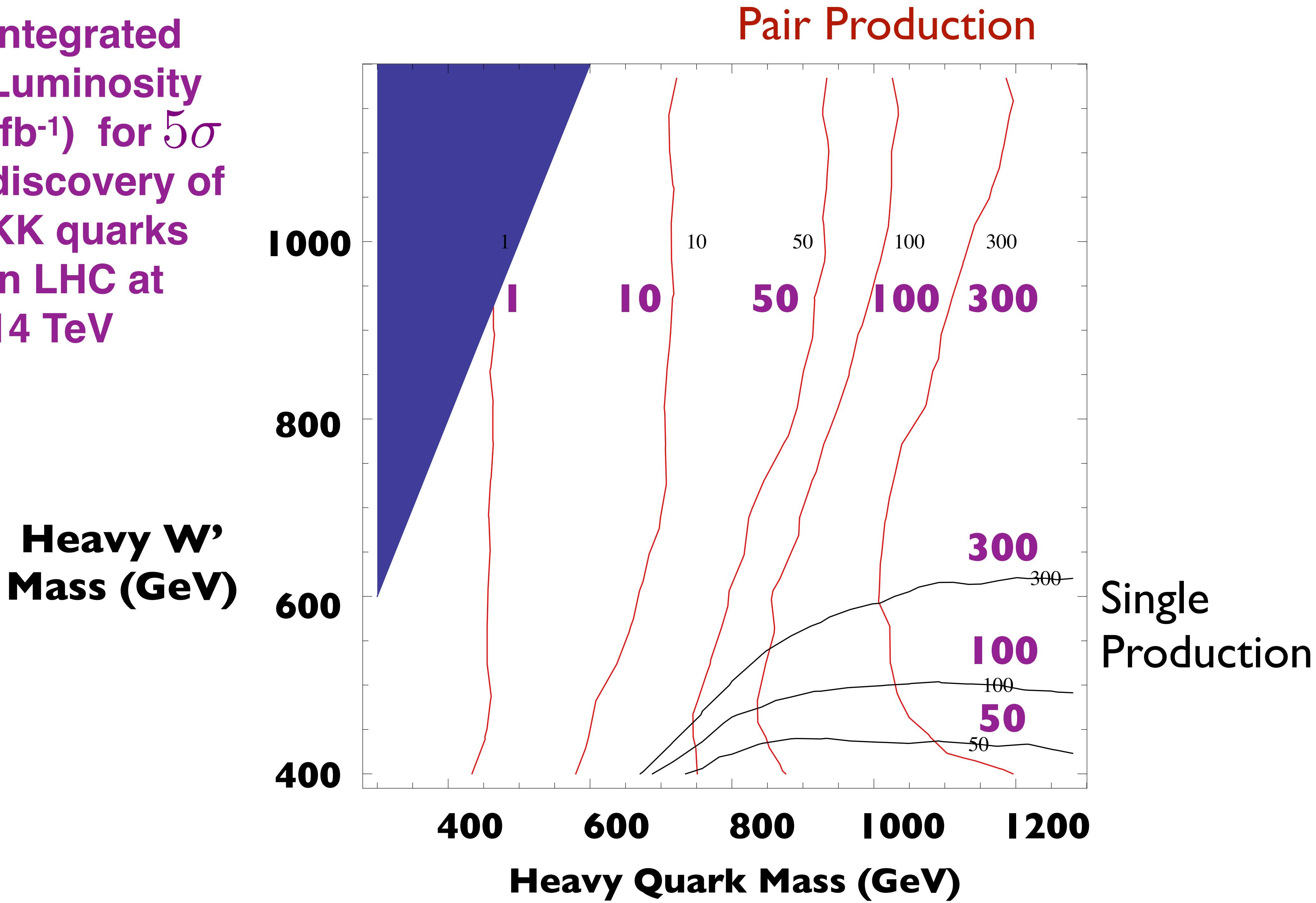
Single Production





LHC Detection of KK Quarks

Integrated Luminosity (fb^{-1}) for 5σ discovery of KK quarks in LHC at 14 TeV



Top sector at LHC

Sample strategy to find states in the top sector and confirm their connection to EWSB:

1. With initial LHC data, find $\mathbf{H_t}$ in $\mathbf{H_t} \rightarrow$ **WW, ZZ**; higher-than-SM production rate will indicate that it is exotic
2. As integrated luminosity grows, find top quark's KK partner **T** via its dominant decay to $T \rightarrow Wb$
3. Confirm the $T \rightarrow H_t\, t$ decay; this shows $\mathbf{H_t}$ is strongly coupled to the top sector as well as the EW sector
4. Discover $\mathbf{\Pi_t}$ in $pp \rightarrow t\, \Pi_t^{\pm}$; this establishes the top-pion's strong link to the top sector
5. Confirm $\mathbf{\Pi_t}$ in $pp \rightarrow H_t\, \Pi_t^{\pm}$; this links the top-pion to the EW sector as well

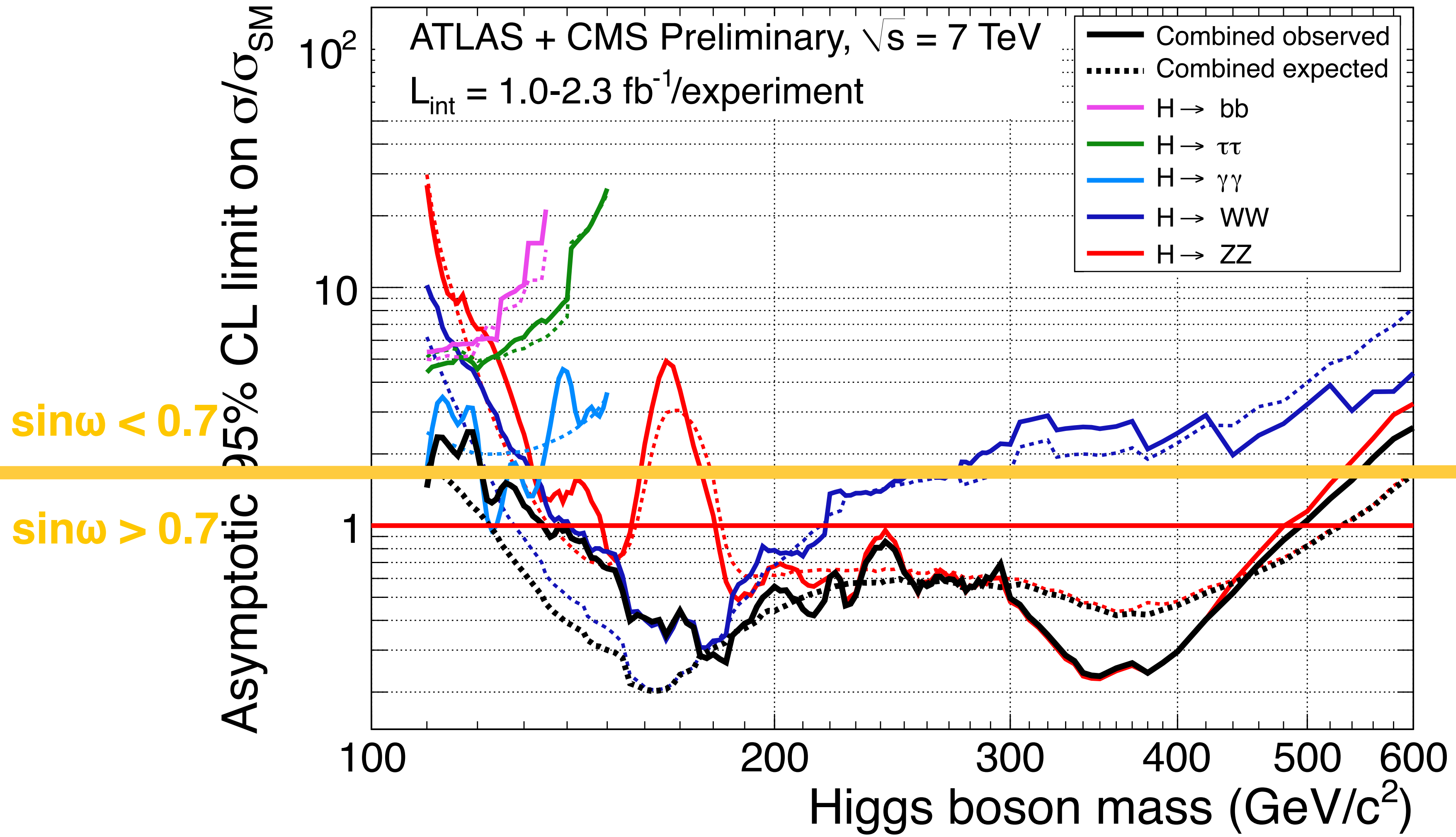
LHC vs. Top-Higgs

Chivukula, Coleppa, Logan, Martin, Simmons
arXiv:1108.4000 [hep-ph]

Chivukula, Coleppa, Ittisamai, Logan, Martin,
Ren, Simmons 2012 [in preparation]

LHC limits on Higgs Production

gg → H_t production is enhanced relative to SM by $[\sin\omega]^{-1}$

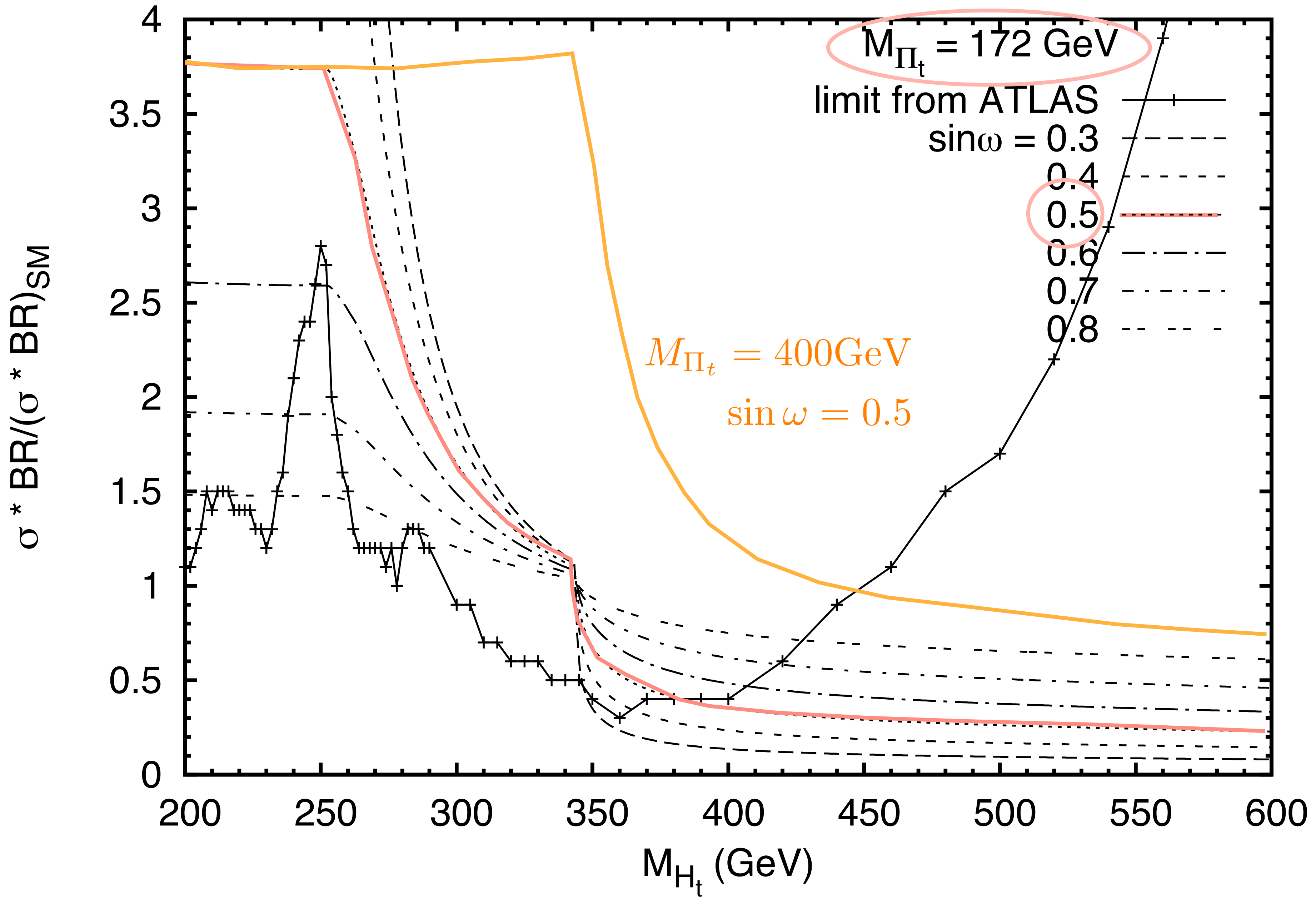


Non-standard H_t are tightly constrained by searches in WW/ZZ

CMS PAS HIG-11-011

ATLAS vs H_T (if top-pion is heavier)

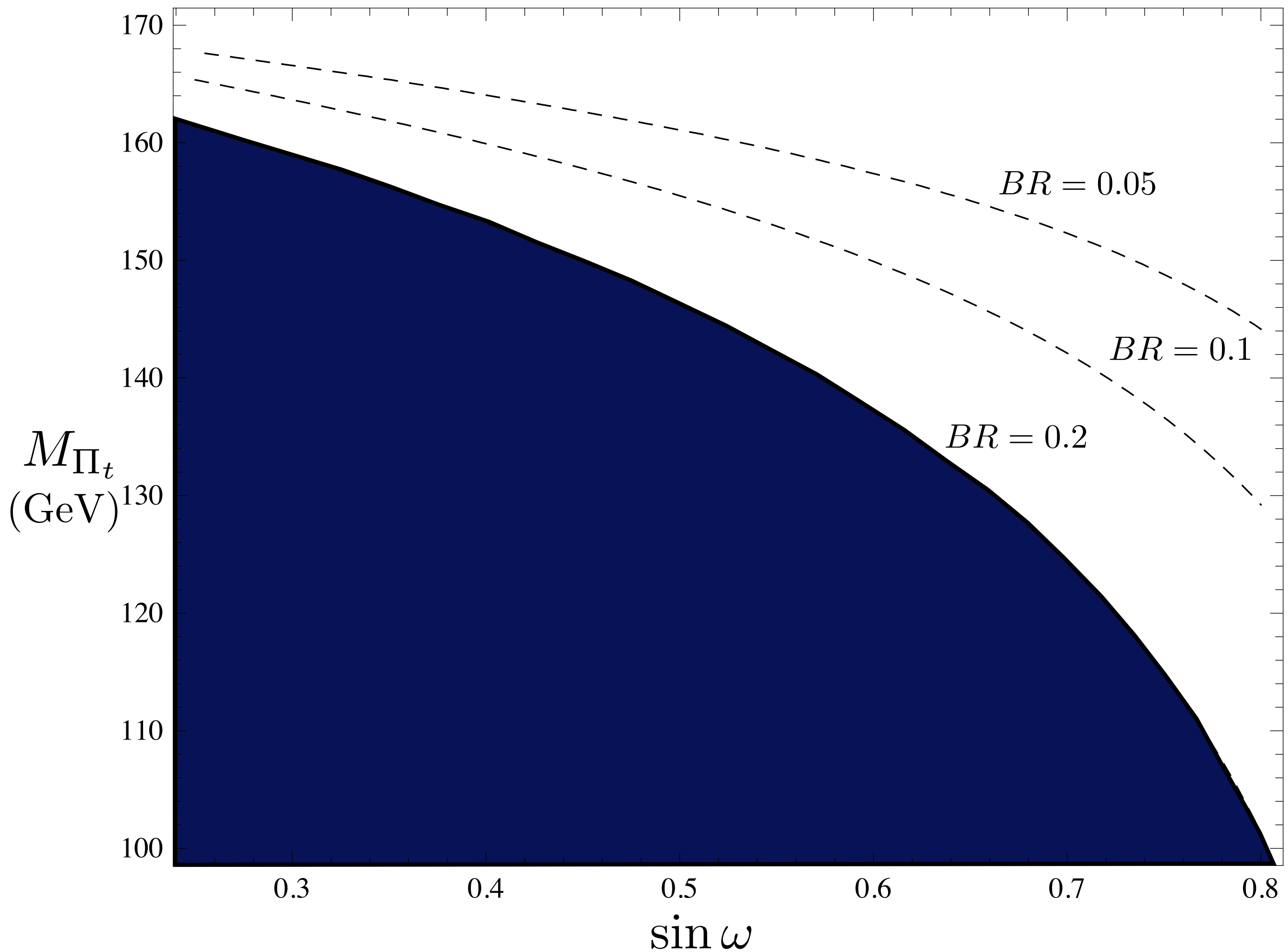
enhanced production, high WW/ZZ B.R. make light H_t visible



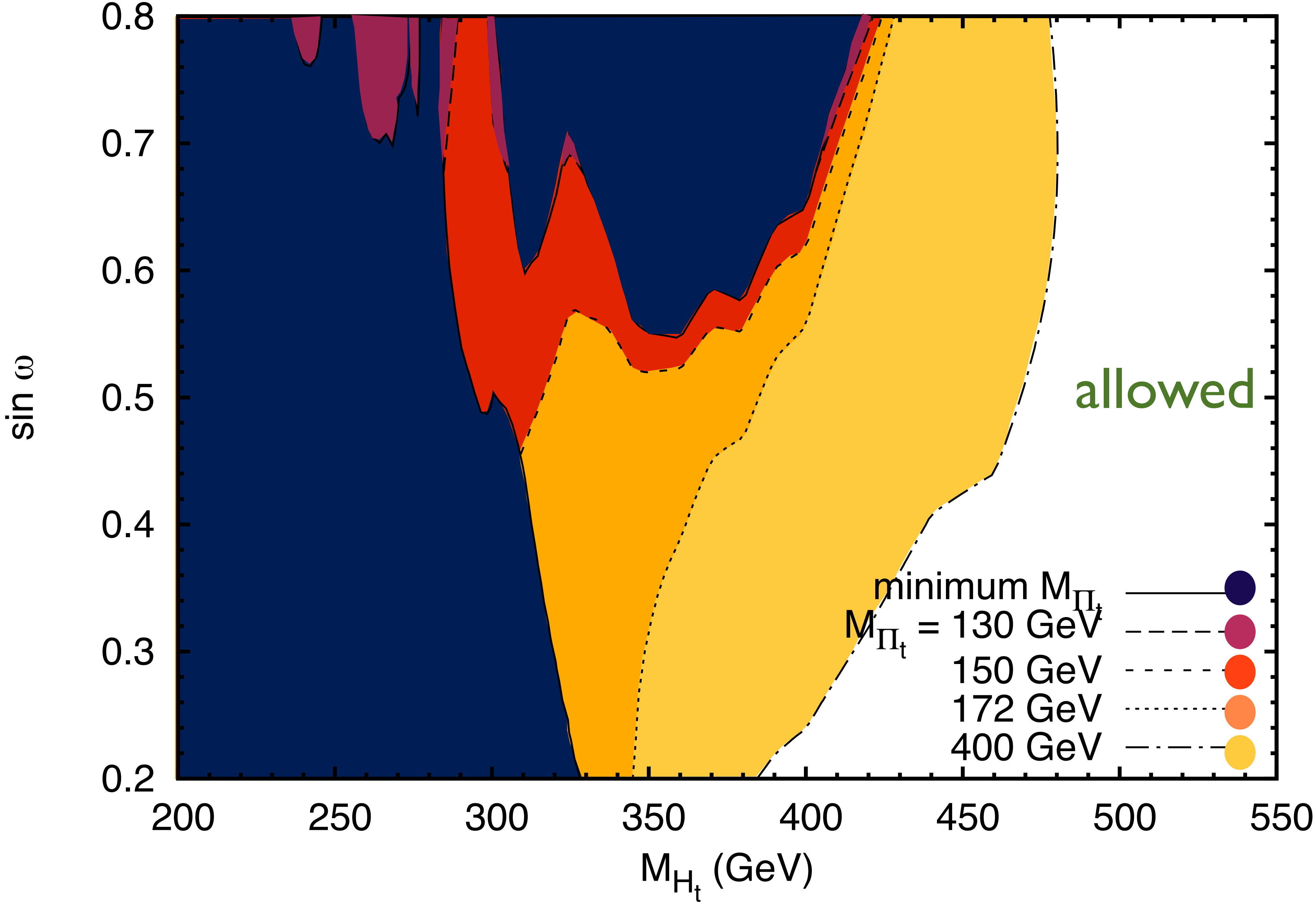
Bounds on Top-Pion Mass

Tevatron bounds on top decays to charged Higgs bosons imply that $BR(t \to \Pi_t^+ b) \leq 0.2$ and exclude the dark-blue region below:

top-pion mass (GeV)



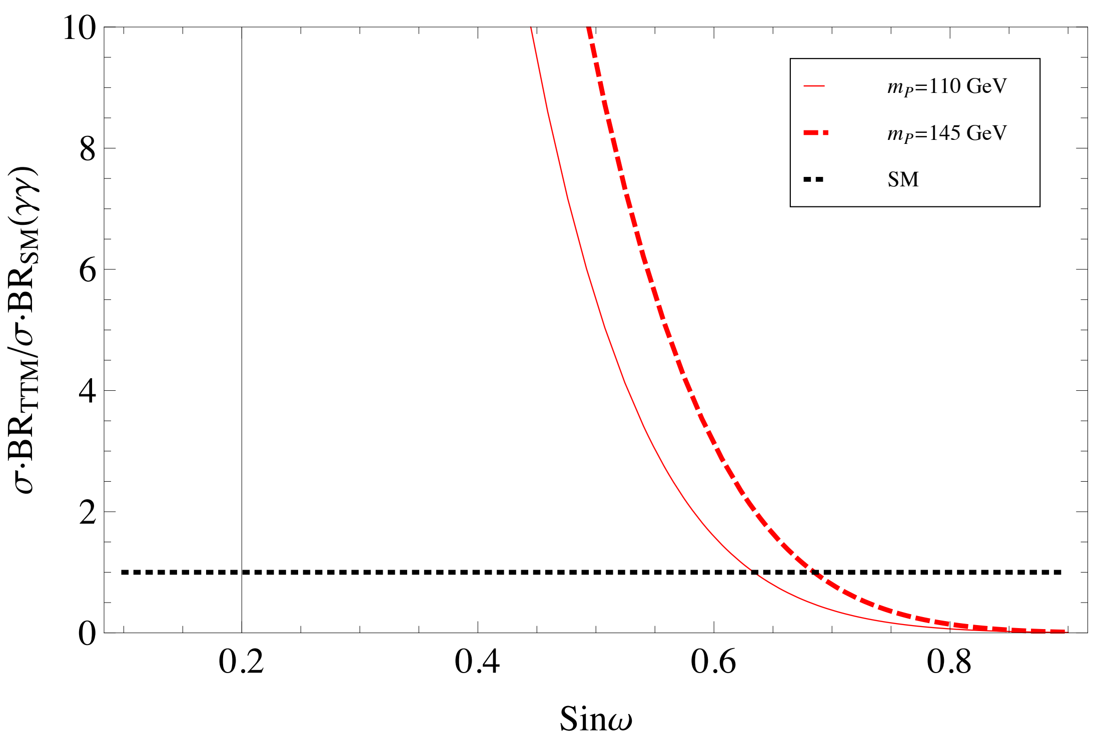
LHC Limits on Top-Higgs (H_t)



New Limits From $\Pi_t^0 \to \gamma\gamma$

- As in Jing Ren's talk, LHC searches for $H_{SM} \to \gamma\gamma$ set strict bounds on technipions containing colored technifermions
- Those searches also constrain Π_t^0 in the top triangle moose, mainly since Π_t^0 production is enhanced (relative to H_{SM}) by $\cot^2\omega$

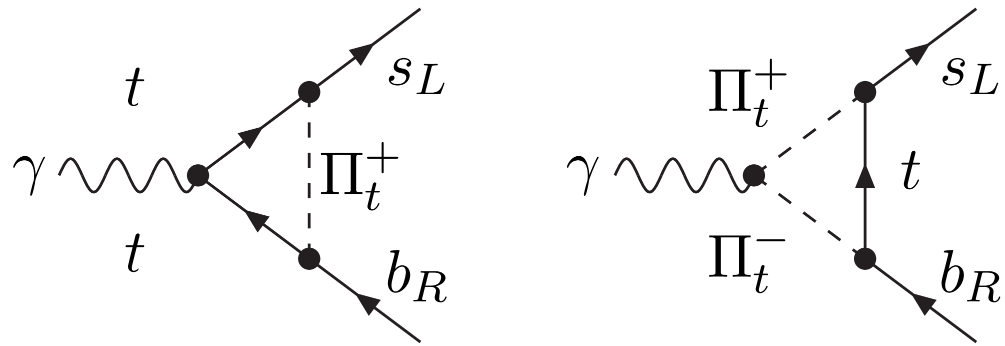
This excludes Π_t^0 for $M_{\Pi_t^0} < 150\ GeV$ if $0.2 \leq \sin\omega \leq 0.6$



New Limits From $b \to s\gamma$

Charged top-pions would contribute to $b \to s\gamma$ like the charged Higgs state in a Type II 2HDM with couplings going as $(\beta \leftrightarrow \omega)$

$$[m_t V_{tb} \cot\omega\, \bar{t}_R b_L + m_t V_{ts} \cot\omega\, \bar{t}_R s_L + m_b V_{tb} \tan\omega\, \bar{t}_L b_R]\Pi_t^+ + h.c.$$



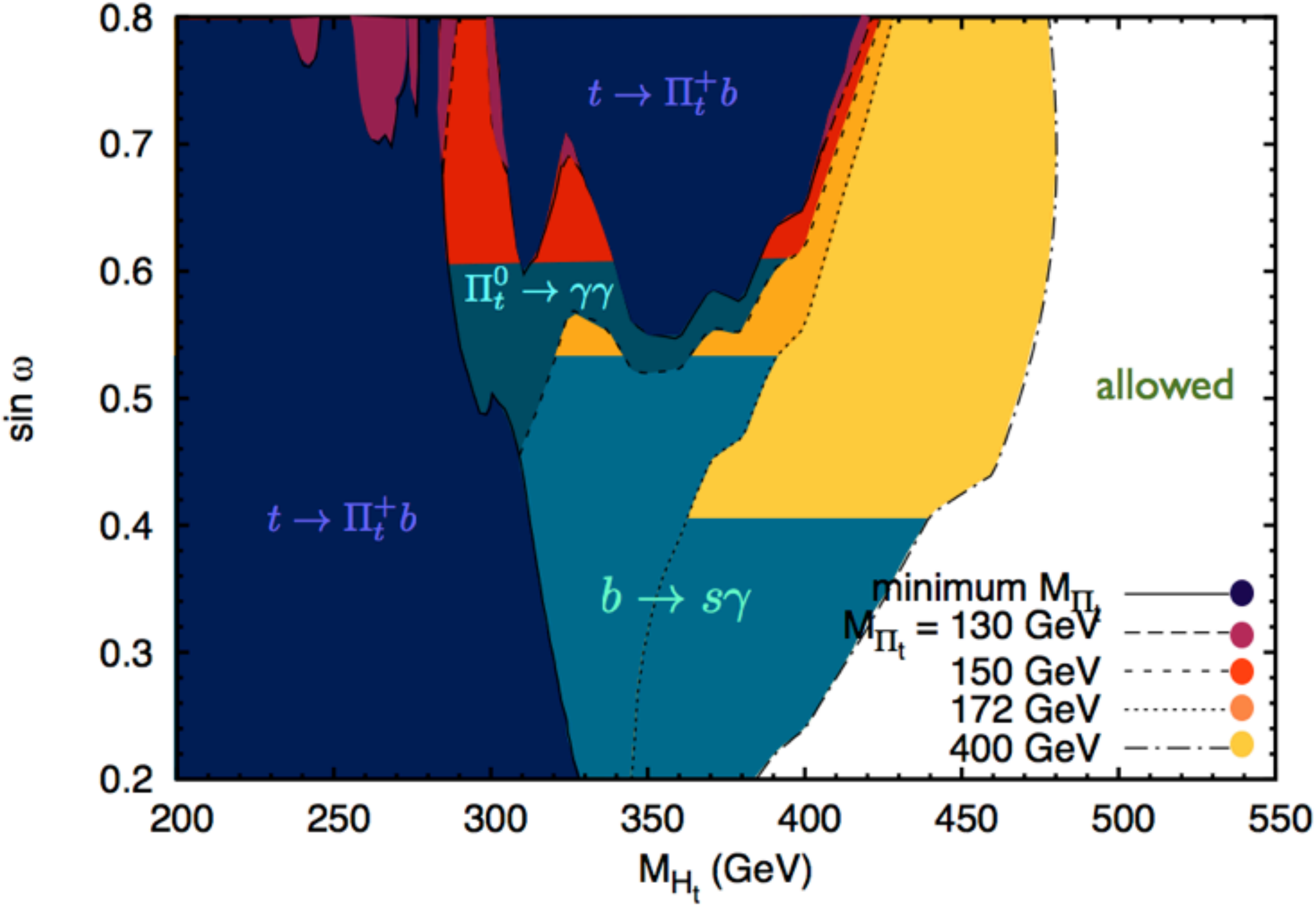
resulting lower bound on Π_t^+ mass

$\sin\omega$	0.26	0.30	0.34	0.40	0.46	0.53
$m_{\Pi_t^+}^{low}(GeV)$	551	500	440	396	363	332

$m_b m_t^2 \cot^2\omega$ dominates

$m_b m_t^2$ dominates

Updated H_T Limits



LHC vs. TC2

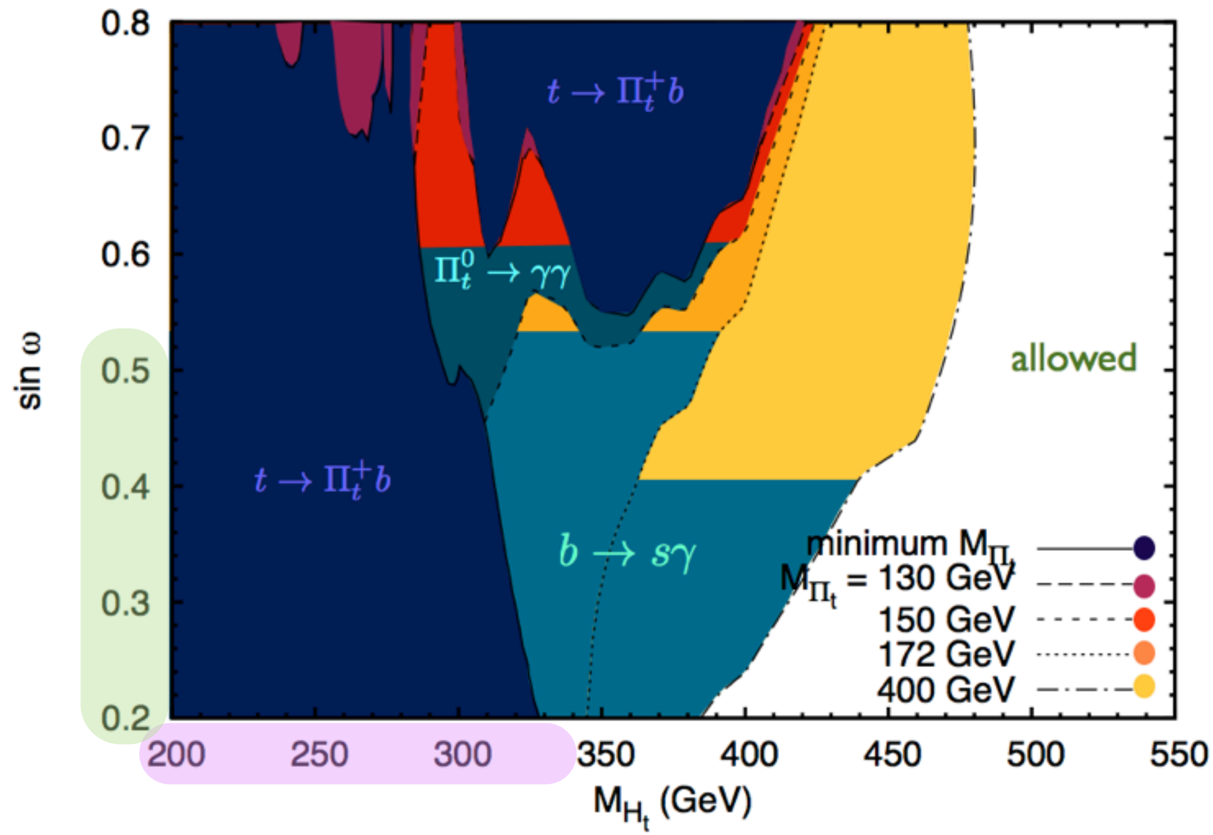
Within the larger effective theory, one would then expect the TC2 model parameters to lie in the following ranges:

$$185 \text{ GeV} < M_{H_t} < 340 \text{ GeV}$$

$$172 \text{ GeV} < M_{\Pi_t} < M_{H_t}$$

$$0.2 < \sin\omega < 0.5$$

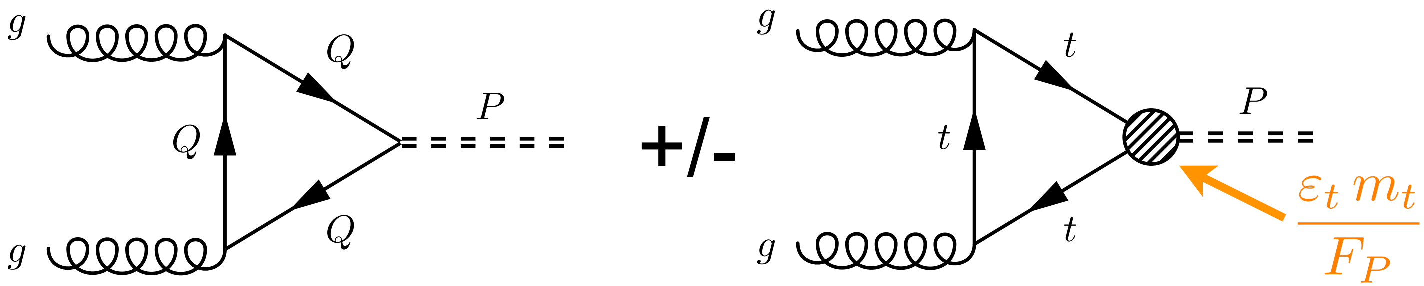
The data from FNAL, LHC, and $b \to s\gamma$ appears to exclude precisely this region.



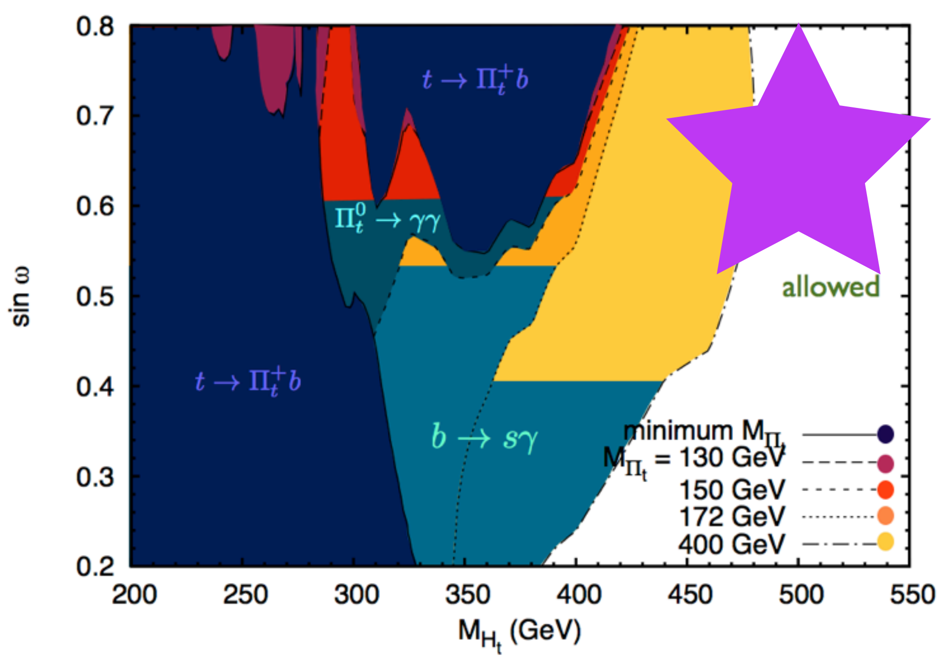
New DEWSB Model Directions

What kinds of models can evade the LHC constraints on neutral states in TC2 Models (colorons, technipions, top-Higgs)?

- Technicolor with substantial ETC contribution to m_t ?



- Top-Seesaw Assisted Technicolor?
- Stay Tuned!



Conclusions

Conclusions and Next Steps

Dynamical EWSB models able to produce fermion masses also predict new states visible to experiment

- LHC searches for a SM Higgs constrain **technipions**.

- LHC can search for **colorons**, incorporating one-loop results for the K-factor and p_T distribution -- and can use $W + C^a$ production to probe the coloron's couplings.

- New states from strong top dynamics include **T, H_t and Π_t**; all should be visible at LHC. Interplay among them would signal a role for top dynamics in EWSB.

- Recent LHC data on $H \to WW, ZZ, \gamma\gamma$ combined with data on $b \to s\gamma$ **exclude the most favored TC2 parameter space**. New models with heavier H_t (e.g. top-seesaw-assisted TC) are required.

What the LHC Can See (detail)

W' searches:

Belyaev, et al., arXiv:0708.2588

KK quarks:

Chivukula, Christensen, Coleppa, Simmons arXiv:0906.5667

KK top quark, top-Higgs, and top-Pions

Chivukula, Coleppa, Logan, Martin, Simmons arXiv:1101.6023

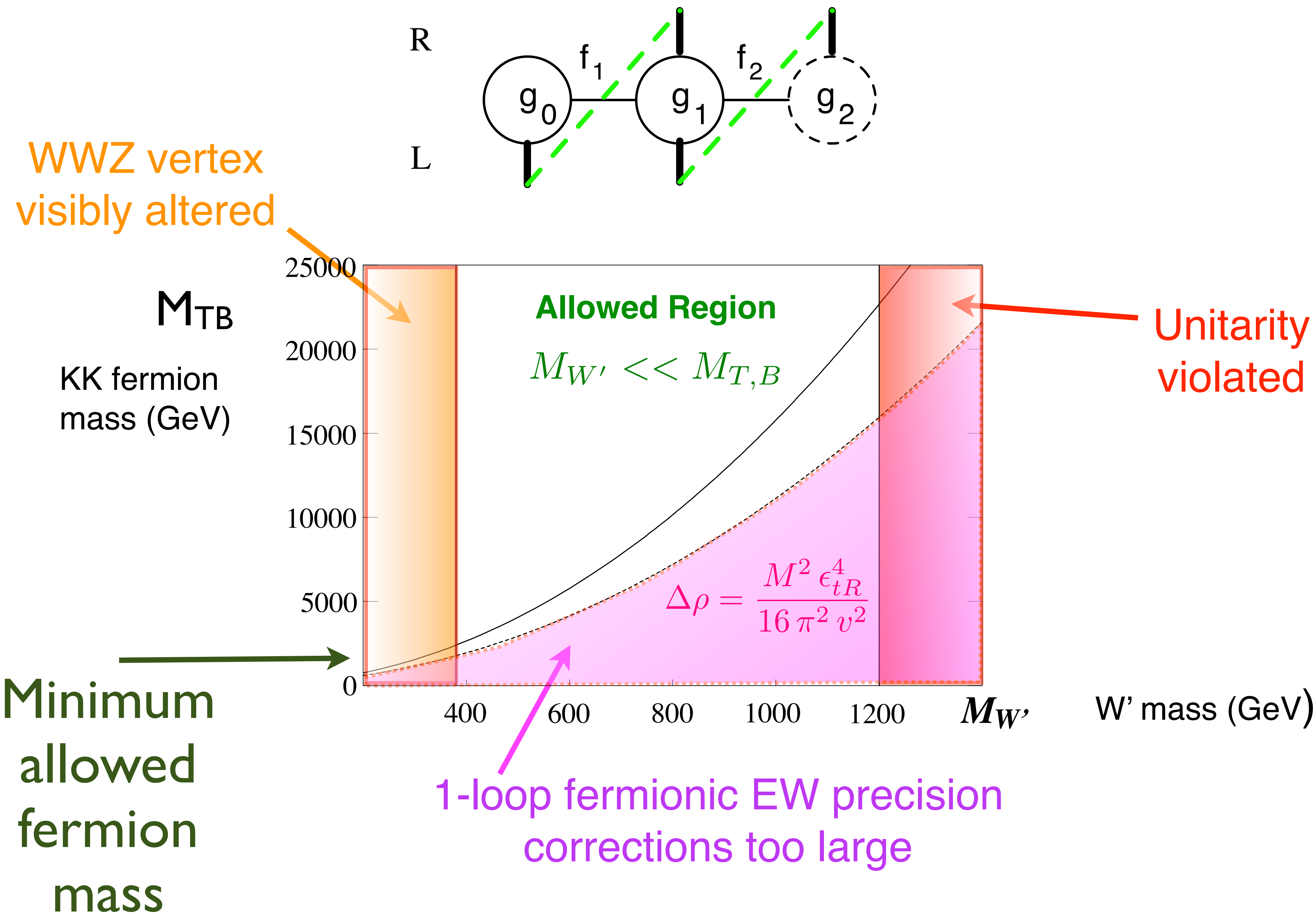
related work:

3-site: Ohl, Speckner arXiv:0809.0023

4-site: Hirn, Martin, Sanz arXiv:0712.3783

4-site: Accomando et al. arXiv:0807.5051

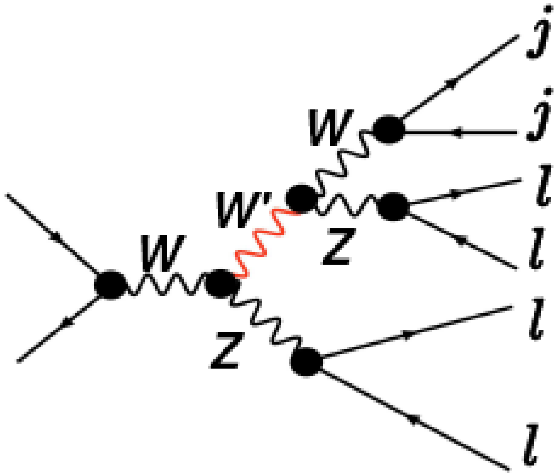
Reminder: 3-Site Model

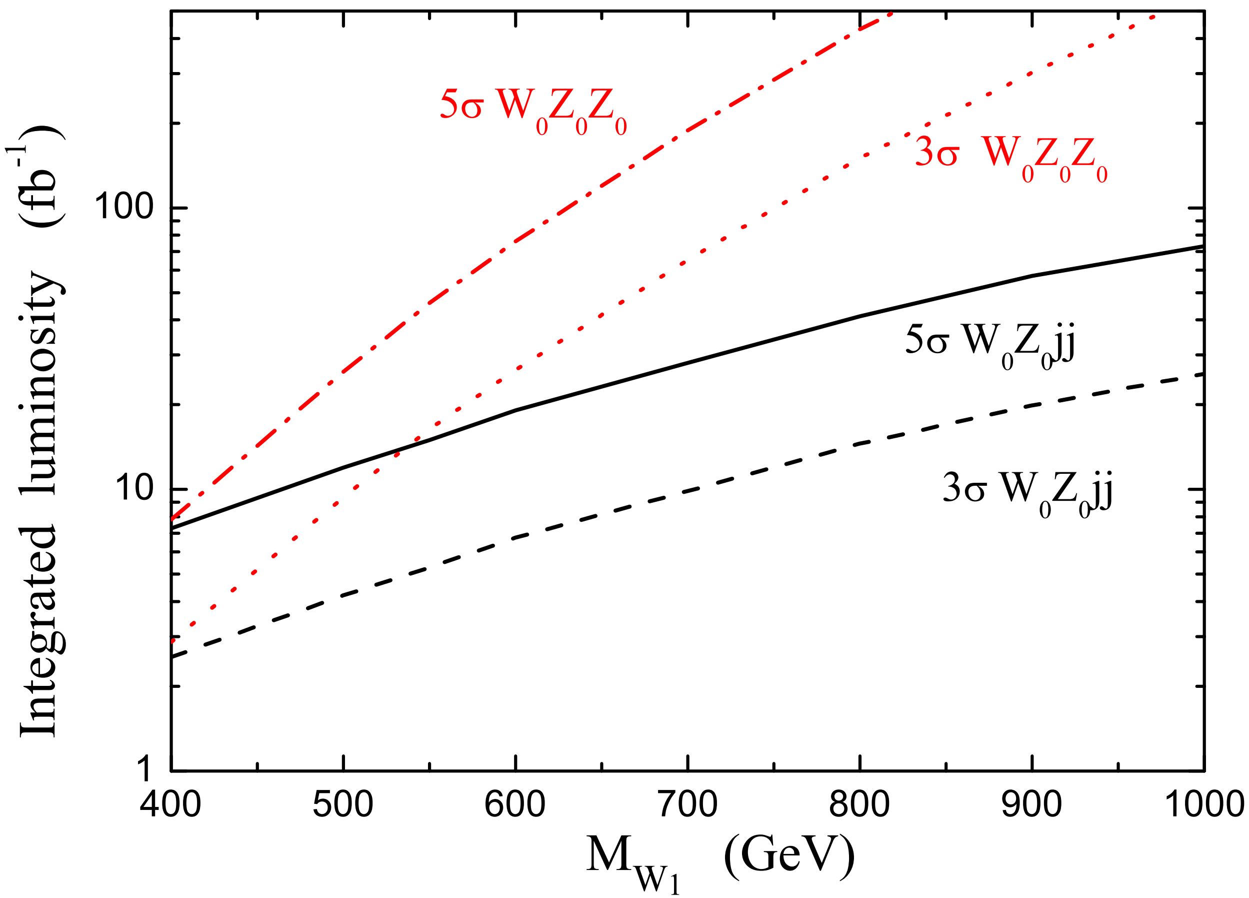


LHC Potential for Finding the W'

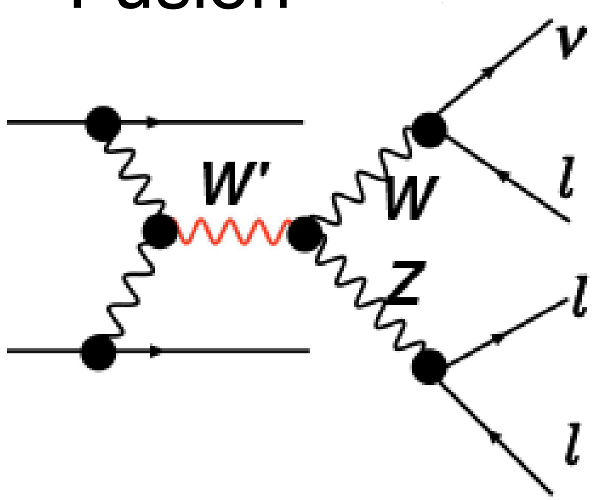
Integrated luminosity needed for 14 TeV LHC discovery of W'

Associated Production



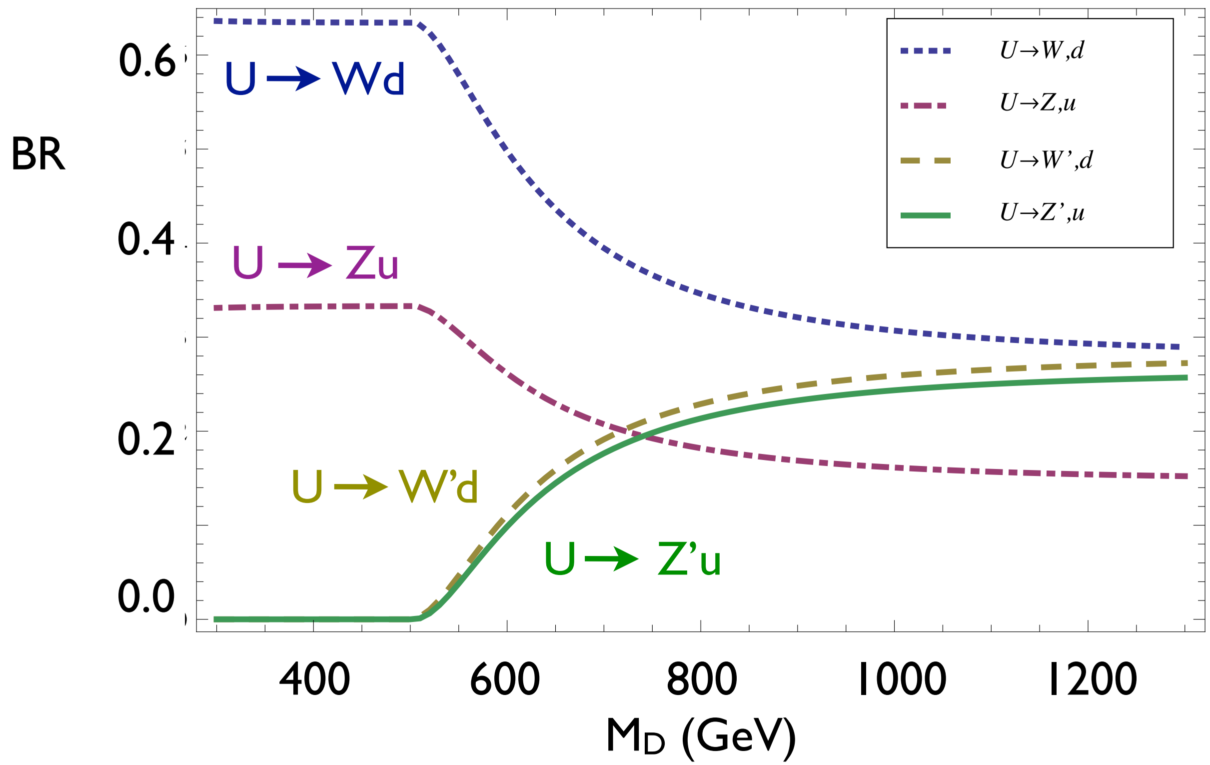


Vector Boson Fusion



KK Quark Decay and Detection

KK fermion decay modes



$M_{Z'}$ = 500 GeV

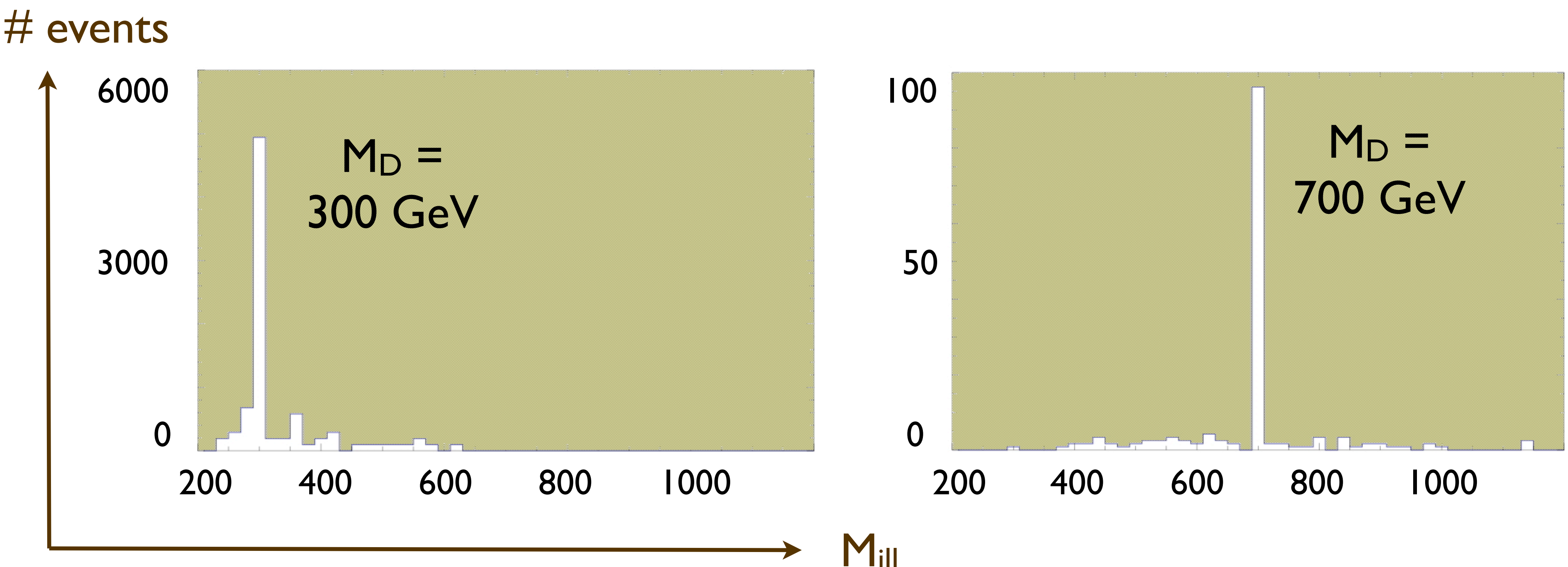
QQ signature: $pp \longrightarrow Q\bar{Q} \longrightarrow WZqq \longrightarrow \ell\ell\ell\, jj\, \not{E}_T$

Qq signature: $pp \longrightarrow Qq \longrightarrow W'qq \longrightarrow WZqq \longrightarrow \ell\ell\ell\, jj\, \not{E}_T$

KK Quark Pair Production

With basic identification and separation cuts on jets and leptons, **a hard jet p_T cut removes nearly all SM background**

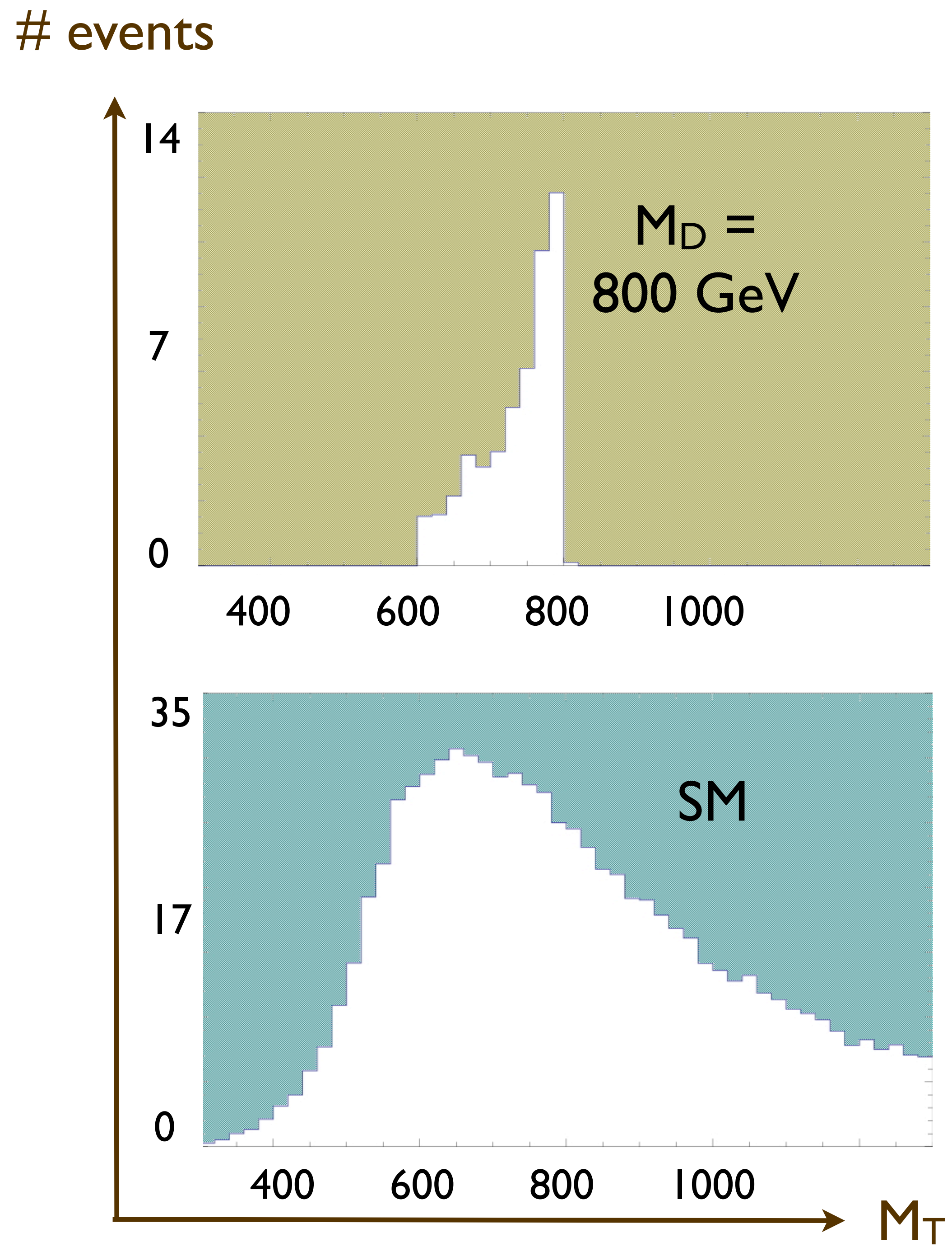
Variable	Cut
p_{Tj}	>100 GeV
p_{Tl}	>15 GeV
Missing E_T	>15 GeV
$\vert\eta_j\vert$	< 2.5
$\vert\eta_l\vert$	< 2.5
ΔR_{jj}	>0.4
ΔR_{jl}	>0.4
M_{ll}	89 GeV$< M_{ll} <$ 93 GeV



KK Quark Single Production

Identification and separation cuts on jets and leptons, **a hard jet p_T cut, and jet & lepton rapidity cuts control the SM background**

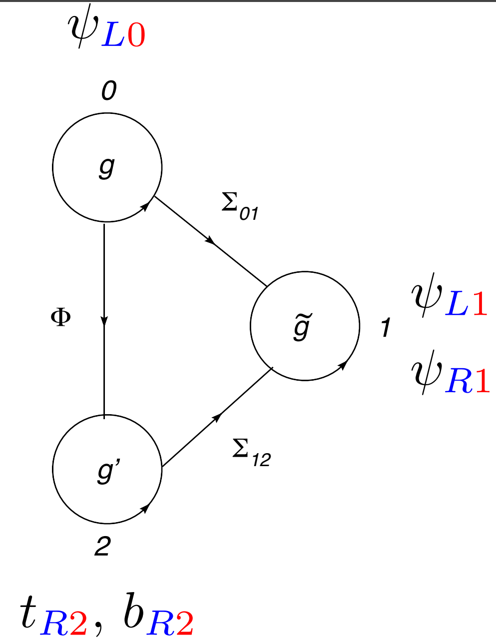
Variable	Cut
p_{Tj} hard	>200 GeV
p_{Tj} soft	>15 GeV
p_{Tl}	>15 GeV
Missing E_T	>15 GeV
$\|\eta_j$ hard$\|$	< 2.5
$\|\eta_j$ soft$\|$	2< $\|\eta\|$ < 4
$\|\eta_l\|$	< 2.5
ΔR_{jj}	>0.4
ΔR_{jl}	>0.4



Key MASS Terms

Top quark: $-\lambda_t \bar{\psi}_{L0}\,\Phi\,t_R$

Top-pions: $4\pi\kappa v^3 \mathrm{Tr}\left(\Phi\Sigma_{01}\Sigma_{12}^\dagger\right)$



All fermions (including top) :

$$M_D\left[\epsilon_L \bar{\psi}_{L0}\Sigma_{01}\psi_{R1} + \bar{\psi}_{R1}\psi_{L1} + \bar{\psi}_{L1}\Sigma_{12}\begin{pmatrix}\epsilon_{uR} & 0\\ 0 & \epsilon_{dR}\end{pmatrix}\begin{pmatrix}u_{R2}\\ d_{R2}\end{pmatrix}\right]$$

ideal delocalization says $\epsilon_L^2 = M_W^2/2M_{W'}^2$

light fermion masses are still of the form $m_f \approx M_D\,\epsilon_L\epsilon_{fR}$

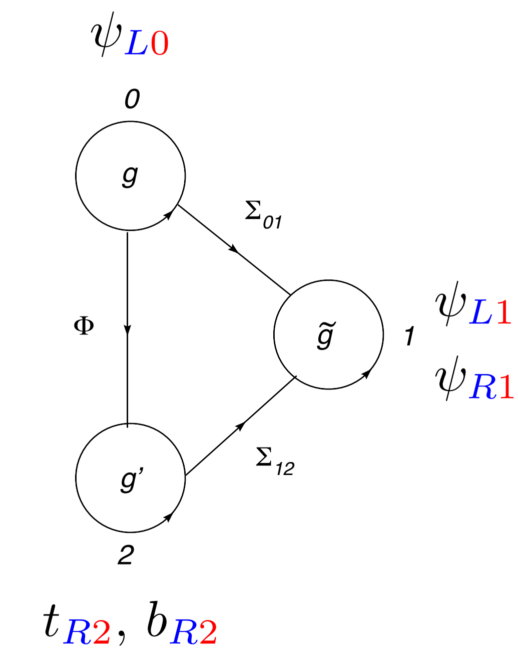
each light mass value is tied to the value of ϵ_{fR}

Top mass value is different...

Top Mass

Top mass matrix:

$$M_t = M_D \begin{pmatrix} \epsilon_{tL} & a \\ 1 & \epsilon_{tR} \end{pmatrix} \qquad a \equiv \frac{\lambda_t\, v \sin\omega}{M_D}$$



Perturbative diagonalization yields...

$$m_t = \lambda_t v \sin\omega \left[1 + \frac{\epsilon_{tL}^2 + \epsilon_{tR}^2 + \frac{2}{a}\epsilon_{tL}\epsilon_{tR}}{2(-1+a^2)}\right]$$

Top mass now depends strongly on λ_t, weakly on ϵ_{tR}

A large top mass no longer conflicts with making ϵ_{tR} small to minimize $\Delta\rho$

$$\Delta\rho = \frac{M_D^2\, \epsilon_{tR}^4}{16\,\pi^2\, v^2}$$

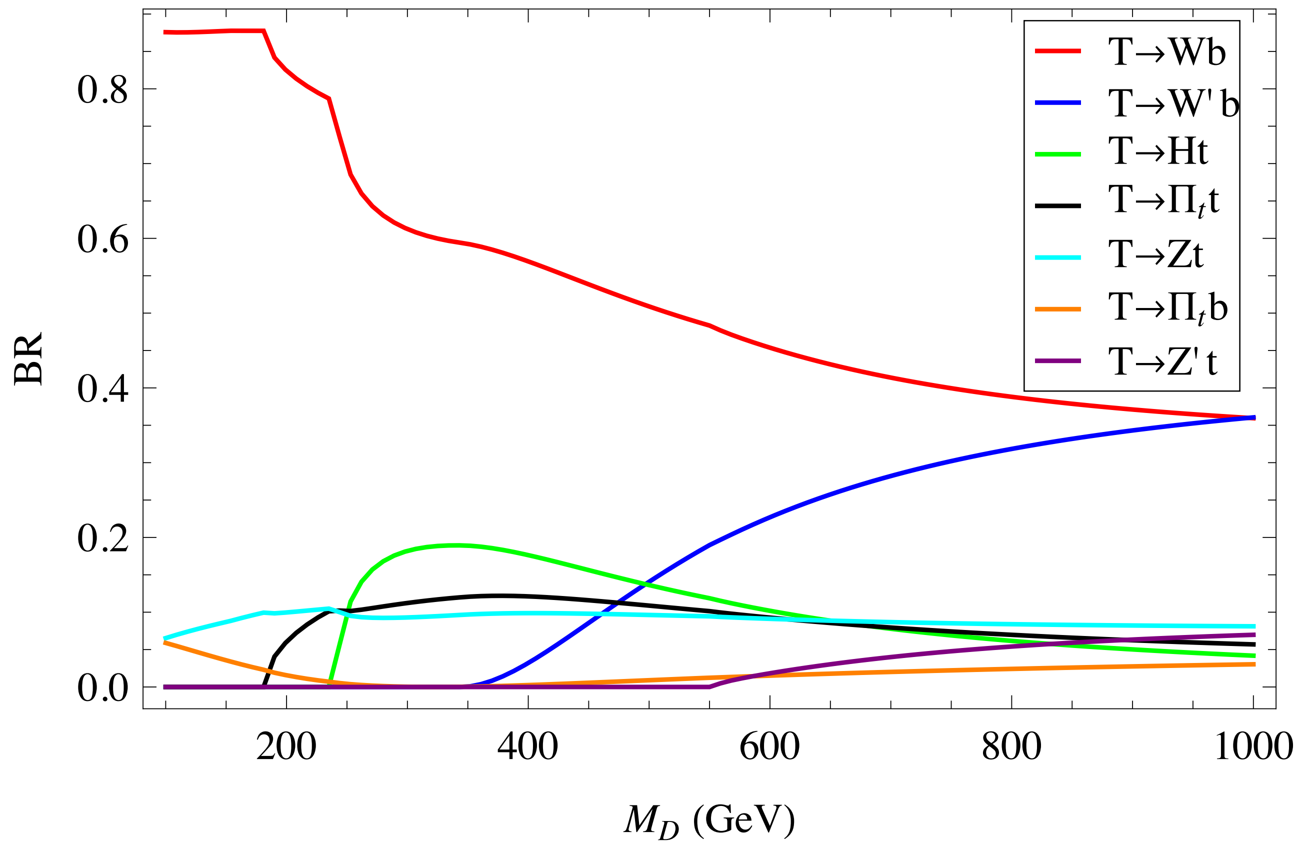
KK fermions are light enough to produce at LHC

Top sector at LHC: T

Top's KK partner, T, will be most visible in T →Wb.

Analysis for other KK quark partners (assuming W→lv) still roughly applies; the channel with one hadronically-decaying W should offer larger signal and full reconstruction of T.

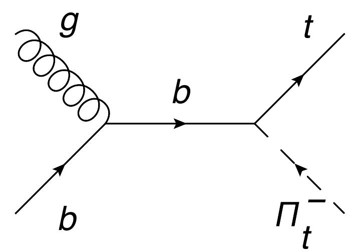
The T →H_t t decays will also be helpful.

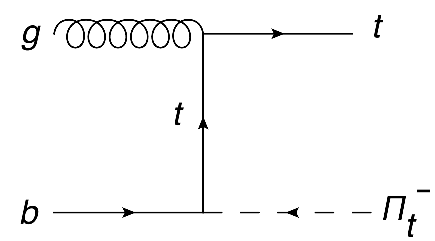


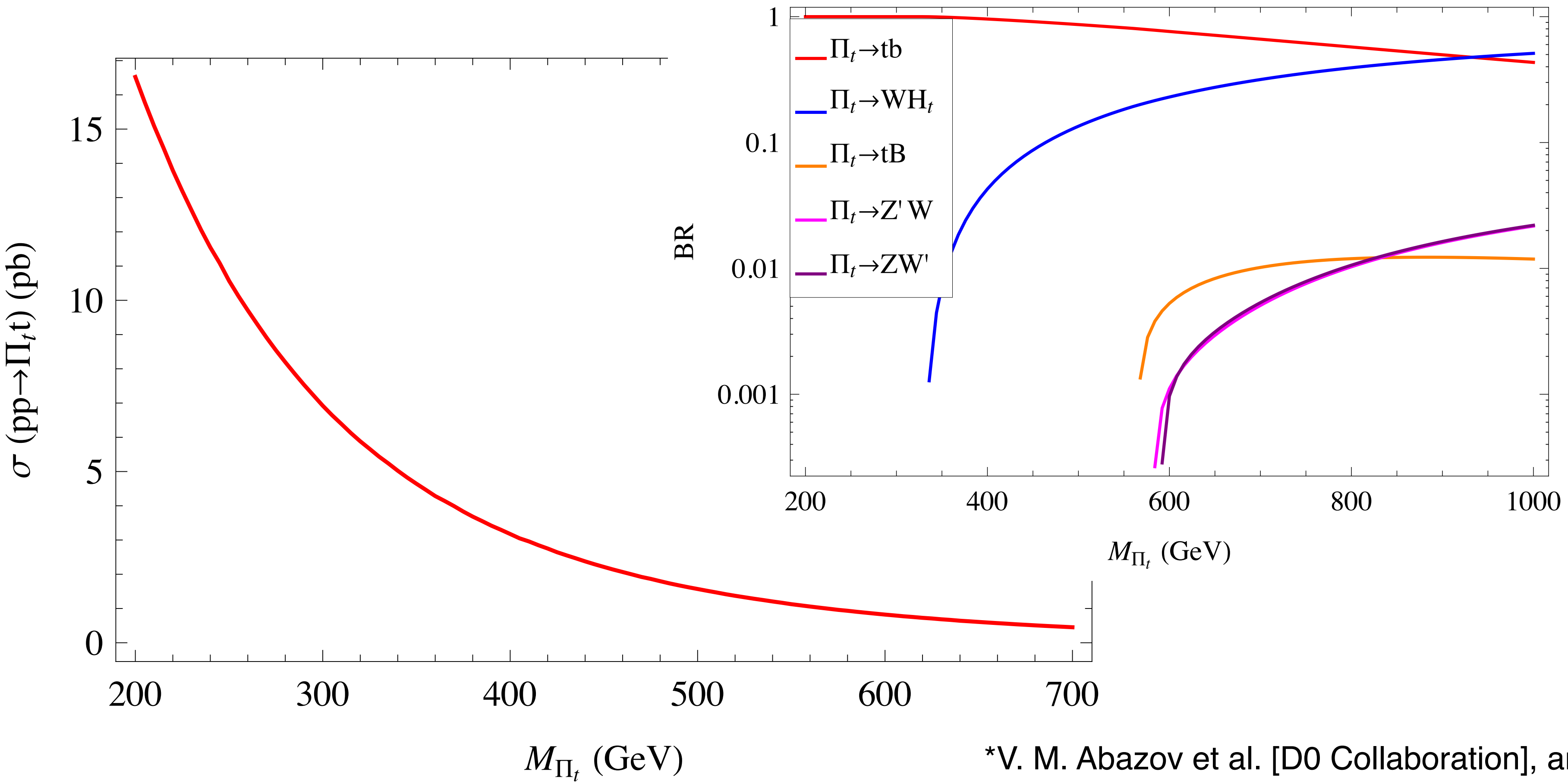
Top sector at LHC: Π_T

FNAL limits* on $t \rightarrow H^{\pm} b$ imply Π_t is heavier than t, so the main production process is pp → t Π_t → t t b.

CMS studies** of $H^{\pm} \rightarrow t b$ imply 30 fb^{-1} of data can find a Π_t up to 400 GeV







Note: Π_t can also decay to W H_t.

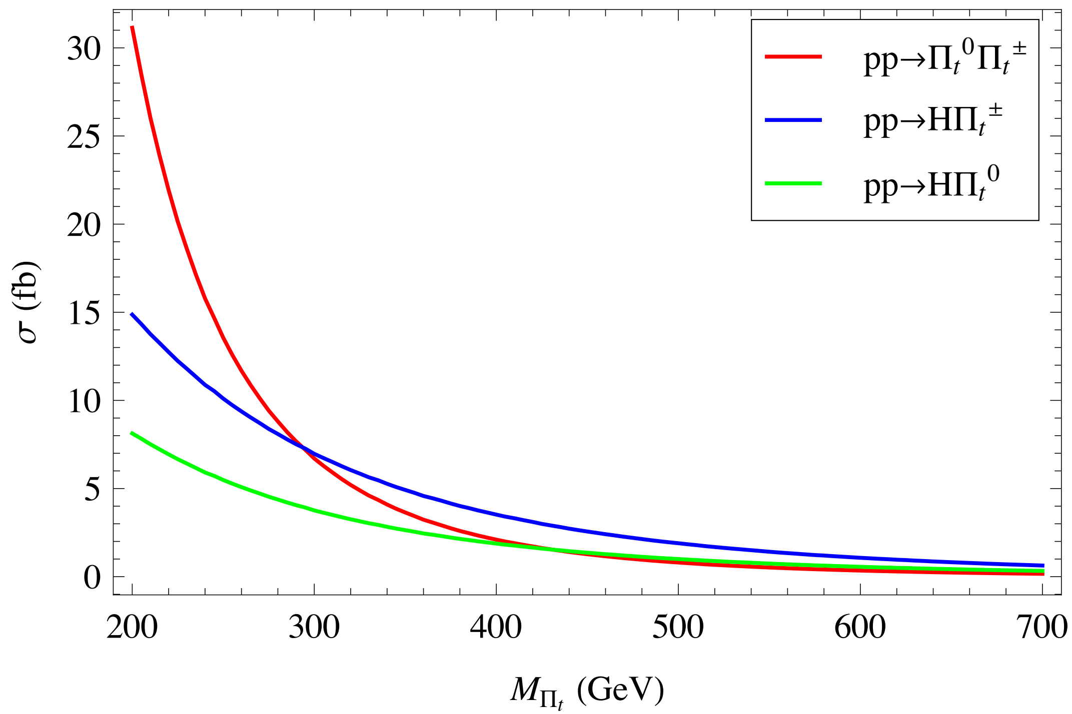
*V. M. Abazov et al. [D0 Collaboration], arXiv:0908.1811

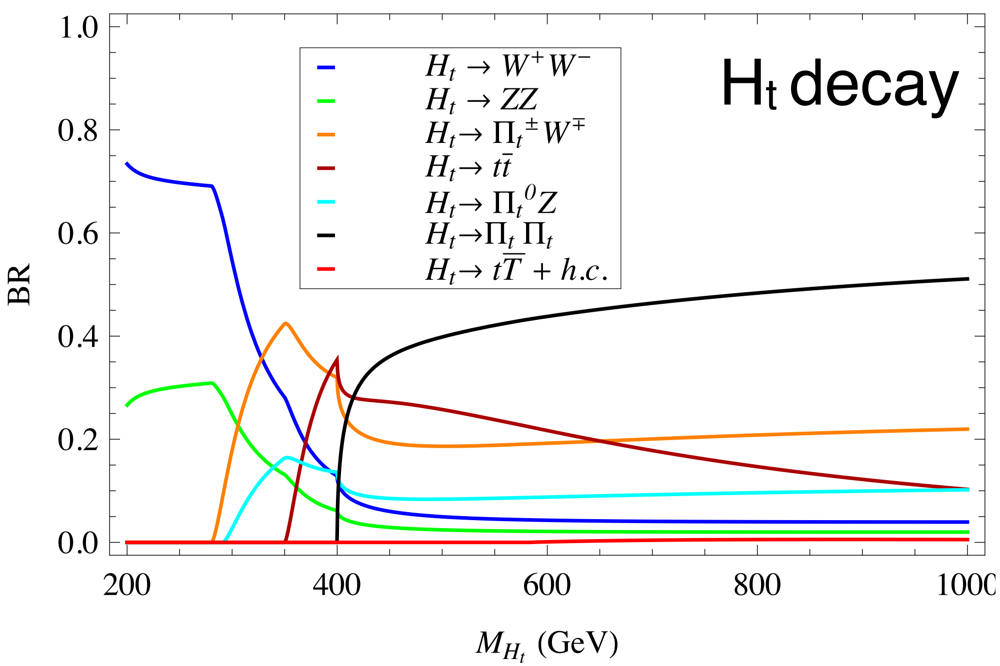
**Lowette, D'Hondt, Vanlaer CERN-CMS-NOTE-2006-109

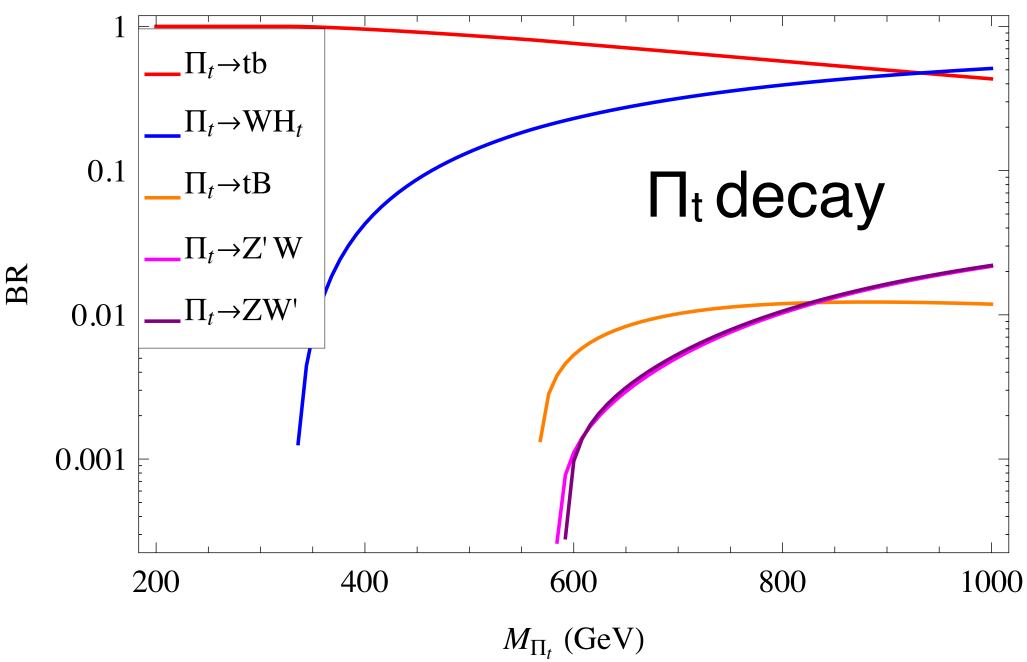
Top sector at LHC: Π_T

Associated production pp → W* → H_t Π_t can provide useful confirmation of the relationship between H_t and Π_t.

Single production followed by either H_t → $W\Pi_t$ or Π_t → WH_t would be similarly informative.

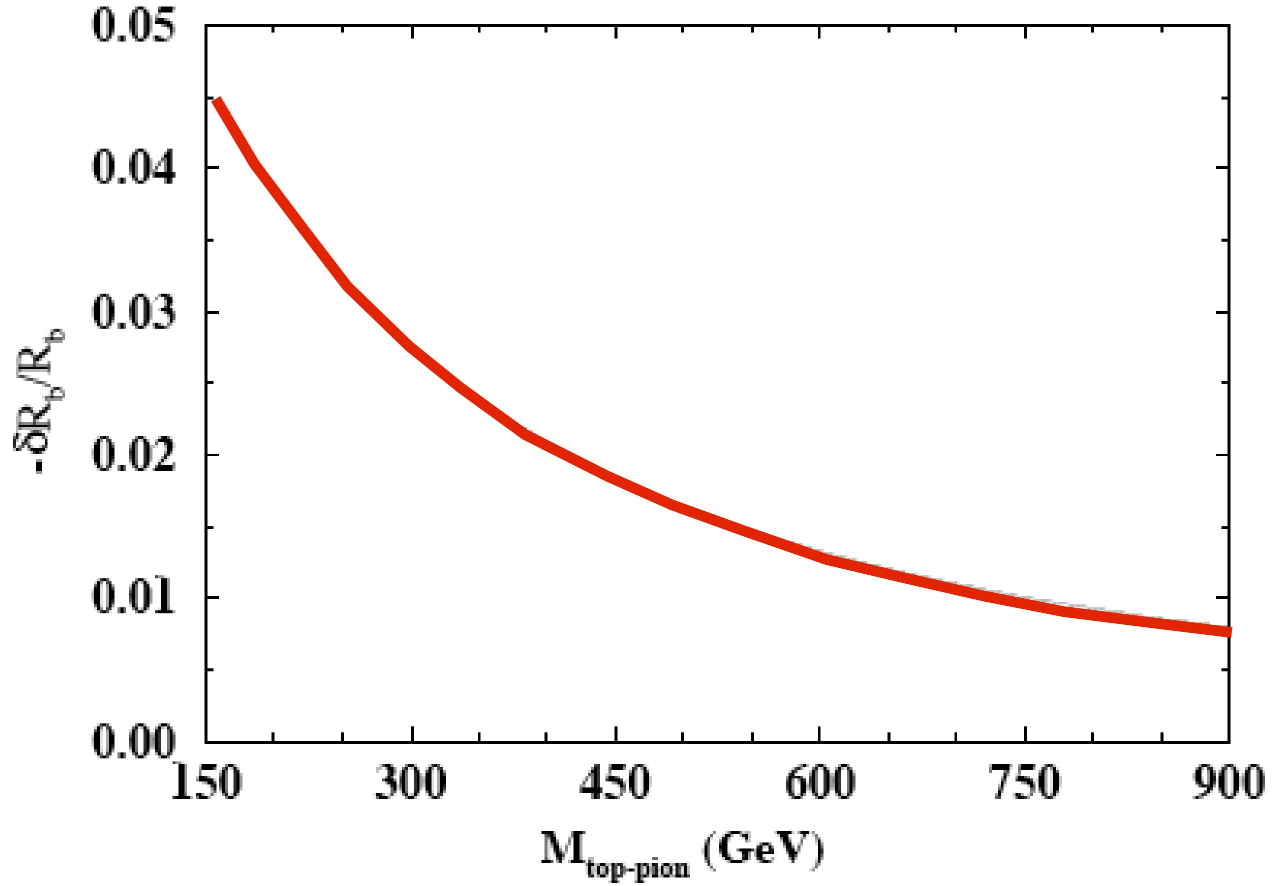






Constraints From Top-Pions

Top-pion exchange significantly% decreases R_b



% Burdman & Kominis hep-ph/9702265

This and other b-flavor-related issues pose additional constraints on model-building...

See also Buchalla et al. hep-ph/9510376; Burdman et al. 0012073; Simmons 0111032;

TC2 Dynamics

The limits above were derived in an effective field theory (top triangle moose) for TC2 and related models:

- A combination of topcolor dynamics and ETC give rise to the top quark mass: $m_t \approx m_t^{dyn} + m_t^{ETC}$ where the latter is only 0.5% - 10% of the total.

- The Pagels-Stokar relation $f_{\Pi_t}^2 = \frac{N_c}{8\pi^2} m_{t,dyn}^2 \ln\left(\frac{\Lambda^2}{m_{t,dyn}^2}\right)$ relates $\sin\omega \equiv f_{\Pi_t}/v$ to the top mass

- The top-pion mass $M_{\Pi_t}^2 = \frac{N_c}{4\pi^2} m_{t,ETC} m_{t,dyn} \left(\frac{\Lambda^2}{f_{\Pi_t}^2}\right)\gamma$ should exceed the top mass to respect bounds on $t \to bH^+$

- The dynamics imply $M_{H_t} \lesssim 2m_{t,dyn}$