Limits on the pions of strong dynamics models from LHC Higgs searches

Jing Ren

Michigan State University & Tsinghua University

May 7, 2012 @ Pheno

Based on arXiv: 1110.3688

Collaborated with R. S. Chivukula, P. Ittisamai, E. H. Simmons

Outline

- Review on Strong dynamics in EWSB
- Technipions in Technicolor models
- LHC bound on neutral pions composed of colored technifermion
- Summary

Review on Strong Dynamics in EWSB

- EWSB: $SU(N_{TC}), (SU(3)_C) \times SU(2)_L \times U(1)_Y \subset G_{chiral}$

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$$\beta_{ab}\frac{\bar{Q}_L T^a Q_R \bar{\psi}_R T^b \psi_L}{\Lambda_{ETC}^2} + \gamma_{ab}\frac{\bar{\psi}_L T^a \psi_R \bar{\psi}_R T^b \psi_L}{\Lambda_{ETC}^2} + \dots$$

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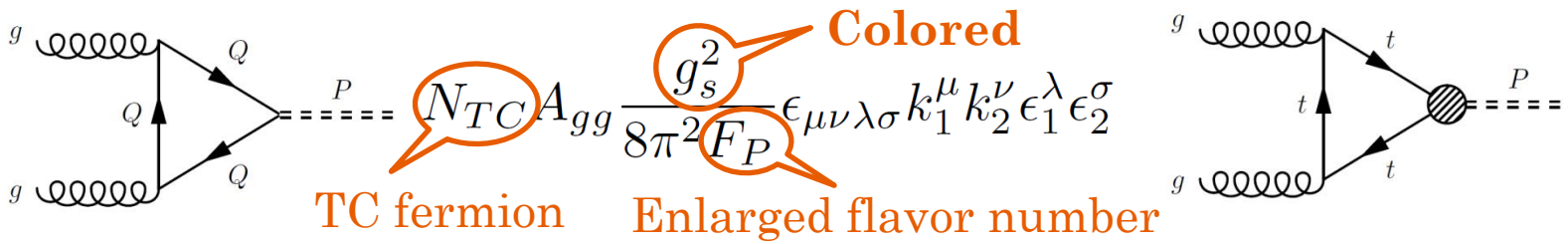
- Low energy spectrum: **technipion**, technirho…
- Top mass: top-color, top-seesaw…

Character of Technipion

- Couplings
  - CP-odd: no tree level coupling to WW/ZZ
  - **Anomalous coupling** to gluon and photon



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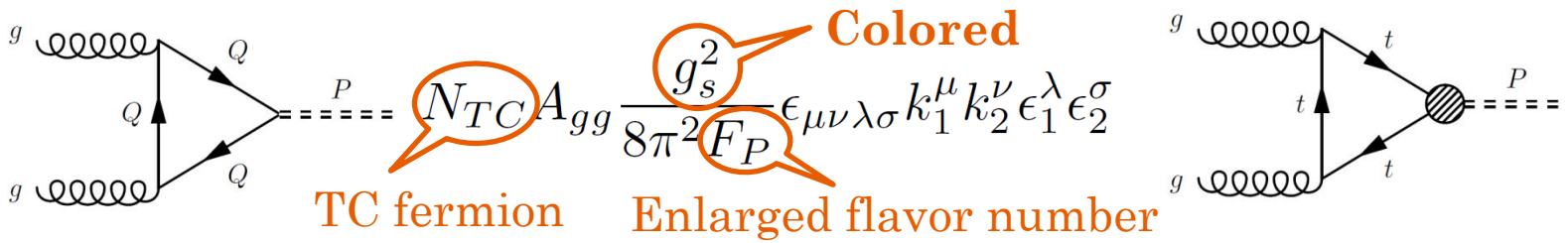

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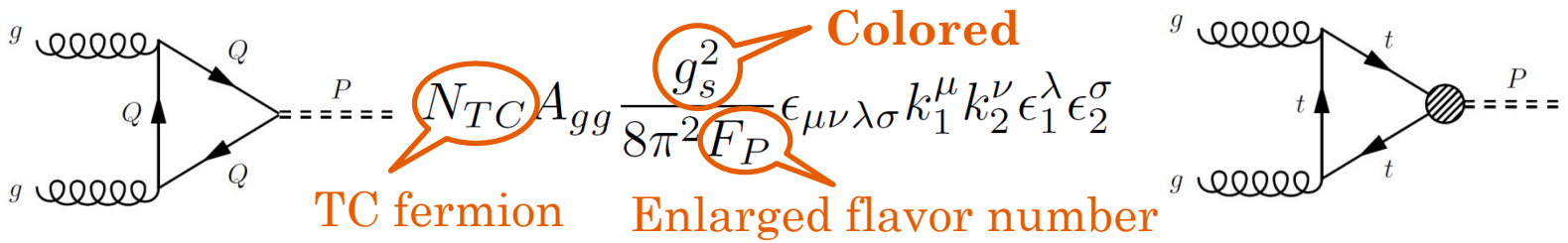

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- **Total enhancement factor**: $yy \to \Pi^0 \to xx$ (narrow width)

$$\kappa^P_{yy/xx} = \frac{\Gamma(P \to yy) \times BR(P \to xx)}{\Gamma(h_{SM} \to yy) \times BR(h_{SM} \to xx)} \equiv \kappa_{yy\ prod}\ \kappa_{xx\ decay}$$

TC models

- Lightest pion

TC models	P	PNGB and content	v/F_P	A_{gg}	$A_{\gamma\gamma}$	λ_l	λ_f
FS one family[38]	P^1	$\frac{1}{4\sqrt{3}}(3\bar{L}\gamma_5 L - \bar{Q}\gamma_5 Q)$	2	$-\frac{1}{\sqrt{3}}$	$\frac{4}{3\sqrt{3}}$	1	1
Variant one family[35]	P^0	$\frac{1}{2\sqrt{6}}(3\bar{E}\gamma_5 E - \bar{D}\gamma_5 D)$	1	$-\frac{1}{\sqrt{6}}$	$\frac{16}{3\sqrt{6}}$	$\sqrt{6}$	$\sqrt{\frac{2}{3}}$
LR multiscale[39]	P^0	$\frac{1}{6\sqrt{2}}(\bar{L}_\ell\gamma_5 L_\ell - 2\bar{Q}\gamma_5 Q)$	4	$-\frac{2\sqrt{2}}{3}$	$\frac{8\sqrt{2}}{9}$	1	1
TCSM low scale[40]	$\pi_T^{0'}$	$\frac{1}{4\sqrt{3}}(3\bar{L}\gamma_5 L - \bar{Q}\gamma_5 Q)$	$\sqrt{N_D}$	$-\frac{1}{\sqrt{3}}$	$\frac{100}{27\sqrt{3}}$	1	1
MR Isotriplet [31]	P^1	$\frac{1}{6\sqrt{2}}(3\bar{L}\gamma_5 L - \bar{Q}\gamma_5 Q)$	4	$-\frac{1}{\sqrt{2}}$	$24\sqrt{2}y^2$	1	1

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- BR of P

$m_P = 130$ GeV

Decay Channel	One Family		Variant one family		Multiscale		TCSM low-scale		Isotriplet		SM Higgs
	$N_{TC}=2$	$N_{TC}=4$	$N_{TC}=2$	$N_{TC}=4$	$N_{TC}=2$	$N_{TC}=4$	$N_{TC}=2$	$N_{TC}=4$	$N_{TC}=2$	$N_{TC}=4$	
$b\bar{b}$	77	56	61	50	64	36	77	56	60	31	49
$c\bar{c}$	7	5.1	0	0	5.8	3.2	7	5.1	5.4	2.8	2.3
$\tau^+\tau^-$	4.5	3.3	32	26	3.8	2.1	4.5	3.3	3.5	1.8	5.5
gg	12	35	7	23	26	59	12	35	14	29	7.9
$\gamma\gamma$	0.011	0.033	0.11	0.35	0.025	0.056	0.088	0.26	17	36	0.23
W^+W^-	0	0	0	0	0	0	0	0	0	0	31

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$b\bar{b}$	44	18	42	20	24	7.7	44	18	20	6.2	0.036
$c\bar{c}$	4	1.6	0	0	2.2	0.69	4	1.6	1.8	0.56	0.0017
$\tau^+\tau^-$	2.6	1	22	11	1.4	0.45	2.6	1	1.2	0.36	0.0048
gg	49	79	35	68	72	91	49	79	34	41	0.085
$\gamma\gamma$	0.047	0.076	0.54	1	0.069	0.087	0.36	0.58	42	51	~ 0
W^+W^-	0	0	0	0	0	0	0	0	0	0	68

Mass dependence

$$\Gamma(P \to gg, \gamma\gamma) \propto \frac{N_{TC} m_P^3}{F_P^2}$$

$$\Gamma(P \to \bar{f}f) \propto \frac{m_P m_f^2}{v^2}$$

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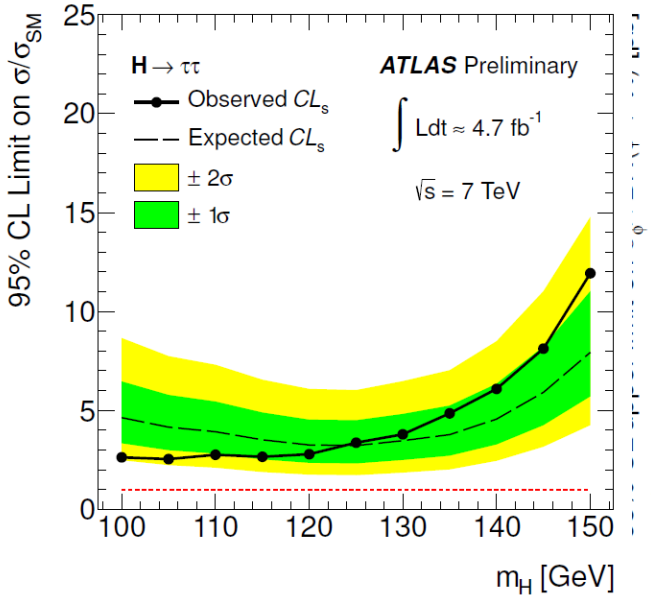
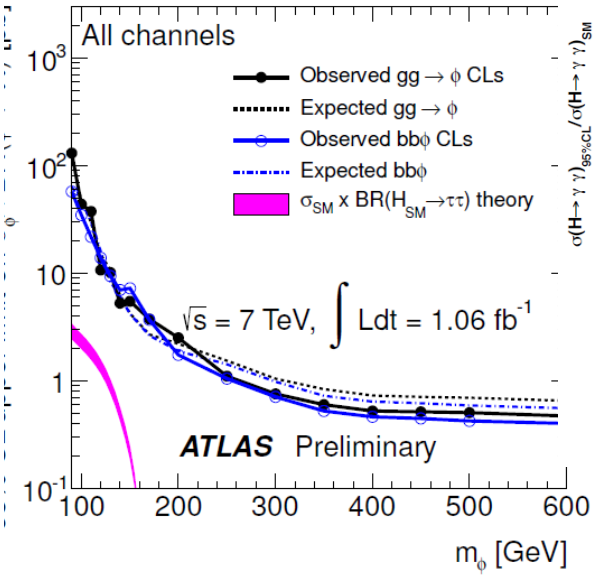
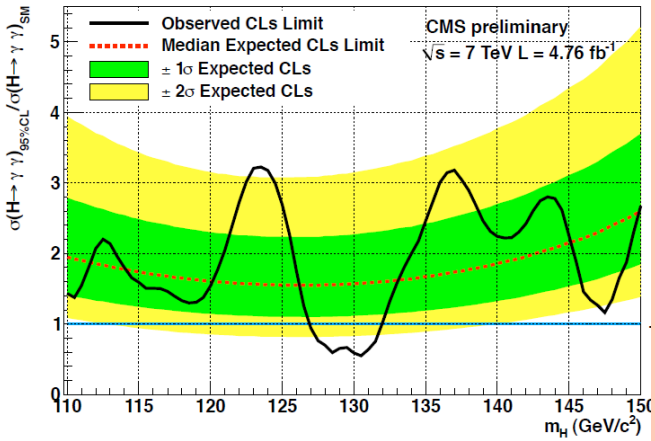
LHC Higgs bound in ditau and diphoton







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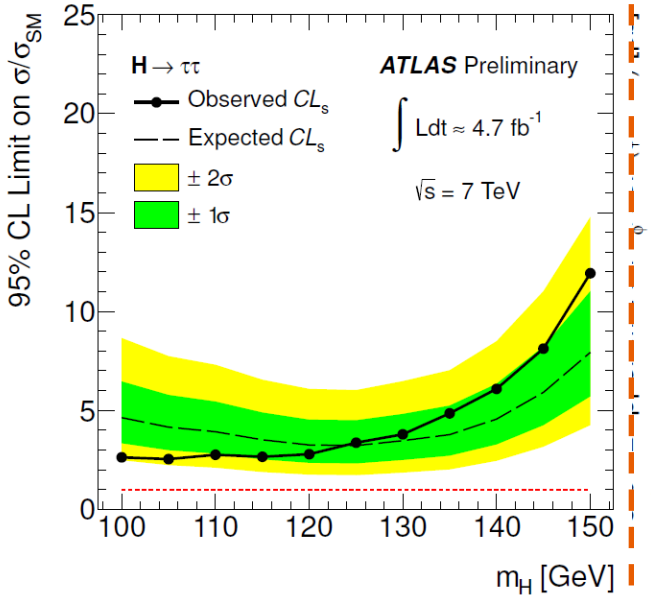
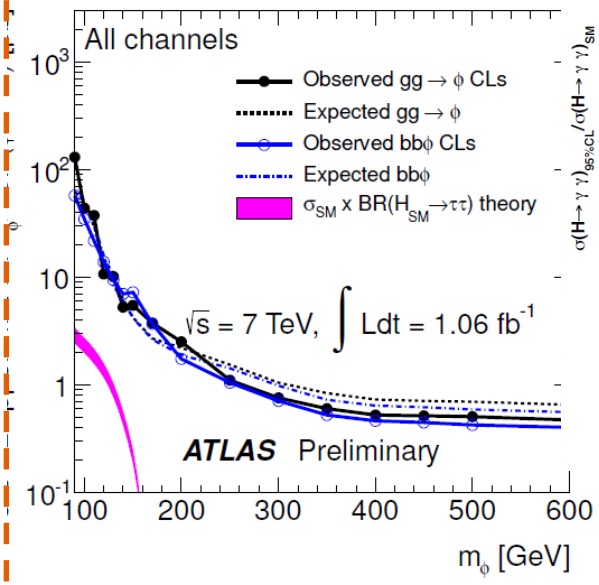
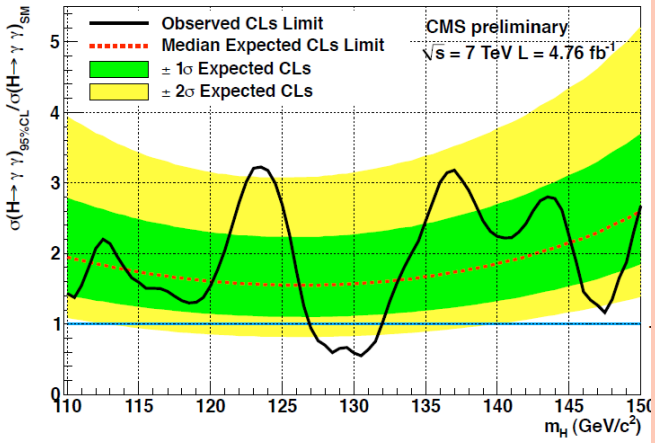
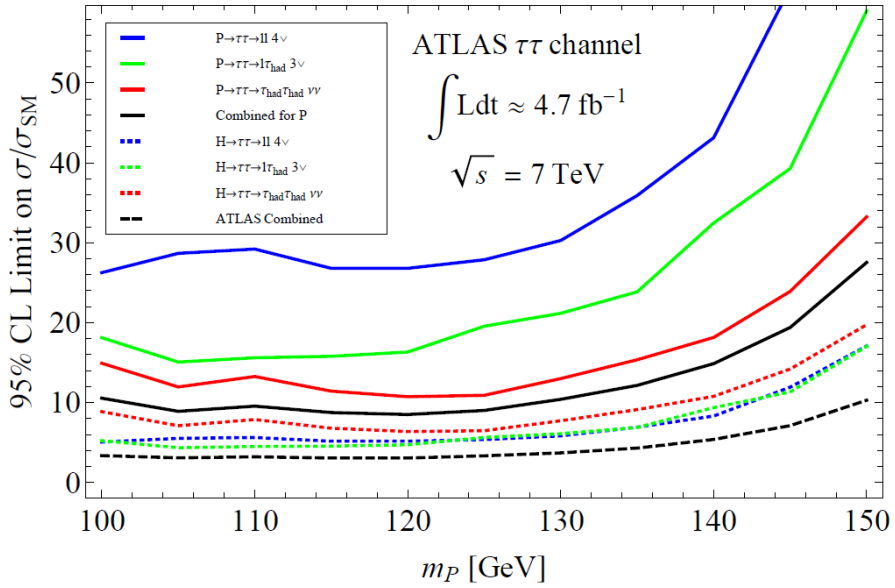


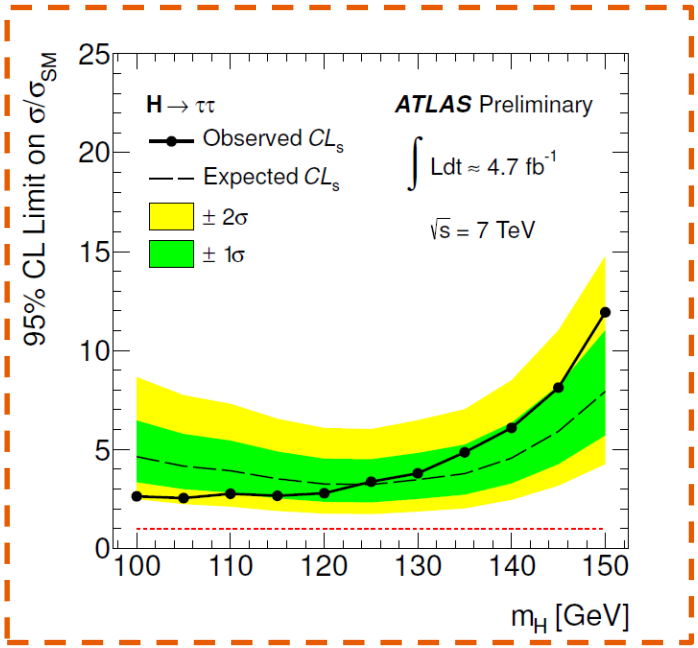




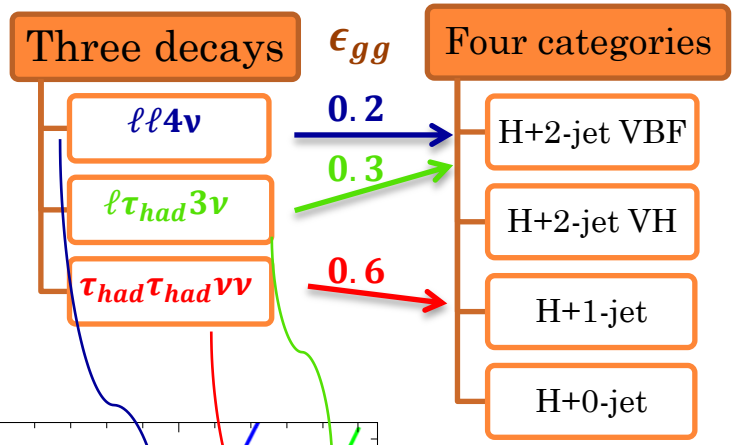
Rescaling to Technipion



Translation of Higgs Bound



Large background: $Z/\gamma^* \rightarrow \tau^+\tau^-$



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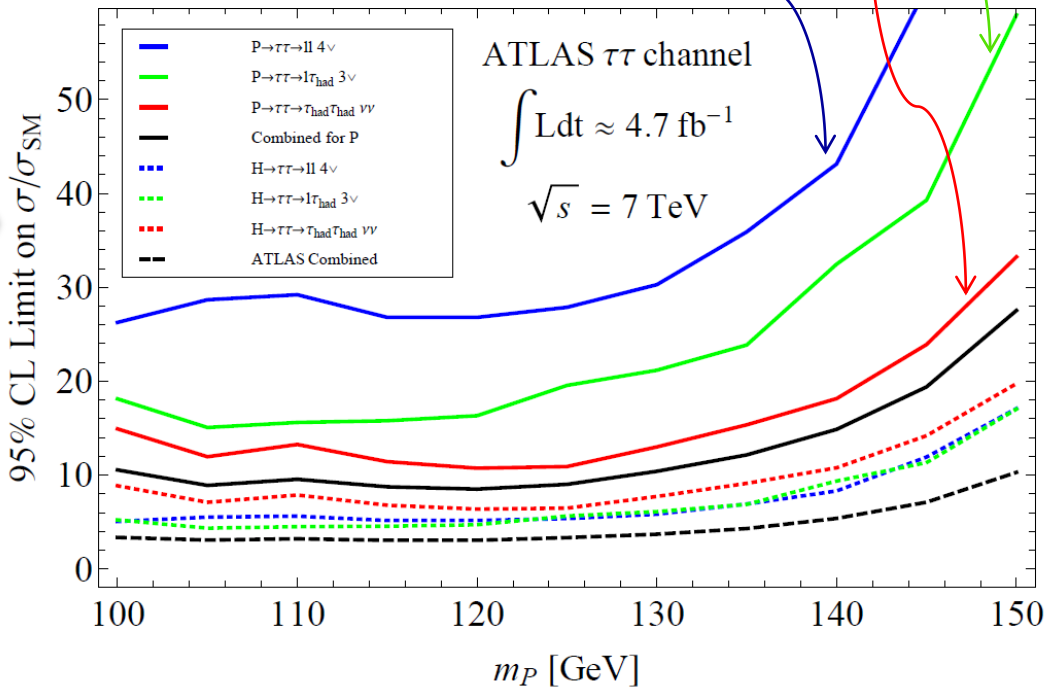
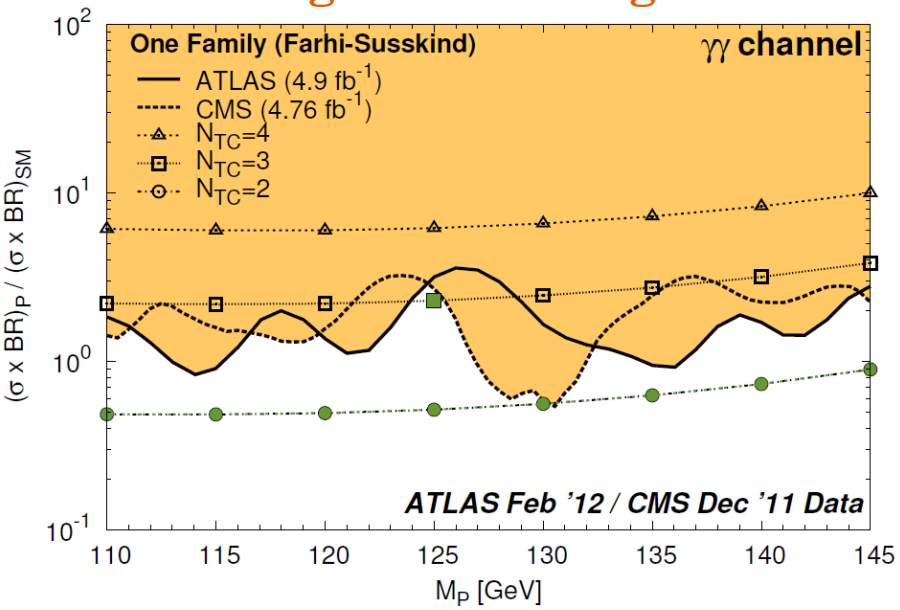
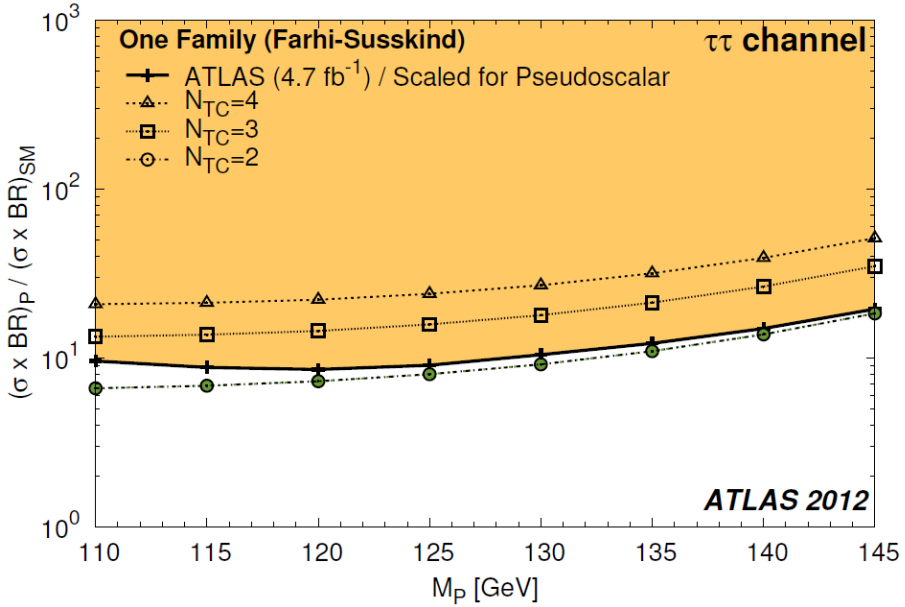


Bound on the Lightest Technipion P

Light mass range





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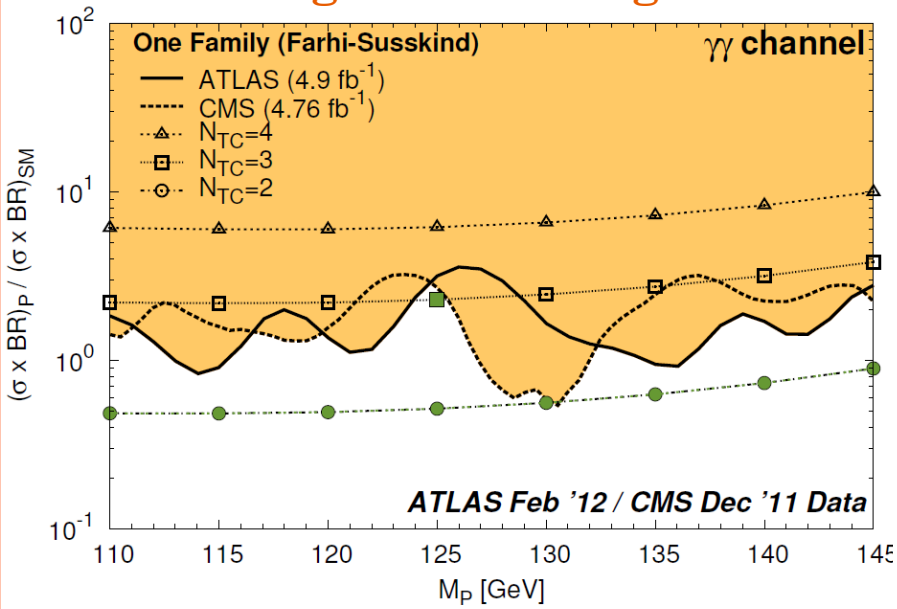
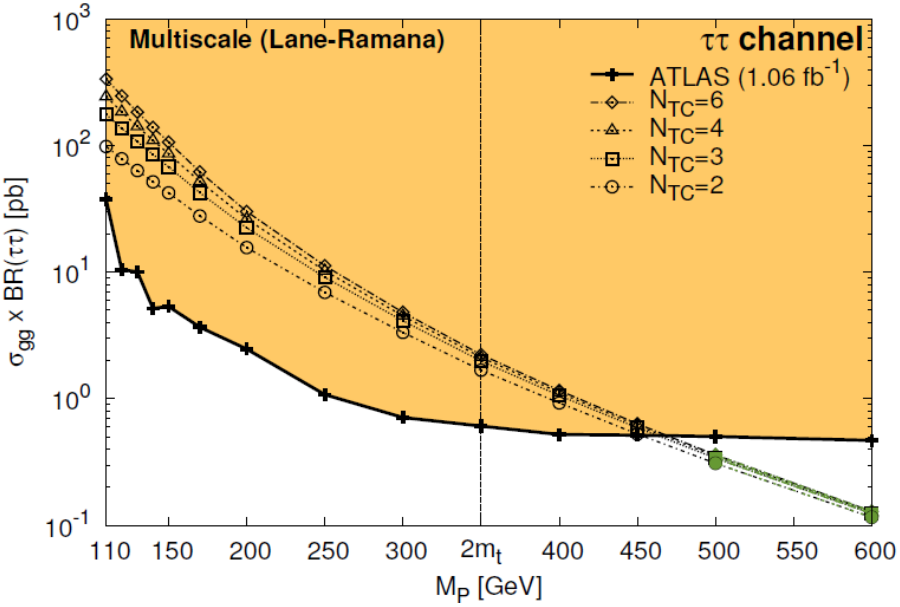
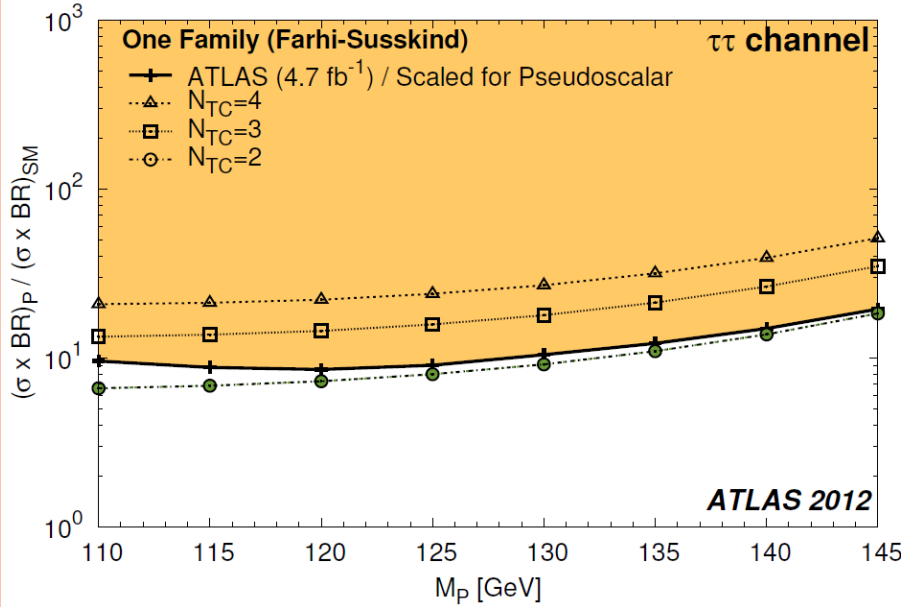
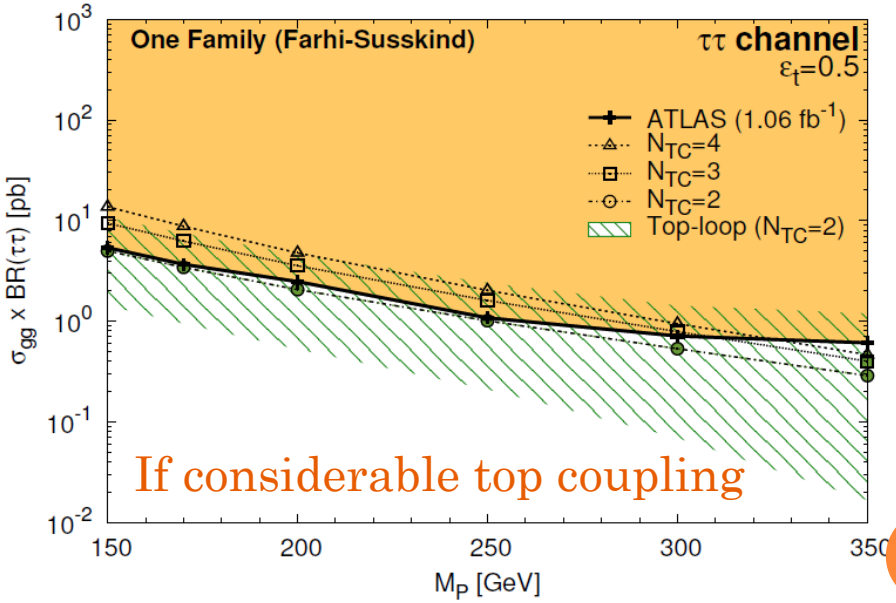


High mass range







If considerable top coupling

Summary

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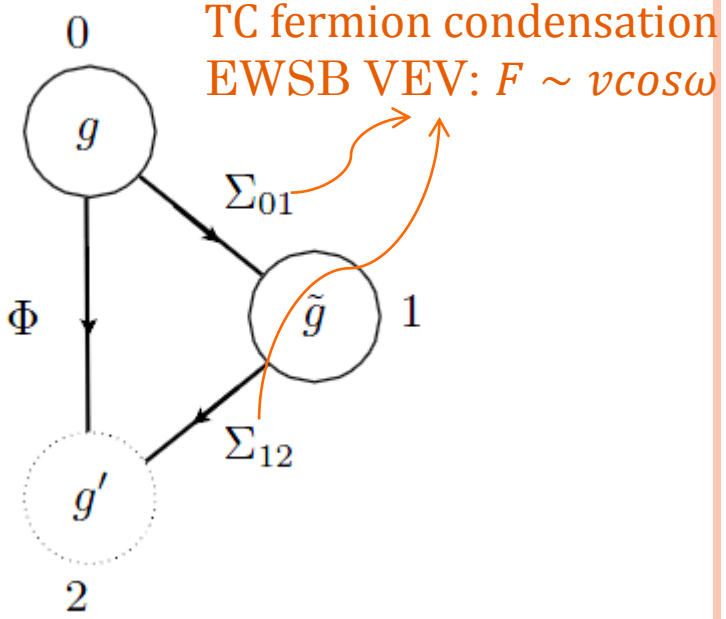
  - Top-pion in TC2: insensitive to TC models
- Ways to escape the limit
  - Interference between technifermion and top loop
  - No colored technifermion ⟶ Colored ETC gauge boson
  - No technipion, special walking scenario

Thank you!

TOP-PIONS IN TC2

- Top triangle moose as EFT

Composite Top-higgs doublet
EWSB VEV: $f \sim v\,sin\omega$



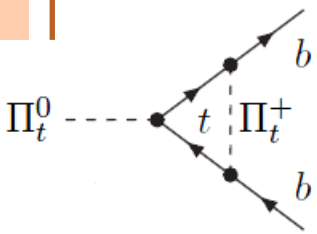
NJL model estimation
$0 \leftarrow sin\omega \rightarrow 1$
Top-color Top-seesaw

- Pion as combination of two would-be GB

$$\Pi_t^a = \cos\omega\,\pi_t^a - \sin\omega\,\pi_{TC}^a$$

- Strongly coupled to top
- Top loop to $A_{gg}, A_{\gamma\gamma}$
- y_t and large correction to y_b

Determined by top-color dynamics



- TC would-be NG
- Vanishing $A_{gg}, A_{\gamma\gamma}$
- Fixed y_f

Insensitive to TC structure!!

Production and Decay of neutral top-pion Π_t^0

- Gluon fusion production

Enhanced in TC2: small top-color VEV

$$N_C A_{gg}^t \frac{g_s^2 \cot\omega}{8\pi^2 v} J\left(\frac{m_\Pi}{m_t}\right) \epsilon_{\mu\nu\lambda\sigma} k_1^\mu k_2^\nu \epsilon_1^\lambda \epsilon_2^\sigma$$

- Decay BR