

Probing Higgs Couplings with High p_T Higgs Production

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ERC Ideas: NPFlavour

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INDEPENDENT

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Big bang moment: Scientists may finally have found 'God particle'

50-Yr Search For Higgs Boson Ends In Triumph

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Ex-Maha CM Aming 13 in Chargesheet

Akhilesh hits reverse gear on car bonanza

ARUBA DAILY

Thursday July 05 2012 - No. 752

NEWS IN BRIEFS
DANNI says: "I've often wondered how quarks and other sub-atomic particles gain mass. So I was relieved to hear of the discovery of a new sub-atomic particle. That's one of the things I was hoping to do with my research."

Double amputee Pistorius set to run at Olympics
New court out Oscar Pistorius. The Blade Runner will be competing in the London Olympics after all at his favorite sport. He has 480 hours of training.

Obama urges immigration reform at July 4 citizen ceremony
President Barack Obama urged an immigration reform bill to be passed by Congress before the July 4 holiday.

EUREKA!

Physicists celebrate evidence of particle

SVENSKA DAGBLADET
Onsdag 4 juli 2012

Mycket står på spel i Burma i veckan
SÄKERHETSPOLITIKEN

Cern har hittat spår av saknad partikel
Så här kan spåret efter Higgspartikeln se ut.

Tampa Bay Times
Where's the best place to nourish a romance? Our food critic has tips.

on toll roads
survey landowners

TO DEBBY

Jutarnjüst

SENZACIONALNO OTKRICE UČENIČA

PRODAJI!

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gazeta

WYBORCZA.PL

Dzisiaj Jak nie odziedziczyć długów
Kiedy lepiej zrobić się apokali... s. 15

Sędziowie, górnicy, rolnicy...
Jak się zmierza przetrwać... s. 17

Samochodowa mapa Europy
Chcesz ją? Za tydzień: mapa Silesia

2,00 zł
6,99 zł

Ukraincy biją się o język Rosyjski
Na piecu Empojskim w czwartek w nocy posyłał i gaz...

SVENSKA DAGBLADET

SVENSKA SIMMARESS HOTAS AV USA-MISSIL

ALMEDALEN

GÖRAN ERIKSSON

350

Mag- och farm-svåg rapportens fördomar om ett dumplande lippo

Assad, in interview, says his office is meaningless

EL PAÍS

miércoles, 4 julio 2012 Actualizado 09:52 CET

Los científicos del CERN anuncian el descubrimiento de una partícula que podría ser Higgs. Sigue la vida explicando un avance que, de confirmarse, supondría un paso esencial de la física para explicar el origen de la materia.

Hallada "la más sólida evidencia" de la existencia del bosón de Higgs

El posible descubrimiento de la partícula es un paso esencial hacia la explicación del origen de la materia

"Puedo confirmar que se ha descubierto una partícula que es consistente con la teoría del bosón de Higgs", dicen los científicos. El descubrimiento de la partícula ayudaría a explicar el origen de la masa. Los físicos del CERN explican en los momentos sus hallazgos

- Diccionario para entender en qué consiste el hallazgo
- La "caza" del bosón de Higgs, por A. RUIZ JIMENO
- VIDEO Una explicación del bosón de Higgs
- Sigue en directo la conferencia del CERN
- FOTOGALERÍA Indicios hallados de la "partícula de Dios"
- "Hacia la partícula de Dios", por JAVIER SAMPEDRO

Registro del CMS que pudiera ser la firma de la partícula de Higgs. / CERN

Časťke Higgsa fyzicy najpierw wymyślili, potem szukali 40 lat BOSKA MASA

Po tym odkryciu świat już nigdy nie będzie taki sam. Najbardziej tajemniczy ze wszystkich składników materii został wreszcie złapany - poinformowali wczoraj fizycy z ośrodka CERN

FILMOWY MAGAZYN DO CZYTANIA

WYBIÓR: GREGORSKA, NITZ, SOBULEWSKI, SZCZWIŁ, ORLIŃSKI, FELIS, MINAJEWICZ, WARGA, SZCZEBRA

ny nya tens

Mag- och farm-svåg rapportens fördomar om ett dumplande lippo

Assad, in interview, says his office is meaningless

350

atomic key to reality

UF physicists help find elusive particle

RECEIVED: *October 3, 2013*ACCEPTED: *December 14, 2013*PUBLISHED: *January 7, 2014*

Probing Higgs couplings with high p_T Higgs production

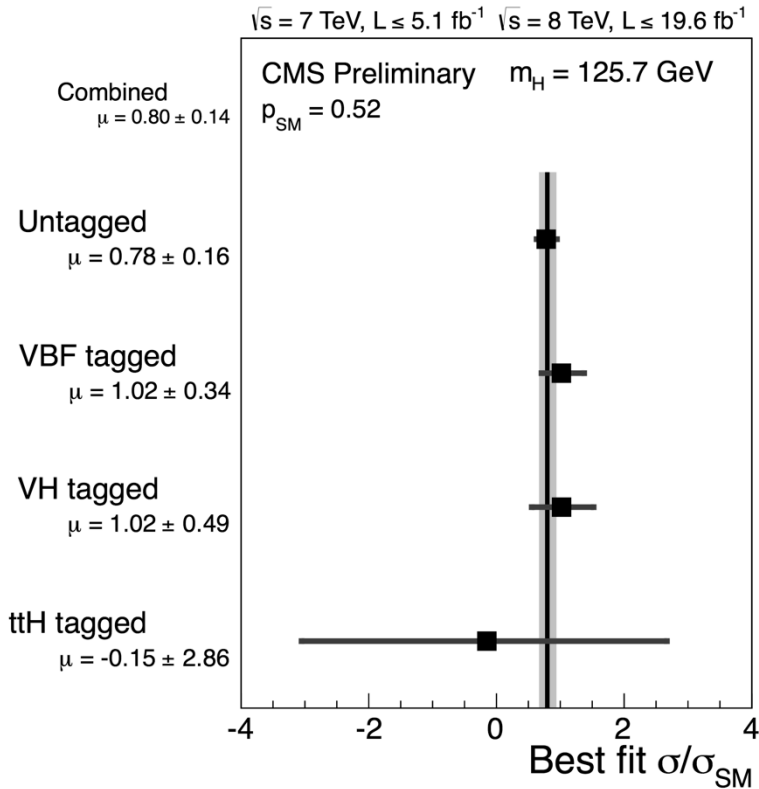
Aleksandr Azatov^{a,b} and Ayan Paul^b

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00185 Rome, Italy*

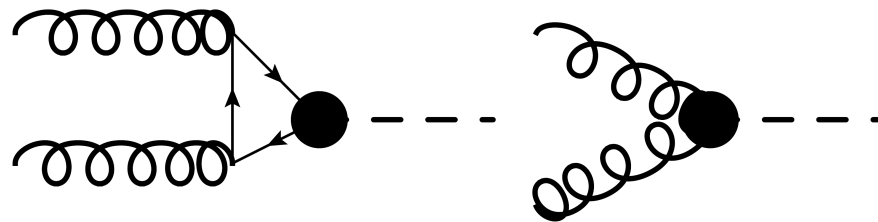
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00185 Rome, Italy*

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The Context



- ✓ Direct measurement of top Yukawa coupling to be made much better in the future.
- ✓ The best constraint on this coupling come from the measurement of the measurement of Higgs production cross-section in the gluon fusion channel.
- ✓ New Physics can possibly modify both the top-Higgs coupling and the Higgs-gluon coupling.



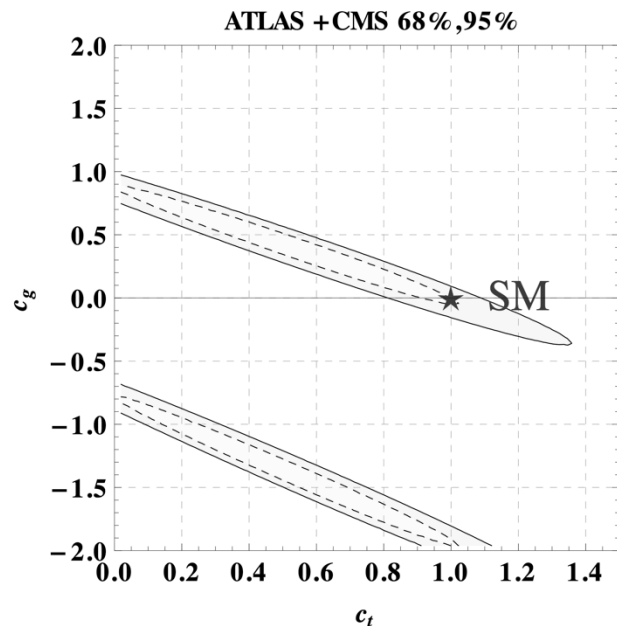
The Context

The modification of the Higgs couplings can be parameterized by:

$$\mathcal{L} = -c_t \frac{m_t}{v} \bar{t} t h + \frac{g_s^2}{48\pi^2} c_g \frac{h}{v} G_{\mu\nu} G^{\mu\nu}$$

Single Higgs production occurring at the scale m_H sensitive only to the linear sum of these two parameters as the top can be integrated out.

$$O_g(m_H) \approx \frac{g_s^2}{48\pi^2} (c_g + c_t) \frac{h}{v} G_{\mu\nu} G^{\mu\nu}$$

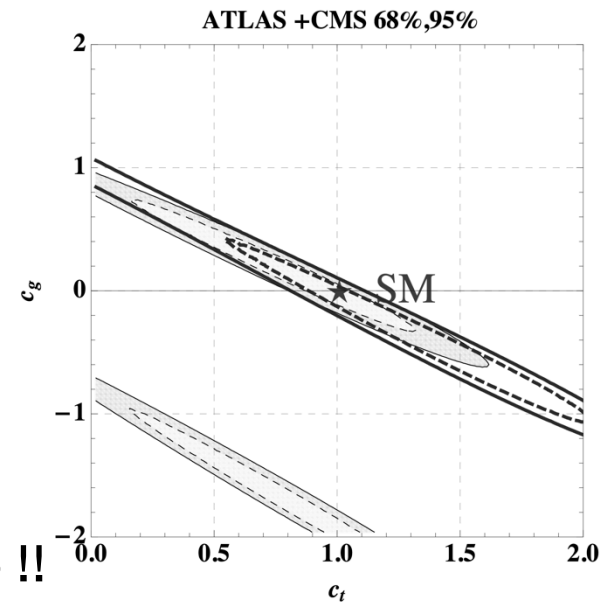


Degeneracy broken by:

- ✓ All $t\bar{t}h$ production channels
- ✓ All channels with $\gamma\gamma$ final state

$$\Gamma(h \rightarrow \gamma\gamma) \propto |1.26 - 0.26c_t|^2$$

!! The latter dominated by W loop !!



For top-like fields with SM top-like quantum numbers:

$$\mathcal{L} = -c_t \frac{m_t}{v} \bar{t} t h + \frac{g_s^2}{48\pi^2} c_g \frac{h}{v} G_{\mu\nu} G^{\mu\nu} + \frac{e^2}{18\pi^2} c_g \frac{h}{v} \gamma_{\mu\nu} \gamma^{\mu\nu}$$

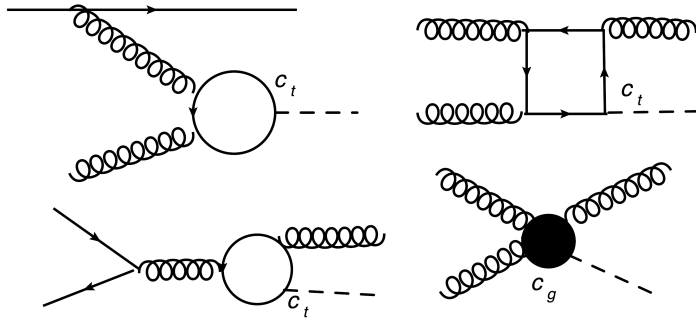
- $t\bar{t}h$ production is the *only* way to resolve this degeneracy...
- This is because we integrate out m_t when at the scale of the Higgs mass...
- So what about looking at Higgs production at high p_T when we cannot integrate out the top anymore...??
[Grazzini, Sargsyan]*

* Also: Harlander and Neumann; Banfi, Martin and Sanz; Grojean, Salvioni, Schläffer and Weiler.

The Idea

$$\left(\frac{d\sigma^{SM}(m_t)}{dp_T} \right) / \left(\frac{d\sigma^{SM}(m_t \rightarrow \infty)}{dp_T} \right) \Big|_{p_T=300\text{GeV}} \sim 0.7$$

Higgs production with an associated jet is driven by:

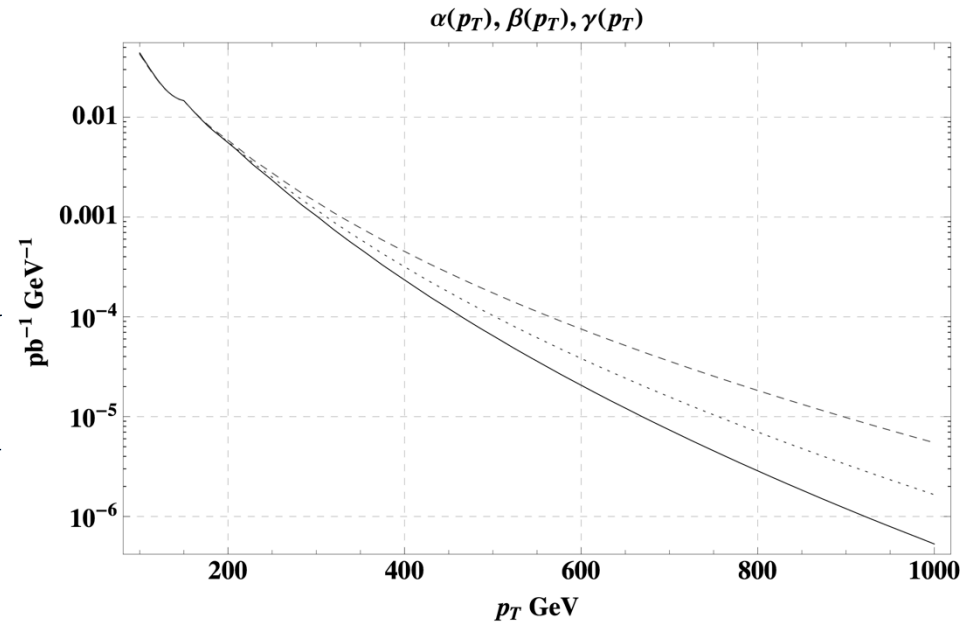


$$\frac{d\sigma}{dp_T} = \sum_i \kappa_i |f^i(p_T) c_t + c_g|^2$$

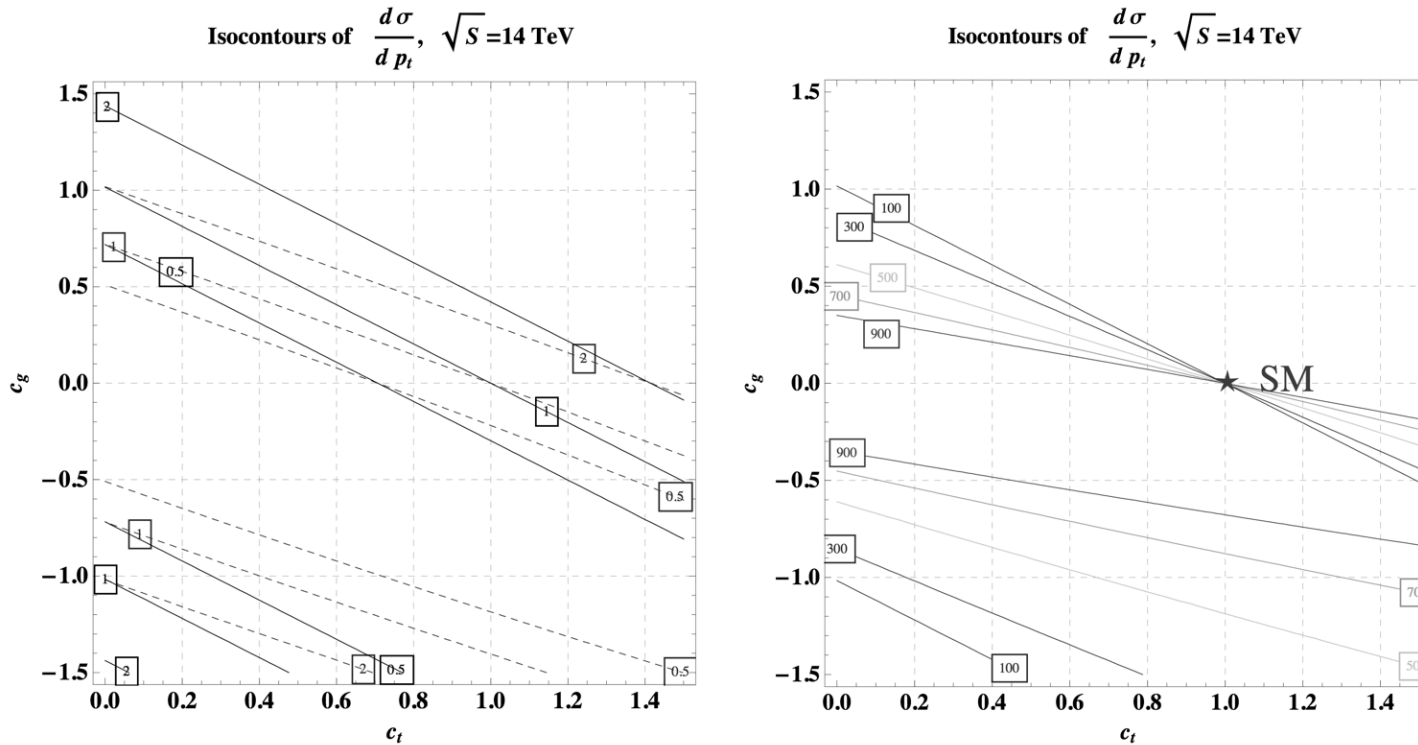
$$\frac{d\sigma}{dp_T} = \alpha(p_T) c_t^2 + \beta(p_T) c_g^2 + 2\gamma(p_T) c_t c_g.$$

$$\sigma^-(p_T < P_T) = \int_{p_T^{min}}^{P_T} \frac{d\sigma}{dp_T} dp_T, \quad N^- = \sigma^- \times \text{Luminosity}$$

$$\sigma^+(p_T > P_T) = \int_{P_T}^{p_T^{max}} \frac{d\sigma}{dp_T} dp_T, \quad N^+ = \sigma^+ \times \text{Luminosity}$$



The Outcome

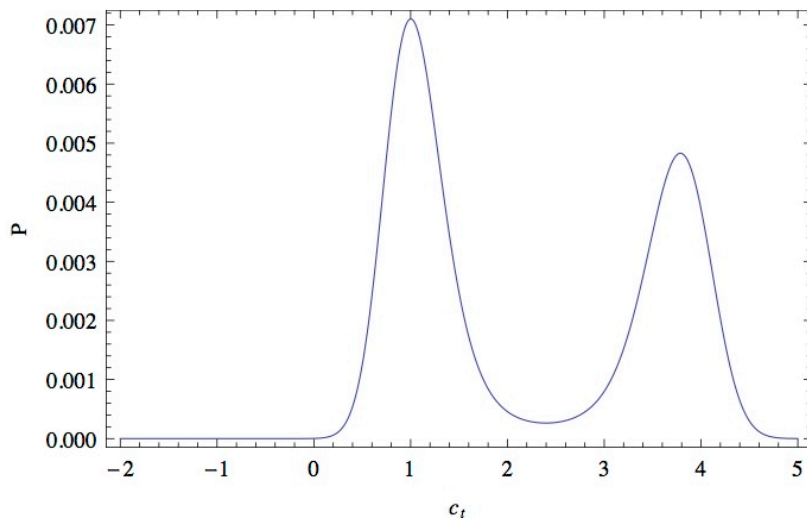
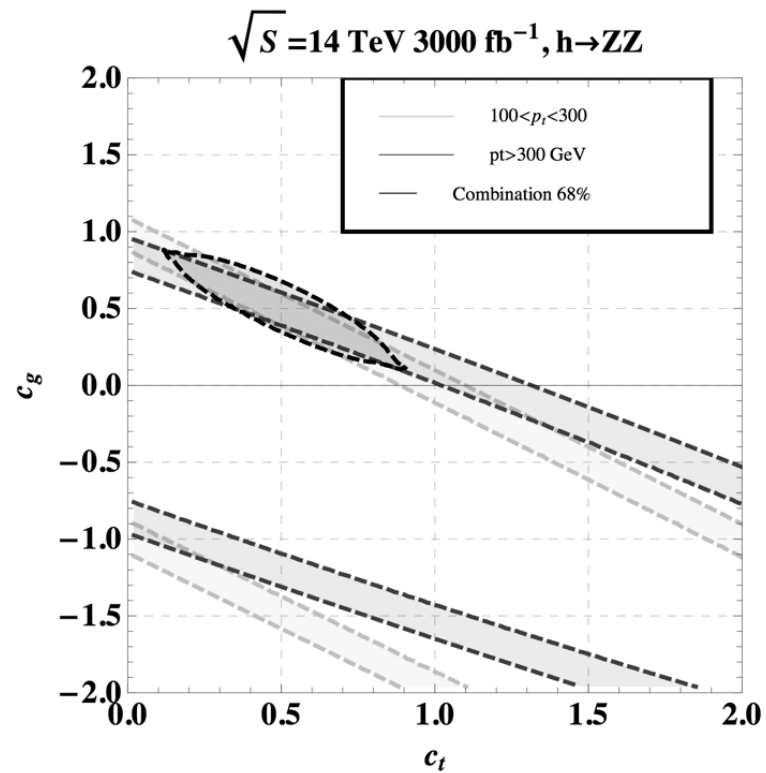
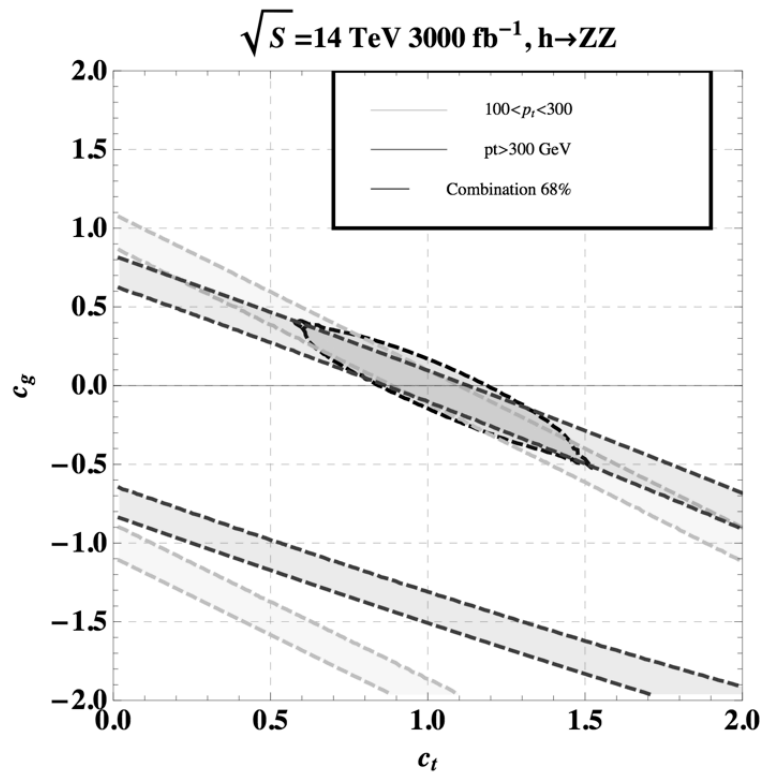


- ✓ Our computation was done with the MSTW 2008 LO PDF sets with the renormalization and factorization scale set to:

$$\mu_r = \mu_f = \sqrt{p_T^2 + m_H^2}$$

- ✓ The NLO computation with full top mass dependence is not available in the literature. We used K factors computed using HqT by Grazzini et. al. with both the LO and NLO defined at the infinite top mass limit.

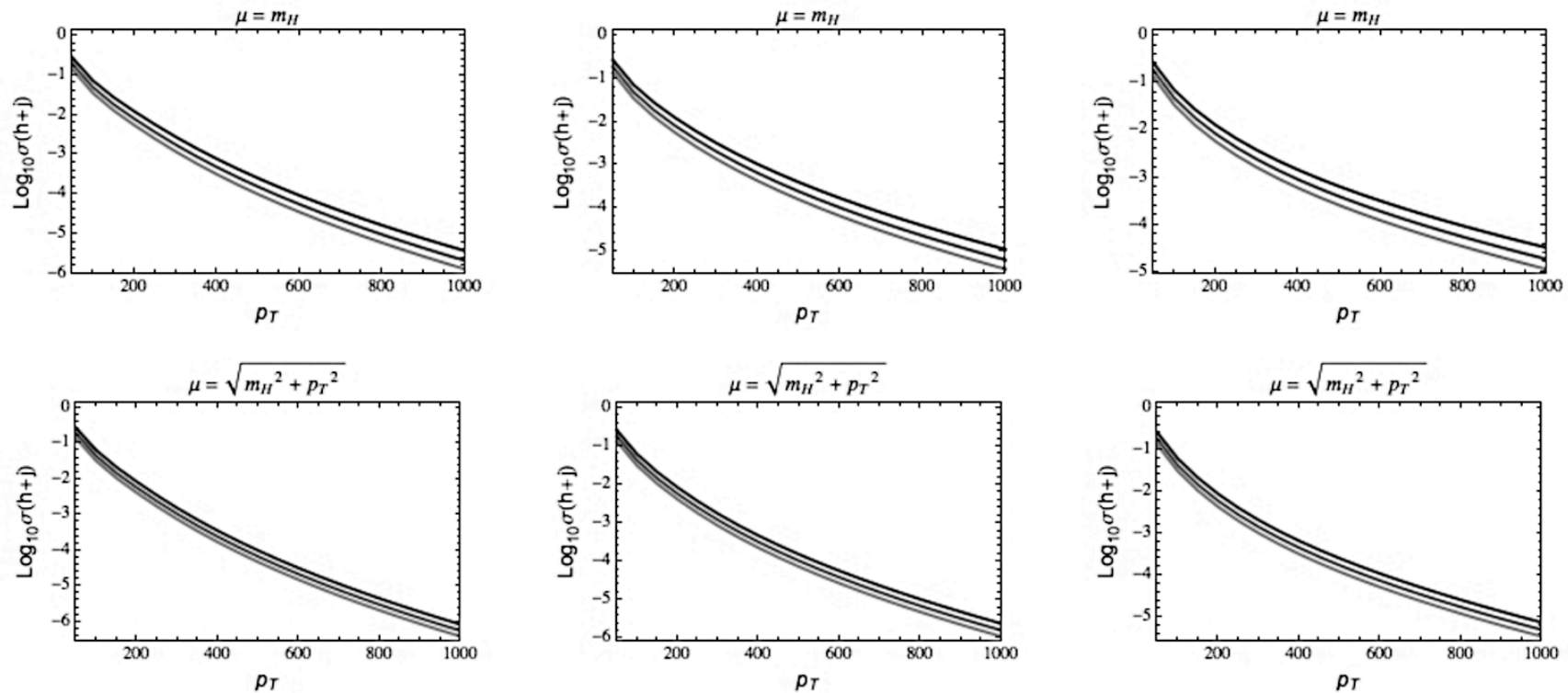
The Outcome



- ✓ We gauge LHC potential by looking into the $h \rightarrow ZZ^* \rightarrow l^-l^-l^+l^+$ channel.
- ✓ We separate the events into a low and a high p_T bins 300 GeV as the discriminating p_T .
- ✓ We get a c_t [0.66, 1.42] at 68% CL from our naïve estimate.

The Uncertainty in the Outcome

Renormalization and Factorization Scale uncertainty:



~ 50% @ LO \rightarrow ~ 25% @ NLO

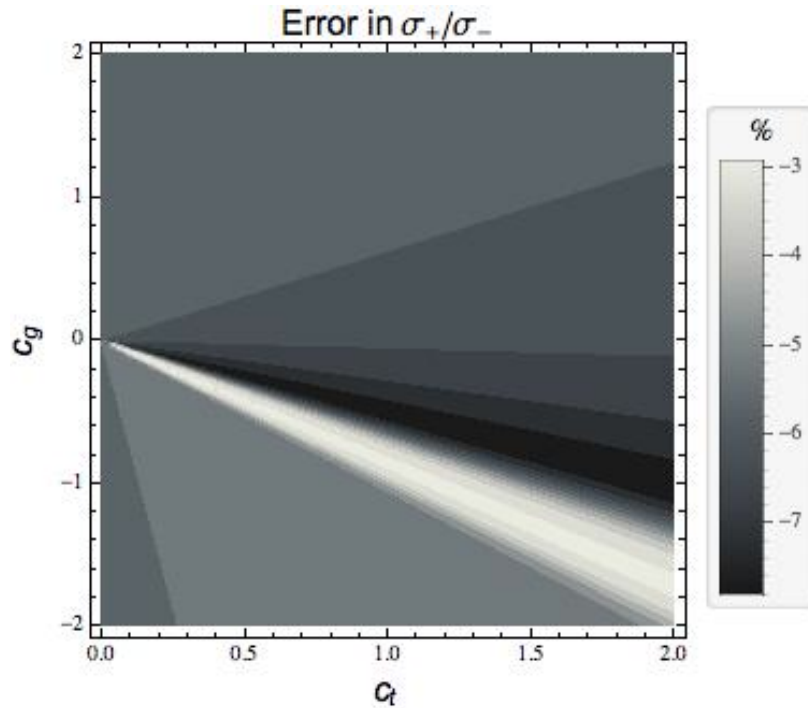
PDF errors:

Subdominant and almost negligible at ~ 5%.

K Factors:

Computed at the infinite top mass limit both at LO and NLO since formalism with finite top mass not available, yet. Scale dependence of K factors ~10%.

The not-so-uncertain Outcome



Can we make the ratio trick work?

$$R_+ = \frac{\sigma^+}{\sigma_{SM}^+} \quad \text{and} \quad R_- = \frac{\sigma^-}{\sigma_{SM}^-}$$

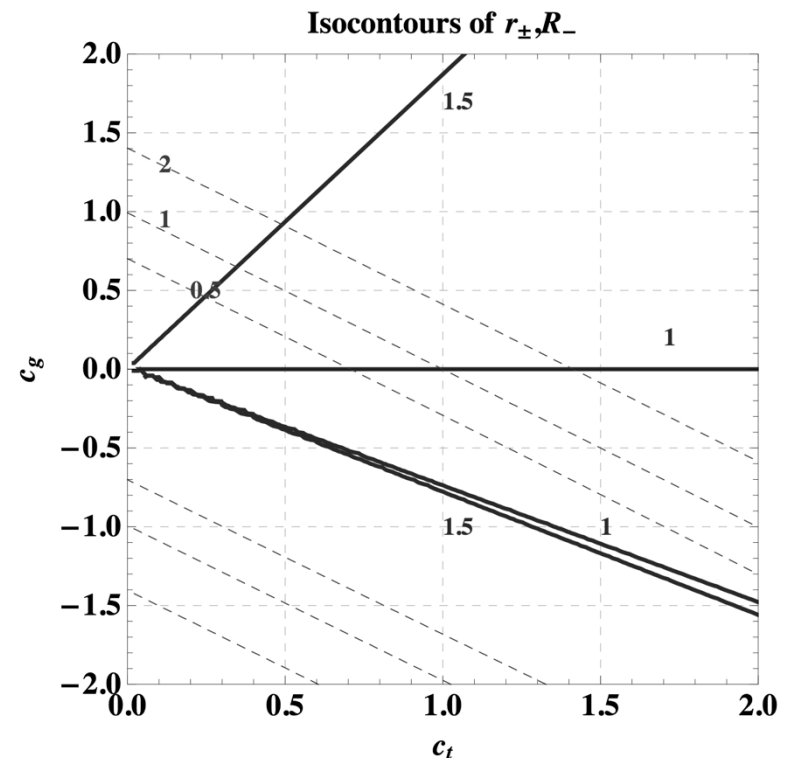
Theoretical error in R_+ and R_- around 2% or less.

However, R_+ and R_- are do not have any implications as experimental observables.

$$r_{\pm} = \frac{R_+}{R_-}$$

$$r_{\pm} = \frac{N^+/N^-}{\sigma_{SM}^+/\sigma_{SM}^-}$$

$r_{\pm} \neq 1$ a definite sign of New Dynamics.



Take Home Snacks

- ✓ Higgs production at large p_T provides an intriguing portal into probing effective Higgs couplings.
- ✓ Theoretical uncertainties can be controlled with judicious choice of ratios.
- ✓ Finite top mass corrections for boosted Higgs production at higher order a necessary direction for theory.

Ever tried. Ever failed. No matter.
Try again. Fail again. Fail better.

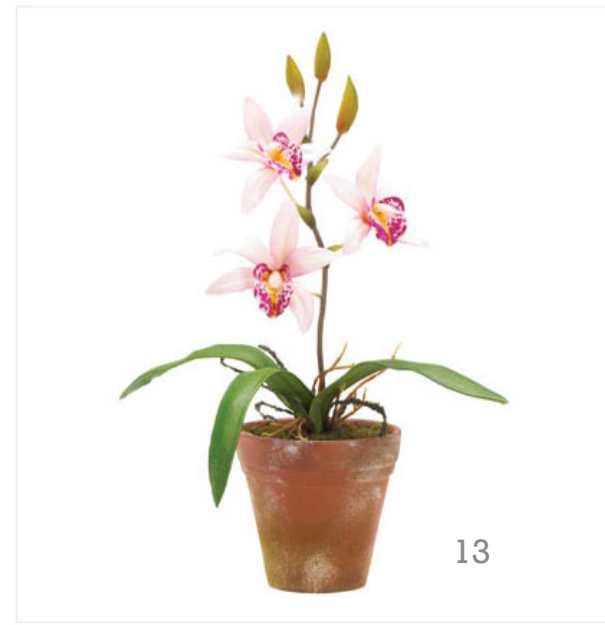
Samuel Beckett
Worstward Ho!



Theatric rendition of:
Waiting for Godot.
Samuel Beckett.

**We are all born mad.
Some remain so.***
Thank you...!!

* Samuel Beckett. *Waiting for Godot.*



For the really curious...

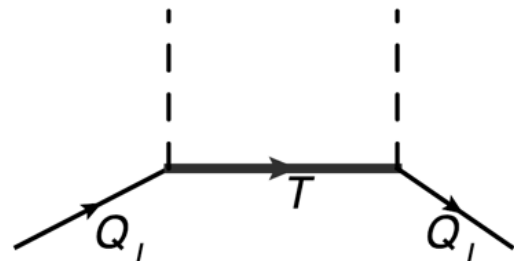
Models with (c_t, c_g) degeneracy

- Simple addition of one vector like fermion

$$\mathcal{L} = -y\bar{Q}_L t_R H - M_* \bar{T} T - Y_* \bar{Q}_L T_R H$$

$$m = \begin{pmatrix} yv & Y_* v \\ 0 & M_* \end{pmatrix} \Rightarrow c_g(m_H) \approx \frac{\partial \log \text{Det} m}{\partial \log v} = 1$$

Higgs coupling to the gluons is exactly the same as in the SM, however Higgs couplings to the top quarks is modified



$$y_t \sim y_t^{SM} \left(1 - \frac{Y_*^2 v^2}{M_*^2} \right)$$

$$\mathcal{L} = -c_t \frac{m_t}{v} \bar{t} t h + \frac{g_s^2}{48\pi^2} c_g \frac{h}{v} G_{\mu\nu} G^{\mu\nu}$$

$$c_t = 1 - \frac{Y_*^2 v^2}{M_*^2} \quad c_g = \frac{Y_*^2 v^2}{M_*^2}$$

To my Mother and Father, who showed me what I could do,
and to Ikaros, who showed me what I could not.

“To know what no one else does, what a pleasure it can be!”

– adopted from the words of
Eugene Wigner.

