PRODUCTION OF VECTOR RESONANCES AT 14 AND 100 TEV

1st Future Hadron Collider Workshop

Riccardo Torre

SISSA & Padova U. & INFN Padova

CERN - 28 May 2014

D. Pappadopulo, A. Thamm, RT, A. Wulzer, 1402.4431 + work in progress

supported by the ERC Advanced Grant "DaMeSyFla" (Electroweak Symmetry Breaking, Flavour and Dark Matter: One Solution for Three Mysteries)

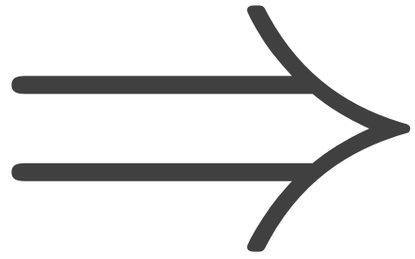
Bridging Theory and Data

Riccardo Torre

Production of vector resonances at 14 and 100 TeV

DATA VS THEORY

DATA



THEORY

DATA VS THEORY

DATA ⇒ THEORY

Method

Full simulation in every point

Time

~ sec for event

~ year with 3 parameters with 10% accuracy

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DATA ⇒ THEORY

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Full simulation in every point

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Different groups

- Analyses based recasting tools
  - Fastlim (SUSY)
  - XQCAT (vector-like quarks) O(100÷1000) times faster
- Matrix element re-weighting
- …

DATA VS THEORY

DATA ⇒ THEORY

	Method	Time
		~ sec for event
	Full simulation in every point	~ year with 3 parameters with 10% accuracy

Different groups	• Analyses based recasting tools
	  • Fastlim (SUSY)
	  • XQCAT (vector-like quarks)
	• Matrix element re-weighting
	• …
		O(100÷1000) times faster

Our approach	Analytic rescaling of the bound (similar to MERW but based on the exclusion instead of event by event)	O(10000) times faster

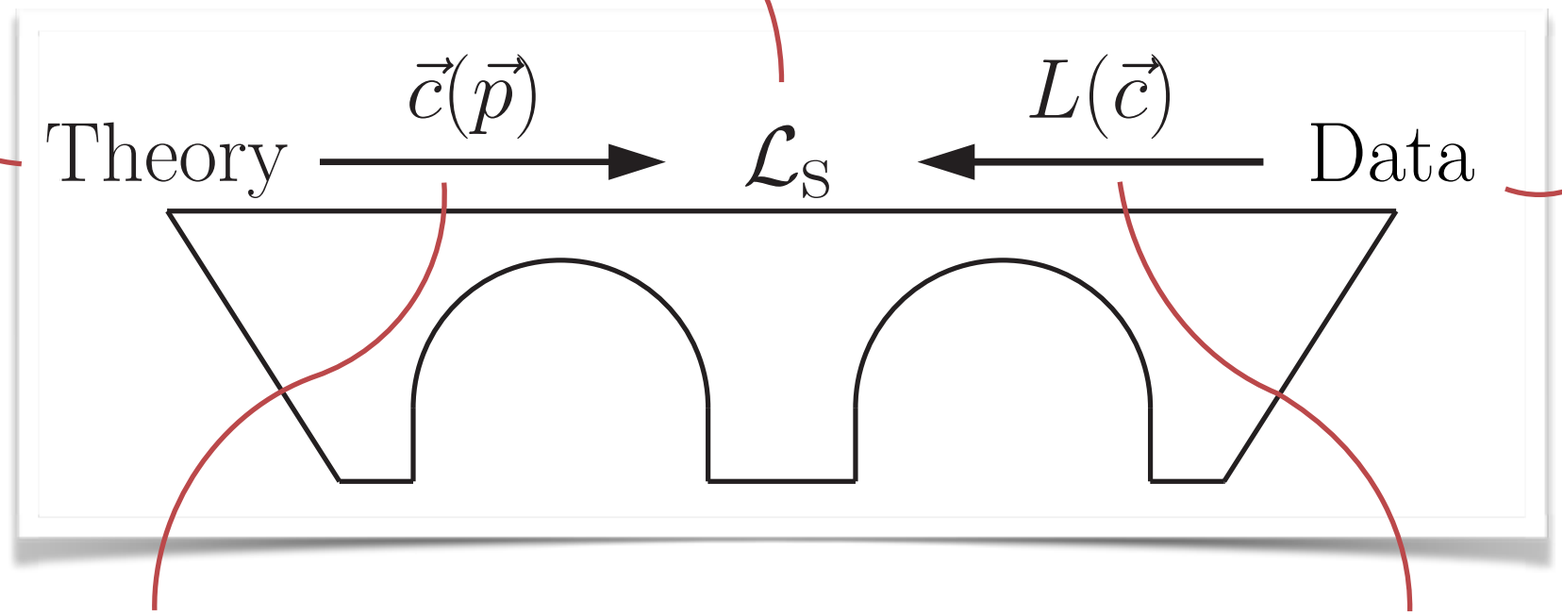
BRIDGING THEORY AND DATA

Simplified Lagrangian

New Physics Model

Limits

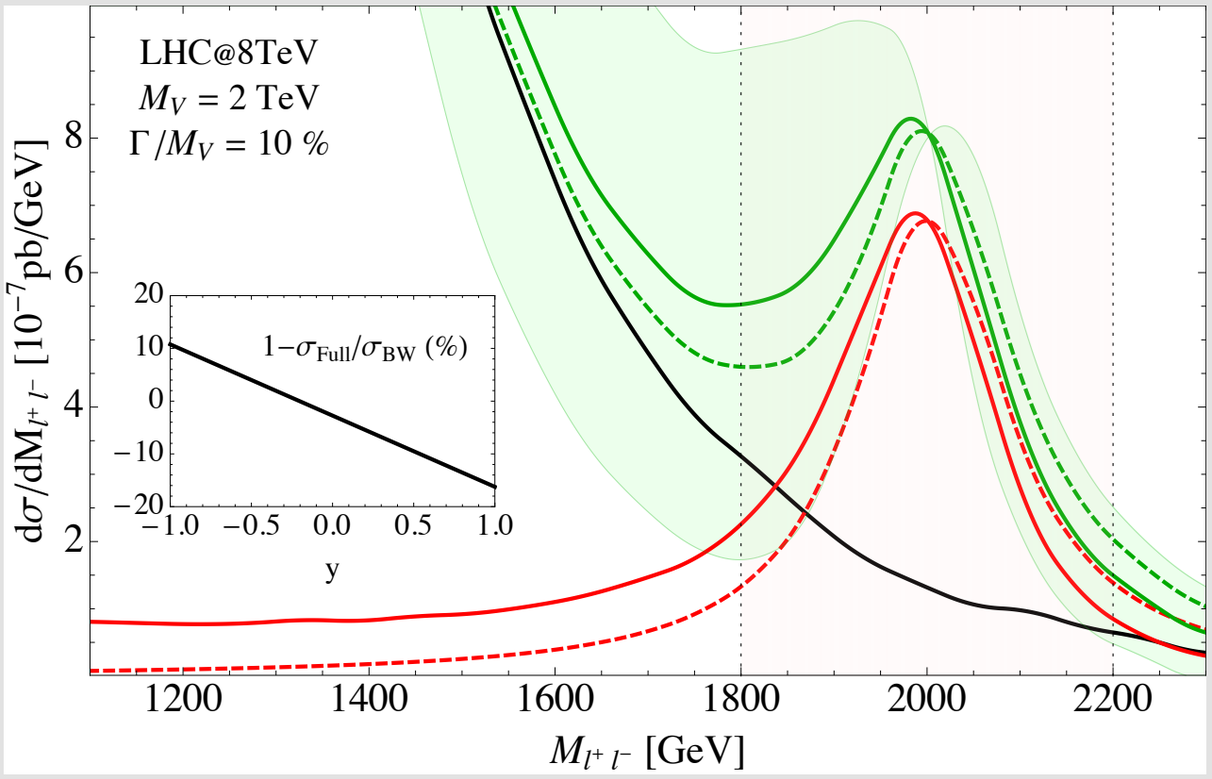
$L(\sigma \times \mathrm{BR}, \Gamma, \ldots)$

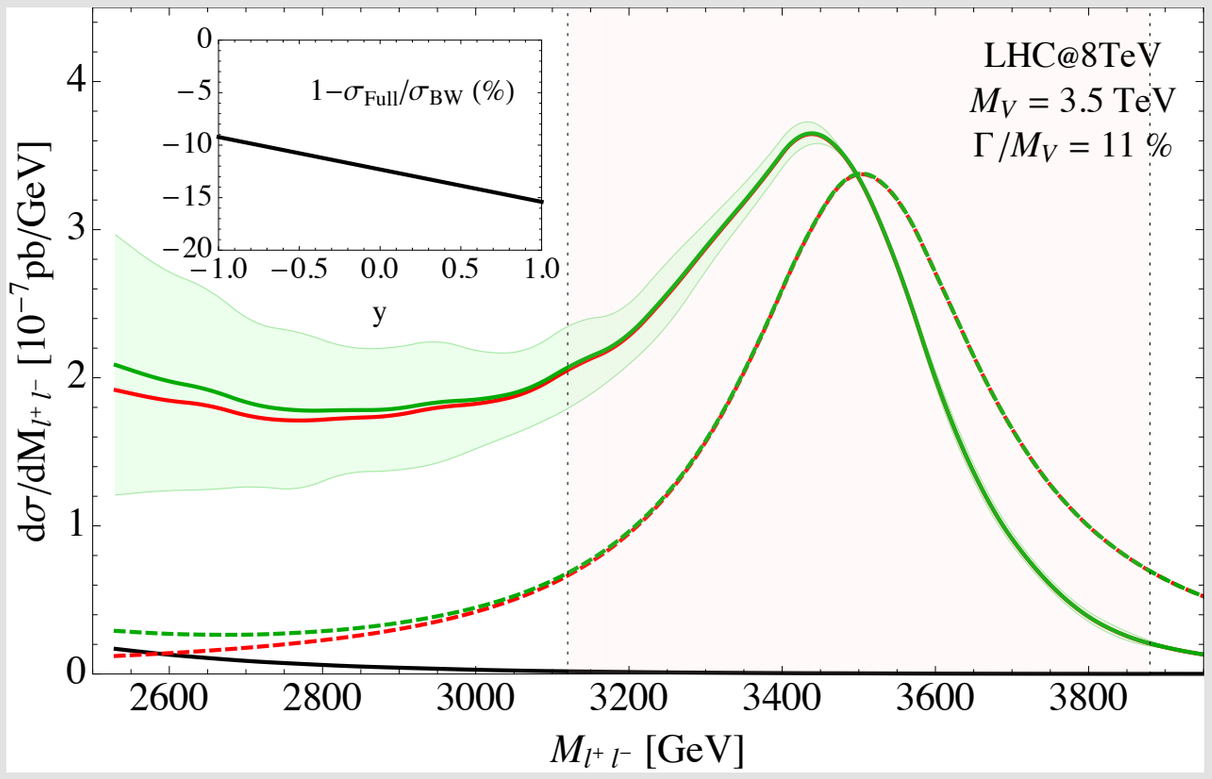


Simplified Lagrangian parameters c fixed in terms of explicit model parameters

Translate the limits into functions of simplified Lagrangian parameters through semi-analytic formulae

BRIDGING THEORY AND DATA





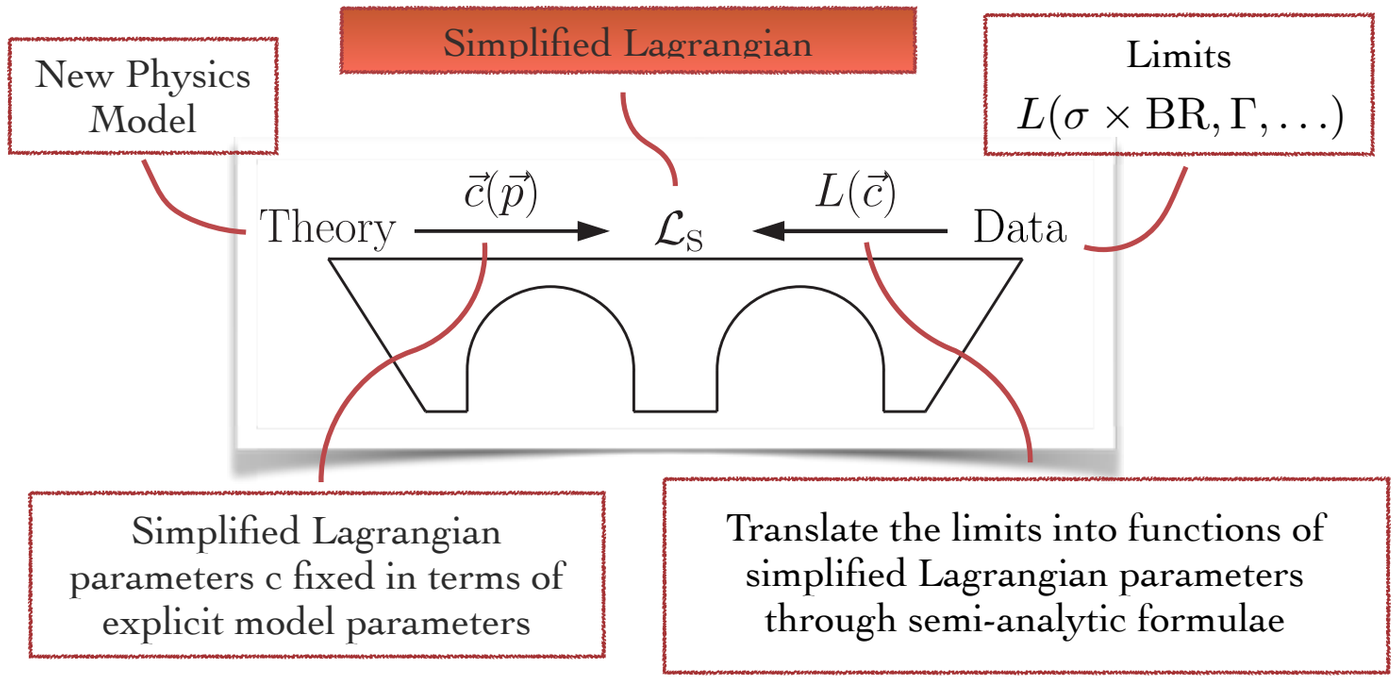
Breit-Wigner valid only in the on-shell region

⇓

Model independent bounds on $\sigma \times \mathrm{BR}$ can be set only focusing on the peak region

Bridge method for heavy vector triplets

PHENOMENOLOGICAL LAGRANGIAN



$$
\begin{aligned}
\mathcal{L}_V \quad = \quad & -\frac{1}{4} D_{[\mu} V^a_{\nu]} D^{[\mu} V^{\nu]\ a} + \frac{m_V^2}{2} V^a_\mu V^{\mu\ a} \\
& + i\, g_V\, c_H\, V^a_\mu H^\dagger \tau^a \overleftrightarrow{D}^\mu H + \frac{g^2}{g_V} c_F V^a_\mu J_F^{\mu\ a} \\
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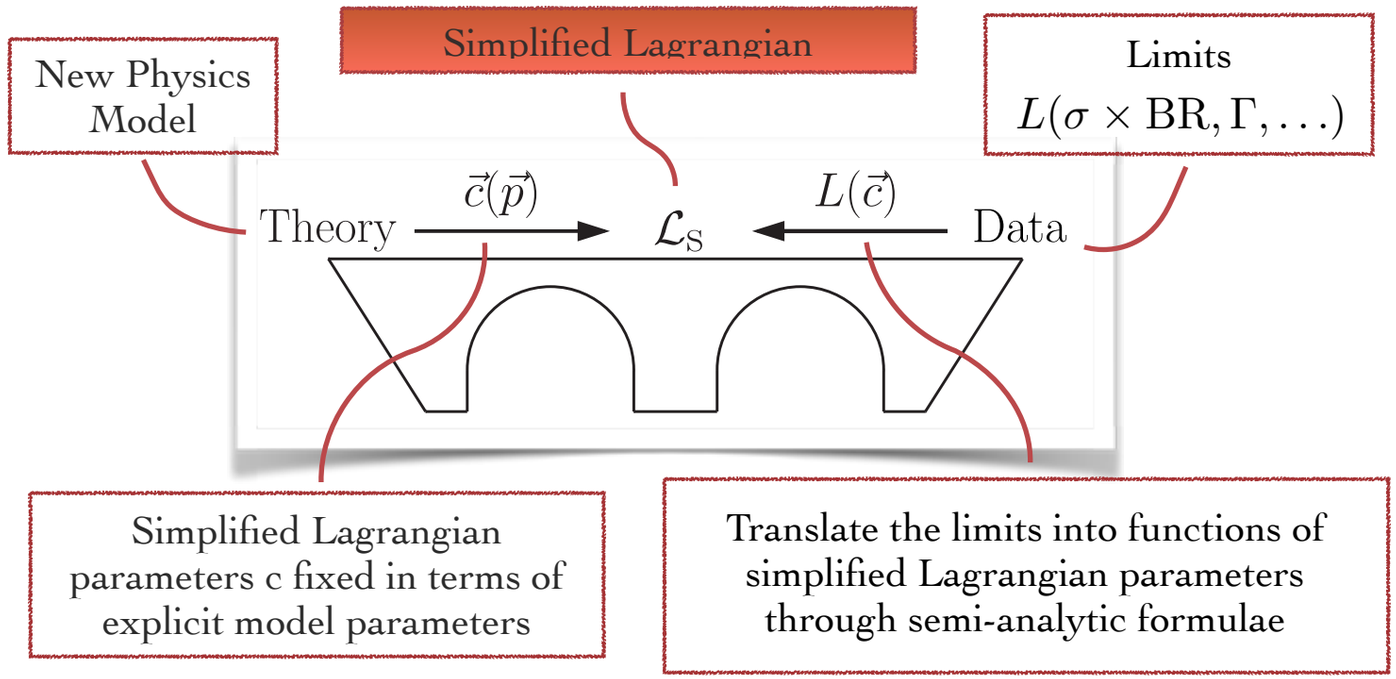

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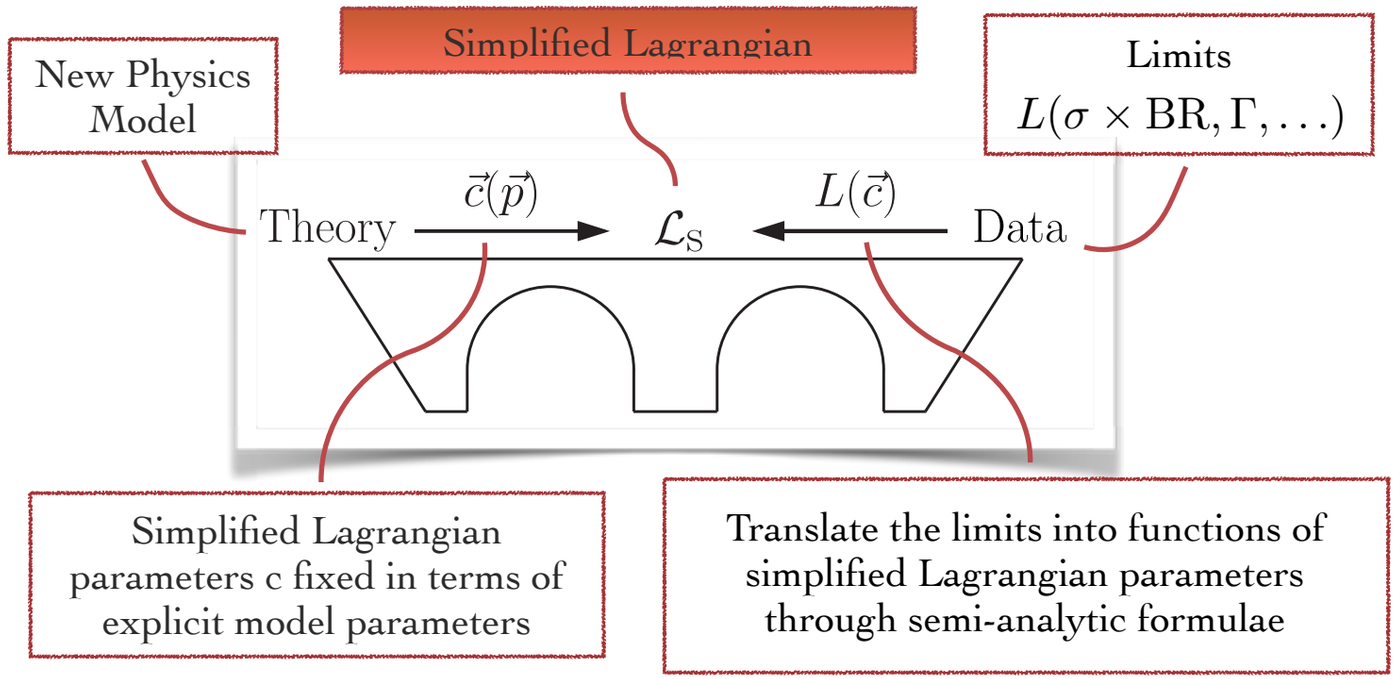

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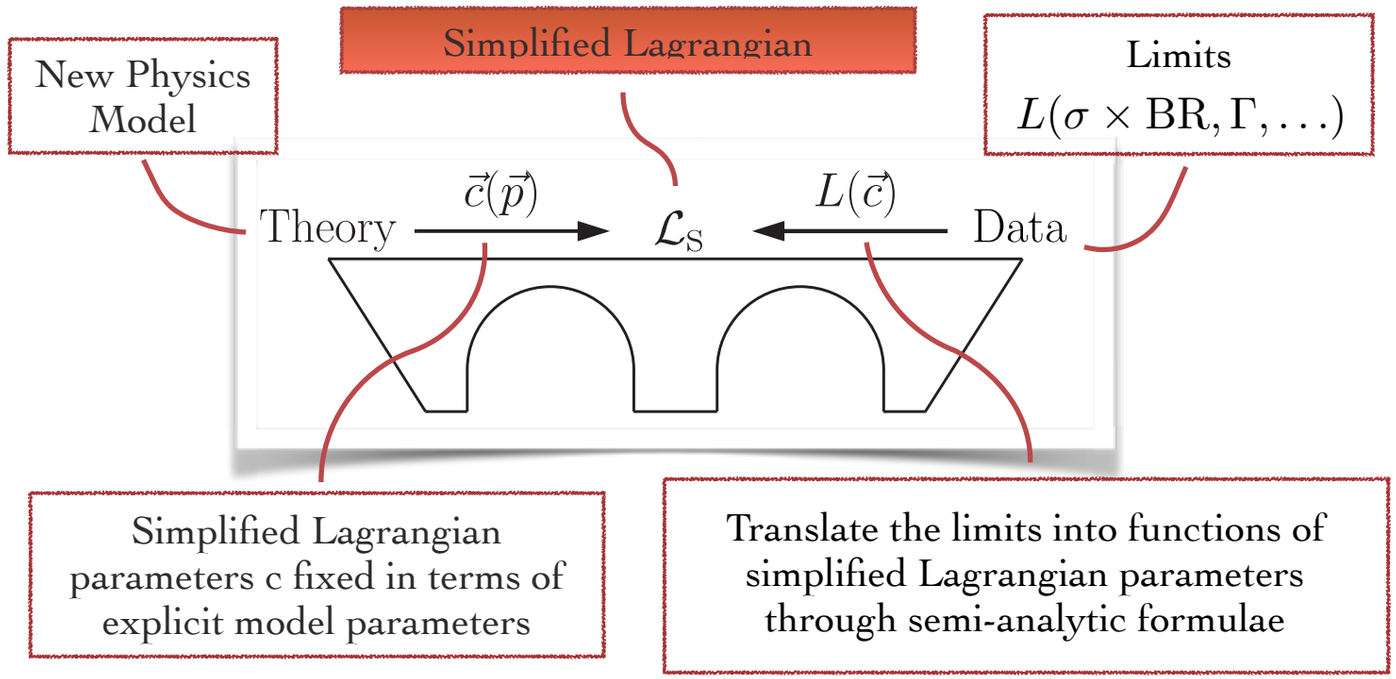

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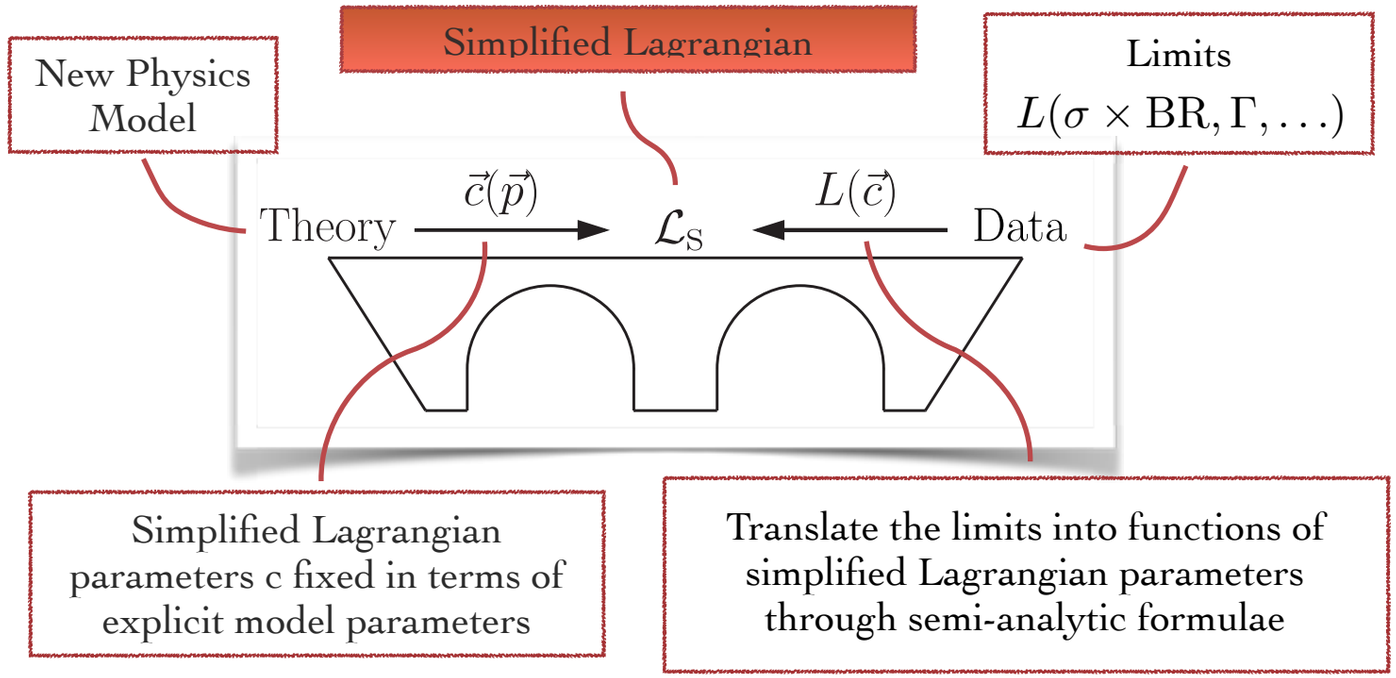
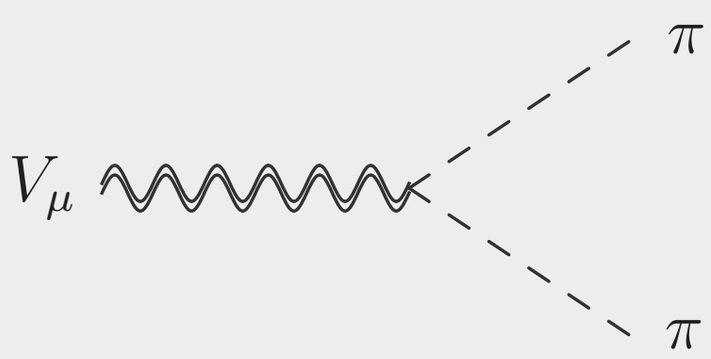
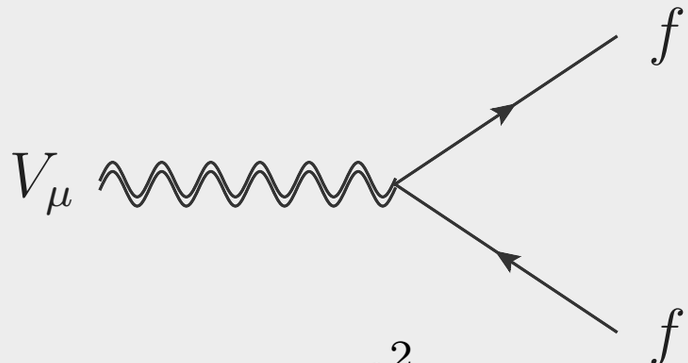


Coupling to longitudinal W and Z



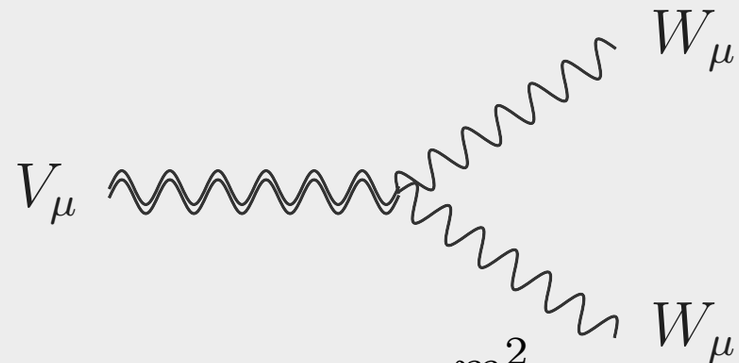
$\sim g_V c_H$

Coupling to fermions



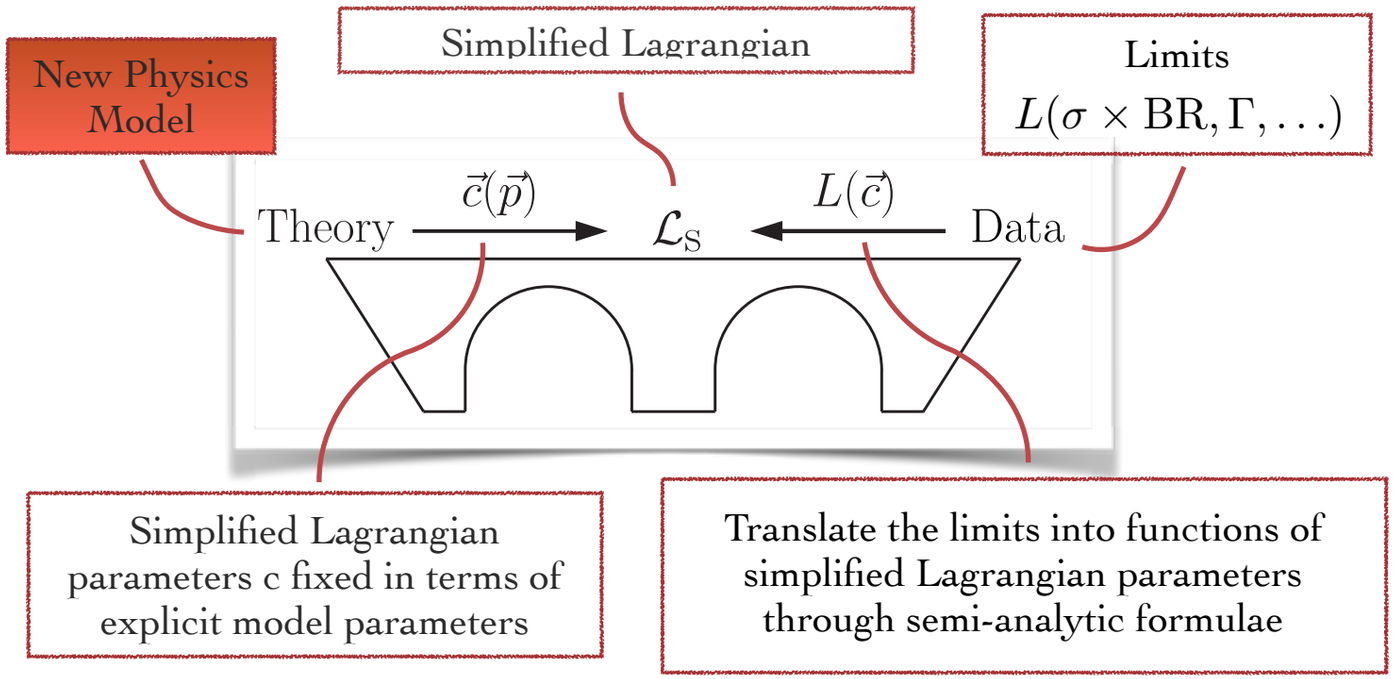
$\sim \frac{g^2}{g_V} c_F$

Suppressed couplings to transverse W and Z



$\sim c_{VVV} c_H^2 \frac{m_W^2}{m_V^2}$

EXPLICIT MODELS: WEAK VS STRONG



Model A: Weakly coupled

$$SU(2)_1 \times SU(2)_2 \times U(1)_Y \to SU(2)_L \times U(1)_Y$$

$$\langle \Phi \rangle = \begin{pmatrix} f & 0 \\ 0 & f \end{pmatrix}$$

Model B: Strongly coupled

$$SO(5) \to SO(4)$$

$$\mathcal{L}_\rho = -\frac{1}{4g_\rho^2}(\rho^a_{\mu\nu})^2 + \frac{m_\rho^2}{2g_\rho^2}(\rho^a_\mu - e^a_\mu)^2$$

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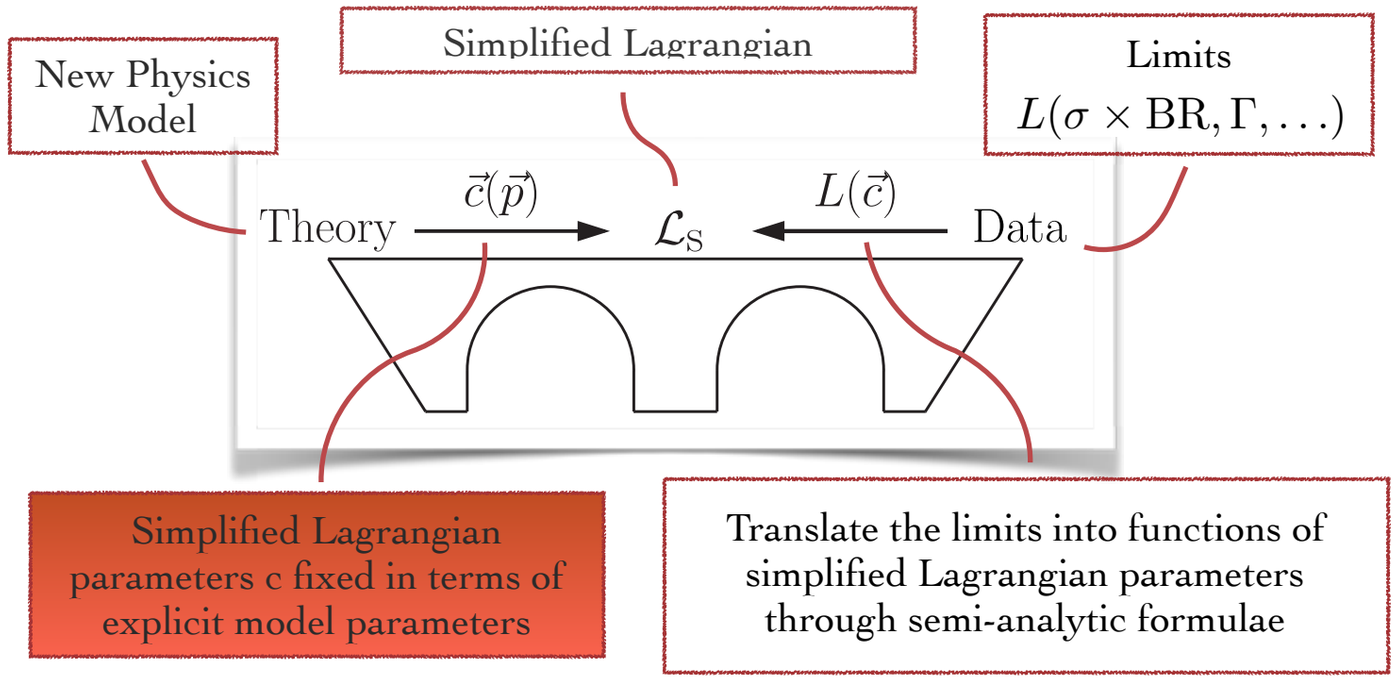

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$$\Downarrow$$

$$\tilde{m}_V = g_V f \qquad \tilde{c}_H = \tilde{c}_{VVHH} = \tilde{c}_F = 0$$

$$\tilde{c}_{VW} = -\tilde{c}_{VVW} = \tilde{c}_{VVV} = -1$$

$$c_H \sim -g^2/g_V^2 \qquad c_F \sim 1$$

Model B: Strongly coupled

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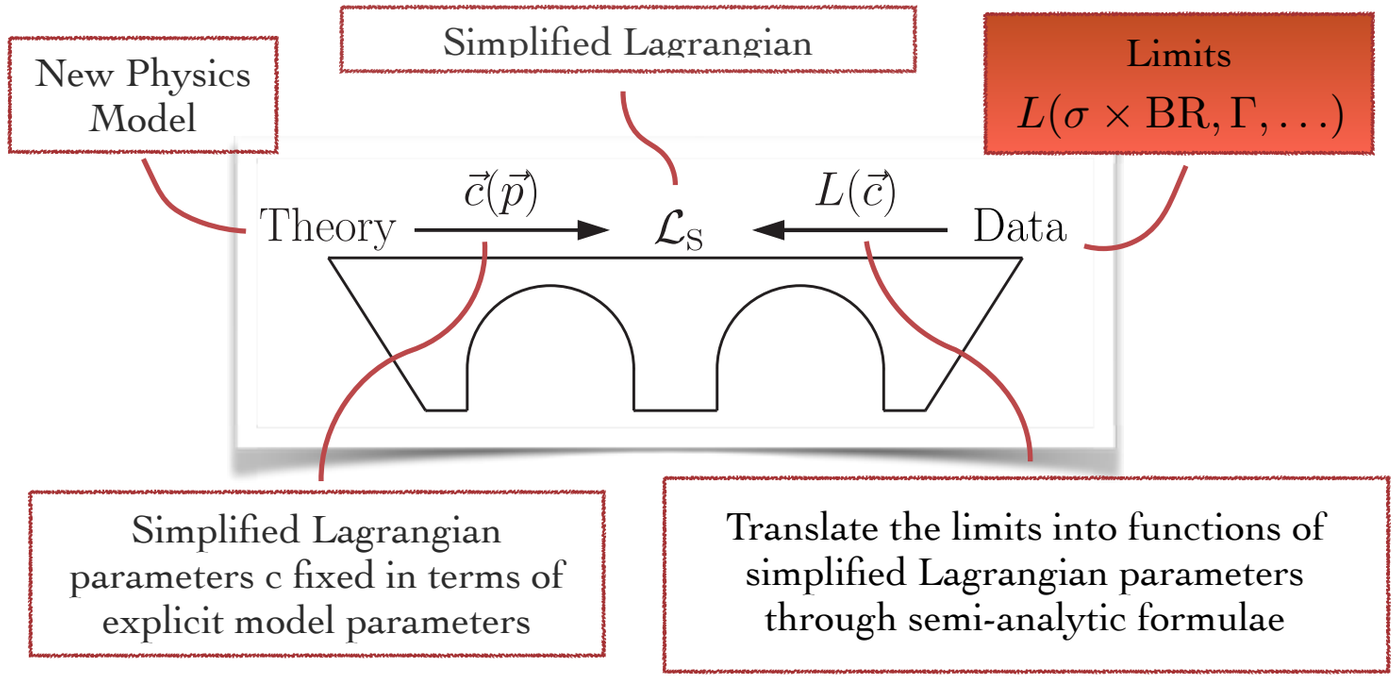
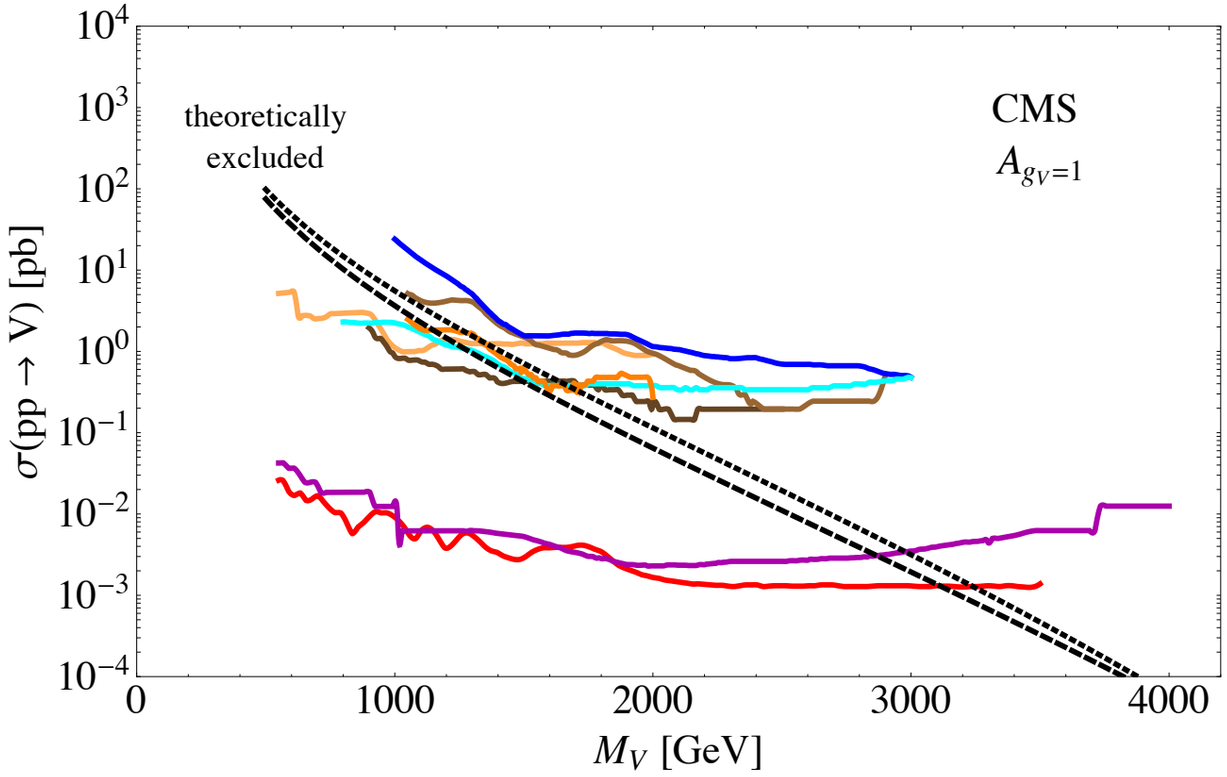
$$\tilde{m}_V = m_\rho \qquad \tilde{c}_{VW} = \tilde{c}_{VVW} = \tilde{c}_{VVV} = 1$$

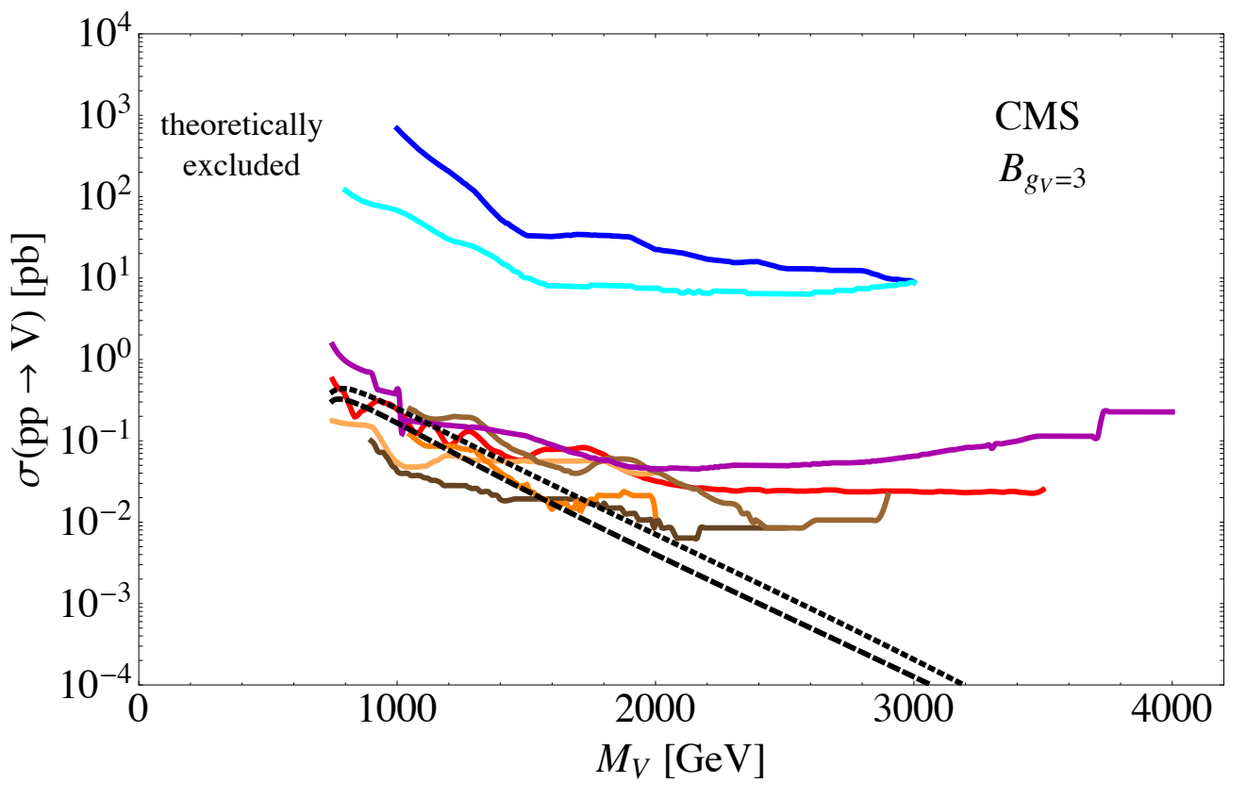
$$\tilde{c}_{VVHH} = \tilde{c}_F = 0 \qquad \tilde{c}_H = -\frac{m_\rho^2}{g_\rho^2 f^2} \equiv a_\rho^2$$

$$c_H \sim 1 \qquad c_F \sim 1$$

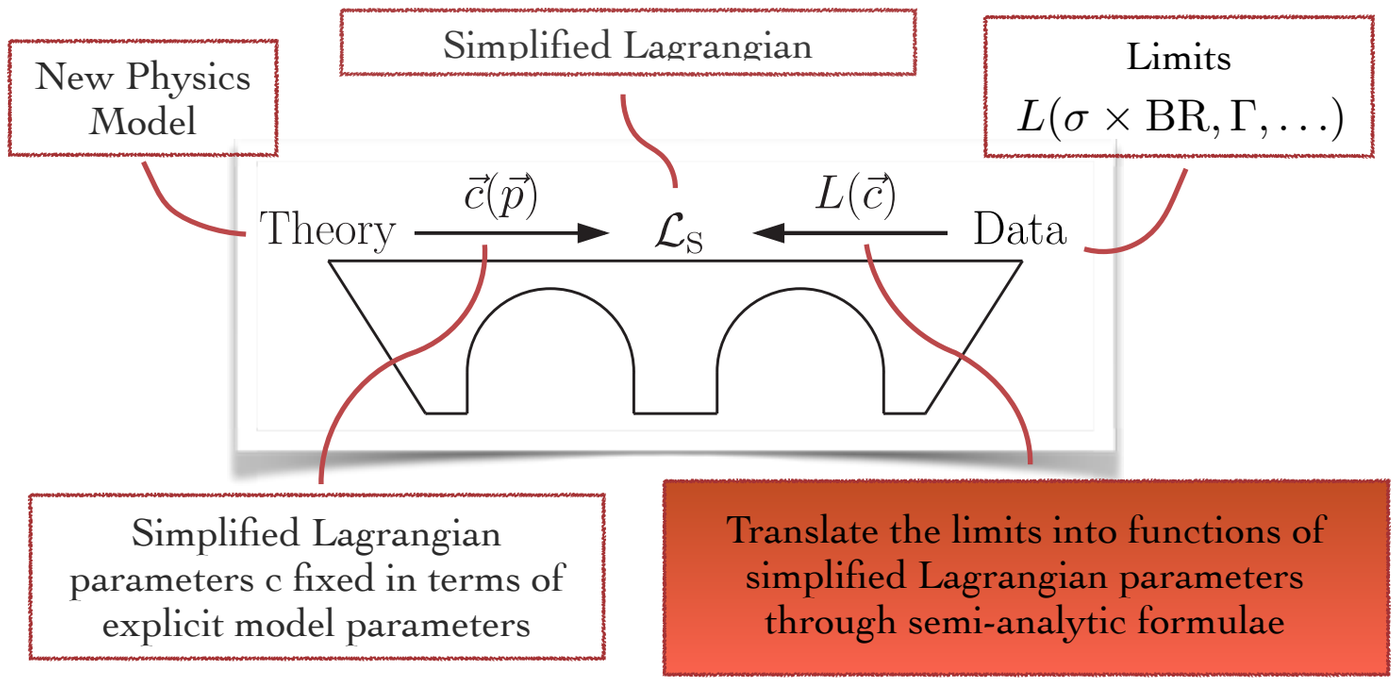
EXPERIMENTAL BOUNDS

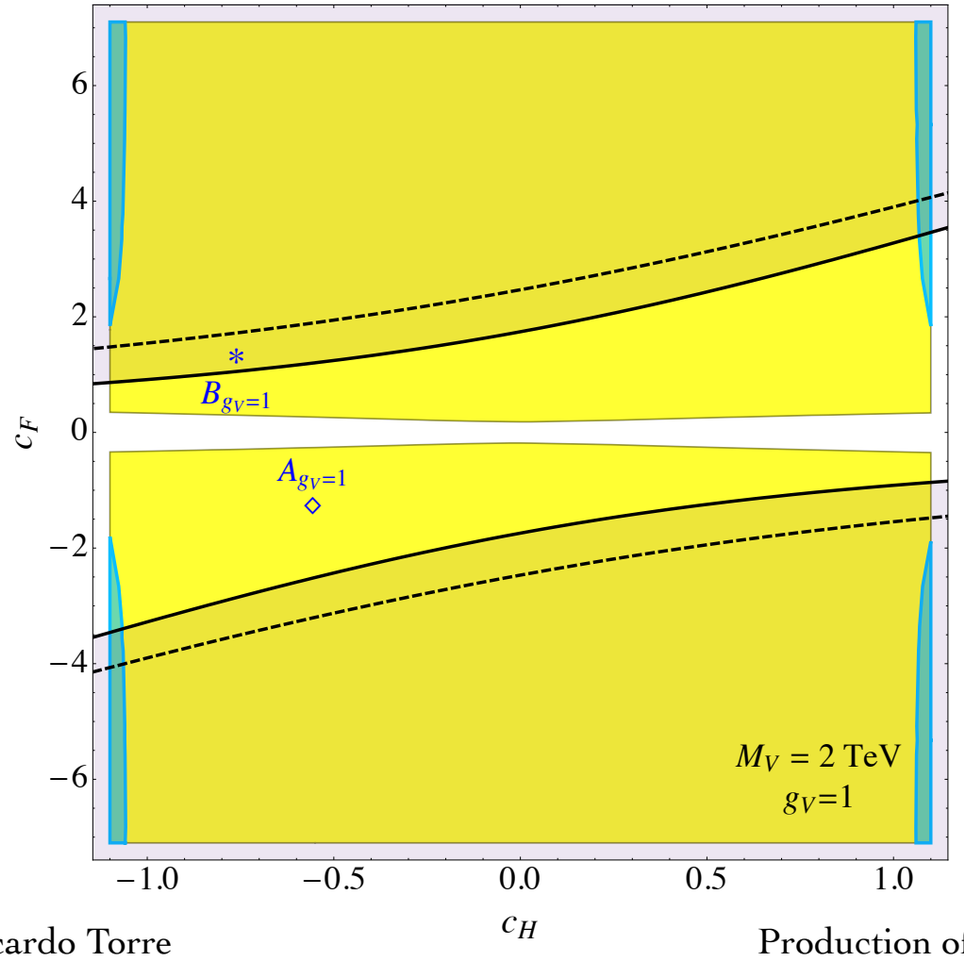


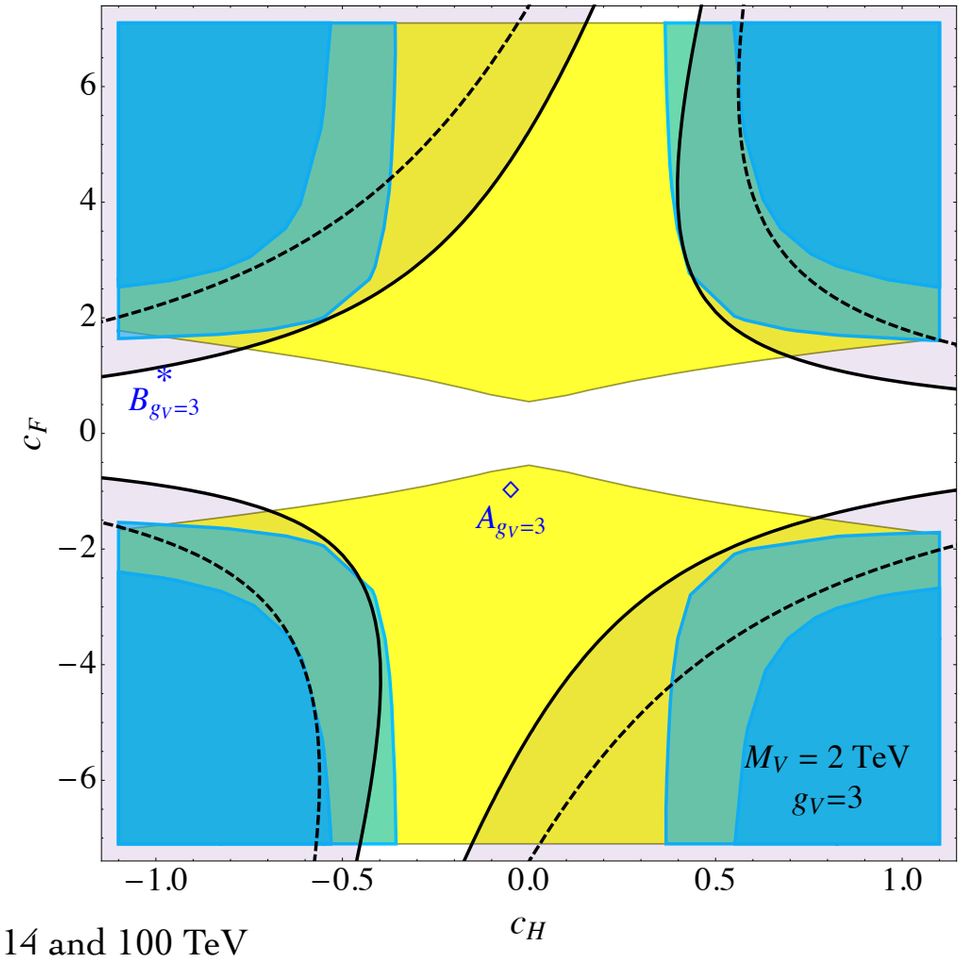




BOUNDS ON PARAMETERS







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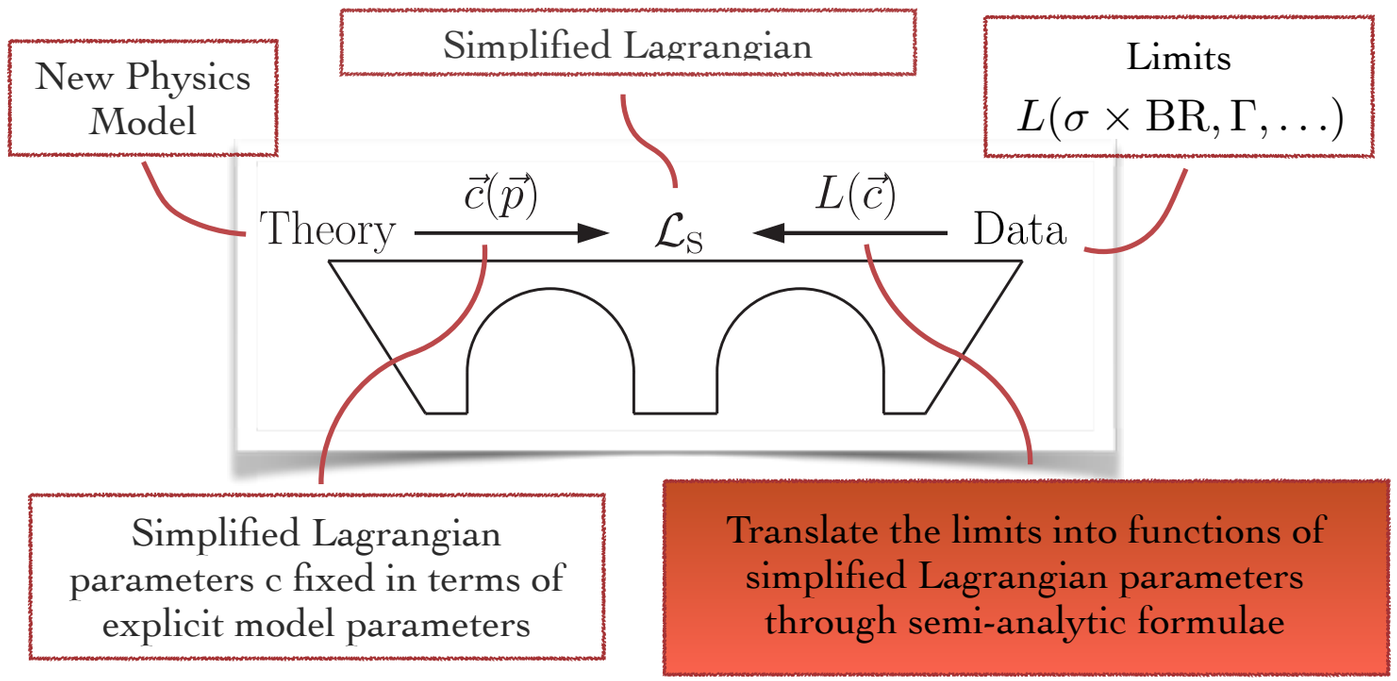

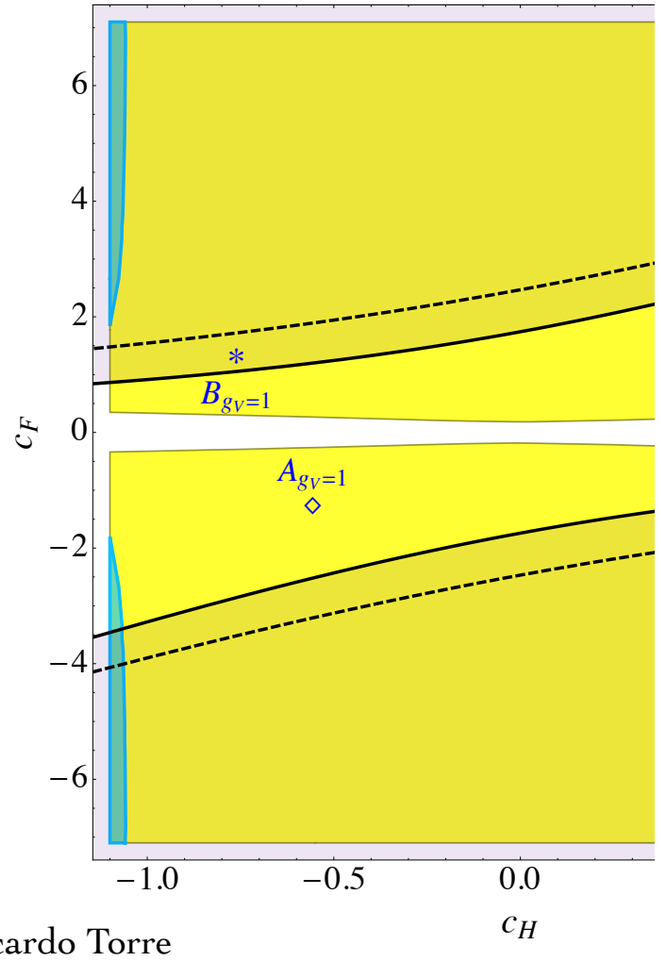

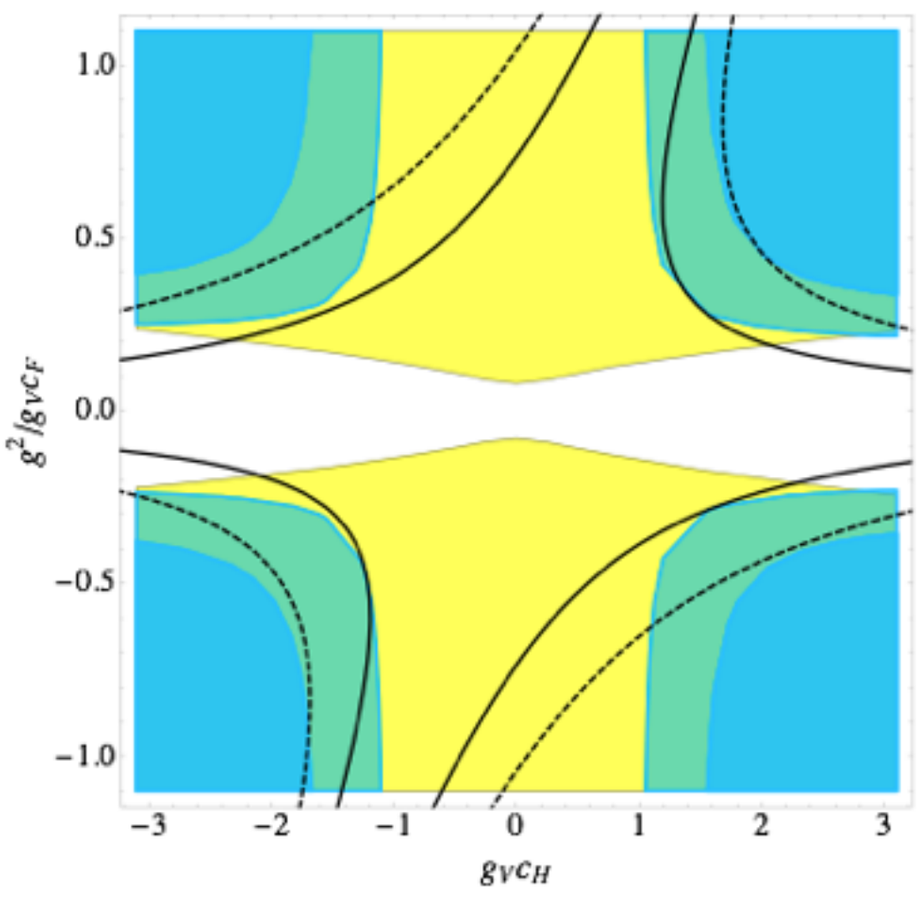

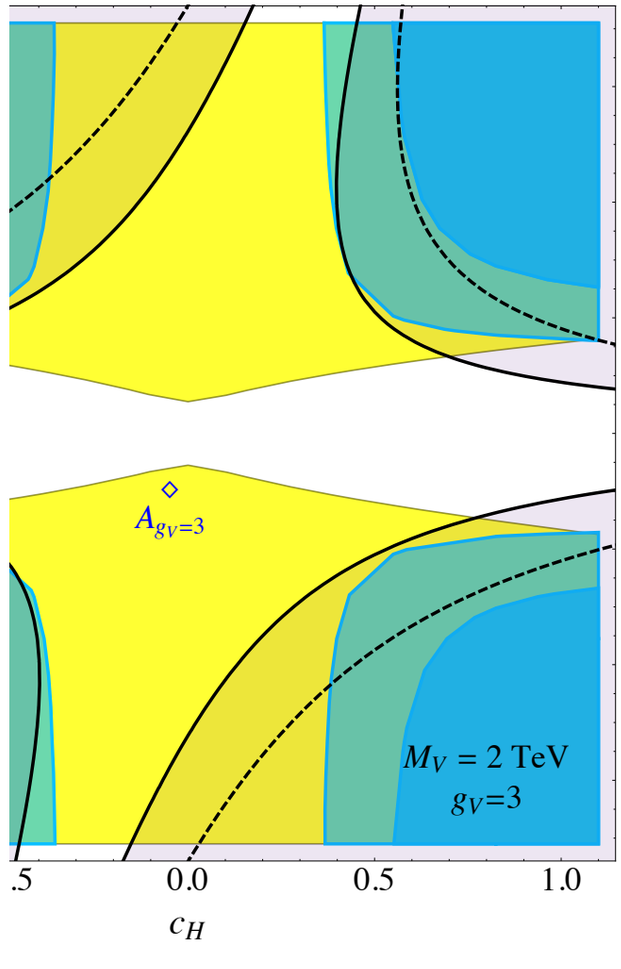

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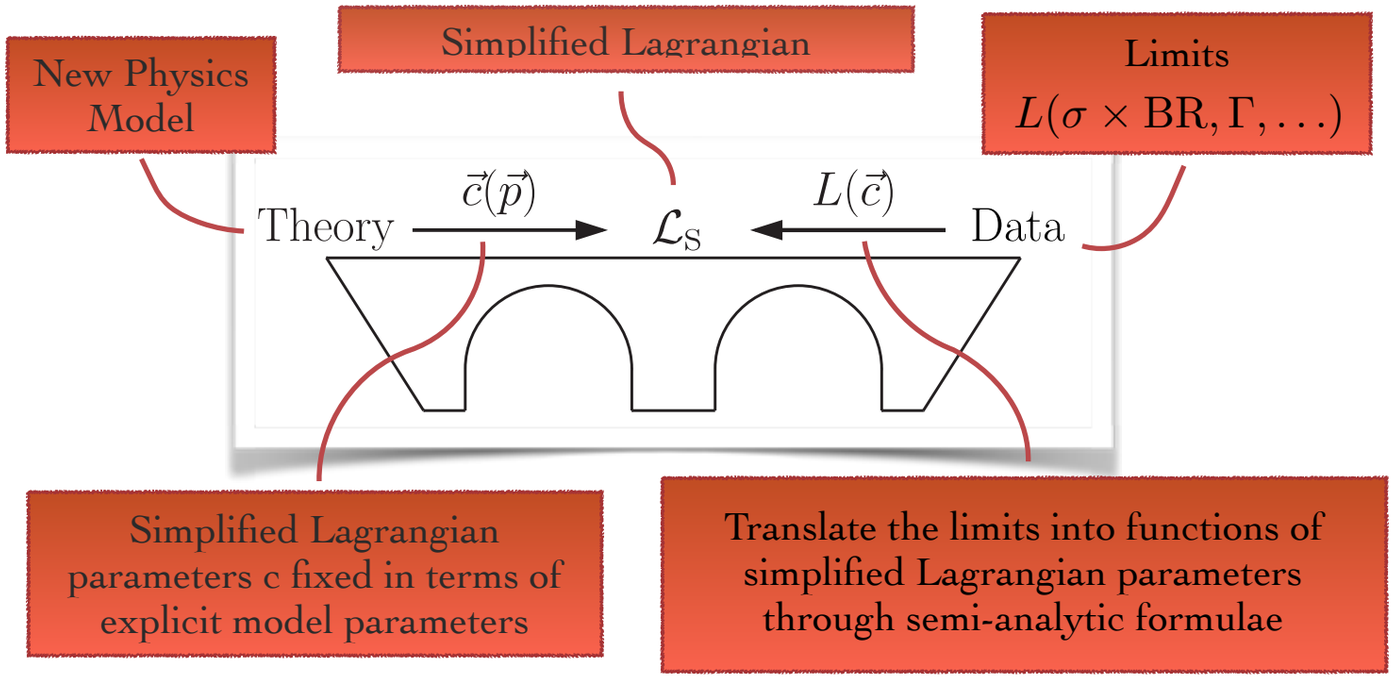

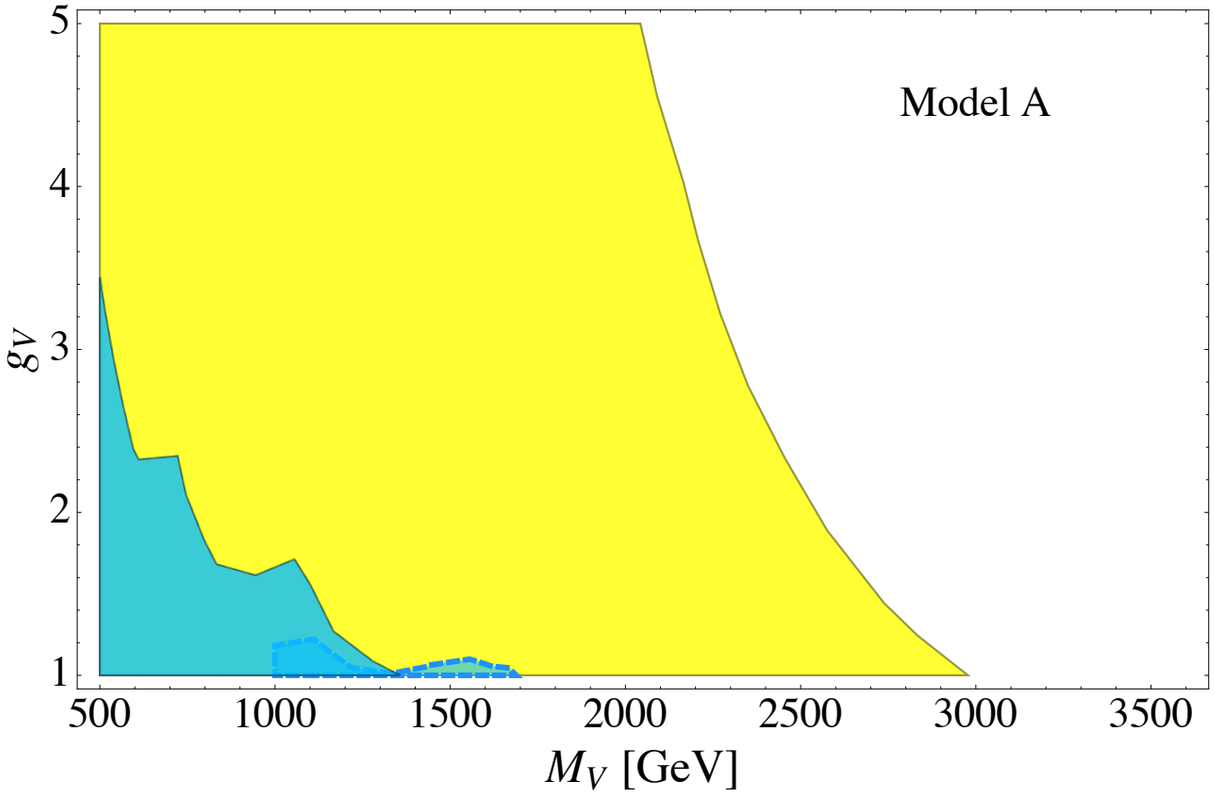

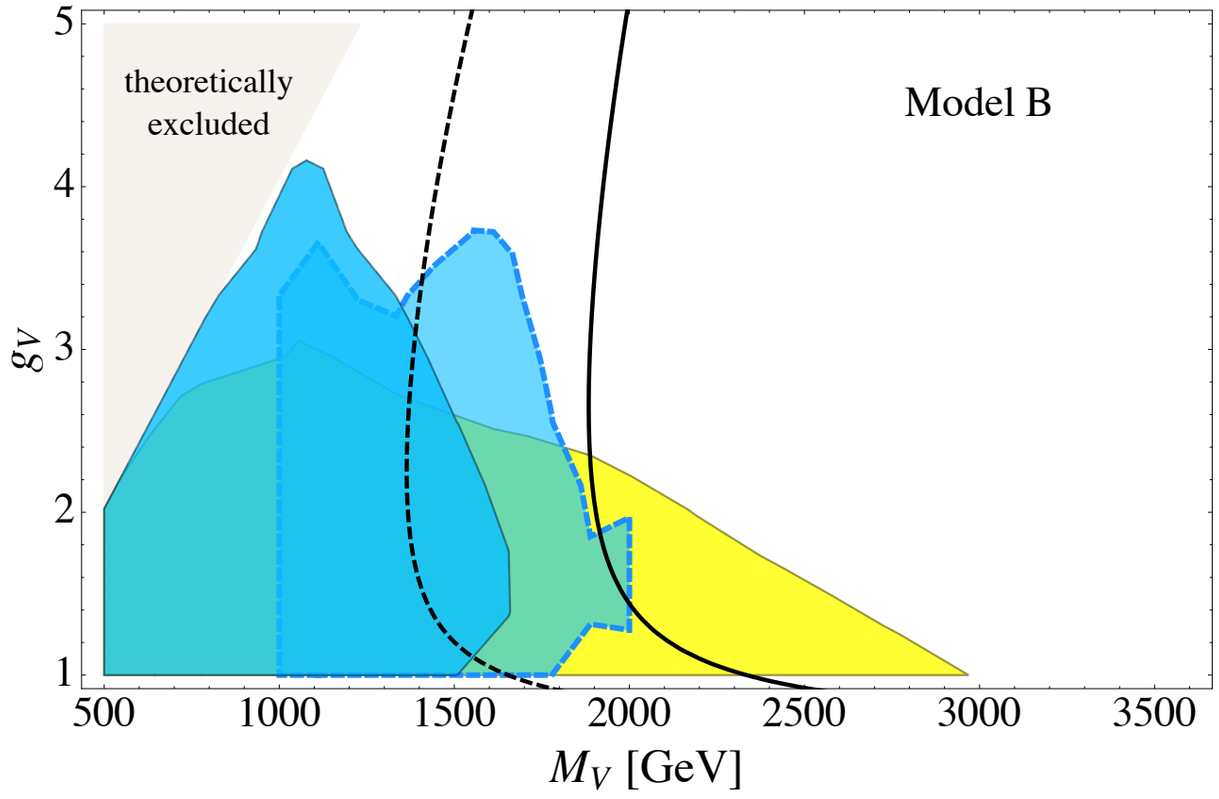

Vectors at 100 TeV

Extrapolation of direct searches

100 TeV against all

Riccardo Torre

Production of vector resonances at 14 and 100 TeV

EXTRAPOLATING BOUNDS

$$N_S^{\rm excl}\left(s_1, M_1, L_1\right) = N_S^{\rm excl}\left(s_0, M_0, L_0\right) \quad \Longrightarrow \quad N_B\left(s_1, M_1, L_1\right) = N_B\left(s_0, M_0, L_0\right)$$

$$\Downarrow$$

$$\sigma_B(s, M) = k\frac{dL}{d\hat{s}}(s, M) \implies L_1\frac{dL}{d\hat{s}}(s_1, M_1) = L_0\frac{dL}{d\hat{s}}(s_0, M_0)$$

only assuming that background
rescales with parton luminosities

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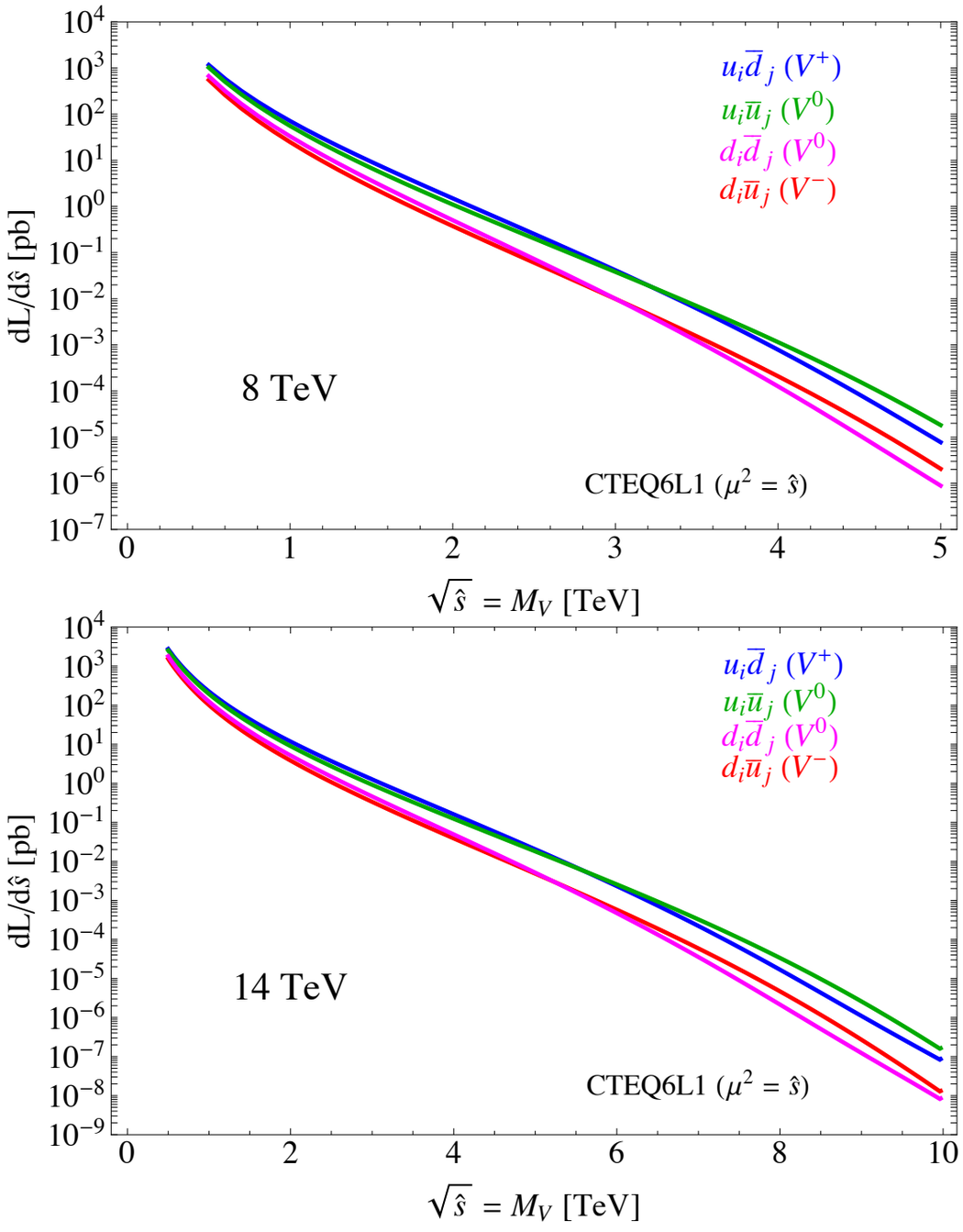

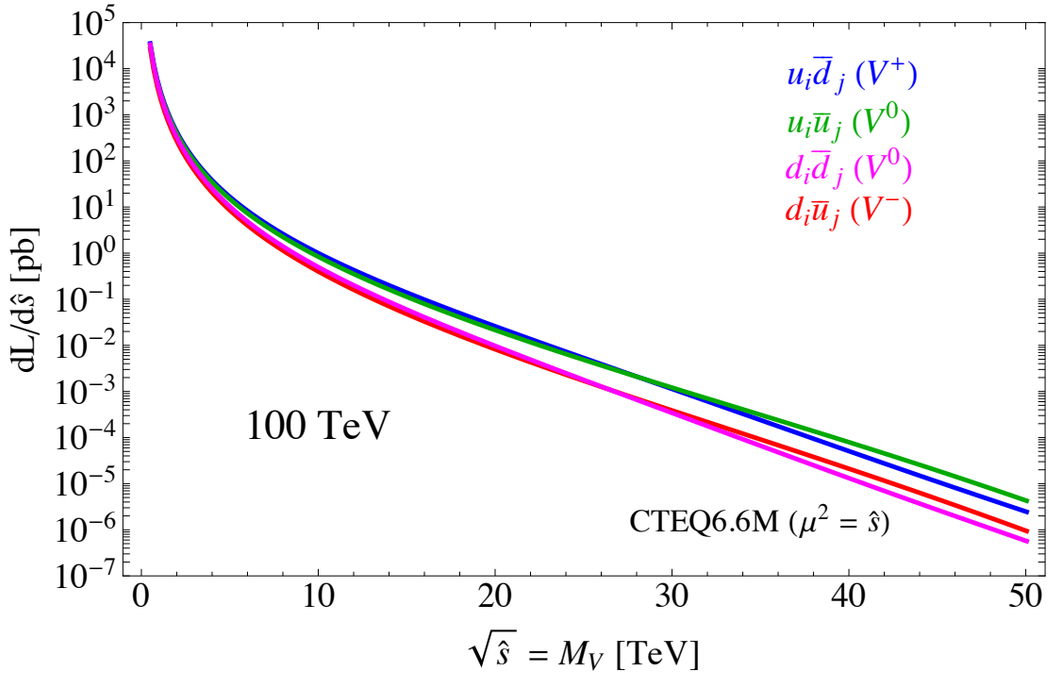

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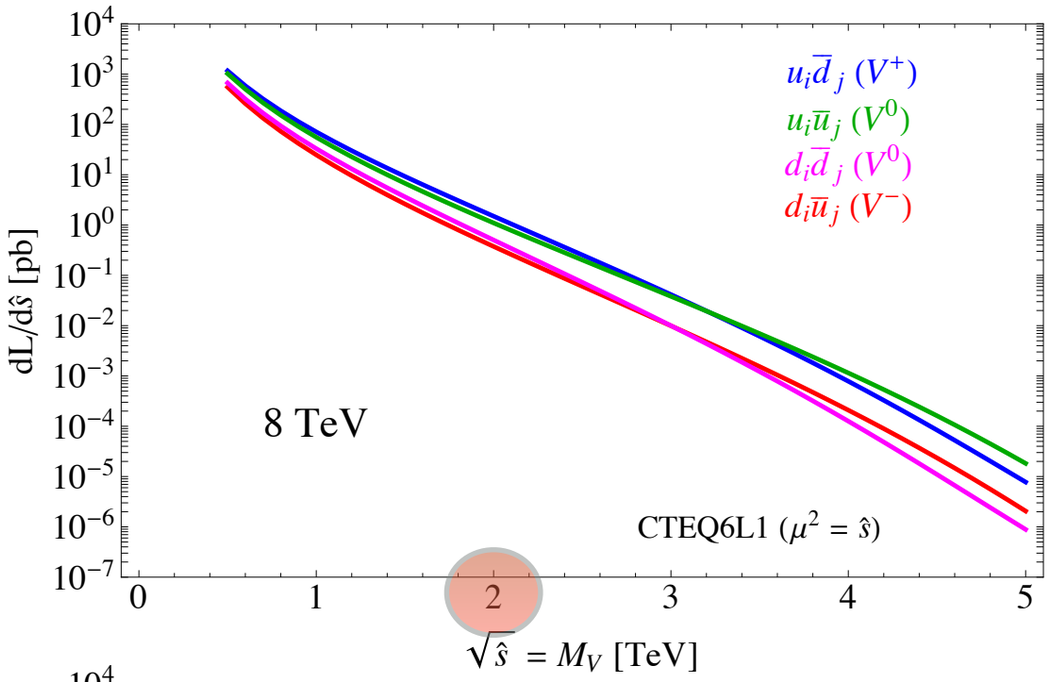

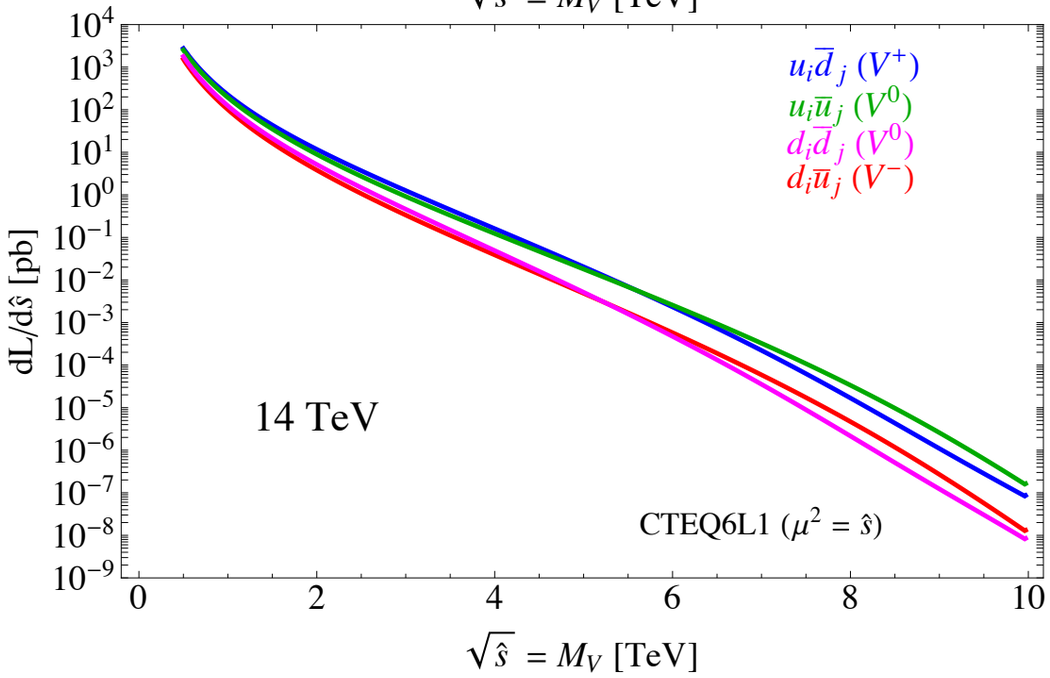

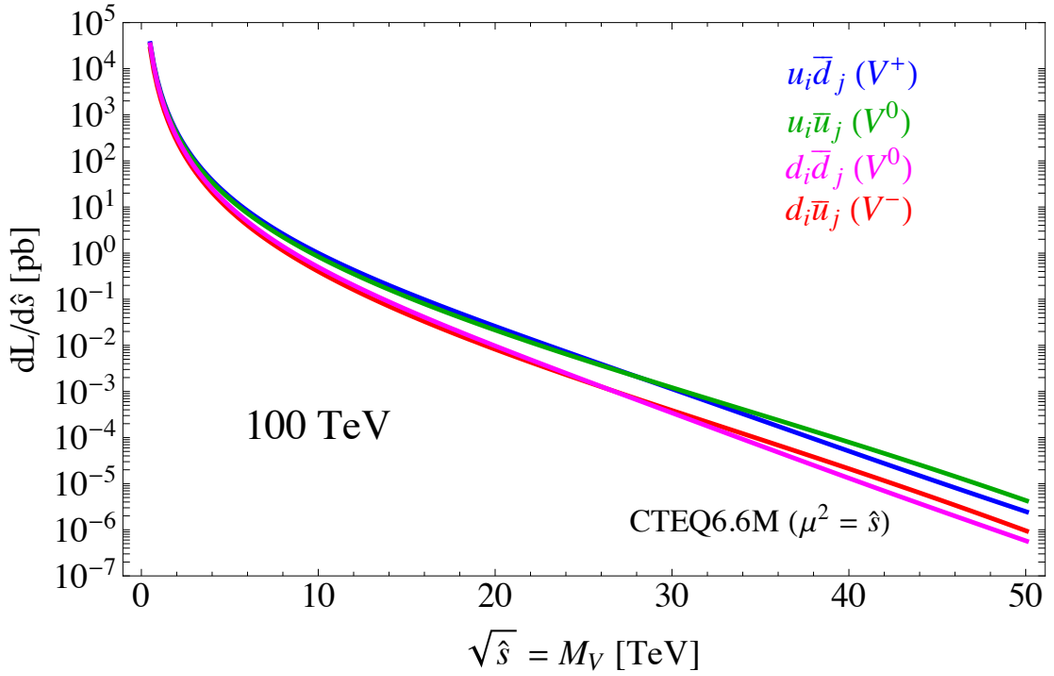

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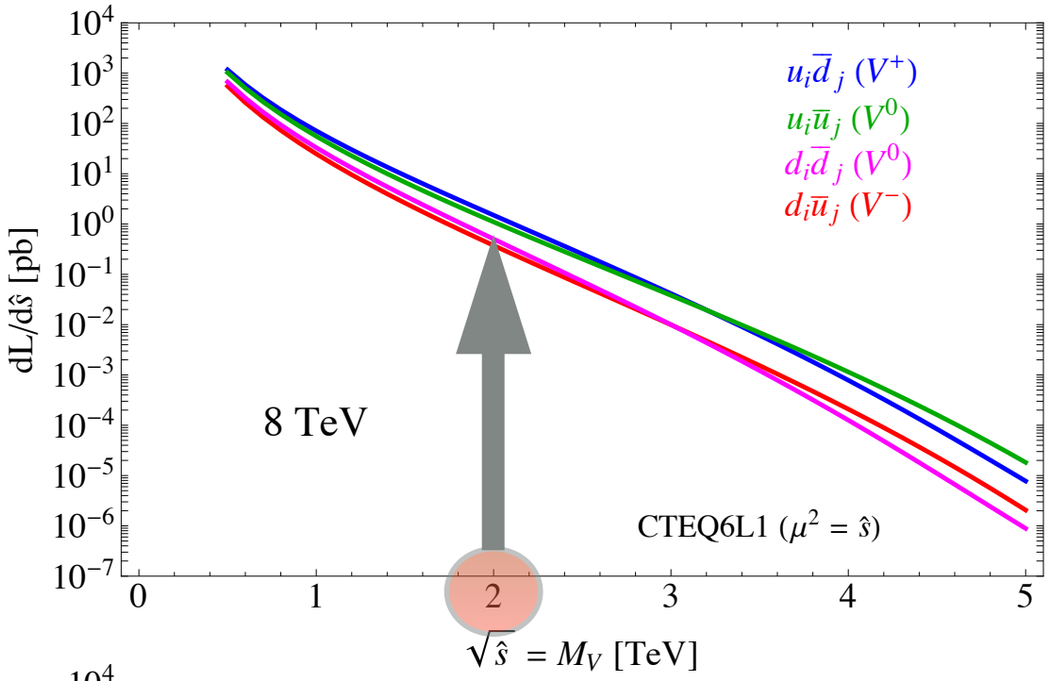

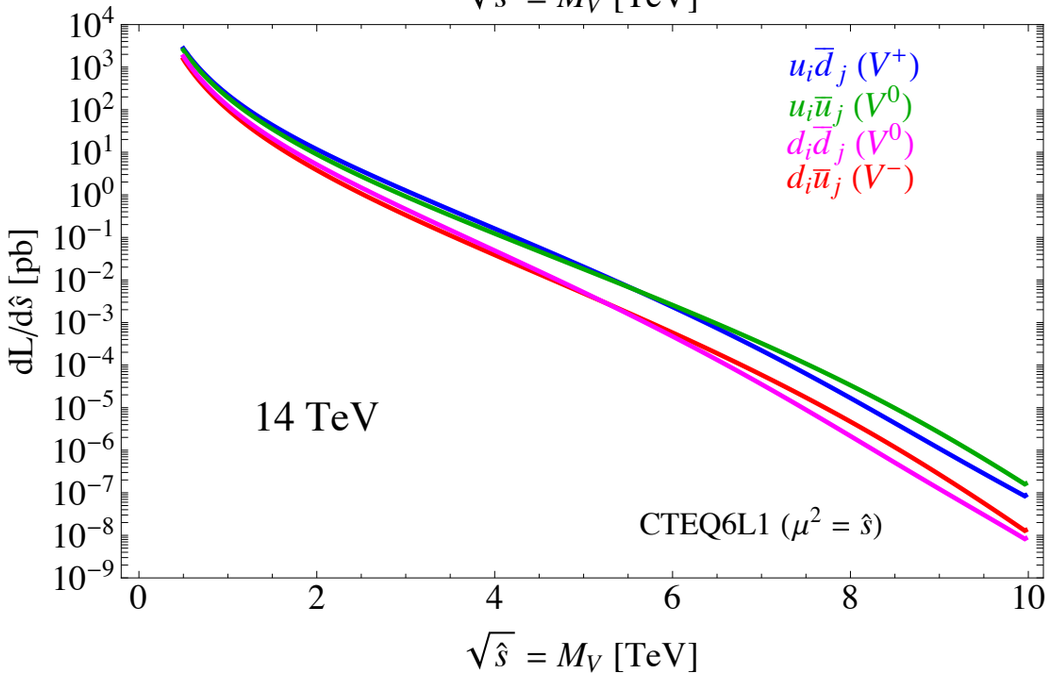

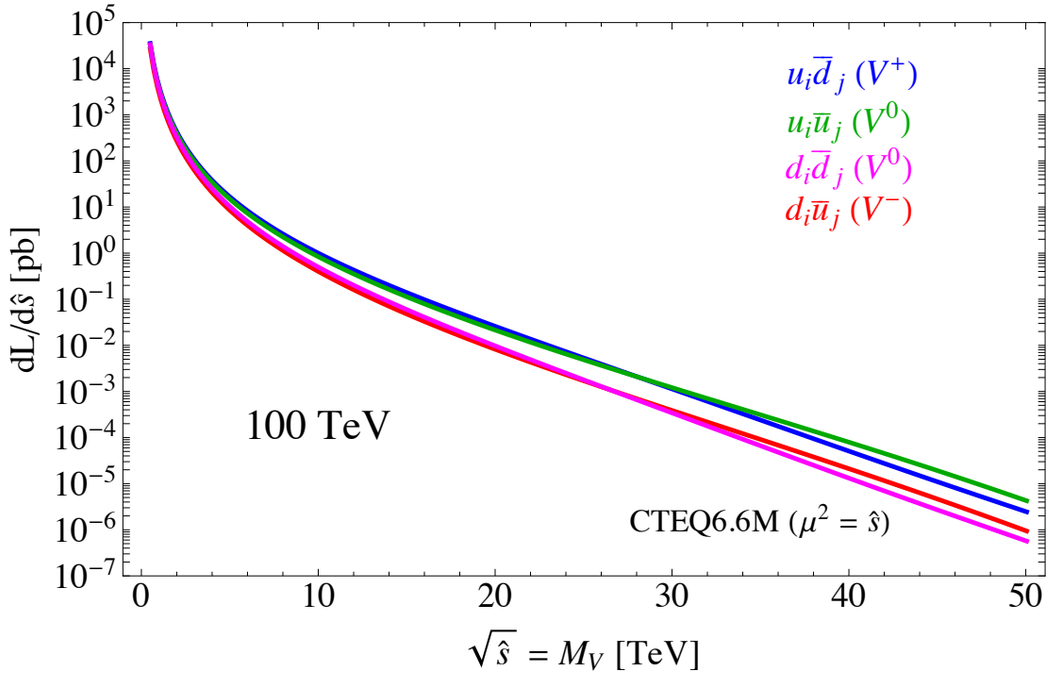

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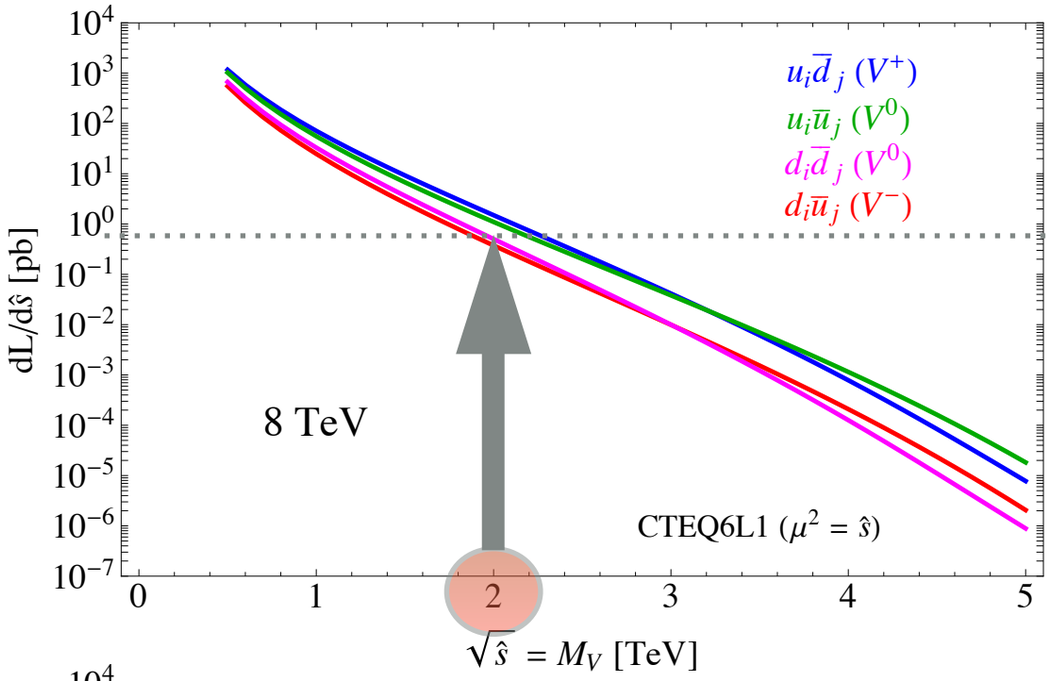

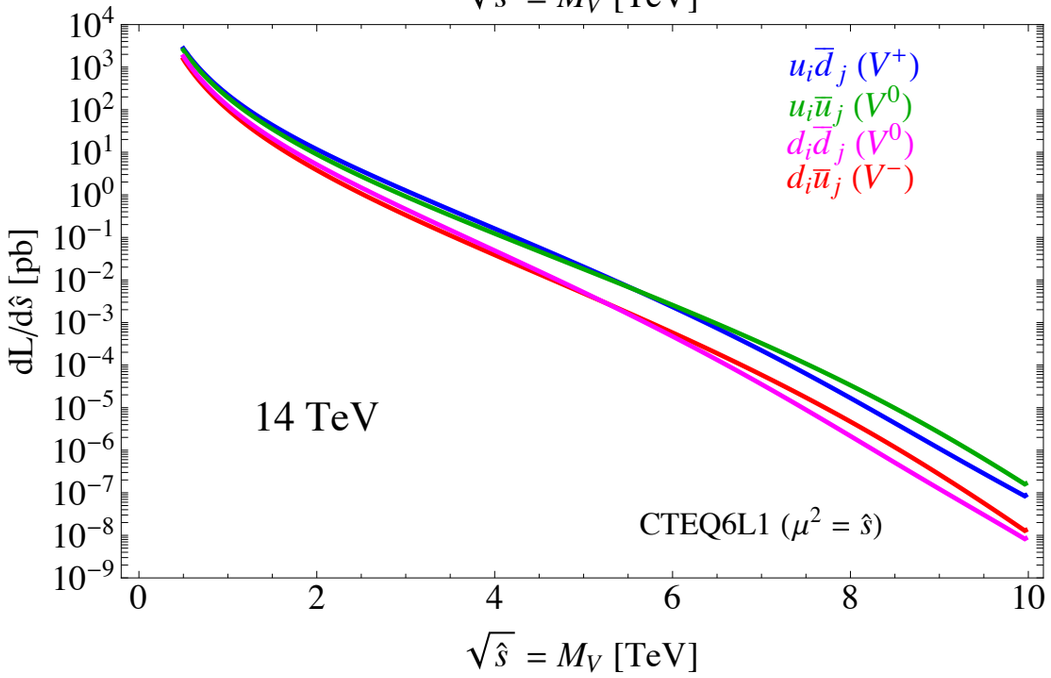

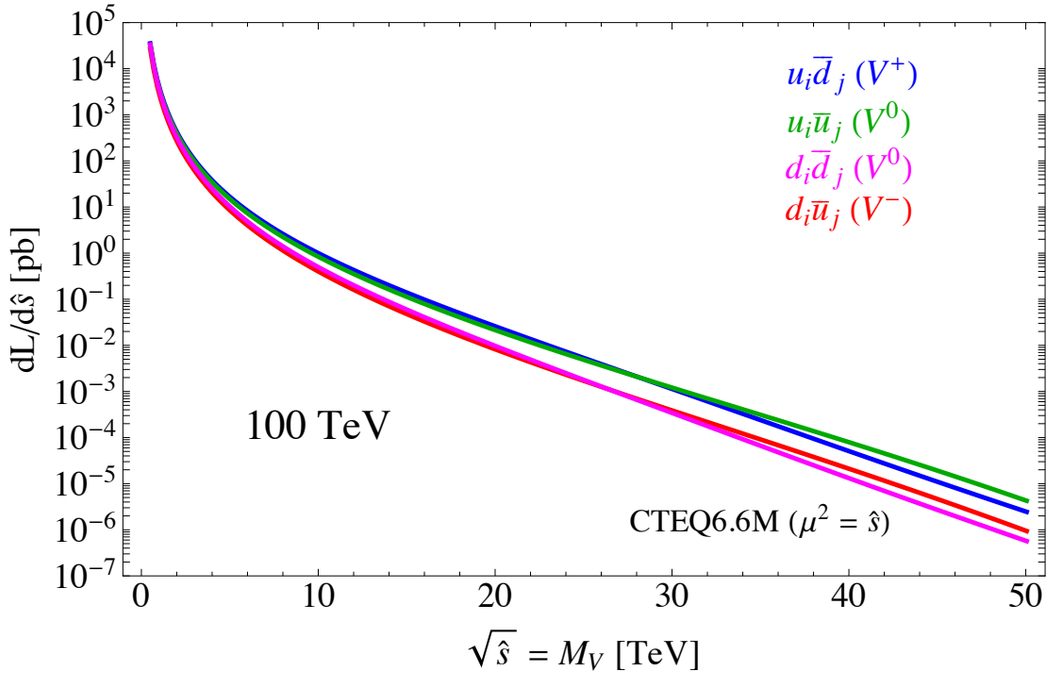

EXTRAPOLATING BOUNDS

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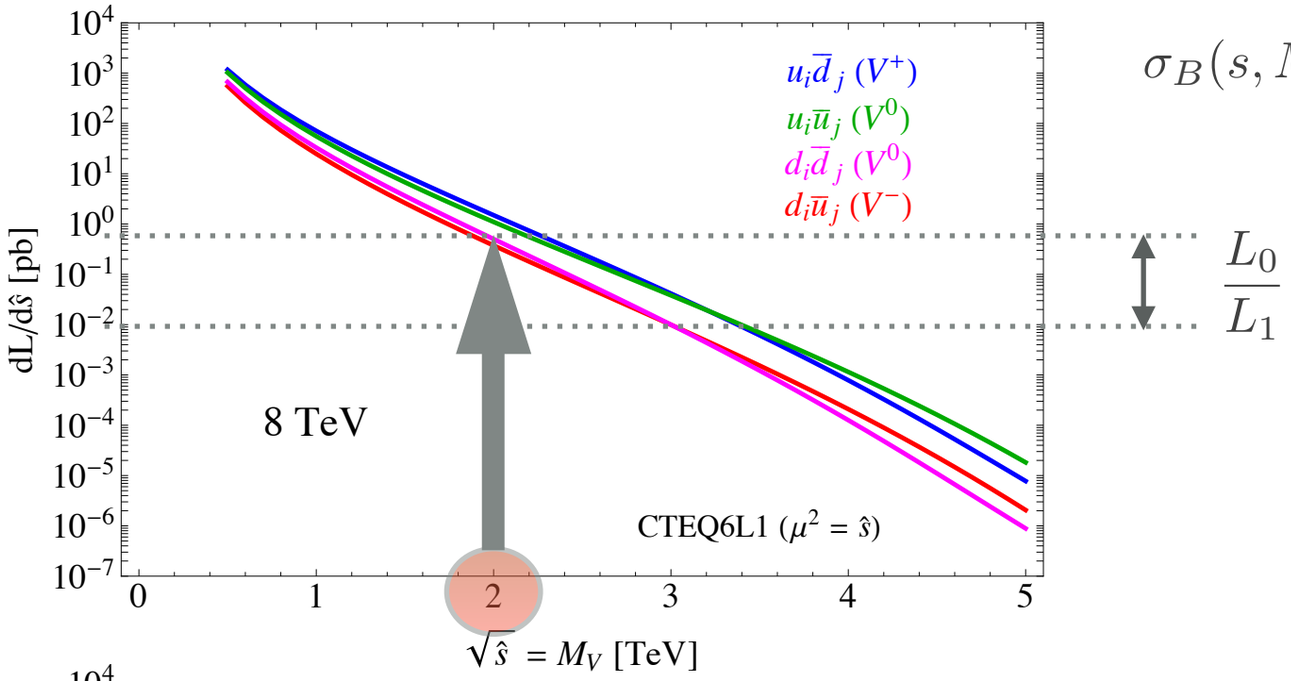
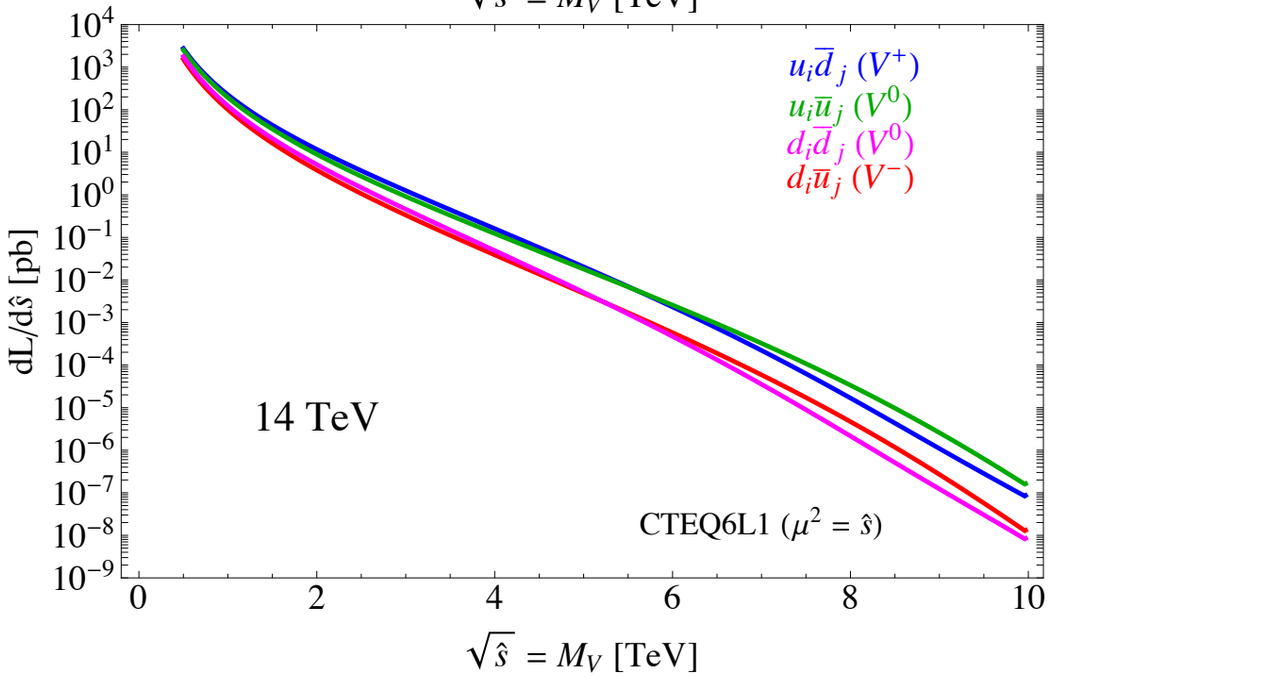
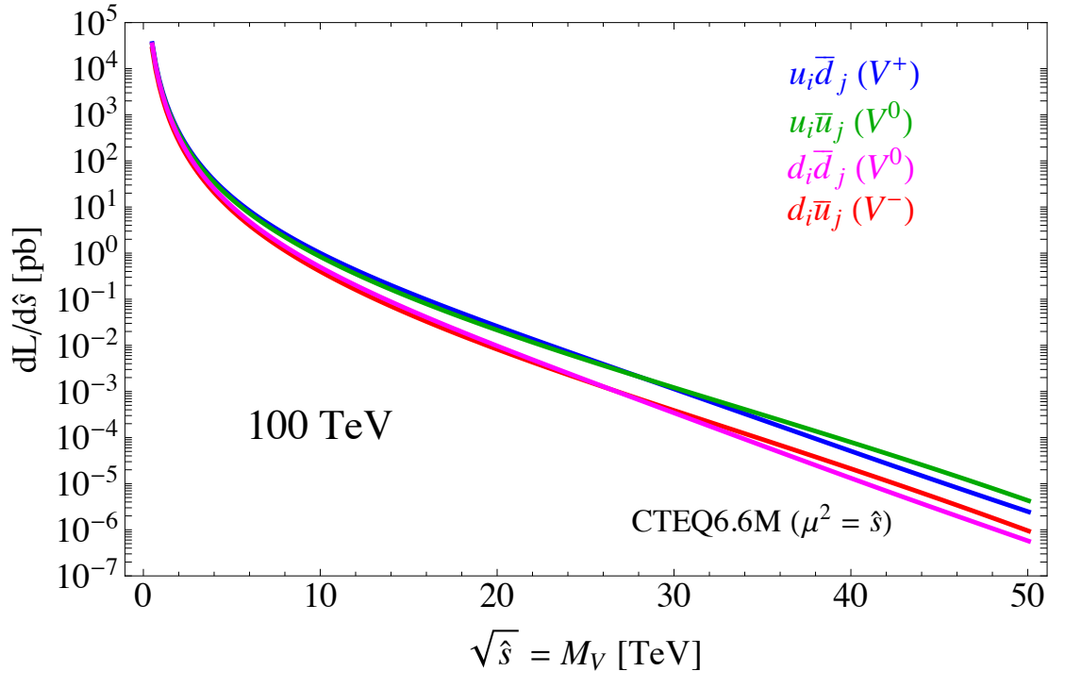


$\frac{L_0}{L_1}$





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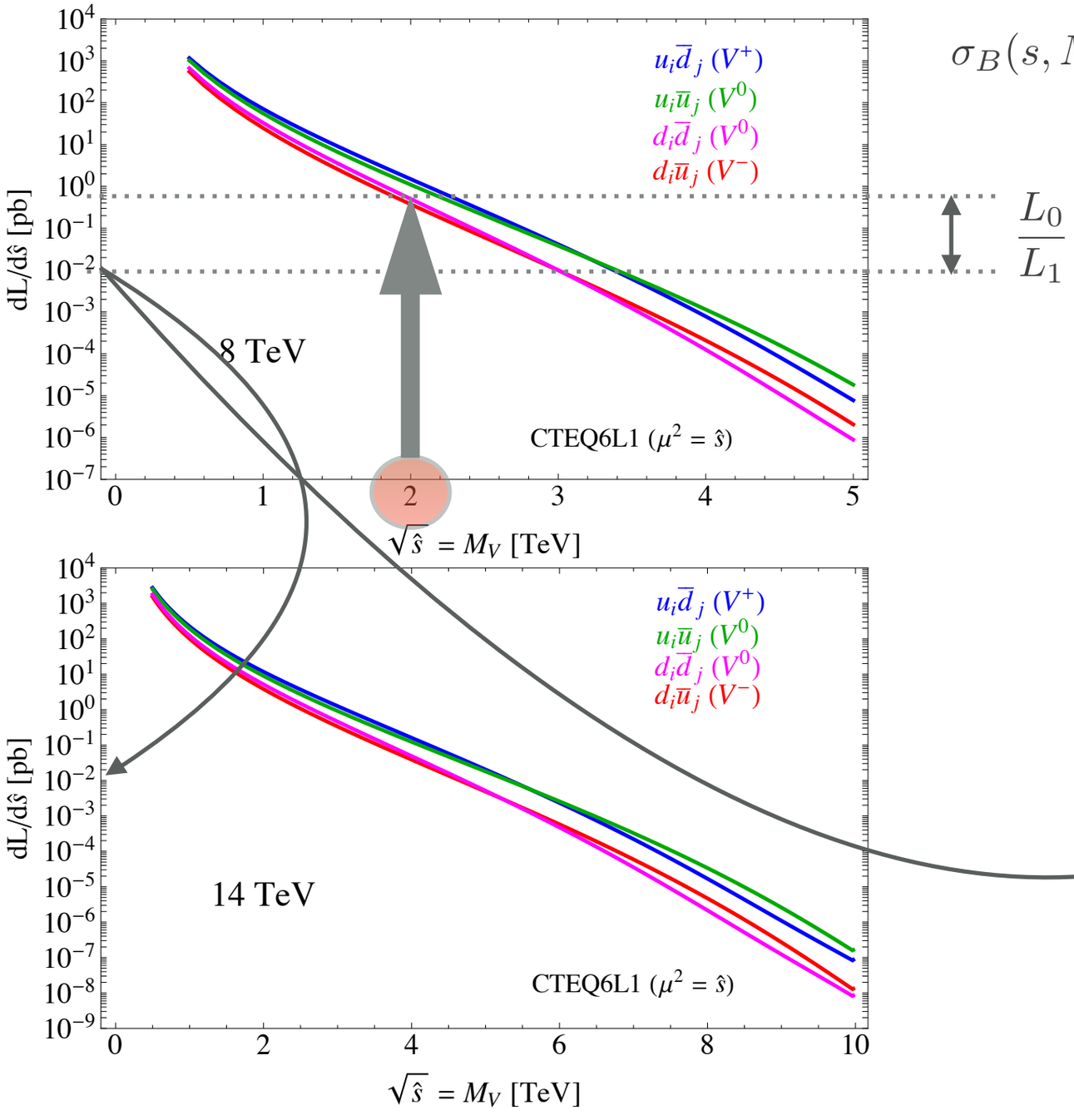

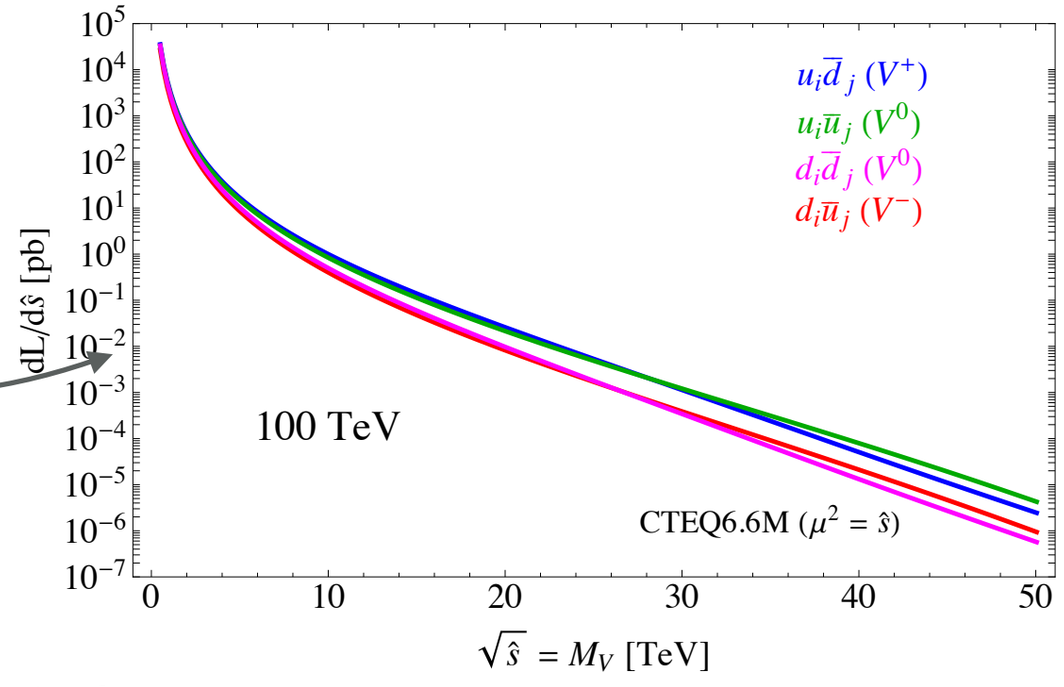

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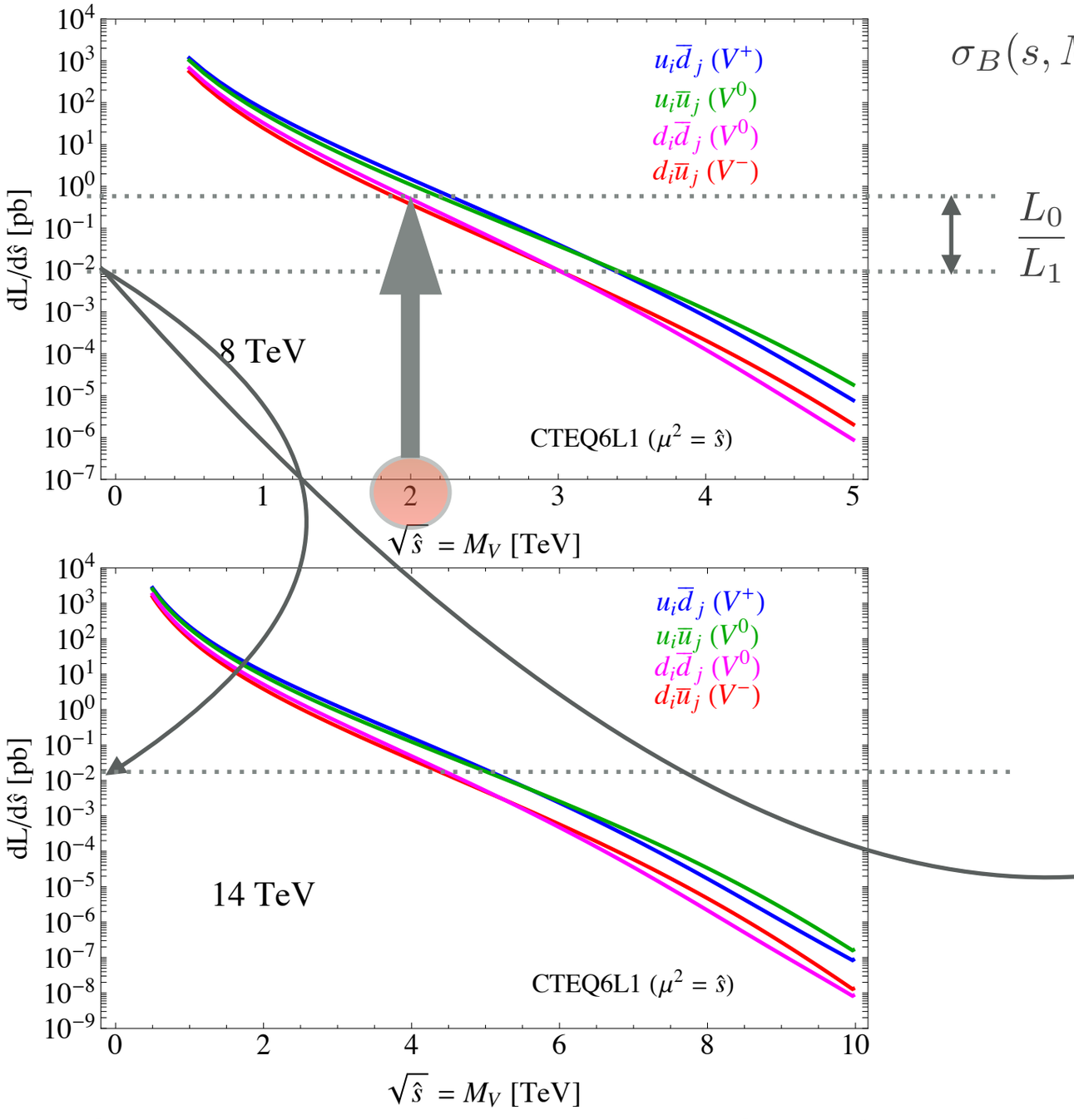

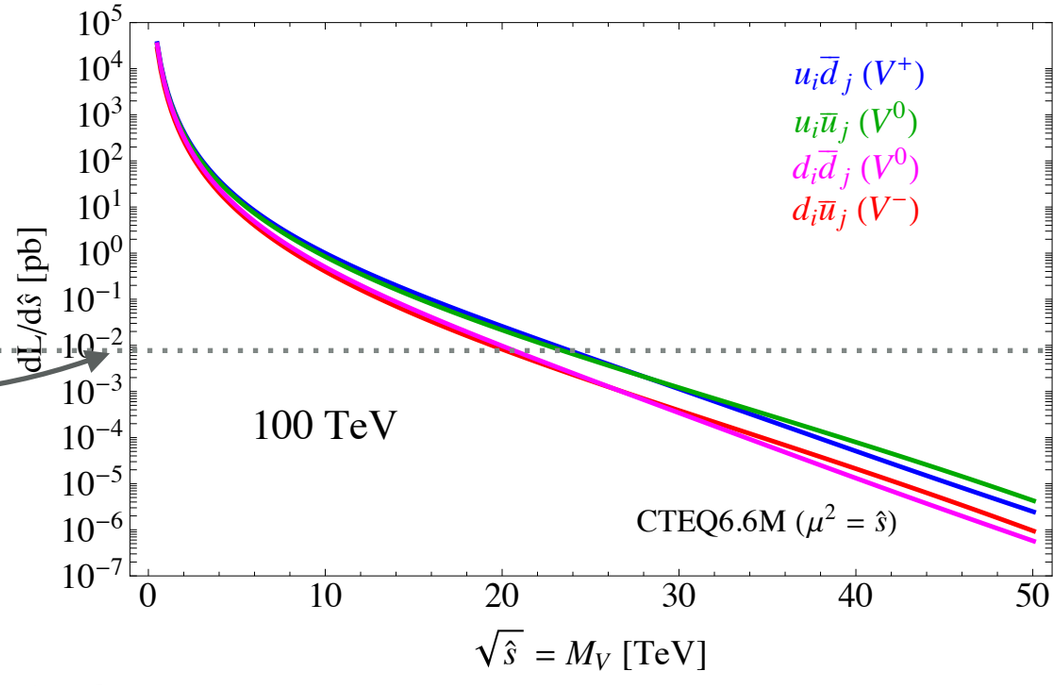

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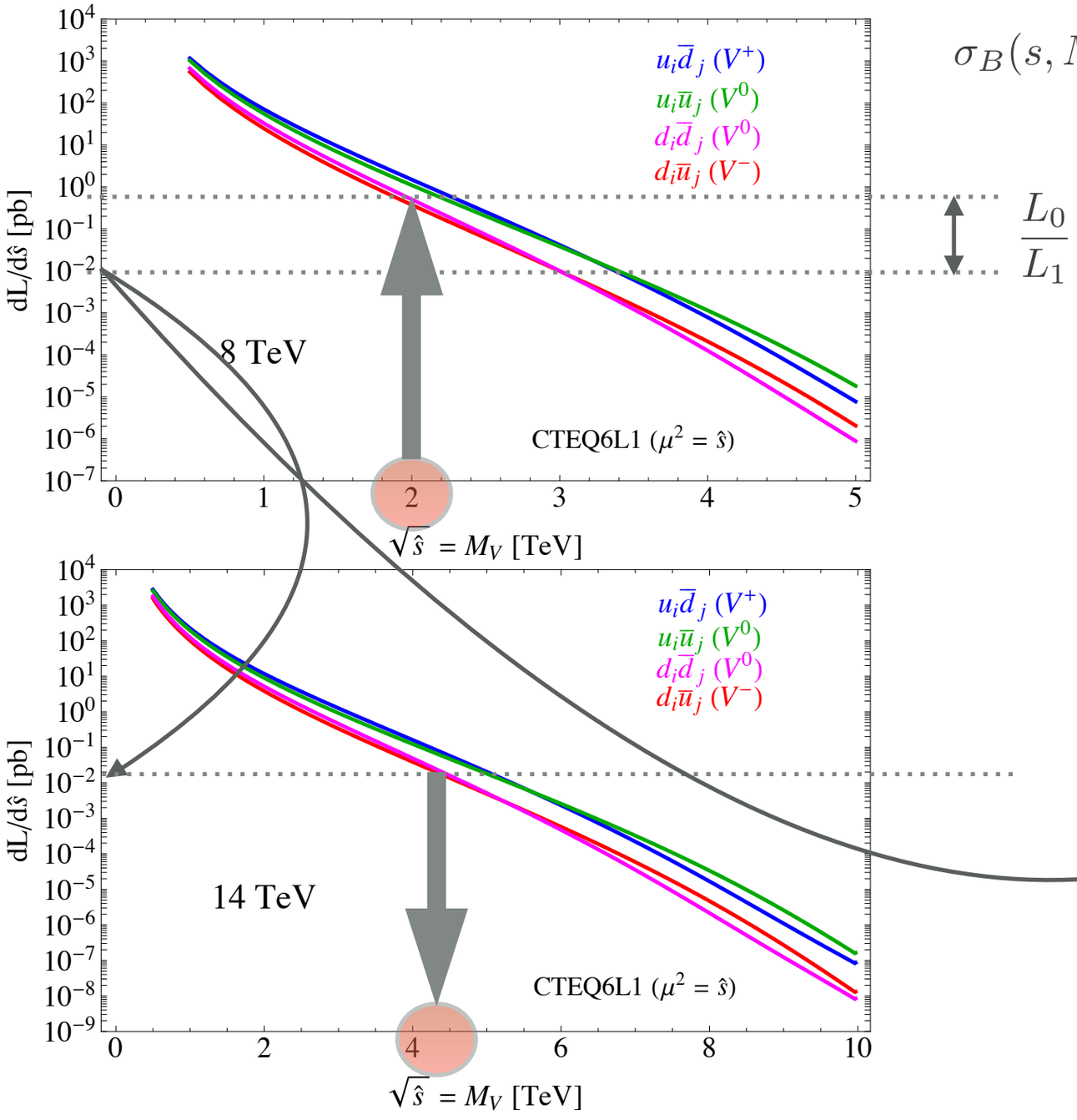
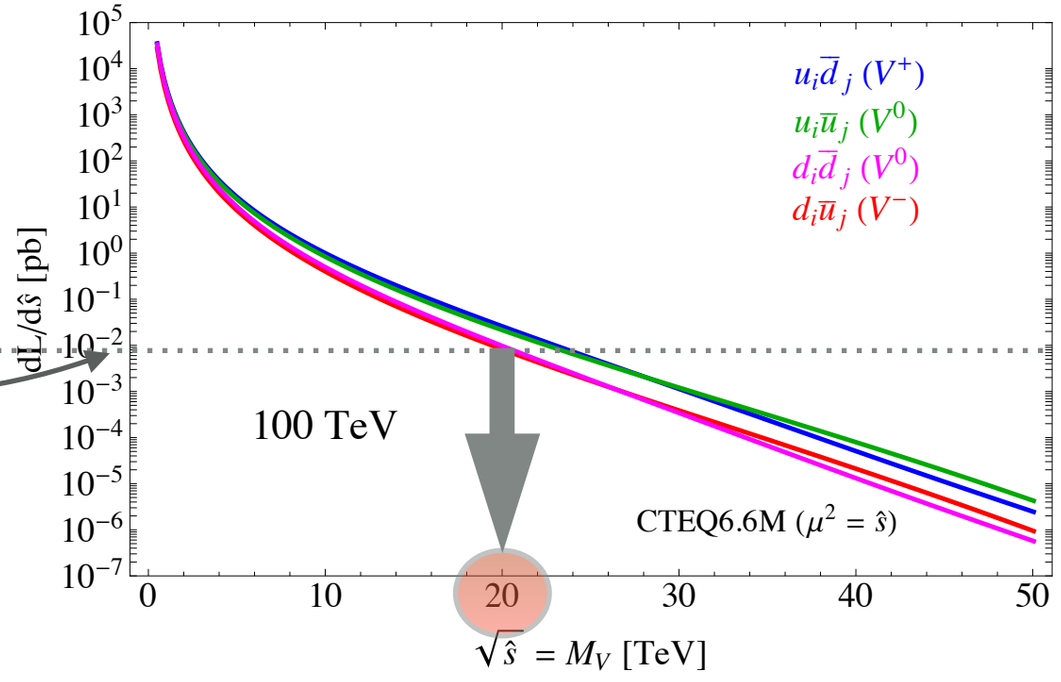
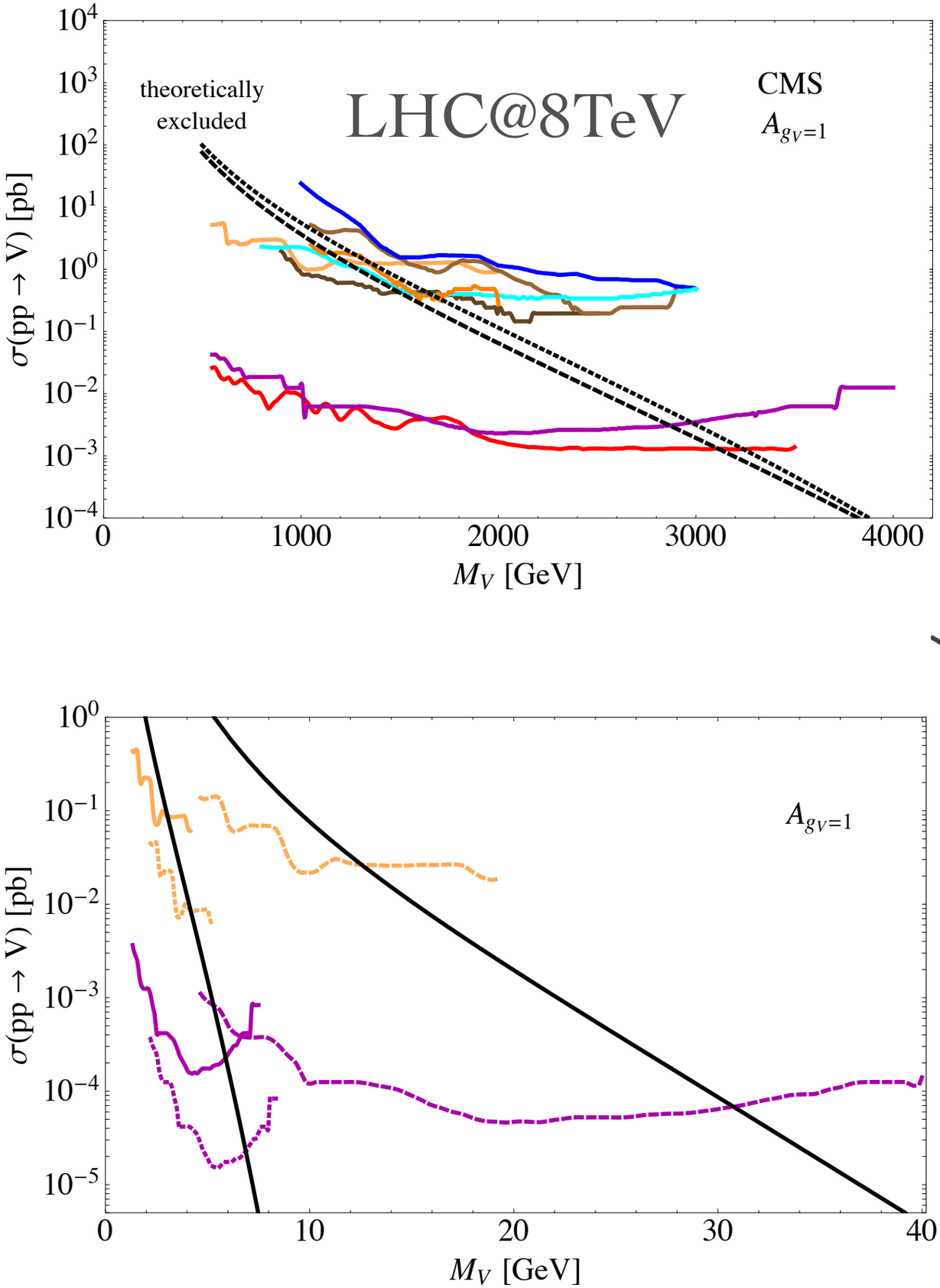
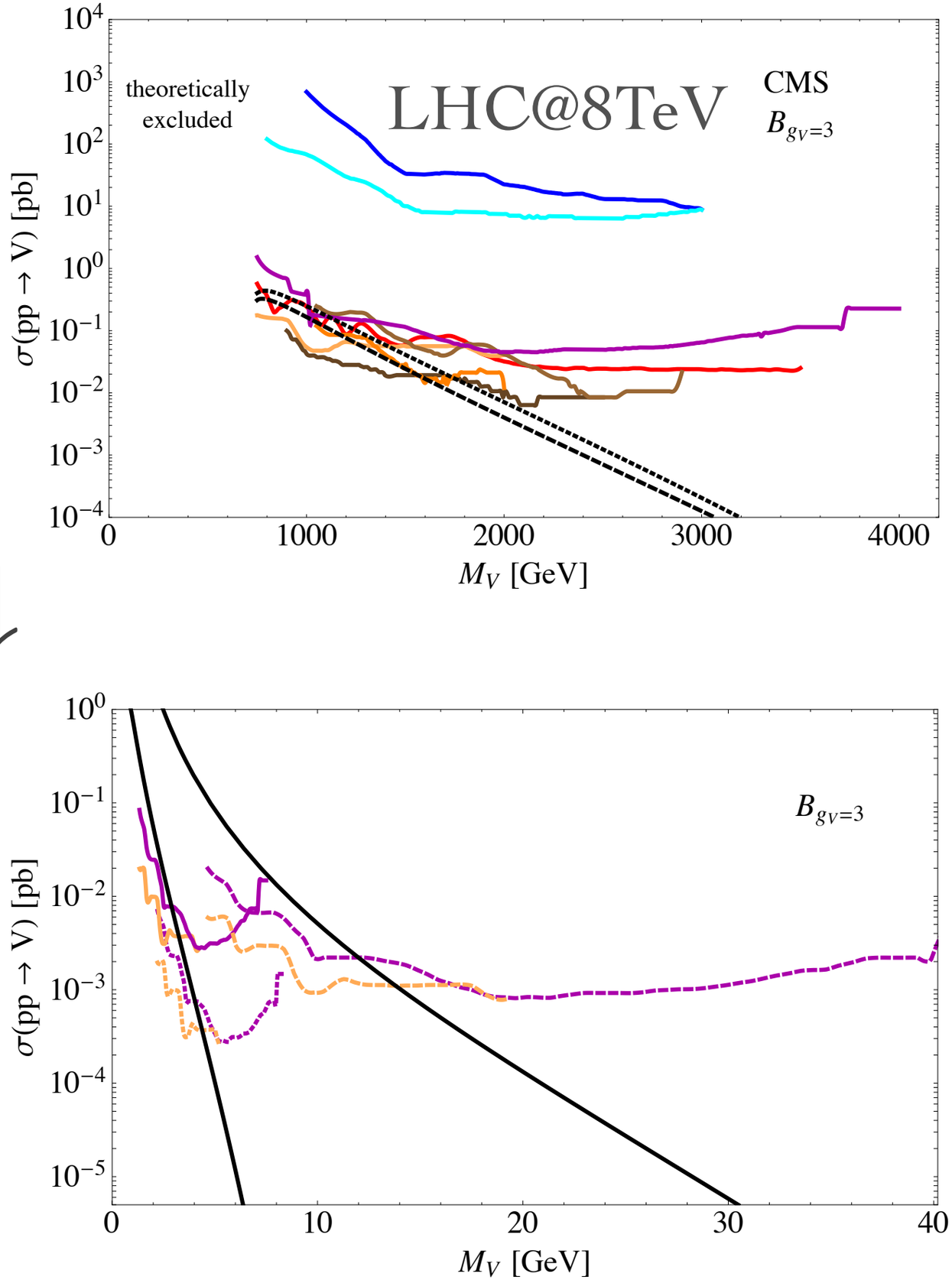


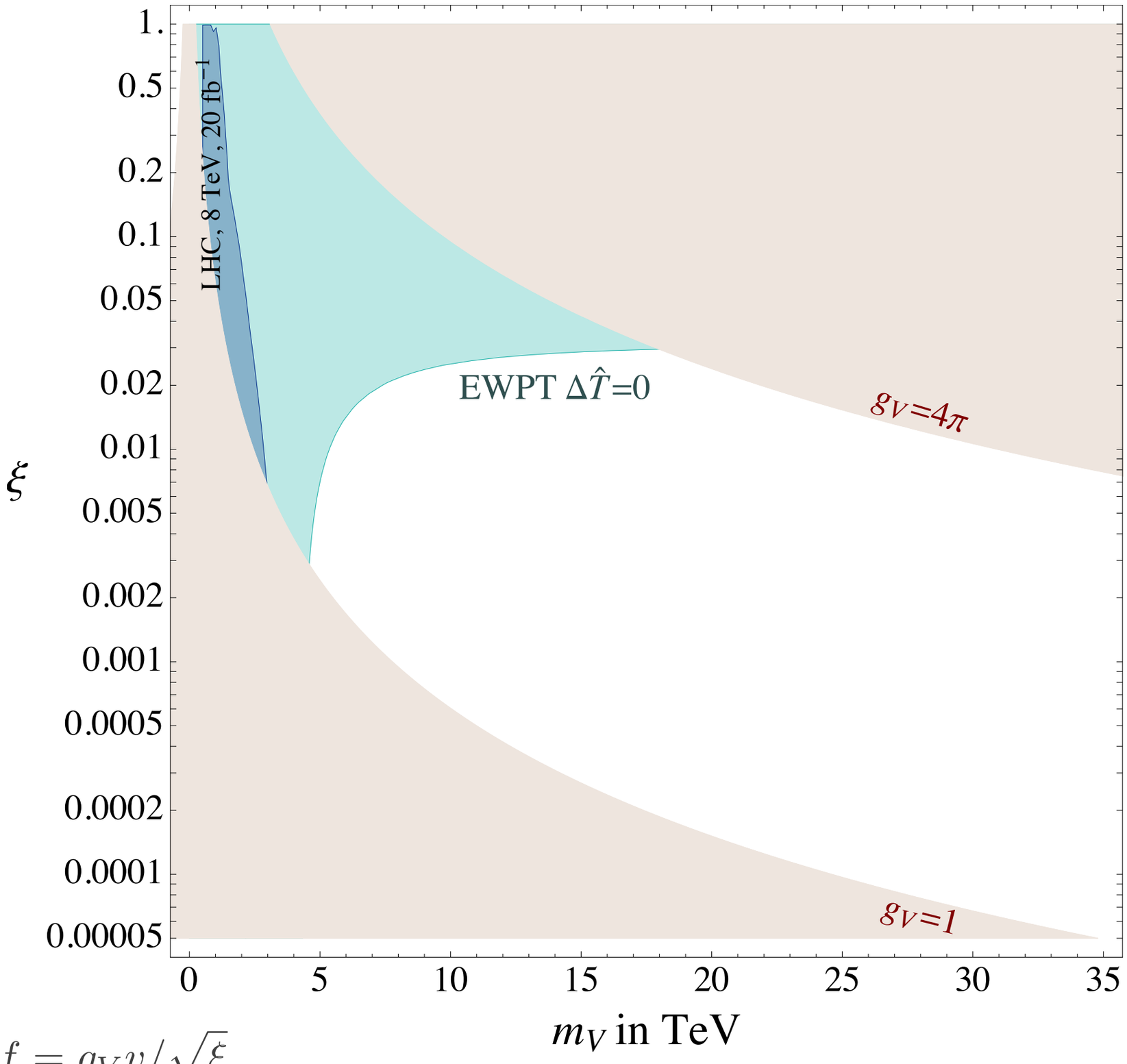


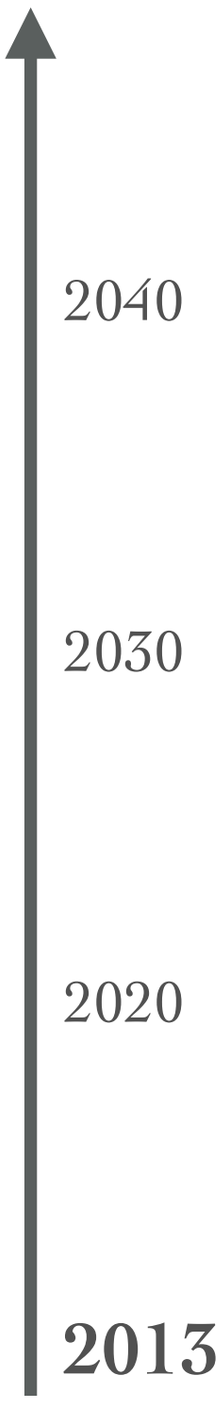
CROSS SECTION BOUNDS AT 100 TEV





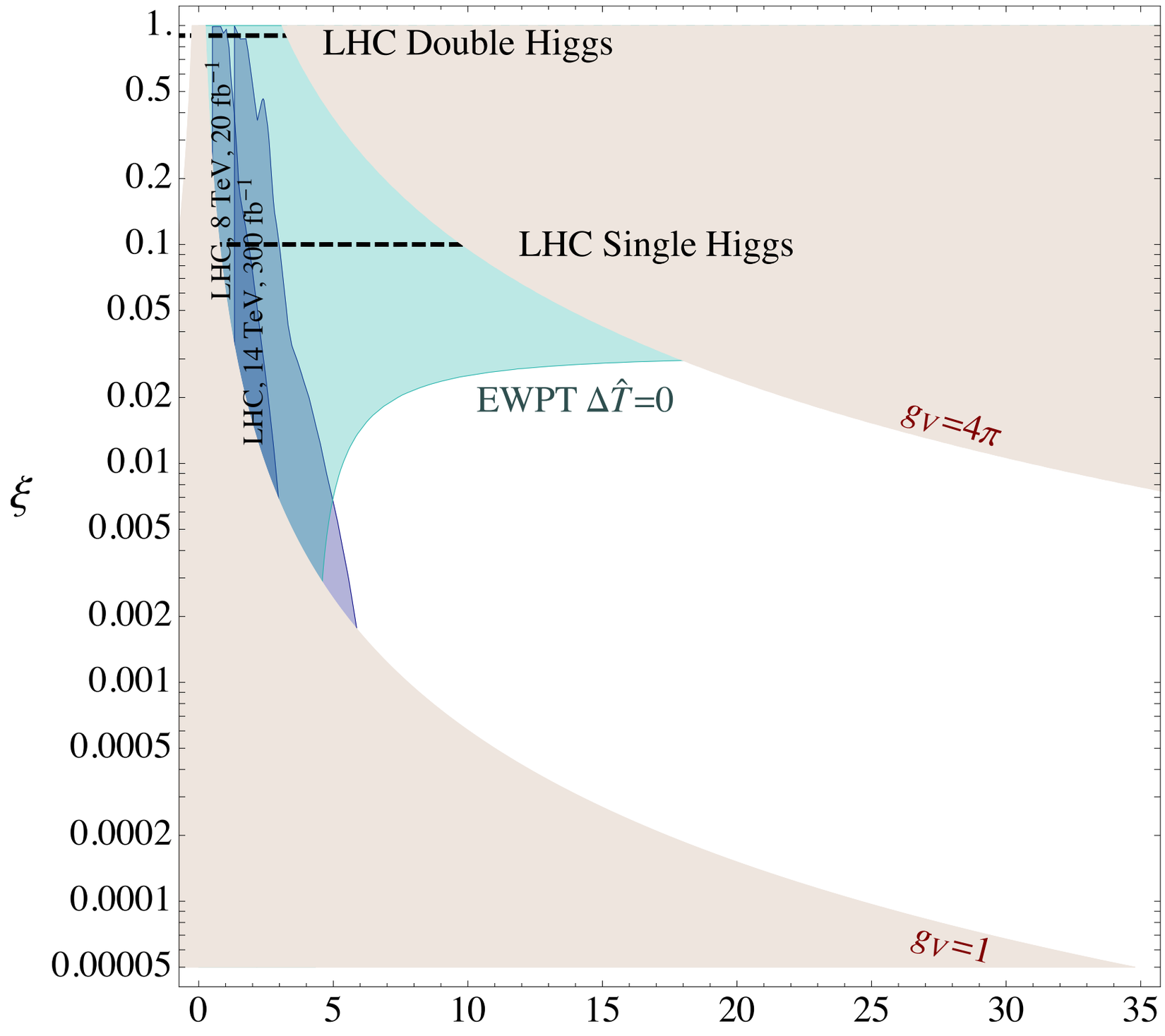
100 TEV AGAINST ALL

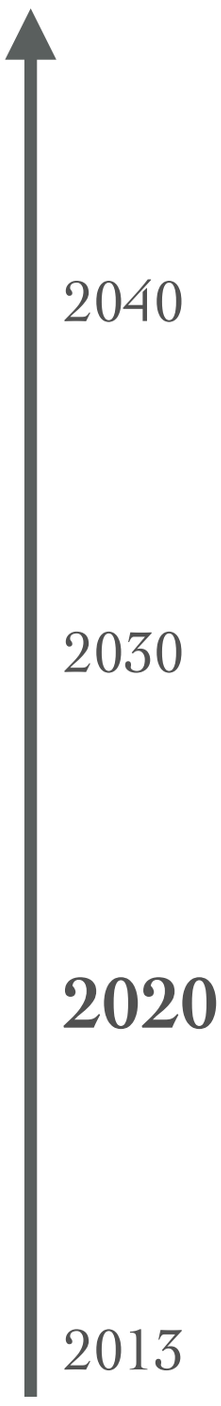




$$m_V = g_V f = g_V v/\sqrt{\xi}$$

100 TEV AGAINST ALL





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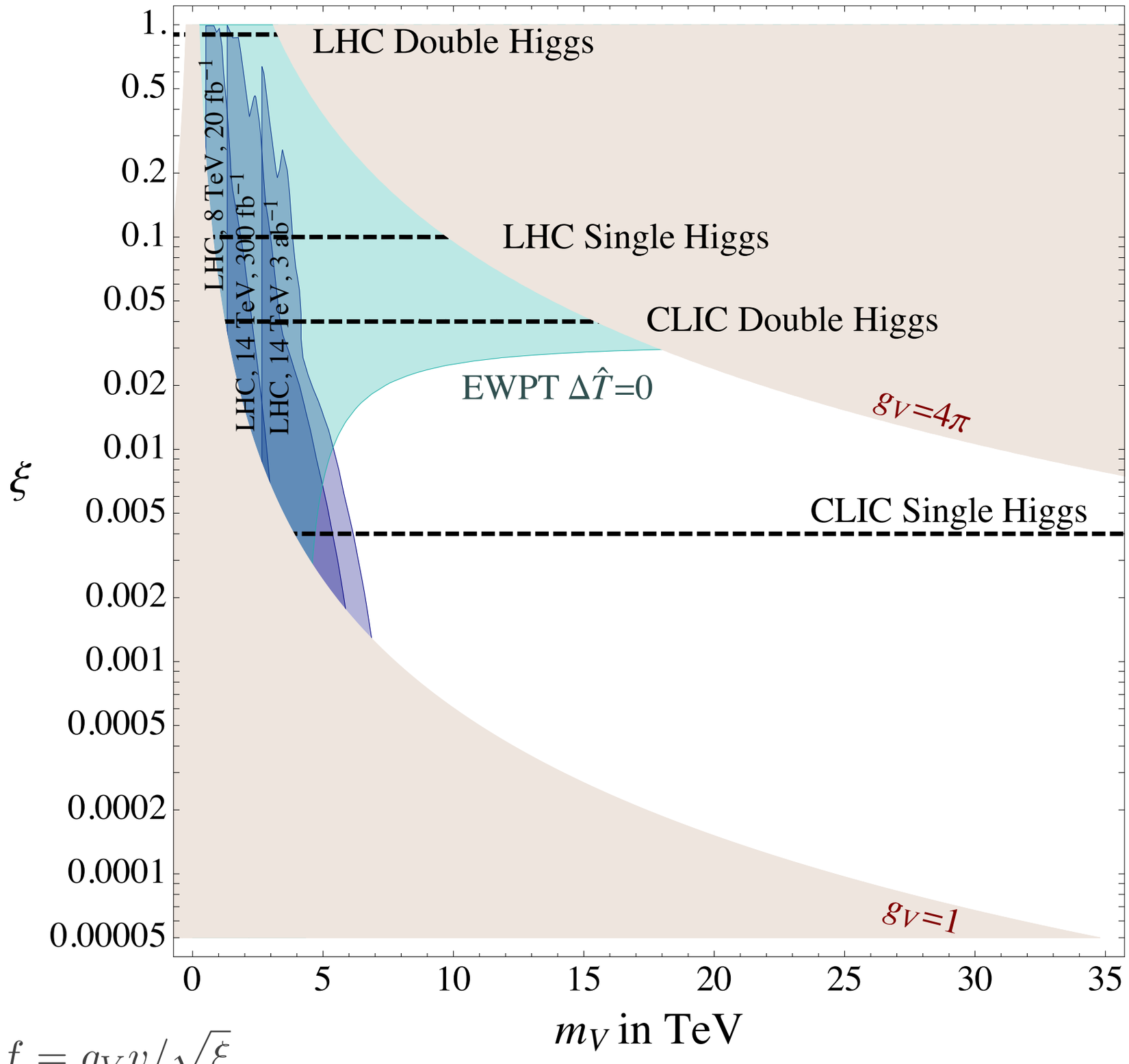
100 TEV AGAINST ALL



2040

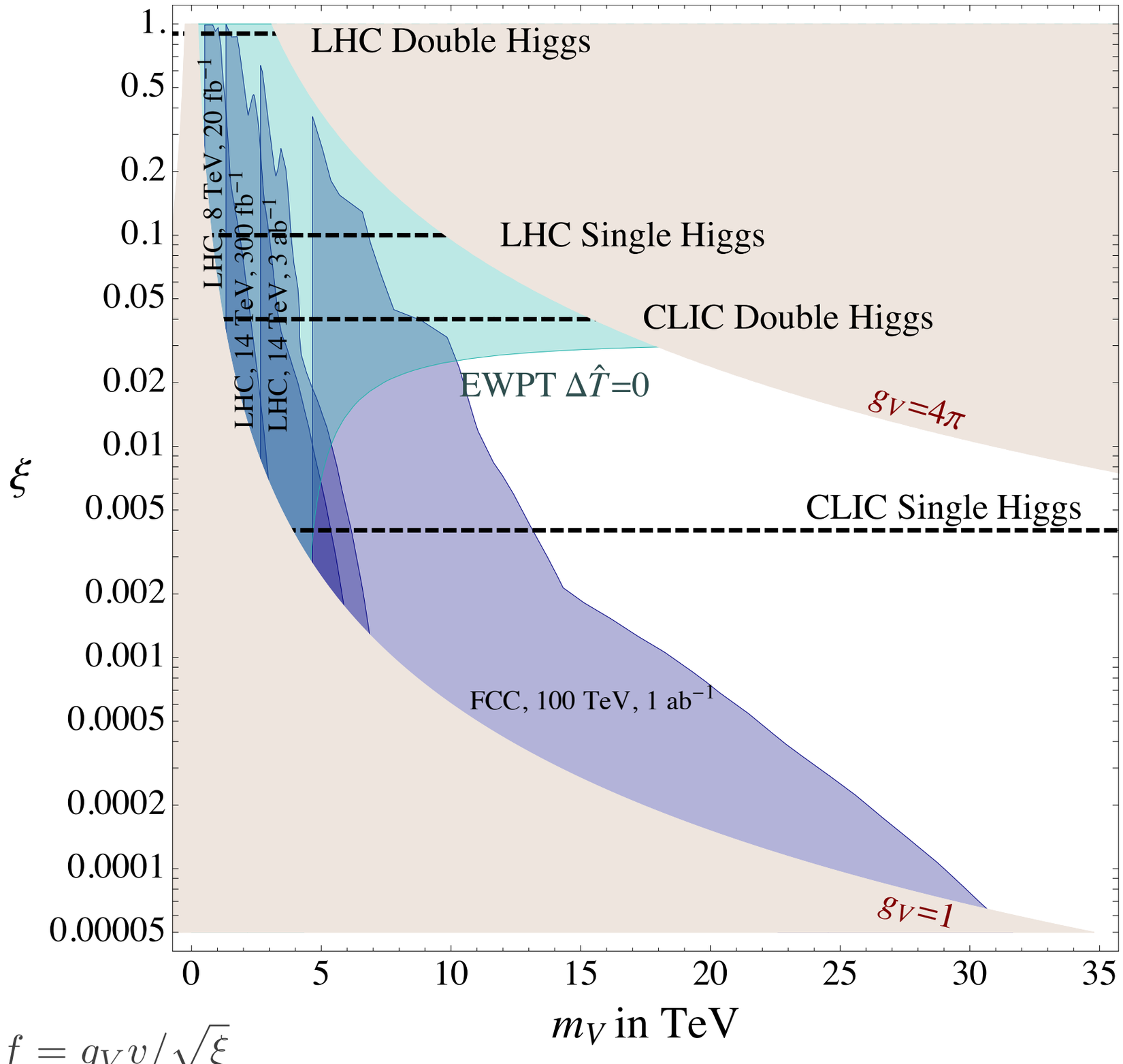
2030

2020

2013

$$m_V = g_V f = g_V v/\sqrt{\xi}$$

100 TEV AGAINST ALL



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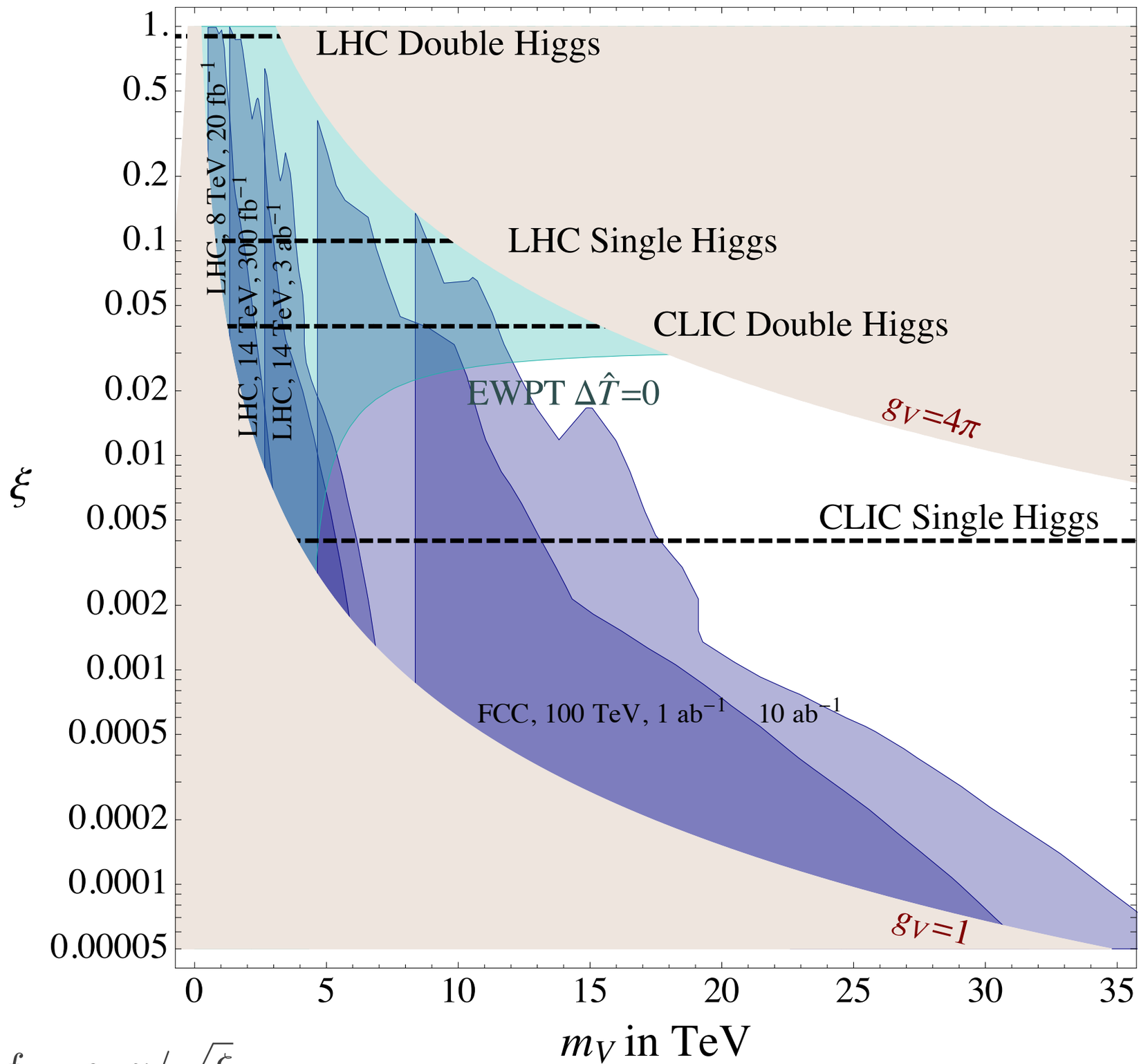
100 TEV AGAINST ALL



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2040

2030

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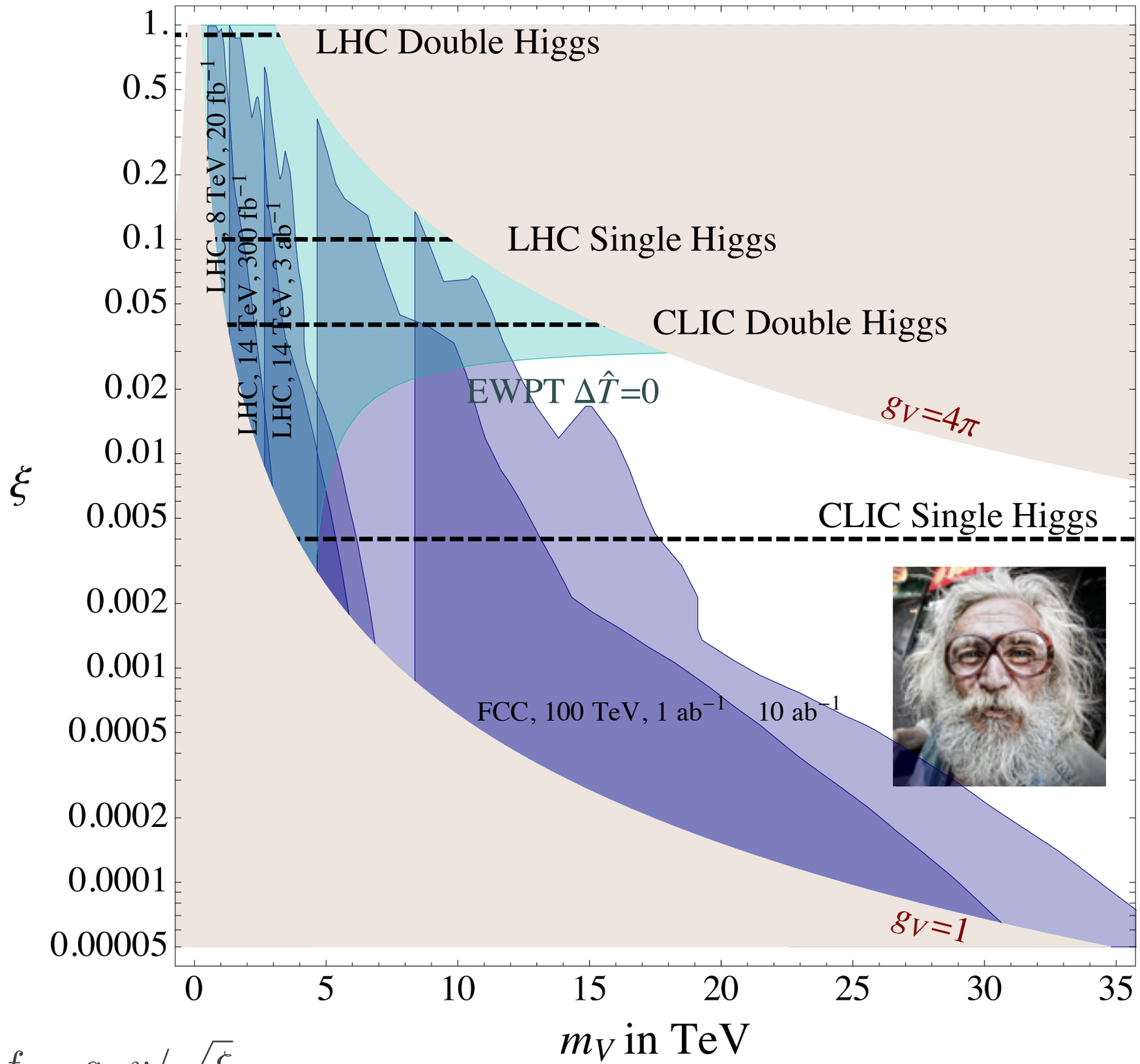
$$m_V = g_V f = g_V v/\sqrt{\xi}$$

100 TEV AGAINST ALL



$$m_V = g_V f = g_V v/\sqrt{\xi}$$

?

2040

2030

2020

2013

TOOLS

Heavy Vector Triplets

back to the Home page

In this dedicated webpage we make available different resources for the study of heavy vectors. In the table below you can find the reference to the relevant paper, to the model files (FeynRules, MadGraph 5, CalcHEP) on the model database HEPMDB and some interactive tools to study the phenomenology and to generate the MadGraph5 "param_card.dat"

	Download the reference paper 1402.4431 [hep-ph]
	Download the MadGraph 5 Model
HEPMDB *High Energy Physics Models DataBase*	Model files at HEPMDB (model ref. hepmdb:0214.0151)
CDF	Interactively compute the dependent parameters, the widths, the Branching Ratios, the cross sections at 8,14,100 TeV, plot the cross sections vs the mass and generate the MadGraph5 "param_card.dat" by simply varying the parameters

New resources will be available soon

CONCLUSIONS

- Important to get the most/the best from experiments

- In simple cases (e.g. resonances searches) the analyses can be used to set bounds in many different models by relying on a phenomenological Lagrangian and a semi-analytical technique (Bridge method)

- Only on-shell quantities should be considered for the approach to be really model independent and the bounds to be really on cross section times branching ratio

- LHC bounds start to be significantly constraining, but direct searches are limited by c.o.m. energy

- A Future Circular Collider can increase the mass reach on a narrow resonance by more than a factor of 5 over the LHC

THANK YOU