

Reopening the Discussion of EFT Truncation and Validity



based on JHEP 2026, 94 (2026)

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Overview of EFT validity

Standard Model (SM): Particle physics
crowning achievement, potentially complete
with discovery of Higgs boson

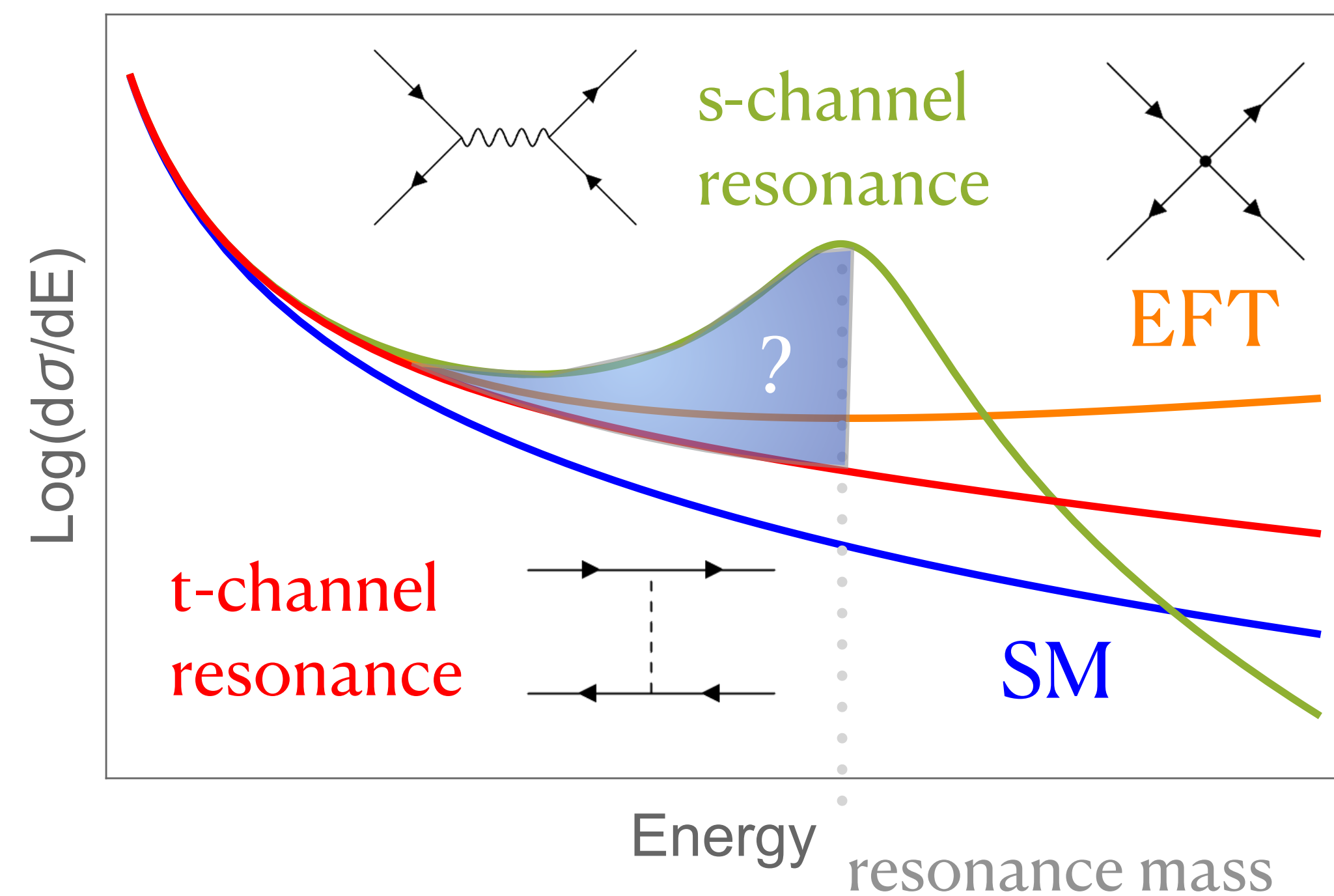
Effective Field Theory (EFT): Framework to look for indirect signals
of new physics in a model independent way

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{new}$$

New terms involving SM particles have mass dimension ≥ 4 ,
must lead to unitarity violating amplitudes that grow with energy

LHC Issue

Energy growth of EFT amplitude leads to signal-rich regions in high energy bins. Sometimes theory tells you something is wrong (e.g. non-unitary or $d\sigma/d\Omega < 0$)



Or EFT description might break down at some energy scale M before it needs to (e.g. resonances)

Notice that bins below resonance masses have notable deviations away from leading order in the EFT, these theory errors can be large and so validity of EFT approximation depends on M scale

How to treat EFT validity issue?

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LHC EFT WG note: Truncation, validity, uncertainties

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Lots of proposals
then, but no
consensus...

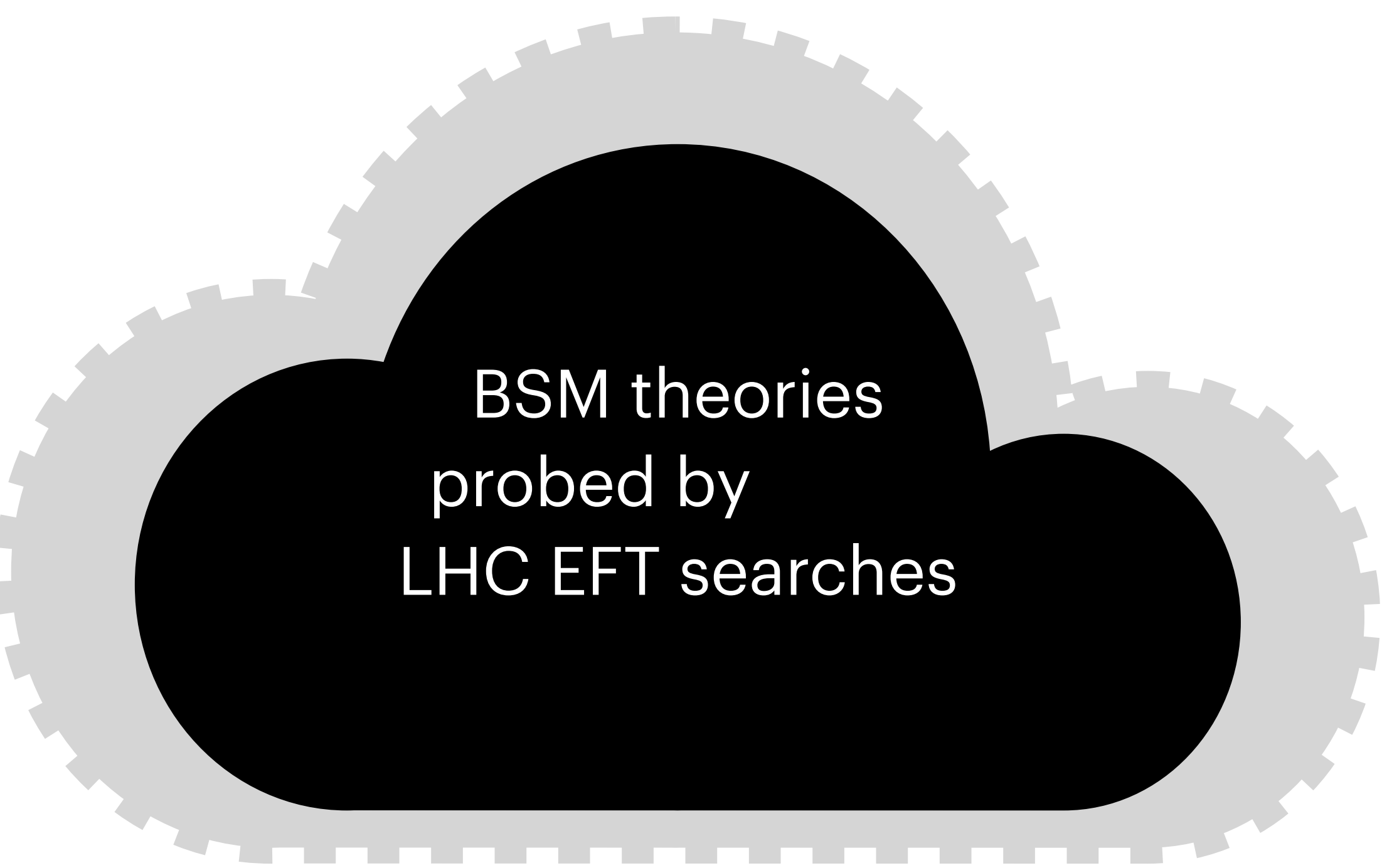
We have many experts
and players in the room,
can we get analyses
the theory and
experimental
community can be
happy with?

Proposed Ground Rules for Discussion (in addition to the MITP code of conduct 😊💧)

- Let's make our assumptions explicit, so that we can argue for ones we can agree upon
- What type of uncertainties should we take into account?
- What statistical procedure should we use to address them?
- Are the proposals easy to implement by experimentalists and to interpret by theorists?
- Can we find a compromise that we can all be happy with?
- Let me try to illustrate some of these issues in the context of my own work...

Theory Priors

Essential to be explicit, since
EFT is not truly model-independent
(e.g. we aren't testing Lorentz violation or
momentum non conservation)
so we need to be providing guidance to
theories we want EFT analysis to apply to

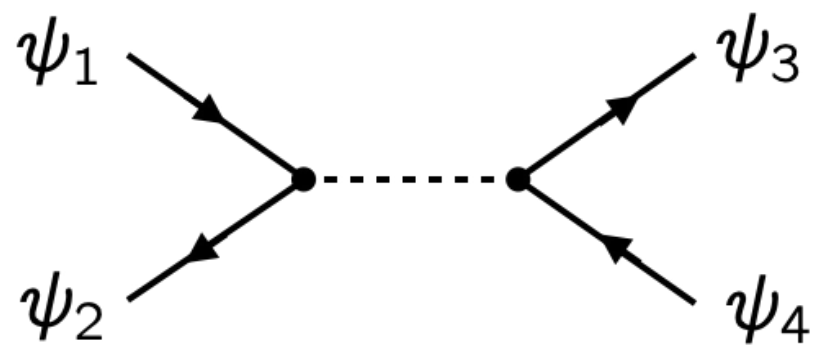


BSM theories
probed by
LHC EFT searches

WARNING!!! Over-theorizing
can kill BSM searches which
could find new physics

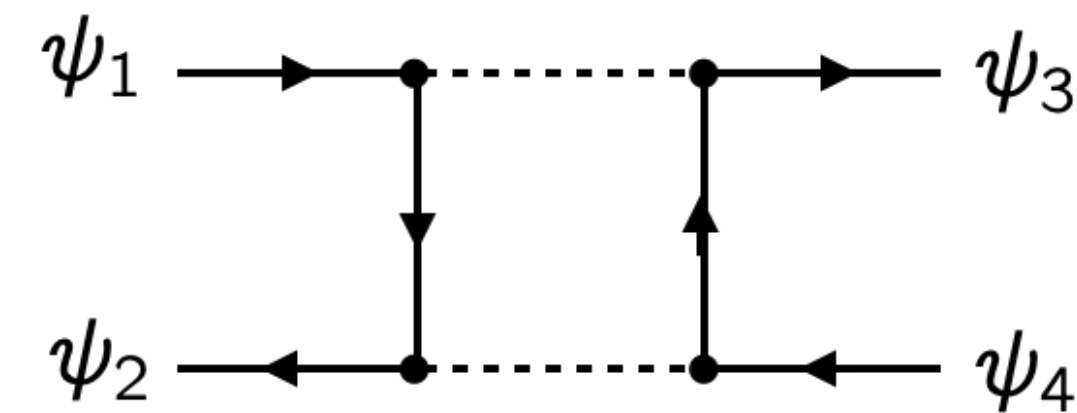
E.g. There can be new physics accessible to LHC at mass scale M with important generic Mandelstam corrections to leading order EFT

s-channel
model

$$\mathcal{M}_{\text{BSM}}(12 \rightarrow 34) =$$


$$= G_{(\bar{\psi}\psi)^2} \left[1 + \frac{\hat{s}}{M^2} + \frac{\hat{s}^2}{M^4} + \dots \right], \quad G_{(\bar{\psi}\psi)^2} = \frac{y^2}{M^2},$$

Loop
model

$$\mathcal{M}_{\text{BSM}}(12 \rightarrow 34) =$$


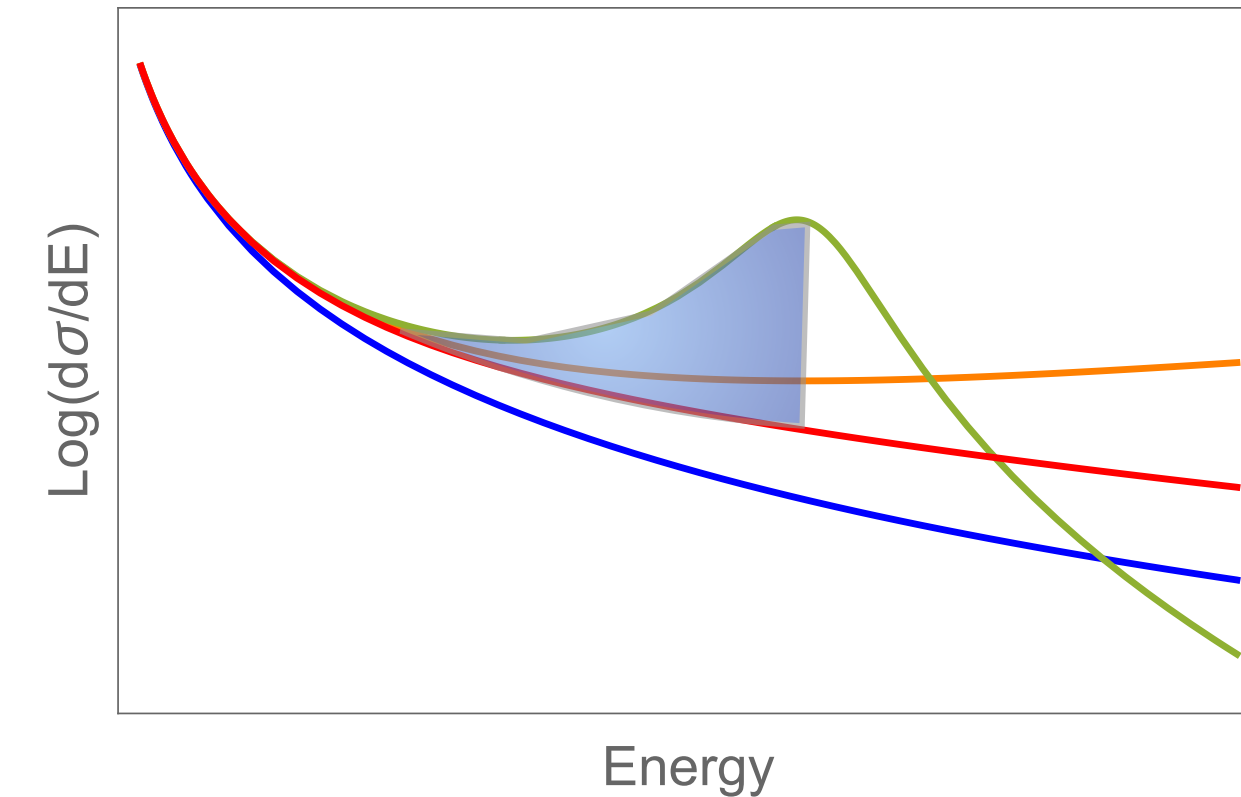
$$= G_{(\bar{\psi}\psi)^2} \left[1 + c_1 \frac{\hat{s}}{M^2} + c_2 \frac{\hat{t}}{M^2} + c_3 \frac{\hat{s}^2}{M^4} + c_4 \frac{\hat{s}\hat{t}}{M^4} + \dots \right] + \dots$$

Generic
model

$$\mathcal{M}_{\text{BSM}}(12 \rightarrow 34) = \sum_{\mathcal{O}} G_{\mathcal{O}} \mathcal{M}_{\mathcal{O}} \left[1 + c_{\mathcal{O},1} \frac{\hat{s}}{M^2} + c_{\mathcal{O},2} \frac{\hat{t}}{M^2} + c_{\mathcal{O},3} \frac{\hat{s}^2}{M^4} + \dots \right]$$

Our Proposal

EFT analyses have a scale M (to be specified) which characterizes scale of new physics, where:



- Energies below M : EFT approximation makes sense as a perturbative operator expansion in M , with dimensionless coefficients that can be at most $O(1)$
- Energies above M : EFT approximation breaks down. Assuming no signal, conservatively assume the amplitude softens its energy growth

Preview: Advantages of our Method

- Quantitative model of EFT uncertainties with explicit, physically motivated priors
- Implementable (via event reweighting, fast convergence)
- Derived bounds are model-independent (consistent when compared to UV models)
- Beyond limits: Can discover non-resonant enhanced new physics
- Can be used globally with M as a universal parameter

$E < M$: Non-leading order EFT as nuisance parameters

Generic
model

$$\mathcal{M}_{\text{BSM}}(12 \rightarrow 34) = \sum_{\mathcal{O}} G_{\mathcal{O}} \mathcal{M}_{\mathcal{O}} \left[1 + c_{\mathcal{O},1} \frac{\hat{s}}{M^2} + c_{\mathcal{O},2} \frac{\hat{t}}{M^2} + c_{\mathcal{O},3} \frac{\hat{s}^2}{M^4} + \dots \right]$$

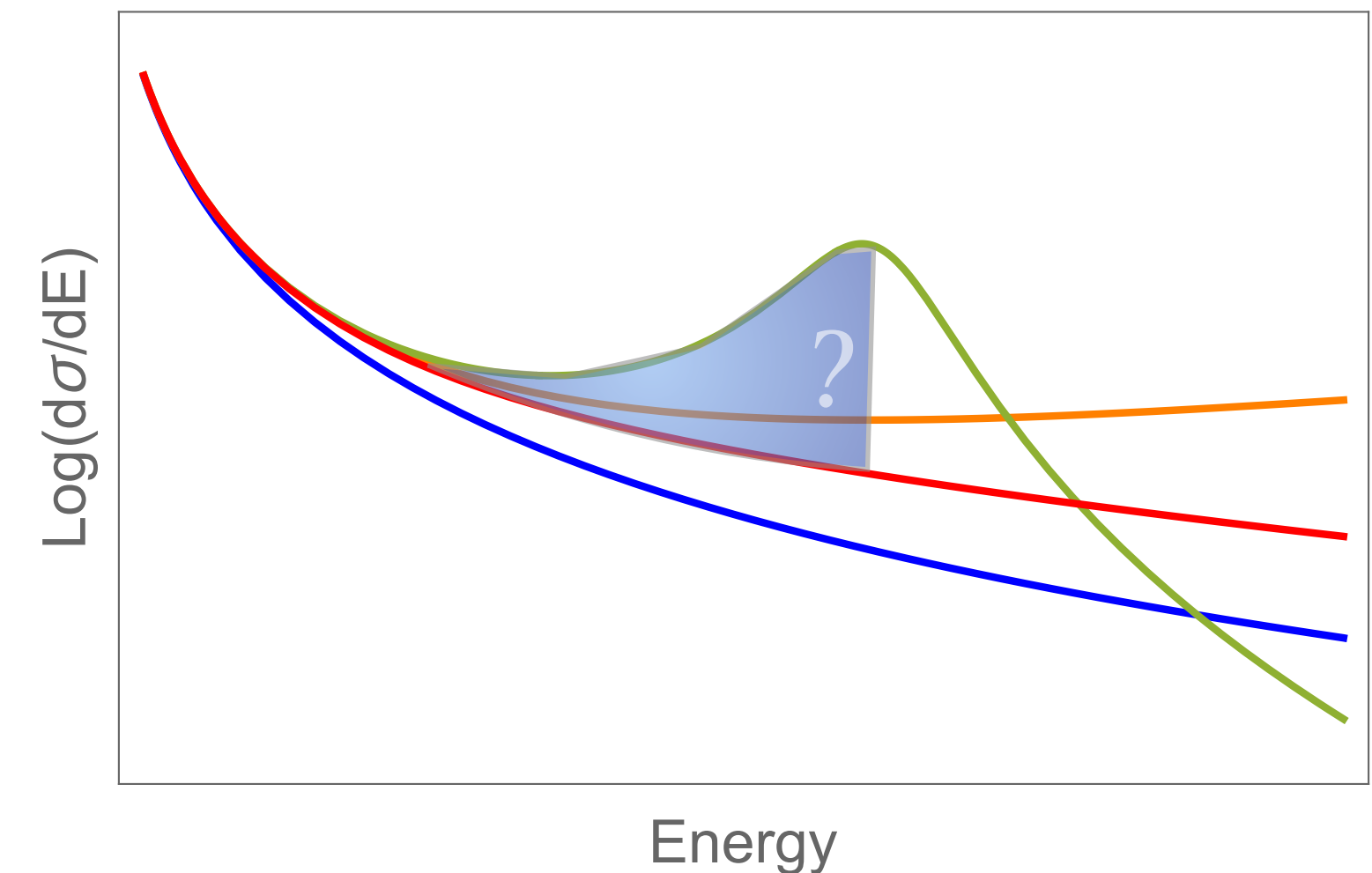
If interested in a leading order coupling $G_{\mathcal{O}}$, profile over the higher order c 's as nuisance parameters, by maximizing likelihood

Prior: c 's have a Gaussian prior centered around zero with std. dev. = 3 to prevent unnaturally large coefficients

We are trying to be agnostic in model-space within reason, to give a **conservative** limit, so that the EFT bounds are indeed model-independent

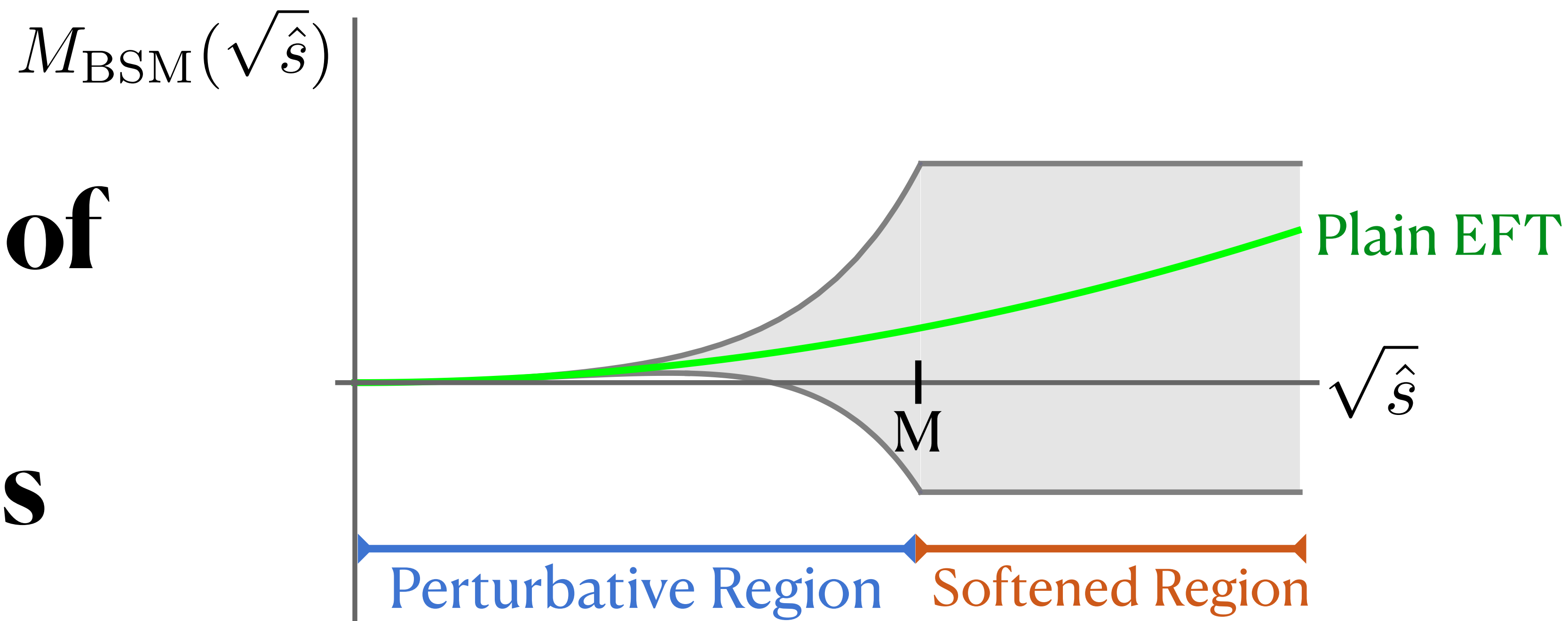
$E > M$: Form factors to soften amplitudes

Above M , EFT perturbative expansion
breaks down
(theory justification: for resonances,
amplitude is non-analytic above M)



We conservatively choose to soften the amplitude's energy growth, so that it is unitary. For 2 to 2 scattering, this requires the amplitude to go to a constant.

Illustration of Our EFT amplitudes



Generic
model

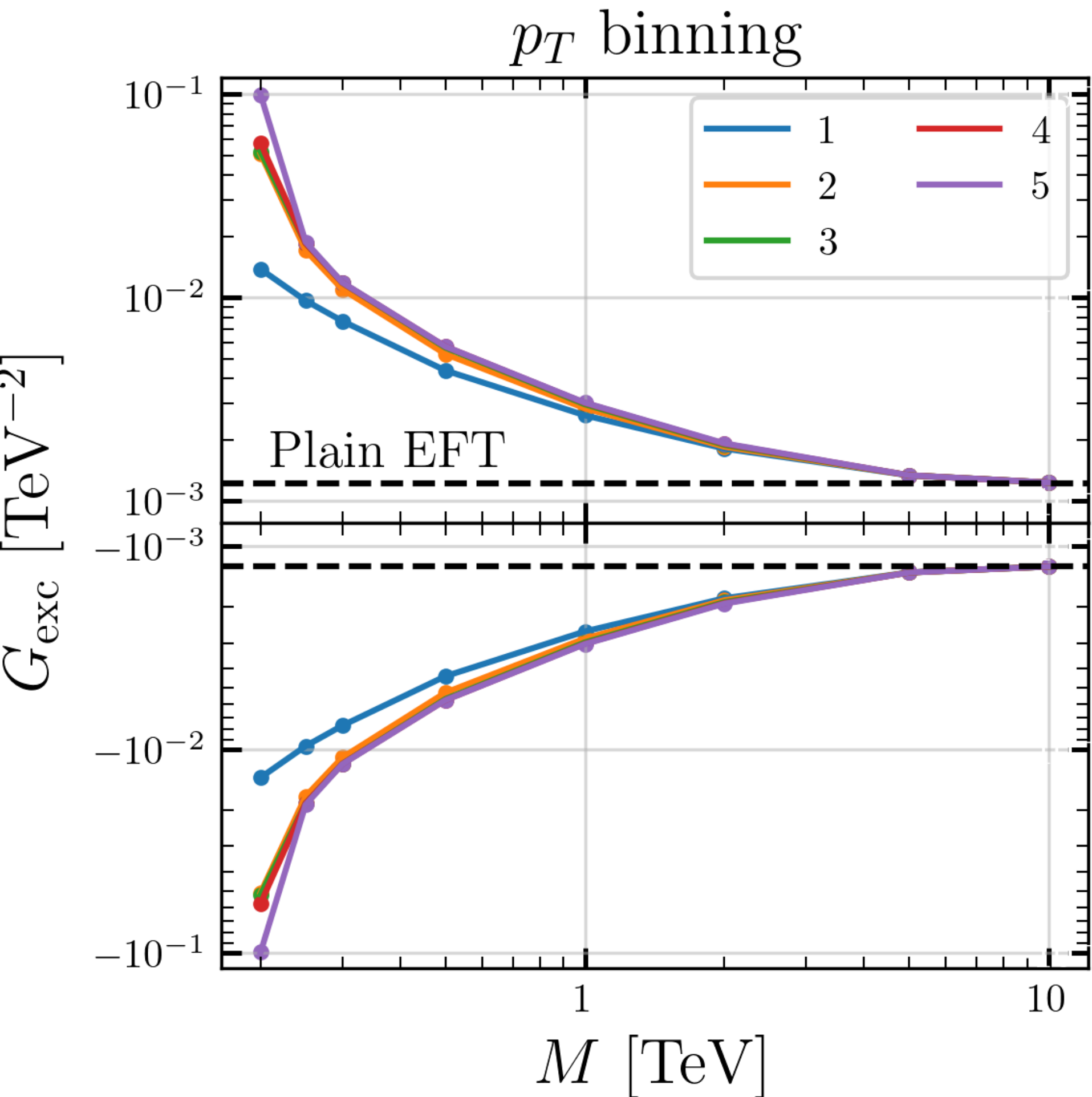
$$\mathcal{M}_{\text{BSM}}(12 \rightarrow 34) = \sum_{\mathcal{O}} G_{\mathcal{O}} \mathcal{M}_{\mathcal{O}} \left[1 + c_{\mathcal{O},1} \frac{\hat{s}}{M^2} + c_{\mathcal{O},2} \frac{\hat{t}}{M^2} + c_{\mathcal{O},3} \frac{\hat{s}^2}{M^4} + \dots \right]$$

$$\leadsto \hat{s} \rightarrow M^2 F(\hat{s}/M^2), \hat{t} \rightarrow M^2 F(\hat{t}/M^2), \hat{u} \rightarrow M^2 F(\hat{u}/M^2)$$

Note: ~ see paper for details
e.g. simple to implement using reweighing

$$F(x) = \begin{cases} x & |x| \leq 1, \\ \text{sign}(x) & |x| \geq 1. \end{cases}$$

Example Toy Model Analysis: QED, QCD, but no W, Z



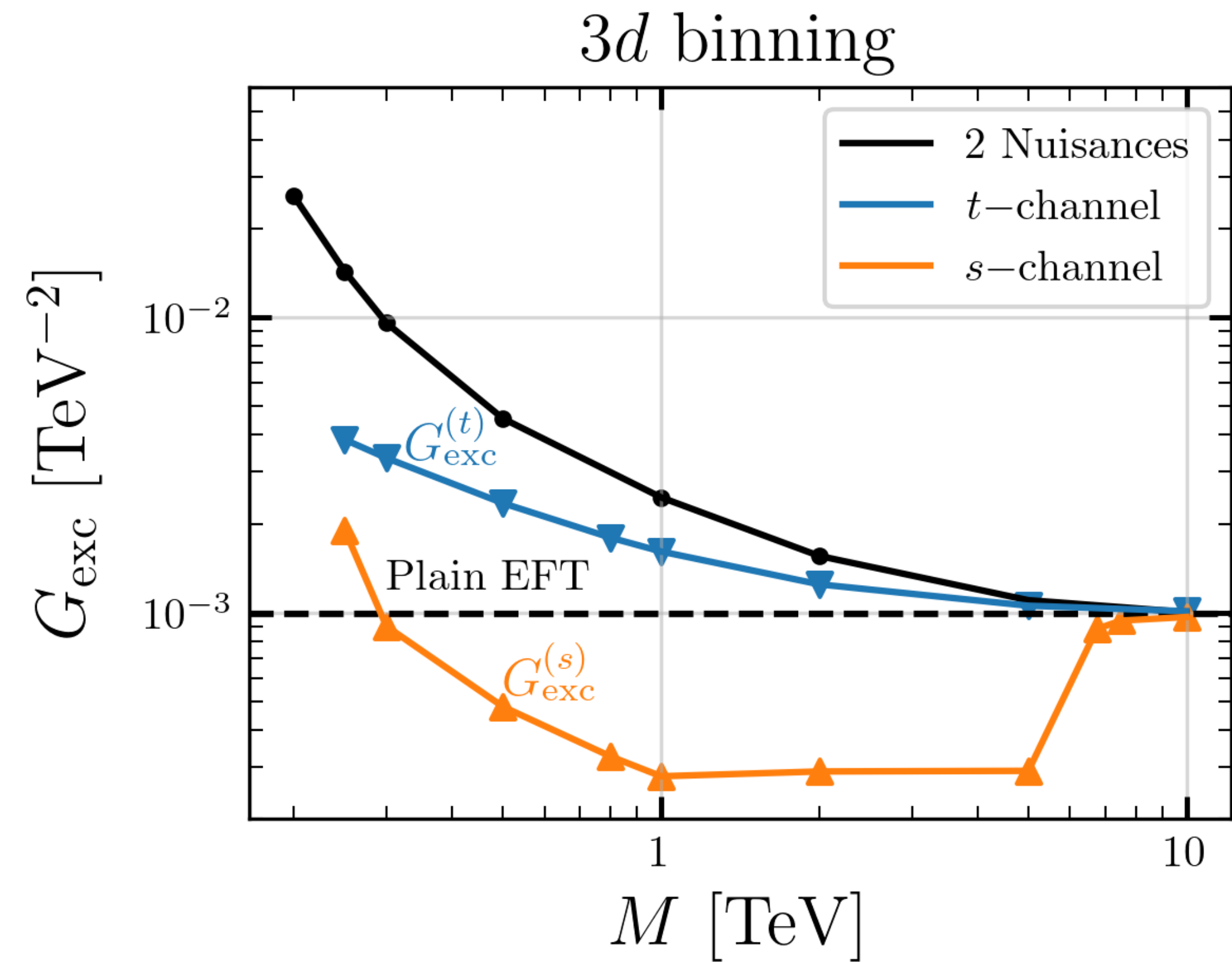
$pp \rightarrow ee$, 13 TeV, 3 ab^{-1}
 95% CL bound, no excess

$$\mathcal{L}_{\text{EFT}} = -G(\bar{u}_L \gamma_\mu u_L)(\bar{e}_R \gamma^\mu e_R)$$

Plot shows “Plain” EFT bound (dashed),
 as well as our bound as a f’n of M ,
 with increasing nuisance parameters (solid)

- 1) Our bound is always weaker than plain EFT agreeing at large M
- 2) Our bound gets weaker with lower M , since predictive region smaller
- 3) Our bound at given M converges with only a few nuisance parameters

Bound comparison to UV model bounds



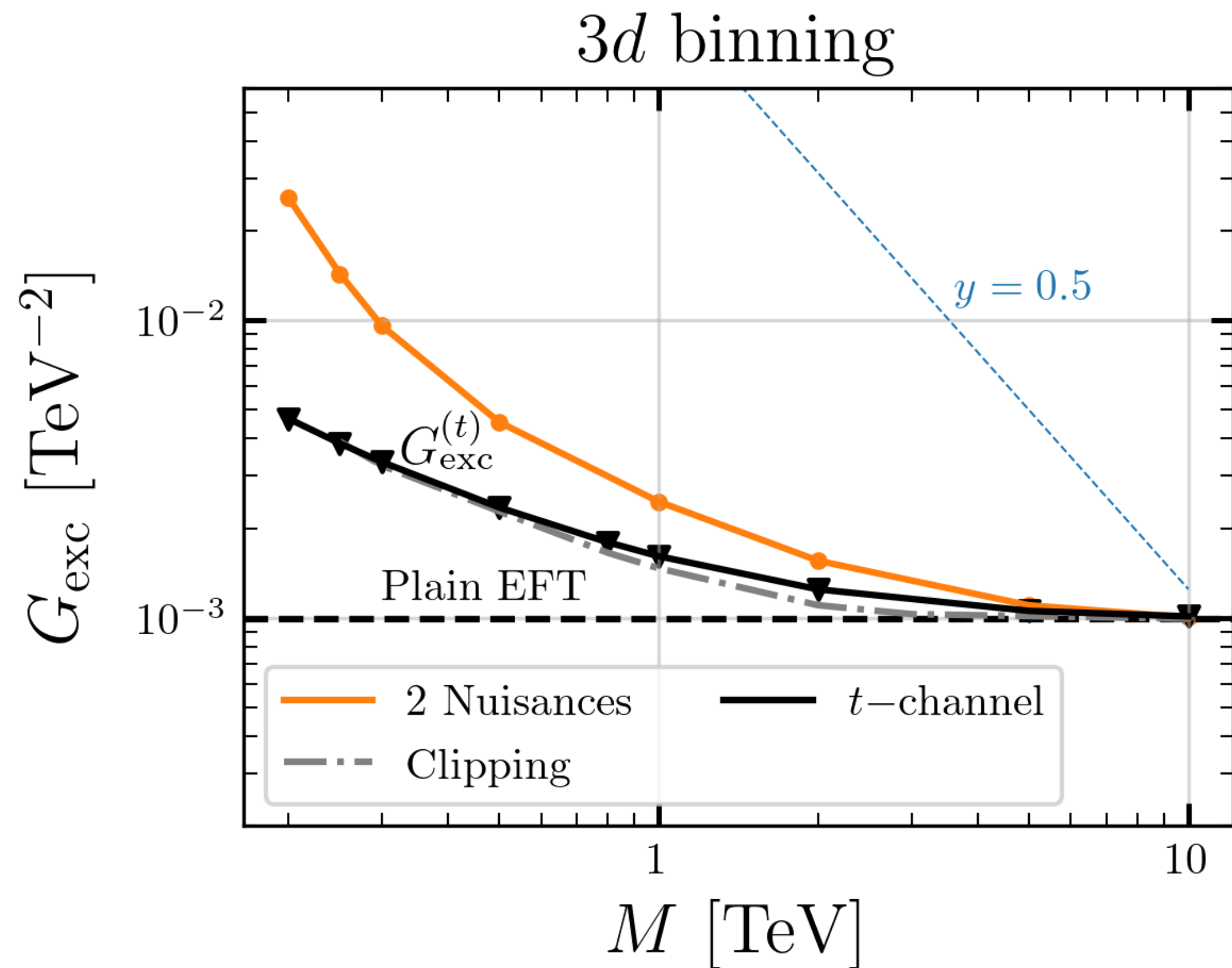
$$\mathcal{L}_{\text{EFT}} = -G(\bar{u}_L \gamma_\mu u_L)(\bar{e}_R \gamma^\mu e_R)$$

Comparison of bounds: ours (black), plain EFT (dashed), t -channel (blue), s -channel (orange)

- 1) Our bound is weaker than s or t -channel model identifying M with resonance mass
- 2) Plain EFT gives stronger bound than t -channel model over the entire range (and s -channel for very low mass)

$pp \rightarrow ee$, 13 TeV, 3 ab^{-1}
 95% CL bound, no excess

Comparison to Clipping approach



$pp \rightarrow ee$, 13 TeV, 3 ab^{-1}
 95% CL bound, no excess

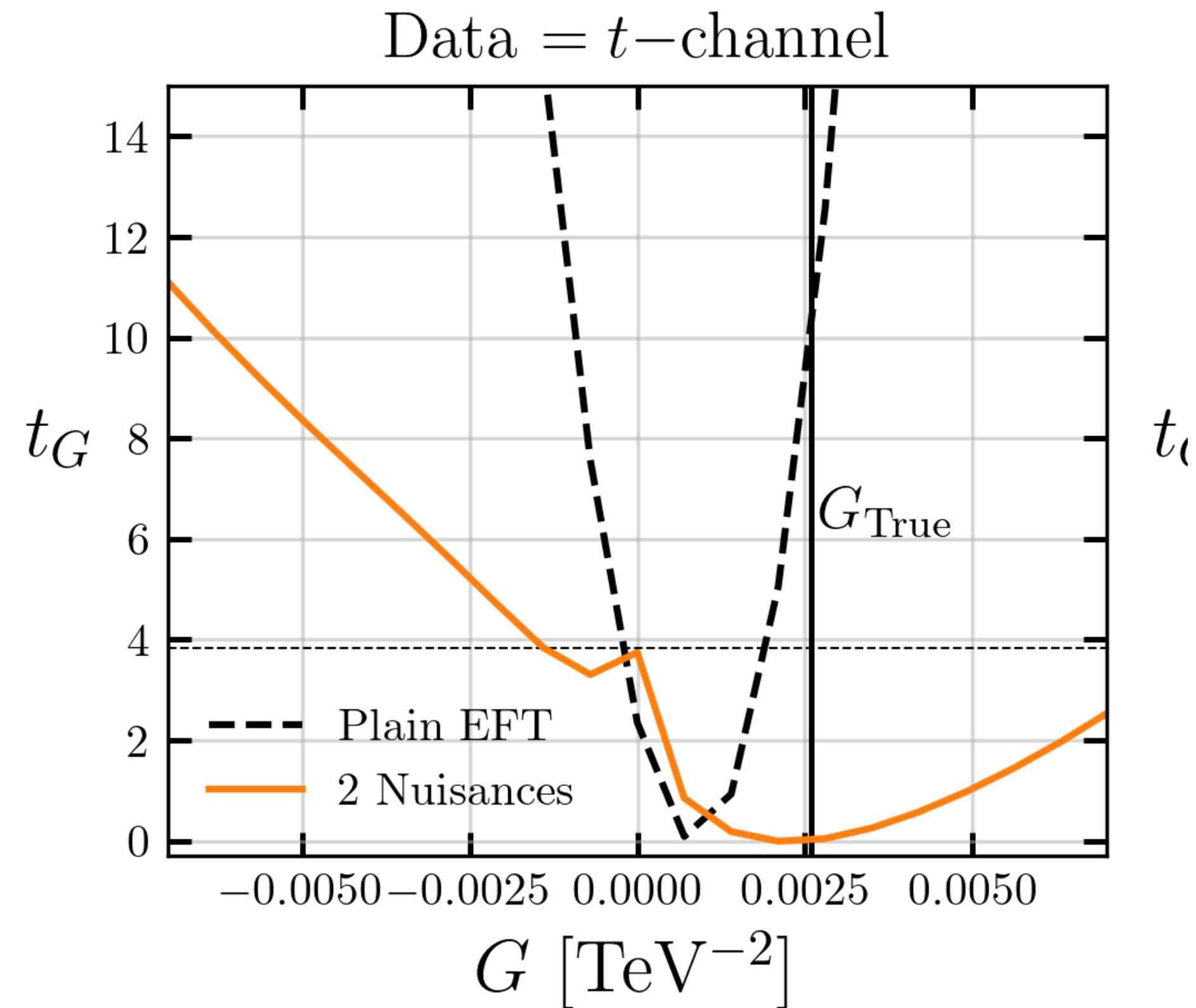
$$\mathcal{L}_{\text{EFT}} = -G(\bar{u}_L \gamma_\mu u_L)(\bar{e}_R \gamma^\mu e_R)$$

Clipping for events $E > M$ (dot-dashed)
 ours (orange), t -channel (black)

Identifying clipping scale M to resonance mass, clipping gives too strong a bound

In UV models, must have some theory uncertainties below M , clipping assumes that leading order is perfect up to M , so this is a process-dependent value

What about excesses?



pp → ee, 13 TeV, 3 ab⁻¹
 95% CL bound, t-channel
model assumed in data

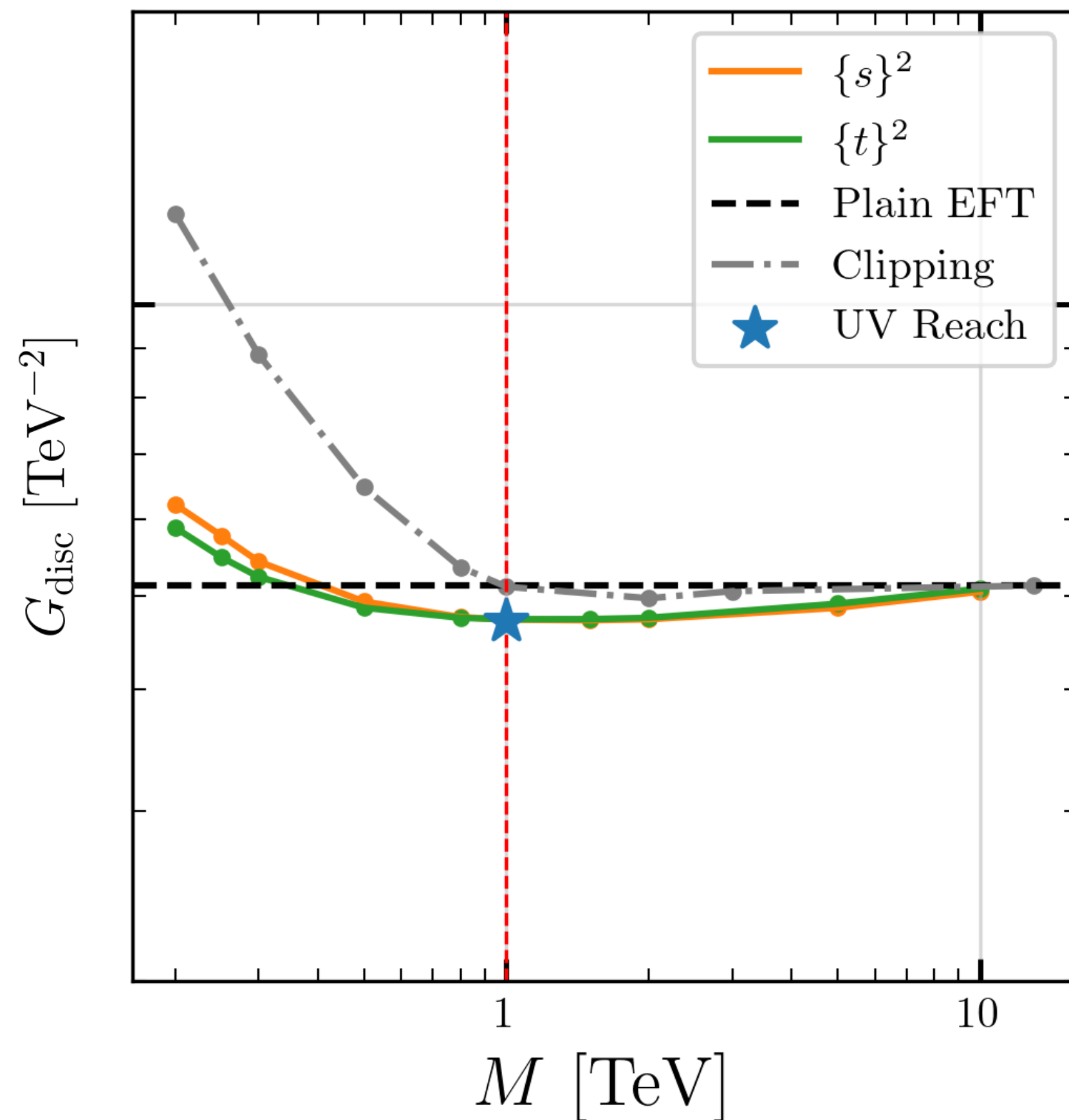
$$\mathcal{L}_{\text{EFT}} = -G(\bar{u}_L \gamma_\mu u_L)(\bar{e}_R \gamma^\mu e_R)$$

For t -channel exchange, our nuisances can fit the signal well, unlike plain EFT which excludes injected signal

For our bound, the test statistic is minimized near true coupling and constrains the SM at 2sigma

What about discoveries?

$$\mathcal{L}_{\text{EFT}} = -G(\bar{u}_L \gamma_\mu u_L)(\bar{e}_R \gamma^\mu e_R)$$



- 1) Plain EFT needs larger coupling to discover UV model, since it fits poorly
- 2) Clipping needs larger coupling since it throws away data that has manageable uncertainties
- 3) Our method appears to agree with the UV reach with the true coupling used in data

$pp \rightarrow ee$, 13 TeV, 3 ab^{-1}
95% CL bound, t-channel
model resonance fixed at 1 TeV

ATLAS approach

unitarity in the underlying quantum field theory. Following recommendations from the LHC EFT Working Group [117], confidence intervals are also derived as a function of an upper energy cut-off on the SMEFT contributions. The diboson invariant mass m_{WZ} , which represents to a good approximation the total energy of the interaction per event, is used to remove the SMEFT events at particle-level predicted above a certain threshold. Confidence intervals were derived for cut-off values of 1 TeV, 1.5 TeV and above.

Table 6: Evolution of the expected 95% CL intervals on CP-even c_W/Λ^2 and $c_{Hq}^{(3)}/\Lambda^2$ Wilson coefficients as a function of an upper energy cut-off on m_{WZ} in the SMEFT contribution. Limits are presented considering both the linear and quadratic contributions. Only one Wilson coefficient is permitted to vary from zero at a time.

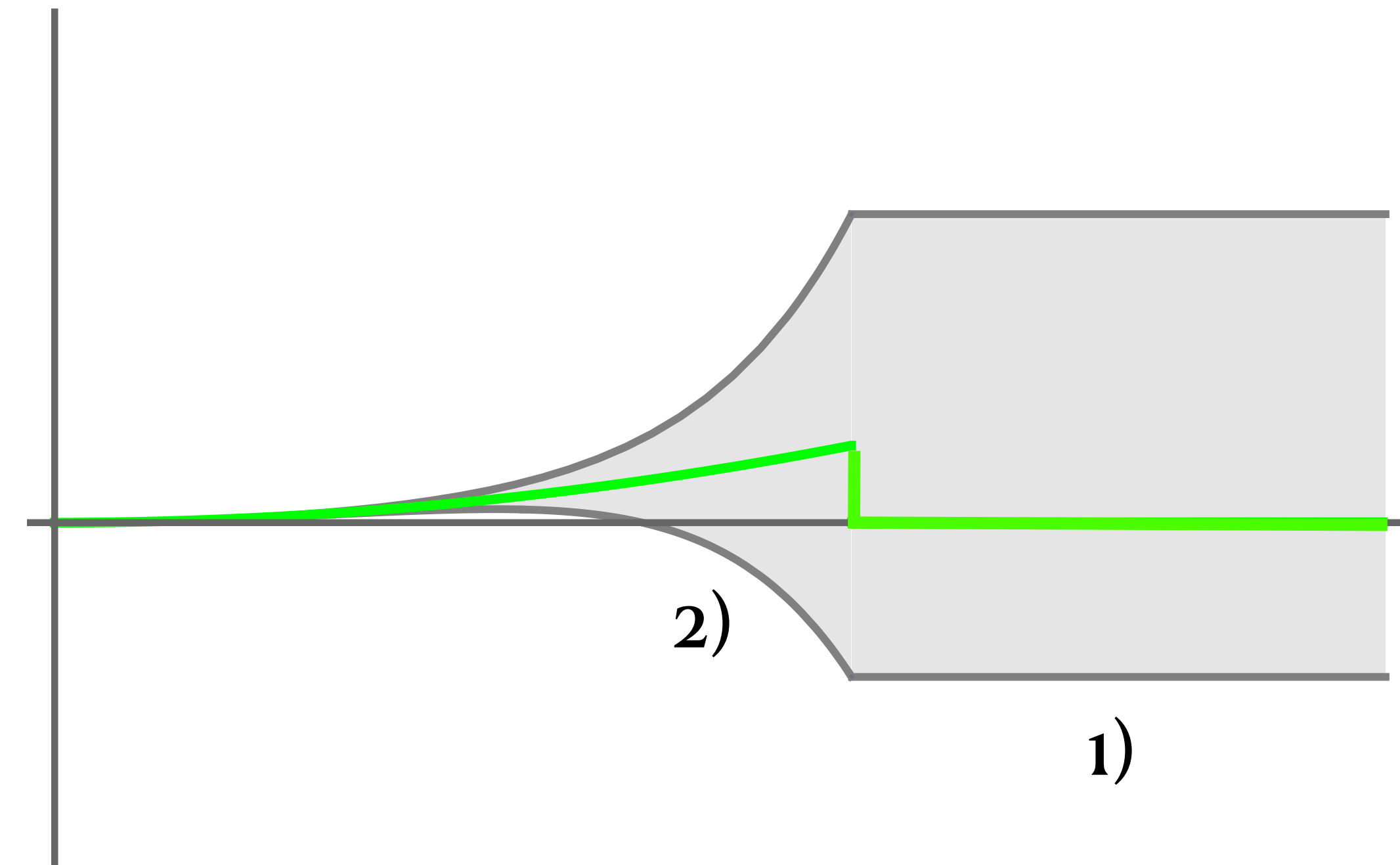
	Cut-off value on m_{WZ} [GeV]		
	1000	1500	no cut-off
c_W/Λ^2 [TeV ⁻²]	[-0.236, 0.208]	[-0.143, 0.130]	[-0.103, 0.095]
$c_{Hq}^{(3)}/\Lambda^2$ [TeV ⁻²]	[-0.286, 0.119]	[-0.195, 0.086]	[-0.145, 0.074]

Thoughts

- 1) Sharp cutoff seems unphysical, would limits change if it went to a constant?
- 2) How much would limits weaken if nuisances were added?
- 3) Use more cut-off values?

Measurements and interpretations of $W^\pm Z$ production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration



Conclusion of my work

- Our proposal is a feasible method to give conservative model-independent EFT constraints
- Need to specify scale M of new physics, extremize over subleading corrections,
- Method can find some excesses: Non-resonant behavior can be fit by model

Discussion Items

- Let's make our assumptions explicit, so that we can argue for ones we can agree upon
- What type of uncertainties should we take into account?
- What statistical procedure should we use to address them?
- Are the proposals easy to implement by experimentalists and to interpret by theorists?
- Can we find a compromise that we can all be happy with?

Type of Uncertainties to Address

- Mandelstam descendants? (to what order?)
- SMEFT specific?
 - Dim 8 as nuisances to dim 6 (Boughezhal et.al., Wilsch et.al., ...)
 - $|M_6|^2$ as way to parameterize/estimate dim 8 (Shepherd et.al.)
- Experimental Uncertainty Tests?: Data clipping (Farina et.al.)
- What is the operator dimension “light cone” we want to explore (and is it SMEFT/HEFT dependent)?

Statistical Procedure

- Prior on nuisance parameters (how to set it? Gaussian, flat, etc...)
- Profile or marginalize?
- Should we recommend more than one scheme (similar to PDG)?
- Provide likelihood so correlations can be utilized in combinations?

Implementable/Utility

- Are our theory priors preventing experimental analyses?
- Do we want strongest bounds or should we be more conservative? (In tension w/ model-independence?)
- How do we make nuisance parameters usable in a specific analysis (e.g. database)? For a global analysis (more bookkeeping)?
- Can theorists utilize the results (ala EWPO post-LEP)?

Can we find a compromise we are happy with?

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March 1, 2027

LHC EFT WG note.⁺⁺ Truncation, validity, uncertainties

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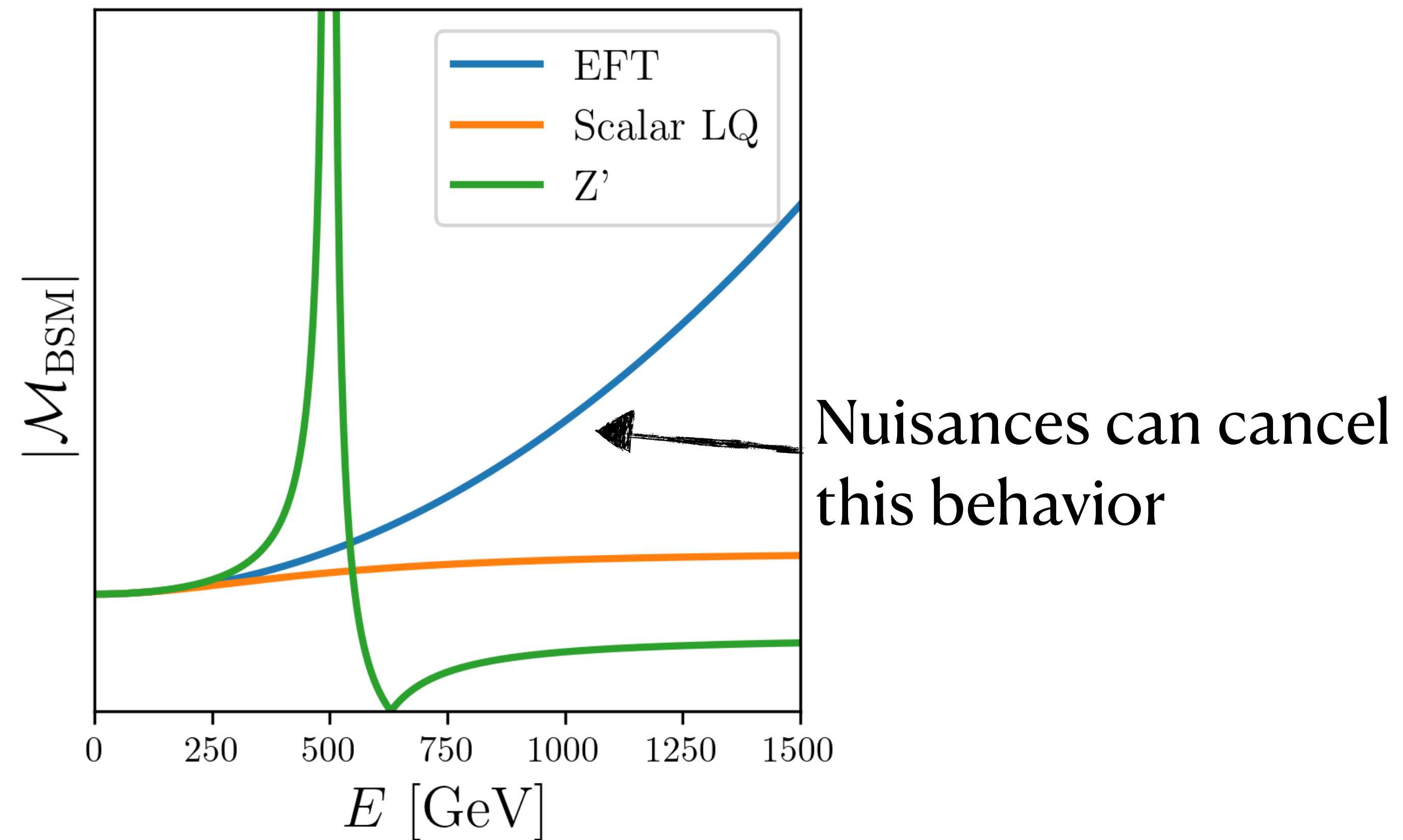


We can do this!
Thanks for your time...

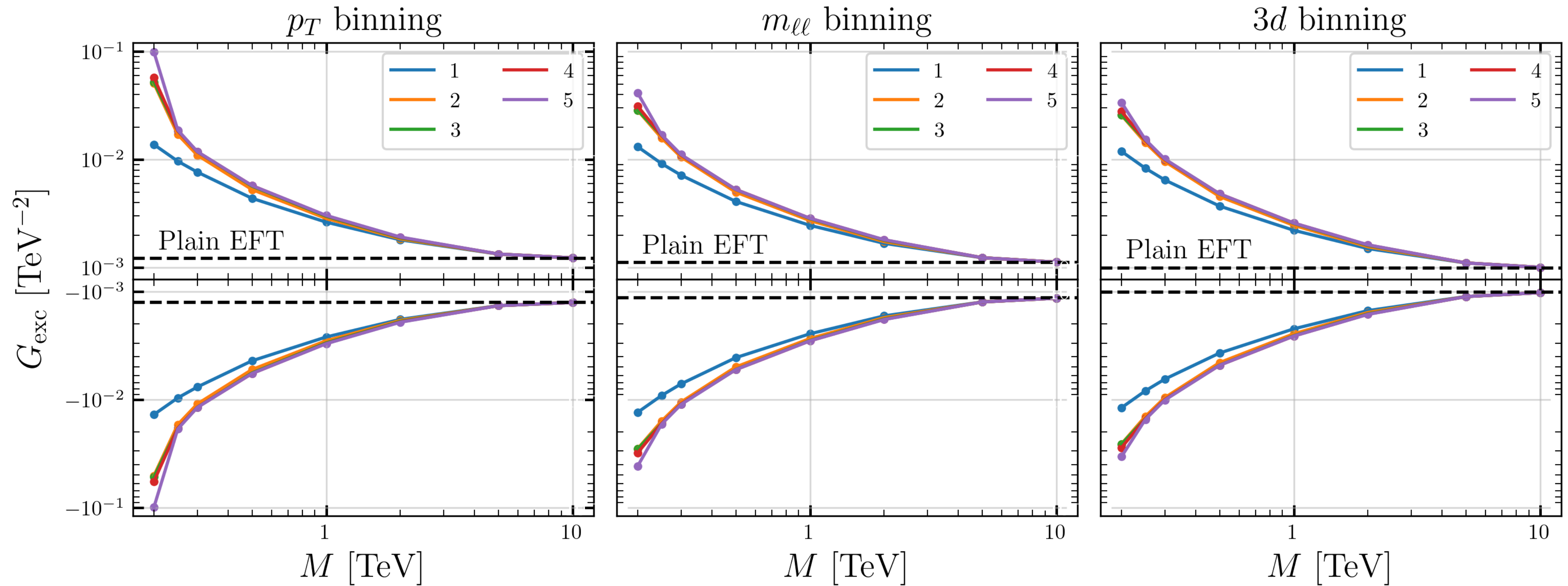
chang2@uoregon.edu

Extra Slides

EFT Amplitude for “plain” and UV models

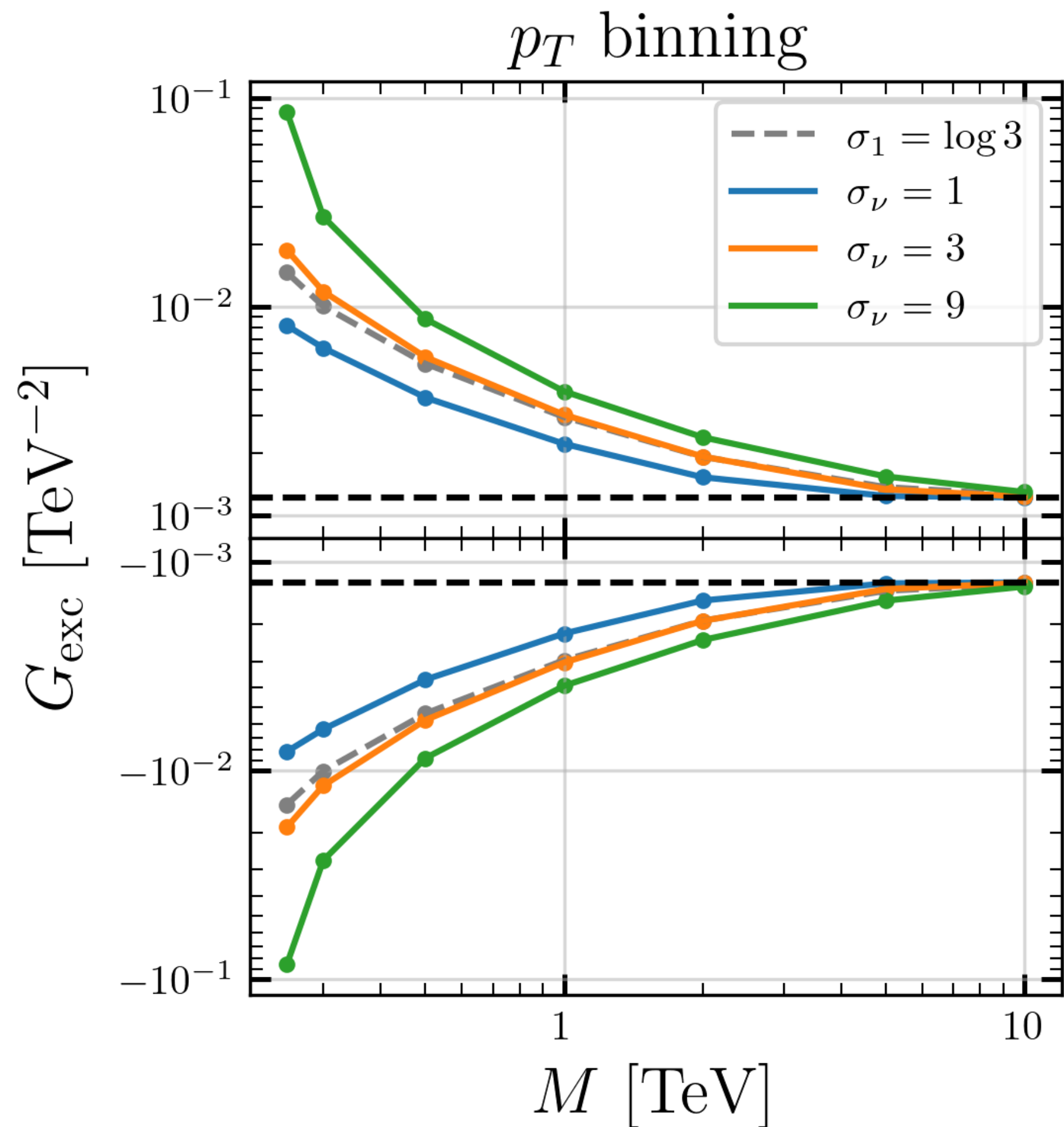


Can be applied to different binning



Multi-variate analysis possible, but only need one universal parameter allowing combination of results

Effect of Prior



Increasing allowed size of c 's weakens the bound

Could also consider prior on c 's that penalizes small values (no fine-tuning)

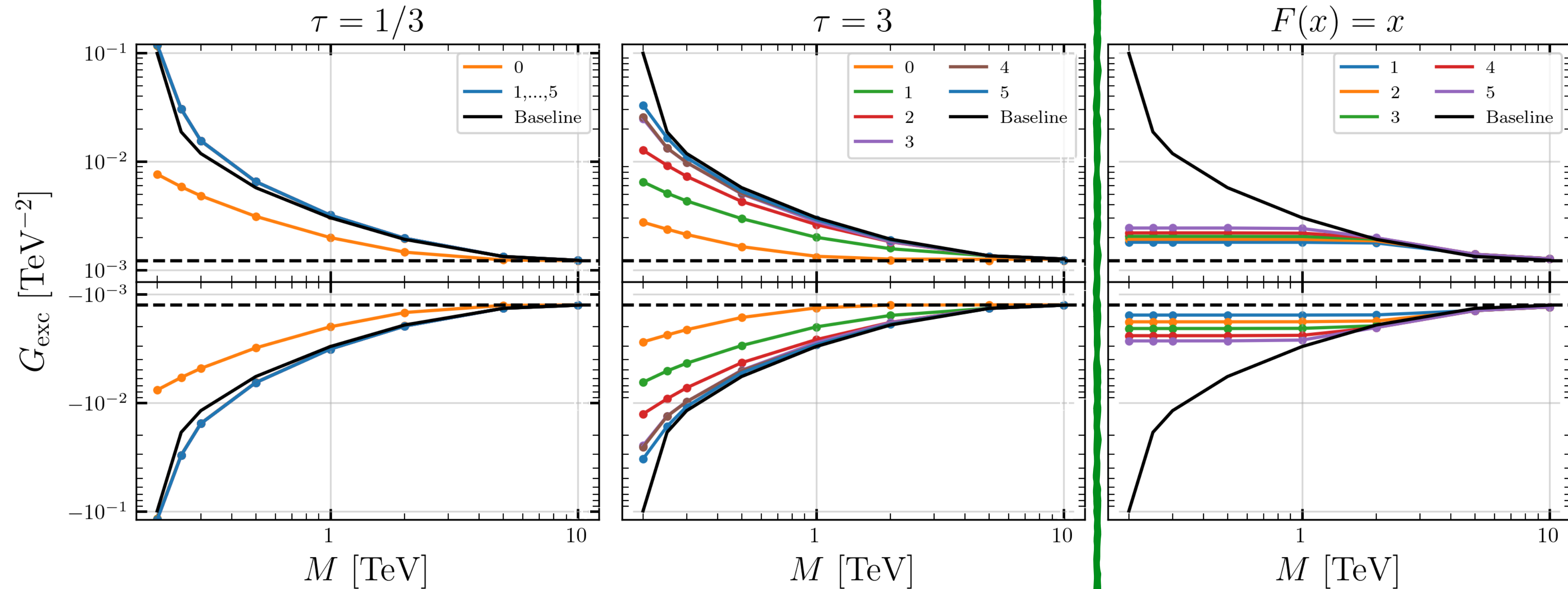
Adaptable to different physical assumptions

Effect of Form Factor

Changing where amplitude softening leads to faster or slower convergence

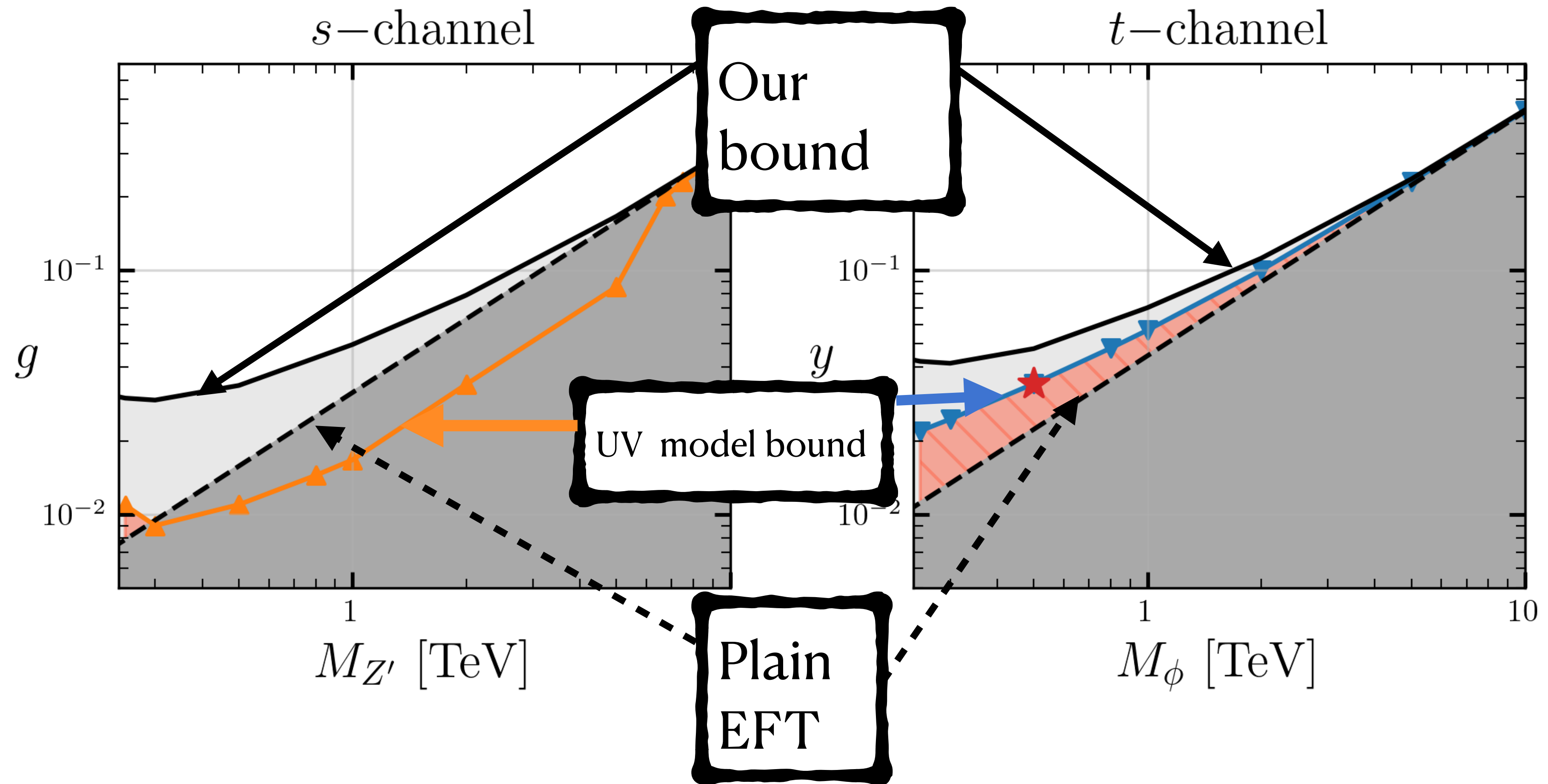
$$F_{\tau}(x) = \begin{cases} x & |x| < \tau, \\ \tau \operatorname{sign}(x) & |x| \geq \tau. \end{cases}$$

Having no amplitude softening for $E > M$, leads to unphysical saturation of bound for low M

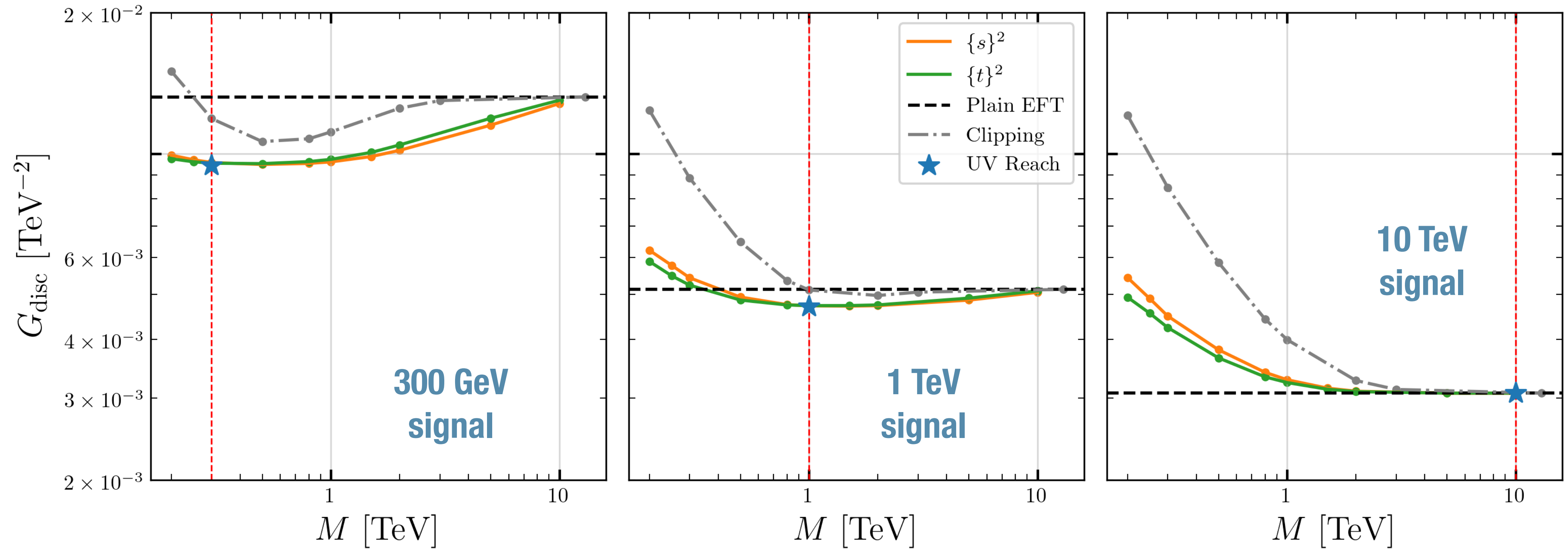


UV Model Parameter Space

Plain EFT isn't model-indpt in
red shaded
regions



Coupling for 5 sigma discovery



Our method requires the same coupling size as the UV model for discovery when M is the mass of the particle