Robust Collider Limits on heavy-mediator DM

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Introduction

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Enormous variety of radically different scenarios, extremely challenging to setup a comprehensive exploration strategy

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Model-independence, i.e. broad exploration of the parameter space is mandatory here!

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DM to SM from high scale dynamics

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- 1) thermal relic calculation
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- 3) indirect search limits

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what instead about …

4) collider limits ??

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Cutoff is part of the EFT definition, one of its free parameters.
In any specific microscopic model, we might read its true value

$$M_{\rm cut} \sim M_{\rm Med}$$

mass of the specific "mediators", or scale of strong UV theory

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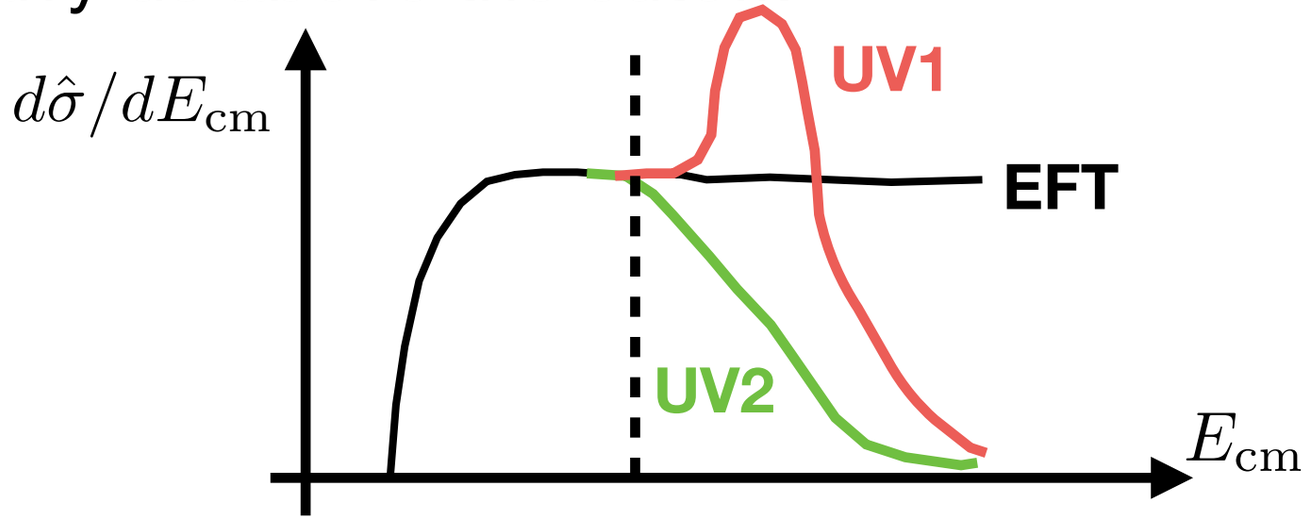
LHC might carry us above the cutoff:



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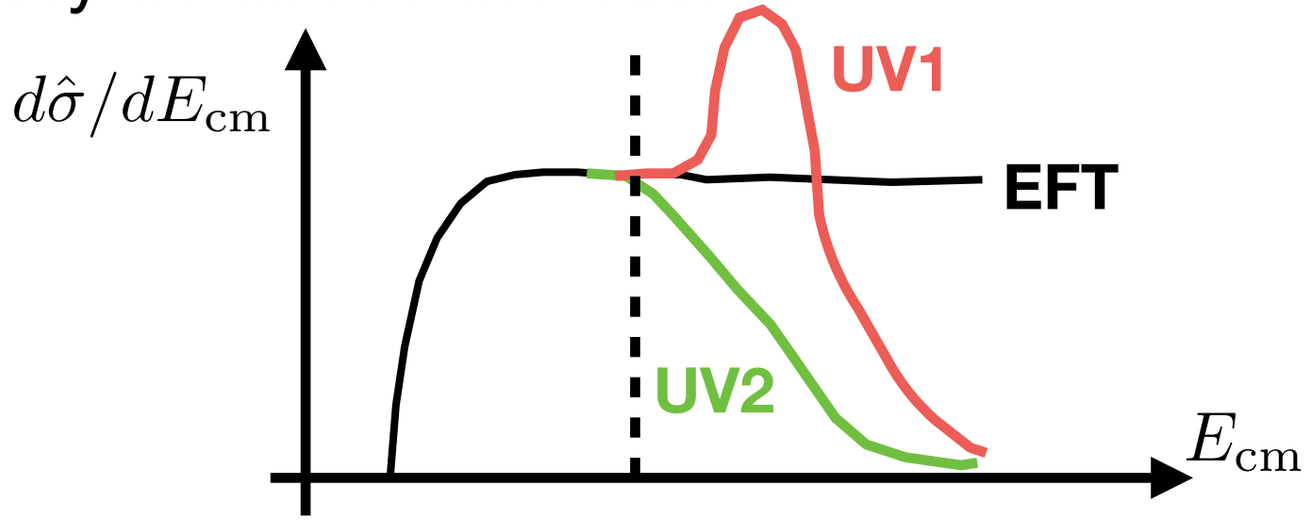

however restricting the signal to the predictable region sets lower bound on the “true” signal, which holds for any mediator model

$$\sigma^S_{EFT}\Big|_{E_{\rm cm}<M_{\rm cut}} \leq \sigma^S_{\rm true} < \sigma_{\rm exc}$$

compared with exclusion upper bound, model indep. limit is set

ATLAS mono-jet recast

chosen operator: $$\mathcal{L}_{\rm int} = -\frac{1}{M_*^2}\,(\overline{X}\gamma^\mu\gamma^5 X)\left(\sum_q \overline{q}\gamma_\mu\gamma^5 q\right)$$

counting in four SR

signal region	SR1	SR2	SR3	SR4
$p_T^{\rm jet}$ and MET	>120	>220	>350	>500
$\sigma_{\rm exc}$[pb]	2.7	0.15	$4.8\,10^{-2}$	$1.5\,10^{-2}$

restricted signal definition:

$$\sigma_{{\rm SR}i}(M_*, m_{DM}, M_{\rm cut}) = \sigma(M_*, m_{DM}, M_{\rm cut}) \times A_i(m_{DM}, M_{\rm cut}) \times \epsilon$$

NOTE: the EFT has **three** parameters

1) $m_{\rm DM}$
2) M_*
3) $M_{\rm cut}$ (as physical as the other two)

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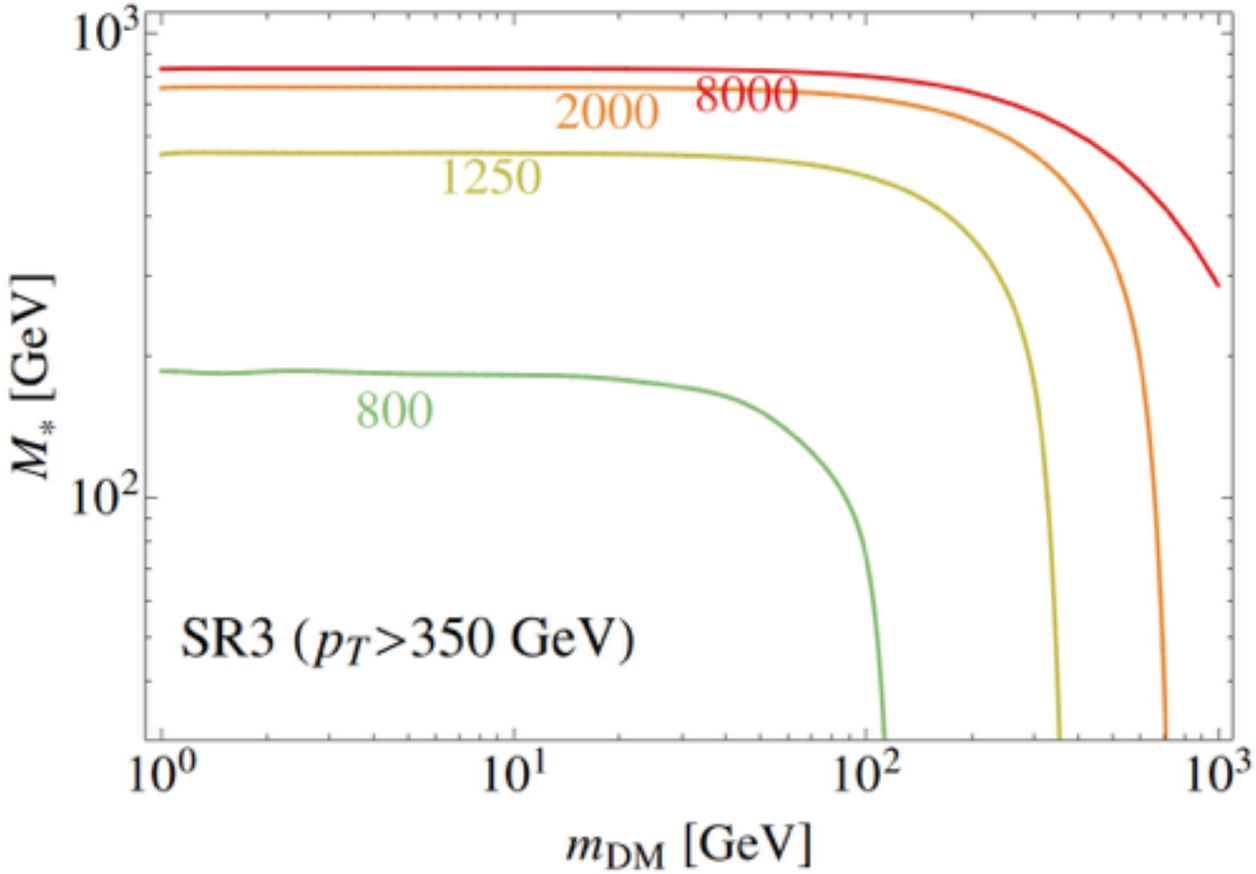
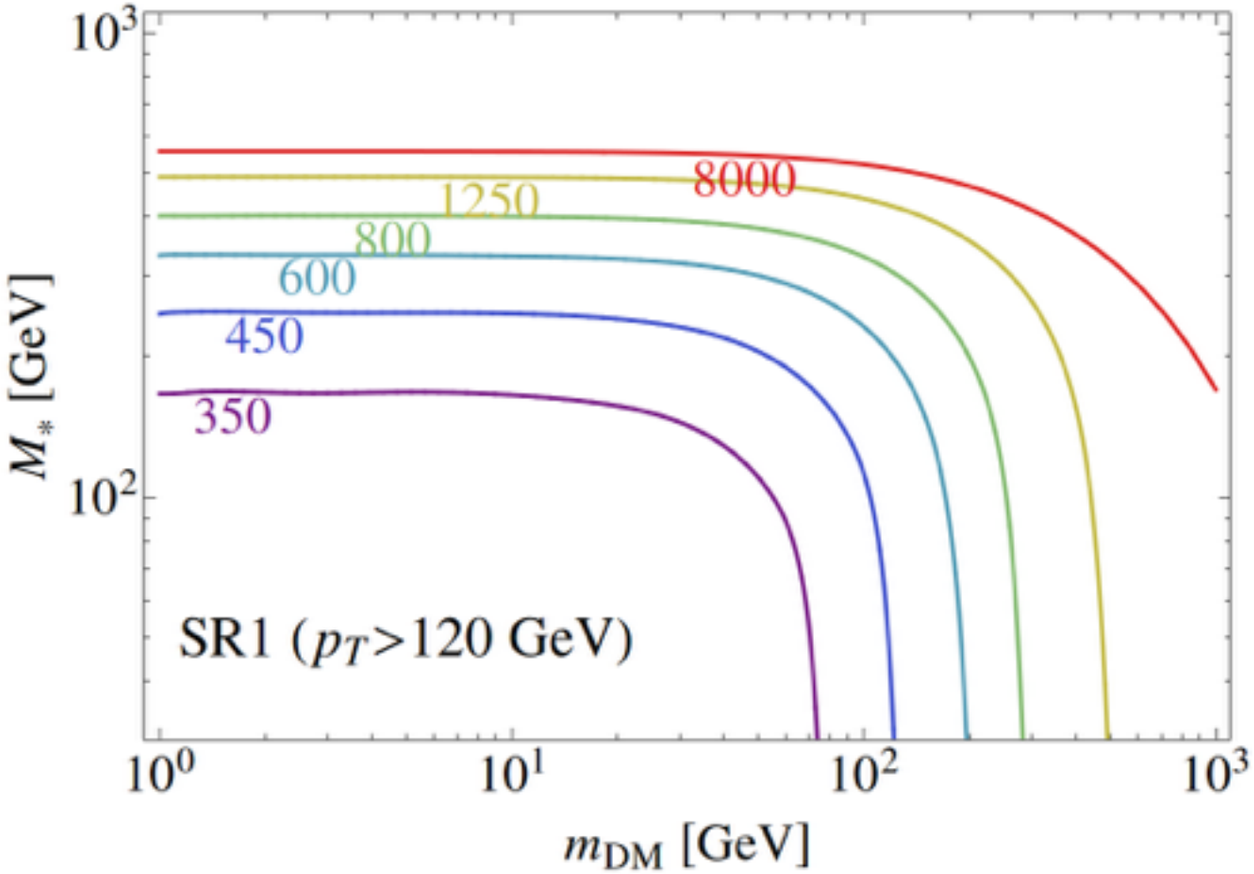
colored lines: fixed $M_{\rm cut}$





Hard signal regions are favored at high cutoff (naive EFT)

But rapidly lose sensitivity: the cut makes distributions softer

ATLAS mono-jet recast

Theoretical connection among M_* and $M_{\rm cut}$:

$$M_{\rm cut} = g_* \, M_*$$

estimated mediator coupling

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1) from examples: $\dfrac{1}{M_*^2} = \dfrac{g_*^2}{M_{\rm med}^2}$

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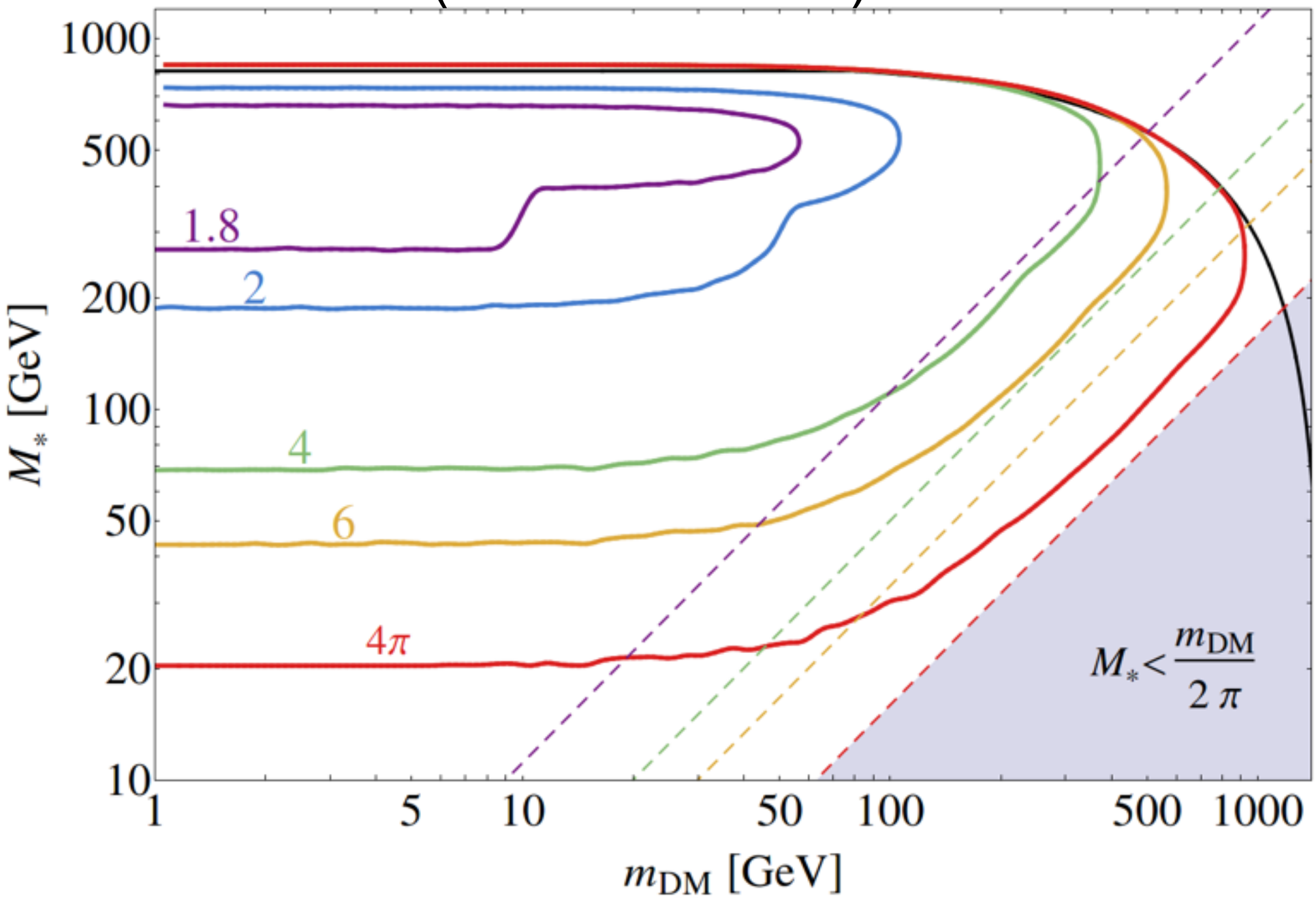
Useful redefinition:

- We know for sure that: $g_* < 4\pi$
- Expected for a WIMP: $g_* \sim 1$

ATLAS mono-jet recast

Fixed g_* limits:
(from all the SR)



Simplified models reinterpretation

Properly set EFT limits hold in any microscopic theory.
They are correct, but conservative.

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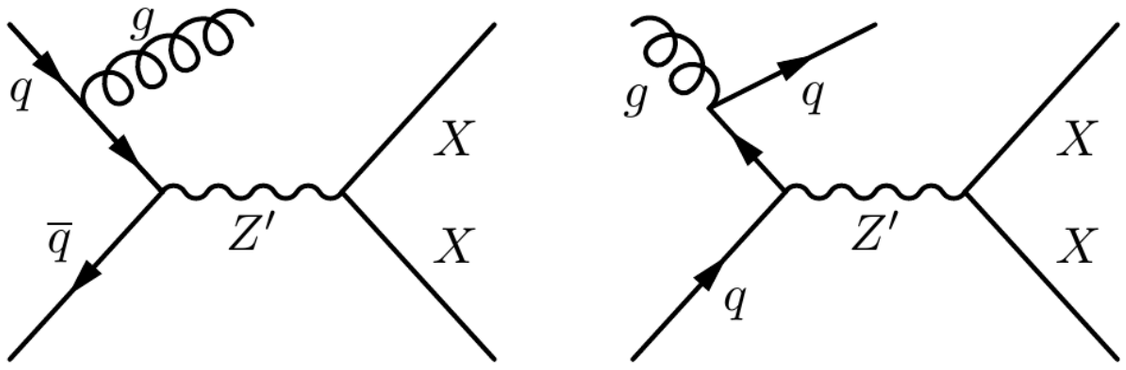
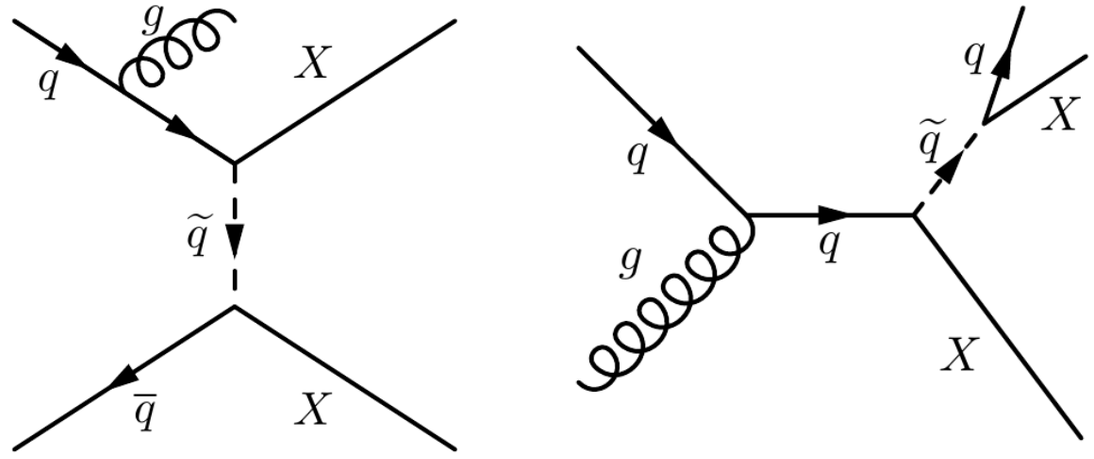


$$M_* = \frac{m_{Z'}}{\sqrt{g_q\, g_X}} \qquad g_* = \sqrt{g_q\, g_X}$$

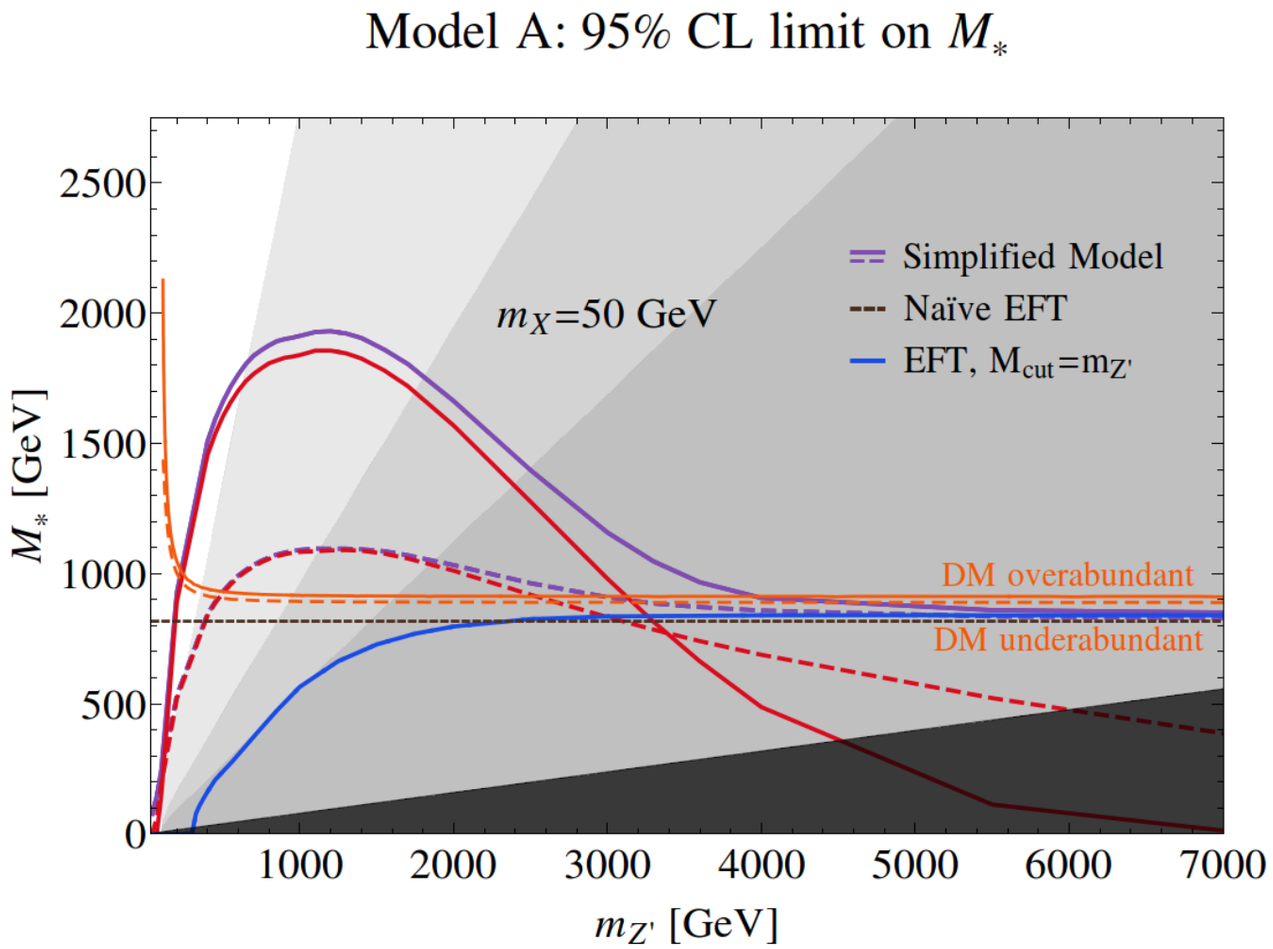
Model B: squark-DM-quark coup.

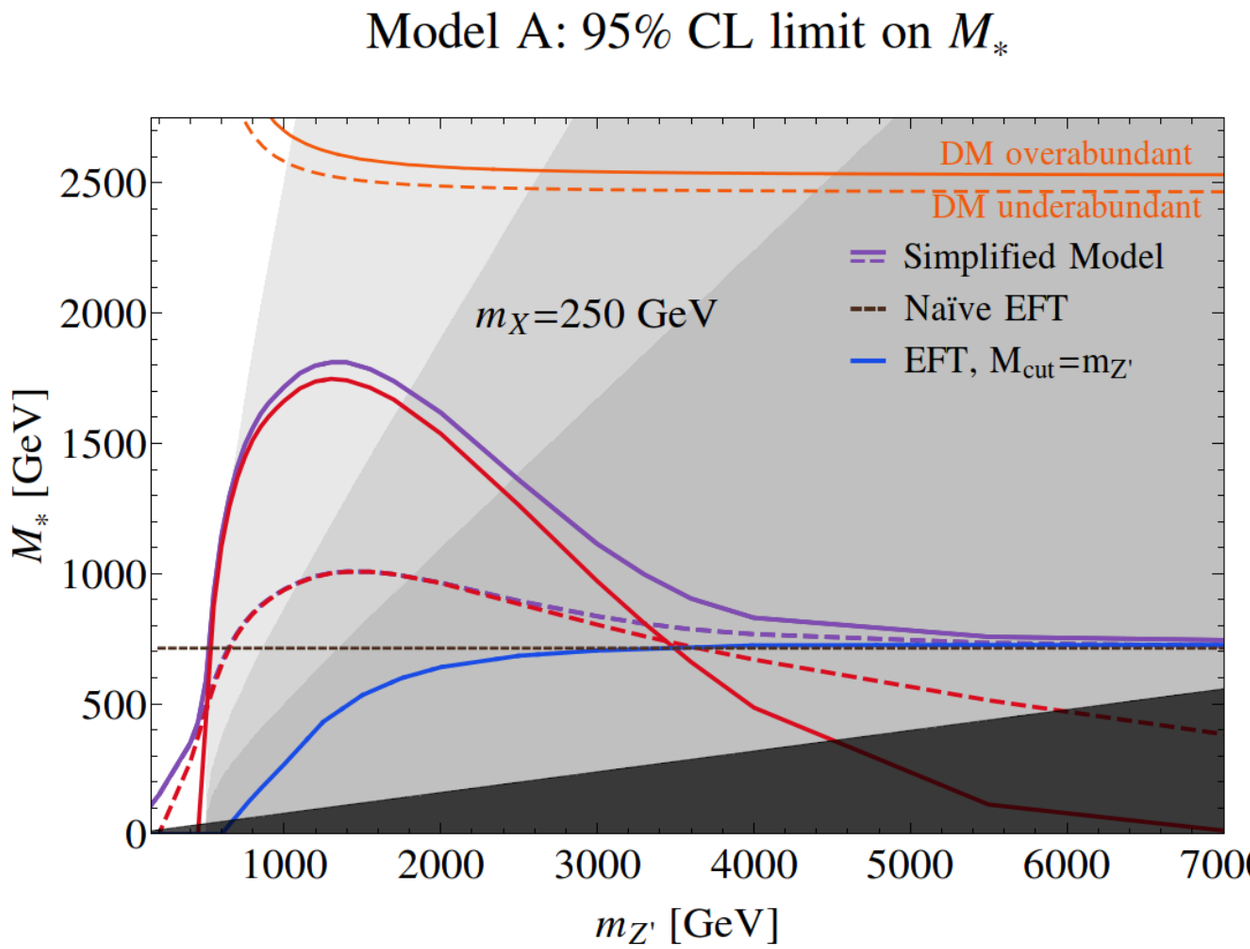


$$M_* = \frac{2\,\widetilde{m}}{g_{\mathrm{DM}}} \qquad g_* = \frac{g_{\mathrm{DM}}}{2}$$

Compute parameters, use EFT limits, obtain bounds.
Compare with direct recasting of mono-jet.

Simplified models reinterpretation





Lines for $\Gamma_{Z'}/m_{Z'} = 1/8\pi$ and $1/3$

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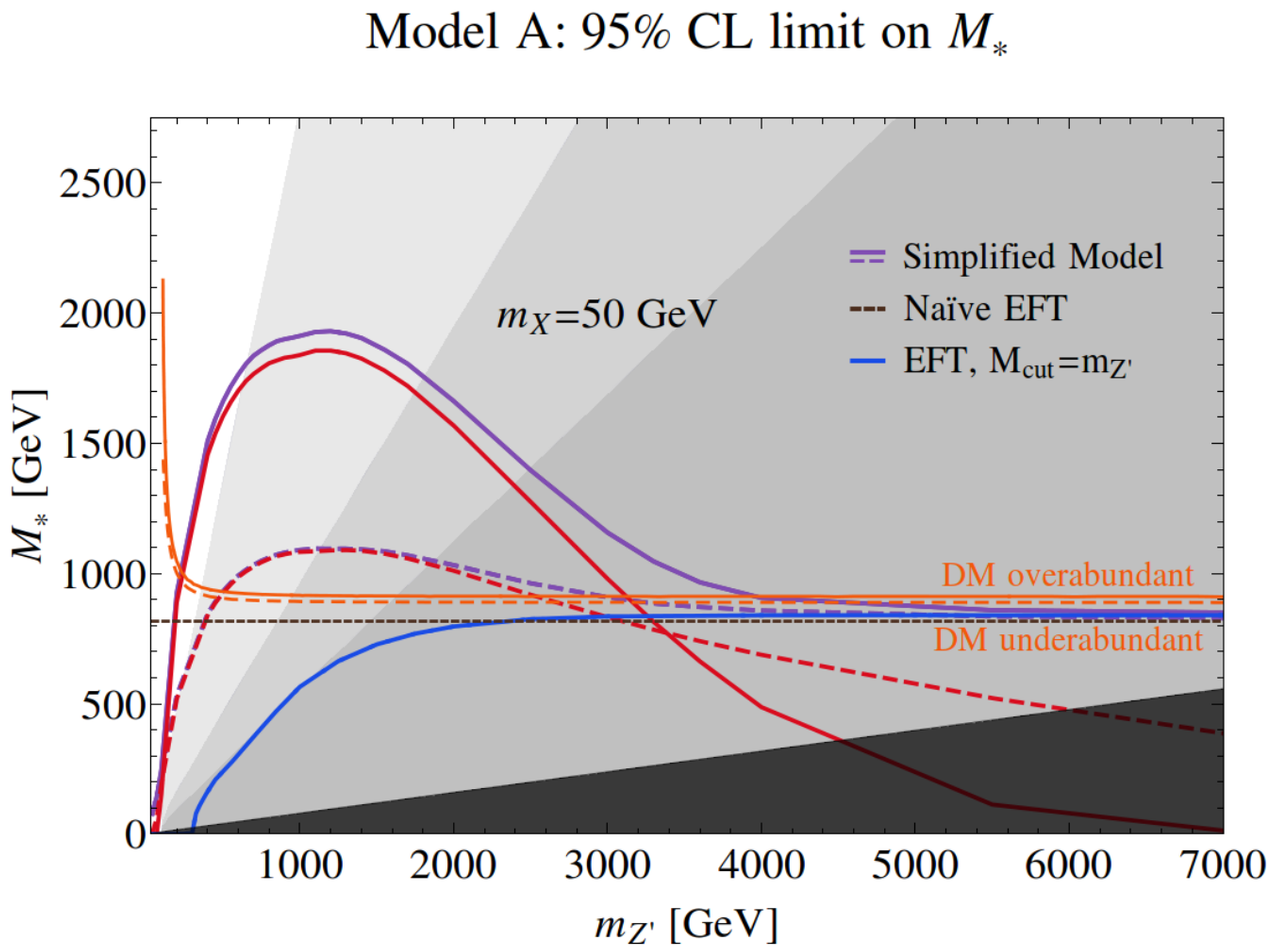

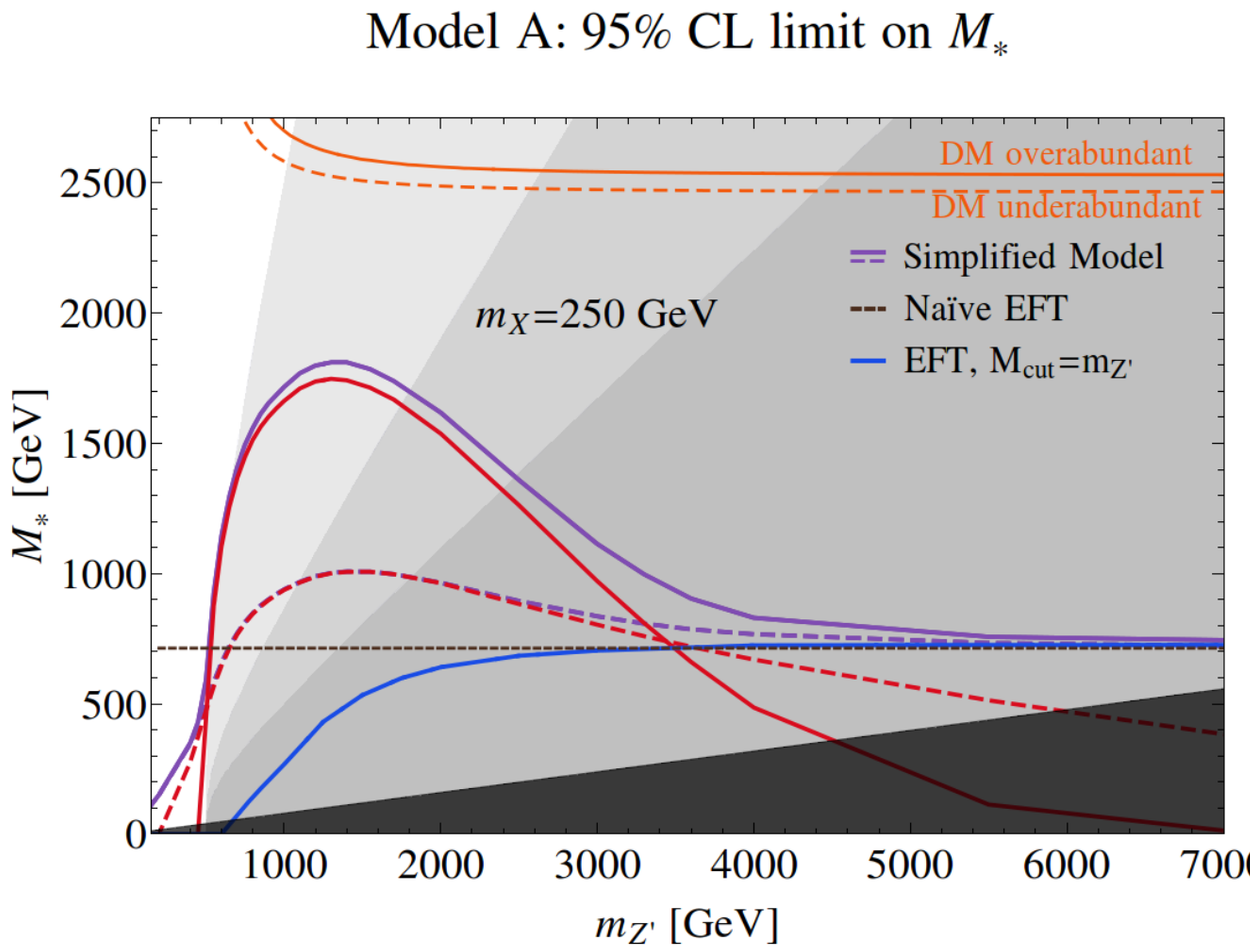

Lines for $\Gamma_{Z'}/m_{Z'} = 1/8\pi$ and $1/3$

Caution remark: most of these lines are **inconsistent**!

$$\frac{\Gamma_{Z'}}{m_{Z'}} = \alpha\, g_q^2 + \beta\, g_X^2 \geq g_q g_X \sqrt{4\alpha\beta} = \frac{m_{Z'}^2}{M_*^2}\sqrt{4\alpha\beta}\,,$$

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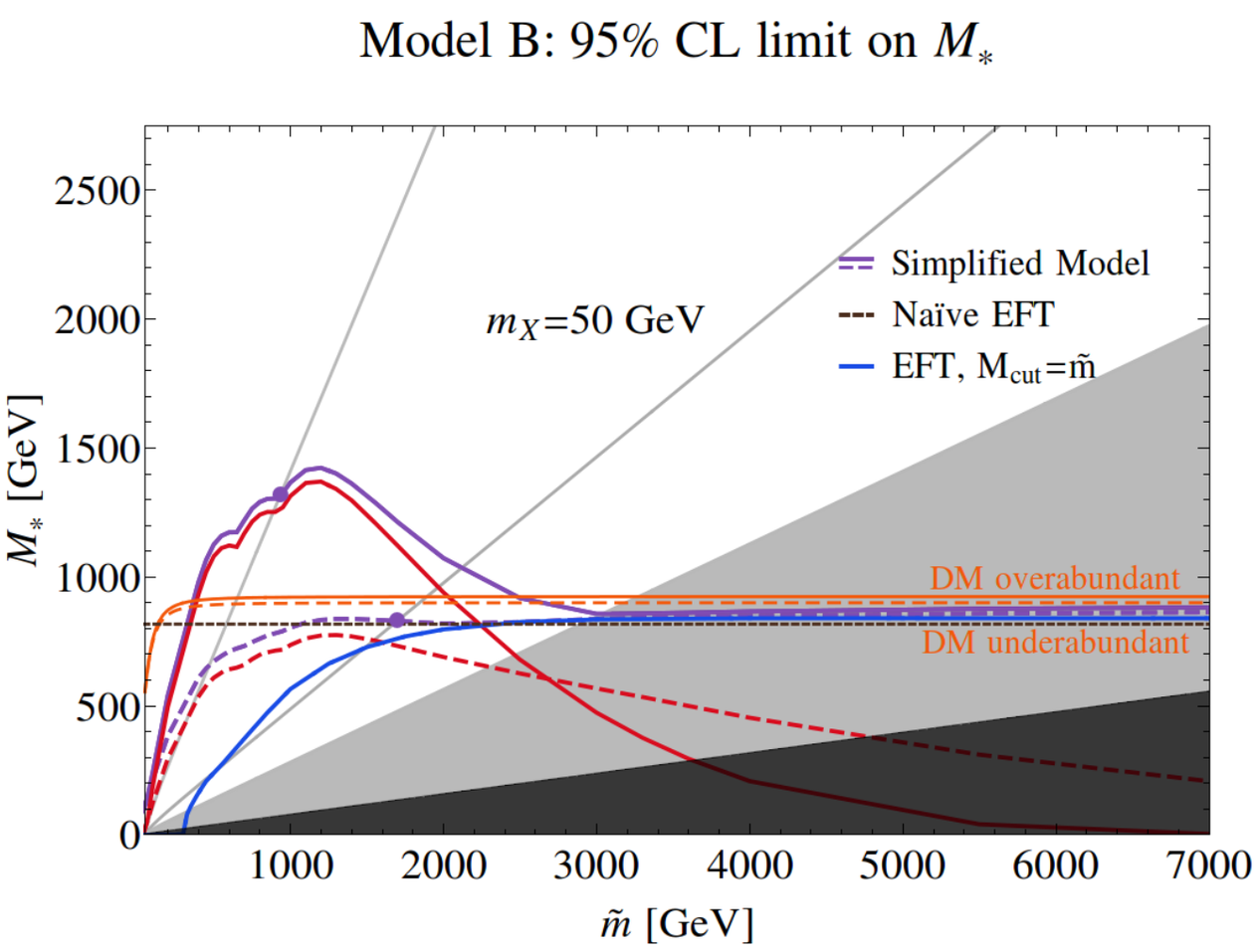

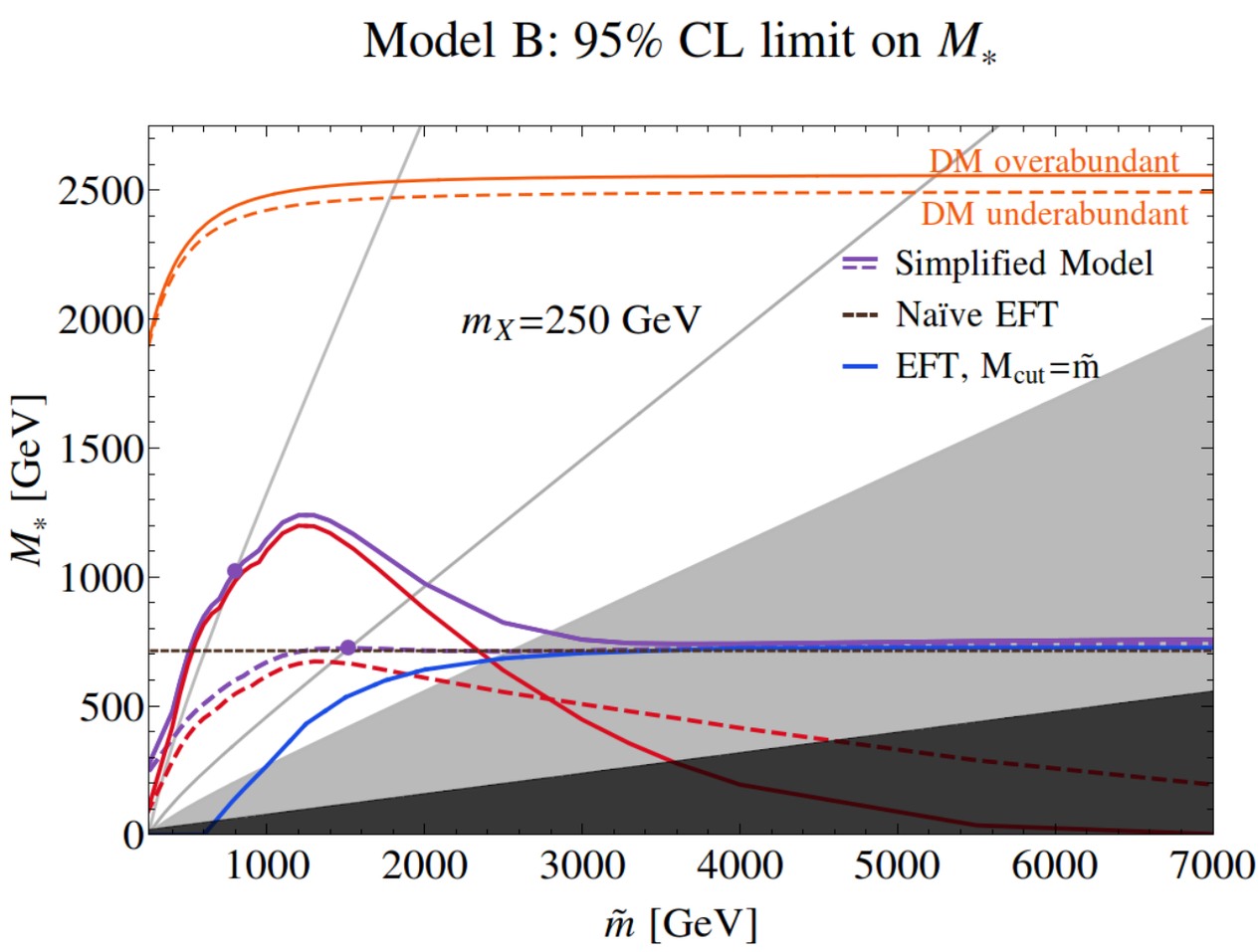

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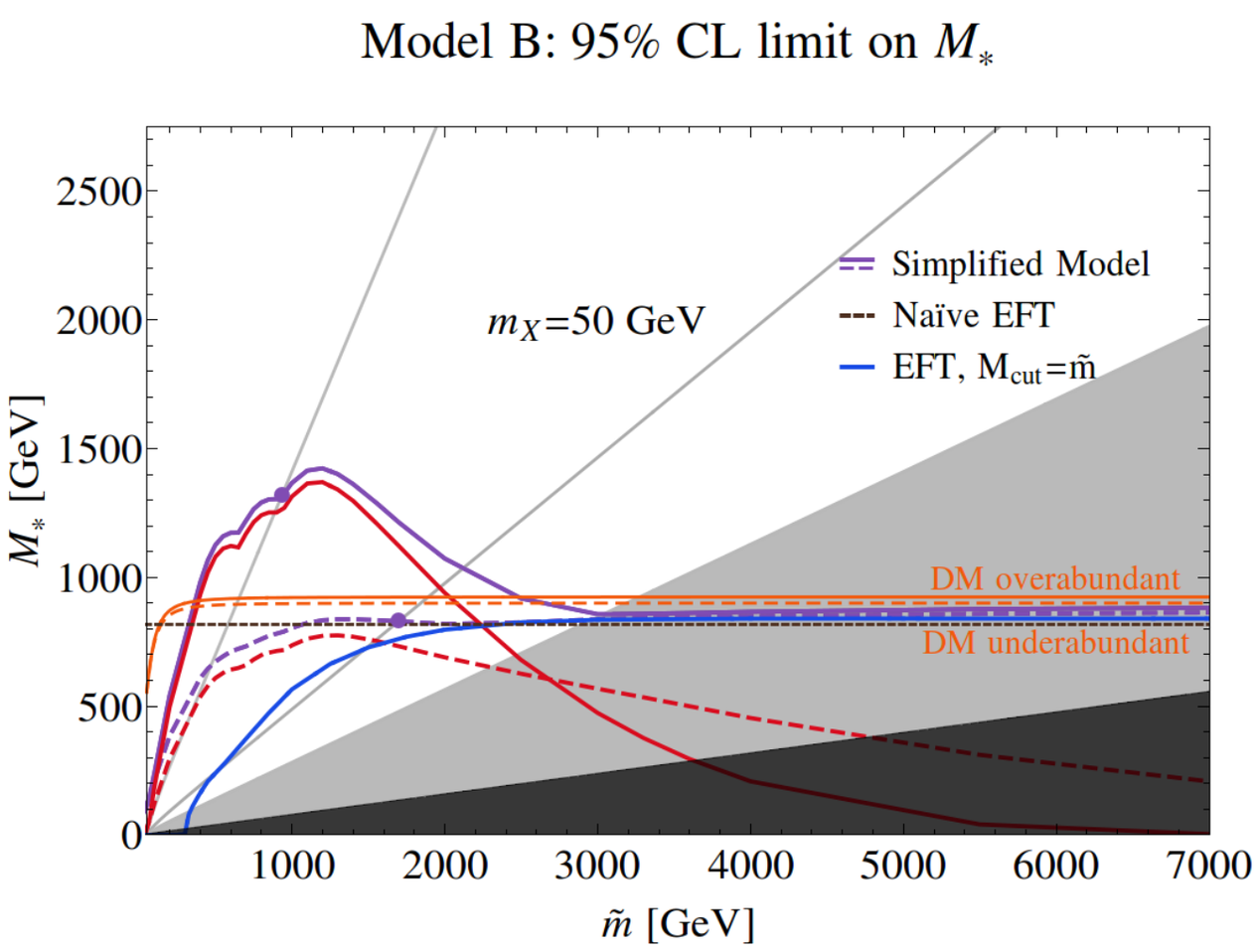

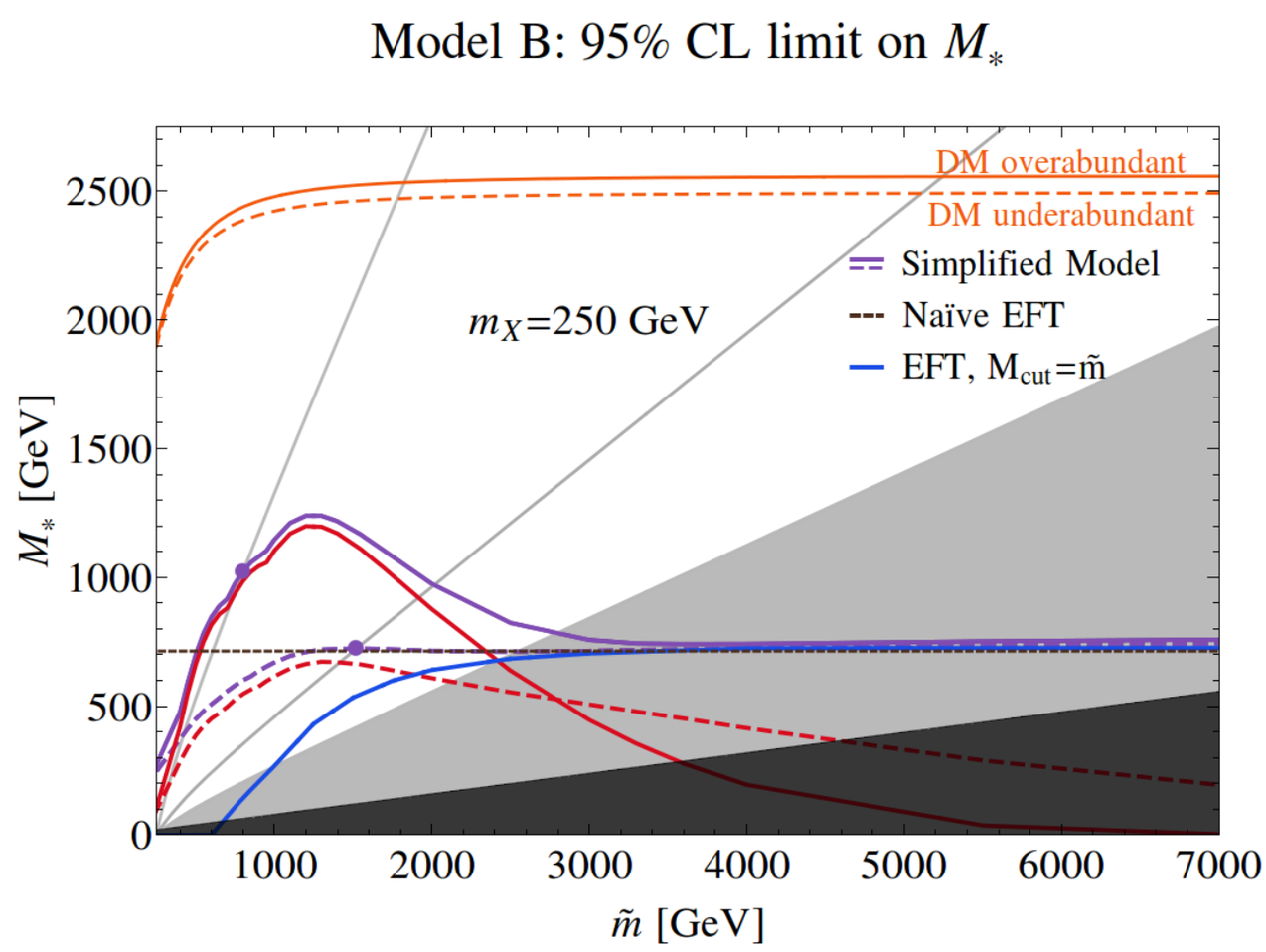

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aside one point …

Other variables

By further specifying mediator dynamics (s- or t-channel)

$Q_{\rm tr}$= max virtuality of mediator propagator

[de Simone, Riotto et. al. 2013]

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$$Q_{\rm tr} = M(DM, DM)$$

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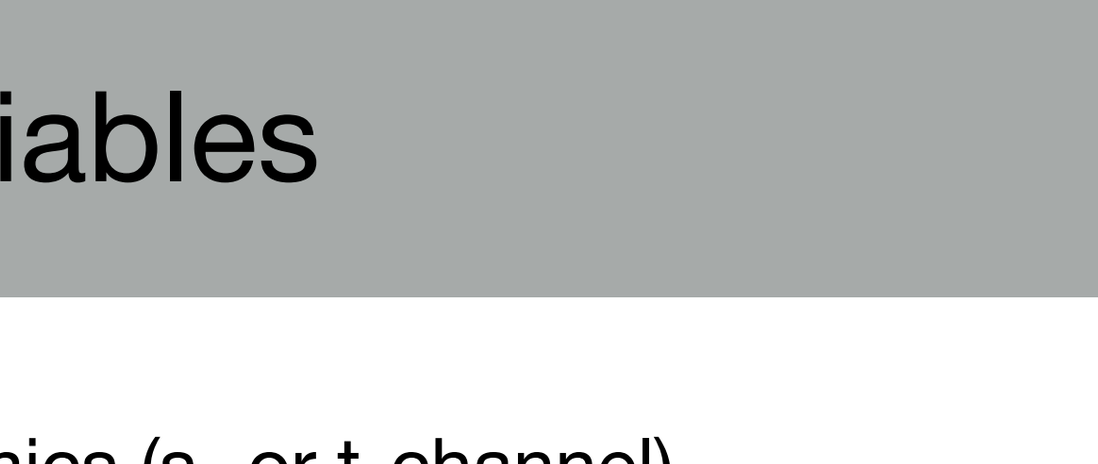

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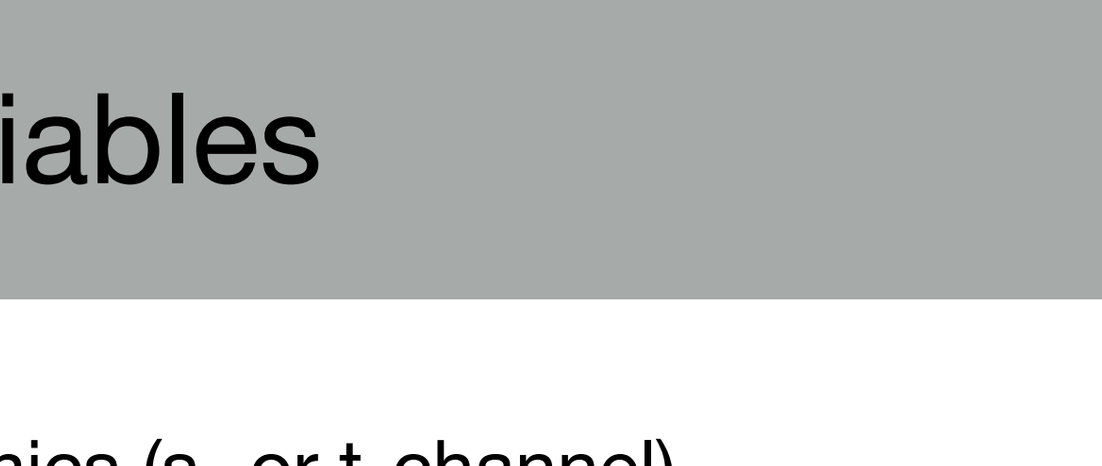

$$Q_{\rm tr} = \dots$$

In all cases (kinematical bound): $Q_{\rm tr} < E_{\rm cm}$

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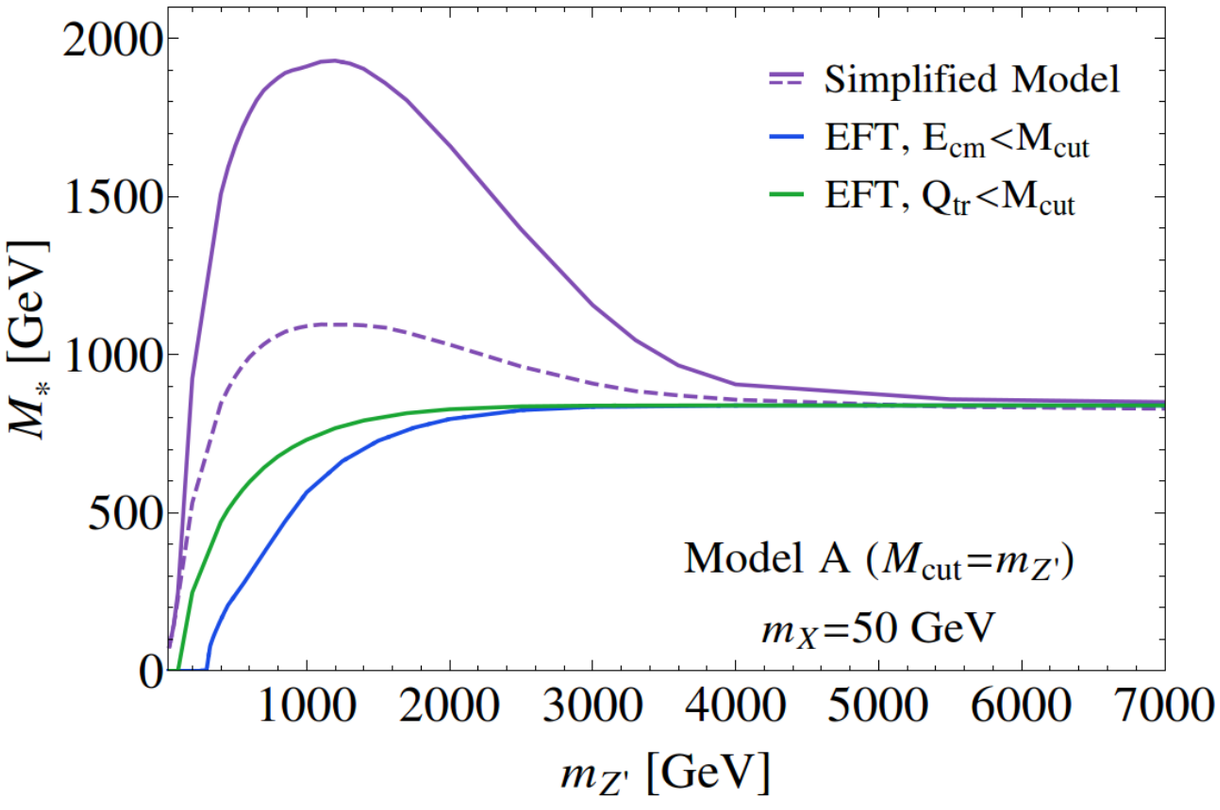

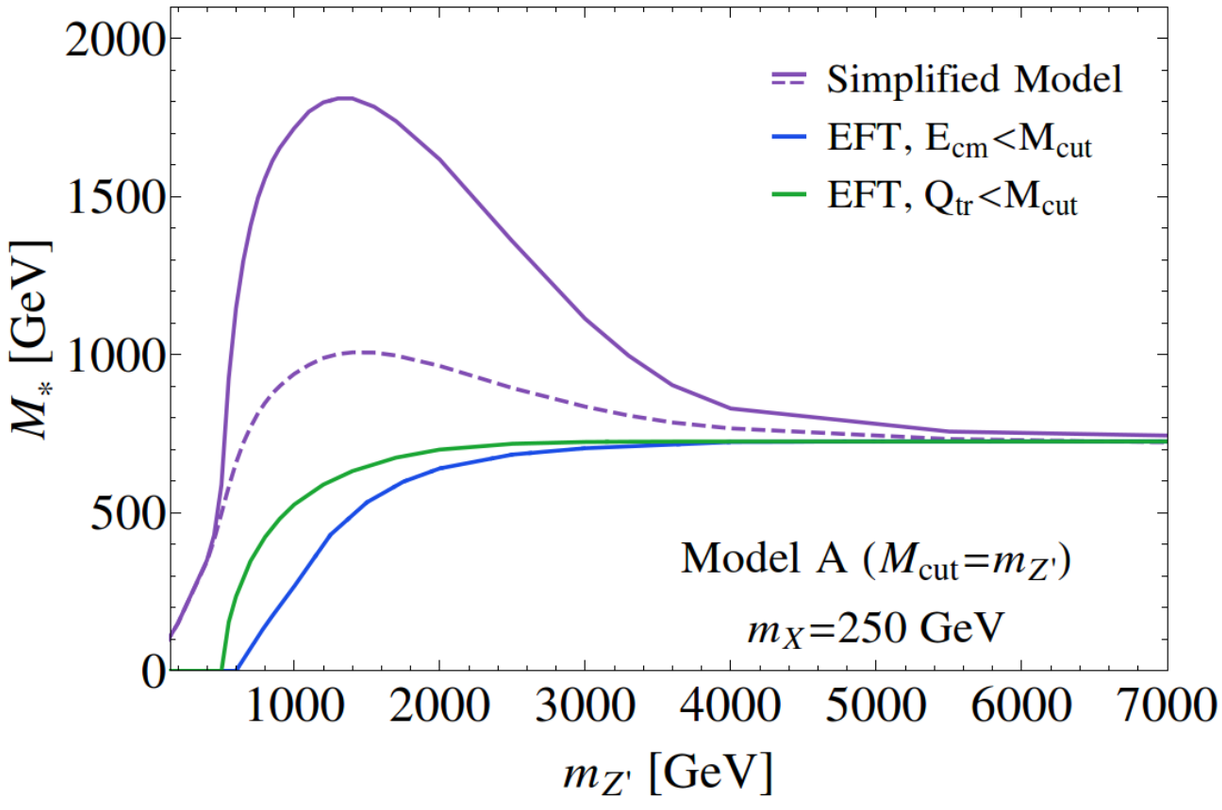

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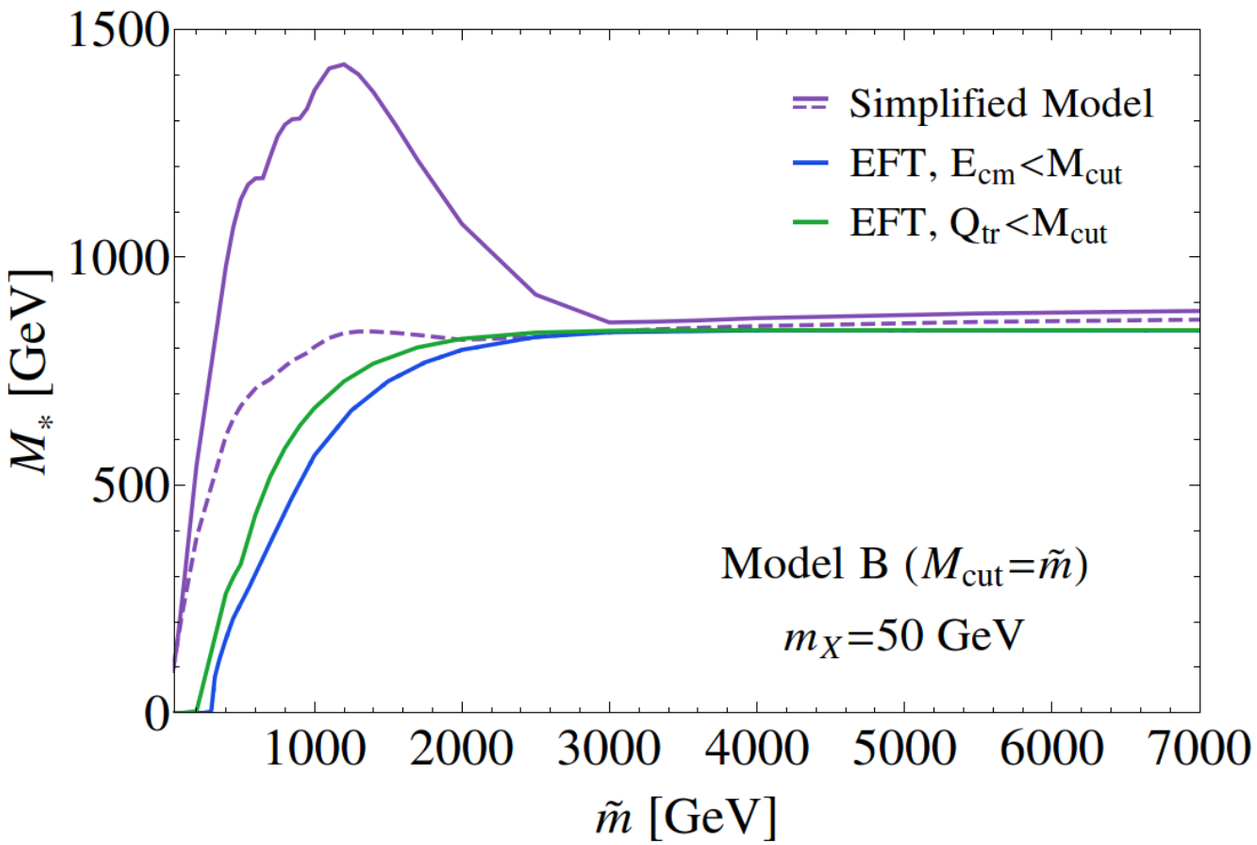

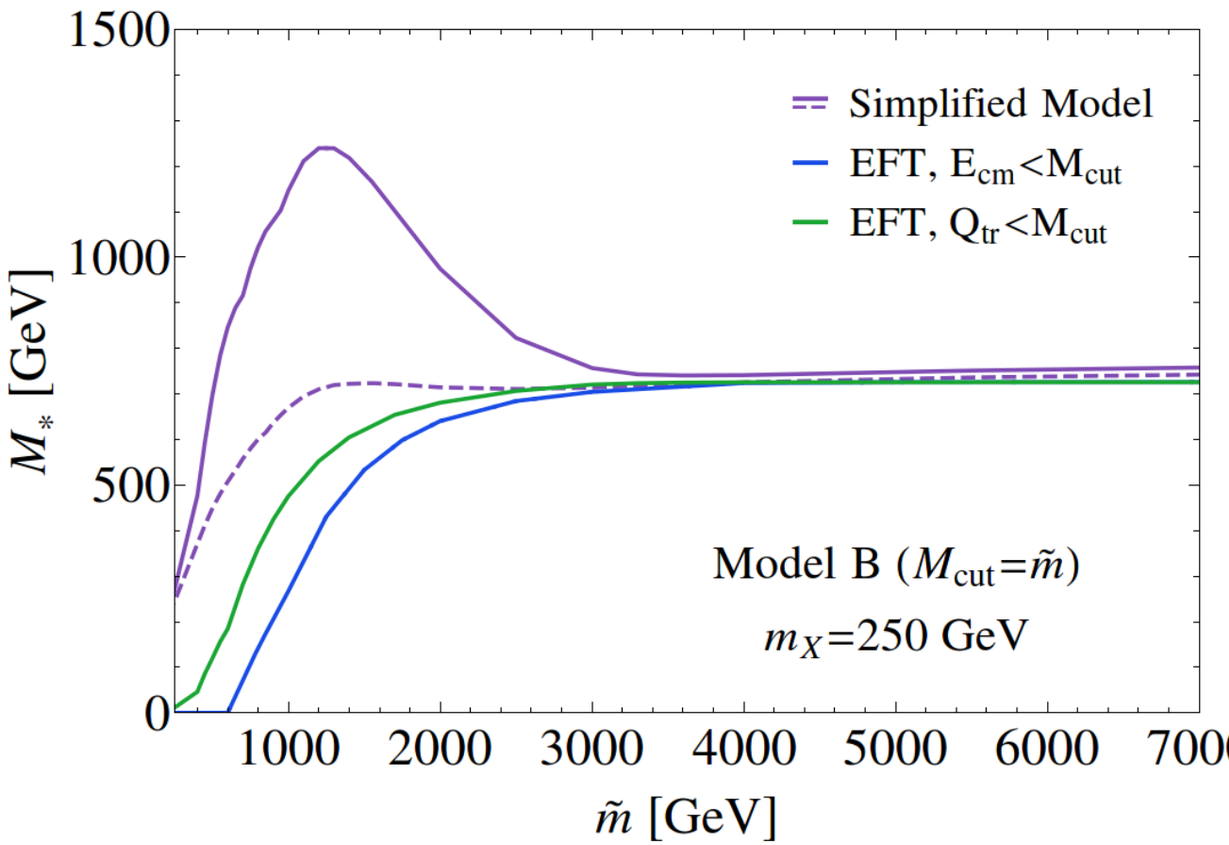

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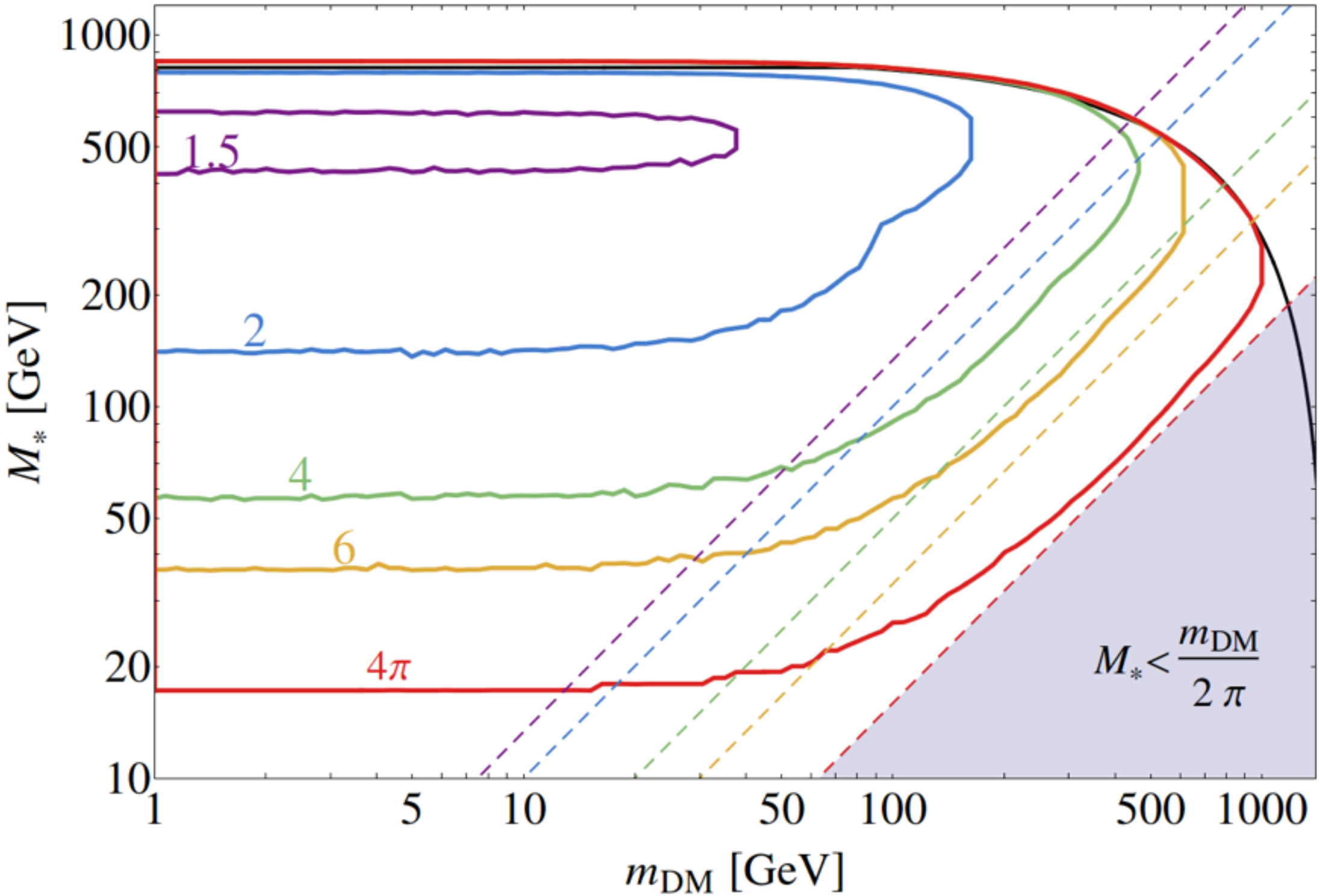
- Covering parameter space by patches?
  from EFT and mediator search side

Backup


1000
500
200
100
50
20
10
1
5
10
50
100
500
1000
M_* [GeV]
$m_{\rm DM}$ [GeV]
1.5
2
4
6
4π
$M_* < \frac{m_{\rm DM}}{2\pi}$