Constraining electroweak and strongly charged long-lived particles with CHECKMATE

Nishita Desai
TIFR, Mumbai

Based on 2104.04542
(with Florian Domingo, Jong Soo Kim, Roberto Ruiz de Austri Bazan, Krzysztof Rolbiecki, Mangesh Sonawane, Zeren Simon Wang)

LLP Signature vocabulary

Displaced

Leptons eμ, μμ

Vertices with muons, lepton veto (n_trk ≥ 5), dimuon

Jets (emerging, lepton, trackless)

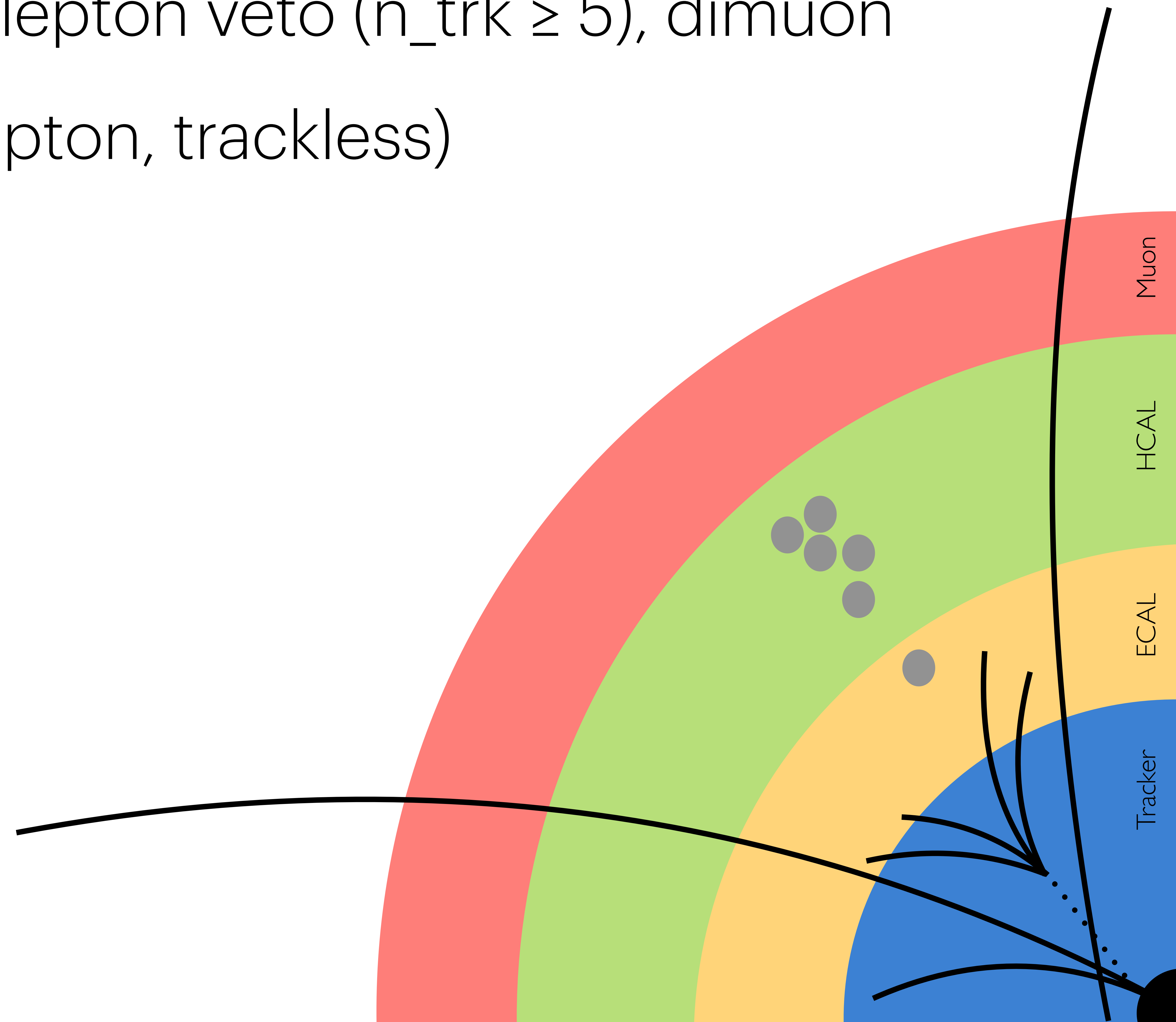
“Prompt”

Heavy charged track

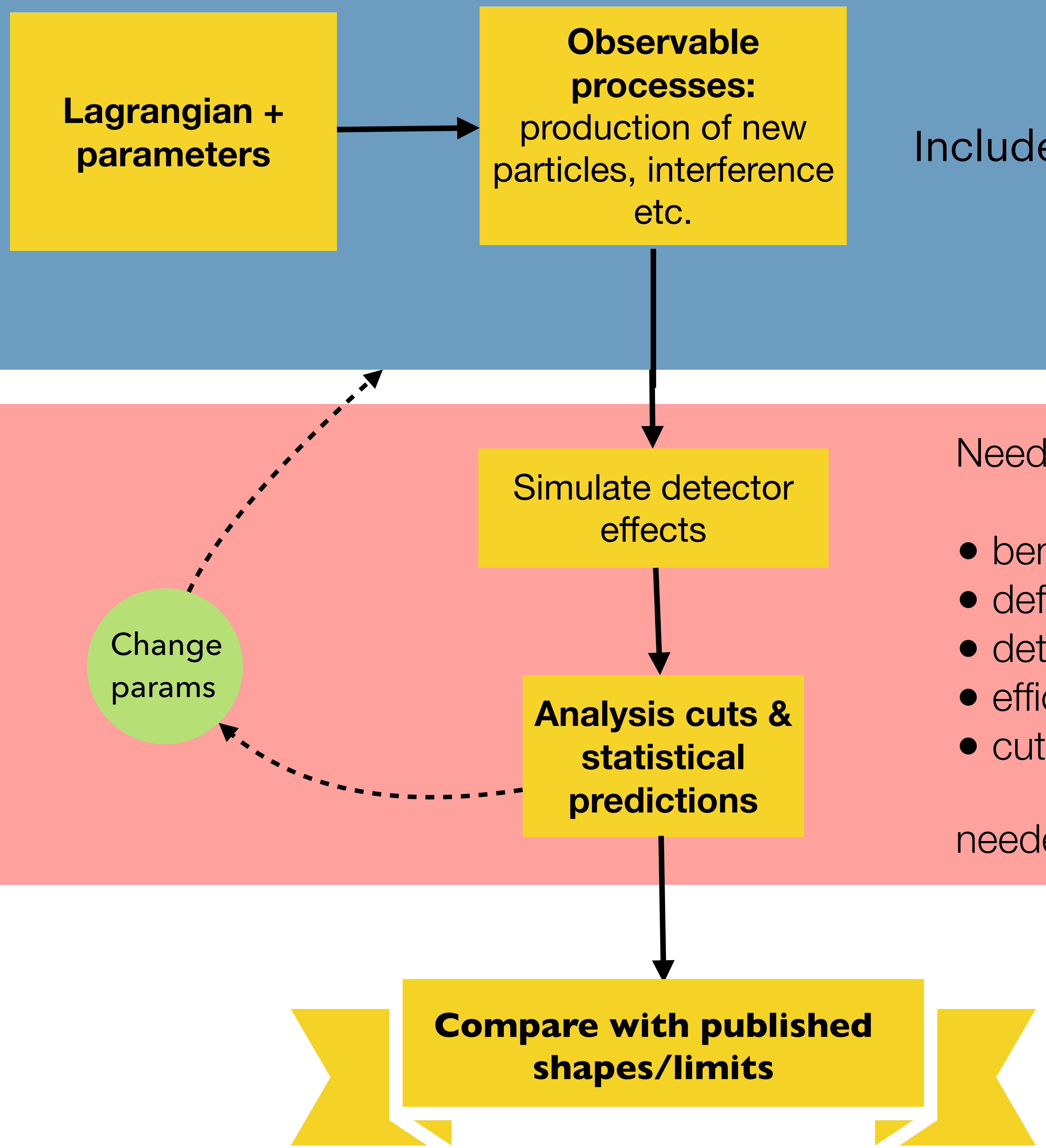
Disappearing track

One-off

SUEP



Monte Carlo



Include the effects you want to observe

Recasting

Needs to be validated!

- benchmarks
- definitions of objects (vertex, jet, etc.)
- detector acceptances
- efficiencies
- cut flow tables

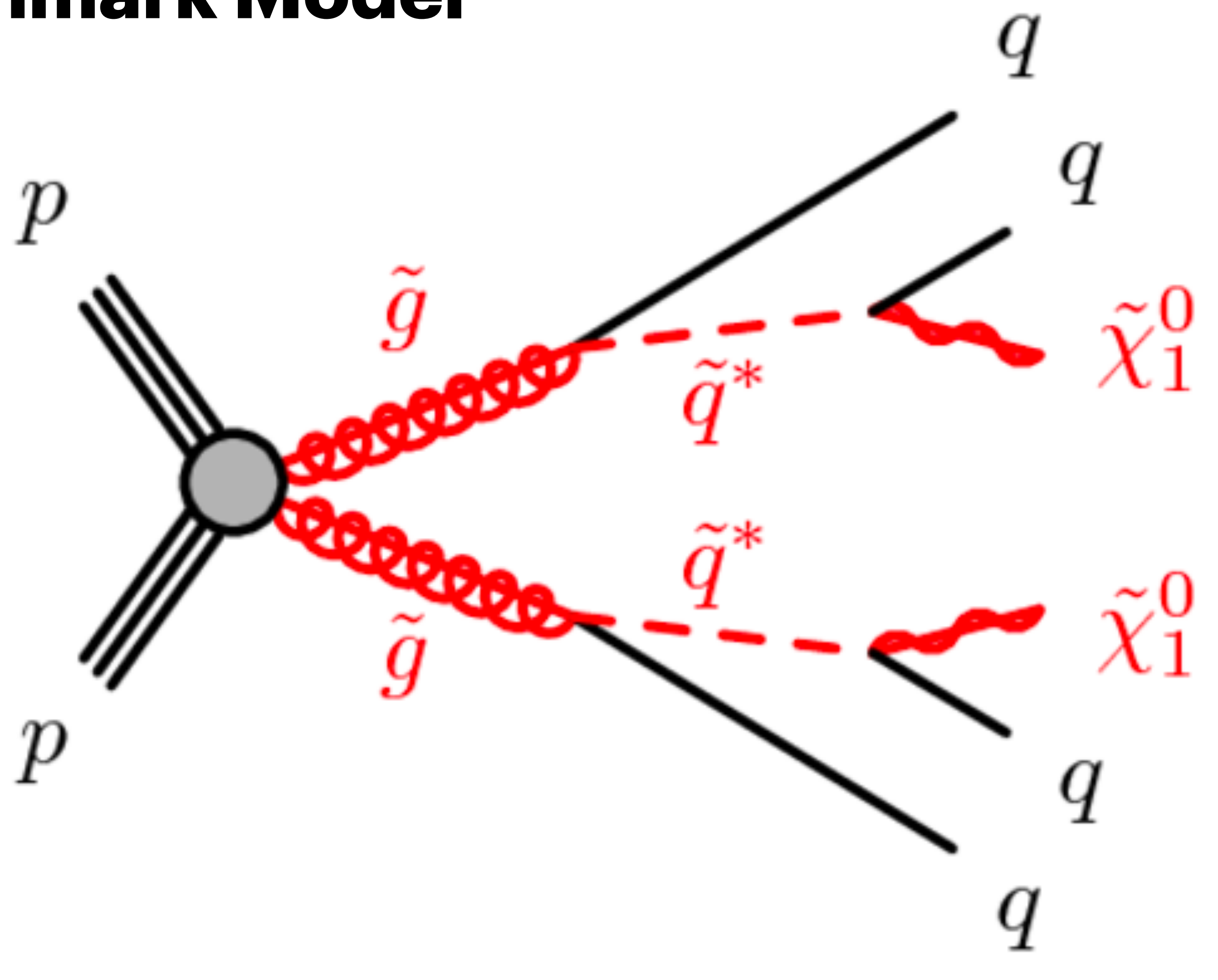
needed to accomplish this

Kinds of LLP searches in CheckMATE

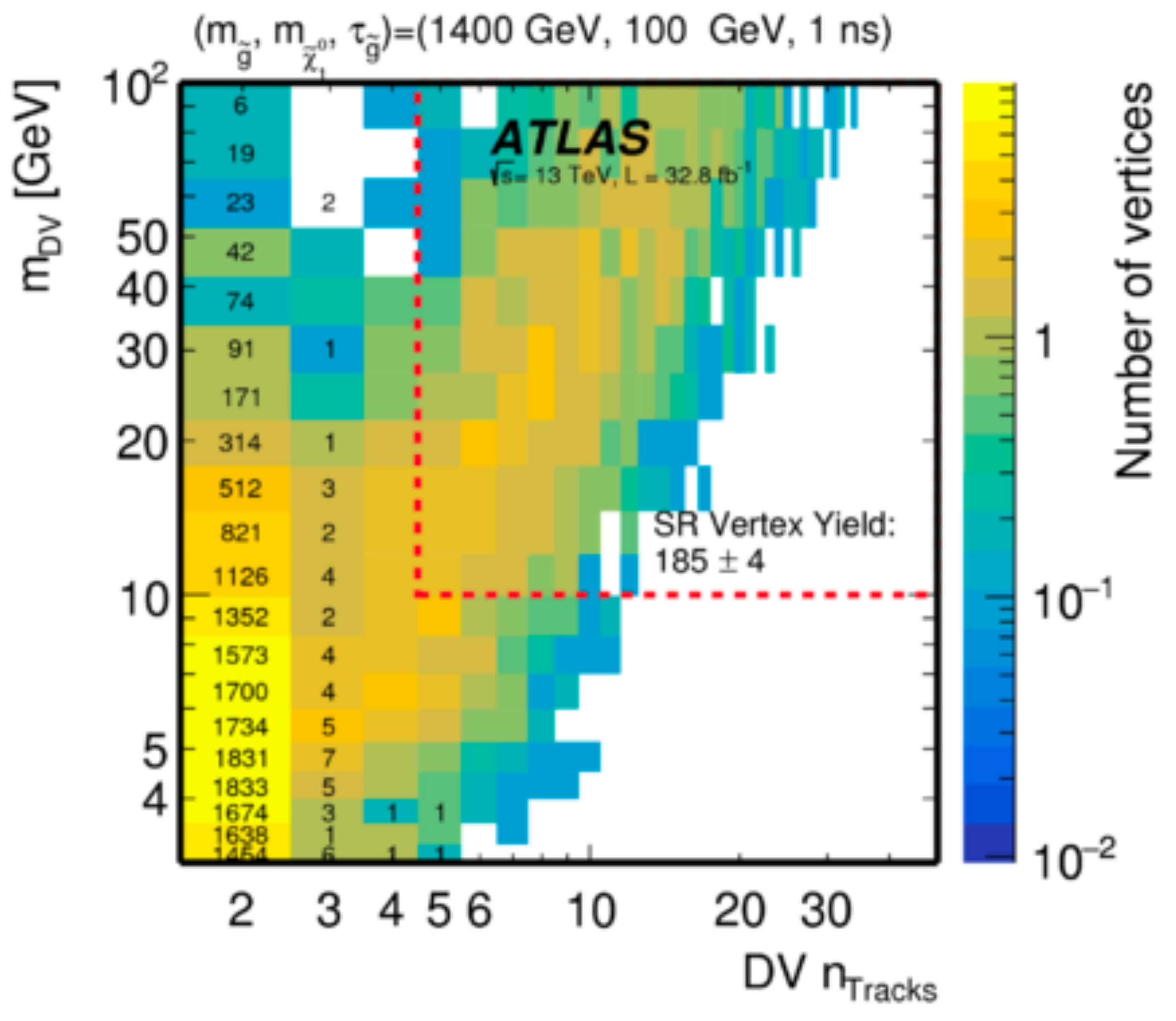
- Displaced vertex + MET (ATLAS, 1710.04901)
- Displaced vertex + μ (ATLAS, 2003.11956)
- Heavy Charged track (ATLAS, 1902.01636)
- Displaced Leptons (CMS, 1409.4789, CMS-PAS-EXO-16-022)
- Disappearing track (ATLAS, 1712.02118)

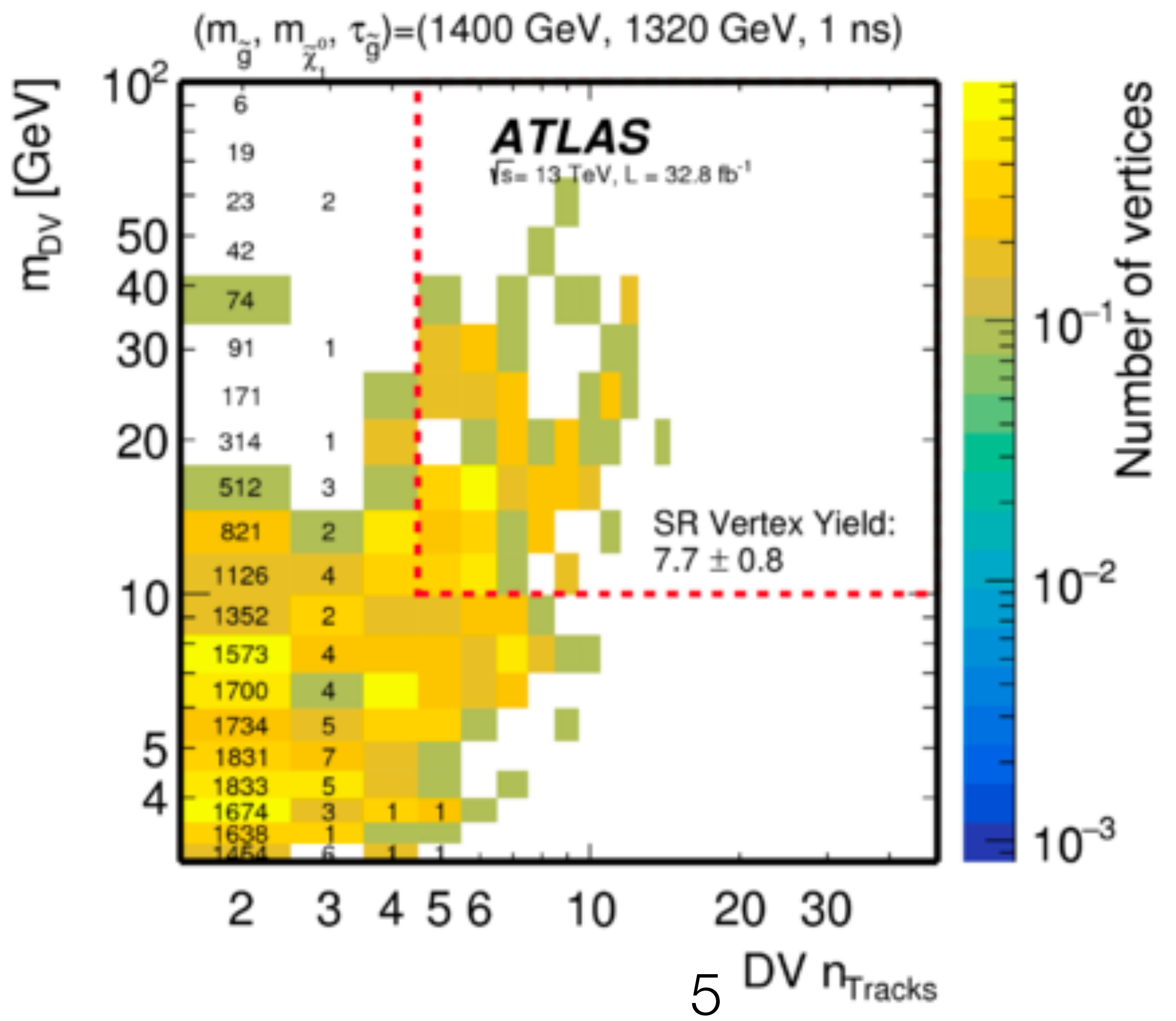
Search 1: Displaced Vertex

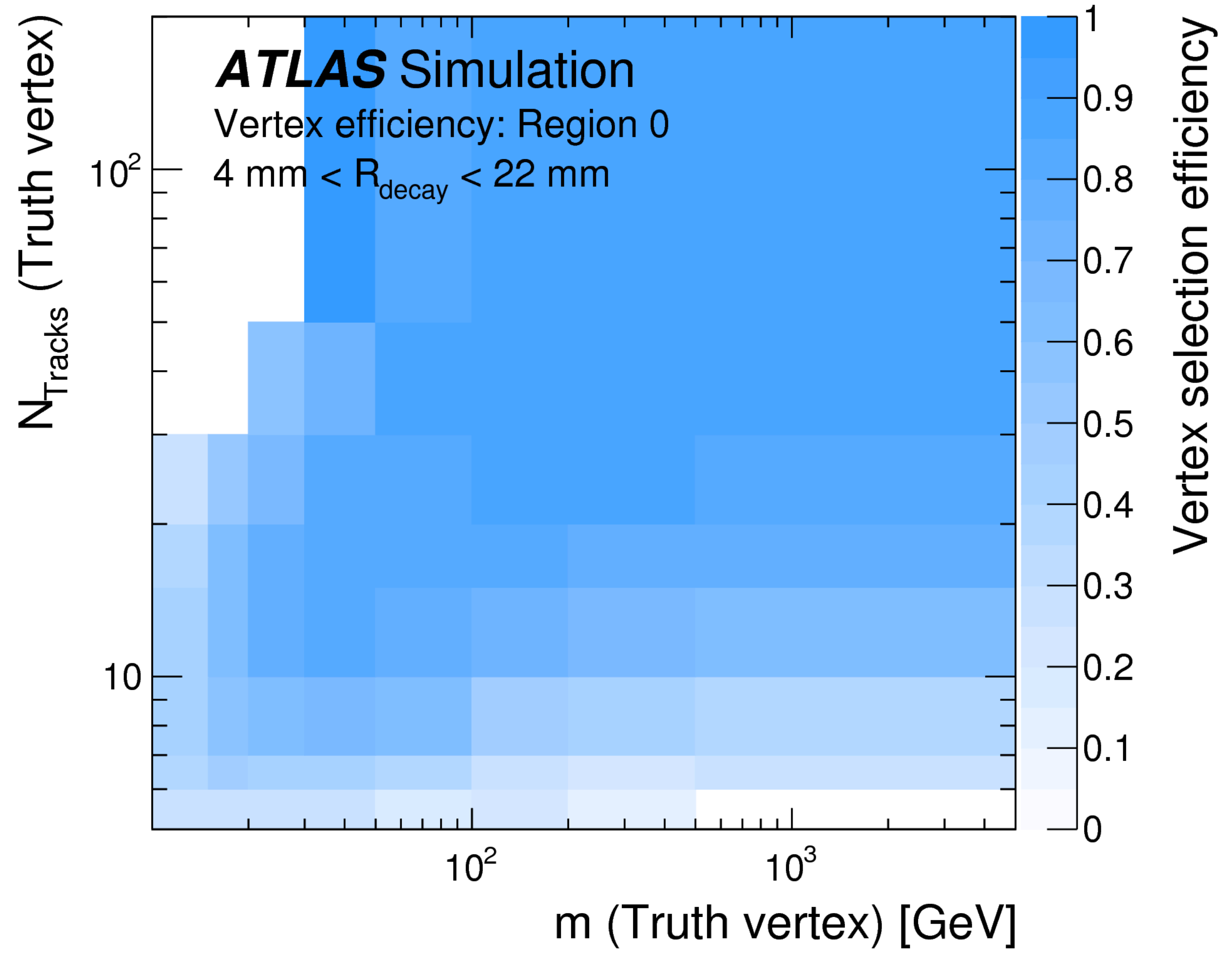
Benchmark Model



(ATLAS, 1710.04901)

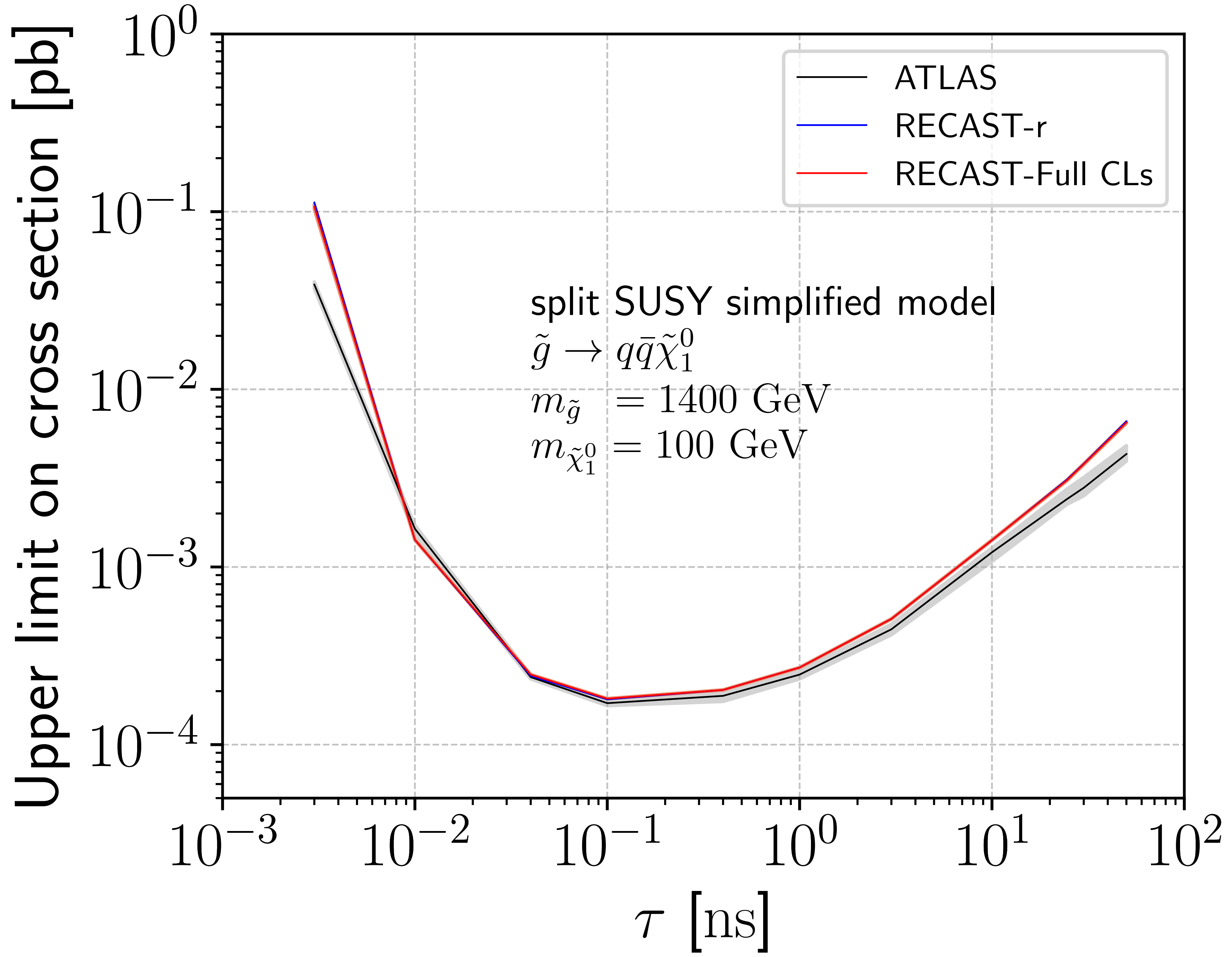


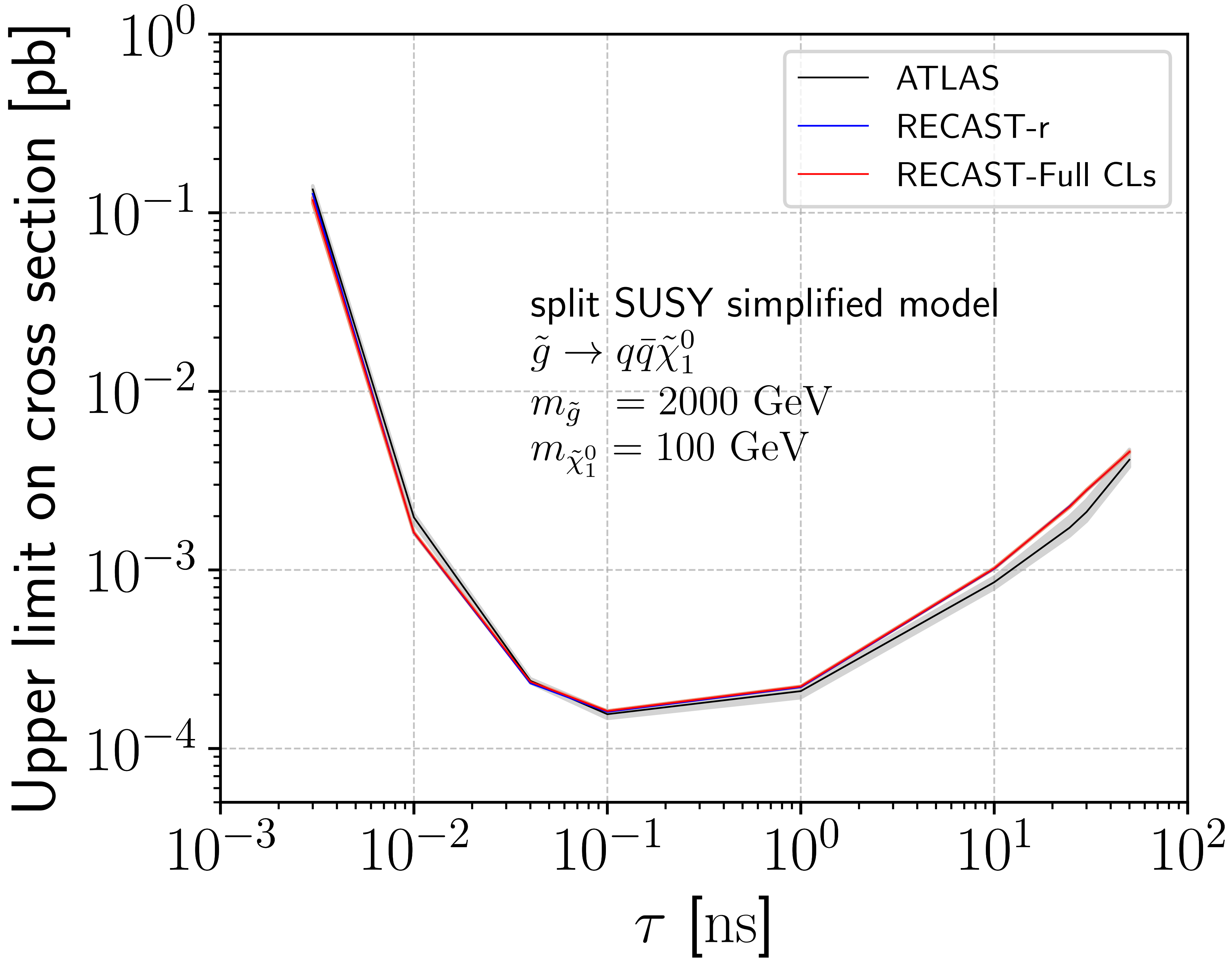




Efficiencies published based on generator-level info, in a model-independent* parametrisation

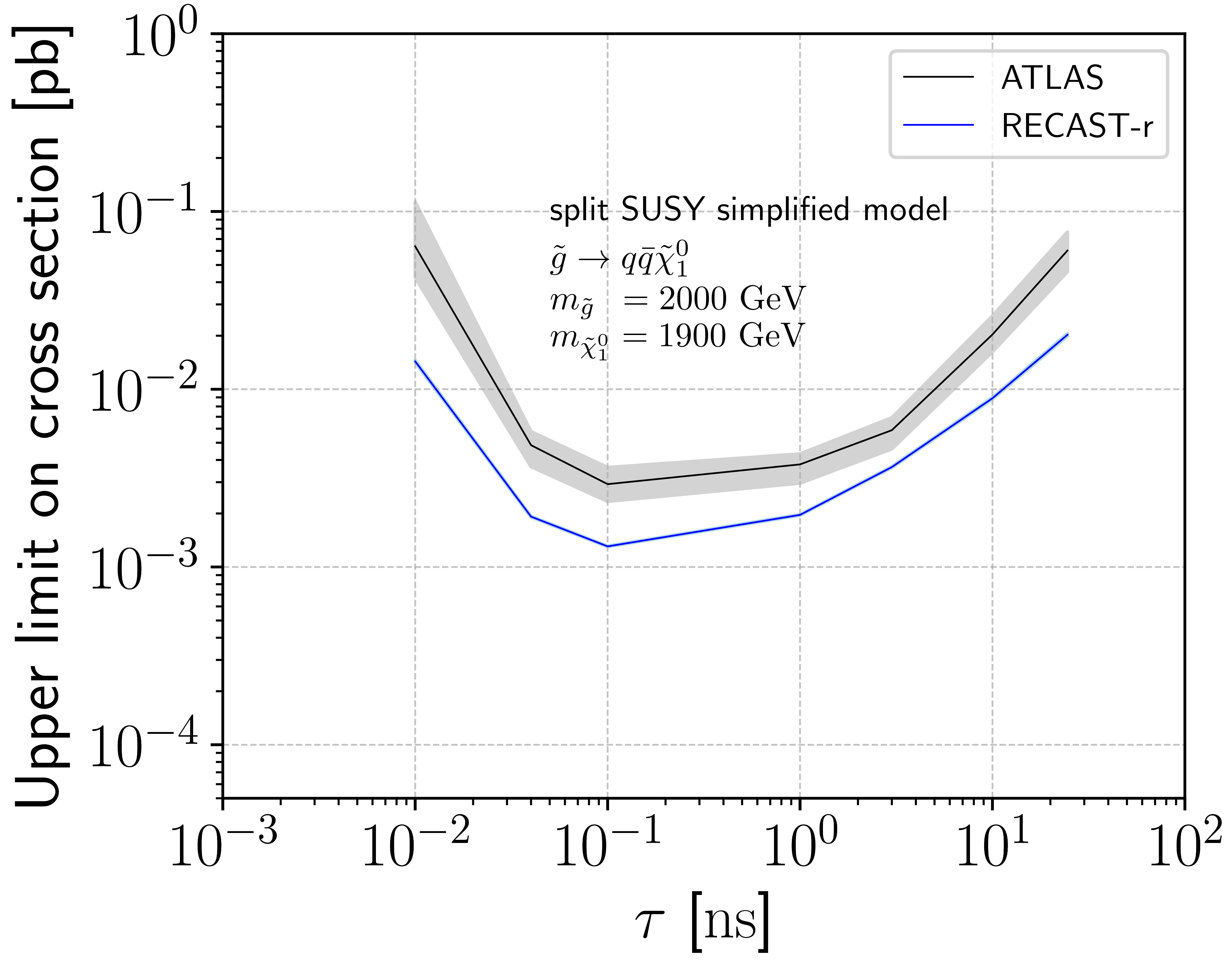
Displaced Vertex - 1

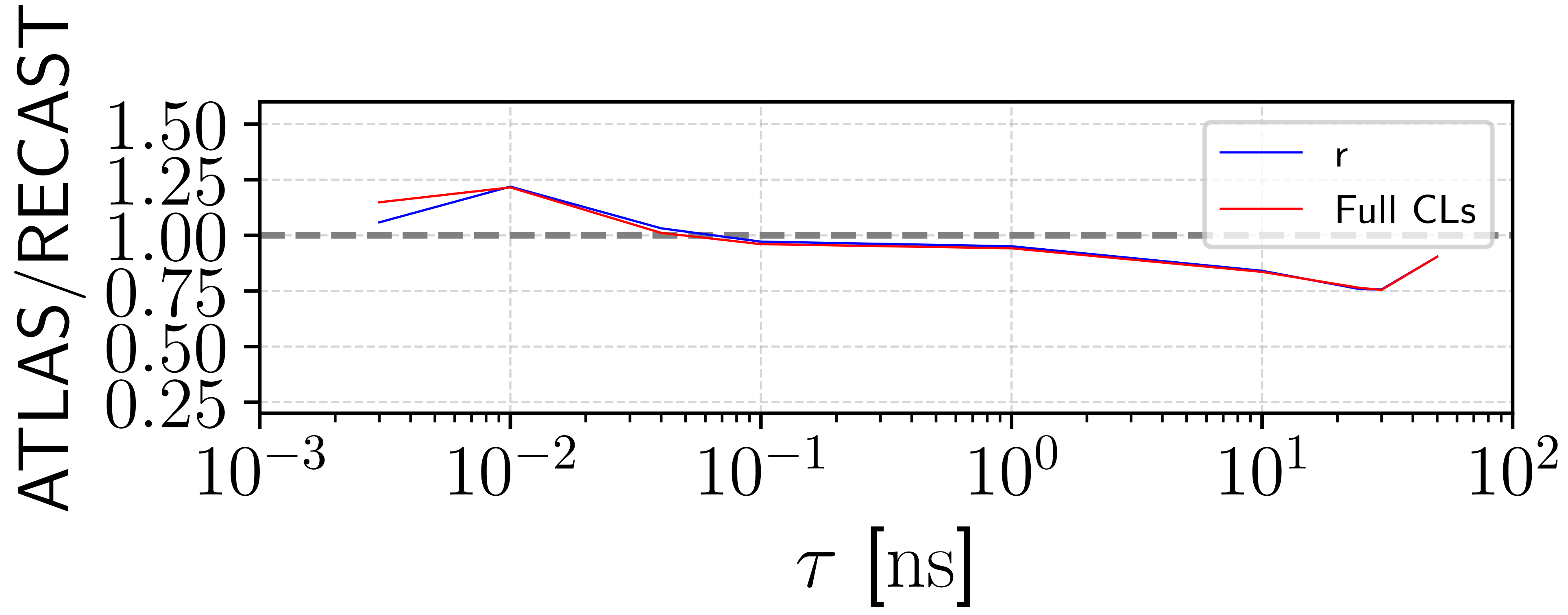




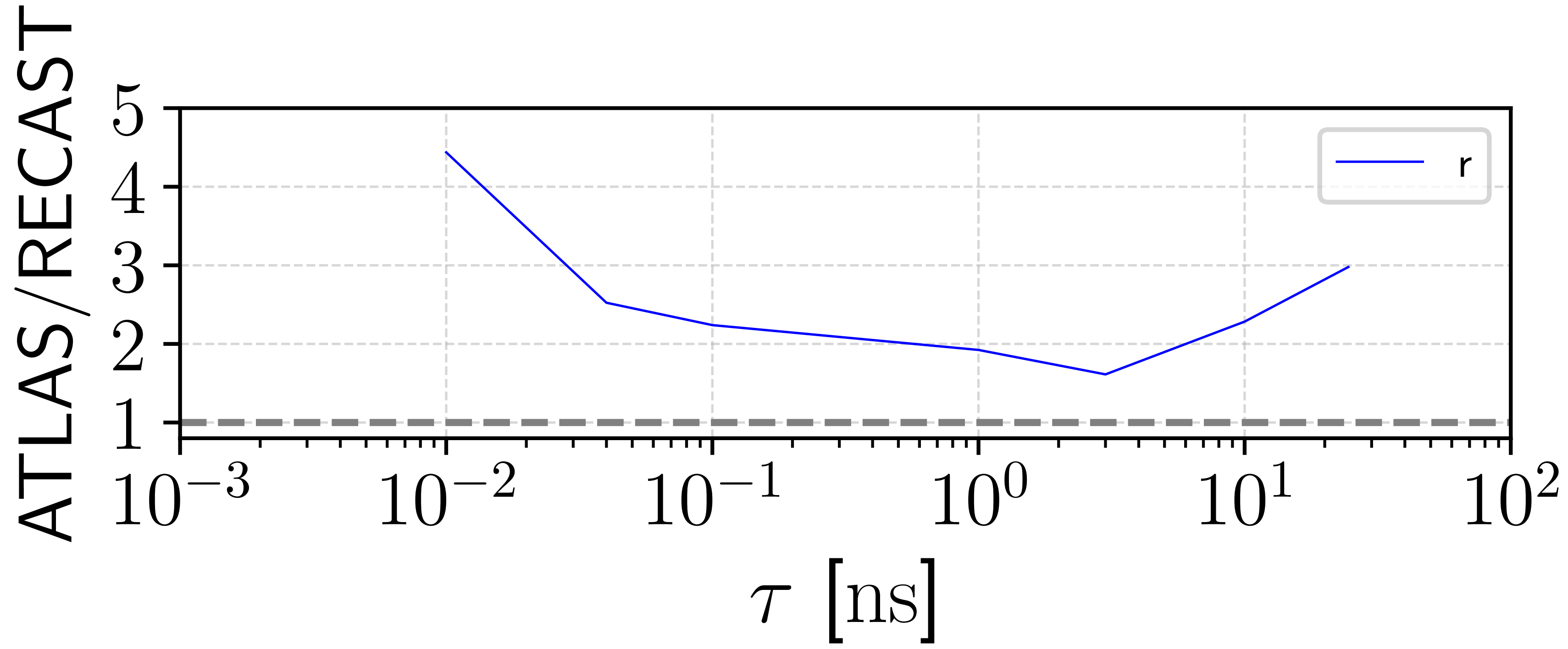
- Reinterpreted limits match published very well for almost entire lifetime range.
- CheckMATE provides ratio of CheckMATE-calculated BSM signal to published 95% upper limit. Calculating CLs based on expected background events works identically.

Displaced Vertex - 1 : compressed spectra





Normal Case

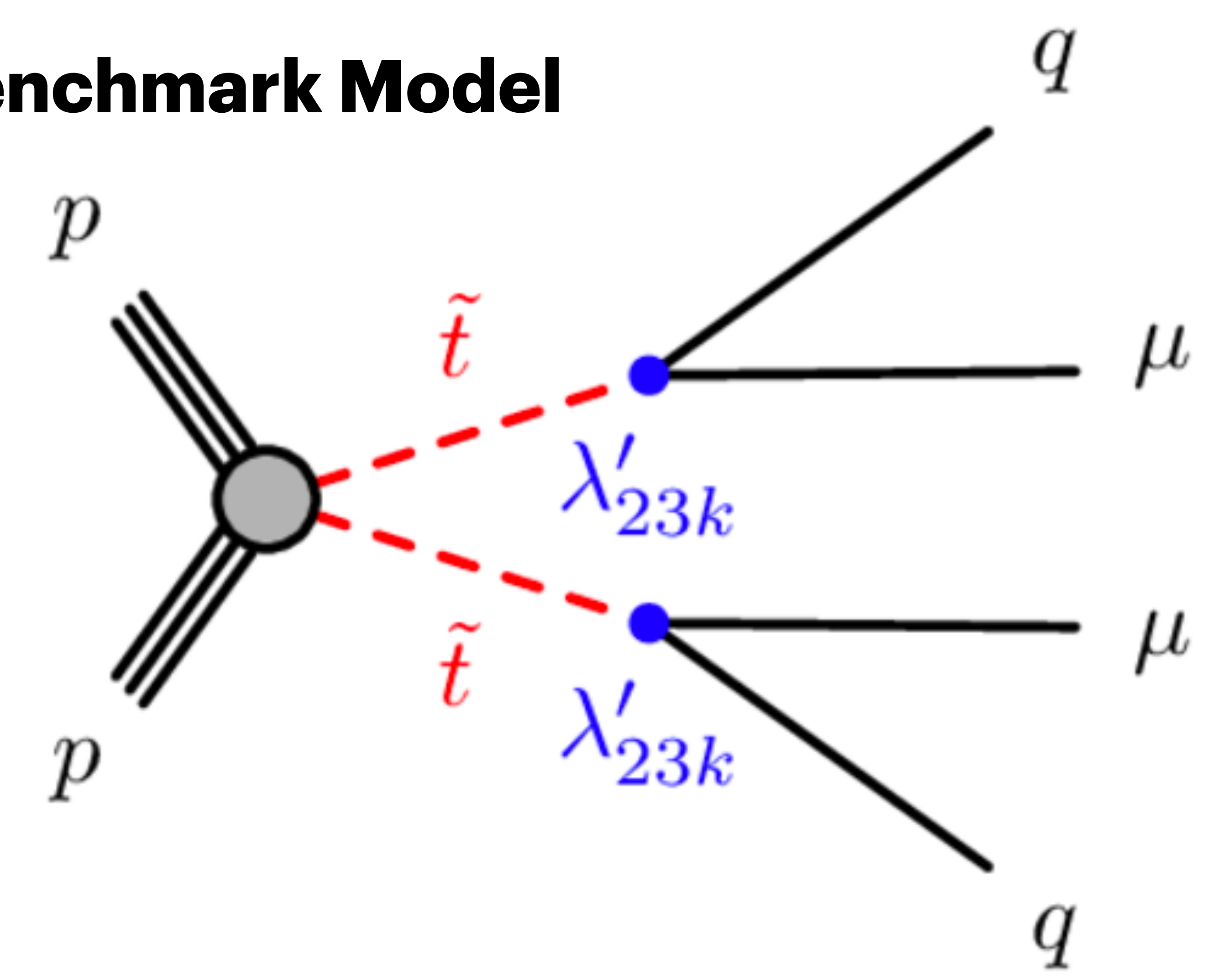


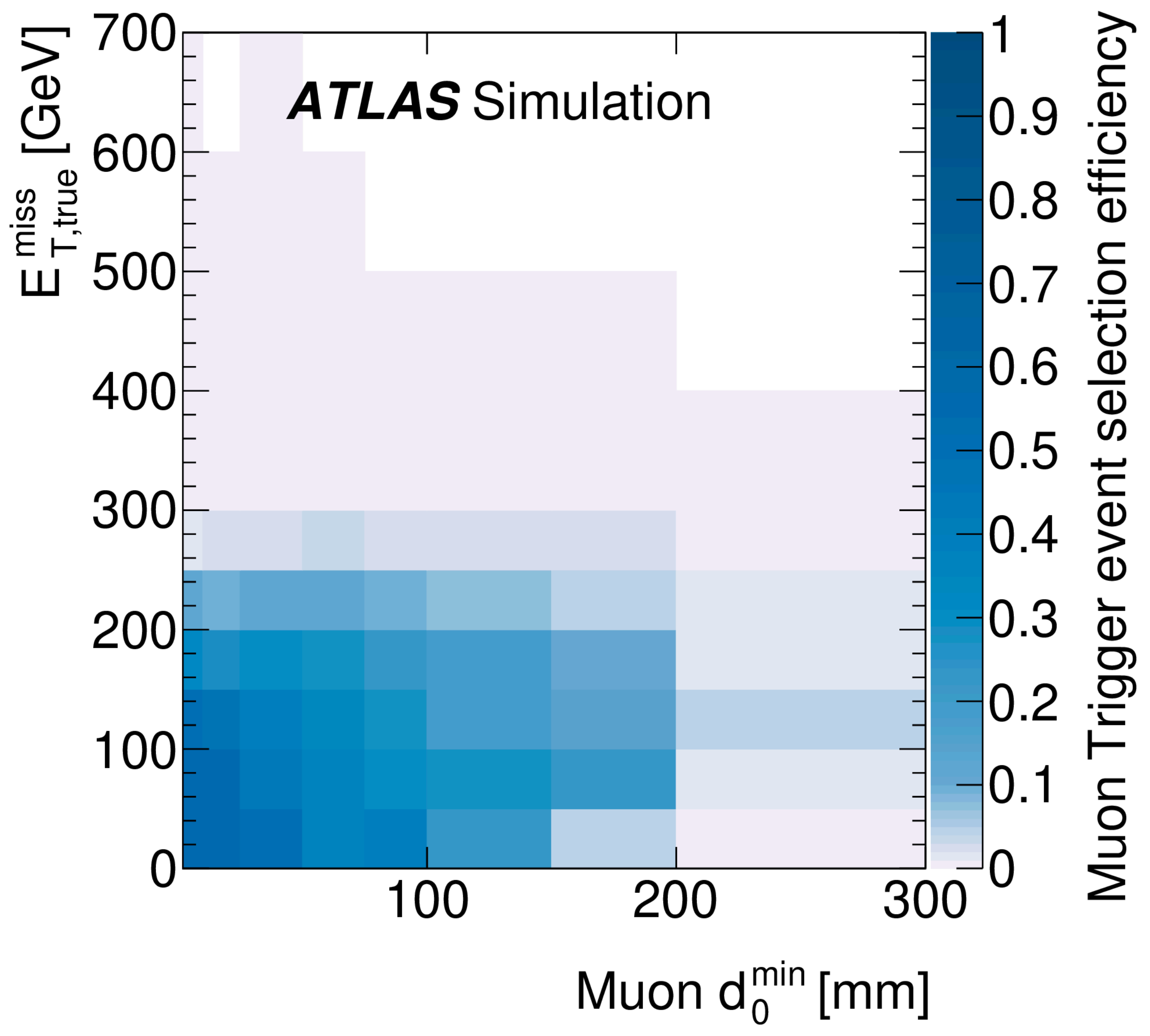
Compressed Case

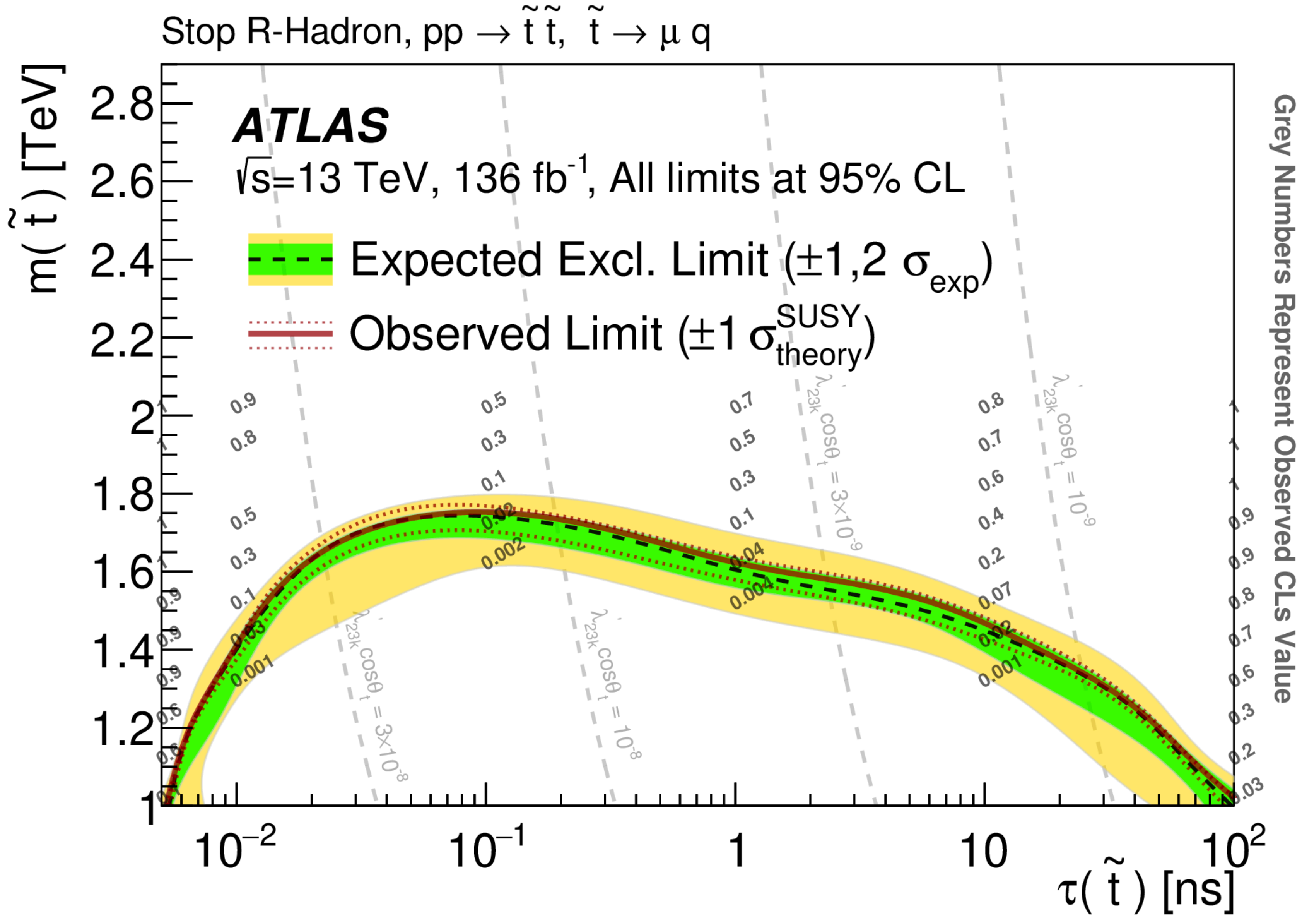
We wait for the 139/fb update

Search 2: Displaced Vertex (+ μ)

Benchmark Model







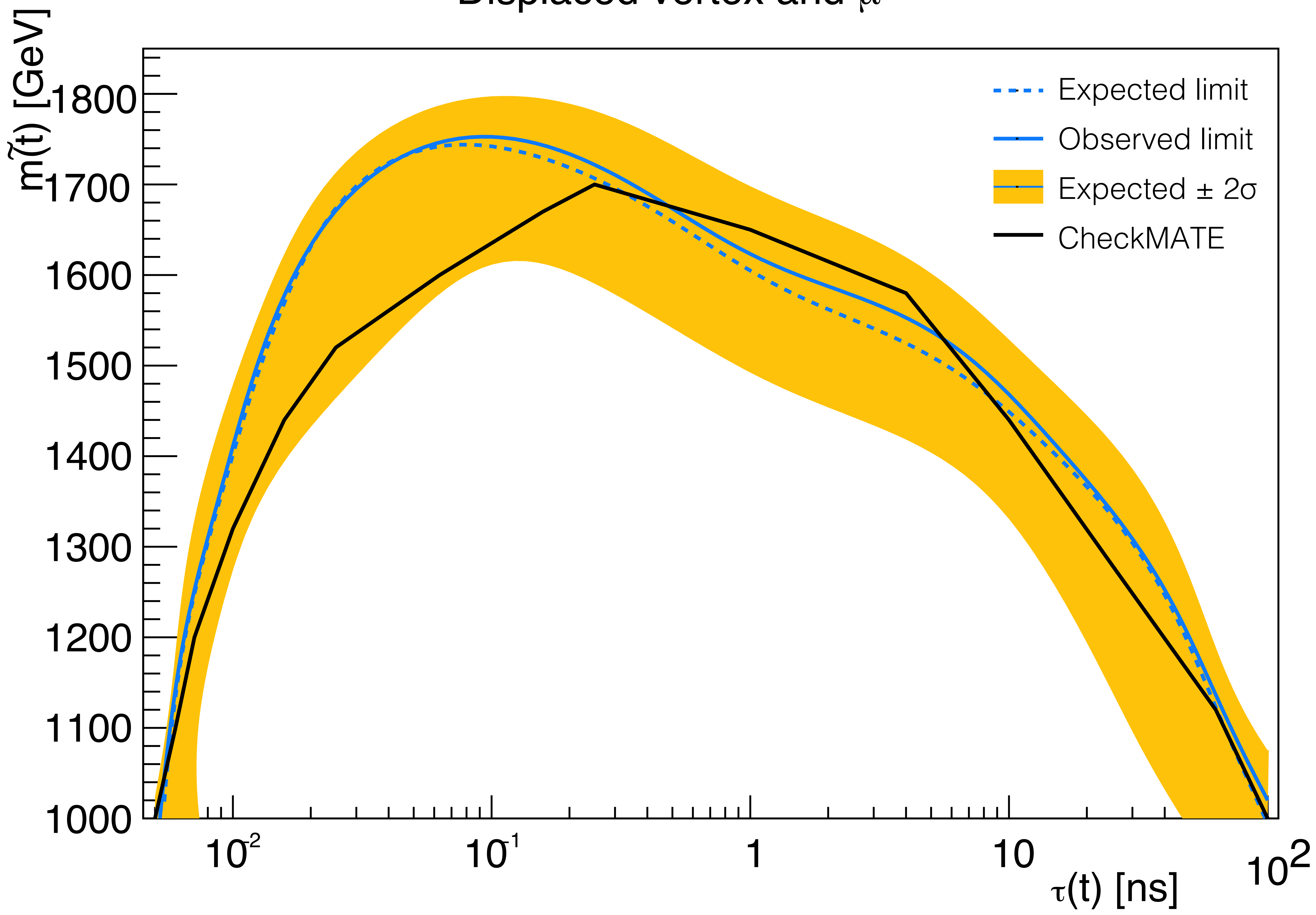
(ATLAS, 2003.11956)

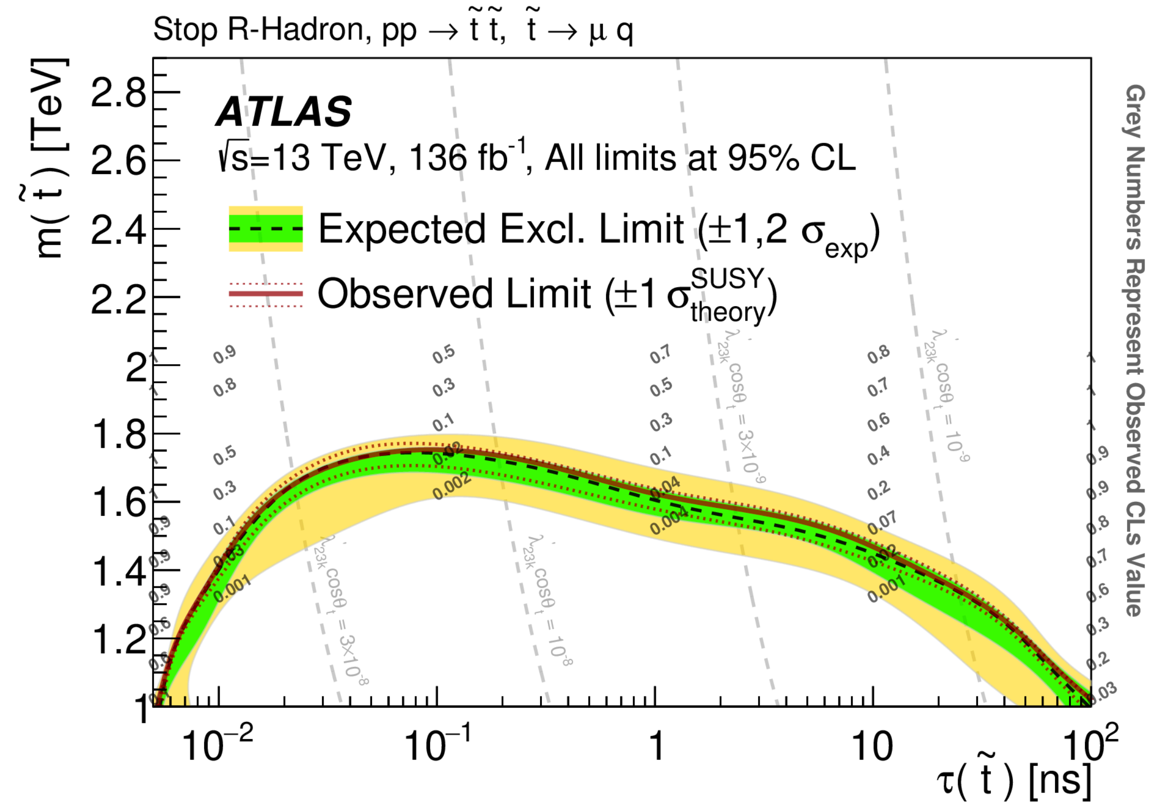
FULL 139/fb!

- Efficiencies published based on generator-level info
- Cut flow tables available for three lifetimes

Displaced Vertex - 2

Displaced vertex and μ



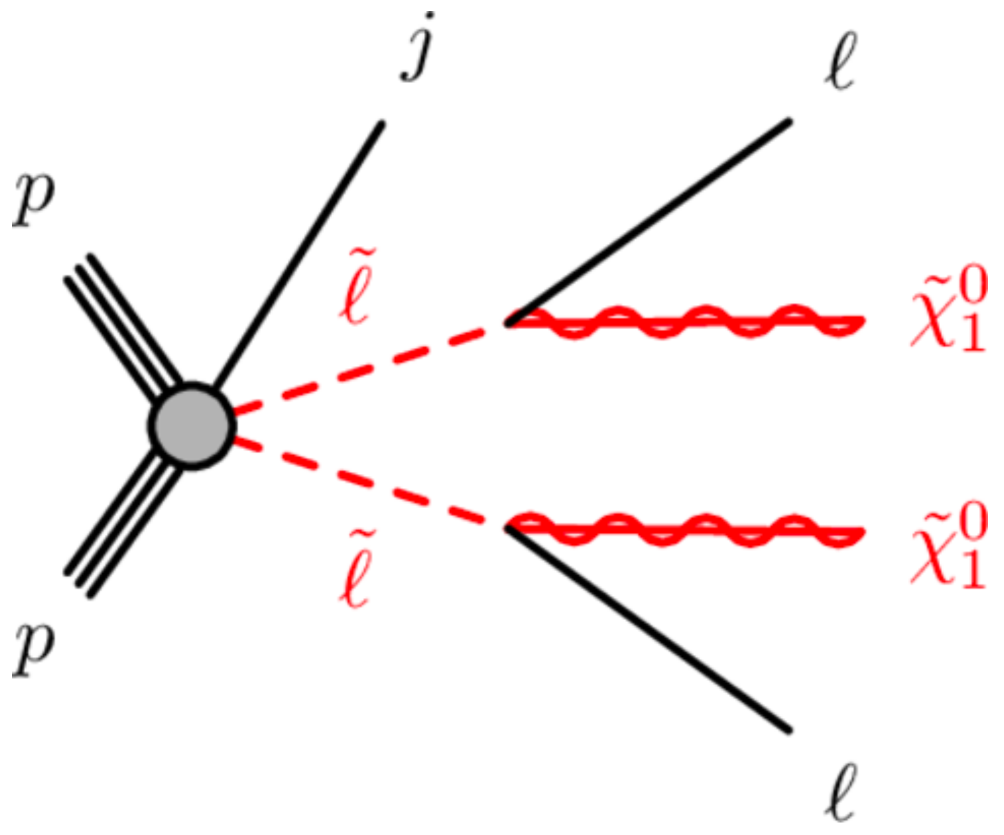


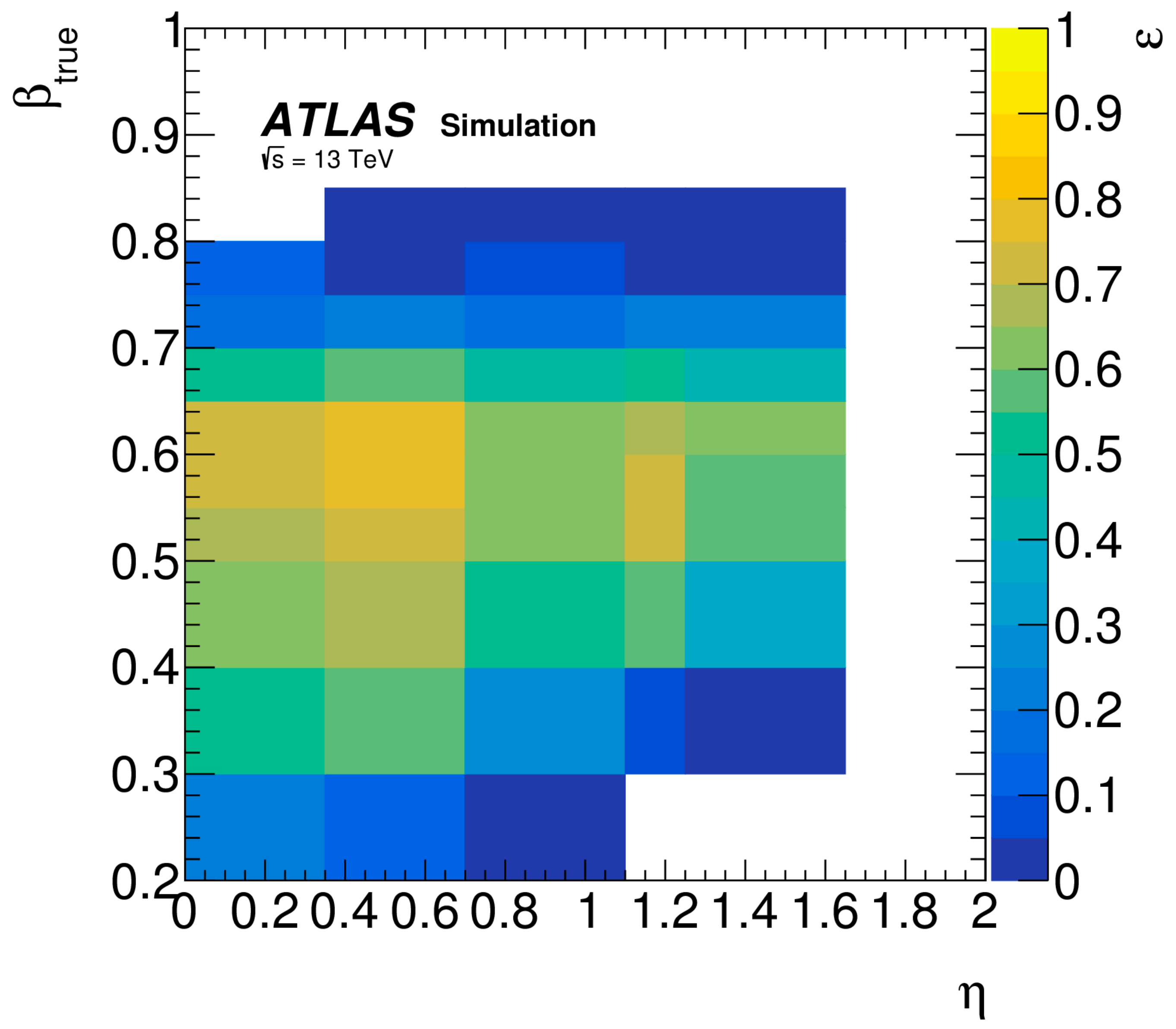
Selection	$\tau = 0.01$ ns		$\tau = 0.1$ ns		$\tau = 1$ ns	
	ATLAS	CM	ATLAS	CM	ATLAS	CM
All	64.2	64.2	64.2	64.2	64.2	64.2
$E_T^{\rm miss}$ trigger	63.0	63.2	63.0	63.3	62.7	63.2
$E_T^{\rm miss} > 180$ GeV	60.9	61.2	61.0	61.3	60.6	61.0
$\geq 1\mu$; $p_T > 25$ GeV, $\lvert\eta\rvert < 2.5$	57.8	60.8	58.7	61.0	52.5	60.6
$2 < \lvert d_0(\mu)\rvert < 300$ mm	11.3	12.8	49.1	52.5	49.5	59.2
$\lvert z_0(\mu)\rvert < 500$ mm	11.3	12.8	49.1	52.5	49.3	58.1
Fake/HF/cosmic veto	9.1	9.9	40.0	42.4	39.4	48.1
At least one DV	8.5	4.4	37.6	29.8	32.6	39.6
DV fiducial volume	8.4	3.7	37.1	29.1	31.2	32.7
Material veto	5.3	2.2	31.0	16.9	22.2	19.0
$n_{\rm tracks}^{\rm DV} \geq 3$	3.8	1.8	26.0	15.5	13.7	17.3
$m_{\rm DV} > 20$ GeV	3.4	1.2	22.7	11.9	10.3	14.0

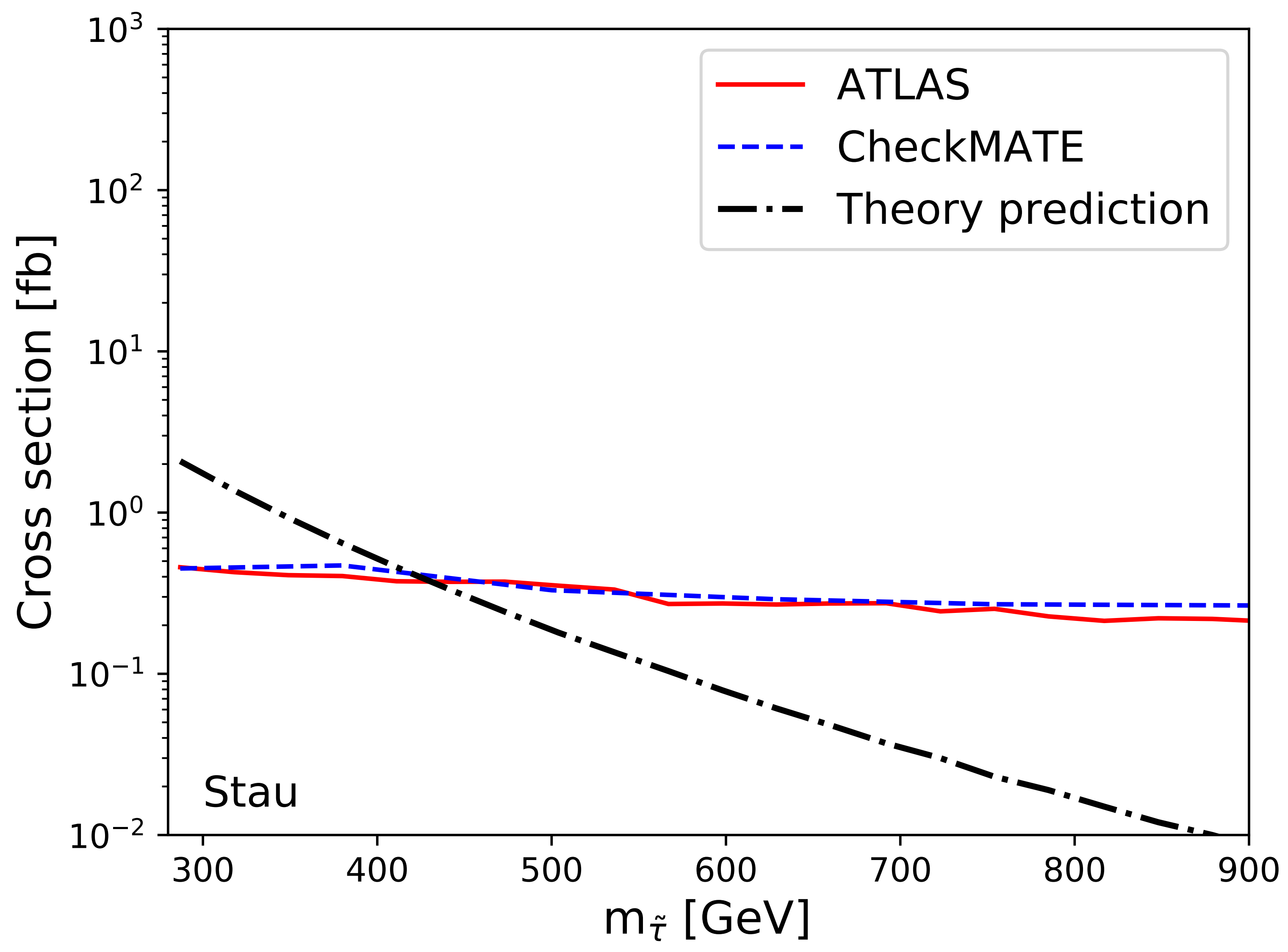
Lifetime behaviour confirmed for three lifetimes

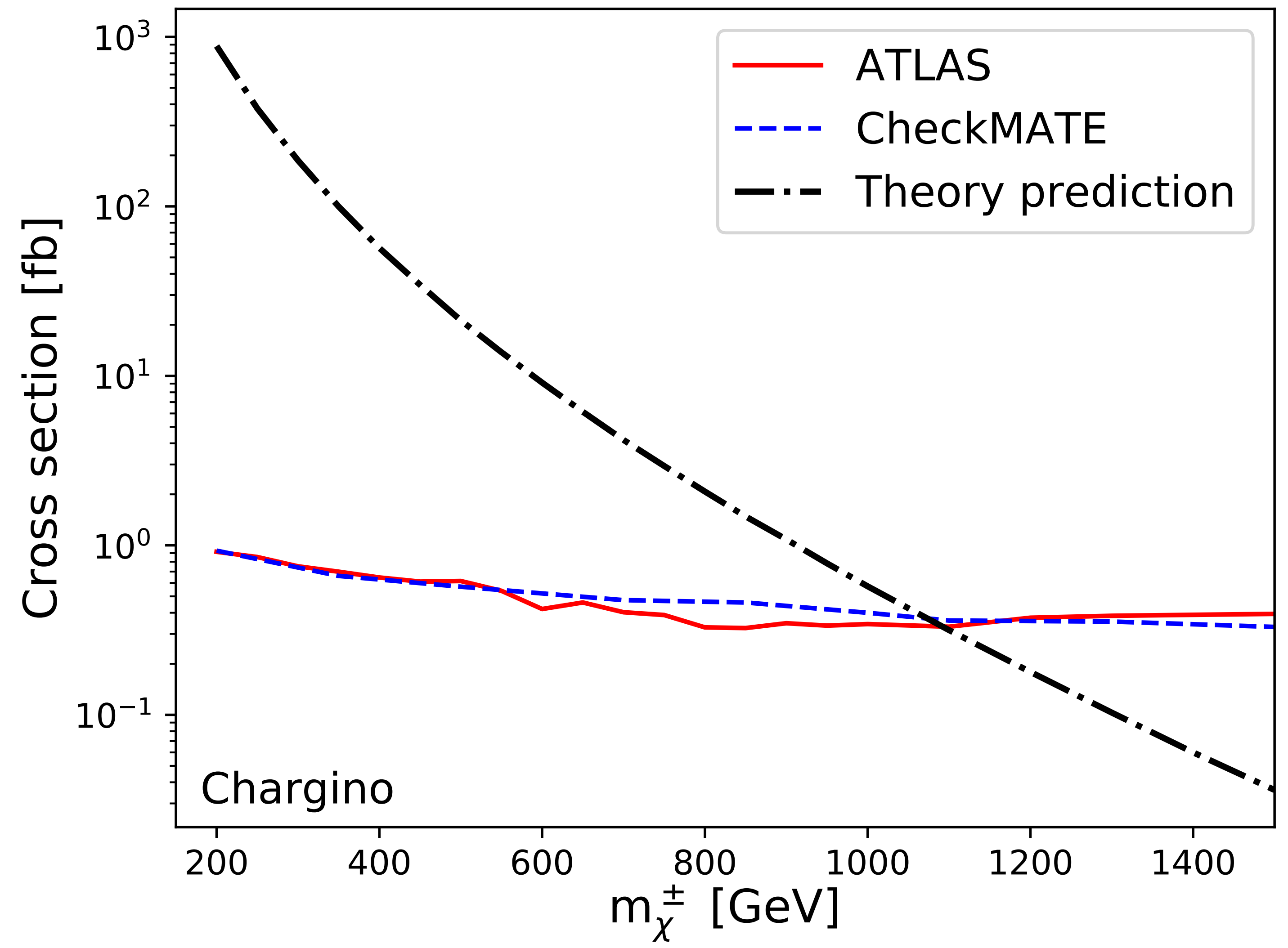
Search 3: Heavy Charged track

Benchmark Model









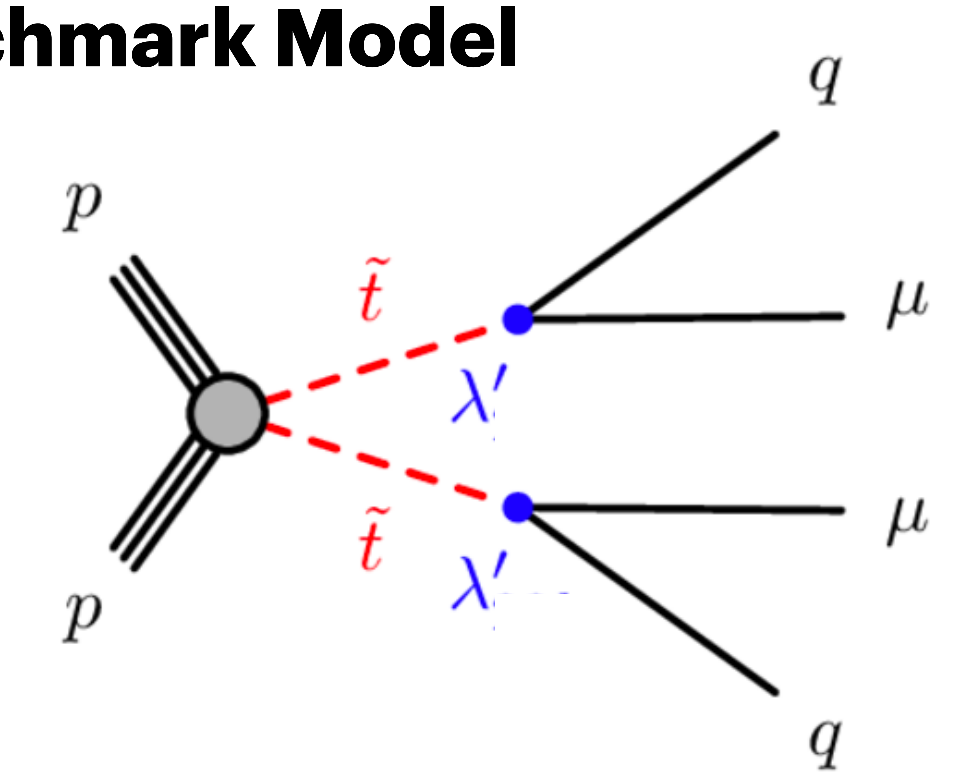
ATLAS, 1902.01636

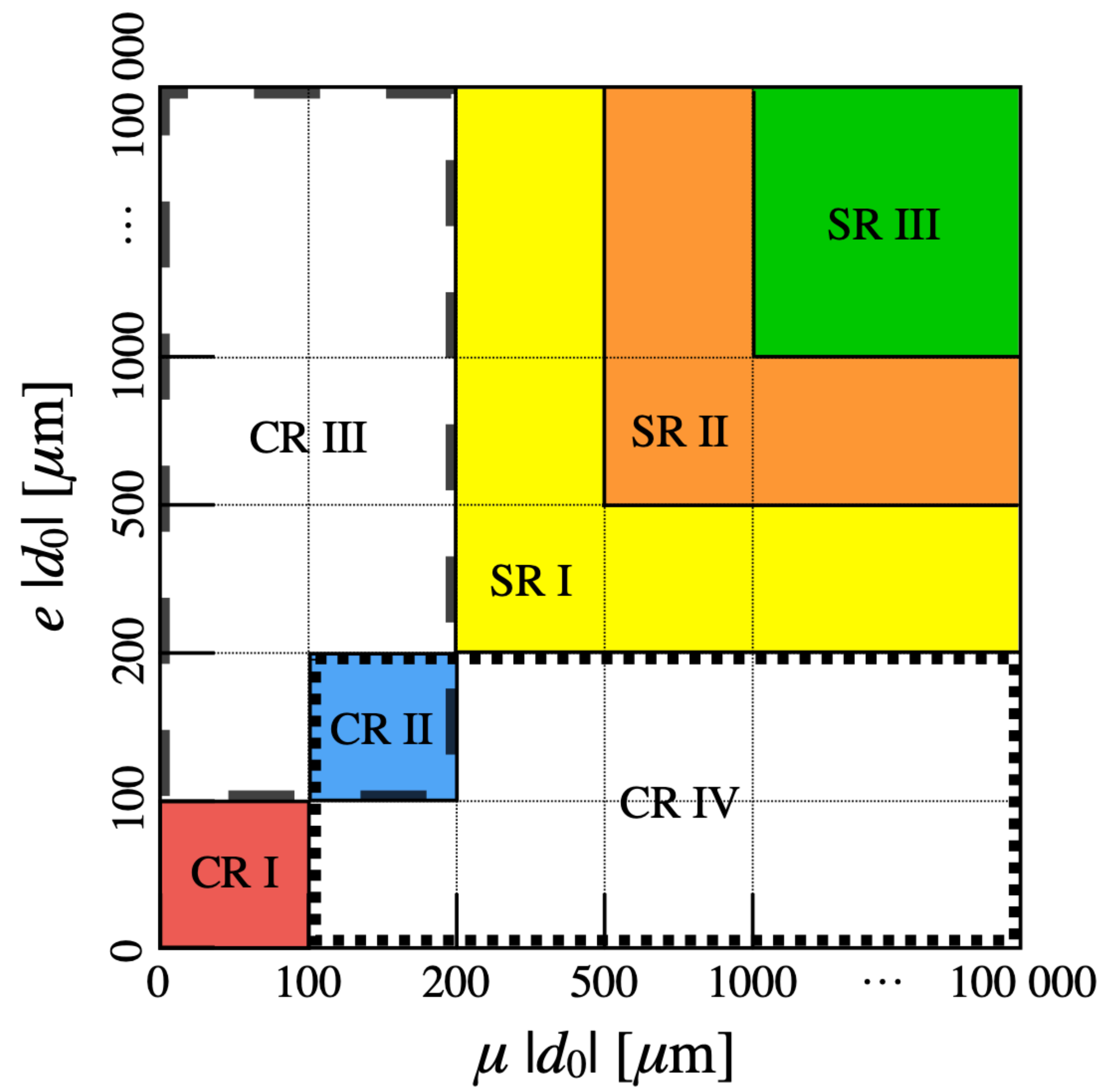
We implement the EW search regions

Efficiencies available based on true boost of particles

Search 4: Displaced Leptons

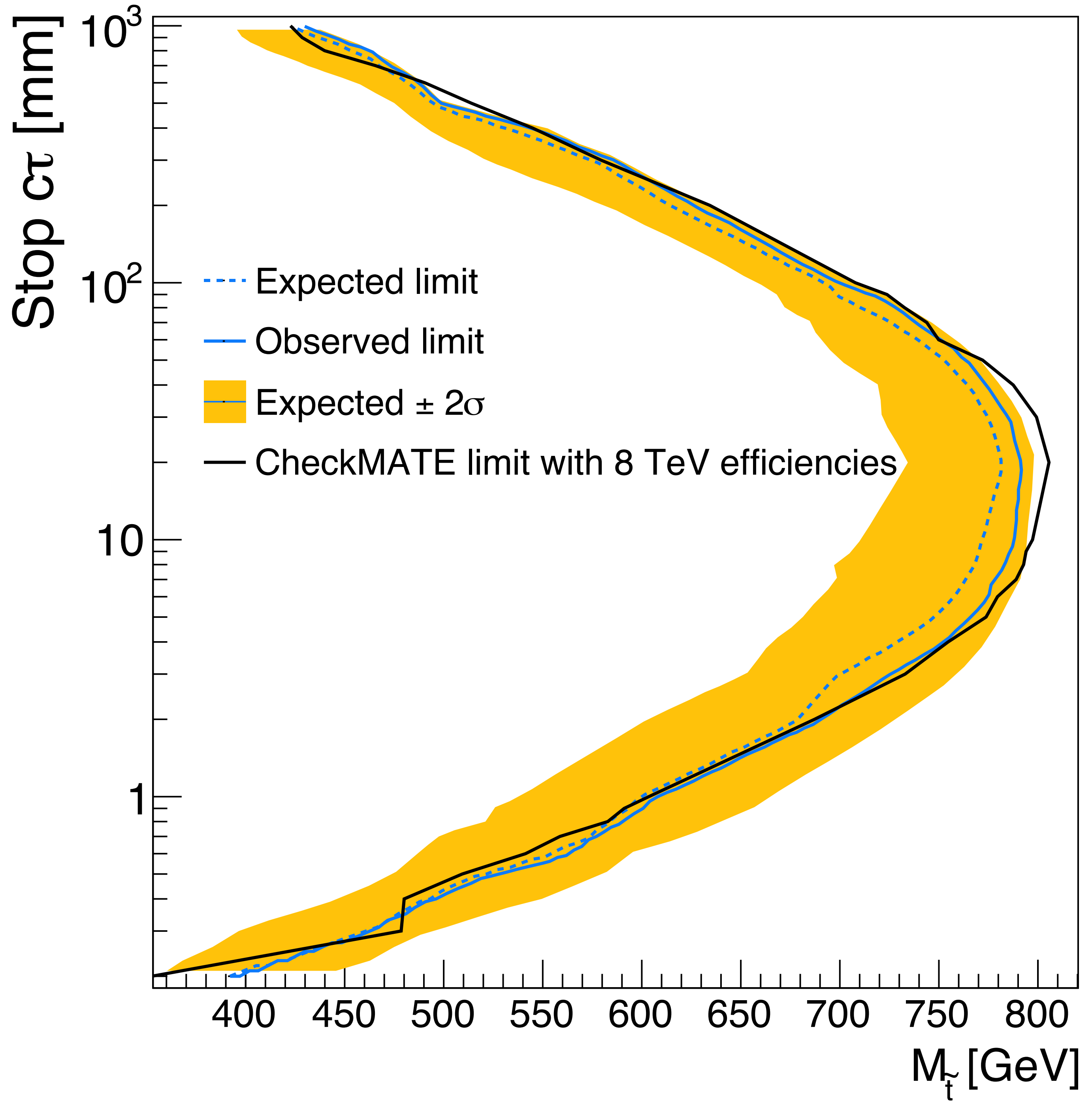
Benchmark Model



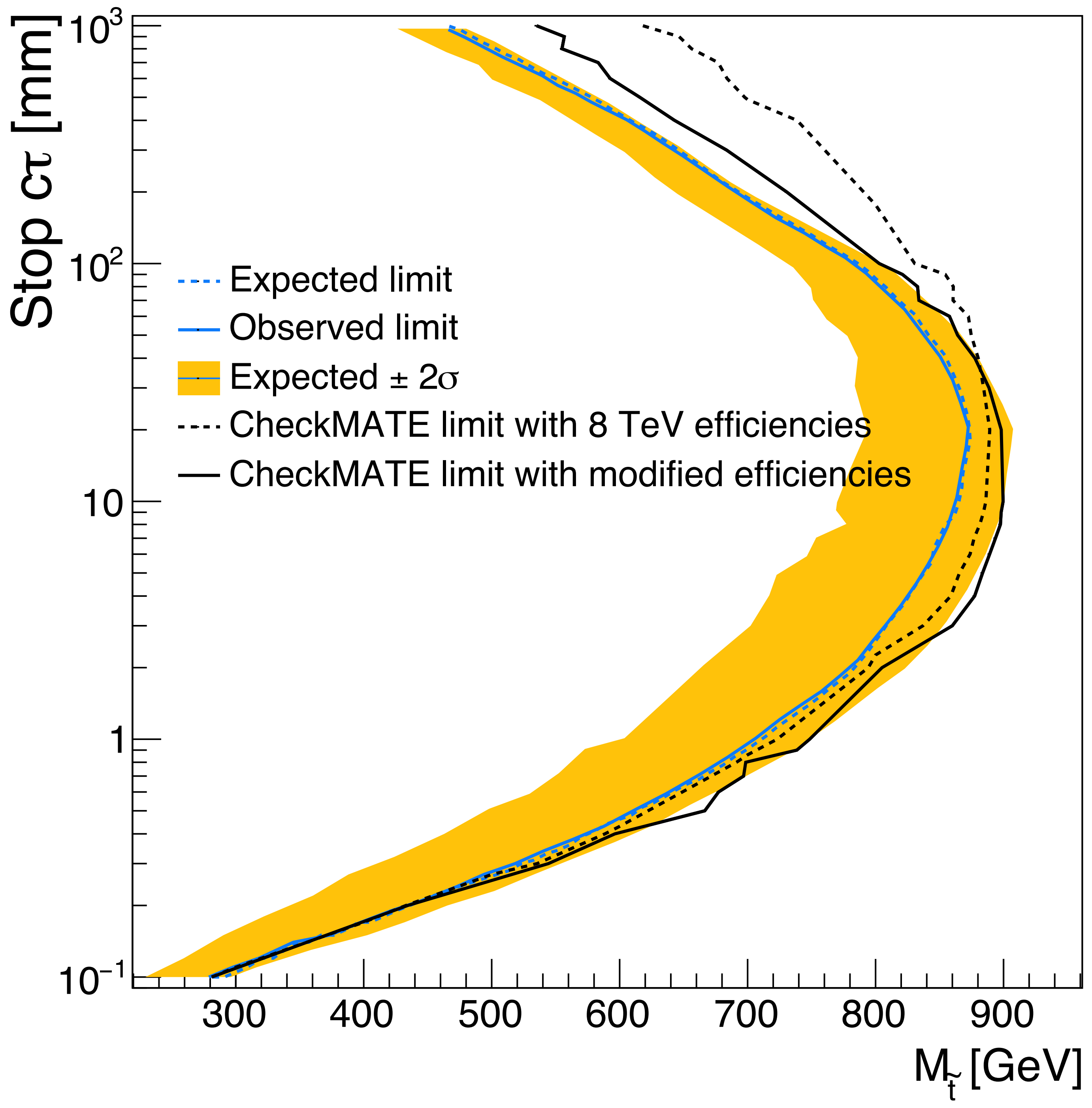


CMS, 1409.4789, CMS-PAS-EXO-16-022

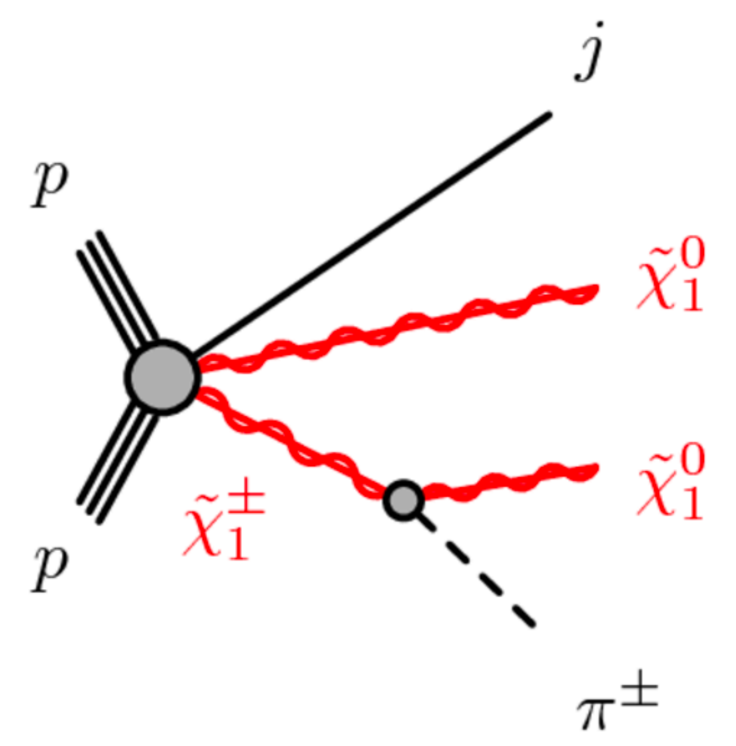
Displaced e/μ [8TeV]



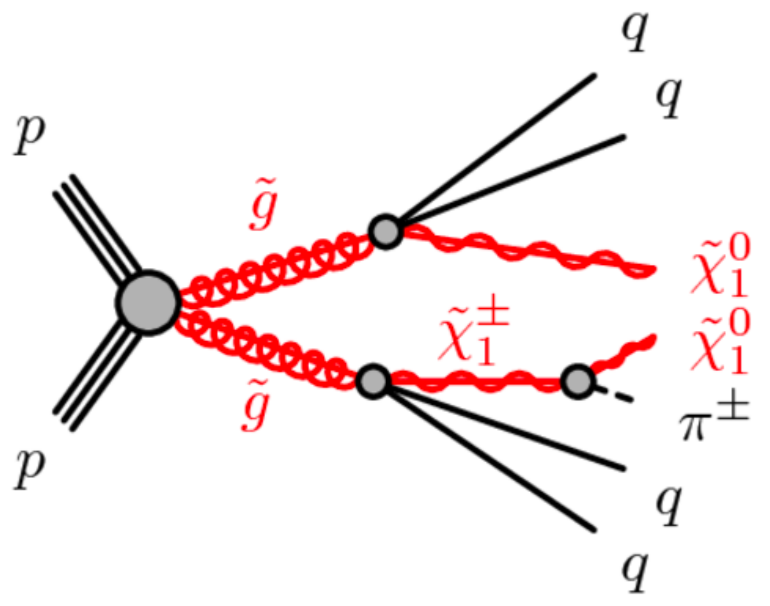
Displaced e/μ [13TeV]



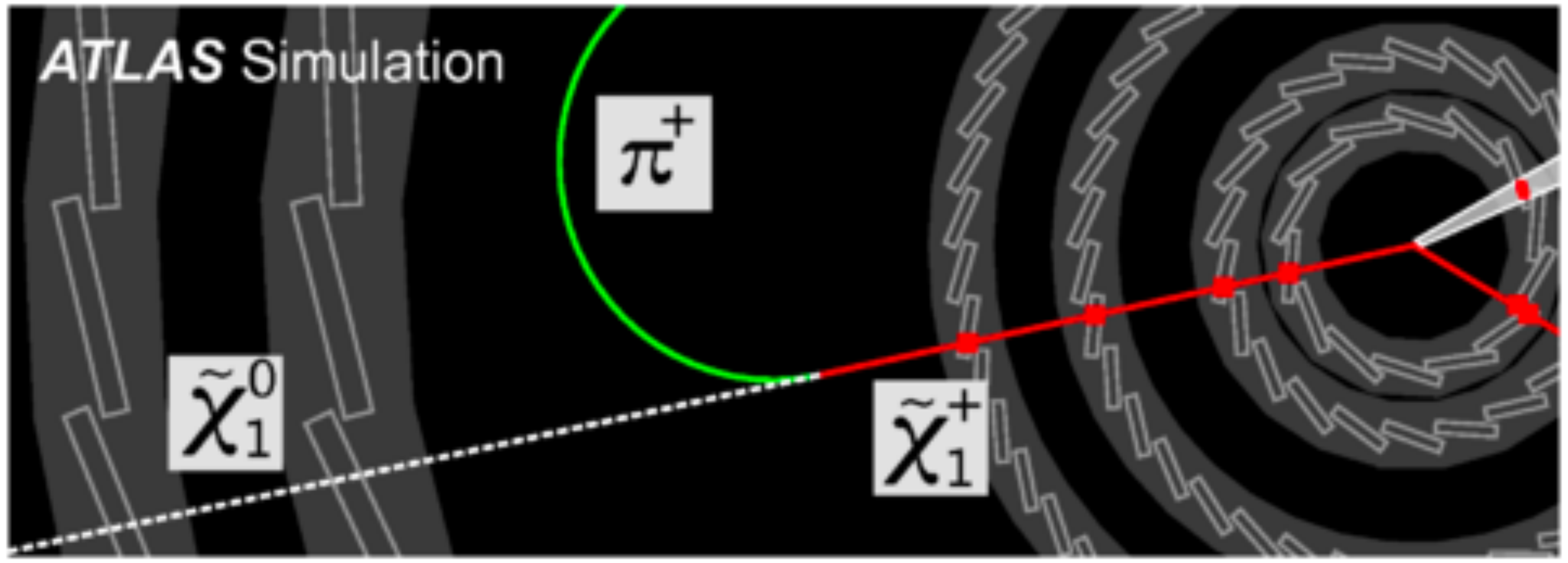
Search 5: Disappearing track



EW benchmark



Strong benchmark



(ATLAS, 1712.02118)

	CM $\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$	CM $\tilde{\chi}_1^+\tilde{\chi}_1^0$	CM $\tilde{\chi}_1^-\tilde{\chi}_1^0$	CM all channels	ATLAS
Trigger	445.1	624.0	274,4	1343.5	1276
Lepton Veto	423.4	608.5	267.3	1308.2	1181
MET and jet requirements	164.2	229.6	101.0	494.8	579
EW SR	5.2	4.4	1.6	11.2	13.5

	CM	ATLAS
Trigger	289	285
Lepton Veto	277	278
MET and jet requirements	216	202
strong SR	11	11

Models to test

EW model

New scalar

Charged under SU(2) only

Produced via Drell-Yan, decays via Yukawa-like coupling to lepton + invisible

Based on lifetime, see in track searches and displaced leptons

Strong model

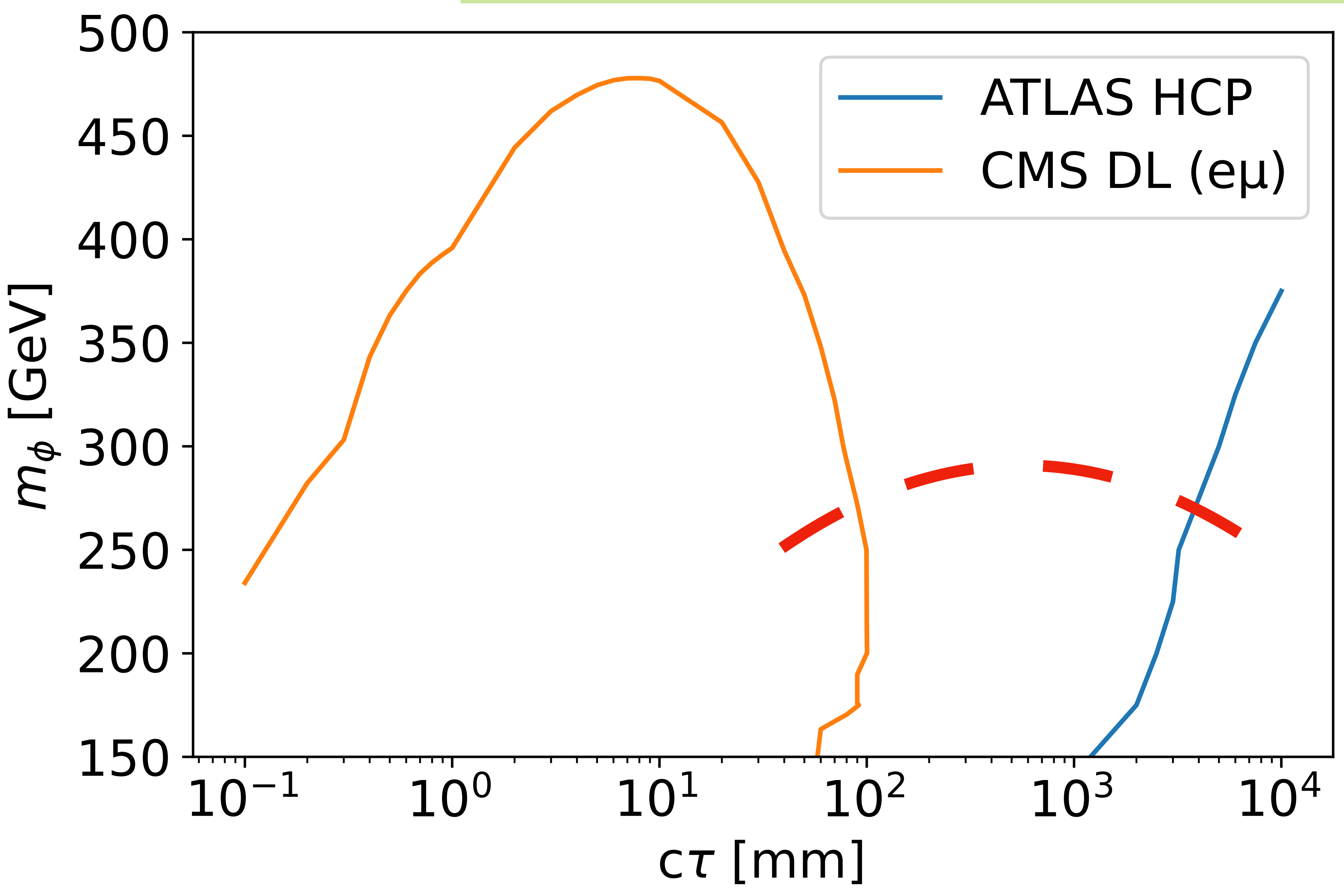
New scalar

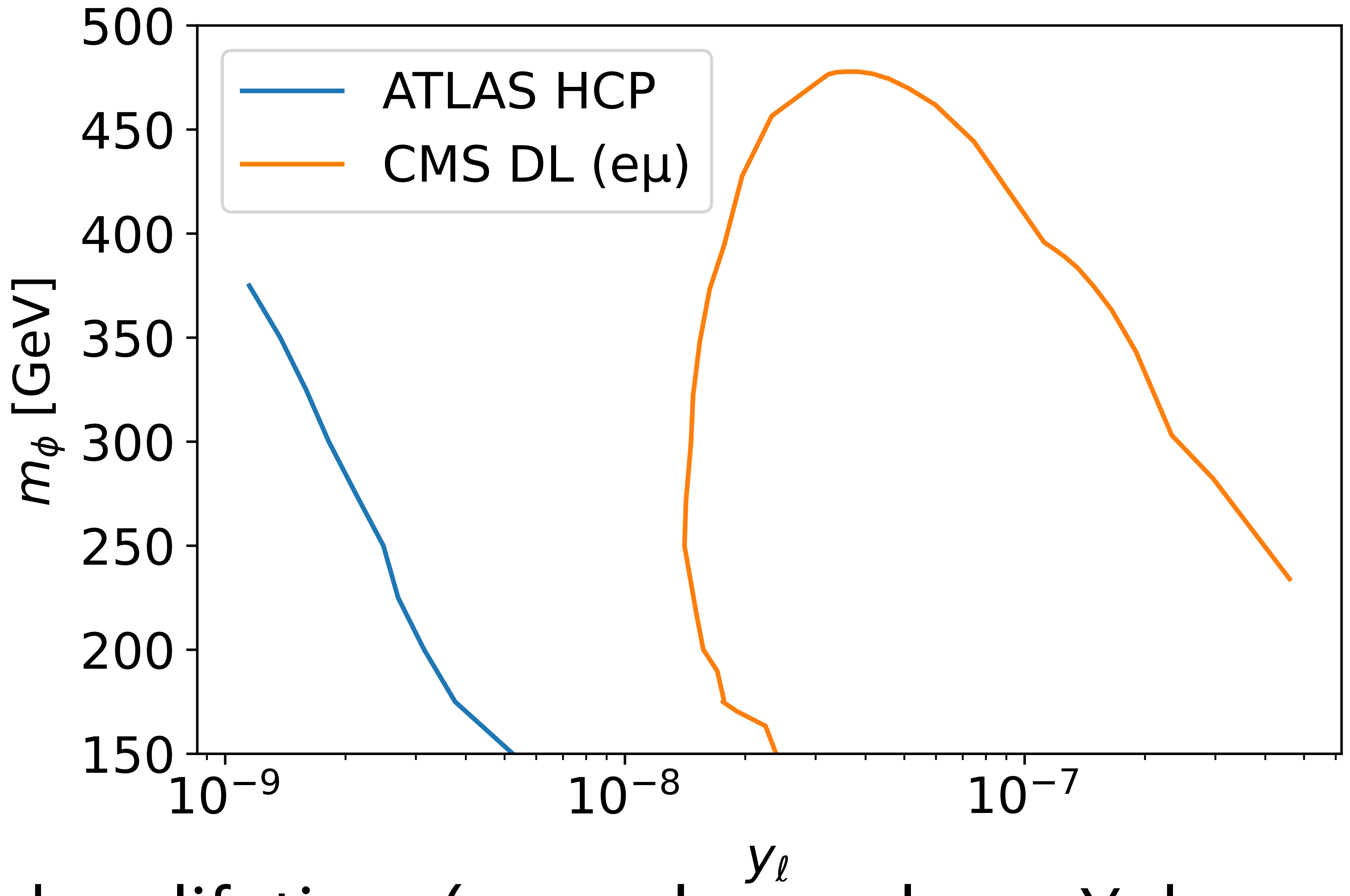
Charged under SU(3) only

Produced via s-channel gluon, decays via Yukawa-like coupling to lepton + quark (SUSY R-parity violating or leptoquark)

See in displaced vertex searches

EW model limits

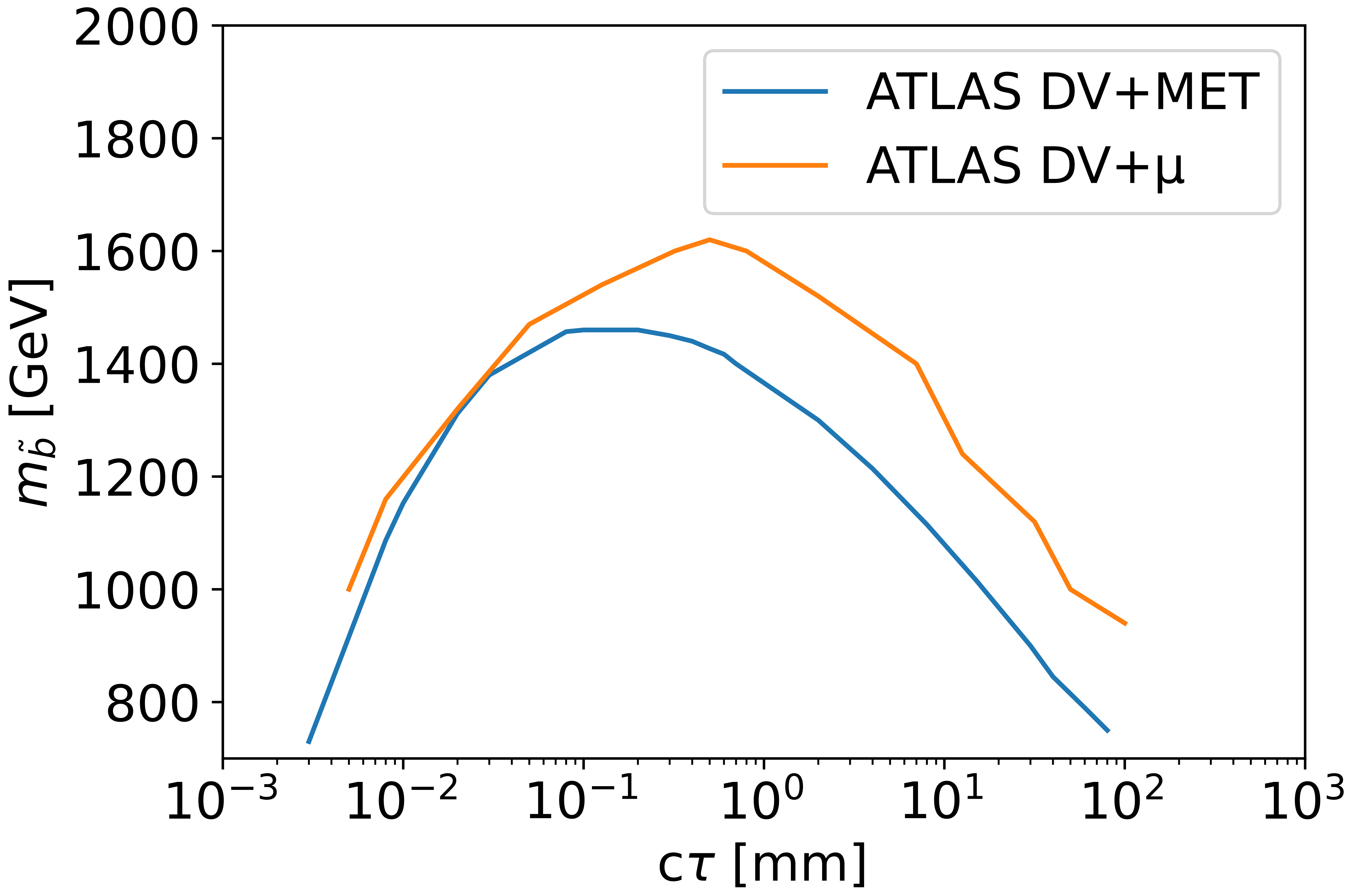


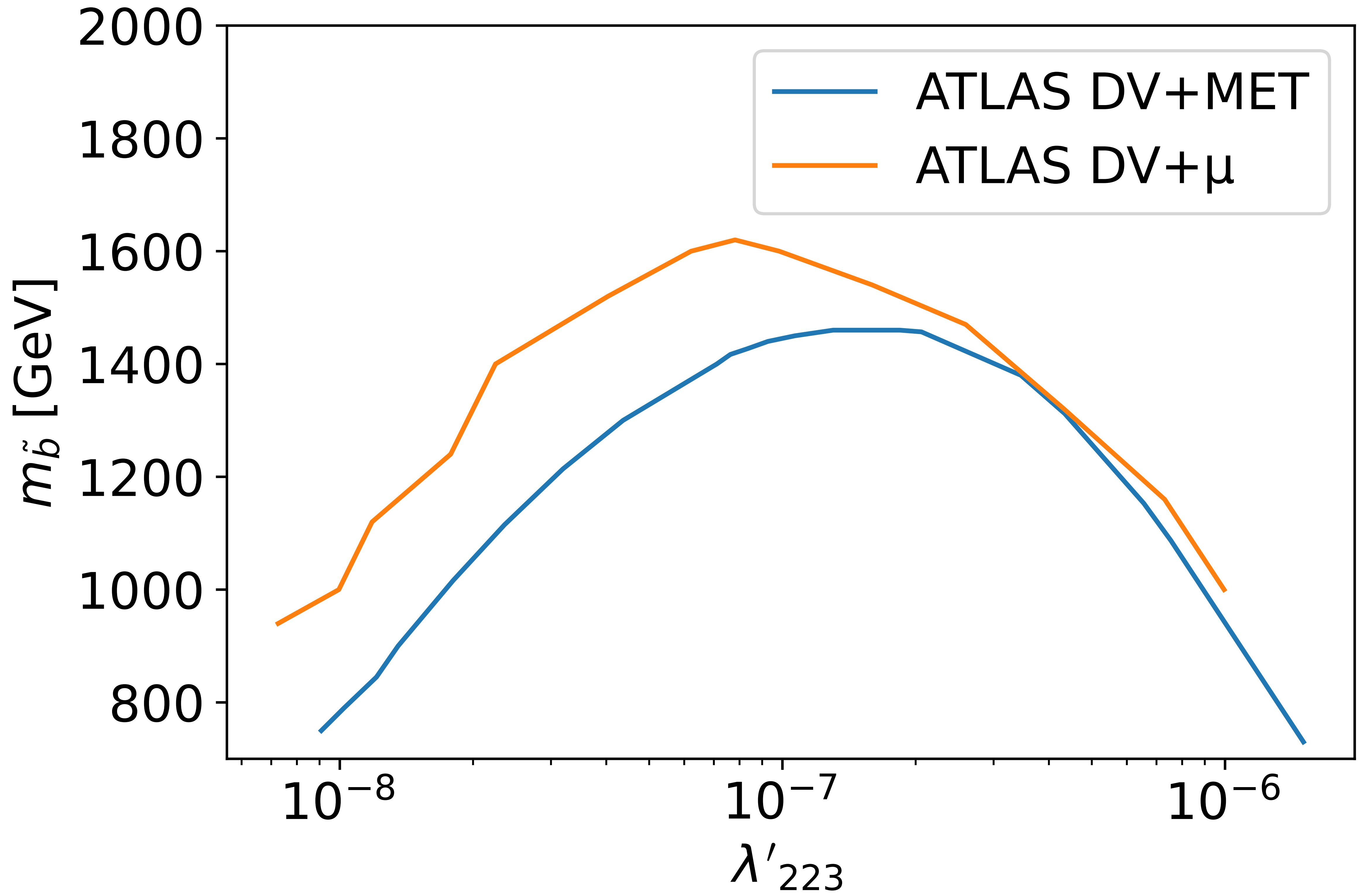


- Upper limits on masses between 150-480 GeV based on lifetime (or analogously on Yukawa coupling). There is a gap between lifetimes ~ 1 cm – 1 m which should in principle be seen by the disappearing track search.

- Intermediate mass range currently not visible in disappearing track because
(1) Large mono-jet trigger cut required kills production cross section (we need other triggers too)
(2) We don't know how if lepton veto works. Likely it should not affect because d0 is too large.

RPV model limits





Limits on masses ~ 800 - 1600 GeV based on lifetime

Alternately, can be interpreted as limits on RPV couplings

DV + MET still to be updated to full Run-2

How to use CheckMATE for your own model

Dercks, ND et al. Comp. Phys. Comm. (2017)

Generate signal events by linking to Pythia/Madgraph or provide LHE / hepMC file

Simulate kinematic cuts

Compare to published upper limits