

Update on Reinterpretation Effort in Phenomenology Community

i.e. How well can we apply the complicated results from PP experiments to new models?

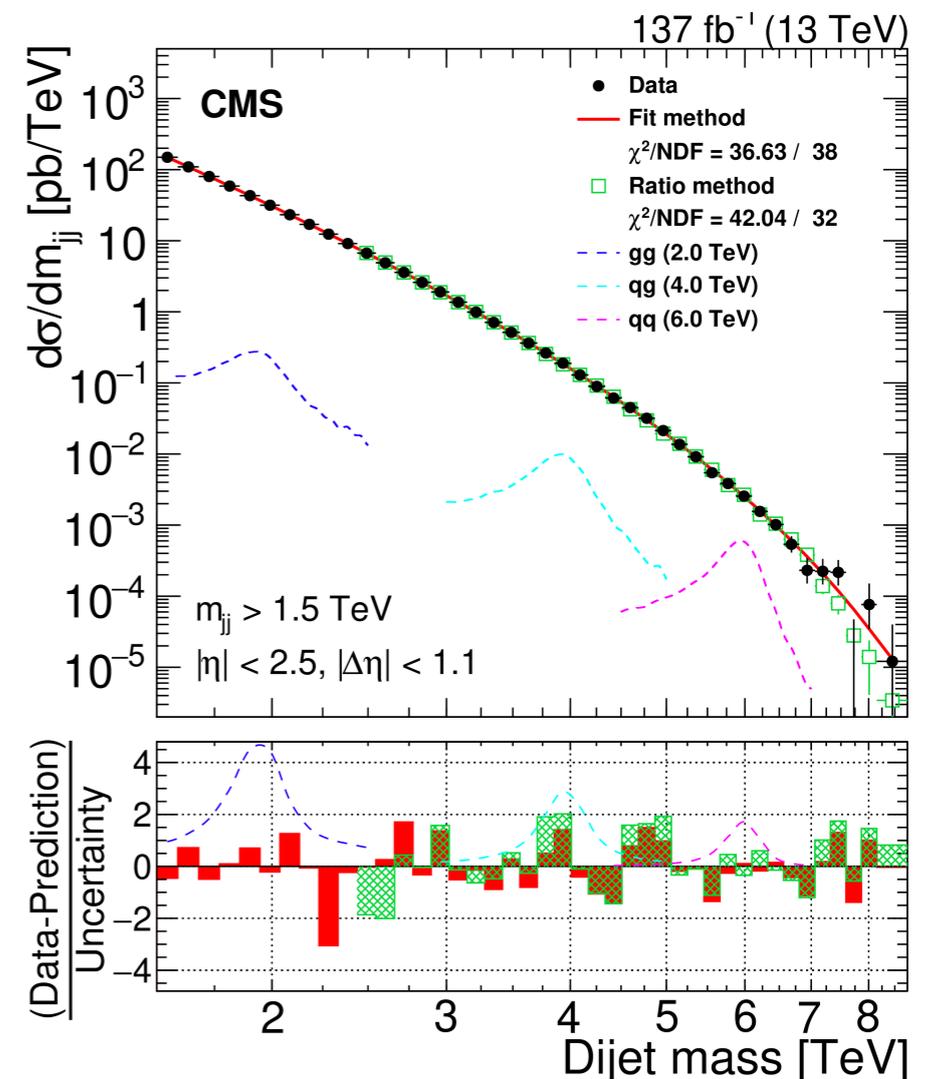
What is reinterpretation (a.k.a "recast")

In the old days: give an "unfolded measurement" for theorists to use

Experimentalists estimate all detector acceptance, efficiencies and divide the observed number of events by these factors to provide CROSS SECTION measurements or limits

You can simply calculate $\sigma \times \text{BR}$ and check whether your model is allowed

This is still useful for simple kinematics e.g. new heavy scalar/ Z' (vectors) that decay into two jets because



Then this was not enough...

In preparation for the LHC turning on, people started think about what happens when we find something at the LHC — how can we be sure of the underlying theory? (a.k.a. the “inverse problem”)

Physics issues

- ➔ Many different theories predict the same final state (e.g. $2l + MET$)
- ➔ Larger SM backgrounds than ever before: important to be super-precise about the kinematic features to be able to make discovery
- ➔ Even same theory predicts different energy spectrum/angular correlations based on parameter choice

Human resource issues

30 years of no “new” physics discoveries meant many, many theories to be tested; experimentalists could not be expected to check all

Running an experimental analysis of data takes time (usually too long for theory students to graduate as they need 2+ papers to get a job after)

Solution to the data interpretation dilemma

Theorists should do their own checks whether their theory agrees with data

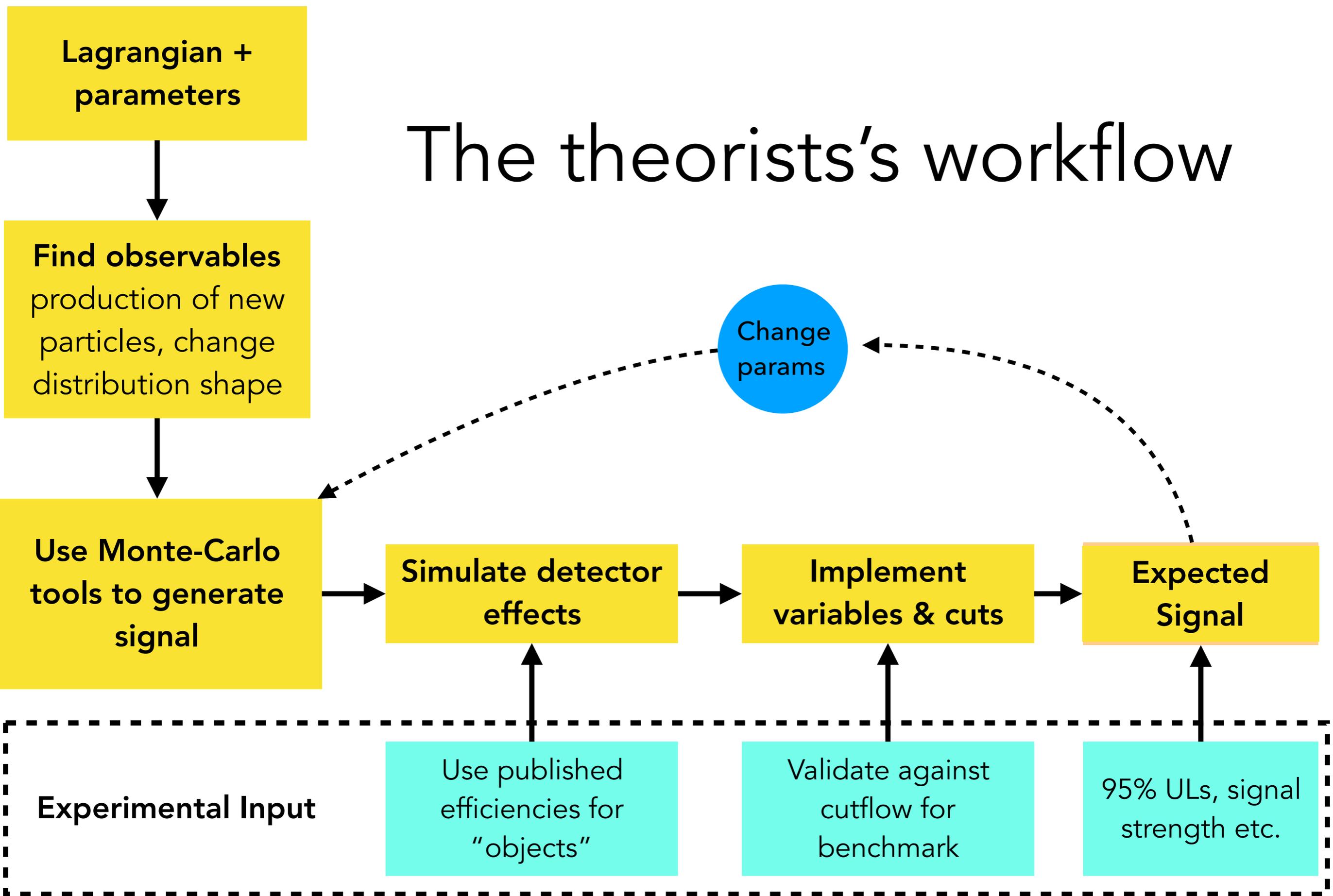
Solution to the data interpretation dilemma

Theorists should do their own checks whether their theory agrees with data

What do we need to understand do this?

1. How do experiments select their events (cuts) ★★★★★
2. Probability of a monte carlo event particle satisfying the detector acceptance (smearing parameters, fast sim, Delphes, ...) ★★★★★☆
3. A way to validate what we're doing is likely to match experiments' own workflow (cutflow tables for multiple benchmarks with different kinematics) ★★★☆☆

The theorists's workflow

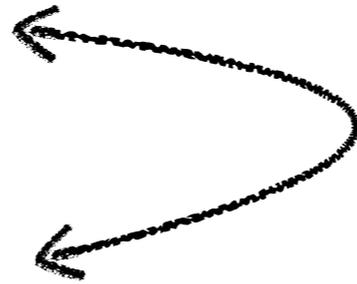


Multi-Analyses public codes

- **CheckMATE**

- MadAnalysis 5

- Gambit



Mainly collider

Optimised for large scans, more low-energy/DM, fewer collider analyses

Other ideas: Smodels (uses simplified models), Contur (uses SM measurements)

The problem with staying on top

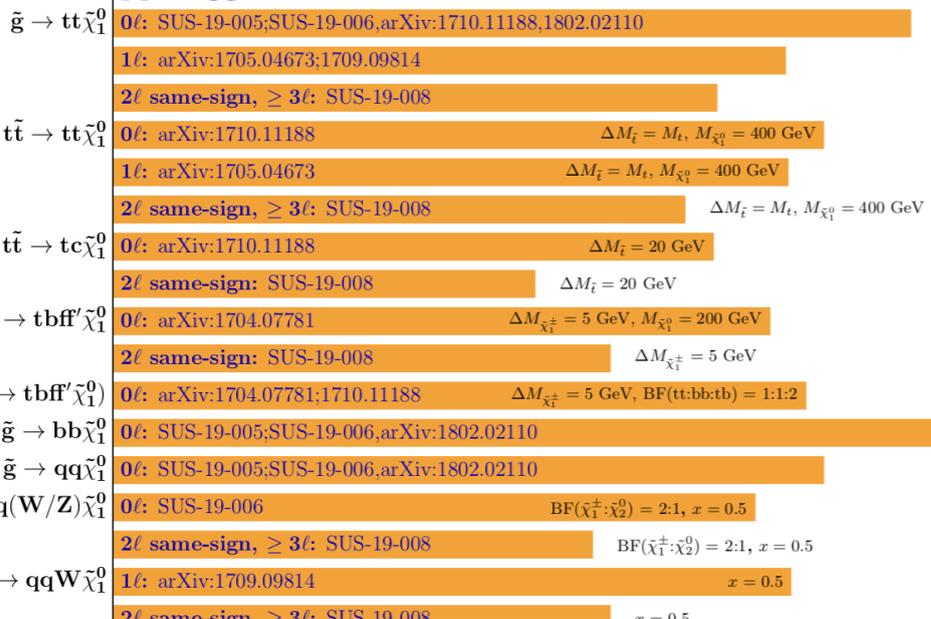
CMS (preliminary)

May 2019

Overview of SUSY results: gluino pair production

36/137 fb⁻¹ (13 TeV)

pp → g̃g̃

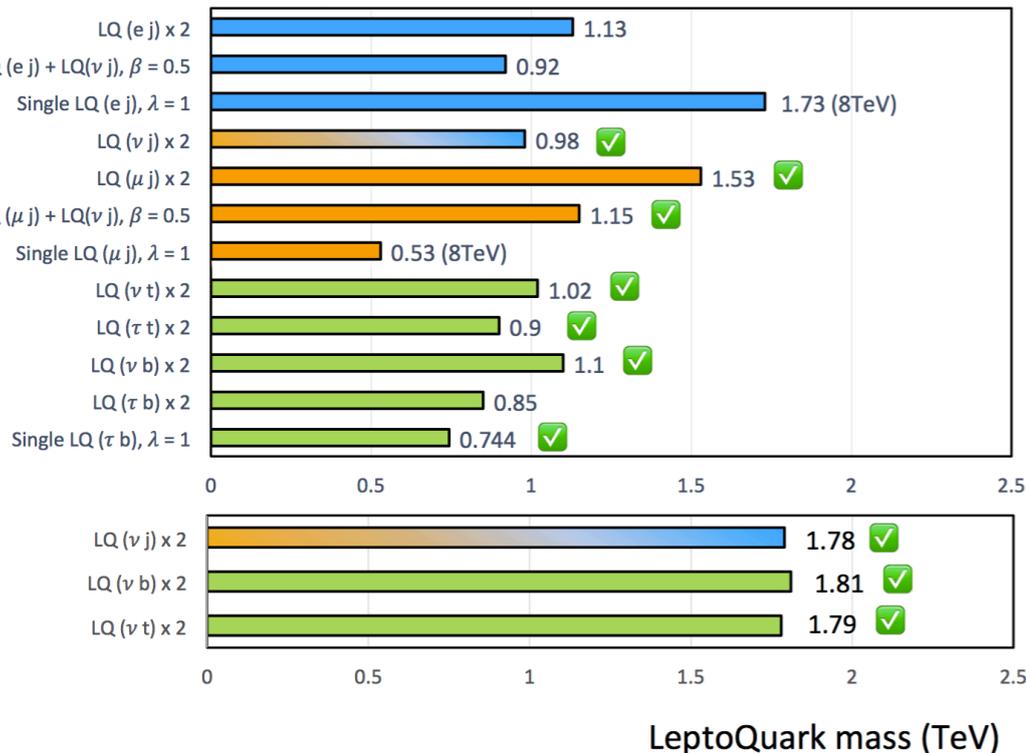


May 2018

LQ → 1st gen. 2nd gen. 3rd gen. Full 2016 dataset

Scalar LQ

Vector LQ (LQ model used: 1801.07641)

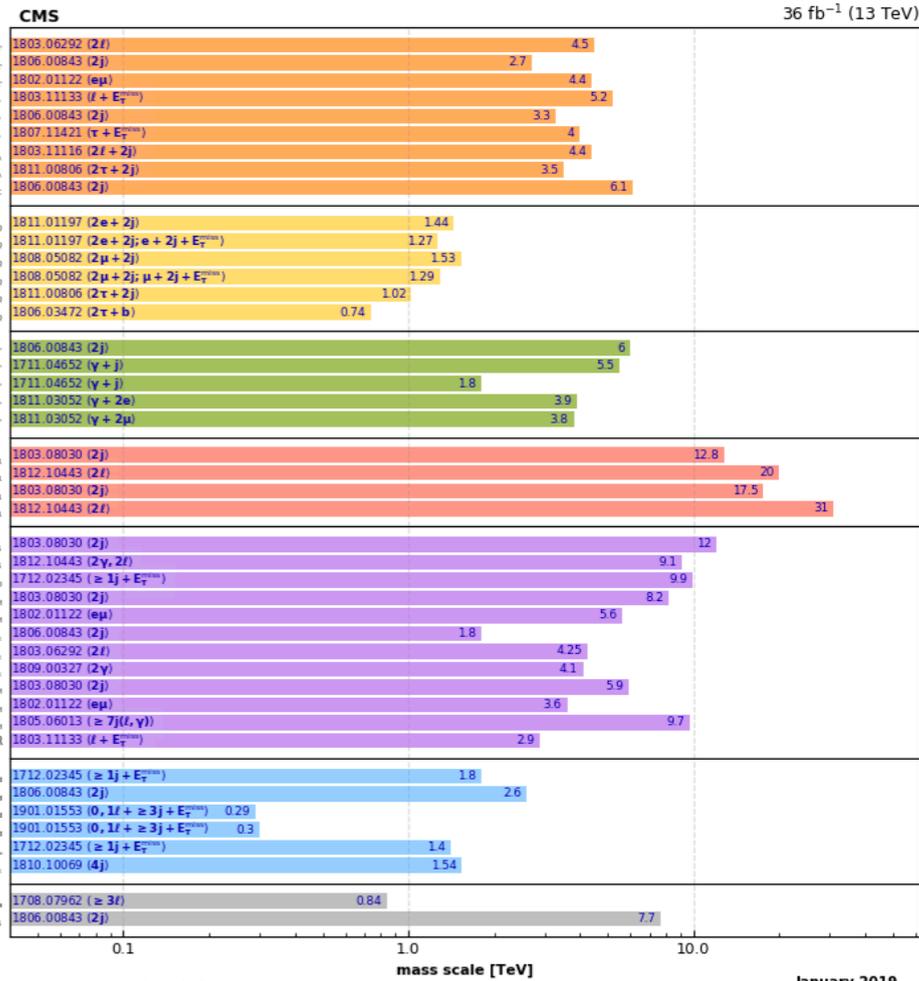


- Heavy Gauge Bosons**
 - SSM Z'(ll)
 - SSM Z'(qq)
 - LFV Z', BR(eμ) = 10%
 - SSM W'(lv)
 - SSM W'(q̄)
 - SSM W'(τν)
 - LRSW W₆(lN₆), M_{N₆} = 0.5M_W
 - LRSW W₆(τN₆), M_{N₆} = 0.5M_W
 - Axigluon, Coloron, color = 1
- Leptoquarks**
 - scalar LQ (pair prod.), coupling to 1st gen. fermions, β = 1
 - scalar LQ (pair prod.), coupling to 1st gen. fermions, β = 0.5
 - scalar LQ (pair prod.), coupling to 2nd gen. fermions, β = 1
 - scalar LQ (pair prod.), coupling to 2nd gen. fermions, β = 0.5
 - scalar LQ (pair prod.), coupling to 3rd gen. fermions, β = 1
 - scalar LQ (single prod.), coup. to 3rd gen. ferm., β = 1, λ = 1
- Excited Fermions**
 - excited light quark (qq), Λ = m_q^{*}
 - excited light quark (qγ), f_s = f = f' = 1, Λ = m_q^{*}
 - excited b quark, f_s = f = f' = 1, Λ = m_q^{*}
 - excited electron, f_s = f = f' = 1, Λ = m_e^{*}
 - excited muon, f_s = f = f' = 1, Λ = m_μ^{*}
- Contact Interactions**
 - quark compositeness (q̄q), η_{L/R,qq} = 1
 - quark compositeness (ll), η_{L/R,ll} = 1
 - quark compositeness (q̄q), η_{L/R,qq} = -1
 - quark compositeness (ll), η_{L/R,ll} = -1
- Extra Dimensions**
 - ADD (jj) HLZ, n_{ED} = 3
 - ADD (γγ, ll) HLZ, n_{ED} = 3
 - ADD G_{KK} emission, n = 2
 - ADD QBH (ij), n_{ED} = 6
 - ADD QBH (eμ), n_{ED} = 6
 - RS G_{KK}(q̄q, gg), k/M_{pl} = 0.1
 - RS G_{KK}(ll), k/M_{pl} = 0.1
 - RS G_{KK}(γγ), k/M_{pl} = 0.1
 - RS QBH (ij), n_{ED} = 1
 - RS QBH (eμ), n_{ED} = 1
 - non-rotating BH, M₅ = 4 TeV, n_{ED} = 6
 - split-UED, μ ≥ 4 TeV
- Dark Matter**
 - (axial-)vector mediator (χχ'), g₅ = 0.25, g_{DM} = 1, m_χ = 1 GeV
 - (axial-)vector mediator (q̄q), g₅ = 0.25, g_{DM} = 1, m_χ = 1 GeV
 - scalar mediator (+t/t̄), g₅ = 1, g_{DM} = 1, m_χ = 1 GeV
 - pseudoscalar mediator (+t/t̄), g₅ = 1, g_{DM} = 1, m_χ = 1 GeV
 - scalar mediator (fermion portal), λ₅ = 1, m_χ = 1 GeV
 - complex sc. med. (dark QCD), m_{W₅} = 5 GeV, cτ_{W₅} = 25 mm
- Other**
 - Type III Seesaw, B_e = B_μ = B_τ
 - string resonance

otherwise mediate

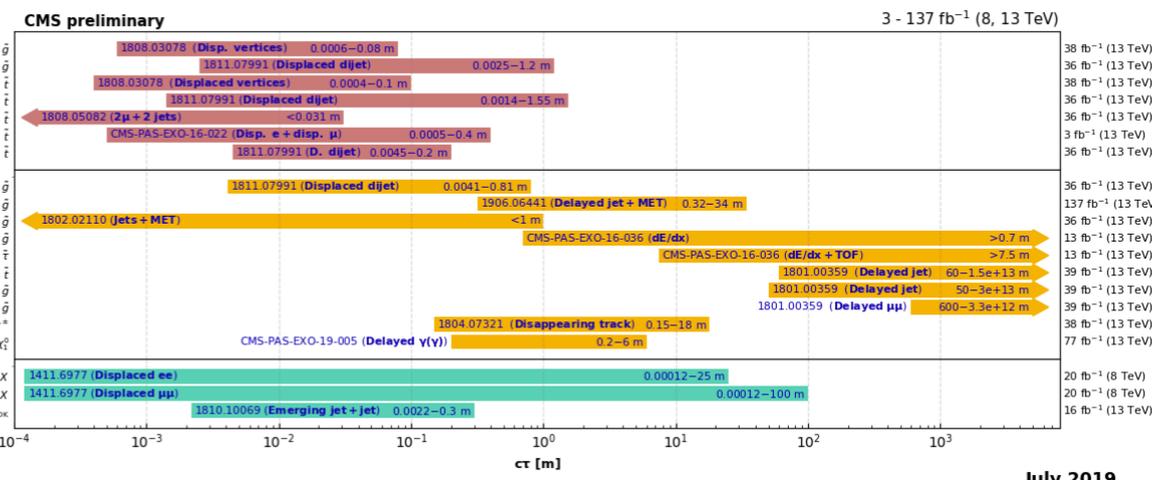
Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included).

Overview of CMS EXO results



January 2019

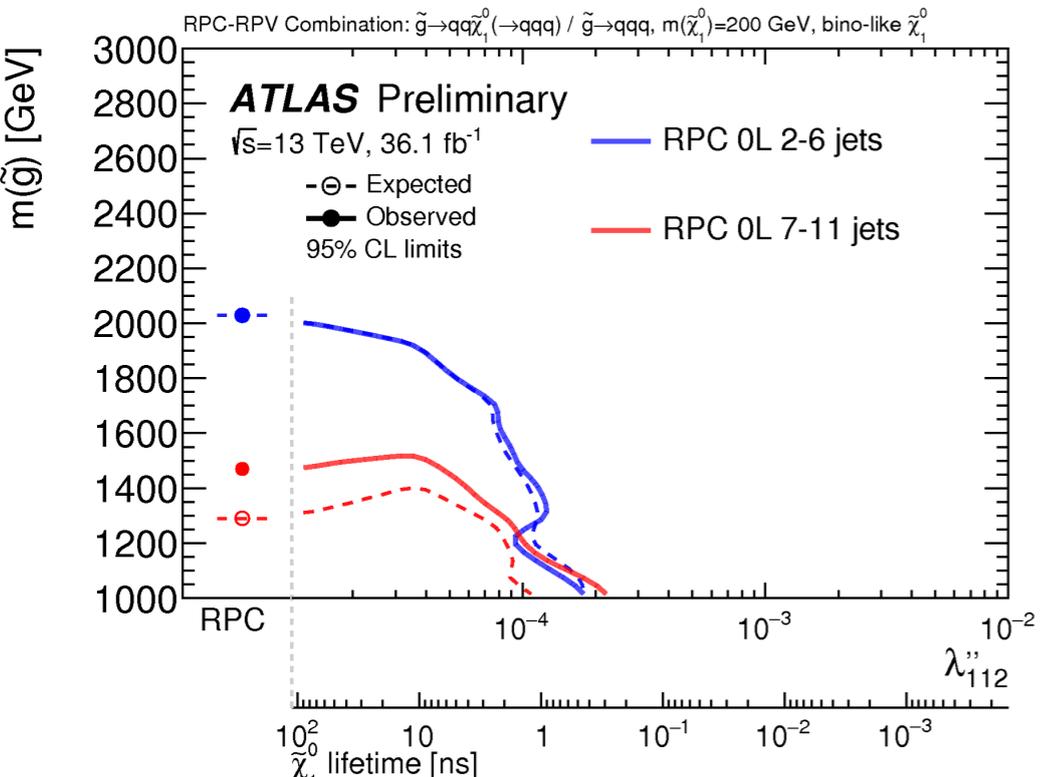
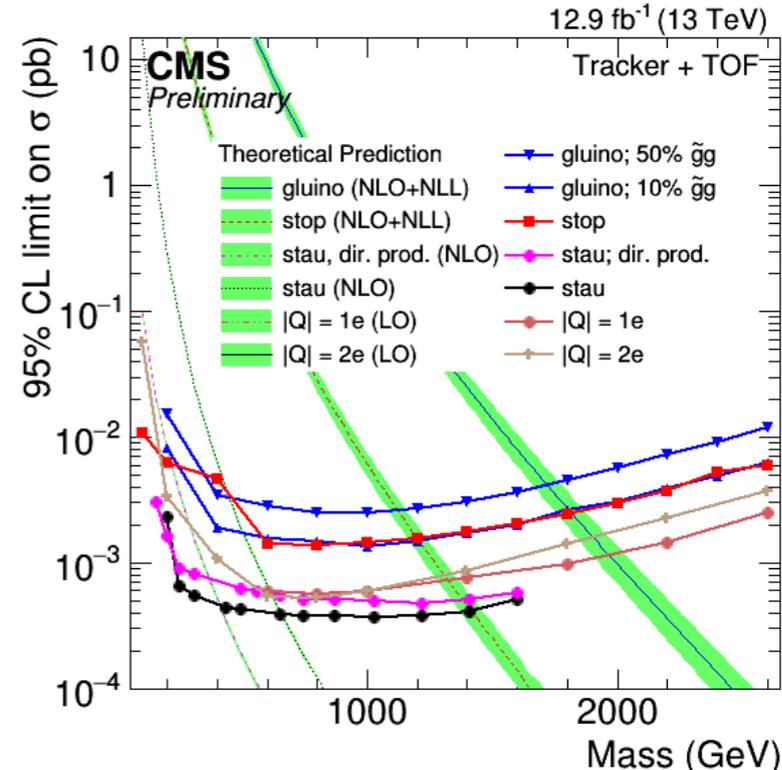
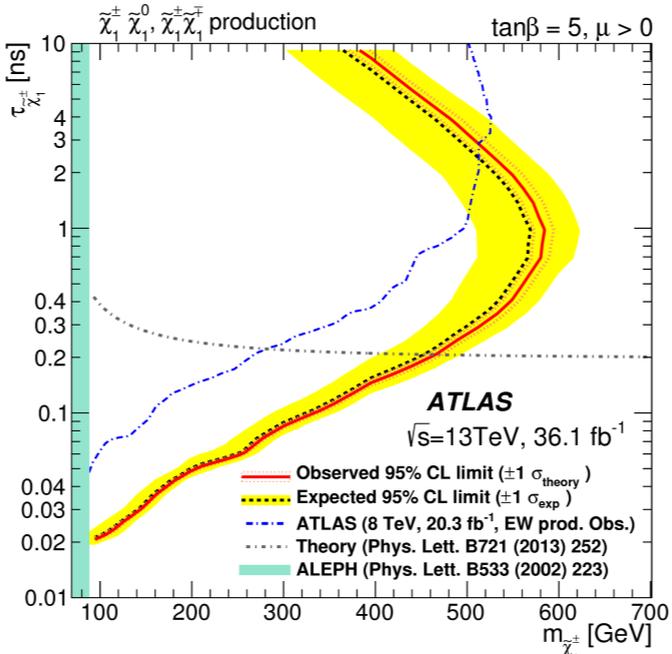
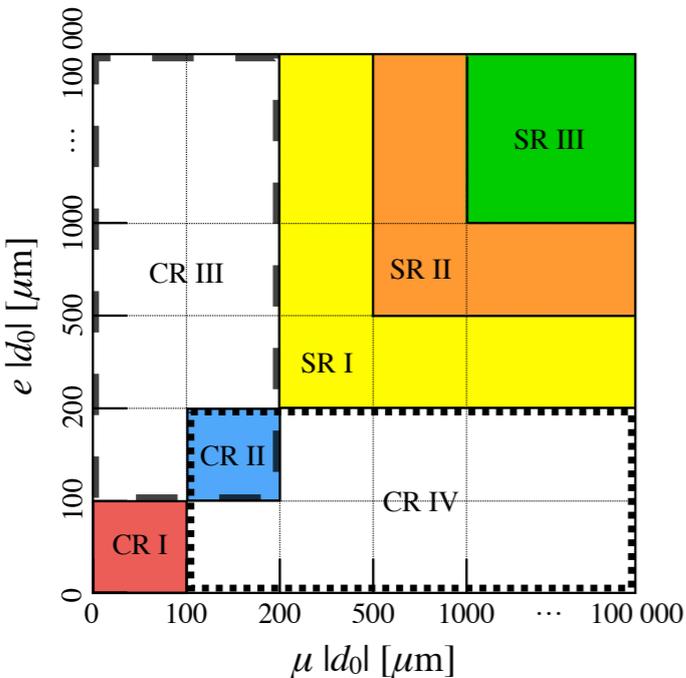
Overview of CMS long-lived particle searches



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

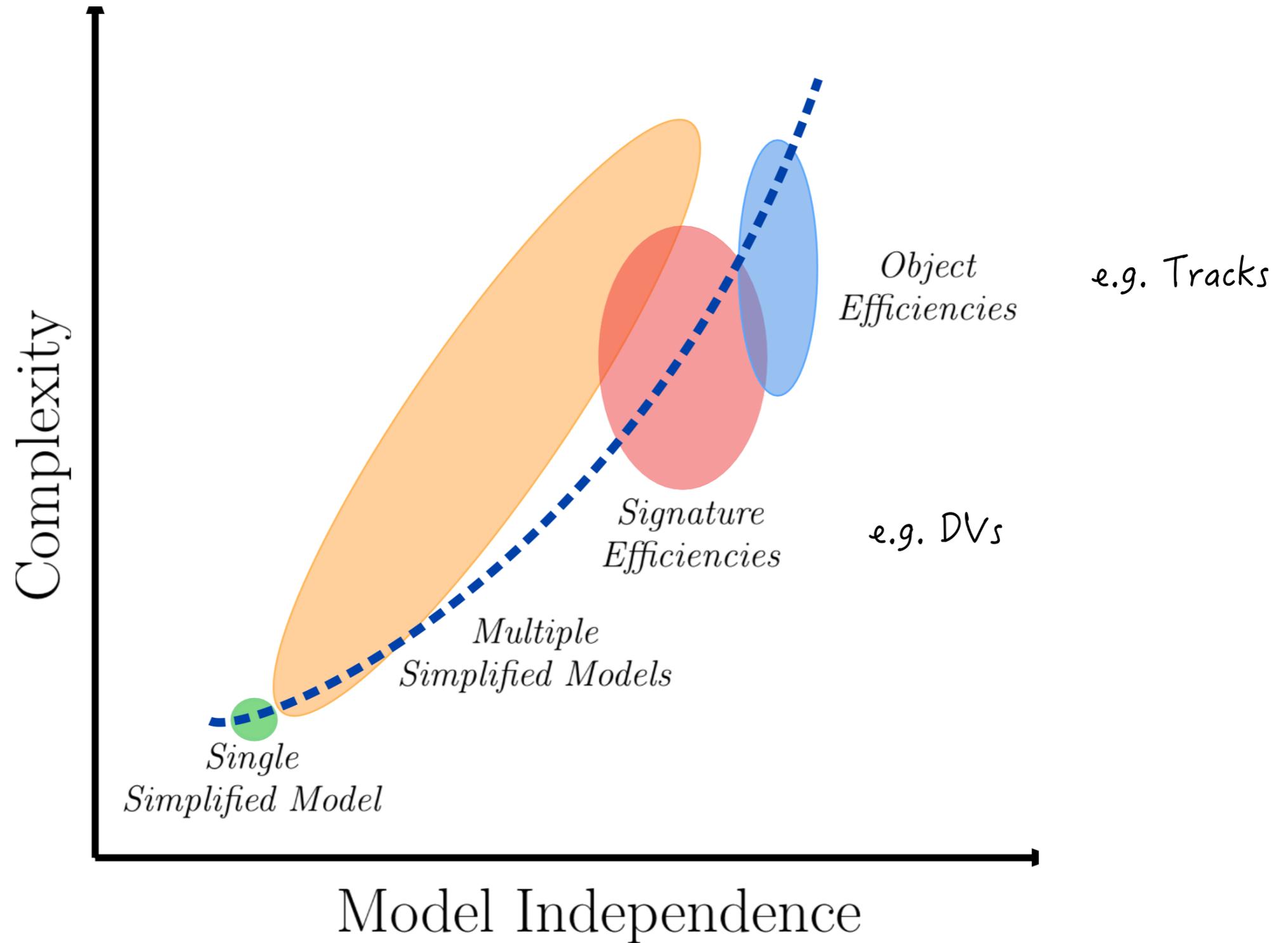
July 2019

New Challenges: Long-lived particles



RPC meets RPV study by ATLAS showed they had been throwing away events that had both prompt+displaced objects as a part of their cleaning cuts: this means the idea that you can always look at inclusive mono-jet later on if you think of a new signature is not really true!

Providing efficiencies



Intermission
(time for commercial break)

Flowchart for Recasting analyses

Write the Lagrangian

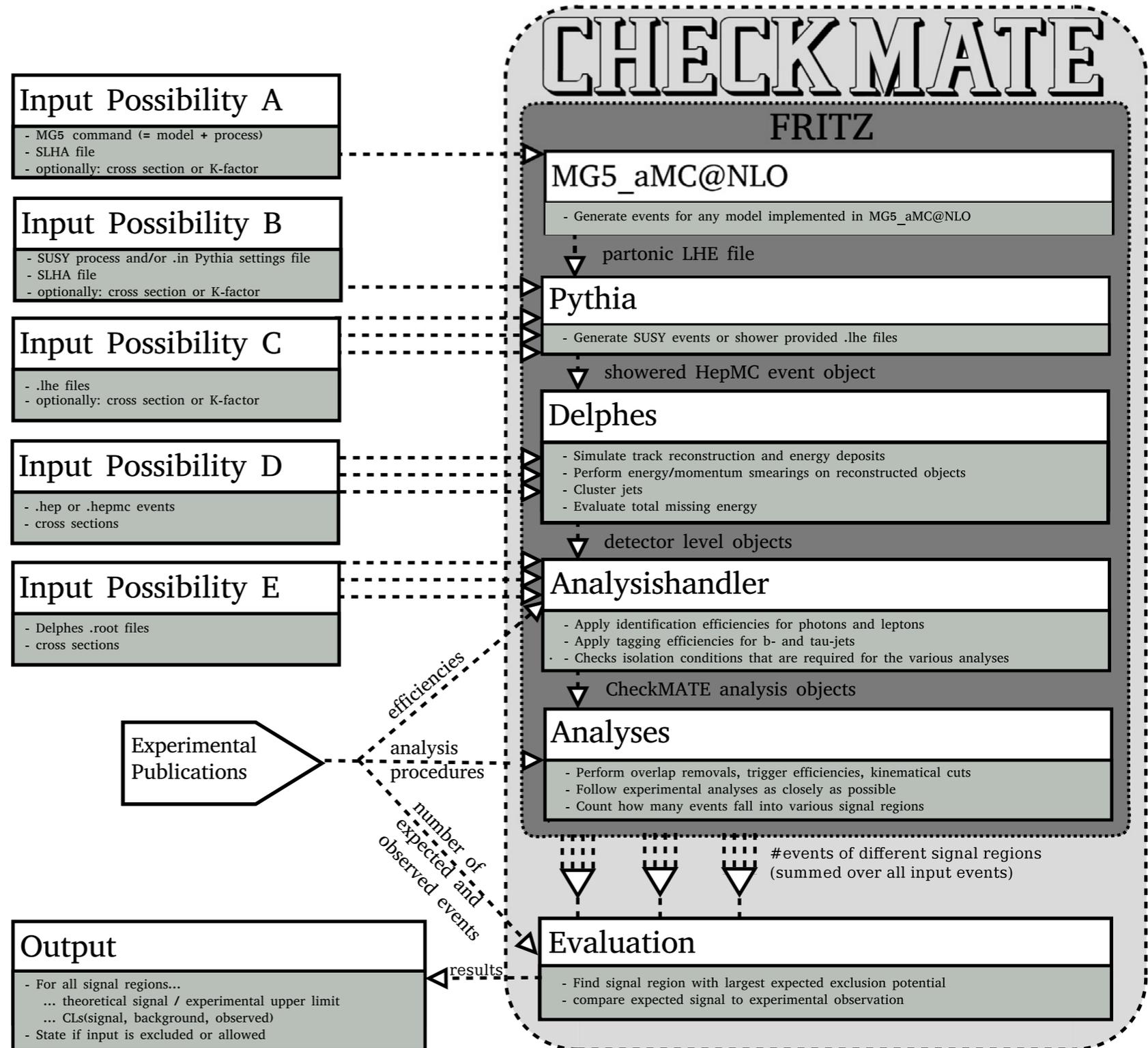
Generate signal events

Include QCD effects

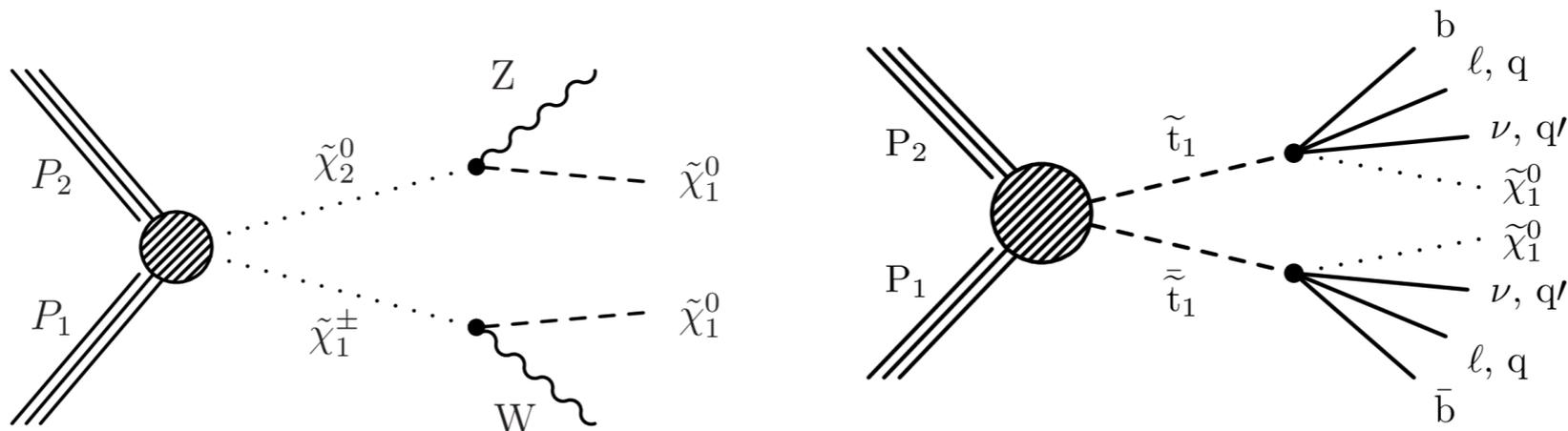
Include detector effects

Simulate kinematic cuts

Compare to published upper limits



Validation



Variable	SR selection criteria
N_ℓ	$= 2 (ee, \mu\mu, e\mu)$
$Q(\ell_1)Q(\ell_2)$	-1
$p_T(\ell_1), p_T(\ell_2)$	$[5, 30]$ GeV
$p_T(\mu_2)$ for high E_T^{miss} \tilde{t} -like SR	$[3.5, 30]$ GeV
$ \eta_\mu $	< 2.4
$ \eta_e $	< 2.5
$d_z(\ell_{1,2})$ & $d_{xy}(\ell_{1,2})$	< 0.01 cm
$Iso_{\text{rel}}(\ell_{1,2})$ & $Iso_{\text{abs}}(\ell_{1,2})$	< 0.5 & < 5 GeV
$p_T(\text{jet1})$	> 25 GeV
$ \eta (\text{jet1})$	< 2.4
$N_b (> 25 \text{ GeV, CSVL})$	$= 0$
$M(\ell\ell)$	< 50 GeV
$p_T(\ell\ell)$	> 3 GeV
E_T^{miss}	> 125 GeV
E_T^{miss} (muon subtracted)	> 125 GeV
E_T^{miss} / H_T	$[0.6, 1.4]$
H_T	> 100 GeV
$M(\ell\ell)$	> 4 GeV
$M(\ell\ell)$	veto $[9, 10.5]$ GeV
$M_{\tau\tau}$	veto $[0, 160]$ GeV
$M_T(\ell_x, E_T^{\text{miss}}), x = 1, 2$	< 70 GeV (for electroweakino selection only)

	$m_{\tilde{\chi}_2^0, \tilde{\chi}_1^\pm}$ [GeV]	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ [GeV]	$N_{\text{SUSY}} / S_{95}^{\text{obs}}$		
			CMS	CheckMATE	DIFF
P1	120	32.5	1.0	0.95	-5%
P2	140	29	1.0	1.0	0
P3	170	24.5	1.0	1.1	10%
P4	170	10	1.0	1.05	5%
P5	195	20	1.0	0.92	-8%

Table 1: Electroweakino-like SR validation table for CMS_PAS_SUS_16_025.

GitHub.com/llprecasting

GitHub, Inc. [US] | <https://github.com/llprecasting/recastingCodes>

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A collection of public codes for recasting long-lived particle searches Edit

Manage topics

3 commits 1 branch 0 releases 1 contributor

Branch: master New pull request Create new file Upload files Find File Clone or download

Commit	Message	Time
andlessa	Updated README	Latest commit f9bca4f 30 minutes ago
	DisplacedVertices	Added first recasting code an hour ago
	HSCPs/CMS-EXO-12-026	Added first recasting code an hour ago
	README.md	Updated README 30 minutes ago

README.md

LLP Recasting Repository

This repository holds example codes for recasting long-lived particle (LLP) searches. The code authors and repository maintainers are not responsible for how the code is used and the user should use discretion when applying it to new models.

Please contribute your code. Send an email to llp-recasting@googlegroups.com

Include a README with citation to your paper to be used by anyone who uses your code.

Public Interest advisory

HEP data

HEPdata

हेप डेटा!

विश्वकर्मा

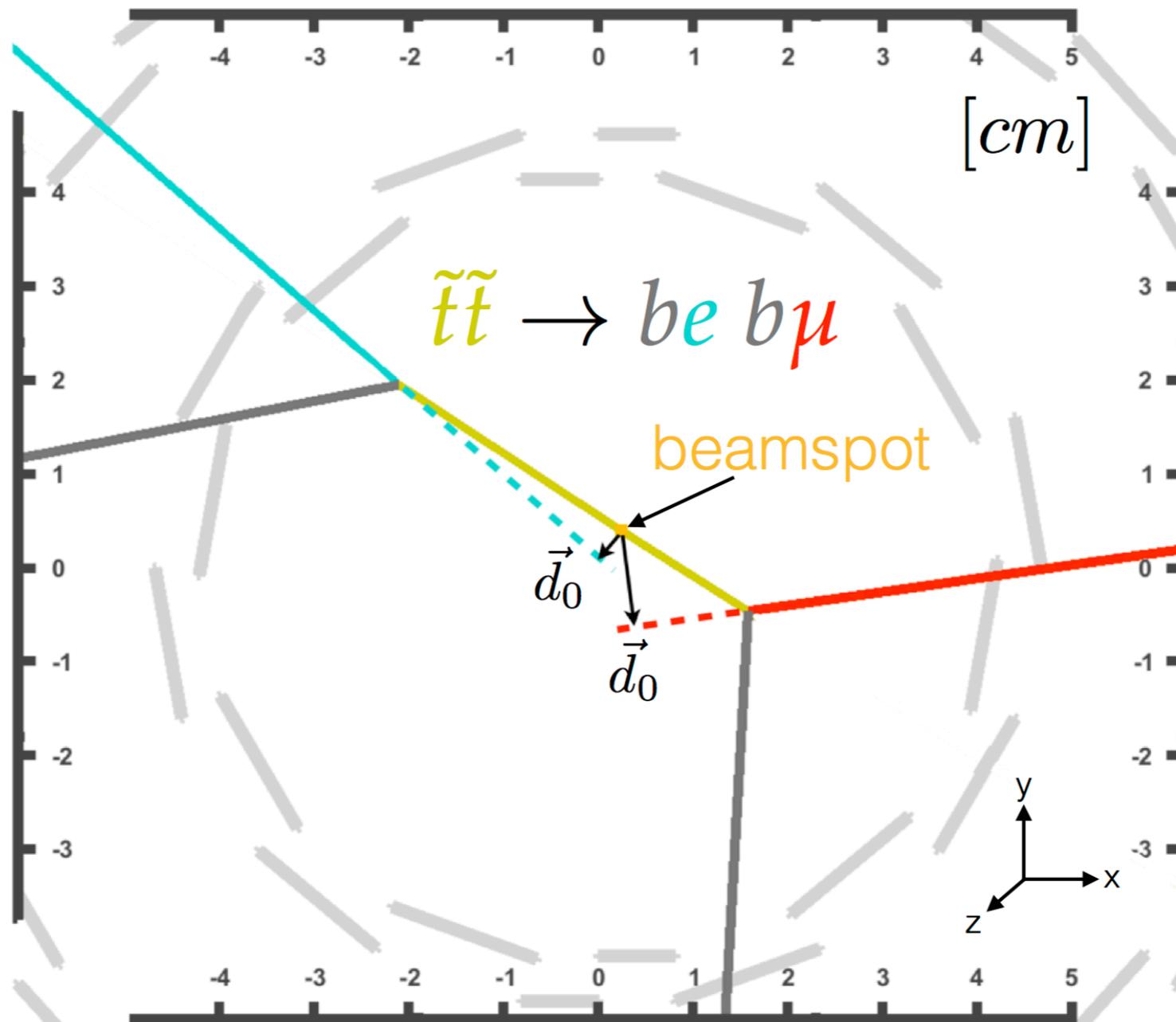
theorist

HEPdata saves lives
^

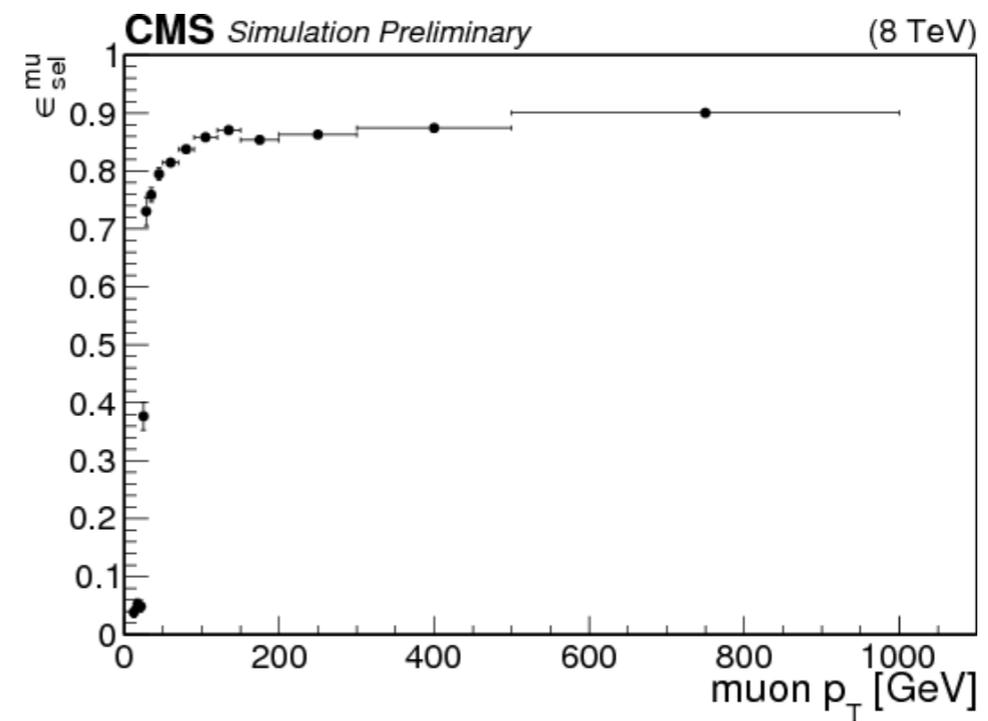
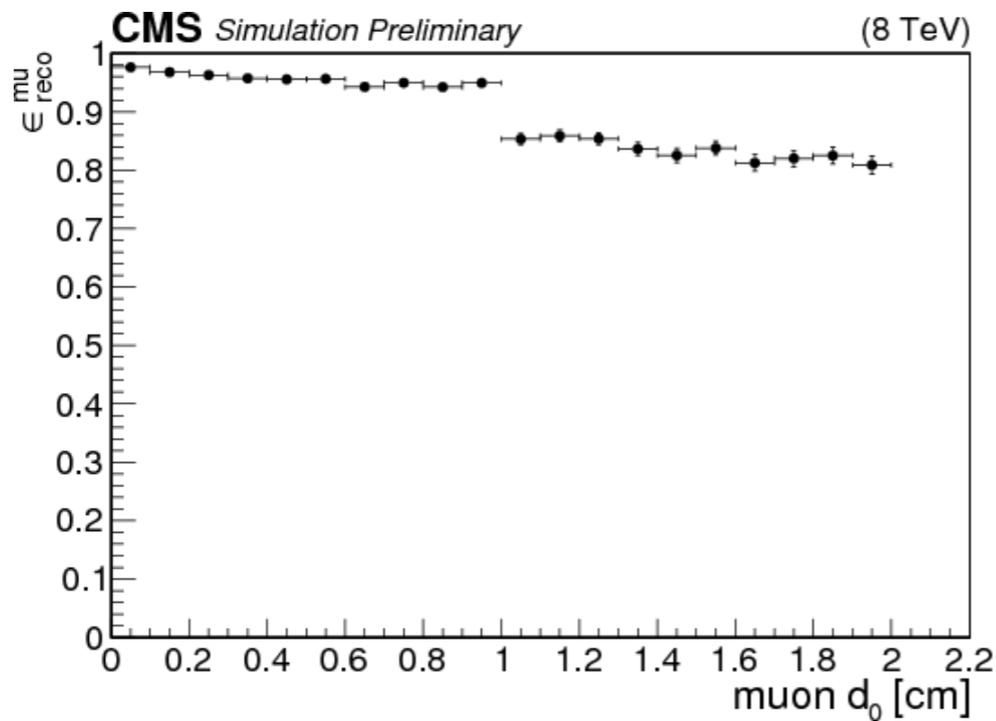
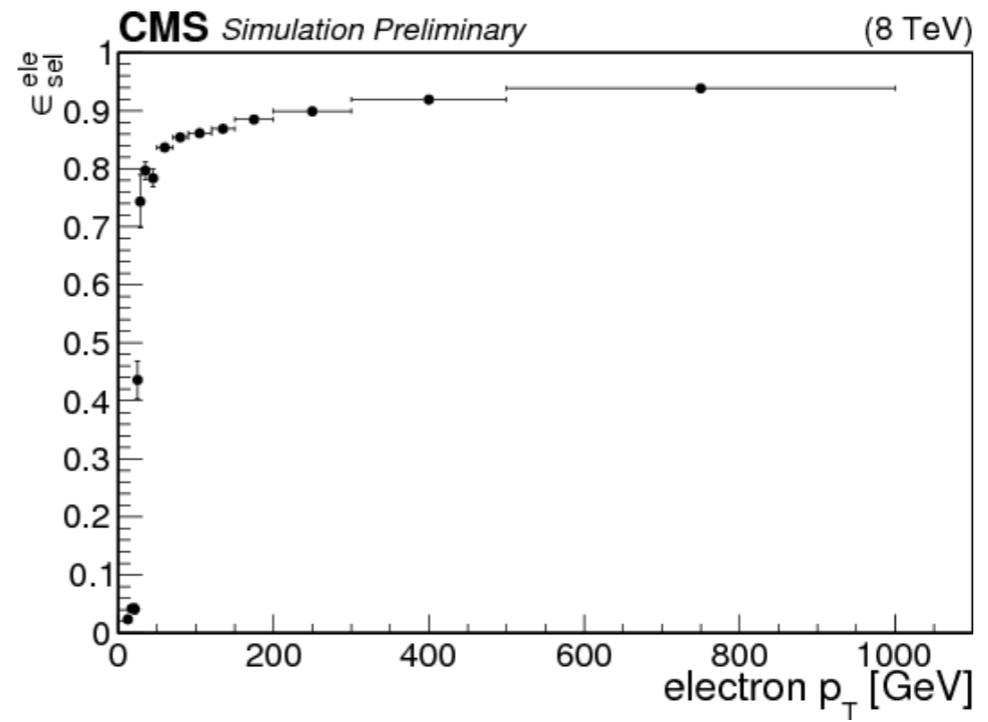
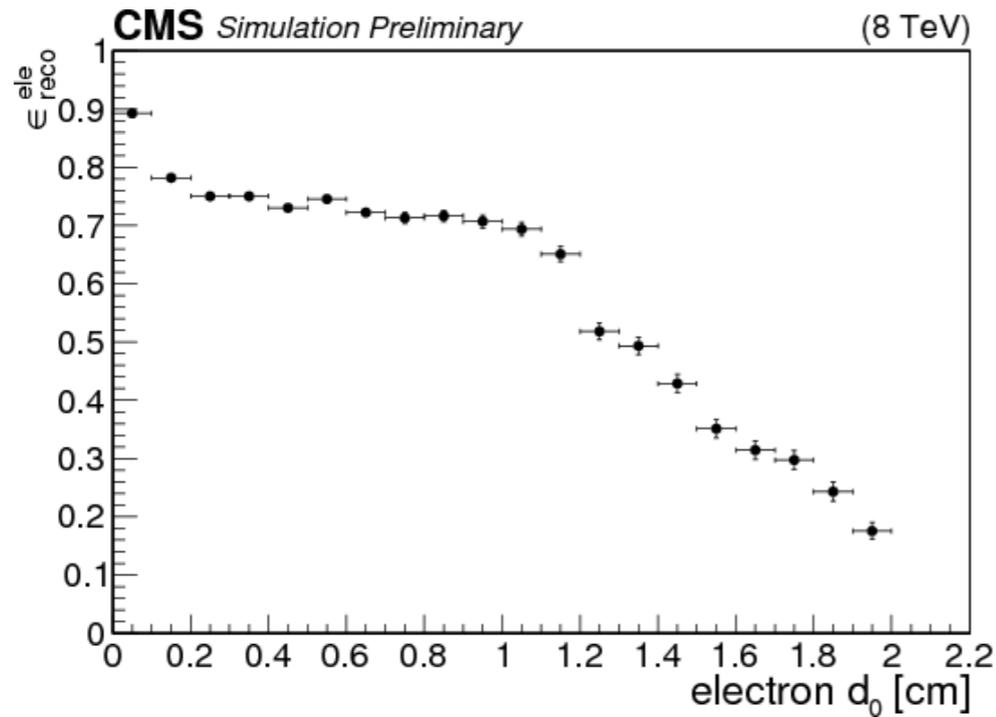
Back to normal
programming

Case 1: CMS displaced lepton

CMS Simulation



Efficiencies provided



Trigger = 0.95

Displaced Lepton search

How to use the parametrisation

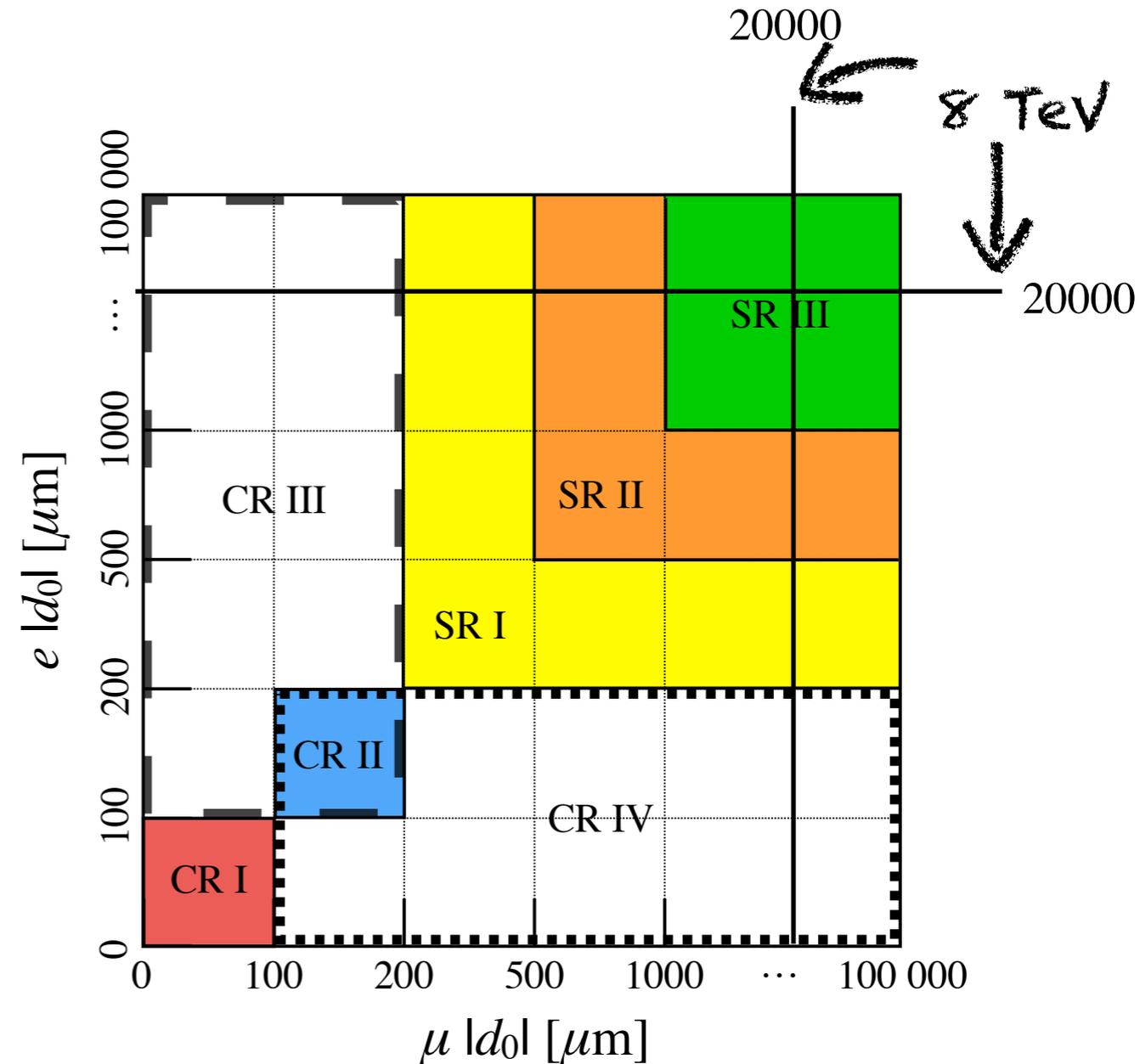
The user should follow all of the steps listed below.

- produce some generated events for the model of their choice
- apply all of the cuts listed below.
- reweight the surviving events with the four reconstruction and selection histograms and the trigger efficiency that are provided below. The five efficiencies are designed to be factorised.
- apply the d_0 cut on the electron and muon to match one of the 3 signal regions listed in the [paper](#) and compare the event yields with those observed in data (see, for example, table 1 of the paper).

List of cuts

Preselection
Event passes standard FilterOutScraping cuts
One good primary vertex
generator electron coming from stop
generator electron with $\eta < 2.5$
generator electron with $v_0 < 4$ cm
generator electron with $v_z < 30$ cm
generator electron with $p_T > 25$ CMS.GeV

⋮



Displaced Lepton search

How to use the parametrisation

The user should follow all of the steps listed below.

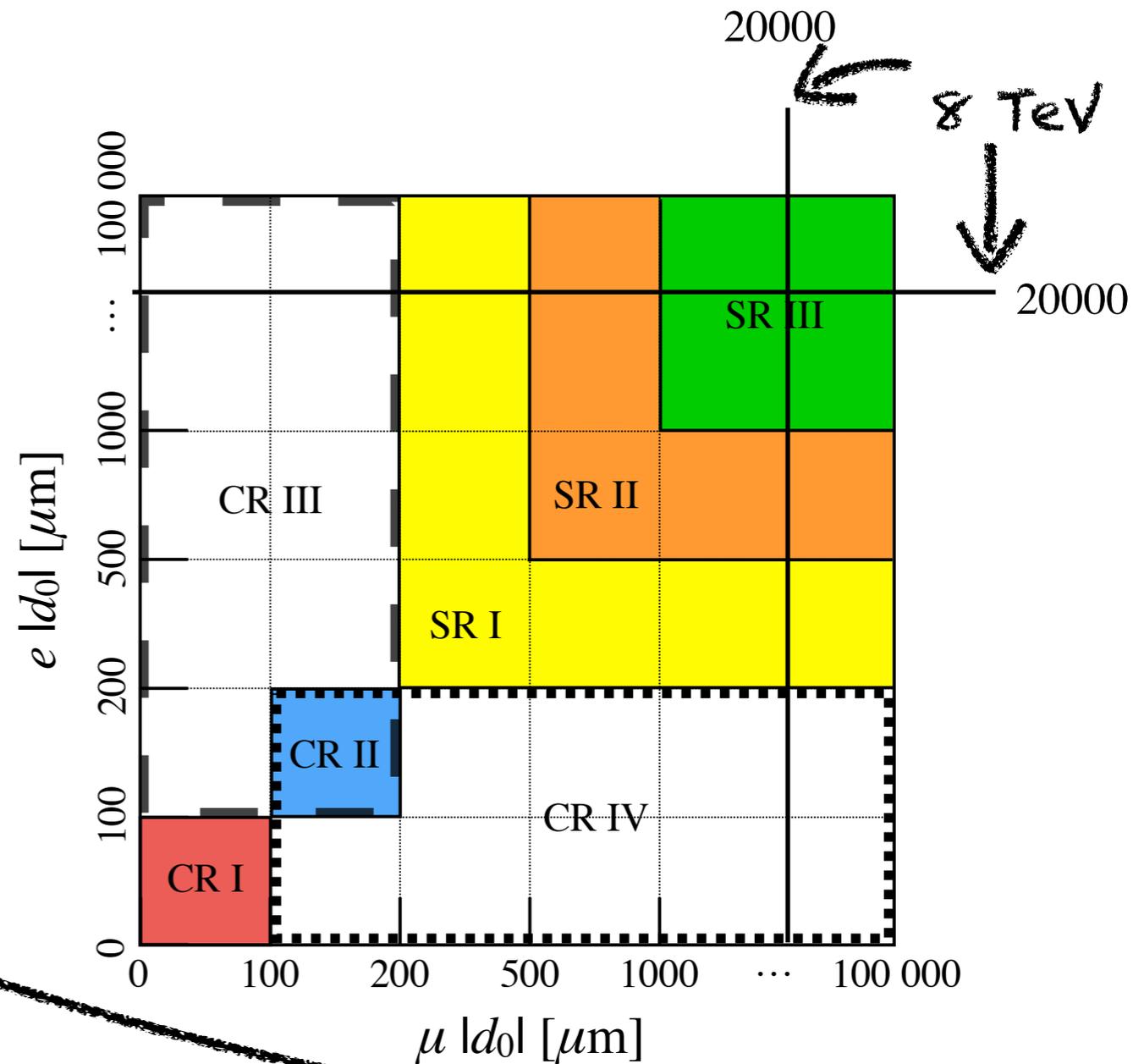
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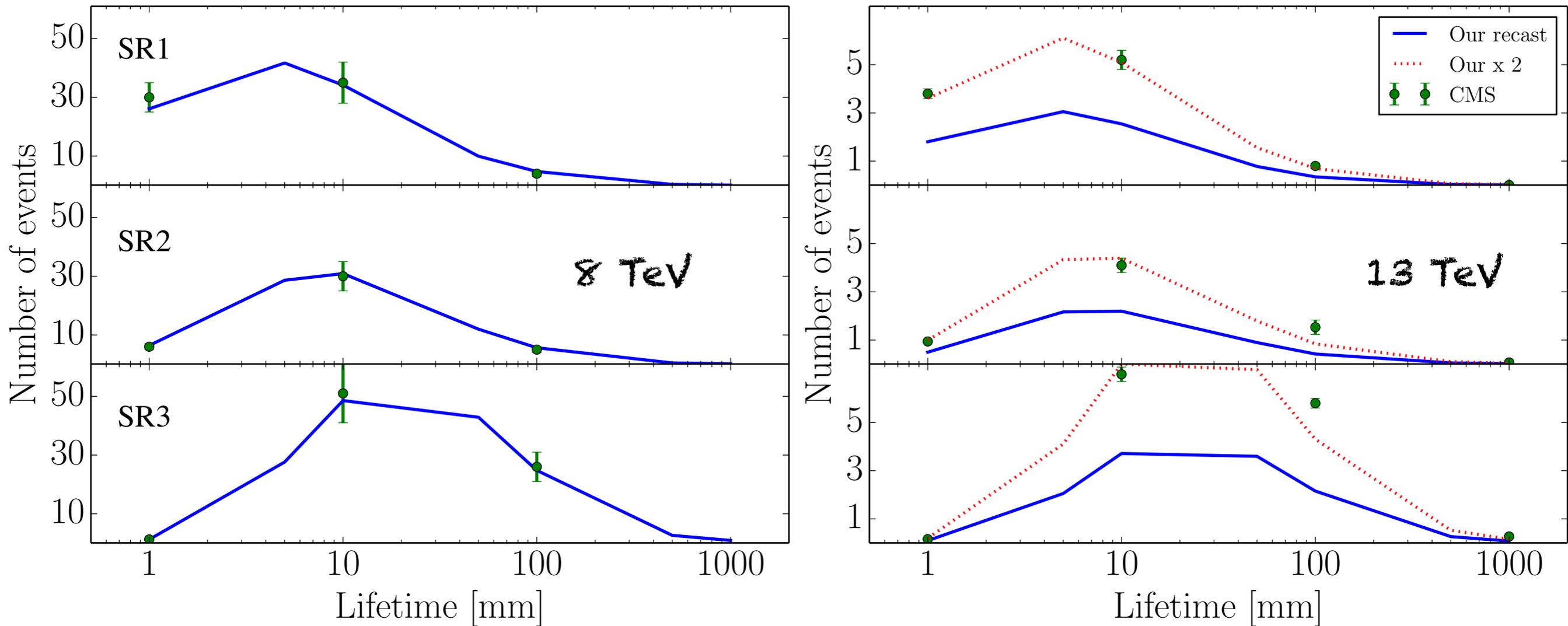
Hmm..



Requires CERN login
Don't know, but probably 100%

Going from 8 TeV to 13 TeV

What changes: 1. p_T cuts are harder, 2. Stop mass 500 \rightarrow 700 GeV



In this case, a almost simple factor of 2.

Lessons learned & Questions

1. Even for really simple models, extrapolation does not work. Need separate efficiencies for every analysis (also for two versions of the same analysis).
2. A cutflow table would have helped in pin-pointing where the mismatch occurs. Experiments have expected signal numbers even for conf-notes, please publish.
3. Finding the efficiencies was hard: 4 nested links from analysis page. Please link to HepData from the top page.

Links: e-print [arXiv:1409.4789 \[hep-ex\] \(PDF\)](#) ; [CDS record](#) ; [inSPIRE record](#) ; [Public twiki page](#) ; [CADI line \(restricted\)](#) ;

 HepData goes here

Lessons learned & Questions

4. The benchmark is a very simple model predicting only two jets besides the leptons (i.e. not much activity). Can we apply the same efficiencies to events with multiple jets? What about isolation requirements? **Use multiple benchmarks or topologies if possible.**

$$pp \rightarrow \tilde{g}\tilde{g} \quad \tilde{g} \rightarrow \bar{t}\tilde{t} \quad \tilde{t} \rightarrow b\ell$$

Up to 8 jets + displaced leptons from b's in top decay

5. Should you be selectively choosing truth signal? **Better to choose a benchmark that's clean.**
- A. Also important pointer for theorists: careful to see that your signal model is not significantly populating the control regions.
- B. Question to experimentalists: what do you recommend in such situations?

Lessons learned & Questions

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Up to 8 jets + displaced leptons from b's in top decay

This ep search is very important because it is so simple and applicable to a variety of models! Please fix...

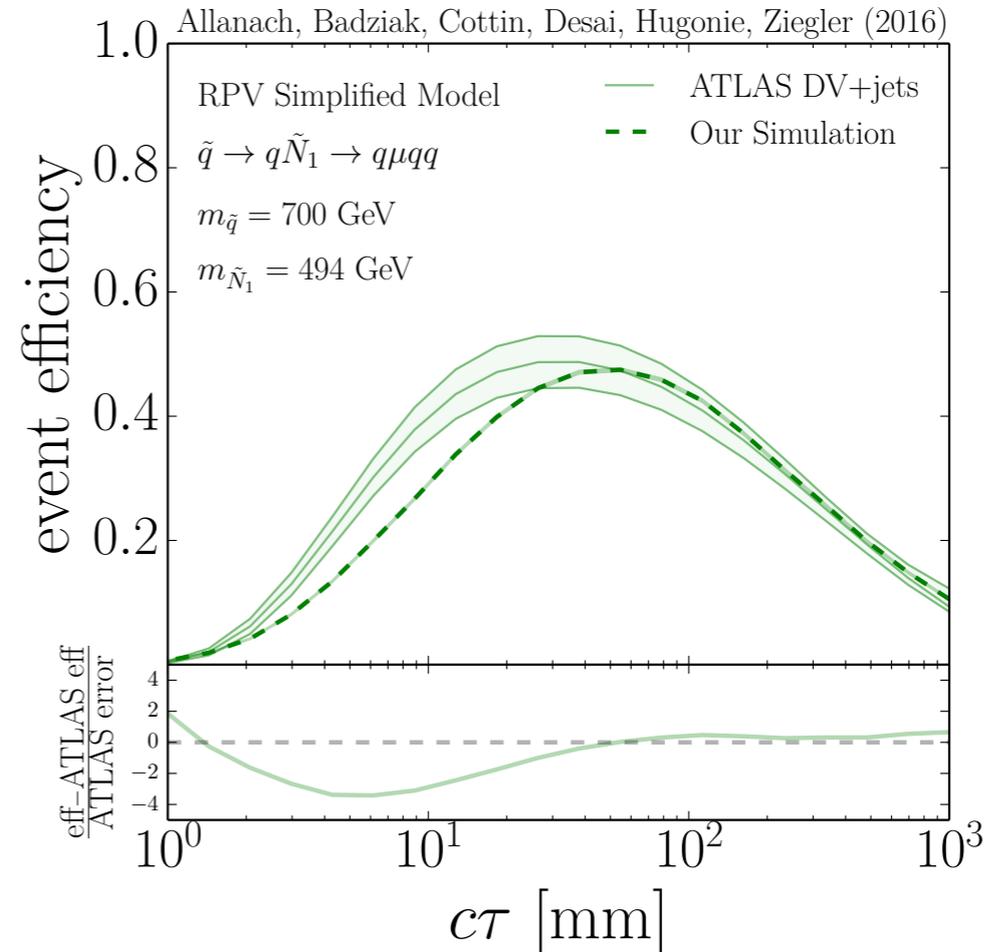
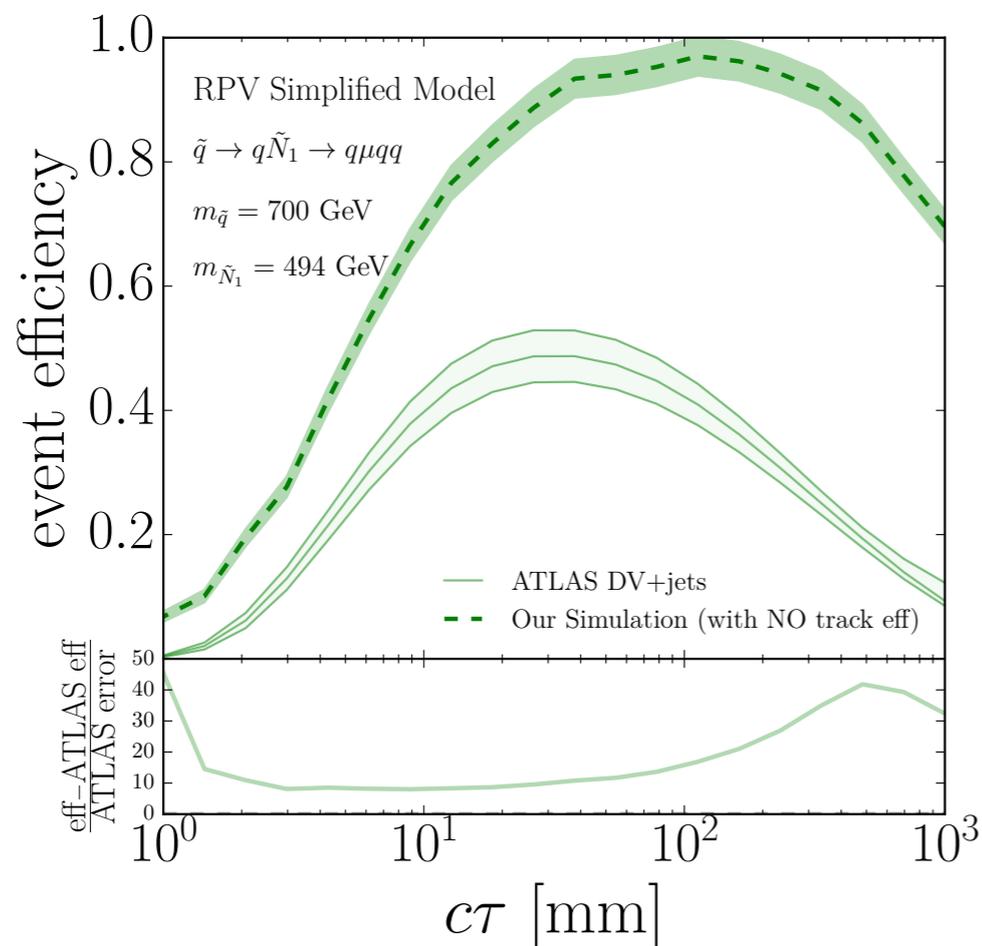
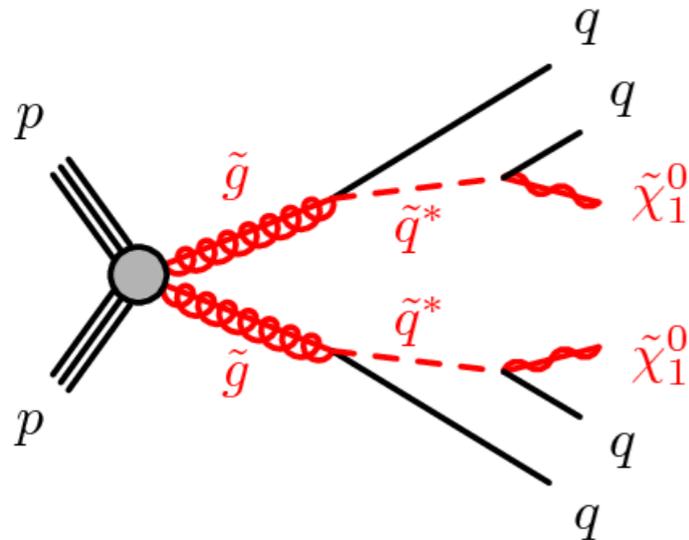
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Case 2: Displaced Vertex search

CERN-PH-EP-2015-065, ATLAS-CONF-2017-026, CERN-EP-2017-202

DV search has come far in providing recasting info from first instance.

V1 (8 TeV): not much recasting info! Recasters defined ad hoc efficiency functions



Case 2: Displaced Vertex search

v2: 13 TeV analysis

ATLAS-CONF-2017-026

1. Trigger

$$E_T^{\text{miss}} > 250 \text{ GeV}$$

2. Take all tracks with

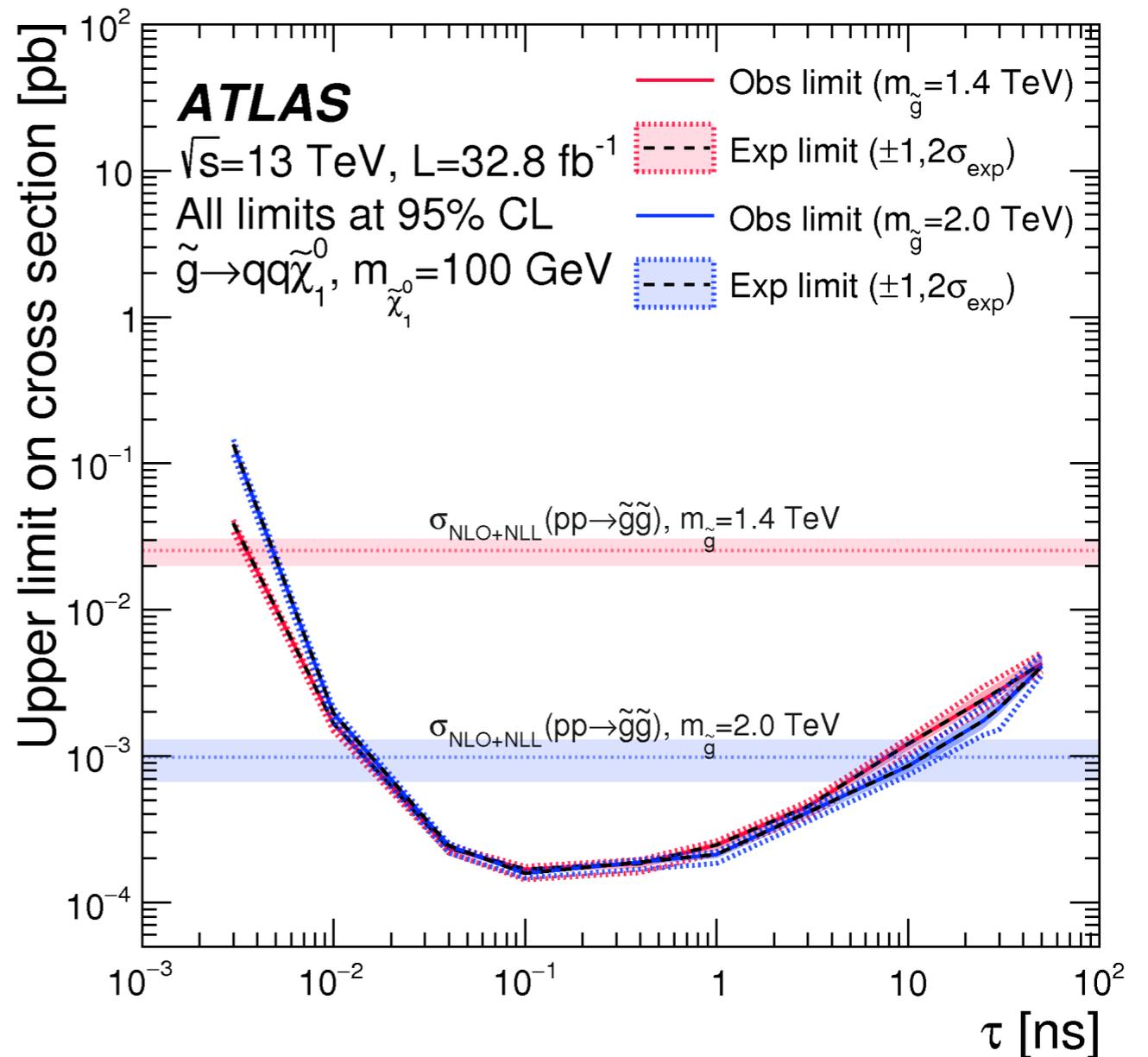
$$d_0(\text{trk}) > 0.2 \text{ mm}$$

3. Make vertices, make sure

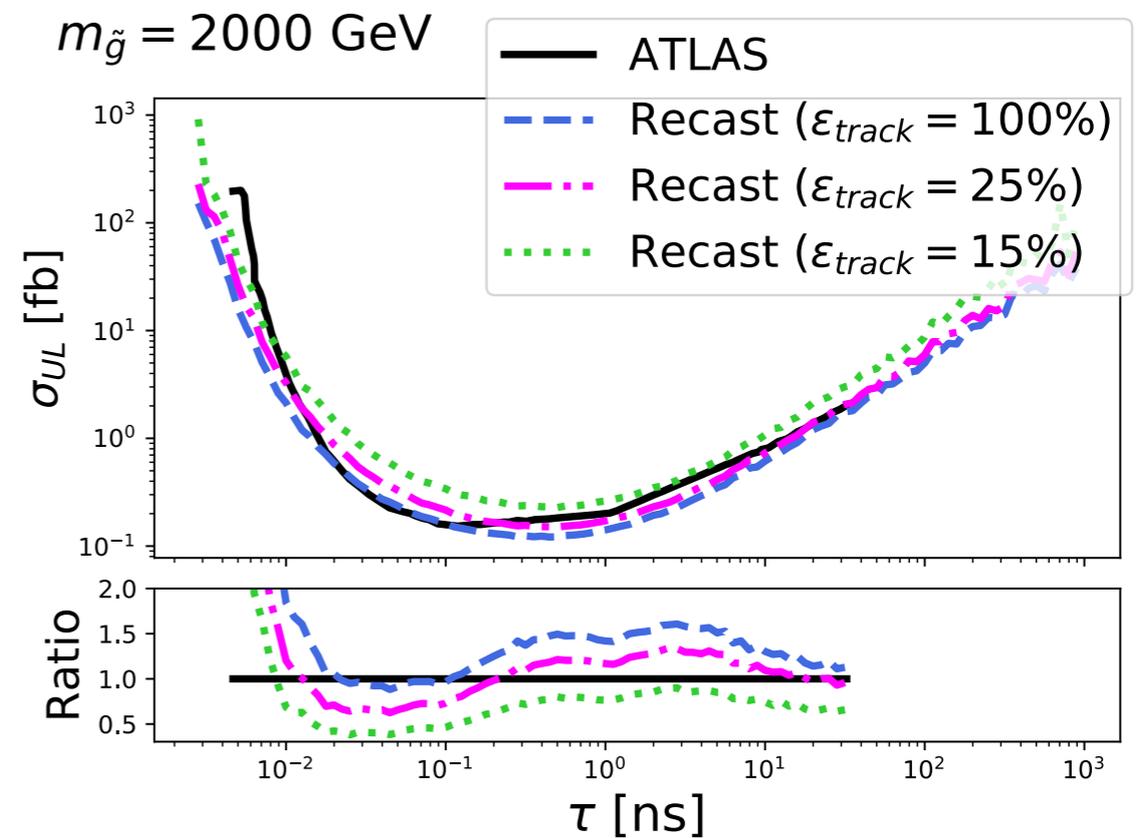
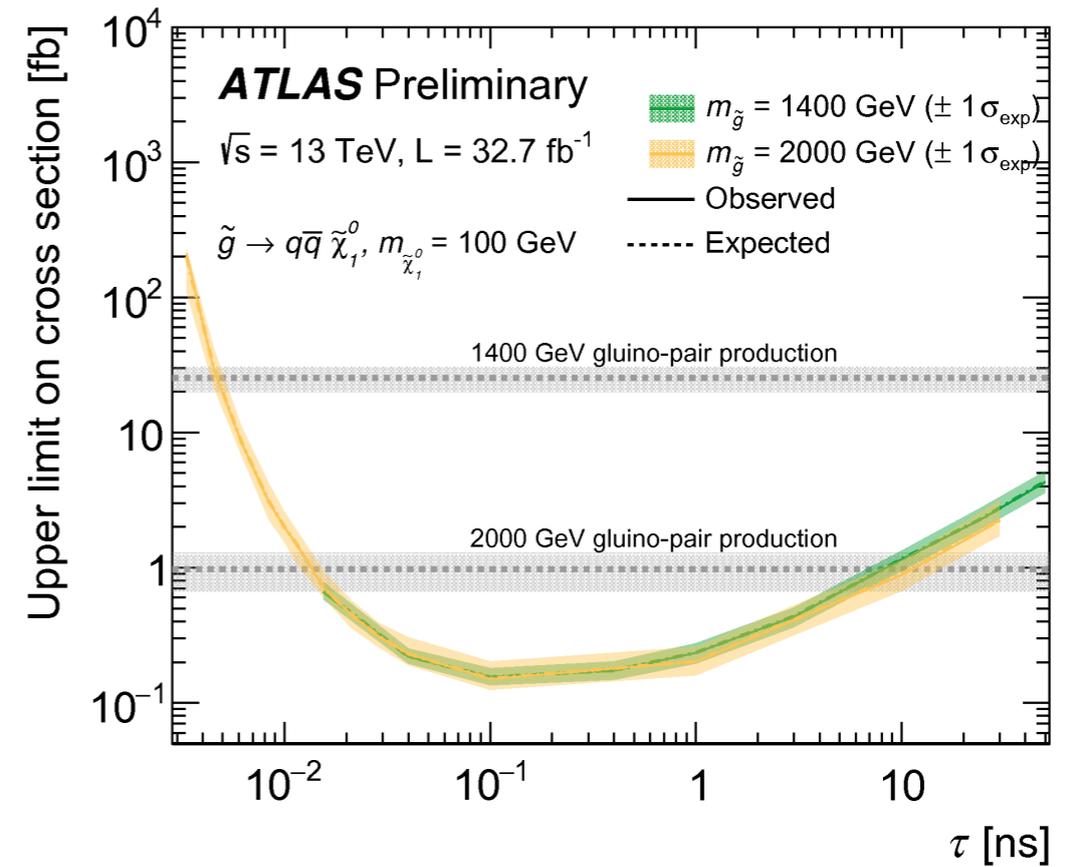
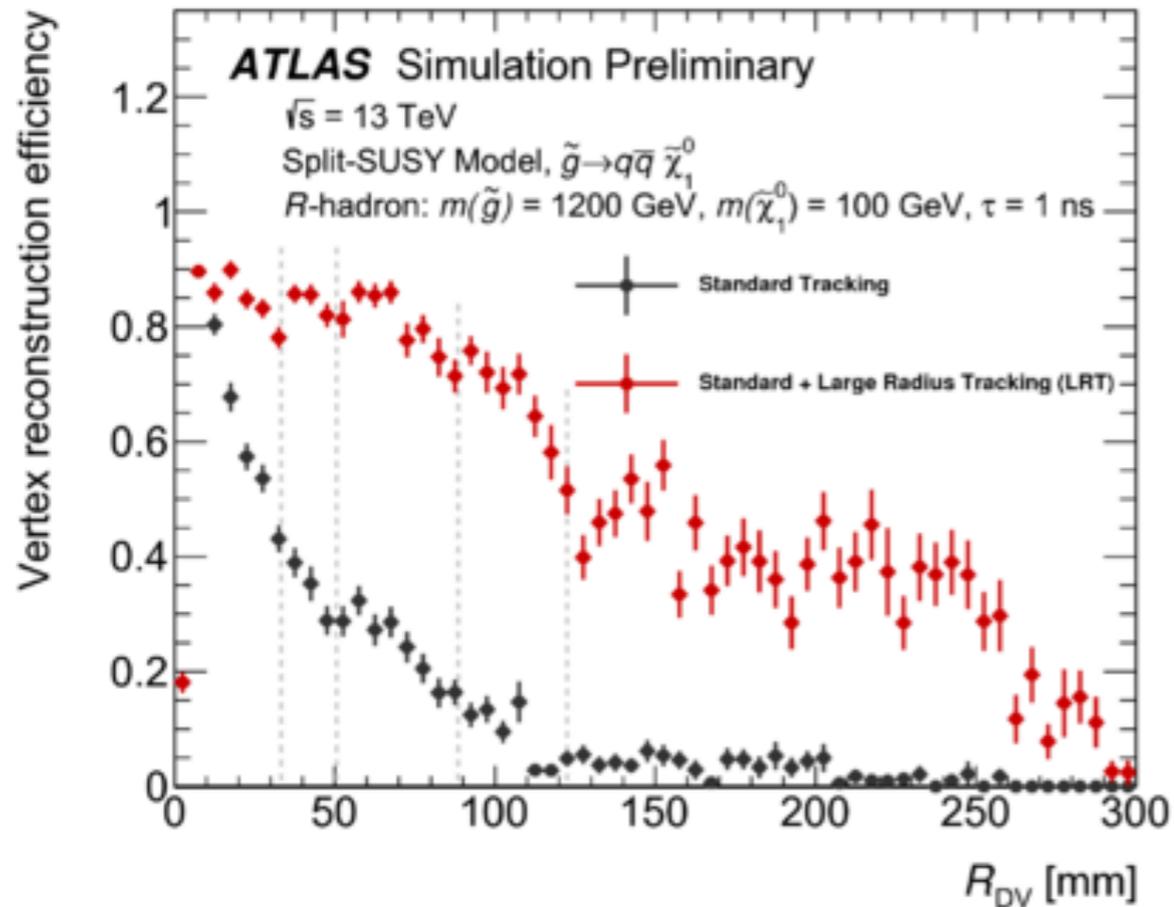
$$R < 300 \text{ mm} \quad |z| < 300 \text{ mm}$$

$$n_{\text{DV}}^{\text{trk}} > 5 \quad m_{\text{DV}} > 10 \text{ GeV}$$

4. Apply material vetoes



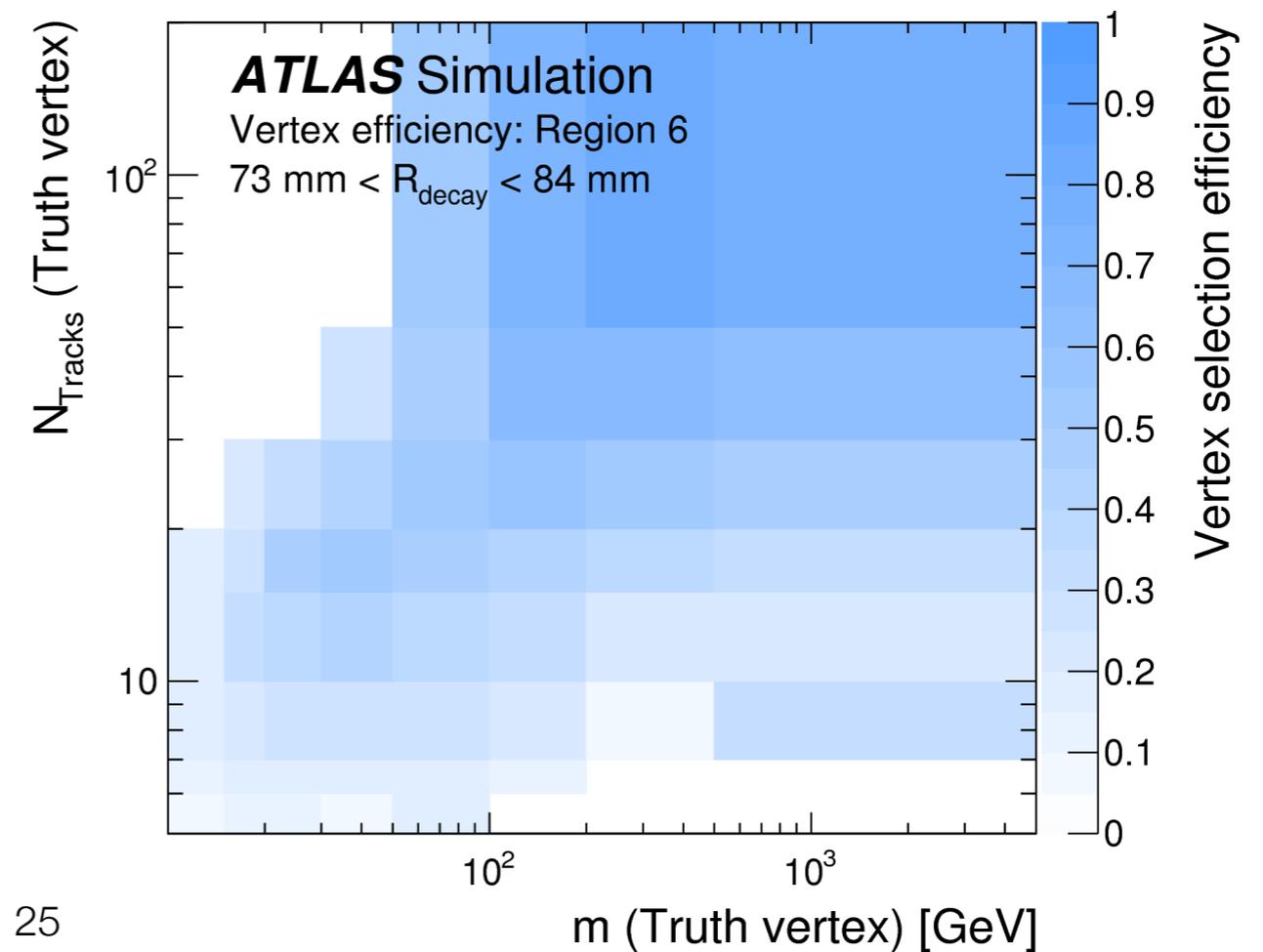
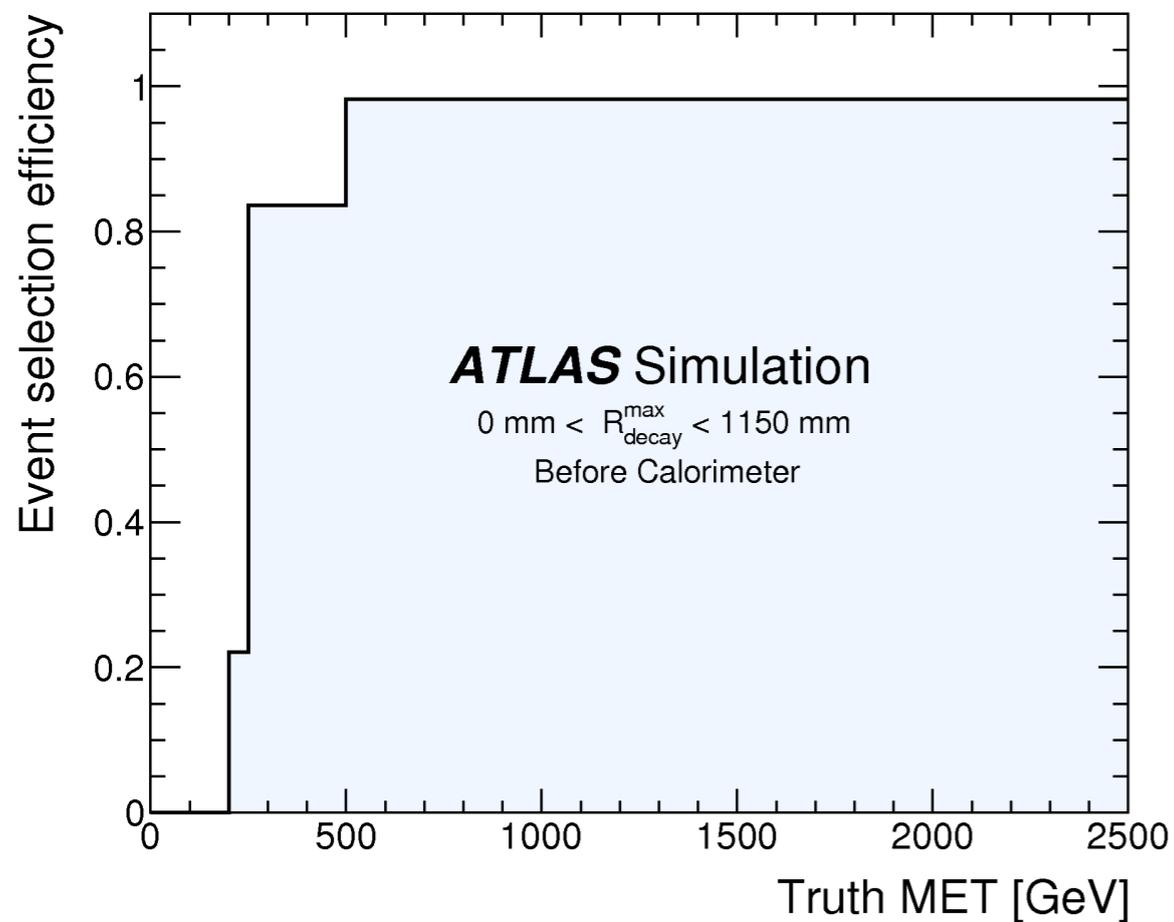
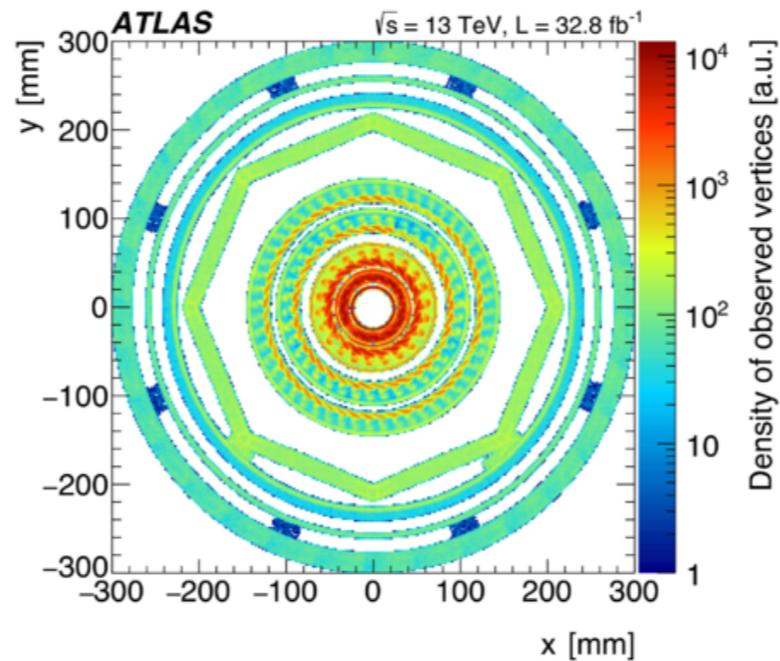
Just efficiency in R_{DV} is not enough



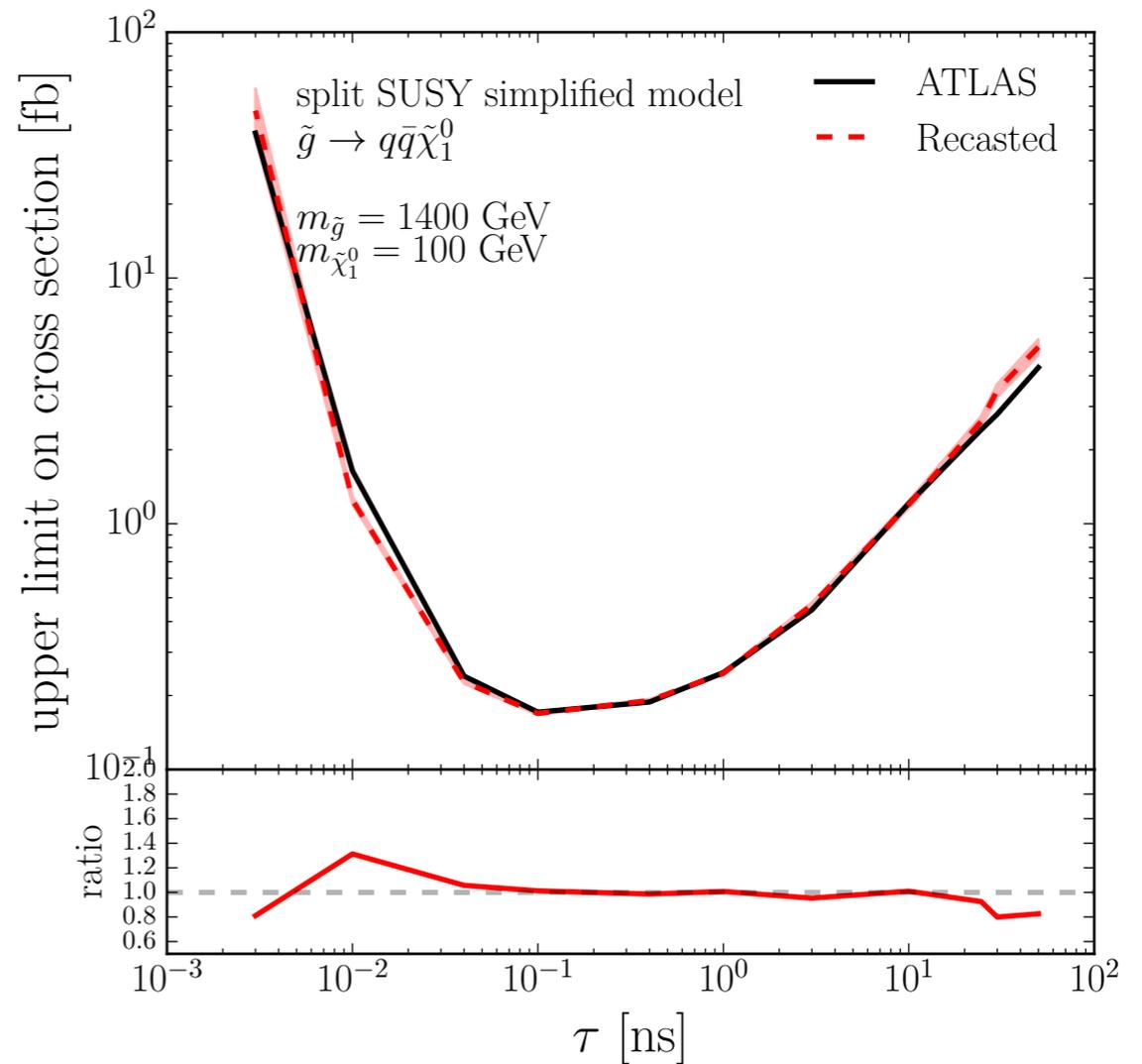
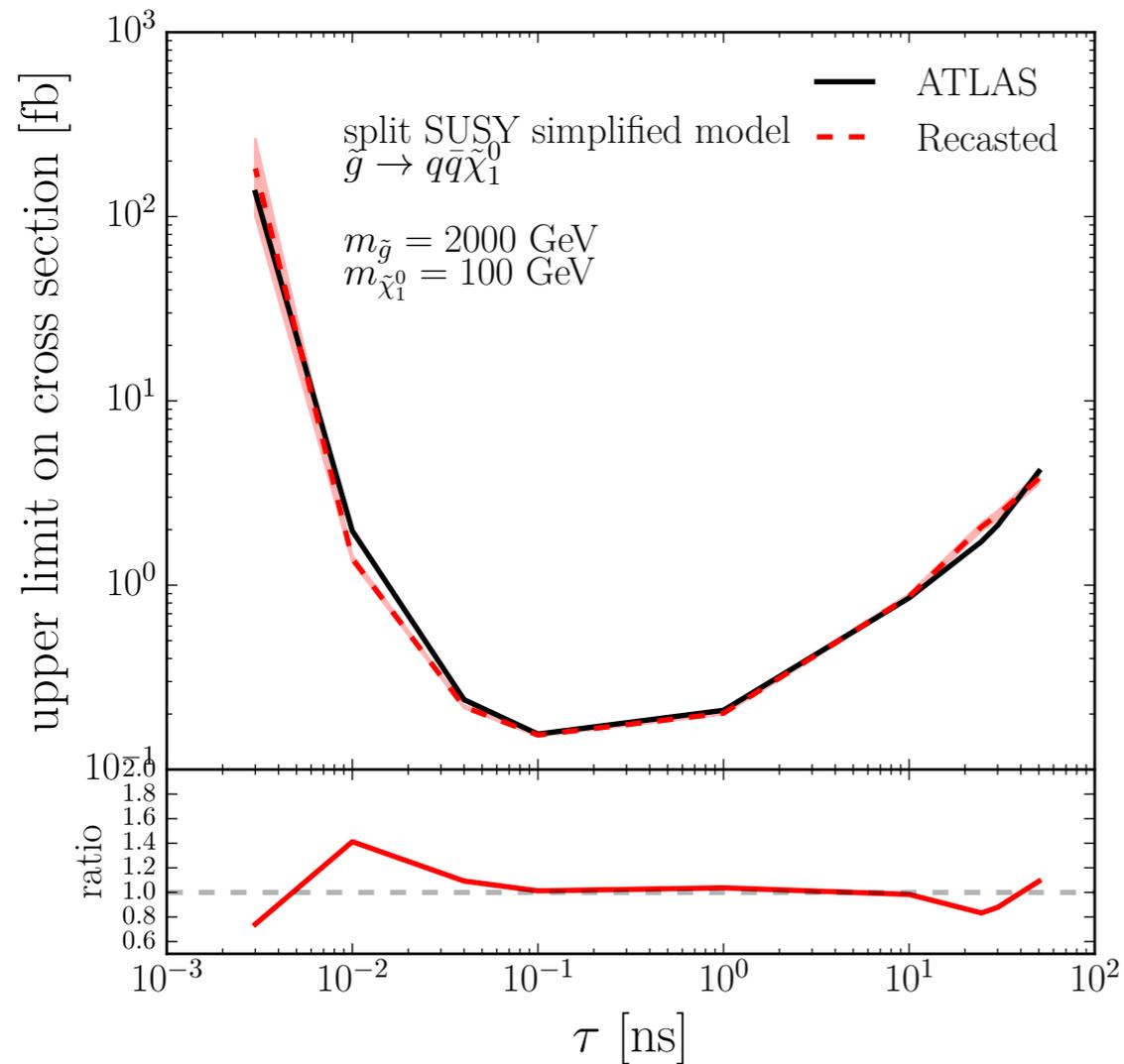
DV efficiency parametrisation

v2.1: 13 TeV analysis

CERN-EP-2017-202



Using new parametrisation



Reinterpretation by G. Cottin. & A. Lessa

Very good agreement with published limits!

Lessons learned & Questions

1. Nearly checks all boxes: has cutflow, efficiencies in an easy parametrisation, HepData accessible, two mass benchmarks for cross check.
2. Calculation of MET is not fully explained except saying "is calculated using all calibrated objects as well as those reconstructed tracks not associated with these objects."
Lesson from prompt recasts "truth MET" is not the same as "reconstructed MET". Important when re-interpreting for scenarios that also have prompt jets/leptons in same event.
3. It would be useful to have cutflow for a different simplified model topology, e.g. RPV with semi-leptonic top(s)
4. Original 8 TeV analysis had many more triggers to e.g. look at non-MET models. Important to re-instate these!