Update on Reinterpretation Effort in Phenomenology Community

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

Nishita Desai • TIFR • WHEPP 2019 • 4 December 2019

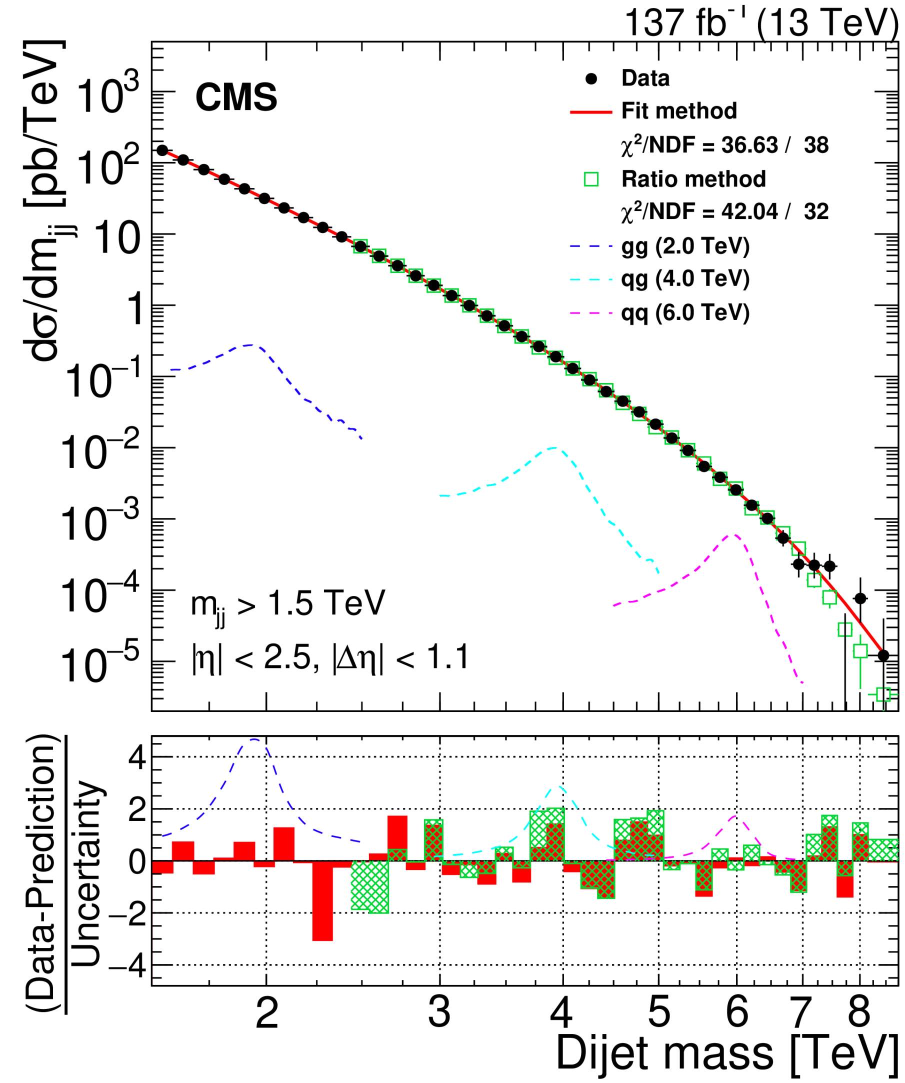
What is reinterpretation (a.k.a "recast")

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 σ x 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

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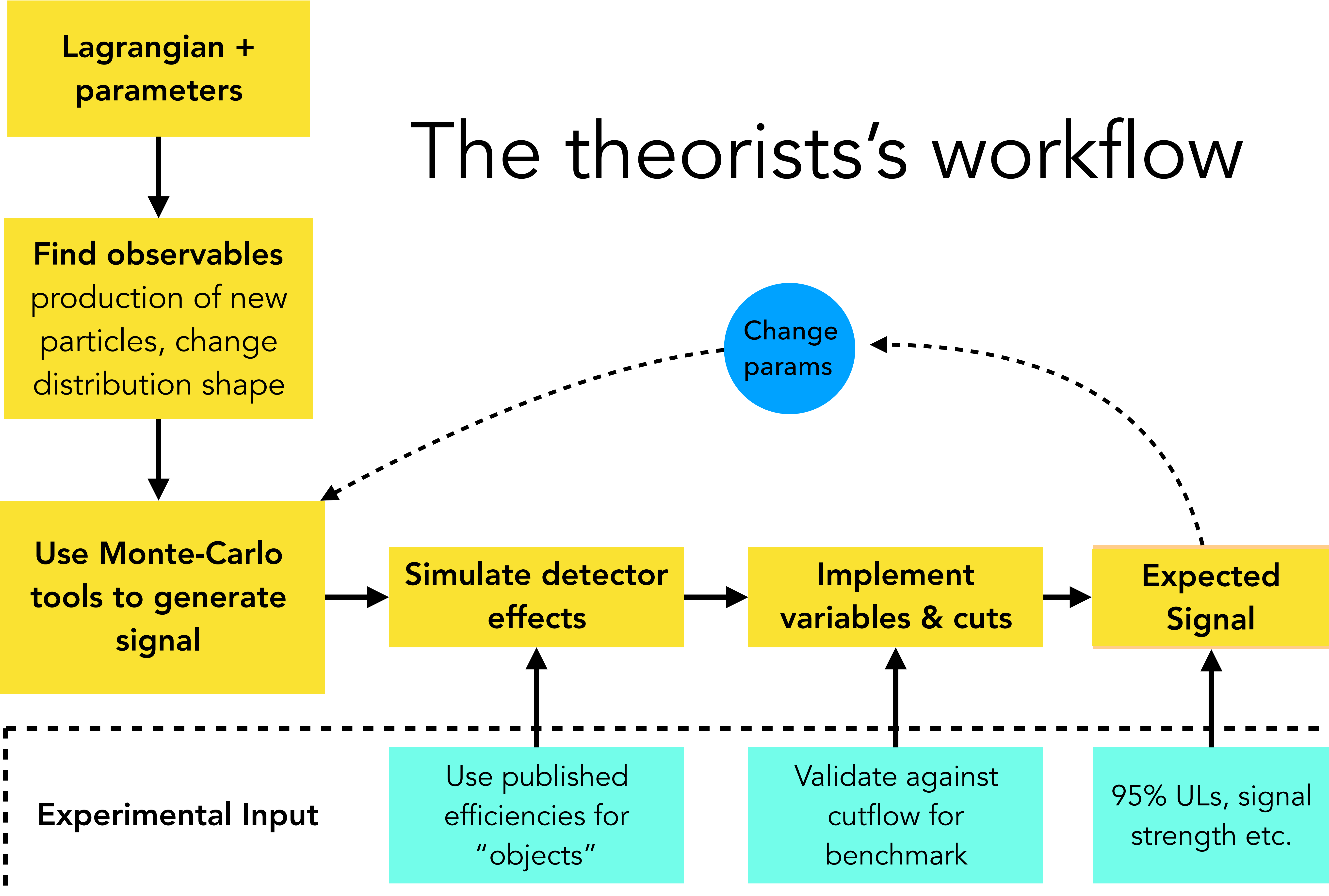
What do we need to understand do this?

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

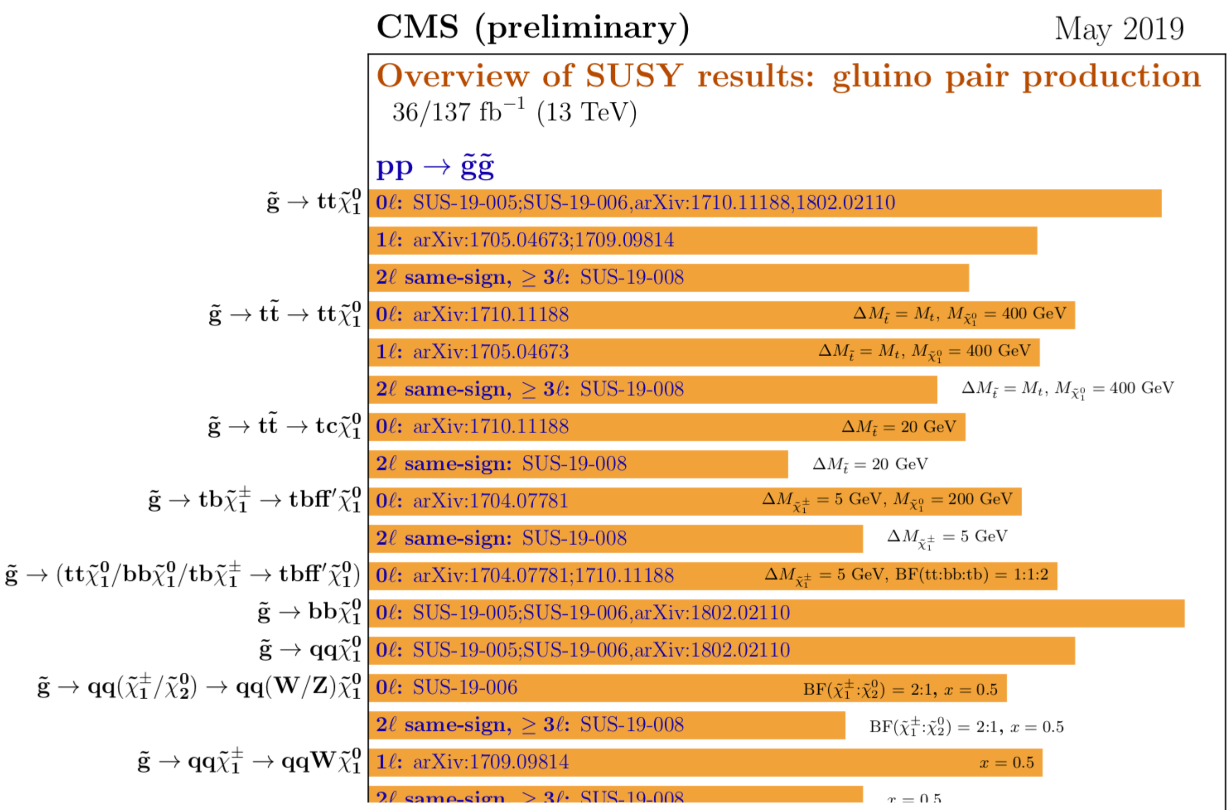
- **CheckMATE**
- MadAnalysis 5
- Gambit

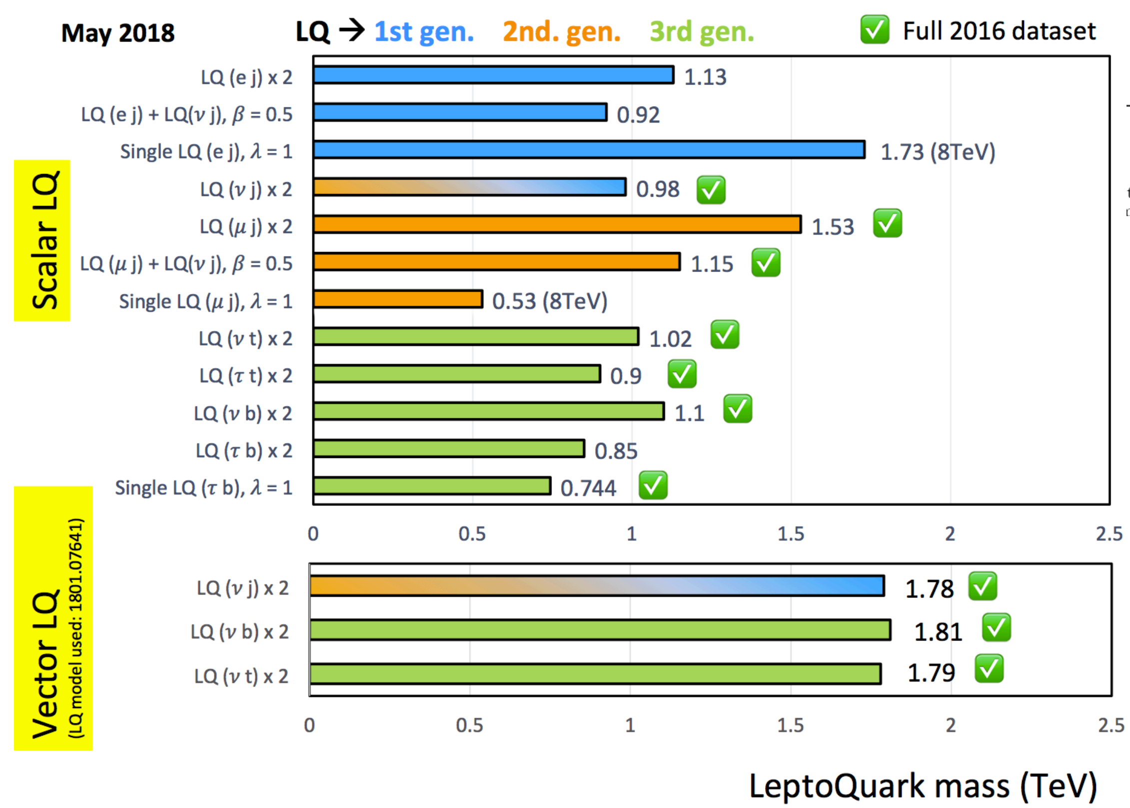
Mainly collider

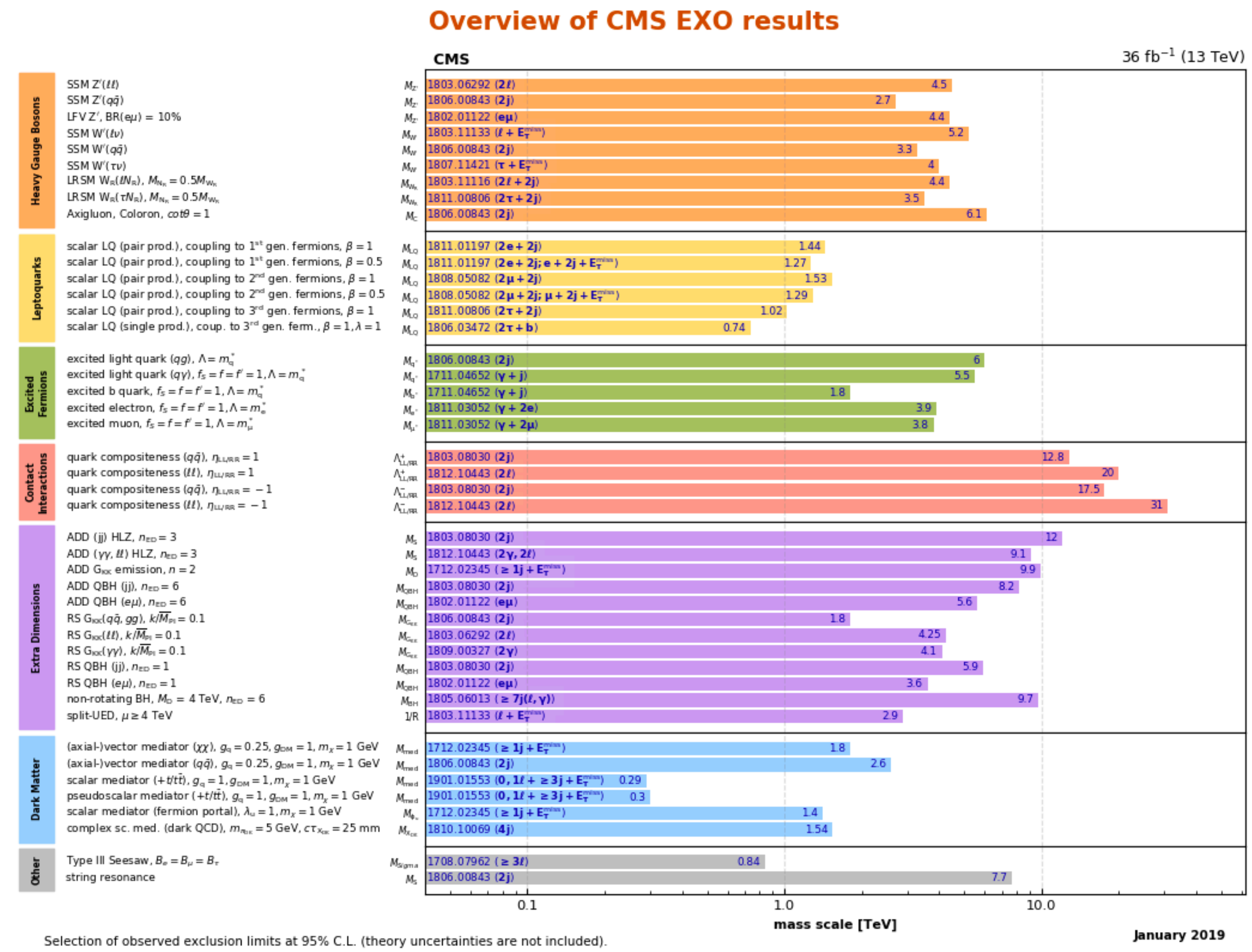
Optimised for large scans, more low-energy/DM, fewer collider analyses

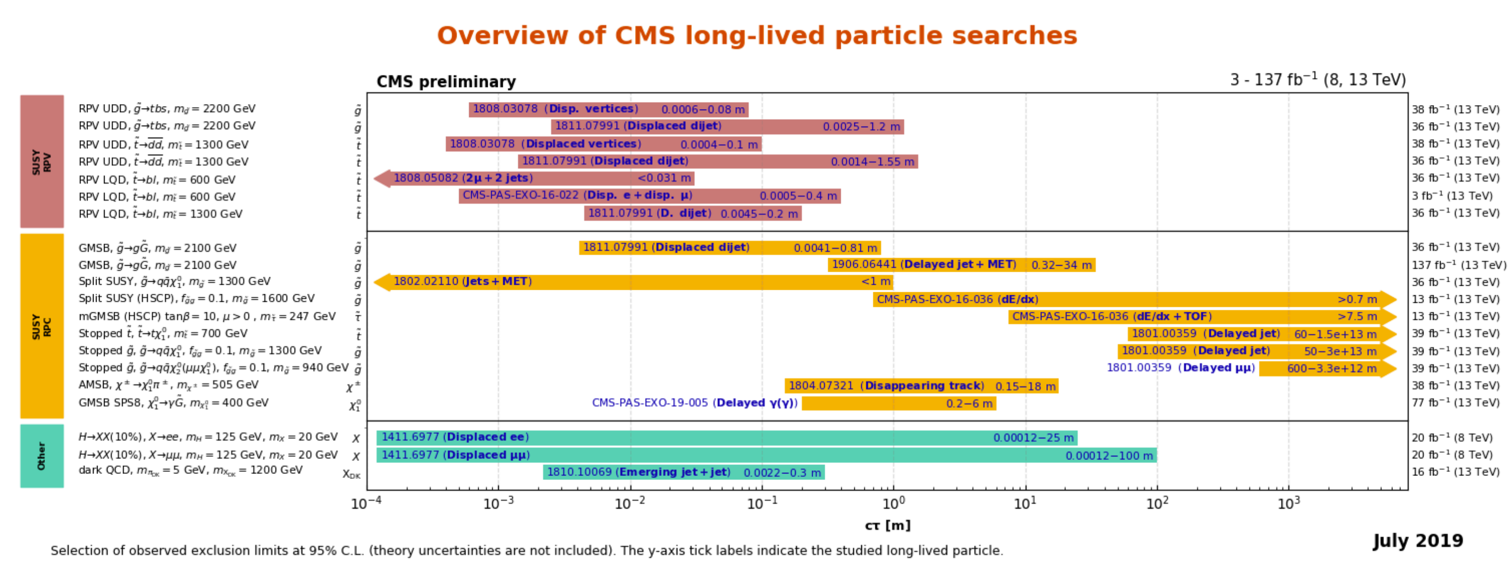
Other ideas: SmodelS (uses simplified models), Contur (uses SM measurements)

The problem with staying on top

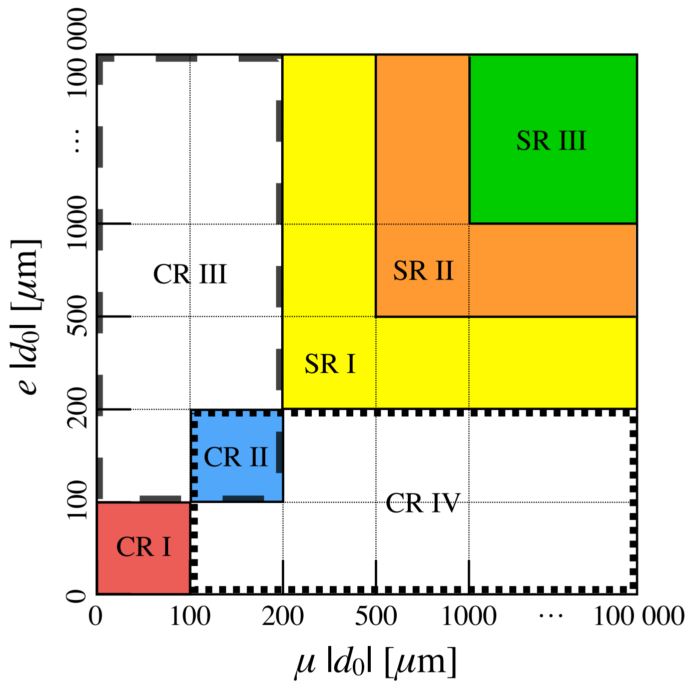


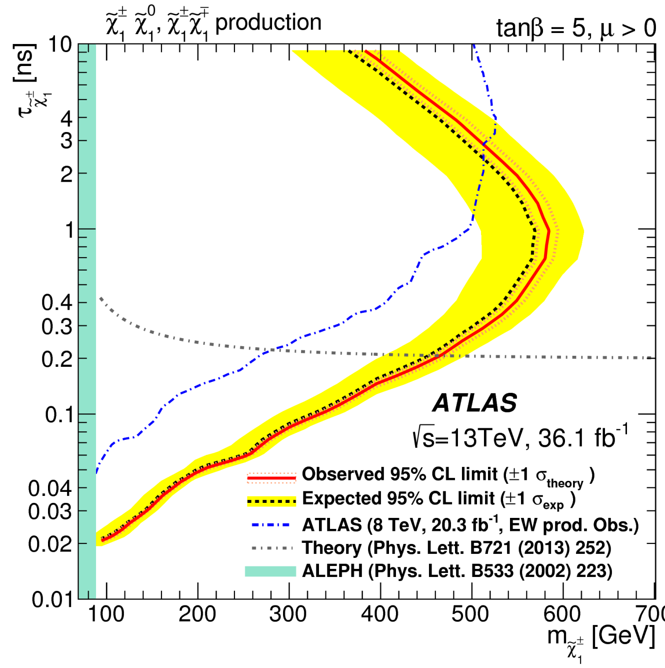


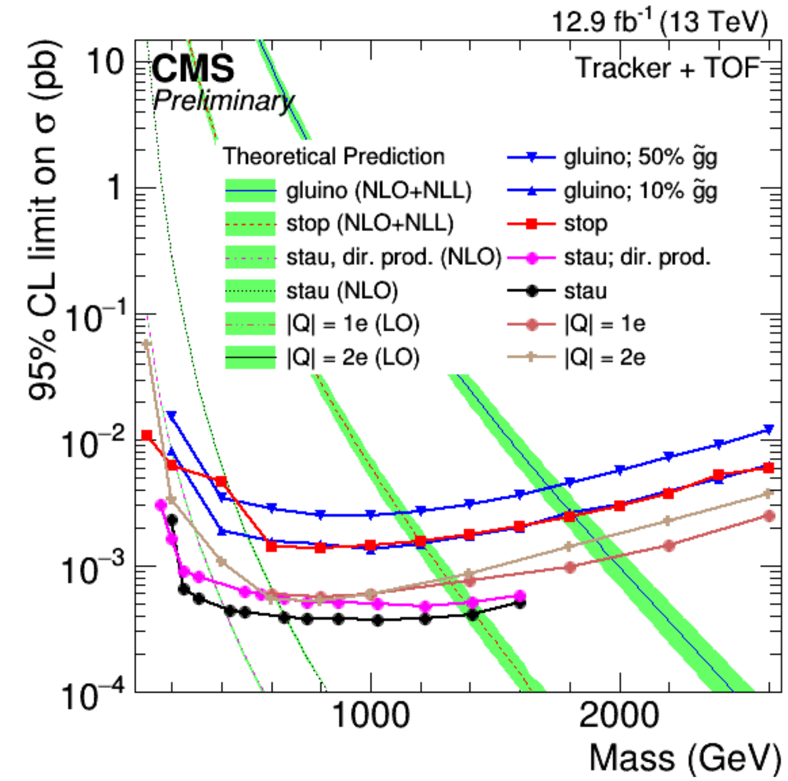


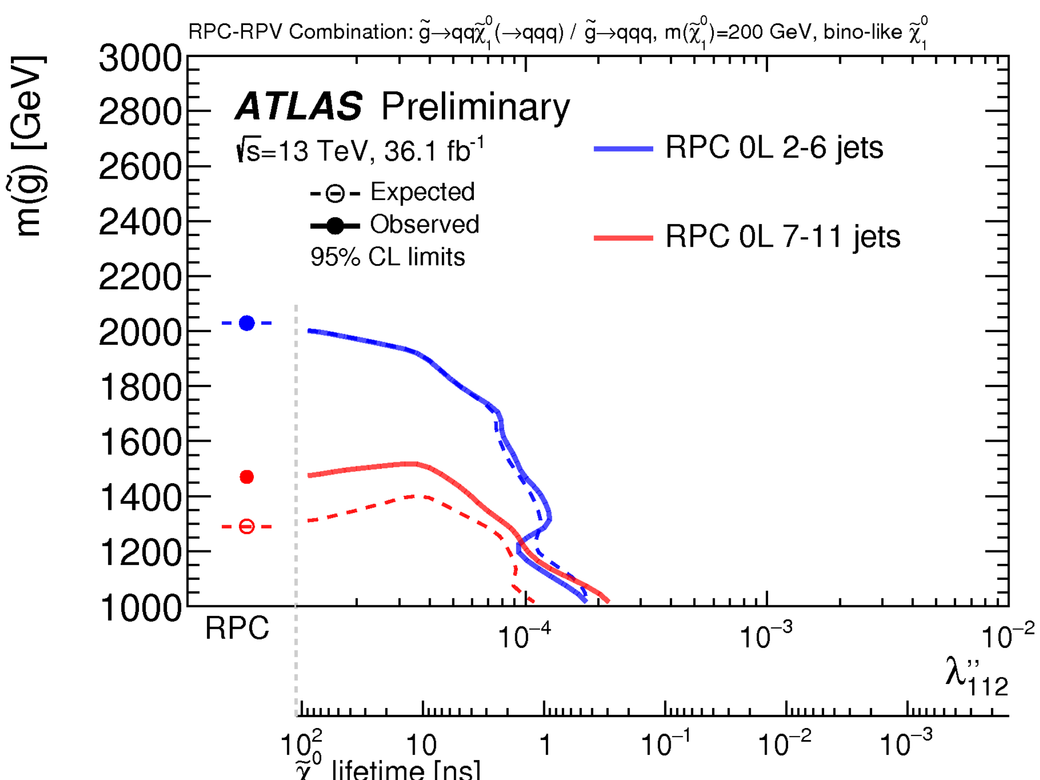


New Challenges: Long-lived particles



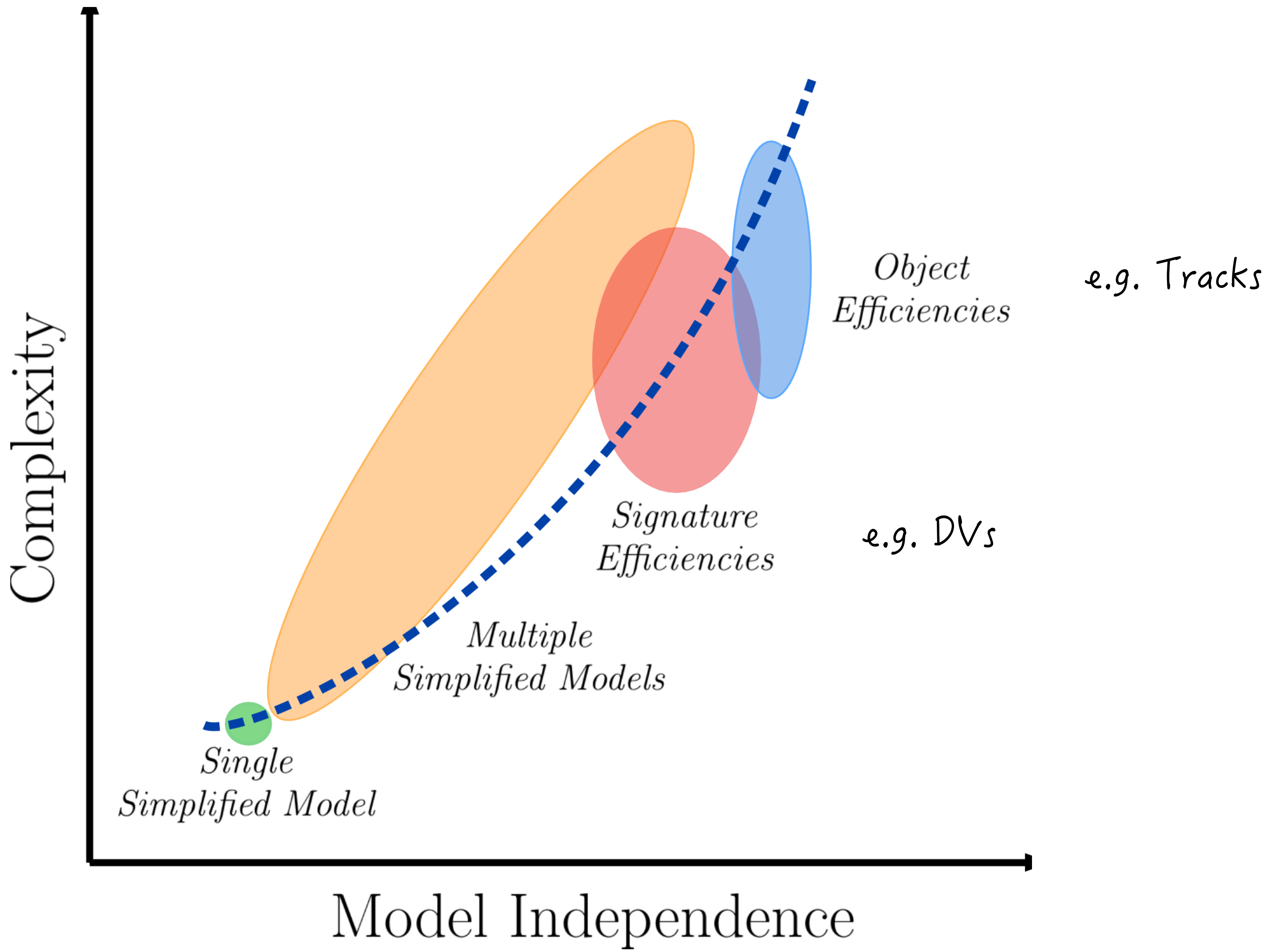






RPC meets RPV study by ATLAS showed they had been throwing away events that had both prompt+displaced objects as a part of their cleaning cuts: this means the idea that you can always look at inclusive mono-jet later on if you think of a new signature is not really true!

Providing efficiencies



Intermission
(time for commercial break)

Flowchart for Recasting analyses

Write the Lagrangian

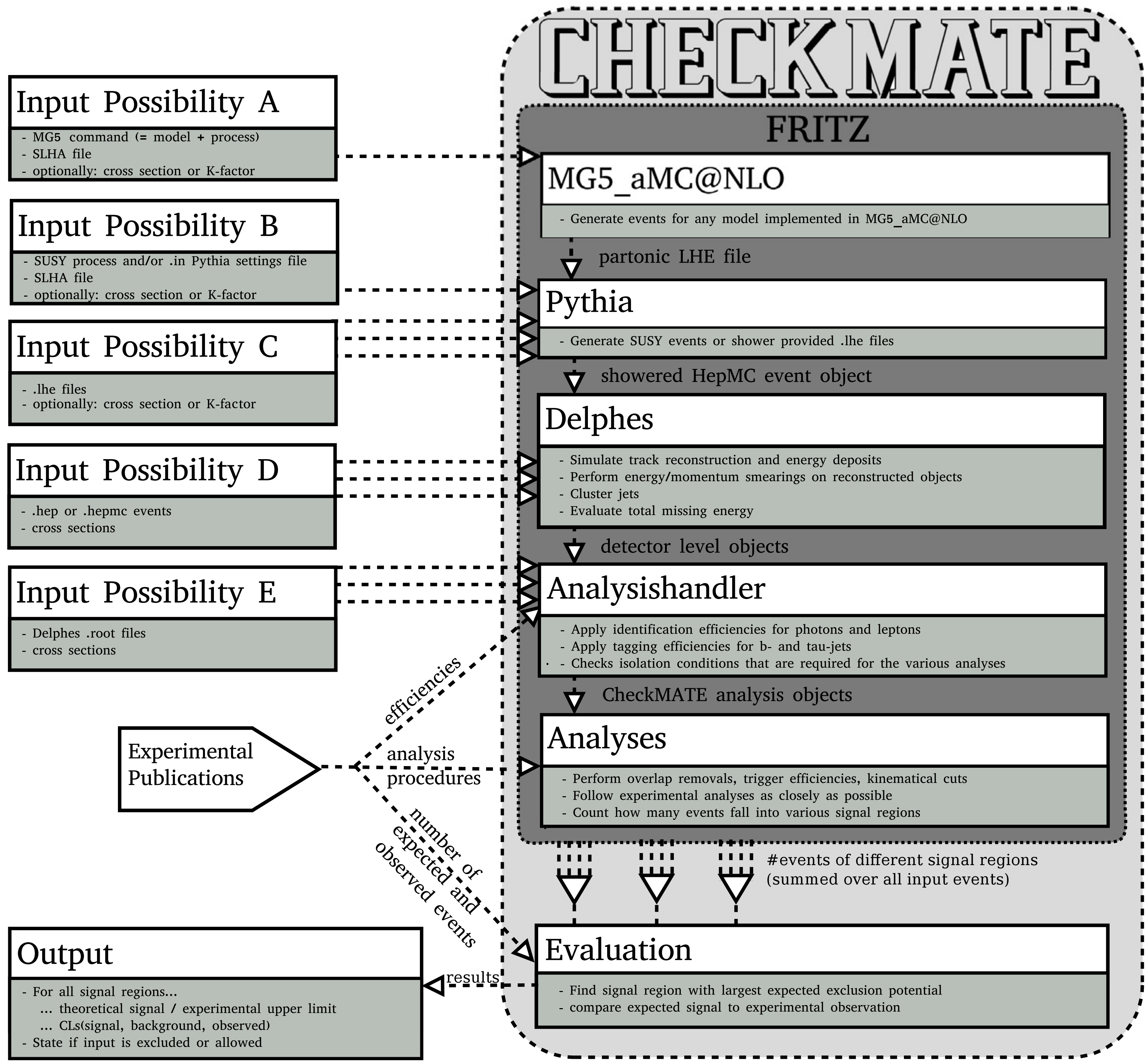
Generate signal events

Include QCD effects

Include detector effects

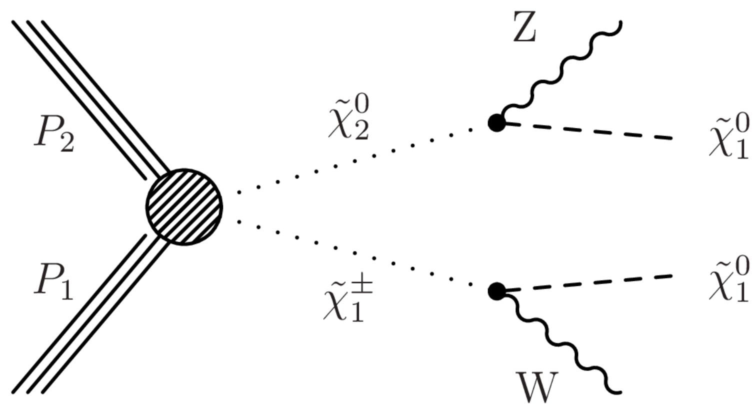
Simulate kinematic cuts

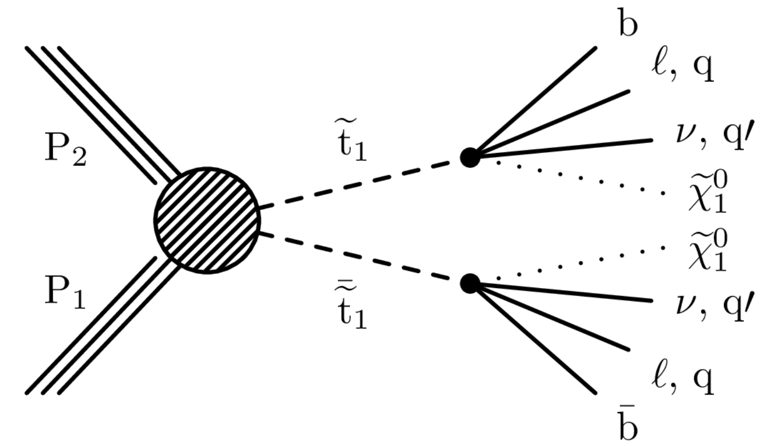
Compare to published upper limits



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

Validation



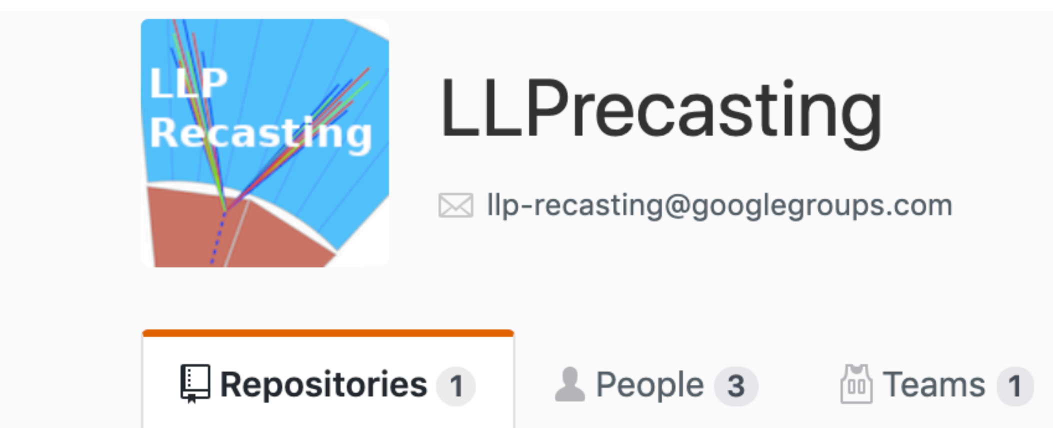


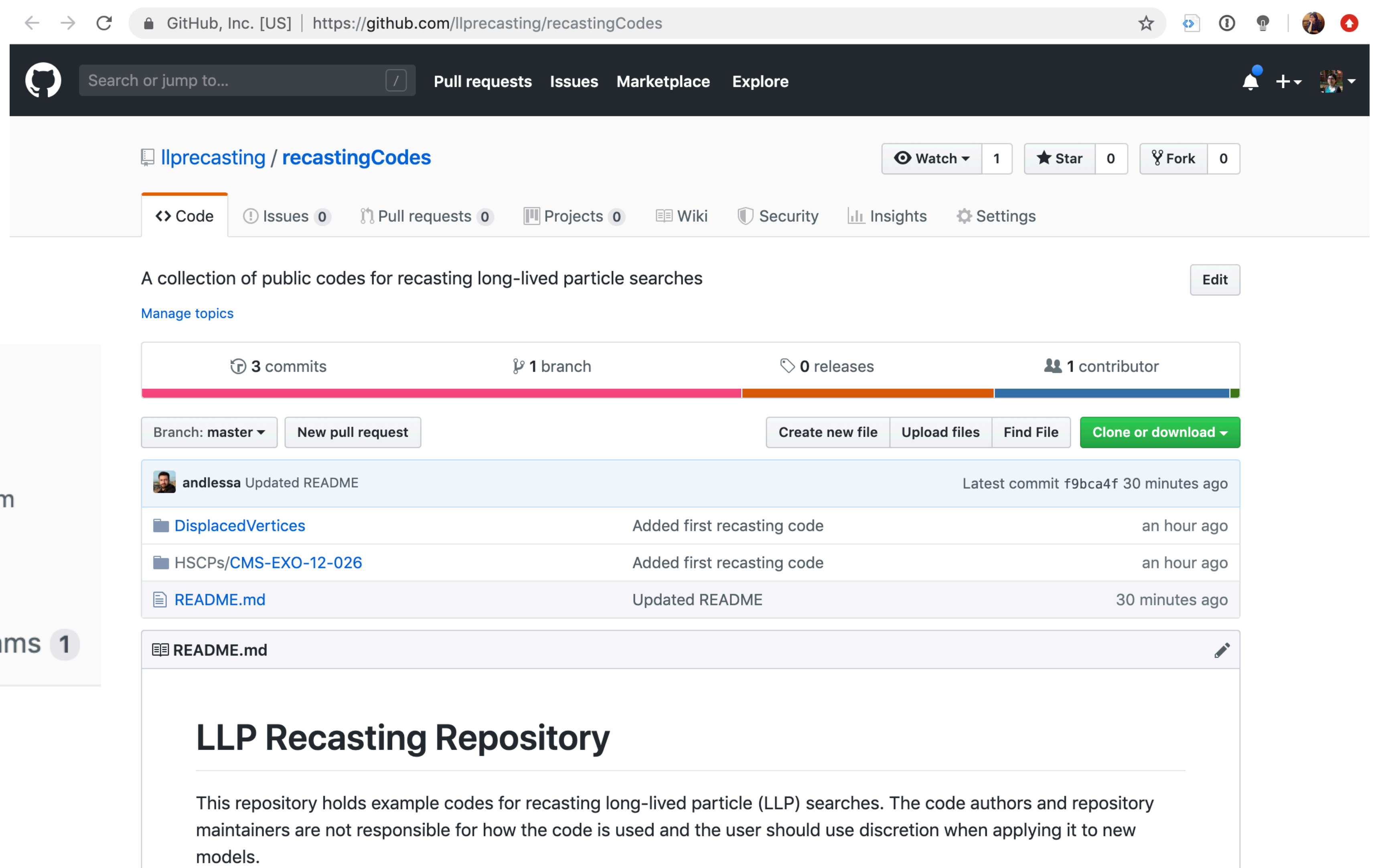
Variable	SR selection criteria
N_ℓ	$= 2$ (ee,$\mu\mu$, eμ)
$\mathrm{Q}(\ell_1)\mathrm{Q}(\ell_2)$	-1
$p_\mathrm{T}(\ell_1)$, $p_\mathrm{T}(\ell_2)$	$[5, 30]$ GeV
$p_\mathrm{T}(\mu_2)$ for high $E_\mathrm{T}^\mathrm{miss}$ $\tilde{\mathrm{t}}$-like SR	$[3.5, 30]$ GeV
$\lvert\eta_\mu\rvert$	< 2.4
$\lvert\eta_\mathrm{e}\rvert$	< 2.5
$d_z(\ell_{1,2})$ & $d_{xy}(\ell_{1,2})$	< 0.01 cm
$Iso_\mathrm{rel}(\ell_{1,2})$ & $Iso_\mathrm{abs}(\ell_{1,2})$	< 0.5 & < 5 GeV
$p_\mathrm{T}(jet1)$	> 25 GeV
$\lvert\eta\rvert(jet1)$	< 2.4
N_b (>25 GeV, CSVL)	$= 0$
$M(\ell\ell)$	< 50 GeV
$p_\mathrm{T}(\ell\ell)$	> 3 GeV
$E_\mathrm{T}^\mathrm{miss}$	> 125 GeV
$E_\mathrm{T}^\mathrm{miss}$ (muon subtracted)	> 125 GeV
$E_\mathrm{T}^\mathrm{miss}/H_\mathrm{T}$	$[0.6, 1.4]$
H_T	> 100 GeV
$M(\ell\ell)$	> 4 GeV
$M(\ell\ell)$	veto$[9, 10.5]$ GeV
$M_{\tau\tau}$	veto$[0, 160]$ GeV
$M_\mathrm{T}(\ell_x, E_\mathrm{T}^\mathrm{miss}), x = 1, 2$	< 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_{SUSY}/S_{95}^{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





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

HEPdata

HEPdata

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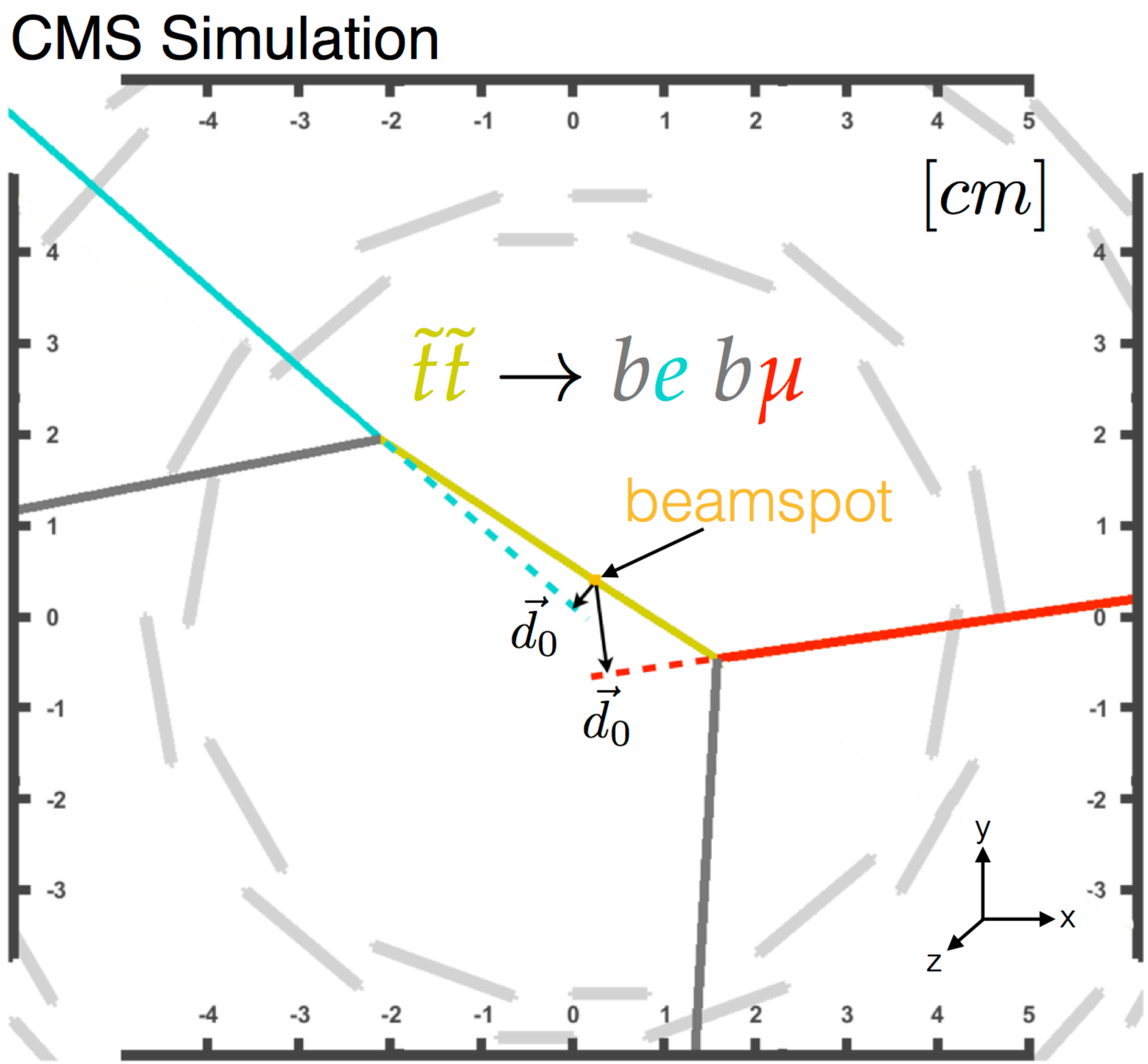
हेप डेटा!

theorist

HEPdata saves ^ lives

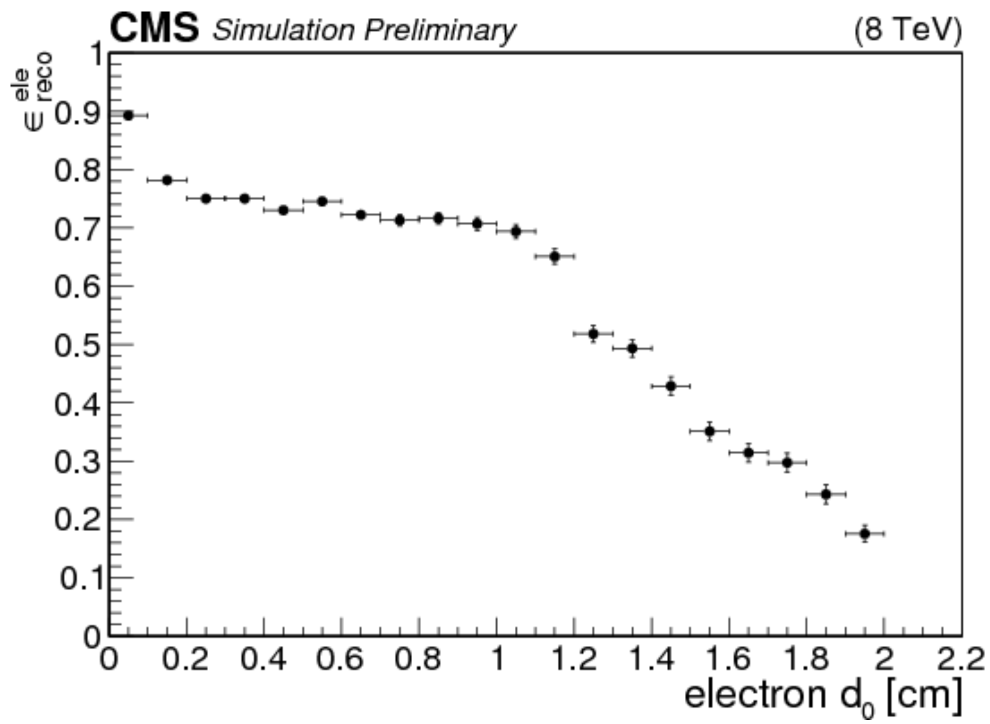
Back to normal programming

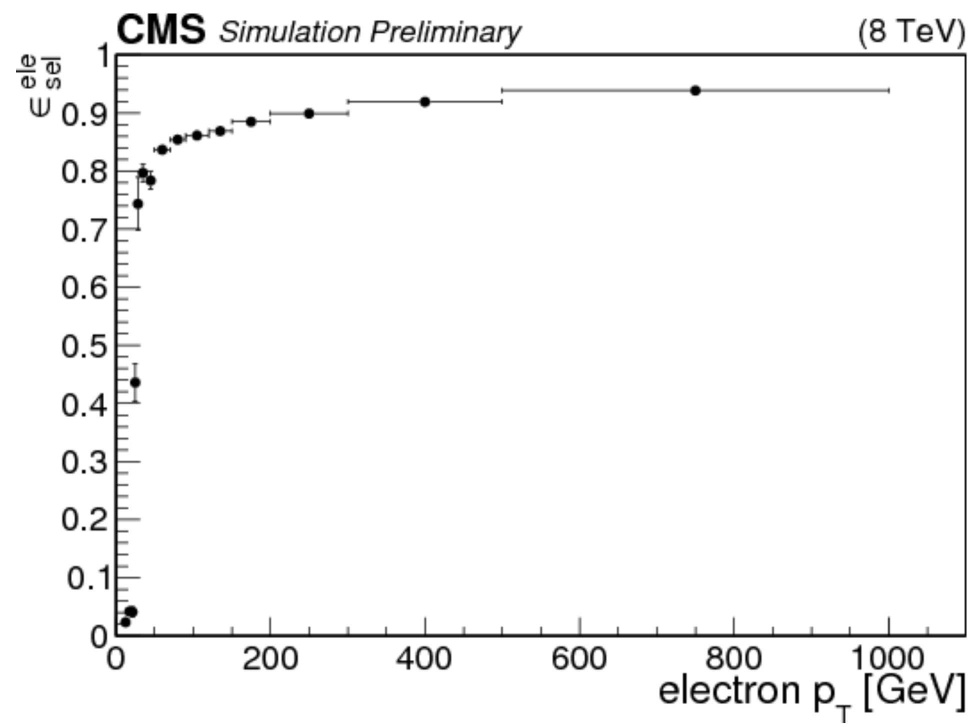
Case 1: CMS displaced lepton

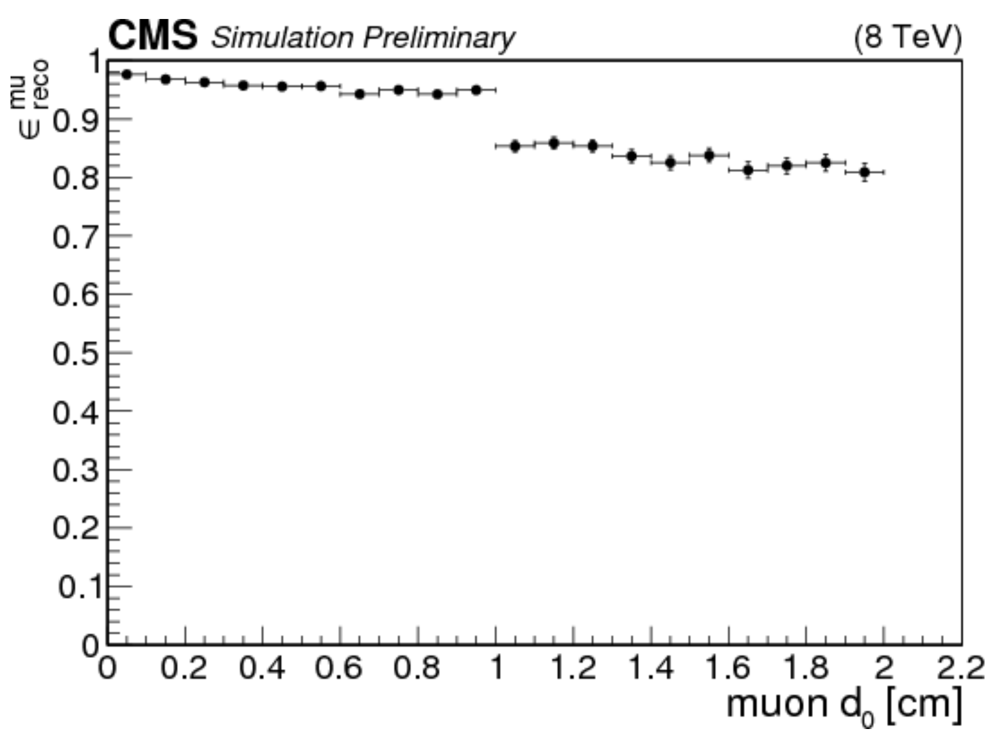


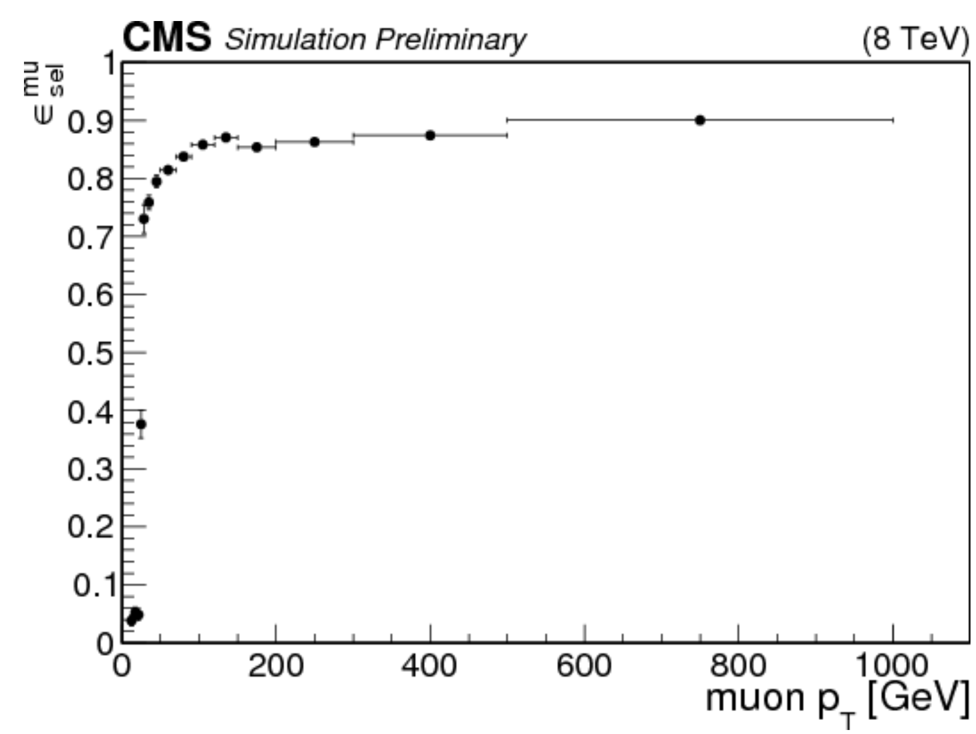
CERN-PH-EP/2013-037, CMS PAS EXO-16-022

Efficiencies provided









Trigger = 0.95

CERN-PH-EP/2013-037

Displaced Lepton search

How to use the parametrisation

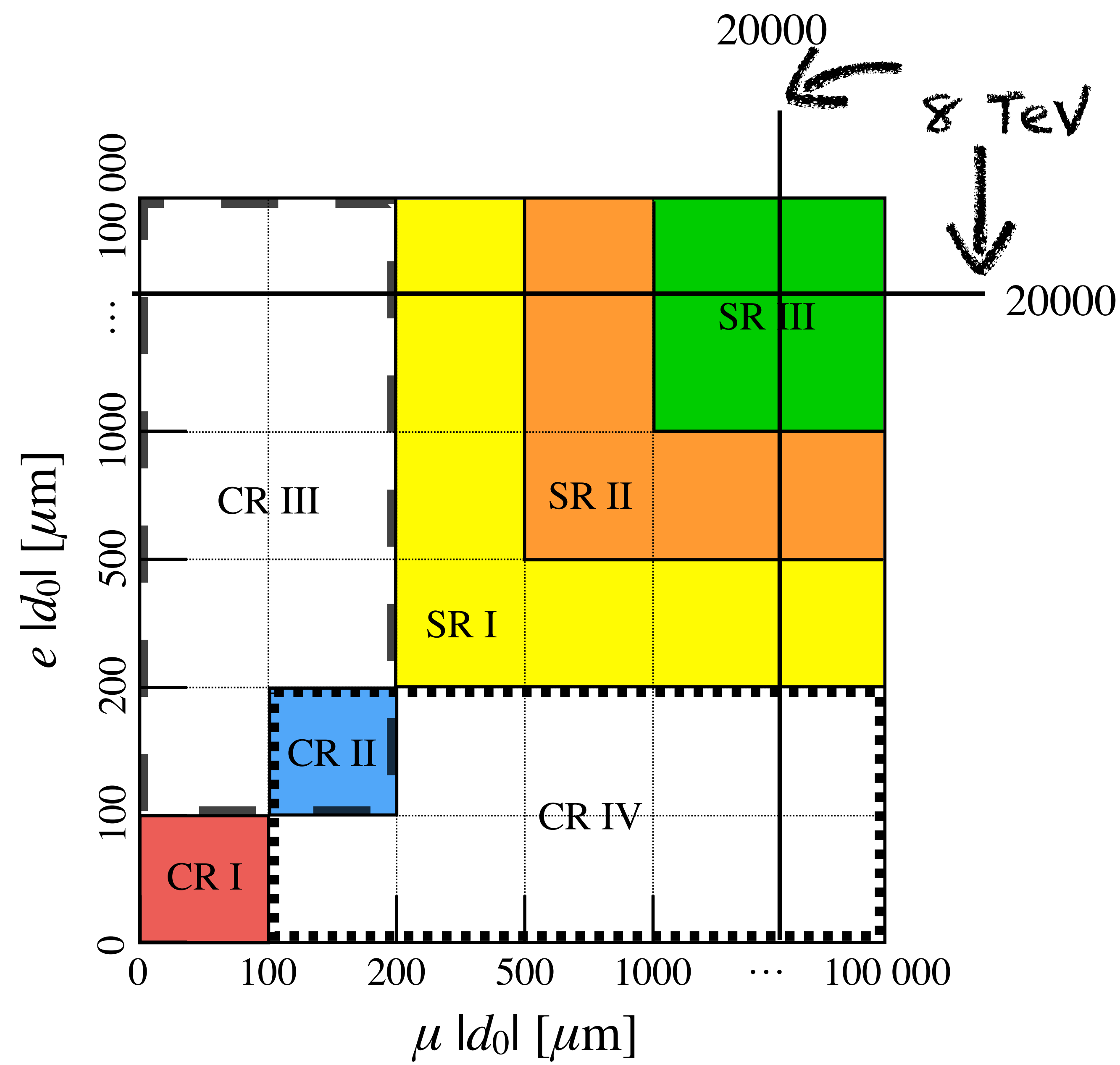
The user should follow all of the steps listed below.

i. produce some generated events for the model of their choice
ii. apply all of the cuts listed below.
iii. 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.
iv. 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 η < 2.5
generator electron with v0 < 4 cm
generator electron with vz < 30 cm
generator electron with pT > 25 CMS.GeV

⋮



CERN-PH-EP/2013-037, CMS PAS EXO-16-022

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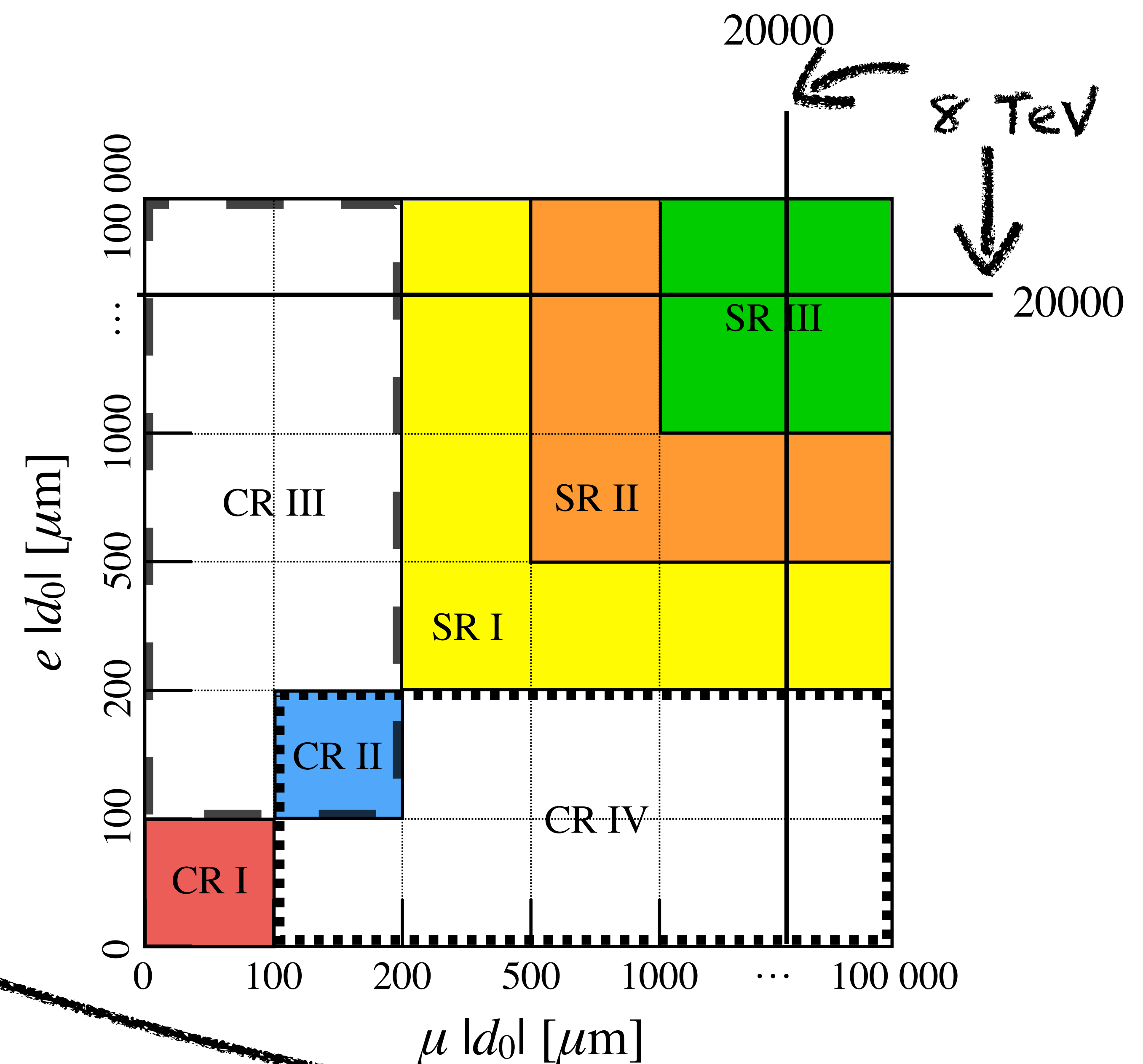


Requires CERN login

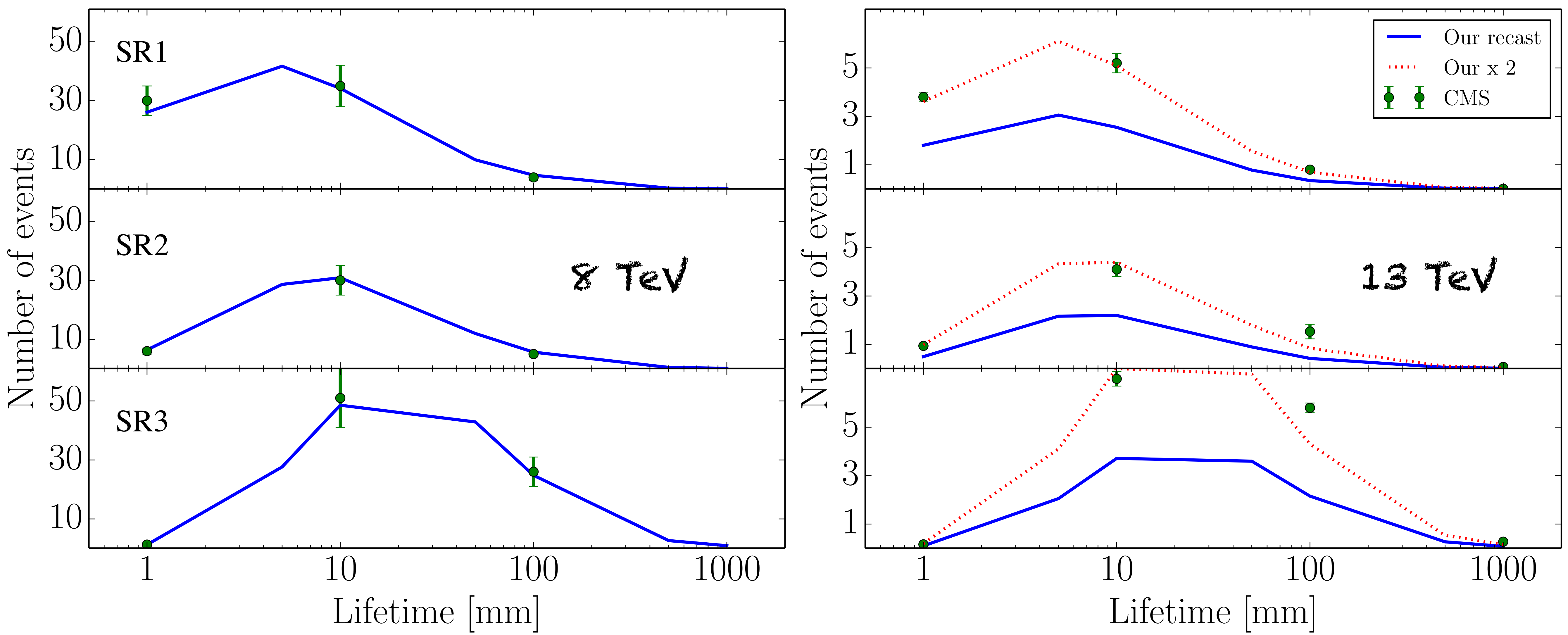
Don't know, but probably 100%

Hmm..

CERN-PH-EP/2013-037, CMS PAS EXO-16-022

Going from 8 TeV to 13 TeV

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



In this case, a almost simple factor of 2.

CERN-PH-EP/2013-037, CMS PAS EXO-16-022

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.**

$$pp \to \tilde{g}\tilde{g} \qquad \tilde{g} \to \bar{t}\tilde{t} \qquad \tilde{t} \to b\ell$$

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 eμ search is very important because it is so simple and applicable to a variety of models! Please fix…

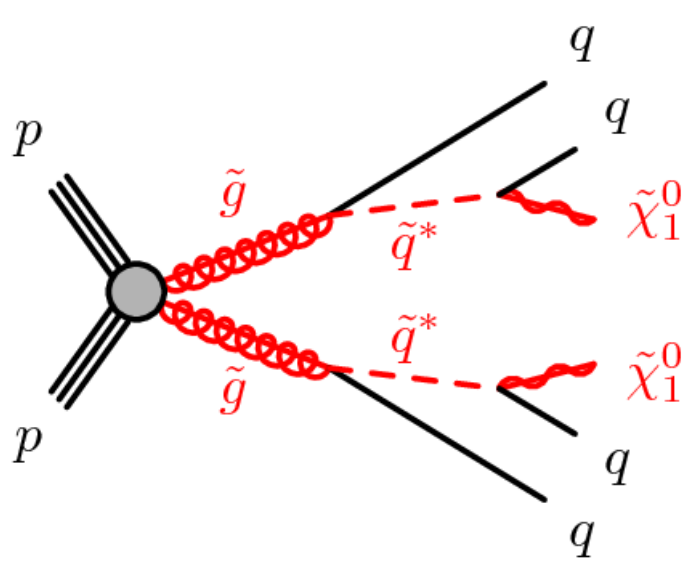
5. Should you be selectively choosing truth signal? **Better to choose a benchmark that's clean**.

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?

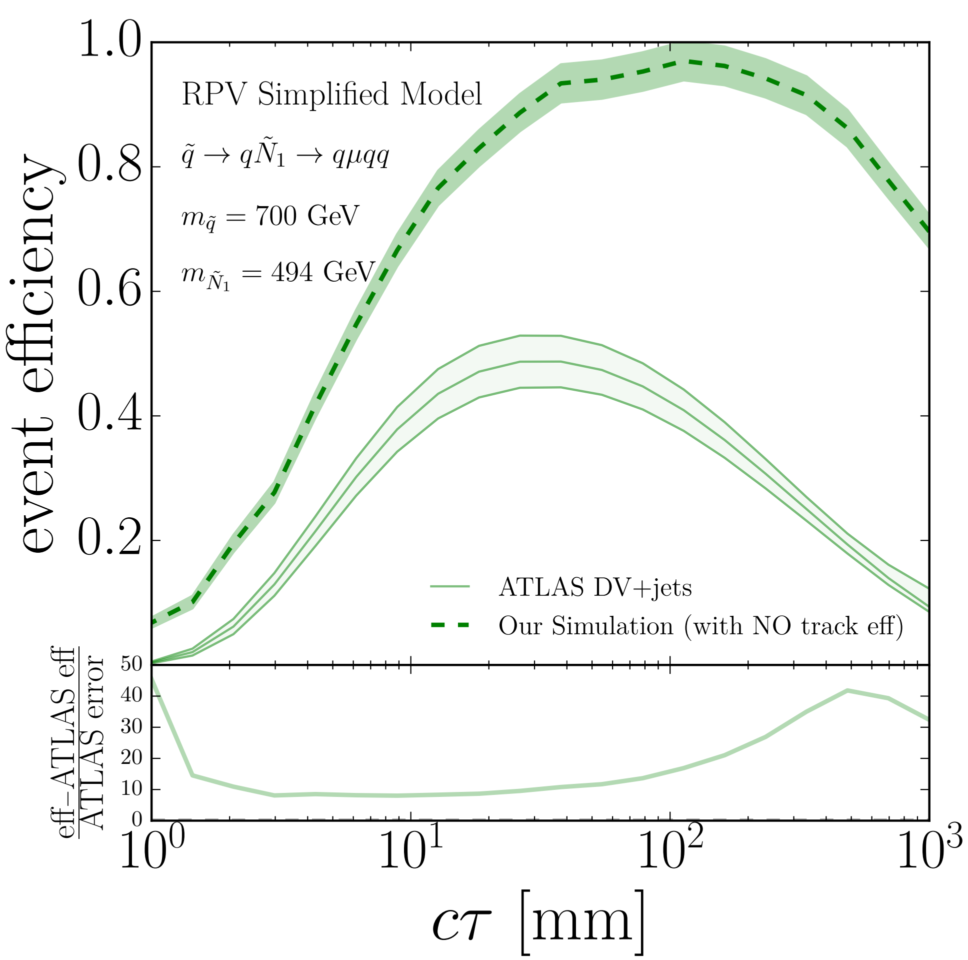
Case 2: Displaced Vertex search

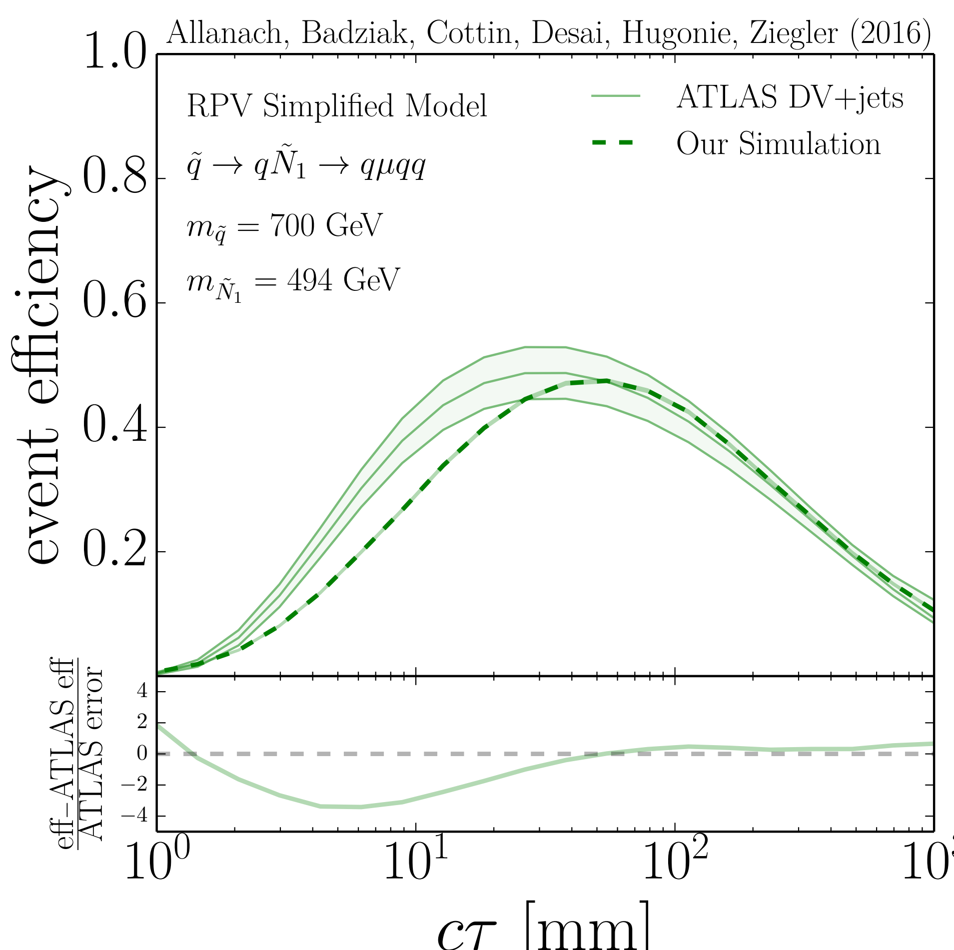
CERN-PH-EP-2015-065, ATLAS-CONF-2017-026, CERN-EP-2017-202



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

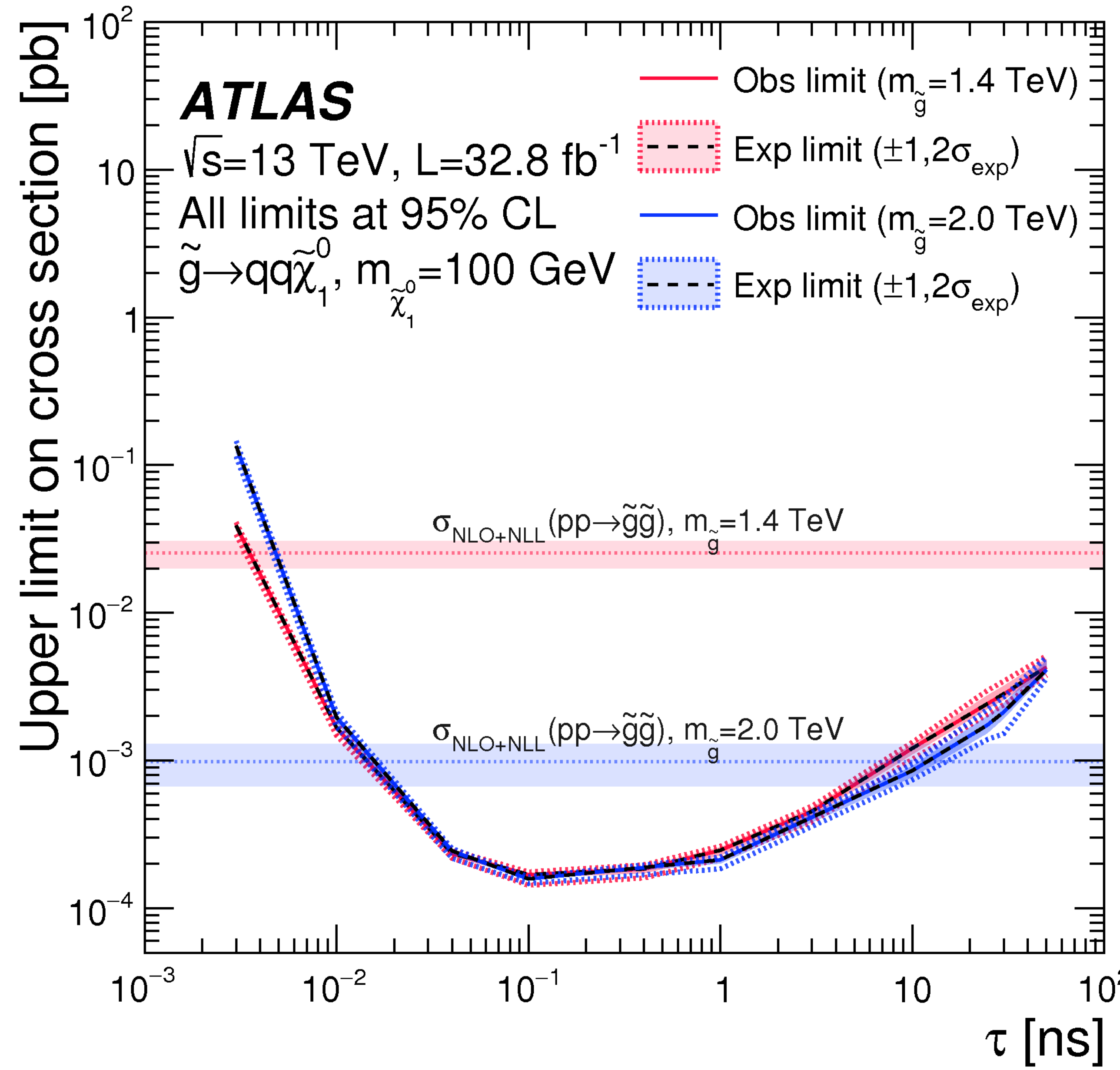
$$d_0(trk) > 0.2 \text{ mm}$$

3. Make vertices, make sure

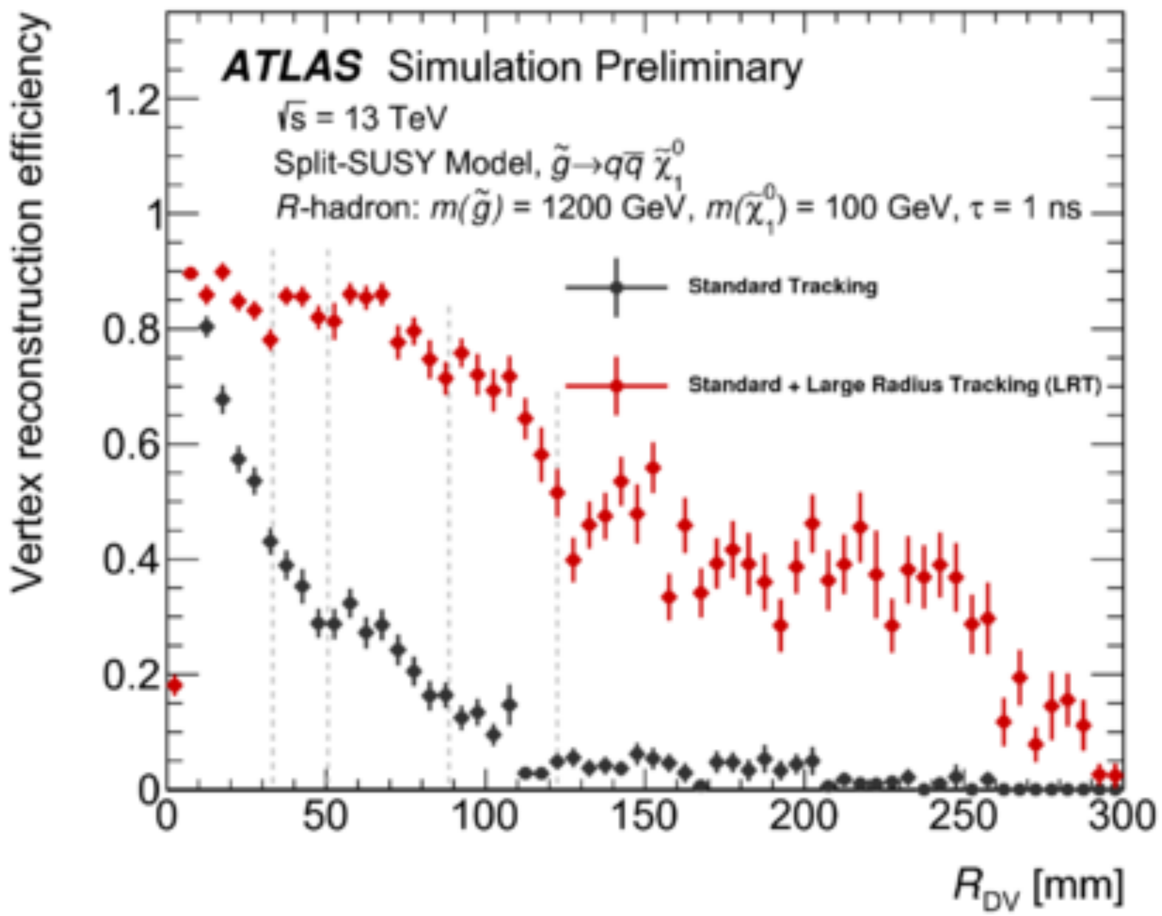
$$R < 300 \text{ mm} \qquad |z| < 300 \text{ mm}$$

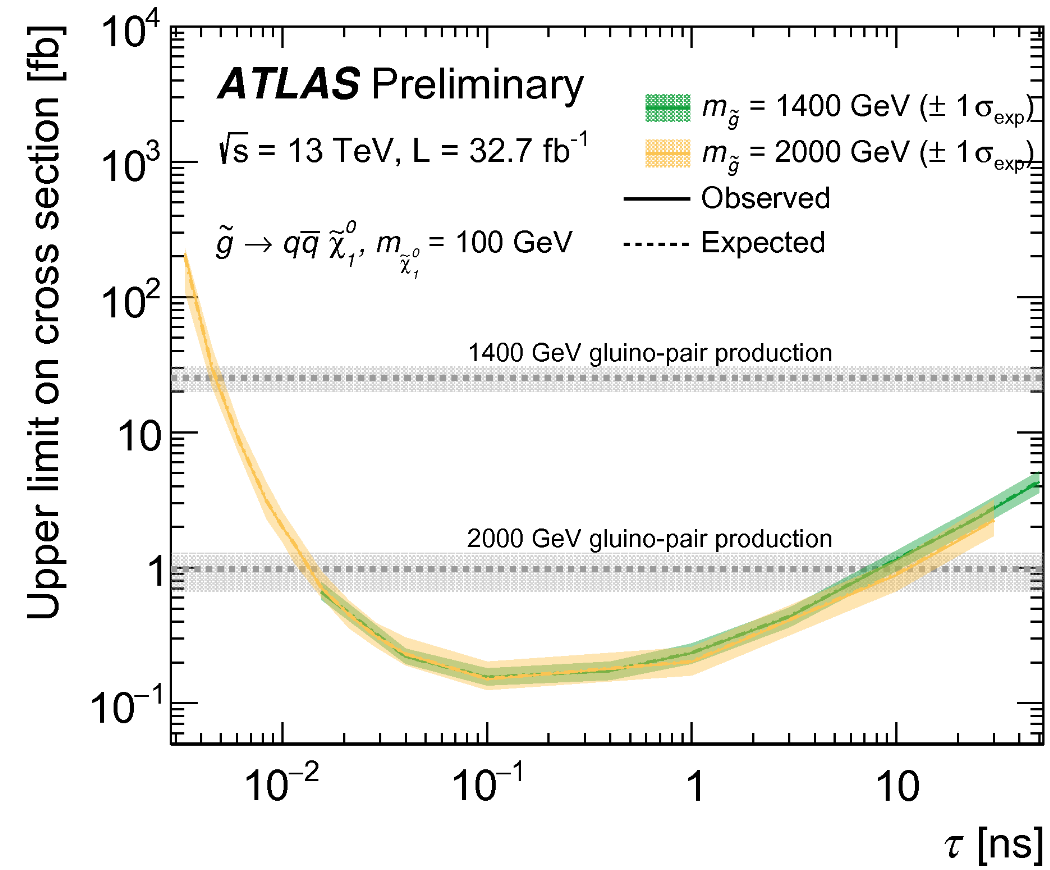
$$n_{\text{DV}}^{trk} > 5 \qquad m_{\text{DV}} > 10 \text{ GeV}$$

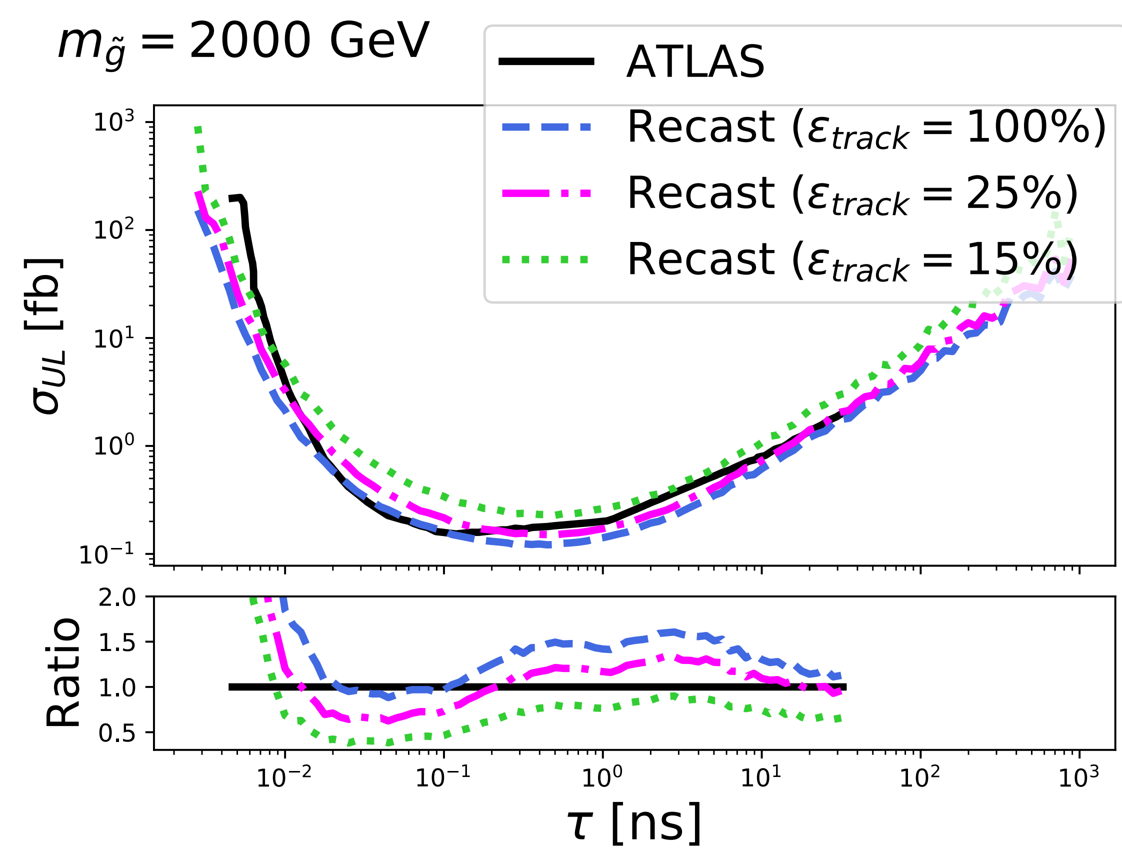
4. Apply material vetoes



Just efficiency in R_{DV} is not enough





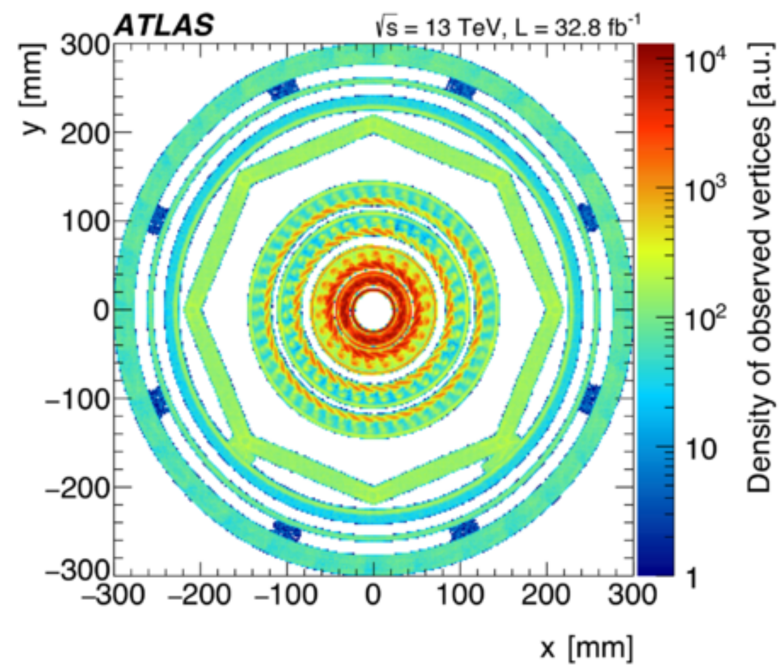


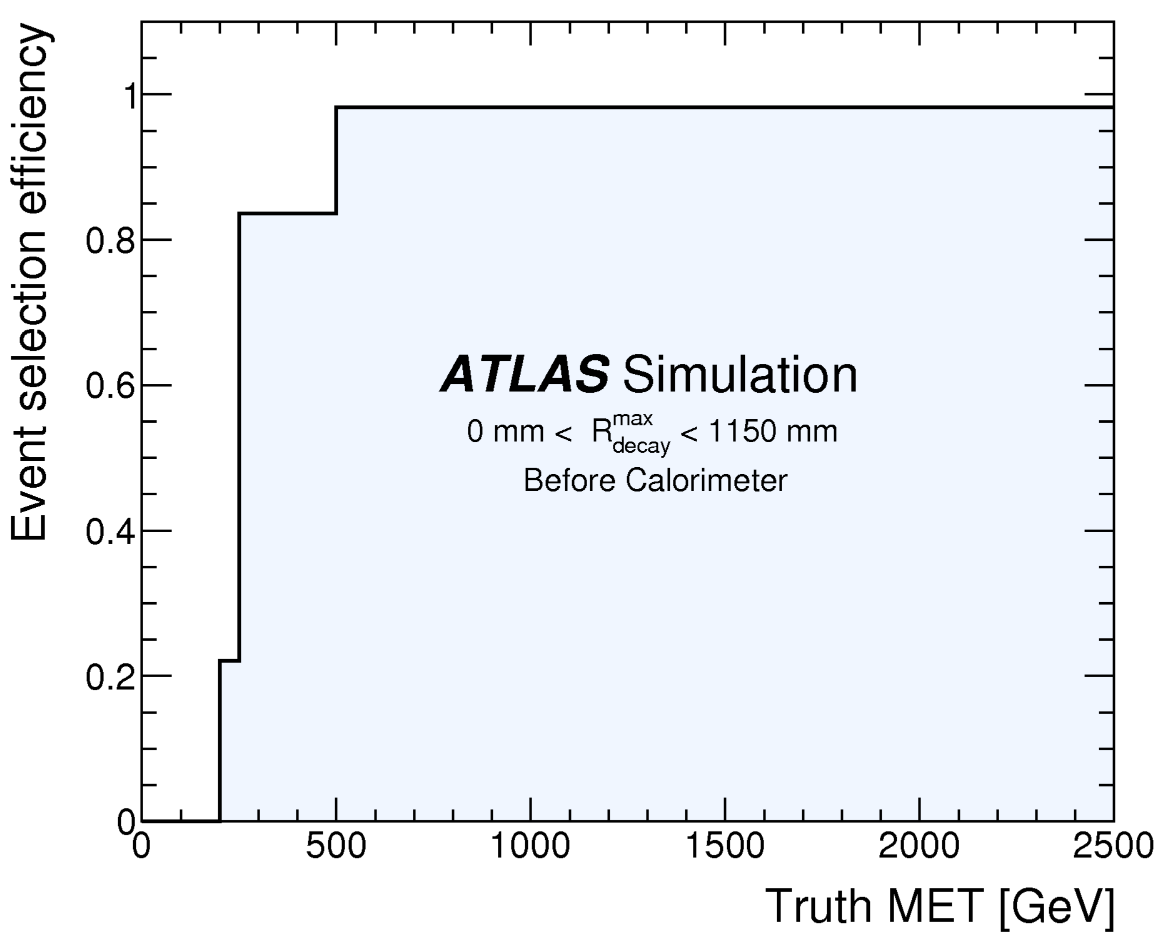
ATLAS-CONF-2017-026
Reinterpretation by A. Lessa

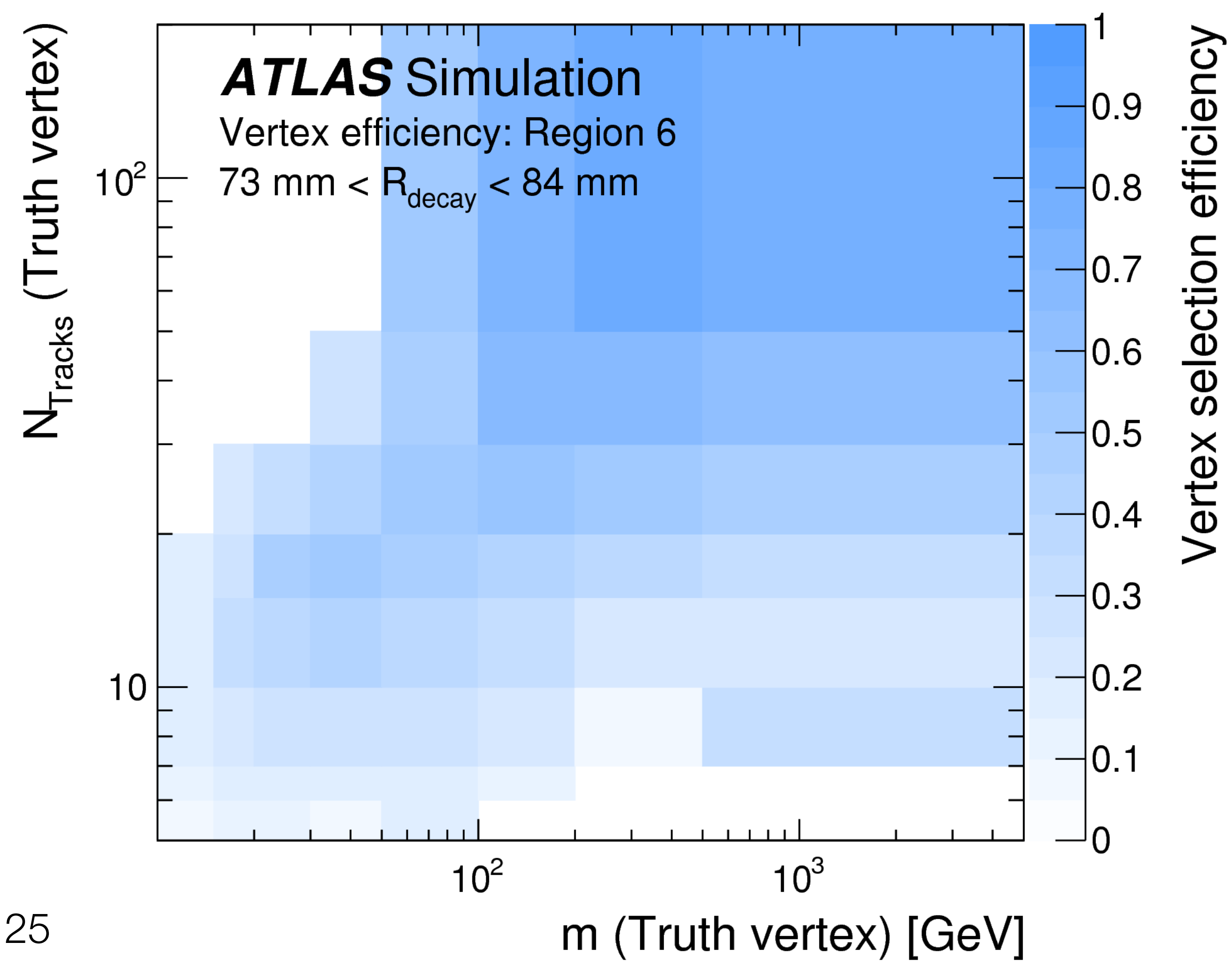
DV efficiency parametrisation

v2.1: 13 TeV analysis

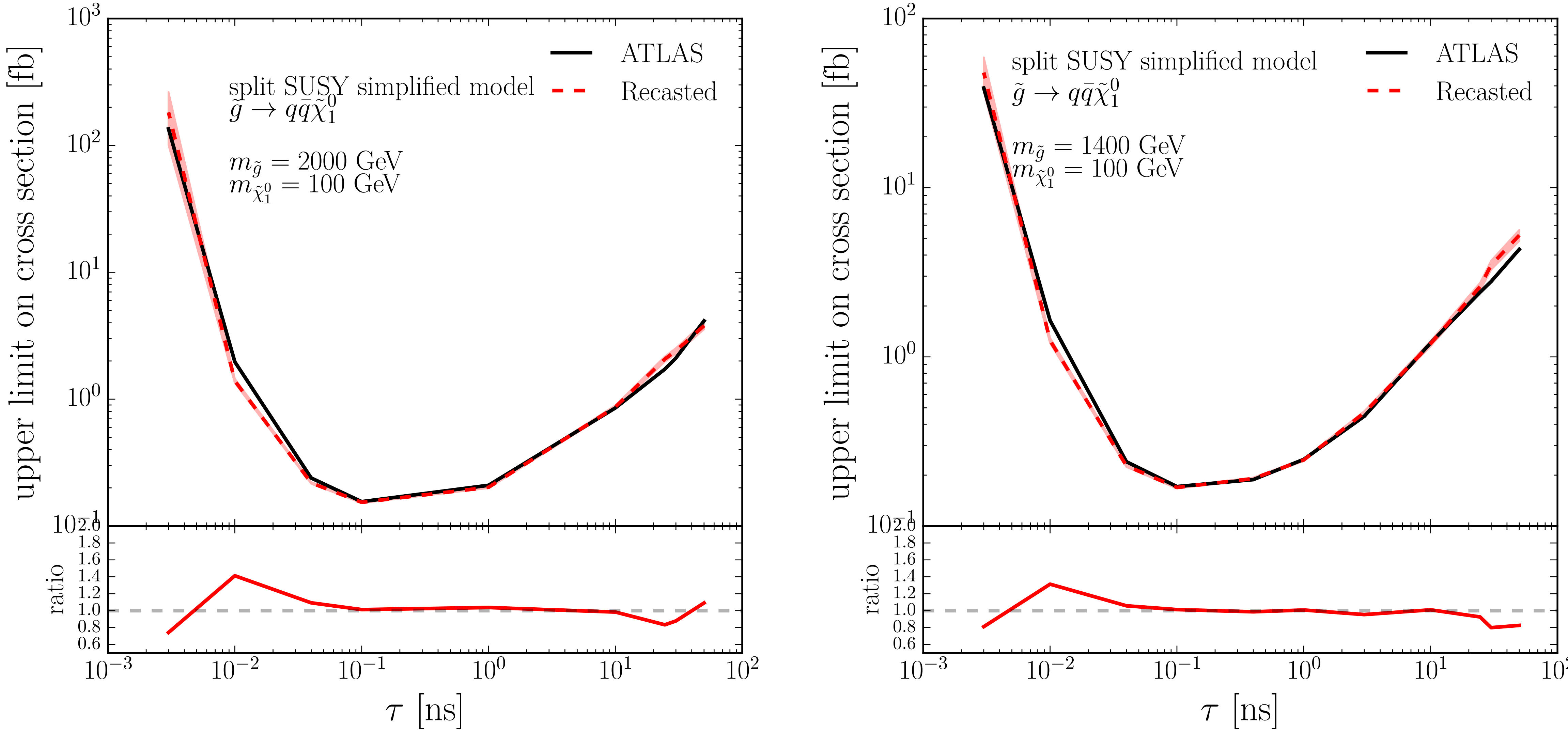
CERN-EP-2017-202







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!