Last but not Least: CMS Contribution

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on behalf of the CMS Exotica long-lived subgroup

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TL;DR*

CMS has a broad program of long-lived (LL) searches that complements other experiments

Limited experimental personpower means it's crucial to prioritize and optimize our interpretation-related efforts

More communication could help identify gaps and improve coverage

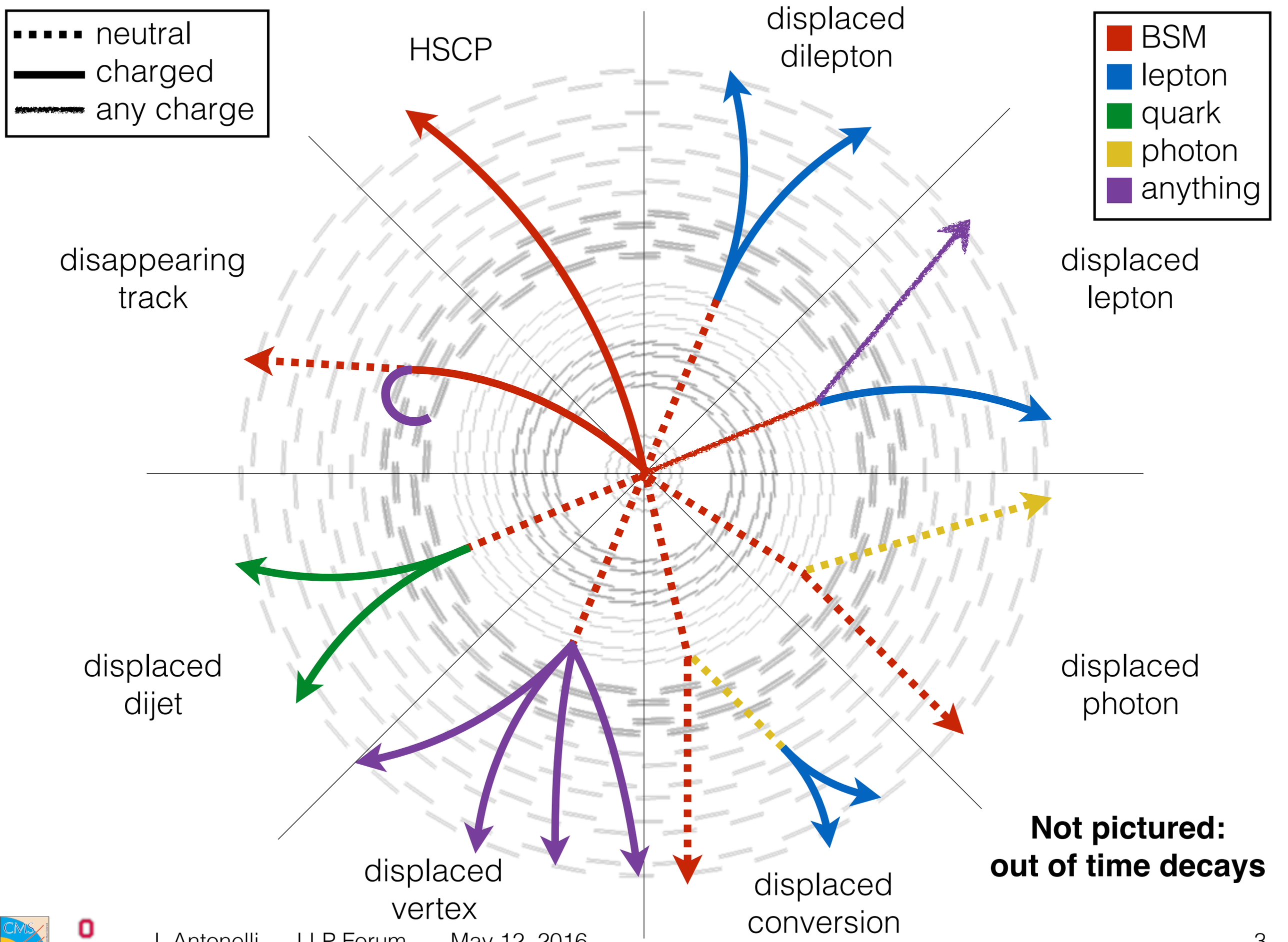
- between LL analysis groups within an experiment
- between LL and "prompt" analysis groups in an experiment
- between experiments
- between experimentalists and theorists

Timing of communication is key (early and often)

It's nontrivial to effectively distribute (re)interpretation-related information

Long-lived searches face many challenges; input from the wider community could help

*https://en.wikipedia.org/wiki/Wikipedia:Too_long;_didn't_read


neutral
charged
any charge
BSM
lepton
quark
photon
anything
HSCP
displaced dilepton
disappearing track
displaced lepton
displaced dijet
displaced photon
displaced vertex
displaced conversion
Not pictured: out of time decays

CMS has a broad, growing LL program

	Final state targeted	7 TeV	8 TeV
1	displaced SF dilepton pairs	1211.2472	1411.6977
2	displaced μ-μ pairs in muon system		2005761
3	displaced e-μ pairs		1409.4789
4	displaced μ-μ pairs (dark photons)		1506.00424
5	displaced photons using ECAL timing	1212.1838	2063495
6	displaced photons using conversions	1207.0627	2019862
7	displaced vertices		to appear
8	displaced dijets		1411.6530
9	short, highly ionizing disappearing tracks		thesis
10	disappearing tracks		1411.6006
11	kinked tracks		thesis
12	fractionally charged particles	1210.2311	1305.0491
13	heavy stable charged particles (HSCP)	1205.0272	1305.0491
14	stopped particles	1207.0106	1501.05603
15	out of time muons		thesis

direct searches

indirect searches

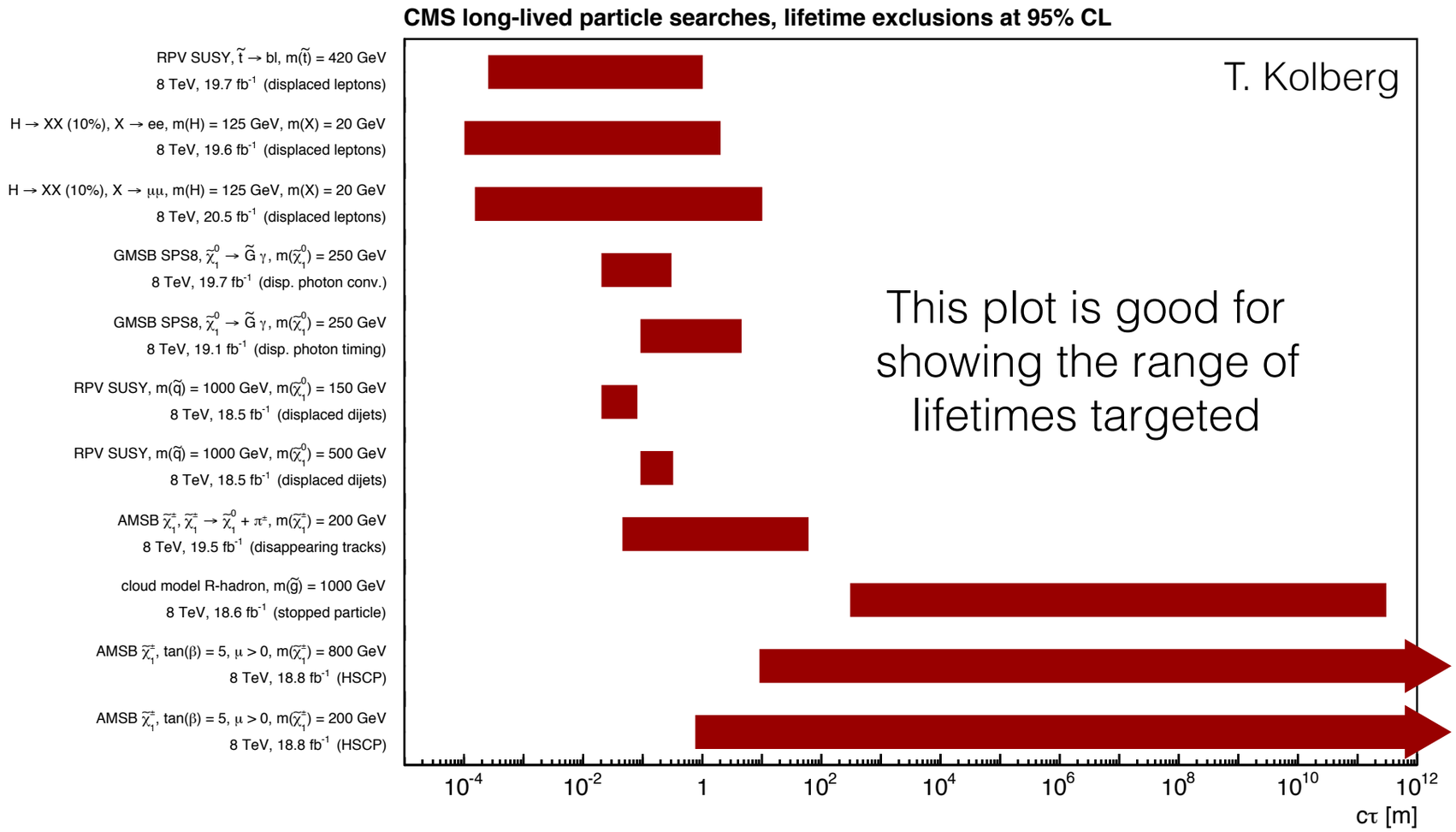
13 TeV HSCP: 2114818

As *signature-driven* searches, interpretation is not the primary focus; we avoid optimizing to a particular benchmark model

We're in a *discovery* phase of LHC data-taking; background-free searches should be done quickly

As a result, "in-house" recasting and exporting of recasting inputs have been relatively rare

Direct comparison within CMS is not easily achievable



Most analyses only consider a single, independently chosen signal model

Makes for an apples to onions comparison (some analyses look artificially good/bad)

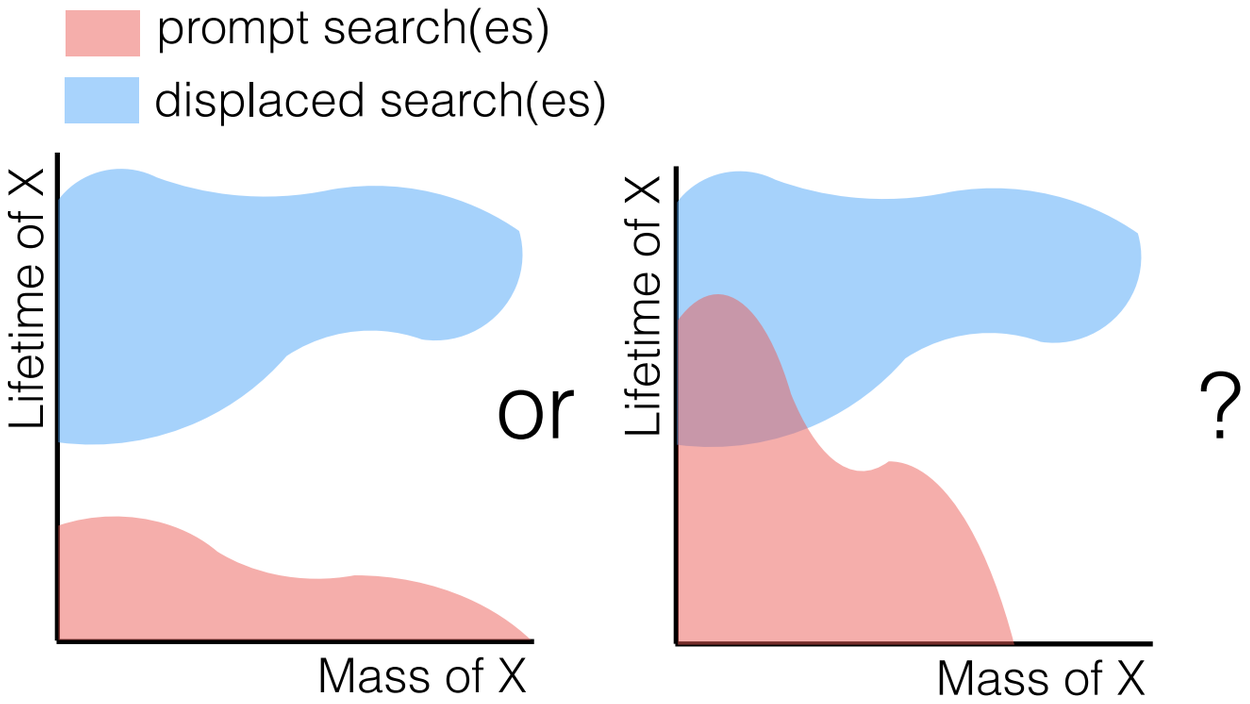
Exclusion comparison possibilities:

1. Lifetime exclusions for given mass (different models)
2. Mass exclusions for chosen lifetime (different models)
3. Exclusions in lifetime vs. mass plane (*requires same model*)
4. Exclusions in cross-section vs. lifetime plane (*requires same model*)

All choices have strengths/weaknesses

Simplified models would be very helpful, e.g. $\tilde{t} \rightarrow t$+MET gives leptons and jets

Finding the gaps requires including prompt searches

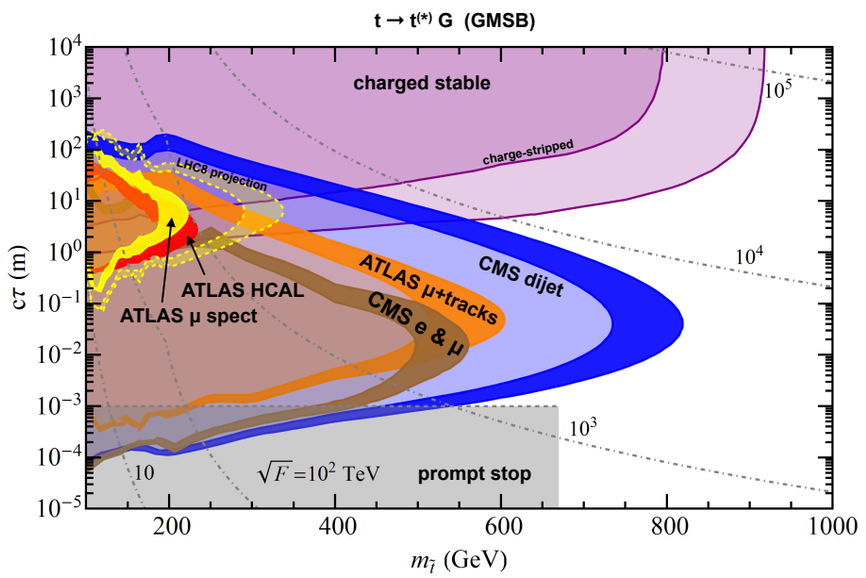


In principle, it's straightforward for "prompt" analysts to run over LL signal samples, *communication is the key*

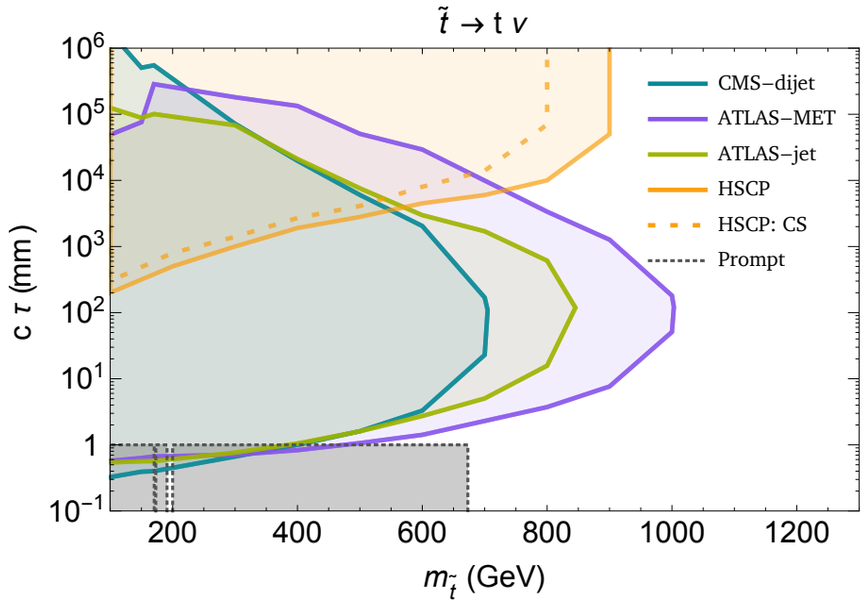
One example from CMS: γ+MET search, limits set on long-lived neutralino model (1507.00359)

Theorists have room for improvement in this area as well (note gray boxes for prompt searches)

Examples of LHC LL recasting by theorists



1503.05923



1505.00784

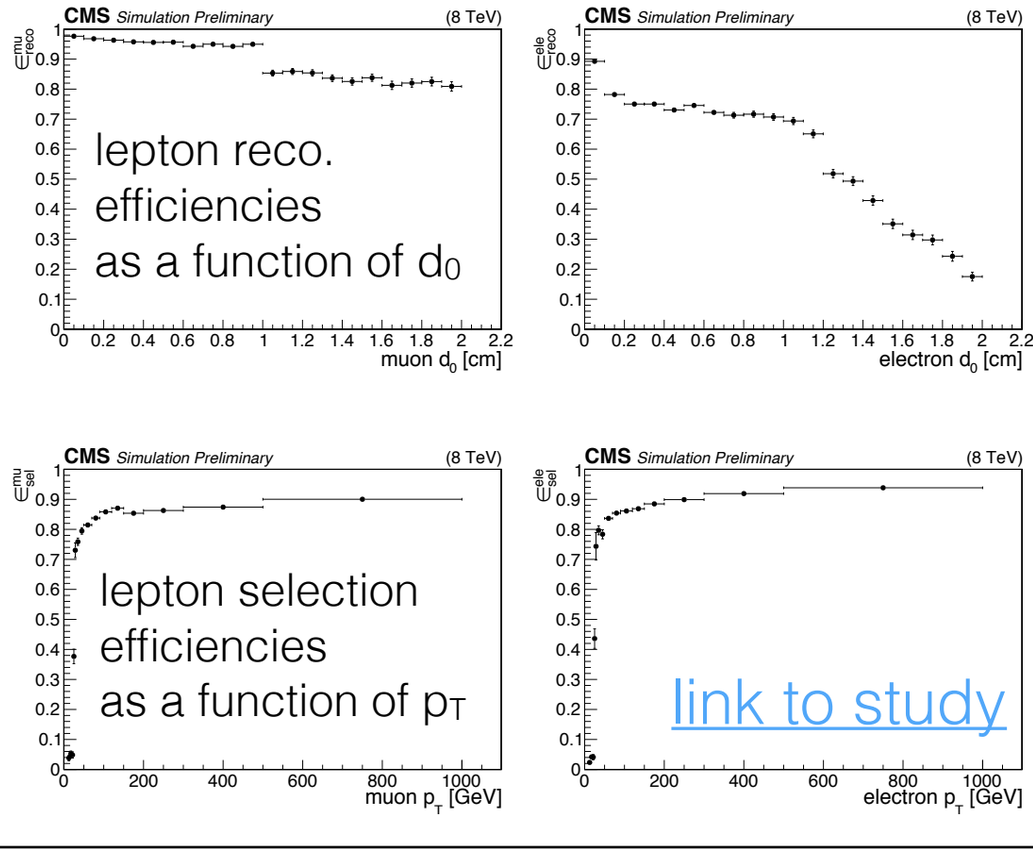
Materials for recasting should be produced *early*

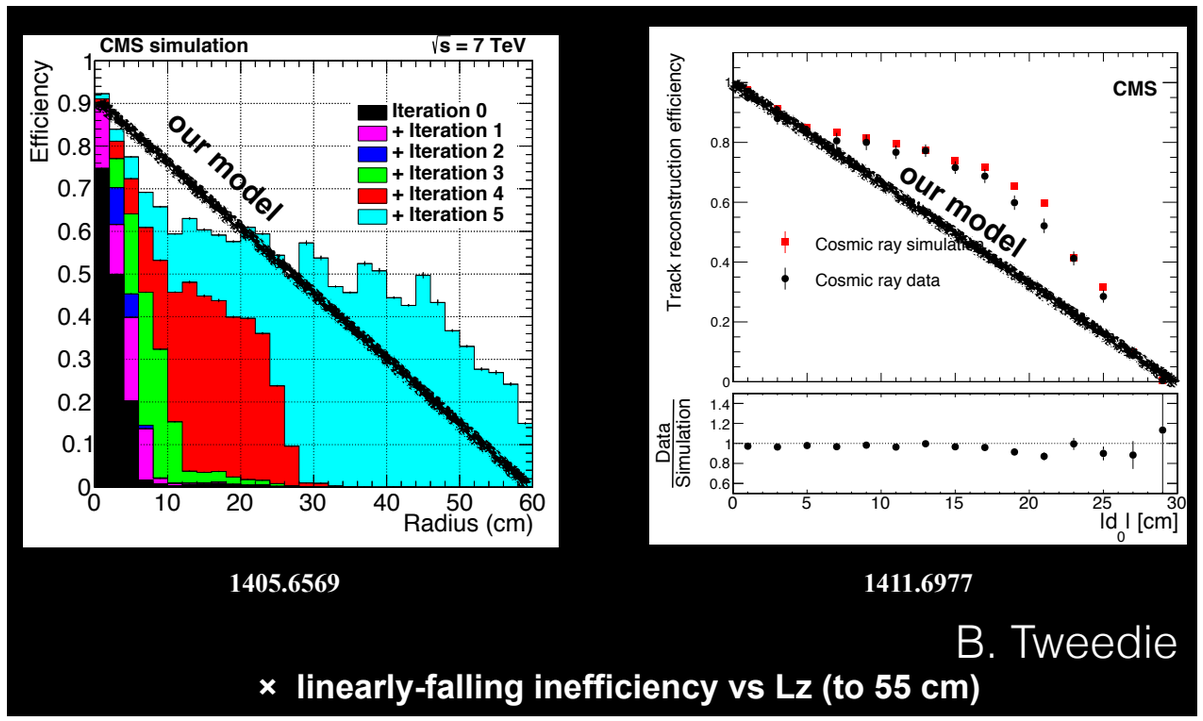
Recasting inputs are only useful if they're available when recasting is happening

Displaced e-μ (1409.4789) analysts produced lepton flavor-specific efficiency curves as part of final result

Theorists recast preliminary result (~1 year earlier) using information gathered from various other sources:
7 TeV tracking performance paper +
SF displaced dilepton search +
ad hoc linear model

Earlier communication between experimentalists and theorists could improve recasting accuracy and reduce the effort required





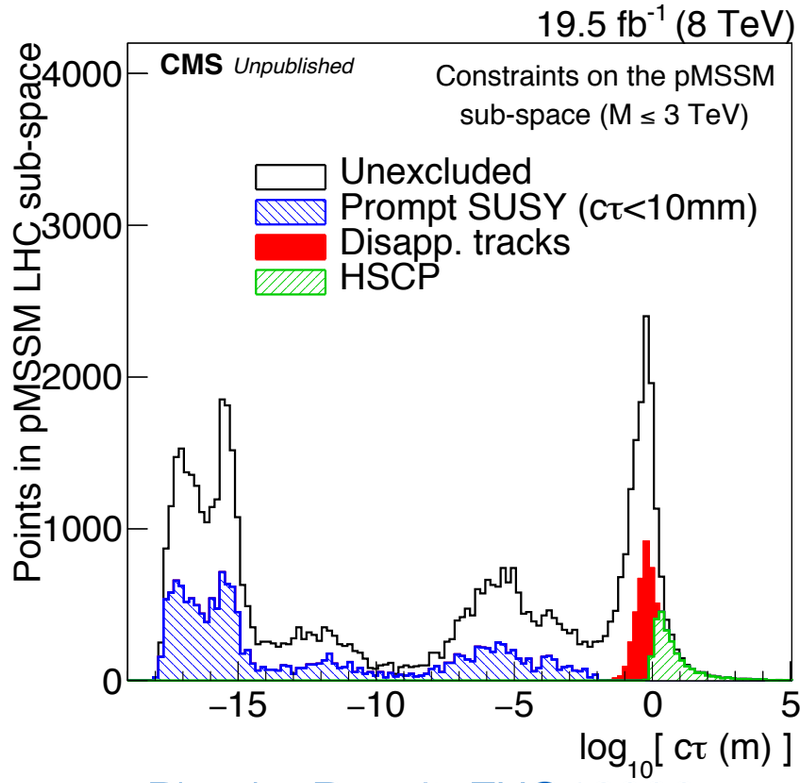
It's challenging to effectively communicate our results

Example 1:

SUSY group, HSCP, and disappearing tracks search produced separate pMSSM recasts

It's good that we performed recasts for multiple signatures onto a single model, but there are some limitations:

1. Sensitivity of prompt searches to long-lived scenarios unknown
2. Potential duplication of effort having 3 recast efforts instead of 1
3. Because of differing timelines, recast comparison was not included in any published document



PhysicsResultsEXO13006

Example 2:

Analysts export bin contents of public plots into HEPData; theorists use pdf parser instead, e.g. WebPlotDigitizer

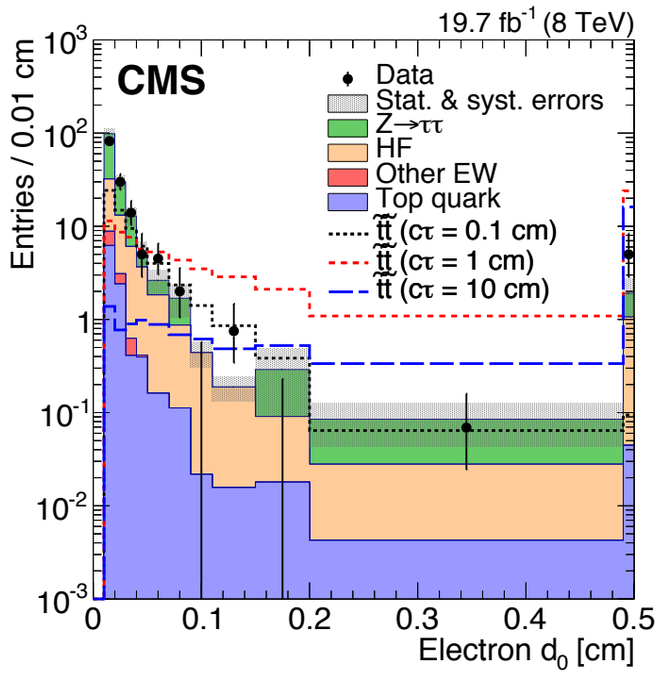


Table 1 (Figure 1, left.) or as: input, plain text, AIDA, PyROOT, YODA, ROOT, mpl, DMelt, MarcXML or YAML

Electron transverse impact parameter distribution for data and expected background processes after the preselection requirements have been applied. The event yields per bin have been rescaled to account for the varying bin sizes. The rightmost bin contains the overflow entries.

reaction keywords: [P P --> STOP STOP]
observable keywords: [N]

RE	P P --> STOP STOP					
SQRT(S)	8000.0 GeV					
Electron d_0 IN CM	data	expected background	Z→ ττ	HF	Other EW	Top quark
0. – 0.01	–	–	–	–	–	–
0.01 – 0.02	82	99 ± 12	66.4 ± 9.4	23 ± 7	3 ± 1	6.22 ± 0.95
0.02 – 0.03	30	30 ± 5	16.7 ± 3.9	10 ± 3	0.69 ± 0.25	2.4 ± 0.63
0.03 – 0.04	14	13 ± 3	6.8 ± 2.5	5.4 ± 1.6	0.22 ± 0.14	0.41 ± 0.13
0.04 – 0.05	5.0	5.3 ± 1.5	1.6 ± 1.1	3.24 ± 0.98	0.019 ± 0.019	0.4 ± 0.13
0.05 – 0.07	4.5	2.63 ± 0.76	0.79 ± 0.57	1.7 ± 0.5	–	0.161 ± 0.059
0.07 – 0.09	2	1.69 ± 0.63	0.82 ± 0.58	0.76 ± 0.23	–	0.112 ± 0.048
0.09 – 0.11	–	0.44 ± 0.13	–	0.42 ± 0.13	–	0.022 ± 0.022
0.11 – 0.15	0.75	0.188 ± 0.056	–	0.173 ± 0.053	–	0.016 ± 0.016
0.15 – 0.2	–	0.3 ± 0.2	0.2 ± 0.2	0.073 ± 0.023	–	0.018 ± 0.013
0.2 – 0.49	0.069	0.085 ± 0.041	0.057 ± 0.041	0.0237 ± 0.0073	–	0.0043 ± 0.0025
0.49 - 2.0	5	1.91 ± 0.85	0.85 ± 0.85	1.017 ± 0.062	–	0.044 ± 0.044

http://hepdata.cedar.ac.uk/view/ins1317640

Long-lived searches face many unique challenges

1. We often choose selections that reduce sensitivity to models we weren't considering
2. It's hard to know what material in what format is most useful for recasting
3. Developing trigger strategies is especially difficult
4. It's hard to know how recasting efforts should be divided between theorists and experimentalists

On all of these issues, we would benefit from input from the wider LL community

We should be planning for the future

We want to take full advantage of CMS upgrades for HL-LHC

- High granularity calorimetry
- Precise timing detectors
- Increased forward tracking acceptance

We want to retain sensitivity to LLPs at HL-LHC

- Ability to measure energy loss in tracker
- Track trigger acceptance for displaced tracks

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