LONG LIVED PARTICLES

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Overview will borrow heavily from work
with Y. Kats, S. Nussinov, M.Papucci,
M. Reece, D. Shih, and D. Shih

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OVERVIEW

• What does long lived mean?

• Signatures: Quantum numbers and decays

• Where do the lifetimes come from

• Typical searches

• Room for improvement

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"But don't you see, Gershon - if the particle is too small and too short-lived to detect, we can't just take it on faith that you've discovered it."

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At least we don't have to worry about this...

Remarkable amount of interesting signatures if they are looked for!!!

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WHAT IS LONG LIVED?

- There is potentially a large range of lifetimes that are "long lived" at the LHC and we have many examples in the SM

  - B decays ~ O(100) microns

  - muons ~ O(1000) meters

  - protons ~ O(**much** bigger than the other examples...)

$$N_{decayed} = N_{produced} \left(1 - e^{-d/L} \right)$$

$$N_{decayed} \approx N_{produced} \frac{d}{L} \quad \text{long lifetime limit}$$

If we are looking for decays we can still have huge lifetimes with events inside our detectors

Can be absolutely stable and still have signals!
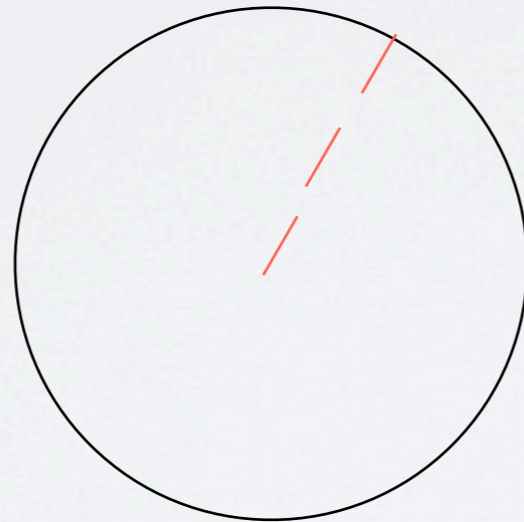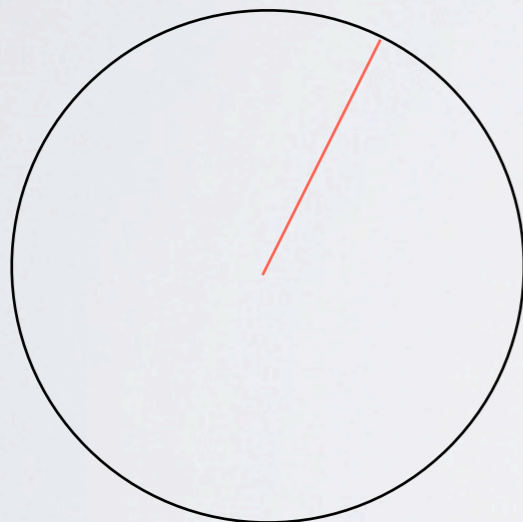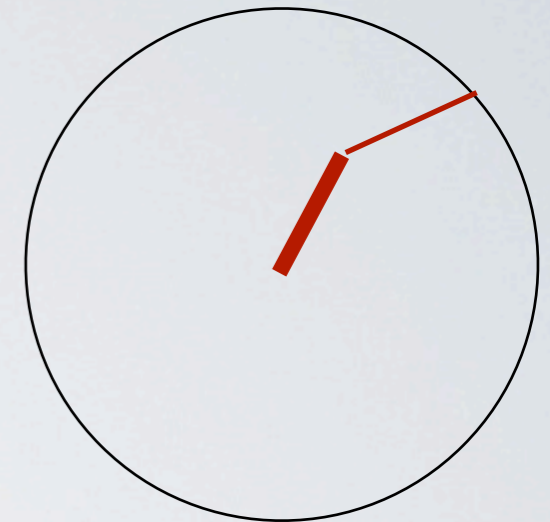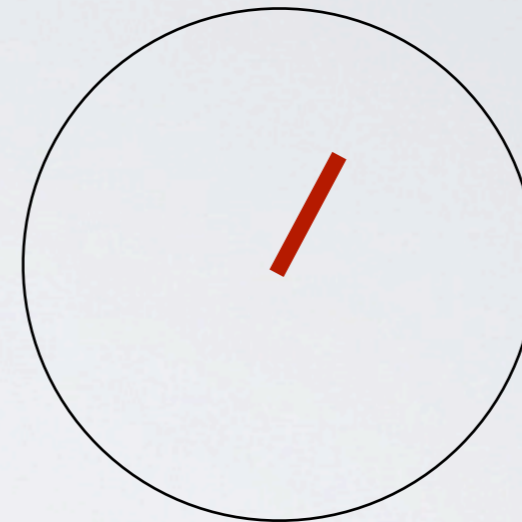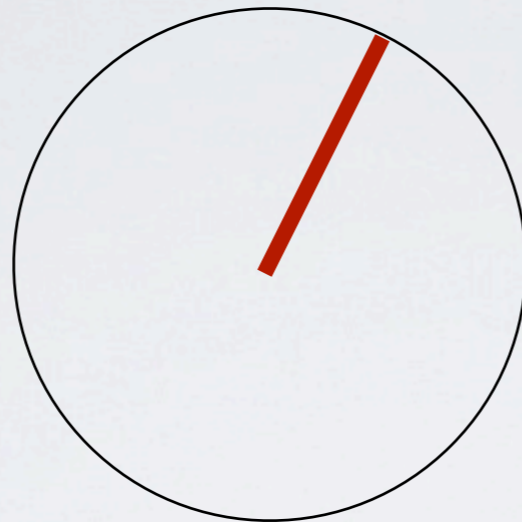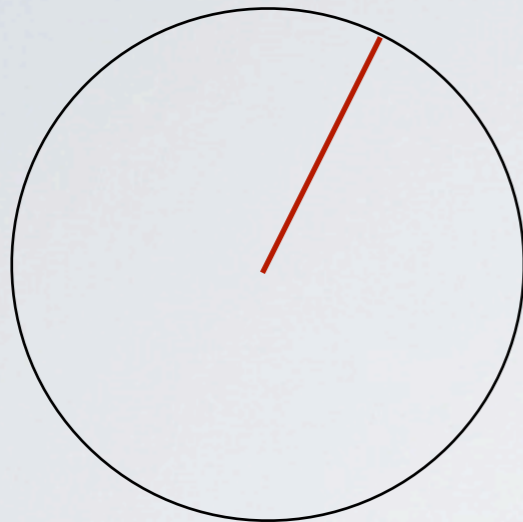
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SIGNATURES

- The particle doesn't have to decay to be interesting!

    - Can come from the properties of the long lived particle itself

    - Can come from the decay of the long lived particle

    - Can be a combination of both!

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LONG LIVED PARTICLE

- Charged

  - Standard CHAMPS/HSCP searches

- Colored

  - Long lived gluinos

- Neutral

  - Is MET really DM?

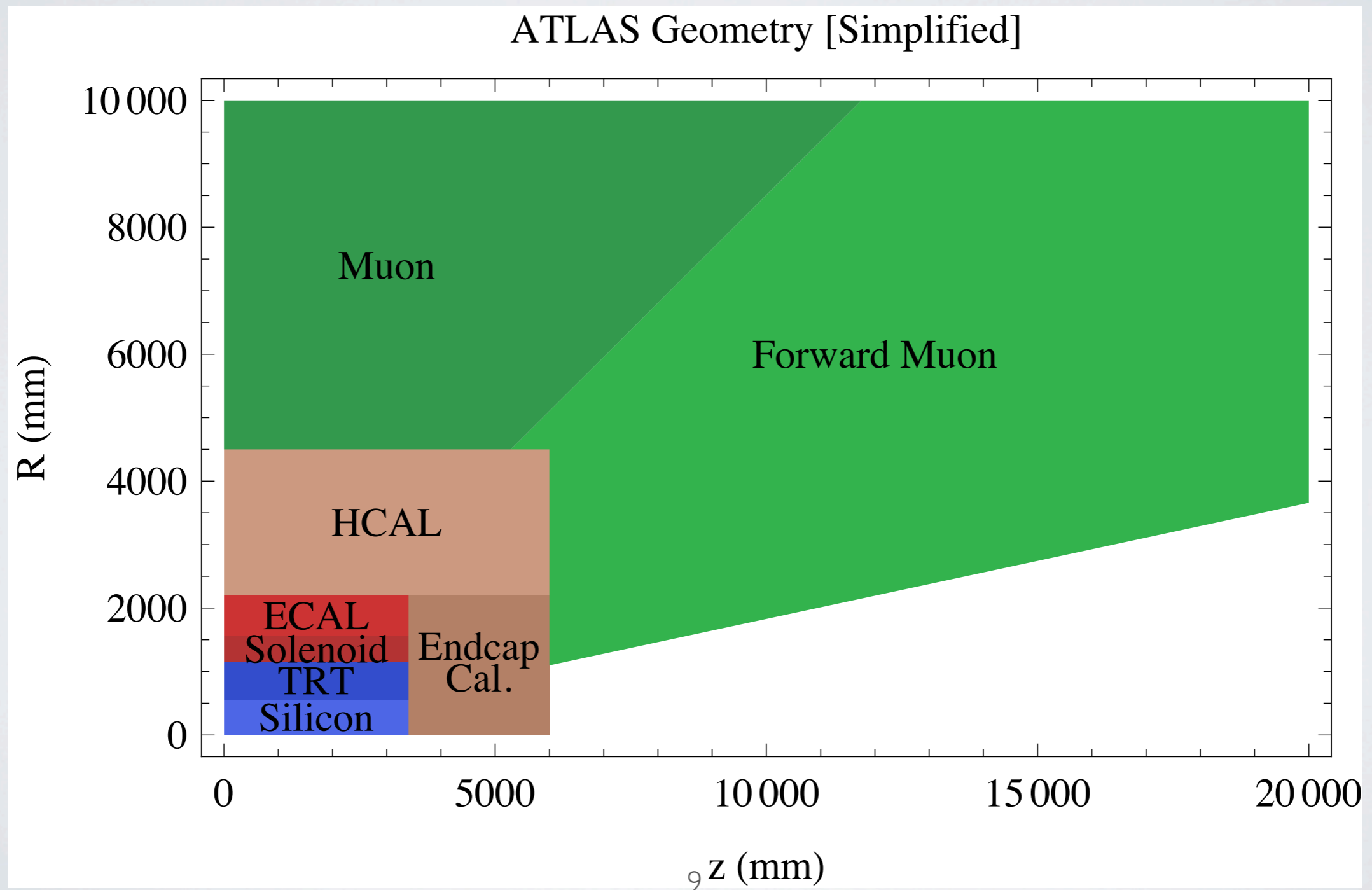Thursday, December 8, 11

NEW ODD TRACKS (NOTS)
Take your favorite "CHAMP" and think a little more

Schematic purposes only

Color corresponds
to dE/dx

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WHERE DOES IT ALL HAPPEN?

ATLAS Geometry [Simplified]

WHERE DOES IT DECAY?

Location of Decays in ATLAS
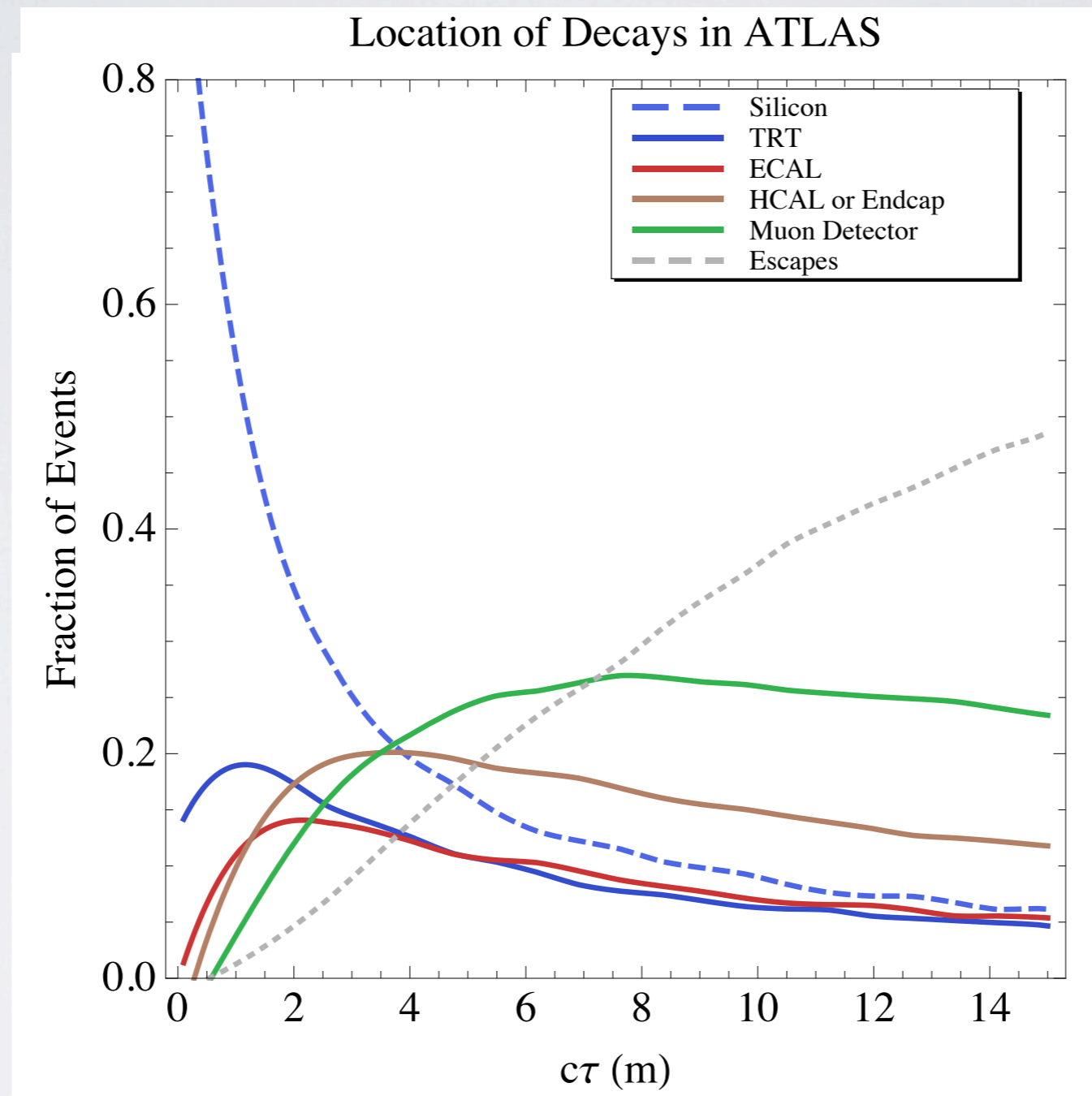
Example: 600 Gev gluino decay to 250 GeV NLSP

REASONS FOR LONG LIFETIMES

- Squeezed Phase Space

- Small Couplings

- Conserved/Approximately Conserved Quantum numbers

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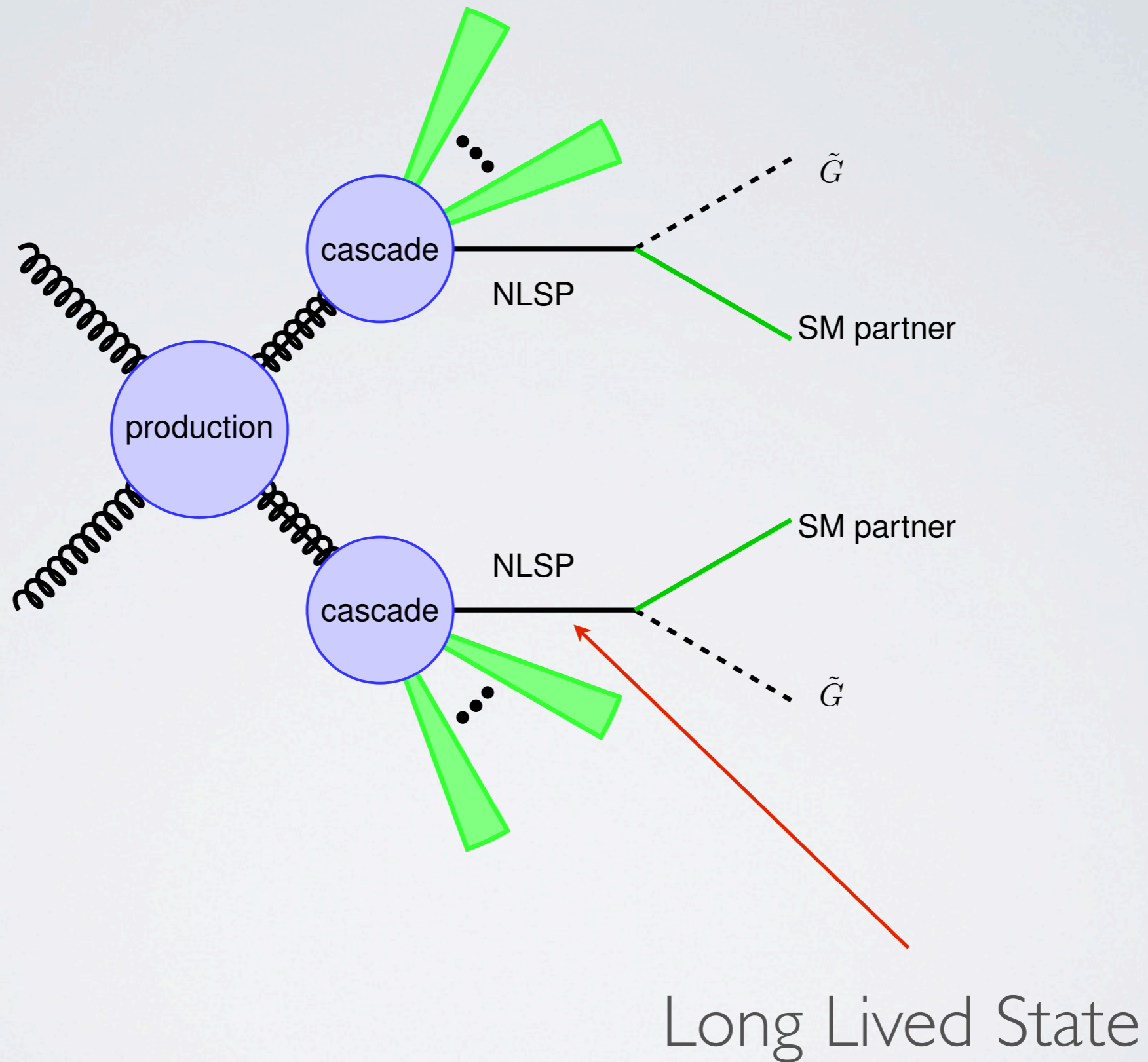
MODELS OF LOLIPS

- SUSY

  - Gauge Mediation

  - Anomaly Mediation

  - Split

  - RPV

- Hidden sectors with various portals

- Quirks

- ...

# HOW DO WE COVER THESE SYSTEMATICALLY?

- One example where this can be done systematically is gauge mediation

    - Any particle can be the NLSP, then the lifetime is simply set by the SUSY breaking scale, can get "most" of the LOLIP possibilities

- General question for later, how to cover the "rest" systematically

cascade

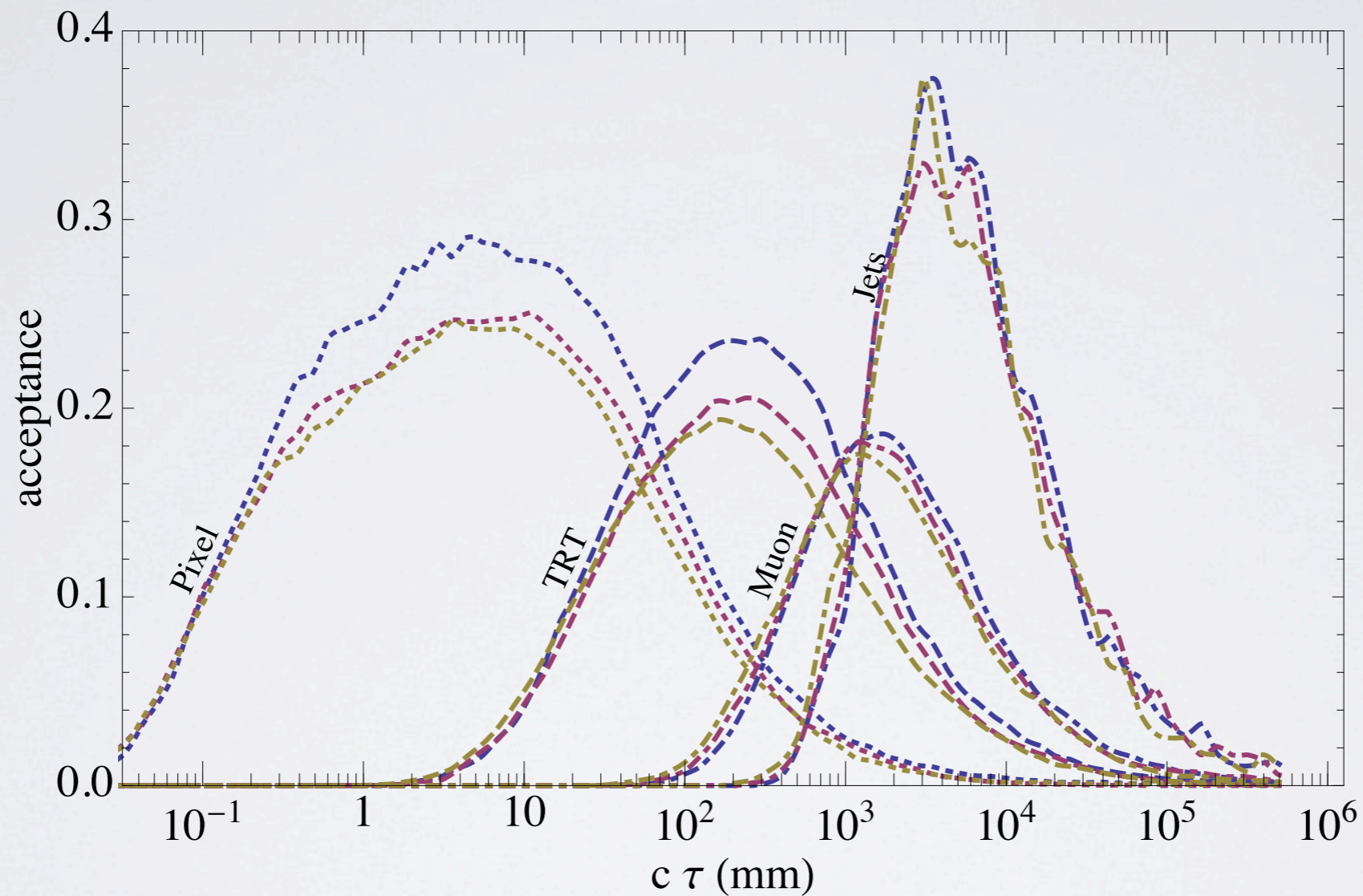production

NLSP

$\tilde{G}$

SM partner

SM partner

NLSP

cascade

$\tilde{G}$

Long Lived State

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$$\mathcal{A} = \frac{m_{\tilde{\chi}_1^0}^5}{16\pi F^2} \approx \left(\frac{m_{\tilde{\chi}_1^0}}{100 \text{ GeV}}\right)^5 \left(\frac{100 \text{ TeV}}{\sqrt{F}}\right)^4 \frac{1}{0.1 \text{ mm}}$$
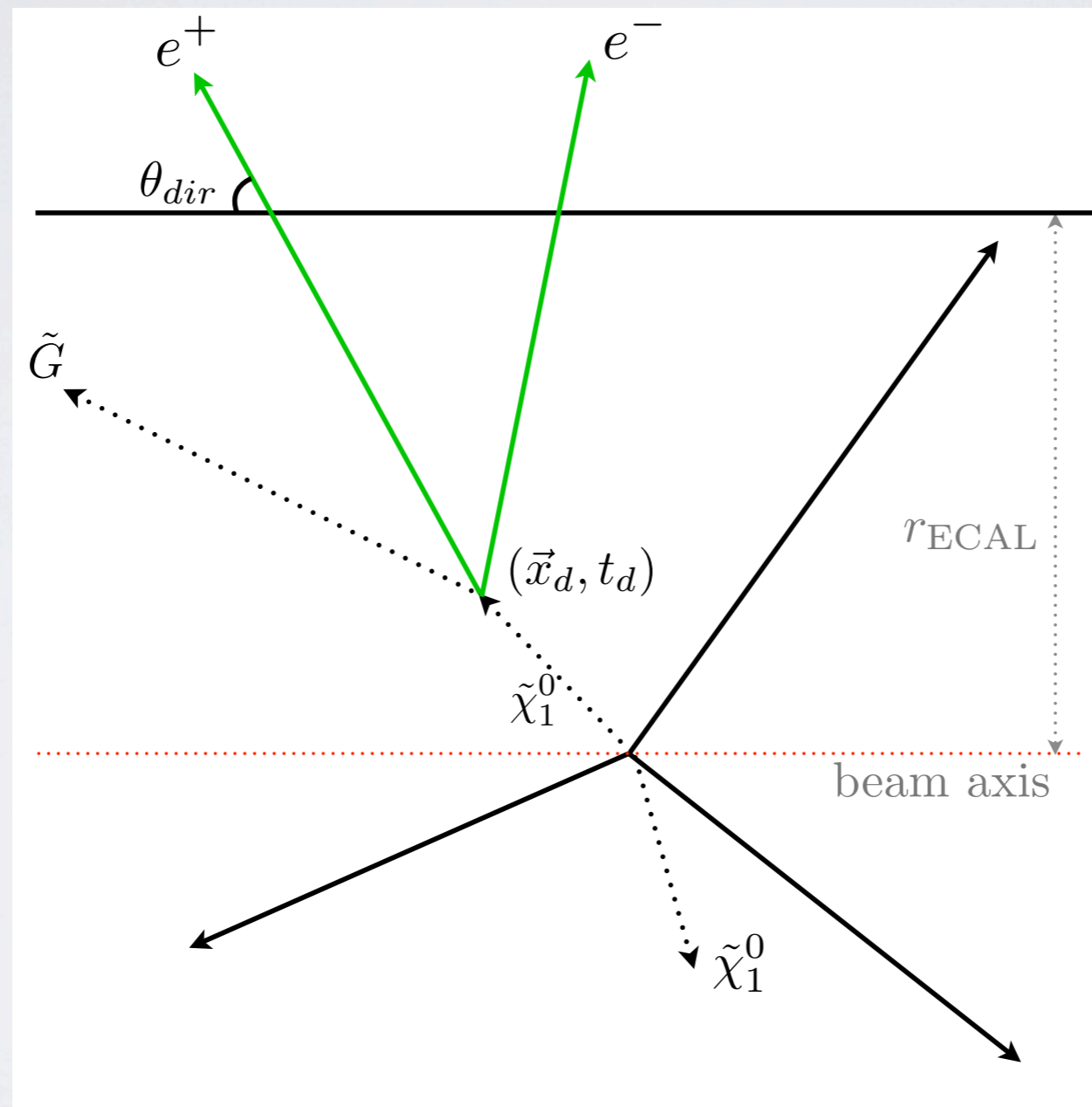
SIX ORDERS OF MAGNITUDE COVERAGE FOR NEUTRAL LOLIPS

Can look at Z->ee, Z->mumu, Z-jets

WHAT CAN YOU DO?

l in 1 fb^{-1} at 7 TeV

$c\tau=1000$ mm

$c\tau=100$ mm

$c\tau=10000$ mm

1000   1200   1400

(GeV)

σ x Br x ϵ (fb) at 7 TeV

$c\,\tau$ (mm)

M_{gluino} (GeV)

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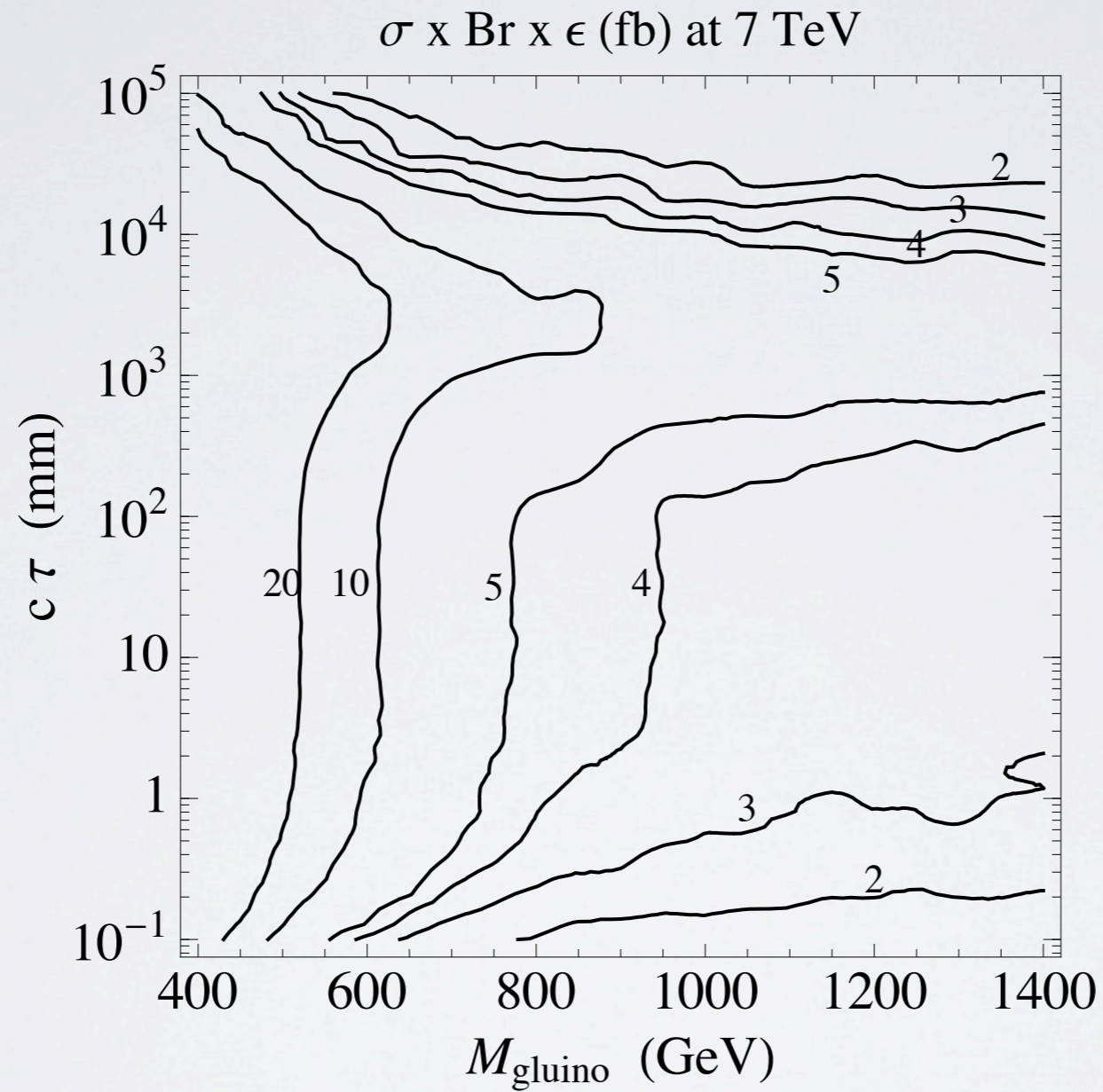
INHERENT PROBLEM... PROMPT SEARCHES AREN'T EVEN FULLY COVERED

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WHAT HAS THE LHC DONE SO FAR?

Analysis	Collaboration	Luminosity (fb^{-1})
Stopped HSCP	CMS	0.9
HSCP (dE/dx, TOF)	CMS	1.1
Displaced lepton pair	CMS	1.1-1.2
Displaced photons	CMS	2.1
Disappearing tracks	ATLAS	1
Displaced jets + high p_T muon	ATLAS	0.033

ROOM FOR IMPROVEMENT

• General NOTS: Weirder tracks

• Combining "signatures", dE/dx with short tracks?

• **Not** being too specific on the extra objects in searches, the long lived particle is the key...

• More modes for displaced decays

• Pushing all general signals to the extremes of the lifetime

PLAN FOR WRITEUP

Theory side problem: Validation and Interpretation

Experimental side problem: Detectors weren't designed for this...

Are there priorities or catch all channels?

?

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