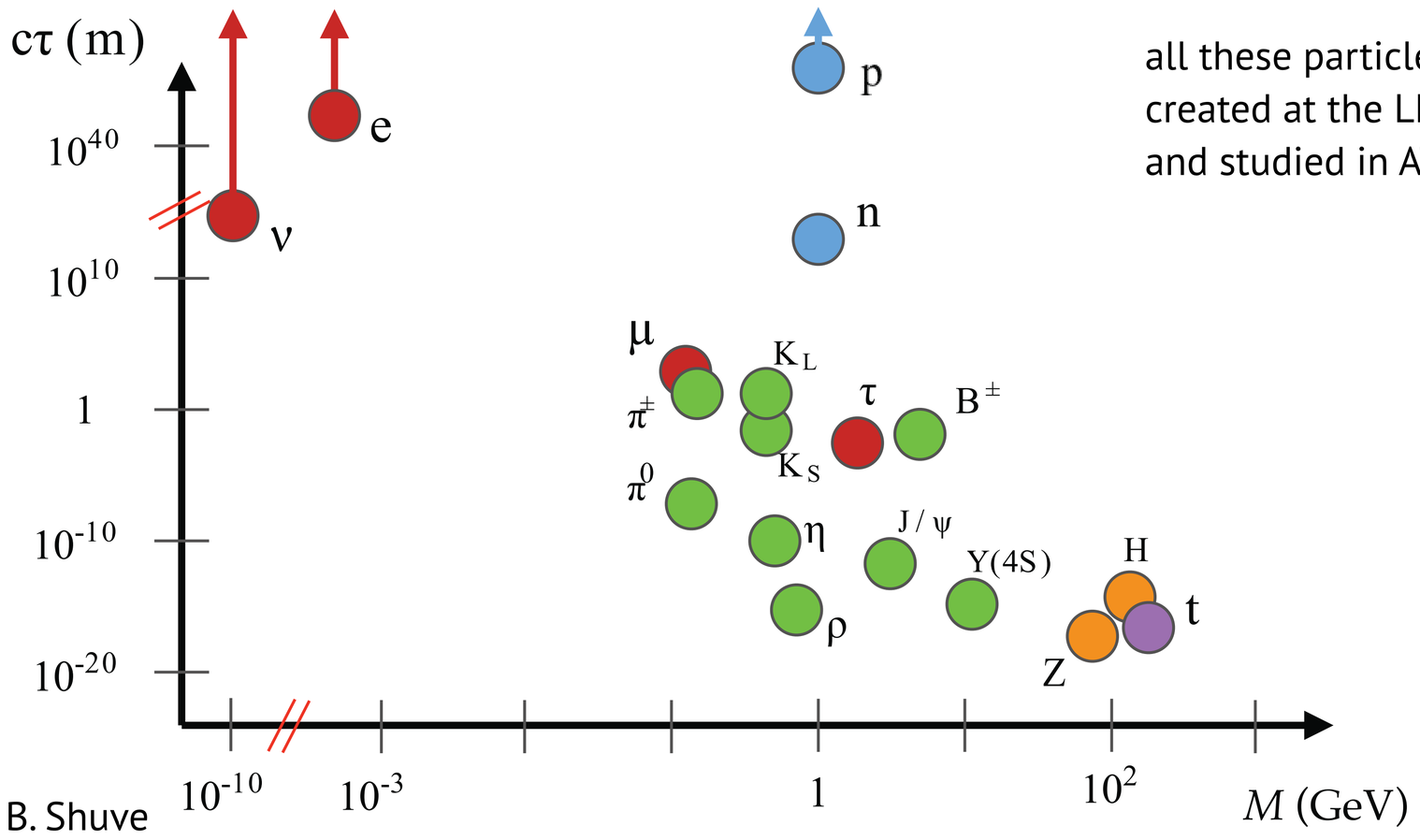
SEARCHES FOR SUSY WITH LONG-LIVED PARTICLES IN ATLAS

ICHEP 2020
July 29, 2020

Tova Holmes, on behalf of the ATLAS Collaboration

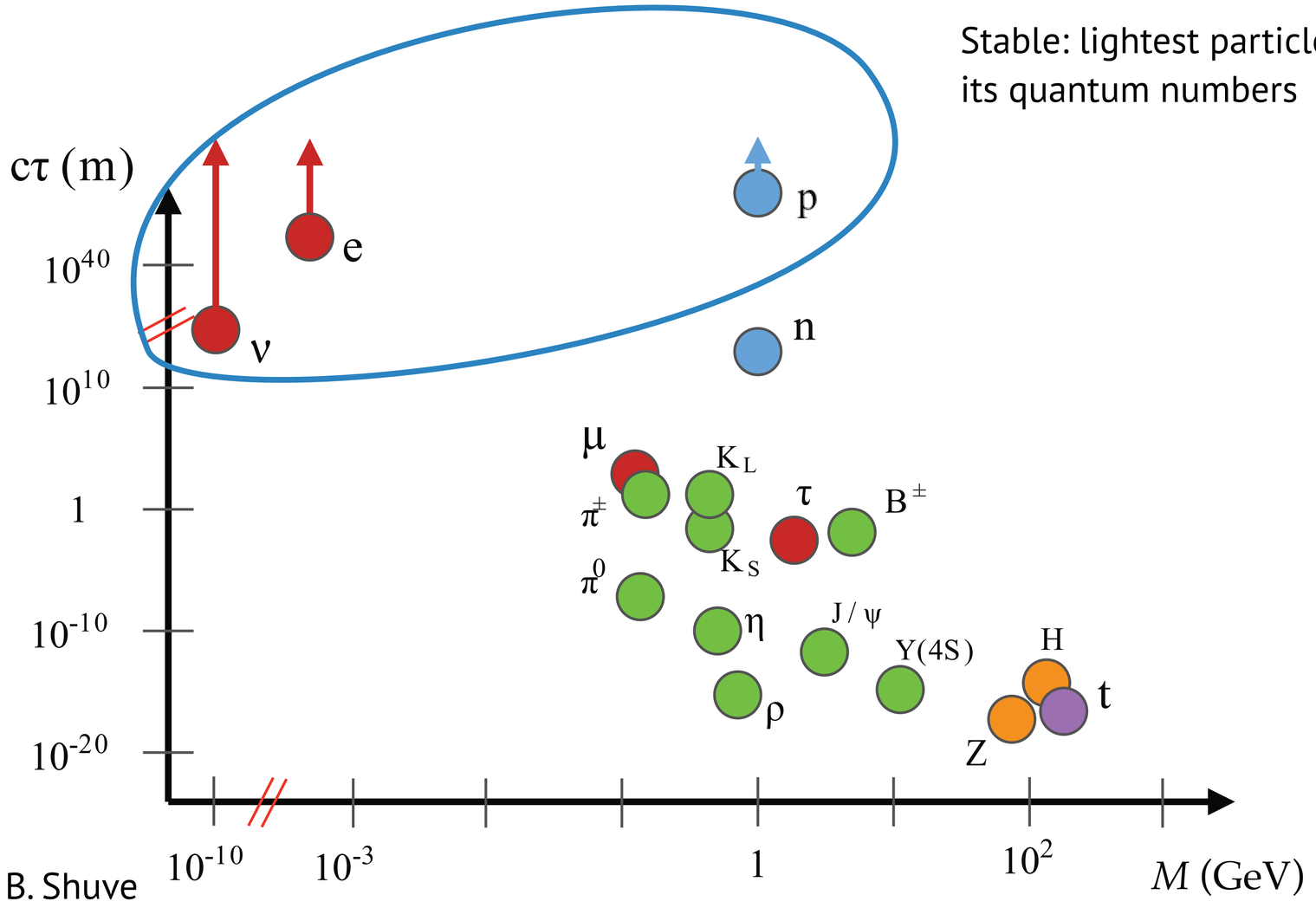
The standard model is full of “long-lived particles”



all these particles are created at the LHC and studied in ATLAS

The standard model is full of “long-lived particles”

Stable: lightest particle with its quantum numbers



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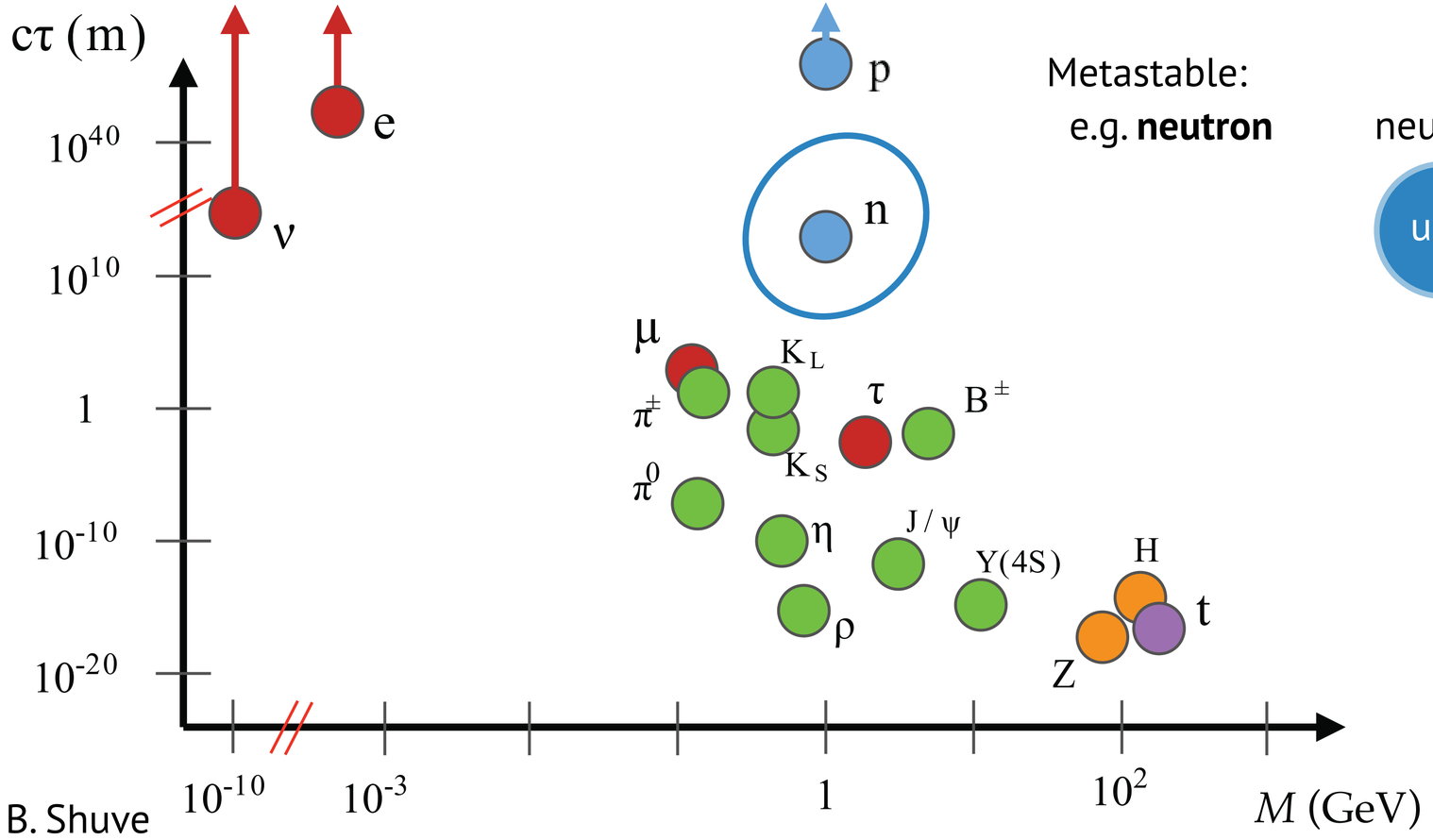
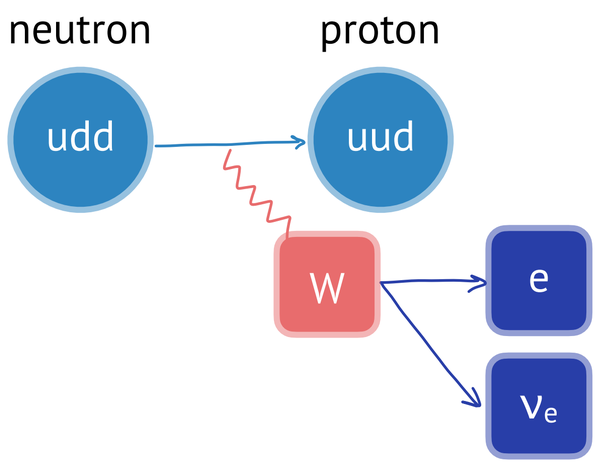
Stable: lightest particle with its quantum numbers

Metastable:
e.g. **neutron**

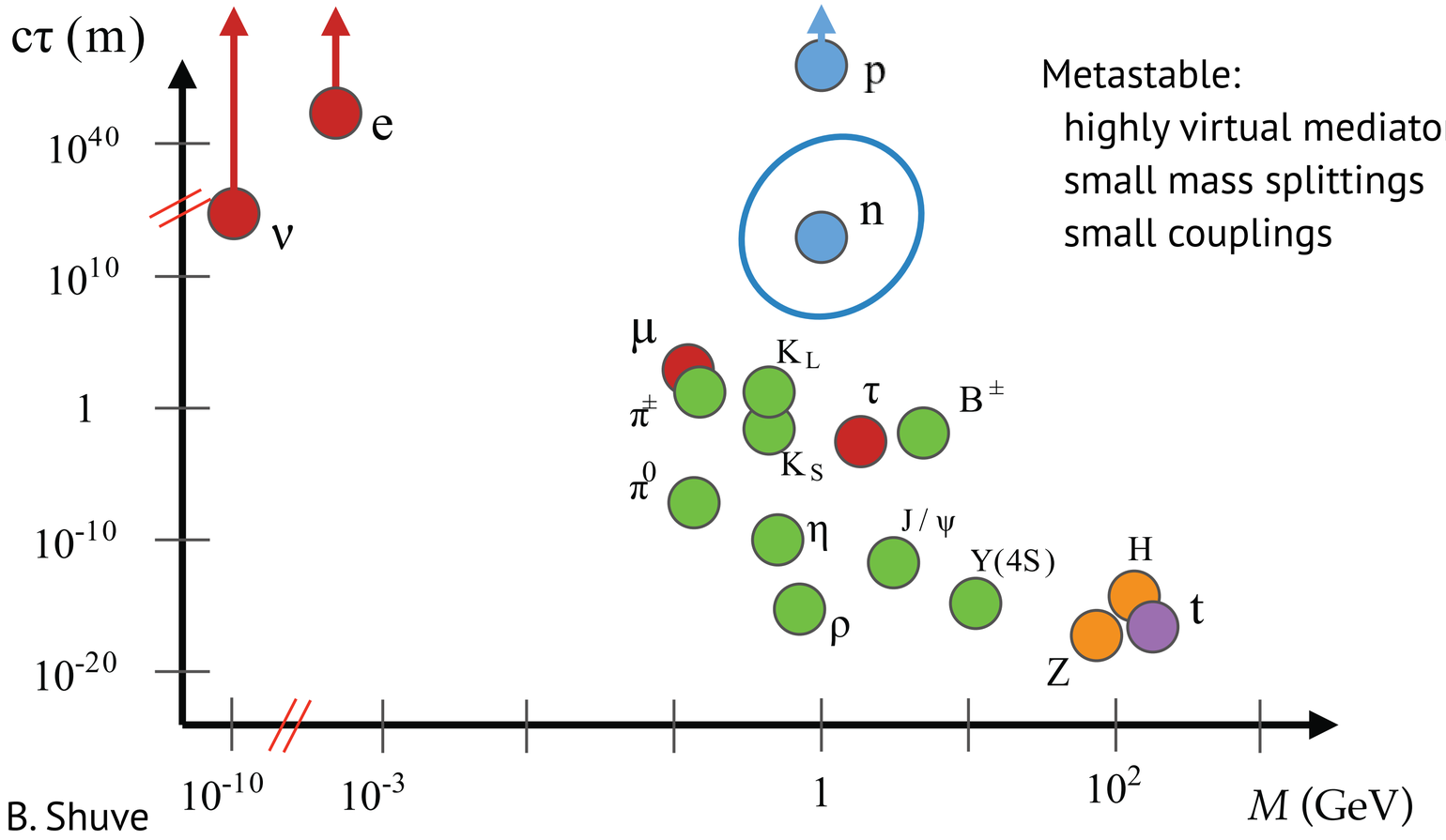




The standard model is full of “long-lived particles”

Stable: lightest particle with its quantum numbers

Metastable:
- highly virtual mediators
- small mass splittings
- small couplings



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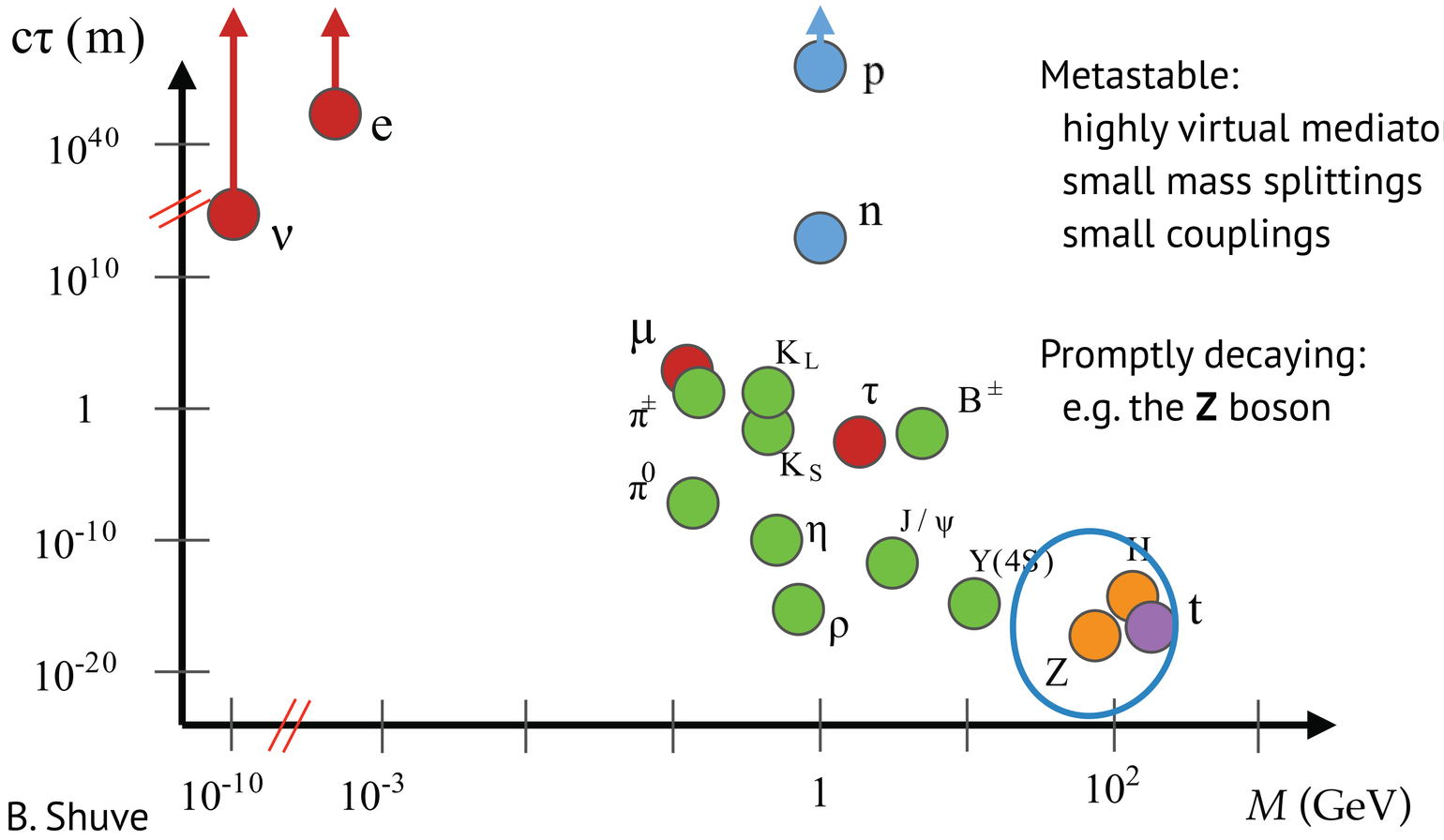

Stable: lightest particle with its quantum numbers

Metastable:
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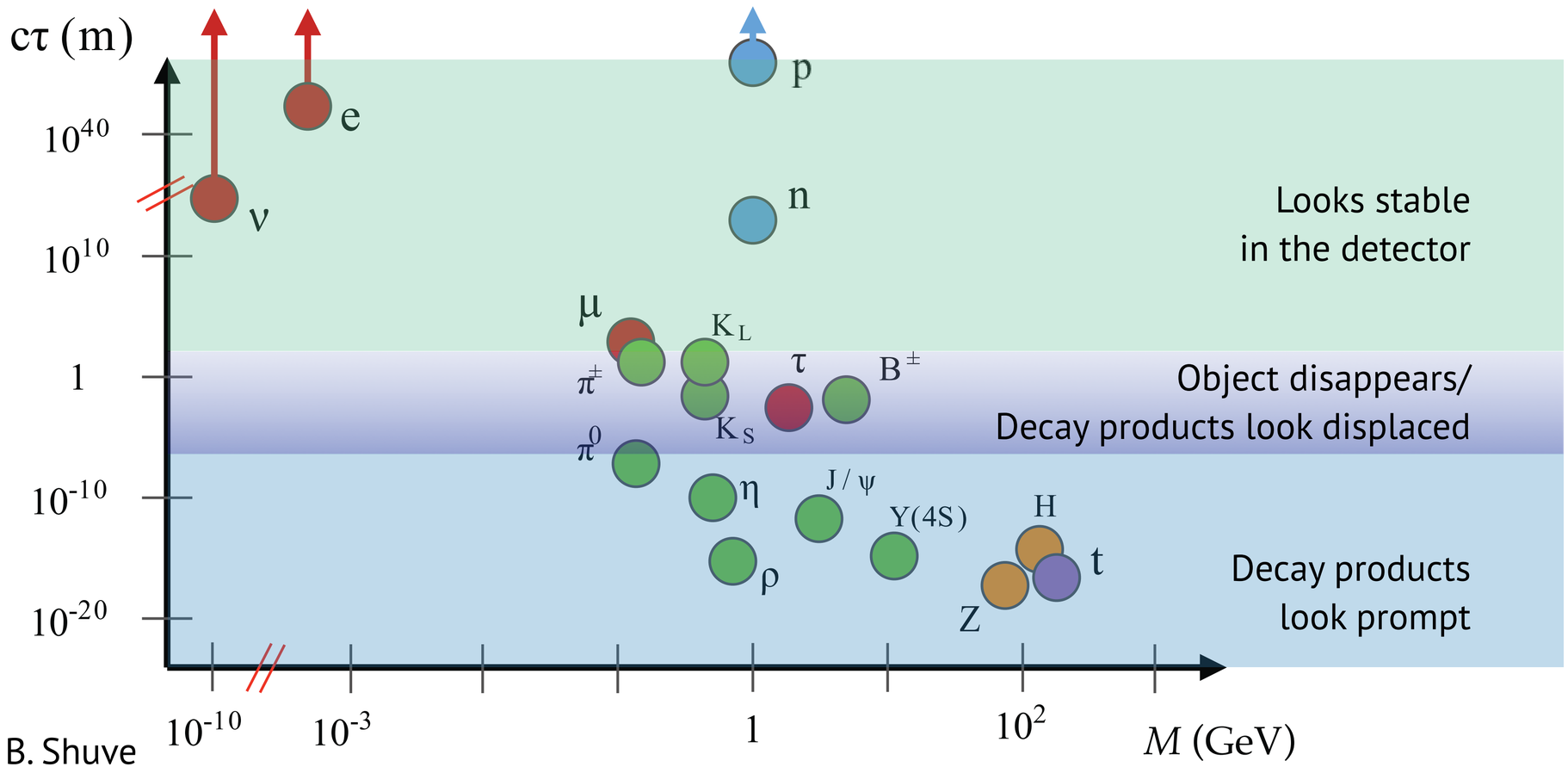
Promptly decaying:
- e.g. the **Z** boson

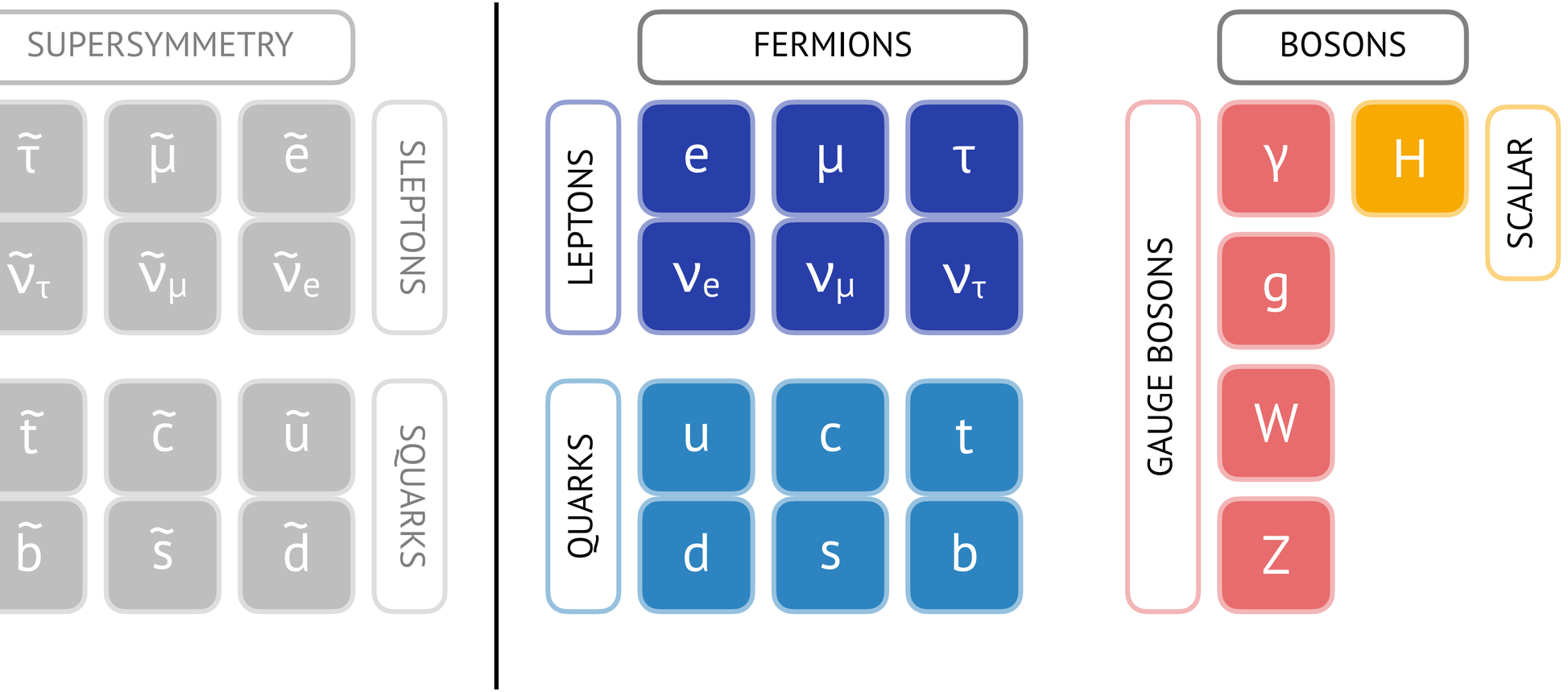
From the experimental point of view...



No reason to think there are only Standard Model long-lived particles…

Beyond-the-Standard-Model particles
can be long-lived for the same reasons
(small mass splittings, small couplings, virtual mediators)

Happens in all kinds of theories of new physics, but I'll focus on one: **SUPERSYMMETRY**



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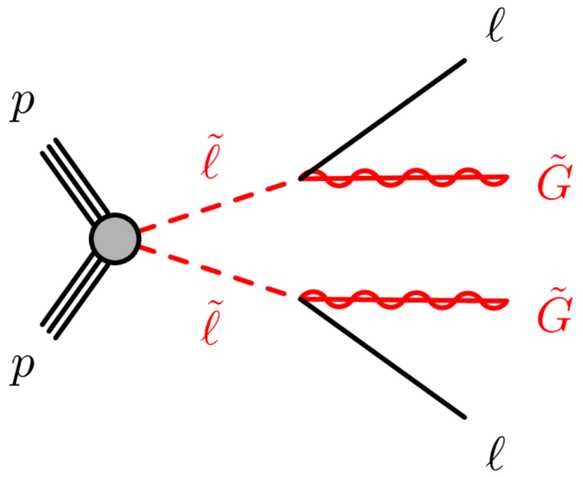
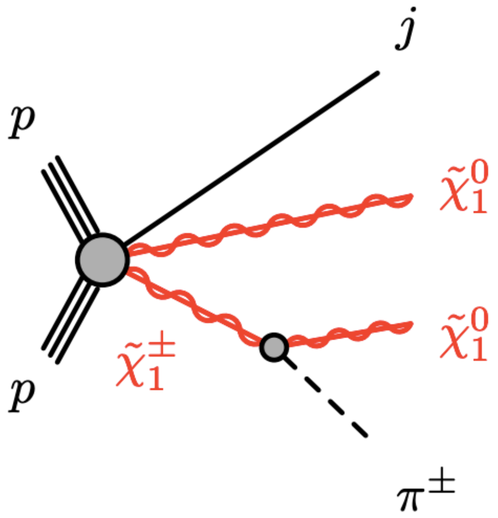
Tiny Couplings



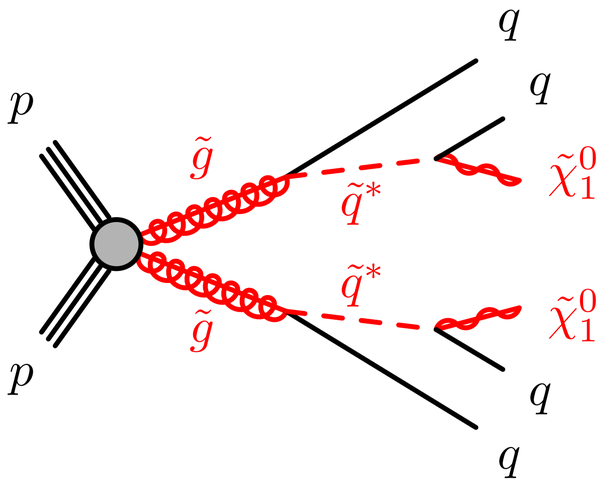
Gauge Mediated Symmetry Breaking

Small Mass Splittings



Anomaly Mediated Symmetry Breaking

Virtual Mediators



Split Supersymmetry

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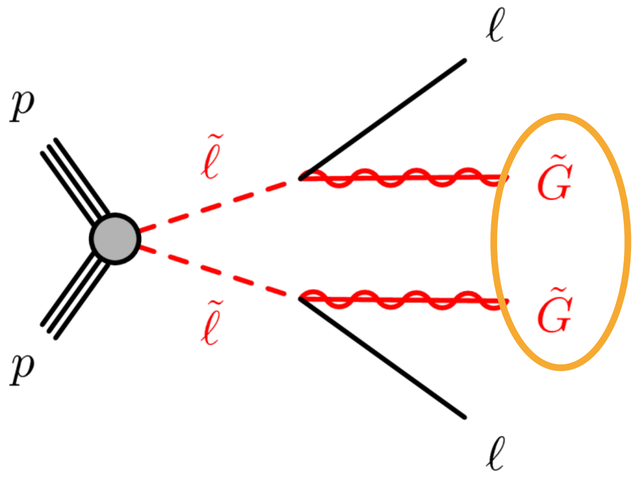

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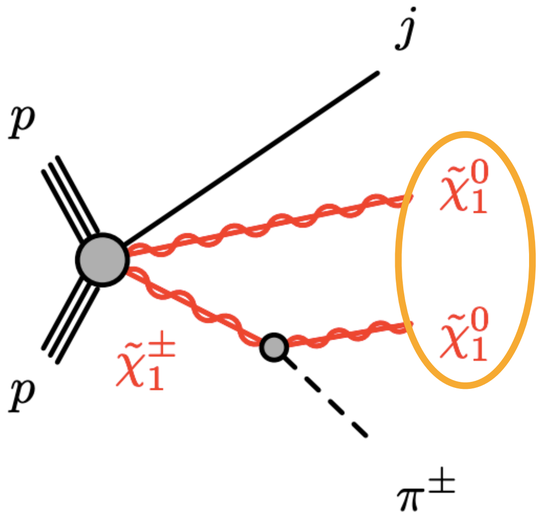

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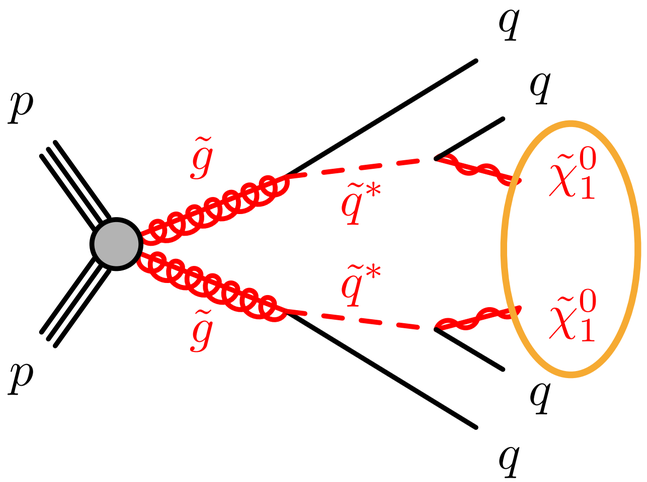

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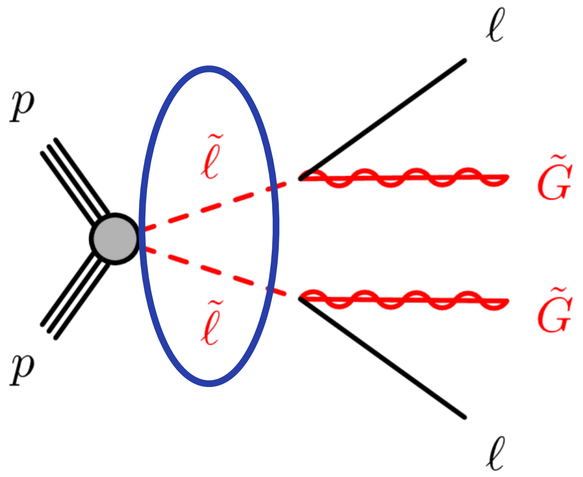

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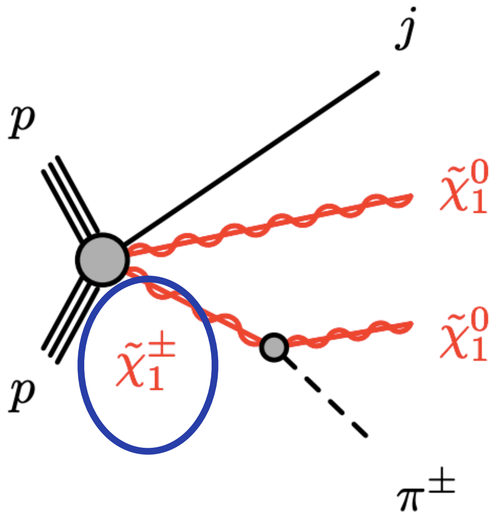

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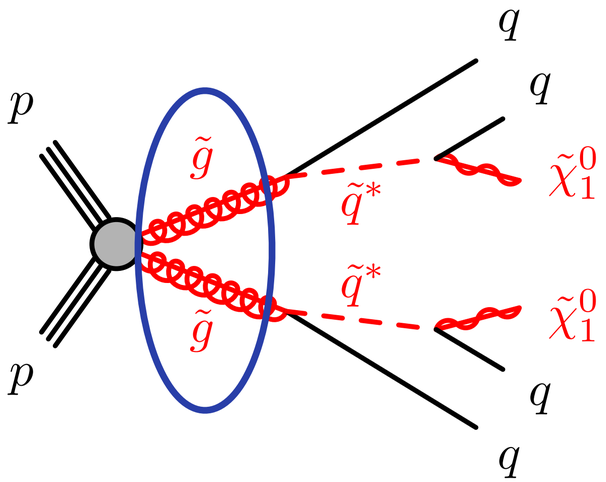


Split Supersymmetry

Happens in all kinds of theories of new physics, but I'll focus on one: **SUPERSYMMETRY**

Why we love SUSY

Gives a solution to the **hierarchy** problem

Gives a **dark matter** candidate

Is a particularly **elegant** mathematical concept

Gives rise to many different particles with complex and ~unpredictable mass spectra (keeps us employed for decades)

Why we don't love SUSY

Happens in all kinds of theories of new physics, but I'll focus on one: **SUPERSYMMETRY**

Why we love SUSY

Why we don't love SUSY

We thought it would be easier to find

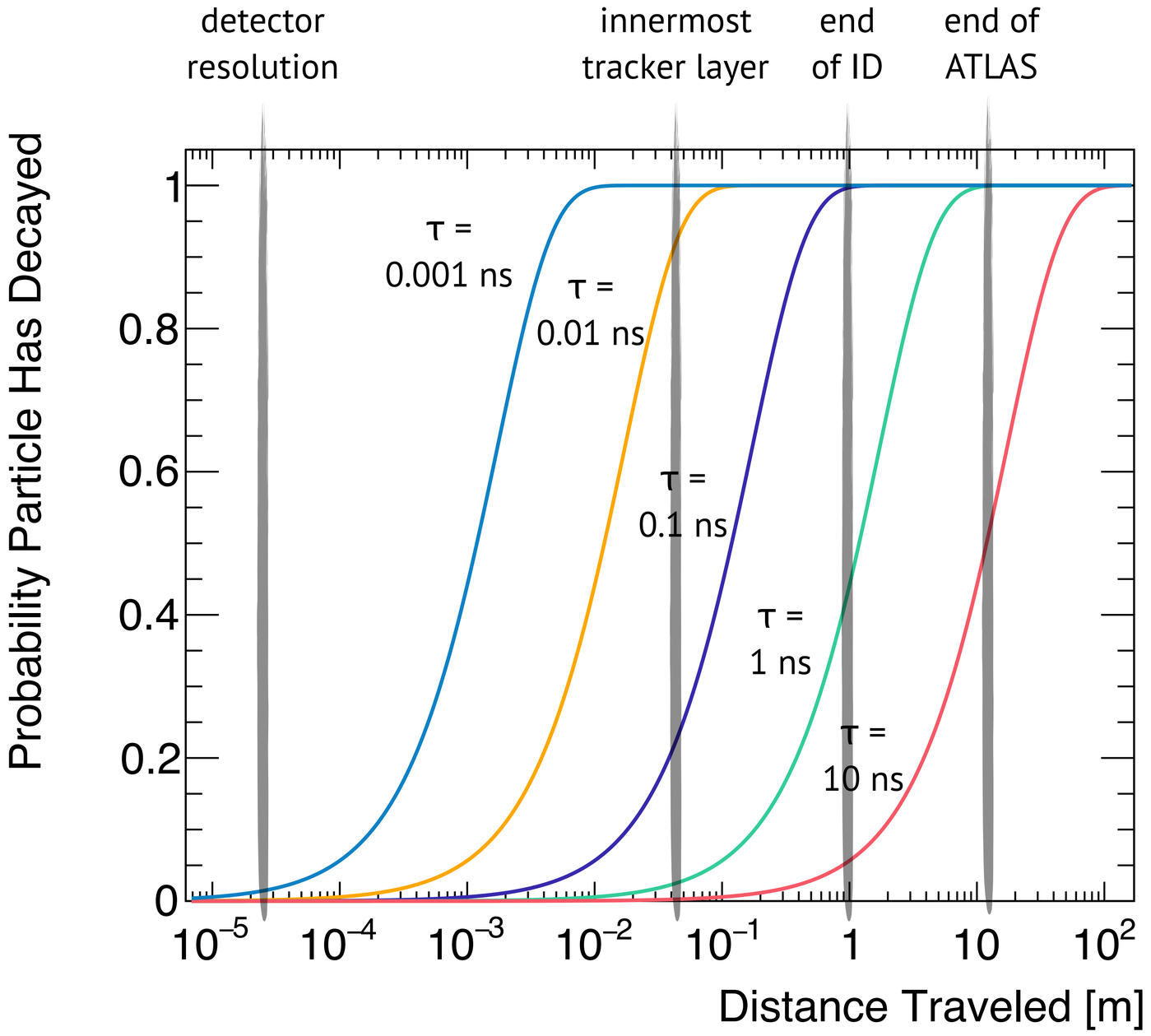
What makes lifetime hard?

Varying lifetime creates completely different **signatures** in our detector

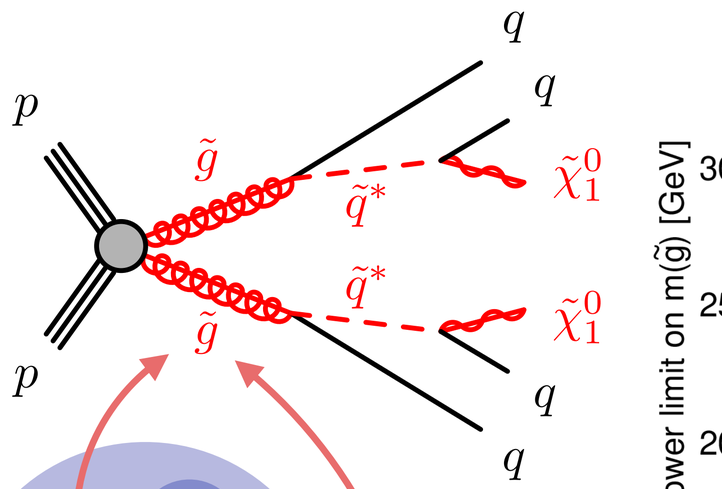
Many of those variations include signatures we **didn't design ATLAS** to reconstruct

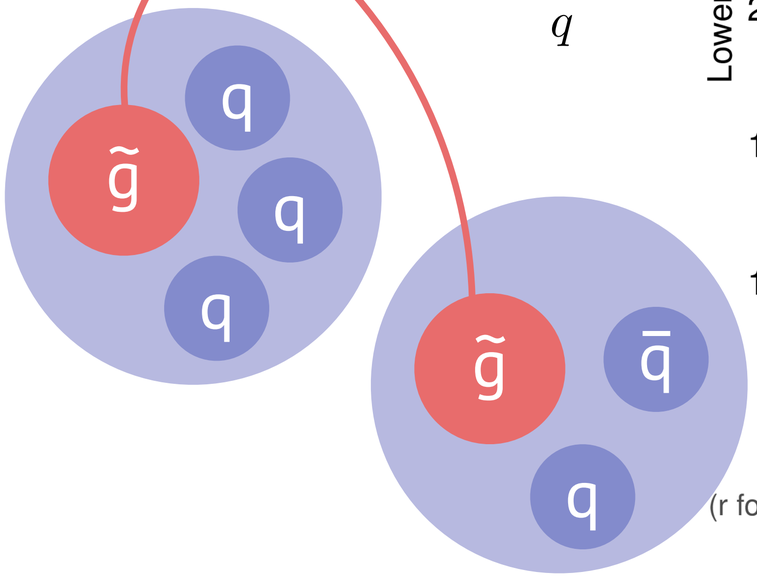
Must have **dedicated** searches for each signature — adds a **new dimension** to the types of searches we need to cover SUSY scenarios!

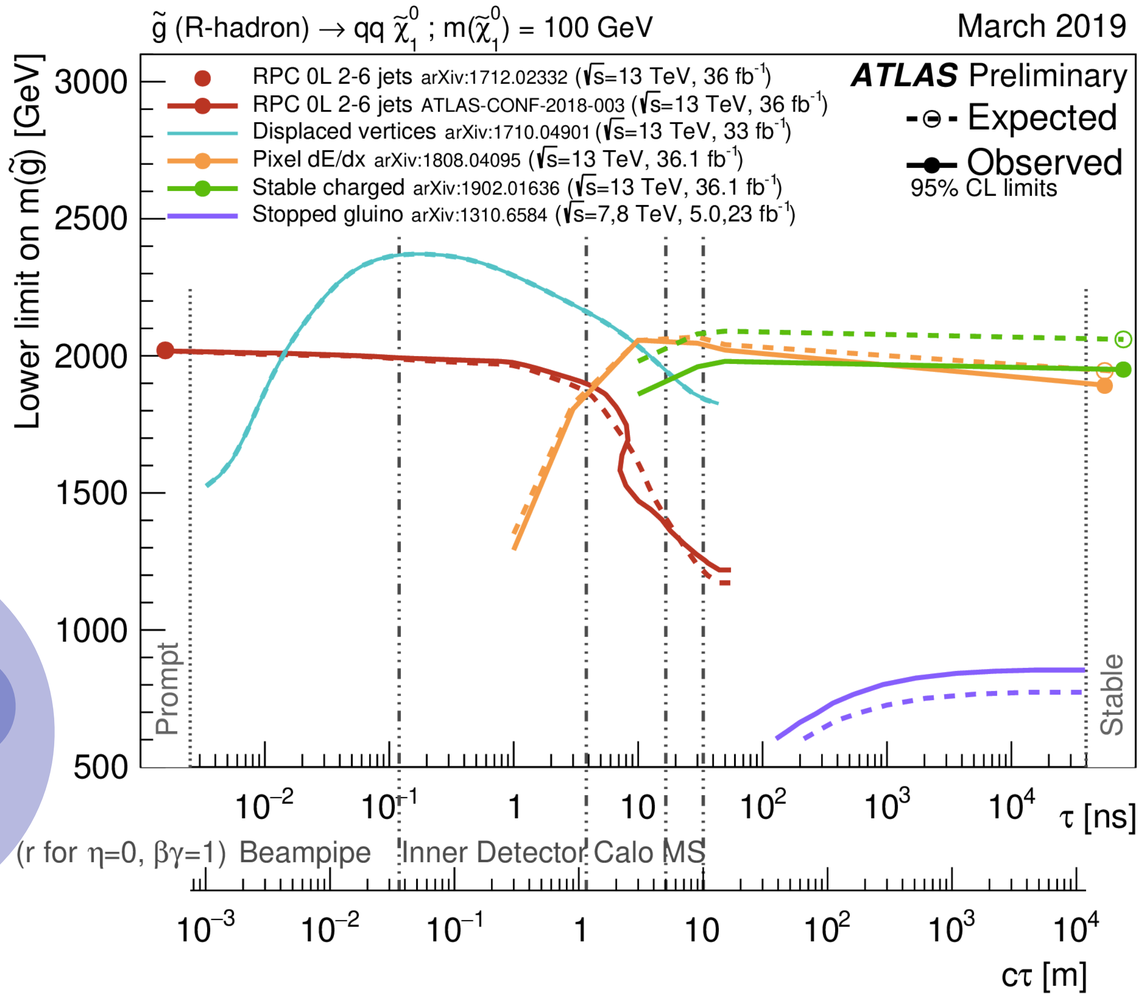
200 GeV particle
energy: 500 GeV



How do we cover the lifetime space?







To cover the full space:

Prompt jet search

Displaced vertex serach

Highly ionizing track search

Adding a lifetime dimension adds a new dimension of searches that need to be done!

And not all models have been as thoroughly covered

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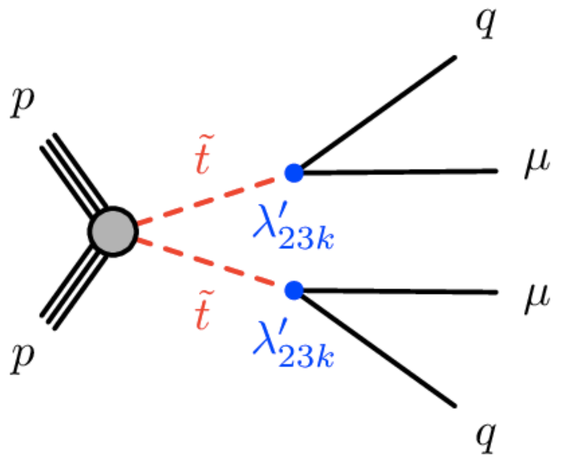
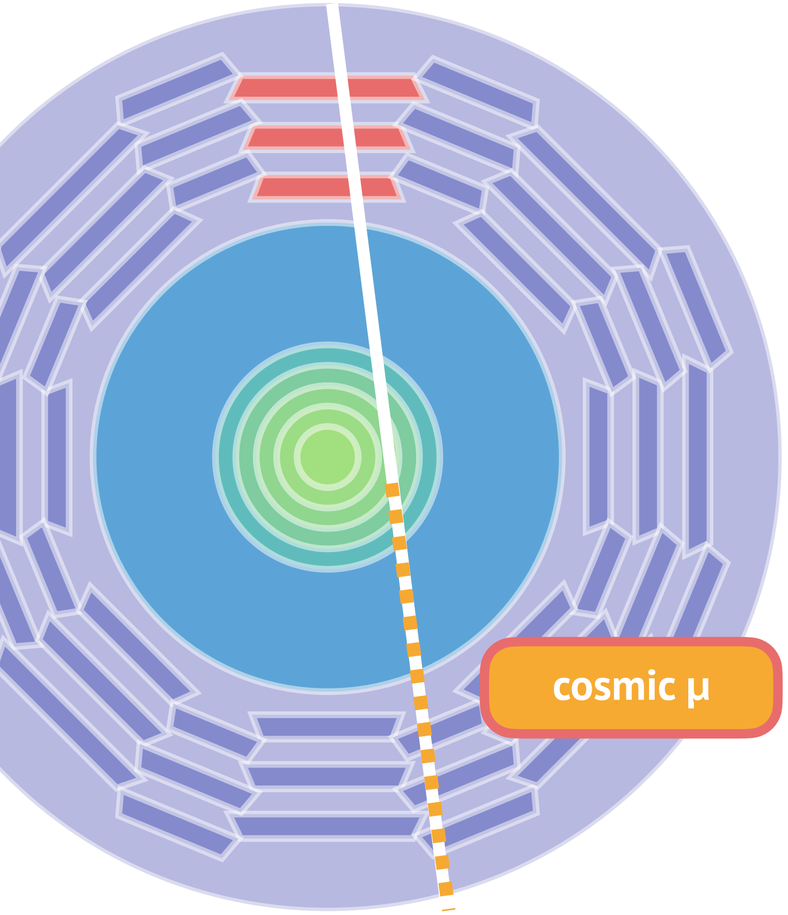
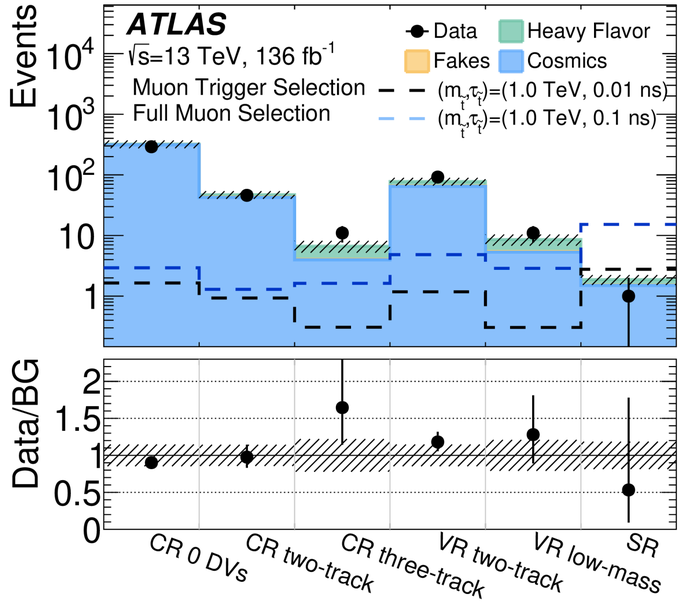
Now repeat for different objects…

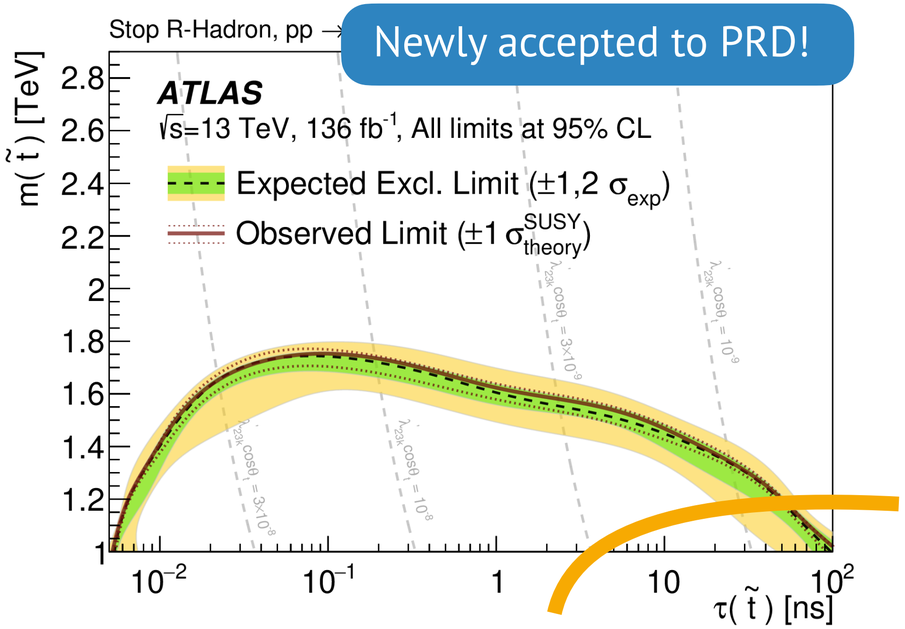
Take a very similar model — still produces an R-hadron, but has muons and fewer jets
Large lifetime can be covered similarly: **highly ionizing tracks**
Smaller lifetimes need new strategy : **displaced muons** (+ displaced vertices)





Now need to handle a new background: **cosmic rays**
Developed a highly efficient tag to bring down backgrounds

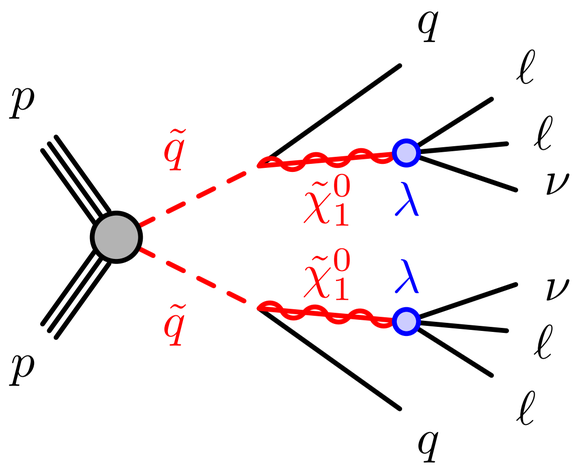




Newly accepted to PRD!

SUSY-2018-33

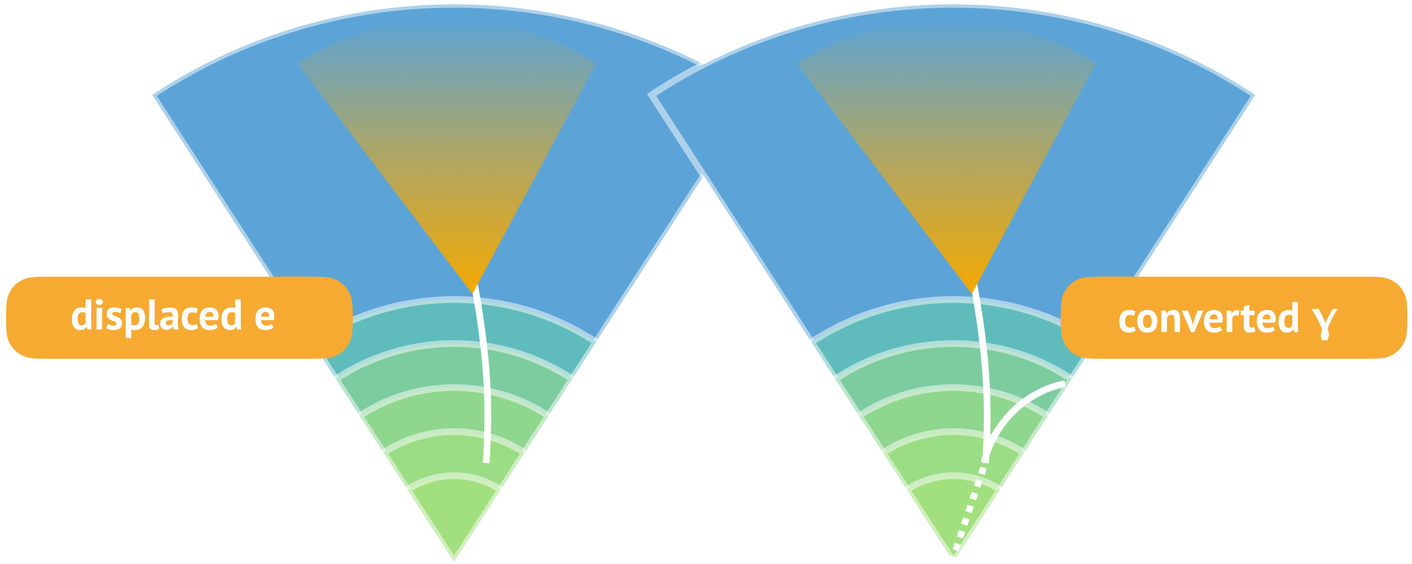
Now repeat for different objects...

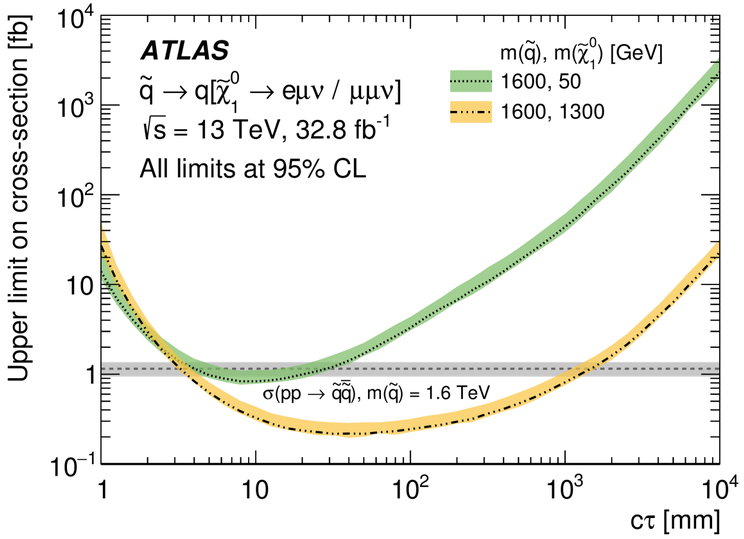


Adding **electrons** to a signature further complicates the search

μ: **clean** signatures, little bremming, few fakes
e: lots of ID and calo activity, brems and conversions **create displaced electrons!**

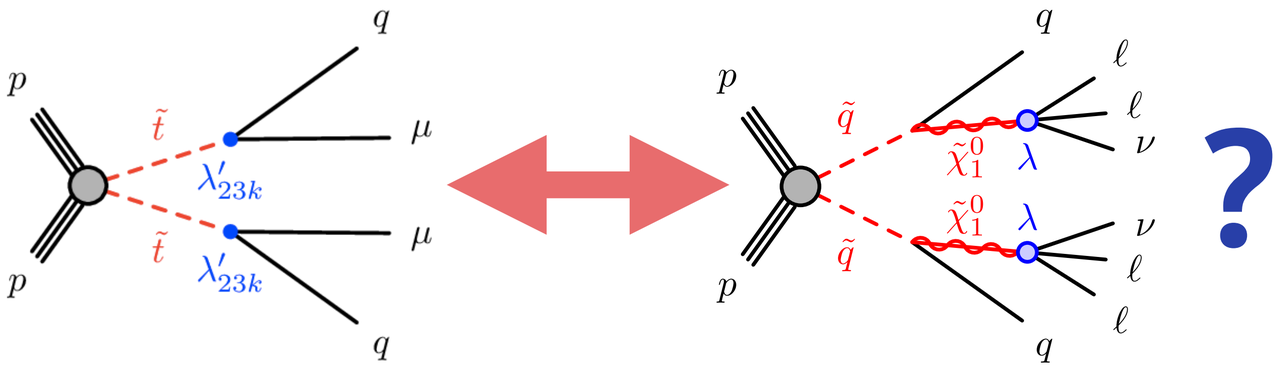
Used a likelihood-based identifier for electrons that didn't depend on d_0, pixel hits, or other displacement-dependent quality parameters

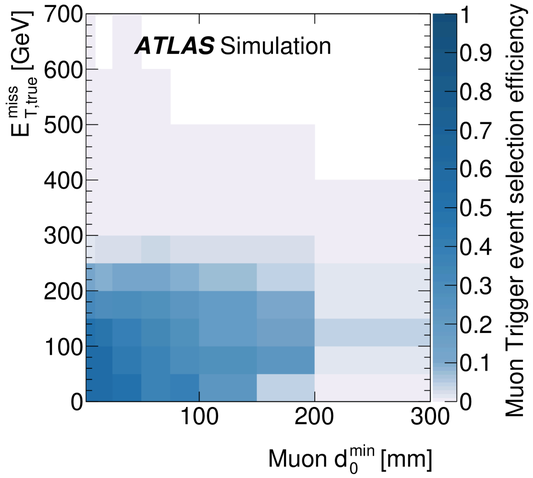


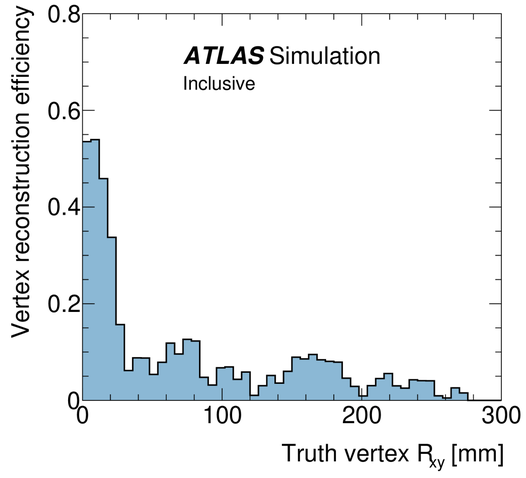


SUSY-2017-04

Not just lots of signatures…





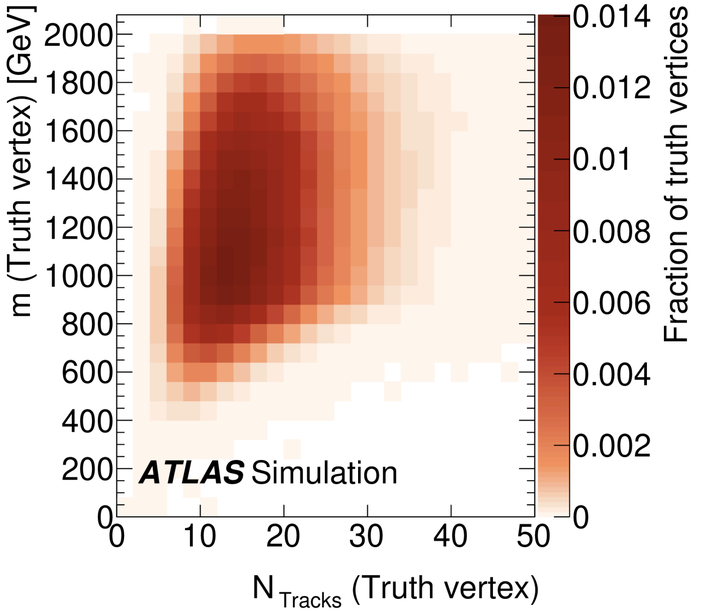


Signatures tend to be generic— can apply to **MANY** models
But not possible to interpret in all of them
LLP grids often very substantial due to extra lifetime dimension

But hard to re-interpret: strong efficiency dependences on many variables

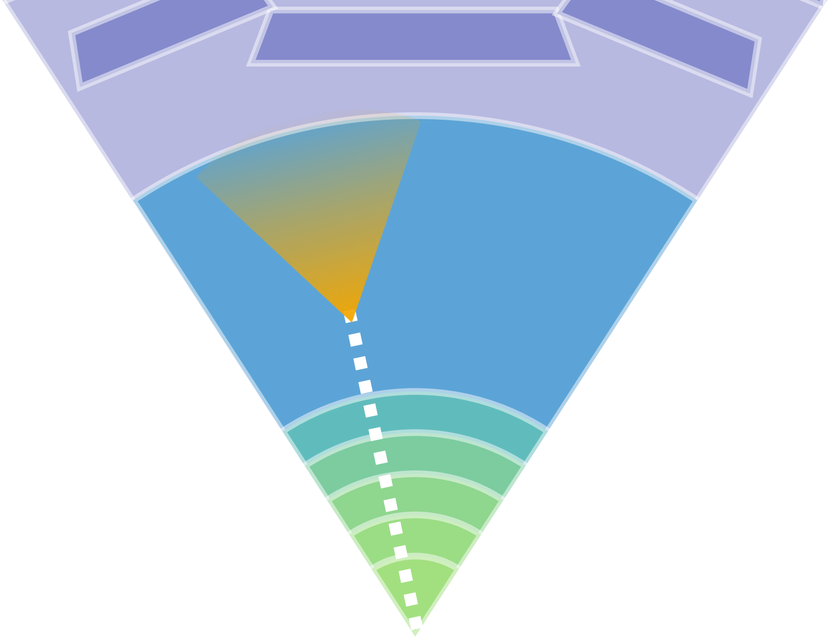
Provide many multi-dimensional **efficiencies**
and **kinematic distributions** for models used

Strategy enthusiastically embraced by theorists!



SUSY-2018-33

Can we do it better in-house?

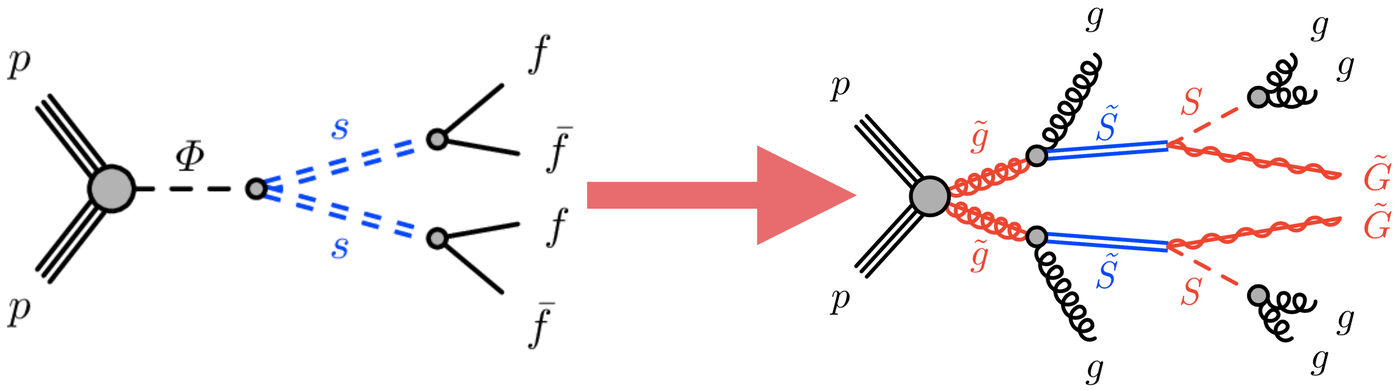


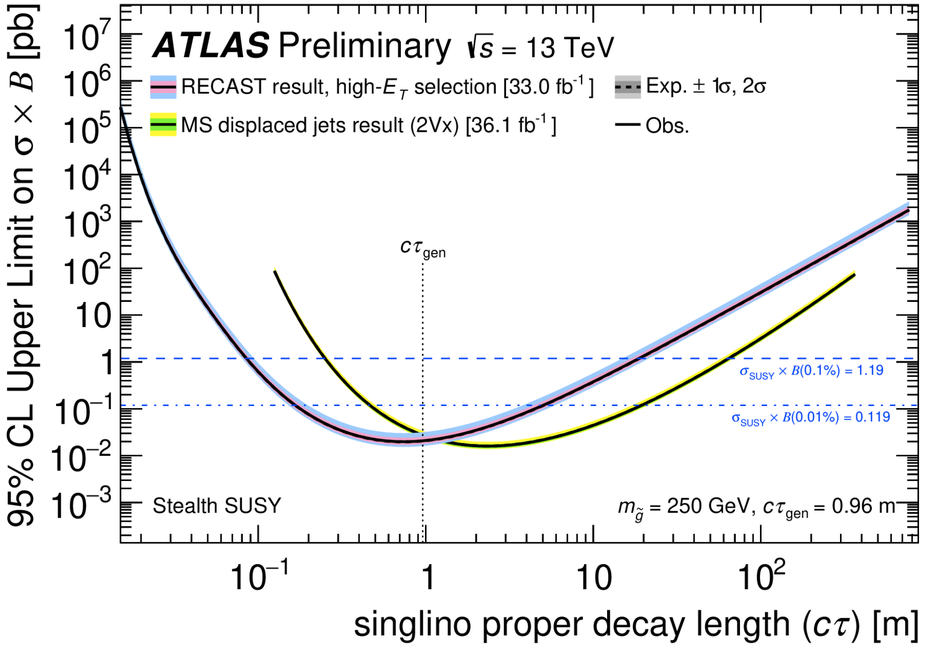
Even better, have recently been able to use RECAST to re-interpret an LLP result with a new SUSY model

RECAST lets us preserve
background estimates, signal sample processing, cutflow
→ if a new model is thought of later, can simply run over and produce new limits

Displaced Jets Search

Identifies unusual activity in the calorimeter
Complex BDT based identification
— very hard to parametrize!





New limits placed on a stealth SUSY model!

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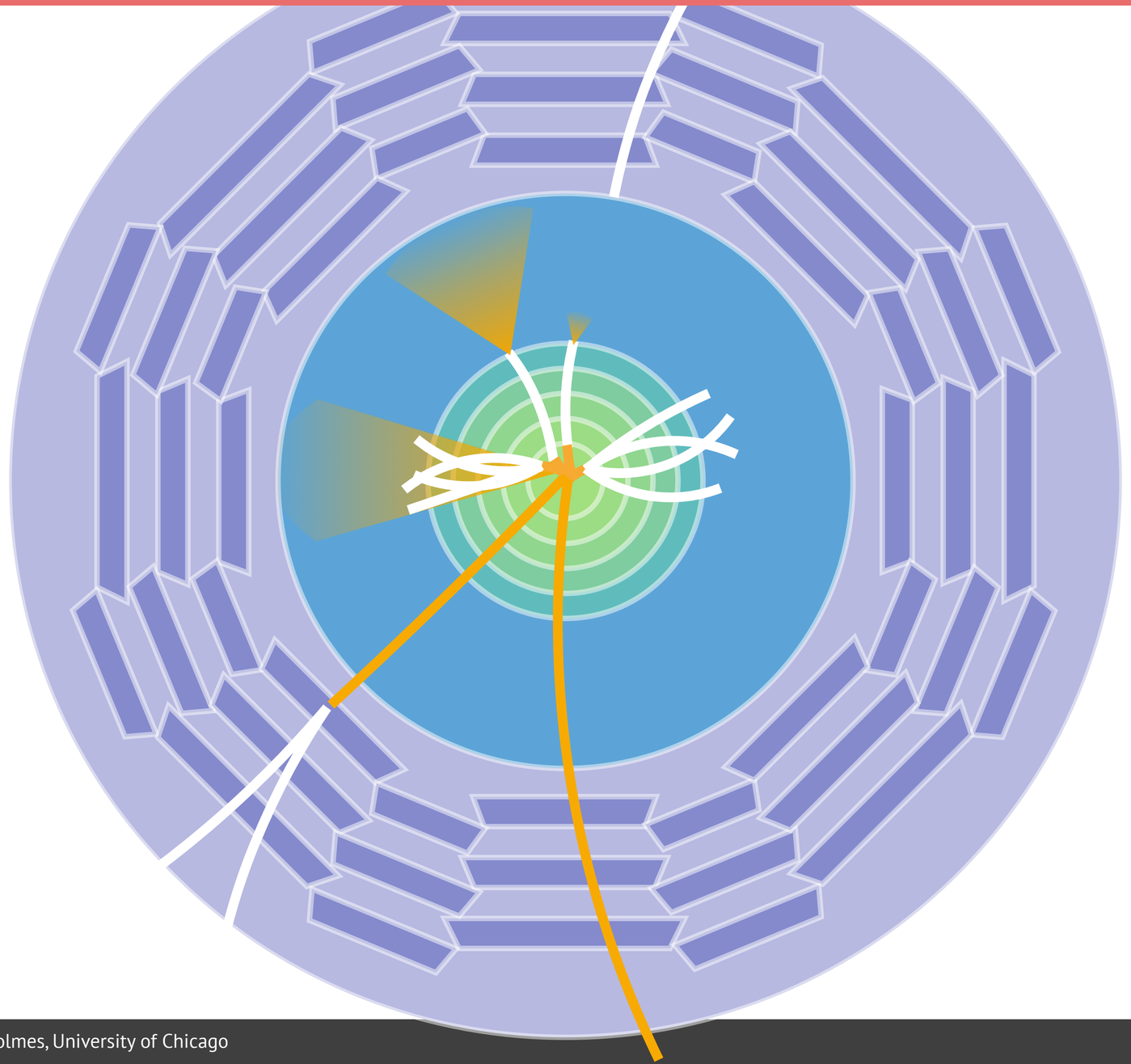
Conclusions



Long-lifetimes are a **common feature** of SUSY models
Means more **unique** searches are required
Exotic object based searches are **broadly applicable**
But very challenging to **re-interpret**

Lots of recent work done with **parameterization** and **RECAST** to make this possible

Of course, reinterpretation materials can't do all the work
Can't cover new signatures!

Many more novel ATLAS LLP searches on the horizon
Stay tuned!

THANK YOU!