LLP DETECTORS AT THE LHC

Searching for Long-Lived Particles at the LHC and Beyond
Eighth Workshop of the LHC LLP Community

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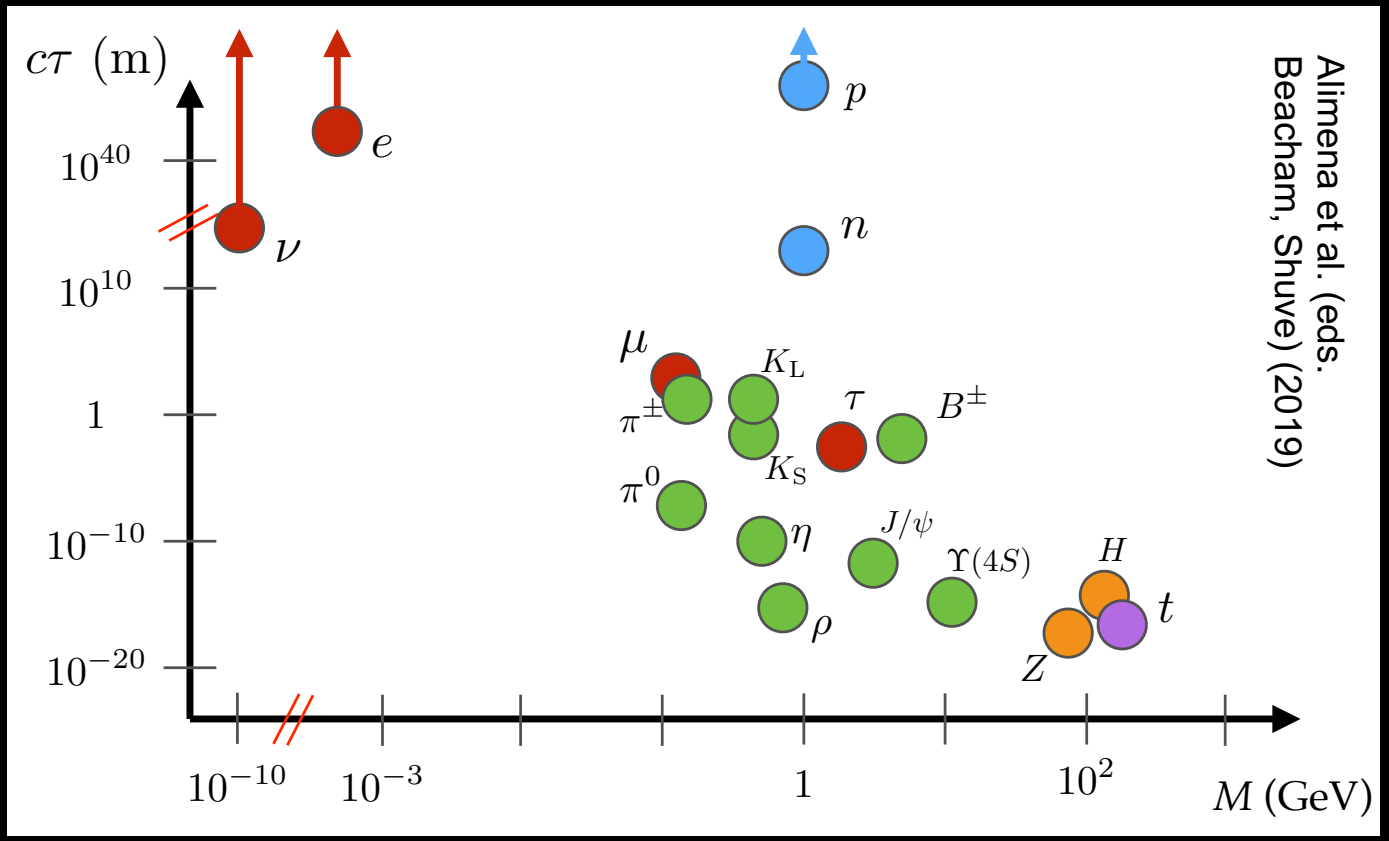
INTRODUCTION

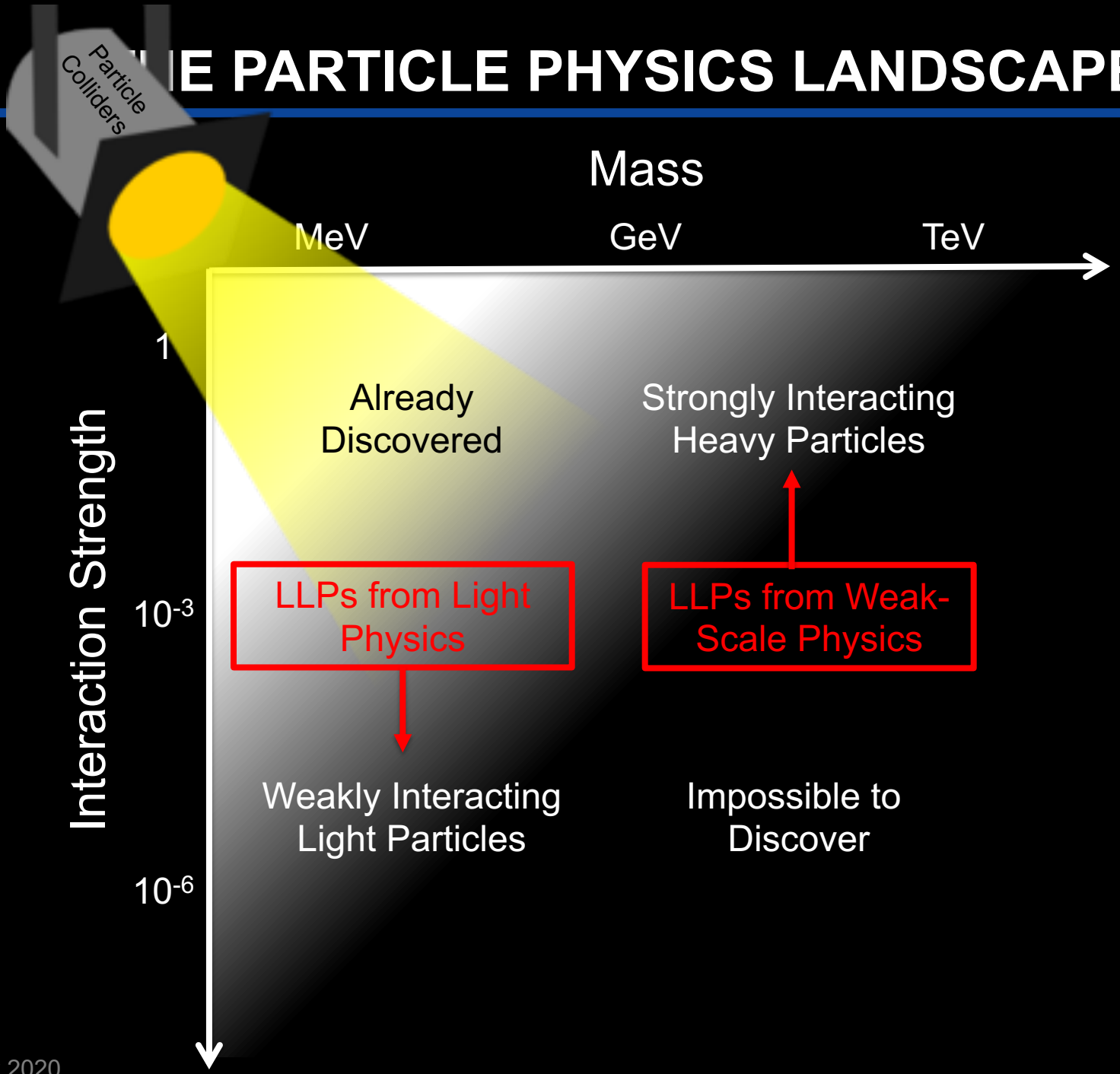
- The next breakthrough in particle physics is likely to involve LLPs
  - LLPs have historically played an enormous role in breakthroughs in our field
  - LLPs are now prevalent in BSM theories, especially those with cosmological significance
  - LLPs can be detected through a huge variety of spectacular signatures – even a few events can be a discovery
  - LLPs have been largely ignored for decades; there is a lot of low-hanging fruit that can be targeted by dedicated experiments, and now is the time to do them.

HISTORICAL PRECEDENT

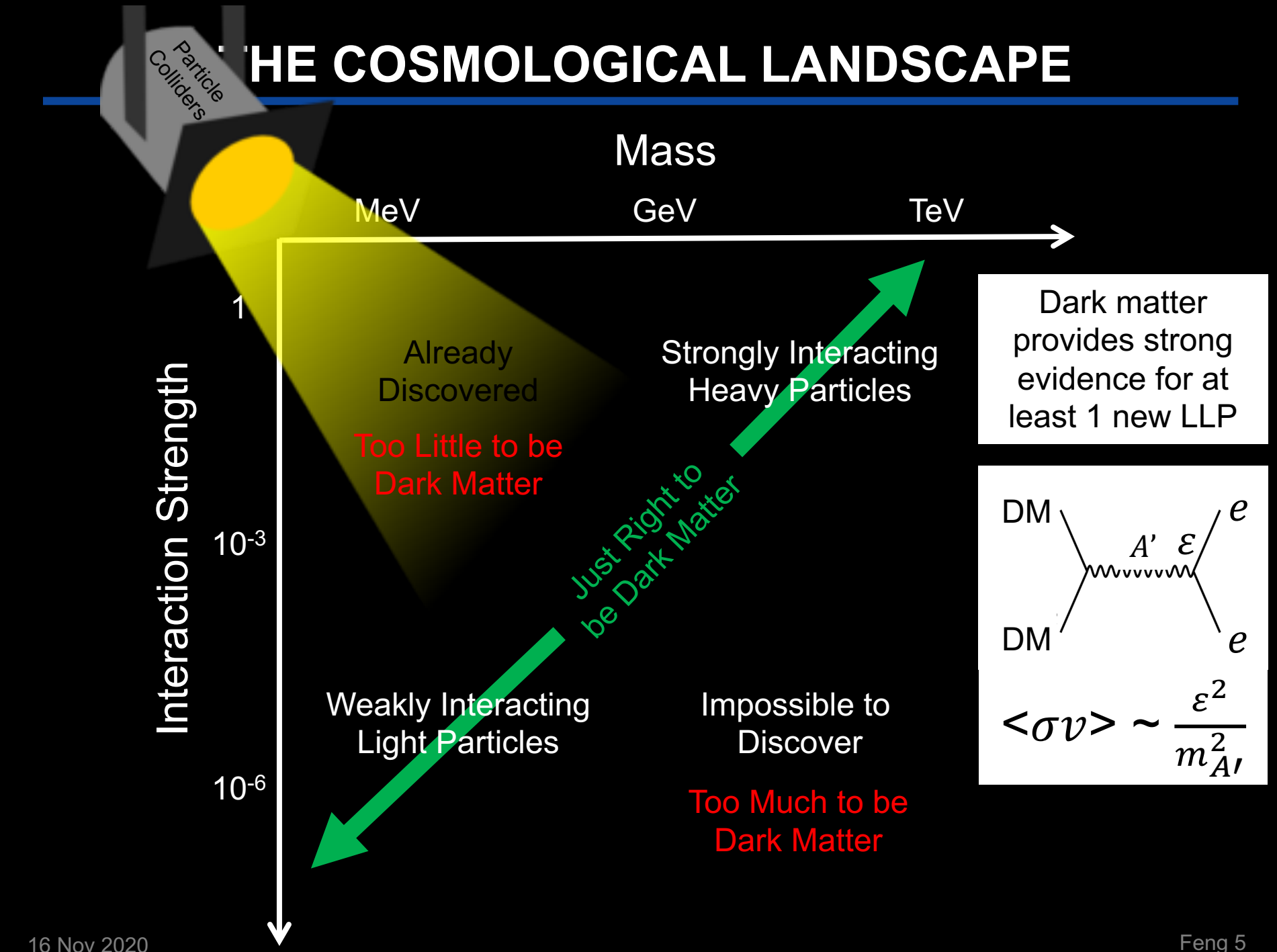
- Long-Lived Particles are not "exotica" in the Standard Model. There are plenty of symmetries (Lorentz, Q, L, B, isospin, …) that lead to several LLPs that have played an essential role in establishing what we know today: *e*, *p*, *n*, μ, $\pi^{\pm}$, *K*, ν, …



THE PARTICLE PHYSICS LANDSCAPE



THE COSMOLOGICAL LANDSCAPE

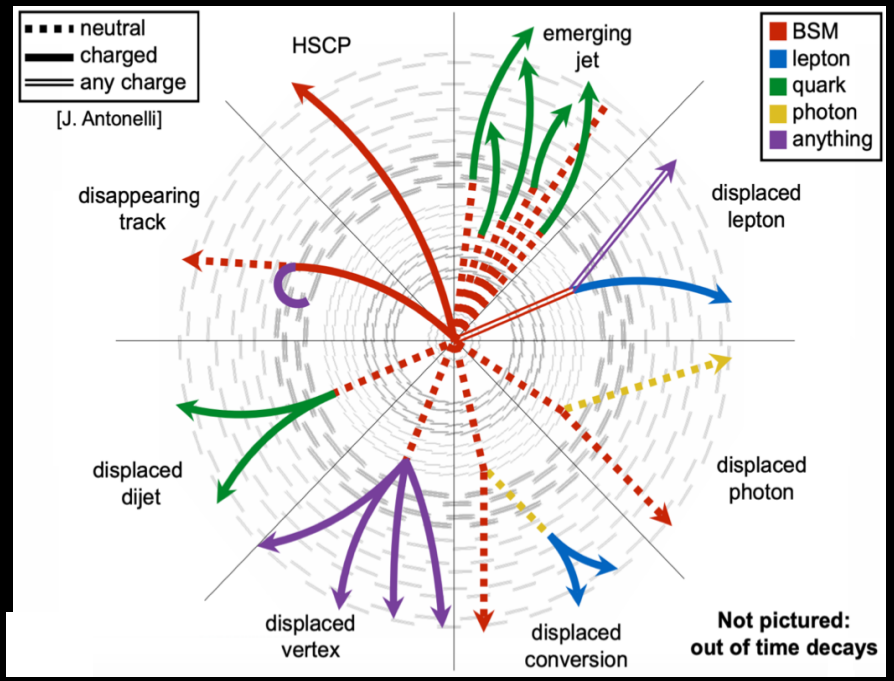


Dark matter provides strong evidence for at least 1 new LLP

$$\langle \sigma v \rangle \sim \frac{\varepsilon^2}{m_{A'}^2}$$

LLP SIGNATURES ARE SPECTACULAR

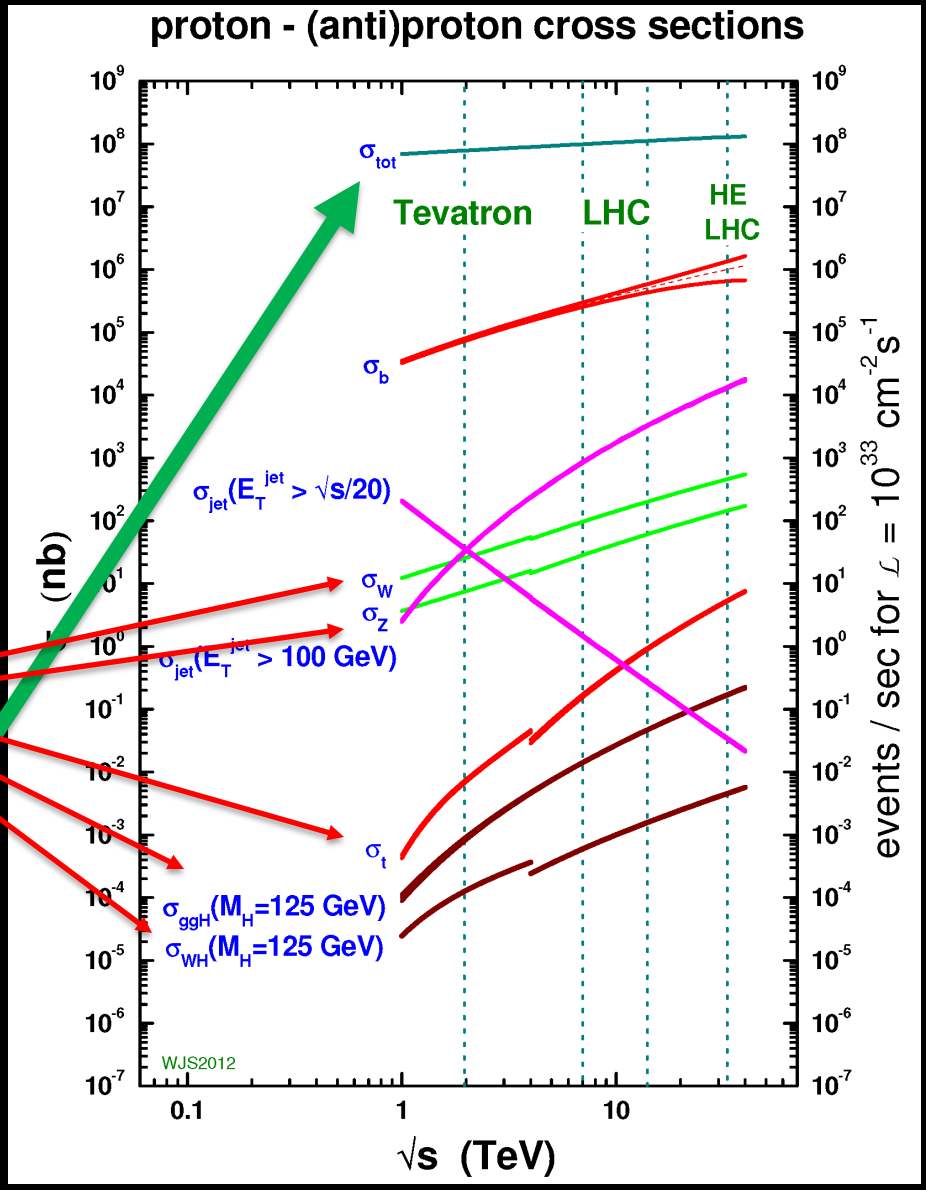
- This is true for searches at ATLAS, CMS, and LHCb.



- But, if anything, it is even more true for dedicated LLP detectors, where one typically goes to some out-of-the-way tunnel/cavern/shaft/plot of land around the LHC and looks for light-shining-through-wall types of signatures.

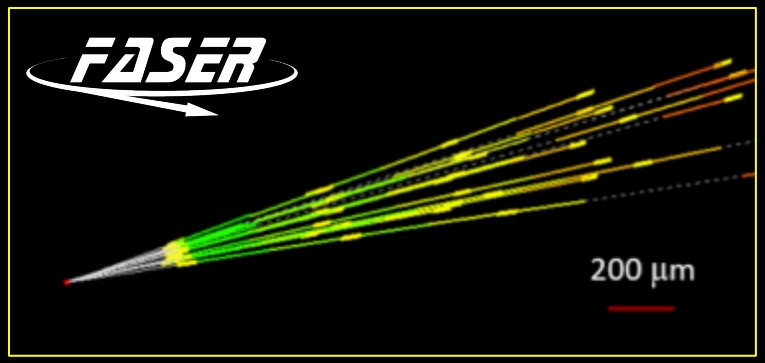
LLPS ARE LOW-HANGING FRUIT

- For decades our field has been consumed by the expectation that new physics would appear as strongly-interacting, heavy states.
- This has largely focused attention on processes with low (fb, pb, even nb) cross sections.
- **But LLPs can be light, produced in the currently "wasted" 100 mb total cross section!**



AN EXAMPLE: NEUTRINOS

- No collider neutrino has ever been detected.
- But there is a huge flux of TeV neutrinos in the far forward direction. De Rujula et al. (1980s)
- In 2018, FASER installed ~30 kg emulsion pilot detectors in the far forward region for a few weeks (inserted and removed in TSs).
- Expect ~10 neutrino interactions. Several neutral vertices have been identified, likely to be neutrinos. Analysis ongoing.
- For Run 3, expect 10,000 TeV neutrino events!



SUMMARY

- These are exciting times for LLPs, LLP detectors, and LLP facilities. In this session: Forward Physics Facility, FASER, FASERν, CMS Forward Detector, Codex-b/β, MilliQan, MoEDAL-MAPP, MATHUSLA, ANUBIS, SND@LHC, and FORMOSA (and there are others).
- The potential for new and better ideas is significant.
- In many cases, a modest investment can significantly enhance the LHC's search sensitivity and physics potential.
- And the future is now: if these investments are not made soon, many opportunities will disappear for decades.