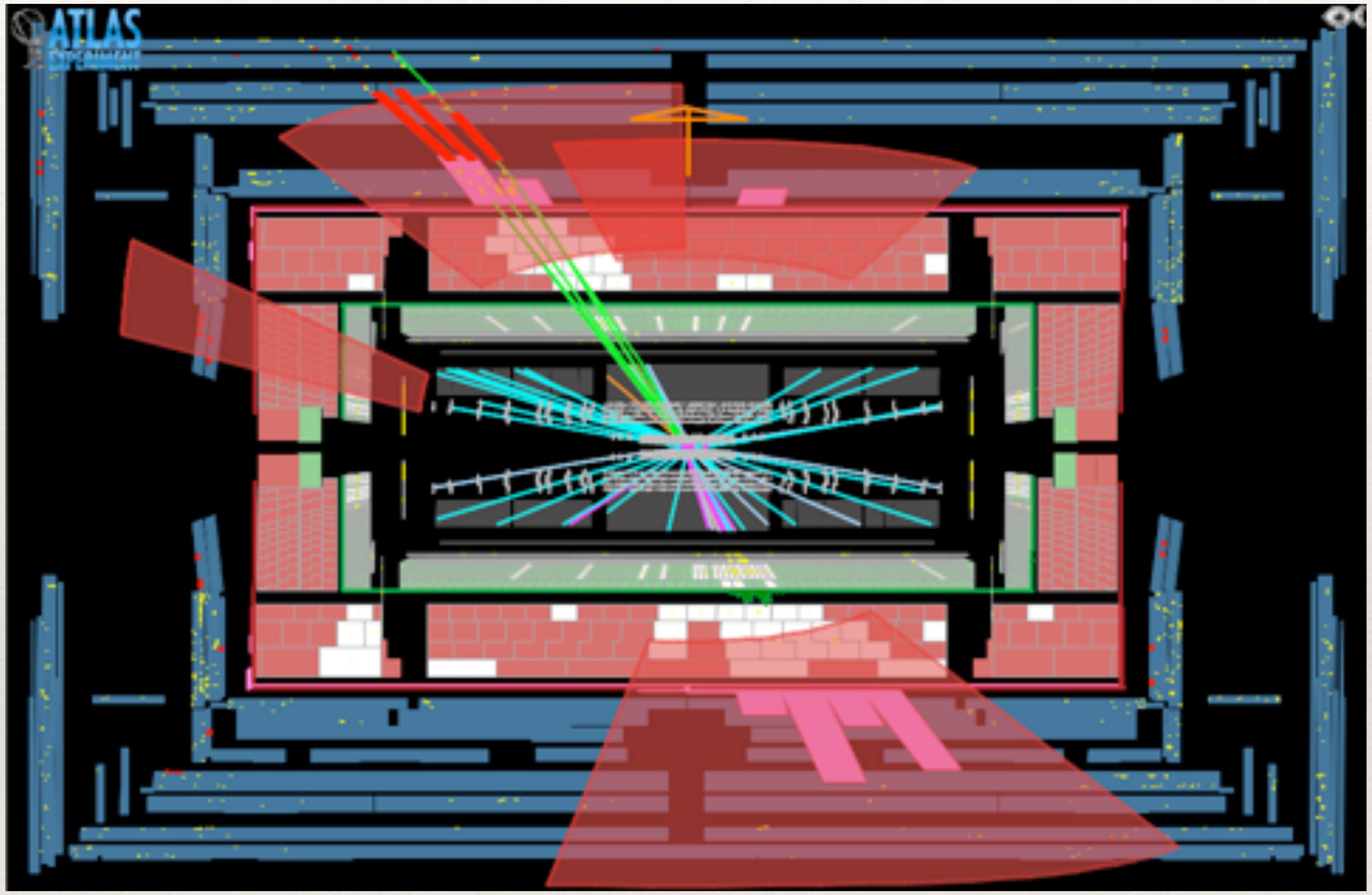
MOTIVATION: NEW IDEAS IN LLP SEARCHES



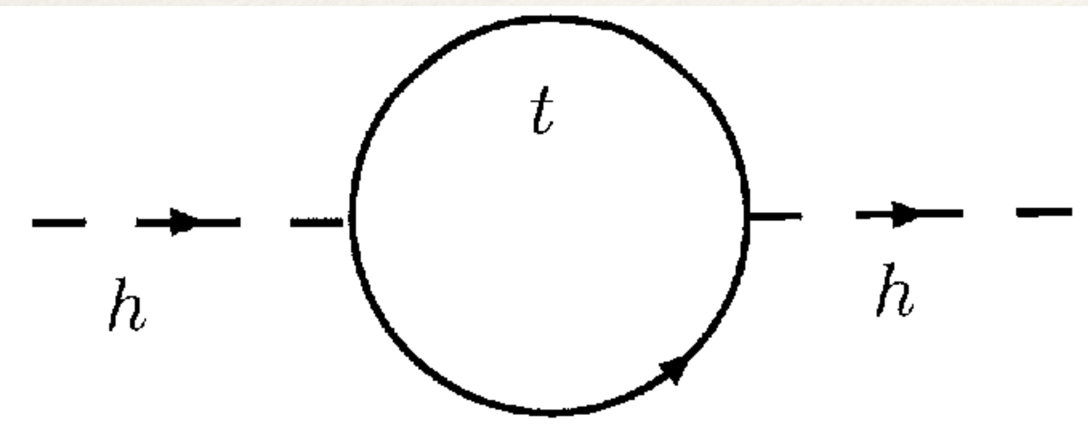
Brian Shuve

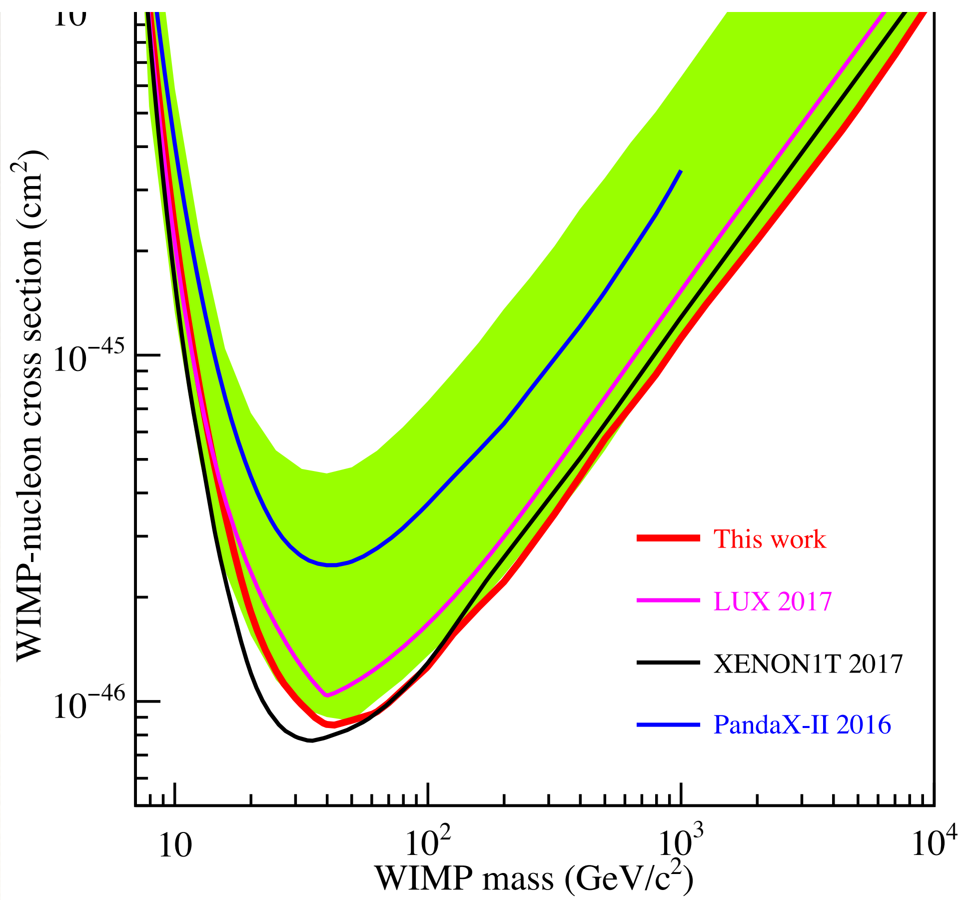
New Ideas for LLPs - LBL 2018

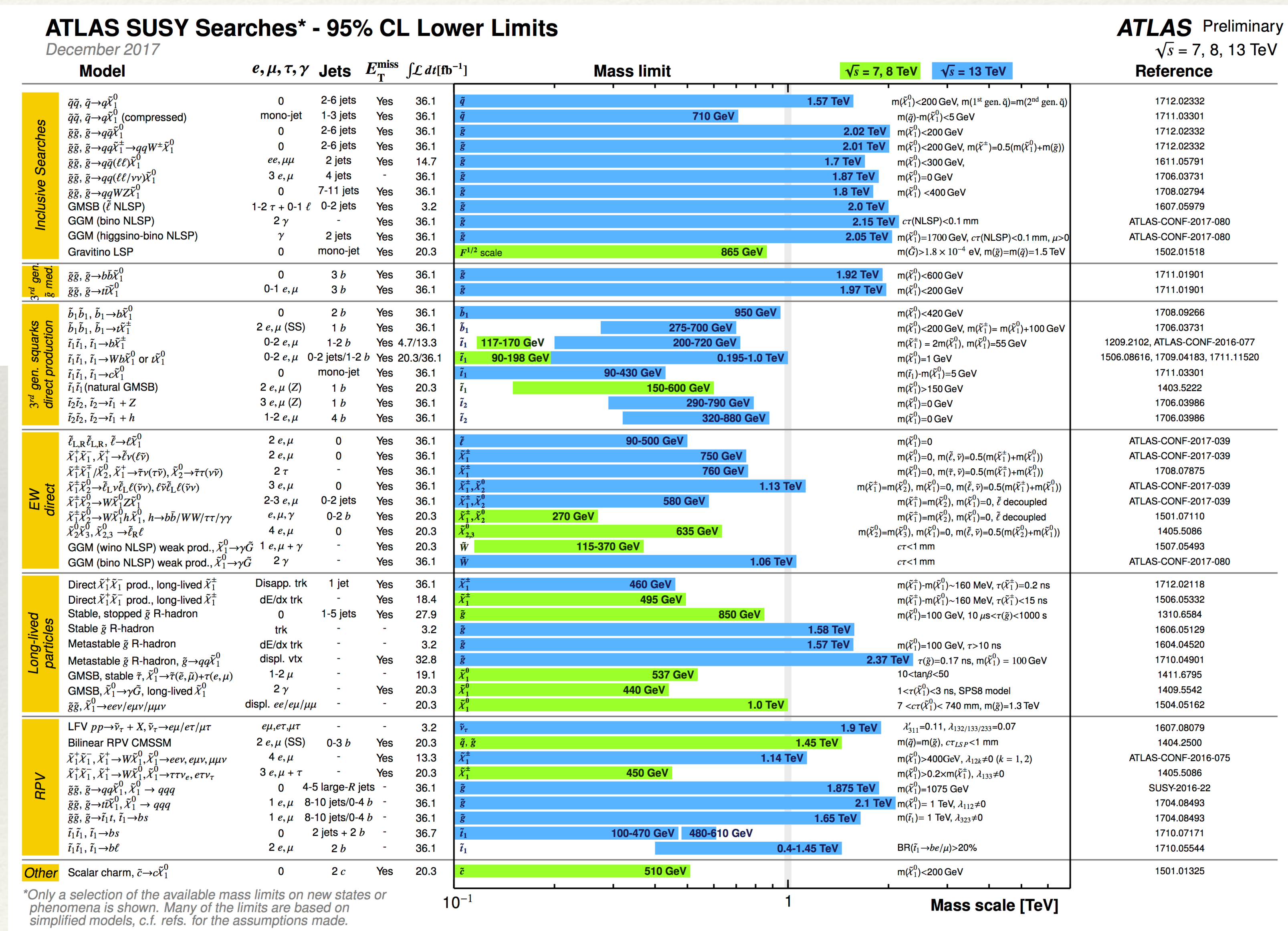
HARVEY MUDD COLLEGE

MOTIVATION FOR LLPS

- What I think concerns a lot of people in our field:

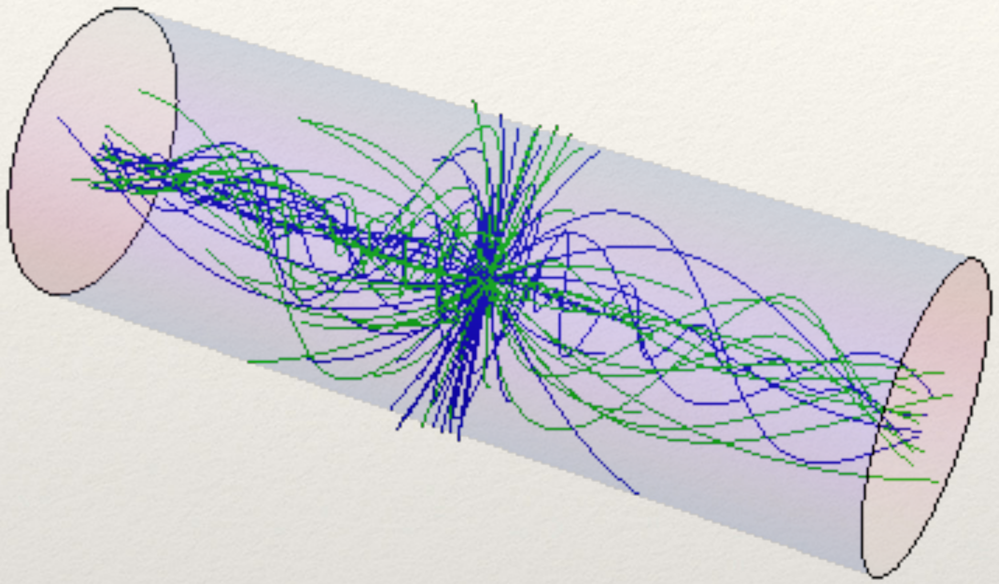


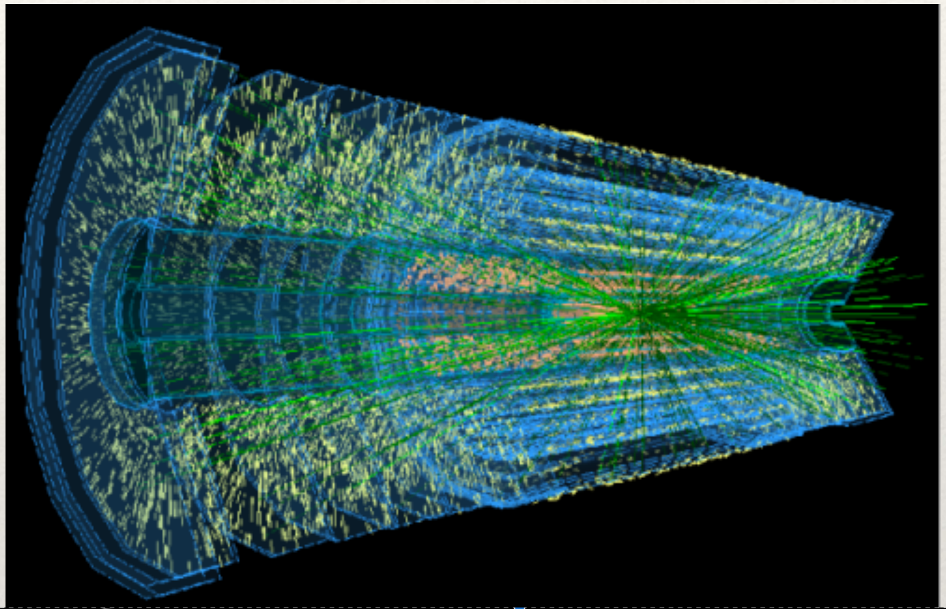


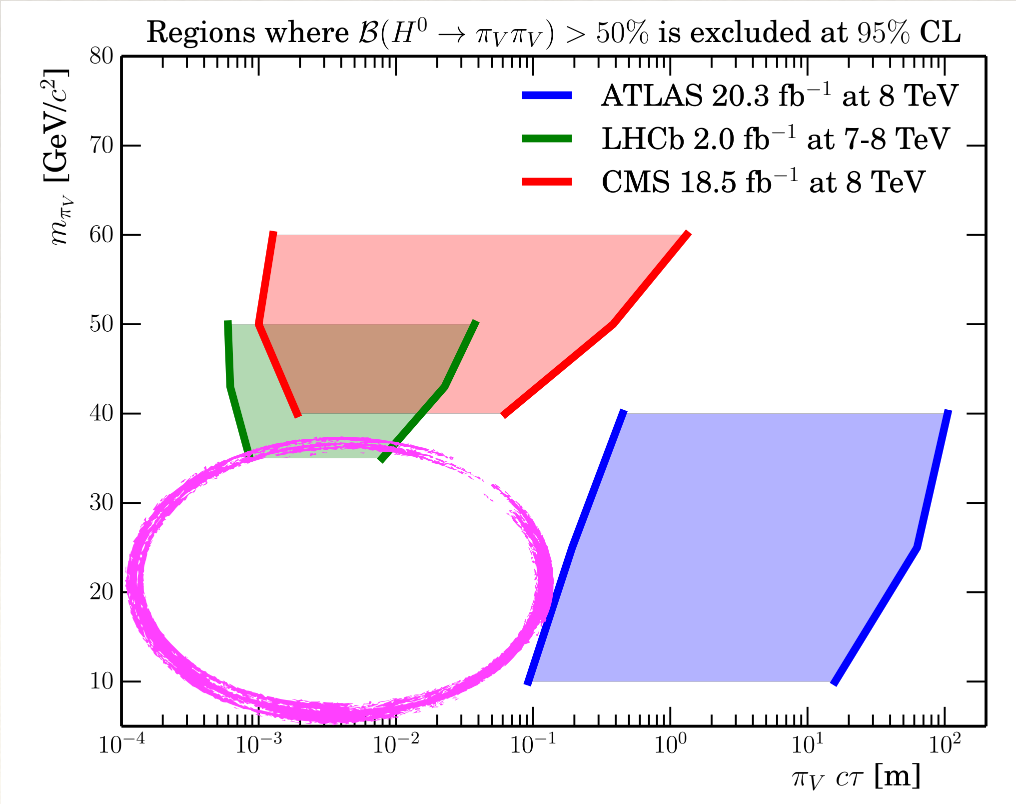


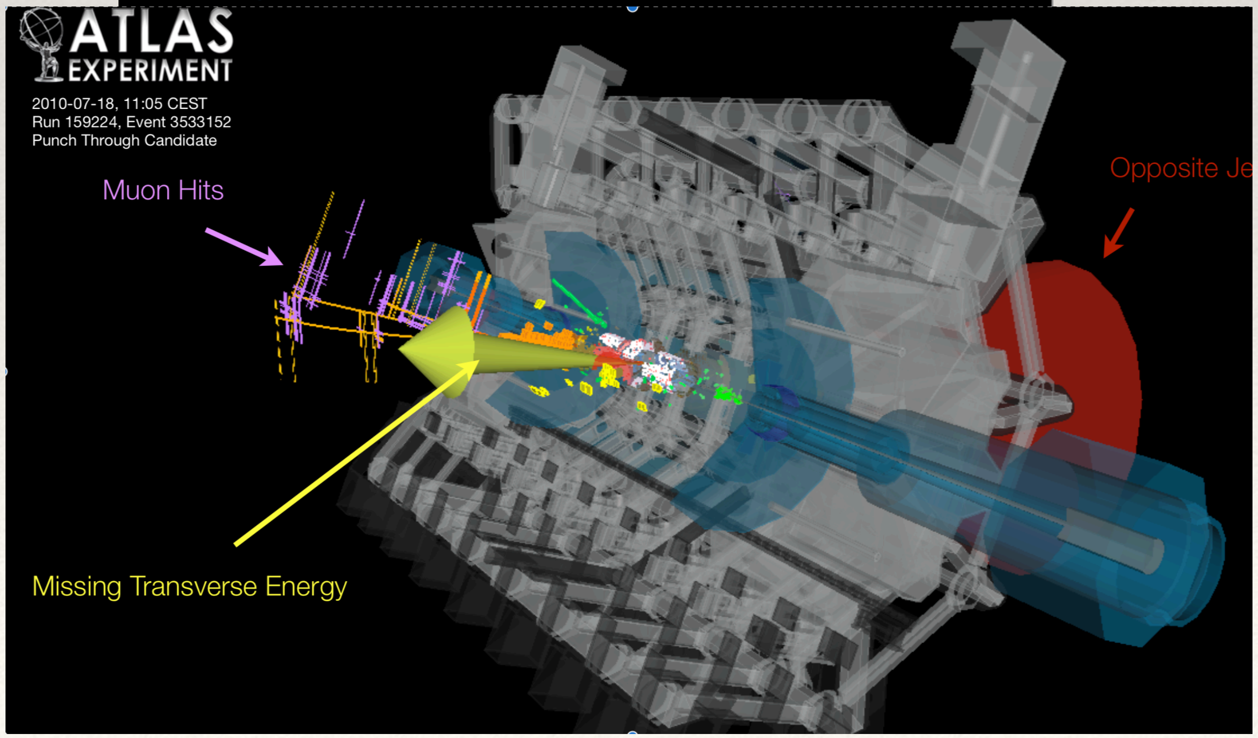
MOTIVATION FOR LLPS

- What I think concerns a lot of people **in this room**



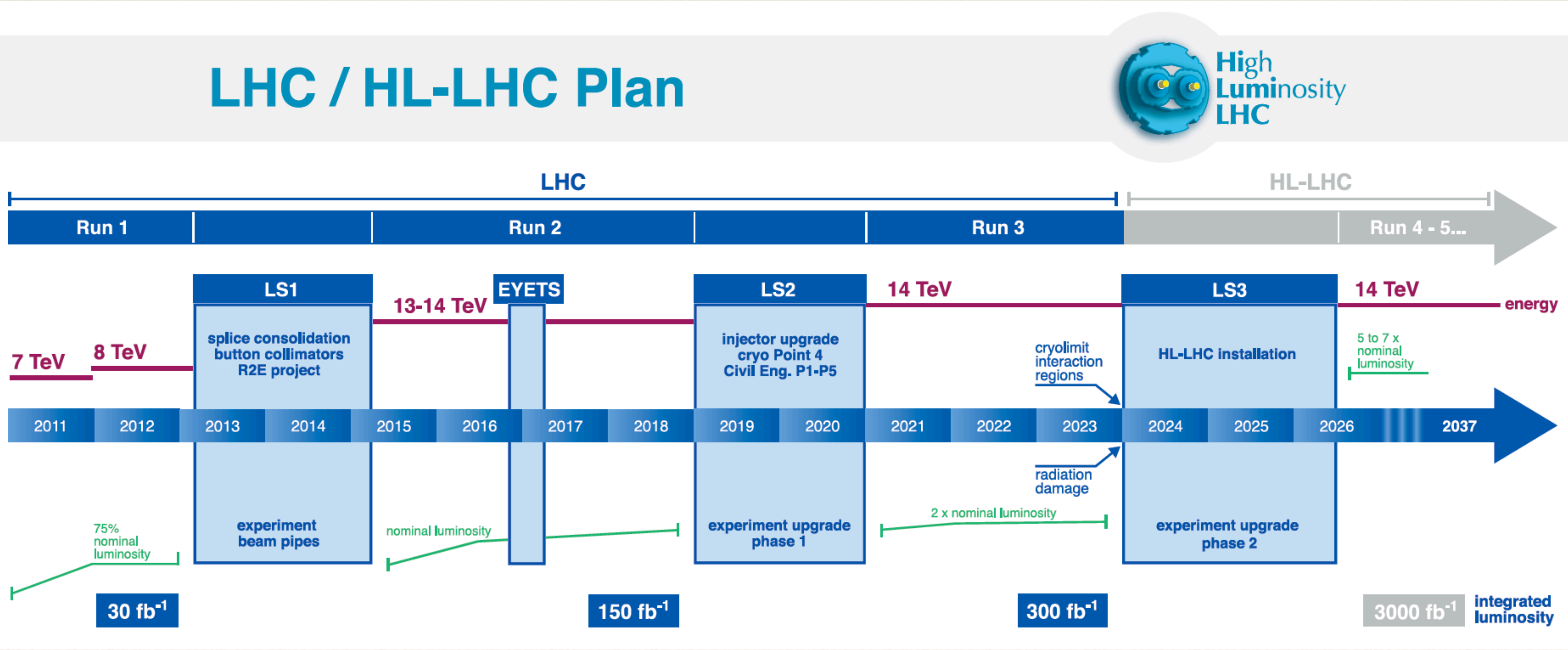






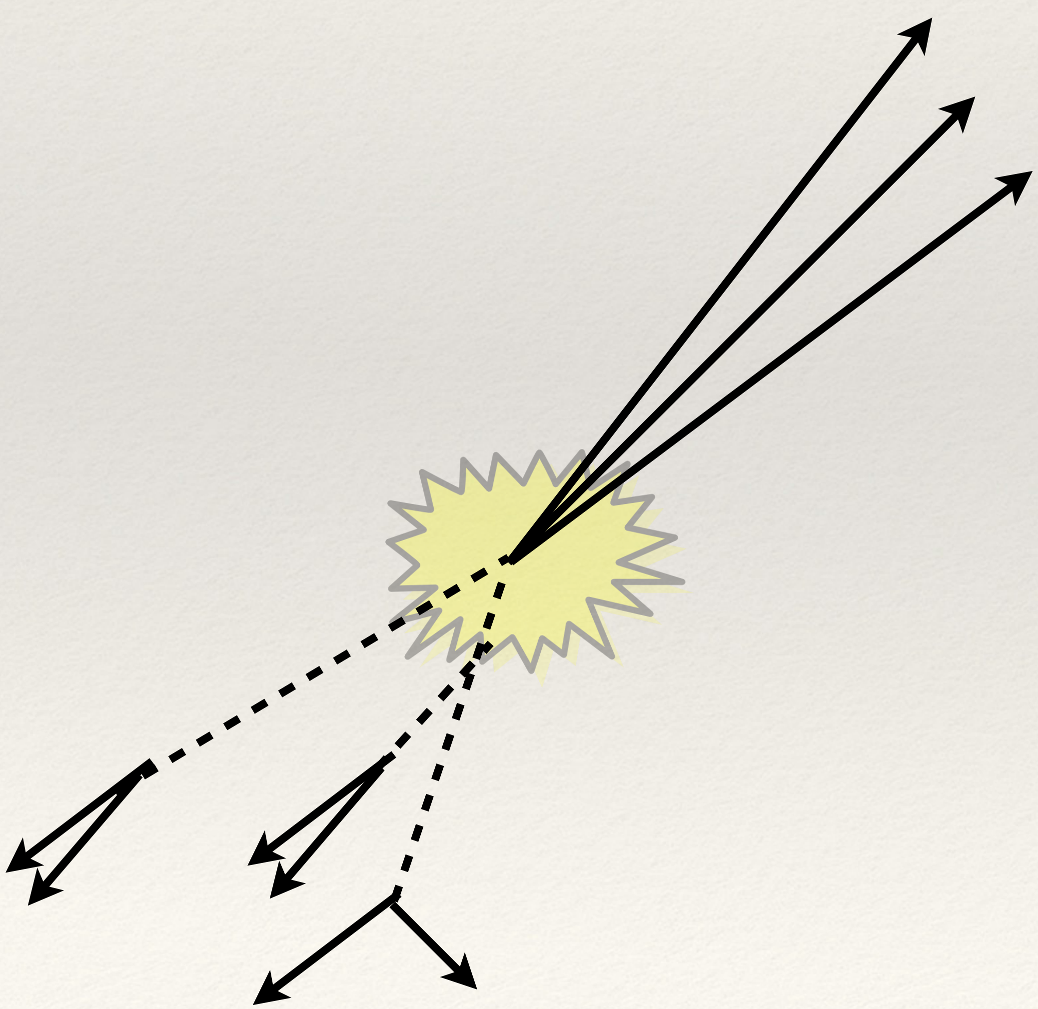
LLPS & HL-LHC

- Combination of energy + luminosity gives LHC unique discovery power for many types of LLP
- How do we best take advantage of this powerful machine?



LLP CHALLENGES: LOW MASS

- Low-mass LLPs are one of the major gaps in coverage at the LHC
- Everything is difficult: trigger, reconstruction, backgrounds



- High multiplicities of soft particles from decay of hidden-sector particles

and/or

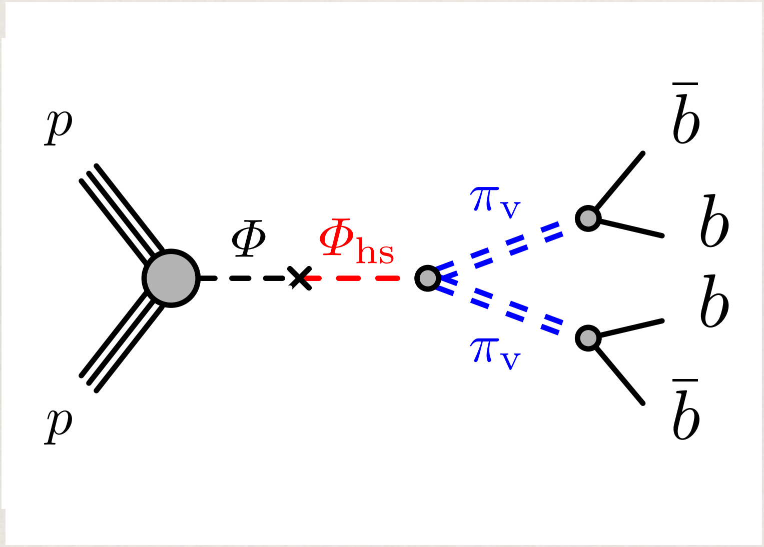
- Associated production of prompt, SM objects

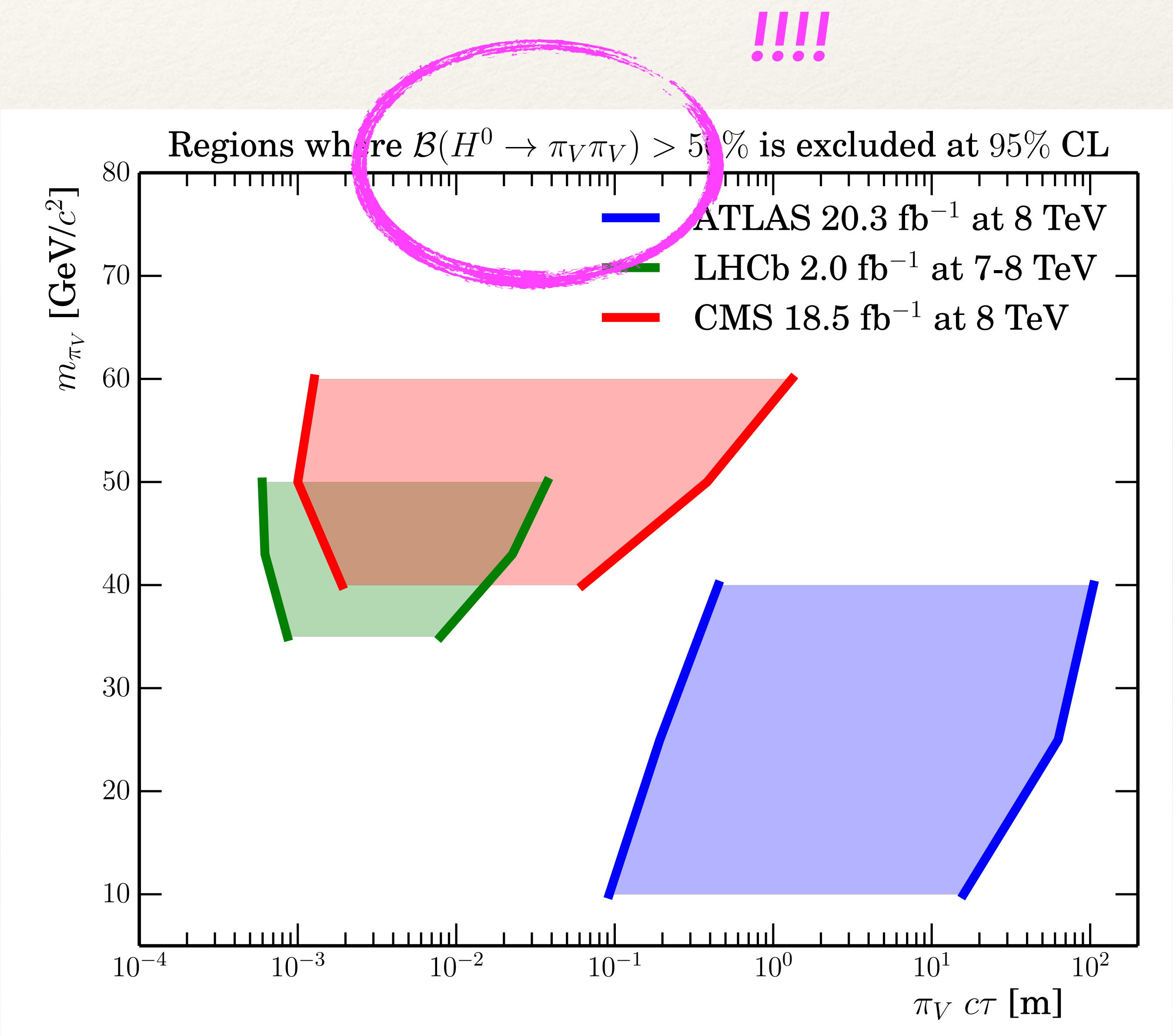
and/or

- Long lifetimes

LLP CHALLENGES: LOW MASS

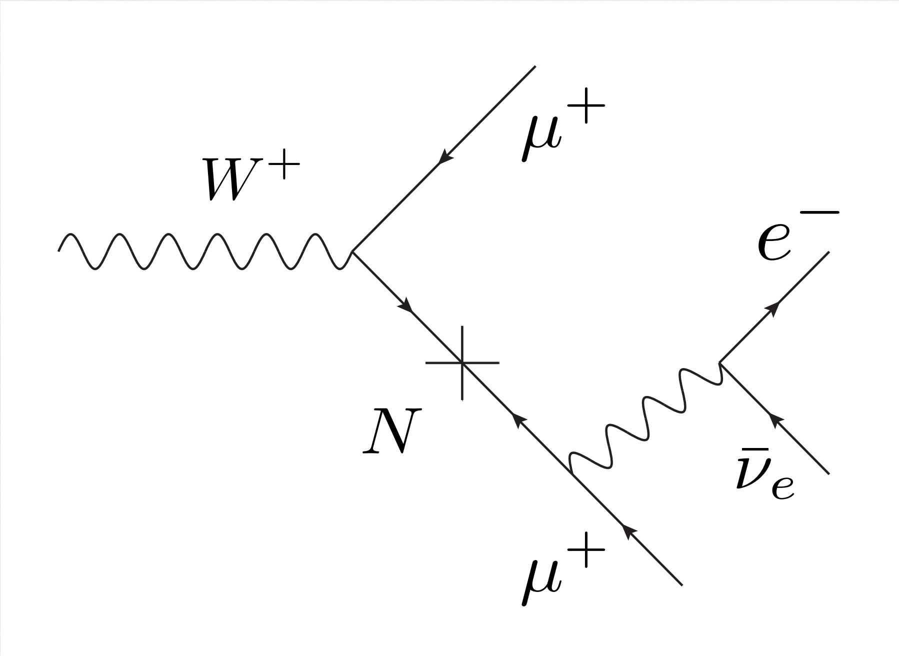
- Examples: hidden valley or Higgs-portal singlet

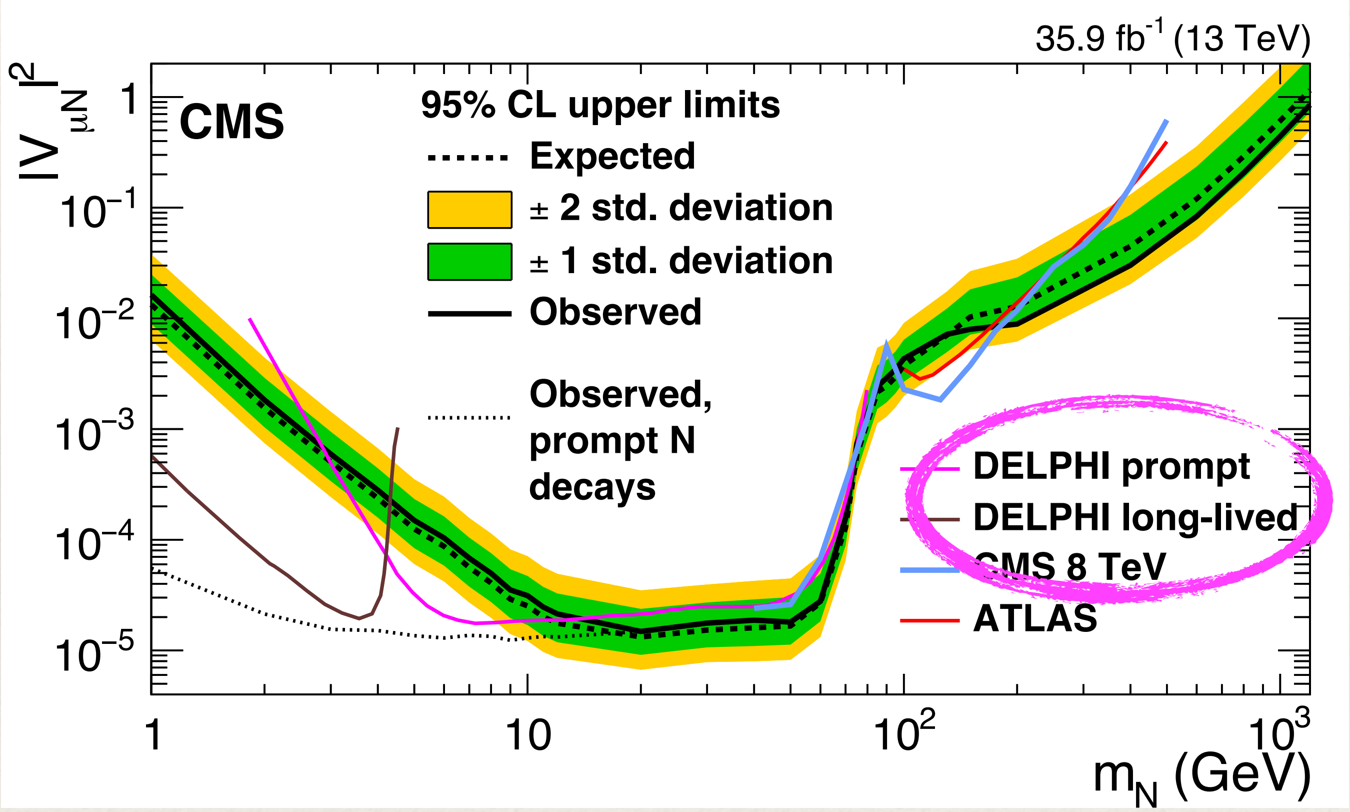




LLP CHALLENGES: LOW MASS

- Examples: Majorana neutrinos (*N*)

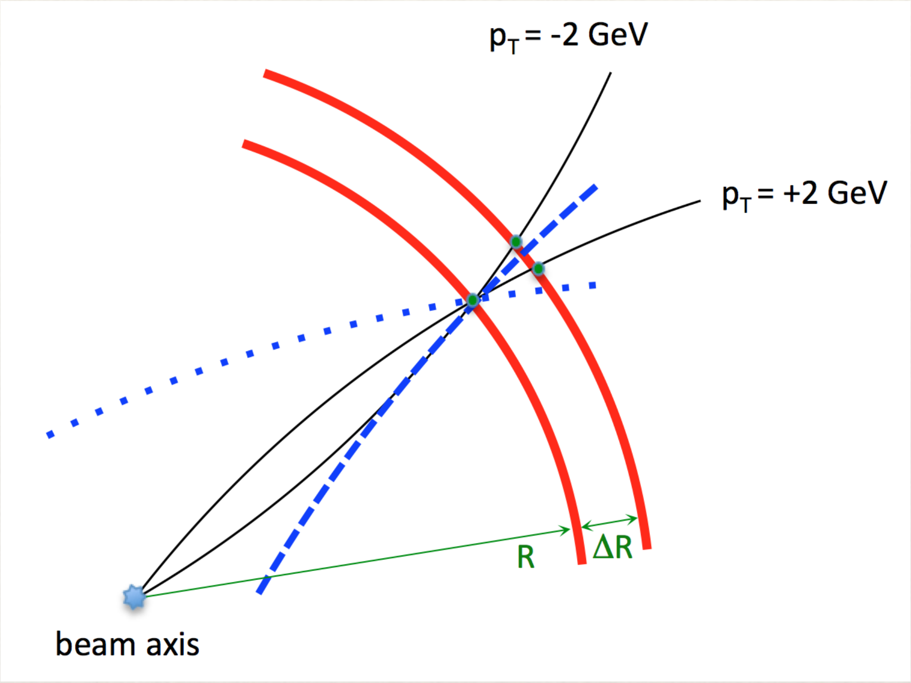




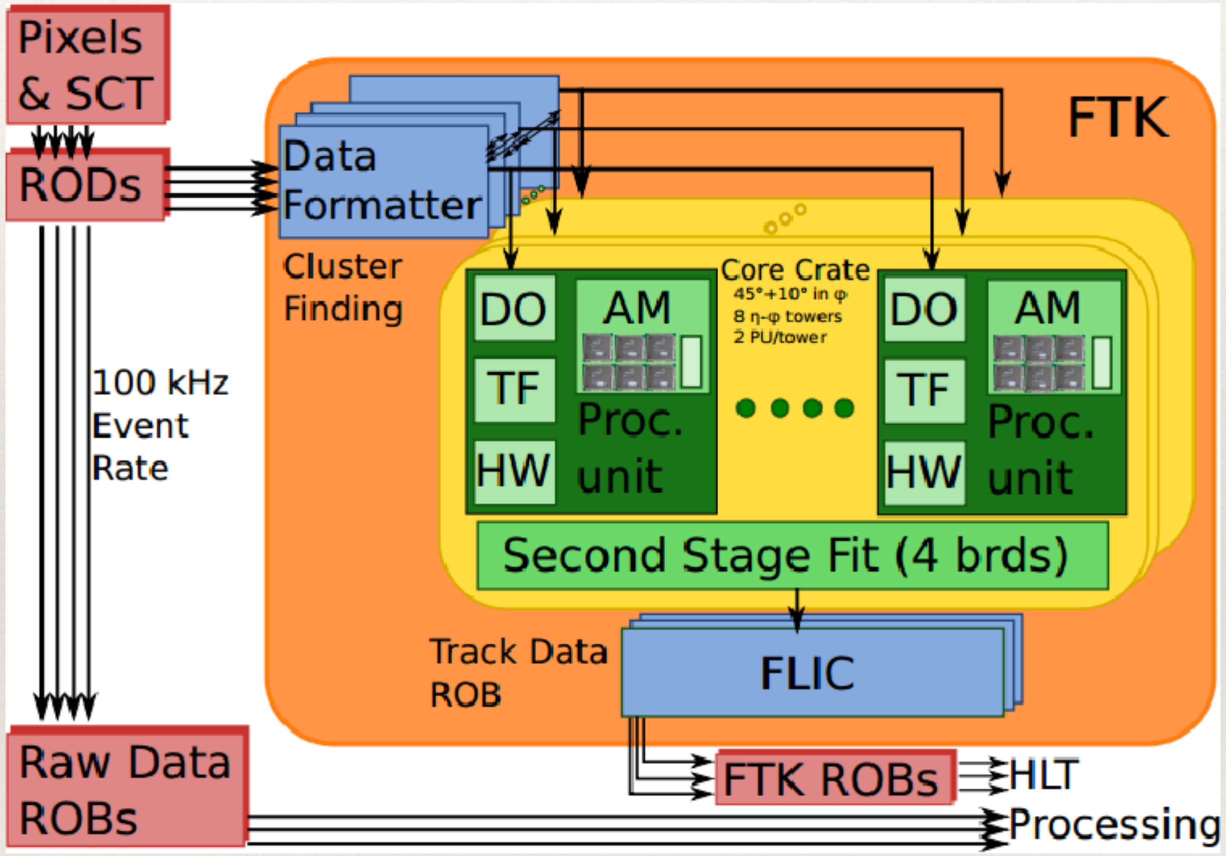
CMS, arXiv:1802.02965

LLP OPPORTUNITIES: LOW MASS

- Track information available at or just after L1



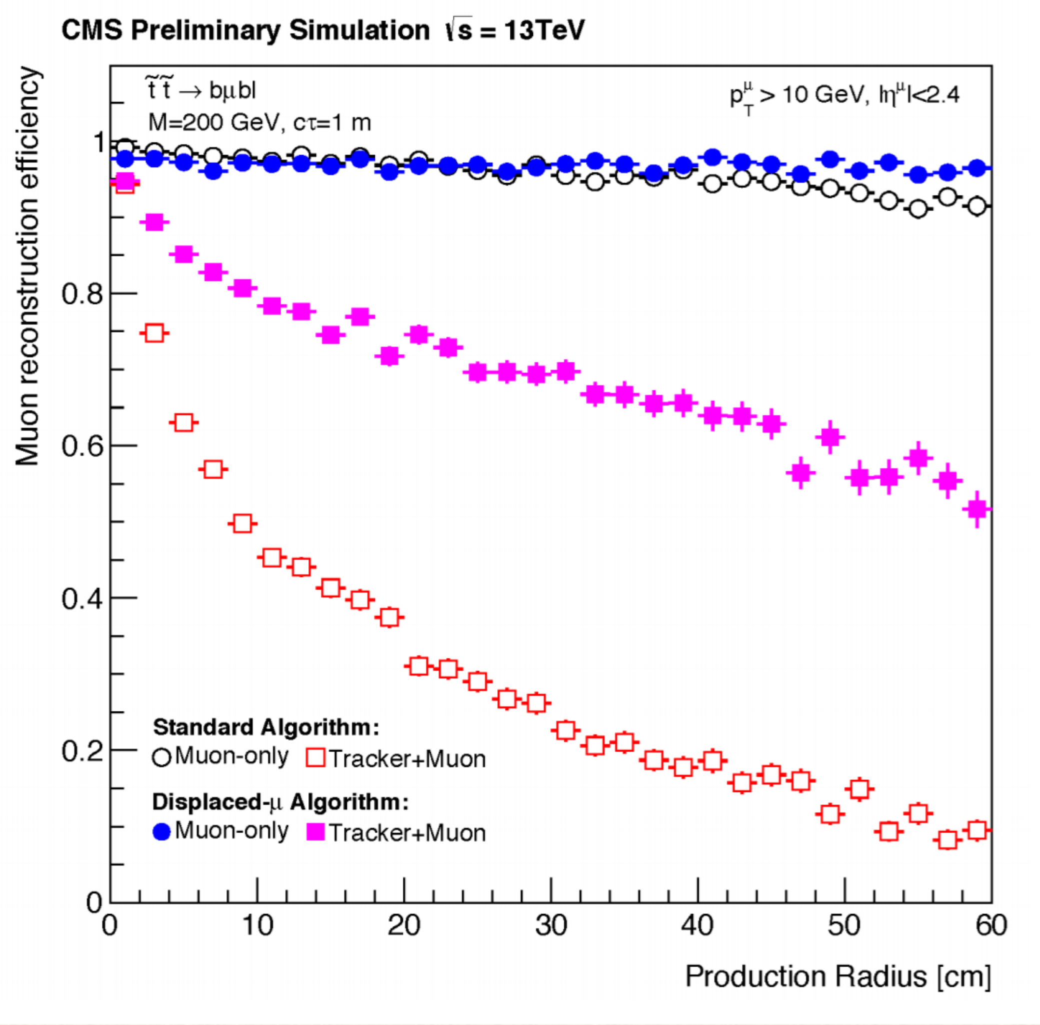
Gershtein, arXiv:1705.04321



- What are the best ways to use this information to trigger on low-threshold displaced objects?

LLP OPPORTUNITIES: LOW MASS

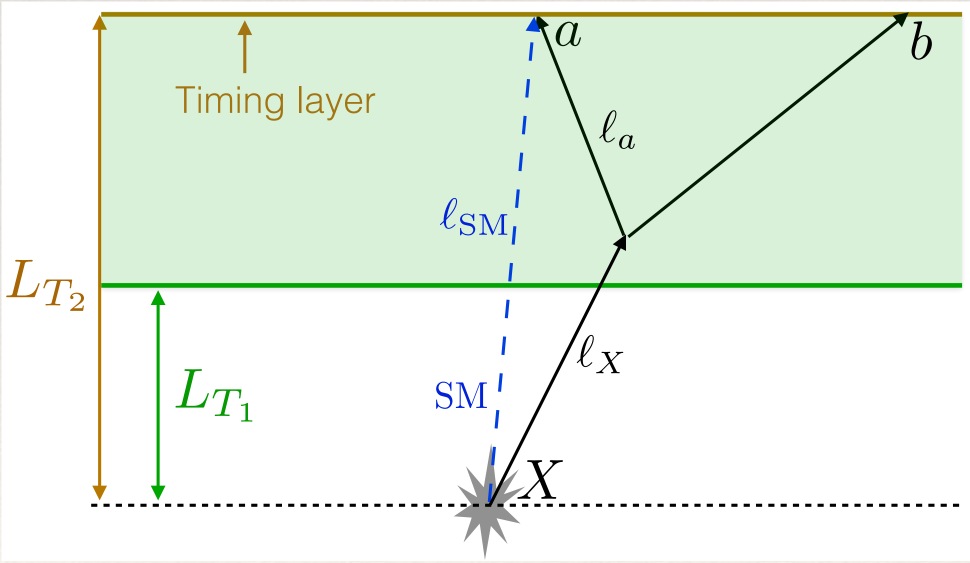
- Need to take care that addition of tracking information at trigger level does not discard displaced objects!

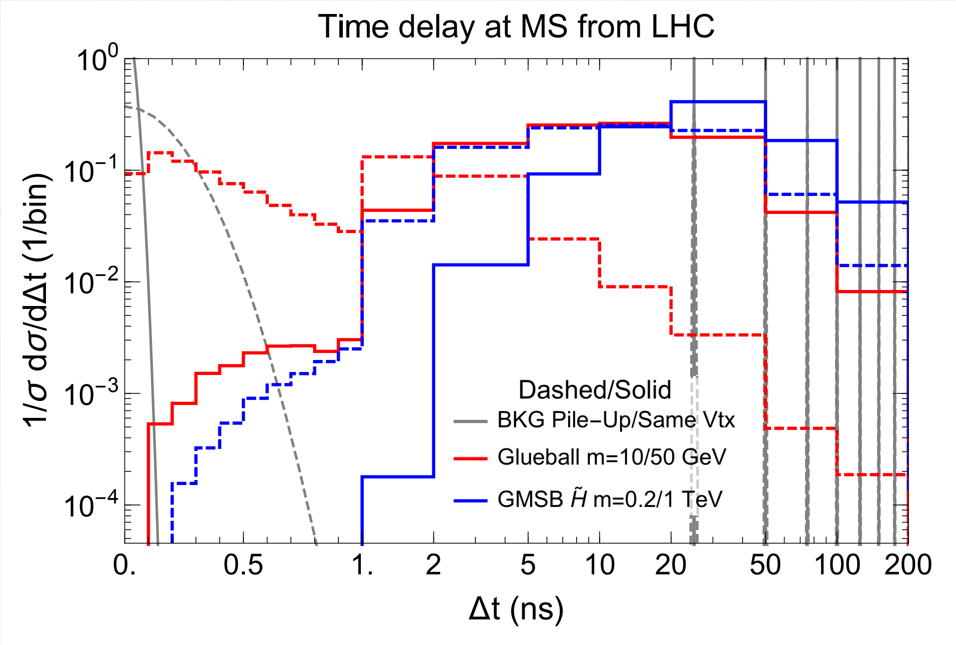


- What about electrons? Non-standard photons?

LLP OPPORTUNITIES: LOW MASS

- The addition of high-precision timing information could add a new dimension to displaced vertex searches
- Could be game-changer for photons from LLP decays (most searches require 2+ energetic photons along with MET or some other hard objects)

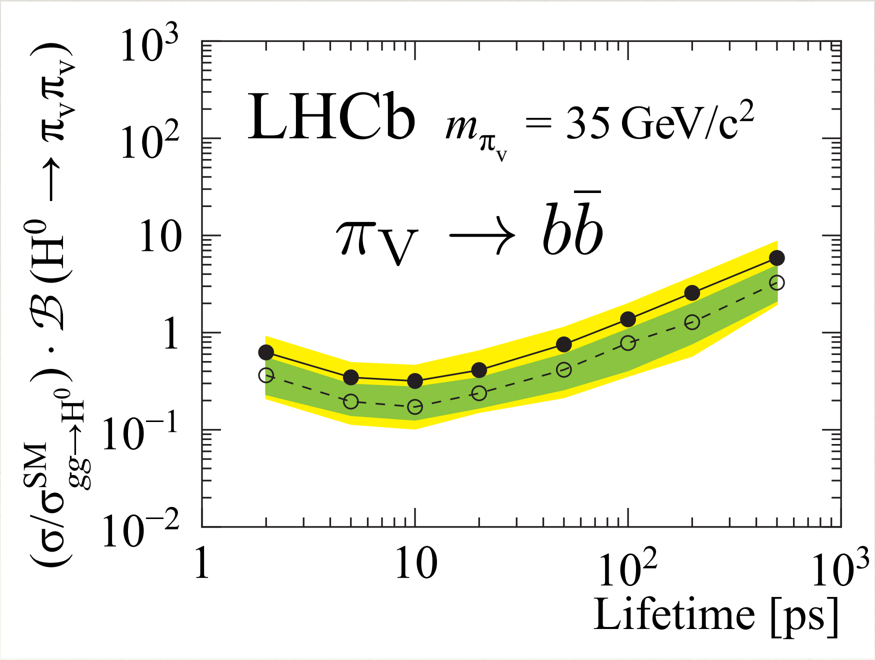




- Can be used at trigger level? Backgrounds?

LLP OPPORTUNITIES: LOW MASS

- LHCb is uniquely positioned to study low pT, forward physics
- Sensitive to low-mass, short-lifetime LLPs, but limited by luminosity and acceptance
- Many opportunities — what is the best way to use excellent vertexing, PID?

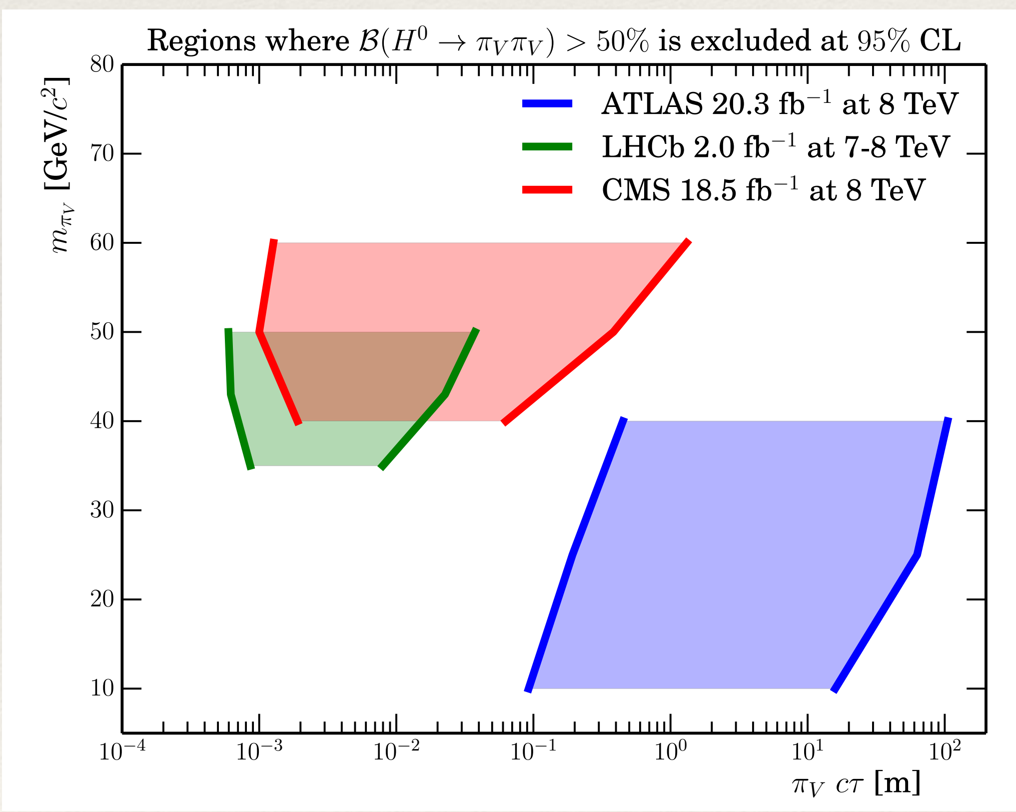


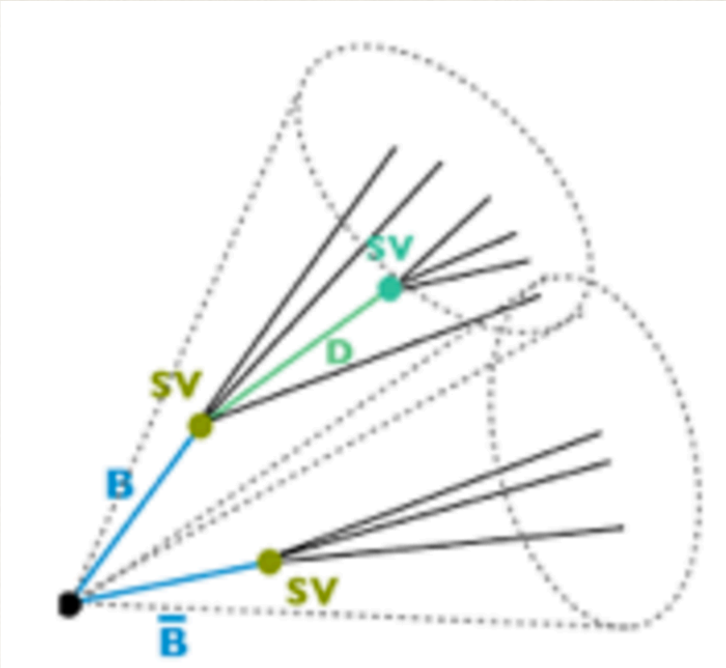
LLP OPPORTUNITIES: LOW MASS

- What are opportunities for trigger upgrade/online reconstruction?
  - Trigger-level analysis has been useful for low-mass dijet searches
  - LHCb online reconstruction of every event has possibility of significantly improving efficiency of low-mass searches
  - What about ATLAS/CMS? From Phil Harris (CMS):
    There may be the possibility to have full read out at 40 MHz and storage of final state particles with the CMS trigger upgrade. For sure we will be able to store the L1 PF candidates of every event above a threshold (which is the pf candidates with tracks having pT > 2 GeV using the CMS strip track trigger and full calorimeter info). However, we may have the possibility to store fully reconstructed strips, pixels and fast timing information.

LLP CHALLENGES: SHORT LIFETIME

- Many searches require > mm displacements to suppress heavy-flavour backgrounds
- However, short-lifetime high-mass vertices could still be striking

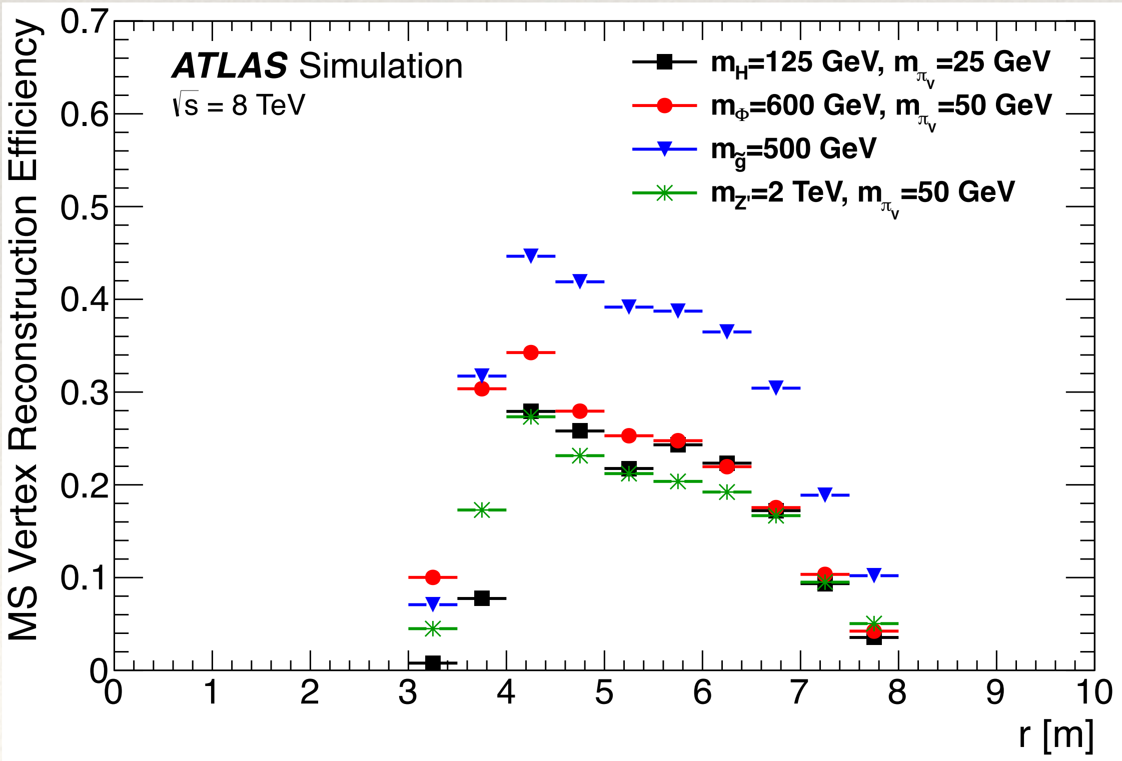




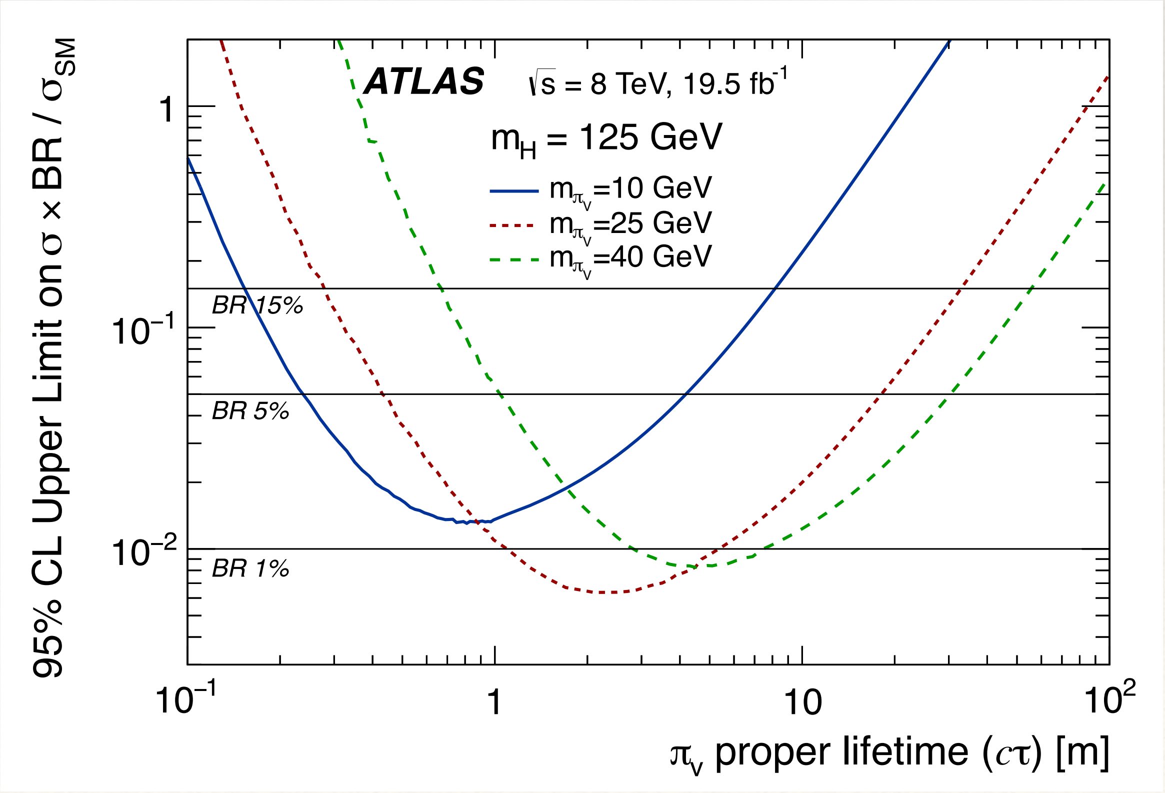
- LLP variant of *b*-tagging to cover "mesoscopic" lifetimes?

LLP CHALLENGES: LONG LIFETIME

- Low probability of decay inside detector
- ATLAS has powerful searches in HCAL & MS sensitive to low mass, but currently need **two** DVs
- One DV search would suffer from large backgrounds



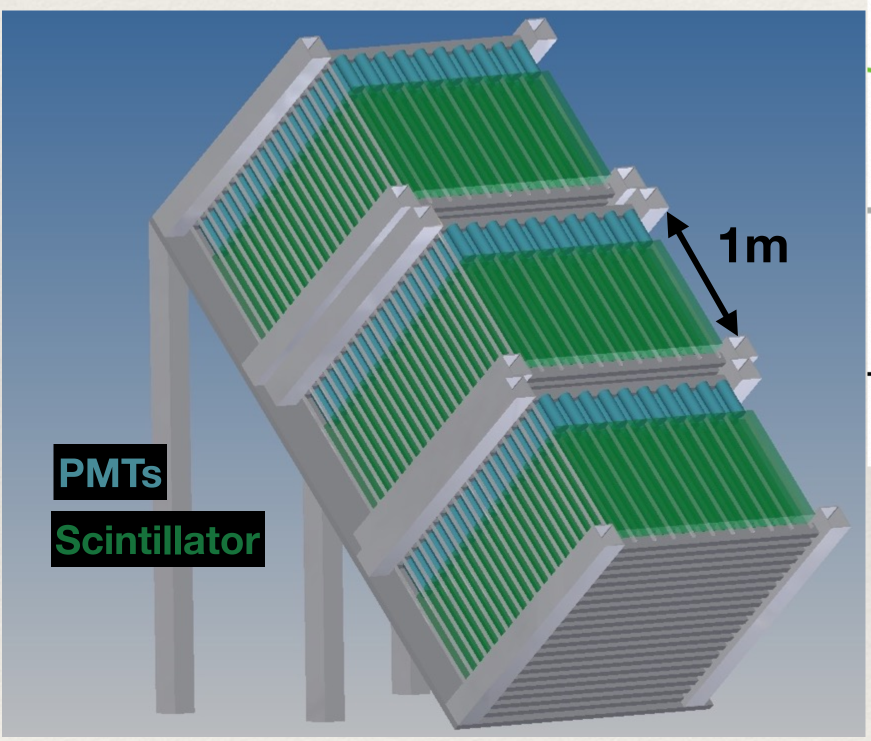
ATLAS, arXiv:1504.03634



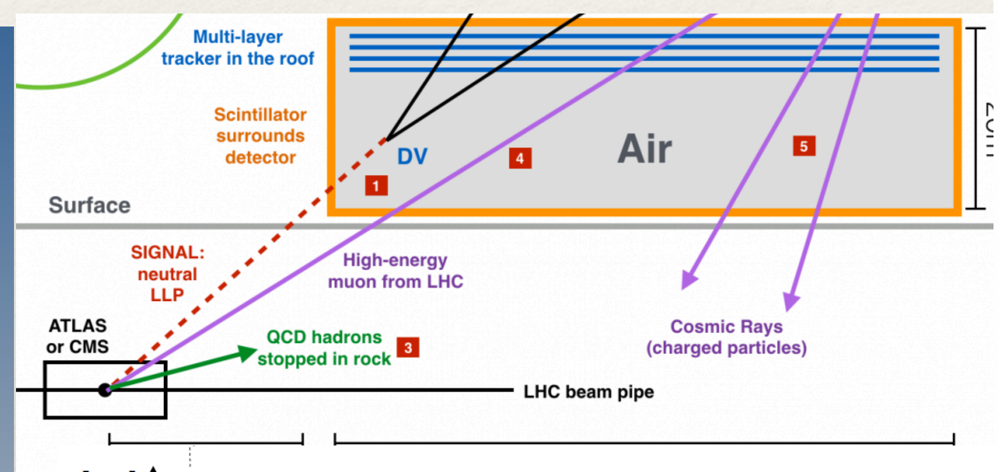
LLP OPPORTUNITIES: LONG LIFETIME

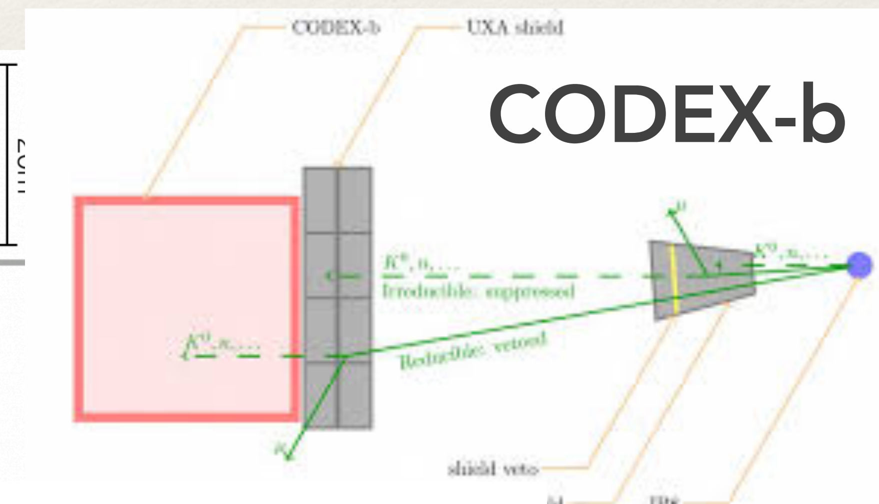
- Distant (shielded) detector to capture large-displacement decays or other soft LLP signals: can they be tweaked to improve reach?

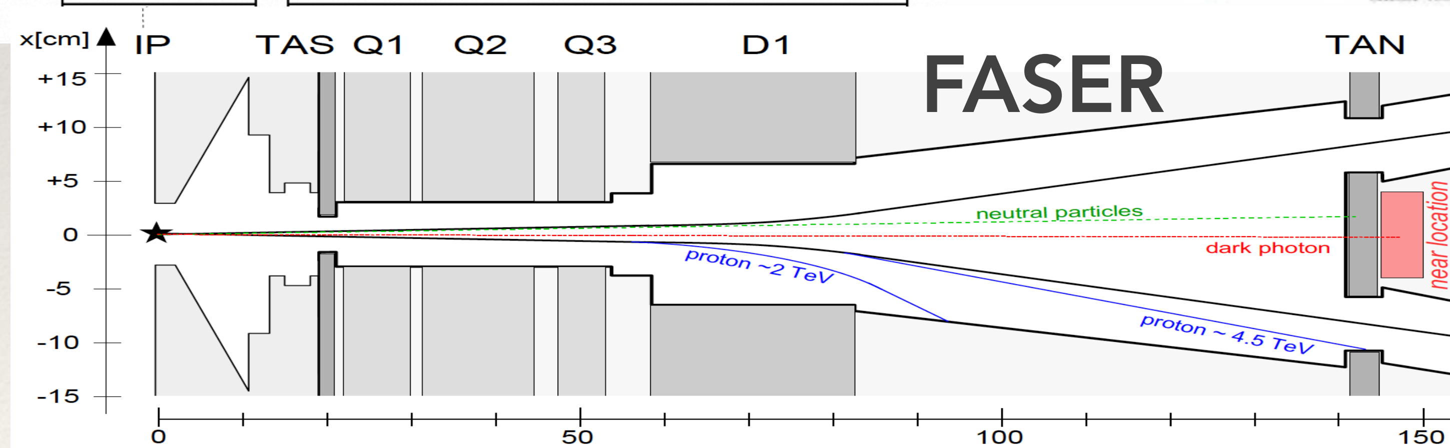
MilliQan



MATHUSLA



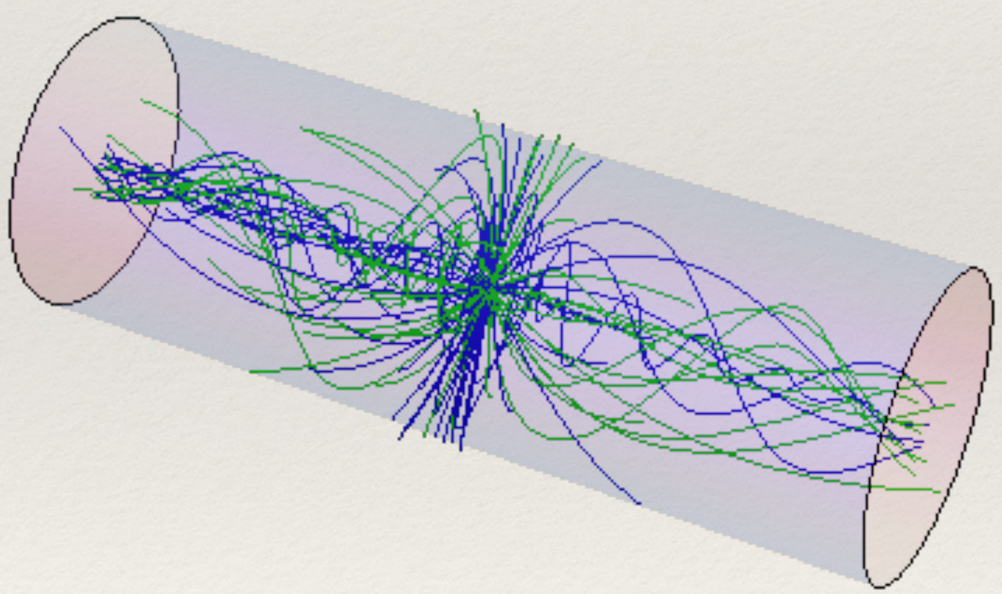




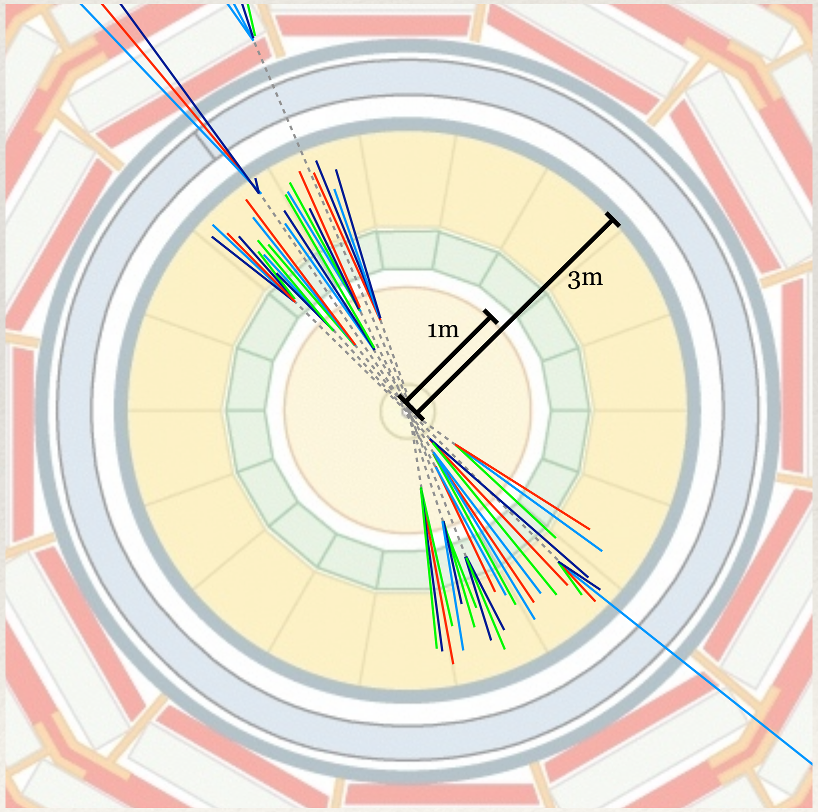
- New ideas for detectors to enhance sensitivity to LLPs?

LLP CHALLENGES: SHOWERS

- Strong dynamics in a hidden sector can be difficult to look for
- We don't always (often?) know how to model the signals!
- How do we comprehensively cover these signatures?



Knapen *et al.*, arXiv:1612.00850



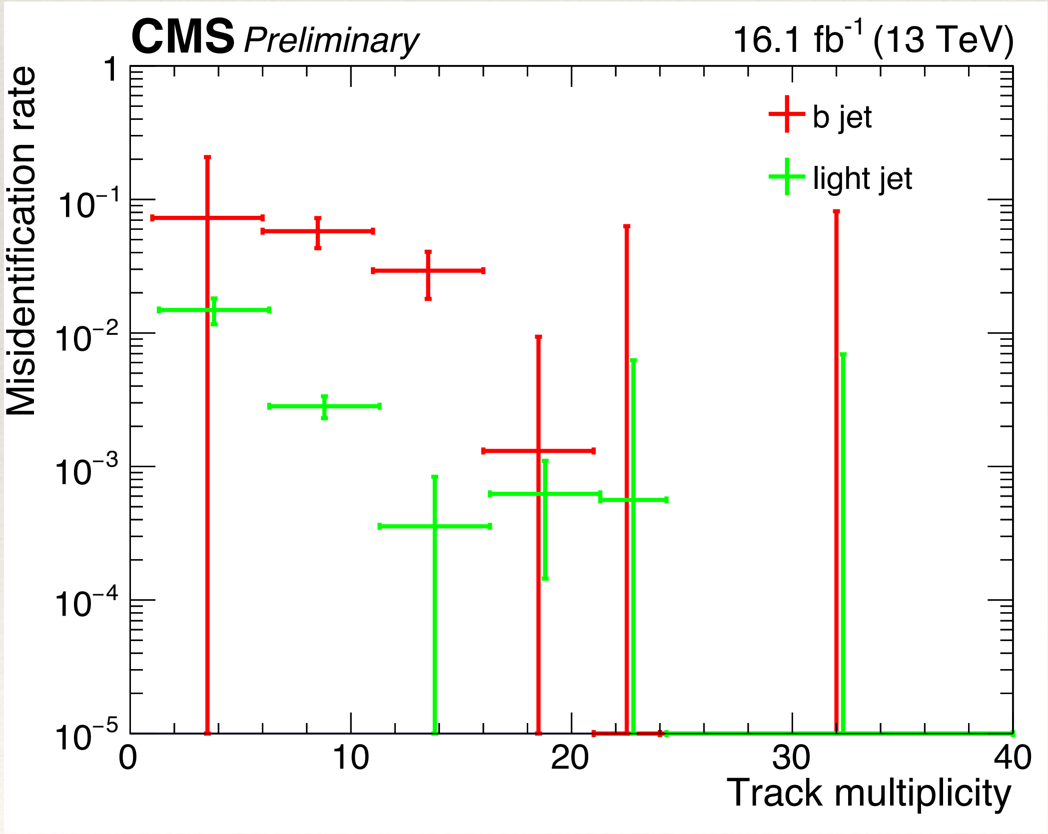
Strassler, Zurek, 2006
Schwaller, Stolarski, Weiler, arXiv:1502.05409

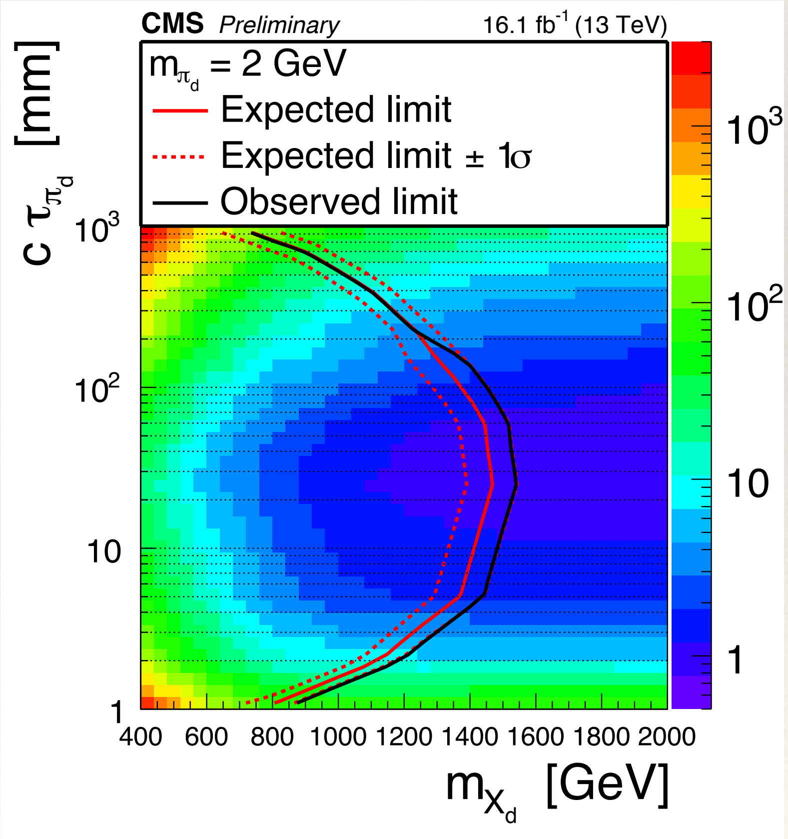
LLP OPPORTUNITIES: SHOWERS

CMS PAS EXO-18-001

Search for new particles decaying to a jet and an emerging jet

The CMS Collaboration

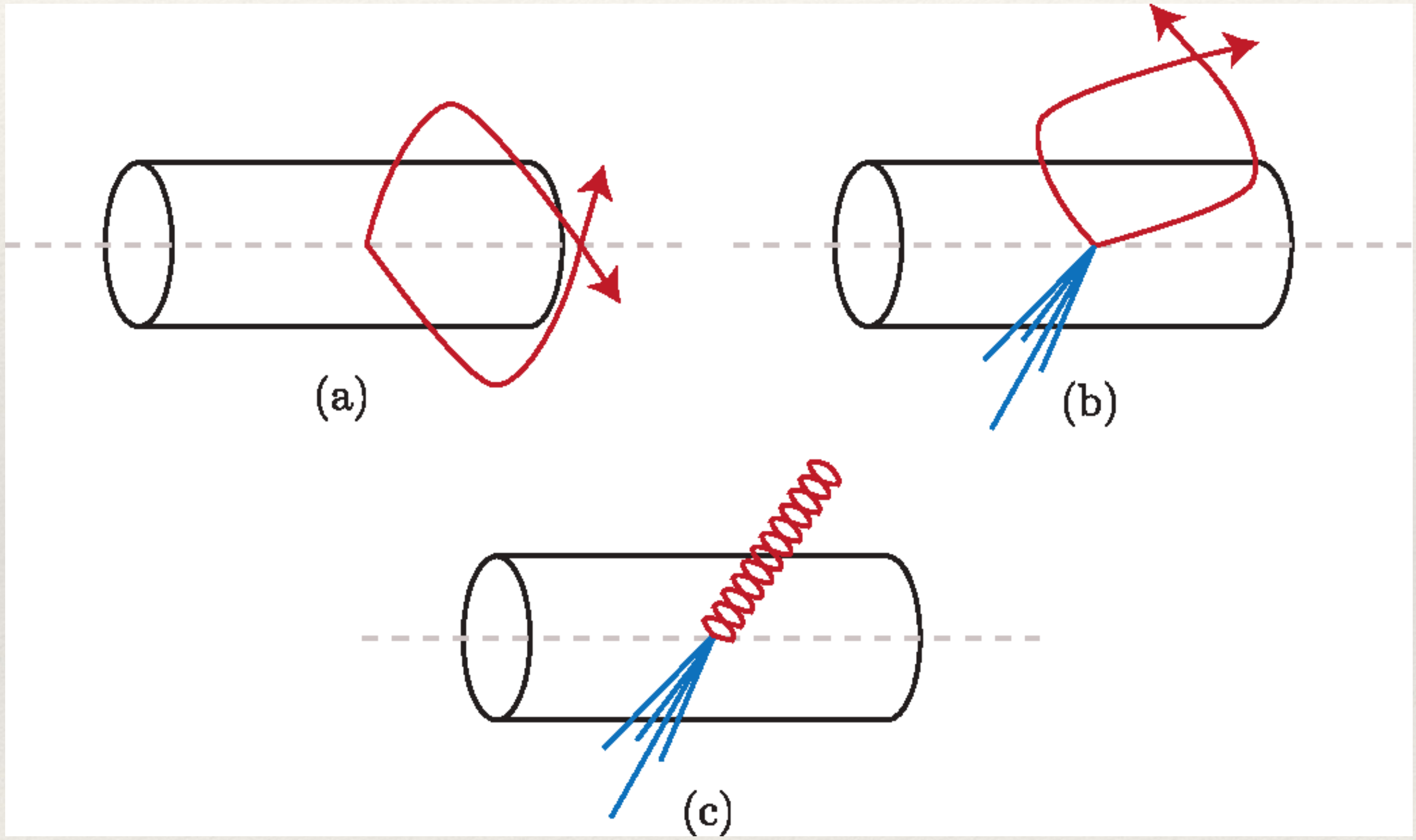




LLP CHALLENGES: EXOTICS

- There are even more difficult things to look for like **quirks**

Kang, Luty, arXiv:0805.4642



- Recent proposals for new searches, but right now propagation not even modelled in Geant4 (to my knowledge…)

Farina, Low, arXiv:1703.00912
Knapen *et al.*, arXiv:1708.02243

NOW IT'S YOUR TURN…

- Lots of challenges to overcome to make the best use of the HL-LHC to discover LLPs
- This workshop is a chance to qualitatively and quantitatively explore new ideas for detecting LLPs
    - Open-ended format is meant for you to explore new ideas that come up in discussions and foster new collaborations
- We're looking forward to seeing your ideas & results on Friday!