Z Boson Decay into the Hidden Sector ($Z \rightarrow \gamma_D H_D$)

BAILEY WEAKLEY

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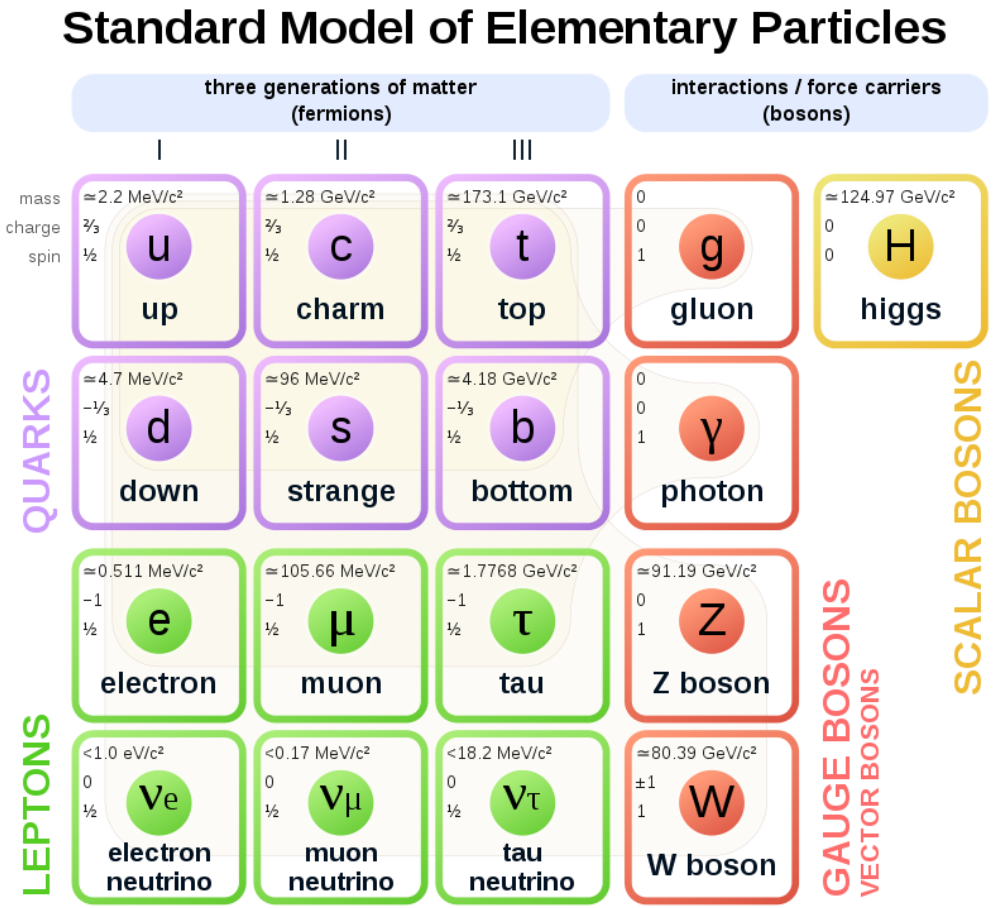
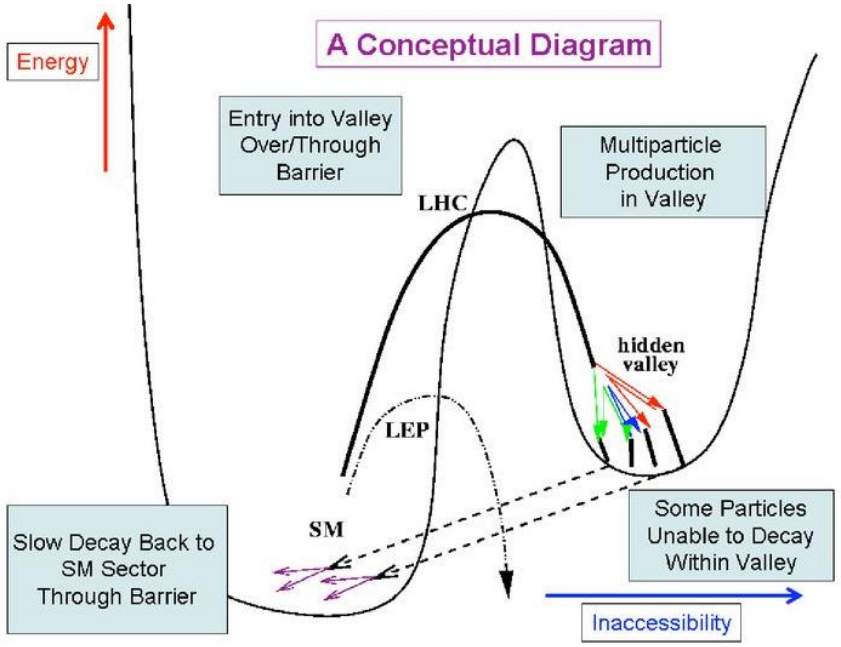
Background - The Standard Model

- Split into fermions (half integer spin) and bosons (integer spin)
- Bosons mediate forces
  - Photon – electromagnetic force
  - Gluon – strong force
  - W and Z bosons – weak force



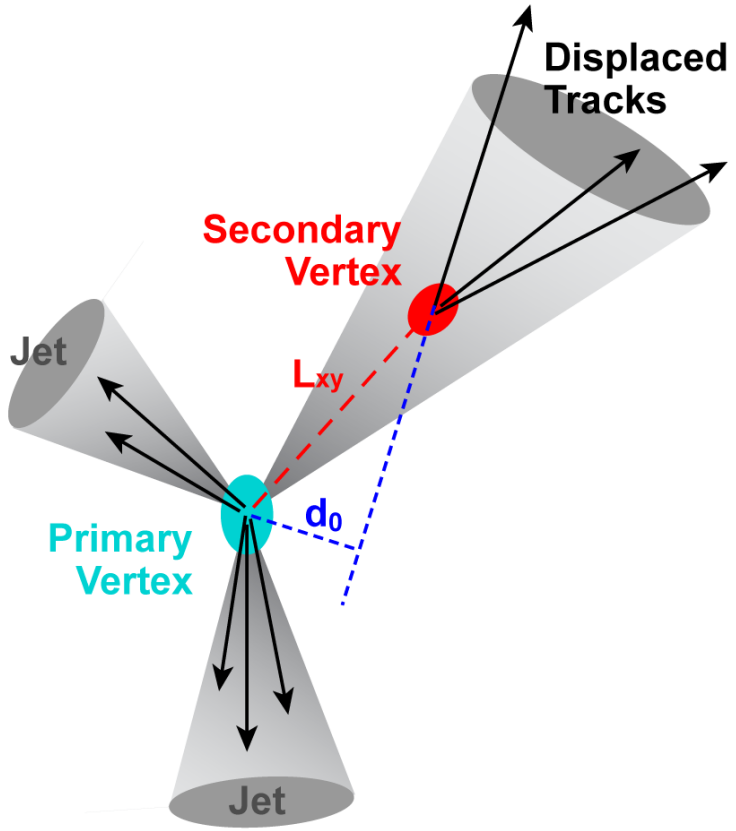
Hidden Sector

- Arise in many theories which attempt to resolve the hierarchy problem
- Hypothetical group of particles that do not interact by SM forces, possibly have their own forces
- Certain dark particles can mix with their SM counterparts, which allows the SM to decay into the hidden sector (HS) and vice-versa



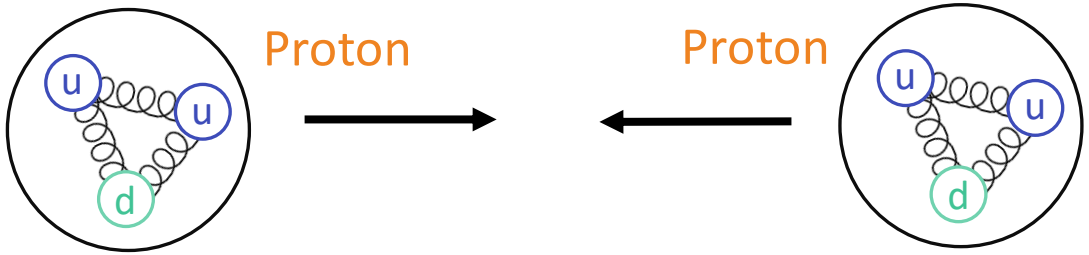
Long Lived Particles (LLPs)

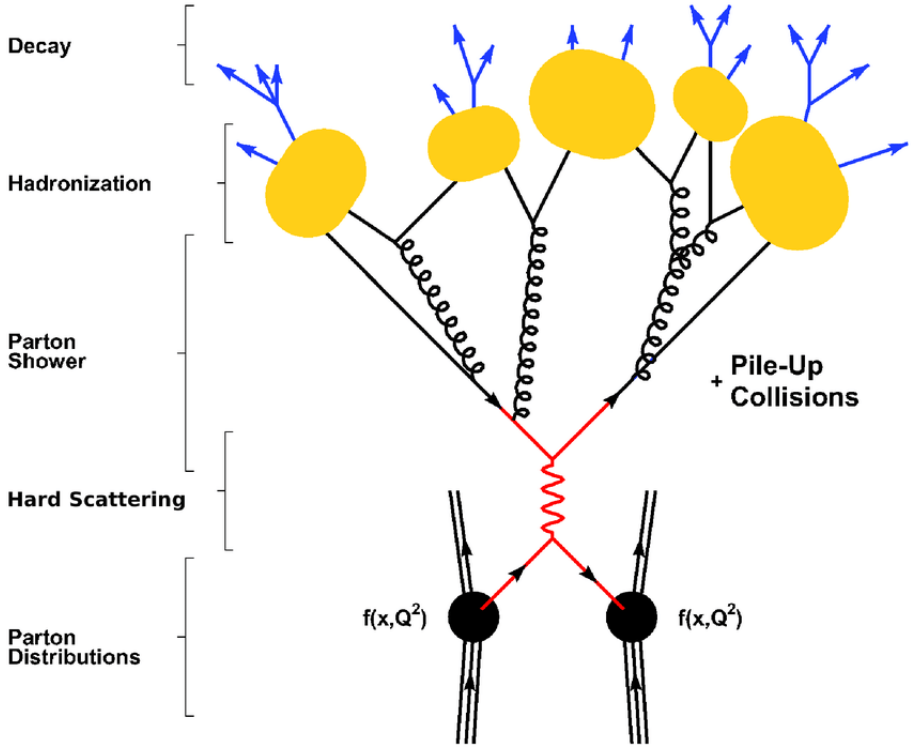
- Hierarchy problem suggests new models of LLPs
- Travels a measurable distance from the primary vertex before decaying in detector
- Detector made for prompt decays
  - Search for displaced vertexes



Collisions at CERN

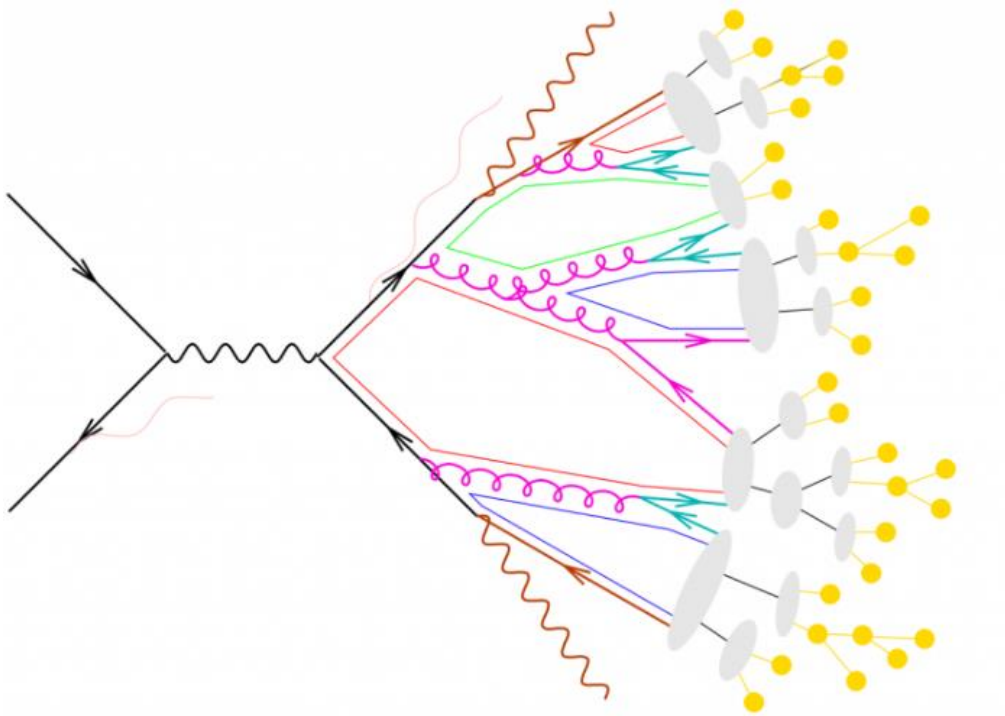
- Large Hadron Collider (LHC) produces pp (proton proton) collisions
  - Protons are made up of quarks and gluons (partons)
- Hard scattering is the interaction between a parton from one proton with another parton from another proton





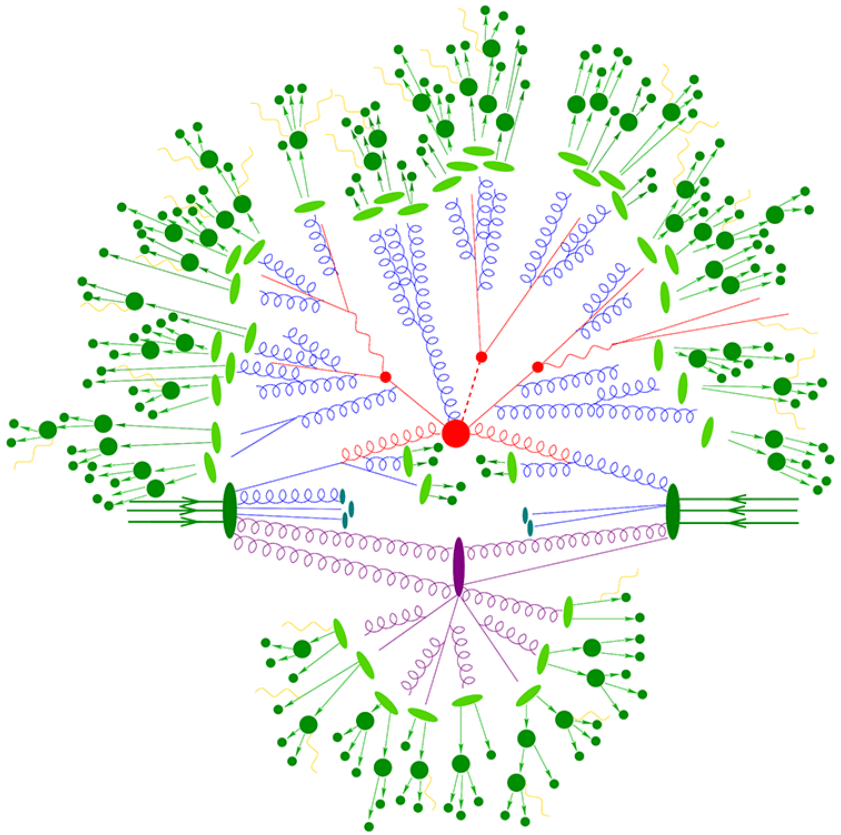
Parton Showers and Hadronization

- Parton Showers
  - Partons: quarks and gluons
  - Pulling quarks and antiquarks out of vacuum
- Hadronization
  - Converts partons into observable hadrons
  - Due to color confinement



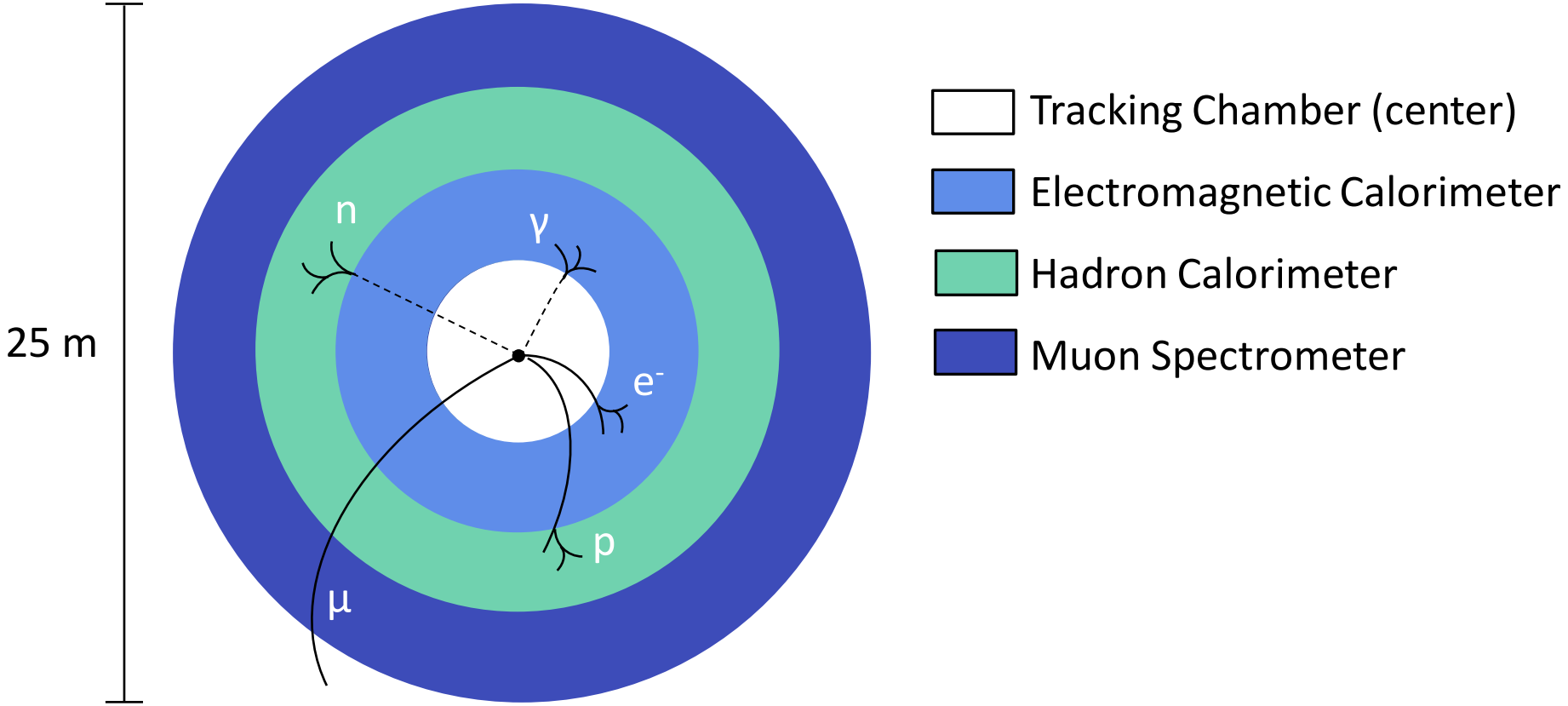
Monte Carlo Event Generator

- Generates simulation of random high-energy particle collisions using SM predictions
- Calculated from probability distributions of particles using perturbation theory
- Based on level of perturbation theory used, you can add corrections to the event generation

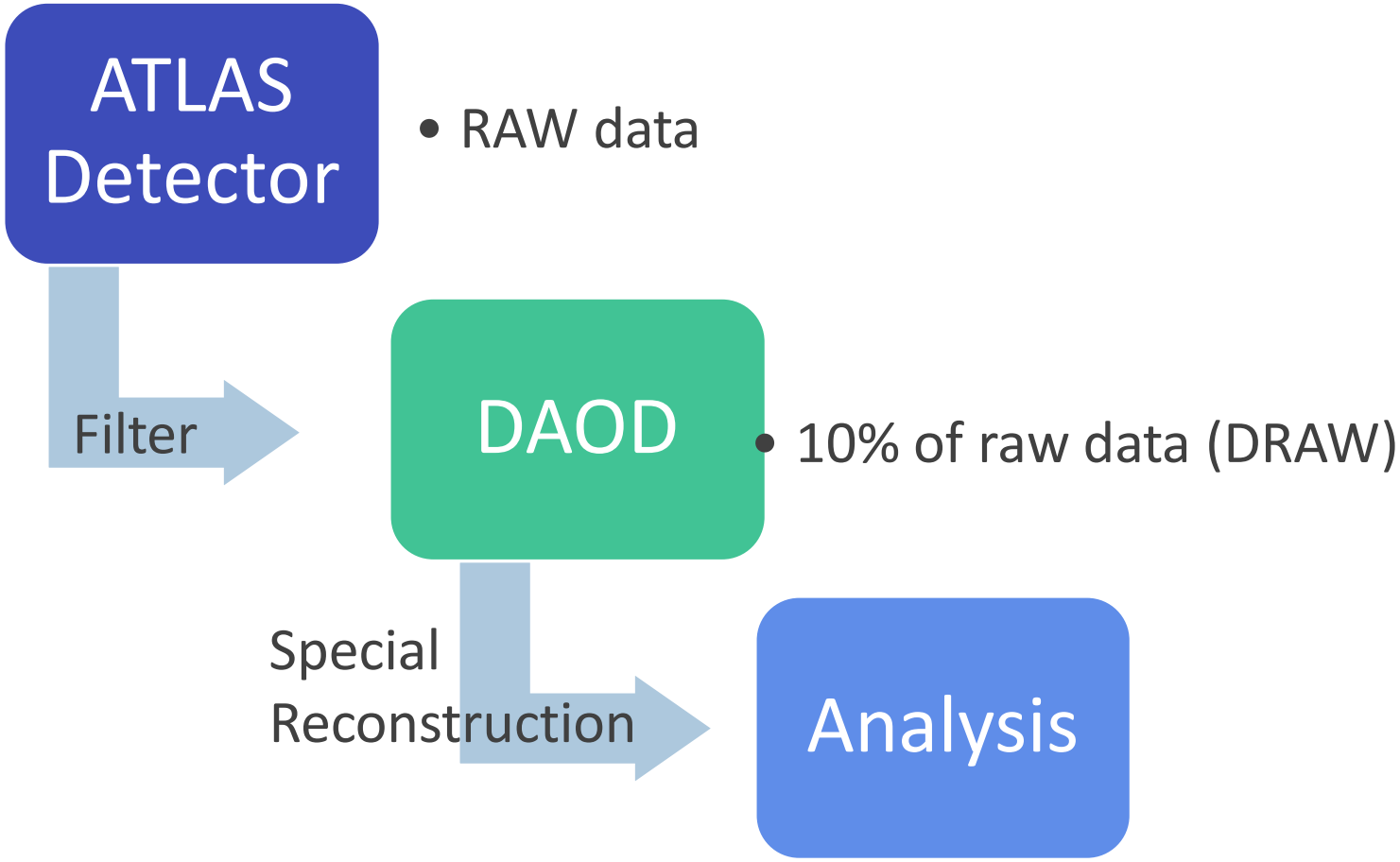


The ATLAS Detector

Simplified Cross-Section of the ATLAS Detector



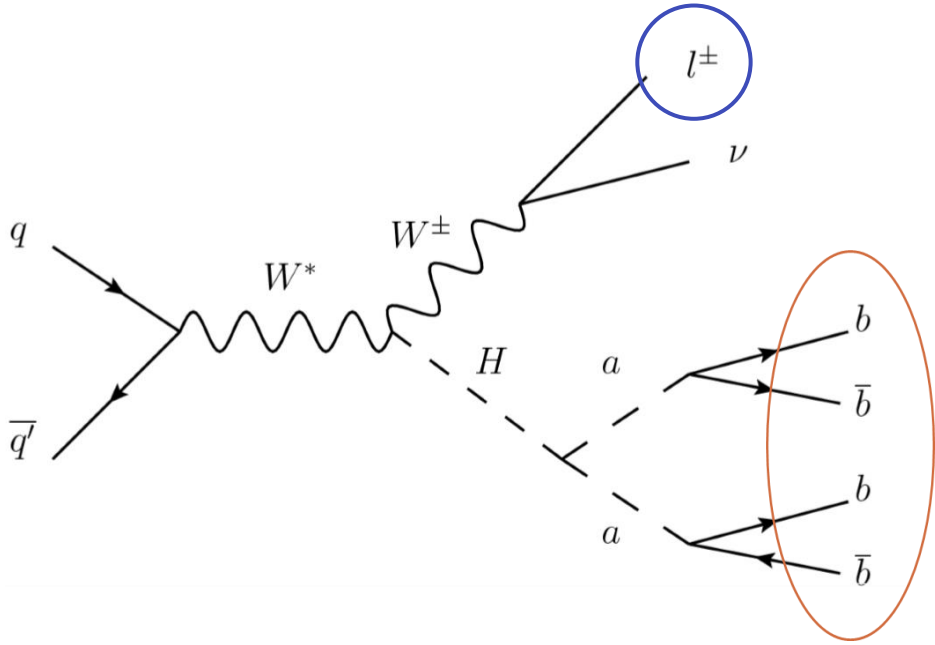
Workflow for Analysis



Credit: Amber Roepe

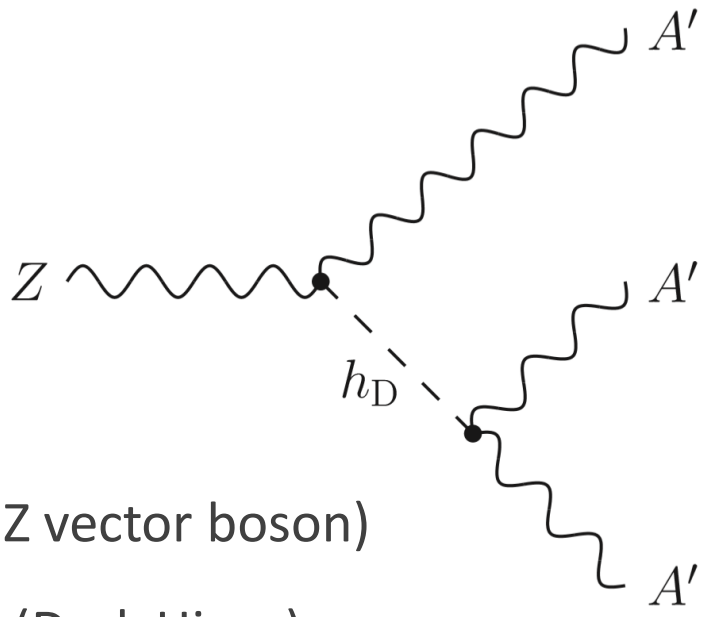
Current search for LLPs

- Current research in H → aa → 4b (VH(4b))
- Higgs-Strahlung process, which is produced with a W boson that decays leptonically
- Signature of interest is (prompt) lepton (W decay) and four displaced jets (aa decay)



Signal Model

- $Z \rightarrow \gamma_D H_D \rightarrow \gamma_D \gamma_D \gamma_D$
- Dark version of the Higgs-Strahlung process
- I am seeing if current analysis from VH(4b) will detect this decay
  - Both decays involve prompt leptons and displaced jets



Z (Z vector boson)

h_D (Dark Higgs)

A' (Dark photon)

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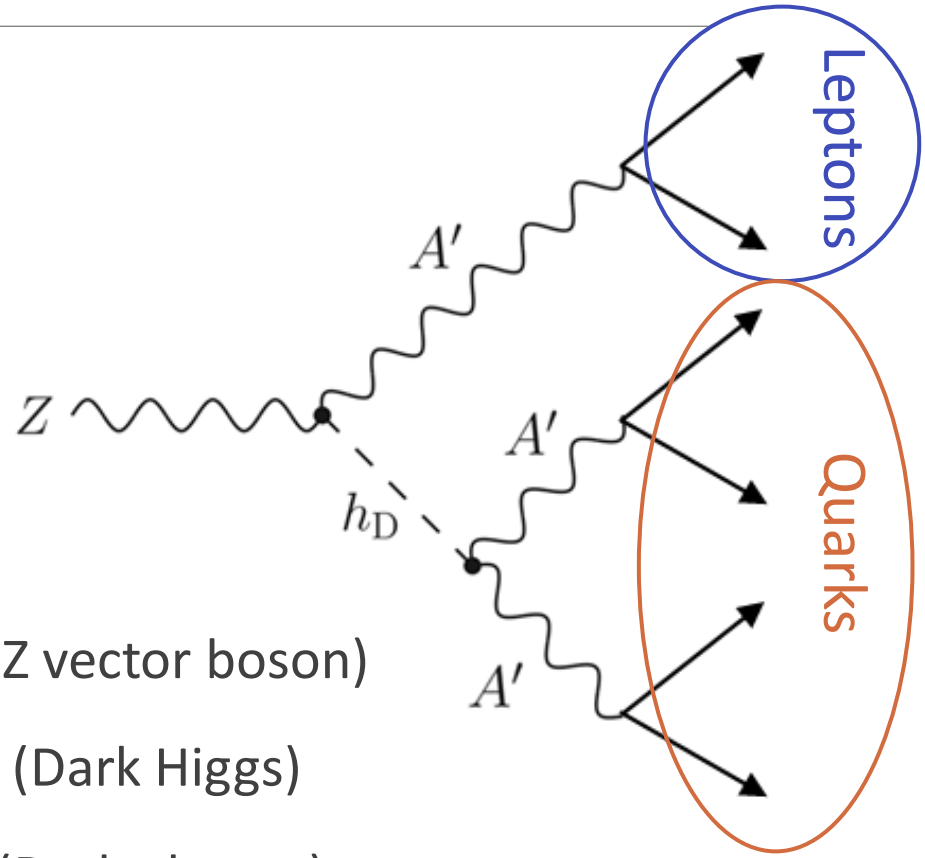


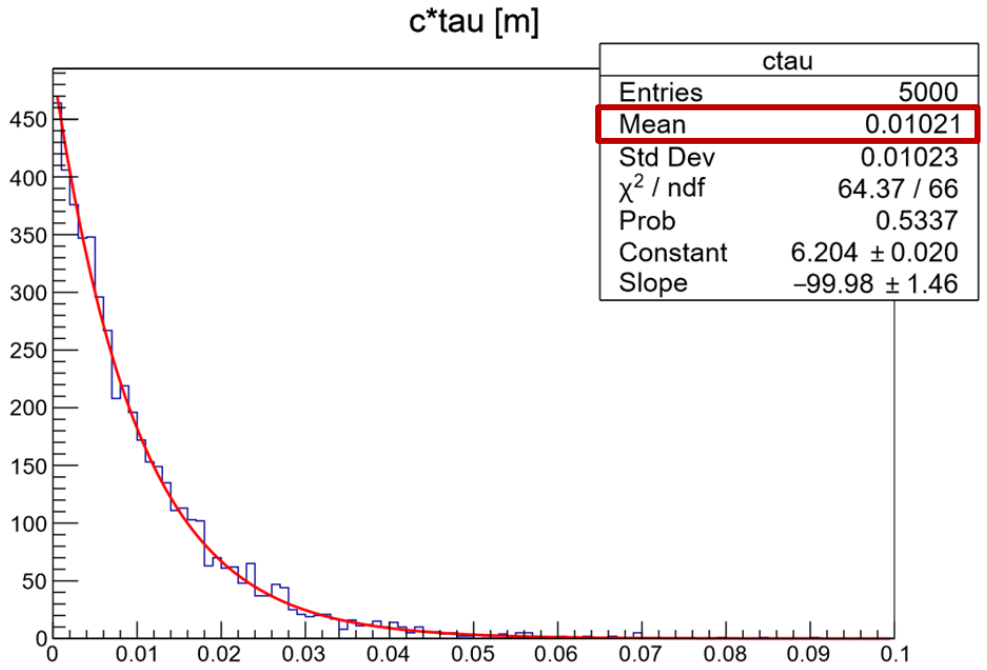
Z (Z vector boson)

h_D (Dark Higgs)

A′ (Dark photon)

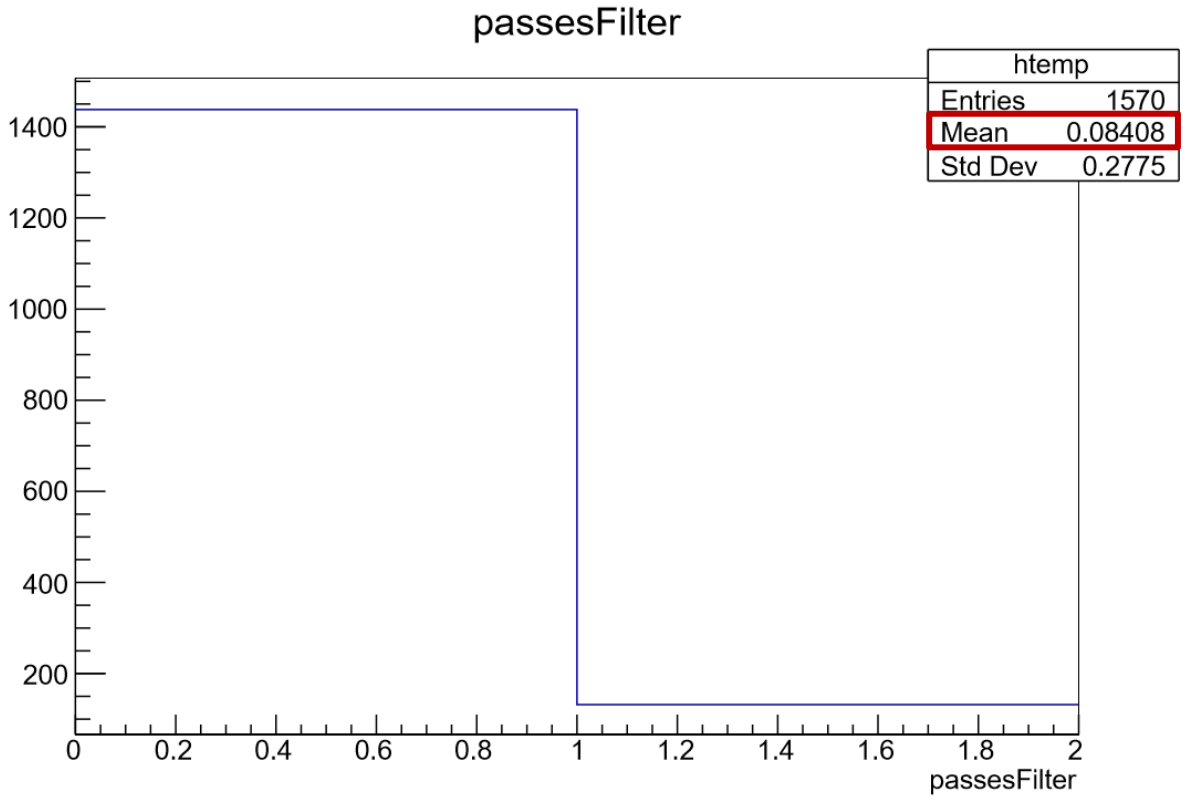
Process

- Use Hto4bLLP Algorithm, which is designed to keep 4b final states, to analyze MC with 2l2q final state
- MC I ran chose m_{DH} = 40 GeV and m_{DP} = 45 GeV
  - These masses could be anything, if $m_{DH} + m_{DP} \leq m_Z$ (91 GeV)
- MC chose LLP mean lifetime of 10 mm



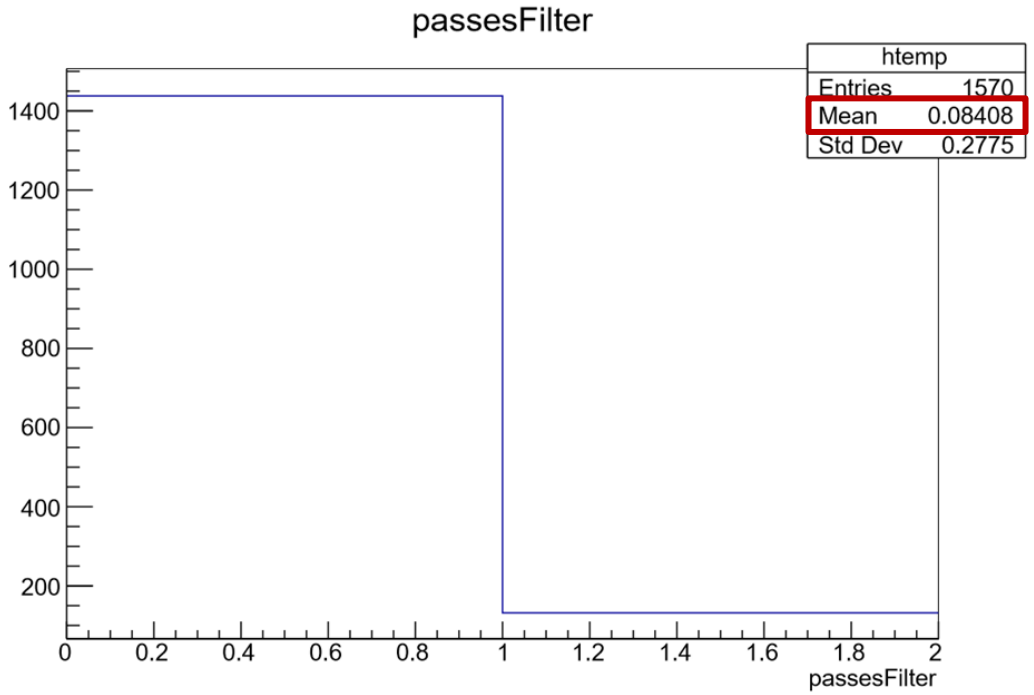
Filter Efficiency

- Filter = produced a displaced jet and a prompt lepton
- 8.4% passed filter
- If events do not pass filter, they do not go through reconstruction

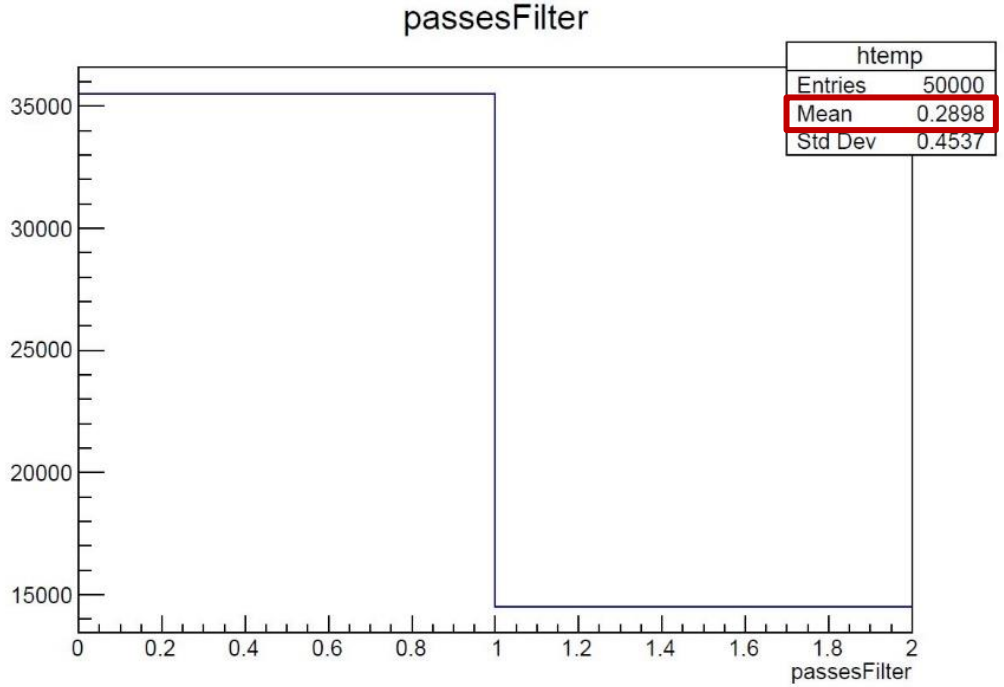


Filter Efficiency

Z → γDHD: 8.4%



4b: 28.98%

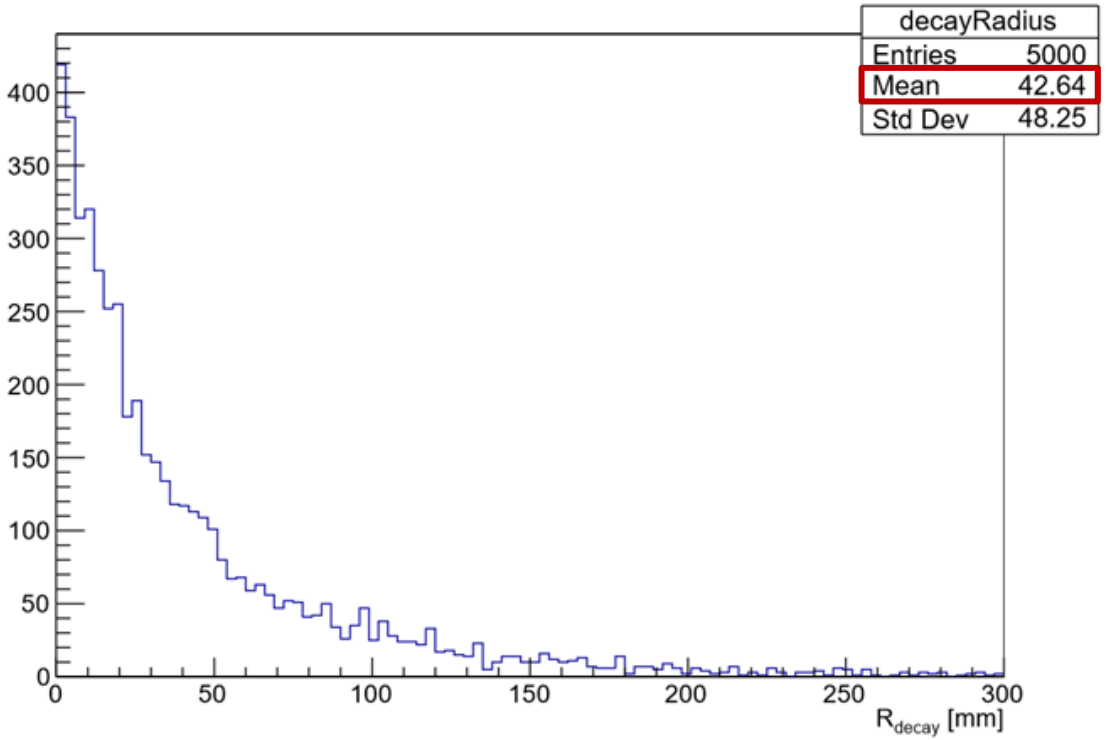


Why are these so different from 4b?

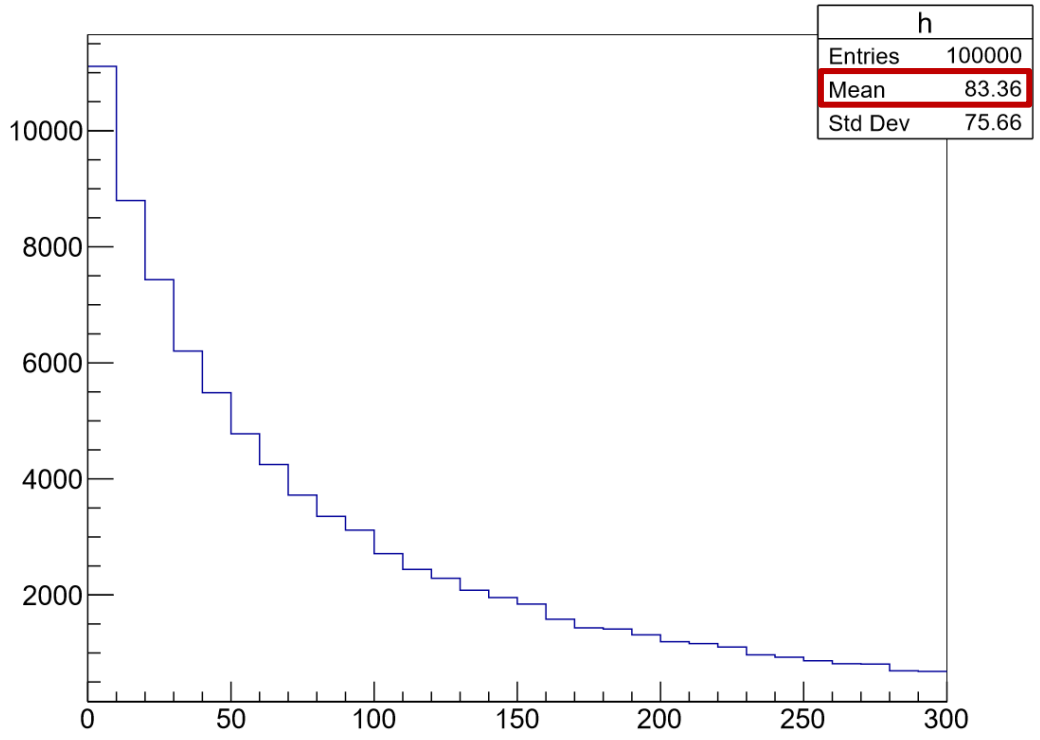
Credit: Bianca Azartash

LLP Lifetime Comparison

Z → γDHD: 42.64 mm



4b: 83.36 mm



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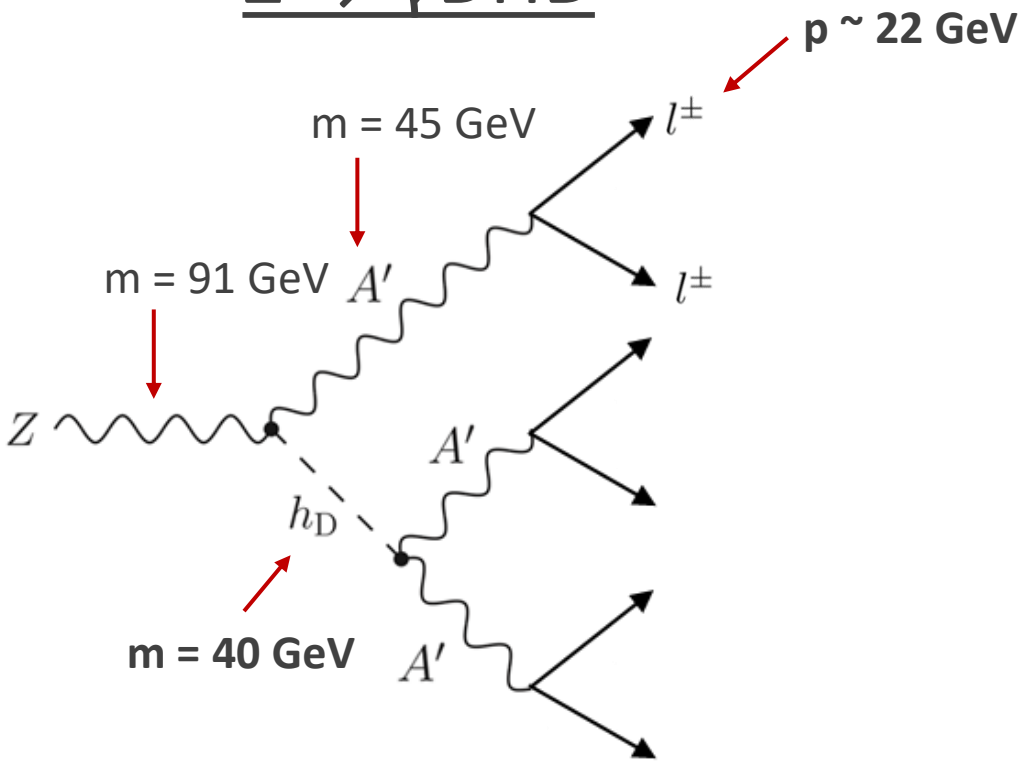
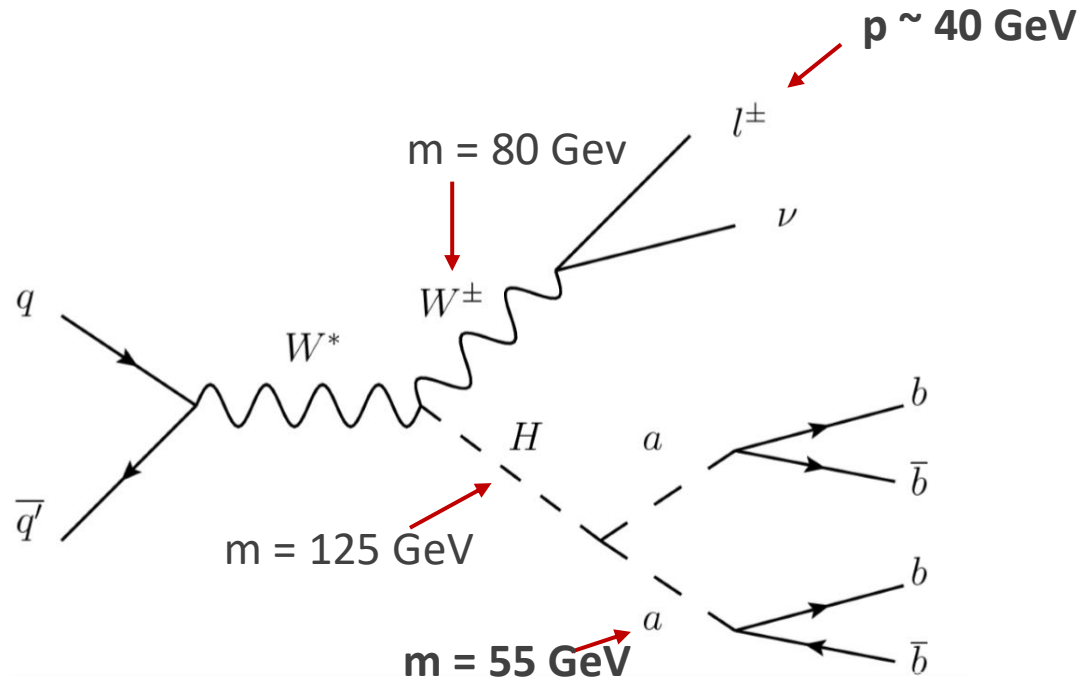
Comparison

Z → γDHD



4b



Filter requires lepton pT > 25 GeV

Conclusion

- Only 8.4% of the decay events passed the filter for the 4b analysis

due to:

  - LLP has shorter proper lifetime, therefore does not look displaced enough
  - Prompt lepton not having enough energy

Questions?

THANK YOU FOR LISTENING!