Search for new physics with long-lived particles

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Introduction

- Various models of new physics predict long-lived particles which travel a significant distance from the interaction point before decaying.

- Strategies capitalizing on the unique signatures improve triggering and reconstruction for such events at ATLAS.

- This talk will focus on Hidden Valley particles produced through Higgs decays.
Outline

- Hidden Valley Scenario
- Experimental Challenges
- ATLAS Trigger
- Decays within the Detector
  - Muon Spectrometer
  - Calorimeter
  - Inner Detector
- Status and Plans
Hidden Valley† Scenarios

- Beyond the Standard Model is a hidden sector (or v-sector) and a communicator interacts with both sectors
- A barrier “hides” the v-sector making production of v-particles rare at low energies
  - Communicator’s high mass
  - Weak couplings….
- Production of v-particles may be observable at the LHC
- Some v-particles may be stable (dark matter candidates) and others decay to Standard Model particles

†see:
Hidden Valley & Higgs Decays

Higgs decay to v-pions

- V-pion is neutral pseudo-scalar
  - Displaced decay mainly to bottom quark
- We use 2 samples to study trigger strategies for this process:
  - Ideal sample (signal only)
  - Signal with pileup
    - pileup for $L=10^{32}$ cm$^{-2}$ s$^{-1}$
    - 4.1 collisions/crossing
    - 450ns bunch spacing
- Parameters:
  - Higgs Mass = 140 GeV
  - $\pi_v$ Mass= 40 GeV
  - $\pi_v$ cτ = 1500 mm
- Events simulated using PYTHIA
- Work in collaboration with M. Strassler

see also:
Experimental Challenges

• Neutral states decaying far from the interaction point lead to challenges for the trigger
  ◦ Current ATLAS triggers center on particles originating from the Interaction Point

• Long-lived Hidden Valley particles will decay throughout the detector volume
  ◦ Depending on where the decay occurs different approaches are required

• We need special triggers for each the signature produced in each system
ATLAS Trigger

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Decays within ATLAS Detector

Probability for πν from gg fusion to decay in each detector region vs cτ for |η|< 2.5 (Inner Detector coverage)
Decays in Muon Spectrometer

- Little or no energy deposited in the calorimeter
- Characterized by a large number of charged tracks and a cluster of muon Regions of Interest (RoIs)
- Only 1 muon reconstructed per muon RoI with standard trigger
Decays in Muon Spectrometer

- Define a new Level 2 trigger algorithm using these signatures as:
  - At least 3 muon Regions of Interest at Level 1
  - Isolation wrt jets and Inner Detector tracks
- >70% Efficient for decays in the barrel Muon Spectrometer
- >25% in the endcap region
Decays in the Hadronic Calorimeter

- Decays in the calorimeter produce very narrow jets
- No reconstructed tracks in the Inner Detector
- Large energy deposited in the Hadronic Calorimeter (HCAL)
- Little energy in the Electromagnetic Calorimeter (ECAL)
Decays in the Hadronic Calorimeter

- Narrow jet shape allows of use a Level-1 \( \tau \) trigger to select these decays
- We define a Level 2 trigger using these signatures as:
  - \( \log_{10}(E_{HCAL}/E_{ECAL}) > 1 \)
  - Isolation wrt Inner Detector tracks
Decays in the Inner Detector:

- Low efficiency for normal tracking algorithms
- Trigger on trackless jets containing muons

Level 2 jet trigger:

- \( E_T \geq 35 \text{GeV} \) in Electromagnetic Calorimeter (ECAL)
- No reconstructed tracks
- Seed with Level 1 muon

Absolute efficiency \( \sim 2\% \) (due to requiring the muon in the event)

Studies ongoing to define a more efficient trigger in the Inner Detector:

- Backtracking and vertex finding in ID
- Jet substructure in the ECAL
Status of Improvements

- **New L2Trigger Algorithms**
  - Cluster of Muon objects isolated from tracks and jets
    - L1 dimuon trigger
  - Narrow trackless jets with high hadronic/EM Energy
    - L1 tau trigger
  - Trackless EM jet with a muon
    - L1 muon & L1 jet triggers

- **Backgrounds**
  - None of 3M minbias events pass the triggers
  - Sample of 10 TeV di-jet events at $10^{32}\text{cm}^{-2}\text{s}^{-1}$ have less than 1 Hz combined L2 trigger rates
Related Searches

• Ongoing work using similar strategies for neutral long-lived particles decaying to lepton jets (Weiner et al., Lin-Tao et al.)

• Trigger and reconstruction improvements for charged stable massive particles in each part of ATLAS
  ◦ Muon system (see talk by Shlomit Tarem)
  ◦ Calorimeters (see talk by Philippe Mermod)
  ◦ Ongoing work on Inner Detector
Conclusions

- New signature-based triggers have been created to reconstruct long-lived neutral particles decaying in ATLAS
  - Improvement in overall Higgs to Hidden Valley event efficiency from ~2% to >20%

- Ongoing work on Inner Detector Decays and Event Filter trigger selection may contribute further improvements

- We are developing strategies to use ATLAS to search for neutral and charged massive long-lived particles in new physics models