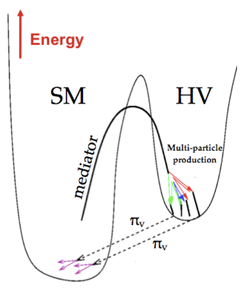
LHCC Poster Session - CERN, 21 March 2012

Search for weakly-interacting long-lived particles with the ATLAS detector

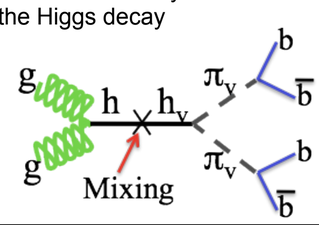
Abstract

A search for the decay of a light Higgs (120 - 140 GeV) to a pair of weakly-interacting, long-lived particles in 1.94 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 7 TeV recorded in 2011 by the ATLAS detector is presented. The search strategy requires that both long-lived particles decay inside the muon spectrometer.

Hidden Valley Models



- "Hidden Valley" (HV) models are a general class of models that naturally produce long-lived particles
- Hidden Valley and SM only communicate through mediator particles (**higgs**)
- The lightest v-particles, "v-pions" (π_v's) are stable in the v-sector, but can decay back to the SM with long lifetimes
- Pseudoscalar π_v's decay to heavy flavor (85% bb, 8%$\tau^+\tau^-$, 5% cc)
- Presence of the Hidden Valley can alter the branching fractions for the Higgs decay

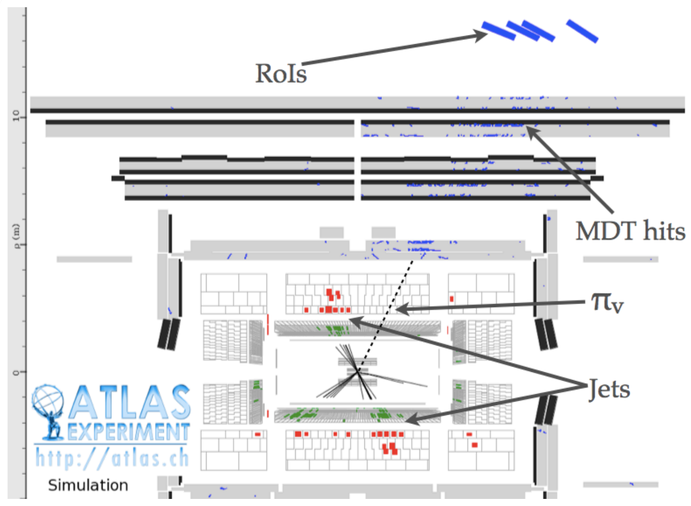


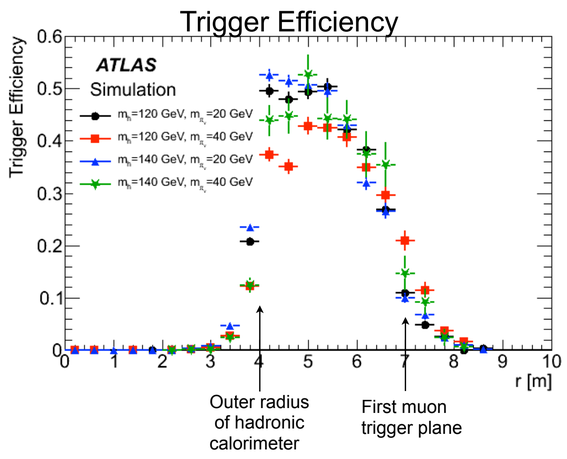
† M. Strassler, K. Zurek, *Echoes of a Hidden Valley at Hadron Colliders*, Phys. Lett. B651 (2007) 374
Arkani-Hamed, et al., *LHC signals for a SuperUnified Theory of Dark Matter*, arXiv:0810.0713

Dedicated Long-lived Particle Trigger

- ATLAS uses a three tiered trigger system
  - Level 1 trigger selects "Regions of Interest" (RoIs) to be processed by the HLT
- Dedicated Level 2 trigger used to select candidate events with a π_v decay in the MS
  - Active in the barrel region ($|\eta| < 1$)
- The Muon RoI Cluster Trigger selects events with at least 3 Muon RoIs in a cone of $\Delta R < 0.4$
  - Requires isolation with respect to:
    - jets (L2 $E_T > 35$ GeV, within $\Delta R < 0.4$)
    - ID tracks ($p_T > 5$ GeV, within $\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$)

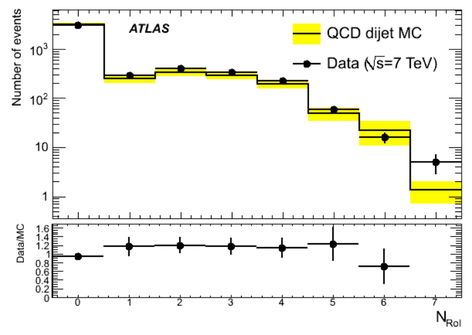
Triggering on Long-lived Particles





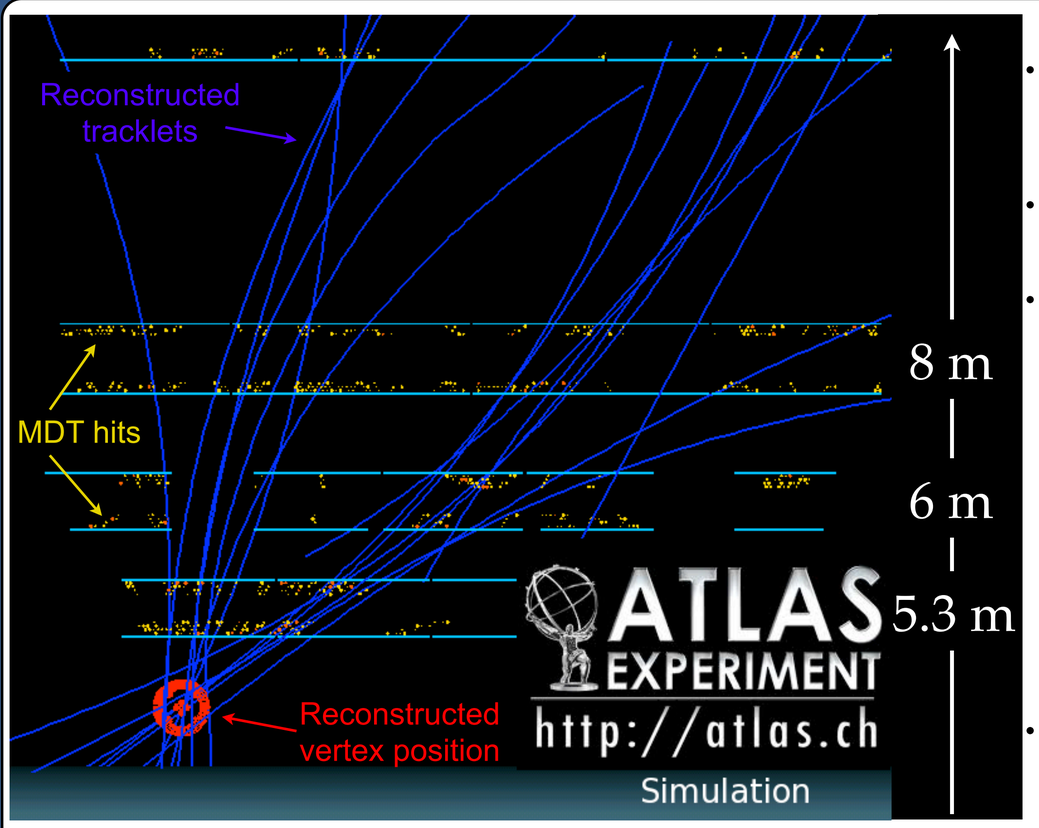
Data/MC Comparison

- Use punch-through jets to get a sample of events with low energy hadrons/photons in the muon spectrometer
- Define a punch-through jet as:
  - $|\eta| < 1.4$ (contained in the extended barrel calorimeter)
  - $E_T > 20$ GeV
  - MET > 20 GeV aligned with the jet axis
  - at least 4 tracks in the ID ($p_T > 1$ GeV) inside the jet cone
  - at least 300 MDT hits in a cone of $\Delta R=0.6$ around the jet axis
- The muon RoI cluster trigger is run on these punch-through jets and the number of muon RoIs contained in the cluster is counted for data and MC



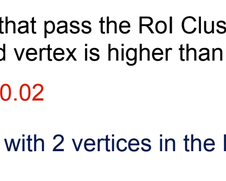
- A horizontal line fit to the ratio of data to MC for $N_{RoI} \geq 1$ yields 1.14±0.09
  - The 14% discrepancy from 1 is taken as a systematic uncertainty on the trigger efficiency
- Uncertainties due to the Jet Energy Scale, ISR spectrum and pileup were found to be negligible

Reconstructing Vertices in the Muon Spectrometer



Tracklet and Vertex Reconstruction

- Due to the ~5 π^0's present in the π_v decay, large EM showers accompany the ~10 charged particles in signal events
  - ~75% of the Monitored Drift Tube (MDT) hits in signal events are caused by the EM shower
- The design of the MDT chambers, which have two multilayers (ML) separated by up to 31 cm, provides a powerful tool for track pattern recognition
- "Tracklets" are reconstructed by matching single ML segments between the two MLs using 2 parameters: Δb and $\Delta\alpha$
  - Δb is the distance of closest approach at the middle plane of the MDT chamber
  - $\Delta\alpha$ is the amount of bending inside the chamber and can be used to measure tracklet momentum with an uncertainty of $\delta p/p \approx [0.06\text{-}0.09]*p/\text{GeV}$



- Vertices are reconstructed as the point in (r,z) which uses the most tracklets to reconstruct a vertex with χ^2 probability greater than 5%

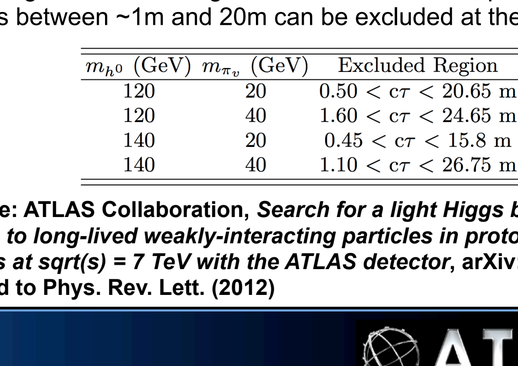
Data/MC Comparison

- The sample of punch-through jets was used to validate the MC description of hadrons and photons in the MS
- The fraction of jets which produce a vertex in the MS as a function of the number of MDT hits is compared between data and MC
- The data-to-MC ratio is fit to a horizontal line with the result 1±0.15

Number of MDT hits	QCD dijet Monte Carlo	Data
$300 \leq N_{MDT} < 400$	10.1±2.2 %	9.1±0.5 %
$400 \leq N_{MDT} < 500$	9.2±2.8 %	10.5±0.7 %
$500 \leq N_{MDT} < 600$	13.1±5.4 %	13.0±0.9 %
$N_{MDT} \geq 600$	16.5±4.5 %	16.7±0.7 %

- The 15% uncertainty is taken as a systematic uncertainty on the vertex reconstruction efficiency
- Additional uncertainties due to the isolation criteria from the Jet Energy Scale, ISR spectrum and pileup contribute 3%, 3%, and 2% respectively
- Total systematic uncertainty on the vertex reconstruction efficiency is 15%

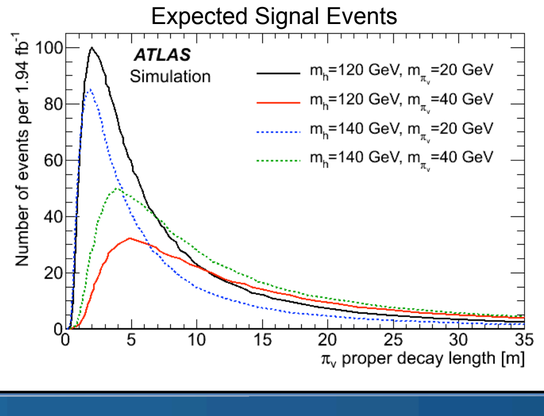
Vertex Reconstruction Efficiency



Analysis Strategy

- Search for two π_v's decaying inside the muon spectrometer
- Select only events passing the Muon RoI Cluster Trigger
- Events will have two MS vertices which are back-to-back ($\Delta R > 2$)
- Require that each vertex satisfy the following criteria:
  - Vertex points to the IP (sum of the tracklet p_z points to IP)
  - Isolated w.r.t. jets with $E_T \geq 15$ GeV and $\text{Log}_{10}(E_{HAD}/E_{EM}) \leq 0.5$ such that $\Delta R(\text{jet,vertex}) \geq 0.7$
  - $|\eta_{vx}| < 2.2$ such that the vertex is contained in the ID tracking coverage
  - Isolated w.r.t. ID tracks with $p_T \geq 5$ GeV such that $\Delta R(\text{track,vertex}) \geq 0.4$

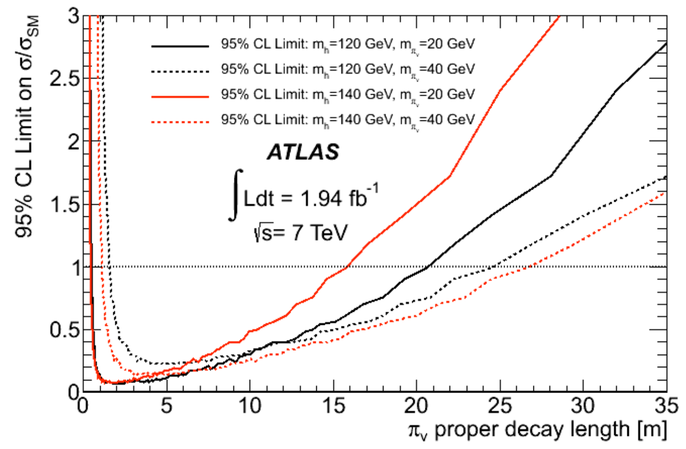
Expected Signal Events



Backgrounds

- Number of fake two vertex events can be calculated as:
  N_{fake}(2 vertex) = N(1 vertex,1 Trig)*P(vertex) + N(MS vertex,2 Trig)*P(reco)
  - N(1 vertex,1 Trig) is the number of events in 2011 data that pass our trigger selection and have a reconstructed vertex in the muon spectrometer (**15543**)
  - P(vertex) is the probability that a random event (no trigger requirement) has a vertex in the muon spectrometer ($2/2.055*10^6$ = **$(9.7\pm6.9)*10^{-7}$**)
  - N(MS vertex,2 Trig) is the number of events with a vertex in the MS that passed the RoI Cluster trigger with 2 distinct RoI clusters (**1**)
  - P(reco) is the probability to reconstruct a vertex in events that pass the RoI Cluster trigger ($15543/(1.3571*10^6)$ = **$(1.11\pm0.01)*10^{-2}$**)
- The first term gives the expected number of events that will have a second vertex in spectrometer from an uncorrelated source (machine background, cosmics, ...)
- The second term gives the expected number of events that will have a second vertex in the spectrometer given there was a second RoI Cluster
  - Topology is different for events that pass the RoI Cluster trigger and the probability to reconstruct a good vertex is higher than P(vertex)
- Therefore, N_{fake}(2 vertex) = 0.03±0.02
- In 1.94 fb^{-1} of data, found 0 events with 2 vertices in the MS

Results



- Assuming 100% branching fraction for $h \to \pi_v\pi_v$, π_v proper decay lengths between ~1m and 20m can be excluded at the 95% CL

m_{h^0} (GeV)	m_{π_v} (GeV)	Excluded Region
120	20	$0.50 < c\tau < 20.65$ m
120	40	$1.60 < c\tau < 24.65$ m
140	20	$0.45 < c\tau < 15.8$ m
140	40	$1.10 < c\tau < 26.75$ m

Reference: ATLAS Collaboration, *Search for a light Higgs boson decaying to long-lived weakly-interacting particles in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector*, arXiv:1203.1303, submitted to Phys. Rev. Lett. (2012)

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