SEARCH FOR LONG-LIVED MASSIVE PARTICLES WITH THE ATLAS DETECTOR

CHRISTOPHER MARINO
ON BEHALF OF THE ATLAS COLLABORATION

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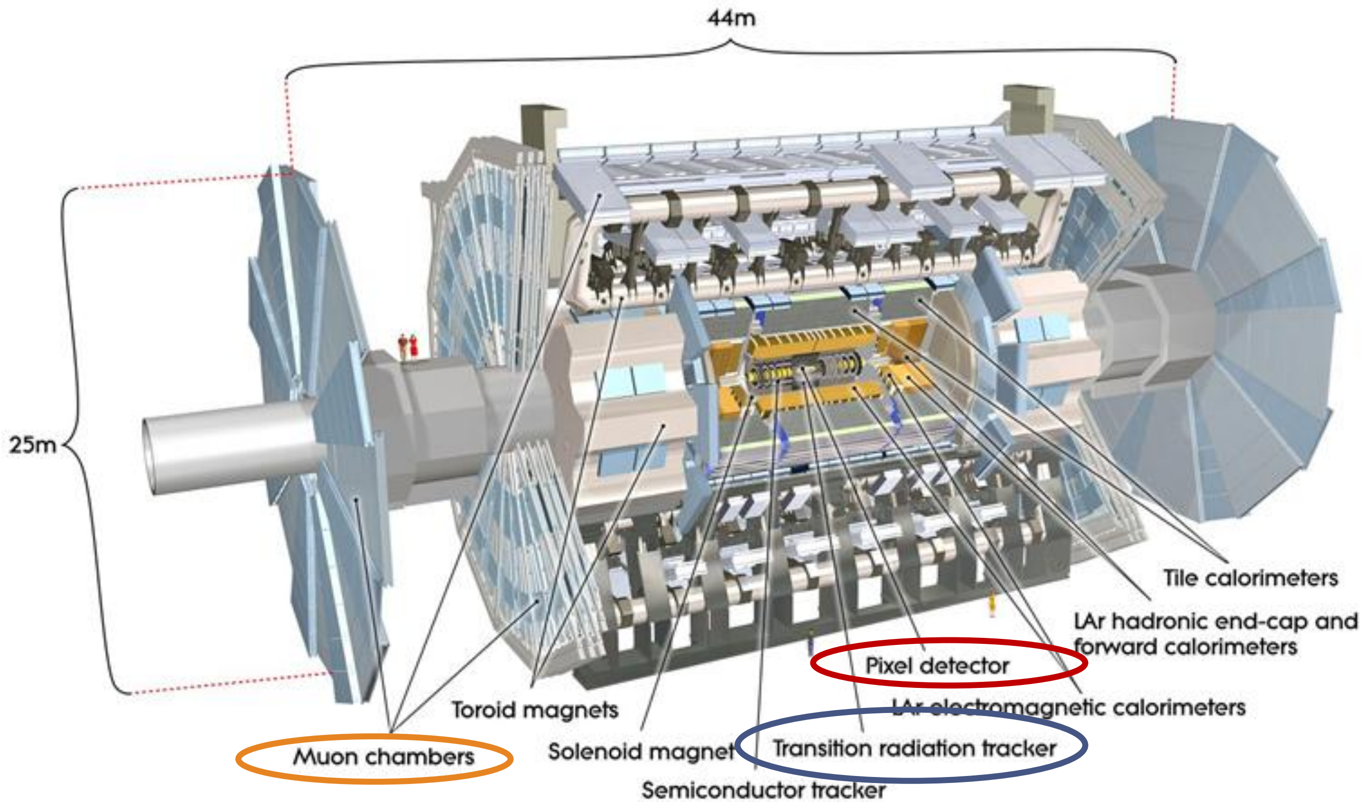
ATLAS EXPERIMENT
http://atlas.ch

University of Victoria

OVERVIEW

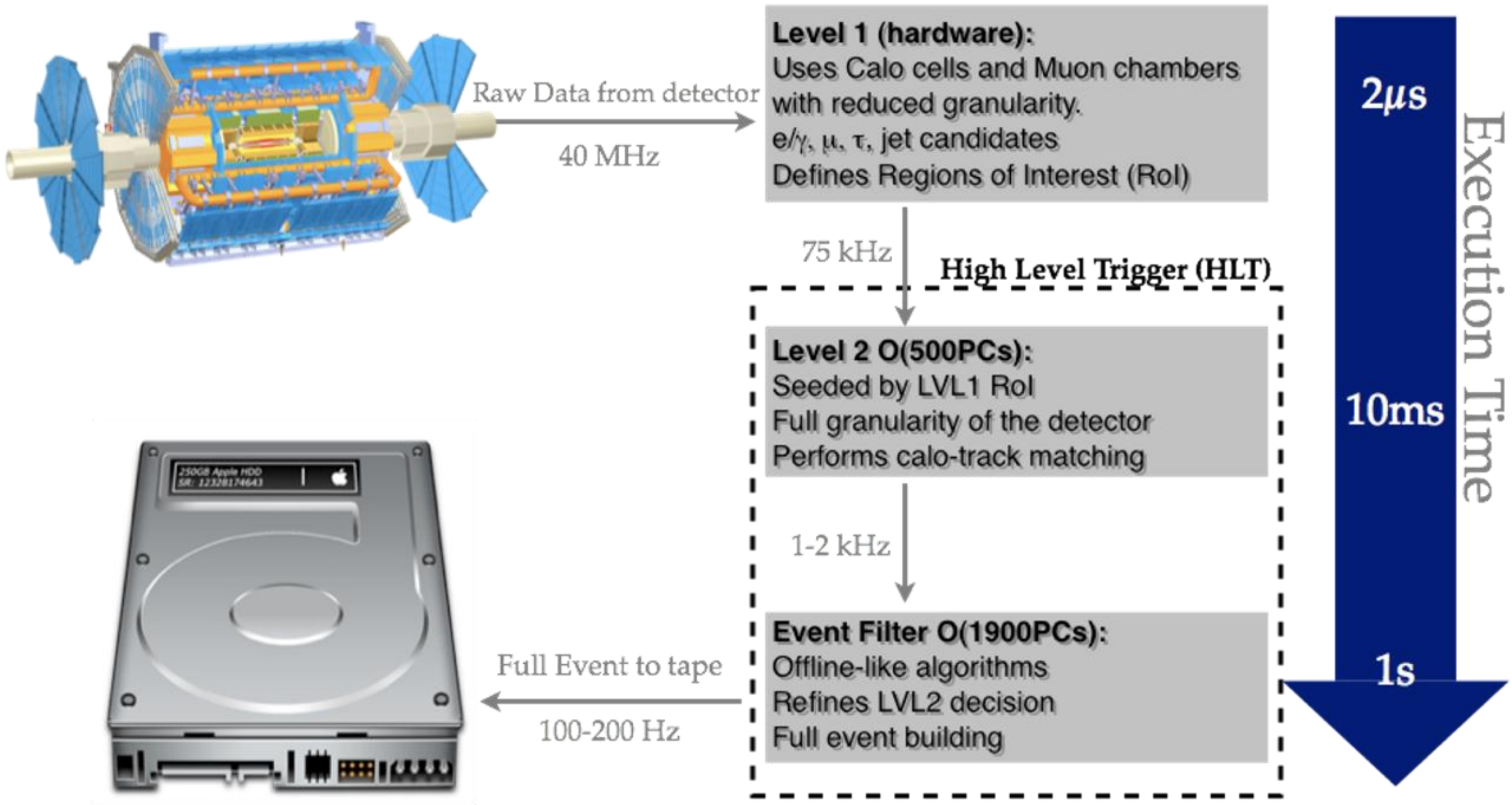
- **ATLAS detector and trigger**
- **Three recent searches for long-lived particles at ATLAS (1-2 fb^{-1} of data)**
  - Anomaly-mediated SUSY using disappearing tracks
  - Hidden Valley light Higgs using displaced decays
  - Hadronically interacting R-hadrons using dE/dx
- **Conclusions**

ATLAS DETECTOR



"Long-lived" means passing through part of the detector before decaying

TRIGGERING

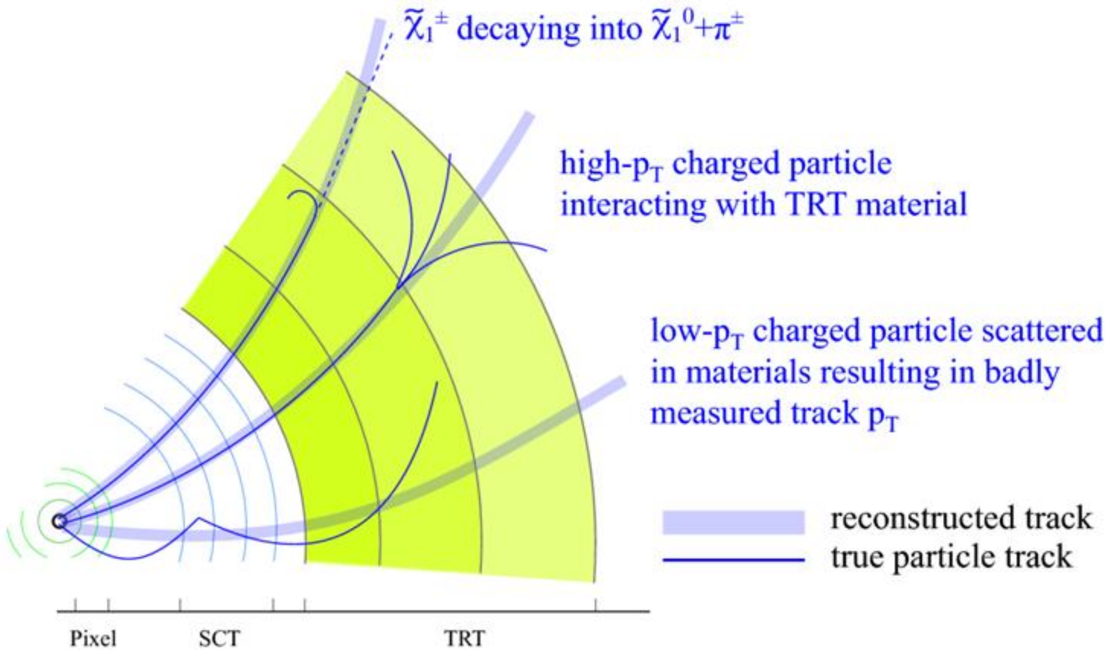


Long-lived Particles utilize signatures that may require special triggers or reliance on associated production:
delayed timing, high ionization, displaced vertices, or disappearing tracks

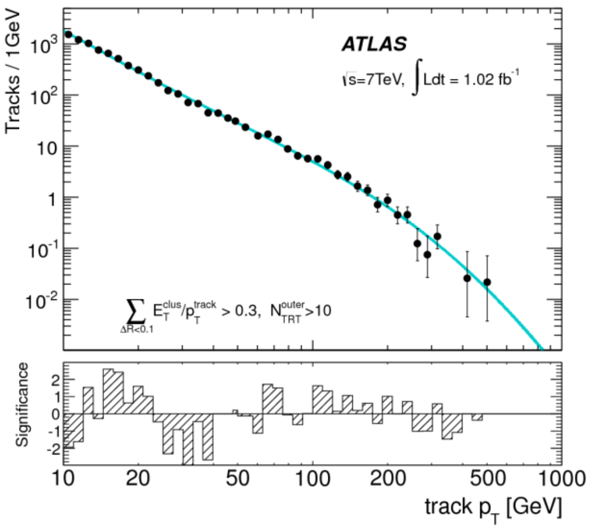
SEARCH FOR AMSB BASED ON HIGH-PT DISAPPEARING-TRACK SIGNATURE

In models of anomaly-mediated supersymmetry breaking (AMSB), the lightest chargino is predicted to have a long lifetime due to small mass difference

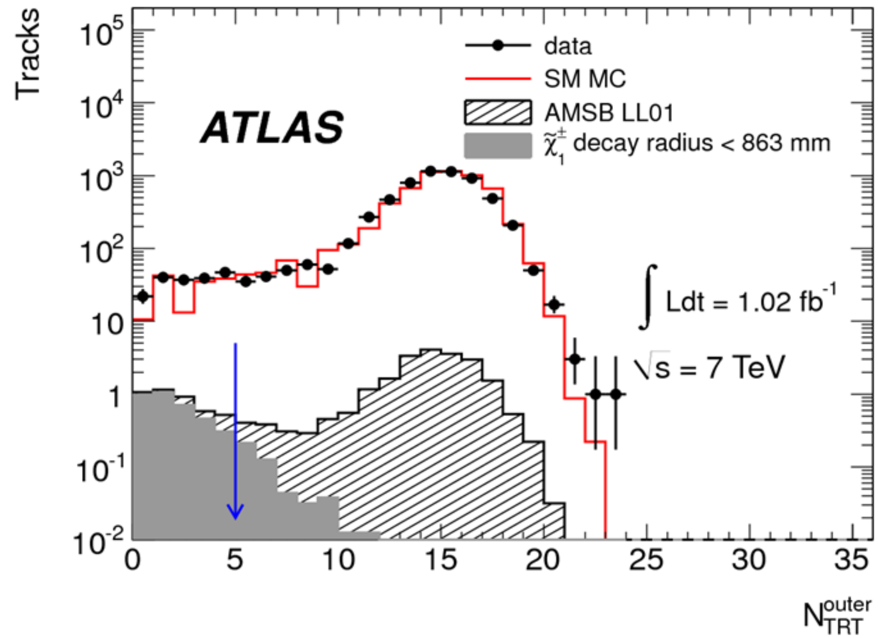
- Chargino decays to LSP neutralino and low-pT pion
- LSP leaves the detector
- Trigger on the high-pT jet and missing energy
- Look for tracks with few hits in the outer part of tracker
- Real and fake backgrounds

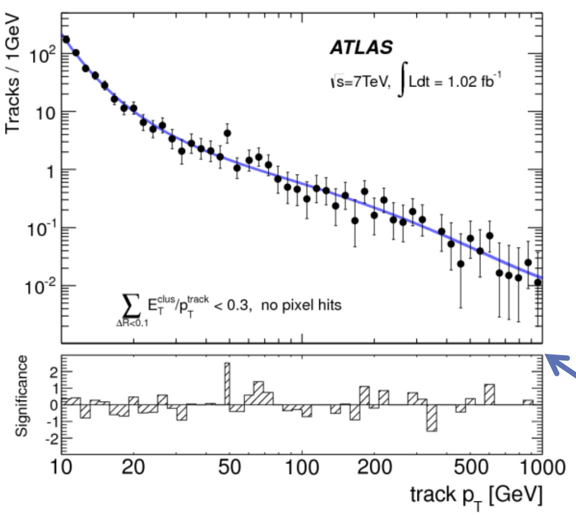


DISAPPEARING TRACKS AND BACKGROUNDS



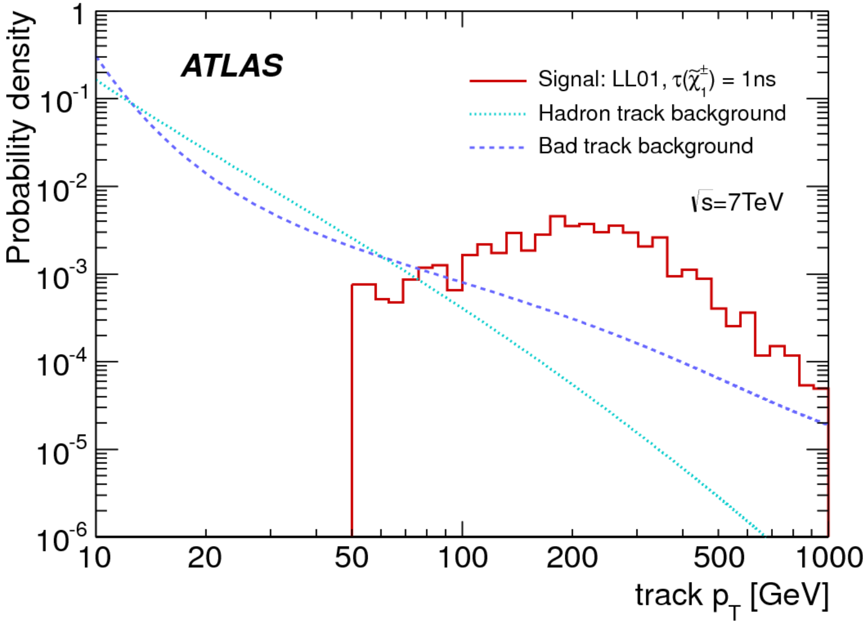
Disappearing tracks are identified by 5 or less hits in the outer layer of the Transition Radiation Tracker

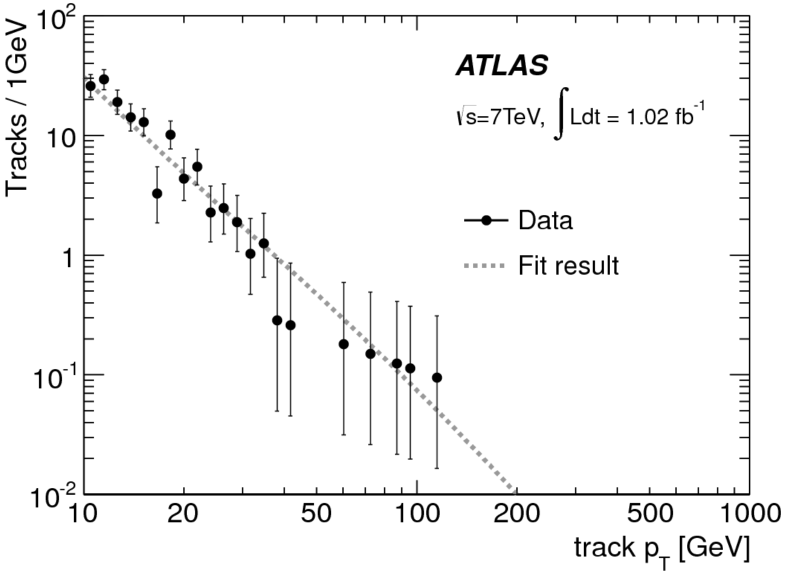




The pT distributions for the high-pT hadron track (non-disappearing tracks) and for the bad track (no pixel hits, low missing energy) background control samples.

AMSB SIGNAL EXTRACTION

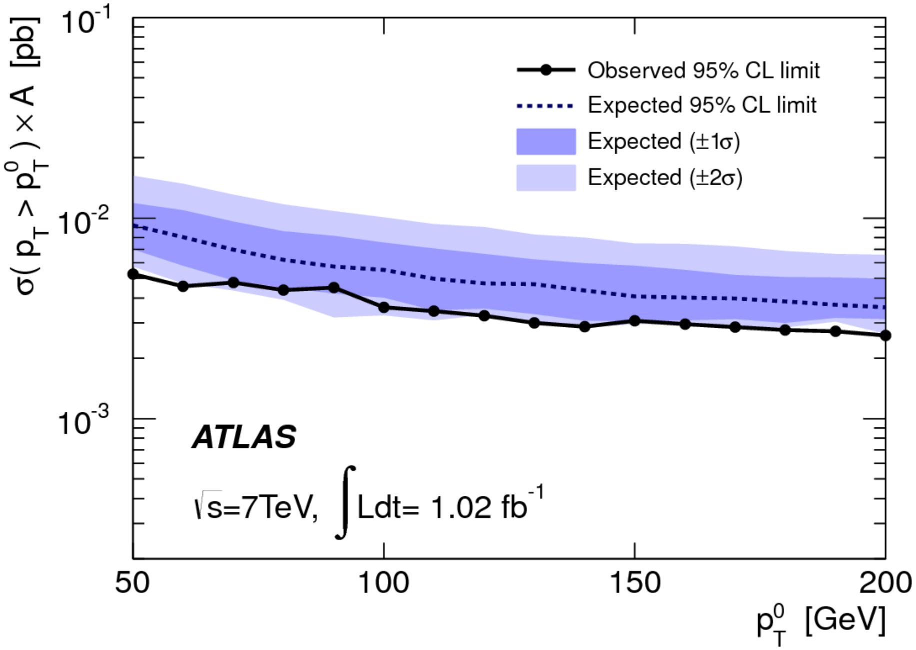




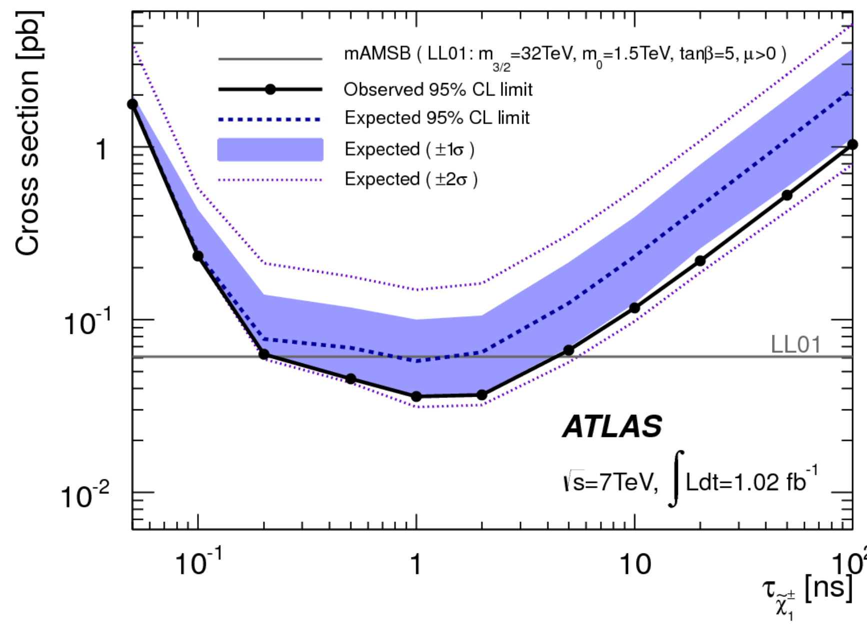
Maximum likelihood fit of pT distributions to data

No signal contribution

LIMITS



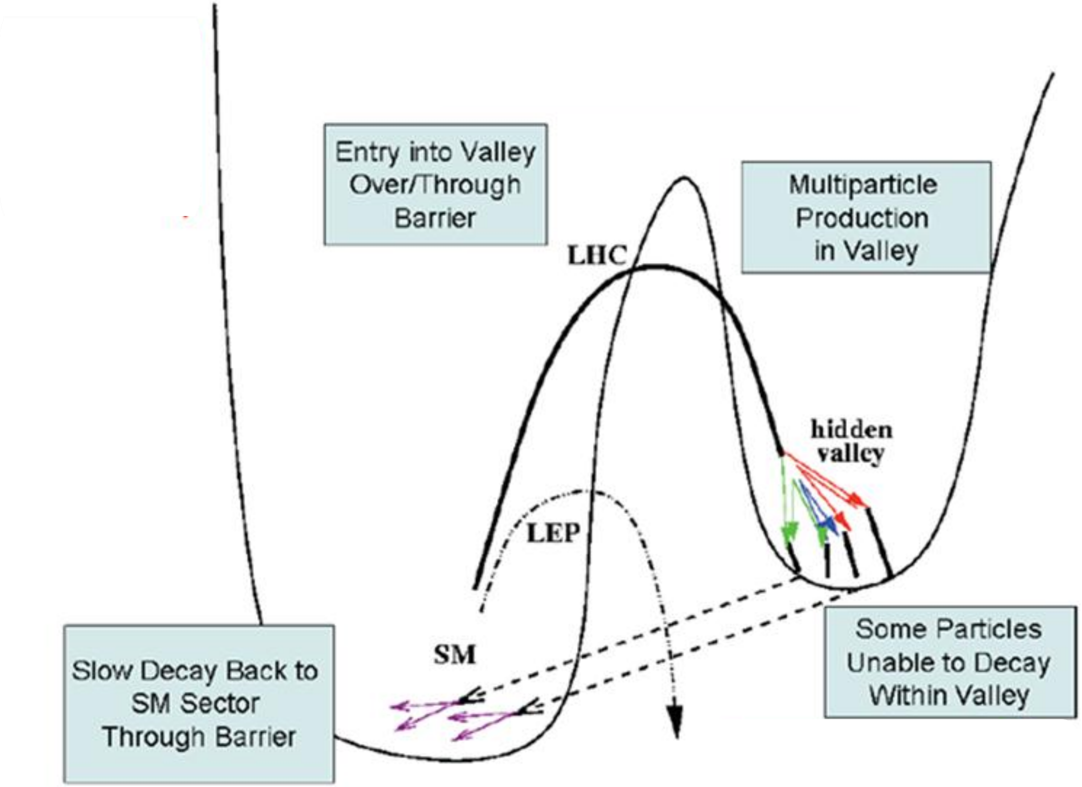
Model-independent limit for a new physics process with an isolated, disappearing track

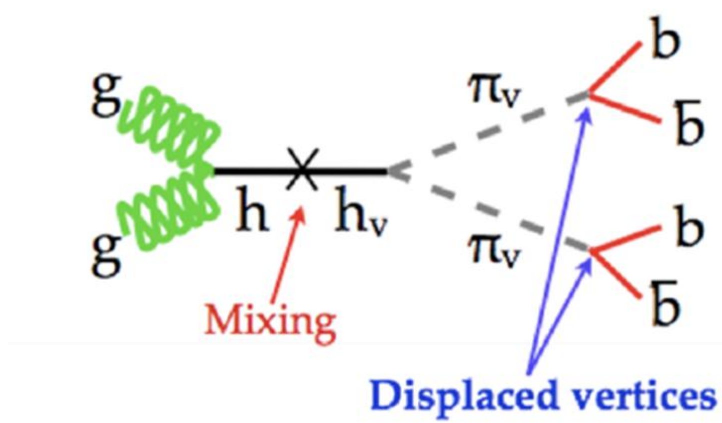


The observed and expected 95% CL upper limits on the signal cross section as a function of chargino lifetime for m(chargino) = 90.2 GeV

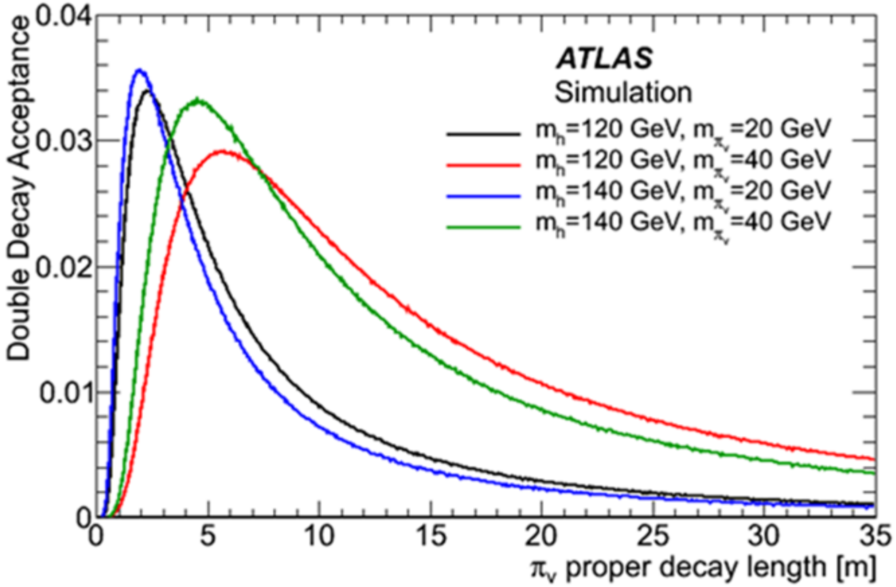
[arXiv:1202.4847v1]

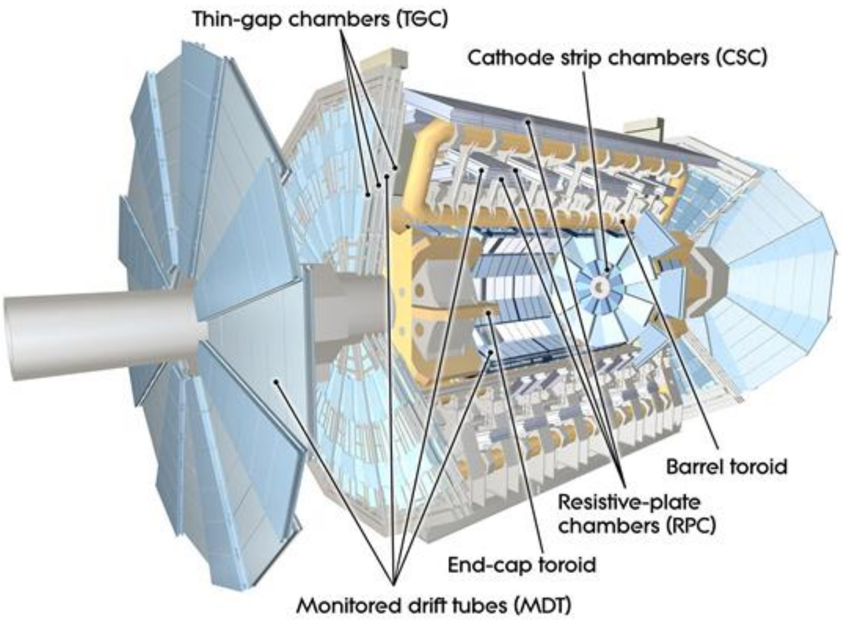
SEARCH FOR A LIGHT HIGGS BOSON DECAYING TO LONG-LIVED WEAKLY-INTERACTING PARTICLES





SIGNAL EFFICIENCY BY DECAY LENGTH

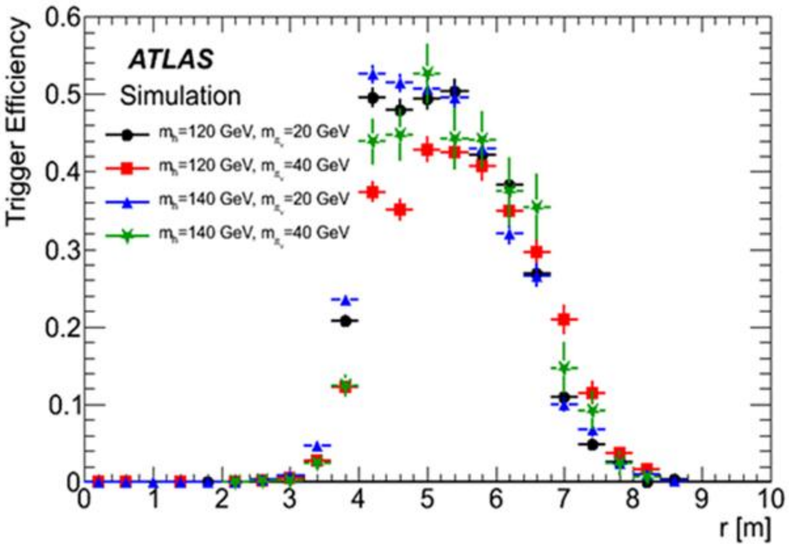


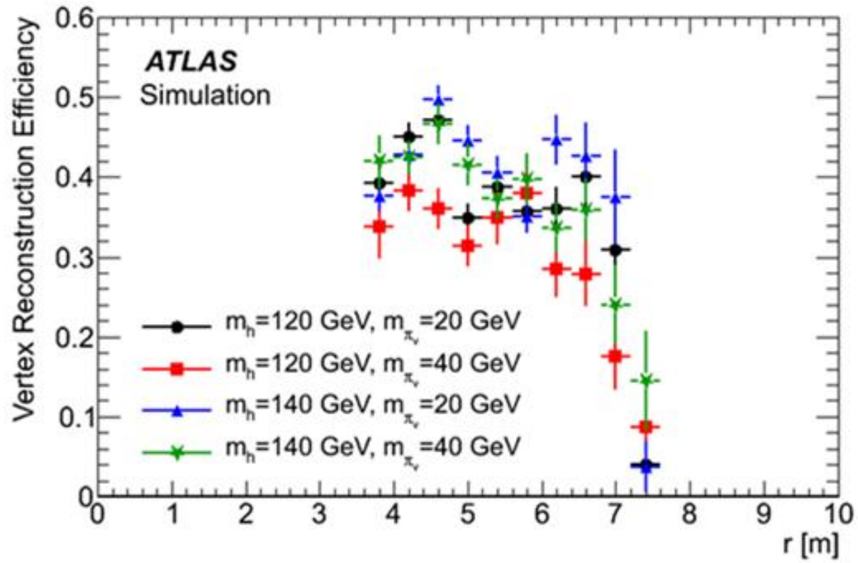


Looking at a range of lifetimes for the v-pion gives decay signatures throughout the detector

Decays near the muon system (from 4.5-11 meters) have been used

HIDDEN VALLEY TRIGGER





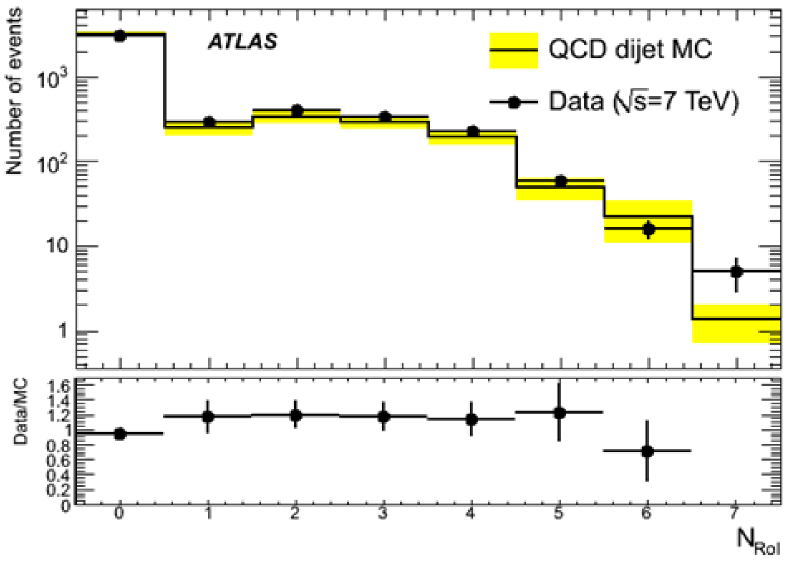
A special trigger has been designed to improve efficiency by ~ an order of magnitude at high radius

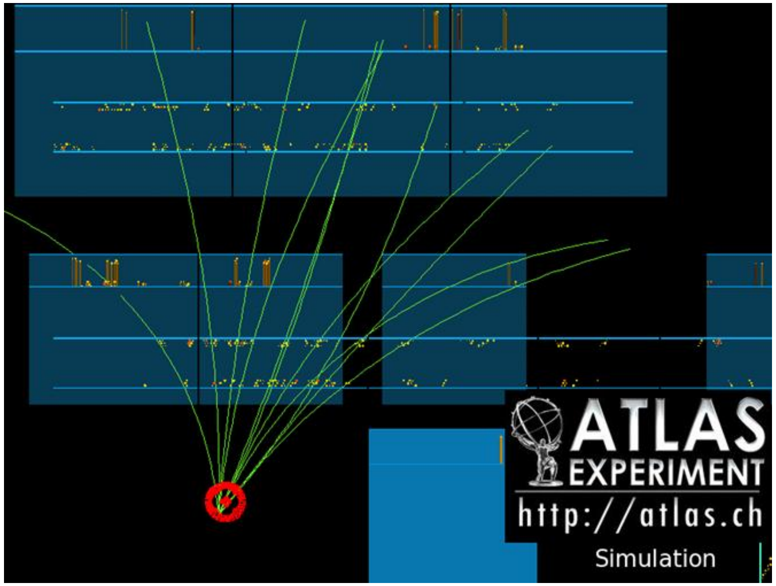
Vertices of several muon tracks not pointing back to the interaction point are identified

VERTICES NEAR THE MUON SPECTROMETER IN QCD AND SIGNAL

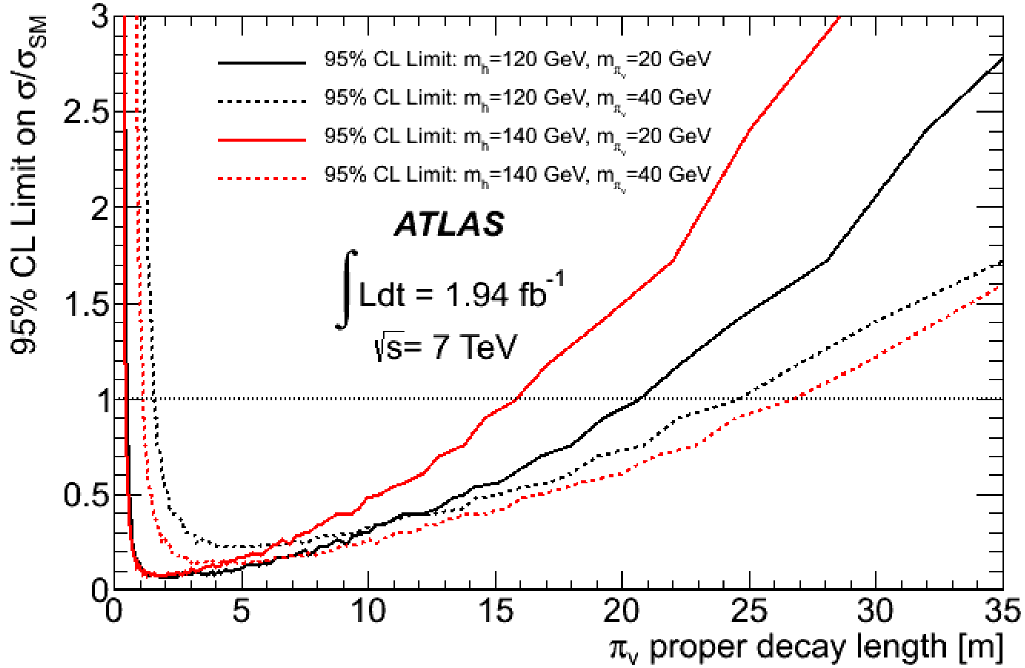
Search is made based on the number of regions of interest (ROI) in the muon system with no tracks or jets nearby – a measure of displaced vertices

Require at least 3 muon ROIs for signal candidates





LIMITS ON HIDDEN VALLEY MODELS



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

arXiv:1203.1303v2

Zero events observed meeting the analysis selection in 1.94 fb^{-1} of pp collisions

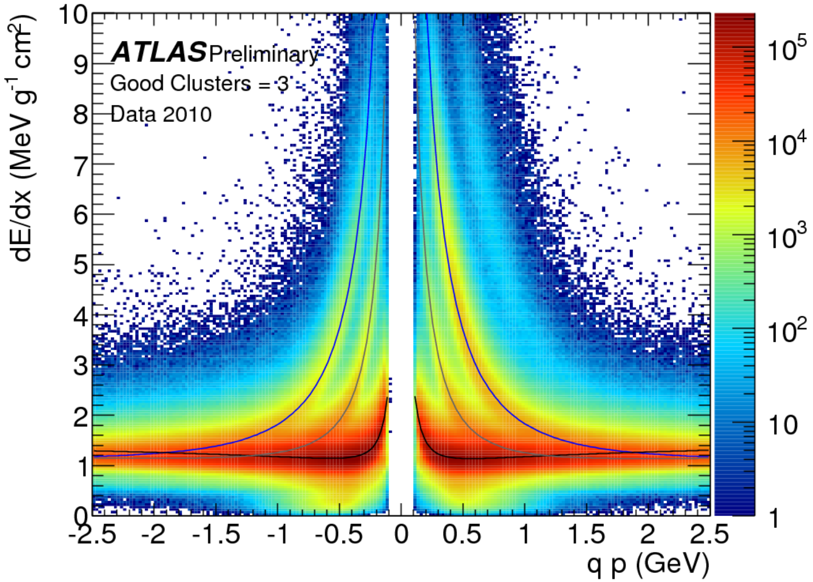
Exclusion limits assume 100% branching ratio for low-mass Higgs to v-pions

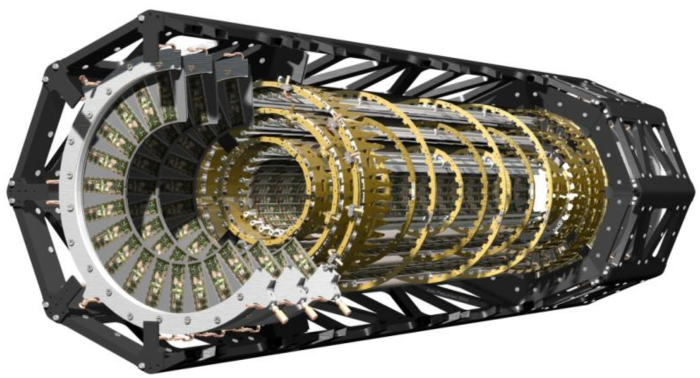
SEARCH FOR CHARGED LONG-LIVED HEAVY PARTICLES WITH THE ATLAS EXPERIMENT AT THE LHC

- **Massive long-lived particles have $\beta \neq 1$, resulting in high ionization**

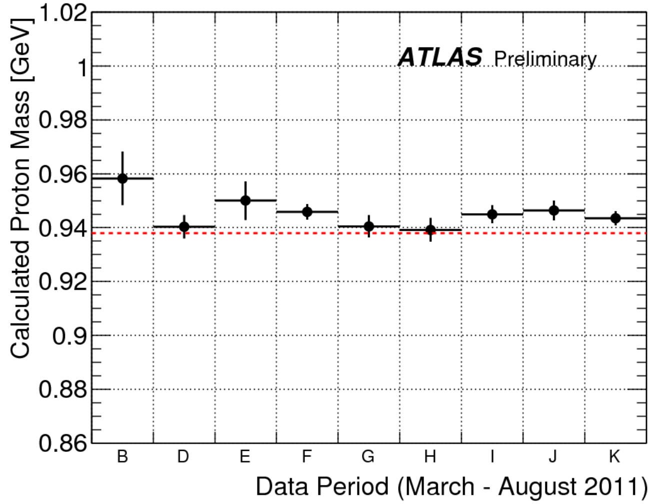
- **Search for R-hadrons**
  - SUSY particles with color charge
  - Can become neutral through hadronic interactions inside the detector
  - Search close to the interaction point

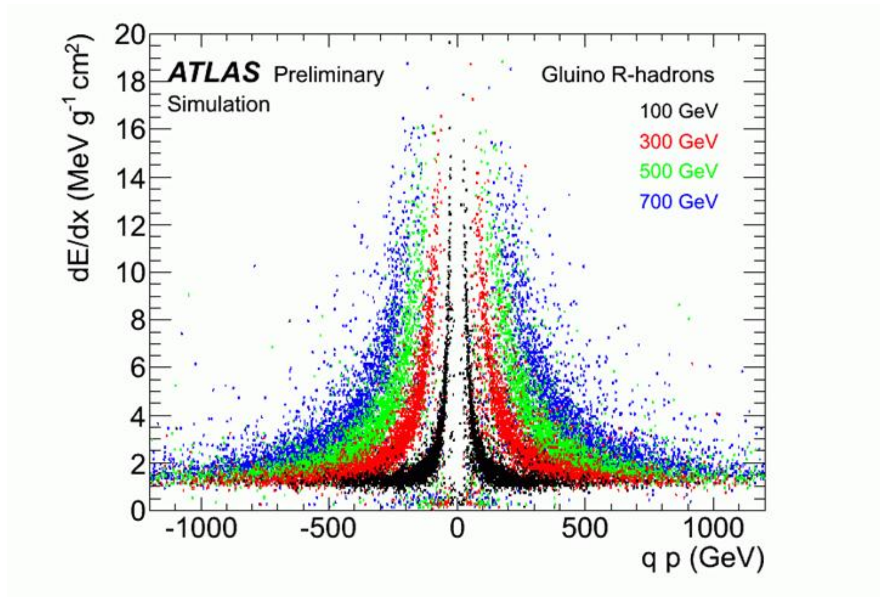
- **Pixel sub-detector uses minimum bias events to calibrate a dE/dx measurement**



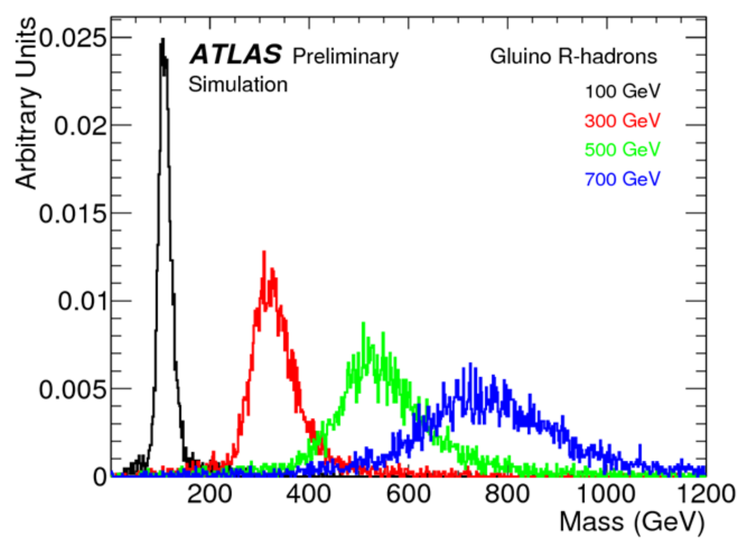


CALIBRATING PARTICLE IDENTIFICATION IN THE PIXEL DETECTOR

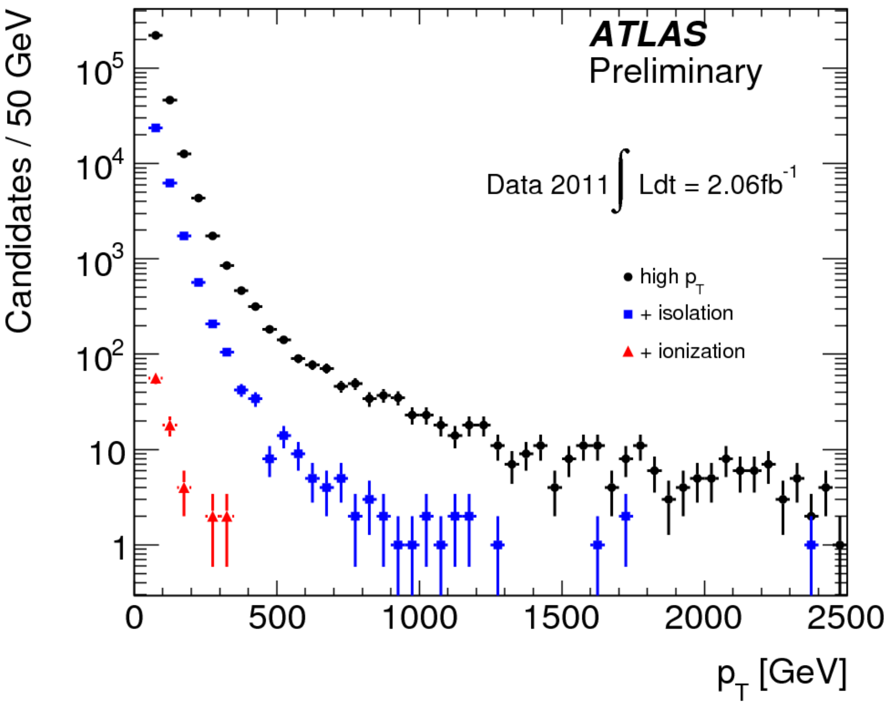




- dE/dx can be used with pT and Bethe-Bloch to determine a mass
- This conversion is calibrated by finding the proton mass
- Extrapolation to R-hadrons is accurate, though widening with higher masses



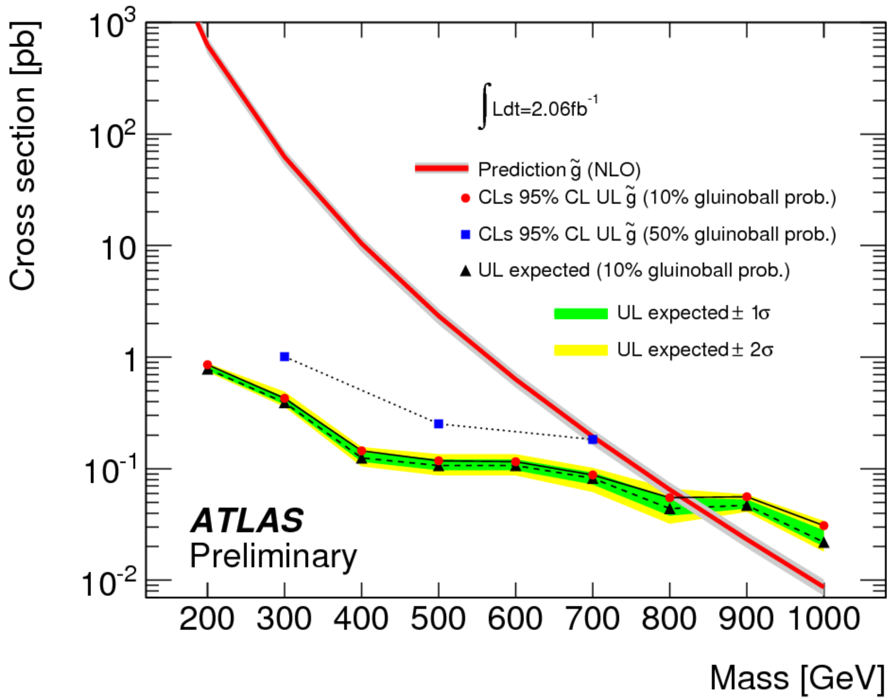
R-HADRON ANALYSIS DETAILS

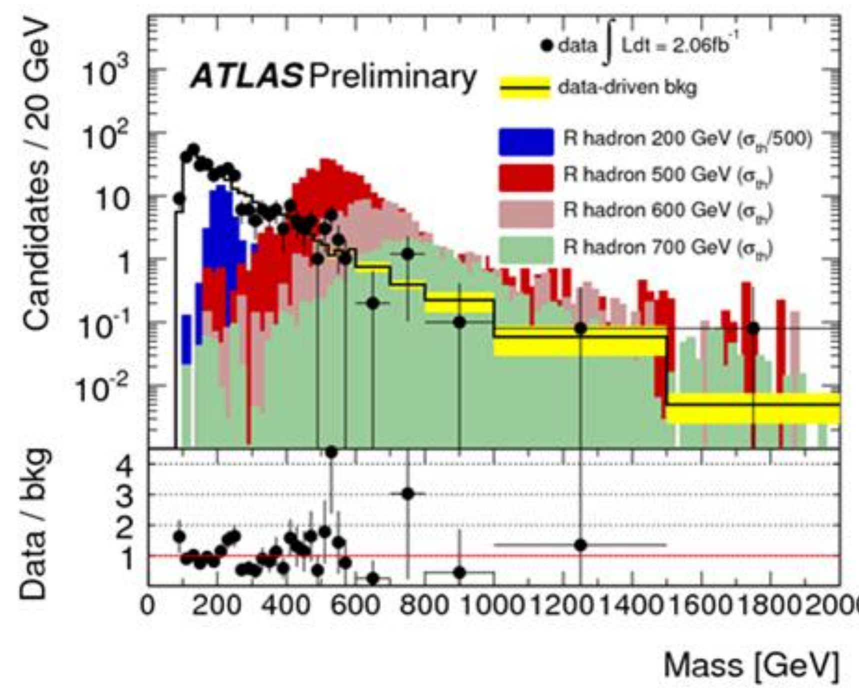


Distribution of pT for the data at the last steps of the applied selection

- **Trigger on missing energy > 150 GeV or muon with pT > 40 GeV**
- **Candidates are isolated, high momentum tracks**
  - pT > 50 GeV, p > 100 GeV
- **Select by high ionization**
- **Data-driven background estimation**
  - p background distribution modeled without dE/dx cut applied
  - dE/dx background modeled for tracks with p < 100 GeV

RESULTS AND LIMITS





333 events are observed in data as is consistent with background estimation

With some model dependent assumptions, this can be interpreted as excluding gluino R-hadrons with masses smaller than 810 GeV.

04/05/2012

Christopher Marino, University of Victoria

ATLAS-CONF-2012-022

CONCLUSIONS

- **Three recent ATLAS searches for exotic long-lived particles have been presented using 2011 data**
  - Anomaly-mediated SUSY breaking using disappearing tracks
  - Hidden Valley light Higgs using displaced decays
  - Hadronically interacting R-hadrons using Pixel dE/dx
- **No new physics has been found but limits have been set and tools for future searches have been developed**
- **New improvements are under way using timing, ionization, displaced vertices, and other unique signatures in several ATLAS sub-detectors and full 2011 data**
- **Searches for new physics will be even more exciting in 2012 as we move to 8 TeV!**