Search for Long-lived Particles with the ATLAS Detector
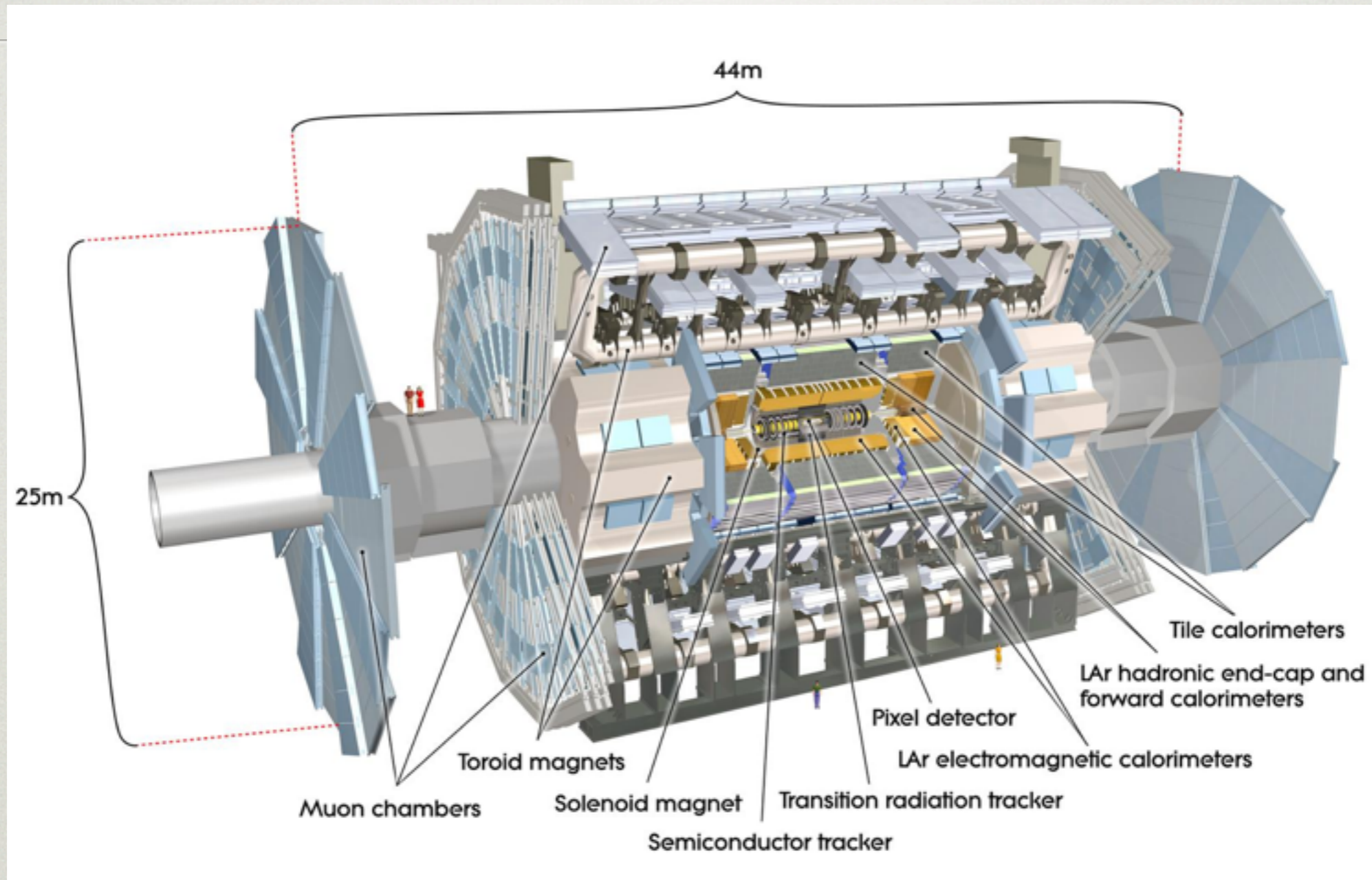
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On Behalf of
The ATLAS Collaboration

Outline

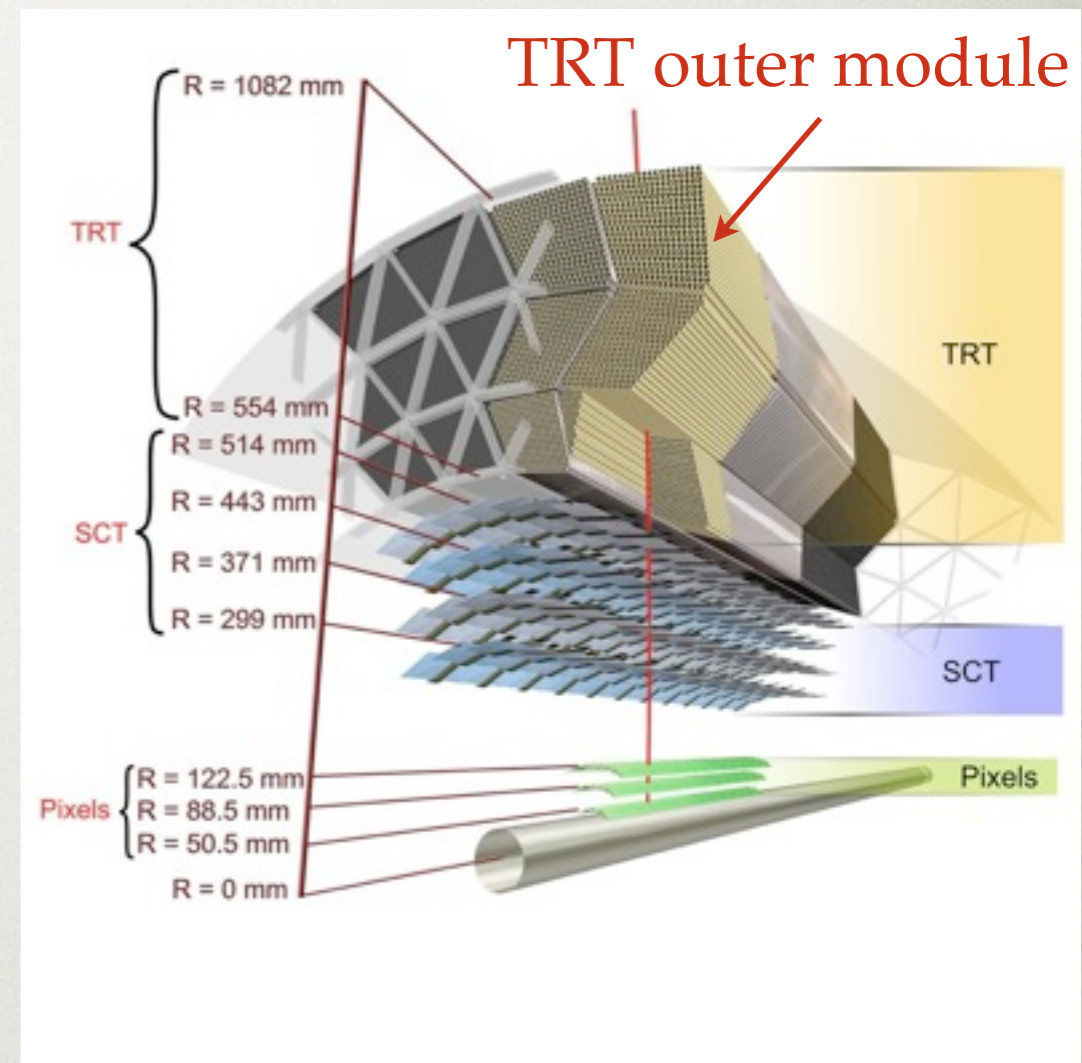
- Disappearing tracks
- Displaced vertices in the inner detector
- Displaced vertices in the muon spectrometer

Disappearing Tracks

Implications of LHC Results: WG3
08/12/2011

- AMSB inspired search for $\chi^\pm \to \chi^0 \pi^\pm$ where $\chi^\pm$ and χ^0 are almost degenerate

  - The $\pi^\pm$ is soft and not reconstructed

- Event selection:

  - 3 jets pT $\geq$ 130, 60, 60 GeV and $|\eta| < 3.2$

  - MET > 130 GeV

  - No leptons with p_T > 10 GeV

- Search Strategy:

- Search for $\chi^\pm$ decays before the TRT outer module

  - Well reconstructed track in the Pixel and SCT ($N_{b\text{-layer}} \geq 1$, $N_{SCT} \geq 6$)

TRT outer module

  - Isolated from other tracks with p_T > 0.5 GeV and $\Delta R < 0.05$

  - Candidate track: highest p_T isolated track (p_T > 10 GeV) in $|\eta| < 0.63$[†]
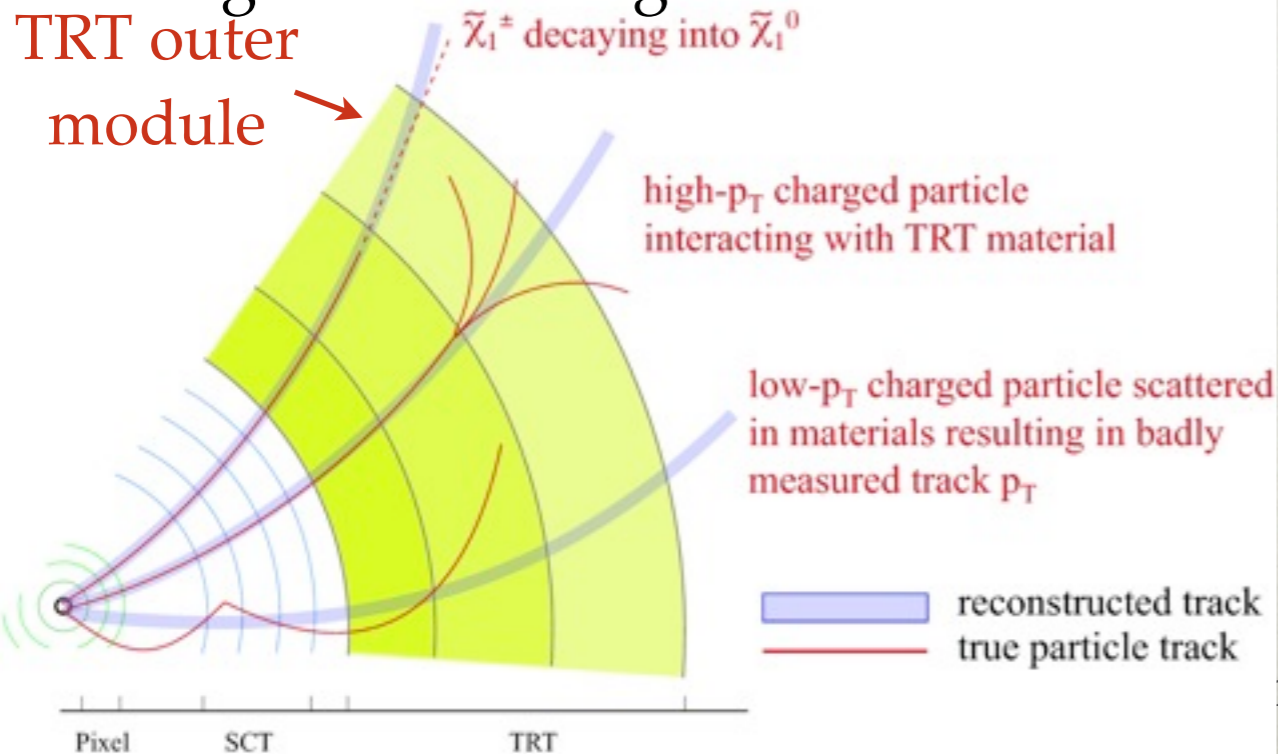
† The candidate tracks are required to be in the fiducial volume of the TRT Barrel and not pass through any inactive regions

DISAPPEARING TRACKS

Number of hits in TRT outer module
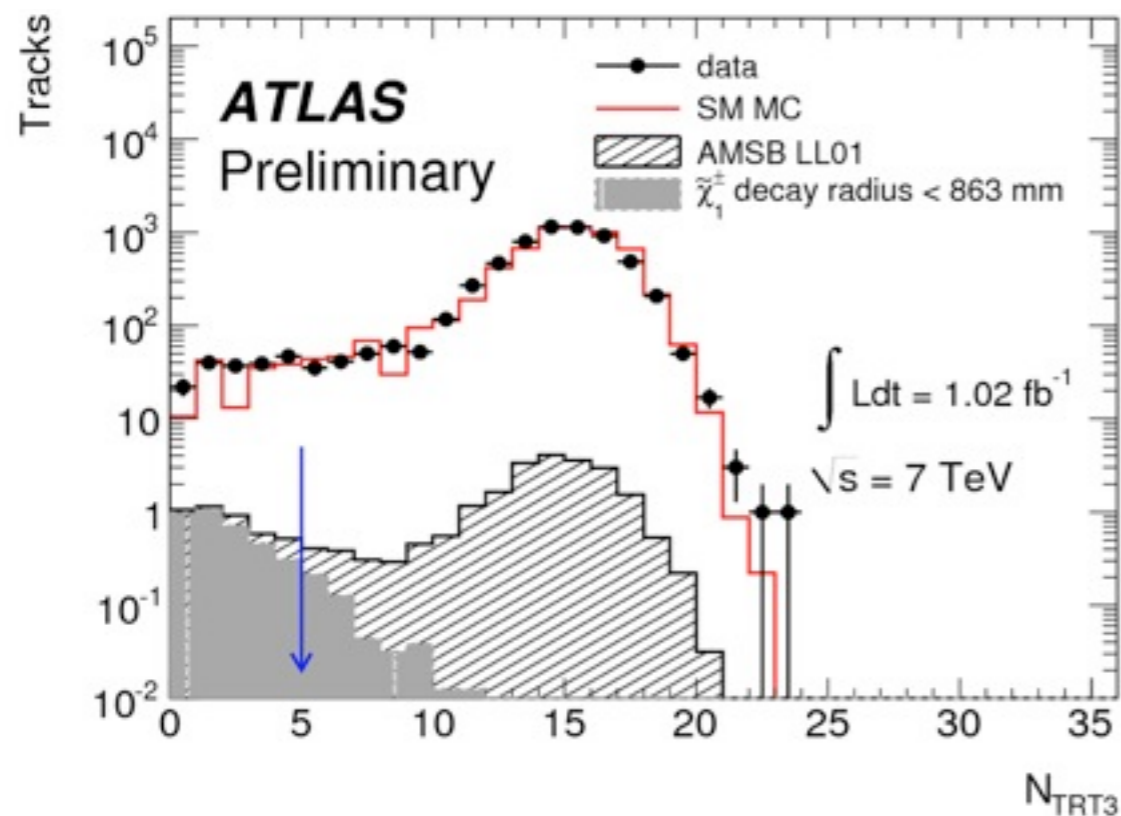

Signal and background like tracks

TRT outer module →

- Typical (well measured) tracks have ~15 hits in the outer TRT module (TRT3)

- $\chi^{\pm}$ decays before TRT3 have $N_{TRT3} \sim 0$

  - Disappearing track selection: $N_{TRT3} < 5$

- Backgrounds:

  - high-pT charged particle scattering inside the TRT

    - Will have a high energy deposit in calorimeter near the track

  - poorly reconstructed track from low-p_T particle that scatters inside ID

    - Will have missing pixel or SCT hits

  - Use background characteristics (calo energy, missing SCT hits) to extract control samples
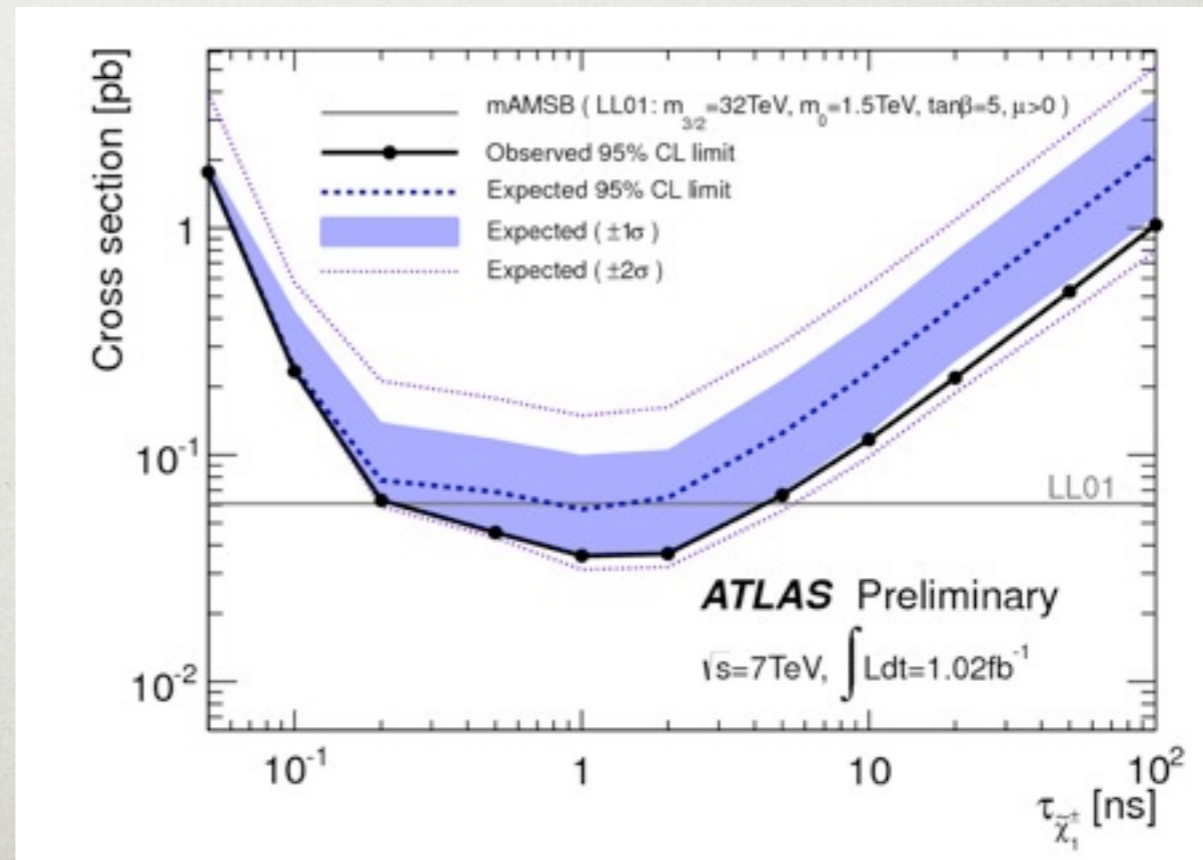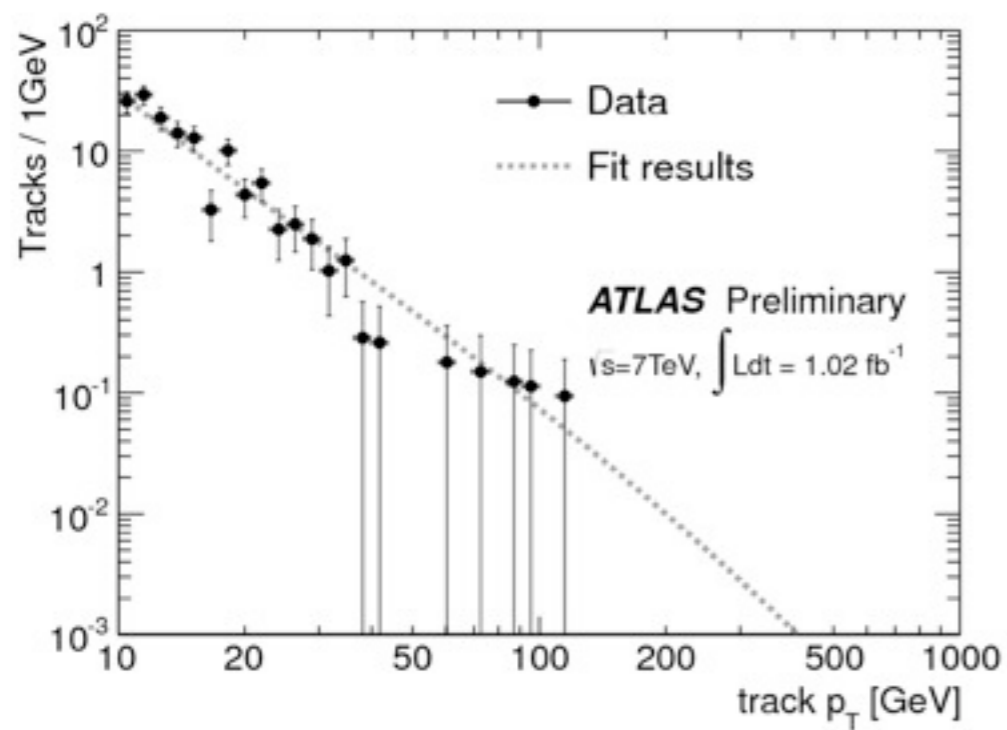
Signal and background PDFs
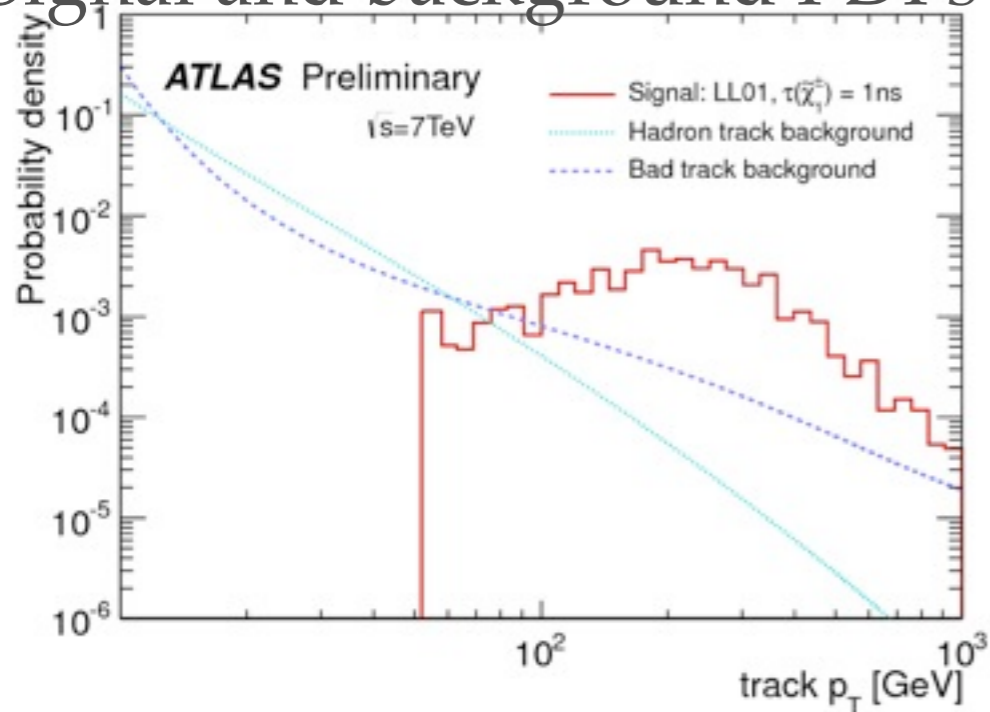
- Background is estimated by fitting the region $10 < p_T < 50$ GeV with the background PDFs

  - Expected background with $p_T > 50$ GeV is 13 ± 1

  - Observed 5 events with $p_T > 50$ GeV

- For the mAMSB point LL01 ($m_0 = 1.5$ TeV, $m_{3/2} = 32$ TeV, $m_{\chi^\pm} = 90.2$ GeV), $\chi^\pm$ lifetimes of $0.5 < \tau_{\chi^\pm} < 2$ ns are excluded at 95% CL
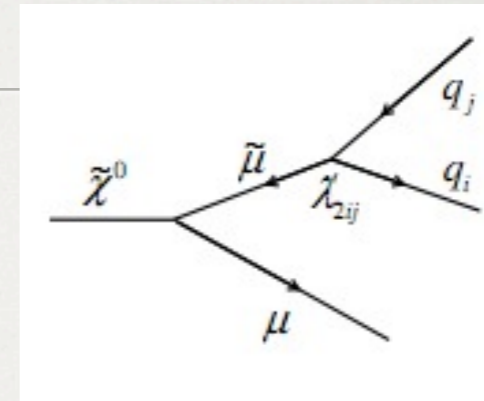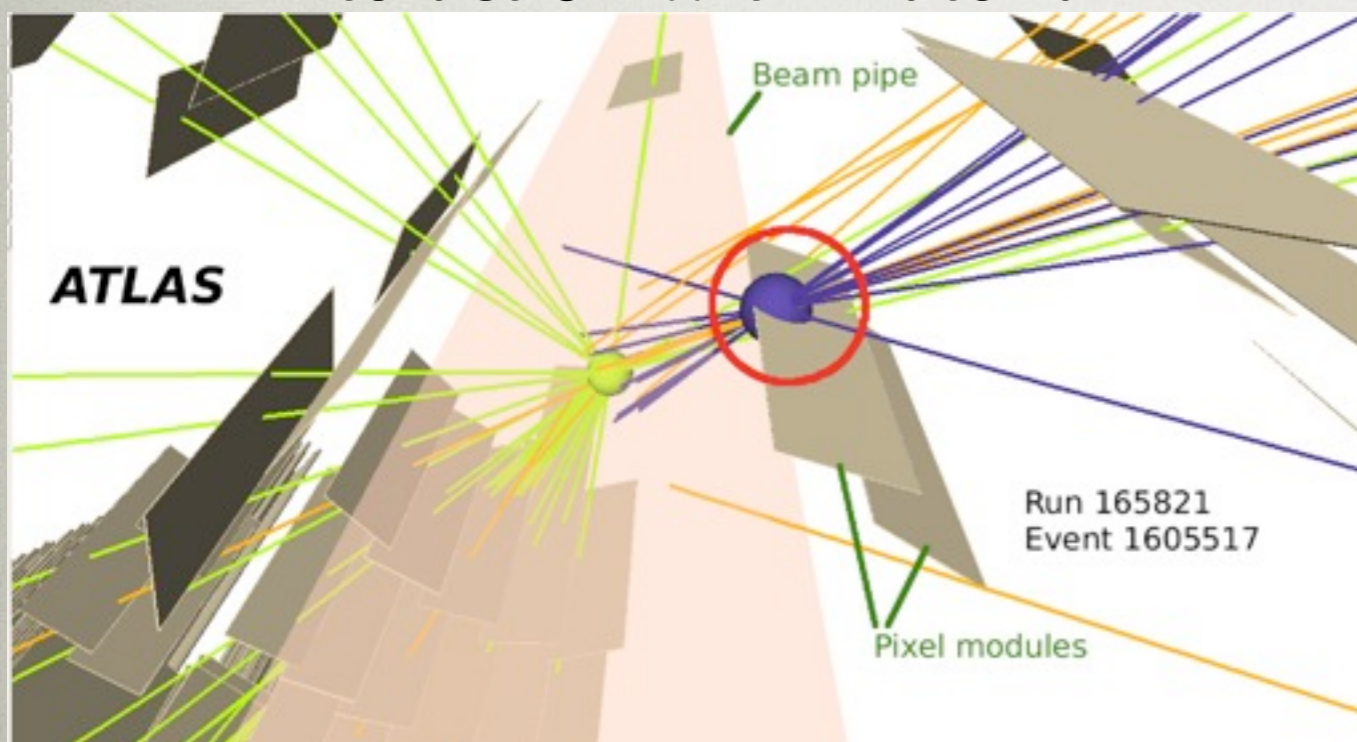
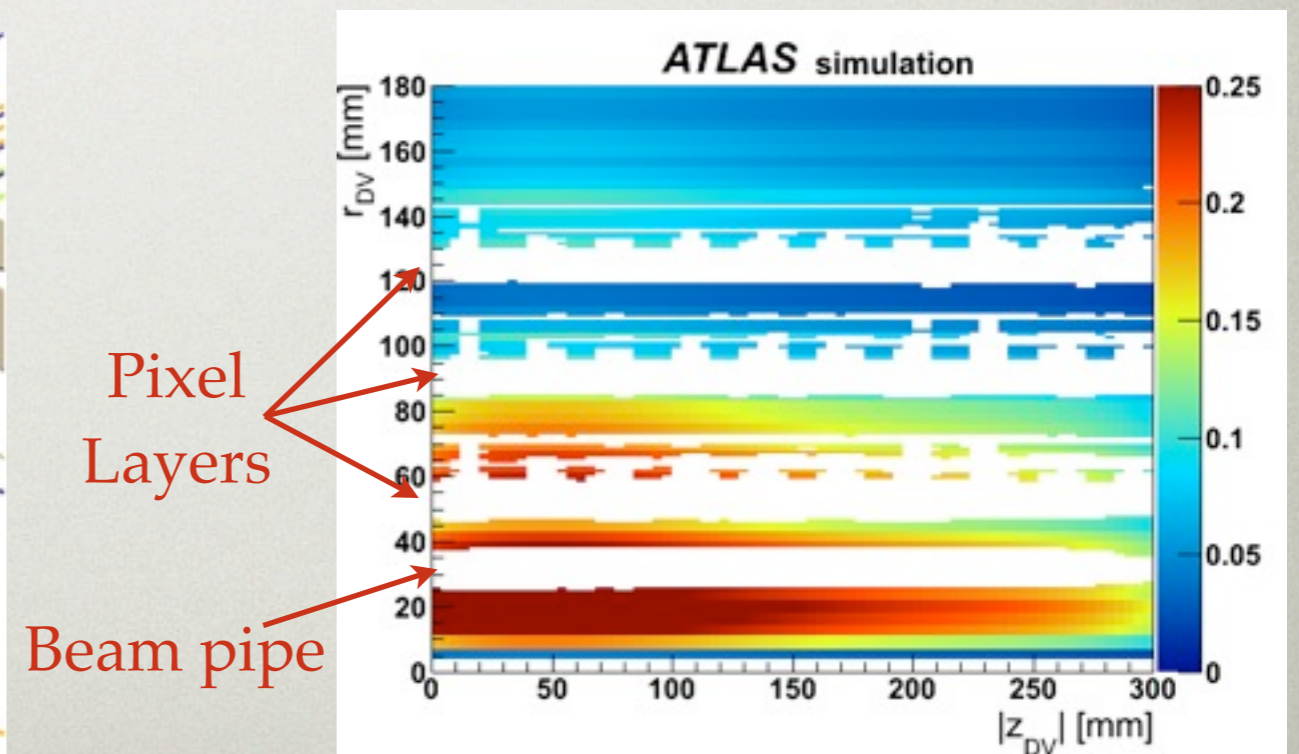# Displaced Vertices in the Inner Detector

Displaced Vertex in the ID

- Search for R-parity violating SUSY

- Require a muon with $p_T > 45$ GeV

- Search for high mass vertices in the range 4 mm $< R <$ 180 mm

- Main background is from material interactions

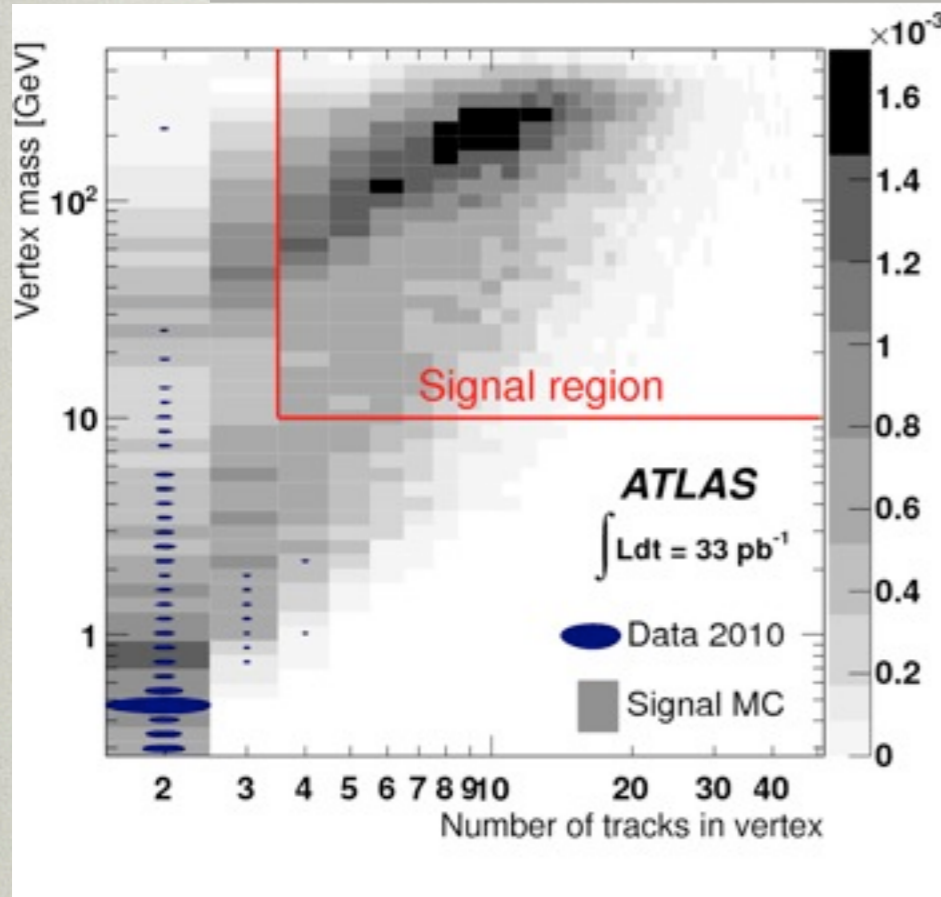   - Veto vertices in areas of high material density
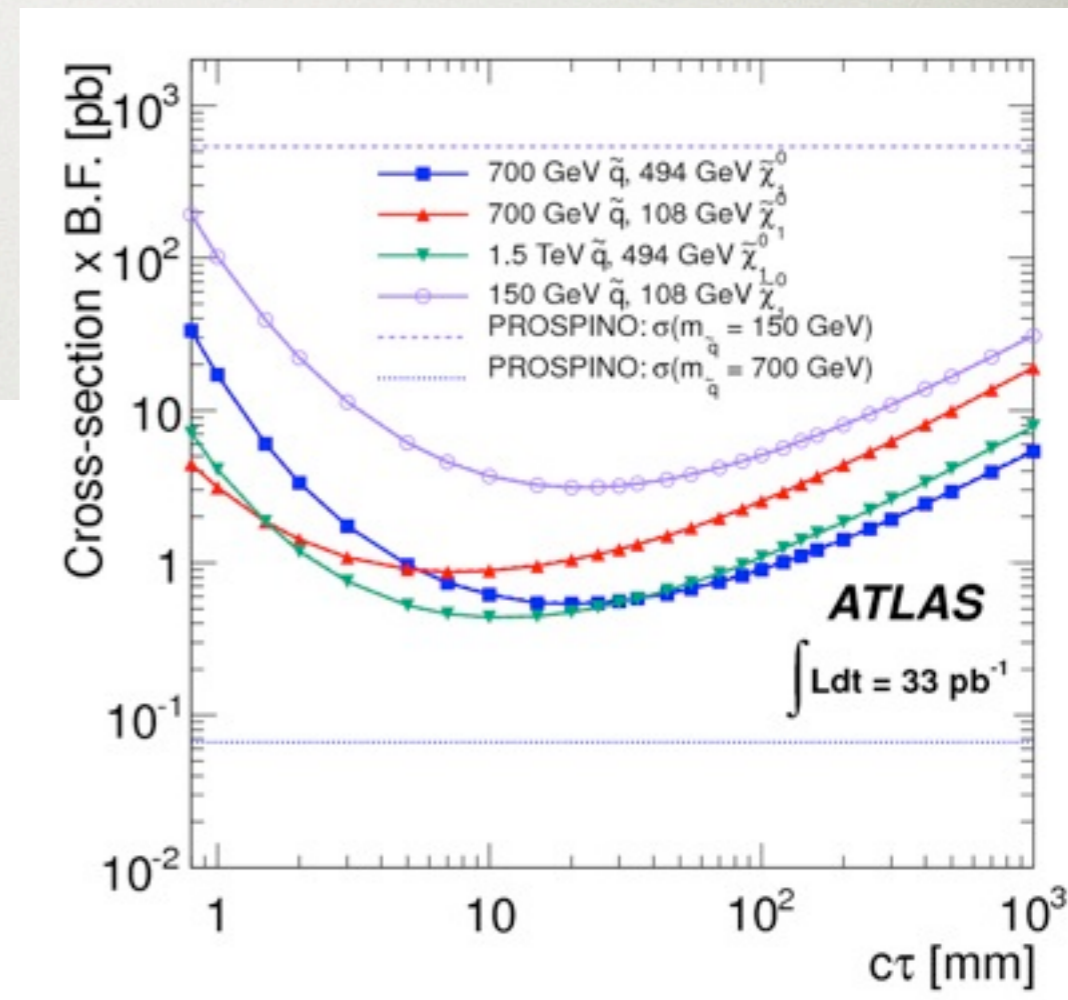
Interaction with material

Vertex reconstruction efficiency
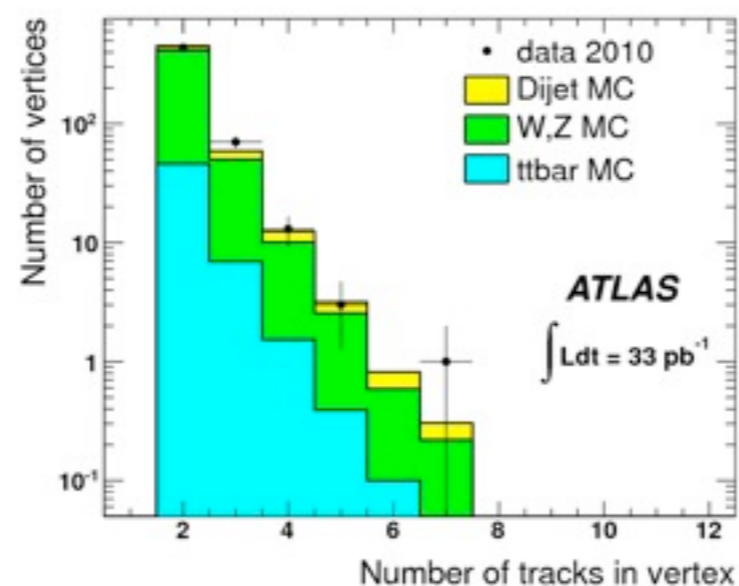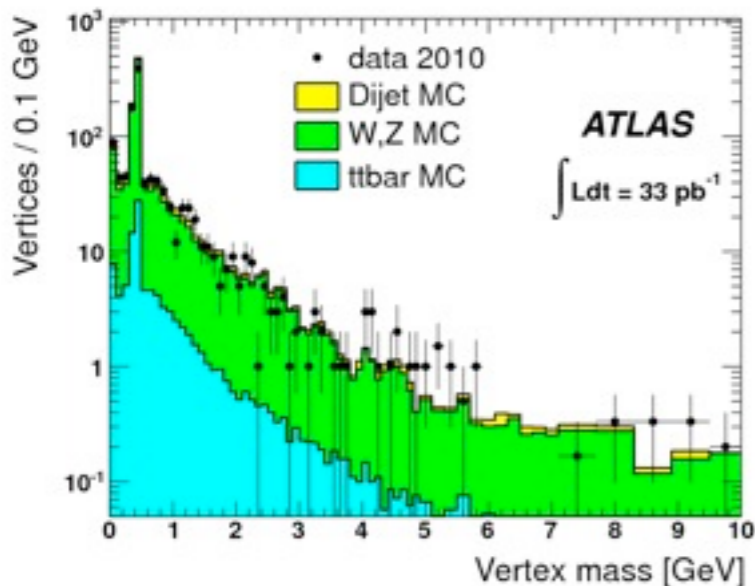
- Require $m_{DV} > 10$ GeV and $N_{DV}^{Trk} \geq 4$
- No events are found in the signal region (expected background ~0.03 events)
- Exclude $\varepsilon * \sigma_{DV} > 0.09$ pb at 95% CL
  - ε is detector acceptance and reco. efficiency

Vertex Mass: Control Region   Vertex Tracks: Control Region

Displaced Vertices in the Muon Spectrometer

Higgs to LLPs

Mixing

Displaced vertices

- Parameters:
  - m_h = 120 GeV, 140 GeV
  - m_{π_v} = 20 GeV, 40 GeV
  - $c\,\tau$ is arbitrary, chosen to give decays throughout the detector
- The pseudo-scalar π_v decays to heavy flavor (85% $b\bar{b}$, 8%$\tau^+\tau^-$, 5% $c\bar{c}$)
  - Assuming $b\bar{b}$ decay: ~10 low p_T charged hadrons & ~5 π^{0}'s
- Assuming 100% Branching Fraction for h→$\pi_v\pi_v$, the cross sections are large
  - σ (m_h = 120 GeV) = 16.3 pb, σ (m_h = 140 GeV) = 12.1 pb

- Search strategy:
  - Search for events with both π_v's decaying in the Muon Spectrometer
    - Require one π_v in the barrel ($|\eta|$ < 1, R < 7m) to satisfy the trigger requirement
   - Second π_v can decay in either the barrel or endcap MS
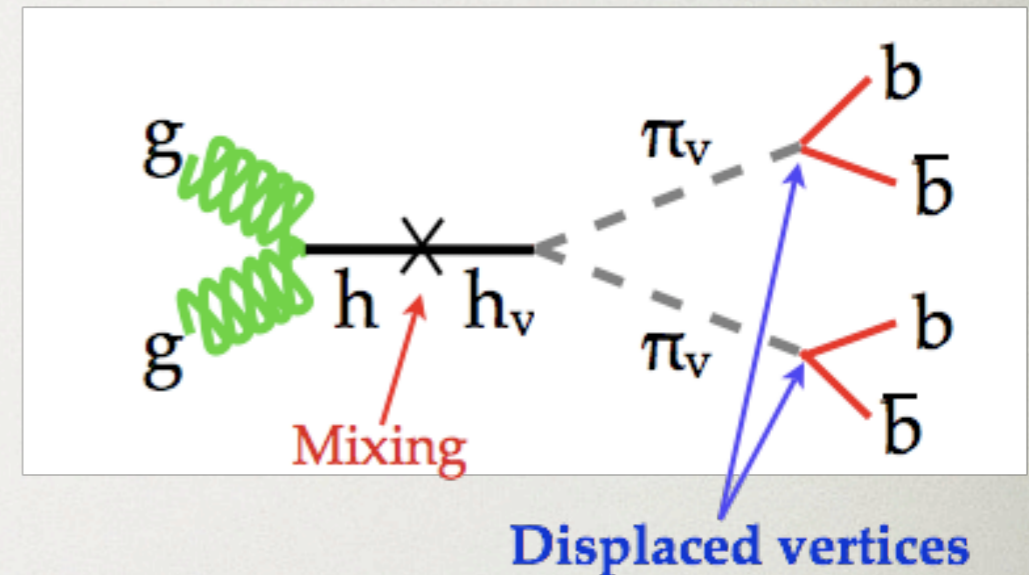
Monte Carlo Caveat

- π_v production and decay was done in Pythia6 with color reconnections enabled

- Quarks from π_v decay can be (incorrectly) color connected to partons at the IP.

  - Hadrons from the string fragmentation are produced at the IP

  - This leads to an underestimate of the signal efficiency for detecting displaced decays due to the isolation criteria applied

- All results presented here are affected by these macroscopic color connections and are to be considered Preliminary

  - Analysis is being redone with corrected MC

Muon RoI Cluster Trigger

- Use a dedicated trigger designed to select π_v decays inside the muon spectrometer (R ~ 4 m - 7 m)

  - Only active in the barrel $|\eta| < 1$

- The Muon RoI Cluster Trigger selects events with at least 3 Muon RoI's[†] in a cone of $\Delta R < 0.4$

"Muon" RoI's

"Muon" hits

Simulation
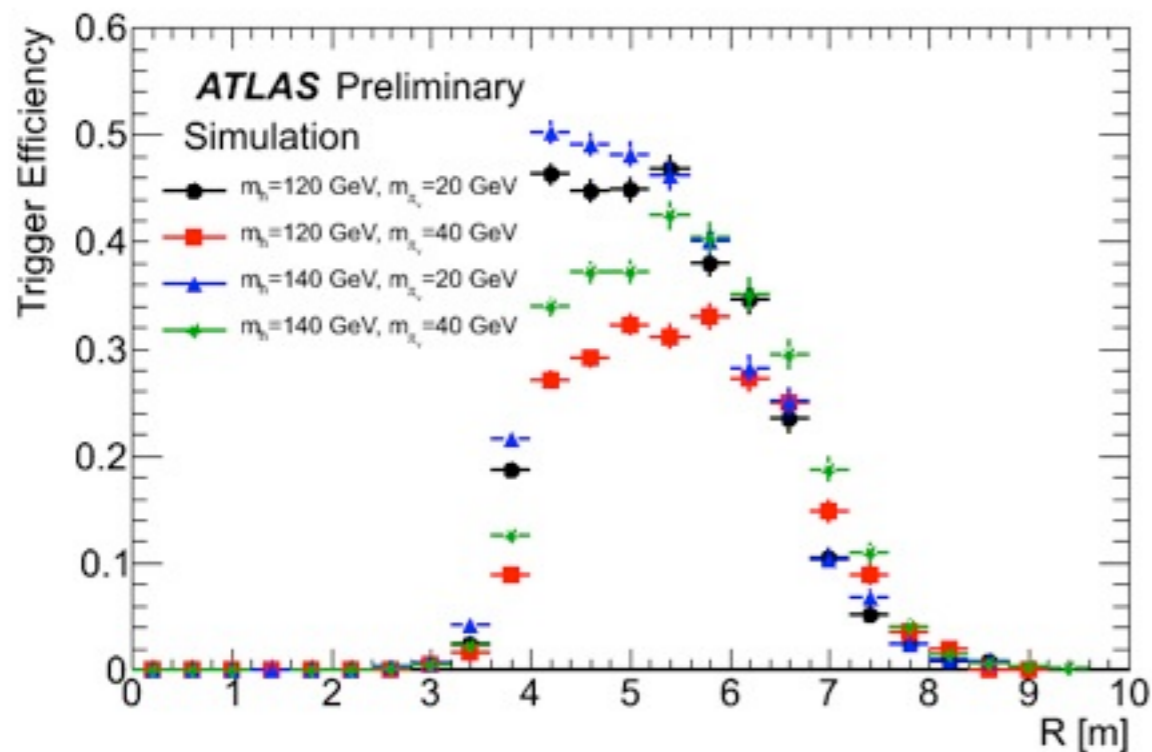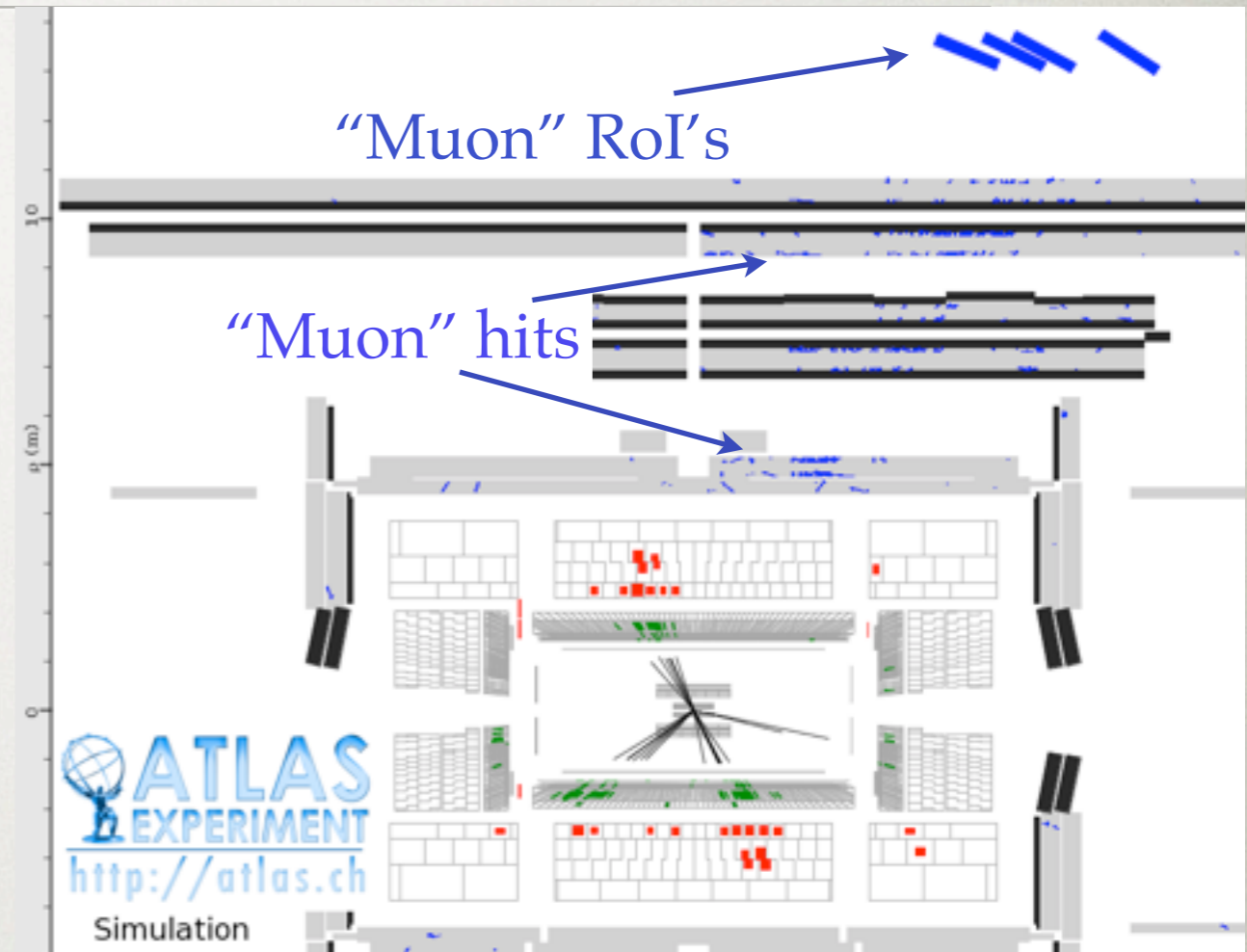
- Requires isolation with respect to both jets (L2 $E_T > 35$ GeV) and ID tracks ($p_T > 5$ GeV)

  - See Pythia6 caveat

† An RoI is a Region of Interest, selected by the L1 trigger as a muon candidate. The RoI's have a spatial extent of 0.2x0.2 ($\Delta\eta \times \Delta\phi$) and are limited to two RoI's per sector

ATLAS Preliminary
Simulation

- m_h=120 GeV, m_{χ_v}=20 GeV
- m_h=120 GeV, m_{χ_v}=40 GeV
- m_h=140 GeV, m_{χ_v}=20 GeV
- m_h=140 GeV, m_{χ_v}=40 GeV

Trigger Efficiency

R [m]

MS Vertex Reconstruction

- A dedicated tracking and vertex reconstruction routine has been developed to identify displaced vertices in the MS

- Resolution of ~20 cm in z and ~32 cm is achieved

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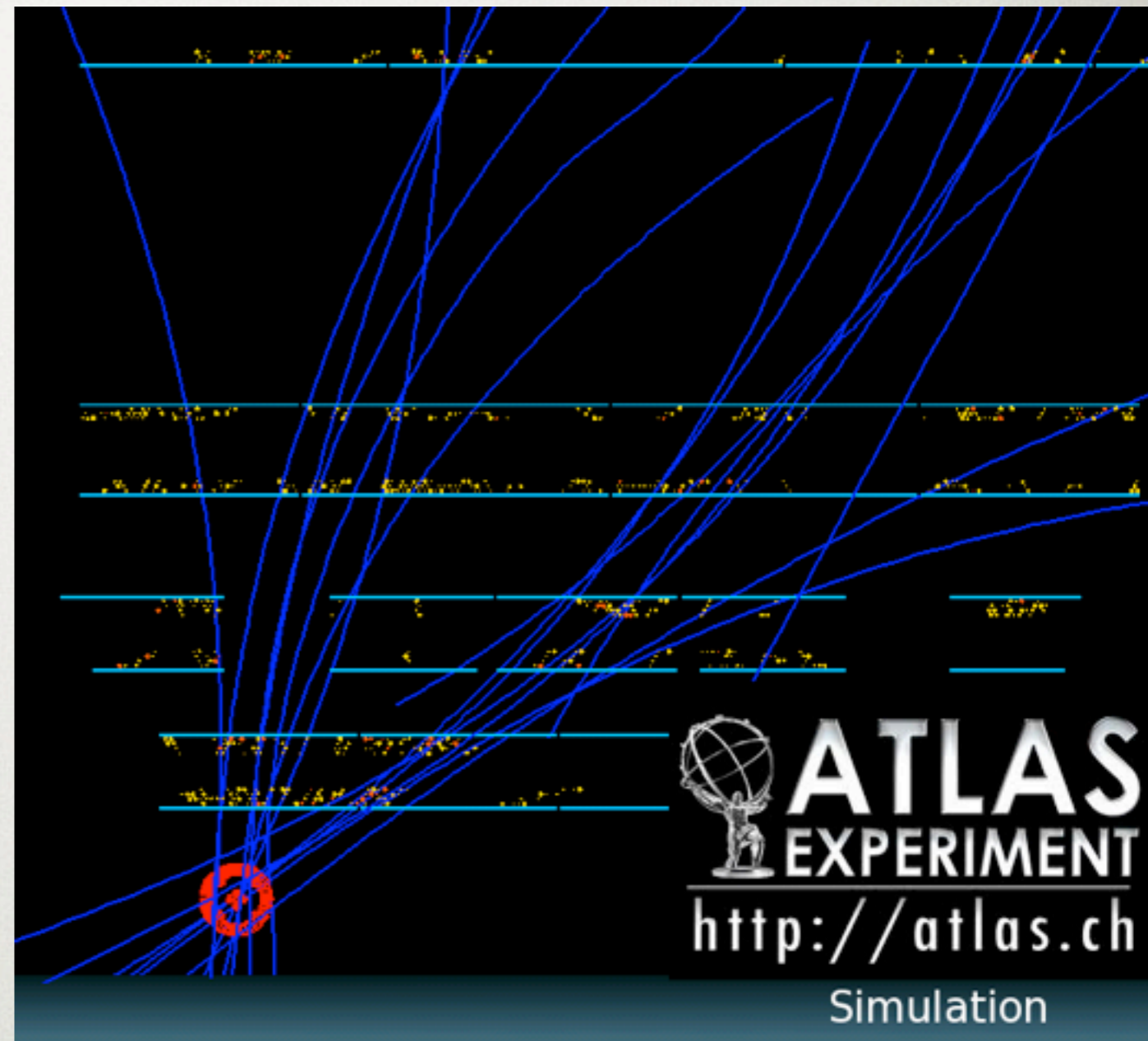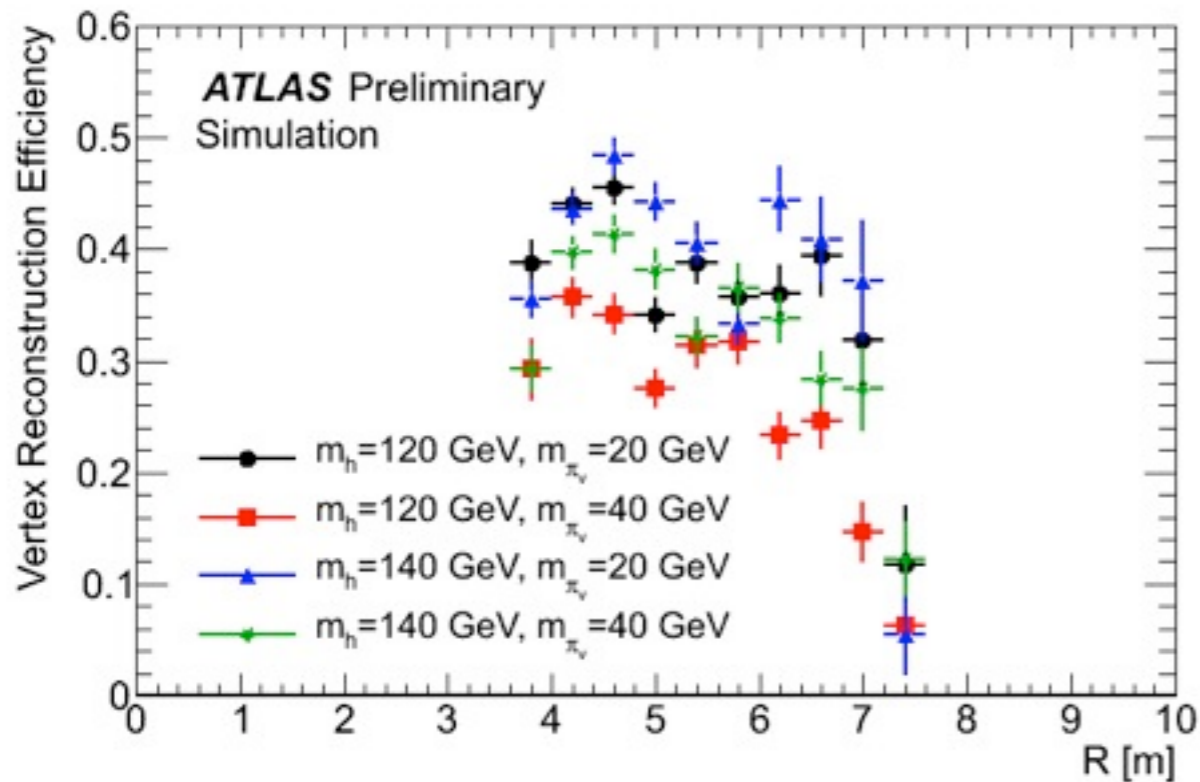
- Search for events with 2 back-to-back ($\Delta R > 2$), isolated vertices in the MS

  - Isolated w.r.t. ID tracks with $p_T \geq 5$ GeV such that $\Delta R(track, vertex) \geq 0.4$

  - Isolated w.r.t. jets with $E_T \geq 15$ GeV such that $\Delta R(jet, vertex) \geq 0.7$

- Expected background is 0.03 ± 0.02 events

- Measured 0 events in 1.94 fb^{-1} of data

- Signal MC is affected by the macroscopic color connections, results are conservative and Preliminary

  - Being redone with corrected MC

m_{h^0} (GeV)	m_{π_v} (GeV)	Excluded Region
120	20	0.50 m $< c\tau <$ 19.15 m
120	40	1.90 m $< c\tau <$ 17.25 m
140	20	0.50 m $< c\tau <$ 15.50 m
140	40	1.25 m $< c\tau <$ 23.0 m
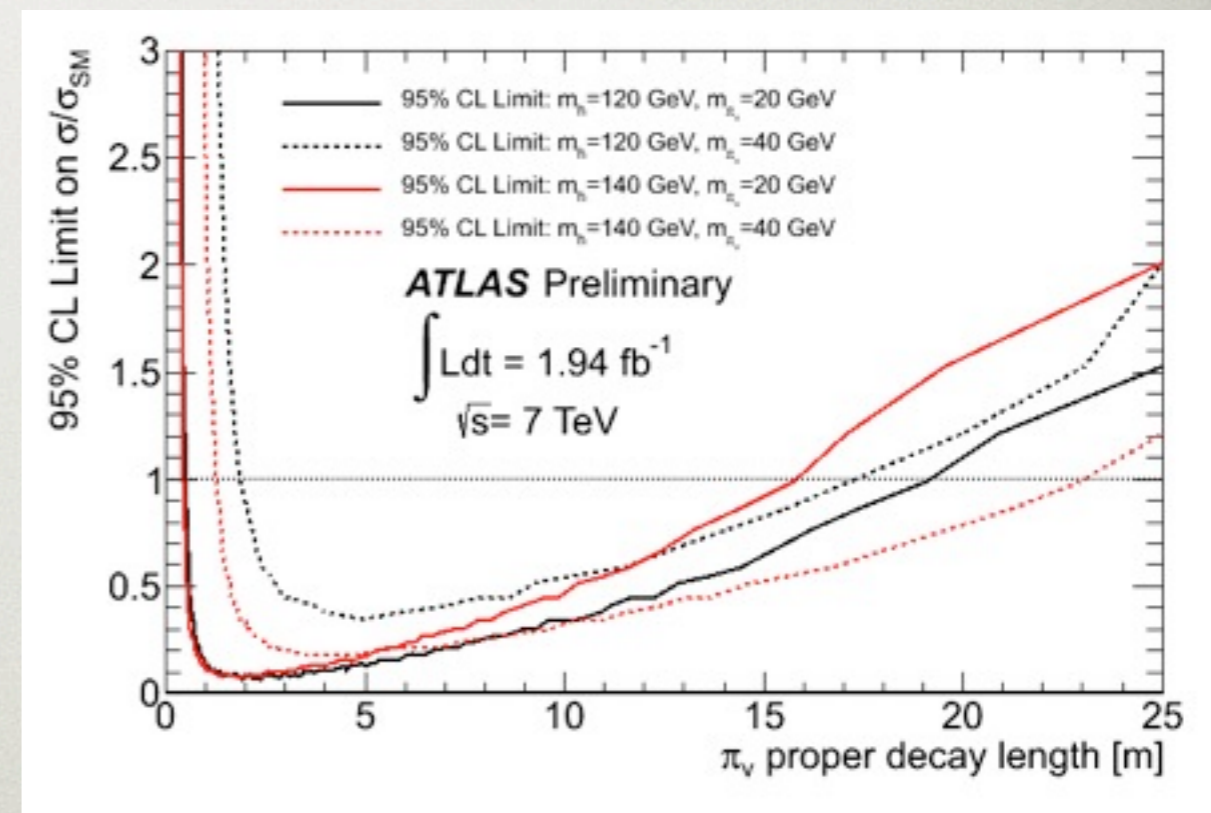
Conclusions

- Several searches for LLPs have been done in ATLAS

- Disappearing tracks (1.02 fb^{-1}):
  - $m_{\tilde{\chi}^{\pm}} < 92$ GeV and $0.5 < \tau_{\tilde{\chi}^{\pm}} < 2$ ns excluded at 95% CL

- Displaced vertices in the inner detector (33 pb^{-1}):
  - $\varepsilon^* \sigma_{DV} < 0.09$ pb (ε is detector acceptance times reco. efficiency)

- Displaced vertices in the muon spectrometer (1.94 fb^{-1})
  - $\sim 1 < c\tau_{\pi_v} < \sim 20$ m excluded at 95% CL

- Many improvements to come with the 5.2 fb^{-1} recorded
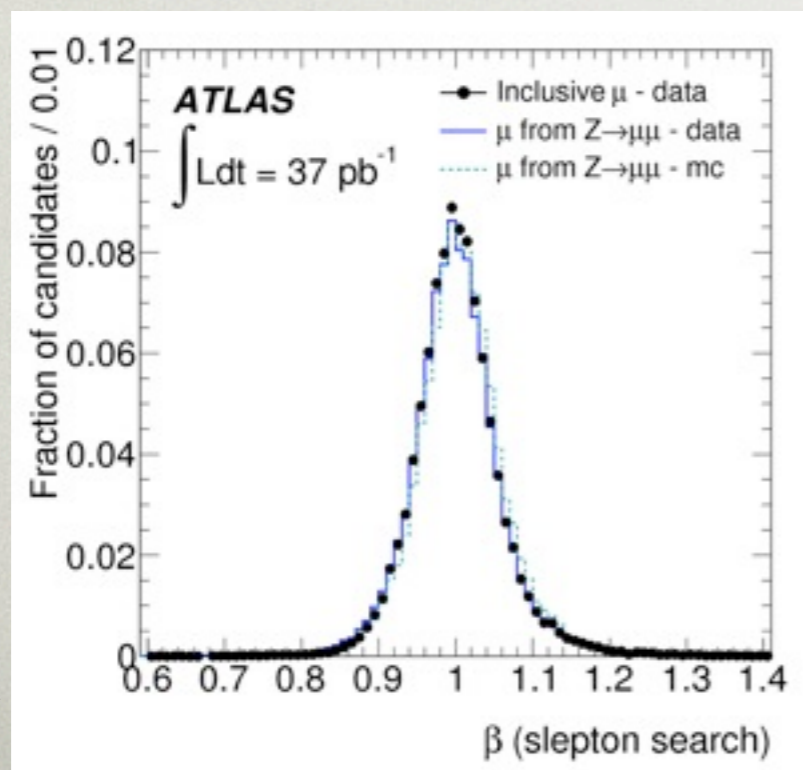
Backup

Heavy long-lived Charged Particles

Implications of LHC Results: WG3
08/12/2011
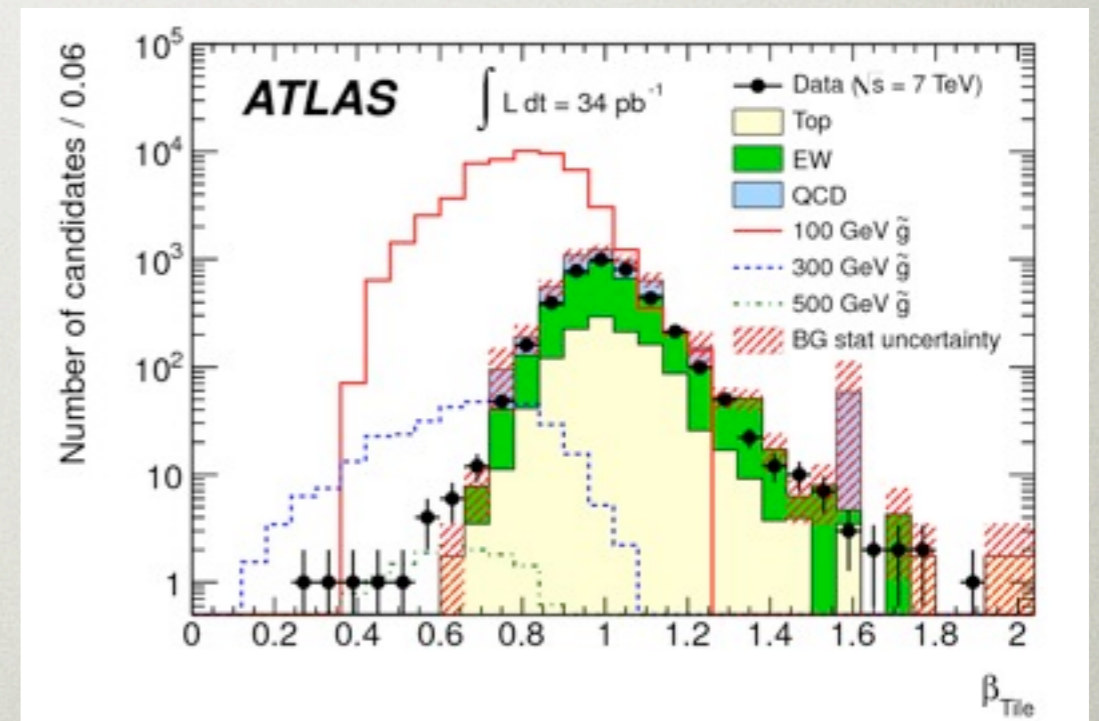
Search using the Muon Spectrometer

- Searching for:
  - Sleptons: ~100 < $m_{\tilde{\tau}}$ < 160 GeV
  - R-hadrons: 300 < $m_{\tilde{g}}$ < 700 GeV

- Search Strategy
  - Use large ATLAS muon spectrometer with good timing resolution
  - Refit the "muon" tracks leaving β as a free parameter
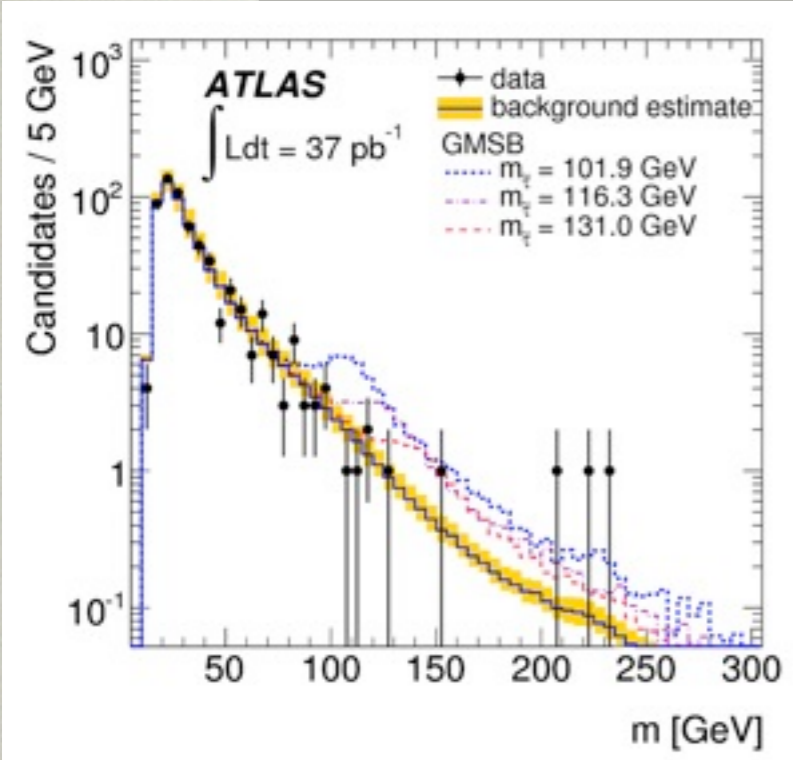
Search using the ID and Calo

- Searching for stable R-hadrons which can be neutral after the calorimeter

- Search Strategy
  - Use pixel dE/dx and Tile Calorimeter time measurement to make two independent measurements of β

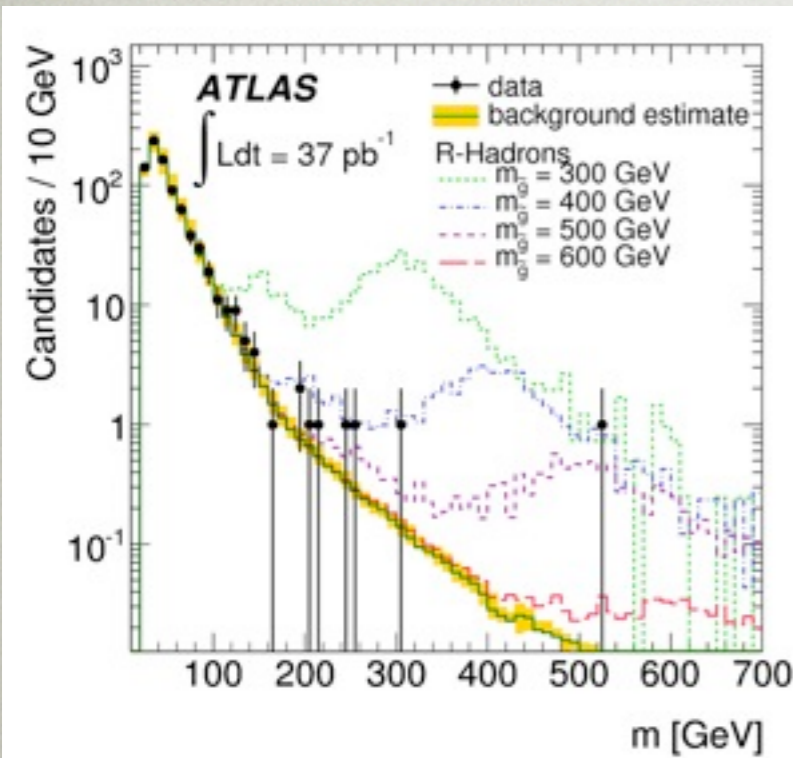Cornell University Library
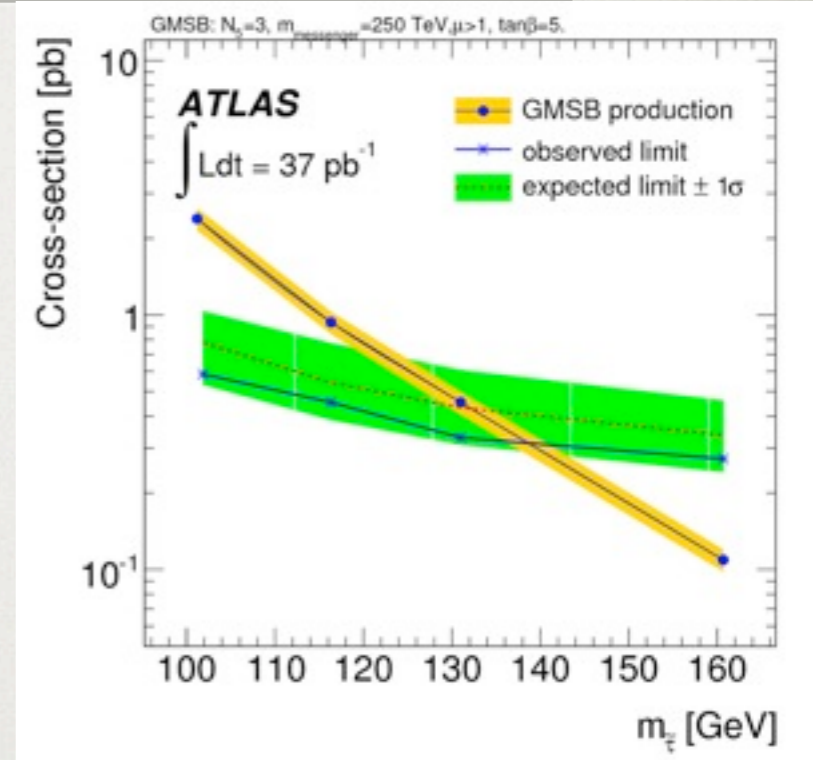
arXiv.org 1106.4495

Slepton Search

- Require Candidates to have:
  - $pT > 40$ GeV and $\beta < 0.95$

$m_{\tilde{\tau}}$ [GeV]	mass cut [GeV]	expected signal	expected background	data
101.9	90	35.9	19.2	16
116.3	110	13.6	9.8	8
131.0	120	7.3	7.2	5
160.7	130	2.0	5.4	4

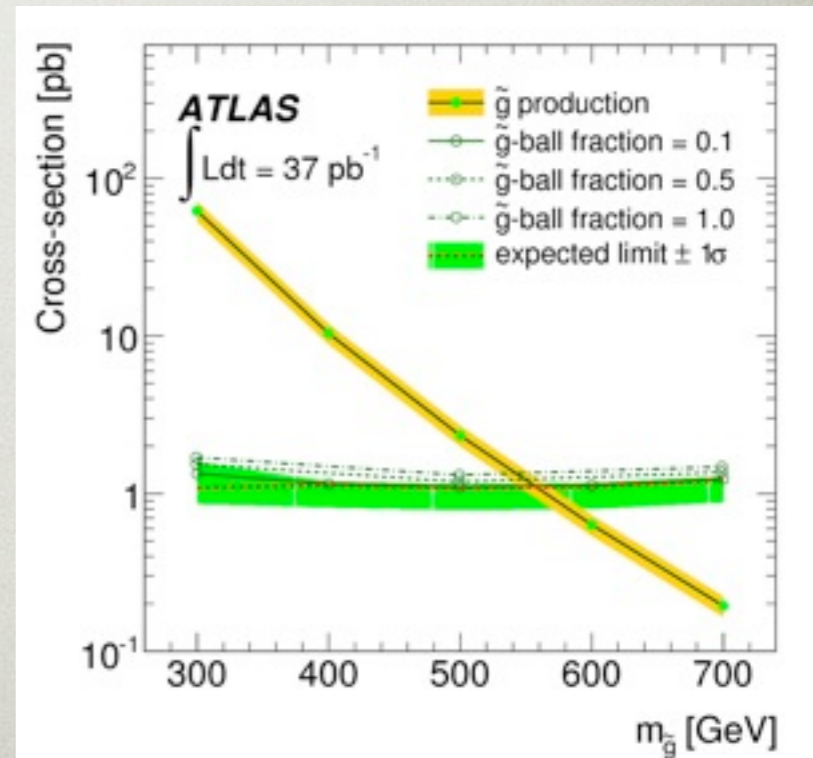The systematics on signal and background are 6% and 15%, respectively

R-hadron Search

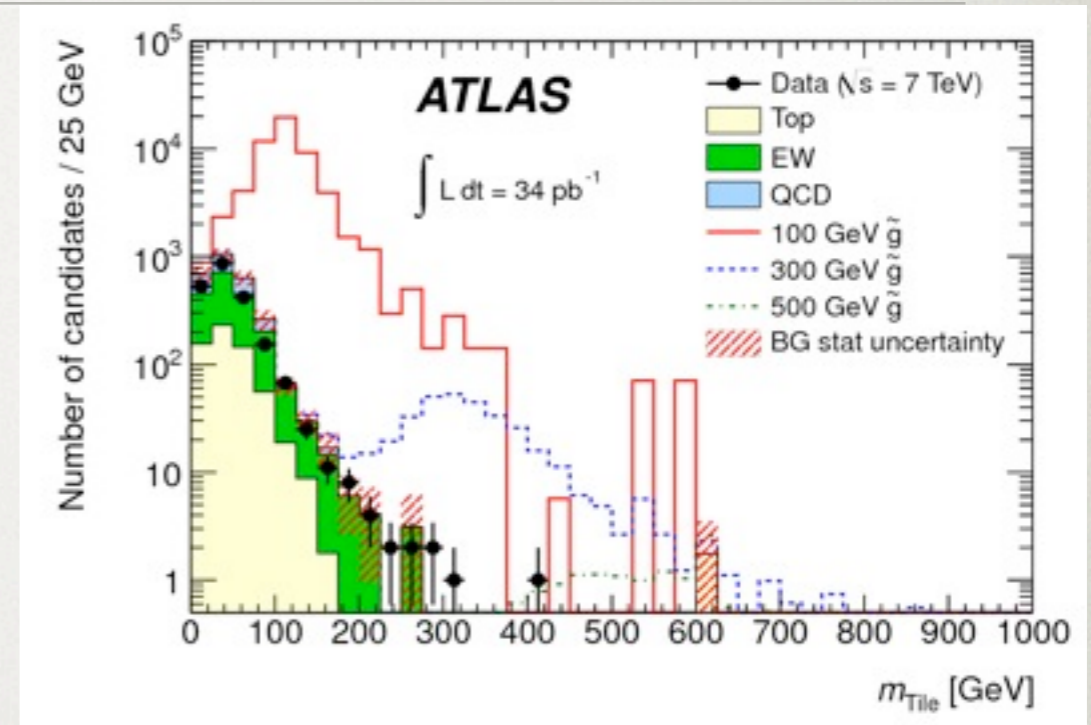- Require Candidates to have:
  - $pT > 60$ GeV and $\beta < 0.95$
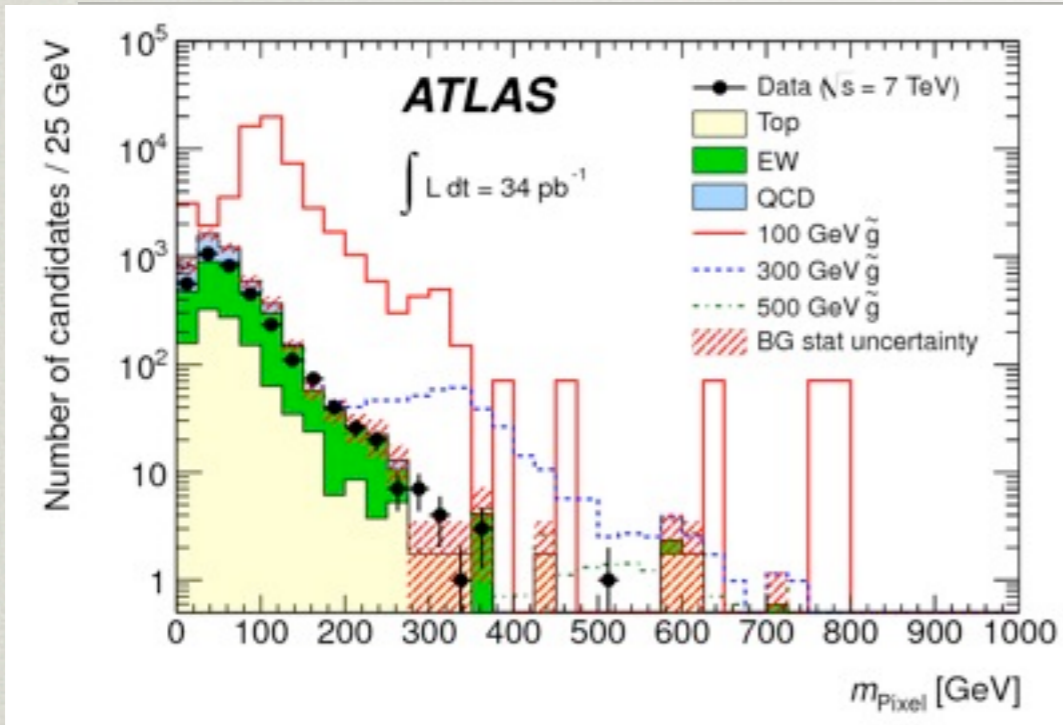
$m_{\tilde{g}}$ [GeV]	mass cut [GeV]	expected signal	expected background	data
300	250	254.4	2.3	3
400	350	36.2	0.7	1
500	350	8.7	0.7	1
600	350	2.2	0.7	1
700	350	0.6	0.7	1

The systematics on signal and background are 6% and 20%, respectively

- Track required to have:
  - $p_T > 50$ GeV
  - isolated from jets ($E_T > 40$ GeV) and ΔR(jet,track) < 0.5
  - m_{pixel} and m_{Tile} are required to agree
- Results
  - $m_{\tilde{b}} > 294$ GeV
  - $m_{\tilde{t}} > 309$ GeV
  - $m_{\tilde{g}} > 562$-586 GeV