Search for long-lived particles with disappearing-track signature in ATLAS

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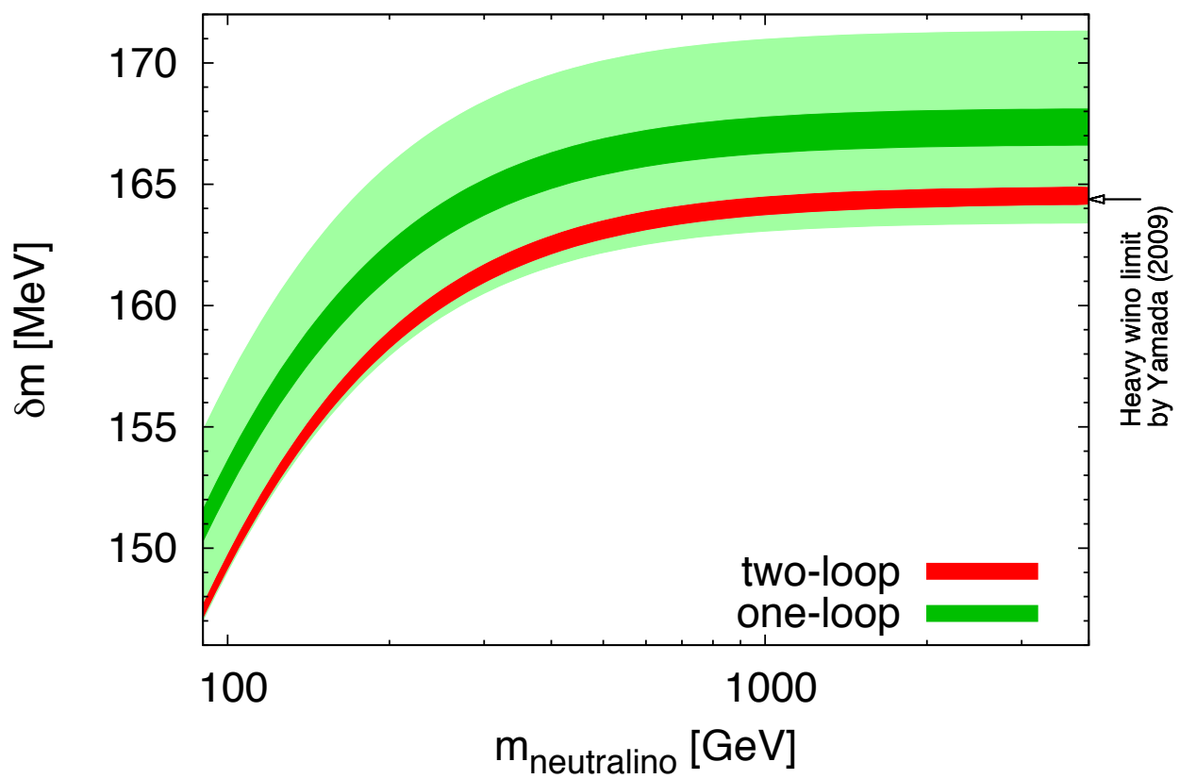
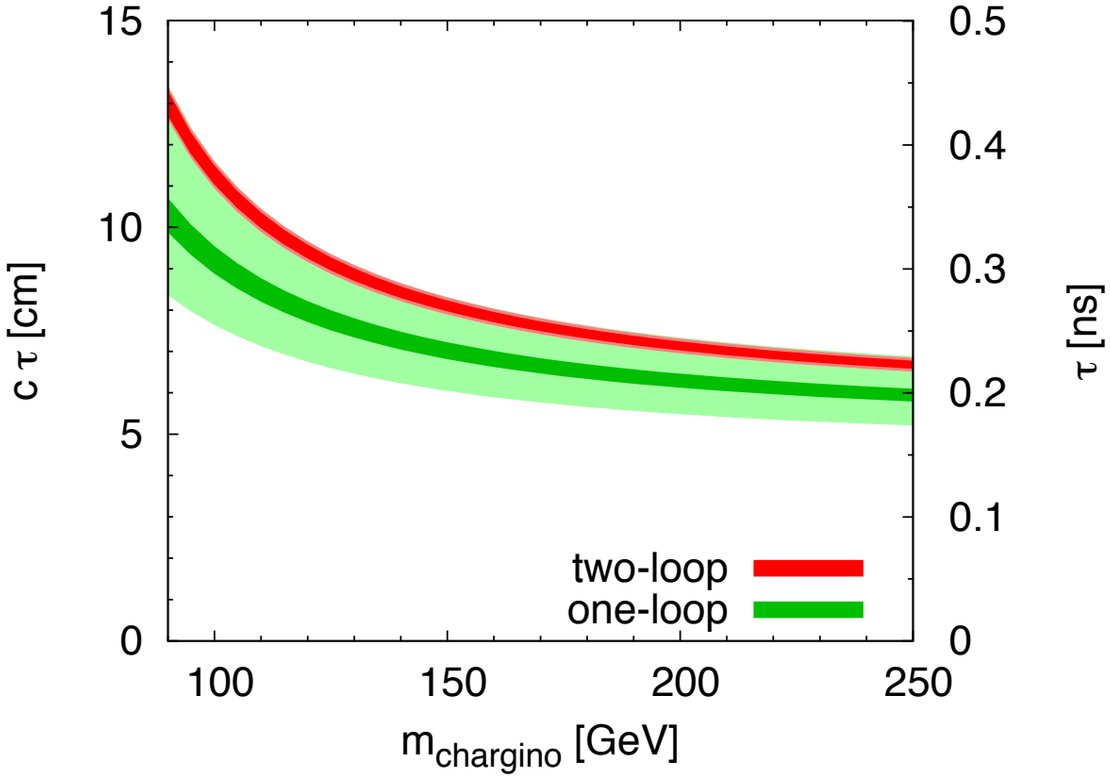
Wino LSP

Many BSM models predict the mass-degeneracy between the stable lightest neutral particle and the next-lightest charged particle.

The lifetime is about 0.2 nsec ($c\tau \sim 6$ cm) and almost independent of the wino mass.

based on [arXiv:1212.5989 hep-ph]



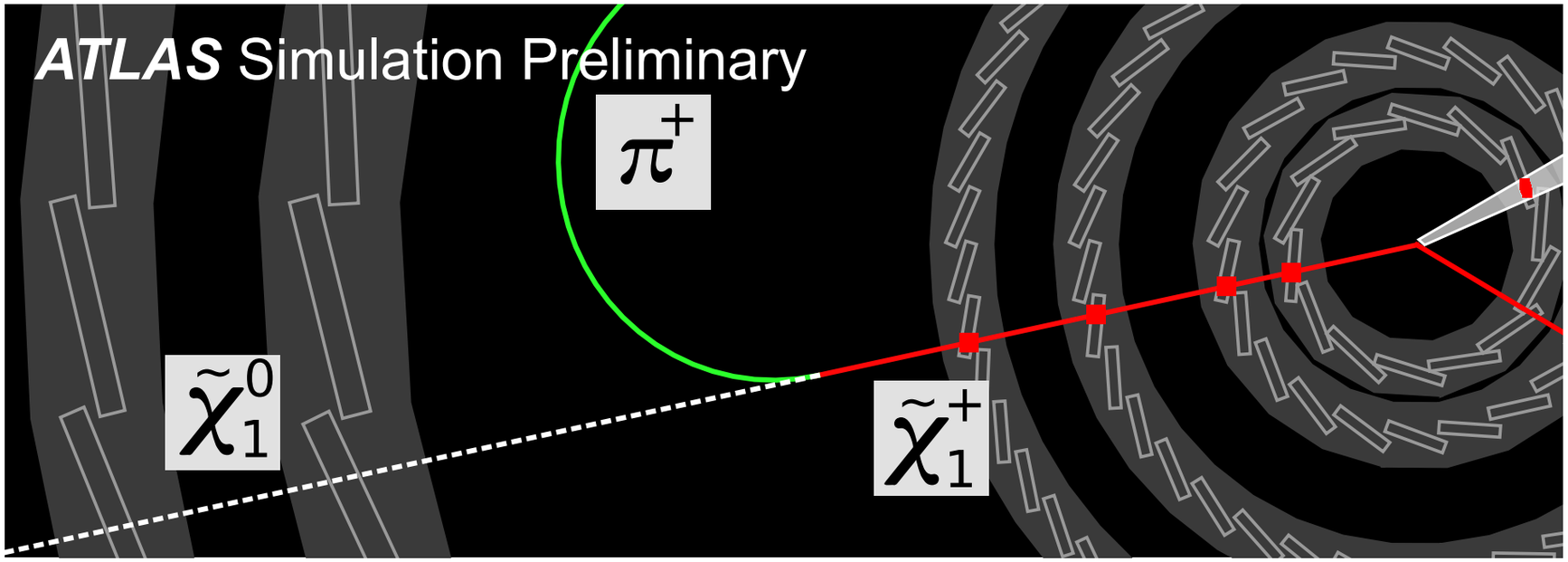


Disappearing track (DT)

A charged long-lived particle may remain a signature as a “disappearing” track

For example,

- **Range of the wino tracks ~ 6cm (or longer due to boost)**
- **A charged wino decays largely into a neutralino and a soft pion (pT < ~500 MeV)**

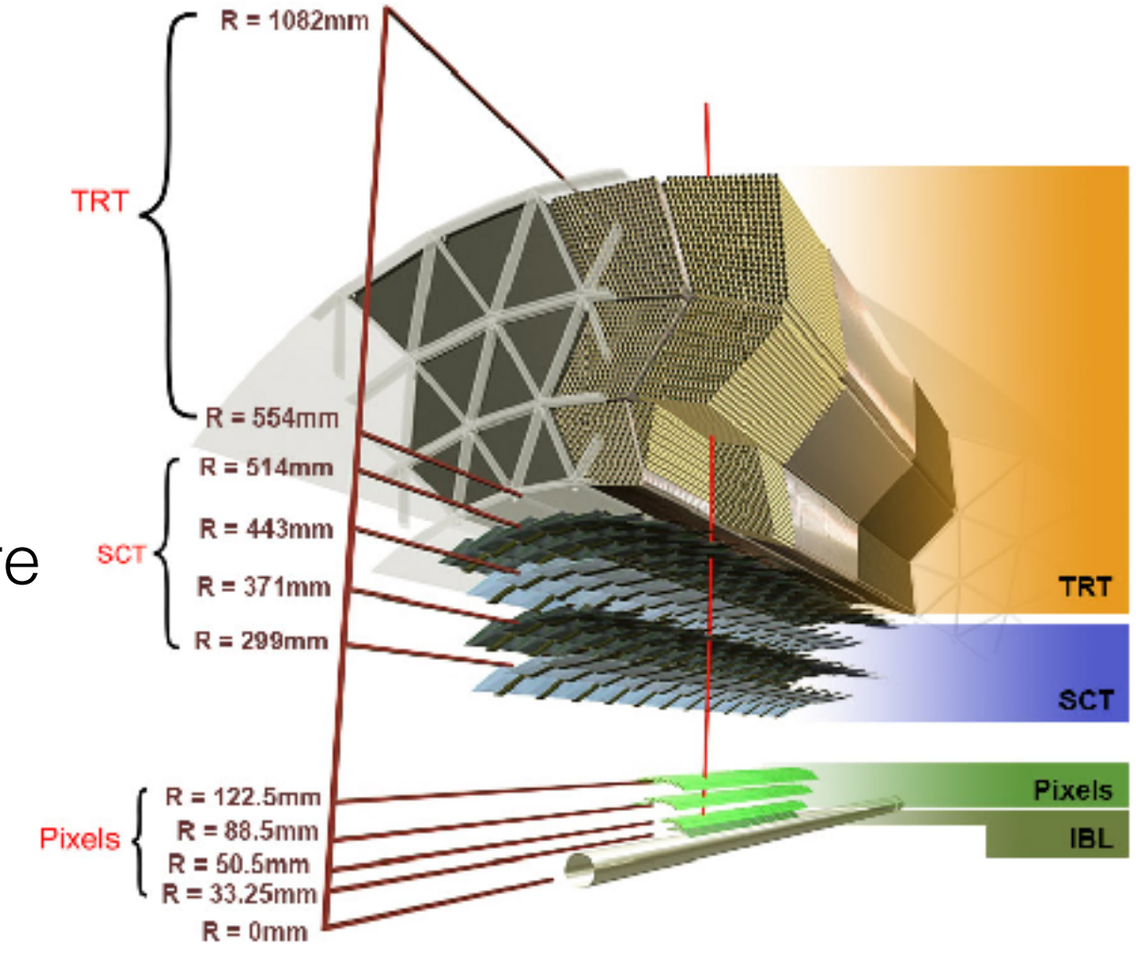


Winos (produced directly or in-directly) may remain disappearing track signature !

New in Run-2

Pixel tracklets

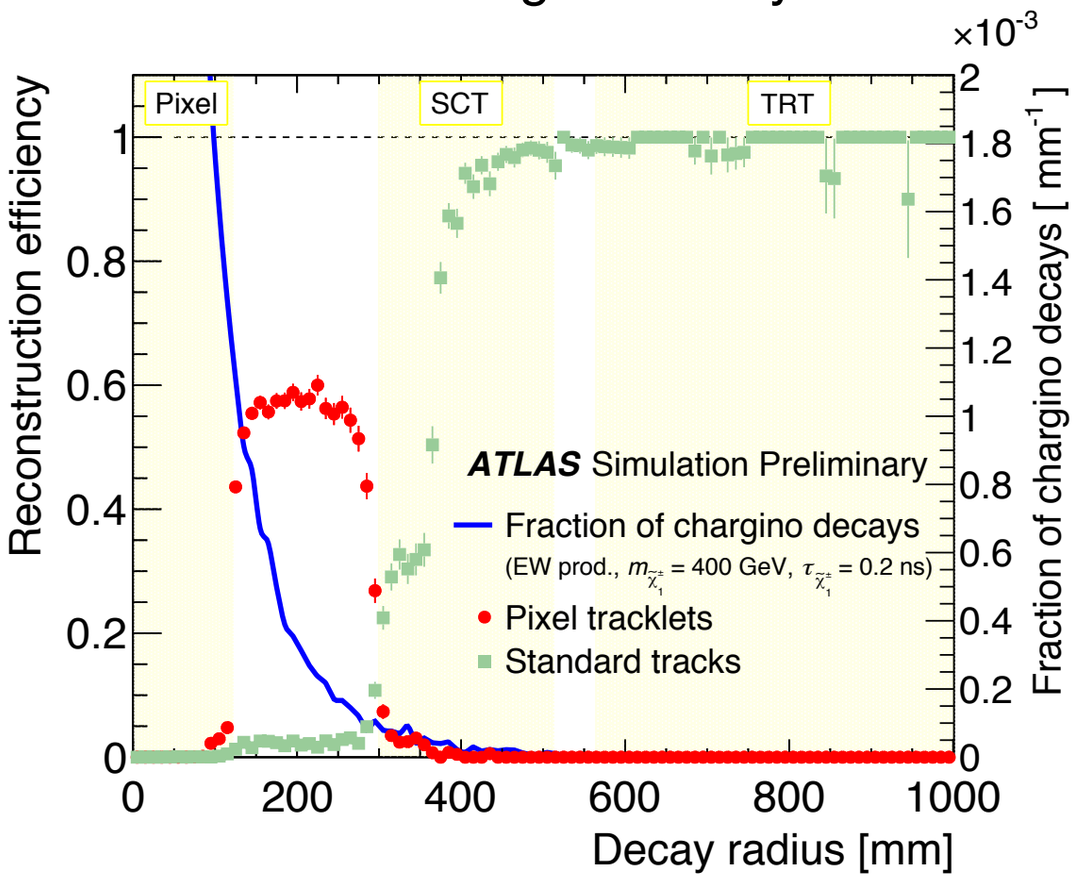
- **Thanks to new Insertable B-Layer**
  - Tracklet length shorten from ~30 cm (Run1) to ~12 cm (Run2)
    - Higher sensitivity for short lifetimes
- **Reconstruction**
  - Use only left-over hits (i.e. hits which are not associated to any standard tracks)
  - Track-fit with at least 4 pixel hits
  - Tracklets extended to SCT



- **Tracklets selection**
  - Isolation from jets, leptons and tracks
  - Good track quality (χ^2, hits in four pixel layers, no bad hits)
  - **Disappearing** (no associated SCT hits)

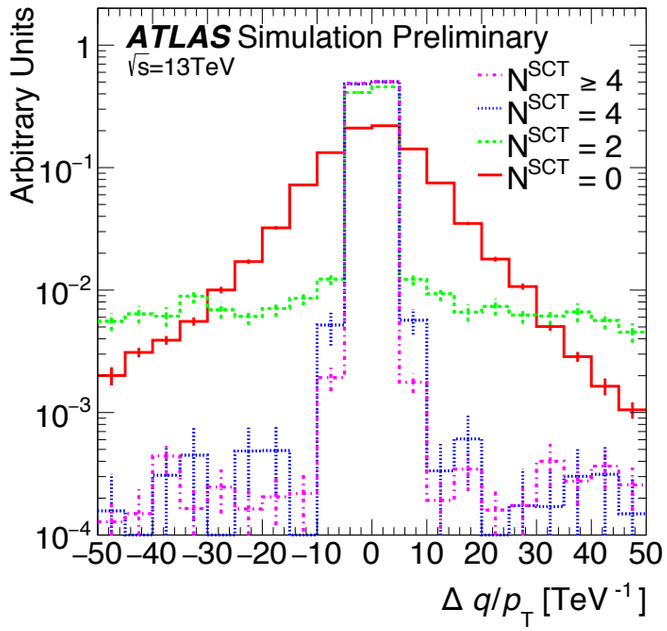
Pixel tracklet performance

Tracking efficiency

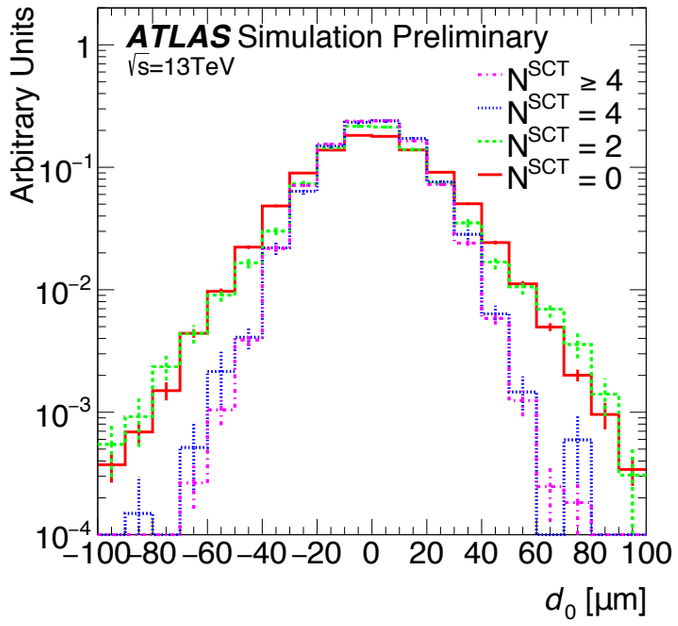


- Efficient in 12 < R < 30 cm
- Inefficiency due to
  - Lost left-over hits : used by (loose?) tracks
  - Temporarily inactive pixel moduls
- Poor momentum resolution
- Moderate pointing resolution

q/pT resolution



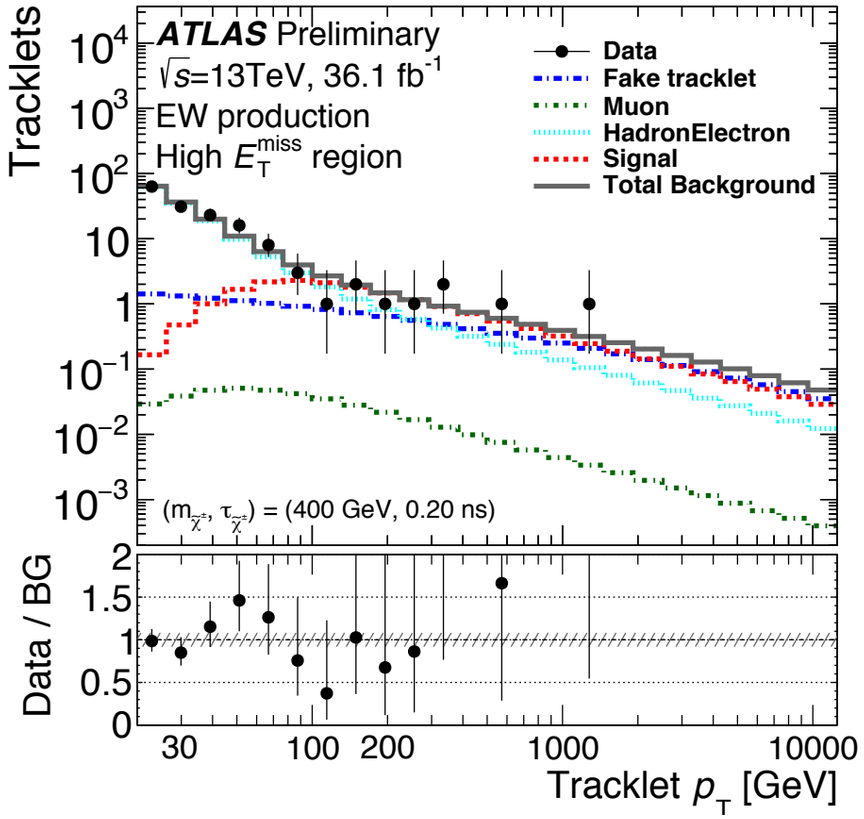
Transverse impact parameter

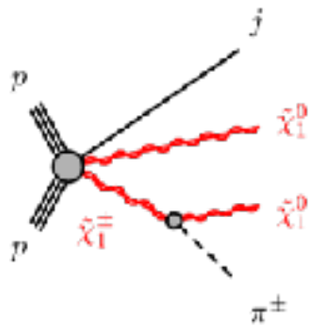


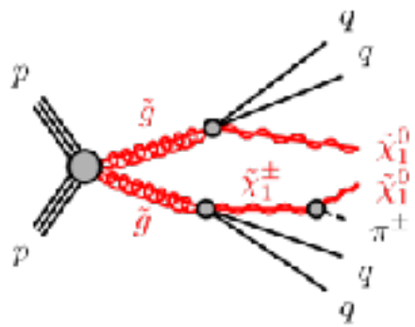
Latest results

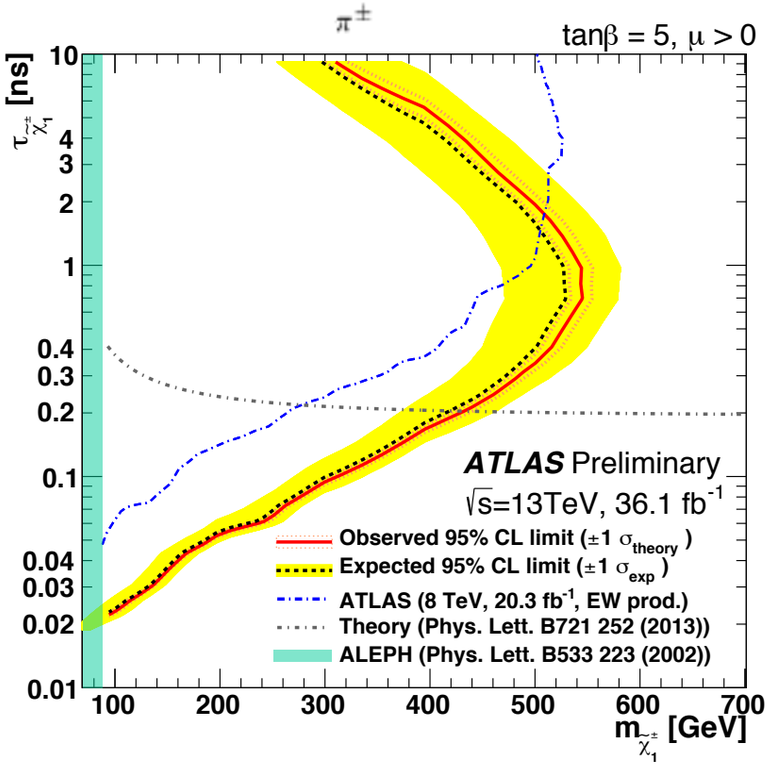
[ATLAS-CONF-2017-017]

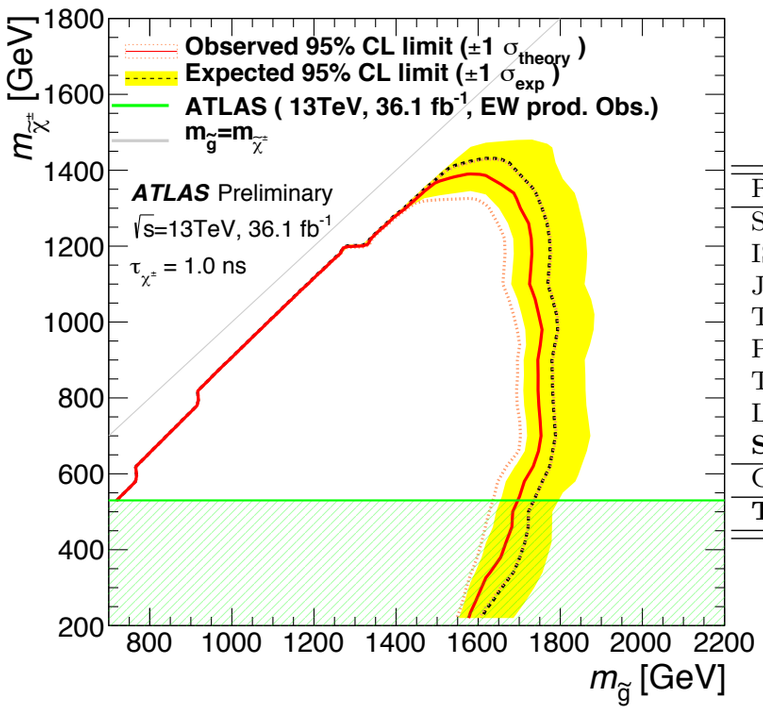
- **Presented in Moriond 2017**
  - Run2 2015+2016 data
  - Signature
    - Electroweak : ISR + MET + disappearing track
    - Strong : Jets + MET + disappearing track
  - Result
    - No excess
    - Stringent limits on wino











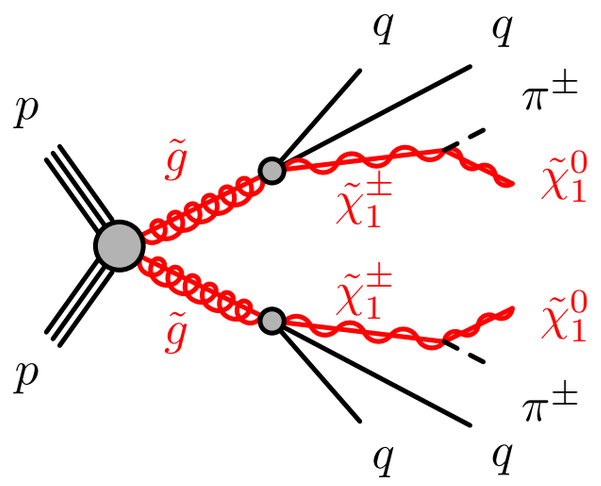
Relative uncertainties (%)	Electroweak channel	Strong channel
Statistics in simulation	6.6	6.5
ISR/FSR	7.6	0.2
Jet energy scale and resolution	2.0	0.7
Trigger efficiency	0.2	0.0
Pile-up modelling	11.0	4.5
Tracklet efficiency	6.9	
Luminosity	3.2	
Sub-total	16.6	11.3
Cross-section	6.4	28.1
Total	17.8	30.2

Ideas for improvement

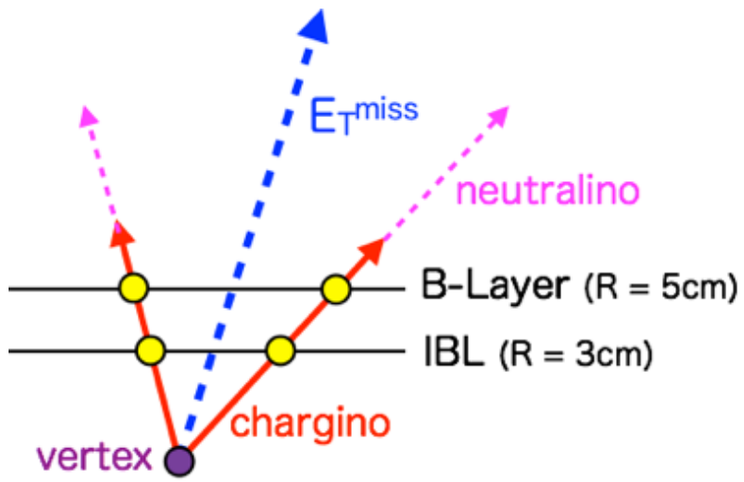
- **Longer tracklets with Pixel+SCT hits**
- **Reduce required number of pixel layers to 3**
  - Recover efficiency due to temporarily inactive pixel modules
  - Shorter tracklets (higher sensitivity for short lifetimes)
    - But the pT resolution would be poorer
- **Track reconstruction only with two inner most layers**
  - Momentum cannot be measured by a tracklet itself
  - New idea to use MET
- **Dedicated trigger ?**
  - Is it possible to triggering on disappearing track (without any pT measurement) and relatively low MET ?

New tool : Very short tracks

Reconstruct only directions from two pixel layers and the vertex



E_T^{miss} ≒ neutralino pt vector sum
≒ chargino pt vector sum



- When there are two disappearing tracks, we can reconstruct pT with splitting MET
- Use dE/dx of pixel hits to select tracks associated to signal (smaller β than BG)

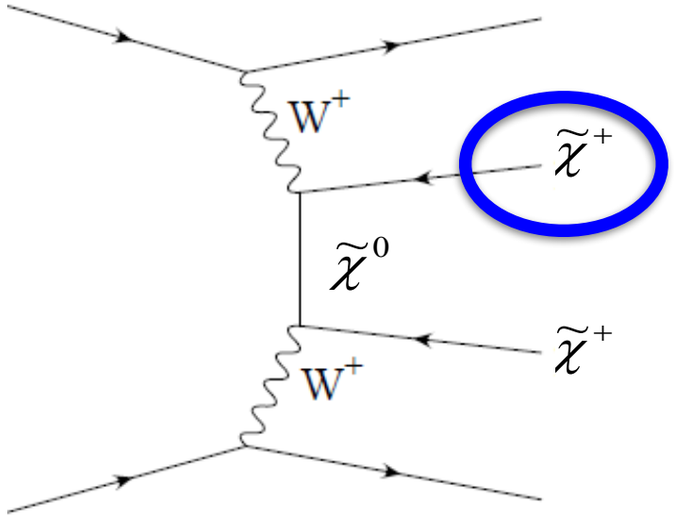
- **Efficient for even shorter lifetimes (5 cm < $c\tau$)**
- **Much better momentum resolution than pixel-tracklet**

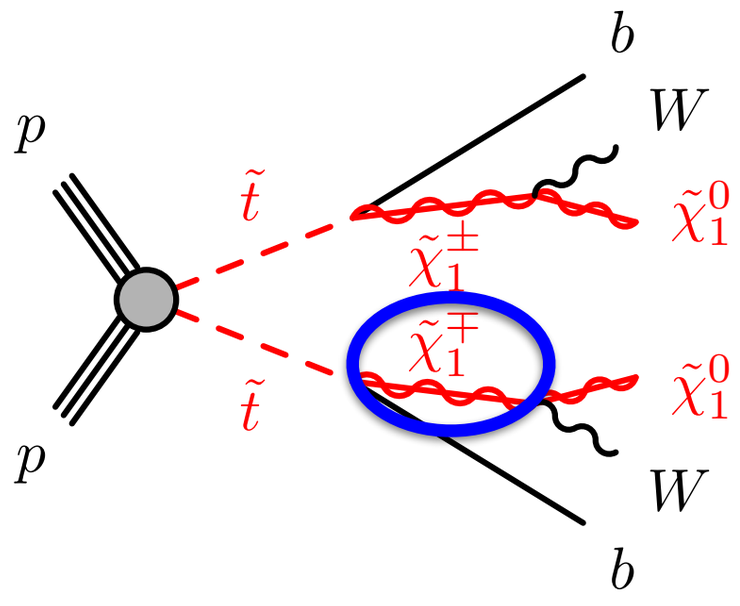
Other search channels

- **Higgsino production**
  - Shorter lifetime and smaller cross section
  - Very-short track should improve the sensitivity

- **Charginos from stop decays**
  - bb + disappearing track

- **Vector boson fusion**





[arXiv:1210.0964]

Summary

- Searches with the disappearing track signature is sensitive to an interesting range of lifetimes of new particles
- From ATLAS, a new result with four pixel layers (12 < decay radius < 30 cm) presented in Moriond
- We are going to improve analysis for longer and shorter lifetimes.
- Ideas for improving tracking to enhance the signal efficiency.