# Disappearing Track Searches at the LHC and Future Colliders

**1703.09675, in preparation**

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December 12, 2017

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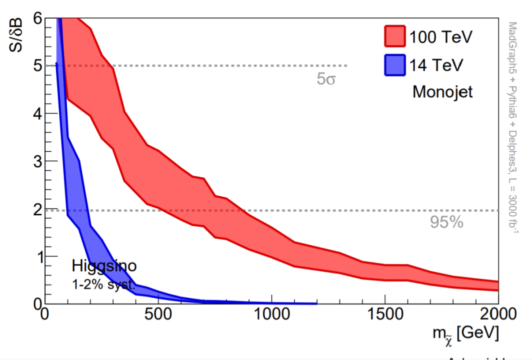
# Dark Matter and Supersymmetry

- DM is rather a *motivation* for SUSY
- Suppose Higgsino LSP as an example
  - Same goes for wino and even the minimal DM
- Thermal abundance fixes the mass
  - $1.1$ TeV for Higgsino DM
  - It still sounds within the range of colliders

# Dark matter @ Colliders

- Basic strategy: $\not{E}_T + X$
- Poorer than the thermal mass even for $100$ TeV

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# Another strategy

- **Disappearing tracks** from the decay of **charged partners**

# Take a detailed look at SU$(2)$ multiplet

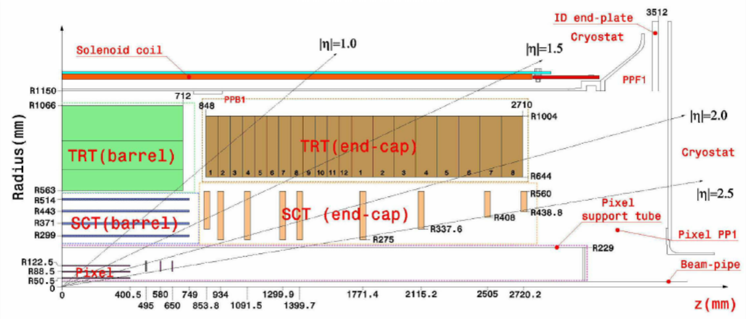
$$\tilde{h} = \begin{pmatrix} \tilde{h}^0 \\ \tilde{h}^+ \end{pmatrix}$$

- Charged partners are *always* there
    - Must be heavier then the neutral one

# Mass difference and the lifetime

- No SU$(2) \times$ U$(1)$ breakdown, no mass diff.
    - Mass diff. is much smaller than the thermal mass
- For smaller mass diff., *larger lifetimes* are expected
    - $c\tau(\chi^+ \to \chi^0 \pi^+) \sim 0.7\,\text{cm} \left(\frac{\Delta m}{350\,\text{MeV}}\right)^{-3}$ for Higgsino

# Disappearing tracks in colliders




ATLAS collabolation, arXiv:1110.6191

- A charged partner decays inside the tracker region → *Disappearing* track
  - The $p_T$ of $\pi^{\pm}$ is not large enough to reconstruct its track

# Two origin of the mass difference

- Radiative correction $\Delta m \sim \frac{\alpha}{4\pi} v_{\mathrm{EW}}$
  - $350$ MeV for Higgsino
- Mixing with other particles

# Mixing with other particles

- For Higgsino: bino or wino-like particle
- Roughly, mass diff. $\simeq$ coupling to Higgs
  - The larger the diff. is, the larger the couplings **to SM particles** are
  - If the mass diff. is large enough, direct detection cross section is larger than the $\nu$-floor

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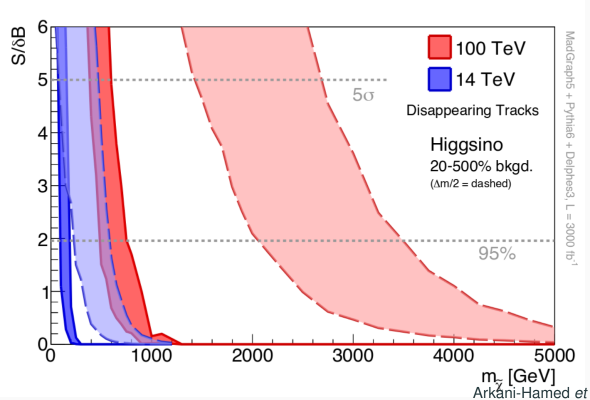
# Setup for disappearing track search

- Assume only radiative mass difference;
    - $c\tau(\chi^+ \to \chi^0\pi^+) \sim 0.7\,$cm for Higgsino
    - (Such “decoupling” DM models are also theoretically motivated like split-type SUSY)

# Conventional study

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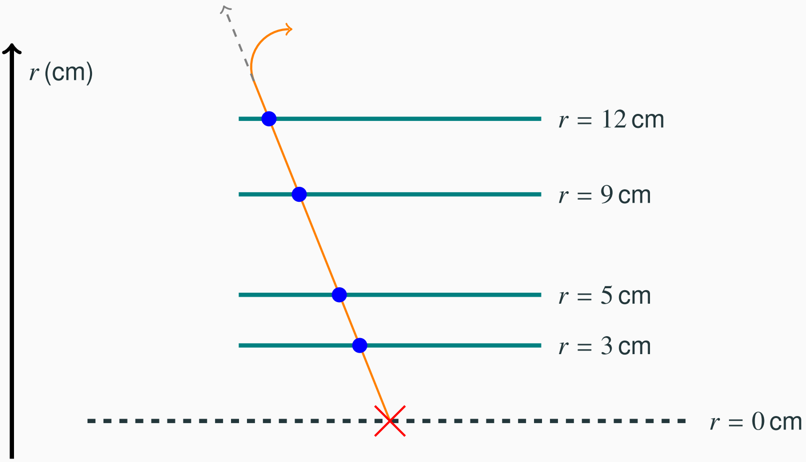
- For Higgsino, even $100$ TeV is still not enough!

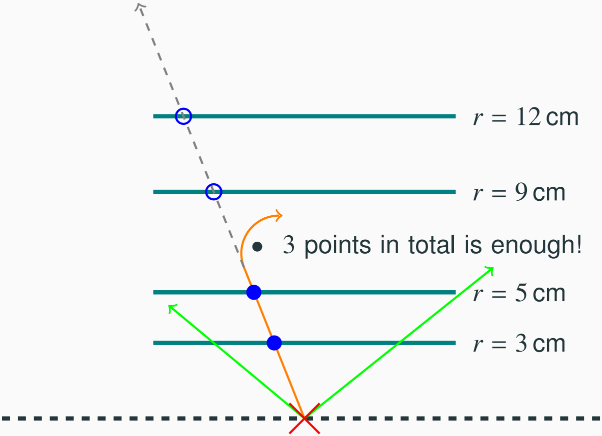
# What limits the sensitivity?

- Numerous Higgsinos are *there*
- Just we can *not* see enough disappearing tracks
- Why? - Matter of analysis/tracker

# Look inside the tracker

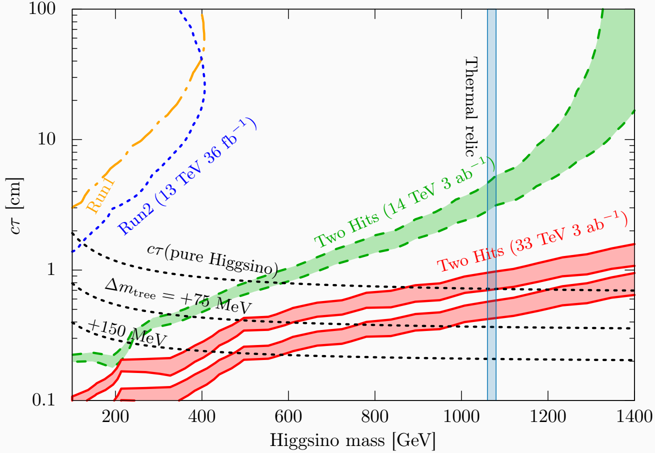


# Improvement to $2$-point search




- Interacting point is determined by the other jet activities

# Result



100
10
1
0.1
$c\tau$ [cm]
200
400
600
800
1000
1200
1400
Higgsino mass [GeV]
Run1
Run2 (13 TeV 36 fb$^{-1}$)
Thermal relic
Two Hits (14 TeV 3 ab$^{-1}$)
Two Hits (33 TeV 3 ab$^{-1}$)
$c\tau$(pure Higgsino)
$\Delta m_{\rm tree} = +75$ MeV
+150 MeV

# Conclusions

- Disappearing track is essential for the DM and **SUSY** search
- We need to not only increase the energy but also **improve trackers and analysis**
- BG estimation & reduction is very important

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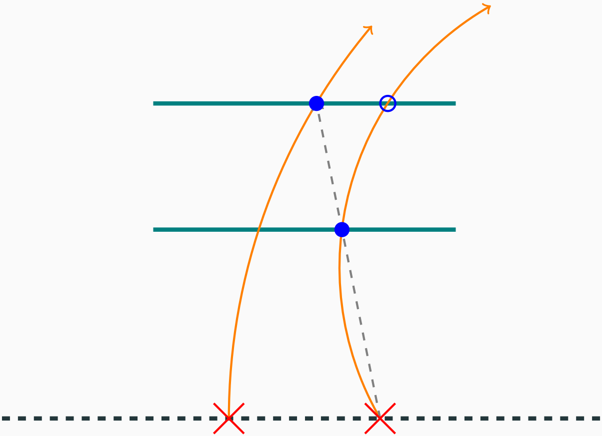
# Backup

# What is the background

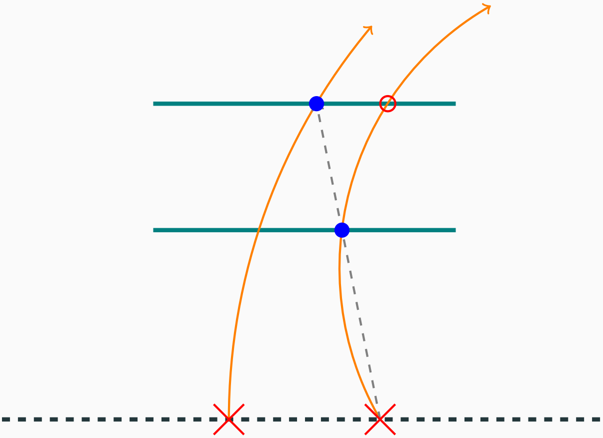
- Misidentification of kink tracks
  - Does not change much for 2-pt strategy
  - Also, the displaced vertex analysis can be used
- **Fake disappearing tracks**

ATLAS-CONF-2017-017

# Fake disappearing tracks



# Reduce them by additional points



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