Disappearing Charged Tracks, revisited

Rakhi Mahbubani, EPFL

with Pedro Schwaller and Jose Zurita, arXiv:1703.05327

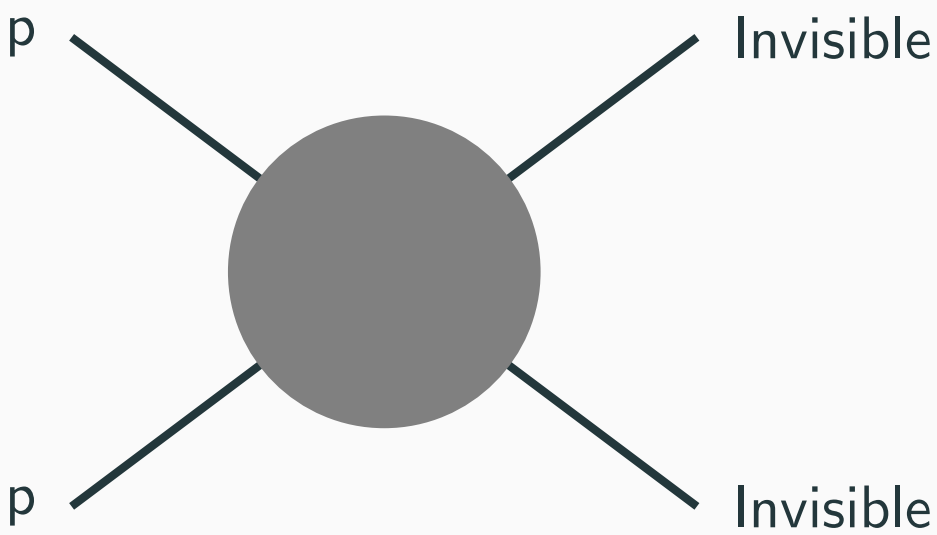
12th June 2017

Invisibles 2017

What Invisibles?

- Pair-produced
- Collider-stable
- May comprise a significant component of dark matter

Invisibles at hadron colliders



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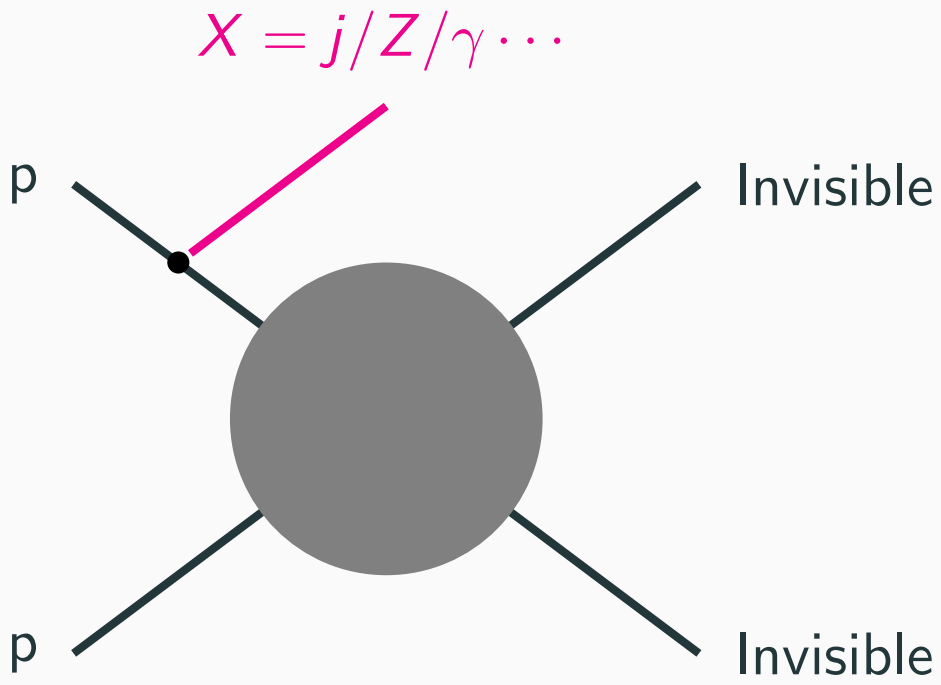

Hard emission of visible particle X

What Invisibles?

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- Collider-stable
- May comprise a significant component of dark matter
- Contains a nearby charged state that decays to it invisibly

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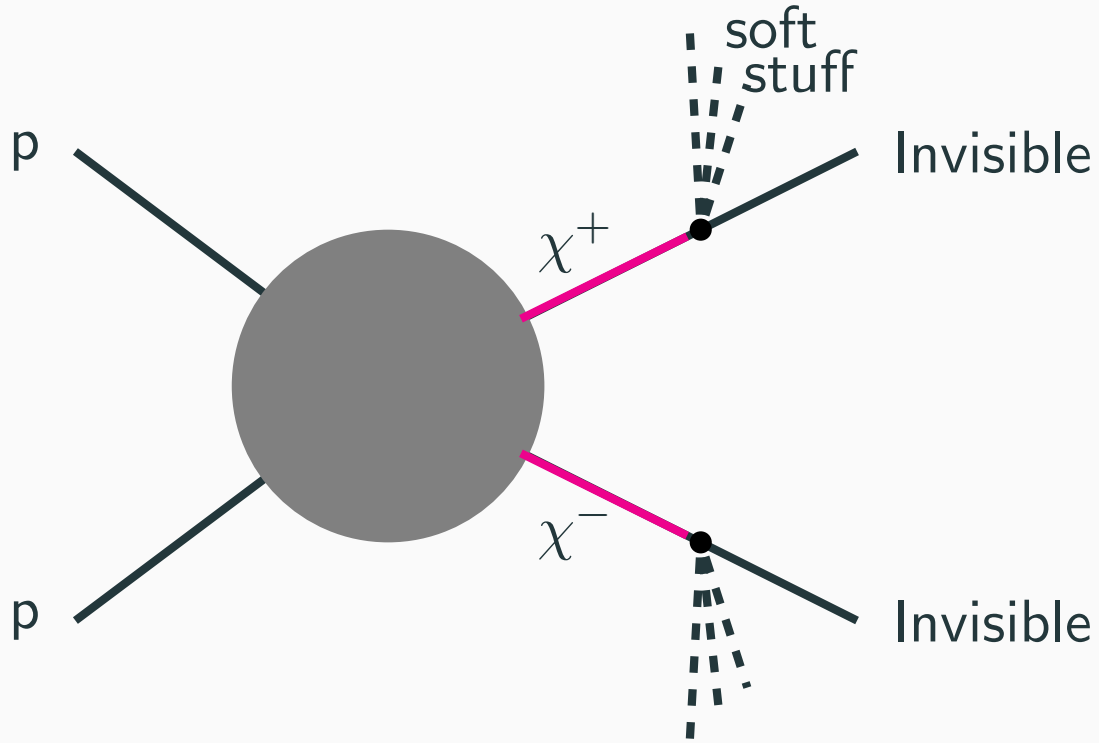

Disappearing charged track

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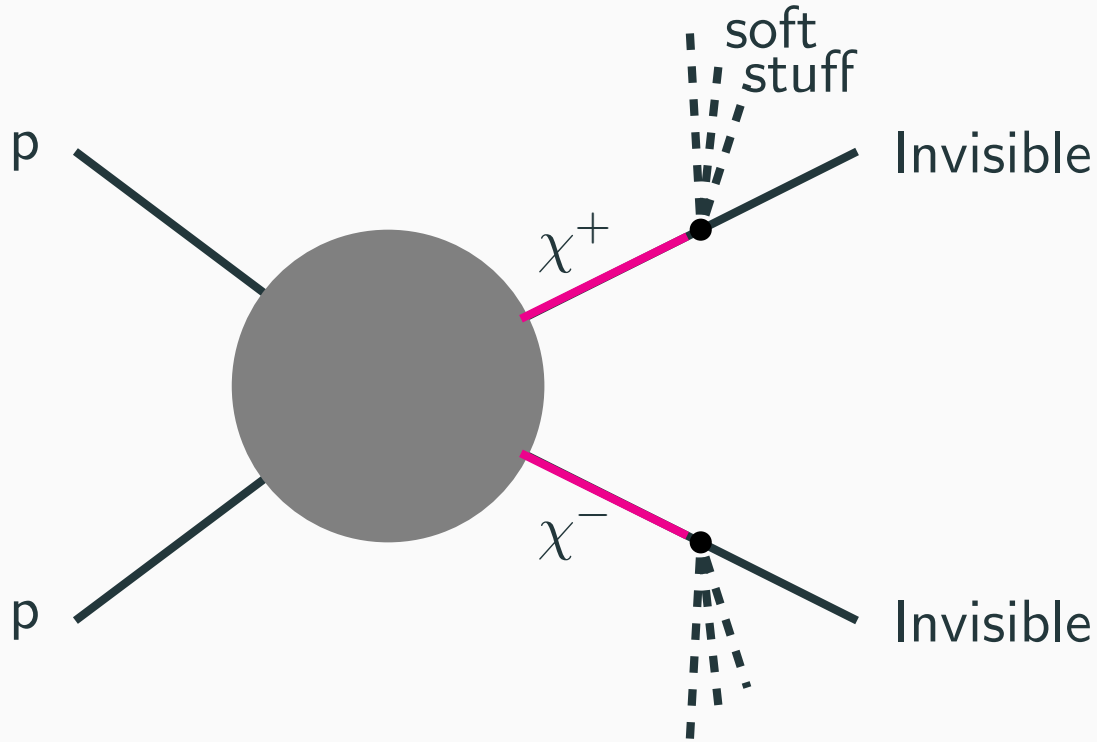
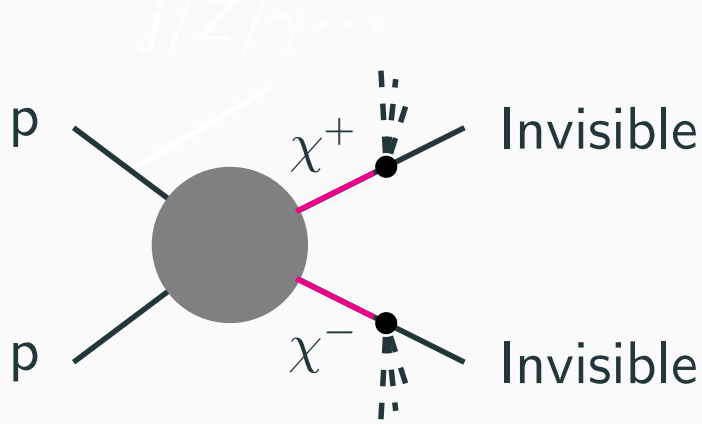


Disappearing charged track

Traditional searches sensitive to charged particles with lab-frame lifetime $\sim$ 1-2 ns.*

How can we increase the sensitivity to disappearing tracks at (current and future) hadron colliders?

Disappearing tracks 101



Disappearing charged track

Charged state has:

- 'nominal decay length' $c\tau$
- lab frame decay length $d_0 = \beta\gamma c\tau$
- number of particles travelling a distance d, $\mathcal{N} = \mathcal{N}_0 \exp\left(-\frac{d}{d_0}\right)$

The setup

We simulate pair-production of a weak doublet fermion χ with hypercharge $^{-1}/_{2}$ and dirac mass m_χ at a proton-proton collider, at 14 and 100 TeV .

$$\mathcal{L} \supset i\bar{\chi}\left(\not{\partial} - ig\not{W} - ig'\frac{1}{2}Y\not{B}\right)\chi + m_\chi\bar{\chi}\chi\,, \tag{1}$$

Analysis efficiencies relatively insensitive to details of model.

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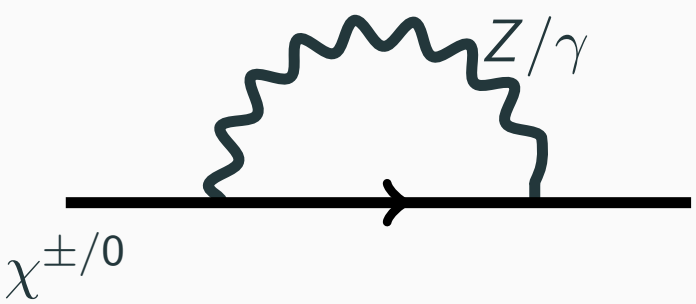

Splitting due to EW loop, $\Delta_+ \sim 0.3$ GeV*. We take as free parameter.

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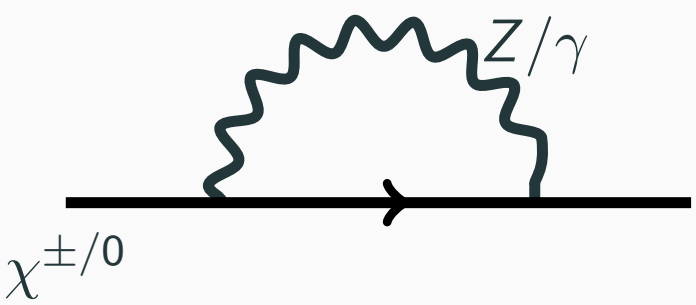

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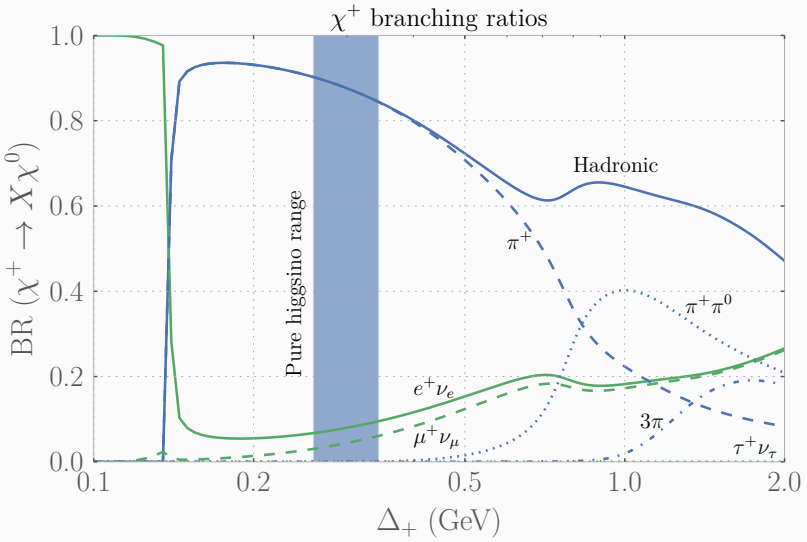
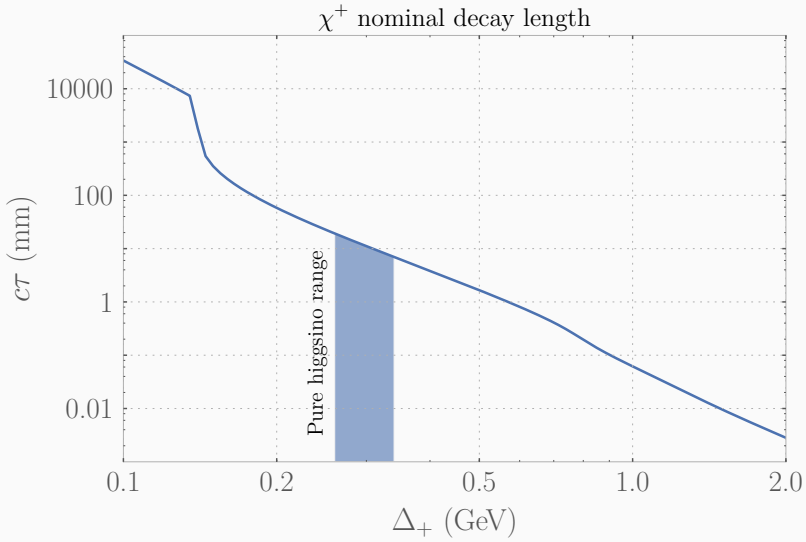
*Corresponds to pure higgsino limit of MSSM

Decays





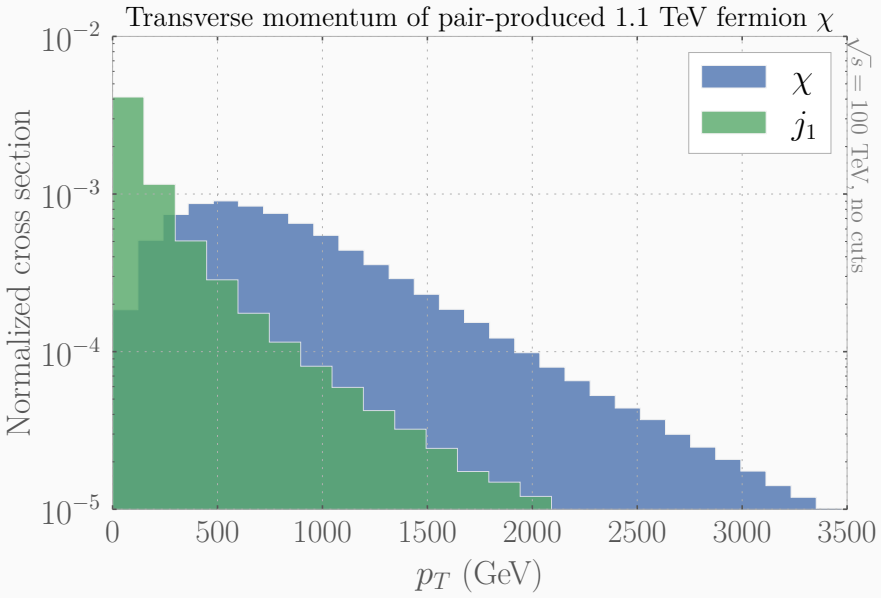
Decay width of doublet strongly dependent on splitting.

For electroweak splitting, decays mainly to soft pion with p_T below threshold for detection, with nominal decay length $<$ cm.

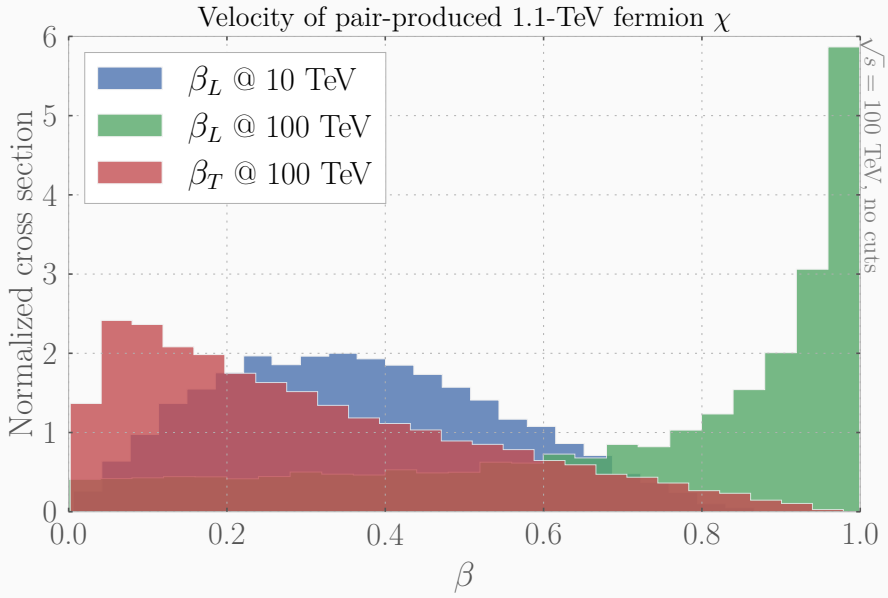
Analysis is insensitive to the identity of the daughter.

Will use $m_\chi = 1.1$ TeV, $c\tau = 6.6$ mm as reference throughout.

Disappearing Charged Track



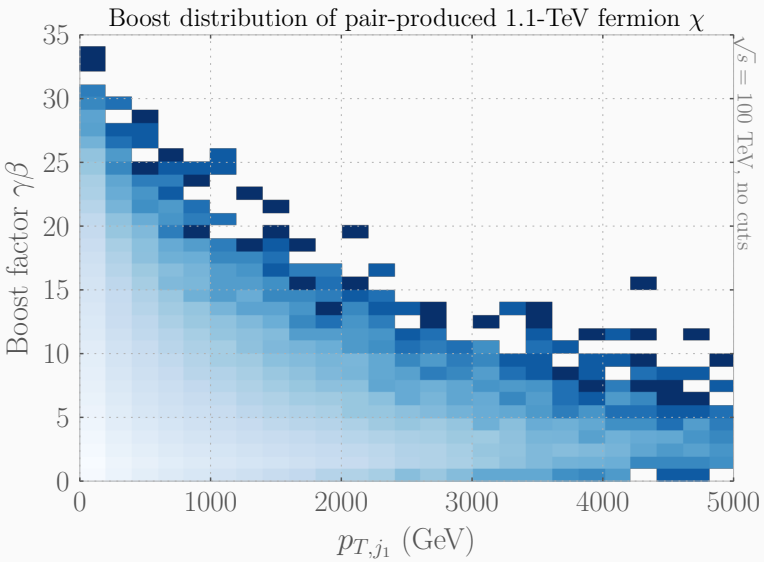
Transverse momentum set by mass scale.



Relevant scale for longitudinal momentum $\sqrt{s}$

Disappearing Charged Track

Conventional analyses trigger on p_T of radiated jet.



Lose particles with largest boost.

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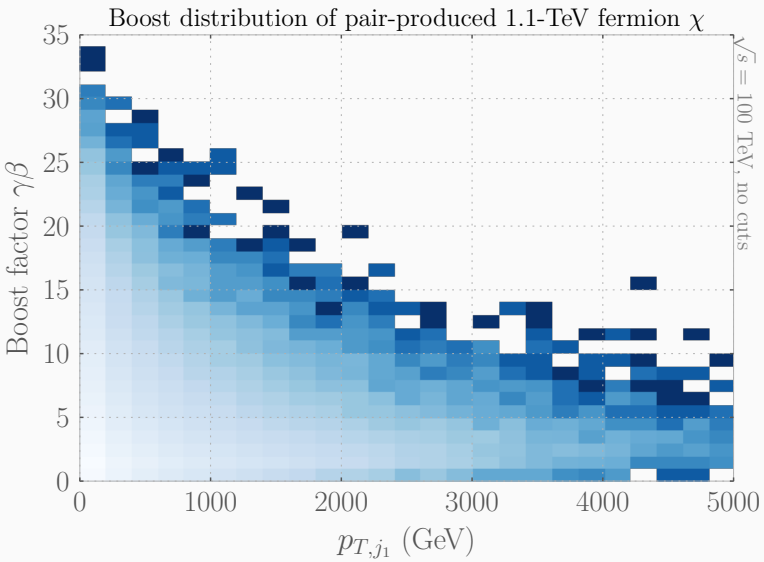

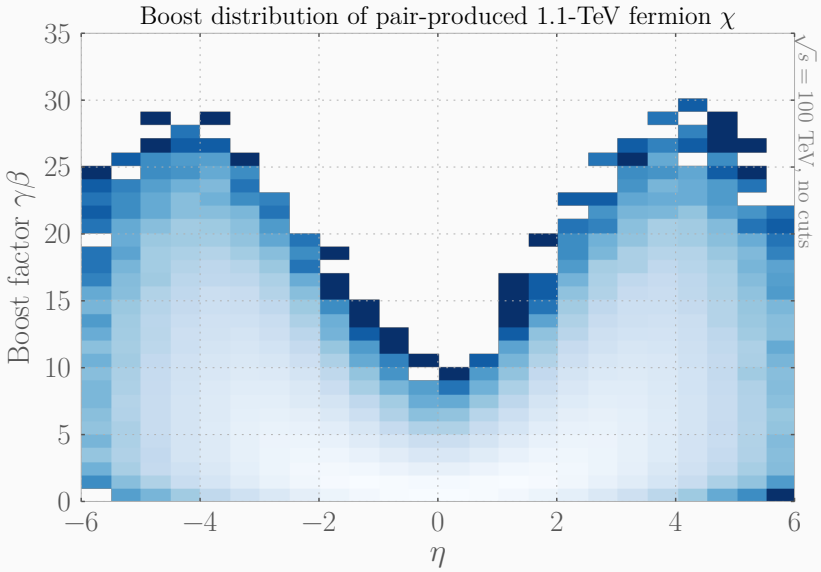

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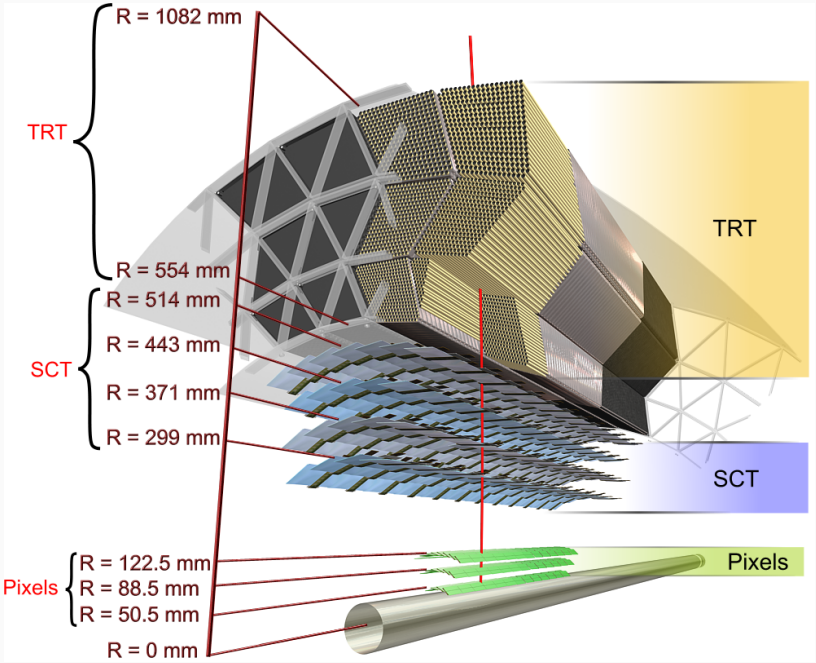
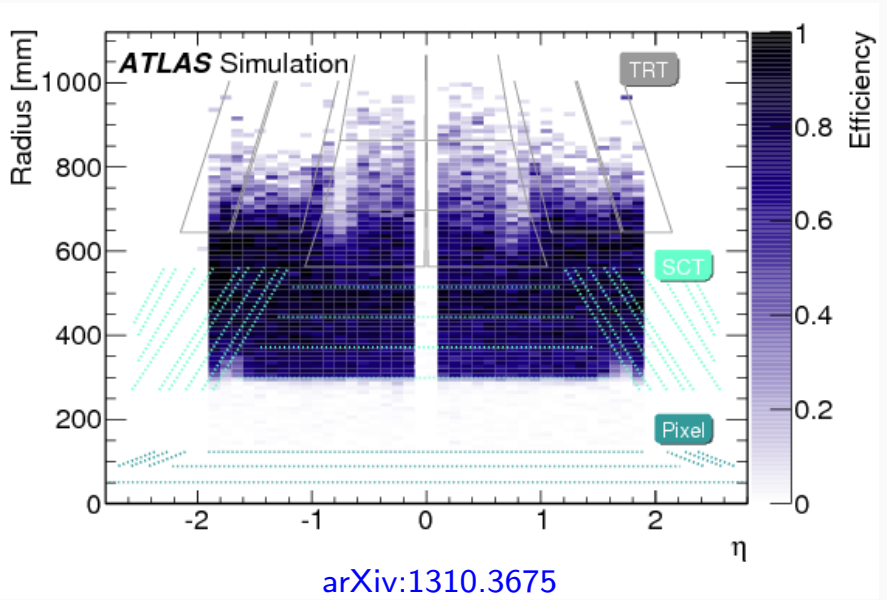
Spoiler: η range of large-boost particles not covered.

Disappearing Charged Track: the problem





arXiv:1310.3675

ATLAS required*:

5 hits in Pixel and SCT for reco.

Veto on tracks with many TRT hits.

100% acceptance @ $r > 30$ cm.

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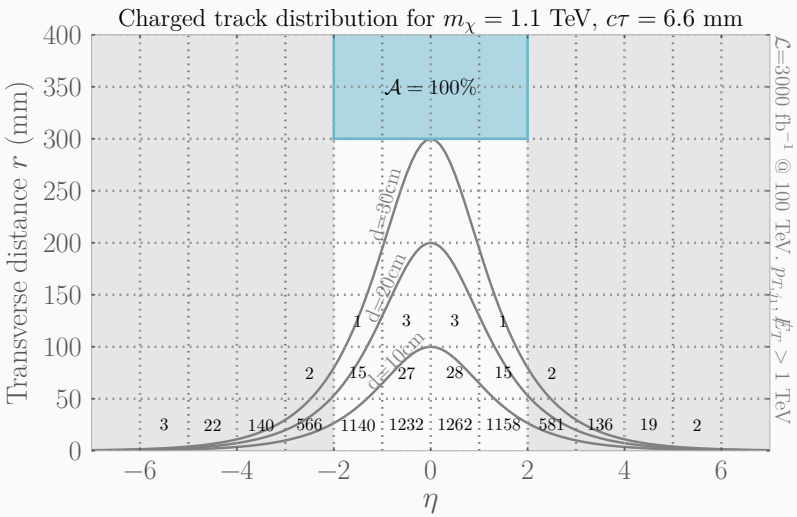

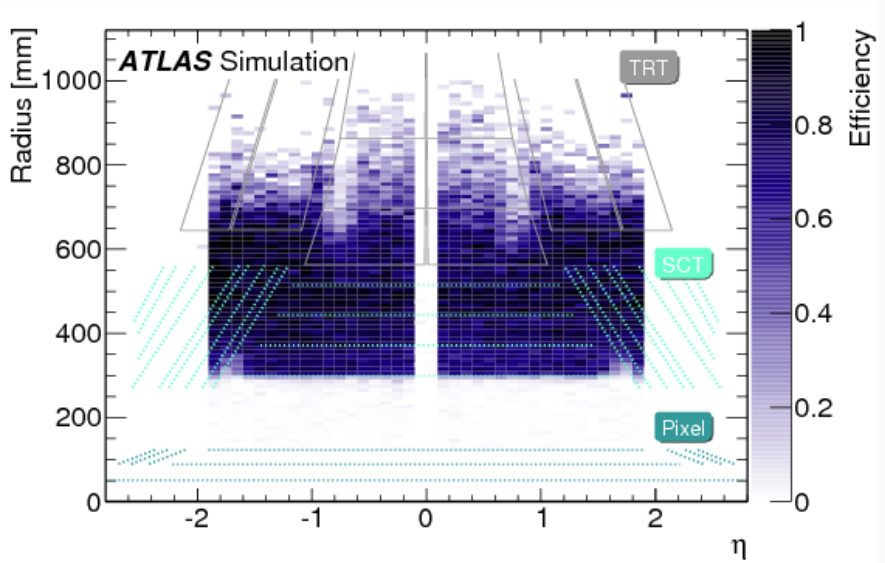

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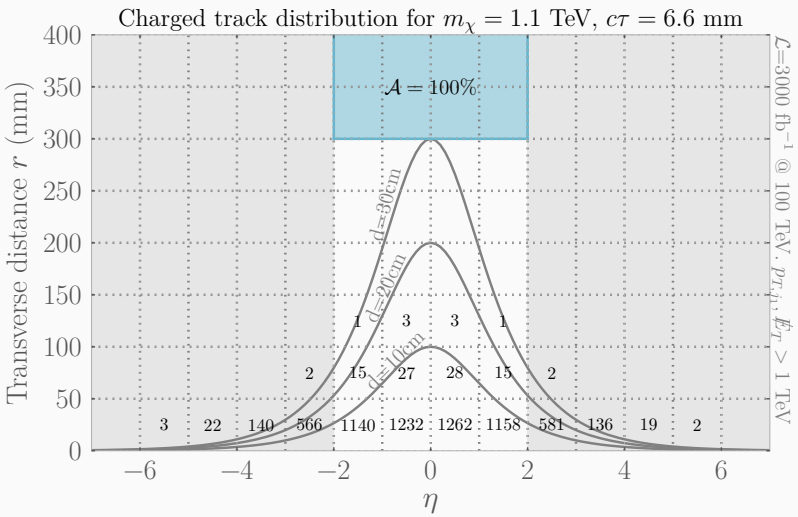

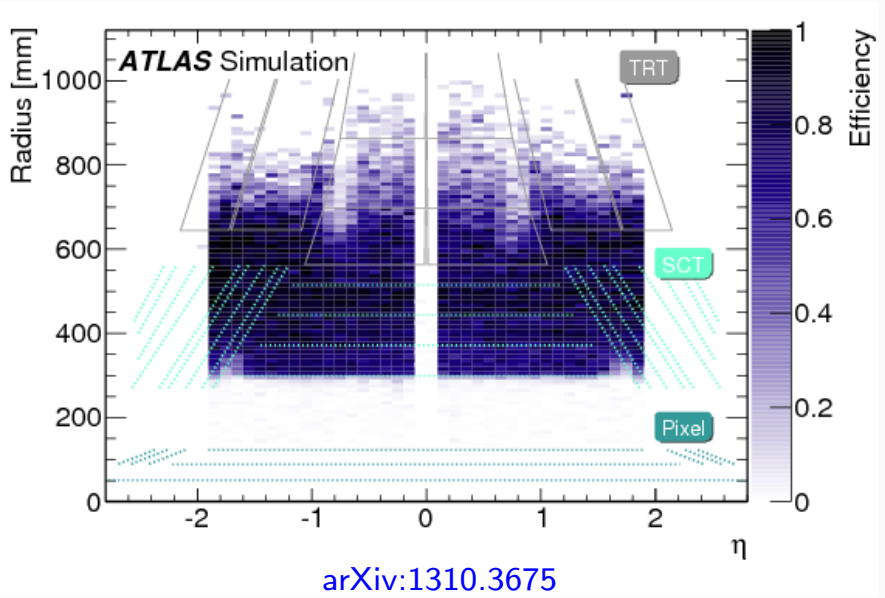

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*Recent LHC13 update uses IBL and pixel tracklets to reach $r > 12$ cm (ATLAS-CONF-2017-017)

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Need to move away from conventional recoil p_T/MET-based search.

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BUT... feasibility? Backgrounds?

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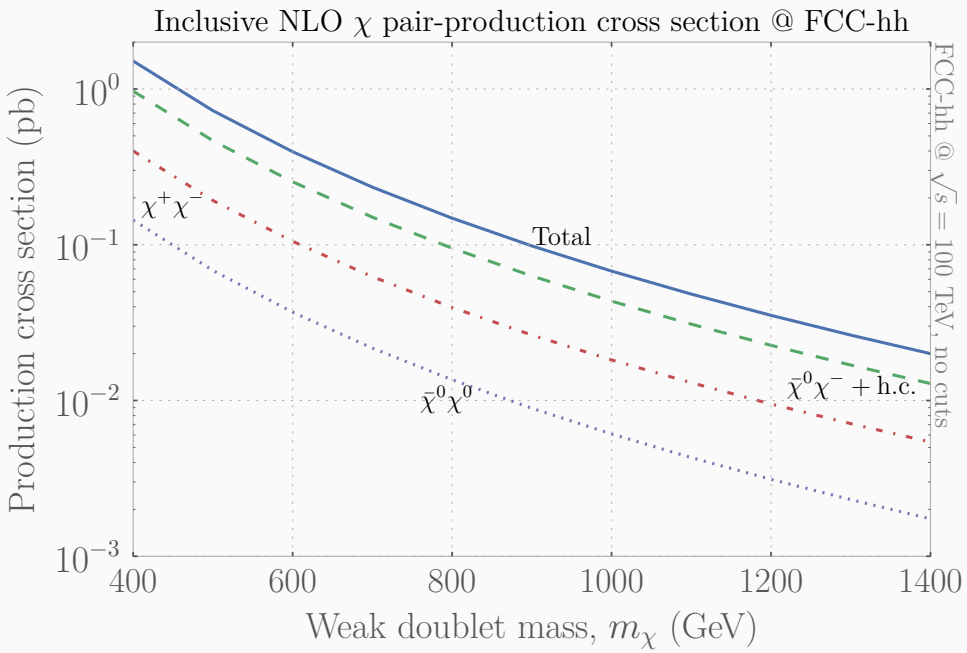
'Conventional' analysis

Modeled on existing ATLAS analysis with rescaled cuts

'Track-based' (TB) analysis

Assume triggering on $p_{\mathrm{track}} \gtrsim$ a few TeV and dE/dx is sufficient.

Disappearing Charged Track: 'Conventional' analysis



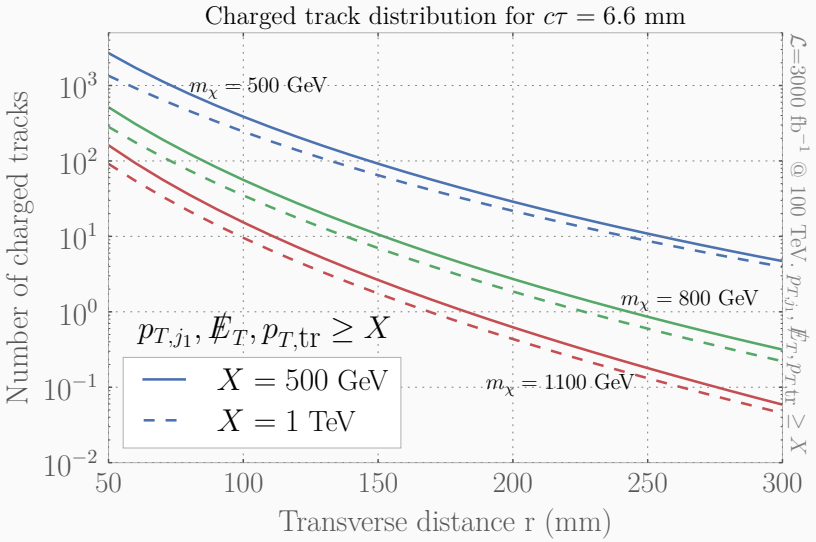
Pre-selection

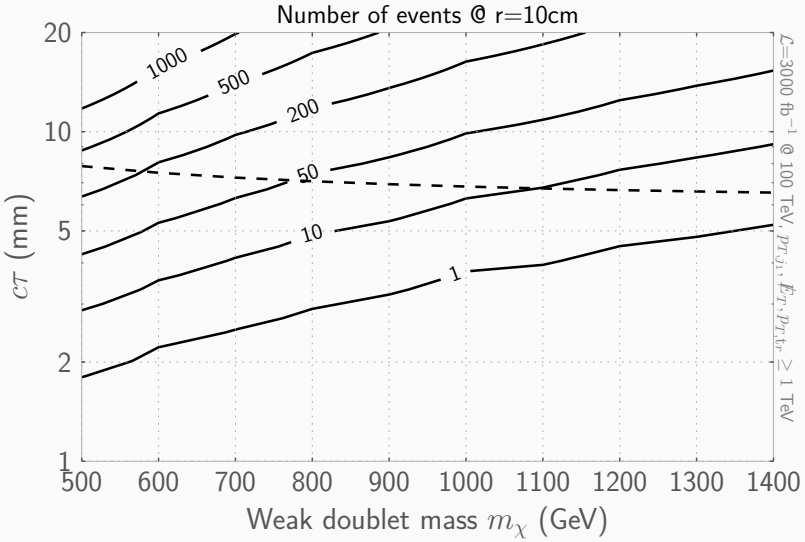
- lepton veto
- p_{T,j_1}, $\not{E}_T > 1$ TeV
- $\Delta\phi^{j,\not{E}_T}_{\text{min}} > 1.5$

Charged-track selection

- $p_{T,\text{track}} > 1$ TeV
- $r_{\text{min}} \leq r_{\text{track}} \leq 65$ cm
- $0.1 < |\eta_{\text{track}}| < 2$

Disappearing Charged Track: Results





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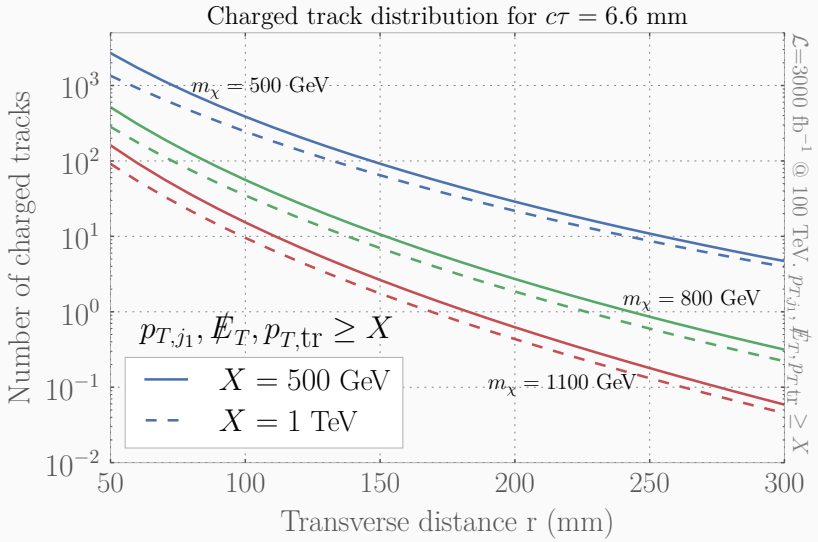

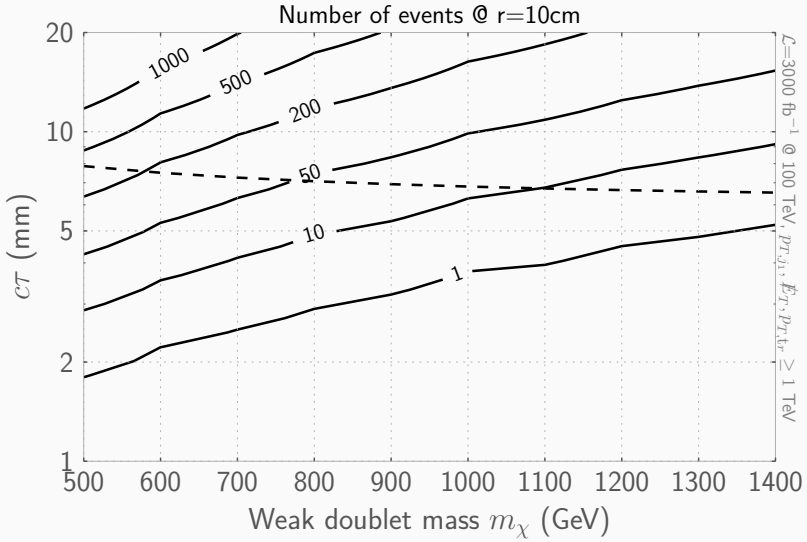

Backgrounds

- Subtracted using data-driven fit at LHC8.
- Dominated by mismeasured p_T due to "high density of silicon hits, hadronic interactions & scattering".
- Dependent on detector properties.
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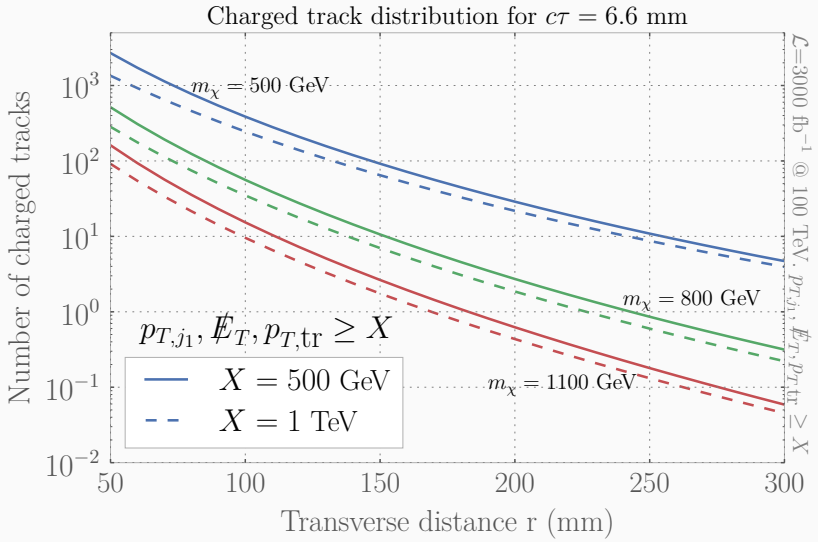

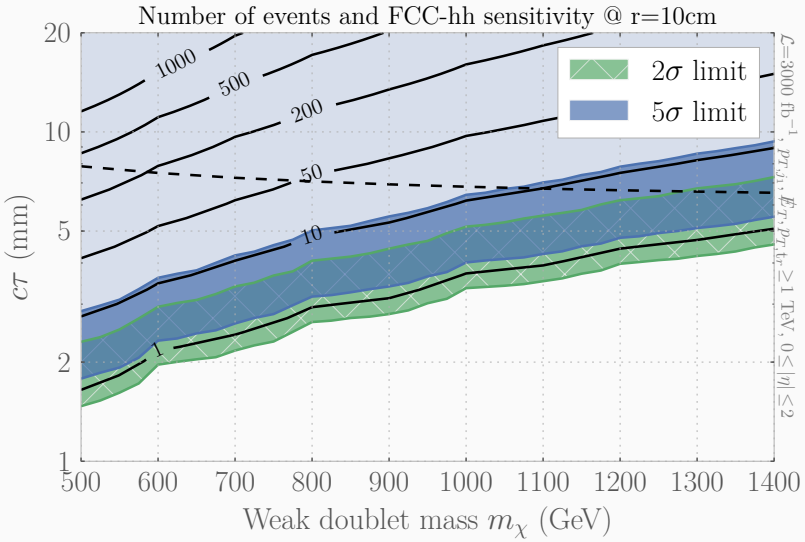

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Disappearing charged track: Track-based analysis

Two non-overlapping signal regions:

Central

- $p_{T,\mathrm{tr}} \geq 3$ TeV
- $0 \leq |\eta| \leq 2$
- 10 cm $\leq r_{\mathrm{tr}} \leq 65$ cm

Forward

- $p_{\mathrm{tr}} > 8$ TeV
- $2 \leq |\eta| \leq \eta_{\mathrm{max}}$

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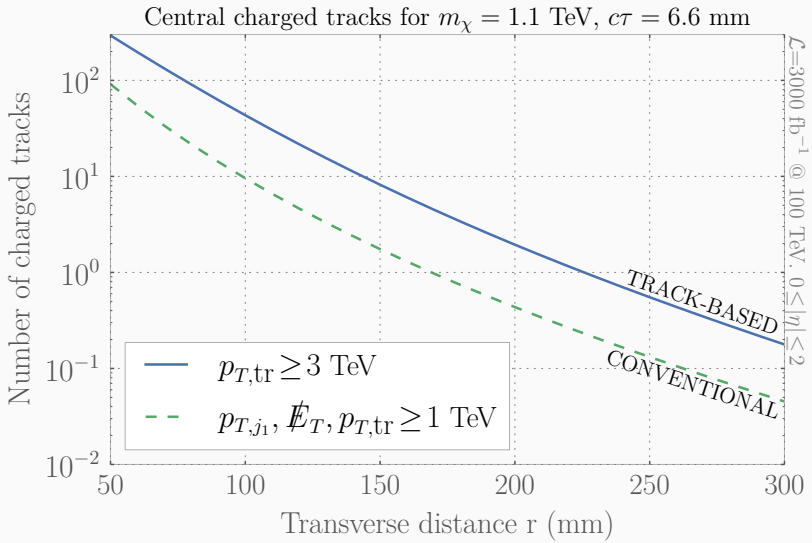

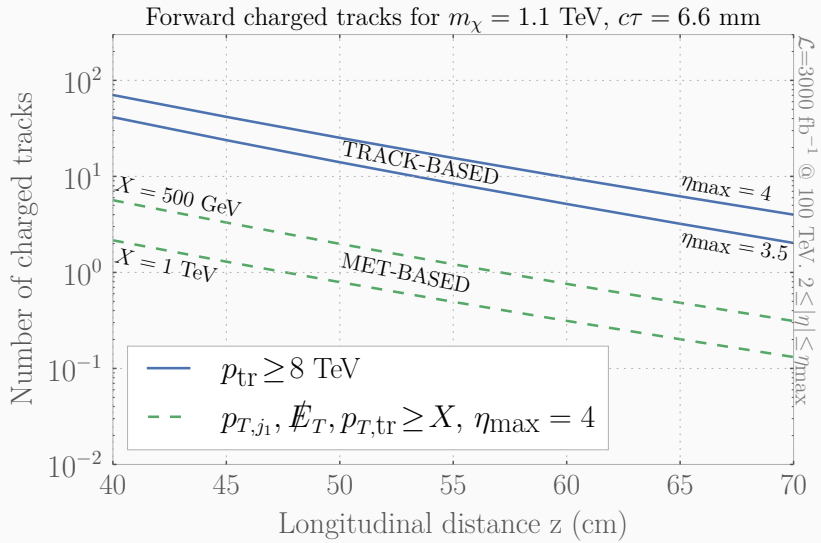

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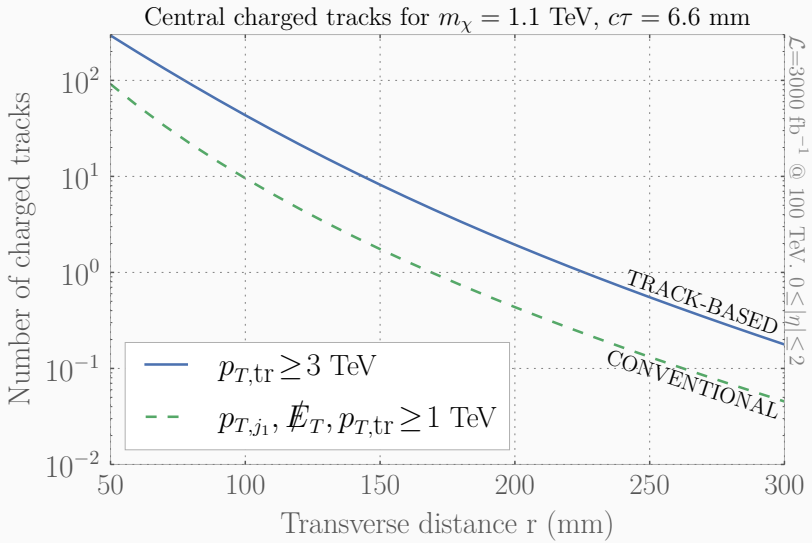
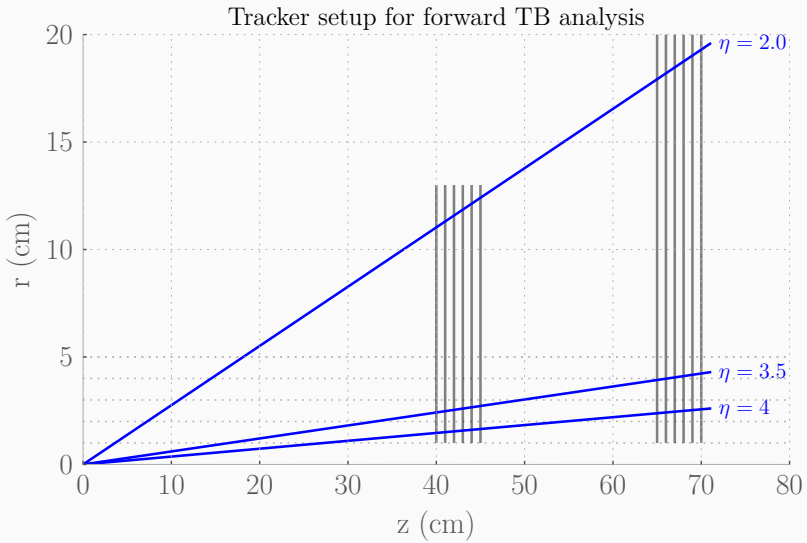
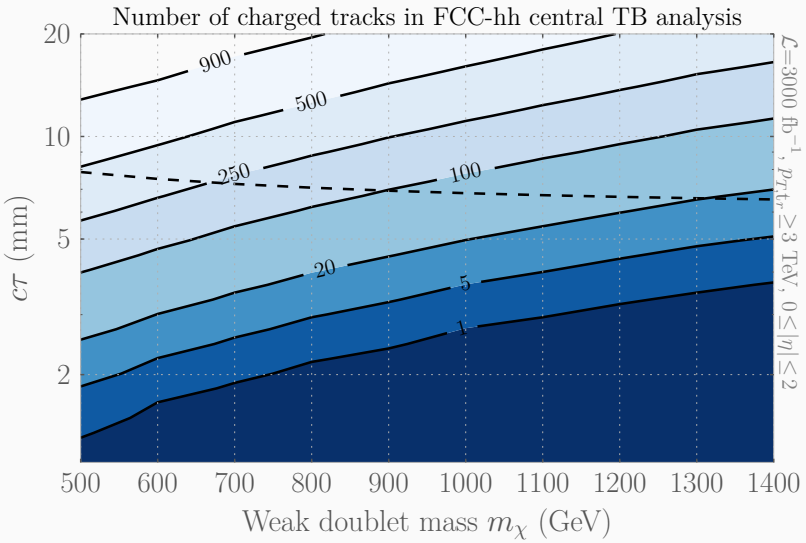
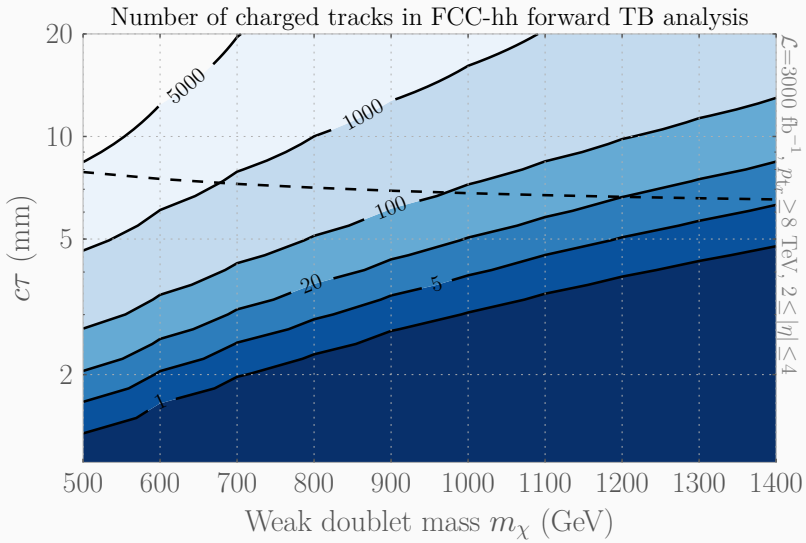




Disappearing charged track: Results II





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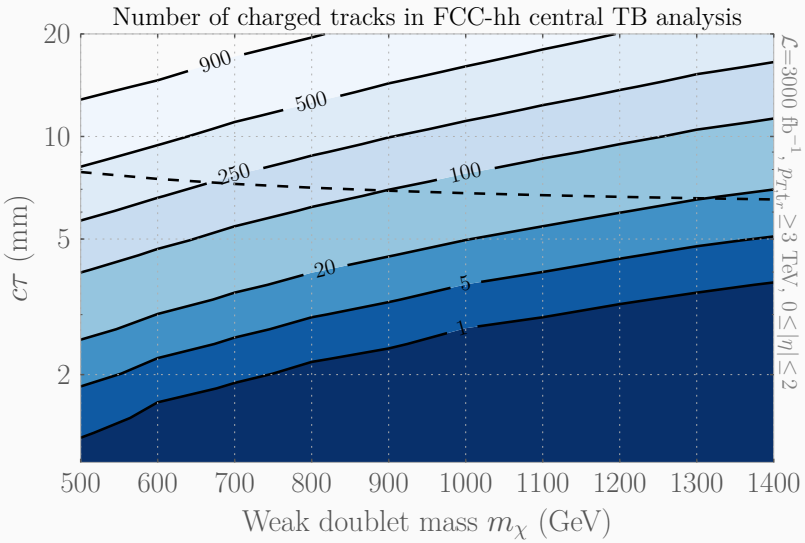
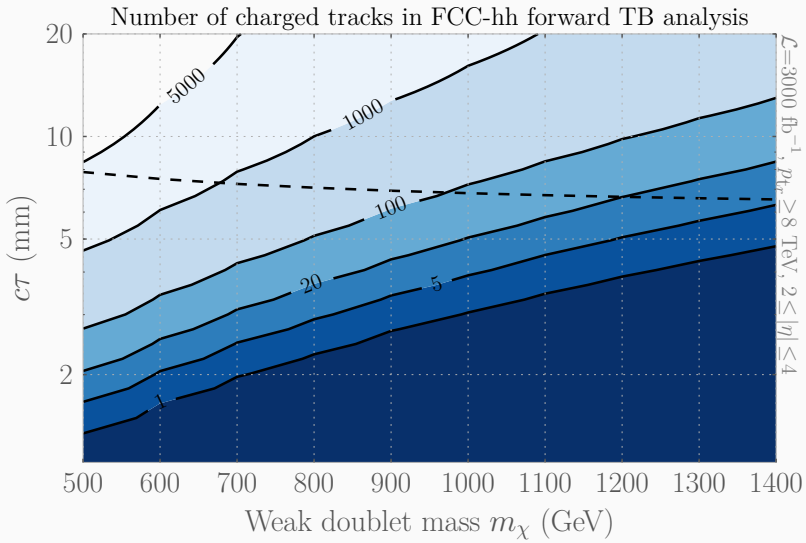
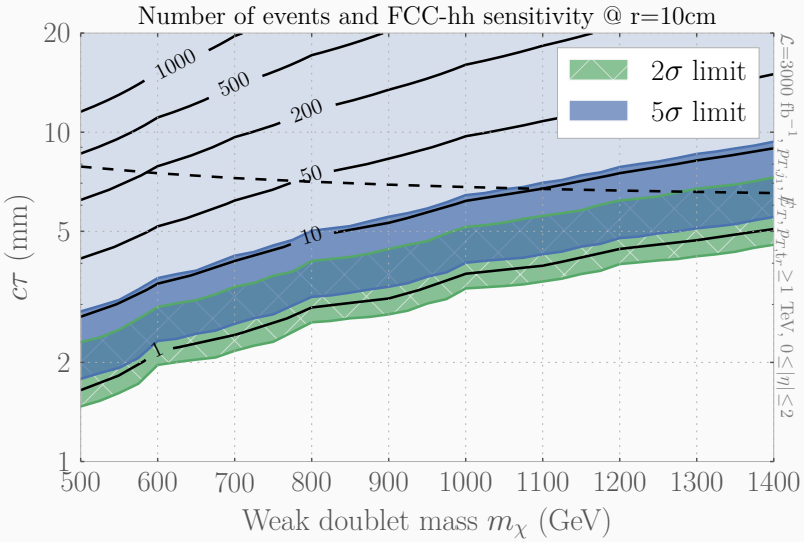


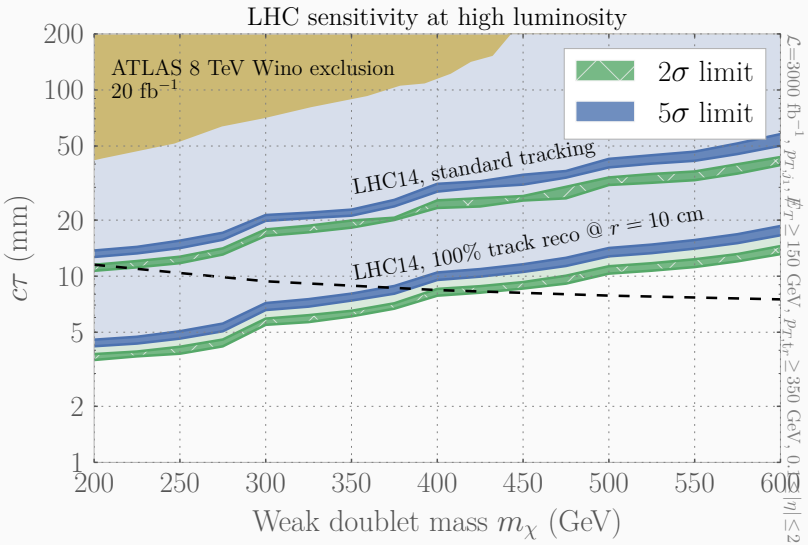


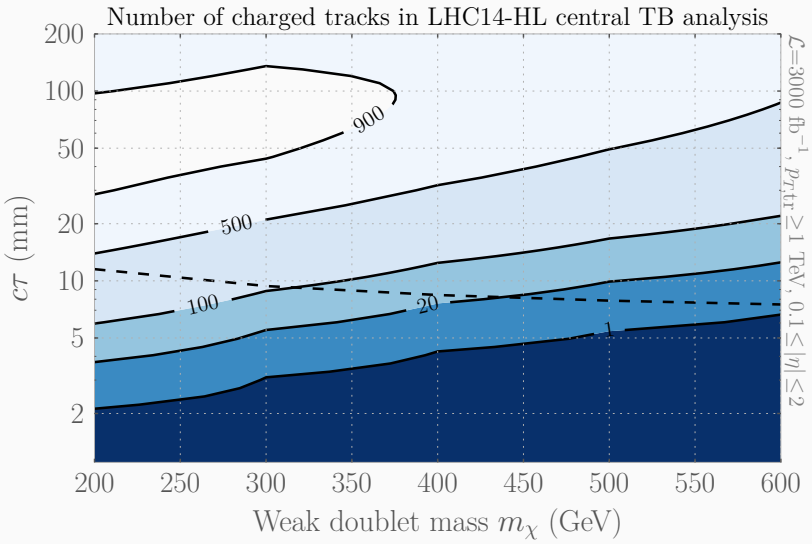


Each track-based analysis yields

$\sim$ 4-fold increase in number of events over conventional analysis

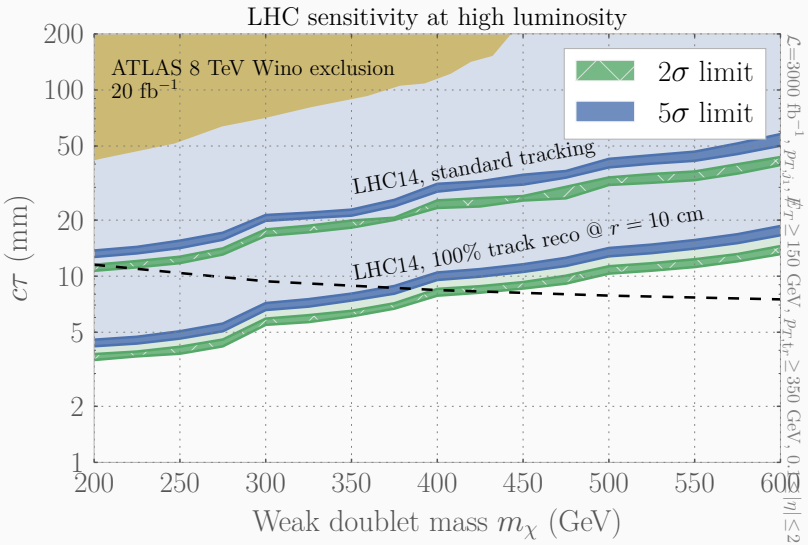
LHC14-HL

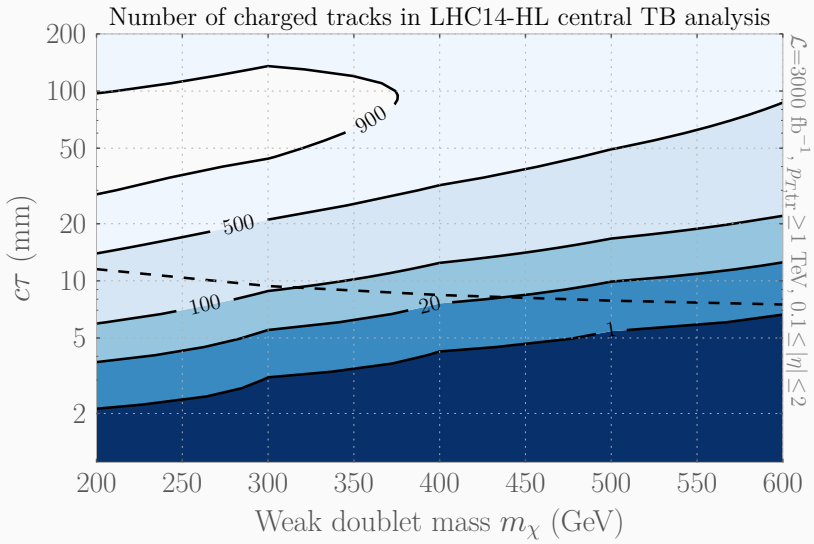




Central TB analysis gives 2-fold enhancement in number of signal events

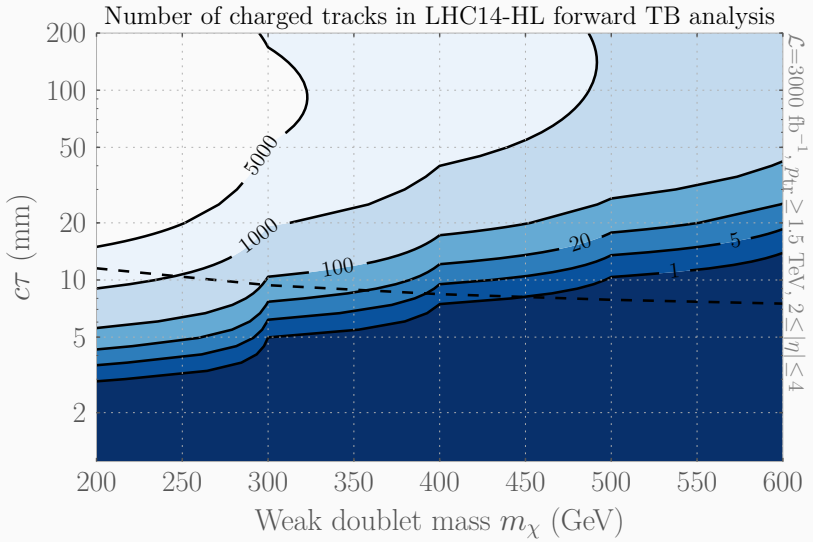
LHC14-HL





Central TB analysis gives 2-fold enhancement in number of signal events

Forward TB not as powerful, due to smaller overall boost



Summary

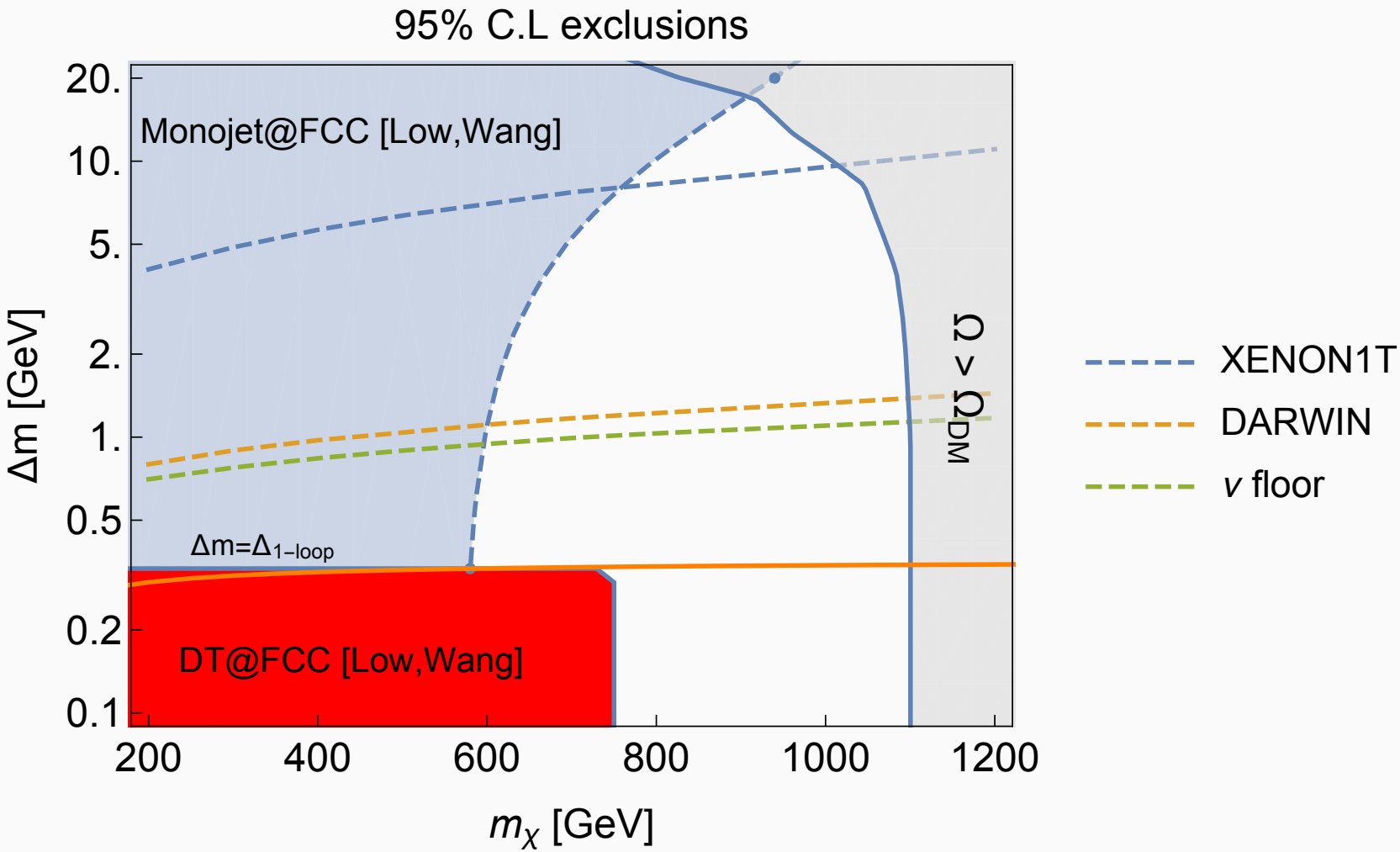
Number and boost of charginos crucial in disappearing track searches; traditional p_T/MET-based analyses limit both.

Switch to track-based searches could yield significant increase in sensitivity.

Could be rephrased as ratio of 'track-MET' to 'calo-MET'

Calo information could also be used for track isolation, to suppress SM backgrounds

Summary II


95% C.L exclusions
Monojet@FCC [Low,Wang]
DT@FCC [Low,Wang]
Δm=Δ1−loop
Ω > ΩDM
XENON1T
DARWIN
v floor
Δm [GeV]
mχ [GeV]
20.
10.
5.
2.
1.
0.5
0.2
0.1
200
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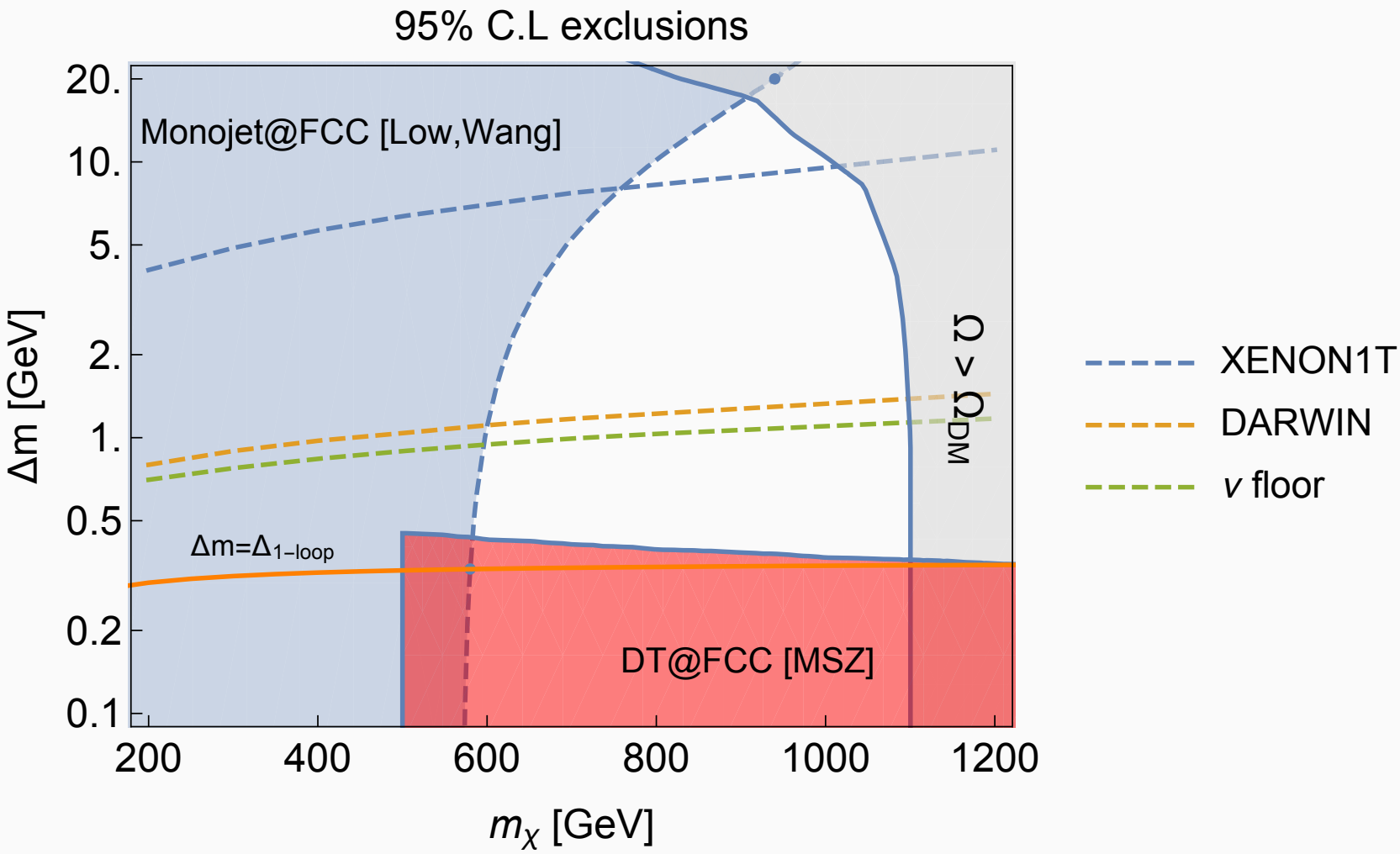
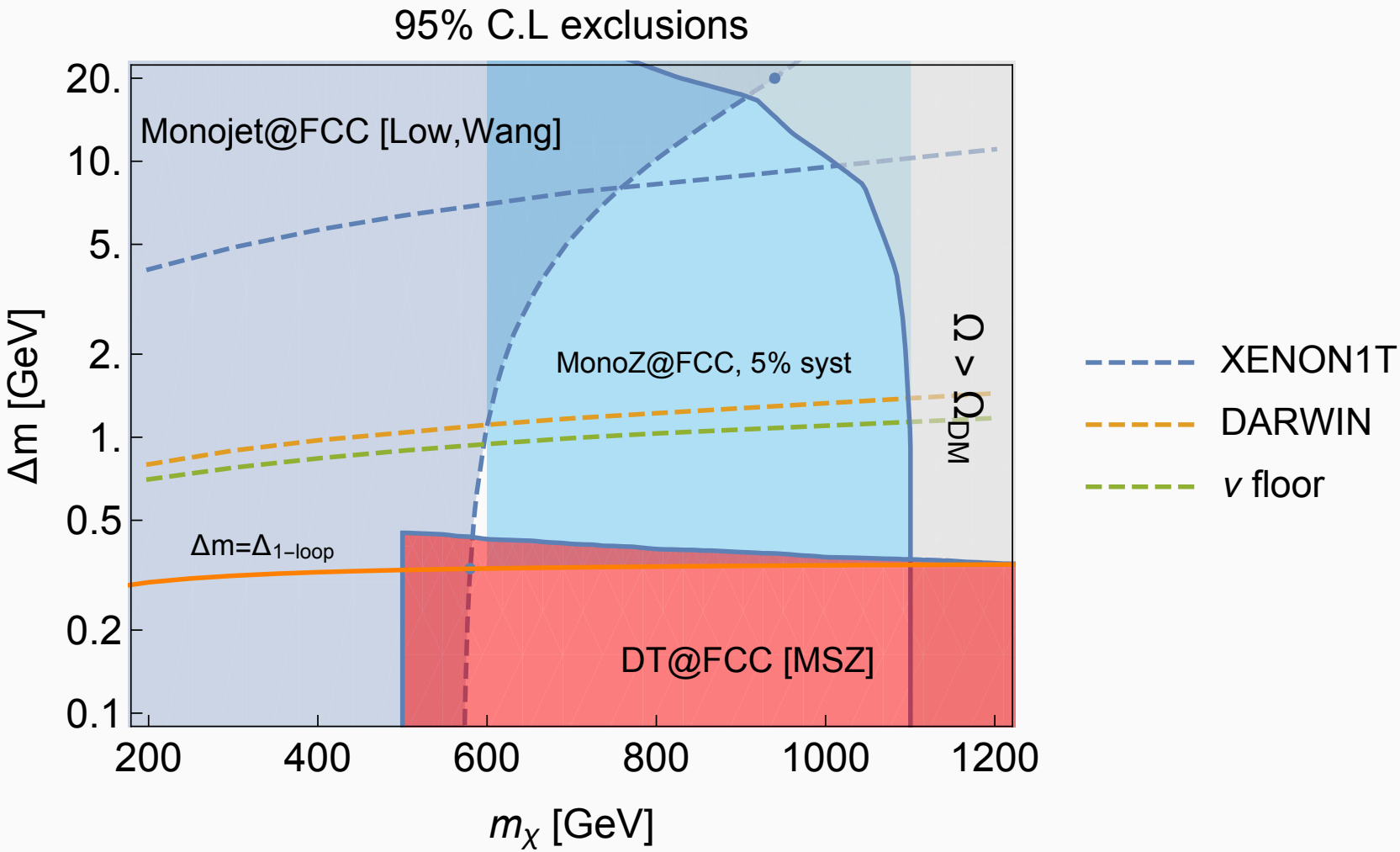

95% C.L exclusions
Monojet@FCC [Low,Wang]
DT@FCC [MSZ]
Δm=Δ1−loop
Ω > ΩDM
XENON1T
DARWIN
v floor
Δm [GeV]
mχ [GeV]
20.
10.
5.
2.
1.
0.5
0.2
0.1
200
400
600
800
1000
1200

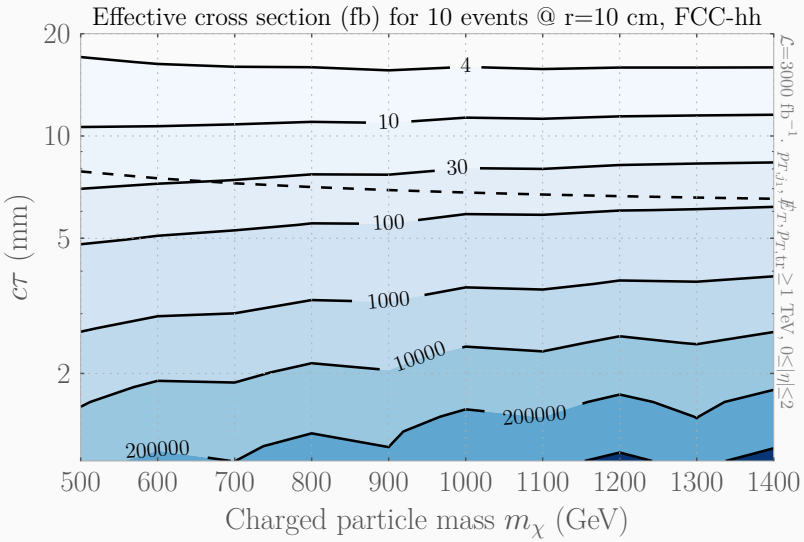
Summary II

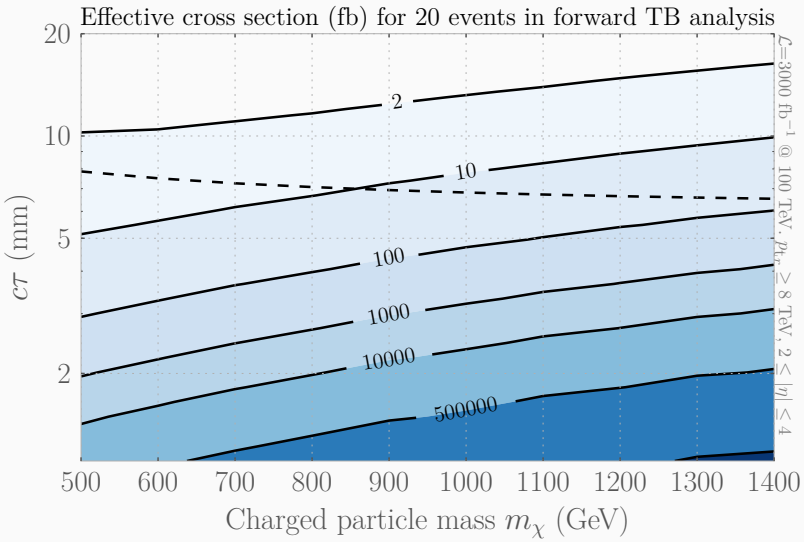


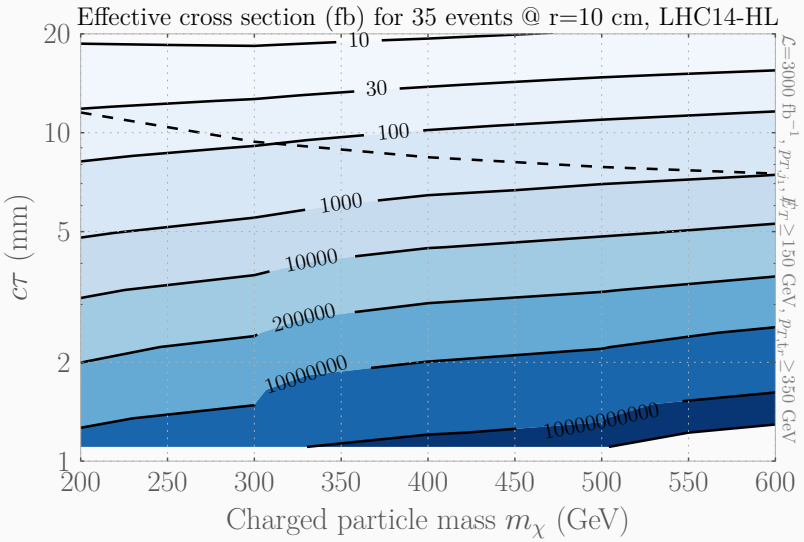
Coming soon!

Backup Slides

Cross Section Required







Summary of Cuts

	LHC14-HL		FCC-hh		
	Conventional	TB Central	Conventional	TB Central	TB Forward
lepton veto	✓	✓	✓	✓	✓
p_{T,j_1} (GeV)	150		1000		
$\not{E}_T$ (GeV)	150		1000		
$\Delta\phi^{j,\not{E}_T}_{\text{min}}$	1.5		1.5		
$p_{T,\text{tr}}$ (GeV)	350	1000	1000	3000	
p_{tr} (GeV)					8000
$\lvert\eta_{\text{tr}}\rvert$	(0.1, 2)	(0.1, 2)	(0, 2)	(0, 2)	(2, 4)
l_{tr} (cm)	r =(10, 65)	r =(10, 65)	r =(10, 65)	r =(10, 65)	z =(45, 70)

Effect of p_T/MET cuts