Searches for EWK SUSY particles

(New Physics Opportunities for Long-Lived Particles at e-p Colliders)

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David Curtin, Kaustubh Deshpande, Oliver Fischer, JZ, [arXiv 1709.nweek]

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Long-lived particles (LLPs)

- LLPs: BSM states with macroscopic lifetimes (ns), theoretically well motivated.

- I will focus here on two examples:

1. SUSY EWK: pure Higgsino (SU(2) doublet) scenario, $m_\chi < 1.1$ TeV from relic density, $m_{\chi+} - m_{\chi 0} \in [298\text{-}344]$ MeV and $c\tau \sim 6\text{-}19$ mm.

    - Mass reach for LHC (FCC-hh):

        i) Mono-jet: 250 (600) GeV.

        Barducci, Belyaev, Bharucha, Porod, Sanz 1504.0247

        ii) Disappearing tracks: 200-370 (1000-1400) GeV, depending on tracker improvements.

        Mahbubahni, Schwaller, JZ: 1703.05327.

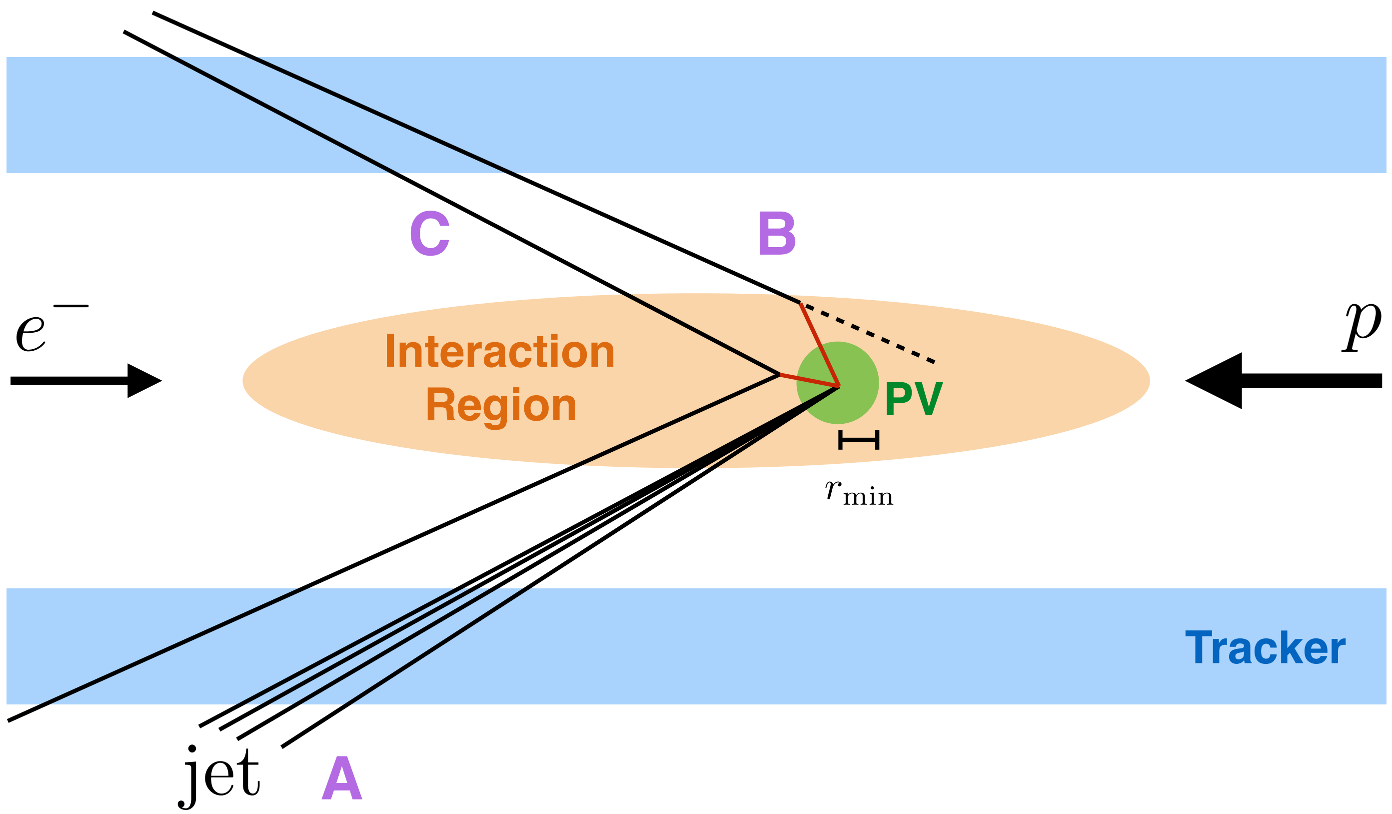
    - At hadron colliders $\chi^+ \longrightarrow \chi^0 \pi^+$ (the pion is always lost!)

2. Exotic Higgs decays $H \rightarrow XX \rightarrow ff\ ff$ (X=LLP, f=SM fermions)

    - $\Gamma(H)$ dominated by $y_b \sim 0.02$: tiny BSM couplings give rise to large exotic BRs.

    - LLPs coming from the Higgs can be the smoking gun of hidden valley, neutral naturalness, WIMP baryogenesis, heavy neutrinos, etc

Displaced objects at e-p colliders



Now r_{min} = 40 μm.
(aggressive? lower?)

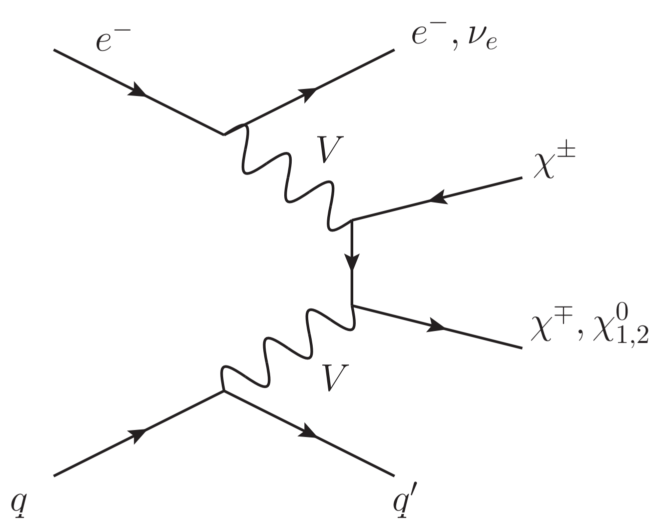
- (A) Hard jet, $pT_j > 20$ GeV, $|\eta_j| < 4.7$: identifies the PV and provides trigger.
- (B) 1 charged particle (π,μ) is displaced if the charged track has impact parameter > r_{min}
- (C) 2+ Charged particles (a,a) give a displaced vertex (DV) if d(PV,DV) > r_{min}

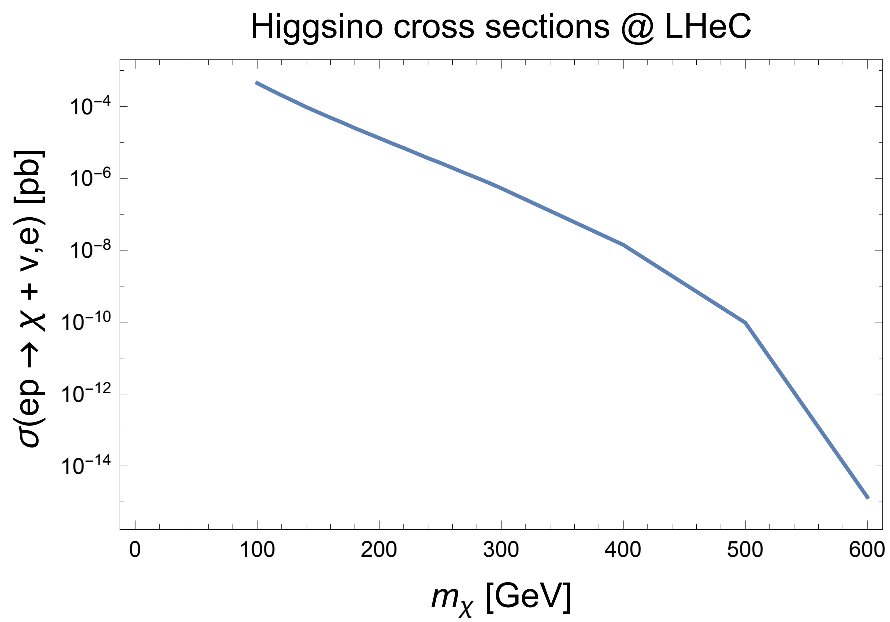
- Charged track: p_T > 100 MeV, 100% reconstruction efficiency.
  (corresponds to O(0.5m) curvature in a 3.5 T field)

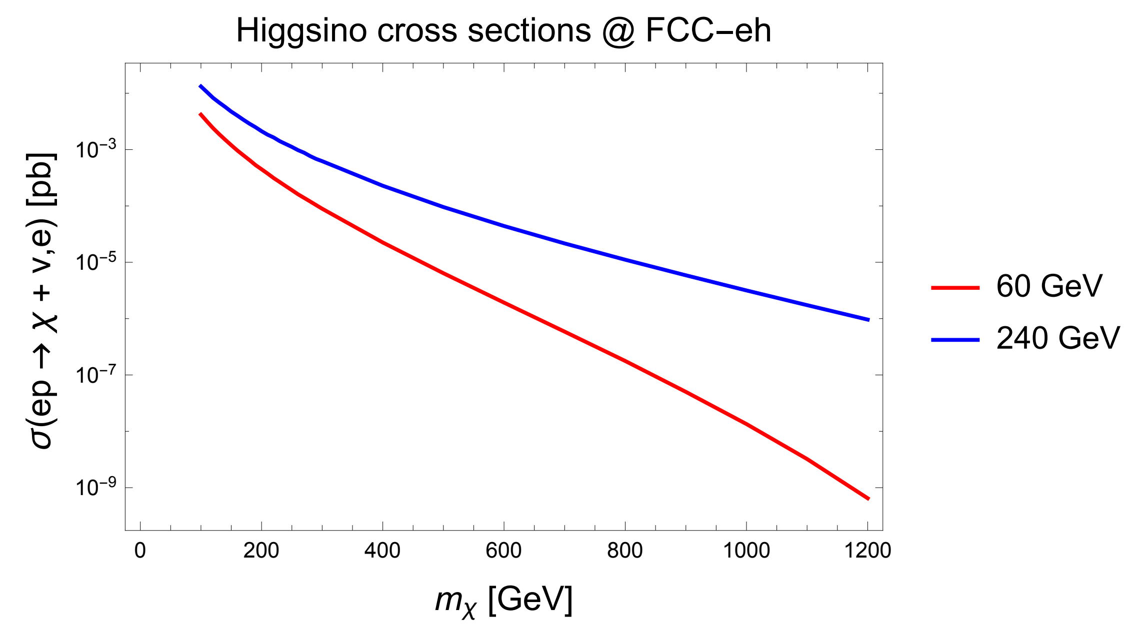
e-p phenomenology

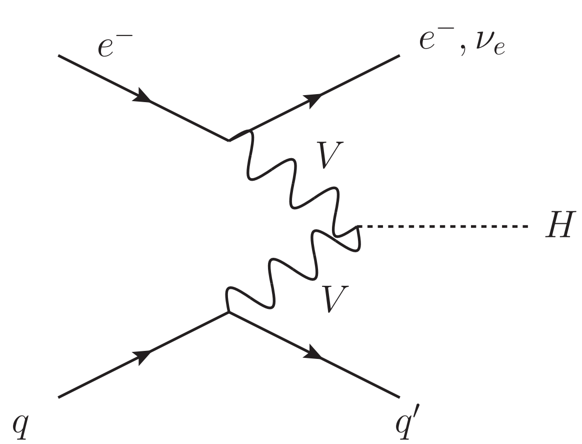
We take (e/GeV,p/TeV) energies to be: (60,7) [LHeC], (60,50) [FCC-eh(60)] (240,50) [FCC-eh(240)]

[The latter option uses the highest achievable e-beams discussed for FCC-ee]









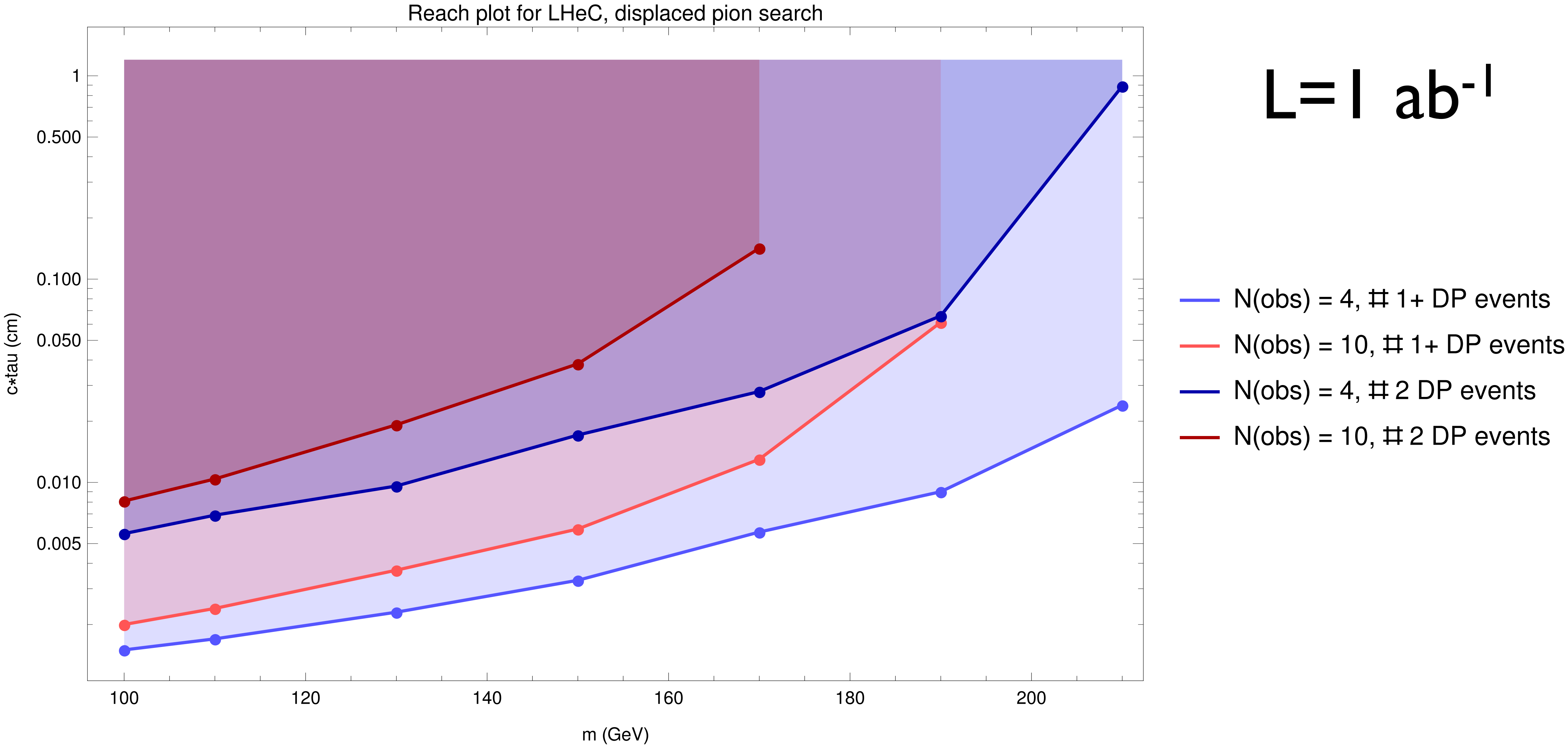
σ(e p -> H(125) -> X X), assuming BR(H->XX = 1 %):

LHeC: 1 fb

FCC-eh(60): 3.4 fb

FCC-eh(240): 10 fb

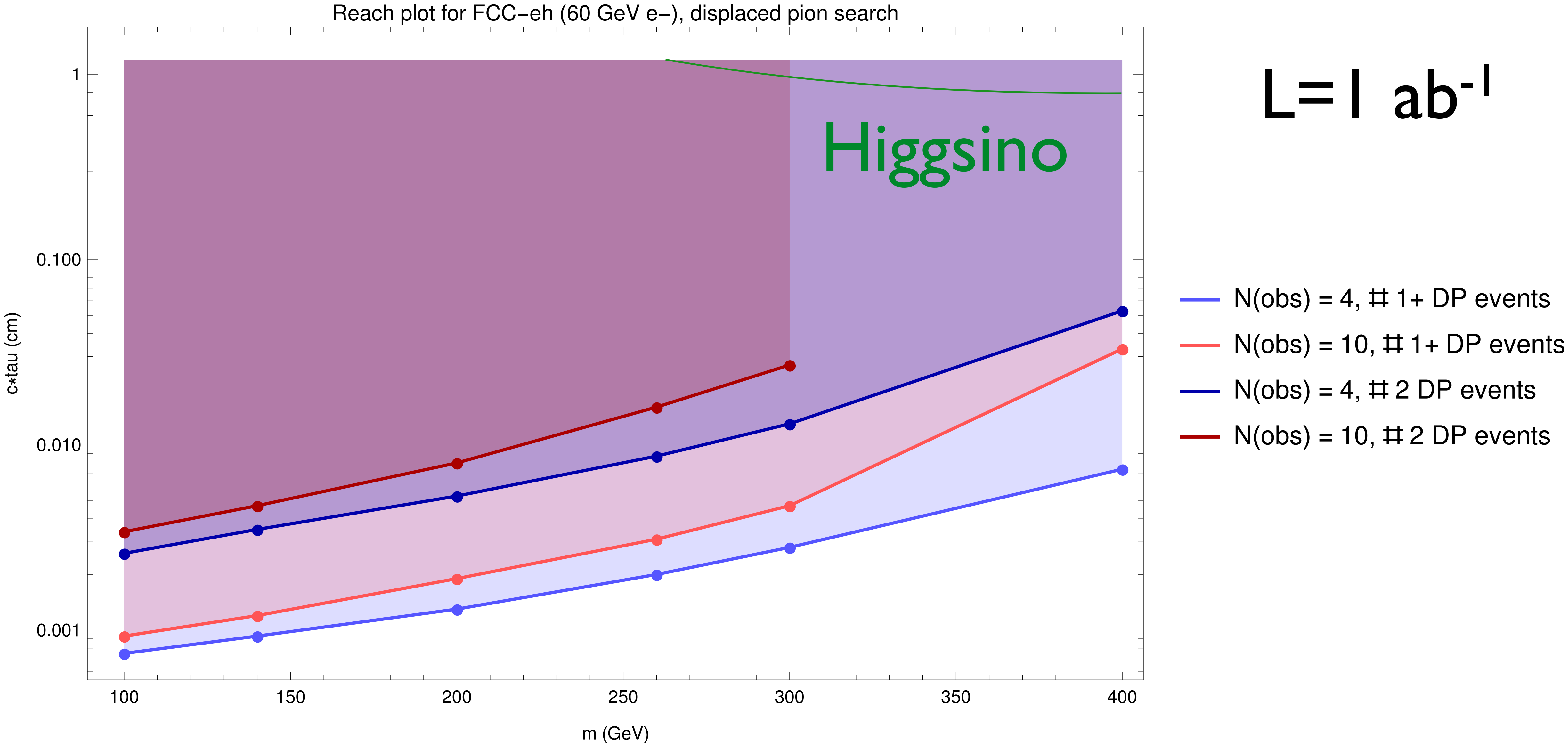
Higgsinos @ LHeC



L=1 ab^{-1}

LHeC can compete with LHC monojet and disappearing tracks!

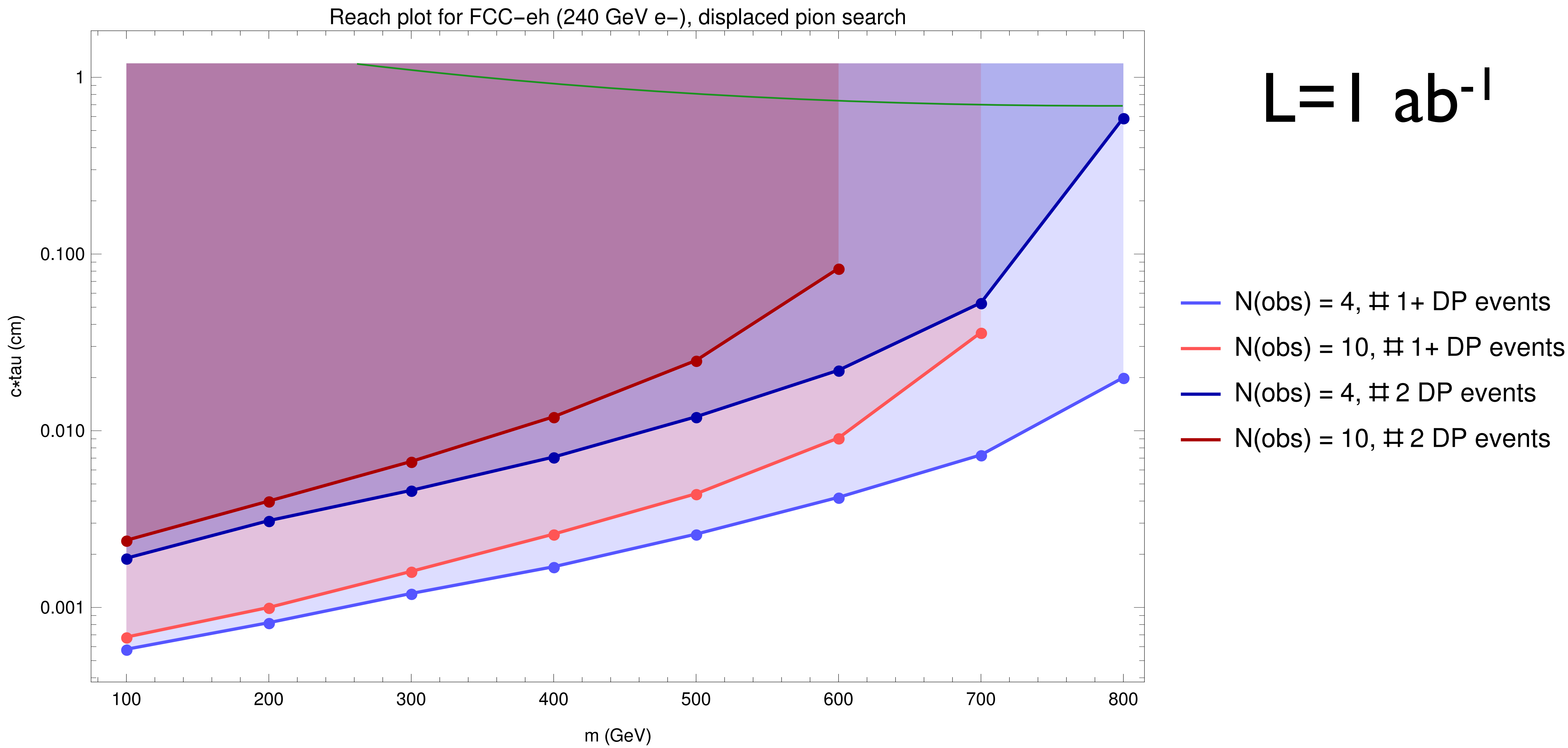
Higgsinos @ FCC-eh (60)



L=1 ab^{-1}

Reach extended to ~ 600 GeV (not shown): comparable with FCC mono jet

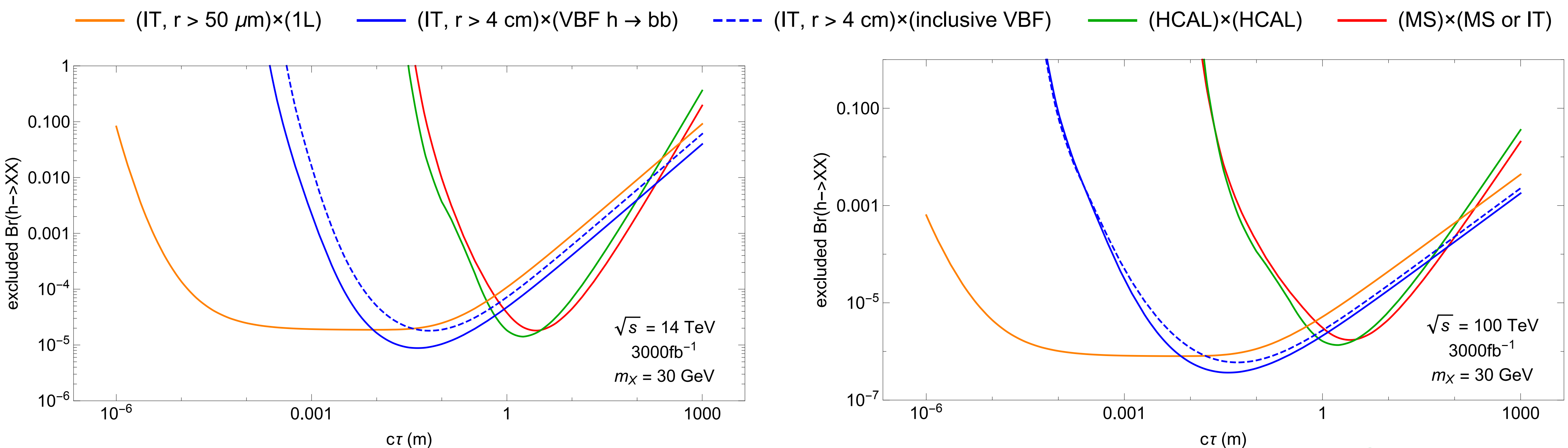
Higgsinos @ FCC-eh (240)



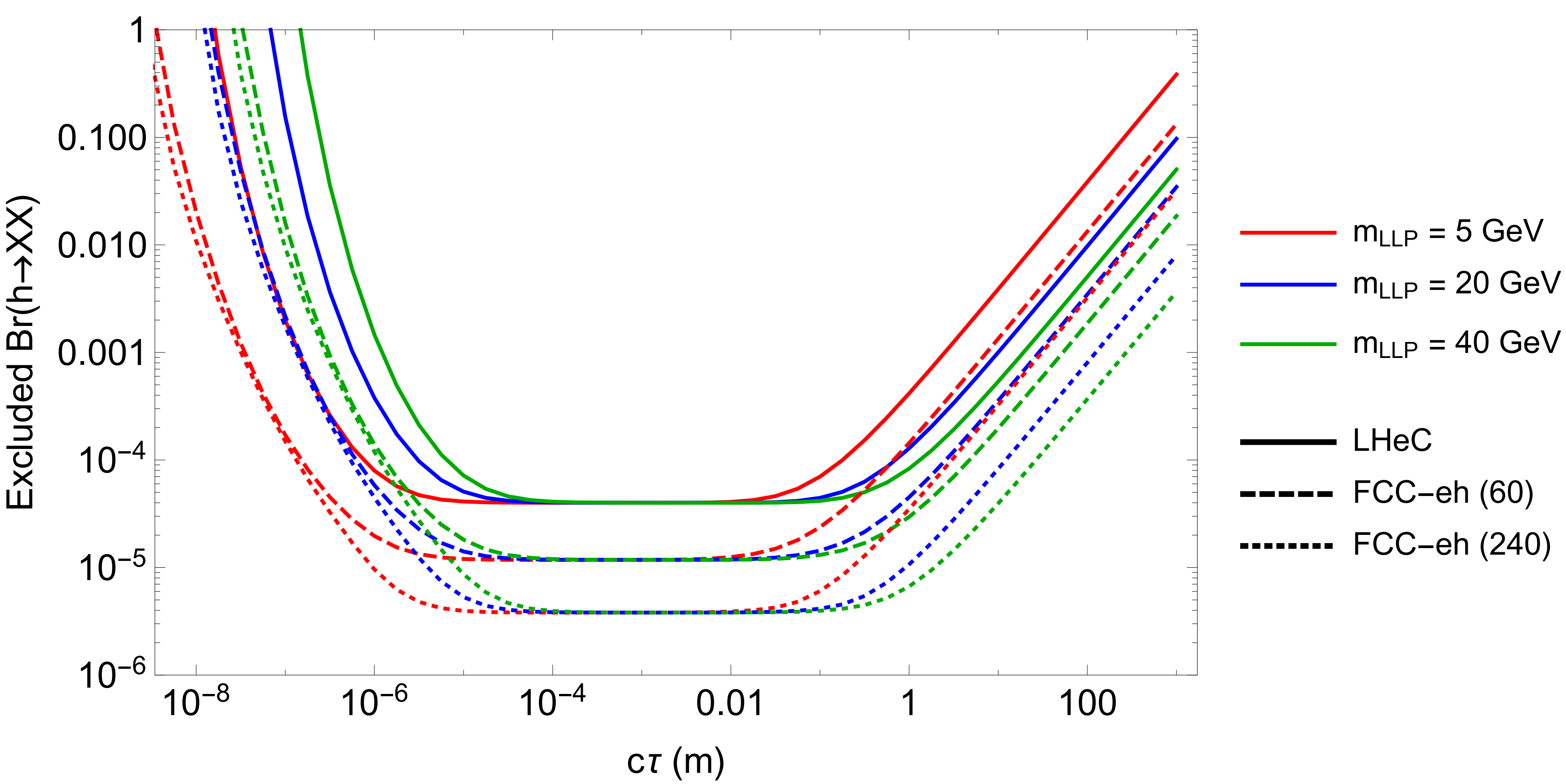
L=1 ab^{-1}

Even larger E_e or more lumi required to probe relic preferred 1.1 TeV mass

Exotic Higgs decays



Curtin, Verhaaren 1506.06141



Curtin, Deshpande, Fischer, JZ, [arXiv 1709.nweek]

e-p vs p-p reach:

- cτ down to μm (mm) for hadronic decays.
- Comparable BR exclusion for cτ < m.

Conclusions

• In an e-p collider the advantages: less (and less complicated) backgrounds, no pile-up, excellent reconstruction efficiency, etc can overcome the low rates.

•I discussed two examples of LLPs at e-p colliders: Higgsino and Higgs rare decays.

• Higgsinos: We studied the *displaced pion* signature, which is exclusive of e-p colliders (I can not imagine doing it at a hadron collider!):
  - •Mass reach are comparable for LHC vs LHeC and FCC vs FCC-eh.
  - •Moreover, an e-p collider could measure $c\tau$, Δ (not possible @ pp colliders!)

• Exotic Higgs (125) decays: focus on displaced vertexes. No novel signature here, but much lower lifetimes can be efficiently covered. Comparable reach on exotic branching ratios (LHC vs LHeC and FCC vs FCC-eh).

• e-p collider can definitely win when the signal is too heavy for ee, and "impossible" at pp colliders. Road paved with interesting opportunities just ahead!

•Input is most welcome! (how crazy are we / our assumptions?)