SUSY EWK at e-p colliders: prompt and non-prompt production

Kechen Wang
(DESY)
Sho Iwamoto
(Isreal Institute of Technology, Technion)
Monica D'Onofrio
(University of Liverpool)
George Azuelos
(University of Montreal)

LHeC/FCCeh workshop
September 11th 2017

Outline

- The scope of these studies, in progress since few months, is to identify and evaluate the feasibility of searches for R-parity conserving (RPC) EWK SUSY scenarios with compressed spectra:
  - charginos, neutralinos and sleptons almost mass degenerate
- Advantage: most relevant scenarios identified in the past years, come with a dark-matter candidate (lightest neutralino), largely unconstrained at the LHC
- **In this talk:**
  - Brief on current constraints on SUSY DM & Sleptons
  - **Scenarios of interest and expected results:**
    - prompt production of chargino/neutralino with/without sleptons
    - Non-prompt production of chargino/neutralino → long-lived particles
      - This is also the target of the next talk from Jose' Zurita

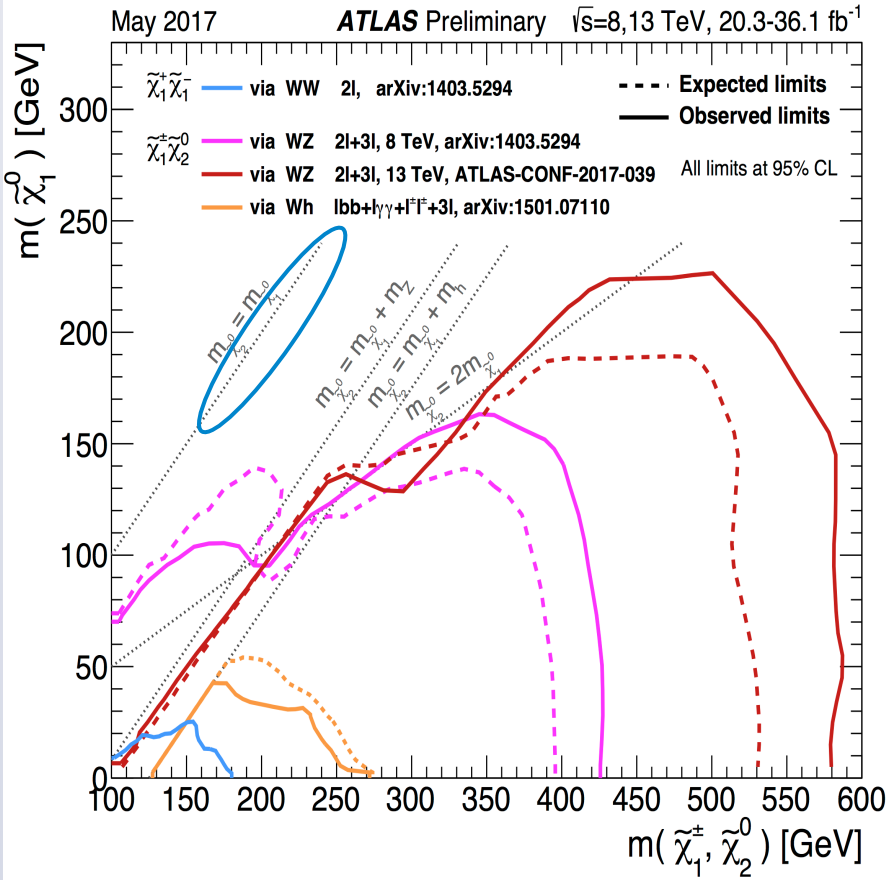
Warning: this is work in progress. We started focusing on FCC-eh, but we will now reconsider also LHeC case as newly reachable scenarios have been identified

Current LHC limits on RPC SUSY (I)

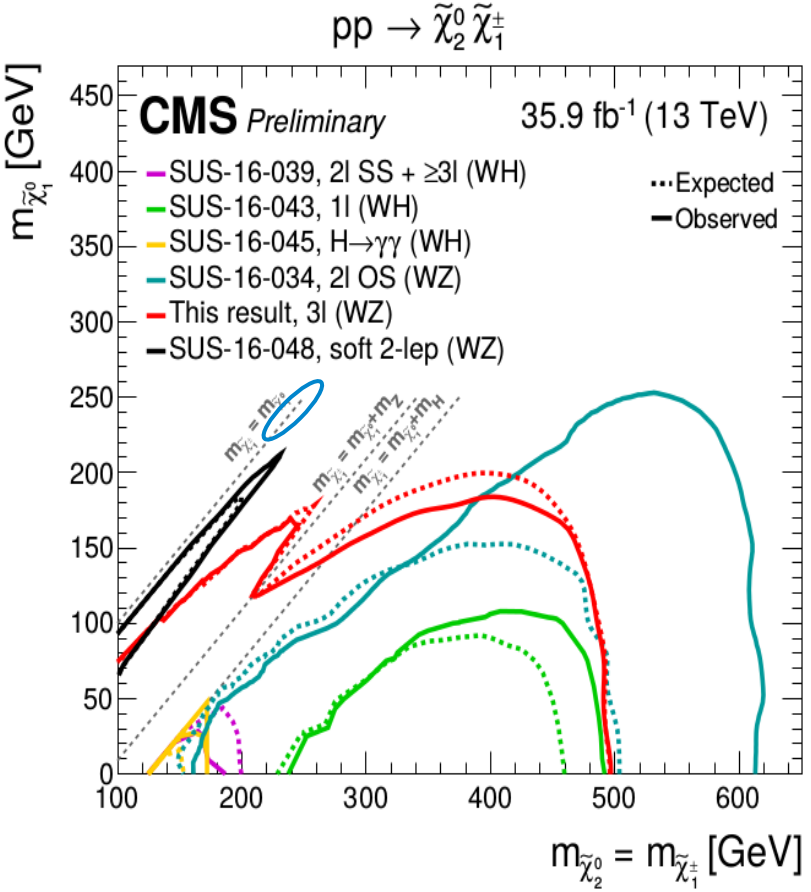
production of pure wino chargino1-chargino1 & chargino1-neutralino2 [SUS-17-004]:

Slepton is heavy and decoupled

chargino1 -> neutralino1 + W with 100% BR;
neutralino2 -> neutralino1 + Z / H



Wide uncovered areas in "compressed" scenarios very difficult at pp

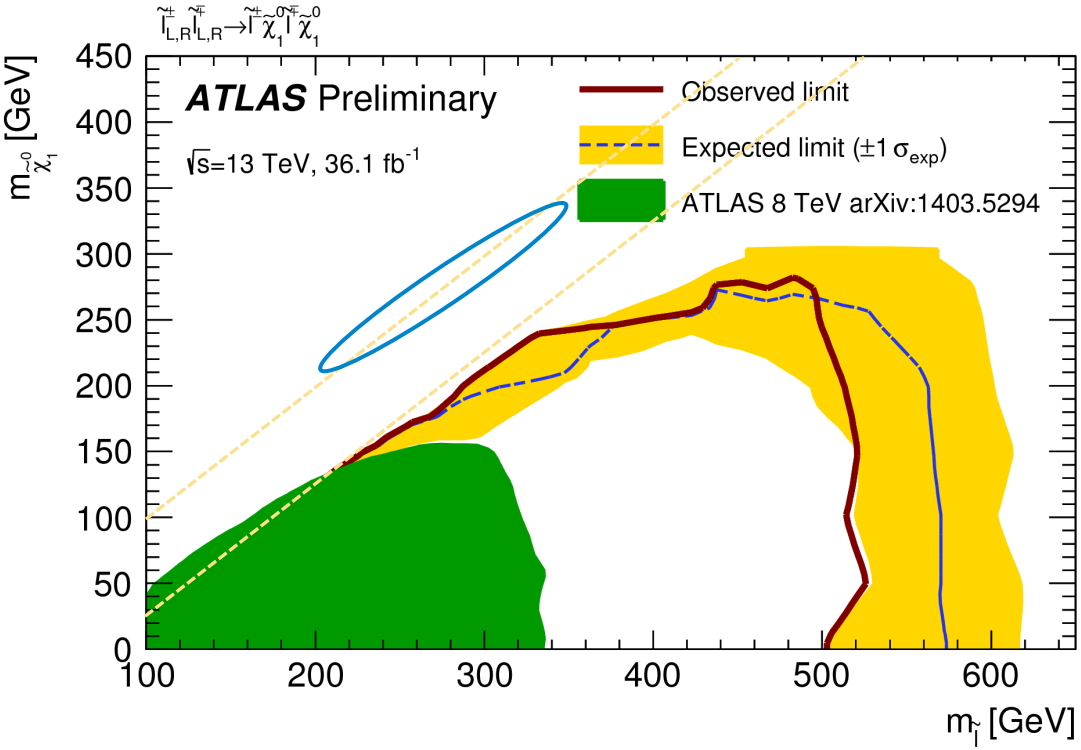


Current LHC limits on RPC SUSY (II)

What if sleptons are not "that" high in mass?

→ each slepton decays to lepton+neutralino1 with a 100% brancing ratio;
→ If lower than charginos, neutralinos – tight constrains from LHC
→ If heavier, they don't play any role in that at the LHC: direct searches

Direct slepton pair production [ATLAS-CONF-2017-039]



→ Again, wide uncovered region

What if sleptons are only slightly heavier than the charg-neut?

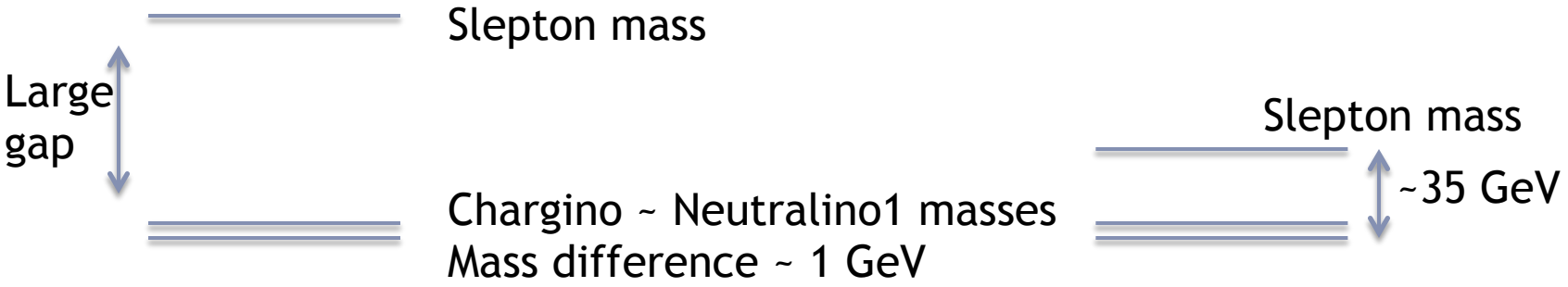
→ No difference for LHC

→ Important for e-p: production rate raises a lot (up to factor 10!)

Plus: In fact, it is very likely that sleptons are not TOO high in mass (e.g. contribution to g-2)

So, what do we target?

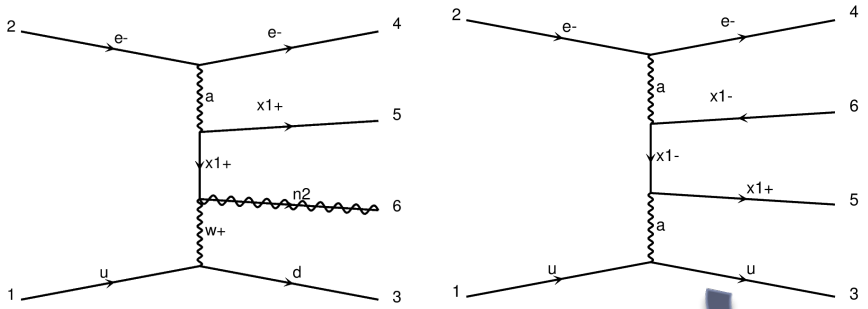
- Target two kind of EWK mass spectra:



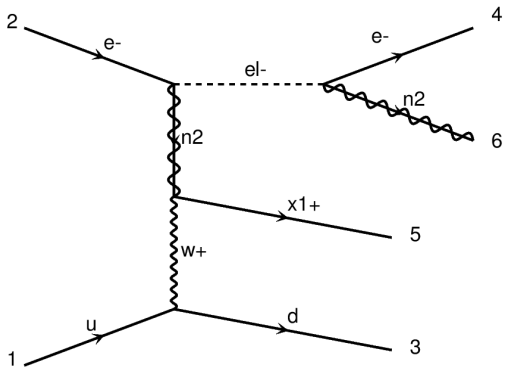
Scenario 1

Scenario 2

Example of production:



In case slepton masses are close to charginos, neutralinos additional diagrams contribute



Increase in cross section up to a factor of 10!!

Analysis

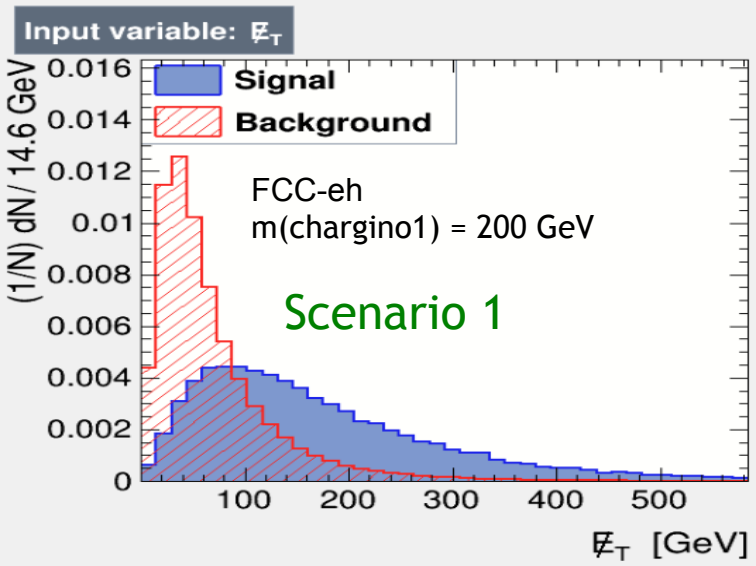
- **Final state**: 1 e- + 1 j + MET

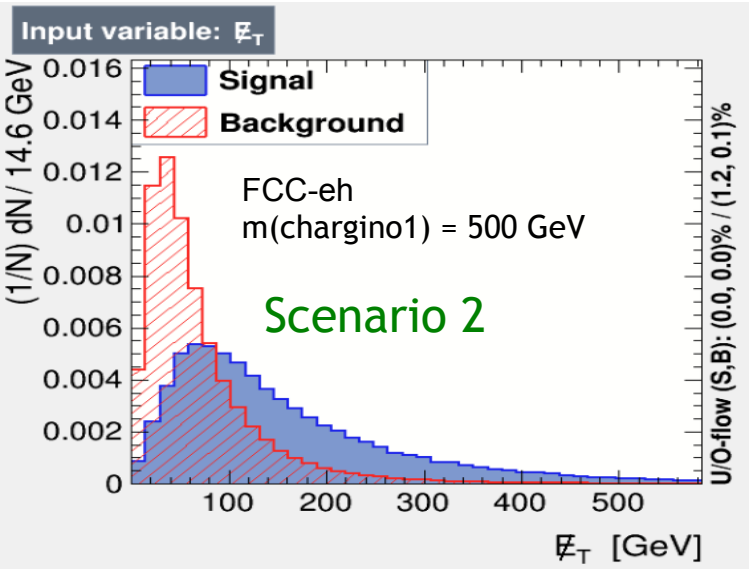
Analysis at detector-level using the BDT method.

Backgrounds: all processes with one or two neutrinos (to also take into account mis-identified leptons)

Pre-selection cuts:
(1) selecting at least 1 jets with p_T > 20 GeV;
(2) selecting at least 1 e- with p_T > 10 GeV;
(3) veto b-jets with p_T > 20 GeV;
(4) veto 2nd electron, any muon with p_T > 5 GeV;
veto any tau with p_T > 10 GeV.

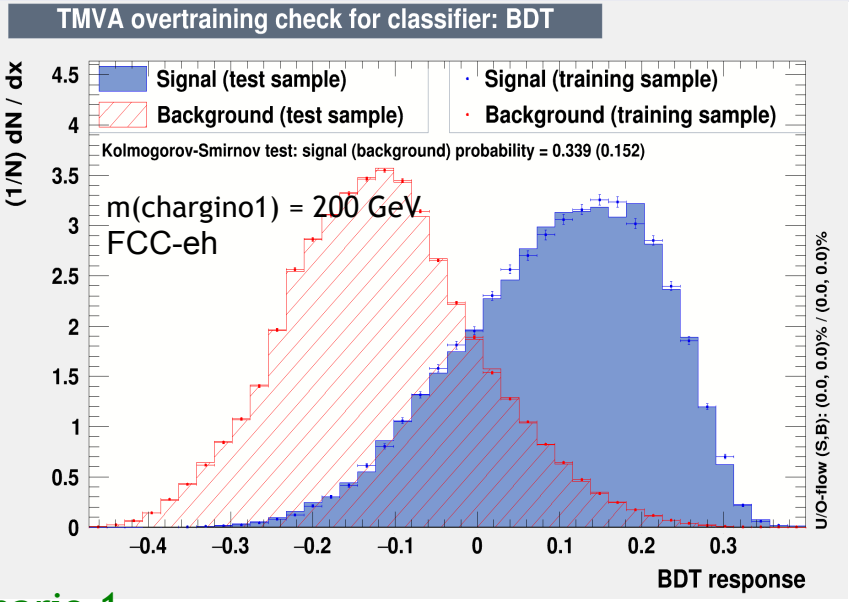
Input observables for BDT Training & Test:
MET, H_T ;
$p_T(j_1)$, $\eta(j_1)$, $p_T(e_1)$, $\eta(e_1)$, $\Delta\eta(j_1, e_1)$, $\Delta\varphi(j_1, e_1)$;
$M_T(MET, e_1)$, $M_T(MET, j_1)$, $\Delta\varphi(MET, e_1)$, $\Delta\varphi(MET, j_1)$
$M(j_1+e_1)$, $p_T(j_1+e_1)$, $\eta(j_1+e_1)$,
$M_T(MET, j_1+e_1)$, $\Delta\varphi(MET, j_1+e_1)$;

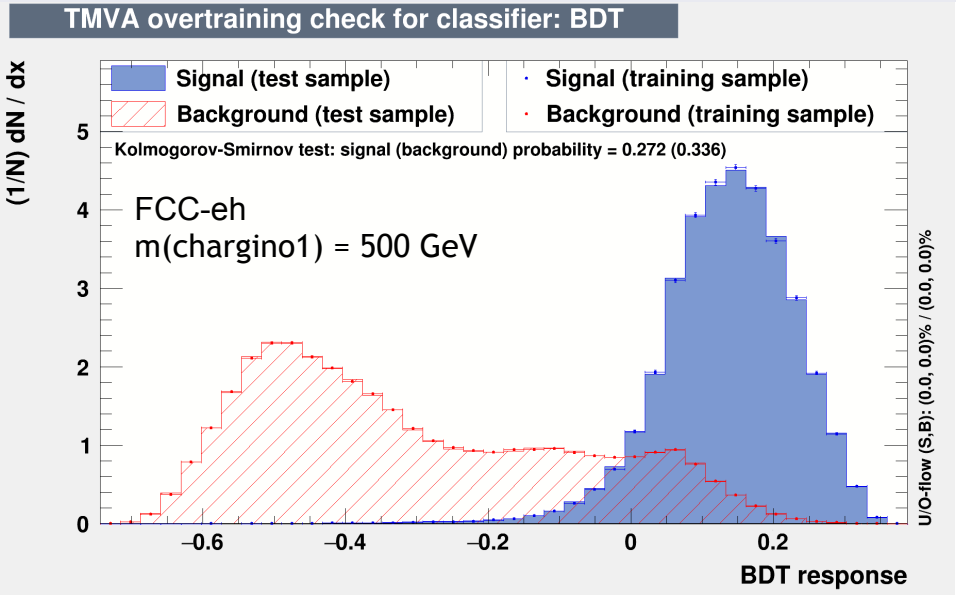




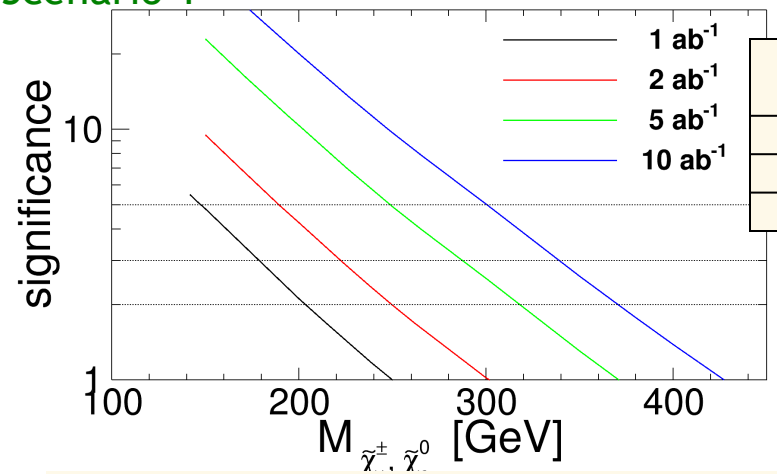
Results

FCC-eh: 1 ab^{-1}



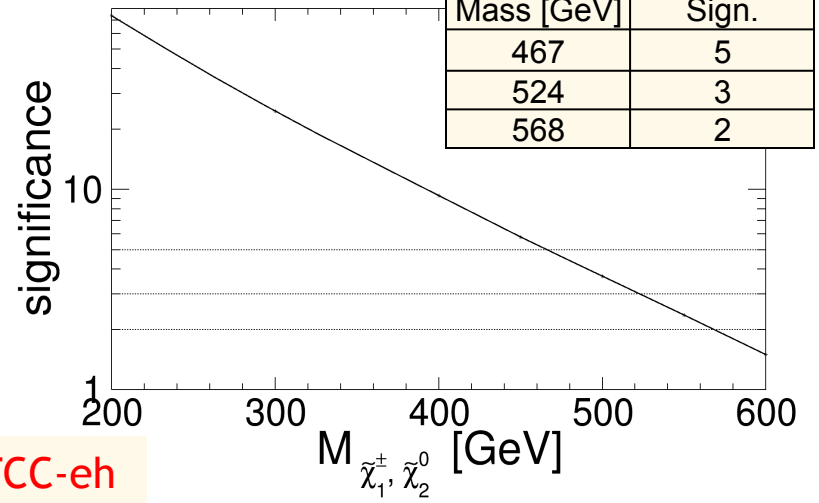


Scenario 1



Mass [GeV]	Sign.
147.6	5
179.7	3
204.1	2

Scenario 2



Mass [GeV]	Sign.
467	5
524	3
568	2

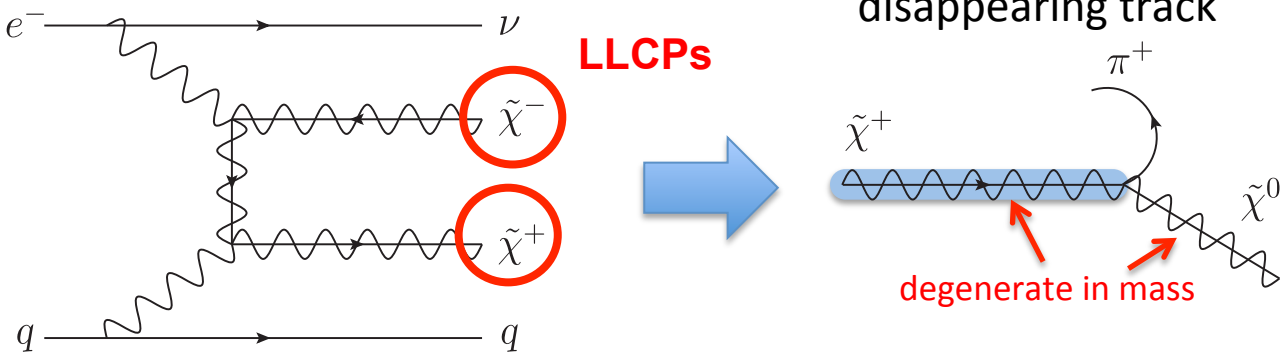
The scenario 2 (light sleptons) well achievable at FCC-eh
TO BE SEEN: check feasibility at LHeC

What if the m(chargino)~m(neutralino1)?

- The decay of chargino is **NOT prompt → long-lived particles (LLP)!**
- Production process not different from scenarios in previous slides

Simplest models at FCC-he: four-body process and tiny cross section

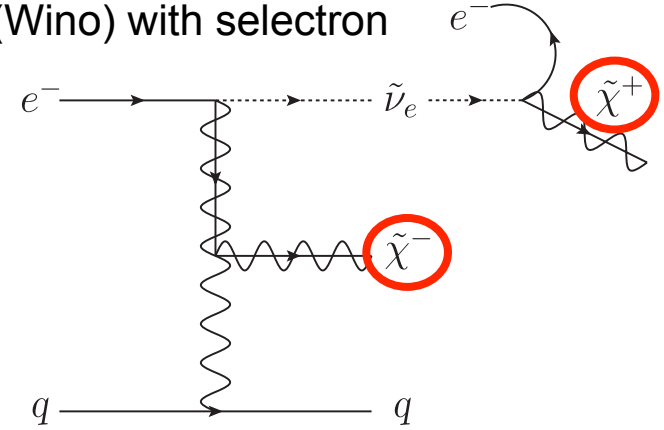
- Charginos (Wino or Higgsino)



Referred to as **4-body** in the following

Cross section enhanced with "co-production"

- Chargino (Wino) with selectron

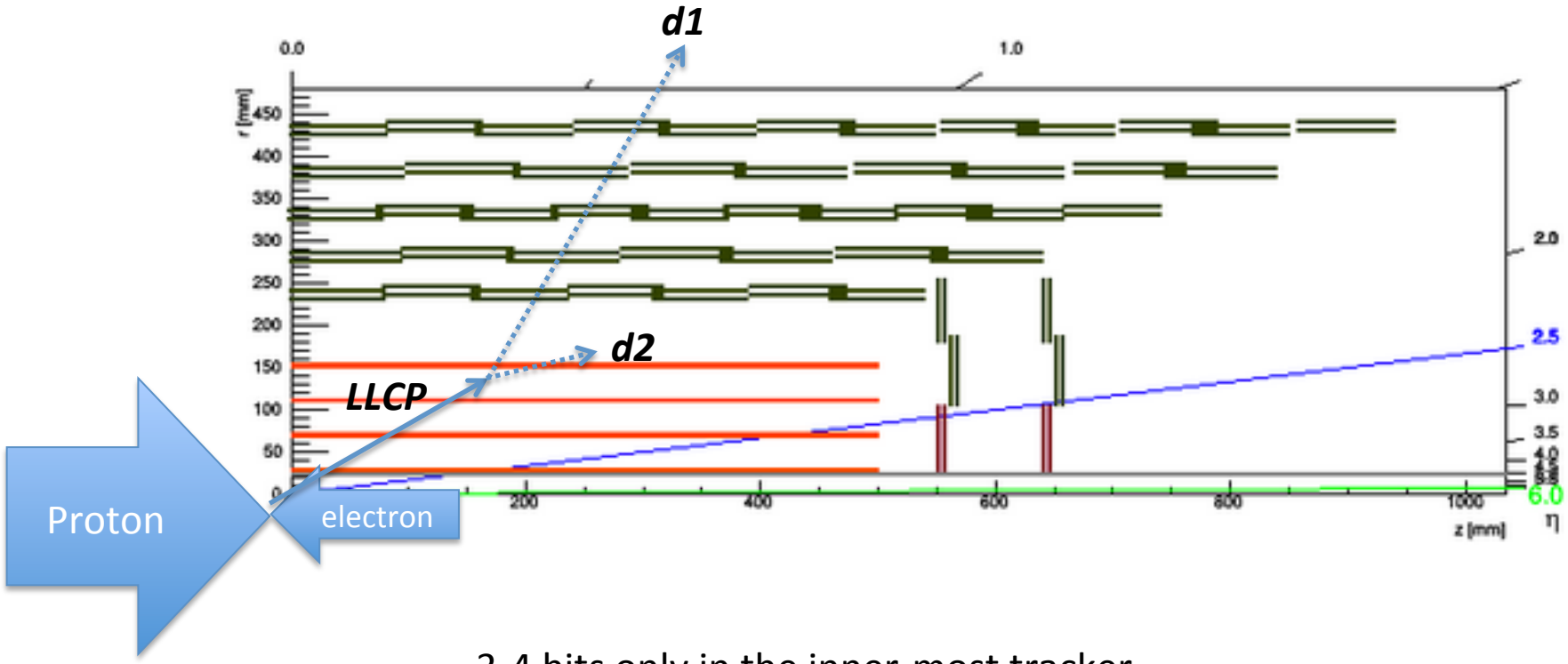


same signature but as before, the production is enhanced because of selectrons

Referred to as **3-body** in the following

Physics of disappearing tracks

Searches for disappearing tracks: LLCP with $c\tau$ >~ 10mm [long-lived charged particles]



3-4 hits only in the inner-most tracker
→ missing (disappearing track)

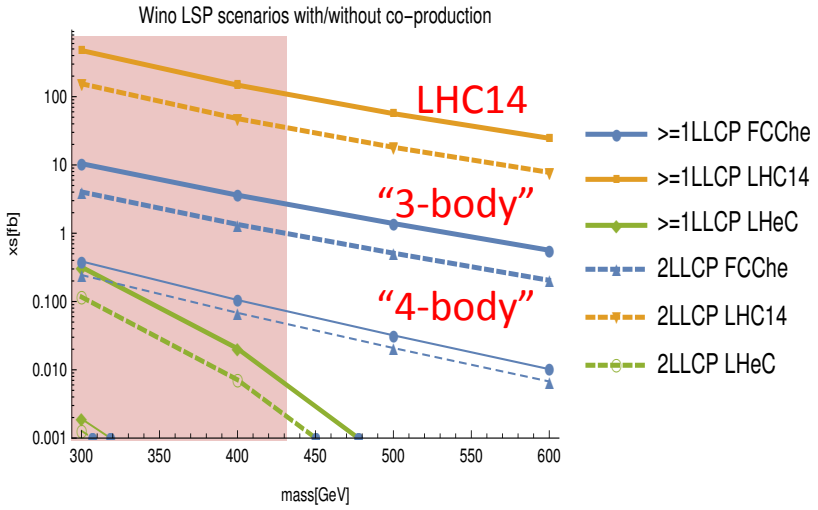
(or a "kink" if the harder daughter ***d1*** is charged)

Feasibility studies (I)

- Can have one or two LLP
- LHC cross section higher, but also the background!

Nominal cross section without acceptance / efficiency

Charginos (Wino LSP)



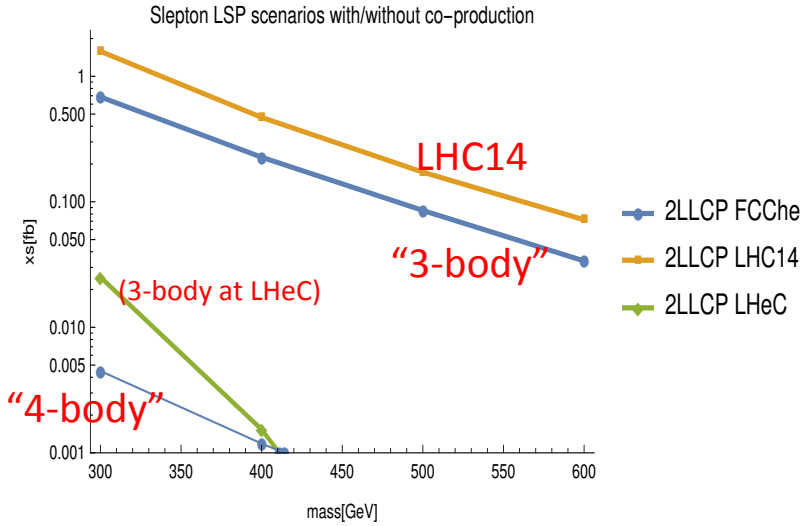
With no polarization.

Shaded region is excluded by ATLAS (13TeV, 36/fb)

FCC-he "3-body" process assumes

$$m_{\tilde{e}_L} = m_{\tilde{\chi}_1^0} + 9 \text{ GeV}$$

Sleptons

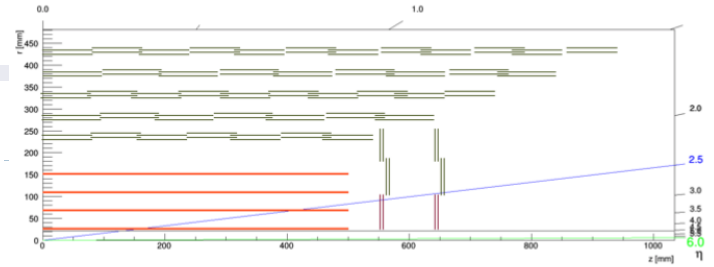


With no polarization.

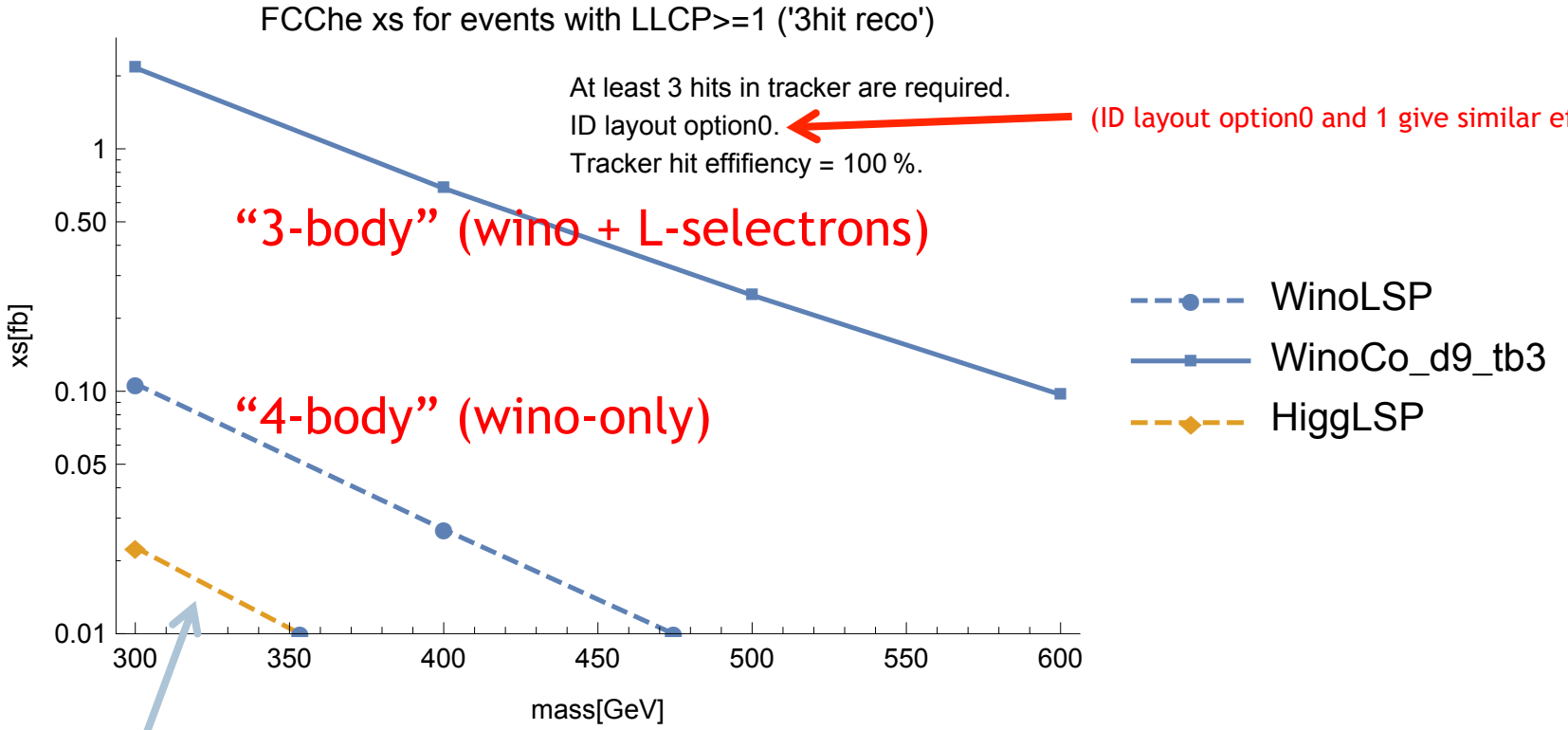
FCC-he "3-body" process assumes

$$m_{\tilde{\chi}_1^0} = m_{\tilde{e}} + 1 \text{ GeV}$$

Feasibility studies (II)



- **FCC-he: with reconstruction eff.**
  - LLCPs are required to decay after 3 layers of IDs.
    (=~ to leave 3 hits in ID)



Higgsino-only scenario: too small $c\tau$.

Assume no polarization.

"3-body" process assumes $m_{\tilde{e}_L} = m_{\tilde{\chi}_1^0} +$ 9 GeV.

- **"Wino+slep" (3-body) model <u>is promising.</u>**
- **reco eff. is governed by the innermost layers**
  - **→ closer / more-precise layers would help a lot**
  - **→ Need to make assumptions for bkg. In progress**

conclusions

- After several studies of the targeted processes, we identified a SUSY mass spectra which is
  - Very likely and possibly explaining g-2 and DM experiments
  - Almost impossible to target at the LHC
    - Too compressed scenarios, eventually mono-jet searches could reach low mass EWK particles
  - Sufficient production rate to be tested at FCC-eh
  - LHeC studies in progress
- If decays of EWK particles is not prompt, signatures can be identified as LLP
  - Expected bkg smaller than at LHC
  - Feasibility studies are very encouraging, but need to make assumptions on the level of background → depends on detector!
- More also in the next talk

Back-up

Current constraints on LL charginos

ATLAS SUSY DM limits **via disappearing track searches**

AMSB model with tan(\beta) = 5 & \mu > 0;
Wino-like chargino is pair-produced and
& decays to the wino-like neutralino and a very soft charged pion.