SUSY Dark Matter & Sleptons at the FCC-eh

G. Azuelos, M. D'Onofrio, S. Iwamoto, K. Wang

Slides for LHeC and FCC-eh Workshop, CERN
September 9, 2017

Outline

Current limits on SUSY DM & Sleptons

Search strategy

Light slepton scenario

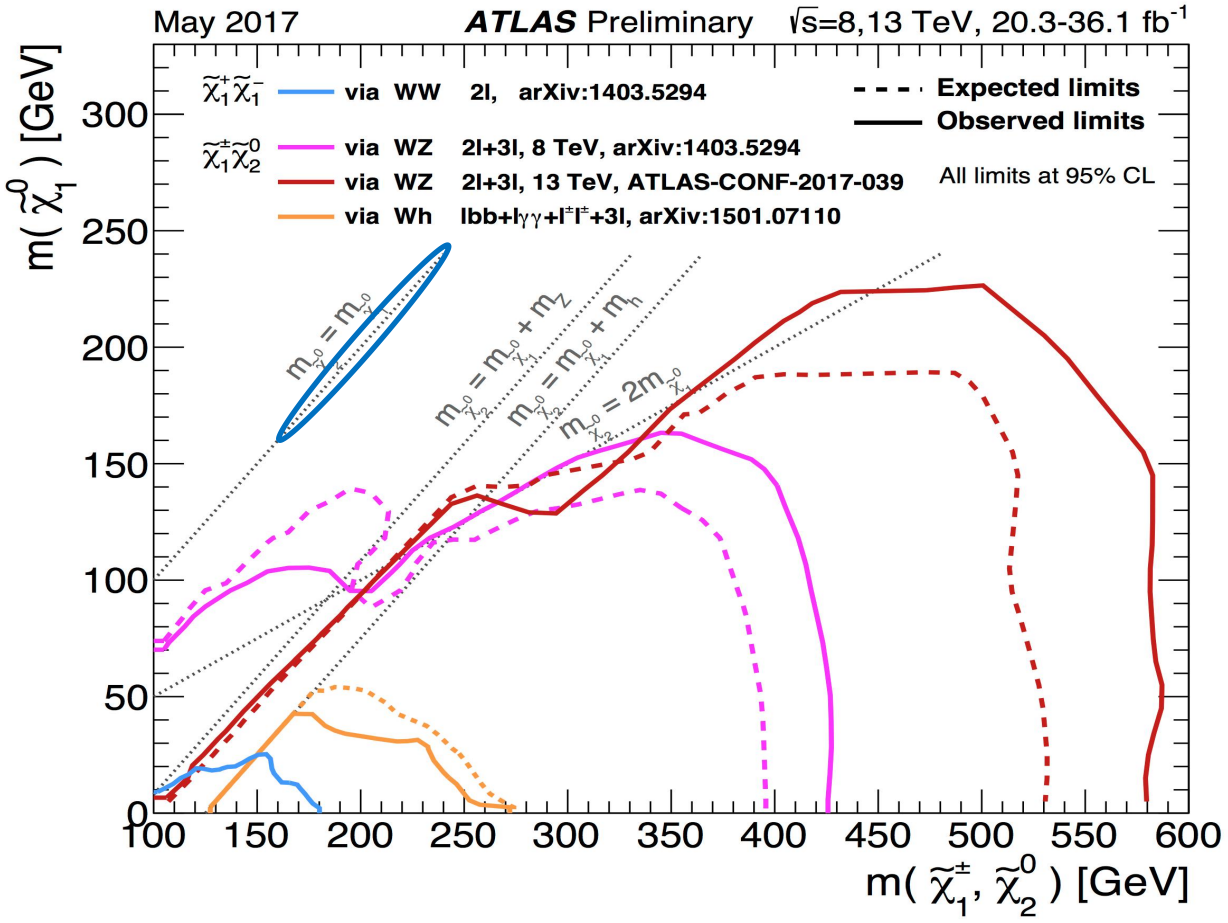
Heavy slepton scenario

Aim: Find the limits for the SUSM DM & Sleptons
when chargino and slepton decay promptly at the ep colliders.

Current LHC limits on SUSY DM

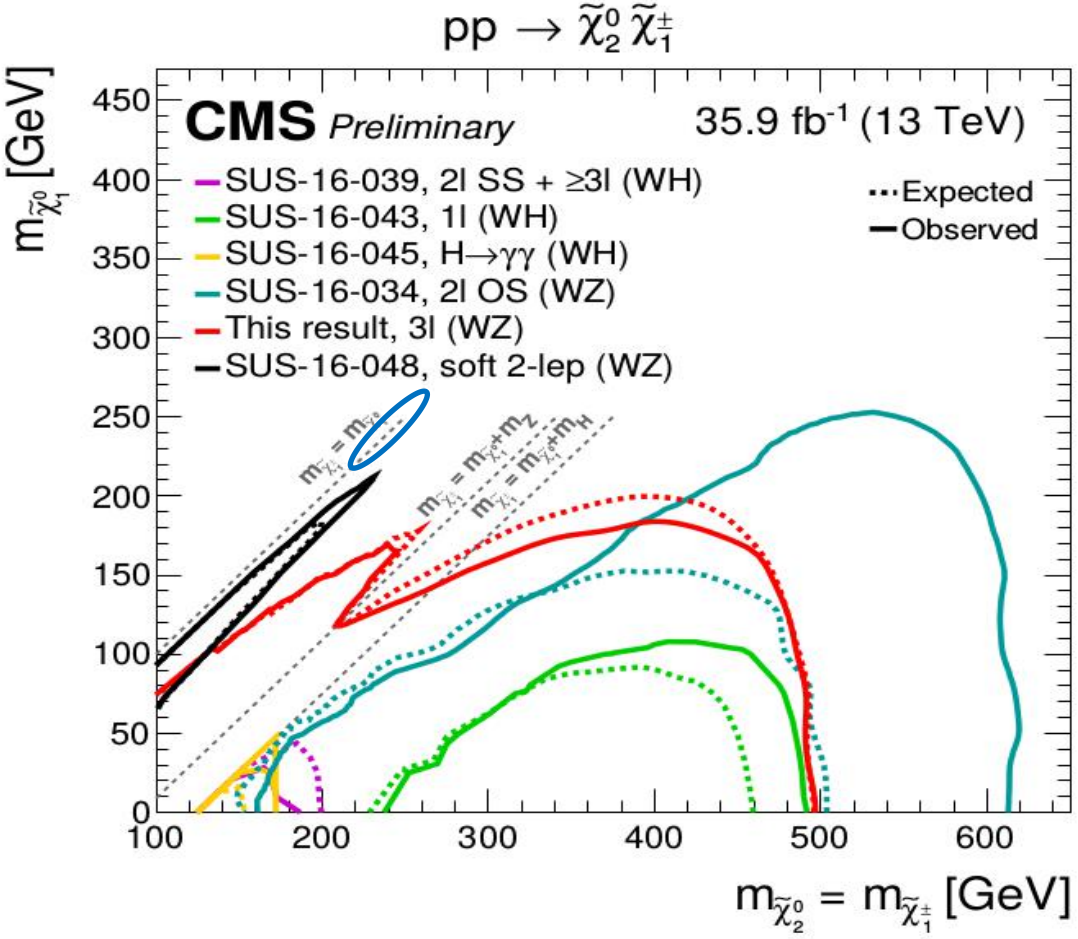
Slepton is heavy and decoupled [arXiv:1509.07152]:

production of pure wino chargino1-chargino1 & chargino1-neutralino2
neutralino1 is pure Bino



[SUS-17-004]:

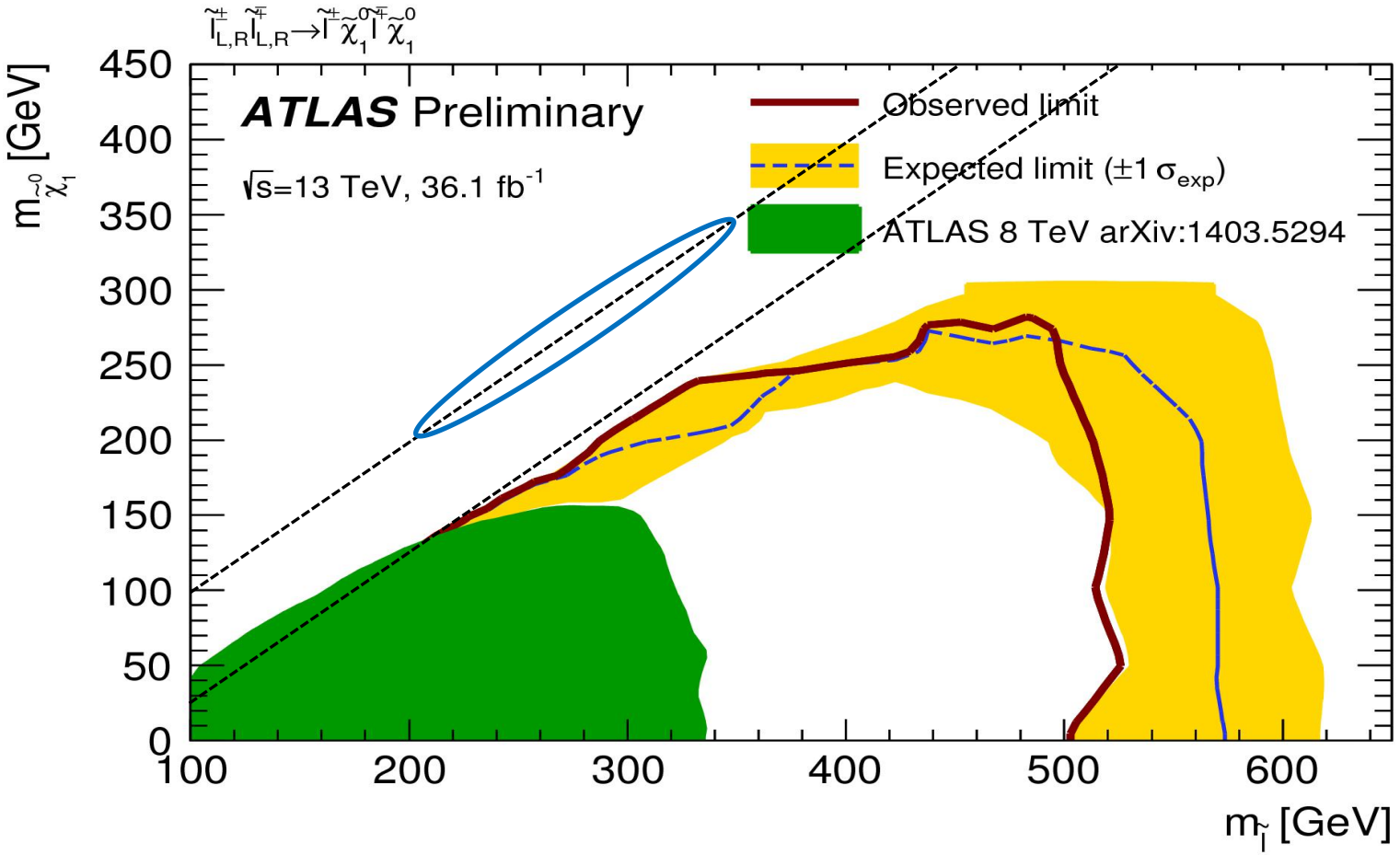
production of pure wino chargino1-neutralino2;
neutralino1 is pure Bino ;
chargino1 -> neutralino1 + W with 100% BR;
neutralino2 -> neutralino1 + Z / H



Current LHC limits on SUSY Sleptons

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

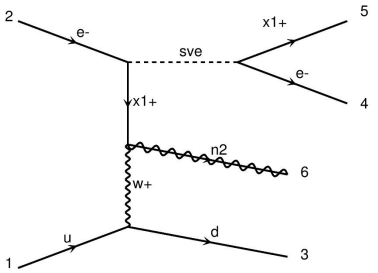
-> combined left-handed slepton and right-handed slepton production & sneutrino does not contribute ;
-> left-handed & right-handed selectrons, smuons and status are degenerate;
-> each slepton decays to lepton+neutralino1 with a 100% brancing ratio;
-> left-handed sleptons and sneutrinos are degenerate;
-> neutralino1 might be Bino .
-> leptons are electrons or muons only, including leptons from tau decay where relevant.



Signal Scenarios

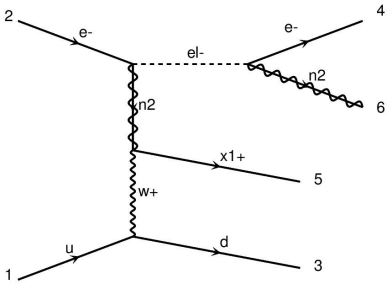
Collider:

FCC-eh (Ep = 50 TeV, Ee = 60 GeV).



Motivations:

(a) Compressed Scenarios:
decay products are very soft, challenging at pp colliders.
(b) Light sleptons:
Can be motivited by the "muon g-2"
DM production can be enhanced by the slepton decays.

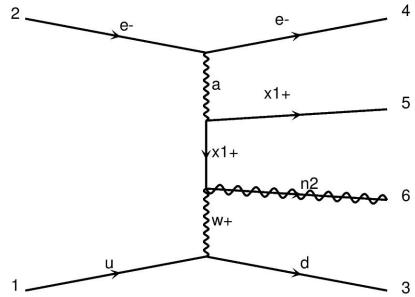


Signal scenarios:

Bino: m_{neutralino1};
Wino: m_{chargino1} = m_{neutralino2} = m_{neutralino1} + 1 GeV;

(1) Light slepton scenario

Slepton: m_{slepton_L} = m_{chargino1} + 35 GeV;
Sneutrino: m_{sneutrino} ~ m{slepton_L} - 9 GeV (tanβ = 30)
BR(slepton -> neutralino2,1 e-): 40%
BR(sneutrino -> chargino1 e-): 60%



(2) Heavy slepton scenario

Slepton & Sneutrino: Heavy and decoupled.

Search Strategy

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

Simulation by "MadGraph + PYTHIA + Delphes".

Signal:
import model mssm
define dm = x1+ x1- n1 n2
generate p e- > j e- dm dm

SM background:
(a) two-neutrino process:
define dm = ve vm vt ve~ vm~ vt~
generate p e- > j e- dm dm

(b) one-neutrino process:
(contributed when one lepton is mis-detected)
generate p e- > j e- l vl

Analysis at detector-level using the BDT method.

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 .

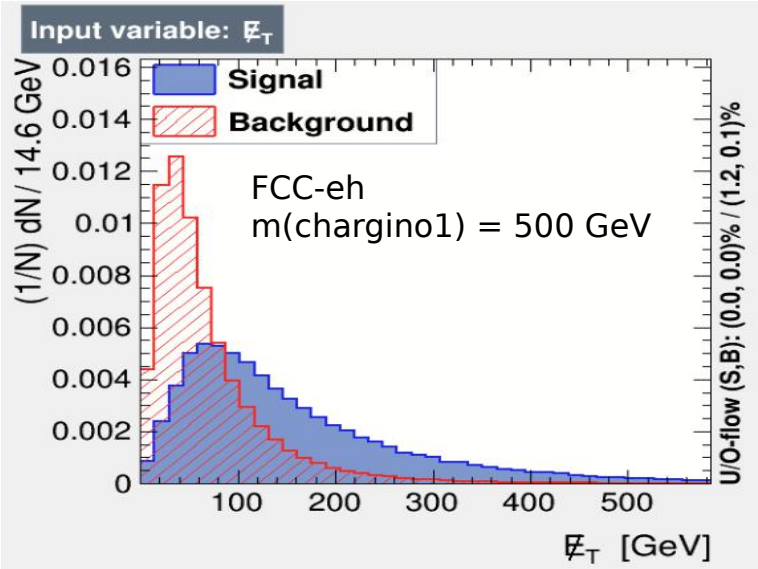
Input observables for BDT Training & Test:

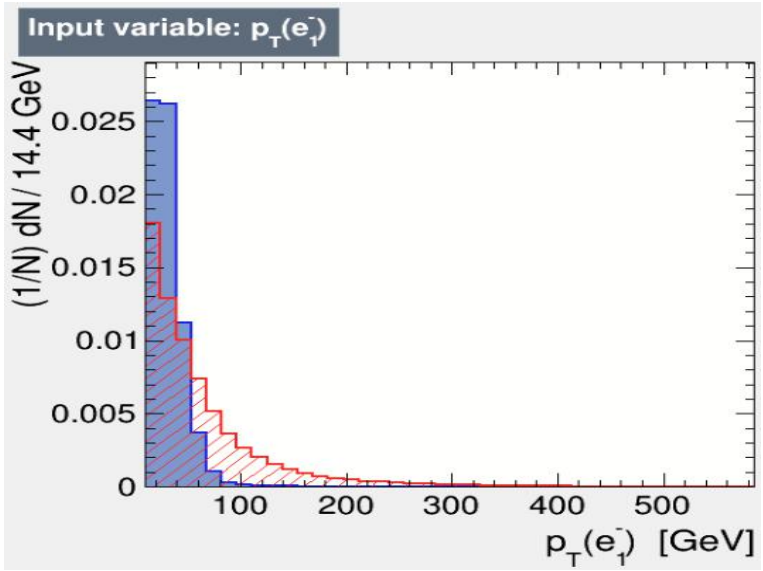
MET, H_T ;

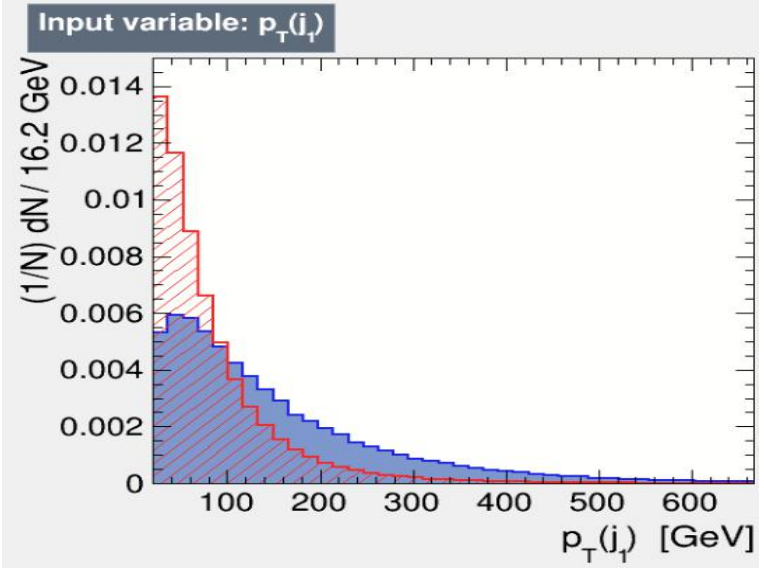
$p_T(j_1)$, $\eta(j_1)$, $p_T(e_1)$, $\eta(e_1)$, $\Delta\eta(j_1, e_1)$, $\Delta\varphi(j_1, e_1)$;
$M_T(\text{MET}, e_1)$, $M_T(\text{MET}, j_1)$, $\Delta\varphi(\text{MET}, e_1)$, $\Delta\varphi(\text{MET}, j_1)$

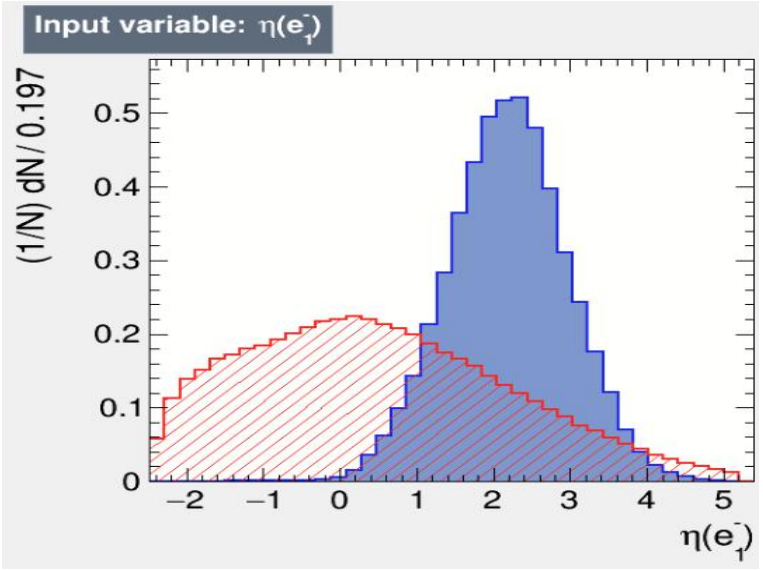
$M(j_1+e_1)$, $p_T(j_1+e_1)$, $\eta(j_1+e_1)$,
$M_T(\text{MET}, j_1+e_1)$, $\Delta\varphi(\text{MET}, j_1+e_1)$;

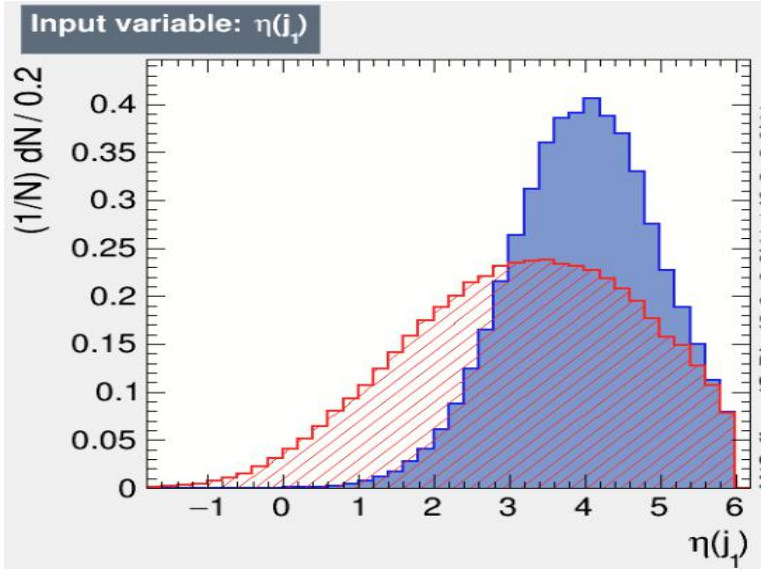
Input Observables for Light Slepton Scenario

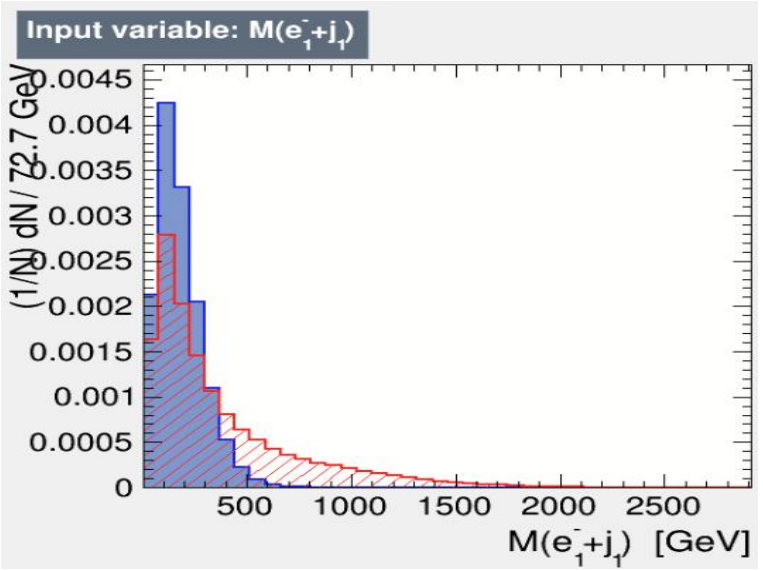






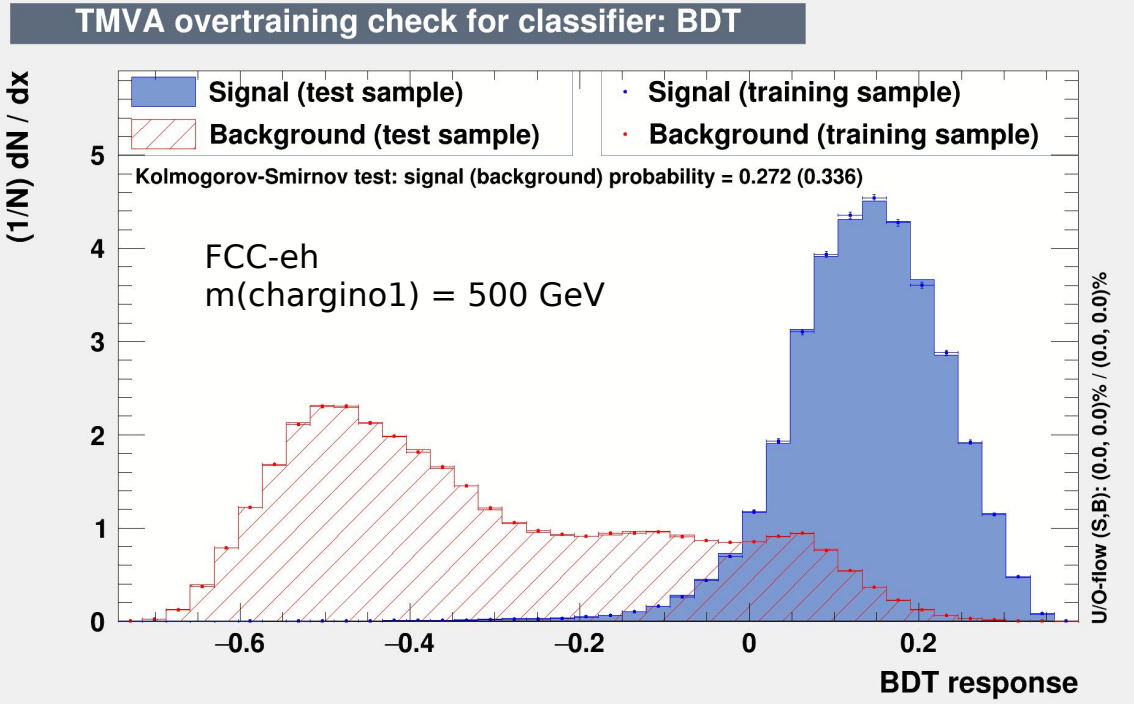




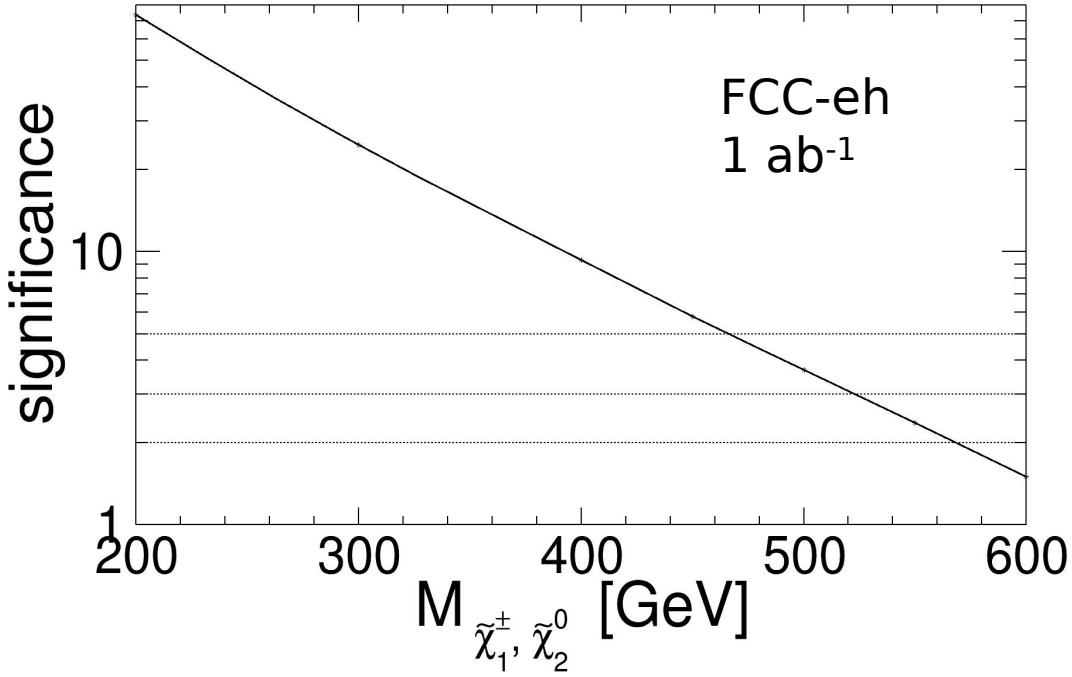


Limts for Light Slepton Scenario

BDT Distribution



Significances



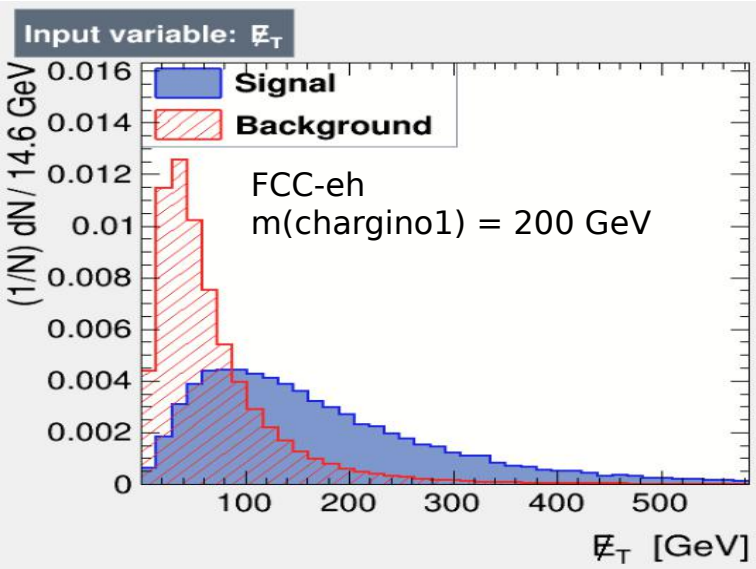
Production

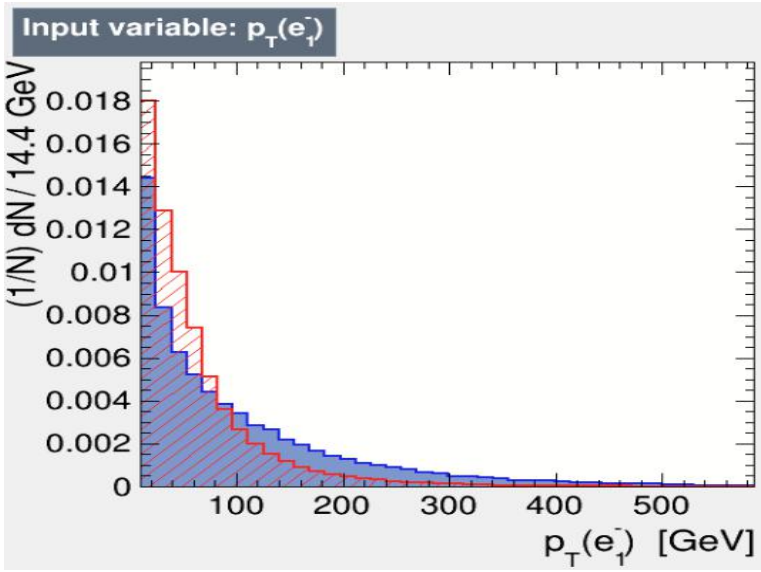
Mass [GeV]	200	300	400	450	500	550	600
cross section [fb]	46.7	13.0	4.6	2.8	1.8	1.1	0.73

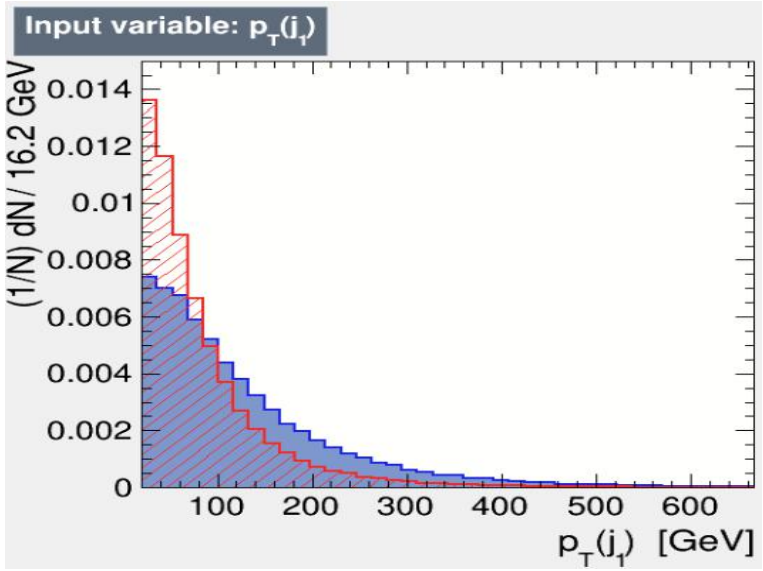
limits @ FCC-eh, 1 ab^{-1}

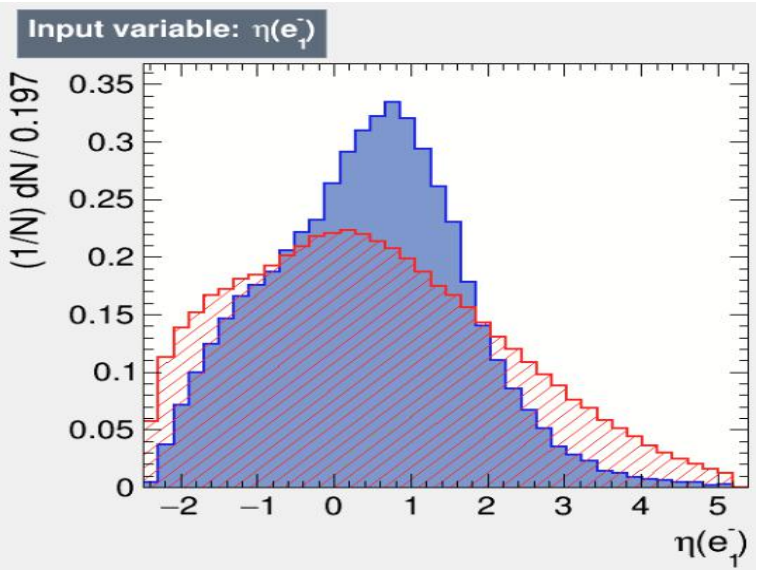
Mass [GeV]	Significance
466.8	5
524.3	3
568.4	2

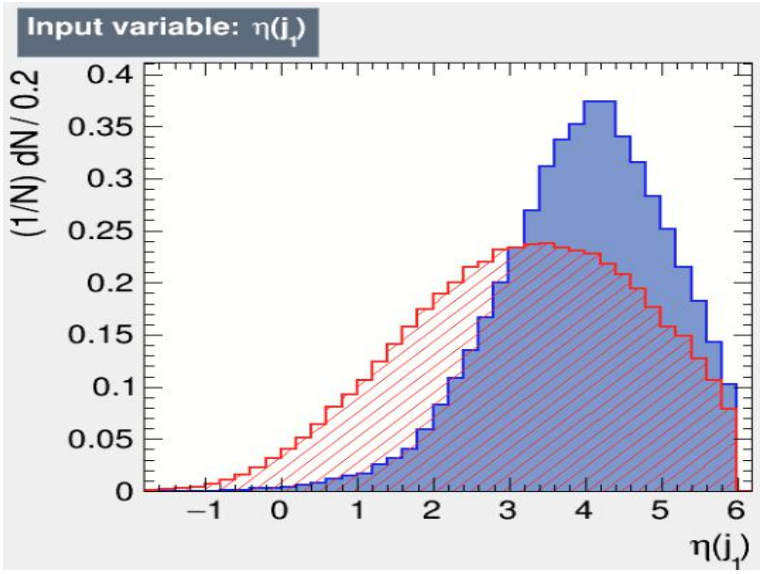
Input Observables for Heavy Slepton Scenario

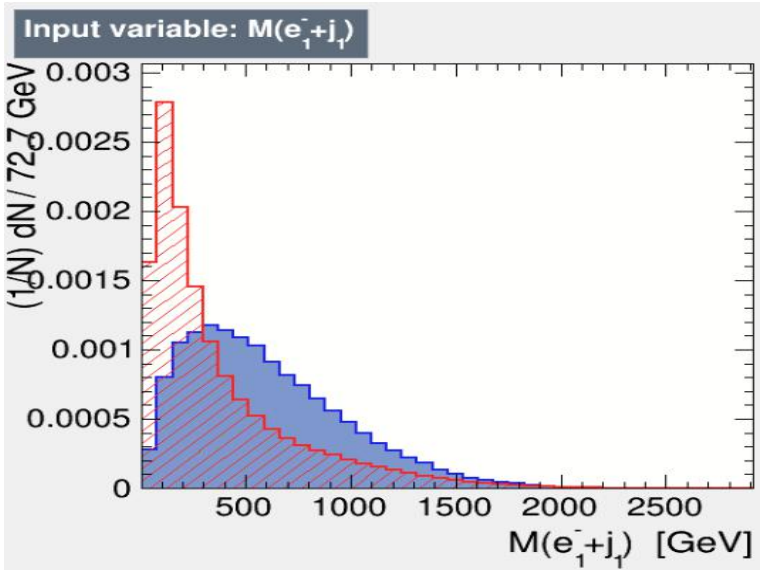






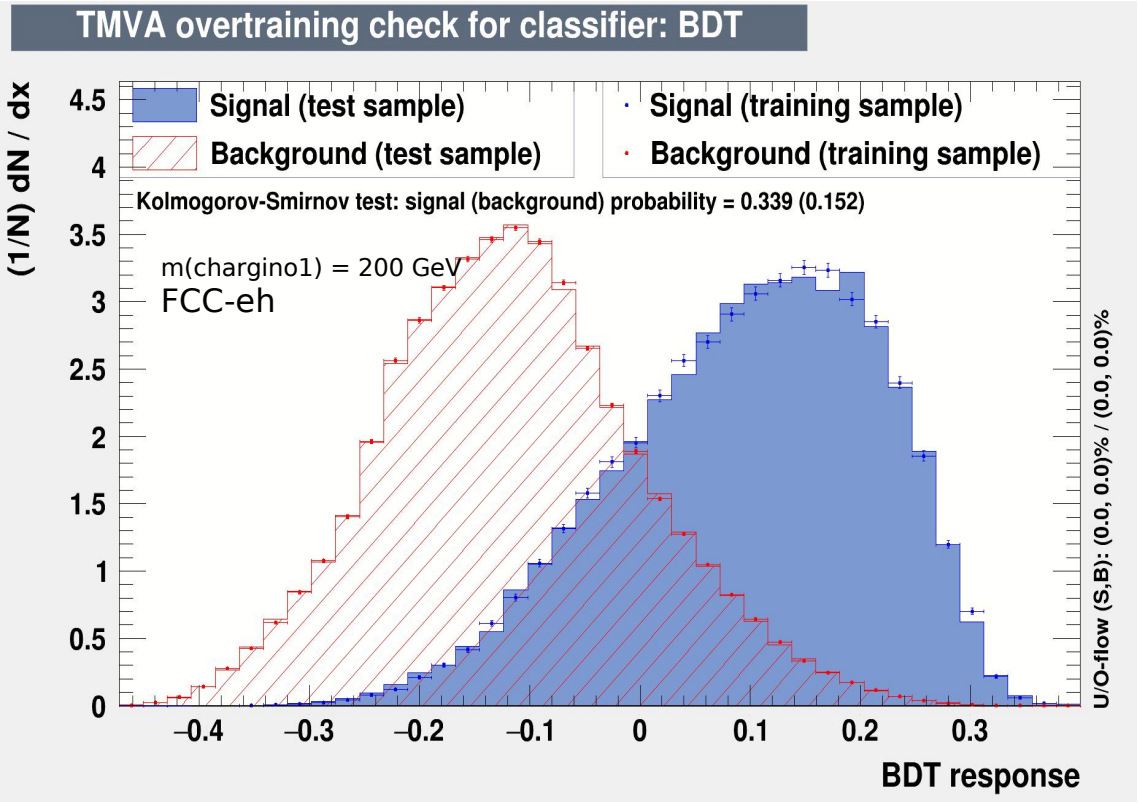




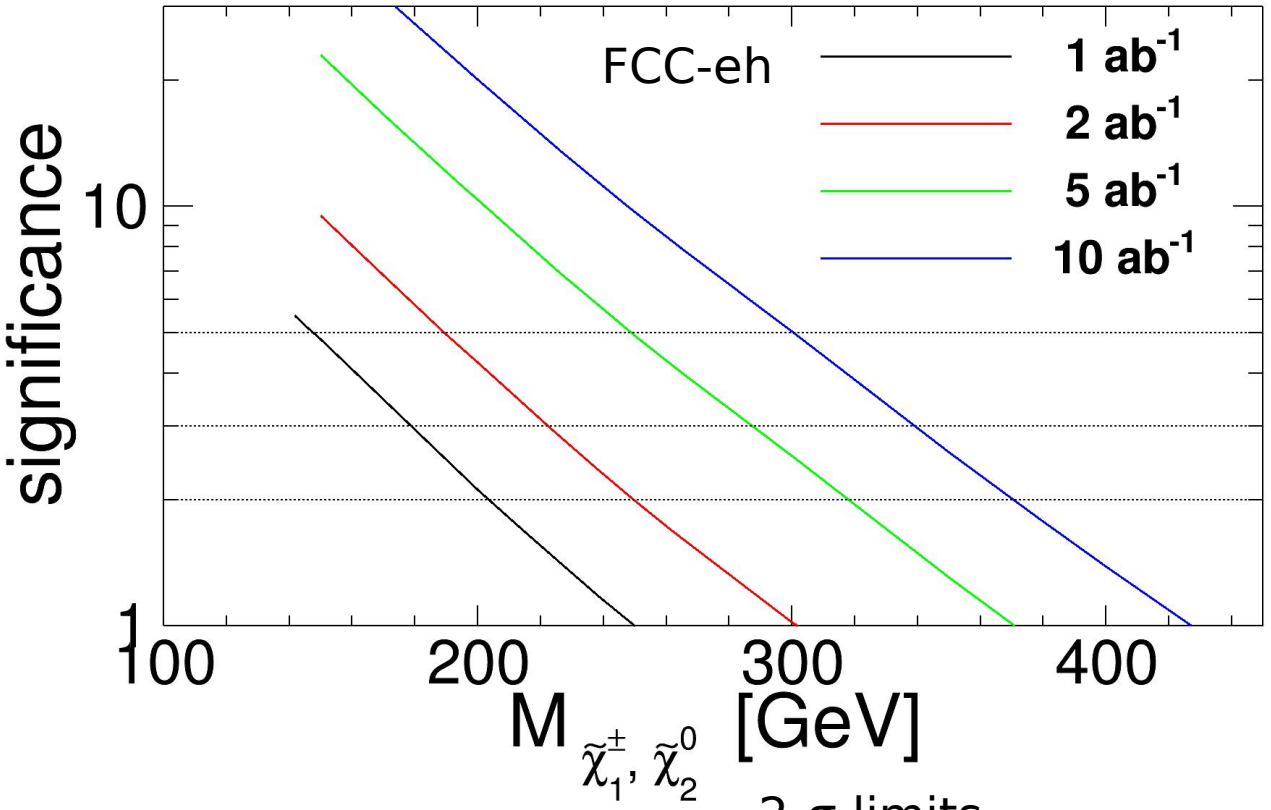


Limts for Heavy Slepton Scenario

BDT Distribution



Significances



Production

Mass [GeV]	150	200	250	300	350	400	450
cross section [fb]	5.6	2.1	0.91	0.43	0.22	0.11	0.061

FCC-eh, 1 ab^{-1}

Mass [GeV]	Significance
147.6	5
179.7	3
204.1	2

2-σ limits

Luminosity [ab^{-1}]	Mass [GeV]
1	204.1
2	249.7
5	318.5
10	371.1

Conclusion

We develop the strategy to searching for SUSY DM & Sleptons
--> when chargino and slepton decay promptly at the ep colliders.

Motivations:
--> Compressed Scenarios:
decay products are very soft, challenging at pp colliders.
--> Light sleptons:
Can be motivited by the "muon g-2"
DM production can be enhanced by the slepton decays.

Final state: 1 e^- + 1 j + MET
--> Analysis at detector-level using the BDT method.

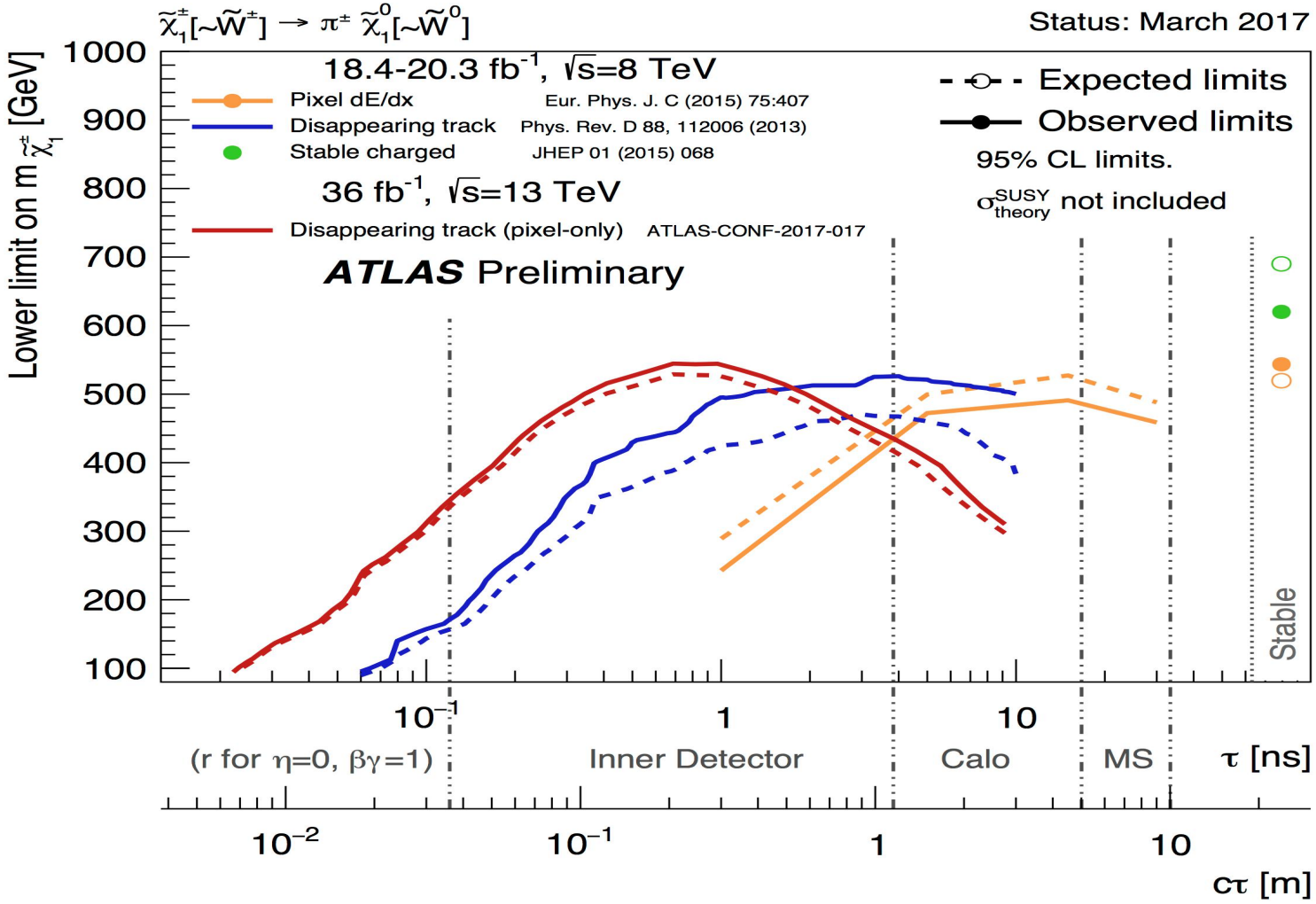
Limits for light slepton scenario:
--> 568.4 GeV for 2-σ @ FCC-eh, 1 ab^{-1}

Limits for Heavy slepton scenario:
--> 204.1 (318.5) GeV for 2-σ @ FCC-eh, 1 (5) ab^{-1}

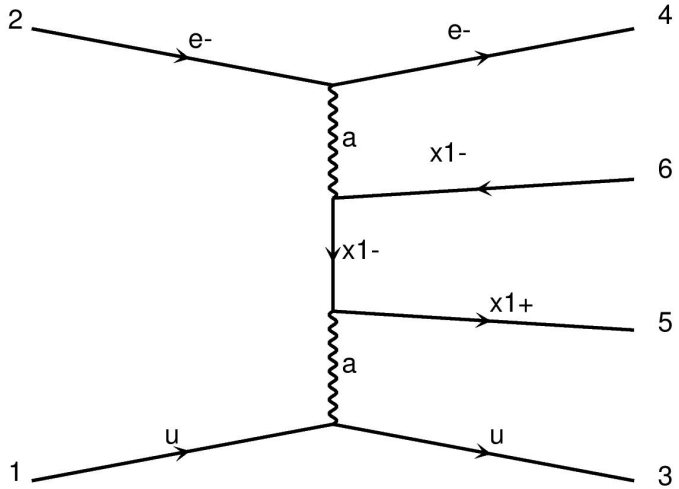
Backup Slides

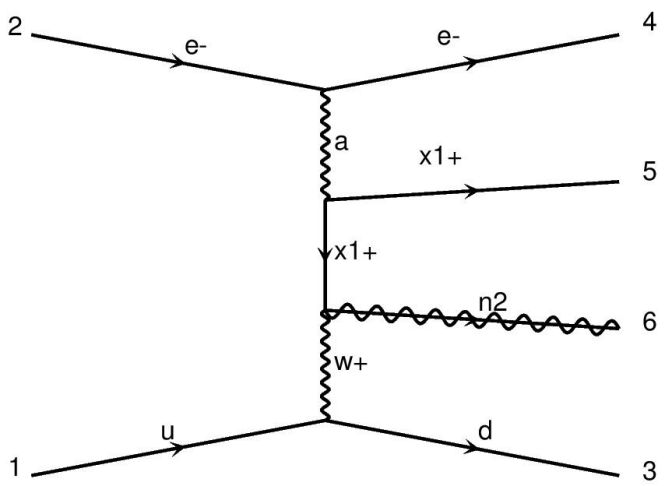
ATLAS SUSY DM limits via disappearing track searches

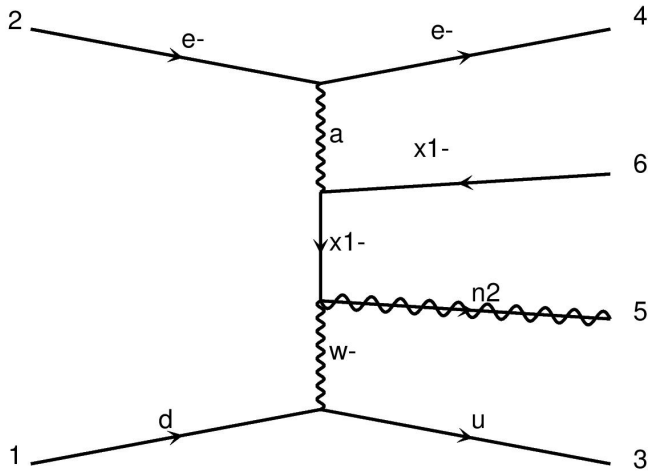
AMSB model with tan(\beta) = 5 & \mu > 0;
Wino-like chargino is pair-produced and
& decays to the wino-like neutralino and a very soft charged pion.

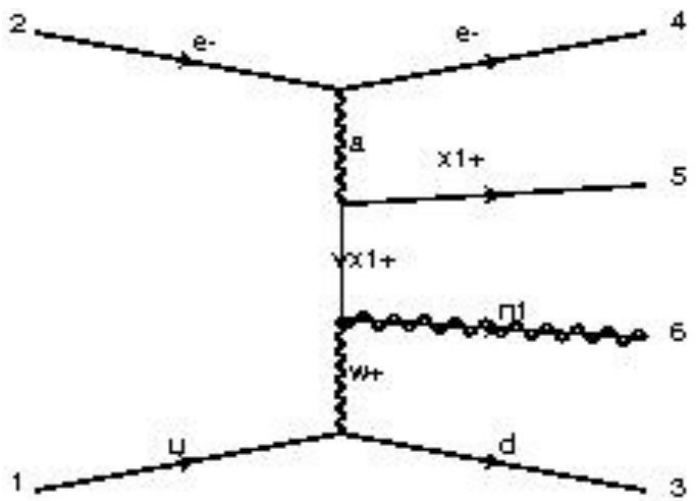


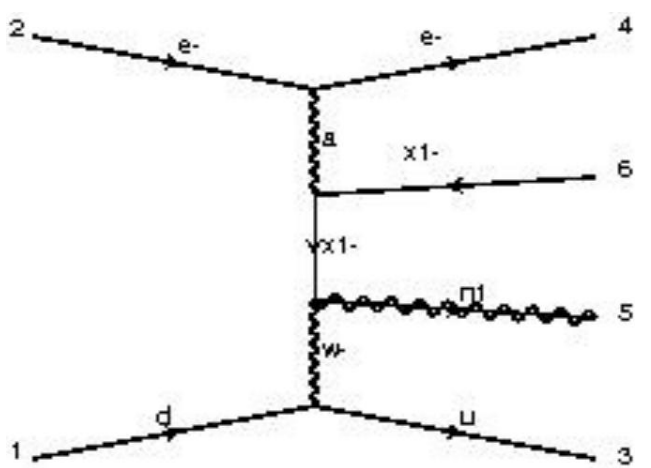
Signal Event Generating for Heavy Slepton Scenario





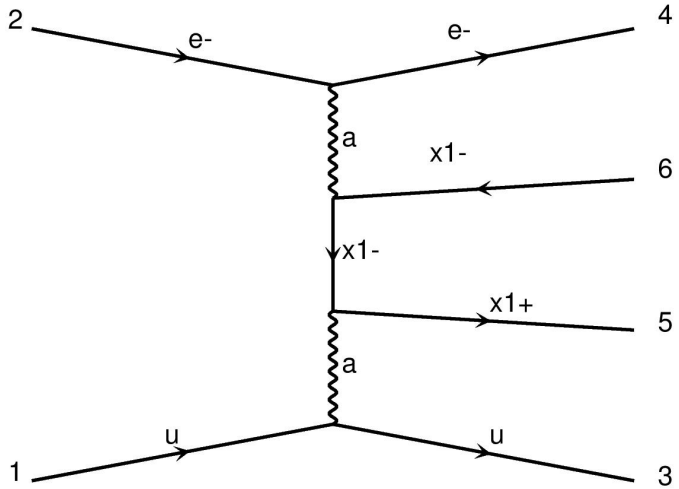


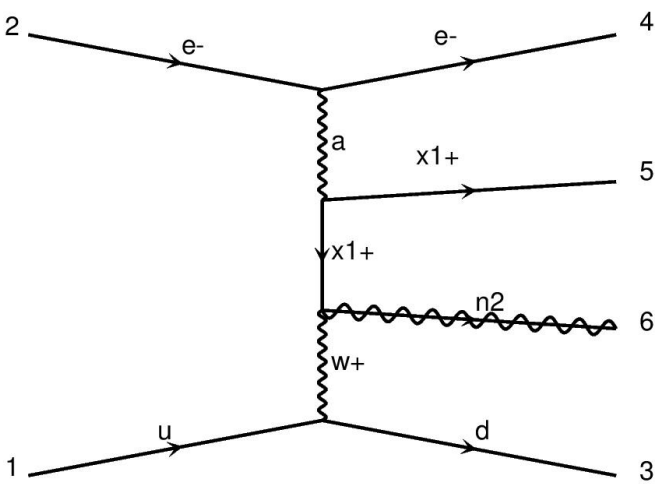


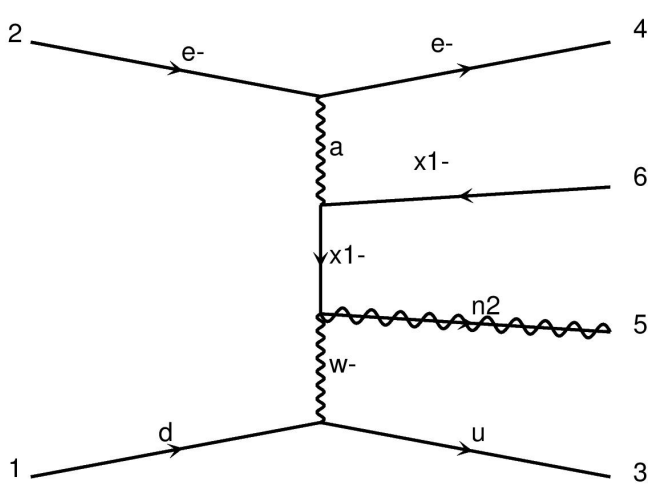


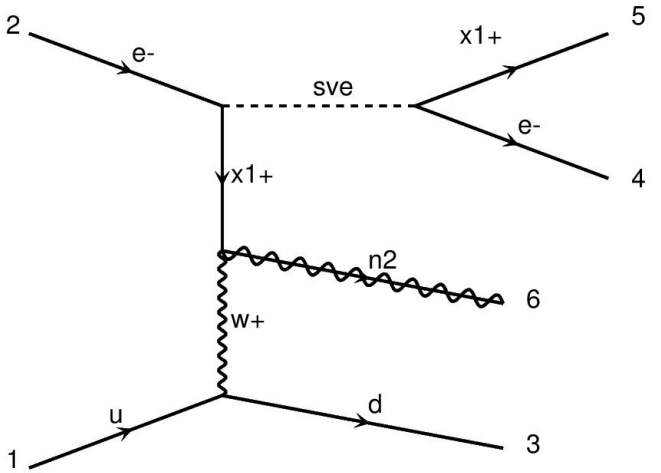
13

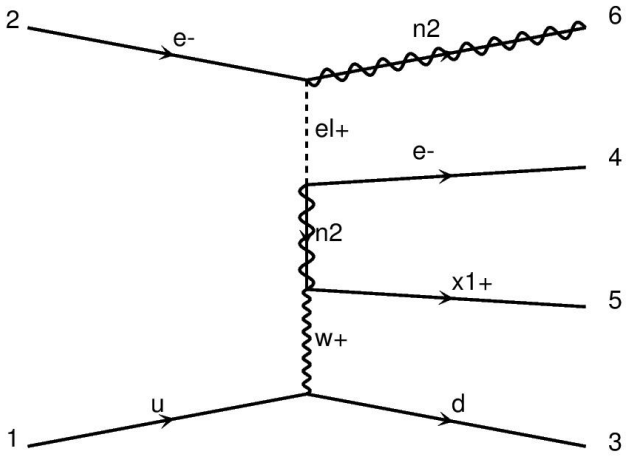
Signal Event Generating for Light Slepton Scenario

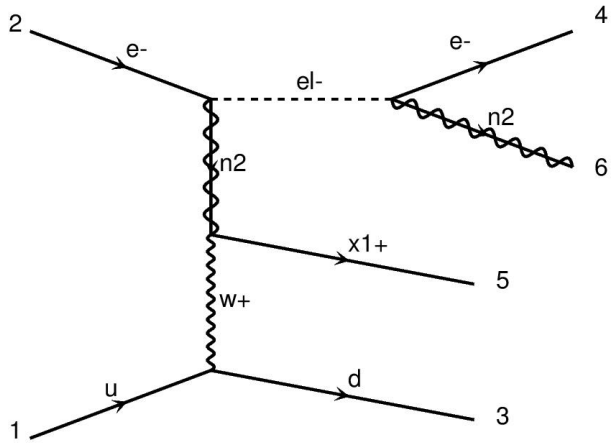












Background Generating