SUSY Search at the CEPC

Jiarong Yuan
Nankai University, Institute of High Energy Physics
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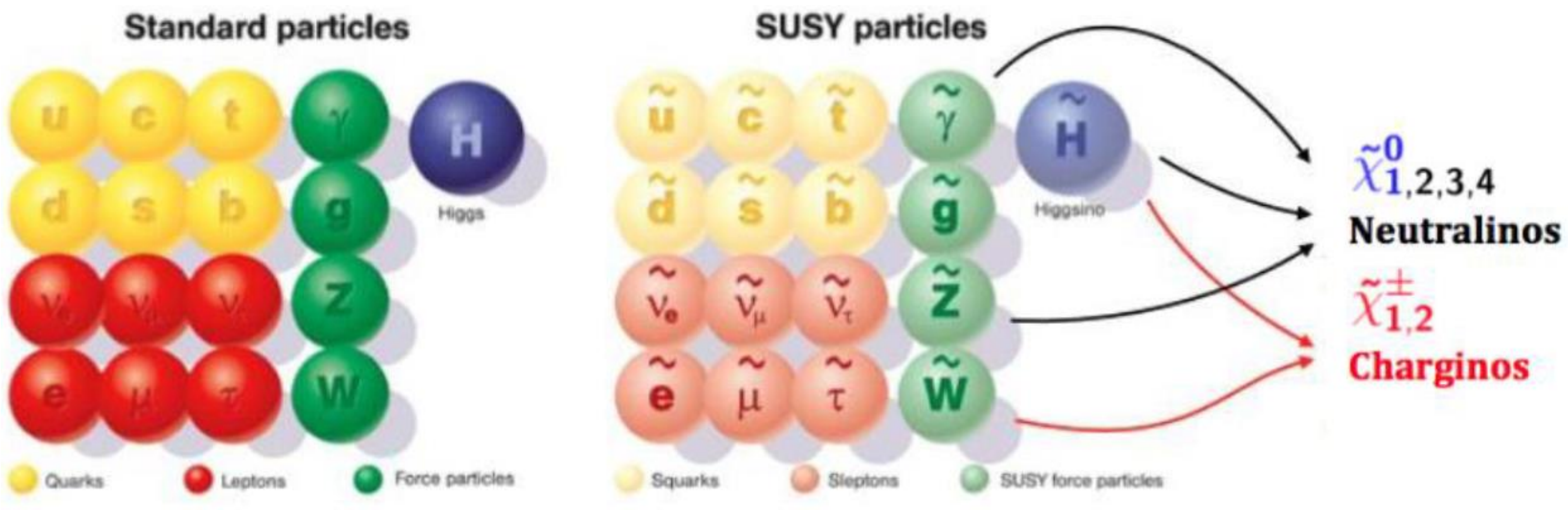
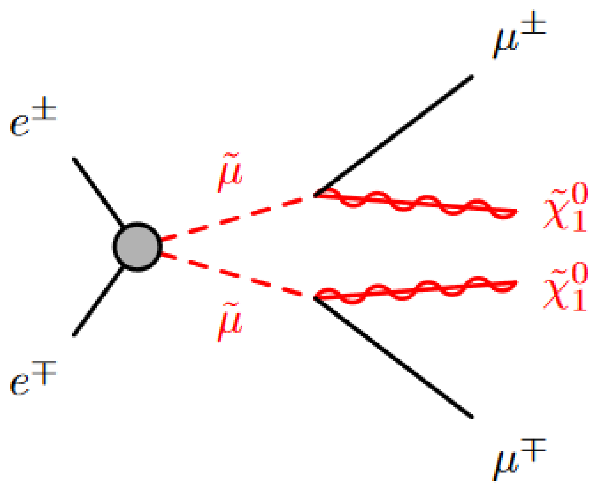
Supersymmetry Introduction

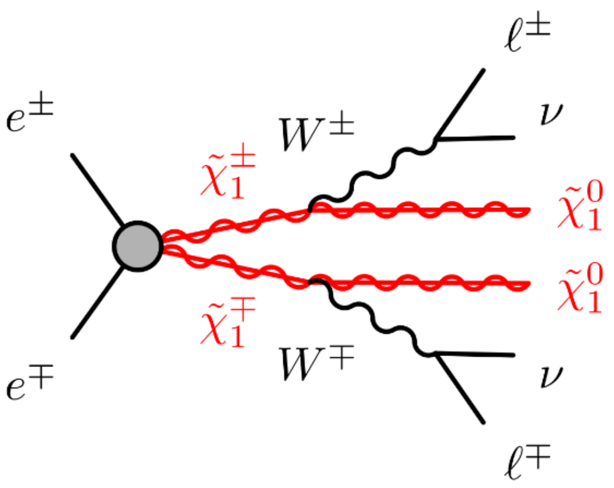


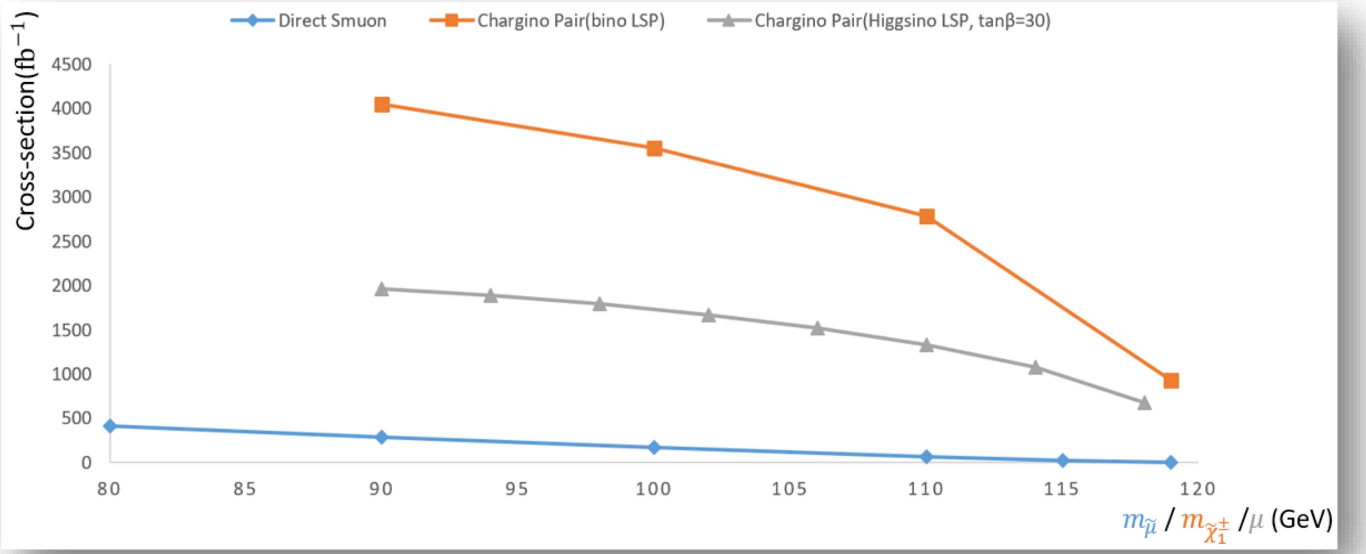
- The Supersymmetry is one of the most appealing BSM theories, which can be helpful for:
  dark matter candidate,
  hierarchy problem,
  grand unification of gauge couplings
  …

Overview

- Search for sleptons and electroweakinos at CEPC.
- Show search results in final states with two opposite sign (OS) charged muons.
- Signal scenarios
  - ➢ Direct production of smuon pairs (can **explain g-2 excess**)
  - ➢ Production of chargino pairs decaying via W bosons (**Bino LSP**, **large cross section**)
  - ➢ Production of chargino pairs decaying via W bosons (**Higgsino LSP, interesting related with higgs**)





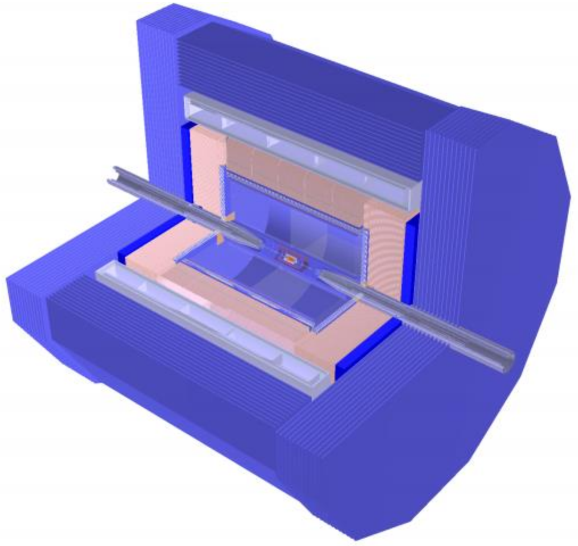


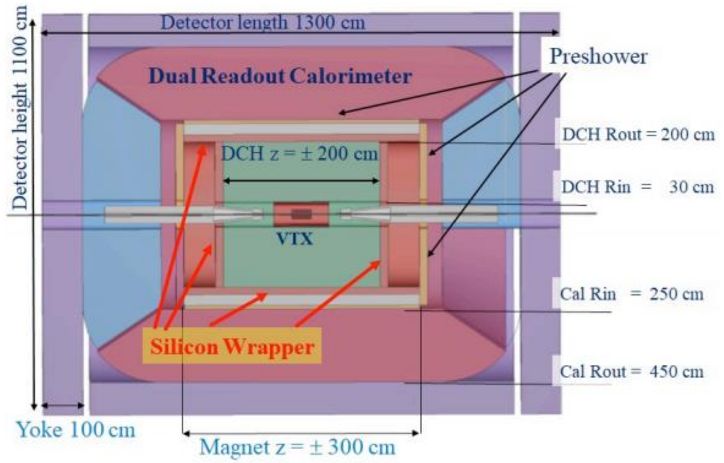
Cross-section based on Madgraph calculation

Technical detail

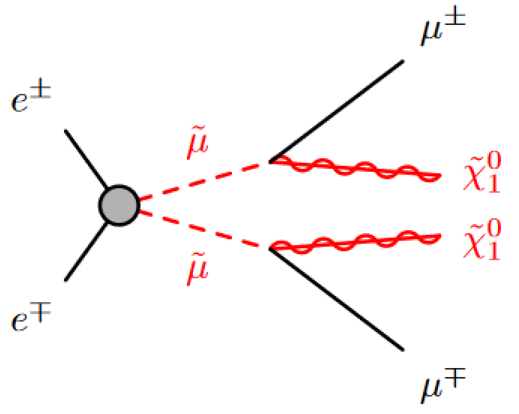
- About CEPC
  ECM=240GeV, higgs factory, 100 km circumference, 2 interaction points.
  ILD-like detector
- Software
  Signal samples: MadGraph+Pythia8
  Simulation: Mokka
  Reconstruction: Marlin
- Normalized to $5050\ \mathrm{fb}^{-1}$
- **Dominant backgrounds: SM processes with two-μ or two-τ final states**

process	Cross Section [fb]
$\mu\mu$	4967.58
$\tau\tau$	4374.94
$WW \to \ell\ell$	392.96
$ZZorWW \to \mu\mu\nu\nu$	214.81
$ZZorWW \to \tau\tau\nu\nu$	205.84
$\nu Z, Z \to \mu\mu$	43.33
$ZZ \to \mu\mu\nu\nu$	18.17
$\nu Z, Z \to \tau\tau$	14.57
$ZZ \to \tau\tau\nu\nu$	9.2
$\nu\nu H, H \to \tau\tau$	3.07





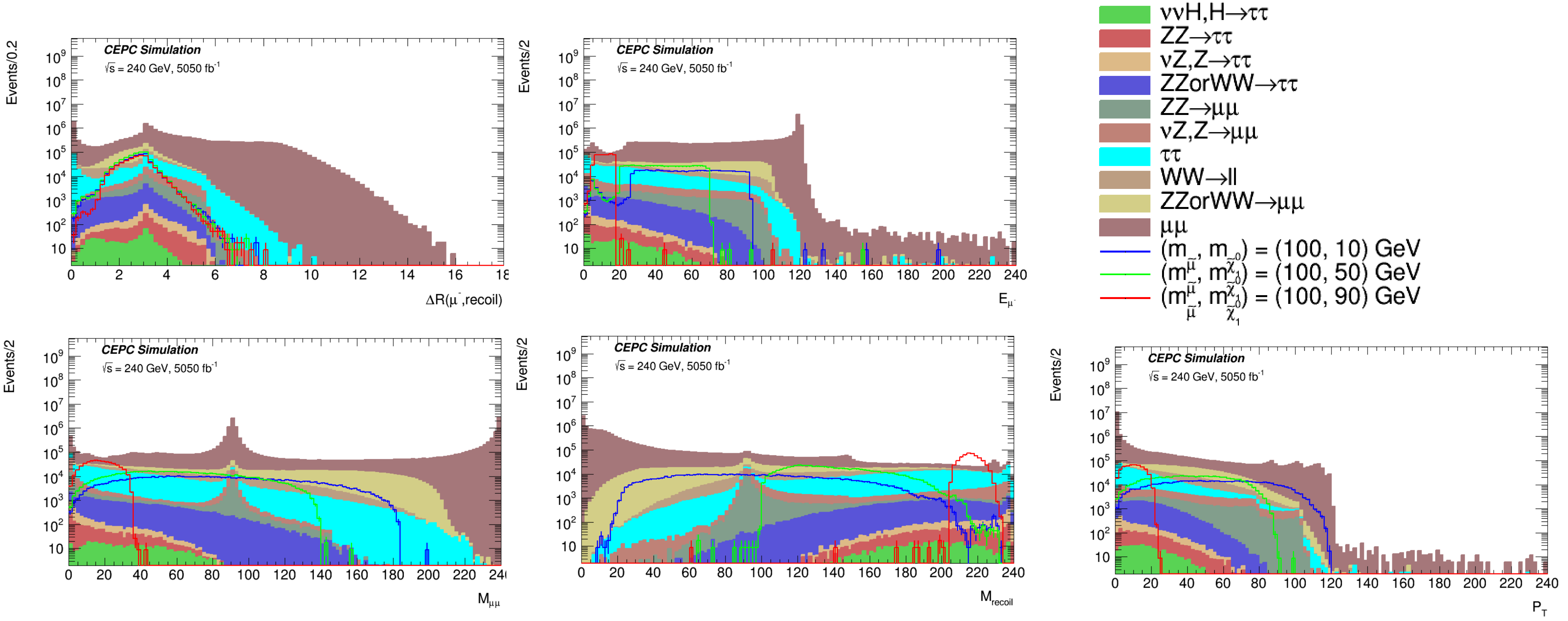
Direct smuon: Optimization Strategy



- Select events with 2 OS muons with energy > 0.5GeV.
- Perform a multi-dimension optimization, considering variables:

$$\Delta R(\mu,\mu), \Delta R(\mu, recoil), \Delta\varphi(\mu,\mu), \Delta\varphi(\mu, recoil), M_{\mu\mu}, M_{recoil}, E_{\mu\mu}, P_T^{\mu\mu}, E_{\mu}, P_T^{\mu}$$

- Check for both upper cut and down cut for each variable.
- Use $\frac{S}{\sqrt{B+dB^2}}$ as a sensitivity measurement (consider statistical uncertainty and 5% systematic uncertainty).

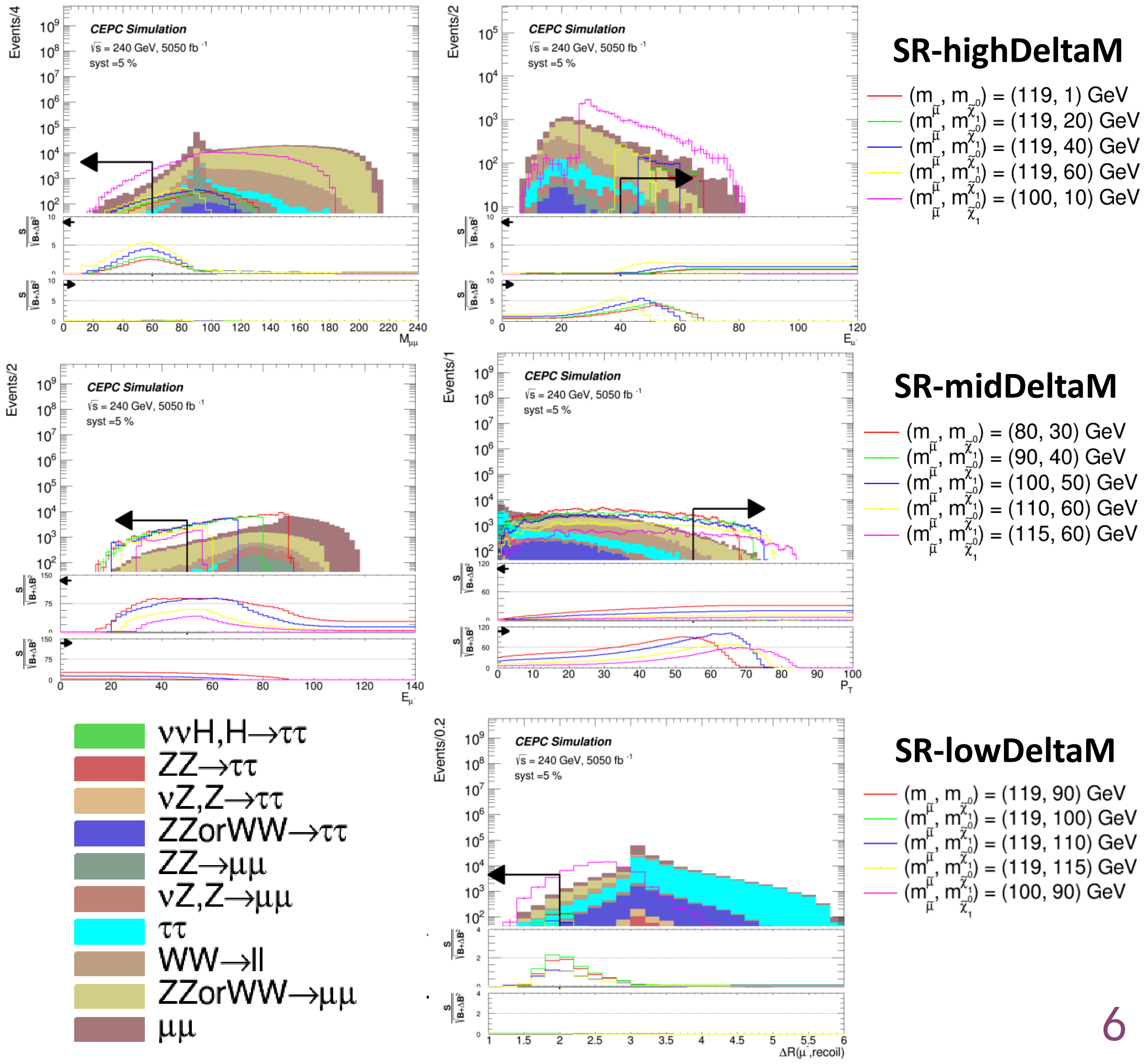


Direct smuon: SR & Results

- Three SRs are defined for different $\Delta m(\tilde{\mu}, \tilde{\chi}_1^0)$.

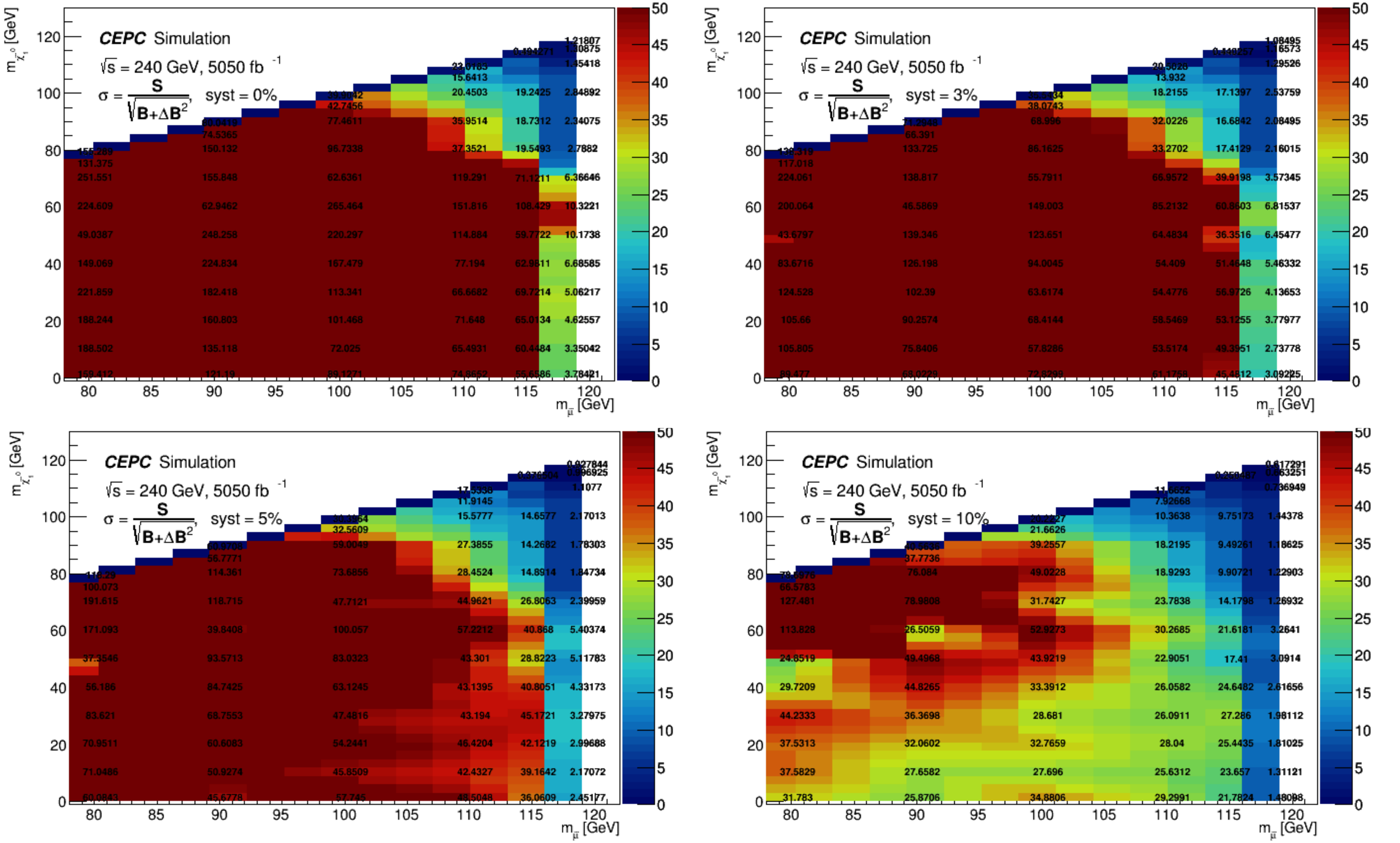
SR-highDeltaM	SR-midDeltaM	SR-lowDeltaM
2 μ (OS, both energy > 0.5GeV)		
$\Delta R(\mu, recoil) < 3$ $E_\mu > 40GeV$ $M_{\mu\mu} < 60GeV$ $M_{recoil} > 25GeV$	$\Delta R(\mu, recoil) < 3$ $E_\mu < 50GeV$ $p_T > 55GeV/c$	$\Delta R(\mu, recoil) < 2$ $E_\mu < 45GeV$

process	SR-highΔm	SR-midΔm	SR-lowΔm
$\tau\tau$	38.59+-9.36	118.04+-16.37	276.94+-25.07
$\nu\nu H, H \to \tau\tau$	0+-0	0+-0	1.71+-0.51
$ZZorWW \to \tau\tau\nu\nu$	0+-0	4.12+-2.06	35.02+-6.01
$ZZ \to \tau\tau\nu\nu$	0+-0	0+-0	0+-0
$\nu Z, Z \to \tau\tau$	0+-0	0+-0	1.48+-1.05
$ZZorWW \to \mu\mu\nu\nu$	889.64+-30.82	2585.63+-52.55	398.36+-20.63
$ZZ \to \mu\mu\nu\nu$	94.11+-11.41	40.14+-7.45	1.38+-1.38
$WW \to \ell\ell$	53.20+-7.38	376.46+-19.62	51.15+-7.23
$\nu Z, Z \to \mu\mu$	100.17+-10.56	70.12+-8.83	4.45+-2.23
$\mu\mu$	1570.45+-97.77	925.22+-75.05	420.00+-50.56
total background	2746.16+-104.37	4119.73+-95.83	1190.5+-60.89
Ref. point (100,10)	8264.62+-267.30	6207.11+-231.65	406.32+-59.27
Ref. point (100,50)	4469.46+-196.57	20151.5+-417.38	821.28+-84.26
Ref. point (100,90)	0+-0	0+-0	5420.42+-216.47

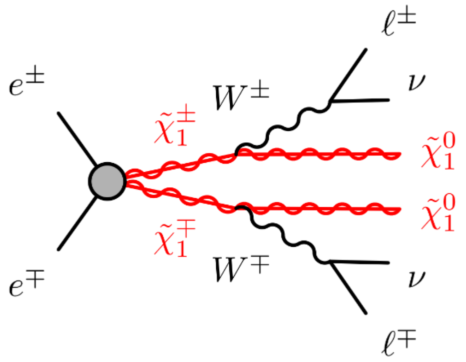


Direct smuon: Sensitivity map

- Assuming 10% systematic uncertainty, the discovery sensitivity reaches up to 115 GeV.



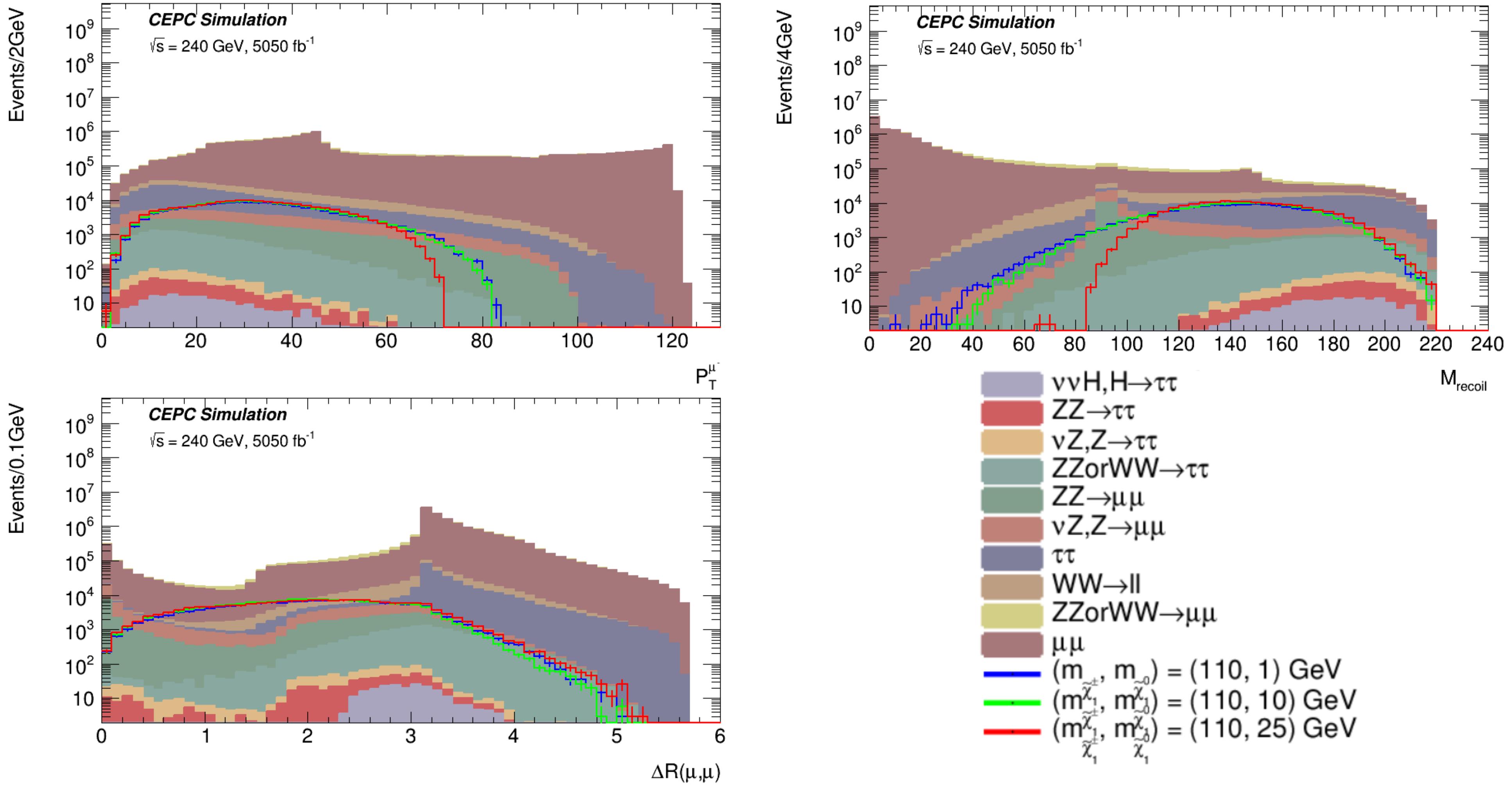
Chargino pair (Bino LSP): Optimization Strategy



- Select events with 2 OS muons with energy > 10 GeV.
- Perform a multi-dimension optimization considering variables:

$$\Delta R(\mu,\mu), \Delta R(\mu, recoil), \Delta\varphi(\mu,\mu), \Delta\varphi(\mu, recoil), M_{\mu\mu}, M_{recoil}, E_{\mu\mu}, P_T^{\mu\mu}, E_{\mu}, P_T^{\mu}$$

- Check for both upper cut and down cut for each variable.
- Use $\frac{S}{\sqrt{S+B+dB^2}}$ as a sensitivity measurement (consider statistical uncertainty and 5% systematic uncertainty).

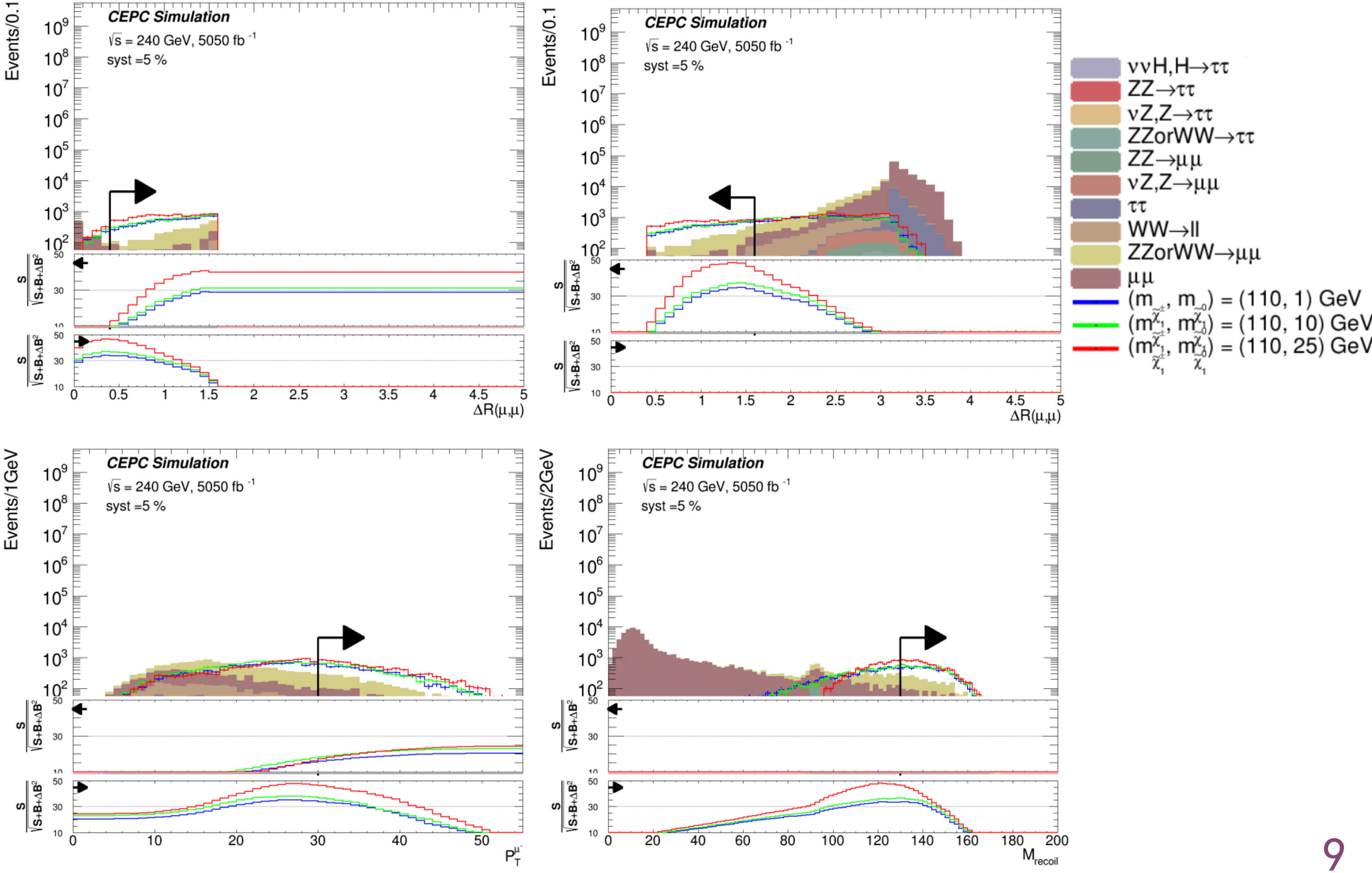


Chargino pair (Bino LSP): SR & Results

- One signal region is defined.

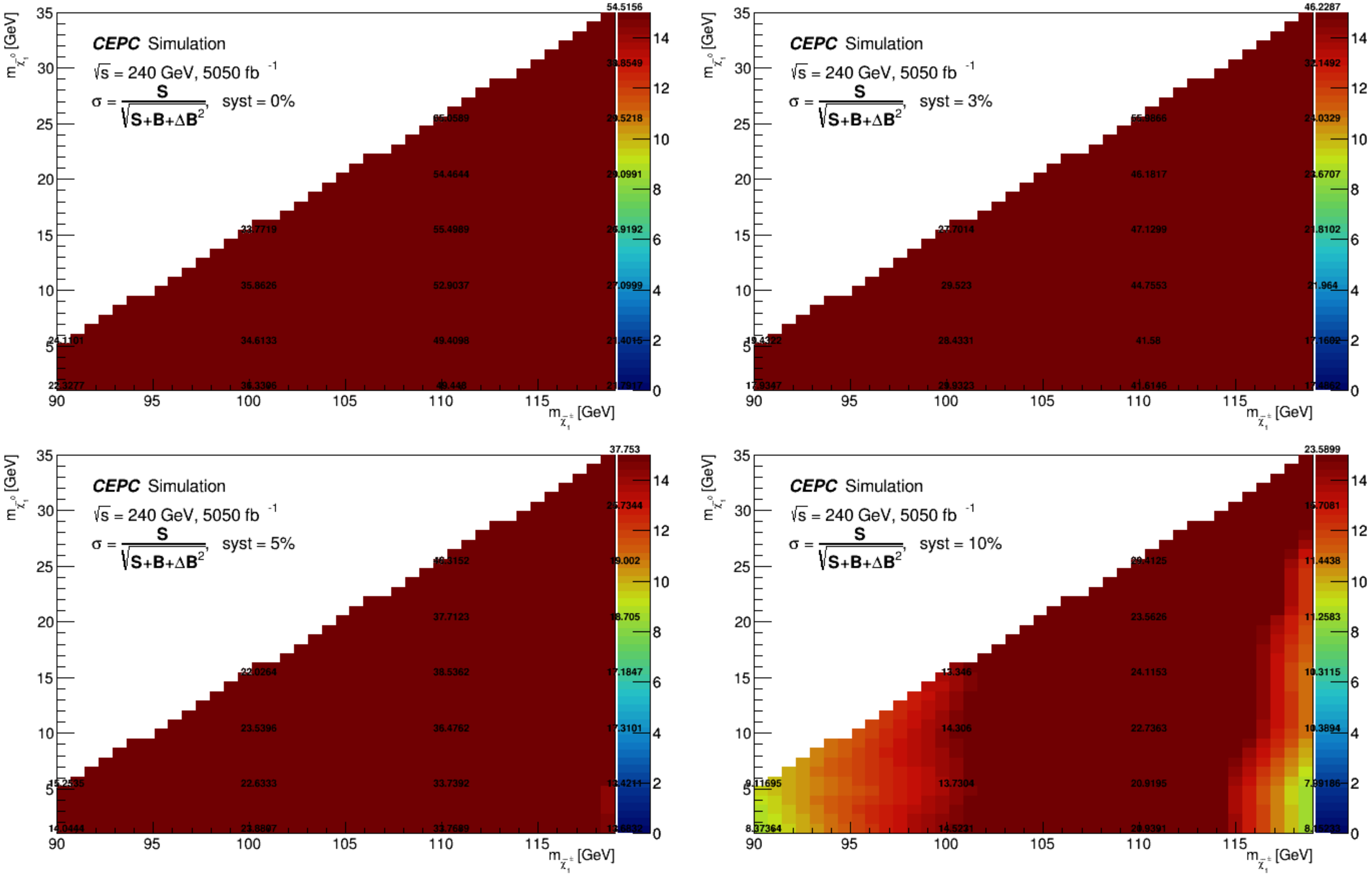
Signal Region
2 μ (OS, both energy > 10GeV)
$0.4 < \Delta R(\mu,\mu) < 1.6$
$M_{recoil} > 130$ GeV
$p_T^{\mu} > 30$ GeV/c

Process	Yield
$\tau\tau$	88.47±14.17
$\nu\nu H, H \rightarrow \tau\tau$	0
$ZZorWW \rightarrow \tau\tau\nu\nu$	0.74±0.74
$ZZ \rightarrow \tau\tau\nu\nu$	0
$\nu Z, Z \rightarrow \tau\tau$	0
$ZZorWW \rightarrow \mu\mu\nu\nu$	1637.9±41.75
$ZZ \rightarrow \mu\mu\nu\nu$	27.68±6.19
$WW \rightarrow \ell\ell$	162.66±12.90
$\nu Z, Z \rightarrow \mu\mu$	47.86±7.30
$\mu\mu$	608.7±60.87
total background	2568.01±76.86
Ref. point (110,1)	5937.33±130.879
Ref. point (110,10)	6468.17±136.60
Ref. point (110,25)	8470.36±156.32

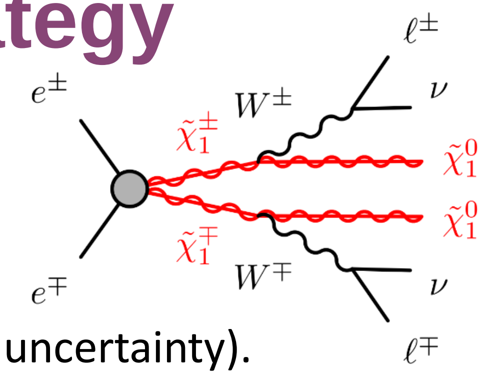


Chargino pair (Bino LSP): Sensitivity map

- Assuming 10% systematic uncertainty, the discovery sensitivity can still reach up to all the mass phase space.



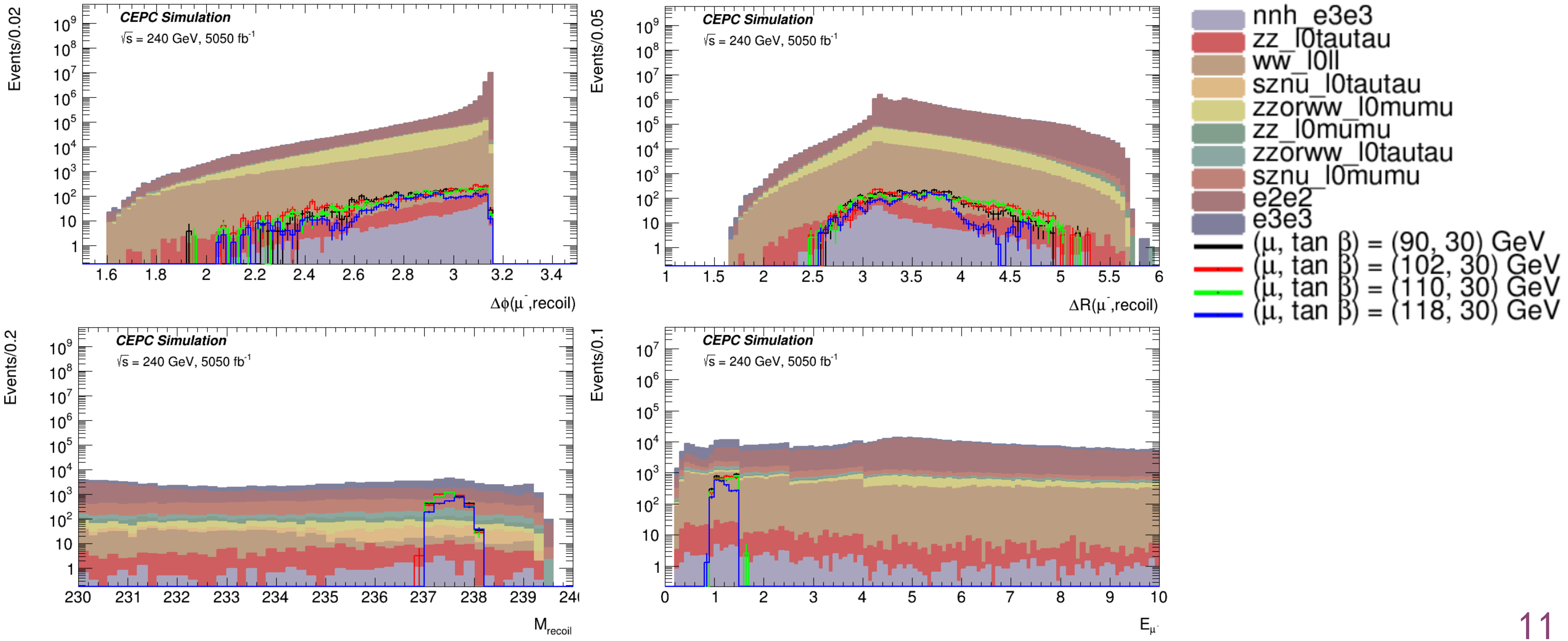
Chargino pair (Higgsino LSP): Optimization Strategy



- Select events with 2 OS muons.
- Perform a multi-dimension optimization considering variables:

$$\Delta R(\mu,\mu), \Delta R(\mu, recoil), \Delta\varphi(\mu,\mu), \Delta\varphi(\mu, recoil), M_{\mu\mu}, M_{recoil}, E_{\mu\mu}, P_T^{\mu\mu}, E_{\mu}, P_T^{\mu}$$

- Check for both upper cut and down cut for each variable.
- Use $Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2p)$ as a sensitivity measurement (consider statistical uncertainty and 5% systematic uncertainty).

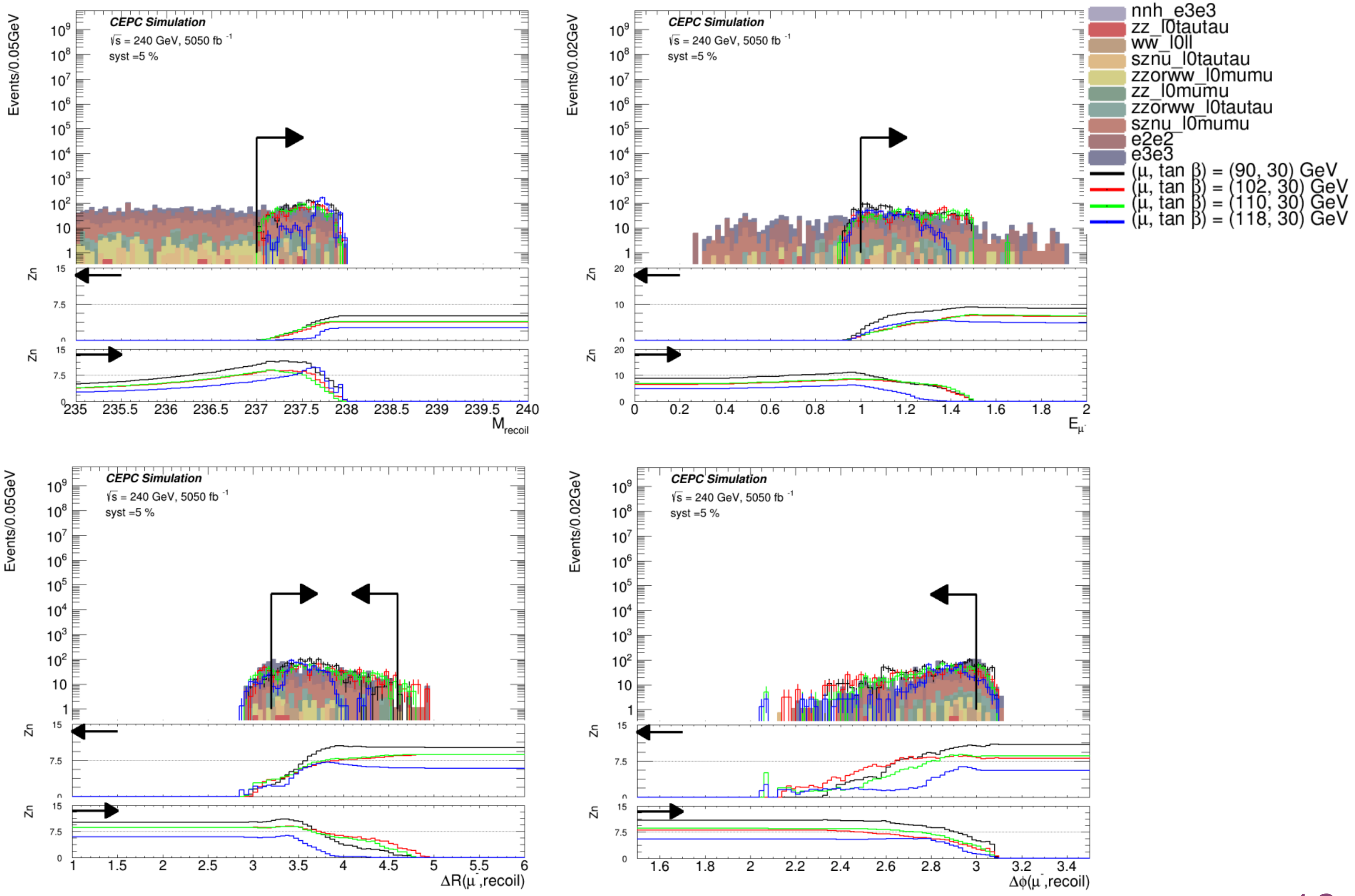


Chargino pair (Higgsino LSP): SR & Results

- One signal region is defined.

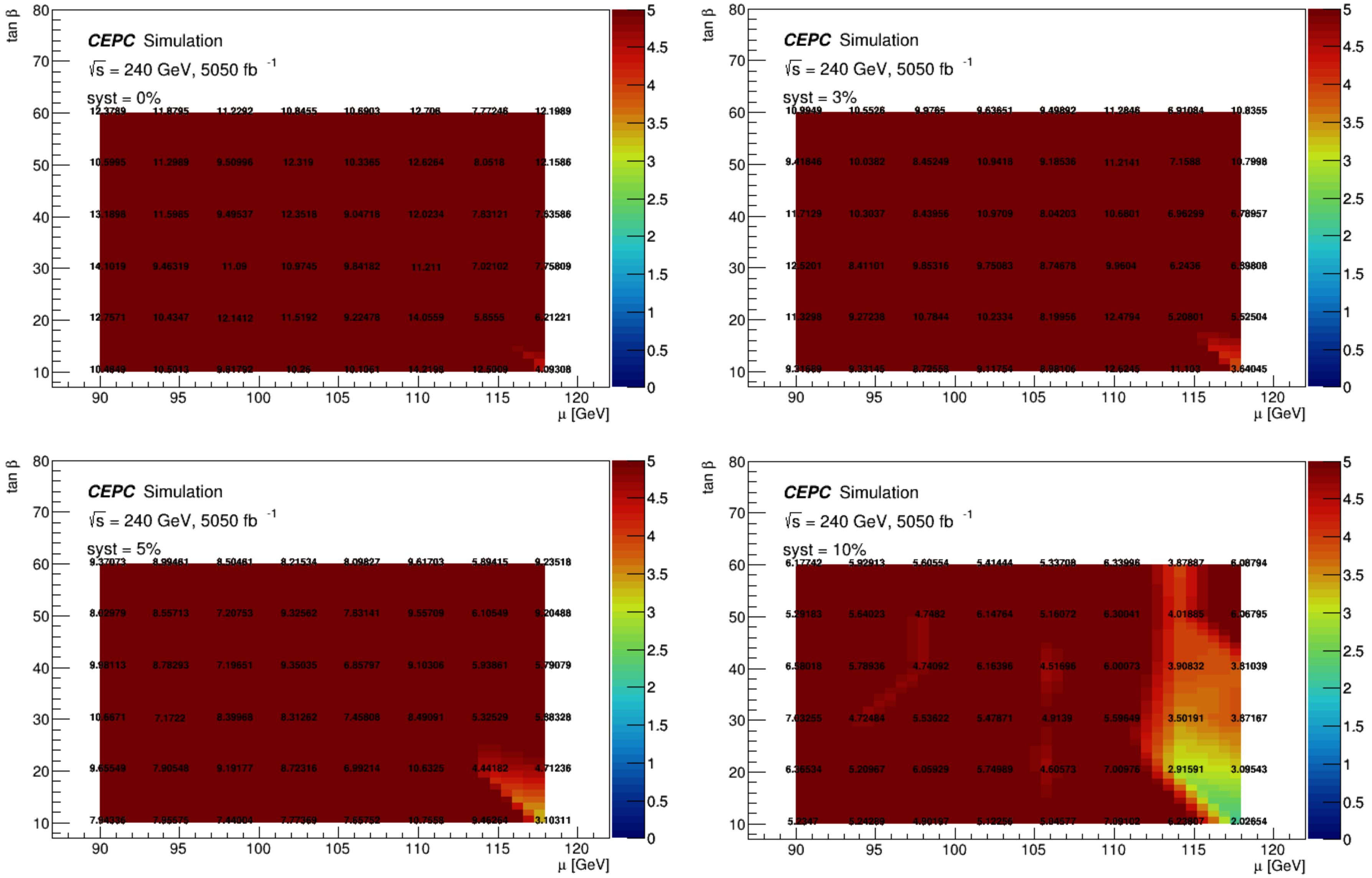
Signal Region
2 OS μ
$M_{recoil} > 237GeV$
E_{μ}>1.0GeV
$3.2 < \Delta R(\mu, recoil) < 4.6$
$\Delta\phi(\mu, recoil) < 3$

Selection	Yields
$\tau\tau$	610.20±37.20
$\nu\nu H, H \to \tau\tau$	0.47±0.27
$ZZorWW \to \tau\tau\nu\nu$	20.65±4.62
$ZZ \to \tau\tau\nu\nu$	1.58±0.91
$\nu Z, Z \to \tau\tau$	4.44±1.81
$ZZorWW \to \mu\mu\nu\nu$	10.68±3.38
$ZZ \to \mu\mu\nu\nu$	22.14±5.54
$WW \to \ell\ell$	5.12±2.29
$\nu Z, Z \to \mu\mu$	171.40±13.81
$\mu\mu$	237.39±38.01
total background	1084.07±55.61
Ref. point (90,30)	1148.18±65.53
Ref. point (102,30)	852.24±52.06
Ref. point (110,30)	873.76±47.11
Ref. point (118,30)	573.30±27.30



Chargino pair (Higgsino LSP): Sensitivity map

- Assuming 10% systematic uncertainty, the discovery sensitivity can reach up to 110 GeV except several points.



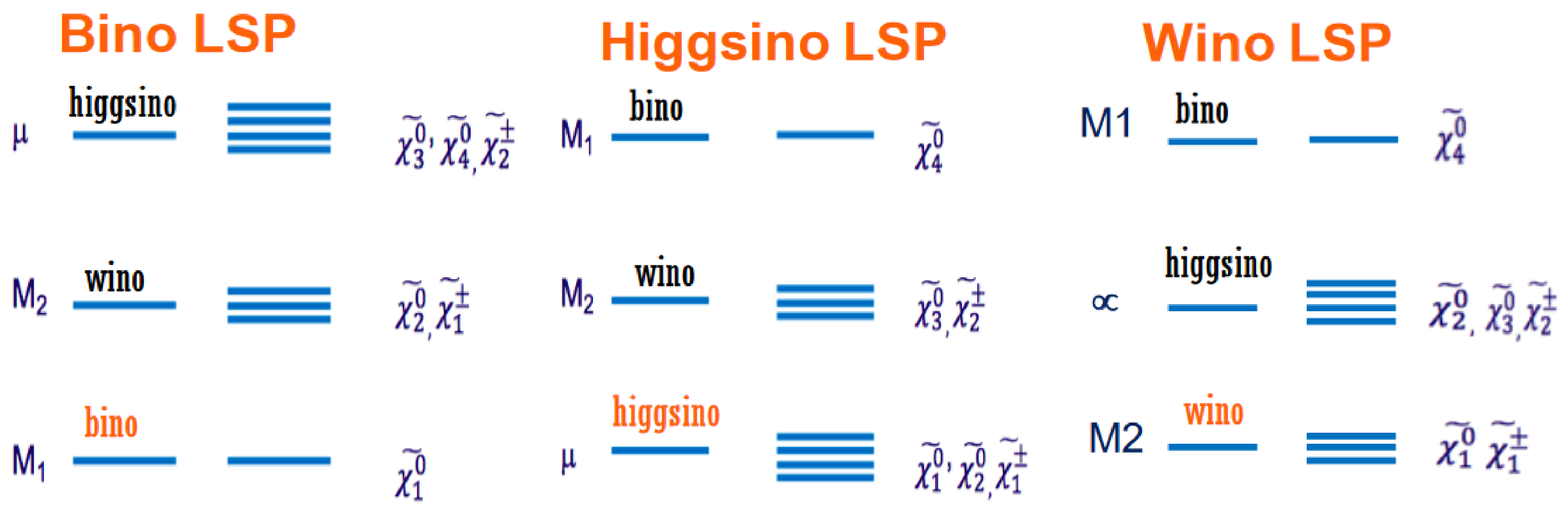
Summary

- A preliminary SUSY sensitivity study has been performed to direct smuon production and chargino pair production (Bino LSP and Higgsino LSP) in CEPC, which is promising. With assuming 10% systematic uncertainty:
  - For direct smuon production, the discovery sensitivity reaches up to 115 GeV.
  - For chargino pair production (Bino LSP), the discovery sensitivity can still reach up all the mass phase space.
  - For chargino pair production (Higgsino LSP), the discovery sensitivity can reach up to 110 GeV.
- Stau search prospects measurement is still on-going.
- Internal note draft is almost done.

Thank you.

Backup

Electrpwikinos mass split



Standard wino-bino case: large Δm between N1 and C1/N2;

➔ MET + hard leptons

N1,N2,C1 almost degenerate: experimental challenging;

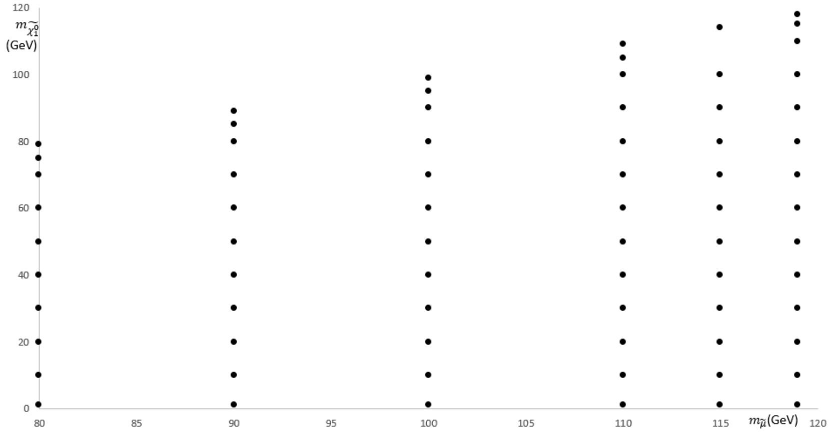
➔ MET + soft leptons

➔ **Lower xsec than higgsino LSP;**

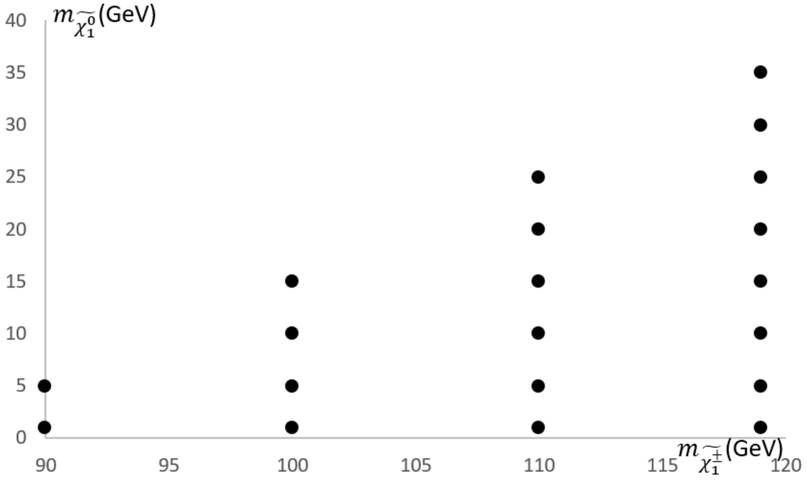
➔ WW+MET dominant;

Samples

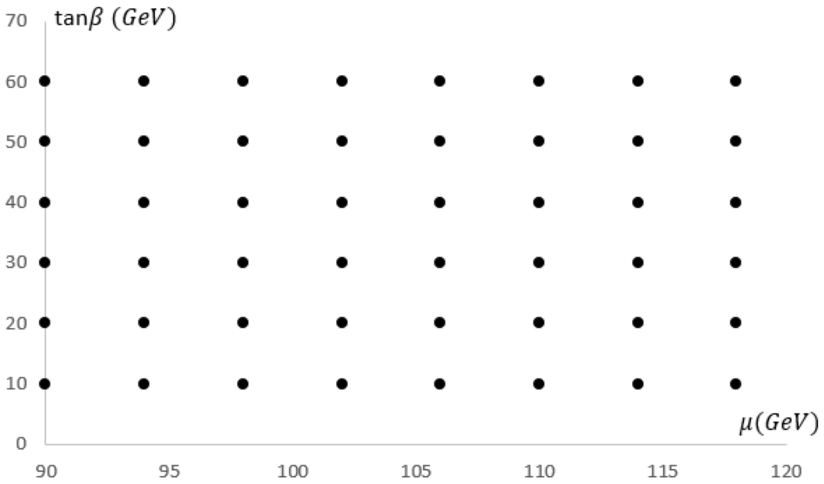
- Direct smuon



- Chargino pair(Bino LSP)



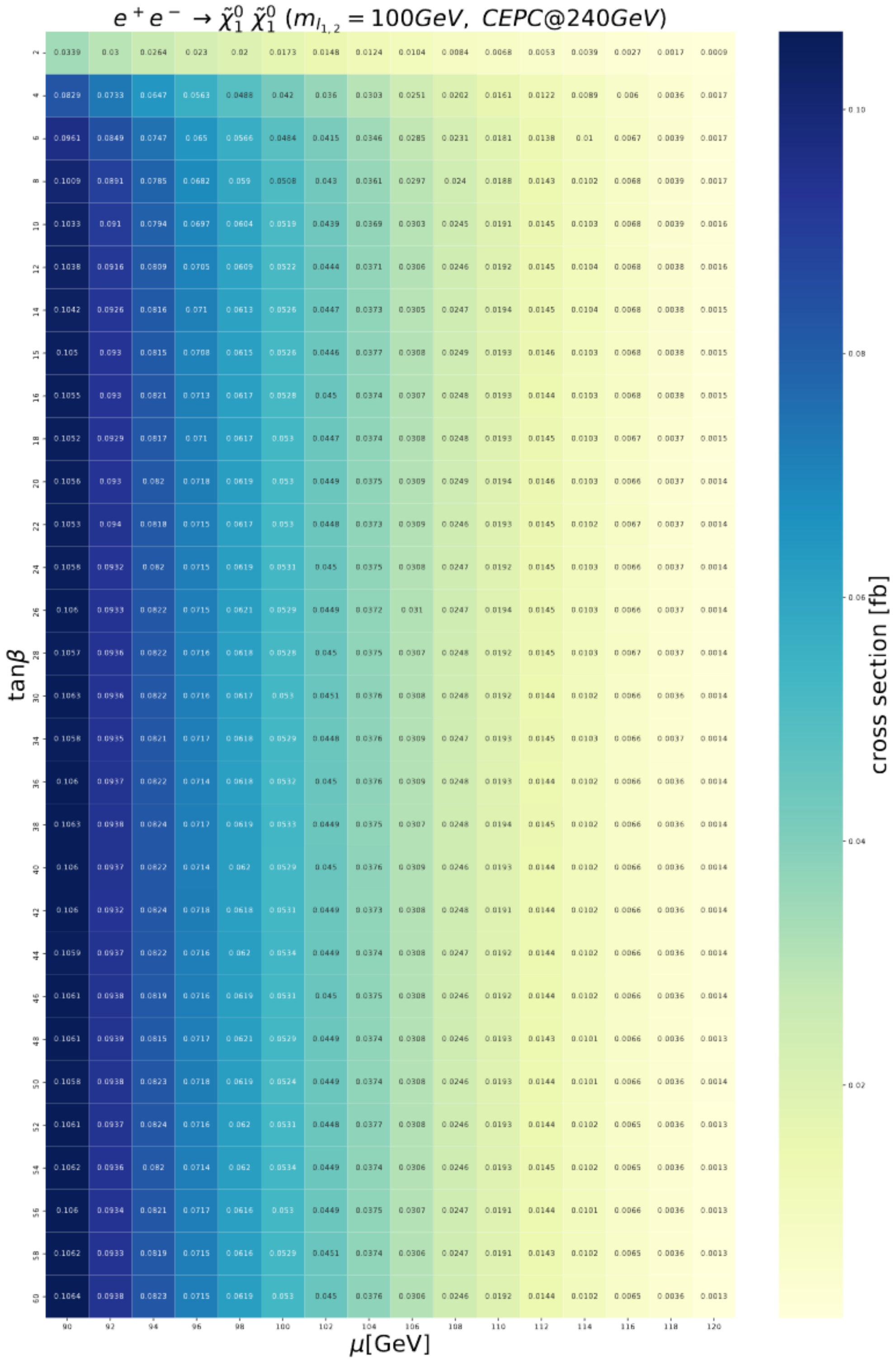
- Chargino pair(Higgsino LSP)

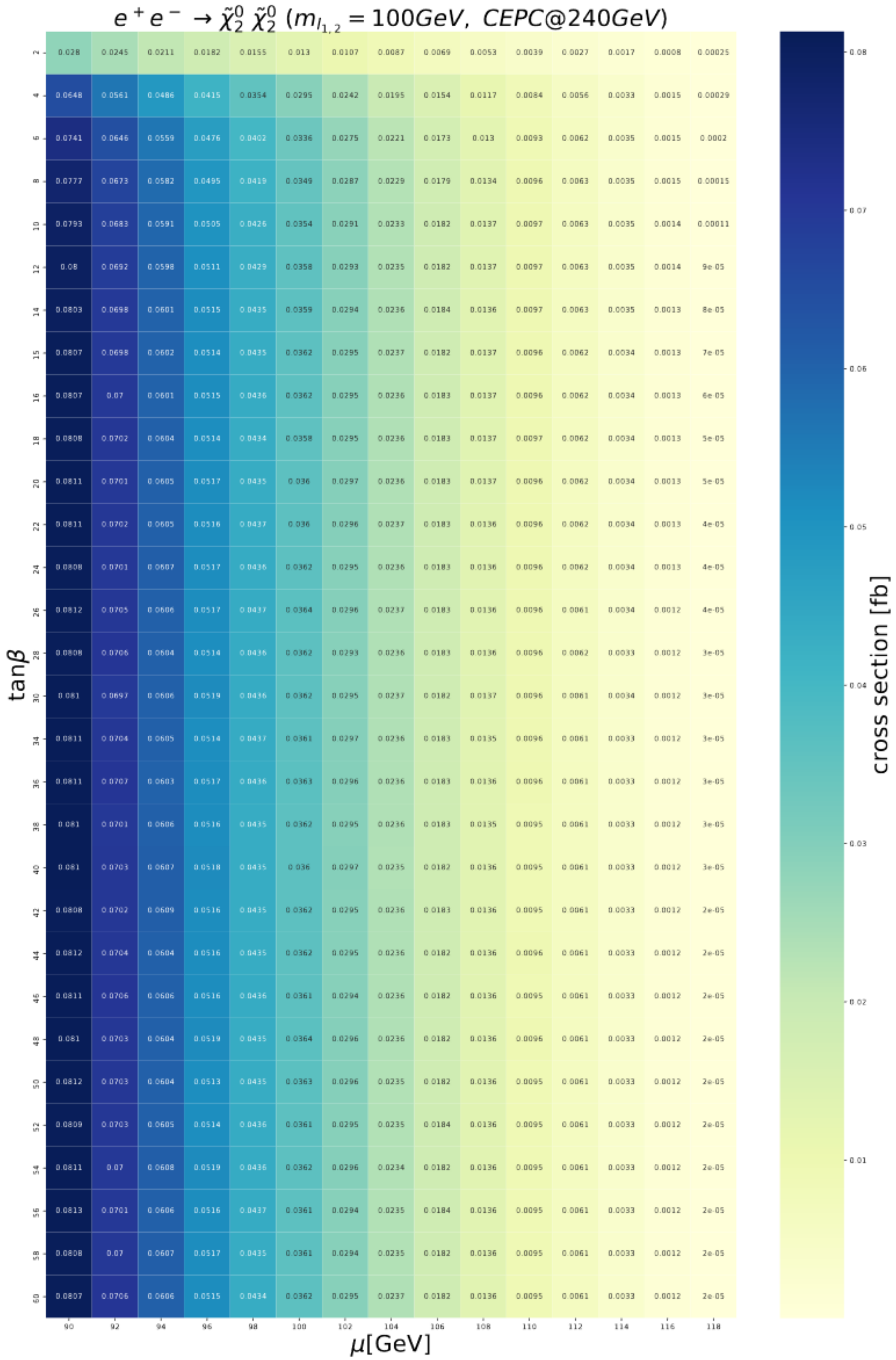


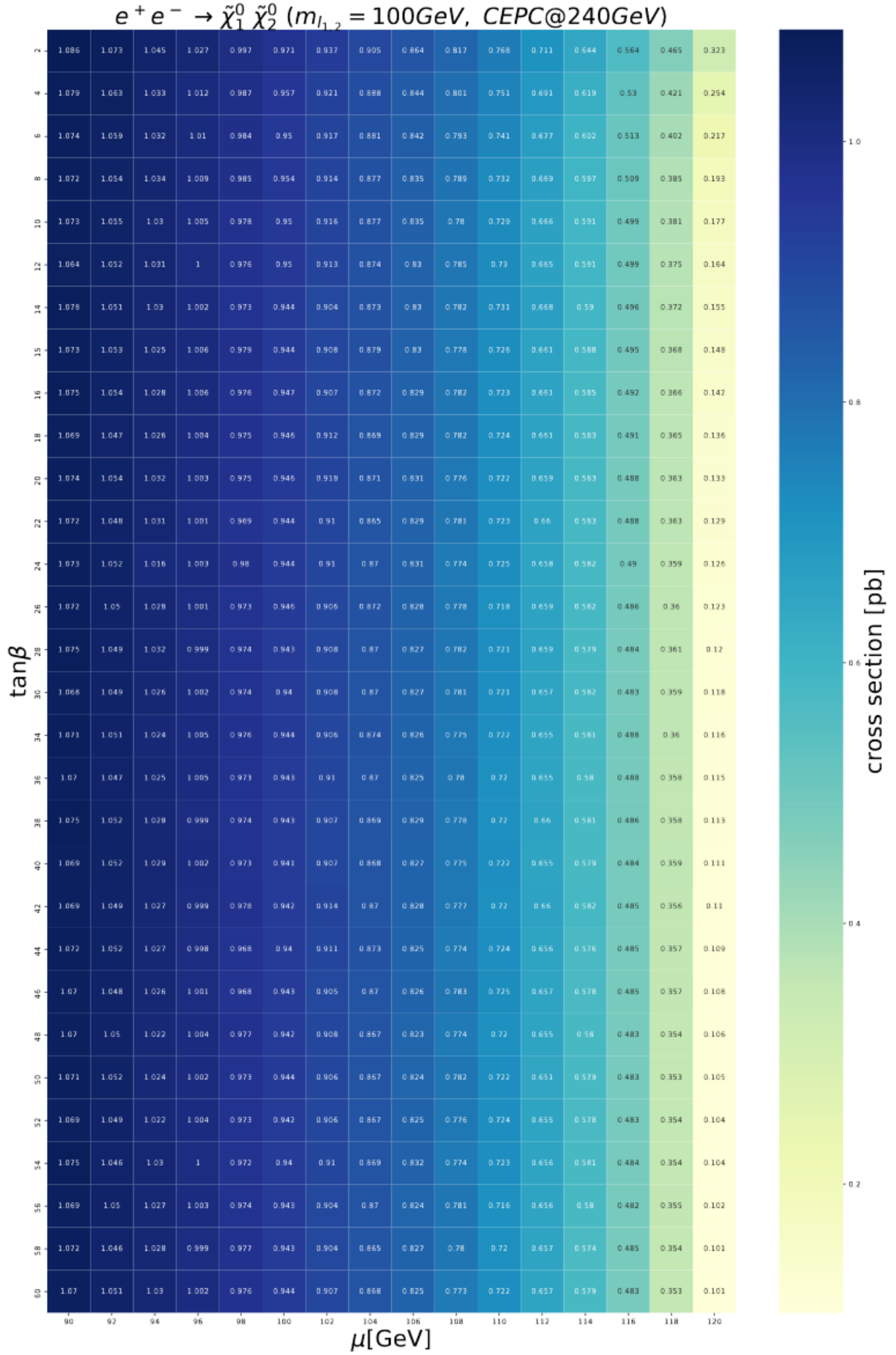
Zn

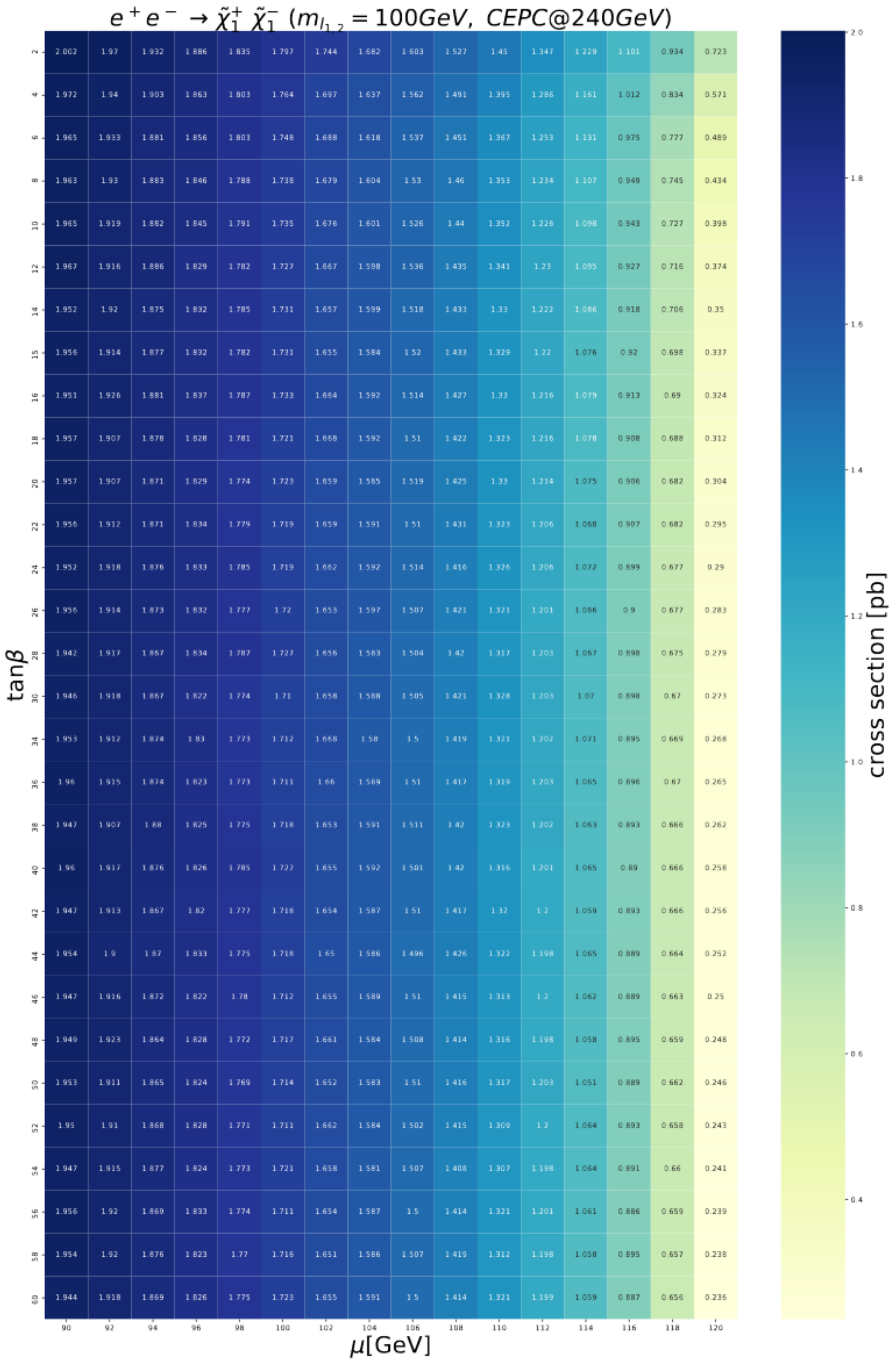
Signal significance Z_n

$$Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2p), \text{ where } p \propto \int_0^\infty db G(b; N_b, \delta b) \sum_{i=N_s+b}^{\infty} \frac{e^{-b} b^i}{i!}$$


$e^+e^- \to \tilde{\chi}_1^0\,\tilde{\chi}_1^0\ (m_{l_{1,2}} = 100GeV,\ CEPC@240GeV)$
$\tan\beta$
μ[GeV]
cross section [fb]


$e^+e^- \to \tilde{\chi}_2^0\,\tilde{\chi}_2^0\ (m_{l_{1,2}} = 100GeV,\ CEPC@240GeV)$
$\tan\beta$
μ[GeV]
cross section [fb]


$e^+e^- \to \tilde{\chi}_1^0\,\tilde{\chi}_2^0\ (m_{l_{1,2}} = 100GeV,\ CEPC@240GeV)$
tanβ
μ[GeV]
cross section [pb]


$e^+e^- \to \tilde{\chi}_1^+\,\tilde{\chi}_1^-\ (m_{l_{1,2}} = 100GeV,\ CEPC@240GeV)$
tanβ
μ[GeV]
cross section [pb]