SUSY Search at the CEPC

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Supersymmetry Introduction

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 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)



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 fb^{-1}

• Dominant backgrounds: SM processes with two- μ or two- τ final states

process	Cross Section [fb]
$\mu\mu$	4967.58
ττ	4374.94
$WW \to \ell \ell$	392.96
$ZZorWW \rightarrow \mu\mu\nu\nu$	214.81
$ZZorWW \rightarrow \tau \tau \nu \nu$	205.84
$\nu Z, Z ightarrow \mu \mu$	43.33
$ZZ ightarrow \mu\mu u u$	18.17
$\nu Z, Z o \tau \tau$	14.57
$ZZ \to \tau \tau \nu \nu$	9.2
$\nu\nu H, H \rightarrow \tau\tau$	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).



 μ^{\pm}

 μ^{\mp}

 e^{\pm}

 $\tilde{\mu}$

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Direct smuon: SR & Results

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

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

process	SR-high∆m	SR-mid∆m	SR-low∆m		
ττ	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		
$ZZorWW \rightarrow \tau \tau \nu \nu$	0+-0	4.12+-2.06	35.02+-6.01		
$ZZ \rightarrow \tau \tau \nu \nu$	0+-0	0+-0	0+-0		
$\nu Z, Z \to \tau \tau$	0+-0	0+-0	1.48+-1.05		
$ZZorWW \rightarrow \mu\mu\nu\nu$	889.64+-30.82	2585.63+-52.55	398.36+-20.63		
$ZZ \rightarrow \mu\mu\nu\nu$	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		
νZ , $Z \to \mu \mu$	100.17+-10.56	70.12+-8.83	4.45+-2.23		
μμ	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+-216.4		



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).



θ±

 $\tilde{\chi}_1^0$

 W^{\pm}

 W^{\exists}

 $\tilde{\chi}_1^{\pm}$

 $\tilde{\chi}_1^{\dagger}$

 e^{\mp}

Chargino pair (Bino LSP): SR & Results

• One signal region is defined.



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:

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

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



Chargino pair (Higgsino LSP): SR & Results

• One signal region is defined.



Chargino pair (Higgsino LSP): Sensitivity map

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



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- 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 △m
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;



• Direct smuon

• Chargino pair(Bino LSP)

• Chargino pair(Higgsino LSP)



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

		е	+ e -	- →	$\tilde{\chi}_1^0 \hat{\chi}_1^0$	$\tilde{\chi}_{1}^{0}$ (n	n _{I1,2}	= 10	00G	eV,	CEF	PC@	240)Gel	/)	
N -	0.0339	0.03	0.0264	0.023	0.02	0.0173	0.0148	0.0124	0.0104	0.0084	0.0068	0.0053	0.0039	0.0027	0.0017	0.0009
4.					0.0488	0.042	0.036	0.0303	0.0251	0.0202	0.0161	0.0122	0.0089	0.006	0.0036	0.0017
9 -						0.0484	0.0415	0.0346	0.0285	0.0231	0.0181	0.0138	0.01	0.0067	0.0039	0.0017
æ .						0.0508	0.043	0.0361	0.0297	0.024	0.0188	0.0143	0.0102	0.0068	0.0039	0.0017
10							0.0439	0.0369	0.0303	0.0245	0.0191	0.0145	0.0103	0.0068	0.0039	0.0016
12							0.0444	0.0371	0.0306	0.0246	0.0192	0.0145	0.0104	0.0068	0.0038	0.0016
14							0.0447	0.0373	0.0305	0.0247	0.0194	0.0145	0.0104	0.0068	8600.0	0.0015
15							0.0446	0.0377	0.0308	0.0249	0.0193	0.0146	0.0103	0.0068	8600.0	0.0015
16							0.045	0.0374	0.0307	0.0248	0.0193	0.0144	0.0103	0.0068	0.0038	0.0015
18							0.0447	0.0374	0.0308	0.0248	0.0193	0.0145	0.0103	0.0067	0.0037	0.0015
20							0.0449	0.0375	0.0309	0.0249	0.0194	0.0146	0.0103	0.0066	0.0037	0.0014
22							0.0448	0.0373	0.0309	0.0246	0.0193	0.0145	0.0102	0.0067	0.0037	0.0014
24							0.045	0.0375	0.0308	0.0247	0.0192	0.0145	0.0103	0.0066	0.0037	0.0014
26							0.0449	0.0372	0 031	0.0247	0.0194	0.0145	0.0103	0.0066	0.0037	0.0014
d 8.							0.045	0.0375	0.0307	0.0248	0.0192	0.0145	0.0103	0.0067	0.0037	0.0014
۳							0.0451	0.0376	0.0308	0.0248	0.0192	0.0144	0.0102	0.0066	0.0036	0.0014
34							0.0448	0.0376	0.0309	0.0247	0.0193	0.0145	0.0103	0.0066	0.0037	0.0014
36							0.045	0.0376	0.0309	0.0248	0.0193	0.0144	0.0102	0.0066	0 0036	0.0014
85 -							0.0449	0.0375	0.0307	0.0248	0.0194	0.0145	8.0102	0.0066	0.0036	0.0014
40							0.045	0.0376	0.0309	0.0246	0.0193	0.0144	8.0102	0.0066	0.0036	0.0014
42							0.0449	0.0373	0.0308	0.0248	0.0191	0.0144	8.0102	0.0066	0.0036	0.0014
44							0.0449	0.0374	0.0308	0.0247	0.8192	0.0144	8.0192	0.0066	0.0036	0.0014
46							0.045	0.0375	0.0308	0.0246	0.0192	0.0144	0.0102	0.0066	0.0036	0.0014
8 -							0.0449	0.0374	0.0308	0.0246	0.0193	0.0143	0.0101	0.0066	0.0036	0.0013
20							0.0449	0.0374	0.0308	0 0246	0.0193	0.0144	0.0101	0.0066	0.0036	0.0014
25							0.0448	0.0377	0.0308	0.0246	0.0193	0.0144	0.0102	0.0065	0.0036	0.0013
54							0.0449	0.0374	0.0306	0.0246	0.0193	0.0145	0.0102	0.0065	0.0036	0.0013
36							0.0449	0.0375	0.0307	0.0247	0.0191	0.0144	0.0101	0.0066	0.0036	0.0013
85 -							0.0451	0.0374	0.0306	0.0247	0.0191	0.0143	0.0102	0.0065	0.0036	0.0013
60	0.1064	0.0938	0.0823	0.0715	0.0619	0.053	0.045	0.0376	0.0306	0.0246	0.0192	0.0144	0.0102	0.0065	0.0036	0.0013
_	90	92	94	96	98	100	102		eV1	108	110	112	114	116	118	12

چ cross section [fb]

0.04

6.02

	$e^+e^- \rightarrow \tilde{\chi}^0_2 \tilde{\chi}^0_2 (m_{l_{1,2}} = 100 GeV, CEPC@240 GeV)$														
n -	0.028	0.0245	6.0211	0.0182	0.0155	0.013	0.0107	0.0087	0.0069	0.0053	0.0039	0.0027	0.0017	0.000B	0.00025
4.	0.0648				0.0354	0.0295	0.0242	0.0195	0.0154	0.0117	0.0084	0.0056	0.0033	0.0015	0.00029
9.	0.0741					0.0336	0.0275	0.0221	0.0173	0.013	0.0093	0.0062	0.0035	0.0015	0.0002
æ .	0.0777					0.0349	0.0287	0.0229	0.0179	0.0134	0.0096	0.0063	0.0035	0.0015	0.00015
11	0.0793					0.0354	0.0291	0.0233	0.0182	0.0137	0.0097	0.0063	0.0035	0.0014	0.00011
12	0.08					0.0358	0.0293	0.0235	0.0182	0.0137	0.0097	0.0063	0.0035	0.0014	9e 05
14	0.0803					0.0359	0.0294	0.0236	0.0184	0.0136	0.0097	0.0063	0.0035	0.0013	8e-05
51	0.0807					0.0362	0.0295	0.0237	0.0182	0.0137	0.0096	0.0062	0.0034	0.0013	7e-05
16	0.0807					0.0362	0.0295	0.0236	0.0183	0.0137	0.0096	0.0062	0.0034	0.0013	6e 05
BI -	0.0808					0.0358	0.0295	0.0236	0.0183	0.0137	0.0097	0.0062	0.0034	0.0013	5e-05
20	0.0811					0.036	0.0297	0.0236	0.0183	0.0137	0.0096	0.0062	0.0034	0.0013	5e-05
57	0.0811					0.036	0.0296	0.0237	0.0183	0.0136	0.0096	0.0062	0.0034	0.0013	4e-05
24	0.0808					0.0362	0.0295	0.0236	0.0183	0.0136	0.0096	0.0062	0.0034	0.0013	4e-05
26	0.0812					0.0364	0.0296	0.0237	0.0183	0.0136	0.0096	0.0061	0.0034	0.0012	4e-05
<i>ت</i> ۽	0.0508					0.0362	0.0293	0.0236	0.0183	0.0136	0.0096	0.0062	0.0033	0.0012	3e-05
rar "	0.081					0.0362	0.0295	0.0237	0.0182	0.0137	0.0096	0.0061	0.0034	0.0012	3e-05
34	0.0811					0.0361	0.0297	0.0236	0 0183	0.0135	0.0096	0.0061	0.0033	0.0012	3e-05
9E	0.0811					0.0363	0.0296	0.0236	0 0183	0.0136	0.0096	0.0061	0.0033	0.0012	3e-05
88	0.081					0.0362	0.0295	0.0236	0 0183	0.0135	0.0095	0.0061	0.0033	0.0012	3e-05
9 -	8.081					0.036	8.0297	0.0235	0 0182	0.0136	0.0095	0 0061	0.0033	0.0012	3e-05
42	0.0808					0 0362	0.0295	0.0236	0 0183	0.0136	0.0095	0 0061	0.0033	0.0012	2e-05
4 -	0.0812					0 0362	0.0295	0.0236	0 0182	0.0136	0.0096	0.0061	0.0033	0.0012	2e-05
- 46	0.0811					0.0361	0.0294	0.0236	0 0182	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05
8-	0.081					0.0364	0.0296	0.0236	0 0182	0.0136	0.0096	0 0061	0.0033	0.0012	2e-05
6	0.0812					0.0363	0.0296	0.0235	0 0182	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05
g -	0.0809					0.0361	0.0295	0.0235	0 0184	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05
54	0.0811					0.0362	0.0296	0.0234	0.0182	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05
56	0.0813					0.0361	0.0294	0.0235	0.0184	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05
85	0.0808					0.0361	0.0294	0.0235	0.0182	0.0136	0.0095	0.0061	0.0033	0.0012	2e-05

0.0362 0.0295 0.0237

100

98

μ[GeV]

0.0182 0.0136 0.0095 0.0061 0.0033

106

108 110 112 20

0.06

0.05

َة cross section [fb]

0.03

- 0.02

- 0.01

0.0012 2e-05

116 114

118

2	[dd]
	section
0	cross

-0.8

- 0.4

	$e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- (m_{l_{1,2}} = 100 GeV)$, CEPC@240GeV)							
~	2.002			1 886											0.934	0.723		
4	1.972													1.012	0.834	0.571		
9	1.965													0.975	0.777	0.489		
	1.963													0.949	0.745	0.434		
10	1.965													0.943	0.727	0.398		
12	1.967													0.927	0.716	0.374		
14	1.952													0.918	0.706	0.35		
15	1.956												1.076	0.92	0.698	0.337		
16	1.951													0.913	0.69	0.324		
BT	1.957													0.908	0.688	0.312		
20	1.957												1.075	0.906	0.682	0.304		
22	1.956												1.068	0.907	0.682	0.295		
24	1.952												1.072	0.899	0.677	0.29		
26	1.956												1.066	0.9	0.677	0.283		
nβ	1.942												1.067	0 898	0.675	0.279		
å s	1.946												1.07	0.898	0.67	0.273		
34	1.953												1.071	0 895	0.669	0.268		
36	1.96												1.065	0 896	0.67	0.265		
38	3.947												1.063	0 893	0.666	0.262		
6	1.96												1.065	0.89	0.666	0.258		
42	1.947												1.059	0 893	0.666	0.256		
4	1.954												1.065	0 889	0.664	0.252		
5	1.947												1.062	0 889	0.663	0.25		
8	1.949												1.058	0 895	0.659	0.248		
20	1.953												1.051	0 889	0.662	0.246		
25	1.95												1.064	0.893	0.658	0.243		
54	1.947												1.054	0 891	0.66	0.241		
36	1.956												1.061	0.886	0.659	0.239		
8	1.954												1.058	0.895	0.657	0.238		
60	1.944	1.918	1.869	1.826	1.775	1.723	1.655	1.591	1.5	1.414	1.321	1.199	1.059	0.887	0.656	0.236		
	90	92	94	96	98	100	102	μ^{104}	eV]	108	110	112	114	116	118	120		

		$e^+e^- \rightarrow \tilde{\chi}^0_1 \tilde{\chi}^0_2 (m_{l_{1,2}} = 100 GeV,$								eV,	, CEPC@240GeV)							
,	1.08														0.564	0.465	0.323	
	r - 1.07														0.53	0.421	0.254	
	p = 1.07														0 513	0.402	0.217	
1	n - 1.07														0.509	0.385	0.193	
-	2 - 1.07														0.499	0.381	0.177	
;	:- 1.0e														0.499	0.375	0.164	
;	; - 1.07														0.496	0.372	0.155	
;	1.07														0.495	0.368	0.148	
;	- 1.07														0.492	0.366	0.142	
5	- 1.0e		47												0.491	0.365	0.136	
5	2 - 1.07														0.488	0.363	0.133	
5	8 - 1.07		48												0.488	0.363	0.129	
;	z - 1.07														0.49	0.359	0.126	
;	ą - 1.07														0.486	0.36	0.123	
η Ω	Q - 1.07		49												0.484	0.361	0.12	
, בפ	g - 1.06		49												0.483	0.359	0.118	
;	g - 3.07														0.488	0.36	0.116	
2	q - 1.0		47												0.488	0.358	0.115	
;	g - 3.07														0.486	0.358	0.113	
:	⊋ - 1.06														0.484	0.359	0.111	
:	¥ - 1.06		49												0.485	0.356	0.11	
:	; - 1.07														0.485	0.357	0.109	
:	ç - 1.0		48												0 485	0.357	0.108	
5	ç - 1.0														0.483	0.354	0.106	
1	g - 1.07														0.483	0.353	0.105	
;	- 1.06		49												0.483	0.354	0.104	
;	r - 1.07		46												0.484	0.354	0.104	
;	g - 1.06														0.482	0.355	0.102	
1	g - 1.07		46												0.485	0.354	0.101	
-	g = 1.0	7 1.0	51	1.03	1.002	0.976	0.944	0.907	0.868	0 825	0.773	0.722	0.657	0.579	0.483	0.353	0.101	
	90	93	2	94	96	98	100	102	µ́[G	eV]	108	110	112	114	116	118	120	

cross section [pb]

-04

- 0.2

č

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