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.
- Signal scenarios
 - Direct production of stau pairs (DM relic density consistent with cosmology observation)
 - 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)
- Search results in final states with two opposite sign (OS) charged muons(in last 3 scenarios).



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 fb^{-1}
- Dominant backgrounds:



- > SM processes with two-e or two- μ or two- τ and large missing energy final states.(DirectStau)
- > SM processes with two- μ or two- τ and large missing energy final states.(Other 3 scenarios)

| process | Cross Section [fb] |
|---|--------------------|
| μμ | 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 |
| $\nu Z, Z 	o \mu \mu$ | 43.33 |
| $ZZ ightarrow \mu\mu u u$ | 18.17 |
| $\nu Z, Z \to \tau \tau$ | 14.57 |
| $ZZ \rightarrow \tau \tau \nu \nu$ | 9.2 |
| $\nu\nu H, H \rightarrow \tau \tau$ | 3.07 |
| $e\nu W, W \to \mu\nu$ | 429.2 |
| $e\nu W, W \to \tau \nu$ | 429.42 |
| $eeZ, Z \rightarrow \nu\nu$ | 29.62 |
| $eeZ, Z \rightarrow vv \text{ or } evW, W \rightarrow ev$ | 249.34 |



Direct stau: Optimization Strategy

- Use the leading track with minus(positive) charge to represent the $\tau^{-}(\tau^{+})$ for simplicity.
- Select events with 2 OS τ with energy > 0.5GeV.
- Perform a multi-dimension optimization, considering variables:

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\Delta R(\tau,\tau), \Delta R(\tau,recoil), \Delta \varphi(\tau,\tau), \Delta \varphi(\tau,recoil), M_{\tau\tau}, M_{recoil}, E_{\tau}
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- 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).



 e^{\pm}

 e^{\mp}

Direct stau: SR & Results

Events/0.05

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

| SR-lowD | eltaM | SR2-highDeltaM | | | | | | |
|---|---------------------------|-------------------------------|---------------------------|--|--|--|--|--|
| | $ \Delta \phi(\tau, reco$ | oil) > 2 | .5 | | | | | |
| | $\Delta R(\tau, rec$ | coil) < 3 | | | | | | |
| $ \Delta R(\tau,\tau) $ | > 1.2 | $ \Delta R(\tau,\tau) > 0.6$ | | | | | | |
| | $E_{\tau} < 1$ | 5GeV | | | | | | |
| $m_{\tau\tau} < 3$ | 0GeV | m_r | _{ecoil} < 180GeV | | | | | |
| | | $m_{\tau\tau} < 35 GeV$ | | | | | | |
| Process | SR-lowDelt | aM | SR2-highDeltaM | | | | | |
| ττ | 199.76 <u>+</u> 21.2 | 2945 | 6.81 <u>+</u> 3.93176 | | | | | |
| $\nu\nu H, H \rightarrow \tau\tau$ | 0.155 <u>+</u> 0.1 | 55 | 0.155 <u>+</u> 0.155 | | | | | |
| $ZZorWW \rightarrow \tau \tau \nu \nu$ | 611.82 <u>+</u> 25.1 | .033 | 41.2 <u>+</u> 6.51429 | | | | | |
| $ZZ \rightarrow \tau \tau \nu \nu$ | 18.76 <u>+</u> 3.17 | 102 | 7.504 <u>+</u> 2.00553 | | | | | |
| $\nu Z, Z \to \tau \tau$ | 50.388 <u>+</u> 6.11 | 1044 | 4.446 <u>+</u> 1.81507 | | | | | |
| $ZZorWW \rightarrow \mu\mu\nu\nu$ | 8.544 <u>+</u> 3.02 | 076 | 1.068±1.068 | | | | | |
| $ZZ ightarrow \mu\mu u u$ | 6.92 <u>+</u> 3.094 | 72 | 0 | | | | | |
| $WW \rightarrow \ell\ell$ | 85.932 <u>+</u> 9.37 | 7595 | 12.276 <u>+</u> 3.54378 | | | | | |
| $\nu Z, Z \to \mu \mu$ | 106.848 <u>+</u> 10. | 9051 | 1.113 <u>+</u> 1.113 | | | | | |
| μμ | 121.74 <u>+</u> 27.2 | 2219 | 0 | | | | | |
| $e\nu W,W ightarrow \mu u$ | 0 | | 0 | | | | | |
| evW,W ightarrow 	au v | 91.637 <u>+</u> 9.60 |)617 | 45.315 <u>+</u> 6.75516 | | | | | |
| $eeZ, Z \rightarrow \nu\nu$ | 3.072 <u>+</u> 1.77 | 362 | 0 | | | | | |
| $eeZ, Z \rightarrow vv \text{ or } evW, W \rightarrow ev$ | 19.855 <u>+</u> 4.55 | 5505 | 5.225 <u>+</u> 2.33669 | | | | | |
| Total background | 1325.43 <u>+</u> 47. | 0509 | 125.112 <u>+</u> 11.4571 | | | | | |
| (100,10) | 1209.58±10 | 2.228 | 751.668 <u>+</u> 80.5873 | | | | | |
| (100,50) | 2531.48 <u>+</u> 147 | 7.891 | 639.35±74.3229 | | | | | |
| (100,90) | 7283.4 <u>+</u> 250 | .854 | 0 | | | | | |



$|\Delta \phi(\tau, recoil)| > 2.5: \tau\tau; ZZorWW \rightarrow \tau\tau\nu\nu; \mu\mu \quad \Delta R(\tau, recoil) < 3: \tau\tau; ZZorWW \rightarrow \tau\tau\nu\nu; \mu\mu$



 $|\Delta R(\tau,\tau)| > 1.2: \tau\tau; ZZorWW \rightarrow \tau\tau\nu\nu; \nu Z, Z \rightarrow \mu\mu \quad E_{\tau} < 15GeV: WW \rightarrow ll; \mu\mu; e\nu W, W \rightarrow \tau\nu$

Direct stau: SR & Results

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

7283.4+250.854

0

SR-lowDeltaM

 $m_{\tau\tau} < 30 GeV$

Process

ττ

 $\nu\nu H, H \rightarrow \tau\tau$

 $ZZorWW \rightarrow \tau \tau \nu \nu$

 $ZZ \rightarrow \tau \tau \nu \nu$

 $\nu Z, Z \rightarrow \tau \tau$

 $ZZorWW \rightarrow \mu\mu\nu\nu$

 $ZZ \rightarrow \mu\mu\nu\nu$

 $WW \rightarrow \ell \ell$

 $\nu Z, Z \rightarrow \mu \mu$

μμ

 $e\nu W, W \rightarrow \mu\nu$

 $evW.W \rightarrow \tau v$

 $eeZ.Z \rightarrow \nu\nu$

 $eeZ, Z \rightarrow vv \text{ or } evW, W \rightarrow ev$

Total background

(100, 10)

(100, 50)

(100, 90)



SR-highDeltaM

Direct stau: Sensitivity map

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



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 | | | | | |
|-------------------------------|-------------------------------|-------------------------------|--|--|--|--|--|
| 2 μ | ieV) | | | | | | |
| $\Delta R(\mu, recoil) < 2.9$ | $\Delta R(\mu, recoil) < 2.6$ | $\Delta R(\mu, recoil) < 2.7$ | | | | | |
| E_{μ} >40 GeV | $E_{\mu} < 50 GeV$ | | | | | | |
| $M_{\mu\mu} < 68 GeV$ | $p_T > 50 GeV/c$ | $M_{\mu\mu} < 85 GeV$ | | | | | |
| $M_{recoil} > 60 GeV$ | | $M_{recoil} > 135 GeV$ | | | | | |

| process | SR-high∆m | SR-mid∆m | SR-low∆m | | |
|--|--------------------------|---------------------------|--------------------------|--|--|
| ττ | 72.64 <u>+</u> 12.84 | 68.1 <u>+</u> 12. 43 | 5361.74 <u>+</u> 110.32 | | |
| $\nu\nu H, H \to \tau\tau$ | 0 | 0 | 60.76 <u>+</u> 3.07 | | |
| $ZZorWW \rightarrow \tau \tau \nu \nu$ | 3.09 <u>+</u> 1.78 | 1.03 <u>+</u> 1.03 | 2242.31 <u>+</u> 48.0581 | | |
| $ZZ \to \tau \tau \nu \nu$ | 1.07 <u>+</u> 0.76 | 0 | 68.608 <u>+</u> 6.06 | | |
| $\nu Z, Z \to \tau \tau$ | 0 | 0 | 115.60 <u>+</u> 9.26 | | |
| $ZZorWW \rightarrow \mu\mu\nu\nu$ | 1561. 42 <u>+</u> 40. 84 | 624.78 <u>+</u> 25.83 | 19535.9 <u>+</u> 114.45 | | |
| $ZZ \rightarrow \mu\mu\nu\nu$ | 69.2 <u>+</u> 9.79 | 15.22 <u>+</u> 4.59 | 218.67 <u>+</u> 17.40 | | |
| $WW \to \ell\ell$ | 163.68 <u>+</u> 12.94 | 154.47 <u>+</u> 12.57 | 7589.64 <u>+</u> 88.11 | | |
| $\nu Z, Z \rightarrow \mu \mu$ | 96.83±10.38 | 12.24 <u>+</u> 3.69 | 736.81 <u>+</u> 28.64 | | |
| $\mu\mu$ | 1095.66 <u>+</u> 81.67 | 298.26 <u>+</u> 42.61 | 11060.10 <u>+</u> 259.47 | | |
| total background | 3063.59 <u>+</u> 94.22 | 1174.11 <u>+</u> 53.21 | 46990.10 <u>+</u> 334.20 | | |
| Ref. point (100,10) | 8817.9± 276.10 | 587.86 <u>+</u> 71.29 | 19771.1 <u>+</u> 413.43 | | |
| Ref. point (100,50) | 8186.81 <u>+</u> 266.04 | 3423. 42 <u>+</u> 172. 42 | 61094.20 <u>+</u> 726.75 | | |
| Ref. point (100,90) | 0 | 0 | 139210 <u>+</u> 1094.03 | | |



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



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:

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

W

- 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. •

Signal Region 2 OS µ $M_{recoil} > 237.5 GeV$ E_{μ} >1GeV

 $3.2 < \Delta R(\mu, recoil) < 4.6$

 $\Delta \phi(\mu, recoil) < 2.9$

| Selection | Yields |
|--|-----------------------|
| ττ | 106.62 <u>+</u> 15.55 |
| $\nu\nu H, H \rightarrow \tau\tau$ | 0 |
| $ZZorWW \rightarrow \tau \tau \nu \nu$ | 2.07 <u>+</u> 1.46 |
| $ZZ \to \tau \tau \nu \nu$ | 0.53±0.53 |
| $\nu Z, Z \to \tau \tau$ | 0 |
| $ZZorWW \rightarrow \mu\mu\nu\nu$ | 3.20 <u>+</u> 1.85 |
| $ZZ \rightarrow \mu\mu\nu\nu$ | 5.54 <u>+</u> 2.77 |
| $WW \to \ell \ell$ | 1.02 <u>+</u> 1.02 |
| $\nu Z, Z ightarrow \mu \mu$ | 27.83 <u>+</u> 5.57 |
| μμ | 42.61 <u>+</u> 16.10 |
| total background | 189.40 <u>+</u> 23.38 |
| Ref. point (90,30) | 400.18 <u>+</u> 38.69 |
| Ref. point (102,30) | 279.84 <u>+</u> 29.83 |
| Ref. point (110,30) | 266.70 <u>+</u> 26.03 |
| Ref. point (118,30) | 296.40±19.63 |



Chargino pair (Higgsino LSP): Sensitivity map

• Assuming 10% systematic uncertainty, the discovery sensitivity can reach up to 118 GeV except a corner at high- μ region.





- A preliminary SUSY sensitivity study has been performed to direct stau production, direct smuon production and chargino pair production (Bino LSP and Higgsino LSP) in CEPC, which is promising. With assuming 10% systematic uncertainty:
 - > For direct stau production, the discovery sensitivity reaches up to 115 GeV.
 - > 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 118 GeV.

Thank you.

Backup

Validation of the angular between tracks vs truth taus

Compare the angular at different truth levels

- Between two truth tau leptons
- Between two leading tracks originating from tau leptons
- > Between two leading tracks with opposite sign \rightarrow least truth info



- Many OS tracks generated from the same parent \rightarrow very close to each other
- Observed in both signal and backgrounds
- In general, promising to use the angular of the OS leading tracks



• Direct smuon

• Chargino pair (Bino LSP)

• Chargino pair (Higgsino LSP)



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

Electrowikinos 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;

| | $e^+e^- \rightarrow \tilde{\chi}^0_1 \tilde{\chi}^0_1 (m_{l_{1,2}} = 100 GeV)$ | | | | | | | | | | | | CEPC@240GeV) | | | | | | |
|------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------------|--------|--------|--------|--|--|--|
| 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 | | | |
| ш. | | | | | | 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 | 0.0038 | 0.0015 | | | |
| 15 | | | | | | | 0.0446 | 0.0377 | 0.0308 | 0.0249 | 0.0193 | 0.0146 | 0.0103 | 0.0068 | 0.0038 | 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 | | | |
| βu | | | | | | | 0.045 | 0.0375 | 0.0387 | 0 0248 | 0.0192 | 0.0145 | 0.0103 | 0.0067 | 0 0037 | 0.0014 | | | |
| å ä | | | | | | | 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 | | | |
| 99 - | | | | | | | 0.045 | 0.0376 | 0.0309 | 0.0248 | 0.0193 | 0.0144 | 0.0102 | 0.0066 | 0 0036 | 0.0014 | | | |
| 90 - 10 | | | | | | | 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 | | | |
| 4 - | | | | | | | 0.0449 | 0.0374 | 0.0308 | 0.0247 | 0.0192 | 0.0144 | 8.0102 | 0.0066 | 0 0036 | 0.0014 | | | |
| -4-6 - | | | | | | | 0.045 | 0.0375 | 0.0308 | 0.0246 | 0.0192 | 0.0144 | 8.0102 | 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 | | | |
| 5 | | | | | | | 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 | μ[G | eV] | 108 | 110 | 112 | 114 | 116 | 118 | 120 | | | |

چ cross section [fb]

0.04

6.02

| | | e | + e - | → χ̂ | $\tilde{\chi}_2^0 \tilde{\chi}_2^0$ | (m _l | 1, 2 = | 100 | GeV | , CL | EPC(| @24 | 0Ge | V) | |
|----------|--------|--------|--------|--------|-------------------------------------|-----------------|---------------|--------|--------|--------|--------|--------|--------|--------|---------|
| ~ | 0.028 | 0.0245 | 0.0211 | 0.0182 | 0.0155 | 0.013 | 0.0107 | 0.0087 | 0.0069 | 0.0053 | 0.0039 | 0.0027 | 0.0017 | 0.0008 | 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 |
| æ. | 0.0741 | | | | | 0.0336 | 0.0275 | 0.0221 | 0.0173 | 0.013 | 0.0093 | 0.0062 | 0.0035 | 0.0015 | 0.0002 |
| | 0.0777 | | | | | 0.0349 | 0.0287 | 0.0229 | 0.0179 | 0.0134 | 0.0096 | 0.0063 | 0.0035 | 0.0015 | 0.00015 |
| 10 | 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 |
| 15 | 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 |
| 18 | 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 |
| 52 | 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 |
| ມ ສ | 0.0808 | | | | | 0.0362 | 0.0293 | 0.0236 | 0.0183 | 0.0136 | 0.0096 | 0 0062 | 0.0033 | 0.0012 | 3e-05 |
| ran ° | 8.081 | | | | | 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 |
| 36 | 0.0811 | | | | | 0.0363 | 0.0296 | 0.0236 | 0 0183 | 0.0136 | 0.0096 | 0 0061 | 0.0033 | 0.0012 | 3e-05 |
| 38 | 8.081 | | | | | 0 0362 | 0.0295 | 0.0236 | 0 0183 | 0.0135 | 0.0095 | 0 0061 | 0.0033 | 0.0012 | 3e-05 |
| 4 | 8.081 | | | | | 0 036 | 0.0297 | 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 | 0.0095 | 0.0061 | 0.0033 | 0.0012 | 2e-05 |
| 20 | 0.0812 | | | | | 0.0363 | 0.0296 | 0.0235 | 0.0182 | 0.0136 | 0.0095 | 0.0061 | 0.0033 | 0.0012 | 2e-05 |
| 25 | 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 |
| 36 | 0.0813 | | | | | 0.0361 | 0.0294 | 0.0235 | 0.0184 | 0.0136 | 0.0095 | 0.0061 | 0.0033 | 0.0012 | 2e-05 |
| 58 | 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

108 110 112 114

25

0.06

0.05

cross section [fb]

0.03

- 0.02

- 0.01

0.0012 2e-05

116

| 2 | [dd] |
|---|---------|
| | section |
| 0 | cross |

0.8

-0.4

| | | | е | + e - | - → | $\tilde{\chi}_1^+ \dot{\chi}_1$ | č_1 (1 | $m_{l_{1,2}}$ | = 1 | 00G | ieV, | CE | PC@ | 924(|)Ge | V) | |
|----|----------------|-------|----|-------|--------|---------------------------------|--------|---------------|-----|-----|------|-----|-----|-------|-------|-------|-------|
| | ~ - | | | | 1.886 | | | | | | | | | | | 0.934 | 0.723 |
| | ۰. | | | | | | | | | | | | | | 1 012 | 0.834 | 0.571 |
| | φ. | | | | | | | | | | | | | | 0.975 | 0.777 | 0.489 |
| | æ . | | | | | | | | | | | | | | 0.949 | 0.745 | 0.434 |
| | я · | | | | | | | | | | | | | | 0.943 | 0.727 | 0.398 |
| | <u>-</u> | | | | | | | | | | | | | | 0.927 | 0.716 | 0.374 |
| | ų - | | | | | | | | | | | | | | 0.918 | 0.706 | 0.35 |
| | 51. | | | | | | | | | | | | | 1.076 | 0.92 | 0.698 | 0.337 |
| | 91 | | | | | | | | | | | | | | 0.913 | 0.69 | 0.324 |
| | 81 | | | | | | | | | | | | | | 0.908 | 0.688 | 0.312 |
| | 27 | | | | | | | | | | | | | 1.075 | 0.906 | 0.682 | 0.304 |
| | <u>7</u> | | | | | | | | | | | | | 1.068 | 0.907 | 0.682 | 0.295 |
| | 24 | | | | | | | | | | | | | 1.072 | 0.899 | 0.677 | 0.29 |
| | 56 | | | | | | | | | | | | | 1.086 | 0.9 | 0.677 | 0.283 |
| nβ | - 28 | | | | | | | | | | | | | 1.067 | 0 898 | 0.675 | 0.279 |
| ta | œ - | | | | | | | | | | | | | 1.07 | 0.898 | 0.67 | 0.273 |
| | 34 | | | | | | | | | | | | | 1.071 | 0.895 | 0.669 | 0.268 |
| | - 3e | | | | | | | | | | | | | 1.065 | 0.896 | 0.67 | 0.265 |
| | 8F - | | | | | | | | | | | | | 1.063 | 0 893 | 0.666 | 0.262 |
| | 6 - | | | | | | | | | | | | | 1.065 | 0.89 | 0.666 | 0.258 |
| | 4. | | | | | | | | | | | | | 1.059 | 0 893 | 0.666 | 0.256 |
| | ŧ. | | | | | | | | | | | | | 1 065 | 0.889 | 0.664 | 0.252 |
| | 46 | | | | | | | | | | | | | 1.062 | 0.889 | 0.663 | 0.25 |
| | 6 - | | | | | | | | | | | | | 1.058 | 0.895 | 0.659 | 0.248 |
| | <u>8</u> - | | | | | | | | | | | | | 1.051 | 0.889 | 0.662 | 0.246 |
| | 25 | | | | | | | | | | | | | 1.064 | 0.893 | 0.658 | 0.243 |
| | 54 | | | | | | | | | | | | | 1.064 | 0.891 | 0.66 | 0.241 |
| | 36 | | | | | | | | | | | | | 1.061 | 0.886 | 0.659 | 0.239 |
| | 2B - | | | | | | | | | | | | | 1.058 | 0.895 | 0.657 | 0.238 |
| | 9 - | 1.944 | | | | | | | | | | | | 1.059 | 0.887 | 0.656 | 0.236 |
| | | 90 | 92 | 94 | 96 | 98 | 100 | 102 | μ[G | eV] | 108 | 110 | 112 | 114 | 116 | 118 | 120 |

| | | е | + e - | _ → | $\tilde{\chi}_{1}^{0} \dot{\chi}_{1}$ | č2 (n | $n_{l_{1,2}}$ | = 10 | 00 <i>G</i> | eV, | CEPC@240GeV) | | | | | | |
|----------------|-------|-------|-------|-------|---------------------------------------|-------|---------------|-------|-------------|-------|--------------|-------|-------|-------|-------|-------|--|
| ~ ~ | 1.086 | | | | | | | | | | | | | 0.564 | 0.465 | 0.323 | |
| 4. | 1.079 | | | | | | | | | | | | | 0.53 | 0.421 | 0.254 | |
| φ. | 1.074 | | | | | | | | | | | | | 0 513 | 0.402 | 0.217 | |
| æ - | 1.072 | | | | | | | | | | | | | 0.509 | 0.385 | 0.193 | |
| 01 | 1.073 | | | | | | | | | | | | | 0.499 | 0.381 | 0.177 | |
| 12 | 1.064 | | | | | | | | | | | | | 0.499 | 0.375 | 0.164 | |
| 14 | 1.078 | | | | | | | | | | | | | 0.496 | 0.372 | 0.155 | |
| 51 | 1.073 | | | | | | | | | | | | | 0.495 | 0.368 | 0.148 | |
| 16 | 1.075 | | | | | | | | | | | | | 0.492 | 0.366 | 0.142 | |
| 81 | 1.069 | | | | | | | | | | | | | 0.491 | 0.365 | 0.136 | |
| 20 | 1.074 | | | | | | | | | | | | | 0.488 | 0.363 | 0.133 | |
| 22 | 1.072 | | | | | | | | | | | | | 0.488 | 0.363 | 0.129 | |
| 24 | 1.073 | | | | | | | | | | | | | 0.49 | 0.359 | 0.126 | |
| 26 | 1.072 | | | | | | | | | | | | | 0.486 | 0.36 | 0.123 | |
| β Ω | 1.075 | | | | | | | | | | | | | 0.484 | 0.361 | 0.12 | |
| ۲a ۳ | 1.068 | | | | | | | | | | | | | 0.483 | 0.359 | 0.118 | |
| 34 | 1.071 | | | | | | | | | | | | | 0.488 | 0.36 | 0.116 | |
| 36 | 1.07 | | | | | | | | | | | | | 0.488 | 0.358 | 0.115 | |
| 89 · | 1.075 | | | | | | | | | | | | | 0.486 | 0.358 | 0.113 | |
| 6. | 1.069 | | | | | | | | | | | | | 0.484 | 0.359 | 0.111 | |
| 42 | 1.069 | | | | | | | | | | | | | 0.485 | 0.356 | 0.11 | |
| 4 - | 1.072 | | | | | | | | | | | | | 0.485 | 0.357 | 0.109 | |
| 46 | 1.07 | | | | | | | | | | | | | 0.485 | 0.357 | 0.108 | |
| -4 -0 -0 | 1.07 | | | | | | | | | | | | | 0.483 | 0.354 | 0.106 | |
| 05 | 1.071 | | | | | | | | | | | | | 0.483 | 0.353 | 0.105 | |
| 25 | 1.069 | | | | | | | | | | | | | 0.483 | 0.354 | 0.104 | |
| 5 | 1.075 | | | | | | | | | | | | | 0.484 | 0.354 | 0.104 | |
| 36 | 1.069 | | | | | | | | | | | | | 0.482 | 0.355 | 0.102 | |
| 58 | 1.072 | | | | | | | | | | | | | 0.485 | 0.354 | 0.101 | |
| 60 | 1.07 | 1.051 | 1.03 | 1.002 | 0.976 | 0.944 | 8.907 | 0.868 | 0 825 | 0.773 | 0.722 | 0.657 | 0.579 | 0.483 | 0.353 | 0.101 | |
| | 90 | 92 | 94 | 96 | 98 | 100 | 102 | µ[́G | eV] | 108 | 110 | 112 | 114 | 116 | 118 | 120 | |

cross section [pb]

-04

- 0.2

č