

*Ph.D. Thesis*

**Probing Electroweakly Interacting  
Massive Particles  
with Drell-Yan Process  
at 100 TeV Colliders**

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## Abstract

(♣ To be written ♣)

# Acknowledgments

(♣ To be written ♣)

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# Section 1

## Introduction

- (♣ Unit:  $\hbar = c = k_B = 1$  ♣)
- (♣ Convention: dot as time derivative ♣)
- (♣ Definition of “SM” ♣)
- (♣ Definition of “WIMP” ♣)

# Section A

## Review of supersymmetry

In this appendix, we briefly review the  $\mathcal{N} = 1$  supersymmetry, which is an essential element of the MSSM reviewed in Sec. ???. Our argument is based on [1, 2].

The  $\mathcal{N} = 1$  supersymmetry is

First example is the MSSM, extension of the SM with the so-called  $\mathcal{N} = 1$  supersymmetry (SUSY) [1, 2] that relates a bosonic particle and a fermionic particle. The supersymmetry transformations for a complex scalar  $\phi$  and its “superpartner” Weyl fermion  $\psi$  are defined as

$$\delta\phi = (\epsilon\psi), \quad \delta\phi^* = (\epsilon^\dagger\psi^\dagger), \quad (\text{A.1})$$

$$\delta\psi = -i(\sigma^\mu\epsilon^\dagger)\partial_\mu\phi, \quad \delta\psi^\dagger = i(\epsilon\sigma^\mu)\partial_\mu\phi^*, \quad (\text{A.2})$$

where  $\sigma^\mu \equiv (\mathbf{1}, \boldsymbol{\sigma})$  with  $\boldsymbol{\sigma}$  being Pauli matrices, while  $\epsilon$  is an anti-commuting Weyl fermionic object that parameterizes the SUSY transformation. The summation over the spinor indices is assumed inside each parenthesis. These transformations, if denoted by operators  $\epsilon Q$  and  $\epsilon^\dagger Q^\dagger$ , are known to form a closed algebra

$$[Q, Q^\dagger] = 2i\sigma^\mu\partial_\mu, \quad (\text{A.3})$$

$$[Q, Q] = [Q^\dagger, Q^\dagger] = 0, \quad (\text{A.4})$$

when fields are on-shell.<sup>‡1</sup>

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<sup>‡1</sup>In order for the algebra to be closed off-shell, one can introduce a new scalar field  $F$  without a kinetic term that is often called as an *auxiliary* field.  $F$  works as a Lagrange multiplier whose equation of motion

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## References

- [1] J. Wess, J. A. Bagger, *Supersymmetry and supergravity; 2nd ed.*, Princeton Series in Physics, Princeton Univ. Press, Princeton, NJ, 1992.  
URL <https://cds.cern.ch/record/320631>
- [2] S. P. Martin, A Supersymmetry primer (1997) 1–98[Adv. Ser. Direct. High Energy Phys.18,1(1998)]. [arXiv:hep-ph/9709356](#), [doi:10.1142/9789812839657\\_0001](#), [10.1142/9789814307505\\_0001](#).