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Education

- Ph. D. in Theoretical Physics
  August 2005
  Michigan State University
  Advisor: Professor C.-P. Yuan
- M. A. in Theoretical Physics
  August 1999
  Beijing University
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Professional Experience

- Aug 2008 — Present, Post-Doctoral Researcher,
  High Energy Physics Division, Argonne National Laboratory, and
  Enrico Fermi Institute, University of Chicago.

- Aug. 2005—Aug. 2008 Post-doctoral Researcher,
  Department of Physics and Astronomy, University of California at Riverside

- Aug. 2000—Aug. 2005 Graduate student,
  High Energy Theoretical Group, Michigan State University

Honors

- Dissertation Completion Fellowship, Michigan State University, 2004 – 2005.
- Referee of Physics Reviews D and European Physical Journal C.

References

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Publications

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Work in Progress

[01] Determining the Model Parameters of Littlest Higgs Model with T-Parity at colliders.
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[02] Dark matter study in the effective field theory approach.
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[03] Dark matter a La carte.
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[04] Supersymmetric Model of Radiative Seesaw Majorana Neutrino Masses.
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[05] RESBOS-A 2.0: a tool for precision measurement of W/Z boson.
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[06] Light Higgs boson hunting guide.
Alexander Byleaev, Qing-Hong Cao, Kazuhiro Tobe, C.-P. Yuan.

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[01] Standard Model Handles and Candles Working Group: Tools and Jets Summary Report.

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[02] Tevatron-for-LHC Report: Top and Electroweak Physics.

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Proceeding of 3rd Les Houches workshop: Physics at TeV colliders, Les Houches, France, May 26 – June 6, 2003, arxiv:hep-ph/0401171.

Seminar / Conference Talk / Lecture

[01] s-channel single top production and decay at the Next-to-leading order.

Tev4LHC workshop, Fermilab, Sep. 16, 2004.

[02] s-channel single top production and decay at the NLO.

2004 PHENOMENOLGY SYMPOSIUM, University of Wisconsin-Madison, April 26-28,2004.

[03] Electroweak corrections to hadron collider phenomenology.

13th International Workshop on Deep Inelastic Scattering, Apr. 29, Madison, Wisconsin.

[04] Single top quark production and decay in hadron collisions at the NLO.

University of California at Riverside, Oct. 12, 2005

[05] Electroweak theory and Higgs phenomenology.

Lecture for experimental graduate student, Dec. 2005 – Feb. 2006.

Research Statement

My recent research focuses on these major components: devising strategies to establish the Standard Model and discover new physics at the LHC, followed by making the connection to astrophysical observations.

Standard Model (SM) of particle physics provides a thoroughly tested quantitative description of the matter particles (quarks and leptons) together with the mediators of the strong and electroweak interactions (gluon, photon, W and Z bosons). Two clear evidences, neutrino mass and dark matter, suggest that the SM is not complete, and that it is merely the low-energy limit of a more fundamental theory, however. The origin of the electroweak symmetry breaking (EWSB) and the flavor symmetry breaking still remains mysterious. In the SM, both of them are related to the generation of mass terms; the first one for generating the mass of gauge boson, and the second one for generating the hierarchical mass pattern of the three families of quarks and leptons. The SM Higgs mechanism can explain both symmetry breakings, but in doing so it leaves many other questions unanswered. Many new physics (NP) models have been proposed to solve those questions. The soon-to-be-operational Large Hadron Collider (LHC) at CERN provides a perfect laboratory for new physics search. Owing to its unprecedented energy and luminosity, the LHC will unveil the mechanism of EWSB and shed light on how matter acquires mass. It might well discover the dark matter that makes up so much of the Universe.

- **Confirming the SM**

Before claiming new physics, LHC experimentalists will have to confirm the SM by verifying several benchmark processes, which will serve as backgrounds to new physics. High accuracy will be necessary if new physics is subtle or convoluted. The lowest-order predictions for many SM processes exhibit significant uncertainties, e.g. the unphysical renormalization and factorization scale dependence, which can be reduced by including higher orders in perturbation theory. There are a lot of SM processes for which more accurate predictions are needed at the LHC. My major interest focuses on the production of the SM Higgs boson, W and Z boson in the Drell-Yan process, and the top quark in pair or singly.

As the key ingredient of the SM, the Higgs boson so far has not been observed. It is important to detect this particle and to determine its interactions with other SM particles, like gauge bosons and heavy fermions, and even interactions with itself. At the LHC, the SM Higgs boson is predominately produced via the gluon fusion process, of which the cross section has been calculated at the next-to-next-leading logarithmic accuracy. However, a fixed order calculation cannot reliably predict the transverse momentum (Q_T) distribution of the Higgs boson at the low Q_T region where bulk events accumulate. One needs to take into account the effects of the initial state multiple soft-gluon emissions to make a reliable prediction on the Higgs boson's kinematics. Recently, in collaboration with Chuan-Ren Chen, I examine the soft-gluon resummation effects in the search of SM Higgs boson via the process $gg \to h \to WW/ZZ \to 4$leptons at the Tevatron and the LHC [5]. We found the resummation effects increase the acceptance of the signal event by about 25% as compared to the Next-to-Leading order (NLO) prediction and also dramatically alter various kinematics distributions, which can be used to measure the properties of the Higgs boson. Such significant effects are very crucial for the Higgs boson search at the LHC. Further work to include the NLO electroweak (EW) correction in the Higgs decay is in order.

Another important production channel of the Higgs boson is the vector-boson-fusion (VBF) process, $qq' \to qq'H$, where the two forward jets in the final state provide a spectacular collider signature. This channel is also important for the NP search. For example, if the dark matter candidate interacts with the SM Higgs boson strongly, then the Higgs boson predominately decay invisibly when the kinematics is allowed [2]. The two forward jets can be used to trigger such an event. It is crucial to have a detailed understanding of the forward jet activity, which can be best achieved by calculating the resummation QCD corrections to the VBF process. Prior to the discovery of Higgs boson, one can learn about the detection efficiency of the forward jet from studying the *t*-channel single top production. This is because in the *t*-channel single top process, the forward jet also results from emitting a *W* boson that interacts with the *b* quark form the other hadron beam to produce the heavy top quark. Hence, the resummation QCD correction to the *t*-channel single top production is also in order.

In the absence of a direct observation of the SM Higgs boson, information on its mass can be obtained from the precision measurements of the *W* boson mass and the top quark mass. The *W* boson mass cannot be measured with high precision at the Tevatron Run II or at the LHC without taking into account the correlation between the transverse momentum spectrum of the *W* boson (originated from multiple gluon emission in the initial state) and the EW radiation of the final state lepton. In collaboration with C.-P. Yuan, I have performed a sophisticated calculation including the large Sudakov soft-gluon resummation effects and the final-state quantum electrodynamics radiative corrections, and developed a Monte Carlo program, called RESBOS-A [16]. Recently, the Next-to-Next-leading order QCD corrections have been included. I plan to implement the full NLO EW corrections so as to reduce the theoretical uncertainties in interpreting the experimental data. Furthermore, the electroweak radiative corrections become large and negative at large di-lepton invariant masses because of Sudakov-like logarithms. It is necessary to resum these terms for new physics searches at the LHC.

- **Discovering new physics at the LHC**

The LHC will revolutionize particle physics by opening the TeV energy region to direct experimental exploration. It will certainly reveal the origin of EWSB. But beyond that, it will probe a variety of possible extensions to the SM, such as supersymmetry, large or small extra dimensions, technicolor, composite and Little Higgs, etc. These models share a handful of signals that will be the focus of early LHC searches. To disentangle the NP signals out of the SM backgrounds, one must understand both accurately. Moreover, after the discovery of the NP signal, the major goal will shift to precision measurement of the masses, spins and couplings of those exotic particles, together with their decay modes and branching fractions. For that, it is crucial to evaluate the higher order quantum corrections to the production and decay of the NP particles. Also, event generators with full NLO corrections and kinematics are needed.

The NP models can also manifest their effects in the SM particle production via the loop corrections. Top quark, because of its heavy mass, is believed to provide a good probe to the EWSB mechanism. LHC will be a true top factory, producing tens of millions of top quarks every year. Given such a large production rate, one is able to measure the production cross section of the top quark pair accurately. It is desirable to calculate the higher order corrections to the top quark pair production in various NP models. Very recently, in collaboration with Chuan-Ren Chen, I calculate the anomalous gluon-top (*gtt*) coupling in the Littlest Higgs Model with T-parity (LHT) using the equivalence theorem. Our study shows that the *gtt* coupling receives substantial leading EW corrections in vast parameter space of the LHT model. Data on indirect signals will be folded in to constrain the allowed range of models.

When the available energy is insufficient to directly produce the heavy excitation underlying the SM, all new physics effects can be parameterized by the coefficients of a series of gauge-invariant operators constructed out of the SM fields; when the heavy physics decouples, these operators have dimensions ≥5 and their coefficients are suppressed by inverse powers of the NP scale (the scale at which the excitations of the underlying theory can be directly probed). In collaboration with Jose Wudka and C.-P. Yuan, I consider single-top production as a probe for new physics effects at the LHC. We argue that for natural theories a small deviation from the SM tree-level couplings in this reaction can be parameterized by 3 higher dimension operators [4, 9]. Precision measurement of these effective couplings in the single-top events, via studying their interference effects with the SM contributions, can discriminate several new physics models.

- **Dark matter: bridge between astrophysics and particle physics**

Dark matter (DM) is at the heart of any study regarding the interface between particle physics, astrophysics, and cosmology. There is mounting experimental evidence that our Universe contains a significant amount of non-luminous matter, while several new theories indicate undiscovered particles close to the ‘tera’ scale, i.e. the highest energies probed by near future experiments. In the meantime, several experiments (in)directly searching for dark matter will be producing data.

Many dark-matter candidates have been suggested in various models beyond the SM, but a nearly universal implicit assumption is that one and only one such candidate is needed and its properties are constrained accordingly. This is of course not a fundamental principle and the possibility of multipartite dark matter should not be ignored. Recently, in collaboration with Ernest Ma, Jose Wudka and C.-P. Yuan, I consider the possibility that there are several coexisting dark-matter particles, and explore in some detail the generic case where there are *two* [1]. We discuss how the second dark-matter particle may relax the severe constraints on the parameter space of the Minimal Supersymmetric Standard Model, as well as other verifiable predictions in both direct and indirect cosmic gamma-ray search experiments.

At the LHC, the dark matter candidate has to be produced in pair, which gives rise to a collider signature of missing energy. But discovery of such excess will not prove that those particles constitute dark matter. Usually, the proof will only come from the consistency of astrophysical observations, indirect and direct detection of dark matter and collider data. Each of these has to yield the same physical properties (mass, quantum numbers, couplings) for the dark matter particle. However, in one scenario of multipartite dark matter model, there is a *super-dark* particle only interacting with the other dark matter candidate but not with the SM particle. All of its information is hidden behind the other dark matter particle and cannot be observed directly. In such a circumstance, it may be revealed nevertheless if apparent discrepancies occur among the data of DM search experiments and the signal at colliders. More detailed studies of multipartite dark matter are in progress.