Personal contribution to the thesis analysis

Inclusive squark/gluino 1L analysis (Nov. 2015 -)

Coordinator: Jeanette Lorenz, Moritz Backes, Stefano Zambito, Da Xu.

Publication

- CONF note for ICHEP 2016, (14.8 fb^{-1} , CONF / INT)
- 2015+2016 paper (36.1 fb^{-1} , Paper / INT)

Contribution to ICHEP analysis

- FAR talk (Link).
- Study on origin of missing lepton and lepton veto (Link).
- Extensive investigation into Ttbar modeling (Link1 Link2).
- Check on events in unblinded signal regions (JIRA).

Contribution to the 2015+2016 paper

- **Development of new data-driven method ("Obj. replacement method"). (Link1, Link2 p9-13)**
- Study on overlap removal. (JIRA)
- Study on bveto/btag categorization of SRs. (Link)

Shion Chen - *Curriculum Vitae*

Date of birth:	17 June 1989
Nationality:	Japan
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Education and Training

2014-2017

Doctoral student, The University of Tokyo, Japan. JPS fellowship.
Thesis: "Search for Gluinos using Final States with One Isolated Lepton in the LHC-ATLAS Experiment".

2012-2014

Master's degree in Physics, The University of Tokyo, Japan.
Thesis: "Test of Bell's Inequality and Entanglement Measurement in Collider Experiments".

Advisors

Ph.D advisor (April 2012-present)

Sachio Komamiya, Professor at The University of Tokyo and Director of International Center for Elementary Particle Physics, the University of Tokyo (ICEPP).

Local supervisor in ATLAS experiment (June 2014-present)

Shoji Asai, Professor at The University of Tokyo and Representative of ATLAS-Japan collaboration.

Selected publications

1. **S. Chen**, Y. Nakaguchi and S. Komamiya
"Testing Bell's Inequality using Charmonium Decays", Prog. Theor. Exp. Phys. (2013) 063A01.

2. Robustness of a SiECAL used in Particle Flow Reconstruction, C.Kozakai, **S.Chen** et.al. (1404.0124) International Workshop on Future Linear Colliders (LCWS13) Tokyo, Japan, November 11-15, 2013.

3. M. S. Amjad, . . . **S.Chen** et al. Beam test performance of the SKIROC2 ASIC. Nucl. Instrum. Meth., A778:7884, 2015.

4. ATLAS Collabolation . . . **S. Chen** . . .
"Search for gluinos in events with an isolated lepton, jets and missing transverse momentum at $\sqrt{s} = 13$ TeV with the ATLAS detector." Eur. Phys. J., C76(10):565, 2016.

5. ATLAS Collabolation . . . **S. Chen** . . .
"Search for supersymmetry with two and three leptons and missing transverse momentum in the final state at $\sqrt{s} = 13$ TeV with the ATLAS detector." ATLAS-CONF-2016-096, 2016

6. ATLAS Collabolation . . . **S. Chen** . . .
"Search for squarks and gluinos in events with an isolated lepton, jets and missing transverse momentum at $\sqrt{s} = 13$ TeV with the ATLAS detector." Accepted by Physics Review D, 2017

Selected Talks at Conferences

1. "Testing Quantum Mechanics in Collider Experiments", International School of Subnuclear Physics 2015, July 2015, Erice, Italy.

2. "Test beam analysis of SiW ECAL physics prototype in 2011 FNAL". CALICE Collaboration Meeting, LAPP, Annecy, France, 2013. 8

3. "Test of Power Pulsing with the HBU-LED System". CALICE Collaboration Meeting, LAPP, Annecy, France, 2013.

4. "A new background suppression technique for LHC-ATLAS Run2 Electroweak Gaugino search", Japan physics society meeting, September 2015, Osaka Japan.

5. “Search for super-symmetric particles in one lepton final state in the LHC-ATLAS experiment Run2.”, Japan physics society meeting, September 2016, Miyazaki Japan.
6. “Searches for squarks and gluinos in final states with an isolated charged lepton, jets, and missing transverse momentum with the ATLAS detector”, Epiphany 2017, January 2017, Krakow, Poland.

Invited Seminar Talks

1. “Test of Bell’s Inequality in the Charm Factory”, Shion Chen, Open Seminar talk, 2 December 2013, IHEP, China.
2. “Testing Bell’s Inequality using momentum-entangled states in Collider Experiments”, Shion Chen, KEK theory seminar, 16 December 2013, KEK, Japan.
3. “Search for electroweak and long-lived SUSY signatures at LHC Run2.”, Workshop for Tera-scale physics, 23 December 2015 Tokyo Tech., Japan.

Research Grants and Awards

1. “Best Science Secretariat Award”, International School of Sub-nuclear Physics 2015 (July 2015, Erice, Italy).
2. CERN relay race, 2nd place, as member of Tokyo HipHoppers (21 May 2015 CERN, Switzerland).
3. Research Fellow (DC1), Japan Society for the Promotion of Science (April 2014 - present).
4. Competitively selected summer student project in DESY (2013).

Languages

Japanese (native), Chinese (native), English (good), French (poor), Brasilian portuguese (poor).

Research Summary

My research career has been focused on the investigation of elementary particles and the fundamental rules lurking behind them. During 5 years as a graduate student at the University of Tokyo, I have been working on various aspects of particle physics:

- theoretical analysis of testing quantum nature in collider experiments
- development of calorimeters for future lepton colliders
- search for supersymmetry in ATLAS at the energy frontier proton-proton collider (Large Hadron Collider; LHC) at CERN.

ATLAS experiment (2014-present)

I joined the ATLAS experiment from 2014 and conducting studies for my Ph.D project. I have been involved in two physics analyses focused on SUSY searches using the early data of LHC Run2 at $\sqrt{s} = 13$ TeV, and contributed to publishing the first round results. While based at CERN, I have also been working on the operation of the muon detector, ensuring the smooth and reliable functioning of the system and good data quality. Additionally, I was involved in the upgrade activity of muon detector (New Small Wheel: NSW), developing a databasing system for the MicroMegas detector.

Search for gluinos in the final state with 1-lepton, jets and missing ET. (2015-2017)

Since the discovery of higgs boson at a mass of 125 GeV, there is a dramatically increased interest in the search for gauginos since in typical minimal models, this mass naively implies a scalar top mass of several tens of TeV, beyond the reach of LHC. In the early stage of LHC Run2, the gluino search was particularly well-motivated as its production cross-section increases by a factor 4-40 due to the doubled center of mass energy with respect to Run1.

I participated in a gluino search through the final state with exactly one lepton. My major contribution to this analysis is in the background estimation. While careful and dedicated background modeling is crucial for a discovery-oriented analysis, it is challenging in this analysis because the signal region lies in the high energy tails of SM process phase space. The background remaining after the selection are very unusual events, typically associated with many ISR jets. Therefore either MC modeling from first principles or traditional semi-data driven methods which extrapolate kinematics from control regions in the bulk to signal regions in the tails using MC tends to be unreliable. To cope with this, I have been developing a new data-driven estimation method that extrapolates from control regions with two leptons into signal regions with exactly one lepton. As the kinematics are set to be the same between the two regions, the error and potential unknown systematics on the extrapolation are significantly reduced. On the other hand, I have also been investigating the MC modeling of standard model processes (especially regarding top-antitop pair production) in collaboration with the physics modeling group, to understand the large discrepancies with data in extreme phase space, as well as to improve the modeling of the state-of-art particle generators as a first feedback from the 13 TeV data.

The analysis has been performed successfully using the Run2 data and two results have been published ([4], [6] in "Selected Publication"). No significant deviation from the standard model was observed, and an exclusion limit was set, in a simplified model in which the gluino decays via a chargino, up to a gluino mass of $1.7 \sim 2.0$ TeV.

Search for direct production of EW gaugino in the 3-lepton final state. (2014-present)

Given that no BSM evidence has so far been observed in Run2, EW-favored split-SUSY scenarios in which the gluino and all other scalar fermions are decoupled become more important. The direct production of electroweak gauginos is the only the probe of such a scenario.

I have been committed to this analysis using the 3-lepton final state. I particularly focused on the scenario favored by minimal SUSY models and consistent with dark matter observations. In this scenario, the mass splitting between the lightest neutralino and the second lightest one is typically small, which results in a soft spectrum for the final state particles and missing ET. Although three leptons are required for the analysis, it is still tough to distinguish signals against standard model electroweak processes for such signatures. Therefore a sophisticated separation algorithm is needed which exploits the difference in angular distributions and correlations between the transverse mass of particles and so on. Multi-variant likelihoods are a powerful toolkit to cope with such complicated handling of phase space. While adoptive machine learning algorithms such as boosted decision trees (BDT) are the most commonly used in ATLAS, I introduced the method of matrix element likelihood in this analysis, taking the advantage of the fact that the four vectors of the final state particles are well-defined, and that higher order effects have limited influence on the 3-lepton final state. I also improved the integration procedure and succeeded in speeding up the algorithm. Preliminary studies show very promising discrimination power and robustness against experimental and theoretical uncertainty, and further study will follow with more improvements.

While these development studies are aiming for a long term analysis with the large datasets expected at the later stage of Run2 and in Run3, I was also involved in the first round Run2 analysis targeting specific models in which the signal cross-section is greatly enhanced by the presence of light sleptons ([5] in "Selected Publication"). Although these models are phenomenologically optimistic, we drastically extended the exclusion limits from to Run1, up to around 1.1 TeV for the second lightest gaugino mass, and also performed the measurement in the tail of the 3-lepton phase space for the first time in Run2. I contributed to this work extensively, from preparation of dataset, trigger studies, signal region optimization and evaluation of systematical uncertainty.

Development of a databasing system for the MicroMegas detector (2014-2015)

MicroMegas is a sub-detector of the New Small Wheel, aimed for fast and precise measurement of muon tracks in the end-caps. After a successful R&D and a proposal with TDR, it is now at the stage of fine-tuning detailed design, including the geometry and electronics and so on. Simulation study in accurate geometry therefor became highly important. As my authorship qualification project in ATLAS, I developed a centralized database storing up-to-date geometrical parameters that are sufficient to define whole active area of MicroMegas in simulation.

Development of calorimeters for ILC/ILD (2012-2014)

The ILC (International Linear Collider) is a TeV-scale electron-positron collider targeting the precise measurement of the higgs boson, and as well as probing new physics in the electroweak sector. As targeted events typically contain electroweak gauge bosons (W/Z), the precise identification, particularly through their hadronic decay mode, is critical for many of the ILC physics program. The requirement is sub-5% of energy resolution for a single jet, and accordingly 3-4 GeV resolution for di-jet invariant mass. To achieve this unprecedented benchmark, the ILD (International large detector) is planning to employ the particle flow algorithm (PFA) in which each jet particle is identified and the energy is measured individually. Calorimeters are the key components in this scheme which resolve the showers inside the jet.

During the second half of my master course, I participated in the development of the silicon-tungsten electromagnetic calorimeter (SiW-ECAL) and analogue hadronic calorimeter (AHCAL) in the CALICE Collaboration.

Commissioning of SiW-ECAL prototypes (2013)

To resolve individual clusters inside jets, a highly granular spatial segmentation is required for ILD calorimeters. A silicon-tungsten sampling calorimeter is the one of the leading candidate technology for the ILD electromagnetic calorimeter where the silicon sensor layers are segmented into 5-10mm pixels. The first generation prototype, with about 10000 readout channels, was developed in the CALICE collaboration in 2006, and regularly tested in test beam experiments since then. I analyzed the data collected at a test beam in FNAL in 2011, and verified that the basic performance (linearity, energy resolution, spatial resolution of cluster centeroid etc.) fulfills the requirements ([2] in "Selected Talks at Confereces"). The second-generation prototype was designed as a test for a fully integrated detector including data acquisition system with newly developed readout ASICs (SKIROC2). A number of test beam experiments were performed, in which I participated in setting up data taking systems. ([3] in "Selected Publication").

Study on performance of PFA/SiW-ECAL in a realistic detector setup (2012-2014)

While simulation studies have shown that PFA with the nominal ILD detector model performs very successfully, there are still a number of industrial challenges to achieve the specification of an ideal detector with ideal digitization, for instance the increased dead volume due to realistic PCB thickness or the protection frames around silicon sensor cells ("guard ring") which did not present in the default design. I performed a set of studies on the impact of such effects due to the features of a realistic detector on physics performance. The jet energy scale and resolution were parametrized as a function of guard ring width, PCB thickness, fraction of dead pixels/ASICs, noise rate, and cross-talk rate between channels etc., and closely evaluated the dependences via simulation. The results illustrate that the performance of PFA under such conditions is very stable and robust ([2] in "Selected Publication"), and also provides primary guidance for the definition of manufacturing requirements in the future.

Commissioning of the power-pulsing scheme for AHCAL (2013)

Due to the beam structure in ILC (1ms of beam train every 200ms), a power cycling scheme called "power-pulsing" has been proposed to reduce the power consumption. In this scheme, power supply is synchronized with beams so that power is turned off when collisions do not occur. The DESY FLC group has been working on implementing this into AHCAL electronics. In 2013, I was involved in the commissioning using the test board for my summer student project in DESY.

The test board consists of a detector layer instrumented with 30mm $\times$ 30mm square cells of plastic scintillator each equipped with a SiPM, and the readout layer with front-end electronics interfaced to the SiPM attached on the back. Tests were performed with injection of LED pulses, to investigate the physical response of the detector and the readout cycle in a realistic setup. The primary observation when running in the power-pulsing mode was unstable behavior shortly after turning on the electronics, for example worse resolution in single photon spectra from the SiPM and a drop in the gain. I evaluated the impact on data quality and measured the time evolution of the behavior, as well as studying the optimal board configuration for mitigating these effects ([3] in "Selected Talks at Confereces").

Testing local-reality in collider experiments. (2012-2013)

While quantum mechanics (QM) is without doubt a very successful theoretical framework in describing the microscopic scale of physics, it has suffered from an obscure and non-trivial foundation where observables are probabilistic rather than deterministic ("non-realism"), and non-local nature of physics ("non-locality") inevitably arises. Such lack of local-realism has been considered a problematic aspect of QM since it was highlighted in the famous "EPR paradox". However, by testing Bell's inequality, local-realism was experimentally excluded in 1970-80s using entangled photon pairs. While there were many loopholes in the early experiments, this has been dramatically improved as a result of rapid developments of photon handling and laser technology.

On the other hand, experiments in systems other than photon pairs are also interesting in terms of testing the universality of quantum nature. In particular, tests with entangled massive particles are non-trivial since they generally behave more classically than photons, as are tests in systems with a high energy scale where particles' Compton wavelength is small and therefore more localized in space. There have been only a few example of such experiments, due to the technical difficulty of preparing and measuring the entangled state. High energy colliders have been suggested for such measurements, since spin-entangled particle pairs can be easily generated via a variety of processes with large statistics, in a wide range of energies from a GeV to an order of 100 GeV, and with various types of interaction. The only problem in this collider regime is that the spin can only be measured through its decay regardless of the observer's free-will, which results in a significant loophole in the interpretation of the experiment.

There has been little discussion on how much the testing power is reduced by this loophole, and what assumption is required to make the test complete. My master degree project was devoted to an extensive analysis of this problem. I started by developing a reformulation specifically for the collider setup, and obtained a new very brief representation of Bell's inequality ([1] in "Selected Publication"). I also discussed the feasibility of such measurements in current and future collider experiments, and illustrated that charmonium decays in BES3, the Drell-Yan process in Belle and $H \to \tau\tau$ in ILC are promising channels for the test. Finally, the size of loopholes was evaluated for each respective channel, and also minimized by imposing consistency with past experiments ([1] in "Selected Talks at Confereces")