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# Preface of Proceedings ICHEP–2018 Seoul

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After 50 years of the standard model, now we begin the next 50 years. Last 50 years of particle physics is briefly sketched in Paul langacker's summary talk as we heard just before, and I wrap up the developments of the last several decades in high energy physics revolved around this conference series. The ICHEP series had glorious plenary sessions but many discoveries were reported in parallel sessions. Here at ICHEP–39, we had 16 parallel sessions, 40 plenary talks and over 1200 participants. Finally, I thank all who helped this 39th ICHEP successful.

*The 39th International Conference on High Energy Physics (ICHEP2018)*
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**Figure 1:**

# The 39th International Conference on High Energy Physics

COEX building, Seoul, Korea, 4 –11 July 2018

Murayama, Hitoshi (Japan)
Muronga, Azwinndini, (South Africa)
Passaleva, Giovanni (Italy)
Quevedo, Fernando, (Italy)
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Jonghee Yoo (CTPU, IBS, and KAIST)
Jin-Hee Yoon (Inha U)
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# Preface

After 50 years of the standard model, now we begin the next 50 years. The last 50 years of particle physics is briefly sketched in Paul langacker's summary. The developments of the last several decades in high energy physics revolved around this conference series. The ICHEP series had glorious plenary sessions but many discoveries were reported in parallel sessions.

The root of this conference series was the war time Manhattan Project at Los Alamos, New Mexico, which is succinctly described in Polkinghorne's book [1]. After the 2nd World War, J. R. Oppenheimer convened 25 leading physicists, including W. Lamb, R. Feynman, J. Schwinger, H. Bethe, E. Fermi and R. Marshak, at Shelter Island located near the tip of Long Island, New York, for one day conference on June 1, 1947. Oppenheimer's conference continued at Pocono Manor, Pocono Mountains, Pennsylvania in 1948 and at Oldstone-on-Hudson near New York in 1949. From the beginning of this series, the infinity first encountered in the explanation of the Lamb shift was the hurdle to be overcome. At the Pocono Mountain Conference Schwinger presented a largely completed work, and Feynman's exposition (largely orchestrated by Oppenheimer) came at the Oldstone-on-Hudson Conference [1]. By this time, quantum electrodynamics (QED) was able to present refined calculations of electron interactions mediated by photon. So, Oppenheimer achieved his goal of understanding the original infinities in QED and finished his conferences.

The so-called "Rochester Conference" were organized by Robert Marshak, initially at the campus of University of Rochester (Rochester 1–7, 10), Rochester, New York, and later including Geneva, Switerland (Rochester–8) and Kiev, USSR (Rochester–9). The 1st Rochester Conference was held at Rochester on Dec. 16, 1950. Rochester 1–6 was the cradle period of particle physics, going over the $\tau - \theta$ puzzle (Rochester–5, 1955) and parity violation (Rochester–6, 1956). In the session presided by R. Oppenheimer on "Theoretical Interpretatioin of New Particles" in the last day of Rochester–6, the puzzle related to $\theta$ and $\tau$ was the main interest. After M. Bloch's experimental talk, Feynman brought up a question "Could it be that the $\theta$ and $\tau$ are different parity states of the same particle which has no definite parity, *i.e.* parity is not conserved." [1]. After it was accepted that parity is violated in the charged current (CC) weak interactions, Rochester–7 was short of announcing the "V–A" theory of CC weak interactions. There is an anecdote at Rochester–7 that E. C. G. Sudarshan a graduate student at Rochester asked R. Marshak to present their recenly completed idea of "V–A" for weak interactions. But, Marshak as the chairman of the LOC did not allow his talk, replying that M. Bloch was supposed to mention their work. But, M. Bloch did not appear, so R. Marshak presented their work at the Padova conference four months later. Between Rochester–7 and 8, the "V–A" theory of CC weak interactions was established by R. Marshak, E. C. G. Sudarshan, R. P. Feynman, and M. Gell-Mann, and it has been known since then that the CC weak intractions needed only one coupling constant $G_F$. From this time on, developments in particle phsics has been centered on finding symmetries required to understanding weak and strong interactions at the level of QED. The "V–A" theory was the cornerstone to the road to the standard model (SM) and Sakata's symmetry was the beginning in the search of strong interaction symmetries. Rochester–10 was held again at Rochester where W. Heisenberg was present. At Rochester–10, Y. Nambu presented a parallel talk on spontaneous symmetry breaking of gauge symmetry but without much attention [1]. After Rochester–10, the conference became the bi-annual series.

From the 1962 CERN conference, the official name has become The International Conference on High Energy Physics (ICHEP) and Rochester–11 was the ICHEP–11.

In the early 1960's there were full of ideas for the future SM. In 1963, N. Cabibbo put the strangeness changing CC at the level of the strangeness conserving CC, with only one unit CC in the octet of currents, which later became the origin of flavor mixing. In 1964, Gell-Mann's mathematical quark (or Zweig's Ace) loomed in his cherished eight-folds of currents, the weak CP violation was observed by the Princeton group, the Brout-Englert-Higgs-Guralnik-Hagen-Kibble (BEHGHK) mechanism was known, and in 1965 an additional SU(3) degree (later known as color) for strong interactions was proposed by M. Y. Han and Y. Nambu. Gell-Mann's mathematical quark and color degree SU(3) waited ten more years to be accepted until the November Revolution of 1974. The BEHGHK mechanism was finally proved by the discovery of the 125 GeV boson in 2012. For the weak CP violation phenomena, it waited until 2006 for three families of quarks in the SM are enough to explain them all. During this crucial period, the ICHEP–12 was held in a small town Dubna, on the banks of Volga River, USSR (August 5–12, 1964). V. Fitch brought and showed here his Princeton apparatus which had discovered the weak CP violation. It was the period when table top experiments could reveal important aspects of particle interactions.

The BEHGHK mechanism has been known by 1965 but even in the ICHEP–13 Berkeley, 1966, plenary sessions did not include spontaneous symmetry breaking. The year 1967 was the year for this to get attention in the conference (with 325 theorists participating) dedicated to the late Robert Oppenheimer [2] and is considered to be the commencement year of the SM by representing the quark and lepton doublets only in the left-handed sector, realizing the "V–A" nature of the weak CC. But, the SM needed a few more years to bloom until the renormalizability of the spontaneously broken gauge theories was proven in 1971. The ICHEP series expanded since the ICHEP–16 Chicago which was held at Fermilab during Sep. 6–13, 1972, with the number of participants exceeding 300.

Until ICHEP–16 Chicago, our interests were split into strong and weak interactions as the following plenary titles of ICHEP–16 show

- Strong Interactions (9 talks): *Meson resonances* (R. Diebold), *Baryon resonances and related phenomenology* (C. Lovelace), *Higher symmetries and baryon resonances* (J. L. Rosner), *Inelastic two-body reactions* (C. Michael), *Strong interactions at high energies* (G. Giacomelli), *Diffraction dissociation* (D. W. G. S. Leith), *High energy collisions production processes at high energy theory and experiment* (M. Jacob), *Dynamics of strong interactions* (F. E. Low), *Problems of diffraction scattering in relativistic theory* (V. N. Gribov)

- Weak Interactions (9 talks): *Electron-positron interactions* (V. Silvestrini), *Electroproduction and deep inelastic scattering – a look at the final states* (K. Berkelman), *Light cone and short distance singularities* (Y. Frishman), *Weak interactions* (C. Rubbia), *Neutrino interactions* (D. H. Perkins), *Perspectives on theory of weak interactions* (B. W. Lee), *The present position and future prospects for the discovery of new particles* (R. K. Adair), *New experimental capabilities and potentialities in high-energy physics* (W. J. Willis), *General status – summary and outlook* (M. Gell-Mann)

Here, B. W. Lee discussed the weak neutral currents (NC) which was the prediction of the SM with one more parameter, the weak mixing angle $\sin^2\theta_W$, in addition to the well-established CC.

After the ICHEP–16, the series focussed on checking physics related to the SM. Plenary talks, mainly reviews on some established ideas, are glorious but short parallel talks contain many new ideas and new discoveries. At Rochester–10, Y. Nambu presented the gauge symmetry and spontaneous symmetry breaking at a parallel session, for example. At ICHEP–17 London, J. Iliopoulos presented a plenary talk on the now famous Glashow-Iliopoulos-Maiani mechanism but B. Zumino introduced the linear supersymmetry (which would dominate the theory community in the next several decades) as a parallel talk, and J. Sacton presented the discovery of the NC event $\bar{\nu}_\mu + e^- \to e^- + \bar{\nu}_\mu$ by the Aachen–Brussels–CERN–Ecole Polytechnique–Milan–Orsay–U.C. London Collaboratio in a parallel session. For a few years since the November Revolution of 1974, discoveries of new particles were annual events: $J/\psi, \tau, b$ quark, etc. At ICHEP–18 Tibilisi, USSR, there was some discussion of 'cooling' of techniques [1] whose eventual solution of the problem was an essential step toward the CERN proton-antiproton collider which produced $W$ and $Z$ in 1983. At ICHEP–19 Tokyo which was the first one in the Asia–Oceania continents, a theoretical plenary talk on weak interaction (emphasizing NC) was presented by S. Weinberg and a plenary talk on unification (emphasizing supersymmetry) was presented by Abdus Salam. An experimental plenary talk on the NC was given by C. Baltay and in a parallel session the NC data from the polarized eD experiment at SLAC was reported by R. E. Taylor. In the parallel session on "Charm Search and Related Topics", R. D. Peccei presented a short review of axions. In the evening of August 30 (Wednesday), 1978, right after the conference, NHK (the Japanese National TV) broadcasted an hour documentary on the developments of gauge theories. Yet, acceptance of the weak NC and gluon jet, completing the gauge structure $\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y \times \mathrm{SU}(3)_c$, needed one more year by the reports at Neutrino-79 Bergen.

At the ICHEP–21 Paris in 1982, there was a great interest on the unification of all elementary particle forces (GUTs), which was reviewed by H. Georgi in a plenary session. But, the report a year later by the Irvine-Michigan-Brookhaven detector on the proton decay revealed that proton lifetime is greater than $2 \times 10^{31}$ years and the SU(5) GUT was not accepted and our interest has quickly shifted to supersymmetric versions of the SM, especially on the minimal supersymmetric SM (MSSM). During the next three decades, no hint on supersymmetry has been revealed even though the confirmation of the SM continued by the top quark discovery. Meantime, a slight modification of the SM was needed as the neutrino oscillation was established. In ICHEP–23 Berkeley in 1986, S. Weinberg demonstrated an oscillating pendulum, mimicking neutrino oscillation in matter, in his summary talk. In the ICHEP–26 Dallas in 1992, R. F. Schwitters expressed full of expectations for the high energy accelerator SSC in the Texas desert and C. Rubbia talked about the LHC plan of CERN. As we know now, the SSC plan was cancelled and the LHC succeeded to be built. S. Weinberg presented another summary talk at this ICHEP.

Since 1990 until 2012, theorists were free to think about beyond the SM (BSM) physics without much new fundamental discoveries to be explained by theorists. During this period, observations into the sky revealed the need to include dark matter and dark energy as important subjects of ICHEP. The BSM related physics included supersymmetry, MSSM, supergravity, superstring, dark matter, WIMPs, "invisible" axions, inflation, and extra dimensions.

In 2012, the discovery of the last ingredient of the SM the BEHGHK boson was jointly reported at CERN and at the ICHEP–36 Melbourne. So, the aim of understanding elementary particles and their interactions at the level of QED since Rochester–1 has been achieved but it seems that



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a new era for particles is open. The LHC discovery of the BEHGHK boson with the 125 GeV mass but no other expected particles at the TeV region offers difficult questions on the understanding of the fine-tuning between constants (including Newton's constant) in the SM, *i.e.* on the hierarchy problem. The ICHEP series started to understand pions even after the successful achievement of QED. To understand pions successfuly, we had to understand the leptons together with the quarks. Now, we have seen all the particles the SM predicted but still we do not understand the relations between parameters present in the SM. To understand the SM satisfactorily, we have to understand the Universe also because these constants dramatically influenced the evolution of the Universe.

At the ICHEP–37 Valencia in 2014, the prime interest was on the BICEP2 report from Anti-Arctica on the possibility of large (tensor/scalar ratio) $r > 0.1$. But more refined study showed that $r$ cannot be that large and it is expected to be less than 0.01. At this Valencia conference, our ICHEP–39 Seoul was approved and we thank the C11 members for approving our proposal.

In 2016, the ICHEP–38 came to Chicago again. This year was the year for gravitational waves after the discovery of GW150914 in 2015. We remember that B. C. Barish presented a comprehensive public talk on gravitational waves at this conference,.

The 39th ICHEP has started in the evening of July 4, 2018. It has 16 subjects which can be compared with just 2 subjects of the ICHEP–16 Chicago. Parallel sessions were open during July 5–7, and plenary talks were presented during July 9–11. On July 8 (Sunday), the conference excursions were provided. Each subject has at least one plenary talk. The numbers of plenary talks, parallel talks and poster presentations were 40, 692, and 195, respectively, and there were more than 1,200 registrations. In the beginning of plenary sessions, three highlight talks were presented. On Tuesday, there was "Directors' Forum & Round-table Discussions" where F. Gianotti, J. Butler, M. Yamauchi, Y. Wang, and J. Bagger presented the current status of the HEP labs and expressed their views on the future labs. The conference banquet was in the evening of Monday. In the evenings of Sunday and Tuesday, there were two public talks by G. Giudice and M. S. Turner. The plenary talks in each subjects were

- Highlights and summary: *ATLAS + ALICE highlights* (T. Carli), *CMS + LHCb highlights* (S. Rahatlou), *Multi-messenger astrophysics* (P. Shawhou), *Summary and outlook* (P. Langacker)

- Higgs Physics: *Higgs boson measurements from ATLAS and CMS* (G. Piacquadio)

- Neutrino Physics: *Long baseline experiments* (M. Yokoyama), *Short baseline experiments* (M. Weber), *Non-accelerator based experiments* (R. Saakyan), *Neutrino theory* (S. Petcov)

- Beyond the Standard Model: *SUSY/A review of the results from the LHC experiments* (S. Strandberg), *Exotics at the LHC* (D. del Re)

- Top Quark and Electroweak Physics: *Top quark & electroweak physics* (L. Skinnari), *Top, Higgs and electroweak theory* (M. Dolan)

- Quark and Lepton Flavor Physics: *CKM & CPV (quark flavor)* (P. Urquijo), *Rare decays of B, D, and K mesons* (N. Tuning), *cLFV/$g-2$/EDM experiment* (S. Mihara), *Flavor theory & outlook* (S. Fajfer)

- Strong Interactions and Hadron Physics: *Lattice QCD for high energy physics* (P. Shanahan), *Strong interaction and hadron physics/experimental* (L. Elouadrhiri), *Experimental overview on exotic hadrons* (S. Fang)
- Heavy Ions: *Experimental heavy-ion collisions–A unique QCD laboratory* (R. Averbeck), *Heavy ions/theory* (T. Hirano),
- Astro-particle Physics and Cosmology: *CMB, cosmology, other astroparticle physics* (M. Hazumi), *The latest results on high energy cosmic rays/AMS* (A. Kounine and S. Ting)
- Dark Matter Detection: *Direct detection of dark matter* (H. S. Lee), *Axion dark matter searches* (Y. K. Semertzidis)
- Formal Theory Development: *From black holes to qubits through string theoretic microscopes* (T. Takayanagi)
- Accelerator: Physics, Performance, and R&D for Future Facilities: *Super KEKb/BelleII status* (K. Akai), *ILC, CLIC, CEPC and FCC(ee)/Future high energy* $e^+e^-$ (X. Lou), *Future neutrino experiments/DUNE & Hyper-K* (J. Yu), *ICFA Report* (P. Bhat and G. Taylor)
- Detector: R&D for Present and Future Facilities: *Detector R&D* (D. Bortoletto)
- Computing and Data Handling: *Future of software and computing for HEP/Pushing the boundaries of the possible* (E. Sexton-Kennedy), *Technology applications and industrial opportunities* (P. Riedler), *Opportunities at Samsung Electronics* (E. Shim)
- Education and Outreach: *Outreach and education* (K. Shaw)
- Diversity and Inclusion: *Diversity and inclusion* (S. Yacoob)

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Jihn E. Kim,
Chair, 39th ICHEP Seoul

## References

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