50 years of science and KEK

+ HOW CHANGES AT KEK SHAPED KEK’S CONTRIBUTION TO HEP

+ HOW CHANGES IN HEP SHAPED CHANGES AT KEK.

Hirotaka Sugawara, KEK, November 9, 2021
A 1960-2020 TIMELINE OF IMPORTANT EVENTS IN HEP AND AT KEK IS USEFUL FOR MANY REASONS.

HOWEVER, THIS PRESENTATION WILL FOCUS ON SOME OF THOSE KEY EVENTS IN HEP AND AT KEK IN ORDER TO DESCRIBE THEIR RELATIONSHIP FROM THE PERSPECTIVE OF AN ACTIVE PARTICIPANT.
High Energy Physics of 1960’s

**Experiment**
- Discovery of many resonances mostly in BNL and in Berkeley
- Discovery of two neutrinos in BNL (AGS machine), 1962
- CP-violation in K-decays, AGS, 1963

**Theory**
- Field theory was powerless in explaining them (S-matrix theory)
- Partial success of current algebra method indicated some usefulness of field theory
- Symmetry breaking can give a finite mass to gauge bosons (Nambu, 1961) standard model of EW, Higgs particle (1967)
Establishment of KEK in 1971

Rather chaotic situation of HEP in 1960’s influenced the establishment

• **Inter-university research institute (大学共同利用機関)**
  more than 10 years of discussions to define IURI
  → Unique Japanese research system
  “Infinitely close to university but it is not a university”

• **Founding fathers == First DG—Suwa, Second DG—Nishikawa**
  Most active committee members—Fushimi, Takeda, Yamaguchi, Kitagaki,—

• **First machine --- 12 GeV synchrocyclotron**
  This was not the highest energy machine in the world (BNL 30GeV)
  But in 1900’s it started the first long baseline neutrino experiment
Two founding fathers of KEK
Left : Shigeki Suwa       right : Tetsuji Nishikawa
素研準備室

クラブハウス
Personal view

• KEK was established 50 years ago as the first major high energy physics laboratory outside of Europe and the US. Considering the current world status of KEK, the establishment has a major historical significance.
• Interuniversity research laboratory (大学共同利用機関) is a unique Japanese system which affected other fields significantly.
• Energy choice of 12 GeV was lower than originally conceived. High energy physicists wanted to compete with BNL or Berkeley. But considering nothing much of physics were left and considering that, at later stage, 12GeV machine contributed HEP greatly by constructing world first long base line neutrino beam line, the choice was a success.
High energy physics of 1970’s

**Experiment**
- Discovery of $J/\psi$, BNL, SLAC, 1974 \textit{charm quark}
- B-meson, FNAL, 1977 \textit{bottom quark}
- $\tau$ lepton, SLAC, 1975
  \textit{(top quark, FNAL 1995, $\tau$ neutrino, FNAL, 2000)}
- Neutral current, CERN, 1973

**Theory**
- Strong interaction can be explained by Color QCD with three quarks
- Asymptotic freedom (1993) (quark confinement)
- Weak and Electromagnetic interaction $\rightarrow$ Standard model
12 GeV PS and its later applications--- PS booster for neutron science and medical application---

• 12 GeV PS was constructed to boost the experimental high energy physics in Japan but the AGS at BNL, Bevatron in Berkeley and PS in CERN had been already working with higher energy. Nevertheless, the expectation of Japanese high energy physics community was very high.

• The expectation had to wait till 1990’s when 12 GeV PS was used to start the world first long base-line neutrino experiment
Neutron facilities (1970’s)

- **Nuclear reactors**
  - HFBR---BNL, HFR---ILL (Grenoble)

- **Accelerators**
  - (certain advantage—pulse, wider energy range (TOF))

  Tohoku University--- based electron linac
  
  ISIS ----Rutherford Lab. UK
KENS was constructed using 500MeV booster synchrotron (late 1970’s)

• Technology developed in Tohoku neutron facility was important in pushing this project------Ishikawa
• KENS and JRR-3 became complimentary facilities for neutron users in Japan in 1980’s

Muon facility (1978)
• It officially belonged to Meson Science Facility of U. of Tokyo
Director Nishikawa giving a speech at the party of ICANS Meeting in KEK, 1980
Neutron as a probe to study material structure

• **Z-independent** → study of smaller Z atoms (lithium)
• Neutron has a magnetic moment → electromagnetic interaction → magnetic property of matter
• **Method:**
  \[
  I(Q) = \sum_{i,j} f_i f_j \exp[iQ(r_i - r_j)]
  \]
  Q: Energy → TOF and scattering angle

Enabling the study of matter
Cristal, liquid, amorphous and nanoparticle
example—roton excitation of superfluid
Proton cancer therapy

- R. Wilson pointed out its possibility (1946)
- Berkeley 1954, Uppsala 1957 started the operation
- KEK working with Medical Division of Tsukuba U. started the operation in 1983
- The technology was accumulated in KEK and it was transferred to the heavy ion therapy facility in
- National Institute of Radiological Sciences
Scene of the proton therapy at KEK
Personal view

- 12GeV machine had so much variety of applications.
- No other machine in the whole world had such varieties.
- The tradition is continued to J-Parc machine
Photon science (use of X-rays)

- Material science
- Biology especially structural biology
- Imaging
- Therapeutic application
- Engineering
History of Photon Facilities

• First generation ---INS electron synchrotron (Taizo Sasaki)—1960’ advantage over traditional x-ray source —intensity, range of frequency--

• Storage Ring
  Early 1970’s  ACO---Orsay, Tantalus—Wisconsin
  1975  INS-SOR
Photon Factory

- Construction started 1978
- Utilization started 1982-1983
Checking the site of Photon Factory
First director of Photon Factory Dr. Kohra giving a speech at its inauguration

Dr. Taizo Sasaki listening to Mr. Shigetou
Personal Experience

- I attended a symposium at Slac in early 2000 and one European researcher gave a presentation, in which he wrongly claimed that SOR machine was first built in Europe. Professor Winick stood up and fiercely corrected it by saying that the first SOR was actually built in Japan. He talked about INS-SOR built by Taizo Sasaki.

- When I was ICFA chair, we discussed synchrotron radiation facility all over the world. Some described Japan as “shining with synchrotron radiation. I was proud of it and hope it will continue to be so.
US-Japan Collaboration in High Energy Physics

• In 1979 the agreement was signed in SLAC

• It continues until now – one of the longest lasting collaboration projects
First US-Japan meeting in SLAC, 1979
Nishikawa, Panofsky, Lederman, ----
Second US-Japan meeting in Gotenba

US-Japan meeting in 1991

B. Richter, Ozaki, H.S.---
TRISTAN Project

TRISTAN, which stands for Transposable Ring Intersecting Storage Accelerator in Nippon, aims at achieving electron-positron colliding beam experiments at a total collision energy of about 60 GeV.

The construction of the TRISTAN accelerators, which began in 1981, is progressing on schedule towards the commissioning, which is planned to take place in November 1986.

Kimura, 1986
Inauguration ceremony for TRISTAN
Nishikawa, Panofsky, Nambu,---
Photos of TRISTAN related activities

Construction of TRISTAN tunnel

Birds eye view of TRISTAN site

TRISTAN Advisory Committee
Experimental groups of TRISTAN

- TOPAZ — Tokyo, Nagoya,
- VENUS --- Kyoto, Tsukuba, Tohoku,
- AMY ----- U. of Hawaii, Virginia Tech, Princeton,
Venus control room

Topaz group

Amy group
Celebrating the completion of TRISTAN machine
TRISTAN machine was the highest energy machine in the world from 1986 to 1989 (LEP in CERN followed)

Original purpose was to find top quark but energy turned out to be too low for this purpose (electron-positron energy is still too low, 2021)
It found instead
• QCD---existence of triple gluon coupling
• EW-----three generation of neutrinos

Almost 100 physics papers and equal number of PhD’s

For ethnographic studies of high energy physics in the US, Europe and in Japan since the 1970s see
Personal summary of TRISTAN Project

• The choice of machine type was influenced by the success of spear discovering charm quark and tau lepton
• TRISTAN was originally designed to discover top quark
• Eventually it was transformed to B factory and it contributed to HEP by affirming the KM model for CP violation
• It has recorded and still keeps recording the world highest luminosity
(Theoretical) Physics of 1980’s

• Completion of QCD and EW model (standard model)
  Asymptotic freedom (1973, Gross, Wilczek, Poltzer),
  Lattice QCD (Wilson, 1974), CKM (1973)

• Effort towards the Grand Unification (SU(5), SO(10))

• Emergence of superstring theory
  absence of anomaly (1983)
  Calabi-Yau (1985)-----Supersymmetry

• M-theory in 10dimension unifies all string models (1990)
Kamiokande and Long Baseline Neutrino Experiment

• Kamioka facility was started as a facility of KEK (1979) and later it was transferred to Cosmic Ray Institute of U. of Tokyo

• Discovery of $\nu_e \nu_\mu$ anomaly in atmospheric neutrion observation (1998),

• KEK started the construction of long baseline for the neutrino beam for Kamiokande (1999)
Photos of Kamioka and related facts

K2K group photo
SSC to LHC and Physics of 1990’s

• SSC (Superconducting Super Collider) in US and LHC (Large Hadron Collider) in CERN were in competition in 1990’s

• SSC ($2\times20\text{TeV}$) and LHC ($2\times7\text{TeV}$) both aiming at the discovery of Higgs particle

• SSC demise came in 1993
“As Congressional opposition grew, SSC construction accelerated in 1992 after a successful superconducting magnet test. Tunnel boring began in January 1993. But William Clinton’s election as President brought a new administration less favorably disposed to the project. At an April 1993 summit with Japanese premier Kiichi Miyazawa, Clinton did not request Japan’s participation in the SSC Laboratory. In June the House voted resoundingly for an amendment to cancel the project, but after heated House and Senate committee hearings, the Senate voted strongly in favor of continuing it. In early October a joint House-Senate committee decided to award the project its full $640 million budget for fiscal 1994. But on October 19, the House dramatically rejected the entire Energy and Water Development bill by a 2-to-1 margin, and Senate support evaporated. The allocated funding was used during the ensuing year to terminate the project and compensate Texas for its investments.”

“The Demise of the SSC, 1991–94”
Michael Riordan, Lillian Hoddeson, Adrienne W. Kolb
DOI:10.7208/chicago/9780226305837.003.0006
Miyazawa had prepared answer

- President Bush had asked Pm Miyazawa to join SSC in Texas
- Pm asked Japanese Academy and Science and Technology Committee to discuss the issue.
- “If Japanese researchers are interested, we will join”.
- Answer (h.s.) was “yes, but on the condition that domestic project (B factory) is to materialize.”
- Final decision:
  accelerator construction---- MITI
  physics participation--------MEXT
B-Factor

- Asymmetric collider of 8 and 3.5 GeV Final goal of luminosity $10^{34}$/seccm$^2$
  ---It was essential to use Tristan main ring rather than AR
- Construction approve after SSC demise
- Physics purpose ----CPV (KM, Bigi-Sanda)
New technologies to reach the luminosity of \( \frac{10^{34}}{seccm^2} \)

- Final focusing
- Cavities—ARES (normal), Super cavity, Crab cavity
- Overcoming the positron emission?
Detector

- SVD was successfully installed
- EM calorimeter CsI crystal

(personal memory----Shanghai Crystal Lab, Moscow, Novosibirsk,---)
CPV was found to be consistent with KM

Details described in a paper:

Physics Achievement from Belle Experiment

B factory was completed in 1998.

The last piece of dipoles installed.
Belle group photo

First event in Belle detector
Celebrating highest luminosity

Event for CP violation discovery
KEK Laboratory to KEK Organization

• KEK became the High Energy Accelerator Organization in 1997
• It is not related to the KEK becoming an “Independent Agency “ that started 2004
• The purpose of the structure change was for INS to leave U. of Tokyo and join KEK----→ to ensure the smooth construction of JHF (Later called J-Parc)
• The current structure was decided at that time
KEK as an Independent Agency

- KEK became an “independent agency” in 2004
- “Inter-university research institutes” status was retained

“Inter-university research institute” idea is unique to Japan. It is also an idea created by the high energy physics community.
Establishment of Advanced Graduate University ---completion of Inter-university Research Institute ---

• Establishment in 1988
• Educational system for “Inter-university research institute”
• KEK has three graduate courses belonging to “Sokendai”
• Ideal place for inter-university research institutes to collaborate
First president of Sokendai, Professor Nagakura
Giving a speach at the time of inauguration
J-Parc project in collaboration with JAEA

Interest of three institutions matched for collaboration

• JAERI——Omega (accelerator driven subcritical nuclear reactor for the elimination of high level nuclear waste, neutron facility complimentary to JRR-3)
• INS——nuclear physics project (Neumatron → JHP → JHF)
• KEK——Upgrading of KENS

• 1992---head of three institutes started the discussion
  (Yamazaki, Matsuura, h.s.)
Results of the negotiation

- **INS** can join KEK leaving U. of Tokyo

- **JAERI** wants the site of the project to be Tokai (it requires the construction of a nuclear reactor)

- **1997---**INS joined KEK---> KEK Organization

- **1999---**Memorandum between JAERI and KEK on the collaboration towards the construction of J-Parc
2001---Merging of STA and Monkasho

J-Parc became the **symbolic project** of the merging of two agencies
Accelerator components agreed between KEK and JAERI

- 200MeV linac as the injector and for ADSNR
- 3 GeV Booster for the main ring booster and for the neutron and muon facility (aiming at 1MW in future)
- 50GeV main ring for nuclear physics and for neutrino beam
International Linear Collider
--- High Energy Physics of 21st Century---

• Tantalizing Higgs particle was found in LHC in 2012
  But it failed to find any “superparticle”
• Theoretical physics of 1990’s were mainly on “superstring theory”
  Failure of LHC to find any “superparticle” was a blow to it

• Does Higgs particle give masses to all elementary particles?
• Why neutrino is so different from other leptons?
• Does it suggest anything beyond the standard model?

→ Higgs factory
- SLAC---------X-band
- DESY---------Super cavity
- KEK---------X-band, C-band, Super cavity

Technology Selection Committee
  Super cavity

- SLAC lost the leadership
- DESY became radiation facility
- KEK is taking the leadership
  - Iwate prefecture as a possible site
Future of high energy physics and KEK

Throughout the 1990’s and in 21 century, theorists are working on superstring theory.

Is it really “Theory of everything” or just “theory of nothing”? Traditionally, high energy theory kept solving problems by introducing heavier particles: pion, Z,W, heavy quarks and leptons,---

String theory is, in a way, along this tradition by introducing infinite number of particles---string excitations---. But what did it solve?
Can superstring theory be saved?
  Maybe or maybe not.

My own ideas:
• It must solve the generation issue. Calabi-Yau is modular?
• It must solve the dark matter issue because it introduced all the particles up to infinite mass.

We must strongly encourage young generation to work on new ideas beyond (or different from) string theory.
Future KEK

----my personal dream----

• After HEP moves out to ILC Lab in Iwate Prefecture,
• KEK becomes a central organization for material science and biological, chemical and medical sciences with appropriate accelerators as its main facilities.
• We must start working right away how 12GeV Tunnel and TRISTAN tunnel can be utilized and what sort of new facilities are to be built.
• Such new ideas as muon microscope, quantum computer based on accelerator, cancer therapy using neutrons (BNCT, for example) and other new ideas must be encouraged and respected.

Young generation is encouraged to come up with new ideas.