

Accelerator Control Class for Graduate Students in SOKENDAI, KEK



Oct. 10, 2023 for ICALEPCS 2023

Norihiko Kamikubota (KEK, Ibaraki, Japan)

and

Kazuro Furukawa, Masanori Satoh, Shuei Yamada, Noboru Yamamoto (KEK)

We are also at **the Graduate University for Advanced Studies, SOKENDAI**, Japan



Contents of the talk

- 1) SOKENDAI and KEK
 - KEK is an “inter-university research institute corporation”
 - More about SOKENDAI
 - Accelerator Science Program, KEK
- 2) Accelerator Control Class
 - Accelerator control class – two courses during 2019-2022
 - “Introduction to Accelerator Control System”
 - “History of Accelerator Control Systems”
 - Issues from the experiences
- 3) Summary

Contents of the talk

- **1) SOKENDAI and KEK**

- KEK is an “inter-university research institute corporation”
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- **2) Accelerator Control Class**

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- **3) Summary**

1) SOKENDAI and KEK

- KEK is an “**Inter-University Research Institute Corporation**”



2021
KEK 50th
anniversary

Inter-University Research Institute Corporation
High Energy Accelerator Research Organization (KEK)
Tokai Campus
J-PARC Center, Accelerator Division



Dr. Norihiko Kamikubota



203-1 Shirakata, Tokai-mura, Naka-gun,
Ibaraki, 319-1106 Japan
TEL: +81-29-284-4272, 4801
FAX: +81-29-284-4805
E-mail: norihiko.kamikubota@kek.jp

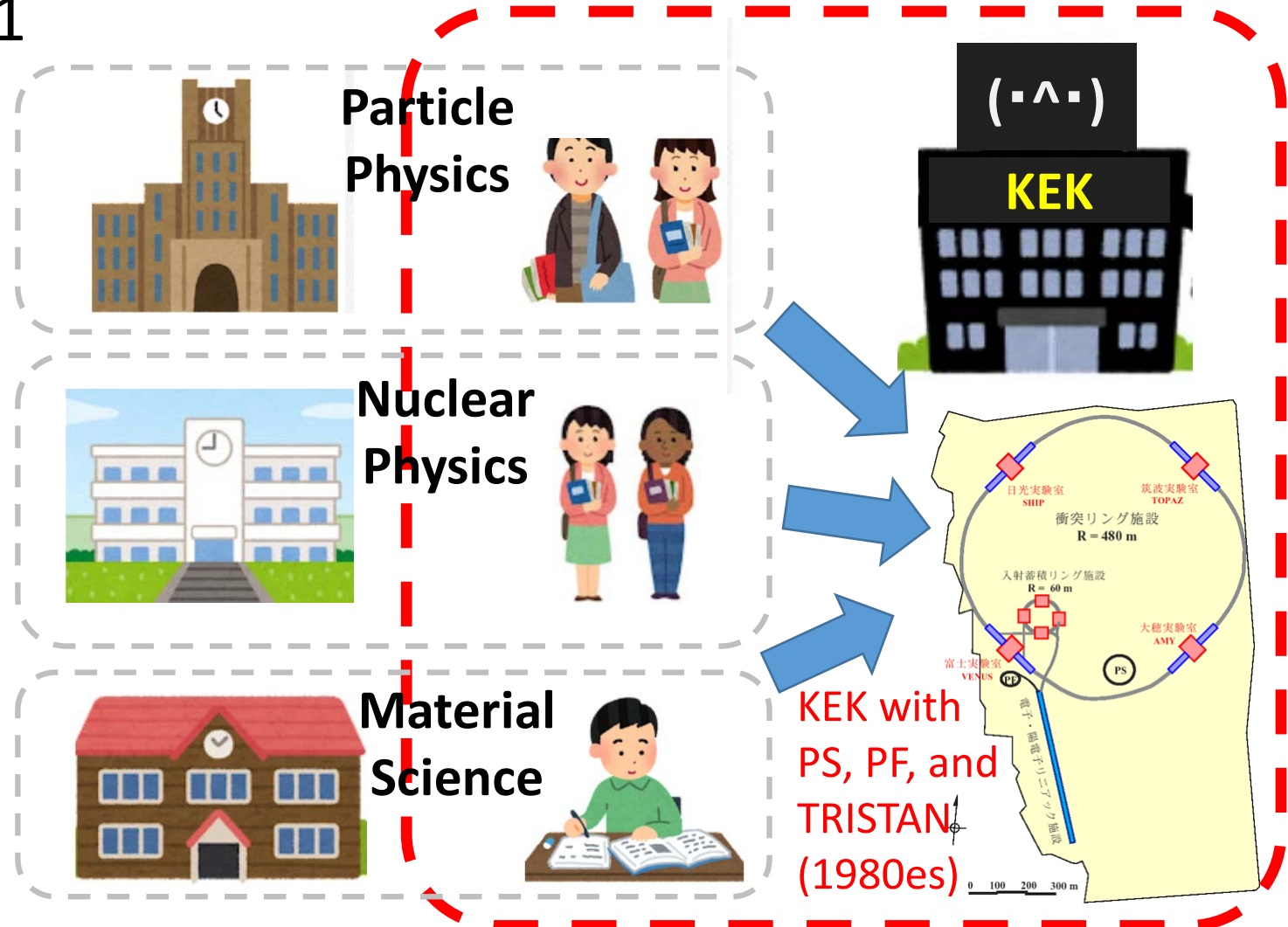
My business card
with the KEK's standard format

1) SOKENDAI and KEK

- KEK is an “**Inter-University Research Institute Corporation**”
- **KEK** was established in 1971

• KEK constructed large accelerators, and accepted university students

⇒ Therefore, “**Inter-University Research Institute**”



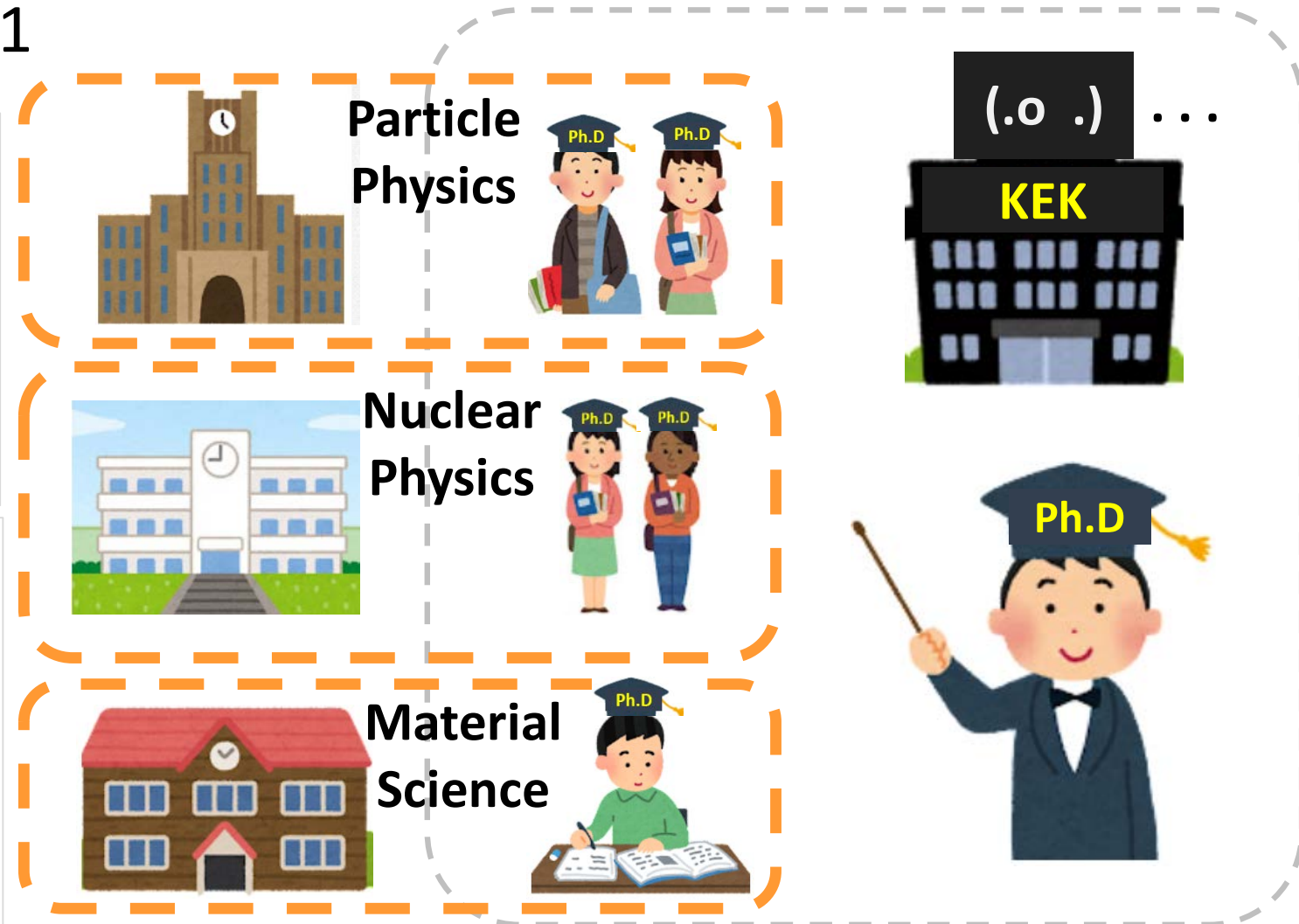
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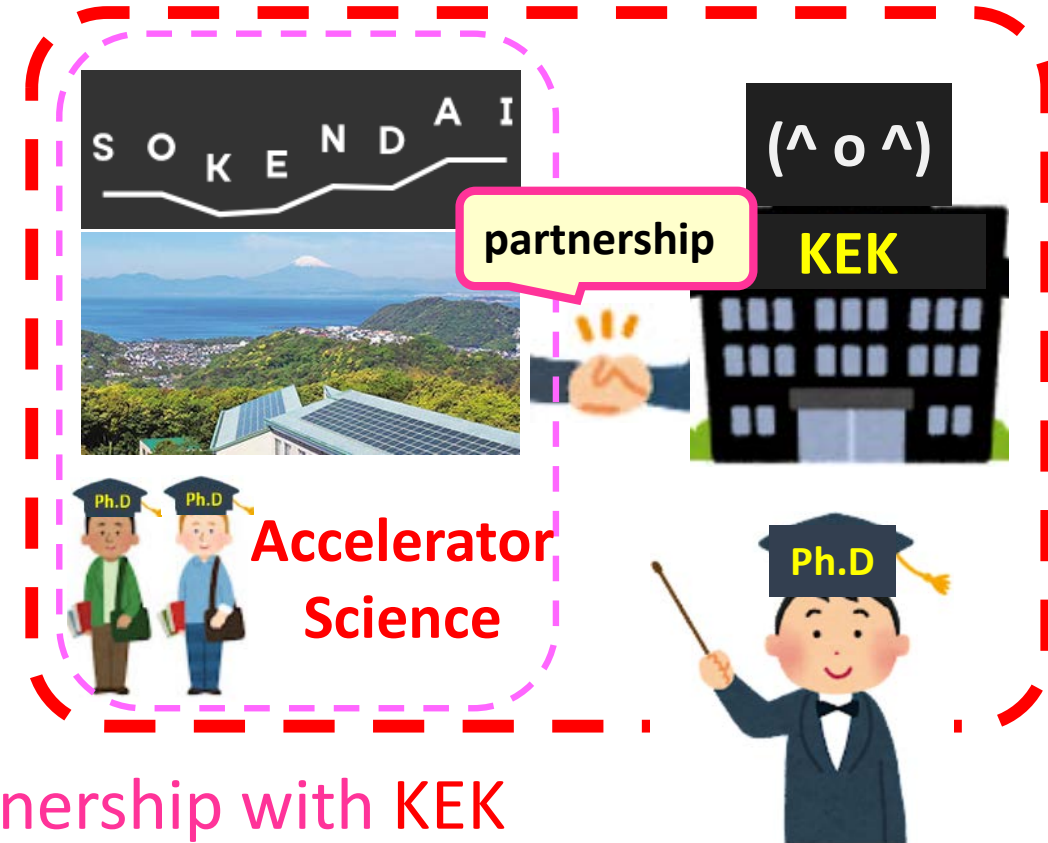
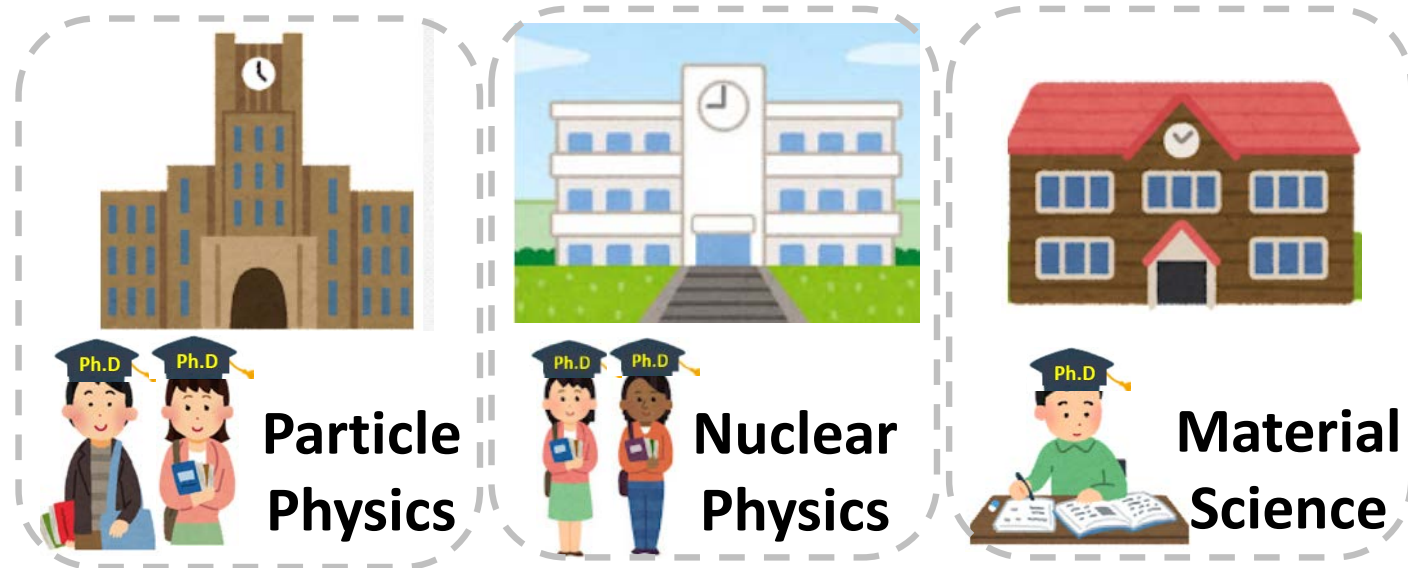
⇒ Therefore, “**Inter-University Research Institute**”

- KEK is **not a university**
- Each university provides a graduate student a Ph.D on Particle physics, Nuclear physics, Material science



1) SOKENDAI and KEK

- KEK is an “Inter-University Research Institute Corporation”
- With SOKENDAI (1988-)



- SOKENDAI is a graduate university, with a partnership with KEK
- SOKENDAI provides a graduate student a Ph.D on “Accelerator Science” Program
- KEK staff members are teachers, contribute to the Ph.D Processes

1) SOKENDAI and KEK

- More about SOKENDAI

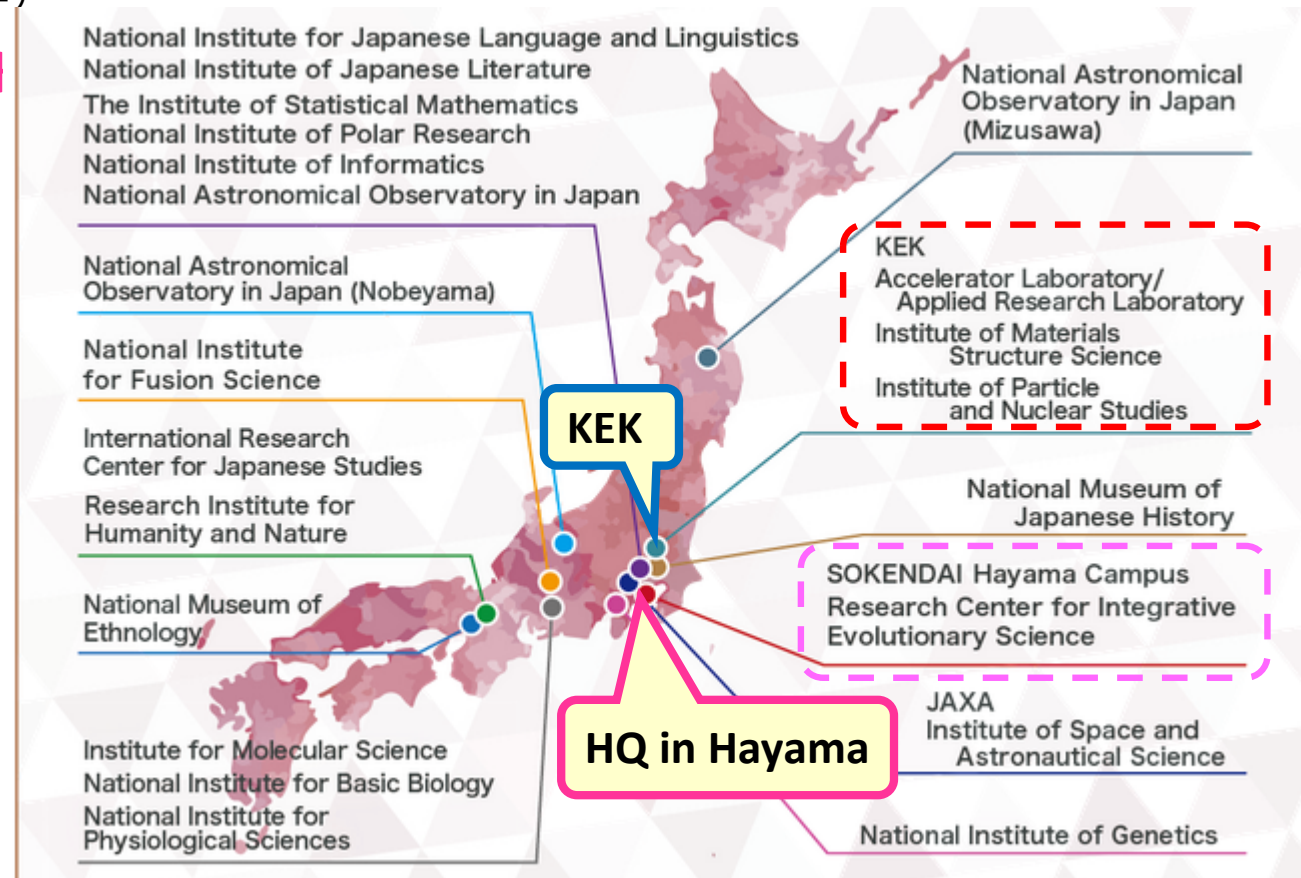
- **The Graduate University for Advanced Studies** (in English)
- SOKENDAI = 総研大 (総合研究大学院大学)
- A **National** university, established 1988
Hayama, Kanagawa, Japan

- SOKENDAI is a graduate university

- No undergraduate course

- SOKENDAI has

- **Partnerships with inter-university research institutes => Map**
- **KEK is one of partner institutes**

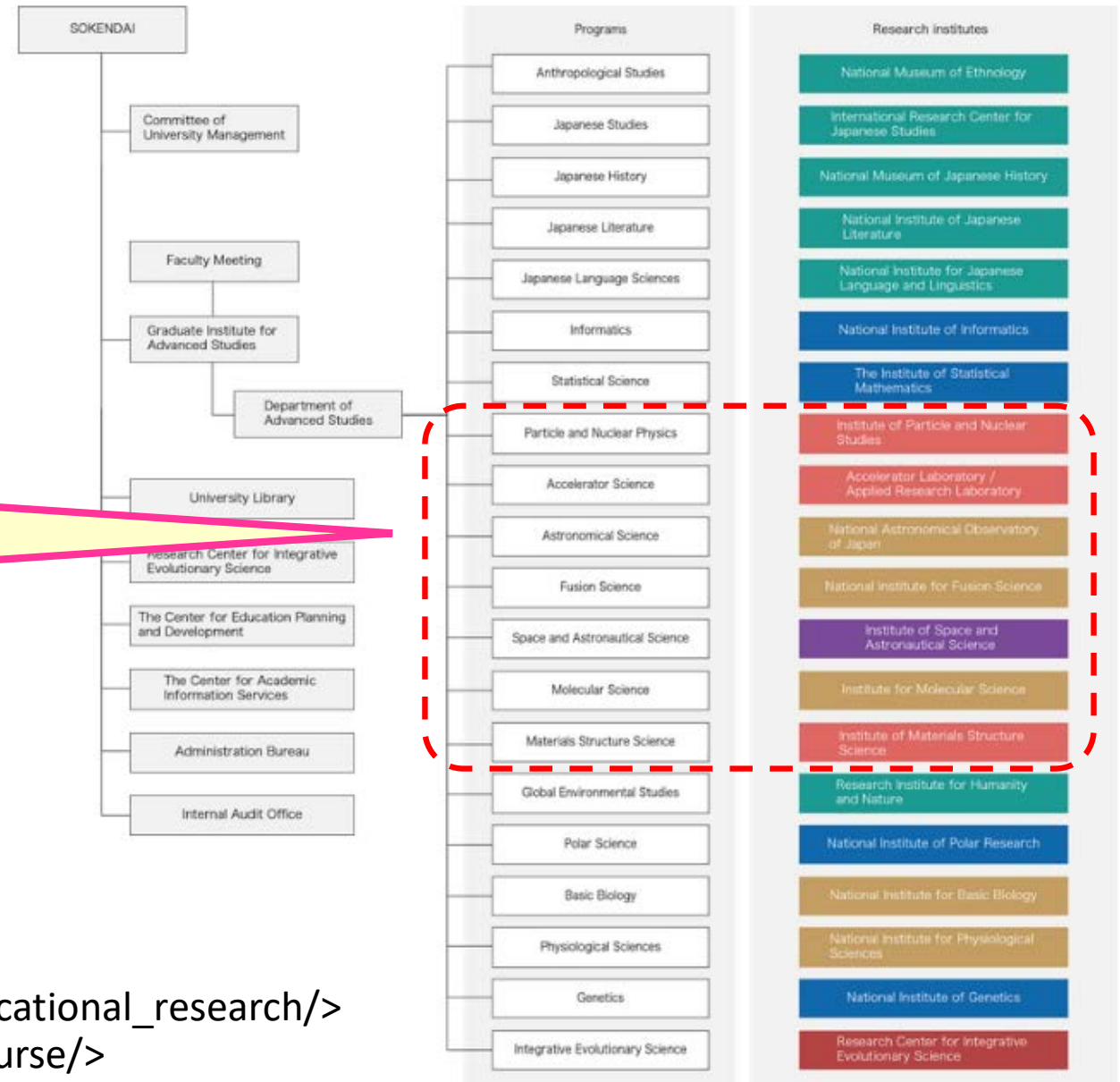


Ref) <<https://www.soken.ac.jp/en/features/>>

1) SOKENDAI and KEK

- More about SOKENDAI
 - 20 research and education programs

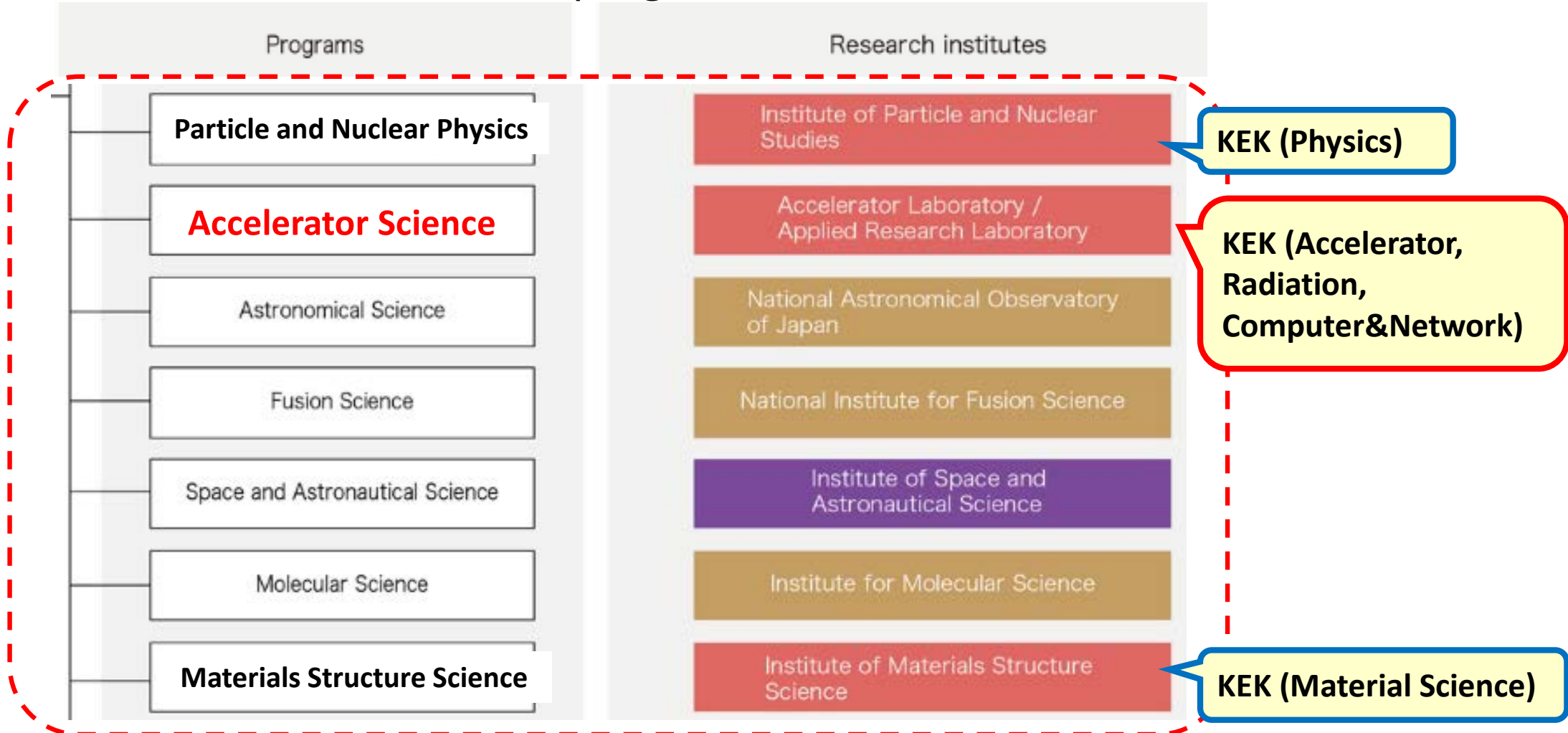
Enlarge this part ..



Ref) <https://www.soken.ac.jp/en/outline/organization/educational_research/>
Ref) <<https://www.soken.ac.jp/en/education/curriculum/course/>>

1) SOKENDAI and KEK

- More about SOKENDAI
 - Research and Education programs



1) SOKENDAI and KEK

- Accelerator Science Program, KEK
 - Students in KEK (2023)

Program	Number of students	International students (non-Japanese) #
Nuclear and Particle Physics	48	13/48 = 27%
Materials Structure Science	8	4/8 = 50%
Accelerator Science	14	5/14 = 36%

mostly from countries in Asia region

- Courses in Accelerator Science Program
 - 44 courses (2023) -> next page
 - 2 of 44 are related to accelerator control

1) SOKENDAI and KEK

- Accelerator Science Program, KEK

- Courses in Accelerator Science Program

- High Energy Accelerator Science Seminar
- Seminar on Introduction to Accelerator
- **Radiation** Physics
- Beam Physics
- Particle Accelerator Design
- Accelerator **magnets and power supplies**
- **Beam instrumentation** basics
- Superconducting technology and **cryogenic** engineering
- Beam acceleration and **RF** systems
- **Vacuum** science and technology for particle accelerators
- **Introduction to accelerator control system**
- ... and more

- Foundation of Data Science
- **Control of distributed devices for large systems**
- Practicum for accelerator science using the education-oriented electron linear accelerator
- Introduction to Robotics

1 credit
(2-day to
a week)

2 credits
(half-year
courses)

- Most of courses are “optional”
- To be **held on request from students**

Complete list
of 44 courses

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2) Accelerator Control Class

- Accelerator control class – two courses during 2019-2022
 - A) **Introduction to Accelerator Control System** (13 times over ~4 month)
 - 12 lectures or hands-on or guided-tours by teachers, 1 presentation day by students
 - B) **Control of Distributed Devices for Large Systems** (2 days)
 - 2-day seminar and hands-on = “**EPICS seminar and hands-on**”
 - Note: KEK sometimes hosts EPICS seminars for young staff, company staff, students
- Statistics of graduate students

Year	Course A) (non-Japanese)	Course B) (non-Japanese)
FY2019-2 (Oct.2019-Feb.2020)	4 (3)	-
FY2020-2 (Oct.2020-Feb.2021)	-	3 (2)
FY2022-1 (May.2022-Aug.2022)	1 (1)	1 (0)
FY2022-2 (Oct.2022-Feb.2023)	1 (0)	-

During 4 years,
10 (7) students
in total

* Among above, 1 from Particle and Nuclear Physics, 1+1 from Material Structure Science (both are KEK's students)

2) Accelerator Control Class

- “Introduction to Accelerator Control System”: C

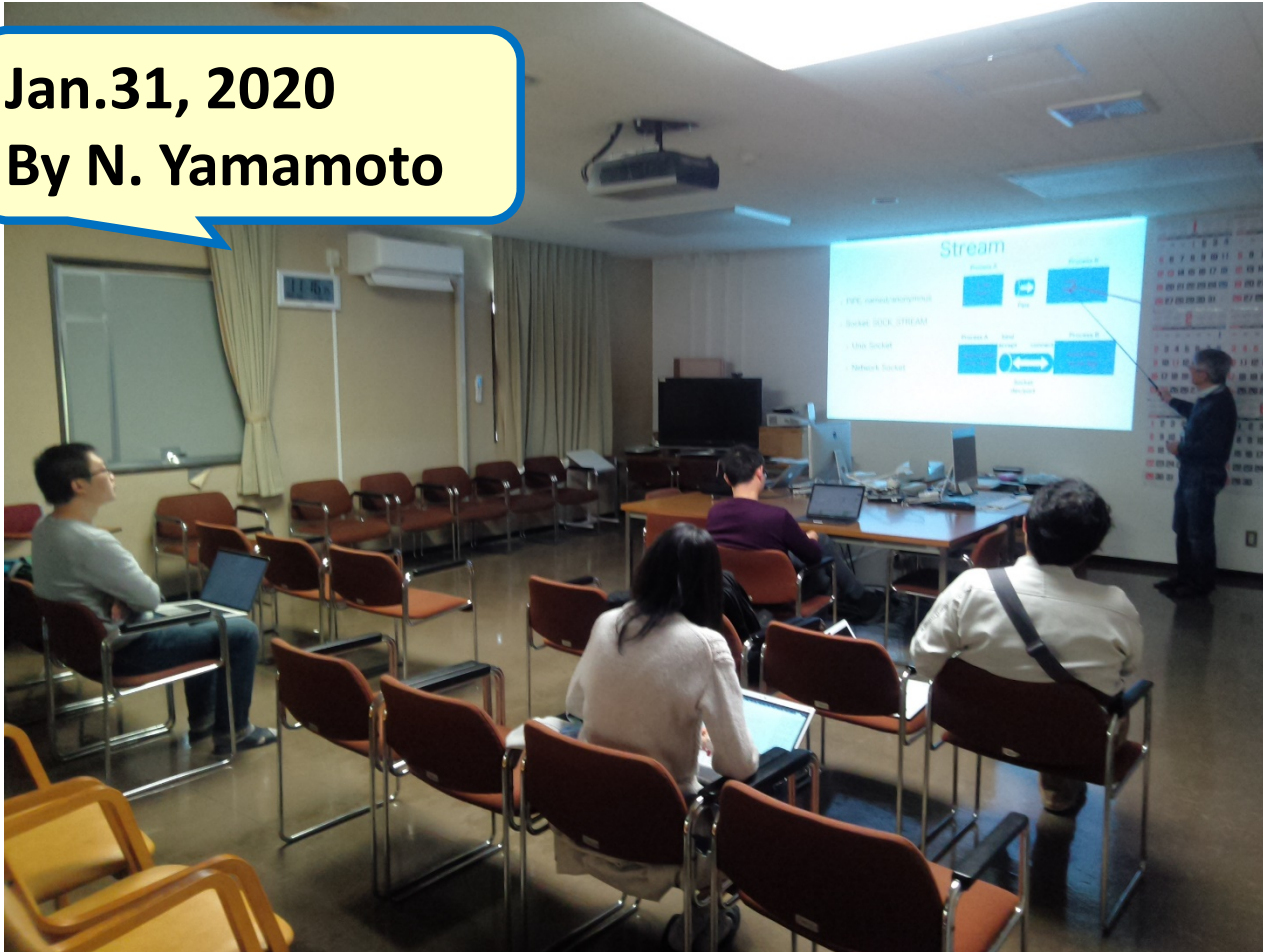
- a) **Lecture by a teacher**
- b) **Guided tour**
- c) **Hands-on**
- d) **Summary by student**

Date	Title	Contents	
1: May 12	Controls: Introduction	Control system design and operation	K. Furukawa
2: May 19	History	History of accelerator control systems	N. Kamikubota
3: May 26	Software	Software technology	S. Yamada
4: June 02	Hardware	Hardware technology	K. Furukawa
5: June 16	Implementation (KEKB&Linac)	Guided tour to KEKB&Linac	M. Satoh, K. Furukawa
6: June 23	Implementation (J-PARC)	Guided tour to J-PARC	N. Kamikubota, S. Yamada
7: July 06	Timing	Timing system	N. Kamikubota
8: July 14	Cyber security	Cyber security for control systems	N. Kamikubota
9,10: July 21 (full day)	EPICS lecture and hands-on	Lecture and hands-on of EPICS with a Raspberry-pi	S. Yamada, N. Kamikubota
11: July 28	International collaboration	Introduction of EPICS collaboration	K. Furukawa, N. Kamikubota
12: Aug.04	Controls: protection	Safety protection systems	K. Furukawa
13: Aug.25	Presentation day	Summary presentation by student	by Student (J.P.)

2) Accelerator Control Class

- “Introduction to Accelerator Control System”
 - Photo of a lecture day (FY2019-2)

Jan.31, 2020
By N. Yamamoto



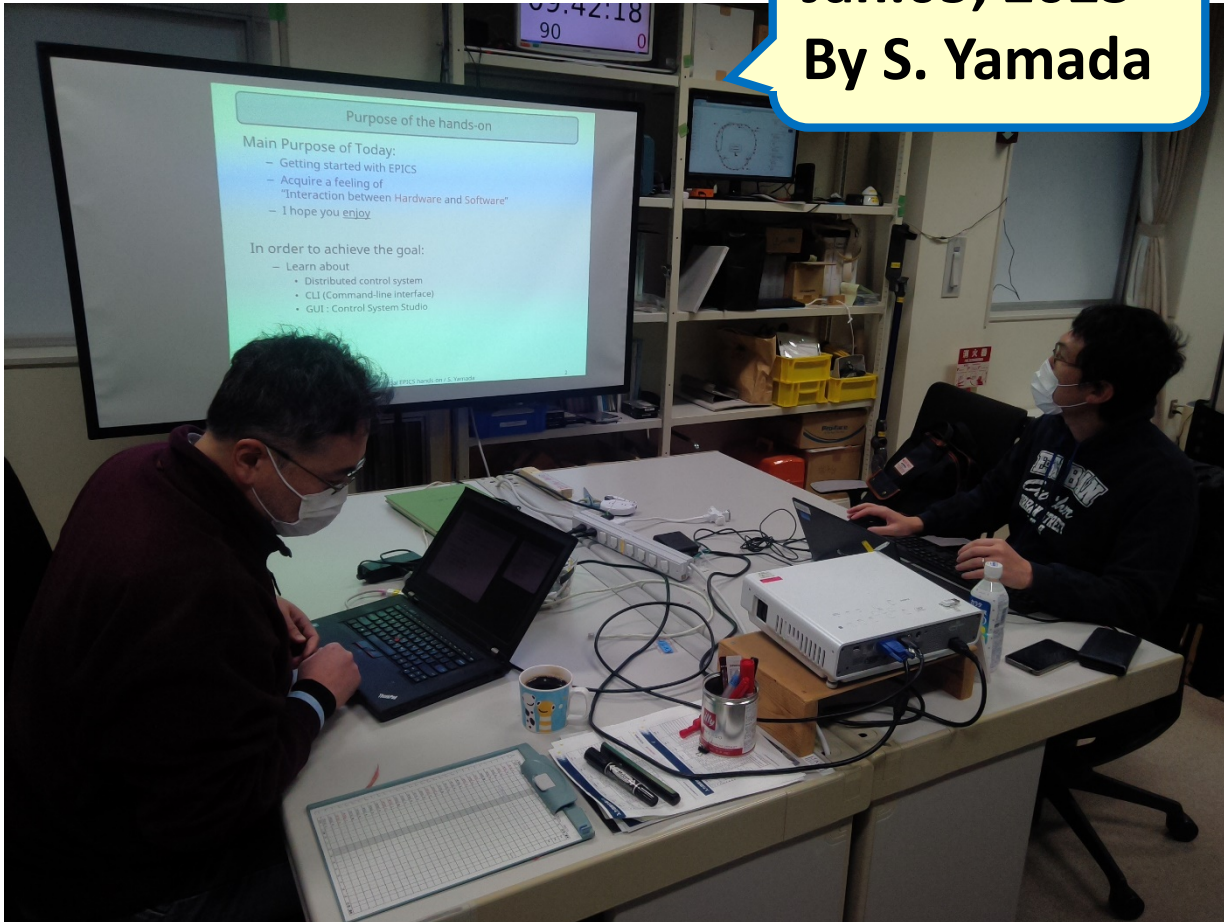
- 1 teacher + 4 students
=> good for education !

2) Accelerator Control Class

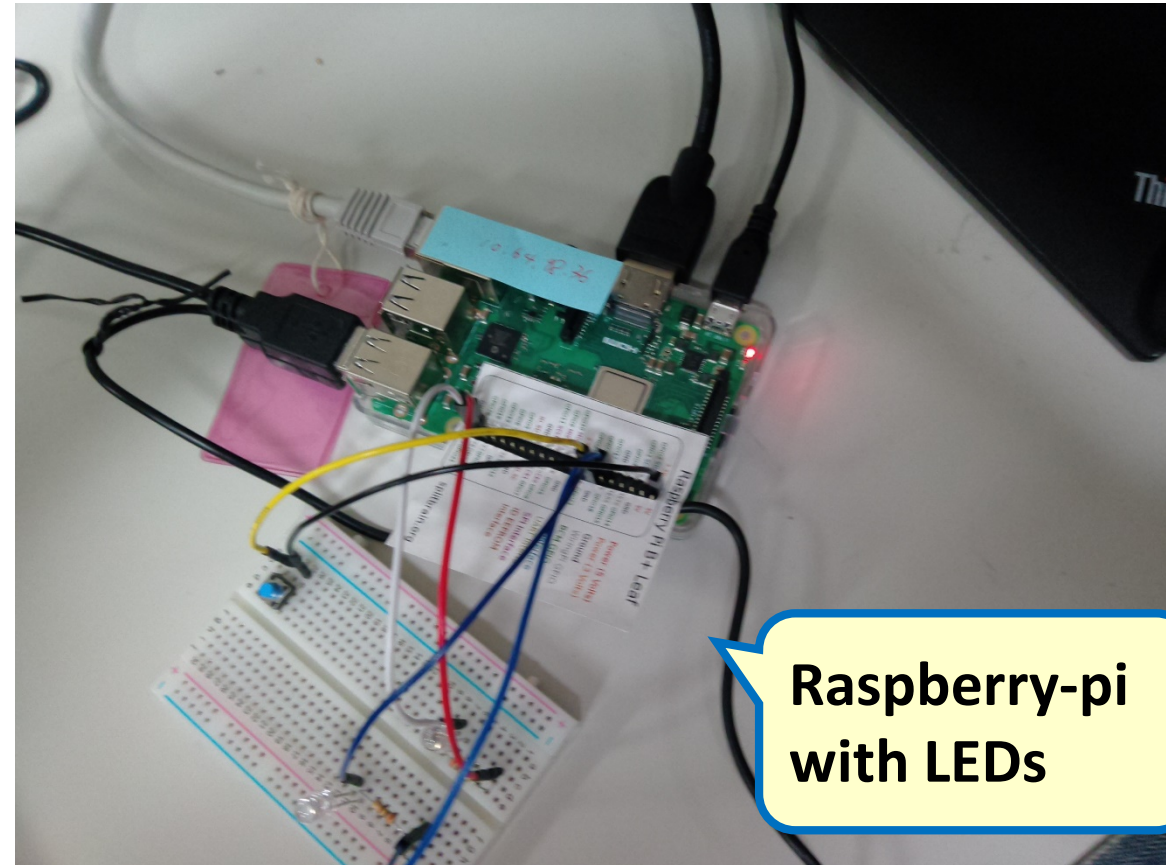
- “Introduction to Accelerator Control System”

- Photo of a hands-on day (FY2022-1)

Jan.05, 2023
By S. Yamada



- 1(+1) teacher(s) + 1 student
=> extremely good for education !!



**Raspberry-pi
with LEDs**

2) Accelerator Control Class

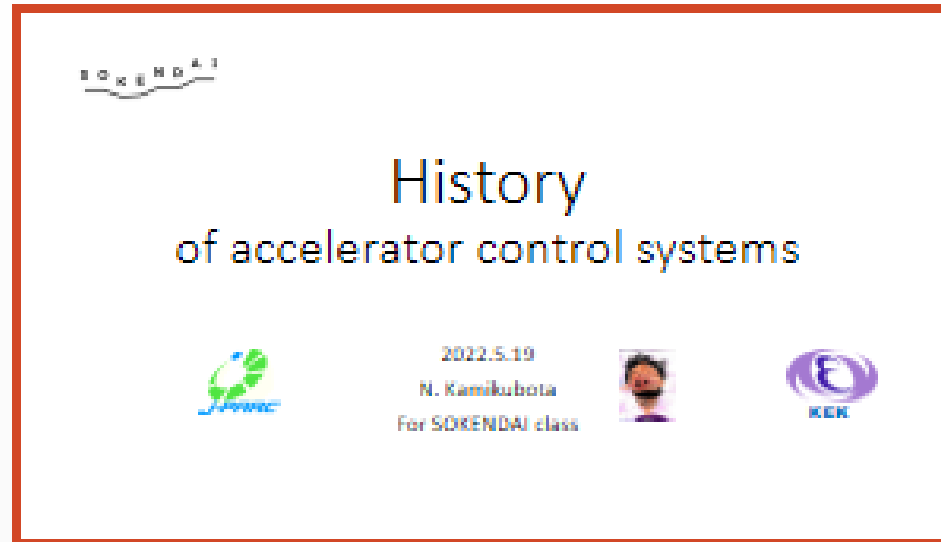
- “Introduction to Accelerator Control System”: Contents overview (FY2022-1)

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**Lecture sample
History**

2) Accelerator Control Class

- “History of accelerator control systems”
 - As a sample of lectures



2) Accelerator Control Class

- “History of accelerator control systems”
 - As a sample of lectures

28 pages
40 minutes
(without discussion time)

40 minutes -> 2 minutes



1



2



3



4



5



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7



8



9



10



11



12



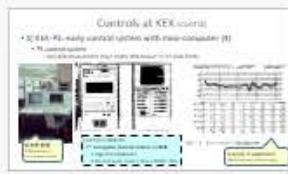
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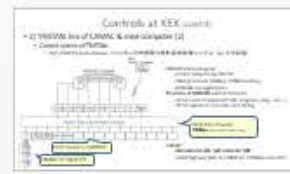
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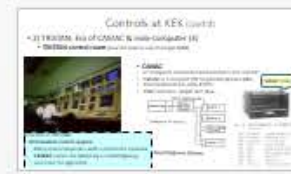
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2) Accelerator Control Class

- “History of accelerator control systems”
 - As a sample of lectures

1959 at CERN
An oscilloscope

1968-71 at LAMPF
The 1st Computer-based system

History of accelerator control systems

2022.5.19
N. Kamikubota
For SOKENDAI class

Contents

- 1) Introduction
 - History of Accelerator Controls and KEK Accelerators
- 3) Controls at KEK
 - 1) KEK-PS: early system with mini-computer
 - 2) TRISTAN: Era of CAMAC & mini-computer
 - 3) KEKB: Era of EPICS and VME
 - 4) Now and Next and ...
- 4) Other view-points:
 - (Software: OS and ADE tools)
 - (Research-oriented and Operation-oriented machines)
 - (My experiences during the last 30 years)

Introduction

- Early Accelerator Controls (1)
 - Before 1960's, accelerators were small
 - CERN: 600 MeV Synchrocyclotron (SC) (1957-1990), and Proton Synchrotron (PS) (1959-still working)
 - Machine size (radius) was ~100m

Control in General:

- no modern control system (i.e. no computers, no networks)
- a control room, with oscilloscopes, buttons and knobs, was at the center of the ring
- manual cables were used to feed signals into a control room

Introduction (cont'd)

- Early Accelerator Controls (2)
 - Before 1960's
 - One room was enough to hard-wire all devices (PwrSupplies, Beam-diag sensors, Vacuum valves, ...)
 - Total number of signals = a few hundreds to one thousand
 - Around 1970's
 - Larger accelerator had more number of signals (> one thousand or more)
 - Need a summarized data displays and trend plots
 - Larger accelerator size required wide-area networks (~km or more)
 - Need a signal-multiplexing mechanism over km size (network)
 - Process-automation scenario was needed to manipulate signals
 - Need computers

Introduction (cont'd)

- Early Accelerator Controls (3)
 - A pioneer of computer-based control
 - LAMPF in Los Alamos, 1968-1971, had a computer-based control from the beginning
 - Ref: NIM A352 (1994)S16-520, S.C.Schaller

1. The early LAMPF control system

In the early 1960s, the use of a computer-based control system as a necessary subsystem of a large accelerator was an unprecedented idea.

The control computer was a SEL-4800 processor with 4K-8K 24-bit words of memory. This was a reliable, but not reprogrammable, separate from the SEL-4800. Again the LAMPF staff wrote a multi-tasking operating system. Operator access to the system was provided by several multiplexed terminals, each of which contained a colour character CRT, a raster scope, software-ethics bench, and an array of buttons (KIOSK). The colour CRT.

Also were displays: FORTISAN was chosen for writing the application programs, and the operator.

Communicating with 5000 signals

The fixed-end was the KICK systems, developed in Los Alamos for previous machines. Later (CERN-1967), LAMPF introduced CAMAC with DEC's VAX computers.

Control of LAMPF:
- LAMPF developed a computer-based control system in 1968-1971

Figure 2
One of the two identical LAMPF CCR operators' consoles. One looks to the rear area for CCR access to various START/STOP systems.

Figure 3
Acceleration control panel for the 800 MeV Proton Synchrotron in graphics scope, selected line displays on alignment scope, and Accelerator Status Test 1: test panel.

Introduction (cont'd)

- おまけ) History of Accelerator Laboratories
 - 1950's to 1970's, accelerator research institutes started

EU:

- CERN 1954
- DESY 1959
- GSI Helmholtzzentrum 1960

ASIA:

- KEK 1971
- The former institute (JNC, Institute of Nuclear Study, Tokyo Univ.) founded in 1955
- The former institute (JMD, Institute of Modern Phys., CAS) founded in 1950
- IHEP Beijing 1973

US:

- SLAC 1962
- Fermilab 1967
- BRENDA 1967



2) Accelerator Control Class

Controls at KEK

- 1) KEK-PS: early control system with mini-computer (1)
- PS Control room (March, 1976)
 - During commissioning to accelerate protons to 8GeV



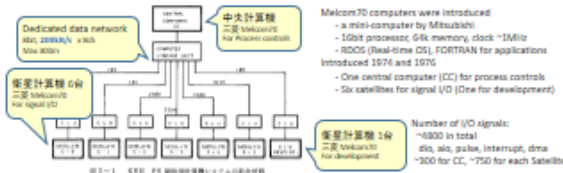
Controls at KEK (cont'd)

- 1) KEK-PS: early control system with mini-computer (2)
- PS Control room (in early days: 1980's?)



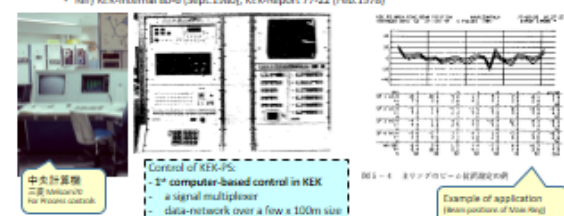
Controls at KEK (cont'd)

- 1) KEK-PS: early control system with mini-computer (3)
- In PS control room, you can find ...
 - Full of buttons, monitors(CRT), oscilloscopes, large CRTs (lightly fixed, not easy to change)
 - Hard-indicators on the wall for status display, a traditional telephone
 - Computers were behind – It was the 1st computer-based control system in KEK



Controls at KEK (cont'd)

- 1) KEK-PS: early control system with mini-computer (4)
- PS control system
 - July KEK-internal 80-6 (Sept. 1980), KEK-Report 77-22 (Feb. 1978)



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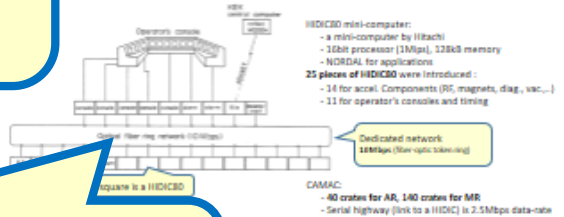
**1976 at KEK-PS
Mini-computer
based system**

Controls at KEK (cont'd)

- 2) TRISTAN: Era of CAMAC & mini-computer (1)
- About TRISTAN
 - e-/e+ collider machine, 300 GeV
 - Searched for TOP quark
 - 1987-1995 in operation
- From KEK PS to TRISTAN
 - [1-N] Many computers and mini-computers
 - [N-1] One central computer
- CAMAC as standard signal I/O with mini-computers
- NODAL is an interpreter language, developed for CERN SP5, for application development
- original NODAL was modified for TRISTAN using NODAL, scientists can develop an application by themselves
- TRISTAN – control signals
- >200 control signals


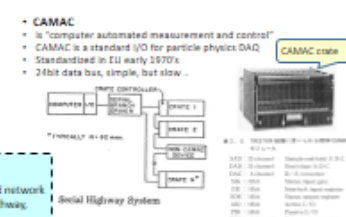
Controls at KEK (cont'd)

- 2) TRISTAN: Era of CAMAC & mini-computer (2)
- control system of TRISTAN
- Ref) OHF'85 by Karokawa, トリスタン用大規模分散計算機制御システム, by 日立評論




Controls at KEK (cont'd)

- 2) TRISTAN: Era of CAMAC & mini-computer (3)
- TRISTAN control room (now the room is used for super-KEKB)

Controls at KEK (cont'd)

- 2) TRISTAN: Era of CAMAC & mini-computer (4)
- B.t.w. combination of DEC's VAX computer and CAMAC was the standard in particle physics in 1980's
- DEC (Digital Equipment Co.)
 - was a computer company during 1960's to 1990's
 - provided PDP-11 (16bit) and VAX-11 (32bit) mini-computers
 - Multi-task Operating System "VMS" with DECnet networking
 - VAX-FOOTAN for applications
 - developed a 64bit RISC "Alpha-chip" in 1991, 64bit OpenVMS in 1992
 - But ... -> Compaq (1998) -> HP (2001)
- Best-sellers
 - VAX11/780 & VMS in 1977 - introduced at CERN, KEK, and many others
 - MicroVAX-4 in 1985 - sold 20,000 sets in the 1st one year
- Experiments of Particle Physics & Nuclear Physics in 1980's
 - MicroVAX + CAMAC was the de-fact standard for DAQ
 - KEK-PS and TRISTAN did not use DEC computers, instead Japanese computers



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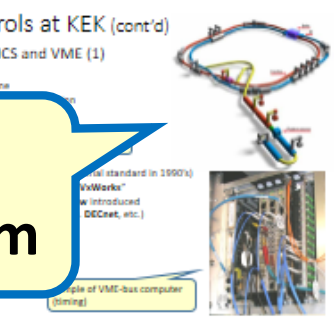
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**1987 at KEK TRISTAN
Distributed control system**

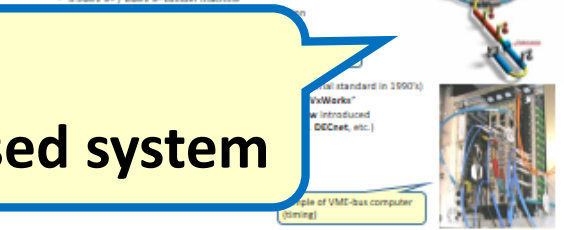
Controls at KEK (cont'd)

- 3) KEKB : Era of EPICS and VME (1)
- About KEKB
 - 3.524 GeV e-/e+ collider machine
- Control system of KEKB
 - Control standard in 1990's
 - VMEWorks
 - introduced DECnet, etc.
- Example of VME-bus computer (timing)



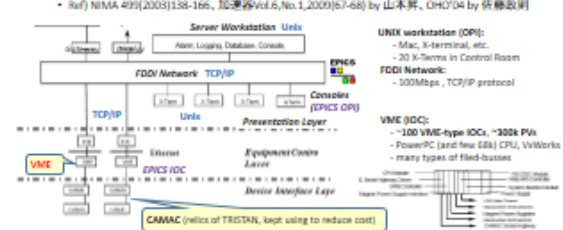
Controls at KEK (cont'd)

- 3) KEKB : Era of EPICS and VME (2)
- Control system of KEKB
- Ref) NIMA 499(2003)138-165, 加速器Vol.6, No.1, 2009(57-68) by 山本昇, OHF'04 by 伊藤誠則



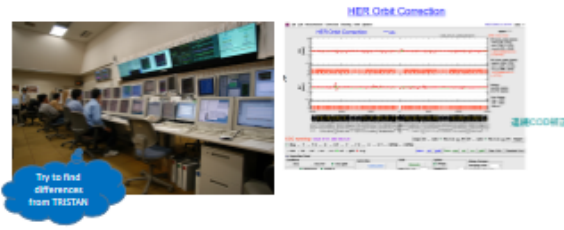
Controls at KEK (cont'd)

- 3) KEKB : Era of EPICS and VME (3)
- Control system of KEKB
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Controls at KEK (cont'd)

- 3) KEKB and J-PARC : Era of EPICS and VME (3)
- KEKB control room (2003?)
- Sample appl. by SAD



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**1998 at KEKB
EPICS+VME+TCP/IP-based system**

2) Accelerator Control Class

- “History of accelerator control systems”
 - As a sample of lectures

Controls at KEK (cont'd)

- 4) Now and Next and ... (1)
 - Summary

Control in General: (Around 1960)

- no modern control system (i.e. no computers, no networks)
- a control room, with oscilloscopes, buttons and knobs, were at the central control room
- metal cables were used to feed signals into a control room

Control of LAMPF: (Around 1970)

- LAMPF developed a computer-based control system in 1968-1971

Control of KEK-PS: (Around 1980)

- 1st computer-based control in KEK
- a signal multiplexer
- data-network over a few x 100m size (~2Mbps net)

Control of TRISTAN: (Around 1990)

- Distributed control system
- Many mini-computers with a dedicated network (30Mbps net)
- CAMAC used for I/O

Control of KEKB: (Around 2000)

- Use common standards (100Mbps net)
- EPICS and VME and TCP/IP were selected
- KEKB specific: SAD and PLCs

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Summary

Controls at KEK (cont'd)

- 4) Now and Next and ... (2)
 - Need more years to conclude ..

Control of J-PARC: (Around 2010-2020)

- (following KEKB)
- Use common standards (1G-10G-40Gbps net)
- EPICS and VME(?) and TCP/IP
- Follow KEKB
- SAD for HL application, PLC (ladder) for I/O
- New ?
- PLC-based Epics IOC, low-cost IOC (micro-server)
- embedded EPICS with FPGA
- external threat (computer virus) (virus, attacker)

Control of (check new accelerator's design, like ESS): (Around 2025)


- (candidates)
- common standards - EPICS and TCP/IP but not VME anymore
- microTCA (especially Ilrf) and etherCAT (simple i/o)
- New ?
- embedded AI
- low-cost IoT sensors
- Epics7 ?
-
-

Let's discuss!
What's will be key terms around 2025 ?

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Topics to discuss with students (H/W standards of each ERA)

2) Accelerator Control Class

- Issues from the experiences
 - The fact, **10 students during 4 years**, is – not a big success yet, but having the accelerator control class at a graduate university is important to enhance future human resources in the accelerator control field.
 - To be honest – a request from student made us **happy**.  At the same time, we were **un-happy**, because preparations and scheduling were often tight with regular duty jobs.
 - Materials have been updated every time, but **more improvements of materials** are preferable.
 - We will keep this class, but **more promotion** to students is needed.

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 - “History of Accelerator Control Systems”
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- **3) Summary**

3) Summary

- SOKENDAI and KEK
 - With [Accelerator Science Program](#) of SOKENDAI, KEK provides research and education environment to graduate students for Ph.D
 - 44 courses, 14 graduate students (5 are non-Japanese) in 2023
- **Two courses related to accelerator controls**
 - A) Introduction to Accelerator Control System. half-year course
 - B) Control of Distributed Devices for Large Accelerators
 - During 2019-2022, [10 students \(Asian and African\)](#)
- For the future
 - **More promotion** to students, **more improvement** of materials
 - Educational materials of FY2022-1 are at: <https://kds.kek.jp/category/2393/>
We welcome feedbacks from world-wide communities

**Pls. do not distribute them elsewhere,
do not make mass copies
For local control team or student studies**