Alex Chao – an Influential and Dedicated Educator

Weiren Chou

October 25, 2019, Alex Chao Symposium, SLAC

Outline

- Introduction
- Some early episodes
- ICFA school on linear colliders
- OCPA school (*courtesy Zhao Zhentang*)
- RAST journal
- A table about accelerator and the Nobel prizes
- A poster about the history of particle accelerators
- Summary

Introduction

- We all know Alex is an excellent accelerator physicist
- We also know he is a wonderful teacher
- But he is more than just a teacher – he is an influential and dedicated educator:
  - he not only teaches
  - he also organizes schools
  - writes textbooks
  - edits academic journals
- There are several major accelerator schools around the world. He plays a critical role in at least three of them:
  - USPAS → (Bill's talk)
  - ICFA LC School → This talk
  - OCPA School → This talk
  - (CERN School)
  - (KEK School)
  - (Russia School)

Some Early Episodes

- The first time to hear about Alex's name was in 1980's when I joined the APS team at Argonne. Yanglai Cho, the APS project leader, gave me two pre-prints to learn about accelerators:
  - Matthew Sands: "*The physics of electron storage rings*"
  - Alex Chao: "*Physics of collective beam instabilities in high energy accelerators*" (which later became a well-known textbook)
- He also said that Alex Chao was perhaps the best accelerator theorist at the time, which impressed me.
- My first meeting with Alex was in 1989 during an SSC interview. While he perhaps was the best accelerator theorist, he perhaps was also a worst interviewer. The first question he asked was – "*why didn't you apply to other places, e.g., LBL or SLAC*?" I got stunned and didn't know how to reply. But happily, he still accepted me.
- The English pronunciation of our family names is similar. This sometimes gives me pleasant surprises, e.g., in early 1990s at a conference in Erice, Italy, a man came to me, introduced himself and then said, "I know your name – you are famous." I thanked him but was surprised and wondering why he said – then I realized that guy must have confused me with Alex. This *Chou* is not that *Chao*. That *Chao* is famous, but not me.

ICFA ILC School

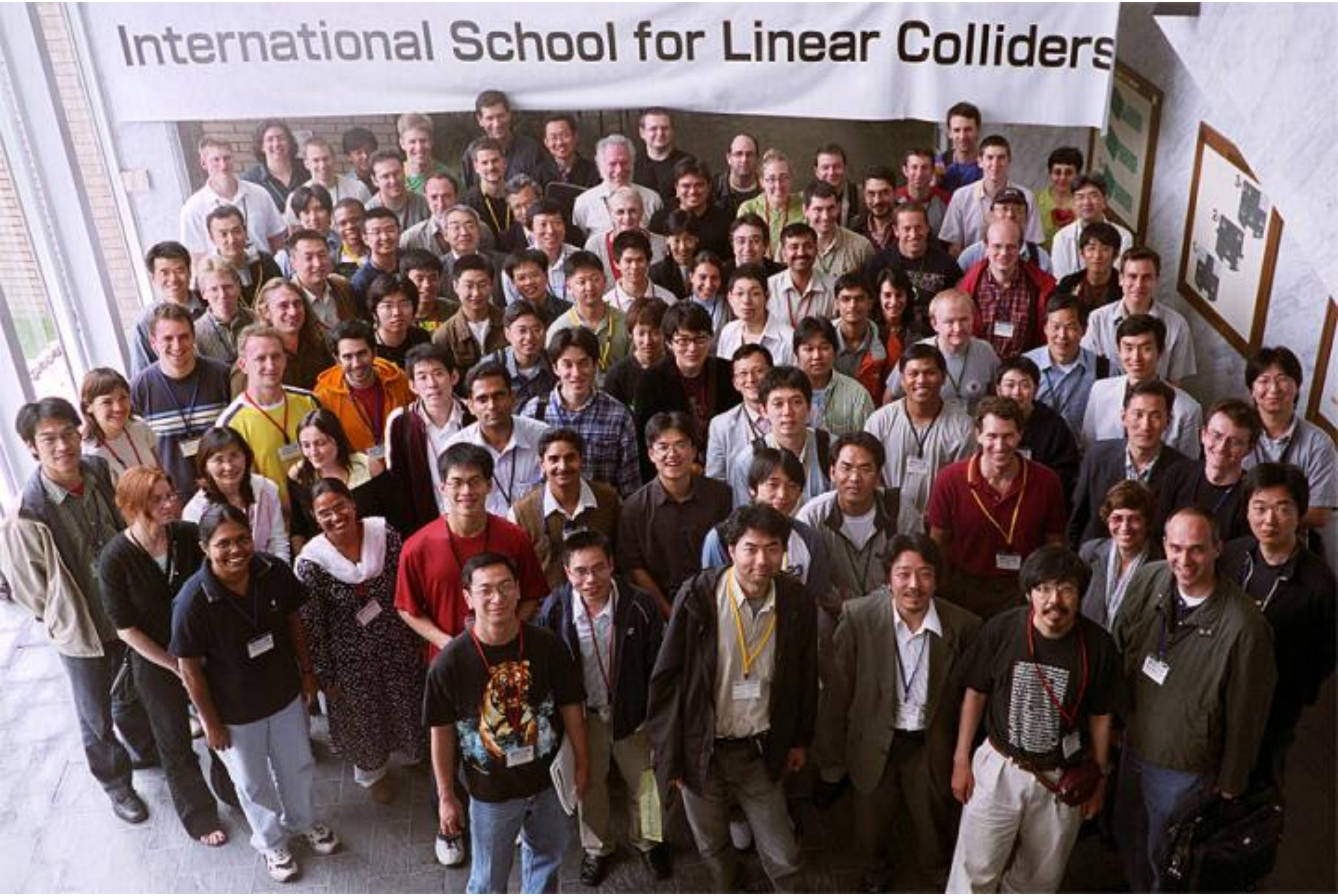
The ILC School

- In 2004, ICFA made a big decision – the next linear collider would be cold and named it the *International Linear Collider* (ILC). ICFA formed the ILC GDE and appointed Barry Barish as the director.

- At the 2005 Snowmass meeting, Barry talked to me and decided to launch an ICFA school dedicated to the ILC. (Later it expanded to also cover the CLIC, muon collider, γγ collider and AAC, but the focus always on the ILC) Barry chaired the organizing committee and asked me to chair the curriculum committee.

- But I was a wrong person as I never organized any accelerator school and had no experience. Fortunately, I was smart enough to ask Alex for help. He kindly agreed, and immediately became a key person of the school:
  - he helped formulate a school curriculum
  - he recommended the best teachers for each class
  - he chaired the North/South America student selection committee
  - he was the "***Exam Czar***" (so students would hate him, not me)
  - he led the exam grading team, selected the top students and gave them awards (certificate, book, or RAST)

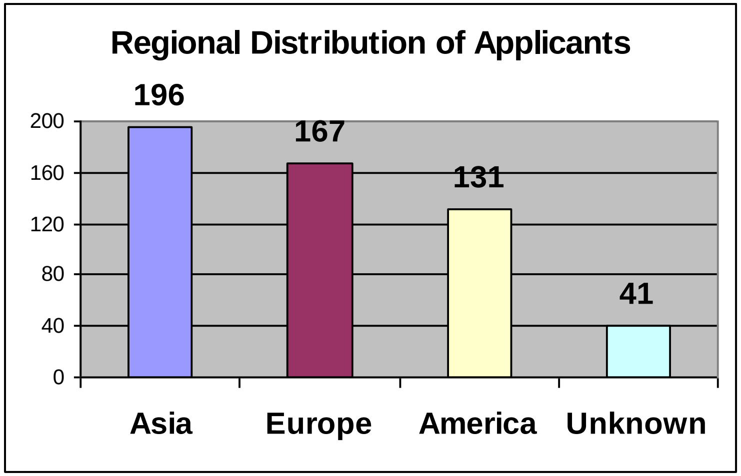

International Accelerator School for Linear Colliders
May 19 - 27, 2006 ✦ Sokendai, Hayama, Japan
Organized by ILC GDE, ICFA Beam Dynamics Panel and the International Linear Collider Steering Committee
ILC International Linear Collider
ICFA
Organizing Committee
Barry Barish (GDE/Caltech, Chair)
Shin-ichi Kurokawa (ILCSC/KEK)
Weiren Chou (ICFA BD Panel/Fermilab)
Rolf-Dieter Heurer (DESY)
Jean-Pierre Delahaye (CERN)
In Soo Ko (PAL)
Kaoru Yokoya (KEK)
Alex Chao (SLAC)
Paul Grannis (US DOE)
Local Committee
Shin-ichi Kurokawa (KEK, Chair)
Junji Urakawa (KEK)
Kaoru Yokoya (KEK)
Satoru Yamashita (U. of Tokyo)
Curriculum Committee
Weiren Chou (Fermilab, Chair)
Alex Chao (SLAC)
Michiko Minty (DESY)
Carlo Pagani (Milano)
Junji Urakawa (KEK)
Jie Gao (IHEP/China)
Eun-San Kim (PAL)
TOPICS
Linear Collider Basics
Super Conducting & Warm RF Technology
Beam Dynamics of Collider Linac & Damping Rings
ILC and its Major Systems
CLIC
Detectors and Physics
the number of students is limited
accepted students will receive financial aid including travel
DEADLINE FOR ONLINE APPLICATION - FEBRUARY 15, 2006
http://www.linearcollider.org/school/
Contact:
Yoko Hayashi
KEK
1-1 Oho, Tsukaba, Ibaraki
305-0801 Japan
email: ilc-school@milk.kek.jp
phone: +81-29-864-5214
fax: +81-29-864-3182
INFN
DESY
CERN
Fermilab
PPARC
CARE
SLAC
ELAN

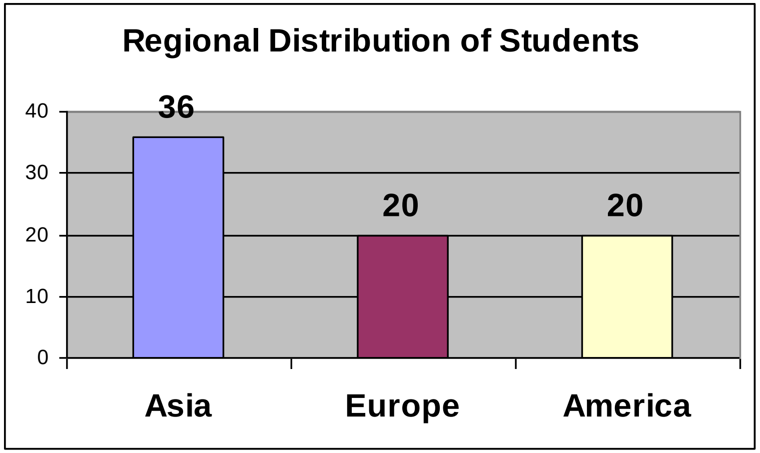

International School for Linear Colliders


International School for Linear Colliders

Applicants *vs*. Accepted Students

- The school received 535 applications from 44 countries
- Due to limited resources, only 76 students from 18 countries were accepted
- Admission was merit-based and “need blind” – no student should be turned away just because he/she can’t afford it





Alex: Student Selection from N/S Americas

Summary report is attached. Unfortunately I did not write down our final decisions for each case, so I had to rely on my recollection and there might be some errors. As a check, let me list what I think our decisions were:

ACCEPT: 285, 113, 117, 121, 149, 153, 228, 324, 333, 349, 369, 393, 423, 424, 492, 495, 511, 548, 586, 602

WAIT LIST: 155, 159, 367, 451

REJECT: 501, 503, 622, 509, 540, 462, 233, 112, 119, 124, 154, 156, 190, 191, 231, 234, 236, 244, 258, 260, 262, 266, 286, 289, 290, 295, 326, 338, 340, 373, 379, 381, 382, 394, 395, 408, 417, 425, 432, 435, 443, 452, 476, 477, 490, 494, 528, 545, 562, 589, 607, 626, 636

MISSING from our hard copied files, which I assume means these cases were simply incomplete: 627, 114, 116, 118, 122, 126, 128, 148, 158, 162, 163,186, 201, 205, 240, 247, 281, 284, 288, 297, 323, 325, 358, 366, 368, 371, 405, 515, 560, 605

Cheers,

Alex

Program

	Saturday, May 20	Sunday, May 21	Monday, May 22	Tuesday, May 23
Morning 09:00 – 12:30	**Opening remarks** (10) **Lecture 1 – Introduction I** (90) **Fumihiko Takasaki** (KEK) • Why LC • What's ILC • Layout of ILC • Overview of issues **Lecture 2 – Introduction II** (90) **Tor Raubenheimer** (SLAC) • Parameter choices & optimization	**Lecture 5 – Damping ring basics** (180) **Susanna Guiducci** (INFN-LNF) • Betatron motion • Synchrotron motion • Beam energy • Beam emittance • Radiation damping • Intrabeam scattering	**Lecture 7 – ILC Linac basics** (90) **Chris Adolphsen** (SLAC) • Linac basic principles • SW linacs and structures • SRF parameter constraints • Beam loading and coupling • Lorentz force detuning **Lecture 8 – ILC Linac beam dynamics** (90) **Kiyoshi Kubo** (KEK) • Lattice layout • Beam quality preservation ○ RF field stability ○ Wakefield and dampers ○ HOMs ○ Alignment tolerances ○ Vibration problems ○ Beam based alignment	**Lecture 9 – High power RF** (60) **Stefan Choroba** (DESY) • RF system overview • Modulators • Klystrons • RF distribution **Lecture 10 – SRF basics** (120) **Shuichi Noguchi** (KEK) • Superconductivity basics • SRF peculiarities • Cavity design criteria • Various constraints • ILC BCD Cavity
Afternoon 14:00 – 17:30	**Lecture 3 – Sources** (120) **Masao Kuriki** (KEK) • e- gun • e+ sources • Polarized sources **Lecture 4 – Bunch compressors** (60) **Eun-San Kim** (Kyungpook Nat'l Univ.) • Bunch compressors • Spin rotator	**Lecture 6 – Damping ring design** (180) **Andy Wolski** (Univ. of Liverpool) • Options • Lattice • Parameter optimization • Machine acceptance • E-cloud, space charge and instability issues • Wigglers • Kickers and other technical systems	**Field trip to Kamakura**	**Lecture 11 – SRF cavity technology** (180) **Peter Kneisel** (Jlab) • Material issues • Cavity fabrication and tuning • Surface preparation • Gradient limit and spread • Power Coupler • HOM Couplers • Slow and fast tuner • Path to ILC
Evening 19:00 – 20:30	Tutorial & homework	Tutorial & homework	Tutorial & homework	Tutorial & homework

Program (cont…)

	Wednesday, May 24	Thursday, May 25	Friday, May 26	Saturday, May 27
Morning 09:00 – 12:30	**Lecture 12 – ILC cryomodule** (60) **Carlo Pagani** (INFN-Milano) • ILC cryogenics and rational • ILC cryomodule concept **Lecture 13 – Room-temperature RF** (120) **Hans Braun** (CERN) • Room temperature cavity and gradient limit • CLIC design	**Lecture 16 – Instrumentation & feedback** (180) **Marc Ross** (SLAC) • Beam monitoring • Precision instrumentation • Feedback systems	**Bus from Sokendai to KEK**	*Group A:* **Lecture 19 – Detectors** (90) **Hitoshi Yamamoto** (Tohoku Univ.) • ILC detectors **Lecture 20 – Physics** (90) **Rolf-Dieter Heuer** (DESY) • ILC physics • Physics beyond 1 TeV • e-e- and γ-γ options • ILC and XFEL *Group B:* **Special lecture – ATF** (60) **Junji Urakawa** (KEK) **ATF experiments** (120)
Afternoon 14:00 – 17:30	**Lecture 14 – Beam delivery** (120) **Andrei Seryi** (SLAC) • Beam delivery system overview • Collimation • Machine-detector interface, shielding and beam dump • Beam monitoring and control at final focus **Lecture 15 – Beam-beam** (60) **Daniel Schulte** (CERN) • Beam-beam interaction	**Lecture 17 – Conventional facilities** (90) **Vic Kuchler** (Fermilab) • Overview • Tunneling • Site requirement **Lecture 18 – Operations** (90) **Marc Ross** (SLAC) • Reliability • Availability • Remote control and global network	**KEK tour** • B-Factory • Photon Factory • SRF • ATF	*Group B:* **Lecture 19 – Detectors** (90) **Hitoshi Yamamoto** (Tohoku Univ.) **Lecture 20 – Physics** (90) **Rolf-Dieter Heuer** (DESY) *Group A:* **Special lecture – ATF** (60) **Junji Urakawa** (KEK) **ATF experiments** (120) *Group A & B:* **Student awards ceremony** **Farewell party**
Evening 19:00 – 20:30	Tutorial & homework	Banquet Tutorial & homework	Free time	Free time

Second International Accelerator School for Linear Colliders

October 1 -10, 2007 ~ Ettore Majorana Center, Erice (Sicily), Italy

Topics

Linear Collider Basics • Super Conducting & Warm RF Technology • Beam Dynamics of Collider Linac & Damping Rings • ILC and Its Major Systems • CLIC • Detectors and Physics

Deadline for online application: June 1, 2007
http://www.linearcollider.org/school/2007/

Number of students is limited
Students will receive financial aid, including travel

Organizing Committee
Barry Barish (GDE/Caltech, Chair)
Shin-ichi Kurokawa (ILCSC/KEK)
Weiren Chou (ICFA BD Panel/Fermilab)
Rolf-Dieter Heuer (DESY)
Jean-Pierre Delahaye (CERN)
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Shin-ichi Kurokawa (KEK)
Carlo Pagani (INFN/Milano)
Junji Urakawa (KEK)
Andrzej Wolski (Univ. of Liverpool)

Contact
Cynthia M. Sazama
Fermilab, P.O. Box 500
Batavia, Illinois 60510 U.S.A.
E-mail: sazama@fnal.gov
Fax: +1-630-840-8589

«ETTORE MAJORANA» FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE

TO PAY A PERMANENT TRIBUTE TO GALILEO GALILEI, FOUNDER OF MODERN SCIENCE AND TO ENRICO FERMI, THE "ITALIAN NAVIGATOR", FATHER OF THE WEAK FORCES

INTERNATIONAL ACCELERATOR SCHOOL FOR LINEAR COLLIDERS

ERICE–SICILY: 1 – 10 OCTOBER 2007

Sponsored by the: • Italian Ministry of University and Research • Sicilian Regional Government • U.S. DOE, U.S. NSF • Fermilab • SLAC • CERN • DESY • KEK • PPARC • INFN • IN2P3 • CARE/ELAN • CHEP/KNU • ICFA • ILC GDE

TOPICS AND LECTURERS

Introduction
• N. WALKER, DESY, Hamburg, D

Sources & bunch compressors
• M. KURIKI, KEK, Tsukuba, Ibaraki, JP

Damping ring
• A. WOLSKI, University of Liverpool, UK

Linac
• P. TENENBAUM, SLAC, Menlo Park, CA, USA

LLRF & high power RF
• S. SIMROCK, DESY, Hamburg, D

Superconducting RF
• K. SAITO, KEK, Tsukuba, Ibaraki, JP

Beam delivery & beam-beam
• A. SERYI, SLAC, Menlo Park, CA, USA

Instrumentation & control
• M. ROSS, Fermilab, Batavia, IL, USA

Operations
• M. ROSS, Fermilab, Batavia, IL, USA

CLIC
• F. TECKER, CERN, Geneva, CH

Conventional facilities
• A. ENOMOTO, KEK, Tsukuba, Ibaraki, JP

Physics & detectors
• J. BRAU, University of Oregon, Eugene, OR, USA

PURPOSE OF THE COURSE

The School aims to educate young generations for the next major accelerator facilities in the high-energy physics field, including the International Linear Collider (ILC) and the Compact Linear Collider (CLIC). We encourage young physicists (graduate students, post doctoral fellows, junior researchers) to apply. In particular we welcome those physicists who are considering changing to a career in accelerator physics. The School will accept a maximum of 70 students from around the world. Students will receive financial aid covering the expenses for attending this School (including airfare, lodging, meals, local transportation and school supplies).

There will be no registration fee.

APPLICATIONS

Persons wishing to attend the Course should complete the online registration form (which can be found at **www.linearcollider.org/school/2007/**) and submit a recommendation letter from his/her supervisor (in electronic form, either PDF or MS WORD), or contact the Co-Director of the School:

- Professor Barry BARISH
  c/o Ms Cynthia M. Sazama
  FERMILAB
  P.O. Box 500, BATAVIA, IL 60510, USA
  Fax +1.630.8408589
  e-mail: *sazama@fnal.gov*

specifying:

i) full name, address, age, nationality;
ii) academic qualification, present position and affiliation;
iii) specific interest in the School.

- PLEASE NOTE
  Participants should arrive in Erice on October 1, not later than 5 pm.

Closing date for application is June 1, 2007

POETIC TOUCH

According to legend, Erice, son of Venus and Neptune, founded a small town on top of a mountain (750 metres above sea level) more than three thousand years ago. The founder of modern history — i.e. the recording of events in a methodic and chronological sequence as they really happened without reference to mythical causes — the great Thucydides (~500 B.C.), writing about events connected with the conquest of Troy (1183 B.C.) said: «After the fall of Troy some Trojans on their escape from the Achaei arrived in Sicily by boat and as they settled near the border with the Sicanians all together they were named Elymi: their towns were Segesta and Erice.» This inspired Virgil to describe the arrival of the Trojan royal family in Erice and the burial of Anchise, by his son Enea, on the coast below Erice. Homer (~1000 B.C.), Theocritus (~300 B.C.), Polybius (~200 B.C.), Virgil (~50 B.C.), Horace (~20 B.C.), and others have celebrated this magnificent spot in Sicily in their poems. During seven centuries (XIII-XIX) the town of Erice was under the leadership of a local oligarchy, whose wisdom assured a long period of cultural development and economic prosperity which in turn gave rise to the many churches, monasteries and private palaces which you see today.

In Erice you can admire the Castle of Venus, the Cyclopean Walls (~800 B.C.) and the Gothic Cathedral (~1300 A.D.). Erice is at present a mixture of ancient and medieval architecture. Other masterpieces of ancient civilization are to be found in the neighbourhood: at Motya (Phoenician), Segesta (Elymian), and Selinunte (Greek). On the Aegadian Islands — theatre of the decisive naval battle of the first Punic War (264-241 B.C.) — suggestive neolithic and paleolithic vestiges are still visible: the grottoes of Favignana, the carvings and murals of Levanzo.

Splendid beaches are to be found at San Vito Lo Capo, Scopello, and Cornino, and a wild and rocky coast around Monte Cofano: all at less than one hour's drive from Erice.

More information about the «Ettore Majorana» Foundation and Centre for Scientific Culture can be found on the WWW at the following address: http://www.ccsem.infn.it

Registration details and more information about the Course can be found on the WWW at the following address: http://www.linearcollider.org/school/2007

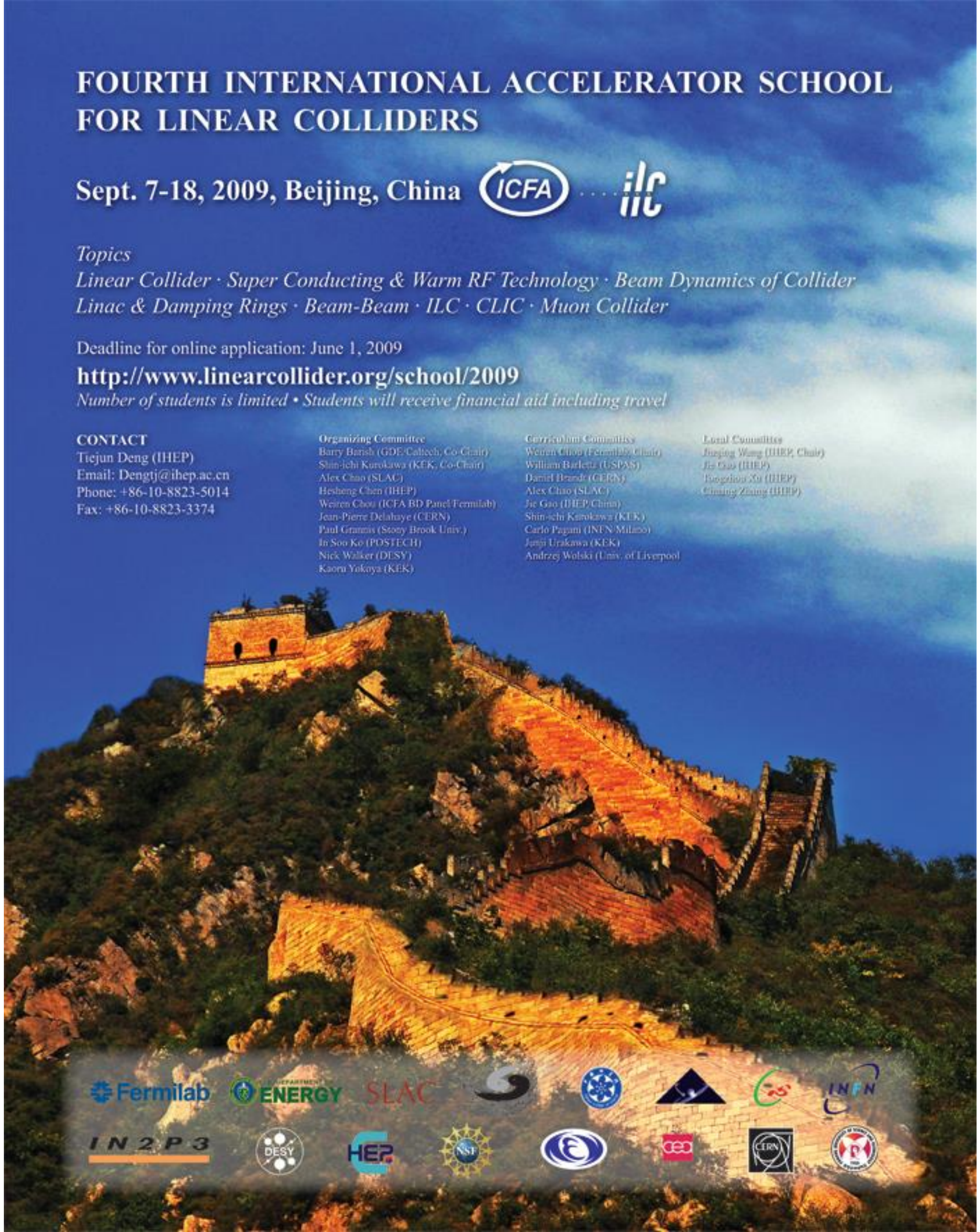
B. BARISH – W. CHOU
DIRECTORS OF THE SCHOOL

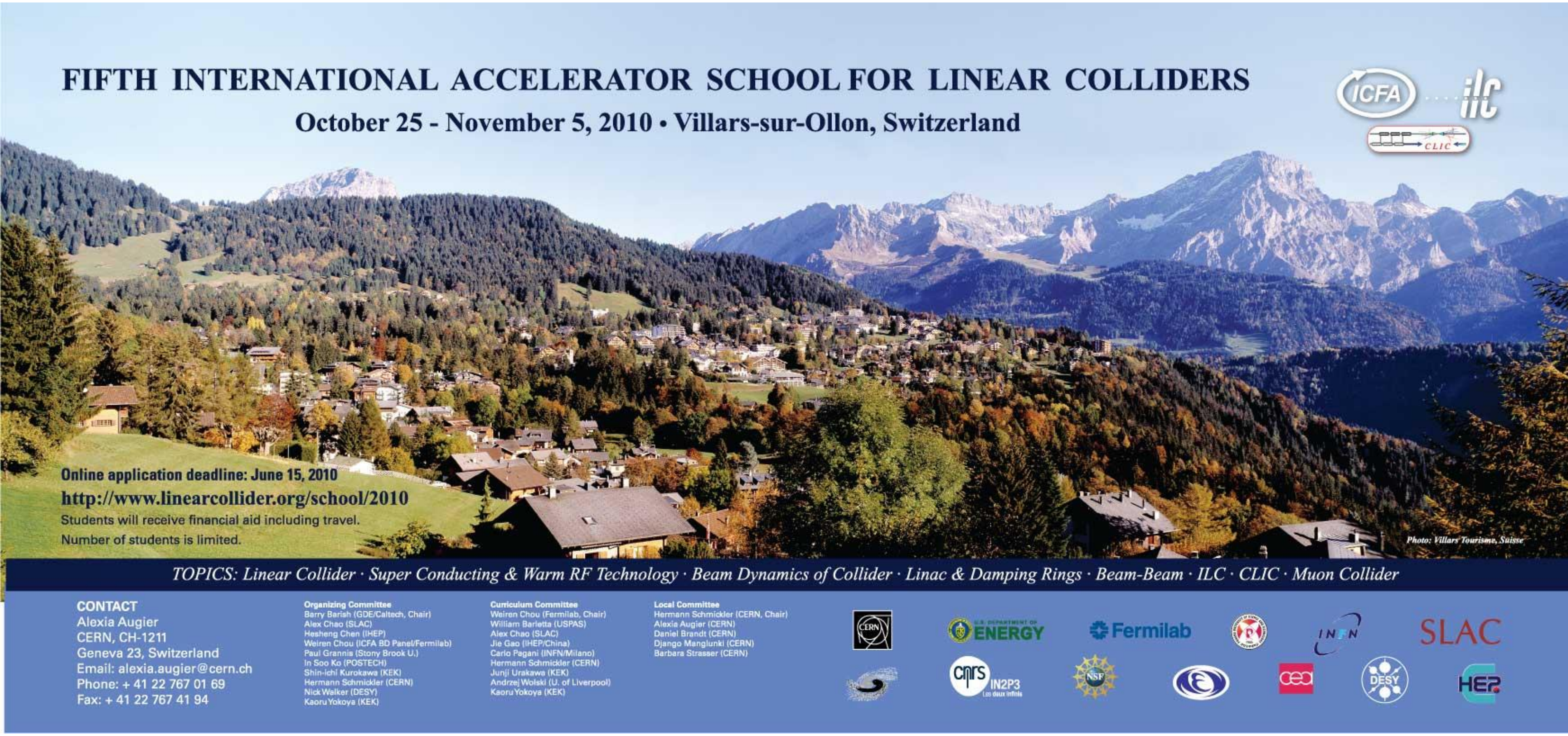
A. ZICHICHI
EMFCSC PRESIDENT AND DIRECTOR OF THE CENTRE


Second International Accelerator School For Linear Colliders
October 1-10, 2007
Erice (Sicily), Italy

THIRD INTERNATIONAL ACCELERATOR SCHOOL FOR LINEAR COLLIDERS
October 19 - 29, 2008
Oak Brook Hills Marriott Hotel, Oak Brook, Illinois, U.S.A.
Topics
Linear Collider Basics • Super Conducting & Warm RF Technology • Beam Dynamics of Collider Linac & Damping Rings • ILC and Its Major Systems • CLIC • Detectors and Physics
ICFA
ilc
http://www.linearcollider.org/school/2008/
Deadline for online application: May 1, 2008


Third International Accelerator School for Linear Colliders
October 19-29, 2008, Oakbrook, Illinois, U.S.A.


FOURTH INTERNATIONAL ACCELERATOR SCHOOL FOR LINEAR COLLIDERS
Sept. 7-18, 2009, Beijing, China
ICFA
ilc
Topics
Linear Collider · Super Conducting & Warm RF Technology · Beam Dynamics of Collider
Linac & Damping Rings · Beam-Beam · ILC · CLIC · Muon Collider
Deadline for online application: June 1, 2009
http://www.linearcollider.org/school/2009
Number of students is limited • Students will receive financial aid including travel
CONTACT
Tiejun Deng (IHEP)
Email: Dengtj@ihep.ac.cn
Phone: +86-10-8823-5014
Fax: +86-10-8823-3374
Organizing Committee
Barry Barish (GDE/Caltech, Co-Chair)
Shin-ichi Kurokawa (KEK, Co-Chair)
Alex Chao (SLAC)
Hesheng Chen (IHEP)
Weiren Chou (ICFA BD Panel/Fermilab)
Jean-Pierre Delahaye (CERN)
Paul Grannis (Stony Brook Univ.)
In Soo Ko (POSTECH)
Nick Walker (DESY)
Kaoru Yokoya (KEK)
William Barletta (USPAS)
Alex Chao (SLAC)
Shin-ichi Kurokawa (KEK)
Carlo Pagani (INFN Milano)
Junji Urakawa (KEK)
Andrzej Wolski (Univ. of Liverpool
Fermilab
ENERGY
SLAC
INFN
IN2P3
DESY
HEP
CERN


FIFTH INTERNATIONAL ACCELERATOR SCHOOL FOR LINEAR COLLIDERS
October 25 - November 5, 2010 • Villars-sur-Ollon, Switzerland
Online application deadline: June 15, 2010
http://www.linearcollider.org/school/2010
Students will receive financial aid including travel.
Number of students is limited.
Photo: Villars Tourisme, Suisse
TOPICS: Linear Collider · Super Conducting & Warm RF Technology · Beam Dynamics of Collider · Linac & Damping Rings · Beam-Beam · ILC · CLIC · Muon Collider
CONTACT
Alexia Augier
CERN, CH-1211
Geneva 23, Switzerland
Email: alexia.augier@cern.ch
Phone: + 41 22 767 01 69
Fax: + 41 22 767 41 94
Organizing Committee
Barry Barish (GDE/Caltech, Chair)
Alex Chao (SLAC)
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Weiren Chou (ICFA BD Panel/Fermilab)
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Andrzej Wolski (U. of Liverpool)
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Local Committee
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Alexia Augier (CERN)
Daniel Brandt (CERN)
Django Manglunki (CERN)
Barbara Strasser (CERN)

Sixth International Accelerator School for Linear Colliders

November 6 – 17, 2011 • Asilomar Conference Center, Pacific Grove, California, USA

Online application deadline: June 30, 2011

http://www.linearcollider.org/school/2011

Students will receive financial aid including travel. Number of students is limited.

CONTACT
Naomi Nagahashi
SLAC National Accelerator Laboratory
2575 Sand Hill Road
Menlo Park, CA 94025, U.S.A.
email: lcschool@slac.stanford.edu
phone: + 1-650-926-2645
fax: + 1-650-926-4365

ORGANIZING COMMITTEE

- Barry Barish (GDE/Caltech, Chair)
- Alex Chao (SLAC)
- Hesheng Chen (IHEP)
- Weiren Chou (ICFA BD Panel/Fermilab)
- Paul Grannis (Stony Brook Univ.)
- In Soo Ko (PAL)
- Shin-ichi Kurokawa (KEK)
- Hermann Schmickler (CERN)
- Nick Walker (DESY)
- Kaoru Yokoya (KEK)

CURRICULUM COMMITTEE

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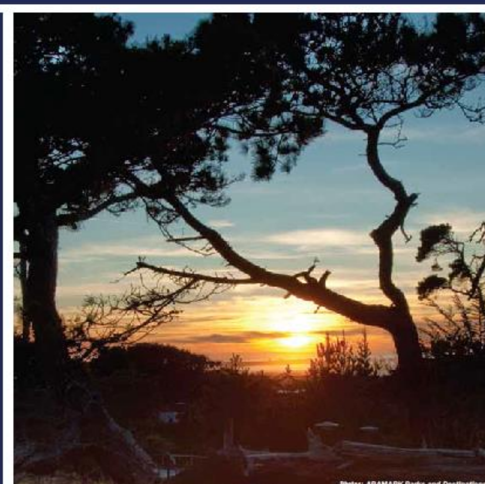
- William Barletta (USPAS)
- Alex Chao (SLAC)
- Jie Gao (IHEP)
- Carlo Pagani (INFN/Milano)
- Hermann Schmickler (CERN)
- Nobuhiro Terunuma (KEK)
- Andrzej Wolski (Univ. of Liverpool)
- Kaoru Yokoya (KEK)

LOCAL COMMITTEE

- Vinod Bharadwaj (SLAC, Chair)
- Alex Chao (SLAC)
- Naomi Nagahashi (SLAC)
- Nick Arias (SLAC)



Photos: ARAMARK Parks and Destinations

TOPICS

Linear Collider
Superconducting & Warm RF Technology
Beam Dynamics of Collider
Linac & Damping Rings
Beam Instrumentation
Beam-Beam
ILC
CLIC
Muon Collider

Seventh International Accelerator School for Linear Colliders

November 27 – December 8, 2012 • Radisson Blu Hotel, Indore, India

Hosted by Raja Ramanna Centre for Advanced Technology

Organizing Committee
- Barry Barish (GDE/Caltech, Chair)
- Alex Chao (SLAC)
- Hesheng Chen (IHEP)
- Weiren Chou (ICFA BD Panel/Fermilab)
- Paul Grannis (Stony Brook Univ.)
- P D Gupta (RRCAT)
- In Soo Ko (PAL)
- Shin-ichi Kurokawa (KEK)
- Hermann Schmickler (CERN)
- Nick Walker (DESY)
- Kaoru Yokoya (KEK)

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- Alex Chao (SLAC)
- Jie Gao (IHEP)
- Srinivas Krishnagopal (BARC)
- Carlo Pagani (INFN/Milano)
- Joerg Rossbach (DESY)
- Hermann Schmickler (CERN)
- Nobuhiro Terunuma (KEK)
- Kaoru Yokoya (KEK)

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- P R Hannurkar (RRCAT)
- S C Joshi (RRCAT)
- S K Shukla (RRCAT)

TOPICS

Linear Colliders • Superconducting & Warm RF Technology
Beam Dynamics of Collider • Linac & Damping Rings
Beam Instrumentation • Beam-Beam • ILC • CLIC • Muon Collider

Online application deadline: July 20, 2012
http://www.linearcollider.org/school/2012

Students will receive financial aid (partial or full) including travel
Number of students is limited

CONTACT
Satish C. Joshi
Raja Ramanna Centre for Advanced Technology
Indore, M. P. – 452013
India
email: lcs2012@rrcat.gov.in
phone: + 91-731-2442244
fax: + 91-731-2442200

ORGANIZING COMMITTEE
Lyn Evans (LCC/CERN, Chair)
Alex Chao (SLAC)
Hesheng Chen (IHEP)
Weiren Chou (ICFA BD Panel/Fermilab)
Paul Grannis (Stony Brook U.)
P D Gupta (RRCAT)
Mike Harrison (BNL)
In Soo Ko (PAL)
Shin-ichi Kurokawa (KEK)
Hermann Schmickler (CERN)
Nobuhiro Terunuma (KEK)
Nick Walker (DESY)

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Avni Aksoy (IAT, Ankara U.)
William Barletta (USPAS)
Alex Chao (SLAC)
Jie Gao (IHEP)
Srinivas Krishnagopal (BARC)
Carlo Pagani (Milano U. & INFN)
Joerg Rossbach (Hamburg U.)
Takayuki Saeki (KEK)
Hermann Schmickler (CERN)
Nobuhiro Terunuma (KEK)

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CONTACT
Avni Aksoy
Ankara University
Institute of Accelerator Technologies
06830 Gölbaşı, Ankara
Turkey

e-mail: ias2013@ankara.edu.tr
phone: +90-312-4851377, ext. 5016
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Eighth International Accelerator School for Linear Colliders

December 4 – 15, 2013 Hotel Rixos Downtown, Antalya, Turkey • Hosted by the Institute of Accelerator Technologies of Ankara University

TOPICS: ILC • CLIC • Superconducting & Warm RF Technology • Beam Dynamics of Colliders • Linac & Damping Rings • Ring Colliders • Beam Instrumentation • Beam-Beam

http://www.linearcollider.org/school/2013 **Online application deadline: September 10, 2013**

Students will receive financial aid (partial or full) • Number of students is limited

Alex's Exam Notes to Teachers

To: ISLC2009 Lecturers
Lecture I1 Barish
Lecture I2 Barish
Lecture I3 Tecker
Lecture I4 Palmer
Lecture A1 Schulte
Lecture A2 Kuriki
Lecture A3 Napoly
Lecture A4 Wolski
Lecture B1 Tantawi
Lecture B2 Saito
Lecture B3 Simrock
From: Alex Chao
Date: August 9, 2009

Greetings!

I am afraid it is time to prepare for the final exam problems for the ISLC2009 school.

As agreed upon earlier, each of you is to provide two candidate problems for the Final Exam. It is suggested that one of these problems be a variation of a homework problem that you assigned during your lecture,(*) while the other is a new problem. It is suggested that problems should not be too difficult but at least one of the problems should not be a simple numerical substitution of an existing formula. Please provide electronic files (source file and pdf file) of these candidate problems, together with their solutions, before the school starts on September 7. Please note that it is important that all problems and solutions be explained very clearly and be without misprints --- we learned some lessons the hard way in the past!

On September 14, we should meet to select a set of final exam problems from the candidate problems. Hopefully all lecturers who are available on that day can come to help. This probably include Masao Kuriki, Olivier Napoly, Bob Palmer, Andy Wolski, Kenji Saito, Daniel Schulte, Sami Tantawi.One of the decisions to be made is whether to prepare two sets of exam problems, one for A-course students and one for B-course students.

Exam papers will be printed on September 17. Exam takes place in the morning on September 18.

Exam papers will be graded in the afternoon on September 18 and grading should be finished before dinner. All lecturers available should help, as this is expected to be a demanding task. The list of these (unfortunate) lecturers probably includes Olivier Napoly, Bob Palmer, Andy Wolski, Stefan Simrock, Frank Tecker, Daniel Schulte, Sami Tantawi.

Alex’s Exam Notes to Students

1. Exam time: 8:00 – 12:30 Sept. 18. Be punctual.

2. Seats divided into A and B regions. Each seat will be equipped a pack of blank answer sheets. Each seat will have room to spread out your books, computer, etc.

3. Open book exam. OK to consult your books, notes, your own computer files.

4. OK to leave the room temporarily during exam. Take a short break if you need to. Return promptly.

5. Don’t talk to others. No emails. No Google or Wikipedia. No Mathematica.

6. **Switch off your cell phone.**

7. Charge up your computer overnight. Bring your calculator. Extra calculators available at the podium.

8. There will be 9 problems. Average 30 mins. per problem. Total score is 81 points (not 100).

9. A timer will show the exam time count-down.

10. Exam problems will be given to you on an **exam paper**. Your answers are to be written on blank **answer sheets** provided at each seat. Write your name clearly on the cover of the exam paper. **Mark clearly** Problem 1, Problem 2, .. on your answer sheets.

11. Return before 12:30 sharp to the podium. **Staple together your exam paper + your answer sheets.** Staplers are provided at the podium.

12. Best students receives prizes (small) at the banquet.

13. At the end of exam, please stay an extra 15 minutes to fill out a survey form to learn how we did.

14. After banquet, retrieve your paper at the banquet room exit.

Exam Sheet Cover designed by Alex

4-th International School for Linear Colliders
Huairou, 7-18, September, 2009

Final Examination for Session A

NAME: ____

For Graders Only

Problem	Grade
I3	
I4	
Linac	
A1	
A2.1	
A2.2	
A3	
A4.1	
A4.2	
Total	

Exam Sheet Cover designed by Alex

4-th International School for Linear Colliders
Huairou, 7-18, September, 2009

Final Examination for Session B

NAME: ____

For Graders Only

Problem	Grade
I3	
I4	
Linac	
B1.1	
B1.2	
B2.1	
B2.2	
B3.1	
B3.2	
Total	

Exam Problems compiled by Alex

Problem I3 (CLIC)

Assume you want to build a CLIC type collider to reach a collision energy of 1 TeV in the centre-of-mass system based on an 18 GHz main beam accelerating structure of 0.3 m active length that needs 125 MW of input power for a nominal effective gradient of 100 MV/m.
On the Drive Beam side, you have one PETS structure to feed two accelerating structures. The PETS has R/Q = 2000 Ω/m and a group velocity of $v_g = 0.5$ c.
Assume you can build a Drive Beam source with a maximum initial beam current I<5 A and an initial bunch repetition frequency in the range of 0.5 – 1 GHz. The final Drive Beam current is 120 A. The final RF pulses must have a length (= final Drive Beam bunch train pulse length) of t_p = 100 ns.

[Hint: not all questions are based on the previous. If you get stuck, have a look if you can solve another one.]

a) What is the length of the PETS structure to generate the required power for two accelerating structures (assuming a single bunch form factor F_b = 1 and assuming perfect power transfer from the PETS to the accelerating structures)?
[2 points]

b) What configurations of Delay Loop and Combiner Ring(s) can you use? [Hint: Remember you need one Delay Loop, and keep the multiplication factor in each Combiner Ring ≤ 5.]
[3 points]

c) Choose your preferred solution (one only) among the possibilities from b), keeping the number of Combiner Rings minimal.
What is your initial beam current?
What is your initial bunch repetition frequency?
[1 point]

d) What is the total length of the two opposing linacs if you need on average a total of 0.2 m per meter of linac for quadrupoles, BPMs or other elements? How many accelerating structures do you need?
[2 points]

e) What is the initial Drive Beam pulse length?
[2 points]

f) What is the approximate length of the Delay Loop and the Combiner Ring(s)? [Hint The RF pulse length determines the length of the Delay Loop. If you have more than one Combiner Ring, keep the highest multiplication factor for the last combination stage. You can neglect the condition that you have to match the ring length precisely to a fractional part of the deflector wavelength.]
[2 points]

g) What are the frequencies of the RF deflectors?
[2 points]

Exam Solutions compiled by Alex

Lecture I3

CLIC two-beam power generation:

Assume you want to build a CLIC type collider to reach a collision energy of 1 TeV in the centre-of-mass system based on an 18 GHz main beam accelerating structure of 0.3 m active length that needs 125 MW of input power for a nominal effective gradient of 100 MV/m.
On the Drive Beam side, you have one PETS structure to feed two accelerating structures. The PETS has R/Q = 2000 Ω/m and a group velocity of v_g=0.5 c.
Assume you can build a Drive Beam source with a maximum initial beam current I<5 A and an initial bunch repetition frequency in the range of 0.5 – 1 GHz. The final Drive Beam current is 120 A. The final RF pulses (= final Drive Beam bunch train pulse length) must have a length of t_p = 100 ns.

(Hint: not all questions are based on the previous. If you get stuck, have a look if you can solve another one.)

a) What is the length of the PETS structure to generate the required power for two accelerating structures (assuming a single bunch form factor F_b=1 and assuming perfect power transfer from the PETS to the accelerating structures)?

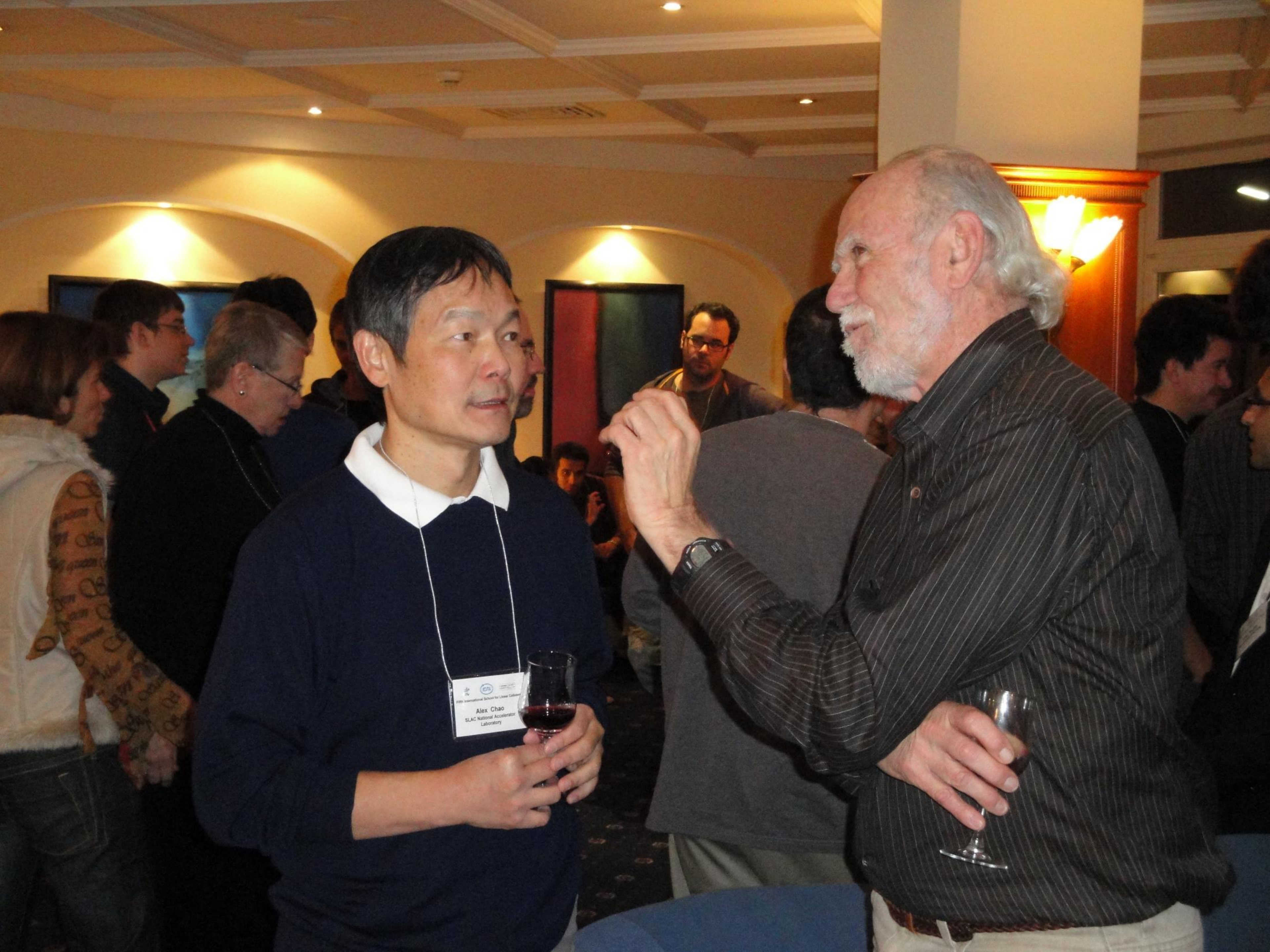
From the formula given in the lecture $P=I^2L^2F_b^2\omega_0 R/Q / (4v_g)$ it follows with F_b=1 that $L = \frac{1}{I}\sqrt{\frac{P*4*v_g}{\omega_0 R/Q}}$. As one PETS has to provide the power for 2 accelerating structures, P=2*125 MW=250 MW. Putting the numbers in, it follows L=0.2146 m.

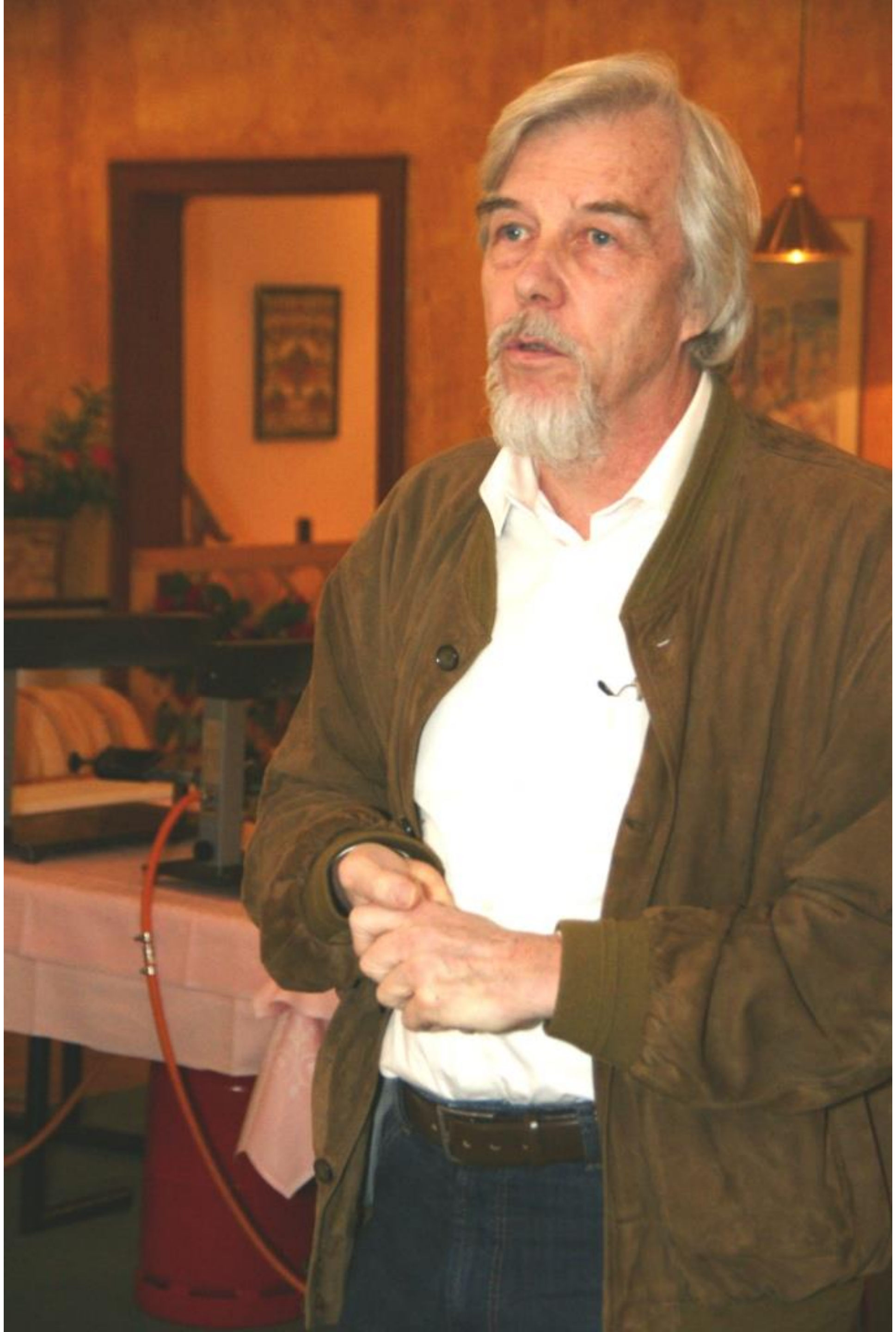
b) What configurations of Delay Loop (DL) and Combiner Ring(s) (CR) can you use (Remember you need one Delay Loop, and keep the multiplication factor in each Combiner Ring ≤ 5.)?

You have the following relations using the total multiplication factor F:
$I_f = F * I_i$ $\quad F = I_f / I_i > 120A/5A = 24$
$f_f = F * f_i$ $\quad F = f_f / f_i = 18\ GHz / f_i$ that means $18 \le F \le 36$.
Taking both together, we obtain $24 < F \le 36$.

So the possibilities would be (odd number excluded by need for DL):
26 = 2 * 13 (too high factor 13)
28 = 2 * 2 * 7 (too high factor 7)
30 = 2 * 3 * 5
32 = 2 * 4 * 4
34 = 2 * 17 (too high factor 17)


Kimwipes


Alex Chao
SLAC National Accelerator
Laboratory

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Alex Chao


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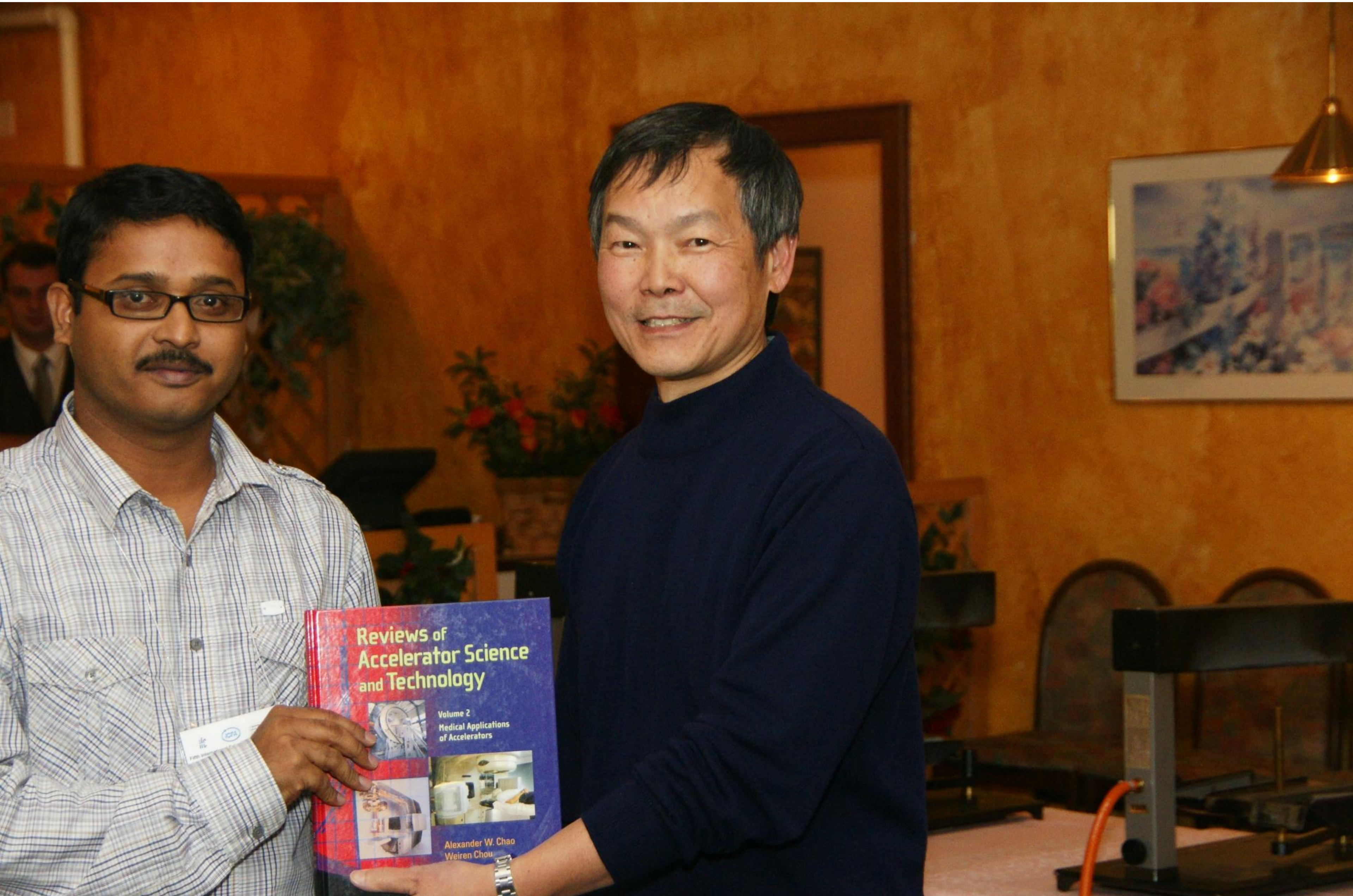
Reviews of
Accelerator Science
and Technology
Volume 2
Medical Applications
of Accelerators
Alexander W. Chao
Weiren Chou


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Poignée de Secours
Nur für den Notausgang
Solamente per Soccorso
Emergency Only
2010/11/01

OCPA School
(Courtesy Zhao Zhentang)

历届世界华人物理学会OCPA加速器学校信息
Some information about previous OCPA Accelerator School

OCPA School Links：

OCPA-1998, 台湾新竹，NSRRC, August 3 -12, 1998

OCPA-2000, 安徽黄山，中科大NSRL，July 18 - 27, 2000

OCPA-2002, 新加坡， July 25 - August 3, 2002

OCPA-2004, 因非典传染病流行，取消 , Cancel

OCPA-2006, 江苏扬州，应物所SINAP, July 27- August 5, 2006

OCPA-2008, 台湾南投， September 1-10, 2008

OCPA-2010, 北京，高能所IHEP， July 27 - August 5, 2010

OCPA-2012, 甘肃天水，近物所IMP， July 29 - August 7, 2012

OCPA-2014, 安徽休宁， 中科大NSRL，July 27 - August 6, 2014

OCPA-2016, 上海，应物所SINAP， July 25 - August 4, 2016

OCPA-2018, 台湾高雄，NSRRC， July 23 - August 1，2018

All previous years OCPA

The 1st OCPA School held in Hsinchu, Taiwan, August 3-12, 1998.

The 2nd OCPA School in Yellow Mountain, Anhui, July 18-27, 2000.

The 3rd OCPA School in Singapore, July 25 to August 3, 2002.

The 4th OCPA School held in Yangzhou, Jiangsu, July 27-August 5, 2006.

The 5th OCPA School in Nantou, Taiwan, September 1-10, 2008.

The 6th OCPA School in Beijing, July 27-August 5, 2010.

The 7th OCPA School in Tianshui, Gansu, July 29-August 7, 2012.

The 8th OCPA School in Xiuning, Anhui, July 27-August 6, 2014.

The 9th OCPA School in Songjiang，Shanghai，July 25-August 4, 2016.

The 10th OCPA School in Hsinchu，Taiwan，July 23, 2018.

ps. The 2004 OCPA school was canceled due to SARS.

第一届世界华人物理学会加速器学校

The 1st Overseas Chinese Physics Association Accelerator School

1998.8，台湾新竹Hsinchu

第二届世界华人物理学会加速器学校
The 2nd Overseas Chinese Physics Association Accelerator School

2000.7，安徽太平Taiping

第三届世界华人物理学会加速器学校
The 3rd Overseas Chinese Physics Association Accelerator School

2002.8，新加坡Singapore

OCPA Topical Accelerator School & Workshop

The 1st OCPA Topical Accelerator School & Workshop held in, Beijing 2009

The 2nd OCPA Topical Accelerator School and Workshop Held in Beijing, 2011.8

The 3rd OCPA Topical Accelerator School and Workshop Held in Dalian, 2013.8

The 4th OCPA Topical Accelerator School & Workshop Held in Hsinchu, 2015.8

The 5th OCPA Topical Accelerator School & Workshop held in Shanghai, 2017.7

The Sixth OCPA Topical Accelerator School & Workshop held in Beijing, 2019.10


世界华人物理学会第一届加速器专题学校


KAOHSIUNG

全球华人物理和天文学会第4届加速器专题学校-质子/重离子直线加速器
The 2nd OCPA Topical Accelerator School and Workshop Held in Changping

2011.8，Beijing

RAST
(Reviews of Accelerator Science and Technology)

How did it get started?

- Around 2007, Alex called me and said he planned to start an accelerator journal and asked me if I was interested.
- After 6 months or so, he called again and said he was serious about it and wanted me to be a co-editor.
- I told him my hesitation – there are already many books, journals and proceedings around, why should we add another one?
- He said, yes, but we need a review journal that did not exist yet.
- His vision – we would edit ~10 volumes in ~10 years, which would sit on people's bookshelf like an encyclopedia in the accelerator field.

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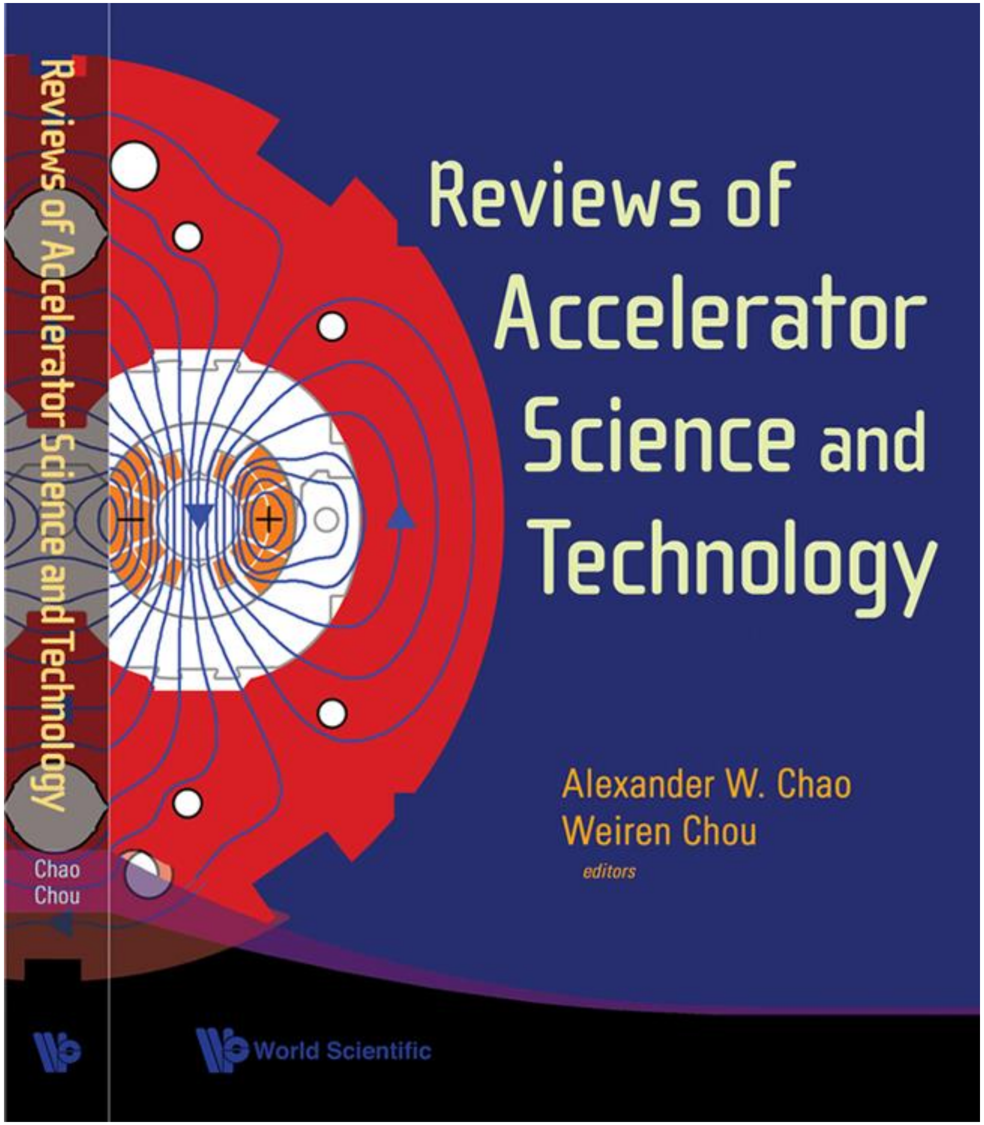
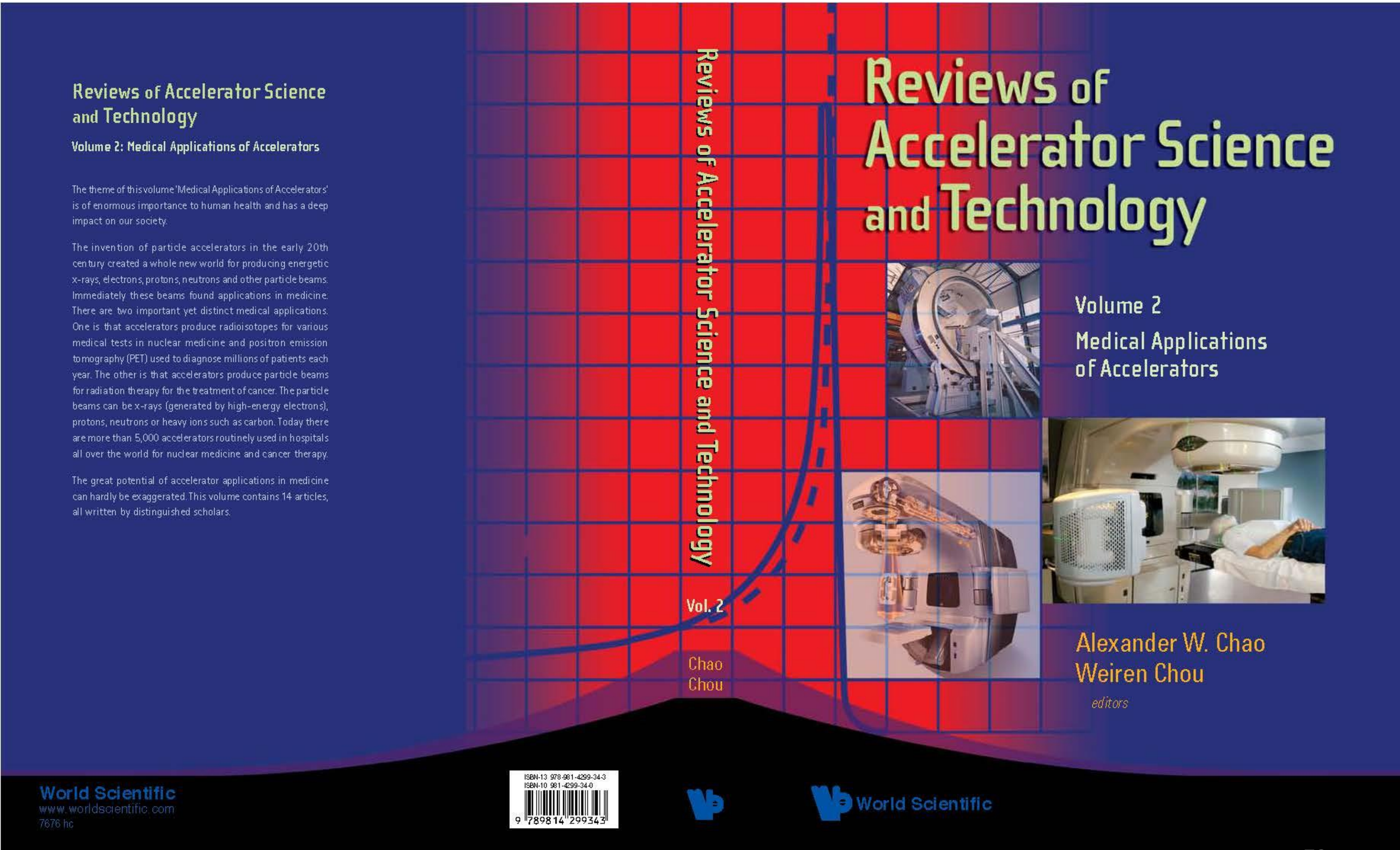
Volume 1 – Overview



Volume 2 – Medical Applications



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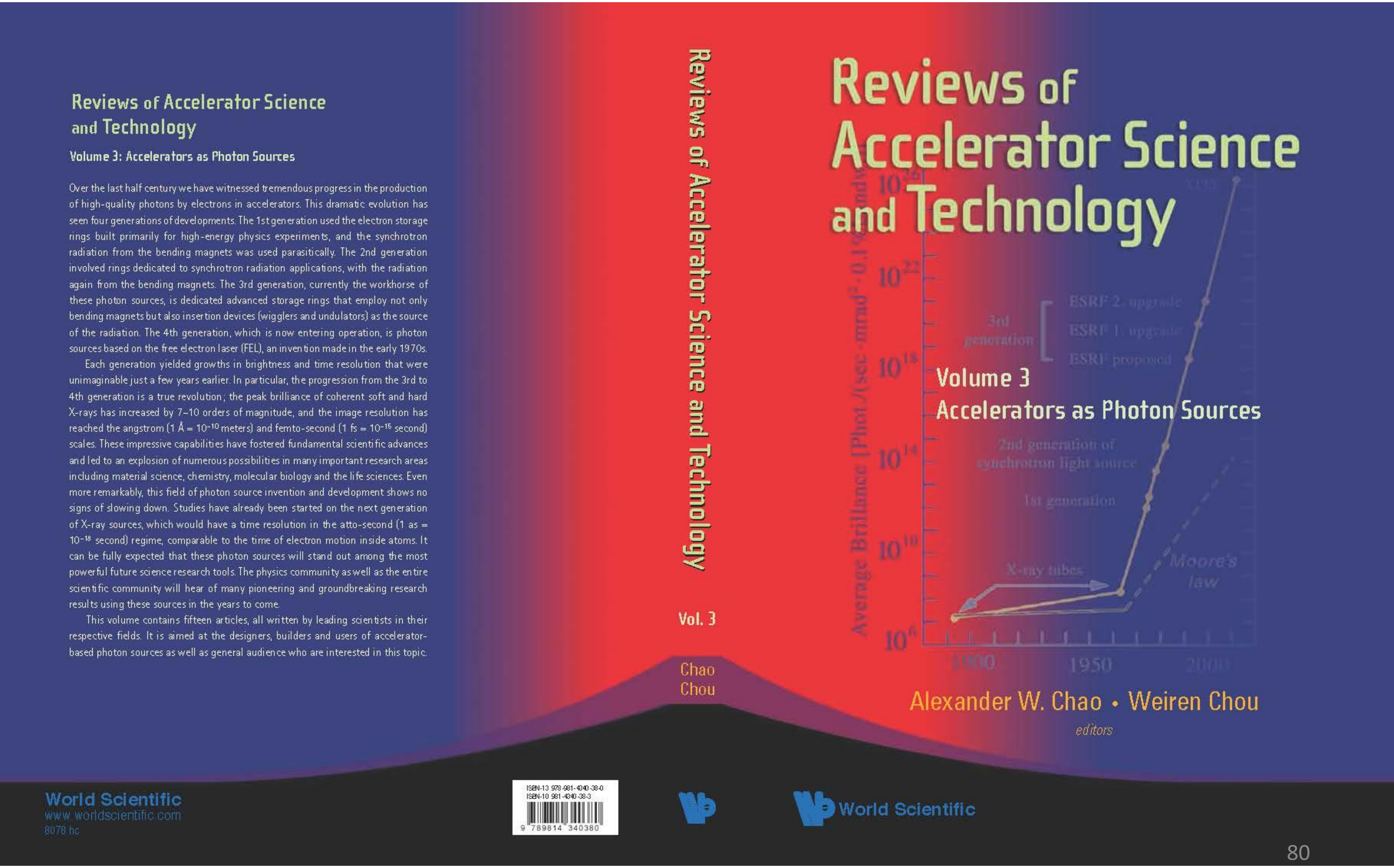
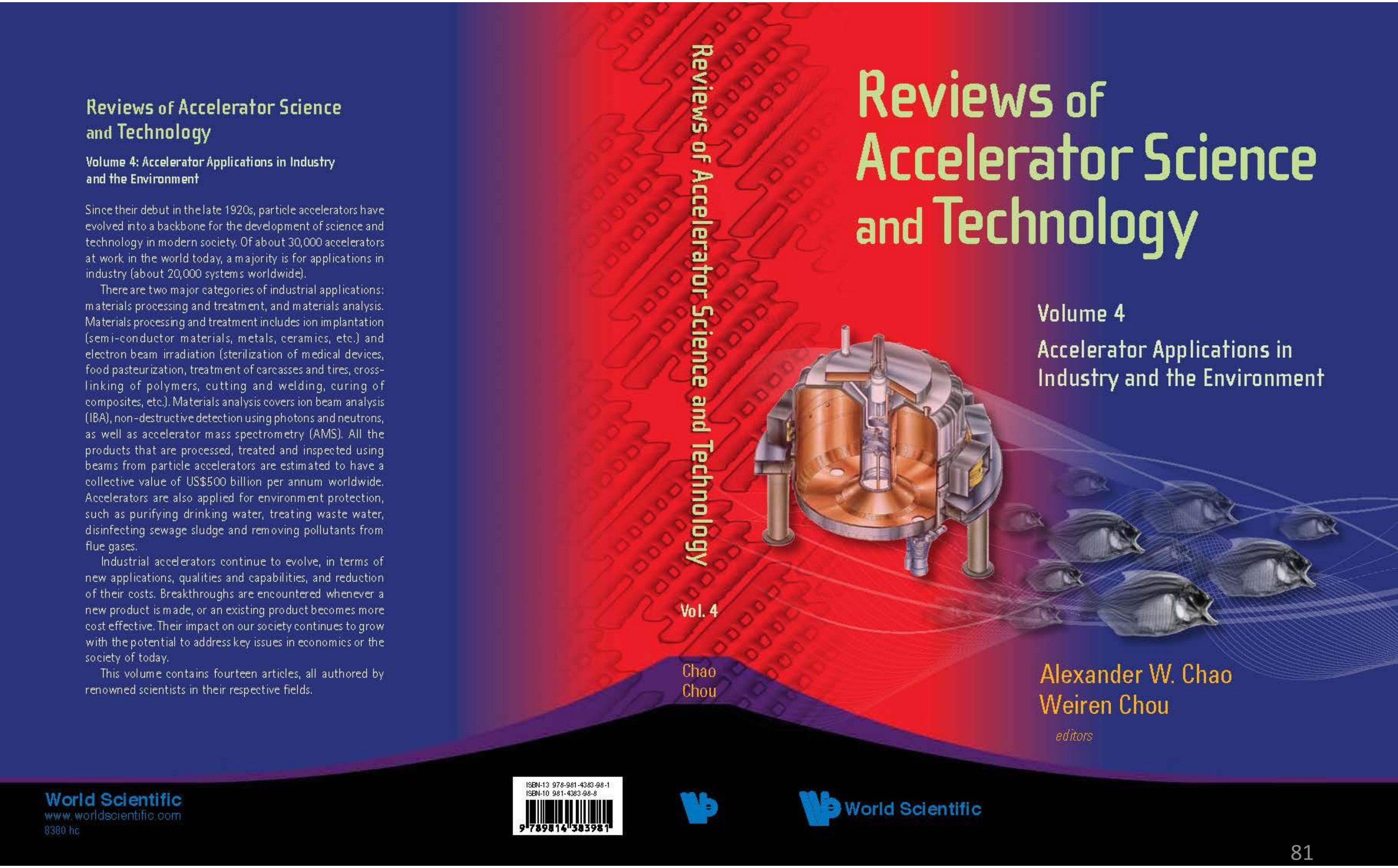
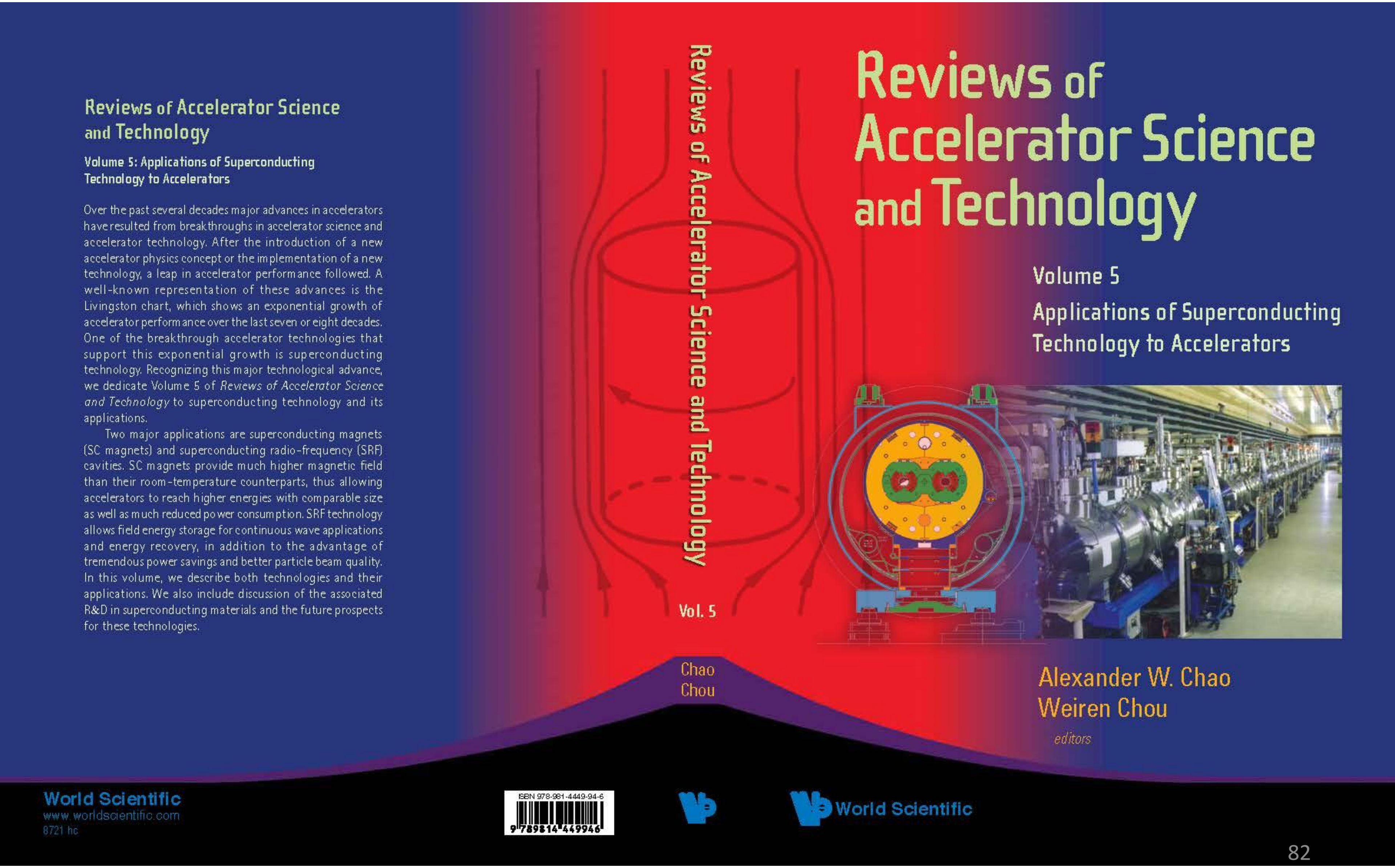


Volume 4 – Industry/Environment Applications

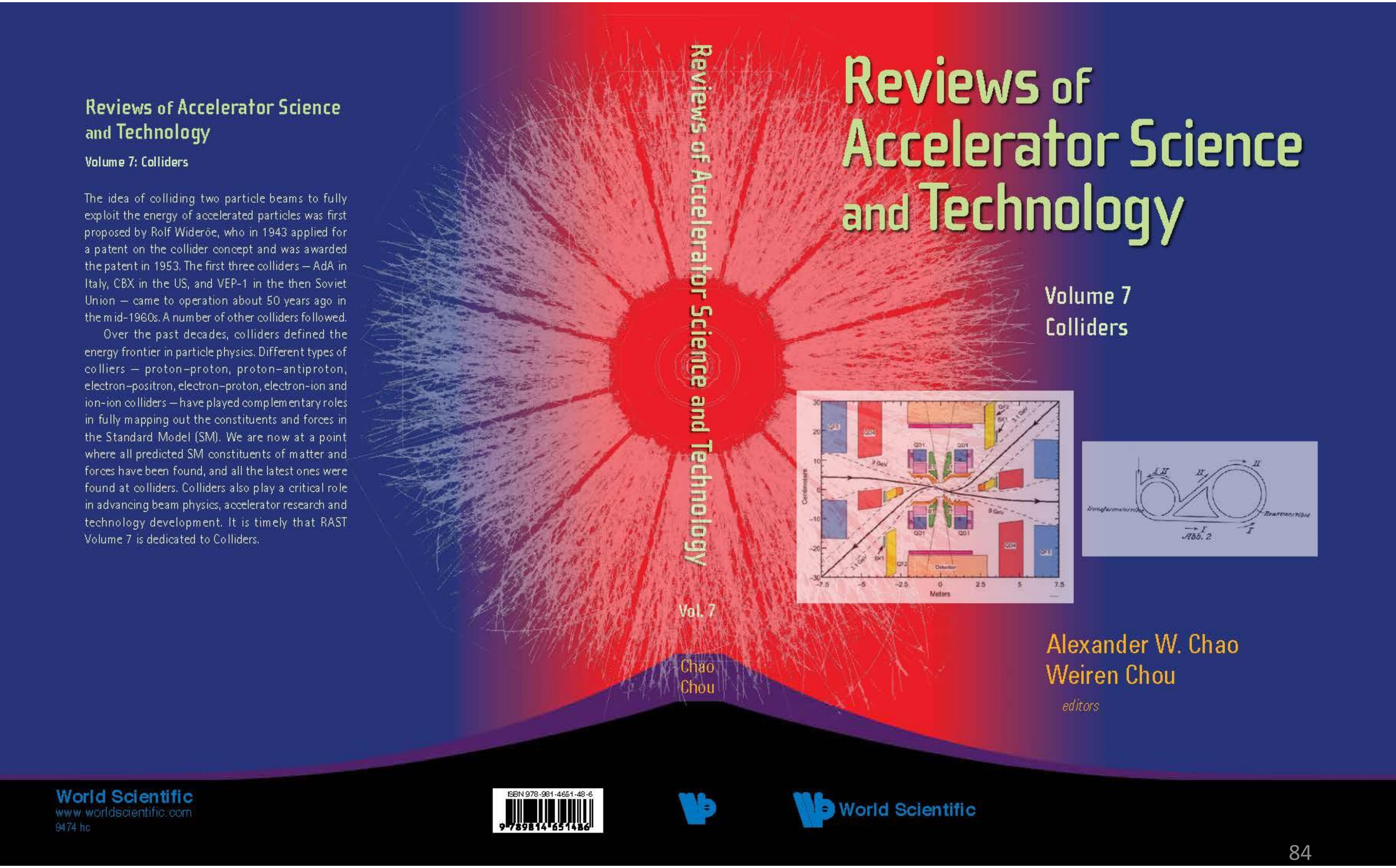


Volume 5 – Superconducting Technology



Volume 6 – High Intensity Beams

Volume 7 – Colliders



Volume 8 – Energy/Security Applications

Reviews of Accelerator Science and Technology

Volume 8: Accelerator Applications in Energy and Security

As accelerator science and technology progressed over the past several decades, the accelerators themselves have undergone major improvements in multiple performance factors: beam energy, beam power, and beam brightness. As a consequence, accelerators have found applications in a wide range of fields in our life and in our society. The current volume is dedicated to applications in energy and security, two of the most important and urgent topics in today's world.

This volume makes an effort to provide a review as complete and up to date as possible of this broad and challenging subject. It contains overviews on each of the two topics and a series of articles for in-depth discussions including heavy ion accelerator driven inertial fusion, linear accelerator-based ADS systems, circular accelerator-based ADS systems, accelerator-reactor interface, accelerators for fusion material testing, cargo inspection, proton radiography, compact neutron generators and detectors. This volume also has a review article on accelerator science and technology in Canada with a focus on the TRIUMF laboratory, and an article on the life of Bruno Touschek, a renowned accelerator physicist.

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ISBN 978-981-3108-89-9
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Reviews of Accelerator Science and Technology

Vol. 8

Chao
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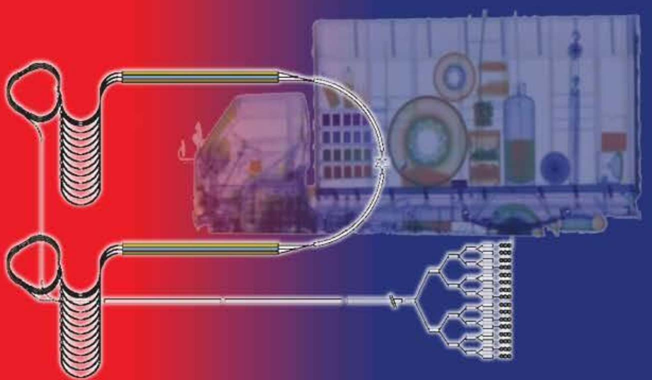

Editors
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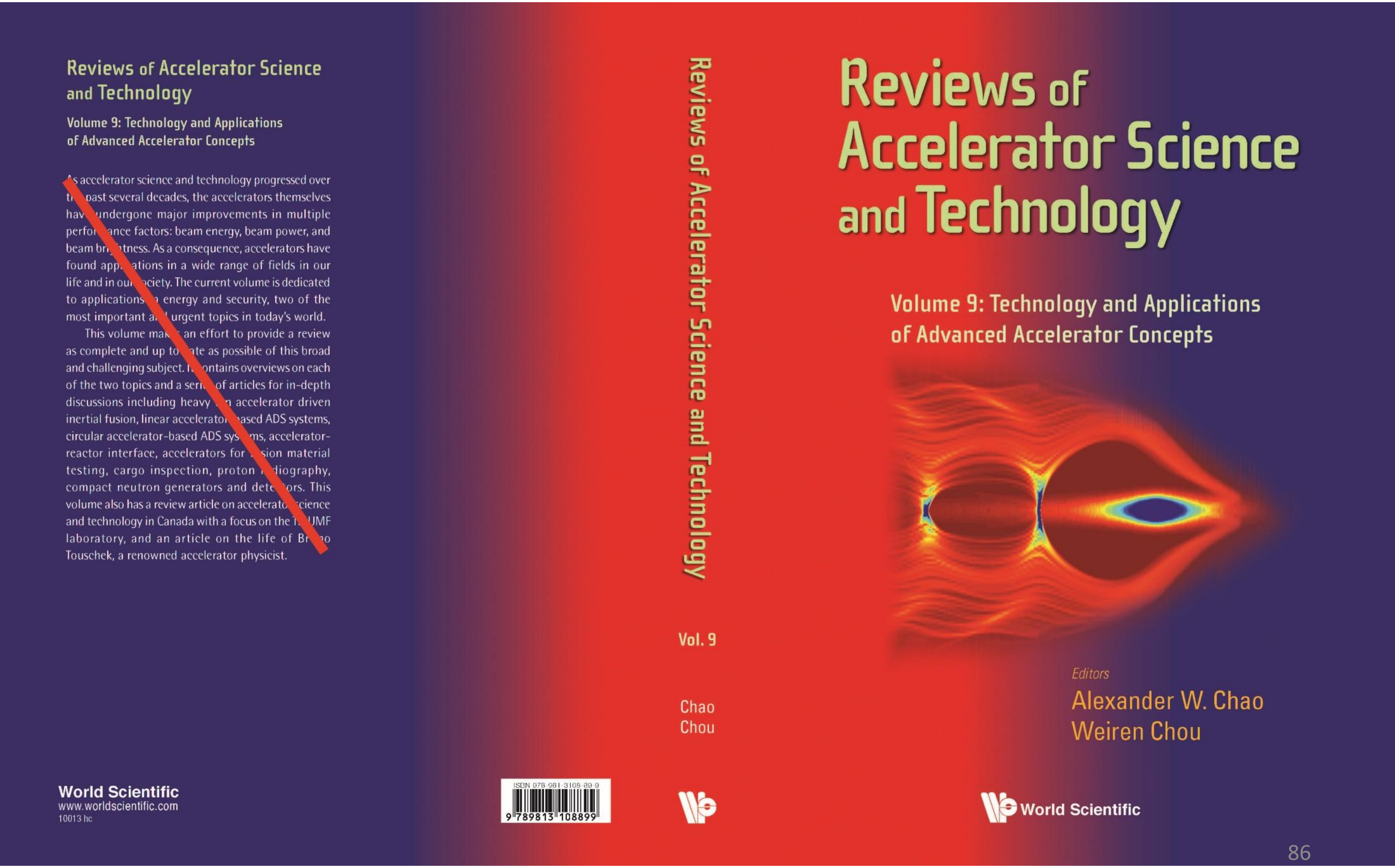
Volume 9 – AAC


Reviews of Accelerator Science and Technology
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Volume 9: Technology and Applications of Advanced Accelerator Concepts
Editors
Alexander W. Chao
Weiren Chou
World Scientific

Volume 10 – Future of Accelerators

A Table about Accelerator and the Nobel Prizes

Letter to the editor (ICFA BD Newsletter, no. 53, December 2010)

1.1 Influence of Accelerator Science on Physics Research

Enzo Haussecker and Alexander Chao[a]
SLAC National Accelerator Laboratory, Menlo Park, California, USA
Mail to: enzo@slac.stanford.edu and achao@slac.stanford.edu

Abstract:
We evaluate accelerator science in the context of its contributions to the physics community. We address the problem of quantifying these contributions and present a scheme for a numerical evaluation of them. We show by using a statistical sample of important developments in modern physics that accelerator science has influenced 28% of post-1938 physicists and also 28% of post-1938 physics research. We also examine how the influence of accelerator science has evolved over time, and show that on average it has contributed to a physics Nobel Prize-winning research every 2.9 years.

- This letter carried out an extensive survey of a large body of literature from Nobel Prize committee and laureates – a total of 331 documents (a stack of 60 cm high).

- From 1939 (when Ernest Lawrence received a Nobel Prize for his invention of the cyclotron) to 2009, nearly 30% of the Nobel Prizes in Physics had a direct contribution from accelerators.

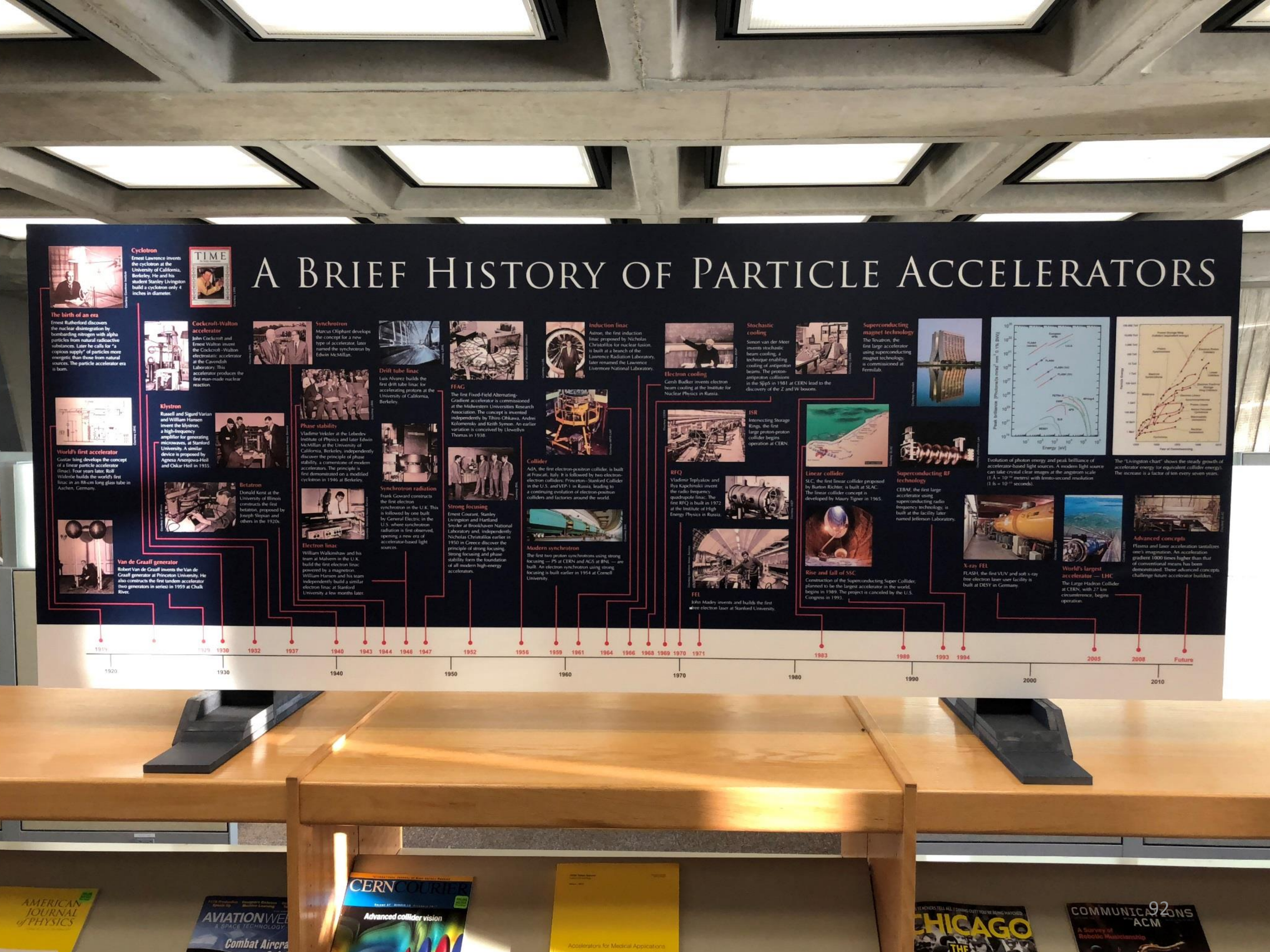
- On the average, accelerator science contributed to a Nobel Prize in Physics every 3 years.

25 Nobel Prizes in Physics that had direct contribution from accelerators

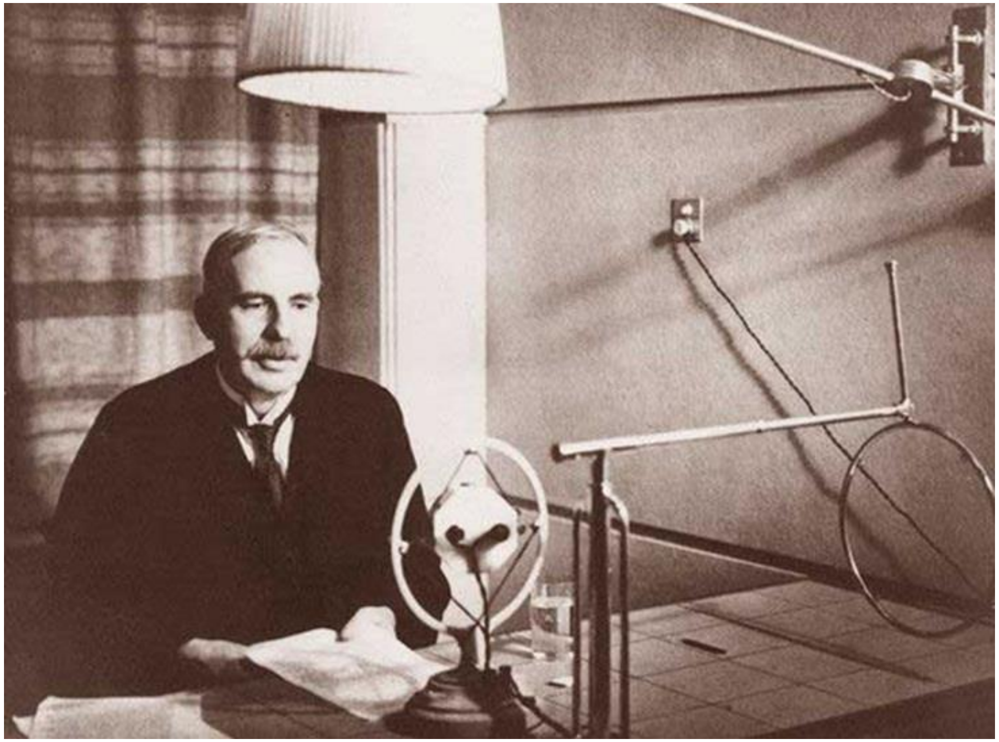
(courtesy: A. Chao)

Year	Name	Accelerator-Science Contribution to Nobel Prize-Winning Research
1939	Ernest O. Lawrence	Lawrence invented the cyclotron at the University of Californian at Berkeley in 1929 [12].
1951	John D. Cockcroft and Ernest T.S. Walton	Cockcroft and Walton invented their eponymous linear positive-ion accelerator at the Cavendish Laboratory in Cambridge, England, in 1932 [13].
1952	Felix Bloch	Bloch used a cyclotron at the Crocker Radiation Laboratory at the University of California at Berkeley in his discovery of the magnetic moment of the neutron in 1940 [14].
1957	Tsung-Dao Lee and Chen Ning Yang	Lee and Yang analyzed data on K mesons (θ and τ) from Bevatron experiments at the Lawrence Radiation Laboratory in 1955 [15], which supported their idea in 1956 that parity is not conserved in weak interactions [16].
1959	Emilio G. Segrè and Owen Chamberlain	Segrè and Chamberlain discovered the antiproton in 1955 using the Bevatron at the Lawrence Radiation Laboratory [17].
1960	Donald A. Glaser	Glaser tested his first experimental six-inch bubble chamber in 1955 with high-energy protons produced by the Brookhaven Cosmotron [18].
1961	Robert Hofstadter	Hofstadter carried out electron-scattering experiments on carbon-12 and oxygen-16 in 1959 using the SLAC linac and thereby made discoveries on the structure of nucleons [19].
1963	Maria Goeppert Mayer	Goeppert Mayer analyzed experiments using neutron beams produced by the University of Chicago cyclotron in 1947 to measure the nuclear binding energies of krypton and xenon [20], which led to her discoveries on high magic numbers in 1948 [21].
1967	Hans A. Bethe	Bethe analyzed nuclear reactions involving accelerated protons and other nuclei whereby he discovered in 1939 how energy is produced in stars [22].
1968	Luis W. Alvarez	Alvarez discovered a large number of resonance states using his fifteen-inch hydrogen bubble chamber and high-energy proton beams from the Bevatron at the Lawrence Radiation Laboratory [23].
1976	Burton Richter and Samuel C.C. Ting	Richter discovered the J/Ψ particle in 1974 using the SPEAR collider at Stanford [24], and Ting discovered the J/Ψ particle independently in 1974 using the Brookhaven Alternating Gradient Synchrotron [25].
1979	Sheldon L. Glashow, Abdus Salam, and Steven Weinberg	Glashow, Salam, and Weinberg cited experiments on the bombardment of nuclei with neutrinos at CERN in 1973 [26] as confirmation of their prediction of weak neutral currents [27].
1980	James W. Cronin and Val L. Fitch	Cronin and Fitch concluded in 1964 that CP (charge-parity) symmetry is violated in the decay of neutral K mesons based upon their experiments using the Brookhaven Alternating Gradient Synchrotron [28].
1981	Kai M. Siegbahn	Siegbahn invented a weak-focusing principle for betatrons in 1944 with which he made significant improvements in high-resolution electron spectroscopy [29].
1983	William A. Fowler	Fowler collaborated on and analyzed accelerator-based experiments in 1958 [30], which he used to support his hypothesis on stellar-fusion processes in 1957 [31].
1984	Carlo Rubbia and Simon van der Meer	Rubbia led a team of physicists who observed the intermediate vector bosons W and Z in 1983 using CERN's proton-antiproton collider [32], and van der Meer developed much of the instrumentation needed for these experiments [33].
1986	Ernst Ruska	Ruska built the first electron microscope in 1933 based upon a magnetic optical system that provided large magnification [34].
1988	Leon M. Lederman, Melvin Schwartz, and Jack Steinberger	Lederman, Schwartz, and Steinberger discovered the muon neutrino in 1962 using Brookhaven's Alternating Gradient Synchrotron [35].
1989	Wolfgang Paul	Paul's idea in the early 1950s of building ion traps grew out of accelerator physics [36].
1990	Jerome I. Friedman, Henry W. Kendall, and Richard E. Taylor	Friedman, Kendall, and Taylor's experiments in 1974 on deep inelastic scattering of electrons on protons and bound neutrons used the SLAC linac [37].
1992	Georges Charpak	Charpak's development of multiwire proportional chambers in 1970 were made possible by accelerator-based testing at CERN [38].
1995	Martin L. Perl	Perl discovered the tau lepton in 1975 using Stanford's SPEAR collider [39].
2004	David J. Gross, Frank Wilczek, and H. David Politzer	Gross, Wilczek, and Politzer discovered asymptotic freedom in the theory of strong interactions in 1973 based upon results from the SLAC linac on electron-proton scattering [40].
2008	Makoto Kobayashi and Toshihide Maskawa	Kobayashi and Maskawa's theory of quark mixing in 1973 was confirmed by results from the KEKB accelerator at KEK in Tsukuba, Ibaraki Prefecture, Japan, and the PEP II at SLAC [41], which showed that quark mixing in the six-quark model is the dominant source of broken symmetry [42].
2013	Francois Englert and Peter W. Higgs	Englert's and Higgs's theory of the Higgs particle in 1960s was confirmed by the ATLAS and CMS experiments at CERN's LHC in 2012.

A Poster about the History of Particle Accelerators


A BRIEF HISTORY OF PARTICLE ACCELERATORS
The birth of an era
Ernest Rutherford discovers the nuclear disintegration by bombarding nitrogen with alpha particles from natural radioactive substances. Later he calls for "a copious supply" of particles more energetic than those from natural sources. The particle accelerator era is born.
Cyclotron
Ernest Lawrence invents the cyclotron at the University of California, Berkeley. He and his student Stanley Livingston build a cyclotron only 4 inches in diameter.
TIME
Cockcroft-Walton accelerator
John Cockcroft and Ernest Walton invent the Cockcroft–Walton electrostatic accelerator at the Cavendish Laboratory. This accelerator produces the first man-made nuclear reaction.
World's first accelerator
Gustav Ising develops the concept of a linear particle accelerator (linac). Four years later, Rolf Wideröe builds the world's first linac in an 88-cm long glass tube in Aachen, Germany.
Klystron
Russell and Sigurd Varian and William Hansen invent the klystron, a high-frequency amplifier for generating microwaves, at Stanford University. A similar device is proposed by Agnesa Arsenjewa-Heil and Oskar Heil in 1935.
Betatron
Donald Kerst at the University of Illinois constructs the first betatron, proposed by Joseph Slepian and others in the 1920s.
Van de Graaff generator
Robert Van de Graaff invents the Van de Graaff generator at Princeton University. He also constructs the first tandem accelerator (two generators in series) in 1959 at Chalk River.
Synchrotron
Marcus Oliphant develops the concept for a new type of accelerator, later named the synchrotron by Edwin McMillan.
Phase stability
Vladimir Veksler at the Lebedev Institute of Physics and later Edwin McMillan at the University of California, Berkeley, independently discover the principle of phase stability, a cornerstone of modern accelerators. The principle is first demonstrated on a modified cyclotron in 1946 at Berkeley.
Electron linac
William Walkinshaw and his team at Malvern in the U.K. build the first electron linac powered by a magnetron. William Hansen and his team independently build a similar electron linac at Stanford University a few months later.
Drift tube linac
Luis Alvarez builds the first drift tube linac for accelerating protons at the University of California, Berkeley.
Synchrotron radiation
Frank Goward constructs the first electron synchrotron in the U.K. This is followed by one built by General Electric in the U.S. where synchrotron radiation is first observed, opening a new era of accelerator-based light sources.
FFAG
The first Fixed-Field Alternating-Gradient accelerator is commissioned at the Midwestern Universities Research Association. The concept is invented independently by Tihiro Ohkawa, Andrei Kolomensky and Keith Symon. An earlier variation is conceived by Llewellyn Thomas in 1938.
Strong focusing
Ernest Courant, Stanley Livingston and Hartland Snyder at Brookhaven National Laboratory and, independently Nicholas Christofilos earlier in 1950 in Greece discover the principle of strong focusing. Strong focusing and phase stability form the foundation of all modern high-energy accelerators.
Induction linac
Astron, the first induction linac proposed by Nicholas Christofilos for nuclear fusion, is built at a branch of the Lawrence Radiation Laboratory, later renamed the Lawrence Livermore National Laboratory.
Collider
AdA, the first electron-positron collider, is built at Frascati, Italy. It is followed by two electron-electron colliders: Princeton–Stanford Collider in the U.S. and VEP-1 in Russia, leading to a continuing evolution of electron-positron colliders and factories around the world.
Modern synchrotron
The first two proton synchrotrons using strong focusing — PS at CERN and AGS at BNL — are built. An electron synchrotron using strong focusing is built earlier in 1954 at Cornell University.
Electron cooling
Gersh Budker invents electron beam cooling at the Institute for Nuclear Physics in Russia.
Stochastic cooling
Simon van der Meer invents stochastic beam cooling, a technique enabling cooling of antiproton beams. The proton-antiproton collisions in the SppS in 1981 at CERN lead to the discovery of the Z and W bosons.
ISR
Intersecting Storage Rings, the first large proton-proton collider begins operation at CERN.
RFQ
Vladimir Teplyakov and Ilya Kapchinskii invent the radio frequency quadrupole linac. The first RFQ is built in 1972 at the Institute of High Energy Physics in Russia.
FEL
John Madey invents and builds the first free electron laser at Stanford University.
Superconducting magnet technology
The Tevatron, the first large accelerator using superconducting magnet technology, is commissioned at Fermilab.
Linear collider
SLC, the first linear collider proposed by Burton Richter, is built at SLAC. The linear collider concept is developed by Maury Tigner in 1965.
Rise and fall of SSC
Construction of the Superconducting Super Collider, planned to be the largest accelerator in the world, begins in 1989. The project is canceled by the U.S. Congress in 1993.
Superconducting RF technology
CEBAF, the first large accelerator using superconducting radio frequency technology, is built at the facility later named Jefferson Laboratory.
Peak brilliance
Energy [eV]
Evolution of photon energy and peak brilliance of accelerator-based light sources. A modern light source can take crystal clear images at the angstrom scale (1 Å = 10⁻¹⁰ meters) with femto-second resolution (1 fs = 10⁻¹⁵ seconds).
The "Livingston chart" shows the steady growth of accelerator energy (or equivalent collider energy). The increase is a factor of ten every seven years.
X-ray FEL
FLASH, the first VUV and soft x-ray free electron laser user facility is built at DESY in Germany.
World's largest accelerator — LHC
The Large Hadron Collider at CERN, with 27 km circumference, begins operation.
Advanced concepts
Plasma and laser acceleration tantalizes one's imagination. An acceleration gradient 1000 times higher than that of conventional means has been demonstrated. These advanced concepts challenge future accelerator builders.
1919 1929 1930 1932 1937 1940 1943 1944 1946 1947 1952 1956 1959 1961 1964 1966 1968 1969 1970 1971 1983 1989 1993 1994 2005 2008 Future
1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
CERNCOURIER
Advanced collider vision
Accelerators for Medical Applications
CHICAGO

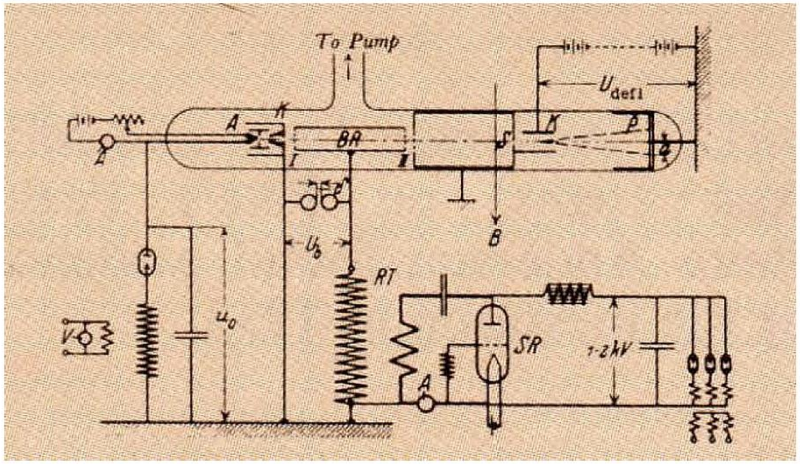
Beginning of the Particle Accelerator Era

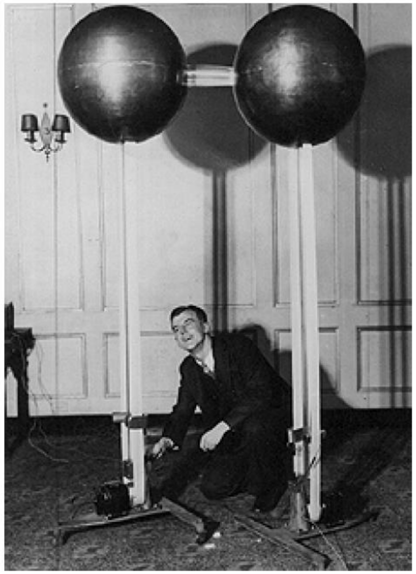


1919: Ernest Rutherford discovered the nuclear disintegration by bombarding nitrogen with alpha particles from natural radioactive substances. Later he **called for "a copious supply" of particles more energetic than those from natural sources.** The particle accelerator era was born.

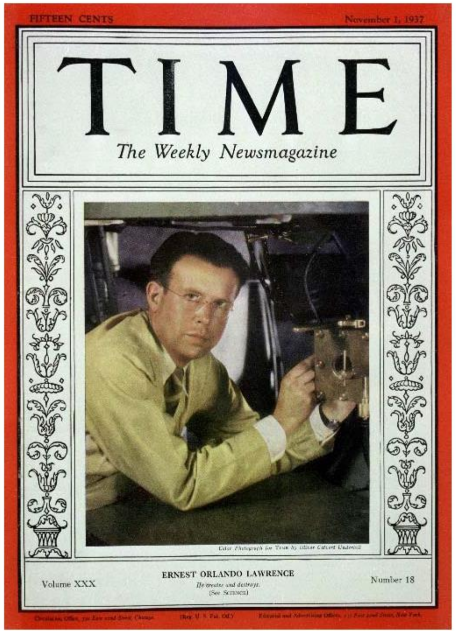
First Generation of Accelerators – 1920-1930s

1928: Rolf Wideröe, 88 cm glass tube linac

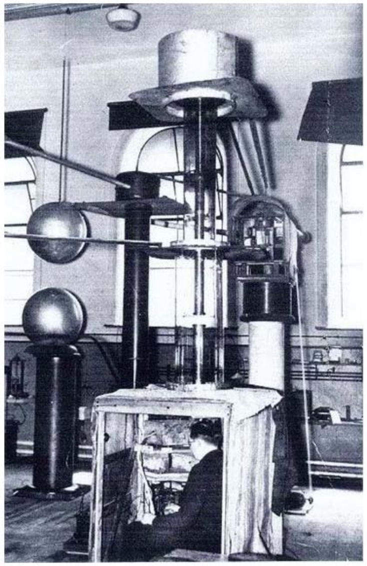




1929: Van de Graaff generator



1930: Ernest Lawrence, 4” cyclotron



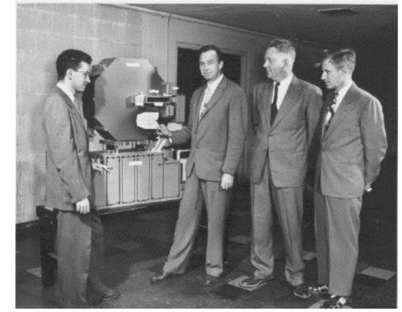
1932: Cockcroft-Walton electrostatic accelerator

Milestones

1943: Synchrotron

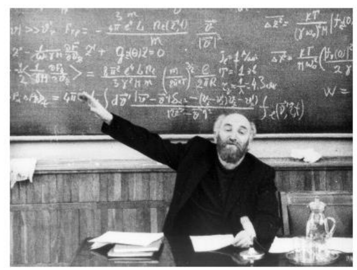
1944: Phase stability

1952: Strong focusing



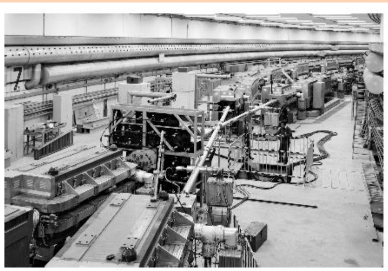
1961: 1st lepton collider

1966: Electron cooling

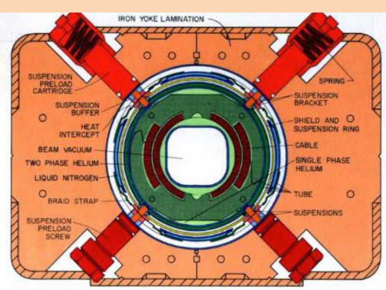


1968: Stochastic cooling

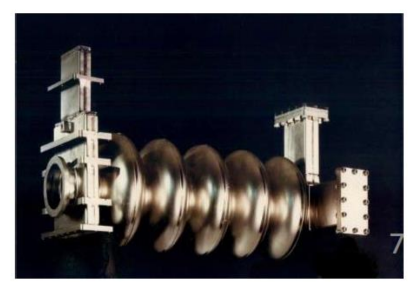
1969: 1st hadron collider



1983: SC magnet

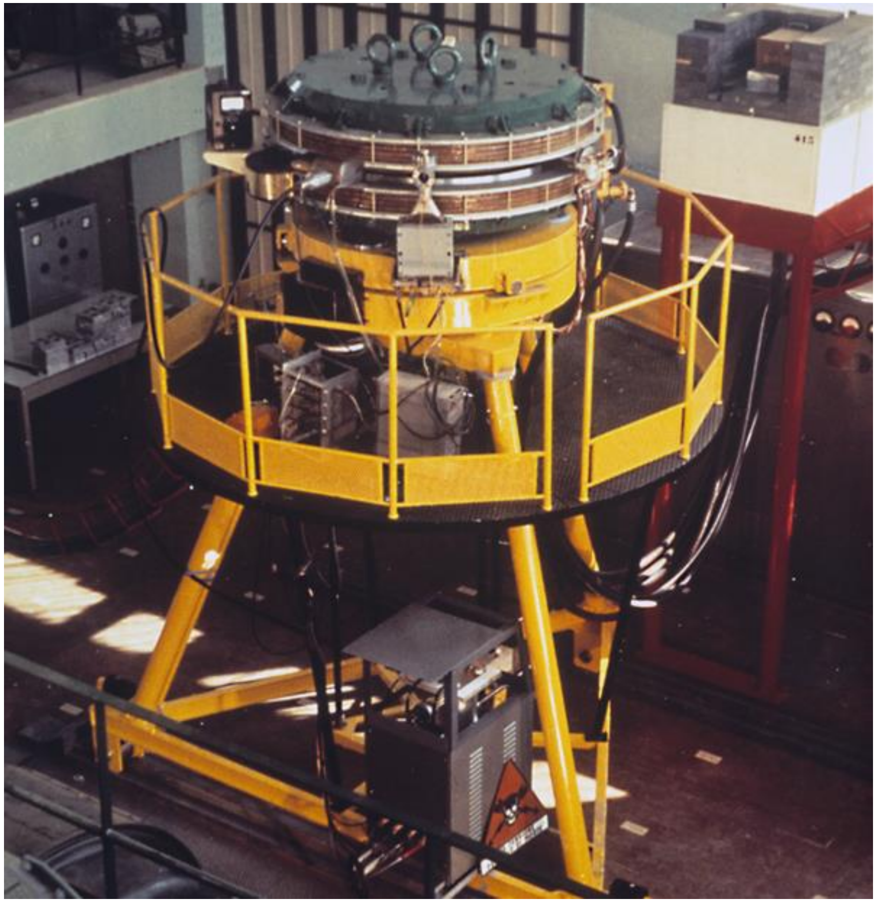


1994: Superconducting RF

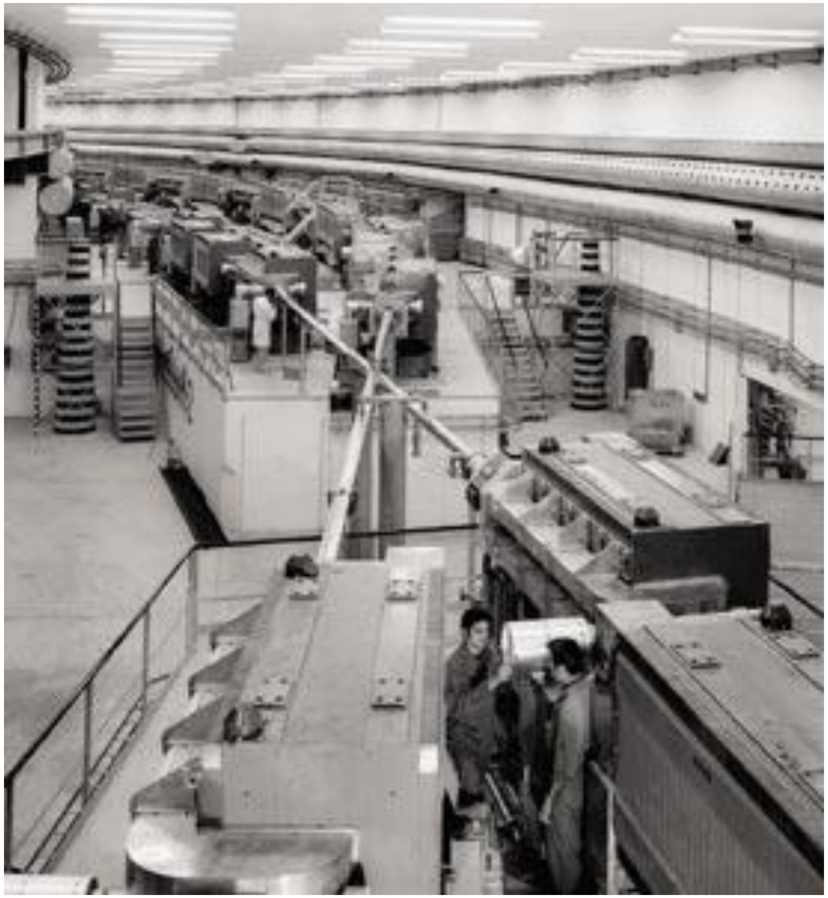


First Generation of Colliders – 1960s

1961: AdA first lepton collider



1969: ISR first proton collider



Tens of Thousands Accelerators were built

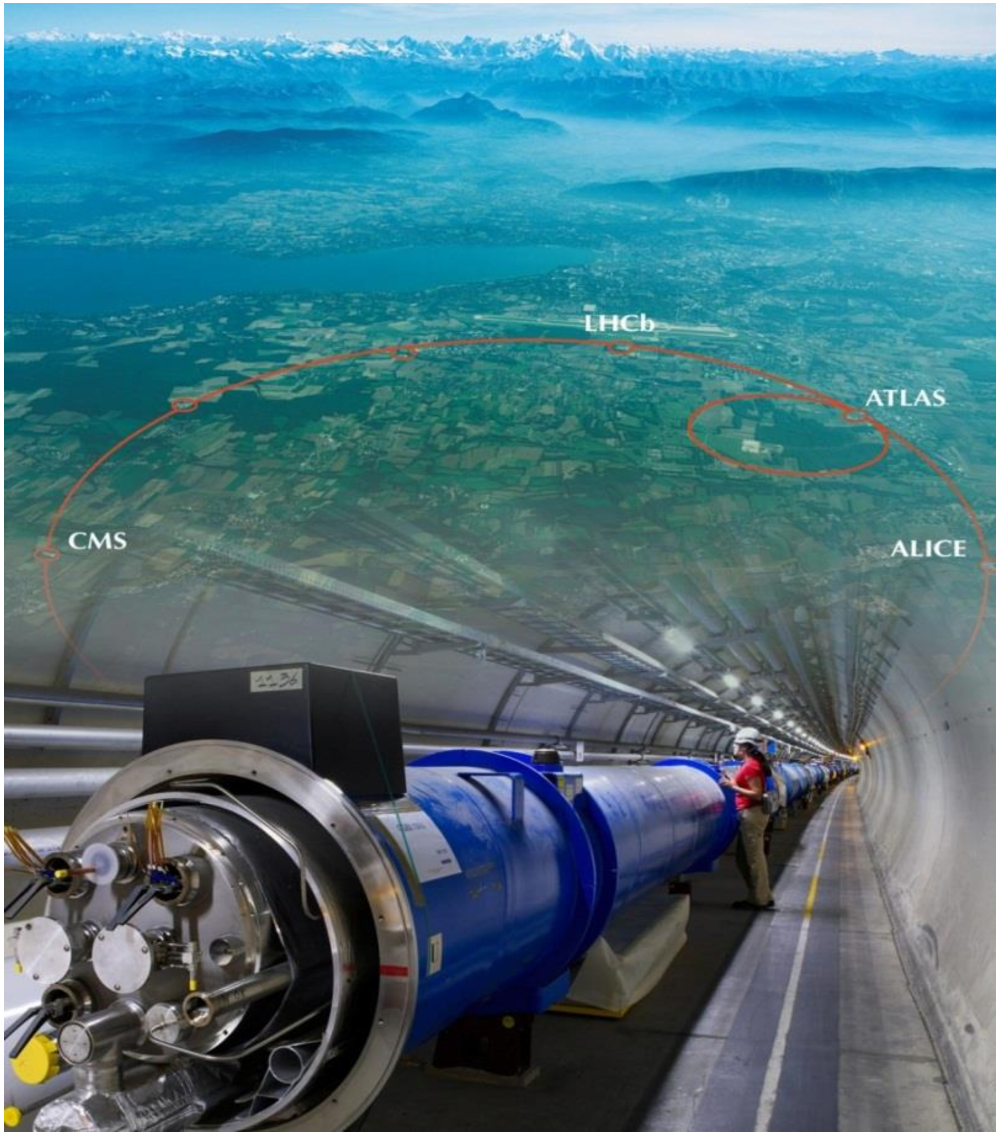
Light Sources

Neutron Sources

Medical Accelerators

Industrial Accelerators

World's Largest Collider – LHC (27 km)



World's Largest Collider – LHC (27 km)

LHC = *Large Hadron Collider*

or

Last Hadron Collider?

Summary

- Alex has dedicated his entire career not only to research, but also to teaching and education.
- In the past several decades, hundreds or maybe even thousands young people have benefitted from reading his books and papers, entering his schools or directly listening to his teaching. Many of them are now playing important roles in the accelerator community around the world or have become leaders in some specific field.
- We want to thank him for his invaluable effort in training and teaching young generations of accelerator scientists.

Thank you, Alex!