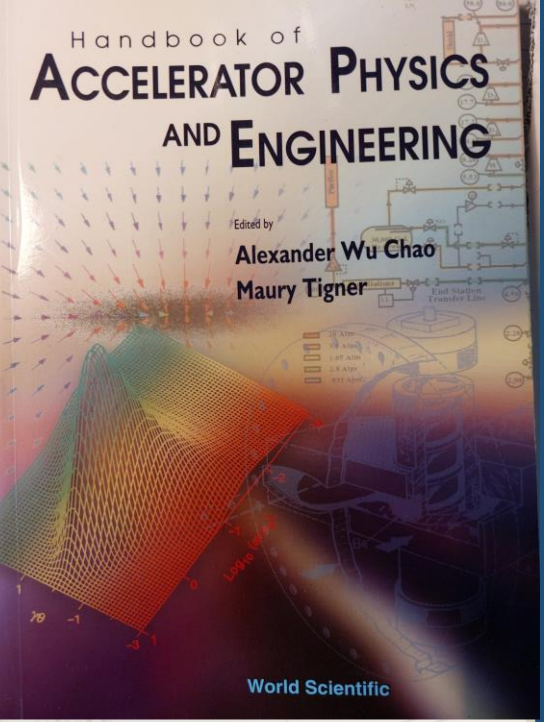
Handbook of Accelerator Physics and Engineering
3^{rd} Edition

Frank Zimmermann, CERN

26 April 2023

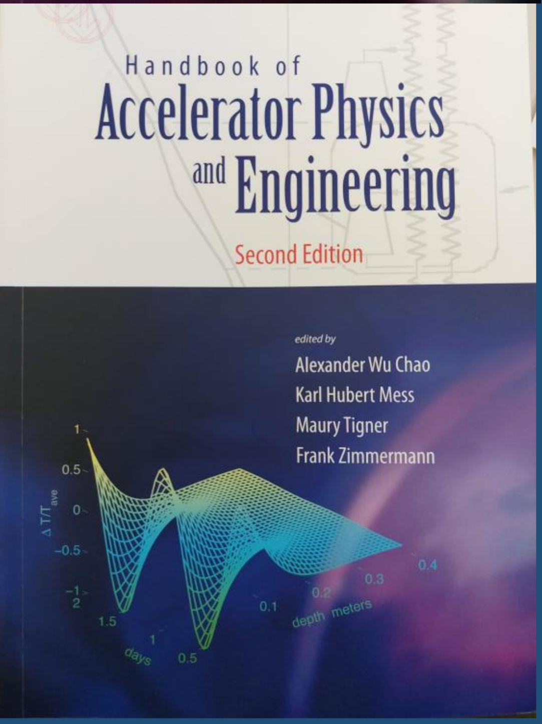
https://indico.cern.ch/event/1275391/



1st edition, 1999

edited by
Alex Chao,
Maury Tigner

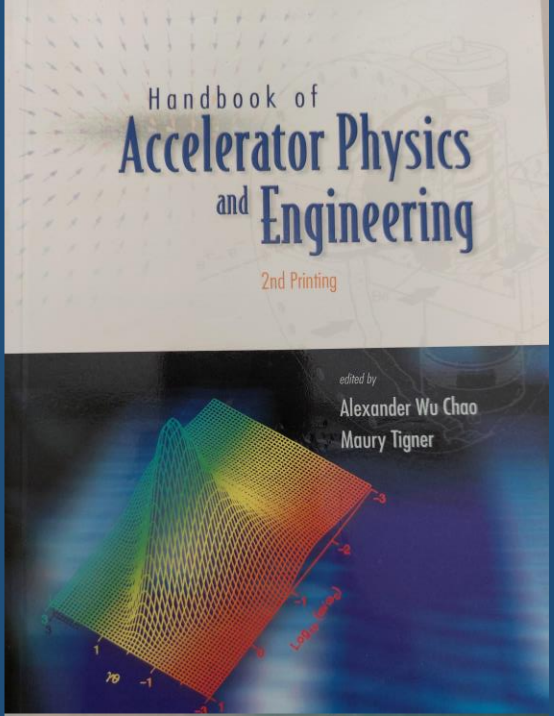
8 chapters,
650 pages



2nd edition, 2013

edited by
Alex Chao, Karl-Hubert
Mess, Maury Tigner,
Frank Zimmermann

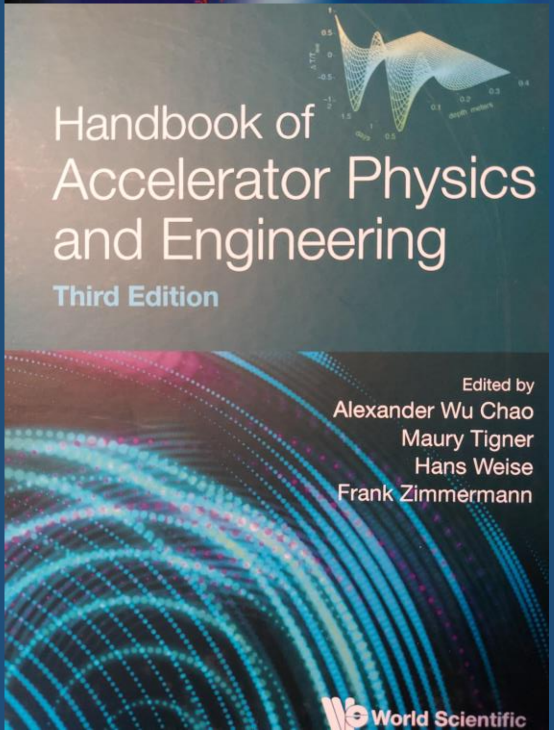
8 chapters,
802 pages



1st edition, 2002
2nd printing

edited by
Alex Chao,
Maury Tigner

8 chapters,
654 pages



3rd edition, 2023

edited by
Alex Chao, Maury Tigner,
Hans Weise,
Frank Zimmermann

7 chapters, 909 pages

Preface

This Handbook is a product of the world community of accelerator physicists and engineers. The first edition was issued September, 1998, a second edition in July 2012, and a third edition in December 2022. With the continued advancing of the accelerator field, a third edition appears now in order.

This is not a textbook but rather a collection of information useful to professionals in research, design, construction, and operation of accelerators. The Handbook has been prepared by more than 200 experienced experts from across the spectrum of accelerator related institutions and to them sincere thanks are due.

In addition to content, a high priority has been given to portability of the book. This has led to a sacrifice of some aesthetics in order to make the text as compact as possible. For that, our apologies go to users and authors alike.

Singularly important are the references to be found at the end of each subsection. Here the user will find locations of tutorial material as well as reliable detail for further reading. The references are not intended to be exhaustive or to indicate priority of discovery or invention, but rather to provide a reliable lead into the literature. In addition, a detailed index gives access to occurrences of important subjects and concepts to be found herein.

Preface cont‘d

The fees and royalties that would normally be paid to authors and editors are donated to provide scholarships to the CERN Accelerator School and to the US Particle Accelerator School.

Authors and Editors have made great efforts to find and eliminate errors. Nevertheless we recognize that there will be errors and have provided for errata to appear on a Handbook website:
https://www.worldscientific.com/worldscibooks/10.1142/13229

Please help in this community effort by sending suggestions for corrections by e-mail to the address frank.zimmermann@cern.ch

major changes

We removed chapter 8 “Radiation effects and protection” except for 8.7 Rad. Damage Thresholds (integrated not Chapter) – chapters 8 from 1st and 2nd edition continue to serve as a reference

We updated, added or extended many new and “hot” topics, e.g.:
LHC, SuperKEKB, RHIC operation etc.
CLIC & CTF3
SC proton linacs
SC e- linacs
EIC, FCC, CEPC
Ultimate storage rings
Advanced FEL schemes
Ultrafast electron diffraction
Top-up injection
Emittance exchange
Multiple frequency rf systems
Machine learning for accelerators
Gamma factory
…

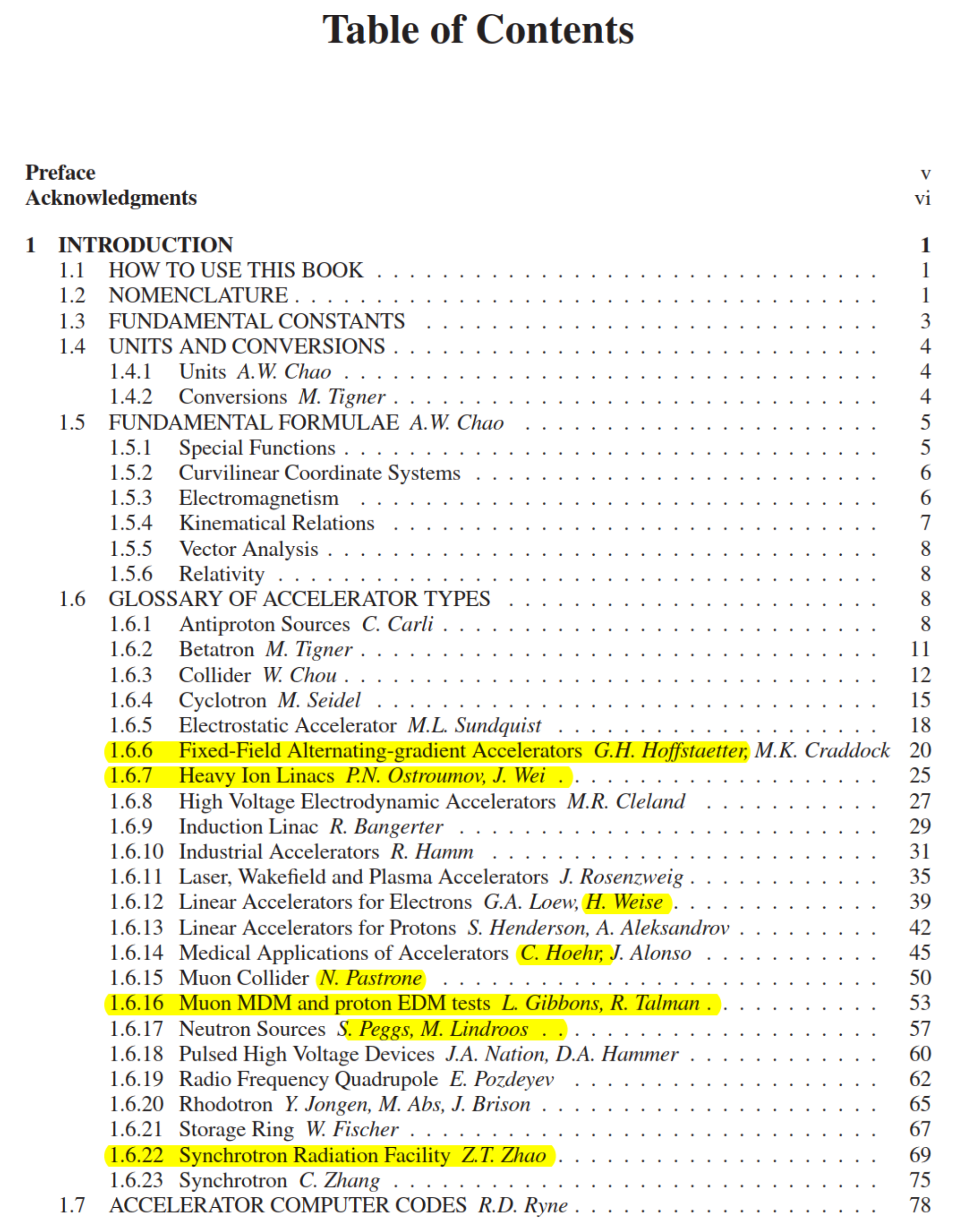
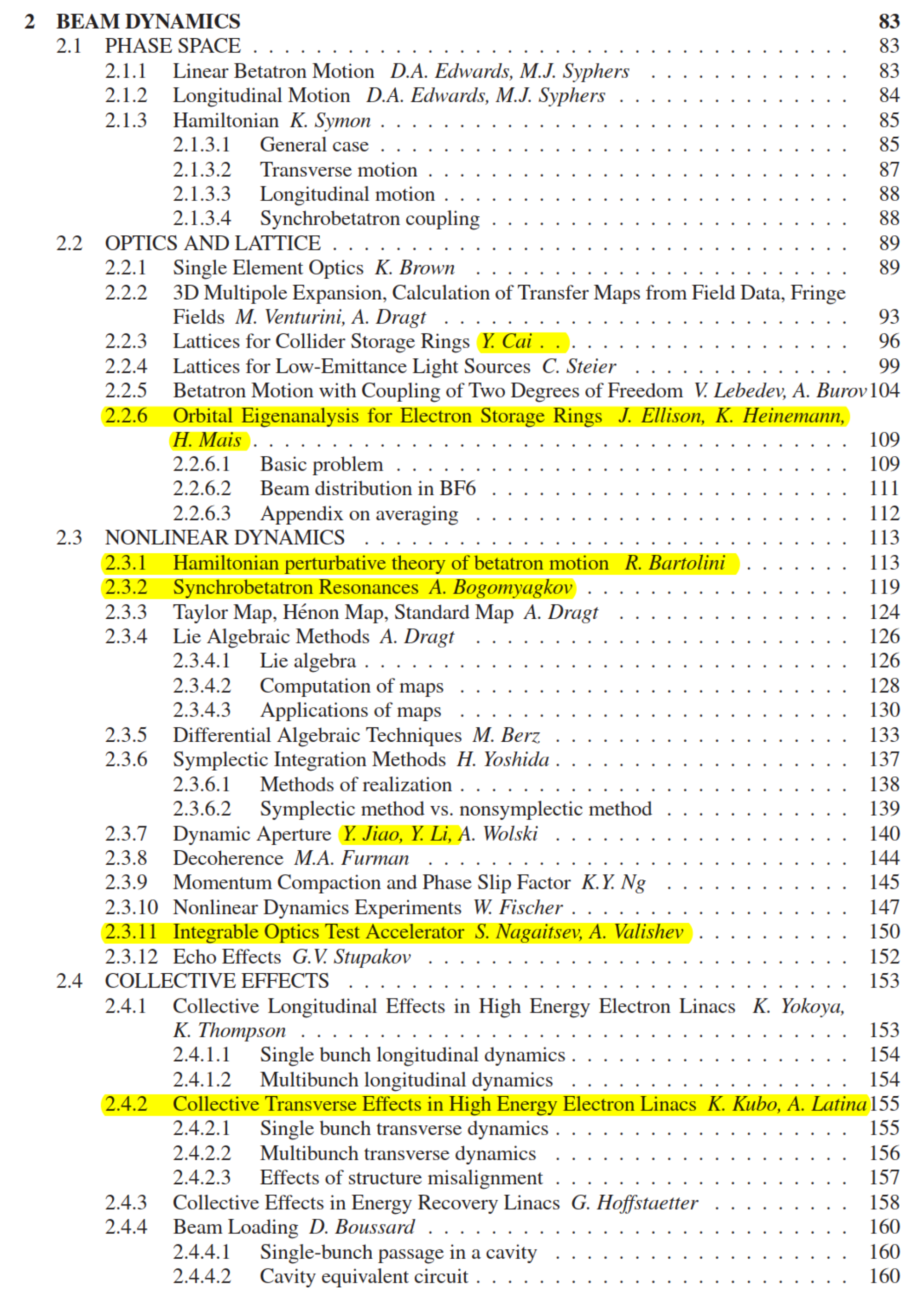
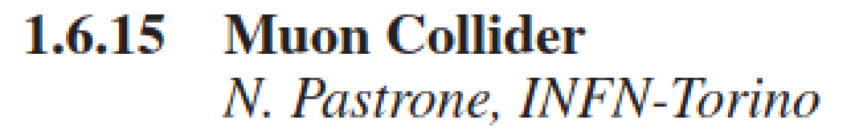


Table of Contents

new sections and new authors high-lighted





1.6.15 Muon Collider

N. Pastrone, INFN-Torino

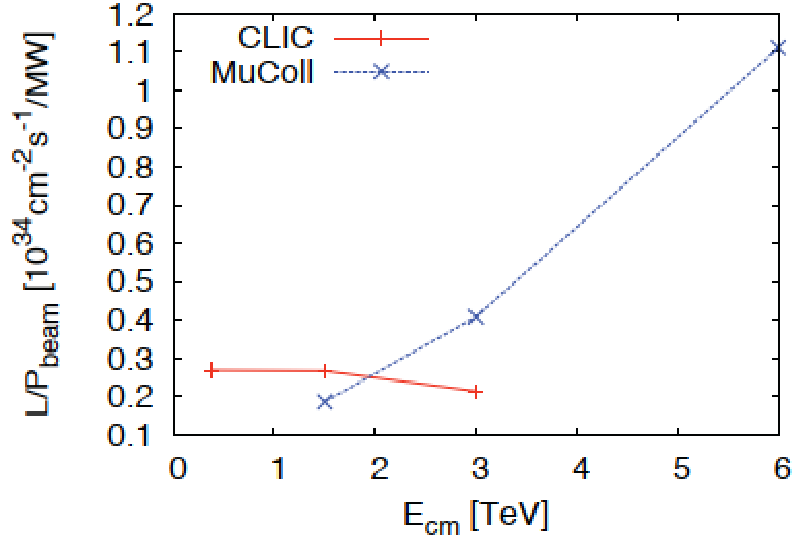
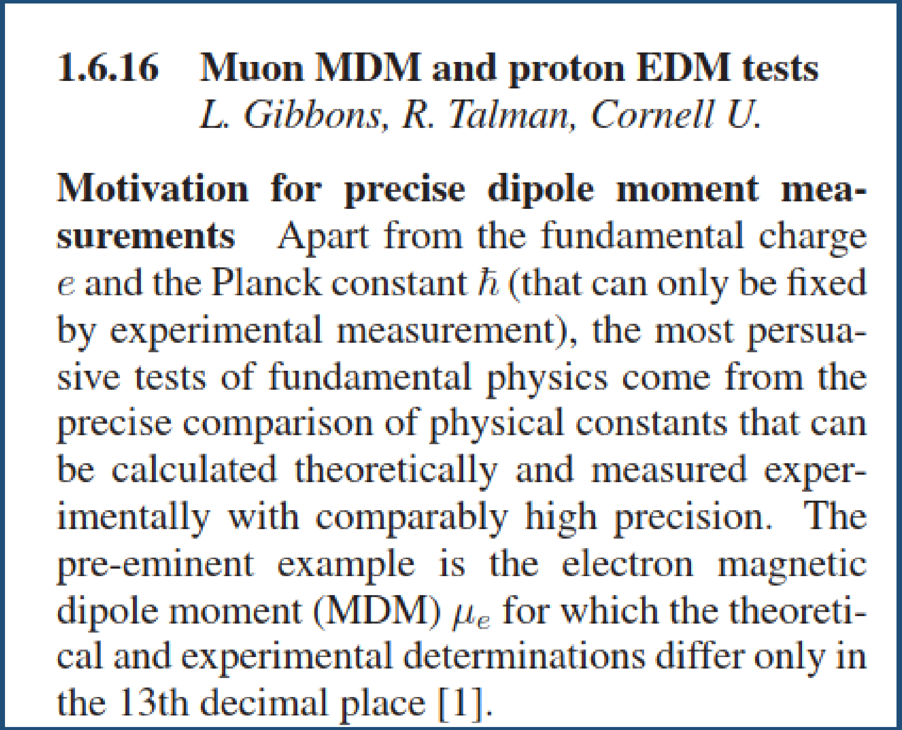


Figure 1: Luminosity per MW of beam power for a proton-based muon collider compared to CLIC, at different centre of mass energy per interaction point. For CLIC the full luminosity is given: at 3 TeV the effects of beamstrahlung increasing with centre-of-mass energy is evident. The muon collider luminosity per power is expected to increase linearly with energy beyond 6 TeV.



1.6.16 Muon MDM and proton EDM tests

L. Gibbons, R. Talman, Cornell U.

Motivation for precise dipole moment measurements Apart from the fundamental charge e and the Planck constant $\hbar$ (that can only be fixed by experimental measurement), the most persuasive tests of fundamental physics come from the precise comparison of physical constants that can be calculated theoretically and measured experimentally with comparably high precision. The pre-eminent example is the electron magnetic dipole moment (MDM) μ_e for which the theoretical and experimental determinations differ only in the 13th decimal place [1].

2.4.6.3 Space charge nonlinear resonances

G. Franchetti, GSI

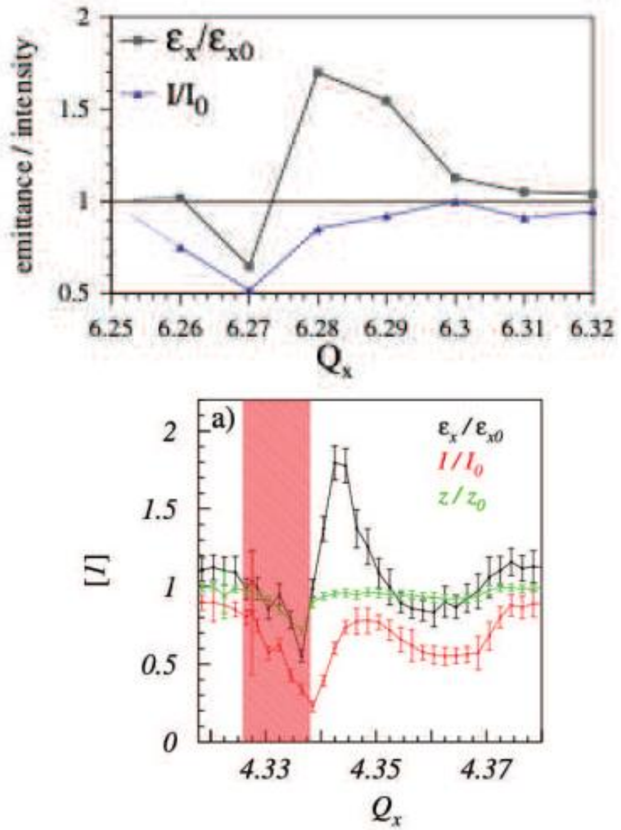


Figure 2: Experimental beam response to 1-D error resonances. Top) with a normal fourth-order resonance carried out at the CERN-PS [8, 9]; Bottom) with a 1-D normal third-order resonance, carried out at the SIS18 at GSI [10].

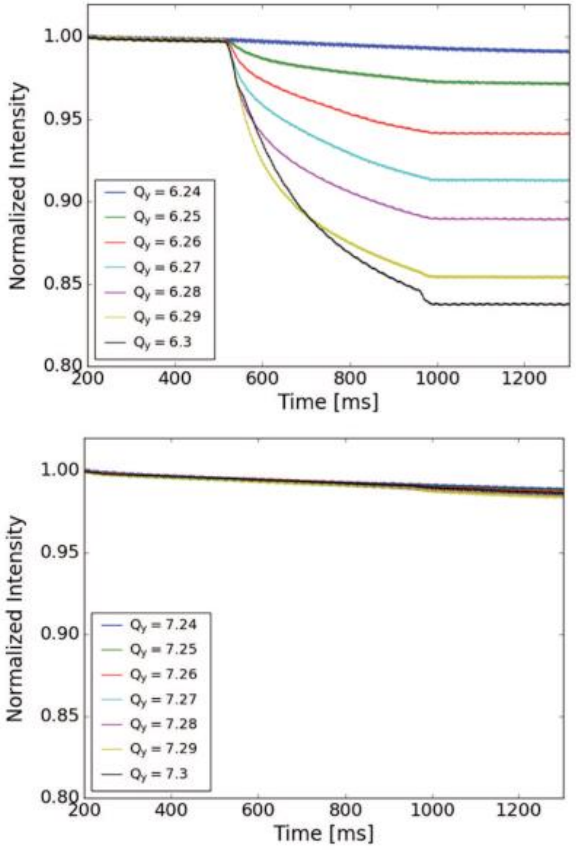


Figure 4: Beam loss by a space charge driven structure resonance [14]. The top picture shows a beam loss over $\simeq$ 500 ms storage with a resonance overlapping varied by changing ν_{y0}. The bottom picture shows the same beam crossing for a changed optics and with no beam loss.

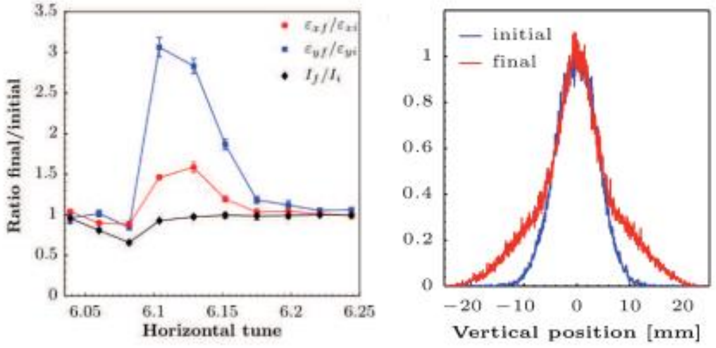


Figure 3: Beam response to a third-order normal coupled resonance excited by a controlled sextupole. The experiment was conducted at the CERN-PS [11]. Left) response to the change of ν_{x0}, being ν_{y0} kept fixed. Right) beam response at the largest vertical emittance growth.

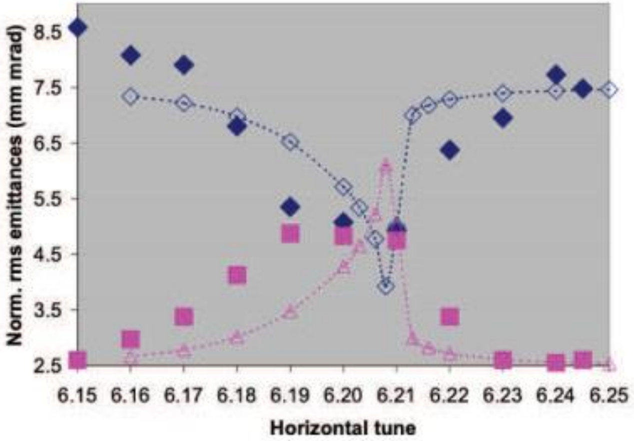


Figure 1: The Montague resonance. Beam emittances after the Montague resonance crossing (full markers, black for horizontal, and magenta for vertical emittance), with empty markers the simulation modeling of the experiment [5].

2.3.11 Integrable Optics Test Accelerator
S. Nagaitsev, A. Valishev, FNAL

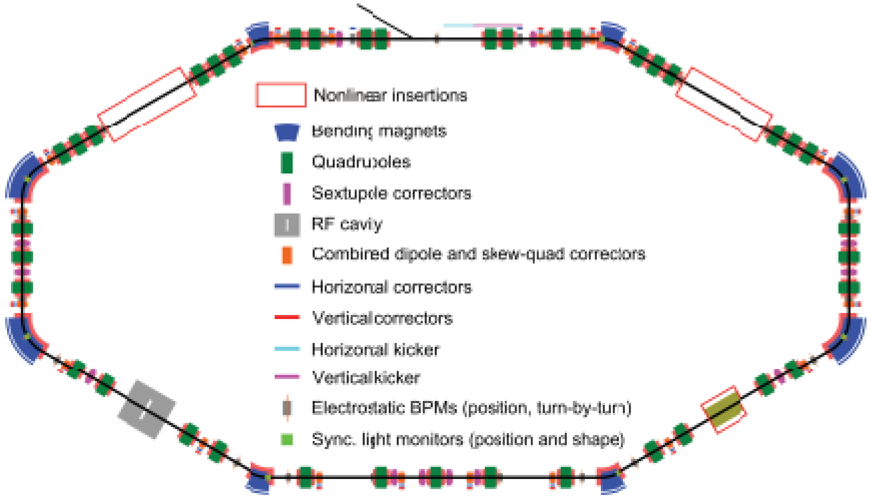


Figure 1: IOTA layout

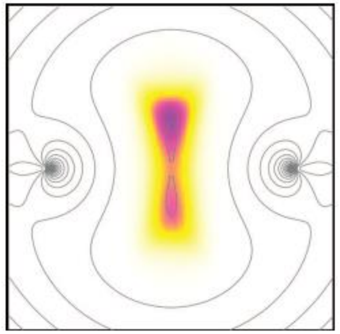


Figure 2: Observed image of beam in the NIO lattice at an integer resonance. Overlaid black contour lines show theoretical nonlinear equipotentials.

2.7 BEAM COOLING

2.7.1 Stochastic Cooling
M. Blaskiewicz, BNL

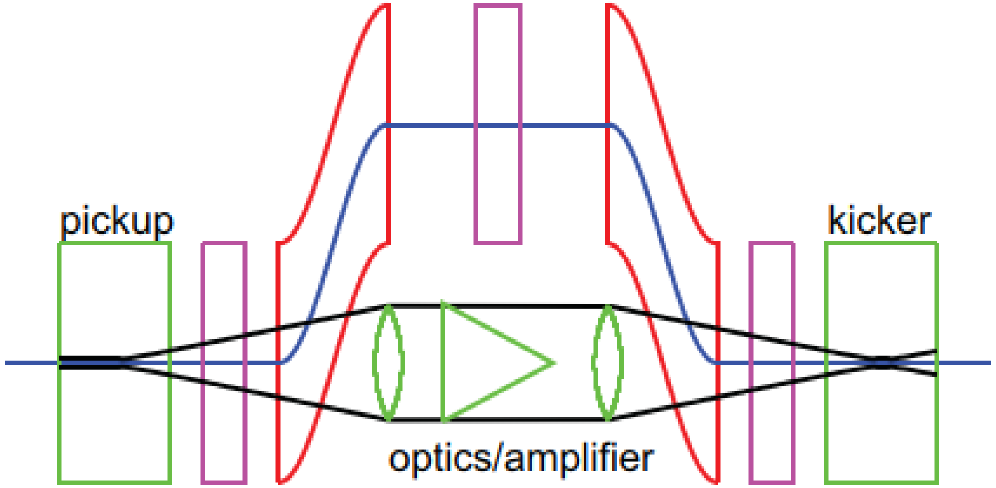


Figure 1: Schematic of OSC: wigglers and optical elements are in green, dipoles are red and focusing elements are magenta. The envelope of the light is black.

2.7.3 Coherent Electron Cooling

G. Stupakov, SLAC

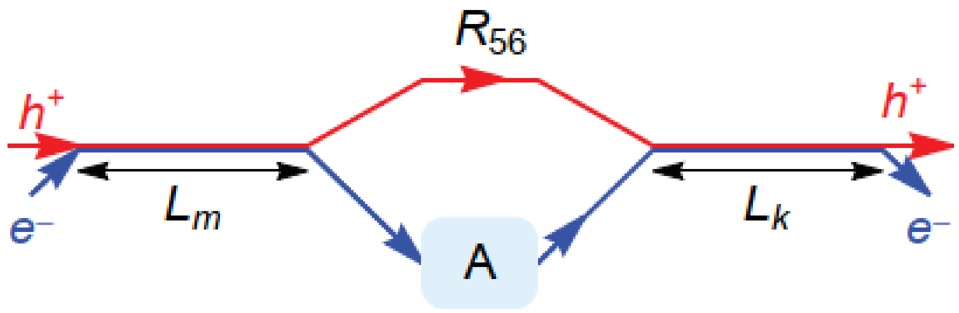


Figure 1: Schematic of a coherent electron cooling system. Blue lines show the path of the electron beam and red lines indicate the hadron trajectory. The amplifier section is marked by letter "A".

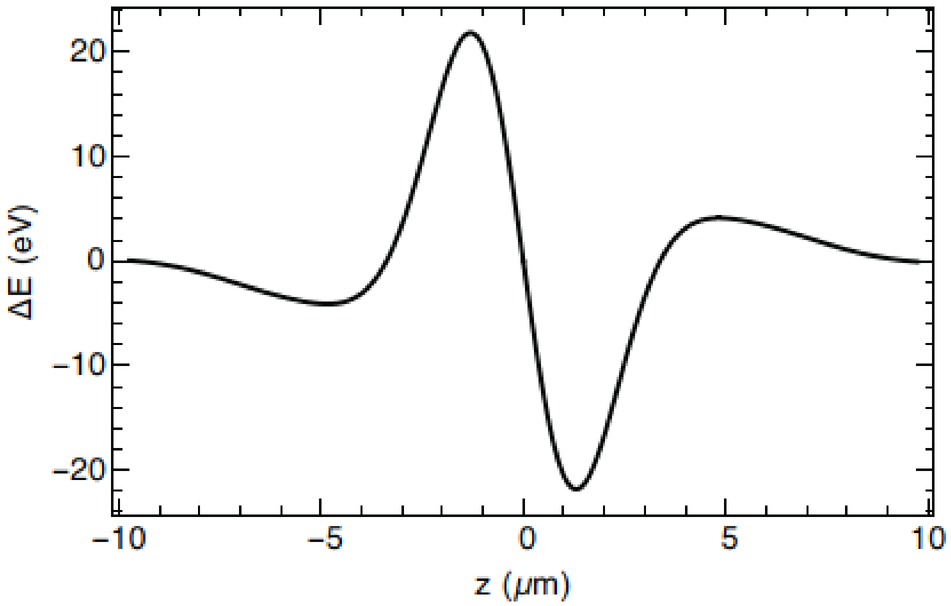
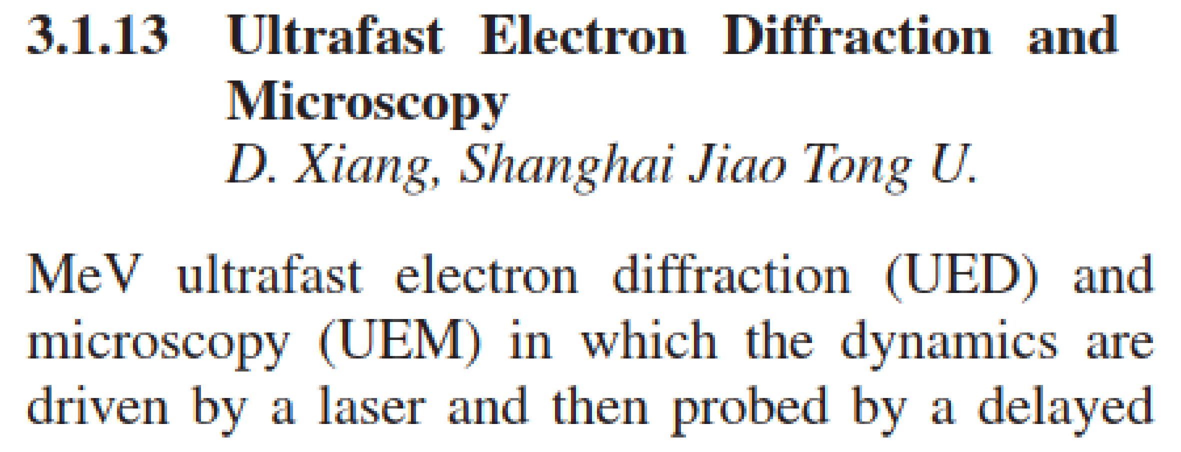


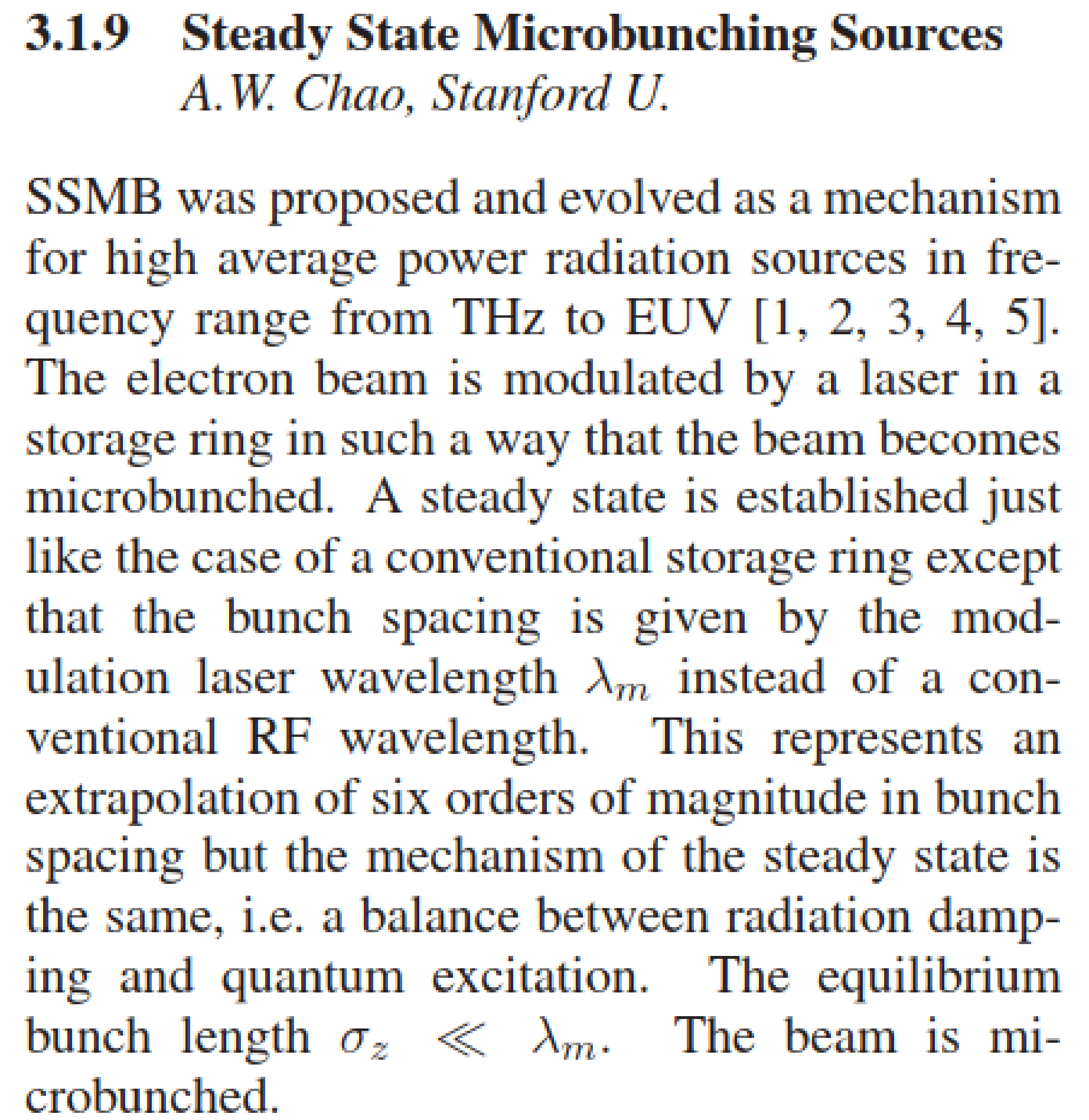
Figure 2: Hadron energy change in the kicker (in electron-volts) as a function of its position z relative to the center of the imprint in the electron beam that a hadron created in the modulator.



3.1.13 Ultrafast Electron Diffraction and Microscopy

D. Xiang, Shanghai Jiao Tong U.

MeV ultrafast electron diffraction (UED) and microscopy (UEM) in which the dynamics are driven by a laser and then probed by a delayed



3.1.9 Steady State Microbunching Sources

A.W. Chao, Stanford U.

SSMB was proposed and evolved as a mechanism for high average power radiation sources in frequency range from THz to EUV [1, 2, 3, 4, 5]. The electron beam is modulated by a laser in a storage ring in such a way that the beam becomes microbunched. A steady state is established just like the case of a conventional storage ring except that the bunch spacing is given by the modulation laser wavelength λ_m instead of a conventional RF wavelength. This represents an extrapolation of six orders of magnitude in bunch spacing but the mechanism of the steady state is the same, i.e. a balance between radiation damping and quantum excitation. The equilibrium bunch length $\sigma_z \ll \lambda_m$. The beam is microbunched.

4.1 LUMINOSITY

M.A. Furman, LBNL
M.S. Zisman, Deceased 2015
F. Antoniou, Y. Papaphilippou, CERN

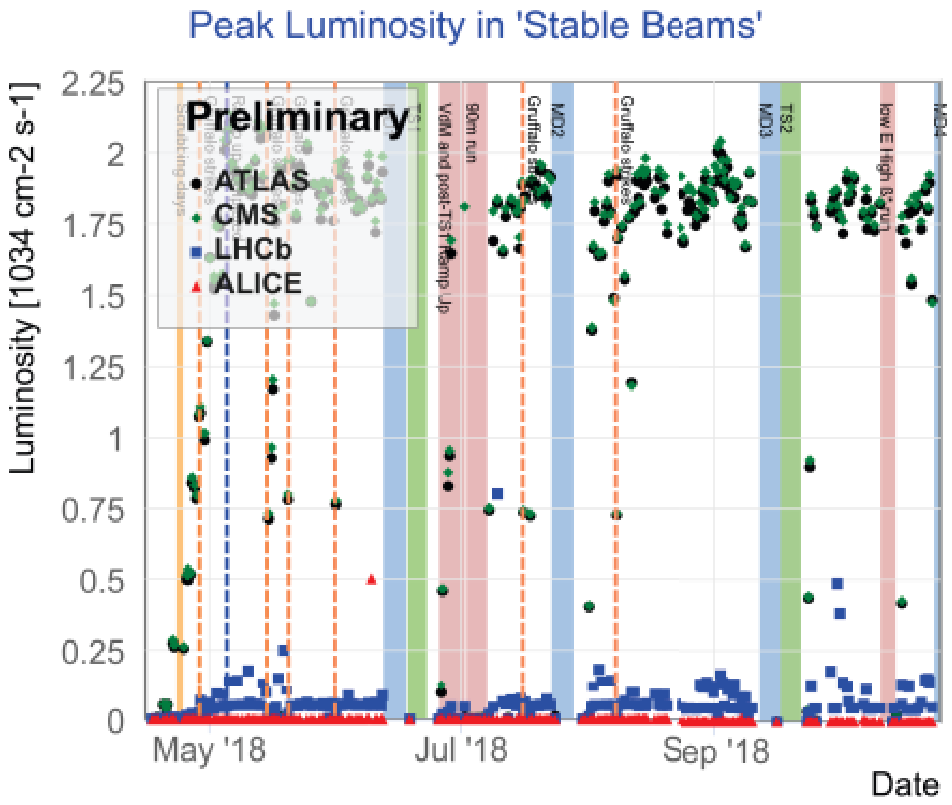


Figure 12: LHC peak luminosity for p–p collisions as observed during 2018 at the four detectors [44].

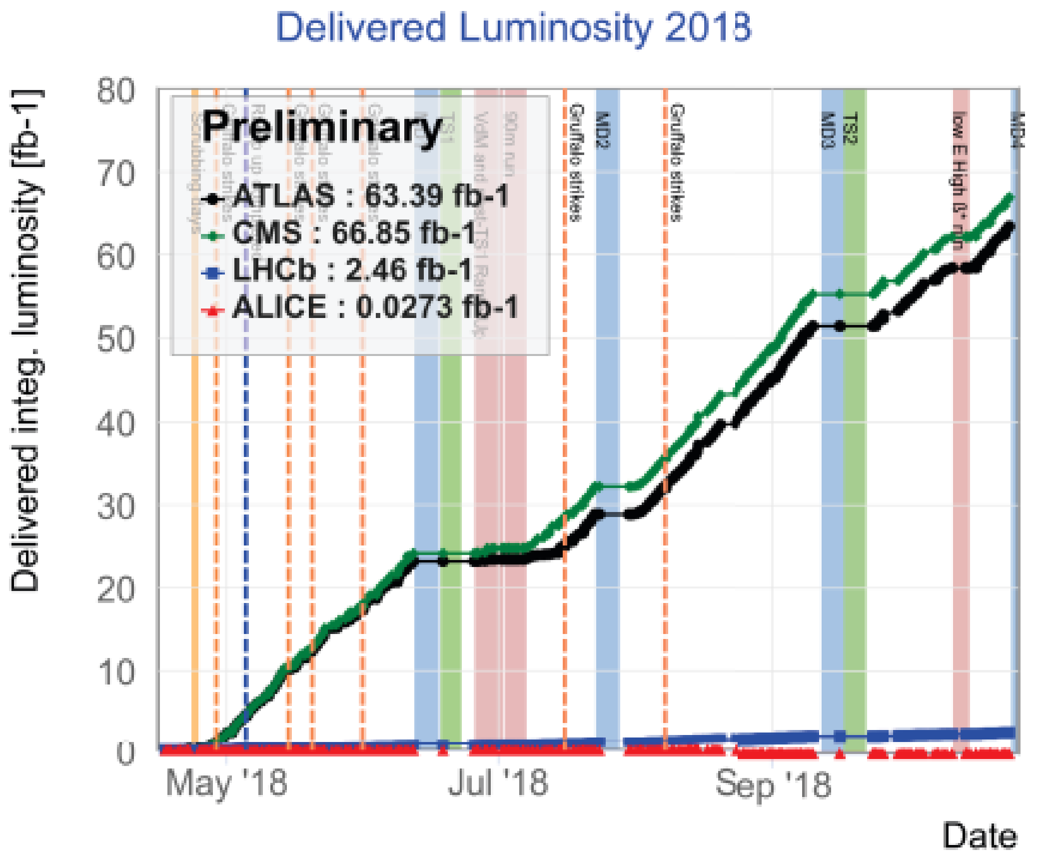
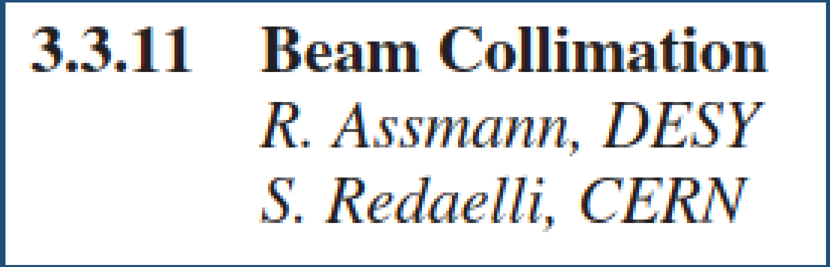


Figure 13: LHC integrated luminosity delivered to four detectors during 2018, for p–p collisions [44].



3.3.11 Beam Collimation

R. Assmann, DESY
S. Redaelli, CERN

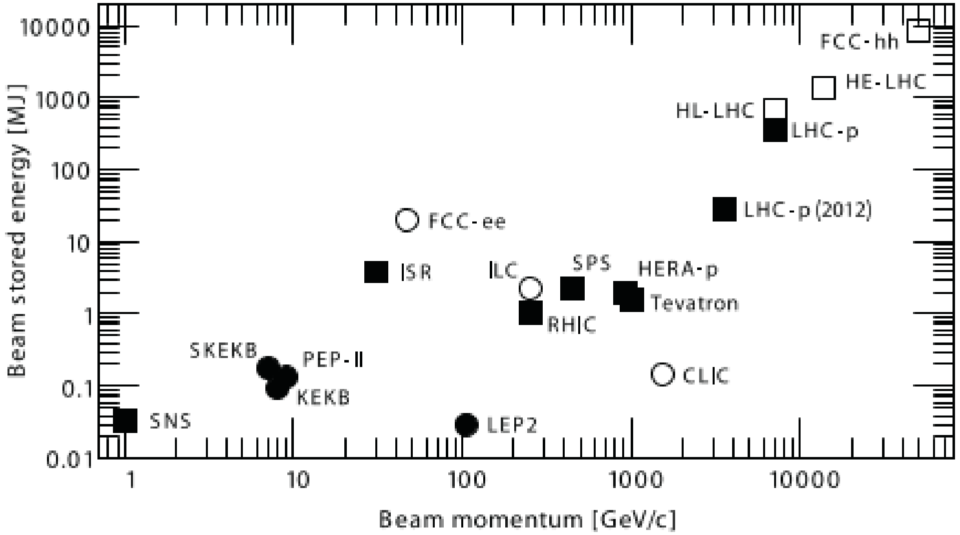


Figure 1: Stored beam energy for different electron (round symbol) and proton (square symbol) accelerators, already achieved (full symbol) or future project (empty symbol).

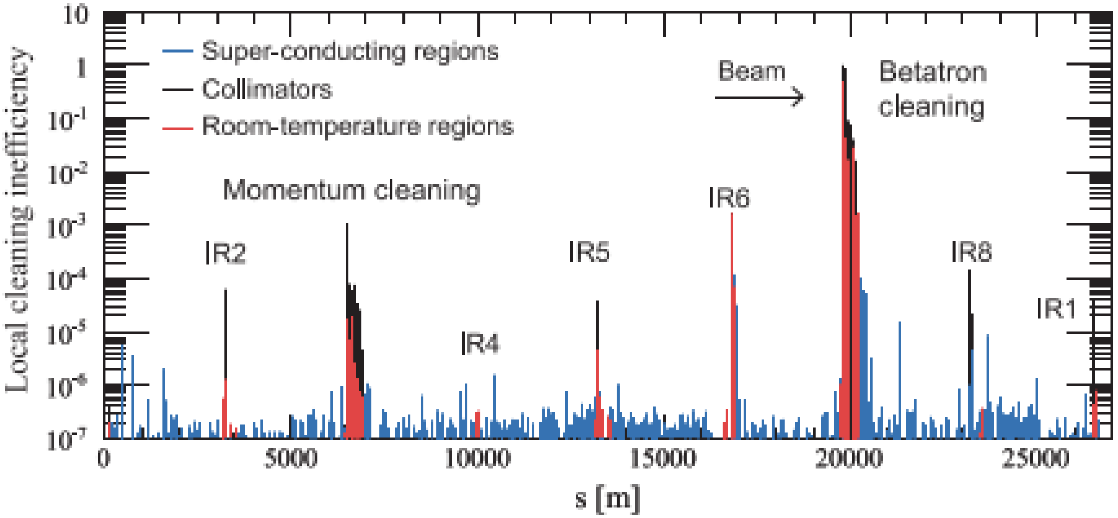
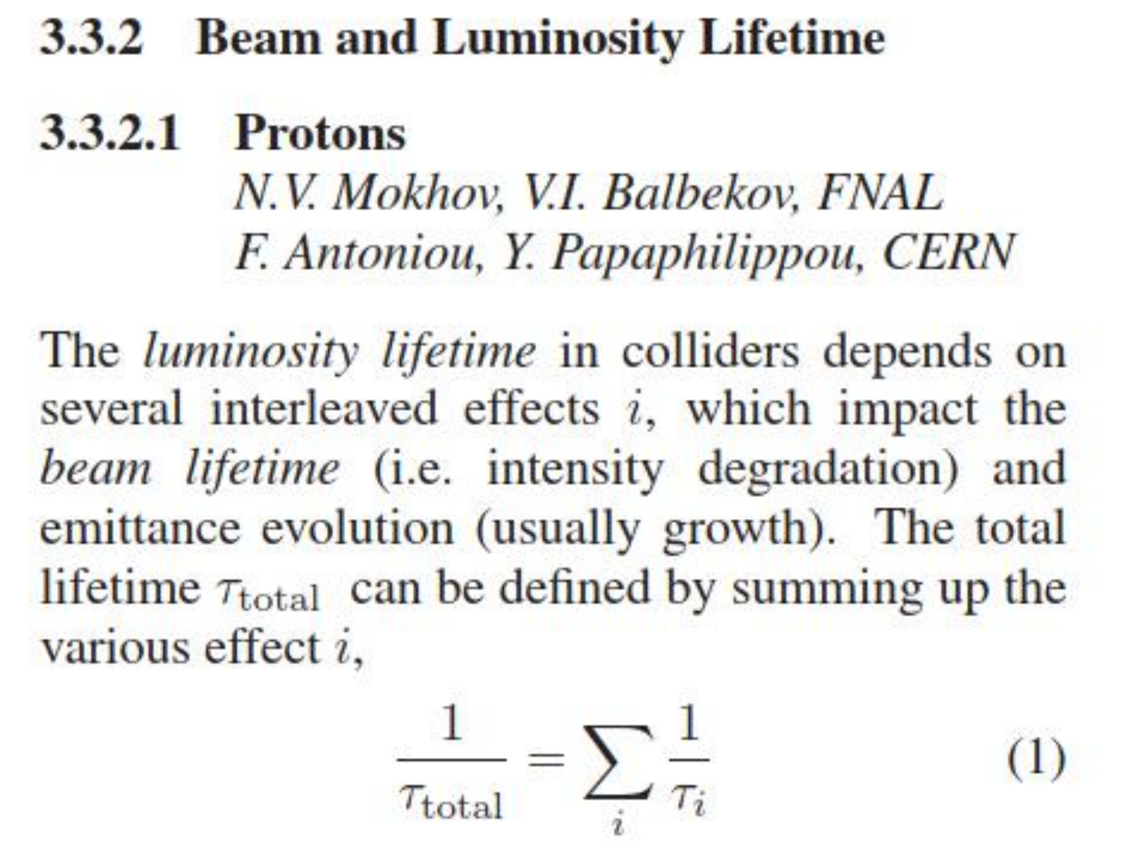


Figure 15: Example measurement of collimation performance in the LHC at 4 TeV [26]. The data show peak integrated losses over 1.3 s. A beam loss in the horizontal plane is provoked for the clockwise beam through an emittance blowup. Losses are normalized to the peak loss in the ring that occur, as expected, at the betatron collimators.



3.3.2 Beam and Luminosity Lifetime

3.3.2.1 Protons

N.V. Mokhov, V.I. Balbekov, FNAL
F. Antoniou, Y. Papaphilippou, CERN

The *luminosity lifetime* in colliders depends on several interleaved effects i, which impact the *beam lifetime* (i.e. intensity degradation) and emittance evolution (usually growth). The total lifetime τ_{total} can be defined by summing up the various effect i,

$$\frac{1}{\tau_{\text{total}}} = \sum_i \frac{1}{\tau_i} \tag{1}$$

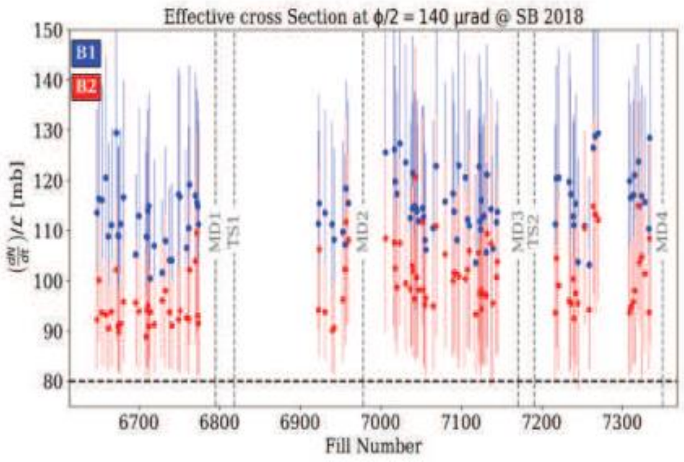


Figure 4: Effective cross section for LHC Beam 1 (blue) and 2 (red) vs. Fill Number for $\phi/2$ = 140 μrad half crossing angle. The inelastic p-p cross section is shown by the black dashed line [13].

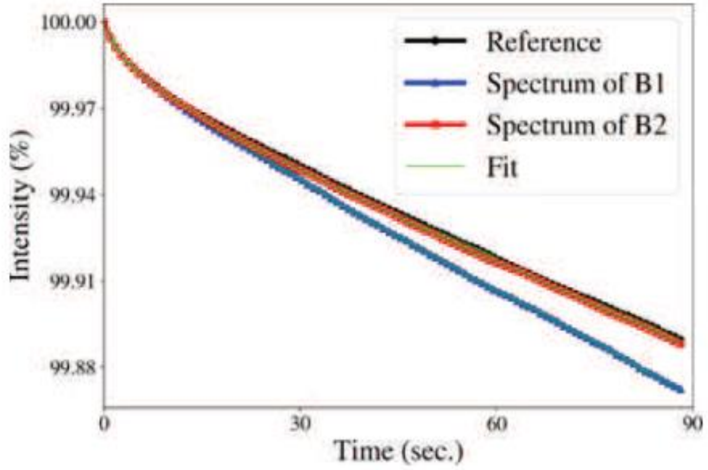
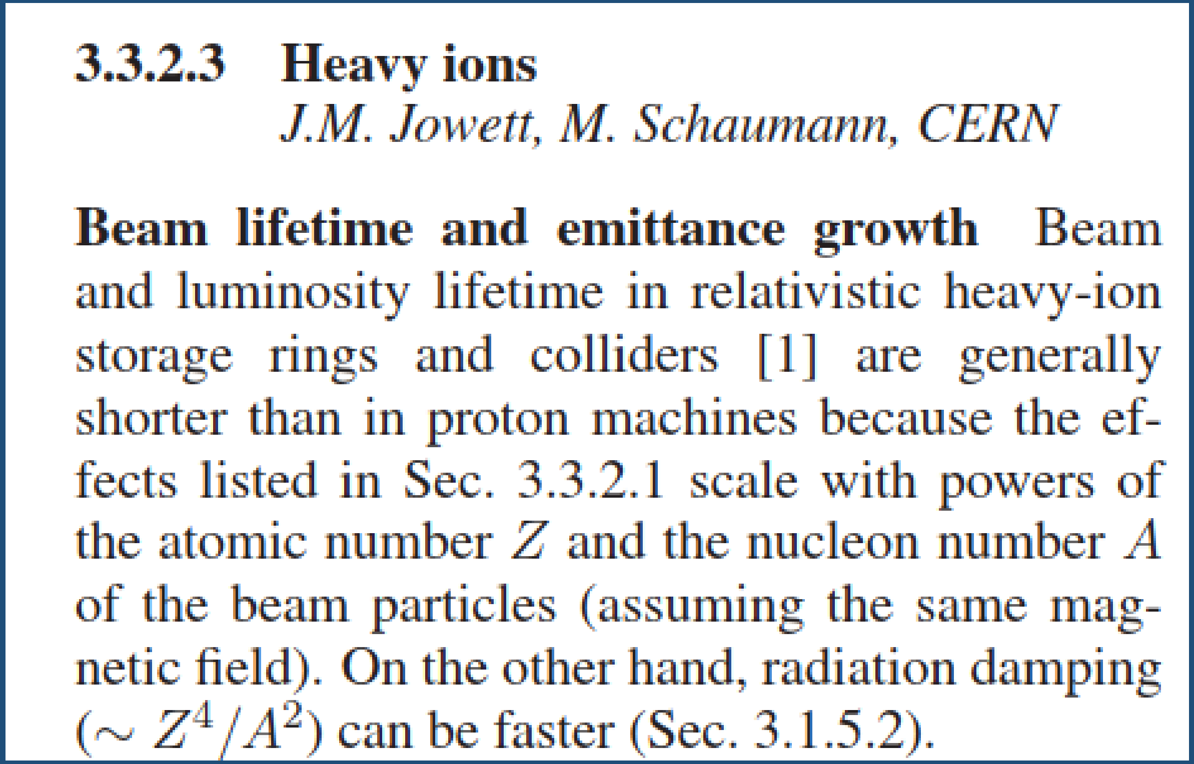


Figure 5: Simulated LHC intensity evolution without power supply ripple (black), and including power supply ripple spectrum of Beam 1 (blue) and 2 (red) [14].



3.3.2.3 Heavy ions

J.M. Jowett, M. Schaumann, CERN

Beam lifetime and emittance growth Beam and luminosity lifetime in relativistic heavy-ion storage rings and colliders [1] are generally shorter than in proton machines because the effects listed in Sec. 3.3.2.1 scale with powers of the atomic number Z and the nucleon number A of the beam particles (assuming the same magnetic field). On the other hand, radiation damping ($\sim Z^4/A^2$) can be faster (Sec. 3.1.5.2).

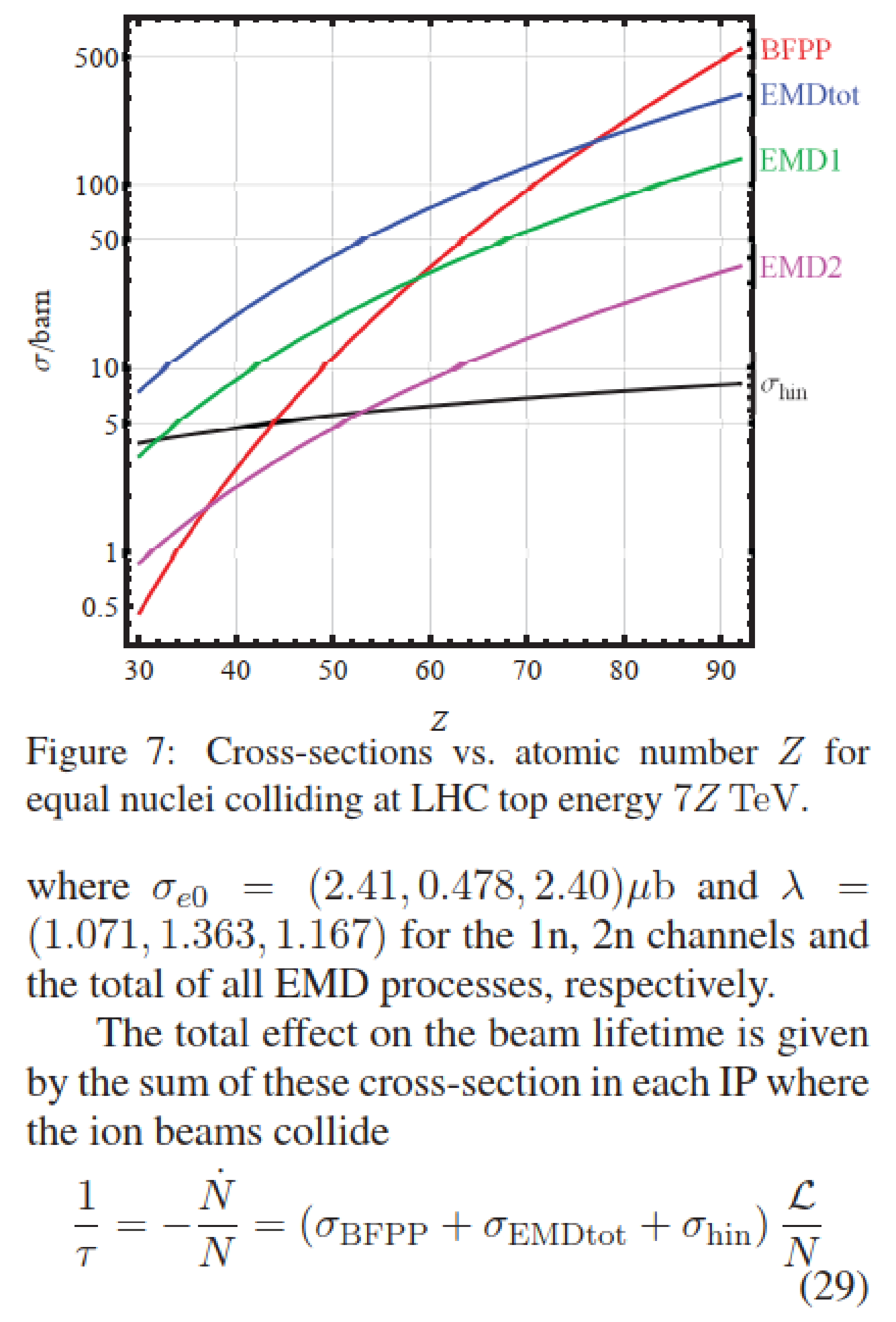
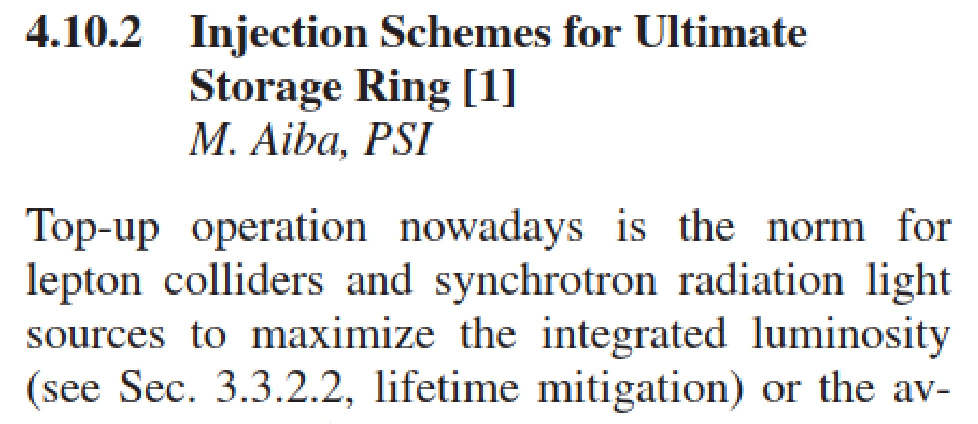


Figure 7: Cross-sections vs. atomic number Z for equal nuclei colliding at LHC top energy $7Z$ TeV.

where $\sigma_{e0} = (2.41, 0.478, 2.40)\mu$b and $\lambda = (1.071, 1.363, 1.167)$ for the 1n, 2n channels and the total of all EMD processes, respectively.

The total effect on the beam lifetime is given by the sum of these cross-section in each IP where the ion beams collide

$$\frac{1}{\tau} = -\frac{\dot{N}}{N} = (\sigma_{\rm BFPP} + \sigma_{\rm EMDtot} + \sigma_{\rm hin})\,\frac{\mathcal{L}}{N} \tag{29}$$



4.10.2 Injection Schemes for Ultimate Storage Ring [1]

M. Aiba, PSI

Top-up operation nowadays is the norm for lepton colliders and synchrotron radiation light sources to maximize the integrated luminosity (see Sec. 3.3.2.2, lifetime mitigation) or the average photon flux. The multi-bend achromat (MBA) lattice d

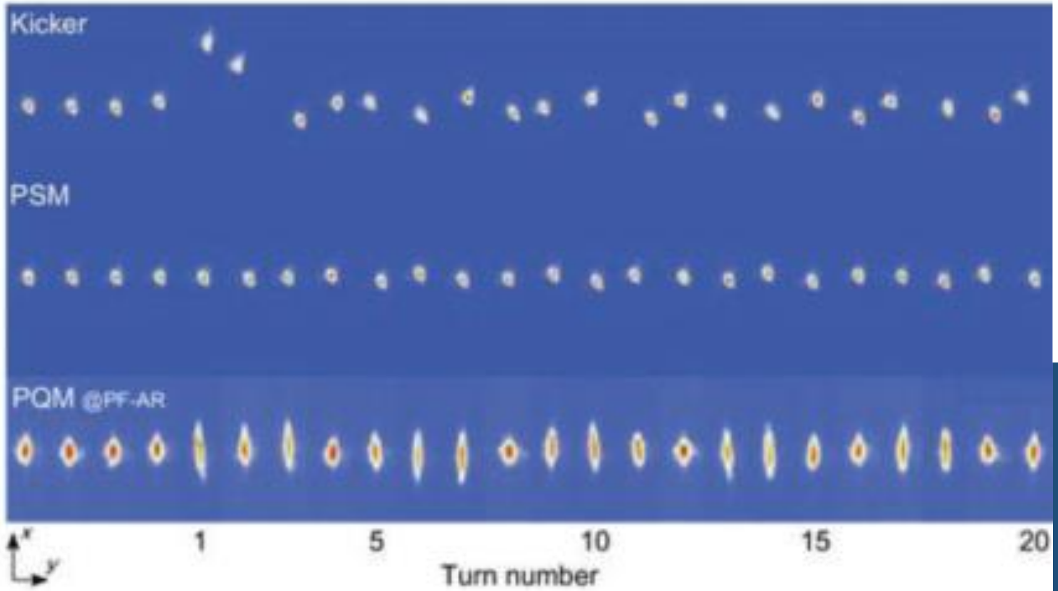


Figure 1: Turn-by-turn stored beam profiles i
conventional, pulsed-sextupole-magnet, and pulsed-
quadrupole-magnet injections [6].

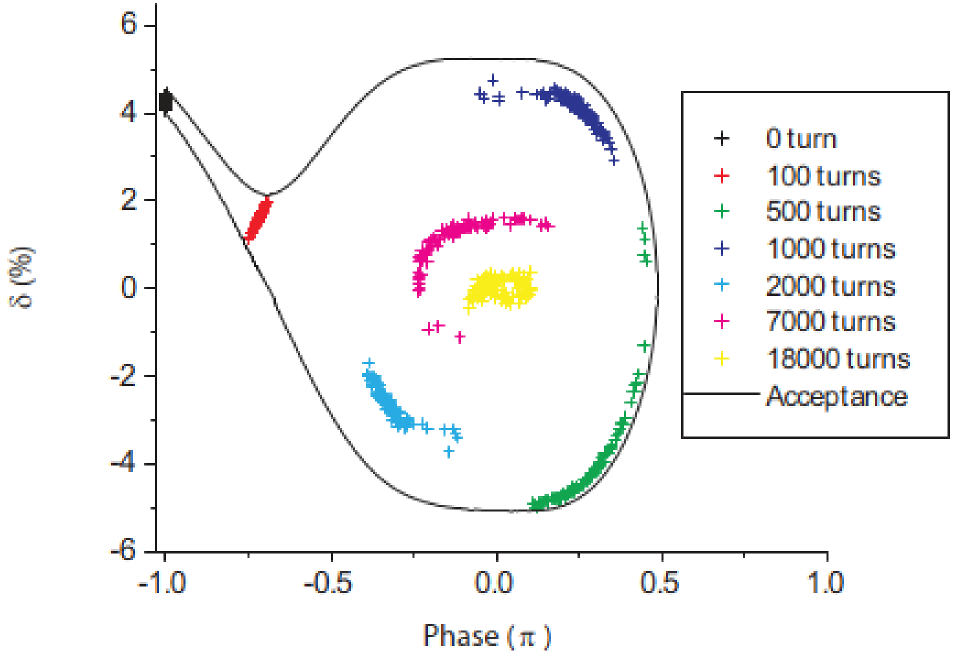


Figure 2: Tracking simulation of longitudinal injection [8].

4.11.1 Design & Operational Considerations for Beam-Beam Effects in Circular Colliders

D. Shatilov, BINP
A. Valishev, Fermilab

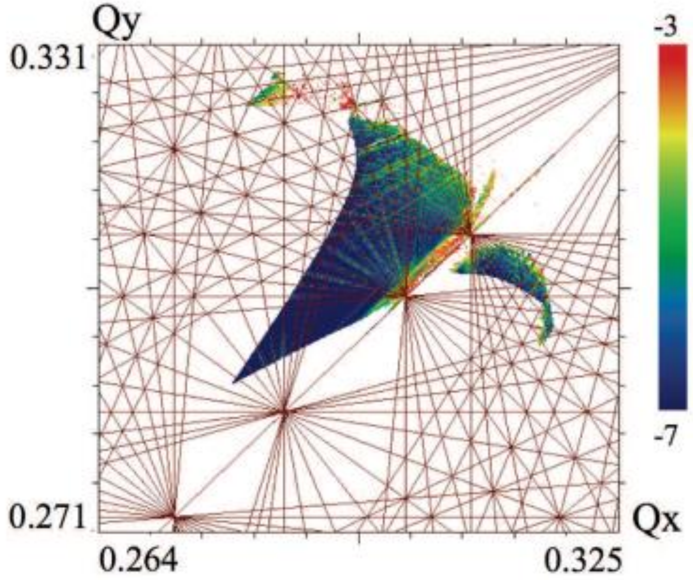


Figure 4: FMA simulation of HL-LHC beam tune distribution superimposed onto a resonance line plot. The color chart shows the logarithm of tune diffusion. Long-range effects intentionally enhanced by reduced crossing angle.

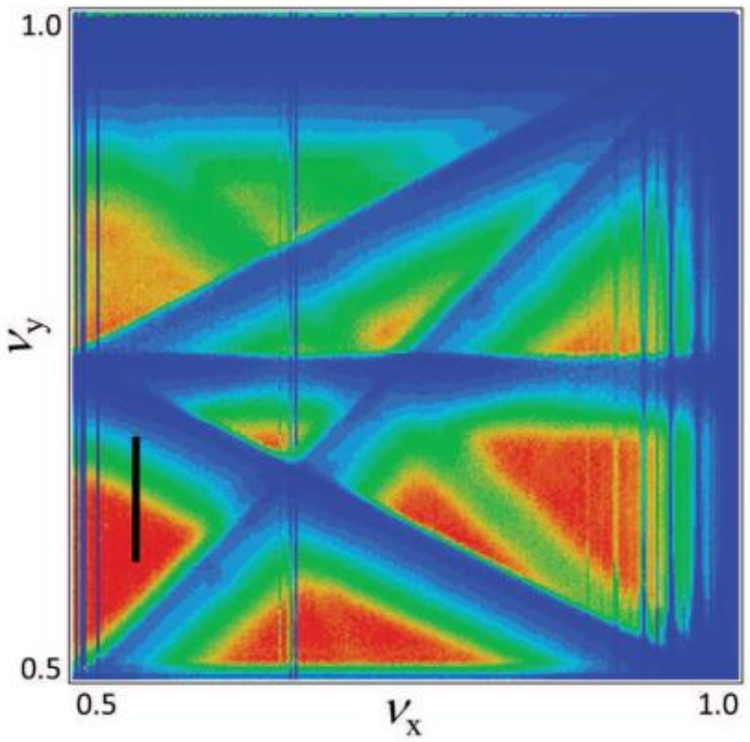


Figure 2: Luminosity of CW collider as a function of betatron tunes, a scale from blue (minimum) to red (maximum). Results of simulations in a simplified weak-strong model, where the strong bunch is not affected and therefore is not crabbed.

4.11.3 Beam-Beam Compensation Schemes

V. Shiltsev, FNAL
G. Sterbini, CERN

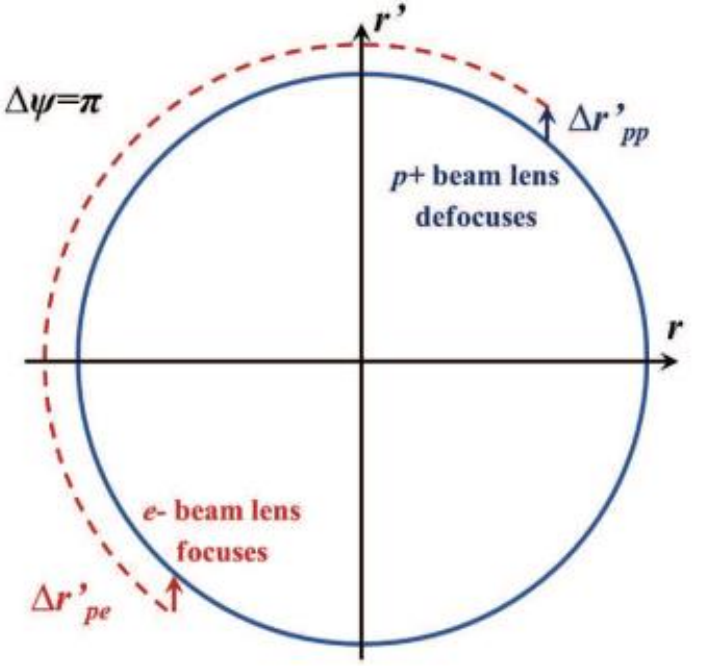


Figure 2: Head-on beam-beam compensation in phase space view. A defocusing kick $\Delta r'_{pp}$ a proton receives from the other proton beam is reversed by a focusing kick $\Delta r'_{pe}$ from the electron lens after a phase advance π.

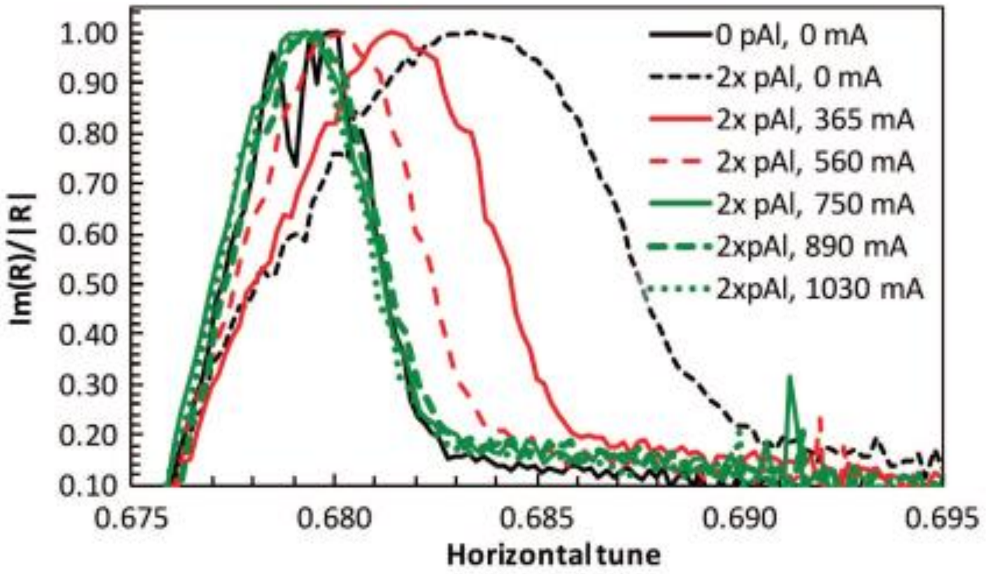
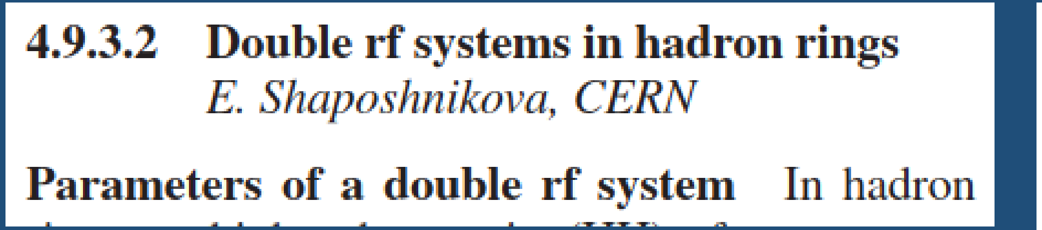


Figure 3: Narrowing of proton tune distribution by the RHIC electron lens, measured for *p-Al* collisions. The width of the distribution caused by two beam-beam collisions shrinks when increasing the electron lens current up to 1.03 A [9].



4.9.3.2 Double rf systems in hadron rings

E. Shaposhnikova, CERN

Parameters of a double rf system In hadron

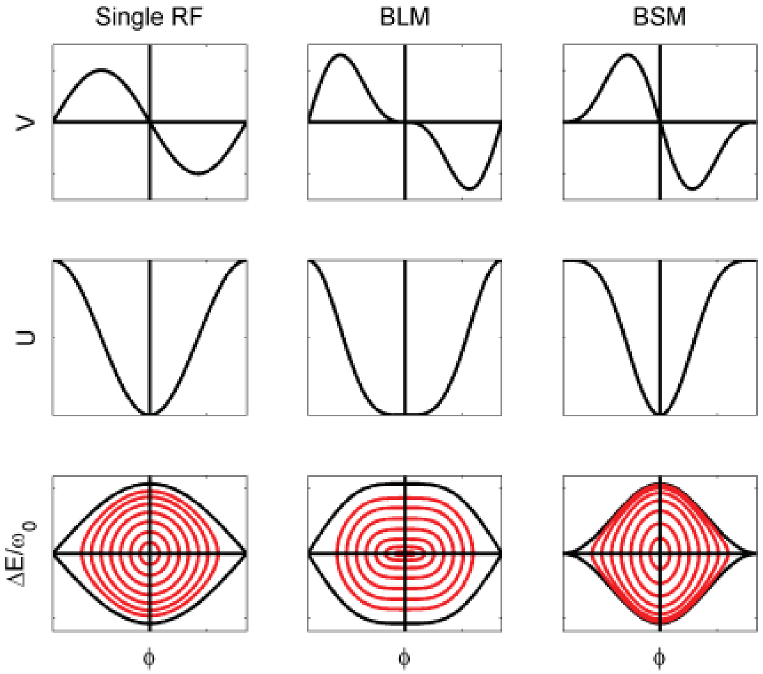


Figure 1: Examples of total rf voltage $V(\phi)$ (top), rf potential $U(\phi)$ and particle trajectories in longitudinal phase space in single (left) and double rf system in BL-mode (middle) and BS-mode (right) for a stationary case (no acceleration) with $n = 2$ and $r = 1/2$.

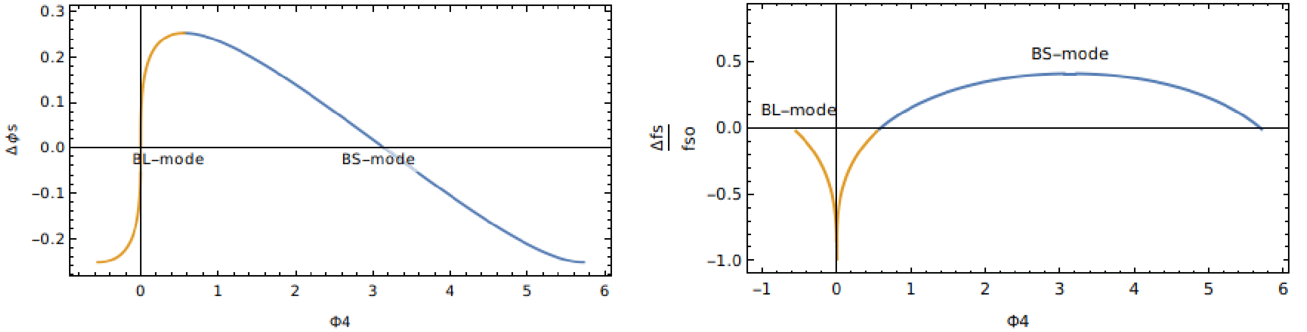


Figure 2: Synchronous phase shift $\Delta\phi_s$ (left) and relative change in synchrotron frequency $\Delta f_s(0)/f_{s0}$ (right) as functions of phase shift Φ_n in double rf system for a stationary case (no acceleration) above transition with $n = 4$ and $r = 1/4$.

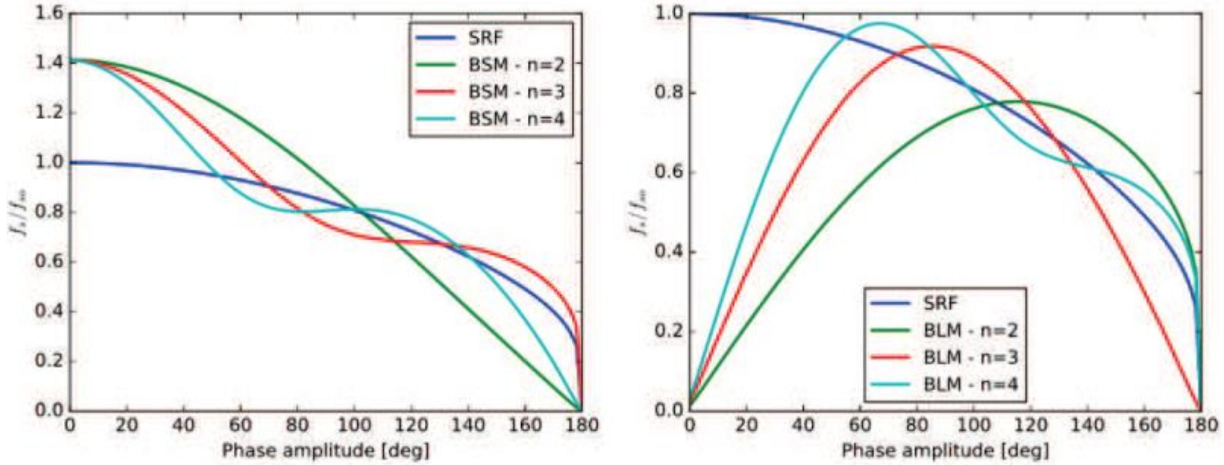


Figure 3: Synchrotron frequency $f_s(\phi_a)/f_{s0}$ as a function of phase amplitude ϕ_a in stationary case with single (blue) and double rf systems for different n or $r = 1/n$ in BS (left) and BL mode (right).

4.9.3.3 Multiple rf systems for unequal bunch lengths in electron rings [1]–[3]

M. Ries, A. Matveenko, HZB

Using multiple and fractional rf frequency harmonics bunches of different lengths can be provided simultaneously.

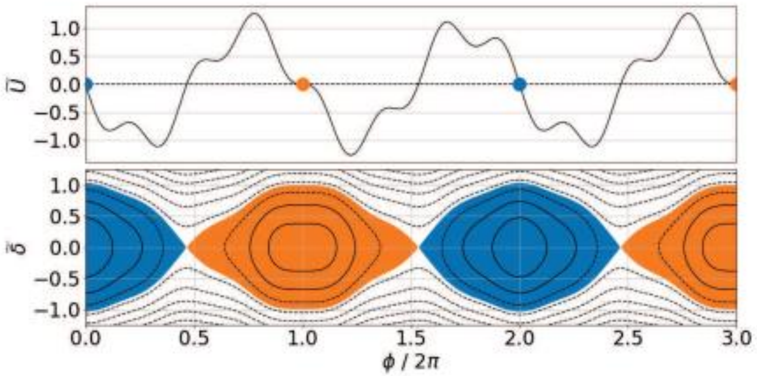


Figure 1: Top: voltage beating of a fundamental rf with a 3.5th harmonic, voltage $\widetilde{U}$ is normalized in units of fundamental rf voltage. Bottom: longitudinal phase space; target buckets are colored blue (adding gradient, i.e. short bunches) and orange (compensating gradient, i.e. long bunches). Momentum deviation $\widetilde{\delta} = \delta/\delta_{\mathrm{acc}}$ is normalized in units of momentum acceptance without harmonics.

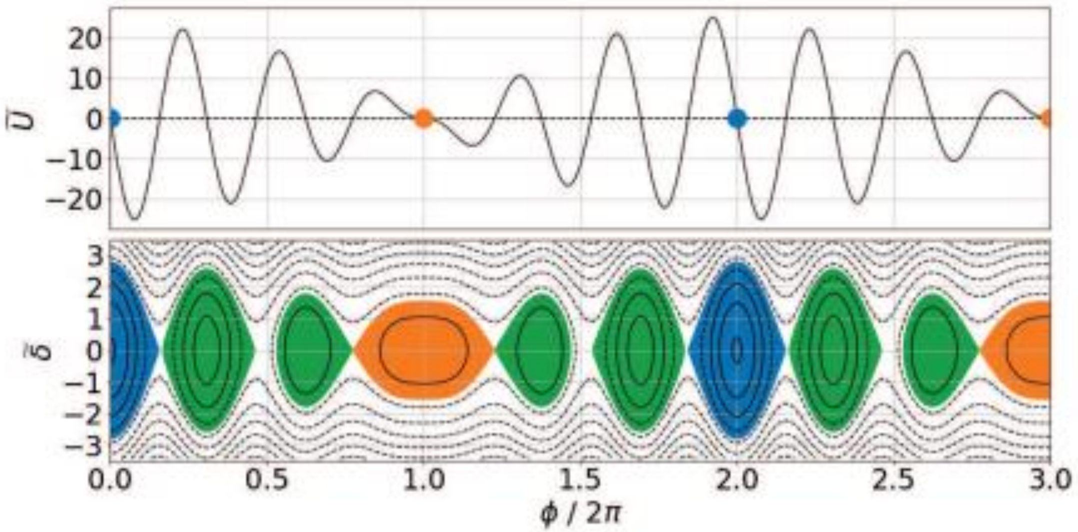
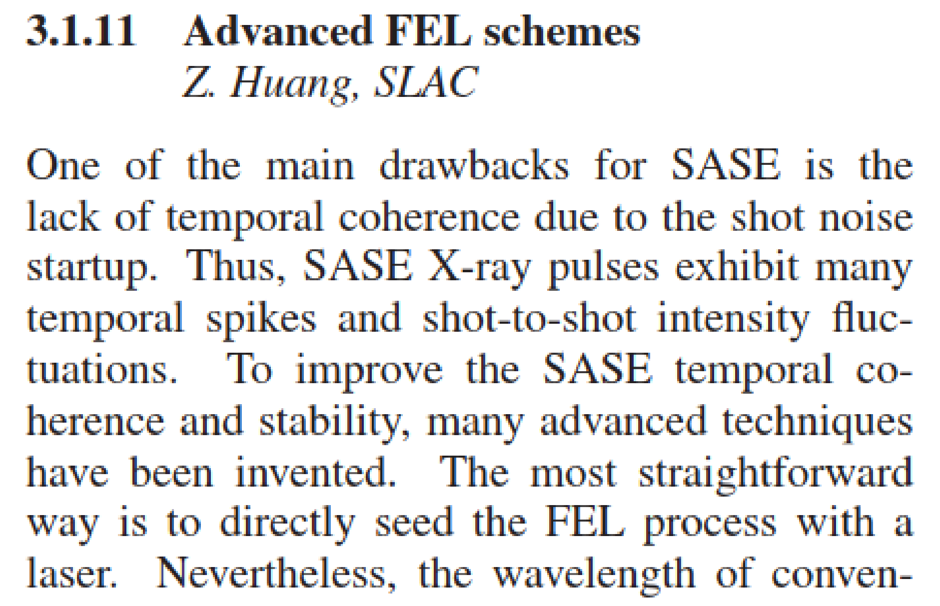


Figure 2: Top: voltage beating of a fundamental rf with a 3rd harmonic and 3.5th harmonic, voltage $\widetilde{U}$ is normalized in units of fundamental rf voltage. Bottom: longitudinal phase space, target buckets are colored blue (adding gradient, i.e. short bunches) and orange (compensating gradient, i.e. long bunches). Momentum deviation $\widetilde{\delta} = \delta/\delta_{\mathrm{acc0}}$ is normalized in units of momentum acceptance without harmonics.



3.1.11 Advanced FEL schemes

Z. Huang, SLAC

One of the main drawbacks for SASE is the lack of temporal coherence due to the shot noise startup. Thus, SASE X-ray pulses exhibit many temporal spikes and shot-to-shot intensity fluctuations. To improve the SASE temporal coherence and stability, many advanced techniques have been invented. The most straightforward way is to directly seed the FEL process with a laser. Nevertheless, the wavelength of conven-

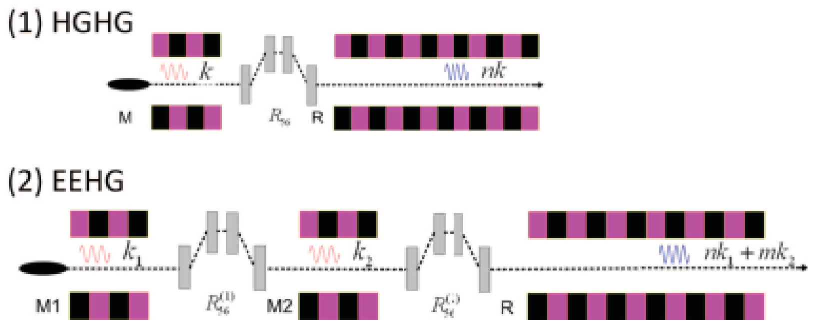


Figure 1: Schematic of HGHG and EEHG FELs. M (R) stands for modulator (radiator).

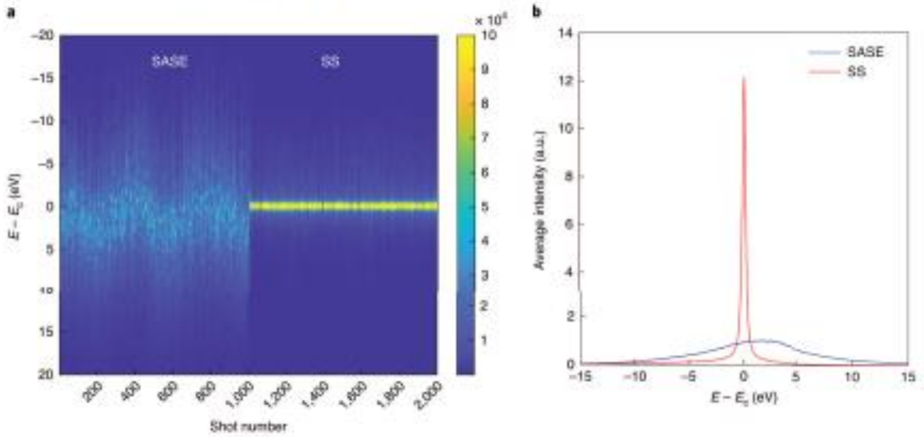


Figure 2: a) 1,000 SASE and self-seeded (SS) FEL spectra measured at PAL-XFEL by a single-shot spectrometer. b) SASE and SS spectra averaged over 1,000 shots (photon energy $E_c = 9.7$ keV) [24].

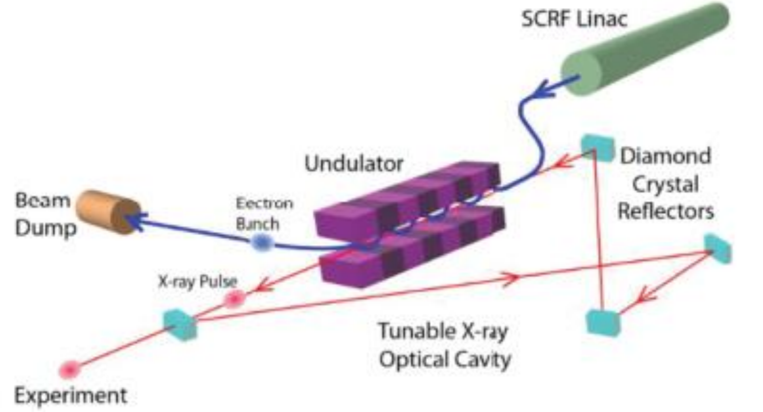
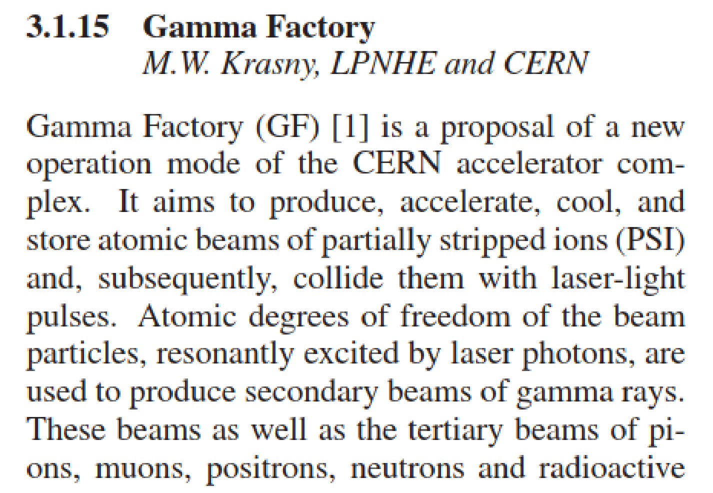


Figure 3: Layout of a cavity-based XFEL facility with a tunable x-ray cavity [29].

“[X-ray cavity-based XFEL facilities] promise to generate Fourier-transform limited x-ray pulses with much better bandwidth and stability than the single-pass FELs. Experiments at LCLS-II and Eu-XFEL [32, 33] to test the essential elements for a cavity- based XFEL are in the advanced planning stage with first results expected in 2024.”



3.1.15 Gamma Factory

M.W. Krasny, LPNHE and CERN

Gamma Factory (GF) [1] is a proposal of a new operation mode of the CERN accelerator complex. It aims to produce, accelerate, cool, and store atomic beams of partially stripped ions (PSI) and, subsequently, collide them with laser-light pulses. Atomic degrees of freedom of the beam particles, resonantly excited by laser photons, are used to produce secondary beams of gamma rays. These beams as well as the tertiary beams of pions, muons, positrons, neutrons and radioactive

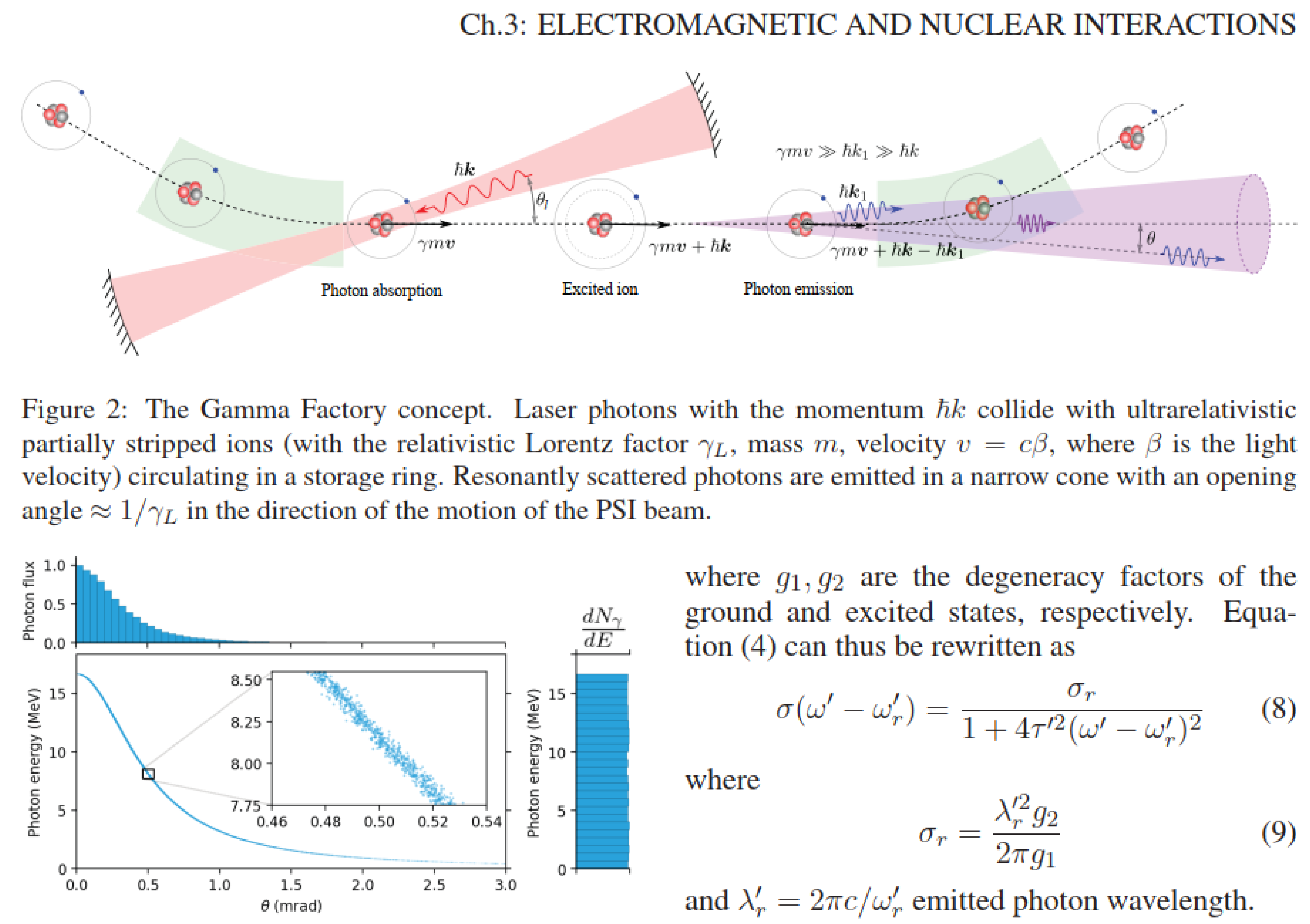


Figure 2: The Gamma Factory concept. Laser photons with the momentum $\hbar k$ collide with ultrarelativistic partially stripped ions (with the relativistic Lorentz factor γ_L, mass m, velocity $v = c\beta$, where β is the light velocity) circulating in a storage ring. Resonantly scattered photons are emitted in a narrow cone with an opening angle $\approx 1/\gamma_L$ in the direction of the motion of the PSI beam.

where g_1, g_2 are the degeneracy factors of the ground and excited states, respectively. Equation (4) can thus be rewritten as

$$\sigma(\omega' - \omega'_r) = \frac{\sigma_r}{1 + 4\tau'^2(\omega' - \omega'_r)^2} \tag{8}$$

where

$$\sigma_r = \frac{\lambda_r'^2 g_2}{2\pi g_1} \tag{9}$$

and $\lambda'_r = 2\pi c/\omega'_r$ emitted photon wavelength.

4.3.3 Operation of High Power Proton and H⁻ Linacs

A. Aleksandrov, ORNL
S. Henderson, JLAB

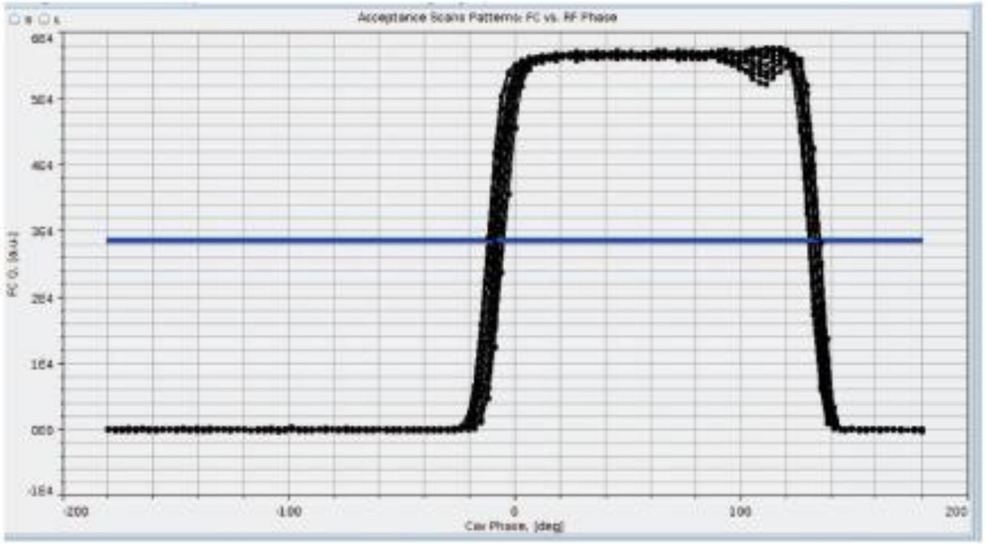


Figure 2: Measured beam current vs. SNS DTL rf phase for several different DTL RF amplitudes. Curves with larger phase width correspond to higher rf field amplitude.

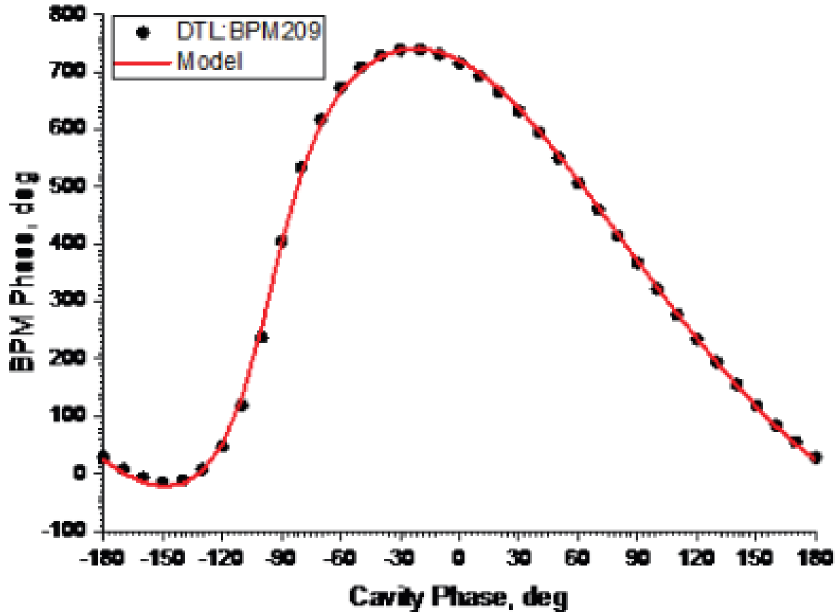


Figure 3: Measured BPM phase vs. SNS DTL rf phase. The points show measured data and the solid curve shows results of the model-based fit.

4.6 TWO-BEAM ACCELERATORS

R. Corsini, CERN

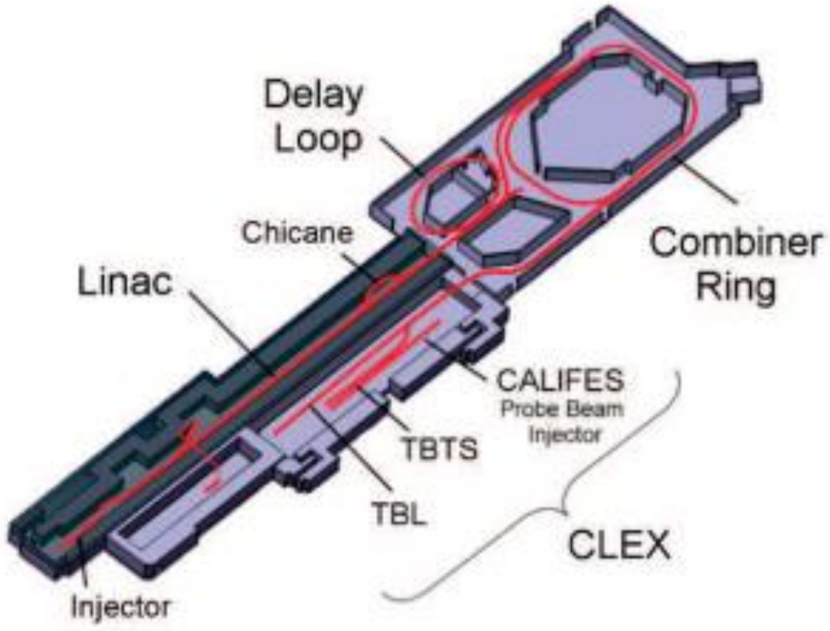


Figure 2: Layout of the CTF3 facility.

4.5 LINEAR-COLLIDER FINAL FOCUS SYSTEMS

A.A. Seryi, JAI
G.R. White, SLAC
R. Tomás, CERN

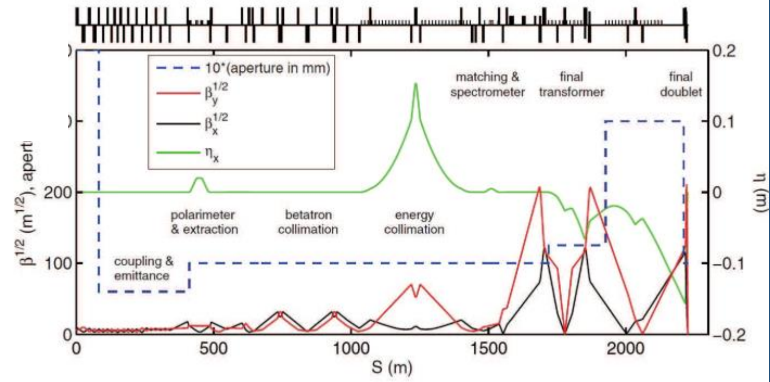


Figure 2: Optics of ILC beam delivery system [19].

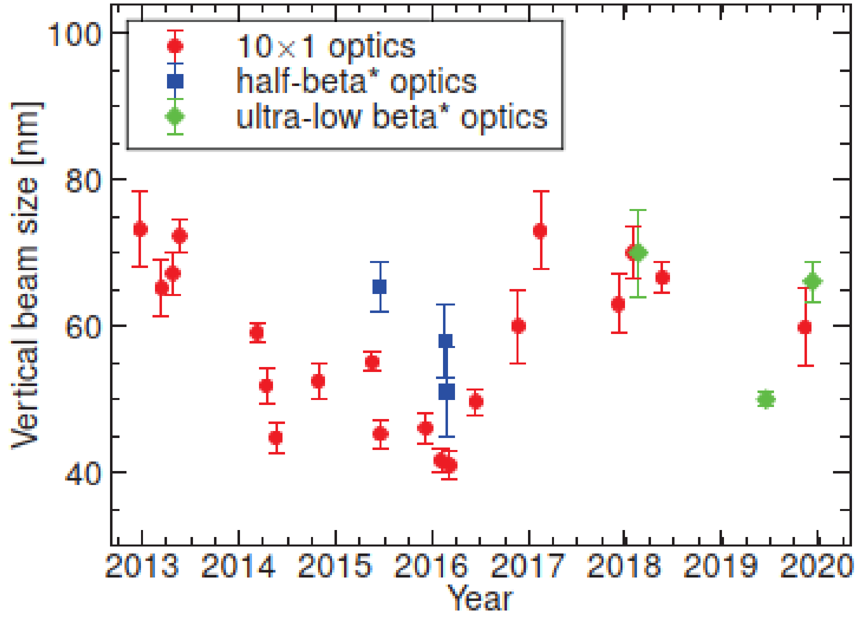
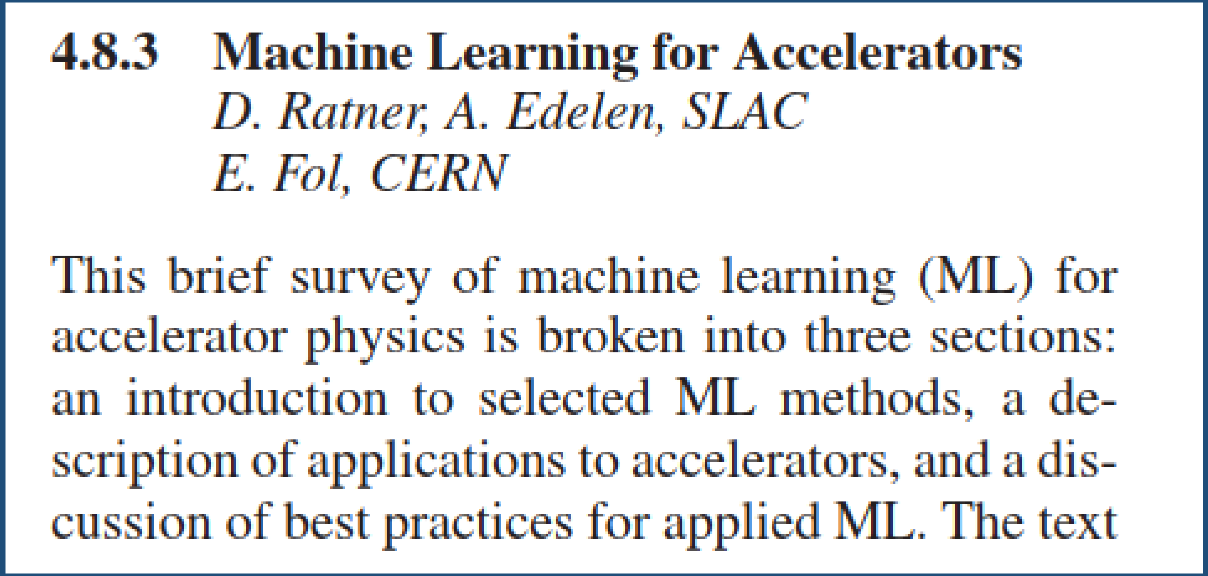


Figure 3: The minimum IP vertical beam sizes obtained from 2012 to 2020 [16].



4.8.3 Machine Learning for Accelerators

D. Ratner, A. Edelen, SLAC
E. Fol, CERN

This brief survey of machine learning (ML) for accelerator physics is broken into three sections: an introduction to selected ML methods, a description of applications to accelerators, and a discussion of best practices for applied ML. The text

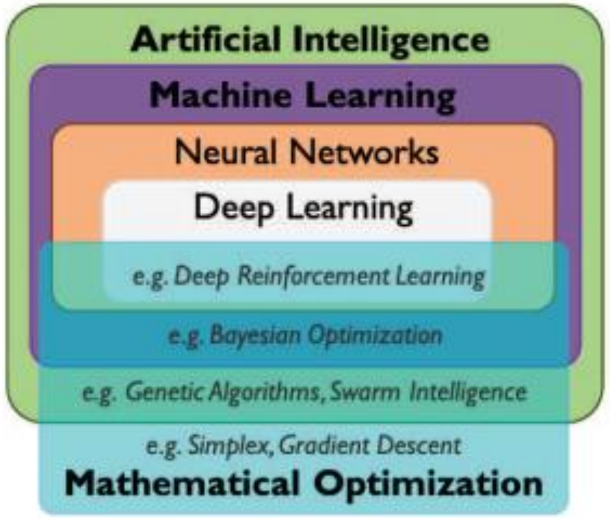


Figure 1: Taxonomy of artificial intelligence and optimization related topics.

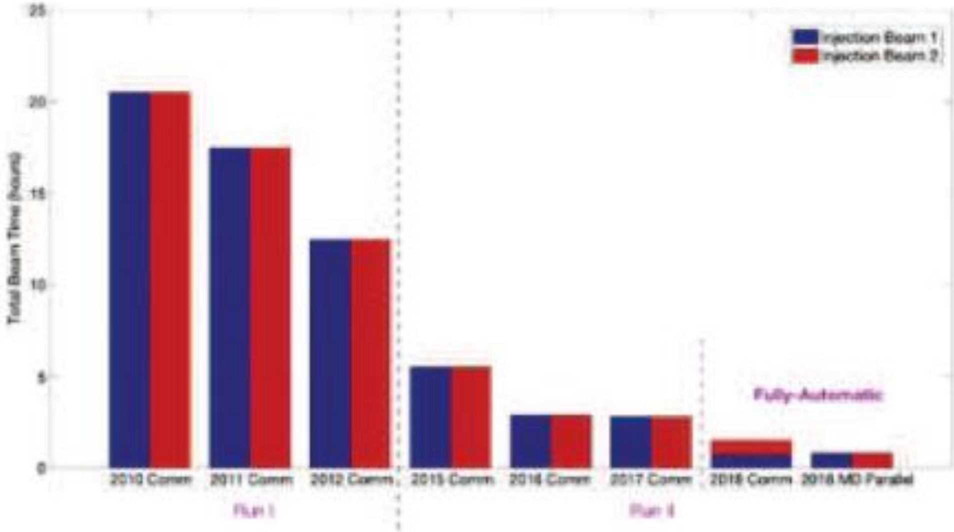


Figure 2: Comparison of the time required to align LHC collimators for beam commissioning before and after introducing ML-based automation [17].

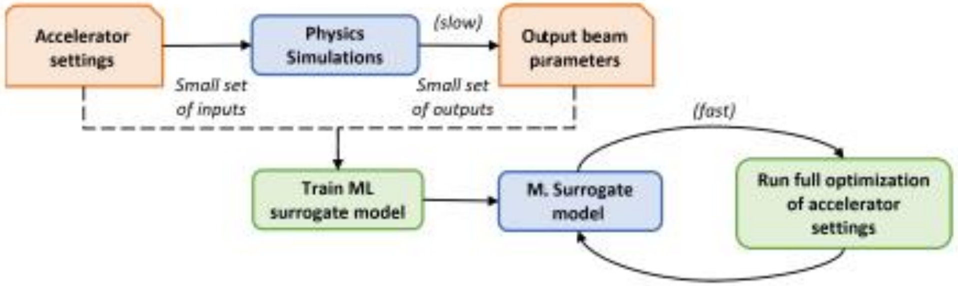
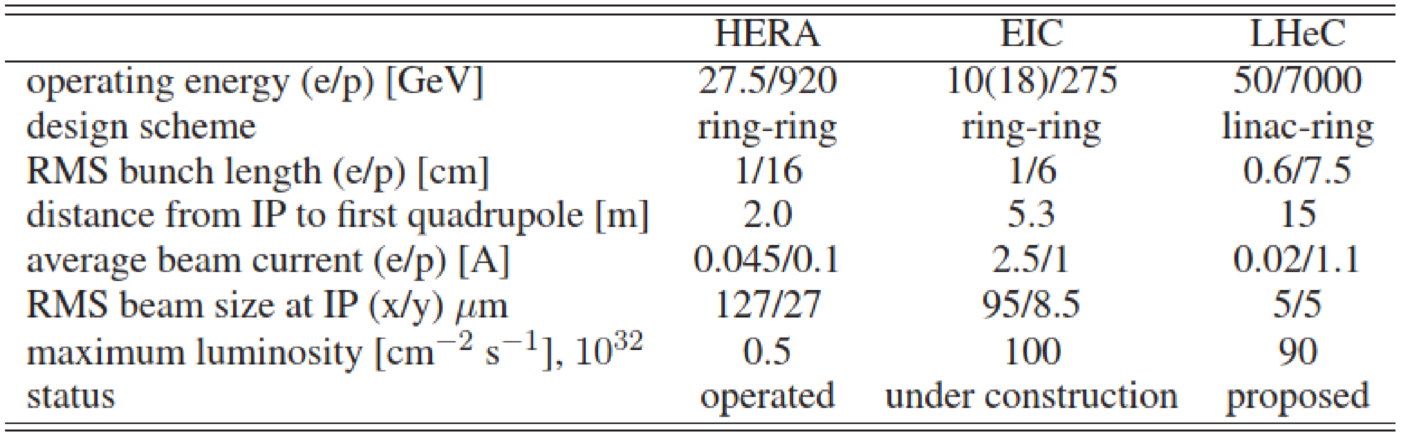


Figure 3: Conceptual representation of using a surrogate model to speed up accelerator design (adapted from [19]).

4.12 DESIGN ISSUES FOR ELECTRON-ION COLLIDERS

C. Montag, V. Ptitsyn, BNL

Table 1: Key parameters of the electron-ion colliders HERA, EIC, and LHeC.



	HERA	EIC	LHeC
operating energy (e/p) [GeV]	27.5/920	10(18)/275	50/7000
design scheme	ring-ring	ring-ring	linac-ring
RMS bunch length (e/p) [cm]	1/16	1/6	0.6/7.5
distance from IP to first quadrupole [m]	2.0	5.3	15
average beam current (e/p) [A]	0.045/0.1	2.5/1	0.02/1.1
RMS beam size at IP (x/y) μm	127/27	95/8.5	5/5
maximum luminosity [cm^{-2} s^{-1}], 10^{32}	0.5	100	90
status	operated	under construction	proposed

4.13.1 Operational Limits in High-Intensity Hadron Accelerators

V. Shiltsev, FNAL

G. Franchetti, GSI

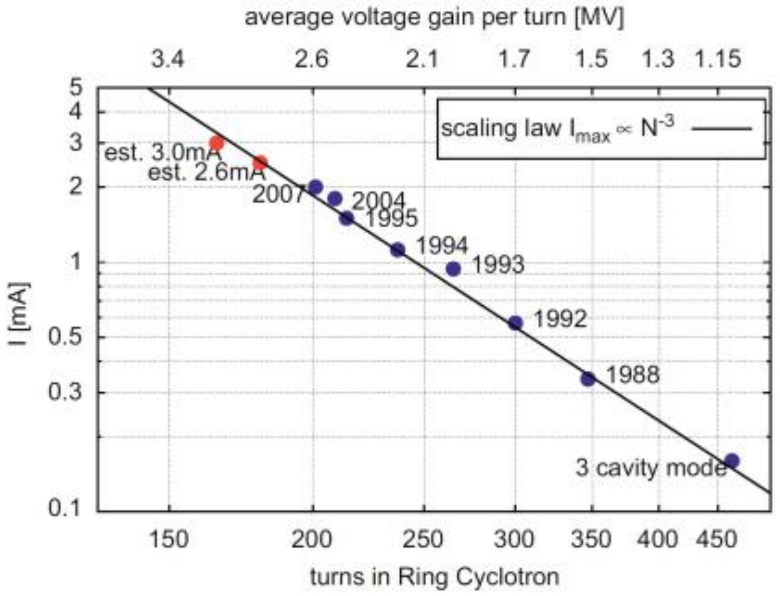


Figure 2: Maximum output current vs. the number of turns in the PSI cyclotron.

5.10.9 Cryogenic Vacuum Systems

V. Baglin, CERN

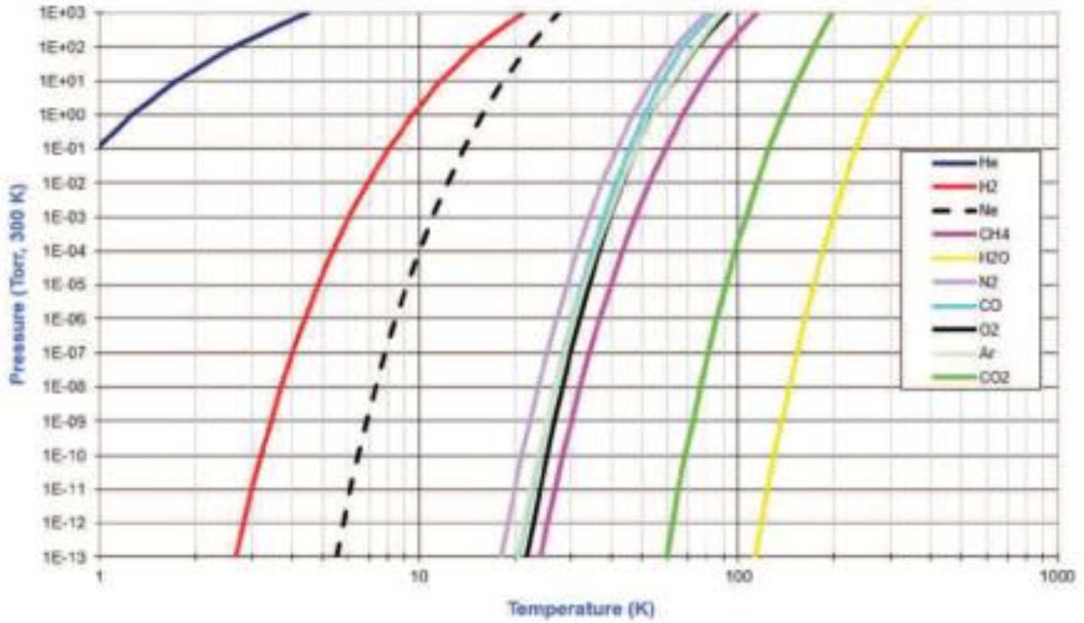


Figure 1: Saturated vapour pressure.

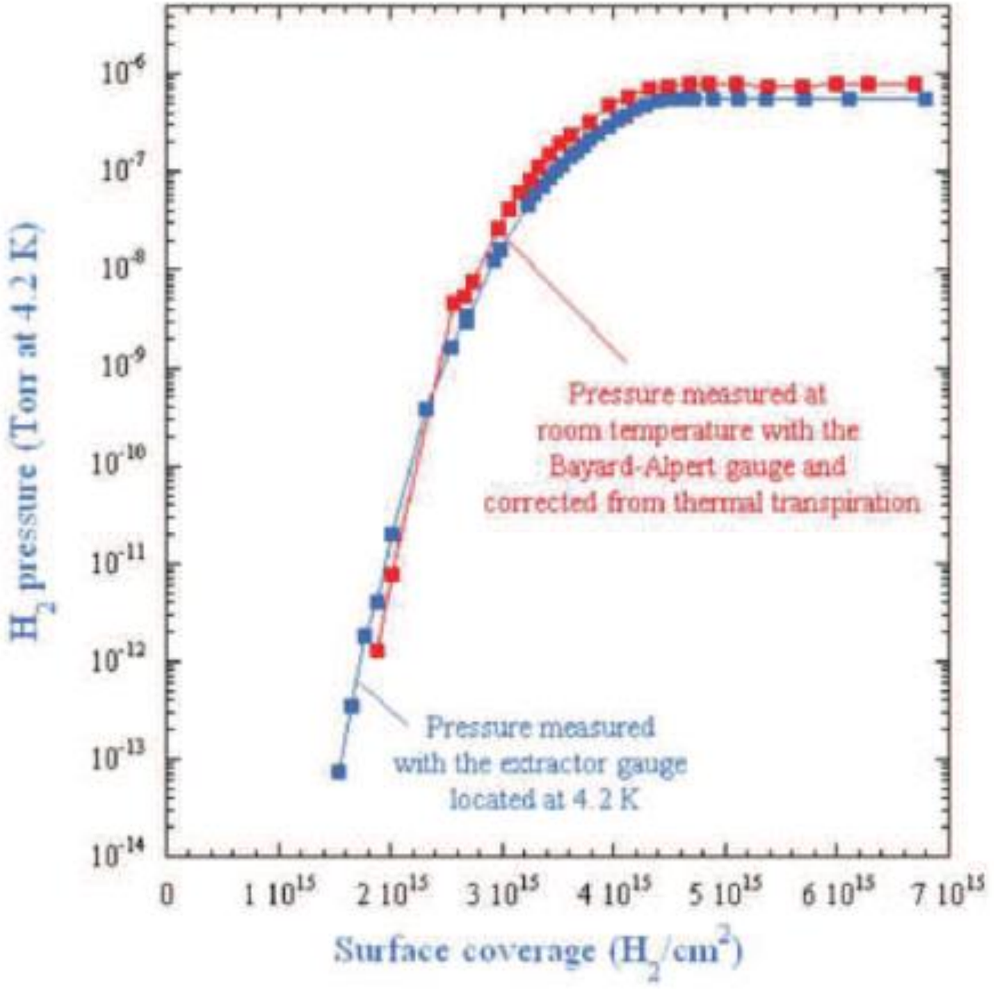


Figure 2: H_2 adsorption isotherm at 4.2 K [2].

6.7.2 Active pulse compression

I. Syratchev, CERN

7.2.15 Beam Deflection and Collimation with Aligned Crystals

W. Scandale, CERN

7.3.13 Plasma Accelerators

C. Schroeder, C. Benedetti, E. Esarey, LBNL

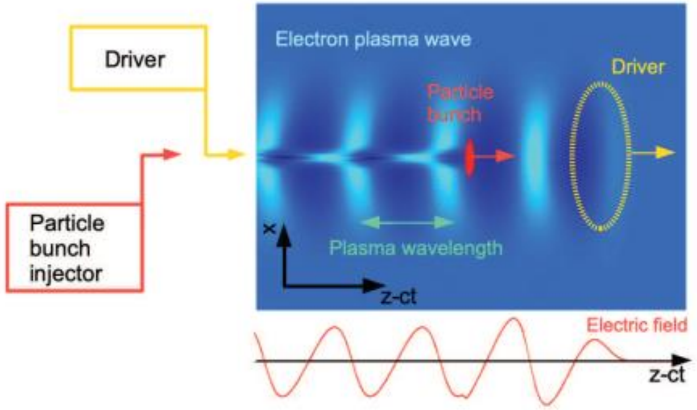


Figure 1: Schematic of a plasma accelerator consisting of a driver (laser or particle beam), a trailing particle (electron) bunch, and a plasma accelerating structure (the wakefield). The two-dimensional color plot indicates the electron plasma density. The red line is the longitudinal electric field associated with the plasma wave.

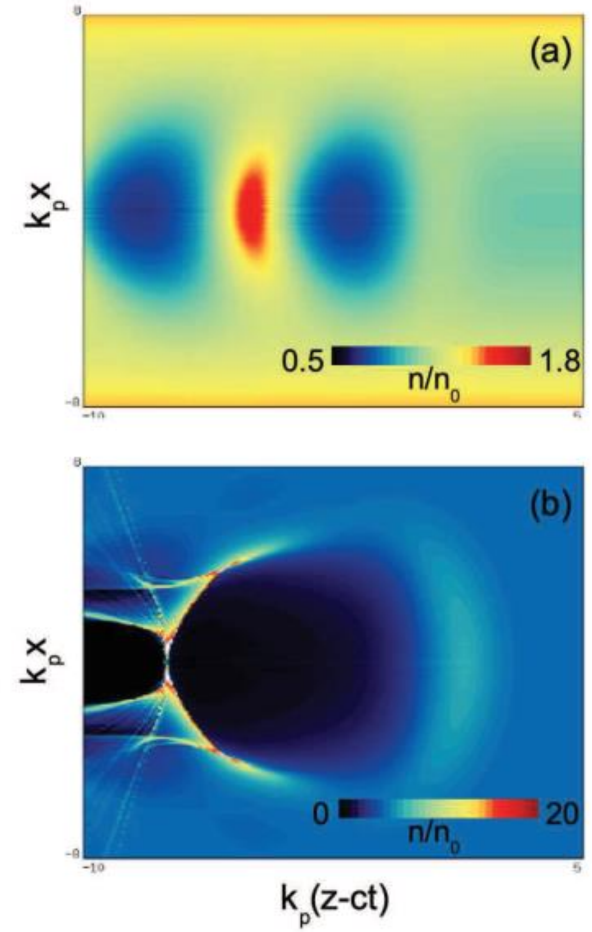


Figure 3: Laser excitation of electron density perturba-
ion n/n_0 in the (a) quasi-linear regime and (b) highly-
onlinear cavitated regime. Profile of the normalized
aser vector potential initially has the form $a =$
$_0 \exp(-r^2/r_L^2 - z^2/4L^2)$ [propagating to the right
nd centered at $k_p(z - ct) = 0$], with $k_pL = 1$ and
a) $a_0 = 1$, $k_pr_L = 5$ in a matched parabolic plasma
hannel and (b) $a_0 = 4.5$, $k_pr_L = 2\sqrt{a_0} \simeq 4.24$ in a
niform plasma.

7.2.15 Beam Deflection and Collimation with Aligned Crystals

W. Scandale, CERN

how to use this book

This is an accelerator designer’s and operator’s handbook of formulae, tables, figures and references. It is meant to be a concise working tool. An effort has been made to provide an index which is as complete as possible. Each subsection (e.g. 2.3.4) is treated as a unit which is more or less self-contained. Numbering of all figures and tables are reset at each subsection, and references are found following each subsection. References are not meant to be exhaustive but represent the experts’ recommendation about a reliable place to begin.
While the linear and circular accelerators for high energy physics and synchrotron radiation applications are our primary concern, we have tried to provide connections to other types of accelerators in the glossary Sec. 1.6.

NEWS AND VIEWS

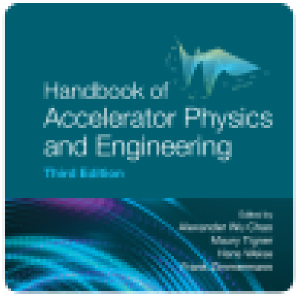
2023 03

WORLD SCIENTIFIC PHYSICS MATTERS

Solvay Conferences on Physics and Chemistry

World Scientific Publishing Company has been publishing the proceedings of the Solvay Conferences on Physics and Chemistry since 2003 and 2014, respectively.

01



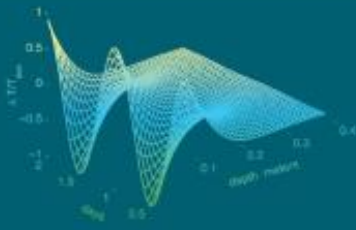
Handbook of Accelerator Physics and Engineering (3rd Edition) (New)

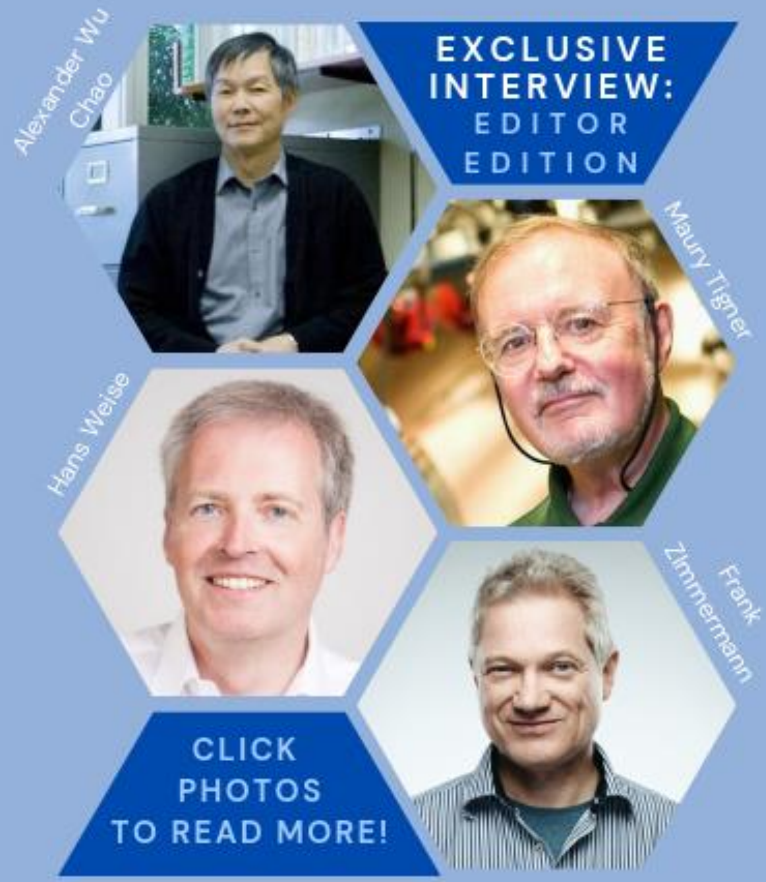
Handbook Editors' message:
The handbook is a joint effort by the Accelerator Physics community, for the Accelerator Physics community. What we wish/envision is to have this handbook continue and grow with the community. Perhaps this goes without saying; the editors will rotate off with time, but the handbook will continue to evolve with the community.

03

Handbook of Accelerator Physics and Engineering

Third Edition





EXCLUSIVE INTERVIEW: EDITOR EDITION

CLICK PHOTOS TO READ MORE!

Alexander Wu Chao

Alex, Great Wall of China, 2022

Into the unknown (of Accelerator Physics)

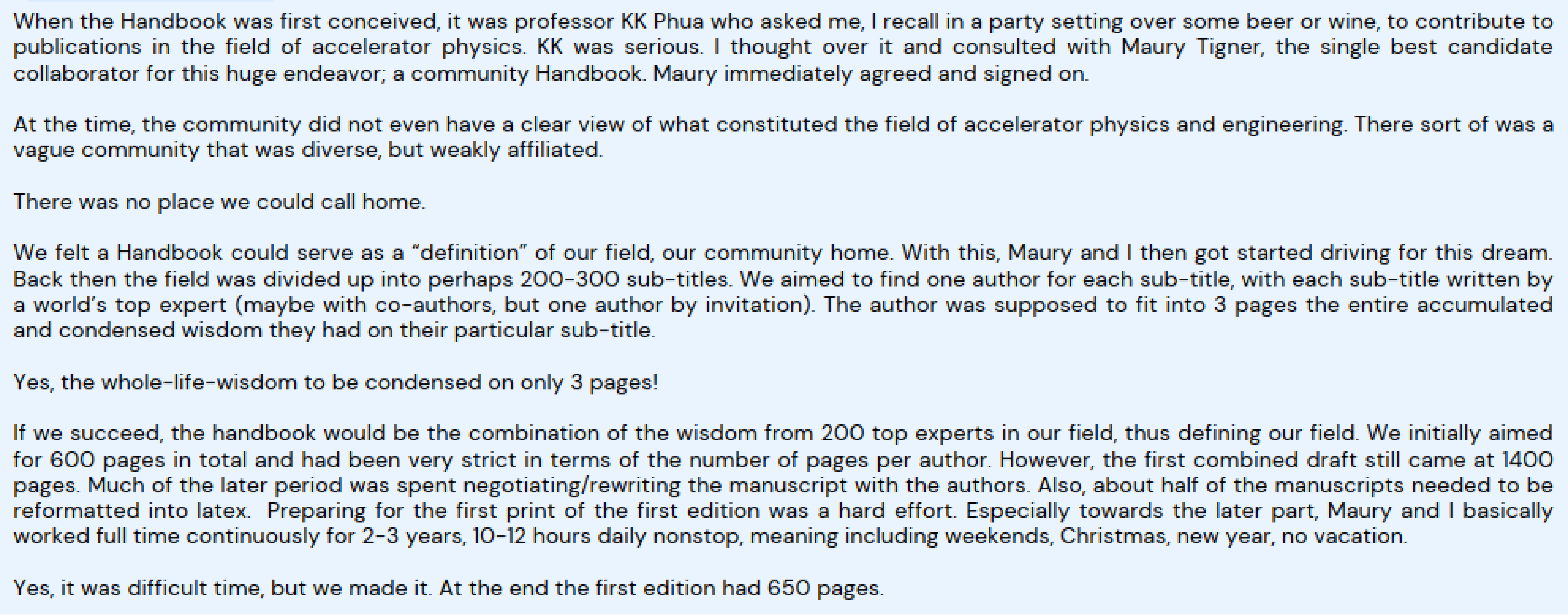
When I started my graduate education, I single-mindedly wanted to be a theoretical physicist. I chose high energy theory and did reasonably OK as a student. However, my advisor, Chenning Yang, had a different idea of what is the best choice for me. He arranged for me to study under another professor, Ernest Courant, to learn accelerator physics. So I learned accelerator physics together with high energy theory.

To my great surprise, this field of accelerator physics, which before that time I had not even heard of, I found, contains such rich and fascinating physics, much more than I had assumed, and totally mis-fitting its name. My PhD Thesis was still in high energy physics, but upon graduation, I needed to make a decision. Yang strongly suggested that I choose accelerator physics, which he felt was a field bound to blossom while high energy physics was winding down. It was a difficult decision for me. At the time, accelerator physics was not a recognized field in physics. If I entered that field at that time, there were no professional organization, no professional journals to publish papers, no school to learn in depth, no community prizes to get community recognition. It would be a lonely struggle along the way. Yes, there will be little competitions, but also, there will be little recognitions. I finally decided to follow Yang's advice. I graduated and chose accelerator physics for my career.

Yang turned out to be correct; the field blossomed over the past 5 decades. My career basically saw its growth, from an unrecognized field to becoming a well established field. Now there are professional organizations in US, Europe, China, Russian, Japan; there are various professional journals; there are textbooks on accelerator physics proper as well as its sub-disciplines; there are community prizes for young people to aim for recognition; and yes, there is the Handbook.

Rough beginnings

Alexander Wu Chao – the rough beginning of the handbook



When the Handbook was first conceived, it was professor KK Phua who asked me, I recall in a party setting over some beer or wine, to contribute to publications in the field of accelerator physics. KK was serious. I thought over it and consulted with Maury Tigner, the single best candidate collaborator for this huge endeavor; a community Handbook. Maury immediately agreed and signed on.

At the time, the community did not even have a clear view of what constituted the field of accelerator physics and engineering. There sort of was a vague community that was diverse, but weakly affiliated.

There was no place we could call home.

We felt a Handbook could serve as a “definition” of our field, our community home. With this, Maury and I then got started driving for this dream. Back then the field was divided up into perhaps 200-300 sub-titles. We aimed to find one author for each sub-title, with each sub-title written by a world’s top expert (maybe with co-authors, but one author by invitation). The author was supposed to fit into 3 pages the entire accumulated and condensed wisdom they had on their particular sub-title.

Yes, the whole-life-wisdom to be condensed on only 3 pages!

If we succeed, the handbook would be the combination of the wisdom from 200 top experts in our field, thus defining our field. We initially aimed for 600 pages in total and had been very strict in terms of the number of pages per author. However, the first combined draft still came at 1400 pages. Much of the later period was spent negotiating/rewriting the manuscript with the authors. Also, about half of the manuscripts needed to be reformatted into latex. Preparing for the first print of the first edition was a hard effort. Especially towards the later part, Maury and I basically worked full time continuously for 2-3 years, 10-12 hours daily nonstop, meaning including weekends, Christmas, new year, no vacation.

Yes, it was difficult time, but we made it. At the end the first edition had 650 pages.

Maury Tigner

Favourite part of Handbook

The Glossary.

Foray into Accelerator Physics

Half way through college i switched from naval architecture to physics.

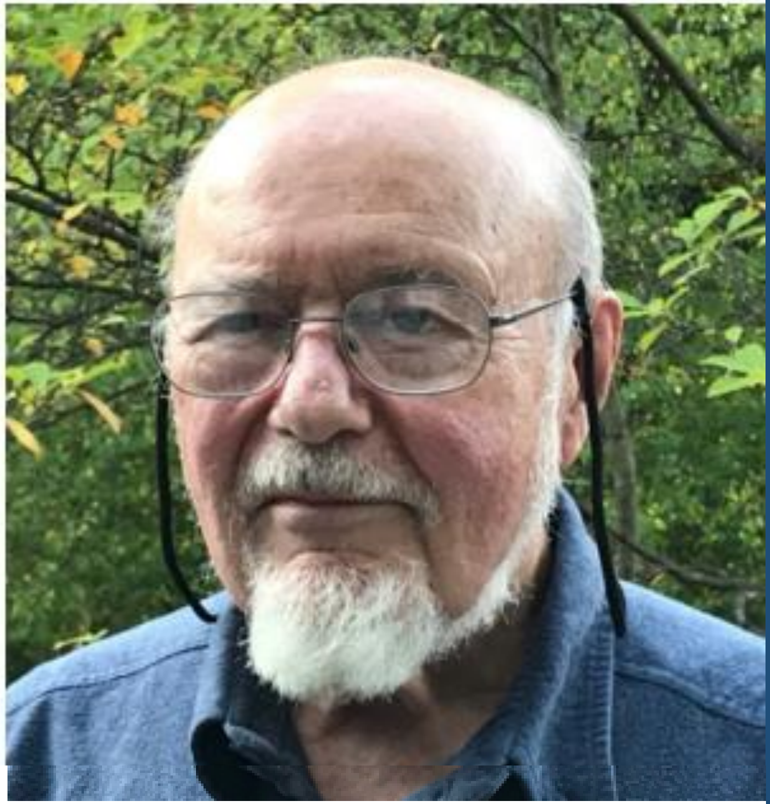
On the first day in Electricity and Magnetism class, the prof announced that there was a part time technician job open at the Accelerator lab and anyone who was interested should come to his office after class... Everyone in the class went to his office! Overwhelmed, the prof said that he would have to ask us one by one why we thought we'd be a good choice for the job. When it came my turn I noted that: I could weld, work in a machine shop and build electronic circuits. I got it! I liked the job and after graduating, I applied to Cornell University (where Robert Wilson, a noted accelerator builder, was director of the high energy physics lab).

The rest is history.

Hopes and gratitude for the field

I hope that the rate of progress in accelerator development continues as it has for the last ten years.

I have been most fortunate to have learned from friends and associates in the field including: the other three editors of this book, the Berkely, CERN accelerator group, Cornell, DESY, Fermilab, Princeton, SLAC.



Did you know:
When the Betatron at Maury's Undergraduate college got its first beam, **Maury was standing in the beam line!**

Hans Weise

Life with Accelerators

I was introduced to accelerators when my later supervisor Achim Richter advertised the advantages of superconductivity for the future operation of the Darmstadt University superconducting recirculating linac S-DALINAC. This happened during my first years at university, in the early 80ies. A little later, I was allowed to join its construction and commissioning by contributing to the assembly and to solving radiofrequency issues. Well-known colleagues and experts in the development of superconducting accelerators like Ilan Ben-Zvi, Herbert Lengeler, Alan Schwettman, Todd Smith, and others supported the fascinating work at the S-DALINAC during those years. As a PhD student I spent even more time with the construction and commissioning, and developed a new electron beam injector to prepare the facility for Free-Electron Laser operation in the near infrared.

In the early 90ies, Bjoern Wiik at DESY invited the accelerator community to improve the superconducting technology further and to develop all subsystems needed for a large high energy physics collider, the TESLA machine. I joined the team at DESY, worked for several years with Maury Tigner, Bernard Aune, Peter Schmüser and under the supervision of Helen and Don Edwards as well as under Bjoern. A great time! Together with Jörg Rossbach, and later Reinhard Brinkmann and others, I led many activities which culminated in the first lasing of DESY's FLASH free-electron laser facility, and later in the construction and operation of the European XFEL. The success of this worldwide longest superconducting linac was the reward for the journey we started as a great team of international experts and friends.

The management of the European XFEL construction came with challenges, with strong effort, and with excitement and gratification. Such large research facilities only exist due to the team spirit of large groups of accelerator scientists, engineers, technicians, but also plant manufacturers. Most of the recent machines were built based on in-kind contributions. Expertise from many laboratories comes together, and finally the first beam, or first lasing; moments in my own career I will never forget! Opening the handbook, I find many co-authors and friends, with major essential contributions to our field. The condensed knowledge of the accelerator community, published in the Handbook, will support us during the development of future machines. Young scientists and engineers will surely benefit.

30 years of Accelerator Physics

Frank Zimmermann

Accelerator physics is a fascinating field, allowing a very diverse set of activities, ranging from theoretical studiers, over computer simulations and beam operation, to hardware development, for the present, next and next-next generation of accelerators, and for numerous different applications.

One of the best lecturing professors at the University of Hamburg was Peter Schmüser, an experimental particle physicist. When I contacted him for a diploma thesis project, he proposed to me an accelerator physics theme related to the design and construction of the HERA proton ring. He also introduced me to Ferdinand Willeke at DESY, a key person for the construction, commissioning, and operation of the electron-proton collider HERA. Later, both Ferdinand and Peter became supervisors for my PhD thesis. During that time, I was a member of DESY group F35H, led by Bjorn Wiik.

The HERA beam commissioning was an exciting time, with many experts from around the world visiting DESY, both for HERA and for the new TESLA Technology Collaboration.

For quite a while I chaired an office with Don and Helen Edwards, in DESY building 1e. I also met Maury Tigner for the first time at DESY then.

In 1992, after a workshop at BNL, together with a few CERN colleagues, I visited the SSC in Waxahachie, Texas. On that occasion, Alex Chao gave me precious advice, which I absolutely heeded.

One year later, on the initiative of Bjorn, I joined SLAC.

Hopes for future of Accelerator Physics

I am hoping that new technologies and the ingenuity of my colleagues will allow us to continue the remarkable accelerator progress we have witnessed over the past century well into the future.

To Frank, the most unexpected result during his career:

The discovery, around 1996, that the SLC spot size waist tuning using beam-beam scans was dominated by the noise of the measurement, and then the LHC accident in 2008.

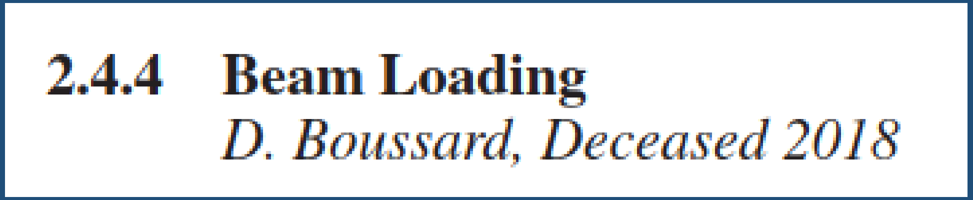
Favorite part of Handbook:

Of course, I like the two chapters, that I have been in charge of (laughing!) and that I am extremely familiar with.

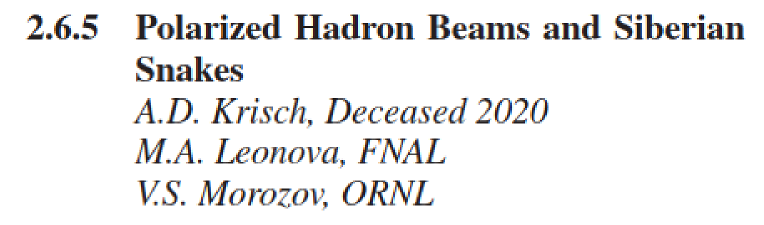
The long tables with wake field and impedances from Bill Ng and Karl Bane condense a large amount of useful information.

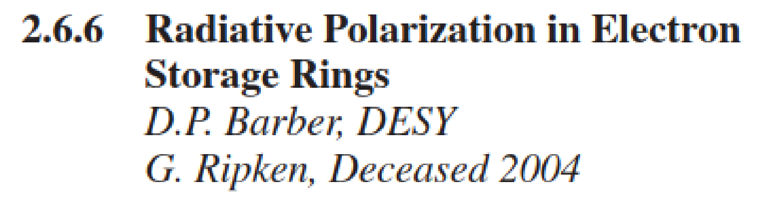
Sections on Free Electron Lasers by my former thesis advisor Peter Schmüser and Zhirong Huang of SLAC are extremely educating and readable.

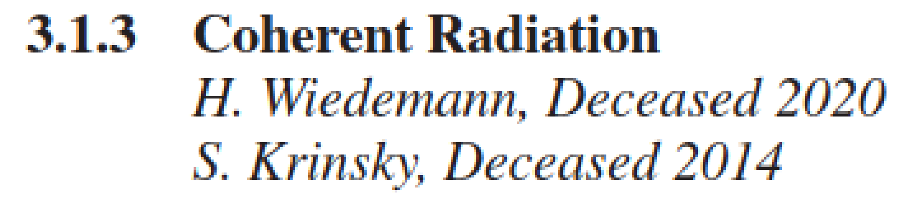
continuity ? – will the “handbook” live forever ?


2.4.4 Beam Loading
D. Boussard, Deceased 2018

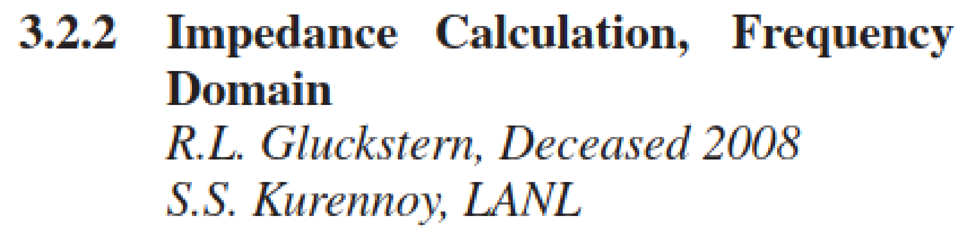

2.4.6.1 Direct space charge effects
B. Zotter, Deceased 2015

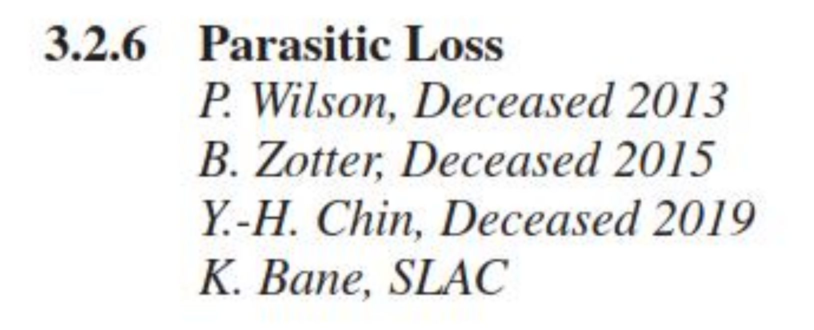

2.6.5 Polarized Hadron Beams and Siberian Snakes
A.D. Krisch, Deceased 2020
M.A. Leonova, FNAL
V.S. Morozov, ORNL

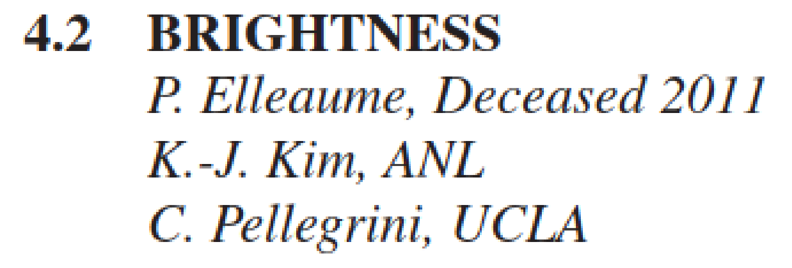

2.6.6 Radiative Polarization in Electron Storage Rings
D.P. Barber, DESY
G. Ripken, Deceased 2004


3.1.3 Coherent Radiation
H. Wiedemann, Deceased 2020
S. Krinsky, Deceased 2014


3.1.16 Beam Solid-Target Photon Physics
K. Ispiryan, Deceased 2016


3.2.2 Impedance Calculation, Frequency Domain
R.L. Gluckstern, Deceased 2008
S.S. Kurennoy, LANL


3.2.6 Parasitic Loss
P. Wilson, Deceased 2013
B. Zotter, Deceased 2015
Y.-H. Chin, Deceased 2019
K. Bane, SLAC


4.2 BRIGHTNESS
P. Elleaume, Deceased 2011
K.-J. Kim, ANL
C. Pellegrini, UCLA

…