

Accelerator Science Education and Schools

E. Métral (20 min)
(CERN BE/ABP-HSC &
deputy director – and former student – of the JUAS school)

=> On behalf of the team

P. Lebrun and L. Rinolfi (current and previous JUAS directors)

H. Schmickler (current CAS director – deputy director: W. Herr)

P. Burrows (Work Package 2 leader in European project ARIES)

N. Delerue (Task Leader 2.4 in European project ARIES)

Many thanks to G. Arduini and universities' contacts (see Appendix)

Accelerator Science Education and Schools

E. Métral (20 min)
(CERN BE/ABP-HSC &
deputy director – and former student – of the JUAS school)

=> On behalf of the team

P. Lebrun and L. Rinolfi (current and previous JUAS directors)

H. Schmickler (current CAS director – deputy director: W. Herr)

P. Burrows (Work Package 2 leader in European project ARIES)

N. Delerue (Task Leader 2.4 in European project ARIES)

Many thanks to G. Arduini and universities' contacts (see Appendix)

- ◆ **If Europe wants to prepare well for its future collider projects, education and training in accelerator science are crucial**
- ◆ **Are we ready to educate the new generations of accelerator scientists?**

Accelerator Science Education and Schools

E. Métral (20 min)
(CERN BE/ABP-HSC &
deputy director – and former student – of the JUAS school)

=> On behalf of the team

P. Lebrun and L. Rinolfi (current and previous JUAS directors)

H. Schmickler (current CAS director – deputy director: W. Herr)

P. Burrows (Work Package 2 leader in European project ARIES)

N. Delerue (Task Leader 2.4 in European project ARIES)

Many thanks to G. Arduini and universities' contacts (see Appendix)

- ◆ **If Europe wants to prepare well for its future collider projects, education and training in accelerator science are crucial**
- ◆ **Are we ready to educate the new generations of accelerator scientists?**

=> Yes!

CONTENTS

- ◆ **Introduction: survey done by TIARA (2011-2015)**
- ◆ **European Union H2020 project ARIES (2017-2021)**

=> MOOC on particle accelerator science and engineering

- ◆ **European schools**

- **CAS** (CERN ACCELERATOR SCHOOL, since 1983)
- **JUAS** (JOINT UNIVERSITIES ACCELERATOR SCHOOL, since 1994)
 - Universities
 - CERN Doctoral Student programme (since 1985)
- **IAS** for Linear Colliders (INTERNATIONAL ACCELERATOR SCHOOL, 2006-2016)
- **NPAS** (NORDIC PARTICLE ACCELERATOR SCHOOL, 2015-2017)

+ 1) **USPAS** (U.S. PARTICLE ACCELERATOR SCHOOL, since 1981)
in USA => <http://uspas.fnal.gov>

2) **JAS** (JOINT INTERNATIONAL ACCELERATOR SCHOOL, since 1985)
=> <http://uspas.fnal.gov/programs/JAS/index.shtml>

- ◆ **Conclusion**

INTRODUCTION: SURVEY DONE BY TIARA (2011-2015)

- ◆ **TIARA = Test Infrastructure and Accelerator Research Area**
- ◆ **Homepage:** <http://www.eu-tiara.eu>
- ◆ **Project funded by the European Union 7th framework programme**
- ◆ **Made a survey of provision of education and training in accelerator science in Europe**
- ◆ **Survey highlighted the need for more training opportunities targeting undergraduate-level students**
- ◆ **WP5 (Education and training):** <http://www.eu-tiara.eu/support/index.php?id=39>



WP5 Deliverables

| Nb | Name | Description |
|-----------|-------------|---|
| D5.1 | ETR | Education and Training Survey Report |
| D5.2 | ETD | Education and Training Resources Data base |
| D5.3 | ASR | Needs for Accelerator Scientists Report |
| D5.4 | PAR | Recommendations for Promoting Accelerator Science and Technology in Europe Report |

ARIES (2017-2021)

- ◆ This need is now being addressed by the European Union H2020 project **ARIES**
- ◆ **ARIES = Accelerator Research and Innovation for European Science and Society**
- ◆ **Homepage:** <https://aries.web.cern.ch>
- ◆ **In particular: preparation of a MOOC (Massive Open Online Course) on particle accelerator science and engineering**
- ◆ **WP2 (Training, Communication and Outreach for Accelerator Science: TCO):** <http://aries.web.cern.ch/content/wp2>



Tasks

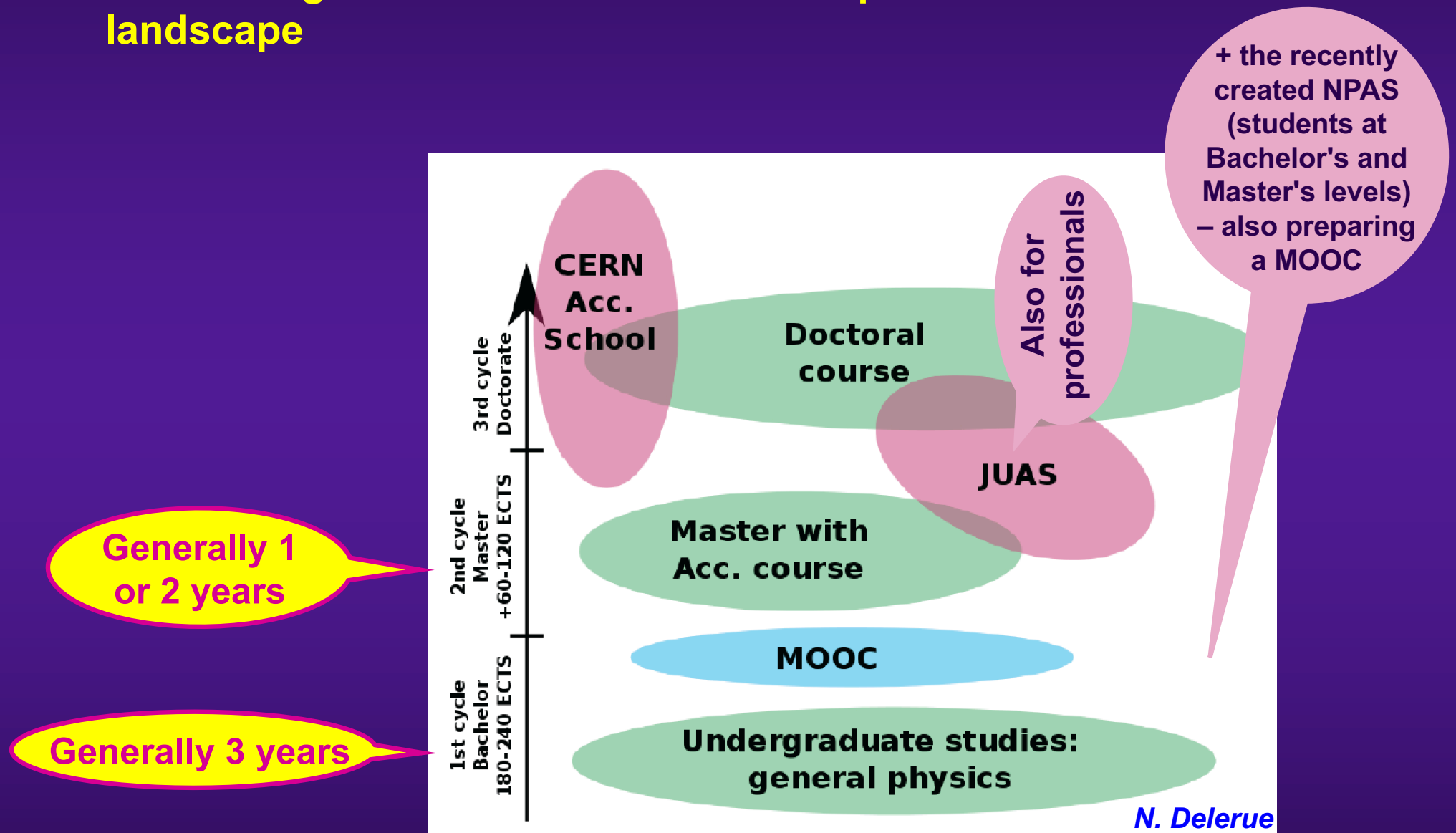
| Task # | Task name | Task leader |
|----------|--|------------------------|
| Task 2.1 | Coordination and work package communication | Phil Burrows (Oxford) |
| Task 2.2 | Coordination, support and enhancement of communications/outreach activities for accelerators in Europe | Jennifer Toes (CERN) |
| Task 2.3 | Coordination, support and enhancement of training activities for accelerators in Europe | Yogi Rutambhara (ESS) |
| Task 2.4 | Provide an e-learning course: introduction to accelerator science, engineering and technology | Nicolas Delerue (CNRS) |

MOOC on particle accelerator science and engineering

- ◆ **Under preparation => IPAC2018 paper by N. Delerue et al. “A Massive Open Online Course on Particle Accelerators”:**
<http://accelconf.web.cern.ch/AccelConf/ipac2018/papers/mopml050.pdf>
- ◆ **Subject:** Introduction to Accelerator Science and Technology
- ◆ **Target audience:** physics and engineering students at the undergraduate level, but potentially accessible to any interested person (such as professionals recently hired to work on a topic related to accelerators)
- ◆ **European countries are part of the EHEA (European Higher Education Area) to unify the higher education processes across countries => “Bologna process”**
- ◆ **In the EHEA, students are awarded credits called ECTS (European Credit Transfer System) for successfully attending a course**
 - 1 ECTS corresponds to ~ 10 h of teaching (~ 20-30 h of student’s work)
 - 1 year usually corresponds to 60 ECTS

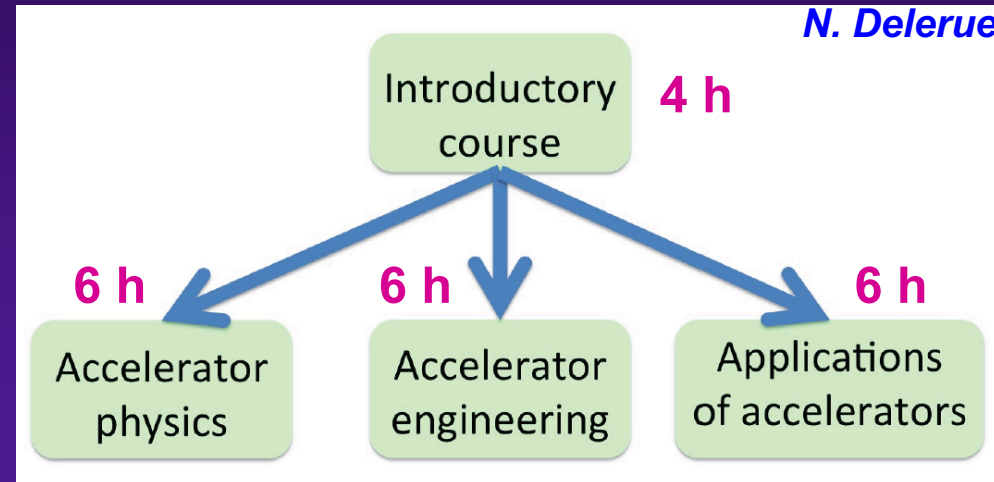
MOOC on particle accelerator science and engineering

◆ Positioning of this MOOC in the European Accelerator Education landscape



MOOC on particle accelerator science and engineering

◆ 4 modules



■ Introductory course => Introduction to accelerators

- What is an accelerator? (1 h)
- Applications of accelerators and the future (1 h)
- Electromagnetism with no pre-requisites (1 h)
- Relativity with no pre-requisites (1 h)

■ Etc.

I am coordinating this topic

◆ Timescale: < May 2020 => Current plan: end 2019

CAS: CERN ACCELERATOR SCHOOL

- ◆ **Homepage:** <http://cas.web.cern.ch>
- ◆ **Takes place in different member states of CERN**
- ◆ **Lectures and tutorials spread over a period of 1 to 2 weeks**
- ◆ **4 courses / year**
 - 2 kinds: general (2 levels, intro and advanced) and topical
 - Intro every year and advanced every 2 years
 - Intro curriculum is similar to JUAS course 1, but JUAS is ~ 2 times longer (+ exams)
- ◆ **Between 70 and 120 people per school => > 5000 people trained**
- ◆ **Topical: ~ 80% on-job training**
- ◆ **Ongoing discussions**
 - Introductory course for non-member states
 - Organise a school with young university teachers as students
- ◆ **1st school devoted to Future Colliders in February 2018 in Zurich**

CAS: CERN ACCELERATOR SCHOOL



The poster for the CAS course on Beam Dynamics and Technologies for Future Colliders features a collage of images: a woman presenting at a chalkboard, the Crowne Plaza Hotel in Zurich, and an aerial view of the CERN site. The design includes geometric shapes and circles connecting different sections of text.

The CERN Accelerator School

The CERN Accelerator School and the Paul Scherrer Institute are organizing a course on

Beam Dynamics and Technologies for Future Colliders

The course will be of interest to staff and students from laboratories and universities who wish to learn about the various options being considered for future colliders for high-energy physics. The material presented will be at an accessible level and cover circular hadron and lepton colliders, as well as linear lepton colliders.

The program will cover the beam dynamics of the colliders presently under consideration and the associated technologies that will be needed to build them. Beam generation and machine protection issues will also be addressed. Students will have the opportunity to work on realistic case studies throughout the school.

21 February to 6 March, 2018
Crowne Plaza Hotel,
Zurich, Switzerland

**CAS course on
Beam Dynamics
and Technologies
for Future Colliders**

CERN Accelerator School
CH - 1211 Geneva 23
cas.web.cern.ch
Accelerator.school@cern.ch



~ 90%
participation from
CERN...

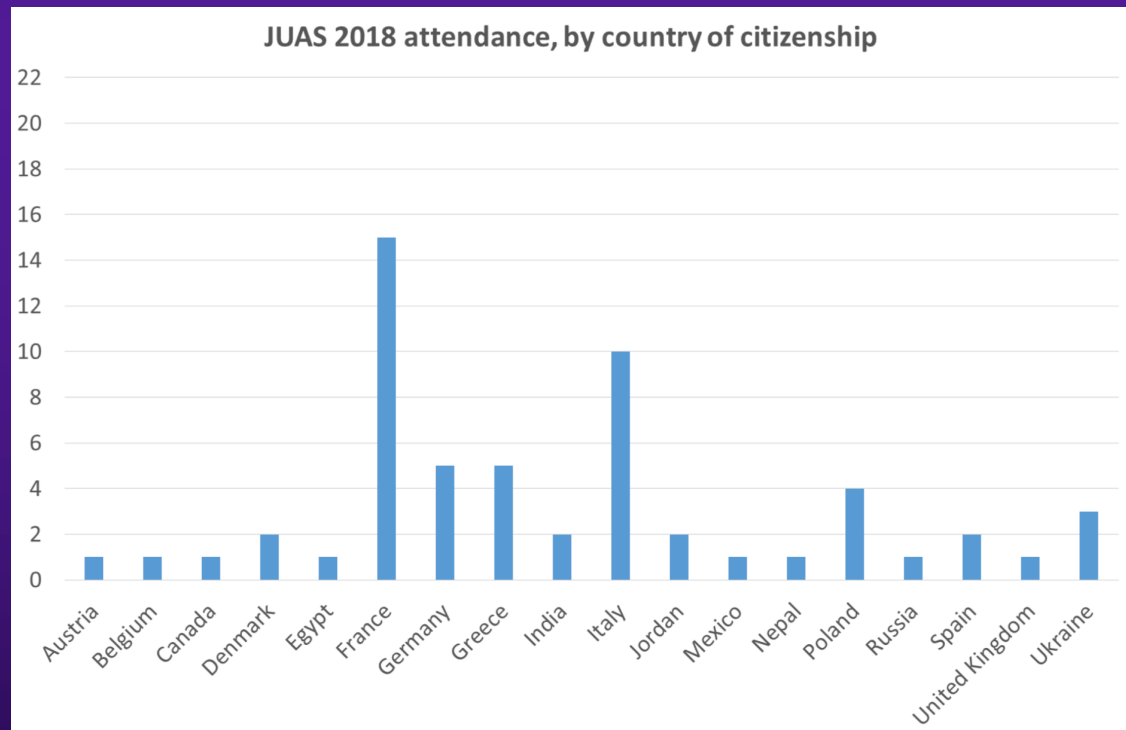
JUAS: JOINT UNIVERSITIES ACCELERATOR SCHOOL

- ◆ **Homepage:** <http://www.esi-archamps.eu/Thematic-Schools/Discover-JUAS>
 - “JUAS celebrates 20th anniversary” in Grenoble (where it all started) in 2014: <https://cds.cern.ch/record/1745045/files/vol54-issue6.pdf> (p. 38)
 - 25th edition of JUAS in 2018: <https://acceleratingnews.web.cern.ch/article/25th-edition-joint-universities-accelerator-school>
- ◆ Organised by the European Scientific Institute in partnership with 16 major European Universities and CERN
- ◆ Takes place from January to March in Archamps (France, ~ 15 min from CERN)
- ◆ Comprises 2 five-week courses
 - Course 1: The science of particle accelerators
 - Course 2: The technology and applications of particle accelerators
- ◆ Each course is concluded by examinations which allow students to earn ECTS credits attributed by their home university



JUAS: JOINT UNIVERSITIES ACCELERATOR SCHOOL

- ◆ **Among the European Student Grant recipients for IPACs (International Particle Accelerator Conferences):** best JUAS student
- ◆ **Target audience:** graduate students from Partner Universities + graduate students from other universities as well as professionals (depending on availability of places)
- ◆ **Between 30 and 40 people / course, from many countries => > 1000 people trained**



UNIVERSITIES

- ◆ “In spite of an increasing large economic and intellectual impact, only a little fraction of universities in the world offer a formal graduate education in Accelerator Science and its core technologies” => Talk from L. Palumbo at JUAS 20th anniversary (2014): <https://espace.cern.ch/juas/SiteAssets/SitePages/20%20years%20of%20JUAS/Palumbo.pdf>

11 Universities provide more than 100 hrs training to Master students:

1. University of Manchester
2. Universitat Autònoma de Barcelona
3. IKP, TU Darmstadt
4. Institut für Kernphysik der Johannes Gutenberg-Universität Mainz
5. University Paris-Sud
6. IKP, FZ Jülich
7. DELTA, TU Dortmund
8. INFN - Milano & Università degli Studi di Milano
9. EPFL: Swiss Institute of Technology Lausanne
10. Università di Roma "La Sapienza"
11. Hamburg University

L. Palumbo, 20th JUAS, April 25th 2014

“UNIVERSITIES MEET LABORATORIES”

■ 2 workshops organised within EuCARD2 (<http://eucard2.web.cern.ch>)

- In 2014: <https://indico.gsi.de/event/2843/>

=> Workshop summary: <https://indico.gsi.de/event/2843/picture/33>

- In 2016: <https://indico.gsi.de/event/4675/>



from September 29, 2014 to October 1, 2014
Frankfurt am Main
Europe/Berlin timezone

Universities meet Laboratories

Universities meet Laboratories

3-4 November 2016
Europe/Paris timezone

Overview

Program Committee

Program

Timetable

Workshop Summary

Workshop Location

Cocktail Reception:
Monday from 19:30

Registration

Registration Form

Participant List

Accommodation

Poster

Pictures from the
Workshop

"Universities meet Laboratories" Workshop

30 Sept. - 1 Oct. 2014,
Johann-Wolfgang-von-Goethe-University in Frankfurt am Main

This is the first EuCAN workshop.

Workshop topics are:

- Do synergies exist between Universities and Laboratories?
- The ranking of the research: Universities and Laboratories, different worlds.
- Training in accelerator physics and technology.
- The attraction of young people starts in the universities; what is the role of Laboratories in attracting students?
- Is the remark "This is academic" always negative?
- Accelerators in Universities as complementary to large National and International Laboratory?
- Preparation of EuCARD-2 EuCAN M18 deliverable "key results of 5 accelerator networks"



Starts Sep 29, 2014 19:00
Ends Oct 1, 2014 22:00
Europe/Berlin



Frankfurt am Main
Max-von-Laue-Str. 1
60438 Frankfurt am Main



Dr. Franchetti, Giuliano
Dr. Papaphilippou, Yannis
Dr. Zimmermann, Frank

Overview

Scientific Program
Committee

Program

Timetable

Registration

Registration Form

Participant List

Poster

Accommodation

How to reach LAL

Workshop Dinner

Questionnaire

Questionnaire (docx)

Workshop Fee

Workshop photos

Following the success of the first "Universities meet Laboratories" in Frankfurt, EuCAN organizes the second meeting to finalize the discussions on synergies and differences between universities and laboratories, to complete the comparison of accelerator research ranking criteria by type of institute and by country, and to prepare a summarizing document.

Location of the meeting

Laboratoire de L'Accélérateur Linéaire
Université Paris-Sud 11
UMR 8607
91898 Orsay cedex



Starts Nov 3, 2016 08:00
Ends Nov 4, 2016 18:00
Europe/Paris



Dr. Faus-Golfe, Angeles
Dr. Franchetti, Giuliano
Dr. Zimmermann, Frank



Workshop secretary: Valerie Brouillard, email: brouilla@lal.in2p3.fr

“UNIVERSITIES MEET LABORATORIES”

=> Workshop summary: <https://indico.gsi.de/event/2843/picture/33>

2014

Global Summary

*G. Franchetti (GSI)
& F. Zimmermann (CERN)*

“Universities meet Laboratories” was a pioneering attempt to bring together representatives of the academic world and of laboratories, in order to confront the interface of joint research, communication and collaborations.

The workshop revealed a unanimous consensus among the participants from universities across Europe that, in general, the field of accelerator physics and technology appears to be often disadvantaged by an inadequate standing in the academic environment.

This perception diffuses down to the students many of whom then do not choose accelerator physics as university study topic. Most students are not even aware of accelerator physics as a possible career path. Greater efforts should be made to attract students in the first stage of their studies.

“UNIVERSITIES MEET LABORATORIES”

=> Workshop summary: <https://indico.gsi.de/event/2843/picture/33>

2014

Global Summary

*G. Franchetti (GSI)
& F. Zimmermann (CERN)*

“Universities meet Laboratories” was a pioneering attempt to bring together representatives of the academic world and of laboratories, in order to confront the interface of joint research, communication and collaborations.

The workshop revealed a unanimous consensus among the participants from universities across Europe that, in general, the field of accelerator physics and technology appears to be often disadvantaged by an inadequate standing in the academic environment.

This perception diffuses down to the students many of whom then do not choose accelerator physics as university study topic. Most students are not even aware of accelerator physics as a possible career path. Greater efforts should be made to attract students in the first stage of their studies.

=> See Appendix for more info about current courses & programmes in several European universities

CERN DOCTORAL STUDENT PROGRAMME

- **CERN Doctoral Student programme is a very strong component of accelerator science education in Europe**

- **Opportunities:** <http://careers.cern/students>

Careers at CERN

Doctoral Student Programme

This programme will soon open for applications.

This is a chance to work on your thesis while spending up to 36 months at the forefront of science. Whether you've already chosen a subject or are still making your decision, if your specialism is Applied Physics, Engineering or Computing, this is an invitation to further your knowledge in a truly unique organization. In fact, it's an invitation to get involved in world-famous experiments of unprecedented scale and scope. An invitation to join an environment like nowhere else on Earth.

Specific programmes are in place for nationals of Germany and Austria. Click [here](#) to find out more.

Technical Student Programme

This programme will soon open for applications.

There's no better way to learn than on-the-job. When that job happens to be in a world-famous organisation and centre of scientific excellence, even better. If you're an undergraduate in Applied Physics, Engineering or Computing and are looking for a practical training period or a place to complete your final project, you could spend 4 to 12 months at CERN during the course of your studies (Bachelor or Master). An extension of up to a maximum of 14 months may be given.

- **Access to PhD theses:**
<https://cds.cern.ch/collection/CERN%20Doctoral%20Student%20Program>
- **> ~ 10 PhD theses / year and 10 MSc / year over last 5 years**



- **Ex: EPFL has had a great collaboration with the CERN doctoral programme, graduating 40 PhDs over the past decade**

IAS (INTERNATIONAL ACCELERATOR SCHOOL) for Linear Colliders

- ◆ **Homepage:** <http://www.linearcollider.org/school>
- ◆ **10 editions between 2006 and 2016 (only 2014 missing)**

The screenshot displays the Linear Collider Collaboration (LCC) website. The top navigation bar includes links for IMAGES, CALENDAR, CONTACT, and social media icons. Below this, a secondary navigation bar lists: About LCC, ILC Home, CLIC Home, Physics & Detectors, Newline, and Tools. The main heading is "International Accelerator Schools for Linear Colliders".

On the left side, there is a list of past schools:

- 2015**

Ninth International Accelerator School for Linear Colliders
26 October – 6 November 2015
Delta Whistler Village Suites, Whistler, British Columbia, Canada
- 2013**

Eighth International Accelerator School for Linear Colliders
4 – 8 December 2013
Hotel Rixos Downtown, Antalya, Turkey

On the right side, the page highlights the upcoming school:

Tenth International Accelerator School for Linear Colliders

8 December – 19 December 2016
KEK and Teijin Academy at Mt. Fuji,
Susono, Shizuoka, Japan

Organised by the Linear Collider Collaboration and the ICFA Beam Dynamics Panel
Hosted by KEK

This school is a continuation of the series of schools started six years ago (2006 in Japan, 2007 in Italy, 2008 in the U.S., 2009 in China, 2010 in Switzerland, 2011 in the U.S., 2012 in India and 2013 in Canada). Based on the needs from the high-energy physics community, the Linear Collider Collaboration (LCC) and ICFA Beam Dynamics Panel will organise a Tenth International Accelerator School for Linear Colliders. The focus of the school will be on TeV-scale linear colliders including the International Linear Collider (ILC), the Compact Linear Collider (CLIC) and other advanced colliders. The target students are graduate students, postdoctoral fellows and junior researchers from around the world. We welcome applications from physicists who are considering changing their career from experimental physics to accelerator physics. This school is adopting an in depth approach. Therefore, former students are welcome to apply if they have a compelling reason to do so. The school will be in lecture style. There will be homework assignments and a final examination, but no university credit will be offered.

Below the text is a poster for the **10th International Accelerator School for Linear Colliders**, featuring a large image of Mount Fuji. The poster includes details about the topics (ILC, CLIC, ICFA Beam Dynamics, Collider Technology Instrumentation, Alignment, Feedback, ILC, CLIC & Compact Ring Machine Detector Interface and Detectors), dates (December 8-19, 2016, at Mt. Fuji, Japan), and application information (Online application deadline: August 31, 2016; Contact: icfa@linearcollider.org; Fee: € 10,000 (2016); URL: <http://www.linearcollider.org/school/2016>).

<http://www.linearcollider.org/school/2016>

- ◆ **After a decade of running dedicated LC schools, a future colliders school was created within the CAS in 2018 to cover both linear and circular future colliders (as seen in slide 9)**

NPAS: NORDIC PARTICLE ACCELERATOR SCHOOL

- ◆ **Homepage of NPAP (Nordic Particle Accelerator Project):** <https://npap.eu/>
- ◆ **NPAS was recently created through a European funding and took place in August at Lund University (Sweden): 2015, 2016 and 2017**
- ◆ **1st edition of the school in 2015**
 - 1-week course
 - 37 students from 9 different countries
- ◆ **MOOC under preparation:** <https://npap.eu/mooc/>

CONCLUSION

- ◆ **If / when decision is taken to build the future collider, everything should be in place with**
 - **CAS** (since 1983), **CERN Doctoral Student programme** (since 1985), **JUAS** (since 1994), **IAS for Linear Colliders** (2006-2016), **MOOC in preparation** (Release < May 2020) - following projects **TIARA & ARIES**, to try and attract **more students at universities** (where only a little fraction of universities offer a formal graduate education in Accelerator Science & core technologies => See Appendix)

CONCLUSION

- ◆ **If / when decision is taken to build the future collider, everything should be in place with**
 - **CAS** (since 1983), **CERN Doctoral Student programme** (since 1985), **JUAS** (since 1994), **IAS for Linear Colliders** (2006-2016), **MOOC** in preparation (Release < May 2020) - following projects **TIARA & ARIES**, to try and attract **more students at universities** (where only a little fraction of universities offer a formal graduate education in Accelerator Science & core technologies => See Appendix)
 - **A CAS course was already devoted to Future Colliders in 2018** (<https://cas.web.cern.ch/schools/zurich-2018>). Next JAS school on “Hadron Colliders” (Dubna, fall 2019)

CONCLUSION

- ◆ **If / when decision is taken to build the future collider, everything should be in place with**
 - **CAS** (since 1983), **CERN Doctoral Student programme** (since 1985), **JUAS** (since 1994), **IAS for Linear Colliders** (2006-2016), **MOOC** in preparation (Release < May 2020) - following projects **TIARA & ARIES**, to try and attract **more students at universities** (where only a little fraction of universities offer a formal graduate education in Accelerator Science & core technologies => See Appendix)
 - **A CAS course was already devoted to Future Colliders in 2018** (<https://cas.web.cern.ch/schools/zurich-2018>). Next JAS school on “Hadron Colliders” (Dubna, fall 2019)
 - **The IAS school for Linear Colliders took place between 2006 and 2016** (<http://www.linearcollider.org/school>)

CONCLUSION

- ◆ **If / when decision is taken to build the future collider, everything should be in place with**
 - CAS (since 1983), CERN Doctoral Student programme (since 1985), JUAS (since 1994), IAS for Linear Colliders (2006-2016), MOOC in preparation (Release < May 2020) - following projects TIARA & ARIES, to try and attract more students at universities (where only a little fraction of universities offer a formal graduate education in Accelerator Science & core technologies => See Appendix)
 - A CAS course was already devoted to Future Colliders in 2018 (<https://cas.web.cern.ch/schools/zurich-2018>). Next JAS school on “Hadron Colliders” (Dubna, fall 2019)
 - The IAS school for Linear Colliders took place between 2006 and 2016 (<http://www.linearcollider.org/school>)
- ◆ **Teachers for colliders are very localized in the few big laboratories around the world**

CONCLUSION

◆ If / when decision is taken to build the future collider, everything should be in place with

- CAS (since 1983), CERN Doctoral Student programme (since 1985), JUAS (since 1994), IAS for Linear Colliders (2006-2016), MOOC in preparation (Release < May 2020) - following projects TIARA & ARIES, to try and attract more students at universities (where only a little fraction of universities offer a formal graduate education in Accelerator Science & core technologies => See Appendix)
- A CAS course was already devoted to Future Colliders in 2018 (<https://cas.web.cern.ch/schools/zurich-2018>). Next JAS school on “Hadron Colliders” (Dubna, fall 2019)
- The IAS school for Linear Colliders took place between 2006 and 2016 (<http://www.linearcollider.org/school>)

◆ Teachers for colliders are very localized in the few big laboratories around the world

See also Appendix for some books & software tools

◆ Publications and dissemination policy also important (EPS-AG, IUPAP WG14,...)

<https://www.eps.org/members/group.aspx?code=EPS-AG>

<http://iupap.org/working-groups/wg14-accelerator-science/>

- JACoW (Joint Accelerator Conferences Website): <http://www.jacow.org>
- Journals => Phys. Rev. Accelerators & Beams: <https://journals.aps.org/prab/>
- ICFA Beam Dynamics Newsletters (2 issues / year): <http://icfa-bd.kek.jp/news.html>

APPENDIX

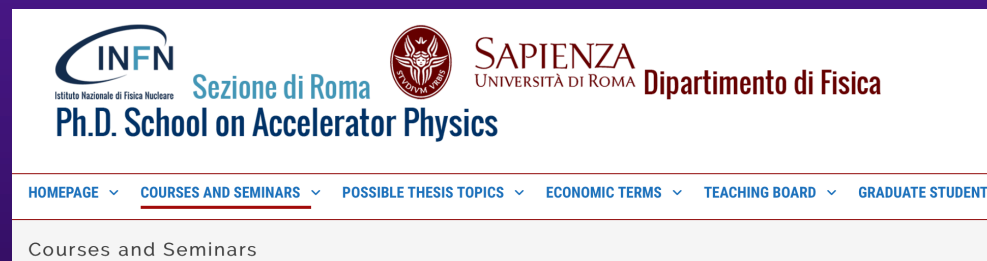
UNIVERSITIES

■ La Sapienza (Rome, Italy): Mauro Migliorati and Andrea Mostacci

- Master course in Electronic Engineering: Accelerator Physics and Relativistic Electrodynamics => ~ 2 - 4 students / year
- Given by A. Mostacci: 60 h (1 semester)
- Website: <https://www.sbai.uniroma1.it/mostacci-andrea/accelerator-physics-and-relativistic-electrodynamics/2018-2019>



- PhD course in Accelerator Physics: Longitudinal and Transverse Beam Dynamics in Circular Accelerators => ~ 8 - 10 students / year
- Given by M. Migliorati: 32 h
- Website: <https://web.infn.it/dottorato-fisica-acceleratori-roma/courses-and-seminars/>



UNIVERSITIES

■ EPFL (Lausanne, Switzerland): Lenny Rivkin and Tatiana Pieloni

- Master course (students at 3rd - 4th year of Physics or Engineering): Introduction to Particle Accelerators => ~ 25 - 30 students / year
- Given by Prof. L. Rivkin and T. Pieloni
- 4 h x 14 weeks (1 semester)
- Website: <https://moodle.epfl.ch/course/view.php?id=13759>
- “TPIVs” at LPAP laboratory at EPFL: 1 day / week devoted to this project for 1 semester (14 weeks) at EPFL, CERN or PSI => ~ 4 - 6 students / year (<https://lpap.epfl.ch/page-48751-en-html/>)

The screenshot shows the Moodle interface for the course 'Introduction to particle accelerators' (PHYS-448). The left sidebar contains a menu with 'Participants', 'Grades', 'Welcome', and a calendar for September and October. The main content area has a 'Welcome' message from the professor, Leonid Rivkin, and a 'Course Contacts' section listing the professor and teaching assistant. The breadcrumb trail is 'Dashboard / My courses / PHYS-448'.

The screenshot shows the EPFL LPAP website. The header includes the EPFL logo and navigation links for 'YOU ARE', 'BY SCHOOL', and 'ABOUT EPFL'. The main content area features the title 'PARTICLE ACCELERATOR PHYSICS LABORATORY LPAP' and a navigation bar with links for 'Research', 'Teaching', 'Publications', 'Members', 'World of Accelerators', and 'Accelerator Scho'. Below this, there is a 'TPIV projects' section with a brief description and contact information for Prof. Rivkin.

UNIVERSITIES

■ John Adams Institute (JAI in UK): Phil Burrows

- John Adams Institute: Oxford University, Royal Holloway, Imperial College
- One of two UK national academic centres of excellence in accelerator science
- 20 faculty, 25 staff, currently 35 PhD students (graduation rate now > 10 / annum)
- Comprehensive PhD training course: Lectures, tutorials, classes, design study project
 - Types of Particle Accelerators
 - Applications of Accelerators
 - Live Connection - LHC Control Centre CERN
 - Transverse Optics I & II
 - Longitudinal Beam Dynamics and Momentum Effects
 - RF Cavities (I, II, and III) and RF Cavity Design
 - Electron Dynamics, Synchrotron Radiation (I, II), Wigglers & Undulators
 - Accelerator Plasma Physics
 - Beam Diagnostics and Instrumentation
- PhD projects with CERN, KEK, Diamond, ISIS, industry ...

UNIVERSITIES

■ Cockcroft Institute (CI in UK): Hywel Owen and Carsten Welsch

- The CI is one of the largest research institutes dedicated to accelerator science and technology; formed in 2005
- The CI consists of 200 researchers drawn from 5 institutes: Manchester, Liverpool, Lancaster, Strathclyde Universities + UK Accelerator Science and Technology Centre (part of our research council STFC)
- We have around 70 current PhD students, and about 60 graduated so far. Our students are based across a number of sites that include the UK, rest of Europe and further afield
- We offer an integrated teaching system across 3 levels of courses: 32 h Introductory, 50 h Advanced, 40 h Options, plus transferable skills training; we group training into 5 themes: general accelerators, RF, beam dynamics, magnets/IDs, short-wavelength accelerators (plasma, dielectric etc). We offer 33 modules in total, plus university-specific additional modules; we have written syllabuses for each module
- Our modules are assessed at 1st-year with 3 assessments that include traditional question/answer papers and project work; we define specific attainments for PhD students
- Our teaching is available in a MOOC-style system with video recording of all lectures
- Our course is accredited by our funding body, and accepted by each University partner as fulfilling the requirements of 1st-year postgraduate teaching and assessment
- We offer an integrated support environment that includes mentoring, personal development and other support, and we publish guidelines for PhD students and supervisors

UNIVERSITIES

- We offer tailored education specific to each PhD student, and in particular have sub-programmes that include our industrial PhD scheme and our EU training networks
- We administer one of the largest sets of EU Innovative Training Networks (ITNs) - they are the largest training networks in accelerator science - and within each network we offer a tailored programme specific to the subject area of the network. These include targeted schools and workshops and a comprehensive set of student exchange secondments between partner laboratories. These ITNs have been recognised as 'best in class' by the EU. They offer a large amount of training that is complementary to their research-focused activity (tech transfer, IP protection, budget maintenance, outreach etc.)
- The ITNs that CarstenW has coordinated from U Liverpool (DITANET, oPAC, LA3NET, OMA and AVA) have now trained close to 100 Fellows in accelerator science. They have also established a 10-year track record of international Schools (similar to CAS on areas relevant to the respective ITN with 60-100 participants each time) and Topical Workshops (half a dozen per ITN with 30-120 participants each, organised all over Europe) for the world-wide accelerator community. Events also included several international conferences and Symposia. All presentations from Schools, workshops, etc. are available via CERN indico and are an excellent educational resource. U Liverpool (member of JUAS) is offering an undergraduate (final year) module on accelerator physics, PHYS481, which CarstenW has been teaching since 2009. We also offer BSc/MPhys projects in accelerator science and a group activity on grant writing PHYS491 for final year Master students. Our postgraduate students follow the CI lecture program. We also host a Centre for Doctoral Training on Big Data Science (www.livdat.org) since last year with currently 24 PhD students; 5 of those are doing their PhD in accelerator sciences (the others are in Particle Physics, Nuclear Physics or Astro physics)

UNIVERSITIES

- **Universitat Autònoma de Barcelona (UAB in Spain): Caterina Biscari**
 - Course since 2014 on Accelerator Physics for undergraduates, at the 4th year of Physics
 - Given by Caterina Biscari (with support of some of the accelerator physicists of ALBA)
 - Course completed with hands-on experience at ALBA on Simulation Codes, Magnetic Measurements and Emittance Measurements
- **RMU (joint Rhein-Main Universities in Germany): Oliver Boine-Frankenheim**
 - Trying to merge the existing accelerator-physics related classes at Uni Frankfurt, Mainz and Darmstadt into a new international masters degree program “accelerator science”, as part of the newly formed RMU (joint Rhein-Main Universities) => Coordinated by Oliver Boine-Frankenheim

UNIVERSITIES

■ **University of Rostock (Germany): Ursula Van Rienen**

- Elective subject for the bachelor's and master's course Electrical Engineering (German taught) Accelerator technology and beam diagnostics (original title Beschleunigertechnologie und Strahldiagnose)
- Given by P. Michel, 6 ECTS (1 semester) – recently introduced, expected number of students: 4 - 6
- **Website:** <https://www.iae.uni-rostock.de/studium-und-lehre/master-studiengaenge/beschleunigertechnologie-und-strahldiagnose/>
- No PhD course but typically 3 - 6 PhD studies running in parallel
- Accelerator topics handed out for bachelor theses, seminar talks, software projects, master theses: in total 4 - 6 students / year

UNIVERSITIES

- **Universitat Politècnica de Catalunya (Barcelona, Spain): Yuri Kubyshin**
 - In the 2nd semester of this academic year 2018-2019: course "Electron Beam Applications" of the Bachelor degree program on Industrial Engineering
 - Two one-semester courses of Master level are in preparation and should start during the next academic year 2019-2020
 - "Large Facilities" in the Master program on Physics Engineering. The topics to be taught include particle accelerators, colliders, synchrotron radiation facilities and their applications
 - "Electron Beam Applications" in the Master of Interdisciplinary Engineering; it is focused on small and medium-size electron accelerators and their industrial and medical applications
 - During last years at least 2-3 UPC students are selected each year for internship at the ALBA synchrotron to carry out small-scale projects proposed by ALBA

UNIVERSITIES

- **Karlsruhe Institute of Technology (KIT in Germany): Anke-Suzanne Müller**
 - Some info can be found in the KIT presentation at "Universities meet Laboratories 2016" (<https://indico.gsi.de/event/4675/session/9/contribution/21/material/slides/0.pdf>)
 - Education in accelerator physics and technology at KIT
 - Regular level master courses in the faculty of physics, 4 h / semester, with tutorials, hands-on training and excursion; 6 or 8 ECTS (typically 10 - 20 students)
 - Seminars on accelerator science (varying focus) 2 ECTS (~ 15 students)
 - Block courses in the frame work of graduate schools
 - Bachelor, master, and doctoral accelerator theses topics offered in physics and electrical engineering (usually ~ 10 doctoral students)
 - Survey of the German Committee for Accelerators (KfB): in its Brochure (https://www.dropbox.com/s/jhlib3hlpovkxln/kfb-broschuere_1.2.3_2016-03-03_web.pdf?dl=0), there is a map of Germany with the 'accelerator landscape' in Germany and the universities, where accelerator physics is taught (in bright red)
 - KfB also provides a page with Weblinks to the accelerator physics programs at the German universities that are shown on the map: <https://www.beschleunigerphysik.de/weblinks/>

UNIVERSITIES

■ **University of Oslo (Norway): Erik Adli**

- Launching a new graduate level course on Accelerator Physics (for MSc and PhD students) in Spring 2019
- Responsible: Erik Adli
- Website: <https://www.uio.no/studier/emner/matnat/fys/FYS4565/index-eng.html>
- Estimation to have ~ 5 - 6 students / year

UNIVERSITIES

■ University Paris-Saclay (France): Sophie Kazamias

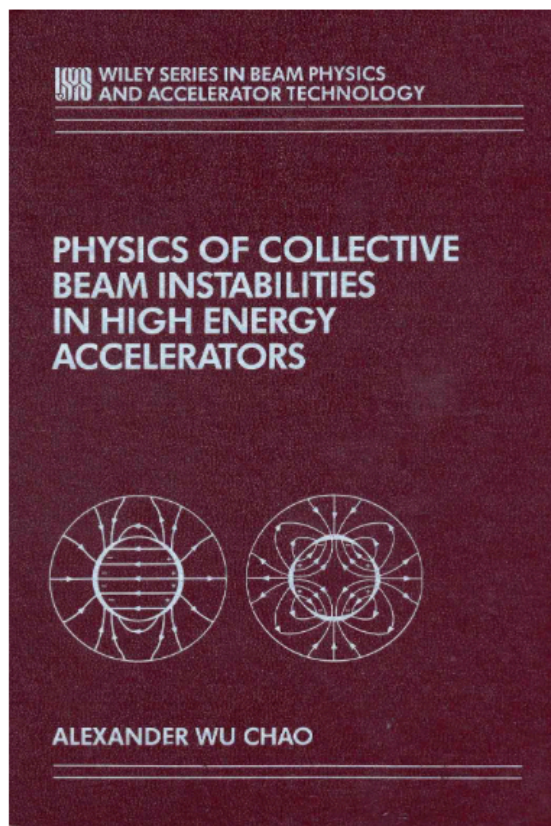
- University Paris-Saclay partners: Paris Sud University / INSTN / Ecole Normale Supérieure de Paris Saclay / Institut d'optique graduate School (IOGS) / Ecole Polytechnique / Ecole Nationale Supérieure des Techniques Avancées (ENSTA)
- Operate together a Master 2 programme on large scale facilities including Accelerators physics / high power lasers / tokamaks and related technologies
- Responsible: Sophie Kazamias (Professor Upsud) and Guy Bonnaud (engineer CEA)
- ~ 15 - 20 students per year (10 on accelerators)
- First semester program (in English):
 - ❑ 24 h on relativity and electromagnetism
 - ❑ 40 h on accelerator physics (taught by a consortium from SOLEIL / LAL / IPN / CEA)
 - ❑ 84 h of practicals on accelerator or high power laser installations around Paris Saclay (large support of SOLEIL)
 - ❑ 27 h on plasma physics
 - ❑ 27 h on laser physics
 - ❑ 27 h on laser / matter interaction
 - ❑ 35 h on numerical methods
 - ❑ 30 h on project management dedicated to large scale installations
 - ❑ 27 h on detection
 - ❑ 40 h on related technologies (vacuum / cryogenics / superconductors / irradiation)
- Websites
 - ❑ <http://www.master-plasmas-fusion.fr/gi/>
 - ❑ <https://www.universite-paris-saclay.fr/fr/education/master/m2-grands-instruments#presentation-m2>

(SOME) BOOKS



(SOME) BOOKS

- On-line book: <http://www.slac.stanford.edu/~achao/wileybook.html>



Frontmatter [pdf](#)

Chapter 1 **Introduction** [pdf](#)

Chapter 2 **Wake Fields and Impedances** [pdf](#)

Chapter 3 **Instabilities in Linear Accelerators** [pdf](#)

Chapter 4 **Macroparticle Models** [pdf](#)

Chapter 5 **Landau Damping** [pdf](#)

Chapter 6 **Perturbation Formalism** [pdf](#)

Index [pdf](#)

Errata [pdf](#) [pdf2](#)

(SOME) BEAM PHYSICS SOFTWARE TOOLS

■ <https://twiki.cern.ch/twiki/bin/view/ABPComputing/Software>

| Name | Category | Short description |
|--|-------------------------------|--|
| ABC | Electromagnetic solver | Azimuthal Beam Cavity Interaction - Time-domain electromagnetic code for impedance and wakefield calculations. |
| ACE3P | Electromagnetic solver | Package for electrodynamics simulations. |
| BimBim | Collective effects | Semi-analytical derivation of coherent modes of oscillation (impedance, feedback, 5D beam-beam) |
| COMBI | Collective effects | Coherent multi bunch interactions. |
| CST Particle Studio | Electromagnetic solver | Tool for analysis of charged particle dynamics in 3D electromagnetic fields. |
| DELPHI | Collective effects | An analytic Vlasov solver for impedance-driven modes. |
| Fastion | Collective effects | Fast Beam Ions instability for electron machines. |
| Footprint Viewer | Tracking | Computation and online visualization of tune footprint based on JMAD. |
| GdFID | Electromagnetic solver | Computation of electromagnetic fields in 3D-Structures using parallel or scalar Computer Systems. |
| GUINEA-PIG | Collective effects | Beam-beam simulator for electron-positron linear colliders. |
| HFSS | Electromagnetic solver | Finite element method solver for electromagnetic structures. |
| IBSimu | Tracking | Simulation package for ion optics, plasma extraction and space charge dominated ion beam transport. |
| ImpedanceWake2D | Electromagnetic solver | Code for the evaluation of resistive wall impedances and wake functions for multilayered flat, cylindrical or elliptical structures. |
| LHC Online Model | Optics | Framework for online and historic parameter extraction and beam modelling. |
| MAD-X | Optics | Methodical Accelerator Design. General purpose tool for particle accelerator design and simulation: lattice description, particle tracking, optics modeling, beam simulation & analysis, machine optimisation. |
| MapClass | Optics | Linac design and optimisation. |
| MOSES | Collective effects | Coherent betatron tune shifts for a Gaussian beam interacting with a resonator impedance. |
| Ninja | Plasma | 2.5D implicit Particle-In-Cell Monte Carlo Collision code for the simulation of inductively coupled plasmas. |
| ONIX | Plasma/beam | 3D particle-in-cell Monte Carlo Collision electrostatic code to simulate the particle transport in electronegative plasmas, in the vicinity of the extraction electrode of an ion source. |
| PageStore | Data Analysis | Python library to save and query large ordered dataset e.g. PyTimber time series. |
| PATH | Tracking | Multiparticle tracking codes for linacs and transfer lines. It includes an error study module and integration in RF field maps. Page still to be edited! |
| PHOTON | Photon | Monte-Carlo simulation of photon flux on the vacuum-chamber wall. Page still to be edited! |
| Placet | Tracking | Linear Accelerator Design. Tools for simulation, correction and efficiency tests. |
| PyECLOUD | Collective effects | Electron cloud simulation code. |
| PyHEADTAIL | Collective effects | Macro-particle simulation code for beam dynamics with collective effects. |
| PyOptics | Optics | Collection of Python tools that complement MadX to read, query, compute, plot optics functions from TFS, SDDS, MadX sources. |
| PyORBIT | Collective effects | Macro-particle simulation code for beam dynamics with space charge effects. |
| PyPARIS | Collective effects | Parallelization Layer for the simulation of two streams instabilities with PyECLOUD-PyHEADTAIL. |
| PyPIC | Collective effects | Library containing several 2D Particle-In-Cell solvers. Used in PyECLOUD for the simulation of e-cloud effects, and in PyHEADTAIL for the simulation of space-charge effects. |
| PySSD | Collective effects | Numerical evaluation of stability diagrams. |
| PyTimber | Data Analysis | Query CERN Logging Database. |
| RF-Track | Tracking / Collective Effects | Relativistic tracking in fieldmaps with multiple-specie beams and space-charge effects. |
| SIRE | Collective effects | Intra beam scattering (CLIC damping ring). |
| SixTrack | Tracking | Tools for fast million turns single particle tracking for dynamic aperture studies (machine stability) and collimation studies. SixTrack + Boinc = LHC@home. |
| SixTrack and Collimation | Tracking | Special framework including SixTrack with special support for collimation with added tools like BeamLossPattern. |
| SUSSIX | Frequency analysis | Frequency analysis of non-linear betatron motion. |
| TRAIN | Collective effects | Self-consistent computation of beam-beam effects (orbit, tunes, chromaticity). |