The CERN Accelerator School

Present CAS Activities and Experience

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(CERN/CAS)

"Universities meet Laboratories"

Workshop, LAL Orsay, 3 - 4 November 2016

- **CERN Accelerator School (CAS) established in 1983, with the mandate:**

  "To preserve and transmit knowledge accumulated, at CERN and elsewhere, on particle accelerators and colliders of all kind"

- **Takes place in different member states of CERN, member states (22) visited at least once, except Israel (member state since 2014), Romania (member state since 2016)**

- **Participants and lecturers from CERN member states and other countries world-wide**

Provide framework for a series of courses:

- **General accelerator physics (annually), alternating "Introductory" and "Advanced" course**
  Very diversified programme to give a global picture, but strong emphasis on beam dynamics ($\approx$ 2/3)
- **Topical schools specialized in a field, yearly up to 2013, now (minimum) two per year due to high demand and TIARA outcome.**
- **Occasional courses within framework of Joint Accelerator School (JAS) together with USPAS, Japan, and Russia**

Previous Schools

- **General courses (33 since 1983):**

  Residential courses, 2 weeks (50-60 hrs). Lectures, exercises, group projects and hands-on courses

- **Specialized topics (32 since 1983, 2 courses per year):**

  Residential courses, 1 week. Lectures, case studies

- **Joint Accelerator School (JAS, 13 schools since 1985):**

  Residential courses, 1 - 2 weeks. Lectures, homework, case studies

Introductory course:

- **Lectures largest part of the programme (typically $\approx$ 45)**

  Core topics: linear beam dynamics and related themes
- **Complemented by tutorials and dedicated discussion sessions**

Advanced course:

- **Strong focus on hands-on courses (all afternoons, lectures only in the morning)**
- **New core topics: Advanced beam dynamics concepts (in particular non-linear dynamics, collective effects, light sources)**

Typical General School (Introductory level, 2016)

DRAFT PROGRAMME FOR INTRODUCTION TO ACCELERATOR PHYSICS
2 – 14 October, Budapest, Hungary

Time	Sunday 2 Oct.	Monday 3 Oct.	Tuesday 4 Oct.	Wednesday 5 Oct.	Thursday 6 Oct.	Friday 7 Oct.	Saturday 8 Oct.	Sunday 9 Oct.	Monday 10 Oct.	Tuesday 11 Oct.	Wednesday 12 Oct.	Thursday 13 Oct.	Friday 14 Oct.
08:30 09:30	ARRIVAL DAY	Opening Talks	Particle Motion in Electro-magnetic Fields I S. Sheehy	Cyclotrons I M. Seidel	Linear Imperfections	Applications of Accelerators S. Sheehy	Non-Linear Beam Dynamics I A. Wolski	EXCURSION	Electron Beam Dynamics I L. Rivkin	Synchrotron Light Machines and FELs I L. Rivkin	Synchrotron Light Machines and FELs II R. Ischebeck	Kickers, Septa and Beam Transfer M. Fraser	DEPARTURE DAY
09:45 10:45		Introduction to Accelerators R. Steerenberg	Linear Accelerators I D. Alesini	Transverse Linear Beam Dynamics II B. Holzer	Longitudinal Beam Dynamics in Circular Machines II F. Tecker	Luminosity and Colliders G. Papotti	Vacuum Technology for Particle Accelerators M. Grabski		Beam Instrumentation E. Holzer	Collective Effects II G. Franchetti	Injection and Extraction M. Fraser	Secondary Beams and Targets K. Knie	
		COFFEE	**COFFEE**	**COFFEE**	**COFFEE**	**COFFEE**	**COFFEE**		**COFFEE**	**COFFEE**	**COFFEE**	**COFFEE**	
11:15 12:15		Electro-magnetic Theory I G. Franchetti	Particle Motion in Electro-magnetic Fields II S. Sheehy	Cyclotrons II M. Seidel	Discussion on Transverse Beam Dynamics	Discussion on Longitudinal Beam Dynamics	Tutorial 1		Electron Beam Dynamics II L. Rivkin	Beam Losses and Machine Protection Issues I. Strasik	Tutorial 2	Tutorial 3	
		LUNCH	**LUNCH**	**LUNCH**	**LUNCH**	**LUNCH**	**LUNCH**		**LUNCH**	**LUNCH**	**LUNCH**	**LUNCH**	
13:45 14:45		Electro-magnetic Theory II G. Franchetti	Transverse Linear Beam Dynamics I B. Holzer	Longitudinal Beam Dynamics in Circular Machines I F. Tecker	**FREE**	Warm Magnets G. de Rijk	Non-Linear Beam Dynamics II A. Wolski		Collective Effects I G. Franchetti	Collective Effects III G. Franchetti	**FREE**	Sources D. Faircloth	
15:00 16:00		Kinematics of Particle Beams I – Relativity W. Herr	Linear Accelerators II D. Alesini	Transverse Linear Beam Dynamics III B. Holzer		Fixed Field Alternating Gradient Machines S. Sheehy	Power Converters J.-P. Burnet		Discussion on Electron Beam Dynamics	Discussion on Collective Effects		Putting It All together W. Herr	
		TEA	**TEA**	**TEA**		**TEA**	**TEA**		**TEA**	**TEA**		**TEA**	
16:30 17:30		Kinematics of Particle Beams II W. Herr	Tutorial Explanations R. Bailey/ W. Herr	RF Systems F. Tecker		Super-conducting Magnets G. de Rijk	Poster Session		Beam Diagnostics E. Holzer	**Seminar** Applications of Lasers in Accelerator Science L. Corner		**Seminar** Advanced Accelerator Concepts M. Ferrario	
17:45	Regis-tration	1 Slide 1 Minute R. Bailey										Closing Remarks	
19:30	Buffet Dinner	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Special Dinner**	

Very diverse programme:

44 hour of lectures + 4 discussion sessions + tutorial

New strategy for tutorial introduced - well received by participants

Previous topical schools - training the skills

- **Magnets and alignment: (1986, 1992, 1997, 2009)**
- **Superconductivity, Cryogenics: (1988, 1995, 2002, 2013)**
- **RF Systems: (1991, 1993, 2000, 2010)**
- **Diagnostics, signal processing: (2007, 2008, 2018)**
- **Vacuum: (1999, 2006, 2017)**
- **Power Converters: (1990, 2004, 2014)**
- **Small machine, high power machines: (1994, 2005, 2011)**
- **Synchrotron radiation, FEL: (1989, 1996, 2003, 2016)**

cont'd:

- **Ion Sources: (2012)**
- **Accelerators for medicine and industry: (2001, 2015)**
- **Colliding beam facilities (1983)**
- **Plasma Wake Acceleration (2014)**
- **Intensity Limitations (2015)**
- **Injection, extraction and beam lines (2017)**

Organization of CAS schools and programme:

CAS management staff, $\approx$ 2.5 FTE (since 2011):

- Roger Bailey (head of school, $\approx$ 80%)
- Werner Herr (deputy head of school, presently 50%)
- Barbara Strasser (administrative assistance, full time)
- Bernhard Holzer (for part of topical courses organizes the preparation and running of the school, part time, $\approx$ 20%)

* Hermann Schmickler (appointed as head of school from 2018)

Not part of CERN departmental structure, reports to CERN Directorate

Consultation with supporting bodies

Organization of CAS schools and programme:

- CAS Advisory Committee (meets once per year):
  - Membership: approved by CERN management (typically 50% - 60% non-CERN members, universities and laboratories)
  - Review previous schools, suggest changes if needed (consider students' evaluation where applicable)
  - Propose subjects for future topical schools

    (consider demands and time since previous school on this topic)
  - Propose venues (country) for future schools
- Proposals subject to approval by CERN directorate

Organization of CAS schools and programme:

- **CAS Programme Committee** (meeting and consultation for each school):
  - Membership: CAS staff, experts on the school topics (normally more than 50 % non-CERN members, universities and laboratories)
  - Local university or laboratory as co-organizer represented
  - Review previous schools, including students' feedback
  - Propose lectures and lecturers for the courses

→ Recommends programme to head of the school for decision

Evolution of the programme:

- **Schools are regularly revised to adapt to evolution in the field and improved teaching methods**
- **Recent (since 2016): updated common syllabus for general schools (Introductory and Advanced level)**

  Purpose:

  - **Ensure a coherent set of lectures, with advanced course as follow up of introductory course**
  - **Take into account advancement in the field**
  - **Input from lecturers and students, single programme committee for both schools**
  - **Provide a well-defined foundation for topical courses**

Financing

- Try to be cost neutral with students' fees: for running of the school, this includes accommodation, all meals, course material (fees strongly depend on local costs and country)
- All expenses for lecturers covered by CAS, but no remuneration for lecture

  (relying on good will and dedication of lecturers, has not been a problem so far)
- Financial support for students (covers only fees, no travel): typically up to 5 students per school

Attendance:

- **Unlike USPAS/JUAS: much less focused on University Students**

  Staff of laboratories and universities (physicists, engineers, technicians), undergraduate and PhD students, post docs, staff from in industry working with accelerators

- **General schools:**
  - **Introductory level: 110 - 130 participants (aim for 120)**
  - **Advanced level: limited to 75 - 80 participants (due to afternoon courses)**

- **Topical schools:**
  - **Depends on topic: 60 - 100 participants**

General schools often oversubscribed (up to 60%), then CV and reference letter required

Origin: Participants

	General schools	Topical schools
Laboratories:	78 %	80 %
Universities:	20 %	16 %
Industry:	max 2 %	4 - 10*) %
Non-member states:**) (by affiliation)	8 %	12 %

*) depending on topic

**) mostly: Russia, Japan, China

Education and background: Participants

As example: Introductory course, Budapest 2016

Participants with post-graduate university degree$^{*)}$ (Physics or engineering) 85 %

Where:

Without PhD:	**49 %**
With PhD:	**29 %**
PhD students:	**22 %**

Others: Technical engineers, technicians, operators, undergraduate students, BSc

$^{*)}$ **Minimum: MSc/Diploma $\Rightarrow$ BSc not counted**

Level, prerequisites for participants (I)

- **Introductory Course:**
  - Basic knowledge in physics or engineering and mathematics (1st year university level)*).
  - No training in accelerator physics expected
- **For this Course: typically rather large spread of background:**

  (technicians, engineers, physicists (various disciplines), senior staff)

→ **Short recapitulation of background knowledge: Classical Electrodynamics, Special Relativity**

*) **Basics of differential equations recommended**

Level, prerequisites for participants (II)

- **Advanced Course**, all **Topical schools**:
  - Good knowledge in mathematics (1st year university level)*) and physics or engineering.
  - Basic training in accelerator physics or experience in Accelerator Operation or Technology
  - Reference letter and CV always required
- In general: material based on Introductory Course

*) Basics of complex calculus and differential equations recommended

Expectations on lecturers

- **General and topical schools:**
  - Working in the field, with good teaching and communication skills, able to adapt to the right level of the course
  - In addition to lectures, contribute as tutor and facilitator in tutorials and group projects (including fields not related to own lectures), actively participate in discussions with students
  - Seek feedback, accept criticism and continue to improve lectures and keep material up to date (difficult)
  - Consult with other lecturers, agree on conventions, avoid contradictions (very difficult)
  - If foreseen: write up lectures for proceedings (extremely difficult)
- **All lecturers invited on a personal basis**

Origin: Lecturers

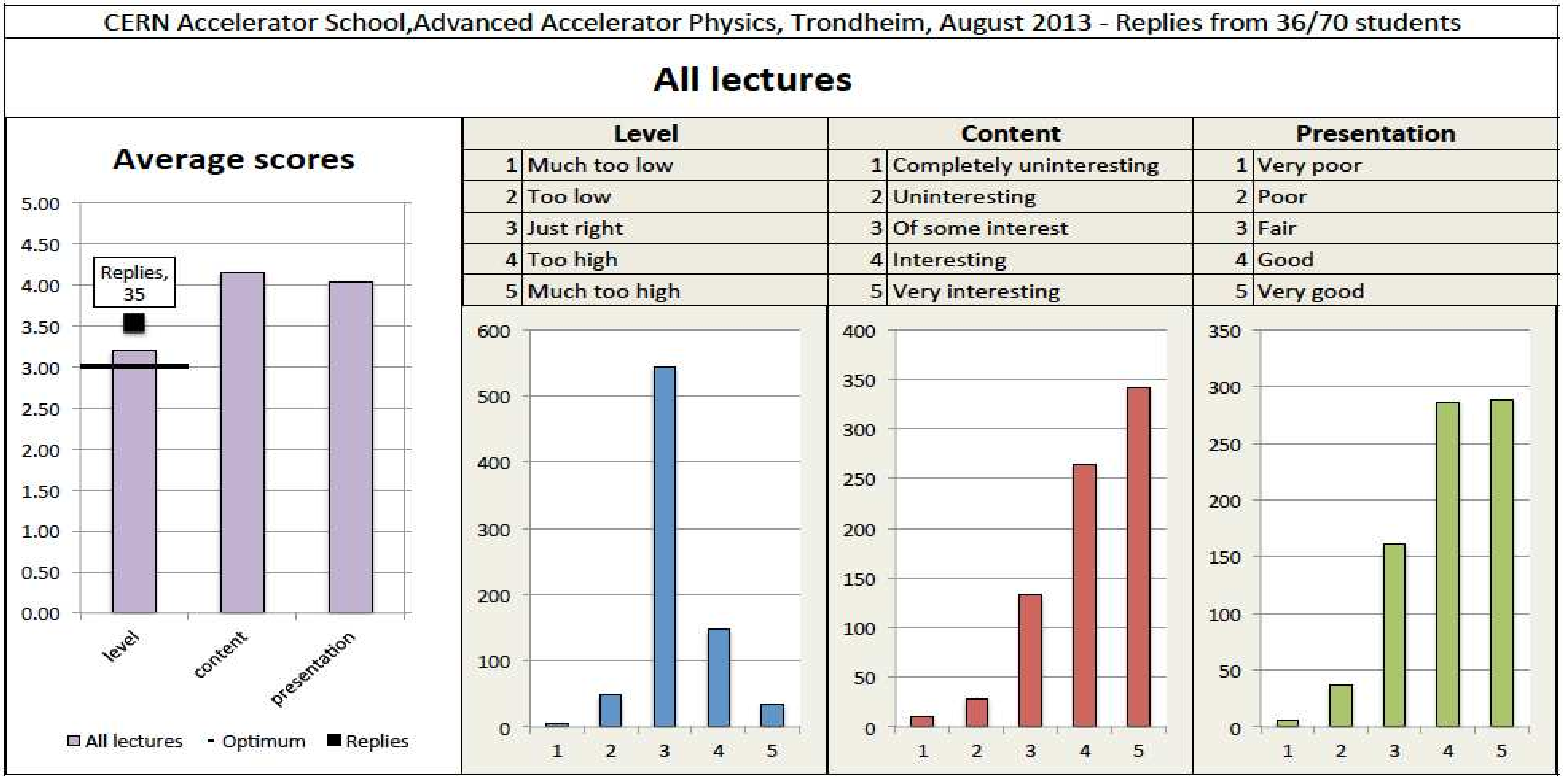
	General schools	Topical schools
Laboratories (CERN):	54 %	34 %
Laboratories (non-CERN):	34 %	47 %
Universities:	10 %	10 %
Industry:	max 2 %	8 %

Rare: retired lecturers

Evaluation of the schools

- **Quality of school and lectures are monitored:**
  - **Participants are asked to evaluate quality and benefit of lectures (level, contents and presentation)**

    (standard questionnaires and additional comments)
  - **Evaluation includes organization and running of the school**
  - **Encourage feedback from teaching staff (not yet very successful)**
- **CAS Committees include evaluation to propose topics, lectures and lecturers**



- **Typical result (overall), separate for each lecture(r) as well**

- **Individual results are send to the lecturer concerned**

  (There is a danger ... !)

Dissemination of material

- **Proceedings for General and Topical schools:**
  - So far: 36 proceedings in printed form
  - General schools: only when programme/contents have changed significantly, most recent: Advanced Course 2013
  - Topical schools: every school
- **On-line:**
  - On-line versions of written proceedings available since 1983 (CERN Document Server), on arXiv since 2010
  - On INDICO since 2007/2009 (all slides and handouts)
  - Material for hands-on courses (including software downloads) since 2003
  - Budapest 2016: all lectures recorded for the first time
- **All free of charge, but CERN copyright (ISBN, ISSN, DOI)**

Credits for participation

- **CAS is more focused on laboratory staff, credits on students' or universities' request**
- **Has to be coordinated with the university concerned, requirements can be:**
  - **Attendance**
  - **Syllabus**
  - **Attendance + Syllabus**
  - **Syllabus + Exam (by a CAS and a university representative)**
- **At CERN: attending CAS accepted as training**

A more general approach is discussed in close collaboration with EPF Lausanne

Although aimed at professionals: want "academic" part

- Intention (sometimes subjected to criticism):
  - Introduce new research fields and new developments (e.g. acceleration techniques, ..)
  - Replace questionable and obsolete treatment, in particular beam dynamics, by contemporary methods
  - Promote teaching of beam dynamics beyond "standard" textbooks (e.g. non-linear dynamics, collective effects, computational methods, ...)

    (very well received by students, sometimes less by some lecturers)
- Improve teaching techniques and methods

Evolution of the teaching strategies

- In early schools: thematically oriented frontal teaching, since 1995 complemented by subject-specific exercises
- Recent strategy:
  - More focus on collaborative and problem based (active) learning (case studies in topical schools and group projects*))
  - Well received in all schools, but strongly increases load on facilitators/tutors (full time available, no formal result)
  - Our challenge: planning, organization and managing, provide necessary software and laboratory equipment

    (supply, transport, customs, setting up, ...)
  - Continuous evaluation of this approach together with students to improve

*) New approach tried at "Introductory Course" in Budapest 2016

General tutorial in Budapest 2016: Design Project

- 2016: design a p-p collider complex, issues to consider:
  - Realistic parameter set, following user requirements
  - Look at: lattice, collective effect (space charge, beam-beam), synchrotron radiation
  - Specification of the necessary injector chain
- Work in groups of 6 people, a tutor available for guidance
- Presentation of the proposals the last day

MUCH better received than previous style of tutorials !

Advanced courses:

- **Strong focus on hands-on courses**
- **All afternoons, lectures only in the morning**
- **Typically 18 - 20 hours, but facilities usually available outside scheduled time (as well as some tutors)**
- **Students choose one of 3 courses (remain there for the entire school):**
  - **Optics design**
  - **RF measurements techniques**
  - **Beam measurements**

Hands-on courses: Optics Development

Personal Computer for each participant

Limited to 25 participants

Typically 3 to 5 tutors

<u>Software installed :</u>

Methodical Accelerator Design (MAD)

PTC, TPSA package (CAS version)

gnuplot, adobe, etc...

LINUX operating system

(WINDOWS versions available)

Courtesy V. Chetvertkova

Hands-on courses: RF Measurement Techniques

- RF measurement techniques with modern equipment
- Typically 2 - 3 tutors for 25 participants

Hands-on courses: Beam Measurement

- Understand basics of measurement principles and their implementation
- Working in small groups and present the outcome
- Interactive simulation tools are available

Final comments

- **Complementary to university courses, different scope and audience, CAS does not replace university courses (or other schools)**
- **Close collaboration with universities and other laboratories:**
  - **Provide infrastructure for lectures and practical work, including instructors**
  - **Strong contacts between participants and lecturers, in particular for practical work. Cannot be replaced by e-learning**
- **Last but not least: many students come back as lecturers ...**

  recent schools (Trondheim, Prague): 19 ex-students (out of 45)
- **CAS is a full success since more than 30 years, increasing number of schools and participants, but ...**