The Swiss Master in Nuclear Engineering: A Collaboration between Universities, Research Centre and Industry

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Introduction


Leibstadt NPP

- 40% of electricity in Switzerland, nuclear
  - Important option for future
  - University-level education in field, crucial national need
- Swiss Federal Institutes of Technology: Lausanne (EPFL), Zurich (ETHZ)
  - Long tradition of nuclear-related education
  - Optional courses (physics, mech. eng.)
  - PhD research, often with PSI collaboration
  - Support of industry (swiss*nuclear*)
- Pooling of resources recently for set-up of new Master of Science in Nucl. Eng. (NE)
  - Present paper: main features, experience with running of this first-ever joint degree

Program Goals

- Provide in-depth knowledge on nuclear energy fundamentals, technology
  - Represents primary goal
  - Strongly inter-disciplinary field implies wide range of subjects to be taught
- Provide complementary knowledge on nuclear fusion
  - Strong background of fusion research at EPFL
- Provide knowledge on nuclear techniques in medicine, research and industry
  - Optional courses in radioisotope applications, accelerator physics
- Provide view of entire fuel cycle, from uranium mining to the back-end
  - Sustainability largely defined by fuel cycle, corresponding compulsory course
- Underline role of nuclear energy as part of a sustainable, global energy mix
  - Several electives related to non-nuclear energy production

Qualification, Employment Prospects

- Qualification profile corresponding to wide range of potential employers
  - From utilities, via nuclear service companies, to NPP vendors and developers
- Thus, in Switzerland
  - Nuclear utilities: Alpiq, Axpo, BKW-FMB
  - Nuclear waste disposal organisations: Nagra, ZWILAG
- Other types of industrial employers mainly abroad
  - Reactor vendors, fuel manufacturers, enrichment plants, reprocessing facilities
- R&D organisations, both inland (PSI) and abroad (GRS, IRSN,…)
- National nuclear safety authorities and other related government institutions
  - Swiss Federal Nuclear Safety Inspectorate (ENSI), …
- Non-nuclear fields, e.g. general energy sector, R&D (fluids, materials,…)

Curriculum Structure

- Student's achievements measured in ECTS credit points
  - Full academic year: 60 ECTS, i.e. 1 ECTS ~ 1h class + 1h homework per week
- Swiss NE Master currently 90 ECTS, i.e. 3-semester, program
  - 2 semesters, course work; 3rd: 8-week industrial internship + 17-week project
- EPFL-ETHZ-PSI-swiss*nuclear* collaboration reflected by:
  - 1st semester fully at EPFL, 2nd at ETHZ, 3rd at PSI
- Overall structure:
  - 28 ECTS compulsory courses, 20 core electives
  - 4 ECTS free elective, 2 entrepreneurship course, 6 Semester project
  - 30 ECTS Master thesis
- Teaching language: English

Compulsory Courses

- Seven compulsories
  - Each to be cleared separately
- First four at Lausanne
  - EPFL: Physics, Materials
- Other three at Zurich
  - ETHZ: Th'hydls, Engineering
- Several courses, "standard"
- Reactor Experiments, uses CROCUS reactor at EPFL
- Special Topics in Reactor Physics, advanced aspects
- Nuclear Systems, fuel cycle and impact on NPP operations

No.	*Course*	*Responsible University*	*Semester*	*Held at*	*ECTS*
1	Neutronics	EPFL	Autumn	Lausanne	4
2	Reactor Experiments	EPFL	Autumn	Lausanne	4
3	Reactor Technology	ETHZ	Autumn	Lausanne	4
4	Nuclear Fuels and Materials	EPFL	Autumn	Lausanne	4
5	Nuclear Safety	ETHZ	Spring	Zurich	4
6	Special Topics in Reactor Physics	EPFL	Spring	Zurich	4
7	Nuclear Energy Systems	ETHZ	Spring	Zurich	4
				Total:	28

Core Electives - 1

- 20 ECTS of core courses (5 electives), chosen from three different tracks"
  - A. Energy Systems
  - B. Physics & Materials
  - C. Thermal-hydraulics
- Tracks, not specializations, solely to guide students in their choice
- Advice also provided by "tutor"

Track A: Energy Systems

No.	*Course*	*Responsible University*	*Semester*	*Held at*
1	Advanced Fossil and Renewable Energy Systems	EPFL	Autumn	Lausanne
2	Hydraulic Turbomachines	EPFL	Autumn	Lausanne
3	Probabilistic Safety Analysis and Risk Management for Critical Energy Infrastructure	ETHZ	Spring	Zurich
4	Renewable Energy Technologies II, Energy Storage and Conversion	ETHZ	Spring	Zurich

Core Electives - 2

Track B: Physics and Materials

No.	*Course*	*Responsible University*	*Semester*	*Held at*
1	Nuclear Fusion and Plasma Physics	EPFL	Autumn	Lausanne
2	Introduction to Particle Accelerators	EPFL	Autumn	Lausanne
3	Radioisotope and Radiation Applications	EPFL	Spring	Zurich
4	Advanced Topics in Nuclear Reactor Materials	EPFL	Spring	Zurich

Track C: Thermal-hydraulics

1	Instability and Turbulence	EPFL	Autumn	Lausanne
2	Two-Phase Flows and Heat Transfer	EPFL	Autumn	Lausanne
3	Multi-Phase Thermal Fluid Dynamics	ETHZ	Spring	Zurich
4	Advanced CFD Methods	ETHZ	Spring	Zurich

Semester Project

- Introduction to nuclear R&D
- 1 day per week during 2nd sem.
  - Preparation for Master thesis
- Basis for choice of topic:
  - Course work during 1st sem.
  - Advice of tutor
  - Visit to PSI at end of 1st sem. (national centre for nuclear R&D), site for Master research
  - Presentation of main R&D activities underway in NES Dept., e.g. in Dec.'09 ➔

No.	*R&D Activity*	*Responsible Laboratory*
1.	Experimental Reactor Physics	Reactor Physics and Systems Behaviour
2.	LWR Core & Transient Analysis	
3.	Gen. IV Fast Reactor Studies	
4.	Thermal-hydraulic Phenomena	Thermal-hydraulics
5.	Severe Accident Phenomena	
6.	Nuclear Fuels R&D	Nuclear Materials
7.	Reactor Component Safety	
8.	High Temperature Materials	
9.	Analytical Techniques (Fuels)	Hot Lab
10.	Waste Management	Waste Management
11.	Technology Assessment	Energy Systems
12.	Risk & Human Reliability	
13.	Materials for Nuclear Fusion	Centre for Research in Plasma Physics (EPFL)
14.	Magnets for Nuclear Fusion	

Master Project

- Master project (30 ECTS): two parts
  - 8-week industrial internship (NPPs, ENSI, Nagra, etc.)
  - 17-week Master thesis, usually built upon semester project
- Master thesis
  - Enhance capability for independent theoretical and/or experimental NE research
  - Condition for starting: clearance of at least 50 ECTS of course work (from total of 60 needed)
  - Supervision: senior PSI/NES scientist + responsible professor

Examples of chosen research topics, 2008 batch ➔

1.	HELIOS analysis of a SCWR-like test lattice in PROTEUS
2.	Improved Monte Carlo calculations of RPV fluence
3.	Analysis of PHENIX pre-shutdown tests
4.	Feasibility study for neutron tomography of 2-phase flows
5.	Validation of CFD modelling results
6.	Modelling of reactor containment flows
7.	An isotopic dilution technique for fission gas analysis
8.	LCA analysis of waste disposal and CO_2 sequestration

Organisational Aspects: Core Group, Tutors

- Program conducted under supervision of NE "Core Group" (NECG)
  - Professors from each university, PSI-NES department head, swiss*nuclear* representative, …
  - Decisions on academic matters by professors (formal ratification by both universities)
- Each student chooses a tutor at start of program
  - Academic mentor, advisor (e.g. on choice of optional courses)
- Many of the courses taught by professors, but not all
  - Additional lecturers needed for meeting demands of wide-based curriculum
  - Necessary academic personnel, largely from among senior PSI-NES scientists
  - Approval from university department through NECG professor

Admission Requirements, Procedure

- Program open to wide range of Bachelor degree holders
  - Mechanical/Electrical/Chemical Engineering, Materials Science, Physics, Chemistry, Maths.
  - Justified by multi-disciplinary character of NE Master
  - Common admission profile, corresponding to ~ first 2 years of Bachelor
    - 18 ECTS Mathematics, 12 ECTS Natural Sciences, 12 ECS Engineering Sciences
- Evaluation of candidates on basis of detailed dossiers
  - NE Core Group, role of Admission Committee (AC)
  - Principal criteria: degree, parent university, academic performance
- Several decisions taken on individual basis
  - Subsidiary course requirements, if necessary
  - Allocation of students from abroad to the 2 different universities (registration)

Administration, Mobility Support, Degree

- Admission / registration for courses, 2 independent procedures
  - All students registered at EPFL for 1st semester, at ETHZ for 2nd
  - Exchange student status for those admitted at “other” university
  - Creditation of courses, responsibility of host university
- Semester, Master projects
  - Responsibility with EPFL or ETHZ professor, depending on topic (may or may not be tutor)
- Mobility support granted by ETH-Domain’s energy competence centre (CCEM-CH)
  - Funding to cover extra expenditure related to “multi-campus” nature of program
- Degree issued jointly by the 2 universities
  - *Master of Science EPF-ETH in Nuclear Engineering*

Experience to Date

- First 2 batches of similar size
  - 12 students in 2008 (4 from Swiss universities, 8 from abroad)
  - 13 students in 2009 (7 from Swiss universities, 6 from abroad)
  - Large fraction of students from abroad, reflection of “Bologna spirit”
- Bachelor degrees of various types (among the 25 students to date)
  - Physics: 11, Mech. Eng.: 6, Nucl. Eng.: 2, Chem. Eng.: 2, Others: 4
  - Domination of Physics, Mech. Eng., in line with “host” departments at EPFL, ETHZ
- Feedback from students, generally very positive
  - Attending classes in 2 different universities with different “cultures”, enriching experience
  - Despite “mixed” background of students, courses found both interesting and challenging
  - Wide range of R&D topics offered at PSI, felt to be a noteworthy strength

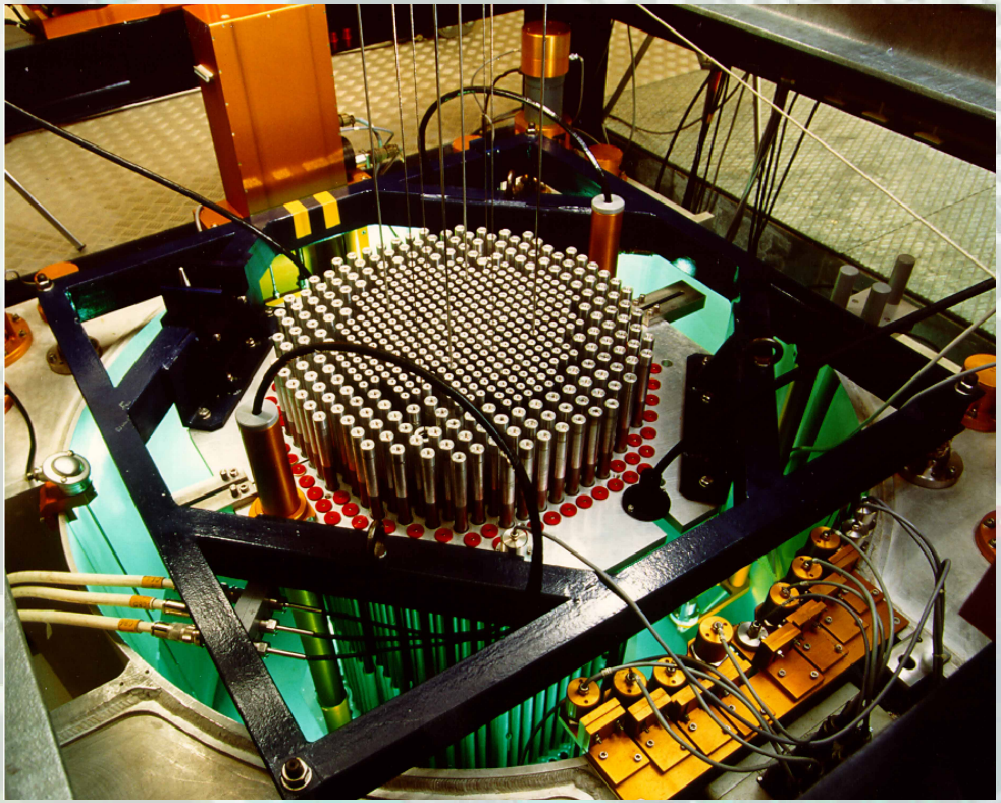
Future Prospects

- Current 90 ECTS (3 semester) program would benefit from upgrade to 120 ECTS
  - Make course work less "dense"
  - Allow greater flexibility in structuring industrial internship, Master project
  - Render program fully compatible with "3 + 2"-year Bologna system
- Deliberations during 2009, decision to implement new curriculum starting this Sept.
  - Main change: additional, new 3rd semester at PSI for semester project and 4 "block" courses

NE core (block) courses in 3rd semester of new 120 ECTS curriculum ➔

No.	*Course*	*Responsible University*	*Course Type*	*Held at*	*ECTS*
1	Radiobiology and Radiation Protection	ETHZ	Compulsory (new)	PSI	4
2	Adv. Topics in Nucl. Reactor Materials	EPFL	Core Elective	PSI	4
3	System Codes Lab	EPFL	Core Elective (new)	PSI	3
4	Beyond-Design-Basis Safety	ETHZ	Core Elective (new)	PSI	3
				Total:	14

Conclusions



Reactor CROCUS at EPFL

- As first-ever common EPFL- ETHZ degree, Swiss NE Master a unique collaboration between universities, research centre and industry
- Although mainly addressing national needs, to be viewed in international context
  - Reflected in high fraction (> 50%) of students from abroad
- Program upgrade to 4 semesters from Sept. 2010 onwards
  - Further strengthening of curriculum
  - Greater conformity with other NE programs, increased prospects for international collaborations

Thank you for your attention!