EXPERIENCES OF ACADEMIA - INDUSTRY COLLABORATION ON ACCELERATOR PROJECTS IN EUROPE

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Abstract

For a successful accelerator project one requirement is a good collaboration between industry and accelerator laboratories. Such a good collaboration has been built up starting with the construction of the first 500 MeV synchrotron at the University of Bonn until LHC at CERN and other projects in between. Also for future projects a good collaboration between the institutions and industry is needed. Today the design of the different accelerator components will be made by the laboratories and the manufacturing will be made by industry. Industry is not only capable to build components it can also manufacture systems like booster synchrotrons or synchrotrons for medical applications.

HISTORICAL REMARKS

After World War II industry built for research in high energy physics as well for medical applications: Cyclotrons, Betatrons, Linacs, Microtrons etc. The principle of most of these machines was the "weak focusing" which restricted the energy to some MeV's. A change took place with the concept of the strong focusing, invented by E.D.Courant, M.S. Livingston, and H.S. Snyder in 1952 [1]. The first accelerator designed and built according to this concept was the 500 MeV synchrotron at the University of Bonn in Germany; the designing phase started in 1952 and the operation started in 1958. The history of the machine is published in a book written by Ralph Burmeister [2]. The driving person of this project was Prof. Wolfgang Paul, the Nobel Prize Winner of 1985. Prof. Paul made an application for a 100 MeV but the review committee proposed to go up to 500 MeV. (this would never happen today). Fig.1 shows a picture of this machine. The lattice of this machine was 9 fold with the structure 0/D/F/D/0. The machine functions are given in Fig.2. The gradient in the defocusing and focusing magnets was 10.06 T/m and 8.81 T/m. During the design no codes were available for the determination of the pole profile. The pole profile was determined by measurements in an "Electrolytic Trough".

At that time the collaboration between industry and the laboratory was a bit different from today. Each component (magnets, vacuum system, power supplies, and so on) was designed by industry in collaboration with the laboratory. There was no template from which they could make a copy. Different from today was also that all designers and builders were later users of the machine.

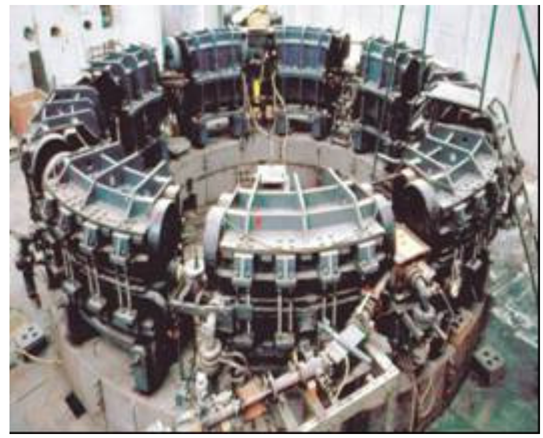

Figure 1: The 500 MeV Synchrotron at the University of Bonn

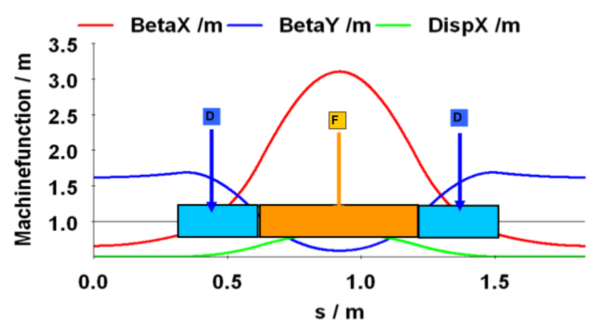

Figure 2: Machine functions of the 500 MeV Synchrotron at the University of Bonn.

For the next generation of accelerators to be built the group of Bonn proposed: "To have enough technical staff for the detailed design and preparation of drawings, according to which industry can manufacture the components. In this case one can save and avoid a lot of trouble". This is the procedure used today.

PRESENT COLLABORATION BETWEEN LABS AND INDUSTRY

The present relationship between industry and the laboratories for manufacturing of the different components is governed by the public call for tenders, to which most of the labs have to adhere, and which can be summarised as follows:

1) Execution of the call for tender process including the technical specifications and the administrative clauses.

2) Receiving and evaluation of the offers.
3) Negotiation with industry about the technical as well financial issues.
4) Signature of the contract
5) Preparation of the design and manufacturing report which has to be approved by the laboratory.
6) Production of the prototype and acceptance by the laboratory.
7) Series production of the component.
8) Factory acceptance test.
9) Site acceptance test.
10) Closing of the contract

According to procedure there is a permanent technology transfer between laboratories and industry (and vice versa), especially regarding points 3) and 6). Because of this technology transfer after some time industry has more experiences in building some components than the laboratories. This means that industry can build the components according to a "conceptual design specifications".

BESSY I Project

The synchrotron light source BESSY I [3] was built by newcomers (most of the staff) with no experience in accelerator physics. The staff had to concentrate on the design and construction of the storage ring.

The 800 MeV injector however was a turn key system designed and built by industry (Scanditronix). The injector consists of a 22 MeV microtron and a 800 MeV booster synchrotron. For the design, manufacturing, installation and commissioning of the booster synchrotron Scanditronix made a collaboration contract with MAX-LAB (Mikael Eriksson). This injector complex (see Fig.3) built in 1982 will also be used as an injector for SESAME [4].

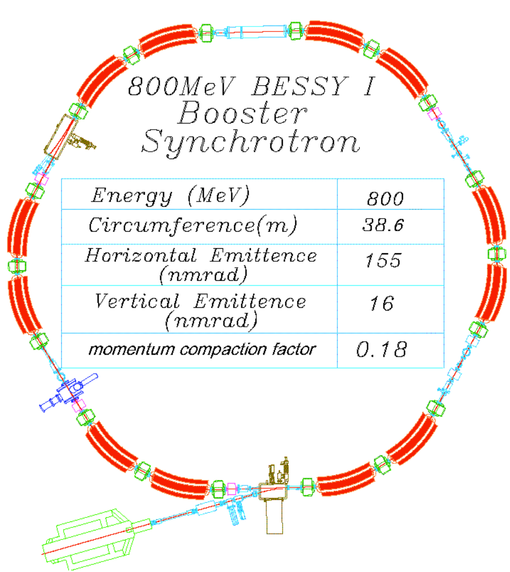

Figure 3: Layout of the injector complex of BESSY I

ANKA Project

ANKA [5] is a 2.5 GeV synchrotron light source which was built from 1996 to 2001. For the injector the same philosophy was chosen as for BESSY I.

The injector complex (53 MeV racetrack microtron and 500 MeV Booster Synchrotron) was built as a turn key system by Danfysik. The knowledge for building the Racetrack Microtron was provided by the experts from ASTRID. For the design and manufacturing Danfysik made a collaboration contract with the University of Aarhus (experts from Astrid [6]).

The commissioning of this injector complex was made by the experts from Astrid.

COSYLAB

In the same way as the different components have been bought from the companies also the control system was outsourced. It was built by Mark Plesko and his group from the Josef Stephan Institute in Slovenia. This was the first control system based on Ethernet Technologies and it was the start of the company COSYLAB, which provides now control systems and software for a lot of accelerator laboratories.

INSTRUMENTATION TECHNOLOGIES

Rok Ursic, an electronics expert, started his career at ELETTRA where he worked in the Diagnostics group. From ELETTRA he went to the Jefferson Lab and later to the Swiss Light Source. After that he founded the company Instruments Technology and built the LIBERA digital electronics for reading out the BPM very precisely.

This system is now used in most of the modern light sources for the determination of the beam position and other measurements. It has the turn by turn capability and can be used for the global feedback system. At present Instrumentation Technologies is providing also a digital version for the RF - low level electronics.

ALBA-Project

The ALBA project [6] (Fig.4) was built in the same way as other synchrotron light sources like SLS, DIAMOND, SOLEIL, etc. The components have been designed in house and manufactured by industry according to the different steps described above.

For the accelerator complex of ALBA around 50 contracts have been made with industry (10 for magnets, 5 for power supplies, 13 for vacuum components, 11 for the RF – system, 3 for diagnostics, 4 for insertion devices and 1 for the front ends). All the components reached the specifications, but there was considerable delay in the delivery of the components. Eleven contracts had a delay from 6 to 18 months. The longest delay was due to the reorganization of a company as this changed ownership.

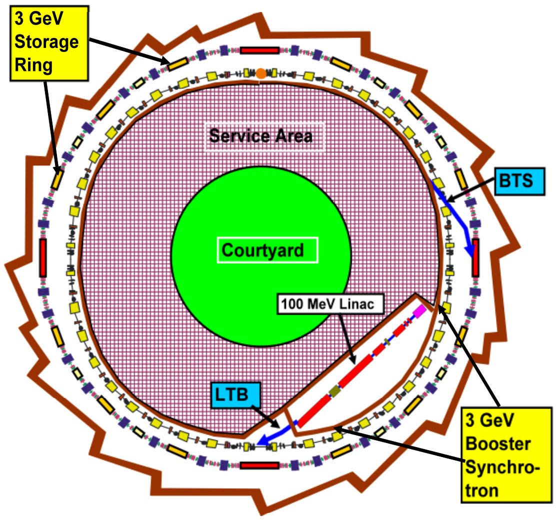

Figure 4: The accelerator complex of ALBA with a 100 MeV linac, a 3GeV booster synchrotron and a 3 GeV storage ring

LHC-MAGNETS

The main part of the LHC storage ring are the superconducting magnets (1232 main dipoles and 392 main quadrupoles) [7]. 20 of the rings circumference 27 km are covered with these magnets. An artistic view of the dipole in its cryostat is given in Fig.5.

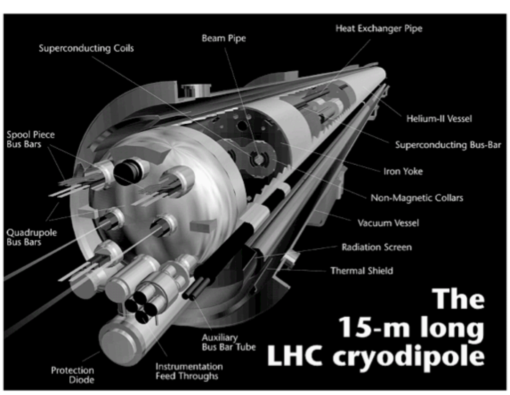

Figure 5: Artistic view of the LHC super conducting dipole in its cryostat

During the ceremony to celebrate the delivery of the last superconducting dipole (see Fig.6) the Head of the MCS group, Lucio Rossi, mentioned: “The production of the LHC superconducting magnets is a fine example of collaboration between research laboratories and industry. We learned a great deal from this cooperation process and our industrial partners are now reaping the benefits of these specially developed techniques”

For the collaboration with industry for the production of the superconducting magnets the following points should be mentioned [8]

Figure 6: Some of the members of the MCS group of CERN celebrating the delivery of the last main dipole.

Technical Specifications: For all main procurements the technical specifications were written by CERN. This was done after an intensive phase of R&D, in most cases carried out together with industrial partners or with intermediate contracts passed to industry. In this aspect, the capabilities of industry were duly taken into account. In certain cases, like the manufacture of the main superconducting dipoles, this passed through a number of technology transfer from CERN to industry.

Prototyping: For all critical components prototypes were built. Prototypes were done at CERN and at industry. For example for the main superconducting dipoles more than 50 short models (1-m long magnets) were made at CERN, several long prototypes in industry, and the initial assembly of long components produced in industry was made at CERN to validate certain assembly procedures (in particular the welding of the helium shells). Concerning tests, in certain cases tests were done in industry, and thereafter repeated at CERN, but in the most complicated cases (like for the main superconducting dipoles) they were done only at CERN. During the prototyping phase CERN had identified all manufacturing and tooling procedures. For the series production CERN has imposed most of procedures and tooling, accepting variants where acceptable. CERN has provided most of components, and in certain cases also the tooling. For example for the superconducting magnets CERN has procured the cable, the insulation, the steel, the helium shells and all critical parts. Concerning acceptance, the technical specifications were written after a consolidated experience on models and prototyping. The deviations to the technical specifications for acceptance were marginal.

Series Production: CERN had a very strict control on the production, by staff regularly visiting the companies, and by permanent inspectors.

The main magnets were not completely made in industry. Industry made the “core” of the magnet, the so called “cold mass”. Thereafter at CERN the cold masses were integrated into the cryostats, aligned, externally connected electrically, up to the installation in the accelerator with an impressive challenge of logistics.

COLLABORATION RF-SYSTEMS AT CERN

Concerning the collaboration with industry for building cavities and RF-systems the following points should be mentioned [9]

Copper system: All accelerating cavities were developed by CERN, including all accessories. Series production was then done in industry. Industry acted purely as subcontractor according to specifications, without responsibility for the functionality or any system responsibility. The integration (assembly of cavities), adjustments and power conditioning was entirely done at CERN. One firm supplied later complete cavity systems to other accelerator projects.

Superconducting system: After extensive development at CERN the cavities were built by three firms. The know-how of sputtering Nb on the Cu substrate was successfully transferred to industry. The firms had to guarantee the performance of the cavities in terms of accelerating field/Q factor.

RF power plant: Contrary to SLAC, CERN had its own klystron production, LEP klystrons were developed by industry according to CERN specifications.

Low level RF system: All electronics systems were developed and integrated by CERN; series production was done in industry. It is very important, to fully master the complete system. This proved to be very precious for later repairs, improvements and upgrades

LEP injector linac: Accelerating structures were developed by CERN and manufactured by industry. Also the RF transmitters were built by CERN, with klystrons from industry. Modulators for the klystrons did not exist in industry, therefore they needed to be developed and built by CERN. The situation now has changed; one can buy a complete linac from industry including the RF power plant.

The RF system for LHC: It followed essentially the LEP model.

Klystrons: were developed by industry.

Collaboration with industry: In general it was good. It is important not to rely on only one supplier. Example: One klystron manufacturer decided to give up high power klystrons (VALVO). Fortunately we had others.

CONCLUSIONS

1) In general the relationship between industry and the laboratories is pretty good. Industry wants that you are satisfied with the final product.
2) Industry is capable to build all the accelerator components.
3) Industry is capable to build systems (injectors) for an accelerator complex.
4) For medical applications industry can build turn key synchrotrons.
5) Have also in mind that industry has to earn some money. They have to pay the salaries for their employees and they have to survive.
6) The companies want to have the contract and therefore the promise you a lot of things, sometimes to much. Therefore:
    a.) Write the "Technical Specifications" for the CFT very careful because it as an appendix a part of the contract. Do not write anything that you do not understand. Take care for the tolerances, use only tolerances which are achievable by industry.
    b.) The companies do not provide all the required answer to your specs, there is a need to clarify everything in the negotiation about technical issues. Any unclear point has to be clarified before signing the contract.
7) Following up the production of the prototype and the series very careful.
8) Take care for the time schedule, (the life is sometimes very complicated).

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REFERENCES

[1] E. Courant, M.S. Livingston, H. Snyder: Phys. Rev. 88, 1190 (1952)
[2] Ralph Burmeister, Die vier Leben einer Maschine, Wallstein Verlag Goettingen, 2010.
[3] D.Einfeld and G.Muehlhaupt, Nucl. Instr. Meth. 172 (1980)
[4] Amor Nadji, these proceedings, WEOARA02
[5] ANKA, these proceedings, http//ankaweb.fzk.de
[6] Astrid, these proceedings, www.isa.au.dk
[7] ALBA, these proceedings WEPEA054,www.cells.es
[8] Lucio Rossi, IEEE Transactions on Applied Superconductivity, Vol.13, No.2, June 2003
[9] Lucio Rossi, CERN BUL-NA-2006-171
[10] Private communication, Davide Tomassini, CERN
[11] Private communication, Guenther Geschonke, CERN