Review Paper

Summary of Accelerator Technology Sessions

A.J. Kreiner[abc*]

[a] Departamento de Física, Comisión Nacional de Energía Atómica, Av. Gral Paz 1499, 1650, San Martín, Buenos Aires, Argentina.

[b] Escuela de Ciencia y Tecnología. Universidad Nacional de Gral. San Martín

[c] CONICET

Abstract. This summary talk on accelerator technology (AT) gives an overview of the work presented during AccApp09 on ongoing developments and as such is a sample of present day activity in this field. It also highlights some of the more advanced developments.

1. Introduction

In this summary talk we try to capture most of the work presented at AccApp09 on accelerator technology, AT, (mainly machine or whole system development), with less emphasis on ancillary equipment and no discussion on applications, that, while being essential, are covered in other summary talks (but without omitting mentioning them). Likewise, no electron machines are discussed (only hadronic-probe generating accelerators are considered) because they are covered in specific sessions (Refer to SM/EB sessions). We have used as a classification parameter the energy of the accelerated particles.

2. Statistics

Four specific sessions on ion accelerator technology were organized. In parenthesis we indicate the actual number of talks (and the number of those related more closely with machine development): Monday: AT/INT (Introductory Lecture)-01..05 (actual talks: 5 (3)). Wednesday: AT/OC (Operation, Instrumentation, Control)-01..05 (4(1)). Wednesday: AT/RD (R&D)-01..05 (4(1)). Friday: AT/RD (R&D) (5(3)).Total number of contributions: 18(8). Others (in other sessions including posters): 15. Grand total: 33(23).

The countries engaged in development of ion accelerator technology (contributing to this meeting) were: Argentina, Belgium, China, France, Germany, Italy, India, Japan, Korea, Russian Federation, Switzerland, Ukraine, United States. China and India have some tradition and new active programs,

[*] Email: kreiner@tandar.cnea.gov.ar

while Argentina and Korea are relative newcomers. The other countries are well established main players.

3. Results

We shall organize the material according to increasing energy regimes and related machine types. In the lower energy regime (0 to few MeV's) one finds many examples of electrostatic technology, while of necessity for higher energies into the GeV range RF machines take over.

3.1. Electrostatic devices and accelerators

The lowest energy interval covers the 0-80 keV range and the first type of devices are ion sources:

- H^- intense (400 mA/cm^2) non-cesiated volume-plasma ion source with magnetron geometry (Baturin et al., AT/P5-05).
- High intensity ECR source (50 keV and 50 mA) (Roychowdhury, AT/P5-17).
- High brightness source (multicusp RF-driven, 130mA/ cm^2) (Storizhko et al., AT/P5-19).

The second energy interval spans 80-150 keV (kV) and covers mainly neutron generators (d-d, d-t). This is a well established field with traditional vendors (France, USA,..) and conventional sealed tube technology. In this meeting we saw some innovation: 1. NSD-Fusion (Sved et al., SM/EN-18): this device has no solid target, reactions take place in a gas-plasma and total production rates of 10^{10} n/s can be achieved. 2. Adelphi (Fuller et al., AP/IE01): open tube set-up using d-d and yields up to 10^{10} n/s.

150- 500 keV (kV): This is the realm of smaller deuteron electrostatic accelerators (Cockcroft-Walton type) for neutron production in ADS systems (TiT targets), e.g.:

- The GENEPI-3C Accelerator for the GUINEVERE Project utilizes an electrostatic generator to produce an intense deuteron beam of 240 keV (peak current 40 mA) to produce 14 MeV neutrons through the T(d,n) reaction and to drive a solid Pb subcritical assembly.(see Baylac et al., ADS/ET-01).
- YALINA Booster program uses a deuteron accelerator (100-250 keV), 12 mA on a Ti-D/T target with max. flux of $2x10^{12}$ n/s (see YALINA collaboration, ADS/ET-02,-04 to 07).
- ADS Program in India. Also here a D-T neutron generator is used(see Nema ADS/INT-03).
- Subcriticality facility at Kyoto. A Cockroft-Walton accelerator has been used to produce pulsed 14MeV neutrons for subcriticality studies (Pyeon et al., ADS/ET-03).

0.5-25 MeV protons and heavier ions(voltages up to approx. 10 MV), Tandems:

- Electrostatic accelerators at IPPE. Tandem accelerators have been developed to produce beams of multiply charged ions in the 6-25 MeV energy range (Gulevich et al., AP/AM-09).

- Development of high power Tandem-ESQ (Electrostatic Quadrupoles). A folded Tandem with a chain of electrostatic quadrupoles to produce a 30 mA, 2.5 MeV proton beam for BNCT and other applications (Kreiner et al., AT/OC-01).

3.2. RF machines

1-5 MeV: RFQ's, cavities:

- The 600 MeV EUROTRANS Proton Driver Linac (Podloch et al, AT/INT-03): In the first demonstrator R&D stage this project envisages a 600MeV, 1.5MW, proton accelerator including a state of the art 4-vane RFQ as injector and CH (cross bar) room temperature cavities taking the beam to 5 MeV. In the final industrial scale stage the project foresees an 800 MeV beam of several 100 MW.
- China High-Intensity Accelerator Technology Developments (Wei et al., AT/INT-04). Here also a 4-vane structure has been chosen and a 49 mA, 3.5 MeV proton beam has already been produced.
- Recent High Power RFQ Development (Bechthold et al., AT/RD-01). A 4-rod RFQ structure has been developed intended as an injector for high power linacs to produce high current ion beams (several mA's) at CW operation. The 4-rod structure has proven its ability to withstand a thermal load of 47.5 kW/m, which opens up a new field of high power applications.
- Proton LINAC for the Frankfurt Neutron Source FRANZ (Meusel et al., AT/RD-07). This facility makes use of the RFQ mentioned in the previous paragraph. It couples this RFQ to an IH-DTL structure to obtain a 2 MeV, 150 mA beam compressed to 1 ns pulses with a repetition rate of 250 kHz

5 MeV to GeV energies: LINACS (e.g., DTL,s, Superconducting technology), Cyclotrons, Synchrotrons.

- The 600 MeV EUROTRANS Proton Driver Linac (Podloch et al, AT/INT-03). The low energy part of this project was mentioned above and it is completed by four superconducting (sc) CH cavities taking the beam energy to 17 MeV at 352 MHz. The intermediate energy section (17-100 MeV) consists of independently phased sc spoke cavities. It is followed by a high energy section with two groups of sc elliptical 5-cell cavities (at 704 MHz). The required operation is cw which prefers sc cavity technology.
- China High-Intensity Accelerator Development (Wei et al., AT/INT-04). After the RFQ mentioned in the previous section the project foresees that the proton beam is accelerated to 80 MeV by a DTL, subsequently by other LINAC's and finally taken up to 1.6 GeV by a rapid cycling synchrotron. The final goal is a spallation neutron source with a beam power of 0.5 MW.
- Multipurpose Accelerator-Accumulator ITEP-TWAC for Nuclear Physics and Practical Applications (Alexeev et al., AT/INT-02). It consists of proton (25 MeV LINAC) and ion injectors, a booster synchrotron and an accelerator-accumulator.
- Performance of the PSI High Power Accelerator (Seidel et al, AT/RD-10). PSI operates a 590 MeV proton accelerator, it drives a neutron spallation source and delivers a beam power of up to 1.3 MW. The major component in the accelerator chain is a ring cyclotron upgraded with new and more powerful accelerating resonators. In this talk an interesting topic was mentioned, namely a discussion on the pros and cons of cyclotrons versus LINAC's in terms of cost, performance, reliability, etc. This discussion is very relevant in view of future ADS systems.

- R&D Program on ADS in JAE (Takei et al., ADS/INT-04). The framework is R&D on accelerator driven subcritical for transmutation of long-lived radioactive nuclides. The accelerator technology being proposed and tested is a sc LINAC able to deliver a 30 MW proton beam.
- New accelerator projects at JINR-Dubna (Shirkov et al.). One of the main goals is heavy ion physics at 5 GeV/n and higher. Core facility is the Nuclotron, a sc Synchrotron, for future NICA facility (Nuclotron-based Ion Collider) and two sc collider rings.
- The Proton Engineering Frontier Project (Kim et al,AP/IA-08). It was launched in 2002 to establish an advanced research facility based on a high power 100 MeV, 20 mA proton Drift Tube LINAC. The facility has been already developed up to the 20 MeV DTL and is schedules to be completed by 2012.
- ARRONAX, a70 MeV Cyclotron (Martino et al., AP/IA-11). This project aims at a more powerful system (70 MeV and 750 microA, also deuterons and alpha particles) for radiochemistry and nuclear medicine.
- R. Lanza mentioned during his presentation (SM/EN-08) promising developments in the field of very compact sc cyclotrons which could have an impact on different fields.

4. Discussion, conclusions and final remarks.

State of the art technology was presented in several of the sectors of accelerator activity. Particularly striking was the development of RFQ's and LINAC's of different kinds. The impressive performance of the PSI cyclotron based accelerator complex calls attention to the question of the more appropriate accelerator for ADS systems (i.e., cyclotron vs LINAC). In particular the development of very compact sc cyclotrons could be a promising avenue to pursue in order to lower costs for different applications including ADS's.

This meeting proves that there is a significant activity in accelerator development due to the highly relevant applications in such fields as:

(1) ADS programs for nuclear waste transmutation and power generation.
(2) Medicine: Proton and hadrontherapy (including BNCT), Isotope production.
(3) Accelerator-based neutron sources for: cargo inspection, neutron diffraction (materials research), nuclear physics (astrophysics, structure,..), etc.
(4) Accelerators for a wealth of applications: implantation, ion beam analysis, damage simulation, environmental problems, nuclear physics, education and training, etc.

Accelerator technology is gaining its place as a mature technology in the nuclear sector and is likely to play an equivalent role to the one nuclear reactor technology has had traditionally. The role of IAEA as a promoter of information exchange, technical discussions and developments, as testified by this meeting, remains very important.