CLOSING PLENARY SUMMARY OF WORKING GROUP E: HIGH-INTENSITY LINACS & RINGS: NEW FACILITIES AND CONCEPTS

F. Gerigk*, CERN, Geneva, Switzerland
P.N. Ostroumov#, ANL, Argonne, IL 60439, U.S.A

Abstract

The International Program Committee of the Workshop and its Chairman have charged us with the following three questions:

- Recent trends in high-intensity proton/ion beam facilities?
- Critical challenges and key research areas for substantial beam power increases?
- Necessary improvements in theory and simulation tools?

Introduction

The program of session E included 16 reports from 12 facilities worldwide. We have divided these facilities to three main categories as is given in Table 1:

I. Existing facilities/funded projects
II. Future projects, R&D
III. Overview & outlook.

Table 1. Three categories of submitted reports: (I) Existing facilities/funded projects, (II) Future projects, (III) Overviews.

Cat.	ID	Facility	Authors	Institution	Application
I	I.1	**RIKEN upgrade**	Hiroki Okuno	RIKEN	Nuclear physics, RIB
	I.2	**SARAF commissioning**	Jacob Rodnizki	SOREQ	Nuclear physics
	I.3	**PEFP status & outlook**	Ji-Ho Jang	KAERI	Material science, transmutation, spallation
	I.4	**FAIR SIS 100 design**	Peter Spiller	GSI	Nuclear physics
	I.5	**HINS R&D**	Giorgio Appollinari, Bob Wagner	FNAL	Neutrino, proton driver
II	II.1	**Project X**	Valerie Lebedev Charles Ankenbrandt	FNAL	Neutrino, proton driver, ILC test facility
	II.2	**LHC-upgrade, SPL/PS2**	Frank Gerigk, Yannis Papaphillippou	CERN	LHC injector upgrade, Neutrino/RIB proton driver
	II.3	**ISIS upgrade**	John Thomason	RAL	Neutron/Neutrino proton driver
	II.4	**ESS**	Ibon Bustinduy	ESS-B	Neutrons
	II.5	**eRHIC/ELIC**	Yuhong Zhang, Vadim Ptitsyn	JLab, BNL	Nuclear physics
	II.6	**Compact Deuteron Linac**	Larry Rybarcyk	LANL	Homeland security (neutrons)
III	III.1	**Scaling & non-scaling FFAGs**	Akiro Sato	Osaka University	R&D, medical, material science, muon, neutrino proton drivers....

Each facility in Table 1 has a list of R&D and remaining key issues that are being pursued by research and operation groups. Following the numeration of facilities in Table 1 we provide a list of main technical challenges and R&D tasks in each Lab. This list may be different from the topics mentioned the presentations, since some of the topics were added during the discussions.

I.1. RIKEN upgrade:

Increase of the beam intensity from the ion front-end. This entails:

- Development of a new 28 GHz Superconducting ECR ion source with the goal intensity of U35+ >15 pμA. Operational tests will start in January 2009 with the goal to improve transmission efficiency from the source to the cyclotrons,
- Test of flattop acceleration in the cyclotrons.

* frank.gerigk@cern.ch
#ostroumov@anl.gov

- Develop a new injector capable of efficient acceleration in the low energy region: avoid emittance growth due to space charge.
- Develop and use charge strippers with long lifetimes.

I.2. SARAF commissioning.

Technical issues are:

- CW operation of the RFQ.
- Cryogenic losses in SC cavities.
- Optimization of the facility parameters to minimize beam losses.
- Beam diagnostics in SC linac environment.

I.3. PEFP status & outlook.

A 700 MHz, 1 MW (CW) klystron prototype was successfully developed. The 4 DTL tanks of the 100 MeV linac are designed to be fed from a single klystron. The linac up to 20 MeV has already been constructed and is now being tested at low duty cycle at the KAERI site. When the new site is ready it will be moved and extended to 100 MeV. The ongoing R&D focuses on the following areas:

- Superconducting RF Linac from 100 to 200 MeV.
- Rapid Cycling Synchrotron for a facility upgrade.
- High Power RF Source – 704 MHz CW 1 MW Klystron.

I.4. FAIR SIS 100 design.

Successful operation of the SIS100 requires understanding and control of dynamic vacuum. The Dynamic Vacuum simulation code STRAHLSIM has been developed and includes linear beam optics and ion stimulated desorption. Further R&D work focuses on the SIS100 Fast Ramped S.C. Magnets:

- AC loss reduction to 13 W/m @ 2T, 4 T/s, 1 Hz.
- Improvement of DC/AC-field quality.
- Guarantee of long term mechanical stability.

In addition, SIS100 RF System requires prototyping.

I.5. HINS R&D

A very innovative 60 MeV linac, which is designed as the front-end of a High Intensity Neutrino Source. Its main challenges are:

- Feeding of multiple cavities from a single klystron: 1st tests of vector modulators successful.
- SC solenoid focusing/spoke cavities from 10 MeV onwards.

The first results of SC spoke cavity tests already exceeded the design gradient of 10 MV/m (up to 13.5 were reached). However, the tests suffered from a helium leak, which is under repair now. The encountered multipacting at around 10 MV/m is expected to vanish with further conditioning. Main R&D effort in SC SRF is to optimize the parameters of the chemical processing.

II.1. Project X

There seem to be no principle physics or technical limitations for the future machine operation. The main challenges are seen in the following areas:

- Multipacting of electrons and related to it ep-instability are the major concern
- Keeping machine operating reliably at full power of 2.3 MW will be a challenging problem
- Machine protection and minimization of beam losses are major tasks for design work

Project X is considered as a first step towards the muon collider at FNAL. However, to satisfy muon collider specifications, the design of the 8-GeV SC Linac should have sufficient flexibility for future upgrades to 2-3 MW or even 10 MW beams.

II.2. LHC-upgrade, SPL/PS2

CERN presented a frequency review for the Superconducting Proton Linac (SPL), which aims to accelerate H- up to 4/5 GeV for LHC upgrades/high power proton users at CERN. The frequency of 700 MHz was confirmed and a temperature of 2 K is considered mandatory for high duty cycle operation. For PS2 there is a preference for transition-less lattices. The main challenges are:

- understanding of collective effects (ecloud, etc),
- realistic beam dynamics simulations with high space charge,

II.3. ISIS upgrade.

In a first stage the idea is to complement ISIS by 2nd RCS raising the beam energy to 3 GeV. In the 2nd stage the existing 800 MeV ISIS RCS will be replaced by full energy injector linac. In the final stage the beam power should reach between 2 and 5 MW. A R&D program is established to:

- Minimize beam losses (understand halo, injection painting…), study of the beam collimation system,
- Study of the longitudinal beam stability for strong tune depression (0.4),
- 3D simulations with space charge,
- Instabilities (EP),
- Detailed linac design (CCL/spokes, frequencies…),
- Hardware design.

II.4. ESS.

A superconducting proton linac is being developed for European Spallation Source in Bilbao (Spain). Current studies include:

- Revision of the last “official” linac design (2003), the linac length is reduced by 45%.
- Now only long-pulse operation at 16.6 Hz.
- Front-end test stand under construction.

II.5. eRHIC/ELIC.

The following R&D issues and technical challenges are being considered by JLAB and BNL:

- Innovative Lattice design (ELIC).
- Very high current ERL (eRHIC).
    - Energy recovery technology for high power beams.
- Electron cooling of high energy ions (250 GeV/u).
    - Proof of principle of the coherent electron cooling.
- Crab crossing and crab cavity.
- Forming and stability of intense ion beams.
- Improve simulations of beam-beam effects:
    - electron pinch effect;
    - the kink instability; and
    - e-beam disruption.
- High intensity polarized electron source.
- Polarized 3He acceleration.
- Site-specific issues: increase number of bunches in RHIC, compact magnet design.

II.6. Compact Deuteron Linac.

A compact duetron linac is being developed using normal conducting IH-type cavities taking advantage of high shunt impedance of IH structures at low energies (here up to 4 MeV). The proposal is to use PMQs for transverse focusing. This allows using regular FODO type focusing and avoids losses in shunt impedance by using bulky EMQs. Some of the challenges are:

- Low-loss operation with high currents (50 mA).
- Deuterons produce neutrons already at very low energy and beam loss must be kept at minimum to avoid radiation damage of PMQs.
- Aperture must be kept small to maintain high shunt impedance and small sized PMQs.

III.1. Scaling & non-scaling FFAGs.

After recent years of aggressive development of FFAGs (almost exclusively in Japan), the new challenges became obvious to achieve higher beam intensities:

- Increase extraction efficiency (so far 90% have been achieved with a 150 MeV proton FFAG in Japan).
- Demonstrate non-scaling FFAGs.
- Develop high-gradient MA cavities for proton & ion acceleration.
- Test various schemes like:
    - Harmonic number jump (pulsed, CW)
    - Magnetic induction acceleration for low beta
    - Gutter acceleration
    - Isochronous FFAG (constant RF frequency).

CONCLUSION

We had very productive discussions of modern trends in development of facilities based on high-intensity, high-power proton and ion accelerators. Summarizing prominent R&D issues related to all facilities we can point out to the following topics:

- Low-loss operation (codes, collimation).
- Simulation of beam-beam effects.
- Code-benchmarking (linacs/rings).
- Modeling of dynamic vacuum behavior.
- Low-beta SC cavities (spoke, quarter-wave, elliptical).
- RF fan-out to multiple cavities.
- Electron cooling of high-energy ions.
- FFAG: extraction & non-scaling machines.