ISIS Upgrades as a Driver for High Power Proton Applications

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August 22, 2020

The aim of this note is to indicate the interest of the ISIS Accelerator Division in future initiatives in neutrino research. ISIS at the UK's Rutherford Appleton Laboratory has been a world leading neutron and muon facility for over 35 years [1]. Although not in the megawatt class needed for the proton accelerators in a muon collider or neutrino factory, ISIS nevertheless embodies many of the features demanded from higher power machines. Its design, construction and operation have had a strong influence on the development of J-PARC [2], SNS [3] and CSNS [4] and there is a wealth of experience in the control of high intensity beams in the UK. An increasing awareness of a shortfall in the provision of neutrons in Europe after 2030 - even with the advent of ESS [5] - is currently driving research into a future, short pulse neutron and muon source to meet users' needs [6]. Referred to as ISIS-II, the project aims for a versatile, megawatt-level pulsed proton accelerator that can feed one or more spallation targets. Several different designs are being investigated from conventional ideologies to innovative ideas that appear promising but would require considerable R&D. While intended primarily for neutron and muon production, the machine could well serve as the basis for any future driver for a neutrino facility. ISIS-II is expected to be an evolution of the existing ISIS facility so as to continue its status as a world leading source over the mid to long-term future. The design work explores a range of operational scenarios: a full energy linac with accumulator ring, a lower energy linac feeding a rapid cycling synchrotron, and, more recently, a linac with a fixed field alternating gradient ring (FFA). Rings are being designed to fit into the existing ISIS tunnel (26 m radius) and green-field, stand-alone options are also being considered.

The more conventional ideas include a 1.25 MW RCS with H^- charge exchange injection taking a beam from 0.4 GeV to 1.2 GeV at a repetition rate of 50 Hz [7]. The beam can be split so as to feed two targets operating at 40 pps and 10 pps. Emphasis will be on aspects such as minimising beam loss, optimising and understanding methods of injection painting, reducing aperture and understanding beam control and instabilities. Whilst designs are based on established technologies, existing limits of technological capabilities could be stretched where there is likely to be significant gain. An interesting alternative is to use direct proton injection via a tilted electrostatic septum, which avoids many of the issues of an H^- linac and difficulties with charge exchange injection [8]; the viability of this method will be tested at the HIAF heavy ion facility under construction at Huizhou, China [9].

Ideas involving FFA accelerators show considerable promise and have the potential for a flexible solution meeting a wide range of neutron and muon users' requirements. Since the first proton FFAs were built at KEK at the start of the millennium, great strides have been made in developing technologies and understanding beam dynamics in such machines [10]. An FFA proton driver has several advantages over a more traditional approach. There is no ramping of magnets so that stable dc power supplies can be used. The driver repetition rate is restricted only by the rf programme, allowing for increased beam power either to a single target or split onto two or more targets at different supply rates. Because of their large momentum acceptance, beam can be stacked in the ring with particles circulating at both injection and extraction energies at the same time. The combined possibility of variable pulse durations, variable intensity and variable repetition rate makes this an attractive option for the neutron users' community. Superconducting or permanent magnets may be within scope, leading to high efficiency, high availability and low operational costs.

However, an FFA proton driver would require a considerable amount of R&D. Proposals are being formulated for a prototype FFA test ring to be built at the ISIS injector test facility. This would have a radius of about 4 m and be used to study linear and nonlinear optics, ring injection, acceleration and extraction, explore techniques such as the beam stacking mentioned above, develop diagnostics and gain experience in designing and building prototype FFA magnets [11]. The FFA could have either an horizontal orbit excursion or the beam could move vertically as it accelerates. There may be advantages in the latter through requiring a smaller footprint in the tunnel.

The study of such a range of options for ISIS-II adds to the already considerable expertise at RAL in the design and operation of high intensity proton machines. Members of the ISIS-II design team held prominent roles in the ESS studies (1994-2002) and in the International Design Study for a Neutrino Factory (1999-2011). Such knowledge and experience should be of value to future initiatives for an accelerator-based neutrino facility.

References

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[6] https://ec.europa.eu/research/infrastructures/pdf/esfri/publications/esfri_neutron_landscape_group-report.pdf, particularly Figure 12.

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