Date: May 22, 2009

To: Rod Gerig, Deputy Director, Accelerators

From: Robert L Kustom

Subject: Comments on the choice of an FFAG as a driver for a neutron spallation source proposal in the 1980s

In the late 1970s and early 1980s, we were interested in developing a spallation neutron source that could provide a significant jump in scientific capability over existing facilities, including the ILL reactor in Grenoble, France. Jack Carpenter and I had a number of discussions on what target, modulator and shielding parameters were possible since they directly affected the kind of accelerator that would best meet the facility goals. Jack felt strongly that the maximum proton beam energy had to be around 1.5 to 2.0 GeV. I felt that a synchrotron for that energy would be an enormous challenge considering the size of the cyclo-convertors, low coupling-Z vacuum chamber design, RF cavity requirements, and overall beam loss requirements. It occurred to me that this would be a good application for an FFAG. The magnetic field is constant and as the energy increases the orbit grows larger. Unlike a cyclotron, the orbits in an FFAG aren't separated turn-by-turn and the frequency ramps from injection to extraction.

MURA pioneered the FFAG up in Stoughton, WI, but it was deemed too complicated and cumbersome for a high energy accelerator. Their problem was that the injection energy was low, ~50 MeV, and the extraction energy was up around 10 GeV. Because of the large momentum change, the magnets were large spiraling blocks of metal that took up most of the orbit and with narrow spiraling straight sections that made RF systems, diagnostics, and vacuum systems complicated. But for a spallation neutron source driver, the extraction energy is low by comparison to what MURA was trying to achieve, and the injection energy could be ~ 200 Mev, so the momentum change would be relatively small. The radial extent of the magnets would only be about 1-1.5 meters with an orbital radius between 17 and 19 meters. Only ~40% of the circumference would have been required for magnets, and there would have been substantial radial gaps between them for RF etc. I felt the main FFAG magnets were well within reason, considerably smaller in fact than the ZGS magnets, and had no more complicated field requirements than the TRIUMPF and SINQ cyclotron magnets.

I felt there were big advantages offered by an FFAG for a spallation neutron source; The DC-magnetic fields eliminated all the inherent problems of synchrotron magnets, like the huge voltages and powers needed to ramp the magnets up and down, the need to develop a low-beam-Z vacuum chamber in the presence of rapidly time varying magnetic fields, and eddy current effects in the vacuum chamber wall and iron. The energy ramp is determined by the RF frequency and bunch stability in an FFAG, which allowed the RF cavities to be more effectively used because the energy ramp could be made nearly linear as opposed to sinusoidal, and there's no reset time for the magnetic field returning to the injection value. I could envision operating an FFAG at ~200 Hz repetition rate. You

could tailor injection time and energy gain to achieve high efficiency capture since you wouldn’t be tied to a resonantly ramping magnet system.

I felt the FFAG had enough going for it to be a really good source, but there were two problems; First, the neutron scattering community was intensely divided between pulsed spallation sources and reactor sources, with a significant fraction of the community wanting an upgraded ILL reactor. And, second, the accelerator community was unsure of the FFAG since only a small electron model was ever built. They also were fixated on separated function synchrotrons and storage rings for which there was a lot of experience and analytical understanding. Too bad, because I still think the FFAG has some attractive features if you’re going to stay at that energy level.