Whitepaper on Cyclotrons as Drivers for Precision Neutrino Experiments

The DAEδALUS Collaboration, January 26, 2013

This whitepaper discusses the potential of cyclotron-based decay-at-rest (DAR) neutrino sources for precision studies and high-sensitivity searches. The project began with development of a CP-violation search (DAEδALUS)[21, 3]; as the phased plan evolved, another opportunity was discovered, IsoDAR [2, 4]. Since then, wider interest in these neutrino sources has been expressed by the cross-section [5, 6, 7, 8] and exotic physics search communities [9, 10, 12, 13, 14, 15]. Therefore, we submit this paper addressing the technology as a generic opportunity, which could conceivably be implemented by coalitions of universities within the neutrino community. The relatively modest cost range (from \$25M to \$100M, depending on design) makes several centers potentially feasible.

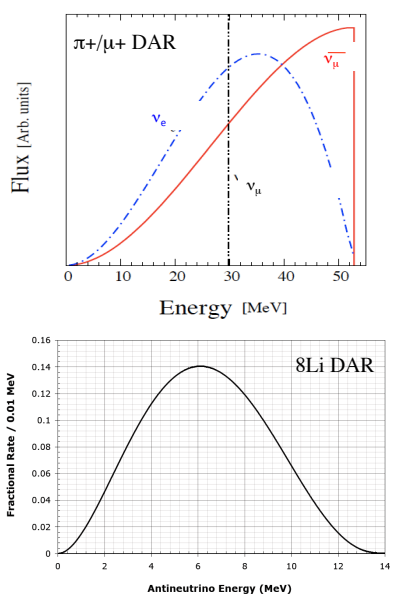

Figure 1: *Fluxes from π/μ and ^{8}Li decay at rest.*

As neutrino physics enters the precision era, π/μ-DAR and isotope-DAR beams (e.g., ^{8}Li), in which the energy dependence and the flavor content is precisely known (see Fig. 1), are valuable. In fact, there is already a history of cross-section physics from π/μ sources [16, 17, 18]. The primary issue for precision measurement with these beams is understanding the absolute normalization. Absolute rates are predicted to ∼20% [19]. However, depending on the detector and application, one can potentially normalize to inverse beta decay or to neutrino-electron scattering, both of which have cross sections known to $< 1\%$, greatly reducing normalization errors.

The sources can be designed to deliver ∼100 kW to 1 MW, depending on the flux required. If space is limited, such as at an underground lab, the optimal energy range for an ^{8}Li DAR driver is about 60 MeV [20]. A variety of detectors can be used for studies (see [5] to [15]). The optimal energy is $\sim$ 800 MeV for π/μ DAR[21]. The accelerators can also be reconfigured to provide charged particle beams (isotopes, pions, and muons), allowing versatility beyond neutrino physics.

While underground facilities and national labs are the most likely first users of these machines, this price range is within the scope of a consortium of local universities, and could lead to "local facilities" that would allow students access to accelerators while remaining at their home institution. There is industry interest, from production of radio-pharmaceuticals at low energies [22] to application as drivers for thorium reactors at high energies [23]. Examples are the partnerships with Best, Inc., AIMA, and IBA formed for tests of the ion source, low-energy beam transport, and axial injection system for the DAEδALUS project.

Accelerators for America's Future has stated: "The United States, which has traditionally led the development and application of accelerator technology, now lags behind other nations in many cases, and the gap is growing. To achieve the potential of particle accelerators to address national challenges will require sustained focus on developing transformative technological opportunities..." [24]. Cyclotrons are a clear example. Though invented in the US, now most cyclotron research and companies are located outside of the US. The major laboratories involved in this initative (INFN-Catania, PSI, and RIKEN) are outside the US. On the other hand, the universities involved in this program are largely US-based. This allows for technology transfer and ensures the next generation of cyclotron physicists in the US. Through this, the program serves a valuable national interest.

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