1 A reactor experiment at the Angra reactor in Brazil

This section will focus on a the features of the site at Angra dos Reis in Brazil. This site has many desirable attributes including good surrounding topography, a single powerful reactor, and good relations with the electrical and nuclear power companies. In addition, the local physics community has become very enthusiastic about this idea and is beginning the process of developing a realistic proposal.

1.1 The Reactor Site

Angra dos Reis is located about ?150km? south of Rio de Janeiro. The nuclear facility contains two operational reactors. The Angra-I reactor is an older low power (about 1.5 GW_{th}) reactor that is not frequently operated. The Angra-II reactor, on the other hand, was brought on-line in 2000 and is consistently operated at about 4.1 GW_{th}. The reactors are located on the coast and the reactor company controls a strip of land that stretches inland about 1-1.5km and is approximately 4 or 5 km along the coast. All experimental constructions which will be considered here would be sited within the reactor companies site boundaries.

Much of this terrain is mountainous granite with multiple peaks in the 200-600m region. This allows good background reduction to be achieved for an experimental hall with relatively cheap civil construction by tunneling sideways into such a mountain. Also within the site boundaries there exists a town, Praia Brava, which houses most of the 2 or 3 thousand people which work at the reactor facility and also contains a hotel and stores. Such already existing infrastructure could make using this facility more attractive.

1.2 Communication with the Power Companies

The company which runs Angra is state owned and operated. One of the unique features of attempting this experiment in Brazil is that the presidents of both the electric power company and it's daughter nuclear power company are former particle physicists who used to do experiments at CERN. As a result, they are very receptive to communications from members of the Brazilian physics community and have been very helpful in providing resources and access to the facility. A one day site visit has already been performed to evaluate the viability of performing the experiment there. Significant assistance was provided by the director of operations from the reactor facility and we spent significant time with the director of civil construction on the site. With their help, we were able to explore all the possible experimental site locations and arrive at a solution which was acceptable to both the reactor facility and the experimental needs. The reactor company has agreed to supply full detailed cost estimates of any civil construction plan that we provide by using their detailed knowledge of the site geology and known contractors.

1.3 The Experimental Design

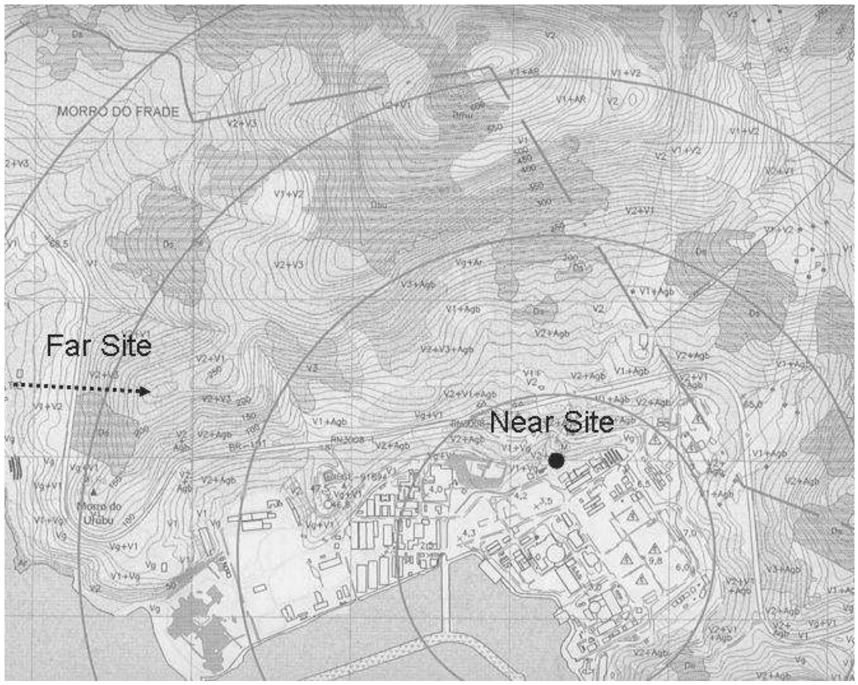

Figure 1: A topographic map of the nuclear reactor site at Angra dos Reis. The concentric circles are at 500 meter radial intervals from the core of Angra-II. Proposed locations for the near and far detector experimental halls as well as the far detector access tunnel are shown.

A topographic map of the site, as supplied by the reactor company, is shown in Fig. 1. The Concentric circles are at 500m radial intervals from the primary Angra-II reactor core. The near site location is 300-350m from the core. It has the possibility to gain about 15-20m of rock overburden (30-50 meters of water equivalent). The far site location would exist under a 240m hill at about 1350m from the reactor core. Access to the far site would come from a 420m tunnel which starts from the western edge of the hillside. This location is easily accessible from the town of Praia Brava and would be very near to the current location of their sewage treatment plant.

It is envisaged to place identical 50ton fiducial detectors at each location. Exact detector designs have not yet been developed, but it is currently assumed that such detectors would build off of the developments from other groups. Most likely a 3 volume detector would be optimal: a central liquid scintillator volume that would be doped with gadolinium (target); a surrounding volume of liquid scintillator without gadolinium (gamma catcher); a non-scintillating buffer to shield the radioactivity of the photo-tubes which would be installed at the outer edge of this volume. An active muon shield would then be required to surround this system. A spherical detector with an active target of 50 tons would have a total diameter of approximately 7.3 meters. The access tunnels and experimental halls have been designed to accommodate these dimensions.

1.4 Experimental Reach

Preliminary estimations have been performed of the signal and background rates for the given detector configuration. The detector at the far location is expected to get about 120 signal events per day, while the near site would be expected to receive about 3000. Some very preliminary background estimations suggest that the far detector would expect less than 10 Hz uncorrelated backgrounds which would easily be vetoed by an active muon shield and about 1-2 correlated background events per day from muon induced radioactive isotopes. Similarly the near detector would expect an uncorrelated background rate of about 830Hz (yielding an active live time of 63% after muon vetoing) and a correlated background of approximately 150 events per day. Having a signal to noise rate of about 100 in the far detector and 20 in the near detector should allow reasonable background rejection while maintaining statistical sensitivity. Fig. 2 shows the expected statistical sensitivity as a function of time, for the best fit value and 90% allowed limits of Δm^2 from Super-Kamiokande. As can be seen, a limit of $sin^2(2\theta_{13}) < 0.02$ at 90% confidence level can be achieved within 3 years. Also in Fig. 2 is shown the complete limit and 3σ discovery potential for a 3 year run over all $sin^2(2\theta_{13})$ and Δm^2.

1.5 Brazilian Community and Support

The Brazilian community has recently been having in-depth discussions about this possibility. There exists significant theoretical and phenomenological support for neutrino oscillation work in Brazil already, primarily located in the Universidade Estadual de Campinas (UNICAMP) and the Universidade do São Paulo. The director of the Centro Brasileiro de Pesquisas Fsicas (CBPF) in Rio de Janeiro has shown great enthusiasm for this project and has offered to make his institution the host of such an experiment. There exist strong experimental particle physics groups based mainly in Rio de Janeiro and São Paulo. They are already strongly involved with the Pierre Auger project as well as experiments based at Fermilab and CERN. They have expressed great interest in pursuing a project that is local to Brazil and several of the experimental members have already started working on producing a more realistic set of cost estimates and site plans.

While it's not possible to put any real faith behind the numbers, some preliminary estimates have concluded that with the cheaper labor costs in Brazil, the civil construction could probably be achieved for 5-7 million dollars (US). The local brazilian community is currently in consultation with the government to get a commitment to this project and for covering the complete costs of civil construction. For the detectors, a very conservative cost estimate concluded

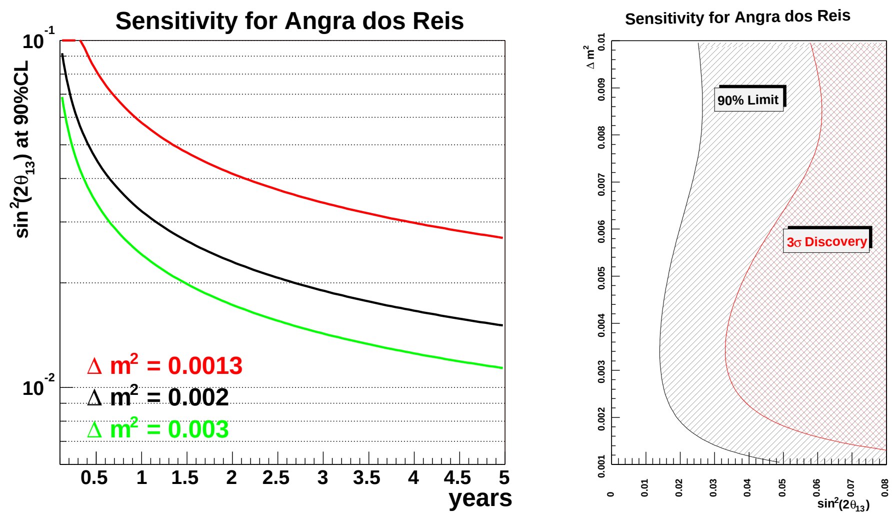

Figure 2: Expected sensitivity to $\sin^2(2\theta_{13})$ which could be achieved by an experiment at Angra dos Reis assuming a 1% systematic error. The plot on the left shows the sensitivity as a function of years of running for three different values of Δm^2. On the right, the full coverage of Δm^2 vs. $\sin^2(2\theta_{13})$ is shown assuming three years of data taking. Curves for both the limit at 90% confidence level and the discovery at 3 σ are shown. The current limit at 90% confidence is $\sin^2(2\theta_{13}) < 0.2$.

that they would require about 7 million dollars each. Thus the total project could probably be completed with an external contribution of less than 15 million dollars (US).