The Braidwood Neutrino Experiment

The Braidwood Collaboration

1 Overview of Project

The Braidwood Collaboration proposes to build a facility at the Braidwood Nuclear Power Station near Joliet, IL, to measure neutrinos from the reactor complex at two underground locations, 200 m and 1500 m from the reactor cores. The goal of the experiment is to make a precise measurement of the θ_{13} mixing angle, one of the most important parameters associated with the mass and mixing of neutrinos. This angle may hold the key to understanding the source of neutrino masses and is a crucial parameter for planning the future US neutrino program. The APS Neutrino study in the Summer of 2004 rated this measurement as high priority, and the recent HEPAP NuSAG panel listed a precision reactor measurement as one of the two next steps to be pursued.

The Braidwood collaboration is composed of 12 institutions (ANL, BNL, Chicago, Columbia, FNAL, Kansas State, Michigan, MIT, Oxford, Pittsburgh, Sussex, and UT Austin) and is led by Ed Blucher of The University of Chicago and Michael Shaevitz of Columbia University. The collaboration has been operating for over one and half years, and has grown into a very strong and capable group to mount this key experiment.

The experiment relies on comparing the neutrino rate and energy spectrum at near and far locations and to determine if some of the anti-electron neutrinos have disappeared before reaching the far detector. The detectors (two at the near site and two at the far site) will be placed 180m underground to reduce backgrounds. Each detector will be composed of a 7m diameter spherical tank filled with liquid scintillator viewed by 1000 photomultipliers. The detectors are designed to detector the neutrino interactions with high efficiency and to reduce backgrounds to very low levels. Each spherical detector is shielded by $\sim 1m$ of heavy concrete that is surrounded by tracking detectors to detect and tag background muons that reach the depth of the detector. With this approach, the Braidwood experiment can measure the relative neutrino rate between the near and far detector sites with less than half a percent uncertainty with three years of data taking.

2 Questions

1. *Project Cost.* The estimated project cost is \$66M, including \$1M of Engineering and R&D funds to prepare a technical design, and \$65M for civil and detector contruction. A proposal for the \$1M in engineering funds was submitted to the NSF and DOE in September 2004.

2. *Contingency.* The \$65 million construction cost includes \$13 million of contingency. The breakdown between civil construction and detectors is:

- Civil construction: \$34M + \$8M(contingency)
- Detectors: \$18M + \$5M(contingency).

3. *Schedule.* If funding to complete engineering for a technical design is provided this year, construction could begin during 2007. The goal is to begin partial operations at the near site (i.e., the site 200 m from the reactor) in 2009, with full operations with both near and far sites in 2010. Figure 1 shows the sensitivity as a function of time for rate and energy spectrum measurements separately, and also for the combined fit. The full design sensitivity of $\sin^2 2\theta_{13} = 0.005$ at 90% c.l., requires three years of data taking. The first months of data, however, will already provide significant sensitivity.

4. *Cost Phasing.* The proposed funding includes \$1M in the first year to complete a full technical and engineering design, and then \$65M spread over three years to do the civil construction at the Braidwood site and to construct the four detector systems.

Table 1: Braidwood Neutrino Experiment Proposed Funding Profile

Year	Funding
1	\$1M R&D/Engineering for Technical Design
2	\$15M Civil Construction; \$3M Detector Construction
3	\$15M Civil Construction; \$10M Detector Construction
4	\$12M Civil Construction; \$10M Dectector Construction
Total	\$66M (including \$13M contingency)

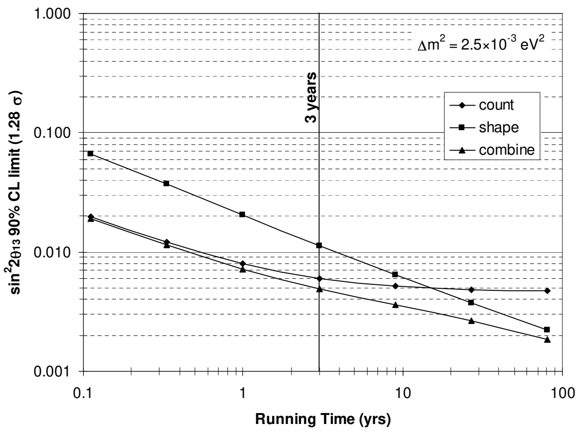

Figure 1: The 90% CL sensitivity of the Braidwood experiment versus running time for $\Delta m^2 = 2.5\times10^{-3}$ eV^2. The nominal data taking period is expected to be three years, which corresponds to a luminosity exposure of 2,800 GW-ton-years in the far detectors. The different types of fits are indicated by the markers on the line.

3 Details of Cost Estimate

Tables 2 and 3 are taken from the engineering/R&D proposal submitted by the Braidwood Collaboration to the NSF and DOE in September 2004. A full copy of the proposal is available at http://braidwood.uchicago.edu/nusag/project_web.ps Other documents are also available at http://braidwood.uchicago.edu/nusag/nusag.html.

Description of Work	Quantity	Units	Unit Cost	Subtotal	Total
General Mobilization	1	each	$3,286,691	$3,286,691	$3,286,691
Shaft					
mobilization	1	each	$512,165	$512,165	
pregrout overburden	15	meters	$7,538	$113,074	
excavate & line soil	15	meters	$62,891	$943,360	
excavate & line rock	160	meters	$42,262	$6,761,941	
water ring	1	each	$87,445	$87,445	
surface facilities	1	each	$104,532	$104,532	
equipment	1	each	$664,844	$664,844	
sump room	1	each	$226,295	$226,295	
decommissioning	1	each	$412,289	$412,289	
Shaft Total	2	each	$9,825,945	$19,602,870	$19,602,870
Detector Room (each room houses 2 detectors)					
excavate	32	meters	$69,156	$2,212,981	
grout	32	meters	$5,641	$180,511	
Detector Room Total	2	each	$2,393,492	$4,786,984	$4,786,984
Tunnel					
excavation	55	meters	$28,237	$1,553,035	
grout	55	meters	$2,247	$123,585	
Tunnel Total	55	meters	$30,484	$1,676,620	$1,676,620
Subtotal					$29,353,165
EDIA	17	%			$4,990,038
Contingency	25	%			$8,585,801
Total					$42,929,004

Table 2: The cost of civil construction for the baseline project estimated using the study of Don Hilton and Associates.

Description	Est. Cost
Spherical Detectors	
Steel tank	$340,000
Acrylic vessel	$500,000
Oil	$89,000
Gd-loaded Scintillator	$640,000
Oil plumbing system	$100,000
Temp regulation system, N2 purge	$40,000
PMTs	$870,000
PMT supports	$100,000
Cable system	$7,000
Tank support system	$50,000
Detector electronics	$150,000
DAQ	$50,000
Assembly Labor	$65,000
Radioactive Source Scanning System	$100,000
Muon System	
Passive shielding	$100,000
Muon tracking system	$1,000,000
Subtotal per Detector and Veto	$4,201,000
Contingency (30%)	$1,260,000
Total for one Detector System with cont.	$5,462,000
Total for four Detector Systems with cont.	$21,847,000
Items independent of number of detectors	Est. Cost
Attenuation Length Tester	$29,000
Storage Tank Farm on Site	$750,000
Subtotal of above items	$779,000
Contingency (30%)	$234,000
Subtotal of above items with contingency	$1,013,000
Overall Total with contingency	$22,859,000

Table 3: Preliminary Cost Estimate for one spherical detector and its associated veto system for the Braidwood Reactor Neutrino Project, and total cost for four detectors.