

Scientific Reach of Future Neutrino Oscillations Exps.

Parameter	T2K	T2HK	Reactor	Nova	Nova2	VLBNO
Δm_{32}^2	✓	✓	-	✓	✓	✓
$\sin^2(2\theta_{23})$	✓	✓	-	✓	✓	✓
$\sin^2(2\theta_{13})^a$	✓	✓	✓	✓	✓	✓
$\Delta m_{21}^2 \sin(2\theta_{12})^b$	-	-	-	-	-	12%
sign of $(\Delta m_{32}^2)^c$	Nova	-	-	T2K	T2K	yes
measure δ_{CP}^d	-	Nova	- Combined measurement -		T2HK	$\pm 13^\circ$
N-decay improv.	x1	x20	-	-	-	x10
Detector (KTons)	50	1000	20	30	30	500
Beam Power (MW)	0.74	4.0	14000	0.65	2.0	1.0
Baseline (km)	295 ^e	295 ^e	1	810 ^e	810 ^e	>2500
Detector Cost (\$M)	exists	~\$\$\$	20	165	+ ???	\$\$
Beam Cost (\$M)	exists	\$\$	exists	\$	\$\$\$	400

^a detection of $\nu_\mu \rightarrow \nu_e$, upper limit on or determination of $\sin^2(2\theta_{13})$

^b detection of $\nu_\mu \rightarrow \nu_e$ appearance, even if $\sin^2(2\theta_{13}) = 0$; determine θ_{23} angle ambiguity

^c detection of the matter enhancement effect over the entire δ_{CP} angle range

^d measure the CP-violation phase δ_{CP} in the lepton sector; Nova2 depends on T2HK

^e beam is 'off-axis' from 0-degree target direction

Comments on Neutrino Oscillations Experiments

- **All parameters of neutrino oscillation can be measured in one experiment**
 - a Very Long Baseline Neutrino Oscillation (VLBNO) at >2000 km
 - the cost of VLBNO is comparable to (or less than) competing proposals
 - the mass of the VLBNO target enables a powerful **Nucleon Decay** search
- **Use of a *broadband neutrino beam at very long distances* is the key**
 - **Oscillatory signal very important for extracting signal from background and measuring parameter without systematics.**
- **Focus on CP because The CP-violation parameter is the most difficult parameter to determine**
 - matter effects interact with CP-violation effects
 - the CP-violation phase δ_{CP} has distinct effects over the full 360° range
- **Off-axis beam method requires multiple distances and detectors to get same science.**
 - each step in offaxis will require of order 10 Snomass years of running
- **All measured oscillation parameters will be limited to ~1% precision by systematic errors except $\sin^2(2\theta_{23})$**

Comments on Neutrino Oscillations Experiments

- A Figure of Merit (FOM) for oscillation experiments is given by:

$$\text{FOM} = [\sum_i (1 / \sigma_i)] / [\text{Facility Cost} + 5 \text{ years Operations}]$$

For the experiments discussed, the computed FOMs are:

<u>Facility</u>	<u>Figure of Merit</u>
T2K	1.9
T2K2	0.3
Reactor	4.0
Nova	1.3
Nova2	0.6
VLBNO	0.6