### MPI jobs

For MPI parallel jobs you must specify how many cpus you need:

```bash
## use 4 CPUs, I don't care if they are on the same node or not
#PBS -l procs=4

## use 4 CPUs all on the same node (eg, for an OpenMP job with no MPI):
#PBS -l nodes=1:ppn=4

## use 4 CPUs, in groups of 2-on-the-same-node (all three groups might land on the
same physical node)
#PBS -l nodes=3:ppn=2

## use 2 CPUs on each of 2 distinct nodes. I really need them to be on different
nodes!
#PBS -l nodes=2:ppn=2 -W x=nmatchpolicy:exactnode
```

### Running MPI jobs with OpenMPI and MVAPICH2

Mercer has two implementations of MPI: OpenMPI and MVAPICH2. Overall the performance and behavior of each is similar, but with either there are special things to consider:

- With OpenMPI, processes may change which CPU (within the node) they use during execution. This can reduce performance, so OpenMPI jobs should be started with the `--bind-to-core` flag:

  ```bash
  mpirun --bind-to-core -np $PBS_NP ./my_program
  ```

- With either MPI implementation, the default behavior is to launch each process on the next available CPU. For hybrid MPI/OpenMP programs, this causes incorrect behavior, as each MPI process needs multiple CPUs for its OpenMP threads.

  For example, if you need two MPI processes with 2 OpenMP threads each, you would request `--nodes=2:ppn=2`. Your job might then be allocated 2 CPUs on node 14-0 and 2 CPUs on node 14-1. Your nodefile (`$PBS_NODEFILE`) will then look like:

  ```
  compute-14-0.local
compute-14-0.local
compute-14-1.local
compute-14-1.local
  ```
MPI uses this to place its processes, so it will, by default, place the first process on compute-14-0.local and the second process on compute-14-0.local. But for a hybrid program, you have multiple threads (in this case, 2) for each MPI process. Threads cannot cross host boundaries, so you will have 4 threads sharing the 2 CPUs of compute-14-0.local, while compute-14-1.local sits idle.

To get the correct behavior with OpenMPI, add --bynode to the mpirun command:

```bash
mpirun --bind-to-core --bynode -np $PBS_NUM_PPN ./my_program
```

With MVAPICH2, you must use a modified nodefile to reserve CPUs for OpenMP threads. The following idiom is effective:

```bash
#!/bin/bash
#PBS -l nodes=2:ppn=20

cd $SCRATCH/my_run_dir
module load mvapich2/intel/2.0rc1

# we want 20 threads per MPI process:
export OMP_NUM_THREADS=$PBS_NUM_PPN

# make a new nodefile with only two entries, one for each MPI process:
sed -n "1~$(($PBS_NUM_PPN))p" $PBS_NODEFILE > my_nodefile
mpirun -f my_nodefile -np $PBS_NUM_NODES my_program
```