**IceCube Institutional Memorandum Of Understanding (MOU)**

**Scope of Work**

**Lawrence Berkeley National Laboratory**

**Spencer Klein**

**Ph.D Scientists** (Faculty Scientist/Post Doc Grads): **5** (3 2 2)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Labor Cat.** | **Names** | **WBS L3** | **Tasks** | **Funds Source** | WBS 2.1 | WBS 2.2 | WBS 2.3 | WBS 2.4 | WBS 2.5 | WBS 2.6 | **Grand Total** |
| Program Coordination | Detector Maintenance & Operations | Computing & Data Management  | Data Processing & Simulation  | Software | Calibration |
| KE | KLEIN, SPENCER | Administration | Supervise LBNL effort | NSF M&O Core | 0.05 |   |   |   |   |  | **0.05** |
|  |  | Computing & Data Management | Oversee raw data storage at LBNL | Institutional In-Kind |  |  | 0.08 |  |  |  | **0.08** |
|  |  | Administration | PINGU Coordination Committee | Institutional In-Kind | 0.03 |   |   |   |   |  | **0.03** |
|  |  | Administration | Gen2 HEA/Surface working group | Institutional In-Kind | 0.05 |  |  |  |  |  | **0.05** |
|   | **KLEIN, SPENCER Total** |  | **0.13** |  | **0.08** |  |  |  | **0.21** |
| PO  | PALCZEWSKI,TOMASZ | Detector Monitoring | Monitoring Shifts | Base Grant |   |  0.09 |  |   |   |  | **0.09** |
|   | **PALCZEWSKI, TOMASZ Total** |  |  | **0.09** |  |  |  |  | **0.09** |
| EN | STEZELBERGER, THORSTEN | Data Acquisition | Maintain DAQ Hardware  | NSF M&O Core |  | 0.15 |   |   |   |  | **0.15** |
|   | **STEZELBERGER, THORSTEN Total** |  |  | **0.15** |  |  |  |  | **0.15** |
| GR | BINDER, GARY | Reconstruction | High-energy combined event reconstruction | Base Grant |   |  |    |   | 0.15 |  | **0.15** |
|   | **BINDER, GARY Total** |  |  |  |  |  | **0.15** |  | **0.15** |
| IT | All, LBNL IT | Central Computing Resources | NERSC Data Archiving, Distributed Computing and Labor | Institutional In-Kind |   |  |   1.00 |   |  |  | **1.00** |
|   | **LBNL IT Total** |  |  |  | **1.00** |  |  |  | **1.00** |
| **LBNL Total**  |  |  | **0.13** | **0.24** | **1.08** |  | **0.15** |  | **1.60** |

LBNL is involved in many aspects of IceCube service. We built the DOM main boards, and many of our service tasks are related to that, including maintenance of DAQ hardware (contributing to firmware and online software updates). Over the past year, PI Klein has gotten in the PINGU coordination committee, and the Gen2 HEA/Surface working group, where he is looking into complete event reconstruction for high-energy (i. e. TeV+) events containing a cascade plus a muon, and also looking at ‘forward muon’ events where a muon takes a large fraction of the air shower energy; this is an important background for downward-going neutrino events.

We are also heavily involved in software work. One new initiative, just getting started is to have LBNL’s NERSC store a copy of all of IceCube’s raw data on their HPSS storage system. The MOU envisions us storing 3.3 petabytes the end of the first year, increasing by about 700 terabytes/year. This is a lot of data, and we have been heavily involved in developing the data transfer procedures. We also have an allocation of 1,000,000 CPU hours this year on NERSC supercomputer systems, and have been expending considerable effort to make IceCube software work on this or similar systems. IceProd, in particular, does not easily run here. We are fortunate in that former IceCube postdoc, now NERSC staffer Lisa Gerhardt is able to take some time to help us with these projects.

Postdoc Tomasz Palczewski is our group “PI” for our computing efforts at NERSC, works on NERSC software issues, and has also taken responsibility for a number of IceCube modules.

We continue to maintain our original responsibilities, including the maintenance and upgrading (including ‘restandardization’) for the truncated mean muon energy measurement. Gary Binder has been looking into an improved maximum likelihood method to further improve TM.

Our analysis efforts are focused in several areas.

 The first is a search for extraterrestrial neutrinos, especially cascades, where we have multiple efforts covering different energy ranges. Gary Binder recently completed the first analysis of the flavor content of astrophysical neutrinos. He is now working on a measurement of inelasticity (muon energy/neutrino energy) in contained events; this can be used to determine the neutrino/antineutrino ratio (at energies below about 40 TeV), and also to search for . This has necessitated developing new reconstruction algorithms to determine the cascade and muon energy in these more complex events.

 Palczewski is working on a study of high-energy down-going neutrinos. He is applying algorithms to select single muon events (developed for the forward muon search) to reject muon bundle background.

Finally, Miarecki is working on a measurement of the neutrino-nucleon cross-section by measuring atmospheric neutrino absorption in the Earth; this was her dissertation topic, and we are working on a paper on this analysis together.

We use the National Energy Research Supercomputer Center (NERSC) to produce Monte Carlo event samples; this has mostly been cascade signal events. T. Palczewski maintains the software installation and coordinates this production. For CY 2016, we have an allocation of 1,000,000 CPU hours on Cori Phase 1 (<http://www.nersc.gov/systems/cori/>), which uses 2.3 GHz Intel Haswell processors. Averaged over 365 days running 24/7, this is equivalent to 114 full-time processors. We have also been allocated enough tape and disk storage to story a complete copy of the IceCube raw data. We anticipate using the CPU time mostly for IceCube, but this is negotiable.

**Faculty:**

R. Stokstad – timing calibrations

D.R. Nygren – “Track Engine” trigger

S.R. Klein – PINGU coordination committee, Gen2 HEA/Surface working group, with a focus on particle physics and cosmic-ray topics; administrative oversight of raw data transfer from Madison to LBNL.

**Scientists and Post Docs:**

Lisa Gerhardt – Software and administrative support for raw data transfer and simulation at NERSC

Tomasz Palczewski – Calibrations. Simulation production at LBNL, programming and technical work on raw data transfer from Madison to LBNL

 Analysis topics: high-energy down-going astrophysical neutrinos

**Graduate Students:**

Sandy Miarecki – Algorithm for measuring muon energy

 Thesis/Analysis topics: muon energy measurement, atmospheric muon neutrinos, and the neutrino-nucleon cross-section

Gary Binder – PMT saturation corrections for analysis

 Thesis/Analysis topics: contained events – cascades and inelasticity measurement