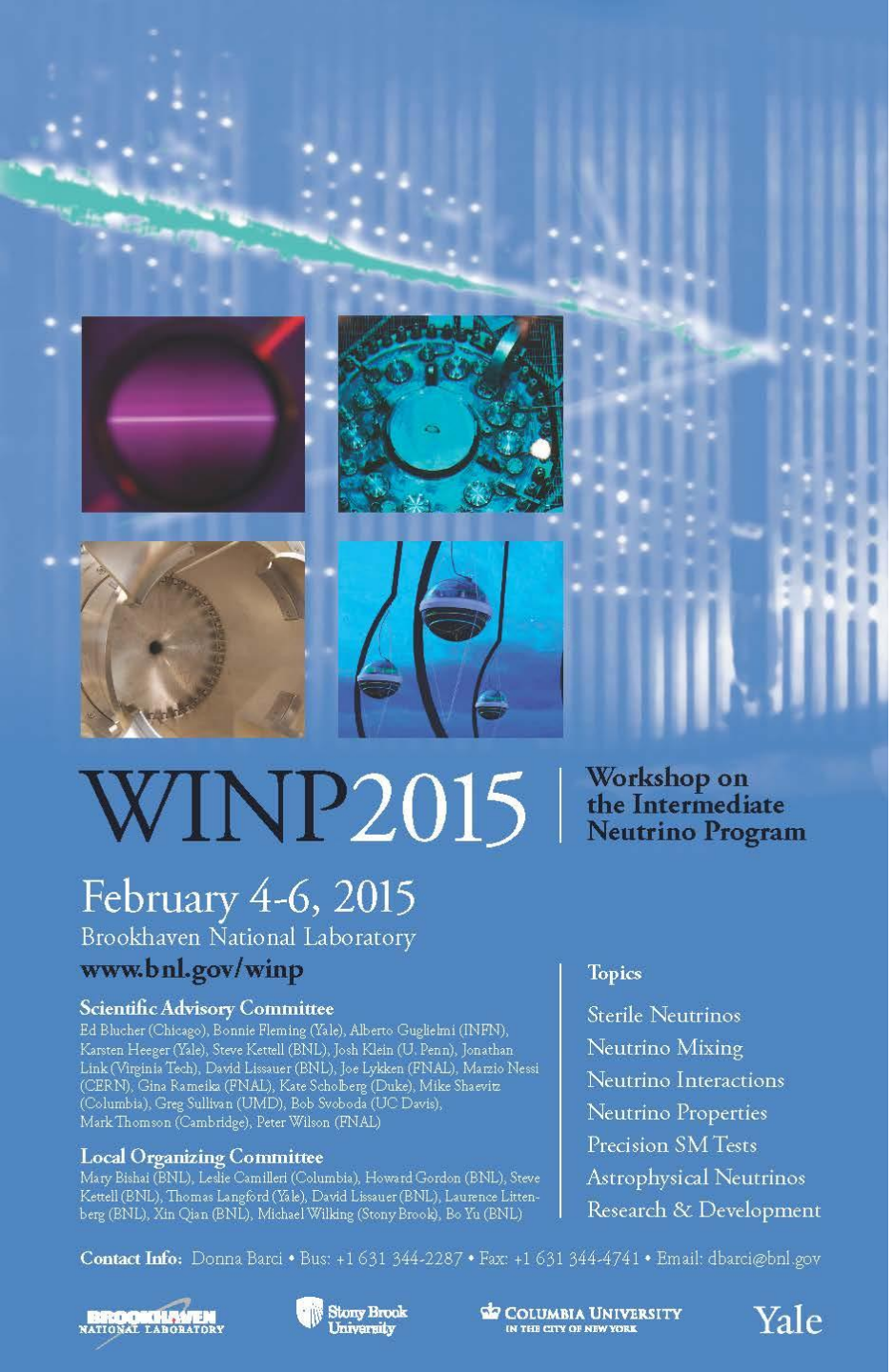
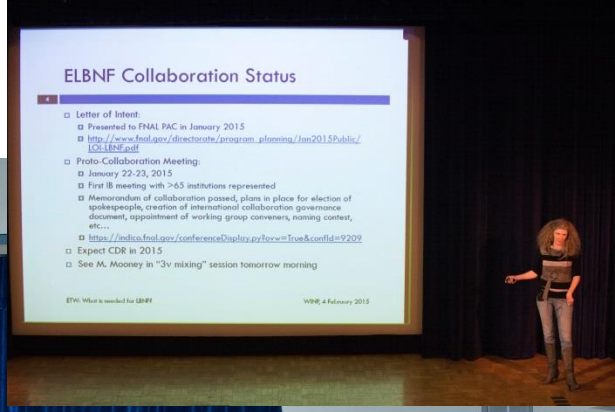


Workshop on the Intermediate Neutrino Program (WINP)

Steve Kettell

BNL

www.bnl.gov/winp



Workshop on the Intermediate Neutrino Program

February 4, 2015

WINP Organization

- **Local Organizing Committee:** Mary Bishai (BNL), Leslie Camilleri (Columbia), Howard Gordon (BNL), Steve Kettell (BNL), Thomas Langford (Yale), David Lissauer (BNL), Laurence Littenberg (BNL), Xin Qian (BNL), Michael Wilking (SBU), Bo Yu (BNL)
- **Scientific Advisory Committee:** Ed Blucher (Chicago), Bonnie Fleming (Yale), Alberto Guglielmi (INFN), Karsten Heeger (Yale), Steve Kettell (BNL), Josh Klein (U. Penn), Jonathan Link (Virginia Tech), David Lissauer (BNL), Joe Lykken (FNAL), Marzio Nessi (CERN), Gina Rameika (FNAL), Kate Scholberg (Duke), Mike Shaevitz (Columbia), Greg Sullivan (UMD), Bob Svoboda (UC Davis), Mark Thomson (Cambridge), Peter Wilson (FNAL)
- **Working Group Convenors:** KS Babu (OSU), Phil Barbeau (Duke), Mu-Chun Chen (UCI), Mark Convery (SLAC), Doug Cowen (PSU), Zelimir Djurcic (ANL), Gerald Garvey (LANL), Concepcion Gonzalez-Garcia (SBU), Alberto Guglielmi (INFN Padova), Patrick Huber (VT), Karsten Heeger (Yale), Steve Kettell (BNL), Josh Klein (Penn), Yury Kolomensky (UCB/LBNL), Jonathan Link (VT), Bryce Littlejohn (IIT), Bill Louis (LANL), Jelena Maricic (Hawaii), Benjamin Monreal (UCSB), Jorge Morfin (FNAL), Marzio Nessi (CERN), Gabriel Orebi Gann (UCB/LBNL), Xin Qian (BNL), Regina Rameika (FNAL), Mayly Sanchez (ISU), David Schmitz (Chicago), Kate Scholberg (Duke), Mike Shaevitz (Columbia), Michael Smy (UCI), Alex Sousa (Cincinnati), Jim Stewart (BNL), Greg Sullivan (UMD), Bob Svoboda (UCD), Mark Vagins (IPMU), Lisa Whitehead (Houston), Jong Hee Yoo (FNAL)

P5 Follow-up

- Two of the five P5 Science Drivers motivate neutrino physics
  - Pursue the physics associated with neutrino mass
  - Explore the unknown: new particles, interactions and physical principles
- The Long Baseline Neutrino Program (LBN) is central to US plans and is advancing. The Intermediate Program leading up to LBN was the focus of this workshop.
- Three of the specific P5 recommendations are addressed by WINP
  - Recommendation 4: Maintain a program of projects of all scales, from the largest international projects to mid- and small-scale projects.
  - Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.
  - Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.
  - Recommendations 1–3, 6–9 on general topics and 13–14 on LBNF, 27–29 on R&D and Computing are also addressed by WINP

WINP

- Community assessment of what are the important physics opportunities in the next 5-10 years
  - Serves many purposes, including assessment of options for the portfolio of small-scale experiments (including explicitly neutrino experiments) recommended by P5.
- Some 200 neutrino physicists with extensive expertise and insight
- Neutrino community broadly represented, including particle, astroparticle and nuclear physicists.
- Many are advocates of specific experiments
- Not an “independent, unbiased review panel” providing direct prioritization advice to the agencies
- Agencies can use WINP as input to their decision making processes.

Experimental Opportunities

Responses

We received responses from 43 experiments/R&D projects to the WINP questionnaire. A total of 180 pages of self-reported experimental information is available, including: status, plans, collaboration, physics reach, cost and schedule. (All are available from the WINP agenda web page at https://indico.bnl.gov/conferenceDisplay.py?confId=918)

1. ANNIE 2. ARA 3. ASDC (Theia) 4. CAPTAIN 5. CENNS 6. CeSOX 7. CHIPS 8. COHERENT 9. Cr51 10. CUORE 11. DAEdALUS 12. Daya Bay 13. ELBNF 14. Hyper-K 15. IceCube 16. IsoDAR 17. Jinping 18. JPARC56 19. JUNO 20. KamLAND 21. KATRIN 22. LAr35ton 23. LAr-CERN-prototype 24. LArIAT 25. MINERvA 26. MINOS 27. NESSiE 28. nEXO 29. NEXT 30. NuLAT 31. NuPRISM 32. OscSNS 33. PINGU 34. Project-8 35. PROSPECT 36. RICOCHET 37. SBN-ICARUS 38. SBN-LAr1-ND 39. SNO+ 40. Super-Kamiokande 41. Super NEMO Demonstrator 42. US NA61 43. WATCHMAN

Agenda

indico.bnl.gov/conferenceDisplay.py?confId=918

Wednesday February 4 morning plenary (Goals, Objectives, Background)			Registration	08:00-17:00
1)	Welcome		Tribble	08:30-08:40
2)	View from the Funding Agencies:		Hallman, Crawford	08:40-09:10
3)	WINP goals/overview of working groups		Kettell	09:10-09:30
4)	The Neutrino Landscape		Marciano	09:30-10:00
5)	What can we learn in the next 10 years		de Gouvea	10:00-10:30
	Coffee break			**10:30-10:45**
6)	Expected physics output of ongoing experiments		Thomson	10:45-11:15
7)	Short Baseline program at FNAL		Wilson	11:15-11:35
8)	What is needed for next LBN experiments		Worcester	11:35-11:55
	Workshop picture			**12:00**
	Lunch (on your own)			**12:15**
Wednesday February 4 afternoon plenary (Summaries of proposed initiatives)				
9)	Summary of upgrades to existing experiments		Klein	13:30-14:15
10)	Large experiments needing R&D or US participation		Svoboda	14:15-15:00
	Coffee break			**15:00-15:30**
11)	Summary of self-contained experiments		Scholberg	15:30-16:15
12)	Discussion		Patterson/Fleming	16:15-17:30
	Reception (included in registration fee)			**17:30-19:30**
Thursday February 5 morning Physics topics working group (parallel)				
	Lunch (on your own)			**12:30**
Thursday February 5 afternoon techniques/approach/technology working groups (parallel)				
	Dinner (included in registration fee)			**18:30-20:00**
Friday February 6 Plenary (Working Group reports)				
1)	Bullet points from	sterile ν WG	WG#1	08:30-08:45
2)	"	3ν-mixing WG	WG#2	08:45-09:00
3)	"	ν interactions WG	WG#3	09:00-09:15
4)	"	ν properties WG	WG#4	09:15-09:30
5)	"	Astrophysical ν WG	WG#5	09:30-09:45
6)	"	SBN WG	WG#6	09:45-10:00
7)	"	Reactor ν WG	WG#7	10:00-10:15
8)	"	source, cyclotron & DAR WG	WG#8	10:15-10:30
	Coffee break			**10:30-11:00**
9)	"	Detector R&D WG	WG#9	11:00-11:15
10)	"	Theory WG	WG#10	11:15-11:30
11)	"	experiment upgrade convenor		11:30-11:45
12)	"	large experiment convenor		11:45-12:00
13)	"	small/midscale experiment convenor		12:00-12:15
	Lunch (on your own, convenors in Berkner B)			**12:15-14:30**
	Friday February 6 afternoon plenary (Summary)			
14)	Discussion/Conclusions		Lykken/Blucher	14:30-16:00

Plenary overview

Parallel Working Groups

Plenary WG summaries

Working Groups

- Physics [2/5 Thursday morning 8:30-12:30]
  - Sterile neutrinos (Huber/Louis/Link/Littlejohn)
  - 3-neutrino mixing (Gonzalez-Garcia/Whitehead/Cowen)
  - Neutrino interactions (Morfin/Garvey)
  - Neutrino Properties (Kolomensky/Monreal)
  - Astrophysical neutrinos (Vagins/Sullivan)
- Technology [2/5 Thursday afternoon 13:30-17:30]
  - Short baseline accelerator neutrinos (Schmitz/Guglielmi/Rameika)
  - Reactor neutrinos (Heeger/Qian)
  - Source, cyclotron and decay-at-rest (Barbeau/Shaevitz/Maricic)
  - Detector R&D (Nessi/Stewart/Orebi-Gann/Sanchez)
  - Theory (Chen/Babu)
- Status [no sessions]
  - Possible upgrades (Klein/Sousa/Cowen/Schmitz)
  - Self-contained expts. (Scholberg/Djurcic/Yoo)
  - Large experiments (Svoboda/Convery/Smy)

Physics Working Group reports

- Sterile:
  - Many proposed experiments in many different modes
  - Direct tests of current anomalies should observe oscillation pattern in energy and/or baseline
  - Test $\nu_\mu \rightarrow \nu_e$ appearance and ν_e disappearance; pion decay with optimized ν_μ disappearance sensitivity
- 3-nu mixing:
  - Current experiments will improve precision on θ_{13}, θ_{23}, Δm^2_{ATM} and may indicate θ_{23} octant and mass hierarchy and may provide hints of δ_{CP} or they will improve uncertainties by improved measurements of ν interactions (e.g. Daya Bay, MINOS+, T2K, NOvA, MINERvA)
  - Proposed experiments focusing on reducing uncertainties include CAPTAIN-MINERvA, US-NA61, NuPRISM
  - Experiments under construction that will measure the mass hierarchy: JUNO
  - Longer term experiments to address remaining unknowns: DUNE, PINGU, Hyper-K, Theia, Daedalus
- Interactions:
  - Need improvements in nuclear models and integration into event generators
  - Current program provides important data: MINERvA, NOvA-ND, MicroBooNE, T2K-ND
  - Proposed experiments include SBN and CAPTAIN-MINERvA
  - Measurements and theoretical work are needed for low energy neutrino interactions from supernovae
- Properties:
  - Neutrino mass: KATRIN is state of art, proposed experiments include Project-8, ECHO/HOMES/NuMECS
  - Coherent scattering: proposed experiments include RICHOCHET, CENNS, COHERENT, ^{51}Cr at LZ (that could also search for a neutrino magnetic moment)
  - Neutrinoless double beta decay: CUORE and CUPID, Majorana Demonstrator, 1-ton Ge, EXO-200, nEXO, NEXT, KamLAND-ZEN, NuDOT, SNO+, Theia, SuperNEMO
- Astrophysical nu:
  - Cosmogenic neutrino (GZK) radio detection (ARA, ARRIANA)
  - R&D on photodetectors, instrumentation and deployment (PINGU, CHIPS, Theia)
  - Theoretical study of high energy neutrino production in atmospheric showers

Technology Working Group reports

- Short-baseline accelerator neutrinos:
  - SBN: sterile search with MicroBooNE and LAr1-ND/ICARUS at BNB
  - ANNIE: neutrino production of neutrons at BNB
  - CAPTAIN: low energy neutrino interactions at BNB and high energy at NuMI
  - NuPRISM: variably off-axis neutrino detection at T2K ND
- Reactor neutrinos:
  - Short-baseline study of reactor anomaly and sterile search: PROSPECT, NuLAT
  - Medium-baseline determination of mass hierarchy: RENO-50, JUNO
- Source, Cyclotron and meson decay at rest neutrinos:
  - Radioactive sources: SOX at Borexino (Ce and Cr), Cr at LZ, SNO+ and RICOCHET
  - Pion/Kaon decay at rest: JPARC-E56
  - Coherent scattering: CENNS, COHERENT
  - Isotope decay at rest: IsoDAR
  - Pion decay at rest: OscSNS
  - Cross section measurements: CENNS, CAPTAIN-BNB, JPARC-E56, COHERENT
- R&D:
  - Wb-LS development for particle identification (Cherenkov and scintillation light), including 1-ton prototype at BNL
  - Cost effective, large area fast photodetectors (LAPPD); Lower cost construction methods (CHIPS)
  - Larger scale proposals include EGADS, ANNIE, WATCHMAN-Phase-2, SNO+, CHIPS, Theia
  - LArTPC test beam characterization with neutrons and charged particles (LArIAT, CAPTAIN, CERN neutrino platform)
  - LAr HV breakdown
  - LAr contamination generation and transport
  - Light generation and propagation in LAr, efficient photon detection development
  - Development of cold electronics, especially for control chip and light detection systems
- Theory:
  - Include theory in FOA
  - Fundamental neutrino properties
  - Neutrino interactions
  - Short baseline and sterile neutrinos
  - Astrophysical and cosmological neutrinos
  - Underlying symmetries behind neutrino mass

WINP report

- The Workshop report is available: arXiv:1503.06637
  - The report is based on bullet points from each working group (posted on the Indico site).

The Intermediate Neutrino Program

C. Adams, J.R. Alonso, A.M. Ankowski, J.A. Asaadi, J. Ashenfelter, S.N. Axani, K. Babu, C. Backhouse, H.R. Band, P.S. Barbeau, N. Barros, A. Bernstein, M. Betancourt, M. Bishai, E. Blucher, J. Bouard, N. Bowden, S. Brice, C. Bryan, L. Camilleri, J. Cao, J. Carlson, R.E. Carr, A. Chatterjee, M. Chen, S. Chen, M. Chiu, E.D. Church, J.I. Collar, G. Collin, J.M. Conrad, M.R. Convery, R.L. Cooper, D. Cowen, H. Davoudiasl, A. De Gouvea, D.J. Dean, G. Deichert, F. Descamps, T. DeYoung, M.V. Diwan, Z. Djurcic, M.J. Dolinski, J. Dolph, B. Donnelly, D.A. Dwyer, S. Dytman, Y. Efremenko, L.L. Everett, A. Fava, E. Figueroa-Feliciano, B. Fleming, A. Friedland, B.K. Fujikawa, T.K. Gaisser, M. Galeazzi, D.C. Galehouse, A. Galindo-Uribarri, G.T. Garvey, S. Gautam, K.E. Gilje, M. Gonzalez-Garcia, M.C. Goodman, H. Gordon, E. Gramellini, M.P. Green, A. Guglielmi, R.W. Hackenburg, A. Hackenburg, F. Halzen, K. Han, S. Hans, D. Harris, K.M. Heeger, M. Herman, R. Hill, A. Holin, P. Huber, D.E. Jae, R.A. Johnson, J. Joshi, G. Karagiorgi, L.J. Kaufman, B. Kayser, S.H. Kettell, B.J. Kirby, J.R. Klein, Yu.G. Kolomensky, R.M. Kriske, C.E. Lane, T.J. Langford, A. Lankford, K. Lau, J.G. Learned, J. Ling, J.M. Link, D. Lissauer, L. Littenberg, B.R. Littlejohn, S. Lockwitz, M. Lokajicek, W.C. Louis, K. Luk, J. Lykken, W.J. Marciano, J. Maricic, D.M. Marko, D.A. Martinez Caicedo, C. Mauger, K. Mavrokoridis, E. McCluskey, D. McKeen, R. McKeown, G. Mills, I. Mocioiu, B. Monreal, M.R. Mooney, J.G. Morfin, P. Mumm, J. Napolitano, R. Neilson, J.K. Nelson, M. Nessi, D. Norcini, F. Nova, D.R. Nygren, G.D. Orebi Gann, O. Palamara, Z. Parsa, R. Patterson, P. Paul, A. Pocar, X. Qian, J.L. Raaf, R. Rameika, G. Ranucci, H. Ray, D. Reyna, G.C. Rich, P. Rodrigues, E. Romero Romero, R. Rosero, S.D. Rountree, B. Rybolt, M.C. Sanchez, G. Santucci, D. Schmitz, K. Scholberg, D. Seckel, M. Shaevitz, R. Shrock, M.B. Smy, M. Soderberg, A. Sonzogni, A.B. Sousa, J. Spitz, J.M. St. John, J. Stewart, J.B. Strait, G. Sullivan, R. Svoboda, A.M. Szelc, R. Tayloe, M.A. Thomsony, M. Toups, A. Vacheret, M. Vagins, R.G. Van de Water, R.B. Vogelaar, M. Weber, W. Weng, M. Wetstein, C. White, B.R. White, L. Whitehead, D.W. Whittington, M.J. Wilking, R.J. Wilson, P. Wilson, D. Winklehner, D.R. Winn, E. Worcester, L. Yang, M. Yeh, Z.W. Yokley, J. Yoo, B. Yu, J. Yu and C. Zhang

DOE Statement of Plans

DOE Process for Intermediate Neutrino Program

- P5 recommended:
  - LBNE(F) as the highest priority major project in the medium term
  - A balanced and coherent program of short baseline neutrino experiments including small projects
- Plans for LBNF/DUNE are moving along well and the FNAL PAC has endorsed a plan for a coordinated FNAL short-baseline LAr program
  - LAr1ND, MicroBooNE, ICARUS in Booster beamline
  - Both a physics program and a technology R&D platform
- There are many other possible short-baseline neutrino experiments using other facilities, with and without accelerator beams
  - Many R&D efforts underway at various stages of maturity
- DOE is interested in understanding these various options and plans in more detail
  - The WINP workshop provided important community input regarding these options, necessary for formulating and executing a successful program based on the P5 strategy

Glen Crawford HEPAP 4/7/15

DOE Plans

DOE Process for Short-baseline Neutrinos

- The workshop gave us the opportunity to hear community ideas for near term (less than 5 year) small-scale experiments (total funding less than ~$10M) that are:
  - Scientifically compelling
  - Competitive in the world program
  - Small enough in scope and technically ready
- WINP Workshop report detailed the science opportunities available that may be addressed by investments in such near term small-scale experiments
- Based on the WINP reports we are drafting a new funding opportunity announcement (FOA) for appropriate small-scale experiments later in FY2015, possible funding in FY2016
  - Specific objectives and requirements will be called out in the FOA

DOE Plans

Other Elements of DOE Neutrino program

- There will be many good ideas that do not fit into the funding or schedule constraints discussed above and we are interested in those, as well
  - For example, there are also important issues to address in technology R&D for future experiments and theory support for the broad neutrino program
  - Reports from the working groups will be helpful in addressing these and other issues
- Possible funding for such efforts will be dealt with through the usual proposal process. There may be additional opportunities for partnerships or other collaborative funding.
  - E.g., DOE Nuclear Physics solicitation for Topical Collaborations in Nuclear Theory, including neutrino-nuclei interactions

DOE Plans

Neutrino FOA Update

- Now working on draft FOA
  - Expect release in late May or early June
  - Letter of Intent will likely be requested to speed review process
  - Full proposals due in summer
  - Reviews early fall
- Science focus on topics highlighted in WINP
- Emphasis on small-scale, near-term experiments that are "ready to go"
  - Contributions to established programs (e.g. FNAL SBN) outside of scope
  - Usual P5 criteria apply
- Expect awards to focus on experiment fabrication, installation, operations
  - Technology R&D and neutrino theory other possible topics
    - Additional guidance on critical R&D/theory milestones for LBN welcome
  - Future FNAL-based SBN proposals ok

Summary

- Workshop was very productive
- Many exciting opportunities leading up to the long baseline experiment (DUNE)
- WINP reinforces rich diversity of neutrino physics opportunities envisioned by P5 recommendation for a portfolio of small scale experiments
- Expect to see a Call for Proposals from DOE-OHEP in ~1.5 months.