Physics Committee Report*

Dan Akerib, chair

(Co-Chairs Jeff Wilkes & Eric Zimmerman)

HUSEP Capstone Meeting
Stony Brook University
4-6 May 2006

* includes slides prepared by Low-Background Facility Committee
Physics Issues

• Just a few simple questions:
  – What is the fundamental nature of matter?
  – What is most of the universe made of?
  – How was this stuff produced in the early universe?
  – How do stars shine and explode?

• Possible answers to these questions suggest the existence of new particles and new types of interactions

• Broad program of particle physics, astrophysics and cosmology requires particle detectors deep underground

• Why deep underground?
  – Observing rare processes requires shielding from cosmic rays

• ...and why at Henderson?
  – Variety of shielding depths will be available on a staged time scale consistent with detector development
  – Location, location, location... (mine/region advantages described earlier)
Proton decay experiments

Observation of proton decay
- tells us about inverse processes (baryogenesis)
- Gives experimental data on Grand Unified Theories!

- Low rates $\rightarrow$ Large detectors
  - Need many protons!
  - Present limits: $T_{1/2} > 10^{33-34}$ years
  - Single (eg, UNO) or multiple (eg, 3M) cavities

- Intrinsically multi-purpose
  - Long-baseline neutrino oscillations (next slide)
  - Neutrino astrophysics / supernova observatory

UNO: ~20 X SuperK
Long Baseline Neutrino Oscillations

Baselines in USA are unachievable in Japan or Europe: VLBNO
Neutrinoless double beta decay

• Single claimed observation is controversial! Significance must be checked

• Major US efforts
  - MAJORANA expt- 500 kg Ge76 (86%)
  - EXO - 1-ton LXe TPC

• Deeper site for later versions of GS experiments?
  - e.g, CUORE - 760 kg TeO2
Dark Matter WIMP Detection

- Detect missing mass candidate in Galactic Halo -- do we understand gravity?
- Multiple approaches aimed at ton-scale
- Study SUSY/new fundamental physics alongside LHC/ILC

Liquid nobles: XENON, DEAP (Ar), ZEPLIN

Directional TPC/DRIFT

Scattered WIMP

Recoil Atom

Drift direction

Cathode

E-Field

COUPP Bubble chamber
Solar Neutrinos

- Next challenge: precision measurement of p-p ν’s
  - Improve test of standard solar model: Energy source other than fusion?
  - Independently confirm ν mixing parameters
Broad Physics Program

• Proton decay
• Long baseline neutrino studies
• Double beta decay
• Dark Matter
• Solar neutrinos

• Nuclear astrophysics
• Gravity (geophysics; gravitational waves)
• Low Background Counting
Physics Committee membership

- Dan Akerib (Case), Chair
- Frank Avignone (South Carolina),
- John Beacom (Ohio State),
- Alessandro Bettini (INFN/Padova),
- Jim Cochran (Iowa State),
- Steven R. Elliott (LANL),
- Enrique Fernandez (Barcelona),
- Maury Goodman (ANL),
- Alec T. Habig (U.Minn/Duluth),
- Karsten Heeger (LBL),
- Chang-Kee Jung (Stony Brook),
- Tony Mann (Tufts),
- Kai Martens (Utah),
- William Louis (LANL),
- Cecilia Lunardini (INT/UWash),
- Clark McGrew (Stony Brook)
- Bob McKeown (CalTech),
- Harry Nelson (UCSB),
- Peter Paul (Stony Brook),
- Andreas Piepke (Alabama),
- Soren Prell (Iowa State),
- Eli Rosenberg (Iowa State),
- Leslie Rosenberg (LLNL),
- David Sinclair (Carleton),
- Walter Toki (CSU),
- Tom Weiler (Vanderbilt),
- Michael Wiescher (Notre Dame),
- Jeffrey Wilkes (UWash), co-chair
- Robert Wilson (CSU),
- Chiaki Yanagisawa (Stony Brook),
- Eric D. Zimmerman (CU), co-chair
Physics Workshop @ CSU, Nov 18~19, 2005

- Topical working groups formed in September, 2005
  - Neutrino mixing studies (atmospheric and long baseline)
    Conveners: Walter Toki, Cecilia Lunardini
  - Dark matter searches and precision radio-assay
    Conveners: Dan Akerib, Harry Nelson, Leslie Rosenberg
  - Nucleon decay
    Conveners: Maury Goodman, Tony Mann
  - Astrophysics (SN, diffuse SN flux, neutrino astronomy)
    Conveners: Alec Habig, Tom Weiler
- Weekly phone/video meetings held
- >100 colleagues were contacted by committee members
- 46 attended the Physics Workshop
  - Distribution of interests (1st choice, where expressed):
    - Neutrino mass 3
    - Neutrino mixing 10
    - Dark matter 13
    - Nucleon decay 3
    - Astrophysics 6
Physics Workshop at CSU

- **Very successful:** good attendance, lively discussions
- **Sessions focused on infrastructure requirements** for physics experiments, interacting with the engineering design team.
- **Valuable discussions** on ramp/drift configurations, power requirements, types of space (MSHA vs. OSHA requirements), life cycle of the laboratory.
- **Joint Education and Outreach session** with Geoscience

Physics Workshop notes & presentations are posted on the HUSEP website:

http://ale.physics.sunysb.edu/husep/MembersOnly/Physics/TopicalWorkshop/Physics-WorkshopNov05/
Candidate Experiment 1p Summaries

• “Bluebook” of summary reports to help define infrastructure requirements for physics experiments
  – Summaries of potential physics experiments, using S1 as starting point, updated and expanded by our own research
  – Use these to generate an 'envelope' of maximal likely infrastructure demands
### Candidate Experiments

- Experiments with 1-page summaries (so far):

<table>
<thead>
<tr>
<th>Dark Matter</th>
<th>Neutrino Detectors</th>
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<tbody>
<tr>
<td>COUPP (Bbl. Chamber)</td>
<td>CLEAN</td>
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<tr>
<td>Eureca</td>
<td>HERON</td>
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<tr>
<td>DRIFT III</td>
<td>HYBRID</td>
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<td>SIGN</td>
<td>LENS</td>
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<td>MOON</td>
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<td>TPC</td>
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<td><strong>Dir. TPC</strong></td>
<td>CLEAN</td>
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<td><strong>Super-CDMS</strong></td>
<td>HERON</td>
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<td><strong>XENON</strong></td>
<td>HYBRID</td>
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<td><strong>ZEPLIN</strong></td>
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<td>MOON</td>
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<table>
<thead>
<tr>
<th><strong>ββ0ν</strong></th>
<th><strong>Proton Decay</strong></th>
<th><strong>Misc./Other</strong></th>
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<tbody>
<tr>
<td>EXO</td>
<td>HSD</td>
<td>ALNA</td>
</tr>
<tr>
<td>MAJORANA</td>
<td>LANDD</td>
<td>N-Nbar</td>
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<tr>
<td>MOON</td>
<td>UNO</td>
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</tbody>
</table>

6 May 2006

HUSEP Physics committee - IAB Meeting
### Example: 1-page summary for ZEPLIN dark matter detector

**HUSEP Physical Sciences: 1-page summaries of potential DUSEL occupants**

<table>
<thead>
<tr>
<th>Experiment / Facility</th>
<th>ZEPLIN IV/Max (Liquid Xenon)</th>
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</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
<td>Dark matter</td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td>Lead white paper</td>
</tr>
<tr>
<td><strong>Timeline</strong></td>
<td>3 yrs until space reqd.</td>
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<tr>
<td><strong>Duration</strong></td>
<td>5 yrs</td>
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<tr>
<td><strong>Collaboration Size</strong></td>
<td>10 institutions ~60 people (current)</td>
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<tr>
<td><strong>Depth / Shielding</strong></td>
<td>&gt;3000</td>
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<tr>
<td><strong>Space, area or volume</strong></td>
<td>8x8x6 m^3 5x4x4 m^3 6x6x6 m^3</td>
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<tr>
<td><strong>Occupancy</strong></td>
<td>six / two</td>
</tr>
<tr>
<td><strong>Radon Background</strong></td>
<td>None (will include self shield in the design for Radon)</td>
</tr>
<tr>
<td><strong>Hazardous Materials</strong></td>
<td>Multi-Tons of Liquid Xenon High Pressure Gas</td>
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<td><strong>Crane</strong></td>
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<td><strong>Chilled Water</strong></td>
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<td><strong>Ventilation</strong></td>
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<tr>
<td><strong>Stable Temp.</strong></td>
<td>(A/C Req'd.) yes</td>
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<tr>
<td><strong>Electrical Power</strong></td>
<td>25 kW</td>
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<td><strong>Clean Areas</strong></td>
<td>(class) yes (1000)</td>
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<tr>
<td><strong>Special/Additional Facilities</strong></td>
<td>Machine shop, clean room, Low level counting, Rn-Free Matl. Storage. LN2 supply</td>
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<td><strong>Length (m)</strong></td>
<td>8 m</td>
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<tr>
<td><strong>Width (m)</strong></td>
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<tr>
<td><strong>Height (m)</strong></td>
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<td><strong>Radius (m)</strong></td>
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<td><strong>Area</strong></td>
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<tr>
<td><strong>Volume</strong></td>
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<tr>
<td><strong>Electrical Power</strong></td>
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<tr>
<td><strong>Depth/Shielding</strong></td>
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<tr>
<td><strong>Depth</strong></td>
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<td><strong>Depth</strong></td>
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Nominal timeline for physics experiments

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<td>Water Cherenkov (UNO)</td>
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<td>CLEAN</td>
<td>Solar neutrino</td>
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<td>DRIFT-III</td>
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<td>Directional TPC (1-ton)</td>
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<td>Majorana</td>
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<td>COUPP</td>
<td>DM; SN nu's?</td>
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<td>HYBRID</td>
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Derived from S1 Matrix & EOI’s

next generation after SNOLAB

Start central & relocate to lower? Mitigate depth w/shielding, vetoes?

4 May 2006

HUSEP Physics committee
Example of initial experiment suite

- Inherent challenge: planning without knowing which experiments will go forward

- *Conceptual* scenario: DUSEL @ Henderson hosts
  - Two double-beta decay experiments
    - Majorana
    - EXO
  - Two dark matter experiments
    - Super-CDMS
    - Directional TPC/DRIFT-III
  - One low-energy solar neutrino experiment
    - LENS
  - One large multipurpose tracking detector
    - LANDD or UNO
  - Space for other opportunities

Ultimately will depend on technical progress in these fields and output of various SAG’s, P5, etc.
Upper campus
(8100’ level, 2500 mwe)

Available early, useful space for prototyping/R&D or experiments without deep requirements
Central Campus, 4200 mwe
Lower Campus, 6000 mwe
Low-Background Facilities*

- Tasks for S2 Study
  - Characterization of radiation sources
    - Radioactivity in core samples
    - Muon intensity vs depth
  - 3D radiation transport codes
    - Efficient shielding designs

* content provided by Tom Borak

Low-Background Facility Subcommittee:
- Thomas Borak, Colorado State U. (chair)
- Jonathan Ormes, Univ. of Denver (co-chair)
- Zeev Shayer, Univ. of Denver
- Frank Calaprice, Princeton
Low-background facilities

- **Upper campus (2500 mwe)**
  - Available early
  - Component screening facility
  - Shielded counting stations + ultralow shielded vault
  - Close to chemistry laboratory
  - Close to cleaning facility
  - Component storage areas

- **Lower campus**
  - Extremely low background
  - Specialized detector (similar to physics experiments)
    - Sensitivity 1 µBq
Example: measurement of core sample for U/Th content
Plans for HUSEP Physics Committee

- **Main deliverable:** contribution to CDR - *conceptual*
  - Prepare timeline of first suite of experiments for S2 report
  - Describe infrastructure needed to host first-suite envelope
  - Long-term capabilities

- **Incorporate/synthesize large body of input**
  - EoI’s, S1 reports, workshops

- **Now through June**
  - Adjust draft plan to workshop input, new opportunities
    - Expand list of potential occupants, pin down details for existing candidates
  - Writing retreats
  - Augment with weekly phone/video meetings
  - Continued close interaction with engineering/infra team
  - *Maintain contacts with groups planning experiments*
Workshop Physics Program

- Physics parallel session -- Fri/Sat
  - Physics scope/issues
  - Presentation of EoI’s
  - Questions to answer
    - Which Henderson DUSEL campus is most suitable for your experiment?
    - What is the required space?
    - Special needs: clean room, cryogenic facility, etc.?
    - Contingent on funding, when does experiment start?
    - Do you need space for R&D and prototypes before the full experiment? If so, when? And what are the needs?
  - Conclude with feedback on CDR process/content