LENS Prototyping Status Report

Presented by S. Derek Rountree
For the LENS Collaboration

Supported by the National Science Foundation
Solar Neutrino Spectrum

- Measurements limited to $^8\text{B}$ at $E > 2.8$ MeV, $^7\text{Be}$, and pep
- Needed -- Precise spectroscopic measurements pp, and CNO neutrinos
LENS Science Objectives

Solar physics:

1. Solar luminosity inferred from neutrino flux - compare to luminosity determined from photon flux
2. CNO flux - metallicity of the sun’s core & stellar opacity; transport of CNO elements- “NEW SOLAR NEUTRINO PROBLEM”

Neutrino physics:

1. Test of MSW-LMA neutrino oscillations - energy dependence of $P_{ee}$
2. Place constraints on Standard Model extensions - non-standard interactions, mass-varying neutrinos, magnetic moments
3. Improve current precision of $\theta_{12}$
4. Is there any evidence for sterile neutrinos at low energies? (LENS-Sterile)

Non-standard interactions

The LENS Experiment

Technique: Tagged charged current neutrino capture on $^{115}\text{In}$ loaded (~8%) in liquid scintillator

\[
\nu_e + ^{115}\text{In} \rightarrow e^- + \gamma + (\gamma/e^-) + ^{115}\text{Sn}
\]

- $^{115}\text{In}$ abundance ~ 96%
- Low threshold = 115 keV (access to 95.5% of pp $\nu$)
- Directly measures neutrino energy
  \[E_\nu = E_e + Q (115 \text{ keV})\]
- Principle challenge: background from $^{115}\text{In}$ beta decay ($\tau_{1/2} = 6.4 \times 10^{14} \text{ years}$)
  \[E_{\text{endpoint}} \sim 499 \text{ keV}\]
  (but this only affects p-p neutrinos, not $^7\text{Be}$, pep, CNO neutrinos)

\[\rightarrow 10 \text{ tons In} \rightarrow 8 \times 10^{13} \text{ decays/year (2.5 MHz)}\]

\[\text{compare to 400 } \nu_{pp} \text{ events/year}\]

1 (R.S. Raghavan, Phys. Rev. Lett. 37, 259 (1976)).
LENS Indium Loaded Scintillator

1. Neutralization

- **HMVA (>98%)**
  - Add NH₃OH
  - Organic
- **NH₄MVA + H₂O**
  - Salt in aqueous solution

2. Online purification

- **TBPO-toluene NH₄MVA**
- **TBPO-toluene NH₄MVA**
- **Organic Waste**

3. Solvent extraction and vacuum evaporation

- **TBPO-toluene InCl₃**
- **TBPO-toluene InCl₃**
- **In(MVA)₃ and LAB in Hexane**
  - Stir
  - Vacuum Evaporation
- **InLAB: In% = 8 S% 34-38 L₁/e > 8 m**
- **Aq. Waste**

---

Virginia Tech
Invent the Future®

S. Derek Rountree  10/29/2012
LENS Scintillation Lattice - Concept

→ High spatial resolution needed to decrease backgrounds
→ Optically segment (in 3D) a volume of scintillator
→ Use total internal reflection to channel the isotropically emitted scintillation light down axes of segmentation

Ideal for cubic lattice: $\theta_{\text{critical}} = 45^\circ \rightarrow n = 1.07 \rightarrow$ no light leakage (for $n=1.52$ scintillator)

$\theta_{\text{critical}} < 45^\circ , n < 1.07 \rightarrow$ no light leakage
$\theta_{\text{critical}} > 54.7^\circ , n > 1.24 \rightarrow$ no light trapped

Indices of some prospect materials:
- Teflon FEP $n \sim 1.34$
- Water $n \sim 1.33$
- Perfluorhexane $n \sim 1.25$
- Air $n \sim 1.0$
Film and structure?

Various single films (Fluoropolymers)
Double films with various fluids

Two methods

Teflon Acrylic (TA) combs
Fiber supported Lattice

Solution: Fiber supported Teflon FEP Lattice (\(\mu\)LENS)
\[ n = 1.34 \quad \theta_{\text{critical}} = 62^\circ \]
about 50% of light channeled with good timing properties
LENS Scintillation Lattice - Fiber Supported Lattice
LENS Scintillation Lattice - Teflon Acrylic Combs

µLENS Scintillation Lattice Filled with LAB
μLENS - A Test bed for LENS Optics Technologies

- Test as built Scintillation Lattice (SL) optics
- Prepare Kimballton Underground Research Facility (KURF)* for the miniLENS prototype
  - Dark containment construction and testing
  - Electronics development
  - Fluid handling construction and tests
  - Spill control systems for total volume
- Benchmark Monte Carlo for miniLENS
- Study KURF background rates for miniLENS
μLENS Status

Detector
• μLENS in place at KURF

Electronics & DAQ
• 36 Channels ready to instrument with TDC’s and QDC’s for initial tests
• Software development for CAEN V1721 ADC. Multiplexed instrumentation using the V1721 soon

Scintillator
• μLENS LAB on site at KURF with fluid handling system near
• 2 to 10L InLAB (8% by wt.) batch production demonstration for miniLENS feasibility test. (this InLAB may be incorporated into the μLENS program)

Infrastructure at KURF (VT)
• KURF (Kimballton Underground Research Facility near VT - 1400 mwe depth)
• Dark Containment
• DAQ housing and power
• Liquid handling spill control systems
To test LENS technologies, we are constructing a ~ 0.5 m³ prototype instrument (~ 0.5% of volume of full LENS detector)
~ 30 kg Indium in center active region → 2.5 kHz In beta decay rate

- Topology of events contained and identical to full LENS
- Bench-mark Monte Carlo
- Demonstrate scale-up route to full LENS
- Mini-LENS :
  - instrumented with 150 PMTs ~20% photocathode coverage.
  - Multiple coverage patterns can be investigated.
**Thanks**

- Special thanks to:
  - National Science Foundation
  - The LENS Collaboration
- Lead institutions:
  - Virginia Tech (R. Raghavan – Spokesman, M. Pitt, B. Vogelaar)
  - Brookhaven National Lab (M. Yeh – PI)
  - Louisiana State University (J. Blackmon – PI)

*And especially to the students & postdocs*

Thank You