The Low-Energy Neutrino Spectroscopy (LENS) collaboration aims to precisely measure the full spectrum of neutrinos emitted from the sun via real-time, charged-current interactions.

LENS is a next-generation solar neutrino experiment targeted towards the Deep Underground Science & Engineering Lab (DUSEL).

Threshold for $\nu_e$ reactions of 115 keV (95% of neutrinos)

Precise (3%) measurement of the spectrum of neutrinos from hydrogen (pp) fusion is main goal.

Also measure flux of neutrinos from reactions originating on CNO nuclei.
Solar physics

Precise comparison of current rate of energy production from fusion in the sun’s core to the photospheric luminosity of the sun.

- Is the rate of energy production in the sun constant?
- Variability of the radiative zone?
- Is energy lost to magnetic fields?
- Is there another source of energy in the sun?

\[
\frac{L_{\nu(\text{inferred})}}{L_{\nu}} = 1.2(0.2)
\]


Direct test of solar models

The shape of the pp neutrino spectrum → temp and location of hydrogen fusion in the core

J.N. Bahcall, PRD 49, 3923 (1994)  
Grieb & Raghavan, PRL98, 141102 (2007)

CNO flux → metallicity of the sun’s core & stellar opacity, transport of CNO elements
Neutrino physics

Precision test of MSW-LMA $\nu$ oscillations
$\sim 99\%$ of solar flux (pp, 7Be)
$P_{ee}(pp)=0.6$ (vac. osc.) & $P_{ee}(^{8}\text{B})=0.35$ (matter osc.)?

Do new physical phenomena show up only at the lowest energies, longest baselines, and high matter densities?

Will place stringent constraints on extensions to the Standard Model of particle physics
- Non-standard interactions
- Mass varying $\nu'$s
- Magnetic moments

Precision measurement of $\theta_{12}$

Determine $\theta_{13}$ ?!

Is there any evidence for sterile neutrinos at low energies?
Charged-current neutrino interactions on $^{115}$In to isomeric state

115 keV threshold

In-loaded (~8%) liquid scintillator (LAB)

High light output & long attenuation length

$(5 \text{ m})^3$ fiducial volume $\rightarrow$ 10 tons Indium

$\sim 400 \, \nu_{pp}$ events/yr (60% eff.) $\rightarrow$ 3% measurement in 3 years

But Indium is radioactive!

10 tons In $\rightarrow$ $8 \times 10^{13}$ decays/year ($\sim 2 \, \text{MHz}$)

How can we possibly suppress this huge background?

Critical issues: light collection, resolution (space/time), calibration
The LENS Architecture

Optically segment (in 3D!) a volume of scintillator

Use total-internal reflection to channel light down axes of segmentation

Ideal material is a highly transparent solid material with low index of refraction

Best solution:
Thin fluoropolymer (n=1.34) coating on poly or acrylic
$\theta_{\text{crit}} \approx 60^\circ$
About 50% of light “channeled”
Allows “digital” identification of position
About 50% direct light
Increases total light output
1350 pe/MeV
Allows for more precise timing
Expected performance

Performance for real $\nu$ events and a litany of background sources modeled

Each Indium $\beta$ decay mimics the prompt electron from $(\nu_e, e)$

Prompt $(\nu_e, e)$ is correlated in time-space with 614 keV $\gamma$’s

Most dangerous background is Bremstrahlung in coincidence with random coincidence with prompt decays.

Require random coincidence within shower radius to mimic cascade $\rightarrow > 10^7$ background reduction

Simulate events and apply cuts on the shower topology and time/energy resolution
1 m³ prototype instrument
Now under construction
Will demonstrate all key aspects
Establish scale-up route
~ 5kg Indium in center active region
non-loaded buffer similar to full LENS

Topology of events in miniLENS is \textit{identical} to the full LENS
Allows the discriminating power of the geometry to be fully tested.

Measurements will be carefully benchmarked to Monte-Carlo to establish the performance of the full instrument $\rightarrow$ straightforward extrapolation

Funding via DUSEL R&D and LA Board of Regents, but not sufficient to allow full instrumentation. About 11% (150 PMT’s) of miniLENS will be instrumented and digitized at once. Series of measurements benchmarked by Monte Carlo will completely characterize the performance of miniLENS.
MiniLENS Status

Mechanical design for MiniLENS
70 liter prototype (μLENS) is currently being tested at VTU
Acrylic + thin fluoropolymer film
Construction of MiniLENS to start next month

Electronics & DAQ
All major electronics (for 150 PMT’s) on hand
Electronics being developed and tested now with few PMT’s
11/2008 - μLENS to be shipped to LSU for DAQ development

Scintillator
Lab for intermediate-scale scintillator production being developed

Goal is to have the 1 m³ detector operating in KURF in ~ 2 years
“S4” Proposal currently in preparation

Targeted towards engineering needed to deploy the full scale LENS instrument at DUSEL

- Structural engineering
  - Outer vessel
  - Infrastructure

- Scintillator
  - Scaling path for processing/purification
  - Storage and secondary containment underground

The timing of S4 with the simultaneous deployment of miniLENS will allow the most cost-effective path scale-up path to be defined.
The **LENS Collaboration**


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**Who**