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TAUP, July 2017
Nature Sets the Scale

$m_h = 120 \text{ GeV}$

Rafael F. Lang, Purdue: Liquid Xenon Rare Event Observatory
WIMPs: Best Motivated Target Still

highly motivated parameter space, e.g.

- SUSY etc.
  here: arxiv hep-ph/0001005
- Higgs Portal
- inelastic couplings (box) to $Z$, $W^+$, $H$

- generic $\sigma \sim \frac{(\varepsilon g_2)^2}{m_\chi^2}$

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Probe WIMPs down to Neutrinos

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Conceptual Design

- Based on proven technologies
- Water Cherenkov shield
- Liquid scintillator neutron veto
- 40 ton liquid xenon TPC
- 2.6m height & diameter
- ~1800 3” or ~1000 4” PMTs
- Exposure >5 years
Background: pp solar $\nu$ signal

$^{136}$Xe (assumes $^{nat}$Xe)

0.1ppt $^{nat}$Kr
(half XENON1T design)

0.1$\mu$Bq/kg $^{222}$Rn
(1% XENON1T design)

materials fiducialized
Challenges & Status

- Xenon - long lead time. Re-use existing experiments’ inventories
- High Voltage - 0.5kV/cm drift requires 130kV. 100kV shown, improved electrode design
- Purity – remove electronegative and radioactive contaminants. Liquid recirculation, online cryodistillation, surface treatment, fluid motion
- Discrimination – collect exposure faster. $10^{-5}$ at 50% acceptance shown

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Three Low-Energy Signal Regions

demonstrated discrimination $>10^{-5}$ driven by light yield and field uniformity
Three Low-Energy Signal Regions

electronic recoils: measure pp solar $\nu$

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**Three Low-Energy Signal Regions**

- Electronic recoils: measure pp solar $\nu$
- Nuclear recoils: search WIMPs
- Demonstrated discrimination $>10^{-5}$
- Driven by light yield and field uniformity

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Three Low-Energy Signal Regions

electronic recoils: measure pp solar $\nu$

nuclear recoils: search WIMPs

nuclear recoils: measure $^8$B solar $\nu$

demonstrated discrimination $>10^{-5}$
driven by light yield and field uniformity
includes all backgrounds, 99.98% ER rejection @30% NR acceptance, likelihood with combined energy scale 5-35 keV\textsubscript{nr} and light yield 8 PE/keV

with signal, measure
• SI & SD couplings
• WIMP mass
• first halo properties
Many Dark Matter Channels

Anything that interacts with electrons or nuclei really:

- spin-independent & spin-dependent WIMPs
- inelastic and general EFT couplings
- S2-only for GeV WIMPs
- with Bremsstrahlung searches for 100 MeV WIMPs
- leptophilic dark matter, axial-vector interactions
- Axion-like particles and Solar axions
- SuperWIMPs
- dark photons
- keV sterile neutrinos
Solar Neutrino Elastic Scattering

3 (keV t yr)$^{-1}$ from pp $\nu_e + e^- \rightarrow \nu_e + e^-$

extra 8% from $^7$Be

flux known to 2% but free electron approximation bad:

- Refine solar models
- Measure $\sin^2 \theta_W$ to ~1%
- Measure $^7$Be $\nu$ flux
Coherent Neutrino Nucleus Scattering

\[ \nu_x + N \rightarrow \nu_x + N \]

once transferred momentum \( p > \hbar / r_{\text{nucleus}} \)
get same coherence effect as for WIMPs: \( \sigma \propto A^2 \)

90 \(^8\)B \( \nu \) from Sun/t/yr
above 1 keV\(_{nr}\):
solve solar metallicity
3 \times 10^{-3} \text{ atmospheric } \nu/t/yr
above 3 keV\(_{nr}\):
probe at low energies
Supernova!

\[ \nu_{e,\mu,\tau} + Xe \rightarrow \nu_{e,\mu,\tau} + Xe \]

few second burst:
S2 only analysis

CC: \( \mathcal{O}(0.1)\bar{\nu}_e/t \)
versus
CNNS: \( \mathcal{O}(10)\nu_x/t \)

sensitivity out to SMC

flavor-independent!

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$^{136}\text{Xe}$ $0\nu 2\beta$ With $^{\text{nat}}\text{Xe}$ Target

$^{136}\text{Xe} \rightarrow ^{136}\text{Ba} + 2e^-$ (abundance 8.9%, i.e. ~4t in target)

Requires large dynamic range of detector

Plus: DEC on $^{124}\text{Xe}$ and $^7\text{Be}-\nu$ capture on $^{131}\text{Xe}$
A Xenon Rare Event Observatory

- Close WIMP gap: probe down to atmospheric $\nu$ signal
- Use scale-up of proven technology
- Xenon sensitive to wide array of dark matter models including spin-dependent and electron couplings
- $^{136}$Xe Double Beta experiment
- pp, $^7$Be, $^8$B and Supernova neutrino detector

- Consortium formed in 2009, commissioning ~2025
- Currently 25 groups from 11 countries
- Many expressions of interest - contact us to join