DUNE as the Next-Generation Solar Neutrino Experiment

Shirley Li
SLAC

SUSY, May 2019
Tension in current data

Solar $\nu$ vs. reactor $\nu$

Data from SK 2016

Tension driven by day-night effect

Reactor: vacuum oscillation

Solar: matter effect

Figure credit: F. Capozzi

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New physics?

Friedland, Lunardini & Pena-Garay, 2004

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Tension in current data

Data from SK 2016

Solar $\nu$ vs. reactor $\nu$

Reactor: vacuum oscillation

Solar: matter effect

Tension driven by day-night effect

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What we want to measure

\[ \sin^2 \theta_{12} \quad \Delta m_{21}^2 \]

\[ P_{ee} \]

\[ \phi_e / \phi_{\text{total}} \text{ as a function of } E_\nu \]

Capozzi et al, 2018

sno.phy.queensu.ca
DUNE - MeV

4 10-kton liquid argon TPC module

- Trigger
- $T_e > 5$ MeV
- Energy resolution 7%
- Angular resolution 25°
Unique advantage of DUNE

CC channel: \( \nu_e + \text{Ar} \rightarrow e + K^* \) --- \( \phi_e \)

ES channel: \( \nu_x + e \rightarrow \nu_x + e \) --- \( \phi_e + \frac{1}{6}(\phi_\mu + \phi_\tau) \)
Unique advantage of DUNE

CC channel: $\nu_e + \text{Ar} \rightarrow e + K^*$ --- $\phi_e$

ES channel: $\nu_x + e \rightarrow \nu_x + e$ --- $\phi_e + 1/6(\phi_\mu + \phi_\tau)$

Improve on $\sin^2 \theta$

Capozzi et al, 2018

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Unique advantage of DUNE

CC channel: $\nu_e + \text{Ar} \rightarrow e + K^*$

Good energy reconstruction:

$$E_e = E_\nu - Q - \Delta E$$

Difficult channel:

$$\nu_x + e \rightarrow \nu_x + e$$

Improve on $\delta m^2$

Capozzi et al, 2018
Event rate in DUNE

100 kton-year exposure

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Capozzi et al, 2018
Results

In addition, $^8$B flux 2.5%, hep flux 10%

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Capozzi et al, 2018
Backgrounds

Requires ~ 40 cm of water / plastic shielding or double the exposure

Capozzi et al, 2018

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Conclusions

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Back up
# Measured metallicities

<table>
<thead>
<tr>
<th>Element</th>
<th>GS98</th>
<th>AGSS09met</th>
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<tbody>
<tr>
<td>C</td>
<td>8.52 ± 0.06</td>
<td>8.43 ± 0.05</td>
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<tr>
<td>N</td>
<td>7.92 ± 0.06</td>
<td>7.83 ± 0.05</td>
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<tr>
<td>O</td>
<td>8.83 ± 0.06</td>
<td>8.69 ± 0.05</td>
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<tr>
<td>Ne</td>
<td>8.08 ± 0.06</td>
<td>7.93 ± 0.10</td>
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<tr>
<td>Mg</td>
<td>7.58 ± 0.01</td>
<td>7.53 ± 0.01</td>
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<td>Si</td>
<td>7.56 ± 0.01</td>
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<tr>
<td>S</td>
<td>7.20 ± 0.06</td>
<td>7.15 ± 0.02</td>
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<td>Ar</td>
<td>6.40 ± 0.06</td>
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<tr>
<td>Fe</td>
<td>7.50 ± 0.01</td>
<td>7.45 ± 0.01</td>
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<tr>
<td>(Z/X)☉</td>
<td>0.02292</td>
<td>0.01780</td>
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## Cross section

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<tr>
<th>i</th>
<th>$\Delta E_i$ [MeV]</th>
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<th>$B_i$(GT)</th>
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<td>3</td>
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<td>4</td>
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<td>0.16</td>
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<td>5</td>
<td>3.870</td>
<td>0.44</td>
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<td>6</td>
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<tr>
<td>total</td>
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<td>4.00</td>
<td>8.29</td>
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</table>
Cross section

cc \left[ 10^{-43} \text{ cm}^2 \right]
Mass square sensitivity

$A_{D/N} \%$

$m_3^2 [10^{-5} \text{eV}^2]$

solar best fit

reactor best fit

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Threshold

Depends on reconstruction & background level

Capozzi et al, 2018
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Sensitivity loss due to statistics
It can be compensated by larger exposure.

Up to $\sim 8$ MeV

Threshold

Capozzi et al, 2018

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Cross section

Current uncertainty: a few %

Capozzi et al, 2018

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Reconstruct neutrino energy

Event Spectrum [ MeV$^{-1}$ ]

Event Energy [MeV]

B CC

Backgrounds

30 degree CC

Backgrounds

Electron + Gamma Ray

Single Electron

Inside Forward Cone

Capozzi et al, 2018

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Worse energy resolution

Capozzi et al, 2018

Shirley Li (SLAC)
Backgrounds

Capozzi et al, 2018

![Graph showing electron kinetic energy distribution with different labels for background sources such as pre-cut spallation, neutron with and without shielding, 39Ar, 42Ar, 42K, and 214Bi from 100 Bq/m^3 222Rn with a 20% resolution.](#)