DUSEL “Megaton” Multi-Module Detector Array Plan

1) Array of 100-150 kiloton fiducial mass $\text{H}_2\text{O}$ Cerenkov Detectors at DUSEL (4200 mwe)

2) 1300 km long $\nu_\mu$ beam - FNAL $\rightarrow$ DUSEL
   (0.7 $\rightarrow$ 1.2 $\rightarrow$ 2.0 Megawatt FNAL beam)

3) Eventual addition of $\sim$ 100 kt liquid Argon tracking detector
Scientific Goals

With FNAL neutrinos

1) Measure $\theta_{13}$, (if not previously determined)

2) Determine neutrino mass ordering

3) Look for non-zero $\delta_{\text{CP}}$

Non-accelerator

1) Proton Decay

2) Relic SN neutrinos

3) Prompt SN $\nu$

4) Atmospheric $\nu$'s

5) Solar Neutrinos
S-K Detector: 40 m dia. x 40 m high

DUSEL Detector modules: 50-60 m dia x 50-60 m high
Layout of First Six Chambers
Single DUSEL
water Cerenkov module
55m diameter
$\nu_\mu$ Disappearance after 1300 km (FNAL $\rightarrow$ DUSEL)

Total event rate with 300 kT and 2 MW is $\sim$200000 cc evts/yr

(no oscillations, raw events)


★ yr$\sim$2x10$^7$ sec
$\nu_e$ appearance signal
300 kT detector and
$10^{20}$ Protons (60 GeV)
on Target at FNAL

$\delta_{CP} = -45^\circ, \quad \delta_{CP} = +45^\circ$

Normal Mass Ordering  Reversed

Mark Dierckxsens(UChicago), Mary Bishai(BNL)
Ultimate Reach
60 GeV, 2MW, 3+3 yrs, 300kT

Mass ordering

\[ \theta \]

CP Violation

\[ \nu + \bar{\nu}, 1300 \text{km} \]
\[ 120 + 120 \times 10^{20} \text{PoT} \]

\[ 3\sigma (\Delta m^2_{31} > 0) \]
\[ 5\sigma (\Delta m^2_{31} < 0) \]

0.007 50% coverage at 3 sigma

stat + 5% syst

Mark Dierckxsens (UChicago), Mary Bishai (BNL)
Nucleon Decay

- Large body of work by HyperK, and UNO.
- Background levels for $e^+ + \pi^0$ mode
  - 3.6/MTon-yr (normal)
  - 0.15/MTon-yr (tight)

Expected Sensitivity on K-$\nu$ mode is about $\sim 8 \times 10^{33}$ yr

Ref: Shiozawa (NNN05)

300 kilotons x 10 yrs $\Rightarrow 10^{35}$ proton yrs
# Uranium, Thorium, and Potassium Values from the Homestake Core Archive*

<table>
<thead>
<tr>
<th>Core / Core Location</th>
<th>U (ppm) ±(5 – 10)%</th>
<th>Th (ppm) ±(5 – 10)%</th>
<th>K (%) ±(1 – 2)%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core #11537 <strong>Yates Member</strong> - vertical hole starting at 4850L (1/2 way between Ross and Yates Shafts) – multiple core samples measured</td>
<td>0.16</td>
<td>0.20</td>
<td>1.54</td>
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<tr>
<td></td>
<td>0.55</td>
<td>0.30</td>
<td>2.12</td>
</tr>
<tr>
<td>Core #11553 <strong>Yates Member</strong> drilled from 4850L – multiple samples measured</td>
<td>0.21</td>
<td>0.30</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>0.19</td>
<td>0.19</td>
<td>0.92</td>
</tr>
<tr>
<td>Core #15537 <strong>Poorman</strong> Formation Horizontal hole at 7200L</td>
<td>0.08</td>
<td>0.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Core #15532 <strong>Yates/Poorman</strong> from 7300L to 7450L – multiple core samples measured</td>
<td>0.08</td>
<td>0.25</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>0.085</td>
<td>0.25</td>
<td>0.125</td>
</tr>
<tr>
<td>Core #18627 <strong>Yates Member</strong> drilled from 7400L – multiple core samples measured</td>
<td>0.18</td>
<td>0.24</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>0.49</td>
<td>0.20</td>
<td>0.57</td>
</tr>
<tr>
<td>Cores #15680 - 820, 17581 - 822, 11553 - 059, 11537 - 180; <strong>Rhyolite dikes</strong> – averaged from four samples</td>
<td>8.6</td>
<td>10.8</td>
<td>2.9</td>
</tr>
</tbody>
</table>

*Al Smith, LBNL Low Background Counting Facility
For other than the **rhyolite dikes** these values are a factor of 10 to 20 lower than typical granites
Conclusion: 4200 mwe provides the necessary Cosmic Ray $\mu$ flux reduction
- North American Power Reactor Map – DUSEL ~ 500 km from nearest reactors – reactor $\bar{\nu}_e$ flux ~ 1/30 of that at S-K
Relic SN $\bar{\nu}_e$ flux at SK –

note: $\mu$ decay bkgnd $\sim$ 20 lower at DUSEL Reactor $\bar{\nu}_e$ flux $\sim$ 30 lower at DUSEL
SN neutrino burst detection

1) For SN in our Galaxy expect \(\sim 10^5\) events in 10 seconds (300 kiloton)

2) For SN in M31 expect about 10-15 events in 10 seconds (300 kilotons)
The DUSEL H$_2$O Cerenkov Modules are enlarged versions of the SK detector.

<table>
<thead>
<tr>
<th></th>
<th>S-K</th>
<th>DUSEL</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>40 m</td>
<td>55 – 65 m</td>
<td>Rock strength</td>
</tr>
<tr>
<td>Height</td>
<td>40 m</td>
<td>55 – 65 m</td>
<td>PMT strength</td>
</tr>
<tr>
<td>Fiducial volume</td>
<td>22 kT</td>
<td>3 x (100 – 170 kT)</td>
<td>Larger &amp; multiple Modules</td>
</tr>
<tr>
<td>PMT dia.</td>
<td>50 cm</td>
<td>25 – 30 cm</td>
<td>Higher photocathode efficiency, stronger, smaller volume, improved timing and position determination</td>
</tr>
</tbody>
</table>
DUSEL Detector Construction

1) Excavate chambers
2) Install water tight liner
3) Mount PMTs – all materials compatible with Gd
4) Fill with purified water
5) Connect electronics
6) LOOK!
Technically Driven Timetable

1) 9/2009-12/2010 - Rock strength studies
2) 1/11-12/11 – Construct access & rock removal tunnels
3) 1/12 - 3/16 – Excavate
4) 4/16 - 3/17 – Install PMTs & water fill module 1 – turn on after 4/17
5) 4/17 - 3/18 – Install PMTs & water fill module 2 – turn on after 4/18
6) 4/18 - 3/19 – Install PMTs & water fill module 3 – turn on after 4/19
7) Financial timetable - ????
The concept originated in 2002 after SuperK and Kamland discoveries.
Location of the Homestake Beamline

Extraction uses upstream portion of NuMI line

New tunnel starts near end of Carrier Tunnel

NuMI/HOMESTAKE

NuMI/MINOS & NuMI/NOVA
Location of the Homestake Beamline

NUMI/HOMESTAKE

NUMI/MINOS & NUMI/NOVA

New Target Hall, Shaft, and Service Building
This elevation view of the Homestake Beamline (-5.84°) is drawn to take the detector to the site boundary at Kirk Road. The maximum decay pipe length available in this configuration is about 627m (compare to NuMI at 675m). The detector hall (and shaft) is about 575 feet deep (compare to MINOS at about 336 feet). This is still in the Galena-Platteville but deep.
This elevation view of the Homestake Beamline (-5.84°) is drawn with the decay pipe limited to 400m. This shortens the beamline by 741 feet, and lifts The detector hall (and shaft) by about 75 feet (500 feet deep). Overall, this configuration will be cheaper to build and is probably adequate.
Where will we be in 10 years?

1) SN burst detection - ≥ 3 detectors – Japan, U.S., Canada, Europe, India

2) Proton Decay ≥ 3 detectors – Japan, U.S., Canada, Europe, India

3) Neutrino beam base lines:
a) 295 km – T2K
b) 730 km – FNAL-Soudan & CERN – Gran Sasso
c) 1300km – FNAL-DUSEL
d) +?????