Future prospects for large area ground & space-based neutrino detectors

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JPL Tracking & Applications Section 335
RADHEP 2000
UHE/EHE Neutrino Detector Possibilities

- Of order $10^{43}$ nucleons if we want $\sim 100$ GZK nu events per year at $>10^{18}$ eV
  - Muon tracking no longer helps above $\sim 1$ PeV because the range grows slowly
  - $\sim 10^4$ km$^3$ of ice
- Detectors fall into 3 classes:
  - **VOLUME ARRAYS (VAs):**
    - Traditional approach to particle detection: instrument a fiducial volume with detector elements of sufficient number density to track the cascade Cherenkov emission
    - RICE (radio), AMANDA, ANTARES, NESTOR (optical) are examples
    - Lowest energy threshold, but most expensive
  - **SURFACE ARRAYS (SAs):**
    - For these types, the Cherenkov is detected at the outer surface of the fiducial volume
    - SuperKamiokande is the primary example for optical Cherenkov
    - A saltbed or ice array could follow this or the previous approach
    - Radio air shower arrays are also in this category
    - Can get large volumes for modest cost in very clear media
  - **EXTERNAL ARRAYS (EAs):**
    - Radiation exits the fiducial volume and is detected at a distance
    - Lunar Radio experiments are the prototype
    - largest volume for lowest cost, but high energy threshold
## UHE/EHE Neutrino Detector possibilities

<table>
<thead>
<tr>
<th>medium</th>
<th>area</th>
<th>depth</th>
<th>solid angle</th>
<th>E_thr</th>
<th>type</th>
<th>description</th>
<th>reference</th>
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</thead>
<tbody>
<tr>
<td>Antarctic ice</td>
<td>1e4 km^2</td>
<td>2 km ice</td>
<td>~2pi</td>
<td>1e18</td>
<td>VA</td>
<td>super-RICE array</td>
<td>RICE collab.</td>
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<tr>
<td>Antarctic ice</td>
<td>1.2e6 km^2</td>
<td>~150m</td>
<td>~0.1</td>
<td>1e19</td>
<td>EA</td>
<td>balloon at 30km altitude</td>
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<td>Greenland ice</td>
<td>1.8e6 km^2</td>
<td>~90m</td>
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<td>1e20</td>
<td>EA</td>
<td>geostationary orbiter</td>
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<tr>
<td>Earth atmosphere</td>
<td>1.6e7 km^2</td>
<td>10mwe</td>
<td>~1</td>
<td>~1e20</td>
<td>EA</td>
<td>Space station array</td>
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<tr>
<td>Dry lake array</td>
<td>160km^2</td>
<td>10mwe</td>
<td>~0.1</td>
<td>3e16</td>
<td>SA/EA</td>
<td>lakebed surface array</td>
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<tr>
<td>Auger array</td>
<td>5e3 km^2</td>
<td>10mwe</td>
<td>~3</td>
<td>1e19</td>
<td>SA</td>
<td>deep EAS, in constr.</td>
<td>Zas et al. 98</td>
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<tr>
<td>Goldstone</td>
<td>2e6 km^2</td>
<td>10mwe</td>
<td>0.05</td>
<td>1e20</td>
<td>EA</td>
<td>existing experiment</td>
<td>this conf.</td>
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<tr>
<td>super-Goldstone</td>
<td>7.5e6 km^2</td>
<td>20mwe</td>
<td>0.05</td>
<td>2e19?</td>
<td>EA</td>
<td>bigger beam, more BW</td>
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<tr>
<td>Compact salt array</td>
<td>10 km^2</td>
<td>100m salt</td>
<td>2pi</td>
<td>1e16</td>
<td>VA</td>
<td>instrument existing mines</td>
<td>M. Chiba, RICE grp.</td>
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<tr>
<td>Giant Salt array</td>
<td>3e4 km^2</td>
<td>300m salt</td>
<td>2pi</td>
<td>1e18</td>
<td>VA</td>
<td>0.5% US evaporite area</td>
<td>M. Chiba, RICE grp.</td>
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<tr>
<td>Lunar orbiter</td>
<td>1.2e7 km^2</td>
<td>20mwe</td>
<td>0.1</td>
<td>1e18</td>
<td>EA</td>
<td>h ~ 2 lunar radii</td>
<td>...</td>
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</tbody>
</table>
RF Propagation in natural dielectric solids

- **Volume and surface arrays:**
  - Require 10’s to hundreds of meters attenuation length for low detector number density
  - Probably limited to ice and clear salt due to low L_atten & ease of penetration
  - Volume/surface arrays generally get large solid angle coverage

- **External arrays**
  - Sand, dry clays, limestone, & granite are all additional possibilities giving reachable depths of ~10-20 m

- **Array limitations:**
  - Volume: requires several antennas per attenuation volume, more for high efficiency
  - External arrays are limited in solid angle, and effective volume must lie within the antenna beam
Desert Playas (Dry lakes): RF surface Array

Area: ~160 km$^2$, near Barstow

Tracking possible by use of polarization measurements:

Plane of polarization preserves projected track direction

~3 cubic kmwe possible for modest array at Coyote Lake!
RF properties of Halite

- Natural salt can be extremely low loss: ~ as clear as very cold ice, nearly 2 1/2 times as dense

- Typical salt dome halite is comparable to ice at -40°C

- Good evaporite halite (salt beds) is still comparable to clearest seawater/ice in optical

SALT curves are for (top): purest natural salt; (middle): typical good salt dome; (bottom) typical good salt bed halite.
Waste Isolation Pilot Plant: Potential Salt Detector Testbed

- GPR measurements (Roggenthen 97) indicate $L_{att} \sim 100\text{m}$ at $100\text{MHz}$
- New measurements planned for early December
- DOE site -- mandate for science support (Richardson 2000)
ISS Radio Neutrino Array: transition & Cherenkov radiation detector utilizing ocean reflectivity

- Geosynchrotron & radio Cherenkov from extensive air showers
- Backward TR from EAS that impact the ocean
- Threshold ~ 1e20 eV
- ~2000 km to horizon from 350km LEO
- Requires 3 or more elements
  - ~ 80m separation possible
  - ~ 5 deg resolution @ 50MHz
  - Dual polarization necessary
  - RFI an issue