Temperature Measurements in a Milagro Outrigger Detector

John A.J. Matthews and Bill Miller

johnm@phys.unm.edu

University of New Mexico
Albuquerque, NM 87131
Where is ... Milagro?

The Milagro TeV $\gamma$-ray detector is at:

- Latitude 35.8 degrees, Longitude $+106.67$ west
- Elevation: 8650ft / 2650m
Outrigger detector ... Details & Dimensions

- **One** central PMT, enclosure ~ 1/2-immersed, **only electronics: PMT-base**
- Water depth *typically* ~30-inches *(i.e. deeper than drawn)*
- Smaller water volume and colder winter temperatures (than Auger South)
- In winter often “several inches of ice on water top surface/sides ...
  **but never close to freezing solid!”**
• Top fill port: 4 temperature sensors

• Hole under detector ~ 22”-deep with 2 temperature sensors: one ~18”-(in) from tank edge [Ch 1] and one ~12”-(in) from tank edge [Ch 2]
In-tank ... string of 4 sensors

Thermocouple string:
- ~13" in from the edge of the tank
- depths (below the surface of the water) of <1" (i.e. "at the surface") [Ch 4], 14" below the surface [Ch 5], 22" below the surface [Ch 6] and 28.5" below the surface (i.e. about 1.5" above the bottom) [Ch 7]
Ambient T [Ch 3] and Solar Sensors [Ch 0]
Sample at 1/minute ... **mid to end Sept 2006**
Tank temperature ... September 2006 details

- [left plot] tank T-sensors show T-gradient: coolest (bottom=black) to warmest (top=violet) ... *large daily temperature variations* ... *not a good thing!*
  
- [right plot] but NO T-gradient on cloudy days!
Upgrade ... solar panel + fix storm damage
Finally surface freezing ... in middle and late Nov
Tank temperature ... November 2006 details

- **[left plot]** tank T-sensors show *inverted* T-gradient: coolest (top) to warmest (bottom) ... with top probably freezing at night and thawing during the day ... **not a good thing!**

- **[right plot]** now the top (**violet**) stays frozen day and night!
Then endless snows ... until late Jan 2007

Milagro experiences significant snow cover during the coldest months.

Tanks in full sun have least snow (cover).

Tanks in the shade (not shown) can be totally covered.
Then endless snows ... until late Jan 2007
• **Note:** likely temperature offset of ~ $1^\circ$ for all sensors

• Many (*more*) examples of tank surface (*violet*) night-time freezing followed by day-time warming

• Other depths in the tank (*orange, brown and black*) above freezing
Tank temperature ... January 2007 details

- Only **one** period of sustained freezing of the tank surface (**violet**)
- Middle of the tank (**orange**) close to $0^\circ$ but probably above freezing
- **Ground temperatures remain above freezing** ($\sim 3^\circ$ C)
Milagro ground temperature ... agree with our data!

- Milagro temperature sensor ~ 12 inches below the surface ... not under a tank
- Temperature record for 2006 top, and 2007 bottom
- Ground temperatures remain above freezing: possibly a consequence of typical snow cover at Milagro during the coldest months.
My own ... **impressions!**

- We observe large temperature variations in the tank ... especially near the top surface. Of these freezing:thawing is probably the most damaging to components in the tank. **Insulation of Auger North tanks should reduce these variations substantially!**

- The ground under the tanks remains *warm* ... and slowly varying in time (*e.g.* through Jan 30, 2007 the ground was warmer than the water!) **This, AND the typical snow cover at Milagro during the coldest months, may explain why: “the Milagro tanks are never close to freezing solid!”**

- Future plans: add insulation to Milagro outrigger tank in **steps.**

- Do we want to do some ground temperature studies in Lamar?