“Solar and Wind Power System for the ARIANNA Array”

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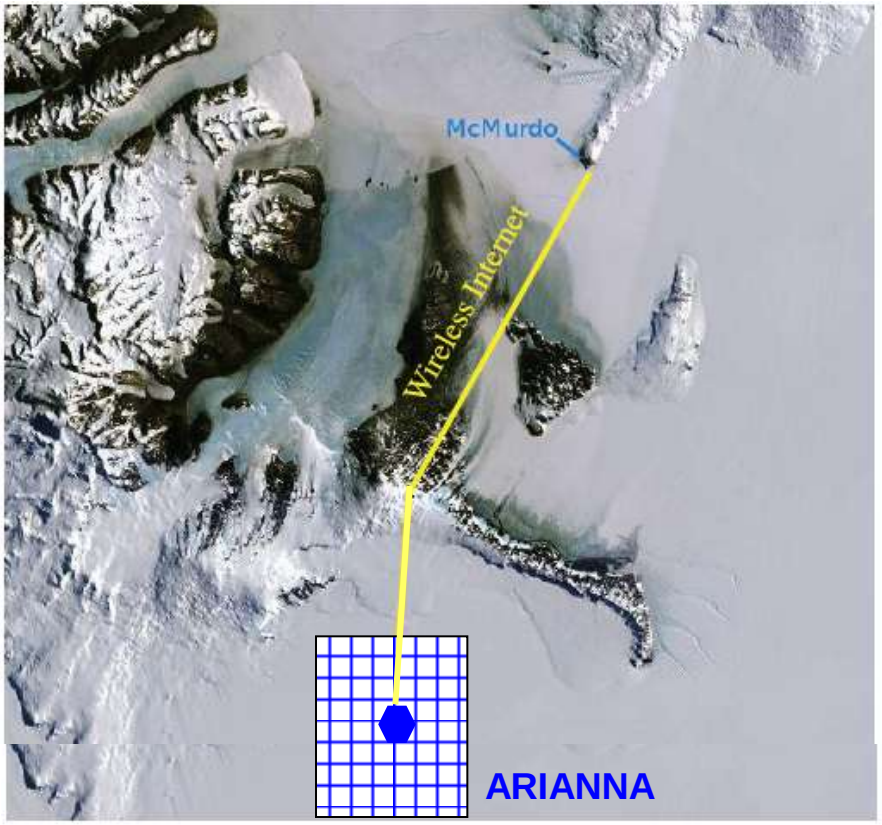
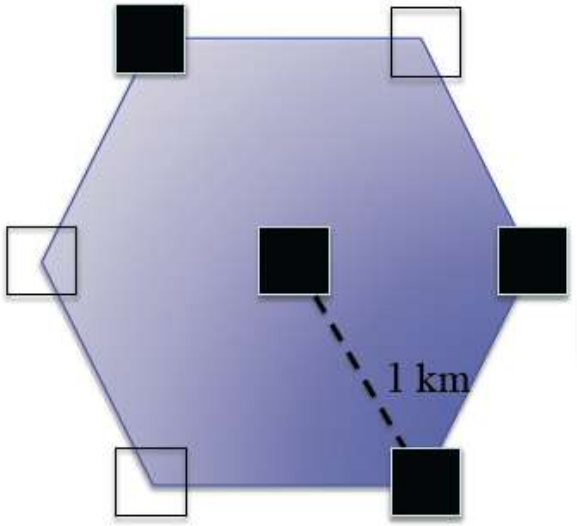
representing the ARIANNA Collaboration
(USA, Sweden, New Zealand)
http://arianna.ps.uci.edu

2013 April 2
Polar Technology Conference

ARIANNA =
Antarctic Ross Ice shelf ANtenna Neutrino Array





Deployed 2012

Planned 2013

7 stations funded by NSF
900 stations envisioned

Communications

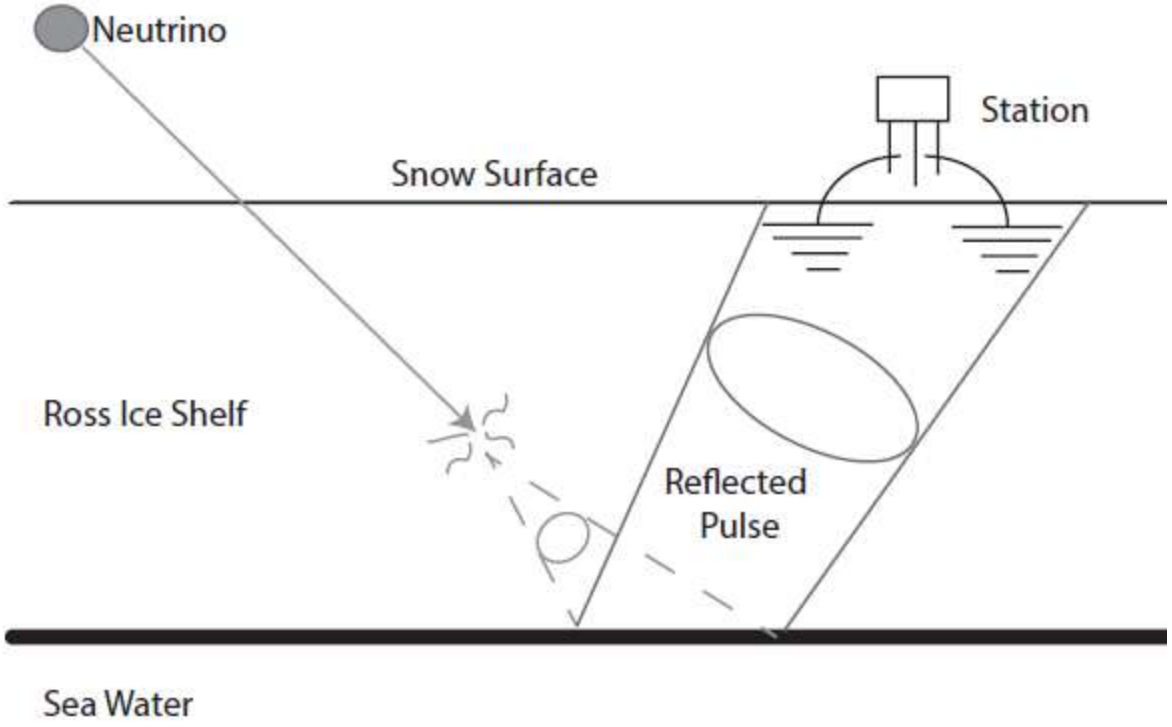
AFAR Communications, Santa Barbara, CA
radio model number AR24027E 2.4GHz WLAN

Each station to USAP Mt. Discovery relay point
then direct to McMurdo

IRIDIUM SBD module, NAL Research
model A3LA-XM 1.6GHz Satellite

Each station through DoD network
then to ARIANNA gmail and UCI server

Ultra-high Energy Neutrino Detection



Radio Cherenkov pulse
Detection band 100-1000MHz

Need LOW NOISE environment!

ARIANNA Station Components

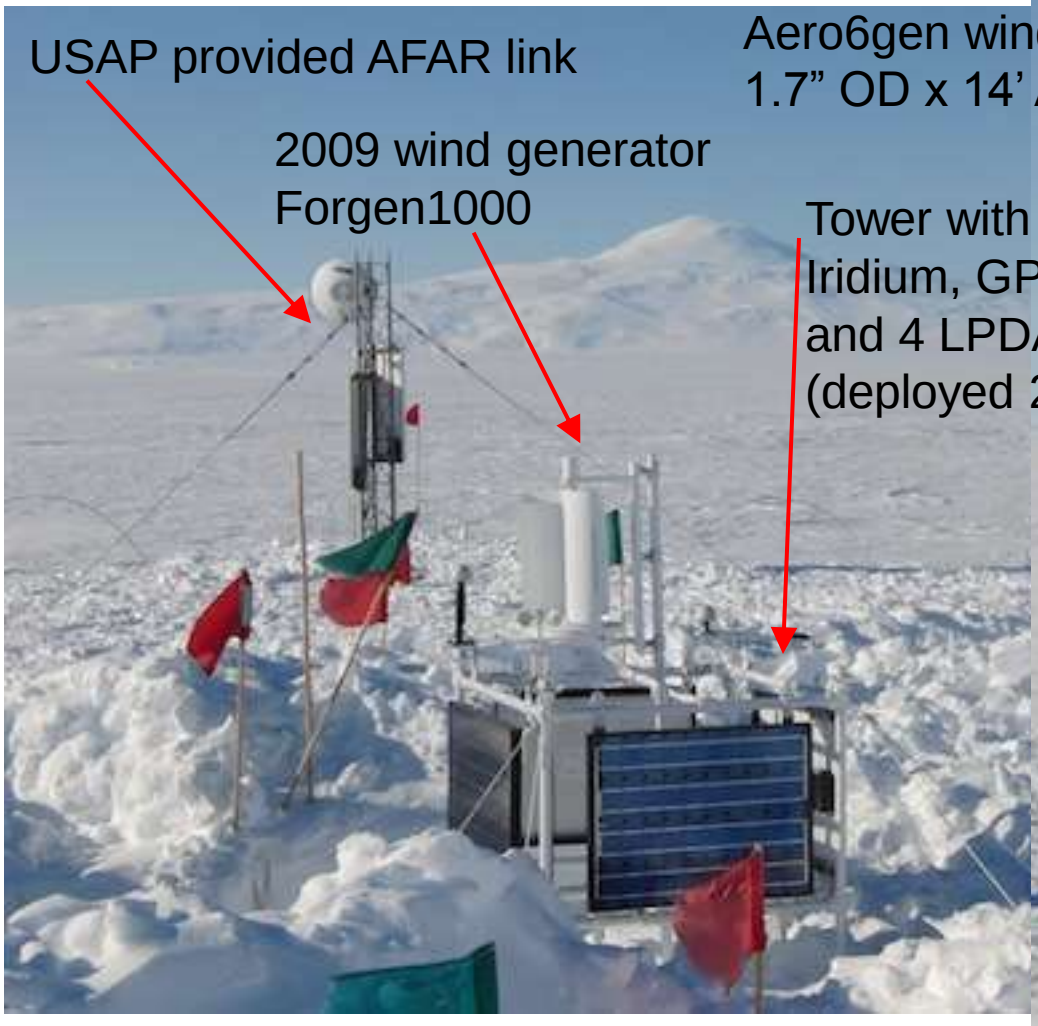
Tower(s) for: Communications antennas
Solar panels for austral Summer operation
Wind generator for potential Winter operation
Batteries (large ice chest; Temp +20 to -40C)
DAQ electronics: custom 2GHz, threshold triggering,
65dB gain amps
4 LPDA antennas

<u>Net power usage:</u>

2009 deployment = n/a, test system
2010 deployment = 30W
2011 deployment = 20W
2012 deployment = 10W
2013 deployment = 10W expected

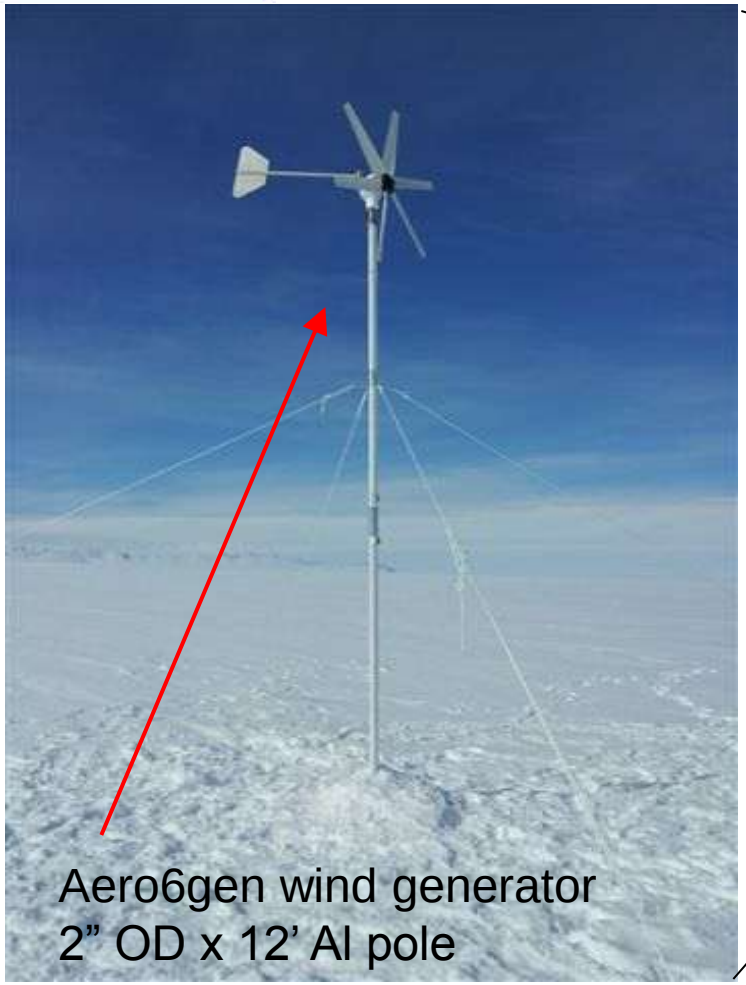
2010 deployment

Barwick, Hanson



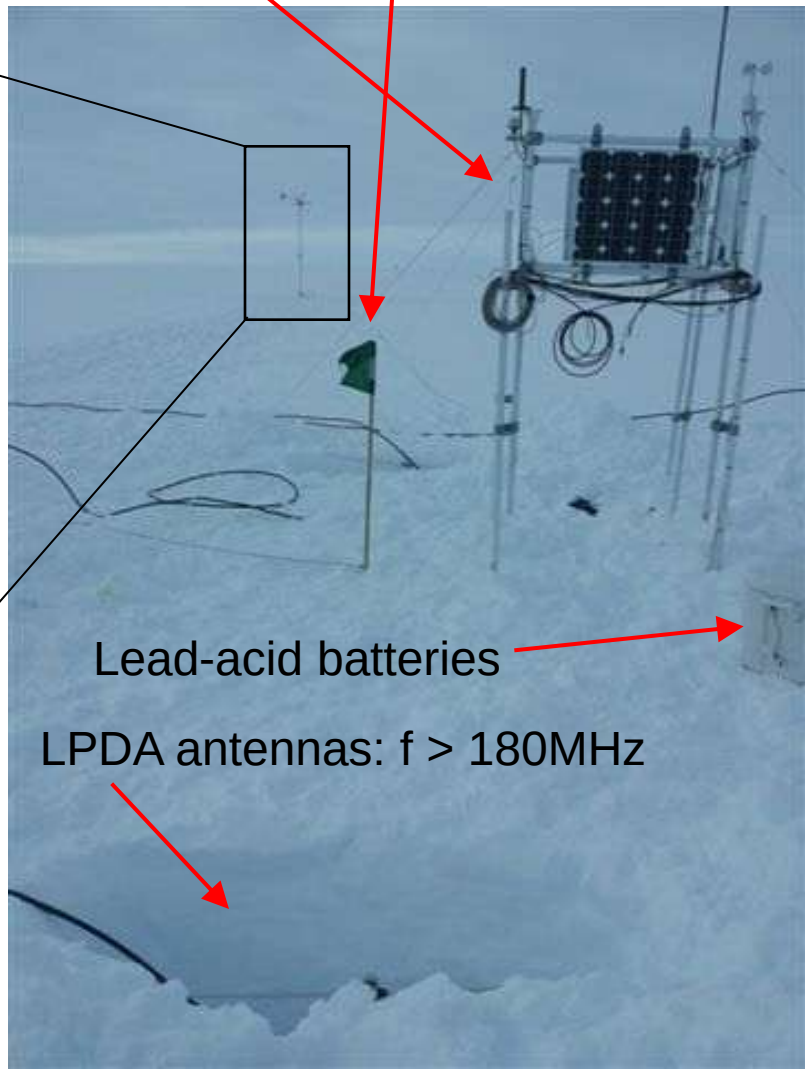
2011 deployment

Berg, Tatar, Hanson

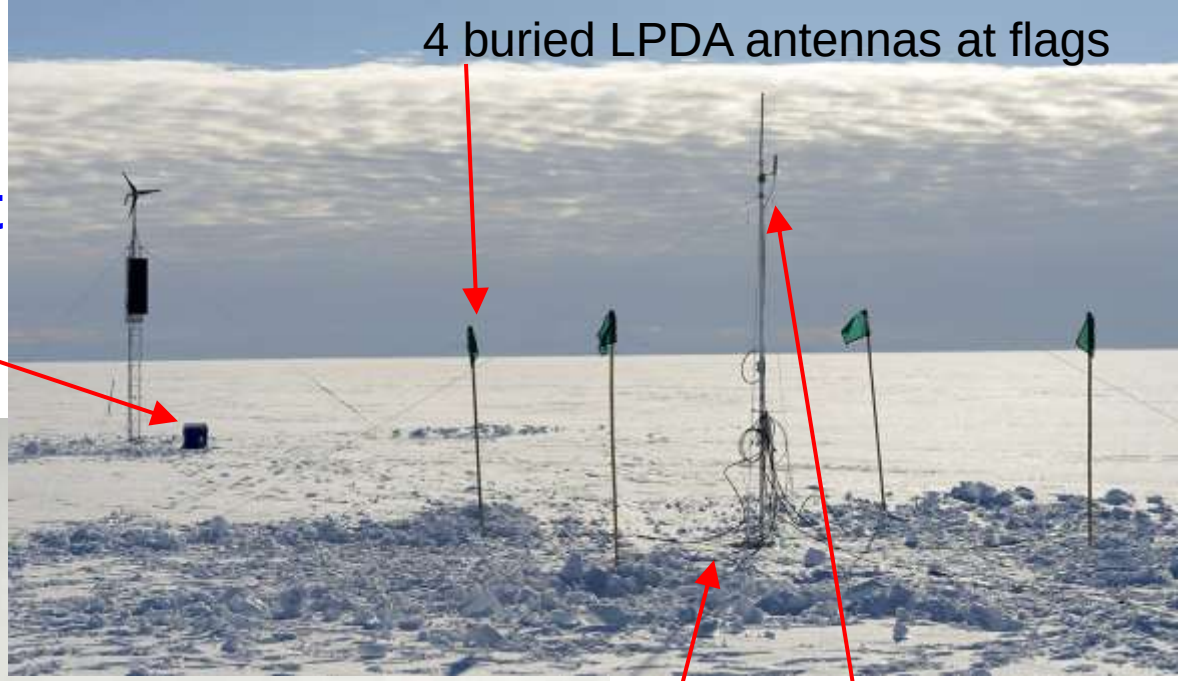


four 30W solar panels,
Iridium, GPS, AFAR,
anemometer

DAQ electronics
to be positioned at flag



2012 deployment



Air40 wind generator
16foot prefab tower

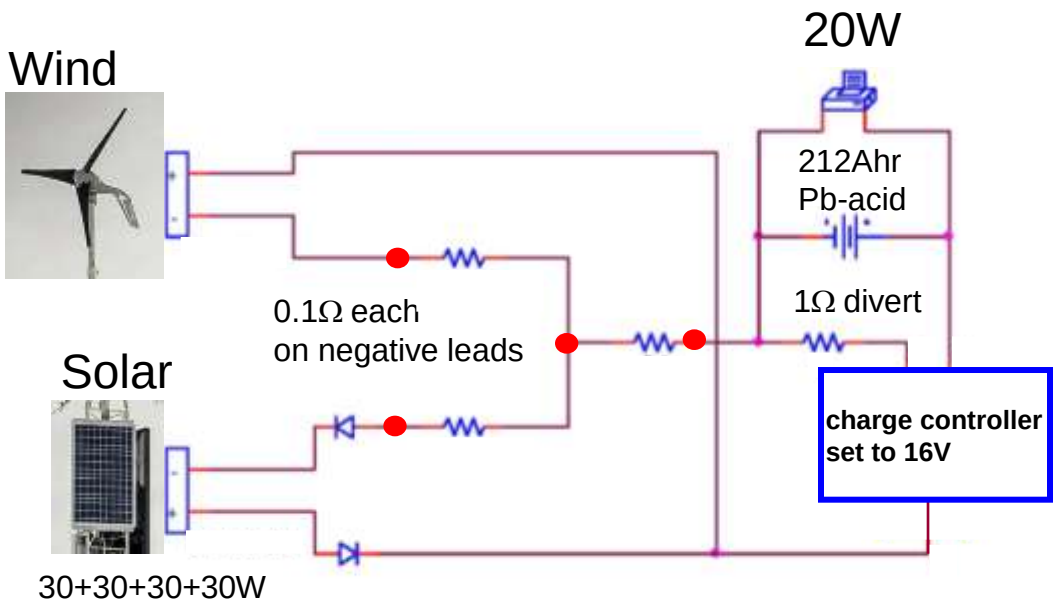
One 100W and
two 30W solar panels

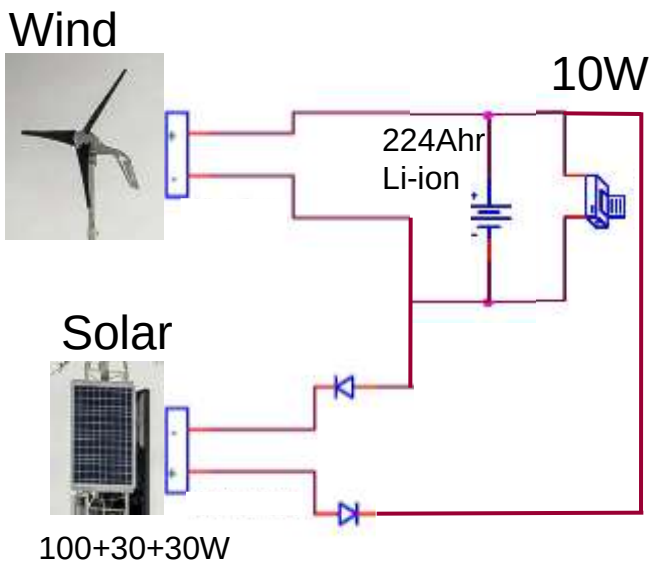
Kleinfelder, Fan,
Brooks (USAP staff),
Tatar, and Reed

Power Schematics

2011 station
monitor voltages at: ●

2012 stations
(7W for DAQ + comms + losses)

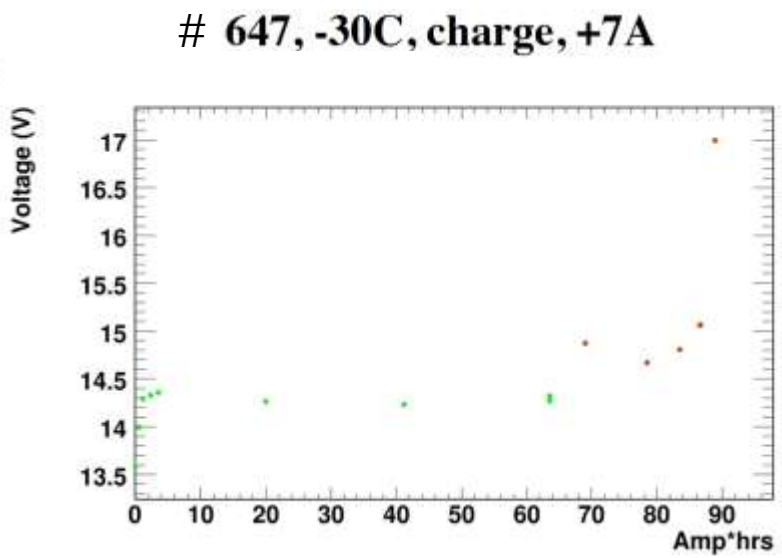


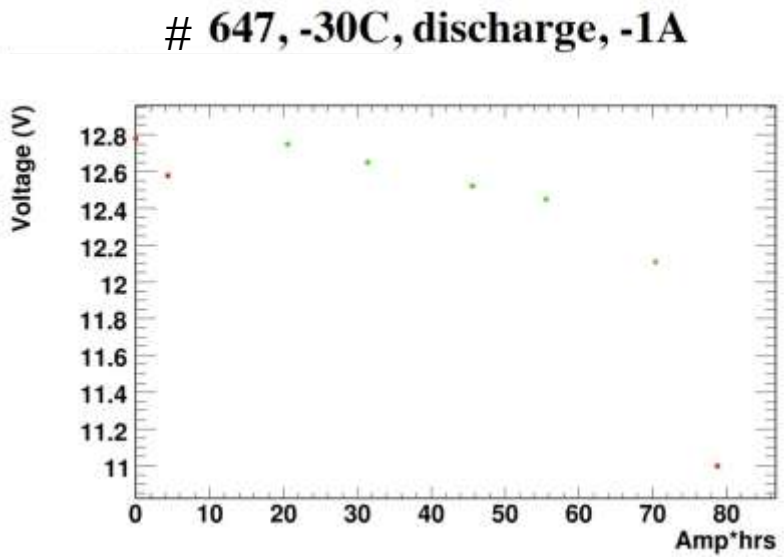


Battery System

Lithium Ion ($Li\ FePO_4$) Braille Batteries:
two sealed 112Ahr 12V batteries (34lbs each)
cold charging (tests up to 7A) ~80Ahr
cold discharging (tests up to 2A) ~60Ahr

internal microcontroller disconnects when
drained (>10.5V) or full (<16.8V) to prevent damage





Lead Acid typically only discharge 30-50% rated Ahr
and <0.1A limited charging

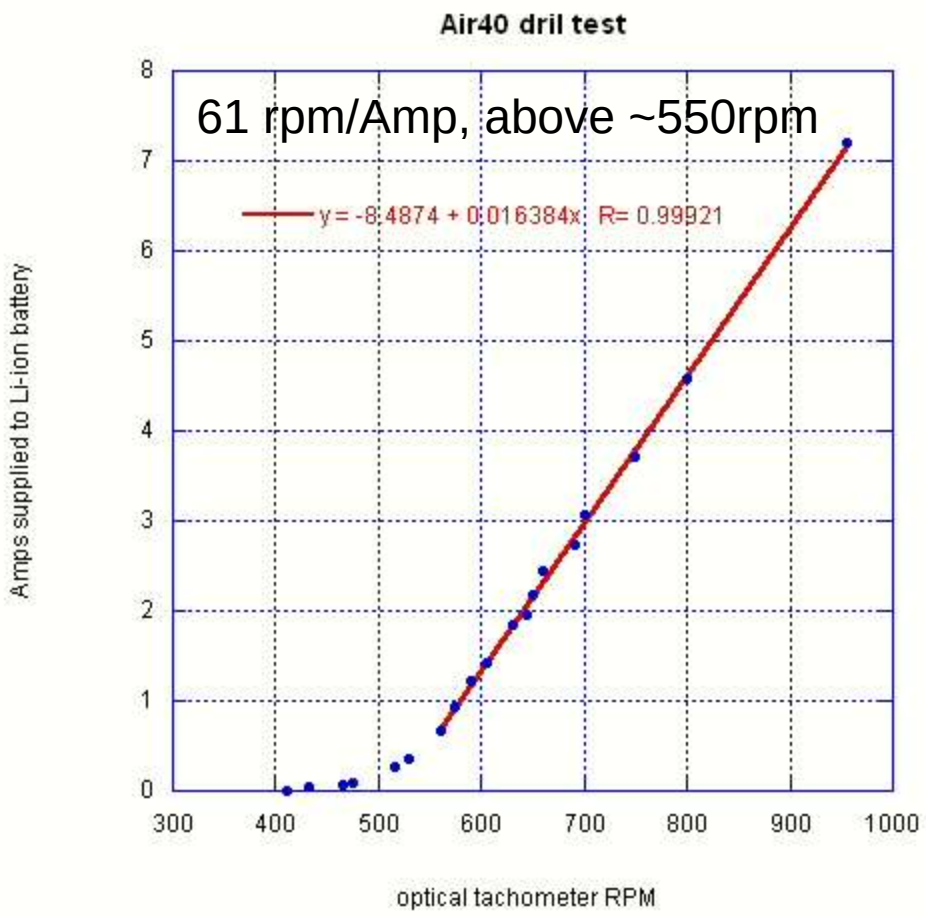
Air-40 Wind Generator Tests

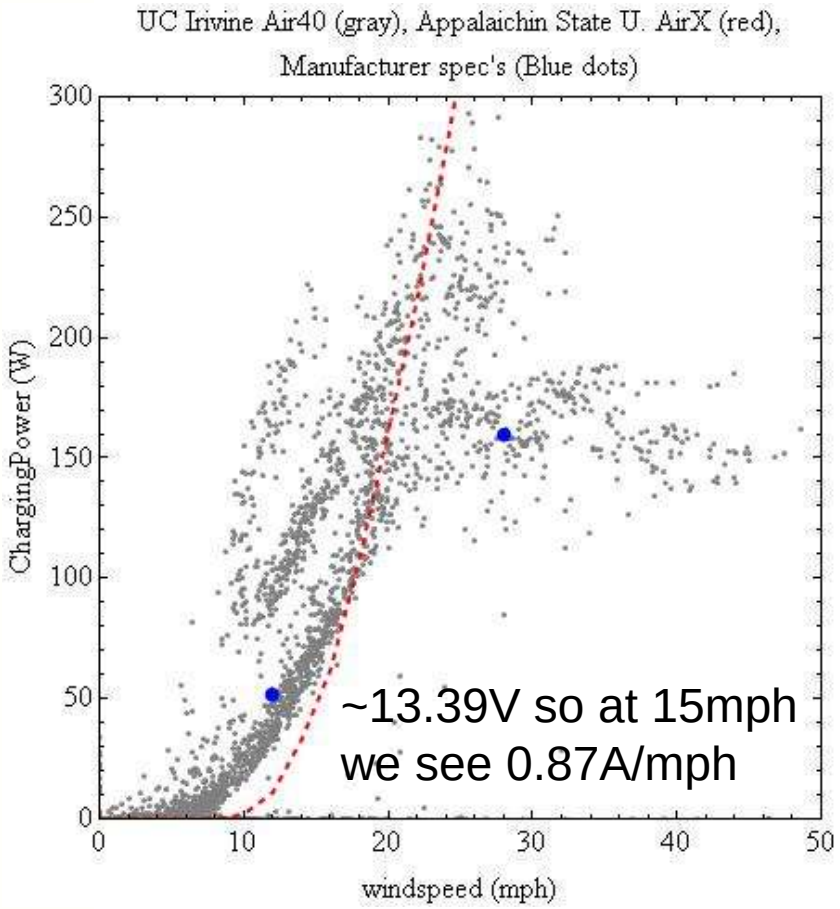
(Southwest Windpower, Flagstaff, AZ)
13lbs, 46”OD, 6-50mph (110mph max), 12V system

Onboard microcontroller:
draws small current to operate
regulates load with proprietary smart algorithm
protection mode (brakes applied) if
over ~50mph or
over voltage (adjustable 13.6 - 17V)

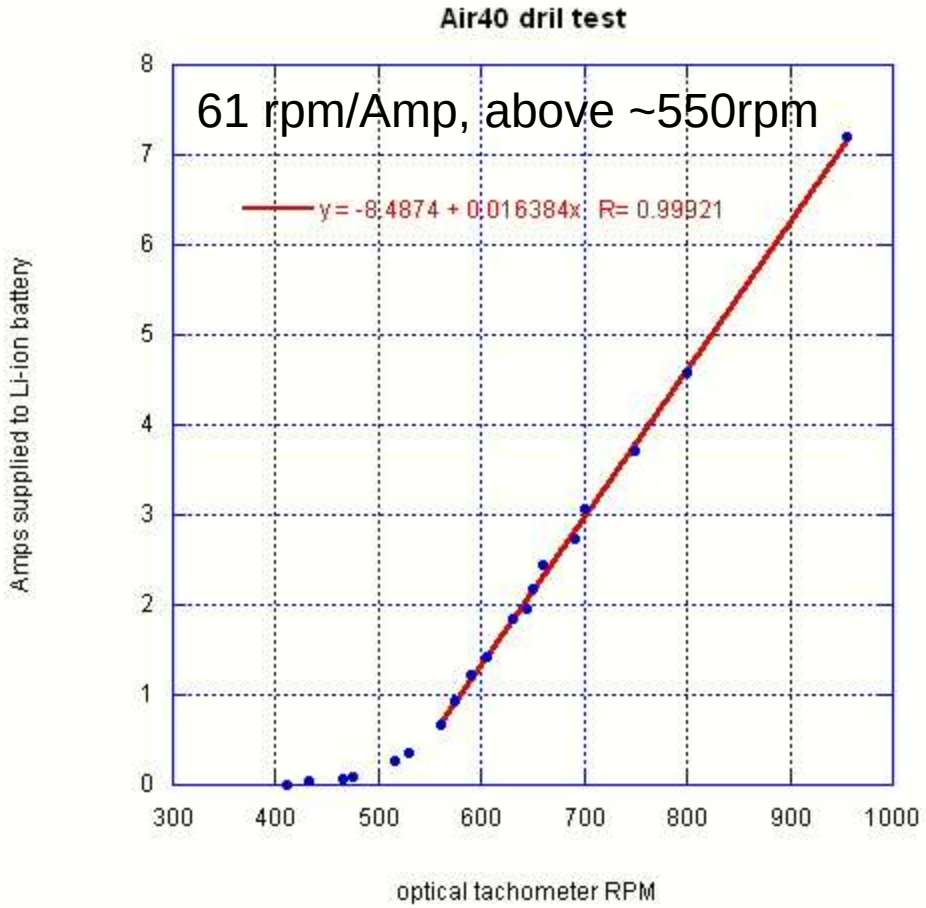
Tested with a hand drill (Amps vs rpm)
Rooftop and driving tests (Amps vs mph)
(Duffin, Griskevitch)

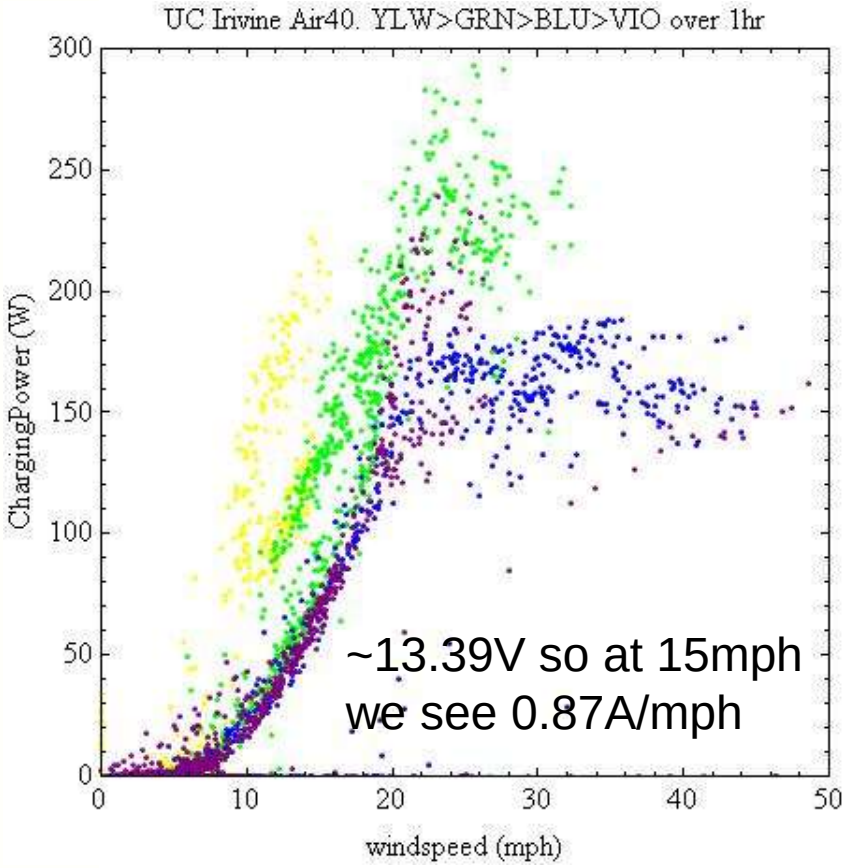
Air-40 Wind Generator Tests



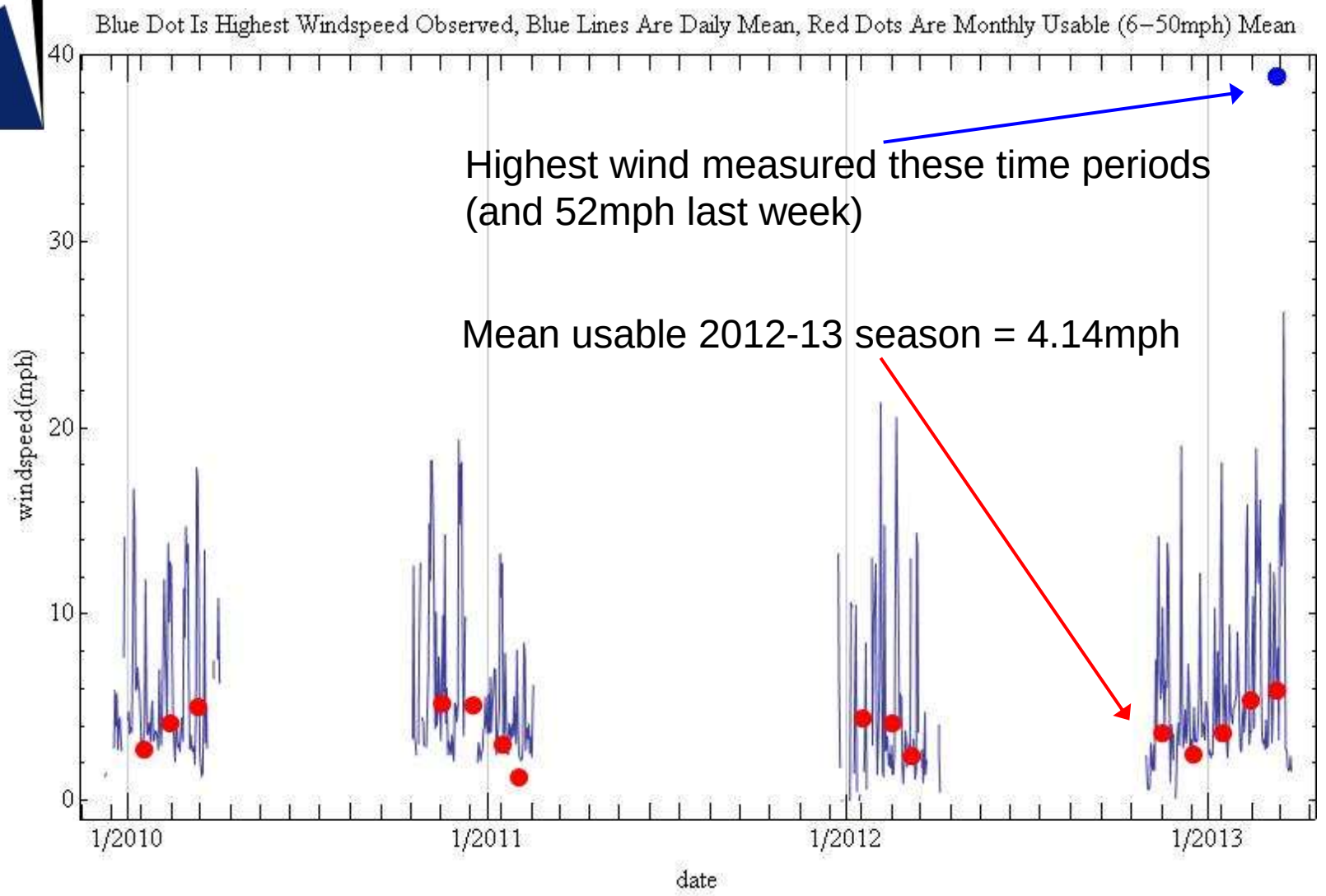


Air-40 Wind Generator Tests

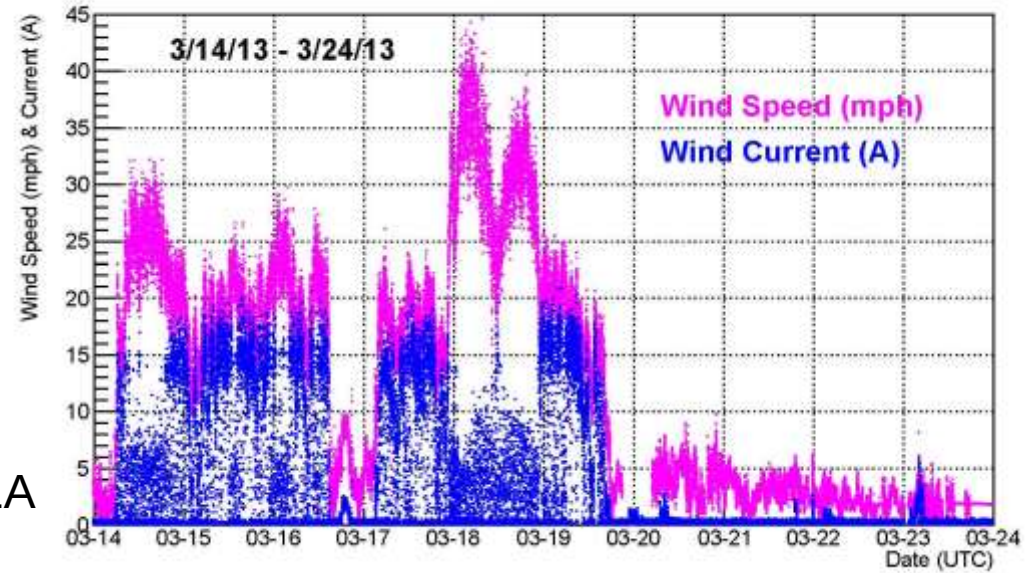




Anemometry on the Ross Ice Shelf

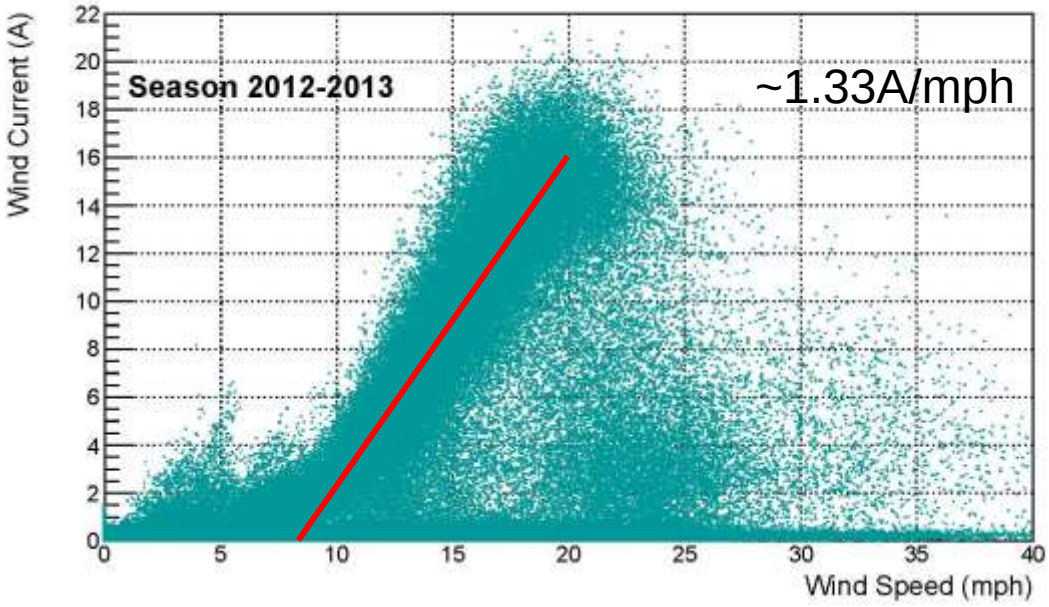


Wind Power on the Ross Ice Shelf



4.14mph season mean useable
*0.87A/mph UCI test = 3.60A
*1.33A/mph deployed Air40 = 5.51A
(mostly into 1 Ohm divert load)
*0.65A/mph deployed Aero6gen

3.36A mean generator current



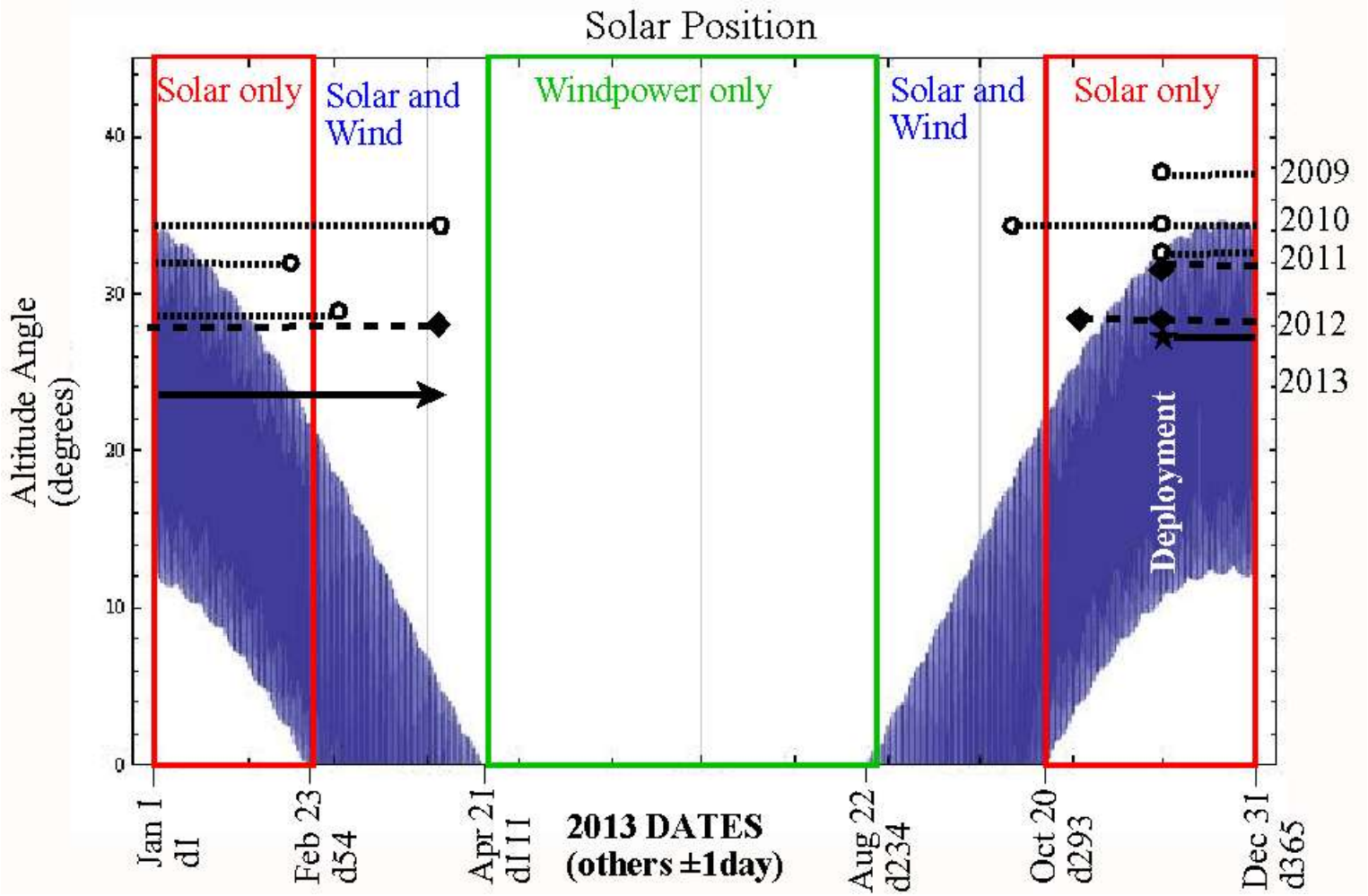
Wind Issues

Multiple internal charge controllers: wind generator, Li-ion batteries
- thresholds at 15.6V (wind, adjustable) and 16.8V (battery, fixed)
  - so charging stops if batteries are charged
  - PRIOR to battery controller overvoltage disconnect
- need solar to activate wind generator to start charging depleted batteries

RF Noise: Air40 contains a controller which produces impulsive RF noise
- shielded cabling and RF filter-pins to suppress
- at 100ft distance, noise at 100-300MHz, if full battery and high wind

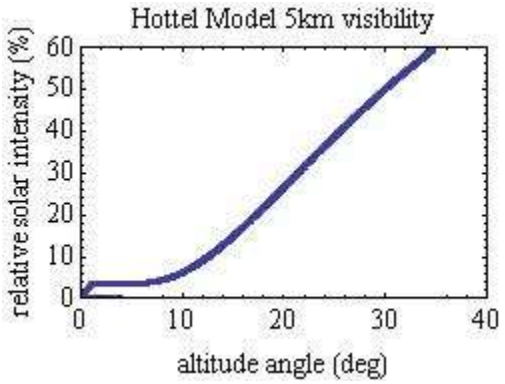
Wind generator destruction:
- 2009-2010 deployment: Forgen1000, OK
- 2010-2011 deployment: Aero6gen blades broke and Aluminum mount broke
- 2011-2012 deployment: Aero6gen blades broke, hitting pole mount
- 2012-2013 deployment: Air40, so far so good

Live Time and Power Source



Solar Charging Model

Model:
astronomical solar position (Mathematica)
realistic horizon features (mountains)
2011 solar array geometry
one parameter “fit” = overall panel rating



Hottel (1976) clear sky model with 5km visibility

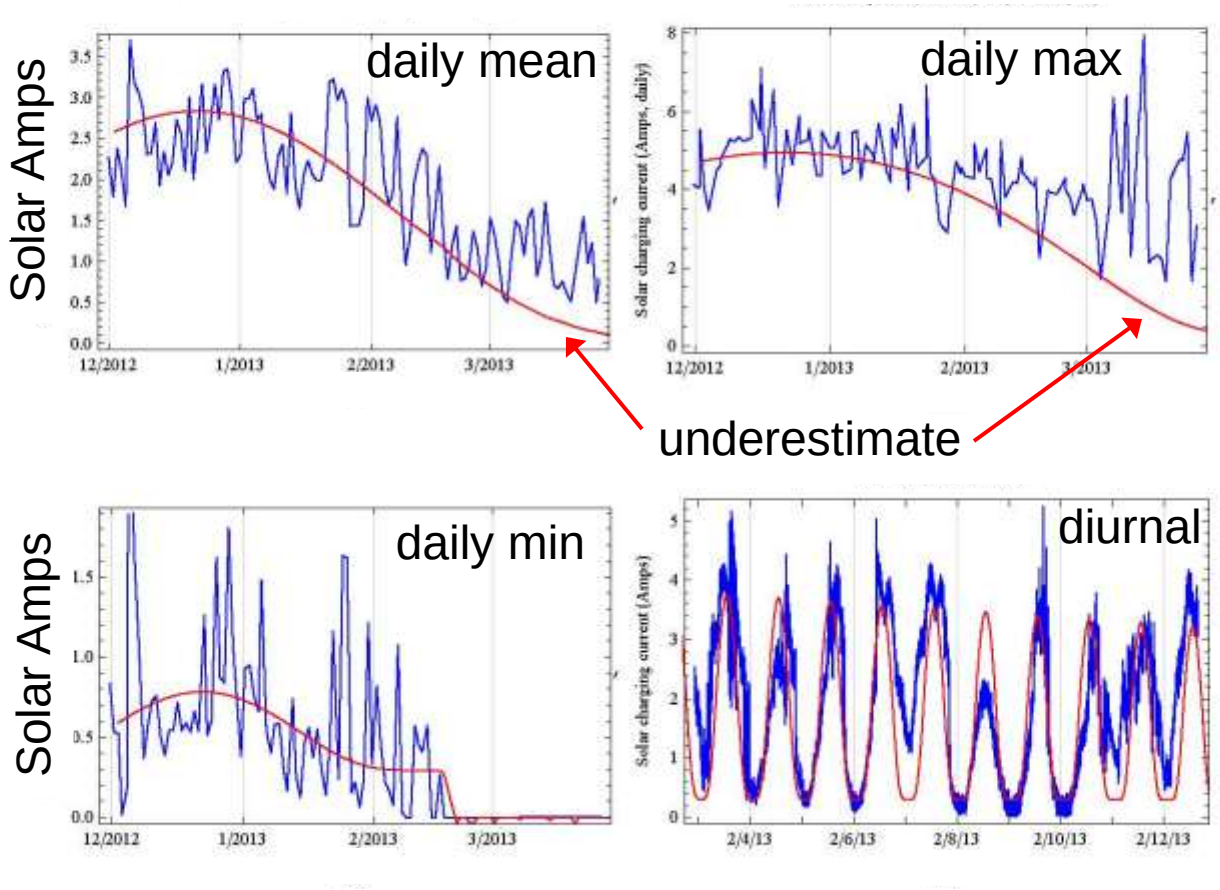
$$I/I_0 = a_0 + a_1 e^{(-\kappa/\cos\theta)}$$

a_0, a_1, κ = altitude dependant constants

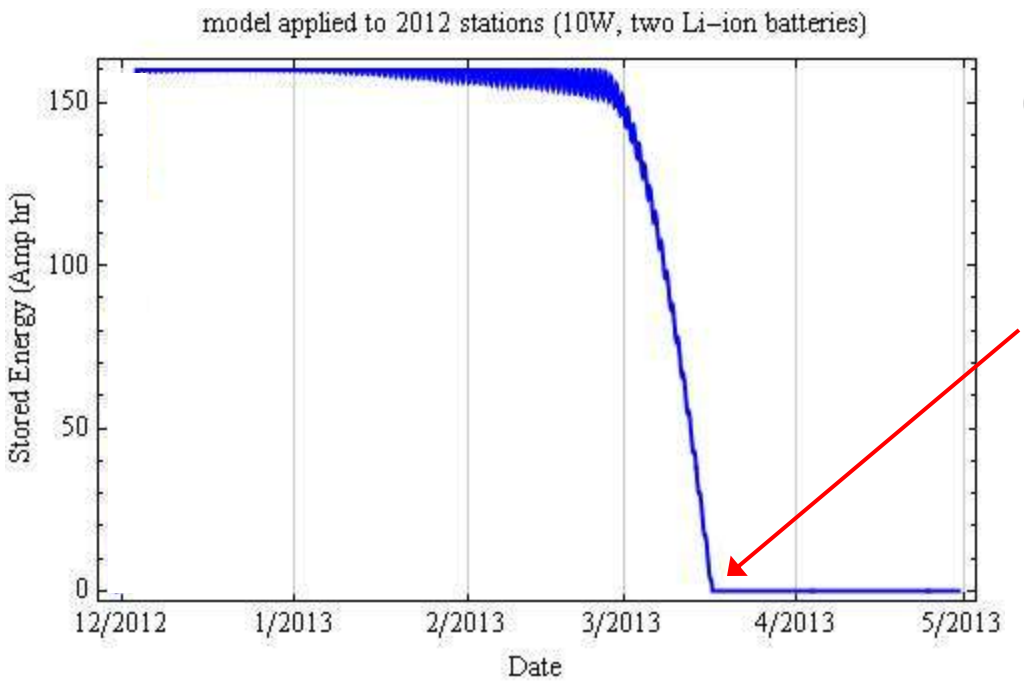
Model improvements needed:
new atmospheric model
add atmospheric refraction
*add snow reflection
fit a_0, a_1, k to data

Solar Charging Data and Model

2012-2013 season



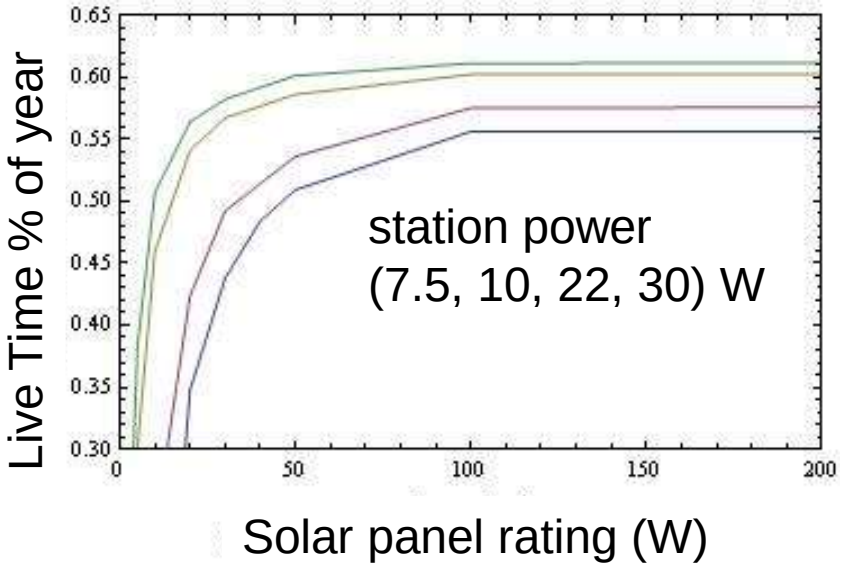
Solar Model and Live Time



(Pb-acid) battery empty on 3/4/12
station shutdown 4/4/12

Model: battery empty 3/17

Panel Rating Dependence



Live time is insensitive to panel rating above ~30W
30W -> 40W 2011 to 2012

CONCLUSIONS

1W stations can operate year-round with batteries alone
1kW stations can operate year-round with an indoor generator

How does one power a 10W station year-round with green technology?

1) We have tested and are in the process of demonstrating the effectiveness of a Li-ion battery system in the cold environment

2) We have site wind data and have tested a number of wind generators, and are in the process of demonstrating effectiveness over winter

3) We have a viable solar model for predicting summer solar-only operation and panel rating dependence

ARIANNA
UCI Physics and Engineering Contingent

Funded by NSF grant # 1126672 and 0970175

* pictured, testing at UCI

Steve Barwick, principal investigator
Stuart Kleinfelder, professor
*Corey Reed and *Eric Berg, project scientists
*Joulien Tatar, Liang Zou, Mahshid Roumi Ph.D. Candidates
Jordan Hanson, Ph.D. graduate (-> Kansas University)
Kelly Margaritis, James Walker, Zongnan Fan graduate students
*Thorin Duffin, B.S. graduate

Extra slides

Ultra-high Energy Neutrinos

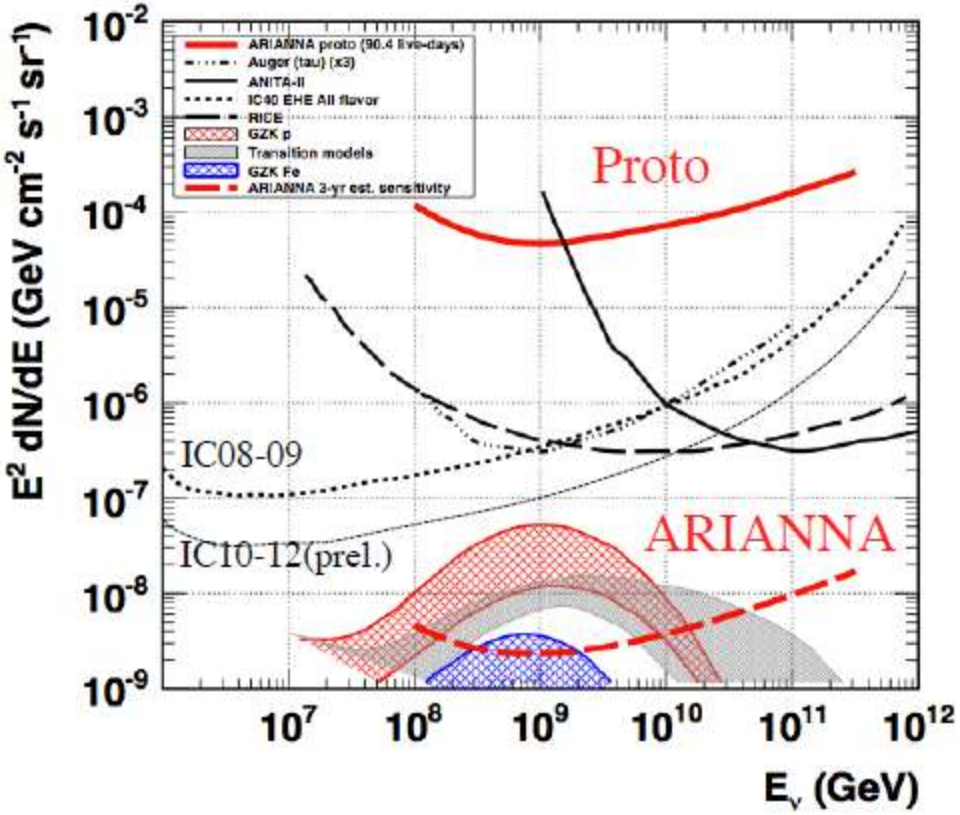
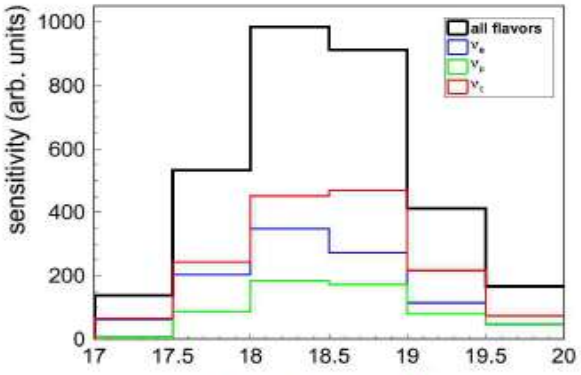


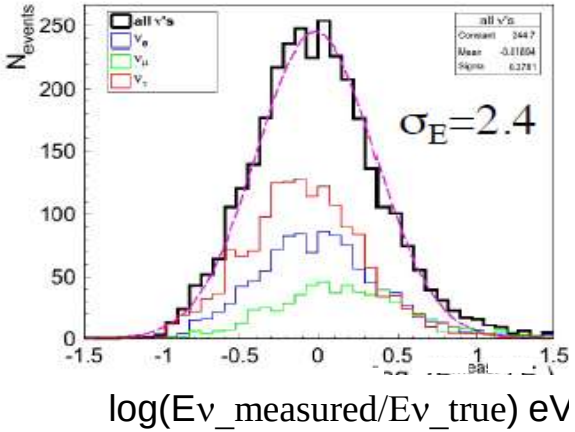
Fig. adapted from Kampert&Unger

Neutrino Resolution

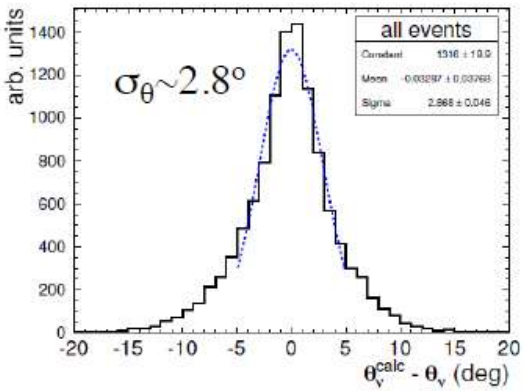
Detection efficiency: expect 0-50 events/year
with 900 stations
operating year-round



Neutrino flavor resolution
flavor = e, μ, or τ



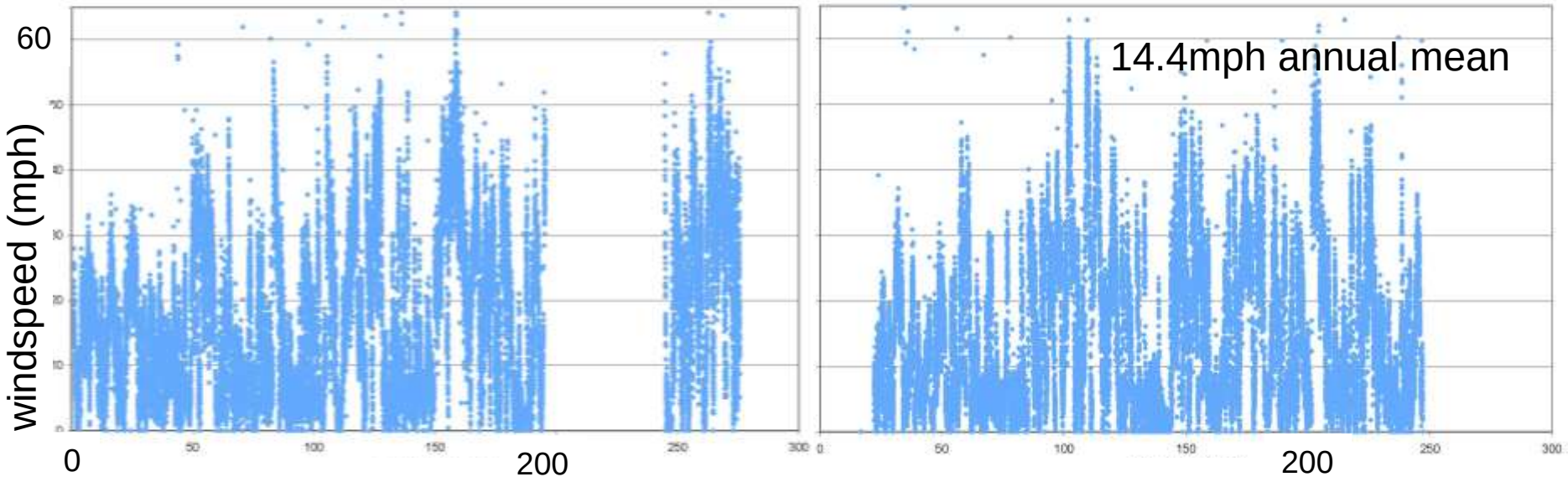
Neutrino energy resolution



angular resolution

Anemometry on the Ross Ice Shelf

Automated Weather Station (AWS), by U. Wisconsin
“Linda” station E. of Mina Bluff (measured/10min)



day of the year 2008 and 2009

12 ->16mph summer to winter