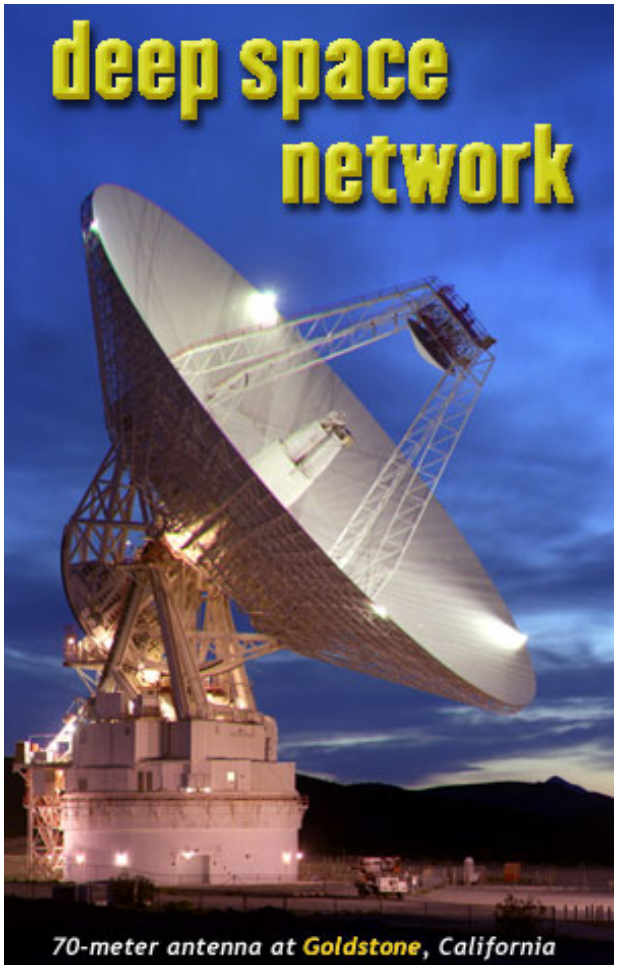
Goldstone Lunar Neutrino Search

Nov. 16 2000



JPL:

Peter Gorham, Kurt Liewer, Chuck Naudet

UCLA:

David Saltzberg, Dawn Williams (2001)

Support:

JPL DSN Science Services (G. Resch & M. Klein) (JPL staff)

Caltech President's Fund (PG & DS)

DOE & NSF Career Awards (DS)

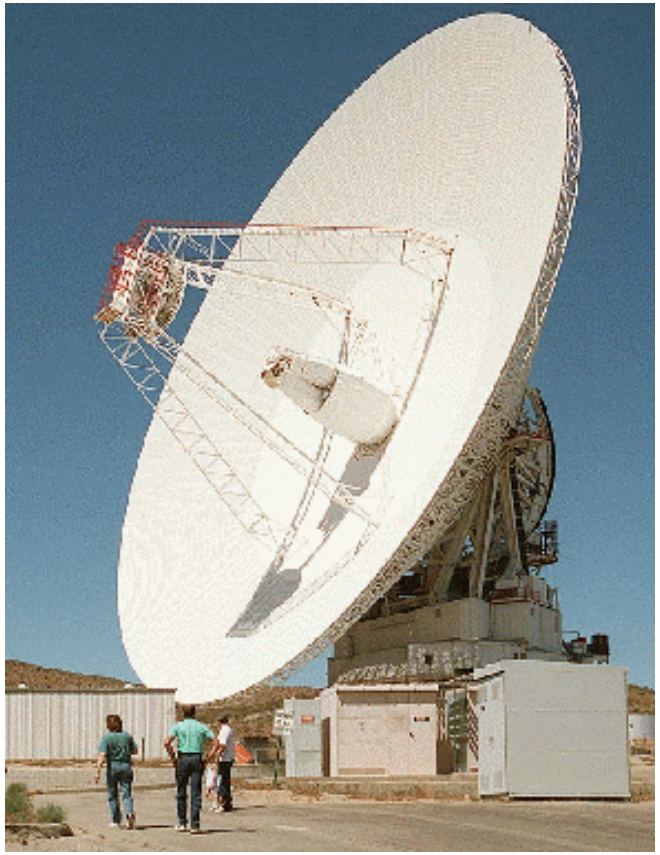
Background & motivation

- G. Askaryan, early 60's:
  - HE particle cascades produce ~20-30% more electrons than positrons
    - compton scattering, e+ annihilation, delta rays, etc.
    - => showers in dielectric produce coherent microwave Cherenkov radiation
  - One should look for low-loss microwave dielectrics abundant in nature
    - Ice, many rocks
    - Lunar regolith--a surface array on the moon!

- Immediate application was found in air showers (J. Jelley)
  - But the dominant process in EAS is not coherent Cherenkov
    - probably boosted dipole radiation from geomagnetic charge separation
  - No follow-up on Askaryan's suggestion of solid dielectrics till 80's

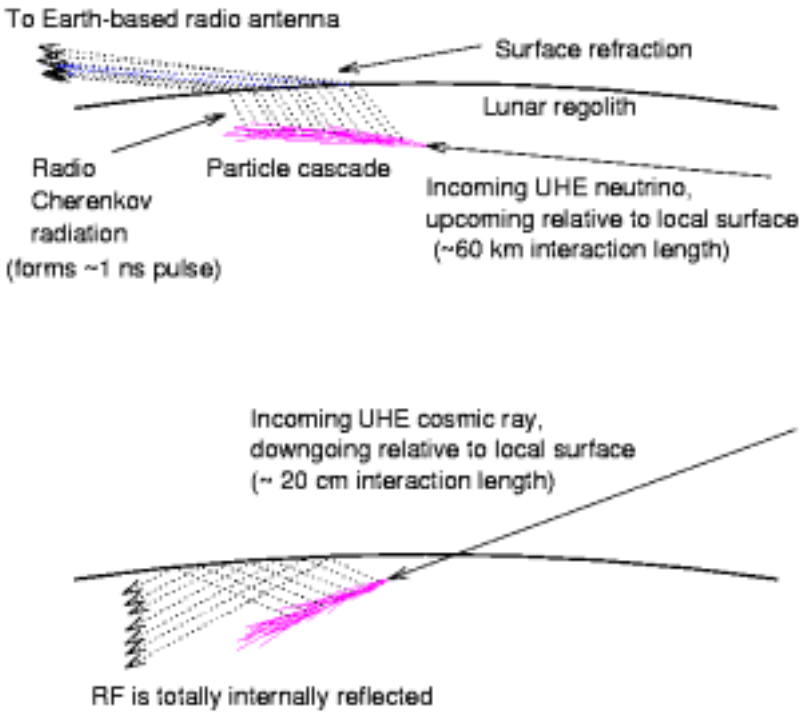
- 1988: I. Zheleznykh & R. Dagkesamansky:
  - propose that 1e20 eV neutrino events may be detectable from earth
  - First experiment (Hankins et al 96) done in 1994 w/ Parkes 64m
    - null result in 10 hours single-dish observation

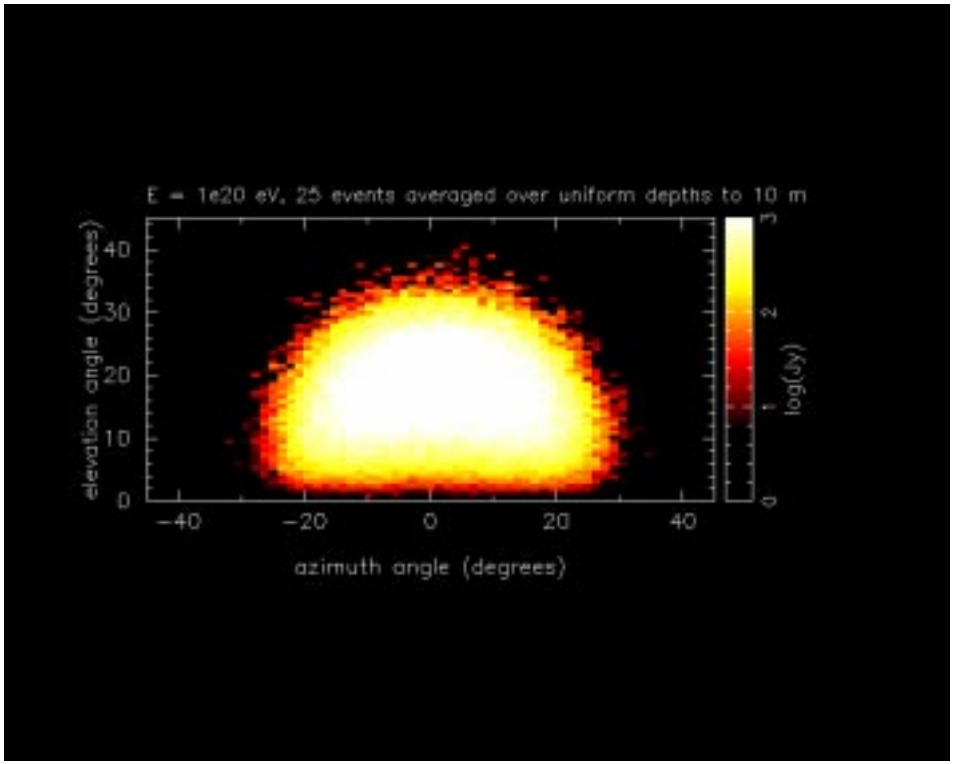
Goldstone experiment



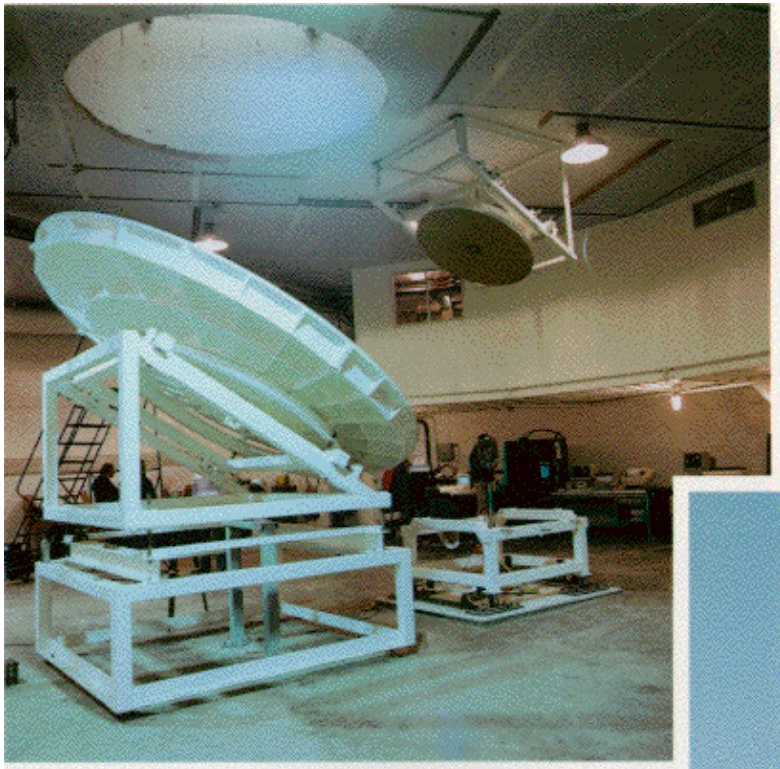
- Utilize Deep Space telecom 70m antenna DSS14 for lunar RF pulse search--fill gaps in SC sched.
- First observations late 1998:
  - approach based on Hankins et al. 1996 results from Parkes
  - utilize active RFI veto
- 1999: add 2nd 34 m fiber-linked antenna DSS13
  - initially used passive recording with local trigger at DSS14
- 2000: DSS14 down for first half, but ~20 hours livetime acquired since July
  - focussed on limb observations, lower threshold, better trigger system

Lunar Regolith Interactions & Cherenkov radiation





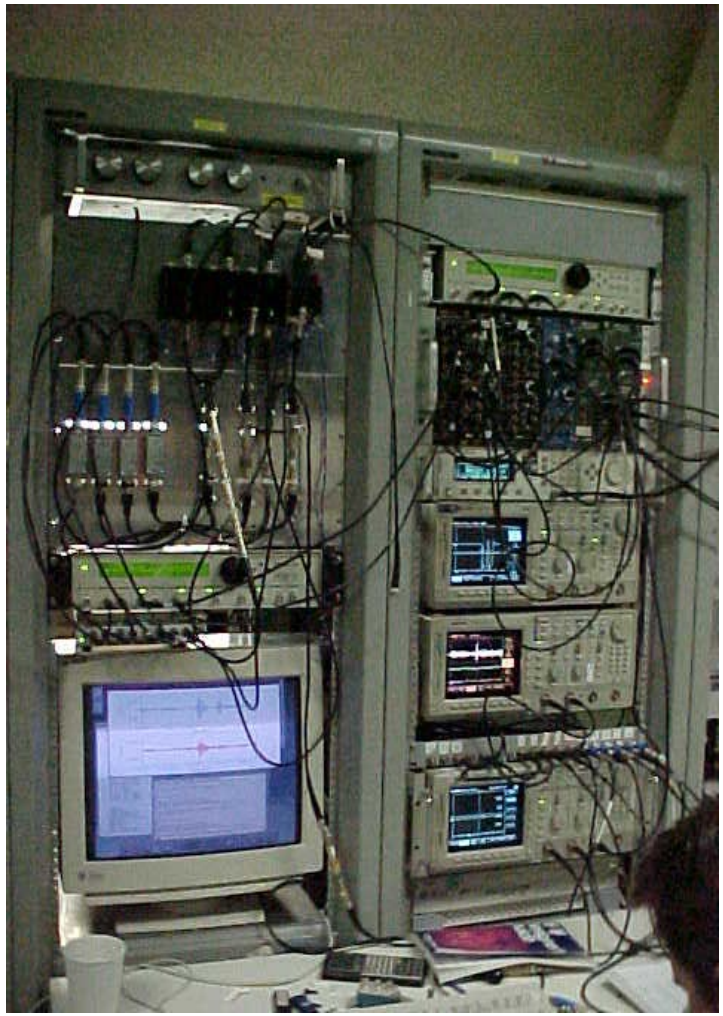
DSS13: 34 m Beam waveguide antenna



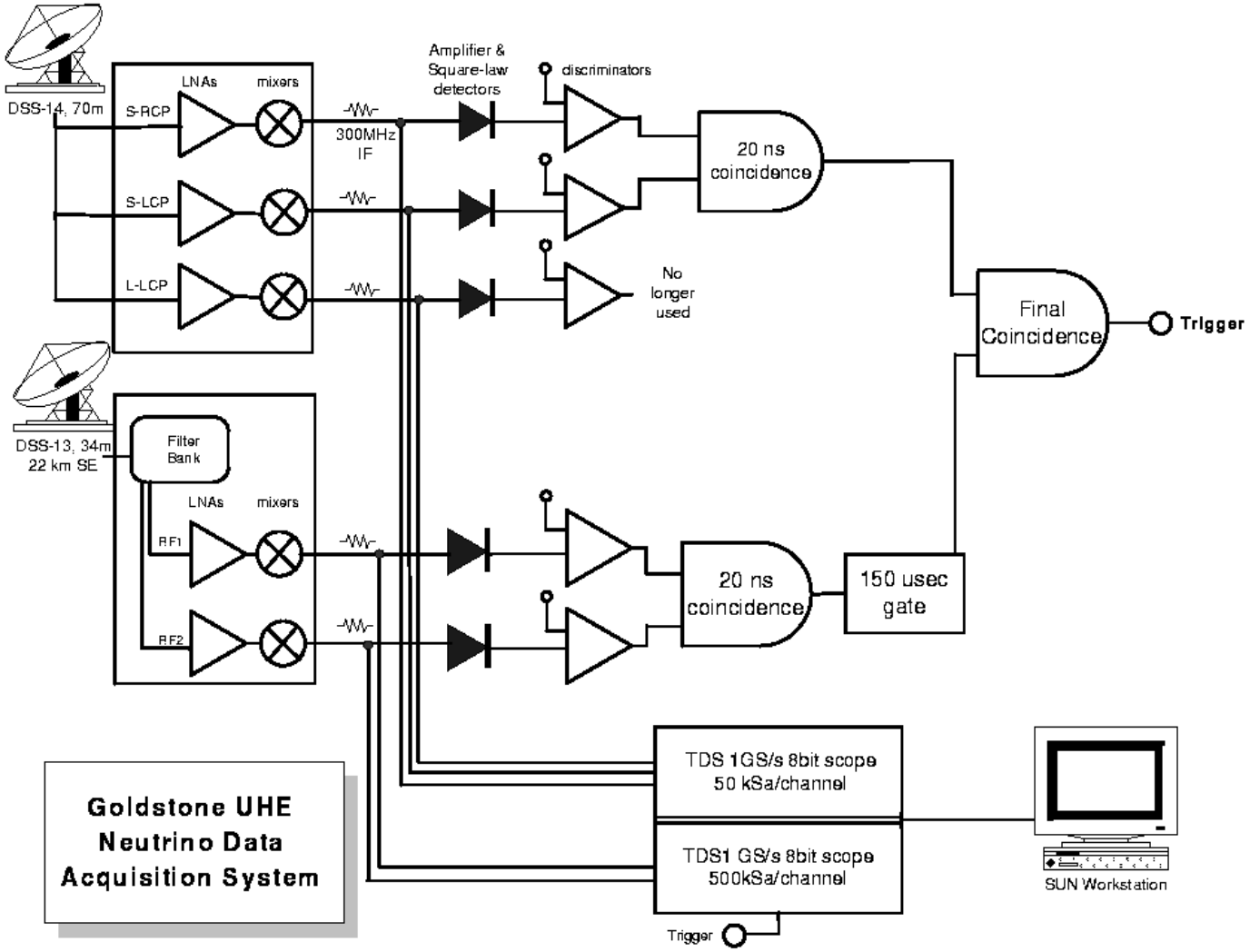
- DSS13: research antenna
- Uses “beam waveguide” optics
  - low-freq cutoff at ~1.8 GHz
- High efficiency, excellent surface
- At present: 140 MHz BW (S-band)
  - single pol, dual pol planned for ‘01

New RARG location

- Two relay racks of our own
- JPL tech support
- DSN committed to 120+ hours of exposure
- New trigger
- ~8 visits, ~ 20-30 hours livetime



New Trigger

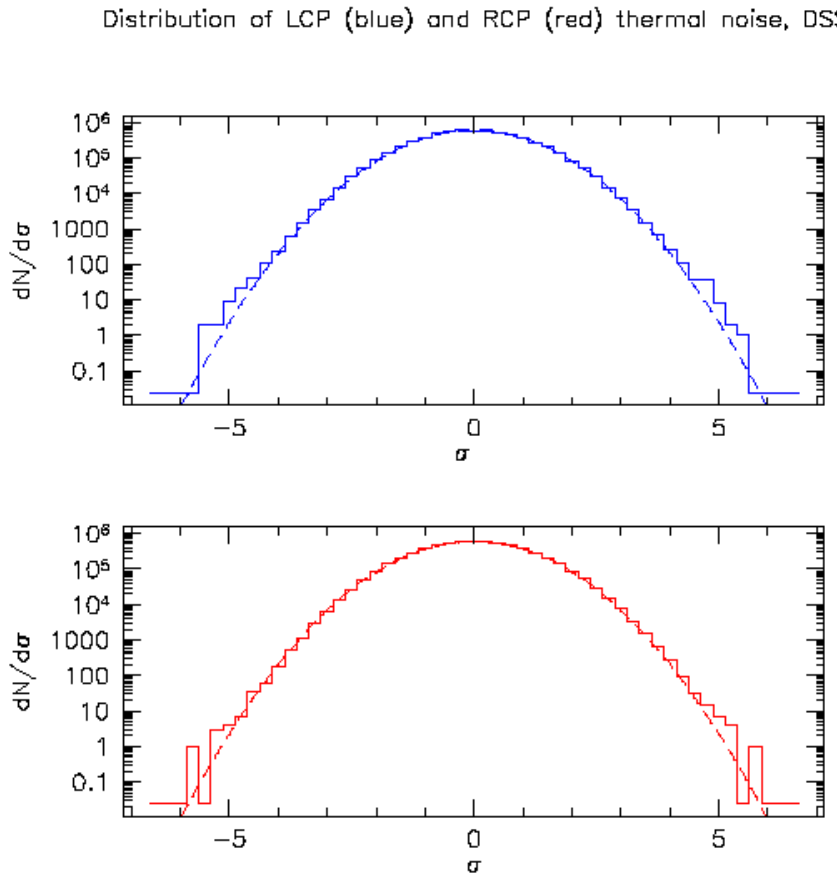


- RFI veto:
  - no longer in trigger
  - record off-axis L-band signal for post-analysis

- Pulses at both antennas now required for trigger
  - powerful interference rejection
  - disc. thresholds set according to relative aperture

- Thermal noise coincidence rates ~0.2 per minute
  - but only ~1/day close to proper moon delay

Thermal Noise Statistics



• Voltages proportional to pulse field strength: pure gaussian:
  •=> dN/dV ~ exp(-V^2)

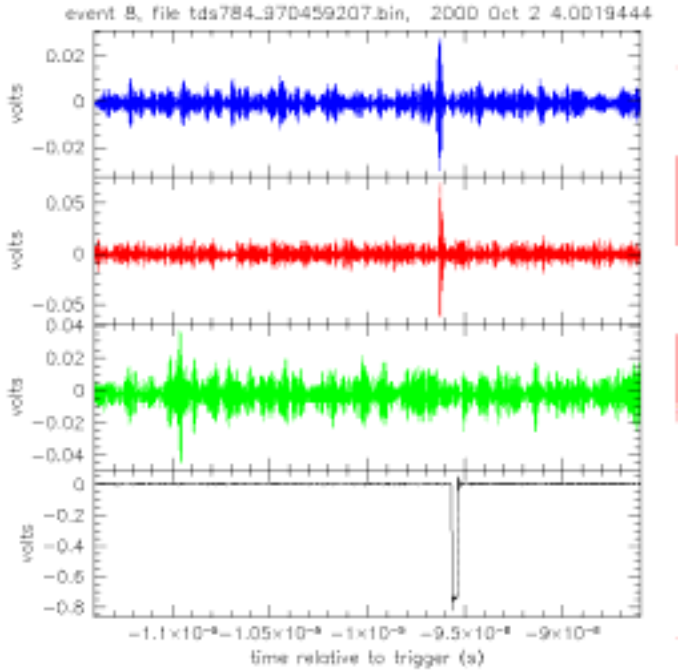
• Square-law detection used for discrimination
  • => Power ~ V^2/Z
  • => dN/dP ~ dN/dV
  • ~ exp(-I)

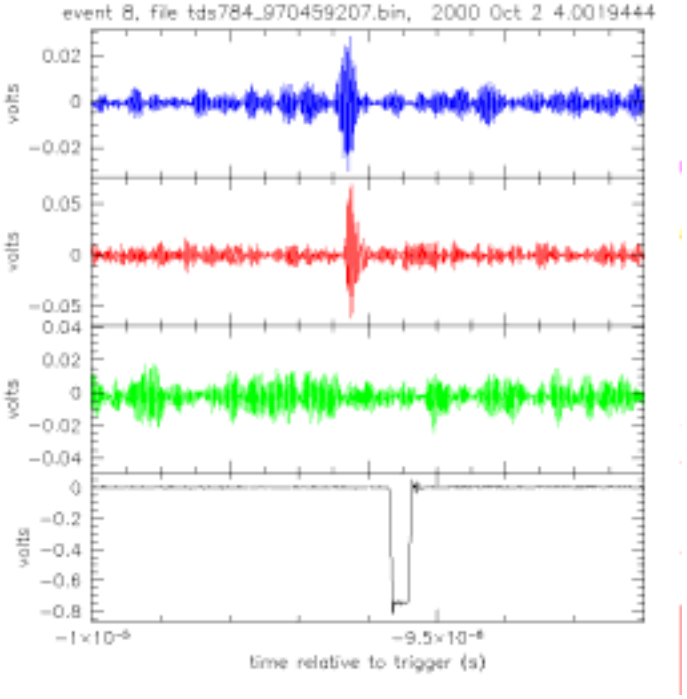
• Statistics of detected power are exponential

• => 5 sigma equivalent significance requires SNR~15

Timing & pulse shape calibration

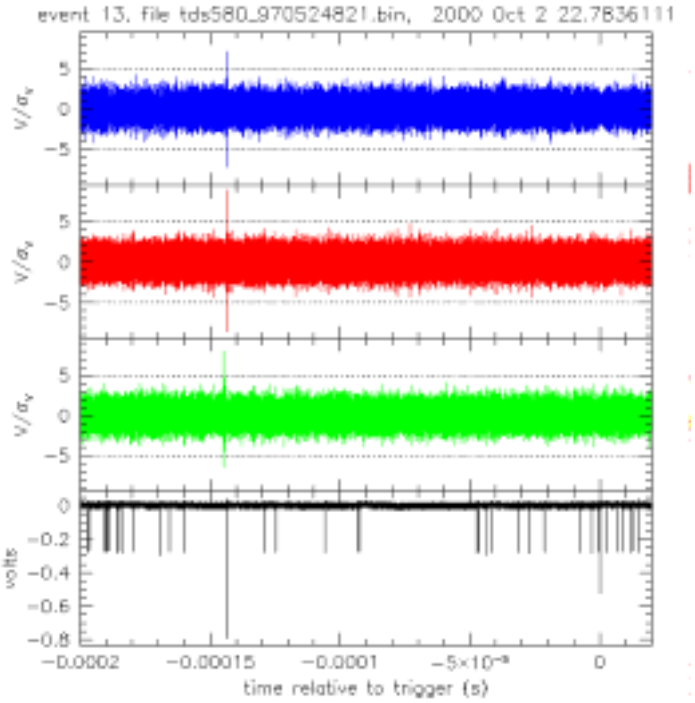
- S-band Monocycle pulser:
  - provides band-limited lin.pol. Pulses
  - checks amp. Linearity, net cable delays, band-limited pulse shape





- Zoomed version: LCP pulse is broader (40 MHz BW), RCP narrower (~100MHz BW); also slight timing offset

Typical RF interference trigger

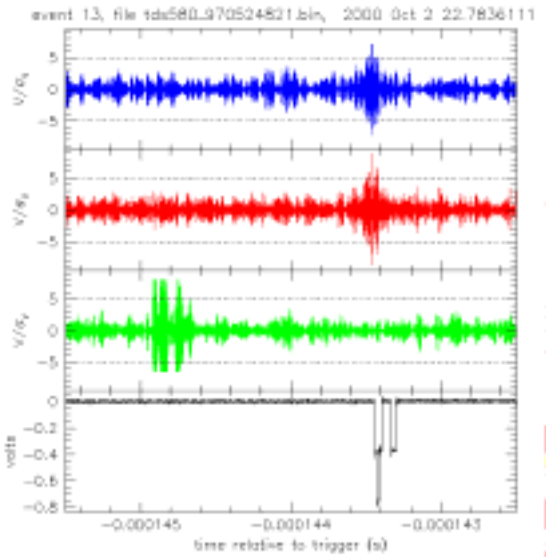


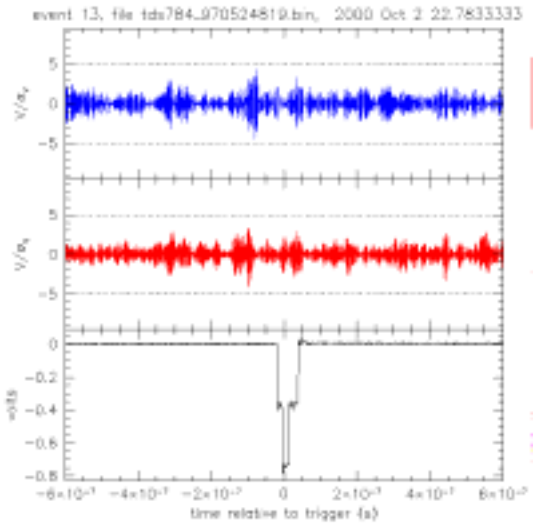
One of the 2 antennas may have high RFI singles rates

Will produce excess coincidence rate with 2nd antenna thermal noise

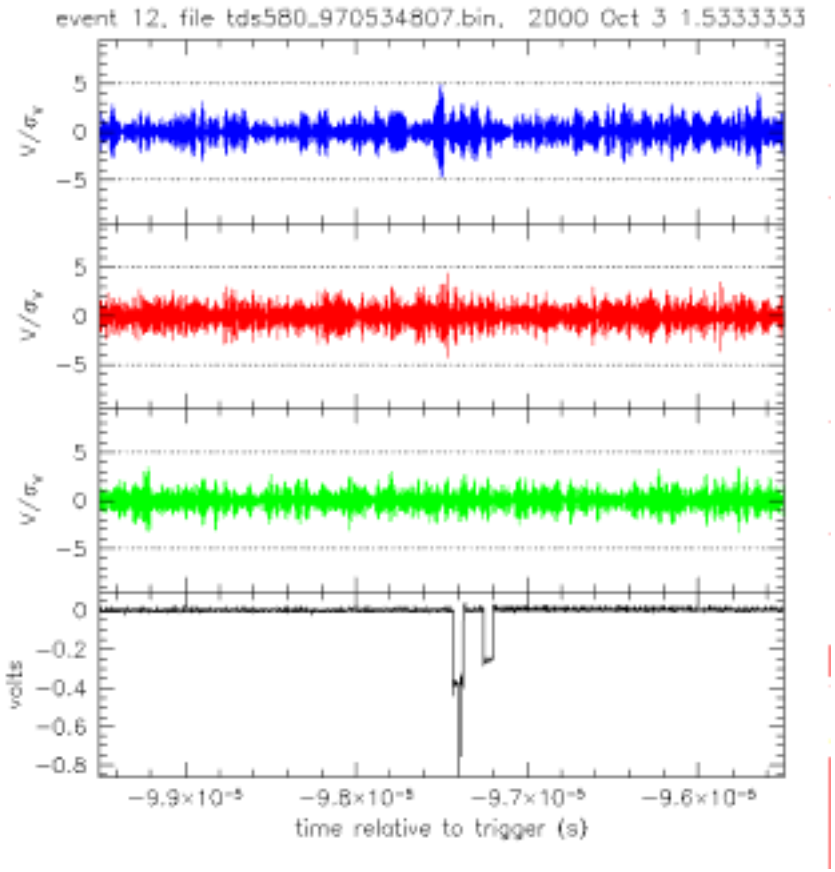
Events are clearly distinguishable: L-band channel pulse is present

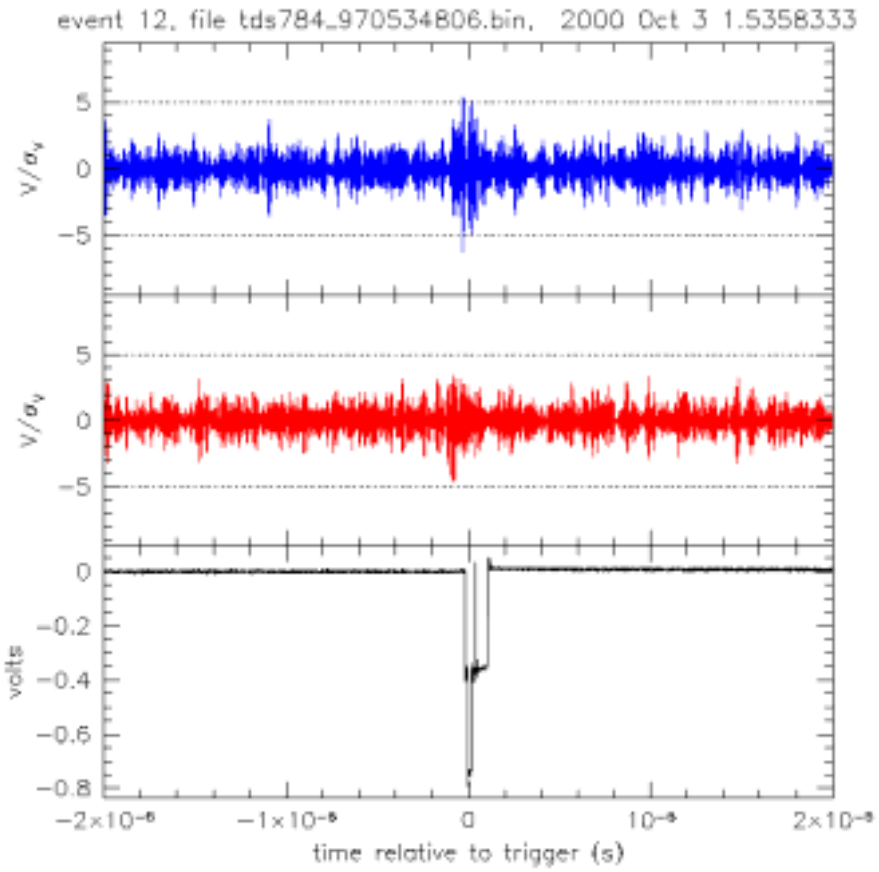
Overall increase in trigger rates ~10%



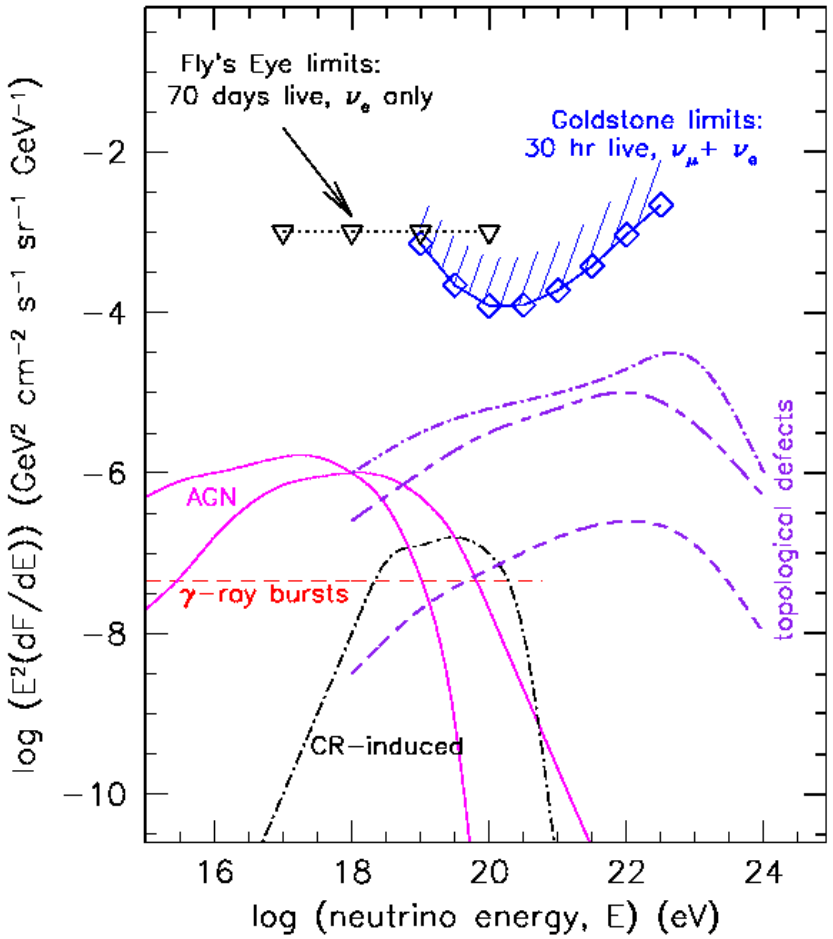


Typical Thermal Noise trigger





Goldstone diffuse neutrino flux limits



~30 hrs livetime (includes previous data)

- No events above net 5 sigma

New Monte Carlo estimates:

- Xsection 'down' by 30-40%
  - moving target effect!
- Full refraction raytrace, including surface roughness, regolith absorption
- Y-distribution, LPM included

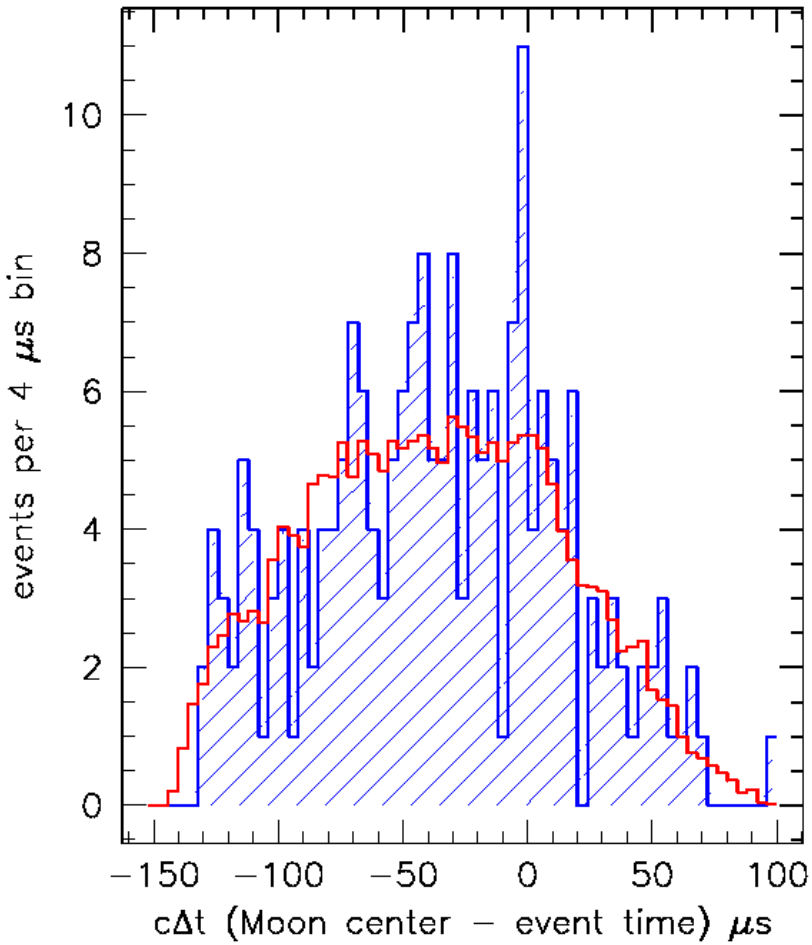
Limb observations:

- lower threshold, but much less effective volume
- Weaker limit but with more confidence

Fly's Eye limit: needs update!

- Corrected here (PG) by using published CR aperture, new neutrino xsections

Statistics of non-RFI triggers near threshold



Cuts applied:

- tighter timing
- pulse width close to band-limited
- not obvious RFI

BKG weight determined by randomizing event UT within run period

Some concentration of events near correct delay:

- not significant yet
- ~2 microsec offset hard to explain

Future plans

- Still ~100 hours more dual antenna time to be scheduled in next 6-8 months
- New strategy: use partial defocussing at DSS14 (J. Ralston suggestion) to improve effective volume
  - expect factor of 5-10 improvement with only modest increase in energy threshold
  - DSS14 beam will better match DSS13 beam & response
- Improve bandwidth, get dual polarization at DSS13
  - Could lead to roughly equal sensitivity for two antennas