UHE TG Status report

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FNAL collaboration meeting

Outline

- Update on sensitivity studies
- Conclusions for Physics Report

TG charge.

- Quantify scientific impact
  - Why make these measurements
  - Expected state of knowledge in 5/10/15 years
- Sensitivity of reference configurations
  - Reference far detector configurations
  - Identify primary backgrounds
- Help make the informed decision for far detector technology.

Scientific impact?

- Reasons for these measurements likely clear many...
  - source of highest energy cosmic rays (potentially AGN, grbs, etc)
  - search for evidence of WIMPs in Sun, Galactic center.
- Precision of these measurements ***not*** a strong driver at this point
  - Discovery regime - need to make sure we have a statistically significant discovery
  - Need good understanding of irreducible backgrounds (atmospheric neutrinos)

State of knowledge in 5/10/15 yr?

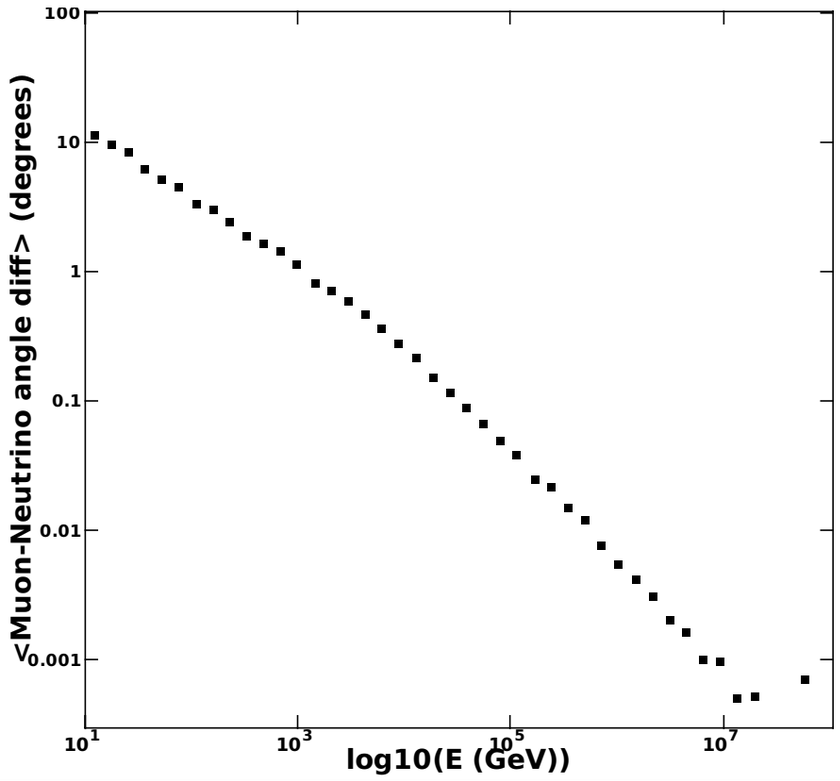
- Most sensitive experiments are the operating neutrino telescopes.
  - IceCube at South Pole
    - Giga-ton detector, sensitivity ~> 1 TeV
    - DeepCore infill detector in IceCube, 15 MT detector, sensitivity ~> 10 GeV.
    - Some ideas being considered as extensions to this
      - Simple: more infilling (~10 MT at ~GeV thresholds or ~70 MT at ~10 GeV)
      - More extreme: Build a 1 MT ring imaging in-ice detector (~10 MeV thresholds)
  - Antares
    - Similar in size to IceCube DeepCore but in Northern hemisphere
    - Proposed KM3Net extension in Mediterranean (higher energies)
- In 5-10 yrs: either stricter limits or discoveries to confirm!

Reference configurations

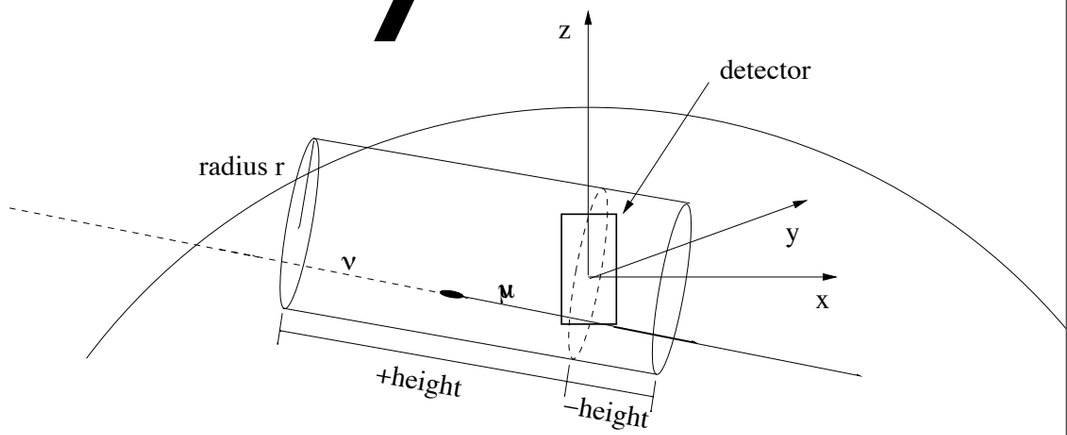
- Reference configurations include several options:
  - 3 @ 100 kT water cherenkov
  - 3 @ 17 kT Liquid Argon detectors
  - 2 WC/ 1 LAr
  - 2 LAr/ 1 WC
- Largely ignoring perturbations in proposed designs (pmt density, Gd loading, depth)
  - Assuming all detectors will be able to trigger in response to and reconstruct ~100 MeV muons in detector.

Sensitivity study

- Focus on higher energy neutrinos
  - Simulating 10 GeV - 100 PeV muon neutrinos
    - CC interaction muons: long path lengths yields increased sensitivity
    - Higher energy neutrinos have good correlation between neutrino and lepton directions.
    - Reduced background from atmospheric neutrinos (that have a softer spectrum)



Sensitivity study



- Simulated neutrinos using ANIS (All neutrino interaction simulation[1]) tool
  - Simulates neutrino flux from earth surface thru detector volume, including CC and NC interactions
  - Events are weighted relative to total neutrino interaction probability.
- Leptons (muons) produced in CC interactions are propagated[2] thru detector volume region.

(1) Comput.Phys.Commun. 172 (2005) 203-213 (arXiv: astro-ph/0406439)
(2) Muon Monte Carlo (MMC) tool ->arXiv: hep-ph/0407075v2

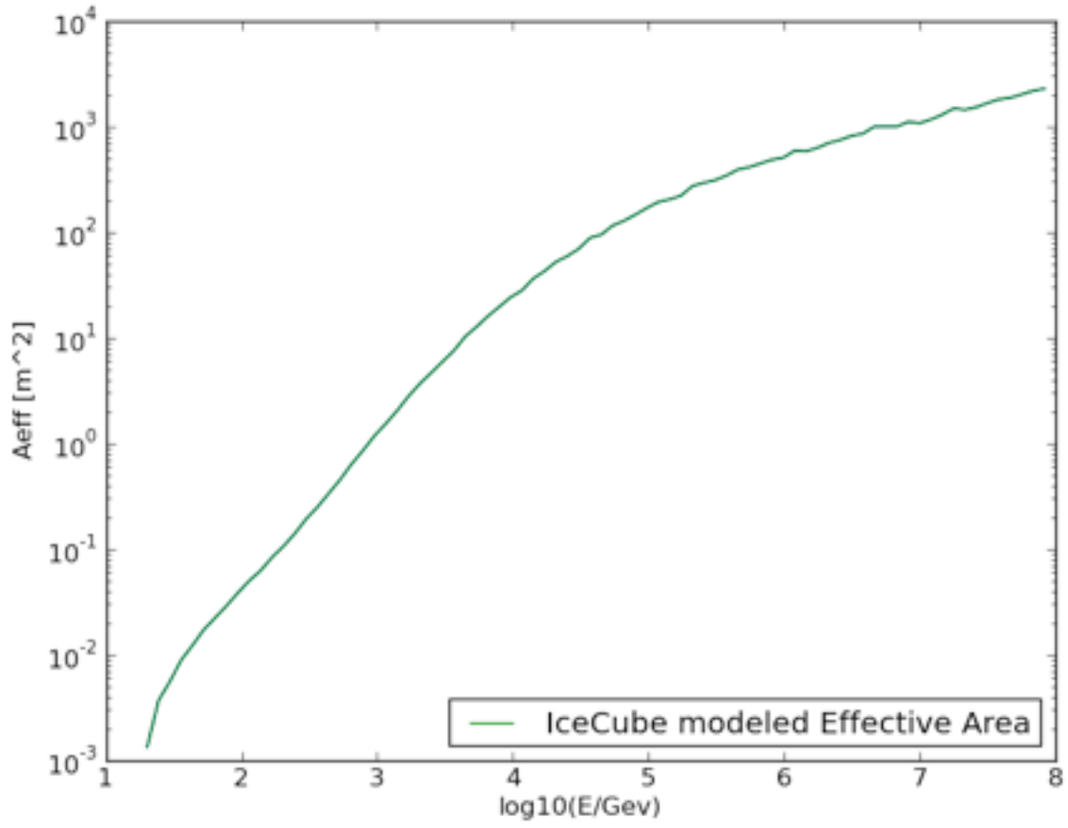
Sensitivity study

- Made simple, basic assumptions about detectors
  - Simplified detector volumes (spheres) and counted any event with ~100 MeV muon in detector volume
    - Detector simulations are still a work in progress at this point
    - Over-estimates the cross sectional area by ~10-20%.
- Events "detected" if pass thru volume.
  - Event count from a particular source is not everything:
    - Backgrounds (atm neutrinos) are a uniform background you must overcome.
    - Several handles (different spectra, time coincidences, etc) allow for separation of signal to background.
  - Require more detailed studies with fuller MC.
  - Study good for ~factor of 2-3 in estimated event rates.
- Neutrino effective area, can be convolved with any flux to get event rate:

$$N_D = \int dt \int d\Omega \int dE \; \Phi_\nu(t, \Omega, E) \, A_{eff}(\Omega, E) \; .$$

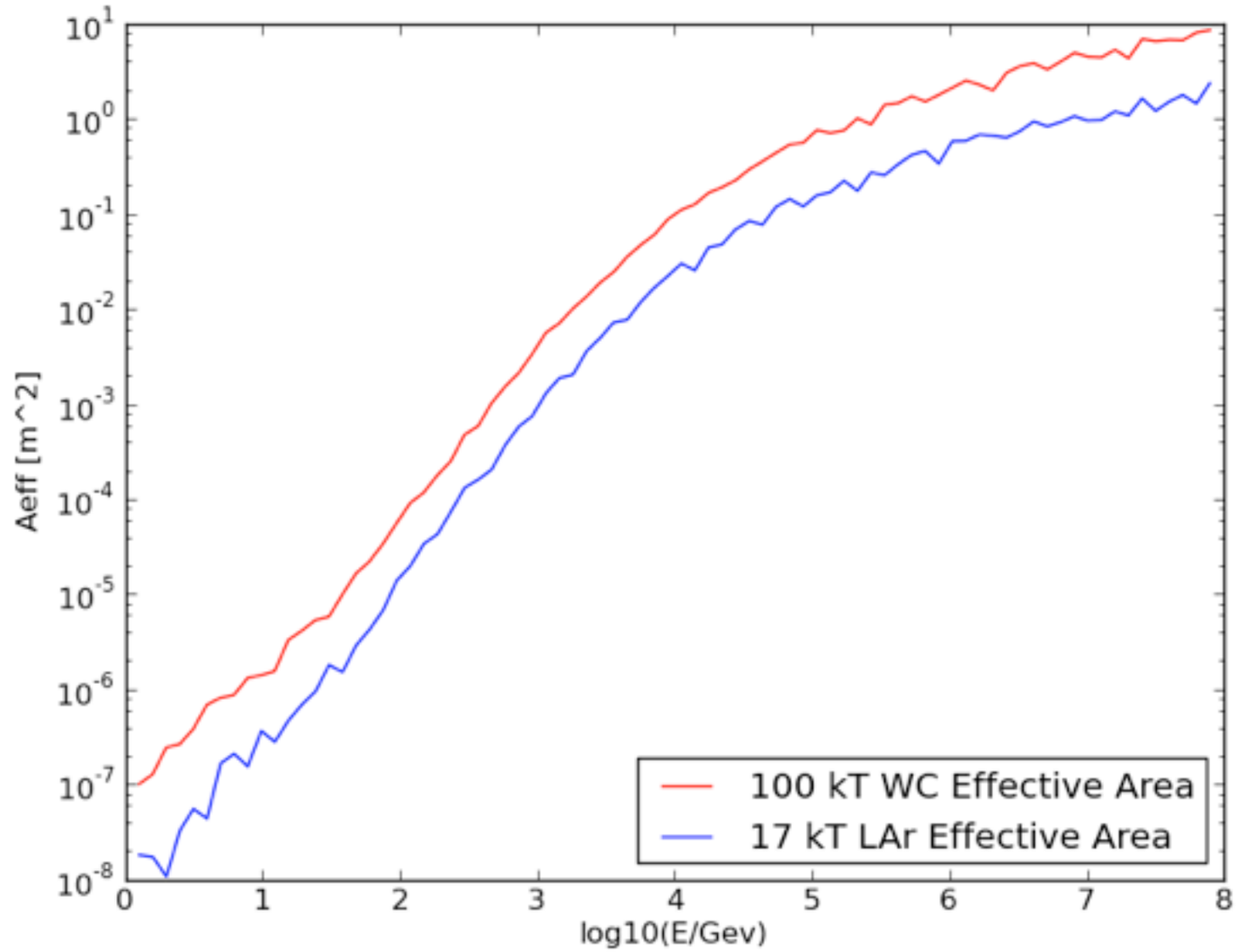
Sanity check

- Applied same simulation to an IceCube like detector (sphere r=500m, muon threshold 20 GeV)
  - Neutrino effective area obtained is very comparable to current sensitivities
    - Event rates from sources for this detector also calculated. Reasonable agreement with existing IC40/IC59 IceCube analyses.



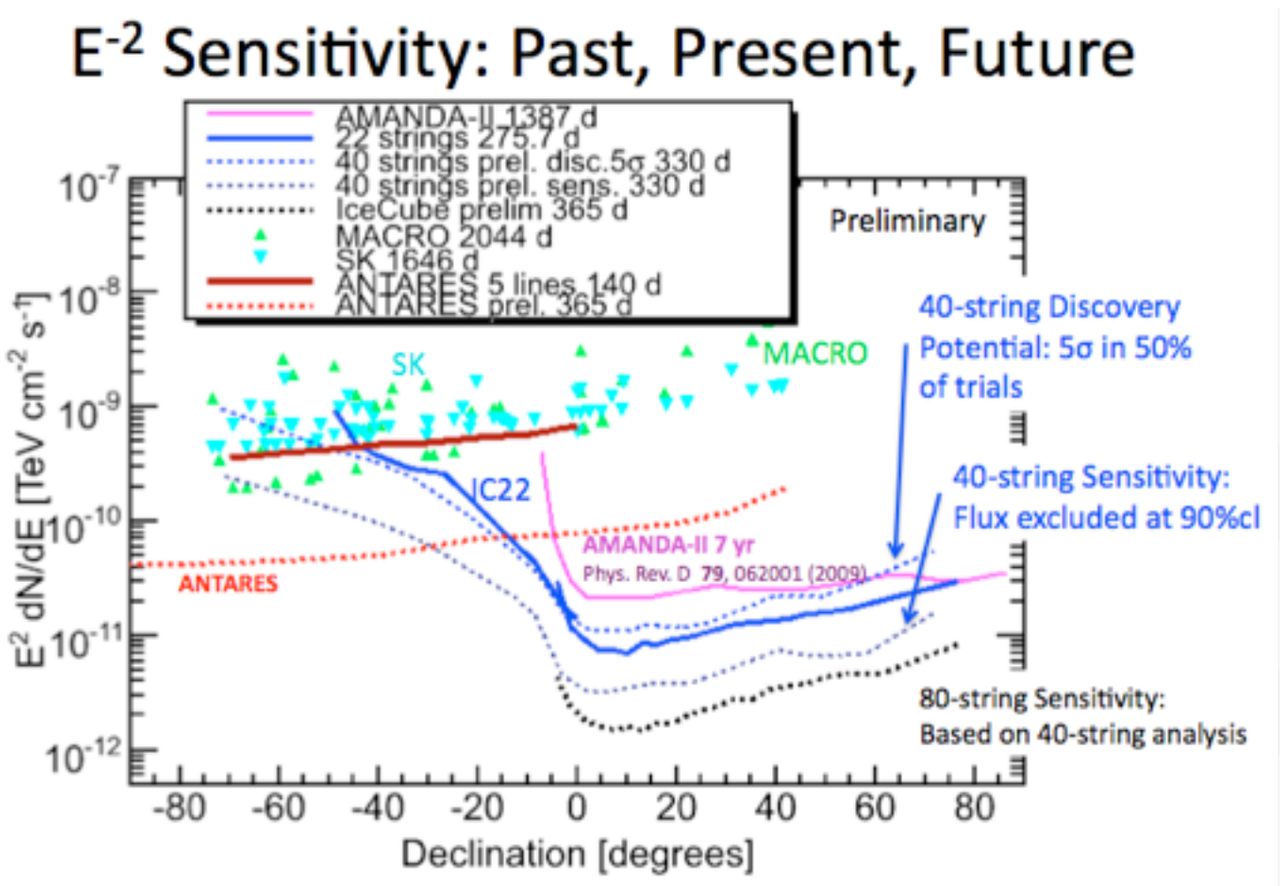
Effective areas for WC and LAr

- WC model
  - Sphere
  - R = 28.8m
    - 100kt
  - A = 2600 m^2
  - Emin = 100 MeV
- LAr model
  - R= 14.2 m
    - 17kt
  - A = 630 m^2
  - Emin = 100 MeV



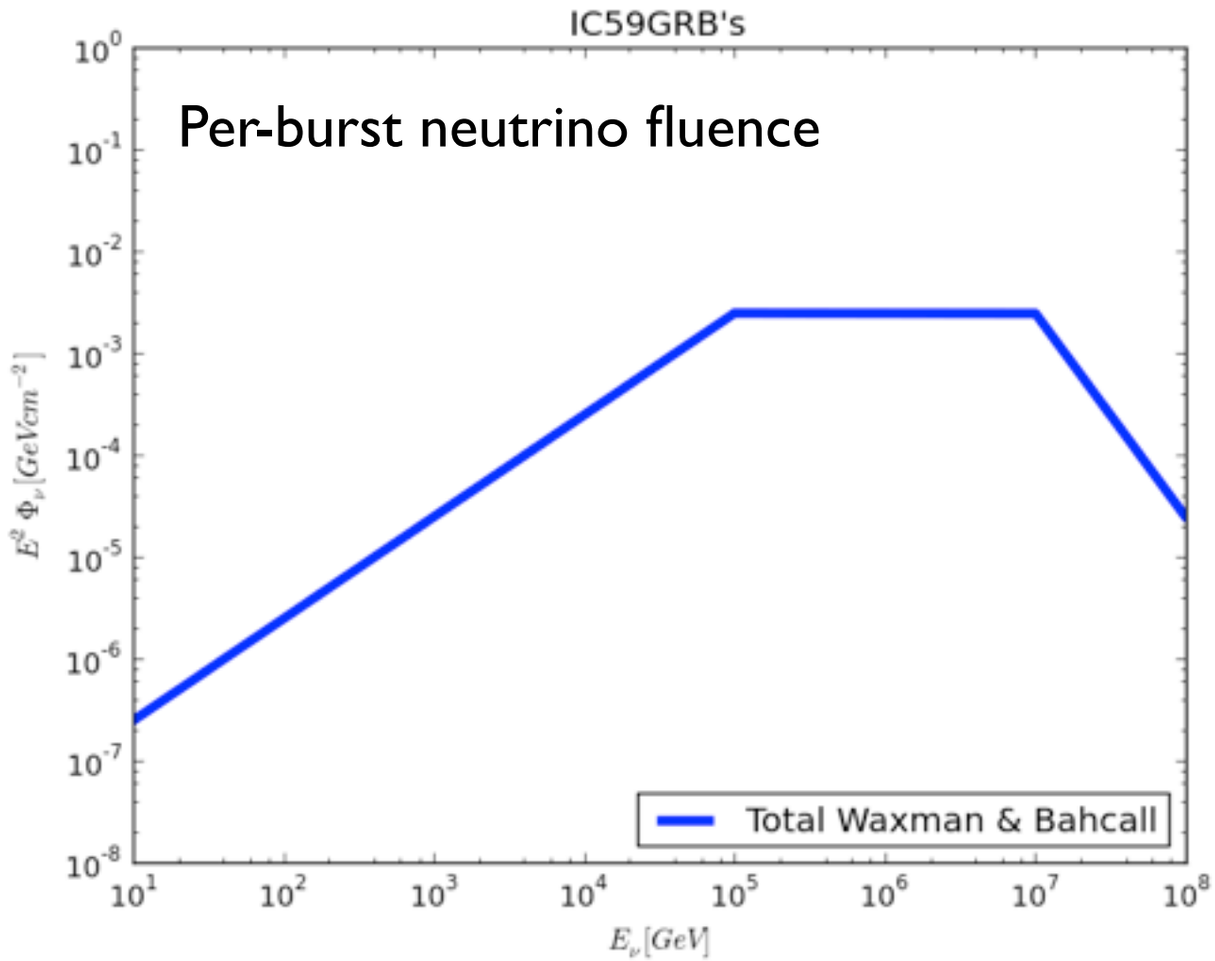
Potential sources studied

- (1) E^{-2} point source in northern hemisphere.
  - At current sensitivity of ANTARES:
  - $dN/dE = 5 \times 10^{-8}$ GeV^{-1} cm^{-2} s^{-1}



Potential sources studied

- (2) WB-like spectrum from ~150 visible GRB year
  - Neutrino fluence based on average burst x-ray spectra



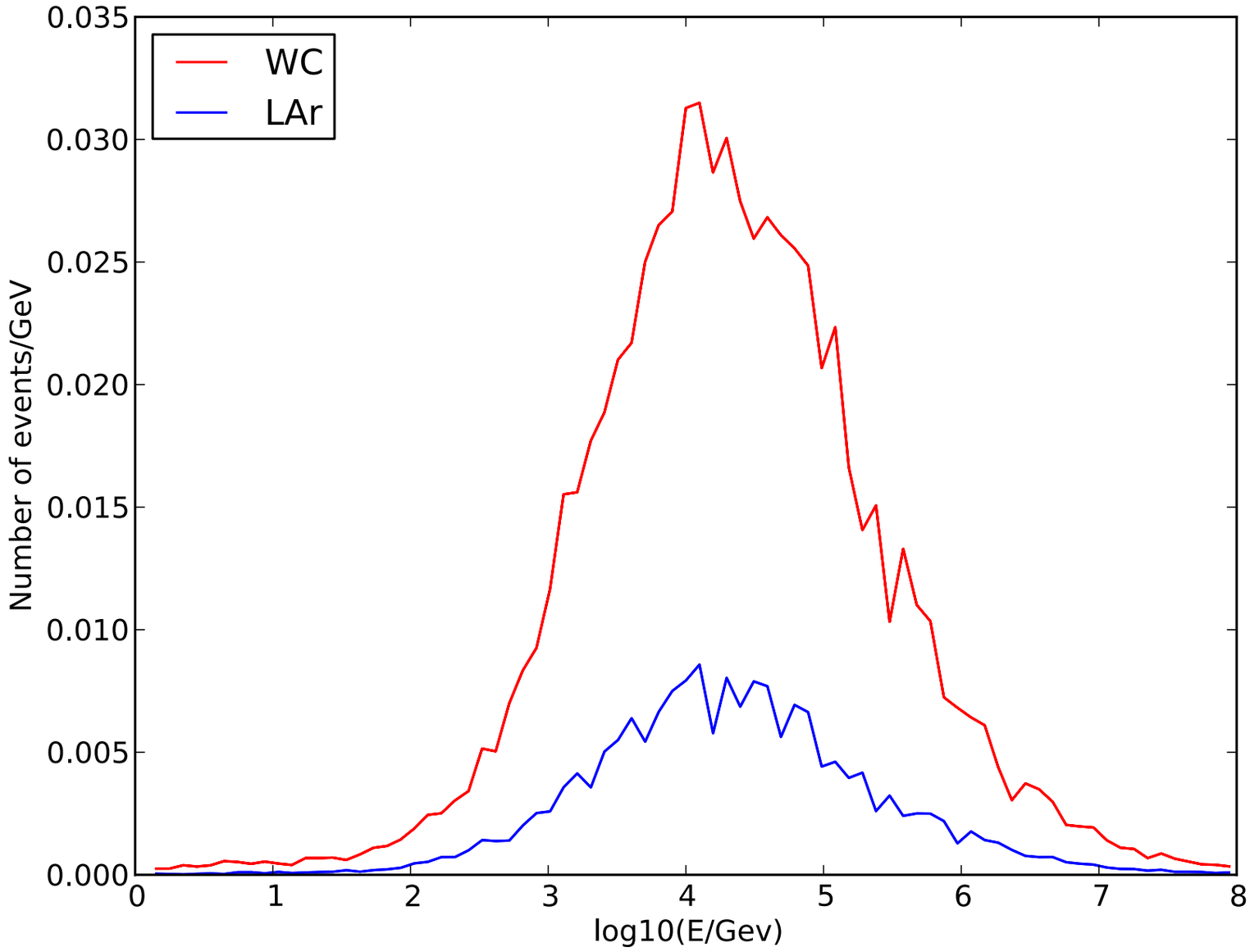
Predicted event rats

- Convolved fluxes with Aeff and obtained total events expected.

Events/yr	(1) Point src	(2) 150 GRB
100kt WC	0.7	0.07
17 kt WC	0.2	0.02
Toy IceCube	214	18

Multiply by N detector to get total event rates

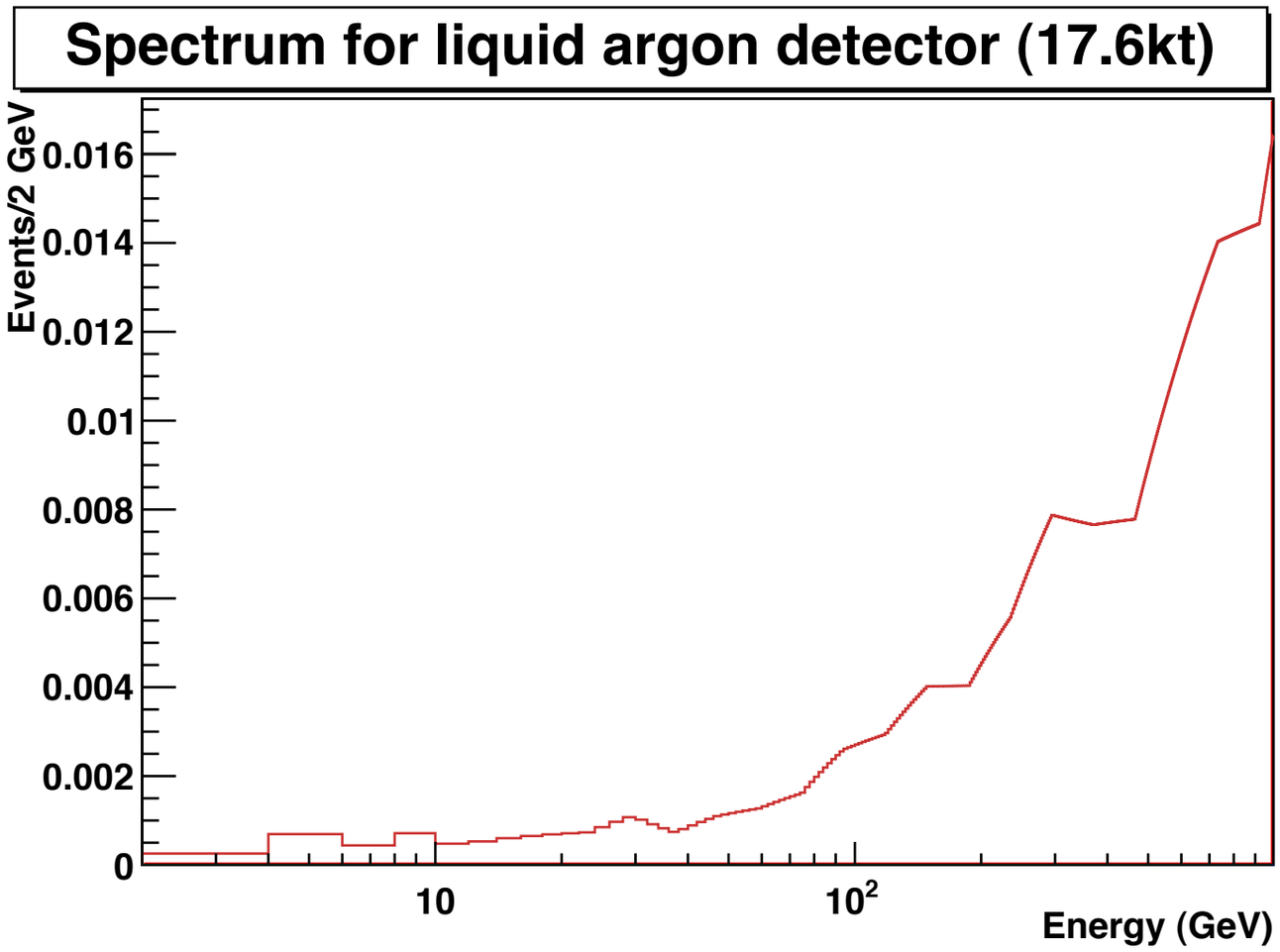
Events from a E^{-2} Point source



Mean energy ~10 TeV

Cross checks...

- Roxanne G. has been investigating LAr sensitivity with GLoBES
- Preliminary results agree with other study to within factor of 3.



Future...

- Certainly not the perfect study, but should set scale for neutrino astronomy possible with LBNE far detector
- Other investigations require more detailed study
  - Any "contained" event signal needs to relatively strong and or very "bursty" be identifiable over irreducible atm neutrino background.
  - Include backgrounds from atm neutrino and atm muons in sensitivity studies.

Physics Report conclusions

- Neither 100-300 kton of WC or 17-51 kton of LAr are optimal detectors for UHE neutrino signals
  - Neither very competitive with current/planned generations of neutrino observatories.
- Slight advantage for WC based on size, but hardly enough to make it competitive.
- Certainly would encourage more study and searches, especially for transient events where time correlations could increase sensitivity.
- Pursuing these studies is definitely encouraged
  - Searches at the "edge" of sensitivity require understanding the irreducible background of atm neutrinos to high precision
  - Excellent learning opportunity for students

What's next?

- Plans to merge the UHE Neutrino TG into the Atm neutrino group.
  - Very limited manpower and limited participation in this TG to date.
- Interest will likely pickup once there is data to look at....
- Look forward to working with Hugh going forward.