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Ultrahigh Energy Neutrinos with a Mediterranean Neutrino Telescope

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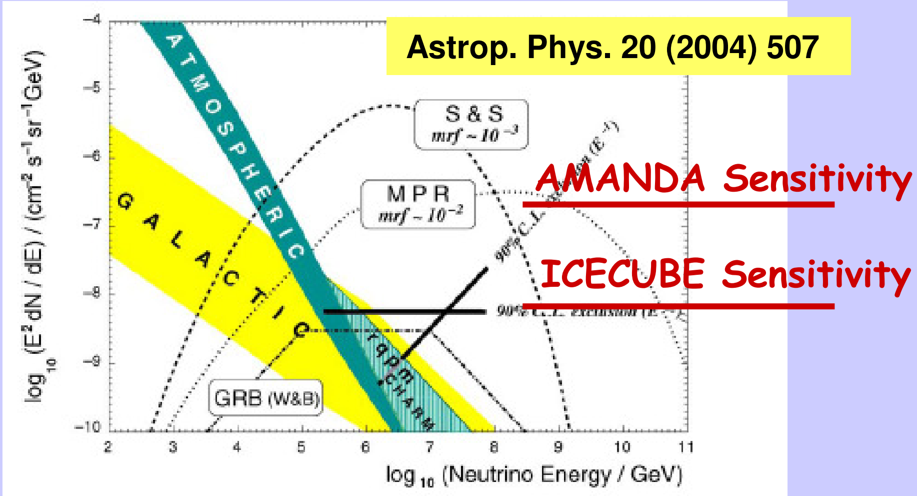
Why to detect UHEν at a 1 Km^3 Neutrino Telescope?



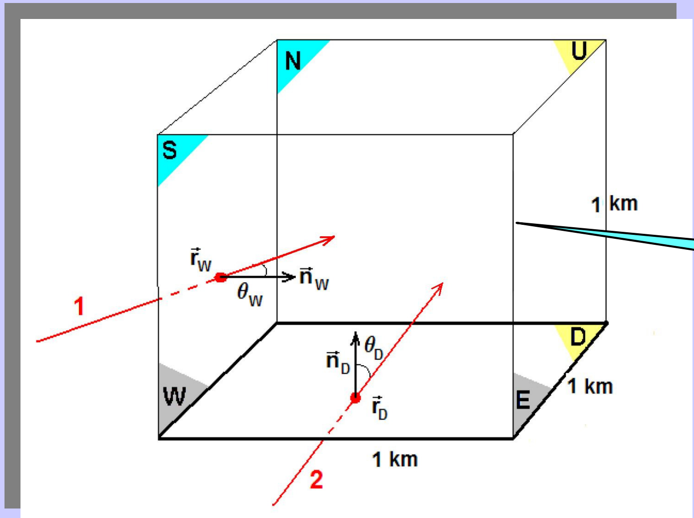
- The extragalactic contribution dominates: extragalactic astronomy
- It is possible to measure simultaneously the neutrino flux and the ν-Nucleon cross section, at energies and kinematical regions never tested. Events ν_τ and ν_μ induced.

The rate of τ-μ events in 1 Km^3

$$\frac{dN_l}{dt} = D \sum_a \int d\Omega_a \int dS_a \int dE_\nu \frac{d\Phi_\nu(E_\nu)}{dE_\nu d\Omega_a} \int dE_l \, \varepsilon(E_l) \cos(\theta_a) \, k_a(E_\nu, E_l; \vec{r}_a, \Omega_a)$$

Probability that an incoming ν, with energy E_ν and direction Ω_a, crossing the earth or the water, produces a lepton l which enters the fiducial volume with energy E_l, through the lateral surface dS_a at the position $\vec{r}_a$.

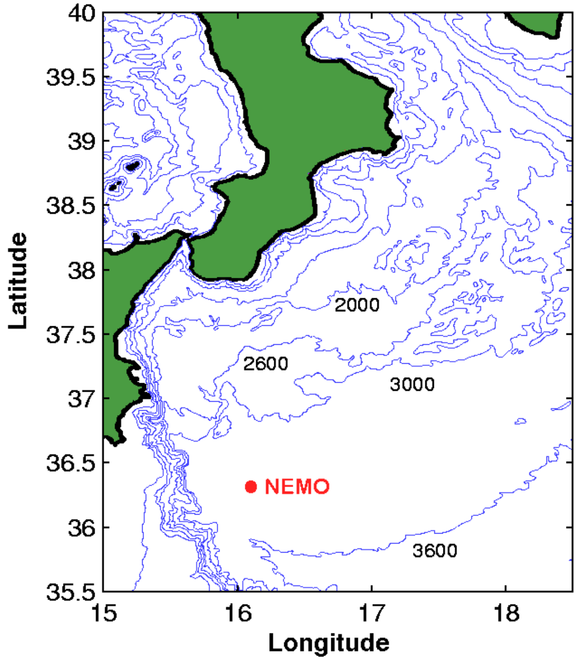
Same calculation for Auger in PLB634:137-142,2006



Fiducial volume,
no experiment characteristics,
just able to recognize τ-μ

a = W, E, S, N, U, D

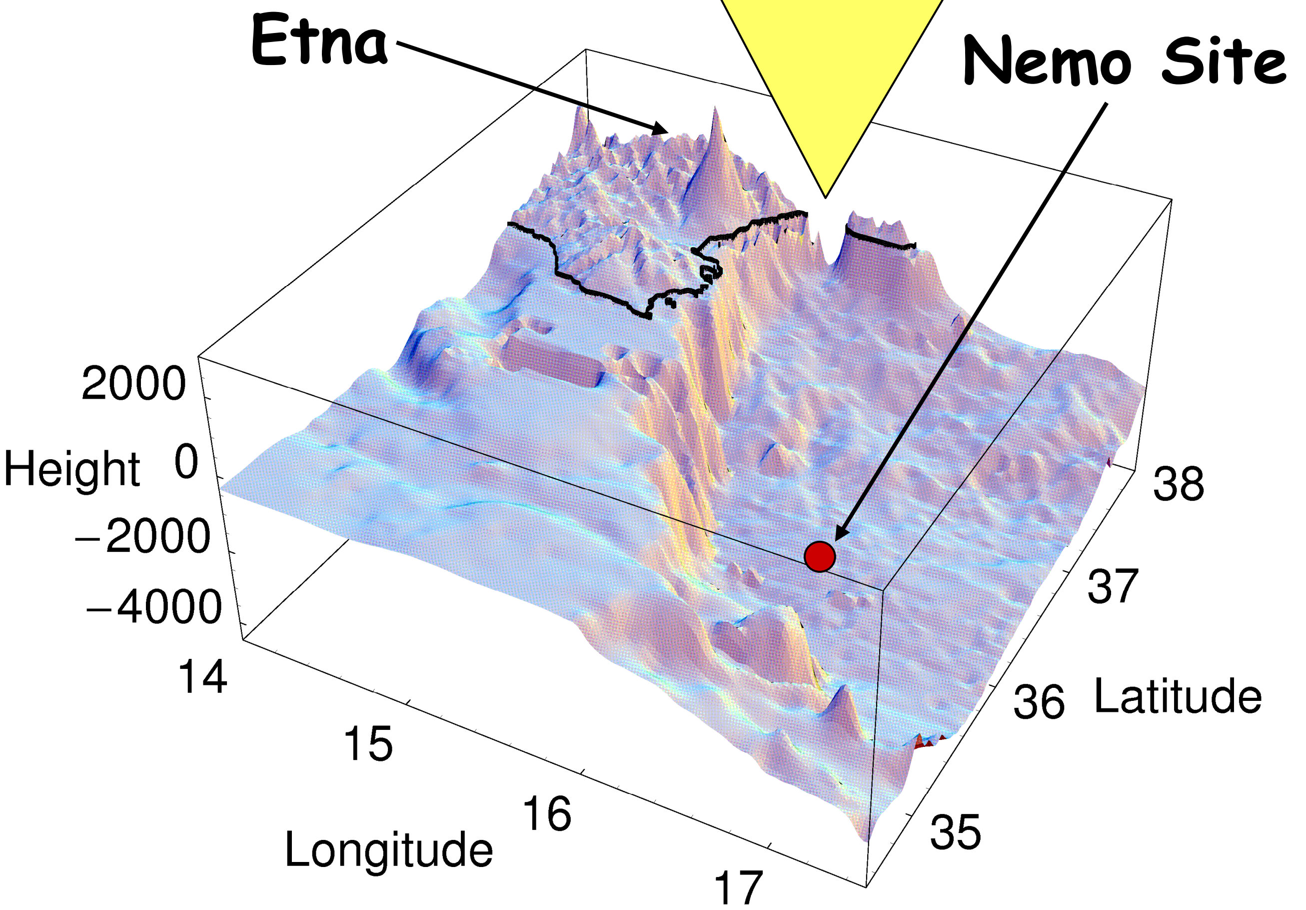
Nemo experiment

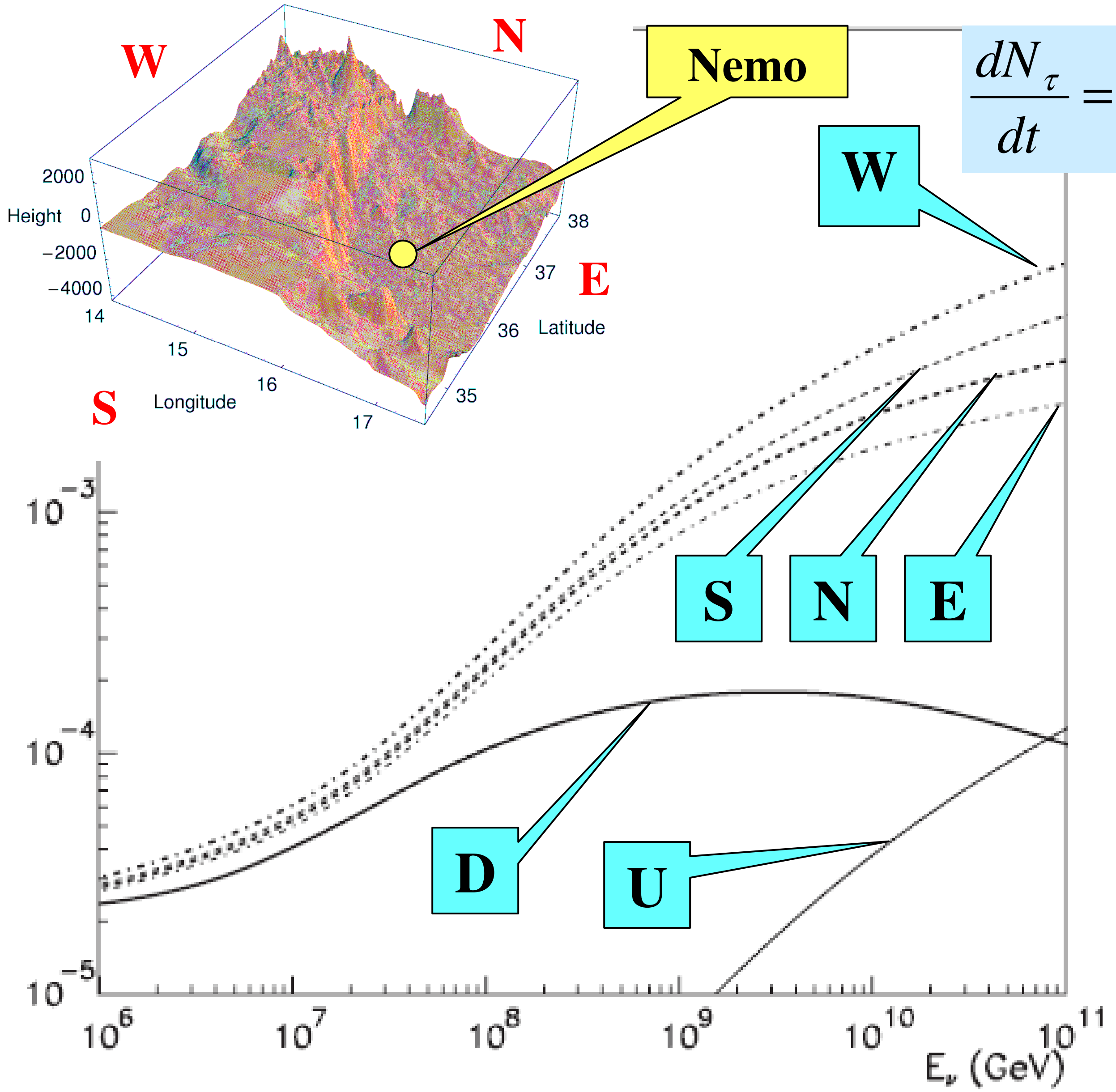


- **Site Location**
  36°21′ N, 16°10′ E

- **Average Deep**
  ~3500 m
  (3424 in our simulation)

Digital Elevation Map (DEM)

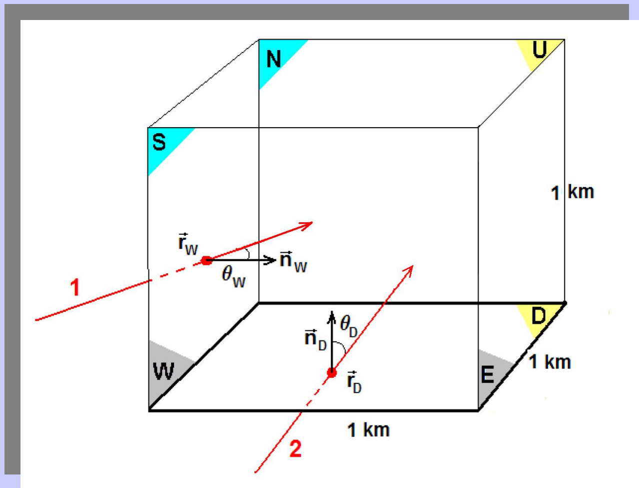




$$\frac{dN_\tau}{dt} = \sum_a \int dE_\nu \, \Phi_\nu(E_\nu) A_a(E_\tau)$$

Apertures for τ tracks crossing the rock in Nemo

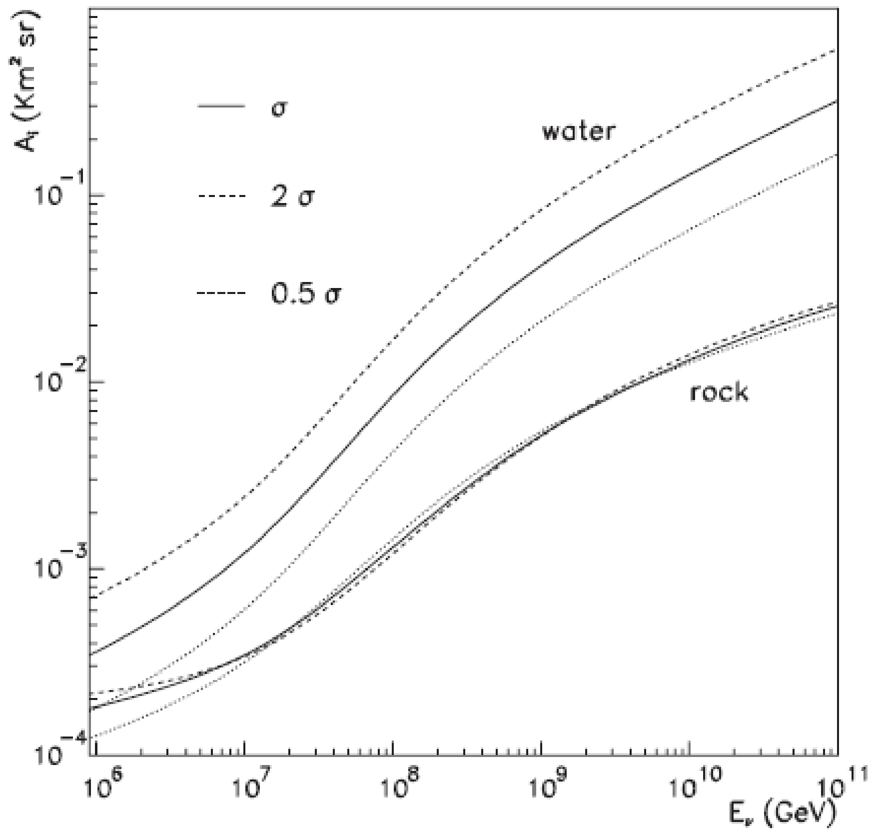
Matter Effect!

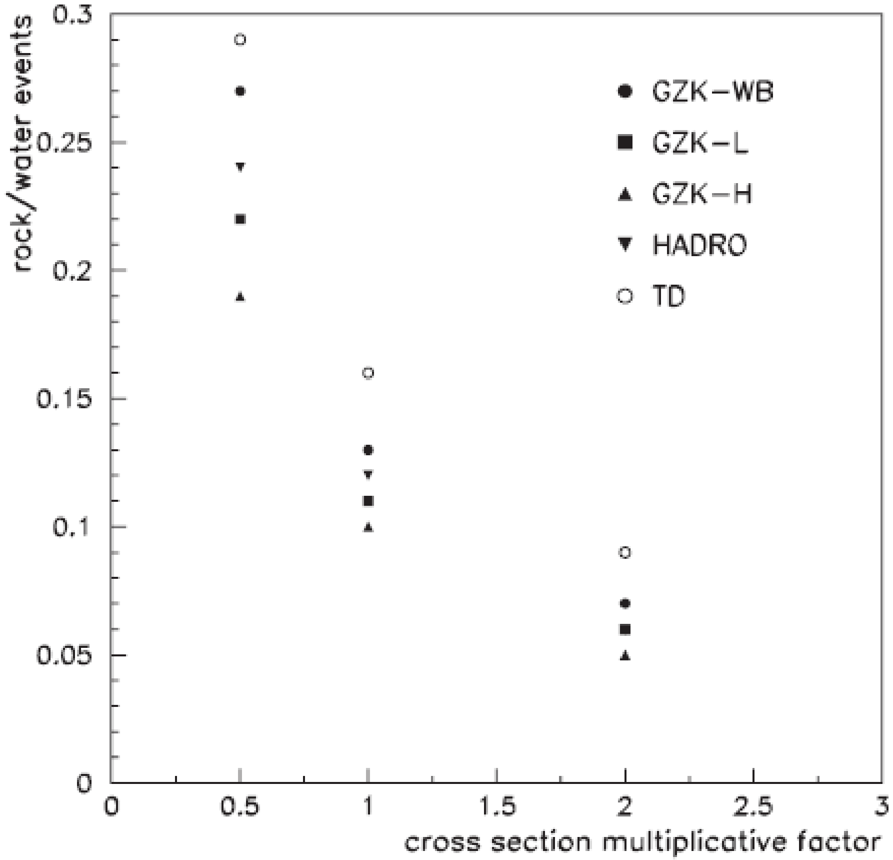


JCAP 0702 (2007) 007

Disentangling flux from cross section

The number of rock/water events is a good estimator of ν flux and ν-Nucleon cross section.





Lepton energy loss in the detector

- μ and τ contributions summed and real observable considered, that is the energy deposited in the detector.

$$\Delta E_l \cong \lambda(\vec{r}_a, \Omega_a)\, \beta_l\, E_l\, \rho_w$$

energy per unit of length

- Detected events properly binned for energy loss and arrival direction to constrain flux and cross section.

$$N_{ij} = T \sum_{\alpha=\mu,\tau} \sum_a \int_{X_i} d(\Delta E) \int_{Y_j} d\Omega \int dS_a \int dE_\nu \, \frac{d\Phi_\nu(E_\nu)}{dE_\nu d\Omega_a} \frac{\cos(\theta_a)\, k_a(E_\nu, E_l; \vec{r}_a, \Omega_a)}{\lambda(\vec{r}_a, \Omega_a)\, \beta_l\, \rho_w}$$

X_i=energy loss bin
Y_j=direction bin

Constraining parameters

- Waxman-Bahcall neutrino flux

$$\frac{d\Phi_\nu(E_\nu)}{dE_\nu\, d\Omega_a} = C \cdot 1.3 \cdot 10^{-8}\, E_\nu^{-2\,D}\ \mathrm{GeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}$$

Phys. Rev. D59 (1999) 023002
Annals Phys. 321 (2006) 2660

- Generalization of standard cross section (change in energy slope)

$$\frac{\sigma_{CC}^{\nu N}}{10^{-33}\,\mathrm{cm}^2} = \begin{cases} 0.677 \cdot 10^{-3}\, E_\nu^{0.492} & E_\nu \leq E_1 \\ 0.344 \left(\frac{E_\nu}{E_1}\right)^{0.492A} & E_\nu > E_1 \end{cases}$$

Phys. Rev. D58 (1998) 093009

$E_1=10^{5.5}$ GeV

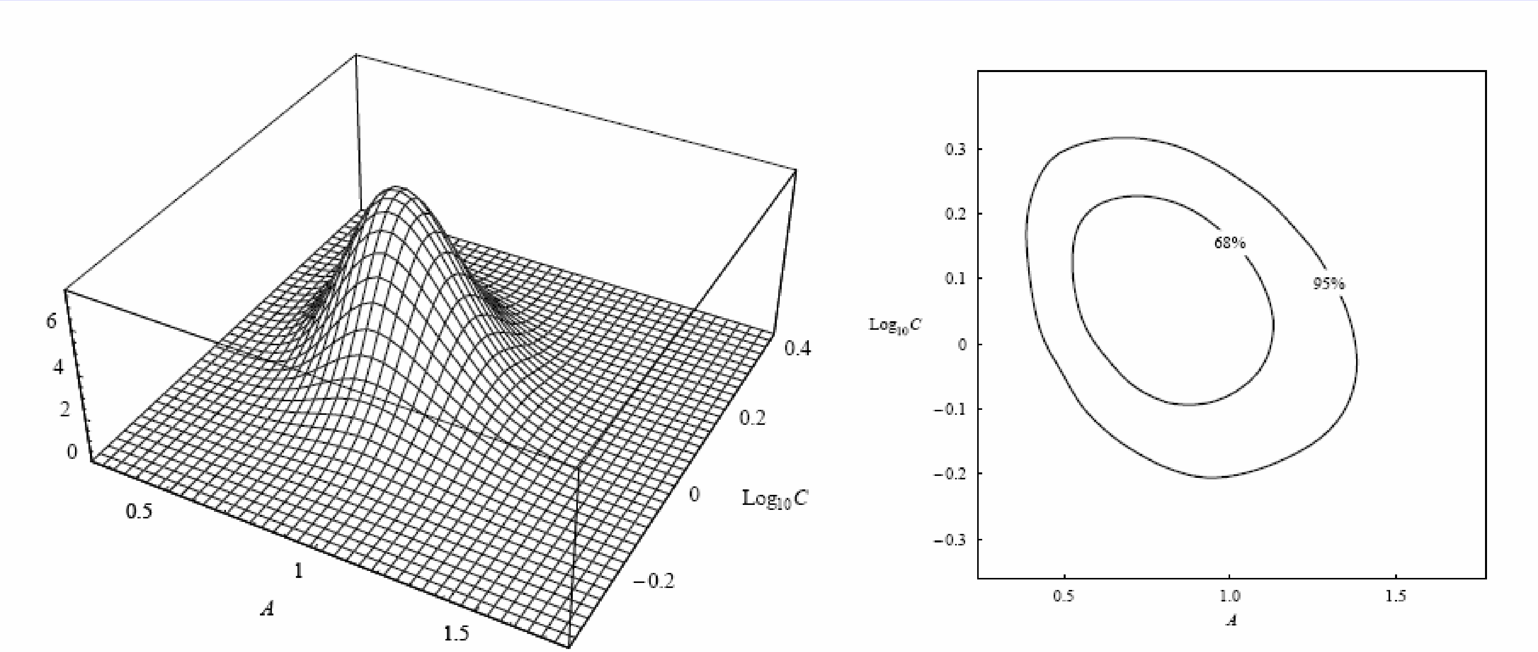
- Multi-Poisson likelihood analysis, with $L=\exp(-\chi^2/2)$ and

$$\chi^2 = 2\sum_{ij}\left[(N_{ij} - N_{ij}^0) + N_{ij}^0 \ln(N_{ij}^0/N_{ij})\right]$$

N_{ij} (A,C,D) = # of events in the i energy and j direction bin

N_{ij}^0= # of events for the reference model

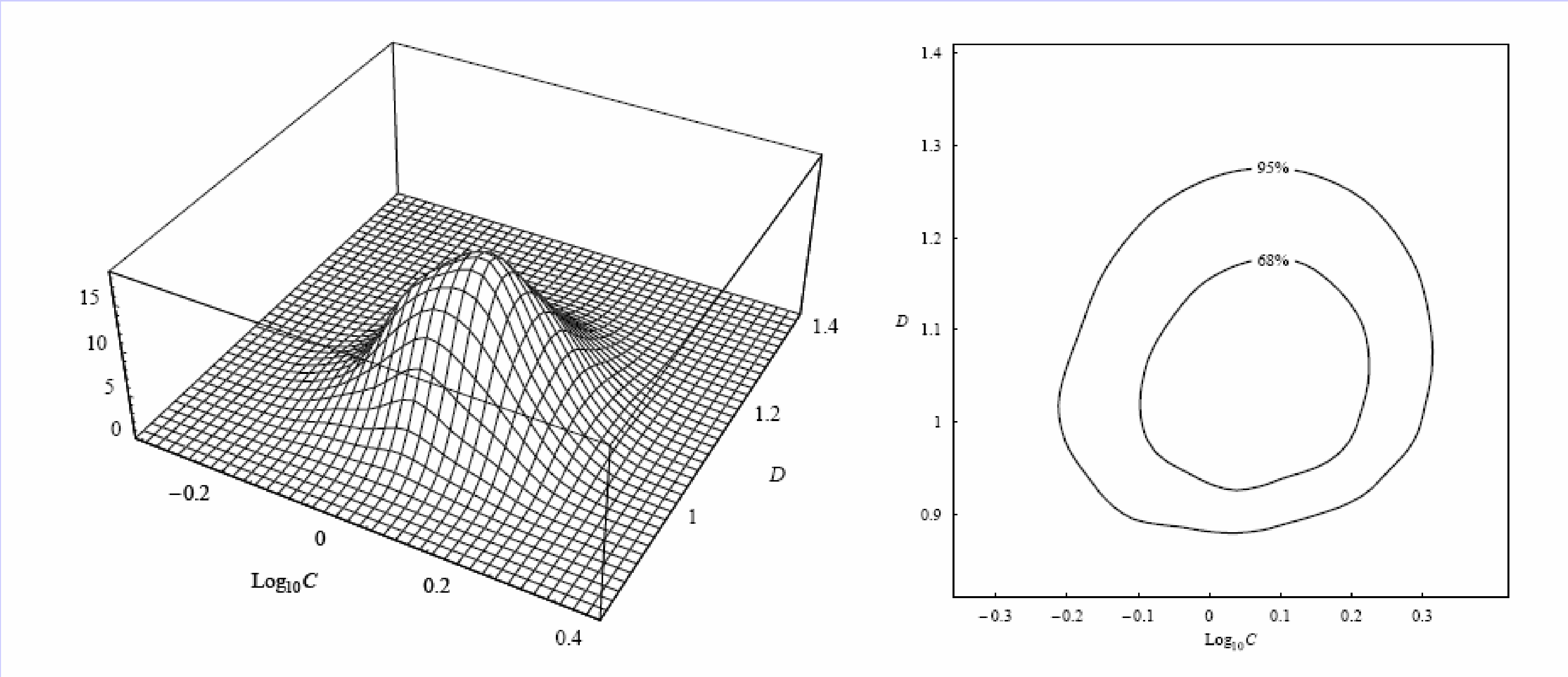
Marginalized likelihoods and contour plots for two energy and three angular bins and an exposure time of 5 years.



$0.6 \leq A \leq 1.1$ (68% CL)

$-0.1 \leq \log C \leq 0.2$ (68% CL)

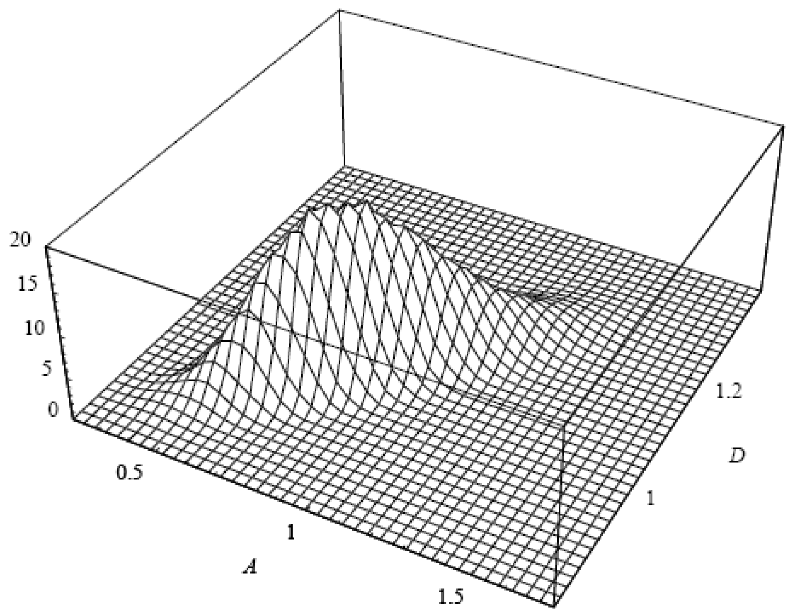
Marginalized likelihoods and contour plots for two energy and three angular bins and an exposure time of 5 years.

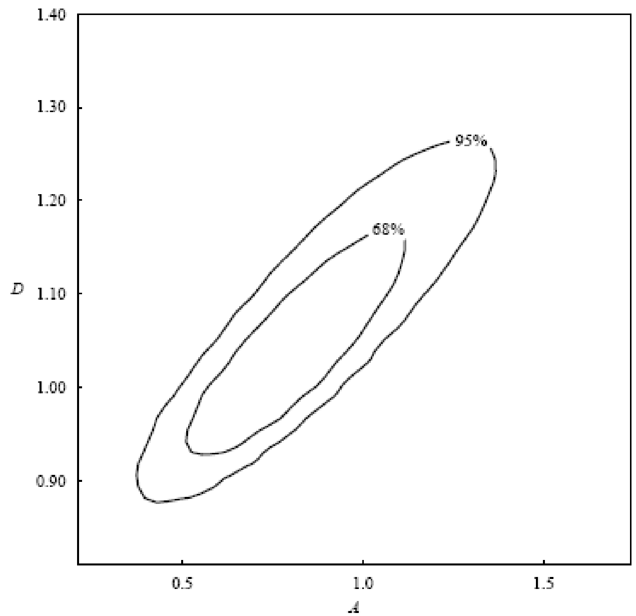


$0.95 \leq D \leq 1.15$ (68% CL)

$-0.1 \leq \log C \leq 0.2$ (68% CL)

Marginalized likelihoods and contour plots for two energy and three angular bins and an exposure time of 5 years.





$0.6 \leq A \leq 1.1$ (68% CL)

$0.95 \leq D \leq 1.15$ (68% CL)

Conclusions and outlook

• UHE ν detection allows for extragalactic ν-astronomy, and makes possible the simultaneous measurements of the νN cross section at energy ranges never explored before (New Physics?), and the value of astrophysical neutrino flux. This can be done using the different behavior of the number of events in different energy and arrival direction bins.

• Simple parameterizations of flux and cross section have been considered, but work is in progress for more general expressions.