# Event Rates at Neutrino Telescopes:

HOW THEY DEPEND ON UHE CROSS SECTIONS & FLUXES

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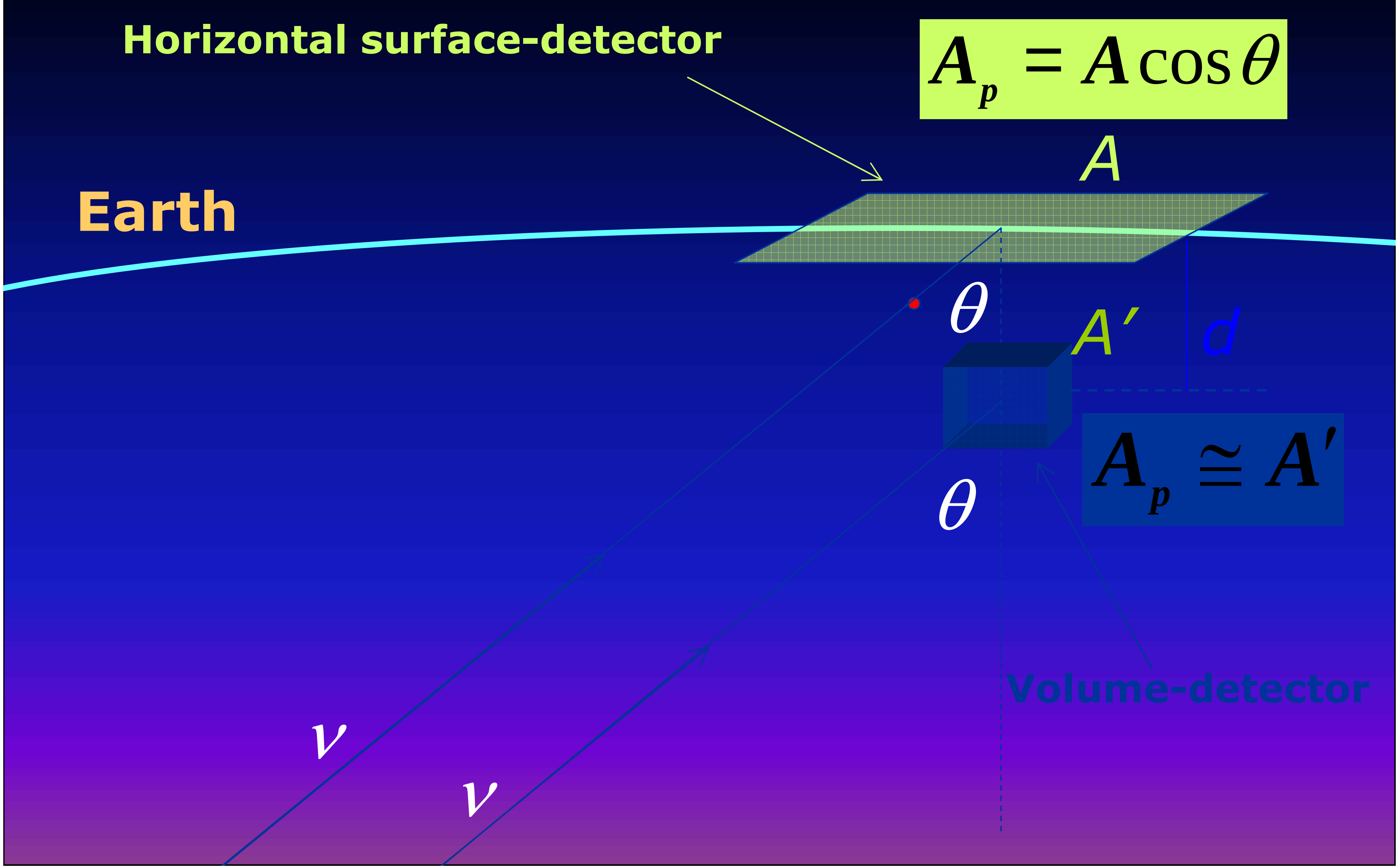
# EVent rates- a simple model



# The overall problem

Suppose your favorite neutrino telescope reports events above a PeV. How do you separate

- The flux of neutrinos to probe the physics of UHE sources
- The neutrino cross section to probe UHE particle physics?

# Power Law Fluxes and X-Sections

Specifically: given a flux $F \sim F_0\ E^{-i}$, how do the rates in a given energy range depend on the flux spectrum and the cross section $\sigma \sim \alpha \sigma_{SM}\ E^{A}$ for up-going events and for down-going events (showers, $\mu$'s, $\tau$'s)?

# Our results in a nutshell

Roughly, in a given bin:

a) Down rates ~ $F_0 \bullet \sigma_{evt}$

b) Up rates ~ $F_0 \bullet \sigma_{evt}/\sigma_{abs}$

c) Up air rates ~ $F_0 \bullet \sigma_{evt}/(\sigma_{abs})^2$

# Why these results?

- Down flux *not* attenuated, hit probability at detector ~ $\sigma_{event}$ , so ***Rate per bin*** ~ $F_0 \bullet \sigma_{event}$

- Up flux *is* attenuated, ~ $1/\sigma_{abs,}$ hit probability at detector ~ $\sigma_{event,}$ so ***Rate per bin ~*** $F_0 \bullet \sigma_{event}/\sigma_{abs}$

# Build up a simple rate model

$$R = A_p \frac{d\phi}{d\Omega} \int_{\ell}^{2R} 2\pi \frac{dl}{2R} \int_{l-\ell}^{l} e^{-x/\lambda_a} \frac{dx}{\lambda_i}$$

$$\sin\vartheta = \frac{l}{2R}$$

# A simple up-rate model

We assumed isotropic flux & uniform ρ; now integrate over sensitive detector depth (x) and polar angle (*l* integration) and get the rate for up events:

$$R(E) = \pi A_p F E \frac{\lambda_a^2}{R\lambda_i}\left(1 - e^{-\ell/\lambda_a}\right)\left(1 - e^{-(2R-\ell)/\lambda_a}\right)$$

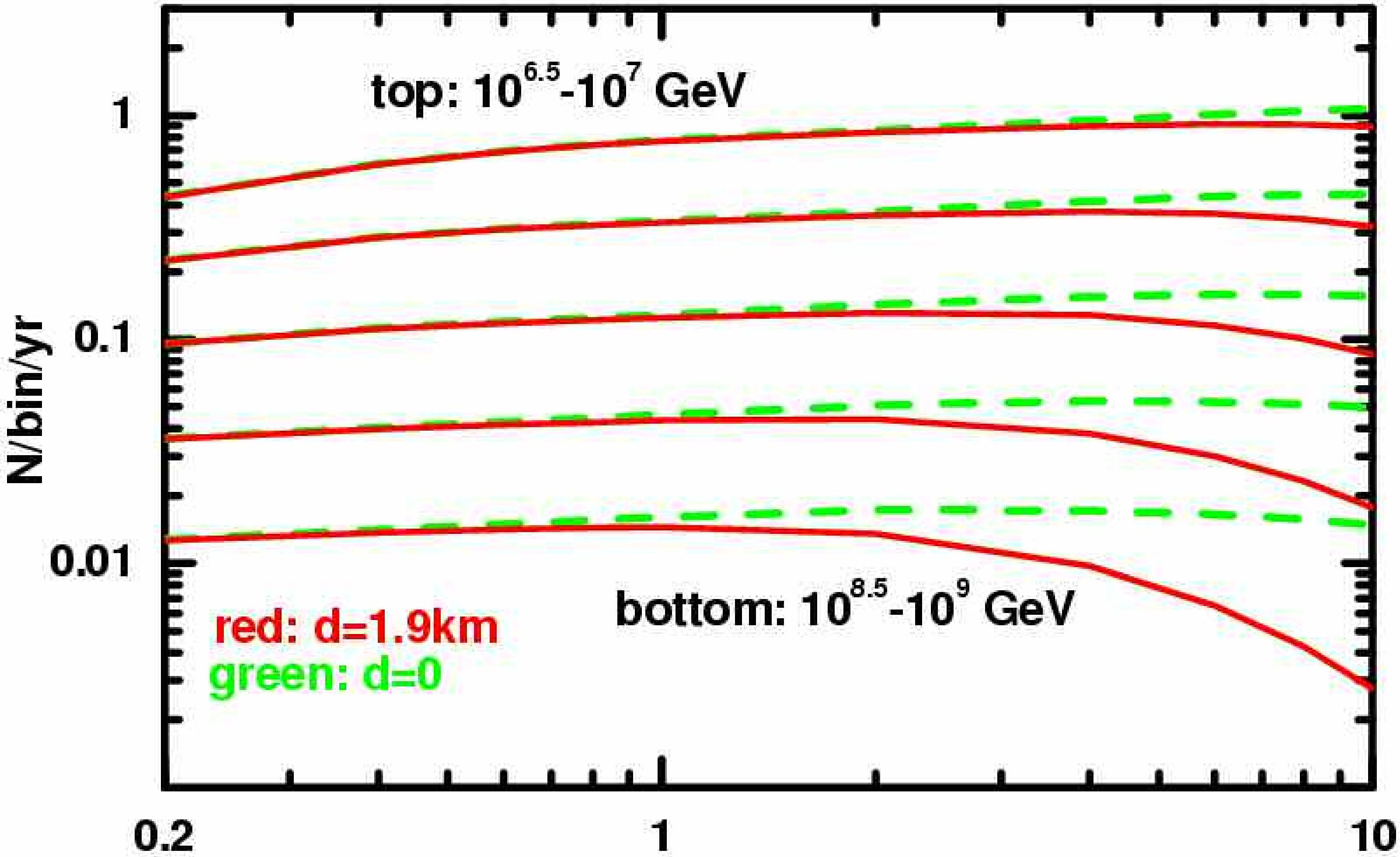
# Detailed simulations include:

- All interactions
- Neutral current downscattering of higher energy flux into lower energy bins
- $\tau$ regeneration

  $\tau$ lifetime
- Lepton energy losses
- IceCube $A_{eff}$ and $V_{eff}$ published simulations
- Detector at depth of 1.9 km.

Case I: $\sigma_{NC}(new) = \alpha\sigma_{NC}(SM)$; $\sigma_{CC}(new) = \alpha\sigma_{CC}(SM)$

Shower rates (per energy bin per yr) vs $\alpha$



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# Down Events: $10^{7} < E < 10^{7.5}$ GeV

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# CONCLUSIONS

- Given some UHE events, we can expect simple cross section dependence for each event type!

- As a consequence, flux-independent cross section values and vice-versa can be extracted!

# Change Flux index to 3 and 1

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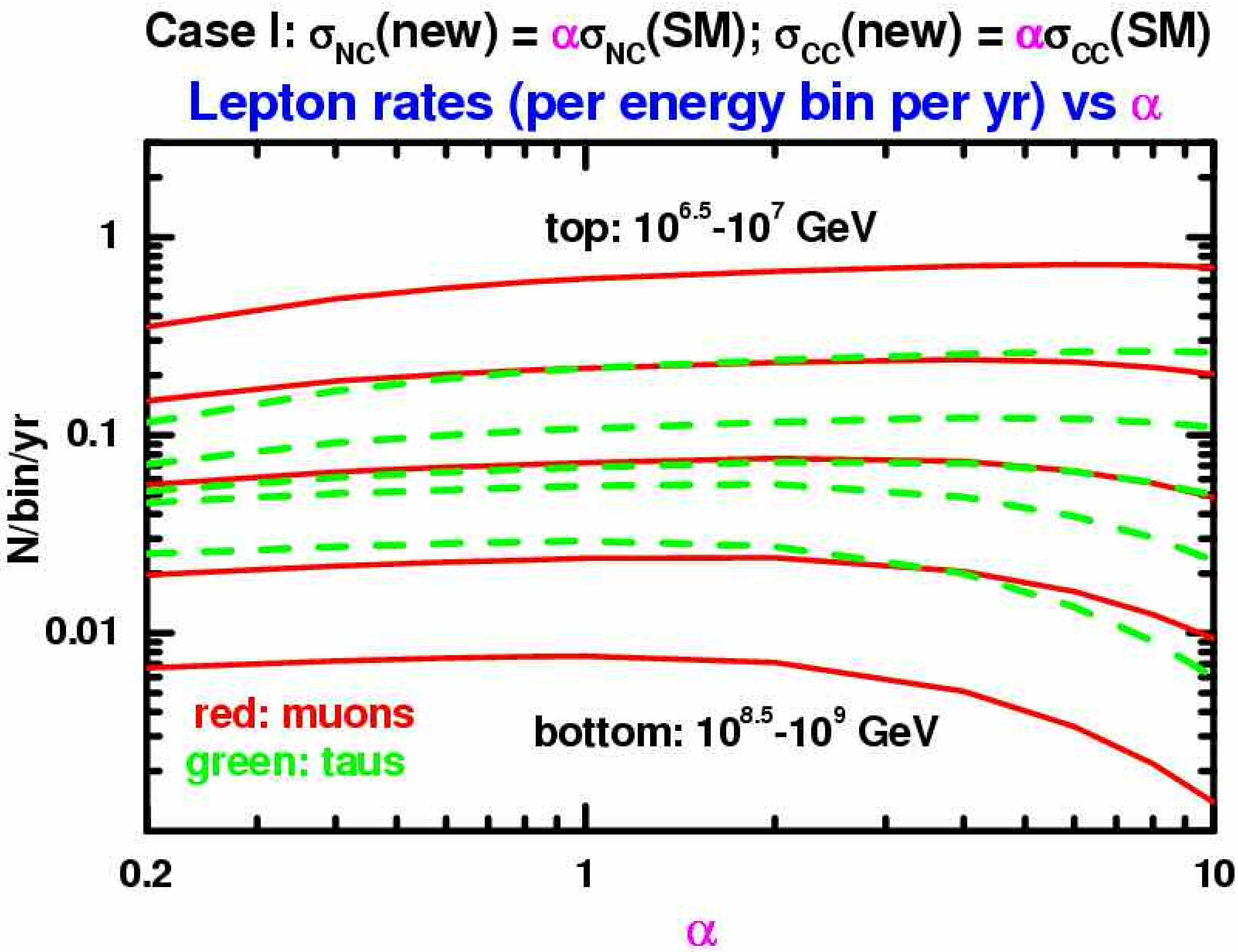
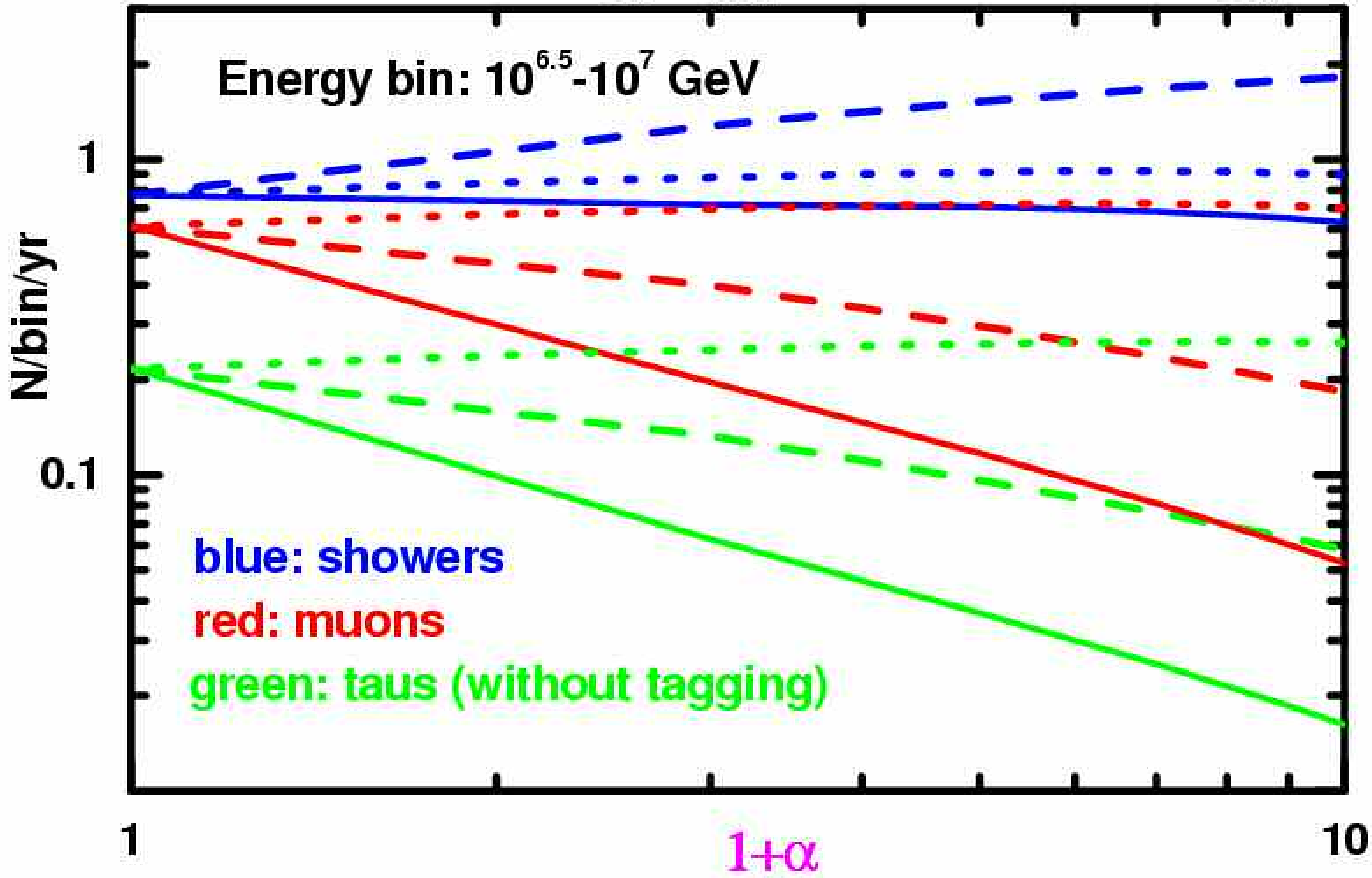


Case I: σNC(new) = ασNC(SM); σCC(new) = ασCC(SM)
Lepton rates (per energy bin per yr) vs α
top: 10^6.5-10^7 GeV
bottom: 10^8.5-10^9 GeV
red: muons
green: taus
N/bin/yr
1
0.1
0.01
0.2
1
10
α

Case I (DOTTED): $\sigma_{new}$ defined on previous slide.

Case II (DASHED): $\sigma_{SM}+\sigma_{new}$(NC-type) = $(1+\alpha)\sigma_{SM}$

Case III (SOLID): $\sigma_{SM}+\sigma_{new}$(BH-type) = $(1+\alpha)\sigma_{SM}$



# Example: Extract flux E-index

$$r_{i/j} \equiv \frac{\int_{bin\,i} F \cdot E^{i}}{\int_{bin\,j} F \cdot E^{j}} \cong \frac{N(bin\,i)_{showers}}{N(bin\,j)_{showers}} \frac{V_{eff}(bin\,j)}{V_{eff}(bin\,i)}$$

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# Up shower rate, limiting case

- With the inequalities

$$2R >> \lambda_a >> \ell$$

$$Rate \to \pi V_{eff} F \frac{1}{R} \frac{\lambda_a}{\lambda_i}$$

# Example:Extract flux norm

- $10^7$ GeV < E < $10^{7.5}$ GeV
- $V_{eff}$ ~ 2 $km^3$
- $R_{earth}$ ~ 6.4 $10^3$ km
- $n_{earth}/n_{ice}$ ~ 3
- $F_0$ ~ 3 $10^{-15}$ GeV $(cm^2\ s\ sr)^{-1}$ @ 2 $10^7$ GeV

- Agrees better than it should with W-B input!

- X-Section from down events also agrees!

# Event rates vs. sigma$_{SM}$ + alpha x sigma$_{new\ physics}$

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- "IceCube" event rates for $10^{6.5}$ - $10^{7}$ GeV for showers (solid), μ's (dash) and τ 's (dot).

***Upper*** curve is totally ***elastic*** new physics and ***lowe***r is highly ***inelastic*** in each case.

# The basic picture again

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