PeV cascades in IceCube: the way ahead

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Neutrino Astrophysics

J Bahcall in Neutrino Astrophysics (1989)

"The title is more of an expression of hope than a description of the book's contents....the observational horizon of neutrino astrophysics may grow ... perhaps in a time as short as one or two decades"

IceCube at the forefront of this new field

Has IceCube finally seen astrophysical neutrinos?

PeV cascades in IceCube

Two cascade events of energy ~ 1 PeV

From CC interactions of ν_e
or NC interactions of all flavors

Widely separated in time – not from a single transient source

Questions

Why are there no tracks in the analysis?

Why are the energies so close to each other?

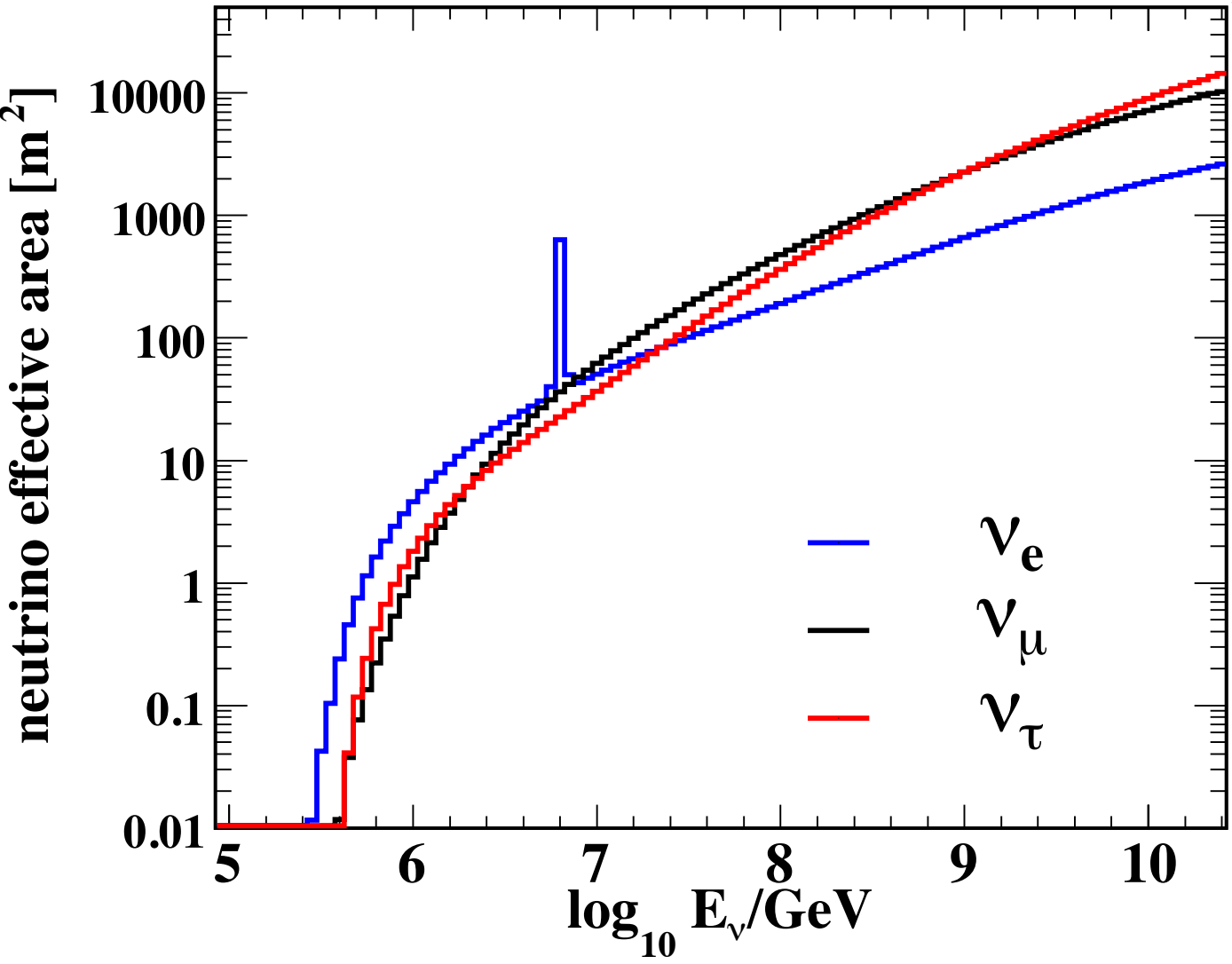
Where do the neutrinos come from?

Is the required flux consistent with previous constraints?

How to quickly distinguish between the source spectrum?

Why ν_e and not ν_μ ?

The search near 1 PeV is most sensitive to ν_e



IceCube collaboration
1304.5356

The signal cuts in this analysis are such that the exposure to muon neutrinos is lower than electron neutrinos around a PeV

Above ~10 PeV, the detection probability of muon neutrinos is enhanced

Why are the energies so close?

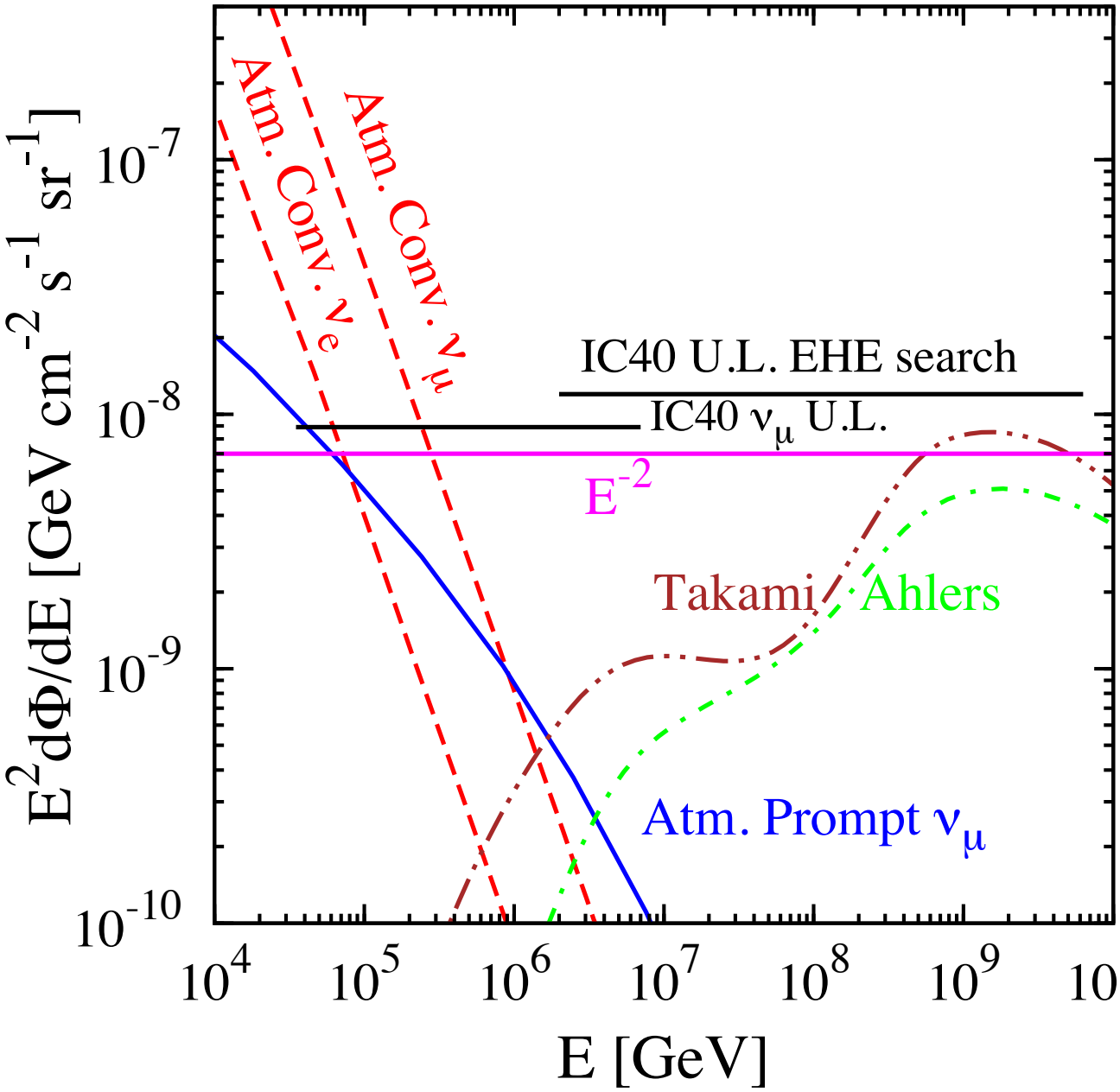
The threshold of the analysis is ~1 PeV

Due to threshold effects we are unable to infer any information about lower energy spectra

Lack of higher energy events suggest that the neutrino spectrum is falling

Excess at lower energies in IC59 data? (Schukraft 1302.0127)

Neutrino fluxes considered in this work

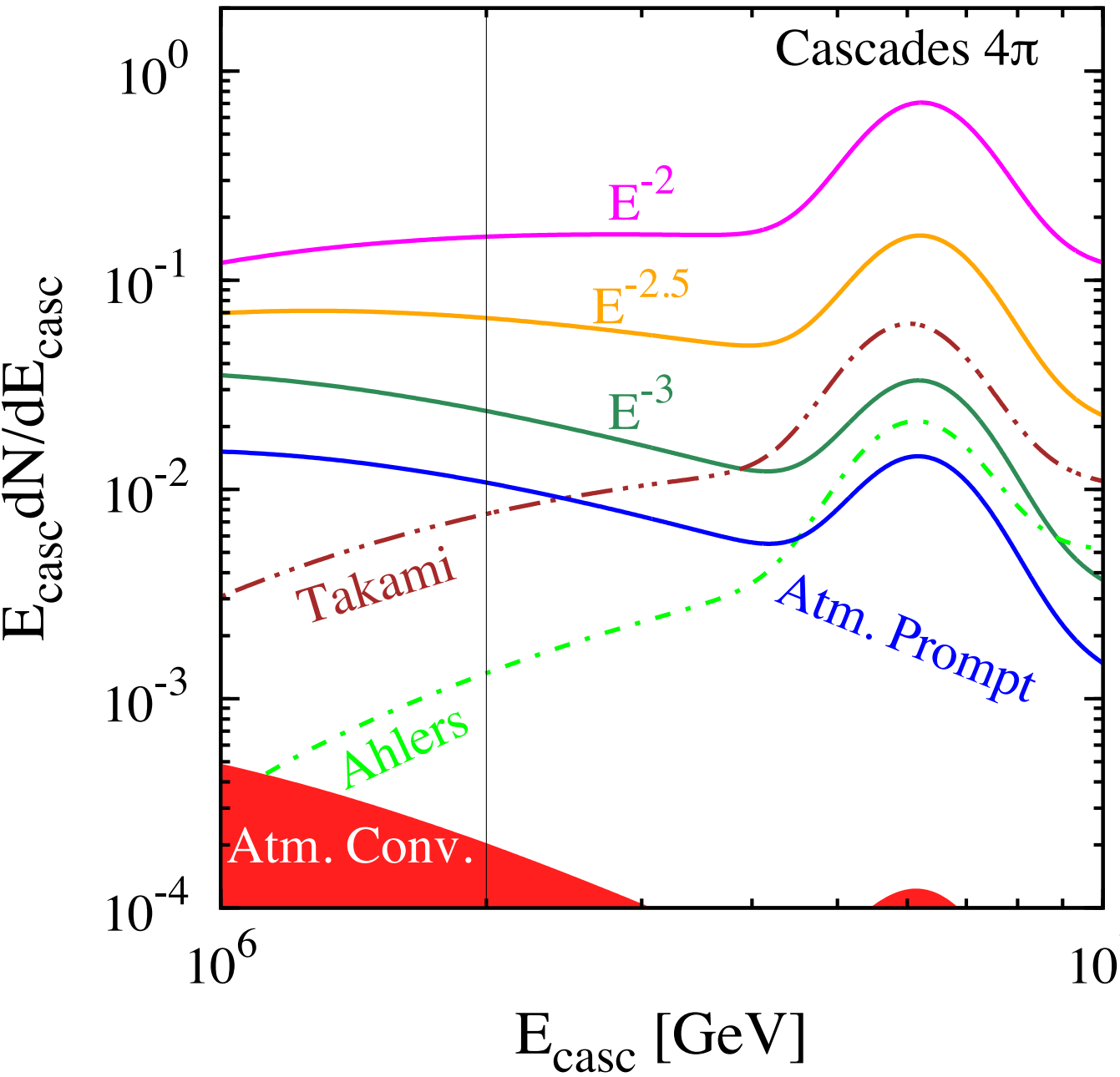


All fluxes chosen to satisfy the previous bounds from IceCube

Atmospheric prompt fluxes taken from Enberg etal

Some representative power law source fluxes taken -- we assume that over a narrow range all fluxes can be described by a power law, but exceptions exist

Event distribution



Atmospheric conventional flux too low

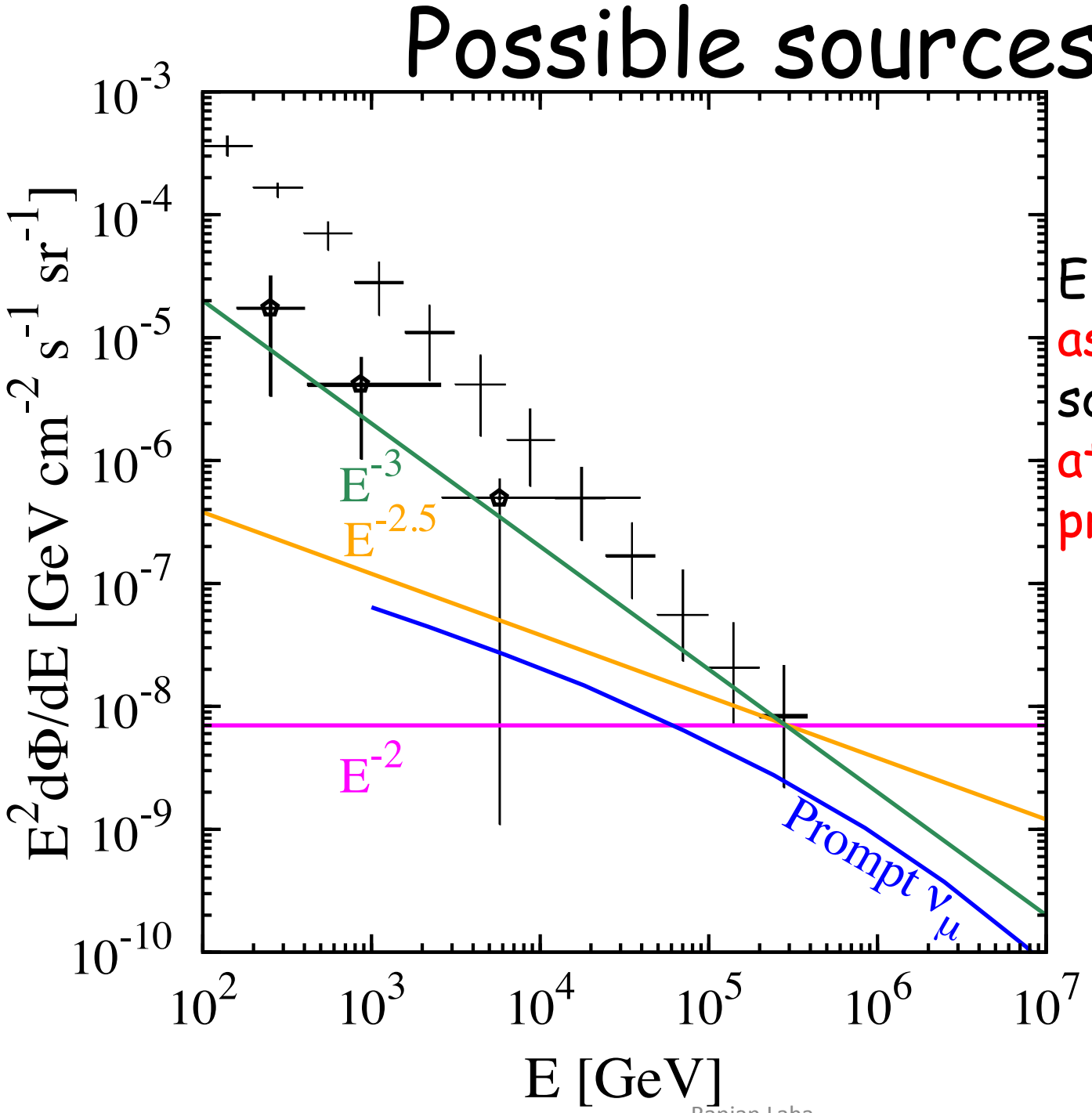
Cosmogenic fluxes will produce vastly too many events at higher energies

What it cannot be

Conventional atmospheric neutrinos – the conventional electron neutrino flux is too low.

Cosmogenic/ GZK neutrinos – the flux peaks at 10^3 PeV – if we see one event in PeV range then we should see numerous events at higher energies

Possible sources



Either diffuse astrophysical source or atmospheric prompt neutrinos

Atmospheric prompt neutrinos

Collisions of cosmic rays with atmospheric nuclei produces short-lived charmed mesons

Due to short lifetime, spectra harder than conventional neutrinos

Uncertain because of hadronic uncertainties, cosmic ray composition

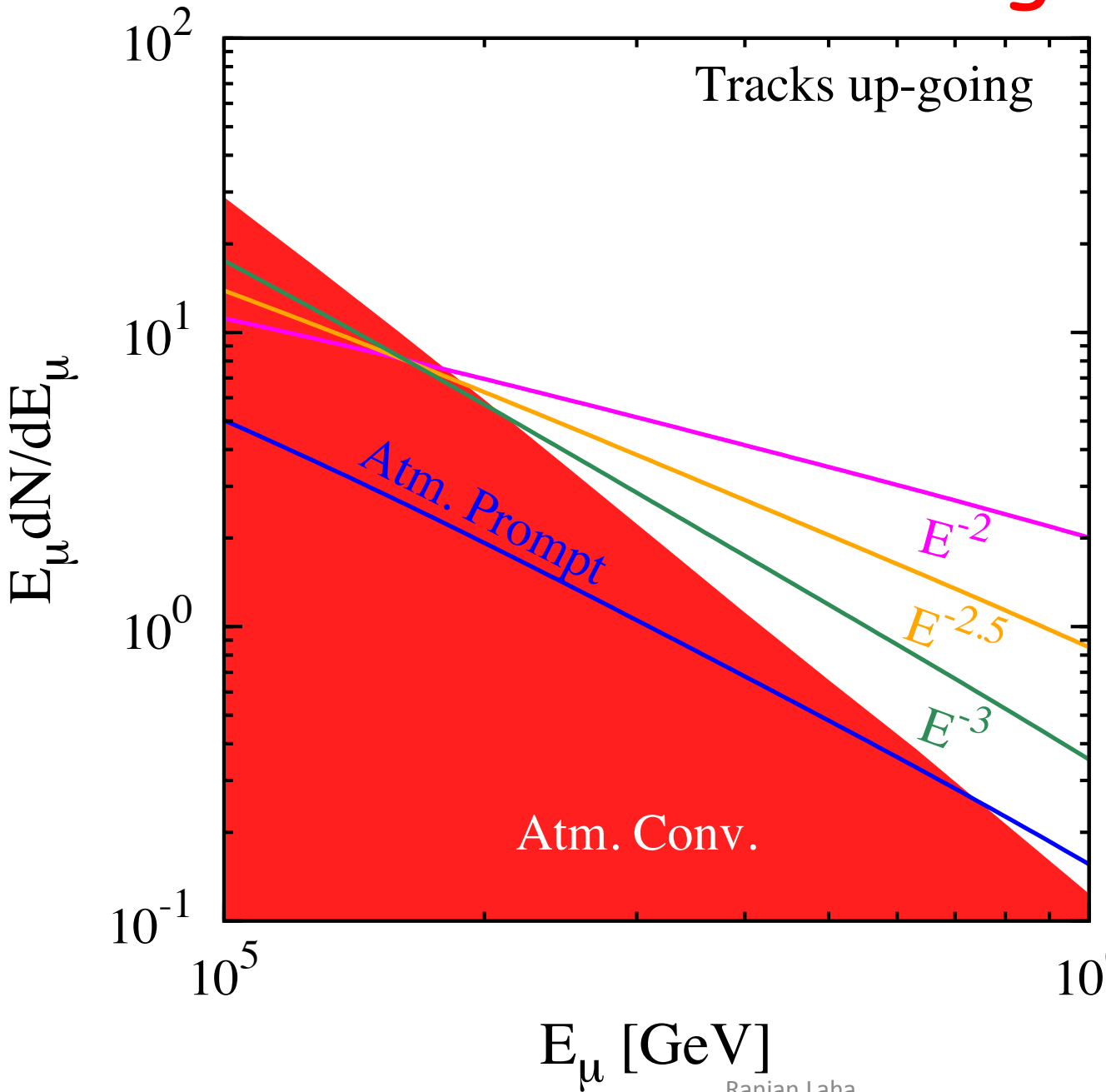
Neutrinos produced inside astrophysical sources

We take 3 representative spectra: E^{-2}, $E^{-2.5}$ & E^{-3}

Tension with the data for E^{-2} power law – steeper power law like E^{-3} favored

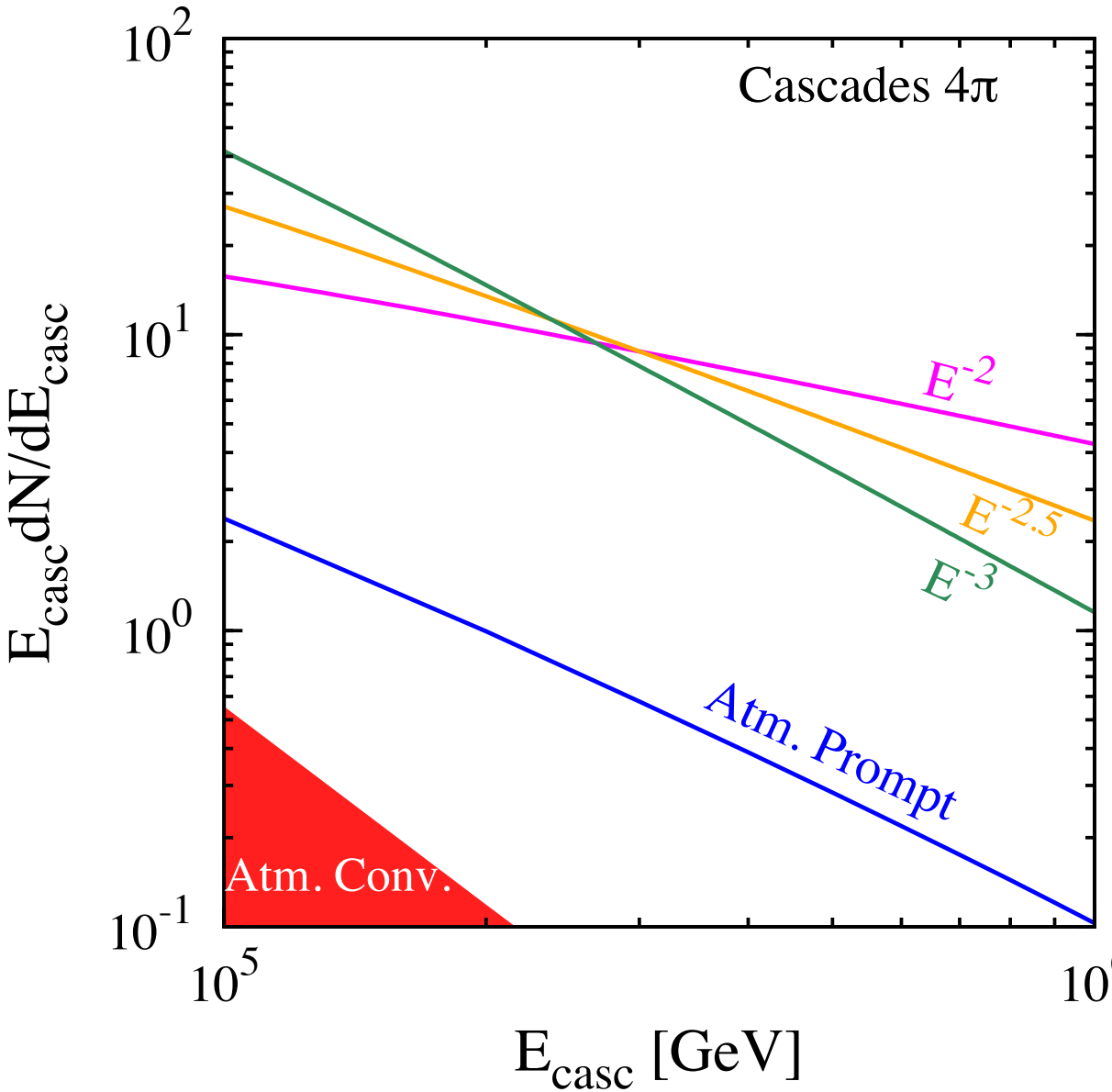
Broken power law which falls steeply beyond ~2 PeV is also favored

How to break the degeneracy?



Due to the large atmospheric neutrino background, searching for muon tracks is not the best idea – most of the flux is buried under the background

Search for cascades at lower energies



Due to lower atmospheric neutrino background, searching for cascades at lower energies offer the fastest way to distinguish between the spectra

IceTop can be useful for atmospheric prompt neutrino spectra

We estimate that ~ 2 years of data will robustly distinguish between the spectra

Conclusions

PeV cascades in IceCube – entry of neutrino astrophysics to the PeV era

Atmospheric prompt neutrinos, neutrinos produced in astrophysical sources can be the PeV flux observed in IceCube

Searching for neutrinos in the lower energies with cascades will determine the source spectrum in the shortest amount of time