



Distinguishing neutrino flavors in high-energy showers



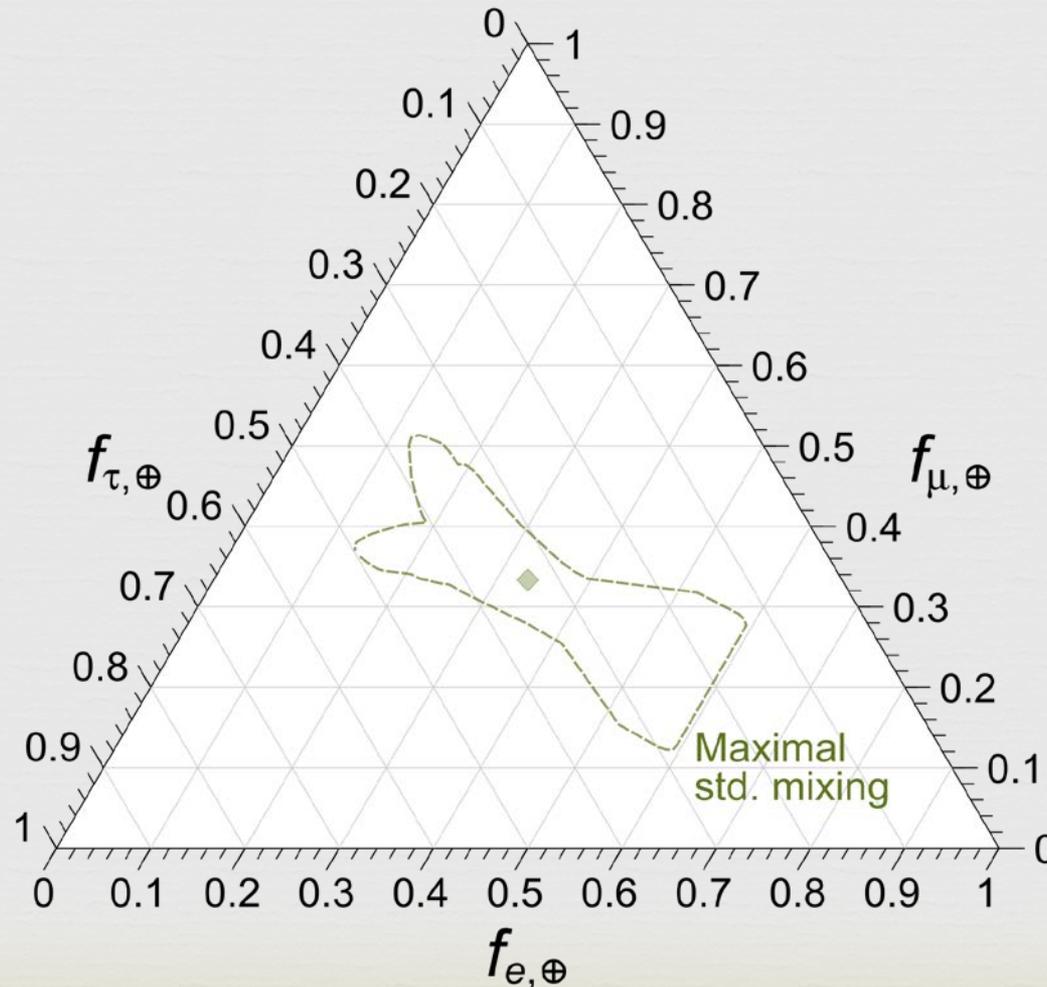
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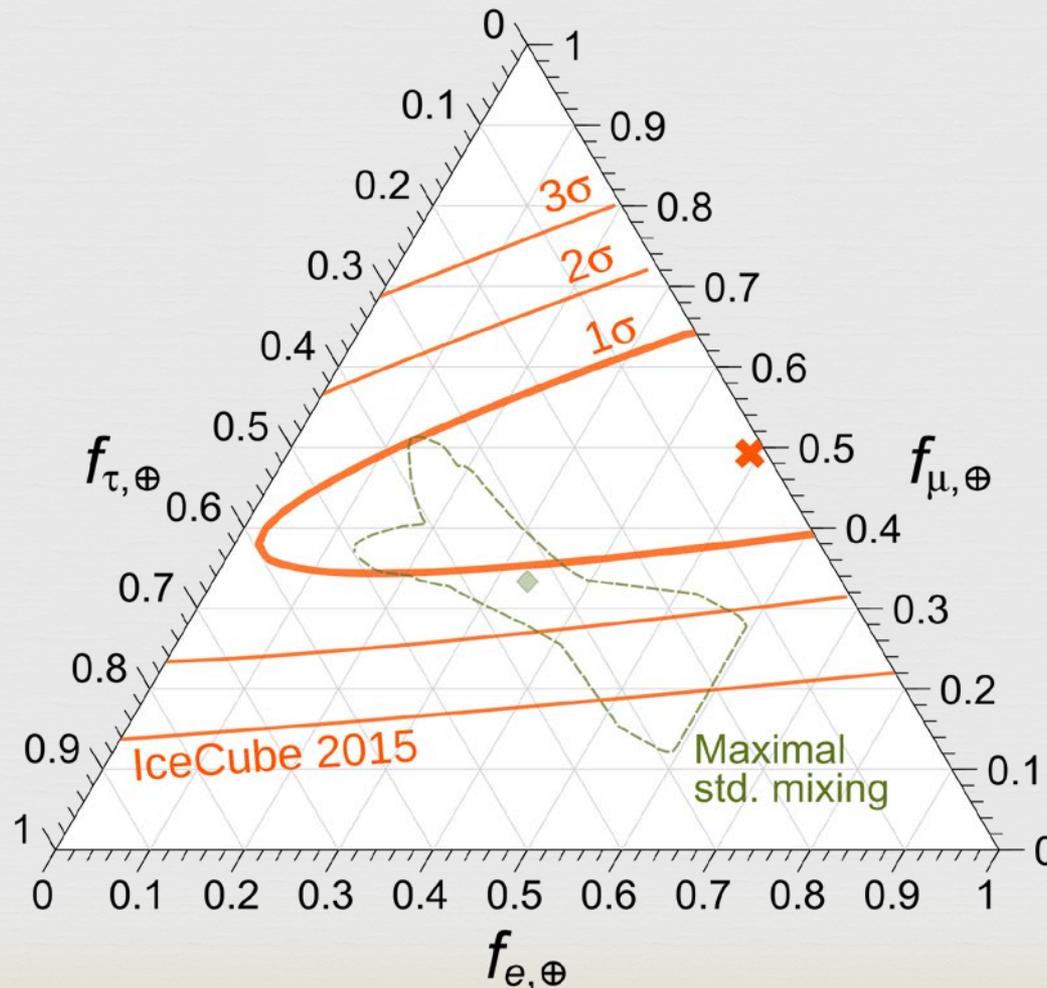
Pheno 2016

Flavor composition: a rich observable



Bustamante *et al.* 2015

Flavor composition: not enough sensitivity



Bustamante *et al.* 2015
Aartsen *et al.* 2015

Track and showers



ν_e

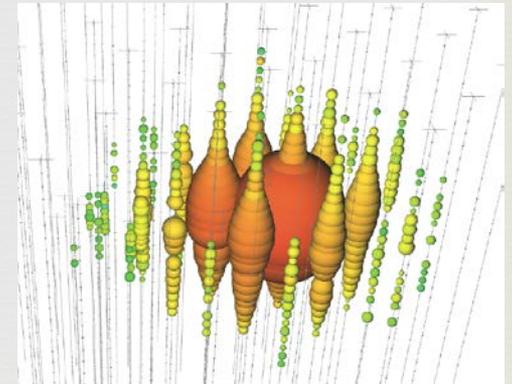
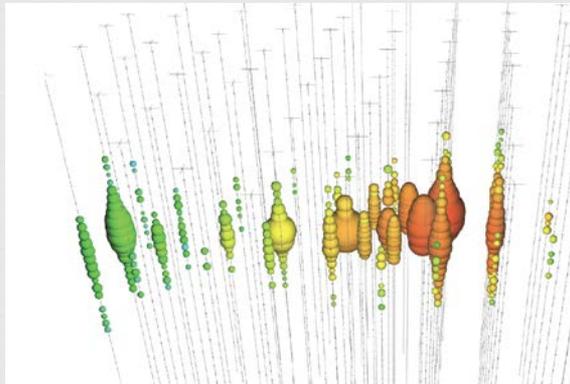
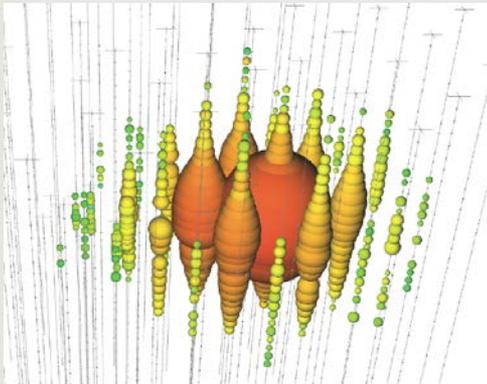
ν_μ

ν_τ

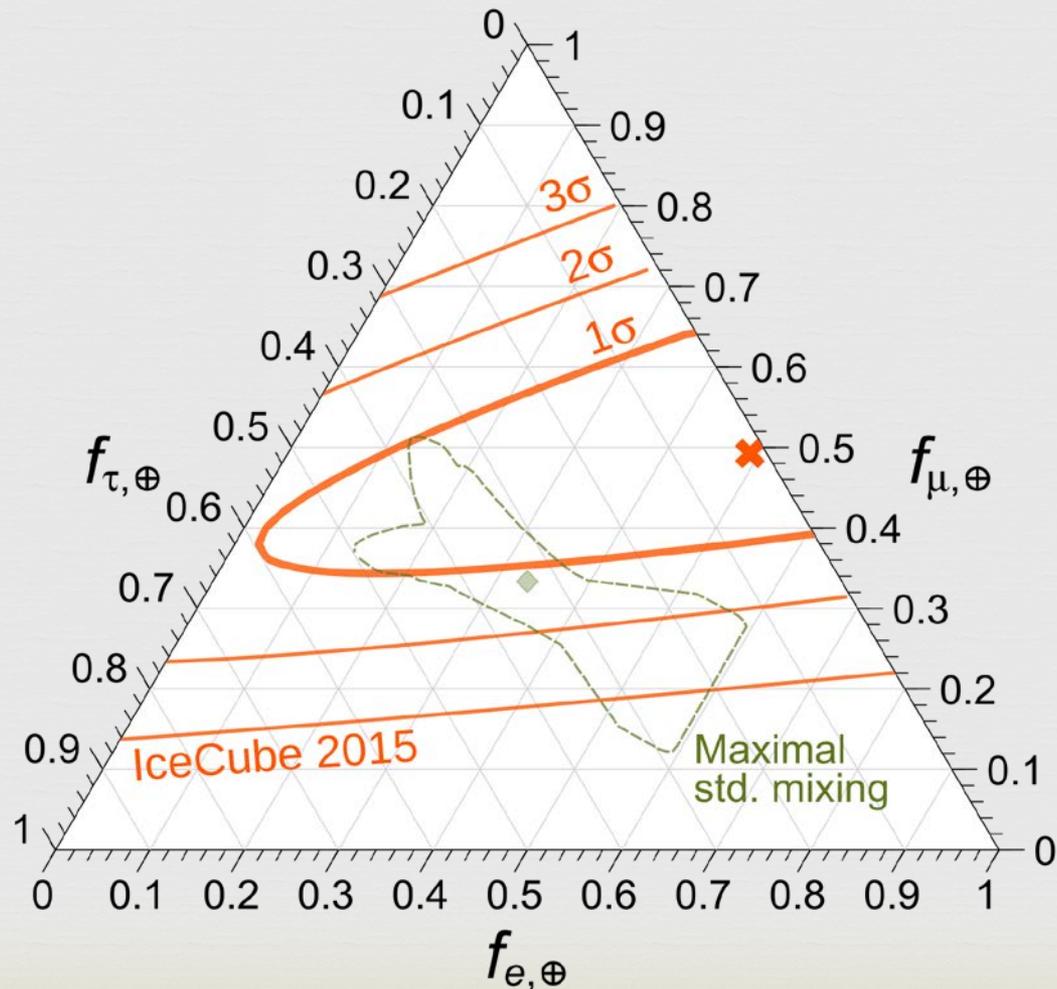
$$\nu_e + N \rightarrow e^- + \text{hadrons}$$

$$\nu_\mu + N \rightarrow \mu^- + \text{hadrons}$$

$$\nu_\tau + N \rightarrow \tau^- + \text{hadrons}$$
$$\tau \rightarrow \begin{cases} e^- + \nu + \nu & (18\%) \\ \mu^- + \nu + \nu & (17\%) \\ \text{hadrons} & (65\%) \end{cases}$$



The problem: ν_e and ν_τ look the same!



Bustamante *et al.* 2015
Aartsen *et al.* 2015

There is a crucial difference between the two channels



ν_e CC showers are more electromagnetic

ν_τ CC showers are more hadronic

Charged-current:

$$\nu_e + N \rightarrow e^- + \text{hadrons}$$

$$\nu_\tau + N \rightarrow \tau^- + \text{hadrons}, \quad \tau \rightarrow \begin{cases} e^- + \bar{\nu}_e + \nu_\tau & (18\%) \\ \text{hadrons} & (65\%) \end{cases}$$

Neutral-current:

$$\nu_l + N \rightarrow \nu_l + \text{hadrons}$$

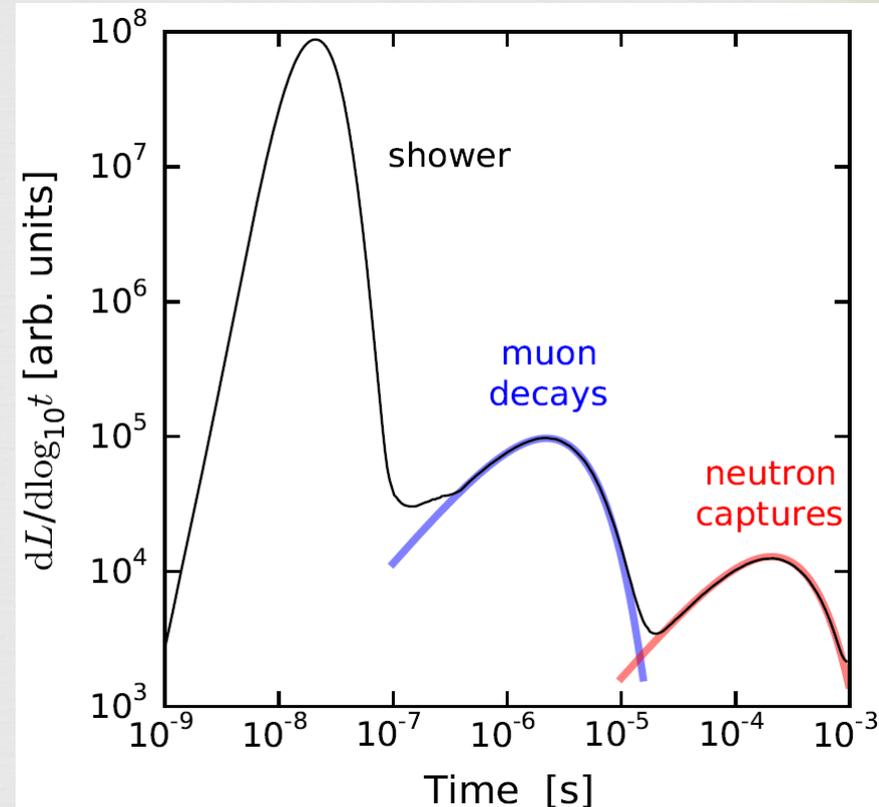
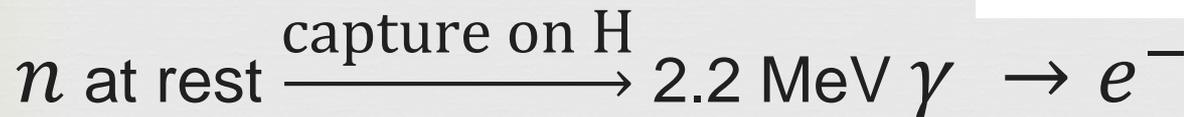
New shower observables



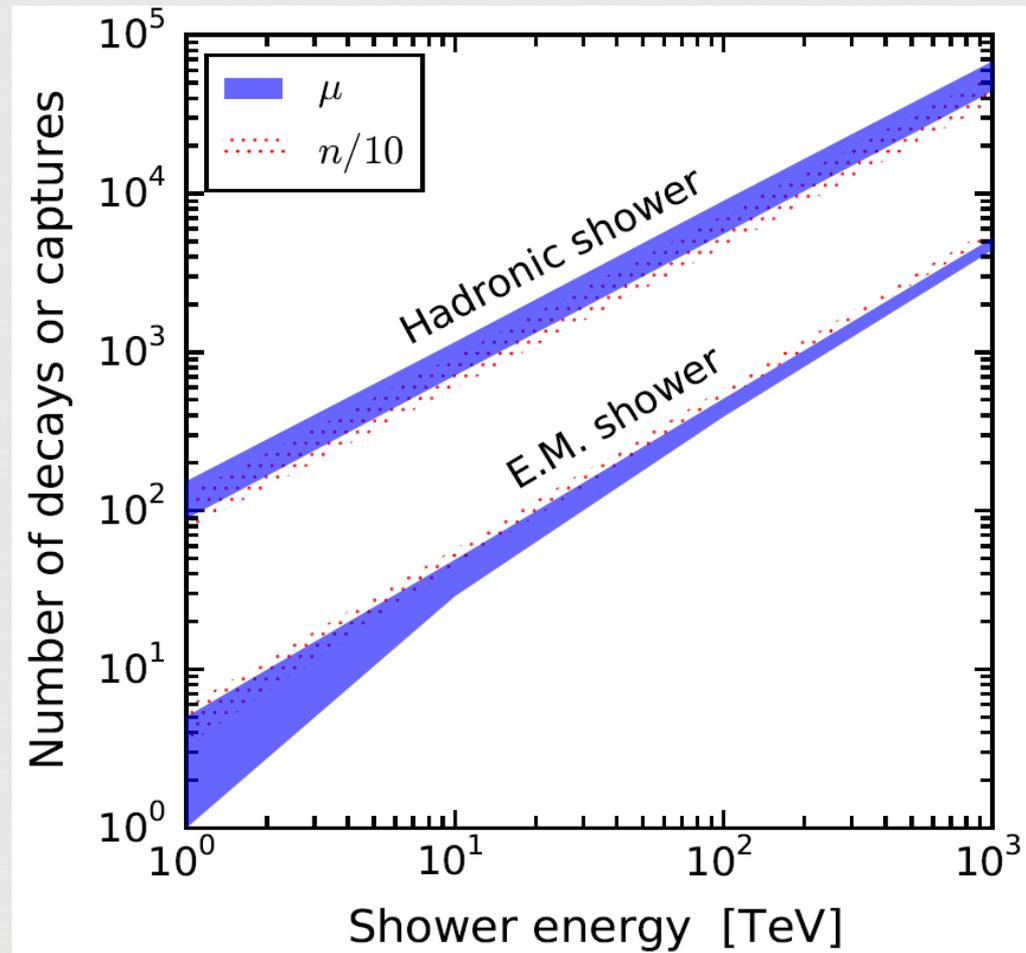
Muon echo:



Neutron echo:

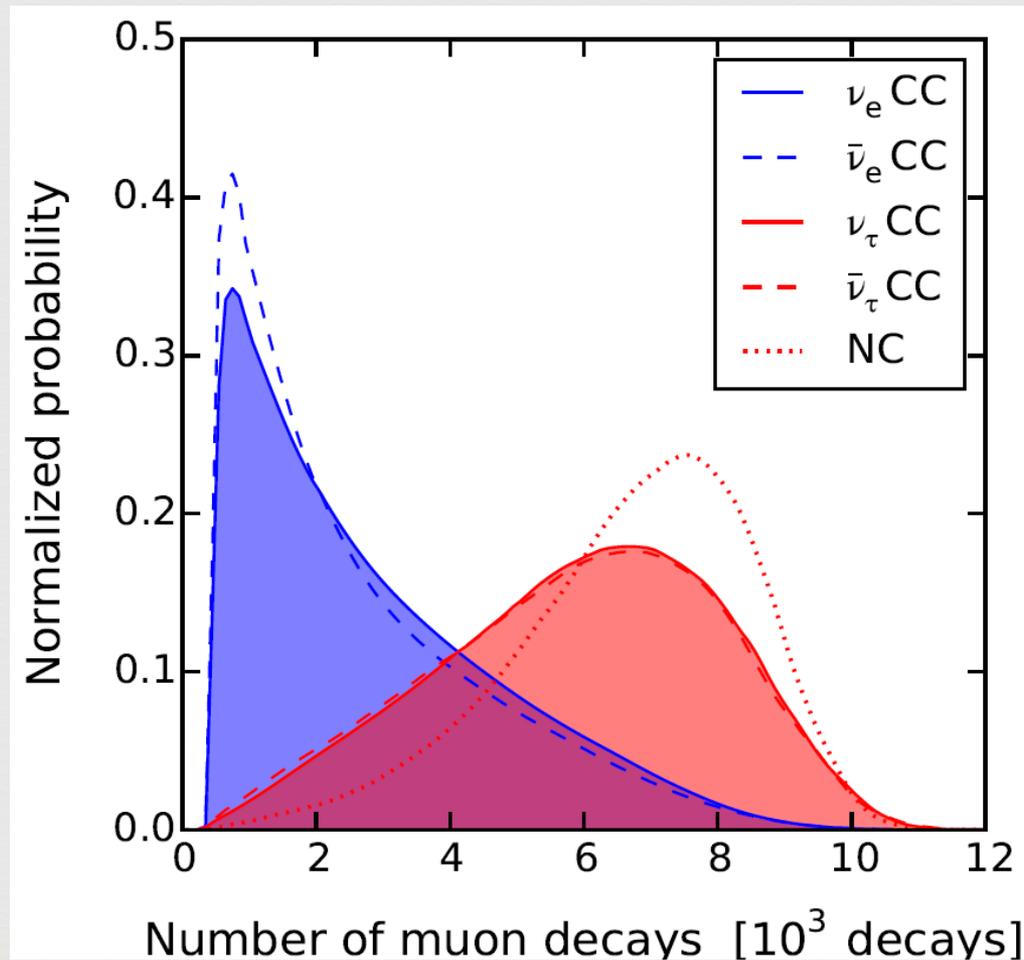


Echoes are stronger in hadronic showers



Li, Bustamante, and Beacom, In prep

Echoes are stronger in ν_τ showers

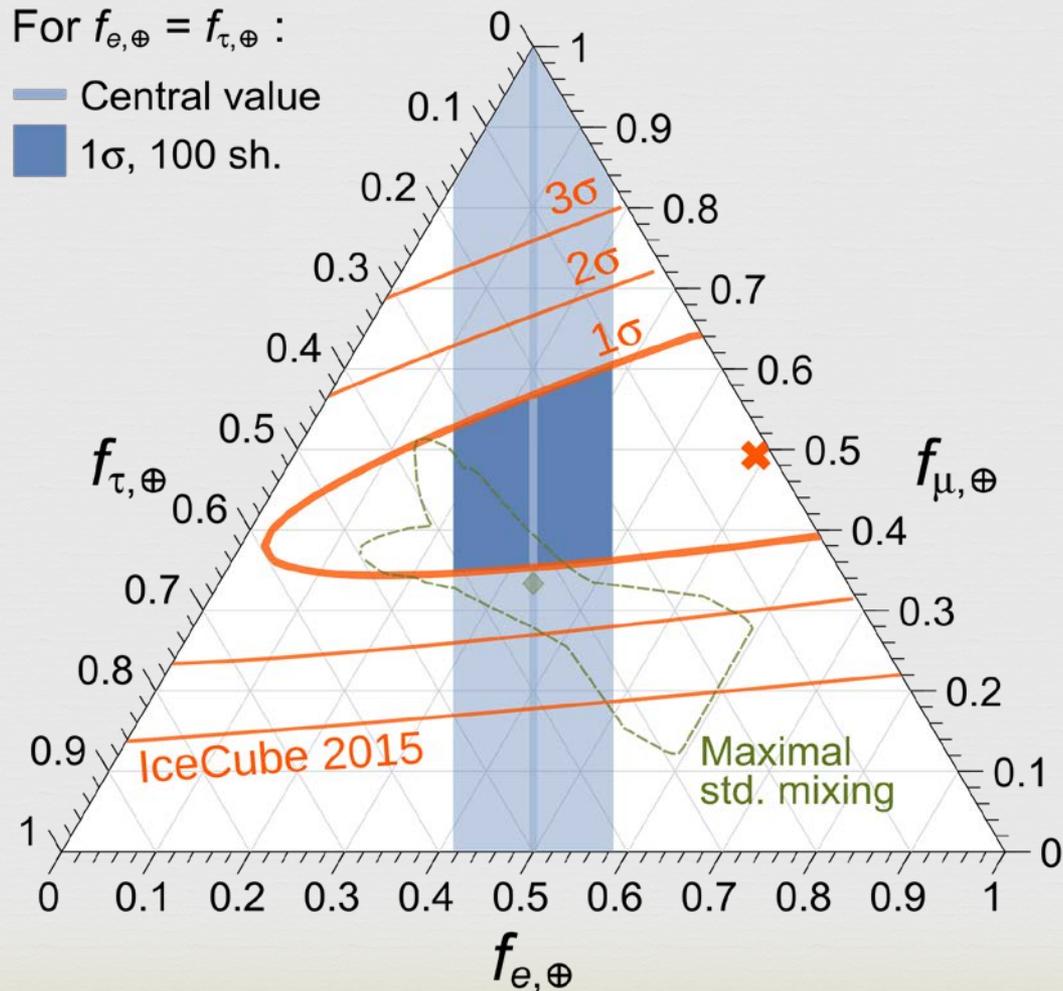


Li, Bustamante, and
Beacom, In prep

IF

we can detect the echoes with
100% efficiency...

Predicted sensitivity

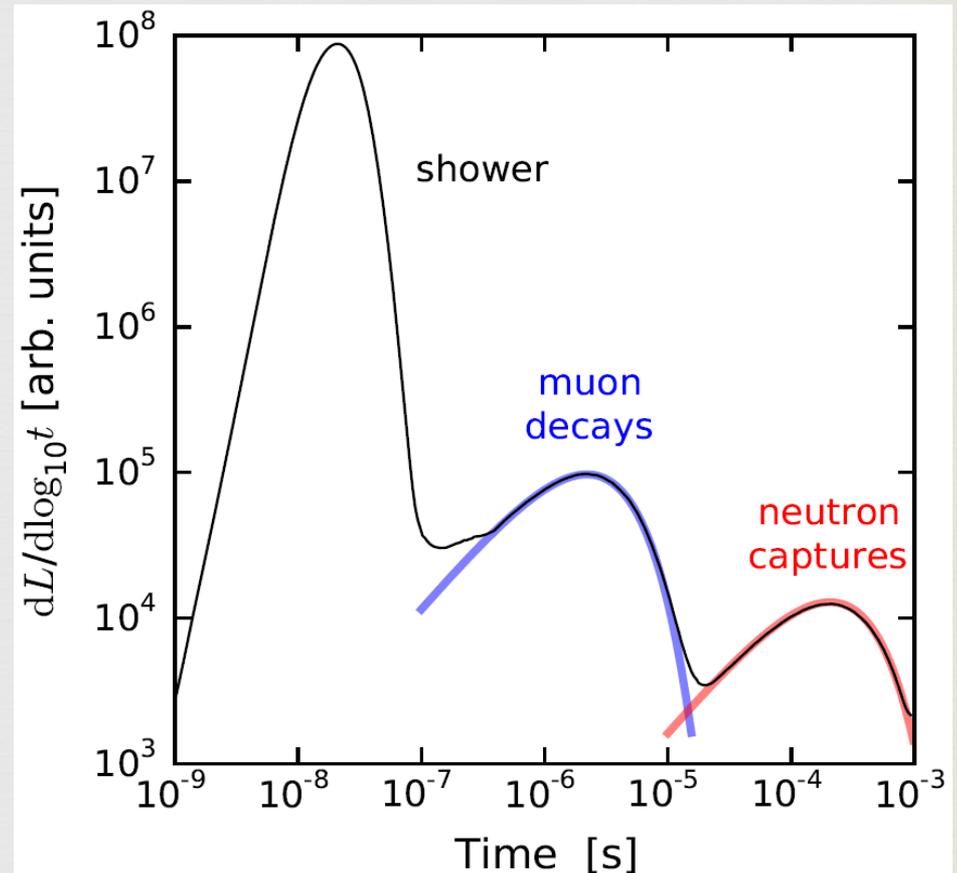


Li, Bustamante, and Beacom, In prep

Caveats - detectability



- Trigger threshold
- Afterpulsing
- Light scattering



Conclusions



- The light, or *echo*, from muon decays and neutron captures can distinguish between electromagnetic and hadronic showers
- They are stronger in ν_τ -initiated showers than ν_e -initiated
- Great physics potential worth going after