

Muon-induced backgrounds for MeV neutrinos

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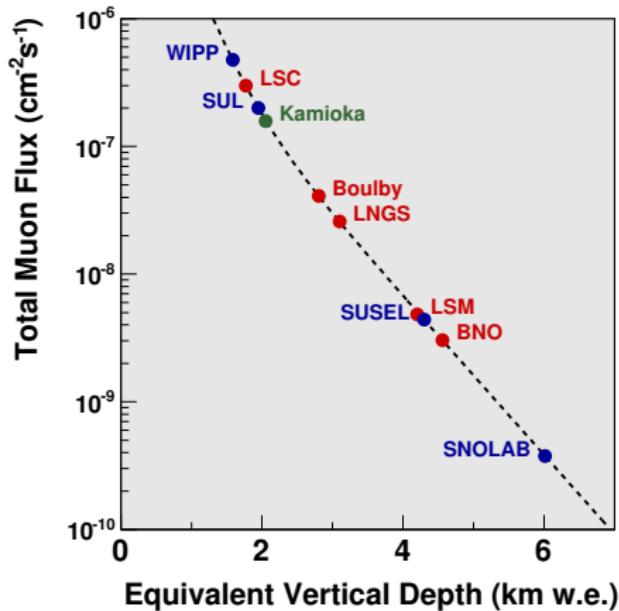
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Cosmic-ray muons produce low-energy backgrounds

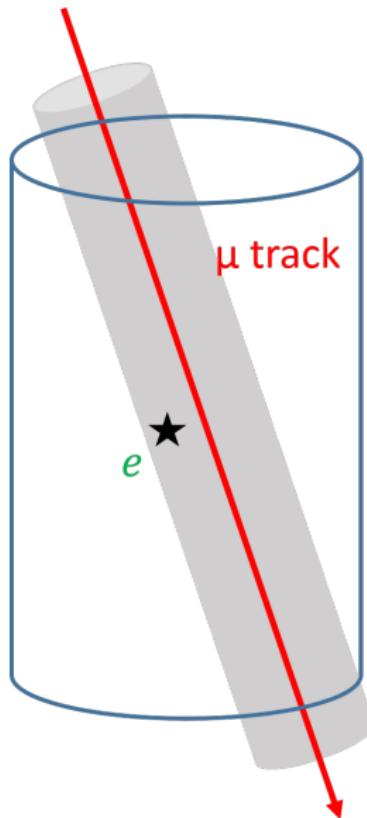
- Cosmic-ray muons are high-energy events
- Muons penetrate rock, interacting with detecting/detector material
- Muons themselves can easily be detected and vetoed
- Muons make **beta-decay isotopes**, and **neutrons**
- keV-MeV experiments, neutrino, dark matter, $\nu 0\beta\beta$, etc



Gomez-Cadenas *et al.*, 2012

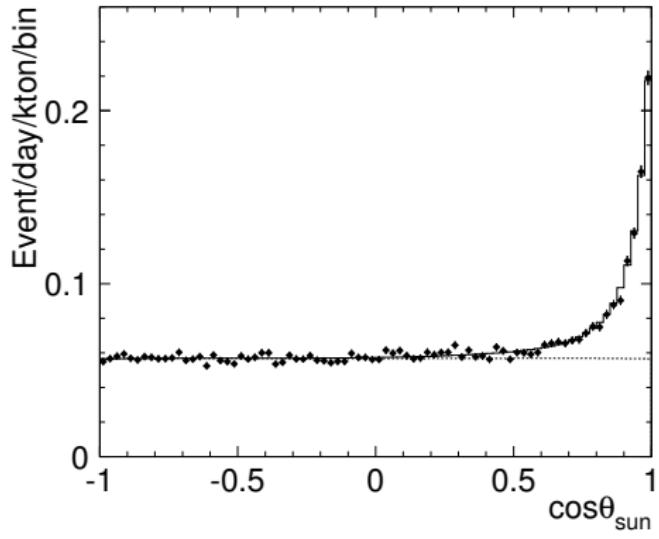
What are spallation backgrounds?

- $\mu + X \rightarrow \mu + X'$,
 $X' \rightarrow e + \text{others}$
- MeV neutrino detection,
 $\nu + e \rightarrow \nu + e$
- The competition is between X' lifetimes and muon rate
- Most isotopes have lifetimes \sim seconds to minutes
- Muon rate: Super-K 2 Hz, SNO 3 per hour



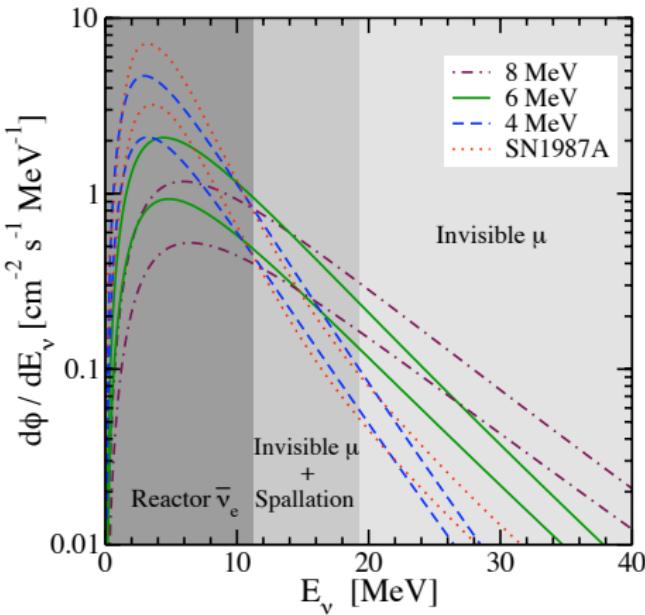
Why spallation backgrounds? ...for theorists

Solar neutrino



Abe *et al.* (Super-K Collaboration), 2011

Diffuse Supernova Neutrino Background



Horiuchi *et al.*, 2009

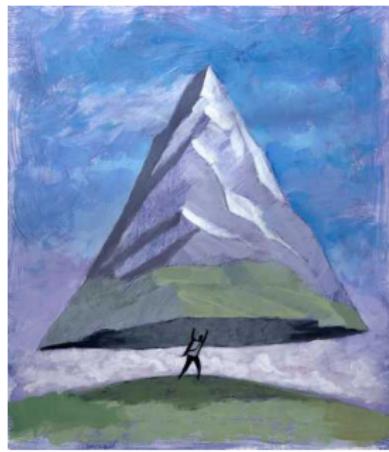
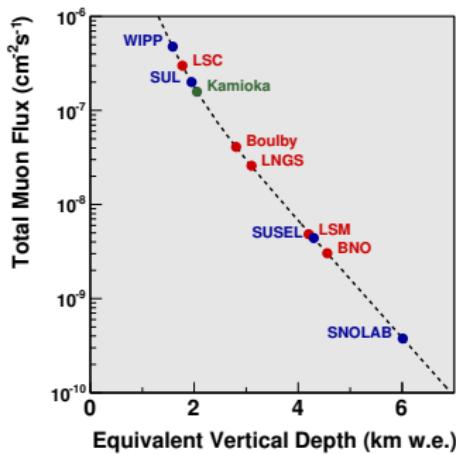
Why spallation backgrounds? ...for experimentalists

Our work has more general applications

- Spallation backgrounds for other materials
- The production mechanism is the same as fast neutrons
- Our results are useful for muon fitting

Our goal

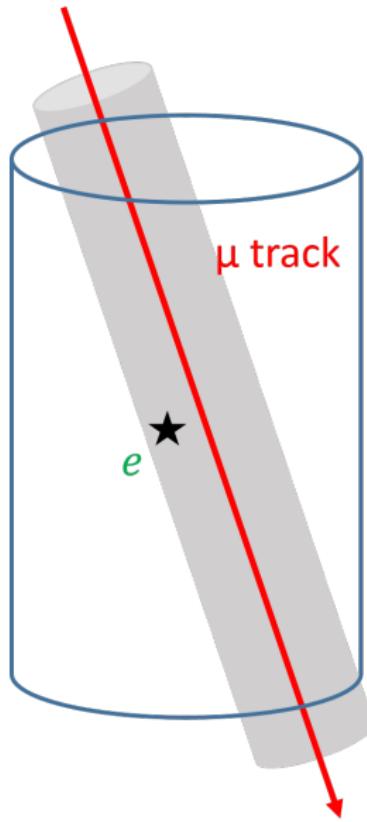
- Model the background production theoretically
- Understand the production features of these spallations
- Find better ways to reject them



Super-K spallation cuts

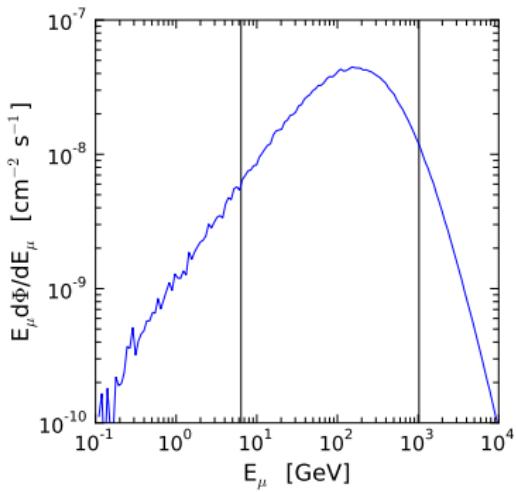
Super-K cuts

- Empirically developed
- Cylinder cut around muon track
(a few meters and a few seconds)
- Likelihood function of ΔL , Δt , and muon energy loss



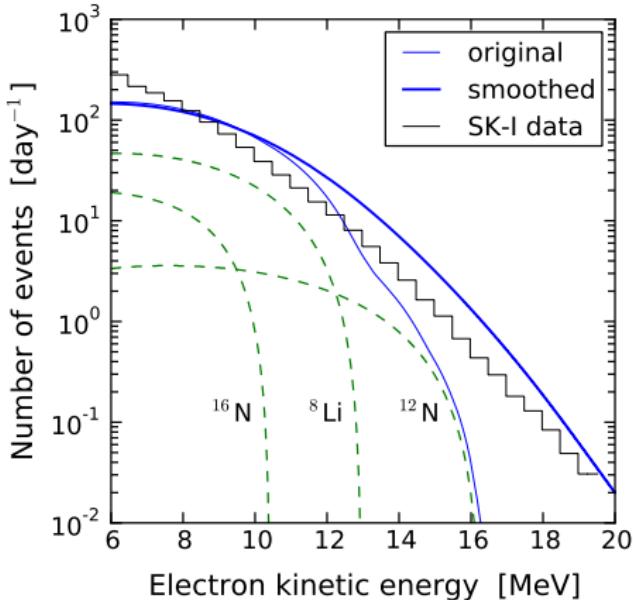
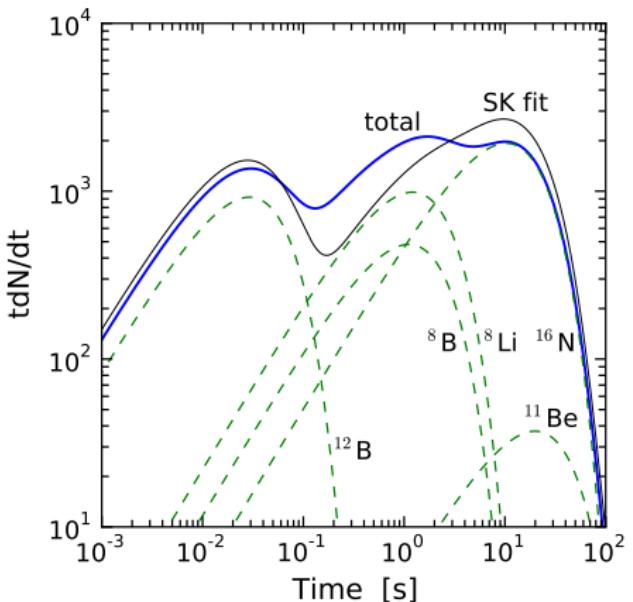
Our setup of the calculation

- We use simulation package FLUKA
- theory uncertainties ~ 2



data taken from Tang et al., 2006

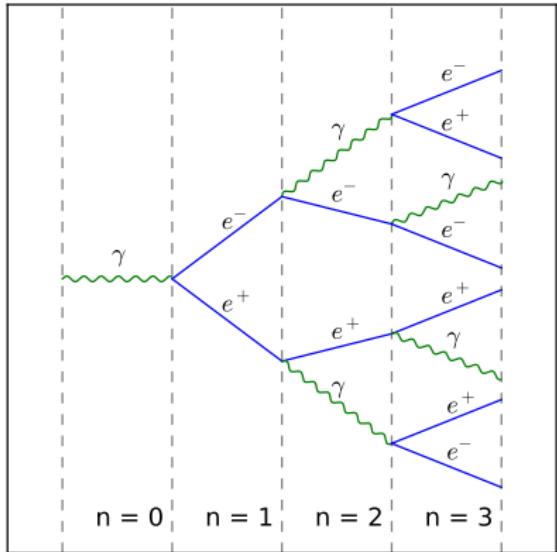
Our calculation of the backgrounds



Li and Beacom, 2014

Isotopes are made by secondary particles.

Muons make bursts of showers



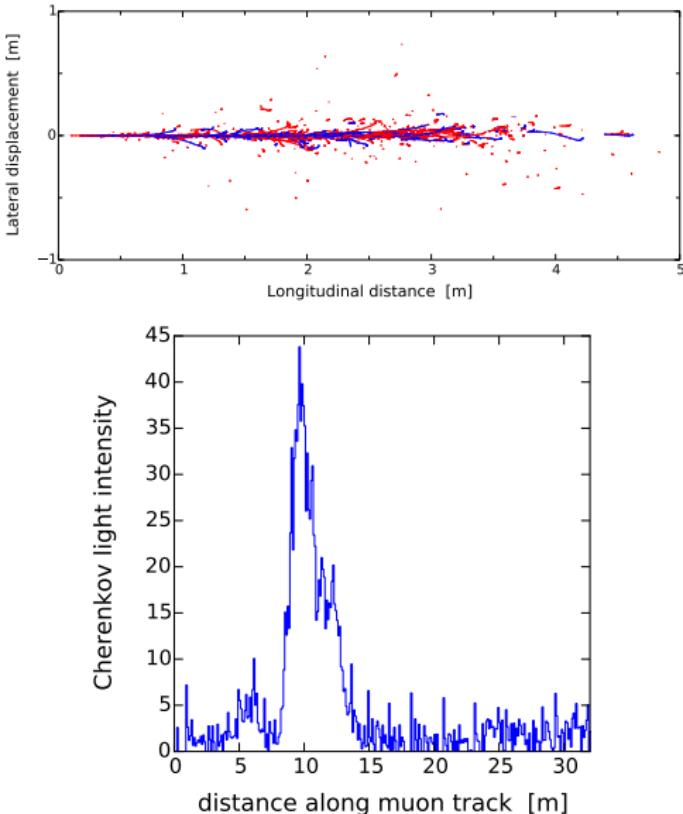
Li and Beacom, 2015

Shirley Li (OSU)

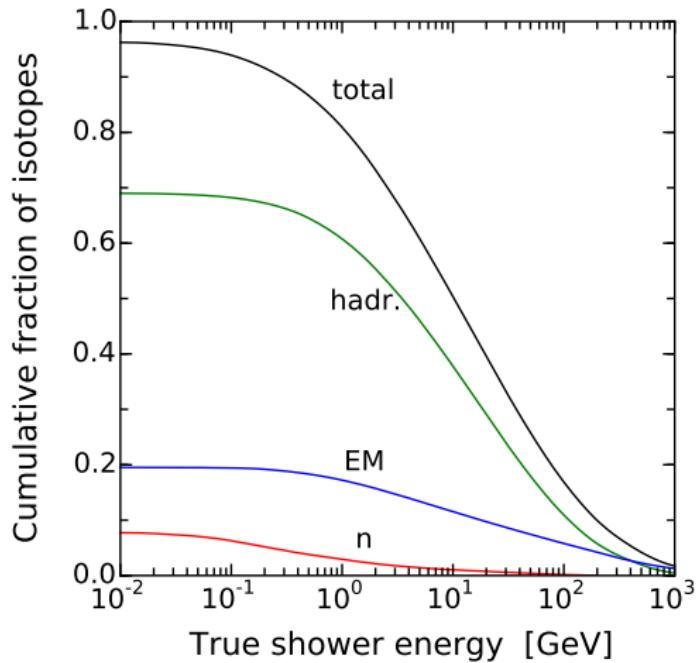
Spallation Backgrounds

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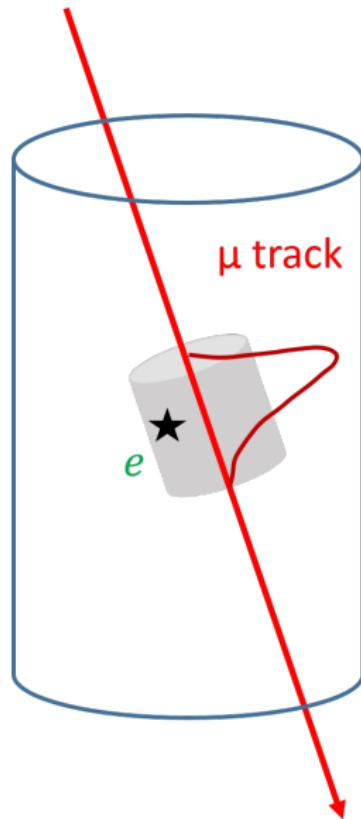
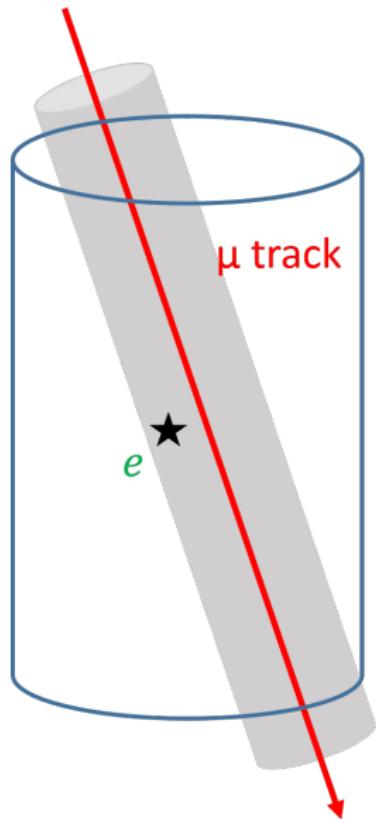


Spallations are made in these showers



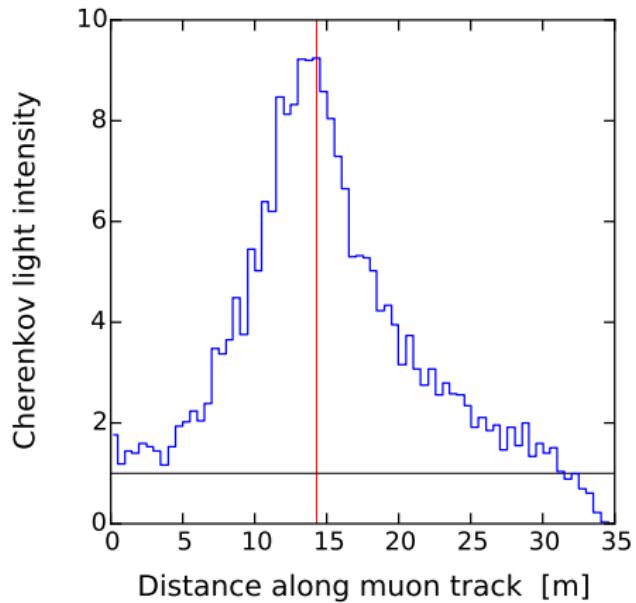
Li and Beacom, 2015

A new way to tag these backgrounds!

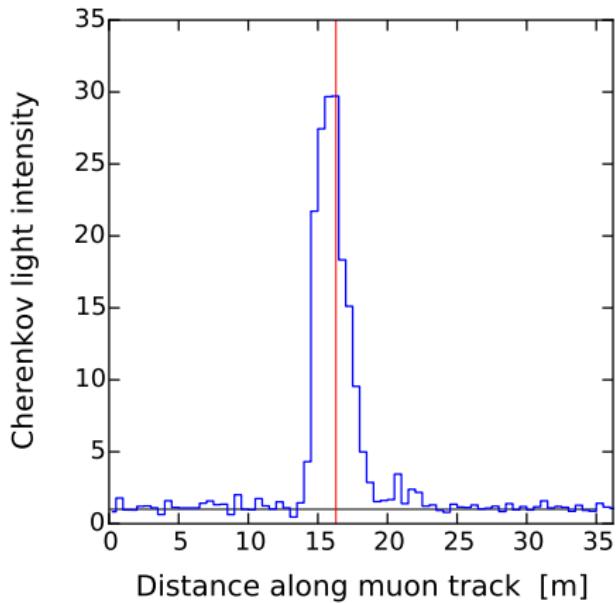


How do these showers appear in the detector?

Super-K reconstruction

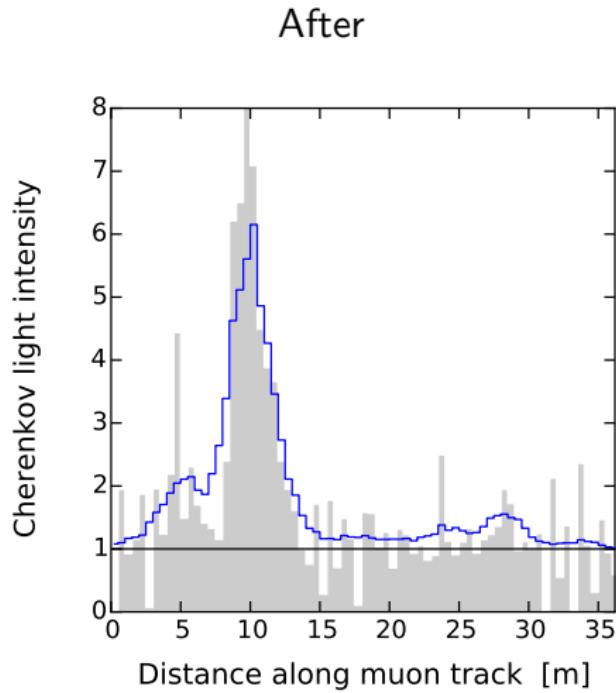
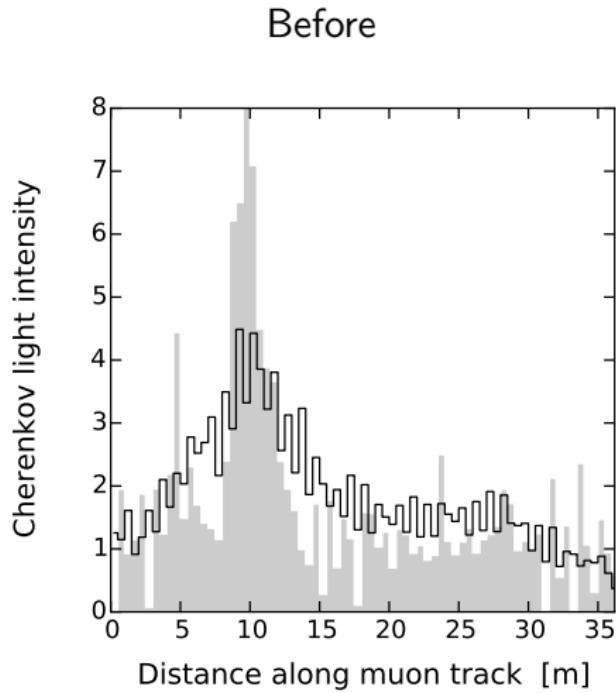


Simulation



Li and Beacom, in preparation

Our improvement on shower reconstruction



Li and Beacom, in preparation

Conclusions

- Spallations are made in muon-induced showers
- Showers can be used to tag background
- We can reconstruct showers with faithful profiles
- We expect dramatic spallation background reduction
- arXiv: 1: 1402.4687, 2: 1503.04823, 3: In preparation