Muon-induced spallation backgrounds in DUNE

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Deep Underground Neutrino Experiment

- GeV neutrino beam from FermiLab
- Long baseline: study CP violation and mass hierarchy
- Will be the largest particle experiment in the US
- Partially funded right now

- Far detector at Sanford - LArTPC
  - 4 * 10 kton liquid argon
  - ~1.5 km underground

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Supernova neutrino detection @ DUNE?
Advantages of DUNE for SNB detection

SNB @ SuperK

- \( \sim 10^4 \) events
- Mostly \( \bar{\nu}_e \)

\[
\bar{\nu}_e + p \rightarrow e^+ + n
\]

SNB @ DUNE

- \( \sim 10^3 \) events
- Favors \( \nu_e \)

\[
\nu_e + ^{40}Ar \rightarrow e^- + ^{40}K^* \\
\nu + e \rightarrow \nu + e
\]
Spallation backgrounds @ DUNE?

- A few work has been done
- Large variations exist
  - What are the production processes?
  - What are the background isotopes?
- Thorough work is highly needed!
Spallation mechanism

- **Signal:**
  \[
  \bar{\nu}_e + p \rightarrow e^+ + n  \\
  \nu + e \rightarrow \nu + e  \\
  \nu_e + ^{40}Ar \rightarrow e^- + ^{40}K^* 
  \]

- **Bkg:**
  \[
  \mu \rightarrow \mu + \text{secondary} \\
  \text{secondary} + X \rightarrow X' \\
  X' \rightarrow e^- + \text{others} 
  \]
Spallation — Muons produce showers

Li & Beacom 2014, 2015, 2015

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Spallation — Showers produce isotopes

Li & Beacom 2014, 2015, 2015
- Detection threshold $\sim 5$ MeV
- Argon-nearby (Ar, Cl, S, P, etc)
  - High yields
  - Do not matter much
- Oxygen-nearby (Li, B, N, etc)
  - Low yields
  - Important
Spallation backgrounds @ DUNE

- Detection threshold ~ 5 MeV
- Argon-nearby (Ar, Cl, S, P, etc)
  - High yields, Long lifetimes
  - Do not matter much
- Oxygen-nearby (Li, B, N, etc)
  - Low yields, Short lifetimes
  - Important
Conclusion

- DUNE is capable to see next galactic supernova burst!

- Detection of supernova neutrinos can reveal important physics.

- Surprisingly, abundantly produced argon-nearby isotopes do not matter much at DUNE. Oxygen-nearby isotopes, with low yields, contribute most to the spallation backgrounds.

- The spallation background rate is way lower than the SNB rates at DUNE. $R_{bkq} \approx 10^{-3}/10s/40kt$