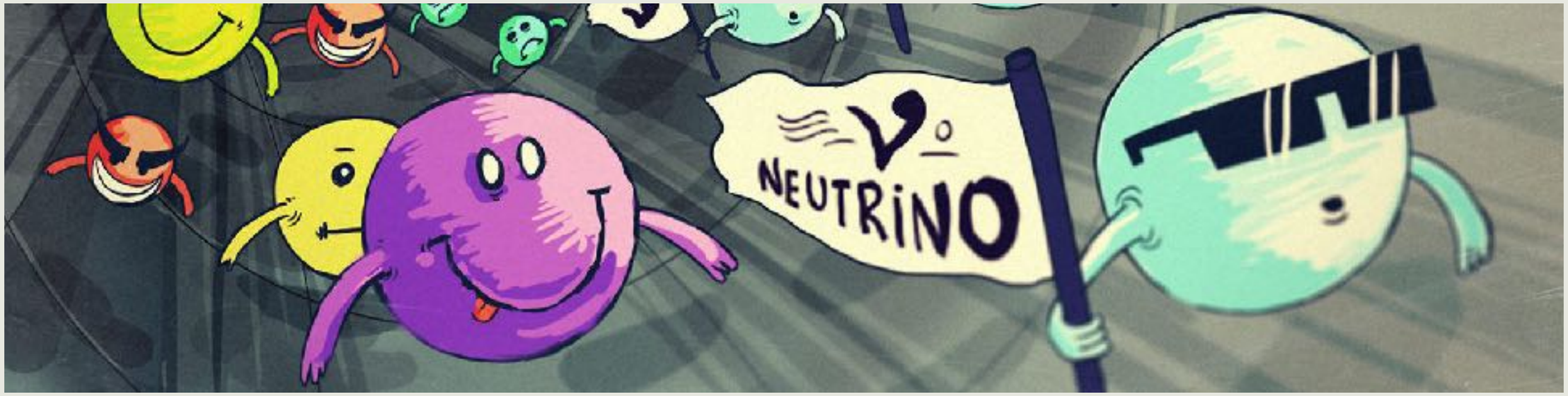


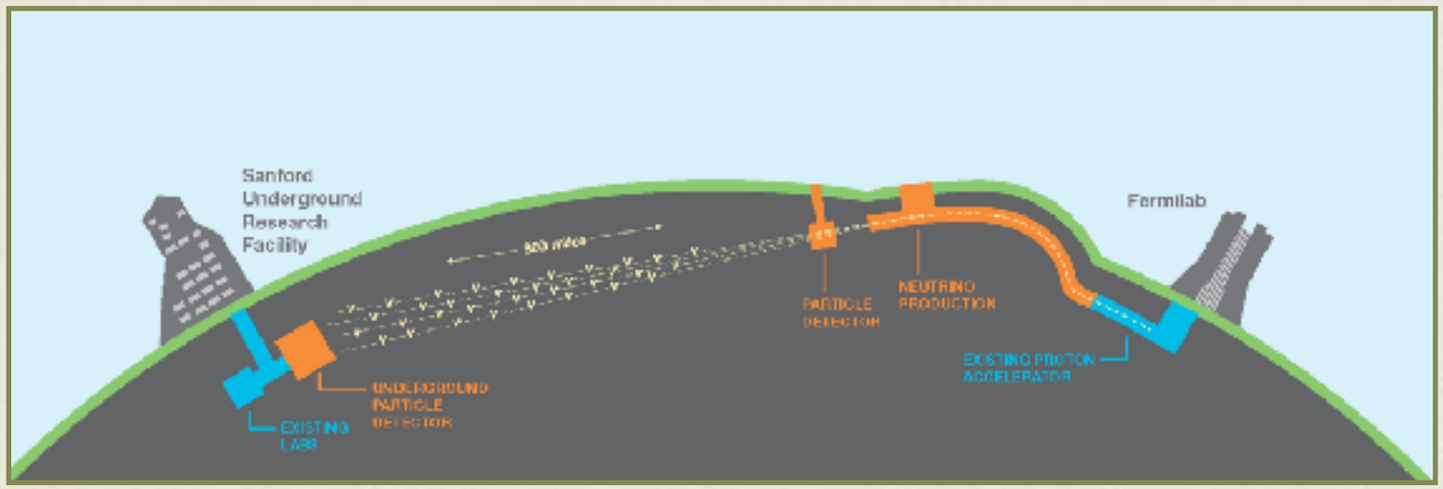
Muon-induced spallation backgrounds in DUNE

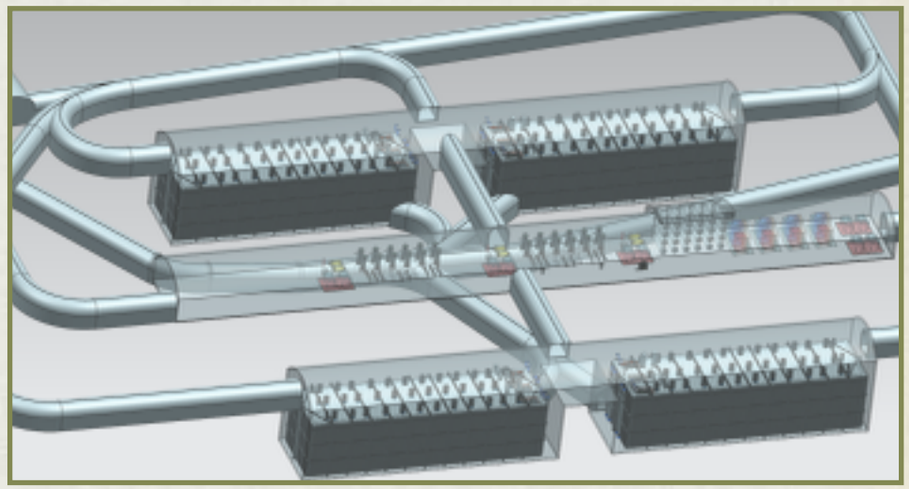
Guanying Zhu

Collaborators: Shirley Li and John Beacom (Ph.D. advisor)

The Ohio State University

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

Supernova neutrino detection @ DUNE ?

Advantages of DUNE for SNB detection

SNB @ SuperK

- ~ 10^4 events
- Mostly $\bar{\nu}_e$

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

SNB @ DUNE

- ~ 10^3 events
- Favors ν_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!

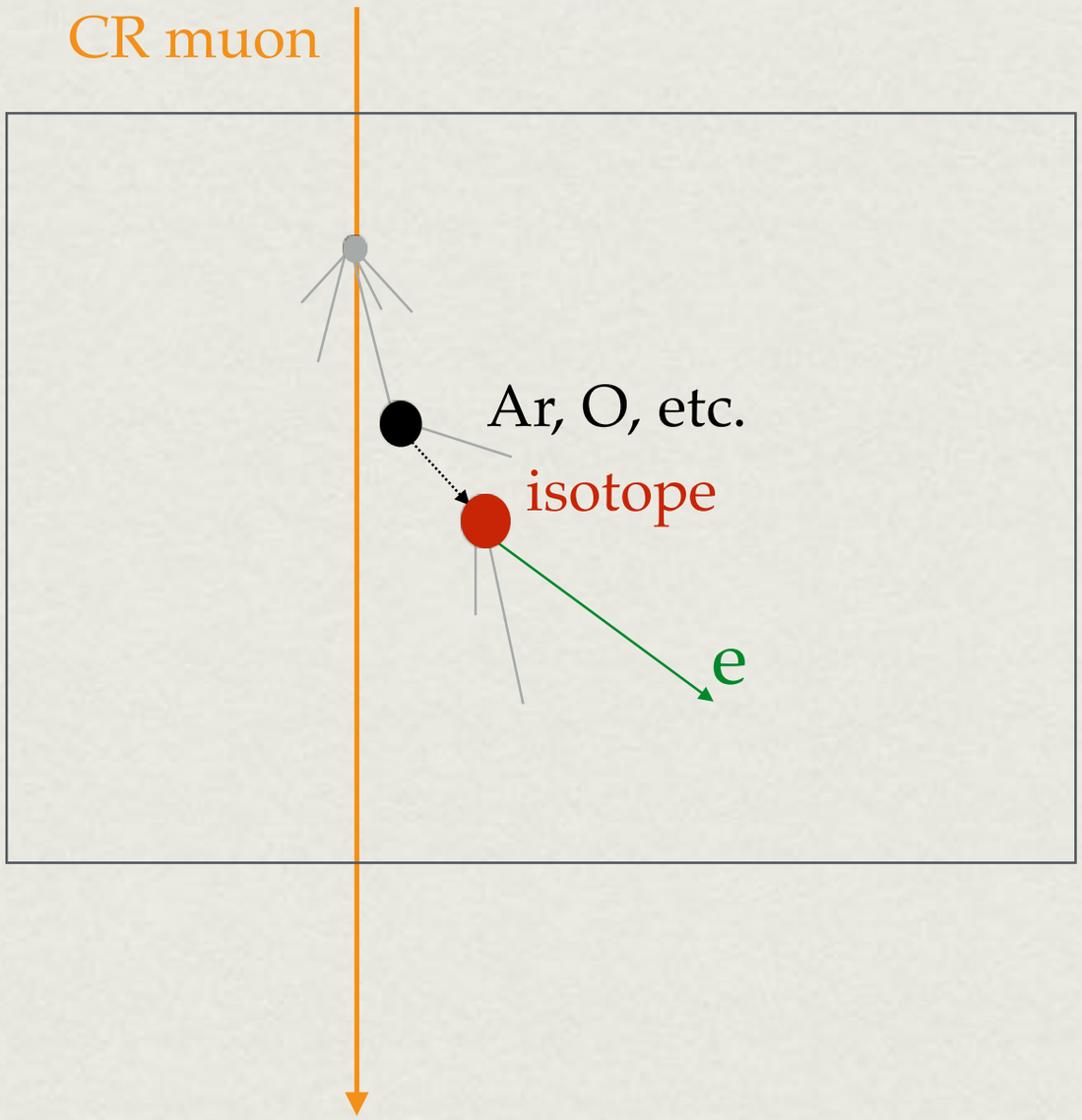
Spallation mechanism

- Signal:

$$\bar{\nu}_e + p \rightarrow e^+ + n$$
$$\nu + e \rightarrow \nu + e$$
$$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$$

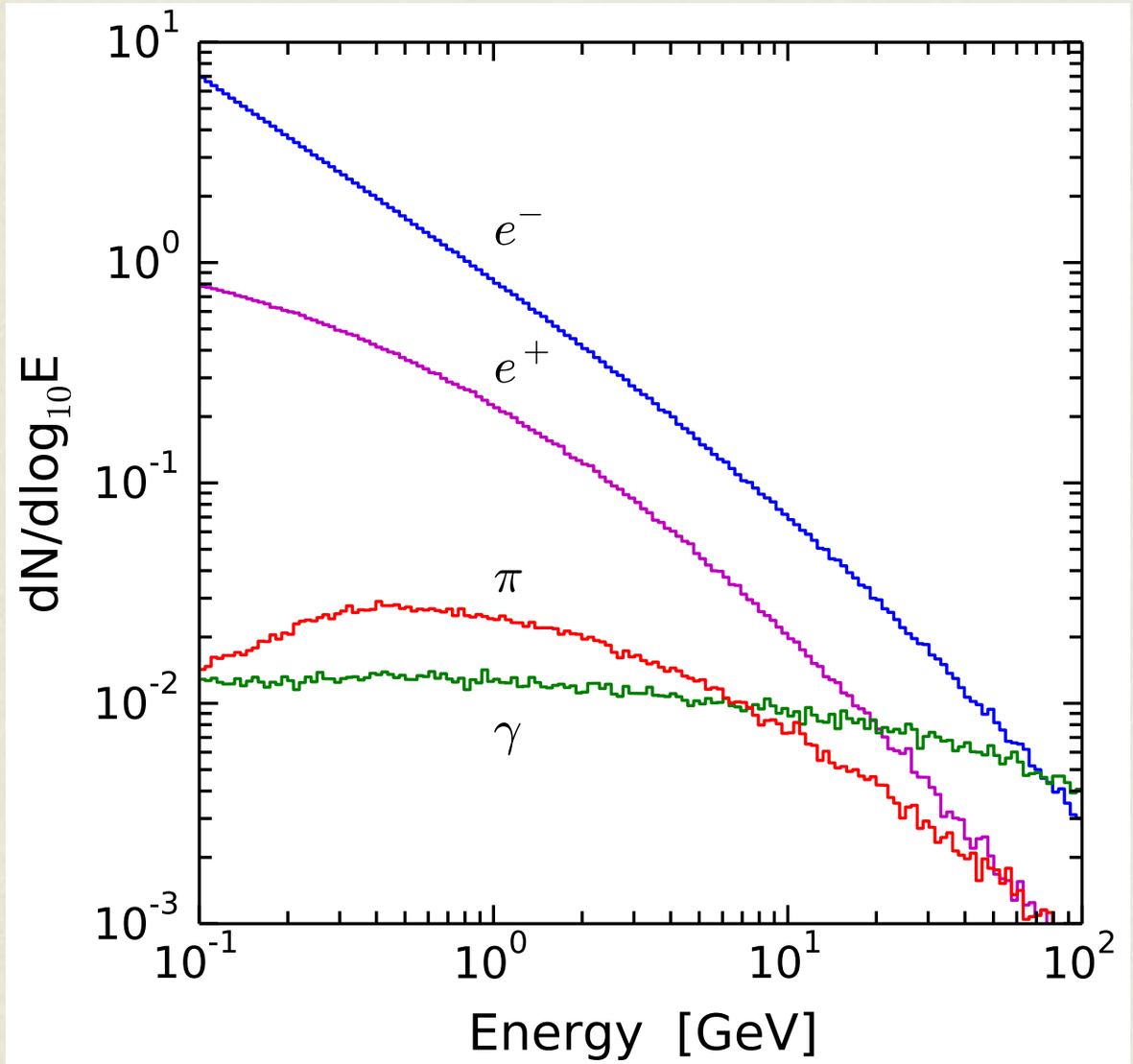
- Bkg:

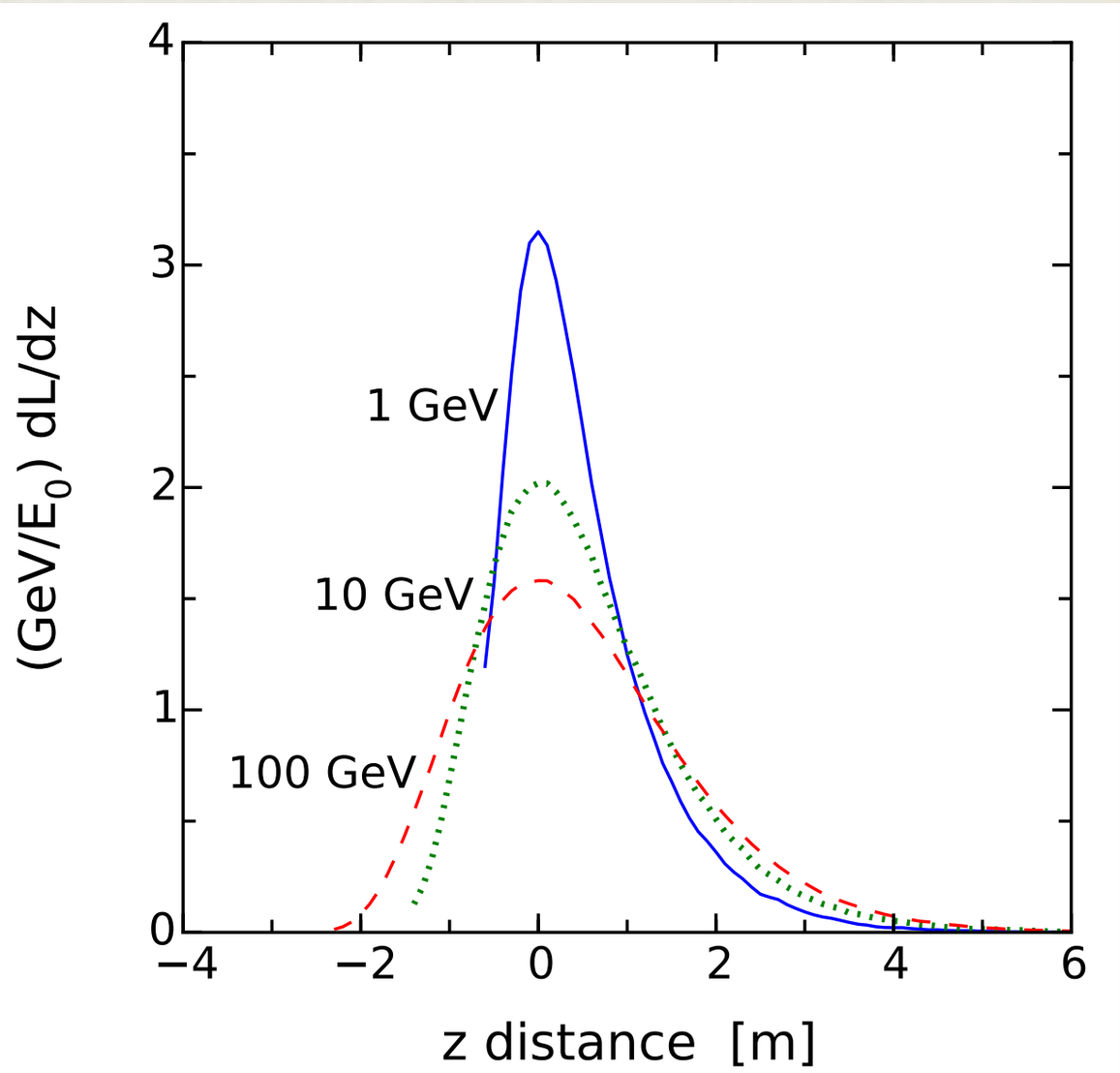
$$\mu \rightarrow \mu + secondary$$
$$secondary + X \rightarrow X'$$
$$X' \rightarrow e^- + others$$



Spallation — Muons produce showers

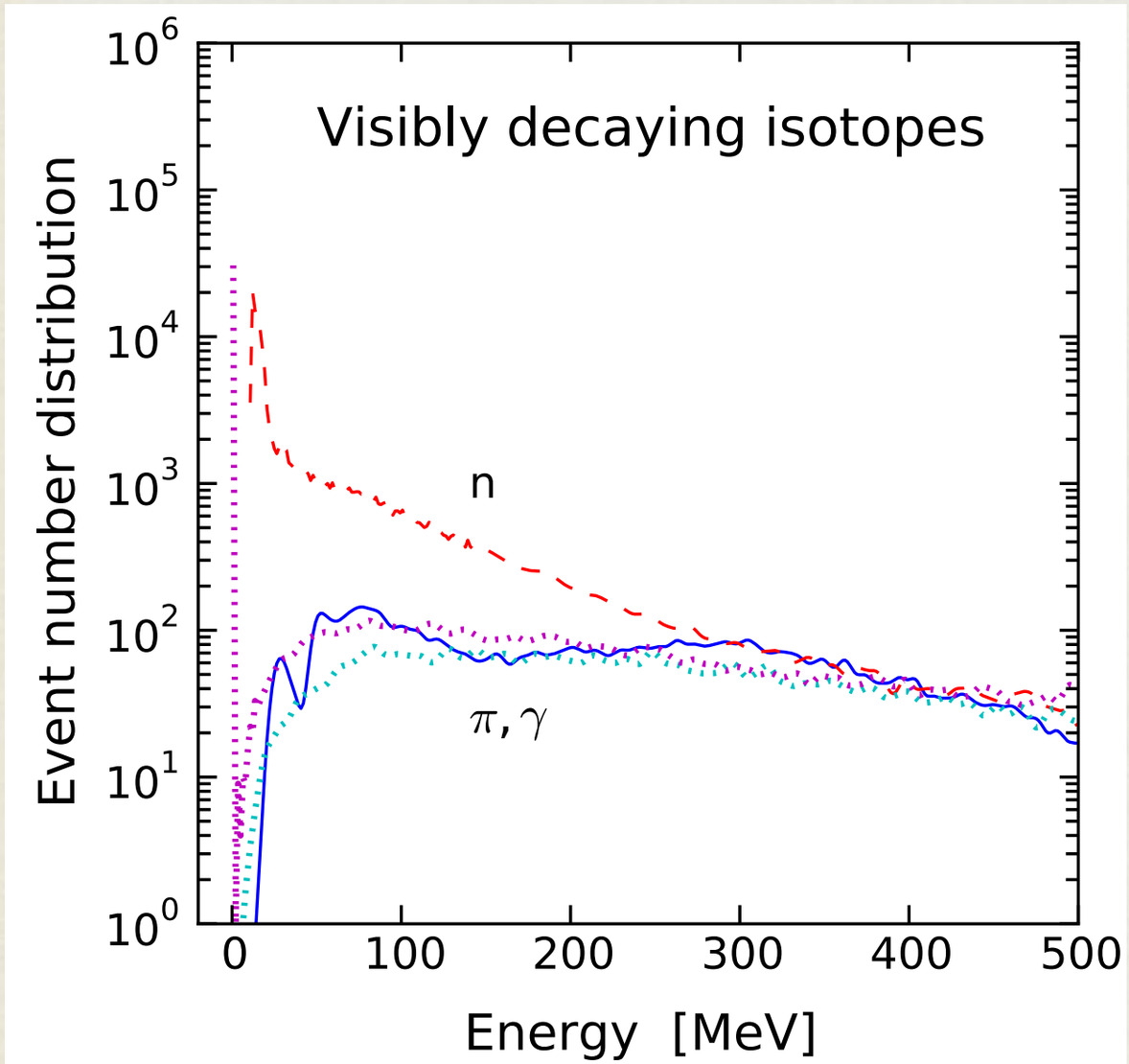
Li & Beacom 2014, 2015, 2015

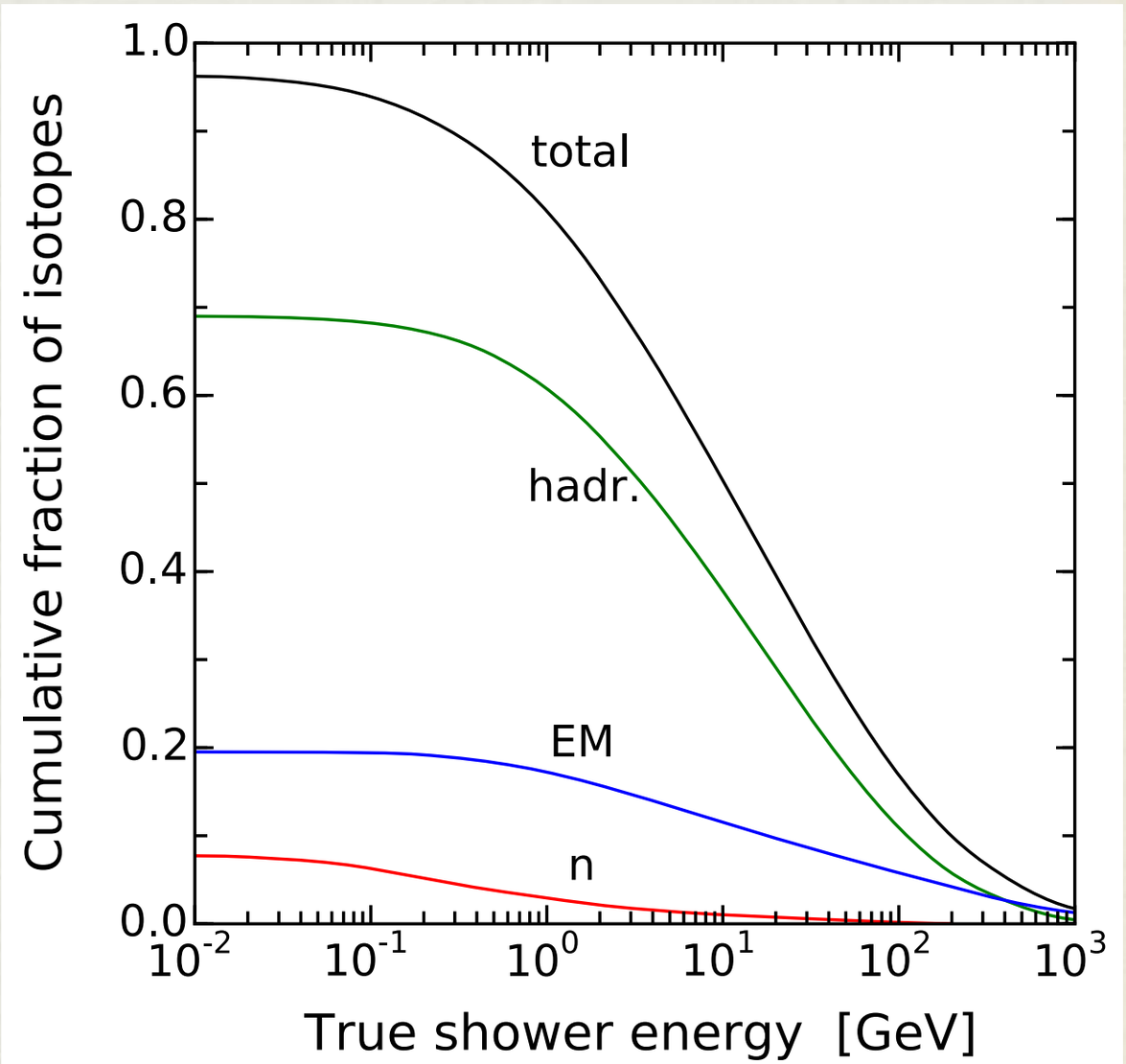




Spallation — Showers produce isotopes

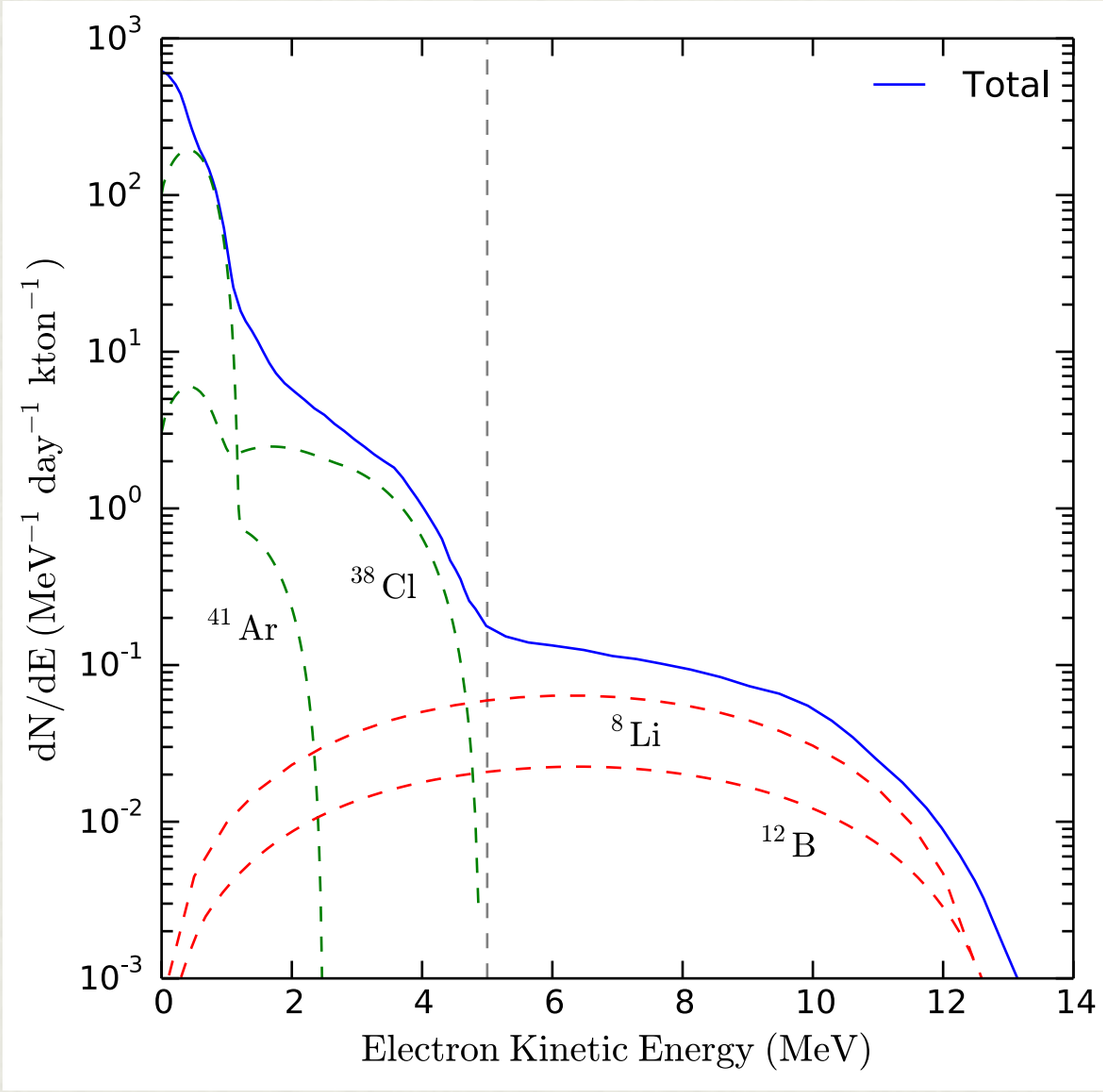
Li & Beacom 2014, 2015, 2015





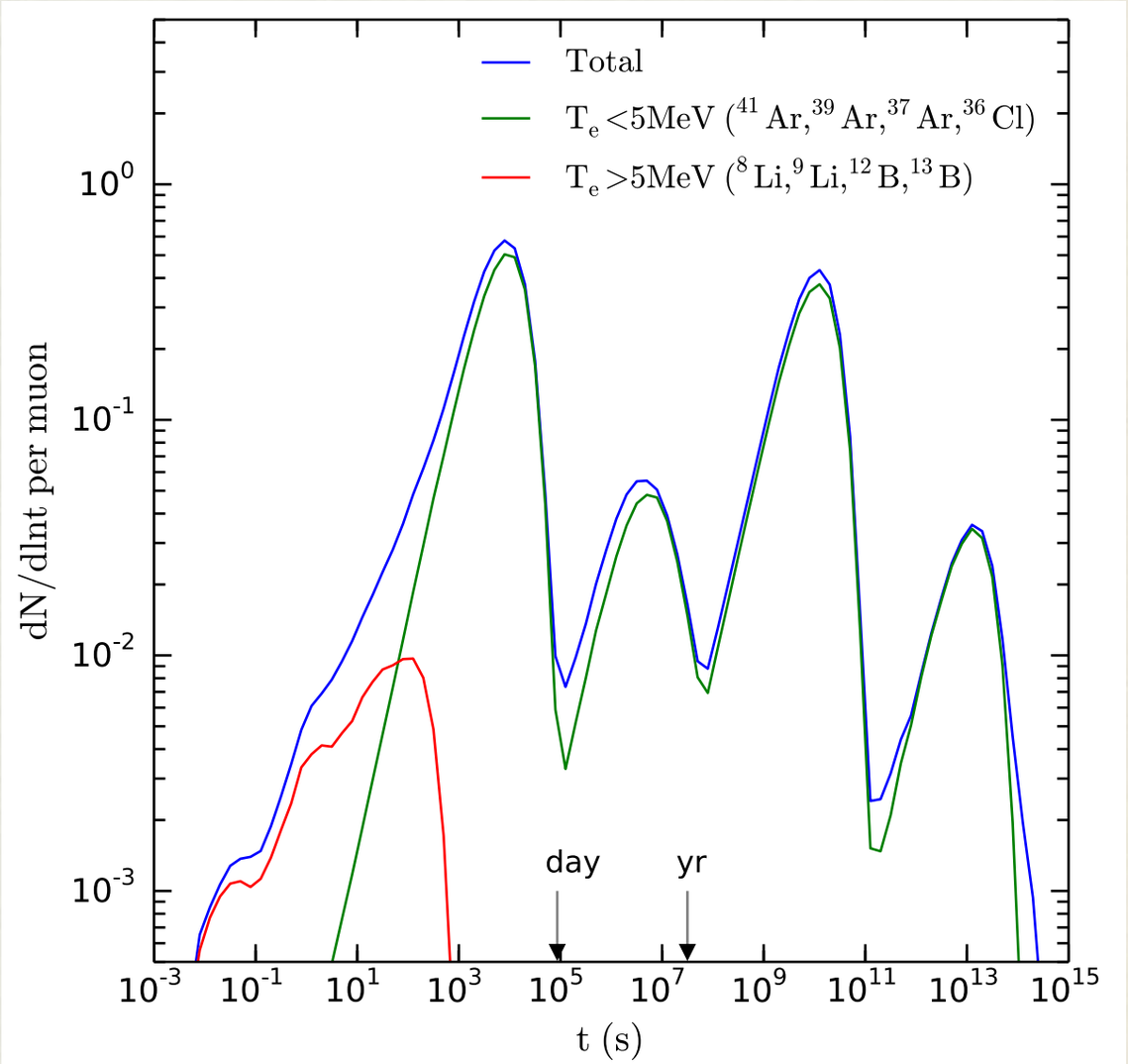
Spallation backgrounds @ DUNE

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



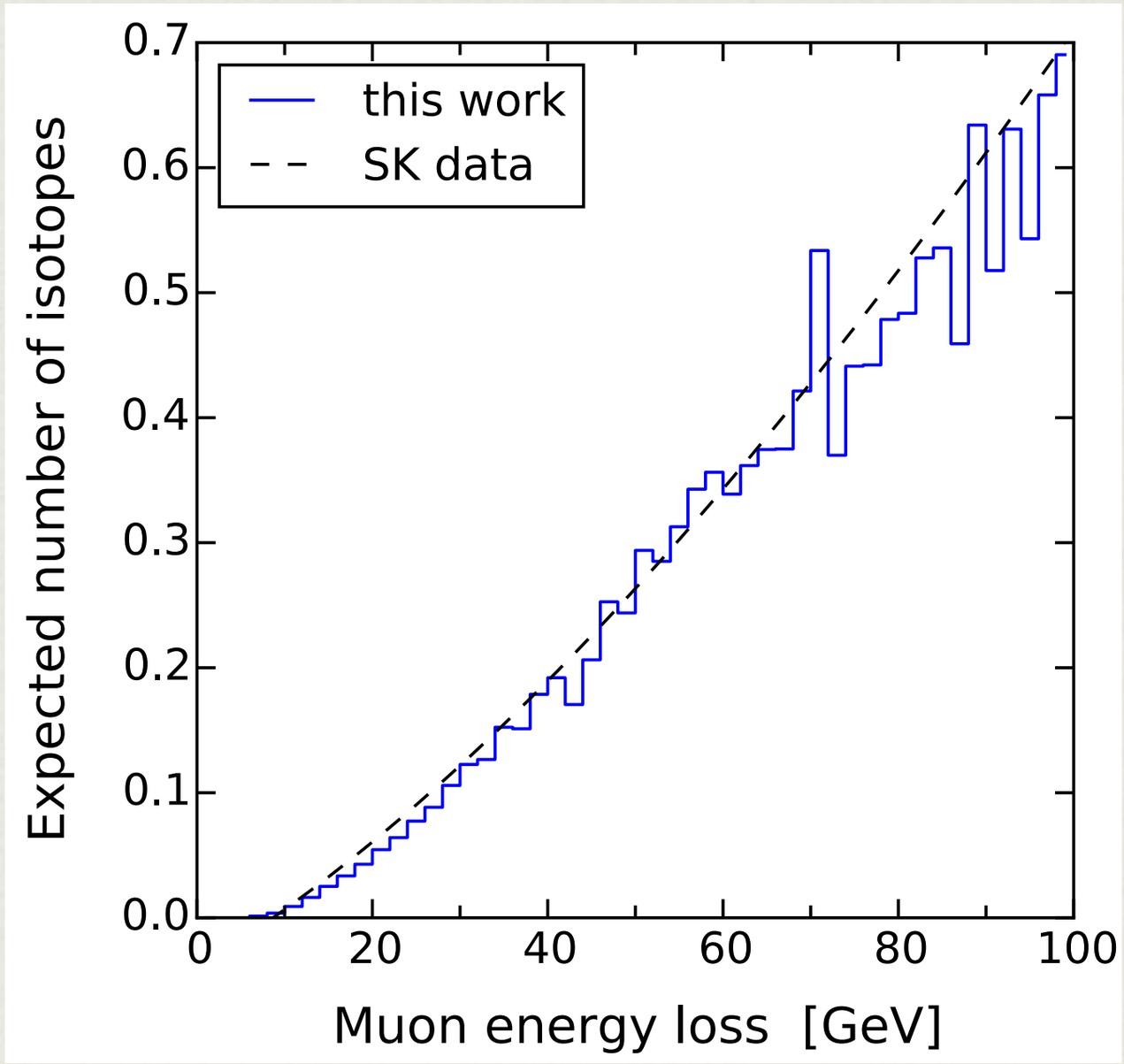
Spallation backgrounds @ DUNE

- 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. $R_{bkg} \approx 10^{-3}/10s/40kt$


this work
SK data
Expected number of isotopes
Muon energy loss [GeV]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
20
40
60
80
100