# Modelling cosmic ray muon spallation for Super & Hyper-Kamiokande DSNB

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# Diffuse Supernova Background Neutrinos

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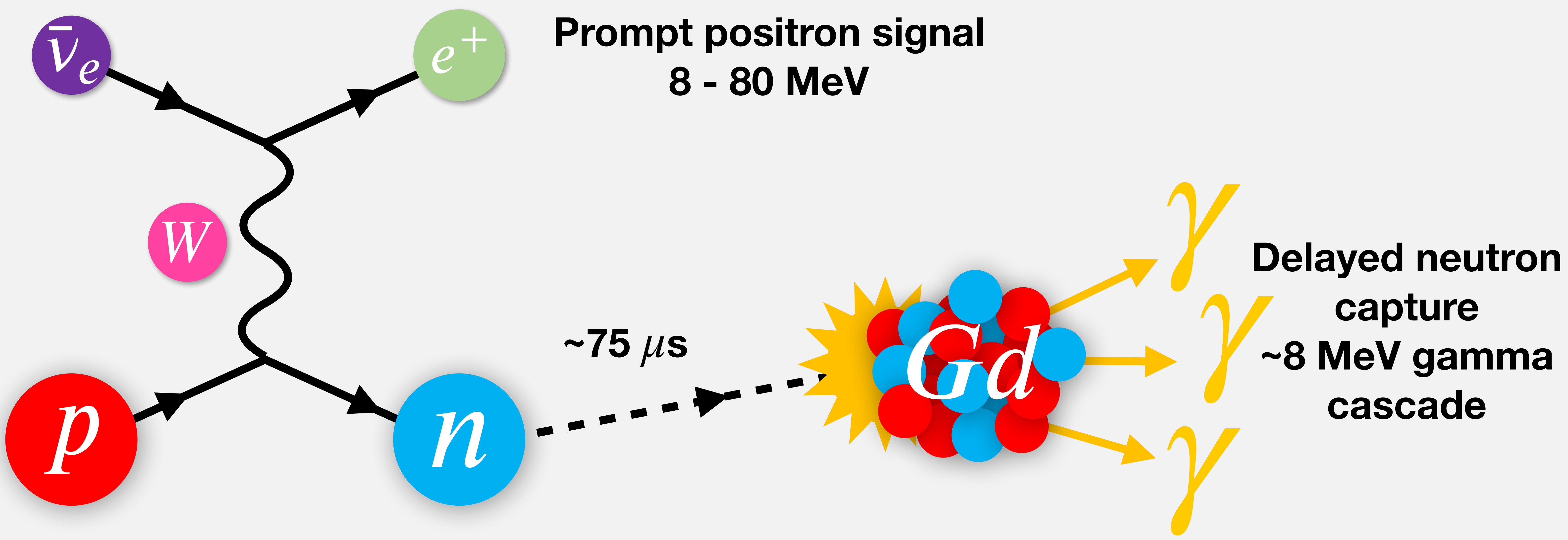
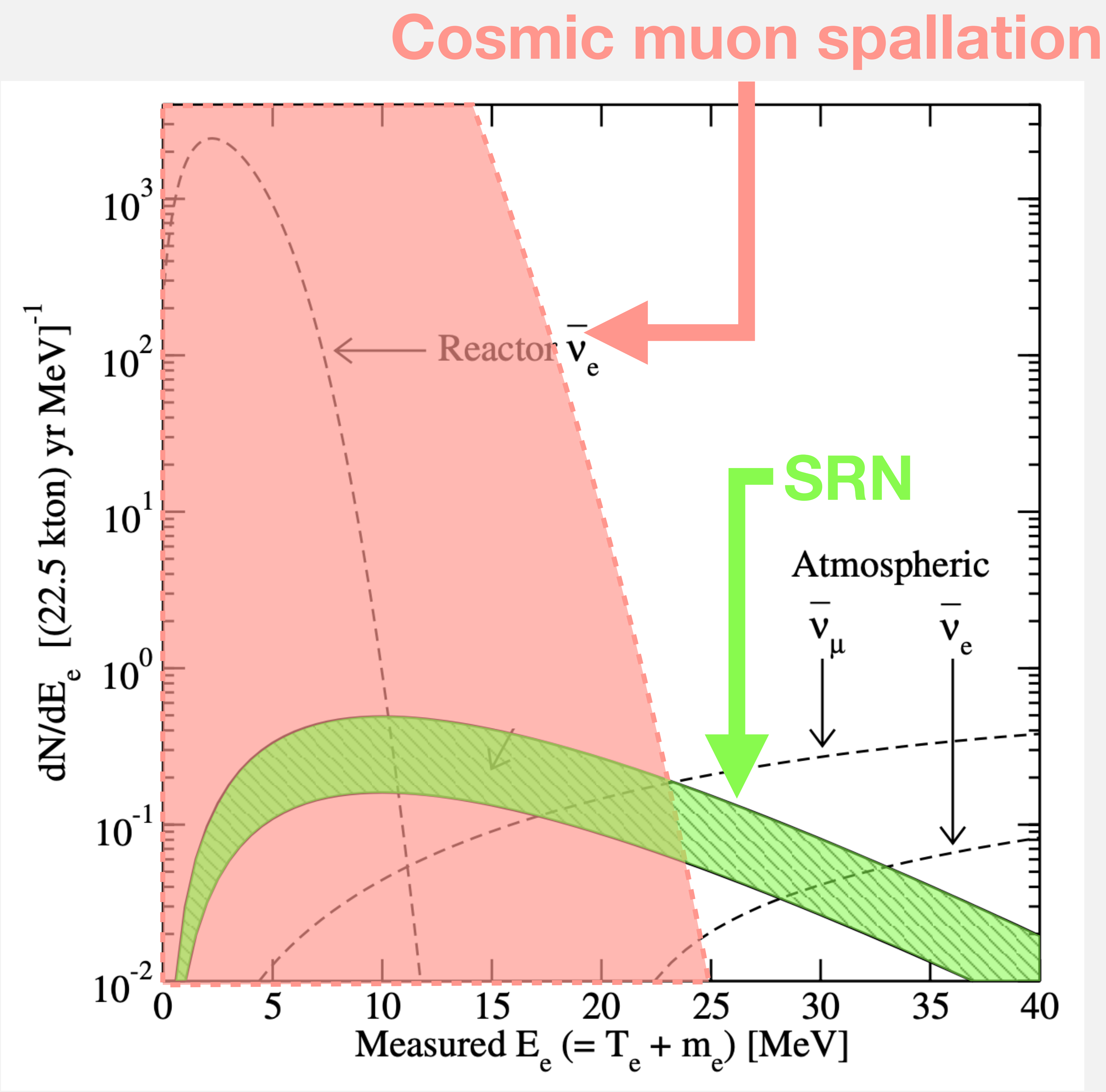
- The **cumulative neutrinos** created by all past **core collapse supernovae** in the universe.
- Estimate **5-20 events/year** from 8-80 MeV for a 50 ktonne water Cherenkov detector.
- Can be identified through inverse beta decay interactions:




**Spallation background overlayed onto the positron kinetic energy spectra for low energy antineutrino events.**
PhysRevLett.93.171101

# How are we going to detect it?

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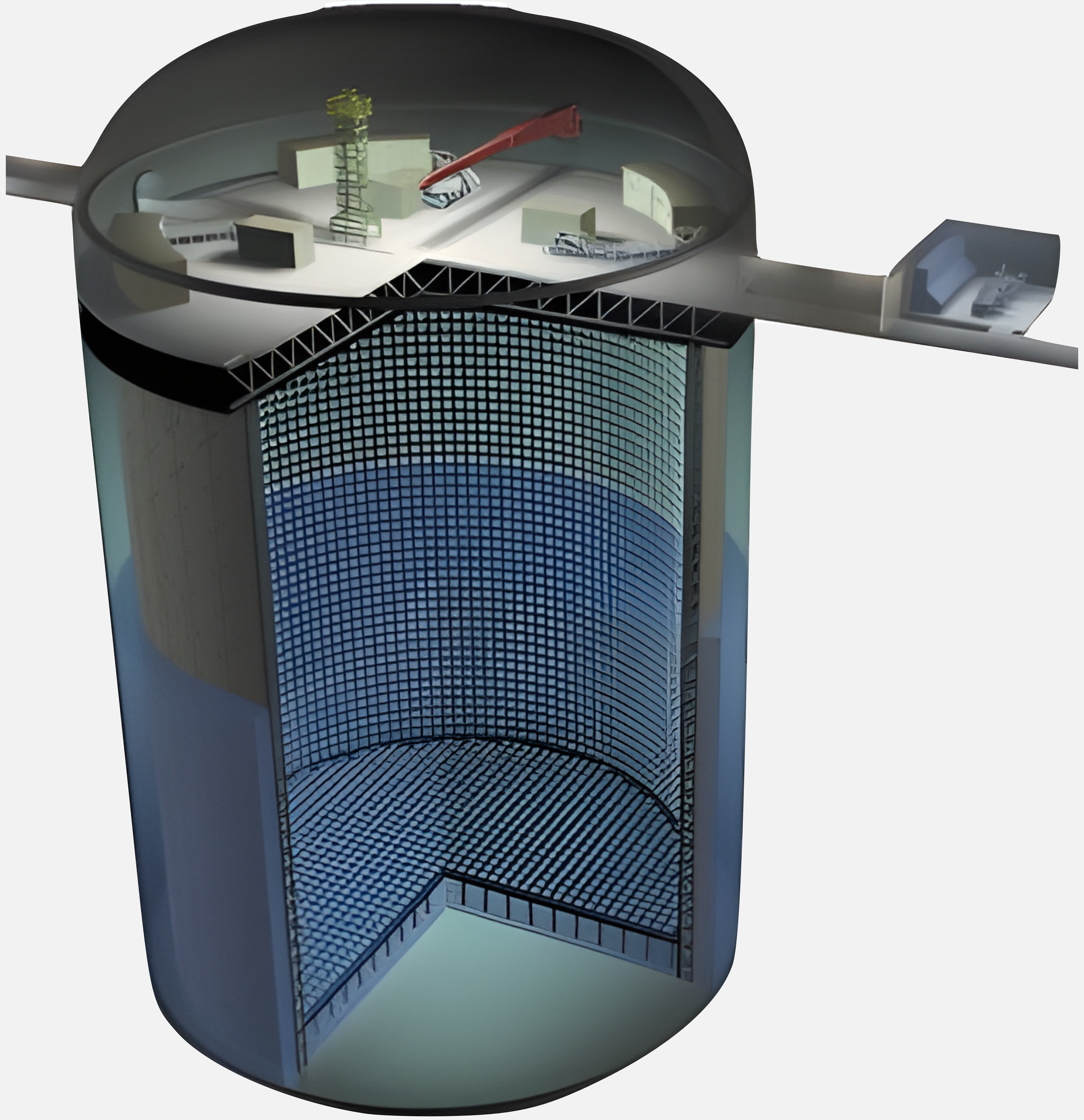
- **Super-Kamiokande Gadolinium (SKGd)**
  - **50 ktonne Gd-water Cherenkov** detector located in western Japan.
  - Underneath 1000 m (2700 m.w.e) of rock. **Reduces muon rate to ~ 2.5 Hz**.
  - Operational since 1996 currently in phase VII with **0.03% Gd by weight**.
- **Hyper-Kamiokande** - Future 260 ktonne pure water Cherenkov detector.
  - 650 m rock overburden (1755 m.w.e) – Muon rate ~45 Hz. Spallation background will be even higher.



**Super-Kamiokande detector. The 2.5 m thick outer detector can be seen.**

# Spallation process

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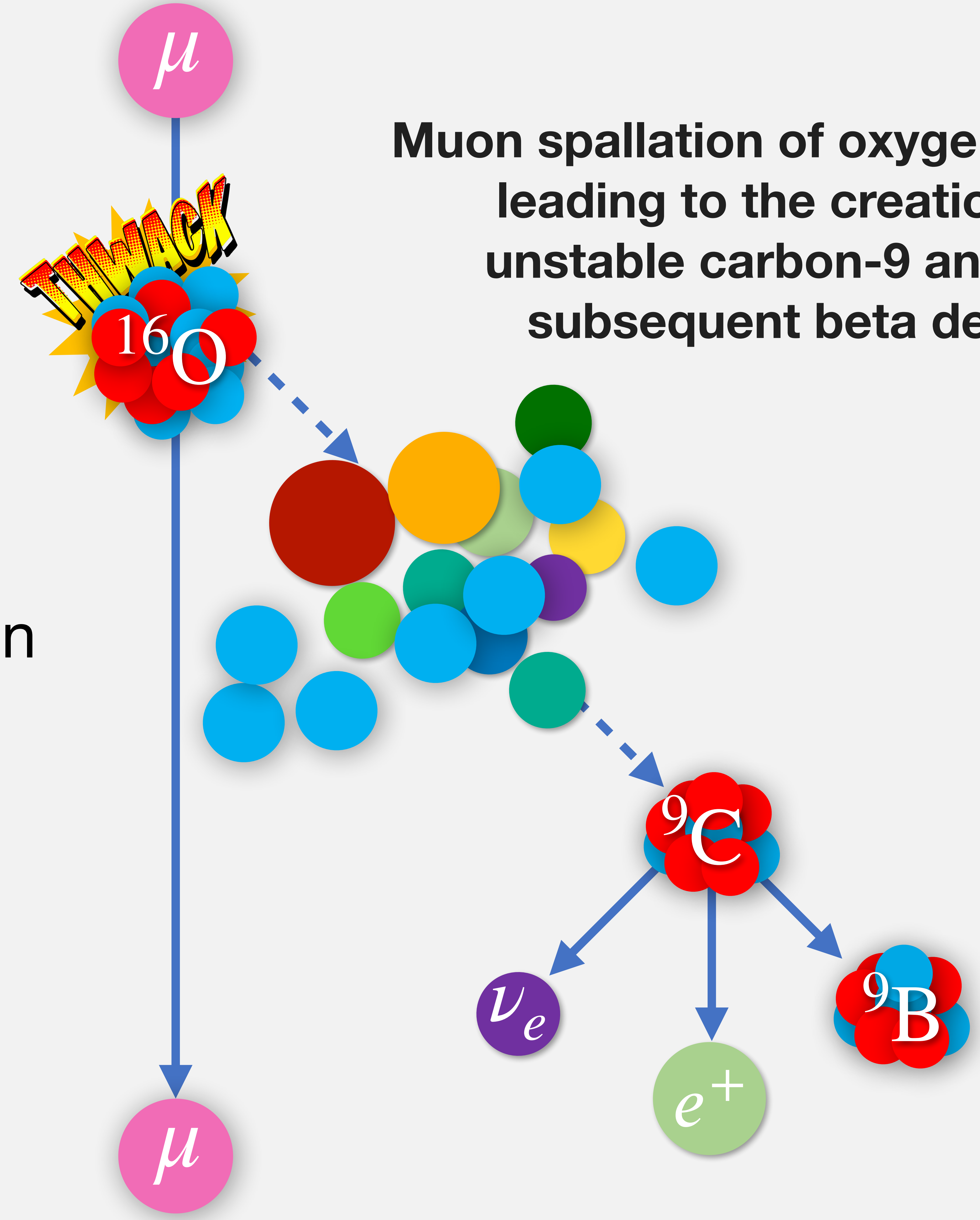
- Muons produce daughter particles that initiate **electromagnetic and hadronic showers through spallation processes**.

- **Hadronic showers** are the dominant production route for **unstable isotopes**.
  - 89% vs 11% for direct interactions between muon and oxygen nuclei.

- Decay products $e^{\pm}$, $n$, $\gamma$, are **produced at low energy** — $< 20\ \mathrm{MeV}$

- Showers can be **located by neutron captures**…

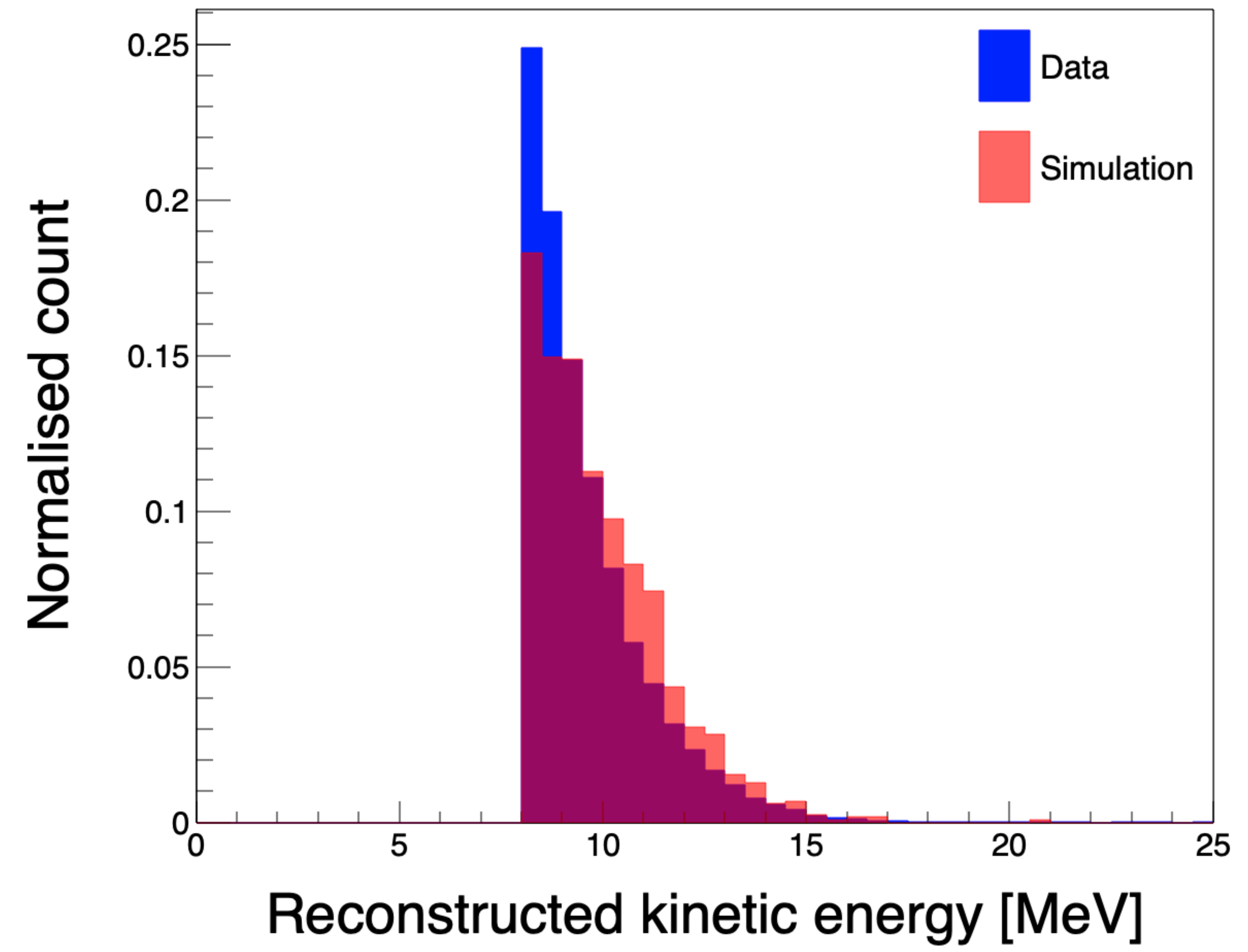



**Muon spallation of oxygen-16 leading to the creation of unstable carbon-9 and its subsequent beta decay.**

# The plan & current results

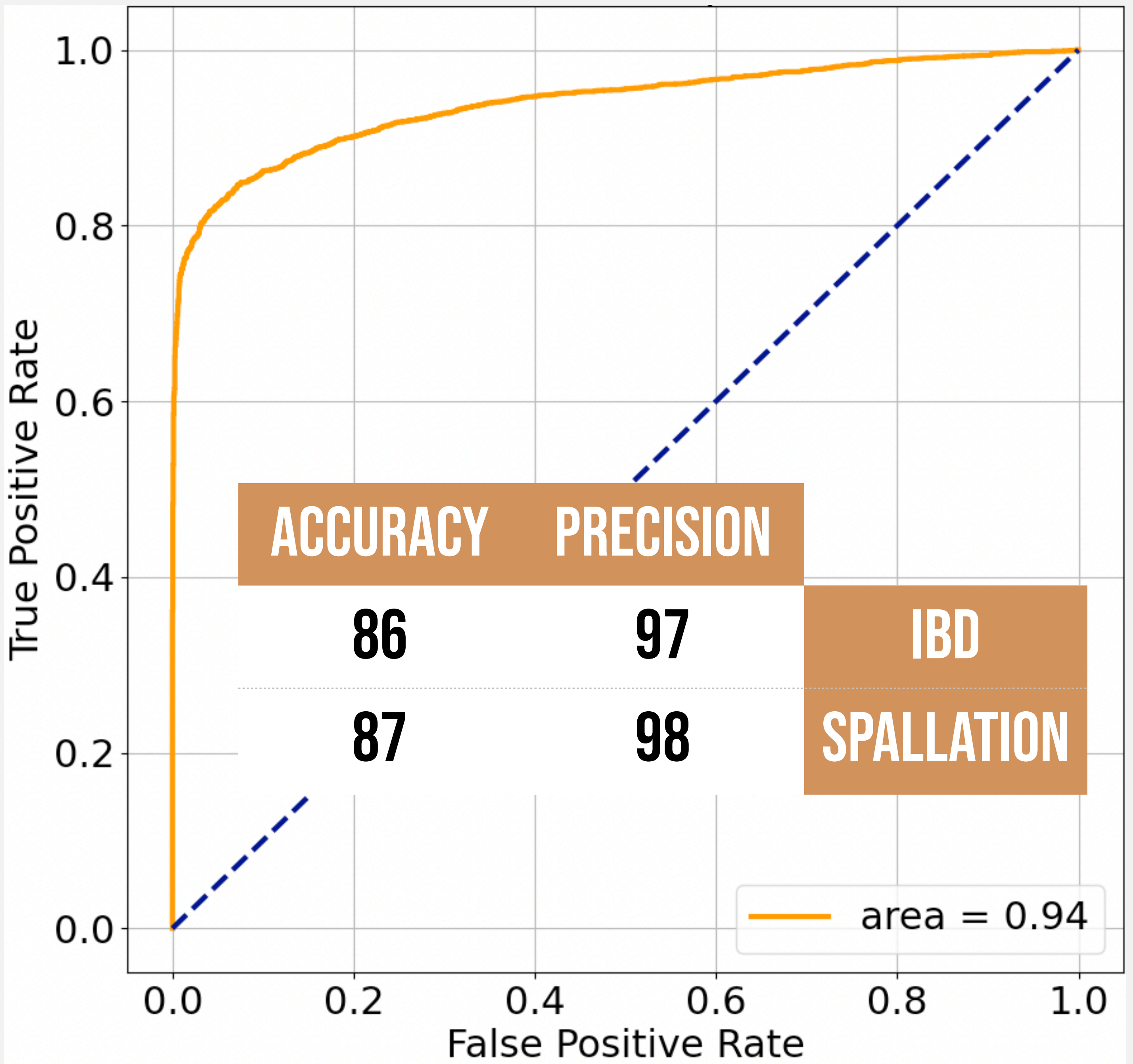
Create a **simulation-based** cut using **machine learning** to classify spallation-caused low-E events against SRN candidates.

**Transport muons with MUSIC** → FLUKA → **Detector response sim** → **Machine learning classification**




Simulation results show a **good agreement with SK data** (left).

Preliminary machine learning classifications show **good discrimination power** between spallation-caused LowE events and IBD events (right).




| | ACCURACY | PRECISION |
|---|---|---|
| IBD | 86 | 97 |
| SPALLATION | 87 | 98 |

# The plan & current results



Create a **simulation-based** cut using **mach**
spallation-caused low-E events agains

**Transport muons with MUSIC** → FLUKA → SK

**Please feel free to chat to me in the poster session at poster EX-15.**

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