UNIVERSITY OF CAMBRIDGE

European Commission

Intense
H2020 MSCA ITN
G.A. 858199

Kaon production Study with Liquid Argon TPC of MicroBooNE for DUNE

Midterm Review Meeting- INTENSE
24 June 2022

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About Myself

- Born in Tokyo, Japan.

- Bachelor degree in Physics (Apr 2015 – Mar 2019)
  The University of Tokyo, Tokyo, Japan.

- Master degree in Physics (Apr 2019 – Mar 2021)
  The University of Tokyo, Tokyo, Japan.
  "Search for proton decay into charged antilepton and eta meson in Super-Kamiokande"

- Started my ESR position as PhD student at University of Cambridge.

Attended Courses, Conferences, and Workshops

- Lecture for modern particle physics
  (Oct. 2021 – Mar 2022)
- Machine learning course
  (Oct. 2021 – Mar 2022)

- LArSoft Workshop
  (1 Nov. – 3. Nov 2021)
- MicroBooNE Analysis Retreat Workshop
  (9 May – 13 May 2021)

- DUNE Collaboration Meeting (virtual)
  (24 Jan. - 28 Jan. 2022)
- MicroBooNE Collaboration Meeting (virtual)
  (7 Feb. – 11 Feb. 2022)

- MicroBooNE Collaboration Meeting
  (2 May. – 6 May. 2022)
- DUNE Collaboration Meeting
  (16 May. – 20 May. 2022)

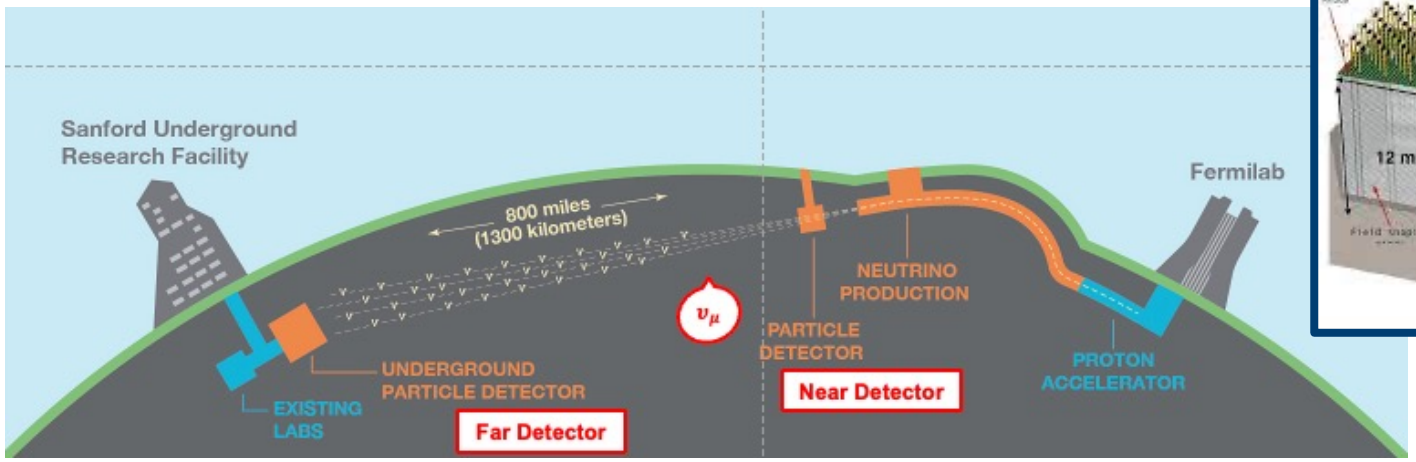
LArTPC Experiments: DUNE and MicroBooNE

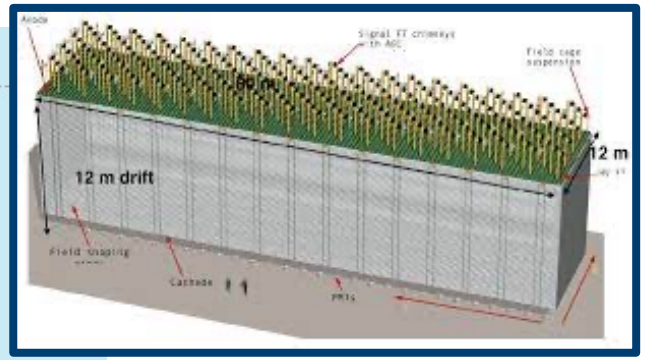
DUNE

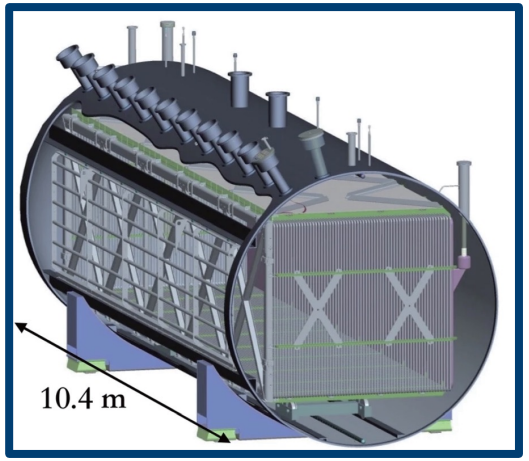
- Detector installation beginning in mid 20s
- Near and Far detectors located ~1300 km apart
  - Near detector: Complex of detectors for $\boldsymbol{\nu}$ properties
  - Far detector: 40 kton LArTPC with ~10^{35} of protons
- **Proton decay search: $p \rightarrow \bar{\nu} K^{+}$**

MicroBooNE

- 85 ton LArTPC running 2015 - 2021
- 0.25-2 GeV υ beam from the Booster Neutrino Beam (BNB) and the Neutrino Main Injector (NuMI)
- **Available data of ~10^{24} POTs**





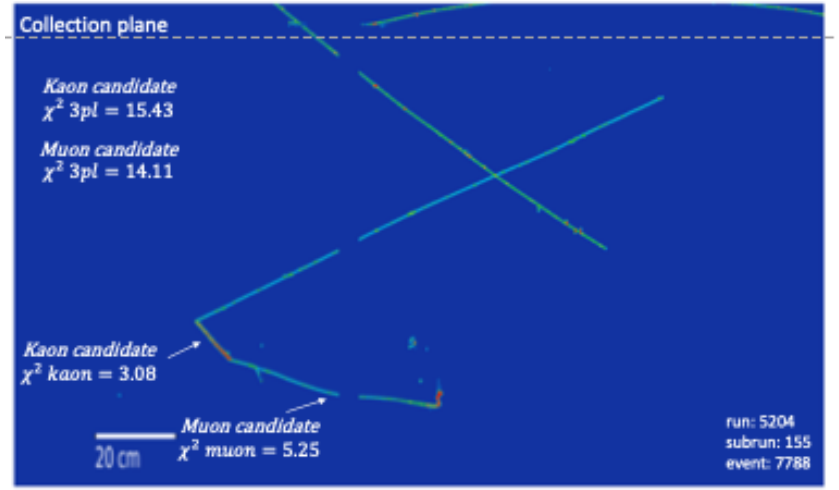


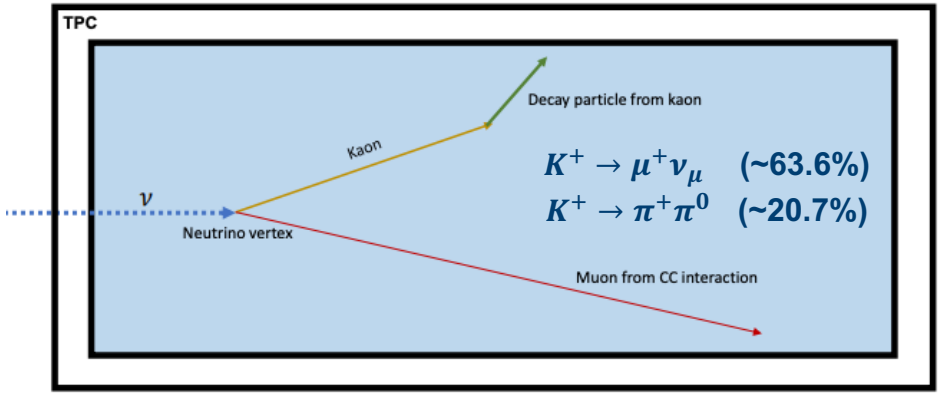
My Research: K^+ Production by CCNu Interactions

- ✓ **Why K+ study is important?**
  - Better understanding of K+ backgrounds from atmospheric neutrinos for future proton decay research at DUNE
  - No measurements on Ar at 1 GeV neutrino energy region

- ✓ **2 modes to produce K^+ by neutrino interactions in Ar**
  - Associated kaon production: ie. $\nu_\mu + p \rightarrow \mu^- + K^+ + \Sigma^+$
  - Single kaon production: ie. $\nu_\mu + p \rightarrow \mu^- + K^+ + p$

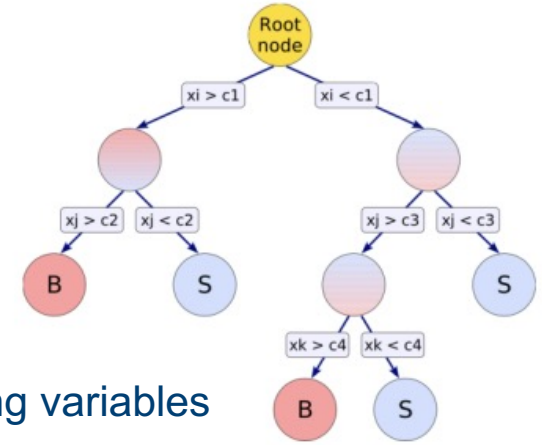
- ✓ **Search K^+ events with NuMI beam by Machine Learning**
  - Measure cross section of K^+ and install for future DUNE simulation
  - Develop better Kaon-proton PID separation





K^+ Event Features and Training by BDT

- ✓ True signal: $\nu_\mu + \mathrm{Ar} \rightarrow \mu^- + K^+ + \mathrm{nucleons/Hyperon}$
- ✓ Possible BG events: $\nu_\mu + \mathrm{Ar} \rightarrow \mu^- + \pi^- + p$

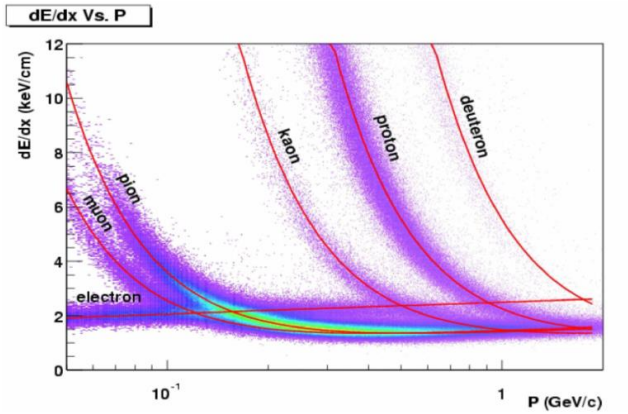


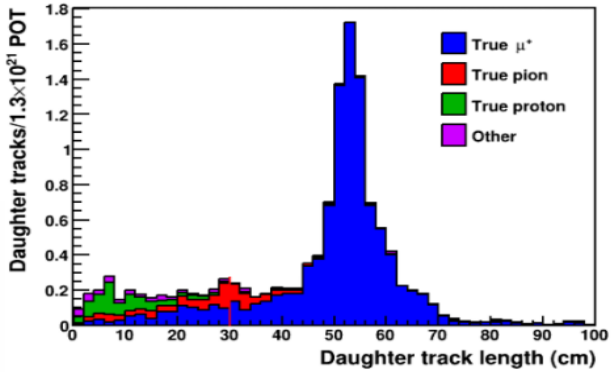
Separation with Boosted Descision Tree (BDT)

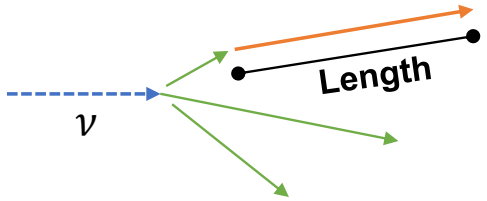
- Binary tree structure: sort events by yes/no decisions on training variables
- Select variables and values for splitting conditions with best separation

Training the BDT with MC events

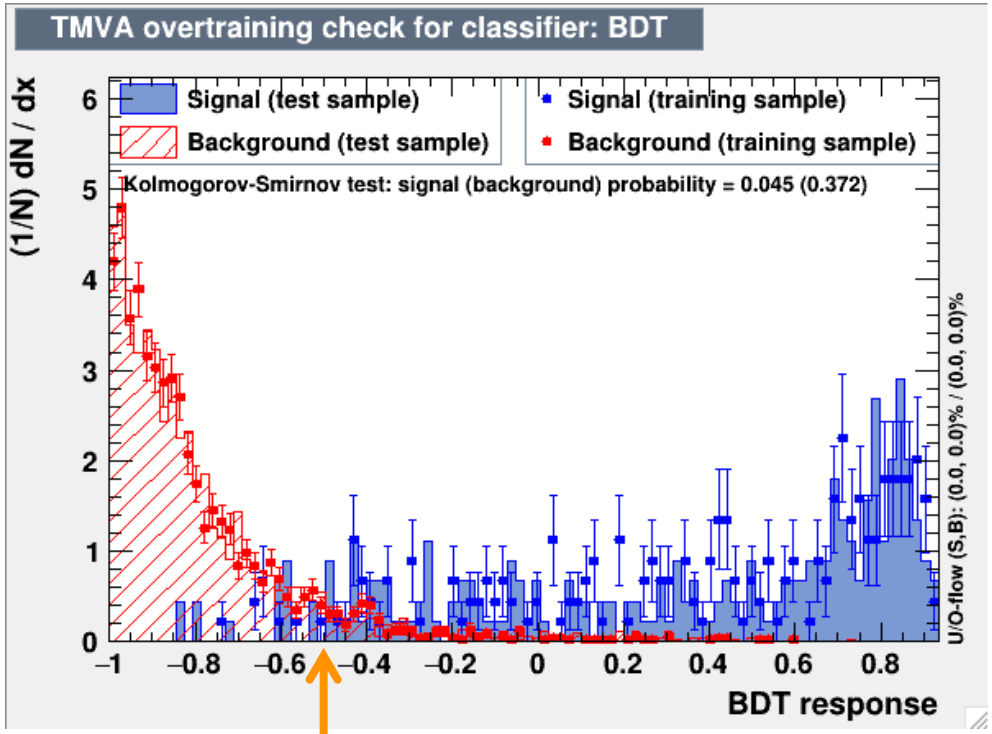
- Select variables well characterize true/BG events:
  - PID score based on dE/dx for kaon/proton separation
  - Lengths of tracks: effective for muon selections

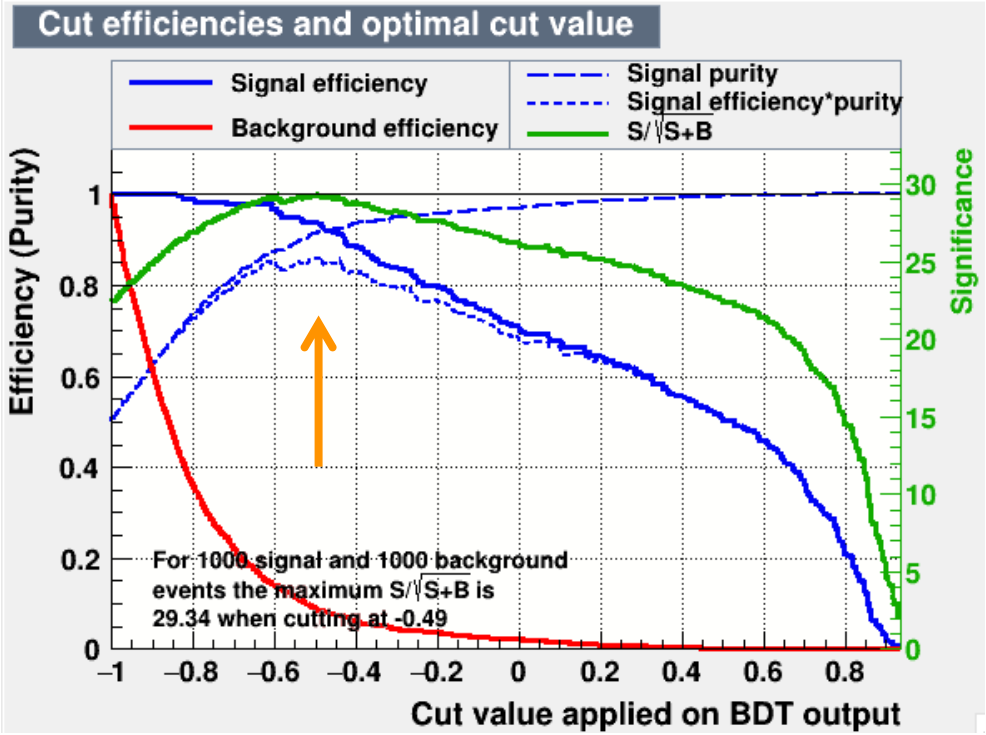






Preliminary Results of Signal/BG Separation





Maximum $Signal/\sqrt{Signal + BG}$ at -0.49

- Signal efficiency: ~92%
- BG efficiency: ~10%
- Purity: ~90%

Future Plans

- ✓ **MicroBooNE K^+ production study**
  - Optimize the BDT training by comparing various algorithms, training parameter sets, hyper-parameter tuninig
  - Systematic uncertainty study as a preparation for real data analysis

- ✓ **Starting DUNE Works**
  - Measurements and developing automated system for DUNE detector printed circuit boards
  - MC event productions for DUNE near detector