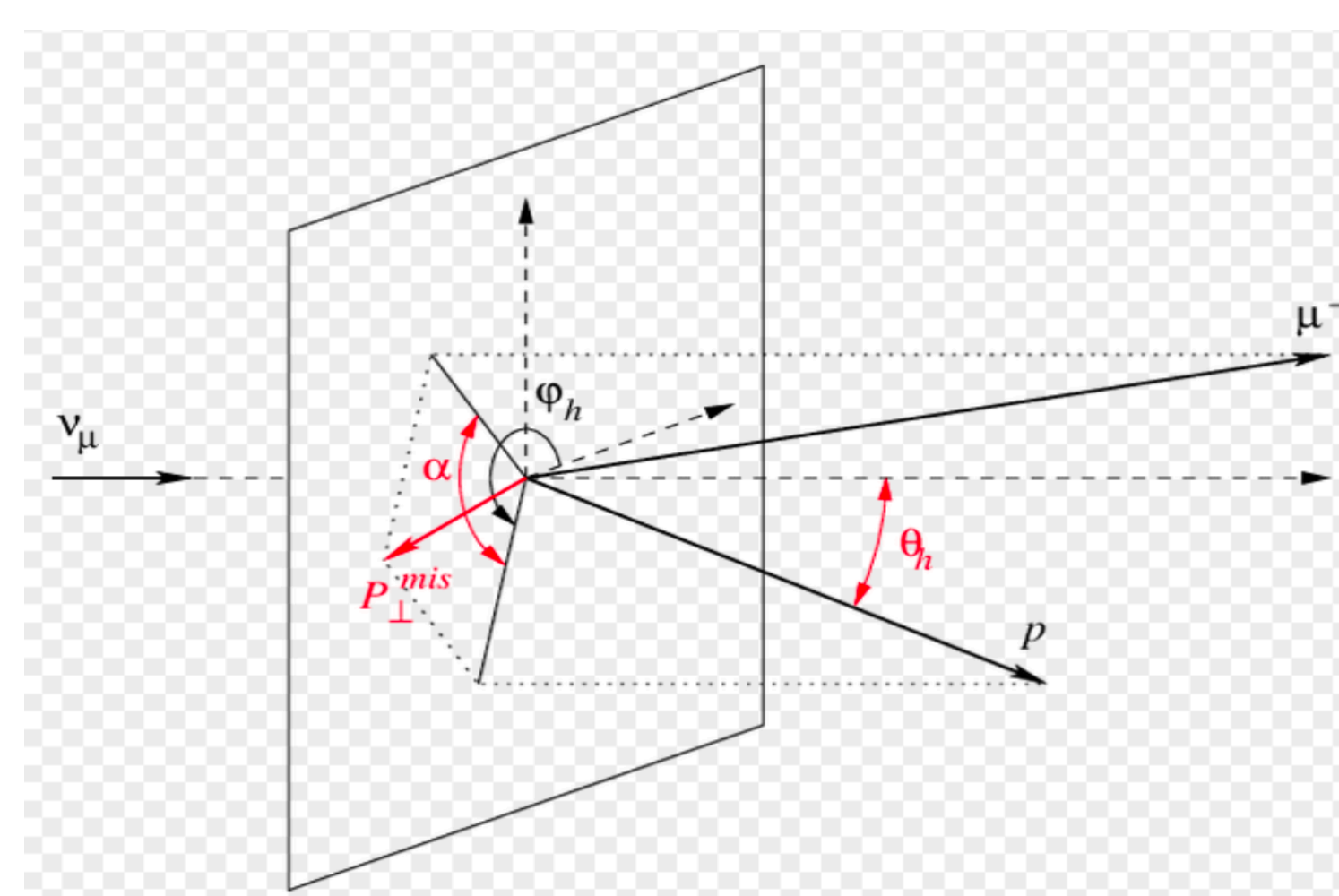


Introduction

The System for on-Axis Neutrino Detection (SAND) is part of the Near Detector complex of the Deep Underground Neutrino Experiment (DUNE). A detector configuration under study for SAND includes a 3-Dimensional Projection Scintillator Tracker (3DST), surrounded by a low-density tracker, and an ECAL and a Magnet repurposed from the KLOE experiment. This system aims at detecting and measuring energies of all final-state particles including neutrons from neutrino charged-current interactions, thus providing a full reconstruction of each individual interaction channel. Such a measurement can constrain the neutrino interaction and flux uncertainty.

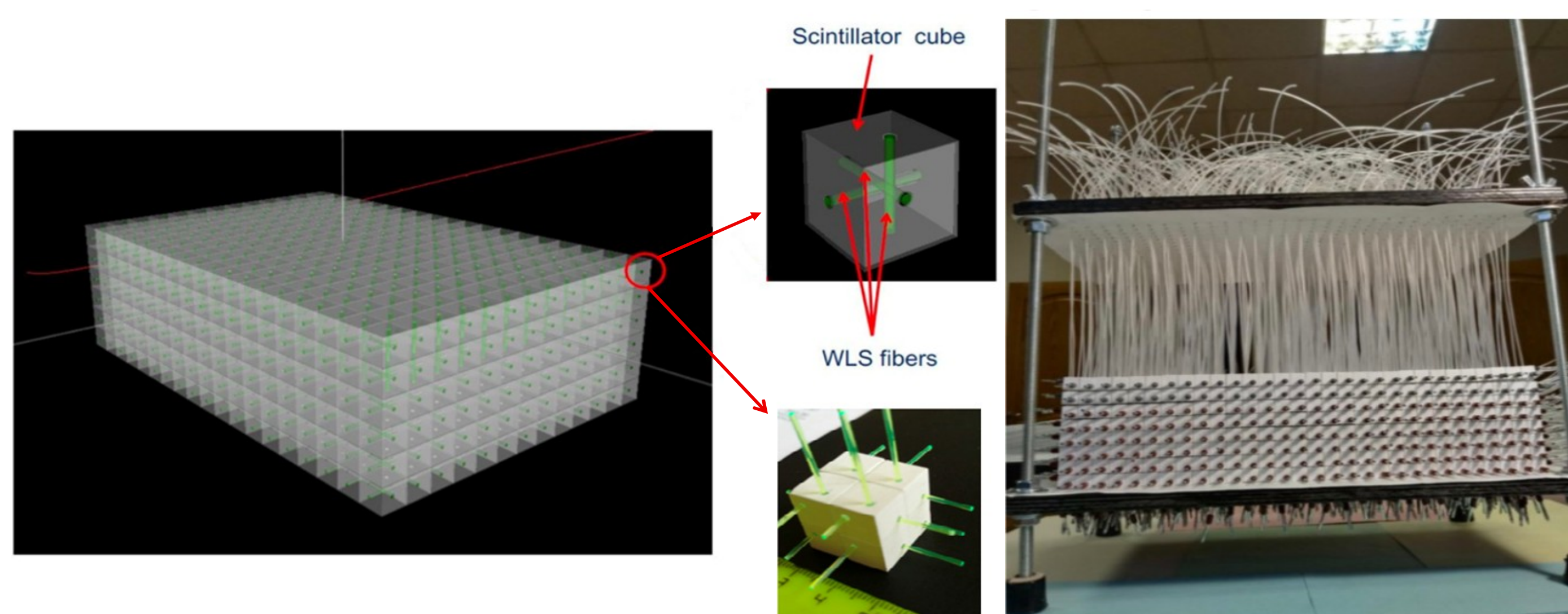
Motivation: Neutron information

Getting all final state particle information greatly improves constraints on the neutrino flux and cross section model.



- Neutron provides the last missing piece of neutrino interaction reconstruction.
- Transverse momentum of all final state particles including neutron is supposed to be 0.
- We can understand better the nuclear effects if we know momenta of all final state particle.

3DST

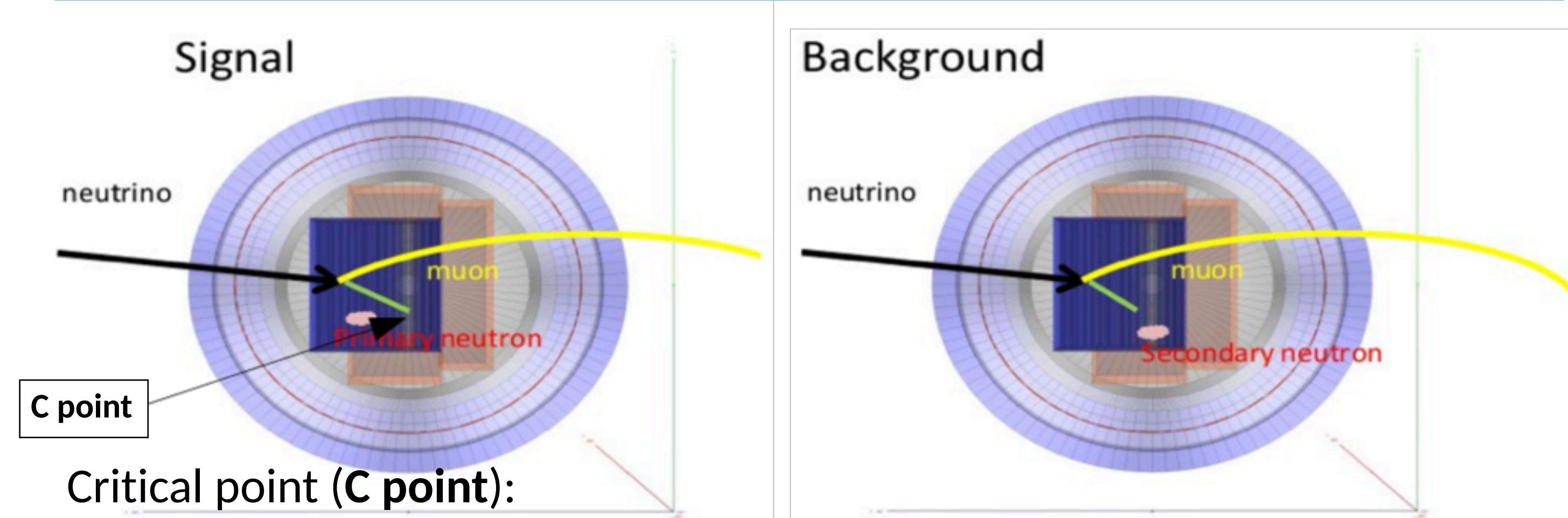


3DST has the following features,

- Full solid angle acceptance
- 3D reconstruction with fine granularity with 1cm^3 cube
- Fast time resolution (0.5 ns) proper to detect the neutron.
- $2.4\text{m} \times 2.4\text{m} \times 2.0\text{m}$
- 11,520,000 cubes, 153,600 channels

Two prototypes constructed for T2K Upgrade and DUNE SAND with size $24\text{cm} \times 8\text{cm} \times 48\text{cm}$ and $8\text{cm} \times 8\text{cm} \times 32\text{cm}$ have been exposed to the LANL neutron beamline, which delivers neutrons that have kinetic energy up to 800 MeV, in order to characterize the neutron response in the detector.

Signal and background



Critical point (**C point**):

- Primary final state particle's end point in 3DST.
- For exiting primary particles, the C point is the last point inside 3DST.

Signal: neutrino CC interaction (vertex) event including a neutron

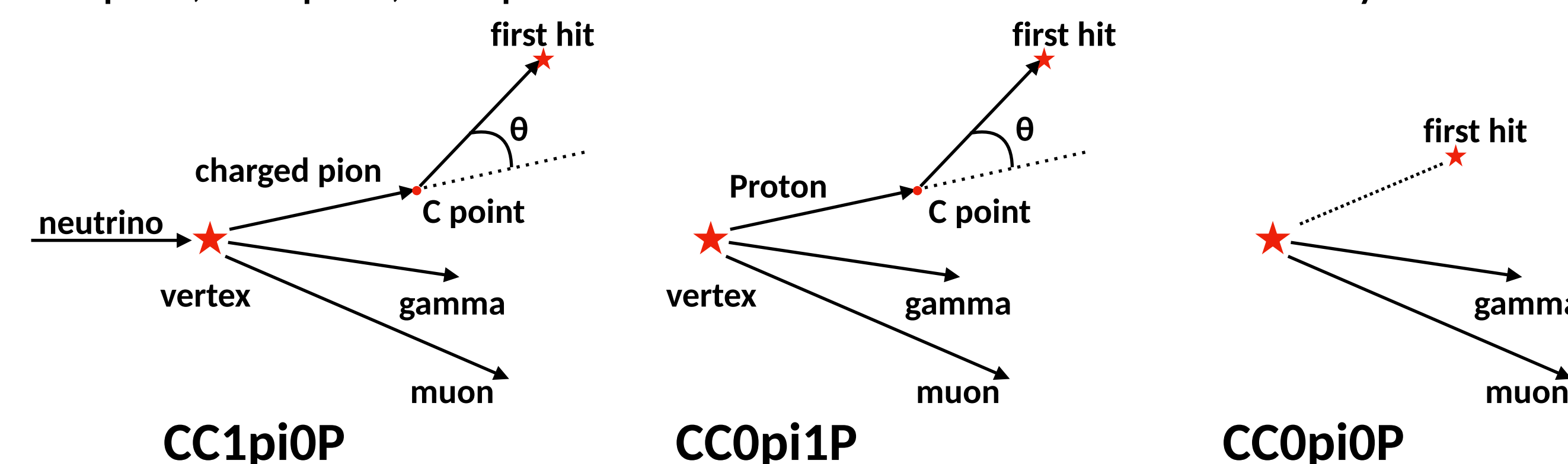
Background: other events; NC, secondary neutron, gamma, etc.

- primary neutron/gamma: neutron/gamma comes from the vertex directly.
- secondary neutron/gamma: neutron/gamma comes from other interactions than the neutrino interaction vertex.

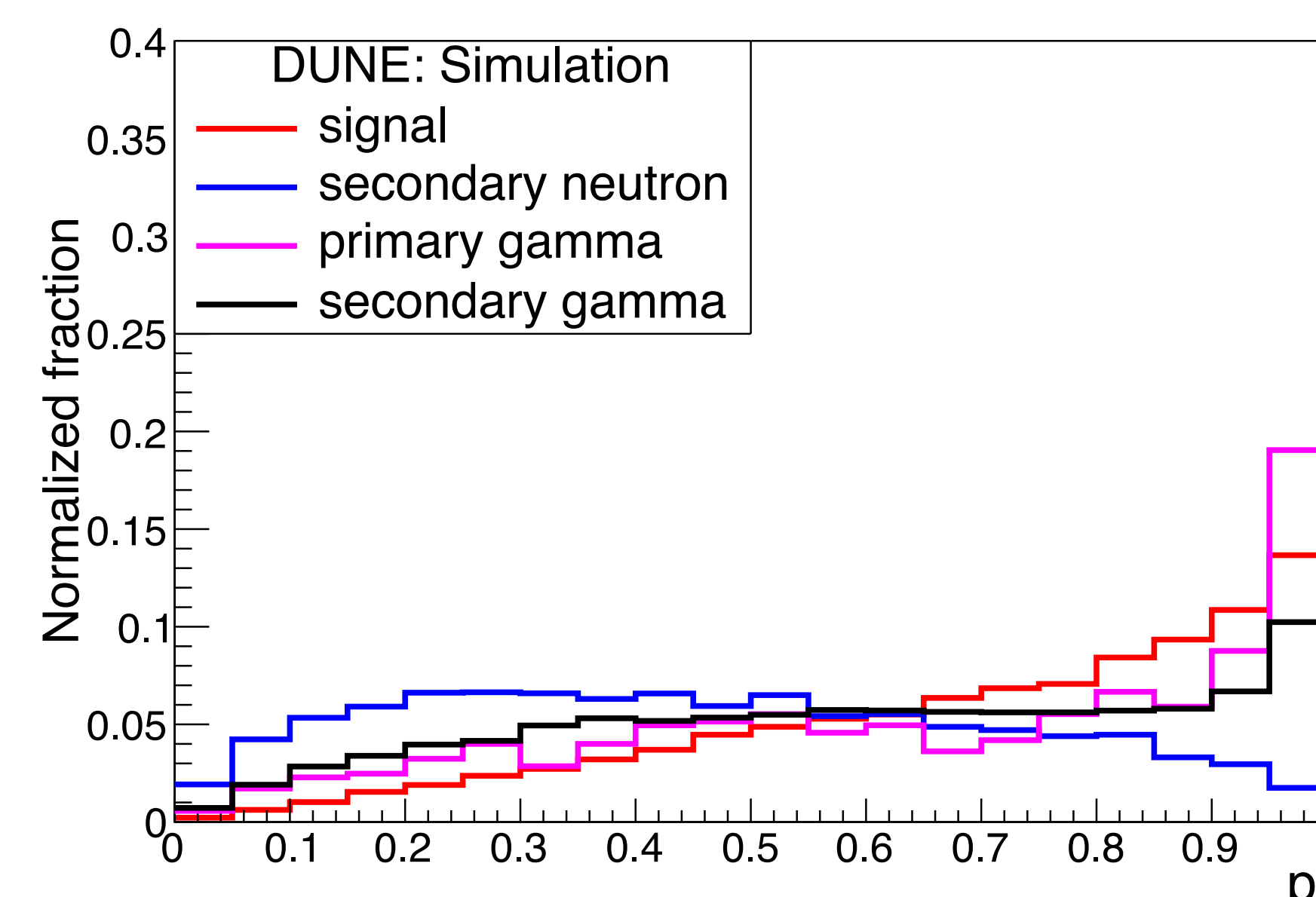
Since out of fiducial volume background is $< 1.5\%$, we focus on secondary neutron and gamma background.

Separation variables

CC1pi0P, CC0pi1P, CC0pi0P channels are considered exclusively

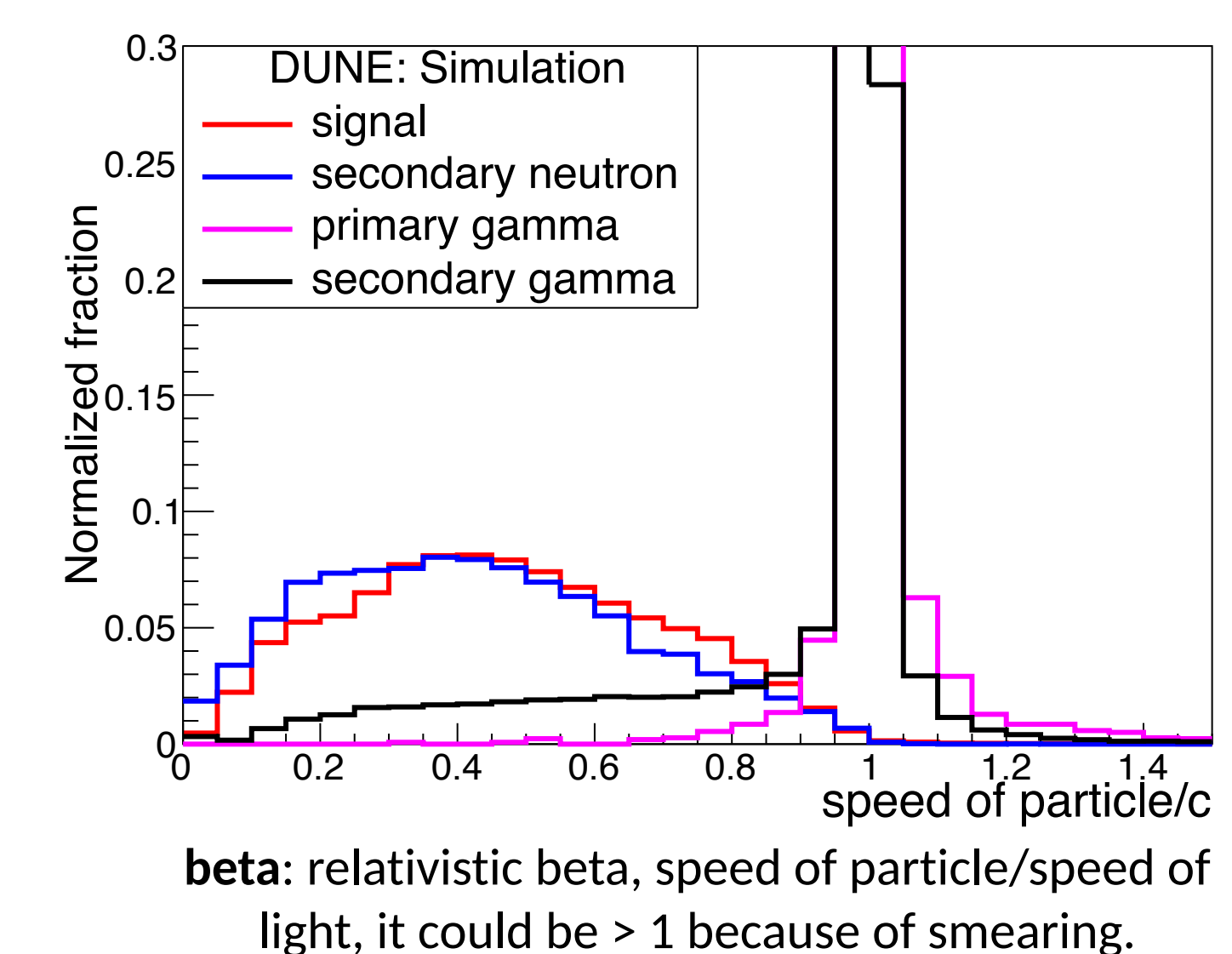
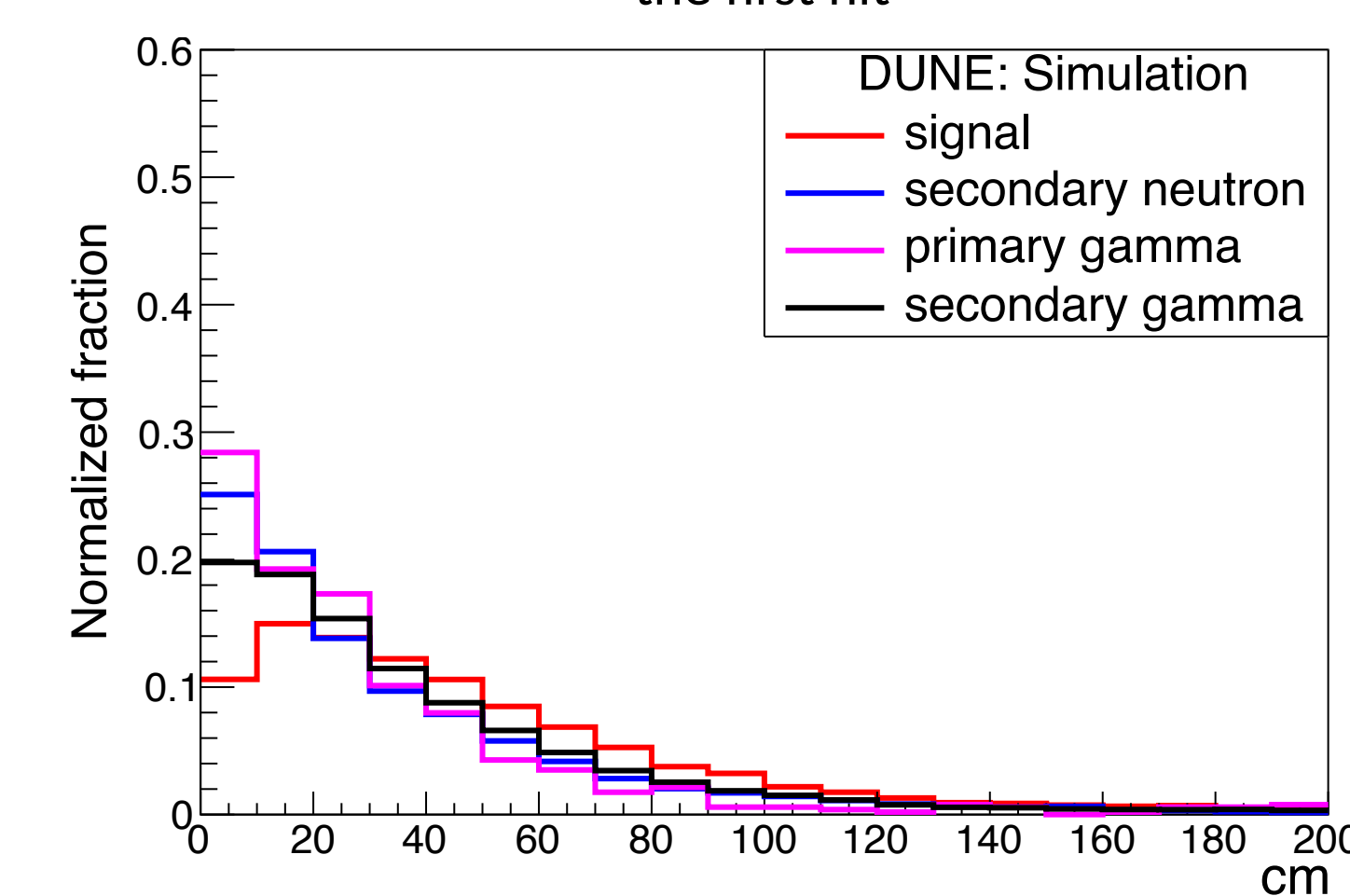
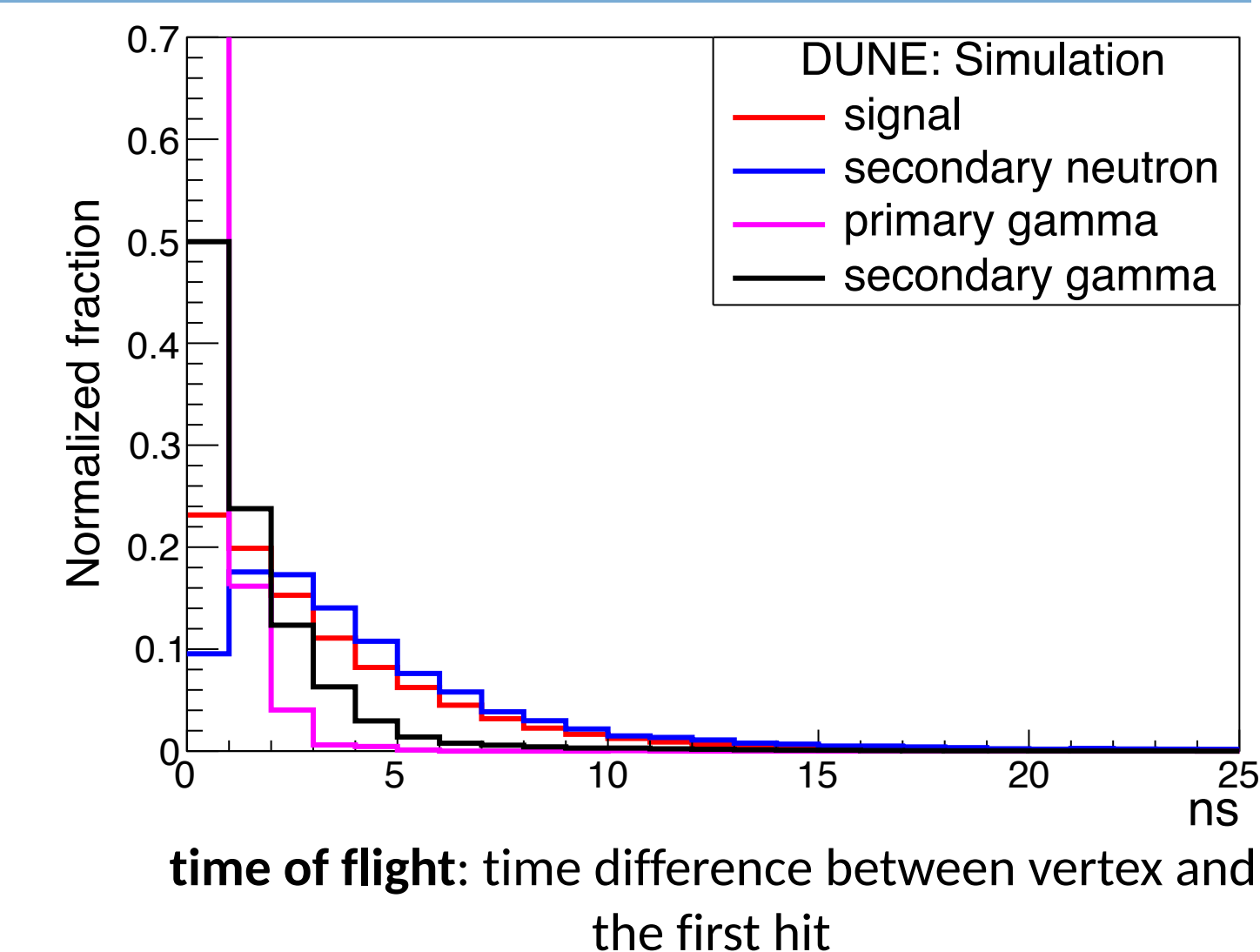
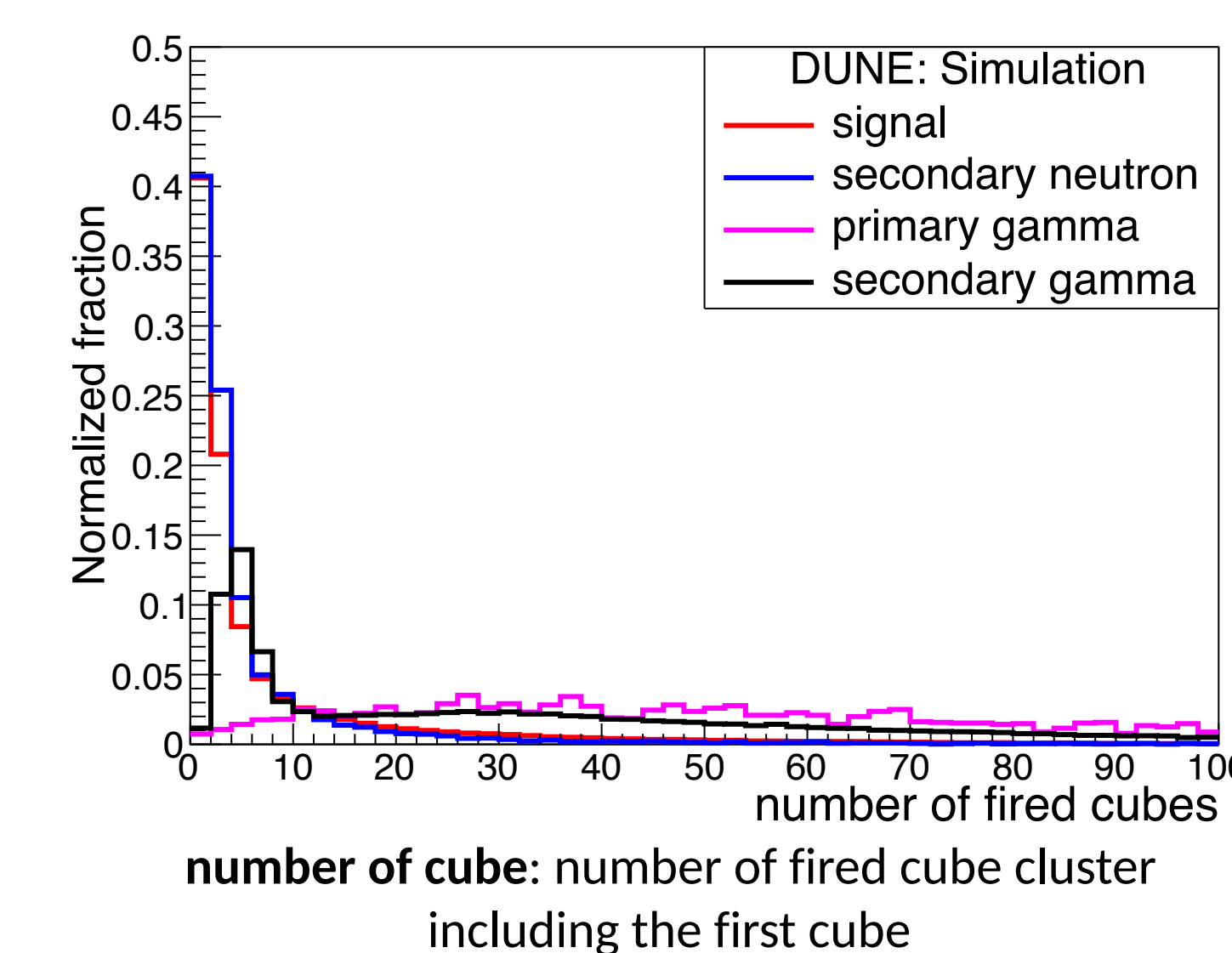
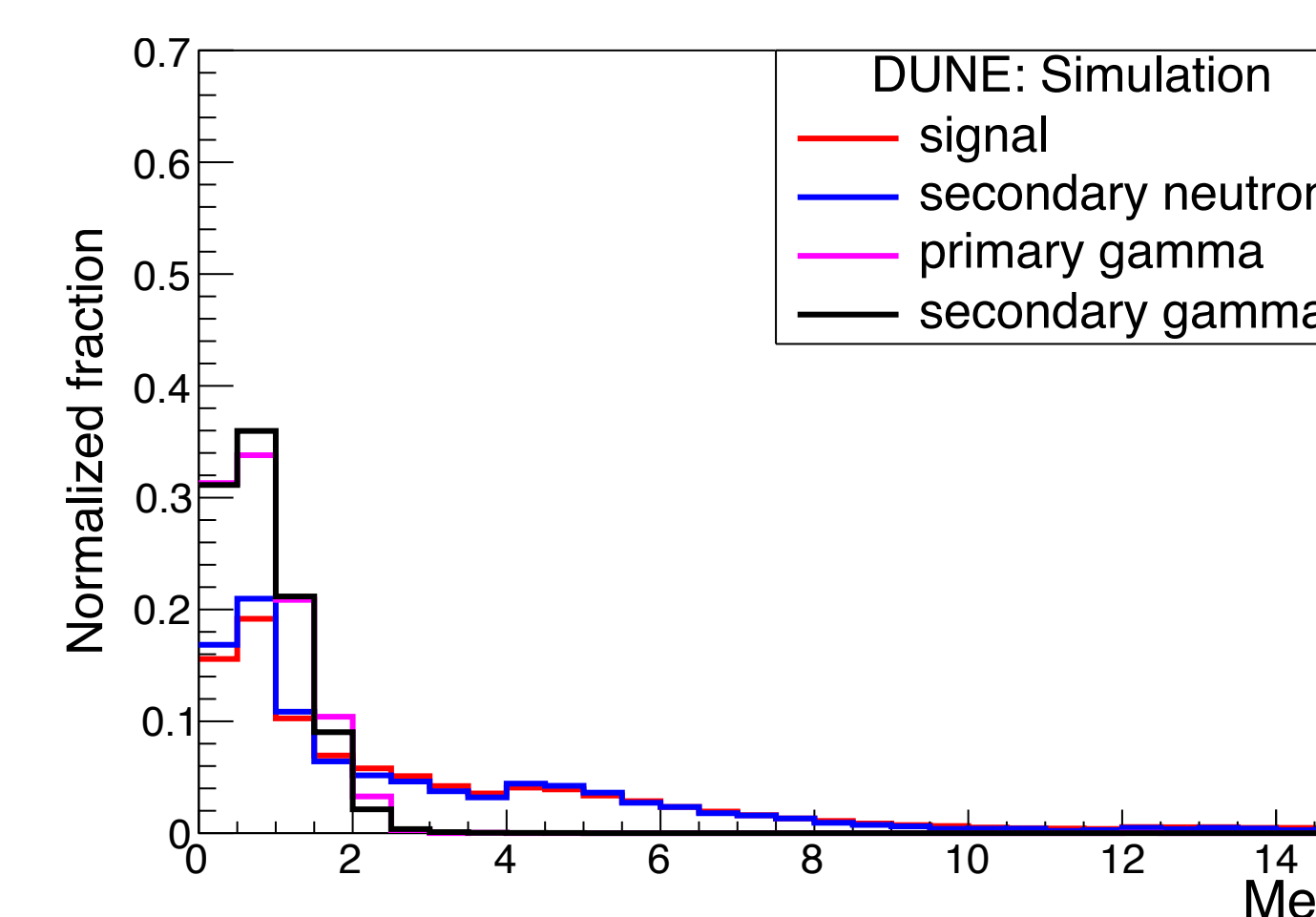
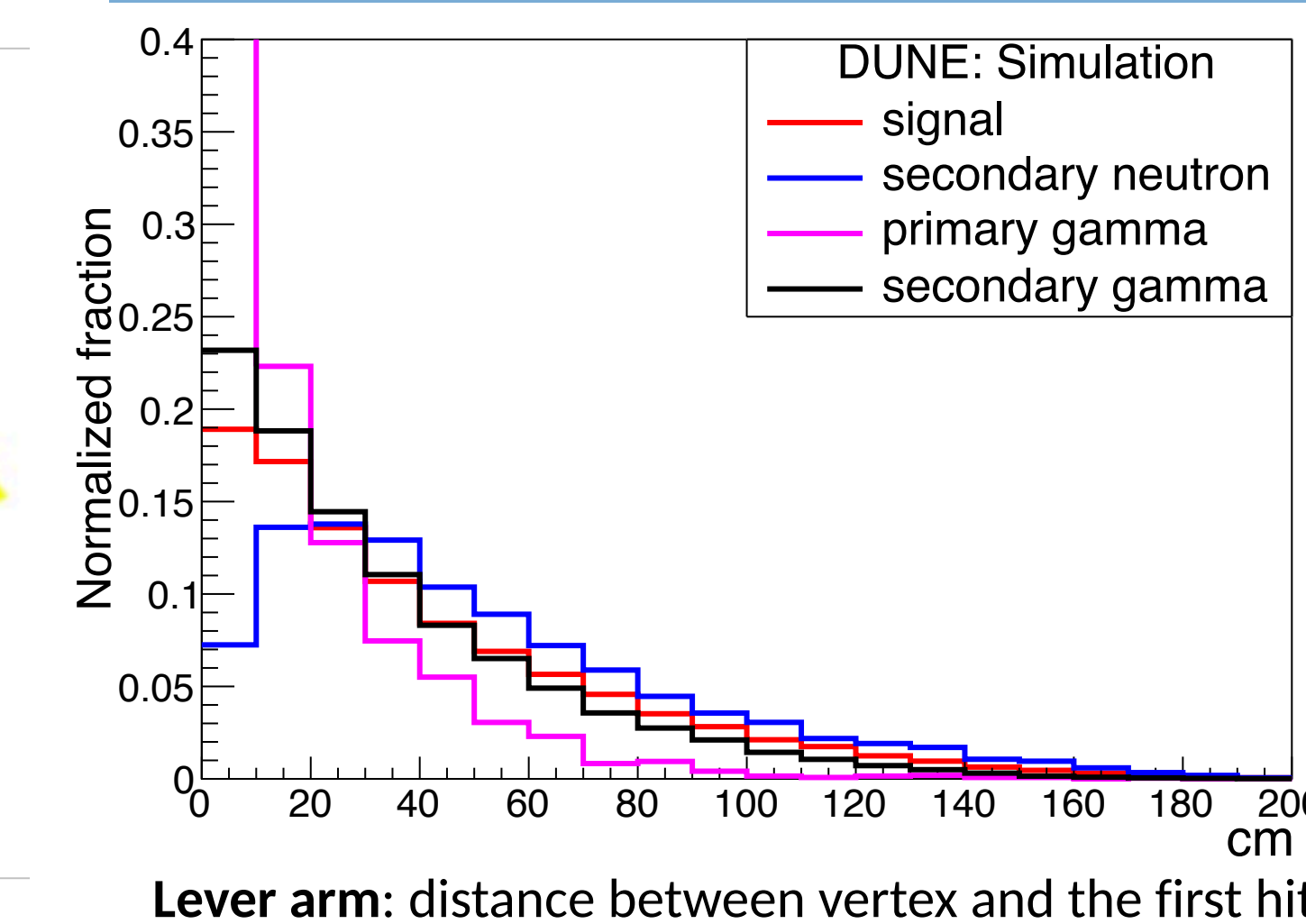


We defined 7 variables to see the features of signal and backgrounds. One example is the **angle** between two directions from the vertex to C point and from C point to the first hit

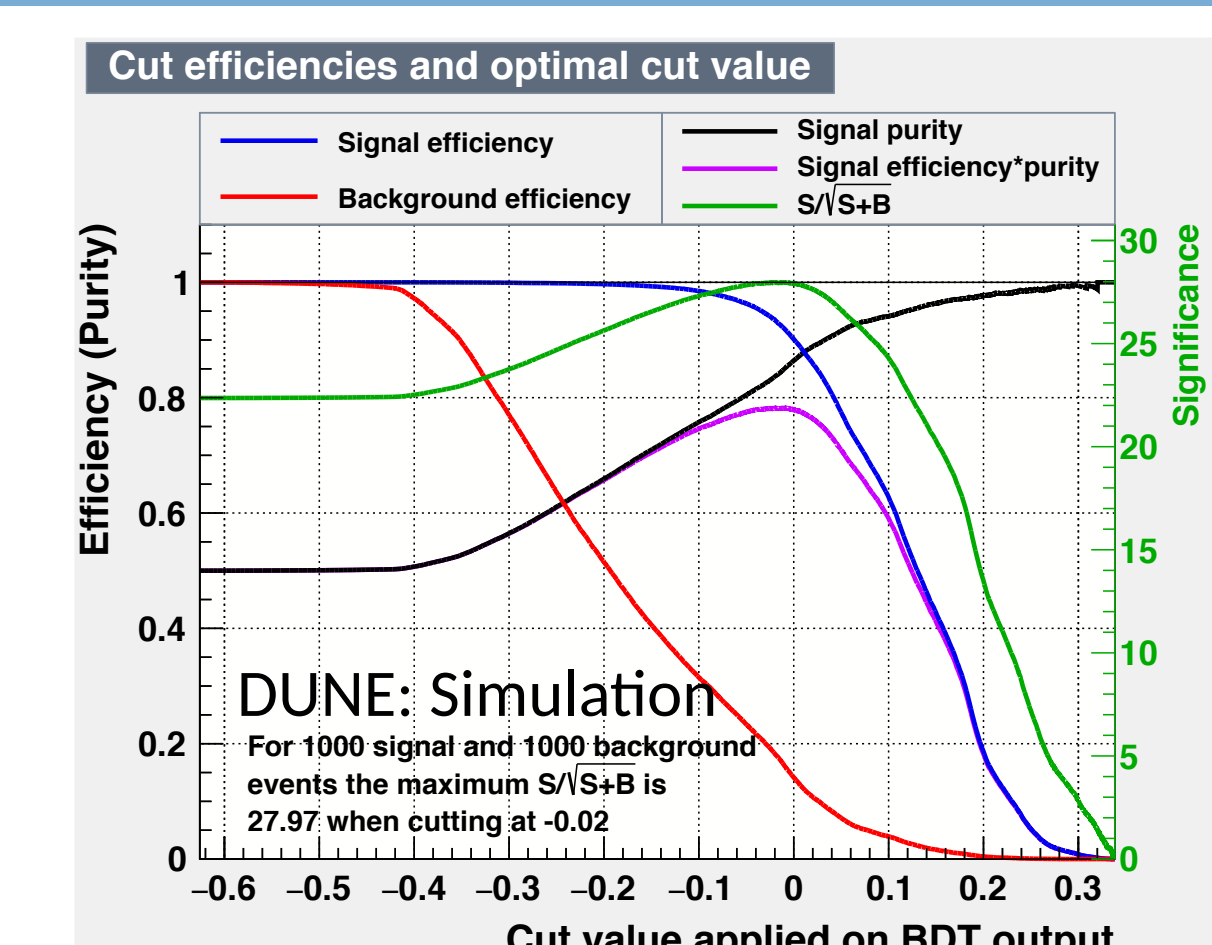
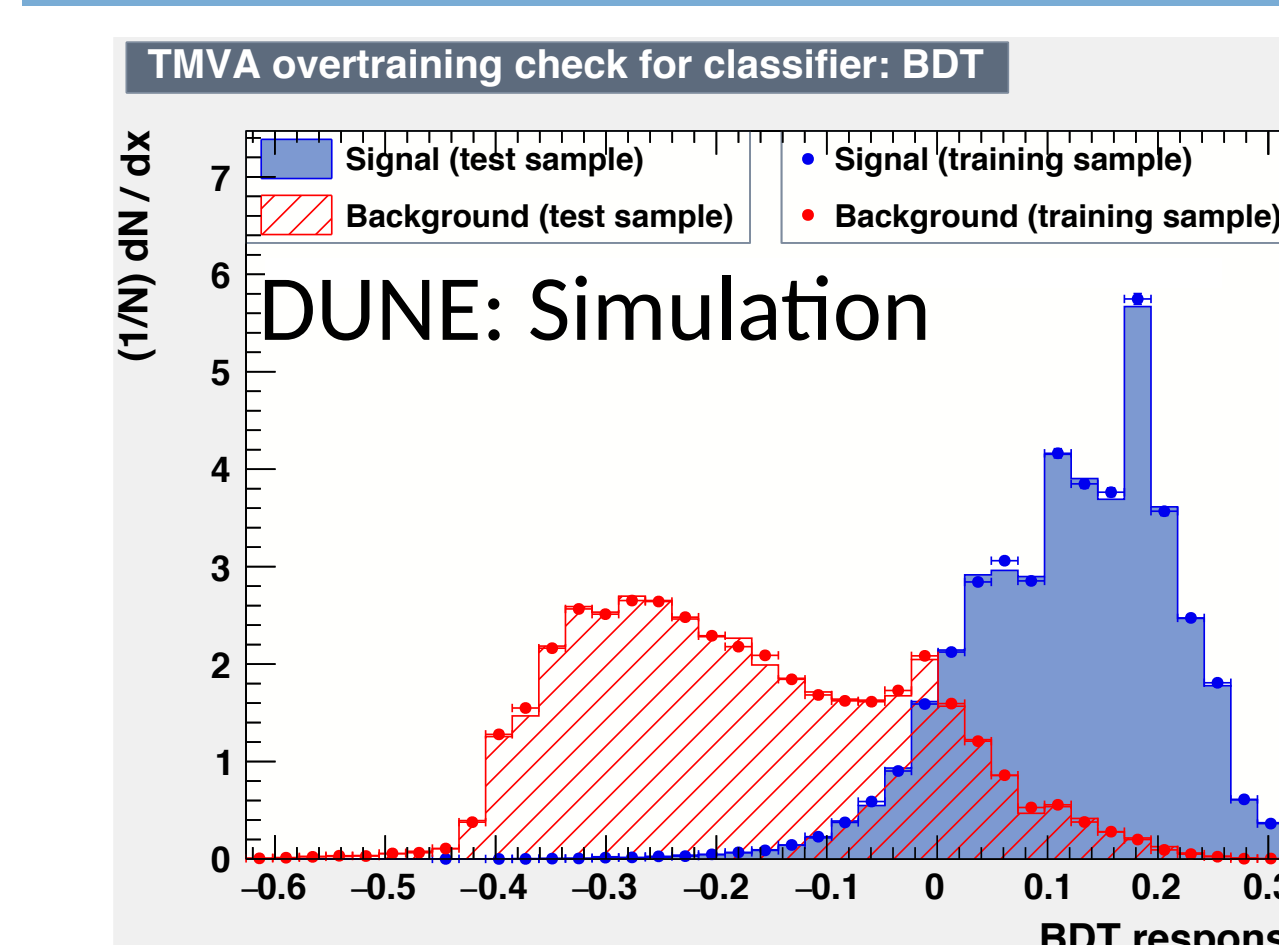


The pion tends to go further than primary neutron, the angle of the primary neutron tends to be big, while secondary neutron is correlated to the C point and tends to go to the same direction with the pion direction therefore the angle tends to be small.

Separation variables



BDT result & conclusion



BDT result of combined case (CC1pi0P + CC0pi1P + CC0pi0P)

	CC1pi0P	CC0pi1P	CC0pi0P
purity	95%	95%	95%
efficiency	70%	80%	65%

This study shows that 3DST can effectively reject the out-of-fiducial volume background, secondary neutron and gamma backgrounds. A pure enough sample can be obtained for further study.