Neutron Detection Background in 3DST

Guang Yang
SAND bi-weekly Jan 21 2020

Introduction

- Two kinds of background (bkg) considered:

  - out-fv bkg → uncorrelated to beam

  - secondary bkg → correlated to beam

- Not considered: correlated gamma bkg
- Default full size: 2.4 x 2.4 x 2 m^3 ; FV 2.2 x 2.2 x 1.8 m^3

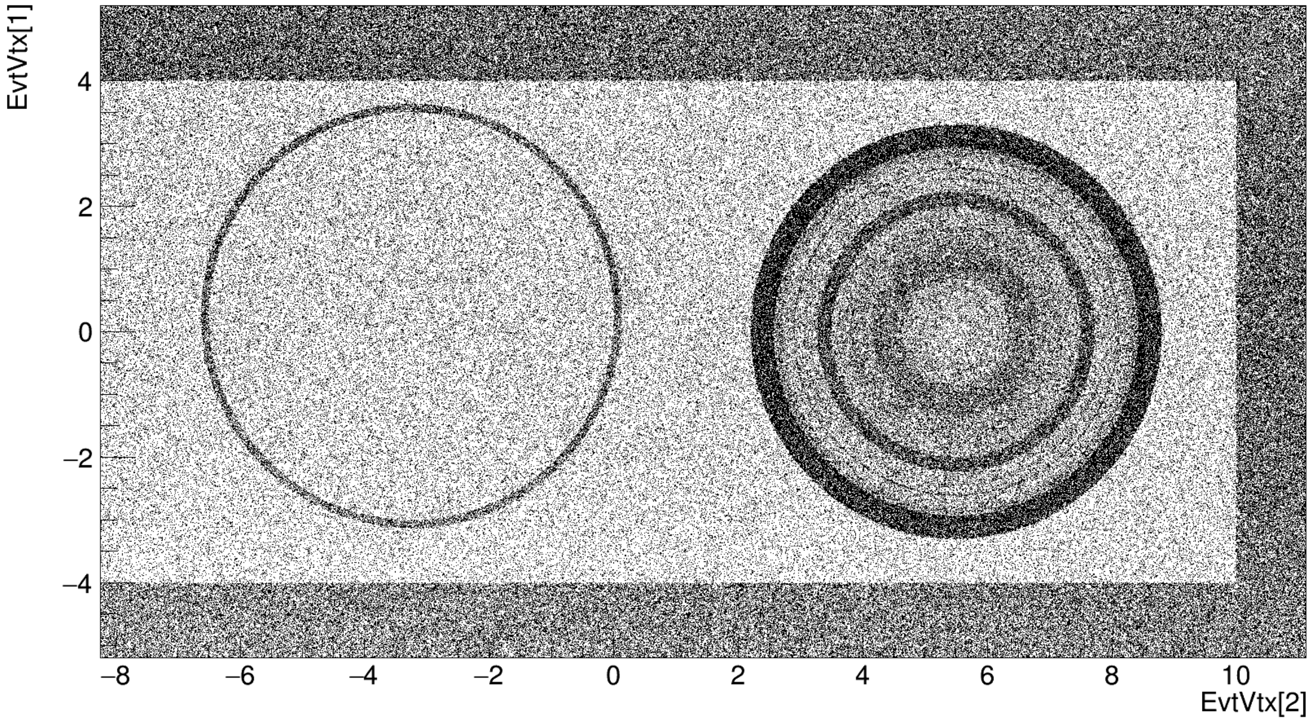
Out-fv background

- Single hit from interactions outside the 3DST
- Mostly come from KLOE;
- Uncorrelated to beam;
- Accidentally above threshold, penetrate into the FV, and just in the signal time window.

Neutrino Interaction

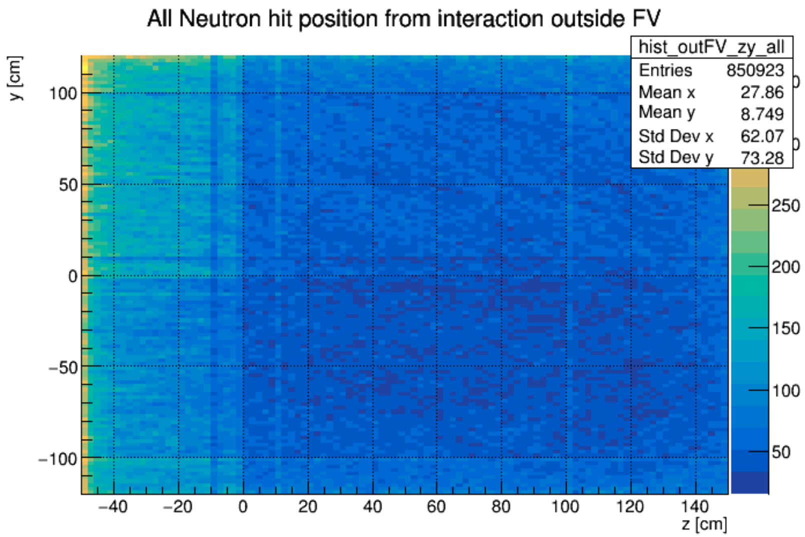
- Main out-fv contributor is KLOE (Rock and upstream stuff are not important for this contribution at all)
- Mass ratio 3DST FV : KLOE 1: 100
- Interaction : 3DST FV 0.75 per spill

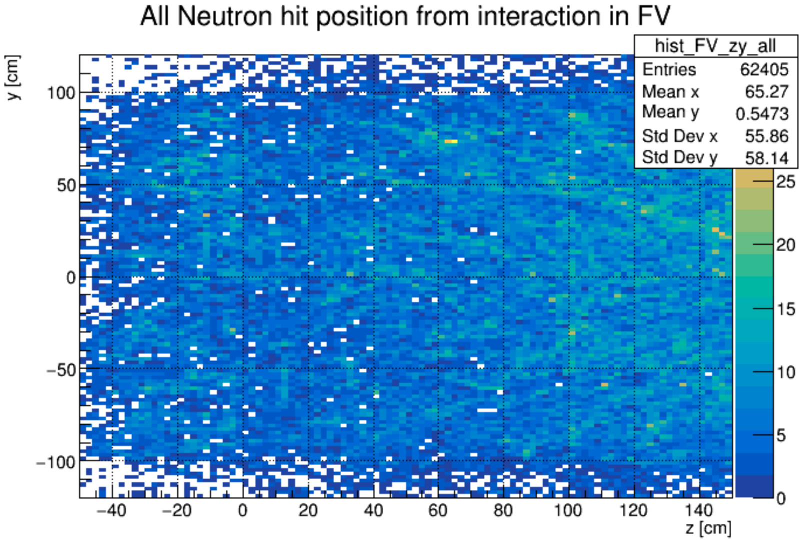
  KLOE 70.06 per spill

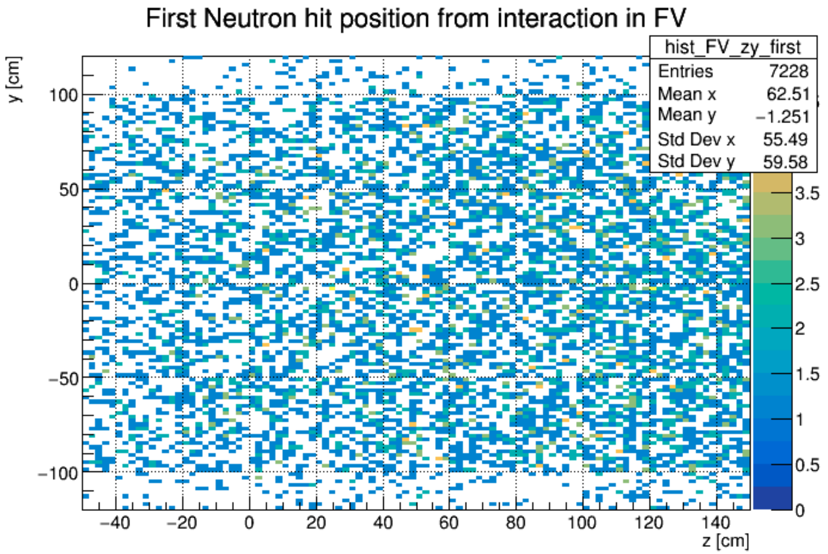


of neutron hits

Each neutron gives an average of ~10 hits

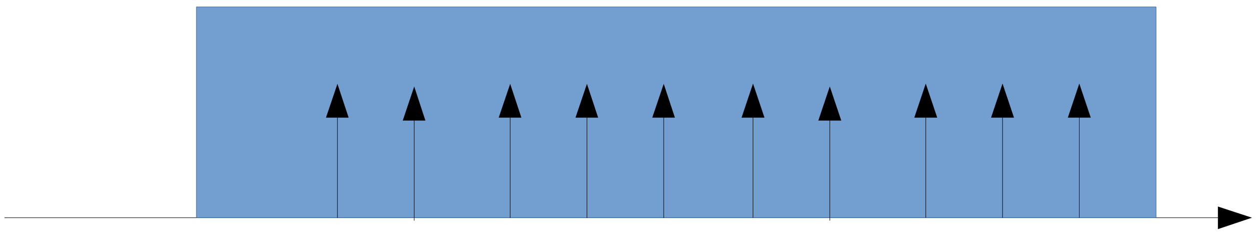


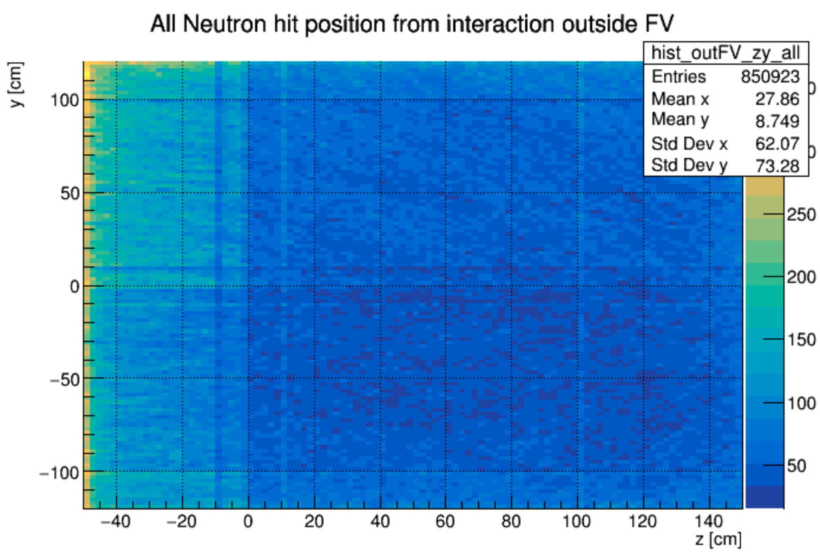




Neutron hit in time structure

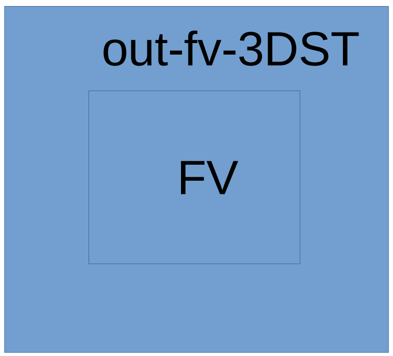
1 spill





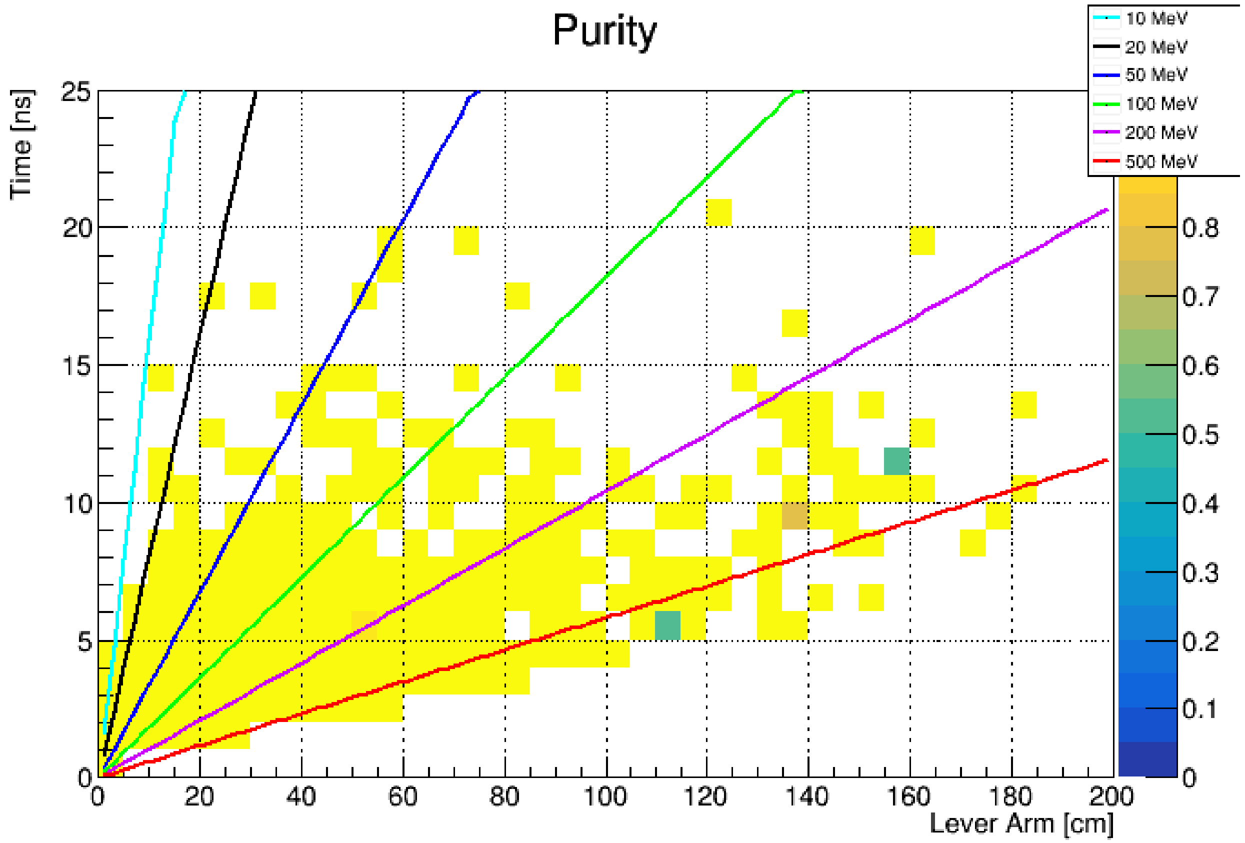
- 860k neutron hits from ~ 17k spill,
- Each 10us spill has 40 events.
- They distribute on 10 us, each 1 ns has 0.004 outfv

- Note: increasing the FV causes less outfv because of the 3DST out-of-FV volume



Purity regarding out-fv bkg

- Every signal will trigger ~3 ns (very conservative), we have bkg rate as 0.004 * 3 = 1.2%

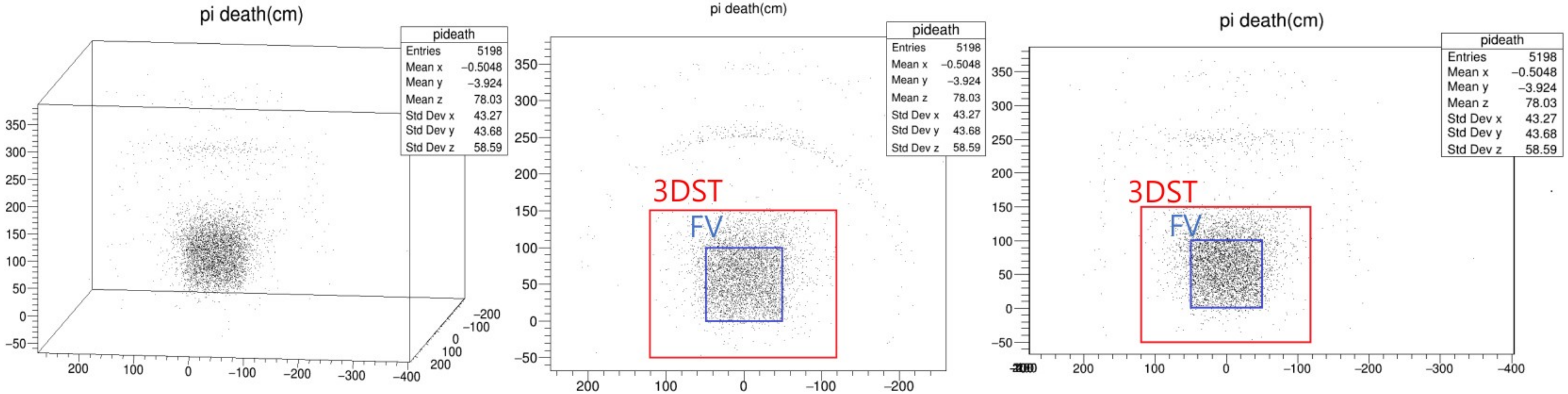


Secondary (correlated) bkg

- Secondary background means the first neutron induced hit after neutrino interaction vertex is from neutrons coming from a primary particle instead of from neutrino interaction vertex : it may bias the neutron kinetic energy reconstruction using TOF technique.
- Requiring secondary neutron induced energy deposit > 0.5 MeV also appearing first in time after vertex: 66% from charged pions, 9% from neutron, 20% from protons, 5% from others. Pions and protons are the main producers.

Charged pion end points

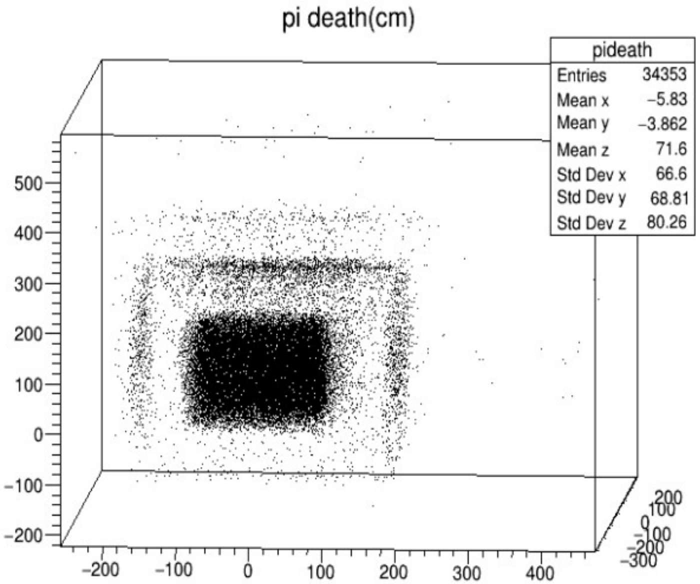
FV 1X1X1

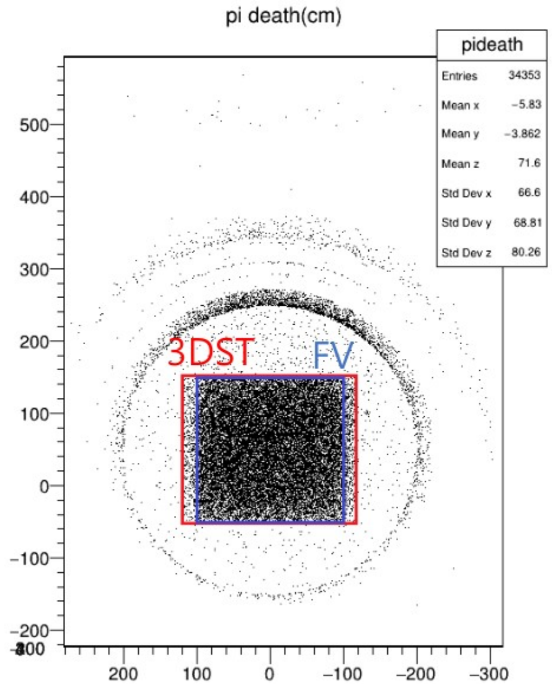


92% of pion death points is contained within 3DST
*using 100 files

Charged pion end points

FV 2X2X2

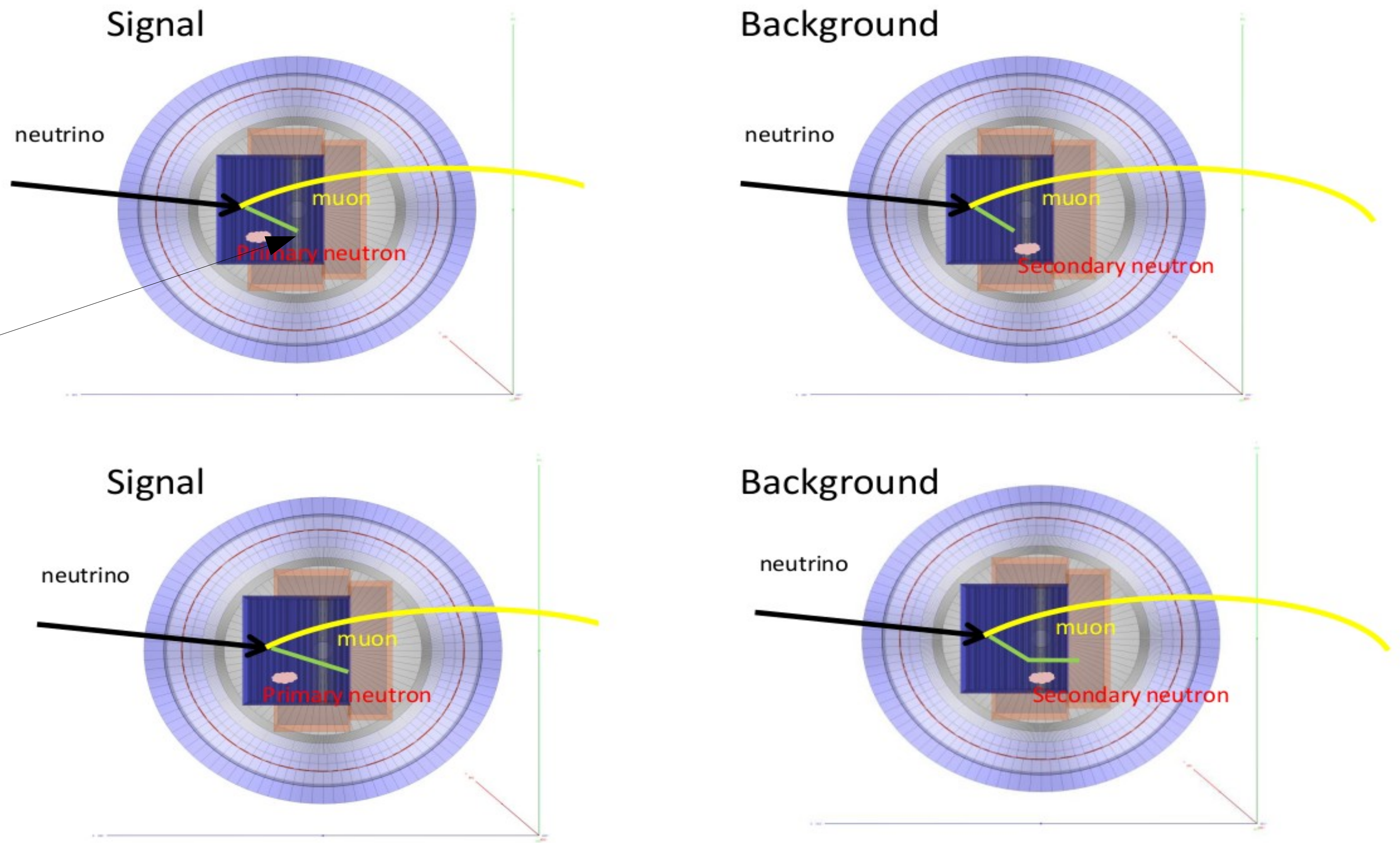




In this study, we are using 1x1x1 in order to demonstrate, 2x2x2 is a thing that we can look into later.

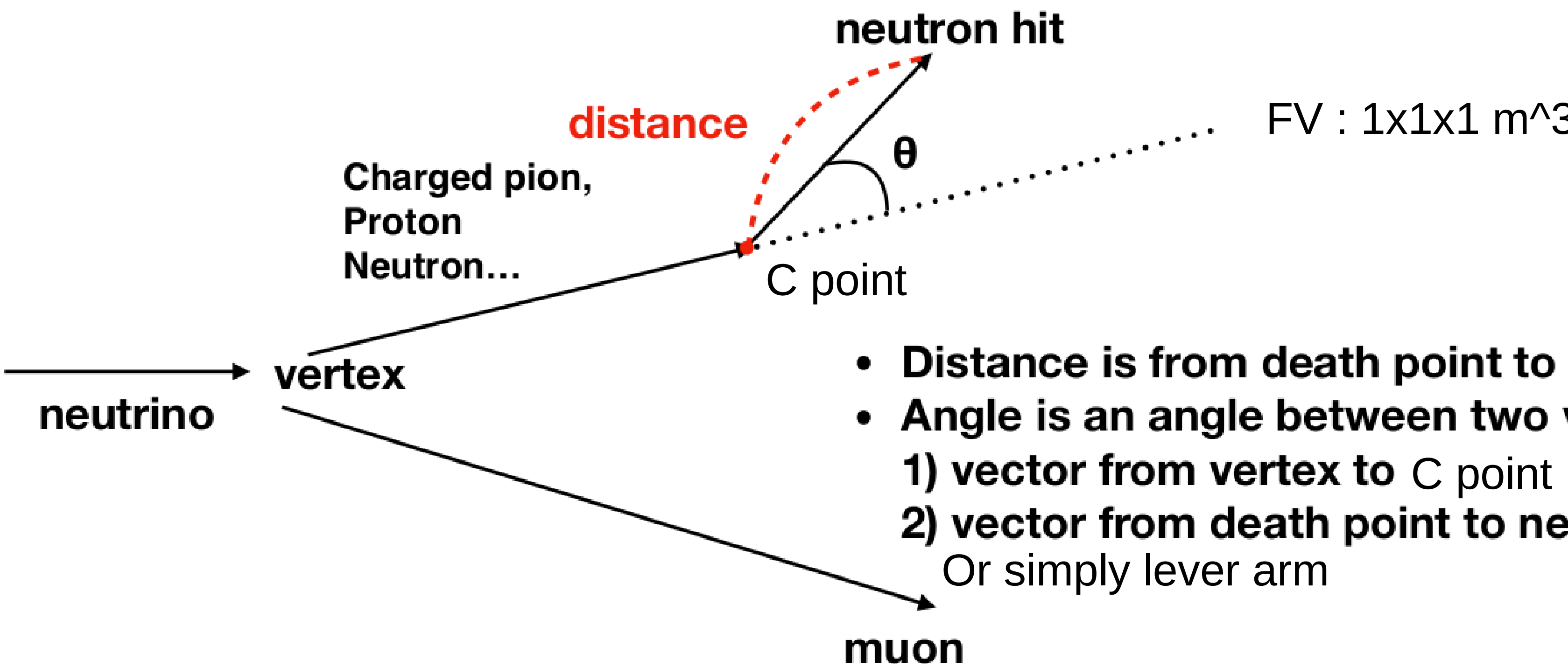
84% of pion death points is contained within 3DST
*using 100 files

Reducing secondary background



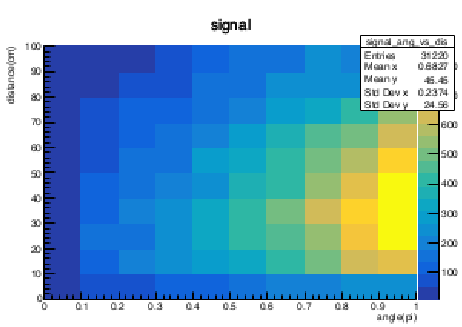
Define a “death point” (will change to “C point”)

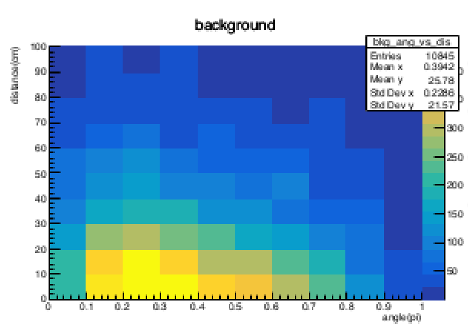
Secondary background



- **Distance is from death point to neutron hit**
- **Angle is an angle between two vector.**
  1) vector from vertex to C point
  2) vector from death point to neutron point
  Or simply lever arm

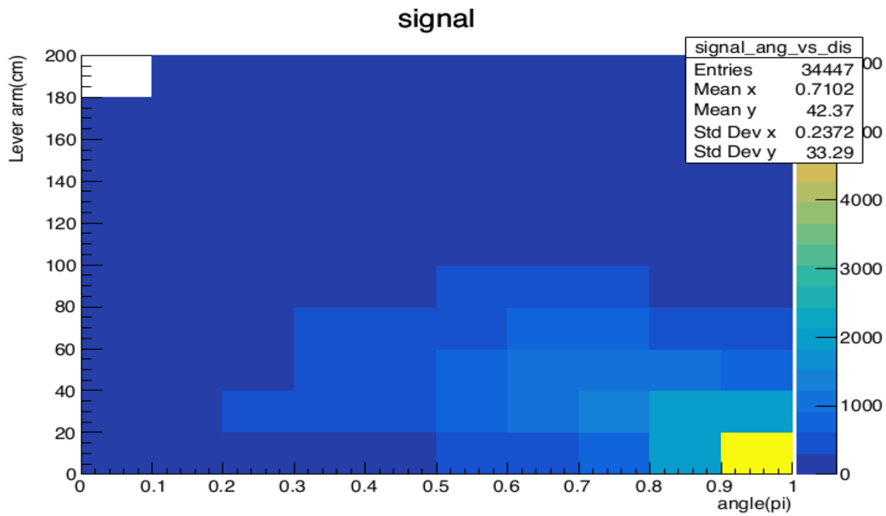
We can get secondary background(which comes from death point) and signal distribution in phase space distance vs angle.

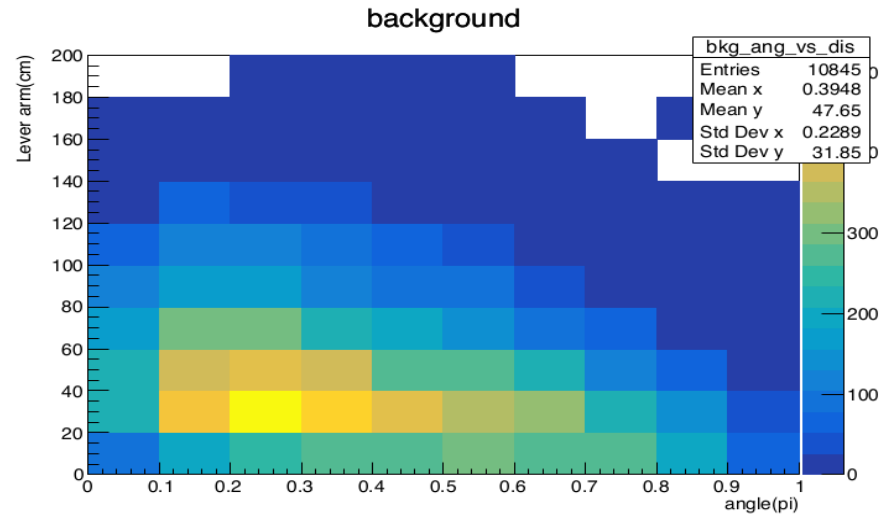




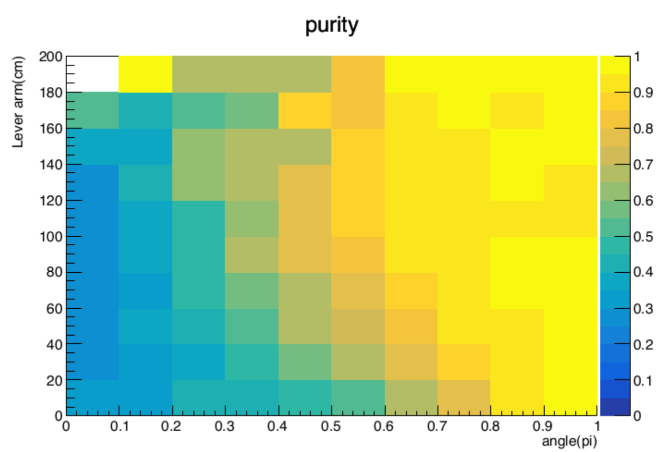
For exiting pions,
Exiting point = C point
Both of them are observables

cc 1 charged pion , 0 proton





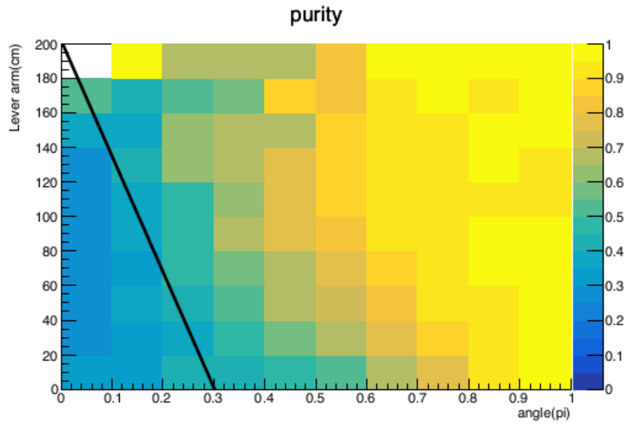
The secondary background which comes from death point is almost around death point.
But the signal is broader than background. So the purity gets better when distance, angle cut get bigger.

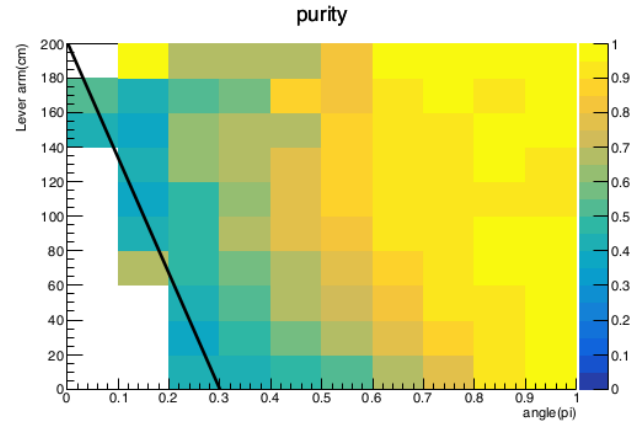


So we can choose area where purity is good(upper right region).

Cut optimization for 1pi0p

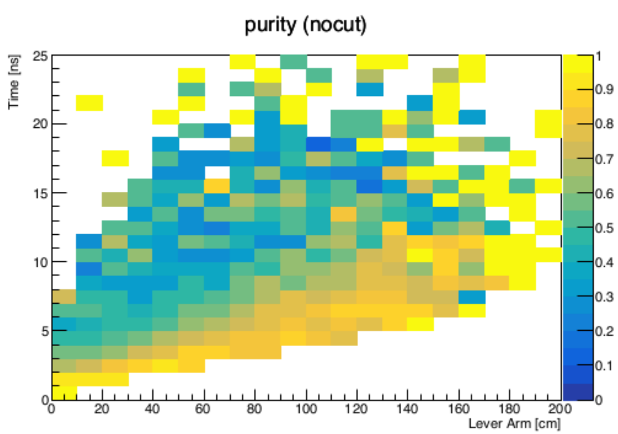
- Example metric here: purity * efficiency
- In real measurement, we may just need pure sample

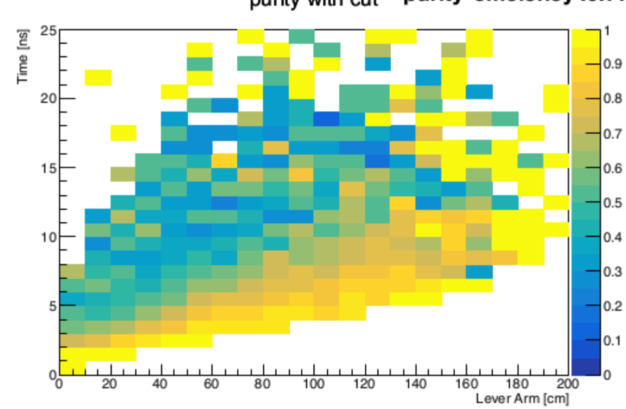




optimized cut: Lever arm+666*angle-200 > 0

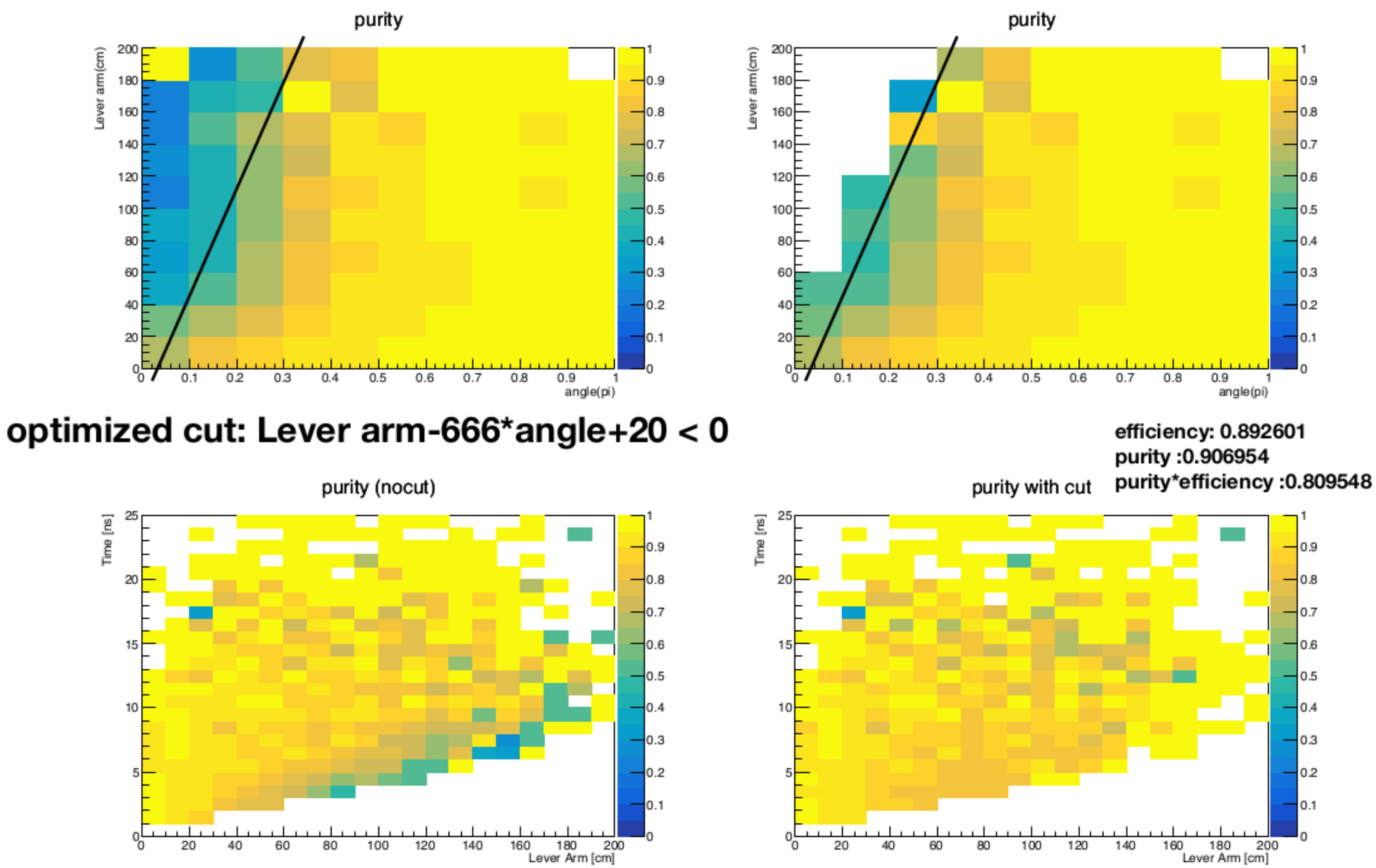
efficiency: 0.957877
purity :0.806650
purity*efficiency :0.772671





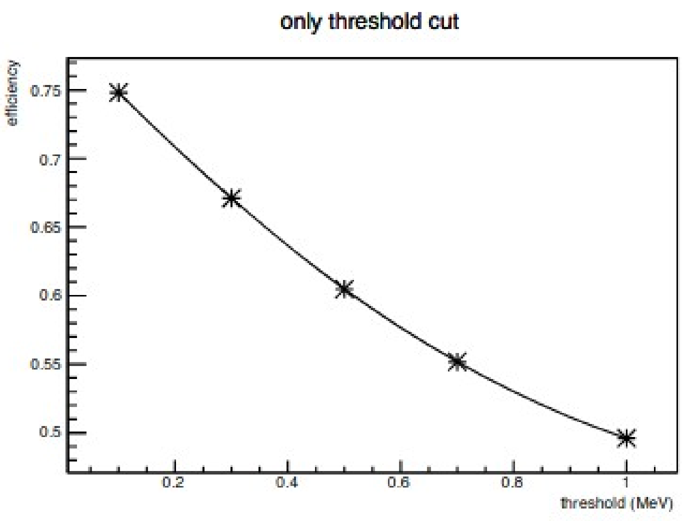
Cut optimization for 0pi1p

- Example metric here: purity * efficiency
- In real measurement, we may just need pure sample



Overall efficiency

- The inefficiency mainly comes from threshold and secondary background cut: 60% and 20%(for 1 pi sample)



	cc1pi0p	cc0pi1p
efficiency	0.167	0.042

99% purity

	cc1pi0p	cc0pi1p
efficiency	0.292	0.167

98% purity

	cc1pi0p	cc0pi1p
efficiency	0.403	0.434

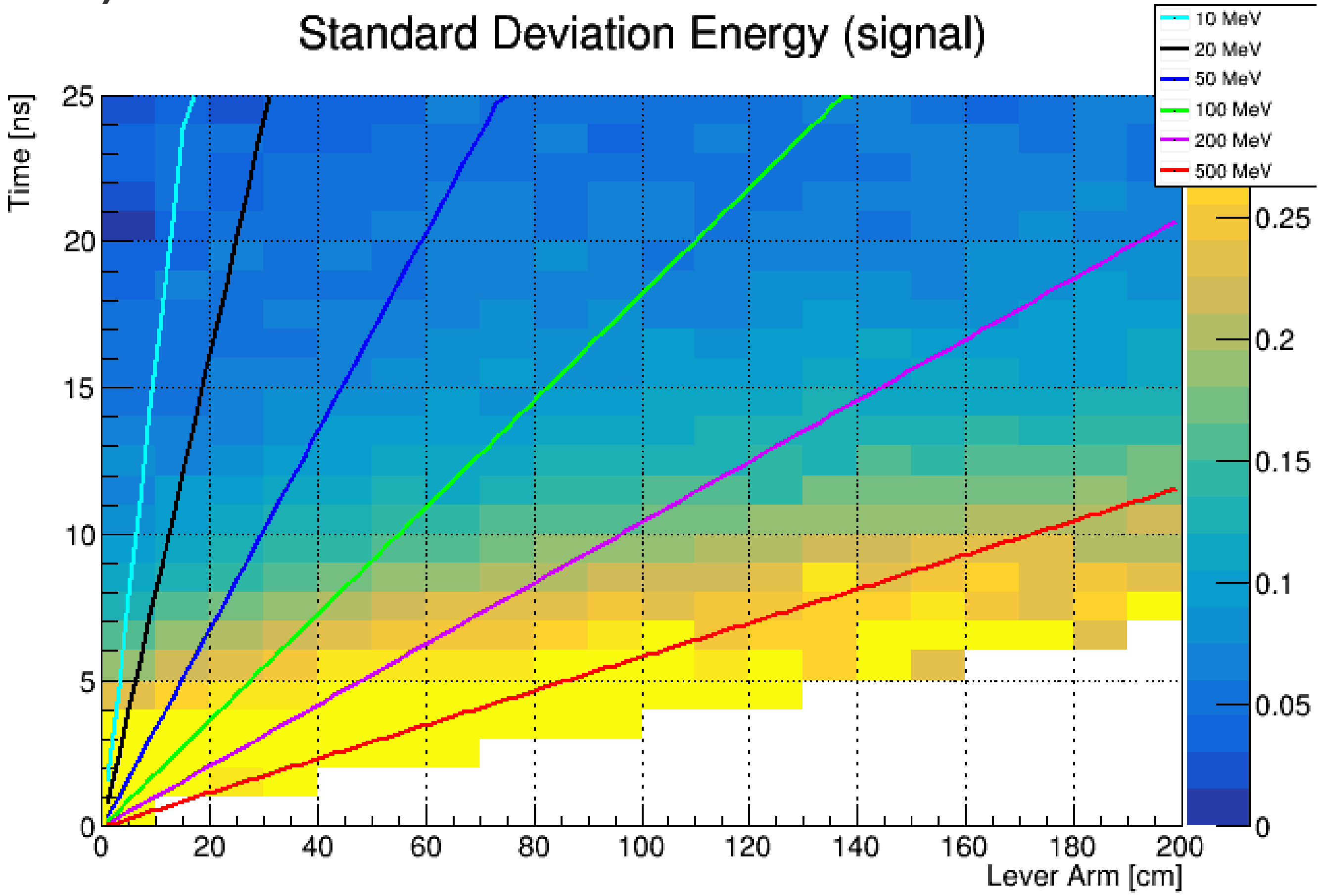
95% purity

	cc1pi0p	cc0pi1p
efficiency	0.790	0.891

90% purity

Signal KE resolution

- For each signal neutron-induced hit, reconstruction based on smeared time (PE dependent, 1 ns single fiber MIP)



Summary

- More channels for secondary backgound can be checked
- Beam correlated gamma will be added