Background contribution in the E14 experiment

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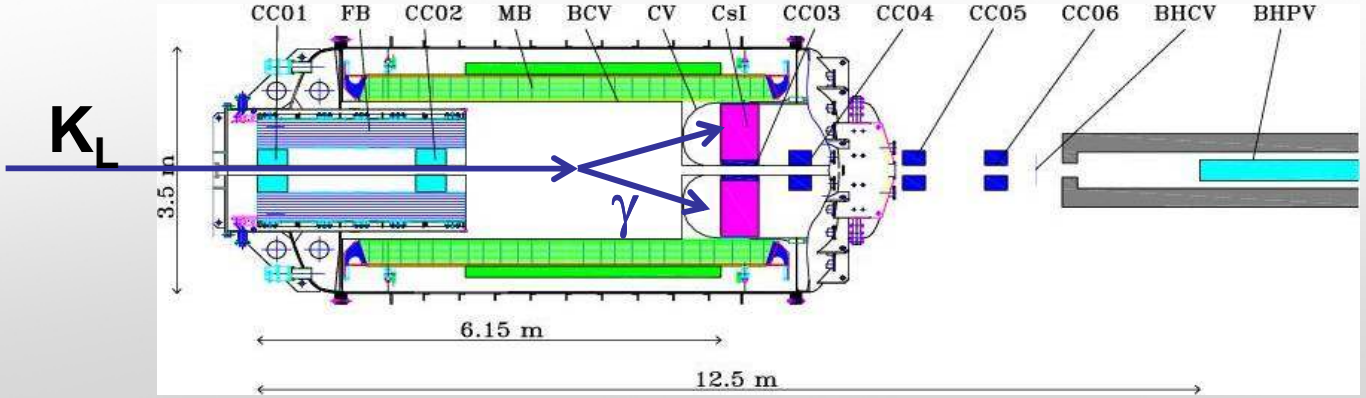
Contents

- Event reconstruction method in a experiment to search for the decay $K_L \rightarrow \pi^0 \nu\nu$(E14)
- Background events in E14 experiment
- Mechanism and feature for each background events
- summary

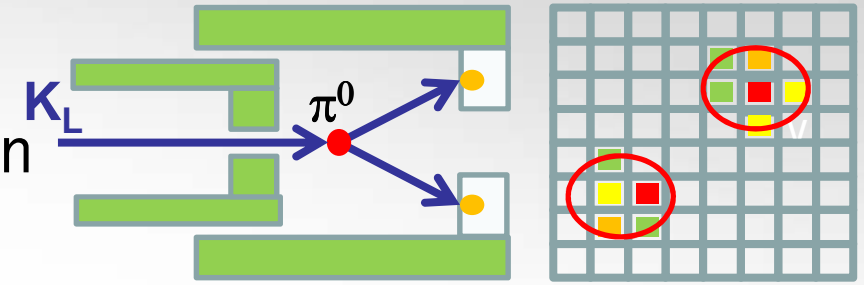
Detector of E14 experiment

- Condition for $K_L \rightarrow \pi^0 \nu\nu$ event
  - There are nothing except for 2γ from π^0
- Feature of detector and K_L beam line
  - Electromagnetic Calorimeter to detect 2γ energies and positions(CsI crystal is used)
  - Hermetic veto system
  - Very narrow K_L beam("Pencil" beam line)

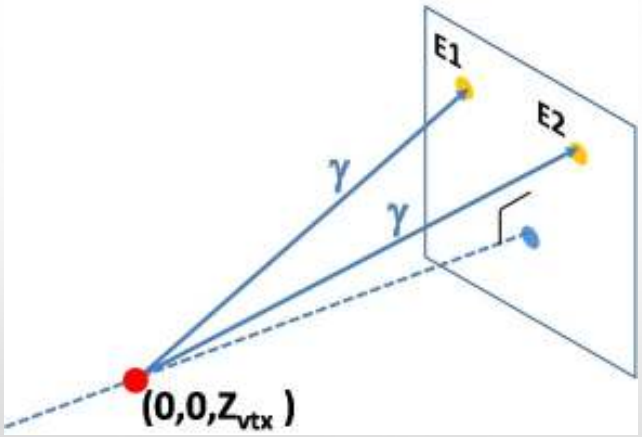


Event reconstruction

- Detect 2γ at Calorimeter
  - Measure energy and position

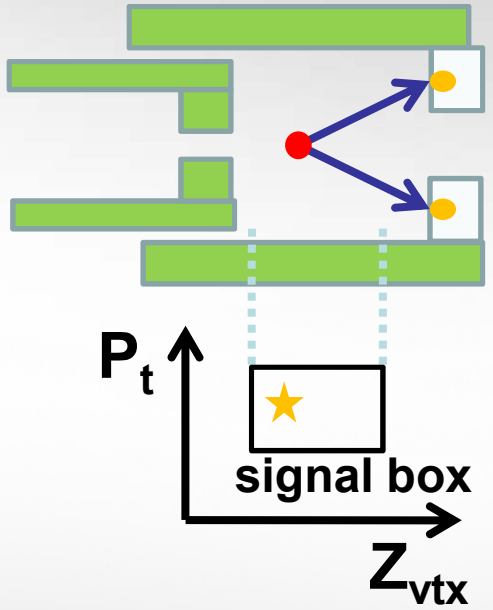


- Reconstruct $\pi^0(K_L)$ decay vertex
  - $\pi^0(K_L)$ decay vertex is assumed on the beam axis
  - $\pi^0(K_L)$ decay vertex is defined as point where invariant mass of 2γ become π^0 mass

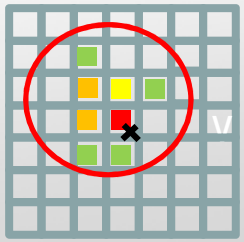


Signal identification

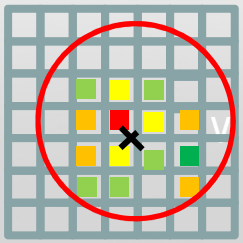
- Confirmed there is no particle except for 2 γ(veto)
- Kinematical cut to identify signal events
  - Require missing Pt
    - Effective to $K_L \rightarrow \pi^+\pi^-\pi^0$ BG (P_t<133MeV)
  - Require vertex in the fiducial region
    - Decay point is covered with veto detector
- Cluster shape cut to identify γ cluster
  - Reject hadron cluster by neutron
  - Reject fusion cluster



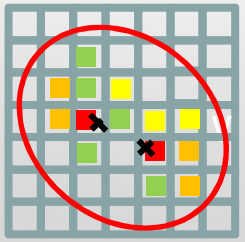
γ cluster



Hadron cluster broader to transverse→



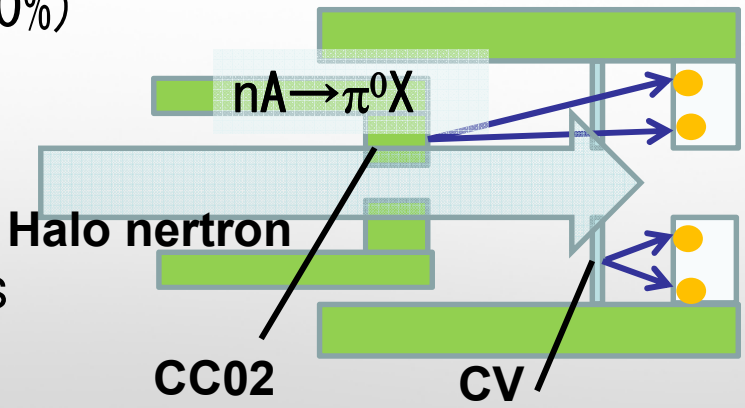
Fusion cluster take the form of an ellipse →



Background event

- Background events by K_L decay
  - $K_L \rightarrow \pi^0\pi^0$ (two photon missing)
  - $K_L \rightarrow \pi^+\pi^-\pi^0$ (two charged pion missing)
  - Other BG($K_L \rightarrow \pi^- e^+ \nu$)
- Background events by halo neutron
  - Halo neutron interact with detector and generate $\pi^0(\rightarrow 2\gamma)$, $\eta(\rightarrow 2\gamma$ 40%)
  - Mistake photon energy $\rightarrow Z_{vtx}$ enters inside signal box
  - Generated point CC02, CV -> set up near beam axis
  - CC02, CV-π^0, CV-η

	Branching ratio
$K_L \rightarrow \pi^0\pi^0$	8.7×10^{-4}
$K_L \rightarrow \pi^+\pi^-\pi^0$	0.125
$K_L \rightarrow \pi^- e^+ \nu$	0.20
$K_L \rightarrow \pi^0\nu\nu$	2.8×10^{-11}



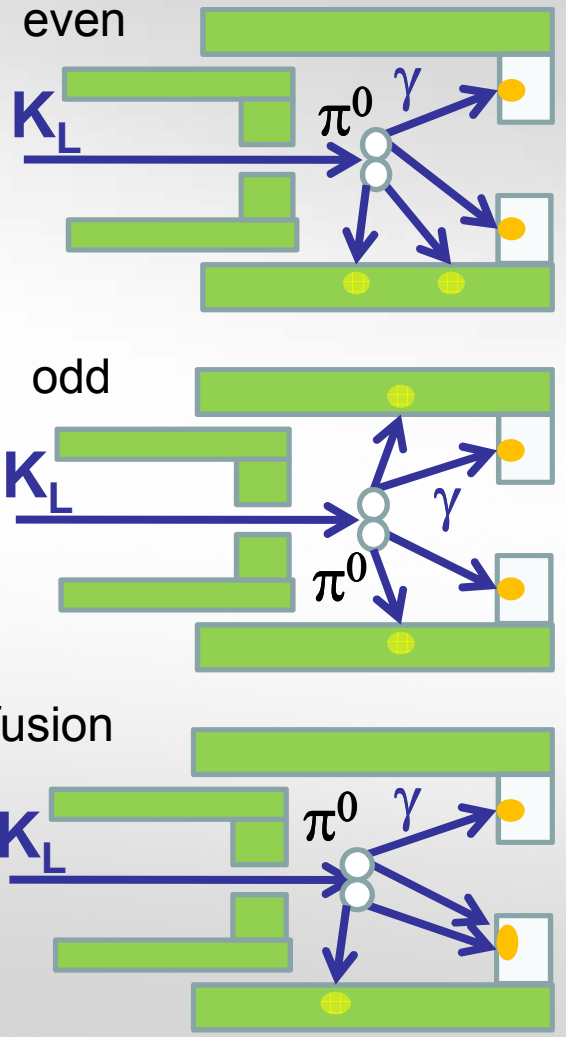
Signal / Background Summary

- 3 snowmass years

		# of event
Signal	$K_L \to \pi^0 \nu\nu$	2.7±0.05
KL BG	$K_L \to \pi^0 \pi^0$	1.7±0.1
	$K_L \to \pi^+ \pi^- \pi^0$	0.08±0.04
	$K_L \to \pi^- e^+ \nu$	0.02±0.001
Halon BG	CV-π^0	0.08
	CV-η	0.3

Classification of $K_L \rightarrow \pi^0\pi^0$ BG

- Classification into three kinds
  - even event
    - Right pairing
    - two photon from single π^0
  - odd event
    - Wrong pairing
    - Two photon from different π^0
  - fusion event
    - A fusion cluster and a γ cluster make two clusters in Calorimeter

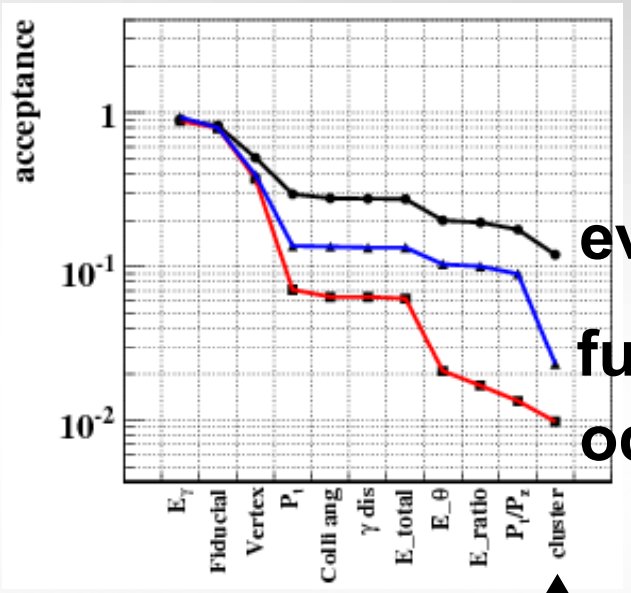


Feature of $K_L \rightarrow \pi^0\pi^0$ background

- even event
  - Right pairing
  - Z_{vtx} and P_t distribution is similar to signal
    - Kinematic cut is not effective
  - Extra photon is two -> veto is effective
- odd event
  - Wrong pairing
    - kinematic cut is effective
  - Extra photon is two -> veto is effective
- fusion event
  - Fusion cluster
    - Distort cluster shape
    - cluster shape cut is effective
  - Extra photon is one -> veto is not effective

➔ even and fusion event is afraid

X axis : name of each kinematic cut

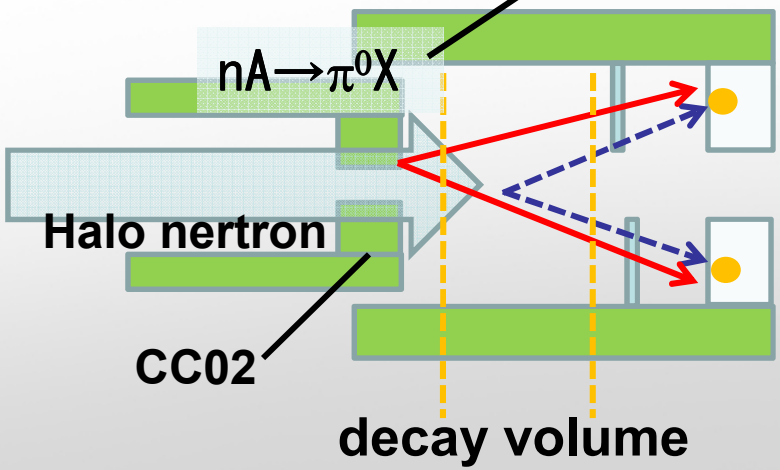


Key point for BG reduction
even event : photon inefficiency
fusion event : cluster shape cut

Mechanism of CC02 BG

- CC02 BG
  - Halo neutron is interacted in CC02 and generated π^0
  - This event has possibility to enter signal box
    - energy leakage at CSI
      - Photo nuclear effect
      - Shower leakage
    - Position resolution

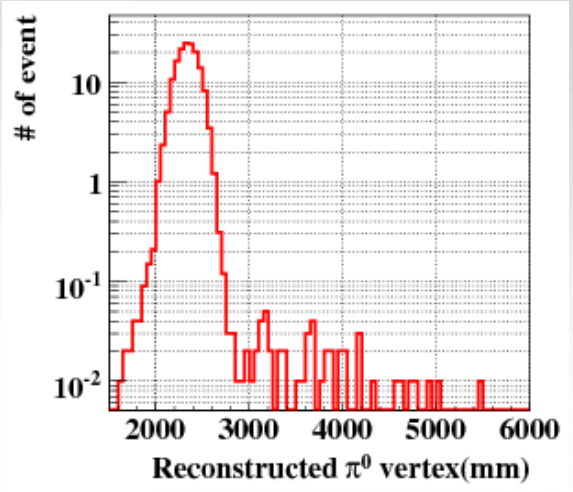
When π^0 is generated,
other secondary particles are generated
at the same time.



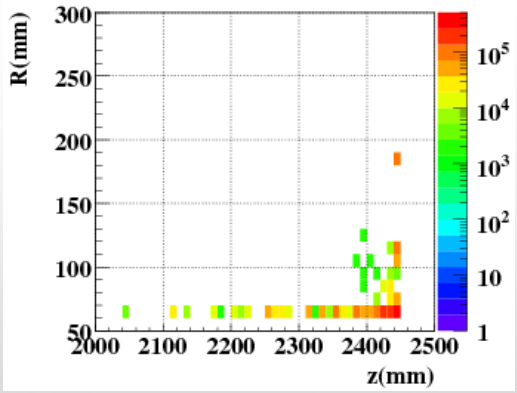
In general,
Veto is important for neutron BG

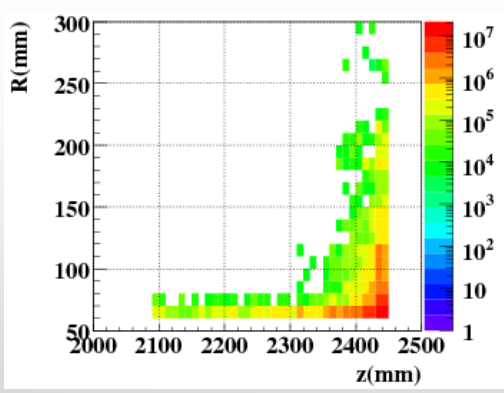
Feature of CC02 BG

- Z distribution
  - There is a peak at CC02 position (Z=2450mm)
  - There is a tail to downstream from CC02 position
- Material of CC02
  - Use material having good ratio of X_0 and λ_I ->suppress and veto γ from π^0
  - Pb+Scinti(E391a) -> CsI(E14)



Key point for BG reduction
CC02 BG : CC02 position
material of CC02



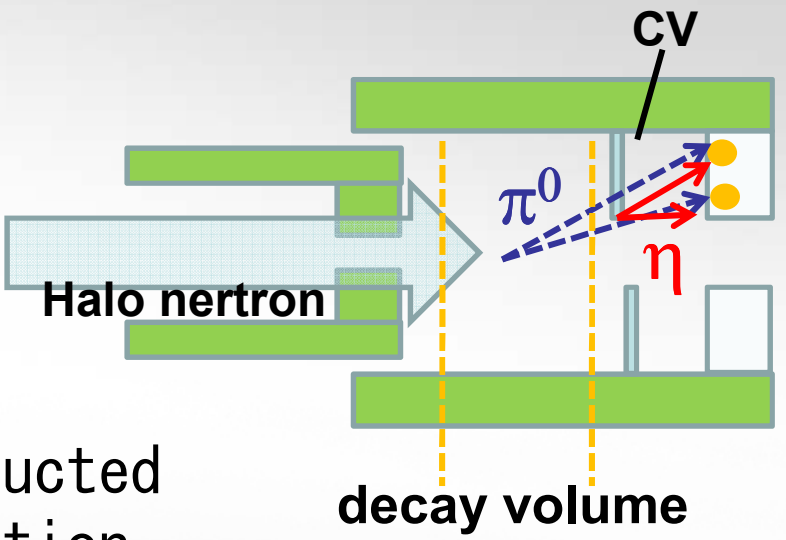


π^0 generated point@CC02
Left : CsI Right : Pb+Scinti

Mechanism for CV-h BG

- Halo neutron generated eta
  - Production point is CV
  - Br($\eta \to 2\gamma$) = 0.4
  - $M_\eta \fallingdotseq 4 \times M_\pi$
  - Vertex position is reconstructed at upstream from decay position

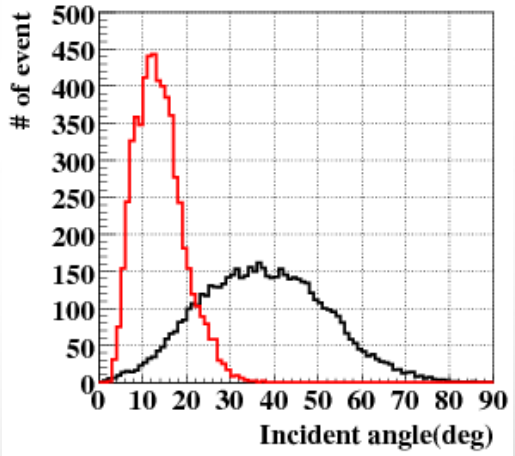
  $\to$ these events have possibility to enter signal box



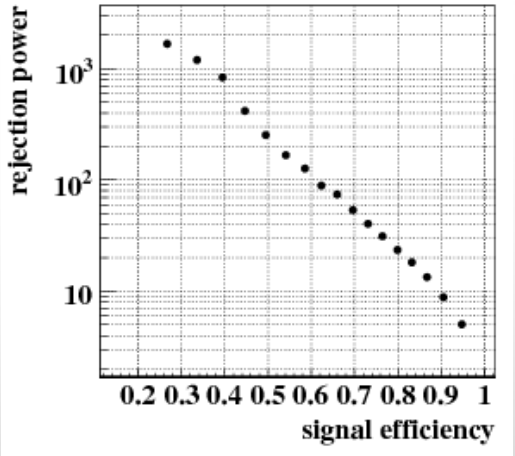
Feature of CV-η BG

- Z_{vtx} and P_t distribution
  - η BG is distributed widely inside the signal box
- Incident angle distribution
  - Different between signal and η BG

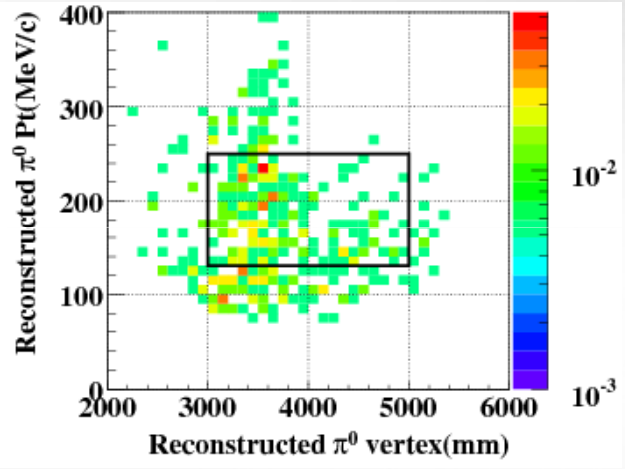
Consistency of angle and shower shape
"cluster shape cut" ➔ introduce ANN



True incident angle of signal (red) and η (black)



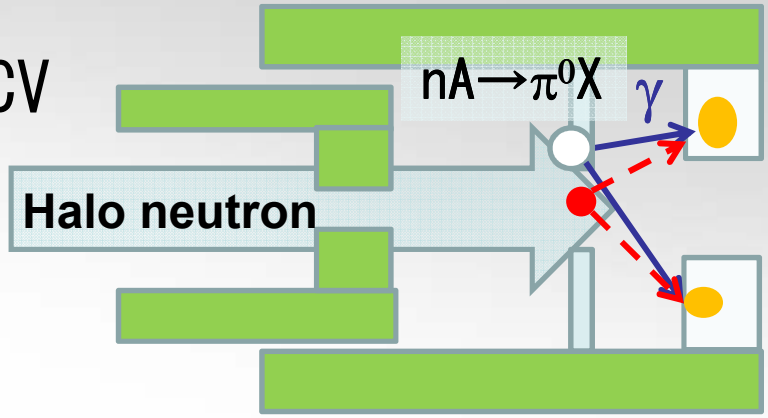
ANN : BG Rejection vs signal acceptance



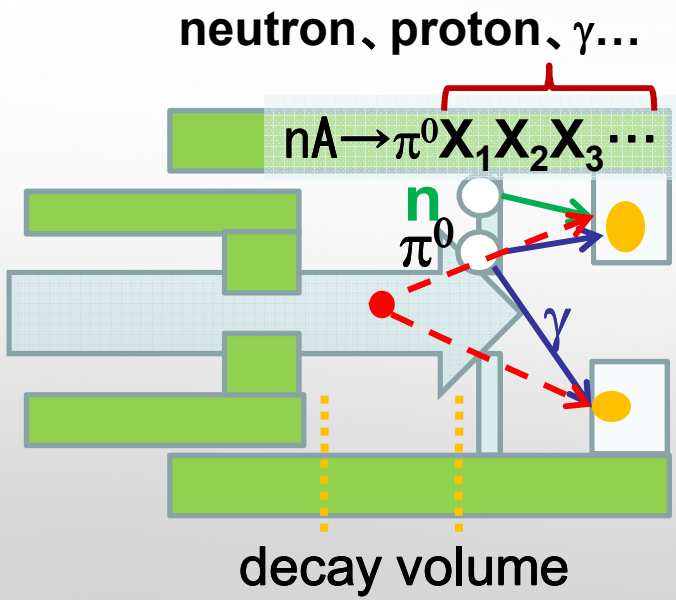
Key point for BG reduction
CV-η BG : cluster shape cut

Mechanism for CV-π^0 BG

- Halo neutron generate π^0 at CV
  - two γ from π^0 make two cluster in calorimeter
    → Z_{vtx} become CV position

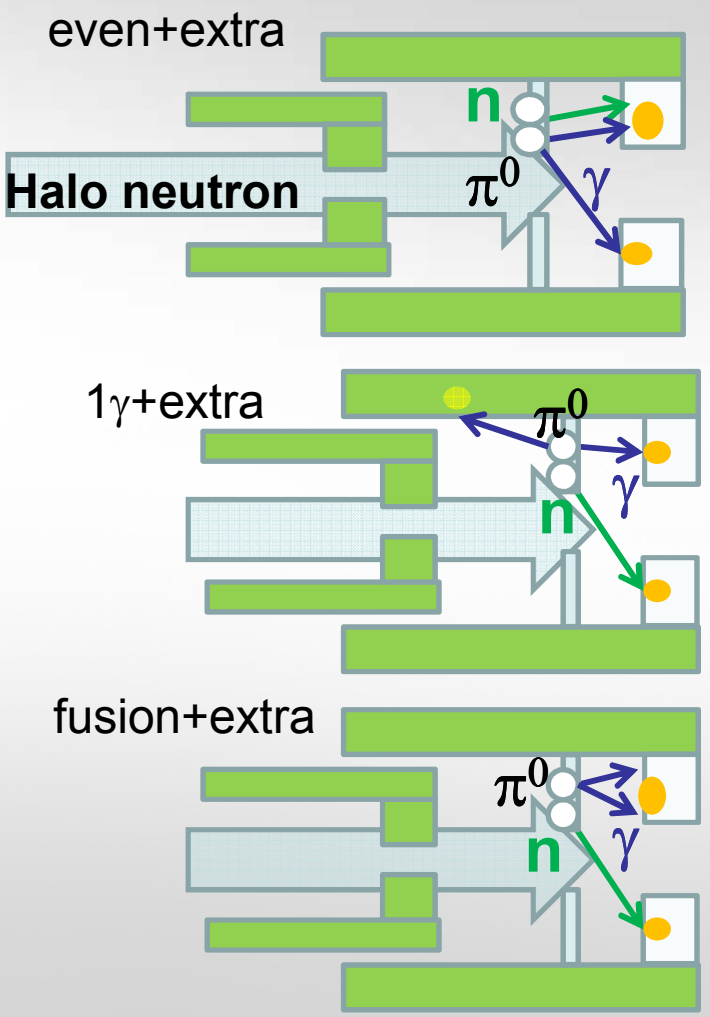


  - Fusion cluster is generated by γ and extra particle (neutron is main)
    → Energy is added to γ cluster
    → Z_{vtx} is moved to upstream from CV position



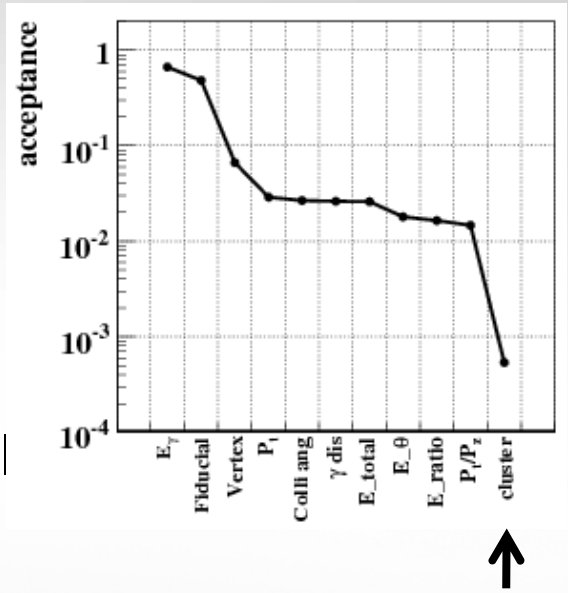
Classification of CV-π^0 BG

- Classification into three kinds
  - even+extra(neutron is main)
    - γ from π^0
    - fusion cluster by γ from π^0 and extra particle
  - 1γ+extra
    - γ from π^0
    - Hadron cluster by extra particle
  - fusion+extra
    - fusion cluster by two γ from π^0
    - Hadron cluster by extra particle

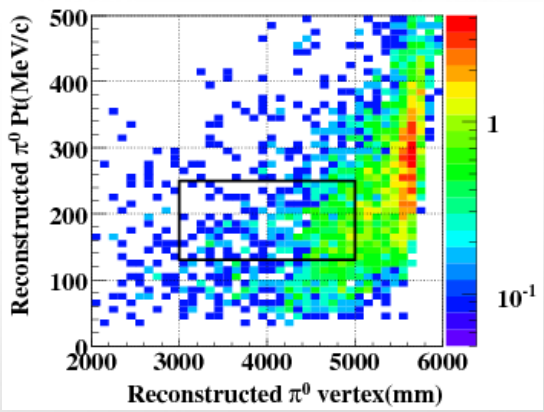


Feature of CV-π^0 background

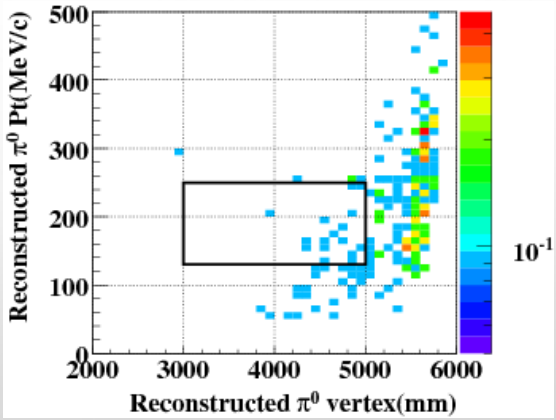
- even+extra, 1γ+extra, fusion+extra
  - All event have cause to distort cluster shape
    →cluster shape cut is effective
- Z_{vtx}-P_t distribution
  - There is a peak at CV position and a tail toward downstream from CV position



cluster shape cut



before cluster shape cut



after cluster shape cut

Key point for BG reduction
CV-π^0 BG : CV position
Cluster shape cut

Key point for BG reduction

- K Background
  - $K_L \rightarrow 2\pi^0$ even BG
    -> photon inefficiency
  - $K_L \rightarrow 2\pi^0$ fusion BG
    -> cluster shape cut
- Neutron BG
  - CCO2 BG
    -> CCO2 position, material of CCO2
  - CV-π^0 BG
    -> CV position, cluster shape cut
  - CV-η BG
    -> cluster shape cut

Summary

- Background event in E14
  - BG by K_L decay $K_L \to 2\pi^0$,
  - BG by Halo neutron CCO2, CV-π^0, CV-η
- Key Point for BG reduction
  - Veto ability
    - $K_L \to 2\pi^0$ even BG -> photon
    - Neutron BG -> secondary particle
  - Position of detector setting up near beam axis(CCO2, CV)
    - these detector is source of Neutron BG
    - These BG has tail from the detector position in Z_{vtx} distribution.
      -> these detector should be kept away from signal box
  - Cluster shape cut
    - To reject fusion cluster(γ+γ , γ+extra particle) and hadron cluster
    - To measure incident angle of γ cluster