# Using new tool to study NC $\pi^0$ BG for $\nu_e$ appearance

6/22/2006

2km meeting

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# Introduction

Motivation

- Study to see is there any possibility to reduce the NC $\pi^0$ BG by improving Polfit or making a new cut
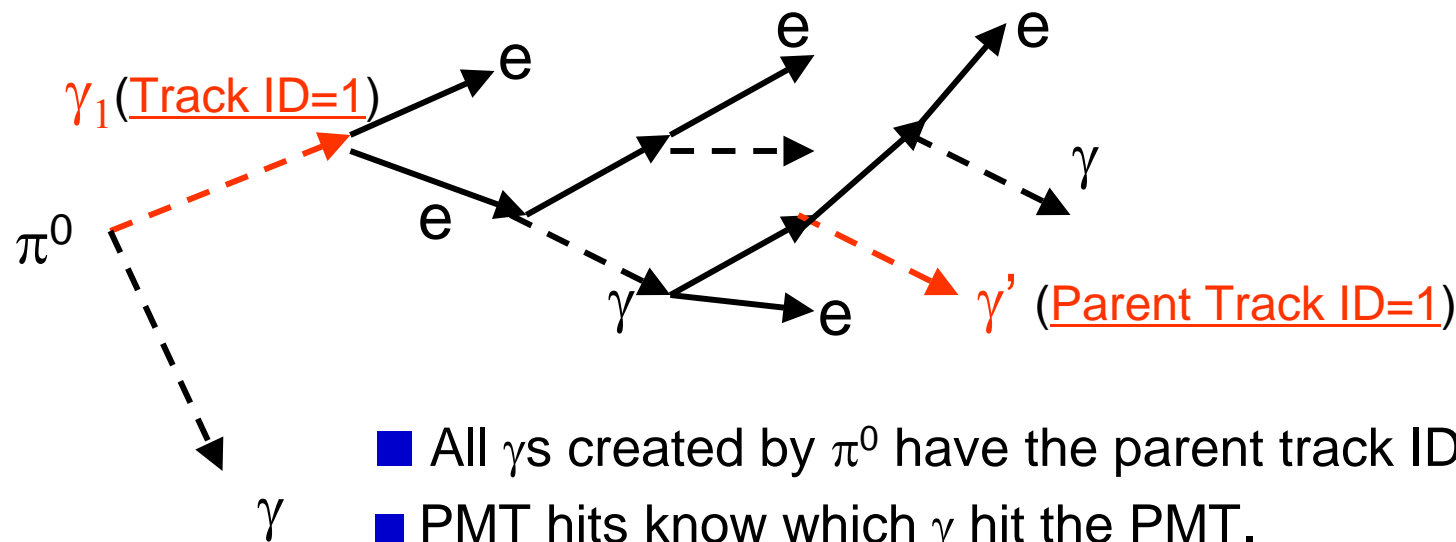
Technique

- Extensions to G4 code allow us to study more true information about $\pi^0$ events

- Because of written in G4, it is now only available at 2km

- Since 2km and SK have very similar results, also apply to SK
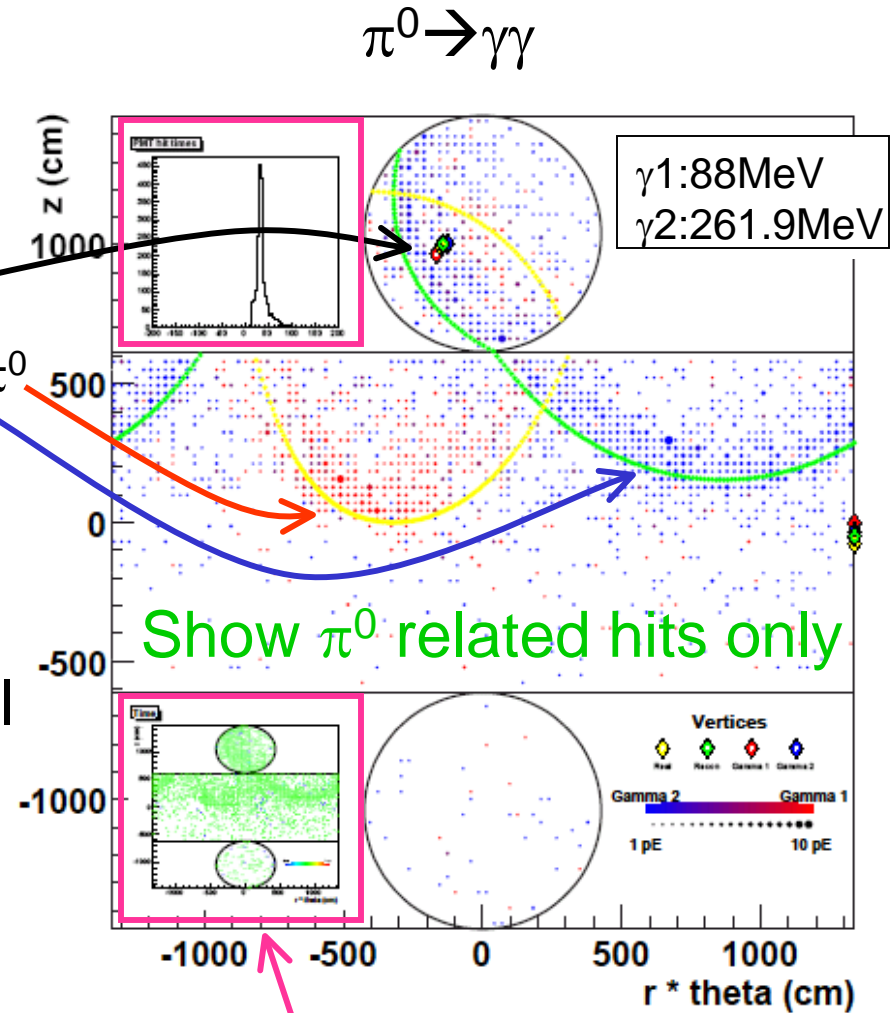
# New Tools (1) : 2km-geant4

- **These tools were developed by TJ Corona (Duke undergrad) for his senior thesis.**

- **Extension to 2km-geant4 saved extra information in the Root file.**

  - All the tracks in G4 record their original parent track ID number

    - →It is possible to determine which of the two initial decay $\gamma$'s created each Cherenkov photon that is detected by a PMT

  - Conversion point, energy of each $\gamma$, $\pi^0$ vertex saved in a bank



$\gamma_1$(Track ID=1)

$\pi^0$

e   e   e   e

$\gamma$   e   $\gamma$'   (Parent Track ID=1)

$\gamma$

- All $\gamma$s created by $\pi^0$ have the parent track ID.
- PMT hits know which $\gamma$ hit the PMT.

# New Tools (2) : 2km-rootdisplay

- Root based event display
- Shows normal information
- Also display true $\pi^0$ info
  - $\gamma$ conversion point / $\pi^0$ vertex
  - PMT color coded by original $\gamma$ of $\pi^0$
- Can access to 2km reconstructed information
- → Can read both original ZBS ntuple and G4 output in parallel

$\pi^0 \rightarrow \gamma\gamma$

$\gamma 1$:88MeV
$\gamma 2$:261.9MeV

Show $\pi^0$ related hits only

Can switch to E,Time,..

# MC event sample of NC BG events

$\nu_\mu$ MC

- Select NC with $\pi^0$ in FV
- Apply 1-ring e-like standard cuts
- Remaining $\pi^0$ misidentified as signal of $\nu_e$ appearance →87 events

| | |
|---|---:|
| No cuts | 518898 |
| NC $\pi^0$ | 52853 |
| FV | 14809 |
| Evis>100 | 9140 |
| 1 ring | 1507 |
| E-like | 1394 |
| Not $\mu$→e decay | 1389 |
| Cos$\theta$(l,$\nu$)<0.9 | 1111 |
| 0.35< rec E$\nu$ < 0.85 | 439 |
| Polfit mass | 110 |
| Polfit likelihood | 87 |

# Category of pi0 BG by eye scan

I categorized the 87 events by eye scan.

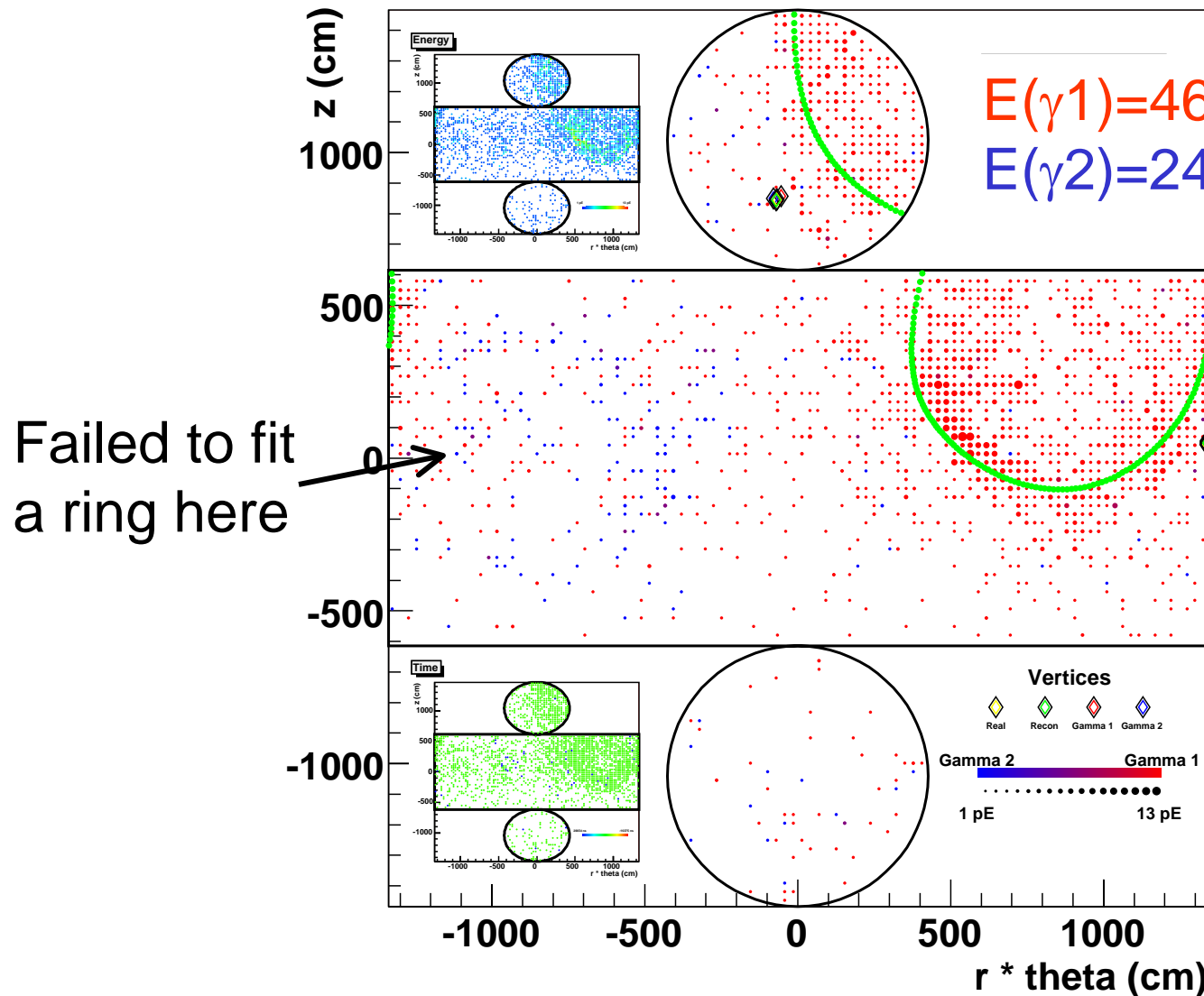| | |
|---|---|
| 1) One of E(g) is too small | 54 |
| 2) 2 rings overlap | 17 |
| 3) Reconstructed vertex is far from real vertex | 6 |
| 4) One of the conversion point of g is considerably further away from the vertex than the other conversion point | 12 |
| 5) Hard to decide between 3) or 4) | 2 |

This makes wrong ring finding

Conversion point

4)

$\gamma$

$\pi^0$

$\gamma$
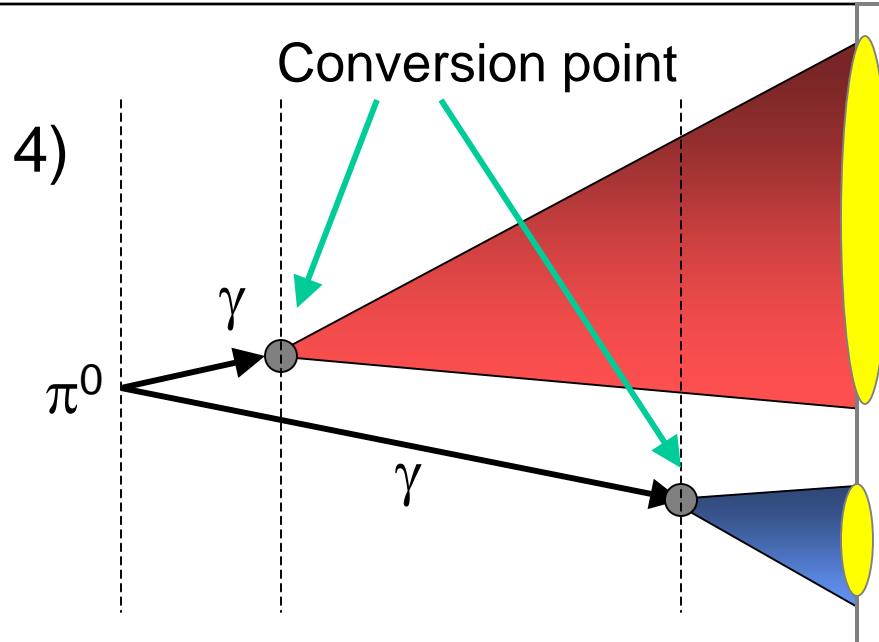
Polfit assumes conversions start at the same point for each $\gamma$ and same size of radius of cones

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# 1) One of E(γ) is too small

E(γ1)=468MeV
E(γ2)=24MeV

Failed to fit
a ring here

Basically
hard to
recover this
kind of event.

# 2) 2 rings overlap

Water Cerenkov Detector: 42 , Event # 20

$E(\gamma 1) = 203\text{MeV}$
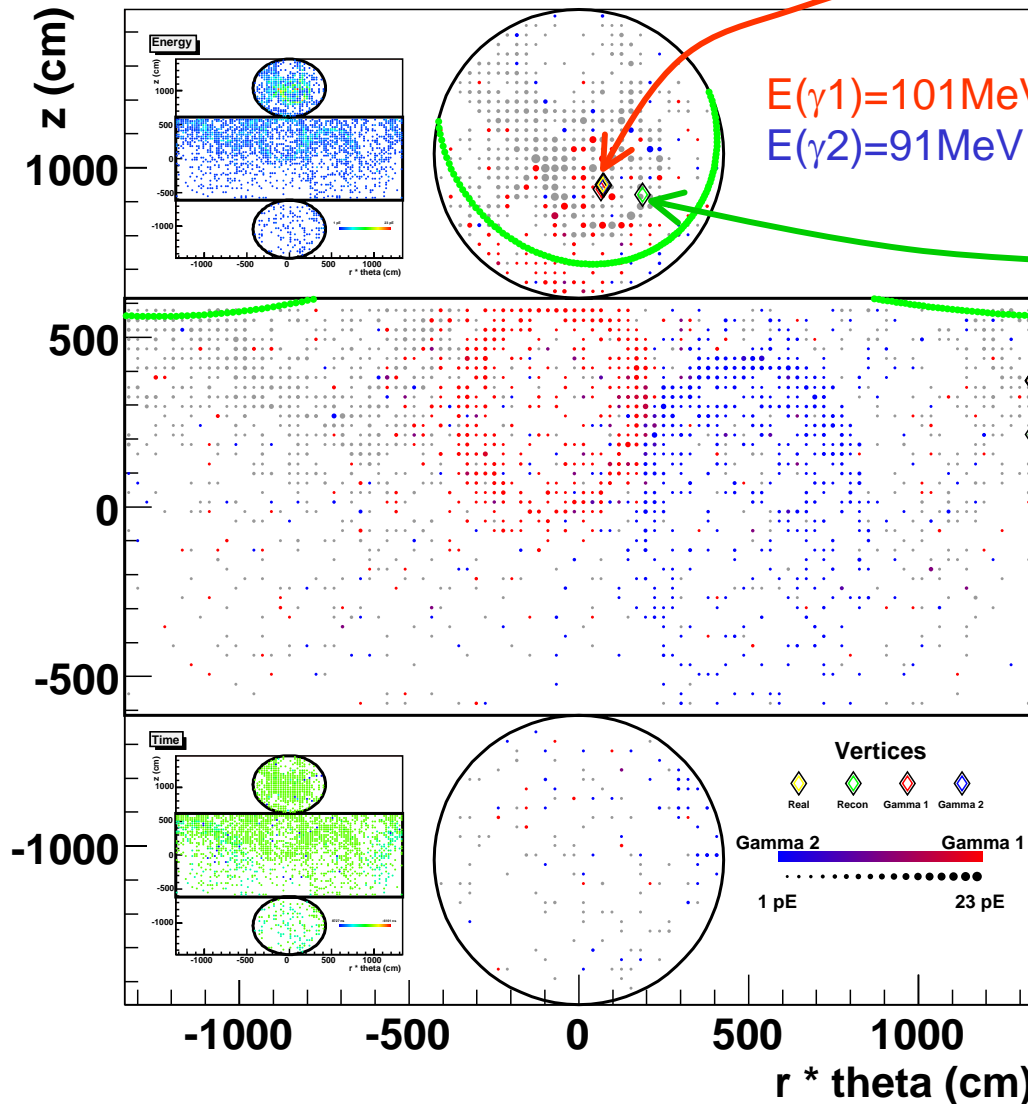
$E(\gamma 2) = 351\text{MeV}$
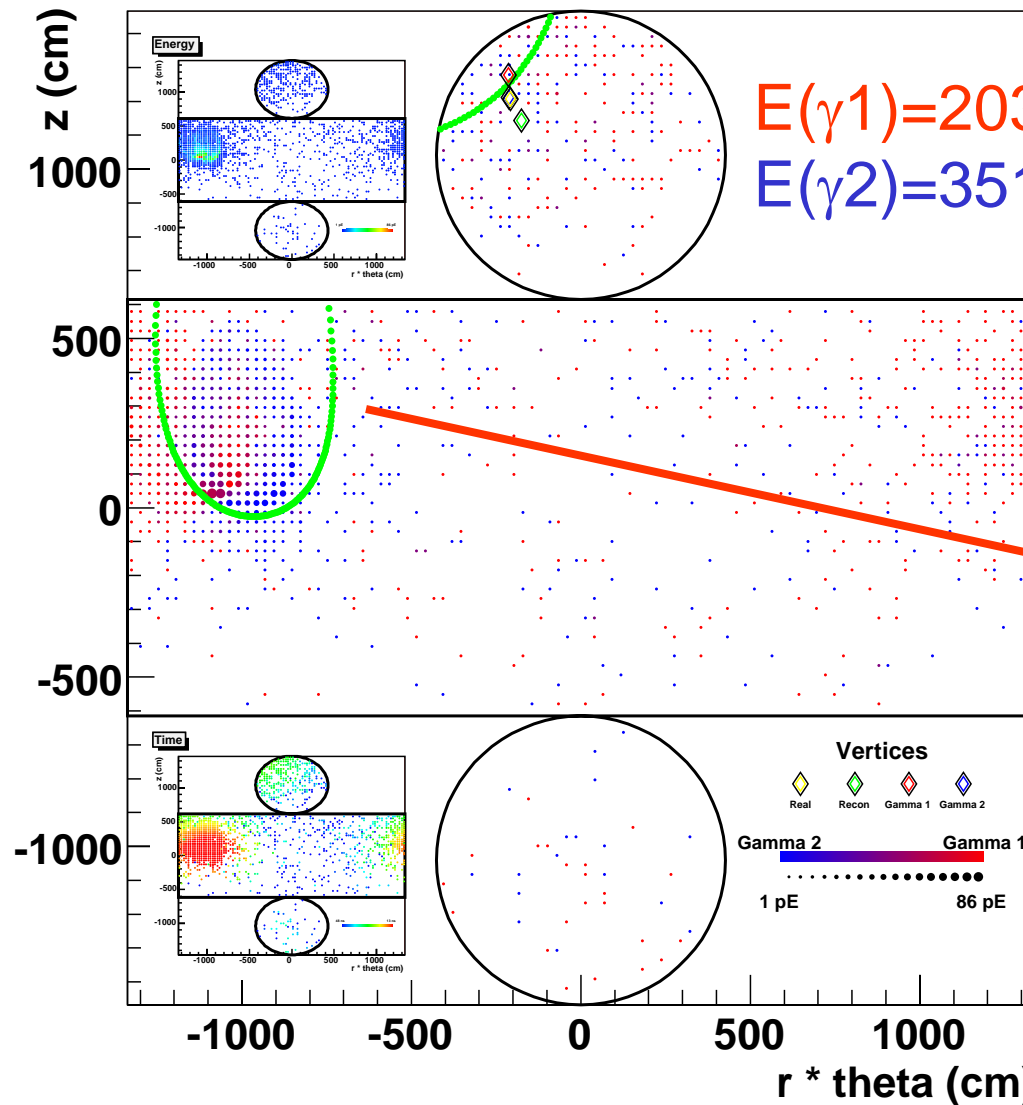
2 rings overlap each other, but it might be possible to separate them.

# 3)Reconstructed vertex is far away from real vtx

Water Cerenkov Detector: 69 , Event # 432

Real vtx, and conversion points

$E(\gamma 1)=101$MeV
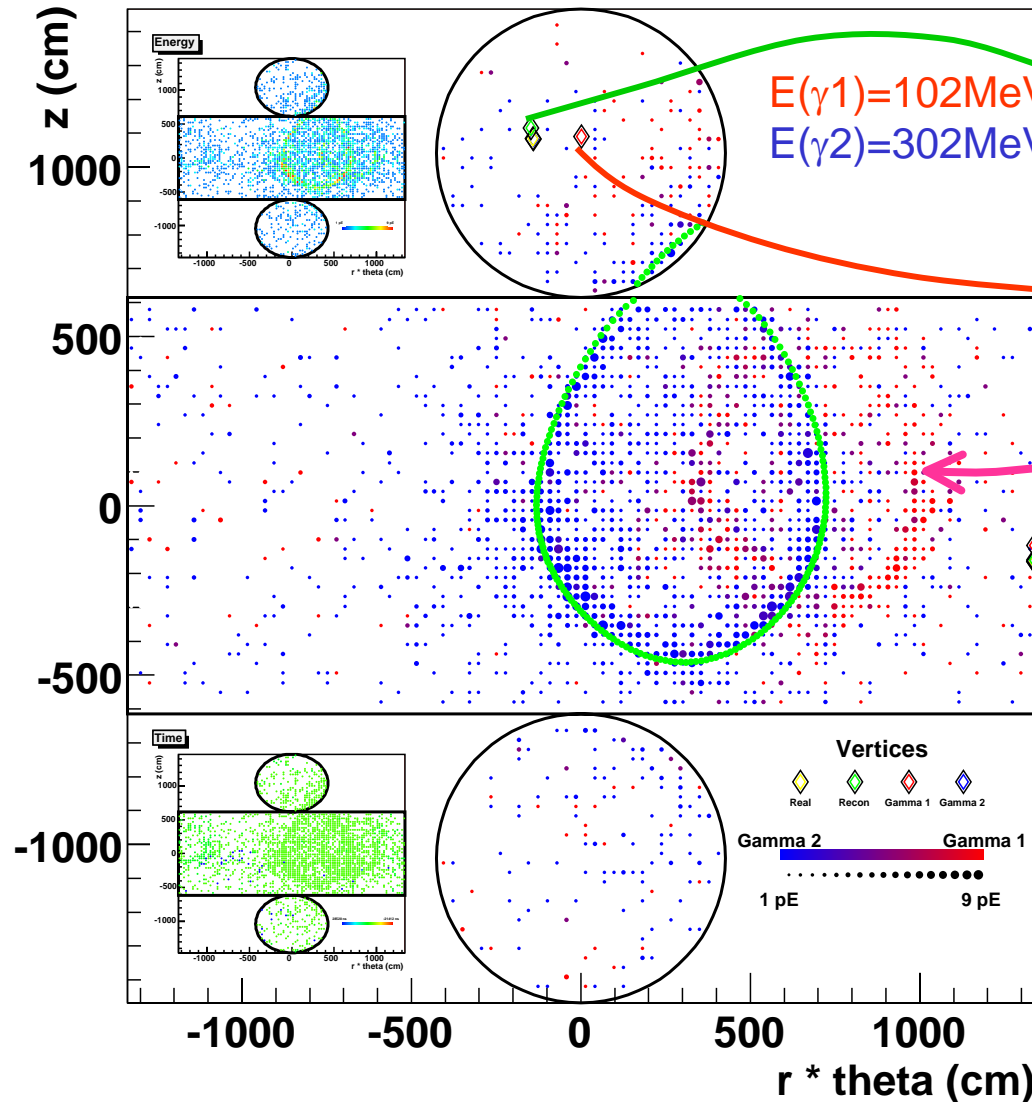$E(\gamma 2)=91$MeV

Reconstructed vertex

Gray : PMT hits from non-$\pi^0$

Wrong reconstructed vertex, wrong fitting,…, but misidentified as signal

# 4) One of conversion point is further away

E($\gamma$1)=102MeV
E($\gamma$2)=302MeV

Real, and reconstructed vertex

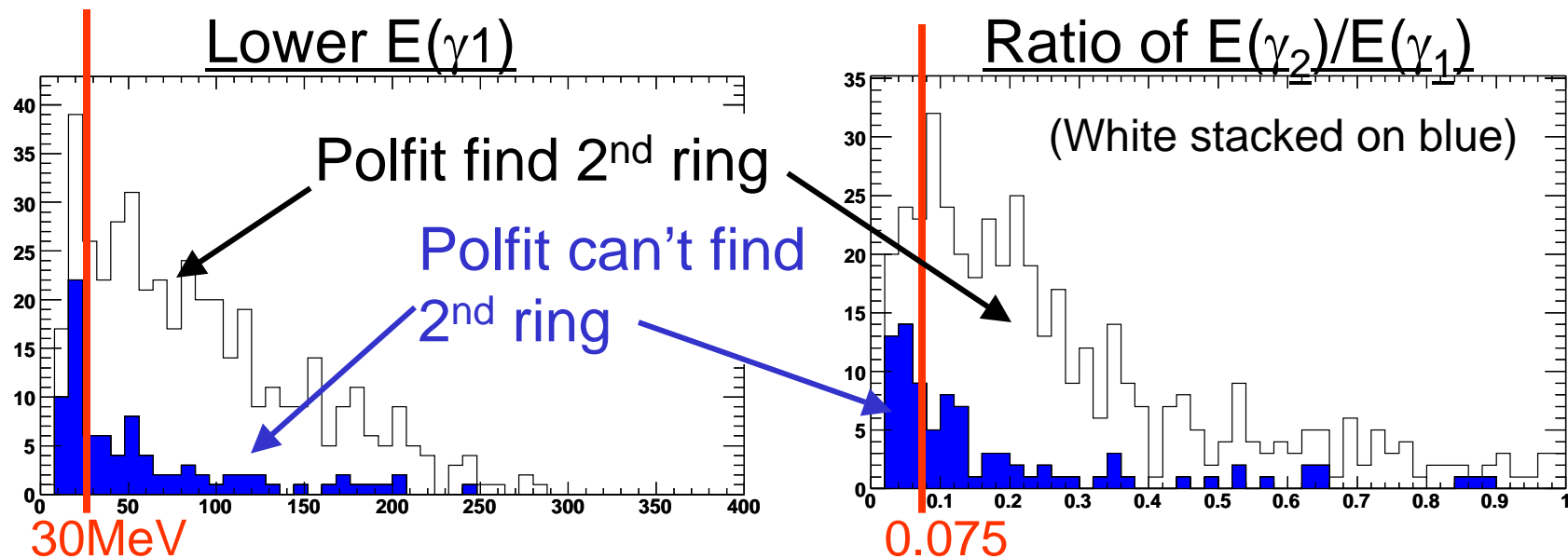One of conversion point is further away(150cm!)

Makes smaller ring!

Polfit failed to find 2$^{nd}$ ring

# Quantify when one of the $E(\gamma)$ is too small

- Using TRUE information (G4 output), I made histograms to quantify the previous results.
- Compare with events which polfit successfully found 2 rings.

Lower $E(\gamma 1)$

Ratio of $E(\gamma_2)/E(\gamma_1)$

Polfit find 2nd ring

Polfit can't find 2nd ring

(White stacked on blue)

30MeV

0.075

Polfit can't find 2 rings for 60~70% of events with $E(\gamma)<30$MeV or $E(\gamma_2)/E(\gamma_1)<0.075$
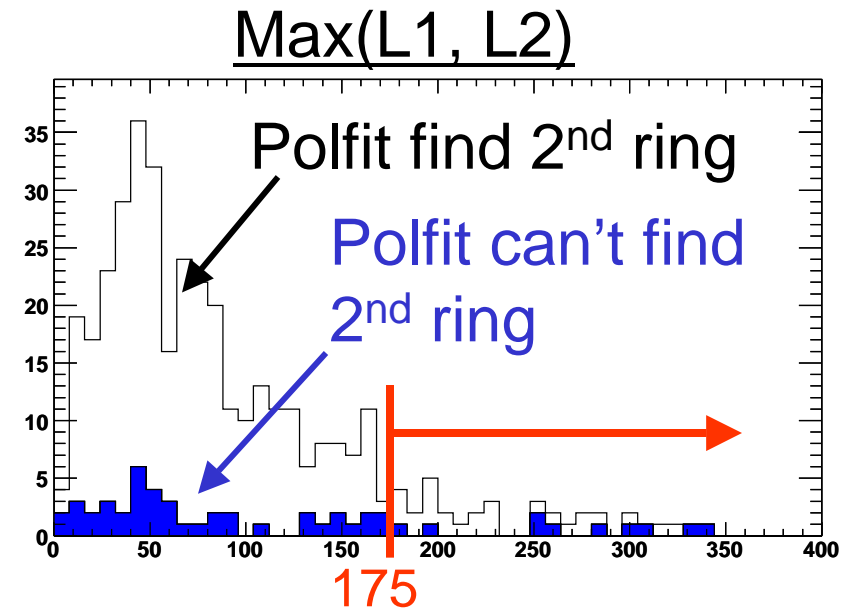→ Intrinsic polfit critical point

# Distance between $\pi^0$ and conversion point

- In order to study the properties of the remaining categories, apply $E(\gamma) > 30\text{MeV}$ or $E(\gamma_2)/E(\gamma_1) > 0.075$
  → 52 events are left
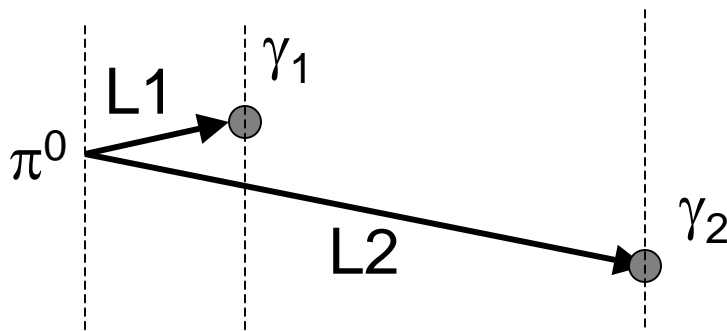


L1 : Distance between $\pi^0$ and $\gamma_1$
L2 : Distance between $\pi^0$ and $\gamma_2$
→Make histogram of max(L1,L2)

## Max(L1, L2)



Polfit find 2nd ring
Polfit can't find 2nd ring
175

Polfit finds 2 ring : 8% at >175
Polfit finds 1 ring : 20% at >175

- If it is possible to identify these events with reconstructed information, then we can reduce the BG.

# Impact on the T2K sensitivity

- If I assume it is possible to develop a cut or improve polfit likelihood to reduce p0 BG except for the events that `one of $E(\gamma)$ is too small (~60%)', how many would the T2K sensitivity improve?

- I scaled NC p0 BG event down to 60% and 0%.



SK+2km w/syst
— default
······· 60% of NC pi0 BG
----- no NC pi0 BG
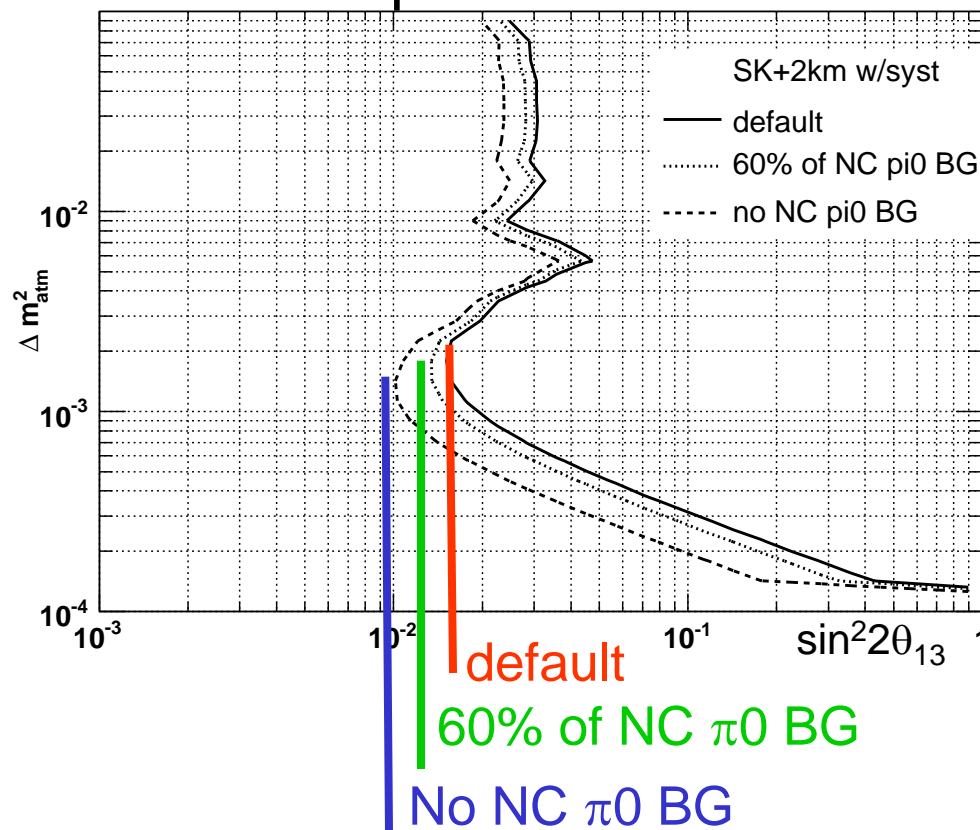
Has non-negligible impact!

default

60% of NC $\pi$0 BG

No NC $\pi$0 BG

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# Conclusion and Plan

- Using the extended G4 information and specialized event display :
  - I categorized $\pi^0$ BG events by eye scan.
  - I found some events failed because one $\gamma$ converted very far from the vertex.

- I will try to see if there is a possibility to use reconstructed information to reduce $\pi^0$ BG events of this category.
  - Timing cut?
  - Polfit extension? (Allow 2nd ring with smaller size?)

# 3)Reconstructed vertex is far away from real vtx



Water Cerenkov Detector: 69 , Event # 432

E(γ1)=101MeV
E(γ2)=91MeV
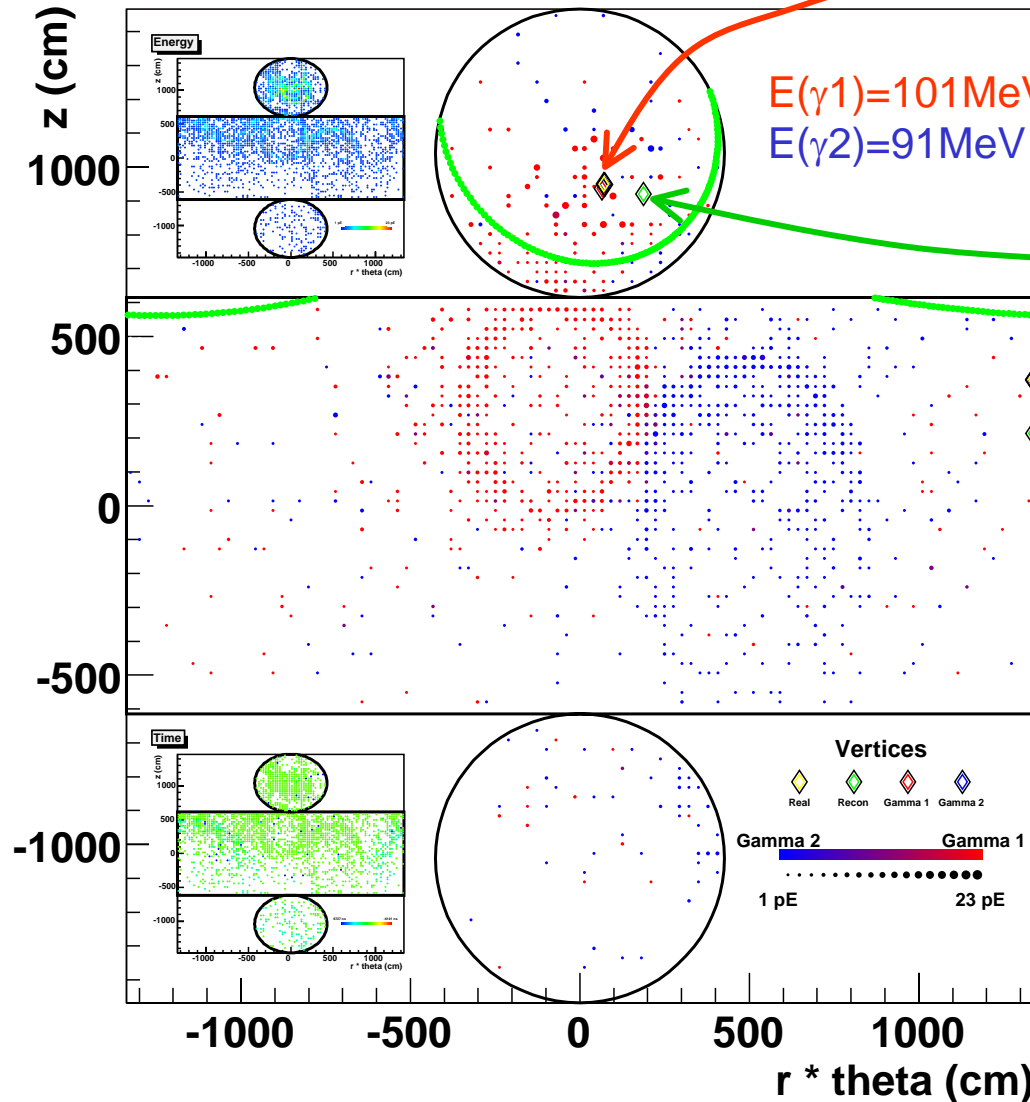
Real vtx, and conversion points

Reconstructed vertex

Wrong reconstructed vertex, wrong fitting,…, but misidentified as signal