Proton Decay with fiTQun
$p \rightarrow e^+\pi^0$

Yusuke Suda (UTokyo)

2015/8/20

fiTQun! Workshop @ TRIUMF

Japan's Matterhorn
(Mt. Yari)

東京大学 大学院
理学系研究科·理学部
SCHOOL OF SCIENCE, THE UNIVERSITY OF TOKYO

Overview

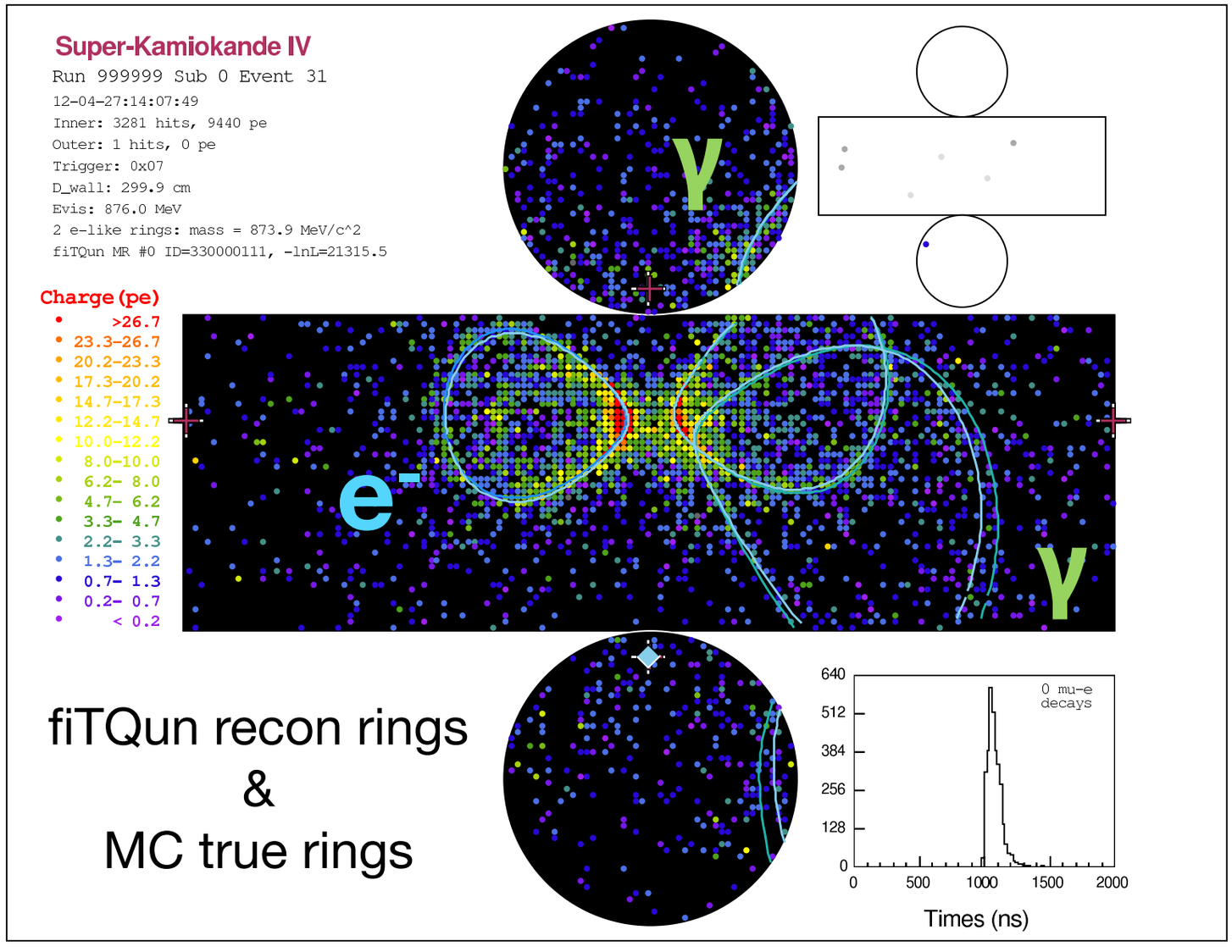
- Target decay modes;

$$p \rightarrow e^+\pi^0, \quad \mu^+\pi^0$$

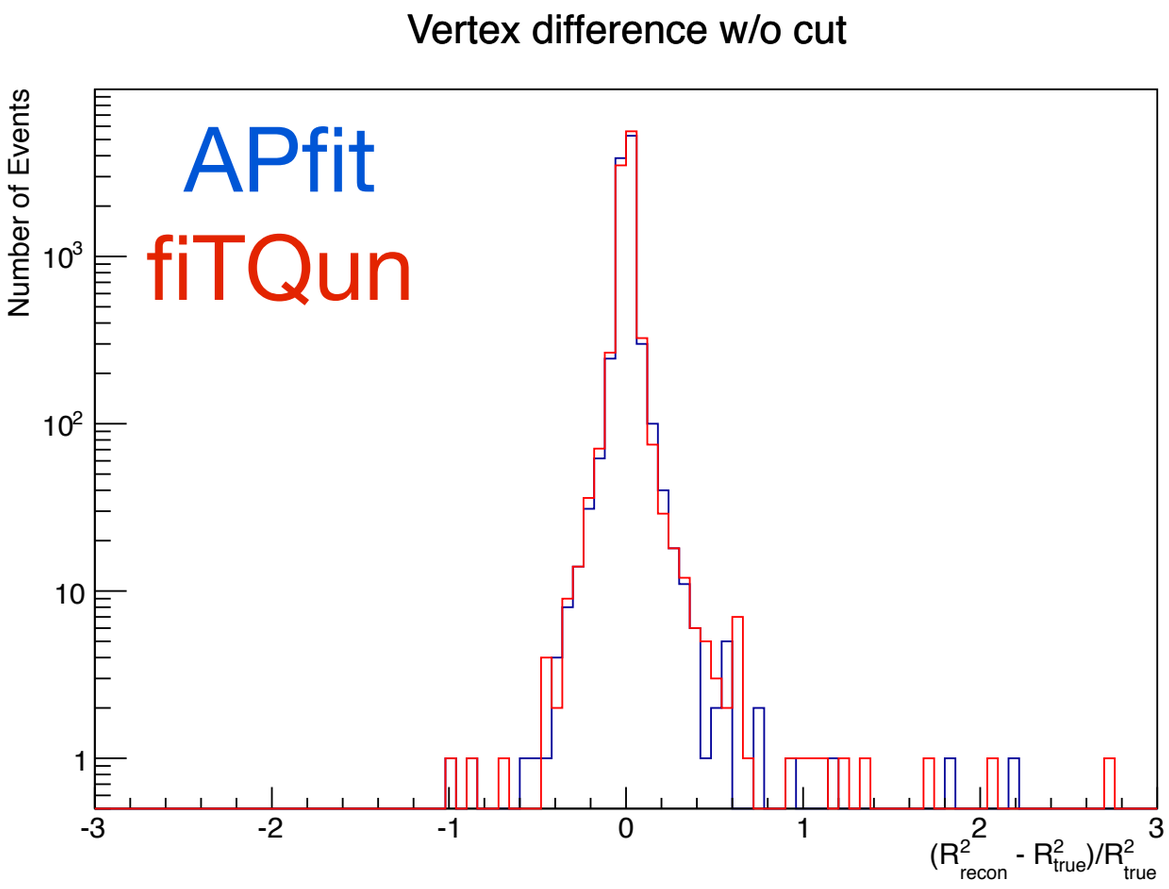
- In order to check what should be studied for $e^+\pi^0$ mode, I processed $e^+\pi^0$ MC (SK4) with fiTQun v4r2
- By applying the SK official event selection, I realized the most critical point is the ring counting
  - Many 4 ring events are observed
    → Should understand why it happen
- As a test, I changed the ring correction criteria and reprocessed fiTQun
  - The ring counting becomes better and the signal efficiency is almost same as APfit

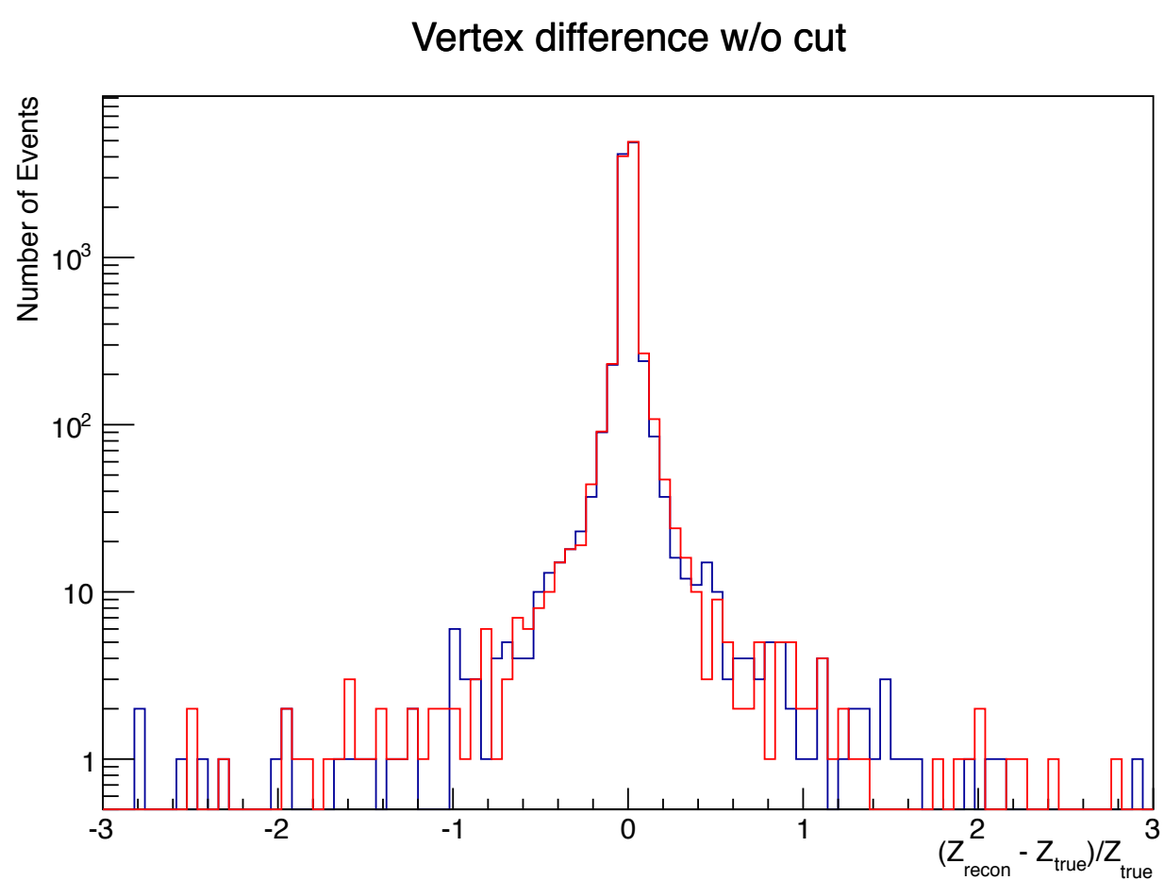
Results of default fiTQun v4r2

($p \rightarrow e^{+}\pi^{0}$)



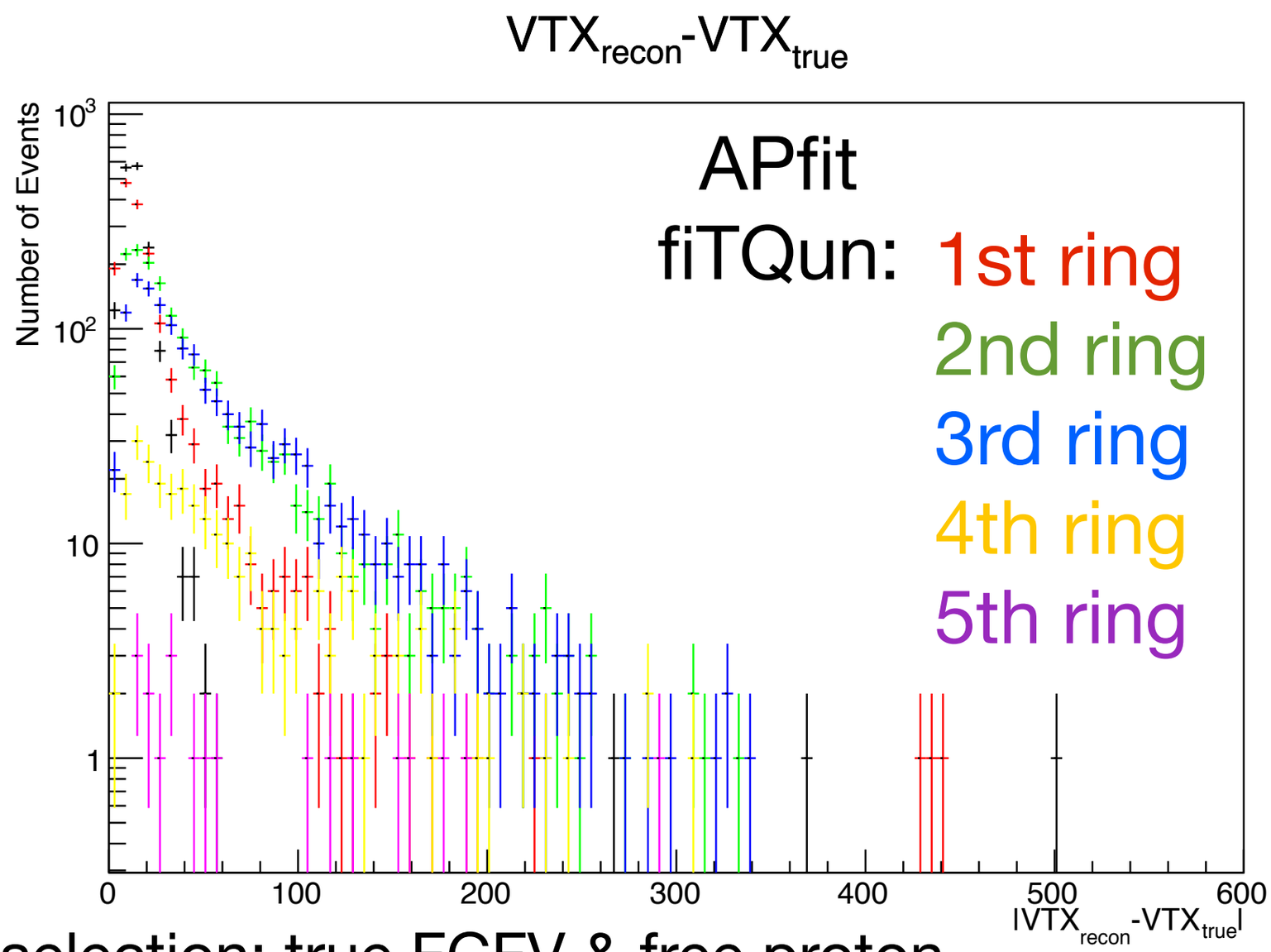
Vertex distribution





- No event selection is applied
- Use the vertex of 1st ring for fiTQun
- The vertex distribution of fiTQun looks same as APfit

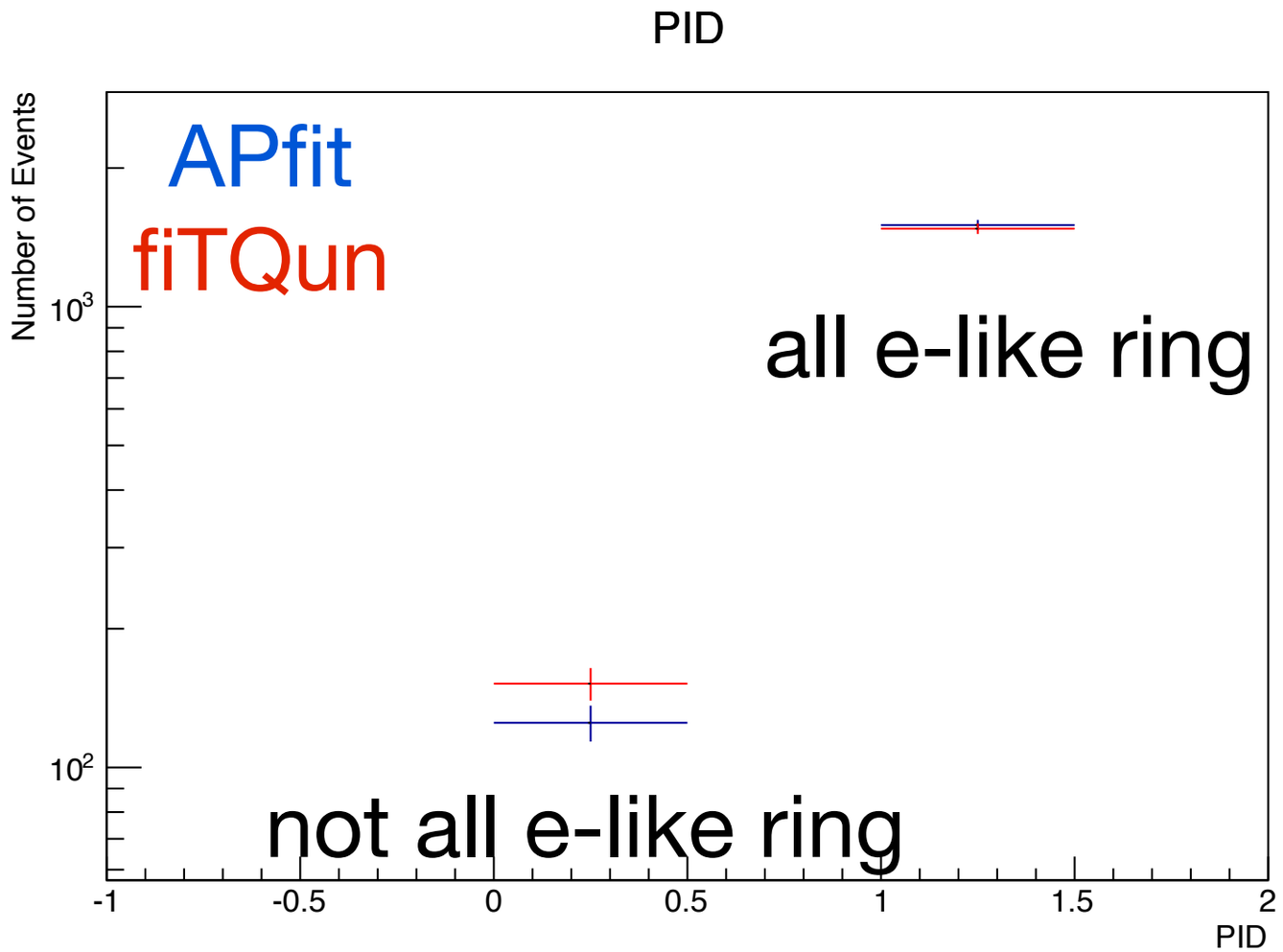
Vertex distribution



- Event selection: true FCFV & free proton

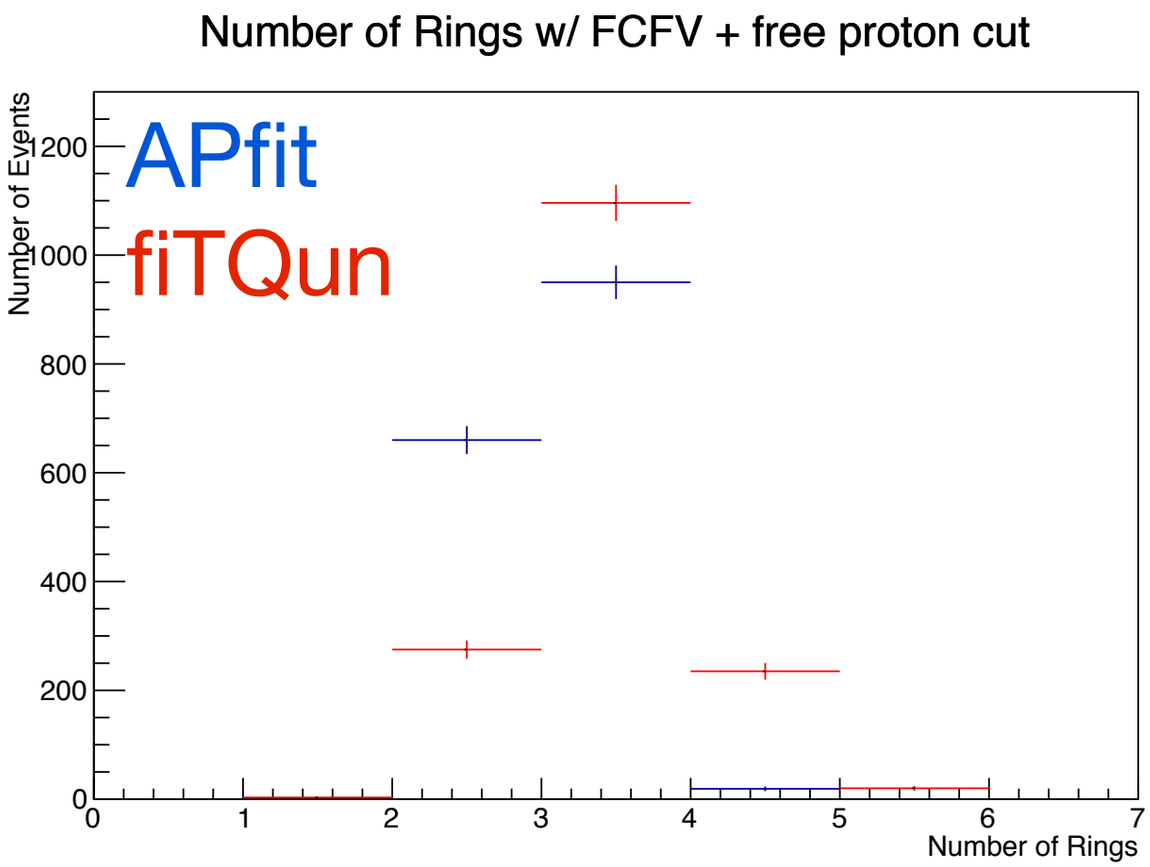
- 2nd & 3rd ring have a broad distribution
  → Due to the photon conversion length in π^0 decay?
  There is a possibility to use this information for π^0 cut
  Need more study

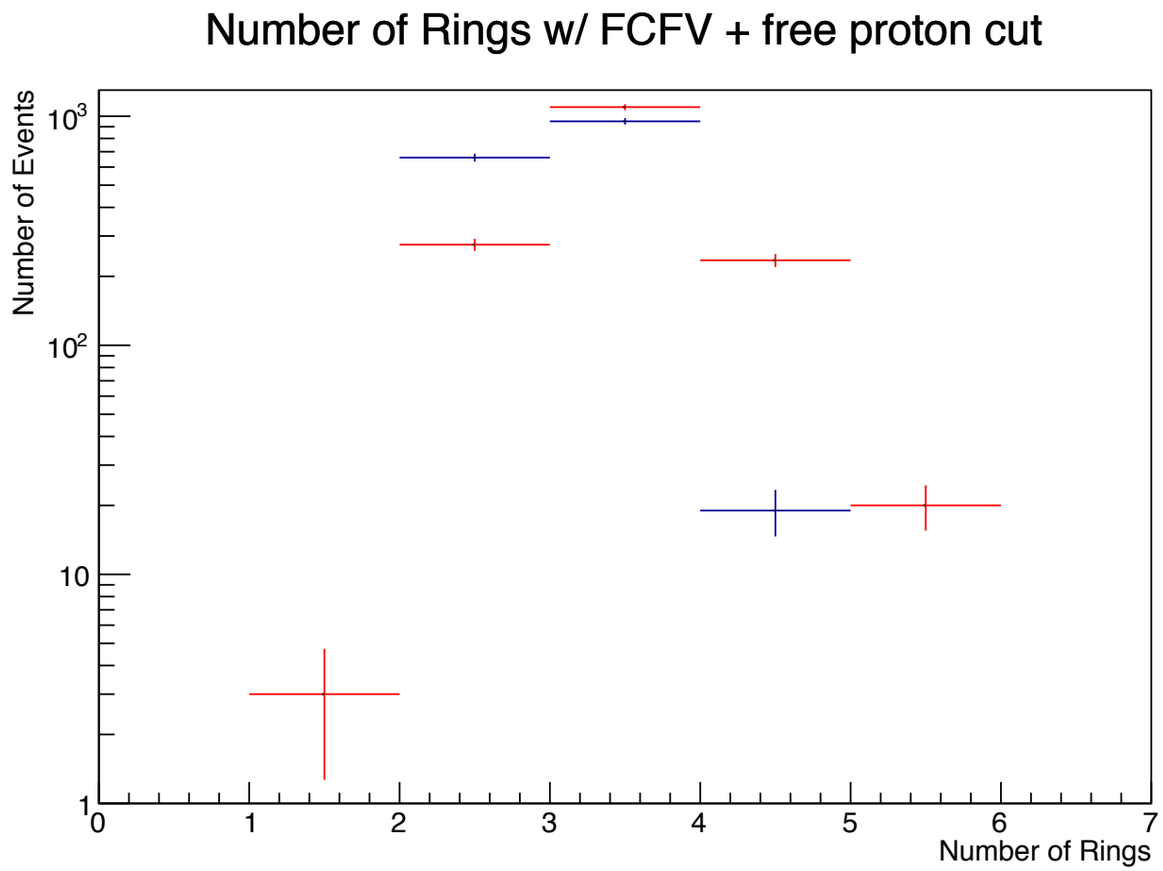
Particle ID



- Event selection: true FCFV & free proton
- For $e^+\pi^0$ events, all ring should be e-like
- FiTQun PID performance looks good

Ring counting



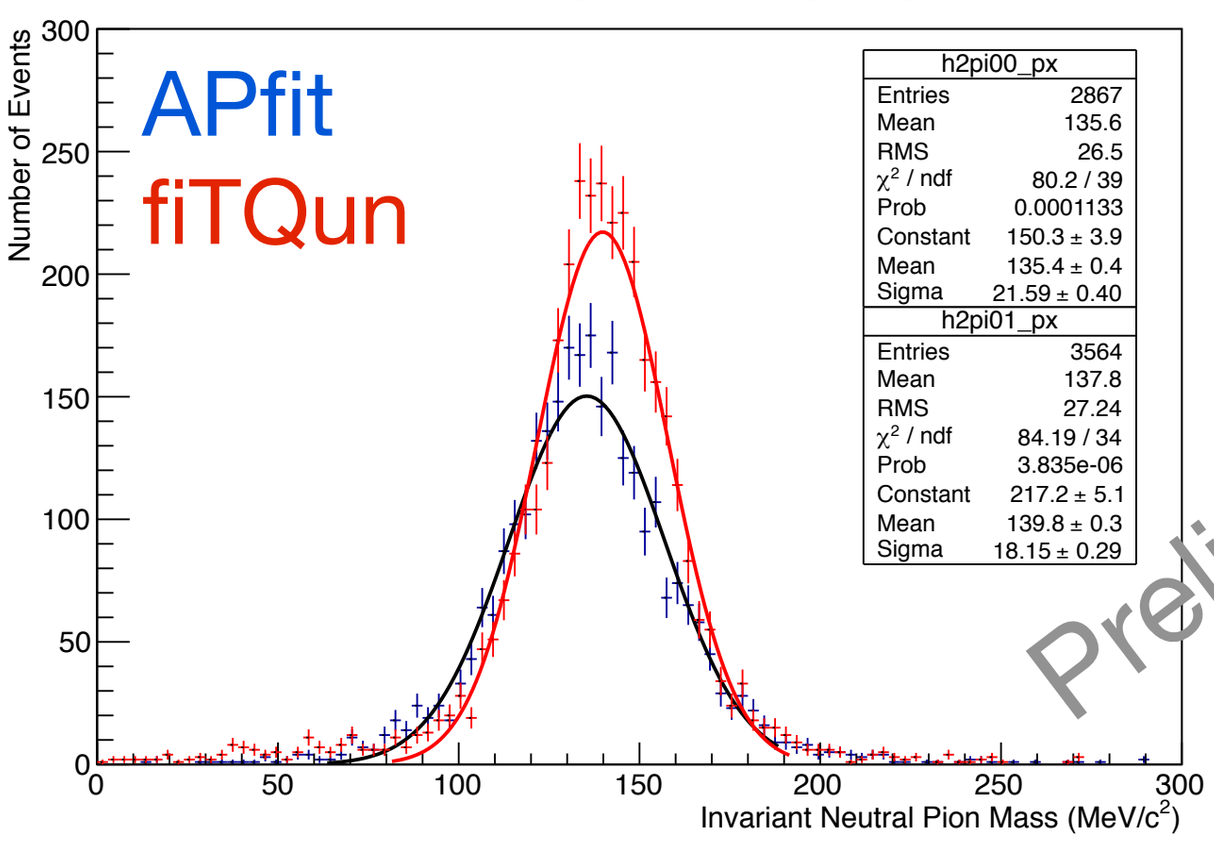


- Event selection: true FCFV & free proton
- For $e^+\pi^0$ events, the number of rings should be 2 or 3
- FiTQun found too many rings
  →Need to understand

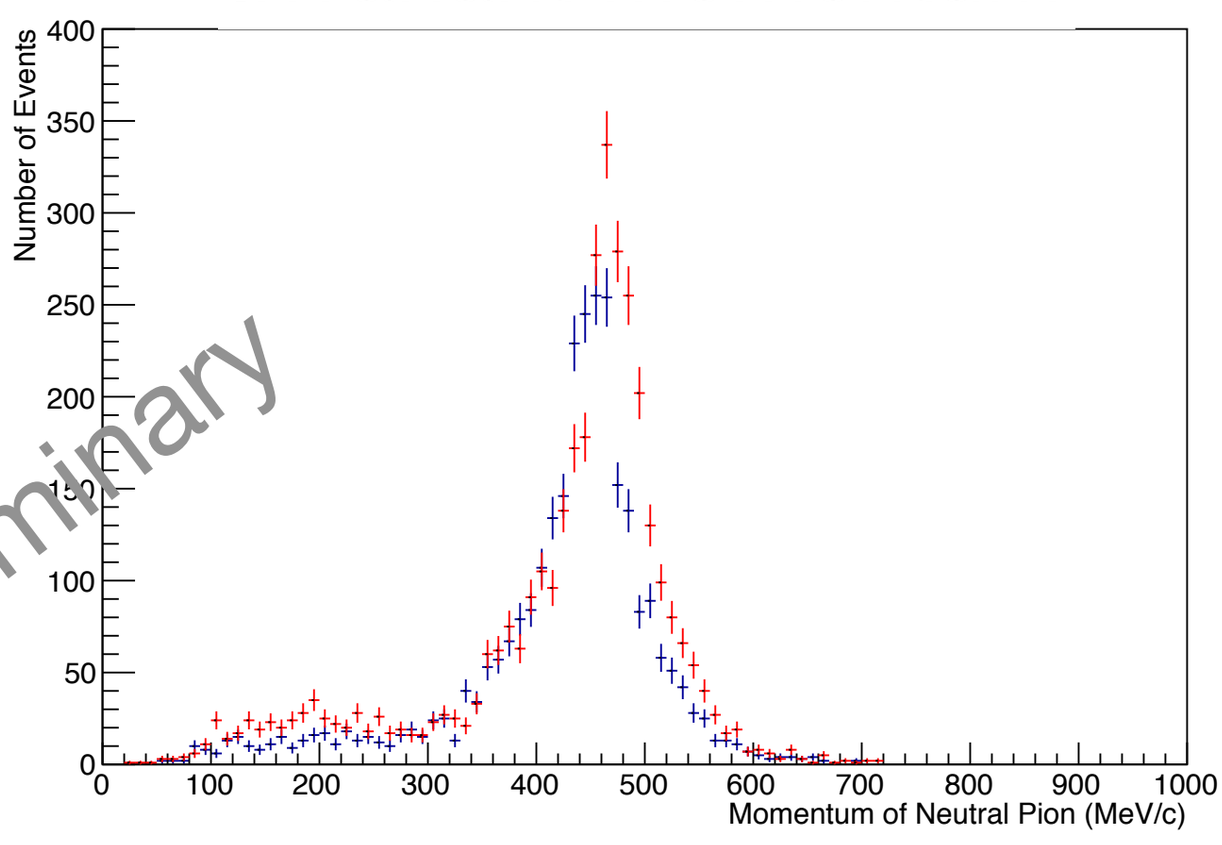
Reconstructed π^0

- Event selection: SK official
- The resolution of pi0 mass is better than APfit
  - APfit: 15.9% → fiTQun: 13.0%
- Momentum distribution becomes more peaky

Invariant Mass



Invariant Momentum

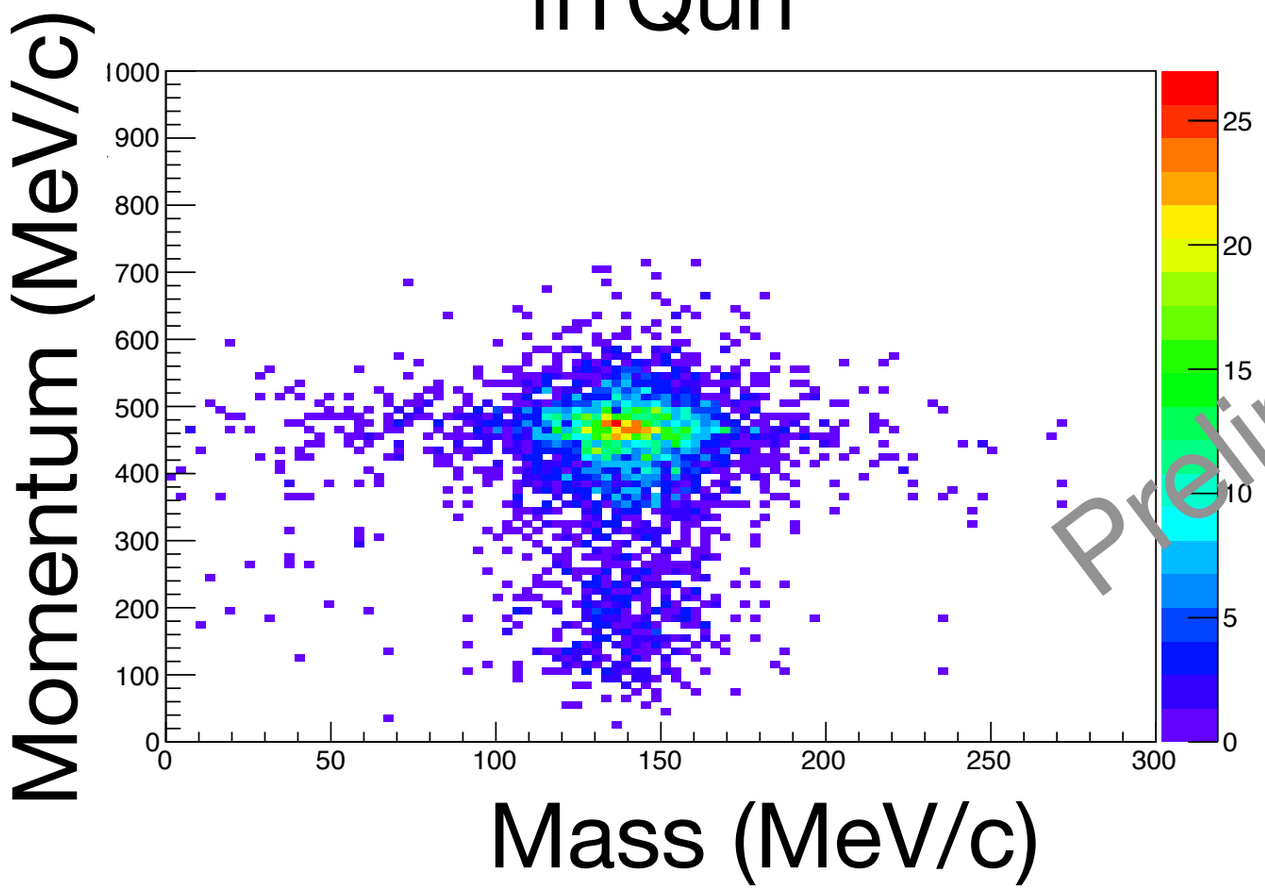


Preliminary

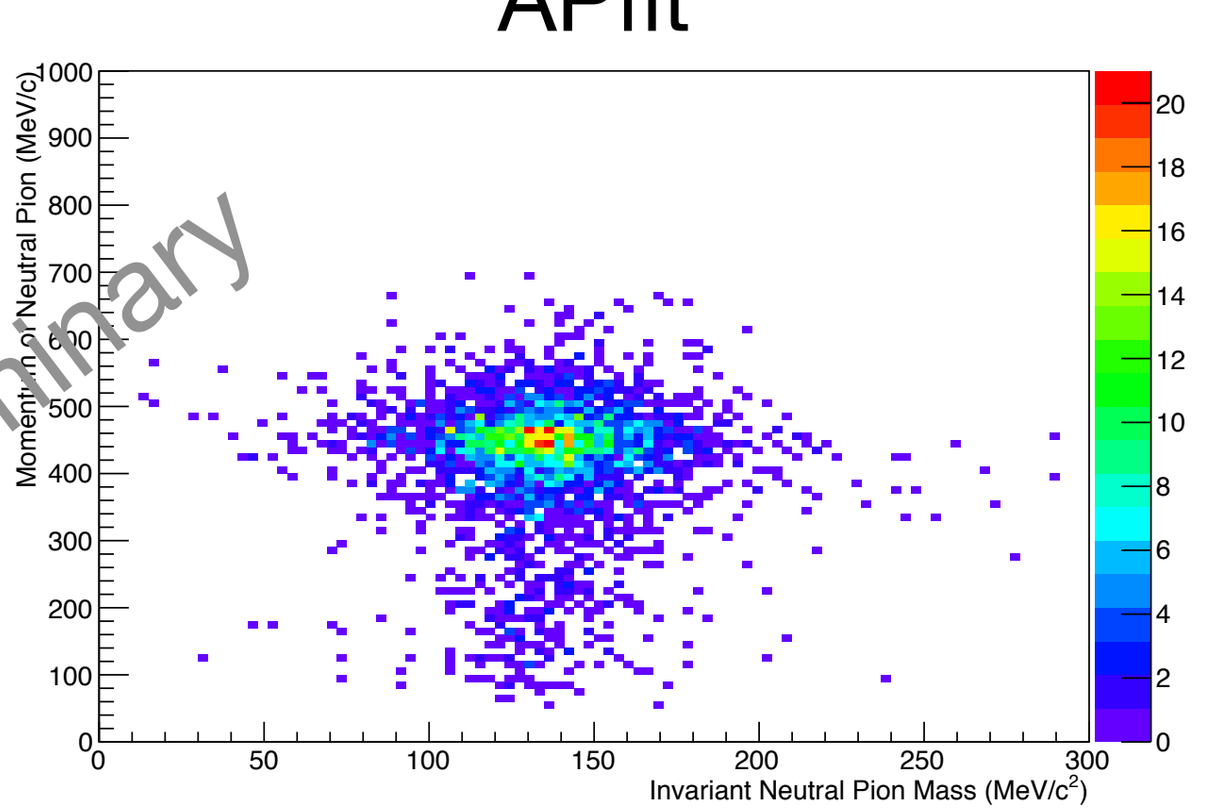
Reconstructed π^0

- Event selection: SK official

fiTQun



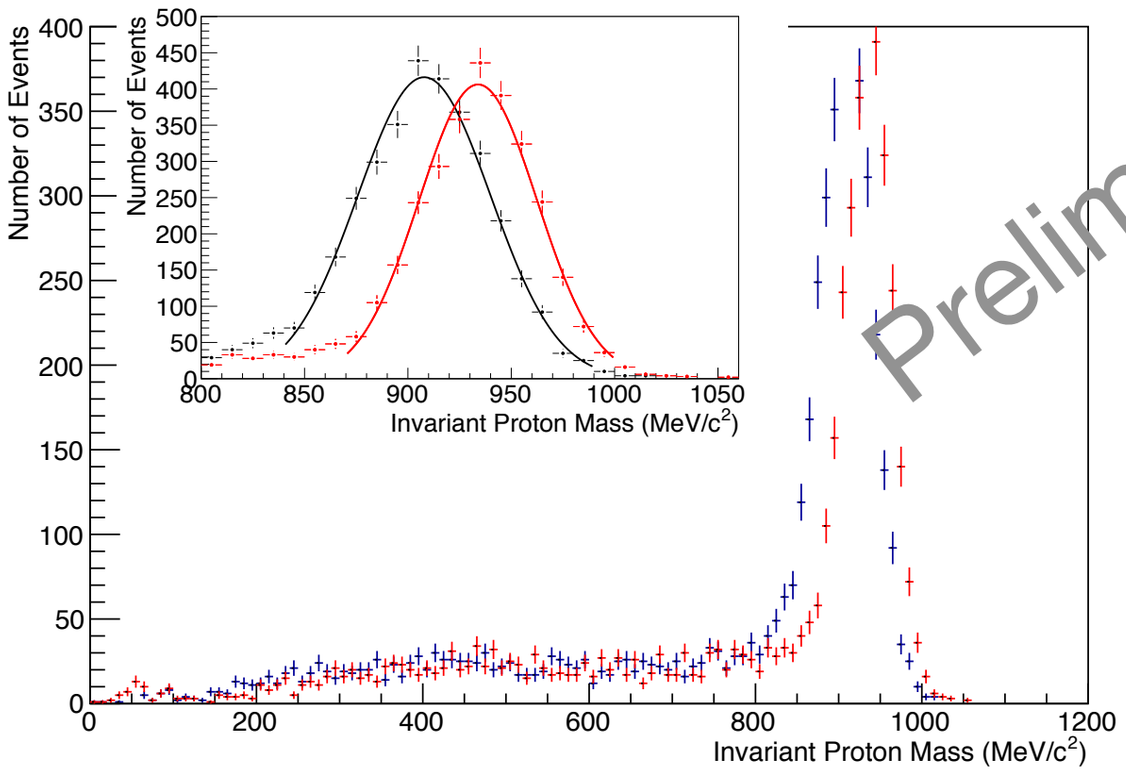
APfit



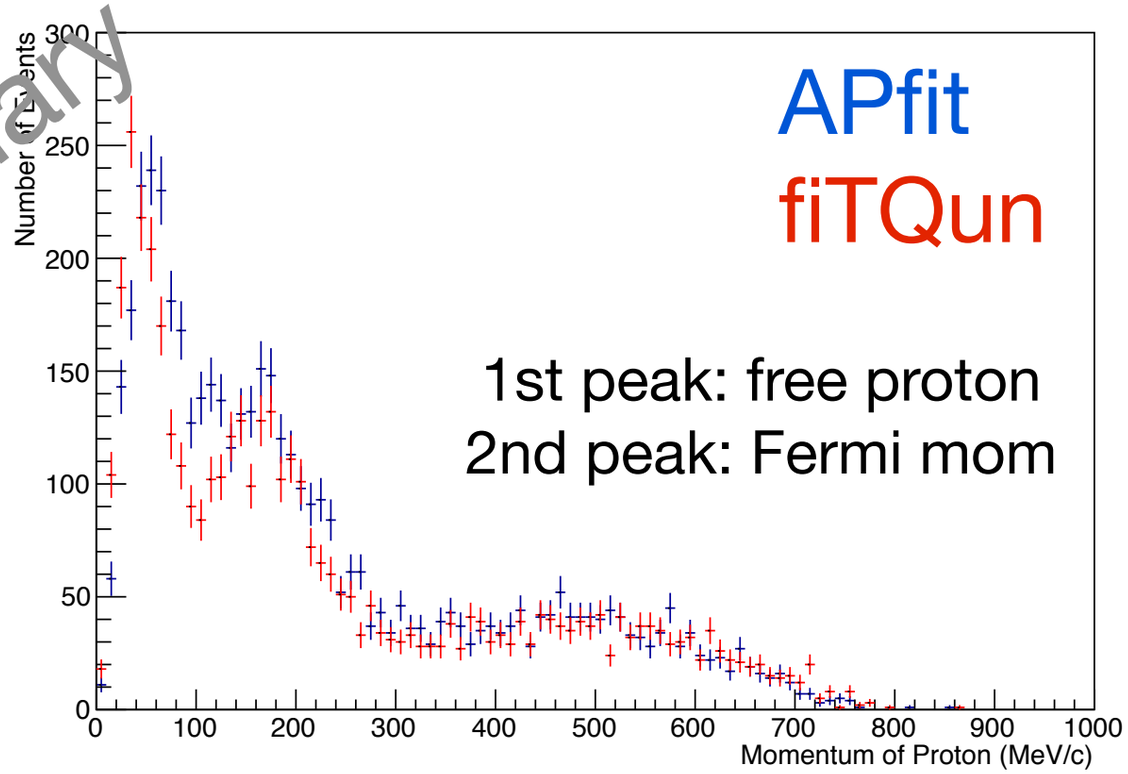
Reconstructed Proton

- Event selection: SK official
- The resolution of proton mass is better than APfit
  - APfit: 35.4% → fiTQun: 30.8%
- Momentum distribution becomes more peaky
- Possibility to apply more tighter momentum & mass cut

Invariant Mass



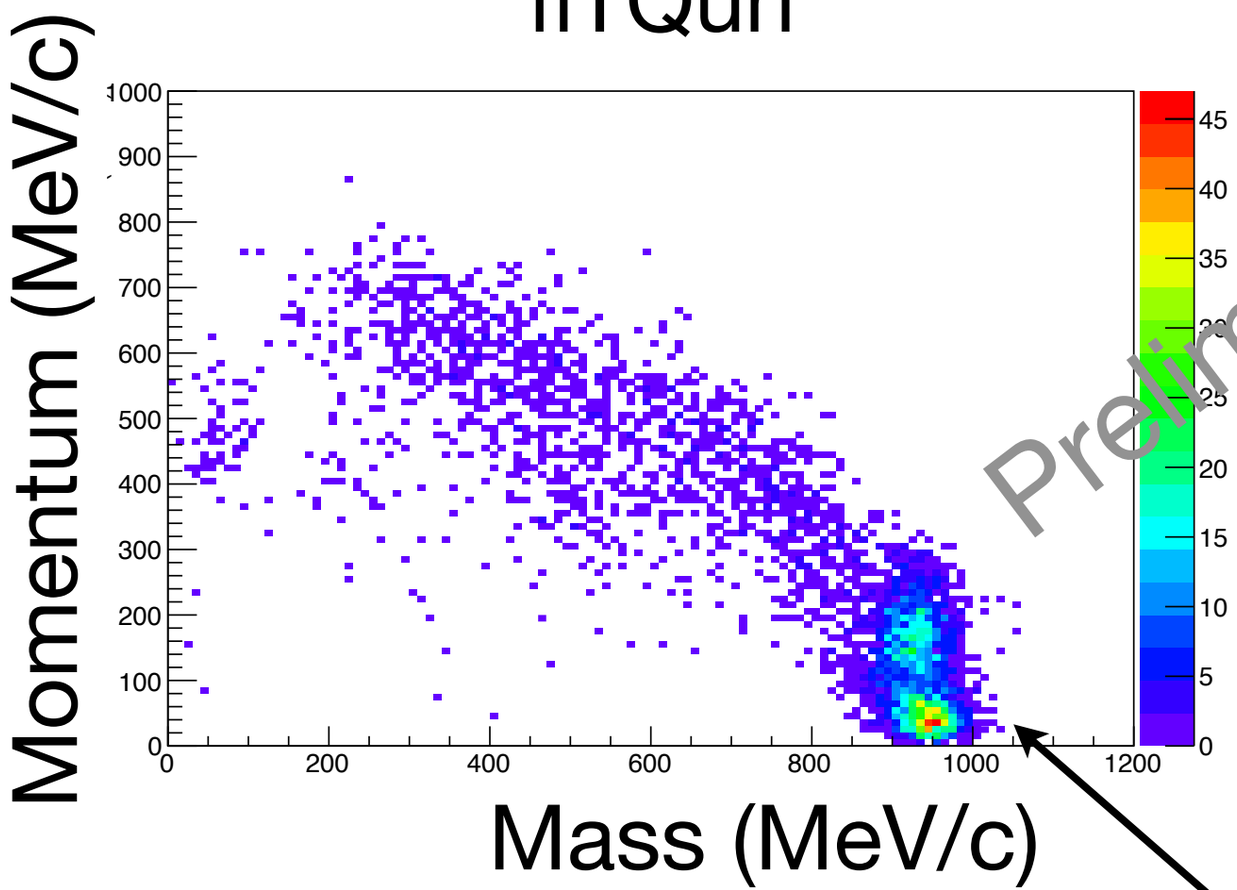
Invariant Momentum



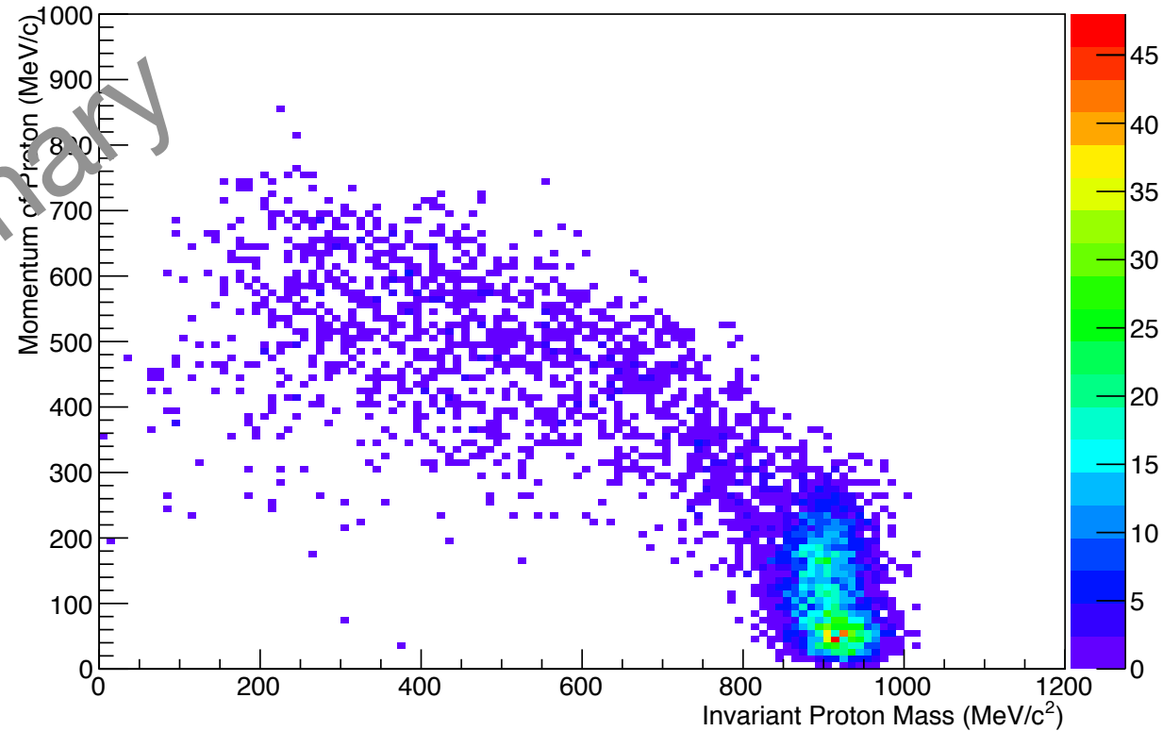
Reconstructed Proton

- Event selection: SK official

fiTQun



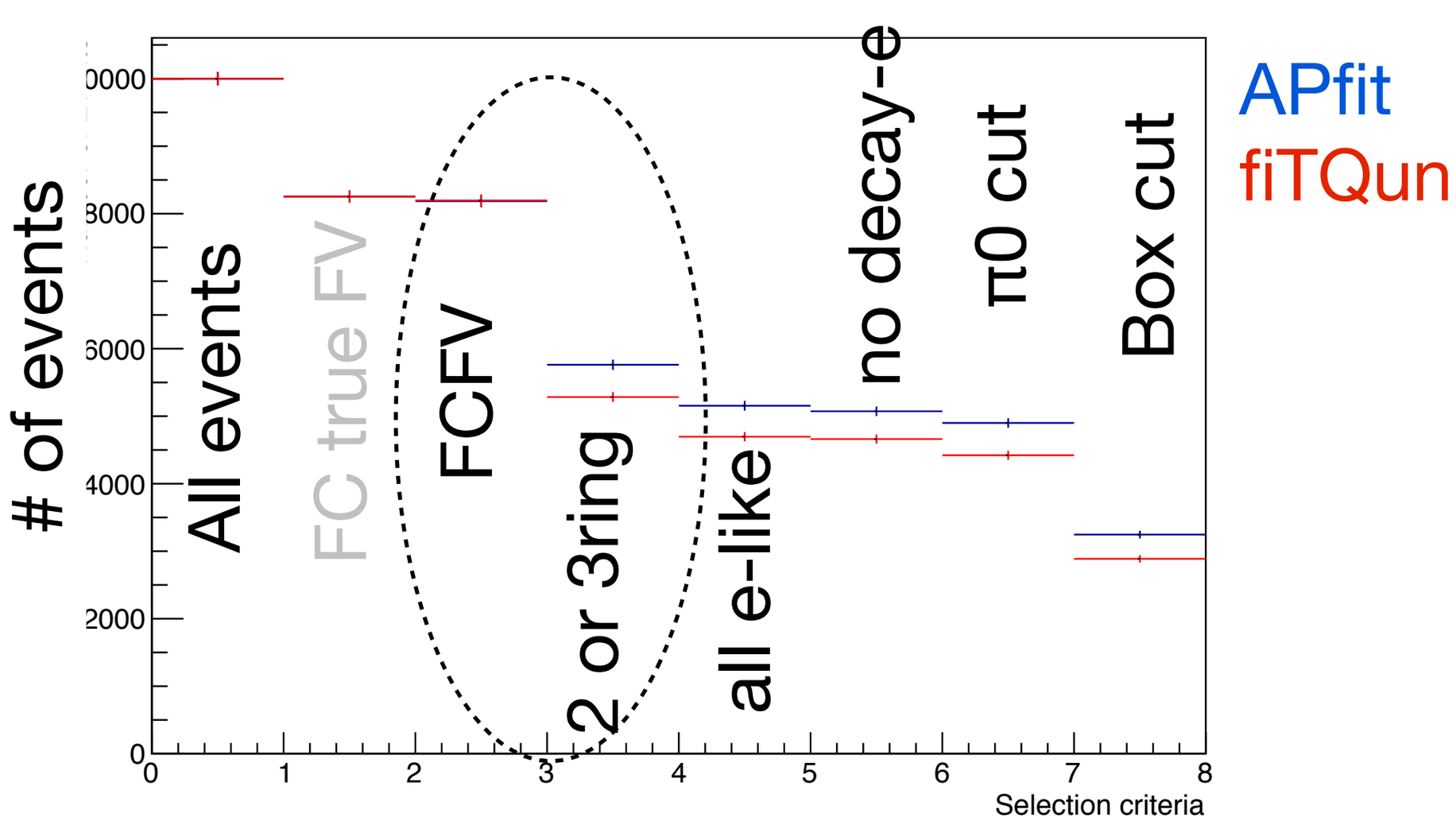
APfit



A free proton cluster can be seen more clearly

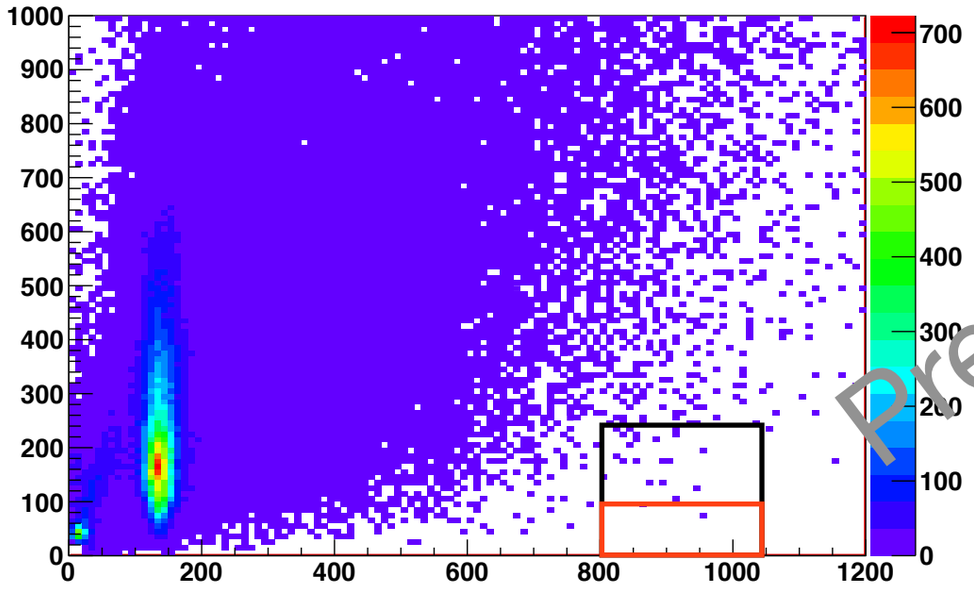
Signal Efficiency

- Efficiency (# of final events/# of FC true FV events)
  - APfit: 39.33% → fiTQun: 34.98%
- Decreasing in efficiency is mainly caused by ring cut

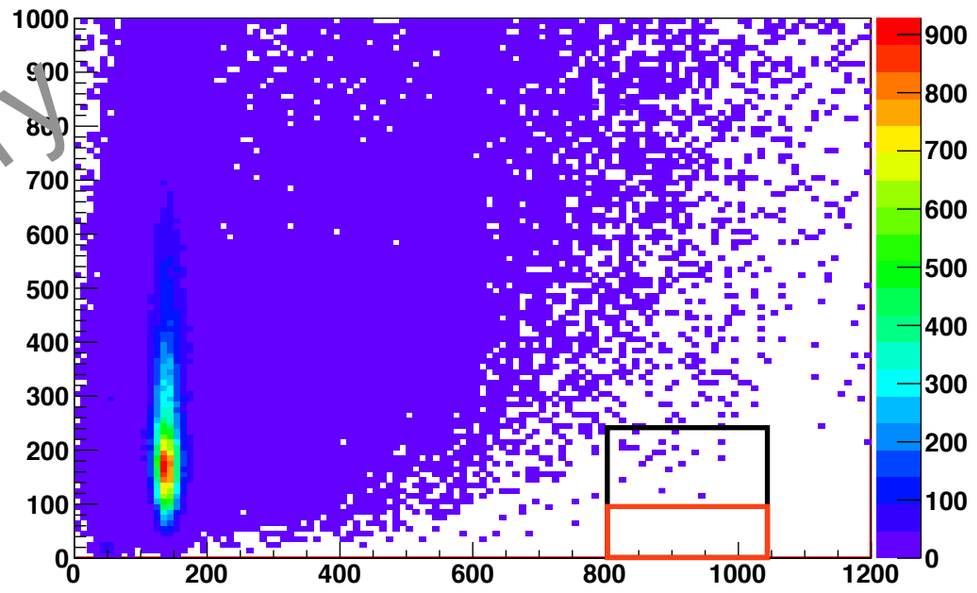


Background (Atm.-ν)

APfit

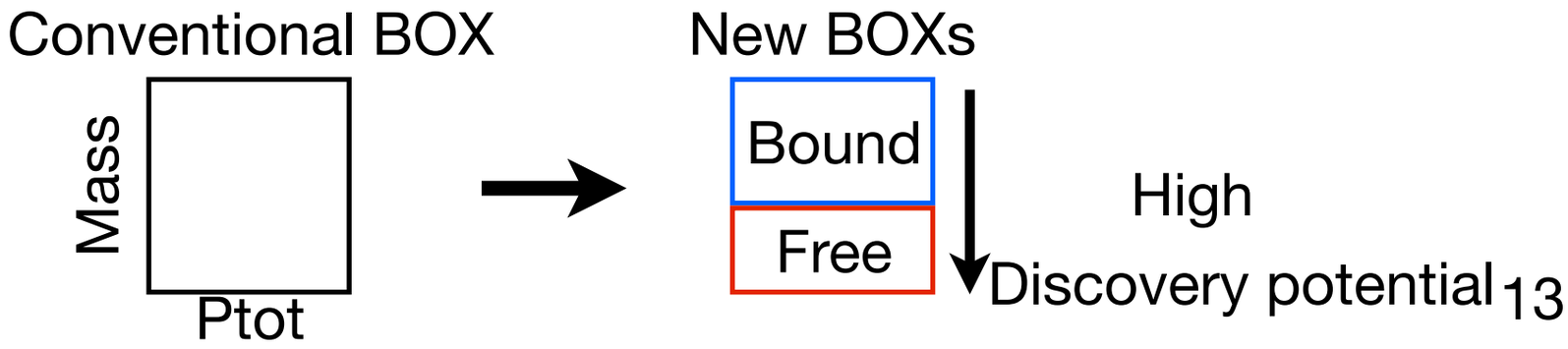


fiTQun v4r2



	APfit	fiTQun v4r2
Conventional BOX:	28.6 events	25.5 events
Tight BOX (p<100MeV/c):	2.03 events	BG free!→ 0.00 events
	in 500 years	in 500 years

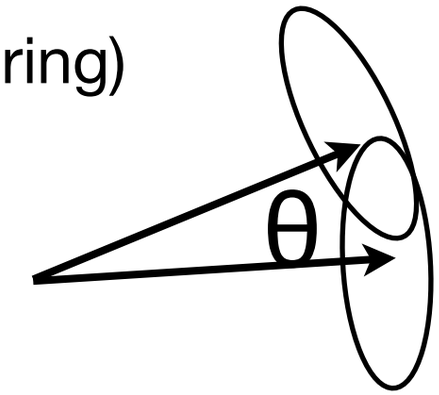
- Currently, PDK group starts to use a combined two BOX analysis improving the discovery potential
- It may be helpful for fiTQun since fiTQun has the sharp peak in free proton momentum and less BG

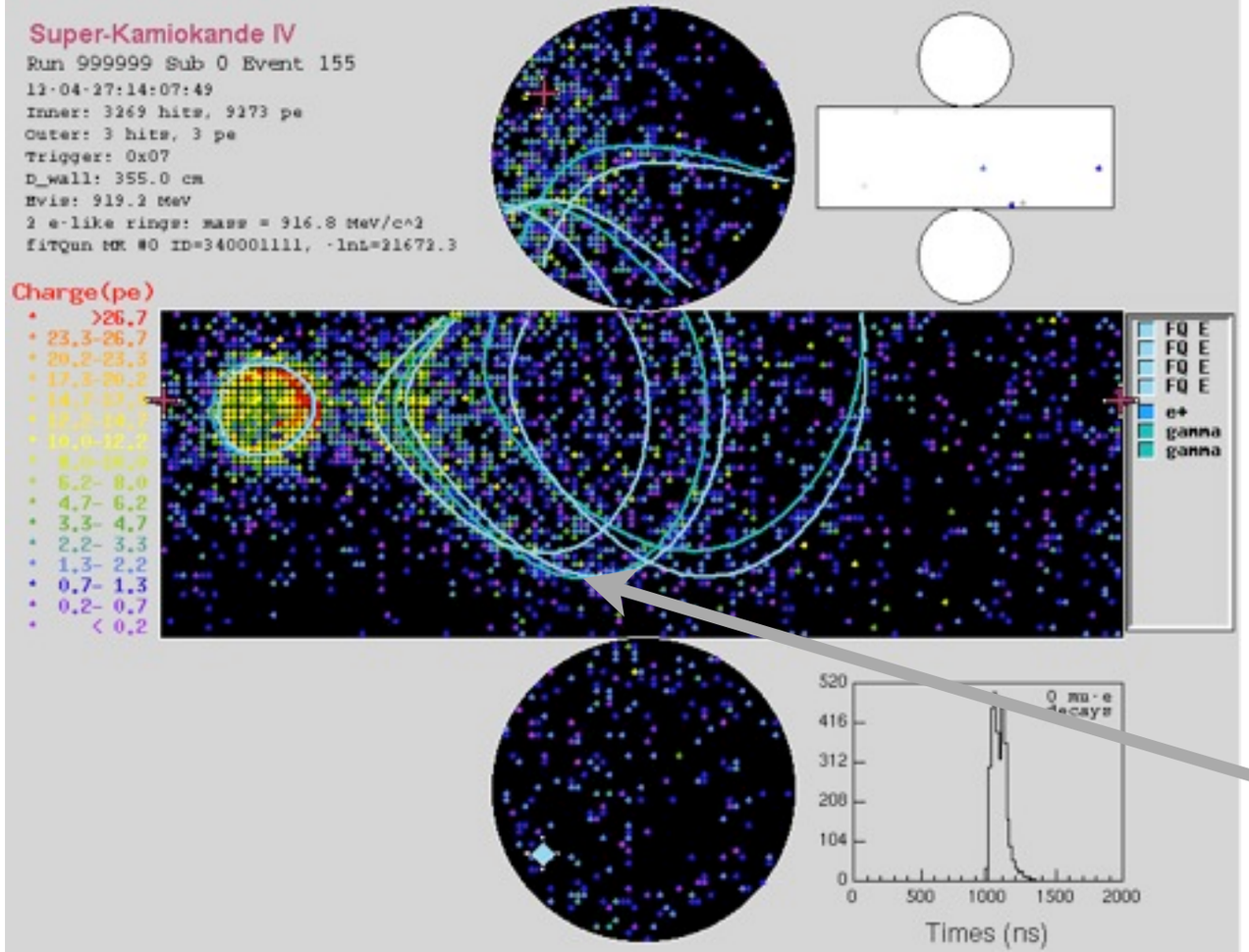


Mis ring counting

Ring Correction

- Main reason of the low efficiency is the miss ring counting
  - Typically, 4 e-like rings (1 ring is close to the other ring)
- Default ring correction:
  {Angle between rings less than 10 deg}
  and
  { (Particle type of ring A != Particle type of ring B)
  or (Most energetic ring is μ (π+)-like ring) }





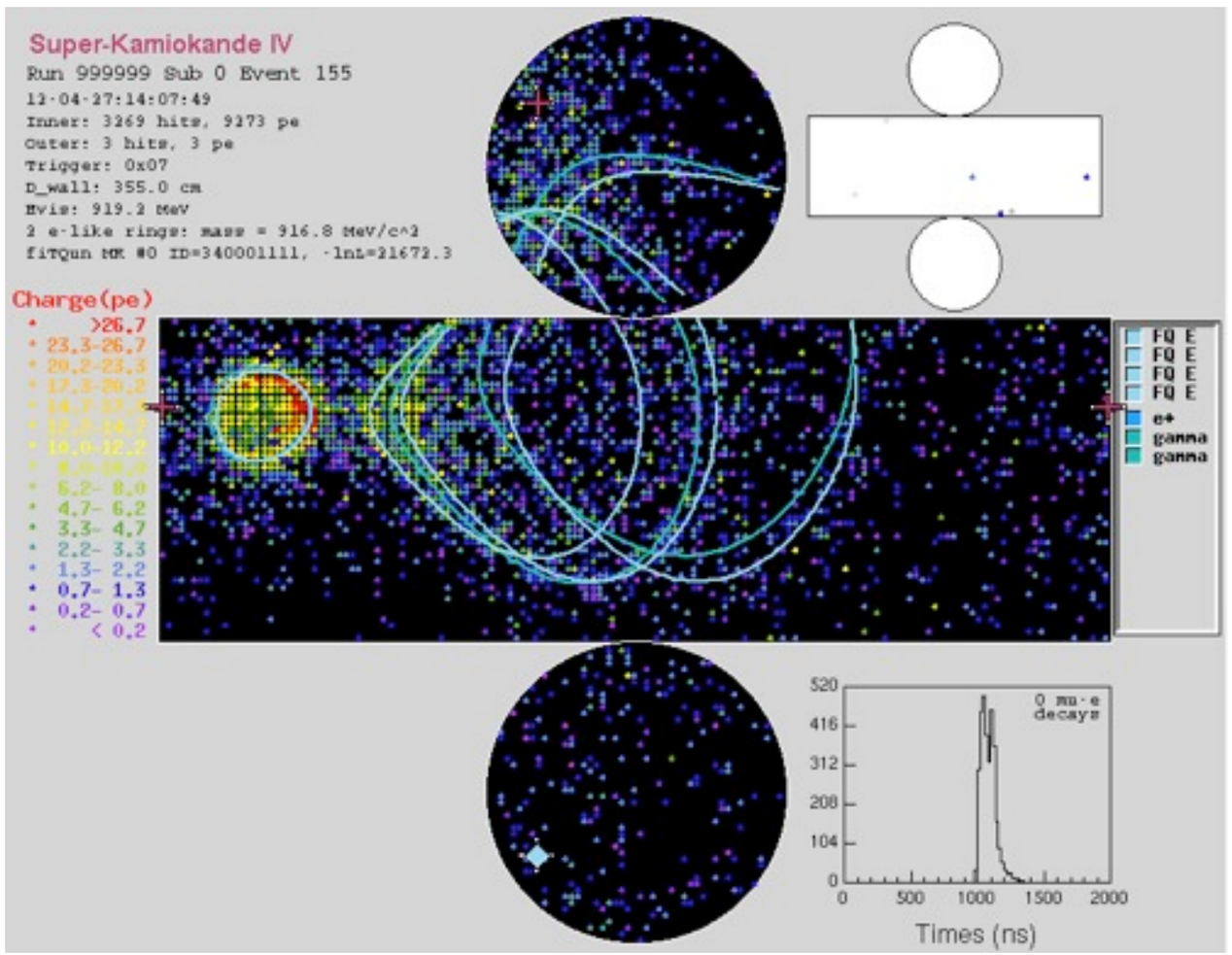
Light blue rings show fiTQun recon e-like rings

There is 1 extra e-like ring

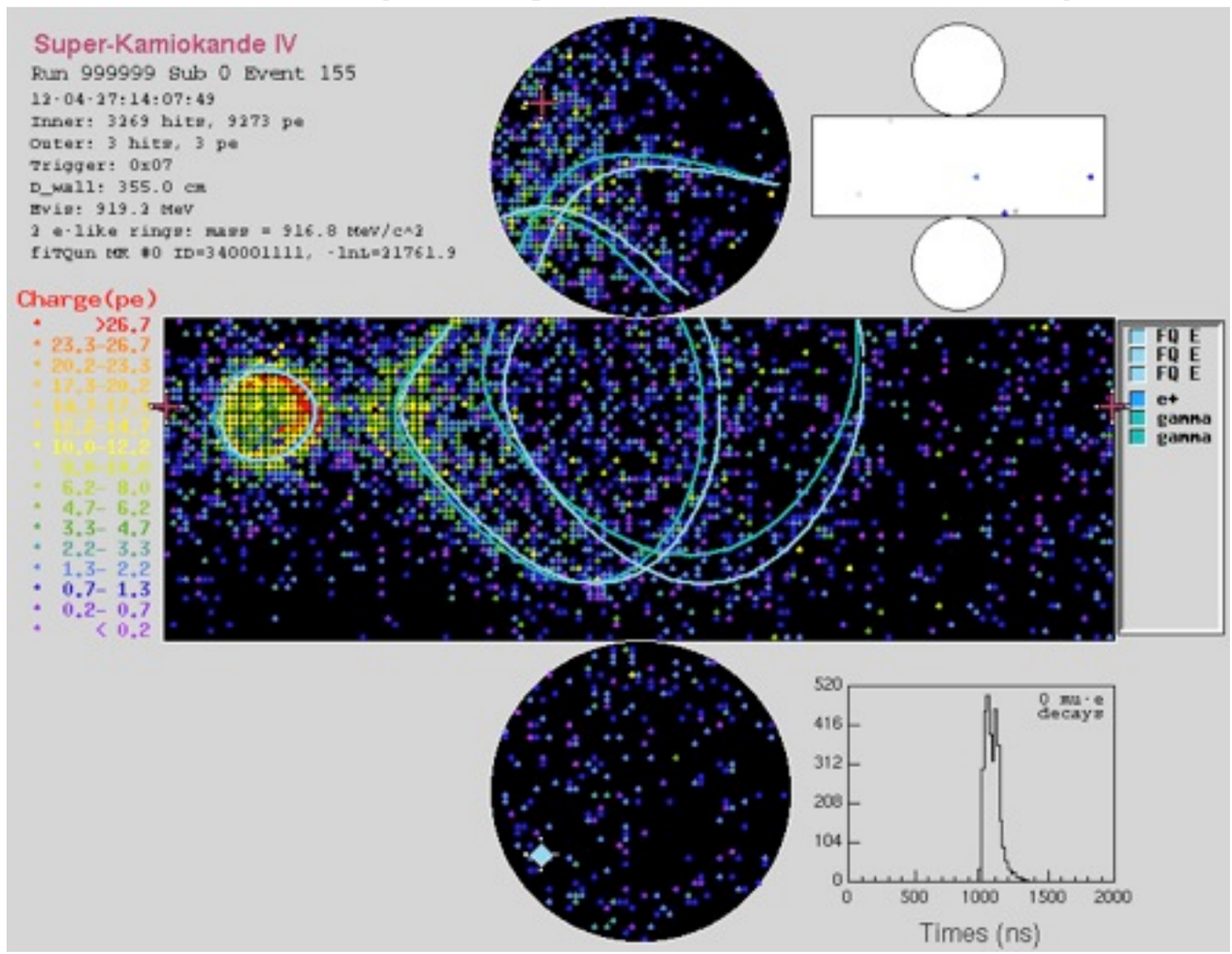
Ring Correction

- I just apply a simple correction to the free proton events
  → Angle between rings less than 20 deg

Before



After (simple correction)



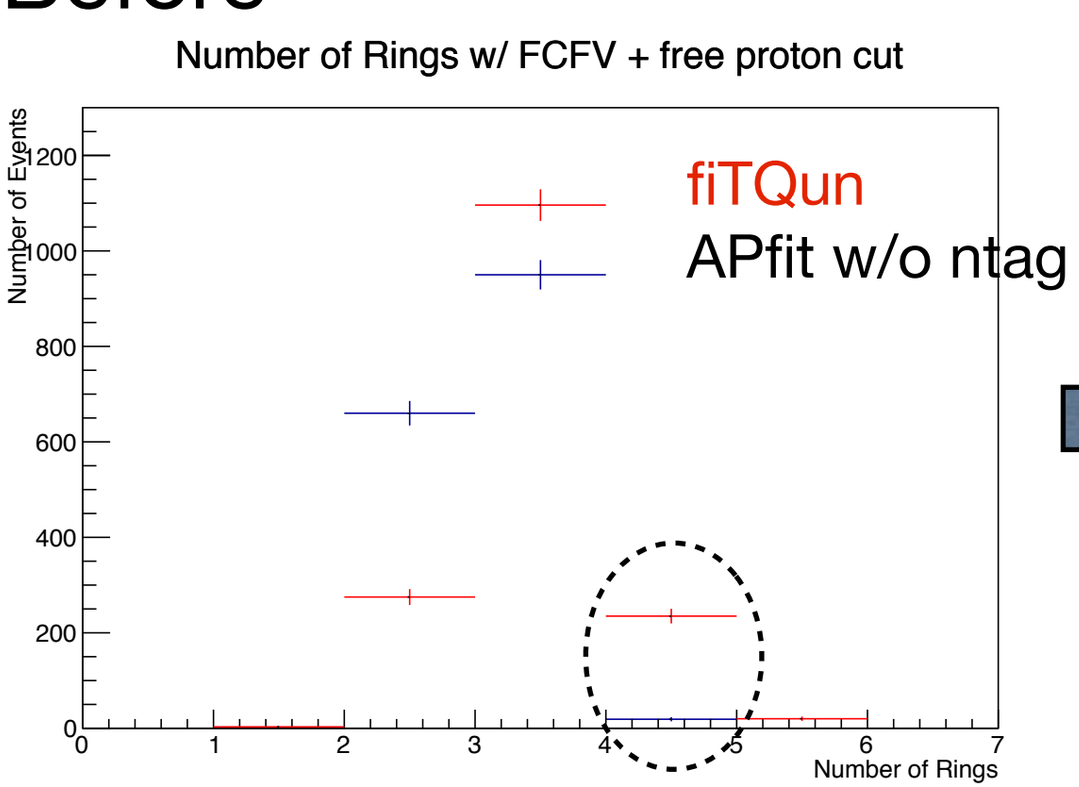
Results of fiTQun v4r2 with modified ring correction

($p \rightarrow e^{+}\pi^{0}$)

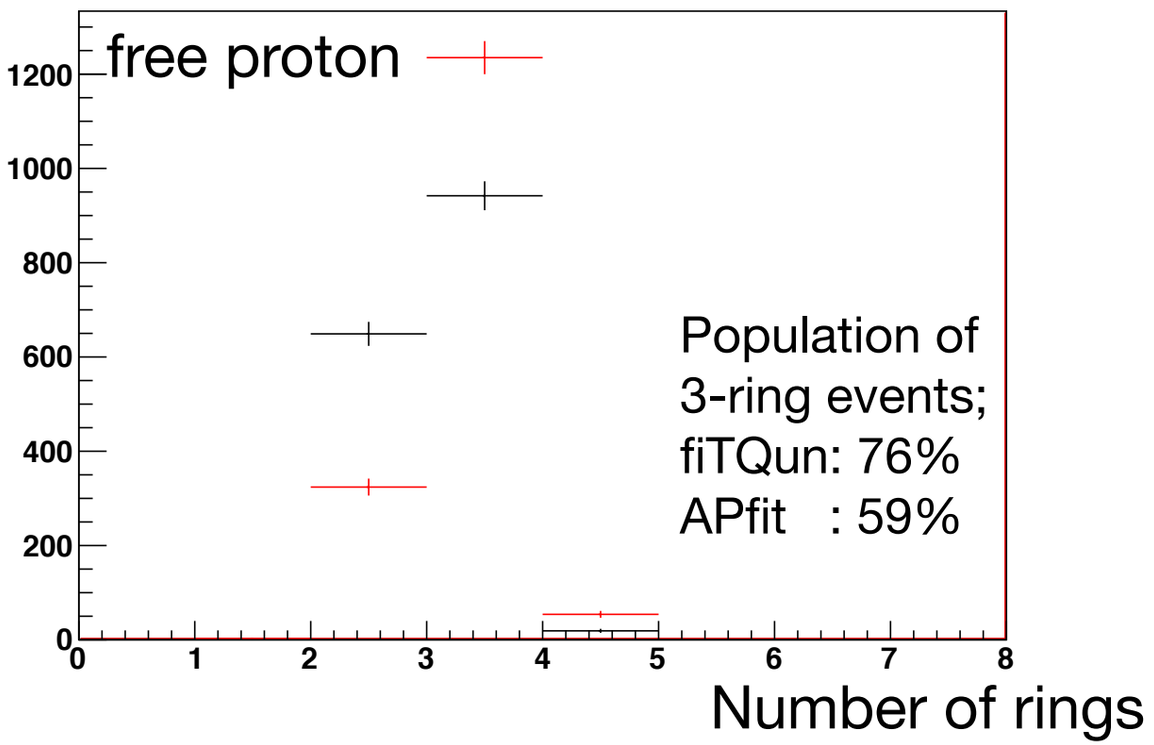
Ring Counting

- Higher population of 3-ring events (APfit: 59%, fiTQun: 76%)
  → More $e^+\pi^0$ event like?

Before

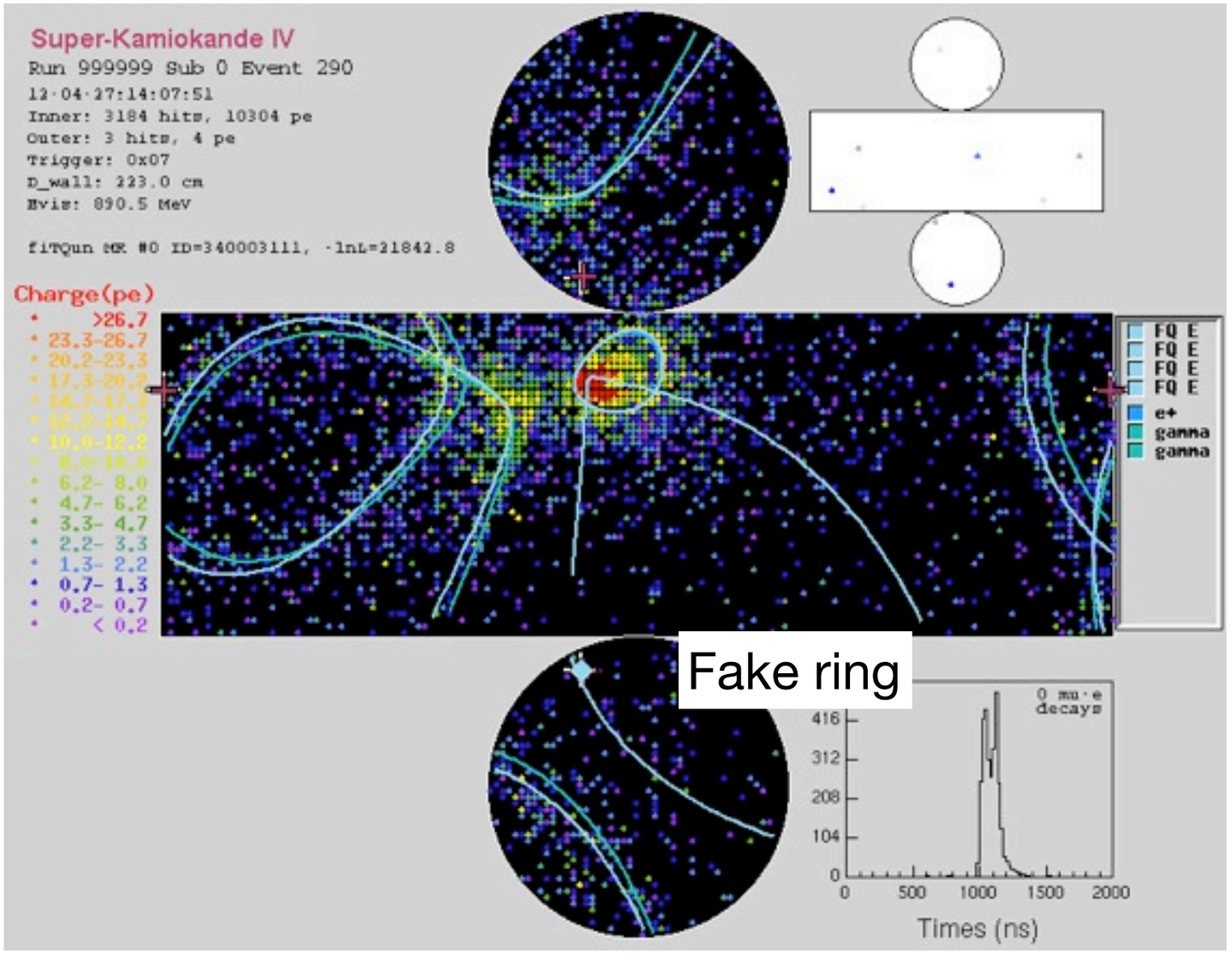


After



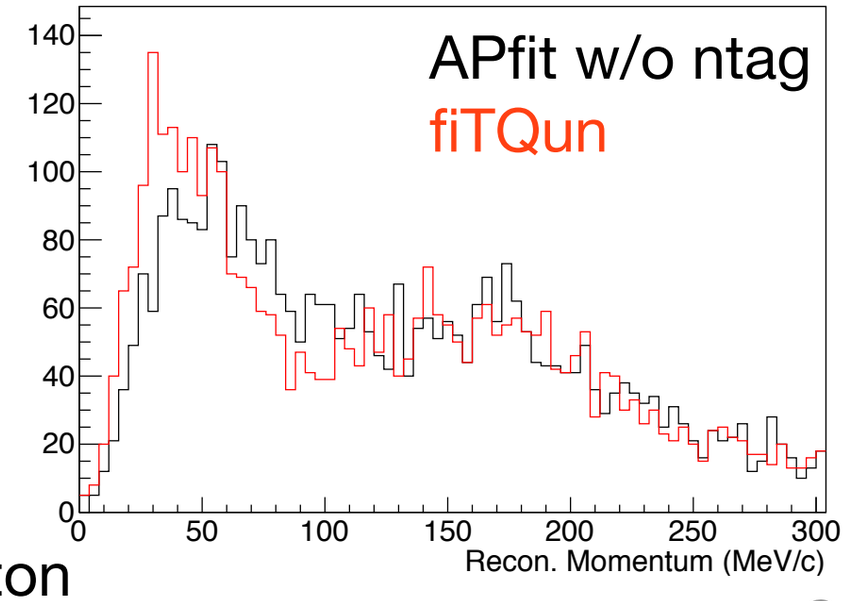
Ring Counting

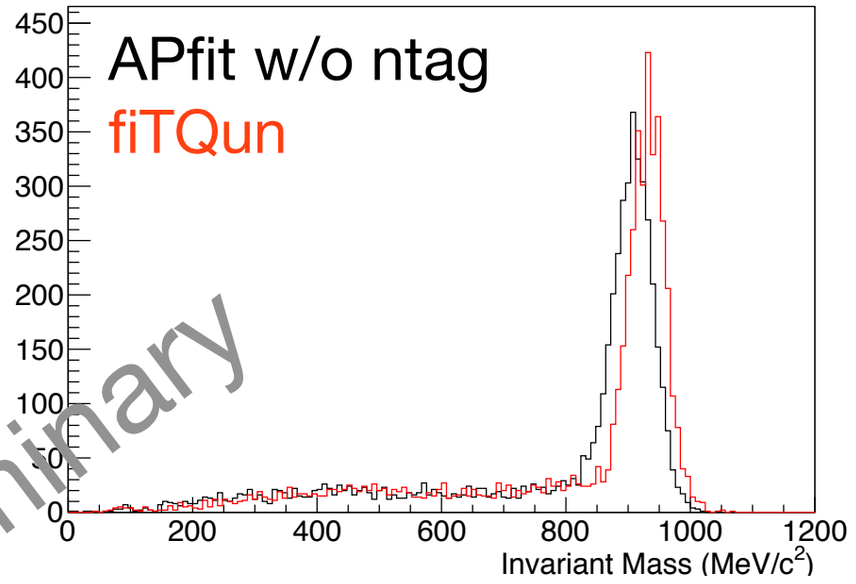
- Still there are 4-ring events
- Need to understand why it is happened and fix the problem



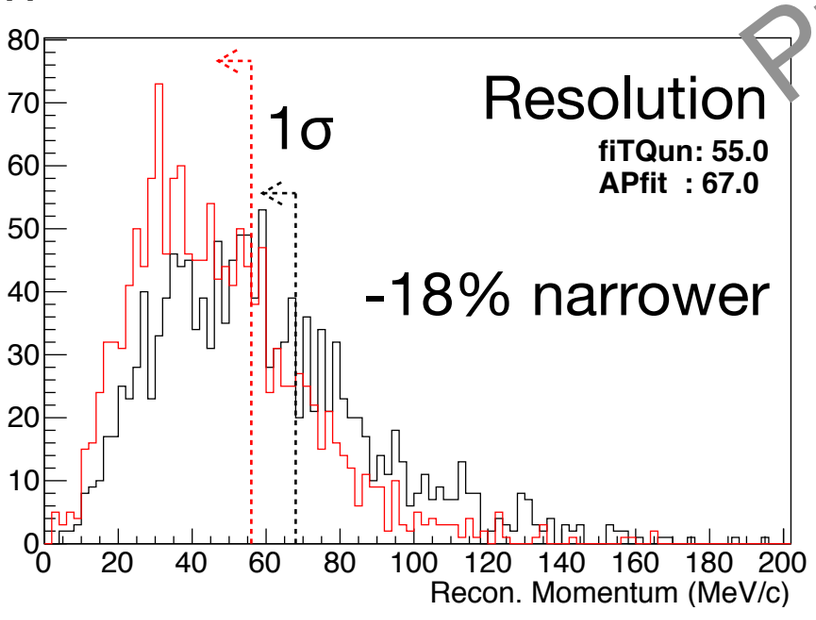
Recon. Proton

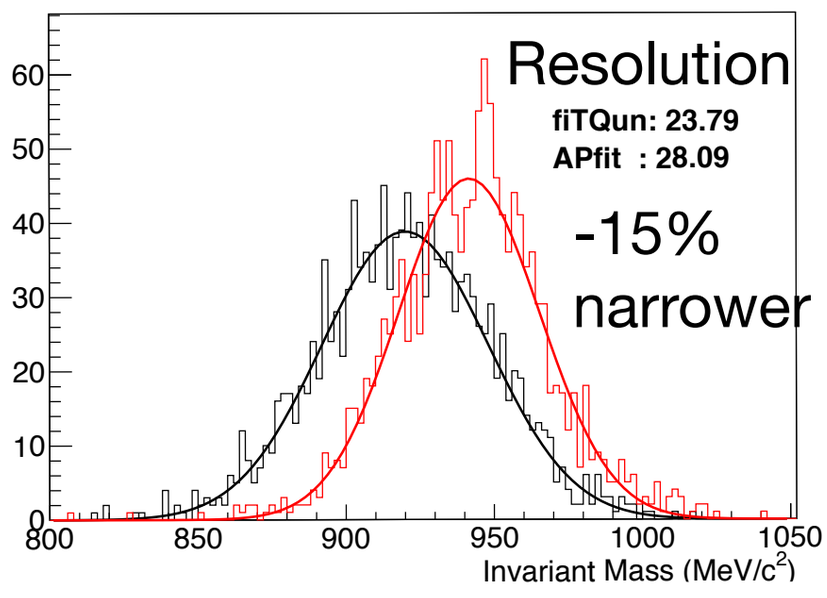
All proton





Free proton

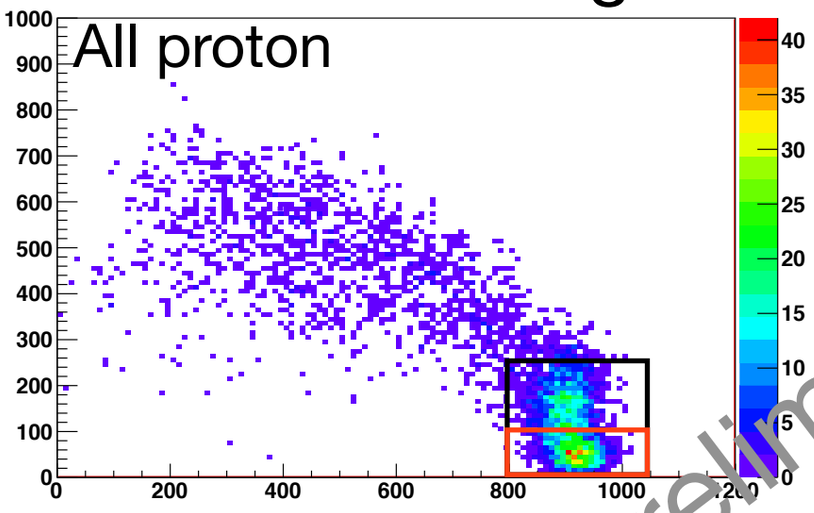




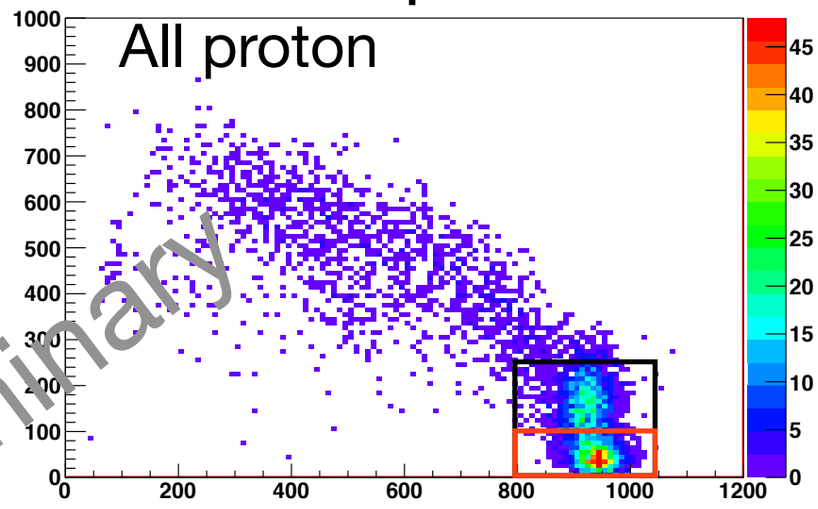
- FiTQun has a more clear separation of free proton and bound one in the momentum distribution than APfit

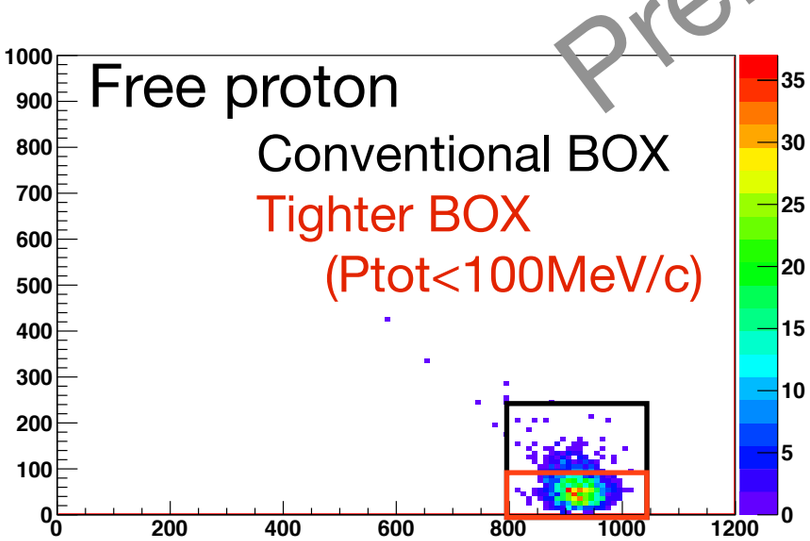
Signal Efficiency

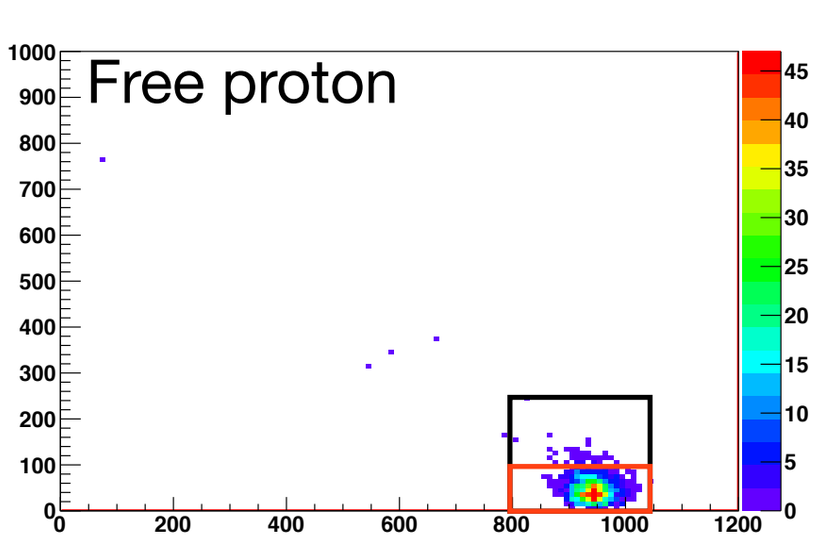
APfit w/o ntag



fiTQun post v4r2

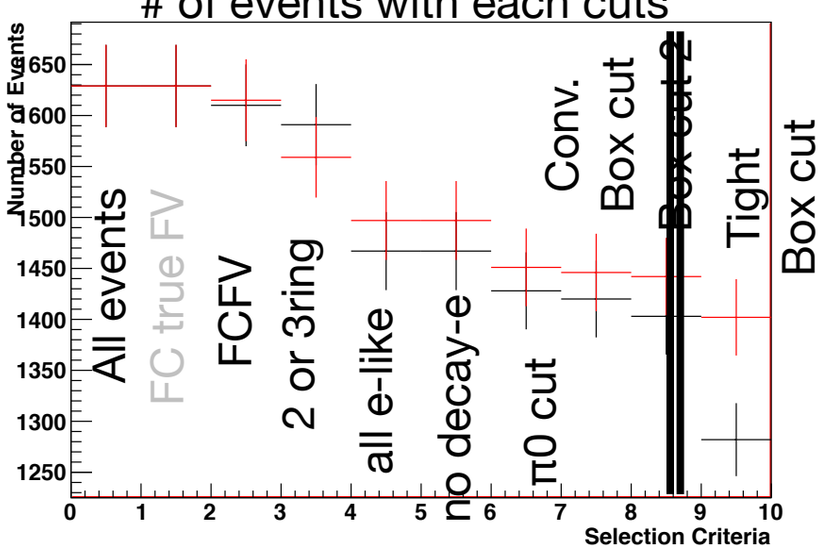






		Conventional BOX	Tighter BOX
APfit	All	39.7%	19.3%
	Free	87.2%	78.7%
fiTQun	All	40.8%	20.7%
	Free	88.8%	86.1%

# of events with each cuts



- fiTQun has a similar efficiency with the conventional BOX as APfit
- Higher efficiency for free protons

How about BG?

- Pre-selection
  - 1. FC true FV cut
  - 2. 8,000 < potot < 11,000
  - 3. apnring > 1
- Total 2,447,952 events

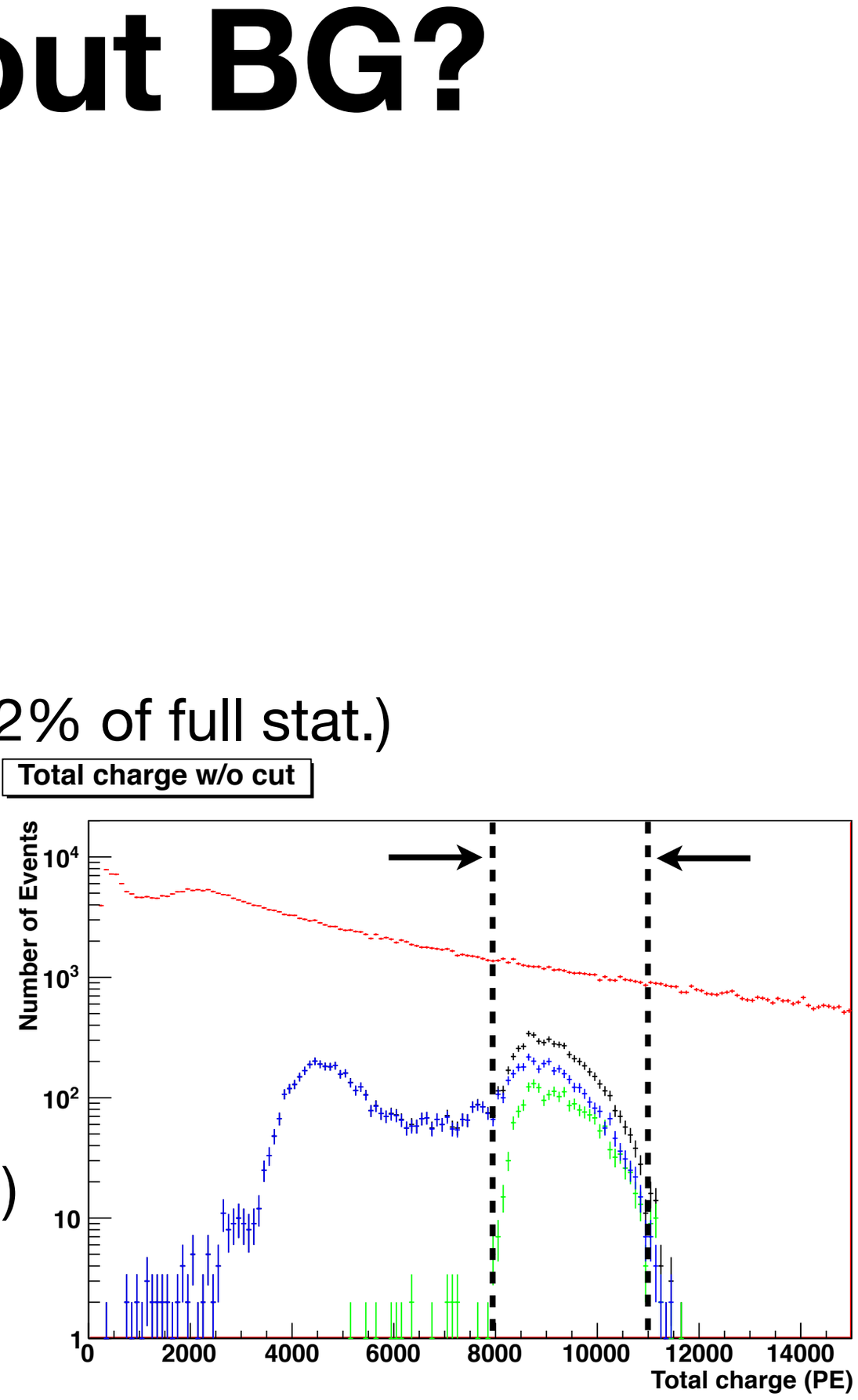
→ 51,703 events are selected (2% of full stat.)

ATMNU MC

e+pi0 MC (all proton)

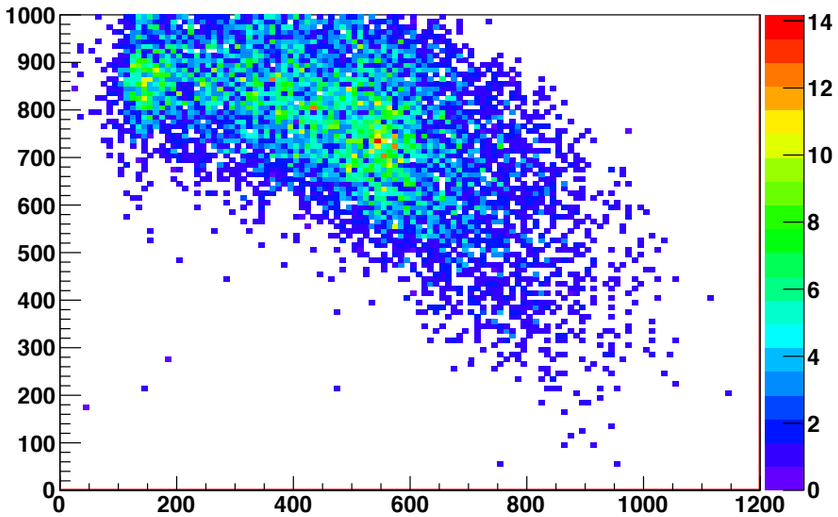
(free proton)

(binding proton)

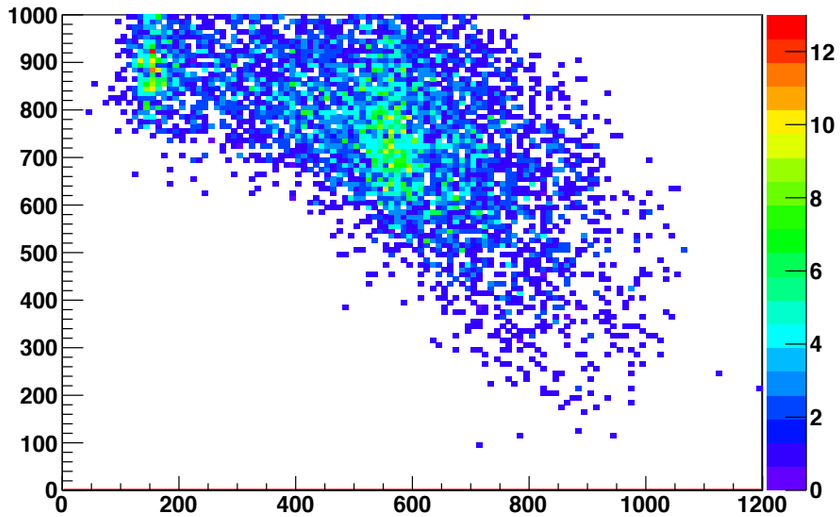


Results

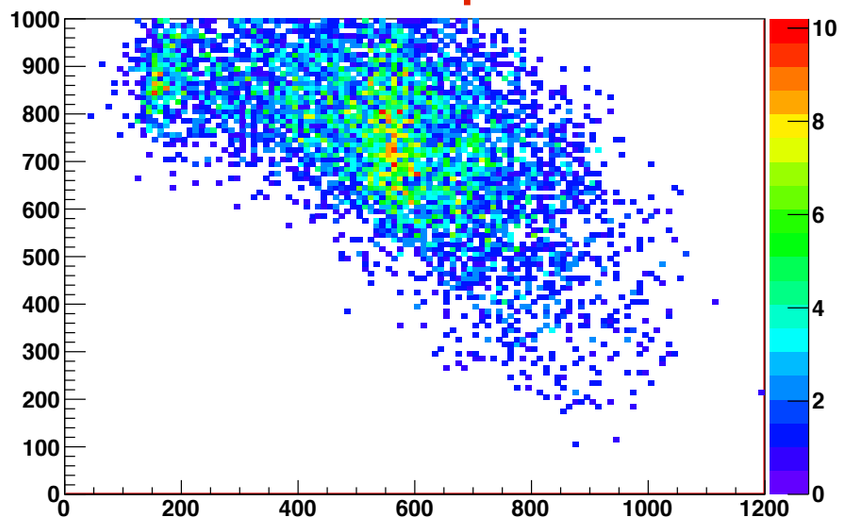
APfit



fiTQun v4r2



fiTQun improved



	Conventional BOX (<250MeV/c)	Tight BOX (<100MeV/c)
APfit	25.5 (28.6)	3.04 (3.04)
fQ v4r2	23.5 (25.5)	0 (0)
fQ improved	24.6	0

Red numbers show # of bkg w/o precut (all events)

- We selected almost all events which can be a candidate and reprocessed with improved version of fiTQun
- It looks the number of events in the improved fiTQun is higher, but the number of background for epi0 is not so much increased
- I think the ring correction is going to the right direction

Summary

- Main issue is ring counting
  → Need to understand and fix problems if possible
- Modified ring correction works well
- FiTQun signal efficiency for $e^+\pi^0$ becomes a similar level compared to APfit
- FiTQun × two BOX analysis maybe provide us a higher sensitivity for $e^+\pi^0$ with high discovery potential
- I will analyze $\mu^+\pi^0$ mode soon!