A Scan Study of ν_e-CC and NC Event Simulated in the LBNE Water Cherenkov Detector

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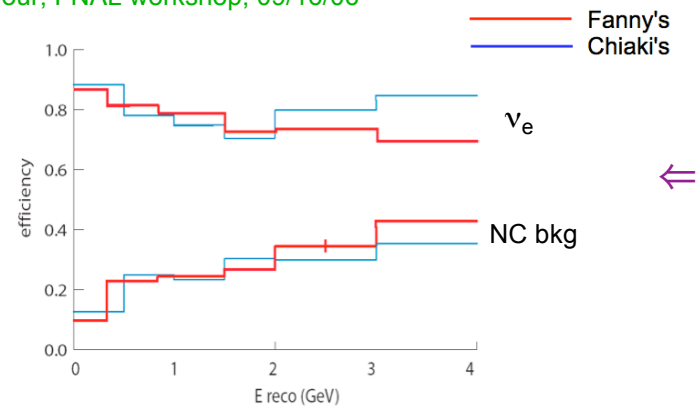
Introduction

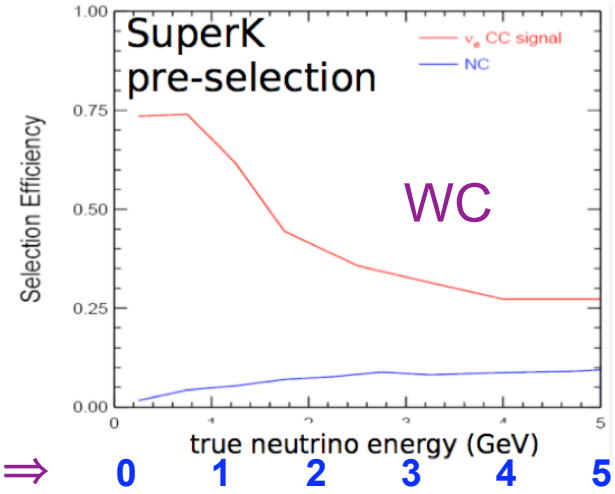
- Water Cherenkov (WC) and Liquid Argon (LAr) are two options under consideration for the far detector (FD) of the LBNE experiment.
- One of the issues is the FD's sensitivity to the ν_e-appearance which involves the detection efficiency of the signal, ν_e-CC, and the background, NC events.
- The proposed WC sensitivity is largely based upon the Super-K (SK) experience, which is not optimized for the LBNE energy in the 1.5--5 GeV region covering the first oscillation maximum.
- We use event scanning as a tool to understand and characterize the neutral current (NC) background processes to the ν_e appearance signal.

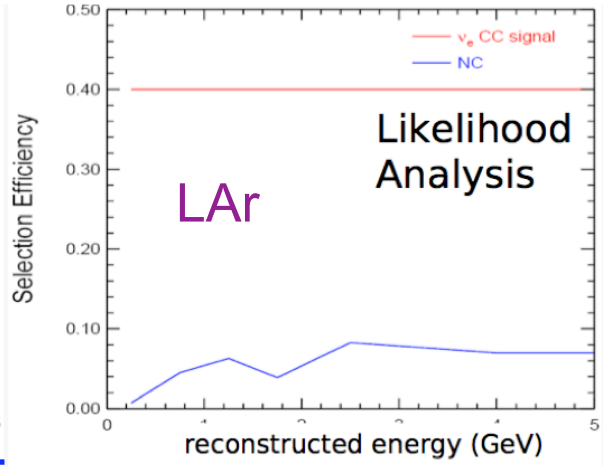
Proposed ν_e-CC and ν_μ-NC Background in WC and LAr (LBNE)

F. Dufour, FNAL workshop, 09/16/06



⇐Pre-selection





Eν(GeV)⇒ **0 1 2 3 4 5**

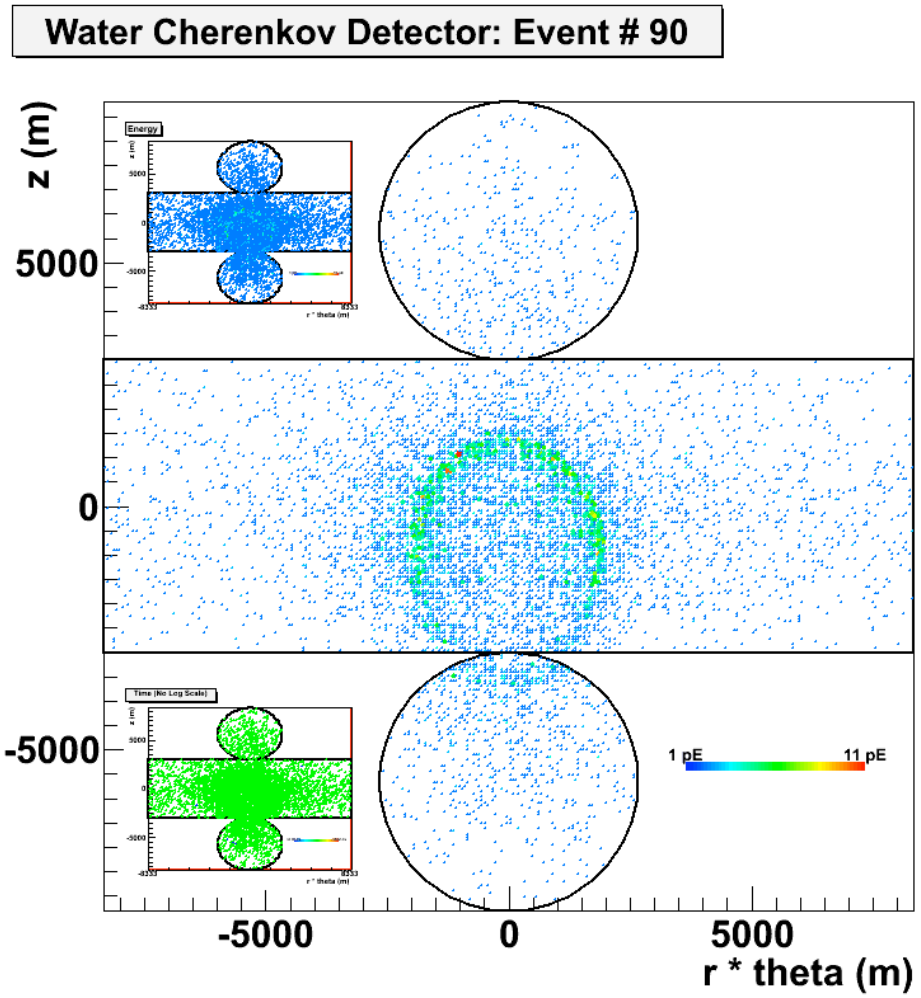
- WC: ~15% for ν_e, ~0.8% for NC at ~ 2 GeV
  (the product of the plots above, which are from SK algorithm)

- LAr: ~80% for ν_e, ~1% for NC

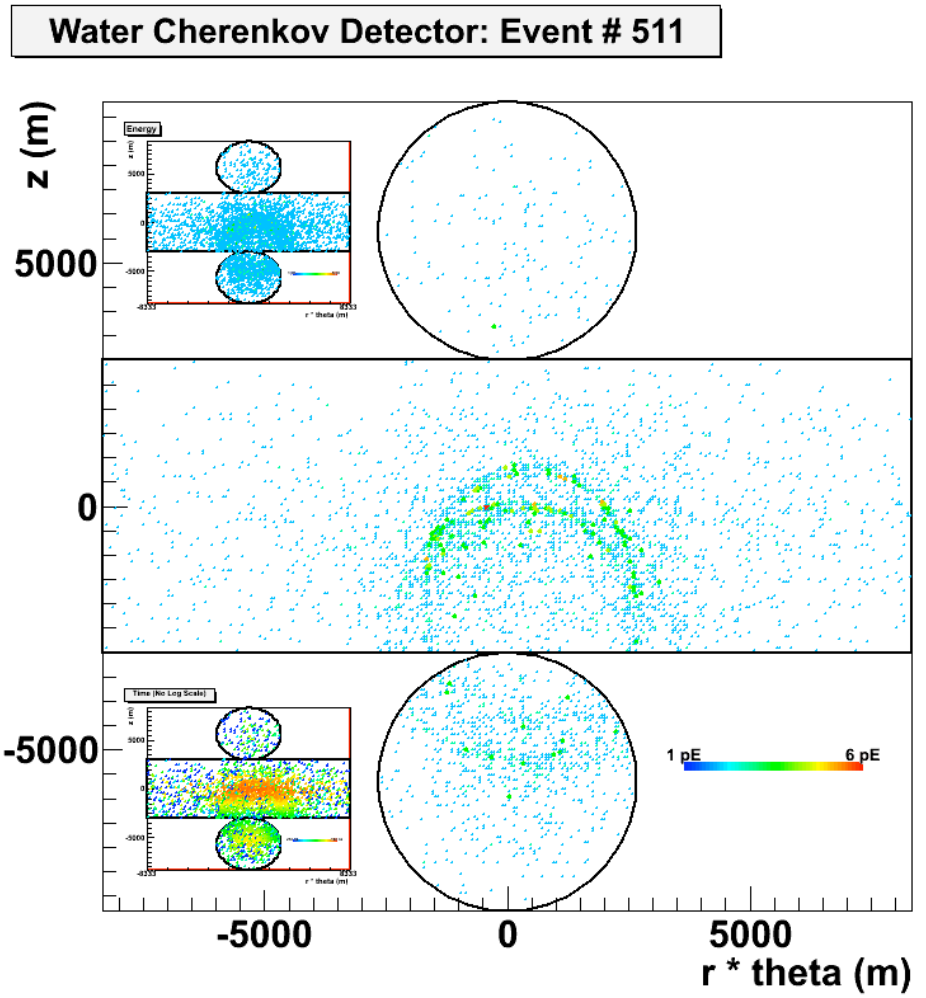
WC Event Scan

- Samples with ~2000 ν_e-CC and ~10000 ν_μ-NC events were generated with WCSim assuming DUSEL 100 kton geometry, 10 inch tube, high QE, 15% coverage.
- Vertex at (0, 0, 0).
- Focus on first oscillation maximum: 1.5 GeV < E_{vis} < 8 GeV (880 ν_e and 2822 NC). 1.5 ~ 4 GeV is the signal around the first oscillation maximum, and 4 ~ 8 GeV is the control region.
- Kinematic cuts applied: *electron energy > 1GeV (ν_e-CC) and * π0 energy > 0.5GeV (ν_μ-NC).
- Pictures of 690 ν_e-CC and 1392 ν_μ-NC events passed the cuts were then mixed and scanned (blindly). The number of rings were counted and their clarity defined.

Example Event Pictures

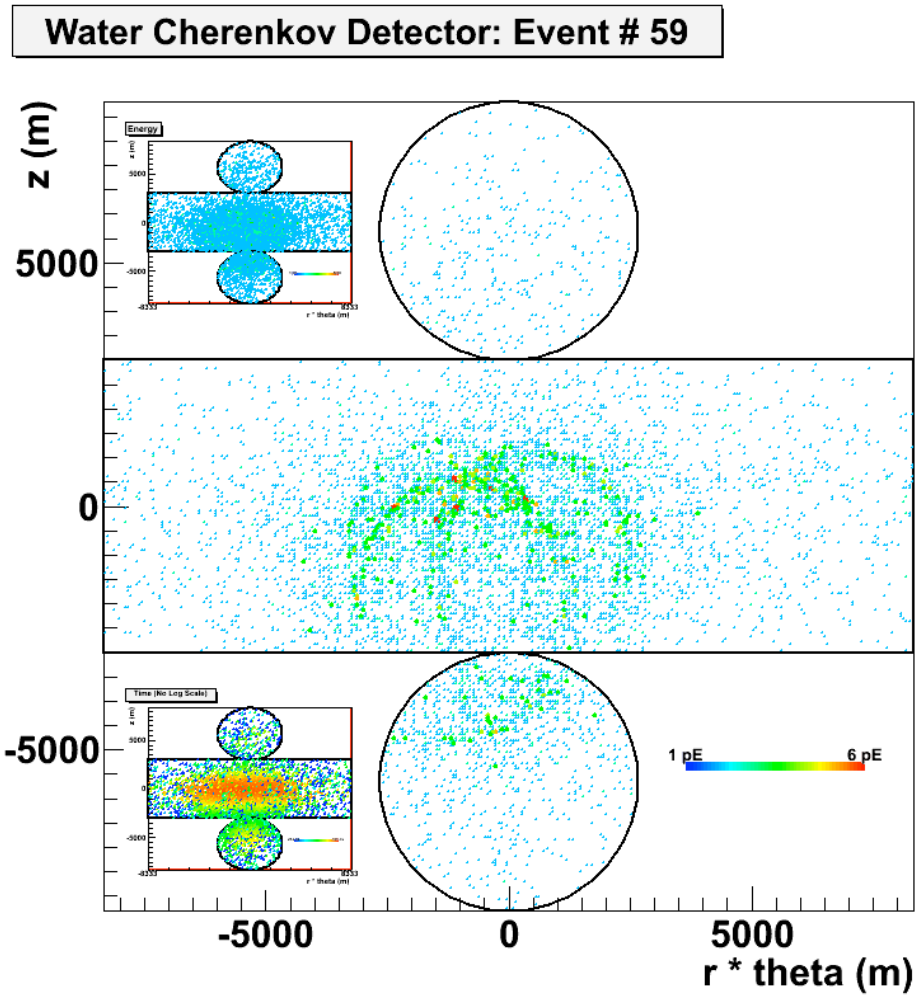


A ν_e event with 1 single electron ring

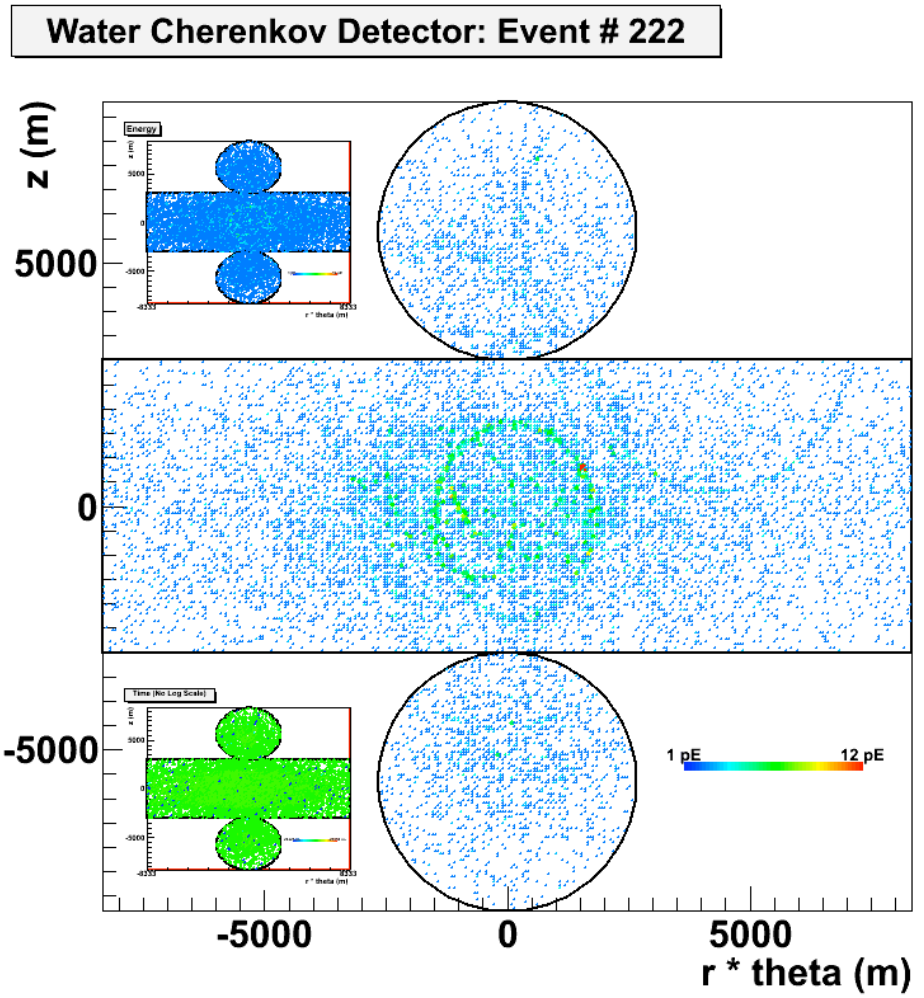


A NC event with 2 gamma rings from π^0 decay

Example Event Pictures



NC event with 3 rings



NC event with 4+ rings

Scan Result

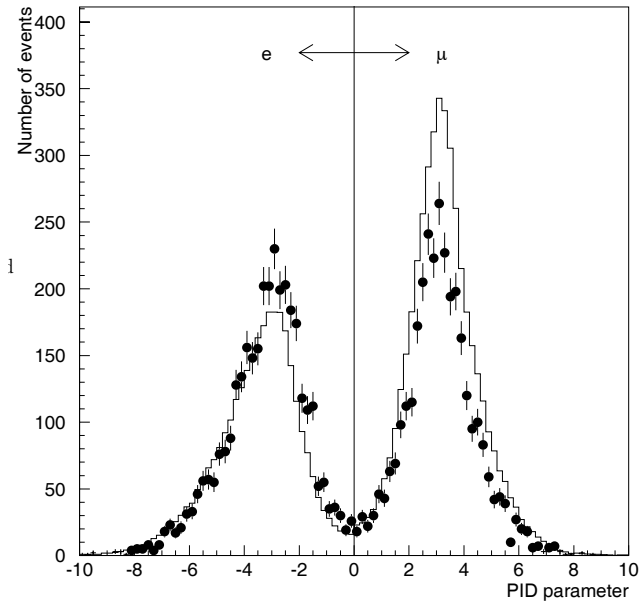
	1 Ring	2 Clear Rings	1 Clear & 1 Not-So-Clear	1 CLear & 1 Unclear	3 Rings	>=4 Rings	Sum
Ve	302	47	54	95	123	69	690

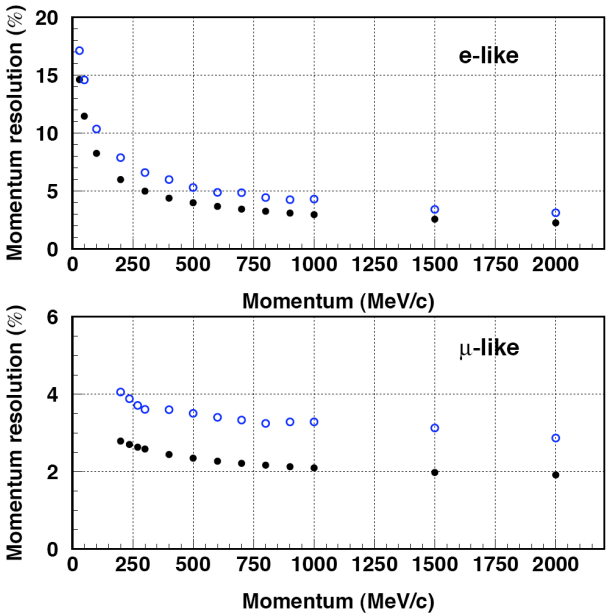
	1 Ring	2 Clear Rings	1 Clear & 1 Not-So-Clear	1 CLear & 1 Unclear	3 Rings	>=4 Rings	Sum
NC	125	157	138	126	450	396	1322

- In visible energy range 1.5 GeV ~ 8 GeV
- Consider 2 clear ring, 1 clear & 1 not-so-clear and 1 clear & 1 unclear events as 2 ring.
- 1-ring and 2-ring events were then used in further analysis.

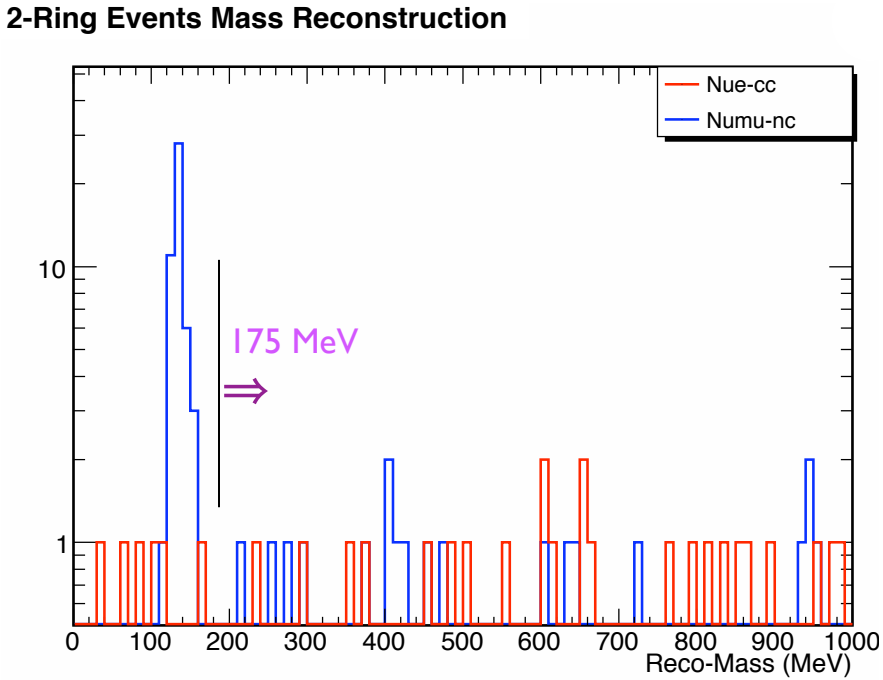
Analysis

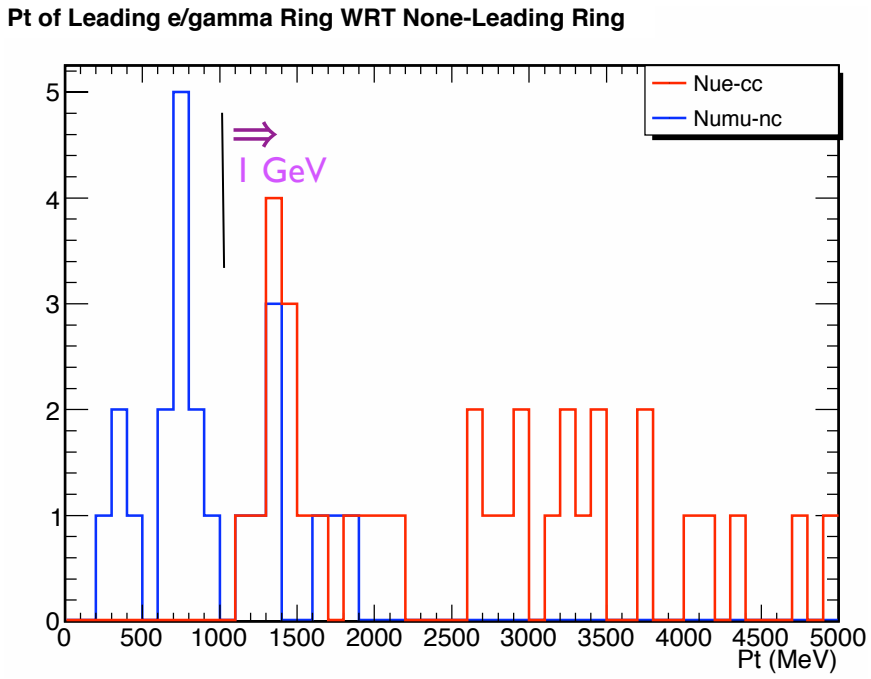
- Classify rings into electron-ring, muon-ring and pion-ring according to generated particle id.
- Smear p and θ using the parametrization based upon SK analysis.
- At least 1 electron-ring with energy >= 1 GeV.
- Classify events into 3 categories:
  *1 electron ring
  *2 electron rings
  *1 electron ring + 1 muon/pion ring
- Apply further kinematic cuts on 2 ring events to reduce NC background.





Kinematic Cuts on 2 Ring Events

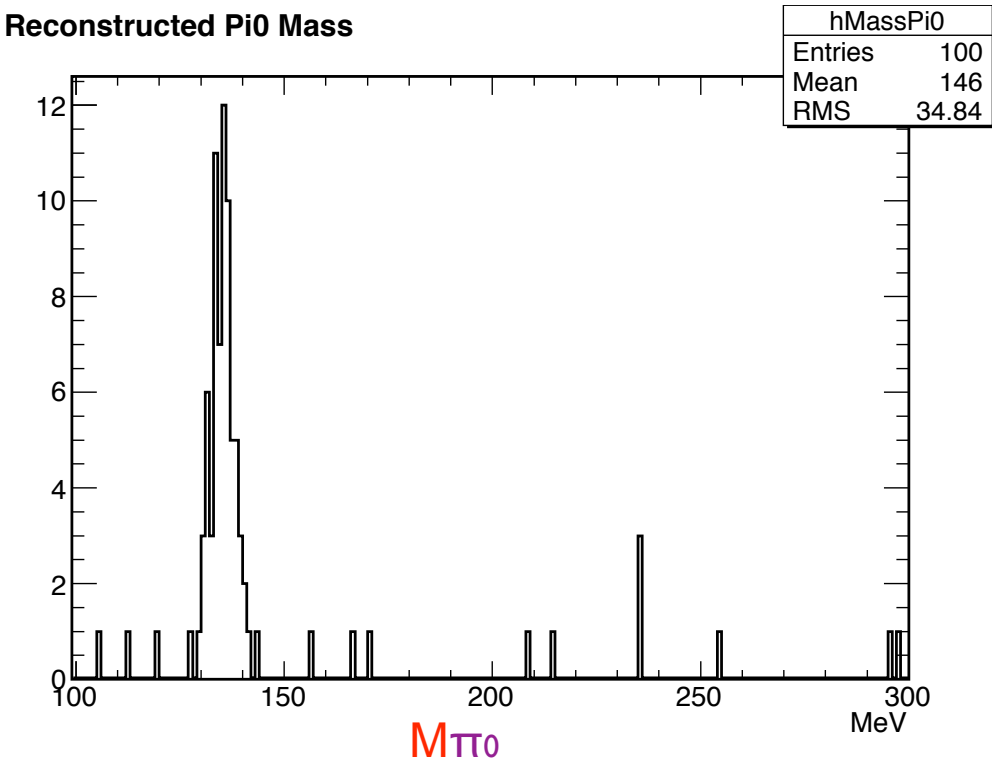


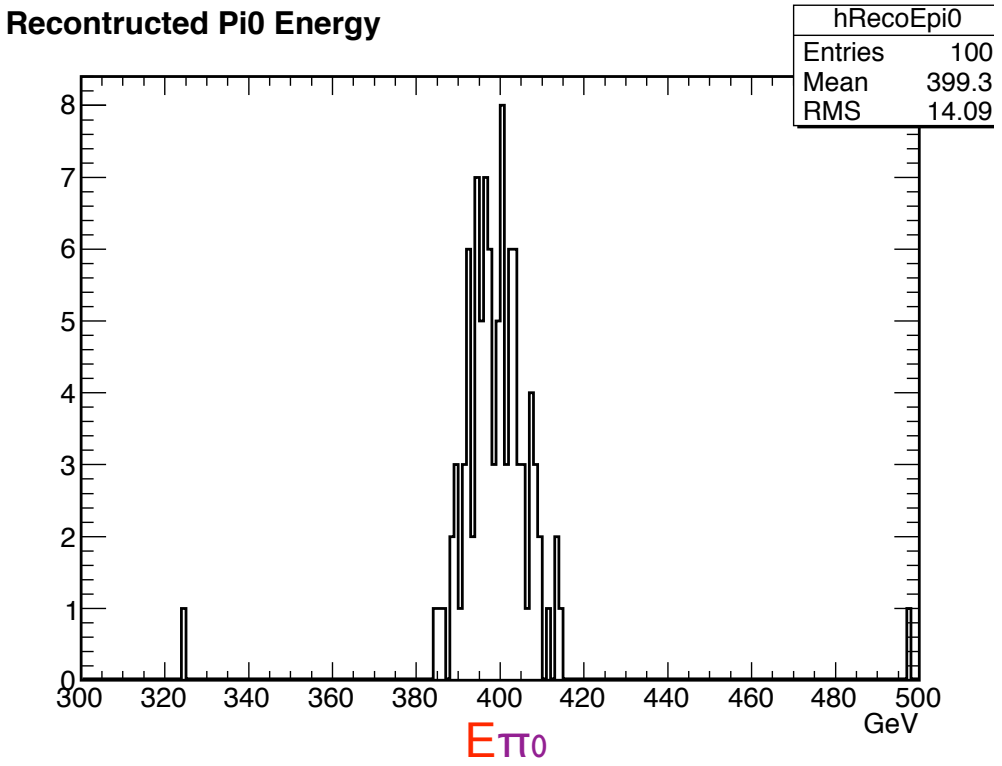


Apply further kinematic cuts on 2 ring events:
*M12 >= 0.175 GeV and *Pt >= 1 GeV to reduce NC background.

Single π0 Events

- Single π0 events were scanned as a check
- 100 events at $E_{\pi 0}$ = 3.5 GeV and 0.4 GeV
- $E_{\pi 0}$ = 3.5 GeV, <2% had 2 rings.
- $E_{\pi 0}$ = 0.4 GeV, 60% had 2 rings.





Result

ν_e	Generated Events	Scanned Events	After Kinematic Cuts
	880	690	443(50.3%)

nc	Generated Events	Scanned Events	After Kinematic Cuts
	2.82E+03	1.39E+03	105(3.72%)

- Generated Events: in visible energy range 1.5 ~ 8 GeV.
- Scanned Events:
  *electron energy >= 1GeV (ν_e-CC)
  * π0 energy >= 0.5GeV (ν_μ-NC)
- Further Kinematic Cuts:
  *Keep 1 ring and 2 ring events
  *At least 1 electron-ring with energy >= 1 GeV.
  *M12 >= 0.175 GeV and *Pt >= 1 GeV (2 ring events)

What Type of Interactions We Are Dealing With?

ν_e	Coh	QE	Res	DIS
Tot	4(0.455%)	154(17.5%)	115(25.8%)	460(52.3%)
Scanned	4(0.803%)	136(27.3%)	175(35.1%)	166(33.3%)
After cuts	4(0.903%)	106(23.9%)	168(37.9%)	149(33.6%)

NC	No-π	1 π^0	1 $\pi^{+/-}$	>=2 π
Tot	87(3.08%)	259(9.18%)	60(2.13%)	2416(85.6%)
Scanned	0(0%)	174(31.9%)	0(0%)	372(68.1%)
After cuts	0(0%)	35(33.7%)	0(0%)	69(66.3%)

Composition of ν_e-CC and NC Samples $1.5 \leq E_{vis} \leq 8$ GeV

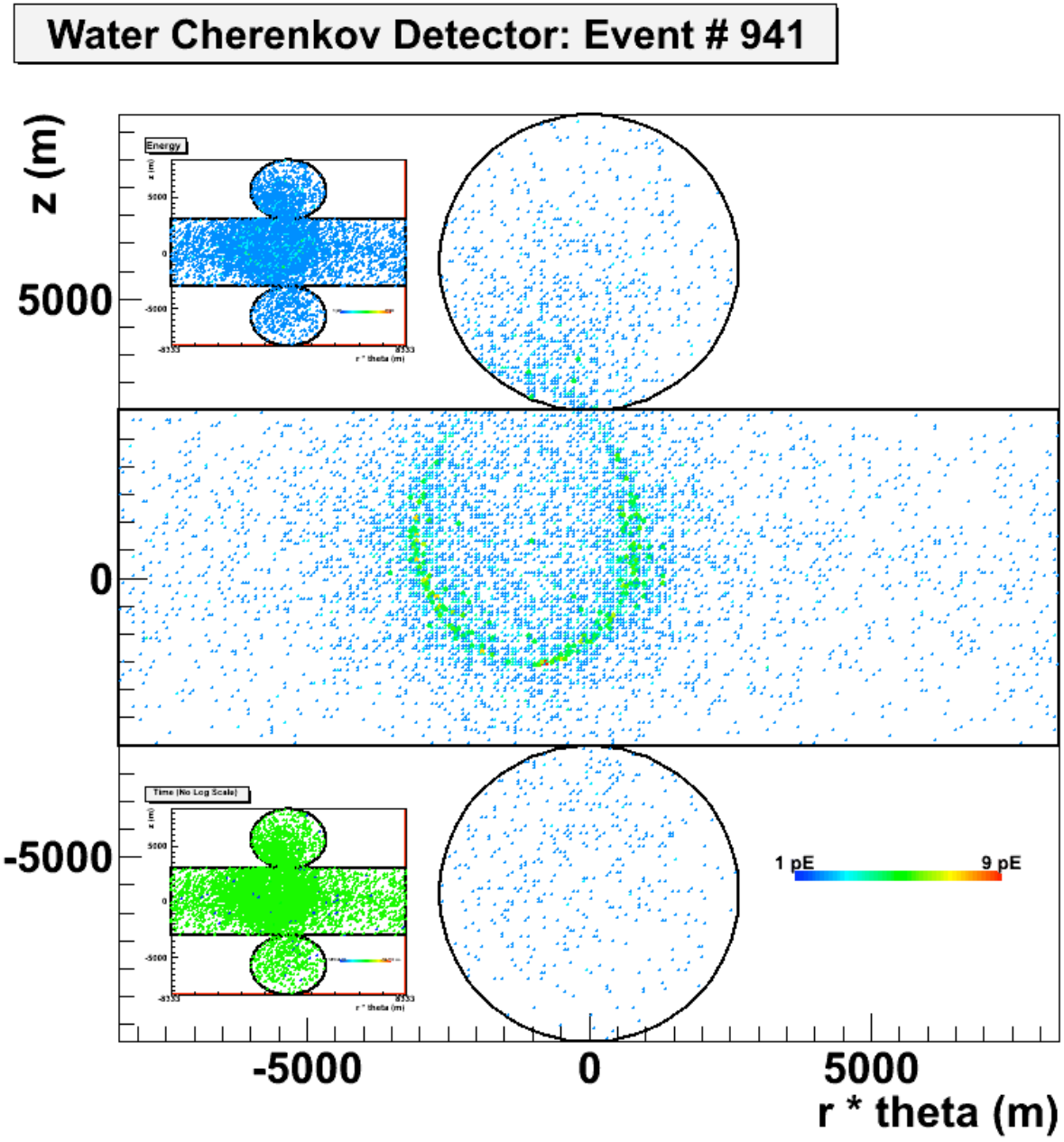
- >70% of the ν_e are non-QE.
- ~70% of NC background have >=2 π.

What Makes The Background?

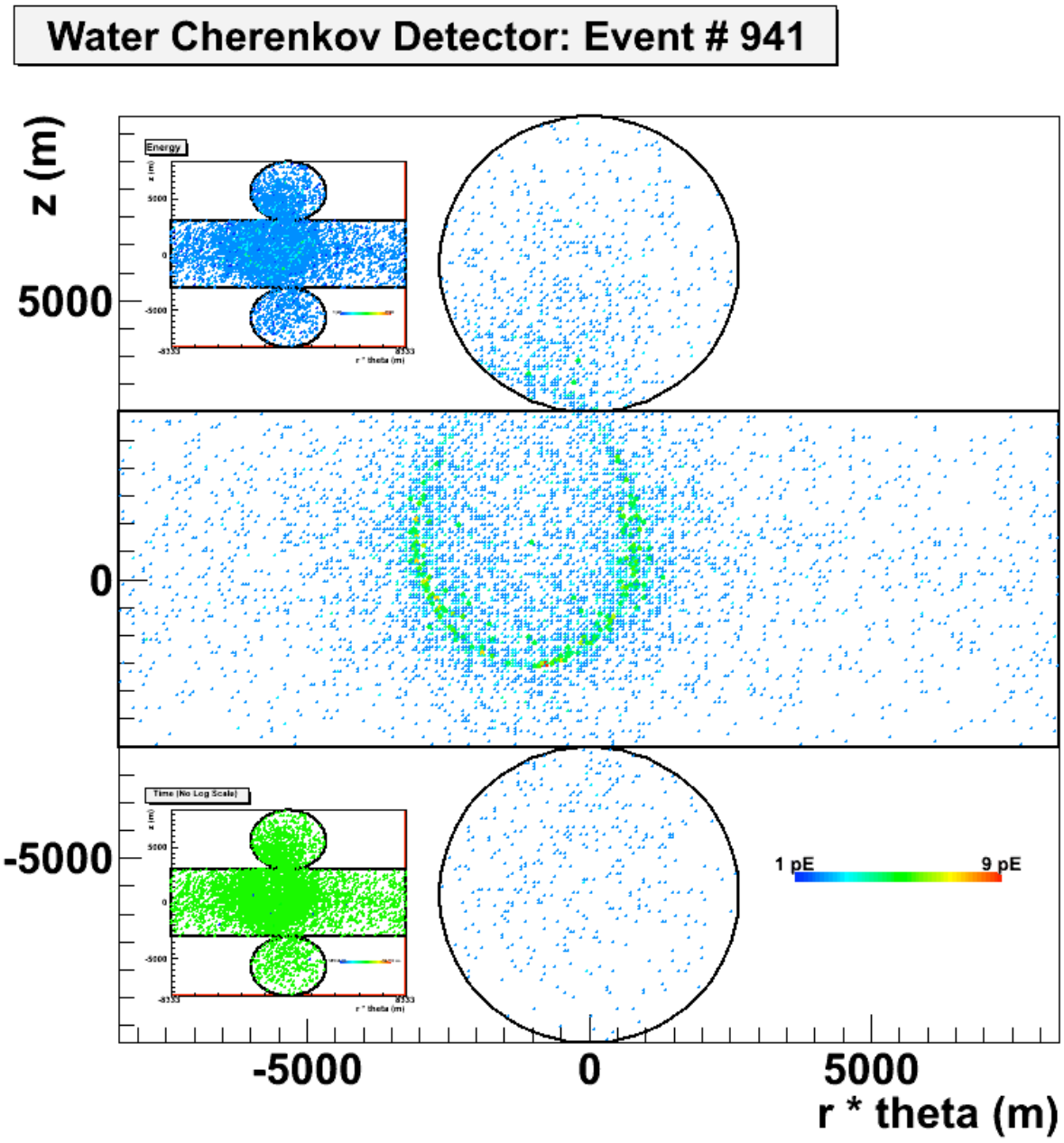
	1 e/γ ring	2 e/γ rings	1 e/γ ring + 1π ring	Sum
ν_e	301	59	83	443

	1 γ ring	2 γ rings	1 γ ring + 1π ring	Sum
NC	79	12	14	105

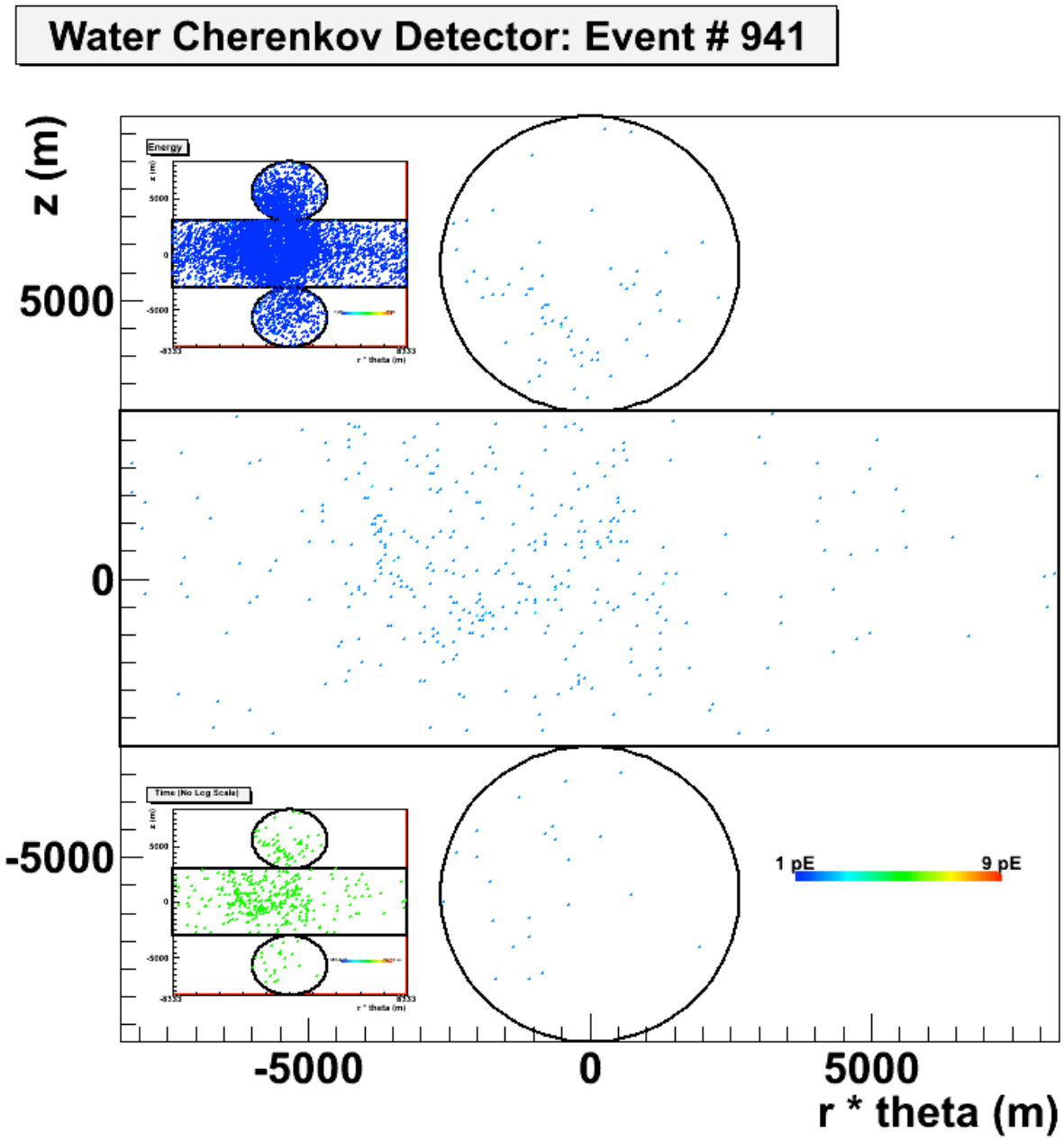
- ~75% of the NC background have 1 γ ring.
- The other γ ring from π0 decay is either too weak or overlapping with the leading ring.



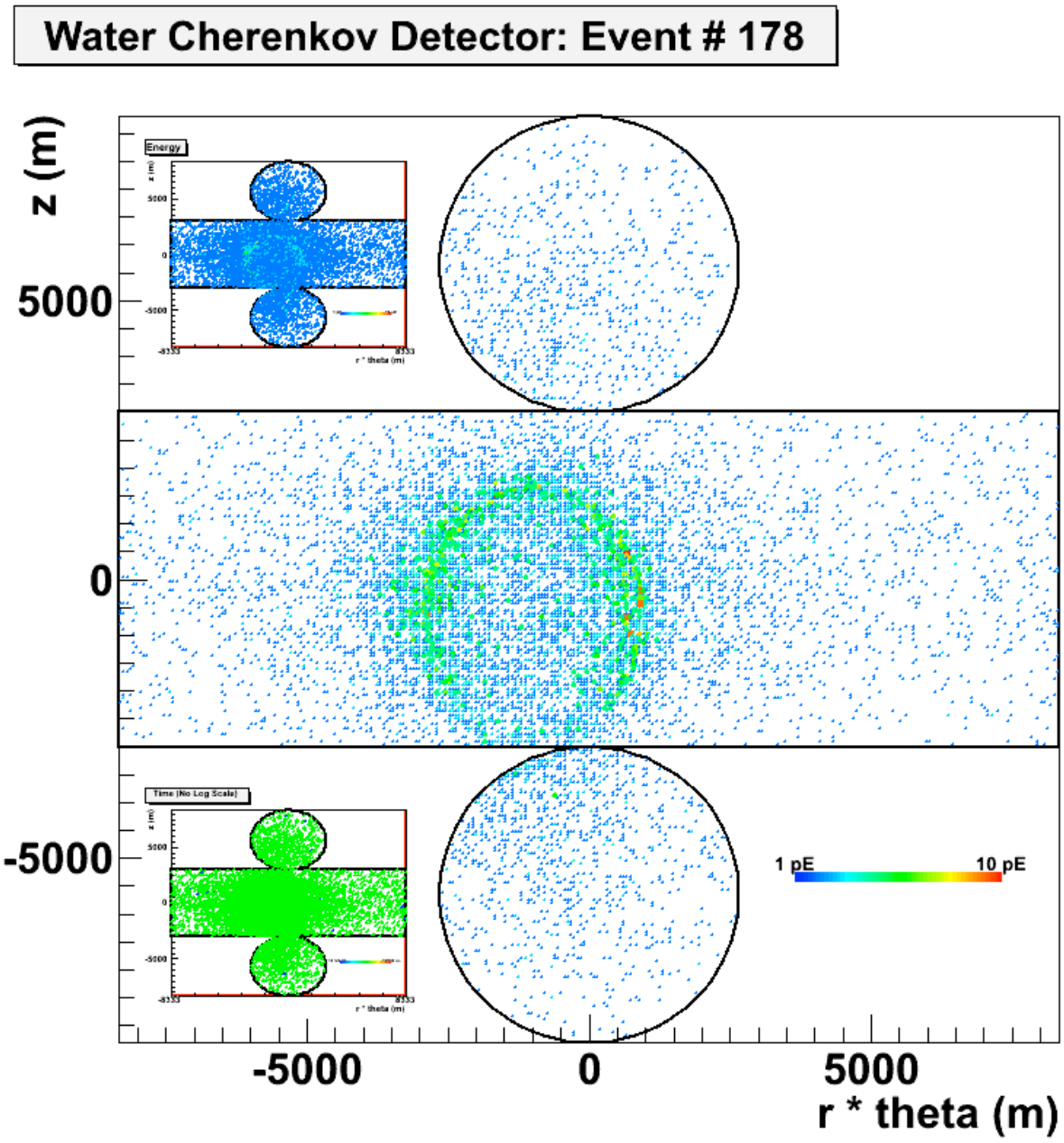
A NC event identified as 1-ring



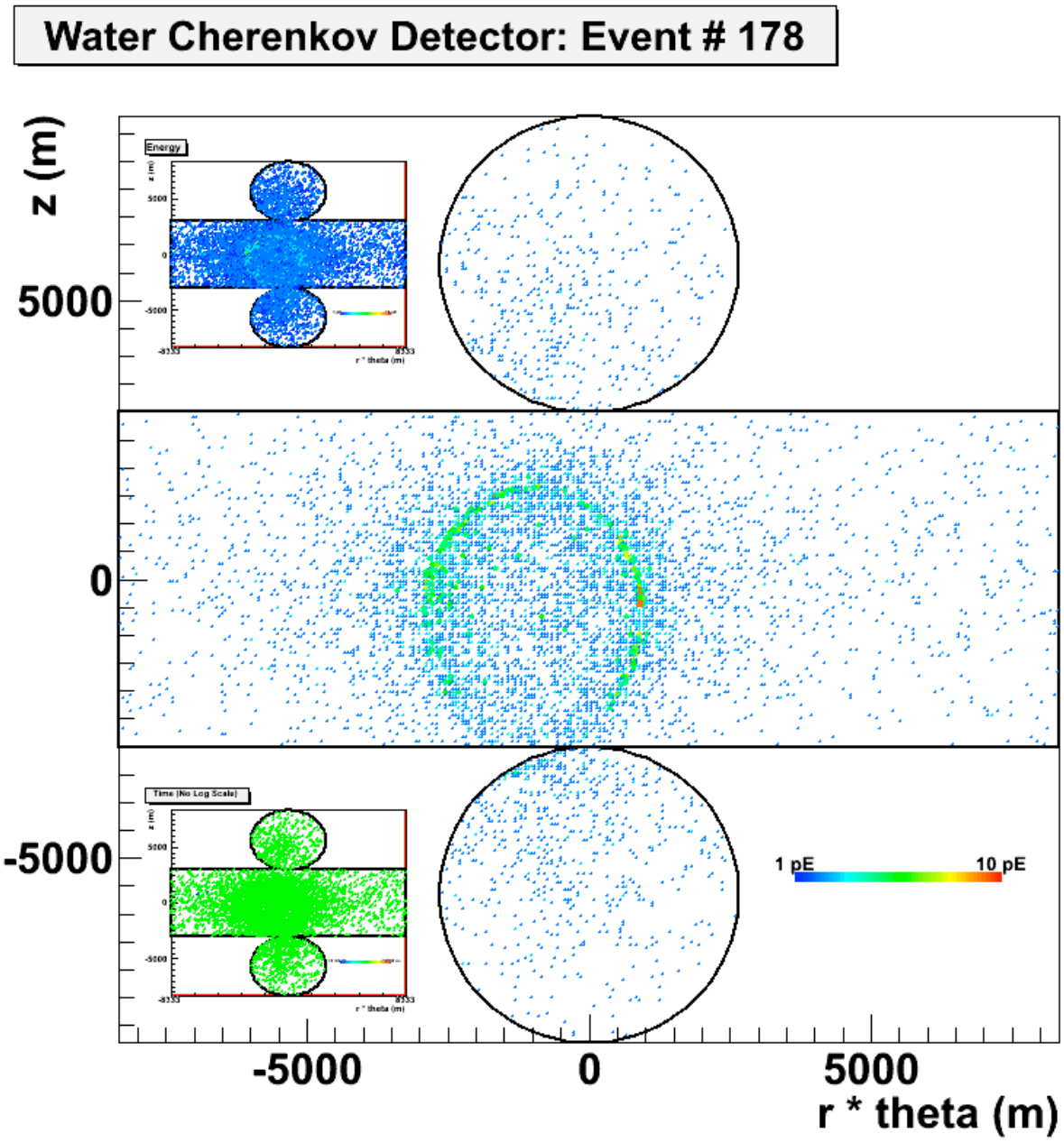
The leading γ ring (switch off γ2)



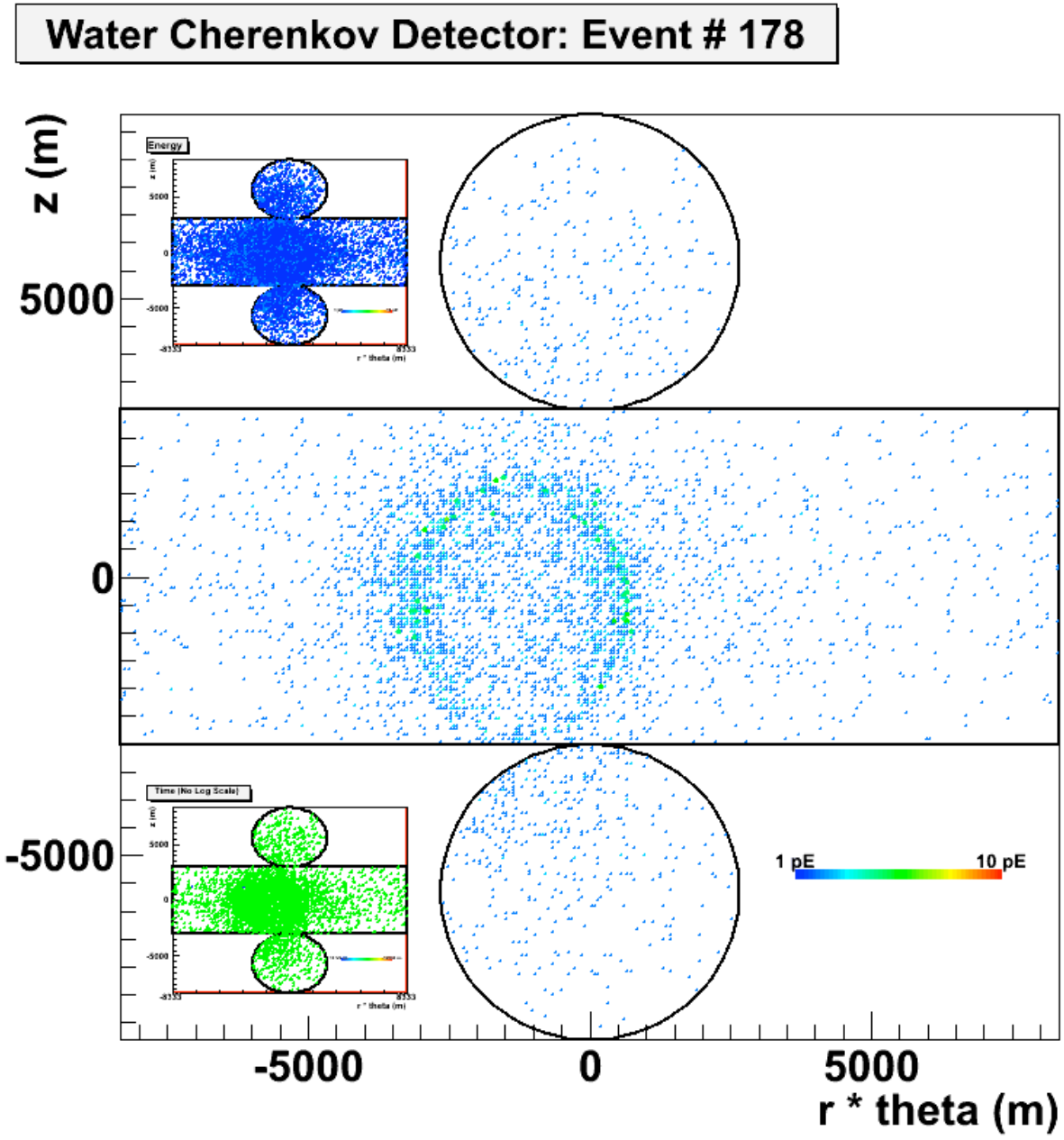
The second γ ring is too weak to identify (switch off γ1)



A NC event identified as 1-ring



The leading γ ring (switch off γ2)



The second γ ring is on top of γ1 (switch off γ1)

Conclusion

In visible energy region 1.5 ~ 8 GeV:

- ν_e signal at level of ~50%
- NC background at level of ~2.5% -- 3%.
- >70% of ν_e are non-QE
- ~70% NC have >= 2 π's
- ~75% of the NC background have1 γ ring with 2nd ring too weak or overlapping with the leading ring

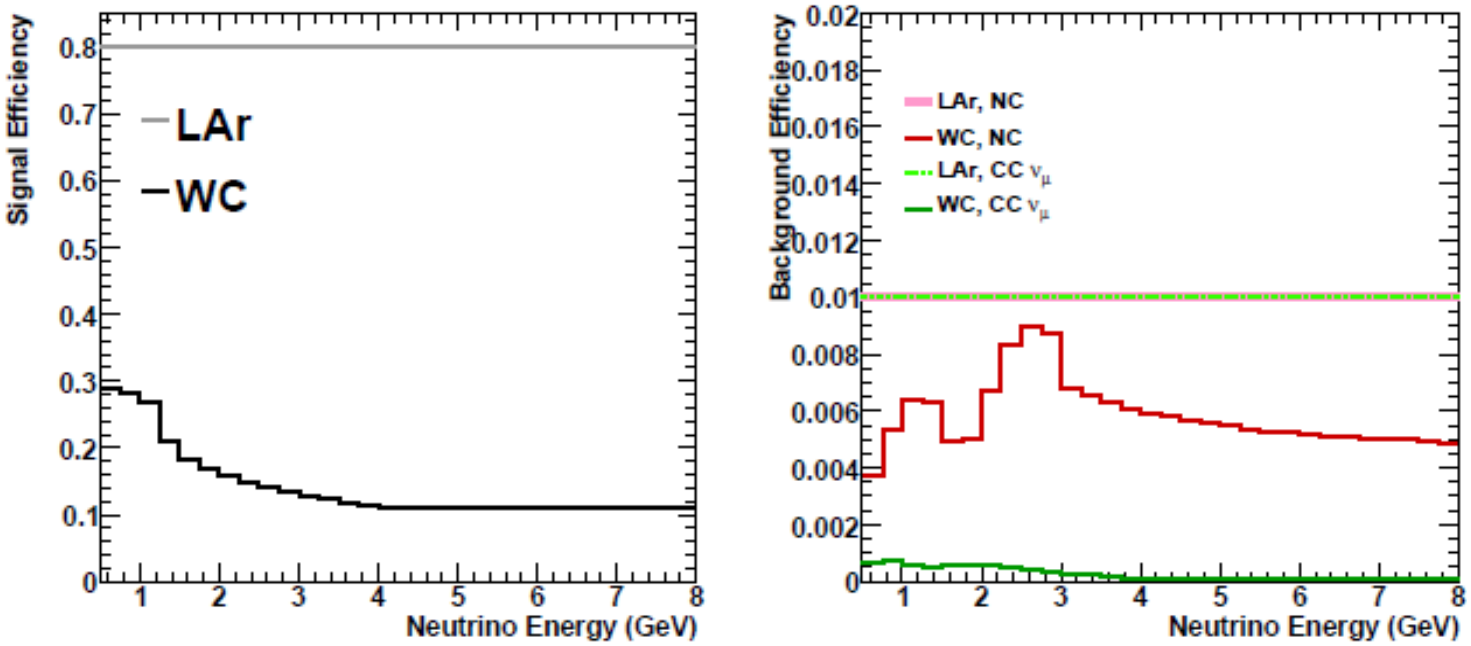
Results are obtained by eye-scanning. No further pattern recognition was performed.

The End

Backup Slides

Proposed ν_e-CC and ν_μ-NC Background in WC and LAr (LBNE)

Nue appearance measurement



(From Long Baseline Physics Working Group Report)

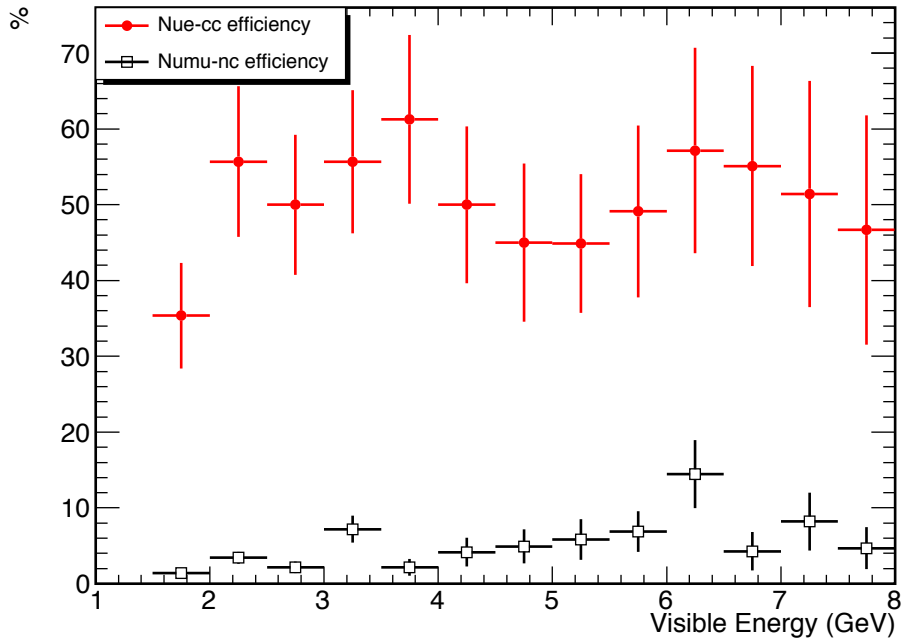
Result

νe

Visible Energy (GeV)	1.5 ~ 4	4 ~ 8	Sum
Generated Events	452	428	880
Scanned	319	371	690
After Cuts	231(51.1%)	212(49.5%)	443(50.3%)

nc

Visible Energy (GeV)	1.5 ~ 4	4 ~ 8	Sum
Generated Events	2.13E+03	688	2.82E+03
Scanned	879	514	1.39E+03
After Cuts	60(2.81%)	45(6.54%)	105(3.72%)



What type of interactions we are dealing with?

ν_e	Coh	QE	Res	DIS
Tot	3(0.664%)	106(23.5%)	66(33.4%)	171(37.8%)
Scanned	3(1.14%)	92(35%)	105(39.9%)	57(21.7%)
After cuts	3(1.3%)	69(29.9%)	101(43.7%)	53(22.9%)

nc	No-pion	1 pi0	1 pi+-	n pi
Tot	87(4.08%)	246(11.5%)	60(2.81%)	1741(81.6%)
Scanned	0(0%)	162(38.2%)	0(0%)	262(61.8%)
After cuts	0(0%)	28(46.7%)	0(0%)	32(53.3%)

Composition of ν_e-CC and NC Samples $1.5 \leq E_{vis} \leq 4$ GeV

What type of interactions we are dealing with?

ν_e	Coh	QE	Res	DIS
Generated	1(0.234%)	48(11.2%)	49(17.8%)	289(67.5%)
Scanned	1(0.426%)	44(18.7%)	70(29.8%)	109(46.4%)
After cuts	1(0.472%)	37(17.5%)	67(31.6%)	96(45.3%)

nc	No-pion	1 pi0	1 pi+-	n pi
Generated	0(0%)	13(1.89%)	0(0%)	675(98.1%)
Scanned	0(0%)	12(9.84%)	0(0%)	110(90.2%)
After cuts	0(0%)	7(15.9%)	0(0%)	37(84.1%)

Composition of ν_e-CC and NC Samples $4 \leq$ Evis ≤ 8 GeV

What Makes The Background?

νe

Visible Energy	1.5 ~4	4 ~ 8	Sum
1 e/γ ring	164	137	301
2 e/γ rings	28	31	59
1 e/γ ring +1π	39	44	83
Sum	231	212	443

nc

Visible Energy	1.5 ~4	4 ~ 8	Sum
1 γ ring	48	31	79
2 γ rings	6	6	12
1 γ ring +1π ring	6	8	14
Sum	60	45	105

- 80% of the nc background have 1 γ ring (1.5 ~ 4 GeV).
- The other γ ring from π0 decay is either too weak or overlapping with the leading ring.